RADIO SOCIETY OF GREAT BRITAIN

RADIO & ELECTRONICS COOKBOOK

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1 A medium-wave receiver

Introduction

Let us start off with something that is really quite simple and yet is capable of producing a sense of real satisfaction when complete – a real medium-wave (MW) radio receiver! It proves that receivers *can* be simple and, at the same time, be useful and enjoyable to make. To minimise the confusion to absolute beginners, *no* circuit diagram is given, only the constructional details. The circuits will come later, when you have become accustomed to the building process. In the true amateur spirit of ingenuity and inventiveness, the circuit is built on a terminal strip, the coil is wound on a toilet roll tube (as amateur MW coils have been for 100 years!), and the receiver is mounted on a piece of wood.

Putting it together

Start by mounting the components on the terminal strip as shown in **Figure 1**, carefully checking the position and value of each one. The three capacitors are all the same, and so present no problem. They (and the resistors) may be connected either way round, unlike the two semi-conductors (see later). The resistors are coded by means of coloured bands. You can refer to Chapter 7 if you have difficulty remembering the colours and their values.

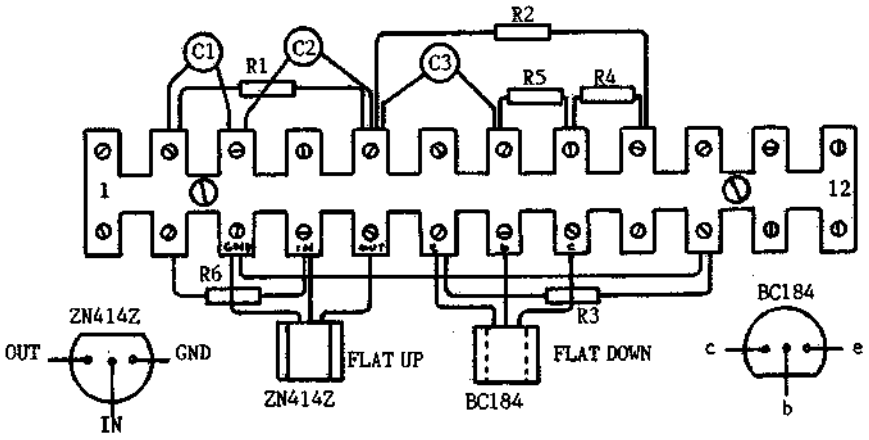

Figure 1 Terminal strip – position of components

1. Brown, Black, Yellow	100 000 ohms	(R1, R5, R6)
2. Green, Blue, Brown	560 ohms	(R2)
3. Red, Violet, Brown	270 ohms	(R3)
4. Brown, Black, Orange	10 000 ohms	(R4)

The integrated circuit (the ZN414Z) and the transistor (the BC184) *must* be connected correctly. Check Figure 1 carefully before fitting each device.

Now wind the coil. Most tubes are about 42 mm diameter and 110 mm long. Don't worry if your tube is slightly different; it shouldn't matter. Make two holes, about 3 mm apart, about 40 mm from one end, as shown in **Figure 2**. Loop your enamelled wire into one hole and out of the other, and draw about 100 mm through; loop this 100 mm through again, thus anchoring the wire firmly. Now wind on 80 turns, keeping the wire tight and the turns close together but not overlapping. After your 80th turn, make another two holes and anchor the wire in the same way as before. Again, leave about 100 mm free after anchoring. Using another piece of enamelled wire (with 100 mm ends as before), loop one end through the same two holes which contain the end anchor of the last winding, wind two turns and anchor the end of this short winding using another pair of holes. Figure 2 shows the layout.

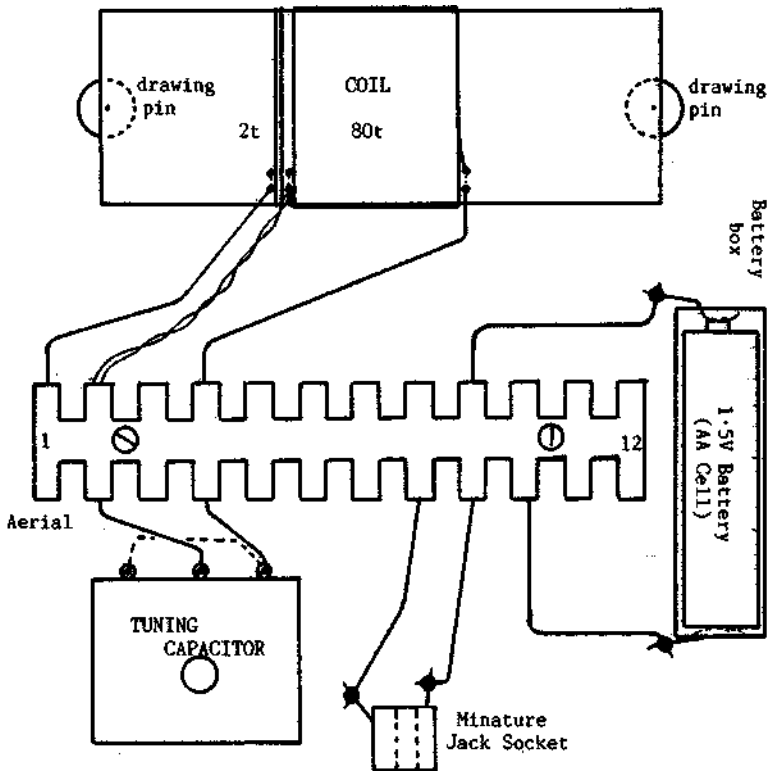

Figure 2 The layout of the parts on the wooden base

With some glass paper, remove the enamel from the ends of both pieces of wire which go through the same holes (i.e. the bottom of the large coil and the top of the small coil), then twist these bare ends together. Remove the enamel from the remaining ends of the coil. The coil is now finished!

The baseboard can be any piece of wood about 150 mm square. Fix the coil near the back edge using drawing pins and connect the wires from the coils to the terminal strip as shown in Figure 2. Using short pieces of PVC-insulated wire (and with assistance if you have never soldered before), solder one piece across the two outer tags of the variable capacitor, shown by the dotted line in Figure 2, and then two longer pieces to the centre tag and one outside tag. Connect these to the terminal strip. Then solder two more insulated wires on to the jack socket (into which you will plug your crystal earpiece), the other ends going to the terminal strip. The last two wires (one must be red) need to be soldered on to the battery box, their other ends going to the terminal strip also. Make sure the red wire goes to the *positive* terminal on the battery, and is connected to terminal 9. The other connection to the battery goes to terminal 10.

Attach the terminal strip to the baseboard with small screws or double-sided sticky tape. The other parts can be mounted the same way.

Listening is done ideally with the recommended crystal earpiece. Don't be tempted to use your Walkman earpieces; they are not the same and will not perform anything like as well. The receiver should work without an extra aerial, but one can be attached to terminal 1 if necessary. A long piece of wire mounted as high as possible is ideal. The *Audio-frequency Amplifier* project will enable you to use a loudspeaker with your receiver, using the signal from the jack socket. No circuit modifications will be needed!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R5, R6	10 kilohms (kΩ)
R2	560 ohms
R3	270 ohms
R4	10 kilohms (kΩ)

Capacitors

C1, C2, C3	100 nanofarads (nF)
	500 picofarads (pF)

Semiconductors

ZN414Z, BC184

Additional items
- 12-way 2 A terminal strip
- 22 metres of 28 SWG enamelled copper wire
- A few short pieces of coloured PVC-insulated wire
- Crystal earpiece
- 3.5 mm jack socket
- 1.5 V AA-size battery and box
- Toilet roll tube
- Double-sided sticky tape or selection of screws

Tools required

Small screwdriver, soldering iron.

2 An audio-frequency amplifier

Introduction

This simple amplifier can be built by anyone who is able to solder reasonably well. It doesn't require any setting up and, provided our instructions are followed exactly, will work very well. The circuit diagram is included for the benefit of our more advanced readers, but it is not needed in the construction process. Please practise your soldering before you start, and don't use a printed circuit board (PCB) until you are confident that your soldering is up to scratch.

The amplifier can be used with other projects; it will provide plenty of sound from the MW Radio or from the Morse Sounder projects. It will usually be built into other pieces of equipment, so a box is not supplied with the kit. There is no reason why it shouldn't be put into a box and used as a general-purpose amplifier to help test other projects.

The components

Before you start, you should check that you have *all* the components to hand. A list and some helpful hints are given below.

1. PCB. The plain side is the *component side* and the soldered side is the *track side*. **Figure 1** shows the track side full size. Make the PCB from the pattern given in Figure 1. Otherwise, build the circuit on a matrix board.
2. Three resistors. Locate the gold or silver band around the resistor, and turn the resistor until this band is to the right. There are three coloured bands at the left-hand end of the resistor. Find the resistor whose colours are YELLOW, VIOLET, RED, and look at the resistor colour code chart which you will find in Chapter 7. From this, you will see that YELLOW indicates the value 4, VIOLET the value 7, and RED the value 2. The first two colours represent real numbers, and the last value is the number of zeros (noughts) which go *after* the two numbers. So, the value is 47 with two zeros, i.e. 4700 ohms. In this way, the resistor coloured BROWN, GREY, BROWN has a value of 180 ohms, and the last one, BROWN, RED, GREEN, has a value of 1 200 000 ohms. The ohm (often written as the Greek letter omega (Ω)) is the unit of resistance. If you do not yet feel confident in identifying resistors by their colours, use the Resistor Colour Codes given in Chapter 7.
3. Four capacitors. The two small 'beads' are tantalum capacitors and will be marked 4.7 μF or 4μ7, with a '+' above one lead. A tubular capacitor with wires coming from each end should be marked 220 μF, with one end marked '+' or '–'. This is called an *axial* capacitor because the wires lie on the axis of the cylinder. This is in contrast to the final capacitor, where both wires emerge from the same end. This is a *radial* capacitor, and will be marked 47 μF. Again, one lead will be marked '+' or '–'. Capacitors marked like this are said to be *polarised*, and it is vital that these are placed on the PCB the right way round, so take notice of those signs!
4. Two diodes. These are tiny glass cylinders with a band around one end, and may be marked 1N4148; this is their type number. Like polarised capacitors, they *must* be put on the PCB the correct way round!

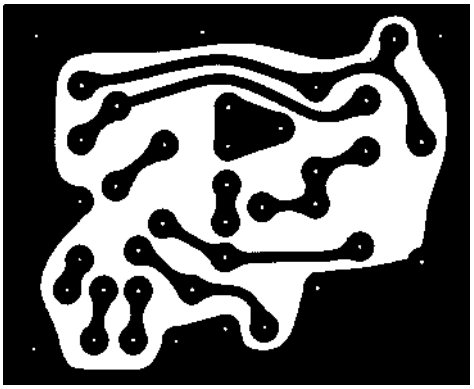

Figure 1 The toil pattern of the PCB – looking from the track side

5. Three transistors. One should be a BC548 (or a BC182), the other two should be BC558 (or BC212).
6. One volume control with internal switch.
7. One loudspeaker. This is quite fragile – don't let anything press against the cone.
8. One PP3 battery clip with red and black leads.

Putting it together

Lay the PCB on a flat, clean surface with the track side downwards. It is always useful to compare the layout with the circuit diagram, given here in **Figure 3**. Although you can't see it, the D-i-Y Radio sign should be at the top. Compare the hole positions with those shown in **Figure 2**. Bend the resistor wires at right angles to their bodies so that they fit cleanly into the holes in the PCB. Push each resistor towards the board so that it lies flat on the board. Then supporting each one, turn the board over and splay out the wires *just* enough to prevent the resistor falling out. Then, solder each wire to its pad on the PCB, and cut off the excess wire. When you have more confidence, you can cut of the excess wire *before* soldering; it often makes a tidier joint.

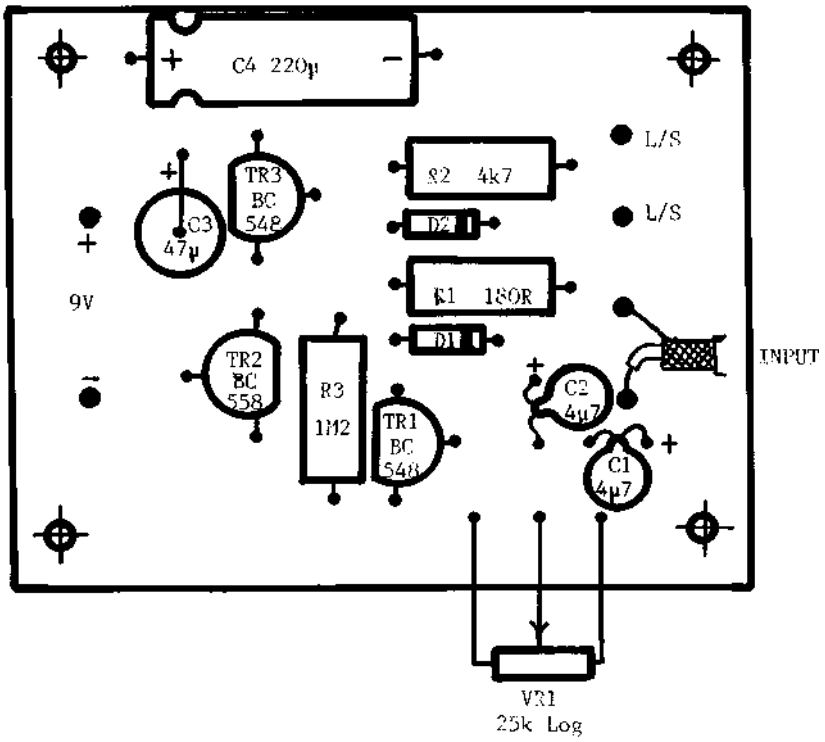

Figure 2 Positions of the components on the printed circuit board (PCB)

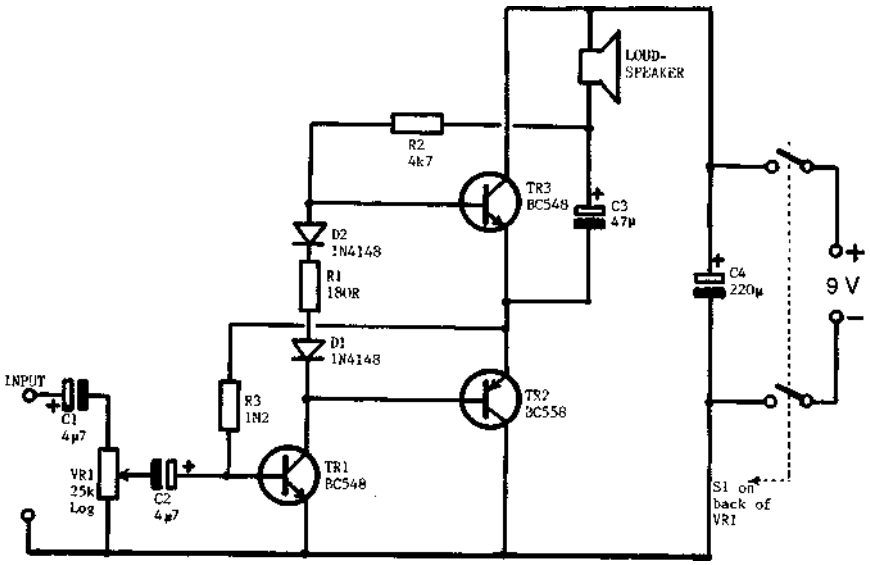

Figure 3 The amplifier's circuit diagram

Now fit the four capacitors. Each must be connected the right way round, so look at each component, match it up with the diagram of Figure 2, bend its wires carefully and repeat the soldering process you performed with the resistors, making sure that the components are close to the board and not up on stilts! Fit the two diodes the correct way round, and solder then as quickly as you can – they don't like to be fried!

Mount the transistors about 5 mm above the PCB. Make sure the correct transistors are in the correct places, and that the flats on the bodies match up with those shown in Figure 2.

Mount the volume control so that the spindle comes out from the front of the board. Use a piece of red insulated wire to the pad marked + on the PCB, and a black piece to the pad marked –, and solder these to the tags on the back of the control, as shown in **Figure 4**. Connect the two leads from the battery clip to the other tags on the switch; Figure 4 will help you. Finally, use two pieces of insulated wire about 100 mm long, twisted together, to connect the loudspeaker to the PCB.

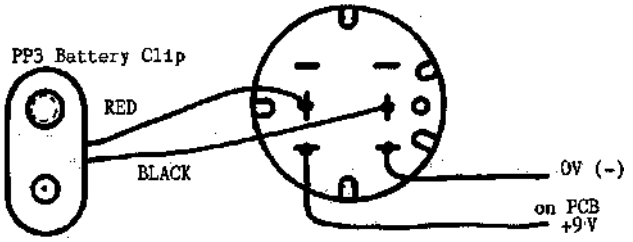

Figure 4 Connections to switch on back of VR1

Box clever!

If you wish to put the amplifier into a box, there is no problem; almost any box that is big enough will do. All that is needed is one hole big enough to accept the bush of the volume control; the PCB will be supported by the volume control. The prototype was not fitted into a box, but mounted on an odd piece of aluminium, bent into an L-shape and screwed on to a wooden base. The loudspeaker was mounted on the aluminium panel by two small pieces of aluminium with 3 mm holes drilled in them, which acted as clips around the edge of the speaker. Drill a few holes in the panel in the position of the speaker to let the sound get out!

Your input signal can be connected to the amplifier with two short pieces of wire, but if the connection needs to be long, use screened cable, with the braid connected as shown in Figure 2.

If you decide to use a different loudspeaker, make sure that its impedance (the resistance value marked on the back of the magnet) is at least 35 ohms. Anything lower may damage TR2 and TR3, and will certainly run down your battery very quickly. You will be surprised at the uses you can find for this little amplifier!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	180 ohms (Ω)
R2	4.7 kilohms (kΩ)
R3	1.2 megohms (MΩ)
VR1	25 kilohms (kΩ) log with DPST switch

Capacitors: all rated at 25 V minimum

C1, C2	4.7 microfarads (μF)
C3	47 microfarads (μF)
C4	220 microfarads (μF)

Semiconductors

TR1, TR3	BC548 npn
TR2	BC558 pnp
D1, D2	1N4148

Additional items

- PCB
- Speaker >35 ohms
- PP3 battery clip and battery

3 A medium-wave receiver using a ferrite-rod aerial

Introduction

This design came from the Norfolk Amateur Radio Club, and enables you to build a simple Amplitude Modulation (AM) receiver for frequencies between 600 kHz and 1600 kHz. It should take you around 2 hours to build, and can be used with Walkman-type earpieces. **Figure 1** shows the circuit diagram.

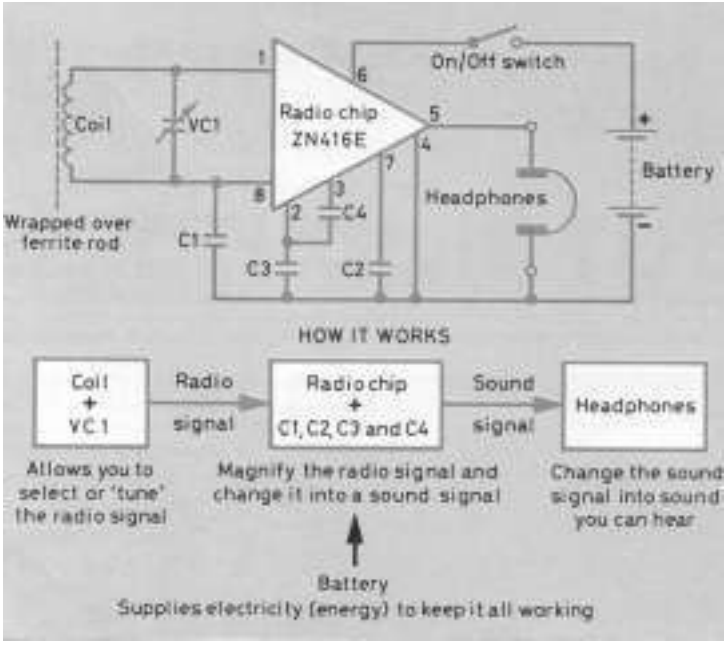

Figure 1 Circuit and block diagrams of the radio

Description

The whole circuit is built on a 50 mm by 50 mm printed circuit board (PCB) designed to fit on the inside of the lid of a plastic box, and is stuck there using sticky pads, the shaft of the variable capacitor going through a hole in

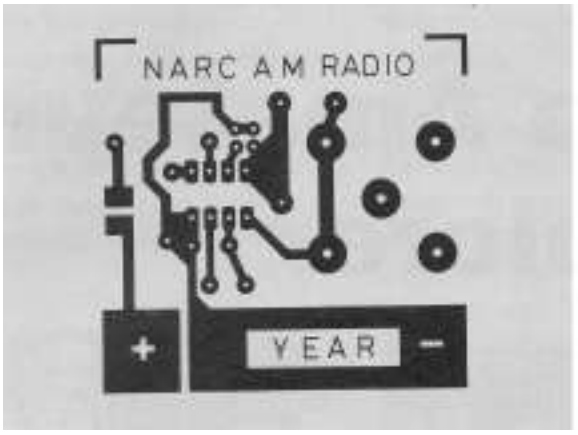

Figure 2a The PCB, solder side

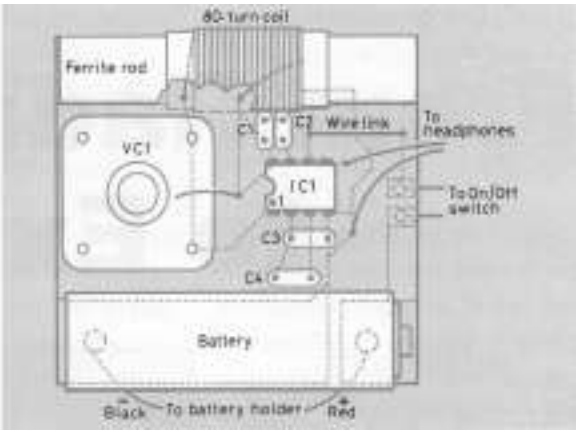

Figure 2b The PCB, component side

the lid. Only two pairs of leads are soldered to the board – one pair goes to the 1.5 V battery in its holder, and the other to the earphone socket. **Figures 2a** and **2b** show the printed circuit and the component layout double size for clarity. You are not obliged to build the circuit on a PCB.

Building it

1. **Check and identify components**. Tick the parts list.
2. **Carefully unwind the wire**. Use paper to make an insulating tube (called a 'former') around the centre of the ferrite rod and secure it with Sellotape. Now, close-wind *all* the wire (leave no gaps between adjacent turns) around the paper former. Secure the winding with more Sellotape, leaving 50 mm of wire free at each end for connection to the circuit. See **Figure 3a**.
3. **Solder in VC1**.
4. **Solder in the integrated circuit holder**. There is a notch in one end of the holder; this should face VC1. Solder also the wire link and the capacitors. Be careful to avoid solder 'bridges' between adjacent tracks on the PCB.
5. **Solder the battery leads**. These must be connected properly – the red battery lead to the + (positive) area and the black lead to the – (negative) area.
6. **Strip bare 1 cm of insulation from the ends of two wires**. Solder them between the PCB and the headphone socket (see **Figure 3b**). Use the end tabs on the socket. Using another pair of insulated wires connect the ON/OFF switch to the PCB tabs shown in Figure 2b.

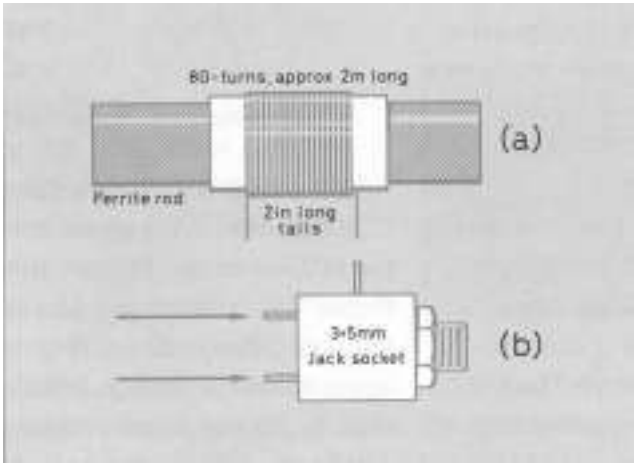

Figure 3 Details of coil and headphone socket

7. **Fix the elastic band**. This goes through the holes at the top of the PCB, with the ferrite rod being slipped through the two end loops. (Note: although the coating on the copper wire is designed to melt away during soldering, it is quite common for difficulty to be experienced in obtaining a good soldered joint; to be on the safe side, remove the coating *before* soldering (with a small piece of sandpaper).) Carefully place the wire ends of the coil through the PCB just above VC1, and solder on the track side.
8. **Fit IC1 into its holder**. This should be done carefully, making sure that *all* the pins are located above their respective clips *before* applying any pressure! Make sure also that the notch on the IC (as shown in Figure 2b) matches the notch in the holder, and faces VC1.
9. **Put battery in its holder**. Listen for some noise in the headphones as VC1 is rotated. Make sure the headphone plug is fully inserted into its socket.
10. **Fix the working board to the lid**. Use the sticky pads and apply *gentle* pressure. Fit the tuning knob, the ON/OFF switch and the earphone socket.
11. **Test again**. If all is still working, fit the lid screws and admire your completed radio!

Parts list

Capacitors

C1, C2	0.01 microfarad (μF)
C3, C4	0.1 microfarad (μF)
VC1	500 picofarads (pF)

Semiconductor

IC1	ZN416E

Additional items

- Plastic box (recommended size 76 × 64 × 50 mm internal)
- 8-pin DIL socket for IC1
- Printed circuit board
- Tuning knob for VC1
- Wire link for PCB
- 2 m of 30 SWG copper wire, self-fluxing
- Piece of paper 25 × 50 mm, to make the coil former
- Ferrite rod 70 mm long by 10 mm diameter, approximately
- Battery, AA size 1.5 V, with holder and attached wires
- Miniature earphone socket (3.5 mm stereo jack)
- ON/OFF switch (push-button SPST latched or slide switch)
- 4 off 100 mm insulated connecting wires, for jack socket and ON/OFF switch
- Pair Walkman-type earphones
- Elastic band, to attach ferrite rod to PCB
- 4 off sticky pads for securing PCB to box lid

Kits

Ready-made PCBs may be available from Alan J. Wright, G0KRU, Hewett School, Cecil Road, Norwich NR1 2PL.

4 A simple electronic organ

Introduction

This project has nothing to do with radio but, let's admit it, *any* electronics project is good experience! Why not build this little organ – it will keep the children amused at least! It uses the popular NE555 integrated circuit, which contains a circuit which will periodically switch the voltage on the output pin between the supply voltage and zero. Just how frequently this switching occurs depends upon the components external to the integrated circuit. If this switching occurs several hundred or thousand times a second, the change in voltage produced will generate a musical note when connected to a small loudspeaker. The circuit is shown in **Figure 1**.

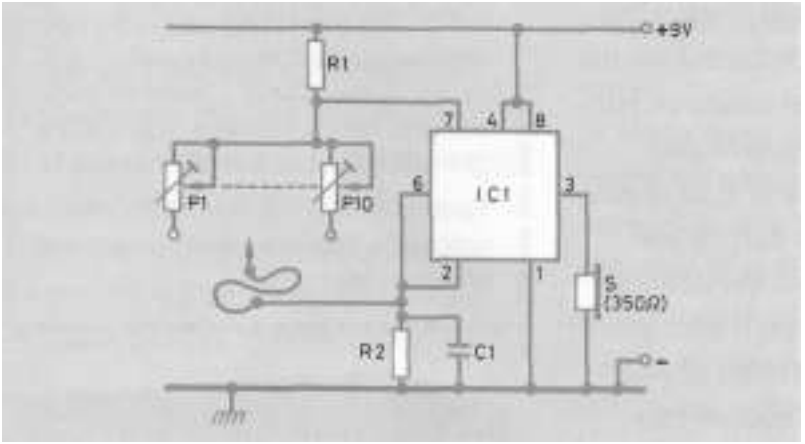

Figure 1 Circuit diagram

Putting it together

(a) Using a PCB. The job is very simple. The placement of components on the unsoldered side of the board is shown in **Figure 2** and the design on the copper track is illustrated in **Figure 3**. Put each component, in turn, on the board, making sure that it lies flat on the board with its tags or wires going cleanly through the holes provided for it; then, solder the wires to the board, cropping them before or after the soldering,

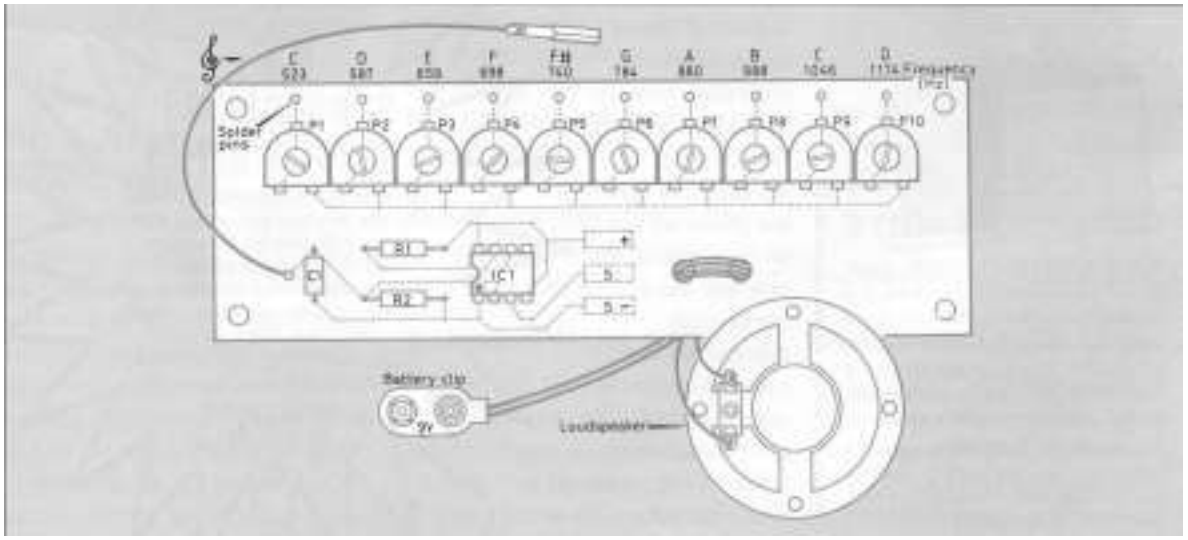

Figure 2 Position of components on the printed circuit board (PCB)

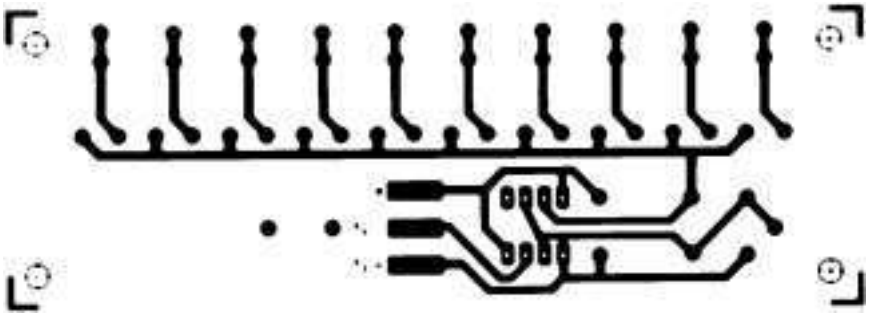

Figure 3 The connections

depending on your preference. If you choose to use a holder for your integrated circuit (highly recommended if your soldering is less than perfect), make sure that the end with a notch in it faces R1 and R2, as shown in Figure 2. Solder the two leads to the speaker to the tabs marked S (either way round), having looped them through the two holes to the right of the tabs in Figure 2. Looping them through the holes acts as a strain relief, ensuring that the soldered joints are not subjected to pulling and bending as you move the wires about. Do the same with the battery leads, the red lead going to the + tab and the negative lead to the – tab (which also has one speaker lead already attached to it). **Figure 4** shows this in detail. Treat the loudspeaker with care – the cone is quite fragile and must not be touched.

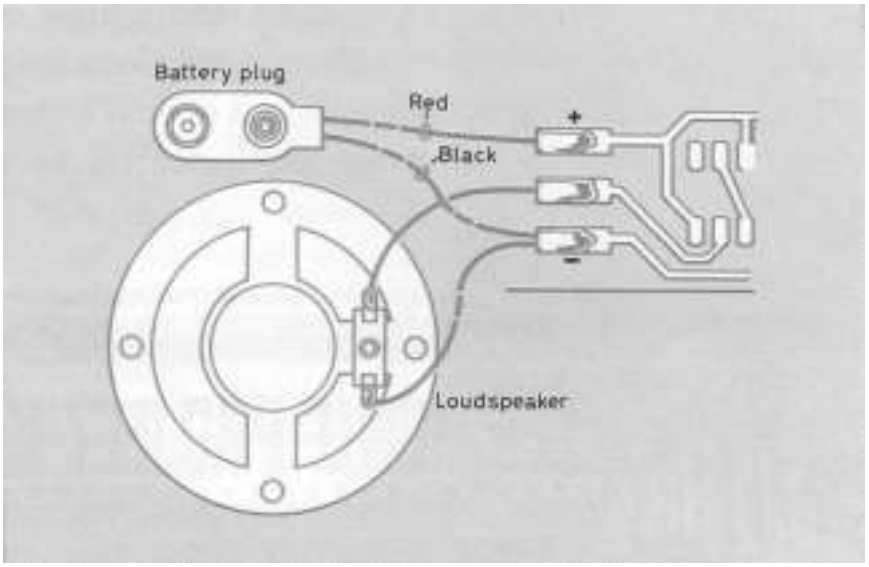

Figure 4 Battery plug and loudspeaker connections

(b) Without a PCB. This is more difficult, and you may need to enlist some help. Using some matrix board (such as Veroboard) is probably the best way of replacing the PCB. You could arrange your circuit in exactly the same way as in the PCB in Figure 3, using wires to replace the copper track.

A simple 'keyboard'

The keyboard is a row of solder pins along the rear edge of the PCB, one for each note covering the range shown in Figure 2. A flying lead with a small spade on it is provided to touch any of the pins in turn, producing any one of ten different notes.

Testing

Check first that each component is in the correct place. When inserting the NE555 chip, first make sure that the end carrying the notch lies over the end of the holder with the notch; then, make sure each pin of the chip lies directly above the hole into which it fits, before pressing *gently* to insert the chip into the socket. Make sure the battery connections are correct, and insert the battery into the clip. Nothing should happen, except for a click from the loudspeaker; touching the spade on any of the pins should produce a coarse note from the speaker. If nothing happens, check everything again; don't *assume* that wires go where you think they go!

After you get the first note, all the others should work, too, but they will sound off-tune at first. The organ needs tuning up by adjusting the 10 preset variable resistors P1 to P10. The approximate frequency to which each note should be tuned is given in Figure 2; if you can beg, borrow or steal a frequency counter, setting up is easy. If you have a piano, the organ can be tuned by comparison of the notes with those on the piano. The frequencies are given in Hertz (abbreviation Hz), and represent the number of times the IC switches on and off every second. If the sound coming from the loudspeaker is too loud or very distorted, then try putting an 330 Ω resistor (colour code orange, orange, brown) in series with the loudspeaker. This is done by taking the resistor and cutting its leads to about 5 mm; then, disconnect one speaker lead from the tab on the PCB (it doesn't matter which). Solder one end of the resistor to the vacated speaker tab, and the free speaker lead to the other end of the resistor. This will limit the volume of sound from the speaker, and lengthen the life of your battery. If it is still too loud, try a resistor of a larger value, or use a smaller resistor to make it louder.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	2.7 kilohms (kΩ)
R2	1 Megohm (MΩ)
P1–P5	Preset resistor 100 kilohms (kΩ)
P6, P7	Preset resistor 50 kilohms (kΩ)
P8	Preset resistor 25 kilohms (kΩ)
P9, P10	Preset resistor 10 kilohms (kΩ)

Capacitor

C1	100 nanofarads (nF) or 0.1 microfarad (μF)

Integrated circuit

IC1	NE555 timer chip

Additional items

S	Loudspeaker >60 ohms (Maplin)
	1 off battery clip (for PP3 battery)
	1 off spade terminal
	12 off solder pins 'Veropins'
	3 off 10 cm lengths of 'hook-up' wire

(This article is based on projects originally designed by Radio Scouting, Netherlands.)

5 Experiments with the NE555 timer

Introduction

Several of the projects in this book use the NE555 timer, an integrated circuit which is at the heart of many circuits whose processes are determined by time intervals. **Figure 1** shows the circuit diagram of an audio oscillator using the 555. The timing voltages (governing the frequency of oscillation) are produced by R1, R2 and C2; a voltage appears at pin 3 which 'switches' at this frequency between zero and a voltage close to the supply voltage, which in this case can be anywhere between 6 V and 14 V. The output current, when applied through R3 to a small loudspeaker, produces an audible tone, provided that there is a DC path between the two test leads.

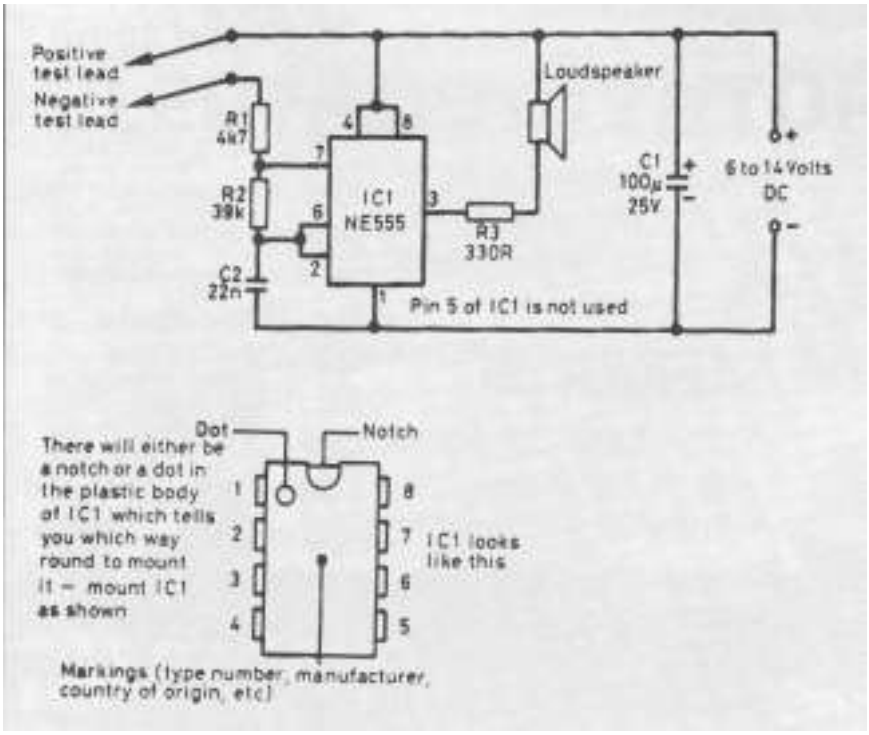

Figure 1 The circuit diagram

Construction

The simplest way to mount the components is on a piece of matrix board (Veroboard), available from any of the good suppliers. The prototype of this circuit used the type of board with copper strips along the underside; these strips are used like the copper tracks on a PCB, to join components together. Firstly, cut the four strips between the positions of the pins of the IC socket, as shown in **Figure 2**. You can buy a tool for this purpose, but a small twist drill (about 3 mm diameter) is just as good. Turn it between your fingers – if you use a drill you will end up with holes right through the board! Then solder in the IC socket (with the notch in the position shown), followed by the four links made with single-conductor insulated wire. Put in each component as shown, ensuring that C1 (an *electrolytic* or *polarised* capacitor) is connected correctly. When all the components have been soldered in, take the *555* chip and lay it on its socket, with its own notch lying above that of the holder. Then, making sure that each pin lies *directly* above its corresponding socket, press down *gently* on the chip, with the board supported on a flat surface.

Testing

Connect the circuit to a battery or small power supply, ensuring that the positive and negative leads are the right way round. Always use red and black leads here, then you are less likely to get it wrong! Switch on. Nothing

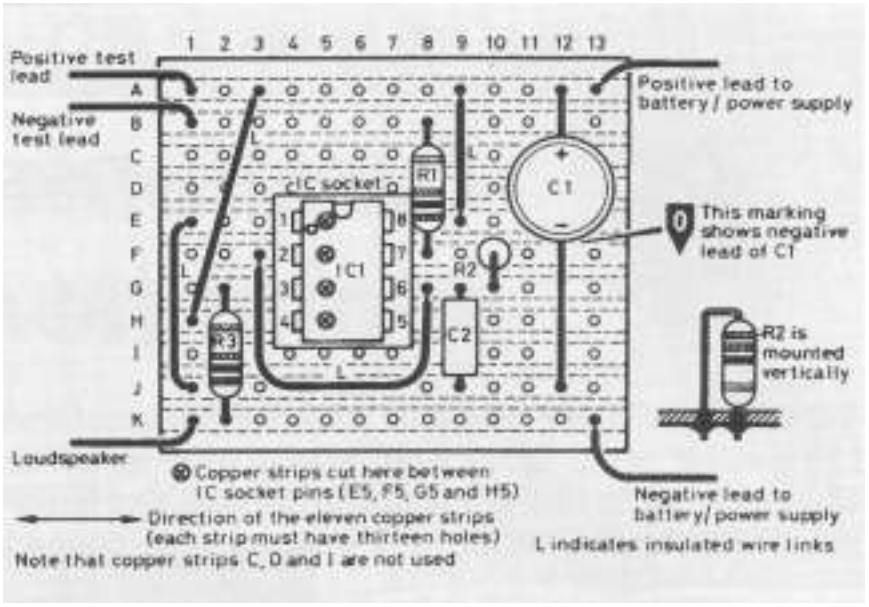

Figure 2 Veroboard layout. If you can read a circuit diagram, the project can be built using other methods

should happen until you short together the two test leads, when there should be a note from the loudspeaker. If this doesn't happen, switch off, disconnect the circuit and check your wiring and soldering. Is it exactly like Figure 2? Are the soldered joints round and shiny? If any are dull, then 'sweat' them briefly with a hot soldering iron until the solder runs, remove the iron, and check that they are as shiny as the rest. Check that there are no solder 'bridges' between adjacent tracks by holding your board up to a strong light. Then, reconnect, switch on and touch the test leads together. All should now work!

Uses of your circuit

1. As a Morse practice oscillator. Simply connect the two test leads to your key and, each time the key is pressed, you should hear a note from the speaker. The frequency of the note may be altered by putting a resistor in series with the key. To do this, remove one test lead from the key and select a resistor; connect one end of the resistor to the free test lead and the other to the empty terminal on your key. Selecting the value of resistor that you need will be a useful experiment in itself.
2. As a continuity tester. You can check fuses and lamp bulbs by connecting them across your test leads. If the speaker remains silent, the fuse or bulb has blown.
3. To indicate changes of resistance. Hold the ends of the test leads in each hand; you should hear a low note, because of the high resistance of your body. Squeeze the ends harder, and the frequency of the note should rise, because you are now making better contact. Repeat this with damp hands and the frequencies will be higher still.
4. As a thermometer. Connect the test leads to a thermistor (a device whose resistance changes with temperature) and warm it with a hair-dryer, or even in your hands, and you will hear the pitch changing with the temperature of the thermistor. A suitable 'bead' thermistor is available from Maplin (order code FX21).
5. As a diode tester. Use any diode, and connect the negative test lead to the end of the diode marked with the ring. This is the cathode of the diode. The other end, the anode, should be connected to the positive test lead, and a note should be heard from the speaker. This does not necessarily mean that the diode is working – yet. Reverse the connections and *nothing* should be heard. If this is the case, the diode *is* working.
6. As a light meter. Use a photoconductive cell (a device whose resistance changes with light intensity) connected between the test leads. A note should be heard. Shading the device with your hand will increase its resistance and the note should decrease in frequency. A suitable device is the ORP12 cell from Maplin (order code HB10).

There are many more applications. **Do not connect the test leads to other circuits that are switched on**. Your circuit, or the circuit you are connecting

it to could be damaged. Think of a *passive* device or circuit (i.e. one *not* requiring a power supply or battery) where changes of resistance occur, and you have found another application!

Parts list

Resistors: all 0.25 watt carbon film types

R1	4.7 kilohms (kΩ) – yellow, violet, red
R2	39 kilohms (kΩ) – orange, white, orange
R3	330 ohms (Ω) – orange, orange, brown

Capacitors

C1	100 microfarads (μF) 25 V radial electrolytic
C2	22 nanofarads (nF) or 0.022 microfarad (μF) polyester type with 10 mm lead spacing

Integrated circuit

IC1	NE555

Additional items

- Miniature loudspeaker (preferably 35, 40 or 80 ohm)
- 8-pin DIL socket for IC1
- 0.1 inch Veroboard ('stripboard'), size 11 strips by 13 holes
- PVC-covered stranded wire for test leads, loudspeaker and battery connections
- PVC-covered solid wire for links on the board
- A power source of between 6 V and 14 V, such as a 9 V battery (PP3)

Component sources

Cirkit
Tandy – many high street shops

6 A simple metronome

Introduction

A metronome is a device used by musicians to indicate the tempo of a piece of music. Until electronics came on the scene, this 'beating of time' was achieved in much the same way as a clock keeps time, i.e. with a pendulum device, the clicking of the escapement indicating the beats of the music.

Those of you who have already built the Morse Key and Buzzer from the designs in this book, will recognise the circuit of this metronome – it is exactly the same as was used to produce the note of the buzzer. This circuit is shown in **Figure 1**.

The circuit

Three components determine the speed at which the circuit oscillates – the speaker (LS), the resistors (VR1 + R1) and the capacitor (C1). VR1 is a variable resistor, so that the speed at which the oscillator operates can be varied. Compared with the component values of the Morse Buzzer (which operated at around 800 Hz), these components now give an oscillation frequency of around 1.25 Hz, which is far too low to be heard as a note. What we *do* hear, however, is a series of clicks, as the voltage across the speaker changes quickly from 0 to 9 V and back again.

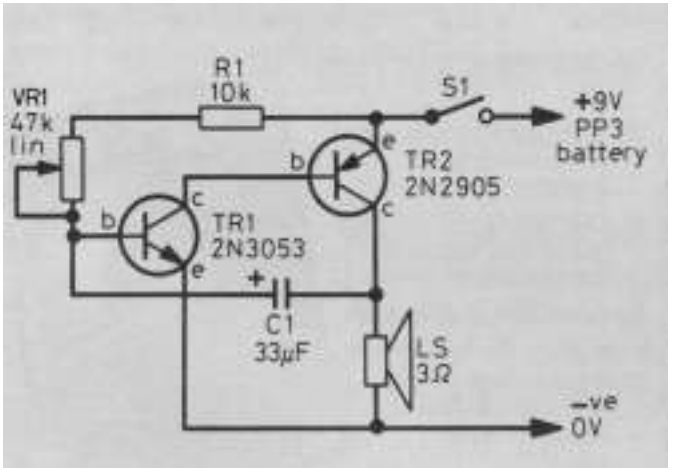

Figure 1 The metronome circuit is rather like the Morse oscillator

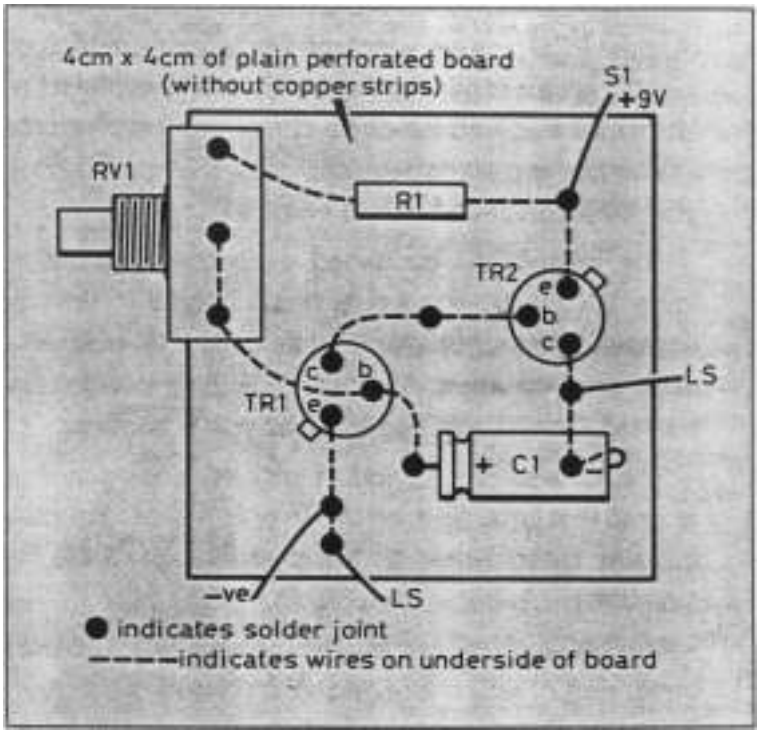

Figure 2 The component wires are pushed through holes in the circuit board and joined together underneath

Variation of speed could be achieved by varying resistance or capacitance. However, as you may already know, variable capacitors have values in the picofarad range, not the tens of microfarads used here, so it is very simple to employ a variable resistor (potentiometer) to control the oscillator. You could use a multi-way switch to switch in one of several capacitors, as well as having the variable resistor, but this was found to be an unnecessary complication. This design operates between about 100 clicks per minute and 200 clicks per minute.

Making the prototype

A single piece of plain matrix board (no copper strips) measuring about 40 × 40 mm is sufficient to hold all the components except the potentiometer and switch (see later). The case can be plastic or aluminium, and one measuring 65 × 100 × 50 mm is about right. Make sure there are holes in the case beside the speaker cone to let the sound out, and larger holes for the potentiometer and switch. If a potentiometer is used with a combined ON/OFF switch, then the extra hole for the switch is not necessary! It is advisable to construct the circuit *before* putting it in the

box, so that it can be tested to ensure that everything is working. If it is, then you can exercise your ingenuity in mounting the speaker, battery and board inside the box. A final test can be made before starting the calibration process.

Calibration

There is no 'easy' way to do this. The frequencies involved are too low to be measured with the average frequency counter, so you will need to resort to using a stopwatch and counting the number of clicks per minute.

Parts list

Resistors: 0.25 watt, 5% tolerance

R1	10 kilohms (kΩ)	
VR1	47 kilohms (kΩ) linear potentiometer	

Capacitor

C1	33 microfarads (μF) electrolytic	

Transistors

TR1	2N3053	npn
TR2	2N2905	pnp

Additional items

S1	SPST	ON/OFF switch
LS	3 ohms (Ω)	loudspeaker
	Knob with pointer for VR1	
	PP3 battery and connector	
	Aluminium case, 65 × 100 × 50 mm	
	Matrix board (plain), 40 × 40 mm	

7 What is a resistor?

Introduction

Materials that carry electricity easily are called **conductors**. They include all metals and salt water, for example. We use wire as a conductor, and the ease with which it passes an electric current depends upon the material, its thickness and its length. Silver (symbol Ag), gold (Au), copper (Cu) and aluminium (Al) are the best metallic conductors. Most wires are made of copper, although the best conductor, weight for weight, is aluminium.

Materials that *don't* carry current (or, at least, do so very badly) are called **insulators**, and they include dry wood, rubber, plastic and glass among their number. Wires are often coated with a layer of insulator to prevent adjacent wires touching and causing an accident.

Resistors

If there wasn't such a thing as resistance, the subject of electronics wouldn't exist; only infinite currents would flow and voltages wouldn't exist either! We need to reduce the flow of current if we are to make current do something useful for us. Components that resist the flow of current are called **resistors**, and they are said to have a **resistance** which is measured in ohms (Ω), named after Georg Ohm, who formulated the law (also named after him) by which the voltage and current through a conductor are related. His law gave rise to the formula *everyone* remembers:

$$I = \frac{V}{R},$$

where I is the current flowing, measured in amps,
V is the voltage across the conductor, and
R is the resistance of the conductor, measured in ohms.

From this equation, you can see that, for a constant value of voltage, V, if the resistance goes up, the current will go down, and vice versa. The circuit symbols for resistors are shown in **Figure 1**. You will find the upper symbol in older magazines; it is still preferred by many engineers. The lower symbol is the prevalent standard symbol.

Resistors are made in several ways, the cheapest using carbon; another type is usually made from a ceramic cylinder (used only as a support) on which

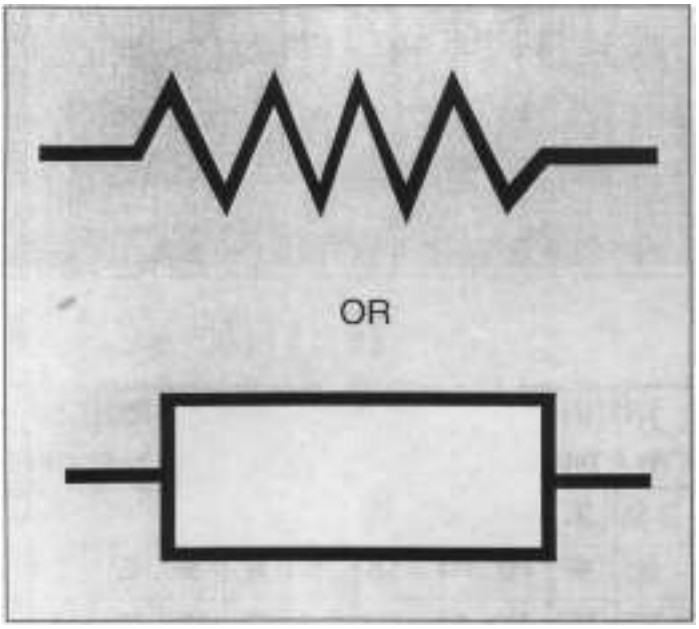

Figure 1 Circuit symbols for resistors

is placed a very thin film of metal – the thinner the film, the greater the resistance. All resistors are coated with a thin film of insulation, for the same reason we discussed earlier.

The colour code

Each resistor has coloured bands on it which enable us to see what value of resistance it has. There are normally three (but sometimes four) at one end, and a single one at the other (see **Figure 2**). The colours indicate figures, according to the list below.

Colour	*Value*	*Colour*	*Value*
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

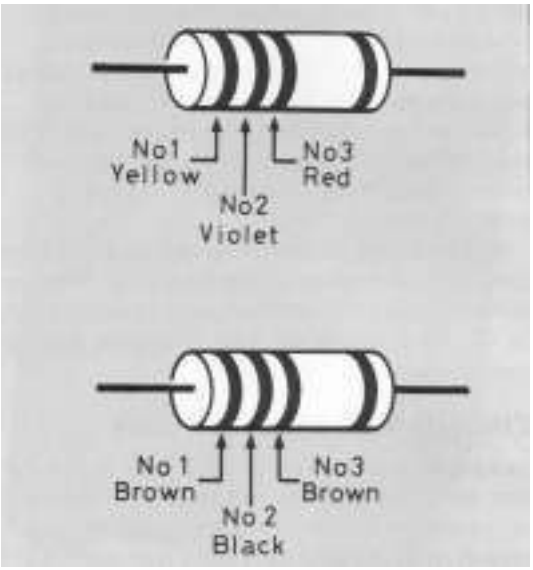

Figure 2 Some examples of resistor colour codes; top 4700 Ω (4.7 kΩ) and bottom 100 Ω

Using the colour codes is easy, once you see the logic behind it. Hold the resistor so that the single band is towards the right. The three colours on the left are read in the normal order from left to right. The first two bands *always* indicate numbers; the third band gives the number of zeros to add to the right of these two numbers. So, looking at the top resistor in Figure 2, yellow, violet, red means 4, 7, and two zeros, giving 4700 ohms! Looking at the lower resistor, brown, black, brown means 1, 0, and one zero, giving 100 ohms.

Remembering the order of the colours may be difficult at first. The colours from red to violet are the colours of the rainbow, in order, so if you know those, you're almost there! Around those colours are black and brown below the red, and grey and white above the violet, which you can imagine as getting brighter from black to white (well, almost!). It won't be long before you don't need to remember them at all.

The isolated band on the right-hand side is not part of the resistor's value; it indicates its *tolerance*, i.e. how close it might be to the indicated value. A brown band indicates ±1%, a red band ±2%, a gold band ±5% and a silver band ±10%. For example, a resistor marked as being 100 ohms with a ±5% tolerance will have an *actual* value somewhere between 95 ohms and 105 ohms.

8 Waves – Part 1

Introduction

Waves are responsible for most of the processes in life where energy is transferred from one place to another. Heat and light energy from the sun, for example, come to us as *electromagnetic waves*. Sound travels through the air as a wave; it is not the same sort of wave as light or heat, but it obeys many of the same properties. Damage is caused to coastal margins by the waves of the sea – again, another type of wave, but still obeying many of the same properties. Radio waves are of the same type as heat and light waves, as are gamma rays, X-rays, ultra-violet waves and infra-red waves. So, once we begin to understand what radio waves do, we are also learning about a huge chunk of physics at the same time! All these waves are part of the *electromagnetic spectrum*. The word 'spectrum' simply means a 'range', so what we have is a range of electromagnetic waves – that's all!

Sensing things

Light waves are invisible, but our eyes can detect the *effect* they have on different materials because the waves produce an effect on the retina of the human eye which the brain can interpret. We cannot see heat waves either, but we can feel the *effect* they have on our skin. Gamma rays and X-rays are also invisible, but their detrimental *effects* on human tissue are well known. It is not surprising, then, that we cannot see radio waves. We cannot sense them, either, until we produce a device upon which they have an *effect*. That device is a **radio receiver**; it is able to process certain characteristics of radio waves, and make these characteristics audible by generating sound waves from the loudspeaker or headphones. Other characteristics of the same waves may be turned into light as a TV picture on a cathode-ray tube, or as a fax image on a sheet of paper.

Visible waves

Let's start our description with some waves that we can actually see! When a small stone is thrown into a pond, we see circular water waves *radiating* from the point where the stone fell into the water, as **Figure 1** shows. (Notice that we use the word *radiating*, even with water waves; it is not a radio term, but one which describes any motion where the *radius* of a circle is increasing. In this case, it is the radius of the circular waves which is

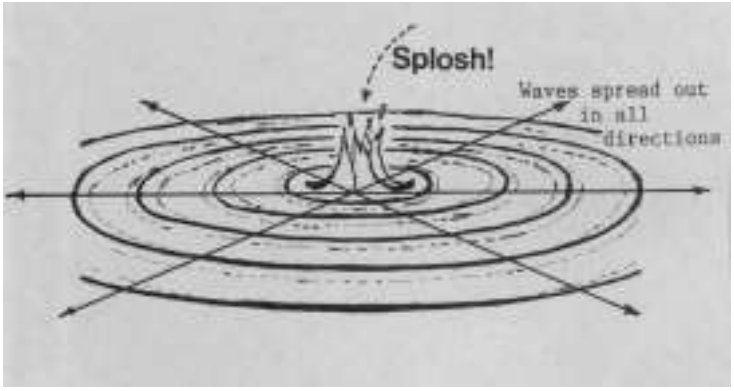

Figure 1 The waves move out from the point where the stone landed

increasing.) If you were to watch the water waves down at the water level, perpendicular to the direction in which they are travelling, you would see something like the illustration in **Figure 2**.

The horizontal line represents the water level before the wave started, and the vertical line represents the direction in which the water is displaced at any instant.

All waves are described in the same way

'Freezing' the motion of the water in this way allows us to define two very important characteristics of a wave, characteristics which we talk about every day – *wavelength* and *amplitude*. The wavelength of a wave is simply the distance (measured in metres) from any point on one wave to the same point on the adjacent wave. Look at the diagram and you will see what is meant by 'the same point on the adjacent wave'. The amplitude of a wave

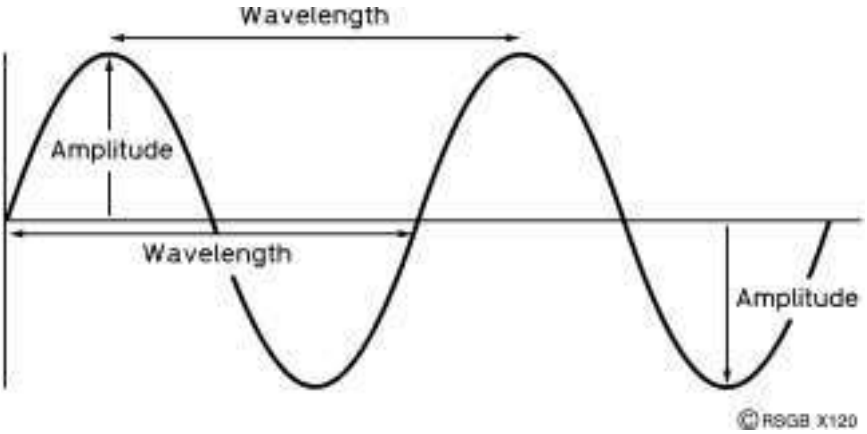

Figure 2 A water wave, viewed in cross-section

is always measured from the centre (undisturbed) position of a wave to the peak (or the trough) of the wave. Both these positions are shown, the arrow indicating that the measurement is taken *from* the centre *to* the peak or trough. The amplitude of a wave is defined as the maximum displacement of the wave from the centre position – the direction (up or down) of that displacement does not matter. Waves of greater amplitude carry more energy with them.

If we now 'unfreeze' the wave, we will see it travel from left to right (or right to left, depending on where we are looking). The speed at which it moves is called its *velocity*, and is measured in metres per second.

Another useful word is *propagate*; it means *travel*. We talk about radio waves propagating from a transmitter to a receiver. This velocity of propagation (for electromagnetic waves) is very fast indeed – they will cover 300 million metres in one second. This is virtually incomprehensible, so think of a radio wave travelling around the earth – it can travel 7½ times round the earth in one second! We use the symbol c for the velocity of radio waves (which is the same as the velocity of light, of course – all electromagnetic waves travel at this speed through air and space).

The last thing we need to know about the wave is its *frequency*. Imagine a cork floating on the water in the path of the wave; it will bob up and down. If we were able to count the number of times it went through its highest position in one second, then that number would be its frequency. Any periodic motion like this is said to go through one *cycle* each time one complete wave passes a point (in this case, our cork). We are thus counting the number of cycles per second of the cork's motion. The unit of frequency is thus 'cycles per second'; this unit is now named after Hertz, a radio pioneer, and is abbreviated to Hz.

Our description of the wave is now quite simple – we need only four quantities:

(a) **Frequency** symbol f – unit, hertz (Hz)
(b) **Wavelength** symbol λ (Greek letter lambda, pronounced 'lamb-da') – unit, metre (m)
(c) **Amplitude** symbol a – unit depends on application
(d) **Velocity** symbol c – unit, metres per second (m/s or ms^{-1})

The basic formula

Whatever may happen to a wave while it travels through different media (vacuum, air, brick, wood, etc.), one thing and **only** one thing remains constant – its frequency. Its wavelength, amplitude *and* velocity may change, but its frequency never does. Three of the four characteristics already identified are connected by the simple relationship

$$c = f \times \lambda.$$

Remember that *c* is constant if the wave travels in air or in a vacuum. This means that waves having higher frequencies (*f* large) must have smaller wavelengths (λ small) and vice versa. You can imagine frequency and wavelengths being on opposite ends of a see-saw!

Divisions of units

Because the frequencies of radio waves are so high (despite them having the lowest frequencies in the electromagnetic spectrum!) we have a problem with writing them down. Do you write in your log book that you have just heard a station on 14 100 000 Hz? Of course not, you write it as 14.1 MHz, knowing that the prefix mega (M) means 'one million'. The prefixes which you need to know (when applied to frequency) are:

kHz	kilohertz	meaning	1000 Hz
MHz	megahertz	meaning	1 000 000 Hz
GHz	gigahertz	meaning	1 000 000 000 Hz.

Notice that the 'k' in kilohertz is a lower case letter. It is **incorrect** to write it as an upper case letter. 'K' is a computer-related prefix meaning **not** 1 000 but 1 024!

When we come on to discuss heat and light waves, we will use wavelengths rather than frequencies, because of the see-saw effect – as the frequencies get larger and larger, the wavelengths get smaller, and hence are numbers which are more manageable, both to talk about and to write down!

Bands

Gamma rays, X-rays, ultra-violet waves, light waves, infra-red waves are all part of the electromagnetic spectrum, but we divide them up because they have different properties. This is why we divide up our radio frequencies into different bands. The radio waves of top-band signals (around 2 MHz) have completely different properties compared with those in the 20 metre band, so we are dividing up the *radio spectrum* in the same way – by property.

9 A beat-frequency oscillator

Introduction

Many readers will know that, although they have a short-wave radio which covers at least one of the amateur bands (e.g. 7 MHz or 14 MHz), they are unable to listen to SSB or Morse signals. This is because the receiver lacks a Beat-Frequency Oscillator (BFO). We need the 'carrier' frequency of a BFO to replace the carrier that has been removed from the signal at the transmitter. When listening to Morse signals, the BFO signal 'beats' with the incoming signal to produce a note in the loudspeaker. If you are a musician, you will be familiar with the method of using 'beats' to tune one musical instrument from another; in the BFO, the beat frequency produced is the tone signal you hear.

In the more complex amateur radio receiver, a BFO is incorporated as part of the whole system. In our model, it is an external circuit that sits alongside your radio. The circuit diagram is shown in **Figure 1**.

Construction

Built on a small piece of matrix board about 80 × 50 mm, the circuit can be fitted inside a small plastic box. For once, we *don't* want to screen the circuit to prevent it interfering with other equipment; we *want* it to interact

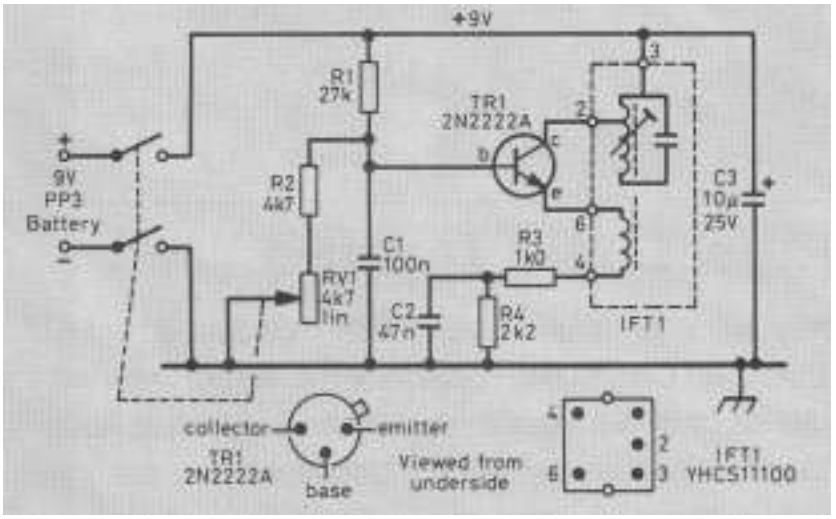

Figure 1 Circuit diagram of the BFO

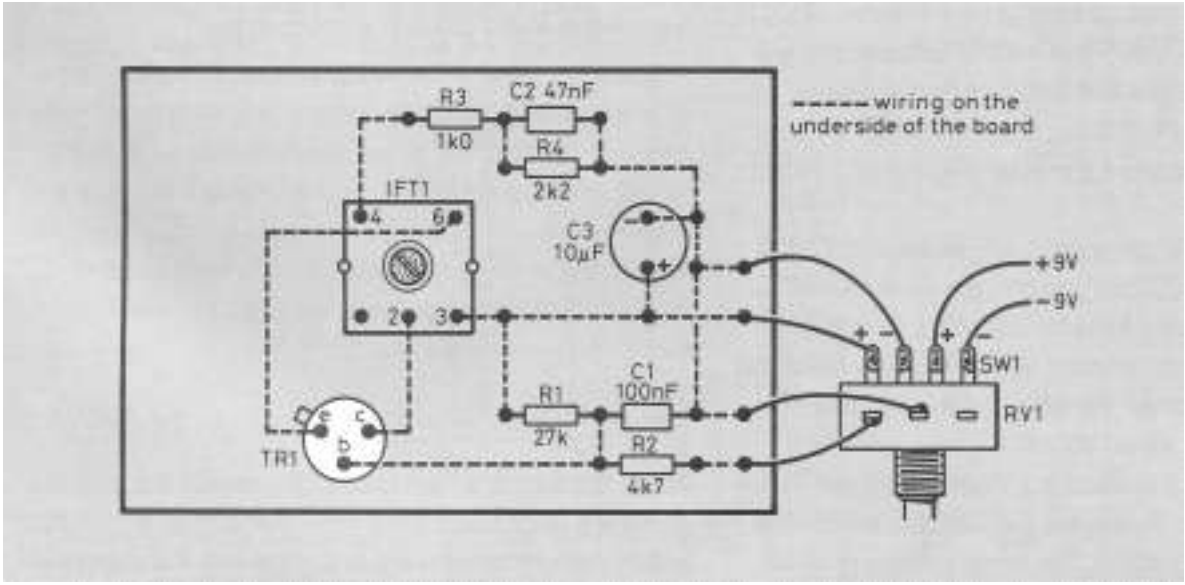

Figure 2 Matrix board layout shown from the component side. Adjust IFT1 carefully for the best results

with our receiver! This is why we use a plastic box. Maplin Electronic Components supply a suitable box, complete with the matrix board to fit inside (order code YU46).

Look at **Figure 2** carefully before you start to build the circuit, so that you can position the components correctly. Firstly, inspect the intermediate frequency (IF) transformer, IFT1, and remove its metal screening can very carefully. Again, this is to allow some signal to escape from our circuit and enter our radio. Having done this, solder the components, using the matrix board as a support. Underneath the board, the components are linked by single-conductor, insulated wire. Take particular care with the polarity of the electrolytic capacitor, C3, and the connections to the transistor, TR1 (see Figure 1).

The variable resistor, VR1, has a switch mounted behind the control itself, and the insulated leads to it from the battery should be about 10 cm long. Connect these before fitting VR1 into the case, so that the BFO can be calibrated (adjusted) correctly.

Calibration

After a final check that all the components have been fitted and soldered correctly, connect the battery, switch on, and hold the transistor between your fingers, to check that it is not getting hot. Place the circuit close to your

receiver, and set RV1 to mid-position. Tune your receiver to find an amateur SSB transmission; the frequencies listed below will help you in knowing where to look. It may sound very strange, but don't worry. *Slowly* turn the core of IFT1 with a small, non-metallic screwdriver or with the correct 'trimming tool'. The core into which the blade fits is very fragile, so attempt this process with care. When the speech sounds as natural as you can get it, leave the core at this position, and use RV1 to make the speech sound natural.

Using the BFO

For best results, you may have to move the BFO nearer or further away from your radio. At the lower end of most bands (for instance just above 7.000 MHz or 14.000 MHz) you should be able to resolve Morse code (CW) signals. If you find that the BFO signal is a little weak, solder a 15 cm length of insulated wire to pin 2 of IFT1, and place it alongside your radio. This should improve signal intelligibility. When you are happy with the performance, switch off, drill a 10.5 mm hole in the box and fit RV1, followed by the matrix board assembly. Screw the base to the box, fit the knob, and the BFO is complete!

Where to listen

Band	**Frequencies (MHz)**
15 m	21.000–21.450
17 m	18.068–18.168
20 m	14.000–14.350
30 m	10.100–10.150
40 m	7.000–7.100
80 m	3.500–3.800

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	27 kilohms (kΩ)
R2	4.7 kilohms (kΩ)
R3	1 kilohm (kΩ)
R4	2.2 kilohms (kΩ)
VR1	4.7 kilohms (kΩ), linear, with DPST switch

Capacitors

C1	100 nanofarads (nF) or 0.1 microfarad (μF), ceramic
C2	47 nanofarads (nF) or 0.047 microfarad (μF), ceramic
C3	10 microfarads (μF), 25 V radial, electrolytic

Additional items	
TR1	2N2222A npn
IFT1	Toko type YHCS11100
Box	plastic, approximate size 100 × 70 × 45 mm
Board	matrix, to fit inside the box
Connector	for PP3 battery
Knob	for RV1

10 What is a capacitor?

Introduction

A capacitor is a device that stores energy in the form of electricity. Much less energy than a battery, and for a shorter time, however. The simplest form of capacitor takes the form of two flat metal sheets separated by air; connections are made to each plate, as **Figure 1** shows. If you imagine a pair of these plates, 30 cm square and separated from each other in air by 1 mm, the capacitance of this device would be almost exactly 80 picofarads (pF), i.e. 80 million-millionths of the unit of capacitance, the farad. Now this is quite a small value, you will agree, and it comes about because the farad is such a large unit. Nevertheless, as you will probably know, we may have capacitors of value 10 000 microfarads (μF) in our radio equipment, and they can be smaller than your little finger, so they are obviously not made the same way!

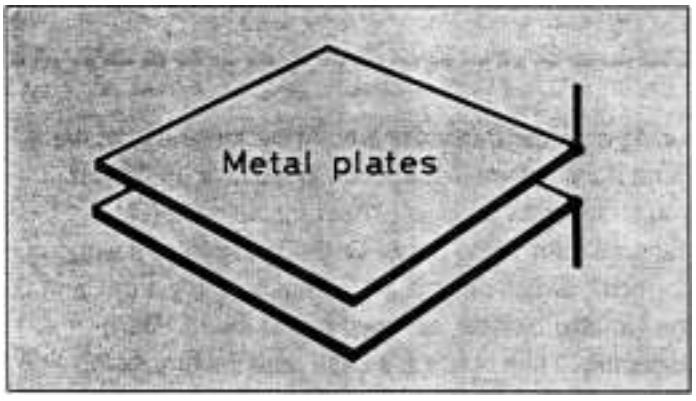

Figure 1

Large and small

We cannot go into the manufacture of capacitors here – after all, we are users of the devices, not the designers! First of all, beware of incorrect statements; the words 'capacitor' and 'capacitance' are *not* the same. For example, a large capacitor would be a description of one the size of a toilet roll. It need not have as large a capacitance as one the size of your little finger. A 'large capacitor' is one which is physically *big*, a 'large capacitance' refers to a capacitor which can store a larger amount of energy when a certain voltage is applied between its plates. The capacitors in a mains power supply are usually big **and** have large capacitances. High-power RF amplifiers may have large capacitors with small capacitances!

Electrolytics . . .

Electrolytic capacitors usually have capacitances of 1 μF or above. They differ from other capacitors in that they **must** be connected the right way round (i.e. they have positive and negative connections, just like a battery). They may explode if the connections are reversed!

. . . and the others

Other capacitors may be connected either way round, despite their names. We have *polystyrene*, *ceramic*, *silver-mica* and *tantalum*. Each has its own advantages and disadvantages, and the parts list for a project will always tell you which type is best.

Storing energy

If you were to connect a large capacitance across a 12 V power supply, nothing would appear to happen. Removing the capacitor from the supply and connecting it to a voltmeter would show that the capacitor has 12 V between its ends. This shows that, while the capacitor was connected to the supply, energy flowed from the supply into the capacitor. We say that the capacitor was *charged up* by the supply. If you are using an *analogue* voltmeter (i.e. one with a meter and pointer), you will notice that the indicated voltage slowly drops until, eventually, there is no voltage across the capacitor. This is because the capacitor has *discharged* its energy into the voltmeter. If you had used a smaller capacitance, the same would happen, except that the voltage would drop to zero more quickly – the capacitor stores a smaller amount of energy because its capacitance is smaller. Capacitors behave like other things in life – a small car can move more quickly than a large bus – a small piccolo emits a

higher note than a flute – the voltages in a circuit containing a small capacitance will change more quickly than those in a circuit with large capacitance.

Varying the capacitance

Some capacitors are capable of having their capacitance changed manually; these are called *variable capacitors*. They work like the basic capacitor of Figure 1. Imagine moving the top plate of the pair a little to one side; the capacitance is determined, not just by the size of the two plates, but by their *area of overlap*. As this decreases, so does the capacitance. Such devices are limited in their capacitance, about 500 pF being the maximum value.

AC and DC

Because the plates of a capacitor do not touch each other, a direct current (DC) cannot pass between them. However, an alternating voltage on one plate can induce an identical alternating voltage on the opposite plate, and thus a capacitor appears to pass an alternating signal, even though currents as such, do not pass between the plates. This property of passing AC and not DC is very important, and a capacitor used in this way is called a *DC blocking capacitor* or, simply, a *blocking capacitor.* A blocking capacitor can be used at the same time, to couple a signal from one circuit to the next; here it would be known as a *coupling capacitor. Decoupling capacitors* are to be found where the capacitor is employed to remove an AC signal while retaining a DC component.

Finally. . .

Unlike resistors, the manufacture of capacitors renders them susceptible to excess voltage, so if you find a capacitor labelled 10 μF 16 V, it means that operating it above 16 V may fatally damage the device (and the circuit around it). This voltage is called the *working voltage* of the capacitor; on some electrolytics, you may find it expressed as *volts working* (i.e. 8 μF 450 V WKG).

Many smaller capacitors have their properties marked on them in a colour code, like resistors. **Figure 2** shows these codes, and their meaning, and the table below summarises the values of the colours.

Table 1

Colour	*Value*	*Voltage (tantalum capacitor)*	*Voltage (polyester capacitor)*
Black	0	10	–
Brown	1	–	100
Red	2	–	250
Orange	3	–	–
Yellow	4	6.3	400
Green	5	16	–
Blue	6	20	–
Violet	7	–	–
Grey	8	25	–
White	9	3	–

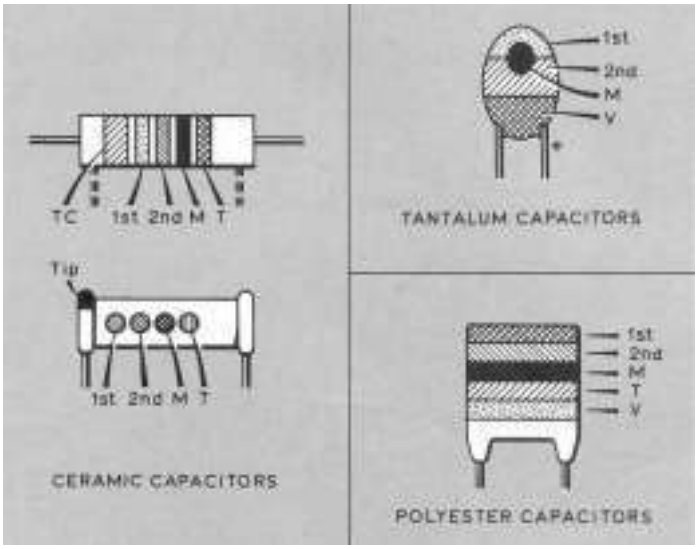

Figure 2 Some capacitors have coloured bands or stripes, rather like resistors. The colour code, which is the same as the resistor code, is shown in Table 1. The band shown on the chart as '1st' is the first number of the capacitor's value in pico-Farads, '2nd' is the second number and 'M' is the Multiplier or number of noughts. For example, a capacitor reads from the top: Brown, Black, Yellow, Black, Red. Its value is One, then Nought, then Four more noughts = 100 000 pF (also referred to as 0.1 μF or 100 nF). Its tolerance (Black) is 20% and the working voltage (Red) is 250 V. The 'V' means the maximum working voltage. The band marked 'T' shows the tolerance, just like resistors, and the one marked 'TC' is only used on special capacitors designed to change their value with temperature

11 Waves – Part 2

Introduction

We left Part 1 with the concept that radio waves are divided up into bands which have different properties. Not *all* the properties are different, though. We need to discuss several wave properties, so we will start with what happens to waves as they propagate over long distances.

Getting weaker

Imagine a torch battery connected to a bulb by wires about 1 metre long. The bulb lights normally. If we now take the bulb 100 metres away from the battery and wire it up, we would expect the bulb to be somewhat dimmer, which is exactly what would happen. It happens because of the resistance of the wires – the wires do not form a perfect conductor. A similar situation occurs with radio waves.

All waves suffer from *attenuation* – they get weaker the further they travel. In cases of extreme attenuation, we need to apply some *amplification* before the attenuated wave can be used in a receiver.

Carrying information

When we speak over the telephone, the range of frequencies in our voices extends from very low frequencies up to about 15 or 20 kHz. In audio terms, this is quite a large *bandwidth* (meaning a wide band of frequencies). For communications purposes, however, most of this bandwidth is not needed, and in the telephone system (and in our transceivers), this is cut down so that it extends from about 200 Hz to 3 kHz, a reduction in bandwidth from 20 kHz to about 3 kHz. A bandwidth of 3 kHz has been found to be sufficient to convey speech intelligibly which, after all, is just what we need!

The radio waves coming from an amateur transmitter convey our speech signals over long distances. By themselves, the speech signals do not travel very far, so they have to be combined with a radio signal that *will* travel long distances. This extra signal is called the *carrier wave* (or just the *carrier*), because its job is to *carry* the speech signals along with it! The process of combining the speech (or Morse code) with the carrier is called *modulation*.

Wider and wider

Sending Morse code is achieved simply by switching (or *keying*) the carrier on and off. The bandwidth of the transmitted signal is only about 100 Hz. Speech, with its reduced bandwidth of 3 kHz, will produce a *single-sideband* (SSB) transmitted signal with a bandwidth of 3 kHz. If the same speech signal were used to produce an *amplitude-modulated* (AM) signal from the transmitter, it would have a bandwidth of about 6 kHz. Perhaps you can now understand why the bandwidths needed to produce hi-fi broadcasts need to be so large. TV signals need bandwidths running into tens of megahertz!

Waves need aerials

Radio waves are produced whenever changing currents flow through a wire, and when that wire is made in such a way as to maximise the *radiation* from the wire, it is called an *aerial* or *antenna*. The same piece of wire will receive radiation from other aerials; an aerial will transmit and receive. This is an important property of the aerial: when a current flows through it, electromagnetic waves are launched into the air; when electromagnetic waves in the air encounter the aerial, currents are produced in it.

From the simplest transmitting aerial, waves travel in all directions, like the waves on the pond that we considered in Part 1. They will travel a long way through air and space before they become too week to be received. They won't travel very far into the earth, however! The earth will *reflect* some of the wave and will *absorb* the rest. That portion of the wave which is reflected will again travel through air and space until it is totally attenuated.

Look at **Figure 1**; A represents a radio transmitter, with B1, B2 and B3 being receiving stations. The two arrows pointing 'downwards' from A represent two of the waves from A which just graze the earth's surface. Waves above

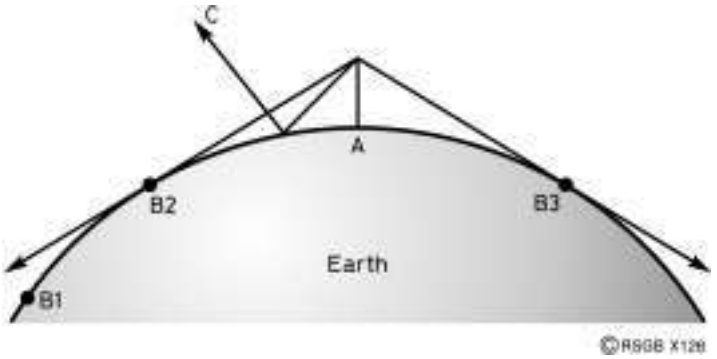

Figure 1 Stations between B2 and B3 receive the *ground wave*

these will travel on into space; waves below them will either be absorbed and reflected by the earth or received by aerials. B1 will not receive any signals from A, because it is below A's horizon. B2 and B3 can receive A's signals because they are *just* on A's horizon. Any stations between B2 and B3 will also receive A's signals, which are known as *ground-wave signals*. The wave at C represents one which is reflected by the ground and travels into space.

This description begs the question of how signals are received from stations well beyond the ground-wave range.

Mirrors in space

Suppose that there was something, out in space, that would reflect radio waves. Waves from A that travel out into space could be reflected off it and return to earth, enabling stations such as B1 to receive A's signals. The situation just described is illustrated in **Figure 2**.

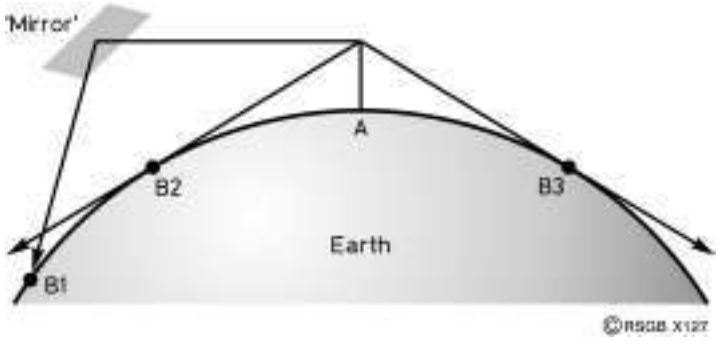

Figure 2 Reception of A's signals at B1 using the *sky wave*

Just such a mirror in the sky really *does* exist. It is not man-made, of course! The earth is surrounded by the atmosphere, a mixture of many gases, such as nitrogen and oxygen. The energy contained in the radiation from the sun is more than sufficient to *ionise* these gases, thus making them into electrical conductors. When a gas is ionised, some of its electrons are physically stripped out of the atoms and are free to move about, just as the electrons of a metal do in a wire. Consequently, we can regard this part of the atmosphere (the part illuminated by the sun) as acting like a sheet of metal, which *reflects* radio signals! It is not a perfect reflector, but is sufficient to produce long-range (DX) radio propagation via the *sky wave* under the right conditions. (A more down-to-earth example of ionised gases conducting electricity can be found in the fluorescent tube and the neon sign – many gases glow when they are continuously ionised.)

This conducting region at the extremity of the atmosphere is called the *ionosphere*, and it exists in layers between 60 km and 700 km above the earth's surface. When the ionosphere is sufficiently ionised, it glows; this is the natural phenomenon known as the *aurora borealis*, or the *northern lights*.

The property of the ionosphere that enables radio waves to be reflected does not act in a uniform way; it is very selective about which waves it reflects, and which waves go straight through it and into outer space. In general, it reflects only those waves with frequencies below about 30 MHz – the HF bands!

In Part 3 we will look at families of waves.

12 An LED flasher

Introduction

The LM3909 is an integrated circuit (IC) which will flash a light-emitting diode (LED). Using only two extra components and a battery, the circuit is cheap and has a very low current drain from a 1.5 V cell. The circuit can be used as a novelty flasher, an indicator for a dummy alarm bell box, or it could be attached to a torch so that it could be found easily in the dark! The simple circuit is shown in **Figure 1**.

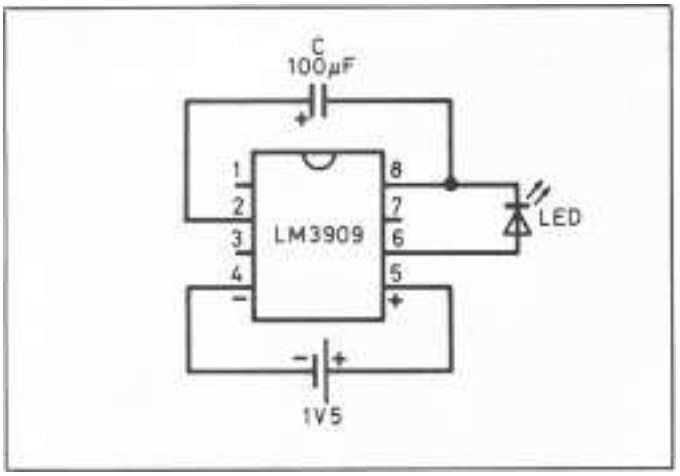

Figure 1 Circuit diagram of the LED Flasher. Pins 1, 3 and 7 of the IC are not used

Assembly

The circuit can be built on a small piece of Veroboard (the piece shown in **Figure 2** measures 15 holes by 10 strips). Using such a board, follow these instructions.

1. Depending on how far away you want the LED from the circuit board, solder a length of insulated wire to each lead of the LED. Use different colours of insulation – say, red and black, connecting the *red* lead to the *anode* (a) lead (the longer one) of the LED, and the black one to the *cathode* (k). Figure 2 shows these leads.
2. Cut the copper tracks as shown in Figure 2, using a 3 mm (⅛ inch) diameter drill, rotated between thumb and forefinger, or use the proper tool. Make *absolutely* sure that the tracks are completely broken!
3. Fit the IC holder in the correct position, using the cut tracks as guides, and make sure the small notch is facing towards the top of the board. Solder the pins to the copper tracks.
4. Mount the capacitor, positive end to the left, so that the positive lead is soldered to track F, which connects it to pin 2 of the IC; the negative lead is soldered to the right-hand side of track E, this being connected to pin 8 of the IC.
5. Solder on the battery leads, positive to the right, and the extended LED leads, positive downwards.

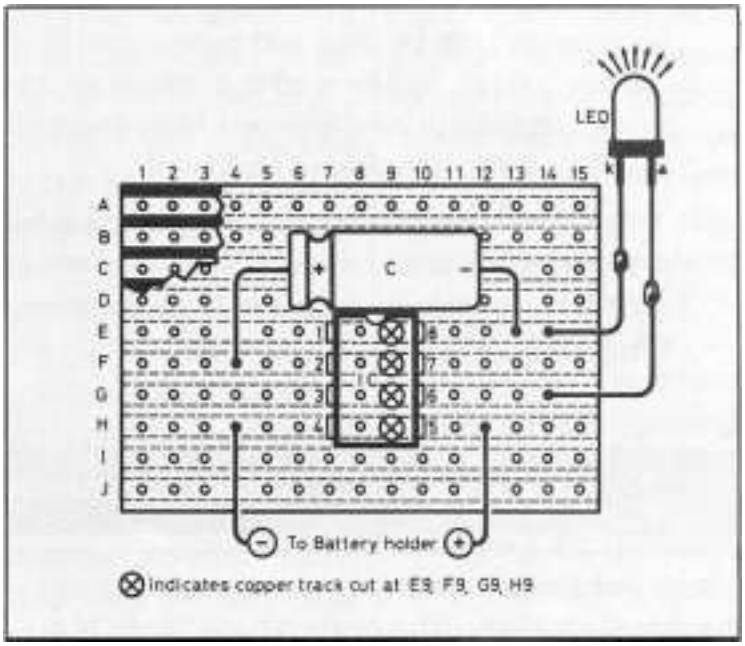

Figure 2 Board layout viewed from the component side. The tracks are cut under the board where shown

6. Check the circuit, and hold up the board to a bright light and look carefully for solder bridges between the tracks and pieces of copper swarf which may have escaped your inspection in 2 above! Remove whatever you find.
7. When all seems well, put the IC into the socket, ensuring that the notch or dot on the upper surface of the IC lines up with the notch on the holder. Line up each pin on the IC with the hole below it before pressing *gently* on the IC with the board supported on a firm surface.
8. Connect the battery; the LED should start to flash. The circuit is complete and working!

If you prefer, the whole circuit (battery included) can be mounted in a small plastic box, with the LED mounted on a clip and protruding through the panel. There are many other possibilities, and it is up to you to find an application for your own use.

Parts list

		Maplin code
LM3909	Integrated circuit	WQ39N
IC socket	8-pin DIL	BL17T
LED	5 mm diameter	WL27E
100 microfarad (μF)	Electrolytic capacitor (10 V)	FB48C
Battery holder	For AA-size cell	YR59P
Battery	1.5 V AA cell	

Small piece of Veroboard (15 holes by 10 strips)
Small plastic box (if required)
LED clip (if required)
Two lengths of coloured, insulated wire for LED (as required)

Availability

All parts can be obtained from Maplin Electronics Ltd.

13 Waves – Part 3

Introduction

When we talk about the spectrum being divided up into bands, this is just for our convenience; there are no natural divisions although, as we have seen, some of the properties of different bands really *are* different! Let's look at **Figure 1**, and see how the frequencies are divided up.

The divisions

- **Very low frequencies** (VLF) cover the range from a few kilohertz up to 30 kHz. Very long-range communication is possible, but at *very* small bandwidths. It is used for special purposes.
- **Long waves** (LW) are used for medium-distance commercial broadcasting and have frequencies from 30 kHz to 300 kHz.
- **Medium waves** (MW) are used for commercial broadcasting, and use frequencies from 300 kHz to about 1.5 MHz (1500 kHz). Typical range is about 200 km.
- **Short waves** (SW) encompass both the low-frequency (LF) and high-frequency (HF) amateur radio bands. There are nine narrow amateur bands in the SW spectrum between 1.8 MHz and 30 MHz. Some of these bands give round-the-world communication.
- **Very high frequencies** (VHF) span the range between 30 MHz and 300 MHz. Relatively short-range communication is possible. They were once used for broadcast TV before it moved to UHF. There are now three

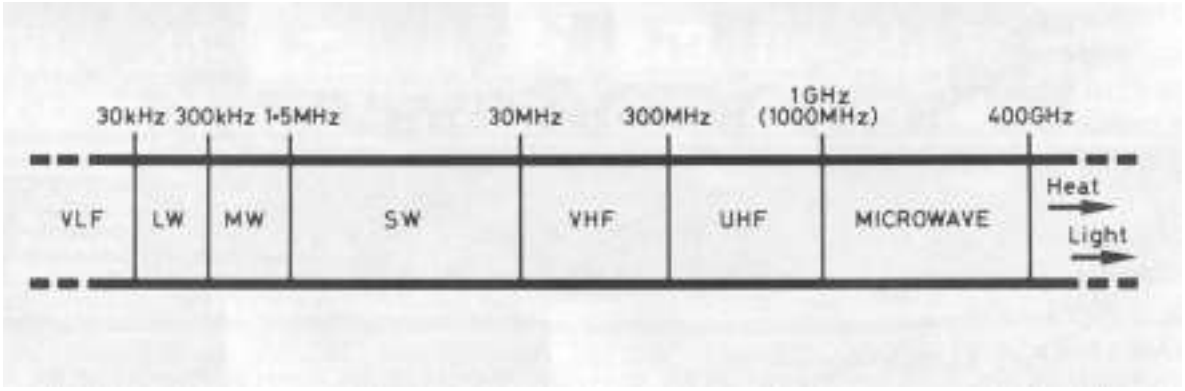

Figure 1 Diagram of radio frequency spectrum

amateur bands here – 6 m, 4 m, and 2 m. Repeaters are used to extend the usable range of mobile stations. VHF waves are not usually reflected by the ionosphere, but when they are, ranges of several thousand kilometres are possible. Weather affects these waves on a regular basis, however. In addition to amateur users, the VHF part of the spectrum is also used by the police, the fire and ambulance services, weather satellites, and many others,

- **Ultra-high frequencies**, sometimes called *centimetre waves*, cover the range from 300 MHz to 1000 MHz (or 1 GHz). The only amateur band in this range is the 70 cm band, and we share it with radar, TV and cellular telephone users as well.
- **Microwaves** begin at 1 GHz and extend to about 400 GHz. They are *never* reflected by the ionosphere, are partially attenuated by buildings, and are reflected from aircraft and cars. Microwave absorption in the atmosphere is quite significant, and rain and fog can attenuate microwaves quite heavily.
- **Heat, light** . . . Above 400 GHz we run into the infra-red bands and on into the visible light and ultra-violet bands. We generally take 400 GHz as being the limit of what we class as radio waves.

Bandwidth again

Complex signals need more bandwidth than simple signals. Even if it were possible, we would not be able to transmit a single television channel in the whole of the MW broadcast band! When TV used part of the VHF band, only five channels were possible in the range from 45 MHz to 68 MHz. By moving TV to the UHF band, we now have 47 channels between 470 MHz and 855 MHz!

It's your choice!

The number of permutations you have amongst all the modes and all the bands is enormous! Only you can decide what you are interested in and what you want to learn about. That is the attraction of amateur radio!

14 Choosing a switch

Simple, but be careful!

A switch is the simplest electronic component, but care is needed in choosing the correct one for the job. Here is a list of the main characteristics of a switch, which will help you to select what you want.

1. **Rating**. This gives the maximum voltage and current that a switch can handle. For example, a 250 V 1.5 A switch will switch mains voltage at a current not exceeding 1.5 A. If the current is greater than 1.5 A, the switch may get hot and fail. If the voltage is too great, the switch may arc each time it is switched off, thus wearing away the contacts.
2. **Number of poles**. A single switch can control many circuits; the number of poles tells you *how many* different circuits it can handle. See **Figure 1**.
3. **Number of throws**. This tells you the number of positions each pole can have. This is best illustrated in Figure 1. The simplest ON/OFF switch is a Single-Pole, Single-Throw (SPST) switch. A Single-Pole,

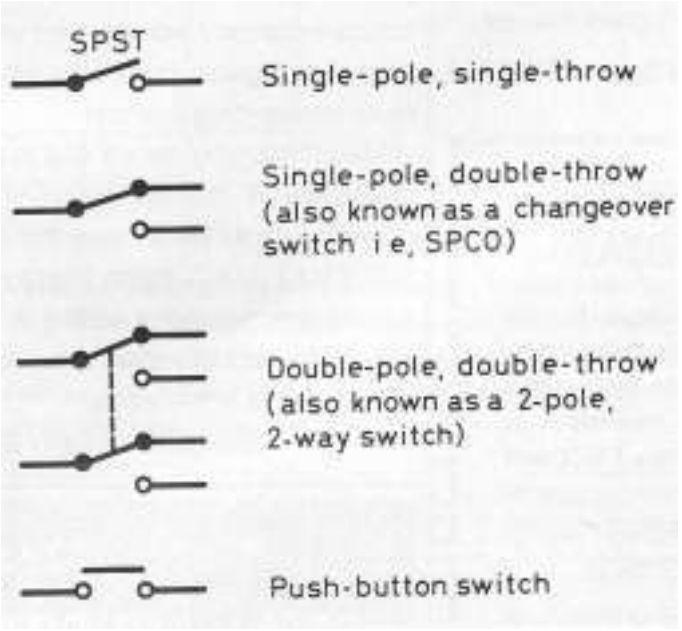

Figure 1 Some circuit symbols for different types of switch

Double-Throw (SPDT) switch may also be used as an ON/OFF switch, but is used mainly to change between two parts of a circuit, and is commonly known as a Single-Pole Change-Over (SPCO) switch. Two or more SPCO switches can be operated at once; Figure 1 shows an example. The two switches are said to be *ganged*. See also 'Types of switch' below.

4. **Number of ways**. When a switch has more than one throw, we tend to use the word 'ways' instead. This means that if a switch has one pole and six throws, we would normally call it a '1-pole 6-way' switch. Such switches tend to be rotary switches, as are described below.

Types of switch

(a) **Push-button**. These are found on calculators, telephones, electronic games and most equipment with a digital display.

(b) **Rotary**. These are switches controlled by a knob, and are turned instead of moved up and down. **Figure 2** shows the rear of such a switch and its circuit symbol. The commoner types of rotary switch are: 1-pole, 12-way; 2-pole, 6-way; 3-pole, 4-way; 4-pole, 3-way; 6-pole, 2-way. All these switches have 12 click positions, as you may have guessed, but each one comes with an adjustable end-stop so that you can set the correct number of ways according to the contacts on the switch.

(c) **Slide**. This switch is common on the cheaper types of radio, mainly as an ON/OFF or band-changing switch. They are not very rugged, but are small and cheap to produce. Very small types are manufactured for use on PCBs.

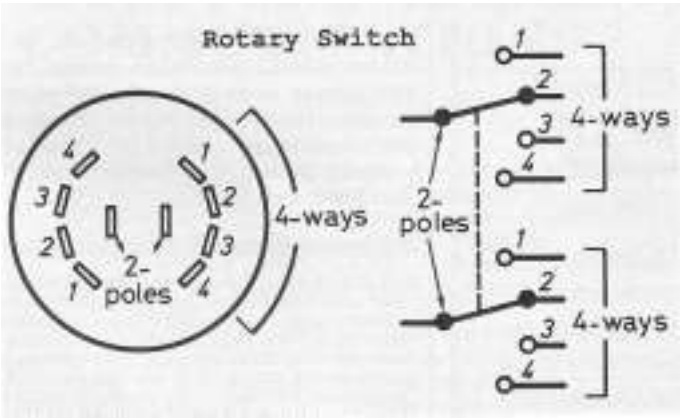

Figure 2 The rotary switch can select several different circuits at once

(d) **Toggle**. Available as two-way types or three-way, with a centre-off position. Can be manufactured to handle very high currents.

(e) **Micro-switch**. These are devices which are usually operated indirectly, such as when the cover is removed from a high-voltage power supply, or when the door of a fridge is opened. The 'micro' part of the name doesn't refer to the size of the switch, but to the *small* movement that is required to activate it.

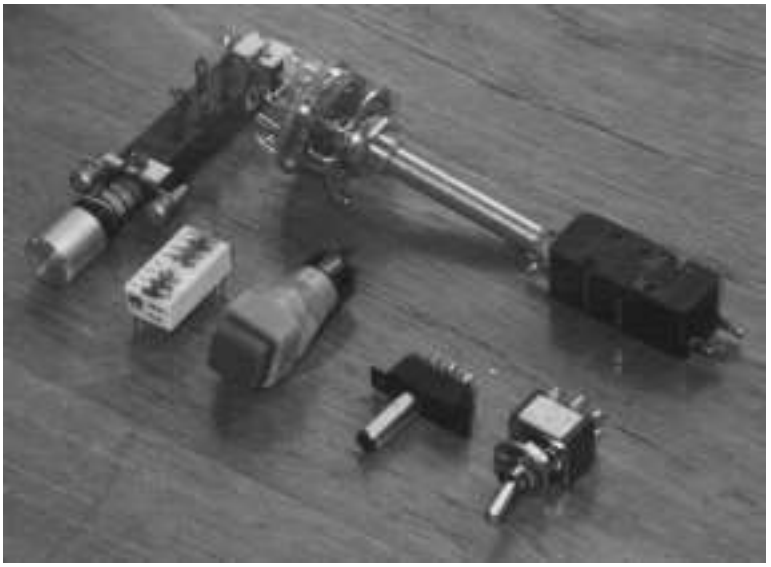

15 An aerial tuning unit for a receiver

Introduction

Any length of wire will act as an antenna (or aerial) but, to get the best results from a transceiver or receiver, an aerial tuning unit (ATU) is required. This matches the *impedance* of your aerial to the impedance at the aerial socket of your radio. Impedance is like resistance, and is measured in ohms, but it is used for alternating currents, and hence is common in audio and RF engineering. Most receivers have an impedance at the aerial socket of about 50 ohms (Ω); aerial impedance, on the other hand, can be anywhere between 20 Ω to over 1000 Ω, depending on its length and its height above ground.

Fortunately, you don't *need* to be able to calculate your aerial's impedance; all you need is a device that will perform the matching operation for aerials with a large range of impedances, and this is exactly what is described here! The subject of *matching* is a complex one, but all you need to know is that most signals will become clearer, and that there will be less noise and interference. Stations will become louder, so you will probably be able to reduce the setting of your RF gain control (always a good thing to do).

This design of ATU covers all amateur and broadcast bands from 10 m (28 MHz) to 80 m (3.5 MHz), and is very easy to build. The circuit is shown in **Figure 1**.

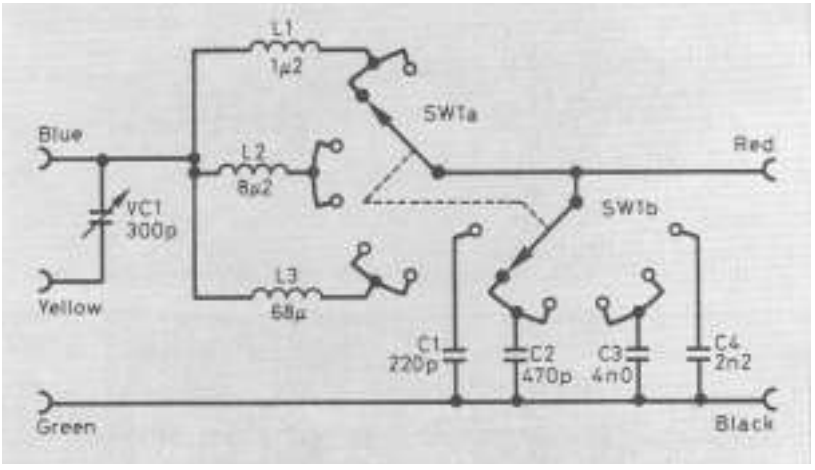

Figure 1 Circuit diagram of the Antenna Tuning Unit, showing the use of a 2-pole, 6-way rotary switch to select inductors (L) and capacitors (C)

Construction

1. Firstly, you will need a simple plastic case in which to house the ATU. The size should be approximately 85 × 145 × 50 mm.
2. Start by drilling two 10.5 mm holes in the front of the case; these are for the 6-way switch and the tuning capacitor.
3. Drill three 8 mm diameter holes in the left-hand side of the box, for the three sockets, coloured blue, yellow and green.
4. On the right-hand side of the box, drill two 8 mm diameter holes for the red and black sockets.
5. Now, fit the 6-way switch (SW1), the tuning capacitor (VC1), and all the sockets to the case. Check that the vanes of the capacitor rotate smoothly when the shaft is turned.
6. Wire up the inductors (coils). Figure 1 and the wiring diagram of **Figure 2**, will help with this. As you can see, each one side of each coil is connected to two switch connections, the other end going to VC1.
7. Solder in the fixed capacitors. One end of each goes directly to the ground socket (black), and the other end goes to the switch.
8. Solder a wire between the green and black sockets. The output from the ATU comes from the red socket, and this is connected to the two tags in the centre of the switch, as Figure. 2 shows clearly.
9. Finally, connect the blue and yellow sockets to the tuning capacitor, and the ATU construction is complete.

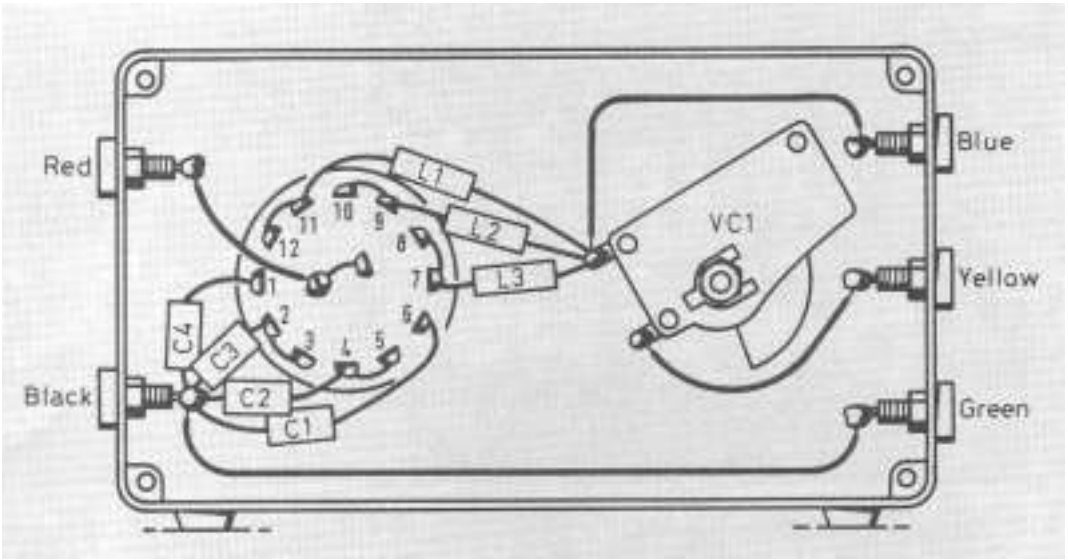

Figure 2 The internal view of the case shows the main tuning capacitor, VC1. This is a solid dielectric type, which has adjustable brass plates

In practice . . .

Figures 3 and **4** show two different ways of connecting your aerial to your ATU. In each case you will need to select each switch position in turn, and rotate the tuning capacitor through its full range while listening to a station. You should find that one switch position enables VC1 to produce a peak in the signal strength in the loudspeaker. At this point, your aerial and receiver are said to be *matched*. Stations in the same band will probably peak with VC1 at the same setting of SW1, but different bands will almost certainly require different positions of SW1.

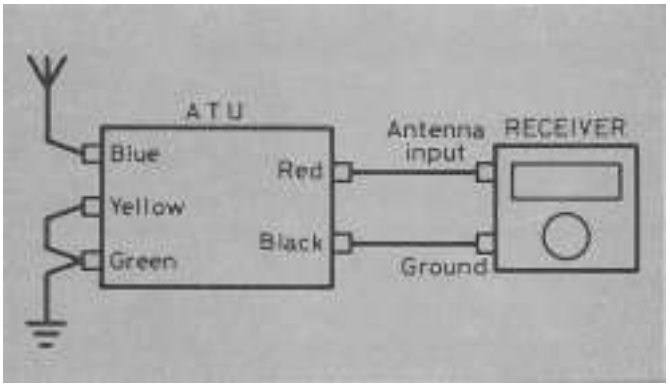

Figure 3 You may find that parallel tuning gives best results with your antenna

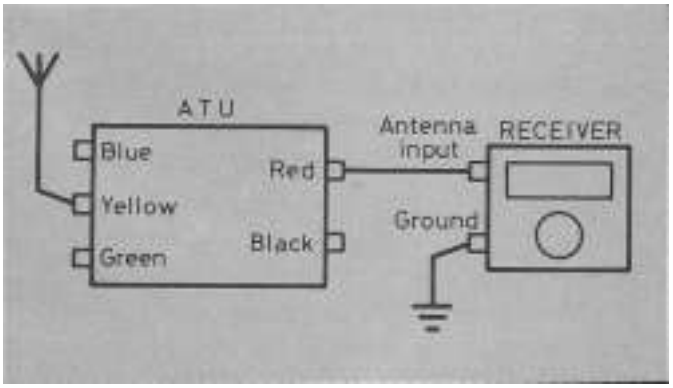

Figure 4 In other cases, series tuning could be the most effective arrangement

Parts list

Capacitors (all rated at 16 V or more)
- C1 220 picofarads (pF) polystyrene
- C2 470 picofarads (pF) polystyrene
- C3 1000 picofarads (pF) or 1 nanofarad (nF) polystyrene
- C4 2200 picofarads (pF) or 2.2 nanofarads (nF) polystyrene

Inductors
- L1 1.2 microhenries (μH)
- L2 8.2 microhenries (μH)
- L3 68 microhenries (μH)

Switch
- SW1 2-pole 6-way rotary

Sockets
- 4 mm type, one each of red, black, yellow, blue, green

Additional items
- Plastic or metal case, e.g. Maplin type YU54
- Two large knobs for SW1 and VC1

16 A simple 2 m receiver preamplifier

Introduction

Designed specifically to complement the modified air-band portable (also described in this series), this can be used with some success on many receivers suffering from 'deafness' on VHF.

The circuit

An RF preamplifier is a device which improves the input signal to an existing receiver, enabling it to work more effectively. Because of the noise which is added to the signal by the preamplifier, *very* weak signals may not be usefully enhanced, but stronger signals will be improved considerably.

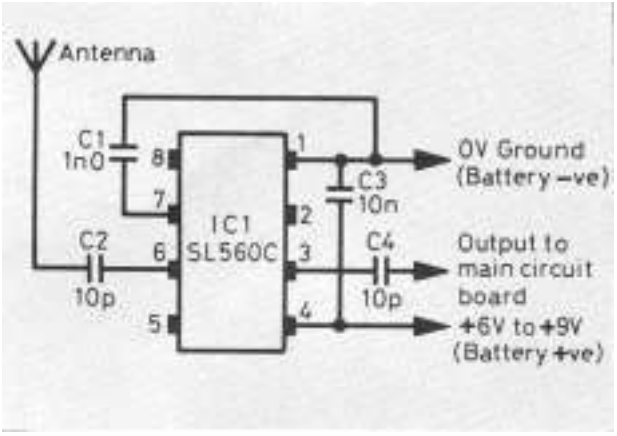

Figure 1 The integrated circuit is mounted upside down. Make sure you identify pin 1 which has a small dot next to it

This little circuit (shown in **Figure 1**) uses a GEC/Plessey integrated circuit type SL560C. With the addition of four capacitors, it is used between your aerial and the aerial input of the radio's PCB.

Putting it together

1. Use a small piece of prototype (matrix) board about 25 mm square. Use an 8-pin DIL socket for the integrated circuit (don't risk soldering the chip – it is seldom a risk worth taking). Figure 1 shows the connections to the socket, *looking from underneath*.
2. Make special note of the pin numbers, so that you know how to put the chip into the socket when you have finished. The positive and negative connections to the circuit are taken from the main PCB *after* the ON/OFF switch – so that the switch operates the preamplifier, too.
3. Unsolder the lead to the radio's telescopic aerial and connect it to the free end of C4, as shown. Then solder a short lead between the telescopic aerial and C2.
4. Sometimes it is possible to cajole your little preamplifier into the radio's plastic case, provided there is room and that you make sure that none of the soldered joints on your little board touch any of the metal inside the case when you replace the back and screw it on again.
5. If there is not enough room inside, then put the preamplifier into its own box, with battery and switch, and its own aerial. Keep the lead from the preamplifier to the aerial connection of the radio as short as possible – perhaps using screened cable.

Because your preamplifier is untuned, you will find not only that it helps with reception on 2 metres, but also that reception on the FM broadcast band is improved!

Parts list

Integrated circuit

IC1	GEC/Plessey SL560C

Capacitors

C1	1 nanofarad (nF) ceramic
C2, C4	10 picofarads (pF) ceramic
C3	10 nanofarads (nF) ceramic

Additional item

Prototype broad approx. 25 × 25 mm

17 Receiving aerials for amateur radio

Introduction

For any radio receiver to work well, it must have some form of antenna, or aerial. In almost all domestic transistor radios, the aerial is built into the set, either as a ferrite rod (which looks like a rod of dark grey metal) on which are wound coils of wire, or as a chromium-plated telescopic metal rod. Some radios have both forms of aerial, using the ferrite rod aerial for long waves (LW) and medium waves (MW) and the metal rod for very high-frequency (VHF) stations using frequency modulation.

There's broadcast reception . . .

No aerial is perfect, and these two types are *far* from perfect! As in most mass-produced equipment, *they serve their purpose*, which is not critical, and they allow the radio to be carried around easily, because they are not

big and bulky. The broadcast stations are very powerful, usually quite close, and the circuits in the radio are quite sensitive, so the need for large aerials disappears.

. . . and there's amateur DX

Here we have an application which, in comparison with the broadcast situation, couldn't be much more different. The stations do not use much power, they may be half the world away, and the requirement for good aerials and very sensitive receivers is paramount. The aerials must be large and they must be as high as possible, away from buildings and trees, which cause reduction in signal strength, and away from man-made sources of interference.

You may not have thought about this but, in general, the larger an aerial becomes, the longer the cable (or 'feeder') must be in order to reach your shack and the receiver inside it. Cables reduce the received signal, so what your aerial gains by being large, the feeder (if you're not careful) will lose!

A simple aerial . . .

We now know that a 'good' aerial is essential. But what is a 'good' aerial? It depends on your purse, your property and your enthusiasm! One of the simplest (and, incidentally, one which is *not* subject to the cable loss problem discussed above) is the **Long Wire**, shown in **Figure 1**. This is, quite literally, a long piece of wire going from a chimney stack to a tree or pole

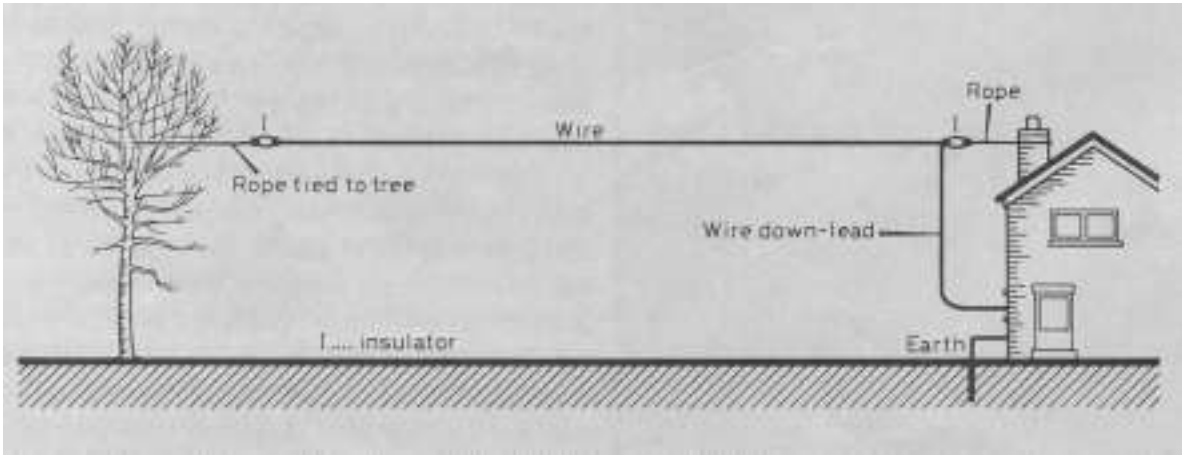

Figure 1 A tree at the bottom of the garden can provide a useful antenna support. Insulators can usually be obtained from Tandy stores or TV aerial suppliers

at the end of the garden. The longer it is, the better. Notice that the wire itself is *not* used to loop around the tree or chimney. Rope is used for both, and is secured to the end of the wire using an insulator of the 'dog bone' or 'egg' variety, to be found in profusion at rallies.

The wire is brought into the house through a window into the shack where the receiver is situated. The long wire aerial is best used with an aerial tuning unit (ATU), which is also described in this book. One of the advantages of the long wire is that it can be used on several frequency bands.

. . . and more complicated ones

Next up the ladder of complexity is the **dipole** (meaning two poles, or two elements). One form of dipole for lower frequencies would take the same basic form as the long wire, except that the feed to the receiver is taken, not from the end, but from the centre. The wire is essentially cut into two halves, and the two ends at the centre are connected to one end of a coaxial cable, which is then taken to the receiver. A smaller form of this is shown in **Figure 2**, which is conveniently mounted in a house loft. Aerials should always be mounted outside for best results, but will work when mounted inside, and the loft space is the logical situation.

The total length of the dipole should ideally be one-half of the wavelength of operation – hence the term 'half-wave dipole'. For example, a dipole for use on 20 m should be about 10 m long. Dipoles are thus 'single-band' aerials. They can be modified for use on several bands, and then become known as 'trapped dipoles', having coils and capacitors at certain points along their lengths.

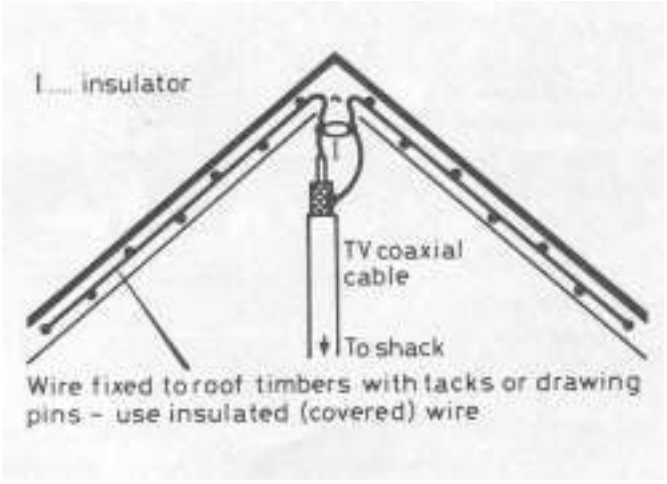

Figure 2 An indoor antenna should be mounted as high as possible

Indoor aerials

For flat- or apartment-dwellers, an indoor aerial is often the only solution, in which case the dipole of Figure 2 may be of great use. Other popular types include the **loop aerial**, of which several types are shown in **Figure 3**. The shape of the loop is of secondary importance, but it should be as large as possible.

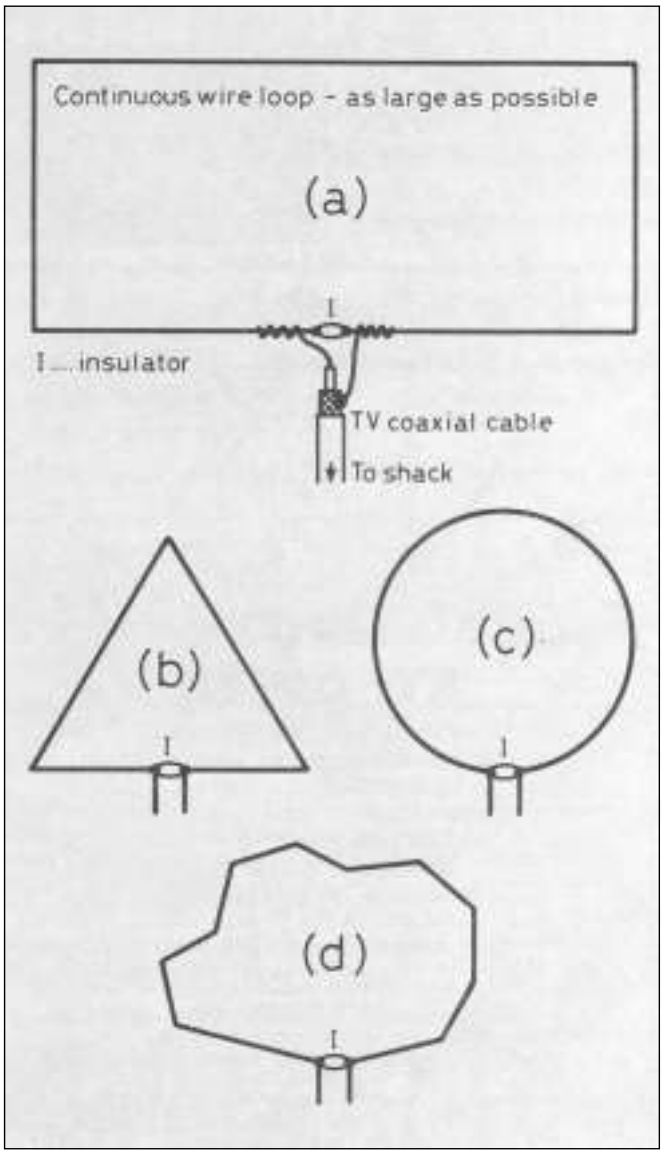

Figure 3 Try different shapes of loop antenna to see which works best

Ingenuity is called for when considering indoor aerials. A dipole can be mounted along a picture rail or pelmet. A vertical loop of aluminium foil can be stuck to an inside wall and covered with wallpaper! The designs are limited only by your imagination, and will give you hours of listening pleasure

Outdoor aerials

If you want to venture beyond the simple long-wire discussed earlier, then the erection of outdoor aerials can be a bit tricky; they can be more than a one-man job, and can involve seeking planning permission. Get some help advice from someone who has done it before – what about your local radio club? Plenty of designs for aerials appear in *RadCom*, so you should never be short of ideas!

18 The Colt 80 m receiver – Part 1

Introduction

This is the first of four parts detailing the design and construction of a simple radio capable of good reception of amateur radio signals on the 80 metre band. If you can solder and have some basic hand tools, at the end of Part 4 you will have a working receiver, in which you can take pride, and start some serious listening on 80 m! For testing, all you will need is another receiver and a multimeter.

Description

The radio will be built in three modules, or stages, as illustrated in **Figure 1**. Each of these is built on a printed-circuit board (PCB) or matrix board and can be tested in its own right. The case will need some holes drilled, and care will be needed to mount the PCBs in the case.

Get to it!

Surprisingly enough, when you are building a radio section by section (which is *always* the best way), it is easiest to start at the output and work

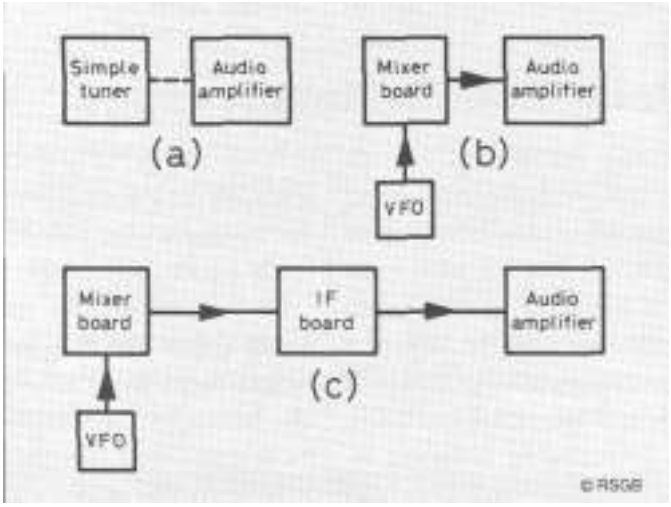

Figure 1 Build your Colt and watch it grow. A simple crystal set (a) becomes a direct conversion receiver (b) and finally an 80 metre amateur band superhet (c)

towards the input, and you can test what you have done stage by stage. You will see what this means as you progress with your construction.

Every receiver needs some audio frequency (AF) amplification to make the sound signals big enough for you to hear. The circuit for the AF amplifier is shown in **Figure 2**. It uses the TDA7052 integrated circuit (IC) plus a handful of extra components. R1 in conjunction with C2 and C3 *decouple* the battery supply, preventing any audio signals getting through to it and affecting other parts of the radio, when they are connected. C1 acts to prevent high frequencies (above the 3 kHz bandwidth) going into the amplifier input. A volume control, VR1, is connected across the amplifier input, so that the amplifier can accept signal inputs over a wide range. **Figure 3c** shows the connections, which are made with screened cable. The

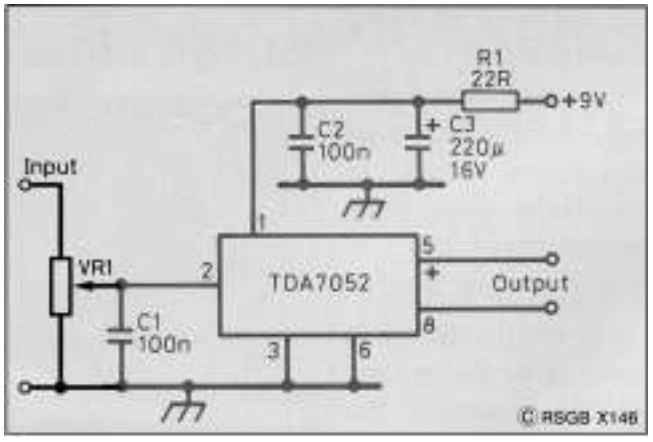

Figure 2 The Philips TDA7052 integrated circuit (IC) used in the audio amplifier needs very few extra components. It has a signal voltage gain of 100 times and the output is suitable for a loudspeaker or headphones

centre conductor of the left lead goes to the point marked 'input' in Figure 2, the braid being connected to the amplifier earth (0 V) tag. The right lead to VR1 goes to whatever signal source you have for testing – see later. VR1 is *not* mounted on the PCB.

The circuit is constructed on a small PCB or matrix board. Make sure that the electrolytic capacitor, C3, is soldered into the board the correct way – its positive and negative connections are shown in **Figure 3b** for reference. If you are **at all** concerned about soldering the IC into the board, enlist some help, *or*, obtain an 8-pin DIL socket, which you can solder in and then carefully insert the chip into the socket, making sure that is the correct way round. The markings on the chip are shown in **Figure 3a**.

The output leads from the amplifier go to a plastic 6.3 mm (¼ inch) mono jack socket, so that *neither* output lead is connected to the metal case. The amplifier will drive a pair of headphones or a small 8 Ω loudspeaker.

The battery leads must be the right way round also; the battery itself can be a PP3 or PP9, or you can use a small DC power supply.

Testing

First, check that all the components are in the right places, that your soldering is good, and that you have headphones or a loudspeaker connected. Set VR1 about halfway along its travel. Connect the battery.

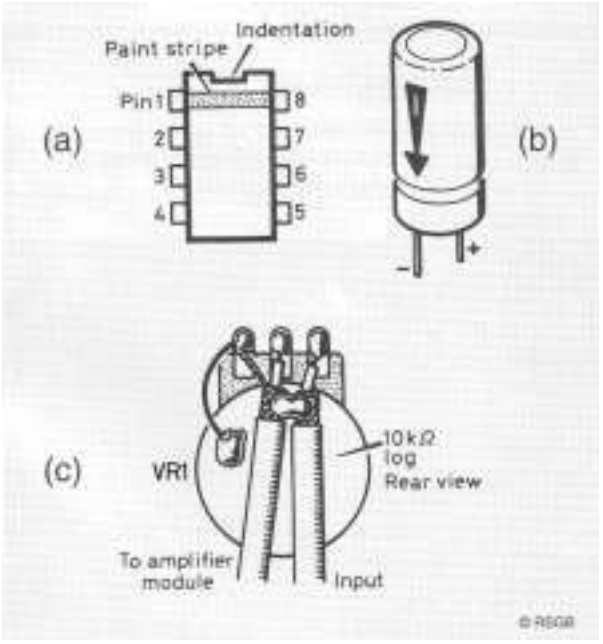

Figure 3 It is important to check the component connections carefully. The diagram shows (a) top view of the IC, (b) electrolytic capacitor and (c) volume control (VR1) connected across the input of the amplifier

A slight hissing noise should be heard; touching the input lead to the amplifier (the centre of the three connections on VR1) should produce a loud buzz. Touching the shaft at the same time will make the buzz quieter. This is the quickest way of confirming that your amplifier *seems* to be working. The only real test is to give it something meaningful to amplify! See the design of our *Crystal Radio Receiver* for full details.

Parts list

Resistors: all 0.25 watt, 5% tolerance
- R1 — 22 ohms (Ω)
- VR1 — 10 kilohms (kΩ) log

Capacitors
- C1, C2 — 0.1 microfarad (μF)
- C3 — 220 microfarads (μF) electrolytic 16 V

Integrated circuit
- IC1 — TDA7052 audio amplifier

Additional item
- PCB — (see below)

Component suppliers:
- Maplin

The next part . . .

The metal case will be marked out ready to receive the completed modules.

19 A crystal radio receiver

Introduction

Here's a quick project to fill in a winter's evening! It was originally designed as a piece of test gear for the *Colt* receiver, but can be successfully used by anyone as a first radio project. Another use for it would be as test gear for any audio amplifier project requiring an audio input for test purposes; this is ideal, as it does not require any power supply!

Details

The initial rough-and-ready test for the audio amplifier of the *Colt* receiver will have whetted your appetite; you will want to prove more conclusively that your amplifier works, and in a way that others in the household will appreciate. Buzzing noises are not convincing in this respect! You are going to put together a simple crystal set – the simplest type of radio that there is – and use it as a signal injector for your amplifier. In this way, you build a real medium-wave (MW) receiver which drives a loudspeaker, as an intermediate product of the construction of an 80 metre amateur band receiver!

The circuit diagram is shown in **Figure 1**. It has a 60-turn coil mounted on a small piece of paper or card wrapped round a ferrite rod. The coil has a connection made to its centre-tap (the middle turn of the coil). The tuning capacitor, VC1, is the most expensive part of the circuit but don't worry, it will be used in the final design of the receiver also! Connect the diode, D1, from the centre-tap to the input to the potentiometer of the amplifier circuit of the *Colt*. Be careful to connect the aerial to the *vanes* of VC1, and not to its *frame*, or you will experience some strange effects when you are tuning. If your amplifier is working correctly, you should be able to receive local stations on medium-waves quite well.

If you think the crystal set will be of use to you in the future as a signal injector, all you will need will be another variable capacitor! If you do not intend to use the amplifier, a small crystal earpiece will allow you to listen. Walkman-type headphones will *not* work!

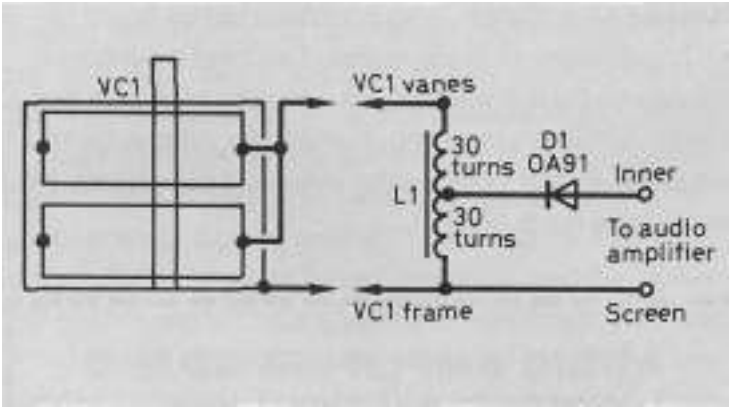

Figure 1 Both sets of moving vanes are joined as shown. L1 is wound on a ferrite rod with 32 SWG wire and centre-tapped. A single winding (no tap) can be used, joining D1 to the top of the winding

Parts list

Variable capacitor

VC1	125 + 125 picofarads (pF) twin-gang

Ferrite rod

About 100 mm to 140 mm long

Diode

D1	OA91 germanium diode

Additional items

Wire	2 m of enamelled copper wire, between 23 SWG and 32 SWG
Earpiece	High-impedance crystal type (only needed if you are not using the amplifier)

20 The varactor (or varicap) diode

Introduction

Many of the circuits for receivers and transmitters presented in this series rely upon the variable capacitor as a means of tuning. Another method of varying capacitance (without any moving parts) is provided by the *varactor diode*, sometimes called a varicap diode. This is a component which changes its capacitance as the voltage across it is varied.

The details

Figure 1 shows how a varactor diode might be connected to demonstrate its operation. Its symbol is that of an ordinary diode, with a capacitor symbol next to it. A variable voltage is applied across it in such a way that the diode is *reverse-biased*. This means that virtually no current passes through it – the positive voltage is applied to the cathode. Varactors are cheaper than variable capacitors, and they are tiny in comparison, very suitable for today's miniature circuits. If A and B were connected across the tuning coil in a simple receiver (with a series capacitor to block the DC from the battery reaching the coil), the tuning operation would be accomplished by turning the knob on the 10 kilohm potentiometer.

Varactors are available with different values, from less than 20 picofarad (pF) for VHF applications to 500 pF for medium-wave radios. They are

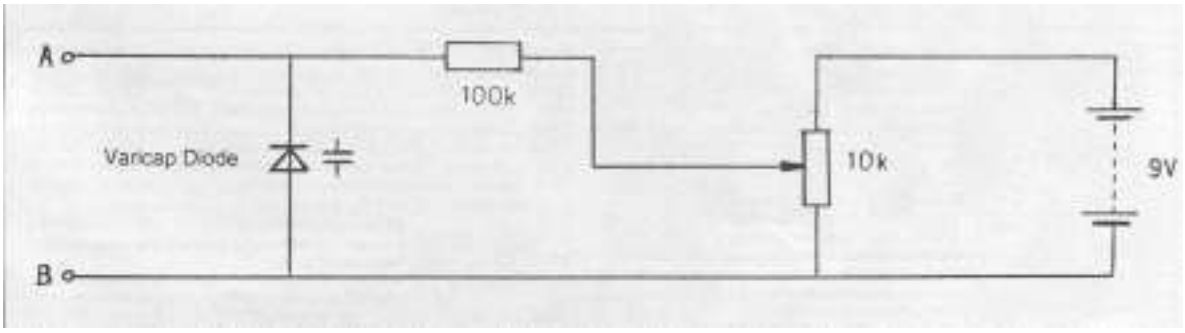

Figure 1 The capacitance of the varicap diode (between A and B) increases as the voltage is reduced, using the variable resistor

tuned usually by voltages between 2 V and 9 V. For a real application of varactors, you should consult the circuit diagram of the *Yearling* 20 metre receiver, elsewhere in this book.

In some circuit designs, several circuits are all tuned to the same frequency in order to improve the overall *selectivity* (the ability of the circuit to reject signals very close in frequency to the wanted signal). Special dual- and triple-varactors are available for circuits like this. Having been made at the same time from the same materials makes their individual characteristics virtually identical. Like all other diodes, they must be correctly wired into the circuit – their *polarity* is important.

Changes in temperature will cause the capacitance to change which, if it were part of an oscillator circuit, would cause the oscillator to drift – you would have to keep retuning the radio! This can be corrected by using a special integrated circuit called a *phase-locked loop* (PLL). Modern TV sets and satellite receivers use varactors and PLLs in this way.

Some useful varactor types

Type No.	*Tuning range*		*Description*
	pF/V	*pF/V*	
BB204B	42/2.0	15/12	Dual VHF
BB212	560/0.5	22/8	AM tuning
KV1235	450/2.0	30/8.5	Triple AM
KV1236	450/2.0	30/8.5	Dual AM
MV1404	120/2.0	9/10.0	HF tuning

21 A portable radio for medium waves

Introduction

The ZN415E integrated circuit (IC) can be used to make a very efficient AM portable MW broadcast radio with a built-in loudspeaker. Here's how!

The circuit

Figure 1 shows the circuit diagram of the portable radio. It's not as complicated as it may appear, especially after you have got started. L1 is a coil of wire mounted on a ferrite rod, acting as an aerial; VC1 is a variable capacitor which works, with L1, to tune in different stations. IC1 contains circuits of its own which boost the selected signal and it includes a *detector* which extracts the audio signal from the incoming RF signal. Earphones could be connected to the output of IC1 (between pins 4 and 5), but the output would not be powerful enough to drive a loudspeaker.

More sound

This is where IC2, an LM386 comes in. This is a small audio *power* amplifier which produces audio signals with enough power to drive a small

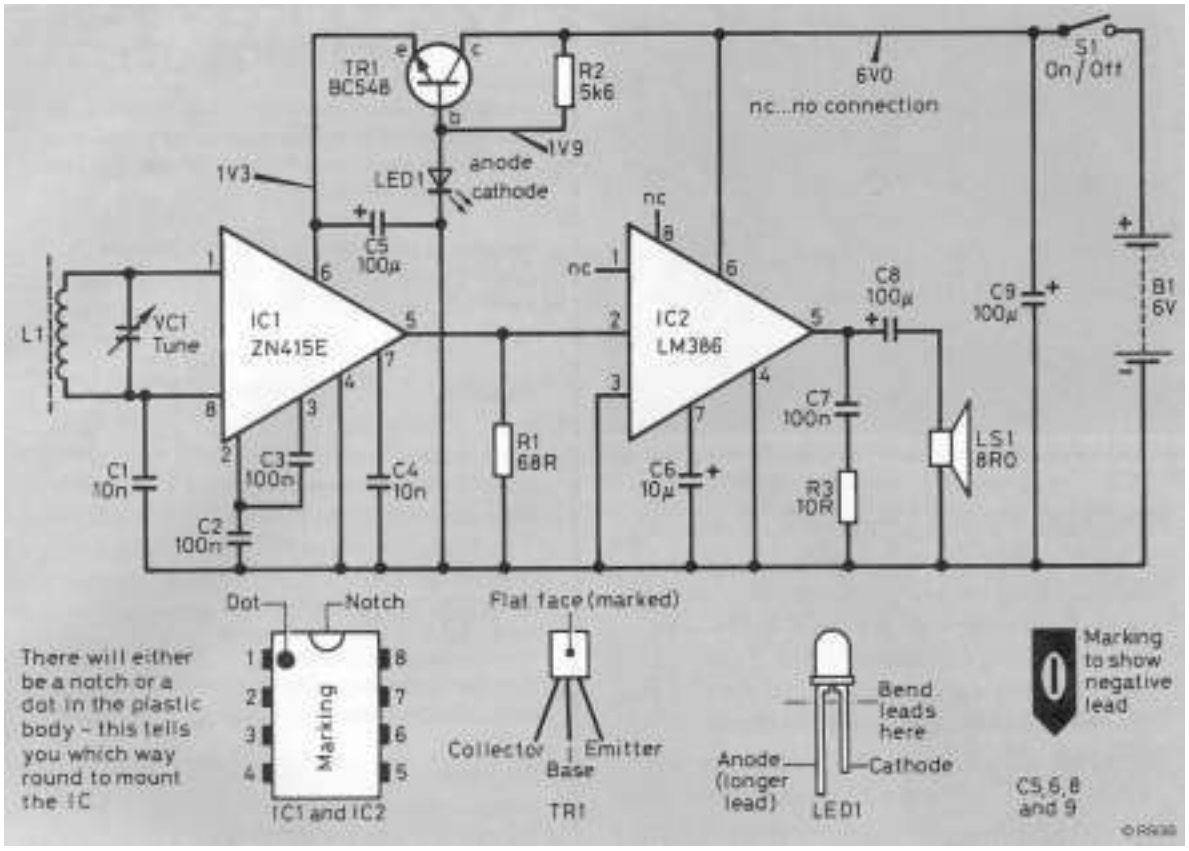

Figure 1 The circuit diagram of our easy-to-build portable radio. Take care to mount the ICs and LED the correct way round

loudspeaker, LS1. The radio uses a 6 volt battery, which is made by connecting four 1.5 volt AA cells in series (4 × 1.5 V = 6 V) using a battery holder designed for this purpose. Although a 6 V supply is ideal for IC2, it is far too great for IC1, which needs only about 1.3 V. This lower voltage is provided from the 6 V supply by TR1 (an npn transistor), R2 and LED1 (a light-emitting diode). When current passes through an LED (see the description of the LED in this series) a reasonably constant voltage of 1.9 V appears between the anode and the cathode. Because of the voltage (0.6 V) that *always* exists between the base and emitter of a working transistor, the voltage on the emitter is about 1.9 V – 0.6 V = 1.3 V, and this is used as the power supply for IC1.

To keep the radio as simple as possible, no volume control has been fitted. Instead, you can use the directional properties of the ferrite rod aerial (see the information on ferrites in this book) to reduce the volume by rotating the set about a vertical axis using the handle provided.

Putting it all together

1. Start by covering the ferrite rod with Sellotape, or alternatively wrap a piece of paper tightly around it, and secure it with Sellotape. Then, with at least 2 metres of 24 SWG enamelled copper wire, wind 75 turns tightly around the rod. To be safe, leave about 50 mm of wire at the ends of the coil, then wrap the whole coil with Sellotape to hold the turns in place, leaving only the ends free. Then, using a small piece of sandpaper, remove the enamel from the last centimetre of each end of the coil.
2. Most of the components are mounted on a piece of Veroboard (the type with parallel copper strips on one side). The piece used on the prototype measured 32 holes by 10 strips, as **Figure 2** shows. Before you start fitting components, cut the copper strips as shown. It is easier to do it now than when the board is littered with components! The strips may be cut with a 3 mm (⅛ inch) twist drill rotated between thumb and forefinger. Resist the temptation to use a hand drill – the idea is just to cut the copper, **not** to drill right through the board!
3. Solder the IC sockets and the other components on the board as shown in Figure 2. Make sure that the IC sockets are fitted with their notches towards the *top* of the board, as viewed in Figure 2. Do not insert the chips yet. Always keep the wires left over from cropping resistors and capacitors, they will come in handy at times like this: make the wire links that are clearly shown in Figure 2. Connect the electrolytic capacitors (C5, C6, C8 and C9), the transistor and the LED the correct way round; then check it again when you have done it!
4. Finally, solder lengths of stranded insulated wire to act as 'flying leads' for future connection to L1, VC1, LS1, S1 and the battery connector.
5. Apart from the battery holder, everything is mounted on the case *lid*. This makes assembly and testing much easier, and eases fault-finding if

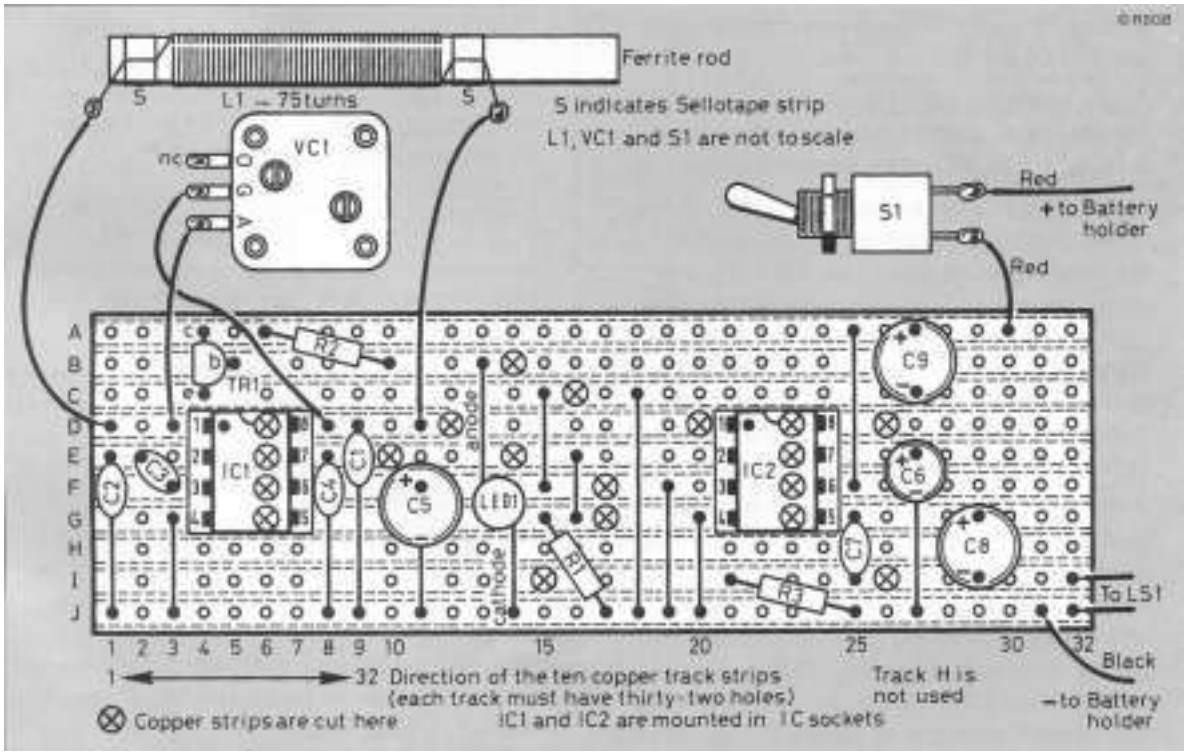

Figure 2 Veroboard layout for the Portable Radio. Make sure that all the wire links are included

the need arises! At the speaker position, make one large hole or a series of small holes to let the sound out. The ferrite rod may be stuck to the lid, as may the loudspeaker. Drill holes of the correct size to fit the particular types of variable capacitor (VC1) and switch (S1) that you are using. The Veroboard may be held in position by Blu-Tack or double-sided sticky tape.

6. Before inserting IC1 and IC2, connect the battery and switch S1 on. The LED should glow dimly (you may have to shield it with your hand in order to see it). If you have a test meter, check that there is about 1.3 V between pins 6 and 4 of IC1. If the reading is around 6 V or there is no glow, you may have connected the LED the wrong way round! When everything seems normal, switch off and disconnect the battery. Insert IC1 and IC2, making sure that the pins are straight and lie immediately above their corresponding holes in the sockets, and that the notches line up with the notches in the holders. Then push *gently* downwards on each IC in turn until the chip is firmly seated in its socket.
7. Switch on! By rotating the tuning capacitor, VC1, you should now be able to tune in many stations, rotating the radio to give you some volume control.

Final touches . . .

The handle was made with part of an old leather belt, secured to the case with 'number plate' nuts and bolts from Halfords. The loudspeaker grille is the lid from a *pot-pourri* container, and some extra holes were drilled in the back to improve the sound. See what you can find to finish off your radio!

Parts list

Maplin order codes are given for most of the parts, but you should get used to using the 'beg, borrow or steal' technique, or to use your ever-expanding junk box.

		Maplin code
Resistors: all 0.25 watt, 5% tolerance		
R1	68 ohms (Ω)	M68R
R2	5.6 kilohms (kΩ)	M5K6
R3	10 ohms (Ω)	M10R
Capacitors		
C1, C4	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic	BX00A
C2, C3, C7	100 nanofarads (nF) or 0.1 microfarad (μF) ceramic	YR75S
C5, C8, C9	100 microfarads (μF) electrolytic, at least 10 V	FF10L
C6	10 microfarads (μF) electrolytic, at least 25 V	FF04E
Semiconductors		
IC1	ZN415E radio chip	
IC2	LM386 audio power amplifier	UJ37S
LED1	3 mm green LED	WL33L
TR1	BC548 npn transistor	QB73Q
Additional items		
LS1	Miniature 8 ohm loudspeaker	WB08J
S1	Miniature SPST toggle switch	FH97F
Ferrite rod	Length approx. 100 mm	YG20W
	24 SWG enamelled copper wire	BL28F

Additional items (*continued*)		
VC1	Tuning capacitor 140 to 300 picofarads (pF)	FT78K
	Tuning knob	FK41U
	8-pin DIL IC sockets (two required)	BL17T
	4 × AA-size battery holder (long)	HF94C
	PP3-type clip for battery holder	HF28F
	Plastic box approx. 158 × 95 × 54 mm	LH51F
	0.1 inch Veroboard, min. size 32 holes × 10 strips	JP46A

Plus
- Stranded insulated conductor for flying leads
- Multicore solder
- Materials for handle and speaker grille
- Double-sided sticky tape or Blu-Tack
- Sellotape
- Glue
- Four AA-size 1.5 V batteries

22 The Colt 80 m receiver – Part 2

Introduction

In Part 1 we constructed the audio amplifier module for the system and tested it in a very simple way. If you did what was suggested and built the simple Crystal Set to use as a signal source, you will know just how well the amplifier works.

The case

Metal cases for the project are available from Maplin, telephone 01702 554 161 (code XB67). From the photograph on p. 72 you can see the way the components are mounted. The audio amplifier is seen at the top right of the base, to the right of the tuning capacitor VC1. The next in this series will deal with the variable-frequency oscillator (VFO) and VC1. The current part deals with preparing the case to receive the components.

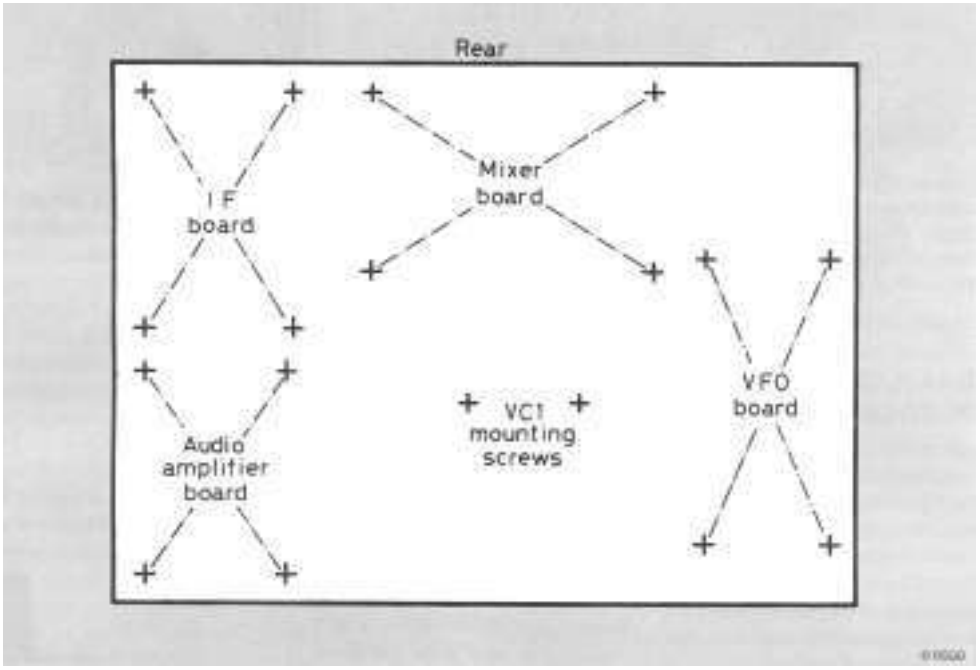

Figure 1 Fixing holes for each module are best measured from each printed circuit board or matrix board

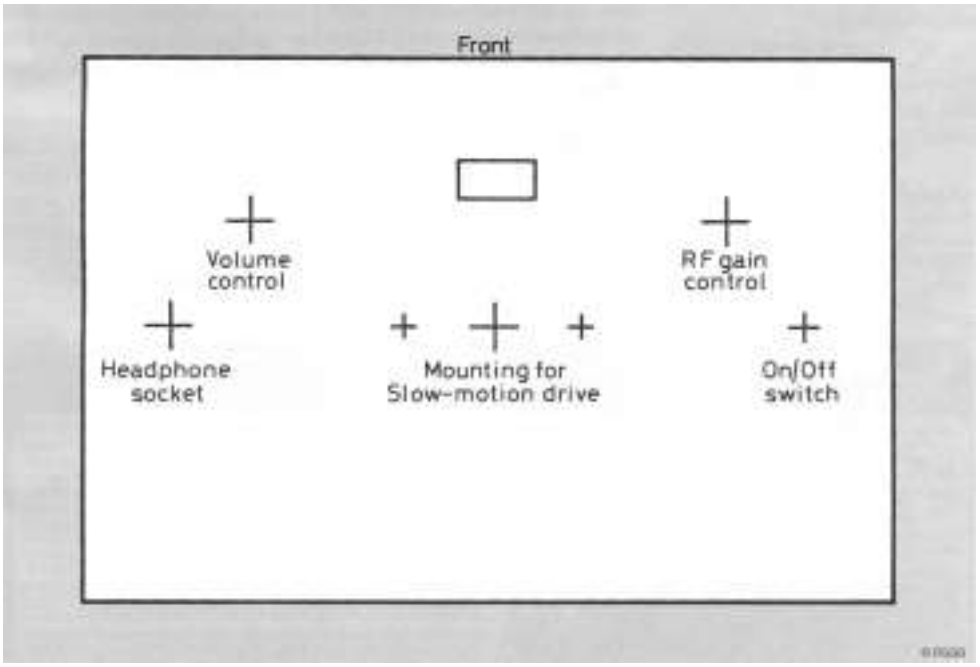

Figure 2 Position the slow motion drive to allow viewing of the tuning dial

Figures 1 and **2** show the markings for preparing the front panel and base. All the circuit boards and the tuning capacitor are mounted on the base using 10 mm stand-off pillars with 6BA bolts. The board locations are shown in Figure 1. The front panel control positions are shown in Figure 2, together with the small rectangular hole for viewing the tuning dial.

The best way to mark out the holes for the boards is to lie the boards flat on the base (before you've started soldering the components in) and marking the base through the holes in the boards. This minimises the scope for errors!

A *reduction drive* is used between the tuning knob and the capacitor shaft. This is simply a gear mechanism that slows down the capacitor shaft by a factor of six compared with the tuning knob, and makes tuning very much easier. The recommended variable capacitor also has a pulley wheel mounted on the shaft. Glued to this wheel will be a scale marked with frequency and is visible through the rectangular hole in the front panel.

The next part . . .

The variable-frequency oscillator and mixer will be added to the project.

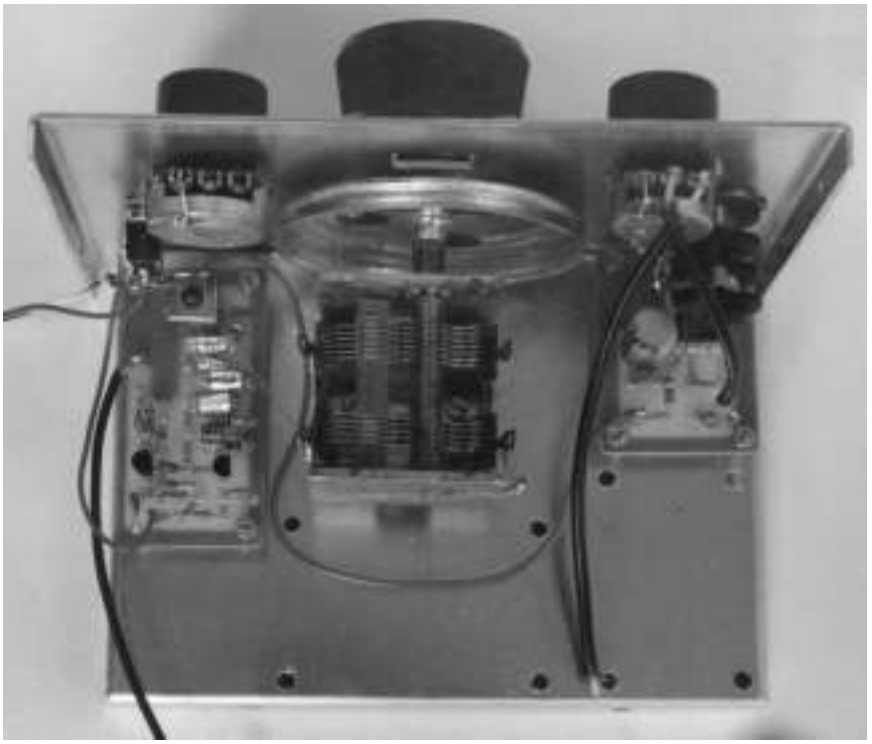

23 A simple transistor tester

Introduction

Although transistors aren't used as much as they were before integrated circuits came along, a transistor tester is still a useful piece of test equipment to have around the shack. This design is about the simplest possible and will produce an indication of whether a transistor is giving any current gain; this does not necessarily mean that the transistor is perfect but that it is working to a certain extent. This tester will **not** test field-effect transistors (FETs). If you buy a bag of transistors at a rally, this tester is useful for giving a yes/no indication of which ones go straight in the bin and which are kept for further use.

How it works

Figure 1 shows the simple wiring circuit. In order to explain the working of the circuit, a circuit diagram is shown in **Figure 2**, with the npn transistor, TR1, under test shown as part of the circuit. The pnp/npn selector switch, SW1, is omitted for clarity.

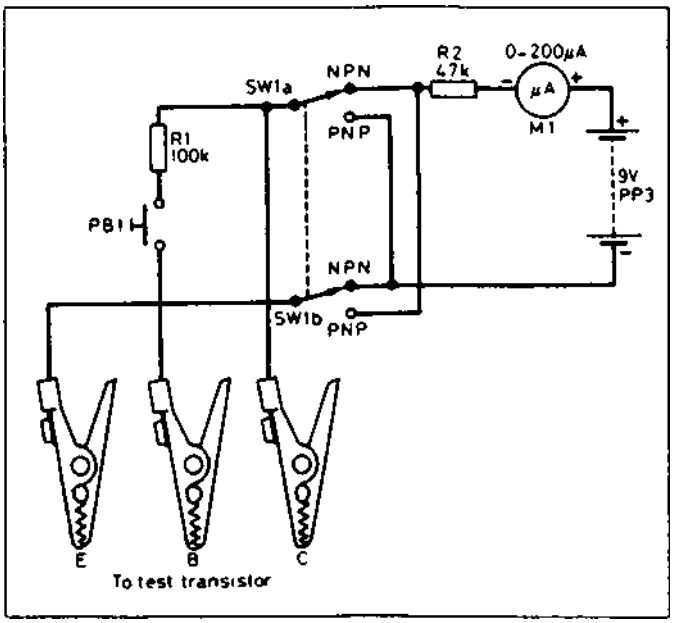

Figure 1 Circuit diagram of the transister tester

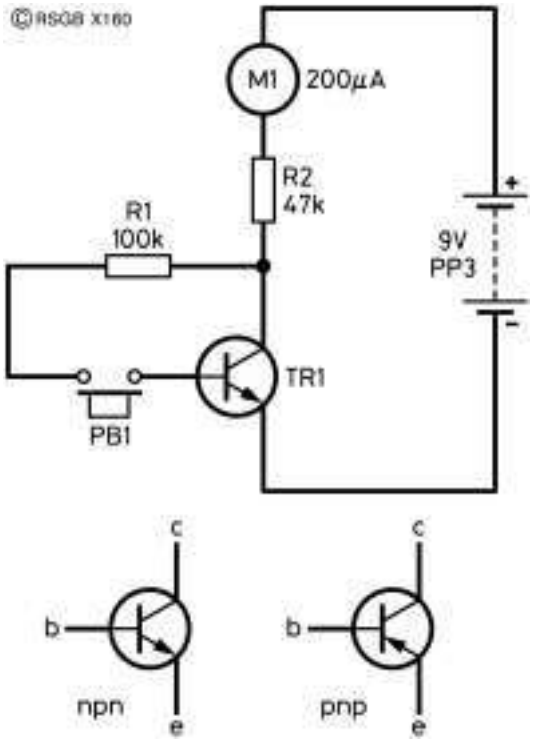

Figure 2 Testing an npn transistor

Any current that flows through the transistor, TR1, must flow from the battery, through the meter, M1, and through the protective resistor, R2. R2 prevents excessive current flowing through the meter and damaging it. Even if there is a short-circuit between emitter and collector, the maximum current that will flow is given by the simple equation

$$I = \frac{V}{R},$$

where I is the current flowing in amps,
V is the battery voltage, and
R is the total circuit resistance in ohms.

Putting in the correct values, gives

$$I = \frac{9}{47\,000} = 0.000191 \text{ A, or } 191 \text{ microamps } (\mu\text{A}).$$

The resistance of the meter, M1, will cut this down a little more, but it is within the indicating range (200 μA) of the meter.

As shown, with the push-button switch, PB1, *open*, a good transistor will not draw any current from the battery, and M1 will thus remain at zero. When PB1 is *pressed*, a *very small* current is injected into the base of the transistor. If the transistor is working, it will produce a much larger current between the collector and emitter, and this current will also flow through M1 and R2, giving a significant reading on M1, showing that all appears to be well. If an appreciable current flows when PB1 is *open*, then your transistor is suspect.

Don't be put off by the apparently complicated switch, SW1. It is there to allow the other type of transistor, the pnp type, to be tested. All it does is reverse the battery connections, so that the emitter goes to the *negative* battery terminal for testing an npn transistor, and to the positive terminal for a pnp type!

Most transistors in common use are of the npn type, which is why Figure 2 shows the testing of an npn type. The connections to the different transistor *encapsulations* (shapes) are given in any good component catalogue. Avoid the trial-and-error method to discover the connections to a transistor. This is unscientific, and can be very frustrating, particularly if the transistor is faulty in the first place!

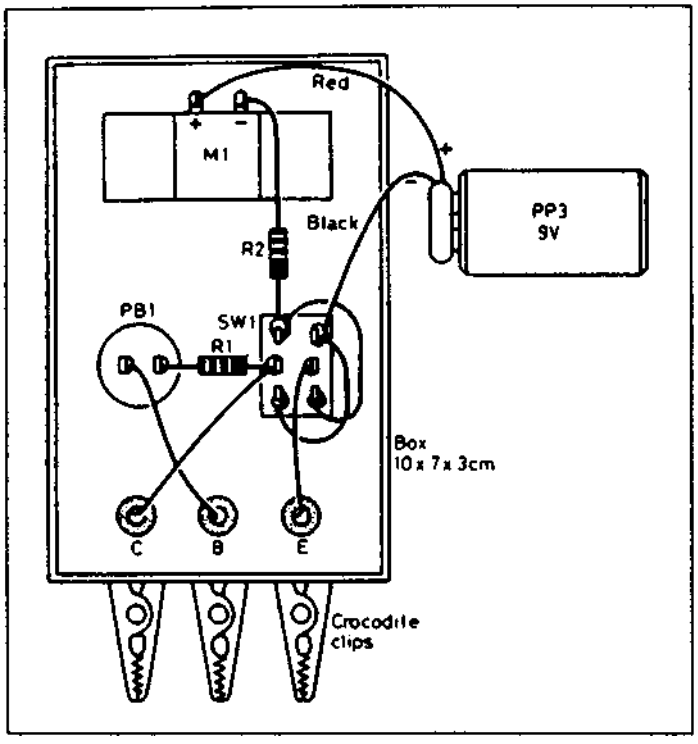

Figure 3 This shows how to wire up the tester

Construction

The unit can be built into a small plastic box, the components being soldered directly to the fixed terminals of the meter and the two switches; no circuit board is necessary! Use different colours of wire for the three test leads, and make sure you know which is which! Check the connections against the wiring diagram of **Figure 3**. When you are confident that all is correct, connect the battery and make sure there is no reading on the meter when nothing is connected to the crocodile clips!

Find any transistor for which you know the connections and the type (npn or pnp). Set the npn/pnp switch accordingly. Connect the three clips, making sure that they do not touch each other. A small reading on the meter at this stage means the transistor is suspect; a large reading means it is not working and should be thrown away! Press PB1 and watch the meter; a reading greater than half of full-scale indicates a good transistor. If it is less than half, you may have a transistor with 'low gain'; it may be usable for non-critical applications, but if you are in any doubt – throw it away!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	47 kilohms (kΩ)

Additional items

PB1	Push-button switch
SW1	DPDT (double-pole double-throw) switch
M1	Micro-ammeter – *not* less than 200 μA full-scale deflection
	Crocodile clips (3 needed)
	PP3 battery and connector
	Plastic box about 10 × 7 × 3 cm

Common types of transistor

BC108, BC109, 2N2369A

These are small-signal npn types, used in audio amplifiers. They are in metal cases (called TO18) and have a tab next to the emitter lead. Common types have a B or C suffix (e.g. BC109C). The C suffix indicates a higher current gain than those with a B suffix. The 2N2369A is specially designed for radio use at high frequencies.

2N3703, BC212L, BCY71
These are pnp transistors, and so must be used with the collector and base *negative* with respect to the emitter. These three types are used in small amplifiers and audio oscillators. The first two have plastic encapsulations (TO92), while the BCY71 has a metal case (TO18).

BFY50, BFY51, BFY52
For slightly higher powers, these are ideal. They have been used in novice transmitters up to 600 milliwatts (mW). The TO5 case is a scaled-up version of the TO18 case. They are all npn types.

2N3055, 2N3773, TIP35C
These are high-power transistors in bigger encapsulations. The thick metal TO3 case of the 2N3055 and 2N3773 is designed to bolt to a heat sink, a large piece of metal which conducts the heat into the air more rapidly than the transistor itself can. The TIP35C is made of plastic but has a thick metal tab by which it, too, can be bolted to a heat sink.

24 An introduction to transmitters

Introduction

We usually think of a transmitter as being a 'black box'. However, that is the form a transmitter takes for our use on the amateur bands. Many electrical circuits are transmitters, even though transmitting may not be their primary function!

Anything that emits electromagnetic energy at *any* frequency is a transmitter, from radio at the low-frequency end of the spectrum, to gamma rays at the high-frequency end. We all know that a magnet will attract certain metals and that a comb rubbed on your coat sleeve will pick up small pieces of paper. The former is an example of the effect of a magnetic field, the latter of an electric field. Electromagnetic fields are combinations of both types of field, and are produced whenever an electromagnetic wave is transmitted.

What frequency?

Many everyday objects have a natural frequency of oscillation. This is called their *resonant frequency*. A wine glass will ring when struck gently; an

empty wine bottle will sound if you blow across the top; a guitar string will vibrate when plucked. These are all examples of resonance, and the resonant frequencies will **not** change unless the objects themselves are changed physically in some way. These are resonances in *sound*; we are primarily interested in electrical resonances.

The basic electrical resonant circuit is the combination of an inductor (coil) and a capacitor, as shown in **Figure 1**.

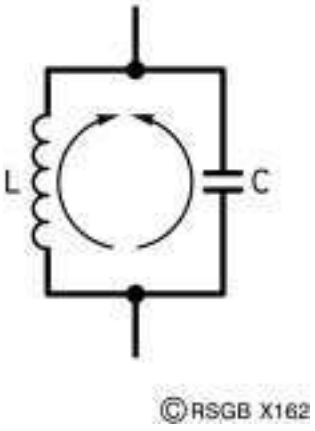

Figure 1 The basic electrical resonator. The energy in the circuit alternates between the inductor and the capacitor

A pulse of energy applied to this *tuned circuit* will make it *ring* (oscillate) at its resonant frequency. The energy in the circuit transfers between the inductor and the capacitor every cycle of the oscillation. Just like the wine glass, its oscillation dies away because it is losing some energy to its surroundings – it is transmitting! The frequency of the resonance depends on the values of L and C.

Keeping it going

If we want to keep the circuit oscillating, rather than having it die away, we must supply the circuit with just enough energy to replace the energy lost both by radiation and by losses in the circuit itself. Because of this, you will find in all oscillator circuits, a transistor, valve or FET working with the tuned circuit to provide this extra energy.

As it stands, of course, even with its transistor, our oscillator will not radiate very far. Connecting an aerial to it, and a Morse key to interrupt the power supply, it would become a very low-power CW transmitter. Add a couple more transistors to form a radio-frequency (RF) amplifier, and you have the basis of a simple low-power (QRP) transmitter.

Resonant circuits can also be made using quartz crystals; these work at the crystal frequency only, and this is marked on the crystal case.

A tiny spark transmitter

This is a simple piece of test gear that will increase your knowledge and understanding of resonance. You can use it to estimate the resonant frequency of most of the inductor/capacitor (LC) tuned circuits that you build. The circuit is shown in **Figure 2**. It operates around a relay. Any relay that operates from a 6 V to 9 V source and has contacts which are normally closed (i.e. closed when the battery is not connected). Fit the relay, a toggle switch and the battery in a metal box, and connected up as shown in the diagram. Some foam rubber inside the box may help to reduce the escaping noise of the relay. A small hole in the side of the box enables the 2-turn loop to emerge. This should be about 40 mm diameter, made with insulated wire. Switch on; there should be a loud buzzing noise from the relay. If not, you have probably chosen the wrong contacts on the relay!

When it is working, bring the loop close to the aerial of a radio – it should produce a loud noise from the speaker!

How it works

When you switch on, current flows through the relay contacts and through the relay coil. The relay operates and opens the contacts, causing the relay to 'drop out'. When it does, the circuit is completed again and the contacts are opened, and the cycle repeats. Each time the relay contacts open, there is a small spark between them, causing very rapid current surges through the wire loop. This makes the loop transmit RF energy, very briefly. In the early days of radio, this type of circuit was known as a *spark transmitter.*

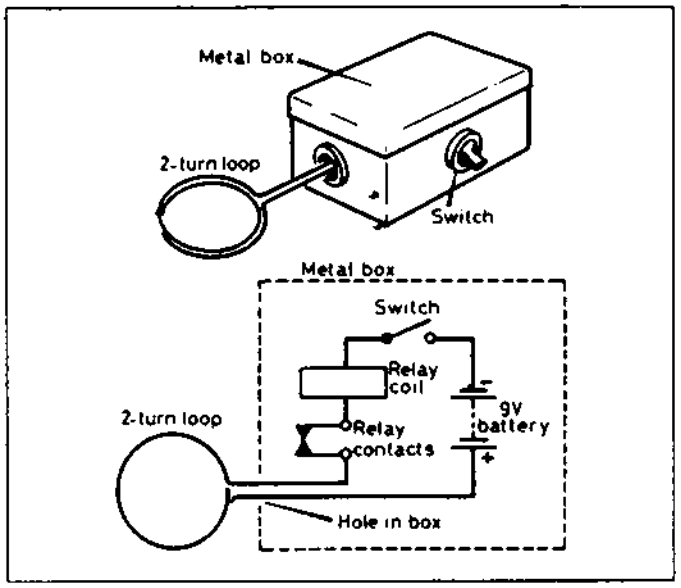

Figure 2 The current path is interrupted when relay is energised as shown above

Make a tuned circuit

Use a discarded toilet-roll centre, and wind about 10 turns of enamelled copper wire round it, keeping each turn close to the next. Scrape off the enamel for about 1 cm at each end, and solder a 100 picofarad (pF) capacitor (or a variable capacitor of about the same value) between the ends. The resonant frequency should be about 10 MHz. If you have used fewer turns or a smaller capacitor, the frequency will be higher.

Measuring the resonant frequency

Set up the buzzer as shown in **Figure 3**, with the loop around one end of your coil. Then make a similar loop, solder it to the end of a piece of coaxial cable going to the aerial socket of a calibrated receiver. Set the buzzer going, tune the receiver around 10 MHz, and search for the maximum noise level from the speaker. When you have found it, move the two loops as far away as possible from the main coil. This is called reducing the *coupling* between the coils, and it may result in a slightly different, but more accurate, resonant frequency.

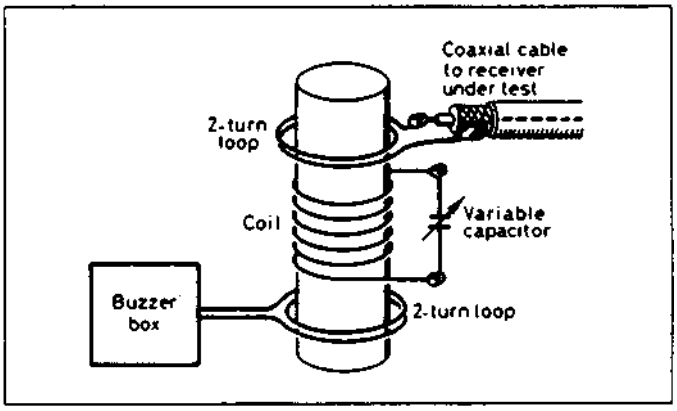

Figure 3 Experiment with the spacing between the loop and the tuned circuit

Parts list

Any small relay which operates between 6 V and 9 V
Metal box – do not use a plastic box!
9 volt battery and connector
On/off (SPST) toggle switch
Plastic foam, as required

25 The Colt 80 m receiver – Part 3

Introduction

In Part 2 we marked out the case ready for installation of the modules when they are completed. In this part, the building of the variable-frequency oscillator (VFO) and mixer will be described. This will produce a type of receiver known as *direct-conversion*, because it converts the radio-frequency (RF) signal directly into an audio-frequency (AF) signal which we can hear in a loudspeaker after amplification. A block diagram of the system is shown in **Figure 1**. The modifications needed to make a full superheterodyne receiver will be left until later.

The direct-conversion receiver covers the 80 metre amateur band and will receive both Morse (CW) and speech (SSB) signals. The audio amplifier was covered in Part 1, so your *Colt* is rapidly taking shape! By the time your construction has reached the end of this part, you will have a receiver ready to use, even if the project is not yet complete!

The direct conversion process

Like most things in radio, the principles of direct conversion are not difficult. From the aerial, the signal we want to hear is selected by the *tuned filter*, which rejects the signals we don't want. The signal then enters the

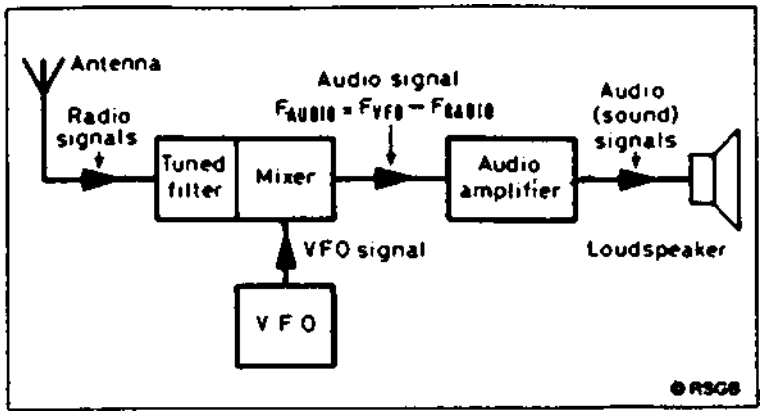

Figure 1 Stages of direct-conversion receiver

mixer, along with the signal from the *VFO*. The VFO produces a sine wave whose frequency can be varied across the whole of the 80 metre amateur band (3.5–3.8 MHz), by turning the knob on the tuning capacitor, VC1. The mixer produces, at its output, *two* signals; one signal is at the frequency of the **sum** of the signal and VFO frequencies, the other is at the **difference** of the two frequencies. It is the latter that we want. Let's look at the numbers involved. If the signal is at 3650 kHz and the VFO is at 3651 kHz, then the sum frequency is 7301 kHz, and the difference frequency is 1 kHz. If we feed the output of the mixer into our audio amplifier, the 7301 kHz signal is automatically removed (it is far too high to be considered an audio signal!) and the resulting 1 kHz signal is amplified and fed to the speaker, producing a note which we can hear!

Building the VFO

Figure 2 shows the circuit of the VFO. It is a tried and tested circuit, and should work first time. It uses a *field-effect transistor* (FET) for TR1, the oscillator itself. RFC is a *radio-frequency choke*, a coil of wire which will pass a direct current (DC) but which will prevent radio-frequency (RF) signals getting through.

All VFOs have a tuned circuit which, in this case, is formed by the coil L1 and the capacitors C1 and VC1. The frequency will also be affected to some extent by C2, C3, C4 and C5. Transistor TR2 is an *emitter follower*, a stage which gives no voltage gain but provides a good *buffer* stage, isolating the VFO from the effects of the stages that follow it. When building a VFO, the

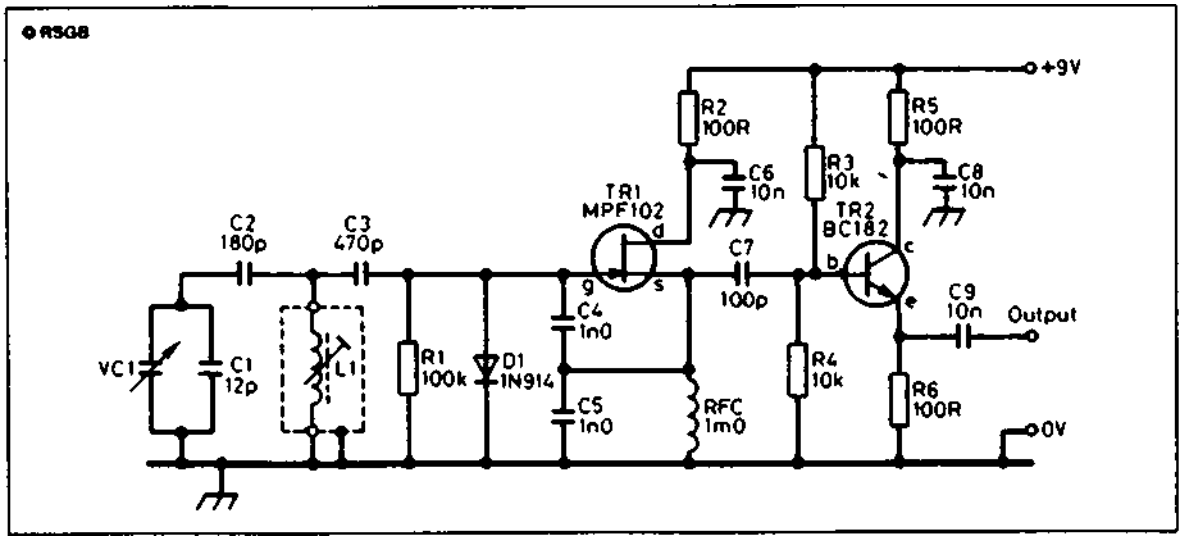

Figure 2 The variable-frequency oscillator uses a field-effect transistor (FET)

parts must be securely mounted. If components move, so does the frequency! At worst, the oscillation will become unstable and the VFO will be useless. Keep the component leads as short as possible – this improves their mechanical stability as well as their electrical stability!

Mount the parts on the printed-circuit board (PCB) or matrix board and, when completed, the VFO should look like the one shown on the left in the photograph on p. 72. Make sure that TR1, TR2 and D1 are the right way round.

On completion, check the component positions then mount it in the case as shown in the photograph, to the left of the tuning capacitor when viewed from the rear. The VFO coil, L1, will need some adjustment, but that will have to wait until the mixer is built. Connections to the other boards are made with screened cable.

The mixer board

So far, we have an audio-frequency (AF) amplifier and a VFO; the addition of a mixer board gives us a complete direct-conversion receiver for 80 m. The mixer circuit diagram is shown in **Figure 3**. Let's follow the signal path.

- From the aerial, the RF signal goes to the gain control potentiometer, RV1. This reduces very strong signals, to prevent them overloading the mixer.
- To select the required band of signals, a *bandpass* filter is made up of RF transformers T1 and T2; these are tuned by C1 and C3, and are coupled together by C2.

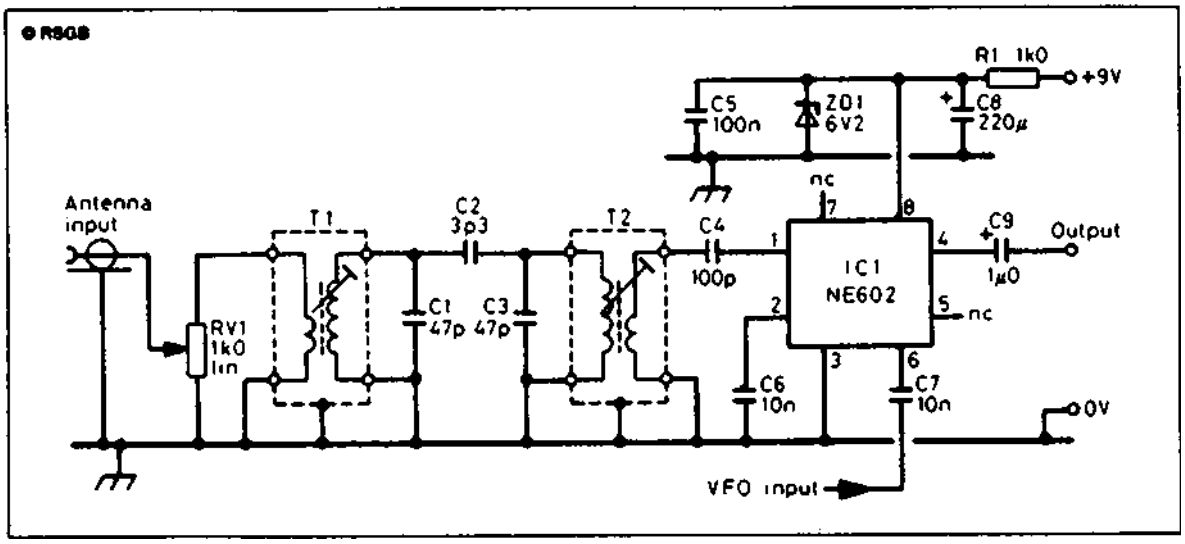

Figure 3 The mixer board has a bandpass filter and stabilised supply

- After the filter, the signal is coupled into the integrated circuit (IC) mixer type NE602, by the capacitor C4. Capacitors C5 and C8 *decouple* the supply line, to prevent unwanted signals on the supply from disturbing the VFO operation. The use of the term *decouple* is exactly the opposite of *couple*; when two circuits are *coupled* together, the signal passes from one to the other; when two circuits are *decoupled*, signals **cannot** pass from one to the other.
- The NE602 works with a 6 V supply; it is produced here from the 9 V supply by the *Zener diode* ZD1 and the resistor R1. ZD1 operates at 6.2 V, and gives a steady output for the mixer. The audio output from the mixer appears at pin 4 or IC1. This is taken to the audio amplifier board via C9 and the volume control (see Part 1).

Care must still be taken to insert some components the right way round. These are the electrolytic capacitors, C8 and C9, the Zener diode, ZD1, and the integrated circuit, IC1. Check all component positions and make sure all your soldered joints are bright and shiny.

Putting it together

The interboard wiring, shown in **Figure 4**, uses screened cable; ideally, this should be thin coaxial cable, but screened microphone cable is suitable. The diagram shows how the two controls, the RF Gain and Volume, are connected to the boards. The leads marked '+9 V' are all connected to the battery supply via a miniature on/off toggle switch. Double check all connections before connecting the battery.

Setting the VFO

Very little adjustment is needed to get the receiver going. Firstly, the VFO must be adjusted to cover the required band, in this case 3.5–3.8 MHz.

If you have a frequency counter, connect it to the output of the VFO. If you haven't, read this part anyway so you understand the process, then another means of setting the VFO will be given especially for you! Rotate VC1 until the vanes are fully meshed. Very carefully, adjust the core of the VFO coil (L1) with a plastic trimming tool so that the frequency approaches and settles at 3.500 MHz. When you rotate VC1, the frequency should increase to **at least** 3.800 MHz at the far end of its travel.

In the absence of a frequency counter, borrow a communications receiver, set it for SSB reception (USB or LSB) on exactly 3.500 MHz. Set VC1 with the vanes fully meshed and turn the core of L1 in both directions until you hear a whistle in the communications receiver. Rotate the core so that the whistle reduces in frequency. It will eventually fade out at around 200 Hz;

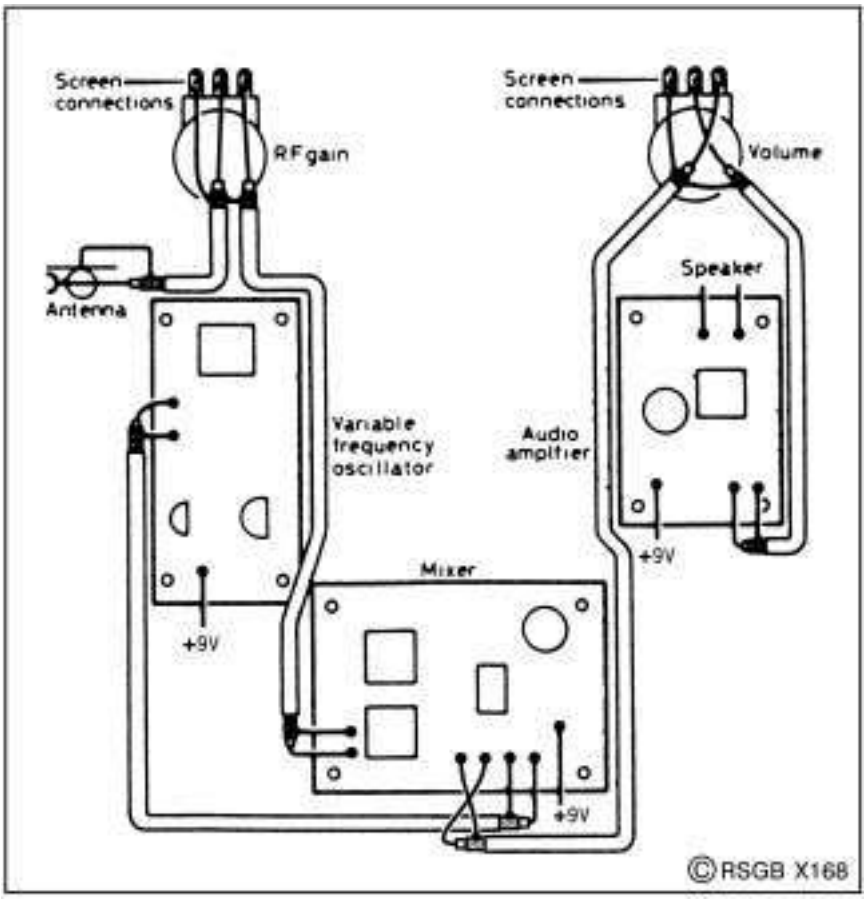

Figure 4 Make sure that interconnections between the boards are correct, including cable screens

turn the core a little further and then leave it at that position. Rotate VC1 right to the other end of its travel, and search for the whistle with the tuning knob of the communications receiver. Check that the VFO frequency is at least 3.800 MHz.

Then, whichever method you are using for frequency measurement, mark the dial with frequency steps of 50 kHz. Setting and calibration are finished!

Setting the mixer

Again, there are various ways of doing this. If you have a signal generator, inject a signal at a frequency within the 80 m band, and adjust the cores of T1 and T2 sequentially for maximum output.

If you haven't a signal generator, connect an aerial to the mixer input, set the RF Gain to maximum (fully clockwise), and find a consistent signal. Adjust the volume control to a comfortable level. Rotating the core of T2 with your trimming tool, maximise the output. Then do the same with T1, although this will have much less effect. Find another station, and check that the positions of the cores aren't too different for a maximum signal.

You may find that your receiver benefits from the insertion of an aerial tuning unit (ATU) between the aerial and the input, to compensate for the impedance of your aerial not being 50 Ω. A design for such an ATU is presented in another part of this series. If the signals are still weak, connect the ATU to the junction of C1 and C2 via a 100 pF capacitor.

Try listening!

Remember that 80 m is a variable band. During daylight hours, your will hear Morse signals at the lower end of the band, and some British and closer continental stations between 3.7 and 3.8 MHz. In the evenings, stations up to 1000 miles away should be heard. Look for Novices around 3.7 MHz!

Parts list – VFO board

Resistors: all 0.25 watt, 5% tolerance		
R1	100 kilohms (kΩ)	
R2, R5, R6	100 ohms (Ω)	
R3, R4	10 kilohms (kΩ)	
RV1	1 kilohm (kΩ) linear	
Capacitors		
C1	12 picofarads (pF) polystyrene	
C2	100 picofarads (pF) polystyrene	
C3	470 picofarads (pF) polystyrene	
C4, C5	1 nanofarad (nF) polystyrene	
C6, C8, C9	10 nanofarads (nF) polystyrene	
C7	100 picofarads (pF) min. ceramic	
VC1	140 + 140 picofarads (pF) variable	
Semiconductors		
TR1	MPF102	FET
TR2	BC182	npn
D1	1N914	silicon
Inductors		
L1	Toko KANK3334	
RFC	1 mH	RF choke

Parts list – mixer board

Resistors: 0.25 watt, 5% tolerance

R1	1 kilohm (kΩ)
VR1	1 kilohm (kΩ) potentiometer (linear)

Capacitors

C1, C3	47 picofarads (pF) min. ceramic
C2	3.3 picofarads (pF) min. ceramic
C4	100 picofarads (pF) min. ceramic
C5	100 nanofarads (nF) min. ceramic
C6, C7	10 nanofarads (nF) min. ceramic
C8	220 microfarads (μF) electrolytic 16 V
C9	1 microfarad (μF) electrolytic 16 V

Integrated circuit

IC1	Philips NE602 or NE602A

Additional items

T1/T2	Toko KANK3333
	On/off switch
	Miniature toggle switch

The next part . . .

The IF amplifier and the Beat-Frequency Oscillator will be added to convert the *Colt* into a superheterodyne receiver.

26 A two-way Morse practice system

Introduction

It is said that the pleasure of sending and receiving Morse code more than compensates for the learning effort needed. Transmitters for Morse code can be much simpler than those needed for any of the speech modes.

Many people choose to learn sending and receiving on their own. It can be much more fun if you have someone to learn with you, and it is for this reason that the following project arose. It comprises just one small circuit, and you build an identical circuit for each of the people who want to learn with you. All the individual circuits are connected with their output leads in *parallel*, as the two-way circuit of **Figure 1** shows.

A simple circuit

This diagram shows two identical circuits, as would be used if two people wanted to learn together. The circuit centres around our old friend the NE555 integrated circuit (IC). As it is connected here, it works as an *astable multivibrator*, a daunting name for what is essentially an oscillator. Each circuit is self-contained, having its own battery, Morse key, sounder and

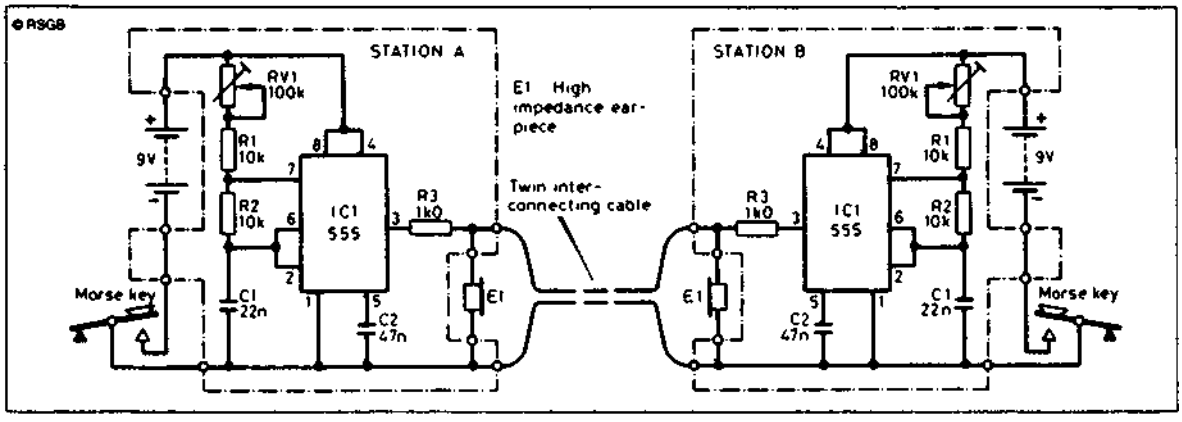

Figure 1 The circuit diagram shows two stations, but you could connect several more if needed

plastic box. The Morse key makes and breaks the power supply to the circuit, thus turning on and off the note emitted by the earpiece. The frequency of the note is controlled by the variable resistor RV1, resistors R1 and R2, and the capacitor C1. The range given by RV1 is approximately from 500 Hz to 2200 Hz.

R3 protects the output of the IC against accidental shorting either to the 0 V or to the 9 V supply rails. For best results, a crystal earpiece or high-impedance headphones should be used. You could try Walkman-type headphones, but the volume may be too low for you.

The units may be interconnected with thin twin cable (the sort used for wiring doorbells) and can be comfortably separated by 25 m, more than enough to communicate between rooms, or even with a neighbour!

In use

When an operator presses his key, the note is heard by himself and by everyone else who is connected. If more than one key is pressed at the same time, two or more notes are heard by everyone! It helps if each person adjusts his own potentiometer, RV1, to give a note which is different from the others. When one operator stops sending, the other can start immediately, without pausing to change from transmit to receive. In practice, this technique is known as *full break-in*.

The current drawn by the circuit is only 10 milli-amps (mA) when the key is down, meaning that the life of a typical PP3 battery will be virtually its shelf-life! No switch is needed, because the key acts as the switch. The current drain will be even less if the NE555 is replaced by an ICM7555 IC. It has exactly the same pin connections as the NE555, so no circuit modifications are needed.

The circuit board

The circuit is constructed easily on a small piece of Veroboard of the copper-strip type. **Figure 2** shows the layout of the prototype, the board measuring 18 holes by 10 strips. **Be aware that there is no row 'I' when you are transferring mental images of where the parts are to real positions on the board!** Break the copper tracks where shown with a 3 mm (⅛ inch) twist drill, rotated carefully between thumb and forefinger. Hold the board up to a bright light to make sure that the tracks are completely broken and that there are no fragments of copper swarf shorting adjacent tracks. Then, solder in the wire links shown in Figure 2, followed by the resistors, RV1, and the capacitors, C1 and C2. Solder the battery connector leads to tracks A and G, G being positive. Use insulated wire to connect from the board to the jack sockets used as connectors for the key and the earphones. If you use

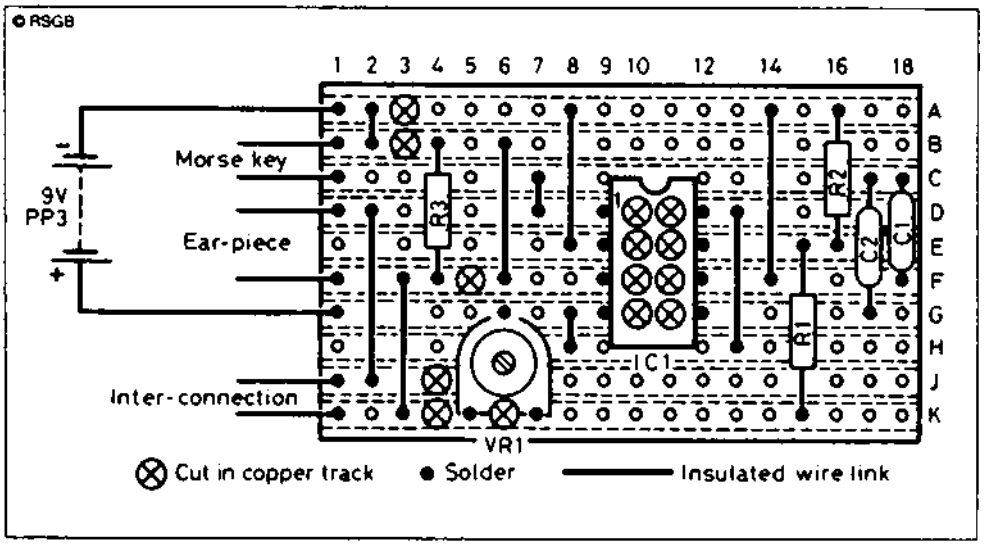

Figure 2 The Morse Duet is an easy project to build on stripboard (Veroboard)

different sized jack sockets (i.e. 2.5 mm and 3.5 mm) you won't plug the earphones into the key socket! A two-screw terminal strip is useful to connect the cable runs between operators.

The key

The circuit is designed to be used with a *straight key* (one that moves up and down). It is a requirement of the UK Morse test that a straight key is used, so it is very sensible to learn sending with a straight key before you try anything more complex! You will find many to choose from at rallies.

Parts list

For each board, you will need:		**Maplin order codes**
Resistors: all 0.25 watt, 5% tolerance		
R1, R2	10 kilohms (kΩ)	M10K
R3	1 kilohm (kΩ)	M1K0
RV1	100 kilohm (kΩ) min. preset (horizontal mounting)	UH06G
Capacitors		
C1	22 nanofarads (nF) ceramic, 25 V	WX78K
C2	47 nanofarads (nF) ceramic, 25 V	RA47B

Integrated circuit	
IC1 NE555	QH66W
Additional items	
8-pin DIL socket	BL17T
Jack plug and socket 2.5 mm	HF76H, HF78K
Jack plug and socket 3.5 mm	HF80B, HF82D
Battery type PP3	
Battery connector	HF28F
Plastic box with lid 114 × 76 × 38 mm	LH14Q
Veroboard 0.1 inch with copper strips	
18 holes × 10 strips	JP46A
Terminal strip (two section)	FE78K
Crystal earpiece	LB25C
Morse key	

27 The Colt 80 m receiver – Part 4

Introduction

In Parts 1 to 3 of this series, the design of an 80 metre direct-conversion receiver has been described. In this final part, we are going to change the circuit to operate as a superheterodyne receiver, or *superhet*. Most radio receivers are superhets, and they change the incoming signal to another frequency, known as the *intermediate frequency*, or IF, before producing an audio signal. The use of a superhet in a good receiver is mandated by the requirements for good *sensitivity* and *selectivity*.

Sensitivity and selectivity

Figure 1 shows the block diagram of the receiver. If you look closely, you will see that it is two similar circuits, one after the other. The incoming

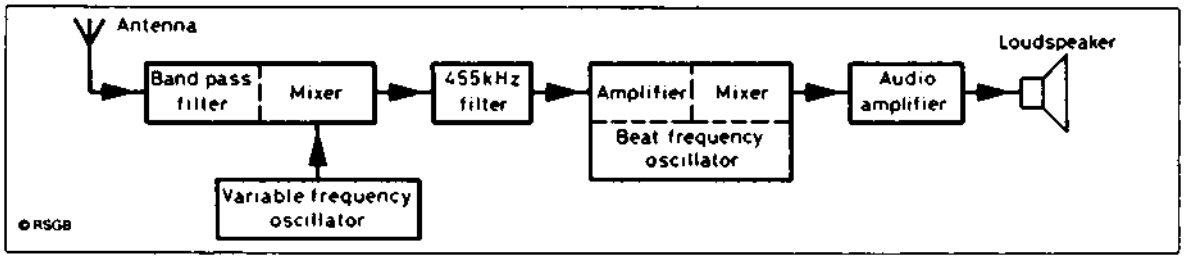

Figure 1 This is how the different stages of the Colt go together to make a superhet receiver

signal is filtered and fed to a mixer where it is combined (mixed) with the signal from the variable-frequency oscillator (VFO). This oscillator operates at a frequency which is 455 kHz higher than the incoming signal from the aerial, and the mixer output is therefore at a frequency of 455 kHz. If you are not sure about this, please refer to the section 'The direct conversion process' in Part 3 of this project. This new frequency is called the *intermediate frequency*, or IF. This frequency doesn't change; the tuning is accomplished by the VFO, and the mixer output is *always* at 455 kHz. The extraction of the audio signal from the IF signal is identical with the direct conversion process which is used in your existing receiver.

This may seem a long-winded way of doing things, but it has its advantages. A receiver must have a good *sensitivity*, or gain, so that it can receive very weak signals. In very general terms, it is easier to handle low-frequency signals than it is to handle high-frequency signals. We are changing our signal frequency from around 3.6 MHz down to 0.455 MHz (455 kHz), which is much lower and can be filtered and amplified relatively easily. A second advantage is that it is easier to provide gain at a fixed frequency than at a variable frequency. Remember that the IF is fixed, and providing gain is, again, relatively simple.

Our receiver also needs good *selectivity*, the ability to separate (or select) one station from another very close to it in frequency. This requirement is significantly simplified by the fact that the IF is fixed, and a good filter in the IF circuits can do wonders for the rejection of adjacent-frequency stations! Several stages of IF amplification and filtering are possible in more adventurous designs.

The filtered signal at 455 kHz passes to another mixer which has an associated oscillator, usually called a *beat frequency oscillator* (BFO). When receiving CW (Morse) signals, the BFO is usually tuned about 1 kHz above or below the IF (i.e. at 454 or 456 kHz) to produce a 1 kHz beat note as the audio signal. This signal is then amplified and fed to a loudspeaker or headphones.

The circuit

Figure 2 shows the circuit of the IF section shown in the photograph on p. 94; this section is added to the existing circuit to make it a superhet. The existing mixer board (described in Part 3) is used as the first mixer. Between it and the audio amplifier is connected the new IF board.

The signal output from the first mixer (at 455 kHz IF) is fed into a *crystal filter*, the most expensive part in the whole receiver. It provides the selectivity which makes the Colt such a good receiver. Another NE602 mixer/oscillator chip follows the filter. The oscillator section is controlled by the tuned circuit in T1, the frequency of which can be altered by rotating the core inside the coil. Once set, it remains fixed.

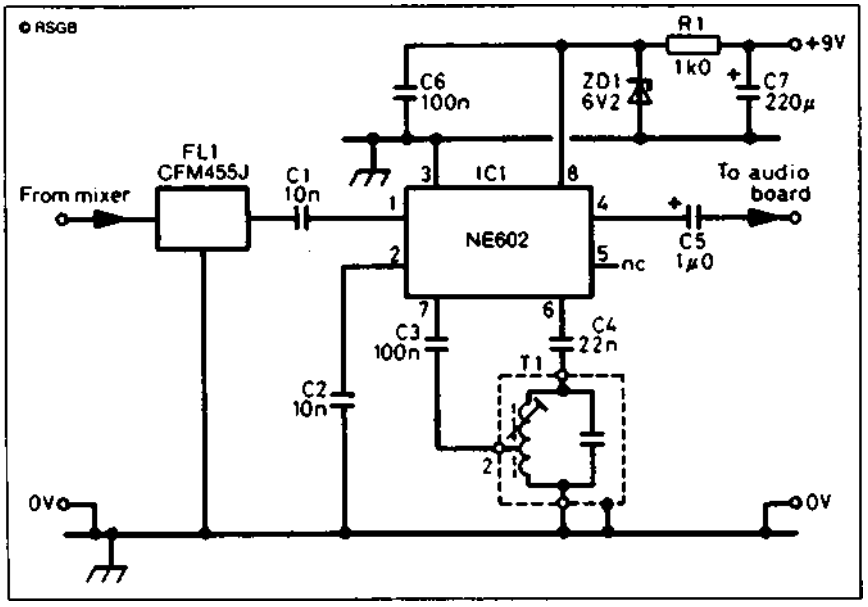

Figure 2 The IF board is connected between the mixer and audio amplifier

At this stage you should have built the first mixer and the audio amplifier, and proved that they *both* work by using the circuit as a direct-conversion receiver. When you have finished constructing and checking the IF board, you will need to add it to your existing circuits.

Adjusting and testing

There are three pairs of connections to the IF board – the 9 V supply leads, the input leads and the output leads. The IF board should be mounted on the metal baseplate, along with the other boards. **In making the following connections, make absolutely sure that the braid of each piece of coaxial**

cable is soldered to the correct connection on each board. The same applies to the polarity of the 9 V leads. Disconnect the screened lead which presently goes from the first mixer board to the AF amplifier at the amplifier end. Connect it instead to the *input* of the IF board. Connect a new piece of screened cable from the IF output to the vacated AF input. Now connect the 9 V supply leads to the same points as the supply leads from the other boards. Check these newly made connections.

You should have confidence at this point that things should be right. After all, you *have* tested the direct-conversion process and you *know* it works. All that you are now testing is the IF board. This is the attraction of building a receiver in modules, working from the speaker backwards, and testing as you go!

The VFO and BFO need to be correctly adjusted. Mesh the vanes of the tuning capacitor and, using the same frequency measurement method as you did originally, set the VFO frequency to 3.955 MHz (which is 3.500 MHz + 0.455 MHz, if you hadn't guessed!). The BFO can be set using a frequency counter, but it is just as good to set it by listening to SSB or CW signals. A high-pitched hissing sound should be heard in the speaker. As you rotate the core, the pitch should reduce, go through a minimum, then increase again. Set the core at the minimum pitch position. You may want to readjust the two cores a little as your listening skills improve but, once you are happy, they will never need to be altered again!

In conclusion . . .

You should now have built a superhet receiver capable of excellent results. It uses the same type of circuit as that found in far more advanced receivers.

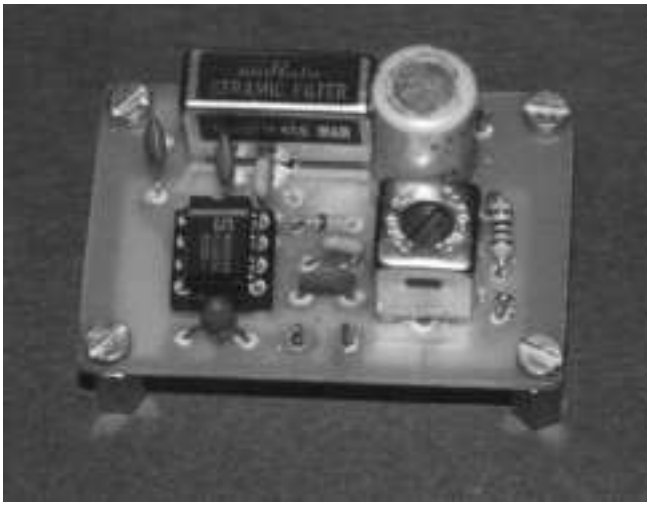

The superhet is far more sensitive than the direct-conversion type, and can weed out those elusive DX stations. You may have found that a station will appear at two places on the dial of the direct-conversion receiver; you will have no such problem with the superhet.

Parts list

Resistor		
	R1	1 kilohm (kΩ), 0.25 watt, 5% tolerance
Capacitors		
	C1, C2	10 nanofarads (nF) min. ceramic
	C3, C6	100 nanofarads (nF) min. ceramic
	C4	22 nanofarads (nF) min. ceramic
	C5	1 microfarad (μF) 16 V electrolytic
	C7	220 microfarad (μF) 16 V electrolytic
Integrated circuit		
	IC1	NE602
Additional items		
	ZD1	Zener, 6.2 V 0.5 watt
	FL1	Crystal filter, Murata CFM455J
	T1	Tuned inductor, Toko YHCS11100AC

28 A simple crystal set

Introduction

There are many designs of crystal set – they are all 'simple', and even the most seasoned radio amateur will build one of these every so often because it is something that never ceases to amaze! Although using modern components, the design is a period piece!

Design and construction

The circuit diagram of **Figure 1** shows the simplicity of the circuit. The prototype was constructed on a wooden baseboard with an aluminium front panel, although this could be made of wood if you prefer.

Winding the coil always causes the most groans but when finished, gives the most satisfaction. The construction of the coil is detailed in **Figure 2**. A discarded toilet roll centre is an ideal *former* on which to wind the coil. The coil will take up about 7 cm of the length of the tube, so assuming the tube is about 11 cm long, the ends of the coil will be about 2 cm in from each end of the tube.

The aerial coil, the *primary winding* of this radio-frequency (RF) transformer, is made from about 30 turns of 26 SWG enamelled copper wire, wound on the matchstick ribs. These ribs should be about 2 cm long, and are glued on **top** of the end of the secondary coil *after* the secondary coil has been wound. The *secondary winding* has 140 turns with *taps* every 10 turns for 70 turns. This coil covers most of the length of the cardboard tube. To make your coil-winding easier, here are some tips for completing the coil and still having some hair left at the end!

- Support the reel of wire on a dowel rod or pencil, clamped in a vice or held rigid in a vertical position by some other means. Don't leave it to trail around on the floor.
- Have a small piece of sandpaper handy to remove the enamel from the copper wire, starting with the end coming from the reel. Remove about 1 cm only, until the shiny copper is visible all round the end of the wire.

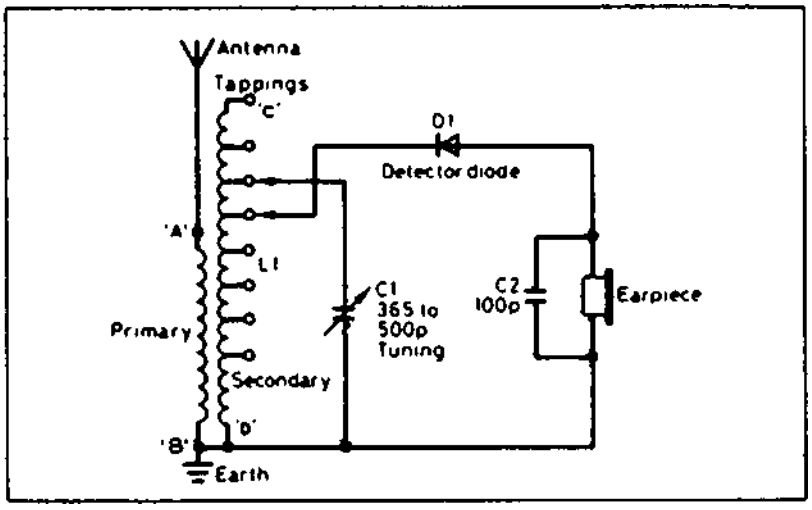

Figure 1 Circuit diagram of the crystal set

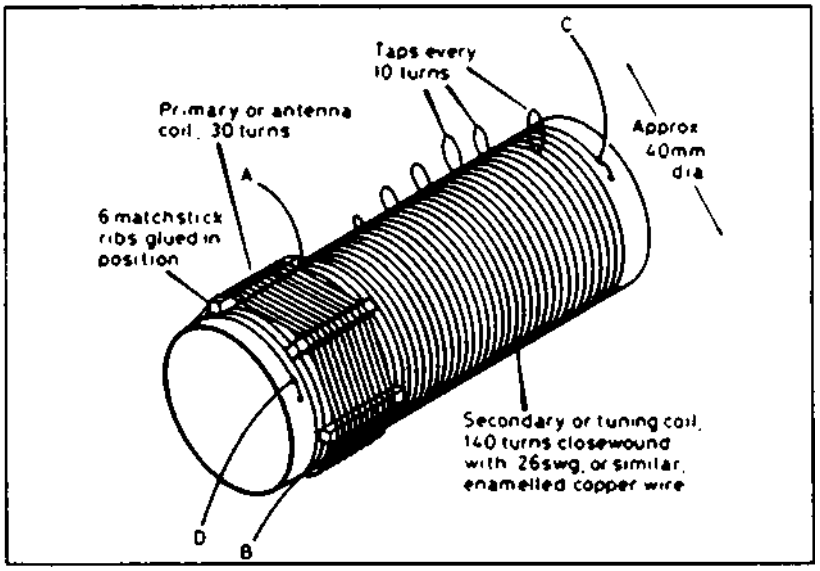

Figure 2 The coil is mounted on a cardboard tube as shown. Exact size is not too important. Try different taps for best results

- This part is the most difficult of all. Seasoned coil winders may have their own favourite ways of doing this, but for first-timers, play it safe and do it this way! Have a second bobbin (or a piece of stout card) ready, on which you will need to wind the wire loosely while you prepare the taps. Then, starting from the free end of the wire, measure 125 cm and, at this point, remove about 2 cm of the enamel with the sandpaper. Bend the wire firmly back on itself in the middle of the bared area, and *tin* (cover with solder) the exposed copper. This is your first tap. Then repeat this six more times at 125 cm intervals, thus giving you seven taps; wrap the wire as you go, on to the second bobbin or piece of card. After the seven taps, you are half-way down your coil so, to begin winding it in earnest, wind the wire carefully from the second bobbin or card **back** on to the original reel of wire.
- Looking at Figure 2, make two small holes about 3 mm apart, about 2 cm down from the top of the tube, where wire C will be entering. Poke the end of the wire into one hole, then bring it out again through the other; leave about 10 cm of wire on the free end. Loop this wire in and out once more, thus anchoring the wire firmly.
- Then, begin winding; keep the wire tight and make adjacent turns touch neatly. As you pass each tap, make sure it sticks outwards while avoiding flexing the wire too much; the wire is inherently weak at each tap.
- When you reach the last 10 cm of wire, stop. Put two more holes, like the first, beside your stopping point, and anchor the end, D, of the coil in the same way as you did with end C. The secondary winding is complete. Take a break *after* you have completed the next step!

- Prepare the six matchsticks for supporting the primary coil and glue these every 60 degrees around the end of the coil at D. Remove the enamel from the free end of the new copper wire on your reel and, using your favourite quick-drying cement, put a drop over the wire on one of the matchsticks, leaving 10 cm free as before. If you are using 26 SWG enamelled copper wire, its diameter is 0.46 mm, so 30 turns should occupy 14–15 mm of the 20 mm matchstick length. This will allow you to position the glued point such that the coil will be roughly in the centre of the matchsticks. When the glue has set, wind the 30 turns and anchor this end of the coil in the same way. Then remove the enamel at the end of the 10 cm lead.

Assembly

The coil former can be screwed to the baseboard at each end, *before* the front panel is screwed to the baseboard! As the photograph on the next page shows, the tuning capacitor is mounted in the centre of the front panel. Five solder tags (or drawing pins as a last resort) should be screwed into the baseboard. The two to the left of the photograph are the connections to the earphones, the two along the rear edge have the diode, D1, soldered to them. One end of the diode (and, for once, you can connect the diode either way round!) is connected to one earphone tag. The other end has a flying lead of about 10 cm attached to it and terminated in a crocodile clip which is used to connect to one of the taps on the coil. The fifth tag secures the end, A, of the primary coil, to which you will attach the aerial. The earth tag on the tuning capacitor, C1, serves as an anchor point for the ground connections to B and D and to the other earphone tag.

Use

The longest piece of wire you have available to use as an aerial should be connected to the aerial tag just mentioned. If you can connect the earth tag of the tuning capacitor to a good electrical earth, this will help also. You should be able to hear something as you turn the tuning knob. Try adjusting the tapping connections on the coil – change only one at a time, or you will never find the optimum positions. You now have a fully operational crystal set!

Simple it may be, but this circuit illustrates some important principles which are used even in the most expensive receivers. Firstly, the coil, L1, and the capacitor, C1, form a *tuned circuit* which *resonates* at the frequency of the station you have tuned in. This *selects* the signal you want to hear. The *modulation* on this signal is removed by the *detector*, D1, and fed to the earphones, which act as *transducers*, turning the electrical energy into sound energy which you can hear. It doesn't need a battery or other power supply either!

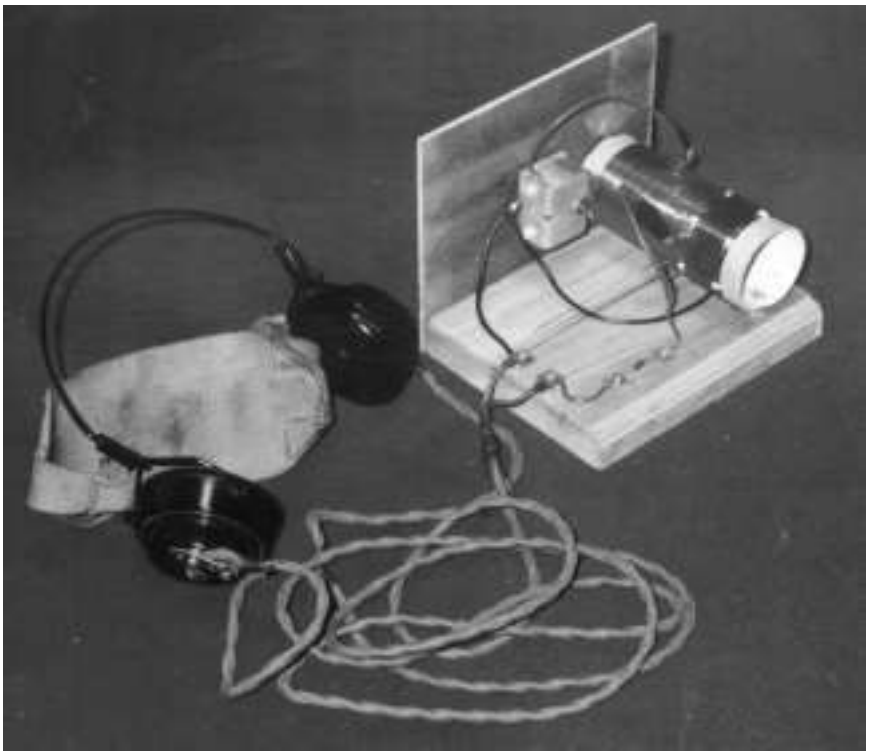

Parts list

Capacitors

C1	Variable capacitor of between 200 and 500 picofarads (pF) maximum
C2	100 picofarads (pF) min. ceramic

Additional items

D1	Germanium, type OA47 or OA90
	High impedance crystal earphone (not Walkman type)
	Tuning knob
	Wooden base, approx. 110 mm square
	Aluminium (or wood) front panel, approx. 80 × 100 mm
	Cardboard tube (toilet roll centre), about 110 mm long, 40 mm diameter
	Reel of 26 SWG enamelled copper wire for both windings of L1

29 A crystal calibrator

Introduction

A crystal calibrator is a device that produces oscillations of a precise frequency which are rich in *harmonics*. A harmonic is an integer multiple of the fundamental frequency; for example, if our fundamental frequency was 100 kHz (as it is in this circuit), there would be harmonics of this frequency at 200 kHz, 300 kHz, 400 kHz, and so on. These harmonics can be used, when picked up by any receiver, to calibrate that receiver, as the harmonics are quite accurate in frequency (see later for an assessment of accuracy). However, a gap of 100 kHz between harmonics is rather wide for most purposes, so we reduce this frequency to 25 kHz, so that the harmonics are then 25 kHz apart, thus producing a much more useful set of *marker points*. A calibrator such as this is often called a *crystal marker*, producing these marker points from 25 kHz to beyond 30 MHz.

The circuit

The circuit diagram is shown in **Figure 1**. The circuit around TR1 is the fundamental oscillator, and its frequency is controlled by the quartz crystal, X1. Even crystal oscillators are not 100% accurate, and the small trimmer capacitor, TC1, is able to 'pull' the frequency to one which is nearer the

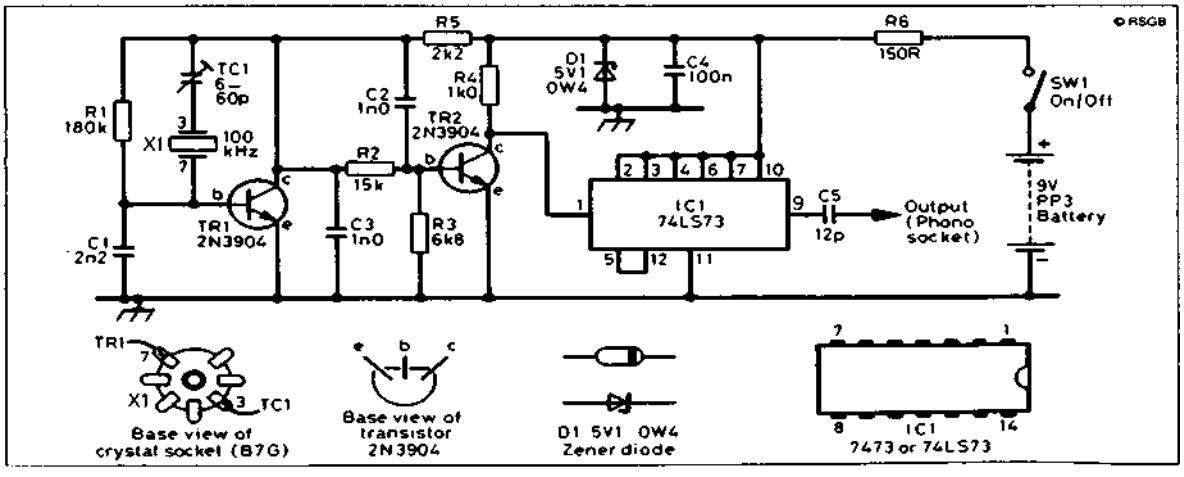

Figure 1 Circuit diagram of the calibrator which uses easily obtainable components

correct one. TR2 is a *buffer* stage, which isolates the oscillator from the rest of the circuit. It acts as a switch, and applies a good signal (switching between 0 and 5 V) to the input of IC1.

IC1 is an integrated circuit which can be connected to do several things. It is connected here to divide the incoming frequency by a factor of 4, producing on pin 9 an output frequency of 25 kHz.

The combination of R6, C4 and D1 produces a supply of 5 V for IC1; it would be damaged if the battery voltage were applied to it. You will no doubt be ready to assemble the circuit, so here is some information for you.

Construction

If possible, always build a circuit in individual stages, which you can test as you go along. It is not always easy in small projects like this, but even the crystal calibrator can be split into two for construction and testing.

It is an ideal project for assembly on Veroboard of the copper-strip type; the prototype layout is shown in **Figure 2**, on a board measuring 11 holes by 24 strips. First of all, remove the copper strip at the locations shown, using a 3 mm drill rotated between the fingers. Hold the board up to the light to ensure that there are no pieces of copper swarf bridging adjacent strips, and that the copper is completely removed where it should be! Assemble the circuit from left to right, but do not wire up anything around IC1. Be aware that the diagram shows the board *from the component side*. Although you

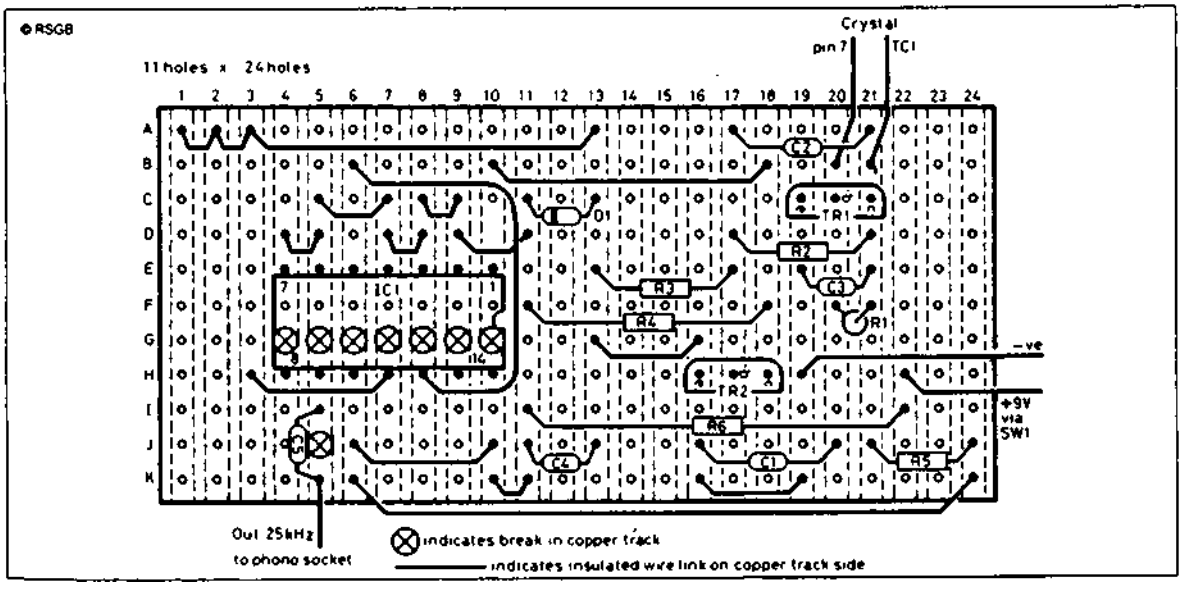

Figure 2 Stripboard, such as Veroboard, should be cut as shown to approx. 62 × 28 mm

can use virtually any kind of crystal, you will need to mount it firmly. If you use a small one, it can be soldered directly in position on the board. With one in a valve envelope, you will need a B7G valveholder. Be prepared to mount the circuit in a **metal** container; the prototype used an (empty) tin of tuna! The valveholder mounts well on any metal case.

Disconnect the aerial of your receiver, and replace it with about 30 cm of wire laid near your oscillator circuit. Connect the battery and switch on. Tune the receiver around until you can hear a whistle on SSB. Rotate the tuning knob to reduce the frequency of the whistle and, as the whistle becomes too low to hear, you have reached one of the calibration markers, and your frequency will be an integer multiple of 100 kHz. If you are already using a calibrated receiver, you will be able to verify this. Going up or down in frequency should locate another marker 100 kHz away, and so on right through the receiver's tuning range. If the signals coming from the circuit are very weak, switch off the calibrator and connect another 30 cm piece of insulated wire to the collector of TR2, and lay it close to (but *not* touching) the wire from the aerial connector. Switch on an try again; you should not now have a problem! If you have access to a multimeter, check that the voltage at the collector of TR1 is very close to 5 V. If it is close to 9 V, you have connected the diode, D1, the wrong way round!

Having verified that the oscillator is working, you can now wire up the integrated circuit socket, being careful to put the notched end of the socket pointing towards R4, the collector resistor for TR2.

Check your connections around IC1, and when you are satisfied that they are correct, line up IC1 with its socket, making sure that the notched ends are together, and press down *gently* to insert the IC into its socket. Insert the 30 cm piece of insulated wire into the output socket, connect the battery and switch on. You should still hear whistles in your receiver, but now they should be 25 kHz apart, rather than 100 kHz apart.

All that now remains to be done is to mount the circuit rigidly inside whatever casing your have chosen. Make sure that none of the connections under the board touch the metal case, and secure the valveholder, on/off switch and output connector to the case. You now have a completed crystal calibrator.

Calibration

The simplest way to calibrate your circuit is with a frequency counter. Most clubs will have one of these and, if not, will know someone who has! Connect it to the collector of TR2, where the frequency should be 100 kHz. Do *not* connect it to any part of the circuit around TR1, or you may alter the frequency you are trying to measure! If the frequency is not exactly 100.000 kHz, rotate TC1 until it is (or is as close as you can get it). Now your calibrator is as accurate as the counter with which you have calibrated it.

Accuracy

Despite your best efforts at calibration, by whatever means, your crystal will *never* have a constant frequency. Such a thing is a scientific impossibility. It is usual to express the accuracy of a crystal in parts-per-million (ppm), and it is governed by many things, principally its temperature. You will be *very* fortunate if your circuit maintains an accuracy better than about ±10 ppm. Expressed in figures, it means that the true frequency can be anywhere between 99.999 kHz and 100.001 kHz, i.e. within 1 Hz of the correct frequency.

Although this may seem more than adequate, it is as well to remember that the accuracy degrades as the frequency increases. At 1 MHz the error will be ±10 Hz and at 10 MHz it will be ±100 Hz. At 30 MHz it will be 300 Hz. Even so, this should be acceptable for most non-critical applications.

Parts list

		Maplin code
Resistors: all 0.25 watt, 5% tolerance		
R1	180 kilohms (kΩ)	M180K
R2	15 kilohms (kΩ)	M15K
R3	6.8 kilohms (kΩ)	M6K8
R4	1 kilohm (kΩ)	M1K0
R5	2 kilohms (kΩ)	M2K0
R6	150 ohms (Ω)	M150R
Capacitors		
C1, C2, C3	1 nanofarad (nF) or 1000 picofarads (pF)	WX68Y
C4	100 nanofarads or 0.1 microfarad (μF)	YR75S
C5	12 picofarads (pF)	WX45Y
TC1	60 picofarads (pF) trimmer	WL72P
Semiconductors		
TR1, TR2	2N3904 npn	QR28F
IC1	7473 or 74LS73N dual JK flipflop	YF30H
D1	5.1V 500 mW Zener	QH07H
Additional items		
100 kHz crystal		
B7G valveholder (found at most rallies)		
14-pin DIL IC socket		BL18U
Phono socket		YW06G
PP3 battery connector		HF28F
PP3 battery		
On/off switch		FH00A
Veroboard		JP47B
Metal case as required		

30 A simple short-wave receiver – Part 1

Introduction

No apologies for yet another design of short-wave radio. This is the beauty of our hobby – there is always something new to try. Not all circuits operate in the same way; not all circuits work equally well; sometimes a simple design suits the operator better than a complicated design. So here is another one for your consideration; it's a good project for a novice, *and* a good one-evening project for someone more experienced.

A basic description

Figure 1 gives the block diagram of the receiver, which employs a *regenerative detector*, one of the earliest techniques by which excellent *selectivity* (the ability to separate two stations very close in frequency) could be combined with good *sensitivity* (the ability to pick up very weak stations) using a very simple circuit. The receiver falls into the category known as *tuned radio frequency* (TRF), meaning that the whole circuit (prior to the extraction of the modulation from the carrier) operates at the incoming radio frequency. In other words, it is *not* a superhet.

As you can see, the regenerative detector has what is called a *feedback loop*, which feeds a small amount of the output signal back to the input. You have heard the effects of feedback with a public address system, when the microphone gain is too great – everything becomes very loud and then bursts into a deafening squeal! This is exactly what the feedback does here, except that it is carefully controlled, thus providing both gain and selectivity. The resulting audio is then amplified for use with headphones.

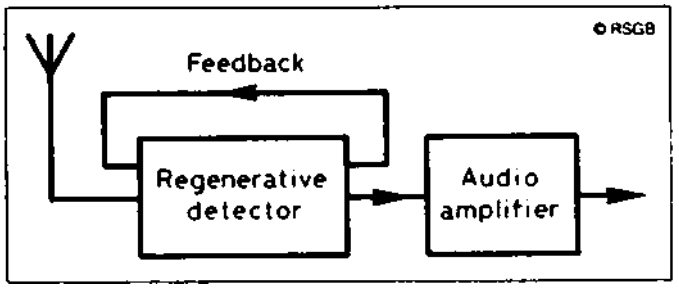

Figure 1 Just two simple stages make up the circuit

The circuit

The circuit of **Figure 2** shows the complete system. TR1 is an untuned *field-effect transistor* (FET) stage, and is used to match the aerial to the next stage. Occasionally, a regenerative detector produces unwanted signals, and TR1 also prevents them from reaching the aerial and being transmitted! The smaller of the two windings on T1 (the *primary* winding) will match a low-impedance aerial, the capacitor input matching a high-impedance aerial.

Ignore TR2 for the moment – the next stage in the signal path is TR3, the detector, using another FET. The tuned circuit is formed by T2, VC1 and VC2 (remember TR1 is untuned). The primary winding on T2 taking the output from TR1. The reason for having two variable tuning capacitors, one large, the other small, is that the large capacitor is the main tuning capacitor, while the small one is used as a *bandspread* control (for very fine tuning). The tuned signals are then detected (converted to audio frequencies) by TR3.

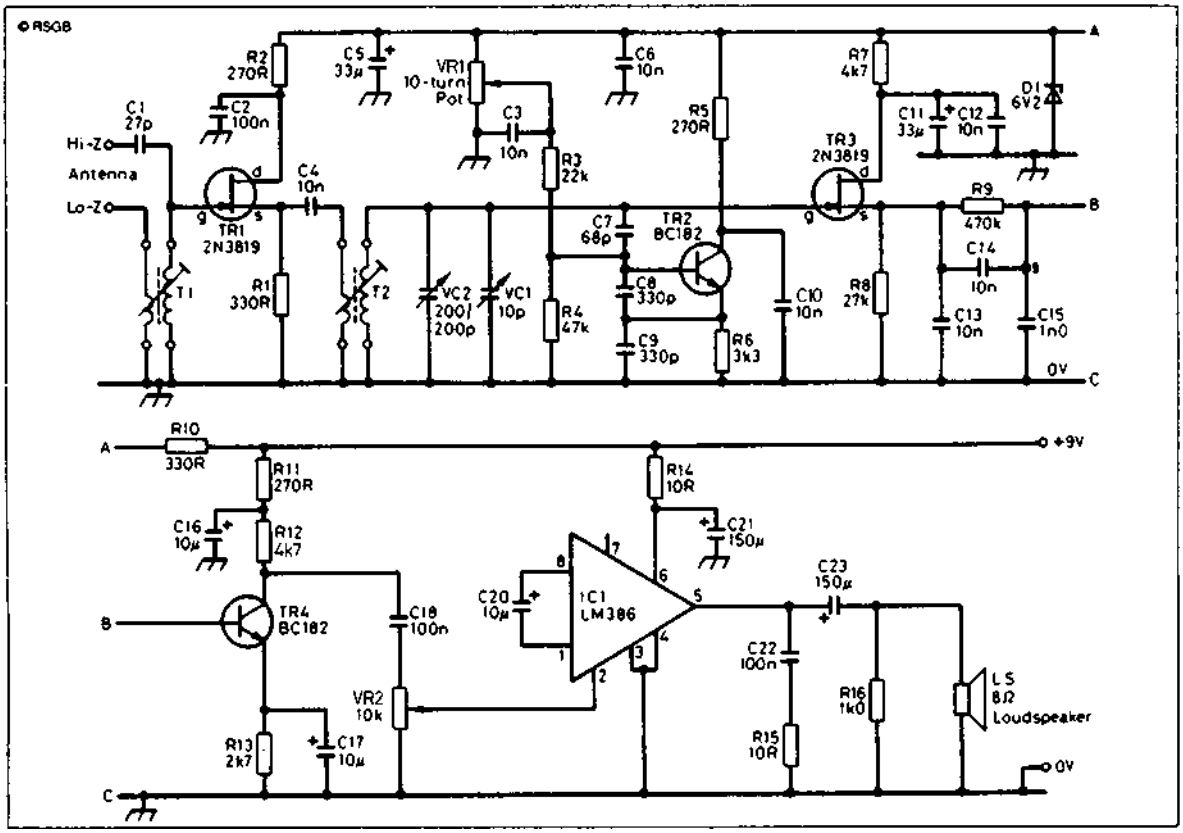

Figure 2 The circuit diagram showing the 10-turn potentiometer VR1. This is the regeneration control for the circuit

TR2 is a *Q-multiplier* stage. It is a Colpitts-type oscillator which uses C8 and C9 to give feedback and produce the oscillation. C7 couples the tuned circuit (and the input to TR3) to TR2. The tuned circuit thus controls the frequency of oscillation of TR2 and the signal passed on to TR3.

The secret of the ease of operation of this receiver is VR2, a 10-turn potentiometer (or *helipot*). The resistance wire is wound in the form of a helix, giving a much greater wire length than in a normal potentiometer, and the shaft must be turned ten times to cover the whole length. Helipots are very useful when very fine adjustments have to be made. Here, VR2 sets the regeneration (or *reaction*) level, depending on the type of signal you are receiving, as will be discussed in Part 2.

TR4 provides the first stage of audio amplification and, after the volume control, VR2, the audio amplifier integrated circuit, IC1, will drive a small loudspeaker or headphones.

In Part 2, the construction will be discussed, together with the choice of aerial, the parts list, and advice on using the receiver.

31 A fruit-powered medium-wave radio

Introduction

This is a one-evening project that will result in a working medium-wave (MW) radio, and will also teach you a little about the way electricity can be generated from the right metals and a little (safe) acid. All you need are three lemons or other citrus fruit, three pieces of copper and three pieces of zinc (or galvanised metal) for your power supply.

Construction

Figure 1 shows the circuit and **Figure 2** its layout on a simple 'plug-in' prototype board. The six pieces of metal are connected as shown, to wire the three lemons in series; use ordinary wire between each lemon and the next. If you have a meter to measure the total voltage, it should be about 1.8 V. Use a standard ferrite rod, and wind on it about 40 turns of single-conductor PVC-insulated wire.

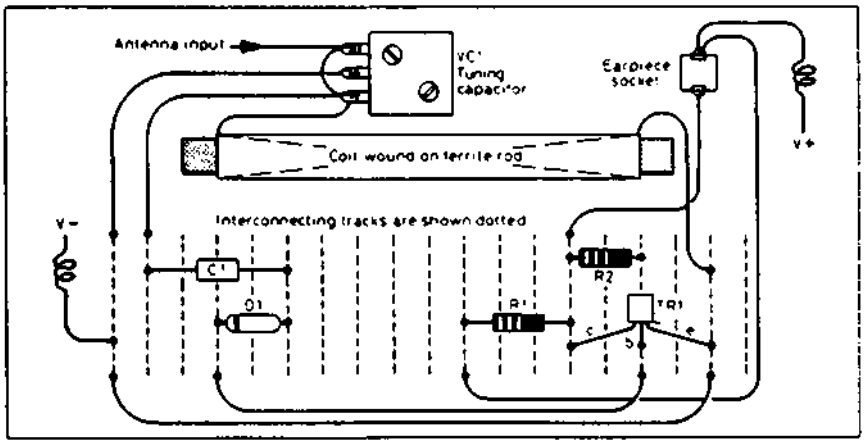

Figure 1 Most parts are plugged into the board as shown – soldering is not required

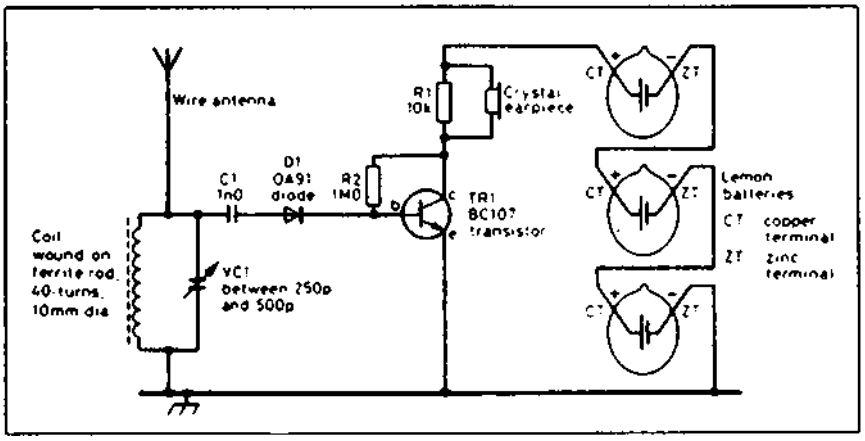

Figure 2 Three lemons power the radio, which gives good results for such a simple circuit

Wire up the circuit on the board as illustrated in Figure 2. Soldering is not required with this type of board – just plug in the components and the wires. Only one transistor is needed. The tuning capacitor, VC1, selects the station you want to hear, and D1 helps to remove the carrier from the RF signal. The resulting audio signal is fed to TR1, a small transistor audio amplifier, which makes the signal big enough to drive a crystal earpiece comfortably. Walkman-type earphones will not work, so invest in a crystal earpiece which you can use in several other projects, too! If you use a smaller capacitor than that specified for VC1, you will need more turns on the aerial coil.

Tests on the prototype indicated that the radio will run for about a week on three lemons!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	1 megohm (MΩ)
R2	10 kilohm (kΩ)

Capacitors

C1	1 nanofarad (nF) min. ceramic
VC1	250–500 picofarad (pF) variable

Semiconductors

TR1	BC107 npn (or BC108, BC109C)
D1	OA90, OA91 germanium (not silicon)

Coil

L1	2 metres of single-conductor insulated wire on a standard ferrite rod

Additional items

Plug-in prototype board, e.g. Maplin YR84F
Wire aerial at least 3 m long
Crystal earpiece
Three juicy fruits

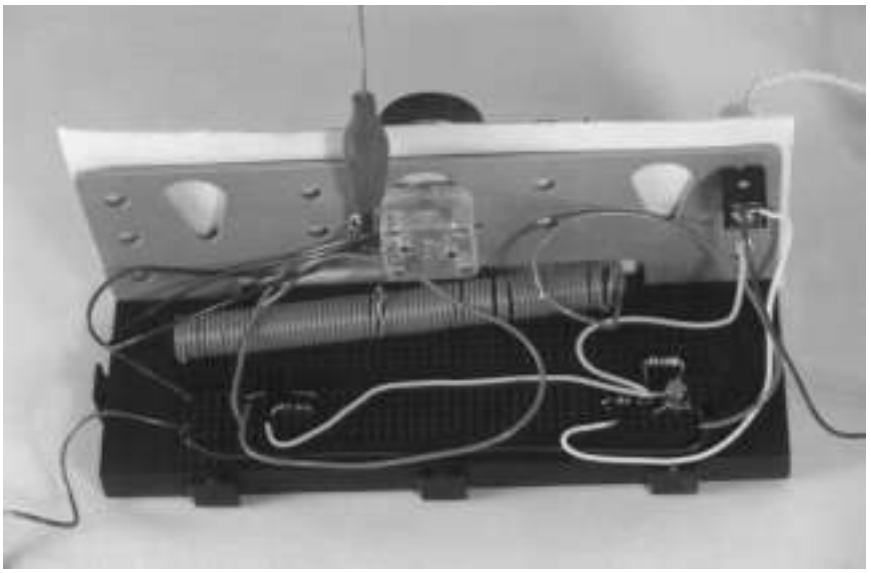

32 A capacitance bridge

Introduction

It is always valuable to have a means of measuring capacitors amongst your test gear. Universal LCR bridges (i.e. systems that can measure inductance, capacitance and resistance) can be found at most rallies, and you can work your way up to owning one of these. In the meantime, a piece of home-made equipment gives you experience as well as resulting in a useful measuring instrument.

The circuit described here is called a *capacitance bridge*, because it balances the effects of one resistor/capacitor pair against another; if one capacitor has an unknown value, then the other can be calculated. The basic bridge circuit is shown in **Figure 1**. To avoid having calculations to perform, this instrument will be calibrated by using capacitors of known values. The bridge is a useful way of performing measurements, because a knob is turned until there is a null in the signal from an earpiece or loudspeaker. The ear is very precise in being able to perceive nulls, which makes the bridge easy to use and reasonably accurate. At the null, the bridge is said to be *balanced*.

How does it work?

Figure 2 is the circuit diagram for this capacitance bridge. Transistors TR1 and TR2 form an oscillator. This is the audio oscillator shown in Figure 1, and produces an alternating voltage which is fed to the bridge. RV1 (in the collector lead of TR2) replaces both R1 and R2 in Figure 1 – that part of

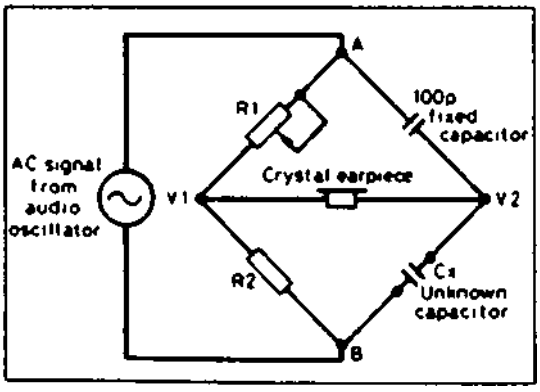

Figure 1 Simplified circuit of a capacitance bridge. R1 is adjusted for minimum sound

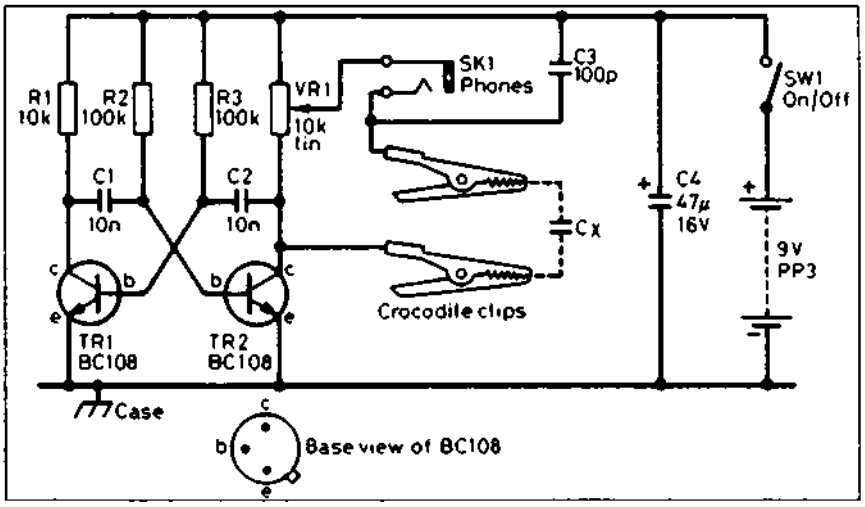

Figure 2 Transistors TR1 and TR2 give an audio signal which is adjusted by variable resistor RV1

RV1 *above* the wiper represents R1, while that part *below* the wiper represents R2. The voltage on one side of the earpiece is determined by the ratio of these values, and is adjusted by rotating RV1. The voltage on the other side of the earpiece is determined by the ratio of C3 to Cx, where Cx is the unknown-valued capacitor. When these two voltages are the same, the bridge is balanced and there is no current through the earpiece.

Figure 3 shows the layout of the components on the matrix board of the prototype. It measures 10 holes by 14 holes, and is of the plain type, i.e. no copper strips. All earth connections are taken to a single solder tag. When

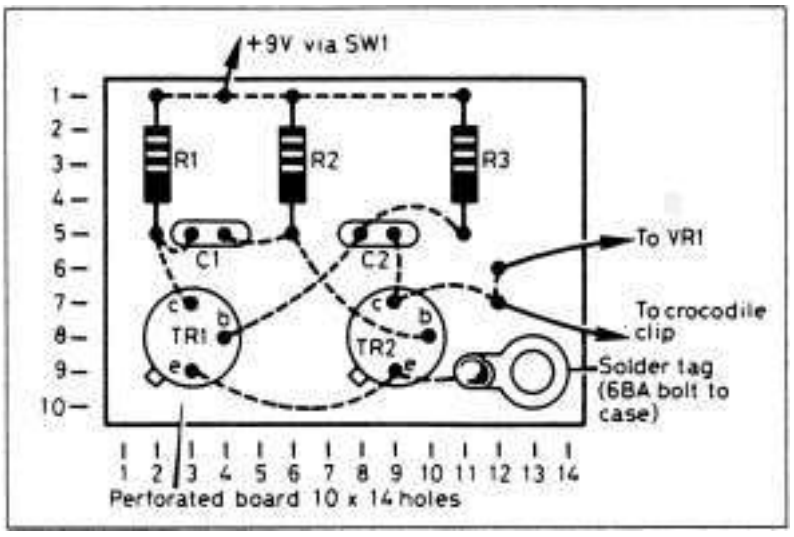

Figure 3 Components are soldered together on a small prototype board

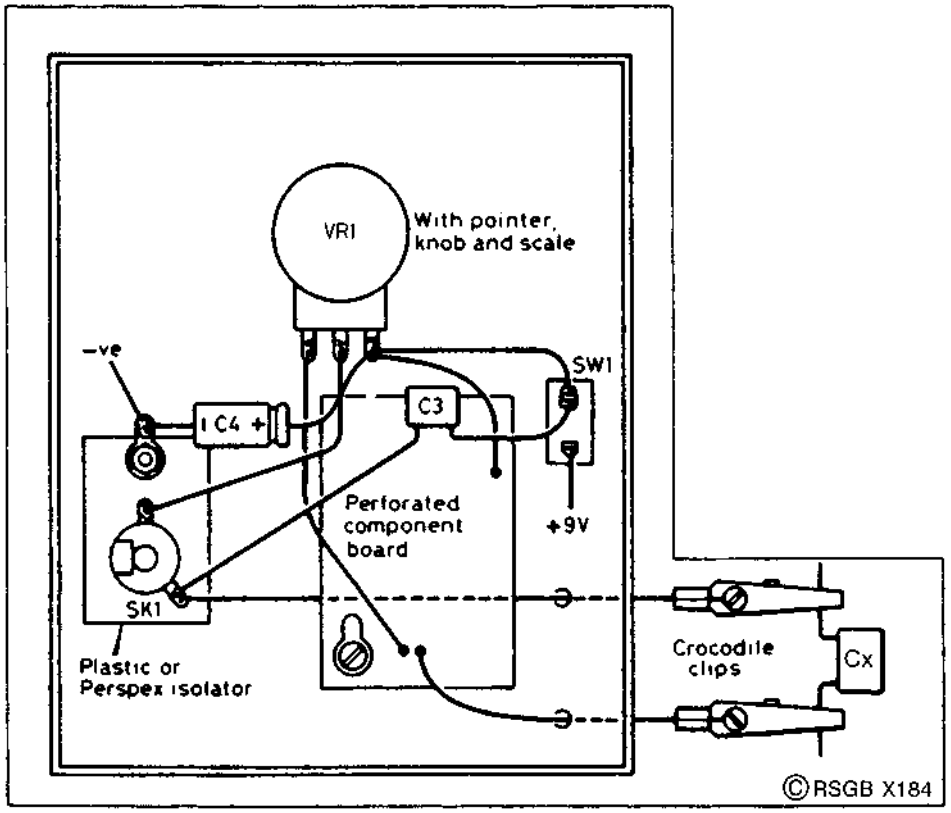

Figure 4 Layout of the parts inside an aluminium box. The earpiece socket is insulated from the case

mounting the board inside a metal box, a long screw is used with extra nuts, to earth the board to the case while providing a stand-off, thus preventing any unwanted short-circuits between the board connections and the case. Be aware that a *crystal* earpiece must be used; low-impedance headphones of the Walkman type are not satisfactory. Solder two flying leads as shown in **Figure 4**, about 15 cm long, terminated in small crocodile clips for attaching to the unknown capacitor.

Calibration

After checking the circuit carefully, attach the battery and switch on; a buzzing noise should be heard in the earpiece. This is the first sign that everything should be OK. If there is no buzz, switch off and recheck the connections.

You will now need a range of close-tolerance (1%) silver-mica capacitors covering the range 10 to 1000 picofarads (pF). Arrange the capacitors in ascending order and connect them to your bridge in sequence. After having prepared a neat piece of card or paper mounted behind the knob on the front panel, mark the dial at the positions of the nulls for all the capacitors. You have now calibrated your capacitance bridge. If you are more likely to want to measure larger capacitors, replace C3 by a 1 nanofarad (nF) capacitor, and the bridge will measure up to 10 nF approximately.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	10 kilohms (kΩ)
R2, R3	100 kilohms (kΩ)
RV1	10 kilohms (kΩ) linear

Capacitors

C1, C2	10 nanofarads (nF) ceramic
C3	100 picofarads (pF) silver mica or polystyrene
C4	47 microfarads (μF) 16 V electrolytic

Semiconductors

TR1, TR2	BC108 npn

Additional items

SW1	SPST on/off switch
	Battery connector, PP3 type
	Earpiece, crystal type
SK1	3.5 mm jack socket for earpiece
	Battery, 9 V PP3
	Matrix board, approx. 10 holes by 14 holes
	Aluminium case, approx. 10 × 8 × 5 cm

33 A simple short-wave receiver – Part 2

Introduction

In Part 1, the design of this receiver was discussed in some detail. Now we are going to put it all together and see how it works. The receiver is laid out on a printed-circuit board (PCB) or on a matrix board.

Construction

The layout of the components is shown in **Figure 1**. Identify each part separately, insert it into the holes in the board and solder carefully. Long leads may be cropped before or after soldering, depending on your skill and preference. All electrolytic capacitors, T1, T2 and IC1, must be connected correctly. The front-panel controls are connected to the PCB terminals shown in Figure 1.

The layout of the controls and the placing of the board inside the case are matters of personal preference. The size of the prototype front panel is shown in **Figure 2**. The prototype had a slow-motion drive fitted to VC2, the main tuning capacitor. This required the capacitor to be fitted on its own small panel. The bandspread control does not need any form of

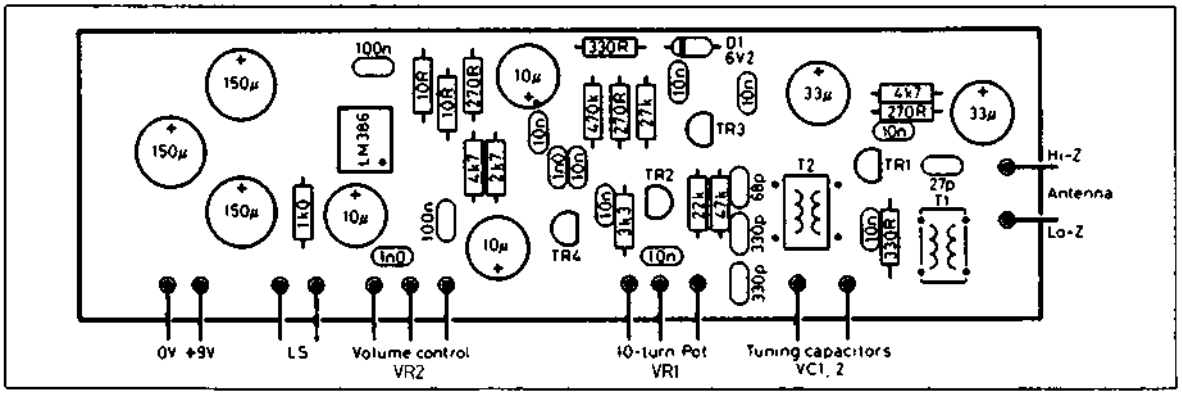

Figure 1 Layout of the receiver circuit board

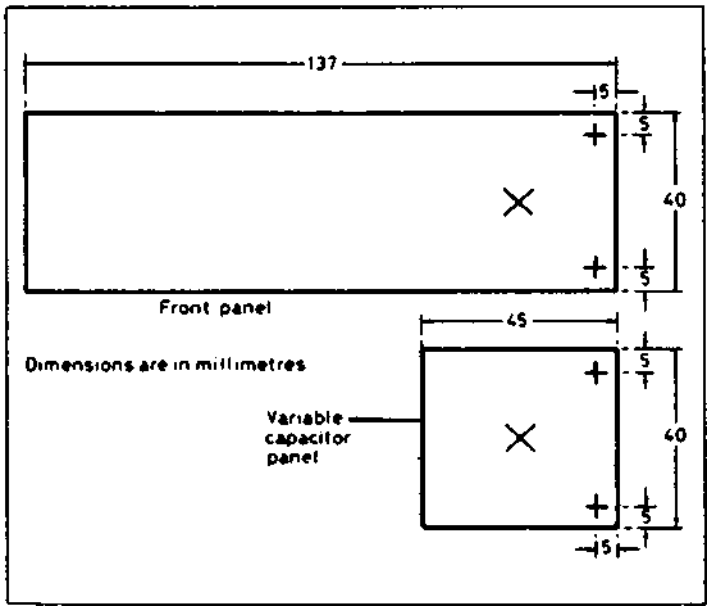

Figure 2 The case can be metal or made from PCB material

slow-motion drive. A tuning dial may be fitted behind the tuning knob on VC2 if required. The volume control, VR2, has its own on/off switch for the battery, which can be mounted behind the back panel, on which are mounted the aerial input sockets and the headphone/speaker socket. Check your soldering carefully, together with all the wiring between the board, the potentiometers and variable capacitors. When you are confident that everything is perfect, connect the battery and switch on.

The first tests

If you have a good aerial and are using an aerial tuning unit (ATU), use the low-impedance input. Excellent results are possible, though, with about 3 metres of wire connected to the high-impedance input. Set the volume control to give a gentle hiss in the headphones or speaker. Advance the reaction control to give a definite hiss. As you tune in an AM station, the hiss will change to a whistle; back off the reaction until the oscillation *just* stops. The receiver is now correctly set for AM reception.

On the amateur bands, the stations will be SSB or CW, and the reaction needs to be set *just above* the oscillation point, and will need slight adjustment from time to time for different qualities of signal. Juggling with the volume, reaction and tuning is part of the pleasure of using regenerative receivers!

In action

Practice is needed for best results. The regenerative receiver is renowned for its versatility in being able to be set up *exactly* for all types and strengths of signal. The basic receiver tunes from 6.5 MHz to 11 MHz approximately; this includes two amateur bands at 7.0 MHz and 10.1 MHz and two broadcast bands.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R10	330 ohms (Ω)
R2, R5, R11	270 ohms (Ω)
R3	22 kilohms (kΩ)
R4	47 kilohms (kΩ)
R6	3.3 kilohms (kΩ)
R7, R12	4.7 kilohms (kΩ)
R8	27 kilohms (kΩ)
R9	470 kilohms (kΩ)
R13	2.7 kilohms (kΩ)
R14, R15	10 ohms (Ω)
R16	1 kilohm (kΩ)
VR1	10 kilohm (kΩ) linear 10-turn potentiometer
VR2	10 kilohm (kΩ) log potentiometer

Capacitors

C1	27 picofarads (pF)
C2, C18, C22	100 nanofarads (nF)
C3, C4, C6, C10, C13, C14	10 nanofarads (nF)
C5, C11	33 microfarads (μF) 16 V electrolytic
C7	68 picofarads (pF)
C8, C9	330 picofarads (pF)
C15	1 nanofarad (nF)
C16, C17, C20	10 microfarads (μF) 16 V electrolytic
C21, C23	150 microfarads (μF) 16 V electrolytic
VC1	10 picofarads (pF) variable
VC2	200 picofarads (pF) variable

Semiconductors

TR1, TR3	2N3819
TR2, TR4	BC182
IC1	LM386
D1	6.2 V 0.5 W Zener

Inductors

T1	3 turns primary, 15 turns secondary, wound on 2-hole ferrite bead, with 28 SWG wire
T2	2 turns primary, 17 turns secondary, wound on a T68-2 toroidal former, with 28 SWG wire

Additional items

- Printed-circuit board
- Battery connector
- PP3 battery
- 8-pin DIL socket
- 8 ohm speaker or headphones (Walkman type)
- Case to suit

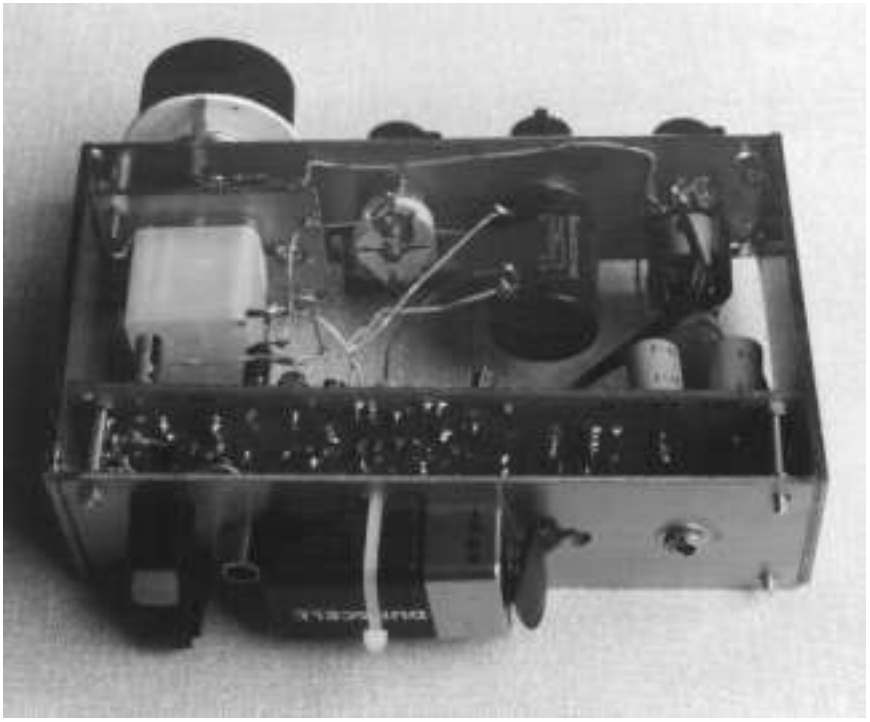

34 A basic continuity tester

Introduction

This little device can be built on a plug-in breadboard, and is ideal for testing fuses and cables, as well as doubling as a signal source for testing amplifiers, etc. It can even be used for testing npn transistors by replacing either of the transistors in the circuit, and seeing if the circuit still works!

Simple and quick to build

Using a plug-in breadboard, this circuit is so simple it could almost be built when you need it, and then dismantled again! If you want the circuit to make a different sound, the components to change are R2, R3, C1 and C2. Always make sure that R2 = R3 and C1 = C2, or the sound may be excessively 'edgy' and lacking in volume.

Basically, the circuit is an oscillator which drives a little loudspeaker directly. The fuse or cable you are testing is connected between the crocodile clips. If there is a current path between the two clips, the current also flows through the circuit, thus operating the oscillator and producing a sound from the loudspeaker.

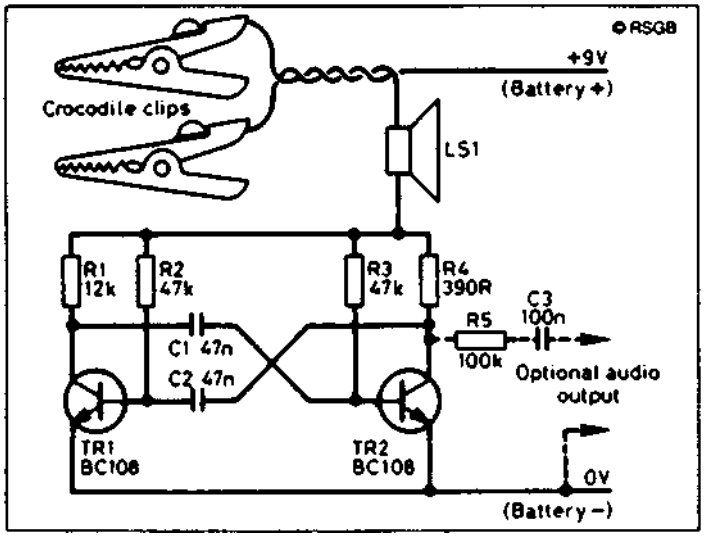

Figure 1 The circuit diagram of the continuity tester

If you want to use the circuit to produce a signal to test an amplifier, for instance, connect the croc clip which comes directly from the battery to the junction of R1, R2, R3 and R4. This supplies current to the circuit while, at the same time, bypassing the loudspeaker. Use the two components R5 and C3 between the oscillator and your amplifier. The loudspeaker is bypassed because you will want to listen to the output from your amplifier, *not* from the oscillator!

Remember, NEVER test any equipment which is still connected to the mains electricity supply. Avoid testing anything which is switched on and has its own power supply. You may damage both your tester ***and*** the circuit you are 'testing'!

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	12 kilohms (kΩ)
R2, R3	47 kilohms (kΩ)
R4	390 ohms (Ω)
R5	100 kilohms (kΩ) optional

Capacitors

C1, C2	47 nanofarads (nF) ceramic
C3	100 nanofarads (nF), 0.1 microfarads (μF) ceramic optional

Semiconductors

TR1, TR2	BC108 npn

Additional items

LS1	Loudspeaker (8 Ω)
	2 crocodile clips
	Prototype circuit board
	PP3 battery connector
	PP3 battery

35 A charger for NiCad batteries

Introduction

The cost of replacing dry batteries can be alleviated to a great extent by the use of rechargeable batteries such as those containing nickel and cadmium (called *NiCads*). They are more expensive than the batteries they replace, but they can be charged hundreds of times and thus prove cheaper in the long run.

NiCads produce only 1.2 V per cell, compared with the 1.5 V of ordinary cells, so before you rush out and buy lots of these, please make sure that the equipment on which you plan to use them will work on the reduced voltage! For example, if you are using four cells to give you a 6 V supply, NiCads will give you only 4.8 V, which is quite a reduction. Using six cells to replace a 9 V battery will give you only 7.2 V. Not all equipment is happy with these reductions!

However, we all use them when we can, and they save substantial amounts of money. Here is the circuit of a charger to keep them in prime condition.

Charging NiCads – the ampère-hour

NiCads require charging at constant current, which means that connecting one across a normal power supply (constant *voltage*) is useless and can destroy it. They need pampering to the extent of needing a long charge (around 16 hours) at a rate dependent upon the *capacity* of the battery. By the capacity of a battery, we mean how much energy it can store. You will probably know that energy is measured in joules. For the purposes of storing energy in batteries, the joule is *not* the ideal unit, so we use one that is! This unit is the ampère-hour (Ah), and must be interpreted with some realism. For example, if the battery is rated at 2 Ah, it will deliver a current of 0.5 amp for 4 hours, or 0.25 amp for 8 hours. Provided the current is not too high, the product of the current (in amps) and the time for which it will flow (in hours) before the battery is flat will always be around 2 Ah. A workable 'rule of thumb' for calculating the charging current is that its value should be around one-tenth of the numerical value of the capacity; so, for our 2 Ah battery, a charging current of around 200 mA (2 ÷ 10 = 0.2 A or 200 mA) would be used.

Constant voltage to constant current

Many integrated circuit (IC) chips are available for use as voltage regulators, i.e. they supply a constant voltage. Most of these can be persuaded to become constant current supplies with one external resistor!

The voltage regulator IC usually has only three connections – 'input', 'output' and 'common'. It is designed (in the case of the LM7805) to produce a constant 5 V output between the 'output' and the 'common' connections, at currents of up to 1 A. If a resistor is connected between these, the IC will maintain 5 V across it. If you look at **Figure 1**, you will see the circuit performing this conversion.

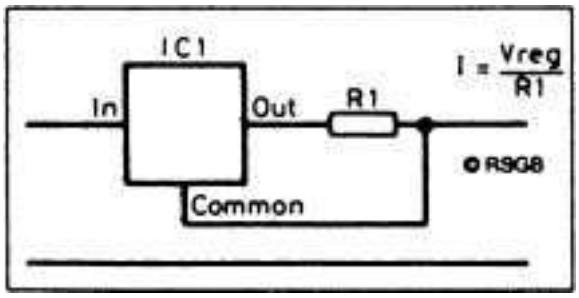

Figure 1 Voltage regulator arranged to produce a constant current

For the previous example, we derived a charging current of 200 mA, so we now need to calculate the value of resistor that will produce this current. Using the equation which is derived from Ohm's law:

$$I = \frac{V}{R}, \text{ from which } R = \frac{V}{I},$$

where R = R1, the resistance in ohms that we are calculating,
V is the voltage across R1 (5 V), and
I is the current flowing (200 mA).

So,

$$\text{R1} = \frac{5}{0.2} = 25\,\Omega.$$

25 ohms is not a 'common' or 'preferred' resistor value, so we must choose the next *largest* value, which is 27 Ω. This reduces the current, but only slightly – it is now 185 mA. When calculating resistor values in power supply circuits, we must *always* check the power that they dissipate and make sure we specify and fit a suitable resistor.

Power (in watts) is the product of the voltage across and the current through a device, so in this case it is given by:

$$\text{Power} = V \times I = 5 \times 0.185 = 0.925\,\text{W}.$$

Rather than use a 1 watt resistor operating very near its limit, it is safer to use a 2 watt resistor operating well within its limits.

Looking again at Figure 1, we now have a constant-current source producing 185 mA, when R1 is a 27 Ω, 2 W resistor. For use with NiCads requiring charging currents other than 200 mA, you will need to repeat the two equations above, using a new value for *I*.

The full circuit and its assembly

This is shown in **Figure 2**, and can be broken down into two parts. The first is the AC to DC conversion produced by the mains transformer, T1, the bridge rectifier, BR1, and the smoothing capacitor, C1. The second is the constant-current section already discussed.

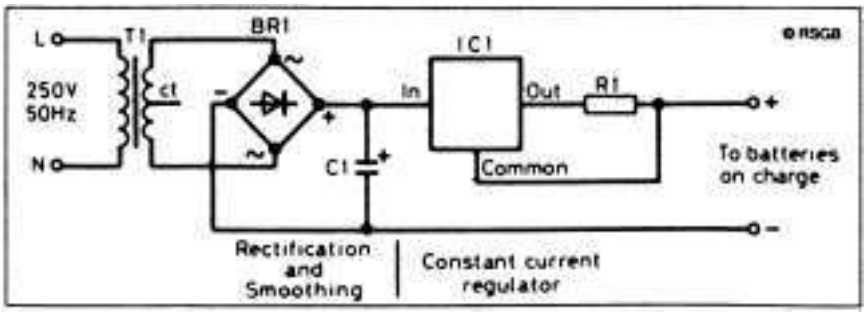

Figure 2 The complete circuit including mains components

The prototype was assembled on matrix board measuring 18 holes by 12 strips, although, as **Figure 3** shows, this is much larger than is strictly necessary. No strip cutting is needed, but make sure that IC1 and C1 are inserted correctly.

Warning! Before you attempt to wire up the transformer and the bridge rectifier, be aware that you will eventually be connecting the circuit to the mains supply, so there are three possibilities for you: (1) get a qualified friend to supervise your completion and testing of the circuit; (2) get your qualified friend to complete and test the circuit for you; (3) replace the transformer and bridge rectifier with a mains adapter.

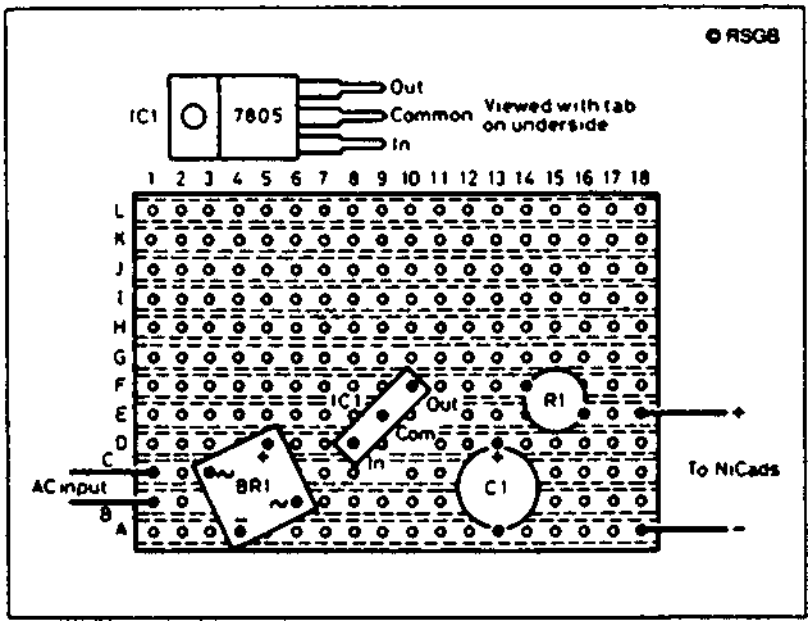

Figure 3 The charger can be built on Veroboard

If you decide to use the mains adapter, its output is connected directly across C1, because T1 and BR1 are now no longer needed. Make sure the polarity (positive and negative) is correct and that the adapter output is set to 12 V.

A quick test

If you have built the mains version, make sure all connections are correct, and that there are no soldered joints which will touch other parts of the circuit. The box must be securely closed before tests begin. The RSGB cannot be held responsible for damage to equipment or batteries! The version using the mains adapter need not be closed during tests.

Switch on. With nothing connected to the output, the unit should run cold. If this is not the case, switch off and recheck your circuit. If all is well, switch on again and connect a DC multimeter (on the current range) across the output. It should indicate only a slight difference from the calculated value of 185 mA. You can now charge your NiCads!

Other charging currents can be set by having different values for R1, perhaps selectable by a rotary switch. Remember to make sure that the values of both resistance *and* power dissipation are correct, and don't exceed the 250 mA rating of the transformer (or the 1 amp rating of the IC if you are using a bigger transformer).

Parts list

		Maplin code
Resistor		
R1	As required – see text	
Capacitor		
C1	1000 microfarads (μF) 35 V electrolytic	FF18U
Semiconductors		
IC1	LM7805 5 V, 1 A regulator	CR14Q
BR1	W005 50 V, 1 A full-wave rectifier	QL37S
Transformer		
T1	9–0–9 V, 250 mA sub-min. transformer	YN15R
Additional items		
Case		FG41U
Veroboard, 18 holes by 12 strips		
Plug to suit NiCads		
Double-sided sticky tape as required		
Insulated wire for battery connections		

36 An 80 metre crystal-controlled CW transmitter

Introduction

A simple transmitter is ideally suited to anyone venturing into our marvellous hobby for the first time. If you are put off by the complexities and prices of the 'black boxes' then this is the transmitter you've been looking for!

The circuit

The complete circuit is shown in **Figure 1**. It is a single-transistor crystal oscillator which is *keyed* (switched on and off) by the Morse key in the +12 V supply rail. The circuit first appeared in *QST* (the American equivalent of *RadCom*) in 1982, and has since appeared in a modified form in the *ARRL Handbook*. The circuit can produce about 2 watts on 80 m, and can be constructed on a piece of plain matrix board; the prototype board measured 7 cm by 3 cm, and its layout is shown in **Figure 2**.

Note that a bare copper wire runs along the bottom edge of the board to act as an earth wire for the relevant components. The only 'difficult' part of the construction is the winding and wiring of T1. The main winding is 38 turns of 26 SWG enamelled copper wire, and there are two link windings of four turns each. Make sure that all windings are wound the correct way round the toroid – Figure 1 shows this and should be studied carefully. If the windings do not have the correct *sense* (i.e. a clockwise coil has been wound anticlockwise, or vice versa), or have been connected incorrectly to the rest of the circuit, the oscillator will not work!

When putting components on the board, wire in the crystal socket *without the crystal in it*. Crystals do not like to be subjected to the horrors of a soldering iron, so keep your crystal to one side during the construction process!

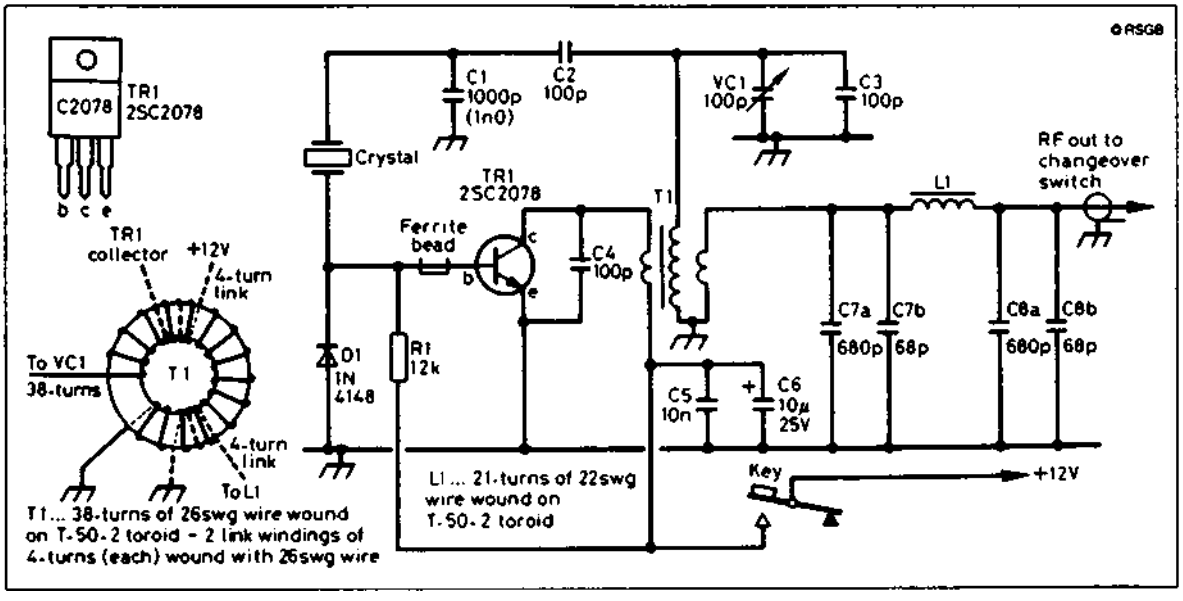

Figure 1 The simplest form of transmitter is a keyed crystal oscillator. Note that L1, C7 and C8 make up a *low-pass filter* which reduces unwanted *harmonics* (outputs at the transmitter frequency multiplied by 2, 3, 4, etc.)

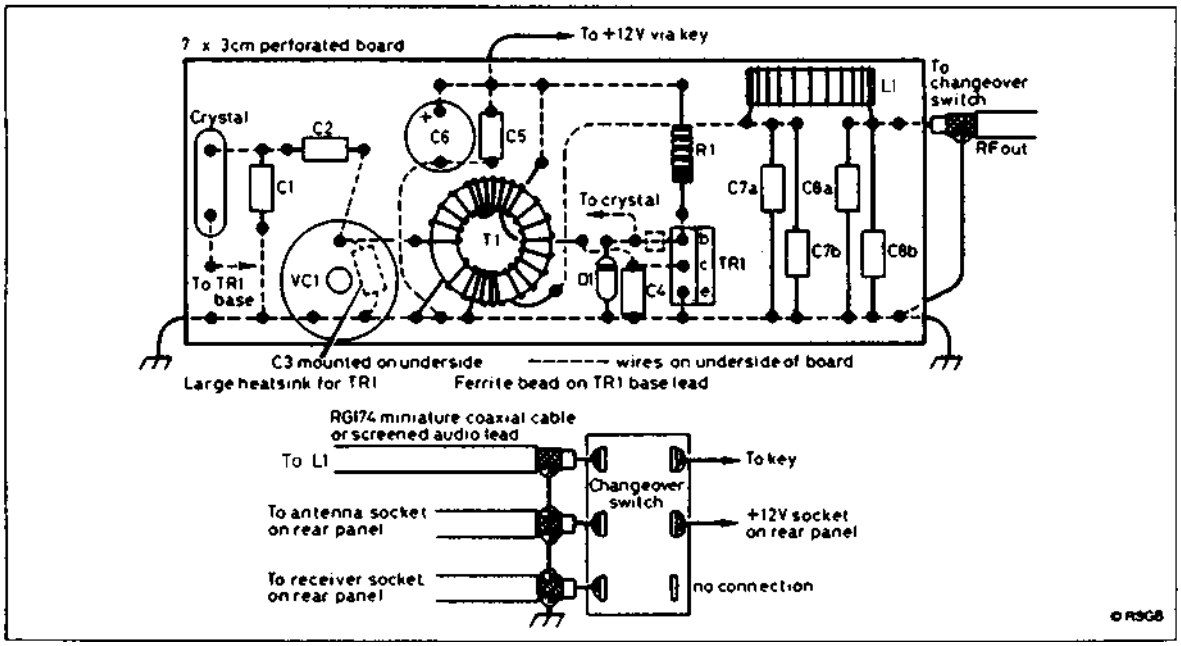

Figure 2 Component layout is straightforward on a 'matrix board' (it has holes but no copper strips). The dotted lines are the connecting wires. The lower part shows the connections for the transmit/receive switch

The output filter, which comprises C7, C8 and L1, is a *low-pass* filter, which helps reduce any *harmonics* present in your signal. Harmonics are integral multiples of your transmitter frequency, so if you are transmitting on a frequency, *f*, harmonics will be present at frequencies 2*f*, 3*f*, 4*f*, . . . and so on. L2 is another inductance using 22 SWG enamelled copper on a ferrite toroid. The changeover switch is external to the transmitter board, and is used to switch your aerial between the transmitter and the receiver; its wiring is shown in Figure 2.

Use a dummy load

A dummy load enables you to test your circuit without actually transmitting a signal. If you haven't such a thing already, it is easy to construct one to use with this transmitter. Don't use it for transmitters of more than 2 watts output, though. Use two 100 ohm, 1 watt resistors, connected in parallel across the end of a short piece of coaxial cable, terminated in a BNC, PL259 or N-type free plug, as shown in **Figure 3**. Plug this into the aerial socket on your transmitter, plug in your crystal and connect the transmitter to a 12 V supply. Have another receiver switched on and tuned to the crystal frequency. Although the radiation from your dummy load is minimal, it will

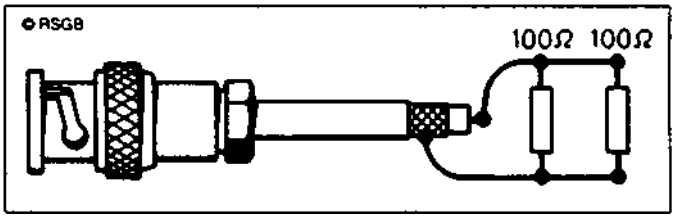

Figure 3 A simple 2 W dummy load can be made from two 100 Ω (ohm) resistors in parallel. The plug should match the socket on your transmitter

be enough to be picked up by a receiver in the same room. Send dashes with the Morse key, and adjust VC1 until the received note is *clean*. It should not sound rough, or have a *chirp* (change its frequency during a dash or dot). Avoid tuning for maximum power; this is seldom the correct setting!

You will need to put your completed transmitter in a metal box, using sockets for the power supply, aerial, receiver and Morse key. The sockets can be chosen to match your existing equipment.

Figures 4–7 are taken from the RSGB book *Practical Antennas for Novices*, and may give you some ideas on the type of aerial to be used with your transmitter.

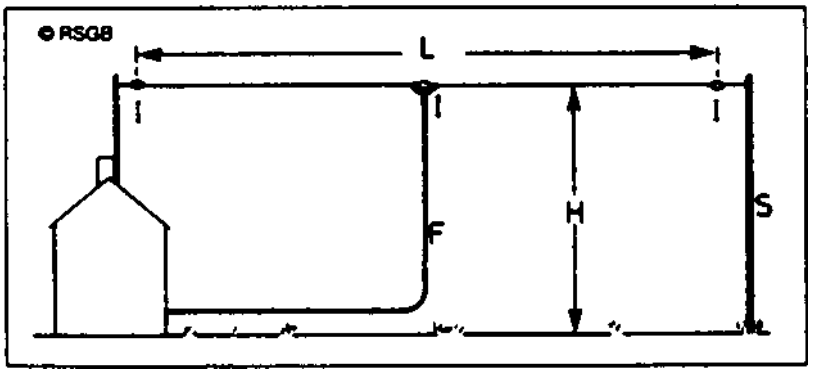

Figure 4 A simple dipole can be very effective. For the 3.5 MHz band, length L is 40 metres and height H should be as large as possible. The far support S can be a tree, pole or building. Insulators I may be home made from strong plastic and the feeder F should be 50 Ω (ohm) coax cable

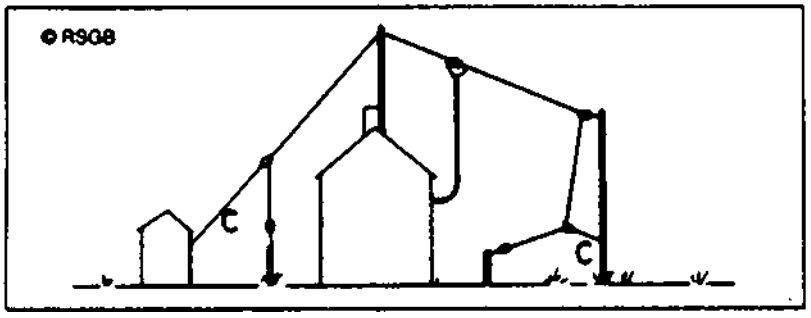

Figure 5 Your signal is radiated mostly from the centre of the dipole so the ends can droop or even be bent but the length may need shortening by a few centimetres because the ground and the bends will detune the dipole. Cords C are best made from strong plastic rope from a sailing or camping shop

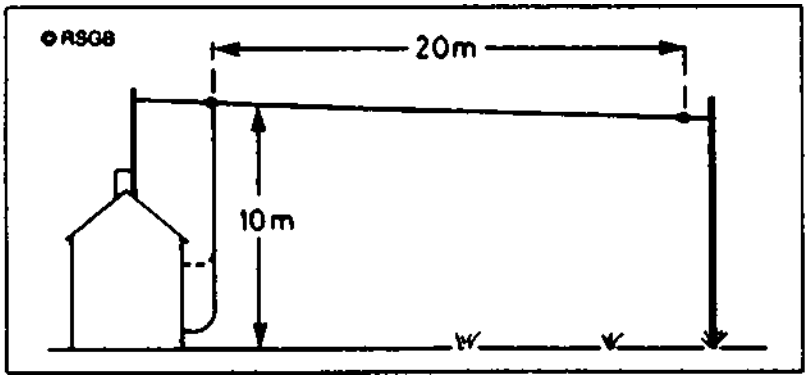

Figure 6 An 'inverted-L' takes up less space than a dipole and doesn't need coax cable. Like the dipole, the end can droop or be bent to save space as in this case most of the radiation comes from the area around the top of the vertical part

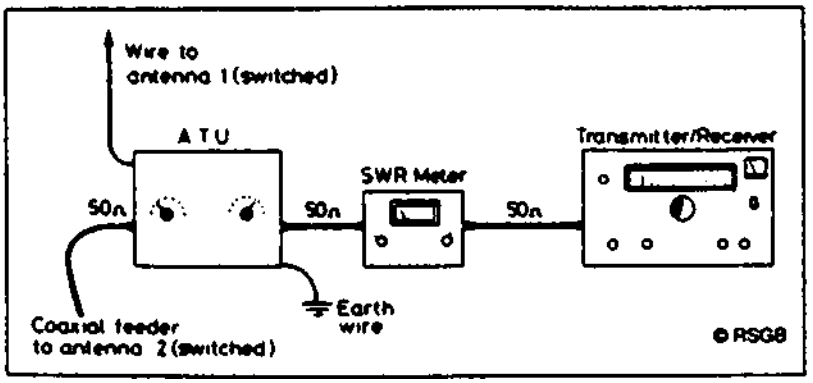

Figure 7 Almost any length of wire more than 10 m or so long will work (though it will work better the longer and higher it is) but an Aerial System Tuning Unit (ASTU or ATU) will be needed

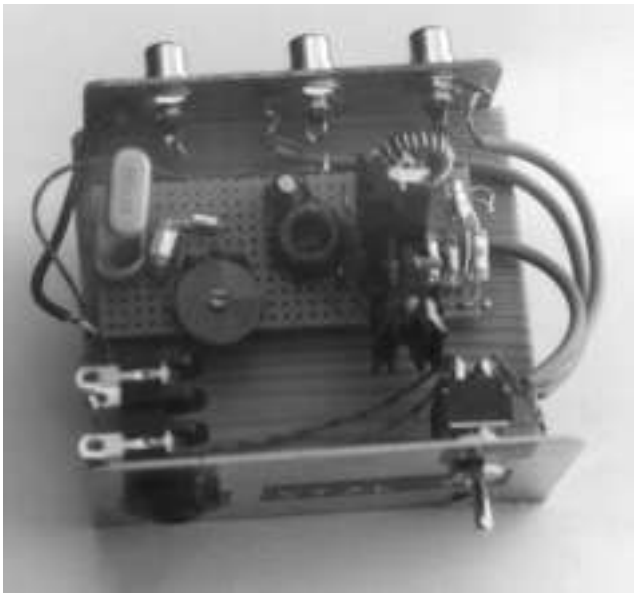

Parts list

Resistor

R1	12 kilohms (kΩ), 0.25 watt, 5% tolerance

Capacitors

C1	1000 picofarads (pF) polystyrene
C2	100 picofarads (pF) polystyrene
C7a, C8a	680 picofarads (pF) polystyrene
C7b, C8b	68 picofarads (pF) polystyrene
C3, C4	100 picofarads (pF) ceramic
C5	10 nanofarads (nF) polyester
C6	10 microfarads (μF) electrolytic 25 V
VC1	100 picofarads (pF) trimmer

Semiconductors

D1	1N4148
TR1	2SC2078 (see sources list)

Inductors

T1	38 turns 26 SWG enamelled copper on T–50–2 toroid, with two link windings of four turns
L1	21 turns 22 SWG enamelled copper on T–50–2 toroid

Additional items

- Ferrite bead
- Crystal (e.g. 3.579 MHz) and holder
- Metal box
- Socket for Morse key.
  This must be totally isolated from the metal of the box, as *both* connections can be at +12 V.
- Sockets for 12 V supply, aerial and receiver
- Switch – DPDT
- Heat sink for TR1
- RG174 miniature coaxial cable for signal leads (see Figure 2)

Component sources

Special components

2SC2078	Cricklewood Electronics Ltd, 40 Cricklewood Broadway, London, NW2 3ET.

37 A solar-powered MW radio

Introduction

What could be more ecologically friendly than a radio powered by the sun's energy? This design is quite standard, and if you have built any of the other medium-wave radios in this series, then this one should present few problems.

The solar panel

The solar panel is to the solar cell as the battery is to the cell; in other words a solar panel is several solar cells connected in series. The solar panel quoted for this radio will generate about 9 V at a current of around 30 mA on a sunny day. The circuit will operate on a supply of around 2 V, so bright sunshine is *not* necessary for satisfactory operation. The volume will be less, of course.

The circuit

The radio uses the ZN415E integrated circuit (IC), connected as shown in **Figure 1**, the complete circuit diagram. The signal is tuned in by the combination of L1 and VC1. L1 is made by winding about 35 turns of 24 SWG enamelled copper wire on a ferrite rod. A standard ferrite rod of 10 cm length and 1 cm diameter is used.

Signals selected by the tuned circuit are passed to IC1, which amplifies the signals and removes the audio component, which is then amplified further by IC2 for driving a small loudspeaker. The removal of the audio component is the process we call *detection*. In addition to this, IC1 provides *automatic gain control* (AGC), which helps to keep the audio signal constant, even when the incoming RF signal may vary due to fading.

The prototype board

Veroboard (also known as matrix board or stripboard) is ideal for the construction of the radio. The layout is shown in **Figure 2**. The board size is 11 strips by 30 holes (**please note that there is no row 'I', so take care with your counting!**). Using a 3 mm (⅛ inch) twist drill rotated between

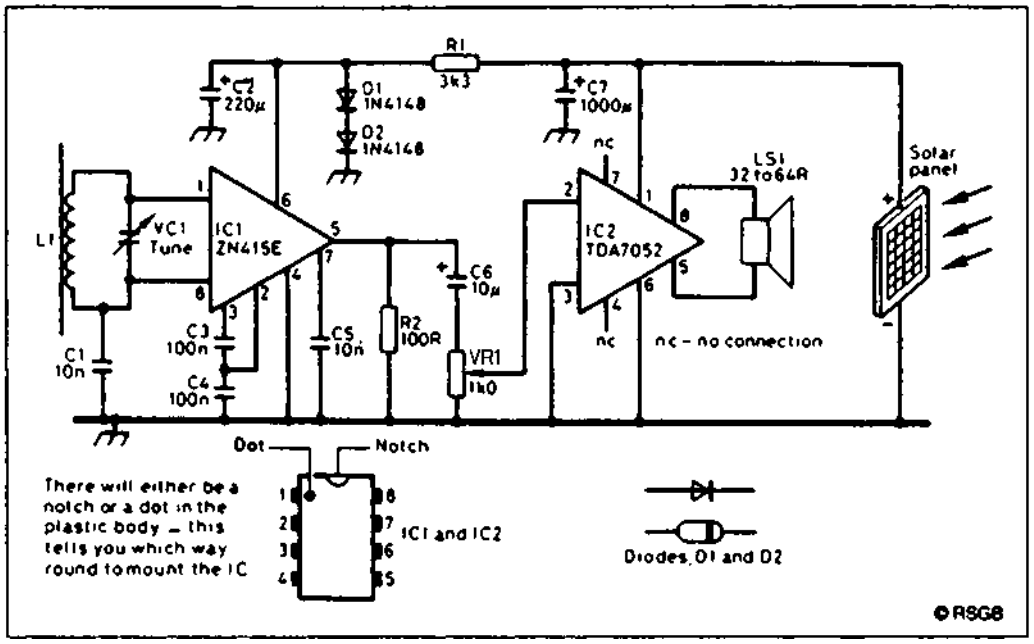

Figure 1 The radio uses just two integrated circuits (chips) and operates at any voltage from 2 to 9 V

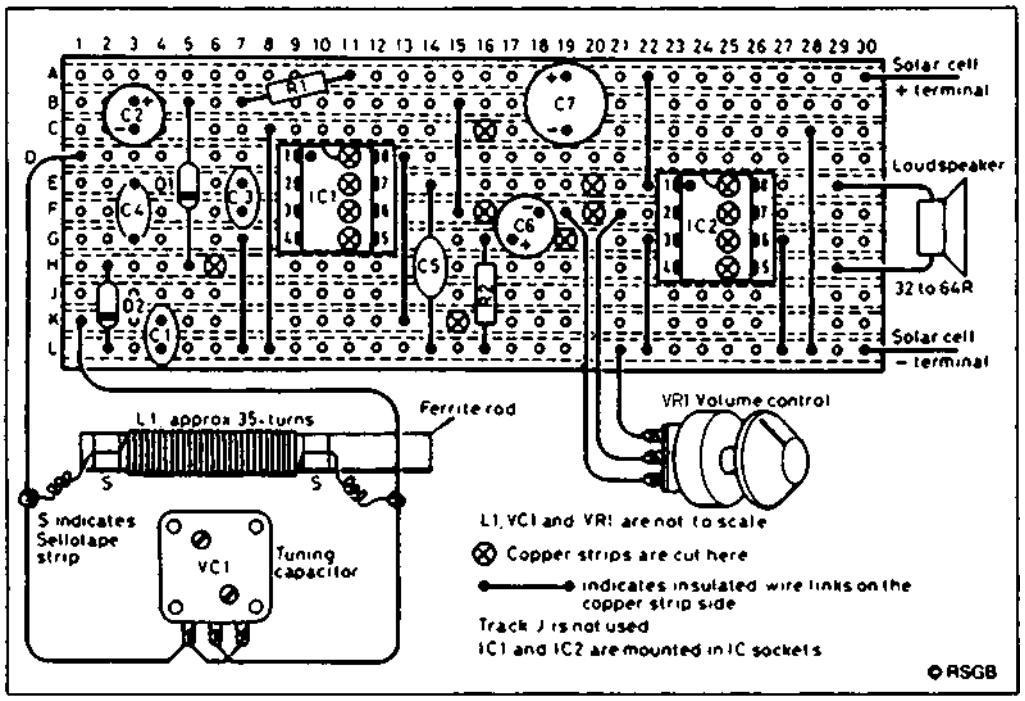

Figure 2 Follow the layout carefully, making sure that all connections are neatly soldered

your thumb and forefinger, break the strips at the points marked with a cross inside a circle. Hold the board up to the light to ensure that the tracks *have* been broken and that there is no copper swarf shorting tracks together.

Firstly, solder in the 8-pin DIL sockets for the ICs, making sure that the notches in the sockets are facing upwards, as shown on the diagram. Then, solder in the wire links, resistors, capacitors and diodes, making sure that the electrolytic capacitors (C2, C6 and C7) and the diodes (D1 and D2) are connected the correct way round. Use different colours of wire for the connections to the volume control, VR1, to avoid incorrect connections. Note the wiring of the tuning capacitor (VC1) shown in Figure 2; a two-section type is used, and both sections are wired in parallel to give twice the capacitance of a single section.

There is no on/off switch – just turn the volume down when you are finished using the set! The solar panel can be mounted parallel to the top of the case, or angled to receive the maximum energy from the sun, as shown in the photograph. You could have a battery available as a standby source to use the radio after dark; any battery of between 6 V and 9 V will do. Wire it with a simple changeover switch, so you can switch between solar and battery power. Ask a friend for help with this if you are not sure how to do it.

You may need to adjust the number of turns on L1 to get the best results, but it should be possible to receive at least five stations at good volume with your sun-powered radio!

Parts list

		Maplin code
Resistors: 0.25 watts, 5% tolerance		
R1	3.3 kilohms (kΩ)	M3K3
R2	100 ohms (Ω)	M100R
VR1	1 kilohm (kΩ) log	FW21X
Capacitors		
C1, C5	10 nanofarads (nF) ceramic	BX00A
C2	220 microfarads (μF) electrolytic (10 V)	FB60Q
C3, C4	100 nanofarads ceramic	YR75S
C6	10 microfarads (μF) electrolytic (10 V)	FB22Y
C7	1000 microfarads (μF) electrolytic (10 V)	FB81C
VC1	140–300 picofarads (pF)	FT78K
Semiconductors		
IC1	ZN415E (or ZN416E)	UR70M
IC2	TDA7052	UK79L
D1, D2	1N4148	QL80B
Solar panel	9 V at 50 mA	RK23A
Additional items		
LS1	32–64 ohm miniature loudspeaker	YT28F
	Ferrite rod	YG20W
	24 SWG enamelled copper wire	BL28F
	Plastic box, approx. 220 × 140 × 70 mm	YN39N
	Veroboard, cut to size	JP47B
	8-pin DIL sockets, 2 required	BL17T
	Knobs, 2 required	FD67X
	Material for speaker grille	
	Connecting wire	

38 A receiver for the 7 MHz amateur band

Introduction

Listening on the 40 metre band (from 7.0 to 7.1 MHz) can be very rewarding – it is a popular haunt for HF Special Event stations, and at night there are signals to be heard from all over Europe. This receiver is designed purely for the 40 m band, and is ideal for those who have built the simpler receivers and are looking for something a little more challenging. The more experienced constructor may prefer to build this on prototype board.

The circuit and its construction

Figure 1 shows the circuit diagram. The receiver will work well with headphones or loudspeaker. Walkman-type headphones and speakers are ideal for use here.

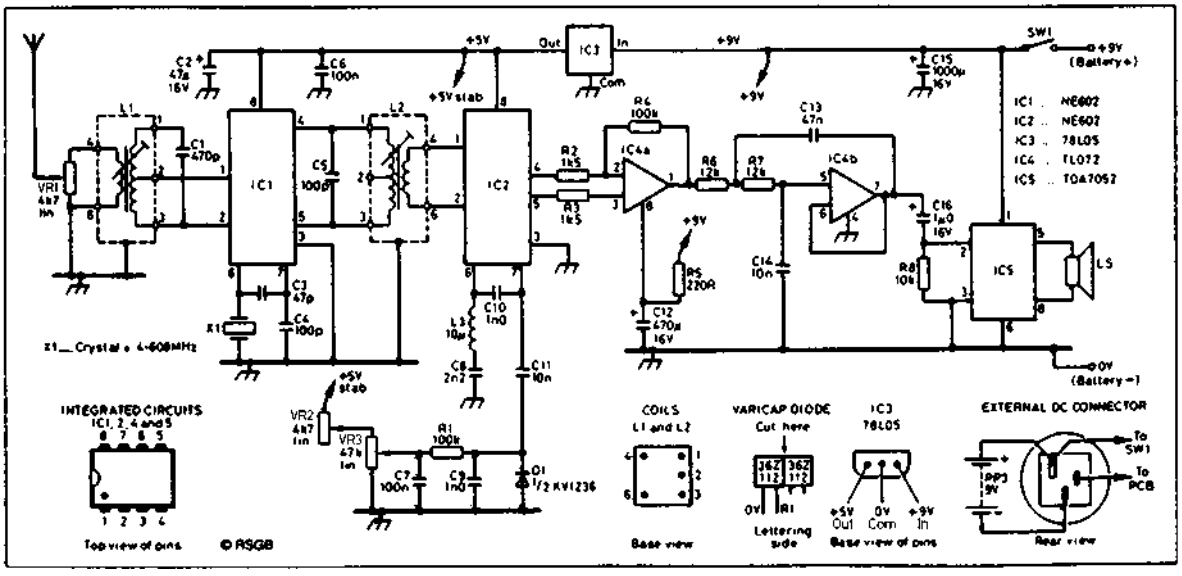

Figure 1 The receiver gives good performance on the 7 MHz amateur band as well as being simple to construct and align

Signals arriving at the aerial are coupled into IC1 via gain control VR1, which also functions as the on/off switch. Tuning is provided by varying the voltage on the *varactor diode* (or varicap), D1. VR3 is the main tuning control, and VR2 is the *bandspread* (fine tuning) control. The varactor diode is supplied as a dual device, which must be cut down the middle *carefully* with a sharp knife; with the lettering upwards, the ground lead (0 V) is on the left-hand side, as Figure 1 illustrates.

Solder in the IC sockets first, followed by the coils. After this come the links, resistors, capacitors and varactor diode. Ensure that IC3, the voltage regulator, is wired correctly, and check the polarity of the electrolytics. The crystal, X1, is very fragile, so take extra care with it. The wiring of the three controls is shown in **Figure 2**.

Before putting the ICs in their sockets, connect up the battery and check the following voltages with the negative voltmeter lead connected to the negative terminal of the battery:

Pin 8	IC1	5 V
Pin 8	IC2	5 V
Pin 8	IC4	9 V
Pin 1	IC5	9 V

When all these have been found to be correct, switch off and put the ICs carefully into their sockets. Use wire of different-coloured insulation to wire up the front-panel controls.

The case can be a small plastic box of size 22 cm by 15 cm by 8 cm, with three 10.5 mm holes drilled in the front and two 8 mm holes in the side for the aerial and earth connections. On one side are a 6 mm hole for the speaker socket and an 11 mm hole for the optional external power supply.

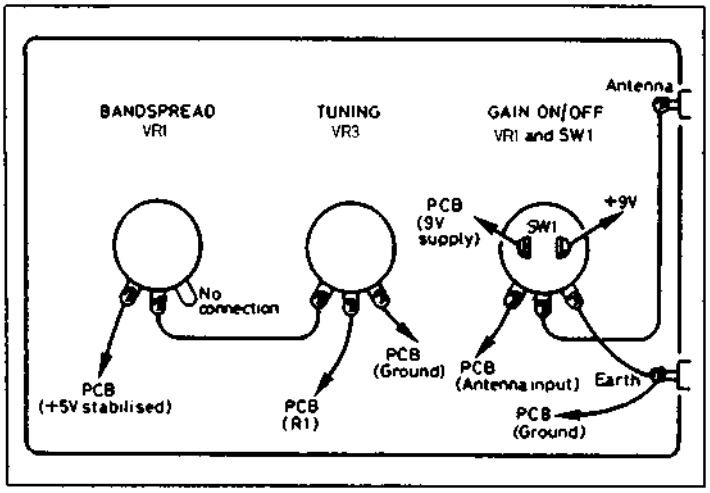

Figure 2 Rear view of the variable resistors. Check the connections carefully to make sure the wires are fitted correctly

Testing and tuning

The aerial for the receiver should be between 30 and 70 feet of wire, mounted as high as you can make it, away from trees and buildings if possible. Connect the battery and switch on. Adjust L1 and L2 for the best results. Tune slowly with VR3; you should find CW stations at the lower end of the band (anticlockwise) and SSB stations at the upper end (clockwise). You may find that it is easiest to make these adjustments *before* mounting the board in the case with double-sided sticky tape or pads. If you are planning to use an external DC supply, make sure it is a safety approved stabilised 9 V type, and **disconnect the battery before you use such a supply!**

If you suspect that the tuning doesn't quite cover the lower CW end of the band, try increasing C9 to 1200 pF. If it is the upper SSB end which is missing, decrease C9 to 820 pF.

It is always advisable to use an aerial tuning unit (ATU) between your aerial and the receiver. A suitable design of ATU is included as a project in this book.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R4	100 kilohms (kΩ)
R2, R3	1.5 kilohms (kΩ)
R5	220 ohms (Ω)
R6, R7	12 kilohms (kΩ)
R8	10 kilohms (kΩ)
VR1	4.7 kilohms (kΩ) linear, with SPST switch
VR2	4.7 kilohms (kΩ) linear
VR3	47 kilohms (kΩ) linear

Capacitors: all rated 16 V or more

C1	470 picofarads (pF) polystyrene 5%
C2	47 microfarads (μF) electrolytic
C3	47 picofarads (pF) polystyrene 5%
C4, C5	100 picofarads (pF) polystyrene 5%
C6, C7	100 nanofarads (nF) ceramic
C8	2.2 nanofarads (nF) polystyrene 5%
C9, C10	1 nanofarad (nF) polystyrene 5%
C11, C14	10 nanofarads (nF) ceramic
C12	470 microfarads (μF) electrolytic
C13	47 nanofarads (nF) ceramic
C15	1000 microfarads (μF) electrolytic
C16	1 microfarad (μF) electrolytic

Inductors

L1	Toko KANK3335R
L2	Toko KANK3333R
L3	10 μH 5%, e.g. Toko 283AS–100

Semiconductors

IC1, IC2	NE602 or NE602A
IC3	78L05 5 V, 100 mA
IC4	TL072
IC5	TDA7052

Additional items

D1	Toko KV1236 cut into two sections (one half used)
X1	4.608 MHz (available from Cirkit)
	3 × silver knobs, one with pointer
	Plastic case approx. 22 × 15 × 8 cm
	Speaker 8–32 Ω, or headphones
	4 × 8-pin DIL sockets for IC1, IC2, IC4, IC5
	2 × 4 mm sockets (red and black) for aerial and earth
	3.5 mm chassis-mounting jack socket for speaker
	DC power socket for external supply (if required)
	Prototype board

Kits

A complete kit is available from JAB Electronic Components.

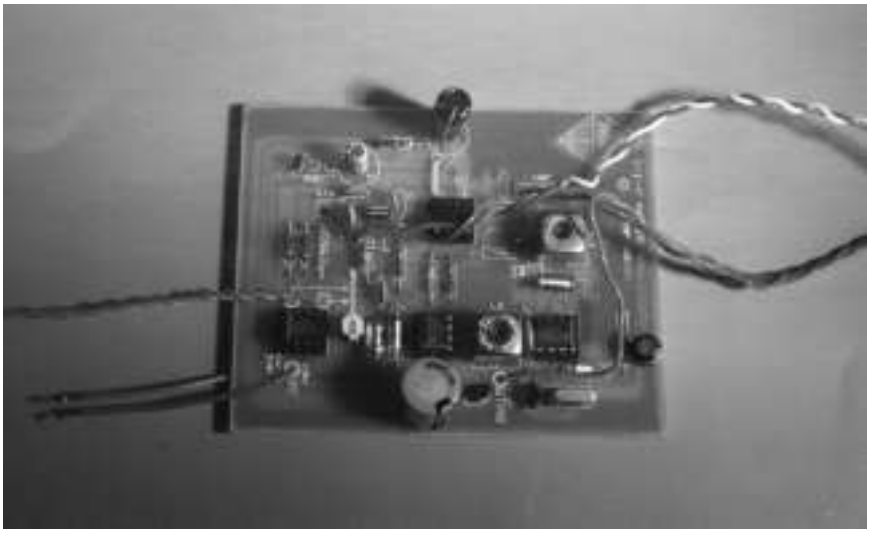

39 Diodes for protection

Introduction

Many semiconductor devices can be destroyed in an instant if their supply is reversed. With the use of batteries as power sources, it is quite common for the battery to be connected 'the wrong way round', and the scope for damaging equipment is significant and very real. Diodes can protect equipment in several ways, and you may do worse than to consider one of these approaches to protect your next expensive project.

Choose wisely!

All the diode circuits given here are so simple as to invite calamity. The circuits are not foolproof but, with a little care, will work first time. Remember that a semiconductor diode has a forward voltage drop of between 0.5 V and 0.7 V, depending on its type and the current flowing. This will be mentioned later.

The first thing you need to do is to insert a good multimeter *in series* with the circuit you want to protect; set the range to Amps DC, and switch on. Check that the circuit works properly. Then, decrease the current range on the meter until a good reading is indicated. Make a note of this current, as it is the normal running current of your circuit.

To choose a diode, you must consult the catalogues or data sheets and find one where the quoted *maximum forward current* exceeds the current you have measured; preferably it should be at least twice your measured current. Secondly, the diode will have a *peak inverse voltage* (PIV); this is the maximum voltage it can withstand when the cathode is made positive with respect to the anode, i.e when it is *reverse-biased* and not conducting. This voltage must be greater than your battery voltage, again by a factor of about 2. Except in the case of the bridge rectifier (see later), these criteria will enable the selection of a suitable diode to be made easily.

The series diode

The simplest and most obvious way to protect equipment is to insert a diode in the positive supply lead, as shown in **Figure 1**, with the diode passing current *only* when the supply is of the correct polarity. Because of the 0.6 V that exists across the diode, your equipment will normally operate on a

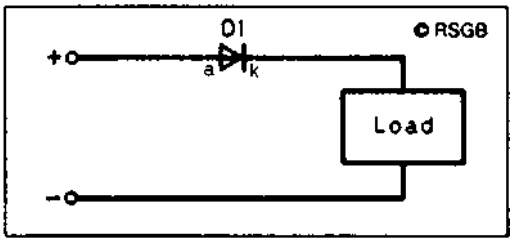

Figure 1 Series diode protection

slightly lower voltage. If you imagine reversing the supply to this circuit, you will see that the negative terminal of the battery is connected to the anode of the diode; the diode becomes reverse-biased and will not conduct any current, thus protecting the load. Your equipment will not operate when the battery connections are reversed.

The parallel diode

The circuit of **Figure 2** overcomes this voltage drop. It places the diode in parallel with the load (your equipment) but in a normally reverse-biased condition so that it draws no current when the battery is correctly connected. Reverse the battery connections, however, and a very large current will flow through the diode, thus blowing the fuse! For this technique to work successfully, the current drawn by the diode when the battery connections are reversed *must* be much greater than the maximum current drawn by the equipment, in order to blow the fuse. This is usually not a problem, however.

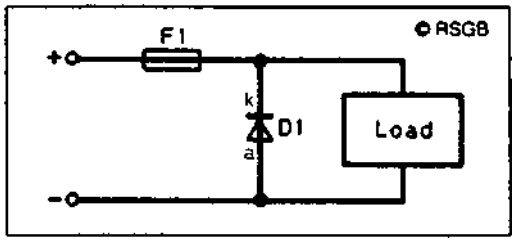

Figure 2 Parallel diode and fuse

The diode bridge

For sheer elegance, the circuit of **Figure 3** takes the biscuit! It uses four diodes connected in the form known as a *bridge rectifier*. Such rectifiers exist, and do not have to be made up from four discrete diodes.

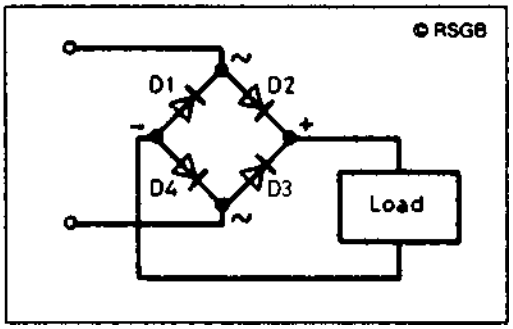

Figure 3 The diode bridge

Follow the current round the circuit from the supply, assuming initially that the top wire is positive and the bottom wire negative. It flows from the positive supply

(a) through D2
(b) through the load (top to bottom)
(c) through D4

and back to the negative of the supply.

Now assume that the bottom supply lead is positive and the top lead negative. The current flows from the positive supply

(a) through D3
(b) through the load (top to bottom)
(c) through D1

and back to the negative of the supply.

So, whichever way round the battery is connected, the current will *always* flow the same way through your equipment!

The circuit does have a drawback, however. Whichever way round the battery is connected, there are always **two** diodes conducting the current at any time. In the first case it is D2 and D4; in the second case, D1 and D3. This means that there is a total voltage drop of about 1.2 V. If your equipment can tolerate that reduction in voltage, then you will not have a problem.

Decoupling

Whenever the supply rail to a piece of equipment, or even to an individual stage of a circuit, is broken for the insertion of a device that will drop voltage, strange things can happen. This is because the supply for any circuit is assumed to have a low resistance to DC and a low *impedance* to AC. (Impedance is the AC equivalent of DC resistance.) These two are not the same, and the insertion of a diode or diodes is certain to make a big

difference to them both. To overcome any irregularities in the operation of the circuit you are protecting in any of the ways described previously, the protected supply needs to be *decoupled* with a capacitor.

If the circuit handles audio frequencies only, placing an electrolytic capacitor directly across the load in all three circuits should solve the problem. The parallel circuit of Figure 2 is less at risk than the other circuits. The size of the capacitor will be determined by the current taken by the circuit, and may need to be chosen within the range 100 μF to 10 000 μF, with a working voltage greater than the supply voltage.

If the circuit is mainly handling RF currents, placing a capacitor of 0.01μF across the load should prevent any problems. A second capacitor, also across the load, of between 10 μF and 100 μF may be needed. Again, the parallel circuit of Figure 2 is less at risk than the other two.

Don't be afraid to experiment, but confine your experimenting (at first) to small equipment and low currents, until you get a 'feel' for the technique.

40 An RF signal probe

Introduction

A radio-frequency (RF) diode probe is a simple device which, when used with a conventional multimeter, enables the measurement of RF voltages in a circuit. When constructed, this will be one of the most useful pieces of test equipment for the experimenter who revels in the construction of transmitters and receivers.

The circuit

Figure 1 shows the simple circuit diagram. It is *almost* the same as a common diode rectifier circuit, but with a simple change to make it more sensitive. The circuit is known as a *voltage-doubler*, and is often found in high-voltage supplies, with beefier capacitors and diodes, of course! Because we are dealing with high frequencies and smaller voltages, the diodes and capacitors can be physically very small. The diode circuit of D1 and D2 *rectifies* or *detects* the RF from the probe, and any remaining AC is removed (short-circuited to ground) by C2. This produces, at the output, a constant voltage proportional to the peak-to-peak RF voltage present at the input; the output voltage is fed to an ordinary multimeter (on a voltage range).

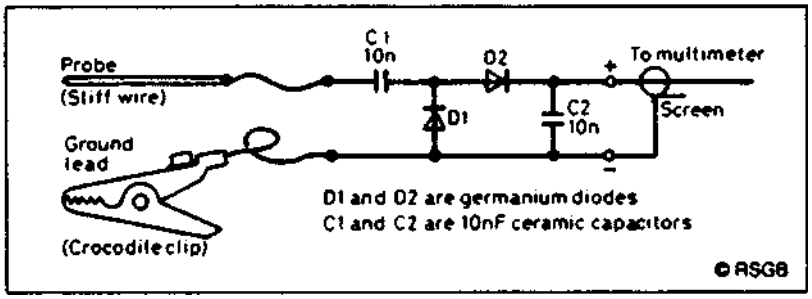

Figure 1 The diode probe can be made from four electronic components

Construction

Although the circuit layout is not critical, a description of the prototype is given here for your information. **Figure 2** has the details. The components are soldered to square pieces of copper-clad printed-circuit board (PCB) glued to a larger piece of PCB. The larger piece serves as a ground connection. Use a stiff copper wire as the probe, and an insulated flexible wire with a crocodile clip to connect the probe to the ground of the circuit under test.

Cut a piece of plain PCB, 30 mm by 45 mm and another of 15 mm by 45 mm. Cut the smaller piece into three measuring about 15 mm square. Stick the three small pieces to the larger piece, ensuring that there are small gaps between each, as Figure 2 shows. Solder the components in place. The connection to the multimeter should be thin coaxial cable or screened microphone cable. If you use unscreened cable, there may be RF pickup here which can lead to false readings.

Simple to use

Using the probe is simple. Connect it to the multimeter and set the meter to around 10 V DC – you may need to reduce this, depending upon the magnitude of the RF voltage you are trying to measure. Hold the probe by

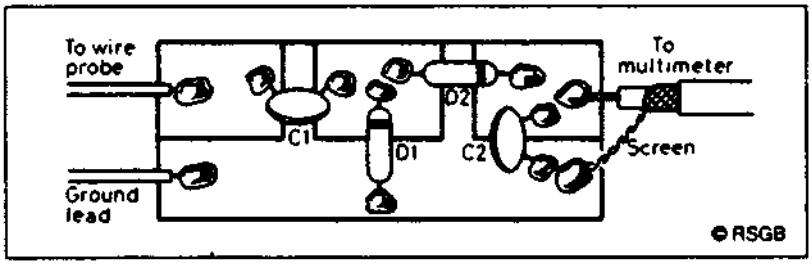

Figure 2 The components are mounted on a copper-clad PCB

its base, being careful *not* to touch any of the components. Connect the croc clip to a ground point on the circuit and touch the probe on the circuit point to be tested. If an RF signal is present, there should be a reading on the multimeter. That's all there is to it!

Parts list

Capacitors
- C1, C2 — 10 nanofarads (nF), or 0.01 microfarad (μF) ceramic

Semiconductors
- D1, D2 — Any *germanium* signal diode, e.g. OA91 or AA119

Additional items
- Stiff copper wire
- Insulated flexible wire
- Copper-clad PCB
- Crocodile clip
- Coaxial or screened cable

Source

All components are available from Maplin.

41 An RF changeover circuit

Introduction

The simplest entry route to operating an HF station is to buy or build a receiver, and to add a simple CW (Morse) transmitter. In theory, this sounds so simple, yet in practice there is one significant hurdle to be overcome. How can they both share the same aerial? A manually operated changeover switch is the obvious solution, but it takes time to perform the switching operation, by which time someone else has squeezed in before you and contacted the DX station! This small circuit accomplishes the changeover automatically, as soon as the transmitter is keyed.

How it's done

The circuit is shown in **Figure 1**, and uses the signal from the transmitter to operate a relay. A relay is a switch which is operated electrically in the following way. A coil of wire with an iron core is used as an electromagnet. When current flows through the coil, it produces a magnetic field which, in turn, is used to pull a set of switch contacts. These contacts will be used to switch the aerial from transmitter to receiver and vice versa. The relay used here has a double-pole changeover (or DPDT, or DPCO) switch. If you are confused by the different types of switch, look at the basic descriptions elsewhere in this book. The *pole* of a switch is the part that doesn't move; in Figure 1, one pole is connected to L1 and the other to the aerial output. In a circuit diagram, the switch contacts are always shown in their *normal* state, i.e. when *no* current flows in the relay coil. The changeover switch is normally in the receive position, so we say the receive switch is *normally closed*, and the transmit switch is *normally open*. We choose to have the circuit in the receive position normally, because everyone spends a lot more time receiving than transmitting. The relay is energised only when you are transmitting.

There are three RF sockets – one for the transmitter, one for the aerial, and one for the receiver. When the transmitter is not in use, there is a direct connection (via the Rx normally closed contacts of the relay) between the aerial and the receiver. The transmitter (which is not keyed at this time) is connected to a 50 ohm dummy load, R1.

When the transmitter is activated by pressing the Morse key, an RF signal appears at the transmitter socket. The wire carrying the signal to the relay

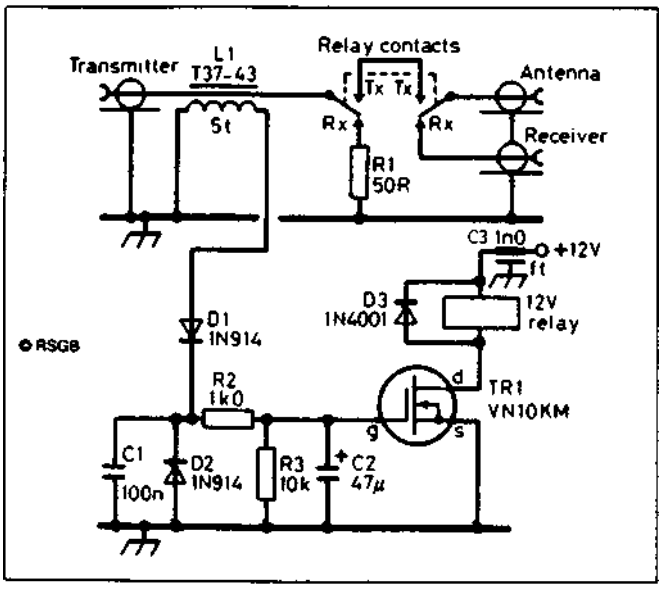

Figure 1 RF activated relay

Tx contacts passes through a toroid (a ferrite coil former, looking like a black Polo mint), which has a five-turn coil wrapped around it. This five-turn coil picks up the signal, which is then detected by D1 and D2, and converted to a steady voltage. C1 removes any remaining RF and C2 provides *hang*. Without it, the circuit would detect the gaps between every dot and dash being sent, and switch the aerial over very rapidly and very frequently! This is *not* what we want. We need the relay to remain in the transmit condition at normal Morse keying speeds, and then return to receive when the sending is complete. The combination of C2 and R3 achieves this.

The voltage appearing across C2 is fed to a VMOS field-effect transistor (FET), TR1, which acts as an electronic switch. When a voltage appears across C2, the FET switches on and passes a current through the relay coil, changing the contacts from receive to transmit. The diode, D3, across the relay winding protects the FET from being damaged by the large reverse-voltage spike which occurs across the coil when the FET switches off.

Construction

This is very simple – a circuit board is not required. The prototype was built into an old 50 g tobacco tin. All ground leads are soldered directly to the tin, thus supporting the components automatically. Phono sockets were used for the aerial, receiver and transmitter; you could use whatever connectors matched the rest of your station. The 12 V supply is fed through the tin using a 1000 pF feed-through capacitor, C3.

The 'dummy load', R1, must be able to withstand the RF output power of the transmitter. For novice use, 4 watts is adequate. Two suggestions for making up R2 from standard resistors are shown in **Figure 2**. Six 330 ohm, 1 watt resistors in parallel have a combined resistance of 330/6 = 55 Ω at 6 W. Two 100 ohm, 2 watt resistors in parallel have a combined resistance of 100/2 = 50 Ω at 4 W.

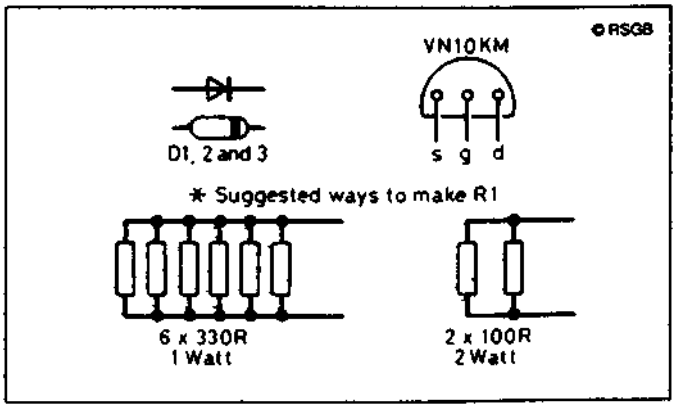

Figure 2 Component details

Make sure all the contacts to the relay are correct; also ensure that TR1, C2, D1, D2 and D3 are correctly wired.

Winding the toroid, L1, is very simple. It is made from PVC-insulated hook-up wire. Each time the wire passes through the centre of the toroid counts as one turn. The wire from the transmit socket to the relay simply passes through the centre! Use thin 50 Ω coax for the leads to the three sockets.

What happens to the receiver?

On transmit, the receiver is not connected to the aerial, but is only the separation of the switch contacts (about 0.5 mm!) away from the transmit lead. The receiver *will* pick up the transmitted signal, and there is a possibility that this signal will be enough to damage the receiver's sensitive input circuits. This can be prevented with the simple addition shown in **Figure 3**. Two diodes are connected back to back across the receiver socket. These act as a *limiter*, reducing the amount of signal that can enter the receiver. Solder these directly between the receiver socket and the tin.

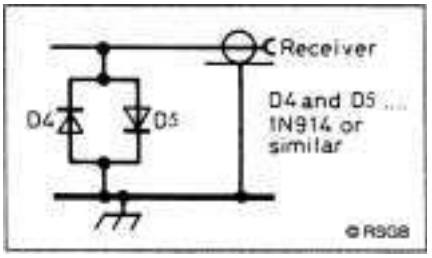

Figure 3 Receiver input protection

Warning

The wiring **must** be thoroughly checked. If the relay switch connections are wrong, there is a **great probability** that the full RF power will be applied to your receiver! You can check these connections as follows. With the 12 V supply connected, check that the relay energises (clicking sound heard) when the FET drain (d) is shorted to earth. Check the aerial and receiver connections with an ohmmeter or continuity tester. Disconnect the 12 V supply, and check that there is continuity between the centre pins of the aerial and receiver sockets. Reconnect the 12 V supply, short the FET drain to earth again (this will not damage the FET) and check that there is continuity between the centre pins of the aerial and transmitter sockets. If these tests show correct operation, disconnect the drain shorting wire (*most* important!) and your aerial auto-changeover is ready for use! Avoid using the device without the lid fitted.

Parts list

Resistors: 0.25 watt, 5% tolerance, unless otherwise stated

R1	50 ohms (Ω) – see text and Figure 2
R2	1 kilohm (kΩ)
R3	10 kilohms (kΩ)

Capacitors

C1	100 nanofarads (nF), 0.1 microfarad (μF)
C2	47 microfarads (μF) 15 V electrolytic
C3	1000 picofarads (pF) feedthrough

Semiconductors

D1, D2, D4, D5	1N914
D3	1N4001
TR1	VN10KM

Additional items

L1	T37–43 toroid
	Relay 12 V DPDT (DPCO) relay
	Three sockets to suit (phono, SO239, etc.)
	Thin coax cable and hook-up wire

42 A low-light indicator

Introduction

This is a simple one-evening project that can be built for the pure fun of it, or to use as the basis of a more complex project to switch your shack lights on when it gets dark! In its prototype form, it simply flashes an LED when the ambient light level drops to a preset point.

Operation

The heart of the circuit shown in **Figure 1** is a *photo-conductive cell*, also called a *light-dependent resistor* (LDR), a device whose resistance changes according to the amount of light falling on it. In bright light, the resistance is low (about 1 kΩ), whereas in the dark, its resistance is very high (up to 10 MΩ). The cell is made from a semiconducting material known as cadmium sulphide (CdS), and is enclosed in a small plastic container. The semiconductor is laid on a flat insulating surface in the form of a small flat ribbon. The ribbon construction gives a good area of surface for a given

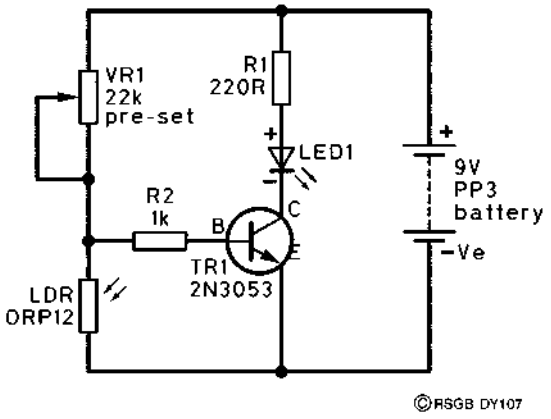

Figure 1 Circuit diagram

length of ribbon, and the length of the ribbon is maximised by laying it out in a zig-zag pattern, as can be seen diagrammatically in **Figure 2**. In the dark, CdS is an insulator; when light falls on it, electrons are released inside the CdS, making it conduct. The more light there is, the more electrons there are, and the resistance falls.

In this circuit, the LDR is connected across the 9 V supply in series with a variable resistor, VR1. In this arrangement, the voltage that exists across the LDR will be determined by the light level. As the light intensity increases, the resistance of the LDR falls, dropping a smaller voltage across it. The

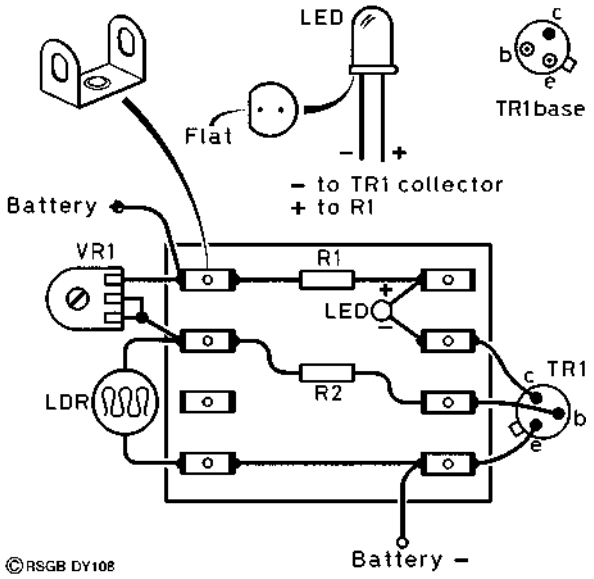

Figure 2 Component layout on tagstrip

reverse happens when the light intensity falls – the voltage across the LDR increases. This voltage is used to drive an npn transistor, TR1, connected as an electronic switch. As the voltage on the base (B) rises, it will reach a point where TR1 will suddenly start to pass current, just as an ordinary switch does when pressed. The current flowing through TR1 also flows through a flashing light-emitting diode (LED), D1 and its series resistor, R1. D1 can be a steadily glowing type, if preferred. If you want to make the circuit switch the LED on at a different ambient light level, adjust VR1.

Construction

The prototype was made on an eight-tag tagboard (Figure 2). The resistors R1 and R2 can be laid on the tagboard for soldering, the rest of the components lying above or to the side of the board. Check the circuit after you have soldered everything on, then connect the battery. The LED should flash if you put your hand over the LDR, and VR1 can be adjusted to vary the point at which the LED lights. The project can be housed in a small plastic box with holes provided for the LDR and LED and an on/off switch if you want one.

Parts list

Resistors: all 0.25 ohm, 5% tolerance

R1	220 ohms (Ω)
R2	1 kilohm (kΩ)
VR1	22 kilohms (kΩ) linear pre-set

Semiconductors

LDR	ORP12
TR1	2N3053 npn
LED1	Flashing LED

Additional items

- Plastic box
- Tagboard with 8 tags
- PP3 battery connector

43 A J-pole aerial for 50 MHz

Introduction

For FM communication (i.e. voice and data) on the VHF bands, a vertical aerial is used to give all-round (non-directional) coverage. This is a half-wave aerial which can be fed at the end, thus removing the principal problem with the conventional vertical centre-fed half-wave dipole, which is that the feeder should leave the dipole at right angles. This is no problem when the dipole is horizontal, but can be difficult for the vertical dipole.

Basic facts

A feeder must be connected to an aerial at a point where the *impedance* (AC 'resistance') of the aerial closely matches that of the feeder. The difference between the two impedances gives rise to the voltage standing-wave ratio (VSWR), which is unity only when the two impedances are the same. With 50 Ω feeders, the feed point of a half-wave aerial is at the centre, where the aerial impedance is around the same value. At the end of a half-wave aerial, the impedance is high, so it is *not* a suitable point to connect a 50 Ω feeder.

Connection at this point can be effected using an RF transformer. RF transformers act in the same way as ordinary transformers, except that they are much smaller, and usually comprise wires of particular lengths adjacent to each other. **Figure 1** is a good starting point. It shows the aerial in its diagrammatic form. Notice that the aerial is in the form of an elongated letter 'J'; this shape gives rise to its nickname – the *J-pole*. The quarter-wave RF transformer is the lower 'U' section below the half-wave element. At the bottom of the U section, the impedance is zero (this may become clearer later) and at the top of the U section it is high, thus matching the aerial impedance. The coaxial feeder cable is connected part-way up the U section, where the impedance is around 50 Ω.

The practicalities

Figure 2 shows the aerial as constructed. As it is about 4.5 metres high, it may be too high for the average house loft, but is ideal for mounting outside, supported by a non-metallic pole or hung from a tree branch. The upper half-wave section is made from 1.5 mm insulated copper wire, as used in domestic mains wiring. The quarter-wave transformer below the half-wave section is made from 300 Ω balanced line ('ribbon cable'). The

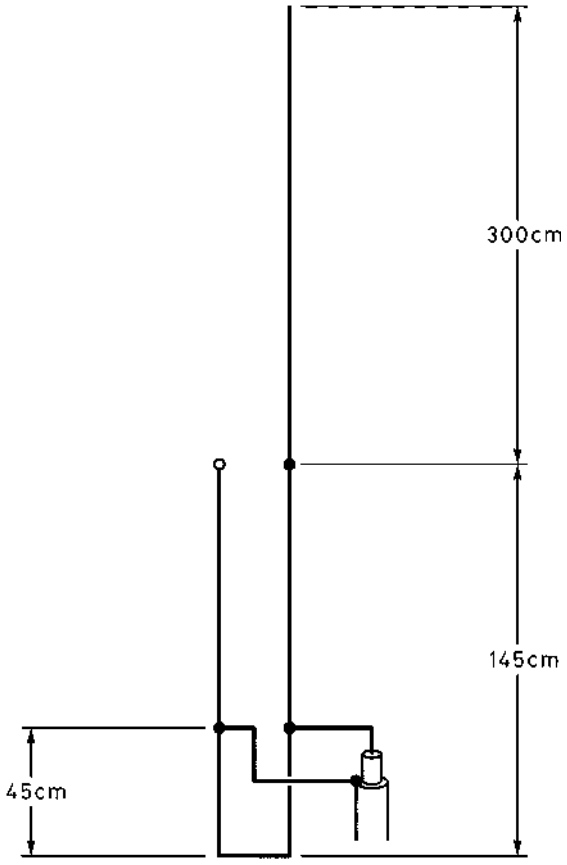

Figure 1 Overall dimensions of the 6 metre J-antenna

wires at the bottom of the transformer section are stripped of their insulation, twisted and soldered. At the upper end, only one wire of the balanced line is soldered to the bottom of the half-wave section. The other wire of the pair is not connected and is left insulated.

At the feed point of the transformer, the insulation needs to be carefully stripped from the balanced line. You will need a standing-wave meter (VSWR meter) in the coaxial line between your transmitter and the aerial, and you will need to adjust the position of the feed point. 45 cm from the bottom was the best point on the prototype, but this position is dependent upon the immediate surroundings of the aerial, and *must* be done when the aerial is in its final operating position. **Warning: *Never* make adjustments to the feed point when the transmitter is on. Make a VSWR measurement, switch off, move the feed point, switch on again, make another measurement, and so on.** You will need to aim for the lowest VSWR you can – certainly better than 2:1. Having found the best position, wrap all the exposed wires with self-amalgamating tape, to seal them against the ingress of moisture.

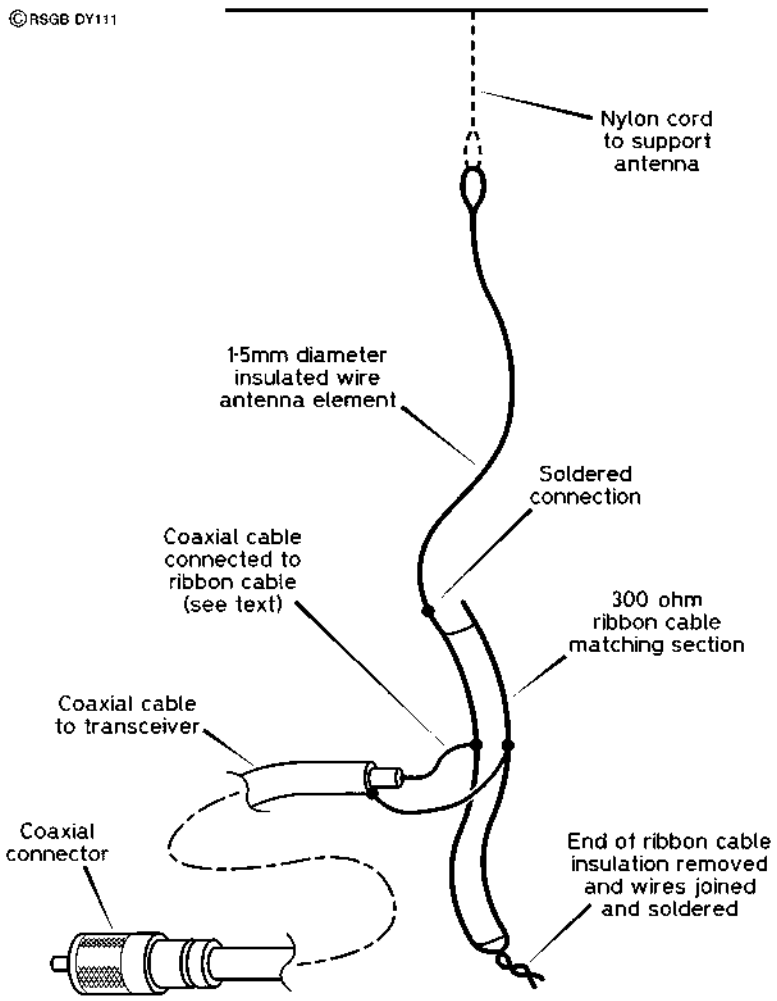

Figure 2 Construction details

How it performs

Figure 3 shows a computer prediction of how the J-pole radiates. It is called a *polar diagram*, and shows the distribution of your transmitted power when viewed 'from the end of your garden'. Most of your signal is sent at a fairly small angle to the horizontal; very little signal goes upwards, which is a good thing, of course. This also shows why the J-pole (or any other vertical aerial) should not be called 'omnidirectional', which means it radiates in all directions. It is omnidirectional *only* in the horizontal plane.

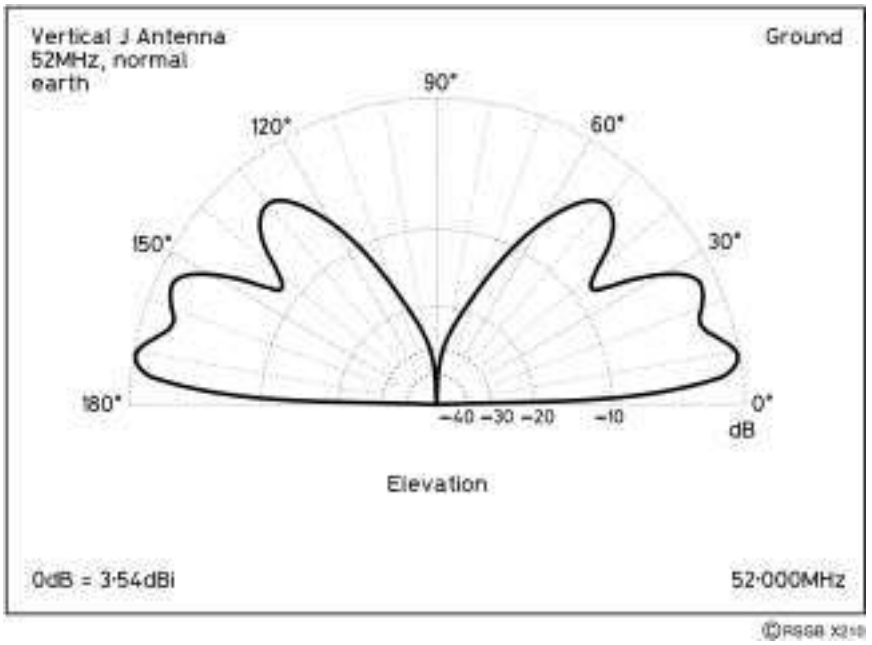

Figure 3 This polar diagram computed for the J-pole

Safety

Where you mount your aerial is a matter of personal preference and the restrictions of height and space, but the following safety rules *must* be applied.

1. Never fix an aerial where it may come into contact with power lines or telephone lines.
2. When climbing a ladder to put up an aerial outside, make sure the ladder is safe and that it is secured.
3. Don't do this alone. Preferably have someone with you. If this is not possible, make sure someone knows where you are.

Parts list

3.00 metres	1.5 mm insulated copper wire
1.50 metres	300 ohm balanced line
As required	50 ohm coaxial cable
As required	Self-amalgamating tape

44 Measuring light intensity – the photometer

Introduction

Before the days of automatic 'point-and-shoot' cameras, a photographer would use a light meter or *photometer* to measure the light level, then manually convert this reading into shutter speed and lens aperture settings to ensure a correctly exposed negative. Modern cameras have quite sophisticated photometers, which control the shutter speed and iris settings automatically.

A short explanation

A simple photometer circuit is shown in **Figure 1**, and is based on a device called a *light-dependent resistor*, or LDR. As its name tells us, its resistance depends upon the amount of light falling on it. In bright light, the resistance is relatively low (about 1 kΩ), whereas in the dark, its resistance is very high (up to 10 MΩ). The cell is made from a semiconducting substance known as cadmium sulphide (CdS), and is enclosed in a small plastic container. The semiconductor is laid on a flat insulating surface in the form of a small flat ribbon. The ribbon construction gives a good area of surface for a given length of ribbon, and the length of the ribbon is maximised by laying it out in a zig-zag pattern. In the dark, CdS is an insulator; when light falls on it, electrons are released inside the CdS, making it conduct. The more light there is, the more electrons there are, and the resistance falls.

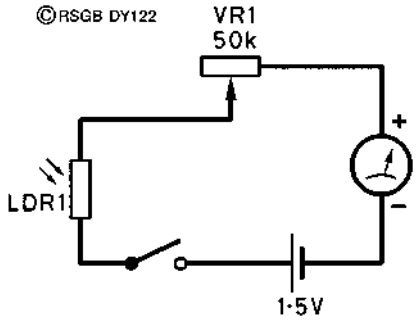

Figure 1 Circuit diagram of photometer

The photometer circuit

The circuit is simply a series connection of four things – the battery, the LDR, a variable resistor and a meter. A switch is also provided. The combination of the LDR resistance and that of VR1 determines the current flowing, which is indicated on the meter. Altering the resistance of VR1 sets the *sensitivity* of the photometer – you may want full-scale deflection of the meter needle for a bright light, or for a dim light.

It is simple to make, and a plug-in type matrix board is ideal to test the circuit, so that you can decide if you want to make a permanent version. Connect all the components in series; the only change you may want to make is the connection to VR1. If you find that the sensitivity control seems to work 'backwards', simply unsolder the wire from the end tag of VR1 and solder it to the opposite end tag. Problem solved!

In use

As soon as you connect up the battery, you will probably have a meter reading because of the daylight falling on the LDR. Shading it with your hand should reduce the reading. If the meter needle is hard over against the end-stop, turn VR1 until it indicates about half-scale. The LDR is very sensitive, and will read zero only in a dark room. If you put on a torch to see what the meter reading is, the LDR will detect the torch light, and will give a reading!

Here is a simple project where you can use the photometer in an experiment which has an analogy in radio. Draw a circle on a large (A3 or bigger) sheet of paper and divide it up into 30-degree sectors, as shown in **Figure 2**. Draw a series of smaller circles which divide the maximum radius into five. Look at the figure if you're not sure about this. Bring the LDR away from the circuit by using two long, flexible wires. The experiment must be performed in a darkened room (preferably in total darkness). Prepare a table with two columns, the left-hand one headed 'Angle (degrees)' and the right-hand one 'Meter reading'. Fill in the left-hand column 0, 30, 60 . . . and so on up to 360°.

Place the torch in the position shown, with its lens at the centre of the circle and pointing along the 0° line; switch it on. Place the LDR facing the torch and adjust VR1 until you have full-scale deflection of the meter needle. Suppose the meter indicates 10 units at this point. Enter this into your table in the 0° row. Keeping the torch the same distance from the circle centre, and pointing at it, move the LDR round all 30° positions and record the meter readings. Switch off the torch and take the sheet of paper and your tabulated results into daylight!

Lay the large sheet of paper on a table with your results beside it; then, at each 30° interval, plot the point along the radius corresponding to the meter

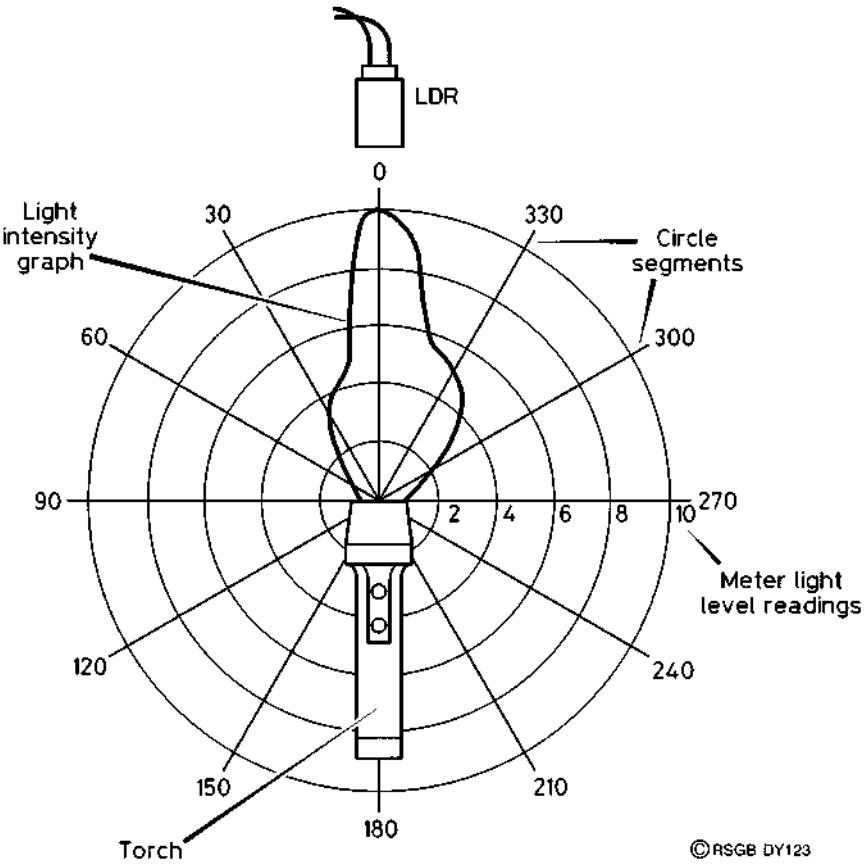

Figure 2 Torch light intensity pattern plotted at RSGB HQ

reading. Then, join up all the points and you have what is called a *polar diagram* of light intensity. The use of the word 'polar' implies that the readings have been taken in a circle and plotted that way.

Light waves and radio waves are both examples of *electromagnetic radiation*. The torch is designed to 'beam' its radiation in a particular direction, just like an aerial does. Hence the use of the word 'beam' for a directional aerial. If a similar polar diagram is drawn for a Yagi-type aerial, it will show the same general characteristics as does Figure 2, namely a main direction (or 'lobe') where most of the energy is concentrated, with evidence of *sidelobes*, indicated by 'lumps' on the otherwise smooth main lobe.

Also in this book you will find a project for the construction of a UHF field-strength meter, which you could use to carry out a measurement of the polar diagram of a UHF aerial.

Parts list

Resistor
VR1 50 kilohms (kΩ) linear

Semiconductor
LDR1 ORP12

Additional items
Meter, 50 or 100 μA
Battery clip for single AA cell
AA cell

45 A 70 cm Quad loop aerial

Introduction

This is a description of how to make an aerial for the 70 cm band which has gain compared with the 'rubber duck' or the dipole aerial. It can easily be dismantled and reassembled, making it ideal for contest use.

The principles

Most aerials which comprise several similar *elements* arranged along a *boom* are variations of the design originated by Yagi and Uda, and which takes the name (for historical reasons) of the former, and is know as the Yagi array. Let us suppose we have a Yagi aerial beaming left to right in front of us. The elements get progressively shorter from the left (look at almost any TV aerial to see this). All the elements on a Yagi aerial are classified as follows:

- The *reflector* – the leftmost element as we look at the array. It is the longest. Next to it is:
- The *driven element* – this is the element connected to the feeder, which in turn runs down to the transceiver. It is slightly shorter than the reflector.
- All the elements beyond the driven element are called *parasitic elements*, or *directors*. They are shorter than the driven element and usually get progressively shorter as we progress to the right along the boom. The directors are mainly responsible for the *directivity* (or *beamwidth*) of the array.

The progression from a simple dipole (a driven element in isolation) to a Yagi array is simple, but is nevertheless important. To make an aerial of two elements, a reflector (*not* a director) is added to the driven element. For three or more elements, directors are added to the two-element design. Adding more and more directors soon becomes impractical, the reduction in beamwidth (such as it is) does not warrant the extra expense, weight and wind resistance that is incurred.

Instead of using linear (straight) elements, as in the generic Yagi, this design uses loops. Designs using squares of wire instead of loops are known as *Quad* aerials, and HF designs require large X-shape frames to support the large squares of wire. At 70 cm, however, the use of wire loops is easier, and they are self-supporting.

Construction

This is quite simple. Any type of material (metal, plastic, wood) can be used for the *boom* (the support for the elements) and for the mast. The elements are made from 14 SWG enamelled copper wire. 16 SWG hard-drawn aerial wire, which is not enamelled, has also been used with success. Thinner wire might result in a rather 'floppy' aerial! The separate parts of the aerial are held together with *jubilee clips* (hose clips).

The driven element is secured to the boom with a jubilee clip and a three-connector plastic connector block as shown in detail in **Figure 1**, and in the photograph. Cut the wire for the driven element 70 mm longer than the 700 mm indicated in Figure 1. Then, using sandpaper, remove the enamel from one end to a distance of 20 mm, and from the other to a distance of 50 mm. After forming the loop of the driven element, bend both stripped ends through 90°, and insert them into the first to holes of the plastic connector block (Figure 1). Do not tighten the screws yet. Push both ends into the block as far as they will go, then bend the 50 mm end back on itself and pull the ends back through the connector block so that the end you have just bent goes into the third hole in the block. Now tighten the screws in the block and in the jubilee clip.

Each director and the reflector should be made 40 mm longer than the circumferences shown in Figure 1. Strip the enamel, as before, from the last 20 mm at each end. Form the wire into the loop, slip the ends under the jubilee clip (Figure 1) and tighten it. You may find that it helps to solder the stripped ends together before securing the jubilee clip.

The boom is fixed to the mast using jubilee clips and wire, as shown in Figure 1. Solder the feeder cable to the driven element, with the braid soldered to the end of the driven element which is connected to the boom (this applies to metal booms; with plastic or wooden designs, the feeder connections are not critical).

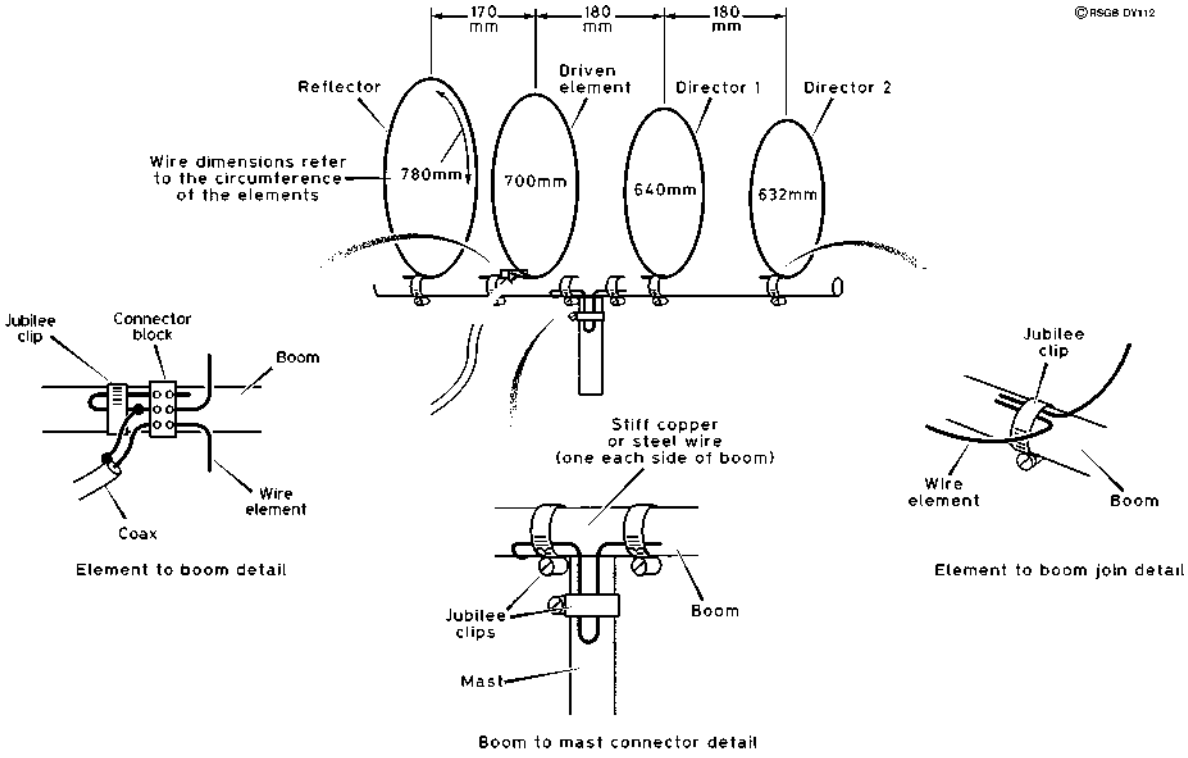

Figure 1 70 cm 4 element quad construction, with detail of how hose clamps are used in the construction

You will need a plug on the shack end of your feeder to suit the transceiver, aerial tuning unit (ATU) or the standing-wave meter (SWM) you are using. Always connect these in the order: transceiver – SWM – ATU – aerial.

Testing

Always test aerials outside and away from buildings (if possible!). This avoids getting misleading results.

Use a rubber duck, or whatever aerial you usually use, and tune around to find a repeater or beacon signal which is consistent. Note the reading on the S-meter. Then, connect your new Quad loop. Rotate it to give the strongest S-meter reading (don't forget it is directional). Verify that the meter reading varies as you rotate it. How does the S-meter reading compare with the original reading? Much depends on the siting of your original aerial; if you are comparing your Quad loop at ground level with a vertical on the chimney, you wouldn't expect your new aerial, even with its gain, to outperform a vertical which is well elevated!

Now a test on transmit is called for. The use of an SWR meter is essential here. Find a clear frequency and check that it *really is clear* before announcing your presence and carrying out the test. A reading of 1:1 is excellent, but any value less than about 1.8:1 would be acceptable. You can measure the directivity of your aerial using the field strength meter, also described in this series.

Materials

4 metres of 14 SWG enamelled copper wire
Material for boom and mast
15 amp connector block
7 Jubilee clips

The enamelled copper wire is available from AA&A Ltd, Sycamore House, Northwood, Wem, Shropshire SY4 5NN. Everything else is available from most hardware stores.

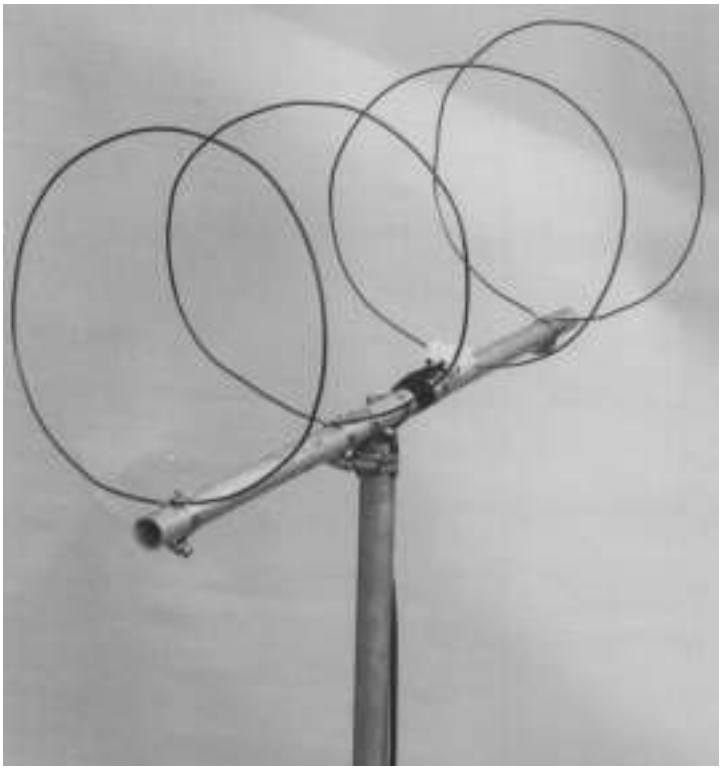

46 A UHF field strength meter

Introduction

It is always interesting, and often useful, to know just *where* the radiation is going from your aerial. How much of your radiated energy is going in the general direction of the station you are in contact with, and how much is being effectively wasted? Some of these questions can be answered with the use of a *field strength meter*. A field strength meter is simply a receiver, stripped down to its bare essentials, such that it responds only to the magnitude of the carrier. The use of a field strength meter assumes that the aerial under test is radiating a continuous carrier. Don't forget to find a clear frequency and identify your transmissions at least every quarter-hour, in order to comply with the terms of your licence.

Description

Two types of field strength meter are shown in **Figure 1**. You will recognise both circuits (Figure 1b particularly) as being types of 'crystal set' with a meter replacing the headphones. Figure 1a is a broad-band HF design (there is no tuning provision) and Figure 1b is tuned in the same way as the crystal set; with a loop of wire as an aerial, it will perform well in the VHF/UHF range.

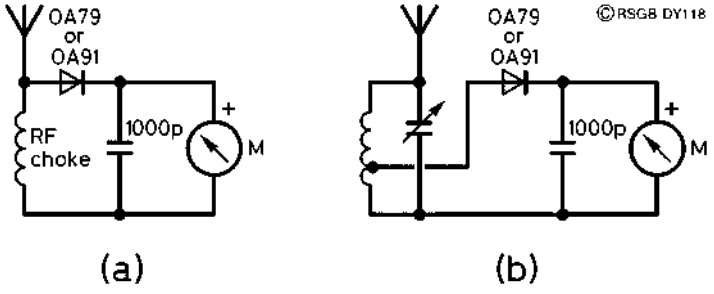

Figure 1 Construction of the UHF field strength meter

A tuned field strength meter also doubles as an *absorption wavemeter* if it is well calibrated. Such devices are useful for detecting transmitter harmonics also. This design is intended for use in the UHF band, so it will have to be sensitive around 432 MHz.

Construction

The field strength meter comprises a loop of wire, 600 mm long, which acts both as aerial and as the tuning inductance, a diode, a capacitor, a connector block, a meter and a length of twin wire. All the components, with the exception of the meter, are fixed to a pole with a jubilee clip, as shown in **Figure 2**. The meter should have a sensitivity of between 50 μA and 100 μA, or a multimeter can be used. The multimeter is more flexible, as you can select different current ranges, giving you a range of sensitivities.

Using the field strength meter

Connect your meter to the ends of the twin wire from the pole. Place a hand-held transceiver about 2 metres away, and press Transmit. If there is no meter reading switch off the transmitter and check the wiring. If the needle attempts to go negative, simply reverse the wires to the meter. If the reading is too high, either move the transmitter further away, or increase the current range on the multimeter. Try changing the orientation of the transmitter aerial, and note how the signal varies.

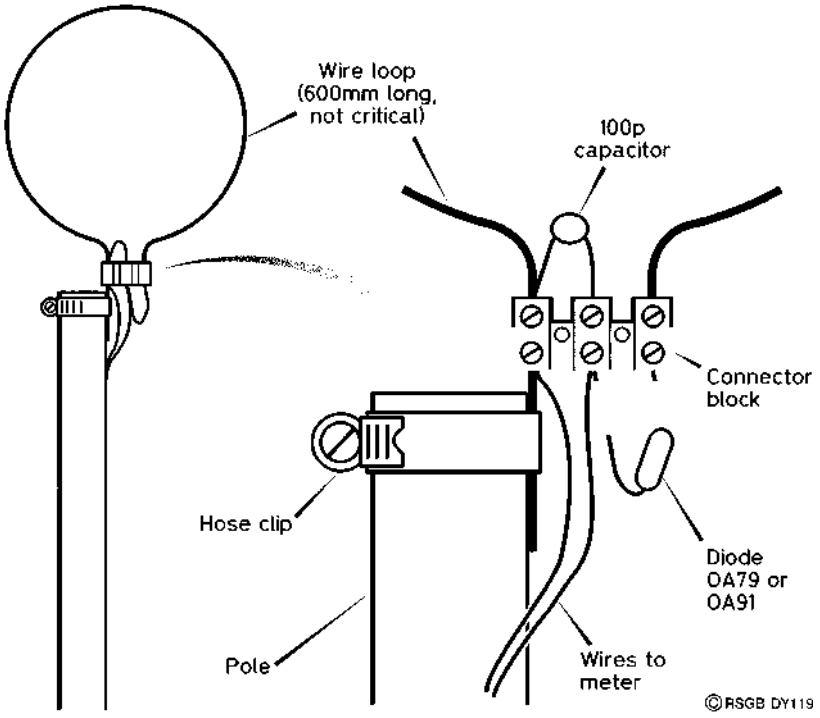

Figure 2 Assembly of the field strength meter

To measure the *polar diagram* (a graph of the signal strength against the angle between the aerial boom and the field strength meter, plotted on polar axes) of a beam aerial, mount the loop as far away from the aerial as you can, preferably at the same height, and rotate the aerial, say 15 degrees at a time, and record the signal strength, until the aerial has been turned through 360 degrees. If you need help plotting the graph, enlist the help of a friend who has done it before, or one who knows about polar graphs! If you have already built the Photometer project, you will have measured and plotted the polar diagram of the light intensity from a torch. Now you will see the great similarity!

Parts list

Capacitor	100 picofarads (pF)
Diode	Germanium, OA79 or OA91
Connector block	10 A, 3-way
Wire	600 mm of 16 SWG enamelled copper
	Length of twin cable for meter connection
Clip	Jubilee (hose) clip

47 Christmas tree LEDs

Introduction

A novelty ideal for the festive season, this circuit causes one LED at a time to light up around a small cardboard Christmas tree.

Warning

This circuit uses members of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which each IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains-earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**
3. **Repeat the process with the second IC.**

The circuit is safe from destruction while it is connected to the battery. However, when the battery is removed, the same care should be exercised with its handling, because there are no supply decoupling capacitors across each IC.

Description

Figure 1 shows the layout, and how the wires are connected from the circuit board to the LEDs around the tree. The circuit, shown in **Figure 2**, is quite complicated, so you need to be confident in your logical approach to circuit-building before you attempt this one! It uses two common integrated circuits (ICs). IC1 is simply an oscillator which provides timing pulses for IC2, which 'counts' up to a maximum of 10. The outputs of the counter are indicated by light-emitting diodes (LEDs); red, orange, yellow and green are common colours which you can use.

The circuit is built on a single piece of Veroboard measuring 29 holes by 12 strips. **Be aware that there is no strip labelled 'I', so don't make mistakes in your counting!**

First of all, cut the tracks in the positions shown in Figure 1 using a 3 mm (⅛ inch) twist drill rotated between thumb and forefinger. Then, solder in the IC sockets, the notches facing row M. Wire up and solder in the links and then the Veropins for the connections to the LEDs and battery. Having done this, the resistors and the capacitor should be fitted. When wiring the LEDs, each cathode (the lead adjacent to the 'flat' on the LED encapsulation) is connected to R4, and the anodes go to separate pins on IC2.

Testing

Hold up your circuit board to the light and check carefully for solder bridges between adjacent tracks. Then check again that the wiring is correct. Place the ICs in their holders, with the notched ends lining up with those on the holders. Connect the battery, and the LEDs should illuminate in sequence.

If you have no success, you are now wishing you had checked the circuit more carefully! Learn something from your mistake and it will not have

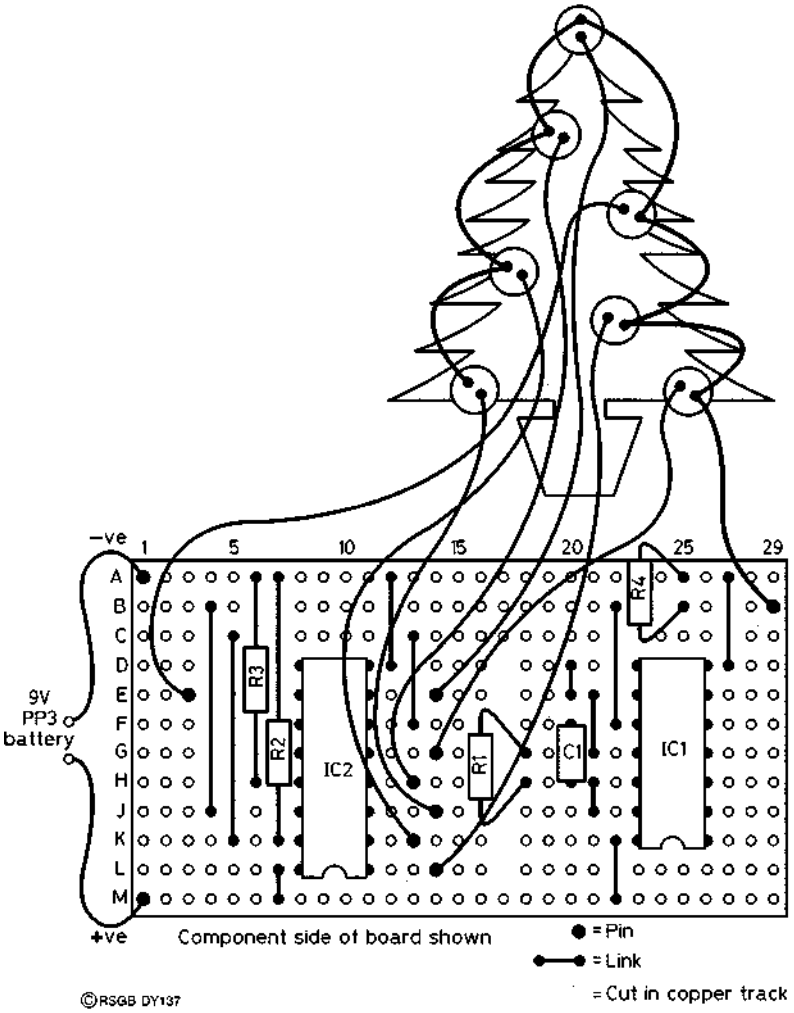

Figure 1 Christmas tree, component layout

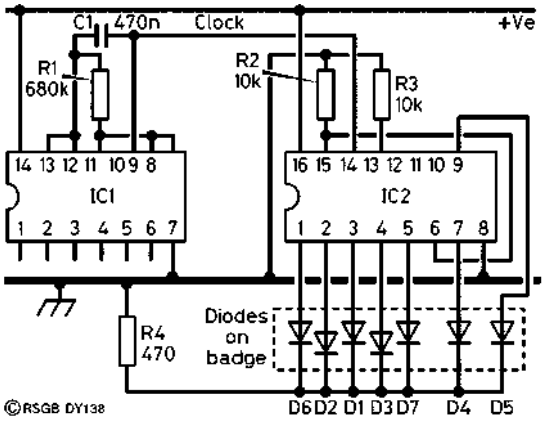

Figure 2 Christmas tree, circuit diagram

been in vain! The first thing to check is that the LEDs are the correct way round. If that is OK, then check the positions where the tracks are broken (intentionally!). After that, are the wire links in the right places – had you forgotten there is no row 'I'? Check *all* the wiring, then check *again* for solder bridges, and switch on again. One of these tests should have revealed a fault. If it *still* refuses to work, perhaps one (or both) of your ICs were damaged by static electricity, despite your precautions – or did you choose to ignore them?

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	680 kilohms (kΩ)
R2, R3	10 kilohms (kΩ)
R4	470 ohms (Ω)

Capacitor

C1	0.47 microfarad (μF) min. metallised polyester film

Semiconductors

IC1	4011
IC2	4017

Additional Items

D1–D7	5 mm LEDs in choice of colours
	14-pin DIL socket for IC1
	16-pin DIL socket for IC2
	PP3 battery clip and battery
	Veroboard, Veropins
	Insulated wire for links

48 An audio signal injector

Introduction

An audio signal injector is a device used to test audio frequency circuits. It is simply an oscillator running at a frequency in the audio range, so that when its output is fed to the input of an amplifier, it will produce a sound in the loudspeaker if the amplifier is working. The oscillation is so rich in harmonics that the signal can also be heard (sounding rather different) when injected into an RF circuit.

The design

The circuit is shown in **Figure 1**, and is a basic *astable multivibrator*, a free-running oscillator producing a roughly rectangular-wave output. The two transistors, TR1 and TR2, operating as switches, switch on and off alternately at a frequency around 500 Hz. The prototype was constructed on plain matrix board (no copper strips), as illustrated in **Figure 2**.

Both transistors are type BC108, which are only a few pence each new, and can be found at almost any rally. You can add an on/off switch, or simply disconnect the battery when you are finished using it. To make the unit in one piece, the battery can be taped to the board, as the diagram shows.

The probe itself is made from a short piece of stiff insulated wire, soldered to a tag on the board; an earth lead is also soldered to the board, and terminated in a crocodile clip to attach to the ground lead of the equipment under test.

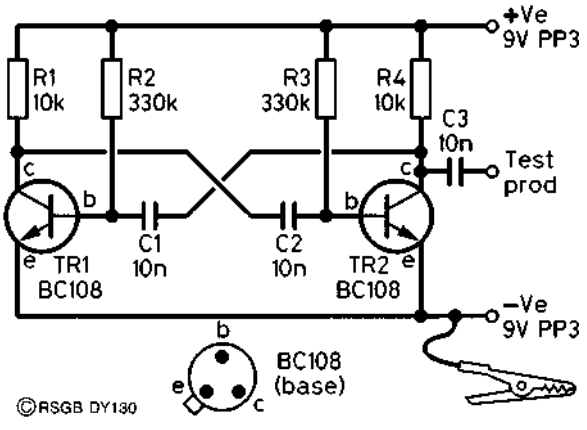

Figure 1 Circuit diagram of the signal injector

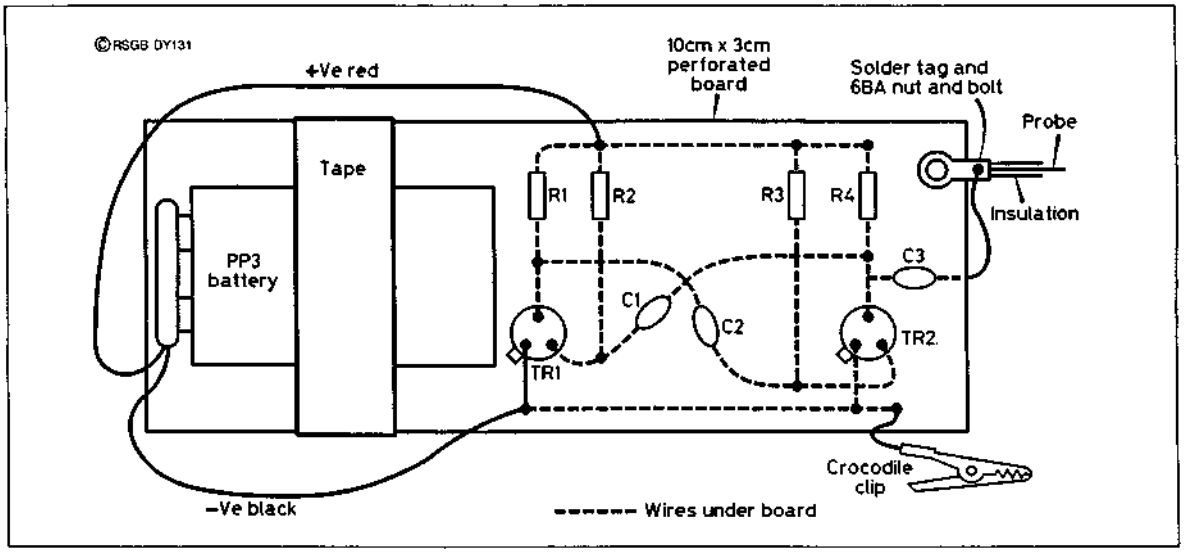

Figure 2 Component layout of the signal injector

Using it

After checking the wiring of the circuit, connect the battery. Find a transistor radio that is known to work. Carefully remove the case, switch on and apply the probe to the centre tag of the volume control. A *very* loud buzz should be heard from the speaker, indicating that the audio circuits of the radio are working. Using the injector to fault-find equipment you have made yourself is rather more instructive and rewarding, because you *know* where to inject the signal, and you should *know* what to expect when you do.

Warning

Do *not* work on any equipment connected to the AC mains. Work only on battery-powered circuits, for your own safety.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1, R4	10 kilohms (kΩ)
R2, R3	330 kilohms (kΩ)

Capacitors

C1, C2, C3	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic

Semiconductors
TR1, TR2 BC108

Additional items
PP3 battery and connector
Matrix board 10 cm by 3 cm
6BA solder tags
Thick insulated wire for probe
Crocodile clip

49 Standing waves

Introduction

Everyone has, or *should* have, a standing-wave ratio (SWR) meter as part of his/her array of test gear. Most people know how to use it, but what does it really do?

Before attempting to answer that question, we need to look at some aerial fundamentals. An aerial is a *transducer*, the word meaning 'to lead across'. We use it whenever one form of energy is converted into another form. A bulb is a transducer; it converts electrical energy in the filament to radiated heat and light energy. **Figure 1** shows the situation.

An aerial, or antenna, is also a transducer; it converts radio-frequency (RF) energy in the feeder (or *transmission line*, to give it its proper name) into radiated electromagnetic energy, in the manner shown in **Figure 2**. The aerial has resistance, just like the bulb filament, and if the filament had zero resistance, there would be no radiated energy. In the same way, if the aerial had no resistance, there would be no radiation from it.

Transmission lines should convey RF energy from transmitter to aerial with the minimum power loss. A common form of transmission line is the *coaxial*

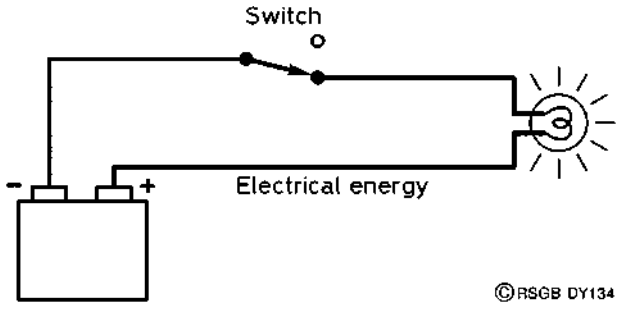

Figure 1 The light bulb converts electrical energy to electromagnetic light energy

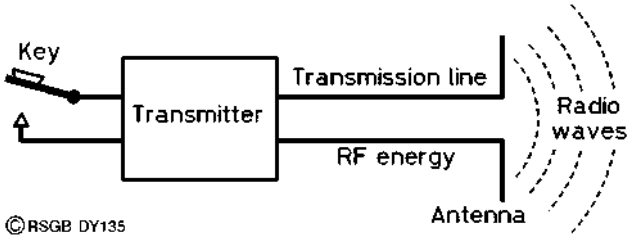

Figure 2 The antenna converts RF current to electromagnetic radio waves

cable. As you might expect, any feeder cable has a DC resistance caused by the resistance of the copper wire from which it is made. It also has an AC resistance, caused by the capacitance between the centre conductor and the braid, and by the inductance of the cable itself. This means that the feeder has an *impedance*, which is constant for the particular type of cable. This is what we call the *characteristic impedance* and, for the cables used in most amateur radio applications, it is 50 Ω.

If this impedance can be made the same as that of the aerial (it is already the same as the impedance of the transmitter output), then the transfer of energy will occur with minimum loss. If the aerial and cable impedances are *not* the same, then there is a *mismatch*, which causes some of the RF energy to be reflected back towards the transmitter. We now have a situation where RF energy is flowing along the cable from the transmitter to the aerial (the *forward* wave) and, at the same time, flowing from the aerial to the transmitter (the *reflected* wave). The two waves interact along the cable and form a stationary pattern of voltage and current. The pattern is known as a *standing wave*, and can be visualised from the waveforms in **Figure 3**. The ratio of the maximum voltage to the minimum voltage on a given wave defines the *voltage standing-wave ratio* (VSWR), or just *standing-wave ratio* (SWR) for short.

The SWR meter is easy to use. It is positioned in the feeder between the transmitter and the aerial tuning unit (ATU) if there is one, or between the transmitter at the aerial otherwise. Most meters have a single meter and a four-position switch. The transmitter is first keyed and, with the switch in

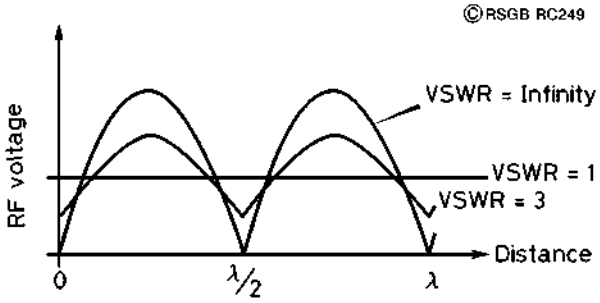

Figure 3 Standing waves on a transmission line

the 'calibrate' position, the sensitivity control is adjusted to give full-scale deflection on the meter. The switch is then changed to 'forward' to read the forward power, to 'reflected' to read the reflected power, and to 'SWR' to read the value of the standing-wave ratio. When there is no reflection (see Figure 3), the meter should read 1:1 or, simply, 1.

Most SWR meters remain in the feeder line while the transmitter is operating, so the condition of the aerial and feeder can be constantly monitored. Problems with the aerial (such as water entering the feeder at its junction with the driven element) are immediately shown up. Without the use of the SWR meter, the situation would slowly deteriorate over several months and you would be left wondering why so few stations were answering your calls!

50 A standing-wave indicator for HF

Introduction

The standing-wave ratio (SWR) meter shows how well the aerial system, including the feeder, is *matched* to the output of the transmitter. This design does not *measure* SWR, but it gives an indication of when the SWR is minimum for a given system of aerial and feeder. The design is usable on the HF bands from 1.8 to 28 MHz, and can be used at 50 MHz with reduced sensitivity.

How it works

There are two types of wave in any feeder: the *forward* wave, which travels from the transmitter to the aerial; the *reflected* wave, which travels back to the transmitter from the aerial. The presence of a reflected wave is evidence that some of your transmitted power is not being radiated, but is being returned to the transmitter to be lost as excess heat. When aerial and feeder are perfectly matched, there is *no* reflected wave, and all the power from the transmitter is radiated.

Referring to the circuit of **Figure 1**, a tiny fraction of the signal is removed by the transformer, T1, and by the capacitors, VC1 and C1. It is then detected by the germanium diodes, D1 and D2, and any residual RF removed by the capacitors, C2 and C3. The currents through the diode and meter (depending on the position of switch, S1) represent the forward and reflected signals. VR1 acts as a sensitivity control for the meter.

It pays to shop around for a suitable meter. Surplus types from tape recorders and hi-fi equipment are usually ideal for this purpose. A new one would cost several pounds. The more sensitive the meter, the more sensitive your indicator will be. Meter sensitivity is given by the current required to give full-scale deflection (FSD) of the pointer. One with an FSD of between 50 and 200 micro-amps (μA) is suitable for this circuit. The higher the FSD, the less sensitive the circuit.

Construction

The meter circuit and the sampling transformer (see **Figure 2**) are built and mounted on Veroboard of the copper-strip variety. It simplifies construction

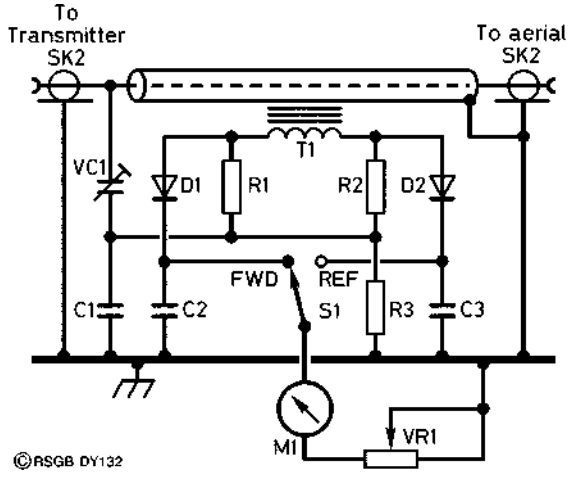

Figure 1 Circuit diagram of the SWR meter

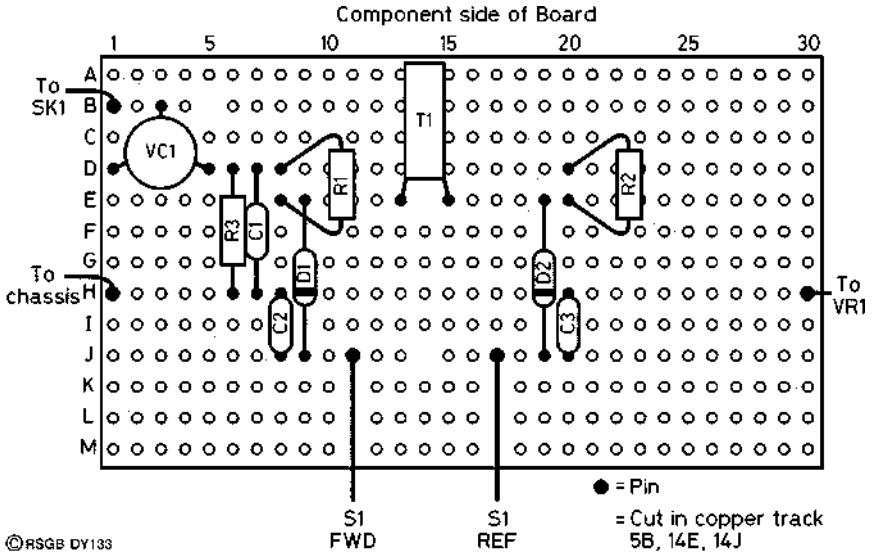

Figure 2 Component layout of the SWR meter

but reduces the operational range of the meter to below 30 MHz because of the capacitive coupling between strips. The board has 13 strips by 30 holes, although you can reduce this if you have a smaller case.

Firstly, cut the tracks at the three points shown. Then insert and solder Veropins for connections to the external components, the switch, variable resistor and the meter. Solder in the components starting with the resistors and followed by the capacitors and the diodes, ensuring that the diodes are inserted correctly.

Now you have to wind the transformer, T1, on a small toroidal ferrite core. Wind the secondary with 15 turns of 36 SWG enamelled copper wire, spaced evenly over about two-thirds of the former. The turns should not overlap, and considerable care must be taken; the wire is very thin, will kink easily and will break if you apply too much tension. The 'primary' is an 8 cm length of 50 Ω coaxial cable which passes through the toroid on its way between the input and output connectors. The braid of the cable is connected to the case at only *one* of the connectors (see Figure 1); this prevents the screen and the metal case between the two sockets forming a single, shorted turn.

The ends of the secondary winding must be carefully stripped of their enamel with sandpaper, before attaching the toroid to the board with cotton or nylon fishing line. On no account must wire be used for this!

Solder the secondary connections of T1 to the board and thread through the coaxial cable ready for soldering to the connectors.

The case used was an aluminium box (Maplin LF02C), but any suitable metal box could be used. Aluminium is preferable, as it is easily drilled with simple tools. Use standoff insulators to mount the board in the case. Once this has been done, the leads from the board to the chassis-mounted components can be soldered. So can the coaxial cable passing through the toroid. Make the lead from the input socket to VC1 as short as possible.

Setting up

You will need a 50 Ω dummy load and a transmitter to set up your indicator. Connect the transmitter to SK1 and the dummy load to SK2. Set the toggle switch, S1, to *forward* and the sensitivity control, VR1, to mid-travel. Switch on the transmitter, and set VR1 for maximum meter deflection. Switch to *reflected* and adjust VC1 until the reading is minimum (ideally zero). This completes the setting up!

Using the indicator

For setting up an aerial, connect your circuit between the transmitter and the cable leading to the aerial. With S1 in the *forward* position, key the transmitter and adjust VR1 for maximum reading on the meter. Switch to *reflected*, and then adjust your ATU to give minimum reflected power. If your adjustments are to be made to the aerial itself, to give minimum reflected power, you must make a note of the reflected reading, switch off the transmitter, make a change to the aerial, key the transmitter, and note whether the reflected power is greater or less than before. Then, make more changes to the aerial. **Never adjust your aerial with the transmitter on.** Make your adjustments on an unused frequency, and do it as quickly as possible, thus avoiding (or minimising) interference to other stations.

Parts list

Resistors: all 0.25 watt, carbon 5% tolerance
(or Maplin 0.6 watt metal film)

R1, R2	27 ohms (Ω)
R3	2.2 kilohms (kΩ)
VR1	10 kilohms (kΩ) linear

Capacitors

C1	220 picofarad (pF) disc ceramic 50 VDC
C2, C3	0.1 microfarad (μF) disc ceramic 50 VDC
VC1	20 picofarad (pF) trimmer

Semiconductors	
D1, D2	OA91 germanium
Additional items	
S1	Single-pole changeover (SPDT or SPCO)
SK1, SK2	Coaxial sockets to suit station standards
	Veroboard – 13 strips by 30 holes
	Veropins (7 off)
	Amidon FT 50–43 ferrite toroid
	Meter, less than 200 μA FSD
	36 SWG enamelled copper wire
	Short length of UR43 or RG58 coaxial cable
	Insulated stranded wire
	Aluminium box
	Standoff insulators for mounting the board
	Knob for the sensitivity control

51 A moisture meter

Introduction

Dry rot (*Merulius Lacrymans*) can strike havoc in buildings, causing the timbers to decay and crumble to dust – hence the term *dry rot*. Wood is attacked only if its moisture content rises above 20%.

Construction

The circuit of the moisture meter is shown in **Figure 1**. The two probes touch the wood, and the current that flows between them depends on the moisture content of the wood. If the moisture is sufficiently high, the current, after amplification, will be enough to light the LED.

The meter can be made on a piece of plain matrix board (no copper strips), as **Figure 2** shows. The board is big enough (10 cm by 2.5 cm) to accommodate the PP3 battery, taped on. No case is needed, unless you want

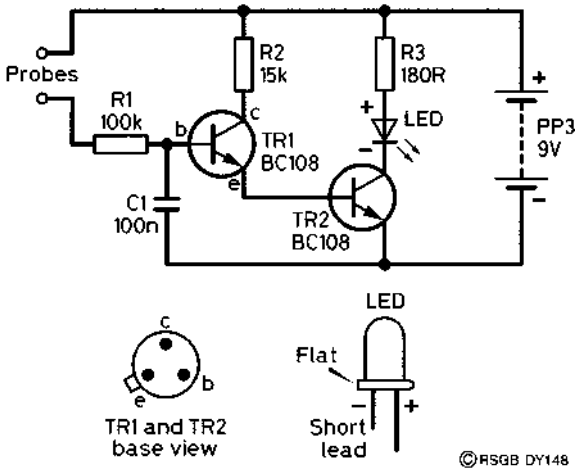

Figure 1 Circuit diagram of a moisture meter

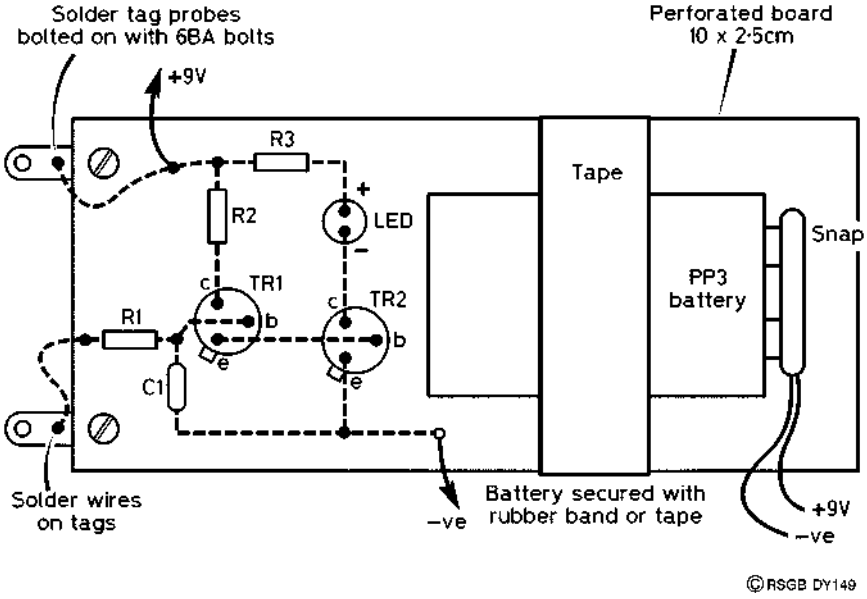

Figure 2 Moisture meter, component layout

to leave the meter in a damp location for a protracted period! Make sure that the transistors and LED are mounted correctly. In Figure 2, the connections as shown to TR1 and TR2 are illustrated as if the transistors were transparent. An on/off switch is not really necessary, as only a very small current flows when the probes do not touch anything. Use solder tags, screwed to the board, to act as probes.

After the assembly is completed, check your circuit one final time, and then connect the battery. Nothing should happen at first. If you lick your forefinger and hold it across the probes, the LED should light.

Using it

The prototype was compared with a commercial moisture meter, and the LED lit when the moisture was around 20%. This was quite fortuitous, as the point at which the LED lights depends both on the separation of the probes and on the gain of the two transistors.

In addition to searching for dry rot, the instrument may be used to monitor the moisture in the soil of household plants. In this case, probes made of 16 SWG copper (*not* enamelled) should be soldered on to the two tags, and should penetrate the soil to a depth of several centimetres, and R1 may require adjusting so that the LED extinguishes if the soil is too dry, and lights if the soil is sufficiently moist. If you wanted to leave the meter with the probes in the soil, an on/off switch *would* be necessary.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	15 kilohms (kΩ)
R3	180 ohms (Ω)

Capacitor

C1	0.1 microfarad (μF) polyester

Semiconductors

TR1, TR2	BC108
LED	Any shape or colour will do

Additional items

- PP3 battery and connector
- Solder tags (2 off) for probes
- Matrix board 10 cm by 2.5 cm

52 Simple aerials

Introduction

The performance of *any* receiver or transceiver, no matter how expensive it is, is limited by the aerial that feeds it. Two of the most frequently asked questions are:

- Which is the best sort of aerial to use?
- Where is the best place to locate an amateur radio aerial?

To answer these questions, you must ask yourself what sort of operation you want to do. Are you interested in local, chatty contacts on the lower bands or VHF, or are you more disposed towards long-distance (DX) contacts, and on what band?

A house with a moderately sized garden is assumed in the diagrams here, to illustrate the configurations of some simple aerials. You would not need all these aerials festooned around your house, because one or two would be sufficient for your needs. The problems incurred by properties with more restricted space will be covered later.

VHF aerials

For VHF operation, the aerial should be mounted as high as possible, either on a mast or on a chimney. For all-round coverage on FM and the local repeaters, a vertical colinear is a good choice. For SSB and CW DX operation, a horizontal rotatable beam is needed. If satellite working is envisaged, you will need to contemplate mounting an elevator on top of your rotator, so that your beam can point in *any* direction, including vertically upwards! An advantage of satellite working is that the aerials do not *necessarily* have to be up in the air, provided you have a relatively uncluttered site. Your rotator and elevator can be at ground level, which is good!

If the VHF aerial is mounted on the chimney, use a double mounting bracket, particularly if you have a beam and rotator. Keep the TV, broadcast FM and amateur aerials as far apart as possible, and keeping the feeders separated is also a good plan.

The dipole aerial

One of the simplest types of aerial for single-band operation is the half-wave dipole. (The name ‘dipole’ simply means ‘two poles’ or ‘two elements’, and

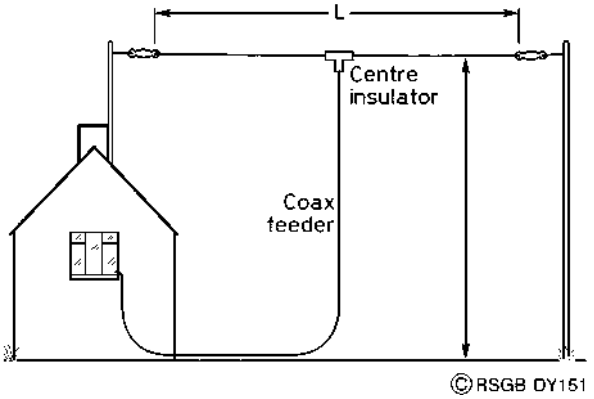

Figure 1 Layout for a dipole aerial

in this case the total length of the dipole is approximately half a wavelength at the operating frequency.) It is usually fed in the centre by coaxial cable as shown in **Figure 1**. The length of the dipole for the lowest frequency in each band is shown in **Table 1**. Normally, the length of the aerial will be 'trimmed' to be tuned to the centre frequency of the part of the band in which you will operate. This is done using the data in the right-hand column of Table 1. As an example, suppose you wanted your aerial to be resonant at 3.7 MHz. The table gives an overall dipole length of 42.86 m for 3.5 MHz. To resonate the aerial 200 kHz *higher*, then this length must be shortened by 2 × 0.595 m = 1.190 m. Your dipole would thus be 41.67 m long. Remember to allow extra wire for fixing the dipole ends to the insulators.

Table 1 Dipole lengths for lowest frequency of each band and the length to be trimmed from each to raise the resonant frequency by 100 kHz

Band (MHz)	*Dipole length (m)*	*Trim each end (mm/10 kHz)*
1.8	83.33	2190
3.5	42.86	595
7	21.43	150
10	14.85	70
14	10.71	35
18	8.33	20
21	7.14	15
24	6.03	12
28	5.36	10
50	3.00	6

On the lower-frequency bands, the lengths become rather large. In this case, you can 'bend' your dipole, as illustrated in **Figure 2**. The length of wire required to give an acceptable value of SWR (less than 2:1 on transmit) may need to be different from the calculated value, so be prepared to experiment!

Dipoles are single-band aerials, although they will often work acceptably on the third harmonic of their design frequency: a 7 MHz dipole often operates reasonably well on 21 MHz. It is possible to operate several dipoles in parallel, as **Figure 3** shows. Interaction between the elements can occur if the spacing between them is less than about 10 cm. A multi-band dipole, as shown in Figure 3, has the elements separated with plastic spacers, and drooping ends to produce maximum spacing between the elements' ends.

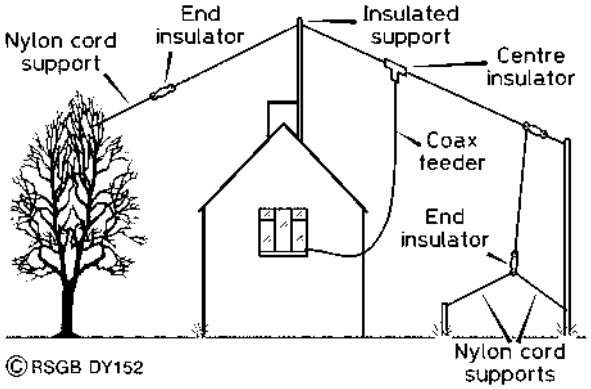

Figure 2 Possible layout for a dipole aerial in a confined space

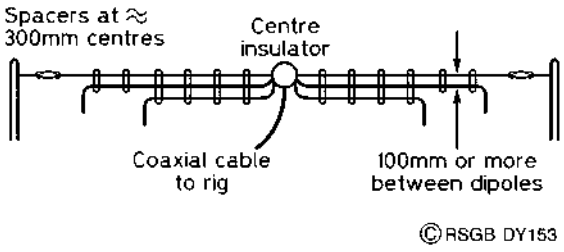

Figure 3 Multi-band dipole aerial

The long-wire aerial

This aerial is simple, cheap, easy to erect, and suits most houses and gardens, as **Figure 4** shows. Using an aerial tuning unit (ATU), an end-fed long wire can function on several bands when used with a set of radials or a counterpoise. **Figure 5** illustrates the setup. The length of the aerial will determine the bands which will be covered.

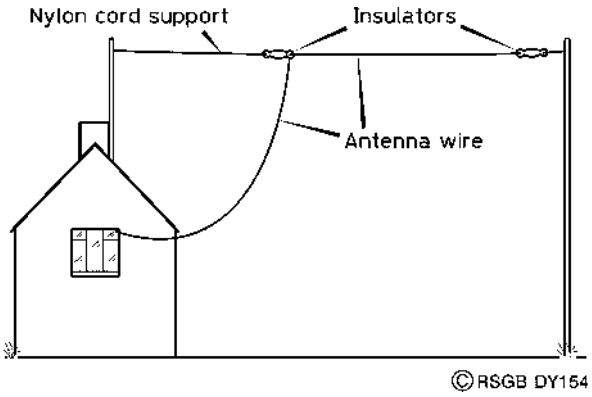

Figure 4 Long-wire or inverted-L aerial

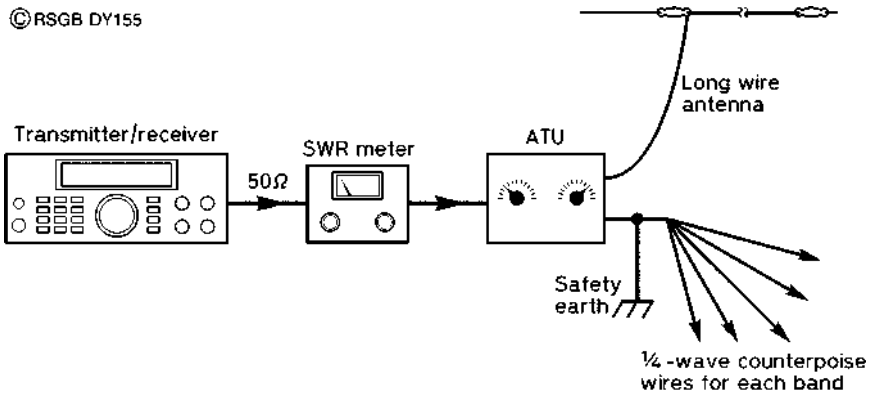

Figure 5 How to connect a radio to a long-wire aerial

A wire length of 10.5 m will work on the 40, 30, 17, 15 and 12 m bands.

A wire length of 15.5 m will work (with an ATU) on the 80, 40, 20 and 12 m bands and possibly (depending on your ATU) on the 17 and 15 m bands.

A wire length of 26.5 m will operate on all bands, but may be difficult to load on 10 m.

The wire lengths given here may need some adjustment because of the geometry of your particular house and garden. For receive-only purposes, the lengths are far less critical.

In general, you cannot get a good radio-frequency (RF) earth from a first-floor (or higher) shack. Unless a good RF earth exists within a small fraction of a wavelength of the transceiver, an *artificial ground* comprising a single $\frac{\lambda}{4}$ radial or counterpoise will be needed. You will need one counterpoise for each band you intend to use, and the wire can be concealed around the skirting-board of the shack, or under the carpet. Make sure that the free end

Table 2 Lengths of elements for vertical antennas, radials for verticals and counter-poises for end-fed long wire antennas

Band (MHz)	*Element length (m)*
1.8	39.66
3.5	20.40
7	10.20
10	7.14
14	5.1
18	3.96
21	3.4
24	2.95
28	2.55

of each counterpoise is well insulated; this point can carry a *very high voltage* when you transmit; anyone coming into contact with this can suffer very severe RF burns. Counterpoise lengths can be read from **Table 2**.

The vertical aerial

The single-band vertical aerial is sometimes used by DX operators because it has a low angle of radiation, which favours long-distance propagation. However, it must be sited clear of obstructions and must have a *good* counterpoise or radial system. Illustrations of the vertical aerial are shown, and the lengths of the vertical and radial sections are given in Table 2. The centre of the coaxial feeder is connected to the vertical section, and the braid to the counterpoise or radial system, which is made up of four or more wires buried just below the surface and joined together near the base of the aerial.

Cable entry to the house

Bringing coaxial cable into the house by an open window must be regarded as a temporary measure. Wooden window frames can be drilled, one hole for each feeder. Make the holes slope downwards from inside to out to prevent rain entering, and treat these with wood preservative. Leads from long-wire and inverted-L aerials should be kept separate from other cables.

Alternatively, a plastic pipe large enough to take all your feeders could be fitted into the brickwork (again, sloping downwards towards the outside). You may want to let a friendly builder do this for you.

53 A breadboard 80 m CW transmitter

Introduction

In the early days of radio, many circuits were built on a wooden baseboard, the parts being screwed down on the board. This was called breadboard construction, because it was a breadboard that was frequently commandeered for the process! Wives have always been generous in this respect, it appears!

This circuit was originally designed by GM3OXX, and became known as the *Oner*, because it was built on a circuit board one inch square! The circuit appeared in the G QRP Club journal *Sprat* and, since that time, many hundreds of *Oner* circuits have been built and used on the air. It is a well-proven circuit.

The transmitter has no tuned circuits in the power amplifier (PA) and thus has a rather high *harmonic* content. It **must** be used with the ***low-pass filter*** described elsewhere in this book. Without the low-pass filter, interference will be caused to other stations.

Simple aerial changeover switching is provided, which allows this circuit to be used with any of the 80 m receivers, such as the *Colt*, described in this book. It can also be used with any kit or commercial receiver for the 80 metre band.

The circuit

The transmitter circuit is shown in **Figure 1**. TR1 is a crystal oscillator, the frequency of which is controlled by crystal X1. A small trimmer capacitor, TC1, is added to allow the frequency of X1 to be varied by a small amount. If adjustment of this trimmer is made possible from the front panel, it is useful to adjust the transmit frequency to avoid other stations already on the crystal frequency. The collector load resistor, R2, of the oscillator transistor, TR1, determines the power output; a value of 3.3 kΩ seems to work well in producing an output of 3 watts.

TR1 is directly coupled to TR3, a VMOS transistor (a type of field-effect transistor (FET)). This acts as the power amplifier (PA) stage. TR3 should

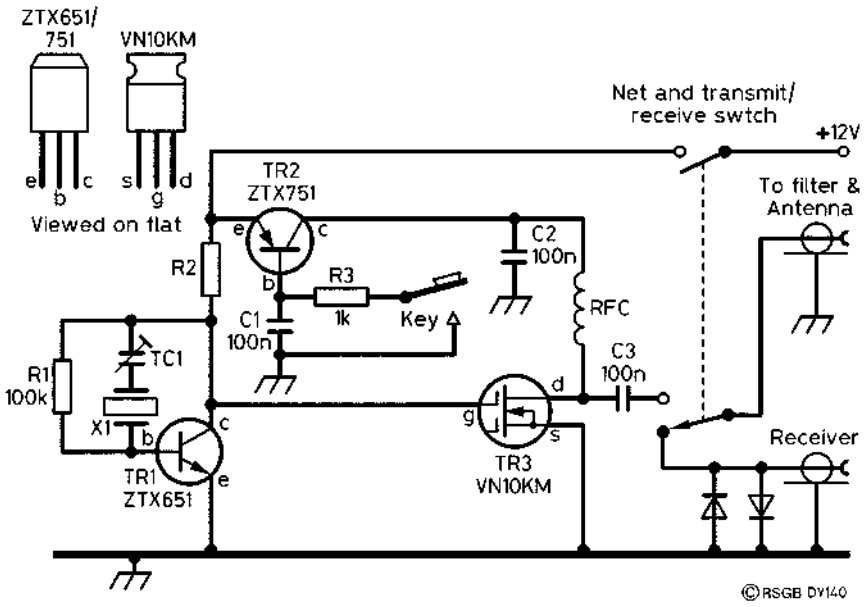

Figure 1 Circuit diagram of the breadboard transmitter

give about 3 W output, which is then coupled to the output by C3. The radio-frequency choke (RFC) providing the drain load of TR3 is simply a few turns of wire on a ferrite bead.

TR2 is an interesting addition to the circuit. It is used as a switch to 'key' the PA, TR3. The transmitter *could* be built without TR2, just placing the Morse key between the top of the RFC and the 12 volt supply. Adding TR2 is helpful, because it means that one side of the Morse key can be grounded (always a good thing), and some degree of *shaping* of the output RF waveform is provided by R3 and C1. This makes the transmission sound a little better and reduces the possibility of spurious frequencies being generated and transmitted. TR2 is a pnp transistor; note that it is the *emitter* of this transistor which is connected to the positive side of the supply.

Some form of changeover switching is needed for the aerial. A double-pole changeover toggle switch can be used. See the chapter on switches, later on in this book. One pole is used to switch the aerial between transmitter and receiver; the other pole is connected in the 12 volt supply line, and is labelled RECEIVE/TRANSMIT – NETTING. Its use will be described later. In this simple circuit, the PA cannot work when the key is open, because the key breaks its supply (via the RFC). When the key closes, TR2 switches on and applies the 12 volt supply to the top of the RFC. C2 is a *decoupling* capacitor, which prevents any residual RF signals at the top of the RFC reaching TR2.

Building

The prototype was put together as follows. Take a piece of plain printed-circuit board (PCB) measuring 5 cm by 4 cm. Then, with a *new*, *sharp blade* in a junior hacksaw, draw the blade horizontally across the surface of the copper in order to make a pattern of 6 squares along the 5 cm side and 5 squares along the 4 cm side. No more pressure should be applied than is necessary to cut through the copper! All the parts will be soldered on these pads in a form of surface-mount construction. To do this, each active pad (i.e. one that is going to have a component soldered to it) needs to be *tinned*. This means coating the pad's surface with solder, and is carried out as follows. Place the hot tip of the soldering iron on to the pad, and hold it there for a second or so. Then, with the tip still in place, touch the end of your reel of solder *on the pad*, not the tip of the iron. The solder should flow evenly all over the pad, and you can remove the iron. The solder should solidify in a rounded, shiny blob! This provides a good surface for making soldered joints.

To join component leads to the pads, cut each lead about 1 cm long, and then bend the last 2 mm at right angles to the rest of the lead. As you did before, tin the 2 mm length of each lead. Place the tinned portion on to the pad, and place the tip of your iron *on the pad*, close to the lead. The solder on the pad and on the lead will melt and run together; remove the iron and *hold the component still* until the solder solidifies. When the joint has cooled, give the lead a gentle tug to make sure you have a good joint (a good *mechanical* joint is usually a good *electrical* joint, too!). Each transistor straddles three pads, so the centre lead will need to be shorter than the other two. Take care here to get the lead lengths right – if you do, you will be surprised how much more firmly the transistor is held than if you just botched the lead lengths by bending them to fit! Make sure the connections to the transistors are correct.

Winding the RFC is quite simple. Seven (or more) turns of thin (32 SWG) enamelled copper wire are threaded through a small ferrite bead. This requires care, because the bead is small and the wire is thin. Trim the ends to within about 1 cm of the bead, remove the enamel carefully with sandpaper and tin the bare ends, prior to soldering the choke to the board.

After completion of the wiring, check the circuit against Figure 1. Breadboarding a circuit like this has its advantages, but it can have disadvantages, too. One of these disadvantages is that it can make circuit checking difficult. For a simple circuit like this, it is not too bad! Check that no solder has run between the pads. Plug in your crystal for the 80 m band, and connect up the 12 V power supply. Do not connect the Morse key yet and do not switch on the power.

Testing and operating

Clear your workbench of all metallic objects, slivers of copper, bits of wire, etc., switch on your power supply. With an external receiver, listen on and

around your crystal's frequency for a signal. Remember that the oscillator runs all the time and, because you haven't yet connected the Morse key, your receiver is close enough to pick up the signal from the oscillator. This confirms that your oscillator is running. Switch off.

Connect the station aerial to the transmitter's aerial socket, and the receiver to the transmitter's receiver socket. Connect the Morse key, put the Receive/Transmit–Netting switch in the receive position and switch on. You should be able to hear stations in the normal way. Now put the switch in the Transmit–Netting position. Signals in the receiver should almost disappear, as the circuit has disconnected the receiver's aerial.

Tune the receiver until you can hear your own crystal oscillator signal. This is known as *netting*, tuning your receiver and transmitter to the same frequency. Pressing the key will now transmit your signals when the switch is in the Transmit–Netting position; switch back to the receive position to listen for stations answering your call. As soon as you are happy that your circuit is functioning properly, **you must build the low-pass filter circuit** before using the transmitter regularly.

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	100 kilohms (kΩ)
R2	See text
R3	1 kilohm (kΩ)

Capacitors

C1, C2, C3	100 nanofarads (nF), or 0.1 microfarad (μF)
TC1	3–60 picofarads (pF) trimmer

Semiconductors

TR1	ZTX651
TR2	ZTX751
TR3	VN10KM

Additional items

RFC	7 turns of 32 SWG enamelled copper on a ferrite bead
Switch	Double-pole changeover (DPDT or DPCO) toggle
Crystal	For 80 m band
Crystal holder	HC25 type
Sockets	According to station fittings

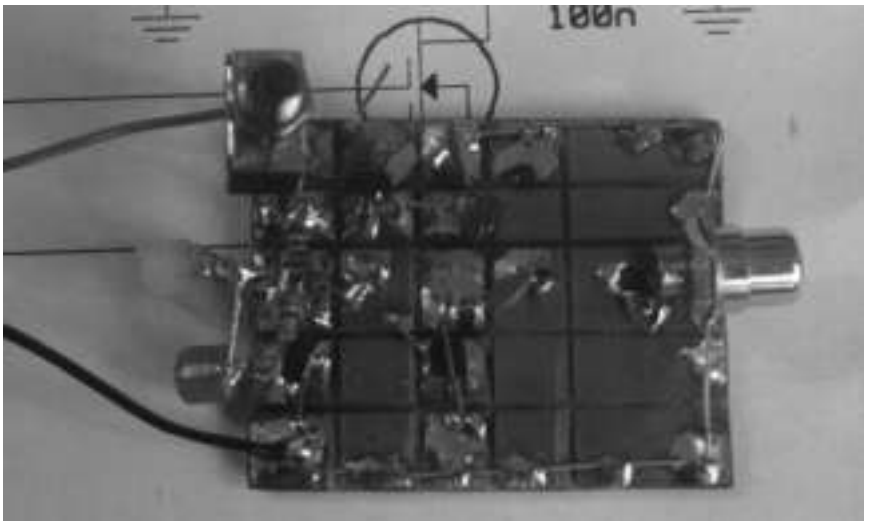

54 A 7-element low-pass filter for transmitters

Introduction

The simpler the transmitter, the more likely it is to radiate *harmonics* of its fundamental frequency. Harmonics are integral multiples of the frequency on which the transmitter is *designed* to operate. If you think you are transmitting on a frequency, *f*, for instance, you will also be radiating the harmonics of *2f*, *3f*, *4f*, . . . and so on. This results in your signals being heard on *several frequencies*, spread over a very wide frequency range. You are also contravening the terms of your licence. To avoid this, it is always advisable to use a *low-pass* filter between your transmitter and aerial. This is a filter which will *pass* your signal frequency, *f*, and all frequencies *below* it, but will *not pass* (attenuate) frequencies above *f* to any significant extent. The value of *f* is known as the *cutoff frequency* of the filter.

A design of 7-element low-pass filter

A 7-element low-pass filter (LPF) is so called because it has seven components, as the circuit diagram of **Figure 1** shows. Filters containing any odd number of elements are possible: a 3-element filter would

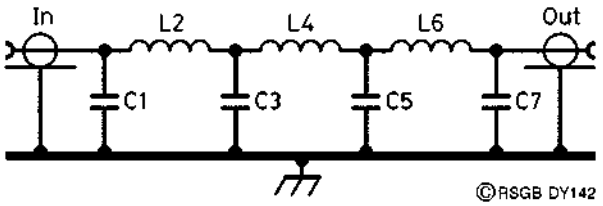

Figure 1 Circuit diagram of filter

comprise C1, L2 and C3 only, and is sometimes called a pi-network because the element disposition resembles the Greek letter pi (π); a 5-element filter would comprise C1, L2, C3, L4 and C5 only, and so on. In general, the more elements the filter has, the more effectively it attenuates signals above *f*.

The circuit of Figure 1 is designed to have an input and an output impedance of 50 Ω, which means that it can be placed in the aerial feed of any common transmitter. Filter design is a very complex business, and is best left to the experts. One such expert is W3NQN, who produced a number of computer designs of LPF using commonly available (*preferred value*) capacitors, and aimed specifically for use on amateur frequencies. The results of this work are condensed into **Table 1**. The inductors are wound on standard toroidal cores, and their details are included in the table.

Table 1 Filter component values for each brand

Band metres	*C1,7 pF*	*C3,5 pF*	*L2,6 turns*	*L4 turns*	*Core type*	*Wire SWG*
80	470	1200	25	27	T37-2	28
40	270	680	19	21	T37-2	26
30	270	560	19	20	T37-6	26
20	180	390	16	17	T37-6	24
15	82	220	12	14	T37-6	24
10	56	150	10	11	T37-6	22

Making the filter

The filter was made originally as an adjunct to the *Breadboard 80 m CW transmitter*, which you will also find in this book. It uses the same constructional technique, based on a single piece of plain, copper-clad

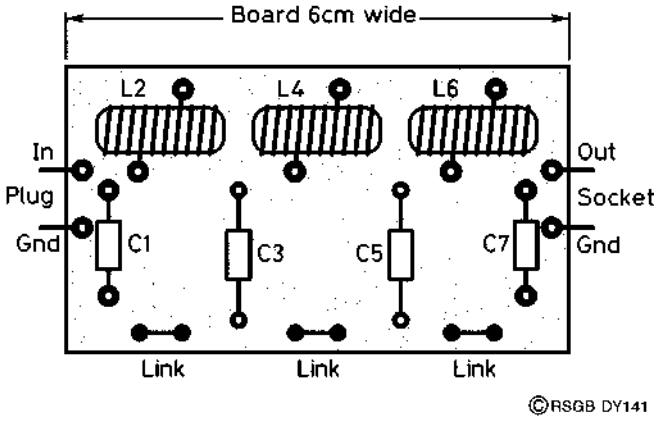

Figure 2 Layout and construction of filter

PCB, with 'pads' created by using a sharp blade in a junior hacksaw. The cuts in the copper are shown in the layout diagram of **Figure 2**. There are two ways of mounting the components: the first way is to drill small holes in each pad, as shown in Figure 2, and mount the components through the holes in the normal PCB manner; the second way is to solder the components directly to the pads, in the way that was described for the *Breadboard transmitter*.

Winding the inductors is quite simple. All you need to remember is that each time the wire passes through the core counts as one turn. Cut off the spare wire at each end of each coil to about 1 cm, scrape off the enamel with sandpaper, and tin the exposed copper. See the transmitter description if you are unsure of how to do this. Note the wire links between each of the lower pads, forming a solid 'ground' for the elements. The prototype had a plug and socket on the ends, to match the transmitter and aerial terminations.

The type of capacitor used in the design is not critical; the polystyrene type works well.

55 Radio-frequency mixing explained

Introduction

Mixers find widespread use in electronic circuitry. Many of the projects in this book, together with every TV set and radio in the home, contain mixer circuits – a good indication of their usefulness.

Confused?

Audio mixers (as used in recording studios and radio broadcast stations) are used to **add** or 'balance' the signals from various sources such as microphones, CD players, etc. These have nothing whatsoever to do with radio-frequency (RF) mixers, and should never be confused with them.

RF mixers and beat frequencies

Instead of **adding** signals (as in the audio mixer), the RF mixer **multiples them together.** As you might expect, this has an entirely different effect. The two signals entering the mixer *beat* or *heterodyne* with each other to produce *signals on other frequencies*. One example of this occurs in sound, when two musical notes of almost the same frequency are heard together. Instead of hearing two separate notes, the listener hears one note whose *intensity* (*loudness*) appears to increase and decrease. This intensity variation is called a *beat*, and its frequency is equal to the difference in the frequencies of the two original notes. The technique is used by musicians to tune their instruments. If one note is known to be a correct frequency, the other can be tuned to it by making the beat frequency as close to zero as is possible.

Multiplying together

The process of mixing presupposes that we have a device which will automatically multiply two signals together. Fortunately, this is easy; so easy, in fact, that it often occurs when we do not want it! Multiplying is achieved by any device which is *non-linear*; this means a device whose output is not a constant factor larger than its input, something that can be achieved by many electronic devices and circuits.

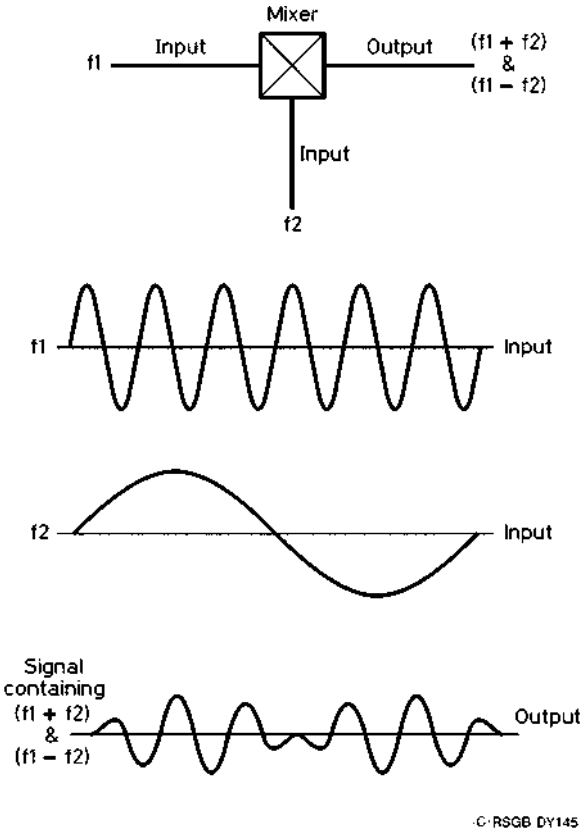

Figure 1 The effect of multiplying (or mixing) two signals together

Let us look now at what a mixer does in concrete terms. Suppose two signals, of frequencies *f*1 and *f*2 go into our mixer. These signals are shown in **Figure 1**. Putting numbers in, to make the situation clearer, suppose *f*1 is 1.000 MHz and *f*2 is 160 kHz. The beat frequency is the *difference* of these: 1.000 MHz – 0.160 MHz = 0.840 MHz, or 840 kHz. A mixer *also* produces an output at the *sum* of these frequencies; in this case the new frequency would be 1.000 MHz + 0.160 MHz = 1.160 MHz.

Suppose you fed the output of your mixer, operating with these input frequencies, into a receiver and tuned around to find what frequencies were present. You would find two signals, one at 840 kHz and one at 1.160 MHz, showing that the two 'new' frequencies were very real!

In addition to drawing out the waveform of the resultant signal, as in Figure 1, we can draw the inputs and outputs on a frequency axis, to form a *spectrum* of the signal components. This is done in **Figure 2**. The top two diagrams show the input signals at *f*1 and *f*2. The bottom diagram shows the output signals in relation to the input signals. Depending on the type of mixer used, one or both of the input signals would be removed.

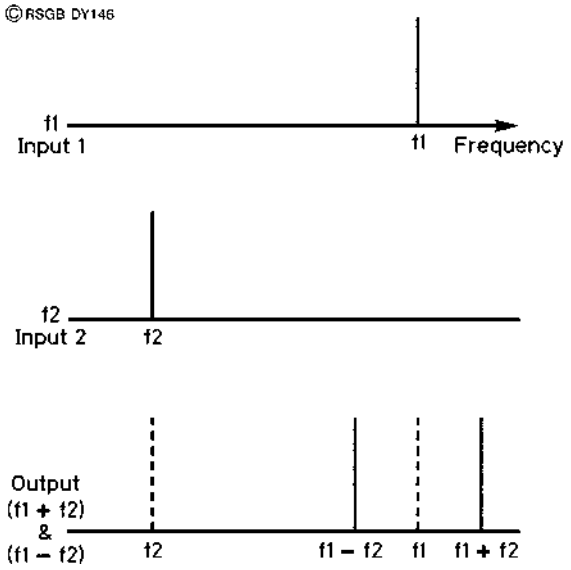

Figure 2 The result of multiplying or mixing two signals together as seen on a spectrum analyser

A mixer in every radio

Basically, a mixer is used to change a signal from one frequency to another, something it does without altering the characteristics of the incoming signal. If the incoming signal is amplitude modulated (AM), then the frequency-changed signal would be AM also. The same applies to FM, SSB, CW, and all other modulation forms you can think of. This explains why mixers are often called *frequency changers*.

Frequency changing is the key process in the type of radio known as a *superheterodyne* (or *superhet*). By mixing the incoming signal with a variable-frequency *local oscillator* as **Figure 3**, shows, the signal can be converted to the fixed frequency of a filter and amplifier. This is useful

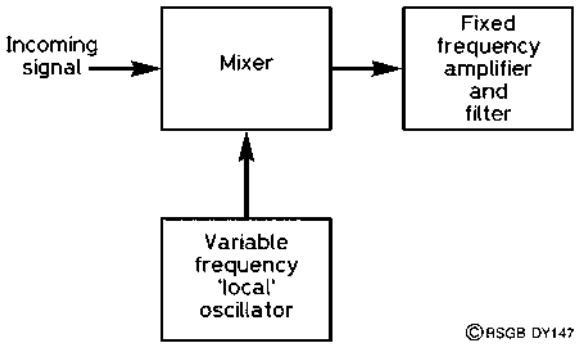

Figure 3 The basic idea of a superhet receiver

because it is easier to make a very high-quality filter and amplifier at a single fixed frequency, than at a variable frequency.

All TV receivers and virtually all radio receivers (and transmitters) use mixers. Both the *Yearling* and *Colt* receivers (see the relevant projects) are superhets, and use mixers.

56 A voltage monitor for a 12 V power supply

Introduction

If for any reason, the stabilisation of your main 12 volt power supply unit (PSU) breaks down, it is possible that a voltage much higher then the nominal 13.8 V will be applied to your precious equipment. If you would like to know the instant that this occurred, and hence be able to switch things off before it was too late, then this circuit is what you need. It will give audible *and* visual indications if the voltage rises above 14.4 V, and a visual indication only if the voltage is reduced.

The circuit

The circuit uses three ICs and is shown in **Figure 1**. The circuit is powered by the PSU whose output is being monitored, and the circuit's immunity to supply line variations is secured by the 6 volt regulator, IC1. The heart of the circuit is IC2, an LM3914; it is a *bargraph driver*, which operates ten LEDs in a display resembling a thermometer – the string of lit LEDs increases in length as the voltage on pin 5 increases.

The input voltage range on pin 5 is 1.2 V maximum, making each LED correspond to one-tenth of this, which is 0.12 V, the *step size*. R1 and R2 act as a voltage divider, so that voltages of up to the maximum of 14.4 V may be applied to R1 without exceeding 1.2 V at pin 5. R3 sets the brightness of the LEDs and R4 determines the step size.

IC3 is an *opto-isolator*, a device containing an LED and a phototransistor in one package. This enables the piezoelectric sounder to operate without affecting the operation of the bargraph driver. The input to IC3 is provided by the voltage on D8, so that if any of the LEDs at or above D8 are lit, the

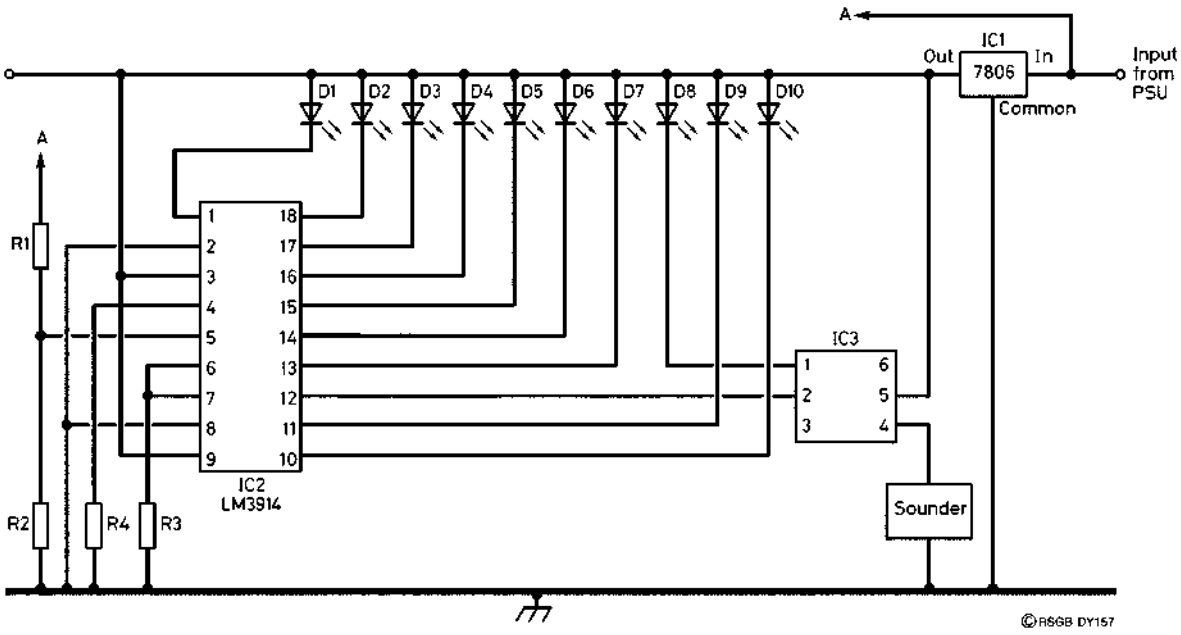

Figure 1 PSU monitor, circuit diagram

sounder will operate, indicating overvoltage. Despite the fact that some of your other equipment might be damaged by this overvoltage, the monitor circuit itself is unaffected.

Construction

The prototype was built on two pieces of Veroboard of the copper-strip variety. The main (circuit) board measured 15 strips by 25 holes, and the display (LED) board measured 4 strips by 30 holes. Track cuts are necessary in each board. The correct places are shown for the main board in **Figure 2**, but there is sufficient flexibility in the layout of the display board for a prescriptive layout not to be needed. All the anodes of the LEDs are connected to the same strip, which makes things comparatively simple!

For the main board, insert the Veropins and the wire links first, and solder them to the copper strips. Then fit the IC holders and the resistors. Fit the IC holders with their notches towards the top of the board. When fitting the voltage regulator, IC1, note than the centre lead (the 'common' lead in Figure 1) does *not* go to position A3; the track should be cut at A3, and the common lead soldered at B3. This is indicated in Figure 2.

Wire up the LED board with its ten LEDs and 11 connecting wires, each about 10 cm long. This length depends on how far away from the main

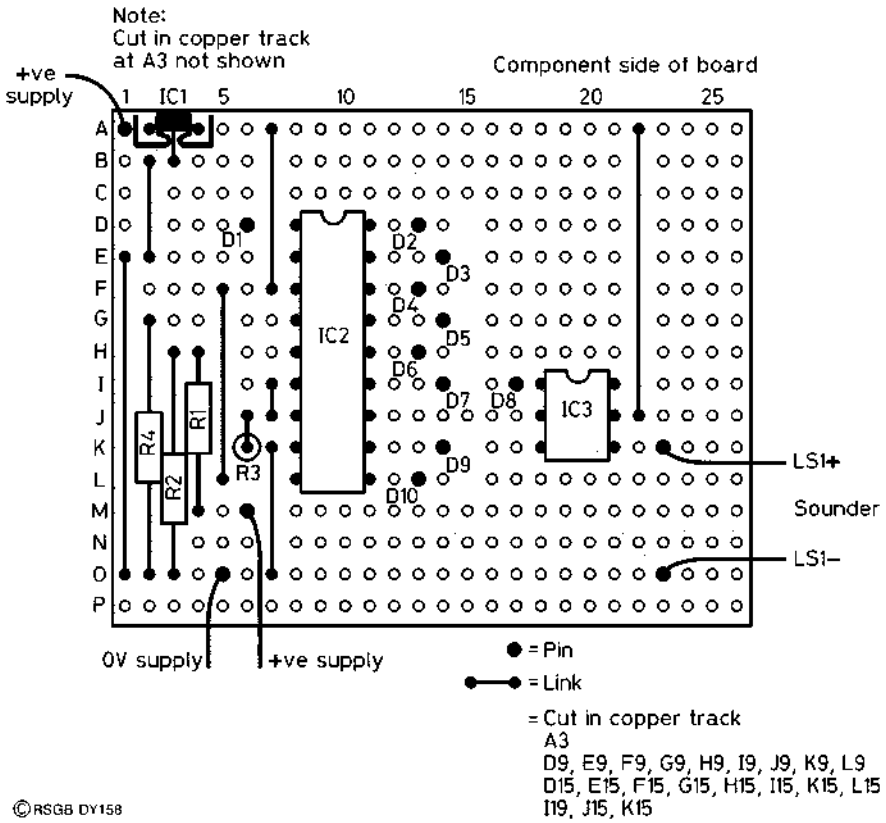

Figure 2 PSU monitor, PCB layout

board you are planning to mount the display. The LEDs should have different colours: three orange, four green and three red, to indicate 'low', 'medium' and 'high' voltage.

Now solder the other ends of these leads to the Veropins on the main board, making sure that the order is correct. Finally, connect the piezoelectric sounder to the main board; the polarity is important, so make sure the red lead goes to pin 4 of IC3 and the black lead to the ground rail. If you were careful to fit the IC holders with their notches in the correct positions, match these up with the notches on the ICs before pushing home the ICs *gently*. Check your circuit for solder bridges and unwanted pieces of copper swarf before screwing the small heat sink to the voltage regulator, IC1.

Testing

(a) **With a variable-voltage PSU**. Set the PSU for 10 V, connect the circuit and switch on. Increase the voltage slowly, and check that each LED lights up after the one before it. As the voltage exceeds about 14.4 V, the

first red LED should light and the sounder should operate. If an LED does not illuminate, you should immediately suspect either a dry joint or an incorrect LED polarity. The voltage at which the first red LED lights can be adjusted by varying R1; increase R1 if the LED comes on too early; decrease R1 if the LED comes on too late.

(b) **Without a variable-voltage PSU**. For your 'variable supply', you can use several AA-type 1.5 V cells (or 1.2 V NiCad cells) in series. The voltages produced by a range of cells is shown in **Table 1** – because of the lower voltage of NiCad cells, more of them are needed to produce a given voltage.

Once the operation of the circuit has been checked, it can be fitted into a plastic or metal box. Only two connections are needed for the PSU. You may want to drill some holes in the case to increase the apparent loudness of the sounder.

Table 1 Test voltages available from batteries in series

No. of batteries	*Voltage, nicads*	*Voltage, dry cells*
7	8.4	10.5
8	9.6	12
9	10.8	13.5
10	12	15
11	13.2	–
12	14.4	–
13	15.6	–

Parts list

Resistors: all 0.25 watt, 5% tolerance

R1	11 kilohms (kΩ) – see text
R2	1 kilohm (kΩ)
R3	1.2 kilohms (kΩ)
R4	18 kilohms (kΩ)

Semiconductors

IC1	L7806
IC2	LM3914
IC3	Opto-isolator – Maplin code WL35Q
D1–D3	3 mm LED, orange
D4–D7	3 mm LED, green
D8–D10	3 mm LED, red

Additional items

LS1	Piezoelectric sounder, wire leads
	6-pin DIL socket for IC3
	18-pin DIL socket for IC2
	Veroboard – two pieces for main and display boards, see text for sizes
	Veropins
	Heat sink for IC1
	Single-core insulated wire for links
	Insulated stranded wire for interconnecting the boards
	Case as required

57 A 1750 Hz toneburst for repeater access

Introduction

Repeaters across the UK and much of Europe need an access tone to switch the transmitter from standby ready for use. Commonly, this is a 1750 Hz tone of duration no greater than half a second. Although many UK repeaters may now be accessed using the *continuous tone-coded squelch system* (CTCSS – see the *RSGB Yearbook*), you may wish to access a repeater whose CTCSS frequency you don't know; in this case, using the universal 1750 Hz tone will gain you access. Commercial transceivers are usually fitted with an automatic toneburst, but if you are using a home-made design, then you may want to incorporate this little circuit.

Warning

This circuit uses a member of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current

and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**

The circuit is safe from destruction while it is connected to the battery.

Circuit description

The circuit is shown in **Figure 1**. The tone is generated by an integrated circuit oscillator (IC1), whose frequency is controlled by a *ceramic resonator*, XL1. Its frequency is very high, and is divided down to the 1750 Hz needed by the same chip. The ceramic resonator is designed to operate at 455 kHz, the intermediate frequency of many receivers. Because all divider circuits use powers of 2, we need the oscillator to run at 448 kHz so that when it is divided by 256 ($256 = 2^8$), we end up with 1750 Hz. Try it on your calculator:

$$\frac{448\ 000}{256} = 1750.$$

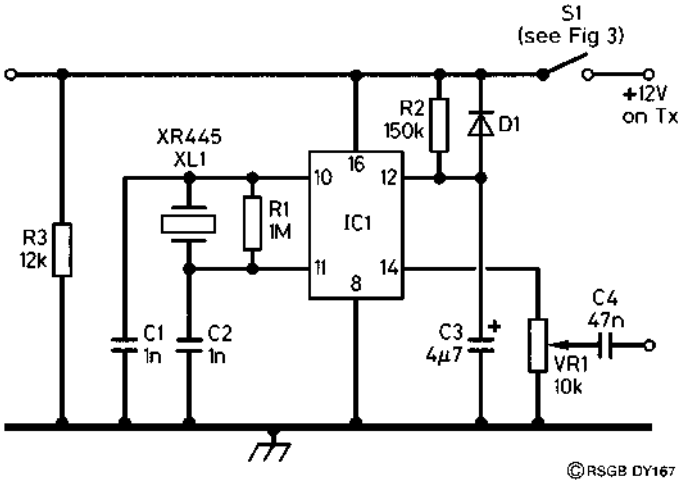

Figure 1 Toneburst module, circuit diagram

We use C1, C2 and R1 to *pull* the frequency of the oscillator away from 455 kHz to 448 kHz. The divider chain has eight *counters* in it, and each counter divides the frequency of the signal it sees by two, giving the final division of 256.

This counting process can be stopped at any time by taking the voltage on the *reset* pin (pin 12) up to the supply voltage. When the circuit is switched on by closing S1, pin 12 is at 0 V because C3 is discharged. The oscillator runs, producing the output frequency of 1750 Hz. As time progresses, C3 charges up through R2 and the voltage on pin 12 rises. When this has risen sufficiently, and in a time determined by the values of C3 and R2, the counter resets and stays in the reset state; no division takes place and there is no output. The duration of the toneburst is thus governed by C3 and R2.

When S1 is opened, the circuit is switched off, and C3 is discharged through D1 and R3, ready for the next toneburst. If you have used a repeater, you will know that a toneburst is needed **only** to activate a repeater in the standby condition; it is not needed once a contact has been established.

VR1 adjusts the amplitude of the tone fed to the microphone, and C4 prevents any voltage that may be present on your microphone connector from damaging the integrated circuit.

Construction

The prototype circuit was built on Veroboard of the copper-strip variety, measuring 20 holes by 14 strips. The layout is shown in **Figure 2**. Make the track cuts first, and check that there are no slivers of copper wedged between adjacent tracks. Then, solder in the IC socket (with the notched end

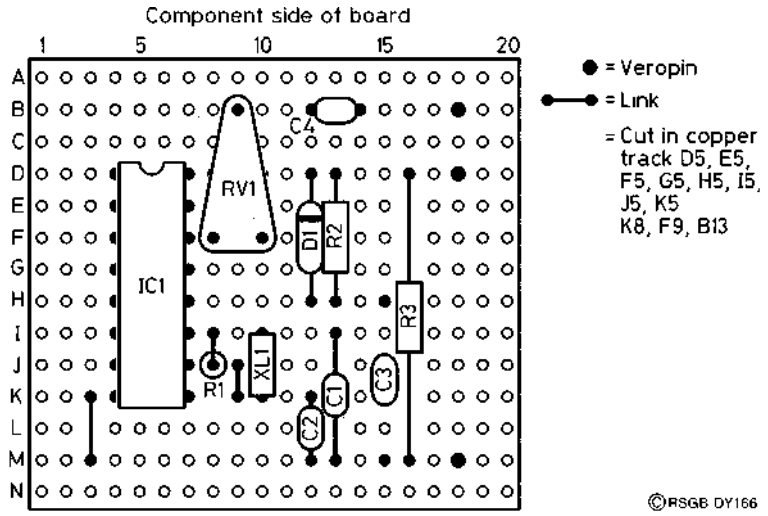

Figure 2 Veroboard component layout

facing towards track A), the wire links and the three Veropins. Having done this, solder in the resistors, capacitors and diode, making sure that D1 and C3 are the right way round! Using your best soldering technique, solder in the ceramic resonator quickly, to prevent heat damage. Recheck your circuit, check for solder splashes and bridges, and then gently insert IC1 into its socket, matching up its notch with that of the socket.

Testing

Set VR1 to half-way and connect a crystal earpiece to the output; apply power to the circuit. You should hear the tone, lasting for about half a second. If there is no tone, disconnect your circuit from the power supply, and check for dry joints in the vicinity of pin 12. Is the diode, D1, the correct way round? Is C3 the correct way round? Did you choose to ignore the CMOS safety precautions given earlier?

Once the circuit is working, you need to decide how you are going to connect it to your transmitter. Two options are shown in **Figure 3**. If you have access to a point in your transmitter circuit that has between 9 V and 12 V positive on it during transmit, you can use this to power your circuit. As the toneburst is needed only for repeaters, the switch, S1, disconnects it when not needed, as shown in Figure 3a. If you want the circuit to be self-powered, then a 9 volt PP3 battery may be used; Figure 3b shows this configuration.

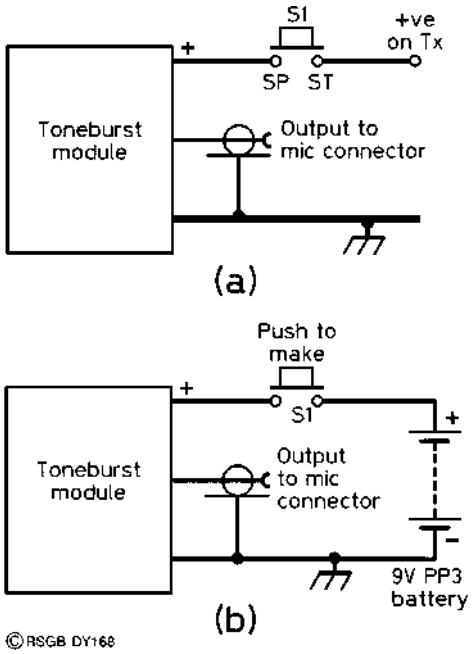

Figure 3 Toneburst module: two alternative switching arrangements

The output from the circuit board is fed directly into the microphone socket, in parallel with the microphone itself; use thin coaxial or screened cable for this lead, or you may induce hum into the microphone circuit and suffer from RF breakthrough into the audio circuits. To adjust the setting of VR1, start with it at the zero output position and connect a dummy load to your transmitter. Slowly, increase the output while monitoring your transmitted signal on another nearby receiver. Make sure you do **not** increase the output so far that the signal sounds distorted. If you would prefer that the tone was on continuously while you made this adjustment, simply connect a wire across C3 remembering, of course, to remove it as soon as you have completed the test!

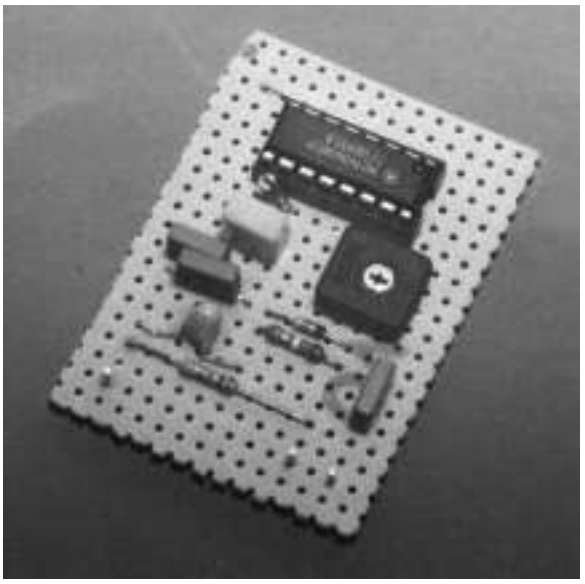

Parts list

Resistors: all 0.25 watt, 10% tolerance (or better)

R1	1 megohm (MΩ)
R2	150 kilohms (kΩ)
R3	12 kilohms (kΩ)
VR1	10 kilohms (kΩ) horizontal preset

Capacitors: all 16 V WKG or higher

C1, C2	1 nanofarad (nF) disc ceramic
C3	4.7 microfarad (μF) tantalum bead
C4	47 nanofarads (nF) disc ceramic

Semiconductors
IC1 4060
D1 1N4148

Additional items
XL1 XR455
Veroboard (see text for size)
Veropins (3)
S1 Switch (momentary action push-to-make SPST)
16-pin DIL socket for IC1
Single-core insulated wire for links
Coaxial or screened cable for microphone connection

58 A circuit for flashing LEDs

Introduction

There are many occasions when one's attention needs drawing to the fact that something important has happened. A single red light coming on is seldom sufficient to attract attention, particularly if it is surrounded by other lights and indicators. The eye is known to be very sensitive to *changes* in its peripheral vision; such changes can be brought about by movement or by differences in light level – a flashing light, for example. So, a circuit that flashes a single LED or a pair of LEDs finds plenty of uses in the amateur station.

Warning

This circuit uses a member of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton

destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**

The circuit is safe from destruction while it is connected to the battery. However, when the battery is removed, the same care should be exercised with its handling, because there is no supply decoupling capacitor across the IC.

Basic description

LEDs can be made to flash (switch on and off) by driving them from sources that switch on and off. Such a source is an *astable multivibrator*. If you have built or read about *A basic continuity tester*, elsewhere in this book, you will have come across such a beast before. That circuit used an astable multivibrator made from two transistors. This new circuit achieves the same behaviour from a single integrated circuit, the CMOS 4011. To give it its full description, the 4011 is a *quad 2-input NAND gate*. Quite a mouthful, but all it means is that inside the chip are four NAND gates, each with two inputs.

A NAND gate needs a positive voltage (known as a *logic 1*) on *both* inputs in order to produce zero volts (known as *logic 0*) at the output. Two NAND gates can be connected, as are A and B in **Figure 1**, to make our astable multivibrator. The combination of A and B has been described as the most perverse circuit in electronics; as soon as the output goes to logic 1, the circuit decides that it would prefer to have a logic 0 there, and switches over. With logic 0 at the output, the circuit now prefers to have logic 1 there, and so it goes on! We are going to use this continuous switching backwards and forwards to flash two LEDs. The rate at which A and B 'change their minds' is the frequency at which our LEDs will flash, and is controlled by the charging and discharging times of C1 through R2 and C2 through R1. As the values of R1 and R2 are the same, and those of C1 and C2 are the same, the ON and OFF states of the circuit are the same.

Gates C and D do not contribute to the flashing action; they act as *buffers* to isolate the LEDs from the multivibrator circuit itself. You will find in electronics that an oscillator is seldom used to drive another device *directly*; there is usually a buffer between it and the stage it drives.

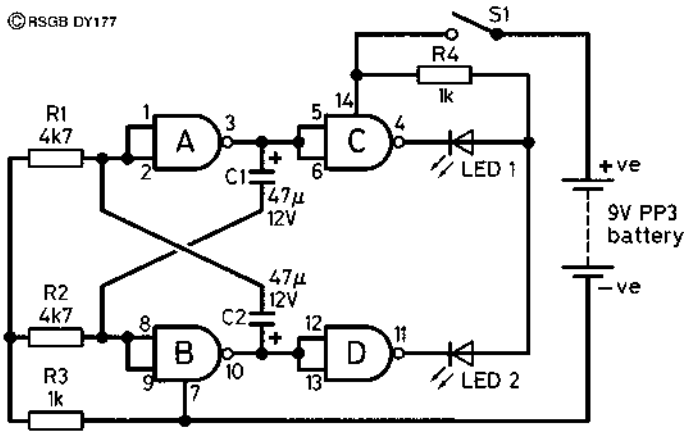

Figure 1 Flashing LEDs, circuit diagram

A characteristic of all multivibrators, astable or not, is that they have two outputs. In this case, those outputs are at pins 3 and 10, which are then buffered and appear at pins 4 and 11, respectively. When one output is at logic 1, the other is at logic 0, and vice versa. This means that LED1 is off when LED2 is on, and LED1 is on when LED2 is off, the two states switching backwards and forwards at the frequency of the oscillator.

Construction

Read the warning at the beginning of this article again. It is not intended to scare you off from building this, but is a genuine piece of advice which can save you time and irritation when all your labours result in a circuit that doesn't work! That extra bit of care can make all the difference!

Veroboard (the copper strip type) is used for the layout, shown in **Figure 2**. It measures 20 holes by 12 strips. **Be aware that there is no row 'I' in the layout, so don't miscount when you are placing components on the board!**

Firstly, cut the tracks using a 3 mm ($\frac{1}{8}$ inch) twist drill held between thumb and forefinger; check that there are no slivers of copper bridging any of the tracks, and that the tracks have been completely cut by the drill. Solder in the components carefully. Leave the IC in its carrier for the time being, and solder in the IC socket, with the notched end facing row A. On completion, check the circuit carefully. If you are happy that it is correct, follow the instructions given earlier and fit IC1 into its socket, matching up the two notches. Connect the battery and switch on. The two LEDs should flash on and off alternately. If only one LED flashes, you have probably connected the other one the wrong way round. Switch off, check and correct if necessary. If neither LED flashes, you must have a significant error in your circuit, which will need checking *again*! Or did you choose to ignore the handling precautions for the CMOS chip?

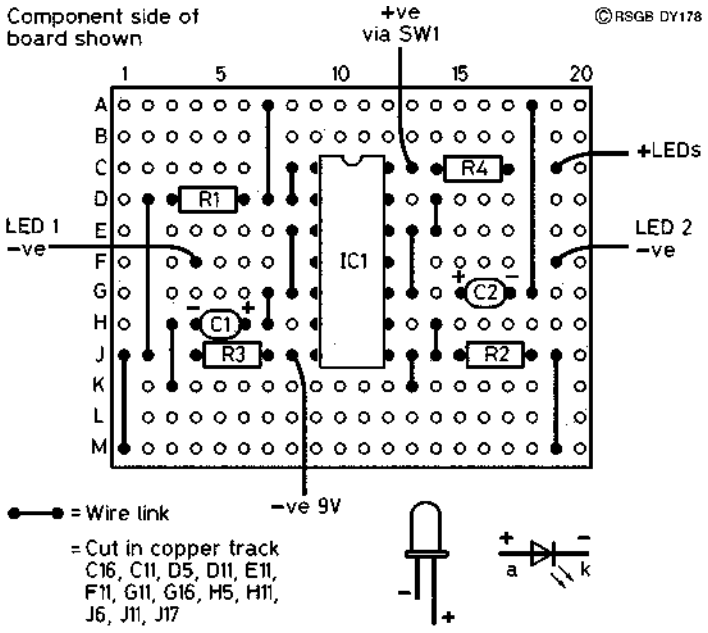

Figure 2 Flashing LEDs, component layout

The board can be mounted near to the point where you want your flashing LEDs to be seen, although long leads to the LEDs are acceptable. The LEDs can be different colours – it's all up to you now!

Parts list

Resistors: all 0.25 watt, 10% tolerance or better

R1, R2	4700 ohms (Ω)
R3, R4	1 kilohm (kΩ)

Capacitors

C1, C2	47 microfarads (μF) 12 V WKG

Semiconductors

IC1	4011

Additional items

LED1, LED2	Any size of LED, any colour
S1	SPST on/off
	Plastic box if needed, 8.5 by 5 by 2.5 cm

Source

Components are available from Maplin.

59 Digital logic circuits

Introduction

Logic circuits form the backbone of even the most advanced computer, yet their basic operation can be demonstrated by a couple of switches, a battery and a bulb.

Logic using switches

Everyone reading this article will look at **Figure 1** and know immediately how it works and be able to write down something like 'When switch A and switch B are closed, the light will come on'. Without knowing it, you have written down a logic statement involving the so-called **AND** operation; the light comes on only when switches A **AND** B are ON. Below the circuit in Figure 1, is a table showing the only possible positions of the two switches and the state of the bulb for each position. This is called a *truth table*, and is frequently used in logic analysis.

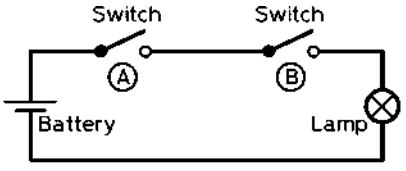

A	B	Lamp
Off	Off	Off
On	Off	Off
Off	On	Off
On	On	On

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Figure 1 Switches and lamp AND gate

Figure 2 shows a different circuit. Here, the two switches are in parallel rather than in series, as was the case in Figure 1. Again, if you analyse the circuit in words, you would say that the light will be on when switch A **OR** switch B is ON. This is an example of the **OR** operation, and its truth table is shown in Figure 2. The statement above is not complete, however; can you see why? The truth table will show you. The light comes on if A is ON, **OR** if B is ON, ***OR*** if A **AND** B are both ON. That third condition is easy to miss, but don't worry about it!

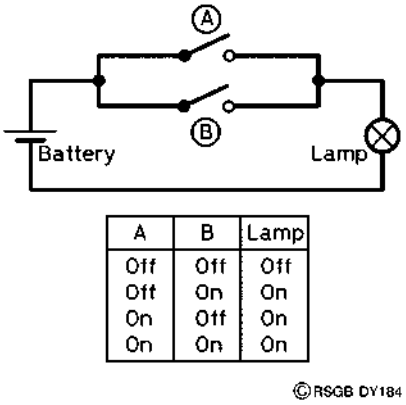

Figure 2 Switches and lamp OR gate

Believe it or not, some very complicated logic is possible (in theory) using switches and lights, but it is highly impractical and would be very slow. This is where electronic logic circuits come in.

Switches with no moving parts

You may have come across projects in this book where a statement is made such as '. . . the transistor is being used as a switch . . .'. Transistors *can* be used as switches, as were thermionic valves in the world's first programmable computer *Colossus*, at Bletchley Park. However, technology has moved on from valves, through transistors to *logic gates*, combinations of electronic switches designed specifically to perform logic functions.

These act on voltage levels as their inputs and produce changes in voltage levels as their outputs. A positive voltage is called *logic 1*, and corresponds to a switch being ON in our previous descriptions; a zero voltage is called *logic 0*, and corresponds to a switch being OFF. The output from a logic gate (normally labelled Q) is also logic 1 or logic 0, corresponding to our light being ON or OFF, respectively, in our switch analogy.

Many logic devices operate from a stabilised 5 V supply, and this determines the *ideal* voltages corresponding to the two logic states:

logic 0 ≡ 0 V,

logic 1 ≡ 5 V.

The world isn't an ideal place, so the *real* voltage ranges used by the logic gates are:

logic 0 ≡ 0.0 to 0.4 V,

logic 1 ≡ 3.0 to 5.0 V.

The **AND** circuit of Figure 1 is now called an **AND gate**, and requires logic 1 inputs on A **AND** B to produce a logic 1 at the output. **Figure 3** shows this. The truth table is identical with that of Figure 1 – logic 1 replaces ON and logic 0 replaces OFF. Now compare Figure 2 with **Figure 4** – circuits and truth tables for the **OR** function. Again, we have exact similarity.

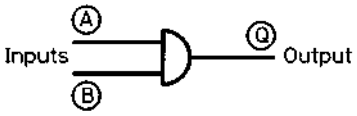

Inputs		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

©RSGB DY183

Figure 3 Electronic AND gate

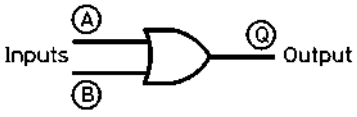

Inputs		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

©RSGB DY190

Figure 4 Electronic OR gate

There is another very common logic gate, which performs the **NOT** function. It is easy to understand. Just ask yourself the question 'What is **NOT** logic 0?', and the answer is obviously 'logic 1'. Similarly, logic 0 is **NOT** logic 1. A **NOT** gate simply changes the logic state of the input; it is also known (because of this behaviour) as an *inverter*. Its symbol and truth table can be found in **Fig 5**. Note the little circle on the output of the gate in Figure 5. In logic circuits, this symbol always implies inversion, or the presence of a **NOT** gate. Keep an eye open for it!

So far, the logic functions we have discussed have all been words which we use in everyday language, which has made the electronic interpretation of them relatively easy. Now we must introduce a function for which there is *no* analogy in normal speech – the **NAND** function. This means a

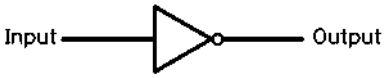

Input	Output
1	0
0	1

©RSGB DY185

Figure 5 Electronic NOT gate

combination of an **AND** gate and a **NOT** gate, and the sharp-eyed reader will have spotted the little circle added on to the normal **AND** gate symbol in **Figure 6**!

To make things easier to understand, the truth table in Figure 6 has four columns, not three as in previous tables. The third column is the standard **AND** output – compare it with the third column in Figure 3. That is the output from the **AND** gate *before* it encounters the little circle that inverts it, so the final output from the **NAND** gate is the output of the **AND** gate, inverted! The third and fourth columns are the inverse of each other.

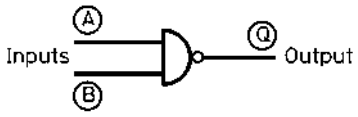

Inputs		and	Output
A	B		Q
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

©RSGB DY186

Figure 6 Electronic NAND gate

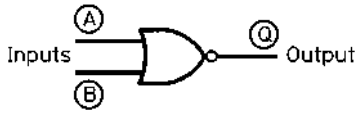

Inputs		or	Output
A	B		Q
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

©RSGB DY187

Figure 7 Electronic NOR gate

We can add the inverting operation to the output of an **OR** gate also, producing a **NOR** gate! The symbol and its truth table are shown in **Figure 7**. Again, notice that the final output is that of the ordinary **OR** gate, inverted!

These new functions of **NAND** and **NOR** are used more than the **AND** and **OR** functions because it makes other circuits easier to design using combinations of these gates.

A taste of Boolean algebra

The design of circuits using combinations of logic gates usually begins with a little mathematics, where the functions to be implemented are analysed. The mathematics used is surprisingly simple, and is a slightly changed version of ordinary algebra called *Boolean algebra*, which allows manipulation of logic functions to be made. Normal algebra has operations in it such as addition, subtraction and multiplication and division. The mathematician Boole found that the logical **AND** operation could be handled by the algebraic operation of *multiplication* (symbols $\times$ or $\bullet$), and the **OR** operation by the algebraic operation of *addition* (symbol +). The **NOT** operation involved a new symbol, that of a bar over the input being inverted, such as $\overline{A}$.

So, our five basic logic operators can now be written in a mathematical form:

AND	$Q = A \times B$
OR	$Q = A + B$
NOT	$Q = \overline{A}$
NAND	$Q = \overline{A \times B}$
NOR	$Q = \overline{A + B}$.

Using logic operations in a mathematical form enables the most complex logic to be designed, simplified and converted into circuit diagram form in a very efficient and rapid way. There are more logic operators than the five we have considered here but, in general, they can all be broken down into combinations of these gates alone!

60 A resistive SWR indicator

Introduction

When a transmitter produces some output power, we want to make sure that as much as possible of this power is radiated by the aerial. This often requires the use of an *aerial tuning unit* (ATU), which matches the aerial impedance to that of the transmitter.

How do you know when this matching has been achieved? The most usual way is to use a *standing-wave ratio* (SWR) indicator. If the impedance of the aerial does not match that of the transmitter output, some of your transmitter power (also known as the *forward* power) is reflected back along the aerial feeder and back into the transmitter, where it causes excess heating. The forward and reflected waves interact along the feeder to produce a wave whose position remains constant, and which is therefore called a *standing wave* or a *stationary wave*. An SWR meter simply indicates forward power and reflected power, and adjustments are made to your ATU until the reflected power is as small as possible (ideally zero, of course). If there is no reflected power then, by a process of elimination, all your forward power is reaching the aerial!

Sampling the RF

Whatever type of SWR indicator you use, it must use some sort of sampling circuit to pick up the forward and reflected waves. The project *A standing-wave indicator for HF*, elsewhere in this book, uses a toroidal transformer to separate the readings for the forward and reverse waves. This design differs in that it measures the voltages across resistors through which the RF current is passing. Its advantages are:

(a) it uses cheap parts – four resistors, two capacitors and a diode, together with a rotary switch, a surplus meter, a preset potentiometer and two sockets;
(b) within this SWR indicator, there is always a resistive path for the RF current from the transmitter, formed by R1, R2 and R3; this can prevent damage to simpler home-made transmitters, which may be damaged during adjustment of the ATU when using more conventional SWR indicators.

The only disadvantage of this form of indicator is that it must be switched out of circuit once the ATU has been adjusted for a particular band.

Construction

The SWR indicator is very simple to build, as most of the components can be mounted on the back of the 3-way rotary switch. This is shown in **Figure 1**. The switch is a 4-pole, 3-way rotary type, of which only two poles are used.

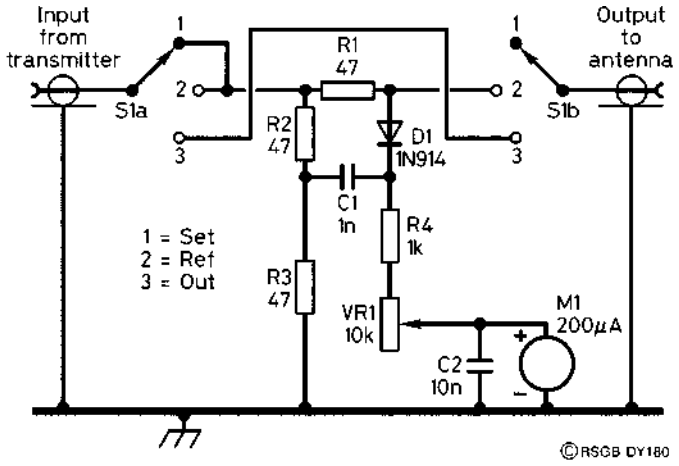

Figure 1 Resistive SWR meter, circuit diagram

Because the other switch contacts are not being used, they can be employed as support tags for other components. The ground wires are all soldered on to the metal frame of the switch. If your switch frame is of all-plastic construction, then a 12 SWG copper wire run around the switch will make a good earth connection to the metal case for the leads shown in Figure 1. The preset potentiometer used to control the sensitivity of the circuit can be mounted directly on the meter tag.

Resistors R1, R2 and R3 handle the RF power during the tuning-up process. If you have them, use 1 watt resistors; otherwise, you can use two 100 ohm half-watt resistors in parallel for each of R1, R2 and R3. The meter, M1, can be any DC type of sensitivity around 200 µA.

In use

First, find a clear frequency, and without the indicator in circuit, check that the frequency really *is* clear by asking and identifying yourself. If it is,

connect the indicator between the transmitter and the ATU which, in turn, is connected to your aerial. Turn SW1 to the SET position and key the transmitter. Adjust VR1 until the meter reads full scale. Switch off the transmitter. Turn SW1 to the REF position and key the transmitter again. Adjust the ATU until the lowest reading is obtained on the meter. Switch off the transmitter. For the chosen frequency, you have adjusted your ATU for minimum reflected power and hence the lowest SWR. You will need to repeat the process when you change bands, and possibly when you change frequency within the same band. Switching SW1 to the OUT position, you are ready to transmit. You may have noticed that it is good practice to switch the transmitter off when operating SW1. Get into that habit!

Parts list

Resistors	
R1, R2, R3	47 ohm (Ω) 1 watt (or 2 × 100 Ω, ½ watt, see text)
R4	1 kilohm (kΩ) 0.25-watt
VR1	10 kilohms (kΩ) preset
Capacitors	
C1	1 nanofarad (nF)
C2	10 nanofarads (nF)
Semiconductors	
D1	1N914 or similar
Additional items	
SW1	4-pole 3-way rotary switch, of which only 2 poles are used
M1	200 μA DC
	Case

61 An audio filter for CW

Introduction

This is a simple passive circuit (it has no power supply) that adds some audio selectivity for Morse code reception and also includes a very simple noise limiter that gives a visual indication of when noise spikes are being removed!

The circuit

Figure 1 shows the complete circuit. The tuned circuit of C1 and L1 resonates very close to 800 Hz, so initially you will have to tune a signal in carefully until it sounds loudest – you will soon be able to do this without thinking. The two LEDs connected back to back across the signal path act as a noise limiter, reducing the amplitudes of static crashes and noise from car ignition systems, etc. The LEDs blink when they conduct – this is not necessary to the operation of the circuit, but adds a little colour to your listening! The noise limiter *does* make listening more comfortable, though.

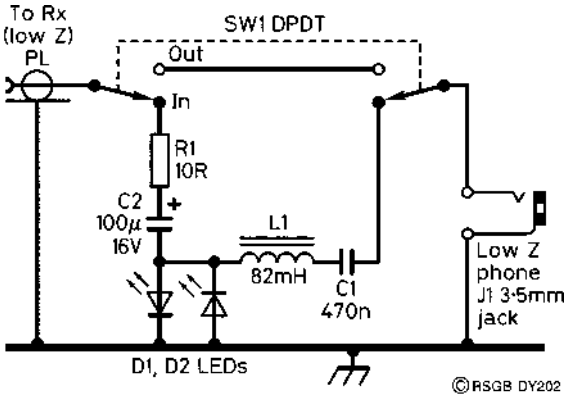

Figure 1 CW filter, circuit diagram

Construction

The circuit layout is shown in **Figure 2**. Point-to-point wiring is used, with a small tag-strip being the only item used for the extra support of C2 and R1. The LEDs and SW1 support the other components. An aluminium box (**Figure 3**) is used to make the circuit tidy and usable.

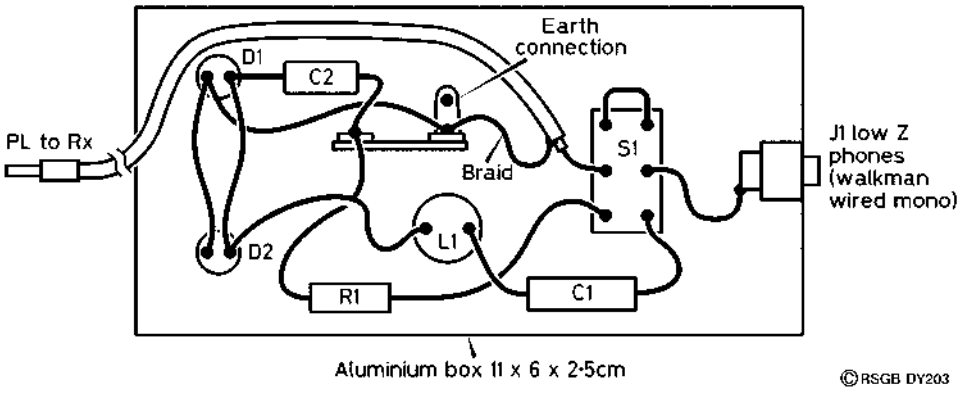

Figure 2 CW filter, component layout

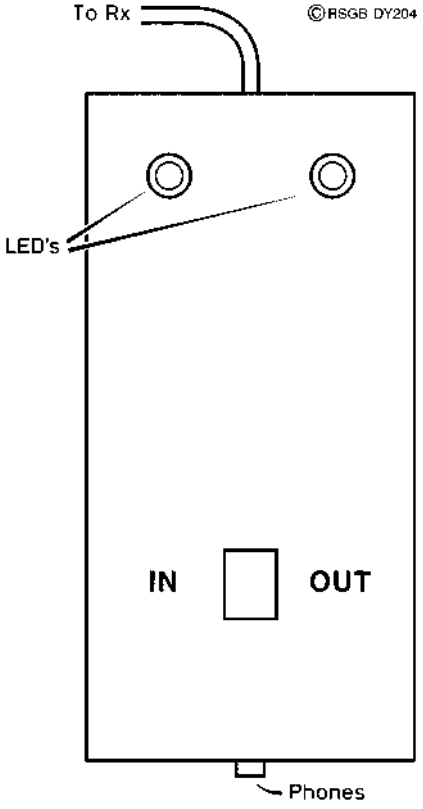

Figure 3 CW filter, front panel

You must use low-impedance headphones for the circuit to perform properly. Plug the completed unit into the headphone socket of your receiver and adjust the volume so that the LEDs are just *not* blinking on normal audio. The unit should be switched out of circuit for speech listening; this is the purpose of the toggle switch, SW1.

Parts list

Resistor
- R1 — 10 ohms (Ω), 0.25 watt, 10% tolerance

Capacitors
- C1 — 470 nanofarads (nF)
- C2 — 100 microfarads (μF) electrolytic, 16 V WKG

Inductor
- L1 — 82 millihenries (mH)

Semiconductors
- D1, D2 — LEDs

Additional items
- SW1 — DPDT
- J1 — 3.5 mm jack socket
- PL — Jack plug to suit receiver
- Aluminium box, approx. 11 by 6 by 2.5 cm

Source

Components are available from Maplin.

62 An electronic die

Introduction

Throwing a die is a venerable way of generating a 'random' number between 1 and 6. A die is easy to lose, so here is an electronic die-throwing circuit which brings the technique up to date and serves as another application of logic circuits. If you need a reminder of the basics of logic, refer to *Digital logic circuits*.

Warning

This circuit uses members of the integrated circuit family known as CMOS (complementary metal-oxide semiconductor). These use very little current and can be completed destroyed if they come into contact with the

magnitudes of static electricity that most of us carry about when we walk on carpets and wear rubber shoes. You will never know if this wanton destruction has happened – all you will discover is that your circuit doesn't work and that you have tested *everything*. To avoid this problem do the following things:

1. **Before you open the little packet in which the IC is supplied, touch something which you *know* to be earthed – the metalwork of any equipment which is mains-earthed, for example. Then open the packet.**
2. **Let the IC fall gently on the bench – don't pick it out with your fingers. Touch your earthed metalwork again. Pick up the IC and insert it gently into its holder.**

The circuit is safe from damage while it is connected to the battery.

Description

The circuit is shown in **Figure 1**. IC1a and IC1b form an *astable multivibrator*, similar to that used in 'An LED Flasher' also in this book. It runs constantly, and its output is fed to IC2 via a single NAND gate, IC1c. The other input of IC1c is held at 0 V by R3 and C3. Whenever one input of a NAND gate is logic 0 (or 0 V), there can be *no output* from the gate, irrespective of what is happening at other inputs. So, despite the fact that the oscillator (or *clock*) is running all the time, its square-wave output never

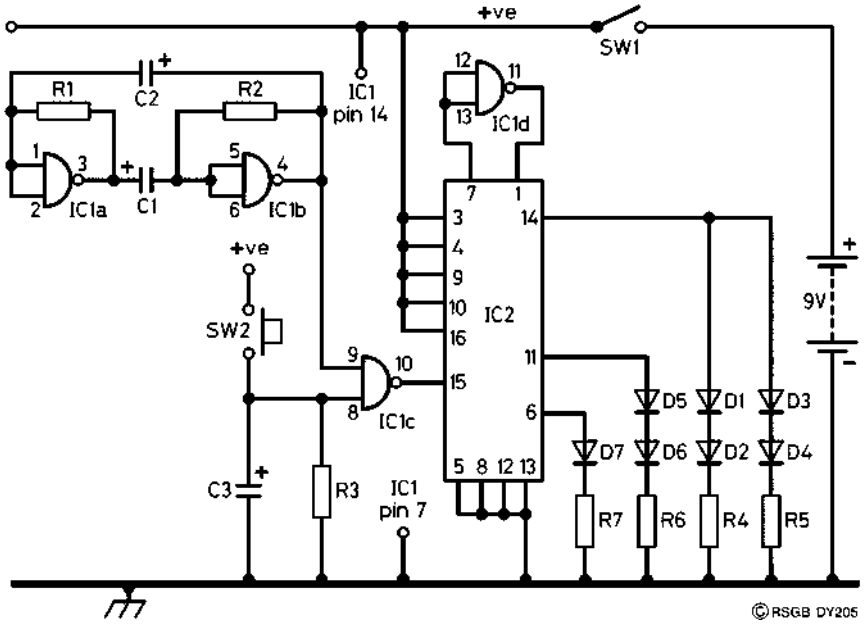

Figure 1 Electronic dice, circuit diagram

reaches IC2 until the 'other' input of IC1c is brought away from logic 0. This happens when SW2 is pressed. Pressing SW2 momentarily, as is normally done, charges up C3 to 9 V, putting a logic 1 on the second input of IC1c and allowing the clock signal through to IC2. As the switch is released, C3 begins to discharge through R3, gradually lowering the voltage on pin 8 of IC1c. As this voltage crosses 4.5 V (half the supply voltage), IC1c then treats this input as logic 0, which cuts off the clock signal from IC2 again. Thus, when SW2 is momentarily pressed, the clock signal is fed to IC2 for a short interval of time, before being blocked again.

IC2 is a binary counter, and the outputs that concern us are from pins 14, 11 and 6. Pin 14 is the *most significant bit* and pin 6 the *least significant bit*. See the panel for an explanation of what happens here.

To understand these outputs, you should be able to count in binary, using three bits. At the start of the counting process, all the bits have zero values, i.e. 000. The left-most bit is called the *most significant bit*, and the right-most bit is called the *least significant bit*. (When we write numbers normally, a number 1 in the left-hand position represents one hundred, 1 in the middle column represents ten, while the number 1 in the right-hand position means one. One hundred is a more significant number than one, hence the nomenclature.)

The three bits of our binary number have values, from left to right, of 4 ($=2^2$), 2 ($=2^1$) and 1 ($=2^0$). This means that a number 1 in the left-hand column signifies the normal number four, in the middle column it would represent two, and in the right-hand column, it would represent one. This should help you understand the patterns of bits which emerge as the clock waveform is counted, as the next paragraph explains.

As each cycle of the clock enters IC2, it increments its internal counter and the values of that counter are shown by the states of pins 14, 11 and 6. After the first pulse, these three pins would have states corresponding to 001; after the second, 010; after the third, 011; after the fourth, 100; after the fifth, 101; after the sixth, 110. This sequence of 3-bit numbers represents a binary count from 1 to 6 in 'normal' parlance. These six states are used to illuminate the conventional pattern of dots on a die, using LEDs.

As the clock cycles are counted, the LEDs flicker as the die is 'rolled'. Resistors R4 to R7 are used to limit the current through the LEDs. When the counter stops, it can be in any of the positions shown in **Table 1**. Because of

Table 1 Dice number relative to counter output

Step	*Pins*			*Dice number*
	14	*11*	*6*	
1	0	0	1	4
2	0	1	0	2
3	0	1	1	6
4	1	0	0	1
5	1	0	1	5
6	1	1	0	3

the way in which the dots are grouped on the faces of a die, the wiring of the LEDs is simpler than it might otherwise be. You can see from Figure 1 that there are really only three sets of connections to the LEDs – one from each bit of the counter output. When pin 14 is at logic 1, four LEDs are lit, corresponding to the number four. For the number five, pins 14 and 6 will be at logic 1. For the number one, only pin 6 is at logic 1. For three, pins 11 and 6 are at logic 1, for six, pins 14 and 11 are at logic 1, and for two, only pin 11 is at logic 1. These conditions are summarised in Table 1.

Construction

Two pieces of Veroboard (of the strip type) are needed – one for the main circuit (**Figure 2**) and the other for the display LEDs (**Figure 3**). The display board is easier to build, so we will do that first. It measures 20 holes by 18 strips.

Cut the tracks as shown in Figure 3, using a 3 mm (⅛inch) twist drill rotated between thumb and forefinger. Insert and solder the Veropins, resistors and the wire links. Then solder the LEDs in place, making sure their polarities are correct. The LEDs are mounted proud of the board (**Figure 4**, which will help when you come to fix the board into a case.

The main board measures 32 holes by 18 strips. As before, remove the tracks in the places shown in Figure 2. Note that track 'L' is *not* broken under the position for IC2. Solder in the IC holders and the links. Solder in R1 and R2 vertically, and R3 horizontally. Then solder in C1, C2 and C3; these all being electrolytics, check their polarities. Solder in the Veropins and prepare the connections to those components not on the main board, using stranded, insulated wire. Check the circuit carefully, and read the handling precautions given earlier before carefully inserting the two ICs.

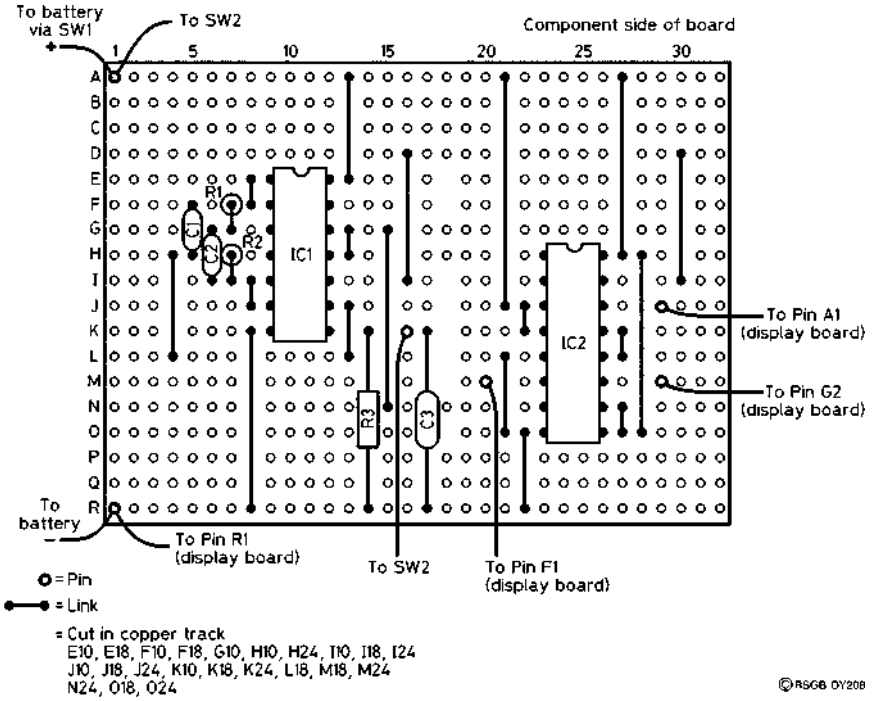

Figure 2 Main board, component layout

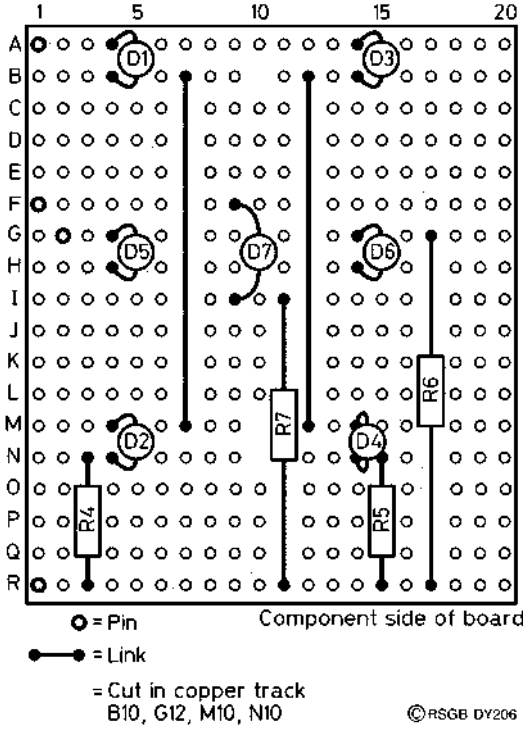

Figure 3 Board for the six LEDs

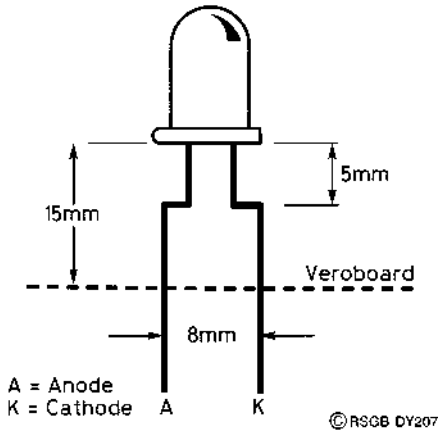

Figure 4 D7 lead bending

Testing and use

When the circuit is switched on, it is likely that the centre LED only will be lit. Press SW2, the 'throw' switch. All the LEDs should flicker, even after the switch is released, but only for a second or so. Then a standard pattern should show, signifying numbers between one and six. If this does not happen, switch off and check your circuit again. Are there any missing links? Are there any obvious dry joints (usually dull instead of shiny)? Can you see any solder bridges between tracks? Did you choose to ignore the handling precautions? If none of these results in a working circuit, try some fault-finding.

- Disconnect the lead to D7 on the main board (marked 'to pin F1' on Figure 2). Touch the lead on to the positive supply rail. D7 should light. Now transfer this lead on to pin 4 of IC1. If it flickers, then the oscillator is running (which it should).
- Transfer this lead to pin 10 of IC2. D7 should flicker when SW2 is pressed, but should be on permanently when it is released. This means that the correct signals are reaching IC2 from IC1.
- If one of the chains of LEDs (i.e. D1 and D2, D3 and D4, D5 and D6) does not light, you may have one *or both* LEDs the wrong way round.

When the die is working, you may care to experiment with the values of R1 and R2, but you should keep their values the same, i.e. R1 = R2. The larger the values of these, the more slowly the die will appear to 'roll'.

Finishing touches

On completion of the project, you will want to mount it in a smart case; any plastic box is suitable for this, with the display board mounted so that the

LEDs protrude through the top and are fixed to it using LED clips. The way in which you mount both boards to the case is entirely up to you.

Parts list

Resistors: all 0.25 watt, 10% tolerance, or better

R1, R2	5600 ohms (Ω)
R3	15 kilohms (kΩ)
R4–R7	470 ohms (Ω)

Capacitors

C1, C2	1 microfarad (μF) electrolytic, 16 V WKG
C3	68 microfarads (μF) electrolytic, 16 V WKG

Semiconductors

IC1	4011
IC2	4029
D1–D7	LEDs, any size and colour

Additional items

SW1	On-off switch SPST toggle
SW1	Push-to-make, non-latching
	Veroboard, 2 pieces, see text for sizes
	Veropins, 10
	Stranded insulated wire for general wiring
	Single-core insulated wire for links
	PP3 battery clip
	PP3 battery
	Plastic box to suit
	LED mounting clips (7)
	Means of mounting boards to box

Source

Components are available from Maplin.

63 The absorption wavemeter

Introduction

The purpose of the absorption wavemeter is to check that a transmitter is radiating within the correct waveband, and to detect any spurious *harmonic* emissions. A harmonic frequency is an integral multiple of the carrier frequency – e.g. if the carrier is at a frequency *f*, the harmonics are at frequencies 2*f*, 3*f*, 4*f* . . . and so on.

It can also be employed as a relative field-strength indicator, being used in experimentation with aerials. What it *cannot* do is to measure the transmitted frequency accurately; all it can do is to place the signal within a particular band, say the 7 MHz or the 18 MHz band (or their harmonics).

How it works

You may recognise the circuit of **Figure 1** as a crystal set with a meter replacing the headphones. It is simply the parallel combination of an inductance with a variable capacitance, which constitutes a resonant circuit with a variable frequency. A dial on the variable capacitor can be roughly calibrated with frequency. The fixed capacitor across the meter helps to improve the meter reading by making it read the peak value of the carrier wave rather than the average value.

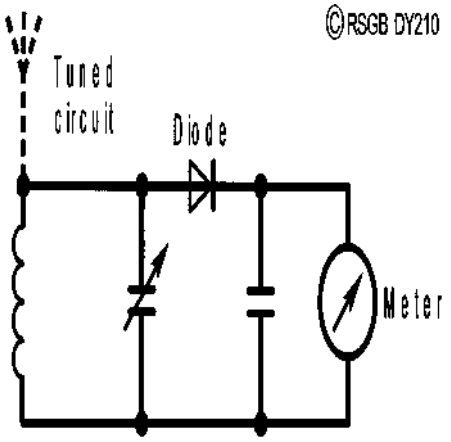

Figure 1 Absorption wavemeter circuit

When the wavemeter is situated in the vicinity of a relatively strong radio-frequency (RF) field, the inductor absorbs a small amount of energy from that field. If the circuit is resonant at the same frequency as that of the transmitter, an RF voltage is produced across the coil and is proportional to the strength of the RF field. The RF voltage is *rectified*, or *detected* (turned from AC into DC) by the diode and the second capacitor, and is displayed by the meter.

The tuned circuit

The formula for calculating the resonant frequency of a coil and capacitor is relatively simple. It is

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where f is the resonant frequency (Hz),
L is the inductance (H), and
C is the capacitance (F).

If this formula puts you off, there is this slightly easier version:

$$f = \frac{159}{\sqrt{LC}},$$

where f is the frequency in **MHz**,
L is the inductance in **microhenries** (**μH**), and
C is the capacitance in **picofarads** (**pF**).

When a variable capacitor is specified, it is usual to quote its maximum capacitance, i.e. the value when the vanes are fully meshed. When the value of the capacitor is small, it is usual to quote its minimum capacitance also, the value when the vanes are fully open. If you use a variable capacitor of 10–100 pF with a 100 μH inductor, you will use the value of 10 pF to calculate the maximum resonant frequency, and the value of 100 pF to calculate the minimum resonant frequency, giving a tuning range of 1.6 MHz to 5 MHz. Check it yourself!

64 An HF absorption wavemeter

Introduction

An absorption wavemeter is basically a simple tunable detector circuit, such as would be used in a crystal set, but with the headphones replaced by a meter, in order to indicate the strength of the received signal.

The circuit

Figure 1 shows the circuit of the wavemeter. It is designed to cover all the HF bands from 1.8 MHz to 28 MHz in four switchable ranges. There is no built-in method of amplification, so a sensitive meter is needed in order to indicate sufficiently using the available absorbed energy. The meter does not need calibrating, it serves to produce only an indication of the absorbed power, *not* its absolute value.

An absorption wavemeter does not have outstanding selectivity, mainly because of the loading effect of the meter. This problem is ameliorated here (but only slightly) by the inclusion of R1 in series with the meter. It gives

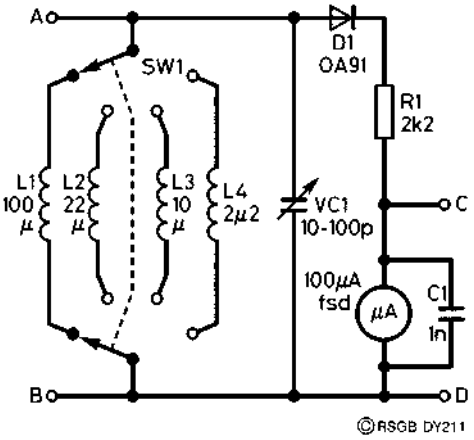

Figure 1 HF absorption wavemeter, circuit diagram

improved selectivity at the expense of a slight loss of sensitivity. The appearance of capacitor C1 across the meter is discussed in *The Absorption Wavemeter*, in the previous section.

Coils

These can be purchased (see the parts list) or hand-wound on short lengths of PVC water pipe or conduit, and the coil-winding details are given in **Table 1**. In theory, the 100 pF tuning capacitor would cover all the HF bands with only three coils, omitting the 22 μH coil. Sample calculations are explained in the previous article. However, its inclusion avoids the common problem of having some bands cramped at the extreme edges of the tuning scales.

Table 1 Close-wound coil values

L (μH)	No of turns	Span (mm)	SWG
PVC FORMER OF OUTSIDE DIAMETER 25 mm			
2.2	9	9	20
10	24	24	20
22	44	44	20
100	110	60	26
PVC FORMER OF OUTSIDE DIAMETER 20 mm			
2.2	10	10	20
2.2	9	5	26
10	32	32	20
10	24	12	26
22	63	62	20
22	41	21	26
100	134	70	26
PVC FORMER OF OUTSIDE DIAMETER 19 mm			
2.2	11	11	20
2.2	9	5	26
10	35	34	20
10	25	13	26
22	68	67	20
22	44	22	26
100	157	79	26

Construction

Hand-wound coils, using 19–25 mm PVC formers, have single-layer windings, with their ends secured by threading the wires through two small holes drilled in the formers at each end of each winding.

You may have wondered about the use of the two-pole switch SW1, as all the lower ends of the coils are grounded anyway. The answer lies in the ease of construction. Each coil can be mounted on the tags of the switch for support. If you are using the commercial coils, they are small enough to be accommodated on a miniature rotary switch; a larger rotary switch is required for hand-wound coils. The specification of a 6-way switch allows for the addition of extra frequency ranges at little extra cost. Rotary switches such as the 2-pole, 6-way variety have an adjustable end-stop which allows the number of ways to be set anywhere between 2-ways and 6-ways. Remove the nuts from the switch, and a 'washer' will fall out. It is not a washer, really, and has a little piece of metal bent over at right angles to the washer. This fits into one of 12 holes in the body of the switch, and prevents the shaft from turning through 360° and selecting the number of ways.

Calibration

This process needs a commercial amateur-bands transceiver, if it is to be done quickly and accurately.

- Connect the transceiver to a dummy load, and connect a piece of flexible wire from point A in Figure 1 and wrap two or three turns around the cable between the transceiver and the dummy load.
- Turn the transceiver power level control to minimum, and set the frequency at 1.81 MHz and the mode to FM or AM. Switch to transmit.
- With the wavemeter set to its lowest frequency range (i.e. 1.8–3.5 MHz), rotate the tuning capacitor until maximum deflection is obtained from the meter needle. Write the frequency on the inner ring of the wavemeter scale at that point.
- Switch off and retune the transmitter to 3.5 MHz. Repeat the above process.
- Repeat, using switch range 2 for 3.5, 7 and 10 MHz, range 3 for 7, 10 and 14 MHz, and range 4 for 14, 18, 21, 24 and 28 MHz.

An alternative source of calibration signal could be an HF signal generator, with a single-turn loop of wire at the remote end of its cable, and the wire from the wavemeter brought close to the loop.

Remember that the marks on the scale represent frequency *bands*, not precise frequencies.

Extending the range

If you would like to experiment with increasing the range to the lower VHF band, then 50 MHz should be achievable with an additional self-supporting coil (no former). Try three turns of 20 SWG enamelled copper wire of 25 mm ID (internal diameter). Wind it on some 25 mm PVC pipe, as before, then slide out the pipe! The same result could be achieved with four turns of 19 or 20 mm ID, or 12 turns of 7.1 mm ID.

Parts list

Resistor
- R1 — 2200 ohms (Ω) 0.25 watt, 10% tolerance

Capacitors
- C1 — 1 nanofarad (nF) min. ceramic
- VC1 — 100 picofarad (pF) variable

Inductors
- L1 — 100 microhenries (μH)
- L2 — 22 microhenries (μH)
- L3 — 10 microhenries (μH)
- L4 — 2.2 microhenries (μH)

Semiconductors
- D1 — Germanium OA91 or 1N4148

Additional items
- SW1 — Rotary 2-pole, 6-way
- Moving-coil meter, 50 or 100 μA FSD (any meter of this sensitivity will do)
- Plastic box, approx. 150 by 80 by 50 mm
- Connecting wire, coloured

65 A vertical aerial for 70 cm

Introduction

If the range of your hand-held transceiver is very limited, what you need is a vertical aerial mounted outside. This design is a half-wave dipole fed at the end instead of the middle. Because the impedance of the dipole is high at its ends (and low in the centre), a matching circuit is needed so that this high impedance can be matched to that of the low-impedance coaxial cable. All that is needed is a coil, which increases the *electrical length* of the aerial to $\frac{5}{8}$-wavelength. (Note that the *electrical* length (i.e. the length as it appears to an RF signal) is not necessarily the same as the *actual* length.)

Construction

The aerial element and the coil are made from a single piece of 1.5 mm welding (brazing) rod, and the dimensions are given in **Figure 1**. Wind the coil around a 4 mm rod or the shank of a twist drill. The lower end is filed to a point and then soldered into the centre conductor of a 4-hole panel-mounting BNC socket. (Try to obtain a good-quality BNC socket with PTFE insulation – the insulation of cheaper sockets is easily damaged.) Trim the element to 427 mm (top of element to top of coil) *after* the wire has been soldered to the socket.

The base coil causes the aerial to be rather 'whippy', so a piece of 5 mm plastic knitting needle can be cut to the length of the coil and then forced into it.

The radials are made from four lengths of 3 mm welding rod. These are bent and soldered into the four mounting holes of the socket, and then cut to the lengths shown in Figure 1.

Testing

Using a standing-wave-ratio (SWR) meter connected between your aerial and the transceiver, measure the SWR (or obtain some indication of the reflected power) on transmit. If it is greater than 1.5, switch off the transmitter, trim about 3 mm off the end of the element, and try again. Repeat the process until the measured SWR (or the reflected power) is as low as you can get it.

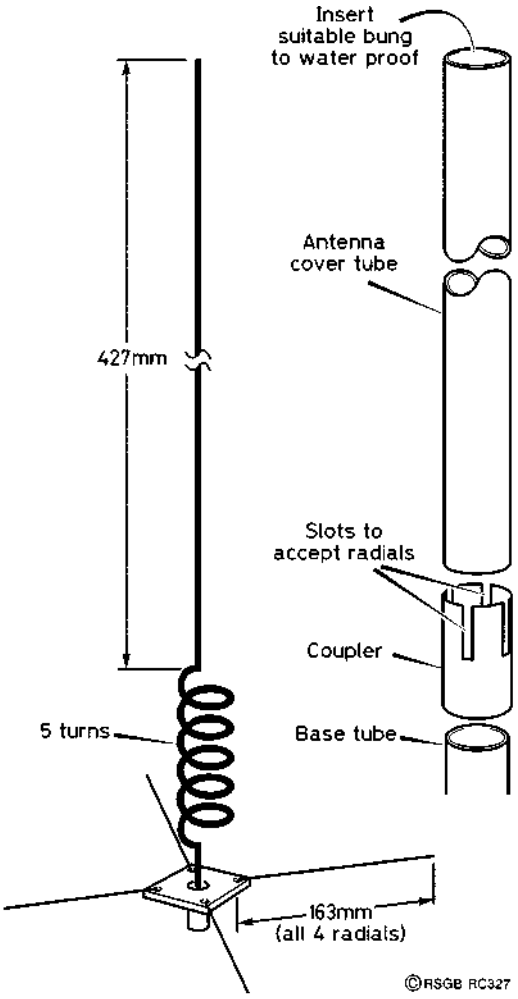

Figure 1 Construction of the 70 cm antenna

Installation

The aerial is made waterproof by enclosing it in a 22 mm diameter PVC waste water pipe. It is 'weldable', and available at plumbers' merchants, usually by the metre. A coupler is slotted to take the radials (Figure 1). File the BNC socket as required, so that it slides inside the coupler until the radials poke out of the slots. Cut a length of plastic tubing which is 30 mm longer than the aerial, and push it into the coupler. You will then need a plastic bung or screw-top to waterproof the top end.

Plastic welding solution is now applied to the joints, sealing the aerial inside the tube. The coupler has been weakened as a result of making the slots, so it is worthwhile applying PVC tape around this joint until the welding solution sets.

A support for the aerial is made from an off-cut of tube pushed into the lower end of the coupler and held with a self-tapping screw.

Parts list

1	4-hole panel-mounting BNC socket
1 m	3 mm brazing rod (may be available from a small garage)
1 m	1.5 mm brazing rod
1 m	22 mm PVC waste water pipe
1	22 mm straight coupler
	Plastic welding solution

66 A UHF corner reflector aerial

Introduction

The corner reflector is a well-known design and is capable of good performance on the VHF and UHF bands. At UHF, the practical implementation of the corner reflector is an ideal constructional project.

Some details

Expressed quite simply, the aerial consists of a $\frac{\lambda}{2}$ dipole (where λ is the standard symbol for wavelength, making a '$\frac{\lambda}{2}$ dipole' a half-wave dipole).

Nothing new in that, you might say. However, the interesting feature is the reflector, which is not the usual single element, but a 90° metal 'corner', acting rather like a parabolic dish as used for satellite signal reception. The wind resistance of this type of reflector makes it impractical so, to reduce the 'windage' quite significantly, we make the 'corner' from closely spaced rods, as illustrated in **Figure 1**.

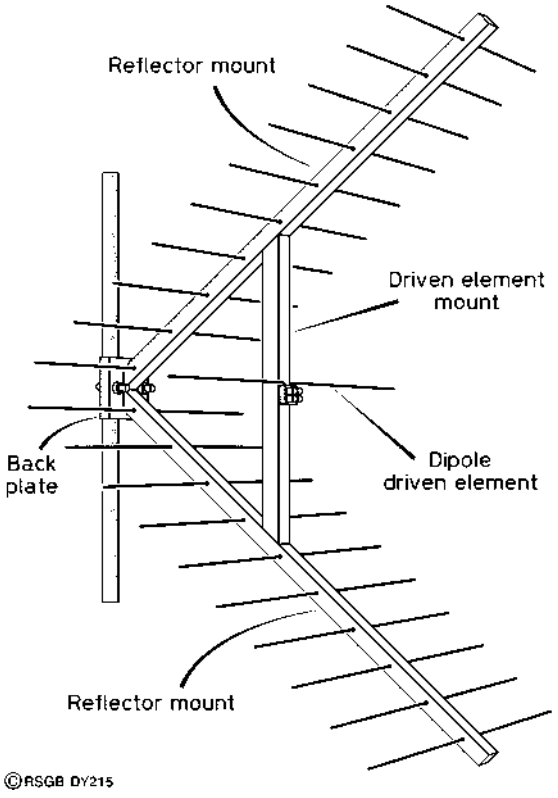

Figure 1 70 cm corner reflector antenna

The reflector consists of a number of 0.6λ rods, spaced from each other by 0.1λ. The aerial frame can be made of metal or wood, but wood is easier to work with, and mounting the elements to the frame is simpler. The prototype was made with wood of 20 mm by 15 mm cross-section, as **Figure 2** shows. The wood was varnished for protection. The elements were made from 1.5 mm diameter copper wire, because a large reel of the wire happened to be available. The wire diameter is not critical; tubing could be used just as successfully. 14 SWG hard-drawn copper aerial wire would be even better than that used in the prototype.

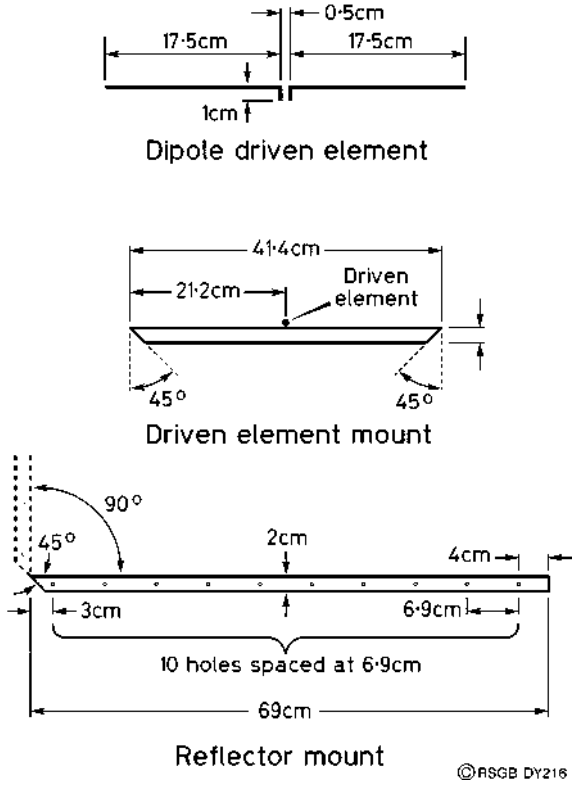

Figure 2 Driven element dimensions, together with boom dimensions for driven element and reflectors

Construction

This project is just as much a woodworking project as a radio project! Follow the instructions carefully, and you should have little trouble.

- Cut the booms for the reflectors, as shown in Figure 2. A mitre block is invaluable here in producing the 45° corners.
- Using the dimensions given on the diagram, mark the hole positions for the reflector elements, and then drill holes of a size which holds the elements firmly.
- Cut the driven element boom according to the diagram, and mark the point midway along the longer side, which will assist you later in positioning the driven element.
- Cut the back plate to size (about 120 mm by 80 mm). You may need to alter this size depending on the size of the U-bolt you will be using to clamp the aerial to the mast.

- If you want to be extra cautious in your construction, use the belt-and-braces approach, commonly known as 'screw-and-glue' to fix the booms to each other and to the back plate.
- Fix the reflector booms to the back plate first, then slide in the driven-element boom until it will go no further, then apply the wood glue and screw the two ends tightly to the reflector booms. Leave for the period prescribed by the glue manufacturers for the glue to harden.
- Varnish the whole structure.
- Cut the driven element to the correct size plus a couple of centimetres (the reason for this will be evident in the *Testing* section), and fix it to the centre of its boom (at the position you marked earlier) with a 'chocolate block' connector to which the coaxial feeder cable will eventually be connected.
- Cut and fix the reflector elements in place. If you find that these are a loose fit in the holes then, *for each element*, drill a pilot hole through the boom to intersect the hole for the element. File off the point of a woodscrew, and screw it gently into the pilot hole until it meets the element and grips it in place. You will now see why the point was filed off! Alternatively, you can glue the elements in place.

Testing

Place the aerial on a mast, clear of obstructions. Connect it to a transceiver with a length of coaxial cable, with a standing-wave-ratio (SWR) meter in circuit. Find a clear frequency, identify your transmission and ask if the frequency *really is* clear. If so, key the transmitter again and note the SWR. **Do not stand in front of any aerial when it is radiating!** The length of the driven element must be adjusted to obtain an SWR of less than 2. If you have to shorten the dipole, bend the ends over rather than cut them off. That way, if you go too far, your can lengthen them again! The dipole was initially cut too long intentionally, to allow for adjustment here! Bending the ends over also reduces the risk of physical damage to clothing, skin and eyes. You may like to consider applying the same technique to the reflector elements for that reason alone.

Moving on . . .

Once you have warmed to the idea of the corner reflector as an aerial, you might like to ring the changes regarding the reflector. How about replacing the 20 reflector elements with a wire mesh, such as garden centres sell as 'chicken wire'? Choose the finest mesh if there is a choice. Some extra support may be needed around the edges of the mesh, but you could go on to make a comparison of aerial gain between the two types, using the *UHF Field Strength Meter* described elsewhere in this book.

Materials

Stiff wire or thin-walled tubing for dipole and reflector
Frame – wood, 15 mm by 20 mm cross-section, lengths given in text
Back plate – stout plywood, dimensions given in text
U-bolt to suit mast
Wood screws
Wood glue
50 W coaxial cable for feeder
2-terminal 'chocolate block' for dipole connection to feeder
Varnish

67 A switched dummy load

Introduction

A dummy load is a pure resistor of value 50 ohms which can replace your transmitting aerial and enable you to operate the transmitter for test purposes without radiating a signal. It sounds simple enough, but there are two main problems. Firstly, it is impossible to delve into your junk box and emerge with a resistor that will dissipate 100 W PEP and still retain its marked resistance value. Secondly, a 'pure resistance' is very difficult to achieve. A pure resistance is a device which has resistance but no reactance. All common resistors have significant reactance at radio frequencies, particularly the wire-wound varieties, which have a helical (i.e. wound like a coil) construction. This is particularly annoying, because wire-wound construction is normally used for large-wattage resistors.

Although all resistors have *some* reactance, not all are quite as bad as the wire-wound type. Carbon film resistors are made by depositing a thin film of carbon on the surface of a small, hollow ceramic cylinder, the thickness of the film of carbon determining the value of the resistor. Provided the lead lengths are kept short, these resistors have a tolerably small reactance, and will be used in this project.

Bearing the load

A 2 W carbon film resistor is hardly going to withstand our 100 W PEP of SSB, so it is obvious that the design of our dummy load must be a little more

complex than a single resistor and a switch, despite what **Figure 1** might suggest! In fact, it uses 20 resistors, each of value 1000 Ω (1 kΩ). How does this solve our problem?

Perhaps a little theory is in order here, but no more than is required by the Radio Amateurs' Examination.

When two *equal* resistors of value r are combined in parallel (i.e. side by side), the total resistance, R_T, is given by:

$$\frac{1}{R_T} = \frac{1}{r} + \frac{1}{r}.$$

Adding $1/r$ to $1/r$ gives $2/r$, therefore:

$$\frac{1}{R_T} = \frac{2}{r}, \quad \text{i.e. } R_T = r/2.$$

So, by connecting *two* equal resistors in parallel, we get a combined resistance which is *half* the individual resistances. If we combine *three* in parallel, we get a *third* of the resistance, and so on.

Here, we are connecting *20* resistors of 1 kΩ in parallel, so we will produce an overall resistance of *one-twentieth* of the individual resistance, i.e. 1000/20 = 50 Ω, which is what we set out to achieve!

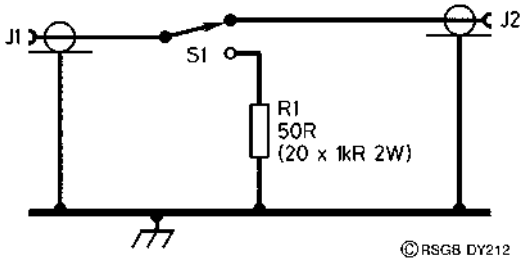

Figure 1 Basic circuit diagram

This is not the only advantage, though. Each resistor is capable of dissipating 2 W, so 20 of them will safely dissipate 40 W, for short periods at least. This power dissipation is approximately the same as 100 W PEP of normal speech, so the design should be capable of use in an 'average' amateur station. The power-handling ability of any dummy load can be improved by providing a 'heat sink' which helps to conduct the heat energy away from the resistors, thus lowering their temperature. One popular heat sink is a can of transformer oil, into which the resistors are immersed. This design uses a rather more mundane heat sink, but which is adequate for the job in hand.

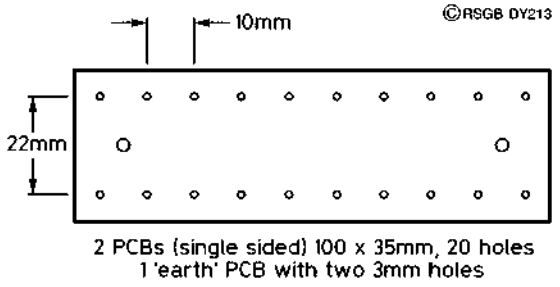

Figure 2 PCB resistor supports

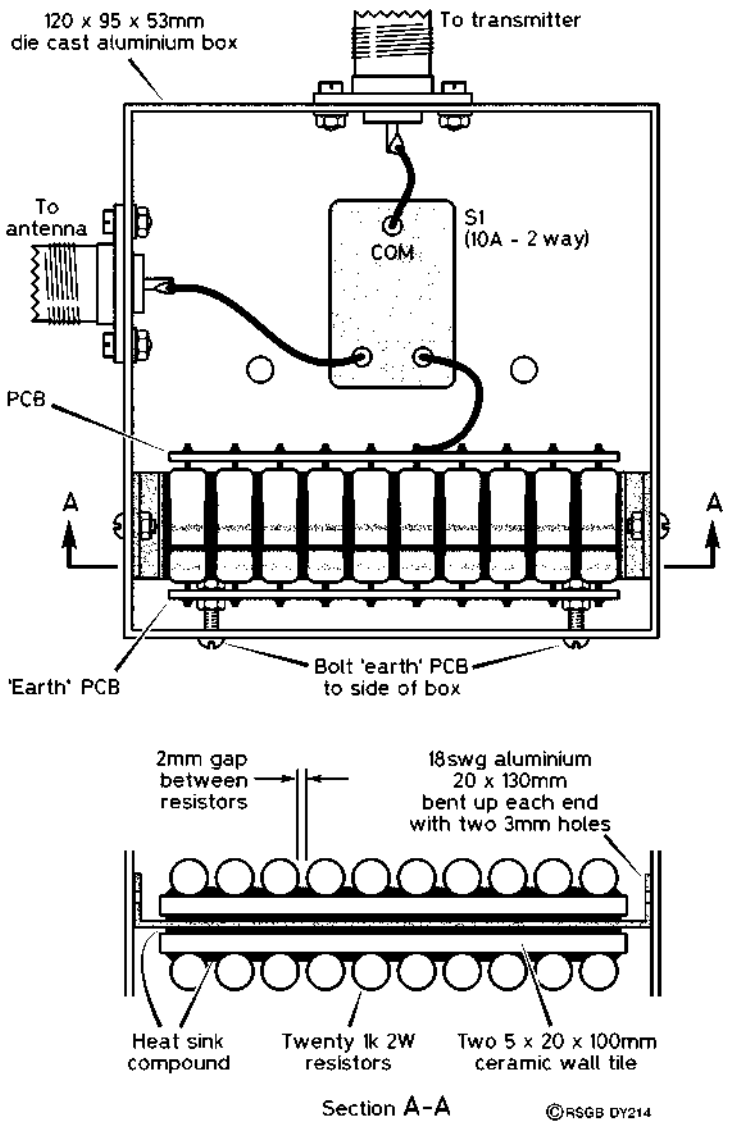

Figure 3 Switched dummy load, component layout

Pouring the heat away

Two basic PCBs are needed, the details being given in **Figure 2**. Both measure 11 × 35 mm. Each has a set of 20 holes of diameter about 1 mm to take the ends of the resistors. Only one of them has two 3 mm holes which are used for mounting the completed load. **Figure 3** shows how the heat sink is assembled. Solder one end of each resistor into the 'earth' PCB, and then mount this to the box using the two bolts as shown in the diagram. Between each rank of resistors is a 'sandwich' consisting of an aluminium strip and two pieces of ceramic wall tile, to act as a heat sink for the resistors. Heat sink compound is used to provide good thermal contact between the resistors and the tiles, and between the tiles and the aluminium strip. This is shown in the lower part of Figure 3. Thread the loose wires of the resistors through the holes in the second PCB, solder into place, and crop the protruding wires.

Switching

A changeover switch must be used so that the transceiver can be switched between the dummy load and the aerial without unscrewing connectors. For most purposes, an ordinary 10 A 230 V changeover switch will suffice, as found in many electrical shops and DIY stores.

Wire this into the circuit as shown in Figure 1 and Figure 3. Check your wiring. Put S1 in the 'dummy load' position. If you have a multimeter which includes an ohmmeter, measure the resistance across the socket, J1, before connecting it to the transceiver. It should be very near 50 Ω. With S1 in the 'aerial' position, there should be an infinite resistance across J1. Move your ohmmeter to read the resistance across J2. It should be infinite for both positions of S1. If all seems correct, close the box and your dummy load is ready for use!

Parts list

Resistors
- 1000 Ω (1 kΩ) 2 W carbon film, 20 required

Additional items
- 10 A 230 V changeover (SPDT) switch
- SO–239 sockets, 2 required
- Aluminium box 120 × 95 × 53 mm or similar
- Ceramic wall tile cut as required
- Aluminium strip, 18 SWG
- Nuts and bolts as required

68 A simple Morse oscillator

Introduction

This is an excellent project which uses the 'junk box' as its source of components. If you have trouble in finding the bits for this one, a good source of the components for this and many other similar projects is to be found with the parts list at the end of the project.

The circuit

This is shown in **Figure 1**, and uses an 'unknown' Plessey chip, which makes the overall circuit extremely easy to build. A 0.1 μF capacitor is connected between pins 7 and 8, a speaker (in the popular 8 to 25 Ω impedance range) is connected between pins 8 and 9. If a 9 V battery is connected with its positive terminal to pin 8 and its negative terminal to pin 1, 3 or 5, a tone will be produced in the speaker.

To make this circuit into a good Morse practice oscillator, it is necessary only to insert a Morse key into the supply rail from the battery.

However, there is another refinement which you may care to build into the circuit. The tone from the loudspeaker is different, depending upon which of pins 1, 3 or 5 you use. In the prototype, a single-pole changeover switch was used to select the tones from pin 1 or pin 3, and the Morse key would be connected to the circuit via a small jack socket. There is no need for an on/off switch, as the Morse key performs that function. The switch and the jack socket can be seen in the photograph.

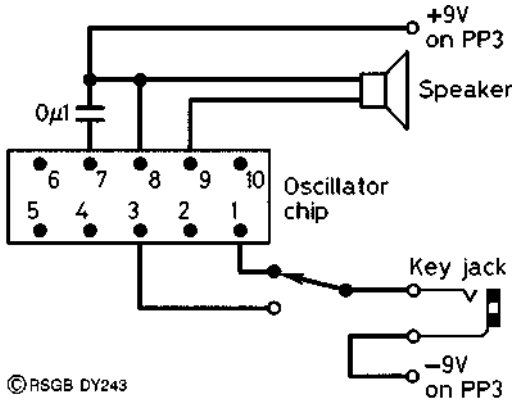

Figure 1 Morse oscillator, circuit diagram

The case

Almost any small loudspeaker will do; the higher the impedance the better. The 'impedance' is the figure usually printed on the rear of the speaker magnet. It is a value given in ohms (Ω). For simple circuits like this, you will usually find that the higher the impedance (within reason), the louder the sound it will produce. Speakers from old transistor radios will work, although their impedances can be rather low sometimes.

Any case big enough to house the components and the battery will be suitable. The prototype used a 'Walkman'-type speaker and case, and is shown in the photograph.

To use the circuit, simply attach a 3.5 mm jack plug to your Morse key, and insert it into the socket. Nothing should happen until you press the key, when a tone should be heard from the loudspeaker.

Another application

Try soldering the two wires of a 'twisted pair' to the 3.5 mm jack plug. Touching the wires together produces a tone from the speaker. This simple circuit can then be used as a 'continuity tester'. Touch the two wires to the ends of a fuse. If there is no sound, then the fuse is blown. There are many other such tests you could perform with this device – to check whether there really *is* a connection between one end of a wire and the other, for example.

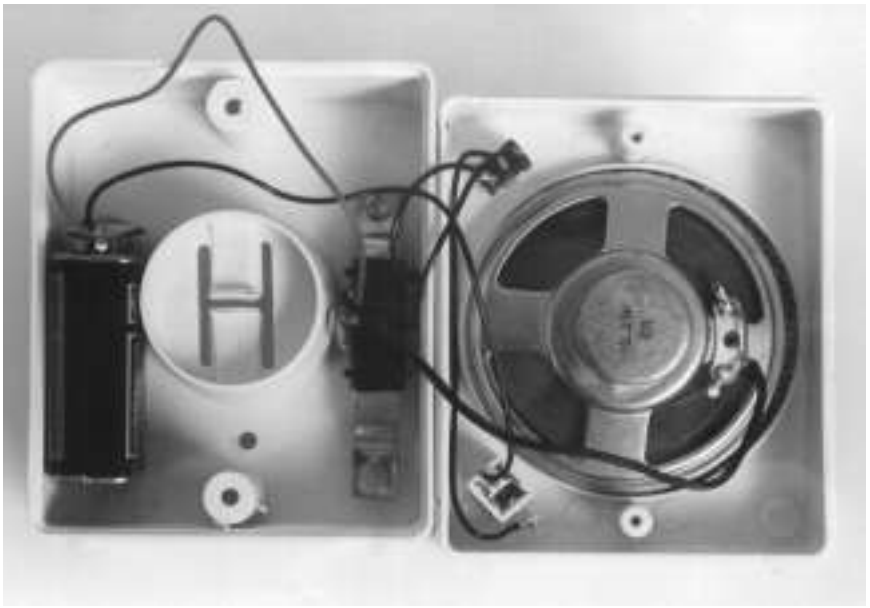

Warning

You must **never** make such tests on any equipment which is connected to the mains supply, even if it is switched off. If you want to make any such tests, make sure you are supervised by someone who understands what you are doing and is competent to advise and supervise you.

Parts list

Plessey oscillator chip
0.1 μF capacitor (disc ceramic)
Loudspeaker 8 to 25 Ω
3.5 mm jack socket (and 3.5 mm jack plug if needed)
Single-pole changeover switch

The Plessey oscillator chip is available from J. Birkett, 25 The Strait, Lincoln LN2 1JF, tel: 01522 520 767.

John Birkett may also provide a kit of parts (the chip, capacitor and loudspeaker).

69 A bipolar transistor tester

Introduction

This is a circuit which will test normal transistors, i.e. npn or pnp. It has the advantage of being able to test devices while they are still connected in their original circuits. However, when such tests are made, **the circuit containing the transistor under test must not be switched on**.

The circuit and how it works

The circuit runs from a 9 V battery such as a PP3 or six AA-type 1.5 V cells. Alkaline cells are to be preferred, as their electrolyte leakage properties are better. The circuit shown in **Figure 1** uses a single CMOS integrated circuit type 4001 or 4011. CMOS circuits require special handling precautions which are described in the project *Christmas Tree LEDs*, elsewhere in this book.

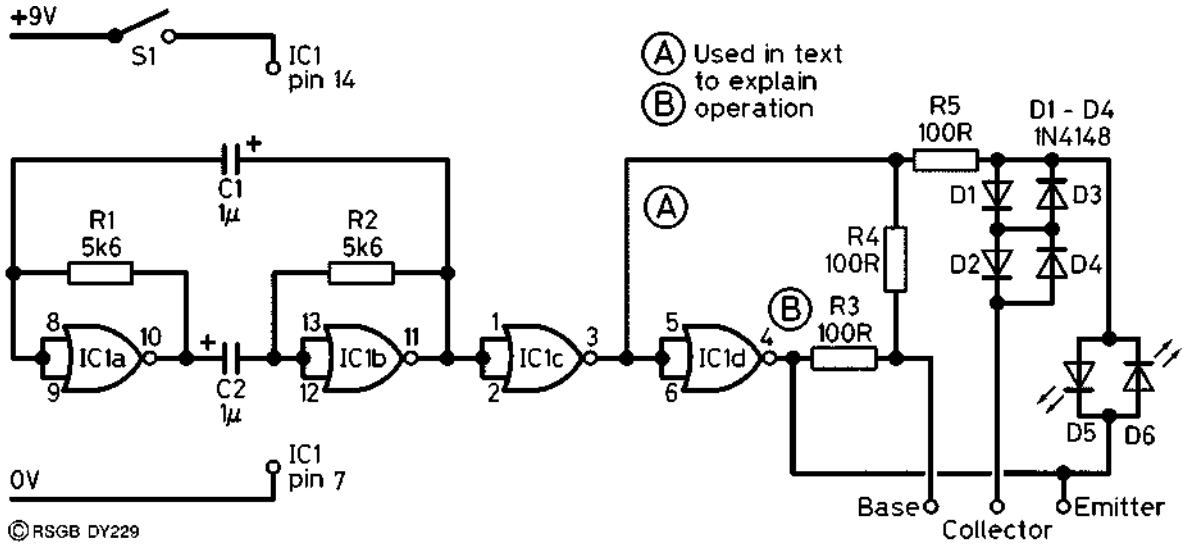

Figure 1 Transistor tester, circuit diagram

Inside the IC are four logic gates (see *Digital Logic Circuits*) which are all connected as inverters, which means that the output signal is always the logical 'opposite' of the input. The first two gates are connected as an oscillator; the circuit being the same as that used in *An Electronic Die*.

The output of the oscillator, at pin 11, is connected to the input of a buffer stage, IC1c, which helps to isolate the oscillator from the circuit that follows it. The buffer output appears on pin 3, which we shall label as *test point A* for future use. Another inverter, IC1d, follows this, its output at pin 4 being labelled *test point B*.

There are two LEDs connected back to back at the circuit output. These are D5 and D6, D5 being red and D6 being green. Whatever the output of the oscillator at any instant, one of the LEDs must be lit and the other unlit. With point A positive and point B zero, the red LED is lit, when A is zero and B is positive, the green LED is lit. Because the oscillator output is repeatedly switching from one polarity to the other, the lit LED is alternately red and green. They switch between the two colours much faster than we can see, so what we think we see are both LEDs lit together.

The two 100 ohm resistors, R3 and R4, provide the bias to the base of the transistor under test. When A is positive and B is zero, the base-emitter junction of the transistor will be forward-biased, and the transistor will switch on (if it is a working npn type). When the transistor is on, it effectively short-circuits D5 (the red LED) and it extinguishes. When point A is zero and B is positive, an npn transistor will be switched off and the

green LED (D6) will light. Thus, for a working npn transistor, only the green LED is lit.

If the transistor under test is a pnp type, it will switch on when A is zero and B positive, thus short-circuiting the red LED (D6). When A is positive and B zero, the transistor is off and the red LED (D5) is lit. Thus for a working pnp transistor, only the red LED is lit.

To summarise, the states of the LEDs indicate the following conditions:

- Both LEDs apparently lit: no transistor connected, or transistor permanently open circuit.
- Neither LED lit: a collector-emitter short-circuit is almost certain.
- Red LED alone: pnp transistor in working order.
- Green LED alone: npn transistor in working order.

Construction

The prototype tester was built on a piece of Veroboard measuring 15 strips by 18 holes. Cut the tracks using a track-cutting tool or a 3 mm (⅛ inch) twist drill, as shown in **Figure 2**. Notice that, in this diagram, there is no

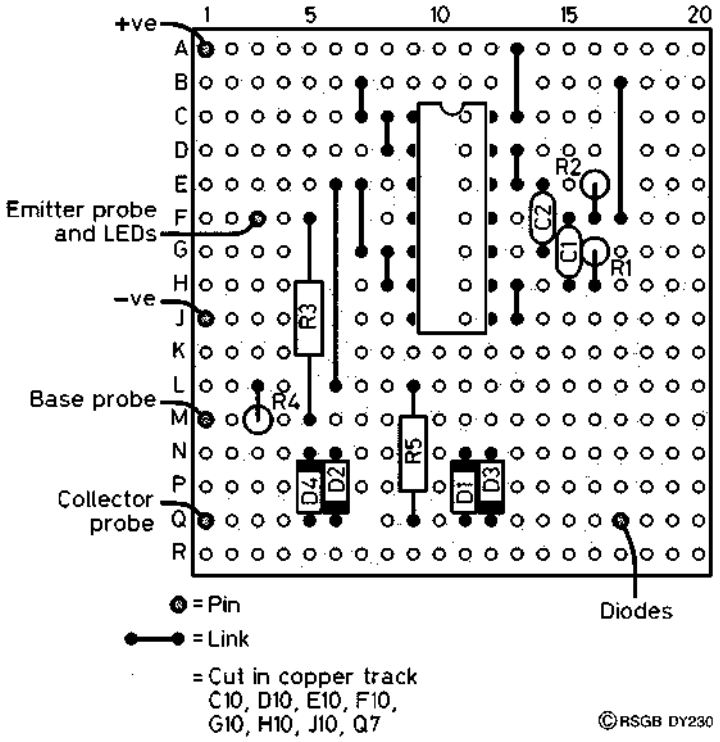

Figure 2 Transistor tester, component layout

track 'I', so try to avoid miscounting when you translate diagram positions to real positions on the board. Hold the board up to a strong light to ensure that there is no copper swarf shorting adjacent tracks together, and that you have made the cuts in the correct places.

Having done this, insert and solder Veropins for all the connections to be made to components not on the board itself. Then solder in the IC holder and the wire links. Then insert the other components in the order resistors, capacitors and diodes D1–D4. Some resistors are mounted vertically so that their connections are on adjacent tracks. Double check the diode polarities – it is easy to make a mistake when wiring diodes in anti-parallel! Next, connect up the off–board components, again making sure that the LEDs have the correct polarity. The probe leads for the emitter, base and collector should be made from different colours of wire and terminated in probe clips (small insulated crocodile clips).

Check carefully for dry joints and errant blobs of solder. Plug the IC into its holder, ensuring that it is inserted the right way round, as shown in Figure 2.

Testing

Without a transistor in circuit, and the battery connected, both LEDs should be lit. Connect a known good npn transistor and verify that the green LED lights. Now simulate two transistor faults: disconnect the base lead and both LEDs should light; remove the transistor and connect the emitter and collector leads together. Neither LED should light.

Repeat the tests with a known good pnp transistor. The results should be the same, except that the correct indication should now be a lit red LED. On your computer, make a small label of the bulleted list above, to fit on your tester showing the states of the LEDs and what they mean. It will act as a useful *aide mémoire* when you use the tester in future.

Using

The circuit will test transistors in isolation or in an existing circuit, i.e. prior to use. You can check the lead identifications in component catalogues such as the Maplin catalogue. The tester is ideal for going through the large bags of unmarked transistors that you can buy for a song at rallies. You can sort them into three piles – npn, pnp and dud!

Parts list

Resistors: all 0.25 watt, 10% tolerance or better

R1, R2	5600 ohms (Ω)
R3, R4, R5	100 ohms (Ω)

Capacitors

C1, C2	1 microfarad (μF) electrolytic, 16 V WKG

Semiconductors

D1–D4	1N4148 general-purpose silicon diodes
D5	Red LED
D6	Green LED

Integrated circuit

IC1	CMOS 4001 or 4011

Additional items

- Veroboard, 15 strips by 18 holes
- Veropins
- PP3 battery and connector (or 6 × AA cells in PP3 clip holder)
- Switch, SPST
- Connecting wire
- One each of known working npn and pnp transistors for test purposes.

Source

Components are available from Maplin.

70 The 'Yearling' 20 m receiver

Introduction

Published to celebrate the first anniversary of *D-i-Y Radio,* this excellent receiver design forms a suitable 'second receiver project' for those who have successfully completed the MW receivers earlier in this series. The receiver is powered from a PP3 battery or from a mains adaptor, and can be built with the help of an experienced constructor, on a prototype board. The circuit diagram and some of the components used are shown in the separate diagram. Headphones or a loudspeaker can be used and, once the radio is completed, a few simple adjustments will make the *Yearling* spring to life!

Building the receiver

Before starting the constructional process, start by identifying all the parts. One by one, tick them off against the parts list. Are their values correct? The varactor diode is a twin type (see circuit diagram overleaf), and must be cut *carefully* down the middle, producing two devices, D1 and D2, with two wires each.

First, solder the IC sockets, followed by the coils (inductors); L1 is pink inside the top, and L2 is yellow inside. Then, solder in the varactors; the lettering on D1 should be next to coil L1, and the lettering on D2 should face resistor R7. After those, the capacitors, wire links and resistors should be soldered to the board. Take care to wire the voltage regulator, IC3, correctly. Solder in the crystal X1 as quickly and deftly as you can – crystals do *not* take kindly to having their leads bent and being fried with a soldering iron! Make sure that the electrolytic capacitors C2, C12, C15 and C16 are fitted the right way round. Most electrolytic capacitors have only the negative lead marked.

Figure 1 shows the rear of the front panel, illustrating the connections from the board and antenna socket to the controls. All normal connecting wires are 22 SWG or thereabouts, with insulation. Their lengths should be about 15 cm, except for the battery lead to the switch, which is about 8 cm. It is recommended that you use different-coloured wire for each connection to a control. **Figure 2** shows this. The variable resistor section of VR5, the AF gain control, uses single screened cable connected to 0 V (ground) at the

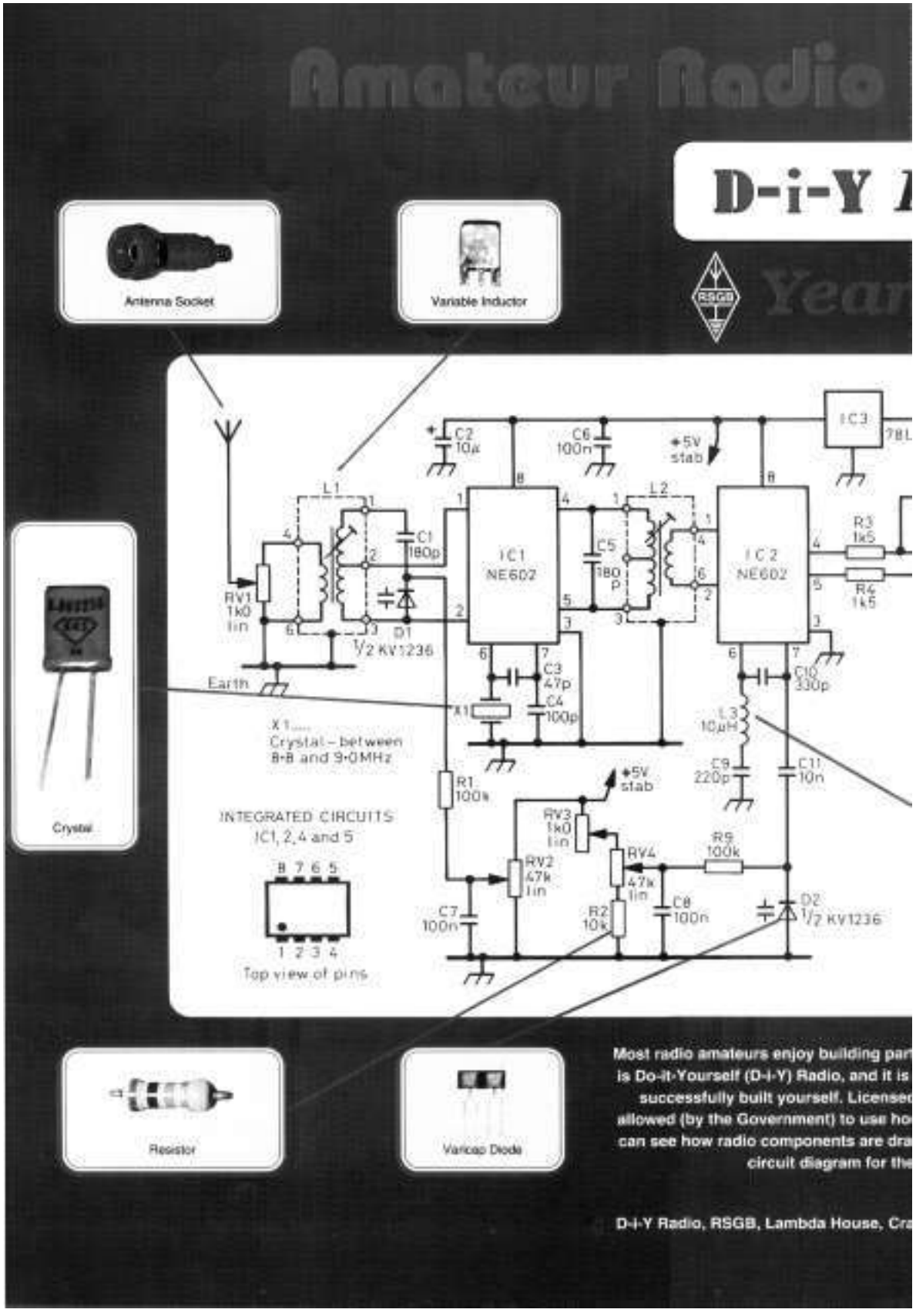
Amateur Radio
D-i-Y
Year
RSGB
Antenna Socket
Variable Inductor
Crystal
Resistor
Varicap Diode
L1
L2
C1 180p
C2 10µ
C3 47p
C4 100p
C5 180p
C6 100n
C7 100n
C8 100n
C9 220p
C10 330p
C11 10n
D1 1/2 KV1236
D2 1/2 KV1236
IC1 NE602
IC2 NE602
IC3 78L
RV1 1k0 lin
RV2 47k lin
RV3 1k0 lin
RV4 47k lin
R1 100k
R2 10k
R3 1k5
R4 1k5
R9 100k
L3 10µH
X1
Earth
+5V stab
X1 ... Crystal – between 8·8 and 9·0MHz
INTEGRATED CIRCUITS IC1, 2, 4 and 5
8 7 6 5
1 2 3 4
Top view of pins
Most radio amateurs enjoy building part
is Do-it-Yourself (D-i-Y) Radio, and it is
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circuit diagram for the
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RADIO

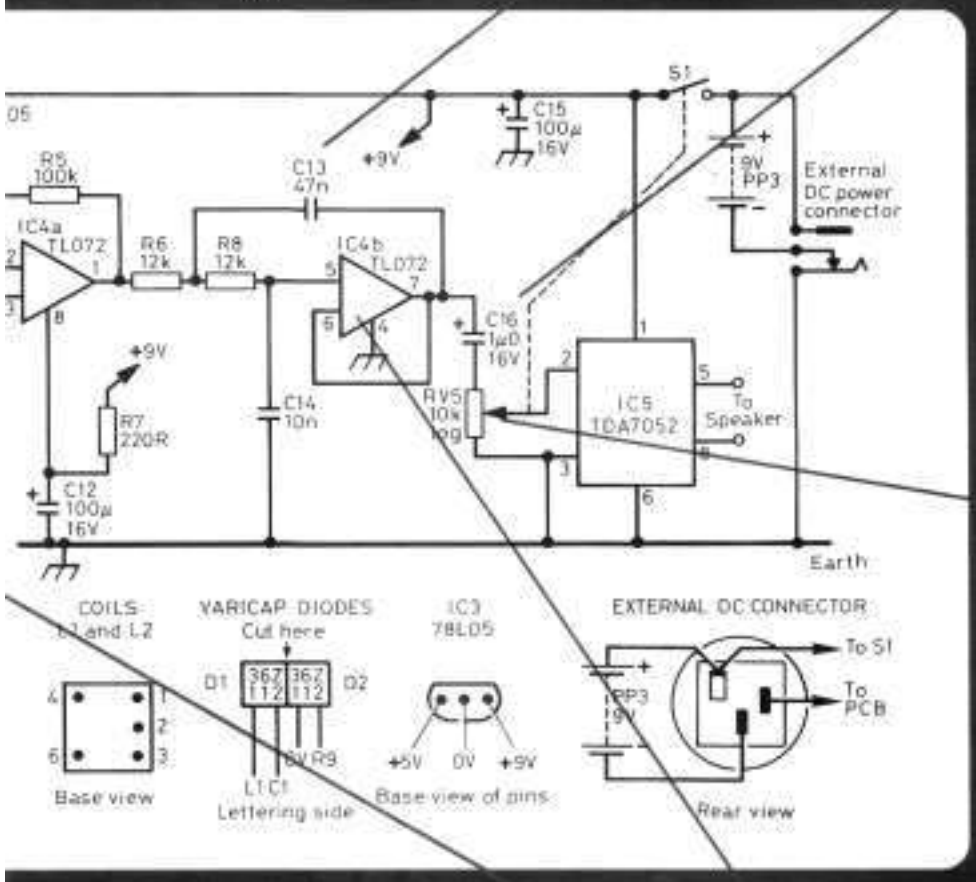

of their radio stations themselves, this very satisfying to use a radio you have radio amateurs are the only people me-built transmitters. On this page you wn on a circuit diagram. This is the full *D-i-Y Radio* Yearling.

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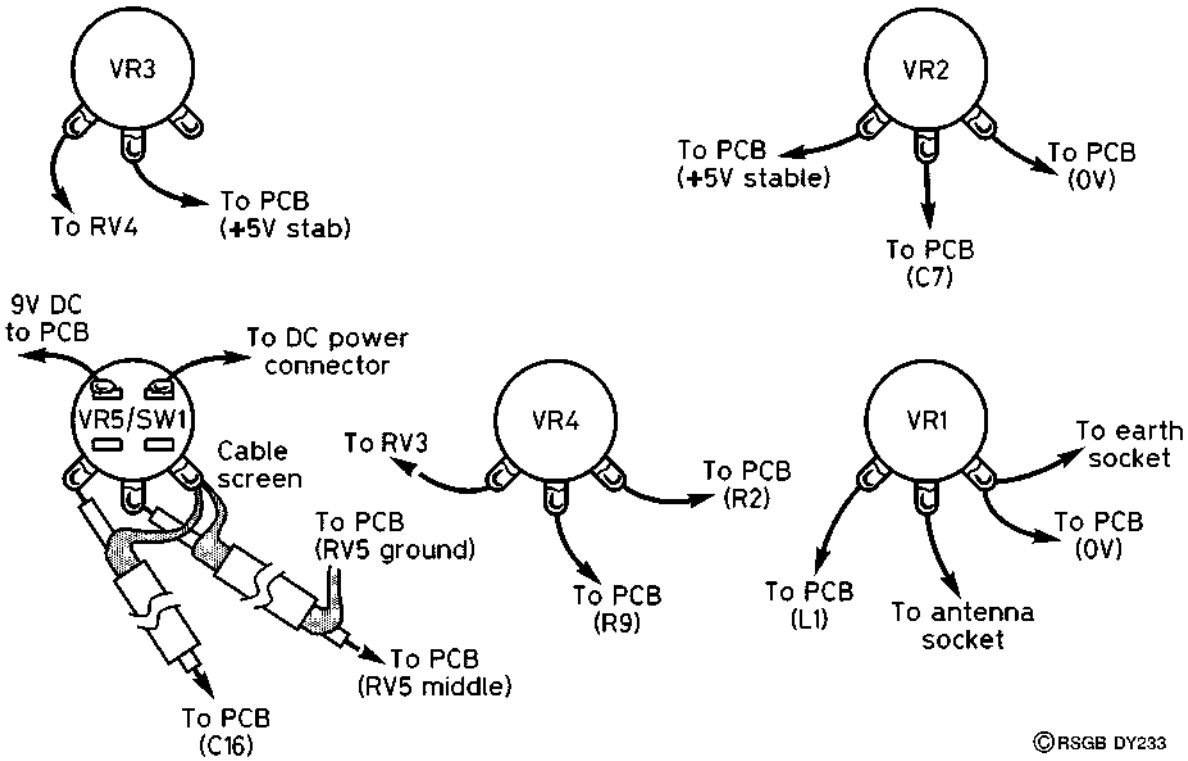

Figure 1 Rear view of the variable resistors. Check the connections carefully to make sure the wires fit the correct holes

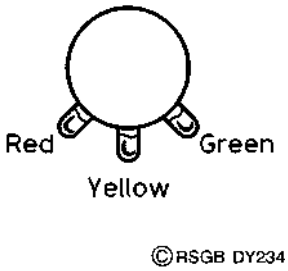

Figure 2 It is helpful to use different colour insulated connecting wires. Wires between each variable resistor and the board should be twisted together to give a neat wiring outfit.

board end. Now fit the ICs into their sockets. Make sure that they are the right way round (see circuit diagram) and that each pin lies directly above its corresponding socket before applying *gentle* pressure with the back of the board firmly supported.

Check that all the connections are correct (don't *assume* this – check the ends of each wire against the circuit diagram) and that all your soldered joints are shiny. Lastly, drill the five 10.5 mm diameter holes for the main controls. On the side of the case, a 6.3 mm diameter hole is needed for the speaker socket, and 8 mm holes for the antenna and earth sockets. The external power socket requires an 11 mm diameter hole.

Adjusting it

Before you can make adjustments, and in order to hear *anything* on your *Yearling*, you will need to connect an antenna (aerial) to the antenna socket. About 8 metres of wire, preferably outdoors and as high as possible, is all you need to connect to the socket. Connect the 3.5 mm jack socket for the speaker, and a 3.5 mm jack to your speaker leads. Connect a battery and switch on.

1. Using a very small screwdriver or, better still, a non-metallic 'trimming tool', *gently* screw in the core of L2 as far as it will go, but *don't force it*. Then unscrew it by three turns anticlockwise.
2. Set VR1, VR2 and VR4 to mid-position and rotate the core of L1 anticlockwise until the hissing noise you hear reaches a maximum intensity. Then adjust L2 for maximum noise.
3. If you now tune carefully with the main tuning control, VR4, you should hear some amateur Single-Sideband (SSB) speech signals. You may have to adjust the bandspread (fine tuning) control, VR3, to make the speech sound normal.
4. Having verified that everything is working, switch off and mount the controls on the front panel and the sockets on the side. To do this, it is much safer to disconnect all the controls and sockets, mount them in their final positions, and then wire them up again.
5. Fit the front panel knobs, connect your aerial and switch on again, checking that everything is working. Then, locate the cluster of CW (Morse) signals to be found at the bottom of the 20 metre band, set the bandspread control to mid-position and slacken off the main tuning knob. Turn the knob (but *not* the control!) until the pointer lies a little clockwise of 14.0 MHz. The SSB signals should now lie roughly between the dial centre and 14.35 MHz. Tighten up the knob.
6. Finally, fix the board to the rear panel, and secure the battery (if you are using one). Attach the rear panel to the back of the box, and you are finished!

Listening!

Make a habit of keeping the bandspread control in its centre position when searching for stations; then you can adjust it either way to make the signals readable. Unless you have a very big aerial, it is best to have the 'RF Gain' control, VR1, at maximum. Use the 'Antenna Tune' control, VR2, to give the best signal, and control the volume with the 'OFF/AF Gain' control. You will find some excellent DX stations with your *Yearling* receiver, and it will serve you well.

Parts list

Resistors (all 0.25 W, 5%)

R1, R5, R9	100 kilohms (kΩ)
R2	10 kilohms (kΩ)
R3, R4	1.5 kilohms (kΩ)
R6, R8	12 kilohms (kΩ)
R7	200 ohms (Ω)

Capacitors (all rated at 16 V or more, tolerance *at least* what is quoted)

C1, C5	180 picofarads (pF) polystyrene 5%
C2	10 microfarads (μF) electrolytic
C3	47 picofarads (pF) polystyrene 5%
C4	100 picofarads (pF) polystyrene 5%
C6, C7, C8	100 nanofarads (nF) or 0.1 microfarad (μF) ceramic
C9	220 picofarads (pF) polystyrene 2%
C10	330 picofarads (pF) polystyrene 2%
C11, C14	10 nanofarads (nF) or 0.01 microfarad (μF) ceramic
C12, C15	100 microfarads (μF) electrolytic
C13	47 nanofarads (nF) or 0.047 microfarad (μF) polyester, 5%
C16	1 microfarad (μF) electrolytic

Variable resistors

VR1, VR3	1 kilohm (kΩ) linear
VR2, VR4	47 kilohms (kΩ) linear
VR5	10 kilohms (kΩ) log with switch

Inductors

L1	Toko KANK3335R
L2	Toko KANK3334R
L3	10 microhenries (μH), 5%

Semiconductors

IC1, IC2	Philips/Signetics NE602 or NE602A
IC3	78L05 5 V 100 mA regulator
IC4	TL072 Dual Op-Amp
IC5	Philips TDA7052 audio amplifier

Additional items

D1, D2	Varactor diode Toko KV1236 (cut into two sections – see text)
X1	Crystal 8.86 MHz type (from Maplin, etc.)
4 off	8-pin DIL sockets for IC1, IC2, IC4 and IC5
2 off	4 mm sockets aerial (red) and earth (black)
1 off	3.5 mm chassis-mounting speaker jack socket
1 off	DC power socket for external supply (if required)
4 off	Red knobs with pointers
1 off	Tuning knob with pointer (e.g. 37 mm PK3 type)
1 off	Printed-circuit board or prototype board
1 off	Plastic case approx 170 × 110 × 6 mm (e.g. Tandy number 270-224)
1 off	Speaker 8–32 Ω impedance (or headphones)

71 Adding the 80 metre band to the Yearling receiver

Background

You will have noticed that your *Yearling* receiver has a dial which shows coverage of the 80-metre amateur band (3.5–3.8 MHz). This band is used for local contacts during the day, and contacts up to about 1600 miles in darkness. Longer distances are possible, particularly in the middle of winter.

The modifications

Only a few extra parts are required, as you may have noticed from the parts list. A low-pass filter, FL1 (one which passes low frequencies and rejects higher frequencies), is switched into the circuit on 80 m. The circuit of the

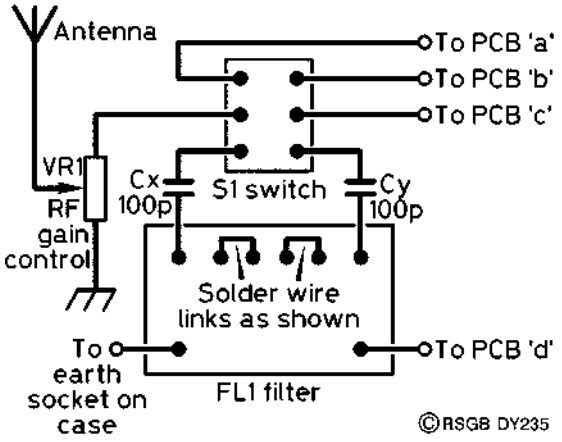

Figure 1 The circuit diagram shows the extra components for 80 m operation. Note the connections to the PCB 'a', 'b', 'c' and 'd'

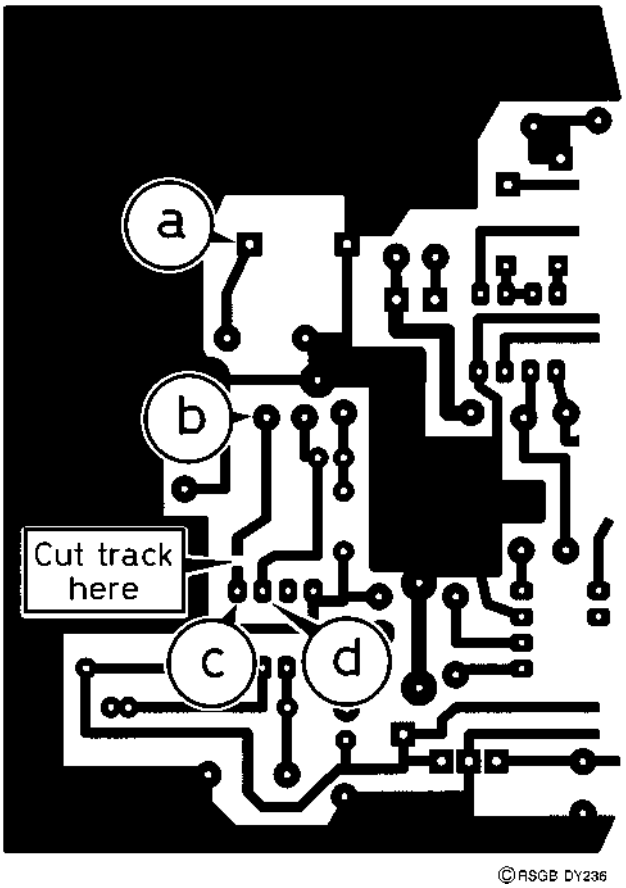

Figure 2 The underside of the PCB. Wires are connected from the switch and filter as shown

switch and its connections is shown in **Figure 1**. Before making the modifications, dismantle the receiver so that you have easy (and safe) access to the case and the track side of the PCB.

1. The first thing to do is to drill a 6.5 mm diameter hole in the side of the case into which the switch fits.
2. Then, using a sharp Stanley knife or scalpel, carefully cut the track on the PCB as shown in **Figure 2**, making a gap about 1 mm wide.
3. Using 10 cm lengths of different-coloured insulated wire, make the four connections, a, b, c and d, to the PCB, as shown in Figure 2.
4. Solder the two links on the filter, and then make the connections to the switch, capacitors and PCB. You will have to disconnect the existing wire between the RF gain control, VR1, and pin 4 of L1 on the PCB.
5. Lastly, check your new connections carefully, then mount the switch in the new hole and fix the filter to the bottom of the case with a little glue, as shown in **Figure 3**. Reassemble the circuit, and replace the back of the case.

More testing!

Firstly, switch your new switch, S1, into the 20 m position, to check that the original circuit still works! If you find that the 'Antenna Tune' control peaks at a slightly different position, don't worry.

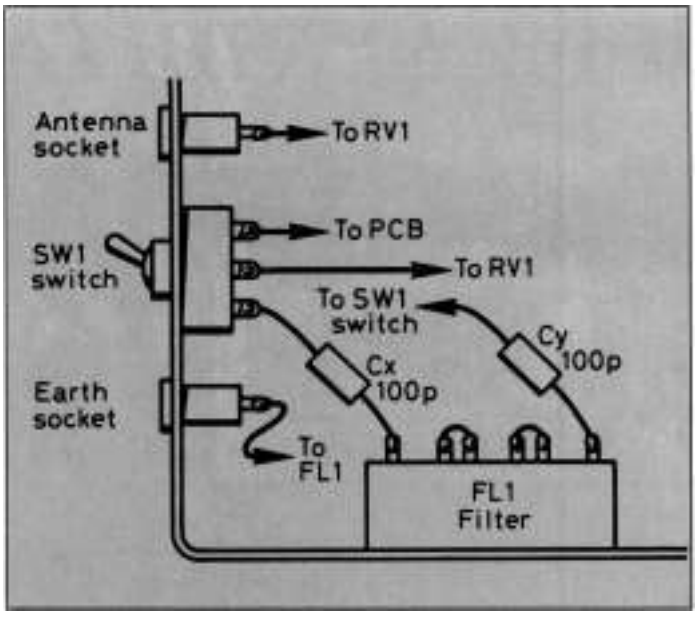

Figure 3 Internal view of the Yearling case. The filter FL1 is attached to the base with glue

Now switch to 80 m, and tune around the anticlockwise end of the dial; you should hear some SSB stations, particularly in the evenings and at weekends, when may people are on the air. At the other end of the travel of the tuning control, you should hear CW (Morse) stations.

The Radio Society of Great Britain broadcasts amateur radio news every Sunday morning on or about 3.65 MHz; the table below has the details. Finally, a good antenna is more important than ever for 80 metre reception – aim for more height and length, and then consider the project concerned with making an Antenna Tuning Unit (ATU)!

Parts list

Capacitors (all rated at 16 V or more, tolerance 10% or better)

Cx, Cy	100 picofarads (pF) polystyrene

Filter

FL1	Toko 237LVS1110 low-pass filter

Additional items

SW1	2-pole 2-way (changeover) toggle switch
7 off	Short lengths of insulated wire of different colours

The RSGB news broadcasts, GB2RS – Sunday mornings

Frequency (MHz)	*Local time*	*Reception area*
3.650	0900	SE England
3.650	0930	Midlands
3.650	1000	SW England
3.650	1100	Yorkshire
3.640	1130	Aberdeen
3.660	1130	Glasgow

The Midlands transmission is repeated at 1800 (6pm) local time on 3.650 MHz. All frequencies are approximate in order to avoid interference, and use lower sideband (LSB). If you also have a 40 metre receiver, there are GB2RS news broadcasts on 7.048 MHz at 0900 local time from Northern Ireland and from 1100 local time from the north midlands.

72 How the Yearling works

Introduction

The *Yearling* was designed to provide an introduction to *Amateur Radio* on the 20 m amateur band. Let's look at how the different sections (or 'stages') of a radio work, and how they fit together to form a complete receiver. **Figure 1** shows a block diagram which you can follow and compare with the circuit diagram of your *Yearling* receiver.

The antenna (or aerial)

Connected to your receiver, it will pick up not only amateur signals, but all other signals as well! This means that the receiver has to select the one signal that interests you, while rejecting all the others. The following stages do just that.

The RF filter

This stage (centred around L1) selects the band of radio frequencies (RF) containing the signal you want, in this case, those having wavelengths around 20 m. Signals from the 40 m band, for example, would not get through.

The crystal oscillator

This is an oscillator circuit designed around a quartz crystal (X1), and has a very stable frequency. It produces a single, very pure frequency to feed into the mixer. A crystal having a frequency between 8.800 MHz and 9.000 MHz is suitable for this circuit. The oscillator and mixer functions are both carried out inside IC1.

The first mixer

Yes, this stage 'mixes' two signals together. In this case, the two signals are (i) from the aerial via the RF Filter, and (ii) from the crystal oscillator. Two

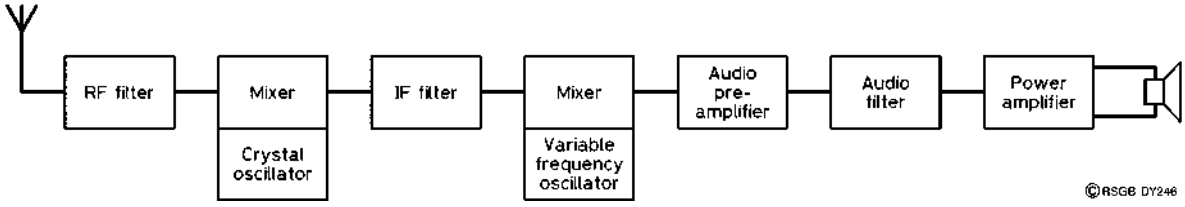

Figure 1 Block diagram of the Yearling, showing how the various stages fit together to make a complete radio receiver

bands of signals emerge from the mixer. The first is centred upon a frequency equal to the incoming signal frequency **added** to the crystal frequency, and the second is centred upon a frequency equal to the incoming signal frequency **subtracted** from the crystal frequency. Look at an example – if the signal is at 14 MHz and the oscillator at 9 MHz, then the mixer outputs will be 14 + 9 = 23 MHz and 14 – 9 = 5 MHz.

Intermediate frequency (IF) filter

It is the purpose of the IF filter (centred around L2) to select only one of these two bands of frequencies emerging from the mixer. In this case, it is the lower band of frequencies (around 5 MHz) which we select. This is because, in general, lower frequencies are easier to handle than higher ones.

Variable-frequency oscillator (VFO)

The VFO (part of IC2) enables us to tune into a particular station, and operates over a band of frequencies between 5 MHz and 5.35 MHz in this receiver. You will notice that IC1 and IC2 are the same type of chip, so that you will be expecting another mixer stage to be associated with the VFO. You are quite right!

The second mixer

This mixer obeys exactly the same rules as those of mixer 1. Sum and difference frequencies are produced, like this. Mixing is between the incoming IF signals (around 5 MHz) and the VFO signals (around 5 MHz), producing output frequency bands centred upon 10 MHz and 0 MHz. The use of the words 'band of frequencies' throughout this explanation is intentional. If all the signals were pure, there would be no bands; the bands are produced because of one thing – the modulation imposed on the pure

frequencies at the transmitter. So, the 'bands' contain the one thing that we want to extract from the signal, and that is the speech or Morse code that the signal contains. The band of frequencies at 0 MHz is just that – the audio frequencies we want in the loudspeaker. Because of this, the audio frequency output of the second mixer is selected and passed on for amplification.

The audio preamplifier

Preliminary amplification of the minute audio signal which emerges from the second mixer is provided by IC4a, which will respond only to audio signals, automatically rejecting the 10 MHz signal.

The audio filter

The bandwidth of normal speech when transmitted by an amateur station is around 3 kHz, so there is no advantage to be gained in amplifying frequencies greater than this. IC4b is known as a low-pass filter, because it passes (lets through) lower frequencies and rejects higher ones.

The power amplifier

IC5 produces the final audio amplification and provides enough power (about 350 milliwatts (mW) to drive a small speaker.

How does it work on 80 m?

If you have fitted the 80 m modification to your receiver, you are probably wondering how the circuit works at this different frequency. Firstly, the filter which you fitted selects the 80 m band instead of the 20 m band. The only other slight difference lies in the way the first mixer stage works. Its job is to produce sum and difference frequencies from the incoming signal and crystal frequencies. On 20 m, it did this by subtracting the crystal frequency (9 MHz) from the incoming frequency (14 MHz) to produce an IF output of 5 MHz. On 80 m, the incoming frequency (3.5 MHz) is subtracted from the crystal frequency (9 MHz) to produce an IF output of 5.5 MHz, which is still within the tuning range of the VFO in the next stage.

73 A field strength meter

Introduction

Having a reliable field strength meter is always useful. There are two basic types – the tuned variety (also known as an absorption wavemeter) and the broad-band variety. A project centred on the tuned variety can be found in this book (*An HF absorption wavemeter*), and the way it works is also presented (*The absorption wavemeter*). This project describes an untuned or broad-band type which is every bit as useful as the tuned type, when it is the level of RF in which you are principally interested.

With the possible exception of the meter, you may have all the parts needed in your junk box. The prototype was distinguished by its meter, found at a rally, and marked 'Safe', 'Dangerous' and 'Explosive' on its scale.

How it works

The basic field strength meter uses the circuit of a crystal set, but with a meter replacing the headphones. A better design, which is used here, is that of a voltage doubler, giving more sensitivity. **Figure 1** illustrates the voltage doubler circuit.

The AC input shown will be our RF input, which will be explained soon. Diode D1 will pass the positive half of the signal and use it to charge up C1 to the peak value of the signal. D2 uses the negative half of the signal to charge up C2 to the same value. Because C1 and C2 are in series, the peak voltage appearing across *both* of them (which is the DC output voltage) is equal to *twice* the peak input voltage, hence the name voltage doubler. If you're wondering why DC is present at the output when AC comes in at the

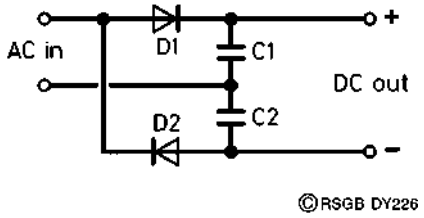

Figure 1 Voltage doubler circuit

input, remember that capacitors pass AC (RF) but block DC; thus the RF is shorted out through C1 and C2, but the steady voltage (DC) remains across the two capacitors. The voltage is thus proportional to the size of the RF signal applied at the input.

The circuit

The voltage doubler is converted into a field strength meter using the circuit of **Figure 2**. A piece of wire serves as the aerial to provide an RF signal across the radio-frequency choke (RFC). A choke is an inductor which is large enough to prevent the RF passing through it – it 'chokes' the RF. This produces the maximum RF signal at the input to the voltage doubler, and the DC output from it is measured on the meter.

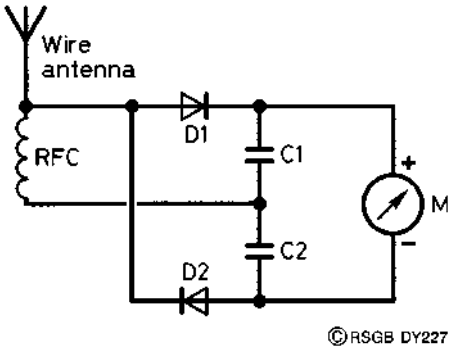

Figure 2 Field strength meter

The parts used are not very critical. The RF choke can have any value between about 1 mH and 2.5 mH. Almost any common diode such as the 1N914 or 1N4148 can be used for D1 and D2. The two capacitors could be any value between 1 nF and 100 nF (0.001 μF and 0.1 μF). The meter should be reasonably sensitive, with a full-scale deflection (FSD) in the range 50 μA to 100 μA. Look for VU meters at rallies – these are ideal.

Construction

The prototype circuit was made on matrix board. If you don't want to use pins with the board, simply push the component leads through the holes and make the connections on the underside of the board, either with the excess component leads themselves, or with ordinary connecting wire.

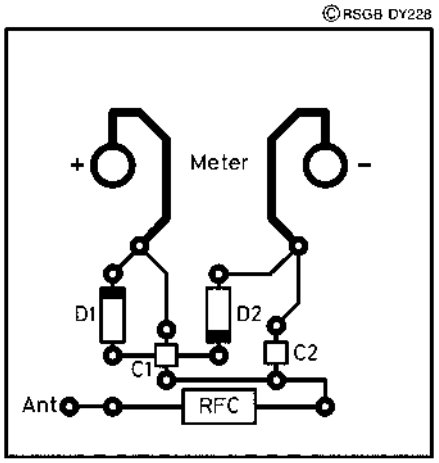

Figure 3 Board layout and interconnections

Figure 3 shows how the parts are placed and connected. The matrix board can be mounted directly on the meter using its terminal bolts!

In use

Needing no power supply other than an RF signal, just connect it all up and leave it to work! A short length of insulated wire is enough to pick up some RF and display it on the meter. Using a 200 μA meter, about 3 metres of wire gave a good deflection on the meter. To increase deflection, the wire can be wrapped around the aerial lead, provided that the wire is PVC covered and doesn't come into contact with the aerial wire.

This requires a little experimentation. Try a long piece of wire first and adjust its position until the meter needle kicks whenever there is a transmission. It is very reassuring to see the meter moving during a transmission. Although SWR meters also indicate power, they are usually set to read reverse power, and show little or no movement during transmission.

Parts list

D1, D2	1N914, 1N4148 or similar
C1, C2	10 nF disc ceramic
RFC	Miniature axial choke (1 mH)
Meter	Surplus VU meter or similar
Matrix board or similar	

Components are available from Maplin.

74 Preselector for a short-wave receiver

Introduction

A preselector is a simple RF tuned amplifier which is inserted between the aerial and the receiver. It provides some extra gain and may improve the overall performance of the receiver. This project uses a Field-Effect Transistor (FET) amplifier in grounded-gate mode.

The design has a tuned circuit at both the input and output which, with excessive gain and poor construction, would produce only one thing – oscillation! So, to avoid this happening, we will have only a low gain, and use a circuit which provides good isolation between input and output. The grounded-gate FET amplifier fulfils both these criteria. It will also cover a frequency range from about 7 to 30 MHz, which includes most of the HF amateur bands.

The circuit

This is shown in **Figure 1**. The signal from the aerial arrives at an RF transformer, the secondary of which is tuned with capacitor VC1a. The output from the tuned circuit is taken from a tap on the secondary to the source of the FET. The gate is grounded (earthed) and the amplified signal appears at the FET drain, which is then fed to the primary of another RF transformer, which is tuned by VC1b. The output to the receiver comes from the secondary of the RF transformer.

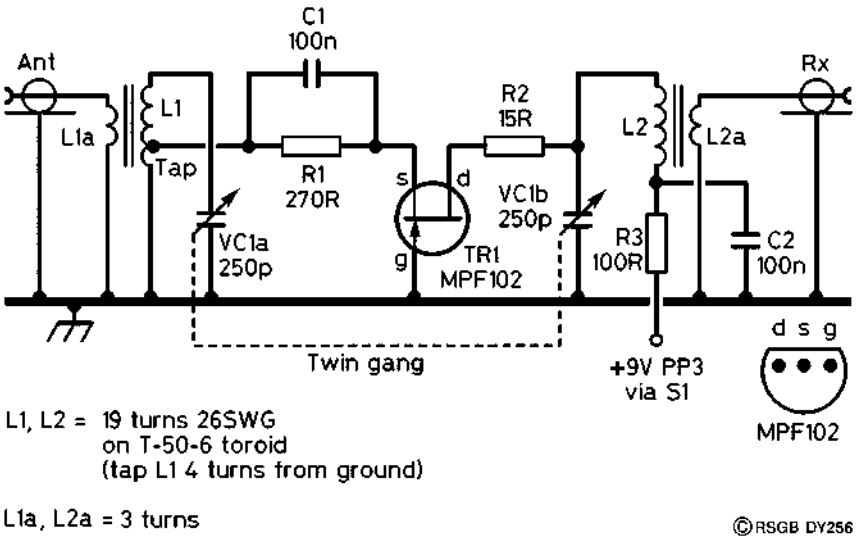

Figure 1 HF preselector, circuit diagram

Notice that the two RF transformers are identical, but they are used 'back to back', with the secondary of the first and the primary of the second being tuned. They are tuned with identical capacitors, fitted on the same shaft of a variable capacitor. We say that the two capacitors are 'ganged'. Because L1 and L2 are the same, and VC1a and VC1b are the same, both RF transformers should be resonant at the same frequency, no matter what that frequency is.

Construction

The final layout should look something like that shown in **Figure 2**. The external connectors and controls being two SO-239 sockets for connection to your receiver and aerial, a tuning control and its associated scale, and an on/off switch.

The circuit can be put together on a plain matrix board, using pins to anchor the components, or simply by pushing the component leads through the board and making connections on the underside. The layout of the prototype is shown in **Figure 3**. Mounting the board to the aluminium box is accomplished with bolts, solder tags and stand-off insulators.

Check your construction against the circuit diagram and against the layout diagram. Wire in the PP3 battery clip, put the switch in the 'off' position, and fit the battery. Testing can be carried out without fitting the top of the box.

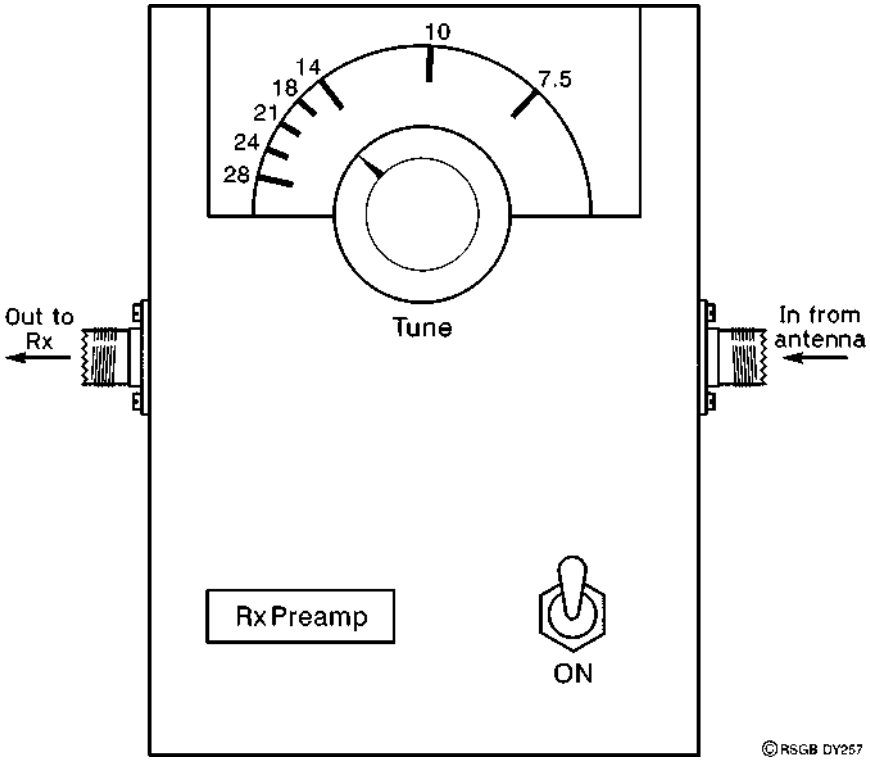

Figure 2 HF preselector, front panel layout

Testing

Don't fit your preselector yet. Tune your radio to a broadcast station, preferably a fairly weak one. Disconnect the aerial and fit your preselector between the aerial and receiver. Switch it on and rotate the tuning knob slowly. You should find a position where your original station is received more clearly than before. If it doesn't work at all, recheck your wiring. Is there a positive voltage on the drain of the FET? If not, work back towards the positive battery terminal. Is there a voltage at the junction of L2 and R2? Is there a voltage at the junction of L2 and R3? Is there a voltage at the junction of R3 and the battery lead? If there isn't a voltage at that point, then you have probably mounted your switch upside down, and it is off, not on! It's a common mistake.

Calibration

This is not obligatory, surprisingly enough. However, if having a frequency scale appeals to you, then using an RF signal generator (or using the services of a friend who has one) is the simplest solution. Feed in a weak modulated

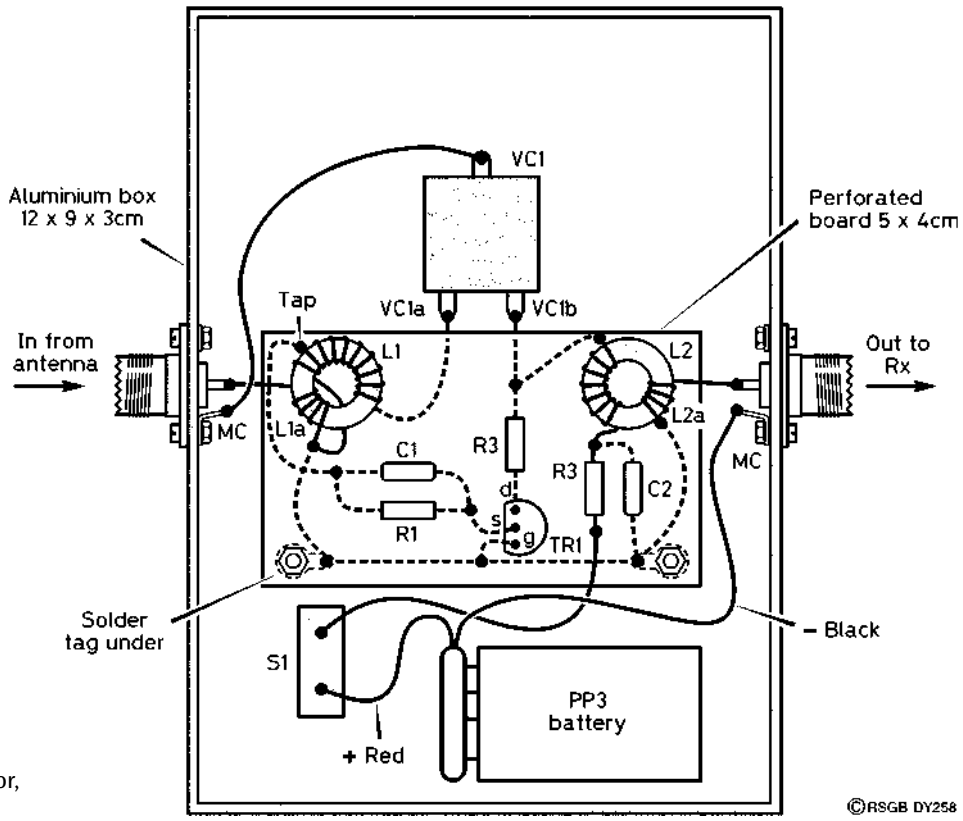

Figure 3 HF preselector, component layout

signal from the generator to the preselector, and rotate VC1 until the signal is maximum. Mark this frequency on your dial. Repeat the process for the frequencies shown on the dial in Figure 2.

If you have a commercial transceiver, feed its output into a dummy load (such as the type described in *A Switched Dummy Load*, elsewhere in this book) using a distinctive modulating signal such as an idling RTTY signal. Set the receiver to the same frequency with the preselector out of circuit. Insert it into the aerial lead, and search for the signal with VC1 until it gives the maximum deflection on your S-meter, then mark the frequency on your dial.

Parts list

Resistors: all 0.25 W carbon film or better

R1	270 Ω
R2	15 Ω
R3	100 Ω

Capacitors

C1, C2	100 nF (0.1 μF) ceramic
VC1	250/250 pF polyvaricon

Inductors

L1, L2	19 turns 26 SWG enamelled copper on T.50.6 toroid L1 has a tap 4 turns from ground end L1a and L2a – 3 turns wound over previous winding

Semiconductors

TR1	MPF102 FET

Additional items

Matrix board	To fit aluminium box (see Figure 3)
Aluminium box	12 × 9 × 3 cm
Battery and connector	PP3 9 V
S1	SPST on/off switch
Knob	As required
SO239	Sockets – 2 required

75 An audible continuity tester

Introduction

This is not the only continuity tester in this book. This alone attests to their use, so you may well want to experiment with several designs, then come up with one of your own! The very simplest form of continuity tester is probably a battery and a bulb in series, with the circuit being closed by connecting it to a fuse or other object being tested for continuity. The bulb could be replaced by a buzzer to give an audible indication. The current taken by the buzzer could damage some components, however. An ohmmeter can also be used, and is very popular for the purpose, as it indicates whether the circuit is low, medium or high resistance. This project has the advantages of indicating whether there is no continuity, some resistance or good continuity, and making an audible sound, so that you don't have to move your eyes from the circuit while making the test.

The circuit

Using only one integrated circuit, four components and a battery, this is a particularly simple circuit, as **Figure 1** shows. IC1 is usually used to flash an LED from a 1.5 V source, and to have a low current consumption. By changing the component values, IC1 is made to oscillate at audio frequencies, and we can hear these through the loudspeaker, LS1. Low-impedance speakers can be used, but result in an increased current drain, so the higher the impedance, the better.

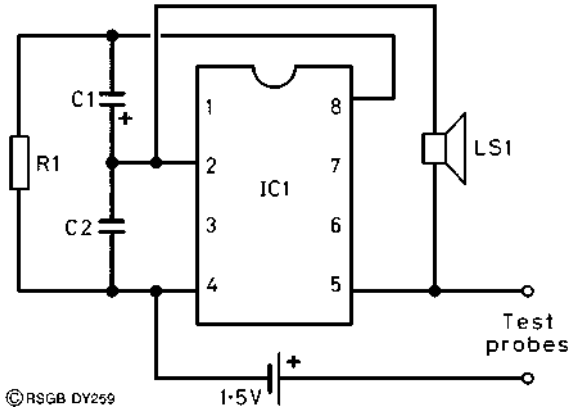

Figure 1 Continuity tester, circuit diagram

Construction

The layout of the circuit on Veroboard measuring 7 strips by 15 holes is shown in **Figure 2**. Start by making the four track cuts which will lie underneath the IC. Use a track cutter or a 3 mm (⅛ inch) twist drill rotated between thumb and forefinger for this. Solder the Veropins in place, followed by the wire link. Then solder in the IC holder, the resistor and the capacitors, making sure that the electrolytic capacitor, C1, is connected the correct way round.

Check, with the board against a bright light, that there are no shorted tracks, either by large blobs of solder or by copper swarf from the track-cutting process. Then insert IC1 into its holder the right way round. The probes can be ordinary connecting wire, the free ends being tinned with solder to prevent wire whiskers from touching components other than the one you are testing.

If you are happy that the circuit and the wiring appear to be correct, fit the battery into its clip. Nothing should happen until the probes are touched together, when you should hear a note from the loudspeaker. If nothing happens, all you can do is to recheck your circuit, as there is nothing else to go wrong!

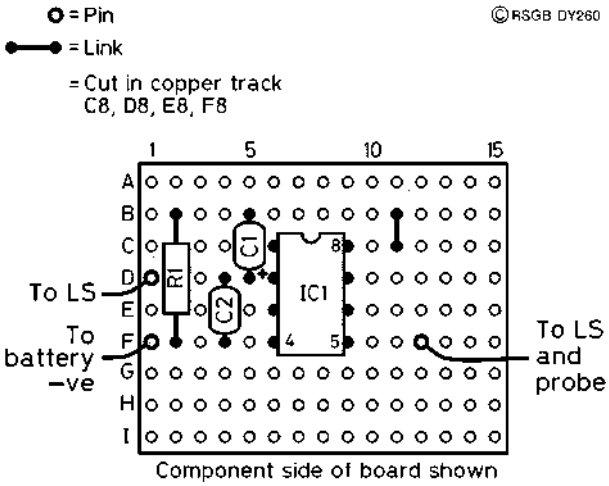

Figure 2 Continuity tester, component layout

Any box can be used; there is no justification for a metal case, unless you want to make use of something, which is to hand, such as a tobacco tin. Alternatively, any suitable plastic box will do.

Use

The tester will give different pitch notes for resistances of different values. The higher the resistance, the higher the pitch from the speaker. Try it with small inductors, and you will learn to recognise the different tones produced by the IC.

Safety notice

Using the continuity tester on components *in situ* is not advisable, as the results could be misleading. It can be dangerous to make measurements *in situ* on equipment, which is operating. If you must make such tests, always disconnect the equipment form its power source first.

Parts list

Resistor

R1	1000 Ω (1 kΩ), 0.25 W carbon, 10% or better

Capacitors

C1	10 μF electrolytic, 16 V
C2	0.1 μF subminiature polyester or ceramic

Integrated circuits
IC1 LM3909N

Additional items
Veroboard 7 strips by 15 holes
LS1 64 Ω miniature loudspeaker
IC holder
Veropins
Connecting wire
Test leads
1.5 V AA alkaline battery

76 An experimental 70 cm rhombic aerial

Introduction

Most commonly used aerials can be classed as *resonant* or *standing-wave* aerials. There is another class known as *non-resonant* or *travelling-wave*. Resonant aerials, such as the dipole, are narrow-band; this occurs because resonance occurs only over a narrow band of frequencies. Travelling-wave aerials, on the other hand, can operate over a wide band of frequencies.

The *rhombic* is an example of a non-resonant or travelling-wave aerial. It is often employed for fixed commercial and military short-wave radio links. Made with wire, it has a diamond shape when looking down on it from above. The four corners are supported on four masts. It is a very effective aerial, and has good gain, a quality which can be judged from the *polar diagram* shown in **Figure 1**. This has been obtained from a computer program, and so is the perfect shape for a rhombic aerial.

Theory (but only a little)

A polar diagram shows graphically the ability of an aerial to radiate (or receive) more effectively in one direction at the expensive of the radiation in other directions. Figure 1 shows the polar diagrams of two aerials, a simple 70 cm dipole and the rhombic described in this project. The dipole has the

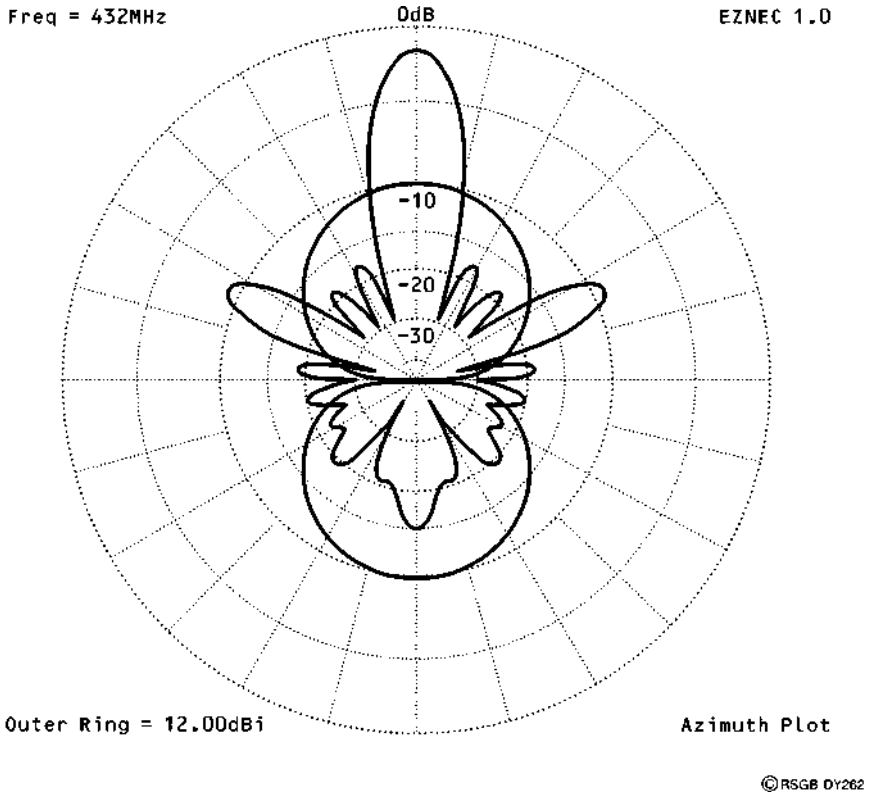

Figure 1 The horizontal polar diagrams of the small rhombic antenna and a dipole compared

well-known figure-of-eight shape, showing a symmetrical angular behaviour about the direction of the aerial and about a direction perpendicular to the aerial. That of the rhombic, on the other hand, is quite irregular by comparison, but is still symmetrical about one axis only, not two. It's this asymmetry that gives the rhombic its gain, by virtue of its *front-to-back ratio*. This is the ratio of the power radiated forwards to that being radiated backwards. Notice the large *lobe* (lump) at the top of the polar diagram; this is the direction in which the aerial transmits best. The lobe in the opposite direction has been reduced significantly, allowing more power to be directed forwards, not backwards

Problems

The rhombic is not found in every amateur's back garden, despite its attractions. To work best each edge of the diamond shape should be about two wavelengths long. Hence, a rhombic for the 20 metre band could be about 80 m from tip to tip! Another disadvantage is that, because of its size, it cannot be rotated.

It will operate well over a range of frequencies. An HF rhombic could work on the 7, 10, 14, 18, 21 and 28 MHz bands. One for the lower VHF frequencies could operate on the 50, 70 and 144 MHz bands.

Its large size is less of a problem at UHF. A portable rhombic can be made for 70 cm which can be used with a hand-held transceiver. The aerial design to be described here will give a gain of up to 9 dB relative to a dipole. This is written as 9 dBd, the second 'd' meaning 'relative to a dipole'. This is equivalent to improving your signal by 1.5 S-points at the receiver or (and you may be surprised by this) by fitting a linear amplifier to your transceiver that would take 5 W input and produce 40 W output to a normal dipole! Consider the relative costs of the two approaches to producing the same received signal. You will also receive everyone else's signals 1.5 S-points better than before!

Unlike the popular Yagi aerial, this design has no critical dimensions and can be folded up for transport by car or bicycle. It has a fairly high input (or feed) impedance, being fed usually by balanced twin feeder. To feed it with standard 50 Ω coaxial cable, a matching transformer in the form of a *balun* is required. A balun will convert the *bal*anced (symmetrical) aerial impedance to the *un*balanced and lower impedance of the coaxial cable. The details of how to build the balun, which in this case is a half-wave transformer, are included in the constructional details.

Construction

The aerial frame is made up of 1 cm × 2 cm strips of wood fixed to a plywood centre using 30 mm long M4 bolts, as shown in **Figure 2a**. The outer bolts fixing the front and side supports can be removed for folding prior to transportation, as shown in **Figure 2b**.

The wires are fixed to the front and rear supports using screw connectors, sometimes called 'chocolate block' connectors. Detail X and Y of Figure 2 show how this is done. The side supports have holes in the ends through which the wire is threaded.

The aerial must be mounted in the horizontal plane using a small shelf bracket attached to the centre plate, using the same bolts that hold the rear support. The other half of the bracket may be mounted to a vertical mast using screws or jubilee clips (hose clips).

The balun

Cut a 23 cm length of coaxial cable; this is to be our half-wave transformer. Cut and remove 2 cm from each end of the sheath. Make the braid into a pigtail at each end. Cut and remove 1 cm of the inner insulator from each

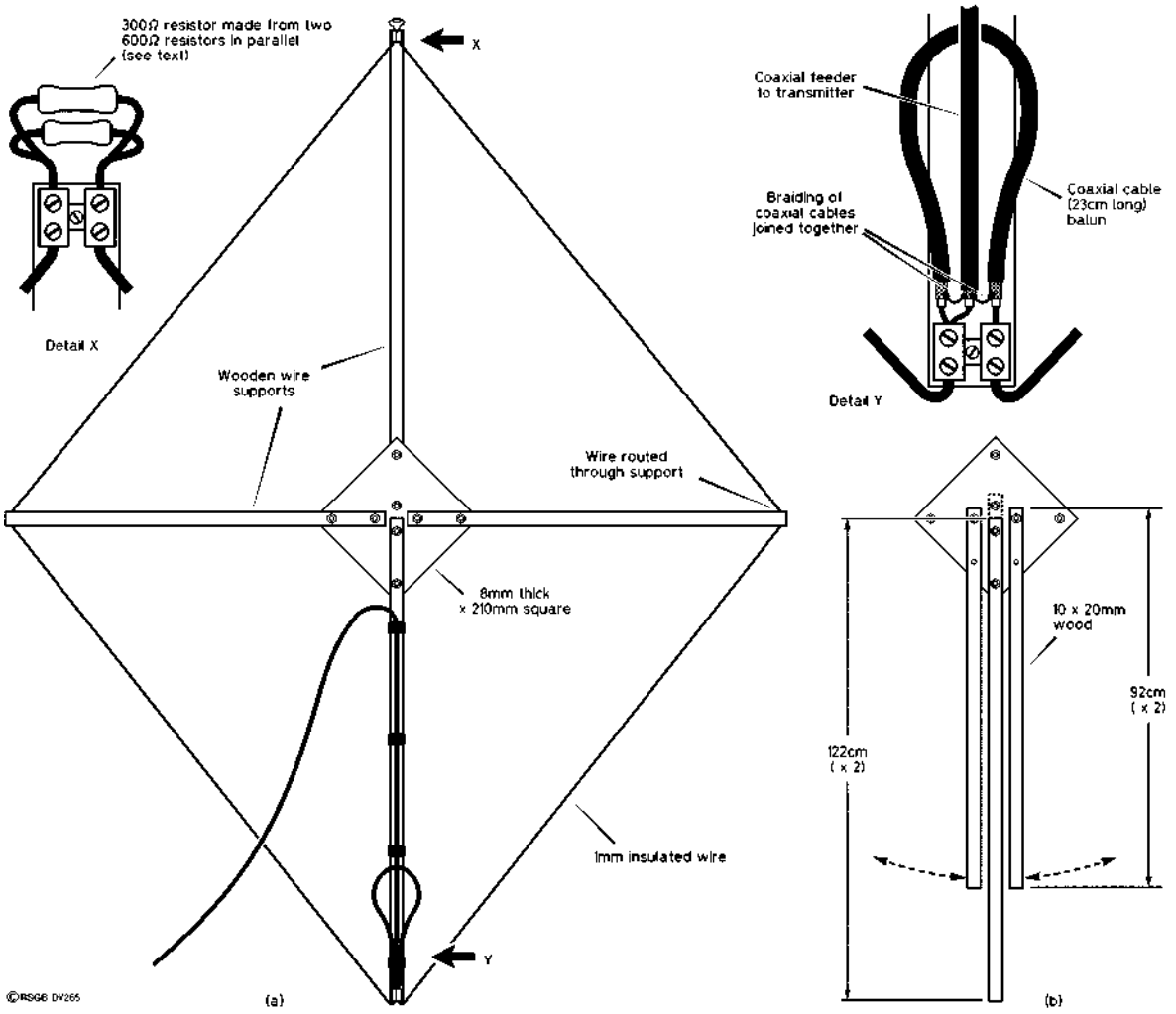

Figure 2 Construction of the UHF rhombic antenna

end, leaving 1 cm of the centre conductor exposed. Fasten this piece of cable to the chocolate block connector together with the coaxial feeder cable as shown in Detail Y of Figure 2. The braids of all three prepared ends are soldered together, but are not connected to anything else. The inner conductor of the feeder from the transceiver is soldered to one end of the centre conductor of the 23 cm piece, and is connected to one end of the rhombic by one side of the chocolate block. The other end of the half-wave transformer also goes to the chocolate block, where it is connected to the other side of the rhombic loop.

The opposite corner of the rhombic, as shown in Detail X of Figure 2, shows that the loop is broken at the chocolate block, and is 'terminated' by two 600 Ω resistors in parallel. This makes the aerial a broad-band travelling-wave device, and gives it its directivity and gain. There is a rule of thumb, which includes a safety factor, which says that the terminating resistor must be able to absorb one-half of the maximum transmitter output power. So, if you use two 2 W 600 Ω carbon resistors (*not* wire-wound resistors) in parallel, you can use a transmitter with an output of 8 W, which is more than adequate for 70 cm hand-helds.

Using the rhombic

Fit the aerial to a pole or mast in the horizontal plane, if you intend to use CW or SSB, but in the vertical plane if you want to concentrate on FM work. In the latter case, a wood or fibreglass pole is mandatory. Tune to a local repeater, whose signal strength you know. Rotate the aerial to face the repeater, and you should see that the signal strength is greatly improved! Verify the directional properties of the aerial by rotating it and observing the changes in signal strength on your S-meter.

77 Water level alarm

Introduction

This is a simple device which, when you have built it, you begin to wonder how you ever managed without it! It will sound a buzzer when the level of water reaches a particular point, which you can set and vary at will.

Detecting water

Water is not too difficult to detect electrically, because it is a conductor of electricity. Not a good one, but sufficiently so to carry enough current to control a warning circuit.

The circuit is shown in **Figure 1**. If you imagine a resistor placed between the ends marked 'water detector', the circuit is then recognisable as a transistor used as an electronic switch. Whether the switch is off or on depends on the value of this resistor. If the resistance is low, the transistor switches on and the buzzer sounds. If the resistance is high, the transistor switches off and the buzzer stops.

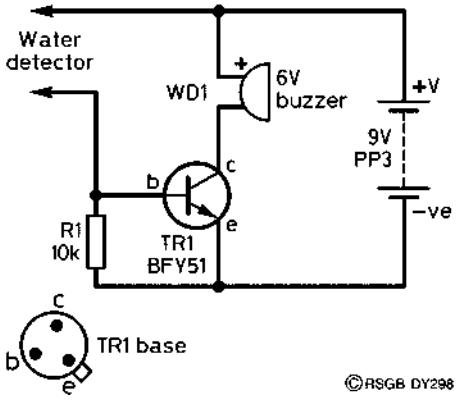

Figure 1 Circuit diagram of the water level detector

Construction

The unit is made in two separate sections – the detector board (**Figure 2**) and the main board (**Figure 3**). The main board is plain perforated board (without copper strips). The components are pushed through holes in the main board and connected together on the underside. The battery is held on with sticky tape. No on/off switch is used, as the circuit consumes virtually no current when it is not sounding the buzzer.

Unlike some buzzers, this type is polarised, and the red lead must go to the supply as shown in Figs 1 and 3.

The detector board is a piece of standard matrix board – the type with copper strips along one side. It measures 9 strips by 15 holes, and is wired in such a way that alternate strips are connected together, as Figure 2 shows. This gives a greater surface area for the water to touch, thus increasing the sensitivity of detection.

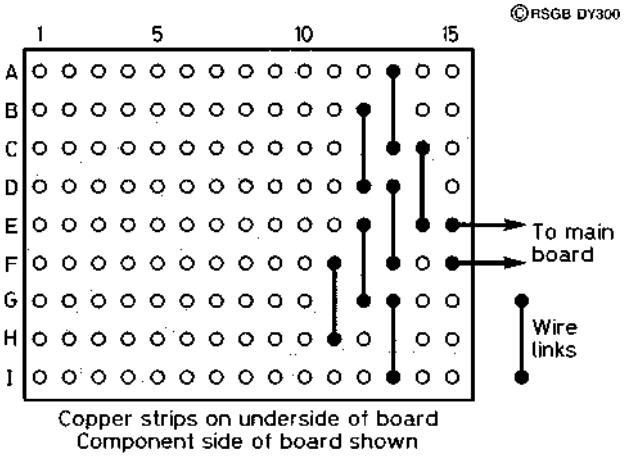

Figure 2 Layout of the main board

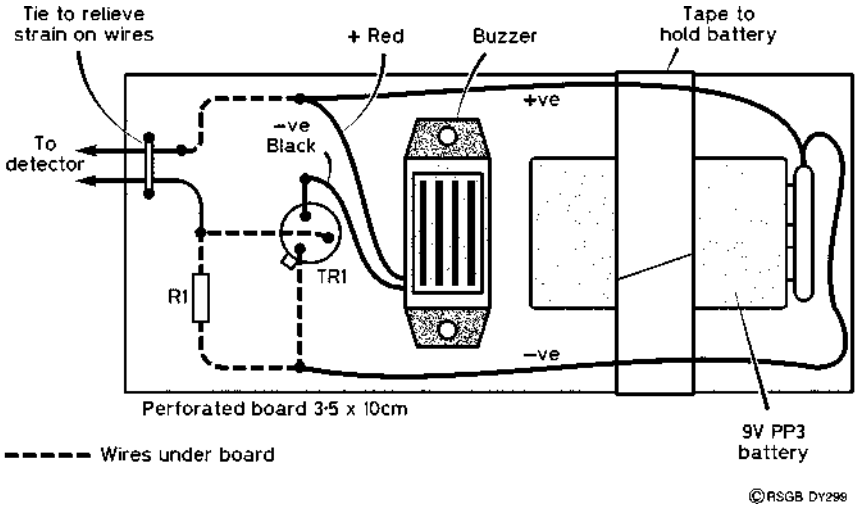

Figure 3 Water detector constructed from stripboard

The two boards are connected by ordinary twisted pair, enabling the detector to hang over the edge of the water container, with the buzzer circuit safely out of the way. When positioning the detector board, the left-hand edge (as shown in Figure 2) should face downwards, with the connecting-wire edge facing upwards. When the water level rises, the water causes current to flow between adjacent strips, and the higher the water, the lower the resistance between them. Eventually, the resistance will be low enough to turn on the transistor and sound the alarm.

Parts list

Resistor

R1	10 000 Ω (10 kΩ), 0.25 W

Semiconductor

TR1	BFY51

Additional items

WD1	6 V miniature buzzer (polarised)
	Battery PP3
	Battery connector
	Strip board 9 strips by 15 holes
	Perforated board 3.5 × 10 cm

78 A delta loop for 20 metres

Introduction

HF aerials take up a lot of room when they are straight. Space can be saved by bending them and, at the same time, giving them properties which are quite different from their original linear forms. The delta loops shown in the accompanying diagrams have the shape of the Greek upper-case letter delta (Δ) upside down. It can be upright, except that it is more practical to have the feed point at the bottom than at the top.

Putting the loop together

This is the design for a loop to be used on the 20 metre band. It is a very popular band and carries most of the amateur radio DX traffic. The aerial is light in weight and operates best if the top section is at least 30 ft above the ground, with the feeder point being about 6 ft above ground. All you need is some good wire, some polypropylene rope, some insulators and a method of matching the output of this 75 Ω balanced aerial to the 50 Ω unbalanced coaxial input of your transceiver or receiver.

Each of the three sides must be 7.2 m long. Using tent pegs or six-inch nails, mark out the three corners on the lawn, making sure that each pair of pegs or nails is exactly 7.2 m apart. Put the wire around the nails, together with two insulators on the wire for the two top corners. These insulators can be of the 'dog bone' variety, or of the home-made type, using a piece of flat plastic with holes in each end. The use of these is shown in **Figure 1**. Located at the positions of two of the tent pegs or nails, they must be secured at those points by any convenient means.

Now attach a support rope to the free end of each of the insulators, ready for suspension, as shown in the diagrams, from any convenient supports (house, tower, tree, etc.). The top section of the loop could be taped to a continuous piece of rope between the two supports. You might like to try this if you think it is easier. Then, when you find some dog-bone insulators, you can change the design and see if there is any noticeable change of performance.

Connecting to the radio

If you are the proud possessor of an aerial tuning unit (ATU) with a balanced output, all you will need is a length of twin cable soldered to the

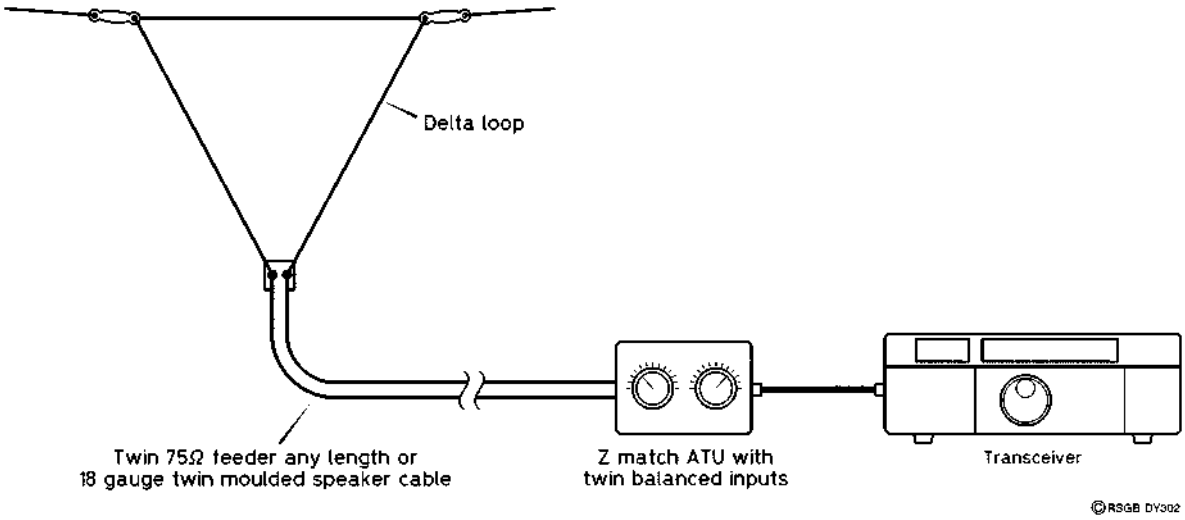

Figure 1 Multiband version of the delta loop connected to the ASTU using 75 Ω twin feeder

ends of your delta loop and connected to the balanced output terminals on the ATU, as Figure 1 shows.

Another way is to buy a ferrite-cored 1:1 balun, and use it as indicated in **Figure 2.** This produces an aerial which will operate over the whole range of amateur and commercial short-wave frequencies, when used with an ATU.

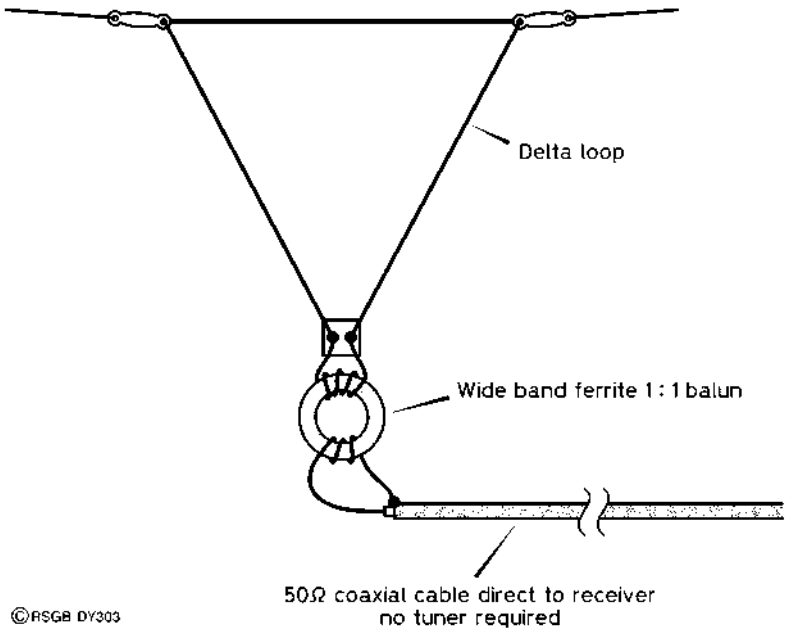

Figure 2 Multiband version of the delta loop using 75 Ω coaxial cable. This arrangement requires an ASTU if used with a multiband antenna

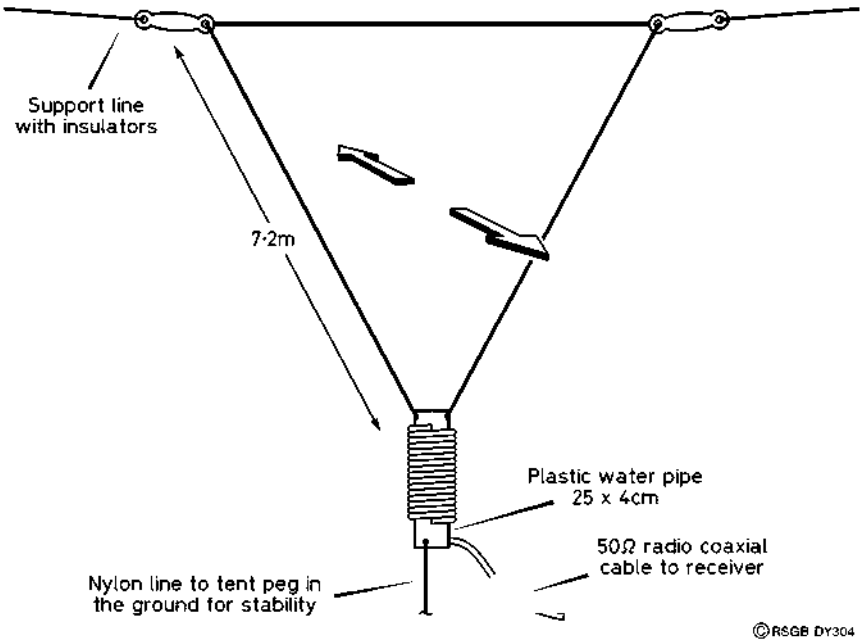

Figure 3 Single band version of the loop antenna using a coaxial balun. The direction of maximum signal strength is indicated by the arrows

However, since this aerial is designed to be a single-band type, there is a simpler answer to the problem of matching the aerial to your 50 Ω coaxial cable – **Figure 3** shows this. Make a tuned balun with a length of plastic water pipe, 25 cm long and 4 cm diameter and a piece of good-quality TV aerial cable. TV aerial cable has a characteristic impedance of 75 Ω, compared with the 50 Ω of the coaxial feeder that we usually use with amateur radio equipment. Use the type with a brown sheath and a closely knit earth braid, not the type having an earth foil inside the sheath.

The length we need for the balun is 3.8 m, but always allow between 3 and 4 cm extra for preparing the ends. Drill two small holes diametrically opposed in the top of the tube; these will be used to anchor the two ends of the delta loop, as shown in Figure 3. Drill another single hole in the bottom end of the tube, which will be used to anchor a nylon line going to the ground to add stability to the loop. Then, after drilling a pilot hole, drill a 5 or 6 mm hole near the top end of the tube, as shown in **Figure 4**. Prepare both ends of the coaxial cable, then feed one end into the tube, far enough for its ends to be soldered to the ends of the loop when the assembly reaches that stage.

Now, close-wrap the cable around the tube until only about 3 cm remain. Holding the cable tightly, drill another 6 mm hole beside the free end of the cable and feed it into this hole. At this point, feed the two ends of the loop into the top two holes and twist it back on itself. Figure 4 shows how this is done. Then, solder the ends of the coaxial balun to the ends of the loop.

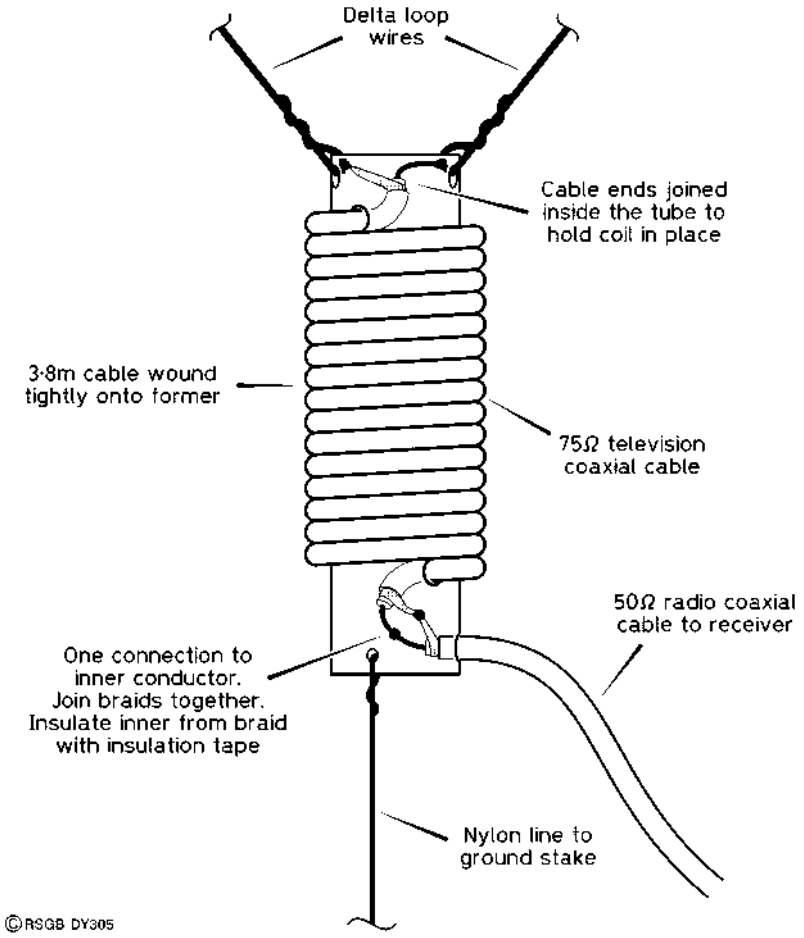

Figure 4 Construction of the balun

The bottom ends of the balun are then soldered to the 50 Ω coax which goes to your shack and to the transceiver.

Hoist the aerial into position carefully, being careful not to pull too hard on the support lines. Then, take the nylon line from the bottom of the balun to a peg in the ground. This adds stability to the aerial.

Using the delta loop

It is a directional aerial, as Figure 3 shows. It produces maximum power (and has maximum receive sensitivity) along a direction perpendicular to its own plane. Don't be too concerned with which direction it is pointing at first. Give it a try 'on the air' and see how it performs. Then you can contemplate how to point it in your favourite direction, to the USA, or Australia, for example.

Experimenting

You may want to enclose the balun in some sort of weatherproof container. Plastic ice cream containers are favourites for this sort of job. Seal all the holes where wires enter it with silicone sealant or self-amalgamating tape.

If you have used ordinary single-strand or multi-strand wire for your aerial, it will stretch over time under its own weight and that of the balun. Its operating frequency will fall slightly as a result. If you notice a significant difference, then dismantle it, remeasure and fix the sides and erect it again, perhaps facing a different direction. You can buy pre-stretched or hard-drawn wire for such purposes, if you feel that periodic tweaking of your aerial is a chore.

You can make a delta loop for different frequencies simply by scaling the lengths of wire for the loop and for the balun according to the design frequency. If your maths isn't quite up to this, enlist the help of someone well versed either in maths or aerial design!

79 A simple desk microphone

Introduction

A hand-held transceiver is usually the first type used by most novices. It is ideal when used out of doors, in the shack or mobile. However, using one in the shack with an outside aerial is not the best of solutions.

This article describes the design of a desk microphone which can be used either for transceivers using a common microphone and push-to-talk (PTT) line, or for those using a separate PTT line.

It is a simple design, using the barrels of two plastic pens, the lid of an old coffee jar, and the plastic sheath of a DIN plug.

Construction

The end caps and the ink tubes should be removed from two ball-point pens, leaving only the two plastic shells. One of them is used for the vertical microphone support, while the other is used to hold the microphone element.

The vertical support should have the pointed end shaped so that it holds the microphone support at a convenient angle, as **Figure 1** shows.

The base should be prepared next – see **Figure 2**. Four holes are required. Two, A and B, are small holes for the cable to be fed through. A third, C, is slightly larger and is used to take one of the plastic end caps. The fourth hole, D, is determined by the type of switch that you want to use for the PTT function.

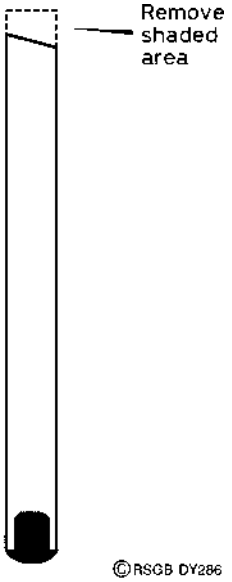

Figure 1 Vertical support made from ball-point pen shell

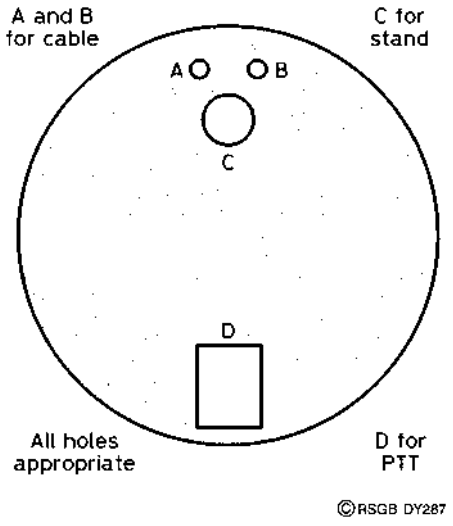

Figure 2 The microphone stand base

Some epoxy resin such as Araldite Rapid is used to mount the separate parts. Mix only a small amount at a time, and glue each part of the base assembly and allow to harden before moving on. Be sure to read and follow the instructions for the use of the glue to prevent accidents.

Firstly, glue the end cap to the base, feeding it underneath and pushing it up through hole C. Then, the vertical pen body is placed over the protruding end cap and glued into place, making sure that the top (shaped) end is pointing in the right direction to hold the other plastic tube carrying the microphone. While the glue hardens, place the DIN plug sheath on the second pen body. Place and glue this pen body on the shaped top of the vertical support, making sure that the whole assembly is supported while the glue sets. What you should have now ought to resemble **Figure 3**, but without the microphone and wiring. Leave everything to set for 24 hours.

Any switch of the press-to-make variety can be used for your PTT switch, but choose one which does not apply too much force to operate! If you find the whole assembly is too light and slides over your table, some plasticine can be pushed into the base when all the wiring has been completed.

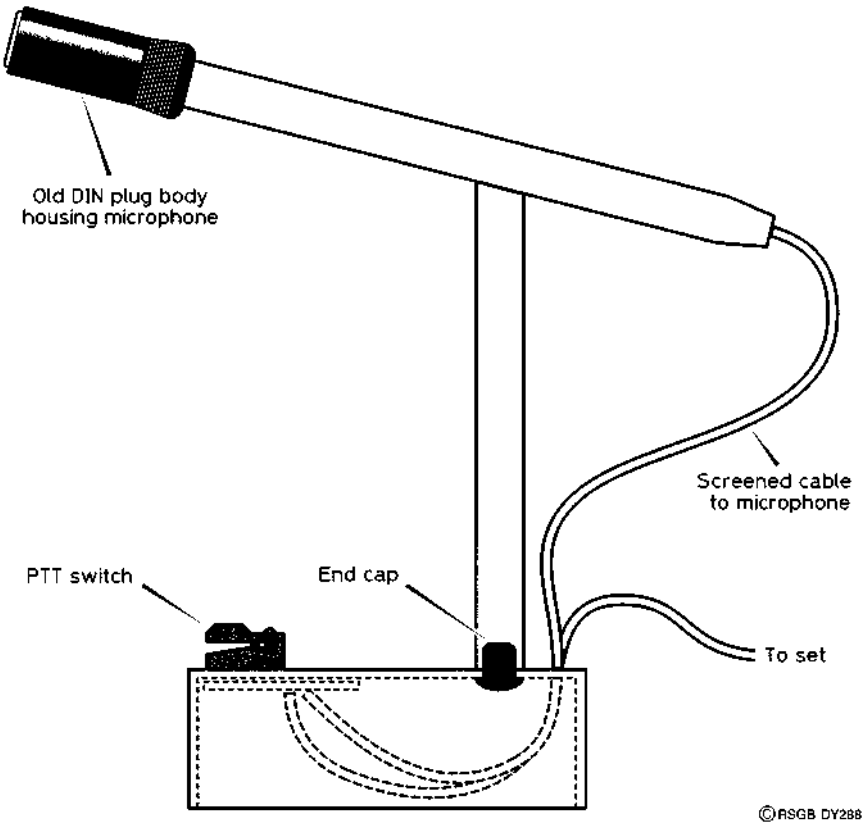

Figure 3 Complete microphone stand assembly

The circuit

A small electret condenser microphone is used, powered by a DC supply. Most hand-held radios use a single screened lead for both the PTT line and the microphone audio lead. In such cases, the circuit of **Figure 4** will operate the PTT function. Note that the PTT switch is in series with the audio lead from the microphone. If you find that the PTT switch does not switch your radio into transmit, reduce R1 from its normal value of 33 kΩ to 27 kΩ. You should find that the original value works with most hand-helds.

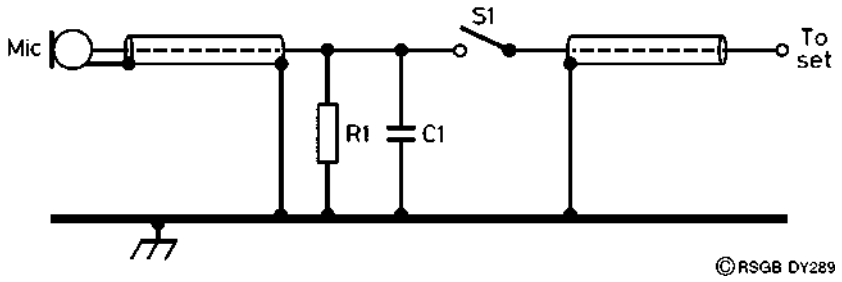

Figure 4 Wiring diagram for hand-held radios

For radios with a separate PTT lead, the circuit of **Figure 5** is used. However, a power supply is needed for the electret microphone. This can be a PP3 battery, or can (in most cases) be derived from the microphone socket on the transceiver. You will need to consult the makers' handbook for this information. Figure 5 shows the PTT switch wired in a 'ground-to-transmit' configuration, which is correct for most base-station transceivers. If you're in any doubt about what your radio needs, consult an experienced friend.

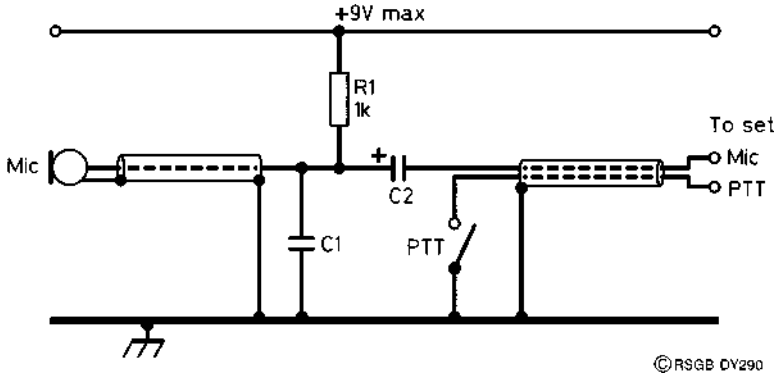

Figure 5 Wiring diagram for radios which use separate PTT lines

The last connections

The microphone element should be connected with screened cable. Tape (masking or insulating) should be wound around the electret insert until it is a snug fit inside the DIN plug sheath. Feed the screened cable through the barrel of the pen until it emerges from the far end. Poke it through hole B and make the connections under the coffee jar lid. The components can all be mounted on the PTT switch or on a small piece of Veroboard mounted under the top surface. The output lead emerges through hole A and is of sufficient length to reach your transceiver. A suitable plug needs to be fitted to it.

Parts list

Resistors: all 0.25 W carbon, 5% tolerance

R1 (Figure 4)	33 000 Ω (33 kΩ)
R1 (Figure 5)	1000 Ω (1 kΩ)

Capacitors

C1 (Figure 4 and 5)	0.1 microfarads (0.1 μF) disc
C2	10 microfarads (10 μF) electrolytic

Additional items

S1	Push-to-make
Mic	Electret microphone (Maplin type FS34W)
Screened cable	As required
Plug	As required by your radio
Veroboard	If required
PP3 battery and clip	If required

Two old plastic ball-point pens
Lid of coffee jar
Plastic sheath from DIN plug
Araldite or similar epoxy resin glue

80 Morse oscillator

Introduction

This is not the simplest Morse oscillator to build, but it differs from the simple circuits in that it produces a pure note, not a coarse, rasping sound. People who have practised Morse using a non-sinusoidal oscillator sometimes find that they have trouble copying Morse code with a pure tone. As the pure tone is the correct way to receive Morse code, it is important that you should learn to listen to the code from a pure oscillator – so here's one!

The twin-T

There are many oscillator circuits, and there are many variations of the twin-T oscillator that we are going to use. **Figure 1** shows one version of a very useful circuit. All oscillators must have positive feedback in order to work. The feedback determines the frequency of the note produced by the oscillator.

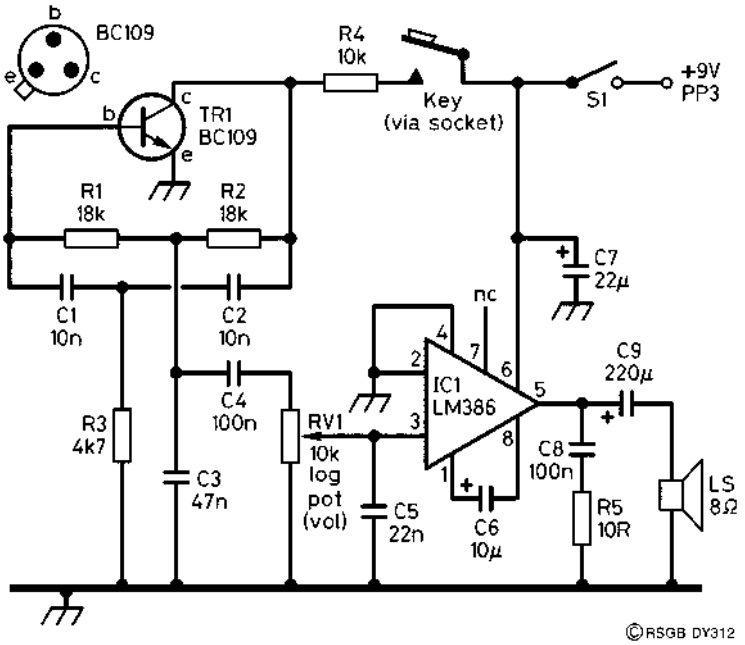

Figure 1 Circuit diagram of the sinewave oscillator and amplifier

Here, the feedback circuit looks like two letter Ts. If you look at Figure 1, one T is formed by R1, R2 and C3, the other by C1, C2 and R3 – hence the name 'Twin-T'. Notice that the two Ts are connected in parallel between the collector and base of TR1, so any signal appearing at the collector is fed into both Ts. What emerges is then fed back into the base, producing in turn a signal at the collector. And so it goes on, producing a sine wave output.

The oscillator output is fed into an integrated circuit amplifier for output via a small loudspeaker.

Putting it together

The prototype was constructed on plain matrix board (the type *without* the copper strips), as shown in **Figure 2**. The components have their leads pushed through the holes in the board, and connections are made underneath.

Build the amplifier circuit first, using a socket for IC1. Connect the 9 V supply and touch pin 3 with an ordinary piece of wire. If a buzz is heard from the speaker, all should be well. If not, check your circuit and make changes until it does.

Build the oscillator circuit, and connect its output to the volume control VR1 via C4. Set VR1 half-way along its travel and switch on. A note should be heard from the speaker when the Morse key is depressed. The component values making up the twin-T determine the frequency of the note. Try varying them if you think your note is too high or too low. Whatever changes you make, either to the resistors or the capacitors, always ensure that R1 = R2 and that C1 = C2.

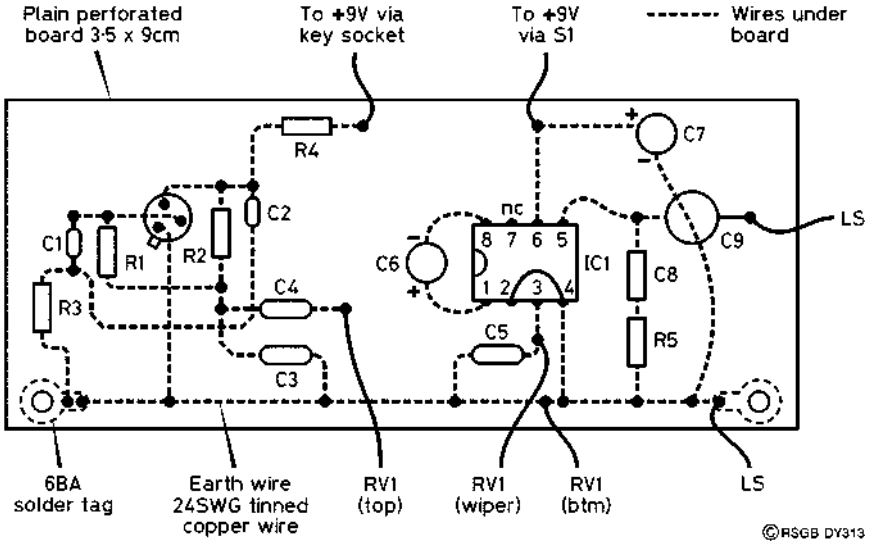

Figure 2 Component layout and interconnection diagram

Parts list

Resistors: all 0.25 W carbon film

R1, R2	18 000 ohms (18 kΩ)
R3	4700 ohms (4.7 kΩ)
R4	10 000 ohms (10 kΩ)
R5	10 ohms (10 Ω)

Capacitors

C1, C2	10 nF (0.01 μF)
C3, C8	47 nF (0.047 μF)
C4	100 nF (0.1 μF)
C5	22 nF (0.022 μF)
C6	10 μF electrolytic, 16 V WKG
C7	22 μF electrolytic, 16 V WKG
C9	220 μF electrolytic, 16 V WKG

Semiconductor

TR1	BC109

Integrated circuit

IC1	LM386

Additional items

VR1	10 kΩ log potentiometer with switch
LS	8 Ω loudspeaker

Matrix board 3.5 × 9 cm
Small jack socket for key input
Box
PP3 battery and clip

81 A simple 6 m beam

Introduction

The attraction of building your own aerials is an abiding feature of our hobby. You can *buy* almost any shape or size of aerial, but one you have made yourself can often work every bit as well as a commercial device costing ten times as much.

The design

This aerial, designed for use on the 6 m band, is essentially a two-element Yagi, with the elements bent in order to reduce the physical size. It is known

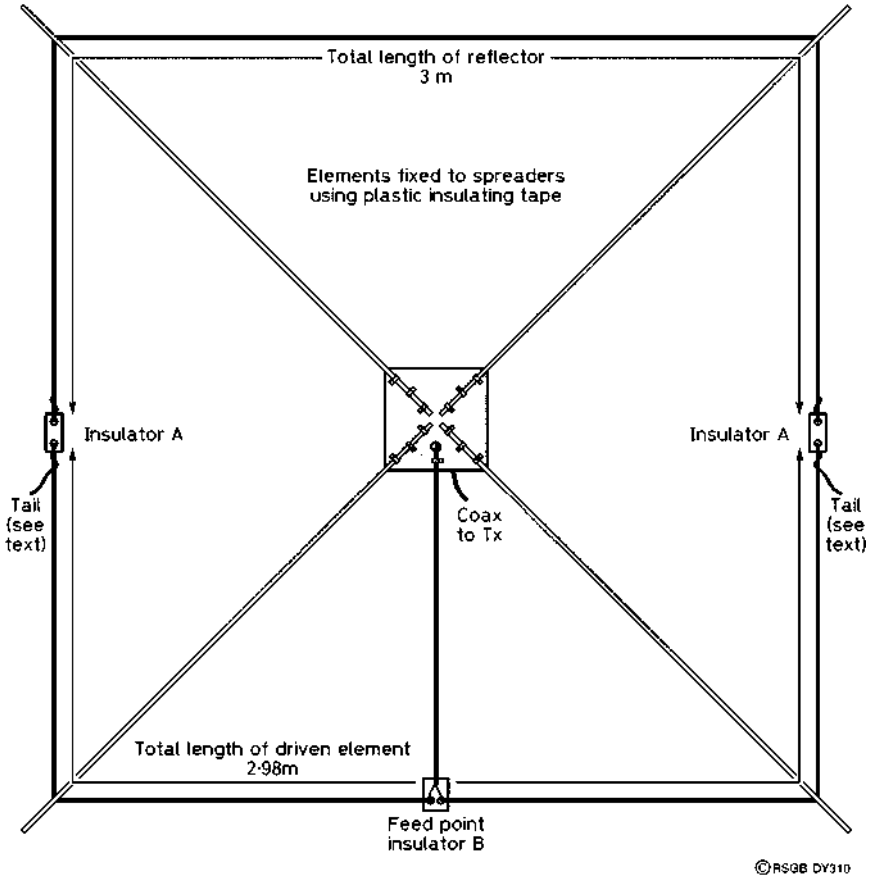

Figure 1 Plan view of the complete 50 MHz VK2ABQ antenna

as the VK2ABQ beam, and was designed originally for the 20, 15 and 10 m bands, principally because of its space-saving qualities. It is made using a wooden frame and wire elements, and is ideal for portable operation.

Tools ready?

The beam is shown in **Figure 1**. The driven element is the one whose centre is fed by the coaxial cable, and lies between the two insulators marked A and the feedpoint at B. The reflector is also anchored at the points A, and lies over the upper half of the frame.

The wooden centrepiece is used to support the cross-pieces and to mount the aerial on the mast, using a common shelf bracket. The cross-pieces, known as *spreaders*, can be wooden canes or dowelling, and are mounted to the centrepiece using cable clips and adhesive. **Figure 2** shows how this is done.

If the aerial is to be a permanent installation, the spreaders should be weatherproofed using a good-quality exterior varnish. The wire elements are PVC covered and fed through holes in the spreaders.

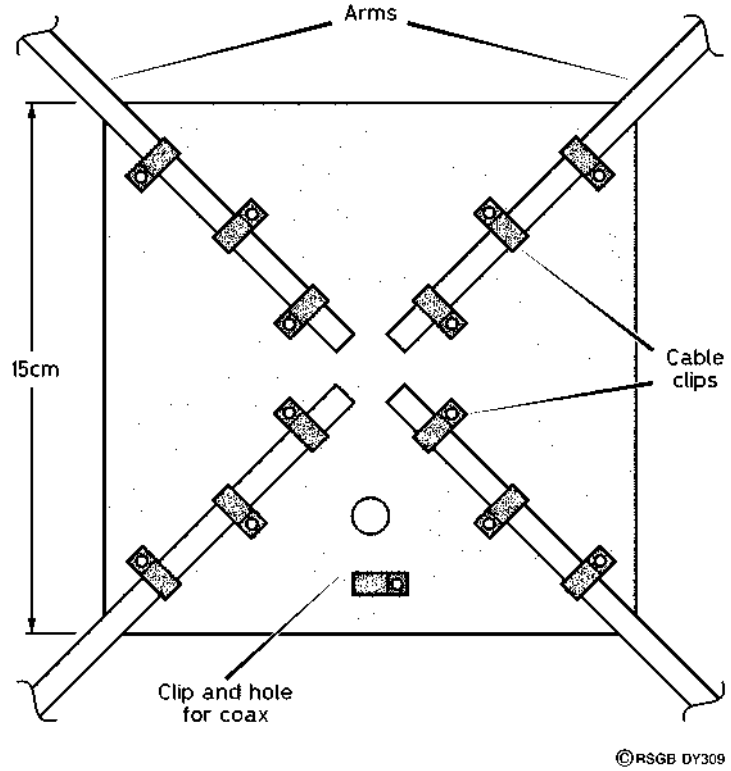

Figure 2 Centre support piece

The end insulators are made of drilled perspex, and the wire passed through the two holes and twisted, as shown in **Figure 3**.

Note: if you have not drilled holes in perspex before, take care! The drill bit must be well-lubricated because it generates a lot of heat (enough to melt the perspex and jam the drill). Never turn the drill for more than a few seconds at a time, and moisten the bit in between. Start with a pilot hole and use bits of increasing size until the hole is the size you want.

Another perspex insulator is used to secure the feeder to the aerial, as shown in Figure 3. The feeder then passes directly to the centrepiece, where it is fastened with a cable clip and then passes down the mast.

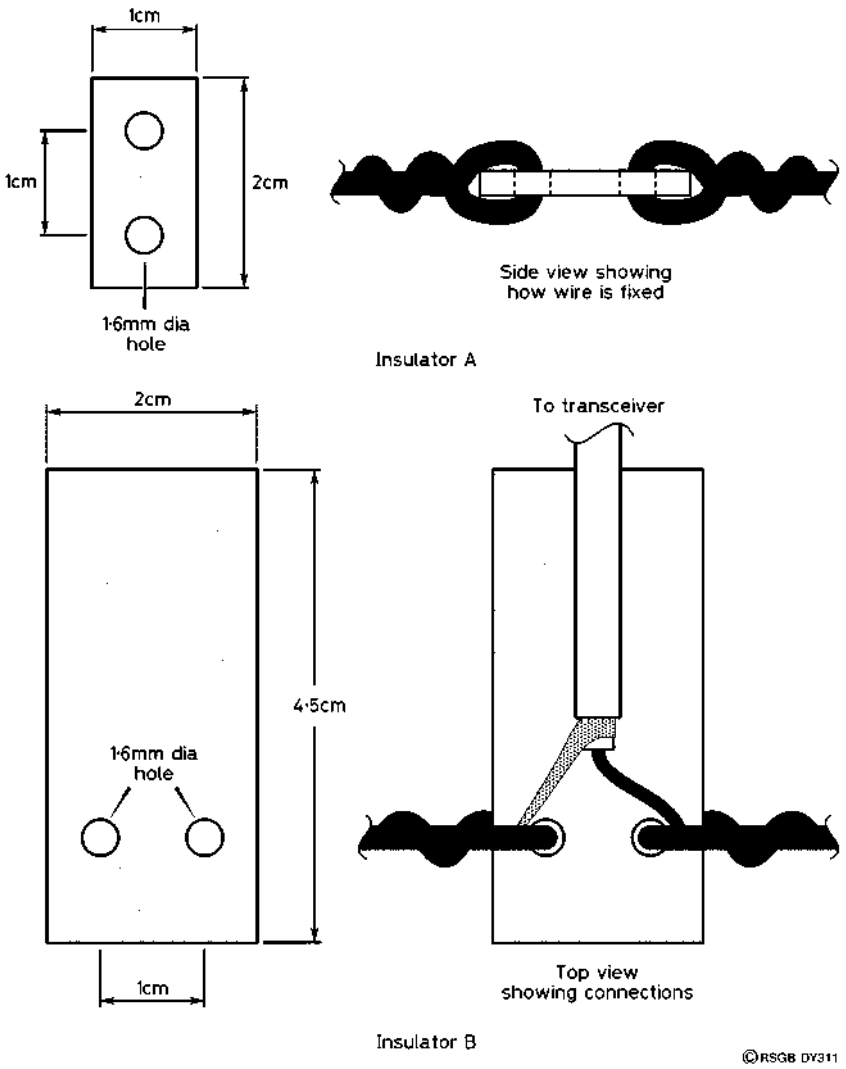

Figure 3 Details of insulators

Adjustment

The driven element (A–B–A) in Figure 1 is fixed to the end insulators in such a way as to have 'pigtails' which are about 10 cm long. Using an SWR meter between the aerial and the transmitter, trim the pigtails equally at each end for minimum SWR in that portion of the 6 m band in which you plan to work. Make sure that the transmitter is off when you trim the ends, as high voltages can be present there. Always listen on the frequency before you transmit and, when you do, ask if the frequency is in use and identify yourself. Use as little power as possible.

The prototype had an SWR of 1.2 at 50.2 MHz and performed well. If you look at Figure 1, which is a view of the aerial from above, you will immediately see that when the aerial is horizontal, it radiates with horizontal polarisation in a direction from the top of the page to the bottom. A metal pole or mast can be used for horizontal polarisation, but if you intend to use the aerial for vertical polarisation, it is much better to use a wooden or fibreglass pole.

Portable use

If you plan to operate portable with this aerial, the only real modifications you need are to the centrepiece and how it supports the spreaders. Instead of using glue and cable clips, nuts and bolts through the spreaders and centrepiece would allow the spreaders to be 'hinged' closed for transport.

Materials

Centrepiece	Hardwood, 15 × 15 × 25 mm
4 spreaders	110 cm long (cane or 6 mm dowel)
Wire	1.5 mm PVC-covered copper
50 Ω coaxial cable	RG58 or similar
Cable clips	6 mm (12 off)
Varnish	Polyurethane for waterproofing
Tape	Self-amalgamating, to waterproof all soldered joints
Insulators	See text

82 An integrated-circuit amplifier

Introduction

A simple audio-frequency amplifier is a very useful building-block in many more advanced electronic circuits. It is also a very useful piece of test equipment. To have one spare in the shack can be a life-saver at times.

Planning

Get into the habit of planning your project. How do you want it to look when it is finished. Do you want it in a box? Do you want it 'open-plan', with all the components on view?

The 'minimalist' approach to any project is simply a front panel and a baseboard, on to which all the components are fitted. In this case, the front panel would accommodate the loudspeaker, the volume control and the input and output jack sockets, and the baseboard would support the circuit board. Once you have decided these things, and know the size of the board, speaker and volume control, you can decided how big the panel and baseboard should be.

The amplifier

Instead of building the amplifier from discrete components (i.e. transistors), as was done in the project *An audio-frequency amplifier* (which you will find elsewhere in this book), we are going to use an integrated-circuit (IC) amplifier. External resistors and capacitors are still needed but, compared with the number of components *inside* the chip, these are very few indeed!

The IC we are going to use is the TBA820M. The circuit may look complicated, but with the use of a matrix circuit board it becomes quite simple. **Figure 1** shows the circuit diagram and **Figure 2** the layout on the board. The external connections to the PCB are shown in **Figure 3**.

To avoid having a separate switch to switch off the power supply when the amplifier is not being used, a volume control which incorporates a switch is used.

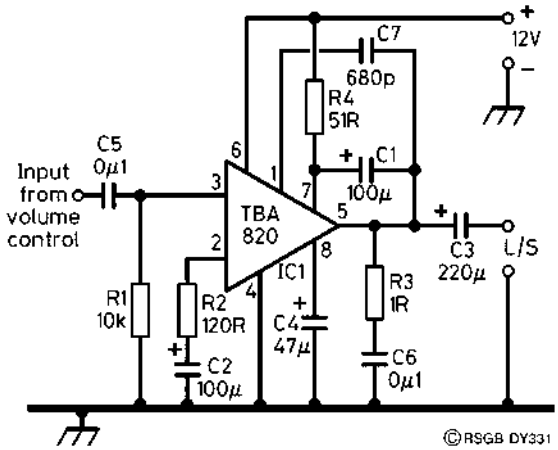

Figure 1 Audio amplifier, circuit diagram

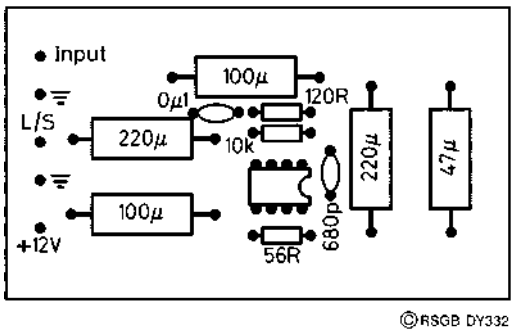

Figure 2 Audio amplifier, component layout

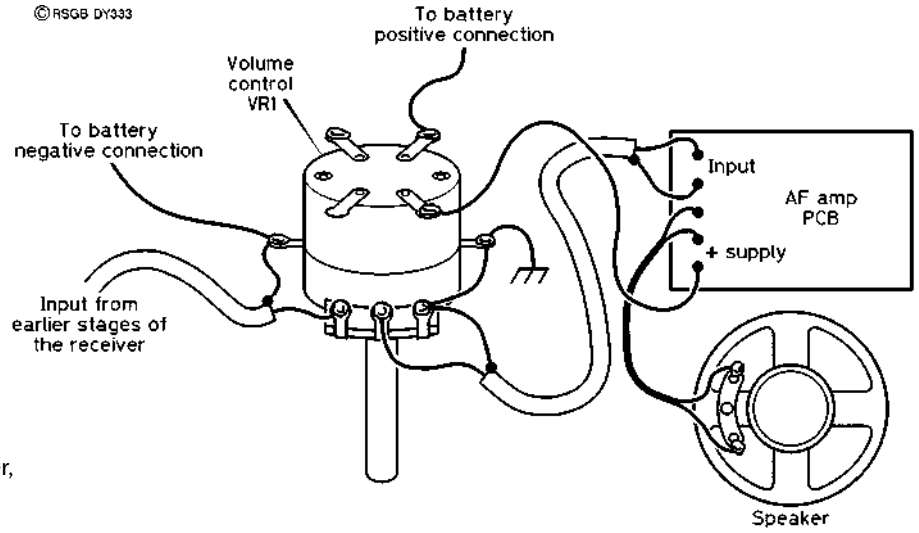

Figure 3 Connecting the circuit board to the speaker, volume control/switch and battery

What power supply?

If the amplifier is to be used only for short periods, as a test instrument, for example, then it can be run from a PP3 battery, which can be mounted on the baseboard. If you intend to use it often, then a connection to an external power supply is preferable. For this option, you may want to consider fixing two terminals to the baseboard for this connection.

83 A novice ATU

Introduction

Having an aerial tuning unit (ATU) is always useful. It is used for adjusting the aerial impedance, as 'seen' by the transceiver, to be the same as that of the transceiver itself, usually 50 Ω. This process is called *matching*, and ensures that the receiver and the power amplifier (PA) stage of the transmitter work efficiently.

This design is due to the late Doug DeMaw, W1FB, and uses readily available components. It will handle up to about 5 W, and operates over the frequency range 1.8 to 30 MHz.

Circuit evolution

The basic circuit of one type of ATU is shown in **Figure 1**. On transmit, the input signal at L1 is coupled into L2, which forms a resonant circuit with C1. The signal across the resonant circuit is fed to the aerial by C2. The combination of L2 and C1 helps to remove signal harmonics, because they are not at the resonant frequency and are shunted to earth. On receive, only those signals which are within the pass-band of L2 and C1 will pass into the receiver. This improves receiver performance by rejecting many out-of-band signals which the simpler receiver doesn't like.

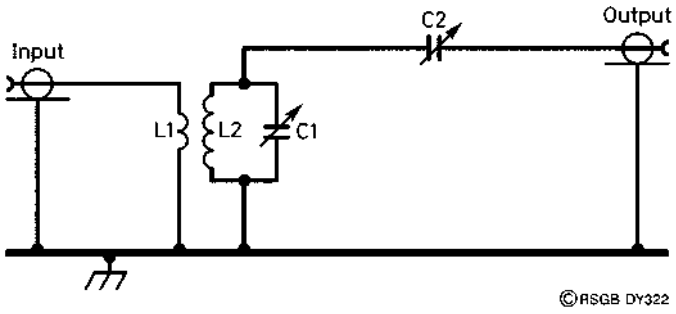

Figure 1 Basic circuit of the ATU

For this design, the all-important resonant frequency is chosen to be in the 80 metre band. If we want to make the circuit operate on other bands, we need to change either L2 or C1. It is easy to change L2 by using a set of switched inductors (L3–L5) as shown attached to S1 in **Figure 2**. Forget about S2 and L6 for the moment.

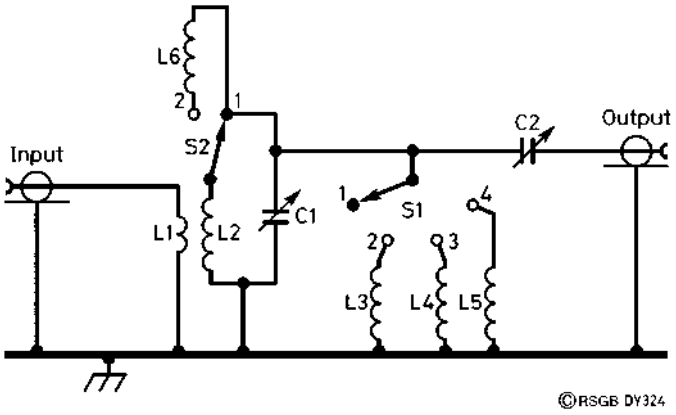

Figure 2 L6 added for 160 m

When S1 is in position 1, the circuit reverts to that of Figure 1. S2 should be brought into circuit only when S1 is in position 1. Looking at the way the circuit is drawn, you can see that when S2 is in position 2, we have two coils in series, which is equivalent to adding more turns to L2. More turns means more inductance, which lowers the resonant frequency still more, and gives coverage of the 160 m band.

Rather than having to remember to flick S2 to the correct position *and* move S1 to position 1 when we want to operate on 160 m, both functions can be combined into one rotary switch with two wafers. This circuit is shown in **Figure 3**.

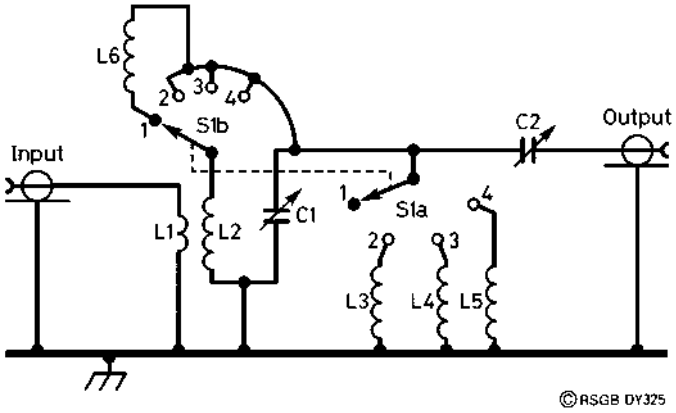

Figure 3 Two-pole switch for all bands

In all positions of S1a *except* position 1, the extra coil, L6, is shorted out. The two halves of the switch, S1a and S1b, move together, as the shaft is turned, so both halves are in position 1 at the same time, position 2 at the same time, and so on. The two switches, S1 and S2, are said to be *ganged*.

Construction

L1 is formed by winding four turns of 22 SWG enamelled copper wire over L2, as in **Figure 4**. L2 already exists on the purchased former. After scraping the enamel off the ends of the wire (with a sharp knife or sandpaper), one end of L1 must be soldered to one end of L2, as shown in Figure 4. The free end of L1 goes to the transceiver aerial socket.

All components except the capacitors are assembled on the switch. Note that the rotor of C1 is earthed, but neither side of C2 is earthed. This means that the metal shaft of C2 is not earthed, and touching it will detune the ATU. Using a plastic knob for C2 will minimise this effect. If you decide to use a metal box, take precautions to ensure that no part of C2 is in electrical contact with the box.

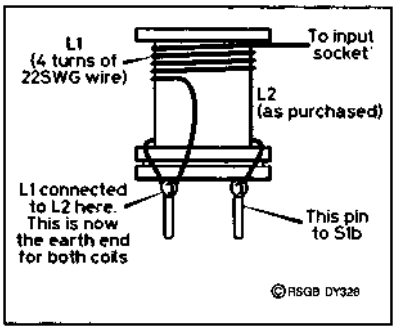

Figure 4 L1 is wound over L2 as shown

The capacitors are mounted using M2.5 screws. Make sure that the screws do not foul the vanes of the capacitor. If your screws are too long, a few washers between the box and the capacitor will solve the problem!

In use

The best indication of a good match is obtained with a standing-wave meter between the ATU and the transceiver. The controls are adjusted alternately to 'feel' your way to a better and better match.

For receive-only use, the same alternate adjustments are used, watching for the maximum signal strength on the S-meter or, for a very weak signal, making the signal from the loudspeaker as large as possible.

Parts list

Capacitors

C1, C2	350 pF variable

Inductors

L1	See text
L2	27 μH
L3	10 μH
L4	2.2 μH
L5	1 μH
L6	65 μH

Additional items

SO239 sockets (2 off)	
S1	2-pole 6-way rotary
Box	as required
Plastic knobs (2 off)	
Stick-on feet (4 off)	
M2.5 screws for capacitors	
Screws, nuts and washers for mounting the input and output sockets.	

84 CW QRP transmitter for 80 metres

Introduction

This is a relatively simple transmitter design having an output of 1 W. The design is not new, having been described before in other amateur radio publications. The components are all available new and the total cost should not exceed £15.

The circuit

Like other simple transmitters (see *An 80 Metre Crystal-Controlled CW Transmitter* and *A Breadboard 80 m CW Transmitter* elsewhere in this book) this one is crystal controlled. This assures frequency stability, but limits the usefulness of the transmitter. The key to increased frequency coverage without a conventional Variable Frequency Oscillator (VFO) is the use of a low-cost 3.58 MHz *ceramic resonator*. The 'pulling' range of a 3.58 MHz ceramic resonator covers the UK novice 80 m sub-band and some of the CW segment below 3.525 MHz.

A ceramic resonator is like a crystal, but not quite as stable in frequency. Its main advantage is its large pulling range.

The block diagram is shown in **Figure 1**. It is very similar to a crystal-controlled transmitter, and includes an oscillator, buffer and final amplifier.

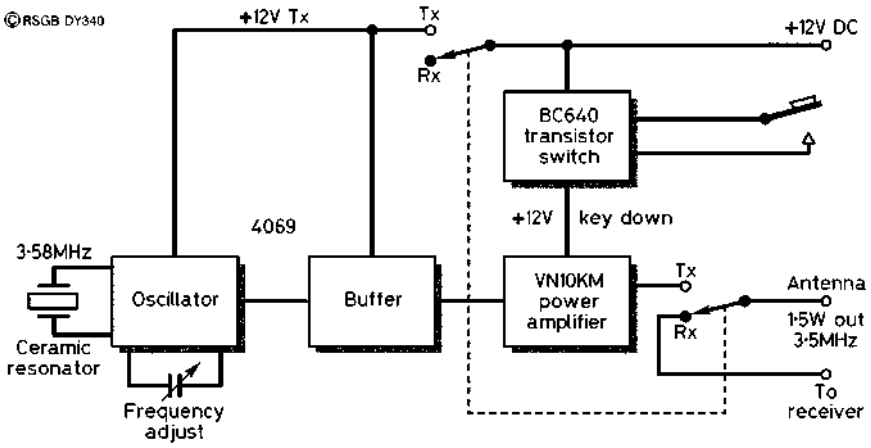

Figure 1 Block diagram of the ceramic resonator controlled 80 m CW transmitter

This amplifier is keyed, the oscillator remaining running all the time. This improves frequency stability because the oscillator is not being continuously stopped and started by the key. It is switched off while receiving, though, to avoid interference with the received signal. Transmit/receive switching is accomplished by a panel-mounted switch controlling both the aerial, oscillator and buffer switching.

Figure 2 shows the transmitter circuit diagram. An unusual aspect of this transmitter is the use of a digital CMOS integrated circuit (IC) type 4069 for the buffer and oscillator stages. The IC houses six inverters, four of which are used in the circuit. One is used as the oscillator, two are used for the buffer stage, and the fourth provides an output for a direct-conversion receiver, should one be added at a later date.

The frequency of the oscillator is changed by varying the capacitance in the ceramic resonator circuit. This is provided by VC1.

The power amplifier (PA) is a small MOSFET (metal oxide semiconductor field-effect transistor), TR1. This is capable of providing an output power of 2 W but, in this circuit, it is run conservatively to give 1.5 W. The output can be varied by changing the resistance (R5 + R6) in the gate circuit. Attempts

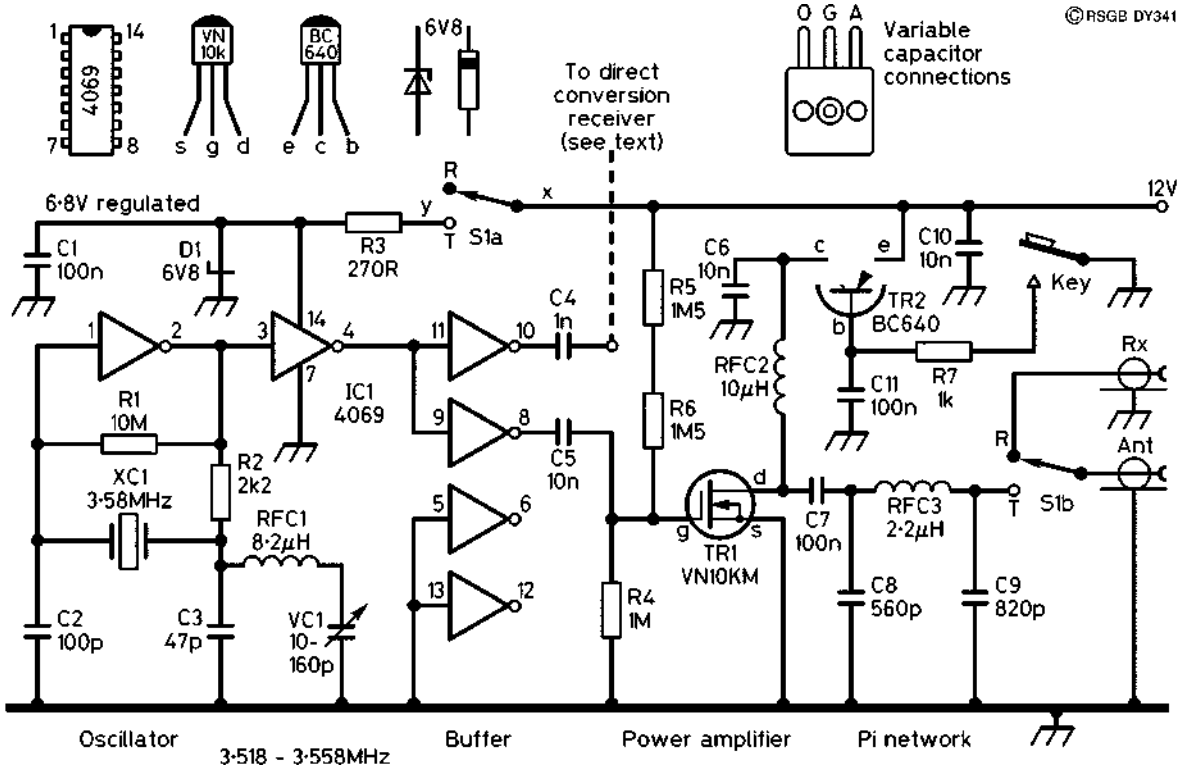

Figure 2 Circuit diagram of 80 metre transmitter

to raise the output power by decreasing the values of these resistors may result in immediate MOSFET failure.

A pi-network (C8, RFC, C9) provides impedance matching to 50 Ω, together with harmonic suppression. Like all inductors in this transmitter, the pi-network inductor is a pre-wound RF choke. A pi-network is so called because the components are arranged in the shape of the Greek letter pi (π).

Keying is carried out by a pnp transistor switch, TR2. Closing the key earths the base and supplies 12 V to the collector of TR2 and to the drain of the MOSFET, TR1, allowing the PA to operate.

Construction

You must house your transmitter in a metal box, to avoid hand-capacity effects and the radiation of spurious frequencies. Size is not important, provided it is large enough to accommodate the transmitter without cramping the components. You may want to allow space for future additions such as a direct-conversion receiver, break-in keying, sidetone or a small power amplifier. A good size is 5 × 15 × 15 cm. You can make your own box, buy it, or even use a biscuit tin!

Front and rear panel connectors can be fitted first. The choice of these is a personal matter, but a good working choice would be:

(a) Power socket – 2.1 mm panel socket – centre pin positive.
(b) Key socket – ¼ inch jack socket.
(c) Aerial and receiver connectors – panel-mounting SO239 type.

Particular attention must be paid to the mounting of the variable capacitor, VC1. Make sure the hole for the shaft is amply big enough, and if you use screws to mount the capacitor on the front panel, then make sure they are not too long, otherwise they will touch the vanes of the capacitor! Mounting can be by means of glue, sparingly applied and kept well away from the shaft.

A board size of about 6 × 10 cm is adequate. Component layout on the board is suggested in **Figure 3**. The prototype used ordinary matrix board, which is preferable to stripboard for a design like this; stripboard has undue capacitance between adjacent strips. Component leads are fed through holes in the board and are connected underneath. Make sure that leads and connections are rigid because, if they can move, there is always the danger of short-circuiting, and capacitance changes.

To facilitate construction, servicing and testing, it is advisable to use Veropins for connections to the variable capacitor, transmit/receive switch,

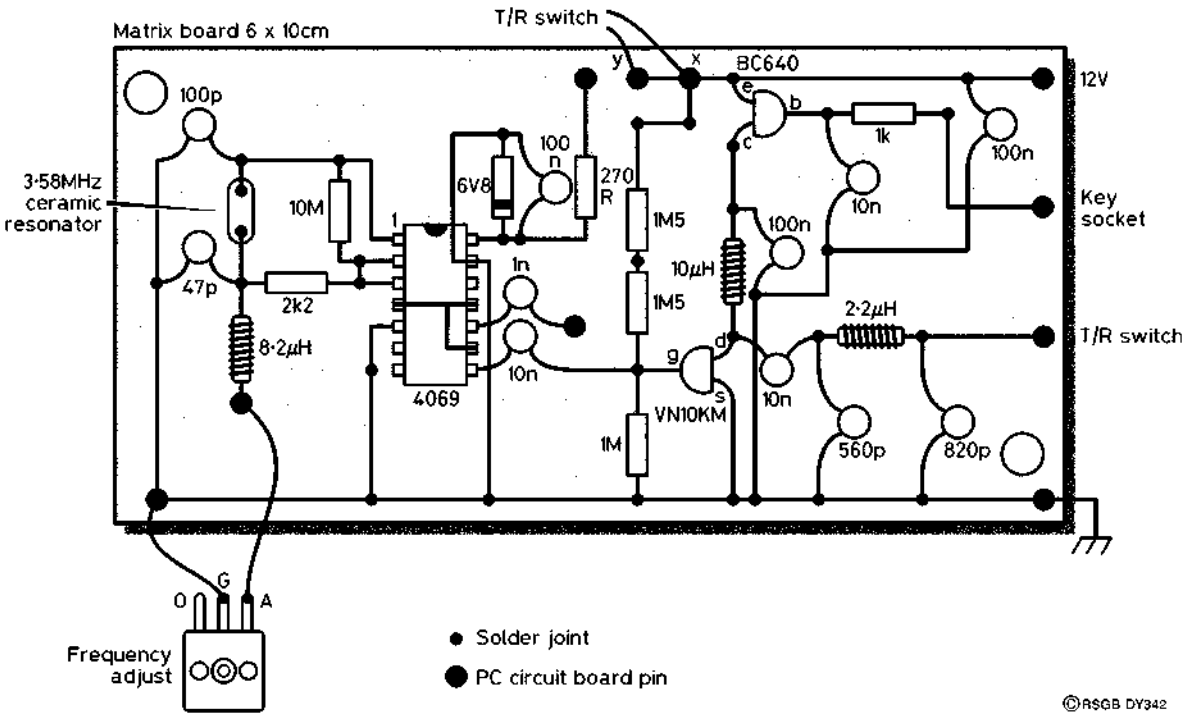

Figure 3 Component layout of the 80 metre transmitter. The transmit/receive switch is not mounted on the board and is not shown in this diagram

aerial and power sockets. Use screws and spacers to mount the circuit board to the box. Mounting the board horizontally assists troubleshooting.

Use a socket for the IC, and observe the CMOS handling precautions given in *An Electronic Die*, elsewhere in this book. When soldering the leads to the ceramic resonator, do it quickly – excessive heat damages the device. The earth lead running acoss the bottom of the board must be connected to the metal case by a short length of stout wire.

Testing

After carefully checking your wiring, both against the circuit diagram and the layout diagram, it is time to test your circuit. You will need a multimeter, an 80 m SSB receiver and a 50 Ω dummy load. A good design of dummy load can be found in the project *A Switched Dummy Load*, also in this book. An RF power meter and frequency counter will also be useful, although if your receiver has a digital frequency readout and S-meter, the latter two items are not really necessary. You will also need a 12 V 1 A power supply unit (PSU) to power the transmitter.

Switch the transmitter to receive and switch on the transmitter. No current should be consumed. Switch to transmit and check that pin 14 of IC1 is 6.8 V positive. With the dummy load connected to the aerial socket, press the key. The voltage on TR2 collector should now be 12 V, dropping to zero when the key is released.

Now check the operation of the oscillator. In transmit mode, you ought to be able to find a strong carrier signal with the receiver, even though the dummy load is connected. Adjusting the variable capacitor should change the frequency. At the lower end of the frequency range, you may find that the oscillator is unreliable in starting, because the circuit is attempting to pull the resonator too low in frequency. If this is the case, set the trimmer at the back of VC1 to minimum capacitance. If your version of VC1 has two trimmers, and you don't know which one to set, set them *both* to minimum capacitance. If there is still a problem, reduce the value of RFC1 to 6.8 or 4.7 μH.

In all probability, the unmodified circuit of Figure 2 will not require any of the changes outlined here. A coverage of 3.518 to 3.558 MHz should be possible, while preserving good frequency stability and reliable oscillation.

A signal probe (see *An RF Signal Probe*, elsewhere in this book) is useful for checking the operation of the oscillator and PA. Alternatively, an RF power meter or the receiver's S-meter can be used. With the PA running, the unit should draw between 200 and 300 mA. If TR1 becomes too hot to touch after a few seconds of transmitting, increase R5 or R6 to limit the transistor's heat dissipation. A small 6.3 V bulb connected across the aerial output is a simple way to check that the PA is working. An orange/white glow when the key is pressed is indicative of correct operation.

The final test is to monitor keying 'quality'. With your dummy load connected, press the key and listen to the note on the receiver's loudspeaker. Then operate the key, sending a string of dits, for example. What you hear should be free of chirps and clicks, as well as being stable in frequency. This test is sometimes better performed with no aerial connected to the receiver, thus preventing receiver overload and its associated plops. No problems should be encountered here.

Frequency tuning

A peculiarity of ceramic resonators is that, every now and again, their frequency changes abruptly by 100 Hz or so, then remains stable for some time. This is certainly noticeable in the received signal, but does not detract from the QSO and no characters are lost as a result. Try to keep the area around the ceramic resonator cool, to avoid temperature variations.

Parts list

Resistors: all 0.25 W, 5% tolerance

R1	10 megohms (MΩ)
R2	2200 ohms (2.2 kΩ)
R3	270 ohms (270 Ω)
R4	1 megohm (1 MΩ)
R5, R6	1.5 megohms (1.5 MΩ)
R7	1000 ohms (1 kΩ)

Capacitors

C1, C7	100 nF
C2	100 pF
C3	47 pF
C4	1 nF
C5, C6, C10	10 nF
C8	560 pF
C9	820 pF
VC1	10–160 pF variable

Inductors

RFC1	8.2 μH
RFC2	10 μH
RFC3	2.2 μH

Semiconductors

IC1	4069
TR1	VN10KM
TR2	BC640
D1	6V8 Zener

Additional items

- Matrix board (see text)
- 14-pin DIL socket
- Pointer knob
- Sockets (see text)

85 An audio booster for your hand-held

Introduction

The audio output from many hand-held transceivers and receivers usually leaves much to be desired, so this little amplifier was designed to increase the output at minimal expense.

All that is needed is a separate amplifier and bigger loudspeaker. This is accomplished using a single integrated circuit (IC), a few components, and a loudspeaker from the junk box. This circuit will enable the output from your hand-held to be heard easily in a car.

The circuit

This is shown in **Figure 1**. It uses only those components necessary to operate the IC amplifier. VR1 is the preset volume control, and varies the signal coming from the 'External speaker' jack on the hand-held before feeding it into the IC for amplification. C1 blocks any constant voltage present on the input.

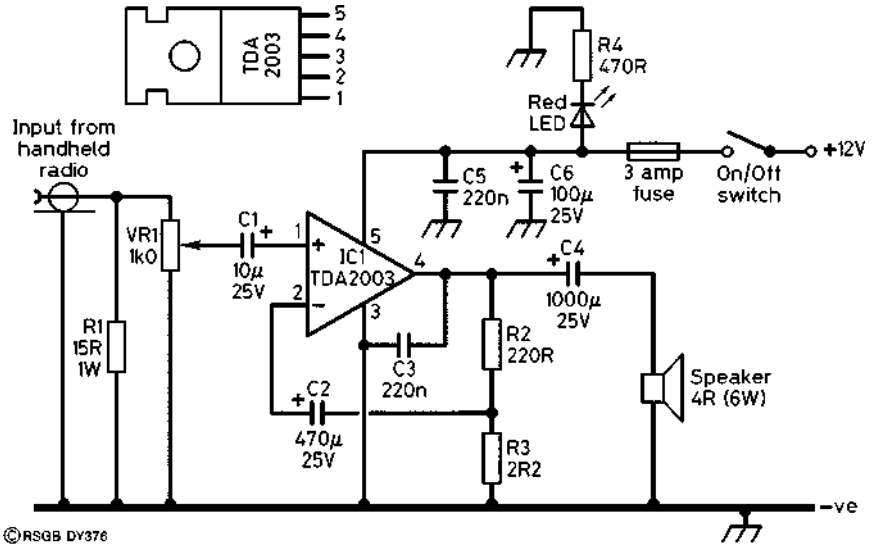

Figure 1 Circuit diagram of the audio amplifier. The power is derived from the cigarette lighter socket and the fuse is in-line with the lead

The IC output comes from pin 4 and is fed via the electrolytic capacitor, C4, to the loudspeaker. The circuit is provided with an on/off switch, fuse and LED to indicate when the circuit is switched on.

Construction

The box is made of aluminium. This is necessary to help to dissipate some of the heat generated by the IC. Do not build the circuit inside a plastic box unless you take special precautions! The IC has a metal mounting tab with a hole, specifically designed to be mounted to a metal box or other metal heat sink. Apply plenty of heat sink compound between the tab and the box, tighten the nut and bolt, and then wipe off any excess compound. The box will get slightly warm in operation.

The size of the box is not specified. You may want to decide on this when you find a loudspeaker. Choose one which will be able to handle 6 W

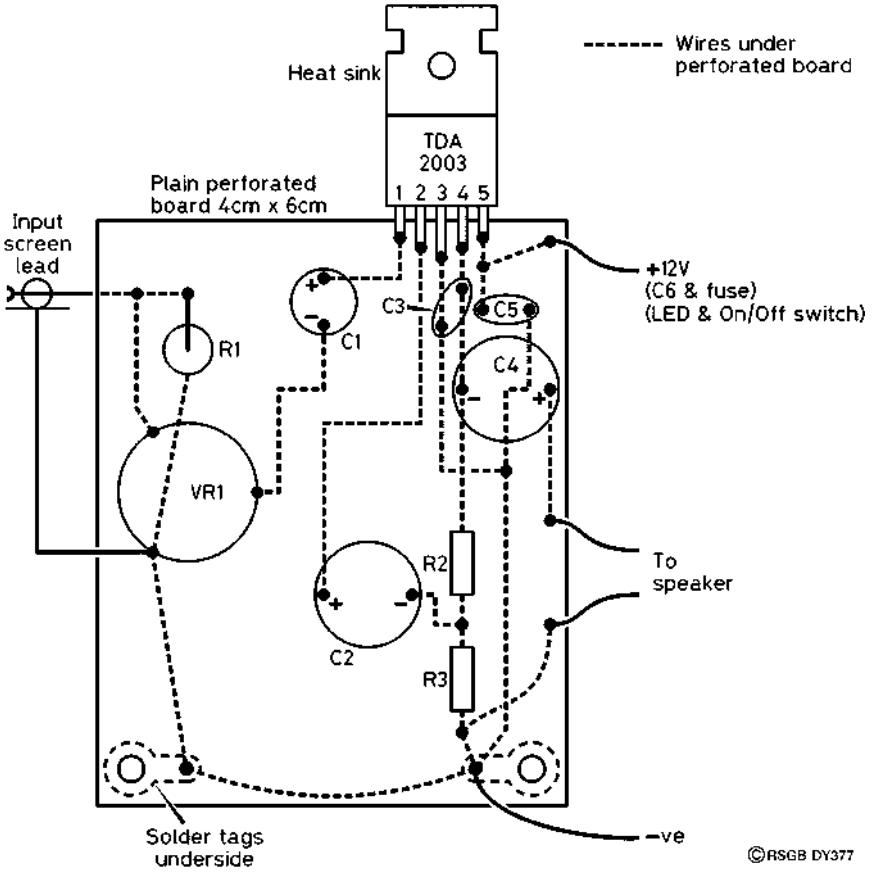

Figure 2 Layout of the components within the box

output. Drill all the holes in the box first. Holes for the speaker, input phono socket and the LED. The amplifier can be constructed on ordinary matrix board, which can be mounted inside the box with screws and spacers.

The layout is shown, for your guidance, in **Figure 2**. The components are mounted by pushing their leads through the holes in the board and making connections on the underside. The preset volume control, VR1, is set such that the hand-held's volume control is sufficient to control the final output over a good volume range. Use a screened lead from the 'External speaker' jack socket to the phono plug.

An external power supply is needed for this circuit. The normal dry battery which we usually use for small projects in this book will *not* work here, so you will need a proper mains power supply producing a stabilised 12 V. If you are going to use the unit principally in a car, then the cigar lighter socket can supply this voltage easily. Do make sure that the polarity is correct before you switch on!

When you plug the jack plug from your booster into the 'External speaker' socket on your hand-held, its internal speaker will be muted, so don't think that something dire has gone wrong! Adjust VR1 for a good volume range on your booster, when the volume control is turned on the hand-held.

Parts list

Resistors: all 0.25 W, 5% tolerance, unless otherwise stated

R1	15 ohms (15 Ω) 1 W
R2	220 ohms (220 Ω)
R3	2.2 ohms (2.2 Ω)
R4	470 ohms (470 Ω)
VR1	1000 ohms (1k Ω)

Capacitors

C1	10 µF 25 V
C2	470 µF 25 V
C3, C5	220 nF (0.22 µF) Mylar
C4	1000 µF 25 V
C6	100 µF 25 V

Semiconductor

LED	5 mm Red

Integrated circuit

IC1	TDA2003

Additional items
- Heat sink compound
- Nuts and bolts
- Loudspeaker 4 Ω 6 W
- 3 A fuse
- On/off switch (SPST)
- Matrix board 4 × 6 cm
- Solder tags
- Plugs and screened cable for connecting lead
- Aluminium box

86 A grid dip oscillator

Introduction

When an inductor and a capacitor are connected, whether in series or parallel, they form a circuit with a natural (or *resonant*) frequency. The circuit stores energy, and this energy is being constantly shifted from the inductor to the capacitor and back again.

The dip oscillator is a simple instrument used to measure the resonant frequency of a tuned circuit without having to make any direct connection to the circuit. The circuit is more commonly known as the *grid dip oscillator* (GDO), from the days when the active device in the circuit was a valve. The FET or Field-Effect Transistor operates in a way which is very similar to that of the valve, so it is not quite a misnomer to call this instrument a grid dip oscillator, too.

The circuit

The GDO uses a calibrated, tunable FET oscillator in the circuit of **Figure 1**. It has a frequency range of 1.6 to 35.2 MHz in four ranges using a set of plug-in coils, shown in **Figure 2**. When the oscillator coil, L1, is placed near an external resonant circuit, some of its RF energy is coupled into the external circuit. A gain in energy of the external circuit must mean a loss of energy in the GDO circuit, resulting in a change of current through TR1, which is measured by the meter, M1.

The current through TR1 is of the order of 5 to 8 mA, but the change of current may be only a few microamps. To measure a very small

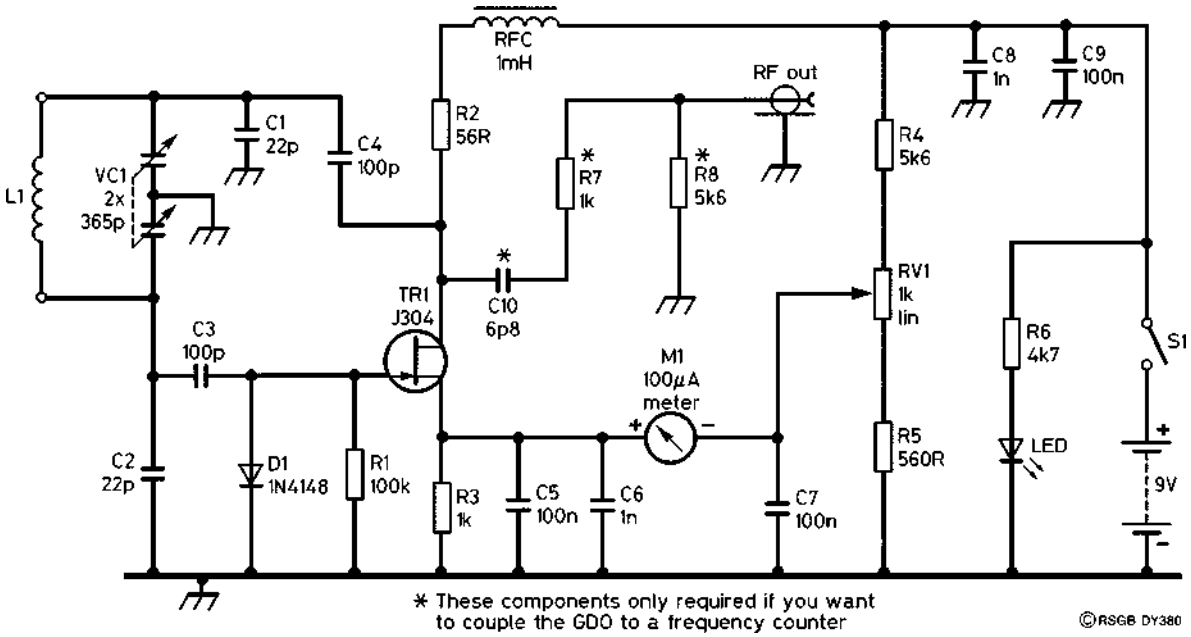

Figure 1 Circuit of an FET GDO. The coils are wound on DIN speater plugs, which provide both a plug-in base and a coil former

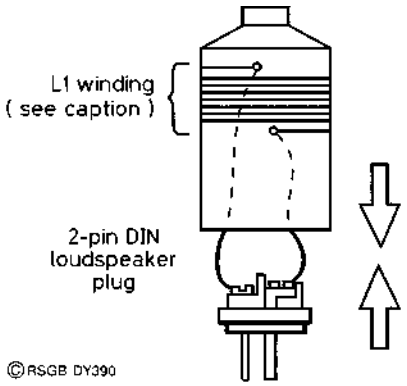

Figure 2 Details of coil construction:
Range 1: 1.6–4.0 MHz 55 turns of 30 SWG
Range 2: 3.3–7.9 MHz 27 turns of 30 SWG
Range 3: 6.3–4.0 MHz 14 turns of 26 SWG
Range 4: 11.9–4.0 MHz 7 turns of 24 SWG.

change superimposed on a much larger standing current, the method of *offset* can be used.

One connection to the meter goes to the source of the FET, while the other goes to a variable offset voltage set by VR1. M1 has a full-scale deflection (FSD) of 100 µA. If the current through TR1 changes, the voltage across R3 changes. When there is no resonance, the voltage at the wiper of VR1 is set to be very slightly greater than that across R3, and there is a 75% FSD meter deflection. When the voltage across R3 decreases very slightly, due to

external circuit resonance, a significant 'dip' in the meter deflection is produced, hence the name of the instrument.

The circuit is not difficult to make on standard matrix board. Provided you can follow a circuit and translate it into a good component layout, then this project is probably only an evening's work.

The most important part of the GDO is the tuning capacitor and its associated frequency-calibrated dial. New, air-spaced tuning capacitors can cost you up to £20, so it is worth delving around in junk boxes, or scouring the tables at a local boot sale or rally. The tuning capacitor from an old transistor radio should be perfect. It may even have a slow-motion drive and a dial which can be remarked for the project.

Choose a coil plug and socket arrangement that is practical. Think about crystal holders or phono plugs and sockets. The prototype shown in Figure 1 and Figure 2 used 2-pin DIN plugs, with the coil wound on the outside of the plastic plug cover. Figure 2 shows the coil construction and the winding details.

If you use a variable capacitor, VC1, with a value different from that shown in the parts list, then the frequency ranges will be different. This does not matter, as it will be taken into account during calibration.

Position VC1 so that the dial will be easy to see and to operate, while locating the coil socket as close to it as possible. **Figure 3** shows the traditional layout of the GDO.

Calibration

Because the GDO also radiates a very small amount of energy, a general coverage receiver can be used to calibrate the dial. Don't try to aim for great accuracy and clutter the dial with marks and figures! If you include C10, R7 and R8 in your circuit, you can connect a frequency counter directly to the GDO and leave it in circuit all the time.

The GDO in use

Always try to place the external tuned circuit with its coil coaxial with the plug-in coil, as shown in Figs 1 and 3. If the coils are at right angles, the GDO may not produce any resonance. Set the offset control to give about 75% FSD and slowly tune L1 through its whole range. If no dip occurs, you may have the wrong coil plugged in. When you eventually find a dip, move the external coil further away until only a minute dip is seen. You may have to retune the dip meter as you do this, but it gives a much more accurate reading of frequency.

Remember that you cannot 'dip' a coil by itself – there must always be a capacitor present.

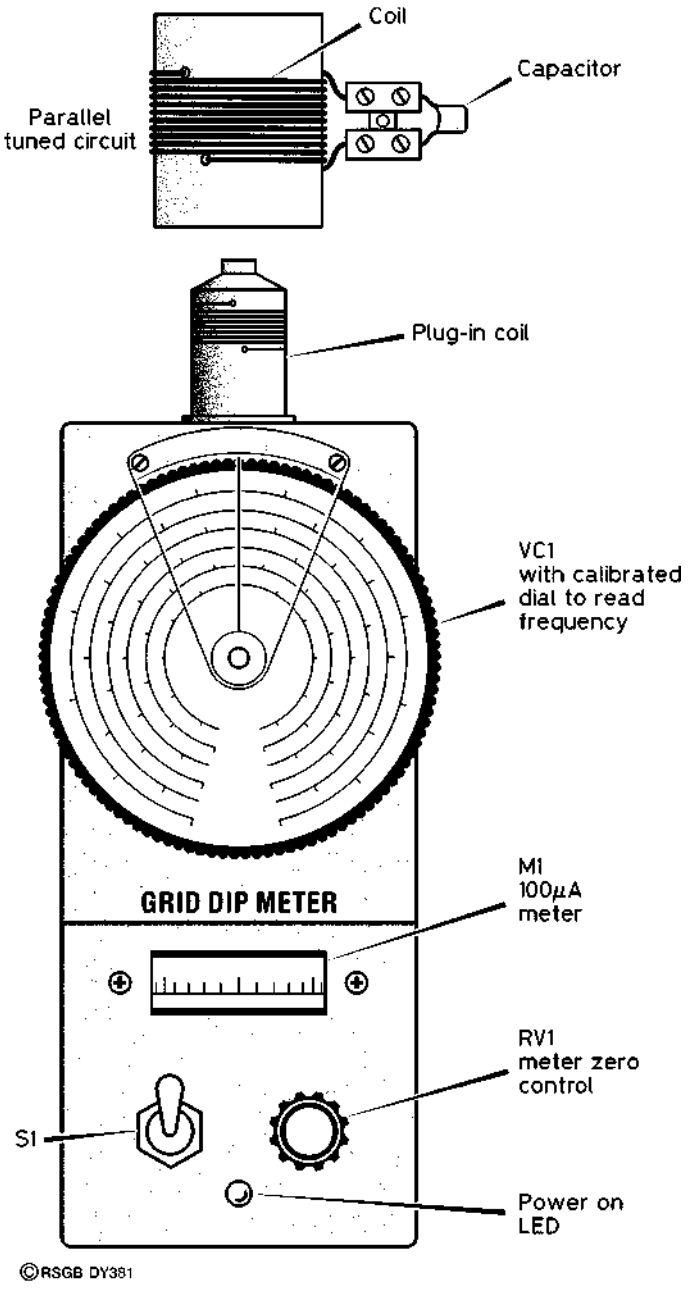

Figure 3 Layout of a typical GDO. The dial, meter and the location of the coil to the circuit under test can all be viewed at the same time. It is shown measuring resonance of a tuned circuit

Aerial resonance

Figure 4 shows how to check the resonance of a dipole aerial. Disconnect the coax feed at the aerial and place a short piece of wire, terminated with crocodile clips, across the centre insulator to short together the two ends of the aerial. By placing the GDO close to the shorting link, a dip should be seen on the meter while VC1 is turned. Alternatively, a loop in the element can be made around the coil, as in Figure 4, or the shorting link can be made long enough to loop over the coil. The latter method does not require tampering with the mounting and tensioning of the dipole wires.

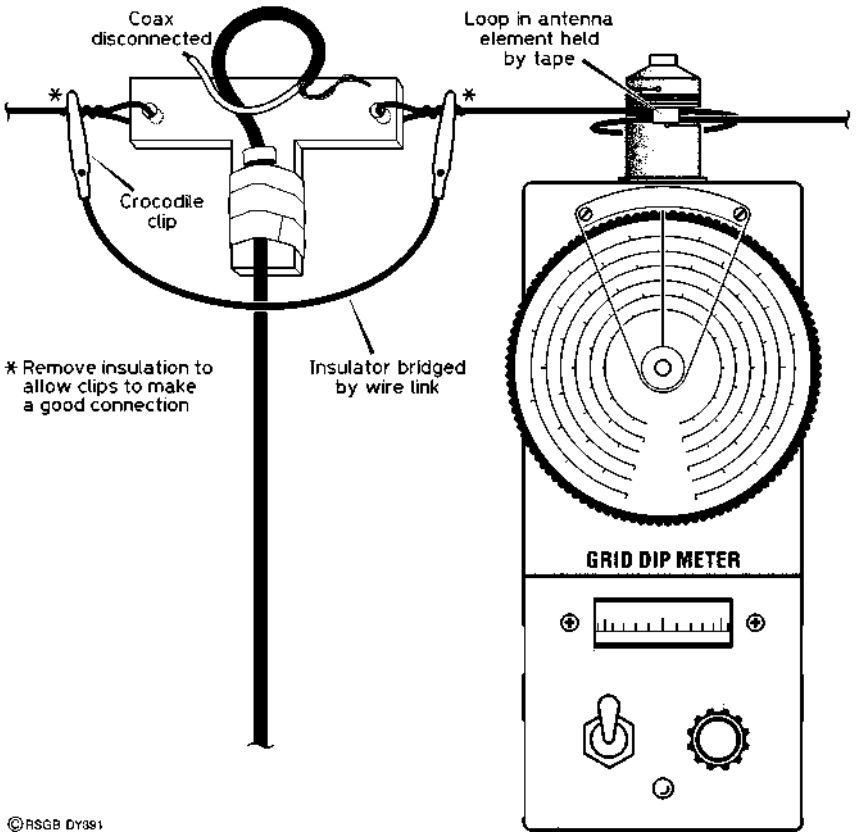

Figure 4 A wire antenna element can be looped into a single turn coil for increased coupling to the GDO

Parts list

Resistors: all 0.25 W, 5% tolerance

R1	100 000 ohms (100 kΩ)
R2	56 ohms (56 Ω)
R3	1000 ohms (1 kΩ)
R4	5600 ohms (5.6 kΩ)
R5	560 ohms (560 Ω)
R6	4700 ohms (4.7 kΩ)
R7	1000 ohms (1 kΩ)
R8	5600 ohms (5.6 kΩ)
VR1	1000 (1 kΩ) linear

Capacitors

C1, C2	22 pF
C3, C4	100 pF
C5, C7, C9	100 nF (0.1 μF)
C6, C8	1 nF (1000 pF)
C10	6.8 pF
VC1	2 × 365 pF

Semiconductors

TR1	J304 or similar
D1	1N4148
LED	

Additional items

L1	See Figure 2
RFC	1 mH
S1	SPST
M1	100 μA

Source

Components are available from Maplin.

87 A CW transmitter for 160 to 20 metres

Introduction

This very small transmitter is designed to work on any band from top band (160 m) to 20 m, with an RF output of 1 W. It will work on higher frequencies but with a reduced output.

The circuit

The three-transistor circuit is shown in **Figure 1**. It comprises a crystal oscillator using a BC182 transistor which drives a 2N3866 power amplifier (PA) keyed by a ZTX750 PNP transistor. The oscillator and PA are coupled by a capacitor and resistor; this provides a very small amount of positive bias to the PA.

The oscillator can be used as a basic crystal oscillator but, by including a variable series capacitor as shown in Figure 1, the crystal frequency can be 'pulled' slightly, making the oscillator a *variable crystal oscillator* (VXO).

Construction

The PCB layout is shown in **Figure 2** and in the photograph. Although the prototype was built around a PCB, this circuit is equally amenable to

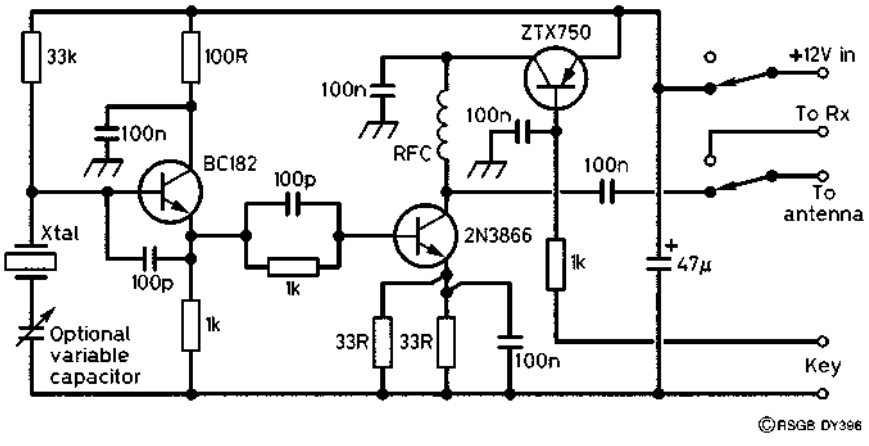

Figure 1 Transmitter circuit diagram

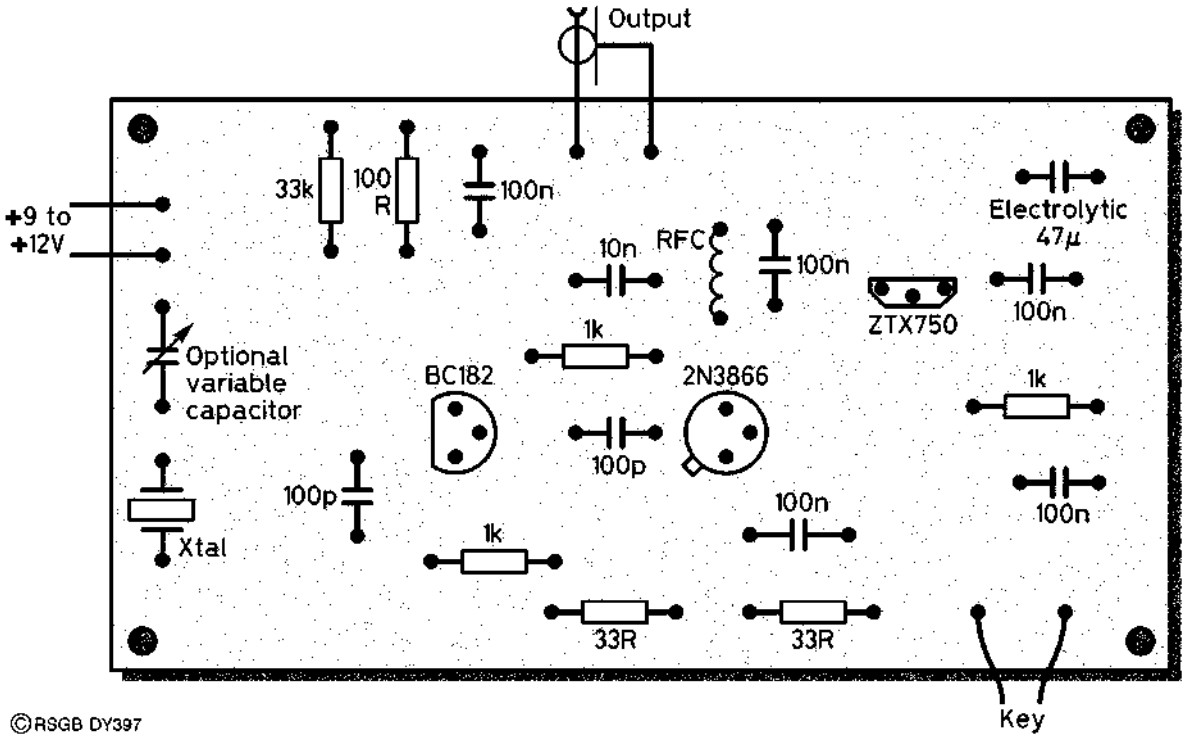

Figure 2 Component placing on the PCB. The external connections are also shown

construction on a matrix board. Populating the PCB is very simple, and you can expect to be able to do this in about one hour. The radio-frequency choke (RFC) is made by winding 10 turns of 33 SWG wire on a ferrite bead. The enamel coating of the wire is intended to vaporise when soldered into the board, thus obviating the need to remove the enamel manually with a knife or sandpaper. However, if you do have problems with the PA either not working or keying intermittently, it is suggested that you investigate the RFC connections immediately!

If you decide to make the VXO version, you will have to cut the track between the crystal and earth, and connect the variable capacitor (250 pF) across the break.

In use

After performing the usual checks on the accuracy of your circuit building and the wiring of the external components, it is time to connect a 12 V battery between the points shown in Figure 2. Do not switch on yet. An aerial needs to be connected to the output via an ATU and a crystal, of frequency matching that of the aerial, fitted. The variable capacitor should

give you a tuning range from about 14.058 to 14.064 MHz. 'Netting' (the process of tuning your transmitter to the same frequency as that of a received station) is achieved simply, because the oscillator is always running, and the leakage of the signal (despite the fact that the PA is not powered) is sufficient to bring the two frequencies to zero beat.

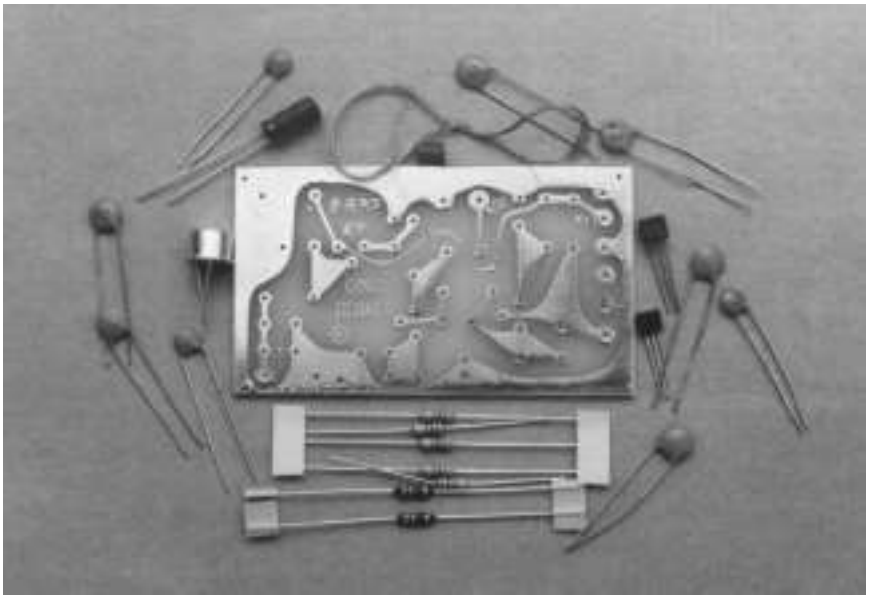

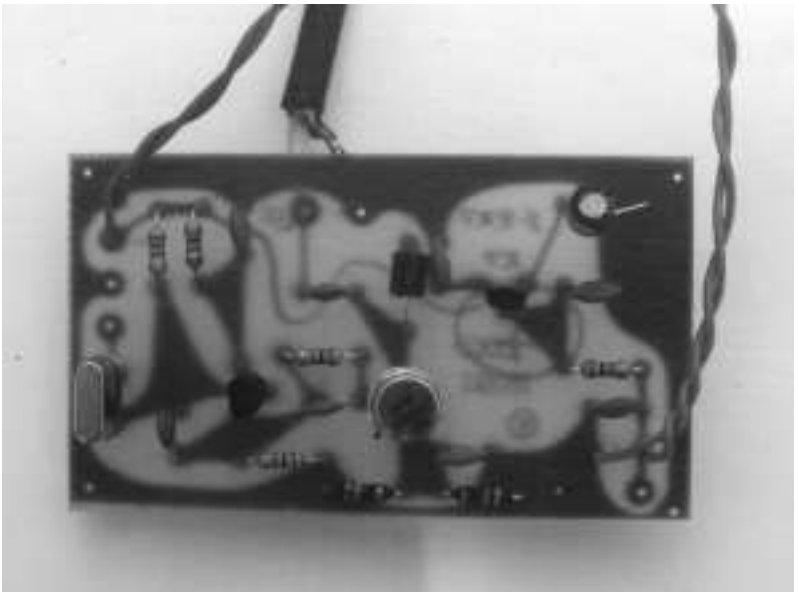

Warning

Note that the transmitter has no filtering; harmonics are not suppressed. It is strongly recommended that you use this transmitter in conjunction with the excellent low-pass filter described in the project *A 7-element low-pass filter for transmitters*, described elsewhere in this book.

88 Matching the end-fed random-wire aerial

Introduction

Many amateurs who do not have the space (or money) for a multi-band beam aerial, make use of the simplest possible alternative – the longest piece of wire that they can erect, with its end connected to the transceiver or receiver by an aerial tuning unit (ATU).

The length of the wire is not of major importance. Any length between 10 m and 80 m, with bends if necessary, will suffice. A good earth connection to the radio is just as important. Bends in the aerial wire can have some interesting effects on the directional properties of the aerial; V- or L-bends, or even a square shape are permitted. The only thing *not* permitted is to fold the wire back on itself in a tight hairpin bend!

Longish wire aerials

The term 'long wire' is usually used (incorrectly) to describe an end-fed aerial. How long is a piece of string? It depends what you mean by 'long'. In aerial parlance, it means 'long with respect to one wavelength'. Again, this depends on the band you are using. A long wire at 20 m is somewhat different from a long wire at 160 m. However, if you have sufficient real estate for a long wire on the 160 m band it must, by definition, be a long wire on all the other bands, too!

This should put you on your guard when analysing published data about feed-point impedance and the directional properties of a long wire aerial. Such theoretical data relate to a *real*, *ideal* long wire which is straight, horizontal, very high above perfect (conducting) ground, and not obstructed in any way. So your aerial doesn't quite match these criteria? Join the club!

Don't let this dampen your ardour when it comes to evaluating what the longish wire can do for you. The following should explain why.

Feed-point impedance

The impedance at the end of a longish-wire aerial can vary from a few tens of ohms to several thousand ohms, depending on the frequency in use and the wire length. It is also affected by factors such as bends, height above ground, proximity to buildings and wire diameter.

The actual value doesn't matter, provided we can make the aerial *appear* to have a 50 Ω impedance at the aerial socket of the transmitter. This process is what we call *impedance matching*, or simply *matching*. It maximises the power transfer from the transmitter to the aerial, and from the aerial to the receiver.

That is why an aerial tuning unit, or ATU, is almost (but not necessarily) obligatory.

The ATU

Many commercially produced HF receivers and transceivers have single 50 Ω coaxial sockets as their one and only means for connecting an external aerial. This means that an external aerial should have a 50 Ω feed impedance if it is to work efficiently, and it rules out most of the aerials being used by amateurs on the HF bands. Some means is necessary to change the aerial feed impedance to 'match' that of the transceiver. Such impedance-matching, or *Z*-matching (because *Z* is the symbol for impedance, just as *L* is the symbol for inductance) is the rôle of the ATU.

These can be bought and will accommodate either an end-fed or a coax-fed aerial. They can be bought ready for use or in kit form. Whether you want one for receiving only, or for use with a low-power (QRP) or high-power (QRO) transmitter, will determine what you need and how much you pay.

A simple single-band ATU

The simplest form of ATU is shown in **Figure 1**. It is simply a parallel LC (coil and capacitor) circuit, resonant at the chosen frequency, with taps on the coil for the aerial and the coaxial feed to the transceiver. If we assume the circuit is resonant, a high impedance exists at the top of the coil, and a low impedance at the bottom.

We said earlier that the end-fed longish wire presented an impedance which was high (or at least higher than 50 Ω). This explains why the aerial is tapped to the coil near the top, where the impedance is high, and the 50 Ω coax is tapped near the bottom, where the impedance is low.

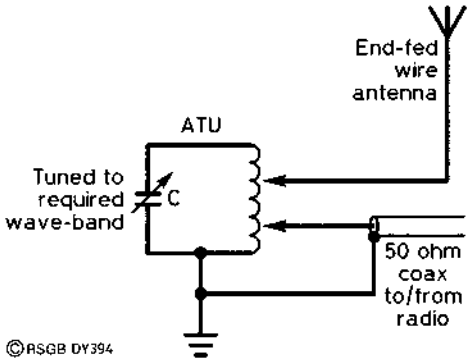

Figure 1 Parallel tuned circuit as single-band ATU for end-fed longish-wire antenna

Because the feed-point impedance of the aerial changes with frequency, so must the point at which the aerial is tapped to the coil to achieve impedance matching. The value of C must be changed also, to ensure that the circuit is resonant, and the 50 Ω tap will require tweaking also.

Setting up an ATU is quite simple. Make up an LC parallel-tuned circuit consisting of 50 turns of enamelled copper wire on an empty 35 mm film plastic container (or similar), tuned with a 500 pF variable capacitor. Make sure the enamel is removed from the ends of the wire before soldering.

Solder the inner wire of the coaxial cable from the radio to the first or second turn of the coil from its grounded end. Then solder the braid to the grounded end. Connect the aerial about one-third of the way down the coil from the top, removing the enamel at the connection point.

Adjust the variable capacitor for maximum noise or signal strength in the receiver. Then, try different tapping points from the aerial, to maximise the signal again. This matches the aerial impedance to that of the tuned circuit. Repeat the process with the coax tap, thus matching the impedance of the radio and the cable to that of the tuned circuit.

You will no doubt find that the tapping process on the coil was not easily accomplished, especially when the enamel must be removed at each tapping point without shorting adjacent turns together. It is therefore logical to produce a design where the taps have been prepared during the winding of the coil, and are selected with a rotary switch. To this end, the following multi-band design is described.

A multi-band ATU

The same type of coil design around a 35 mm film container is used (see **Figure 2**). The tapping points can be prepared in advance by a little judicious planning. Dismantle your original coil and measure the length of wire on it. It will be a little more than a calculation of $50 \times \pi D$ would suggest (where D is the diameter of the film container), due to the lack of tension in the coil and the wire diameter itself. You will need aerial tapping points at turns 1, 2, 3, 5, 10, 15, 20, 25, 30, 35, 40 and 45, corresponding to all the bands from 28 MHz to 1.8 MHz. The coaxial cable tap is fixed at turn 2 (an acceptable compromise). All the turns are counted from the earthy end.

Cut another piece of enamelled copper the same length as you used originally. Then, with the aid of an ordinary calculator, work out the positions of the points where the enamel must be removed for the taps. For example, turn 15 will have to be made $\frac{15}{50}$ of the way along the wire, turn 20 tap made at $\frac{20}{50}$ of the way along. So, if the length of wire is, say 4.7 metres, the two taps in question will be made at $\frac{15}{50} \times 4.7 = 1.41$ m and $\frac{20}{50} \times 4.7 = 1.88$ m from one end. This must be repeated for each of the tap positions, and the enamel removed ready for the wire to be soldered to it. With a

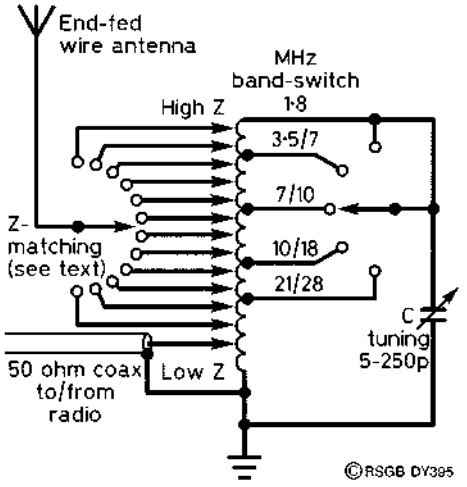

Figure 2 Simple multi-band ATU for end-fed longish-wire antennas

soldering iron, tin each tap point while the copper is shiny, thus ensuring a good, low-resistance connection. Do not solder on the taps yet.

The coil can now be wound as before. The taps can be soldered on, taking the lead from each one to the wafer of a single-pole 12-way rotary switch, the pole being connected to the aerial.

The tuning of the ATU is carried out by the same 250 pF capacitor, with a single-pole 5-way rotary switch used to select the band. Its tapping points will need to be chosen manually, using the method described earlier. Don't attempt to make new tapping points on the coil for this – use the taps available on the wafer of the other rotary switch, and find which is optimum for each band.

Notes

- For the aerial, use PVC-covered stranded tinned copper, of size 16/0.2 mm or 24/0.2 mm.
- Make the wire as long as possible, but anything over 10 m should be OK.
- Keep the wire as high as you can, in the clear and away from obstructions.
- Don't worry about bends, but don't use hairpin bends.
- Use a good insulator to attach your aerial – anything plastic will do.
- Anchor the wire near the point of entry to the building, but use a U-bend to prevent ingress of water.
- The wire can be brought in through the corner of a window, the PVC acting as an insulator. If you must drill a hole in the brickwork, make sure it slopes upwards from outside, so that water is deterred from entering.
- Use a good RF earth (as opposed to an electrical earth) such as half a dozen bare copper wires buried under the lawn in a fan shape. They should be joined together at the point of the fan and strapped to the earth connector of your ATU.

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THE ANKH

African Origin of Electromagnetism

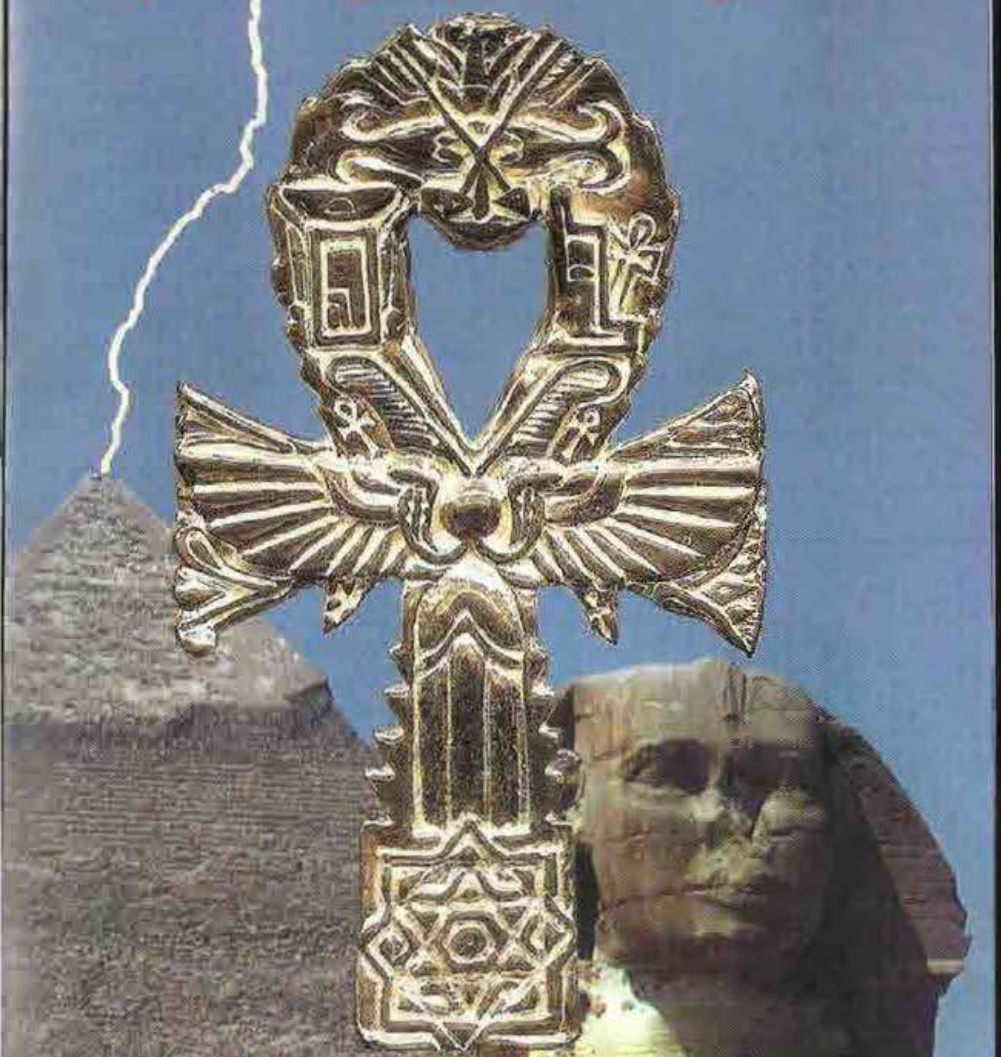

NUR ANKH AMEN

afterword

Heru Ankh Ra Semahj Sa Neah

Adrift upon an electron sea
Dying of thirst how could this be?
With water everywhere,
I search for money without a care
Never once did I stop to think
maybe it's time to take a drink

Nur

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AFTERWORD
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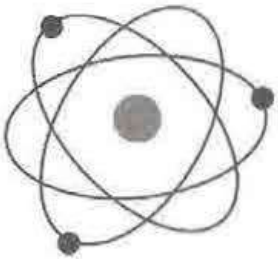

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National Council of Churches of Christ
The Egyptian Organization of Antiquities

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Introduction

DUE TO THE INCREASING INTEREST IN Egyptian science, the achievements of the Nile Valley civilization of Africa have been brought into focus. Depictions on tombs, pyramids and temples, provide a glimpse of the rich spiritual, cultural and scientific wisdom of Kemit.

These astonishing achievements point to the fact that Africa invented the Modern World. The origin of every scientific discipline, from algebra to zoology can be traced to the Nile Valley civilization in Africa. However in the face of overwhelming evidence to support an African origin of science and technology, the racist scientific community continues to deny its recognition. African Egyptologists fighting to return Egypt to Africa, have only been partially successful against the repressive colonial Academic Power that endeavors to hold our minds in slavery. The truth is the Real Estate over which we must be prepared to die, for a lie is far more dangerous, not only to ourselves but to our collective consciousness.

Now the war has taken a new turn on a different front: that of electronics. The most powerful tool of modern technology is electronics and its origin has, like most things, been attributed to the European minds of the early eighteenth century. With damaging consequences for our youth, the discovery of electronics has been claimed as the sole domain of Europeans without a single mention of any prior knowledge in Africa.

The European concept of discovery should be examined in the light of its political consequences on others, for a pattern exists which invariably results in domination and exploitation. The pattern eradicates the truth, and replaces it with lies designed to promote White supremacy. This is the prime directive: to maintain control over all other civilizations, by academic interference and distortion of traditional religious beliefs.

The discovery of the New World by Christopher Columbus is an example of this concept in action. Its awful brutality is fully documented and the results are evident on the native population even today, five centuries later. Discovery has nothing to do with original use, it is a means by which a Claim can be pursued and adjudicated by Colonial Powers.

The strategy is still used in all areas of endeavor, to allowing the expropriation of wealth, whether it be land, inventions, art or culture.

Evidence is mounting which proves that the so-called discoverers of electronics like Volta, Hertz and Benjamin Franklin, were merely Columbus's of the electronic frontier. The evidence also points to an extensive cover-up, which became imperative because of the legal aspects governing discovery. They are today known as Patent Laws. Subsequent knowledge of an invention could preclude any financial gains, rendering them useless to the new profiteer.

The cover-up and denial of prior electronic use in Africa allowed many inventions to be patented creating massive profit for the inventors and this new industry. One lie begets another and academia's role is to perpetuate these lies for future generations. However, to quote Professor Leonard Jeffries, "the truth is our most powerful weapon."

The parallel between the sudden rise in electronic inventions and European Egyptological excavations (grave-robbery) has been suspiciously ignored. It is no coincidence that the most important discovery in electronics, the pile or battery, and Napoleon's scientific expedition to Egypt occurred almost simultaneously.

Foremost in Egyptian electronics is the ☥ Ankh, and although the European Egyptologists claim that what it represents is still unknown, this is convenient ignorance.

The implication of Ankh Science is enormous and can only be fully understood through the spiritual awareness of the African, which allows him to appreciate and develop the technical sophistication with regard to its importance. I say Africans, because the ☥ Ankh is a symbol of our unique spiritual heritage. Although physical evidence of African electronic devices have long decayed or were expropriated for later examination by the plunderers of Egypt in the 18th and 19th centuries, there still remains sufficient proof of wide-spread knowledge and use in Kemit, prior to the Greek and Assyrian presence in the Nile Valley.

This book will be of special interest to those of us who have been educated in traditional electronics and science courses, and felt disenfranchised as White inventors were lauded for their contributions to a science our ancestors originated.

Author's Notes

IT IS THE AUTHOR'S HOPE IN writing this book, that serious investigation of this subject will follow, with the aim of restoring our traditional greatness and spirituality in these original African sciences.

My introduction to the ☥ ankh came in 1986 when I, as a jeweler, was asked, to make a silver ankh for a customer. I became extremely fascinated with the symbol that seem to communicate something about my ancestral past that resonated with my very soul. Trips to the local library and questions to so-called experts all gave a limited view on the subject. With the aide of my spiritual guide, Sankhamen, I investigated the Ankh for six years; studying every mention, drawing or article of jewelry. I came to the realization that the ☥ Ankh was the ultimate spiritual icon.

My traditional educational history was a disaster. I had difficulty understanding some concepts, because my professors were more concerned to label me as incompetent in science, rather than trying to educate me. The curriculum was designed to promote White

supremacy and discourage deeper understanding. There was something they did not want me to know, something that seemed to arouse great fear and anxiety in them. Somehow they knew I was different, that I was not buying "the great White scientist routine;" I wanted the truth. A truth that I later found them incapable of supplying. Was I asking to be educated or spoon fed?

I decided to wean myself from the American Educational System and pursue a deeper understanding of science through spiritual discipline and divine inspiration.

Through these methods I was taken to the heights of celestial wisdom and knowledge so vast in scope, that they could not be explained in the scientific precepts or language used today. My impressions are that spiritual precepts are a higher order of the same scientific concepts but separated by a yet unrecognized form of sensory perception. It was like trying to see with one's nose or attempting to describe a scene based solely on one's sense of hearing. No wonder the spiritualists were frustrated, they could not express to anyone what they knew to be true from these intensely personal spiritual experiences.

I have come to the conclusion that we can no

longer allow ourselves to be educated in the same manner, by a system based on cranial capacity, while ignoring our superior spiritual faculties, simply because they cannot be expressed in language to the satisfaction of our academic slave-masters. Divine inspiration is a supernatural form of communication and the ultimate goal of a truly liberated African Education System, a system that I contend is still intact today. Our professors and teachers are our ancestors, alive in a realm where belief is the door and the ☥ Ankh is the key.

What about credibility? Why do we need the Established Academic Apparatus to legitimize our theories, and why do we need degrees to expound on those we present? Why? Let the truth speak for itself.

They do not try to disprove the substance of what we are saying, instead they mount personnel attacks on us to discredit us, or worse , they will use one of our own. Maybe a respected Black Egyptologist, whose authority will be threatened by this revolutionary view of Kemit, which he, with all his scholarly acclaim could not bring to light.

The Ankh and Popular Myth

Anyone familiar with the ☥ Ankh will tell you it is the key of life and for some that explanation is sufficient, but for others the next question is, "what is life ?"

1. *Life:*
   a: the quality that distinguishes a vital and functional being from a dead body.
   b: a principle or force that is considered to underlie the distinctive quality of animate being compare
2. *Vitalism:*
   a: an organismic state characterized by capacity for metabolism, growth, reaction to stimuli, and reproduction.
   b: the sequence of physical and mental experiences that make up the existence of an individual.
   c: one or more aspects of the process of living
3. *Biography*
   a: spiritual existence transcending physical death.

Life is harmonious coordination of energy and matter, of such sophisticated construction and efficiency as to appear divinely ordained and self sustaining.

How could an object like the ☥ Ankh come to be representative of life? The only conclusion is that the Ankh is a mechanism that possesses a living characteristic.

An examination of the word and its usage in Egypt will reveal that the Ankh meant more than organic life.

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ankh life, to live, living

ankh- "life, stability, blessing [or, good fortune]

ankh- ever-living," living forever

ankhu human life, male.

ankh the living incarnation of God.

ankh- "to whom life is granted." life giving.

ankh ☥ 𓏏 𓏏 a living entity.

ankh ☥ 𓏏 the house of life

Ankhet ☥ 𓏏 the land of life, the etheric realm.

ankh ☥ 𓏏 life in a tomb.

The Encyclopedia of Hieroglyphics states:
The ankh is commonly known to mean life in the language of Ancient Egypt, where numerous examples have been found that were made from metal, clay and wood. It is usually worn as an amulet to extend the life of the living and placed on the mummy to energize the resurrected spirit. The gods and kings are often shown carrying the ankh to distinguish them from mere mortals. The ☥ ankh symbolized eternal life and bestowed immortality on anyone who possessed it.

There is no consensus among Egyptologists as to what object the ankh represents.

It is believed that life energy emanating from the ☥ ankh can be absorbed by anyone within a certain proximity. An ankh serves as an antenna or conduit for the divine power of life that permeates the universe.

The Amulet is a powerful talisman that provides the wearer with protection from the evil forces of decay and degeneration.

The Encyclopedia of Ancient Egypt defines the ankh as:

The symbolic representation of both physical and eternal life. The ☥ ankh is the original cross with a loop that was held by the gods. It is associated with Isis and Osiris in the Early Dynastic Period, and although the knowledge of what object it signified was lost, it remained a hieroglyphic symbol of life to the Christian era.

The ankh was used in various religious and cultural rituals involving royalty. In the Treasures of Tutankhamen, the ankh is explained away as:

A stylized version of a sandal strap.

Zolar's Encyclopedia of Omens, signs and superstition says:

The circle symbolizes eternal life and the cross below it represents the material plane. The ☥ ankh is called the "Crux Ansata," it is of Egyptian origin and can be traced to the Early Dynastic Period, appearing frequently in artwork of various material and in relief, depicting the gods.

It is usually held to the nose of the deceased king

by the gods to represent the breath of life given in the after-world. The ☥ ankh resembles a key and is considered the key to eternal life after death.

Its influence was felt in every dynastic period and survives as an icon possessing mystical power throughout the Coptic Christian Era.

Amen: The secret waters of the Great Pyramid.

The ankh was the key used to control the flow of water in the underground flow of the Nile, the way a tap is used in today's faucets.

The wire ankh has been used in Dowsing, which is the pseudoscience of detecting water underground.

Stonehedge: Large volts of energy have been emitted from a megalith to a wire shaped in the form of an ankh.

The ankh possessed by each god had power associated with that god. The ankh of Anubis related to the protection of the dead, that of Sekmet war, Hapi related to the living waters of the Nile and Amen, the spirit god, the breath of life. It is being suggested that the ankh box found in the tomb of Tutankhamen was actually a mirror case. Although no such mirror was found and mirror cases were not completely enclosed, as only the mirror face needed protection, it is still referred to as a mirror case.

The ankh box of Tutankhamen

The box contained Tutankhamen's ankh device, which today is no doubt sitting in the private collection of some wealthy European collector. Some say it's in the Vatican.

One very curious theory suggest the ankh ☥ produced high pitch ultrasound inaudible to our human ear but effective in frightening wild animals like jackals and hyenas. This would have been especially useful in the wilderness at night, protecting travelers from unseen dangers.

Not only were the living protected but the dead as

well. Ultrasound has the effect of frightening insects, rodents and maggots that would devour the bodies of the deceased. By producing tiny air bubbles in the body of pests, the ultrasonic environment is very uncomfortable.

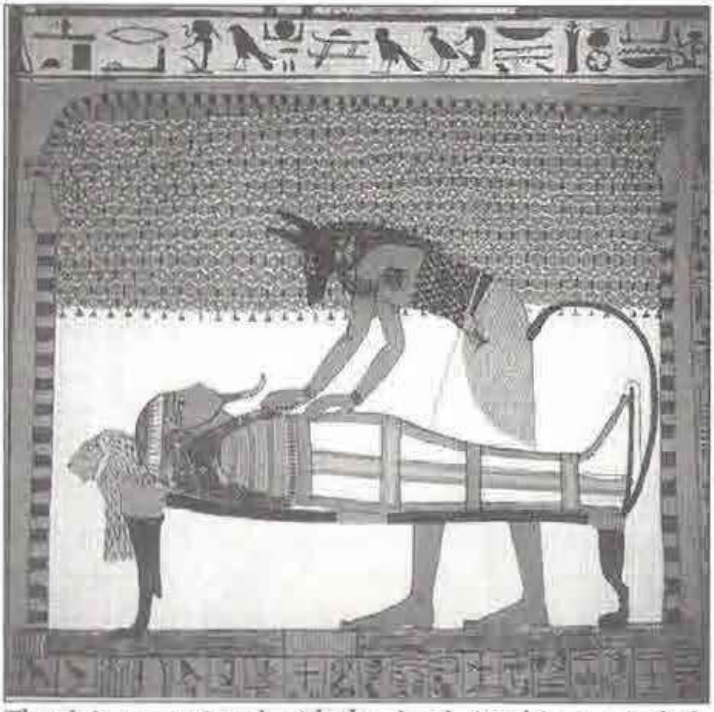

The deity associated with the dead, Anubis, is a jackal-headed god with his ears pointed up, able to hear what is inaudible to man.

Although the basic shape has remained constant, closer examination reveals subtle differences in design and construction of ankhs at different periods. The

different shapes suggest refinement or varied usage.

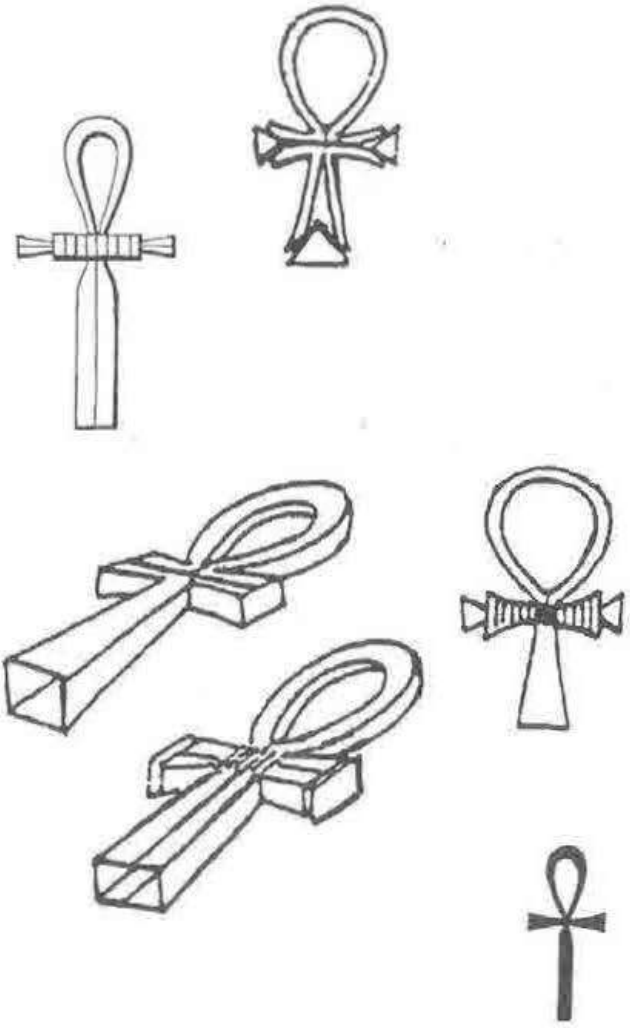

The ☥ ankh is often depicted in combination with other symbols, but it is usually attached to its power source, the djed.

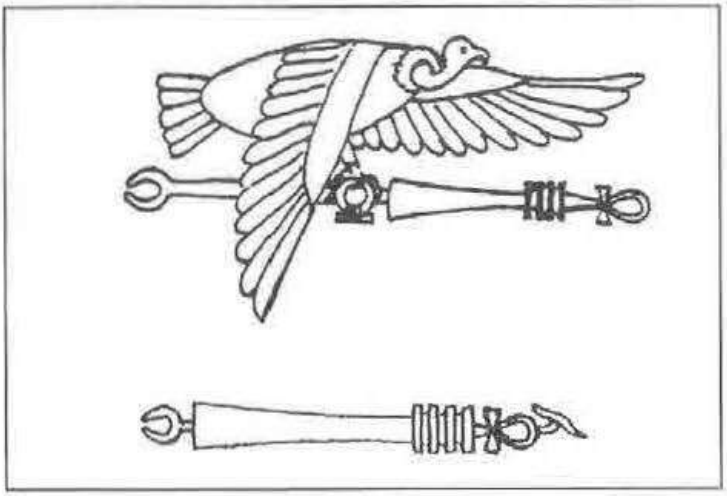

The gods Ptah and Khonsu hold this combination scepter.

Ankh Science and the History of European Electronics

THE EARLIEST RECORD OF studies in electrical and magnetic phenomena by Europeans, were done by priests of the Jesuit Schools in the 17th Century. The mysterious properties of amber, which attract small pieces of paper when charged, and the lodestone or magnet were investigated.

The core knowledge of these schools relied on the works of Greek philosophers like Pythagoras and Aristotle, who were students at the feet of the Africans in Kemit. The electron is named after the Greek word for amber.

Experimentations of the 17th Century culminated in the discovery of means by which large static electrical sparks could be produced by various contraptions which reproduced the effect of rubbing one's shoes on the carpet and touching a door knob.

An accidental discovery enabled electrical charges

to be stored in what is called a leyden jar or capacitor in 1742. This device stimulated interesting experimentation all over Europe and as far away as Japan. Electrical current could be passed from person to person in a chain and a terrific lightning bolt could be produced by the discharge.

A leyden jar or capacitor is constructed by placing an insulating material, usually wood or glass, between two sheets of metal. This invention was known 5000 years before in Ancient Egypt. Shrines were built of wood and covered with sheets of gold inside and out, then charged to protect sacred objects placed inside.

One of the most famous of these shrines was the Ark of the Covenant. Built by Moses the Egyptian, to protect the tablets of the Ten Commandments and to serve as a reminder of the presence of God. Once charged this portable shrine was potentially lethal if touched, as was evident in the Old Testament account. A priesthood specially trained to handle the shrine wore special clothing for protection and used a rod to ground or discharge the Ark. When the shrine was discharged by the priest it could be handled safely.

Exodus 25

10 "They shall make an ark of acacia wood; two cubits and a half shall be its length, a cubit and a half its height

11. And you shall overlay it with pure gold, within and without shall you overlay it, and you shall make upon it a molding of gold round about.

12 And you shall cast four ring of gold for it and put them on its four feet, two rings on the one side of it, and two rings on the other side of it.

13 You shall make poles of acacia wood, and overlay them with gold.

14 And you shall put the poles into the rings on the sides of the ark, to carry the ark by them.

15 The poles shall remain in the rings of the ark; they shall not be taken from it.

16 And you shall put into the ark the testimony which I shall give you.

17 Then you shall make a mercy seat of pure gold; two cubits and a half shall be length, and a cubit and a half its breath.

18 And you shall make two cherubim of gold; of hammered work shall you make them , on two ends of the mercy seat.

19 Make one cherub on the one end, and one cherub on the other end; of one piece with the mercy seat shall you make the cherubim on its two ends.

20 The cherubim shall spread out their wings above, overshadowing the mercy seat with their wings, their face one to another; toward the mercy seat shall the face of the cherubim be.

21 And you shall put the mercy seat on the top of the ark; and in the ark; and in the ark you shall put the testimony that I shall give you.

22 There I will meet with you, and from above the mercy seat, from between the two cherubim that are upon the ark of the testimony, I will speak with you of all that I will give you in commandment for the people of Israel.

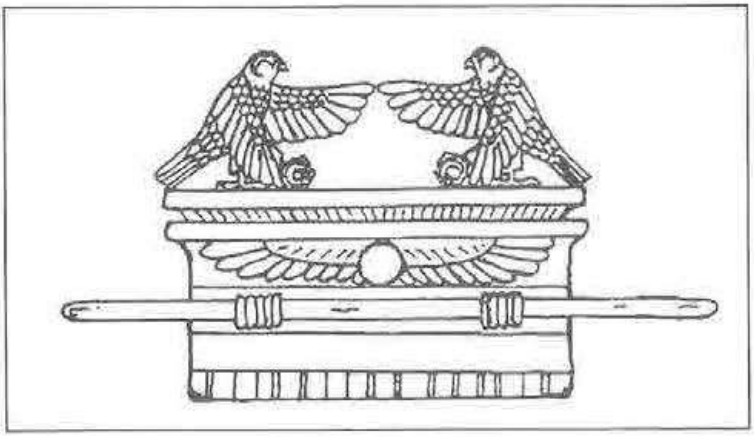

The Ark of the covenant

> And when they come to the threshing floor of Chidon, Uzzah put out his hand to steady the ark, when the oxen stumbled. And the wrath of the Lord was kindled against Uzzah; and he smote him because he put forth his hand to the ark; and he died there before God.
>
> *1 Chronicles 13: 9*

When the positive and negative terminals of a charged capacitor or shrine where brought close to each other, a spark could occur and if the capacitor is attached to a stable source of current, charging and discharging occur at a specific rate.

The high voltage necessary to charge the shrine or ark was provided by the atmospheric potential difference between the sky and the ground. The electrical gradient above the earth is 60 to 100 volts per meter in

fair weather and increases to 6000 to 12,000 volts per meter under a thunderstorm.

Shrines were usually placed on high mountains, natural or artificial, to take advantage of this effect. Moses was no doubt an eye witness to the ark in the King's Chamber of the Great Pyramid at Giza. The sarcophagus contained the electrified mummy of the God-King Khufu as part of a high voltage circuit.

With this tremendous power, the God-king could still communicate his will in this world from the ankhet (the other-world). So powerful was this achievement that certainty of an afterlife was firmly engraved in the psyche of Egypt, lasting thousands of years. Communication was not necessarily in words, like radio, it was a spiritual communion or revelation which was impressed upon the mind resulting in a prophetic experience.

They were communications of a highly moral nature, coming from beings who had been freed from the sinful bodily nature and viewed us as being almost like children.

The pillaging and grave robbing in Egypt continued for hundreds of years by foreigners of every description. Total disregard for the African was the only rule, so much so that the mummies or corpses

were ground and boiled to make potions for sale. The European trade in mummies in the 16th and 17th century took on a feverish pace, because they were thought to have medicinal value. The melanin rich corpses of your ancestors were eaten by these savages.

By the 18th Century, the plundered skeletal remains of Egypt were under the control of intellectual scavengers in search of occult wisdom, by which they could feed the already mesmerized and addicted European aristocracy. Collectors were willing to spend fortunes to acquire these objects of antiquity, especially if they were rumored to possess some mysterious supernatural powers. Many of these curious objects are still kept secretly in private collections throughout the world.

In 1798 Napoleon recruited 167 scientists and technicians to accompany the French fleet in the conquest of Egypt. And in 1801 Volta, the so-called discoverer of the pile or battery, was given a medal and a pension by Napoleon for his contribution. The British invasion of Egypt in 1801 seemed primarily aimed at stopping the French savants from exporting anymore artifacts. It was viewed as a matter of National Security in those days.

Volta's discovery of the principles by which the

djed produced a stable electrical current, is considered to be the greatest invention of the 19th Century.

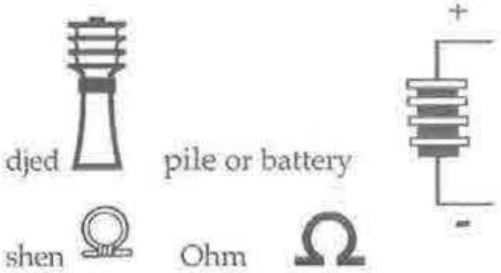

symbol for water and hieroglyph "n"

electronic symbol

Note the similarity between these symbols.

The Encyclopedia of Ancient Egypt defines the djed as:

The Egyptian symbol of stability. The djed is a pillar with bands across the top and base. This hieroglyphic symbol is associated with the Osirian mortuary cult practice of mummification. Serving as a powerful symbol in Egyptian magic and reincarnation, where it was used to symbolize the metamorphosis which the body underwent at death. The transformation of the physical being into its eternal celestial form.

The djed is thought to represent the backbone of Osiris, who's sparks were as bright as the Sirius Star.

It is also associated with Jacob's Ladder.

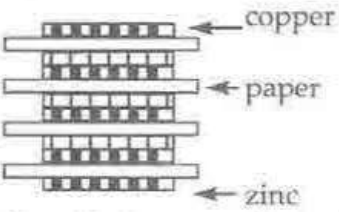

A djed or battery is made by placing two dissimilar metals on either side of a piece of papyrus soaked in salt water or acid. Greater power can be realized by increasing the number of units. For instance, a single unit of zinc and copper can produce 0.759 volts and the current has greater magnitude than that produced by electrostatic machines. Napoleon gave the Ecole Polytechnic University a battery with 600 units.

Passing voltage through all sorts of material, experimenters using these batteries were able to produce many chemical reactions and split molecules like water into hydrogen and oxygen.

Egyptologists have long suspected the use of direct current in Egypt by the many examples of electroplated jewelry and their knowledge of other chemical processes. The Egyptian word for electroplating of silver or gold is sem (sem means: a kind of, similar i.e. likeness of gold) which contains the ideo-

graphs conveying the entire process. The uas: an indicator of electric current and nub, a gold in solution. However rather than accept the scientific evidence, these artifacts are often attributed to accidental occurrence or some still unknown process.

A good example is their promotion of iron as a Hittite technology, despite evidence of prior usage in Kemit. Chiekh Anta Diop claims iron usage originated in the Ancient Empire (2700 B.C.) and that the steel blade of Tutankhamen's dagger, could only have been produced by very deliberate means. He theorized that such a purity of iron would require the type of sophisticated processes used in modern electrolytic refinement. The ideograph for pure gold is proof that the Egyptians knew that the electrolytic process led to the purest metals.

Plating was in common use during ancient times as evidenced by the many words for it. Yet no such words in Coptic (a Greek-Egyptian language) have survived, except in a reference to Alchemy from a variation of the word 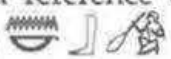 NHB neb; to smelt or work in metal (gold).

Alchemy, the transmutation of base metals, i.e. lead, to gold, was the most sought after secret of the Medieval Period. The origin of the word chemistry, it is a reference to Egypt and the philosophy held by the Blacks concerning the transmutation of the body to an immortal spirit.

Had Egyptology been in the hands of Africans or people without a racist agenda, more knowledge would have been gathered concerning these batteries. For instance, the origin of the lead acid batteries in popular use today, may well be Ancient Egypt. Both lead and lead oxide, the elements of its construction were widely used by 3000 B.C. But what is most interesting is the word tet (battery or djed), it sounds like teht, Copt ⲦⲀⲈⲦ the word for lead.

With the principle of the djed fully understood, the principles of the Ankh remained the greatest challenge to European scientist, however it would not yield its secrets for another 87 years.

Early attempts to unravel its secrets were made by Henry, now credited with the discovery of self- induction.

Henry reports that...

When a short wire is connected across a battery, no

spark is perceived when the connection is formed or broken. But if a wire 30 or 40 feet long is used instead of the short wire, although no spark will be seen when the connection is made, yet when broken a vivid spark is produced. The effect appears somewhat increased by coiling the wire into a helix; and it also seems to depend in some measure on the length and thickness of wire...

Henry had rediscovered self-induction, the method of producing electricity from a changing magnetic field.

Hans Christian Oersted (1777-1851) observed in 1820 the magnetic action of an electric current, opening the study of electromagnetism. He observed the deflection of a magnetic needle during a thunderstorm.

In 1842, Henry observed that the effects of sparks in one location could be detected some distance away by their magnetic effects in another location. The analogy between the rippling waves, caused by a stone dropped in the center of a pool, and the spark transmitting rippling waves in an ether-like medium, were attributed to Henry. He also noted that the effects of a single spark could be detected thousands of feet away.

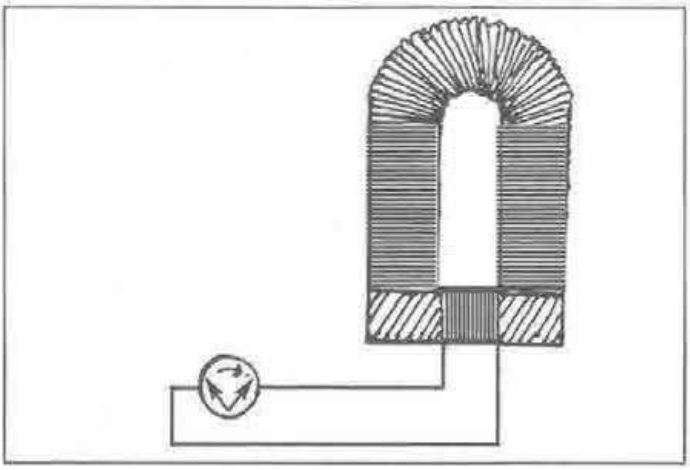

Hertz, experimenting with various sizes of loop detectors, was able to detect electromagnetic waves and determine quantitatively the effect known as resonance. Using the spark from an induction coil, electromagnetic waves could be detected in a loop some distance away. In other words, a spark in one location produces a spark between the gap of a loop detector in another location.

A hertz oscillator consists of a coil and a capacitor, made from two flat sheets of metal B and a spark gap G. One can easily see the similarity to an ankh oscillator, which produces a higher frequency because the coil is one turn or loop.

As mentioned before, the English defeated the French in Egypt, taking over the scientific explorations and

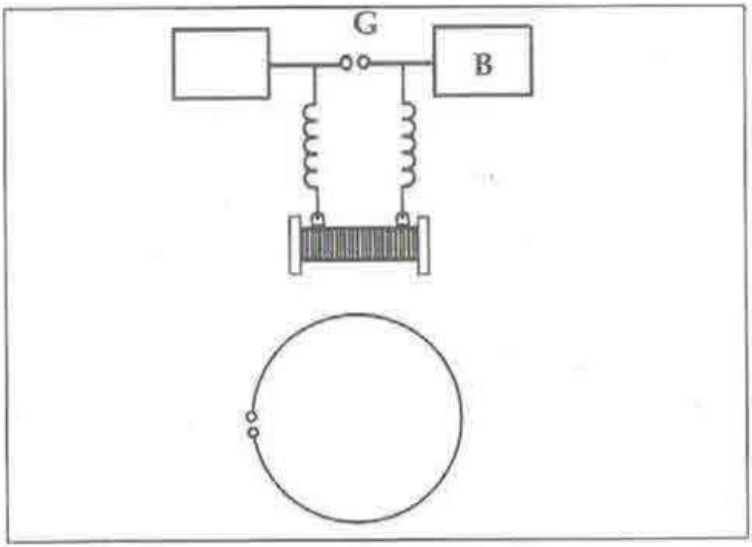

Apparatus used by Hertz to demonstrate the wave like nature of electromagnetism.

other antiquities excavated by the French. Among these were strange devices, numerous scientific and mathematical papyri and most notably, the "Rosetta Stone."

As a result of this scientific coup d'état, Newton, the famous mathematician provided the mathematical language to codify the theory of wave transmission and the action-at-a-distance properties of electromagnetic waves. Budge was able to translate the so-called Book of the Dead, and Sir Oliver Lodge discovered the properties of the ☥ Ankh.

Lodge was the first European to prove that lightning and sparks between the gap, were high-frequency discharges. Current would rather flow through the high resistance path across the gap, than the low dc-resistance wire loop. He was able to show that this occurs because of the high impedance presented by the wire loop at higher frequencies. Lodge was fascinated with the subject of psychic phenomena and communication with the dead. He spent much of his time trying to give scientific legitimacy to Spiritualism.

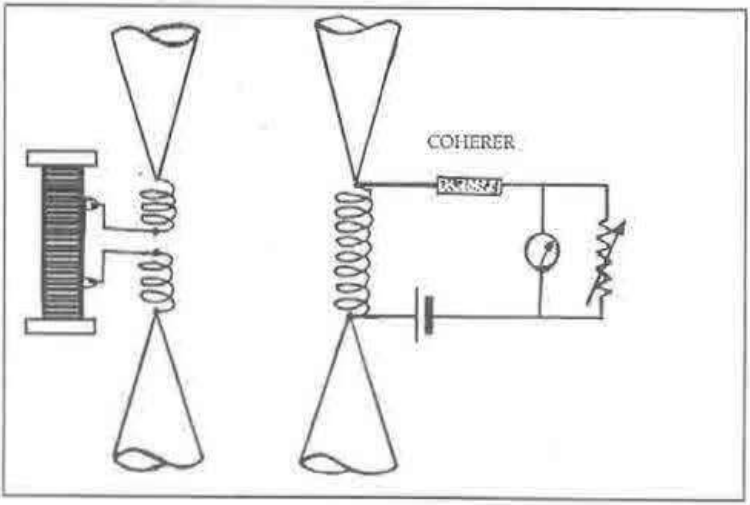

Lodge's transmitter and receiver.

You may have noticed a set of grooves or lines in the center of some ankhs, especially the one belonging to

Tutankhamen. Well, after the discoveries of Hertz, a Professor Righi invented a very sensitive spark gap made from a sheet of glass covered with tin foil. This foil was divided into several strips by very fine razor cuts. When used in a Hertz loop detector, sparks are easily observed jumping across each gap in the foil. I would think Professor Righi was 4000 years late.

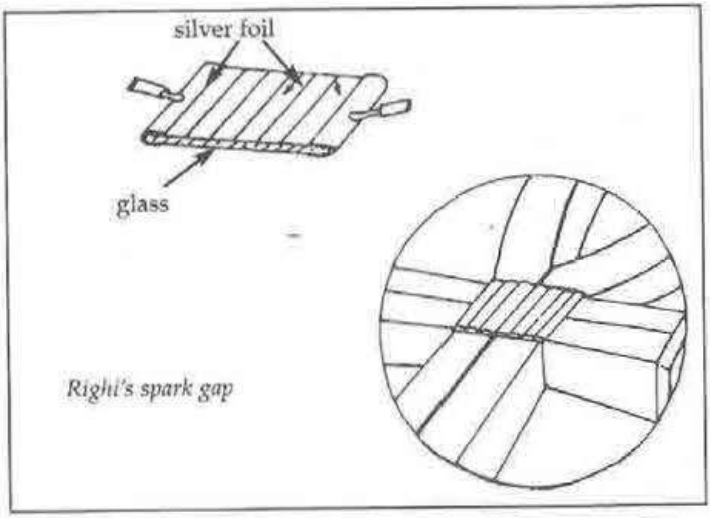

Righi's spark gap

The early telegraph and radio circuits used detectors of various construction and material. Detectors are required because the high frequency of the oscillator is inaudible. A very sensitive detector was galena (lead sulfide) crystals, some of which were found in Tutankhamen's tomb.

The hieroglyphic symbol for stone in the cen-

ter of the ☥ ankh, suggests the usage of crystal or even semiconductor technology. For instance, continuous wave oscillation can be produced by attaching oscillating components (capacitor and inductor) and a battery across a galena-galena contact. This black stone, kam a representative of Egyptian Spirituality, is the most sensitive crystal, detecting electromagnetic waves well into the infrared frequencies known as heat.

Maat with her eyes closed

If you subscribe to the belief that the ankh of a god had power associated with that god, then the ankh of Maat would be instrumental in the realm of law and righteousness. Maat is the goddess of truth, indispensable in the cause of justice. Her symbol is the feather of truth, against which the heart is weighed in the judgment. Therefore, she is representative of the solar archetype Libra.

The ankh she is holding, is the oracle of truth,

operating on a principle known as galvanic skin response (GSR) named after the Italian experimenter Luigi Galvani, who in 1750 discovered the reflex action of a frogs leg to electrical stimulus, it is widely used as a part of a modern polygraph test.

The conductivity of the skin varies with one's emotional state and what makes (GSR) so effective is how totally involuntary these skin responses are. An electrode is placed in the hand or taped to the finger of the subject and the conductivity or resistivity of the skin is measured in response to questioning. The skin is the key to the soul, portraying subtle psychological changes, it does not lie.

Vesica Piscis

Changes in conductivity of the skin alters the capacitance of the ankh, creating frequency changes as a result. By holding the ankh in this way, the emotional and spiritual responses can be communicated as a frequency modulated transmission.

A high frequency oscillator, like the ankh, has the advantage of producing high voltages at low current,

so they can be handled safely. Tesla was known to have attached a high frequency coil to himself and produced corona-like discharges from his body. Luminous effects produced by high voltage high frequency coils are used today in Kirlian photography. Objects appear to have a glowing aura around them, when subjected to high voltage.

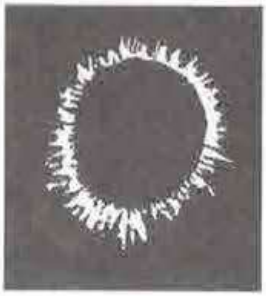

Kirlian photograph of a fingertip

The Europeans have skillfully rewritten history in such a way as to present themselves as the sole provenance of all science. Weaving a concoction so convincing, that one can only conclude that they alone have brought progress to the world. This part of their racial policy is important if they are to convince the world to tolerate their murderous onslaughts and exploitation as a necessary side effect in the cause of civilization.

One chord seems consistent in the propaganda of their discovery: a diversionary claim of ignorance and the naming of other Europeans on whose work they hold up as the basis or source material for their discovery.

Columbus used the diversion of seeking a route to

India, even though he was in possession of maps and accurate information gleaned from West African sailors who had been traveling across the Atlantic for 200 years. He claimed the Portuguese as his information source. It is the same with Volta and Galvani in the concealment of the piles Egyptian origin.

This stranglehold caused by European editorial censorship of Egyptology, is preventing the spiritual reconnection with our glorious past. Without the oppressive scrutiny of the Academic Establishment, you are free to develop your own conclusions about the ☥ ankh using your knowledge of electromagnetism as a guide.

It is imperative for us as Africans to develop a way of teaching electronics, that is both interesting and culturally relevant, if we are ever to compete successfully in the new millennium

FREE THE PEOPLE!!

The Ankh is essential to the liberation of African peoples throughout the world. Without the Ankh and it's associated technology we will remain dependent on the inferior technology permitted by the maintainers of the status quo.

As a Free Energy Generator the Ankh represents

the symbol of our liberation. It produces electricity indefinitely without any fuel or other energy sources such as wind, solar or hydro power.

Ankhs of different sizes or capacities may be used to power boats, cars or airplanes giving them infinite range. Imagine, never running out of fuel or paying another utility bill; enjoying the freedom to live in remote regions of earth and sky as UFOs that are powered by ☥ Ankhs.

The Oscillator

AN OSCILLATOR IS A circuit which produces or responds to electromagnetic waves, usually within a range of frequencies. The circuit may consist of only a single wire, crystal or transistor semiconductor device. They respond most strongly to vibration at their resonant frequency.

Everything in nature is an oscillator and God is the spark projecting all frequencies to which everything responds. Atoms and molecules are perfect oscillators, which respond to light by absorbing and emitting at specific frequencies. Even complex organic molecules like melanin exhibit quantum states once thought to be limited to atoms and molecules. An oscillator's ability to absorb and emit energy, explains a host of phenomena which were once considered mysterious.

Oscillator: a sine wave within a circle, is the modern symbol that corresponds to while the uraeus which is the ancient symbol, representing the serpents undulating or oscillating movements across the sand.

A circuit containing a capacitor, inductor and resistor are the components of an oscillator, which operates within a defined range of frequencies depending on their values.

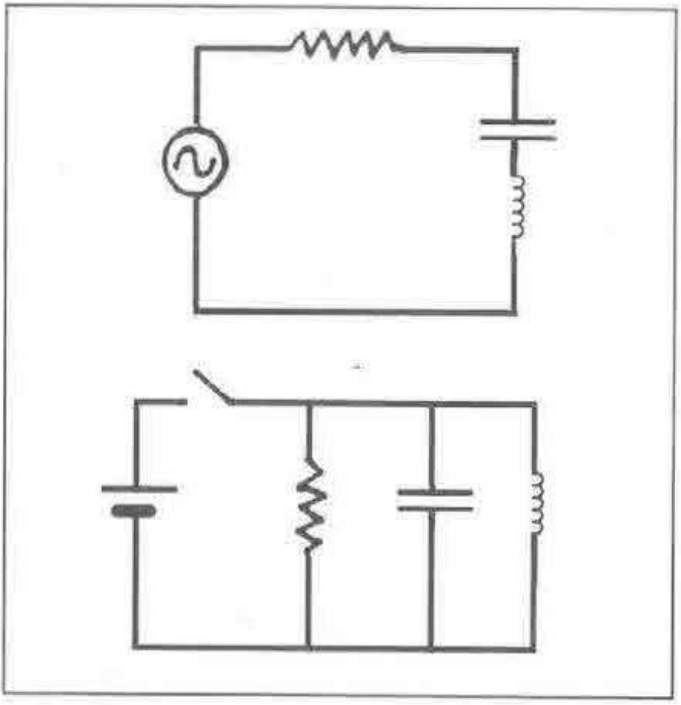

Because of the frequency-restricted nature of these oscillators they are called filters. They are also called tank circuits because of their ability to store energy.

When the switch is opened, oscillations are produced by the opposing nature of the reactive components. However, without a method of amplification in

the LC circuit, the resistance eventually quells these oscillations. The result is a dampened waveform.

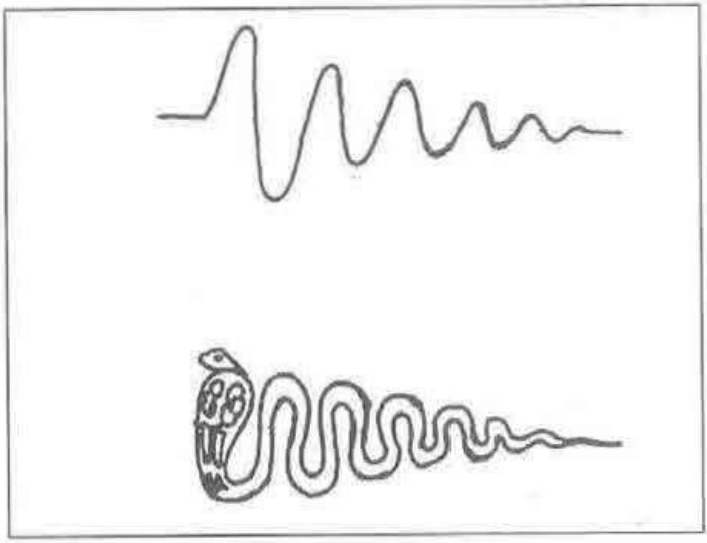

The components of a typical oscillator can be traced to the Amen Priesthood, which wielded power based on knowledge kept secret from the masses.

The symbols in many hieroglyphic reliefs are in fact elements of electronic circuit design, meant to convey knowledge of the hidden force of electromagnetism, to the future generations of this Order. These symbols would hold supreme religious significance only to the descendants of a race of Photonic Beings.

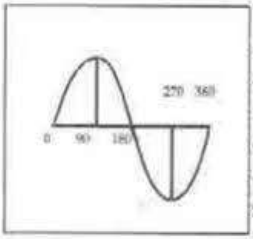

The mathematical description of a sine wave is attributed to Fourier, one of the 167 French savants who accompanied Napoleon in the conquest of Egypt. His formula describing a wave as a distinctive sum of sine waves, defined by their frequency, amplitude and phase, predates the European discovery of electromagnetic waves by almost a century.

Like Volta's discovery of the djed, Fourier's mathematical description of the serpent, has made a profound impact on all areas of analysis from sound to quantum physics.

The scepter (rod, conductor or connector) is an important electronic component, used in the conveyance of current through a circuit and in discharging a capacitor (shrine).

The gods are often shown holding the scepter to symbolize their power over the lethal force of electrical discharge. This rod, having a loop at its base which allowed a free swinging connection, is a switch. Once planted by the loop, it was thrown against the shrine to affect an electrical discharge flow to ground.

Hence the phrase "throw the switch."

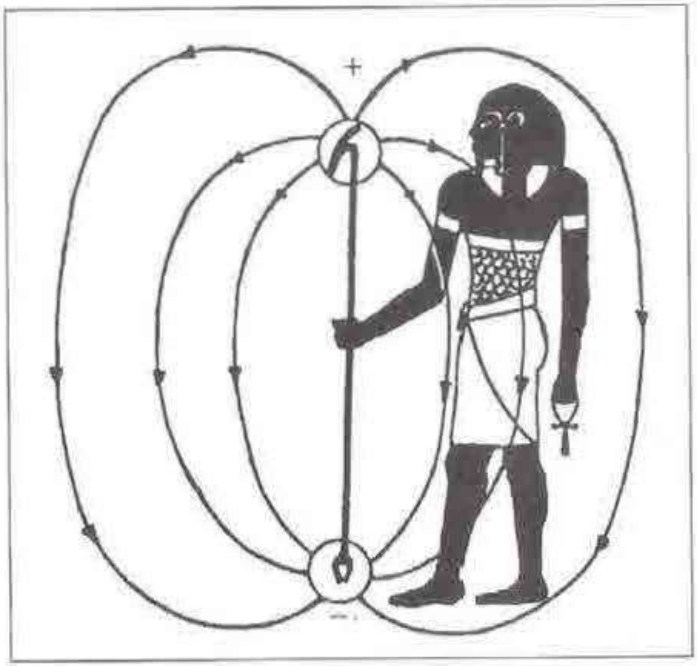

The electric field around a dipole antenna.

The mark of the beast Set (, a canine) and the mark of Cain are one and the same, the symbol of Christendom (+). The ion only the Setian could consider positive. While the ideograph of the earth is the ground and a source of the electron (-).

The Egyptians were fully aware of the fact that a spark produced high-frequency discharge and understood the inductive properties of rods and wires.

> So Moses and Aaron went to Pharaoh and did as the Lord commanded; Aaron cast down his rod before Pharaoh and his servants, and it became a serpent. Then Pharaoh summoned the wise men and sorcerers; and they also, the magicians of Egypt, did the same by their secret arts. For every man cast down his rod, and they became serpents.
>
> *Exodus 7: 10*

A conductor wrapped in coiled fashion, as a serpent is known to coil itself around a rod, is an electromagnet.

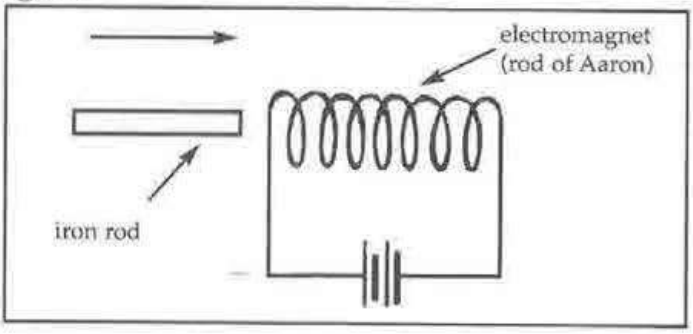

... But Aaron's rod swallowed their rods.

The Egyptian name for this coil circuit is qeb, which is also the name of the multi-coiled mythological serpent Qeb. The magnetic attraction of a coil was well known to the Egyptians, 4000 years before the European named Gauss, Henry or Weber as units of magnetic force.

Another device attributed to Moses is the Helicial

antenna, made in the form of a copper serpent and suspended on a pole. It was supposedly built in the wilderness (Egypt), and as the golden calf, represented the goddess Hathor, the serpent was symbolic of the goddess Isis The serpent built by Moses was destroyed by Hezekiah during a period when Israel was under intense pressure from the Assyrians to abandon their spiritual, cultural and military alliances with Egypt.

> He removed the high places, and broke the pillars, and cut down the Ashe'rah. And he broke in pieces the bronze serpent that Moses had made, for until those days the people of Israel had burned incense to it; it was called Nehushtan.
>
> *2 Kings 18:4*

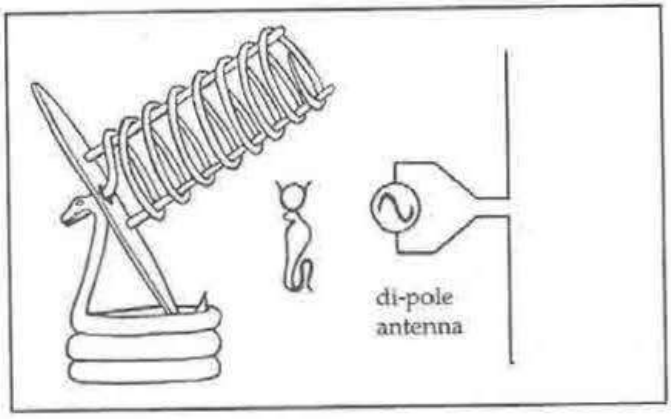

Antennas are resonant circuits which detect a speci-

fied range of frequencies. Two forms of these are the half-wave dipole and loop antenna. Used extensively by Hertz to prove the existence of electromagnetic waves, the loop antenna was used to detect the waves emitted from a dipole antenna.

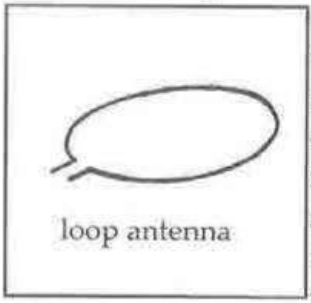

At the turn of the century the basic concepts of the Ankh were understood, as evidenced by the Duddell's musical Arc. The arc or spark-gap has negative resistance, where the resistance to electron flow is greatly reduced. If an oscillating circuit (inductor and capacitor) is placed across a spark-gap, oscillations are induced in that circuit.

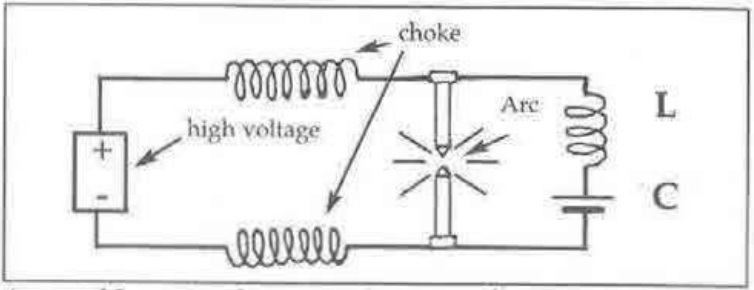

A metal loop in close proximity to the spark-gap could be excited into oscillation, due to the ultraviolet rays ionizing the air between the gap of the loop.

Perhaps the closest circuit that describes the ☥ ankh's operation is the Liebowitz Mercury Generator,

invented in 1914. Using a mercury vapor tube instead of a spark-gap, continuous oscillation was produced.

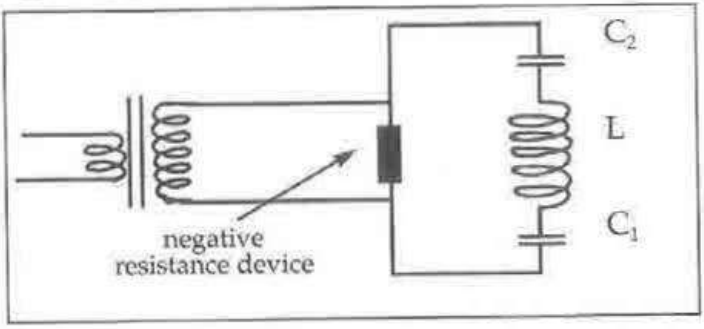

With the advent of other negative resistance devices, like the vacuum tube and the transistor, spark-gap oscillators were no longer used. They were considered noisy for the purpose of communication.

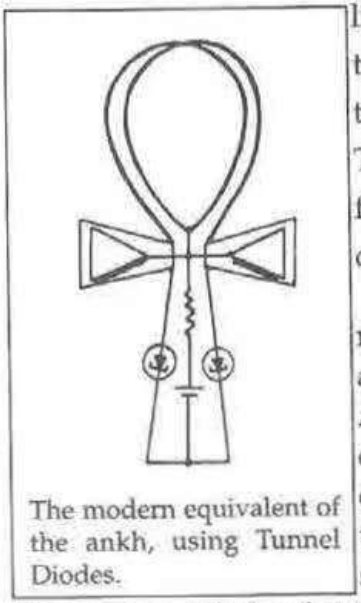

The modern equivalent of the ankh, using Tunnel Diodes.

The question still remains, whether a method of amplification existed in Ancient Kemit. An essential component in the production of continuous wave oscillation, amplification is necessary in overcoming the dampening effects of circuit resistance. It is my belief that both evacuated glass tubes (vacuum tubes) and semiconductor type active components were known

and used by the Egyptians.

symbolic representation of amplification.

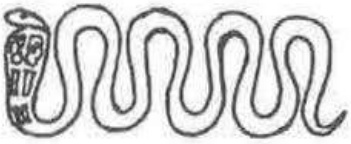

a representation of continuous waves

Continuous waves have been produced in circuits using an ark light bulb as an active device. And it should be remembered, that the first vacuum tubes were invented through experimentation with ordinary light bulbs.

You maybe asking yourself why the Europeans did not use the ☥ Ankh for its intended purpose, or how could an object so popular in the Nile Valleys of Africa be virtually ignored in Europe.

This is because the Europeans lacked melanin, which is an organic semiconductor, that acts as a detector (the sixth sense). Without an electric skin, an ankh is practically useless. However the principles on which the ankh operated would give birth to the many electronic gadgets in use today.

Melanin

Melanin is a pigment in the skin of people of color, which is produced by melanocyte cells, and deposited in the epidermal tissue. Melanocytes are neuron-like cells which produce melanin and numerous proteins in response to electromagnetic radiation.

The production of melanin starts with the conversion of tyrosine by the enzyme tyrosinase to 5, 6-iodole quinone.

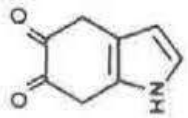

chemical stucture of 5, 6-iodole quinone

Tyrosinase is a copper-containing enzyme which catalyzes the conversion of tyrosine (an amino acid) and stabilizes the conformation of the melanin structure.

The metal ion acts as a backbone for the polymer structure of melanin, resulting in a metal-organic complex. The amino acid forms peptide-linked formations with the metal ions. The ligands are attached at the nitrogen atoms.

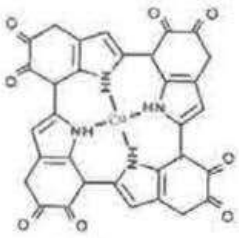

The proposed structure resembles a swastika, with the interactions occurring between the central Copper (Cu) ions. This complex metal compound is the only substance in the body that qualify as a organic semiconductor.

Black and brown melanin granules are oval in shape, forming a small dipole antenna. The field due to one dipole can induce a dipole in another melanin granule nearby.

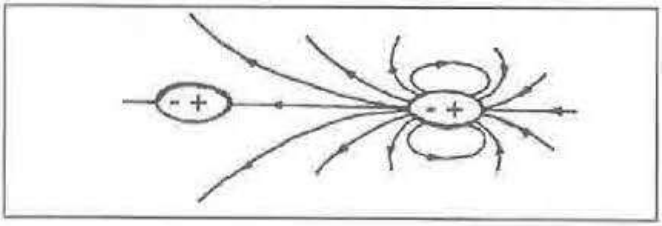

Melanin granules act as tiny primitive eyes, forming a large neural network structure, whose function is to absorb and decode electromagnetic waves. Neural-network computers are learning machines which are made with a number of receptors that can adjust their weights (quantitative properties) to produce a specific output.

The bodies of Africans contain massive amounts of melanocytes that encode all life experiences in their

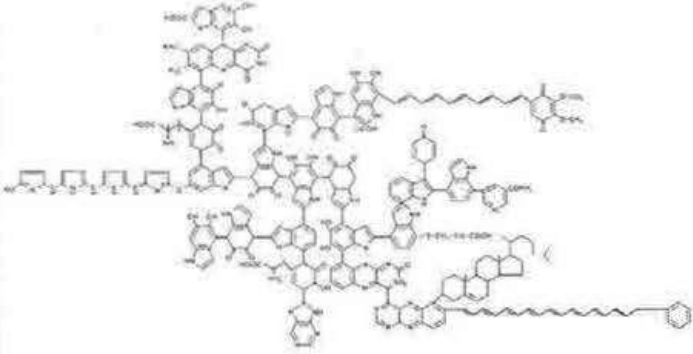

chemical stucture of melanin molecule

melanin production, with the aim of creating an actual- reality state after death. During life, visions appear frequently and ESP is common.

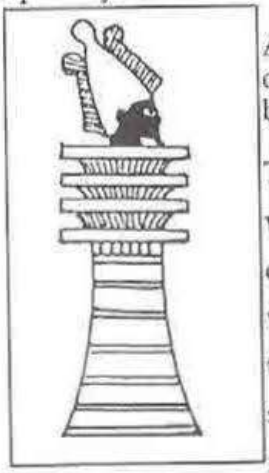

A representation of a higher form of life, in the superconducting body of Osiris (the mummy)

The reason for mummification was to preserve the skin which contained a living neural-network of melanin. The conductivity of melanin increases with age, so Tutankhamen's mummy is more alive in the spiritual plane than our own. Consider the difference in flammability between living green trees and coal.

As a semiconductor, melanin has an energy gap. The absorption of energy is required before electrons can jump into the conduction band and make melanin conductive. An increase in conductivity increases the sensitivity of melanin to the electromagnetic world of etheric beings, astral projections and spiritual entities.

At low frequencies, the conductivity of melanin is small, but at ultra high frequencies (UHF), melanin is a superconductor. Maximum current flows only on the skin, due to the skin-effect, at melanin's UHF resonant frequency.

King Tutankamen on his throne

Melanin is the most important substance in the human body. It is an oxidized form of RNA, which enables the body to coordinate the production of Proteins

needed in cellular repair. Wherever there is cell damage melanin is seen surrounding the site, functioning as a neurotransmitter in coordination with melanocyte protein production for the repair of damaged DNA.

Knowledge of the medicinal value of melanin is suppressed by the Medical Establishment in order to deny its supremacy.

The most damaging attack on African health is the promotion of albino domesticated animals for consumption. In fact only albino animals are considered domesticated. The yellow pigment in chicken and the lack of tyrosinase in albino animals, are responsible for premature aging.

Illustrates the curative properties of negative ions, the electromagnetic energy of mental concentration can be directed through the breath of life, by a competent Psychic healer.

The laying of hands on which is known to emit energy from the aura.

The Spiritual or Electromagnetic Worlds

THE MYSTERIOUS NATURE of God is central to Christian doctrine. Most believers and their preachers maintain the mystery through ignorance and confusion. The various interpretations of the Bible leaves one wanting for a simpler understanding and a more practical version of God. Despite the many scientific discoveries into the nature of the world, a separation between science and religion has prevented the understanding of anything spiritual, from an objective point of view. This separation is the result of a pathological condition among non- pigmented people, which renders them incapable of becoming in tune or sensing these higher forces directly. Imprisoned by this condition, our white ruler's viewpoint on spiritual affairs cannot be trusted despite its domination over more traditional nature-based religions of the world.

It is obvious that the early Christians' religious concepts came to Europe from Ethiopia, as evidenced by the language used to describe the spiritual realm.

ethereal 1. a: of or related to the regions beyond the earth b: celestial, heavenly c: unworldly, spiritual.
2 a: lacking material substance: immaterial, intangible.

ether 1 a: the rarefied element formally believed to fill the upper regions of space
b: the upper regions of space: heavenly
2 a: a medium that in the undulatory theory of light permeates all space and transmits transverse waves
b: the medium that transmits radio waves

ethic the discipline dealing with what is good and bad and with moral duty and obligation.
2 a: a set of moral principles or values
b; a theory or system of moral values (the present-day materialistic)

Ethiopic 1 a: a Semitic language formally spoken in Ethiopia and still used as the liturgical language of the Christian church in Ethiopia
2 a: the Ethiopic group of Semitic languages.

utopia 1: an imaginary and indefinitely remote place 2 a: a place of ideal Perfection esp. in laws, government and social conditions.

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The rise of materialism brought new language, electromagnetic replaced the word "ether," in describing the heavenly medium, thus erasing the link between spiritual and natural phenomena. The pathological condition of race caused them to enforce this separation academically and religiously, by claiming that the classical ether was unnecessary and the vacuum was somehow endowed with odd and unusual characteristics. With their strong emphasis on materialism, all electromagnetic theory was co-opted for material implementation, therefore losing all spiritual application.

Anyone displaying an interest in electromagnetic spiritualism was considered to be a pseudo-scientist and ridiculed. There were many devices which claimed to photograph, or record the voices of the dead. These ghost detectors were routinely rejected by the materialist' scientific community.

The seventies brought renewed interest in Psychic Phenomena and ESP around the world. Knowing that belief is the prerequisite to the use of ones psychic ability, the scientific community conspired to take over this research with the aim of disproving and suppressing any attempt at legitimizing this field. So most people continue to experience vivid dreams, visions,

premonitions and a host of strange occurrences, which scientists refuse to recognize because of their threat to the materialistic power structure.

African culture and history are rich with examples of the unity of spirit and matter; heaven has always been our birthright. Today those faculties that put us in tune with the spiritual world are weak from lack of exercise. We have allowed the TV, radio and the telephone to replace our telepathic abilities, few now believe or would accept the notion of astral-travel.

Service to the materialist's society requires the denunciation of the spiritual. When bills are on our minds, we dream less as we focus on the depressing condition of this earthly prison, with our tormentor on our backs. The ☥ Ankh is the key to the door of eternal life, strengthening our faith in a world unseen, where our souls can be free.

Osiris The First Resurrected Christ

Statue of Osiris

THE CORRELATION BETWEEN the myth of Osiris and the story of the Christ have been illustrated by many prominent historians, who have shown that the evolution of Christianity is rooted in the religion of Isis, Horus and Osiris. This religion survived in its last outpost in Nubia until the Temple at Philae was destroyed by Justinian in 6th century A.D.

Although there are many versions, the essential theme of the Osirian legend, states that Osiris was once king of Egypt. He came to an untimely death at the hand of his brother Set, who had the parts of the dismembered body of Osiris hidden in various locations all over Egypt. Isis, wife and sister of Osiris found all the parts and was

Horus, Osiris and Isis

able to reconstruct the body with the exception of the penis, which was thrown in the Nile and eaten by fish. Her lamentations were heard by Ra, who sent his fourth son Anubis to wrap the body with bandages and perform all rites due one of his stature. Isis caused the breath of life to enter into the body by the rapid beating of her wings, whereupon Osiris was resurrected and became the king of the other world. While hovering over the body she became pregnant and later conceived a son Horus, who would avenge his fathers death.

Hence-forth all the dead of Egypt were considered Osiris, wrapped in the bandages of the familiar mummy, with the hope of resurrection in the spirit world of the ankhet "the land of life."

If the Egyptians seemed to be preoccupied with the dead, it is from a belief that life on Earth was merely a preparation for an eternal life. The proof of this could be demonstrated by the ankh, which become the symbol of life, because of its ability to detect the energies of that realm.

Further proof that life on Earth was preparation for another life is the manner in which we dream. Dreams are our fledgling entrance into the spirit world while we are still alive. Our earliest attempt at spiritual flight are short. While dreaming the penis is usually erect (the phallus of Osiris is unnecessary) and the body is kept rigid by powerful chemical secretions from the brain; which prevent it from acting out the experience. During those brief seconds we are as if dead, yet alive in the other world.

> The days of our years are three score years an,reason of strength they be four score years, yet I labor and sorrow; for it is soon cut off, and we fly away.
>
> *Psalm 90: 10*

According to Gerald Massey's book *Ancient Egypt Light of the World* , Osiris is the Corpus Christi. The word Christ comes from the Greek word "Kristos" which means "anointed." In Egypt "krst" means; to embalm, to knot, to make the mummy.

Central in Christian theology is the resurrection of Christ from the dead. This concept has an undying appeal for the masses of humanity from the dawn of the human experience.

> The thief cometh not, but for to steal, and to kill, and to destroy: I am come that they might have life, and that they might have it more abundantly.
>
> *John 10: 10*

Acceptance of the Egyptian definition of "Krst" could put the confusion within Christianity to rest. For Christianity did not start with the Jews, but was of Egyptian origin, revolving around mummification and the spiritual resurrection of the dead. The followers of Jesus, after his supposed death and resurrection, were only later called Christians because their beliefs were similar in nature to what was practiced in Egypt

for thousands of years.

Unfortunately the misinterpretation of this mystical gospel would ultimately inspire the outrageous behavior of ingesting the flesh of mummies (Krst, Christ) in hope of attaining immortality. This felonious religion let loose among a canine race, already predisposed to cannibalism, found easy acceptance in a god who offered his flesh and blood as a means of salvation.

> And he said to me, "It is done! I am the Alpha and the Omega, the beginning and the end. To them that thirst I will give water without price from the fountain of the water of life."
>
> *Revelation 21:6*

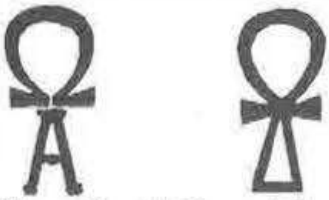

These Greek letters, alpha and Omega, have come to represent Christ.

In the original myth, Horus lost an eye in his victorious battle against Set. After his wound was healed by Thoth, he gave the eye to Osiris to eat, which vivified and strengthen him. The eyes of Horus are the sun and moon. Our sun is living water, made mostly of hydrogen that has not suffered the death of oxidation.

There is much evidence to conclude that life ener-

gy may be harnessed to prolong the life of the living. Our ancestors took full advantage of this wholistic science, allowing some to live hundreds of years. This technology predates the Early Dynastic Period in a time when the Earth, according to the Egyptian, was inhabited by demigods and kings. Obviously the Ancients had different priorities. The accumulation of wealth was superseded by a desire for wisdom and life.

The mythological story of the creation of man, recorded in Genesis, was taken from the original Egyptian story of the creator god Khnum who formed man and his Ka on a potter's wheel.

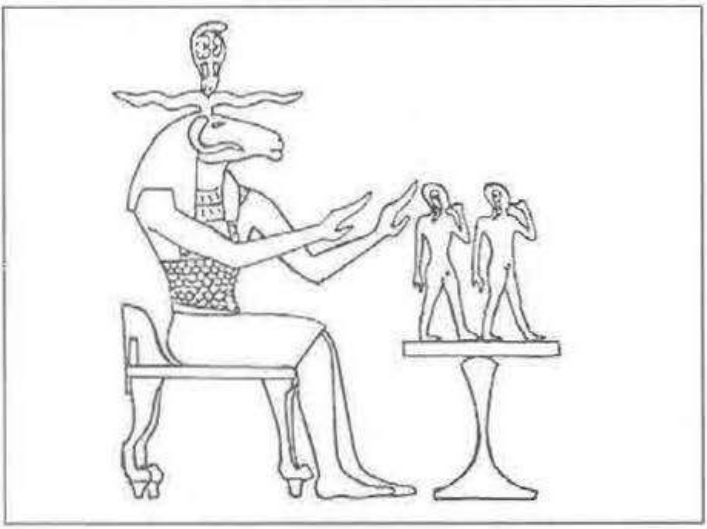

The hieroglyphic symbol which represents Khnum consists of a Tet between the raised arms of the Ka symbol and the word aun, which means light-tower, another name for the God Amen.

> "Allah" is the light of the heavens and the earth. A likeness of his light is as a pillar on which is a lamp. The lamp is a glass, the glass is as it were a bright shining star-lit from a blessed olive tree, neither eastern nor western, the oil whereof giveth light, though fire touch it not - light upon light. Allah guides to his light whom he pleases."
>
> *Surah 24:35*

The Tet is the orthodox illustration of a tree and according to Gerald Massey, it represents the eternal life after death.

> The Lord God formed man from the dust of the ground and breathed into his nostrils the breath of life, and man became a living being. The Lord God planted a garden in Eden away to the east and in it he put the man he made. The Lord God made trees to grow up from the ground, every kind of tree pleasing to the eye and good for food; and in the middle of the garden he set the tree of life and the tree of the Knowledge of good and evil.
>
> *Genesis 2:7-9*

Notice that the tree of life was not planted but set in the middle of the garden. After Adam and Eve ate of

the fruit of knowledge of good and evil they became knowledgeable.

> The man has become like one of us, knowing good and evil; what if he now stretch forth his hand and takes the fruit of the tree of life also and eats it and live forever? So the Lord God banished him from the garden to till the ground from which he has been taken.
>
> *Genesis 3:22*

The tree of life was no ordinary tree.

> She replied. "We may eat the fruit of any tree in the garden. But the tree in the middle of the garden, we may not eat or even touch it lest we die."
>
> *Genesis 3:2*

The Tet is a high voltage power source, touching it may have been lethal to those without knowledge. Adam, who now possessed knowledge knew that the ankh portion of the tree was a high-frequency source that could be handled safely.

Tet 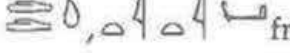 fruit tree., Danger do not touch.

Now we have come full circle and in our midst is the tree of good and evil, the modern computer and the Tree of Life, which is the Ankh Science of our Spiritual Nature. The moral question faces our gener-

ation, whether to trust Satan's path or the path which leads to Eternal Life as gods.

For it is not simply a question of a machine, but the programming of falsified information aimed at seducing you from your Divine Nature.

Who said you were ignorant, for you were created clad in Divine Wisdom and light.

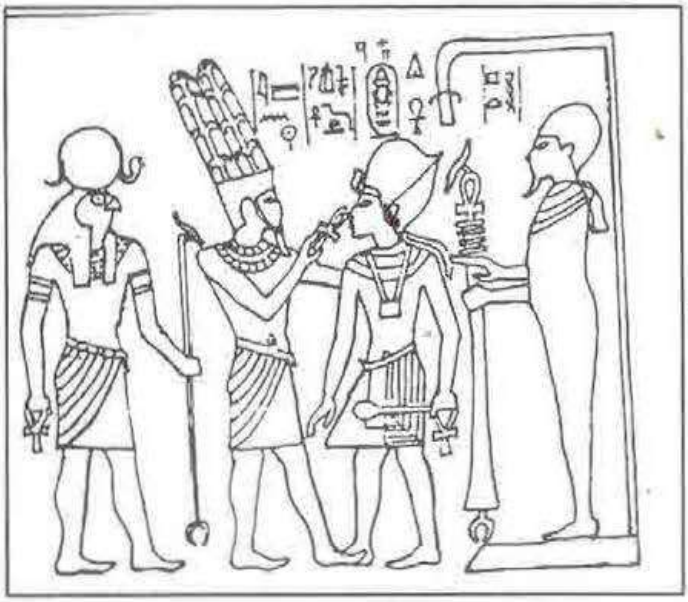

The depiction above shows Ra, Sun-god and his etheric double, Amen-Ra, the hidden force behind the sun. Our sun has a surface temperature of 6000 degrees, yet its corona (spirit or aura) exceeds 2 million degrees. The difference in temperature is caused by laser-like

effects produced by the strong electric and magnetic fields within ionized gases over the highly reflective surface of the sun.

King Tut is also depicted with his etheric double and like Ra his name Tutankhamen expresses the hidden source of life. All living systems have electromagnetic phantoms. The phantoms of atoms and molecules are called photons, they are the essence of nuclear life, governing the energy states of the material world.

The ankh is held to the nose area because of its sensitivity to electromagnetic waves. The area between the fifth and sixth chakra is centered around the nasal cavities, where a massive quantity of neural receptors, responsible for the sense of smell, are exposed to the environment. The sensations are often confused with sound because of their proximity to the ears, sounding like the noise you hear from a TV set tuned to an unused channel or like the sound of the ocean.

Sensitivity can be increased and with practice one can detect the presence of high frequency waves close by. Some highly spiritual people, are so sensitive to these waves, that their neurons can demodulate radio broadcasts, causing them to hear voices. Many end up in psychiatric wards because they hear voices other can't.

The gods, who are a spiritual race of photonic beings, made man in their own image and likeness, to serve them on Earth. However man became aware of his own divinity and sought to be like the gods while in the flesh.

The story in Genesis also relates the longevity of Adam and his sons, whose average life span was 900 years.

> Then the Lord said, "My spirit shall not abide in man for ever, for he is flesh, but his days shall be a hundred and twenty years"
>
> *Genesis 6:3*

So it is the spirit (photonic or electromagnetic energy) which gives man the ability to live an extended life span. A tree deprived of a important nutrient like sunlight or water would wither and die in a shorter time. Without this vital ingredient we grow old and die prematurely.

The first signs of aging are apparent in the skin and is related to some melanin dysfunction. There is an increase in yellow pigment and among Caucasians there is premature wrinkling and melanoma. If the resonant frequency of melanin was known, the appropriate energy could be absorbed to vitalize the skin and delay aging.

Electromagnetic radiation may cause cancer among Whites because non-pigmented skin, has no defense against a high frequency wave which penetrates deeply in human tissue.

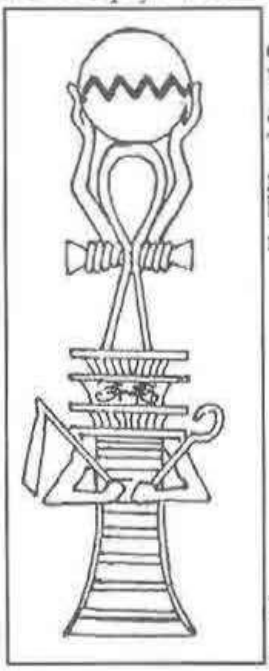

A drawing of the World's First electronic clock, built by Nile Valley Africans to represent their ancestral spirit Tet Ankh Ka Ra, The Ankhi (Khnum, chronos). The glowing globe was slowly rotated by the precise electromechanical movement of the arms.

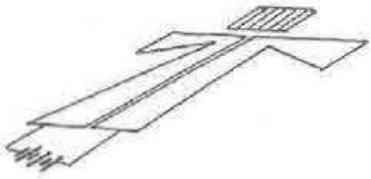

The Tree of Life provided sufficient power for the creation of electromagnetic radiation (angelic or spiritual beings) and the rotation of the world. The Egyptians not only knew the world was round, they knew the force which turned it was a perpendicular electric and magnetic field. They used elements of electronic circuitry to represent the spiritual nature of life. The circuit on the right of the tree is a relaxation oscillator, charging

and discharging through the spark gap, to provide excitation for the loop circuit in the figure below. A minimum of 300 volts is required to produce a spark across the gap.

The relaxation oscillator is an inefficient method of excitation, because the discharged cannot be synchronized. However, with the use of kam (galena), a more effective continuous wave excitation oscillator can be made that requires significantly lower voltage.

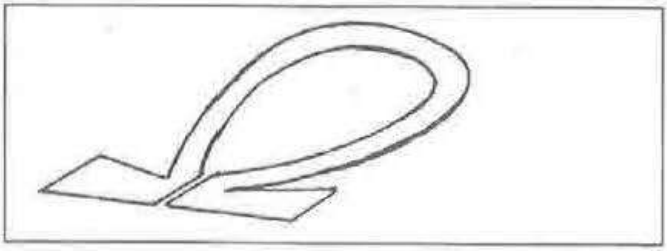

The loop and plates above are also a tank circuit which is shunted across the gap and capacitively coupled to the input resonant circuit. This transmitter radiates UHF power to ankhs of comparable size within the vicinity.

The spark was considered to be an indication of Gods presence because within a spark all frequencies are generated, therefore, all circuits are compelled to respond. The large capacitance of the shrine or ark could provide powerful sparks of lightning sufficient

to excite an ankh into oscillation, especially when this discharge was through the gap of a transmitting ankh circuit.

A circuit consisting of a loop and plates could also provide lighting at night or in the darkness of the tomb. It has always been a mystery as to what method of lighting was used to allow those intricate paintings to be produced on the walls of some of those tombs. No soot was found on the ceiling suggesting that some other method besides the torch was used. Again we are asked to believe it was done with mirrors reflecting sunlight, because the truth of electric lighting in tombs would suggest widespread use similar to our modern use, but superior, because power would be wireless transmitted..

The pectoral of King Senusret II embodies the spiritual and scientific principles governing the universe. The ankhs illustrated have coils on either side of the loop, and Heru (falcon) is standing on the senk Ω , a divine light.

When this type of ankh was constructed and attached to a battery, it operated like a motor and produced high voltage spikes at audible frequencies.

The coils on both sides of the loop, form an electromagnetic switch, which switches on and off under the influence of magnetic attraction and the flexibility

of the loop. The high voltage produced is a result of the sudden interruption of current flow through the coil.

This by itself did not seem strange, for on closer examination of the output, it was discovered that the

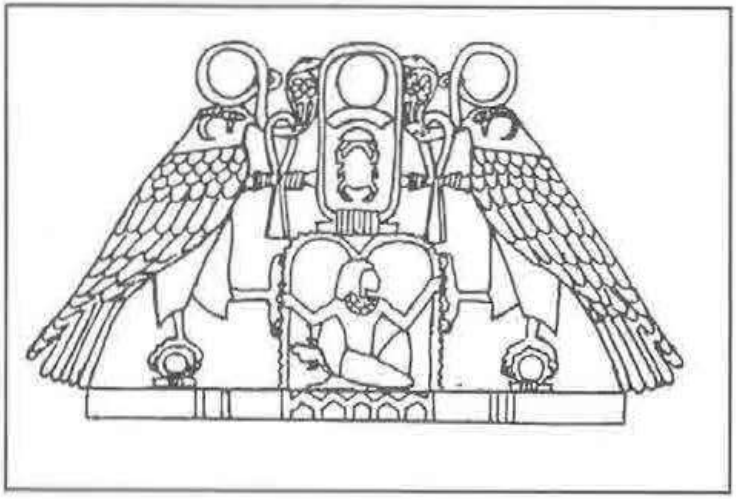

output power exceeded the input power. With the use of rectifiers and rechargeable batteries, the excess power kept the ankh in a state of perpetual motion. The latent energy within the magnetic field was harnessed to produce electricity.

The kneeling figure in the center of the pectoral is Heh the god of Eternity, holding the notched chain of infinity.

This type of ankh was undoubtedly the power transmitter for the loop circuit of the senk.

snk , to see the light

snk light rays

snk , night or darkness (note the senkh is upside down over the symbol for sky)

sen or   kh senk or senkh.

sen means, similar, dual, two or alike.

Similar to today's fluorescent lamp, the senk was used extensively before the numerous invasions put this light of Egypt out forever.

Since there are no known surviving examples of the senk, its basic operation can only be extrapolated from fluorescent light theory and examples depicted in Egyptian Art. The primary elements of the senk's construction are:

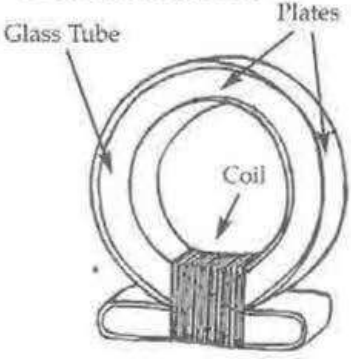

1. partially evacuated glass tube
2. coil or loop (inductance)
3. plates (capacitor)
4. DC. voltage

A partially evacuated glass tube can be made to glow when placed within a

rapidly changing electrostatic field. The air in the tube is ionized by the presence of high-frequency oscillation in the coil and plates, at 10 to 50 MHz. The ionized gas in the tube becomes conducting and establishes direct current flow from the battery through the tube, further increasing the intensity and duration of the glow.

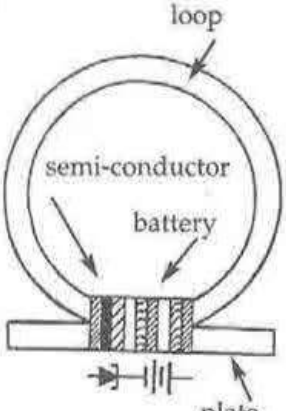

The ionized gas tube of the senk can be adapted for use as a diode (rectifier) or as an active device by exploiting it's negative resistance for amplification. By adding an extra set of plates to isolate the DC voltage, the senk could easily be modified to produce continuous wave oscillation. However since the Egyptians had knowledge of galena, it is likely that the vacuum tube was abandoned in favor of more efficient semiconductor technology. If all the components of modern radio transmission and reception were known and used in Kemit, 4000 years before their re-emergence in this century, then the super technology of the UFO's need not have come from

other planets, but could have developed right here on Earth.

These are the questions which will arise to disturb the status quo if knowledge of ☥ Ankh science is made public. It would necessitate a complete re-examination of Kemitic religion to explain the connection between the African and these electromagnetic circuits, which were of such high spiritual significance. This would provide a direction for research into what we truly are as a people.

The atmosphere is a rarefied ocean inhabited by numerous spiritual entities living in realms which vary in activity levels between night and day or during cloudy weather conditions which causes the spirits to take on a higher density.

The electronic circuitry of the Egyptians was used to facilitate greater contact with the spirit world, known as the Kingdom of Heaven. The lords of this Kingdom are called the "grays" and many consider them negative aliens because of the fear they arouse and their enigmatic behavior.

"The fear of the Lord is the beginning of wisdom."

Ankh Circuits

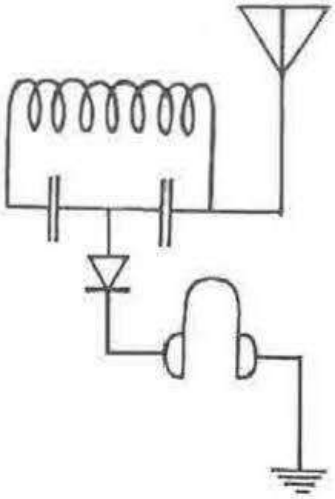

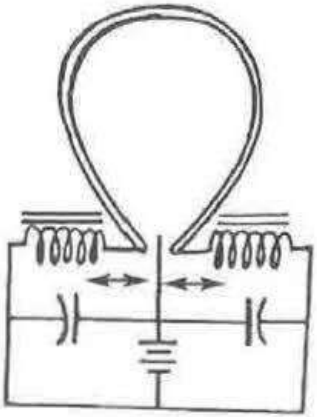

Ankh Circuits continued

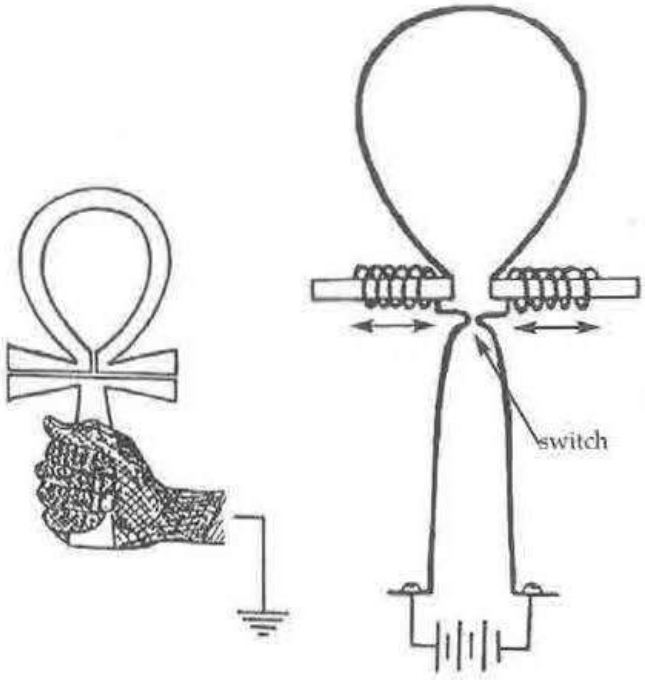

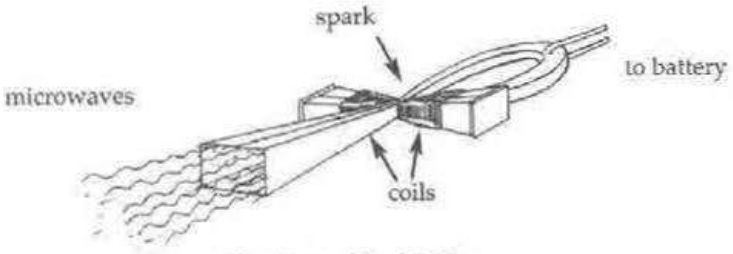

The War ankh of Sekhet

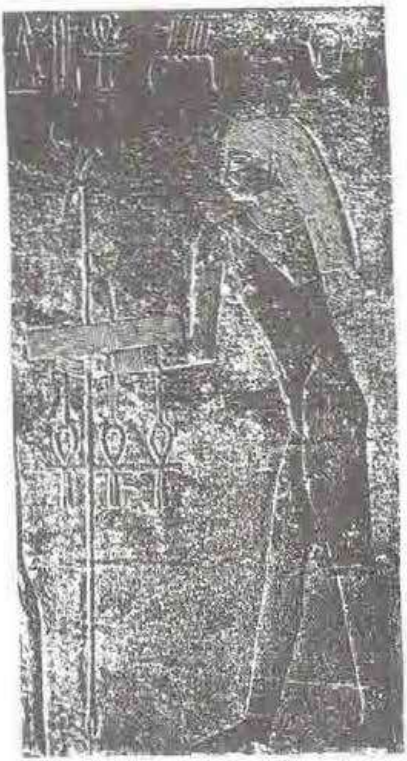

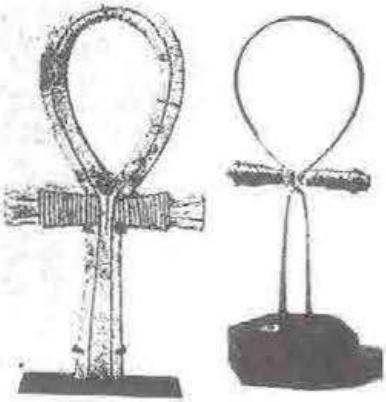

The Heavens

Although the Egyptians considered heaven to be the abode of the eternally blessed, it contained all the elements of a blissful earthly life. The dead were usually buried with their earthly possessions and provisions to sustain a life similar to their earthly one.

Everyone seems to agree that this realm is located in the sky above the clouds somewhere, but no one wants to specify its exact location. Here also, the separation of matter and spirit create

the usual confusion characteristic of modern religious theology and the materialist scientific aristocracy. If both spiritual and scientific evidence concerning heaven are examined objectively by someone with a unified perception, they would conclude that heaven was in the ionosphere. Our ancestors, who were not afflicted with this modem schism, knew this also.

> In the beginning God created the Heavens and the Earth.
>
> *Genesis 1: 1*

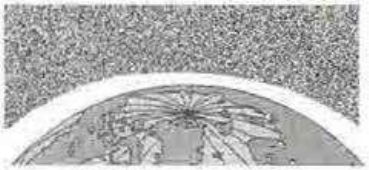

The aureole of the Earth created by the breath of Ra.

The Egyptian symbol of this Creator-God Khnum is the most profoundly esoteric, containing all the elements which could explain the nature of divine existence.

This is the god that created night and day by the rotation of the earth and made man on this revolving potter's wheel.

-island vacuum glass tube ... au

-breakdown discharge, "N" water, aurora.

-Ka, spirit, power, image-double.

-Horizon, the God Amen, aun; which means lamp or light post

-Tet, djed, battery or voltage Osiris, Jacob's ladder.

As we have discussed before, the evacuated tube provides an easy path in the flow of electrons, creating the

ionization and negative resistance used for continuous waves, and glowing when these electrons and ions recombine to form neutral atoms.

All these activities occur in the near-vacuum of the ionosphere, which is a region of high electron density, about 300 km above the Earth's surface. This layer is maintained by ultra violet radiation and high energy particle emissions from the sun. The high voltage (potential difference or electric field) between the earth and the ionosphere, represented by the Tet, is responsible for the rotation of the planet. This is due to the Earth's magnetic field being perpendicular to that electric field and in exactly the same way as the force which rotates the shaft of an electric motor created. The four bands at the top of the Tet represents the fact that the ionosphere is divided into four layers, the two uppermost levels F1 and F2 merge into one layer at the first hour of the Tuat (night).

Because of its high electron content, this layer reflects electromagnetic waves, allowing extended range to radio transmission.

> And he who talked to me had a measuring rod of gold to measure the city and its gates and walls. The city lies foursquare, its length the same as its breadth; and height are equal. He also measured its wall, a

hundred and forty-four cubits by a man's measure, that is, an angel's

Revelation 21:15

Khnum at his potter's wheel fashions a person out of clay. One figure represents the physical body while the other represents the spirit. Both came together to create one new being.

The description of the measurement are those of a sphere whose height is defined by the cut-off frequency of 1,440 Mhz. Because the measure of a man, that is of the angel is the Ka 𓂓, ten million.

And he dreamed that there was a ladder set up on the earth, and the top of it reached to heaven; and behold, the angels of God were ascending and descending on it! And behold, the Lord stood above it and said, "I am the Lord, God of Abraham your father and the God of Isaac; the land on which you lie I will give to you and to your descendants; and your descendants shall be like the dust of earth ...

Genesis 28:12-14

Heaven

Genesis Chap. 1-1
And the spirit of God was moving over the face of the waters.

The word "ankh" also means mirror, "that which sees the face," in the language of ancient Egypt.

Genesis Chap. 1-27

So God created man in his own image, in the image of God he created him; male and female he created them.

Earth

Chap. 2-7

then the Lord God formed man of dust from the ground, and breathed into his nostrils the breath of life; and man became a living being.

An

Phonetic Value	Hieroglyphic character	Meaning of the ideograph
ankh		life
n		water
kh		dust (symbolized by a sieve)

examination of the word ankh, reveals the nature of our earthly and heavenly incarnation in the eternal cycle of life. The word contains three ideographs, each representing an aspect of the Trinity, Father, Son and Holy Spirit. If you can accept the concepts ... Our

Father who art in Heaven,... I and the Father are one and... Son of man, you will be well on your way to an understanding of eternal life.

From the Egyptian point of view, 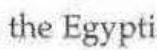 ;(pet) heaven was made from a material called 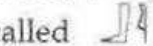 baa. This baa (baa; metallic substance i.e. black meteoric iron) was known to have metallic properties such as conductivity and reflectivity.

The ionosphere is a mirror image of the electromagnetic emissions from the Earth, no matter how faint. The spiritual characteristics of every object on Earth is duplicated in Heaven, because their emissions cause the electrons there to vibrate in such a way as to emit an exact electrical image of all earth transmission.

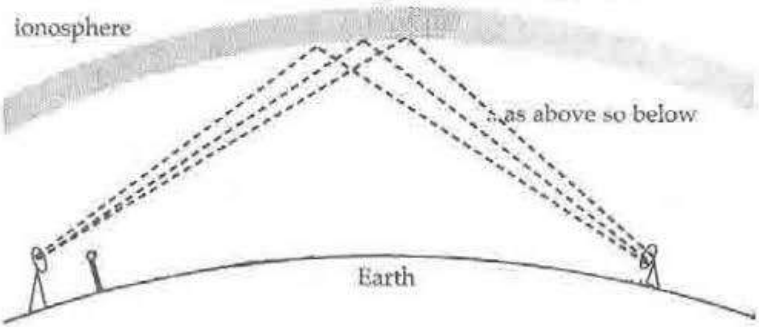

The body was preserved with the knowledge that its electromagnetic nature would continue to be reflected in the Heavens. The concept of a spiritual abode in heaven is as perplexing to the materialist of

today as it was in the time of the Messiah. In John chapter 3, the Messiah attempts to explain to a White man why he cannot go to or understand heaven.

> Jesus answered, "Truly, truly, I say to you, unless one is born of water and spirit, he cannot enter the kingdom of God. That which is born of the flesh is flesh, and that which is born of spirit is spirit. Do not marvel that I said to you, 'You must be born anew.' The wind blows where it wills, and you hear the sound of it, but you do not know whence it comes or whither it goes; so it is with everyone who is born of Spirit." Nicode' mus said to him, "How can this be?" Jesus answered him, "Are you a teacher of Israel, and yet you do not understand this? Truly, truly, I say to you, we speak of what we know, and bear witness to what we have seen; but you do not receive our testimony. If I have told you earthly things and You do not believe, how can you believe if I tell you heavenly things? No one has ascended into heaven but he who descended from heaven, the Son of man. And as Moses lifted up the serpent in the wilderness, so must the Son of man be lifted up, that whoever believes in him may have eternal life.
>
> *John 3:5-14*

It would be fruitless at this point to attempt to untangle the enormously confusing theology of the Trinity proposed by Whites who, having discovered themselves excluded, sought to deny the Divinely Blessed the knowledge of their birthright. The secret

ingredient, for which our race has been made to suffer is melanin, the dust of the Kha. The word Kha ranges in meaning, from dead body or corpse to powdered medicine or simply the dust of the dead.

Allow me to digress for a moment to examine the use of dust in the early days of radio. A phenomenon, which permitted the detection of radio waves, was the response of dust particles to electromagnetic waves caused by a spark. Particles of dust tend to stick together (coherence) aligning themselves in such a way as to increase the current flow in a certain direction. The early rectifiers, known as coherers, were made by filling a tube with an electrically responsive dust or filings, (See Lodge's transmitter and receiver). When there was a passage of electromagnetic waves the coherer would conduct, however once aligned they were no longer responsive and needed to be tapped periodically to loosen the particles to respond to the next incoming wave. This is the reason why the dreamer's body must be kept rigid, like the dead, for movement disrupts the alignment reducing conductivity.

Christ said to Mary, "Touch me not, for I am not yet ascended unto my father."

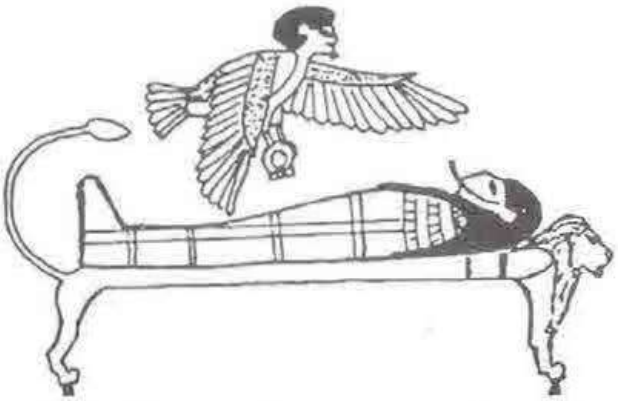

The senkh held by the Ba represents the electromagnetic emissions of the Kha.

The majority carriers (type of charge transport) of melanin are electrons as opposed to (+) holes. Therefore, in the Judgment of Osiris, described by the Millikan's oil drop experiment, the etheric body rises.

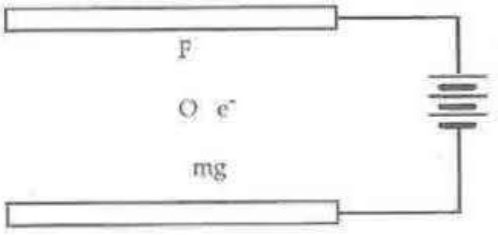

In Millikan's oil drop experiment, an electrically charged oil drop is suspended between two plates by the upward force of an electric field against it's weight mg.

Who Knoweth the spirit of man that goeth upward, and the spirit of beast that goeth downward to the earth?

Ecclesiaste s 3:21

The confusion as to the direction of charge flow displays Greek ignorance and Egyptian wisdom. Electrons flow from the so-called negative potential, known as the cathode, which canes from the Greek word "Kathodos" meaning 'the way down'. The Egyptian root of the word "Ka," is represented by the raised arms ⌊⌋ representing the true direction of electron flow, from the ground upwards.

Each melanin granule is a tiny feather and, when energized by the ankh of levitation, the gods were given the power of flight.

The ankh of levitation was related to the goddess of the Upper Kingdom, the Divine Vulture. These vultures are often seen soaring around large clouds during a thunderstorm. The reason for this behavior was thought to be related to upward convection currents of air. And it was believed that these birds used these currents to attain great heights without effort. This assumption neglected the fact that thunderclouds possessed strong electrostatic charges which exerted a force of attraction on the birds in the same way that a charged plastic comb attracts small pieces of paper.

The goddess Nekhbet represented this principle, by which the Messiah was taken up into the clouds. By holding a high frequency emitter like the tet-ankh scepter, one could soar into the sky as the Medieval witches were said to do. At sufficiently high frequencies, the dipole of the melanin granule cannot respond rapidly enough to remain in step with the changing electric field. Therefore, a displacement current arises and the granule behaves as a dielectric, subject to the force of electrostatic attraction and repulsion

The winged serpent is the most compelling argument in the link between spiritual and electromagnetic phe-

nomenon. While representing all the elements of airborne electromagnetic wave transmission, it evokes the wisdom and spirituality associated with Isis.

SETI (Search for ExtraTerrestrial Intelligence)

In October 1992, NASA will engage in the study of the heavens under the guise of a search for extraterrestrial intelligence in the galaxy. This project, with the very Egyptian sounding acronym, will use the World's largest radio telescopes and advanced multichannel scanners to canvas the sky in an attempt to discover the source of angelic communications.

It is no coincidence that the frequencies of interest to these researchers is around the 21 cm wavelength of the constituents of water (hydrogen: H and hydroxyl: OH), called the "water hole." This is the most prudent choice since the Messiah referred to these beings as composed of water and spirit.

These beings have the some color as the clouds, a glowing gray, and it is said that their appearance is like unto the "the sons of men," that being like children.

Despite the sophistication of the computerized equipment, the project is doomed to failure. Even if angelic communications were detected among the

noise of terrestrial transmission, the language of the angels is unknown. I am not suggesting that communication with Angelic Beings is impossible. What is required is nothing less than Ankh Science in the hand of the Oracle.

The synthesis of amino acids (the building blocks of life) under the condition of a primordial atmosphere, with the use of electrical discharge, confirmed the existence of extraterrestrial life. If the chemical composition of amino acids (hydrogen, oxygen, carbon, nitrogen and other trace elements), can be found

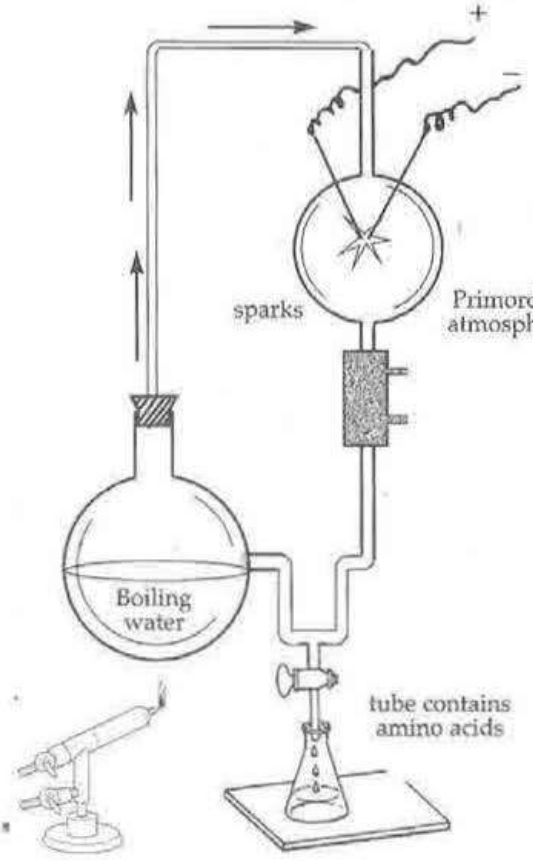

in the upper- atmosphere, then why should life be limited to the earth. The synthesis of more complex molecules (protein and nucleic acids) by linking together amino acids, involves the bonding of an amino group (H_2N) and an acid group (COOH). The C—N bonding results in the removal of (H and OH) a water molecule, exactly what SETI is searching for. In this hospitable environment, of the heavenly ocean, the holographic projection of the recently dead is reconstructed, giving birth to the Son of man. This is what is meant by the return of Christ in the clouds, now revealed in the present age of Aquarius.

It is said that these beings traverse the heavens in boats or barges. These UFO's are the Fishers of men. The Government is fully aware of the existence of these beings, and has launched an extensive campaign of disinformation to prevent its citizens from knowing the truth. How could they explain to their people that the lowly Africans are merely beings in a caterpillar stage, destined to be transfigured into an image of splendor and glory. Creatures whose total existence is so eloquently expressed in the life cycle of the Scarab beetle.

The Scarab Beetle

Symbol of Christianity
the fish or UFO's

The Scarab, symbolic of the god Kheper is a dung beetle commonly found in Egypt. It. is usually seen rolling a ball of dung which contains it's larvae, around the countryside, creating in the mind the Egyptians an analogy with solar orbit. In Egyptian cosmology, the universe is represented as a cow called Nut.

The ball of cow dung is obviously the earth, although the European Egyptologist would like us to believe that our ancestors were as ignorant as theirs were of the Earth's orbit of the Sun.

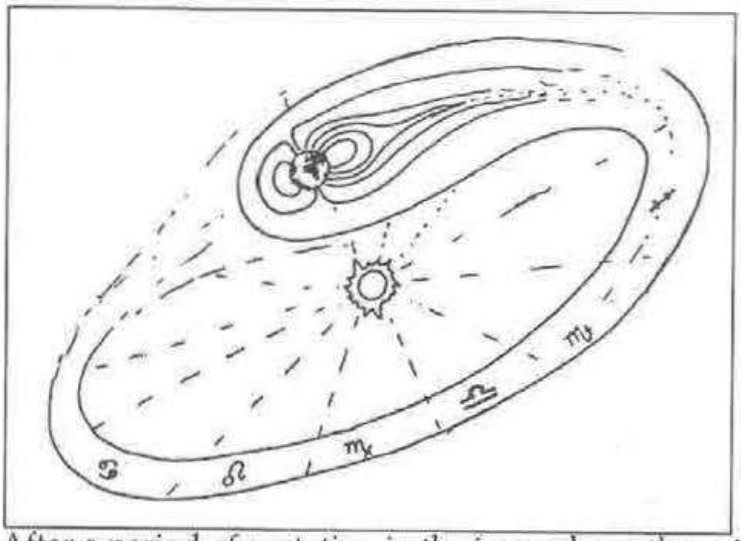

After a period of gestation in the ionosphere, the spiritual body returns to it's astral homeland, one of twelve regions, from which it came. There it will find a glorious existence beyond description, an existence where there is no night only day and it's every desire will be fulfilled in Amentet.

African Astrophysics

THE THEOSOPHICAL CONFLICT between the Big-Bang and the Steady-state model of the universe, is unresolved after 4000 years. It is deeply rooted in the Osirian and Amenite perspectives concerning the origin of the universe.

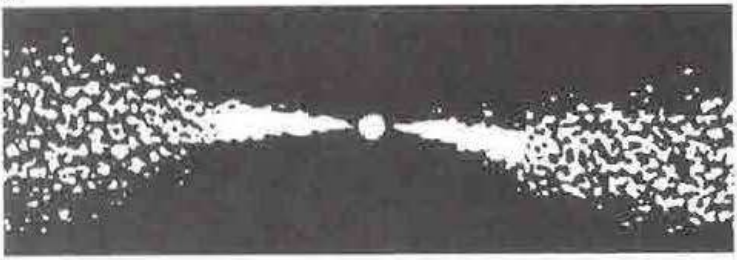

Fig. 1 Radiograph of a typical radio galaxy with jets projecting from its whirling black hole nucleus.

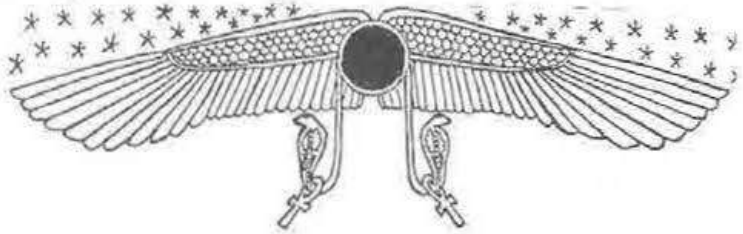

Fig 2 The twin serpents illustrate the unique feature of a radio galaxy which appear as two separate radio sources.

Osiris, God of continuity through the resurrection of the dead, is the Steady-state universe. A philosophy which arose from the African's view of himself as a reflection of the God Osiris, the Ultimate Black. The Ancient African Astrophysicist, studying the universe, also looked inside himself and found that the connection between melanin and the black hole, was the electron (the breath of life 4).

The Grand Unification Theory, which eluded Albert Einstein, has already been solved. The Africans discovered that subatomic particles, like the electron, were created when ordinary matter (energy) passes through a black hole. However, since the Europeans cannot accept Osiris, their scientists have sought diverse theories in order to circumvent the truth of an all powerful Black God.

African Plasma Physics

In the original myth, Horus lost an eye in his victorious battle against Set (Typhon, typhoon). After his wound was healed by Thoth, he gave the eye to Osiris to eat, which vivified and strengthened Him.

This myth, handed down from Ancient Times, relate the events occurring in the eye of a radio galaxy. Where stars and planets are swallowed by the central black hole and resurrected as fourth-dimensional matter (plasma).

A plasma is characterized by its high electron content. About 95% of the matter in the universe is in this state. A low pressure gas plasma need not be strongly ionized to respond to or produce electromagnetic effects. Black skin, which is composed of a layer of organic semiconductors can be considered a plasma or fourth dimensional matter. And since neuro-melanin and melanocytes are the basis of higher mental activ-

ity, it stands to reason that our moral nature is an expression of a more direct contact with God through the spirit. In other words, melanin is your link with the Universal Mind of God and morality is the Universal Law of reconciliation characteristic of our God Osiris. Osiris is the God of Judgment and the cross-road, whether to go right or left on the Path that leads to Him and Peace in the eye of the storm. The Egyptian symbol of a plasm 𓈖 is the same as "n" or water, but it must be considered as living water. It is also illustrated in the symbol of the aurora 𓇋 which most people can recognize as an electrical discharge in what is now called a cathode-ray tube.

Osiris

African Quantum Physics

Since the discovery of the electron, modern physicists have found themselves in lockstep with a more ancient reality already defined by our African ancestors. The Tuat is the fourth- dimensional world of the electron and the core of the particle- wave paradox in quantum physics. Only the names have been changed to protect the guilty.

Our present reality is defined by the speed of light, beyond which nothing material can be transmitted, however in the actual reality world of the Tuat, the eye of the Ka sees another light. The light described in the Quran as 'light upon light' and in the Bible as an incomprehensible light that shines in darkness. The Bible is replete with descriptions of this immaterial world, providing a source for physicists, who behind closed doors, are probing the tenents of spirituality in search of answers.

> But, beloved, be not ignorant of this one thing, that one day is with the Lord as a thousand years, and a thousand years as one day.
>
> *2 Peter 3:8*

Here the existence of a non-local reality is defined by a difference in time reference. For if a thousand years is as a day, then something is traveling 365,000 times faster.

The intermediary between this world and the Tuat is the electron, the substance of the soul. It is indivisible, eternal and connected to the mind of God. This alternate reality can be understood in the analogy of the whale, whose dorsal fin emerges when the whale surfaces for air. What we observe is the point-like character of the electron or fin, but beneath the surface lies the greater glory of the whale. The Ka, which surfaces periodically from the sea of eternity, is represented not only as a particle but also a wave (the mythological serpent Qeb. The human body is merely the skin of this mystical serpent which is shed periodically and in which the god walks upon the Earth.

Nur Ankh Amen
The Religious Institute of Kemitronics.

The Science of Kemit

The religious concepts of Ancient Egypt were structured on scientifically verified electromagnetic theory, not unsubstantiated traditional beliefs, as ours are today. Separation of science and religion is a modern phenomenon where clashes between cultures in a shrinking world, force compromises with the perception of truth.

Most of us are unprepared to cope with the idea of a superior African science. Years of slavery and colonial domination have damaged our belief in the ability of our race to have accomplished these feats of mental genius. In spite of the pyramids and other colossal monuments, which are a testimony to our greatness, most of us are still in disbelief.

Electromagnetic religion in Kemit can be seen to have played a role in the evolution of monotheism during the reign of Amenhotep IV in the 18th Dynastic Period. The reason for the conflict between the polytheistic doctrine of the past and the singular universal god Aten may have been the result of the

discovery of a new source of electromagnetic radiation called Cosmic Background Radiation,

In 1964, experimenters at Princeton University studying the possibility of leftover radiation from the "Big-Bang," discovered the universal microwave radiation hypothesized by Akenaten 3500 years before. The Aten was represented by a disc with many rays ending in hands holding the ankh (symbol of life). Because this source of radiation was universal, it was difficult to depict, therefore, the instrument used to detect its microwave emissions was used.

The Disk of aten was an ancient solar device, used to focus sunlight to a point or beam of extreme intensity. These large domed disks were made of highly polished metal (the word aten means mirror) to concentrate the heat of the sun on a focal point for a variety of uses, which include the splitting of large stone blocks. A stone block was exposed to a narrow beam and, when heated, cold water was poured causing the stone to split in precise dimensions lines.

With the rise of the Amenites, the technology concentrate other invisible electromagnetic wave obsessed with the building of larger and more requiring massive quantities of gold and silver shrines of the

ancient gods, which ruined the national economy and created enemies throughout Egypt. The disks were dismantled during the reign of Tutankhamen, to fund the restoration of the ruined temples of the Ancient gods.

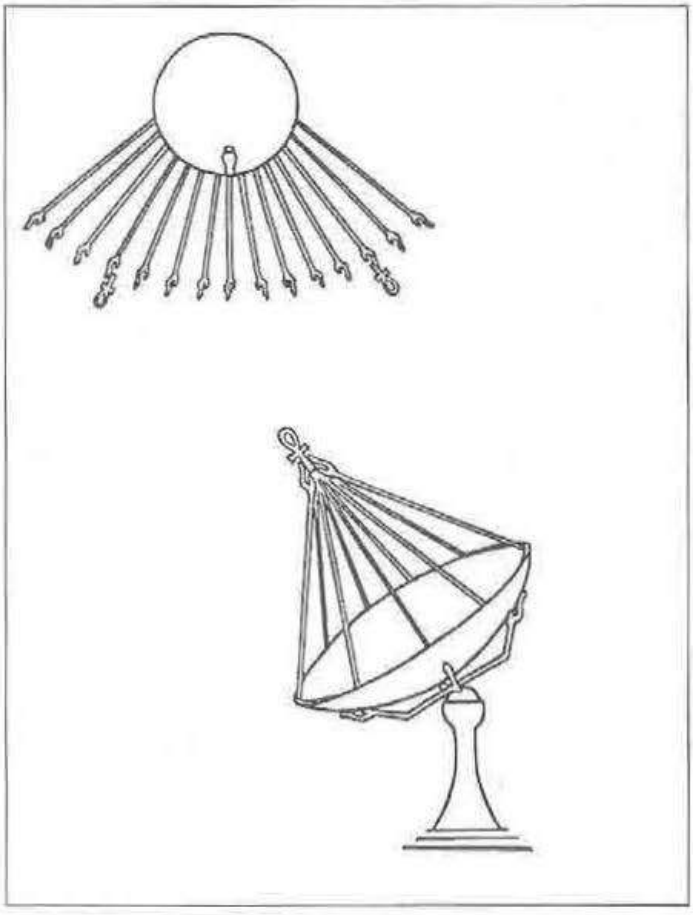

This may be difficult to accept if you are unfamiliar with the two dimensional convention of Egyptian Art

as opposed to the modern three dimensional representation.

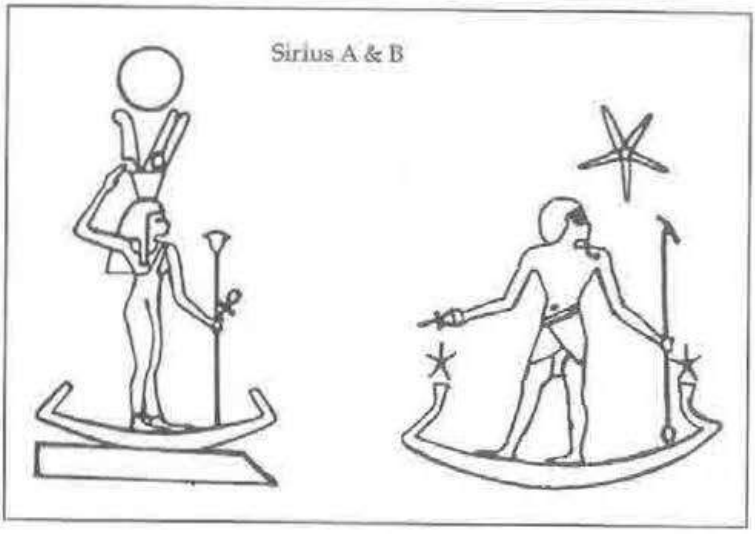

Invisible Sirius B was "discovered" in 1970. She is composed of super-dense matter created by an encounter with a black hole.

The Aten was rejected as the universal source of all life because the faintness of the emissions suggested weakness in comparison to the more powerful gods of the past.

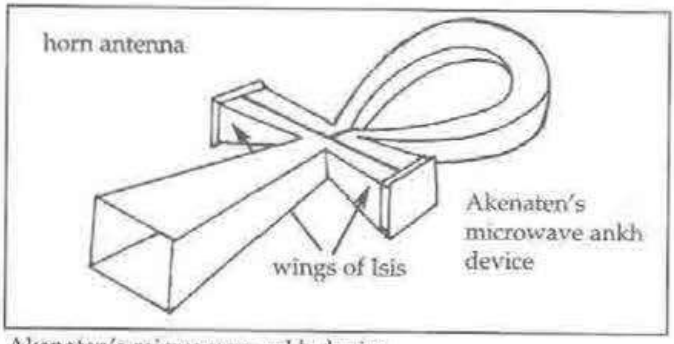

Akenaten's microwave ankh device

The disc of Aten, concentrated the microwave radiation into the horn antenna, exciting the wings of Isis (resonant cavity) into oscillation. The natural frequency of her wings and the incoming microwaves are mixed (heterodyned) and the lower difference frequency, which resulted from the mixing, is detected by the loop. An explanation of the loop's function in this FM discriminator requires an excessive use of technical jargon, which would only detract from the spiritual essence of this divinely inspired device.

This radio telescope could detect radiation from stars and other stellar activities in the cosmos. Akenaten was dismissed as a heretic and is not a favorite among European Egyptologists because of his distinctly African appearance. but he was undoubtedly one of the greatest astronomer- scientists in human history. For he not only discovered the remnants of the Original Spark (the Aten, the Big bang) from which all life originated, but he founded the first religion based on the Oneness of God.

Higher on the electromagnetic frequency scale above microwaves are the invisible infrared rays also known as heat. And by exploring infrared we come to the real reason the pyramids were built.

The word "pyramid" means, fire within (pyr; fire, heat & mid; middle), not the familiar flames, but the Ankhet living fire." A special fire whose flames were life giving. These rays were concentrated

or focused by the pyramid into the sacred chamber under its base.

The pyramid was simply a lens which focused a specific frequency of infrared waves on the sacred chamber.

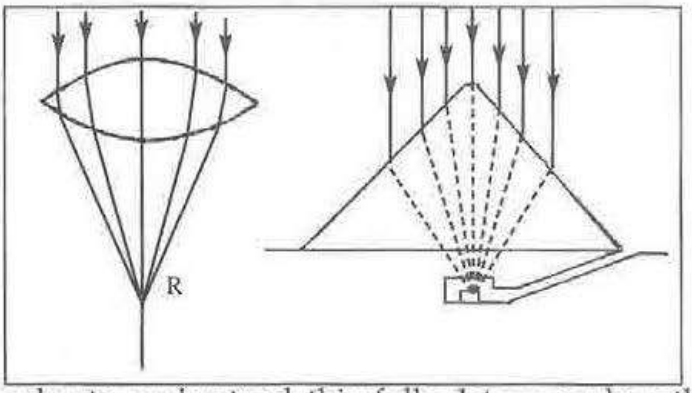

In order to understand this fully, let us explore the question of "living fire."

A by product of both life and combustion is carbon dioxide. If living fire is to exist, carbon dioxide must be eliminated or exhaled and fresh oxygen supplied for further combustion of fuel (organic, fossil or sugar). A flame in an enclosed area would die from the lack of oxygen, which would have been consumed and converted into carbon dioxide.

If carbon dioxide could somehow be converted to it's constituents, carbon and oxygen, the oxygen could be re-used to further continue combustion and pro-

duce a living fire.

Carbon dioxide molecules can be split into carbon and oxygen by absorbing energy at specific resonant frequencies. The molecule vibrates in response to the energy absorbed and if there is sufficient concentration of these photons, the molecule splits and oxygen is liberated.

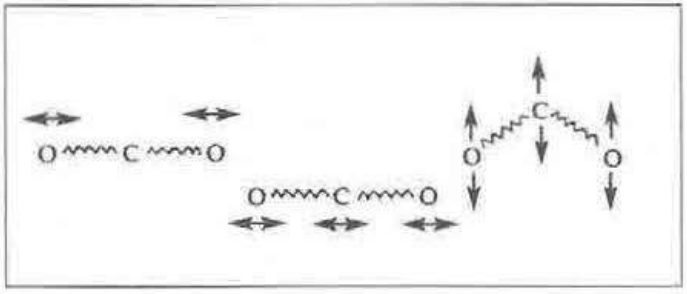

modes of vibration of CO_2

Every object with a temperature above zero degrees Kelvin (K), emits infrared by what is known as Black Body Radiation. The frequency and intensity of the radiation is related to the temperature of the object. At the pyramid's natural temperature of 300 K, there is sufficient infrared at the proper frequency, which the shape of the pyramid can concentrate on the sacred chamber to effect dissociation of carbon dioxide. If the incorrect frequency is used the molecule could split into poisonous carbon monoxide.

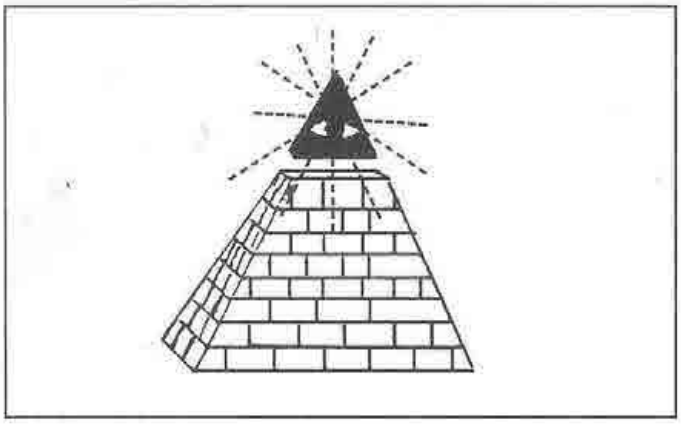

The Sacred Chamber was a special life promoting environment where the dead were revived and incredible surgical procedures could be carried out safely. This technology is specific to Africans, simply because white skin is too reflective and would not allow enough energy to be absorbed.

Imhotep, builder of the first pyramid

The first pyramid was built by Imhotep, the African multi-genius, whom the Greeks called Asclepius, their god of medicine.

ASCLEPIUS

Legend has it that Asclepius, god of healing and son of Apollo, was delivered by cesarean section performed on his dead mother Coronis by Thoth (Hermes) and taught the art of medicine. Another version states that he was abandoned on a mountain and suckled by goats. The shepherd who discovered him was frightened when he observed a mysterious aura of glistening corona discharges emanating from the child's skin.

His wisdom and skill in the healing arts were unsurpassed, for Asclepius discovered the secret of the Gorgon's blood, which was both a medicine and a deadly poison. With this knowledge he developed a method of bringing the dead back to life. After reviving many people he himself was killed with a lightning bolt from Zeus, for fear that he might reveal the secret which would give immortality to human beings. Apollo, angered by the

Thoth

murder, responded by killing the thunder-making Cyclopes of Zeus.

Asclepius was associated with serpents and his emblem of twin winged snakes is still used as the insignia of the medical profession.

Focused infrared rays were also used to dehydrate the bodies of the dead. This sophisticated form of mummification, usually reserved for nobility, produced the most life-like mummies because of the precision of the dehydration process.

However the ultimate use of infrared rays, involved the semiconductor nature of melanin, which requires an infusion of energy to bridge the gap between it's levels of conduction. With this constant source of power the Kha of the Pharaoh would remain an electrically active antenna, supporting his heavenly reflection in divine splendor.

The Ankh of Science

WHEN SANKH WAS HIGH PRIEST, Ankh Science had long ago reached it's zenith in Kemit. The Priesthood of the 𓋹 Ankh, an established University of Ankh Science, maintained the temples and shrines of numerous ankh possessing gods. The most notable of these were the shrine of khonsu, miraculous healing, and Ptah, the god of creative insight. However the Priests of Amen possessed the most powerful shrine, that of spiritual flight or teleportation. There power arouse from a knowledge of themselves, the knowledge that the photonic essence of man which emanated from the soul was indeed his truest self.

> In him was life, and the life was the light of men. And the light shineth in darkness; and the darkness comprehended it not.
>
> *St. John 1:4-5*

> The light of the body is the eye: if therefore thine eye be single' thy whole body shall be full of light.
>
> *Matthew 6:22*

After receiving this revelation, I beseeched my lord and master, the High Priest Sankhamen, continually to grant me the knowledge of the secret workings of the ankh of light, which was referred to as the Neb ankh. Understanding of the Neb ankh was achieved at the culmination of a lifetime of study and religious discipline. Although I am only a messenger, with a message already too complex for those who would receive it, I felt compelled to include some mention of it's enormous importance.

The Neb ankh was an awesome experience which would change forever, the initiate's perception of reality. For it was a foretaste of life after death, a discovery of an existence outside the mass of the body, a feeling of total weightlessness and an inter-dimensional access to the Tuat (the otherworld).

Superior African Technology has already achieved levels which are still thought to be science fiction.

The rewards of African Nationalism will be the ability to mount large scale research efforts, akin to the Space Program or the Manhattan Project, to revive ancestral wisdom. Imagine the cohesive power and national unity in Kemit during the Era of Pyramid Building. Modern technology is still in its infancy and can only scratch the surface of this enormously com-

plicated issue. We should abandon the Pale god and return to the worship (study) of Osiris (the Black God, the electronics of Black skin).

Ptah, portrayed as a mummy, with his hands protruding from the wrappings, holding a staff that combines the djed pillar, ankh sign and sceptre.

Although the active component is the melanin granule, its random orientation renders it ineffective. The electromagnetic emissions from the ankh and the uas (scepter) were used to align these tiny dielectric resonator antennas, in order to produce a coherent radiation pattern. The position of a granule can be adjusted. Because, as shown on page 56, the field of a melanin granule could exert a dipole moment on its neighbor, creating the proper alignment of this microscopic antenna array.

Coherence is the essential property of a laser (Light Amplification by Stimulated Emission of Radiation), and Black skin can be made to lase.

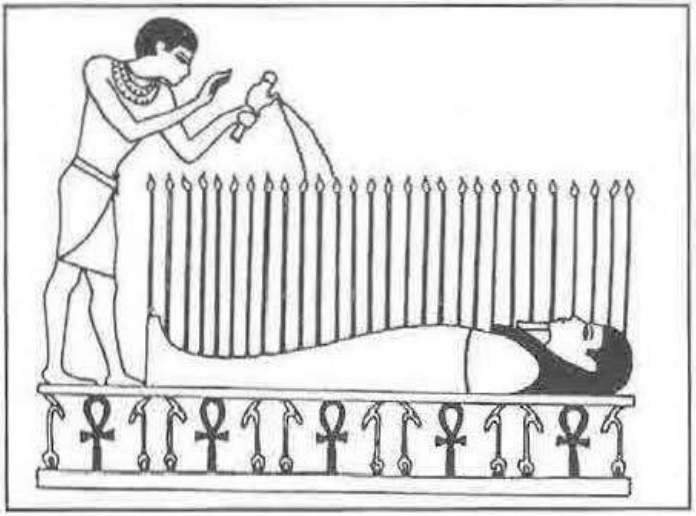

Light rays, in the form of beams tipped by tiny flames, emitted from the body of Osiris, the Neb Ankh.

Conclusion

The basic character of African Science is the promotion of life, as opposed to the Euro-centric preoccupation with destructive or weapons based technology. Because of this mind-set, the view that all science has some weapons potential, Europeans are intent on suppressing Ankh Science as a matter of National Security. Their need to mis-educate African children results from a very real fear, that the genetic memory of these mental giants will be awakened. This policy has been in effect since the Greeks first encountered this advanced extraterrestrial civilization of the Nile Valley.

Because of the barbaric nature of the Greeks, the Amen Priests were killed, libraries burned, religion distorted and hieroglyphic writing forbidden. This arms race mentality is a permanent feature of Euro-science, having the effect of placing all science under the scrutiny and directorship of the governing body, in order to prevent a departure from science that is only beneficial to Whites. The encounter with an alien

civilization, possessing science developed over thousands of years around unique genetic differences, forced Whites to institute policies of mis-education.

The photo-active nature of melanin is an evolutionary quantum-leap, generating a science, culture and religion totally alien to the invaders of the Nile Valley. If allowed unimpeded development, this advantage could be exploited with miraculous consequences for the African, the greatest benefits being in the medical arena, where laser technology and the protein-producing melanocytes will be wedded to create cures unheard of since the time of Imhotep And speaking of Imhotep, could reviving the dead by using infrared laser techniques to dissociate carbon dioxide in the body be far away? This might not be our greatest achievement, for within the genetic memory of an African child is the knowledge to deoxidize melanin and put flesh on dry bones.

Afterword

WHEN I FIRST READ *The Ankh:African origin of electromagnitism,* I was elated, because all positive information about the Ankh is necessary to awaken the Nubian Kamitik Giants sleeping in the belly of Amenta (the West). The Ankh is the old rugged sign that has been despised by the world. The four major world religions: Hebrew-Israelite, Buddhism, Christianity and Islam were all nurtured by the Ankh people of the Nubian Hapi (Nile) Valley. In this scintillating book, the electromagnetic power of the Ankh has been scientifically investigated by Nur Ankh Amen.

The Egyptological would-be suppressers of AfrakaNubian Spiritual High Kulture continue to deny the primacy of Afrakan Kosmik thought and its application in the mundane realms. These humble Black farmers of the Nile Valley could not possibly have knowledge of electricity and atomic energy. Long before the atom was discovered and misused by western man, Atum appeared on the temple walls of Khamit (Egypt) as the primordial principle of unmanifested potential. It was Atum, cradled on the head of Ptah, the unmoved mover who copulated within her-

himself to bring forth Shu-Nifu, the fire fed wind and Tefnut-the materialization of H_2O. These complementary elements sustain the Ankh (Life) principle of the wombniverse.

Nur Ankh Amen has not been criticized because of fear that the reclamation of Ankh Spiritual Science by Afrakan people, will make the foreign imposed religions obsolete. The oppressor knows this much, that the Ankh sign itself is a primordial mental key to unlock the gates of ancestral memory. In his book, *Black Seminarians Without a Black Theology*, Dr. Yosef Ben Jochannan issued a call for restoration of the Ankh to its place of primacy in Afrakan Spiritual High Kulture.

The Ankh is also carried by Nubian Kamitik initiates in the major cities of the West. Bearers of the Ankh are very courageous people who are undaunted by the slander against the Ankh. They have seen beyond the lie that the original AfrakaNubian bearers of the Ankh were 'pagan' and 'heathen' people who 'worshiped idols.' Yet this slander has caused many people of Afrakan ascent to turn away from Ankh science. Bearers of the Ankh are keepers of a sacred legacy which calls them to service as healers in the earth. On the temple walls of Aton-Ra Akhet (called El-Armana today) the Aton Ra (Sun) is chiseled in stone projecting rays terminating in Ankh (Life). The rays of Aton-

Ra are the food of plants. To consume green plants is the way we feed our internal sun within the pineal gland.

The first Ankh bearer was called Heru (in Greek Horus). The aim of all initiates in Ankh Sacred Science is to become transformed into Heru. Heru is the Ankh (Life) advocate ruling the upper realms of your Konsciousness. Heru Asr, the Nubian Falcon of the Holy Spirit, is pictured on temple walls flying with Ankhs in its talons. Heru - the Ankh (Life) messenger came with words of healing and life.

The Socio-Spiritual Meaning of the Ankh

In woman the loop of the Ankh represents the womb, the crossbar the fallopian tubes, the staff the birth canal. In man the loop is his prostate, the crossbar his testes, the staff his penis. Ankh is a life wand. Khamitically speaking our ecological Ankh is that loop of mist drawn up through the power of Aton-Ra's (the Sun's) rays to make clouds which is purified by the Kosmik kiss of Tefnut (moisture). It falls back to earth (the crossbar) as Nun (Rain) or Hapi (die inundated river) fertilizing and bringing the seed of new life (the staff) out of the ground as vegetal food of life in the first times. Ptah's face was green with the promise of renewal and regeneration of life through eating and drinking the green. Queen Afua who as Mut Nebt-Het is Chief Priestess of Purification says,

"Eat green, wear green, walk on green" and Priestess Tehuti adds, "Put green in your pocket." Remember electromagnetic Ankhs utilized copper which is oxidized as green. This is the great drama of the rebirth of Asar the Resurrected One. Ankh is the perennial symbol of the Divine Afrakan family in perpetuity. However you look at it, Ankh is life.

Special Note: For Bearers. Wearers and Keepers of Ankh

Ankhians are not selfish, we share the gifts of healing and life with all people who respect the primordial Aftakan source of all earth life. The mitochondrial Eve is a Nubian Khamit woman - Ta-Urt Sekemet Mut Ast.

The Ankh is an Afrakan re-birth concept and symbol which Afraka gave to the world when she preserved the Ankh on temple walls and as amulets. Ankh may be worn by all who adore NTR the one life source as NTR Ankh (Divine Supreme Womb/Seed Source of Life) the Mother/Father Creator. A wearer of the Ankh is not racist, is not violent, does not eat dead or live animals, nor flesh, avoids any foods that cause putrefaction or fermentation stinking up the body and does not eat creatures with eyes. An initiate wearer, carrier or user of the Ankh honors the feminine (womb) principle as the first and eldest manifestation of divine in Kosmos and on earth. She/he is cognizant of the need of Maat in a patriarchal world. Ankh supporters practice Maatiarchy - balanced

Execution of power in female/male relationships. Ankh demands focus and attention to spiritual and material needs simultaneously.

However you see the Ankh either as a Spiritual, Kultural, healing or scientific tool or wand, it is essential to remember that the Creators of the Ankh instrument caused the rise of the longest lasting most righteous civilization in the Hapi (Nile) Khamitic Valley and sent messengers of Ankh (Life) to all people of earth. So tenacious is humanity's hold on Ankh (Life) that Ankh subliminally creeps up in all English words of continuity. All gerund (ing) words/sounds conceal the Hesi (mantra) Ankh - "ing" is continuity throughout all time and all space. The anchor which secures the lives of passengers on a stormy sea conceals the hesi (word/sound) Ankh. When we thank the Creator, we use the word Ankh. Connect conceals Ankh in the letters "onnec." Our interconnectedness with NTR (Divine) is the greatest lesson taught by Ankh (Life Eternal) science. Ask your k-nee (reverse the sound and the movement). Ask your ankle, ask your tongue which stimulates the waters which form the sound of your voice. Ankh the very word in MTU NTR begins with the wave, (Nu) water. According to Gerrald Massey in Ancient Egypt Light of the World, the very word King conceals the Khamite hope of life eternal. Nkh, Ankh - -g may he live. -g Live the -g.

The Ankh unifies us all in spite of religious and philosophical differences because it is the sign of the Wombniversal AfraKosmik Spiritual source of all religions. Without Ankh (life) of what use is religion? Meditate on ankh as you hesi (chant) Ankh over and over. Come to Ankh. Come to Life.

May this book serve to fill in open gaps in your knowledge. Add this scientific and spiritual portion to your store of Ankh knowledge (reverse the first three letters in know what do you get? Onk, life.) Ink makes the word permanent. The written words of wisdom gives life. I offer this humble addendum as I have been asked. May you take your Ankh back. RISE AFRAKANUBIANKHAMITIKUSHITE PEOPLE, RISE!

Forever yours in Ankhtuity,
For Ankhternity,
Ankhtually,
Heru Ankh Semahj sa Ptah
Studio of Ptah
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New York, NY, 10013
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1-212-343-9706

Glossary

ankh: A tau cross with a loop on top.

diety: A person or thing revered to as supremely powerful or beneficent.

djed: Cruciform symbol with at least three cross bars.

lodestone: naturally occurring mineral that is strongly magnetic.

aurora: Intermittent electrical discharge that occurs in the rarefied upper atmosphere.

ionosphere: An ionized layer in a planetary atmosphere where free electrons and ions with thermal energies exist under the control of earth's gravitational and magnetic fields.

ions: electrically charged atoms or group of atoms.

electron: negatively charged elementary particle of the atom.

DNA: The nucleic acid forming the genetic material of all cells.

Heh: God of infinity.

chakras: The points located along the body that are known as energy centers. They are seven of them.

diode An electrical device that allows electricity to flow in one direction only.

SETI: Search for Extraterrestrial Intelligence

UFO Unidentified Flying Object.

Khnum: A Ram-headed creator god often depicted at a pot-

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Saleh Faruque
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Preface

By inventing the wireless transmitter or radio in 1897, the Italian physicist Tomaso Guglielmo Marconi added a new dimension to the world of communications. This enabled the transmission of the human voice through space without wires. For this epoch-making invention, this illustrious scientist was honored with the Nobel Prize for Physics in 1909. Even today, students of wireless or radio technology remember this distinguished physicist with reverence. A new era began in Radio Communications.

The classical Marconi radio used a modulation technique known today as "Amplitude Modulation" or just AM. This led to the development of Frequency Modulation (FM), amplitude shift keying (ASK), phase shift keying (PSK), etc. Today, these technologies are extensively used in various wireless communication systems. These modulation techniques form an integral part of academic curricula today.

This book presents a comprehensive overview of the various modulation techniques mentioned above. Numerous illustrations are used to bring students up-to-date in key concepts and underlying principles of various analog and digital modulation techniques. In particular, the following topics will be presented in this book:

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Bandwidth occupancy in AM and FM
- Amplitude shift keying (ASK)
- Frequency shift keying (FSK)
- Phase shift keying (PSK)
- N-ary coding and M-ary modulation
- Bandwidth occupancy in ASK, FSK, and PSK

This text has been primarily designed for electrical engineering students in the area of telecommunications. However, engineers and designers working in the area

of wireless communications would also find this text useful. It is assumed that the student is familiar with the general theory of telecommunications.

In closing, I would like to say a few words about how this book was conceived. It came out of my long industrial and academic career. During my teaching tenure at the University of North Dakota, I developed a number of graduate-level elective courses in the area of telecommunications that combine theory and practice. This book is a collection of my courseware and research activities in wireless communications.

I am grateful to UND and the School for the Blind, North Dakota, for affording me this opportunity. This book would never have seen the light of day had UND and the State of North Dakota not provided me with the technology to do so. My heartfelt salute goes out to the dedicated developers of these technologies, who have enabled me and others visually impaired to work comfortably.

I would like to thank my beloved wife, Yasmin, an English Literature buff and a writer herself, for being by my side throughout the writing of this book and for patiently proofreading it. My darling son, Shams, an electrical engineer himself, provided technical support in formulation and experimentation when I needed it. For this, he deserves my heartfelt thanks.

Finally, thanks are also to my doctoral student Md. Maruf Ahamed who found time in his busy schedule to assist me with the simulations, illustrations, and the verification of equations.

In spite of all this support, there may still be some errors in this book. I hope that my readers forgive me for them. I shall be amply rewarded if they still find this book useful.

Grand Forks, USA Saleh Faruque
May 2016

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Chapter 1
Introduction to Modulation

Topics

- Background
- Modulation by Analog Signal
- AM and FM Bandwidth at a Glance
- Modulation by Digital Signal
- ASK, FSK and PSK Bandwidth at a Glance

1.1 Background

Modulation is a technique that changes the characteristics of the carrier frequency in accordance with the input signal. Figure 1.1 shows the conceptual block diagram of a modern wireless communication system, where the modulation block is shown in the inset of the dotted block. As shown in the figure, modulation is performed at the transmit side and demodulation is performed at the receive side. This is the final stage of any radio communication system. The preceding two stages have been discussed elaborately in my previous book in this series [1, 2].

The output signal of the modulator, referred to as the modulated signal, is fed into the antenna for propagation. Antenna is a reciprocal device that transmits and receives the modulated carrier frequency. The size of the antenna depends on the wavelength (λ) of the sinusoidal wave where

$\lambda = c/f$ m
c = Velocity of light = 3×10^8 m/s
f = Frequency of the sinusoidal wave, also known as "carrier frequency."

Therefore, a carrier frequency much higher than the input signal is required to keep the size of the antenna at an acceptable limit. For these reasons, a high-frequency carrier signal is used in the modulation process. In this process, the

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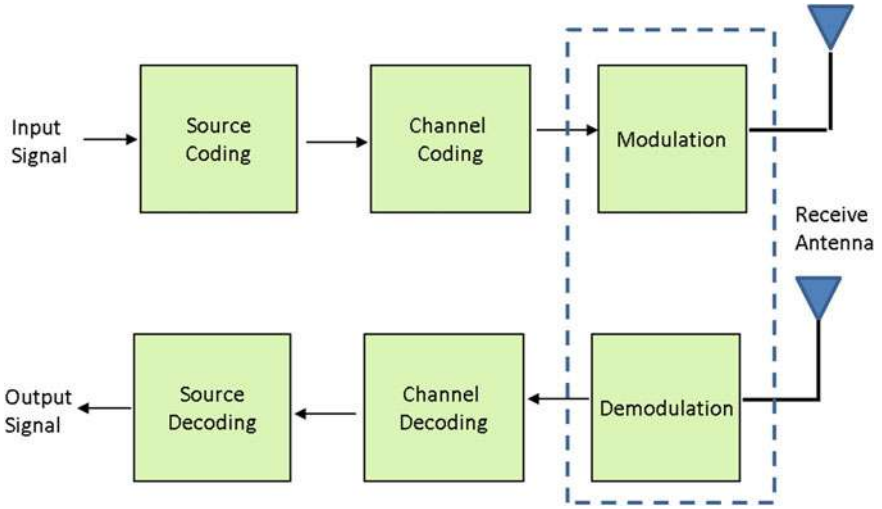

Fig. 1.1 Block diagram of a modern full-duplex communication system. The modulation stage is shown as a *dotted* block

low-frequency input signal changes the characteristics of the high-frequency carrier in a certain manner, depending on the modulation technique. Furthermore, as the size and speed of digital data networks continue to expand, bandwidth efficiency becomes increasingly important. This is especially true for broadband communication, where the digital signal processing is done keeping in mind the available bandwidth resources.

Hence, modulation is a very important step in the transmission of information. The information can be either analog or digital, where the carrier is a high-frequency sinusoidal waveform. As stated earlier, the input signal (analog or digital) changes the characteristics of the carrier waveform. Therefore, there are two basic modulation schemes as listed below:

- Modulation by analog signals and
- Modulation by digital signals.

This book presents a comprehensive overview of these modulation techniques in use today. Numerous illustrations are used to bring students up-to-date in key concepts and underlying principles of various analog and digital modulation techniques. For a head start, brief descriptions of each of these modulation techniques are presented below.

1.2 Modulation by Analog Signals

1.2.1 AM, FM, and PM

For analog signals, there are three well-known modulation techniques as listed below:

- Amplitude Modulation (AM),
- Frequency Modulation (FM),
- Phase Modulation (PM).

By inventing the wireless transmitter or radio in 1897, the Italian physicist Tomaso Guglielmo Marconi added a new dimension to the world of communications [3, 4]. This enabled the transmission of the human voice through space without wires. For this epoch-making invention, this illustrious scientist was honored with the Nobel Prize for Physics in 1909. Even today, students of wireless or radio technology remember this distinguished physicist with reverence. A new era began in Radio Communications. The classical Marconi radio used a modulation technique known today as "Amplitude Modulation" or just AM. In AM, the amplitude of the carrier changes in accordance with the input analog signal, while the frequency of the carrier remains the same. This is shown in Fig. 1.2 where

- $m(t)$ is the input modulating audio signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the AM-modulated carrier frequency.

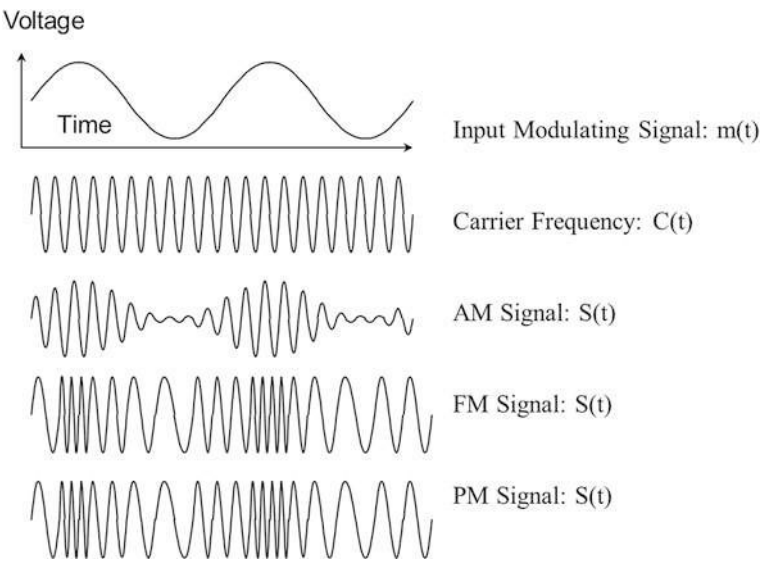

Fig. 1.2 Modulation by analog signal

As shown in the figure, the audio waveform changes the amplitude of the carrier to determine the envelope of the modulated carrier. This enables the receiver to extract the audio signal by demodulation. Notice that the amplitude of the carrier changes in accordance with the input signal, while the frequency of the carrier does not change after modulation. It can be shown that the modulated carrier $S(t)$ contains several spectral components, requiring frequency-domain analysis, which will be addressed in Chap. 2. It may be noted that AM is vulnerable to signal amplitude fading.

In Frequency Modulation (FM), the frequency of the carrier changes in accordance with the input modulation signal as shown in Fig. 1.2 [5]. Notice that in FM, only the frequency changes while the amplitude remains the same. Unlike AM, FM is more robust against signal amplitude fading. For this reason, FM is more attractive in commercial FM radio. In Chap. 3, it will be shown that in FM, the modulated carrier contains an infinite number of sideband due to modulation. For this reason, FM is also bandwidth inefficient.

Similarly, in Phase Modulation (PM), the phase of the carrier changes in accordance with the phase of the carrier, while the amplitude of the carrier does not change. PM is closely related to FM. In fact, FM is derived from the rate of change of phase of the carrier frequency. Both FM and PM belong to the same mathematical family. We will discuss this more elaborately in Chap. 3.

1.2.2 AM and FM Bandwidth at a Glance

The bandwidth occupied by the modulated signal depends on bandwidth of the input signal and the modulation method as shown in Fig. 1.3. Note that the unmodulated carrier itself has zero bandwidth.

In AM:

- The modulated carrier has two sidebands (upper and lower) and
- Total bandwidth = 2 × base band.

In FM:

- The carrier frequency shifts back and forth from the nominal frequency by Δf, where Δf is the frequency deviation.
- During this process, the modulated carrier creates an infinite number of spectral components, where higher-order spectral components are negligible.
- The approximate FM bandwidth is given by the Carson's rule:
  - FM BW = $2f\,(1 + \beta)$
  - f = Base band frequency
  - β = Modulation index
  - $\beta = \Delta f/f$
  - Δf = Frequency deviation.

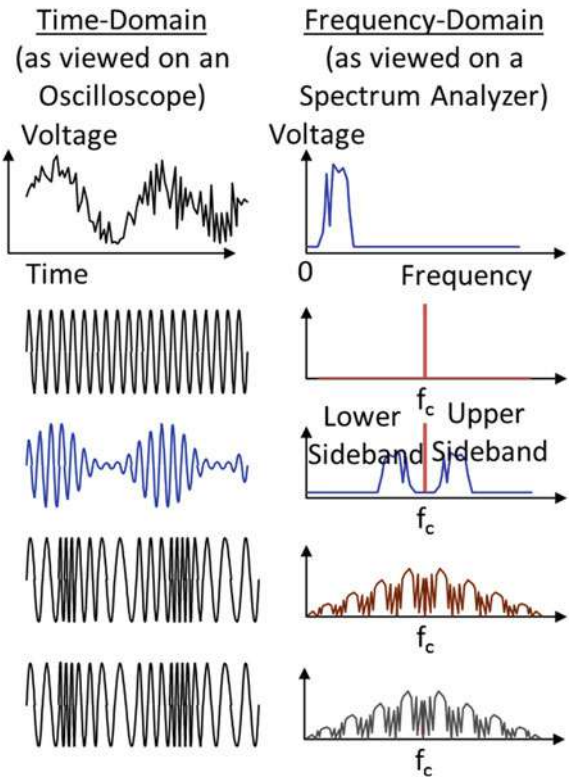

Fig. 1.3 Bandwidth occupancy in AM, FM, and PM signals

1.3 Modulation by Digital Signal

For digital signals, there are several modulation techniques available. The three main digital modulation techniques are as follows:

- Amplitude shift keying (ASK),
- Frequency shift keying (FSK), and
- Phase shift keying (PSK).

Figure 1.4 illustrates the modulated waveforms for an input modulating digital signal. Brief descriptions of each of these digital modulation techniques along with the respective spectral responses and bandwidth are presented below.

1.3.1 Amplitude Shift Keying (ASK) Modulation

Amplitude shift keying (ASK), also known as on–off keying (OOK), is a method of digital modulation that utilizes amplitude shifting of the relative amplitude of the

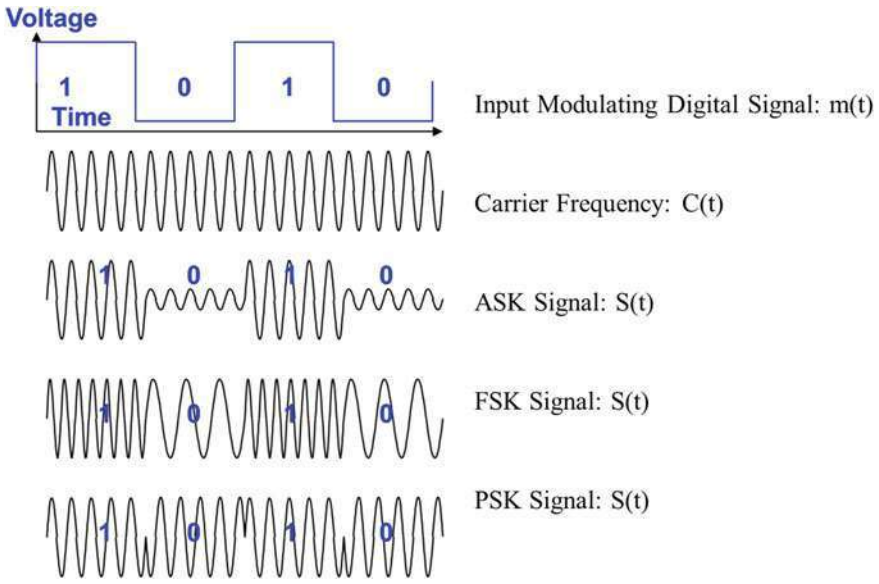

Fig. 1.4 Modulation by digital signal

career frequency [6–8]. The signal to be modulated and transmitted is binary; this is referred to as ASK, where the amplitude of the carrier changes in discrete levels, in accordance with the input signal, as shown.

- Binary 0 (bit 0): Amplitude = Low and
- Binary 1 (bit 1): Amplitude = High.

Figure 1.4 shows the ASK-modulated waveform where

- Input digital signal is the information we want to transmit.
- Carrier is the radio frequency without modulation.
- Output is the ASK-modulated carrier, which has two amplitudes corresponding to the binary input signal. For binary signal 1, the carrier is ON. For the binary signal 0, the carrier is OFF. However, a small residual signal may remain due to noise, interference, etc.

1.3.2 Frequency Shift Keying (FSK) Modulation

Frequency shift keying (FSK) is a method of digital modulation that utilizes frequency shifting of the relative frequency content of the signal [6–8]. The signal to be modulated and transmitted is binary; this is referred to as binary FSK (BFSK),

where the carrier frequency changes in discrete levels, in accordance with the input signal as shown below:

- Binary 0 (bit 0): Frequency = $f + \Delta f$.
- Binary 1 (bit 1): Frequency = $f - \Delta f$.

Figure 1.4 shows the FSK-modulated waveform where

- Input digital signal is the information we want to transmit.
- Carrier is the radio frequency without modulation.
- Output is the FSK-modulated carrier, which has two frequencies ω_1 and ω_2, corresponding to the binary input signal.
- These frequencies correspond to the messages binary 0 and 1, respectively.

1.3.3 Phase Shift Keying (PSK) Modulation

Phase shift keying (PSK) is a method of digital modulation that utilizes phase of the carrier to represent digital signal [6–8]. The signal to be modulated and transmitted is binary; this is referred to as binary PSK (BPSK), where the phase of the carrier changes in discrete levels, in accordance with the input signal as shown below:

- Binary 0 (bit 0): $\text{Phase}_1 = 0°$.
- Binary 1 (bit 1): $\text{Phase}_2 = 180°$.

Figure 1.4 shows the modulated waveform where

- Input digital signal is the information we want to transmit.
- Carrier is the radio frequency without modulation.
- Output is the BPSK-modulated carrier, which has two phases φ_1 and φ_2 corresponding to the two information bits.

1.4 Bandwidth Occupancy in Digital Modulation

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth. The transmission bandwidth depends on the following:

- Spectral response of the encoded data,
- Spectral response of the carrier frequency, and
- Modulation type (ASK, FSK, PSK), etc.

Let us take a closer look!

1.4.1 Spectral Response of the Encoded Data

In digital communications, data is generally referred to as a non-periodic digital signal. It has two values:

- Binary-1 = High, Period = T.
- Binary-0 = Low, Period = T.

Also, data can be represented in two ways:

- Time-domain representation and
- Frequency-domain representation.

The time-domain representation (Fig. 1.5a), known as non-return-to-zero (NRZ), is given by

$$\begin{array}{ll} V(t) = V & <0<t<T \\ = 0 & \text{elsewhere} \end{array} \tag{1.1}$$

The frequency-domain representation is given by "Fourier transform" [9]:

$$V(\omega) = \int_0^T V \cdot e^{-j\omega t} dt \tag{1.2}$$

$$|V(\omega)| = VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]$$

$$P(\omega) = \left(\frac{1}{T}\right)|V(\omega)|^2 = V^2 T\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]^2 \tag{1.3}$$

Here, $P(\omega)$ is the power spectral density. This is plotted in (Fig. 1.5b). The main lobe corresponds to the fundamental frequency and side lobes correspond to harmonic components. The bandwidth of the power spectrum is proportional to the frequency. In practice, the side lobes are filtered out since they are relatively insignificant with respect to the main lobe. Therefore, the one-sided bandwidth is given by the ratio $f/fb = 1$. In other words, the one-sided bandwidth $= f = f_b$, where $f_b = R_b = 1/T$, T being the bit duration.

The general equation for two-sided response is given by

$$V(\omega) = \int_{-\alpha}^{\alpha} V(t) \cdot e^{-j\omega t} \mathrm{d}t$$

In this case, $V(\omega)$ is called two-sided spectrum of $V(t)$. This is due to both positive and negative frequencies used in the integral. The function can be a voltage

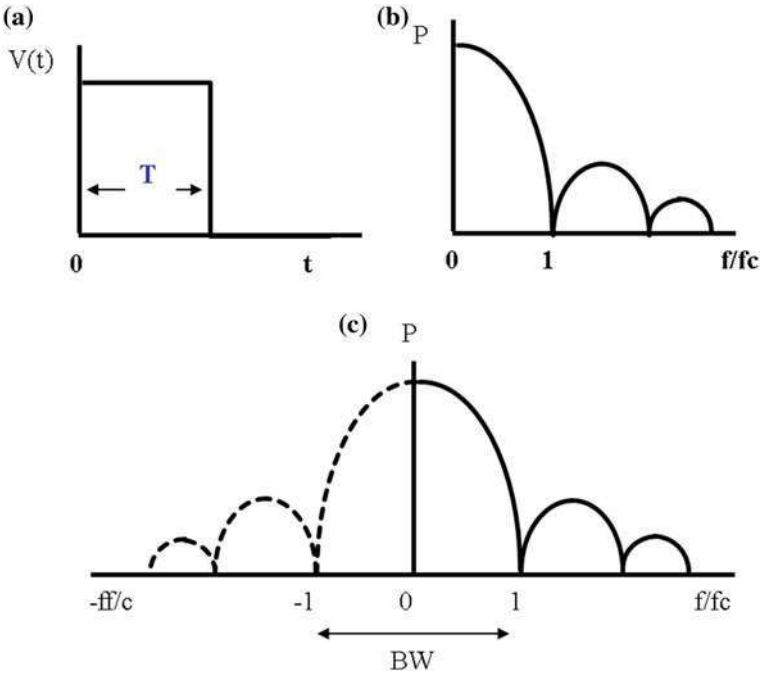

Fig. 1.5 **a** Discrete time digital signal, **b** it is one-sided power spectral density, and **c** two-sided power spectral density. The bandwidth associated with the non-return-to-zero (NRz) data is $2R_b$, where R_b is the bit rate

or a current (Fig. 1.5c) shows the two-sided response, where the bandwidth is determined by the main lobe as shown below:

$$\text{Two sided bandwidth (BW)} = 2R_b \,(R_b = \text{Bit rate before coding}) \tag{1.4}$$

1.4.2 Spectral Response of the Carrier Frequency Before Modulation

A carrier frequency is essentially a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component. For example, the sine wave is described by the following time-domain equation:

$$V(t) = V_p \sin(\omega t_c) \tag{1.5}$$

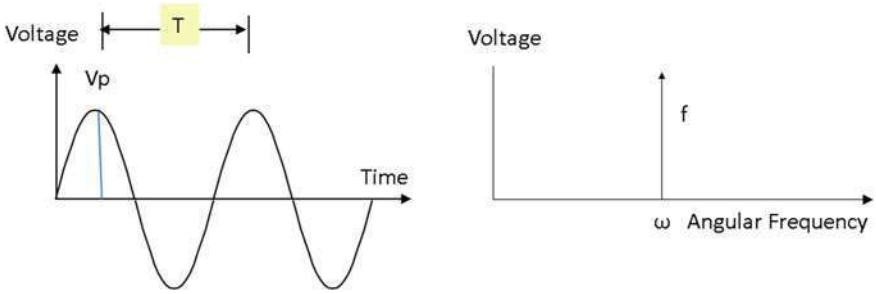

Fig. 1.6 A sine wave and its frequency response

where

$$V_p = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$
- f_c = Carrier frequency in Hz

Figure 1.6 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

1.4.3 ASK Bandwidth at a Glance

In ASK, the amplitude of the carriers changes in discrete levels, in accordance with the input signal where

- Input data: $m(t) = 0$ or 1.
- Carrier frequency: $C(t) = A_c \cos(\omega_c t)$.
- Modulated carrier: $S(t) = m(t)C(t) = m(t)A_c \cos(\omega_c t)$.

Since $m(t)$ is the input digital signal and it contains an infinite number of harmonically related sinusoidal waveforms and that we keep the fundamental and filter out the higher-order components, we write:

$$m(t) = A_m \sin(\omega_m t)$$

The ASK-modulated signal then becomes:

$$\begin{aligned} S(t) &= m(t)S(t) = A_m A_c \sin(\omega_m t)\cos(\omega_c) \\ &= A_m A_c \cos(\omega_c \pm \omega_m) \end{aligned}$$

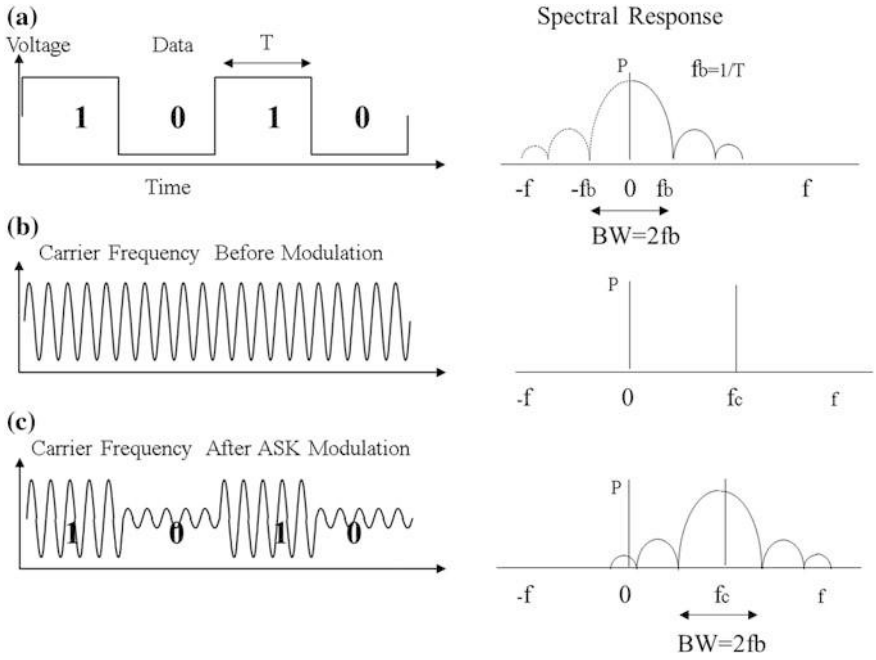

Fig. 1.7 ASK bandwidth at a glance. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation. The transmission bandwidth is $2f_b$, where f_b is the bit rate and $T = 1/f_b$ is the bit duration for NRZ data

The spectral response is depicted in Fig. 1.7. Notice that the spectral response after ASK modulation is the shifted version of the NRZ data. Bandwidth is given by,

BW = $2R_b$ (coded), where R_b is the coded bit rate.

1.4.4 FSK Bandwidth at a Glance

In FSK, the frequency of the carrier changes in two discrete levels, in accordance with the input signals. We have:

- Input data: $m(t) = 0$ or 1
- Carrier frequency: $C(t) = A \cos(\omega t)$
- Modulated carrier: $S(t) = A \cos(\omega - \Delta\omega)t$, For $m(t) = 1$
  $S(t) = A \cos(\omega + \Delta\omega)t$, For $m(t) = 0$

where

- $S(t)$ = The modulated carrier,
- A = Amplitude of the carrier,

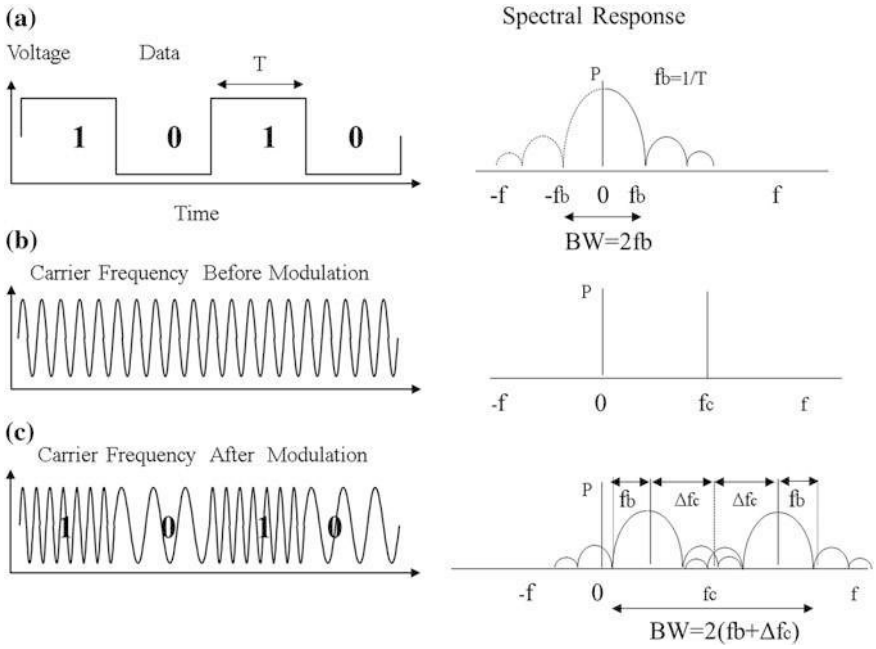

Fig. 1.8 FSK bandwidth at a glance. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation. The transmission bandwidth is $2(f_b + \Delta f_c)$. f_b is the bit rate and Δf_c is the frequency deviation = $1/f_b$ is the bit duration for NRZ data

- ω = Nominal frequency of the carrier frequency, and
- $\Delta\omega$ = Frequency deviation.

The spectral response is depicted in Fig. 1.8. Notice that the carrier frequency after FSK modulation varies back and forth from the nominal frequency f_c by $\pm\ \Delta f_c$, where Δf_c is the frequency deviation. The FSK bandwidth is given by

$$\text{BW} = 2(f_b + \Delta f_c) = 2f_b(1 + \Delta f_c/f_b) = 2f_b(1 + \beta),$$

where $\beta = \Delta f/f_b$ is known as the modulation index and f_b is the coded bit frequency (bit rate R_b).

1.4.5 BPSK Bandwidth at a Glance

In BPSK, the phase of the carrier changes in two discrete levels, in accordance with the input signal. Here, we have:

- Input data: $m(t) = 0$ or 1
- Carrier frequency: $C(t) = A \cos(\omega t)$
- Modulated carrier: $S(t) = A \cos(\omega + \varphi)t$

where

- A = Amplitude of the carrier frequency,
- ω = Angular frequency of the carrier, and
- φ = Phase of the carrier frequency.

Table below shows the number of phases and the corresponding bits per phase for MPSK modulation schemes for $M = 2, 4, 8, 16, 32, 64$, etc. It will be shown that higher-order MPSK modulation schemes ($M > 2$) are spectrally efficient.

Modulation	Number of phases φ	Number of bits per phase
BPSK	2	1
QPSK	4	2
8PSK	8	3
16	16	4
32	32	5
64	64	6
:	:	:

Figure 1.9 shows the spectral response of the BPSK modulator. Since there are two phases, the carrier frequency changes in two discrete levels, one bit per phase, as follows:

$\varphi = 0°$ for bit 0 and
$\varphi = 180°$ for bit 1.

Notice that the spectral response after BPSK modulation is the shifted version of the NRZ data, centered on the carrier frequency f_c. The transmission bandwidth is given by

$$\text{BW(BPSK)} = 2R_b/\text{Bit per Phase} = 2R_b/1 = 2R_b$$

where

- R_b is the coded bit rate (bit frequency).
- For BPSK, $\varphi = 2$, one bit per phase.

Also, notice that the BPSK bandwidth is the same as the one in ASK modulation. This is due to the fact that the phase of the carrier changes in two discrete levels, while the frequency remains the same.

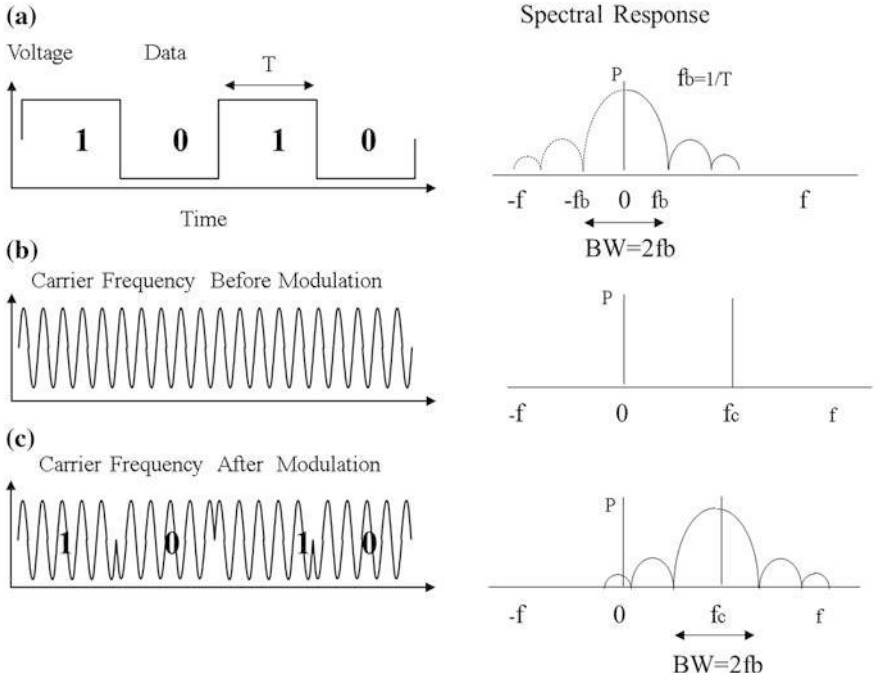

Fig. 1.9 PSK bandwidth at a glance. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation

1.5 Conclusions

This chapter presents a brief overview of modulation techniques covered in this book. Numerous illustrations are used to bring students up-to-date in key concepts and underlying principles of various analog and digital modulation techniques. In particular, following topics will be presented in this book:

- Amplitude Modulation (AM),
- Frequency Modulation (FM),
- Bandwidth occupancy in AM and FM,
- Amplitude shift keying (ASK),
- Frequency shift keying (FSK),
- Phase shift keying (PSK), and
- Bandwidth occupancy in ASK, FSK, and PSK.

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Chapter 2
Amplitude Modulation (AM)

Topics

- Introduction
- Amplitude Modulation (AM)
- AM Spectrum and Bandwidth
- Double Side Band Suppressed Carrier (DSBSC)
- DSBSC Spectrum and Bandwidth
- Single Side Band (SSB) Carrier
- SSB Spectrum and Bandwidth

2.1 Introduction

By inventing the wireless transmitter or radio in 1897, the Italian physicist Tomaso Guglielmo Marconi added a new dimension to the world of communications [1, 2]. This enabled the transmission of the human voice through space without wires. For this epoch-making invention, this illustrious scientist was honored with the Nobel Prize for Physics in 1909. Even today, students of wireless or radio technologies remember this distinguished physicist with reverence. A new era began in Radio Communications.

The classical Marconi radio used a modulation technique known today as "Amplitude Modulation" or just AM, which is the main topic of this chapter. In AM, the amplitude of the carrier changes in accordance with the input analog signal, while the frequency of the carrier remains the same. This is shown in Fig. 2.1, where

- $m(t)$ is the input modulating audio signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the AM-modulated carrier frequency.

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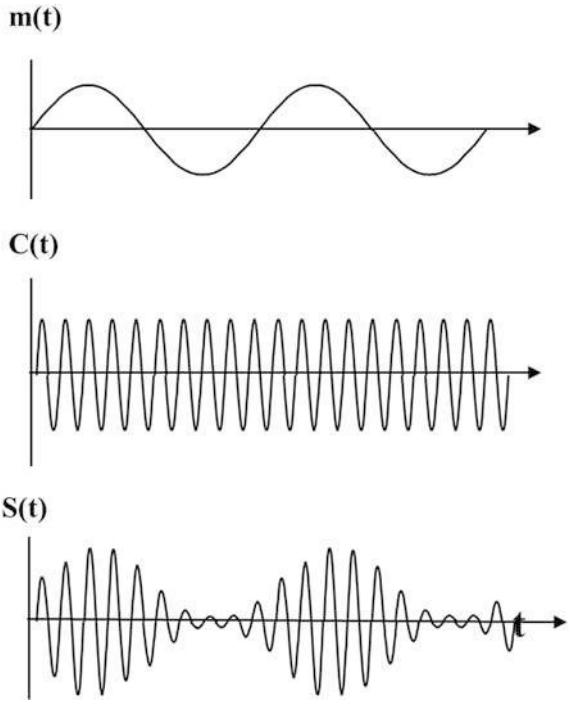

Fig. 2.1 AM waveforms. The amplitude of the carrier changes in accordance with the input analog signal. The frequency of the carrier remains the same

As shown in the figure, the audio waveform changes the amplitude of the carrier to determine the envelope of the modulated carrier. This enables the receiver to extract the audio signal by demodulation. Notice that the amplitude of the carrier changes in accordance with the input signal, while the frequency of the carrier does not change after modulation. However, it can be shown that the modulated carrier $S(t)$ contains several spectral components, requiring frequency domain analysis. In an effort to examine this, this chapter will present the following topics:

- Amplitude Modulation (AM) and AM spectrum
- Double Sideband-suppressed carrier (DSBSC) and DSBSC spectrum
- Single sideband (SSB) carrier and SSB spectrum

In the following sections, the above disciplines in AM modulation will be presented along with the respective spectrum and bandwidth. These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

2.2 Amplitude Modulation

Amplitude Modulation (AM) is a method of analog modulation that utilizes amplitude variations of the relative amplitude of the career frequency [3–5]. The signal to be modulated and transmitted is analog. This is referred to as AM, where the amplitude of the carrier changes in accordance with the input signal.

Figure 2.2 shows a functional diagram of a typical AM modulator for a single tone. Here, $m(t)$ is the input analog signal we want to transmit, $C(t)$ is the carrier frequency without modulation, and $S(t)$ is the output AM-modulated carrier frequency. These parameters are described below:

$$\begin{aligned} &\bullet \quad m(t) = A_m \cos(2\pi f_m t) \\ &\bullet \quad C(t) = A_c \cos(2\pi f_c t) f_c \gg f_m \\ &\bullet \quad \begin{aligned} S(t) &= [1 + m(t)]C(t) \\ &= C(t) + m(t)C(t) \end{aligned} \end{aligned} \tag{2.1}$$

Therefore,
When $m(t) = 0$:

$$\bullet \quad S(t) = A_c \cos(2\pi f_c t) \tag{2.2}$$

When $m(t) = \mathrm{A_m} \cos(2\pi f_m t)$:

$$\bullet \quad S(t) = A_c \cos(2\pi f_c t) + A_c A_m \cos(2\pi f_m t) \cos(2\pi f_c t) \tag{2.3}$$

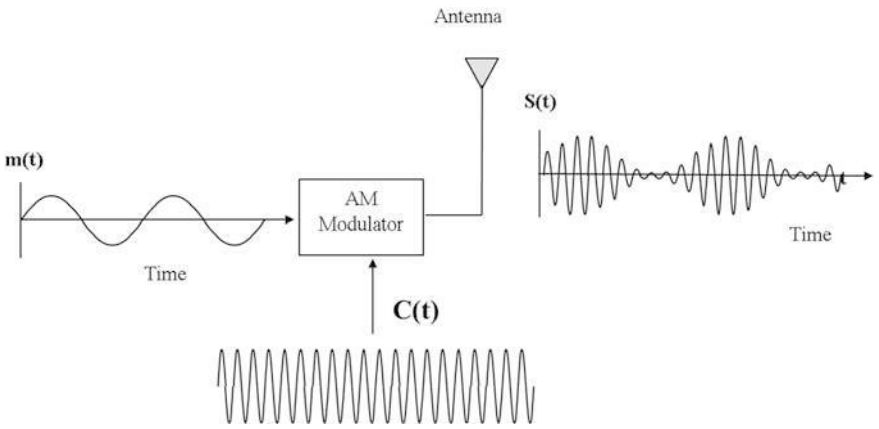

Fig. 2.2 Illustration of amplitude modulation. The amplitude of the carrier $C(t)$ changes in accordance with the input modulating signal $m(t)$. $S(t)$ is the modulated waveform which is transmitted by the antenna

In the above equation, we see that:

- The first term is the carrier only, which does not have information
- The second **term** contain**s the** information, which has several spectral components, requiring further analysis to quantify them.

2.3 AM Spectrum and Bandwidth

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth and modulation. The transmission bandwidth depends on the following:

- Spectral response of the input modulating signal
- Spectral response of the carrier frequency and
- Modulation type (AM, FM ASK, FSK, PSK, etc.)

Let us take a closer look!

2.3.1 Spectral Response of the Input Modulating Signal

In AM, the input modulating signal is a continuous time low-frequency analog signal. For simplicity, we use a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component. For example, the sine wave is described by the following time domain equation:

$$V(t) = V_p \sin(\omega_m t) \tag{2.4}$$

where

- Vp = Peak voltage
- $\omega_m = 2\pi f_m$
- f_m = Input modulating frequency in Hz

Figure 2.3 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis at f_m, and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

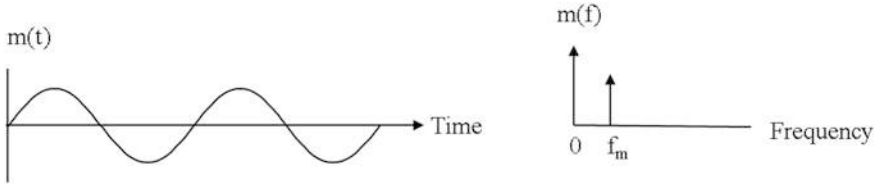

Fig. 2.3 A low-frequency sine wave and its frequency response

2.3.2 Spectral Response of the Carrier Frequency

A carrier frequency (f_c) is essentially a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component, which is much higher than the input modulating frequency ($f_c \gg f_m$). For example, the sine wave is described by the following time domain equation:

$$V(t) = V_p \sin(\omega_c t) \tag{2.5}$$

where

$$V_p = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$
- f_c = Carrier frequency in Hz

Figure 2.4 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis at f_c and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

2.3.3 AM Spectrum and Bandwidth

Let us consider the AM signal again, which was derived earlier:

$$S(t) = A_c \cos(2\pi f_c t) + A_c A_m \cos(2\pi f_m t) \cos(2\pi f_c t) \tag{2.6}$$

Using the following trigonometric identity:

$$\cos A \cos B = 1/2\cos(A+B) + 1/2\cos(A-B) \tag{2.7}$$

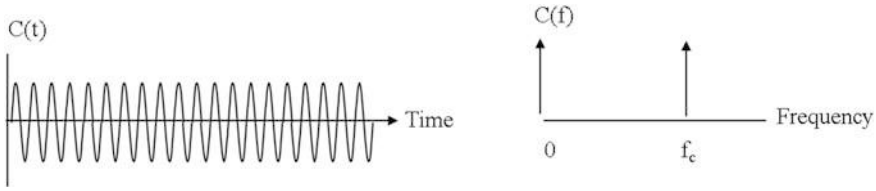

Fig. 2.4 A high-frequency sine wave and its frequency response

where

- $A = 2\pi\ (f_c + f_m)t$
- $B = 2\pi\ (f_c - f_m)t$

we get

$$S(t) = A_c \cos(2\pi f_c t) + (1/2)A_c A_m \cos[2\pi(f_c + f_m)t] + (1/2)A_c A_m \cos[2\pi(f_c - f_m)t] \tag{2.8}$$

This is the spectral response of the AM-modulated signal. It has three spectral components:

- The carrier: f_c
- Upper sideband: $f_c + f_m$
- Lower sideband: $f_c - f_m$

where f_c is the carrier frequency and f_m is the input modulating frequency. This is shown in Fig. 2.5. The AM bandwidth (BW) is given by

$$\text{BW} = 2f_m \tag{2.9}$$

Notice that the power is distributed among the sidebands and the carrier, where the carrier does not contain any information. Only the sidebands contain the information. Therefore, AM is inefficient in power usage.

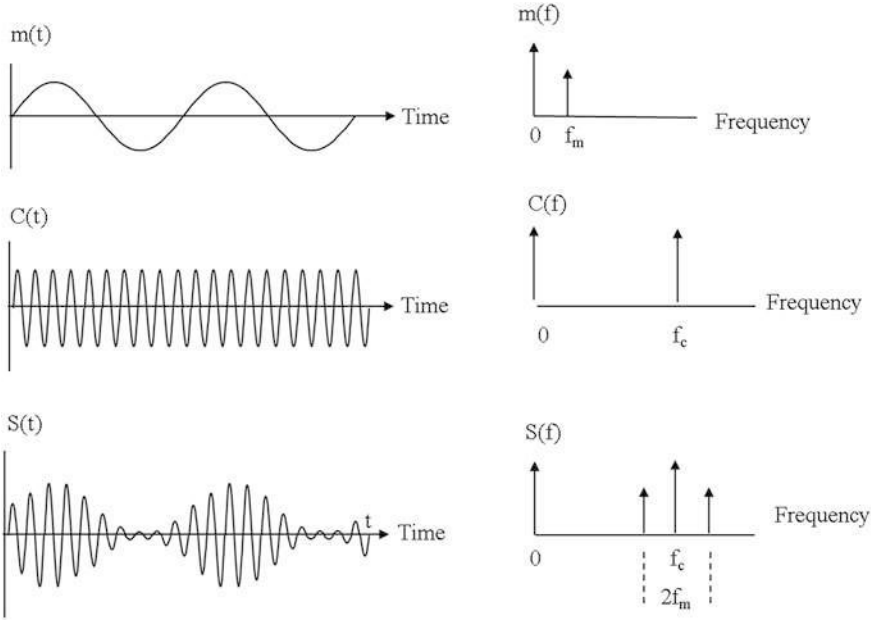

Fig. 2.5 AM spectrum. The bandwidth is given by $2\ f_m$

2.3.4 AM Response Due to Low and High Modulating Signals

If $m(t)$ has a peak positive value of less than +1 and a peak negative value of higher than −1, then the modulation is less than 100 %. This is shown in Fig. 2.7.

On the other hand, if $m(t)$ has a peak positive value of +1 and a peak negative value of −1, then the modulation is 100 % [3–5]. Therefore,

$$\bullet \quad \text{For } m(t) = -1: \quad S(t) = A_c[1-1]\cos(2\pi_c t) = 0 \tag{2.10}$$

$$\bullet \quad \text{For } m(t) = +1: S(t) = A_c[1+1]\cos(2\pi f_c t) = 2A_c\cos(2\pi f_c t) \tag{2.11}$$

This is called 100 % modulation, as shown in Fig. 2.6. The percent modulation is described by the following equation:

$$\begin{aligned} &\text{The overall modulation percentage is:} \\ &\%\,\text{Overall Modulation} = \frac{A_{\max} - A_{\min}}{A_c} \times 100 \\ &= \frac{\max[m(t)] - \min[m(t)]}{2A_c} \times 100. \end{aligned} \tag{2.12}$$

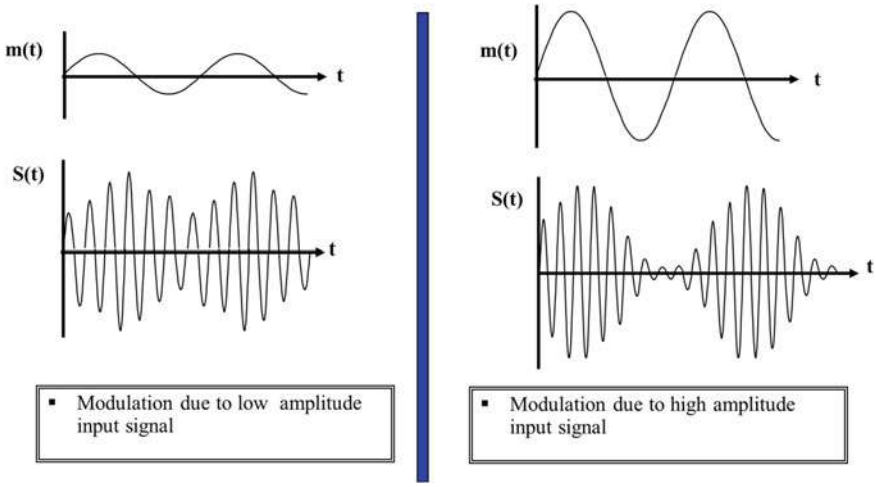

Fig. 2.6 Amplitude modulation due to low and high modulating signals

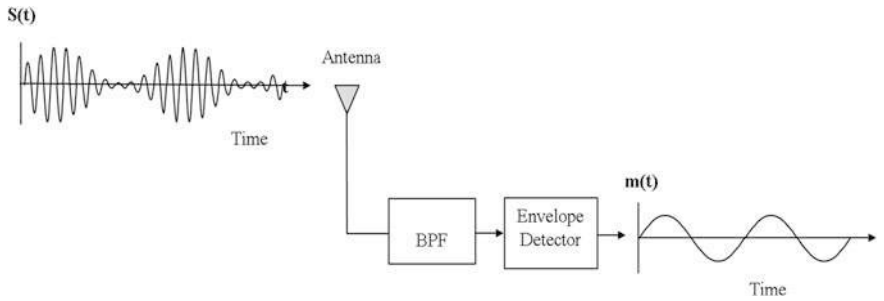

Fig. 2.7 AM demodulation technique. As the signal enters the receiver, it passes through the band-pass filter, which is tuned to the carrier frequency f_0. Next, the recovered signal is passed through an envelope detector to recover the original signal that was transmitted

2.3.5 AM Demodulation

Once the modulated analog signal has been transmitted, it needs to be received and demodulated. This is accomplished by the use of a band-pass filter that is tuned to the appropriate carrier frequency. Figure 2.7 shows the conceptual model of the AM receiver. As the signal enters the receiver, it passes through the band-pass filter, which is tuned to the carrier frequency f_0. Next, the recovered signal is passed through an envelope detector to recover the original signal that was transmitted.

2.3.6 Drawbacks in AM

- The modulated signal contains the carrier; carrier takes power and it does not have the information
- Therefore, AM is inefficient in power usage
- Moreover, there are two sidebands, containing the same information
- It is bandwidth inefficient
- AM is also susceptible to interference, since it affects the amplitude of the carrier.

Therefore, a solution is needed to improve bandwidth and power efficiency.

Problem 2.1 Given:

- Input modulating frequency f_m = 10 kHz
- Carrier frequency f_c = 400 kHz

Find

- Spectral components
- Bandwidth

Solution
Spectral Components:

- f_c = 400 kHz
- $f_c + f_m$ = 400 kHz + 10 kHz = 410 kHz
- $f_c - f_m$ = 400 kHz − 10 kHz = 390 kHz

Bandwidth

- BW = 2 f_m = 2 × 10 kHz = 20 kHz.

2.4 Double Sideband-Suppressed Carrier (DSBSC)

2.4.1 DSBSC Modulation

Double sideband-suppressed carrier (DSBSC), also known as product modulator, is an AM signal that has a suppressed carrier [3–5]. Let us take the original AM signal once again, as given below:

$$\begin{aligned} S(t) = A_c\cos(2\pi f_c t) + (1/2)A_cA_m\cos[2\pi(f_c + f_m)t] \\ + (1/2)A_cA_m\cos[2\pi(f_c - f_m)t] \end{aligned} \tag{2.13}$$

Notice that there are three spectral components:

- The first term is the carrier only, which does not have any information
- The second and third terms contain information.

In DSBSC, we suppress the carrier, which is the first term that does not have any information. Therefore, by suppressing the first term we obtain the following:

$$S(t) = (1/2)A_cA_m\cos[2\pi(f_c + f_m)t] + (1/2)A_cA_m\cos[2\pi(f_c - f_m)t] \tag{2.14}$$

Next, we use the following trigonometric identities:

- $\cos(A + B) = \cos A\ \cos B - \sin A\ \sin B$
- $\cos(A - B) = \cos A\ \cos B + \sin A\ \sin B$

With $A = 2\pi f_m t = \omega_m t$ and $B = 2\pi f_c t = \omega_c t$, we obtain:

$$S(t) = A_cA_m\cos(\omega_m t)\ \cos(\omega_c t) \tag{2.15}$$

Now, define

- $m(t) = A_m\ \cos\ (\omega_m t)$
- $C(t) = A_c\ \cos\ (\omega_c t)$

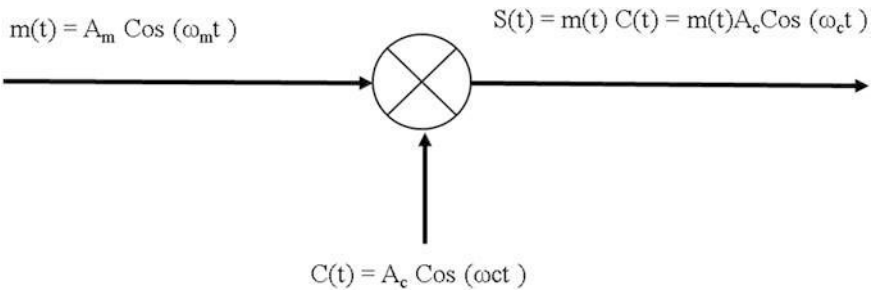

Fig. 2.8 Symbolic representation of DSBSC, also known as product modulator

Then, we can write the above equations as:

$$S(t) = m(t)\, C(t) \tag{2.16}$$

This is the DSBSC waveform. Since the output is the product of two signals, it is also known as product modulator. The symbolic representation is given in Fig. 2.8, where $m(t)$ is the input modulating signal and $C(t)$ is the carrier frequency.

2.4.2 *Generation of DSBSC Signal*

A DSBSC signal can be generated using two AM modulators arranged in a balanced configuration as shown in Fig. 2.9 [3–5]. The outcome is a cancellation of the discrete carrier. Also, the output is the product of two inputs: $S(t) = m(t)\ C(t)$. This is why it is called "product modulator."

Proof of DSBSC

Consider the DSBSC modulator as shown in Fig. 2.9. Here, the AM modulators generate $S_1(t)$ and $S_2(t)$, which are given by:

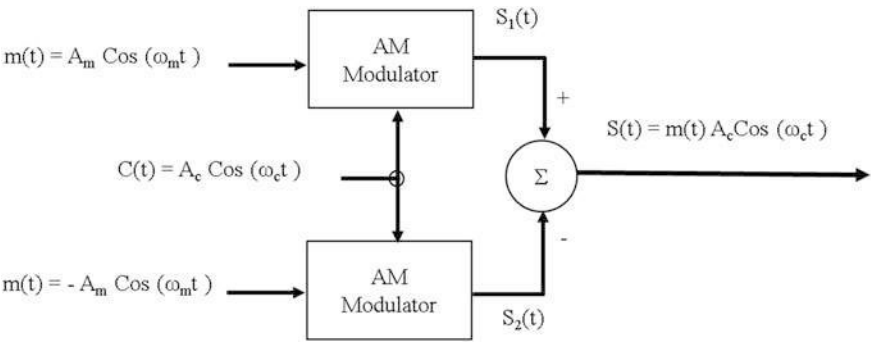

Fig. 2.9 Construction of DSBSC modulator. The output is the product of two signals

$$S_1(t) = A_c[1 + m(t)]\cos(\omega_c t) \tag{2.17}$$

$$S_2(t) = A_c[1 - m(t)]\cos(\omega_c t)$$

Subtracting $S_2(t)$ from $S_1(t)$, we essentially cancel the carrier to obtain:

$$\begin{aligned} S(t) &= S_1(t) - S_2(t) \\ &= 2\,m(t)\,A_c\,\cos(\omega_c t) \end{aligned} \tag{2.18}$$

Therefore, except for the scaling factor 2, the above equation is exactly the same as the desired DSBSC waveform shown earlier, which does not have the carrier. In other words, the carrier has been suppressed, hence the name double sideband-suppressed carrier (DSBSC).

2.4.3 DSBSC Spectrum and Bandwidth

We begin with the DSBSC-modulated signal:

$$S(t) = 2\,m(t)\,A_c\cos(\omega_c t) \tag{2.19}$$

where

$$m(t) = A_m\cos(\omega_m t)$$

Therefore,

$$S(t) = 2\,A_c A_m\cos(\omega_m t)\,\cos(\omega_c t) \tag{2.20}$$

This is the desired DSBSC waveform for spectral analysis.
Now, use the trigonometric identity:

- $\cos A\,\cos B = 1/2\,\cos(A + B) + 1/2\,\cos(A - B)$ (2.21)

where

$$A = \omega_m t = 2\pi f_m t \text{ and } B = \omega_c t = 2\pi f_c t$$

Therefore,

$$\begin{aligned} S(t) &= A_c[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t] \\ &= A_c[\cos\,2\pi(f_c + f_m)t + \cos\,2\pi(f_c - f_m)t] \end{aligned} \tag{2.22}$$

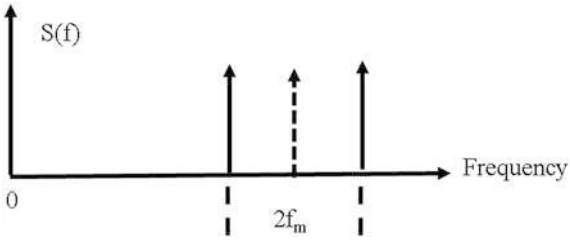

Fig. 2.10 DSBSC spectrum where the carrier frequency is suppressed. The bandwidth is given by $2\,f_m$

Notice that the carrier power is distributed among the sidebands (Fig. 2.10). Therefore, it is more efficient. The bandwidth is given by:

$$\mathrm{BW} = 2f_m \tag{2.23}$$

2.4.4 DSBSC Drawbacks

- There are two identical sidebands.
- Each sideband contains the same information
- Bandwidth is $2\,f_m$
- Unnecessary power usage

Therefore, a solution is needed to improve bandwidth efficiency.

Problem 2.2 Given:Two product modulators using identical carriers are connected in a series, as shown below:

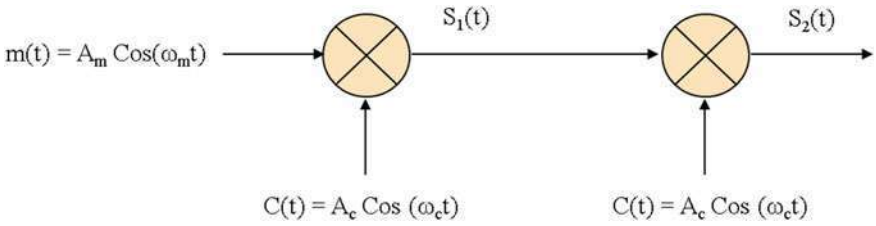

Find

(a) The output waveform $S_2(t)$
(b) What is the function of this circuit?

Solution

(a)
$$S_1(t) = m(t)\,C(t)$$
$$S_2(t) = S_1(t)\,C(t) = m(t)C^2(t) = A_m \cos(\omega_m t)\,Ac^2 \cos\,2(\omega_c t)$$

(b) The function of the circuit is to demodulate DSBSC signals, where the carrier frequency is filtered out.

2.5 Single Sideband (SSB) Modulation

2.5.1 Why SSB Modulation?

- The basic AM has a carrier which does not carry information—*Inefficient power usage*
- The basic AM has two sidebands contain the same information—*Additional loss of power*
- DSBSC has two sidebands, containing the same information—*Loss of power*
- Therefore, the basic AM and DSBSC are bandwidth and power inefficient
- SSB is bandwidth and power efficient.

2.5.2 Generation of SSB-Modulated Signal

Single sideband (SSB) modulation uses two product modulators as shown in Fig. 2.11 [3–5], where

$$\bullet \quad m(t) = A_m \cos(\omega_m t) \tag{2.24}$$

$$\bullet \quad m(t)^* = A_m \sin(\omega_m t) - (\text{Hilbert Transform}) \tag{2.25}$$

$$\bullet \quad C(t) = A_m \cos(\omega_c t) \tag{2.26}$$

$$\bullet \quad C(t)^* = A_c \sin(\omega_c t) - (\text{Hilbert Transform}) \tag{2.27}$$

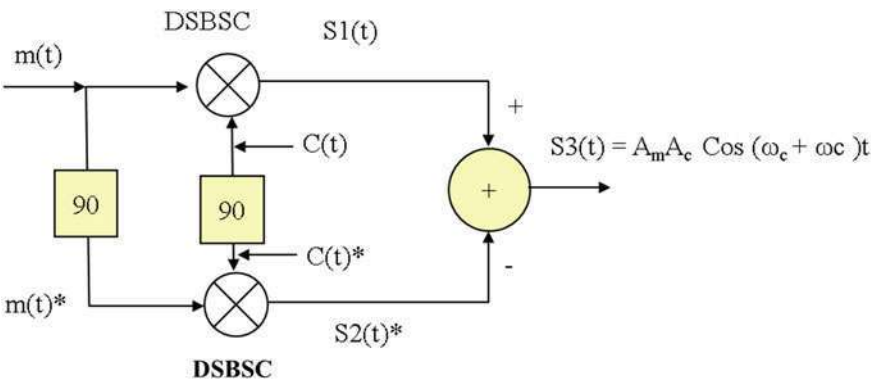

Fig. 2.11 Generation of SSB signal

Solving for S_1, S_2, and S_3, we obtain:

- $S_1(t) = A_c A_m \cos(\omega_m t)\cos(\omega_c t)$ (2.28)
- $S_2(t) = A_c A_m \sin(\omega_m t)\sin(\omega_c t)$ (2.29)

$$\begin{aligned} S_3(t) &= S_1(t) - S_2(t) \\ &= A_c A_m \cos(\omega_m t)\cos(\omega_c t) - A_c A_m \sin(\omega_m t)\sin(\omega_c t) \end{aligned} \tag{2.30}$$

Using the following formula:

- cos$A$ cos$B$ = 1/2cos(A + B) + 1/2cos(A − B)
- sin$A$ sin$B$ =1/2cos(A − B) − 1/2cos(A + B)

Solving for S_3, we get:

$$S_3 = A_c A_m \cos(\omega_c + \omega_m)t \tag{2.31}$$

In the above equation, $S_3(t)$ is the desired SSB signal, which is the upper sideband only.

2.5.3 SSB Spectrum and Bandwidth

Let us consider the SSB signal again:

$$\begin{aligned} S_3 &= A_c A_m \cos(\omega_c + \omega_m)t \\ &= A_c A_m \cos\, 2\pi(f_c + f_m)t \end{aligned} \tag{2.32}$$

Here, we see that the SSB spectrum contains only one sideband. Therefore, it is more efficient. The SSB bandwidth is given by:

$$\text{SSB BW} = f_m \tag{2.33}$$

Figure 2.12 displays the SSB spectrum.

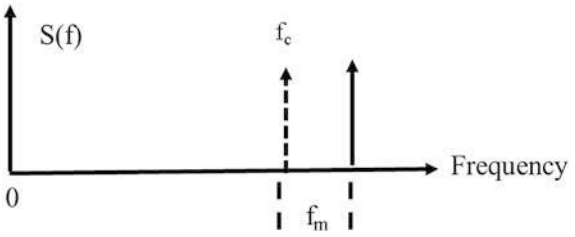

Fig. 2.12 SSB spectrum showing the upper sideband. The SSB bandwidth is f_m

Problem 2.3
Given:

- $m(t) = A_m \cos(\omega_m t)$
- $m(t)^* = A_m \sin(\omega_m t)$ − (Hilbert Transform)
- $C(t) = A_c \cos(\omega_c t)$
- $C(t)^* = A_c \sin(\omega_c t)$ − (Hilbert Transform)

Design an SSB modulator to realize the lower sideband. Sketch the spectral response.

Solution
Solving for S_1 and S_2, we obtain:

- $S_1(t) = A_c A_m \cos(\omega_m t) \cos(\omega_c t)$
- $S_2(t) = A_c A_m \sin(\omega_m t) \sin(\omega_c t)$

Obtain S_3 as:

$$\begin{aligned} S_3(t) &= S_1(t) + S_2(t) \\ &= A_c A_m \cos(\omega_m t)\cos(\omega_c t) + A_c A_m \sin(\omega_m t)\sin(\omega_c t) \end{aligned}$$

Using the following formula:

- $\cos A \cos B = 1/2\cos(A + B) + 1/2\cos(A - B)$
- $\sin A \sin B = 1/2\cos(A - B) - 1/2\cos(A + B)$

Solving for S_3, we get:

$$\begin{aligned} S_3 &= A_c A_m \cos(\omega_m - \omega_c)t \\ &= A_c A_m \cos 2\pi(f_c - f_m)t \end{aligned}$$

In the above equation, S_3(t) is the desired SSB signal, which is the lower sideband only. The spectral response, showing the lower sideband, is presented below.

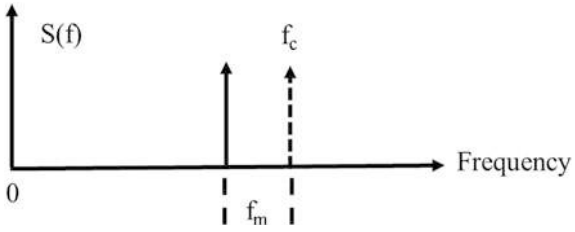

2.6 Conclusions

This chapter presents the key concepts and underlying principles of Amplitude Modulation. It was shown how the audio waveform changes the amplitude of the carrier to determine the envelope of the modulated carrier. It was also shown that the modulated carrier contains several spectral components that lead to DSBSC and SSB modulation techniques. In particular, the following topics were presented in this chapter:

- Amplitude Modulation (AM)
- AM spectrum and bandwidth
- Double sideband-suppressed carrier (DSBSC)
- DSBSC spectrum and bandwidth
- Single sideband (SSB)
- SSB spectrum and bandwidth

These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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Chapter 3
Frequency Modulation (FM)

Topics

- Introduction
- Frequency Modulation (FM)
- FM Spectrum
- Carson's Rule & FM Bandwidth
- Bessel Function & FM Bandwidth
- FM bandwidth Dilemma

3.1 Introduction

In Frequency Modulation (FM), the frequency of the carrier changes in accordance with the input analog signal, while the amplitude of the carrier remains the same [1–5]. This is shown in Fig. 3.1, where

- $m(t)$ is the input modulating audio signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the FM-modulated carrier frequency.

As shown in the figure, the audio waveform changes the frequency of the carrier. This enables the receiver to extract the audio signal by demodulation. Notice that the frequency of the carrier changes in accordance with the input signal, while the amplitude of the carrier does not change after modulation. However, it can be shown that the modulated carrier $S(t)$ contains an infinite number of spectral components, requiring frequency domain analysis [3]. In an effort to examine this, this chapter will present the following topics:

- The basic Frequency Modulation (FM),
- FM spectrum, and
- FM bandwidth.

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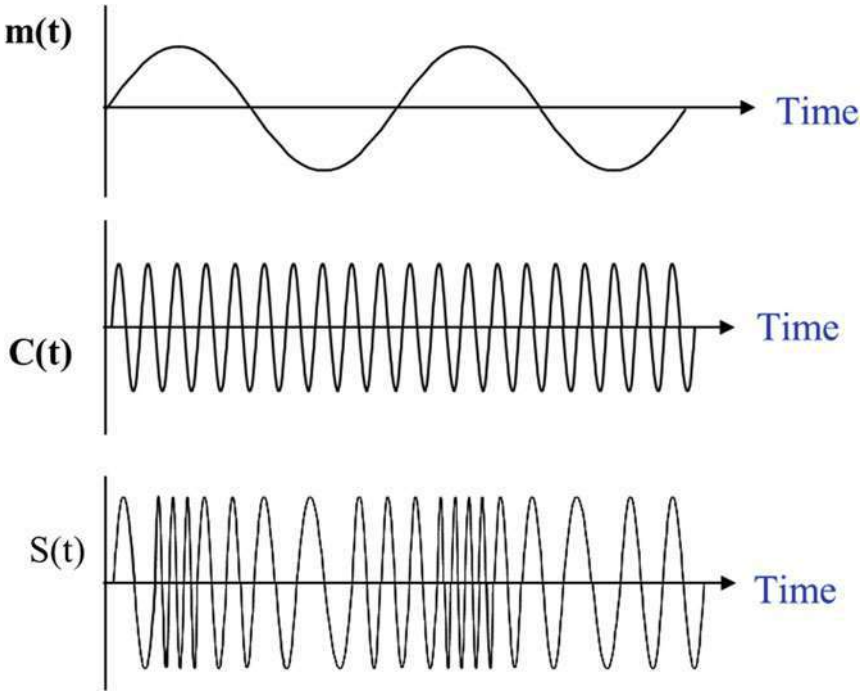

Fig. 3.1 Illustration of FM

3.2 Frequency Modulation (FM)

3.2.1 Background

FM is a form of angle modulation, where the frequency of the carrier varies in accordance with the input signal. Here, the angle refers to the angular frequency (ω). The angular frequency ω is also recognized as angular speed or circular frequency. It is a measure of rotation rate or the rate of change of the phase of a sinusoidal waveform as illustrated in Fig. 3.2.

Magnitude of the angular frequency ω is defined by one revolution or 2π radians:

$$\omega = 2\pi f = \mathrm{d}\theta/\mathrm{d}t \quad \text{Radians per second} \tag{3.1}$$

where,

- ω = Angular frequency in radians per seconds,
- f = Frequency in Hertz (Hz) or cycles per second, and
- θ = Phase angle.

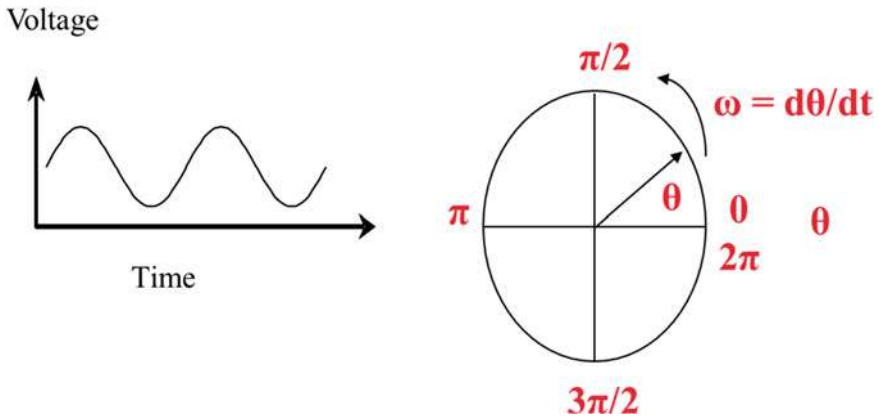

Fig. 3.2 A sinusoidal waveform in the time domain and its representation in the phase domain

Notice that in Eq. 3.1, the angular frequency ω is greater than the frequency f by a factor of 2π. Now solving for the phase angle, we obtain,

$$\theta_i(t) = 2\pi \int_0^t f_i dt \tag{3.2}$$

- θ_i = Instantaneous phase angle and
- f_i = Instantaneous frequency.

This forms the basis of our derivation of FM as presented in the following section.

3.2.2 The Basic FM

Frequency Modulation (FM) is a method of analog modulation that utilizes frequency variation of the relative frequency of the career [1]. The signal to be modulated and transmitted is analog. This is referred to as FM, where the frequency of the carrier changes in accordance with the input signal. The modulated carrier frequency f_c varies back and forth and depends on amplitude A_m and frequency f_m of the input signal.

Figure 3.3 shows the functional diagram of a typical FM, using a single-tone modulating signal. Here, $m(t)$ is the input analog signal we want to transmit, $C(t)$ is the carrier frequency without modulation, and $S(t)$ is the output FM-modulated carrier frequency. These parameters are described below.

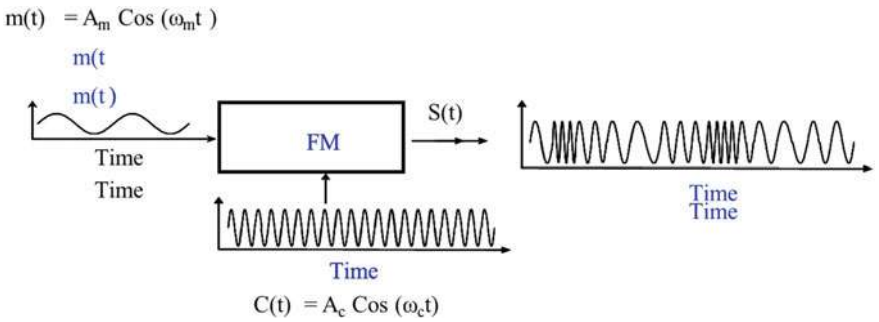

Fig. 3.3 A functional diagram of a typical FM modulator using a single-tone input modulating signal. Here, $m(t)$ is the input analog signal we want to transmit, $C(t)$ is the carrier frequency without modulation, and $S(t)$ is the output FM-modulated carrier frequency

We examine this by means of a single-tone input modulating signal and its angular frequency as shown in Fig. 3.2. Since the frequency of the carrier varies in accordance with the input signal, the instantaneous frequency of the carrier is given by

$$f_i(t) = f_c(t) + D_f m(t) \tag{3.3}$$

where,

- f_i = Instantaneous frequency,
- f_c = Carrier frequency,
- D_f = Constant, and
- $m(t) = A_m \cos(wmt)$.

The FM-modulated signal is given by

$$S(t) = A_c \cos(\theta_i) \tag{3.4}$$

where Ac is the amplitude of the carrier frequency and θ_i is the instantaneous angle. Substituting Eq. (3.2) into Eq. (3.4) for θi, we get

$$S(t) = A_c \cos[2\pi \int_0^t f_i dt] \tag{3.5}$$

where f_i is the instantaneous frequency. Substituting Eq. (3.3) into Eq. (3.5) for fi, we obtain

$$S(t) = A_c \cos[2\pi \int_0^t \{fc(t) + Df\, m(t)\} dt] \tag{3.6}$$

where $m(t) = A_m \cos(\omega_m t)$ is the input modulating signal. Integrating the above equation, we obtain the desired FM signal as follows:

$$\begin{aligned} S(t) &= A_c \cos\left[2\pi f_c t + \left(\frac{\Delta f}{f_m}\right)\sin(2\pi f_m t)\right] \\ &= A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)] \\ \beta &= \left(\frac{\Delta f}{f_m}\right) = \text{Modulation Index} \quad \Delta f = DfAm = \text{Freq. Deviation} \end{aligned} \tag{3.7}$$

where,

- $S(t)$ = FM-modulated carrier signal,
- f_c = Frequency of the carrier,
- A_c = Amplitude of the carrier frequency,
- $\Delta f = D_f A_m$ = Frequency deviation,
- f_m = Input modulating frequency,
- Am = Amplitude of the input modulating signal,
- D_f = A constant parameter, and
- $\beta = \Delta f / f_m$ = Modulation index.

Note that the modulation index β is an important design parameter in FM. It is directly related to FM bandwidth. It may also be noted that FM bandwidth depends on both frequency and amplitude of the input modulating signal. Let us take a closer look.

3.3 FM Spectrum and Bandwidth

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth and modulation. The transmission bandwidth depends on the following:

- Spectral response of the input modulating signal,
- Spectral response of the carrier frequency, and
- Modulation type.

Let's take a closer look!

3.3.1 Spectral Response of the Input Modulating Signal

In FM, the input modulating signal is a continuous time low-frequency analog signal. For simplicity, we use a sinusoidal waveform, which is periodic and

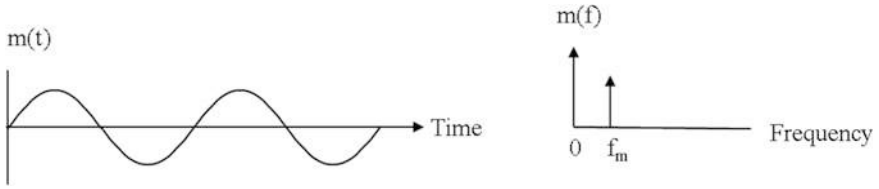

Fig. 3.4 A low-frequency sine wave and its frequency response

continuous with respect to time. It has one frequency component. For example, the sine wave is described by the following time domain equation:

$$V(t) = V_p \sin(\omega_m t) \tag{3.8}$$

where,

- Vp = Peak voltage,
- $\omega_m = 2\pi f_m$, and
- f_m = Input modulating frequency in Hz.

Figure 3.4 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis at f_m and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

3.3.2 *Spectral Response of the Carrier Frequency*

A carrier frequency (f_c) is essentially a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component, which is much higher than the input modulating frequency ($f_c \gg f_m$). For example, the sine wave is described by the following time domain equation:

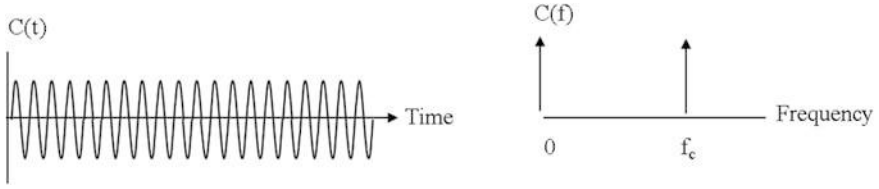

Fig. 3.5 A high-frequency sine wave and its frequency response before modulation

$$V(t) = V_p \sin(\omega_c t) \tag{3.9}$$

where

$$V_p = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$ *and*
- f_c = Carrier frequency in Hz.

Figure 3.5 shows the characteristics of a high-frequency sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis at f_c and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

3.3.3 FM Spectrum

In FM, the frequency of the carrier changes in accordance with the input signal. Here, we have:

$$\begin{aligned} &\bullet \text{ Input Signal :} && m(t) = A_m \cos(\omega_m t) \\ &\bullet \text{ Carrier Frequency :} && C(t) = A_c \cos(\omega_c t) \\ &\bullet \text{ Modulated Carrier :} && S(t) = A_c \cos[(\omega_c t) + \beta \sin(\omega_m t)] \end{aligned} \tag{3.10}$$

where

- $S(t)$ = The modulated carrier,
- Ac = Frequency of the carrier,
- ω_c = Nominal frequency of the carrier frequency,
- $\beta = \Delta f/fm$ = Modulation index,
- $\Delta f = D_f A_m$ = Frequency deviation,
- D_f = Constant, and
- A_m = Amplitude of the input modulating signal.

By inspecting the modulated carrier frequency, we observe that $S(t)$ depends on both frequency and amplitude of the input signal. The spectral response is given in Fig. 3.6. Notice that the carrier frequency after modulation varies back and forth from the nominal frequency f_c as depicted in the figure. In Fig. 3.6, we see that:

- As time passes, the carrier moves back and forth in frequency in exact step with the input signal.
- Frequency deviation is proportional to the input signal voltage.
- A group of many sidebands is created, spaced from carrier by amounts $N \times f_i$.
- Relative strength of each sideband depends on Bessel function.
- Strength of individual sidebands far away from the carrier is proportional to (freq. deviation $\times$ input frequency).
- Higher order spectral components are negligible.

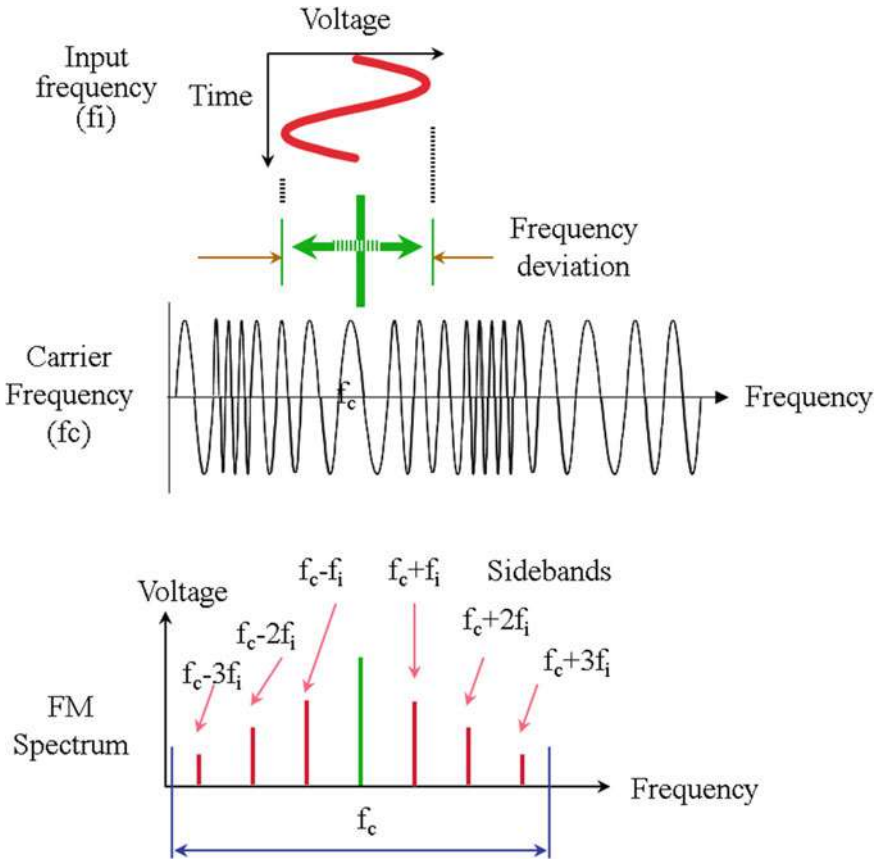

Fig. 3.6 FM spectrum. As time passes, the carrier moves back and forth in frequency in exact step with the input signal and generates an infinite number of sidebands

- Carson's rule can be used to determine the approximate bandwidth: bandwidth required = 2 × (highest input frequency + frequency deviation).

3.3.4 Carson's Rule and FM Bandwidth

The Carson's rule, a rule of thumb, states that more than 98 % of the power of FM signal lies within a bandwidth given by the following approximation:

$$\text{FM Bandwidth (BW)} = 2f_m(1+\beta) \tag{3.11}$$

where

Table 3.1 Bessel function table

β	J0	J1	J2	J3	J4	J5
0	1					
0.25	0.98	0.12				
0.5	0.94	0.24	0.03			
1	0.77	0.44	0.11	0.02		
1.5	0.51	0.56	0.23	0.06	0.01	
2	0.22	0.58	0.35	0.13	0.03	

- $\beta = \Delta f/fm$ = Modulation index,
- Δf = Peak deviation of the instantaneous frequency from the center of the carrier frequency, and
- fm = Highest frequency of the modulating signal.

3.3.5 Bessel Function and FM Bandwidth

FM bandwidth can be estimated by means of Bessel function of the first kind. For a single-tone modulation, it can be obtained as a function of the sideband number and the modulation index.

For a given β, the solution for $S(t)$ is given as follows:

$$\begin{aligned} S(t) &= A_c \cos[(\omega_c t) + \beta \sin(\omega_m t)] \\ &= J_0(\beta)\cos(\omega_c t) \\ &\quad + J_1(\beta)\cos(\omega_c t + \omega_m t) + J_2(\beta)\cos(\omega_c t + 2\omega_m t) + J_3(\beta)\cos(\omega_c t + 3\omega_m t) + \ldots \\ &\quad - J_1(\beta)\cos(\omega_c t - \omega_m t) - J_2(\beta)\cos(\omega_c t - 2\omega_m t) - J_3(\beta)\cos(\omega_c t - 3\omega_m t) + \ldots \end{aligned} \tag{3.12}$$

Here, J's are the Bessel functions, representing the amplitude of the sidebands. $J_0(\beta)$ is the amplitude of the fundamental spectral component, and the remaining spectral components are the sidebands. Each sideband is separated by the input modulating frequency. These values are also available as a standard Bessel function table.

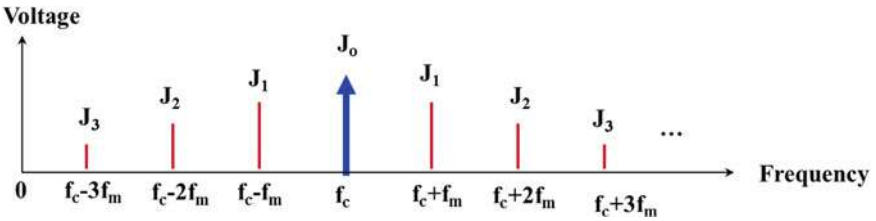

Fig. 3.7 FM sidebands. Power is taken from the carrier *J*0 and distributed among the sidebands *J*1, *J*2, *J*3,…, etc. Each sideband is separated by the modulating frequency f_m

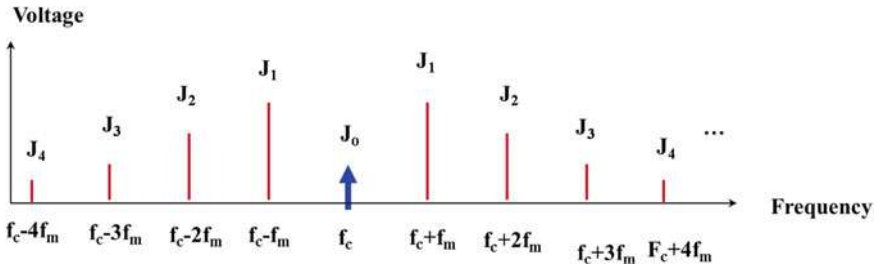

Fig. 3.8 FM sidebands for large β. More power is taken from the carrier $J0$ and distributed among the sidebands $J1$, $J2$, $J3$, $J4$,… Each sideband is separated by the modulating frequency f_m

As an example, Table 3.1 provides a few Bessel parameters to illustrate the concept. In this table, the carrier and sideband amplitude powers, $J0$, $J1$, $J2$,…, etc., are presented for different values of β. Here, $J0$ is carrier power before modulation. After modulation, with a given value of β, power is taken from the carrier and distributed among the sidebands. Also, there is a unique value of β, for which the carrier amplitude becomes zero and all the signal power is in the sidebands.

Note that, in FM, the sidebands are on both sides of the carrier. Therefore, the total bandwidth includes spectral components from both sides of the carrier. For a given low β, this is shown in Fig. 3.7. Here, J0 is the spectral component of the carrier. $J1$, $J2$, $J3$, etc., are the sidebands. Each sideband is separated by the input modulating frequency f_m. After modulation, power is taken from the carrier J0 and distributed among the sidebands, depending on the modulation index β.

Figure 3.8 shows another scenario where β is large. In this case, more power is taken from the carrier and distributed among the sideband, while creating more significant sidebands, requiring more bandwidth.

3.3.6 FM Bandwidth Dilemma

In FM, we notice that if the modulation index is low, the occupied bandwidth is low and the sidebands take less power from the carrier, making the modulation less efficient. On the other hand, if the modulation index is high, the occupied bandwidth is also high, while the sidebands retain most of the power, making the modulation more efficient at the expense of bandwidth. This is a dilemma in FM. However, FM is more popular because it is less sensitive to noise.

Problem 3.1
Given:

$$f_m = 1\,\text{kHz}$$
$$f_c = 1\,\text{MHz}$$
$$\beta = 1$$

Find:

(a) The FM bandwidth using Carson's rule and
(b) The FM bandwidth using Bessel function

Solution:

(a) FM BW (Carson's rule) = 2 f_m (1 + β) = 2 × 1 kHz (1 + 1) = 4 kHz.
(b) For β = 1, See Table 3.1:

- $J0$ = 0.77, $J1$ = 0.44, $J2$ = 0.11, $J3$ = 0.02

where $J0$ is the carrier and $J1$, $J2$, and $J3$ are the sidebands. Here, we can neglect $J3$ since it has a negligible power. Therefore, there are two significant upper and lower sidebands, and each sideband is 1 kHz apart. Therefore, FM bandwidth is 2 × Number of significant sidebands = 2 × 2 = 4 kHz. See figure below.

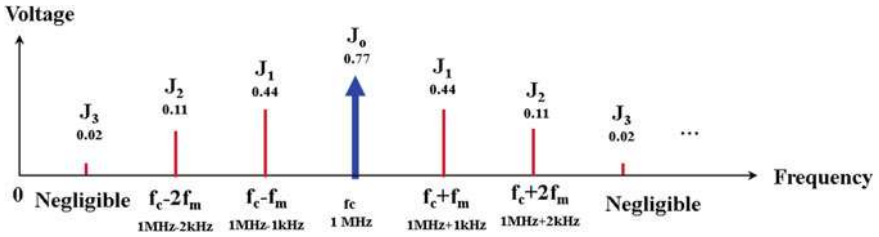

Problem 3.2
Given:

$$fm = 1\,\text{kHz}$$
$$fc = 1\,\text{MHz}$$
$$\beta = 2$$

Find:

(a) The FM bandwidth using Carson's rule and
(b) The FM bandwidth using Bessel function

Solution:

(a) FM BW (Carson's rule) = 2 f_m (1 + β) = 2 × 1 kHz (1 + 2) = 6 kHz.
(b) For β = 2, See Table 3.1:

- $J0$ = 0.22, $J1$ = 0.58, $J2$ = 0.35, $J3$ = 0.13, $J4$ = 0.03

Here, we have 4 upper and 4 lower sidebands, and each sideband is separated by 1 kHz. Since the J4 is negligible, we take 3 upper sidebands and 3 lower sidebands. Therefore, the FM bandwidth is 2 × 3 = 6 kHz. See figure below.

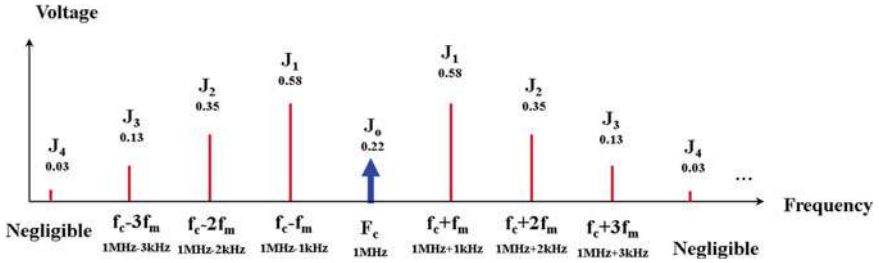

3.4 Conclusions

- This chapter presents a brief overview of Frequency Modulation (FM) and its attributes.
- The key concept and the underlying principle of FM are presented with numerous illustrations to make them easier for readers to grasp.
- FM spectrum is addressed with illustrations.
- FM bandwidth is estimated by means of Carson's rule and Bessel function.
- FM bandwidth dilemma is explained, and problems are given to illustrate the concept.

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Chapter 4
Amplitude Shift Keying (ASK)

Topics

- Introduction
- Amplitude Shift Keying (ASK)
- ASK spectrum
- ASK Bandwidth
- Performance Analysis

4.1 Introduction

In amplitude shift keying (ASK), the amplitude of the carrier changes in discrete levels in accordance with the input digital signal, while the frequency of the carrier remains the same. This is shown in Fig. 4.1, where

- $m(t)$ is the input modulating digital signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the ASK-modulated carrier frequency.

As shown in the figure, the digital binary signal changes the amplitude of the carrier in two discrete levels. This enables the receiver to extract the digital signal by demodulation. Notice that the amplitude of the carrier changes in accordance with the input signal, while the frequency of the carrier does not change after modulation. However, it can be shown that the modulated carrier $S(t)$ contains several spectral components, requiring frequency domain analysis.

In the following sections, the above disciplines in ASK modulation will be presented along with the respective spectrum and bandwidth. These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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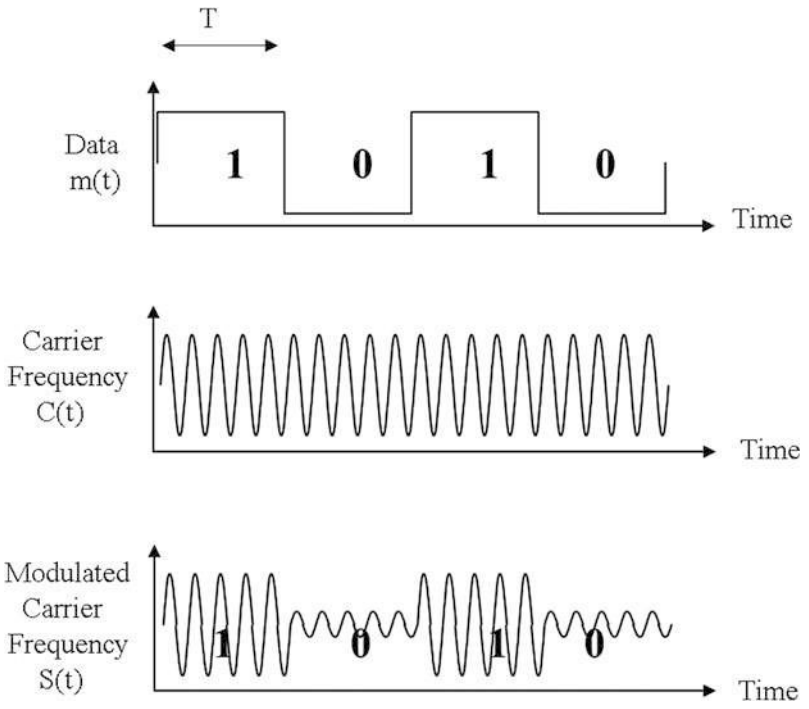

Fig. 4.1 ASK waveforms. The amplitude of the carrier changes in accordance with the input digital signal. The frequency of the carrier remains the same

4.2 ASK Modulation

Amplitude shift keying (ASK), also known as on–off keying (OOK), is a method of digital modulation that utilizes amplitude shifting of the relative amplitude of the career frequency [1–3]. The signal to be modulated and transmitted is binary, which is encoded before modulation. This is an indispensable task in digital communications, where redundant bits are added with the raw data that enables the receiver to detect and correct bit errors, if they occur during transmission [4–16].

While there are many error-coding schemes available, we will use a simple coding technique, known as "Block Coding" to illustrate the concept.

Figure 4.2 shows an encoded ASK modulation scheme using (15, 8) block code where an 8-bit data block is formed as M-rows and N-columns ($M = 4$, $N = 2$). The product $MN = k = 8$ is the dimension of the information bits before coding. Next, a horizontal parity P_H is appended to each row and a vertical parity P_V is appended to each column. The resulting augmented dimension is given by the product $(M + 1)(N + 1) = n = 15$, which is then ASK modulated and transmitted row by row. The rate of this coding scheme is given by

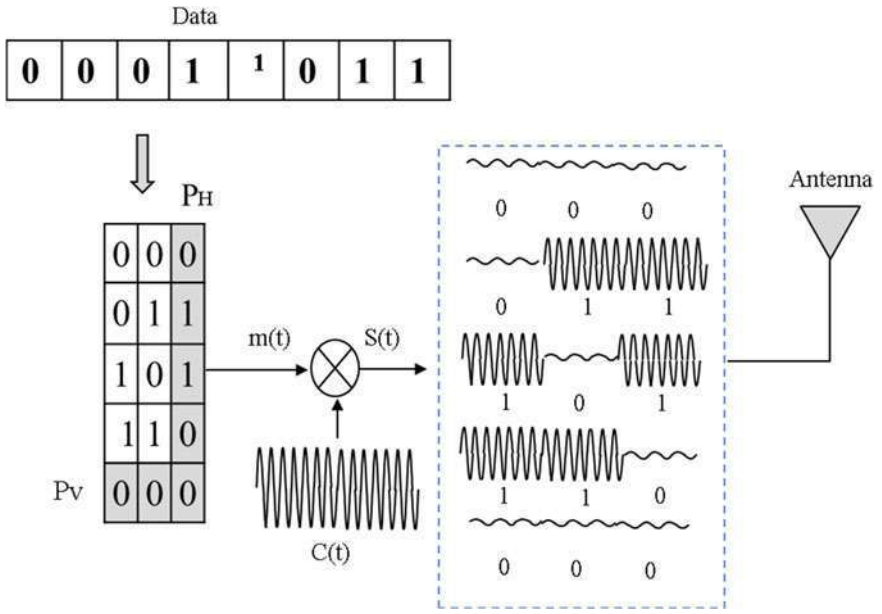

Fig. 4.2 Amplitude shift keying (ASK) is also known as on–off keying (OOK). The input encoded data block is transmitted row by row. The amplitude of the carrier frequency changes in accordance with the input digital signal

$$\text{Code Rate: } r = (MN)/[(M+1)(N+1)] = (4 \times 2)/(5 \times 3) = 8/15 \tag{4.1}$$

The coded bit rate R_{b2} is given by

$$R_{b2} = \text{Uncoded Bit Rate}/\text{Code Rate} = R_{b1}/r = R_{b1}\,(15/8) \tag{4.2}$$

Next, the coded bits are modulated by means of the ASK modulator as shown in the figure. Here,

- The Input digital signal is the encoded bit sequence we want to transmit
- Carrier is the radio frequency without modulation
- Output is the ASK-modulated carrier, which has two amplitudes corresponding to the binary input signal. For binary signal 1, the carrier is ON. For the binary signal 0, the carrier is OFF; however, a small residual signal may remain due to noise, interference, etc., as indicated in the figure.

As shown in the figure, the amplitude of the carrier changes in discrete levels, in accordance with the input signal, where

- Input Data : $m(t) = 0$ or 1 (coded data)
- Carrier Frequency : $C(t) = A\cos(\omega t)$ (4.3)
- Modulated Carrier : $S(t) = m(t)C(t) = m(t)A\cos(\omega t)$

Therefore,

$$\begin{aligned} &\text{For } m(t) = 1 : S(t) = A\cos(\omega t) \text{ i.e. the carrier is ON} \\ &\text{For } m(t) = 1 : S(t) = 0, \text{ i.e. the carrier is OFF} \end{aligned} \tag{4.4}$$

where A is the amplitude and ω is the frequency of the carrier.

4.3 ASK Demodulation

Once the modulated binary data has been transmitted, it needs to be received and demodulated. This is often accomplished with the use of a band-pass filter. In the case of ASK, the receiver needs to utilize one band-pass filter that is tuned to the appropriate carrier frequency. As the signal enters the receiver, it passes through the filter and a decision as to the value of each bit is made to recover the encoded data block, along with horizontal and vertical parities. Next, the receiver appends horizontal and vertical parities P_H* and P_V* to check parity failures and recovers the data block. This is shown in Fig. 4.3 having no errors. If there is an error, there will be a parity failure in P_H* and P_V* to pinpoint the error.

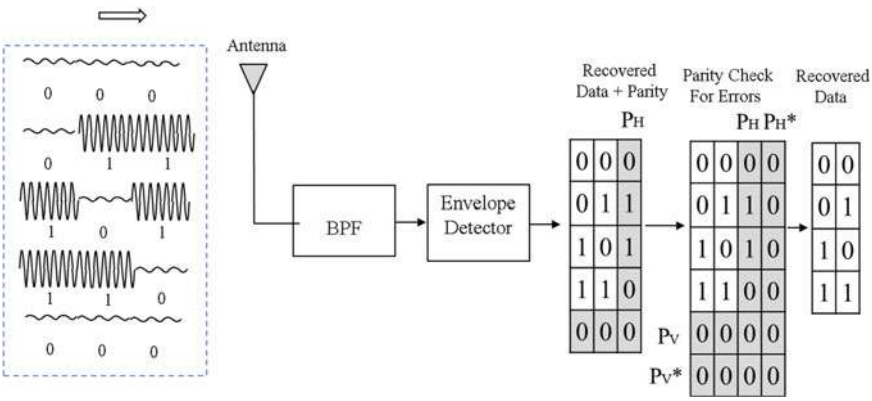

Fig. 4.3 Data recovery process in ASK, showing no errors. If there is an error, there will be a parity failure in P_H* and P_V* to pinpoint the error

4.4 ASK Bandwidth

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth in error control coding and modulation. The transmission bandwidth depends on:

- Spectral response of the encoded data
- Spectral response of the carrier frequency, and
- Modulation type.

4.4.1 Spectral Response of the Encoded Data

In digital communications, data is generally referred to as a non-periodic digital signal. It has two values:

- Binary-1 = High, Period = T
- Binary-0 = Low, Period = T

Also, data can be represented in two ways:

- Time domain representation and
- Frequency domain representation

The time domain representation (Fig. 4.4a), known as non-return-to-zero (NRZ), is given by:

$$\begin{aligned} V(t) &= V \qquad < 0 < t < T \\ &= 0 \qquad \text{elsewhere} \end{aligned} \tag{4.5}$$

The frequency domain representation is given by "Fourier transform":

$$V(\omega) = \int_0^T V \cdot e^{-j\omega t} dt \tag{4.6}$$

$$\begin{aligned} |V(\omega)| &= VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right] \\ P(\omega) &= \left(\frac{1}{T}\right)|V(\omega)|^2 = V^2 T\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]^2 \end{aligned} \tag{4.7}$$

Here, $P(\omega)$ is the power spectral density. This is plotted in Fig. 4.4b. The main lobe corresponds to the fundamental frequency and side lobes correspond to harmonic components. The bandwidth of the power spectrum is proportional to the frequency. In practice, the side lobes are filtered out since they are relatively insignificant with respect to the main lobe. Therefore, the one-sided bandwidth is

given by the ratio $f/f_b = 1$. In other words, the one-sided bandwidth $= f = f_b$, where $f_b = R_b = 1/T$, T being the bit duration.

The general equation for two-sided response is given by:

$$V(\omega) = \int_{-\infty}^{\infty} V(t) \cdot e^{-j\omega t} dt$$

In this case, $V(\omega)$ is called two-sided spectrum of $V(t)$. This is due to both positive and negative frequencies used in the integral. The function can be a voltage or a current. Figure 4.4c shows the two-sided response, where the bandwidth is determined by the main lobe as shown below:

$$\text{Two-sided bandwidth (BW)} = 2R_b \ (R_b = \text{Bit rate before coding}) \tag{4.8}$$

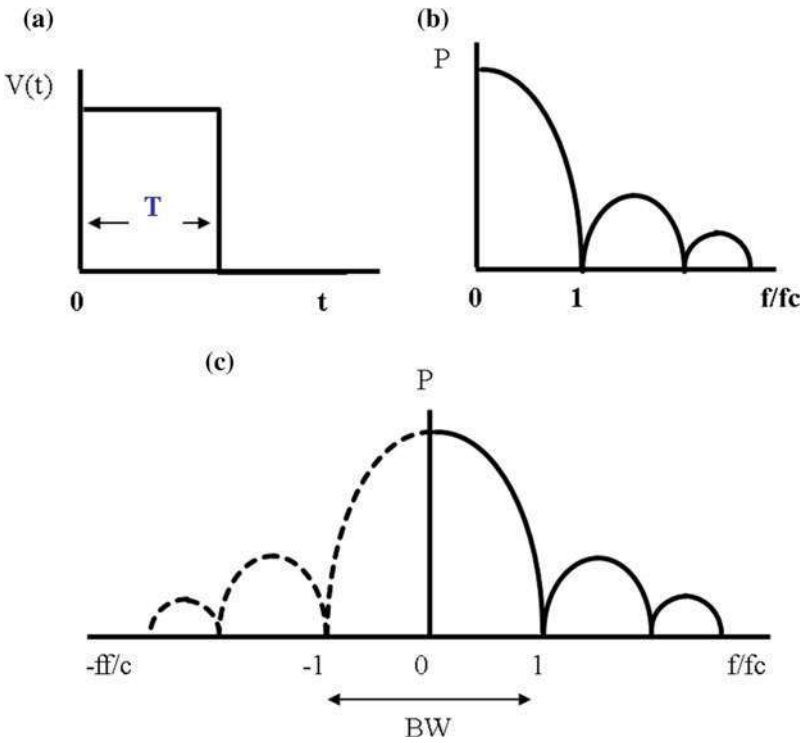

Fig. 4.4 **a** Discrete time digital signal **b** it is one-sided power spectral density and **c** two-sided power spectral density. The bandwidth associated with the non-return-to-zero (NRZ) data is $2R_b$, where R_b is the bit rate

Important Notes

1. If R_b is the bit rate before coding, and if the data is NRZ, then the bandwidth associated with the raw data will be $2R_b$. For example, if the bit rate before coding is 10 kb/s, then the bandwidth associated with the raw data will be 2×10 kb/s = 20 kHz.
2. If R_b is the bit rate before coding, code rate is r, and if the data is NRZ, then the bit rate after coding will be R_b (coded) = R_b (uncoded)r. The corresponding bandwidth associated with the coded data will be $2R_b$ (coded) = $2R_b$ (uncoded)/r. For example, if the bit rate before coding is 10 kb/s and the code rate r = 1/2, then the coded bit rate will be R_b (coded) = R_b (uncoded)/r = 10/0.5 = 20 kb/s. The corresponding bandwidth associated with the coded data will be 2×20 = 40 kHz.

4.4.2 Spectral Response of the Carrier Frequency Before Modulation

A carrier frequency is essentially a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component. For example, the sine wave is described by the following time domain equation:

$$V(t) = V_p \sin(\omega t_c) \tag{4.9}$$

where

$$V_P = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$
- f_c = Carrier frequency in Hz

Figure 4.5 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

4.4.3 ASK Bandwidth at a Glance

In ASK, the amplitude of the carriers changes in discrete levels, in accordance with the input signal, where

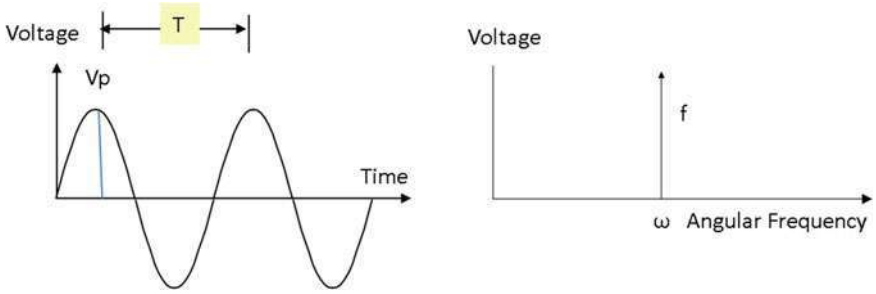

Fig. 4.5 High-frequency carrier frequency response

- Input Data : $m(t) = 0$ or 1
- Carrier Frequency : $C(t) = Ac\cos(\omega_c t)$
- Modulated Carrier : $S(t) = m(t)C(t) = m(t)A_c\cos(\omega_c t)$

Since $m(t)$ is the input digital signal and it contains an infinite number of harmonically related sinusoidal waveforms and that we keep the fundamental and filter out the higher-order components, we write:

$$m(t) = A_m \sin(\omega_m t)$$

The ASK-modulated signal then becomes:

$$\begin{aligned} S(t) = m(t)S(t) &= A_m A_c \sin(\omega_m t)\cos(\omega_m t) \\ &= 1/2\, A_m A_c \left[\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t\right] \end{aligned} \tag{4.10}$$

The spectral response is depicted in Fig. 3.14. Notice that the spectral response after ASK modulation is the shifted version of the NRZ data. Bandwidth is given by:

BW = $2R_b$ (coded), where R_b is the coded bit rate (Fig. 4.6).

Problem 1

Given:

- Bit rate before coding: R_{B1} = 10 kb/s
- Code rate: r = 8/15
- Modulation: ASK

Find:

(a) the bit rate after coding: R_{B2}
(b) Transmission bandwidth: BW

Solution

(a) Bit rate after coding (R_{B2})
$R_{B2} = R_{B1}/r$ = 10 kb/s (15/8) = 18.75 kb/s

(b) Transmission BW = 2 × 18.75 kb/s = 37.5 kHz.

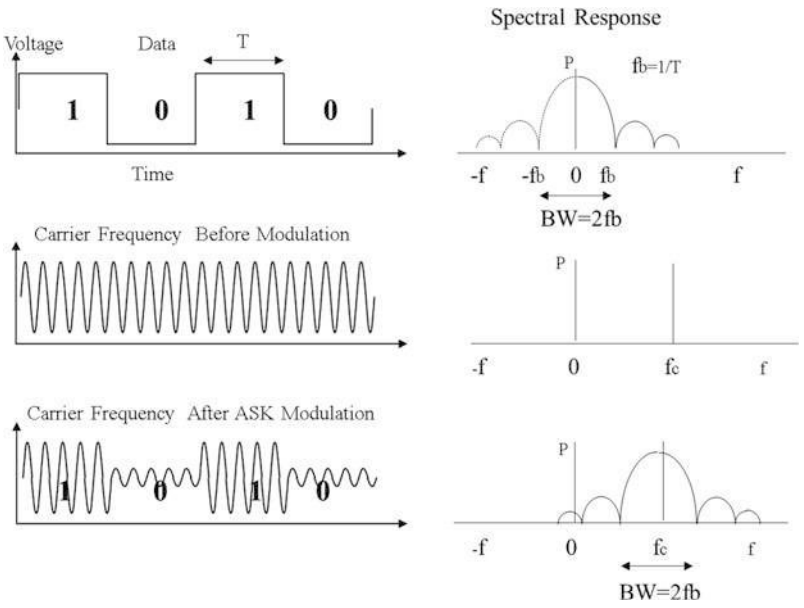

Fig. 4.6 ASK bandwidth at a glance. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation. The transmission bandwidth is $2f_b$, where f_b is the bit rate and $T = 1/f_b$ is the bit duration for NRZ data

4.5 BER Performance

It is well known that an (n, k) bock code, where k = number of information bits, n = number of coded bits, can correct t errors [4, 5]. A measure of coding gain is then obtained by comparing the uncoded word error WER_U with the coded word WER_C. We examine this by means of the following analytical means.

Let the uncoded word error be defined as (WER_U). Then, with ASK modulation, the uncoded BER will be given by:

$$\mathrm{BER}_U = 0.5\,\mathrm{EXP}(-E_B/2N_0) \tag{4.11}$$

The probability that the uncoded word (WER_U) will be received in error is 1 minus the product of the probabilities that each bit will be received correctly. Thus, we write:

$$\mathrm{WER}_U = 1 - (1 - \mathrm{BER}_U)^k \tag{4.12}$$

Let the coded word error be defined as (WER_C). Since $n > k$, the coded bit energy to noise ratio will be modified to E_c/N_0, where $E_c/N_0 = E_b/N_0 + 10\log(k/n)$. Therefore, the coded BERc will be:

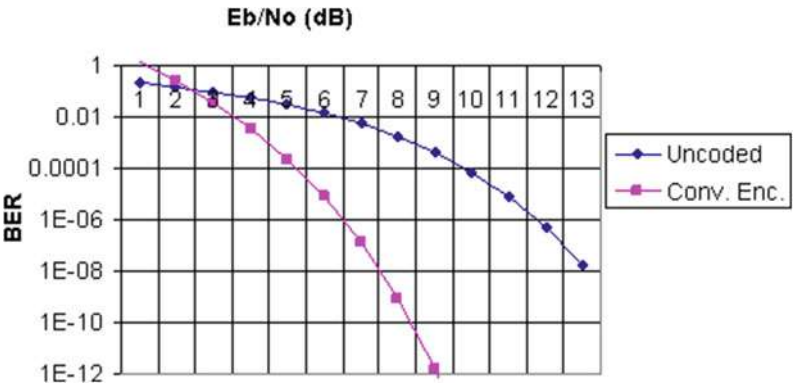

Fig. 4.7 Typical error performance in AWGN

$$\mathrm{BER}_C = 0.5\,\mathrm{EXP}(-E_C/2N_0) \tag{4.13}$$

The corresponding coded word error rate is given as:

$$\mathrm{WER}_C = \sum_{k=t+1}^{n} \binom{n}{k} \mathrm{BER}_C^K (1-\mathrm{BER}_C)^{n-k} \tag{4.14}$$

When $\mathrm{BER}_c < 0.5$, the first term in the summation is the dominant one; therefore, Eq. (4.14) can be simplified as

$$\mathrm{WER}_C \approx \binom{n}{k} \mathrm{BER}_c^k (1-\mathrm{BER}_c)^{n-k} \tag{4.15}$$

Using (15, 8) block code (n = 15, k = 8, t = 1), we obtain the coded and the uncoded WER as shown in Fig. 4.7. Coding gain is the difference in E_b/N_0 between the two curves. Notice that at least 3–4 db coding gain is available in this example where $r = k/n = 8/15$.

4.6 Conclusions

- This chapter presents ASK modulation and its attributes.
- Numerous illustrations are provided to show how amplitude of the carrier changes in discrete levels in accordance with the input digital signal, while the frequency of the carrier remains the same.
- The Fourier transform is used to derive the spectral components and ASK bandwidth is calculated.

- Bit error rate (BER) performance is presented.
- These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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Chapter 5
Frequency Shift Keying (FSK)

Topics

- Introduction
- Frequency Shift Keying (FSK)
- FSK spectrum
- FSK Bandwidth
- Performance Analysis

5.1 Introduction

In frequency shift keying (FSK), the frequency of the carrier changes in discrete levels in accordance with the input digital signal, while the amplitude of the carrier remains the same. This is shown in Fig. 5.1 where

- $m(t)$ is the input modulating digital signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the FSK-modulated carrier frequency.

As shown in the figure, the digital binary signal changes the frequency of the carrier on two discrete levels. This enables the receiver to extract the digital signal by demodulation. Notice that the frequency of the carrier changes in accordance with the input signal, while the amplitude of the carrier does not change after modulation. However, it can be shown that the modulated carrier $S(t)$ contains several spectral components, requiring frequency-domain analysis.

In the following sections, the above disciplines in FSK modulation will be presented, along with the respective spectrum and bandwidth. These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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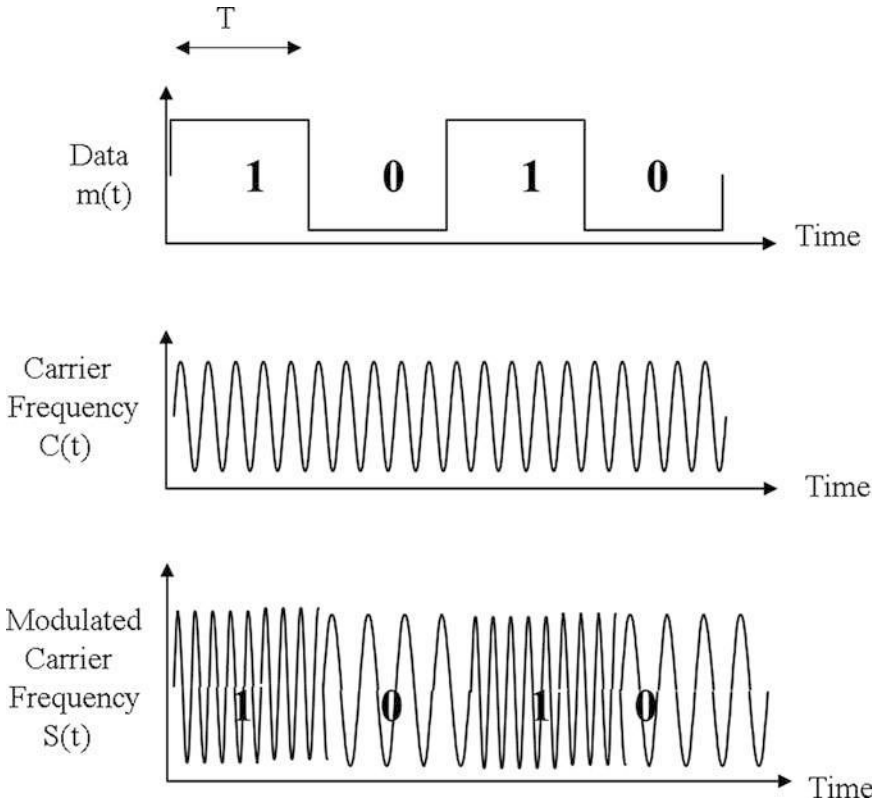

Fig. 5.1 FSK waveforms. The frequency of the carrier changes in accordance with the input digital signal. The amplitude of the carrier remains the same

5.2 Frequency Shift Keying (FSK) Modulation

Frequency shift keying (FSK) is a method of digital modulation that utilizes frequency shifting of the relative frequency content of the signal [1–3]. The signal to be modulated and transmitted is binary, which is encoded before modulation. This is an indispensable task in digital communications, where redundant bits are added with the raw data that enables the receiver to detect and correct bit errors, if they occur during transmission [4–16]. While there are many error-coding schemes available, we will use a simple coding technique, known as "block coding" to illustrate the concept.

Figure 5.2 shows an encoded FSK modulation scheme using (15, 8) block code where an 8-bit data block is formed as M rows and N columns ($M = 4$, $N = 2$). The product $MN = k = 8$ is the dimension of the information bits before coding. Next, a horizontal parity P_H is appended to each row and a vertical parity P_V is appended to each column. The resulting augmented dimension is given by the product $(M + 1)$

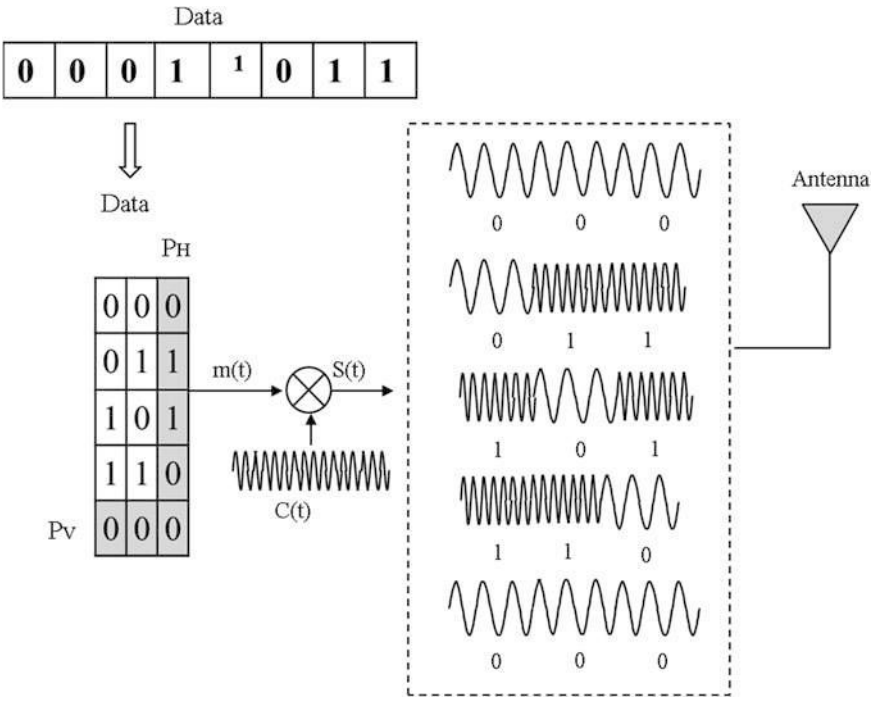

Fig. 5.2 Binary frequency shift keying (BFSK) modulation. The input encoded data block is transmitted row by row. The frequency of the carrier changes in accordance with the input digital signal

$(N + 1) = n = 15$, which is then FSK-modulated and transmitted row by row. The rate of this coding scheme is given by:

$$\text{Code Rate} : r = (MN)/[(M+1)(N+1)] = (4 \times 2)/5 \times 3) = 8/15 \qquad (5.1)$$

The coded bit rate R_{b2} is given by:

$$R_{b2} = \text{Uncoded Bit Rate}/\text{Code Rate} = R_{b1}/r = R_{b1}(15/8) \qquad (5.2)$$

Next, the coded bits are modulated by means of the FSK modulator as shown in the figure. Here,

- The input digital signal is the encoded bit sequence we want to transmit.
- Carrier is the radio frequency without modulation.
- Output is the FSK-modulated carrier, which has two frequencies corresponding to the binary input signal.
- For binary signal 1, the carrier changes to $f_c - \Delta f$.
- For binary signal 0, the carrier changes to $f_c + \Delta f$.
- The total frequency deviation is $2\Delta f$.

As shown in Fig. 3.8, the frequency of the carrier changes in discrete levels, in accordance with the input signals. We have:

$$\begin{aligned} &\bullet \text{ Input Data:} && m(t) = 0 \text{ or } 1 \\ &\bullet \text{ Carrier Frequency:} && C(t) = A\cos(\omega t) \\ &\bullet \text{ Modulated Carrier:} && S(t) = A\cos(\omega - \Delta\omega)t, \text{For } m(t) = 1 \\ & && S(t) = A\cos(\omega + \Delta\omega)t, \text{For } m(t) = 0 \end{aligned} \tag{5.3}$$

where

- A = Frequency of the carrier
- ω = Nominal frequency of the carrier frequency
- $\Delta\omega$ = Frequency deviation. (5.4)

5.3 Frequency Shift Keying (FSK) Demodulation

Once the modulated binary data has been transmitted, it needs to be received and demodulated. This is often accomplished by the use of band-pass filters. In the case of binary FSK, the receiver needs to utilize two band-pass filters that are tuned to the appropriate frequencies. Since the nominal carrier frequency and the frequency deviation are known, this is relatively straightforward. One band-pass filter will be centered at the frequency ω_1 and the other at ω_2. As the signal enters into the receiver, it passes through the respective filter and the corresponding bit value is made. This is shown in Fig. 5.3. In order to assure that the bits are decoded correctly, the frequency deviation needs to be chosen with the limitations of the filters in mind to eliminate crossover.

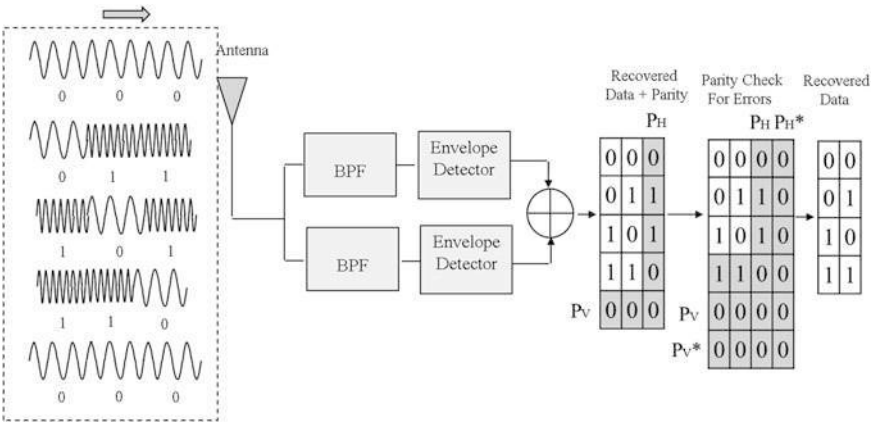

Fig. 5.3 Binary FSK detector utilizing two matched band-pass filters

5.4 FSK Bandwidth

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth in error control coding and modulation. The transmission bandwidth depends on the following:

- Spectral response of the encoded data
- Spectral response of the carrier frequency and
- Modulation type.

5.4.1 Spectral Response of the Encoded Data

In digital communications, data is generally referred to as a non-periodic digital signal. It has two values:

- Binary 1 = high, period = T
- Binary 0 = low, period = T

Also, data can be represented in two ways:

- Time-domain representation and
- Frequency-domain representation

The time-domain representation (Fig. 5.4a), known as non-return-to-zero (NRZ), is given by:

$$\begin{aligned} V(t) &= V \quad < 0 < t < T \\ &= 0 \quad ; \text{elsewhere} \end{aligned} \tag{5.5}$$

The frequency-domain representation is given by "Fourier transform":

$$V(\omega) = \int_0^T V \cdot e^{-j\omega t} dt \tag{5.6}$$

$$|V(\omega)| = VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right] \tag{5.7}$$

$$P(\omega) = \left(\frac{1}{T}\right)|V(\omega)|^2 = V^2 T\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]^2$$

Here, $P(\omega)$ is the power spectral density. This is plotted in Fig. 5.4b. The main lobe corresponds to the fundamental frequency, while side lobes correspond to harmonic components. The bandwidth of the power spectrum is proportional to the

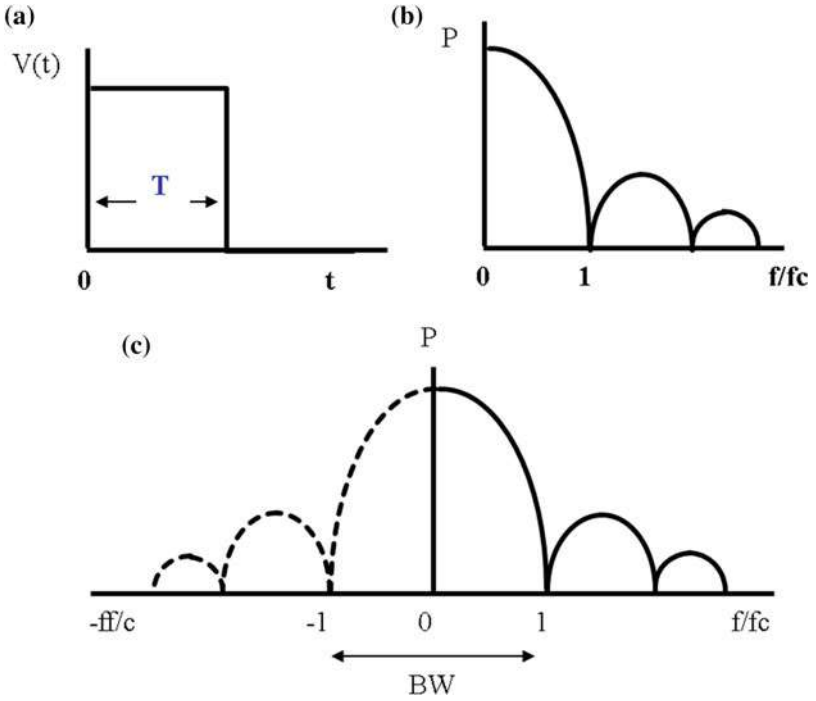

Fig. 5.4 **a** Discrete-time digital signal, **b** its one-sided power spectral density, and **c** two-sided power spectral density. The bandwidth associated with the non-return-to-zero (NRz) data is $2R_b$, where R_b is the bit rate

frequency. In practice, the side lobes are filtered out, since they are relatively insignificant with respect to the main lobe. Therefore, the one-sided bandwidth is given by the ratio $f/f_b = 1$. In other words, the one-sided bandwidth $= f = f_b$, where $f_b = R_b = 1/T$, T being the bit duration.

The general equation for two-sided response is given by:

$$V(\omega) = \int_{-\infty}^{\infty} V(t) \cdot e^{-j\omega t} dt$$

In this case, $V(\omega)$ is called the two-sided spectrum of $V(t)$. This is due to both positive and negative frequencies used in the integral. The function can be either a voltage or a current. Figure 5.4c shows the two-sided response, where the bandwidth is determined by the main lobe as shown below:

$$\text{Two sided bandwidth (BW)} = 2R_b (R_b = \text{Bit rate before coding}) \tag{5.8}$$

Important Notes:

1. If R_b is the bit rate before coding, and if the data is NRZ, then the bandwidth associated with the raw data will be $2R_b$. For example, if the bit rate before coding is 10 kb/s, then the bandwidth associated with the raw data will be 2×10 kb/s = 20 kHz.
2. If R_b is the bit rate before coding, code rate is r, and if the data is NRZ, then the bit rate after coding will be R_b (coded) = R_b(uncoded)r. The corresponding bandwidth associated with the coded data will be $2R_b$ (coded) = $2R_b$ (uncoded)/r. For example, if the bit rate before coding is 10 kb/s and the code rate r = 1/2, the coded bit rate will be R_b (coded) = R_b (uncoded)/r = 10/0.5 = 20 kb/s. The corresponding bandwidth associated with the coded data will be 2×20 = 40 kHz.

5.4.2 *Spectral Response of the Carrier Frequency Before Modulation*

A carrier frequency is essentially a sinusoidal waveform, which is periodic and continuous with respect to time. It has one frequency component. For example, the sine wave is described by the following time-domain equation:

$$V(t) = V_p \sin(\omega t_c) \tag{5.9}$$

where

$$V_P = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$
- f_c = Carrier frequency in Hz

Figure 5.5 shows the characteristics of a sine wave and its spectral response. Since the frequency is constant, its spectral response is located in the horizontal axis and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

5.4.3 *FSK Bandwidth at a Glance*

In FSK, the frequency of the carrier changes in two discrete levels, in accordance with the input signals. We have:

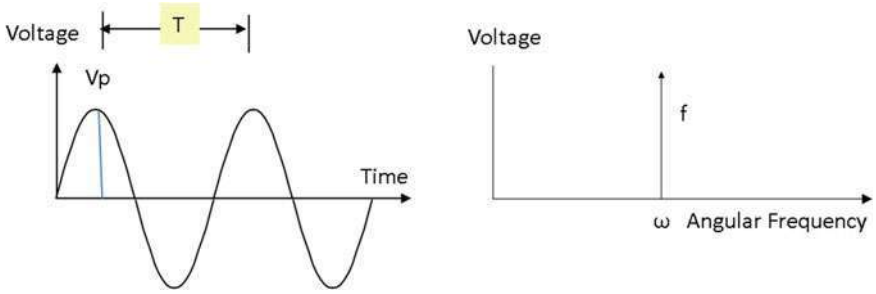

Fig. 5.5 High-frequency carrier response

- Input Data: $m(t) = 0$ or 1
- Carrier Frequency: $C(t) = A\cos(\omega t)$
- Modulated Carrier: $S(t) = A\cos(\omega - \Delta\omega)t$, For $m(t) = 1$
  $S(t) = A\cos(\omega + \Delta\omega)t$, For $m(t) = 0$

where

- $S(t)$ = The modulated carrier
- A = Amplitude of the carrier
- ω = Nominal frequency of the carrier
- $\Delta\omega$ = Frequency deviation

The spectral response is depicted in Fig. 5.6. Notice that the carrier frequency after FSK modulation varies back and forth from the nominal frequency f_c by $\pm\Delta f_c$, where Δf_c is the frequency deviation. The FSK bandwidth is given by:

$$\begin{aligned} \text{BW} &= 2(f_b + \Delta f_c) \\ &= 2f_b(1 + \Delta f_c/f_b) \\ &= 2f_b(1 + \beta) \end{aligned} \tag{5.10}$$

where $\beta = \Delta f/f_b$ is known as the modulation index and f_b is the coded bit frequency (bit rate R_b). The above equation is also known as "Carson's rule."

Problem
Given:

- Bit rate before coding: R_{B1} = 10 kb/s
- Code rate: r = 8/15
- Modulation: FSK
- Modulation index β = 1

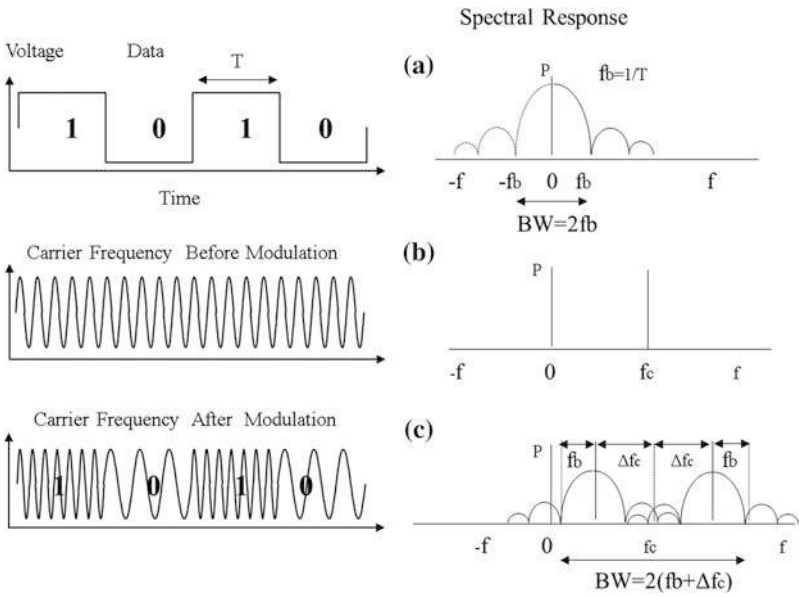

Fig. 5.6 FSK bandwidth at a glance. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation. The transmission bandwidth is $2(f_b + \Delta f_c)$. f_b where f_b is the bit rate and Δf_c is the frequency deviation $=1/f_b$ is the bit duration for NRZ data

Find:

(a) the bit rate after coding: R_{B2}
(b) Transmission bandwidth: BW

Solution

(a) Bit rate after coding (R_{B2}):
$R_{B2} = R_{B1}/r$ = 10 kb/s (15/8) = 18.75 kb/s
(b) Transmission BW = 2 $R_{B2}(1+\beta)$
= 2 × 18.75 kb/s (1 + 1) = 75 kHz.

5.5 BER Performance

It is well known that an (n, k) bock code, where k = number of information bits and n = number of coded bits, can correct t errors [4, 5]. A measure of coding gain is then obtained by comparing the uncoded word error WER_U, to the coded word WER_C. We examine this by means of the following analytical means.

Let the uncoded word error be defined as (WER_U). Then, with FSK modulation, the uncoded BER will be given by:

$$BER_U = 0.5\,EXP(-E_B/2N_0) \tag{5.11}$$

The probability that the uncoded word (WER_U) will be received in error is 1 minus the product of the probabilities that each bit will be received correctly. Thus, we write:

$$WER_U = 1-(1-BER_U)^k \tag{5.12}$$

Let the coded word error be defined as (WER_C). Since $n > k$, the ratio of coded bit energy to noise will be modified to E_c/N_0, where $E_c/N_0 = E_b/N_0 + 10\log(k/n)$. Therefore, the coded BER_c will be:

$$BER_C = 0.5\,EXP(-E_c/2N_0) \tag{5.13}$$

The corresponding coded word error rate is:

$$WER_C = \sum_{k=t+1}^{n} \binom{n}{k} BER_C^K (1 - BER_C)^{n-k} \tag{5.14}$$

When $BER_c < 0.5$, the first term in the summation is the dominant one; therefore, equation can be simplified as

$$WER_C \approx \binom{n}{k} BER_c^k (1 - BER_c)^{n-k} \tag{5.15}$$

Using (15, 8) block code ($n = 15$, $k = 8$, $t = 1$), we obtain the coded and the uncoded WER as shown in Fig. 5.7. Coding gain is the difference in E_b/N_0 between the two curves. Notice that at least 3–4-db coding gain is available in this example where $r = k/n = 8/15$.

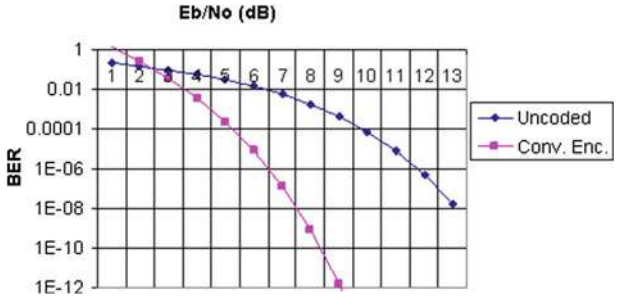

Fig. 5.7 Typical error performance in AWGN

5.6 Conclusions

- This chapter presents FSK modulation and its attributes.
- Numerous illustrations are provided to show how frequency of the carrier changes in discrete levels in accordance with the input digital signal, while the amplitude of the carrier remains the same.
- The Fourier transform is used to derive the spectral components, and FSK bandwidth is calculated.
- Bit error rate (BER) performance is presented.
- These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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Chapter 6
Phase Shift Keying (PSK)

Topics

- Introduction
- Binary Phase Shift Keying (BPSK) Modulation
- QPSK Modulation
- 8PSK Modulation
- 16PSK Modulation
- PSK spectrum and Bandwidth
- SSB Spectrum and Bandwidth

6.1 Introduction

In phase shift keying (PSK), the phase of the carrier changes in discrete levels in accordance with the input digital signal, while the amplitude of the carrier remains the same. This is shown in Fig. 6.1, where

- $m(t)$ is the input modulating digital signal,
- $C(t)$ is the carrier frequency, and
- $S(t)$ is the PSK-modulated carrier frequency.

As shown in the figure, the digital binary signal changes the phase of the carrier on two discrete levels. This enables the receiver to extract the digital signal by demodulation. Notice that the phase of the carrier changes in accordance with the input signal, while the amplitude of the carrier does not change after modulation. However, it can be shown that the modulated carrier $S(t)$ contains several spectral components, requiring frequency domain analysis.

In the following sections, the above disciplines in PSK modulation will be presented, along with the respective spectrum and bandwidth. These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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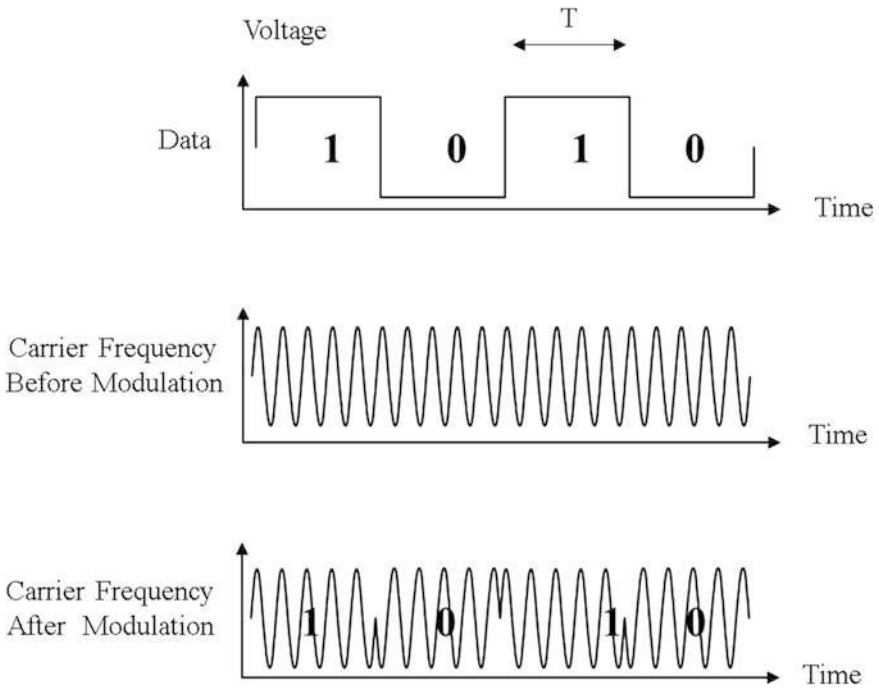

Fig. 6.1 Binary PSK (BPSK) waveforms. The phase of the carrier changes in accordance with the input digital signal. The amplitude of the carrier remains the same

6.2 Binary Phase Shift Keying (BPSK)

6.2.1 BPSK Modulation

Phase shift keying (PSK) is a method of digital modulation that utilizes phase shifting of the relative phase content of the signal [1–3]. The signal to be modulated and transmitted is binary, which is encoded before modulation. This is an indispensable task in digital communications, where redundant bits are added with the raw data that enable the receiver to detect and correct bit errors, if they occur during transmission [4–16]. While there are many error-coding schemes available, we will use a simple coding technique, known as "Block Coding" to illustrate the concept.

Figure 6.2 shows an encoded BPSK modulation scheme using (15, 8) block code where an 8-bit data block is formed as M-rows and N-columns ($M = 4$, $N = 2$). The product $MN = k = 8$ is the dimension of the information bits before coding. Next, a horizontal parity P_H is appended to each row and a vertical parity P_V is appended to each column. The resulting augmented dimension is given by the product $(M + 1)\ (N + 1) = n = 15$, which is then PSK modulated and transmitted row by row. The rate of this coding scheme is given by

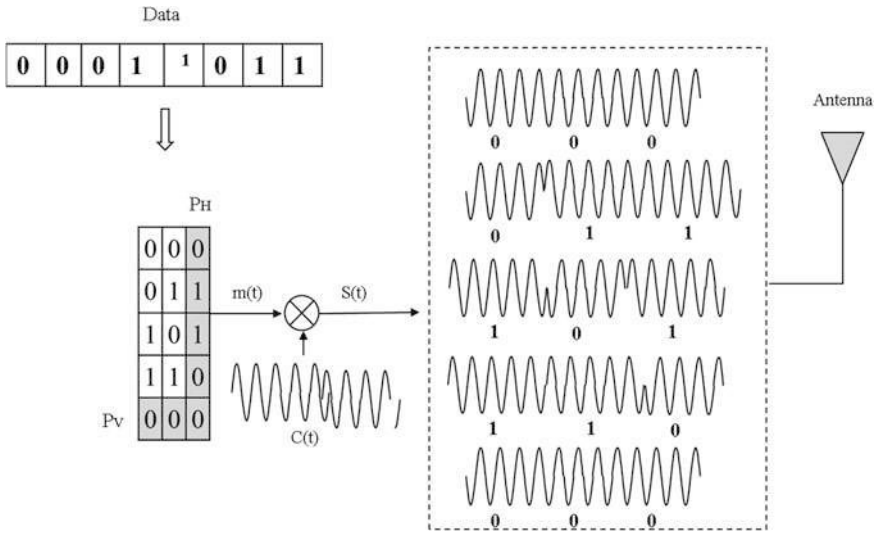

Fig. 6.2 Binary phase shift keying (BPSK) modulation. The input encoded data block is transmitted row by row. The phase of the carrier changes in accordance with the input digital signal

$$\text{Code Rate} : r = (MN)/[(M+1)(N+1)] = (4 \times 2)/5 \times 3) = 8/15 \tag{6.1}$$

The coded bit rate R_{b2} is given by:

$$R_{b2} = \text{Uncoded Bit Rate}/\text{Code Rate} = R_{b1}/r = R_{b1}(15/8) \tag{6.2}$$

Next, the coded bits are modulated by means of the PSK modulator as shown in the figure. Here,

- The Input digital signal is the encoded bit sequence we want to transmit;
- Carrier is the radio frequency without modulation;
- Output is the PSK-modulated carrier, which has two phases corresponding to the binary input signals;
- For binary signal 0, φ = 0°; and
- For binary signal 1, φ = 180°.

As shown in Fig. 6.2, the phase of the carrier changes in two discrete levels, in accordance with the input signals. Here, we have the following:

- Input Data : $m(t) = 0 \text{ or } 1$
- Carrier Frequency : $C(t) = A\cos(\omega_{ct})$
- Modulated Carrier : $S(t) = A_c \cos[\omega_c t + 2\pi/M)m(t)] \quad m(t) = 0, 1, 2, 3, \ldots M-1$

(6.3)

where,

- A_c = Amplitude of the carrier frequency
- ω_c = Angular frequency of the carrier
- $M = 2, 4, 8, 16, \ldots$
- In BPSK, there are two phases 1 bit/phase($M = 2$) (6.4)
- In QPSK, there are four phases, 2-bits/phase, $M = 4$
- In 8PSK, there are 8 phases, 3-bits/phase, $M = 8$
- In 16PSK, there are 16 phases, 4-bits/phase, $M = 16$

We can also represent the BPSK modulator as a signal constellation diagram with M = 2, 1 bit per phase. This is shown in Fig. 6.3, where the input raw data, having a bit rate R_{b1}, is encoded by means of a rate r encoder. The encoded data, having a bit rate R_{b2}, = $R_{b1}r$ ($r < 1$), is modulated by the BPSK modulator as shown in Fig. 6.3.

The BPSK modulator takes one bit at a time to construct the phase constellation having two phases, also known as "Symbols," where each symbol represents one bit. The symbol rate is therefore the same as the encoded bit rate R_{b2}.

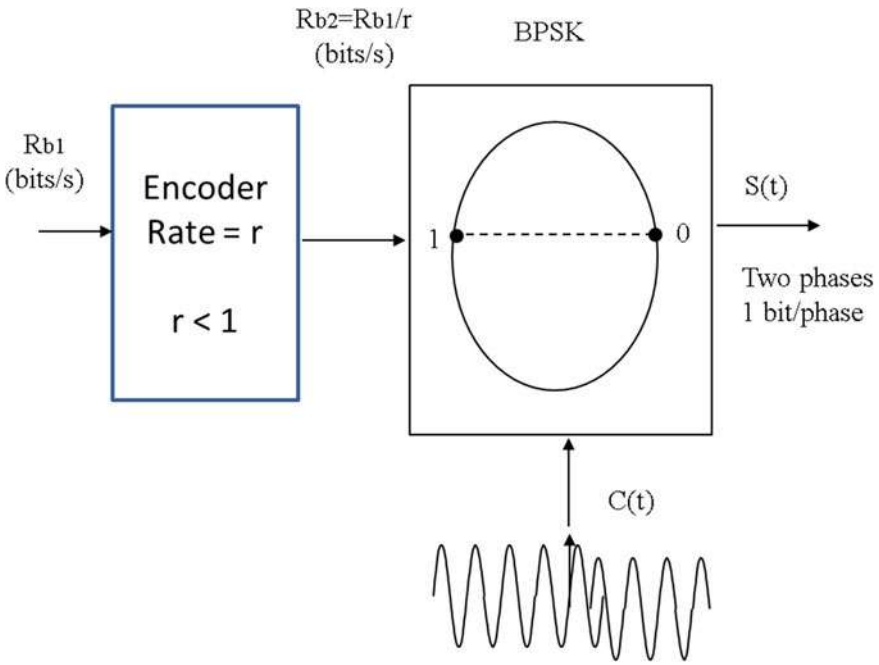

Fig. 6.3 BPSK signal constellation having 2 symbols, 1-bit per symbol

Therefore, the BPSK modulator has the following specifications:

- 2 phases or 2 symbols;
- 1-bit/symbol,

The above specifications govern the transmission bandwidth, as we shall see later.

6.2.2 BPSK Demodulation

Once the modulated binary data has been transmitted, it needs to be received and demodulated. This is often accomplished with the use of a phase detector, typically known as phase-locked loop (PLL). As the signal enters the receiver, it passes through the PLL. The PLL locks the incoming carrier frequency and tracks the variations in frequency and phase. This is known as coherent detection technique, where the knowledge of the carrier frequency and phase must be known to the receiver.

Figure 6.4 shows a simplified diagram of a BPSK demodulator along with the data recovery process. In order to assure that the bits are decoded correctly, the phase deviation needs to be chosen with the limitations of the PLL in mind to eliminate crossover.

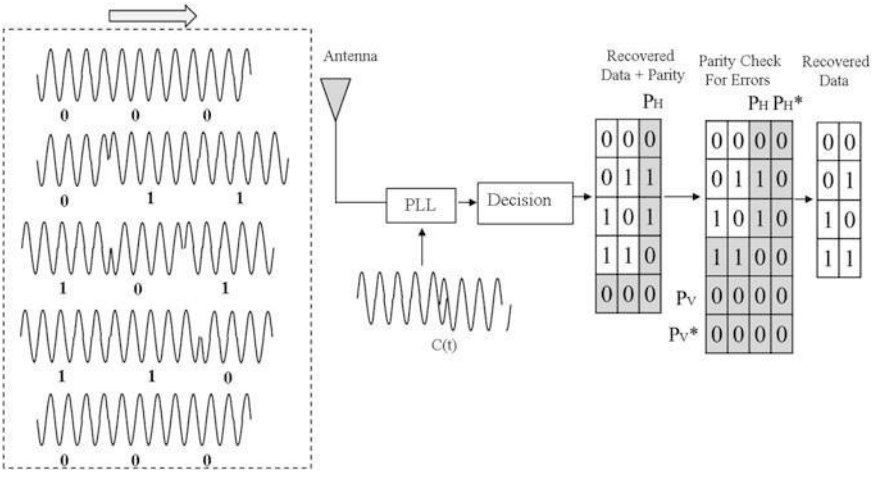

Fig. 6.4 Binary PSK detector showing data recovery process

6.3 QPSK Modulation

In QPSK, the input raw data, having a bit rate R_{b1}, is encoded by a rate r ($r < 1$) encoder. The encoded data, having a bit rate $R_{b2} = R_{b1}/r$, is serial to parallel converted into two parallel streams. The encoded bit rate, now reduced in speed by a factor of two, is modulated by the QPSK modulator as shown in Fig. 6.5.

The QPSK modulator takes one bit from each stream to construct the phase constellation having four phases, also known as "Symbols," where each symbol represents two bits. The symbol rate is therefore reduced by a factor of two. The QPSK modulator has four phases or 4 symbols, 2-bits/symbol as shown in the figure.

Therefore, the QPSK modulator has the following specifications:

- 4 phases or 4 symbols
- 2-bits/symbol

The above specifications govern the transmission bandwidth, as we shall see later.

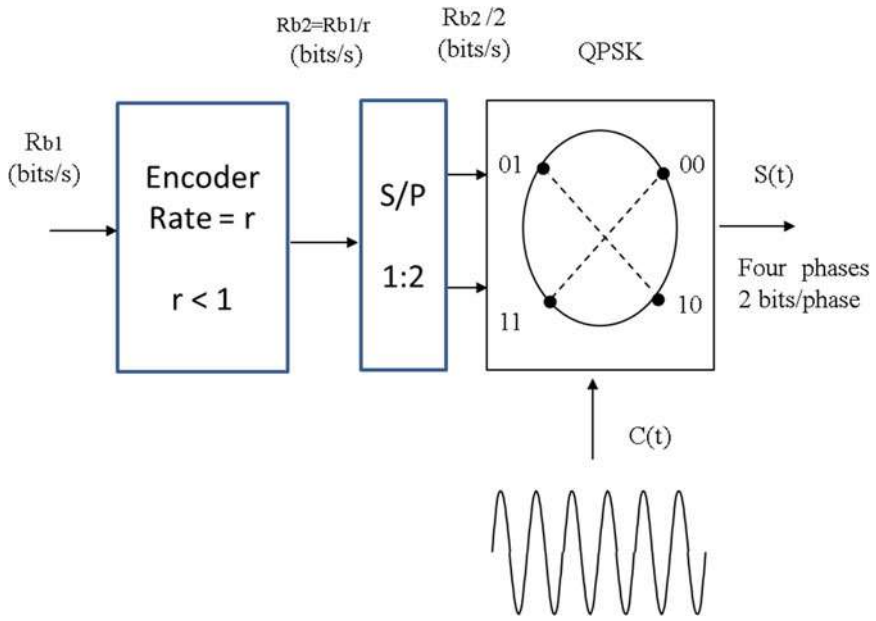

Fig. 6.5 QPSK signal constellation having 4 symbols, 2-bits per symbol

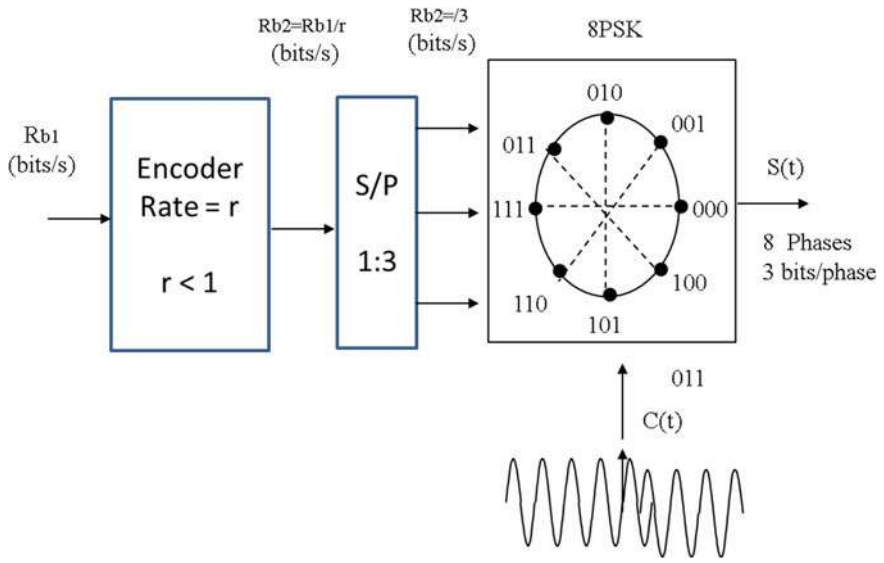

Fig. 6.6 8PSK signal constellation having 8 symbols, 3-bits per symbol

6.4 8PSK Modulation

In 8PSK, the input raw data, having a bit rate R_{b1}, is encoded by a rate r ($r < 1$) encoder. The encoded data, having a bit rate $R_{b2} = R_{b1}/r$, is serial to parallel converted into three parallel streams. The encoded bit rate, now reduced in speed by a factor of three, is modulated by the 8PSK modulator as shown in Fig. 6.6.

The 8PSK modulator takes one bit from each stream to construct the phase constellation having 8 phases, also known as "Symbols," where each symbol represents 3-bits. The symbol rate is therefore reduced by a factor of 3. The 8PSK modulator has 8 phases or 8 symbols, 3-bits/symbol as shown in the figure.

Therefore, the 8PSK modulator has the following specifications:

- 8 phases or 8 symbols;
- 3-bits/symbol.

The above specifications govern the transmission bandwidth, as we shall see later.

6.5 16PSK Modulation

In 16PSK, the input raw data, having a bit rate R_{b1}, is encoded by means of a rate r ($r < 1$) encoder. The encoded data, having a bit rate $R_{b2} = R_{b1}/r$, is serial to parallel converted into four parallel streams. The encoded bit rate, now reduced in speed by a factor of four, is modulated by the 16PSK modulator as shown in Fig. 6.7.

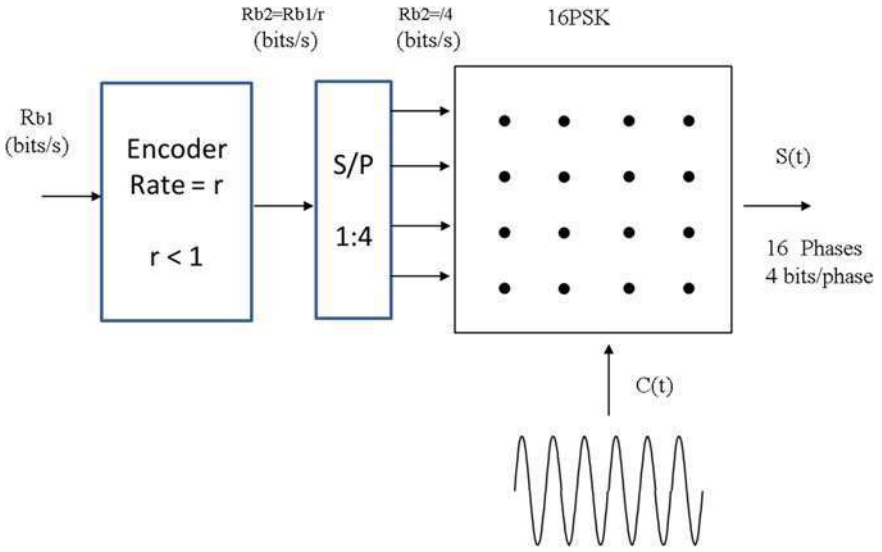

Fig. 6.7 16PSK signal constellation having 16 symbols, 4-bits per symbol. Here, each symbol is represented by a *dot*, where each dot represents 4-bits

The 16PSK modulator takes one bit from each stream to construct the phase constellation having 16 phases, also known as "Symbols," where each symbol represents four bits. The symbol rate is therefore reduced by a factor of four. Therefore, the 16PSK modulator has 16 phases or 16 symbols, 4-bits/symbol as shown in the figure.

Therefore, the 16PSK modulator has the following specifications:

- 16 phases or 16 symbols;
- 4-bits/symbol.

The above specifications govern the transmission bandwidth, as we shall see later.

Table 6.1 shows the number of phases and the corresponding bits per phase for MPSK modulation schemes for $M = 2, 4, 8, 16, 32, 64$, etc.

Table 6.1 MPSK modulation parameters. $M = 2, 4, 8, 16$, and 32

Modulation	Number of phases φ	Number of bits per phase
BPSK	2	1
QPSK	4	2
8PSK	8	3
16	16	4
32	32	5
64	64	6
:	:	:

6.6 PSK Spectrum and Bandwidth

In wireless communications, the scarcity of RF spectrum is well known. For this reason, we have to be vigilant about using transmission bandwidth in error control coding and modulation. The transmission bandwidth depends on:

- Spectral response of the encoded data;
- Spectral response of the carrier phase; and
- Modulation type.

Let us take a closer look:

6.6.1 Spectral Response of the Encoded Data

In digital communications, data is generally referred to as a non-periodic digital signal. It has two values:

- Binary-1 = High, Period = T
- Binary-0 = Low, Period = T

Also, data can be represented in two ways:

- Time domain representation and
- Frequency domain representation

The time domain representation (Fig. 6.8a), known as non-return-to-zero (NRZ), is given by:

$$\begin{aligned} V(t) &= V \quad < 0 < t < T \\ &= 0 \quad \text{elsewhere} \end{aligned} \tag{6.5}$$

The frequency domain representation is given by "Fourier Transform":

$$V(\omega) = \int_0^T V \cdot e^{-j\omega t} dt \tag{6.6}$$

$$\begin{aligned} |V(\omega)| &= 2\left(\frac{V}{\omega}\right)\sin\left(\frac{\omega T}{2}\right) = VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right] \\ P(\omega) &= \left(\frac{1}{T}\right)|V(\omega)|^2 = V^2 T\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]^2 \end{aligned} \tag{6.7}$$

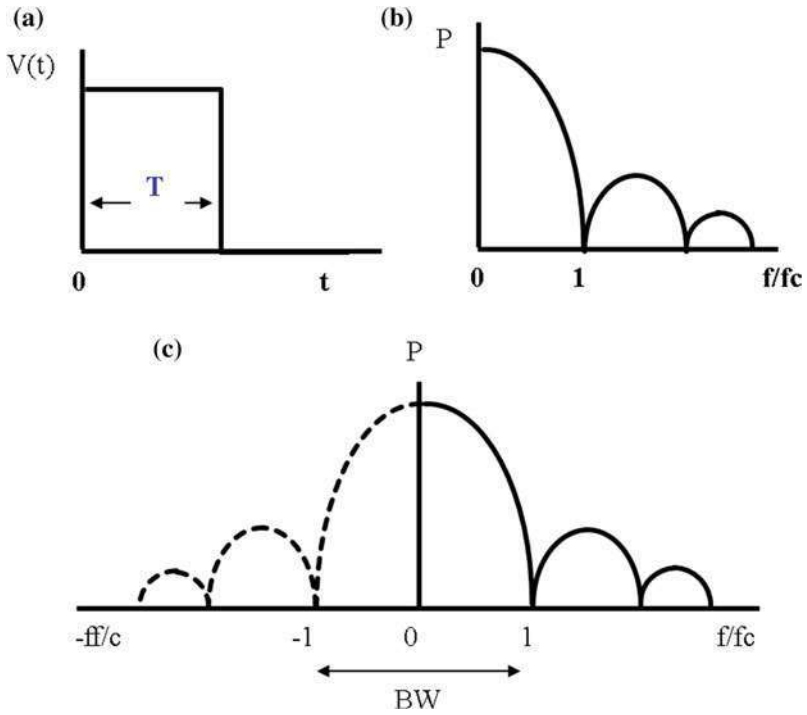

Fig. 6.8 **a** Discrete time digital signal **b** it is one-sided power spectral density and **c** two-sided power spectral density. The bandwidth associated with the non-return-to-zero (NRz) data is $2R_b$, where R_b is the bit rate

Here, $P(\omega)$ is the power spectral density. This is plotted in Fig. 6.8b. The main lobe corresponds to the fundamental frequency, while the side lobes correspond to harmonic components. The bandwidth of the power spectrum is proportional to the frequency. In practice, the side lobes are filtered out, since they are relatively insignificant with respect to the main lobe. Therefore, the one-sided bandwidth is given by the ratio $f/fb = 1$. In other words, the one-sided bandwidth $= f = f_b$, where $f_b = R_b = 1/T$, T being the bit duration.

The general equation for two-sided response is given by:

$$V(\omega) = \int_{-\infty}^{\infty} V(t) \cdot e^{-j\omega t} dt$$

In this case, $V(\omega)$ is called the two-sided spectrum of $V(t)$. This is due to both positive and negative frequencies used in the integral. The function can be either a

voltage or a current. Figure 6.8c shows the two-sided response, where the bandwidth is determined by the main lobe as shown below:

$$\text{Two-sided bandwidth (BW)} = 2R_b \; (R_b = \text{Bit rate before coding}) \tag{6.8}$$

6.6.2 Spectral Response of the Carrier Before Modulation

A carrier frequency is a sinusoidal waveform, which is periodic and continuous with respect to time. It has one phase component. For example, the sine wave is described by the following time domain equation:

$$V(t) = V_p \sin(\omega_c t) \tag{6.9}$$

Where

$$Vp = \text{Peak voltage}$$

- $\omega_c = 2\pi f_c$
- f_c = Carrier phase in Hz

Figure 6.9 shows the characteristics of a sine wave and its spectral response. Since the phase is constant, its spectral response is located in the horizontal axis and the peak voltage is shown in the vertical axis. The corresponding bandwidth is zero.

6.6.3 BPSK Spectrum

In BPSK, the input is a digital signal and it contains an infinite number of harmonically related sinusoidal waveforms. This is given by (see Sect. 6.6.1):

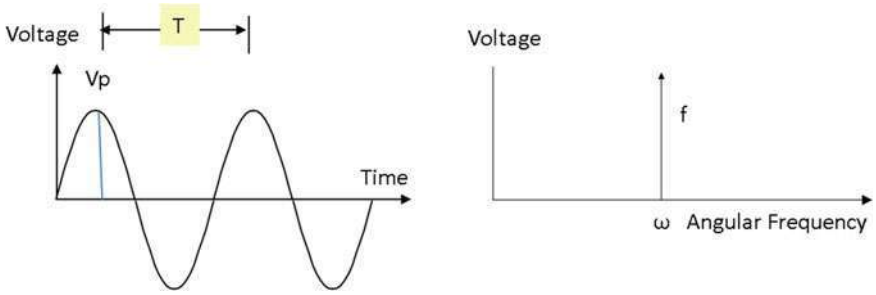

Fig. 6.9 High-frequency carrier response

$$|V(\omega)| = 2\left(\frac{V}{\omega}\right)\sin\left(\frac{\omega T}{2}\right) = VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right] \tag{6.10}$$

Here, $V(\omega)$ is the frequency domain representation of the input digital signal, which has a $\sin(x)/x$ response that governs the phase of the carrier frequency.

With $V(t) = m(t)$, we write the following as:

$$S(t) = A_c \cos[\omega_c t + \beta\, m(t)] \tag{6.11}$$

where β is the phase deviation index of the carrier and $m(t)$ has a $\sin(x)/x$ response, which is given by

$$m(t) = VT\left[\frac{\sin(\omega mT/2)}{\omega mT/2}\right] \tag{6.12}$$

Therefore, the spectral response after BPSK modulation also has a $\sin(x)/x$ response, which is the shifted version of the NRZ data, centered on the carrier frequency f_c, as shown in Fig. 6.10. The transmission bandwidth associated with the main lobe is given by

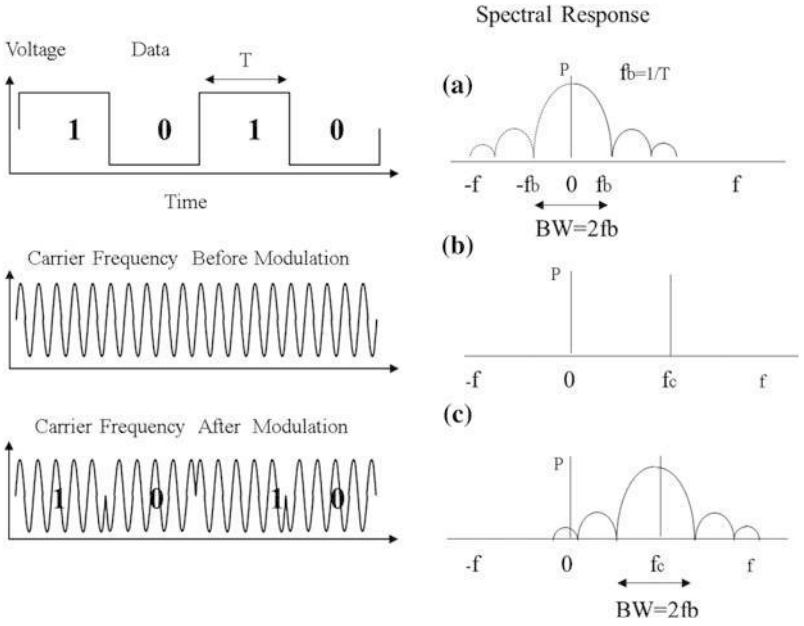

Fig. 6.10 BPSK bandwidth. **a** Spectral response of NRZ data before modulation. **b** Spectral response of the carrier before modulation. **c** Spectral response of the carrier after modulation

$$\begin{aligned} \text{BW (BPSK)} &\approx 2R_{b2}/\text{Bit per Phase} \\ &\approx 2R_{b2}/1 \approx 2R_{b2} \end{aligned} \tag{6.13}$$

where R_{b2} is the coded bit rate (bit frequency). Notice that the BPSK bandwidth is the same the ASK bandwidth. It may be noted that the higher-order spectral components are filtered out.

Problem 6.1
Given:

- Uncoded input bit rate: R_{b1} = 10 kb/s
- Code rate: r = 8/15
- Carrier frequency fc = 1 MHz
- Modulation: BPSK, QPSK, 8PSK, and 16PSK

Find:

(a) Coded bit rate R_{b2}
(b) BPSK bandwidth (BW)
(c) QPSK bandwidth (BW)
(d) 8PSK bandwidth (BW)
(e) 16PSK bandwidth (BW)

Solution:

(a) Coded bit rate: $R_{B2} = R_{B1}/r$ = 10 kb/(15/8) = 18.75 kb/s
(b) BPSK bandwidth: $BW = 2R_{B2}/1 = 2 \times 18.75 = 37.5$ kHz
(c) QPSK bandwidth: $BW = 2R_{B2}/2 = 2 \times 18.75/2 = 18.75$ kHz
(d) 8PSK bandwidth: $BW = 2R_{B2}/3 = 2 \times 18.75/3 = 12.5$ kHz
(e) 16PSK bandwidth: $BW = 2R_{B2}/4 = 2 \times 18.755/4 = 9.375$ kHz

NOTE: Higher-order PSK modulation is bandwidth efficient.

Problem 6.2
Given:

- Input bit rate R_{b1} = 10 kb/s
- Code rate r = 1/2
- Modulation: BPSK, QPSK, 8PSK, 16PSK

Find:

(a) Bit rate after coding R_{b2}
(b) Transmission bandwidth BW

Solution:

(a) $R_{b2} = R_{b1}/r$ = 10 kb/s × 2 = 20 kb/s
(b) Transmission bandwidth:

- BPSK $BW = 2R_{b2}$/Bits per Symbol = 2 × 20 kb/s/1 = 40 kHz
- QPSK $BW = 2R_{b2}$/Bits per symbol = 2 × 20 kb/s/2 = 20 kHz
- 8PSK $BW = 2R_{b2}$/Bits per symbol = 2 × 20 kb/s/3 = 13.33 kHz
- 16PSK $BW = 2R_{b2}$/Bits per symbol = 2 × 20 kb/s/4 = 10 kHz

NOTE: Higher-order PSK modulation is bandwidth efficient.

6.7 Conclusions

- This chapter presents PSK modulation and its attributes.
- Numerous illustrations are provided to show how phase of the carrier changes in discrete levels in accordance with the input digital signal, while the amplitude of the carrier remains the same.
- The Fourier transform is used to derive the spectral components and PSK bandwidth is calculated.
- These materials have been augmented by diagrams and associated waveforms to make them easier for readers to grasp.

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Chapter 7
N-Ary Coded Modulation

Topics

- Introduction
- N-ary Complementary Convolutional Coding and M-ary Modulation
- N-ary Complementary Orthogonal Coding and M-ary Modulation
- Coding Gain and Bandwidth
- Conclusions

7.1 Introduction

N-ary coded modulation is a multi-level channel coding and multi-level modulation technique, where instead of coding one bit at a time two or more bits are encoded simultaneously and then modulated by means of M-ary modulation. In its most basic construction, the input serial data is converted into several parallel streams. These parallel bit streams, now reduced in speed, are mapped into a bank of N unique convolutional or orthogonal codes. The coded information bits are then modulated by an M-ary PSK modulator and transmitted through a channel. At the receiver, the decoder recovers the data by means of code correlation. A lookup table at the receiver contains the input/output bit sequences. Upon receiving an encoded data pattern, the receiver validates the received data pattern by means of code correlation.

In this chapter, we will present the key concept, underlying principles and practical application of N-ary coded modulation schemes, offering spectrum efficiency with improved error correction capabilities. Construction of N-ary coded modulation schemes based on convolutional and orthogonal codes will be presented to illustrate the concept.

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7.2 N-Ary Convolutional Coding and M-Ary Modulation

7.2.1 Background

In convolutional coding, a sequence of data signals is transformed into a longer sequence that contains enough redundancy to protect the data [1–6]. This type of error control is also classified as forward error control coding (FECC), because these methods are often used to correct errors that are caused by channel noise. In a typical convolutional encoder, k information bits enter into the encoder sequentially. The convolutional encoder generates n parity bits as encoded bits ($n > k$). The code rate is defined as $r = k/n$. The coded information bits are modulated and transmitted through a channel.

Another class of convolutional codes, known as parallel concatenated codes or turbo codes [7–9], is popular in wireless communications because of its superior error control capabilities. Yet, turbo codes are limited to two convolutional codes connected in parallel, where delays are introduced due to concatenation and interleaving, thereby limiting high-speed data communications in wireless communications. In addition, it is also too complex to realize.

In this section, a modified technique, defined as N-ary complementary convolutional coding, along with M-ary modulation, is presented to overcome these problems. N-ary complementary convolutional coding is a multi-level convolutional code, where more than two convolutional codes can be used simultaneously to further enhance coding gain without concatenation and interleaving.

7.2.2 Generation of Complementary Convolutional Codes

In a typical convolutional encoder, k information bits enter into the encoder sequentially. The encoder generates n parity bits as encoded bits ($n > k$). The code rate is defined as $r = k/n$. The proposed N-ary convolutional codes are a block of n-convolutional codes and their complements.

In its most basic construction, as shown in Fig. 7.1, a typical convolutional encoder is taken as the basis to generate a block of n-convolutional codes. Next, each convolutional code is inverted to construct a block of n-antipodal codes. Therefore, a block of N-ary convolutional code has n-convolutional codes and n-antipodal codes, for a total of $2n = N$ complementary convolutional codes. In short, we shall define this as N-ary complementary convolutional codes.

Let us consider Fig. 7.1 once again and assume that the input bit sequence to the encoder is:

$$m(t) = 1\ 0\ 1 \tag{7.1}$$

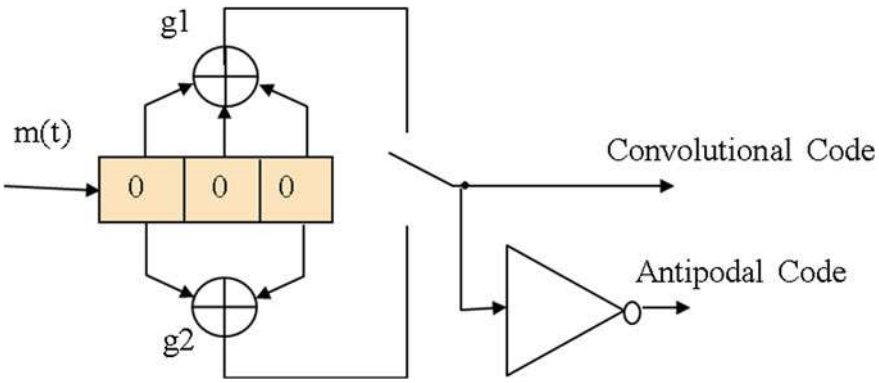

Fig. 7.1 Generation of N-ary complimentary convolutional codes

Which is described by the following polynomial?

$$\begin{aligned} m(X) &= 1 + 0X + 1X^2 \\ &= 1 + X^2 \end{aligned} \tag{7.2}$$

The encoder is described by the following generator polynomials:

$$\begin{aligned} g1(X) &= 1 + X + X^2 \\ g2(X) &= 1 + X^2 \end{aligned} \tag{7.3}$$

Then, the product of polynomials for the encoder can be described as follows:

$$\begin{aligned} m(X)g1(X) &= (1 + X^2)(1 + X + X^2) = 1 + X + X^3 + X^4 \\ m(X)g2(X) &= (1 + X^2)(1 + X^2) = 1 + X^4 \end{aligned} \tag{7.4}$$

with $X^2 + X^2 = 0$, the output bit sequence can be found as $U(X) = m(X)g1(X)$ multiplexed with $m(X)g2(X)$, where $m(X)$ is the input bit sequence [7]. We write the above two equations as follows:

$$\begin{aligned} m(X)g1(X) &= 1 + 1X + 0X^2 + 1X^3 + 1X^4 \\ m(X)g2(X) &= 1 + 0X + 0X^2 + 0X^3 + 1X^4 \\ \text{---------- } & \text{---------- ----------} \\ U1U2 &= (1,1) + (1,0) + (0,0) + (1,0) + (1,1) \end{aligned} \tag{7.5}$$

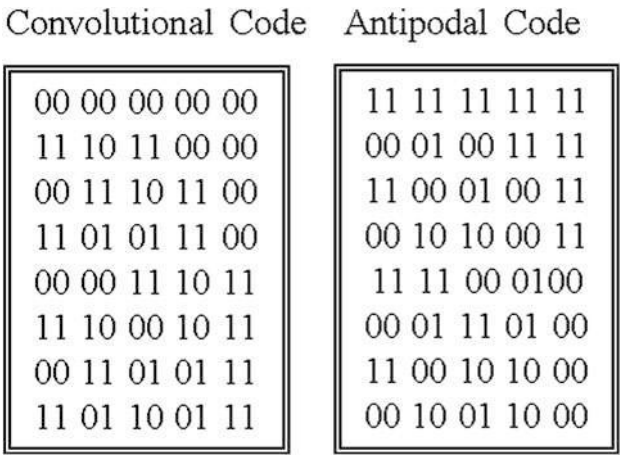

Fig. 7.2 N-ary complimentary convolutional code blocks

Taking only the coefficients, we obtain the desired convolutional code sequence corresponding to the input bit sequence $m(T) = 101$ as follows:

$$\text{Convolutional Code} = 1\,1 \quad 1\,0 \quad 0\,0 \quad 1\,0 \quad 1\,1 \tag{7.6}$$

The corresponding antipodal code is obtained simply by inverting the convolutional code as shown in the figure. This is given by:

$$\text{Antipodal Code} = 0\,0 \quad 0\,1 \quad 1\,1 \quad 0\,1 \quad 0\,0 \tag{7.7}$$

As can be seen, each 3-bit data corresponds to a unique 10-bit convolutional code. Antipodal code is just the inverse of the convolutional codes. Since a 3-bit sequence has 8 combinations, the above convolutional encoder generates 8 unique convolutional codes and 8 unique antipodal codes, for a total of 16 complementary convolutional codes. These code blocks are displayed in Fig. 7.2.

7.2.3 2-Ary Convolutional Coding with QPSK Modulation

A 2-ary ($N = 2$) coded QPSK modulator can be constructed by inverse multiplexing the incoming traffic into 6-parallel streams as shown in Fig. 7.3. These bit streams, now reduced in speed by a factor of 6, are partitioned into two 8×3 data blocks. The first 8×3 data block maps the 8×10 convolutional code block, and the next 8×3 data block maps the next 8×10 antipodal code block. These code blocks are stored in two 8×10 ROMs. The output of each ROM is a unique 10-bit

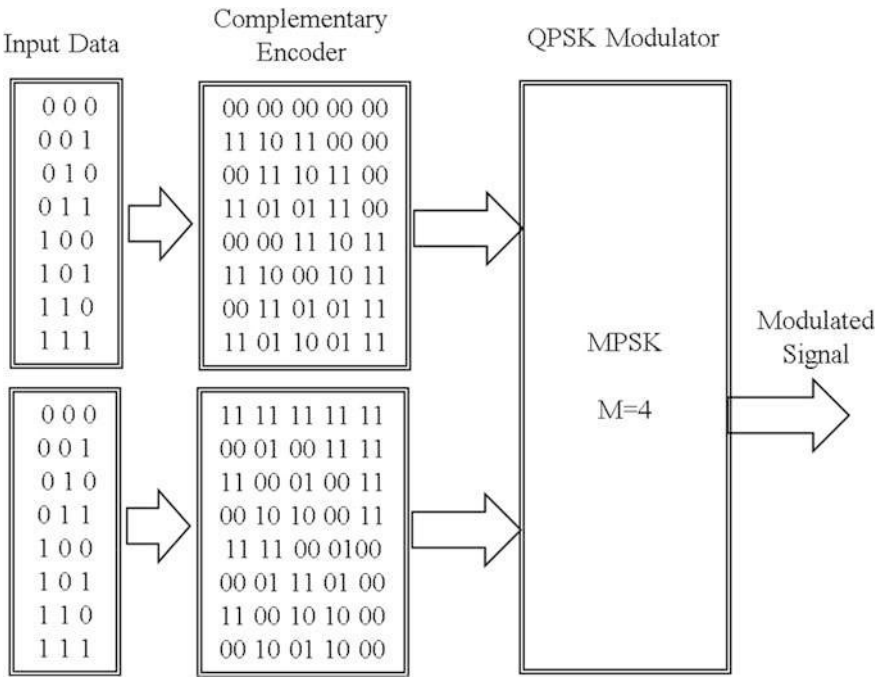

Fig. 7.3 2-ary convolutional coding with QPSK modulation

convolutional/antipodal code, which is modulated by a QPSK modulator using the same carrier frequency. The code rate is given by:

$$\text{Code Rate: } r = 6/10 = 3/5 \tag{7.8}$$

Since there are two convolutional waveforms (one convolutional and one antipodal), the number of errors that can be corrected is doubled. Moreover, the transmission bandwidth is also reduced, which is given by:

Transmission bandwidth: $BW = 2R_{b2}$/bits per symbol Hz

$$B = 2R_{b2}/2 = R_{b2} \tag{7.9}$$

where $R_{b2} = R_{b1}/r$. R_{b2} is the coded bit rate, and R_{b1} is the uncoded bit rate.

7.2.4 4-Ary Convolutional Coding with 16PSK Modulation

A 4-ary ($N = 4$) coded 16PSK modulator can be constructed by inverse multiplexing the incoming traffic into 8-parallel streams as shown in Fig. 7.4. These bit streams, now reduced in speed by a factor of 8, are partitioned into four 4×2 data

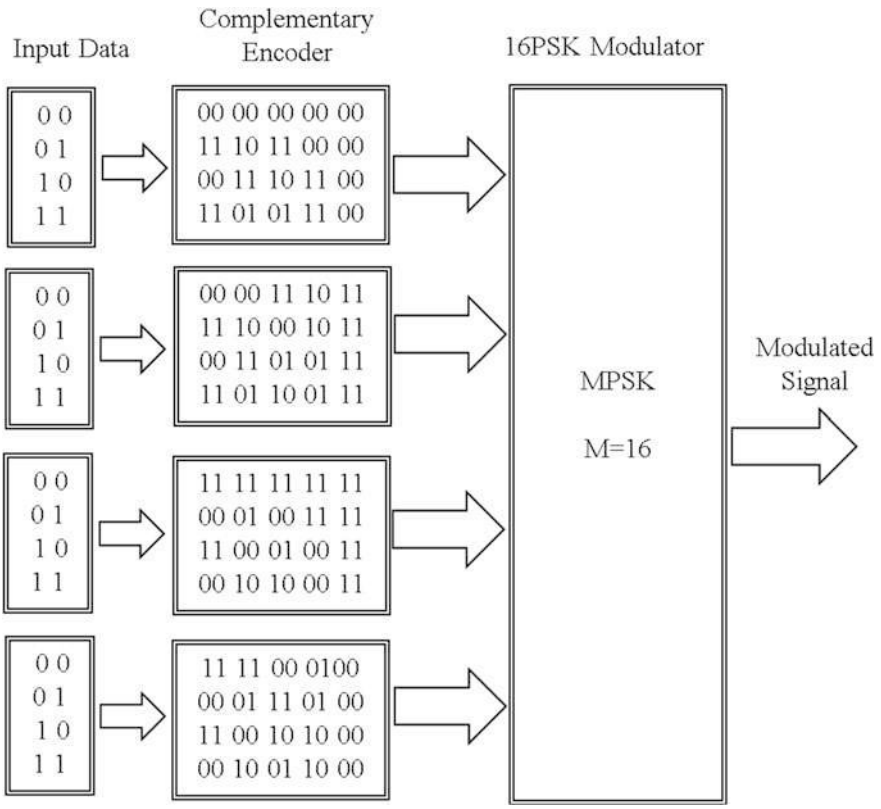

Fig. 7.4 4-ary convolutional coding with 16PSK modulation

blocks. Each 4×2 data block maps corresponding 4×10 convolutional code blocks. These code blocks are stored in four 4×10 ROMs. The output of each ROM is a unique 10-bit convolutional/antipodal code, which is modulated by a 16PSK modulator using the same carrier frequency. The code rate is given by:

$$\text{Code Rate:} r = 8/10 = 4/5 \tag{7.10}$$

Since there are four convolutional waveforms (two convolutional and two antipodal), the number of errors that can be corrected is quadrupled. Moreover, the transmission bandwidth is further reduced, which is given by:

Transmission bandwidth: $BW = 2R_{b2}$/bits per symbol Hz

$$= 2R_{b2}/4 = R_{b2}/2 \tag{7.11}$$

where $R_{b2} = R_{b1}/r$. R_{b2} is the coded bit rate, and R_{b1} is the uncoded bit rate.

7.3 N-Ary Convolutional Decoder

7.3.1 Correlation Receiver

Decoding is a process of code correlation. In this process, the receiver compares the received data with the expected data set to recover the actual data. The expected data is stored into a lookup table [see Table 7.1]:

- The lookup table at the receiver contains the input/output bit sequences.
- For $m = 3$, there are 8 possible output combinations of 3-bit data.
- For each combination of 3-bit data, there is a unique encoded 10-bit data (see table).
- The receiver receives one of 8 output sequences.
- Upon receiving an encoded data pattern, the receiver validates the received data pattern by means of code correlation.

Let us examine the correlation process using the following example:

- The input bit pattern $m = 0\ 1\ 1$
- Encoded transmit data: $U = 00\ 11\ 01\ 01\ 11$
- Received data with errors $U^* = 00\ 11\ 01\ 01\ \mathbf{00}$

Notice that the last two bits are in error, identified in bold. Now, let us determine how the receiver recovers the correct data, where the actual input data is $m = 0\ 1\ 1$. This is a correlation process, requiring several tests to validate the actual data. The correlation process is described below:

Test 0:

This test compares the received data with the 1st row of data stored in the lookup table and counts the number of positions it does not match. This is accomplished by MOD2 operation (EXOR operation). The result is presented below:

- Received data: 00 11 01 01 **00**
- 1st row of data in the lookup table: 00 00 00 00 00
- Mod-2 Add: 00 11 01 01 00

Table 7.1 Lookup table a

Input (m)	Output (U)
0. 0 0 0	00 00 00 00 00
1. 0 0 1	00 00 11 10 11
2. 0 1 0	00 11 10 11 00
3. 0 1 1	00 11 01 01 11
4. 1 0 0	11 10 11 00 00
5. 1 0 1	11 10 00 10 11
6. 1 1 0	11 01 01 11 00
7. 1 1 1	11 01 10 01 11

- Correlation value = 4 (count the number of 1's in MOD2 Add)
- Verdict: No match, continue search.

Test-0: Look Up Table

Input *(m)*	Output *(U)*	Correlation Value
0. 0 0 0	00 00 00 00 00	4
1. 0 0 1	00 00 11 10 11	
2. 0 1 0	00 11 10 11 00	
3. 0 1 1	00 11 01 01 11	
4. 1 0 0	11 10 11 00 00	
5. 1 0 1	11 10 00 10 11	
6. 1 1 0	11 01 01 11 00	
7. 1 1 1	11 01 10 01 11	

Received Data: 00 11 01 01 00

Test 1:

This test compares the received data with the 2nd row of data stored in the lookup table and counts the number of positions it does not match. This is accomplished by MOD2 operation (EXOR operation). The result is presented below:

- Received data: 00 11 01 01 00
- 2nd row of data in the lookup table: 00 00 11 10 11
- Mod-2 Add: 00 11 10 111 11
- Correlation value = 7
- Verdict: No match, continue search

Test 1: Look Up Table

Input (m)	Output (U)	Correlation Value
0. 0 0 0	00 00 00 00 00	
1. 0 0 1	00 00 11 10 11	7
2. 0 1 0	00 11 10 11 00	
3. 0 1 1	00 11 01 01 11	
4. 1 0 0	11 10 11 00 00	
5. 1 0 1	11 10 00 10 11	
6. 1 1 0	11 01 01 11 00	
7. 1 1 1	11 01 10 01 11	

Received Data: 00 11 01 01 00

The remaining tests may be conducted by using the same method to reach the final verdict as given below:

Final Verdict:

Collect the correlation values and validate the data that indicates the lowest correlation value. This is presented in the following lookup table.

Final Verdict: Look Up Table

Input (m)	Output (U)	Correlation Value
0. 0 0 0	00 00 00 00 00	4
1. 0 0 1	00 00 11 10 11	7
2. 0 1 0	00 11 10 11 00	3
3. 0 1 1	00 11 01 01 11	2
4. 1 0 0	11 10 11 00 00	5
5. 1 0 1	11 10 00 10 11	8
6. 1 1 0	11 01 01 11 00	4
7. 1 1 1	11 01 10 01 11	7

Accept → | ← Accept

In examining the above table, we find that:

- The lowest correlation value is 2.
- The corresponding data is $m = 0\ 1\ 1$.
- This is the data which has been transmitted to the receiver.

7.3.2 *Error Correction Capabilities of N-Ary Convolutional Codes*

An n-bit convolutional code is generated by a rate ½ encoder of constraint length K where

$$n = 4K - 2 \tag{7.12}$$

In the above equation, K is the length of the shift register and the factor −2 is due to the initial content of the shift register, which is 000. For example, a rate ½ convolutional encoder with $K = 3$ generates 00 when the initial content of the shift register is 000. Therefore, the value of n is reduced by 2. Therefore, each 3-bit data sequence corresponds to a unique 10-bit convolutional code. The antipodal code is just the inverse of the convolutional codes. Since a 3-bit sequence has 8 combinations, the above convolutional encoder generates 8 unique convolutional codes and 8 unique antipodal codes, for a total of 16 complementary convolutional codes.

These code blocks are displayed in Fig. 7.2. As can be seen, each code is unique and there is a minimum distance $d_{\min}$ between any two convolutional codes where

$$d_{\min} \leq n/2 \tag{7.13}$$

This distance property can be used to detect an impaired received code by setting a threshold midway between two convolutional codes. It can be shown that an n-bit convolutional code can correct the errors, where

Table 7.2 Error correction capabilities of N-ary convolutional codes

Constraint length (K)	Number of errors corrected if the modulation scheme is (BPSK)	Number of errors corrected if the modulation scheme is (QPSK)	Number of errors corrected if the modulation scheme is (16PSK)
3	2	4	8
5	4	8	16
7	6	12	24
9	8	16	32

$$t \leq d_{\min}/2 \leq n/4 \leq (4K-2)/4 \tag{7.14}$$

where

- t = Number of errors that can be corrected by means of a single convolutional code
- n = Code length
- K = Constraint length

The proposed N-ary coded modulation is a multi-level channel coding technique, where instead of coding one bit at a time two or more bits are encoded simultaneously. Therefore, we modify the above equation to obtain

$$N\,t \leq N\,d_{\min}/2 \leq Nn/4 \leq N(4K-2)/4 \tag{7.15}$$

Table 7.2 displays error correction capabilities of N-ary convolutional codes.

7.4 N-Ary Orthogonal Coding and M-Ary Modulation

7.4.1 Background

Orthogonal codes are used in CDMA cellular communications for spectrum spreading and user ID [10–13]. The use of orthogonal codes for forward error control coding has also been investigated by a limited number of authors [14–16]. This chapter presents a method of channel coding based on N-ary orthogonal codes [17–20]. N-ary orthogonal coding is a multi-level channel coding technique, where instead of coding one bit at a time two or more bits are encoded simultaneously. This type of channel coding is bandwidth efficient and further enhances the coding gain with bandwidth efficiency. In the proposed scheme, the input serial data is converted into several parallel streams. These parallel bit streams, now reduced in speed, are mapped into N-ary orthogonal codes. The coded information bits are then modulated by means of MPSK modulator and transmitted through a channel. At the receiver, the decoder recovers the data by means of code correlation. The proposed coded modulation scheme is bandwidth efficient and offers a coding gain near the Shannon's limit.

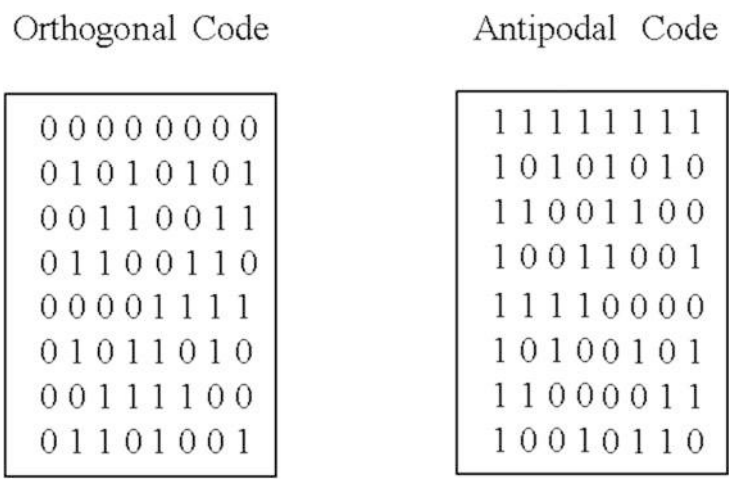

Fig. 7.5 Bi-orthogonal code set for $n = 8$. An 8-bit orthogonal code has 8 orthogonal codes and 8 antipodal codes for a total of 16 bi-orthogonal codes

7.4.2 Orthogonal Codes

Orthogonal codes are binary-valued and have equal numbers of 1's and 0's. Antipodal codes, on the other hand, are just the inverse of orthogonal codes. Antipodal codes are also orthogonal among them. Therefore, an n-bit orthogonal code has n-orthogonal codes and n-antipodal codes, for a total of 2n bi-orthogonal codes. For example, an 8-bit orthogonal code has 8 orthogonal codes and 8 antipodal codes, for a total of 16 bi-orthogonal codes, as shown in Fig. 7.5 [12]. Similarly, a 16-bit orthogonal code has 16 orthogonal codes and 16 antipodal codes for a total of 32 bi-orthogonal codes, as shown in Fig. 7.6.

We note that orthogonal codes are essentially (n, k) block codes, where a k-bit data set is represented by a unique n-bit orthogonal code ($k < n$). We now show that code rates such as rate ½, rate ¾, and rate 1 are indeed available out of orthogonal codes. The principle is presented below.

7.4.3 2-Ary Orthogonal Coding with QPSK Modulation

A 2-ary orthogonal coded QPSK modulator with $n = 8$, having 16 complementary orthogonal codes, can be constructed by inverse multiplexing the incoming traffic into 6-parallel streams, as shown in Fig. 7.7. These bit streams, now reduced in speed by a factor of 6, are partitioned into two data blocks. Each data block is mapped into an 8×8 code block, as depicted in the figure.

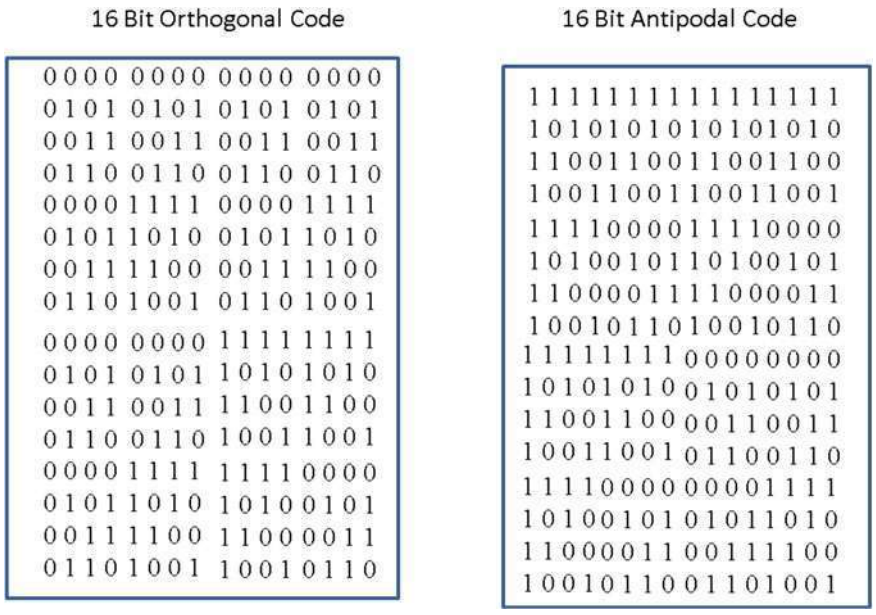

Fig. 7.6 Bi-orthogonal code set for $n = 16$. A 16-bit orthogonal code has 16 orthogonal codes and 16 antipodal codes for a total of 32 bi-orthogonal codes

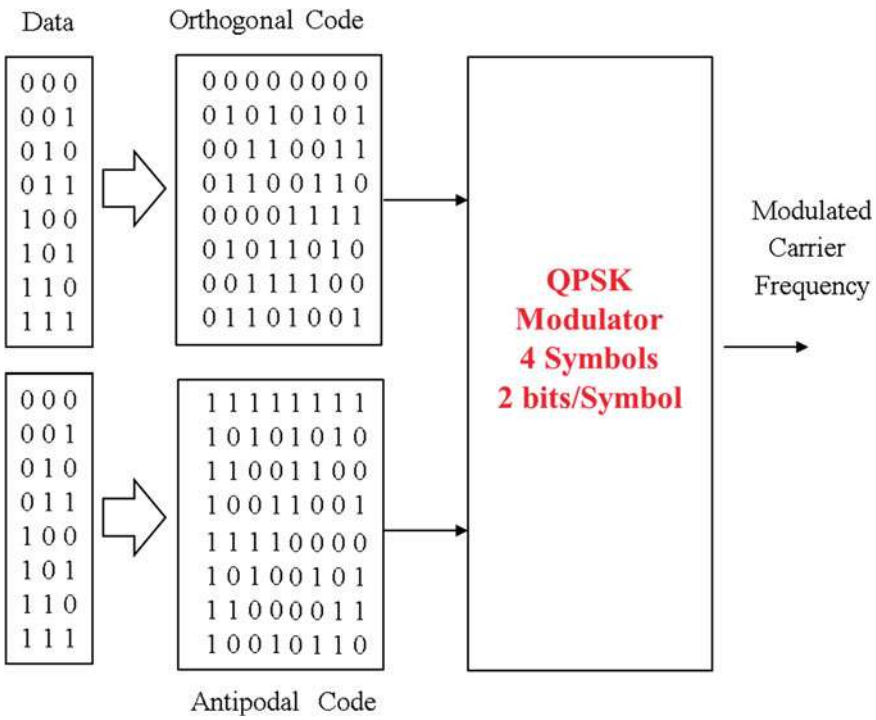

Fig. 7.7 2-ary orthogonal coding with $N = 2$

According to the communication scheme, when a 3-bit data pattern needs to be transmitted, the corresponding orthogonal/antipodal code is transmitted instead, requiring a QPSK modulator. The modulated waveforms are in orthogonal space and have fewer errors. The code rate is given by:

$$\text{Code Rate: } r = 6/8 = 3/4$$

Since there are two orthogonal waveforms (one orthogonal and one antipodal), the number of errors that can be corrected is doubled. Moreover, the transmission bandwidth is also reduced, which is given by:

Transmission Bandwidth: $BW = 2R_{b2}$/bits per symbol Hz

$$= 2R_{b2}/2 = R_{b2}\,\text{Hz} \tag{7.16}$$

where $R_{b2} = R_{b1}/r$. R_{b2} is the coded bit rate and R_{b1} is the uncoded bit rate.

7.4.4 4-Ary Orthogonal Coding with 16PSK Modulation

A 4-ary orthogonal coded 16PSK modulator, with $n = 8$, having 16 complementary orthogonal codes, can be constructed by inverse multiplexing the incoming traffic into 8-parallel streams, as shown in Fig. 7.8. The bit streams, now reduced in speed by a factor of 8, are partitioned into four data blocks. Each data block is mapped into a 4×8 code block as depicted in the figure. According to the communication scheme, when a 2-bit data pattern needs to be transmitted, the corresponding orthogonal/antipodal code is transmitted instead, requiring a 16PSK modulator. The modulated waveforms are in orthogonal space and have fewer errors. The code rate is given by:

$$\text{Code Rate: } r = 8/8 = 1 \tag{7.17}$$

This is achieved without bandwidth expansion.

Since there are four orthogonal waveforms (two orthogonal and two antipodal), the number of errors that can be corrected is quadrupled. Moreover, the transmission bandwidth is further reduced, which is given by:

Transmission bandwidth: $BW = 2R_{b2}$/bits per symbol Hz

$$= 2R_{b2}/4 = R_{b2}/2\,\text{Hz} \tag{7.18}$$

where $R_{b2} = R_{b1}/r$. R_{b2} is the coded bit rate, and R_{b1} is the uncoded bit rate.

7.4.5 2-Ary Orthogonal Decoding

Decoding is a correlation process. Notice that the entire biorthogonal code block is partitioned into two code blocks. Each code block represents a data block as shown in Fig. 7.9. Upon receiving an impaired code, the receiver compares it with each

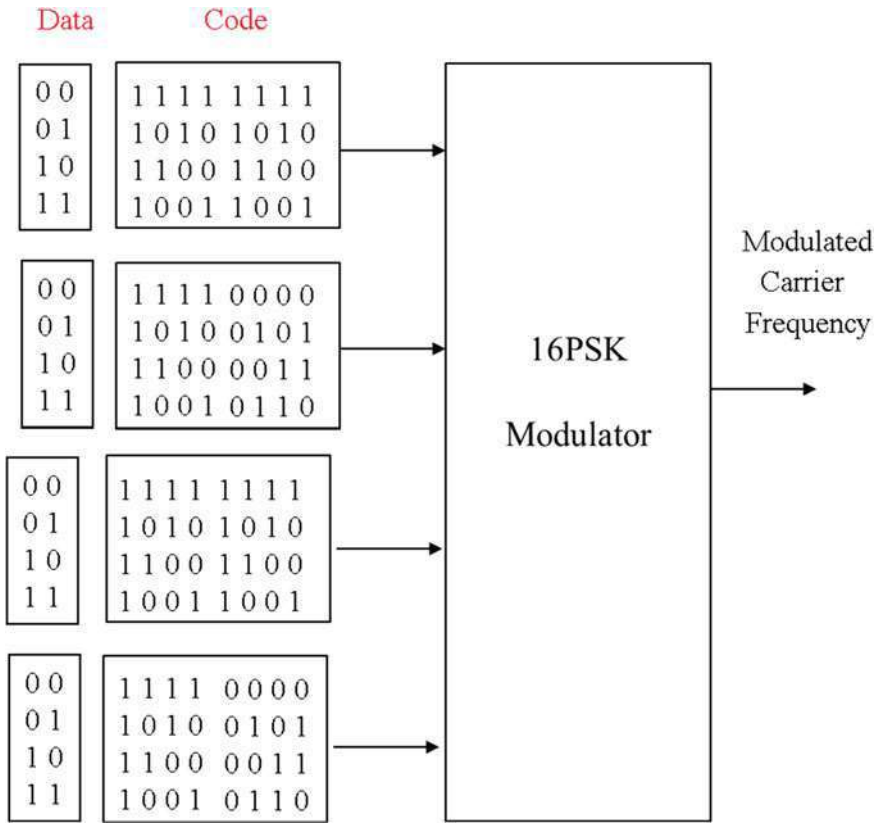

Fig. 7.8 N-ary orthogonal coding with $N = 4$

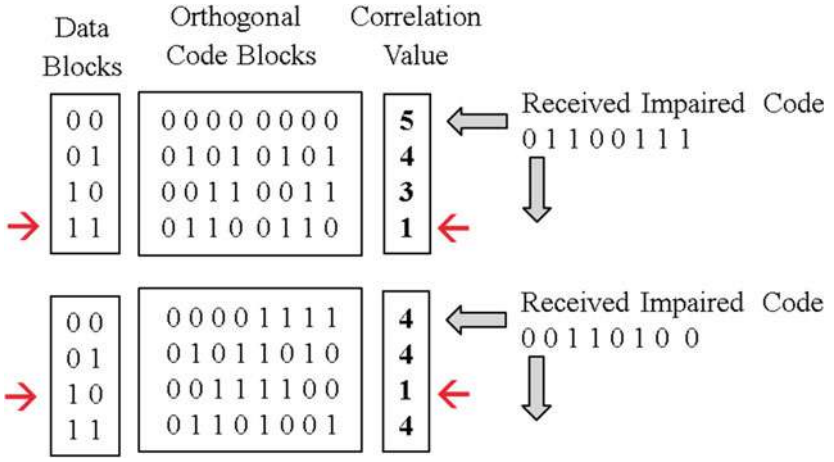

Fig. 7.9 2-ary orthogonal decoding

entry in the code block and appends a correlation value for each comparison. A valid code is declared when the closest approximation is achieved. As can be seen, the minimum correlation value in each block is 1 as depicted in the figure. The corresponding data is 1 1, 1 0, 1 1, 1 0, respectively.

Since there are two orthogonal waveforms (one orthogonal and one antipodal), the number of errors that can be corrected is given by $2 \times 1 = 2$. Moreover, the bandwidth is also reduced, as presented below:

$$BW = 2Rb2/\text{bits per symbol} = 2_{Rb2}/2 = \mathrm{R}_{b2} \tag{7.19}$$

7.4.6 4-Ary Orthogonal Decoding

Decoding is a correlation process. Notice that the entire biorthogonal code block is partitioned into four code blocks. Each code block represents a data block, as shown in Fig. 7.10. Upon receiving an impaired code, the receiver compares it with each entry in the code block and appends a correlation value for each comparison. A valid code is declared when the closest approximation is achieved. As can be seen, the minimum correlation value in each block is 1 as depicted in the figure. The corresponding data is 1 1, 1 0, 1 1, 1 0, respectively.

Since there are four orthogonal waveforms (two orthogonal and two antipodal), the number of errors that can be corrected is given by $4 \times 1 = 4$. Moreover, the bandwidth is further reduced as presented below:

$$BW = 2Rb2/\text{bits per symbol} = 2_{Rb2}/4 = R_{b2}/2 \tag{7.20}$$

7.4.7 Error Correction Capabilities of N-Ary Orthogonal Codes

Error correction capabilities of orthogonal codes have been discussed earlier [16]. We present it again for convenience. An n-bit orthogonal code has $n/2$ 1's and $n/2$ 0's; i.e., there are $n/2$ positions where 1's and 0's differ. Therefore, the distance between two orthogonal codes is $d = n/2$. This distance property can be used to detect an impaired received code by setting a threshold midway between two orthogonal codes as shown in Fig. 7.11, where the received code is shown as a dotted line. This is given by:

$$d_{th} = \frac{n}{4} \tag{7.21}$$

where n is the code length and d_{th} is the threshold, which is midway between two valid orthogonal codes. Therefore, for the given 8-bit orthogonal code, we have

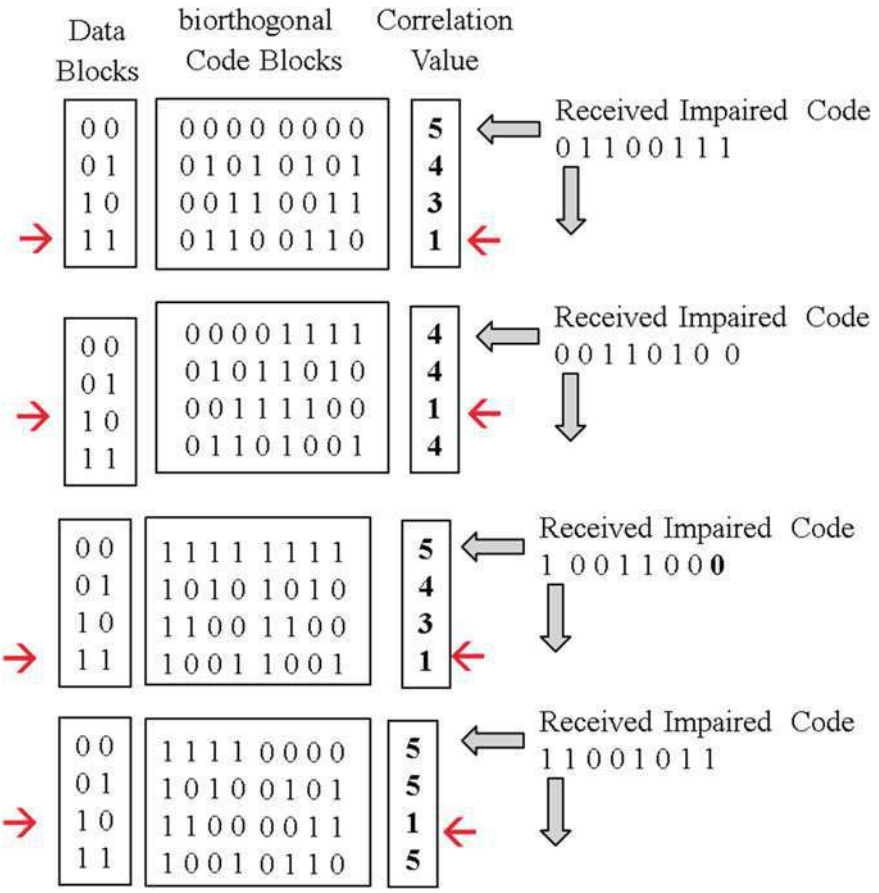

Fig. 7.10 4-ary orthogonal decoding

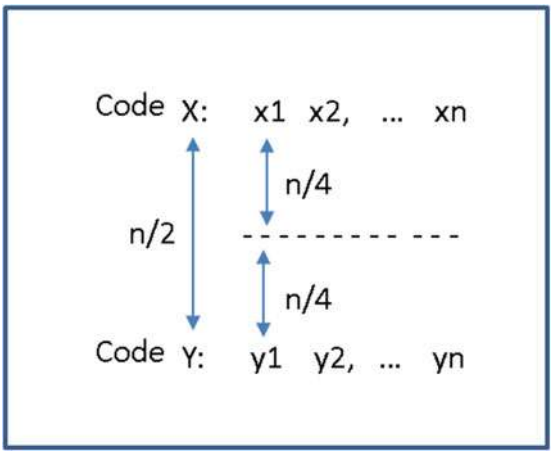

Fig. 7.11 Distance properties of orthogonal codes

d_{th} = 8/4 = 2. This mechanism offers a decision process, where the incoming impaired orthogonal code is examined for correlation with the neighboring codes for a possible match.

The received code is examined for correlation with the neighboring codes for a possible match. The acceptance criterion for a valid code is that an n-bit comparison must yield a good autocorrelation value; otherwise, a false detection will occur. The following correlation process governs this, where an impaired orthogonal code *i*s compared with a pair of n-bit orthogonal codes to yield:

$$R(x,y) = \sum_{i=1}^{n} x_i y_i \geq (n - d_{th}) + 1 \tag{7.22}$$

where x and y are two n-bit orthogonal codes, $R(x, y)$ is the autocorrelation function, n is the code length, and d_{th} is the threshold as defined earlier. Since the threshold is in the midway between two valid codes, an additional 1-bit offset is added to Eq. 7.21 for reliable detection. The average number of errors that can be corrected by means of this process can be estimated by combining Eq. 7.21 and Eq. 7.22, yielding:

$$t = n - R(x,y) = \frac{n}{4} - 1 \tag{7.23}$$

In the above equation, t is the number of errors that can be corrected by means of an n-bit orthogonal code. For example, a single-error-correcting orthogonal code can be constructed by means of an 8-bit orthogonal code (n = 8). Similarly, a three-error-correcting orthogonal code can be constructed by means of a 16-bit orthogonal code (n = 16) and so on. Table 7.3 shows a few orthogonal codes and the corresponding error-correcting capabilities.

Problem 7.1 This problem relates to N-ary convolutional codes and M-ary PSK modulation.

Given:

- Input bit rate before coding: R_{b1} = 10 kb/s
- K = 3, Rate ½ complementary convolutional codes
- 4-ary convolutional coding (N = 4)

Table 7.3 Error correction capabilities of N-ary orthogonal codes

Code length n	Number of errors corrected per code t	Number of errors corrected by N-ary code Nt N = 1, 2, 4, 8, …
8	1	N
16	3	3 N
32	7	7 N
64	15	15 N

Find:

(a) Modulation level M
(b) Code rate r
(c) Bit rate after coding R_{b2}
(d) Transmission bandwidth BW
(e) Number of errors corrected

Solution:

(a) A 4-ary ($N = 4$) coded modulator can be constructed by inverse multiplexing the incoming traffic into 8-parallel stream. These bit streams, now reduced in speed by a factor of 8, are partitioned into four 4×2 data blocks. Each 4×2 data block maps a corresponding 4×10 convolutional code blocks. These code blocks are stored in four 4×10 ROMs. The output of each ROM is a unique 10-bit convolutional/antipodal code, which is modulated by a $2^4 = 16$ PSK modulator using the same carrier frequency. Therefore, $M = 16$.
(b) The code rate is given by:

$$\text{Code Rate: } r = 8/10 = 4/5$$

(c) Bit rate after coding $R_{b2} = R_{b1}/r = (5/4)$ 10 kb/s = 12.5 kb/s
(d) Transmission bandwidth: $BW = 2R_{b2}$/bits per symbol Hz

$$= 2R_{b2}/4 = R_{b2}/2 = (12.50\,\text{kb/s})/2 = 6.25\,\text{kHz}$$

(e) Since there are four convolutional waveforms (two convolutional and two antipodal), the number of errors that can be corrected is quadruple, $4t = 4 \times 2 = 8$ [Each code corrects 2 errors.]

Problem 7.2 This example relates to N-ary orthogonal codes and M-ary PSK modulation.

Given:

- Input bit rate before coding: R_{b1} = 10 kb/s
- $n = 8$ orthogonal codes having 16 complementary orthogonal codes
- 4-ary orthogonal Coding

Find:

(a) Modulation level M
(b) Code rate r
(c) Bit rate after coding R_{b2}
(d) Transmission bandwidth BW
(e) Number of errors corrected

Solution:

(a) A 4-ary orthogonal coded modulator, with $n = 8$, having 16 complementary orthogonal codes, can be constructed by inverse multiplexing the incoming traffic into 8-parallel streams. The bit streams, now reduced in speed by a factor of 8, are partitioned into four data blocks. Each data block is mapped into a 4×8 code block. According to the communication scheme, when a 2-bit data pattern needs to be transmitted, the corresponding orthogonal/antipodal code is transmitted instead, requiring a $2^4 = 16$ PSK modulator. Therefore, $M = 416$.

(b) The code rate is given by:

$$\text{Code Rate: } r = 8/8 = 1$$

(c) The bit rate after coding is given by:

$$R_{b2} = R_{b1} r = 10\,\text{kb/s}\ (r = 1)$$

(d) The transmission bandwidth is given by:

$$\begin{aligned} BW &= 2Rb2/\text{bits per symbol Hz} \\ &= 2R_{b2}/4 = 2 \times 10\,\text{kb/s}/4 = 5\ \text{k Hz} \end{aligned}$$

(e) Since there are four orthogonal waveforms (two orthogonal and two antipodal), the number of errors that can be corrected is quadrupled, i.e.,

$$4t = 4 \times 1 = 4$$

7.5 Conclusions

A method of coded modulation, based on N-ary complementary codes and M-ary PSK (MPSK) modulation, is presented. N-ary coded modulation is a multi-level channel coding and multi-level modulation technique, where instead of coding one bit at a time two or more bits are encoded simultaneously and then modulated by means of M-ary modulation. At the receiver, the decoder recovers the data by means of code correlation. A lookup table at the receiver contains the input/output bit sequences. Upon receiving an encoded data pattern, the receiver validates the received data pattern by means of code correlation. Construction of N-ary coded modulation schemes based on convolutional and orthogonal codes is presented to illustrate the concept. The proposed coded modulation schemes are bandwidth efficient and offer a coding gain near the Shannon's limit.

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by George Trinkaus

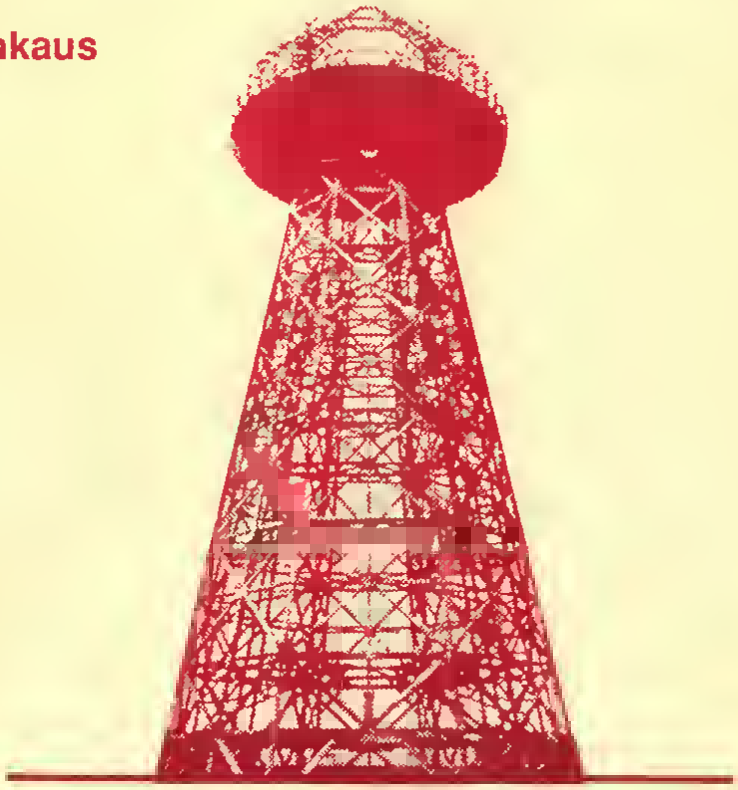

In clear English, 66 illustrations, and a minimum of math, this booklet details the peculiar radio technology of Nikola Tesla. Early elemental radio devices like Tesla's are fascinating and worthy of study because they remind us that powerful radio technologies can be so simple and accessible. Tesla's transmitters produced high-voltage, sudden-pulse disturbances conducted through the earth at low frequencies. His radio is as taboo in official science as his wireless power, which works on the very same principles. Tesla said the radio physics of Hertz, still in vogue, was an "abberation," a "fiction." Modern radio took a lot from Tesla, but what did it ignore? Also in these pages: spark reconsidered, grounding rediscovered, low frequency revived, lament on solid state, underground radio, license-free radio, the suppression of amateur radio, carrier-current radio, radio-free energy...

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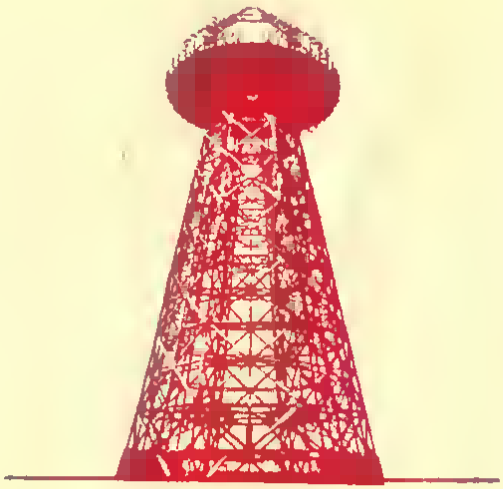

"Oscillations of low frequency are ever so much more effective in transmission." — Tesla, page 10

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Introduction

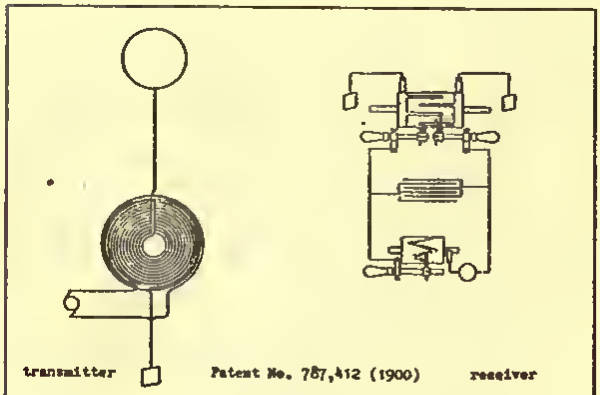

Tesla radio system

When radio was born around the turn of the 20th century, various inventors, who are not celebrated today, created their own peculiar radio technologies, which are largely ignored today. Among these inventors is Nikola Tesla, though there are others, like Nathan Stubblefield and Mahlon Loomis, who are even more obscure. The radio technology that is peculiar to Tesla, though it got a few years of public exposure in its time, gets even less acceptance in today's technology than Tesla's disk turbine, his tesla coil, or his high-frequency lighting, and Tesla's radio is as taboo in official science as his wireless power, which works on the very same principles.

In 1943, only a few months after Tesla's death, the U.S. Supreme Court, yielding finally to the pressure of a suit fought over many years, declared that Tesla's radio patents were among those that had been infringed upon by Marconi and thus, in effect, wrote into the official record Tesla's status as a founder of radio. This was a purely symbolic victory, for Tesla's radio was suppressed, and the technology that developed is distinctly different in many essential respects.

During the period of radio's most rapid growth (1915-1940), Tesla watched quietly from the sidelines, for by this time he had fallen out of favor with the media, or rather with the establishment that controls it. Still, some of his comments have made it into the published record. In 1927 he said that broadcasting "is now carried out with unfit apparatus and on a commercially defective plan." Of radio technology generally Tesla said in 1932 that "the transmitting and receiving apparatus is ill-conceived and not well adapted for selection. The transmitter generates several systems of waves, all of which, except one, are useless. As a consequence only an infinitesimal amount of energy reaches the receiver, and dependence is placed on extreme amplification."

"Radio experimenters of this age," Tesla said of the hams of 1934, "are following ancient theories." By this he meant backward theories. Tesla's favorite backward theorist was Heinrich Hertz, who saw the phenomenon of radio as some kind of straight-line radiation akin to light. Tesla said Hertz' theory, which is still in vogue today, was "one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history." This was not a reckless statement, for Tesla reports that he had carefully reviewed Hertz' experiments, conducted comparative tests with his own brand of radio and had come to a different set of conclusions. Tesla said, "I considered this so important that in 1892 I went to Bonn, Germany to confer with Dr. Hertz in regard to my observations. He seemed disappointed to such a degree that I regretted my trip and parted from him sorrowfully." Tesla made subsequent tests in 1900 with the same results and kept abreast of articles on Hertzian radio-telegraphy, which, he said, always impressed him "like works of fiction."

suppressed information

In this book I attempt to break down Tesla's radio into a set of specific principles and to survey the whole of radio technology from Tesla's perspective. While I have studied some out-of-print literature, much of my information comes from reprints still available. These titles I cite at a chapter's end together with addresses for ordering. (Addresses given on first mention only.)

For the core material on Tesla, what you have in

print is one fat hardcover book, *Colorado Springs Notes*, eight U.S. patents, and a few magazine articles by Tesla himself, one of which is titled "The True Wireless." The biggest single source, *Colorado Springs Notes*, embraces only one year (1899) of Tesla's many years in radio, albeit a very intense year. Though this work is rich in information, it represents only a tiny fragment of Tesla's total legacy, which has been said to amount to some 100,000 documents, including 34,552 pages of scientific material and 5,297 pages of technical drawings and plans. Though much of Tesla's research into radio took place in New York City in years prior to his Colorado adventure, there is no published volume called "New York Notes."

Colorado Springs Notes itself has a bizarre publishing history. Tesla's papers, confiscated by the U.S. government upon his death, surfaced years later in a Tesla Museum in Belgrade, Yugoslavia, or at least a large chunk of the expropriated material did. When the Museum, thirty or so years after Tesla's death, published the Colorado fragment, it did so in Serbo-Croatian, a curious choice since Tesla, though of Serbian origin, wrote these notes in English. What the Museum published as *Colorado Springs Notes* in 1978 (under the imprint NoLit) had been translated back into English from the Serbo-Croatian. The translator, in his appended notes, tends to discredit Tesla's version of radio. The discrepancies between the original and the translation have prompted a study by Tesla scholar John Ratzlaff called *Serbo-Croatian Diary Comparisons*.

These frustrations noted, you still have to be grateful for the relatively abundant documentation of Tesla's radio relative to what you would find in print on any other deviant radio pioneer, such as Loomis or Stubblefield.

To put Tesla in perspective, I have also read extensively in the literature of conventional radio, and, by way of grounding this information, have invested perhaps an inordinate amount of time in designing, building, and experimenting with elemental transmitters and receivers, a couple of which are illustrated in this book.

Tesla's radio principles

Tesla believed that radio was conduction, not radiation. A radio transmitter should put out high voltage delivered in pulses sharp and sudden. Tesla's radio was grounded rather than aerial. He saw radio as most potent in the lower frequencies. For both transmitting and receiving, the magnifying of effects, he believed, should be achieved with resonance and capacitive discharge rather than amplifier stages. He believed radio was a disturbance of a pervasive medium called the ether. Rather than a radiating antenna, he employed an aerial capacity. Tesla's radio inventions, like his others, show a striving for simplicity rather than complexity. He eschewed the miniaturization fashionable today, conducting his experiments on a fearless scale. Fundamental to resonant tuning was Tesla's quarter-wave principle. Tesla planned, promoted, and began construction of a World System of radio founded on these principles.

On these same transmitting principles, and with about the same equipment, Tesla experimented with his wireless power. This was a radio-like system that was to be a successor to the wired grid, which was built on Tesla's own 60-cycle alternating-current patents. Tesla's wireless power system (also patented) was designed to deliver by means of earth-electrical vibration power sufficient for industrial demands.

Tesla boasts of the simplicity of his wireless-power receiving system: "Any person skilled in the mechanical and electrical arts can utilize to advantage the practical applications of the system," by which he means that any person so skilled can construct the apparatus, receive the energy, and put it to use. Thus Tesla's system short-circuits the techno-priesthood, inviting suppression.

Tesla's wireless power has never been duplicated. Tesla is on record as saying that he lit up 10,000 watts worth of Edison bulbs wirelessly 26 miles from his magnifying transmitter at Colorado Springs, but if Tesla wrote an entry on this remarkable experiment, it is not to be found in the English version of the published *Notes*. Whatever the viability of Tesla's wireless power, his conviction that such a thing was possible testifies to his belief in the special power of his peculiar radio technology.

for more information

Tesla's Colorado Springs Notes (No-Lit) is distributed by Twenty First Century Books (P.O. Box 2001, Breckenridge, CO 80424, www.tfcbooks.com) as are John Ratzlaff's **Complete Patents** of Tesla, **Serbo-Croatian Diary Comparisons**, and Ratzlaffs' **Tesla Bibliography**.

1. High Voltage, Sudden Pulse

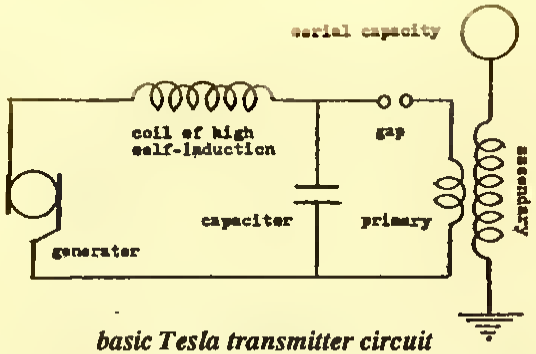

basic Tesla transmitter circuit

Tesla-style radio transmitting applies high electromotive force to the aerial-ground system – "hundred thousands or millions of volts," said Tesla. These extraordinary-sounding pressures can be achieved using the tesla coil, and fact is that Tesla's transmitters were tesla coils.

The tesla coil, with the addition of a resonant third coil and a few other alterations, becomes Tesla's magnifying transmitter, which Tesla boasted "would enable the obtainment of practically any emf, the limits being so far remote that I would not hesitate to produce sparks thousands of feet long in this manner." In Tesla radio you are happening only when your aerial glows blue.

In modern transmitters potentials in the hundreds of thousands, much less millions, of volts are unheard-of. Rarely does the voltage anywhere in vacuum-tube transmitter circuits exceed ten thousand and is usually under 1500. Antenna voltage rarely exceeds 1000. In calculating the performance of a modern transmitter, focus is on antenna current, not voltage.

sudden pulse

In addition to the high voltage, Tesla-style transmission requires sudden pulsings, in Tesla's words, "an immense rate of momentary energy delivery." This also comes easily to the tesla coil transmitter, driven as it is by the sudden capacitive discharges of Tesla's spark-gap oscillator.

Tesla's transmitters

"With electromotive impulses not greatly exceeding 15 to 20 million volts, the energy of many thousands of horsepower may be transmitted over vast distances, measured by many hundreds and even thousands of miles." So writes Tesla in a basic radio and wireless-power patent. Among the uses for this electromotive energy Tesla cites the transmission of "intelligible messages to great distances," power for "industrial purposes," the production of nitric acid and fertilizer by electrifying nitrogen in the atmosphere, and the illumination of "upper strata of air," this last item referring to Tesla's outrageous scheme to light up areas of the planet at night by beaming oscillating electric energy into the sky.

"It is a form of oscillator of great simplicity," Tesla wrote. "A coil of high self-induction is connected in series with a condenser, and across the condenser is placed a break generally in series with the primary of the coil. Very sudden discharges are produced when using a fine stream of electrolyte or mercury to effect short circuit," says Tesla, referring to one of his patented circuit controllers.

engineering

The engineering of the Tesla transmitter is the engineering of the tesla coil, and I offer, as supplement to my booklet on the subject, the following guidelines from Tesla's patents and Colorado notes:

The primary coil's inductance, and its resistance, should be as low as possible. Just one turn of heavy double cable sufficed for the 51-foot diameter primary of Tesla's Colorado transmitter, and the coil with which Tesla demonstrated wireless before the patent examiners, a coil with a flat spiral secondary, had a primary of a single turn.

The primary and secondary should have equal weights of metal. This principle helps determine the thickness of the primary conductor.

Of the secondary, Tesla wrote that its resistance, too, should be as low as possible, but the self-induction should be as high as possible. The flat spiral secondary of the coil mentioned above had 50 turns of number 10

wire. The helical secondary of the Colorado transmitter had 24 turns of number 8 on its 51-foot diameter.

A loose coupling between primary and secondary is desirable. "The mutual inductance should be small so as to permit free oscillation," said Tesla; a coil oscillates most vigorously when it is "inductively free of other circuits." The incredible excitation of a magnifying transmitter's tertiary coil Tesla attributes to its freedom from the damping effects that would result from a more closely coupled secondary. The tertiary, or "extra coil," as Tesla called it, can be located some distance from the coil stimulating it. Within the Colorado transmitter's

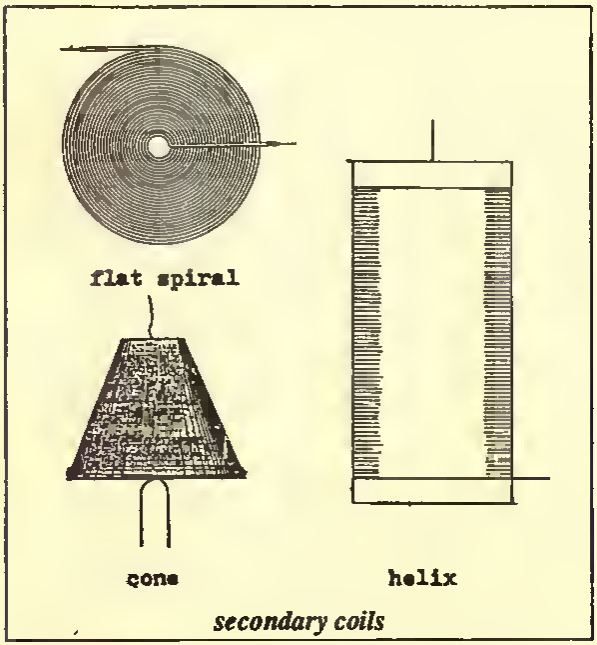

secondary coils

51-foot diameter primary-secondary coil system, Tesla would set down a tertiary, not necessarily centered. One Colorado photo shows several of these extra coils, ranging in diameters from seven inches to eight feet, placed here and there within the 51-foot enclosure, each spouting sparks.

Loose coupling for a more free and swinging oscillation is an engineering objective behind the flat-spiral secondary design. As the coil spirals in, turns become more and more remote from the primary and its inertial influence. Also, since the secondary takes on higher voltage as it spirals inward, the outer turns nearer the primary are at relatively low potential, and this helps to thwart arcing between the coils. A cone-shaped secondary offers similar advantages and is also considered superior to the customary helical.

The magnifying effect of the interacting coils, Tesla said, is "directly proportionate to the inductance and frequency and inversely to the resistance of the secondary system." This need for low resistance invites the builder to consider conductors superior to conventional copper wire. A video from Borderland Sciences

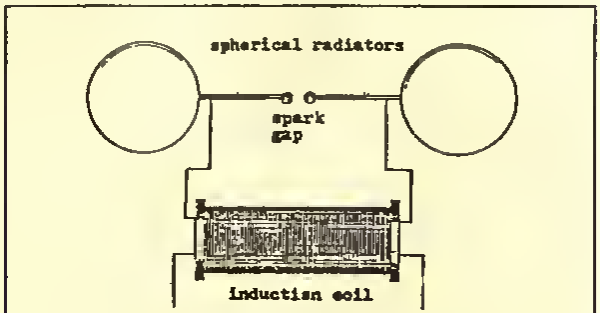

Hertz resonator

demonstrates a Tesla-style transmitter with a flat-spiral secondary made of silver-teflon coaxial cable; the shielding is the conductor. The same coil has a primary of bronze strap.

Tesla tuned his transmitters for "maximum rise of

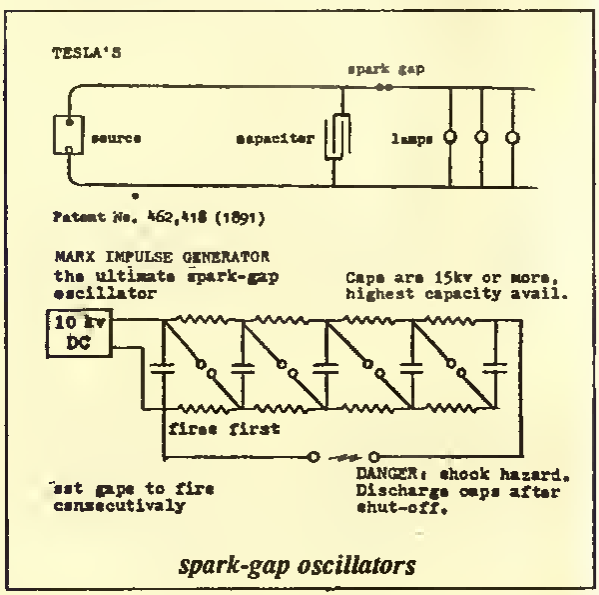

spark-gap oscillators

emf on the excited system," as indicated by a small incandescent bulb connected in a single loop around the final coil. Tuning was aided by a regulating coil and by an adjustable spark gap in the ground circuit or by a gap shunting part of the secondary. He observed that "the tuning is remarkably exact, 1/8 turn of the self-induction box reducing the effect very much." He said, "It becomes easy to locate the maximum rise within one-quarter of one percent." He described his transmitter's tuning as "very sharp."

spark

Spark radio is high-voltage, sudden-pulse. Spark is as old as radio itself. Radio was supposedly discovered by somebody wondering about spark noises in a telephone. Hertz' experiments used spark. The induction coil with spark gap is the first radio transmitter. The next advance put a capacitor in the circuit, as in Tesla's spark-gap oscillator. This Tesla invented not for radio but for an early high-frequency lighting system. For radio, Tesla used his all-purpose oscillator, the tesla coil.

As radio moved into the future, leaving Tesla behind, the spark transmitter that came into general use was not a tesla coil but a truncated version in which the magical resonant secondary was lopped off. The power supply was an induction coil which one could build or buy. One manufacturer advertised eleven models providing sparks from 1/4 inch to 8 inches. Antenna and ground were connected to a primary-like helical coil called a transmitting helix. The rarity of true tesla-coil transmitters in the literature suggests that this potent oscillator may have been a well-kept secret even in the spark era.

"spark forever"

"Using spark allows obtaining of great suddenness," said Tesla. No modern tube or semiconductor can match disruptive discharge for rapid switching of high energy without blowing apart. The history of radio reports that operators were satisfied with spark. "The pervading spirit was one of complete complacency with regard to the technical status of the art," according to one historian. A 250-watt spark set went 300-400 miles, and with spark that power was easy to come by. The circuitry is simple, the parts easy to find even today for those in the know about tesla-coil building. If you needed to throw together a telegraphic radio signalling device in a pinch,

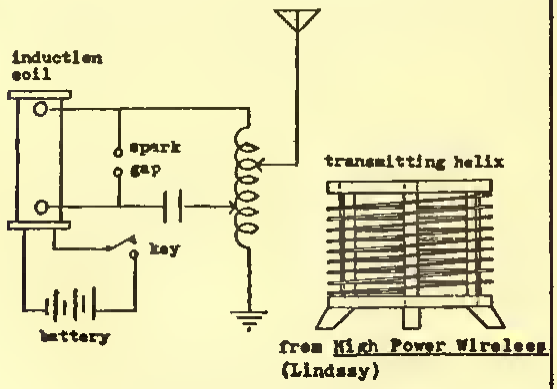

spark-gap transmitter with helix

spark might be the way to go, and even voice modulation is possible, as we shall see.

The sudden-pulse spark-gap oscillator could be used to drive a microwave cavity resonator (page 7).

Could a self-powered spark transmitter be created from a static machine? (Also page 7)

Radio operators, both commercial and amateur, resisted mightily the movement to suppress spark and replace it with tube oscillators, which they saw as costly, complex, and relatively ineffectual. The anti-spark movement was imposed from above by industry and government. Imprinted on some of the QSL cards

author's experimental spark transmitter

hams sent through the post to confirm contact was the slogan "spark forever." Resistance continued into the 1930's, and, who knows, there may still be a few covert spark operators out there in the night.

cleaning up spark

The problem imputed to spark was broadness of signal and harmonic noise in radio bands which were becoming progressively more crowded with competing communicators. Desired was a sharp, clean signal that occupied only the thinnest slice of the busy radio spectrum. There is nothing in the FCC Code for amateurs that prohibits spark itself. The Code does set strict emission standards that the rudimentary transmitter of the spark era had trouble conforming to.

The common historical impression is that spark transmitters were uniformly and inevitably crude and

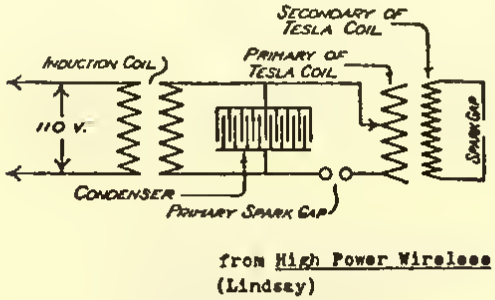

tesla-coil transmitter (1910)

that the new vacuum-tube transmitters, using feedback principles of oscillation, came along like white knights and cleaned up the spectrum. Fact is, though, that toward the end of the spark era transmitters using evolved spark technologies were developed, manufactured in numbers, and saw long service on land and sea, sharing the bands with the incoming tube (and arc) transmitters. Although any spark transmitter, no matter how sophisticated, dissipated some of its power in harmonics, these advanced spark rigs produced relatively clean and narrow fundamental signals and the smooth, damped, "continuous waves" boasted by the

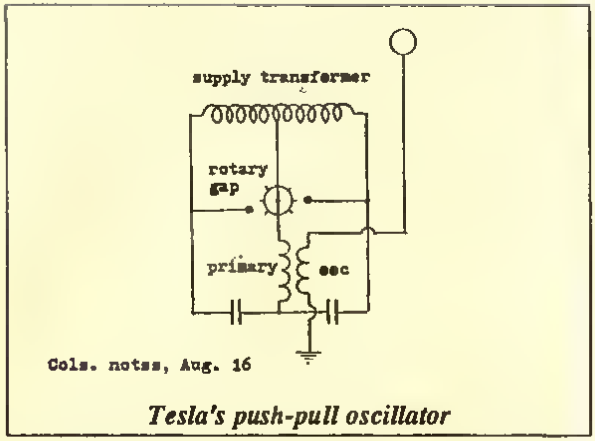

Tesla's push-pull oscillator

promoters of the new tube transmitters. Even after ships were routinely equipped with tube rigs, radio operators insisted on keeping on board as auxiliaries their old reliable units with spark.

The engineering of superior spark transmitting focused on improving the quenching (shutting off) of the gap: the technology of airtight series gaps, magnetic blow-outs, and rotary gaps. Perfecting of the spark gap got a lot of attention from Tesla, and perhaps his patents were studied by radio engineers, but not necessarily.

Tesla anticipated the push-pull circuit common in

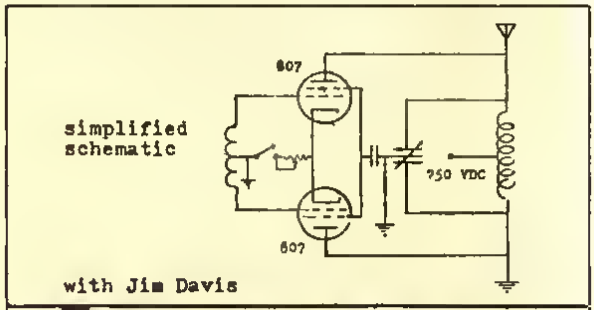

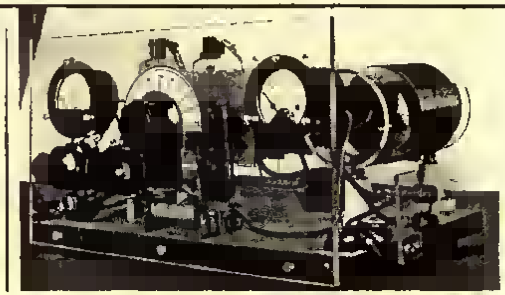

author's push-pull tube transmitter

amplifiers and transmitters. Tesla ultimately replaced the spark gap altogether and achieved disruptive discharge with ingenious high-energy mechanical "breaks," including rotary mercury switches and mercury jets. Tesla said that his transmitters produced continuous

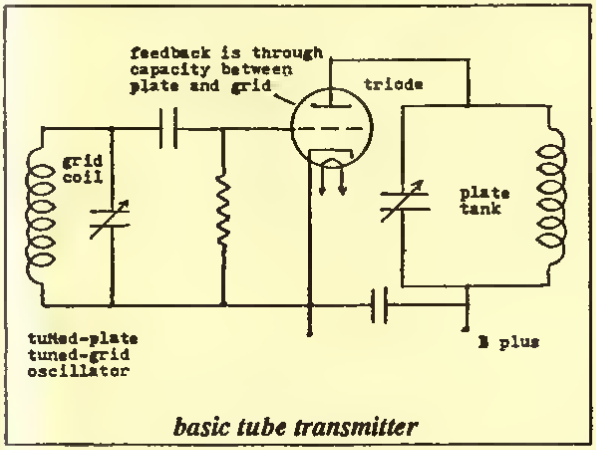

basic tube transmitter

waves. Evolved spark transmitters used synchronous rotary gaps which coordinated the charging rhythm of the capacitor with the frequency.

A feature of Tesla's magnifying transmitter design that discourages undamped waves is the single-turn

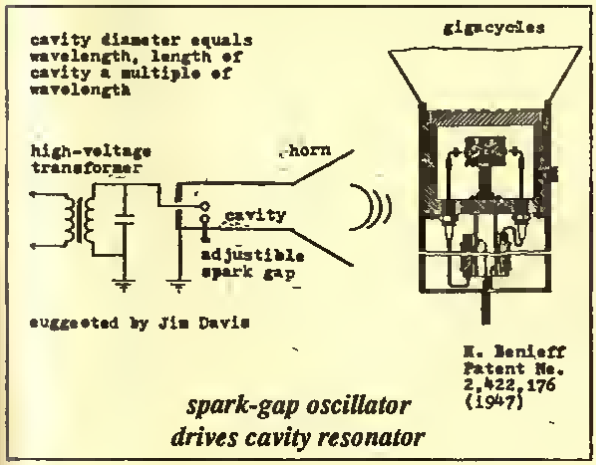

spark-gap oscillator drives cavity resonator

primary. This reduces the induction of the primary circuit so that unwanted oscillation cannot occur there. The same provision shows up in the only magnifying transmitter circuit I have seen in radio outside of Tesla's.

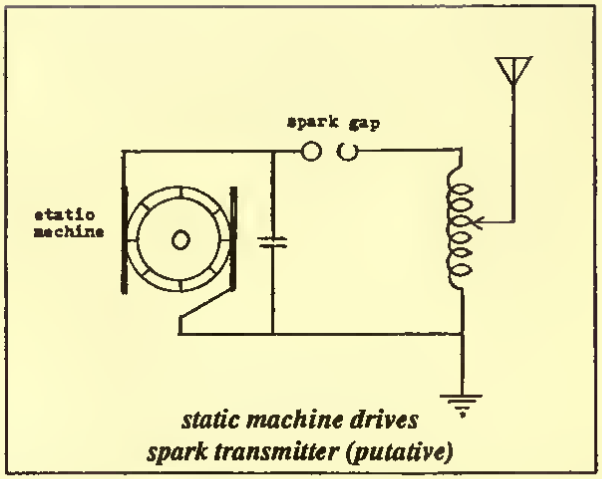

static machine drives spark transmitter (putative)

Called the impact transmitter, this circuit from the spark era featured quenched gaps in tandem. The name belies an understanding of Tesla-style sudden-pulse transmitting. Knowledge of the impact transmitter, patented by Oliver Lodge, was never widely circulated to the public and remained a secret.

Can you modulate spark?

The general impression is that spark is strictly telegraphic, but, fact is, spark transmitters can be modulated.

For telegraphy, tone modulation is inherent in spark, the tone being determined by the frequency of the gap. Rotary and series gaps produce characteristic tones

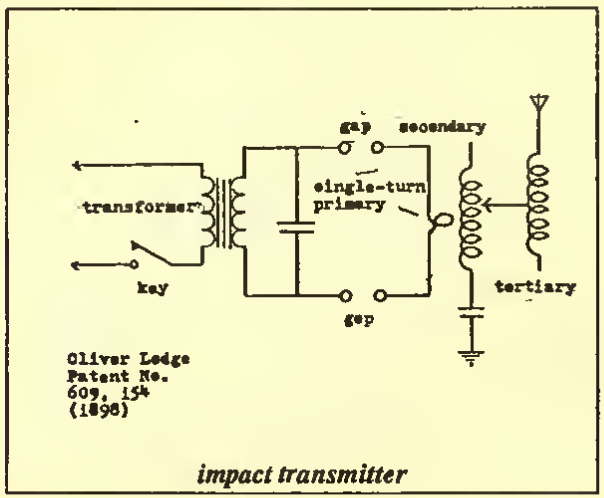

impact transmitter

that help telegraphic signals cut through static noise. (Tube and transistor transmitters require separate audio-oscillator circuits to impose a tone, yet another complexity.) Voice modulation requires that this spark sound be eliminated, that the frequency of spark dis-

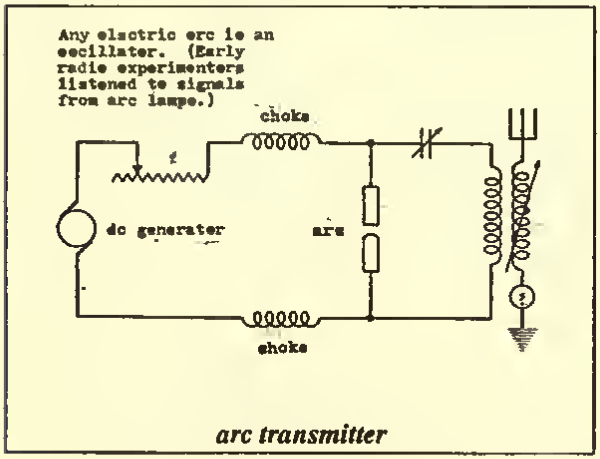

arc transmitter

charges be raised to at least 5000 sparks per second. As early as 1900, Reginald Fessenden achieved bona-fide radio telephony with a spark transmitter. He probably used a very simple and now-forgotten method known as absorption.

A precedent for absorption modulation is to be found in the technology of alternator transmitters. Tesla, the inventor of the ac generator, or alternator, had

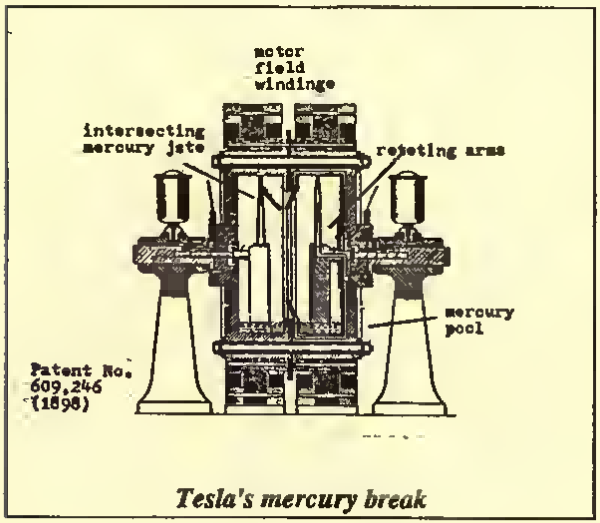

Tesla's mercury break

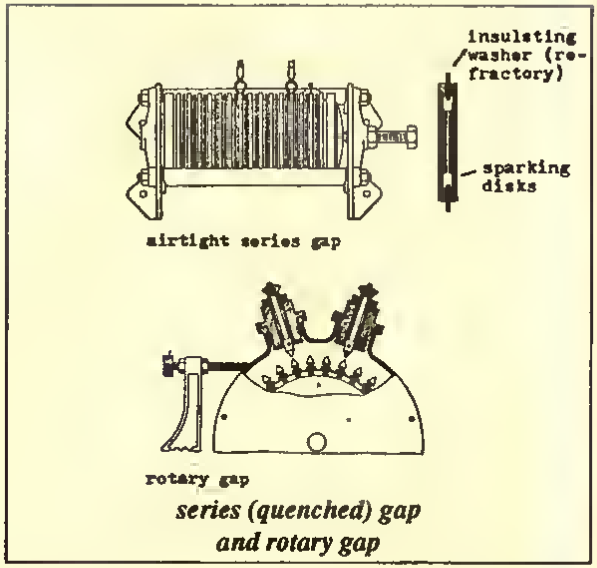

series (quenched) gap and rotary gap

experimented with units having many poles and capable of frequencies of up to 20 or 30 kc. These he intended to use not for radio but for his high-frequency lighting. Tesla abandoned the alternator early on in his experimenting because of its frequency limitations and developed his spark-gap oscillator and tesla coil for his lighting. Ironically, it was an alternator quite similar to Tesla's that became the first overseas radio transmitter. Fessenden developed a 50-kilowatt dynamo. Alexanderson scaled this up to 200 kilowatts. These huge alternators (they looked like power-plant dynamos) were put into service parallel with spark. Alternator radio necessarily remained low-frequency (often so low that voice was not possible) with long antennas and deep groundings. Unlike spark, the high-RPM alternator could not be turned on and off for telegraphy. So how did they key an alternator? The solution was a magnetic shut-off, which works on a principle similar to that of absorption modulation. Notice that the shut-off is in the ground circuit, suggesting that alternator radio was construed as a grounded radio. Absorption modulation for radio-telephony was installed in the circuits of either the antenna or the ground. Fessenden, in 1906, broadcast a program of music and speech with an 80 kc alternator.

In vacuum-tube transmitting, expensive high-power audio amplifiers are necessary for plate modulation, the respectable mode; grid- and screen-modulation also

require audio amplifiers, though of lesser power. The inexpensiveness and simplicity of absorption modulation tempts experimenters who seek a simpler radio technology. I have seen the method described as "crude" in a 1924 radio book where it pops up, but no specifics

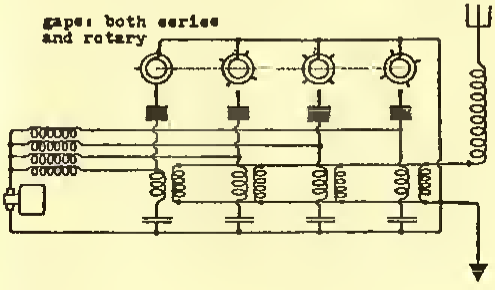

continuous-wave spark transmitter

were given. Is it necessarily low-fi? Does it cause unwanted FM effects, widening the band-width unacceptably? I have seen reference to the carbon microphone overheating in multi-kilowatt rigs. The cure was a water-cooled microphone. KQW in San Jose, California broadcast voice and music circa 1912 on an arc transmitter heard for about a thousand miles, and WLW in Chicago boomed on the AM band in the early '30's with a half-megawatt spark transmitter. Both used the antenna-absorption method.

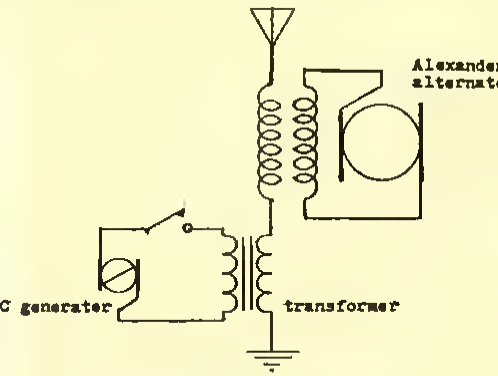

magnetic shut-off

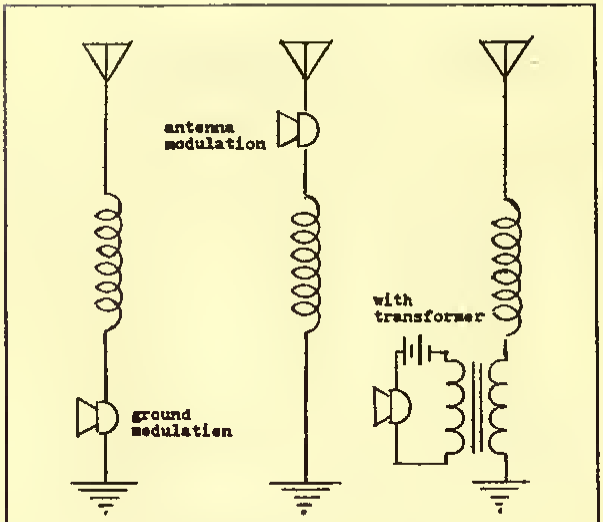

absorbtion modulation

Tesla's available notes and patents tell us very little about his particular modulation schemes (his Colorado notes show an "arc controller"), but as the promoter of a world broadcasting system he seemed supremely confident that his magnifying transmitters could be modulated.

The passing of spark marked the end of Tesla-style high-voltage, sudden-pulse transmitting.

for more information

Tesla Coil by George Trinkaus. A how-to for the nonexpert. How Tesla did it. How you can from off-the-shelf parts. (High Voltage Press). **The Tesla Coil Designer** by Walt Noon is a computer program. (3283 Belvedere, Riverside, CA 92507). **Theory of Wireless Power** (book) and **Tesla's Longitudinal Electricity** (video) are among many Tesla titles from Borderland Sciences (P.O. Box 6250, Eureka, CA 95502). **Lindsay Publications** has many pertinent titles. (P.O. Box 12, Bradley, IL 60915).

2. Low Frequency

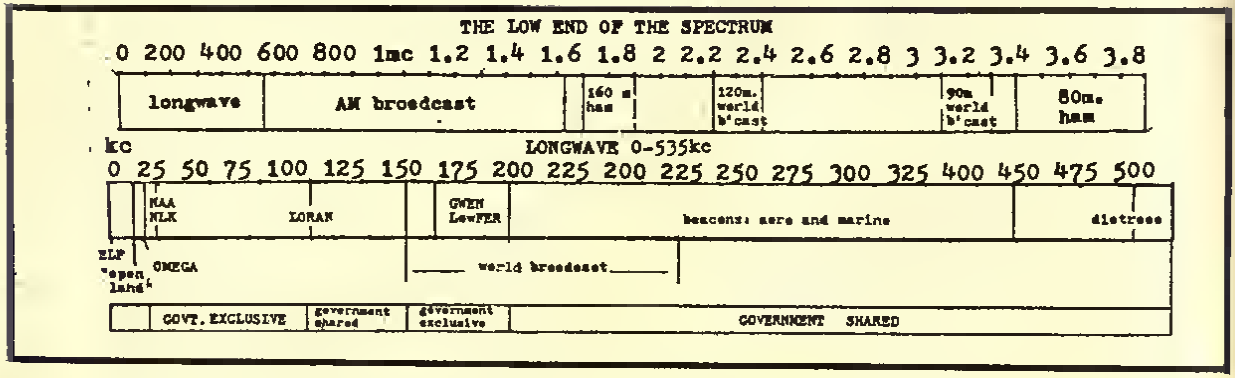

"Oscillations of low frequency," said Tesla in 1919, "are ever so much more effective in transmission, which is inconsistent with the prevailing idea." Radio at low frequencies (below the AM broadcast band) delivers more distance per watt. It is less vulnerable to atmospherics than shortwave. It does not suffer from the fade-in-fade-out syndrome that plagues shortwave. Low frequency radio is less affected by the sun. While much of shortwave is blotted out in daytime, low-frequency propagation is strongest at midday.

In early radio, the superiority of low-frequency was taken for granted. Shortwave was considered useless. But as radio attracted more practitioners, there inevitably developed a struggle for elbow room within the limited confines of the recognized radio spectrum.

who owns the ether?

Not surprisingly, the very first entity to claim ownership of the increasingly precious spectrum real estate was Government, in particular that of the U.S. through its navy. The U.S. Navy between 1900 and 1910 made several attempts to put radio under its sole control. The Navy, which during this period was already developing global marine communications and radio-navigation systems, was so assured of its right to rule the ether that it campaigned Congress for a monopoly of all of radio, both point-to-point and broadcast on sea and land worldwide.

The Navy also fought for the phase-out of spark and the development of a more refined radio. It set the specs for industry to develop the new continuous-wave technology.

Of course, the spectrum had not been waiting silently for government to step in and regulate it. The ether was already abuzz with activity, much of it conducted by the independent citizen-experimenters who ultimately became labelled (did they think it condescending?) as "amateurs."

The Navy introduced into Congress a series of bills that had the standard formula of providing for different classes of stations that would be registered and licensed, and then making it illegal for any outsider to interfere with these stations. No mention was made of the amateurs, whose transmitting stations (largely spark) were to number about 6000 by 1916. Thus, in these early legislative attempts, the hams were rendered de-facto outlaws. The Navy's campaign was ultimately joined by the Department of Commerce and by such commercial interests as Marconi's United Wireless. The hams, to defend themselves, organized into the still-active American Radio Relay League.

The legislation that finally passed (1912) did recognize the hams but banished them from any activity in the low frequencies. This was in the spirit of yes-you-can-go-swimming-but-don't-go-in-the-water, for low-frequency radio was all the radio there was. The short waves were then considered not only inferior but unworkable, the desert real estate of the spectrum.

The Government's final solution to the problem of a peoples' experimental radio was achieved, albeit briefly, in World War 1 when all amateur radio was

flatly outlawed for the duration. The Emergency Order, which came from the Dept. of Commerce and was signed by the Navy, banned not only transmitting but short- and long-wave listening as well. The order put radio under the full control of the Navy, which then tried to persuade Congress to make this situation permanent. Ultimately, federal control of radio was to pass out of the control of the Navy and into the Dept. of Commerce, until the Radio Act of 1934 created the FCC.

WWI also provided the opportunity for the government's destruction by dynamite of Tesla's magnifying transmitter tower, which still stood sturdily at Wardencliff, Long Island, a curiosity to passers-by. The excuse given was that the tower could be used by "spies," but the intention must have been to erase this monument to Tesla's alien radio and wireless power.

During WWII the government ordered another blackout of amateur radio.

The hams are still on the defensive. As I write the ARRL is dealing with a threat to yet another amateur territory way up in the spectrum at 222 megacycles, a band United Parcel Service and others are pressuring the FCC to reallocate to land-mobile uses.

The low frequencies, under the control of government, have been allocated to military and other bureaucratic functions, to navigation beacons, like Omega (10-14 kc) and LORAN (100 kc), and for weather stations, and time registers. Tesla had suggested low-frequency navigation systems. Some of the military transmitters are humungous, like the Navy's 3000 acre NAA command facility (24 kc) that runs 2 million watts and ELF down at 76 cycles, which uses antennas over 50 miles long.

citizens' radio

The government-military takeover of radio (nearly 100 percent of the low bands and much of the upper spectrum as well) has impacted on the amateurs, who have had to justify themselves as a quasi-government "service" in order to retain the privilege of radio. The amateurs' awkward posture is: "We are an emergency service, but, until an emergency comes up, we'll just be jawboning here to keep these bands open."

As early as 1925 the hams were building close functional relationships with the military. During the amateur blackout of WWII, many hams, as a way of staying active, enlisted in a military-run civil-defense program called the War Emergency Radio Service. Before government had a police radio, there was an amateur service that assisted the police in matters such as recovering stolen cars.

The fact that there is any nongovernment or noncommercial radio is obscured from the public consciousness. While hams sometimes get a few seconds on the tv news when they are performing their public service during an earthquake, the general public is given little awareness via the mass media that such a thing as a citizen's radio exists. On the tv the only character holding a radio mike is a cop.

A colorful wall-poster chart of the entire radio spectrum published by the Office of Spectrum Management (a bureaucracy within the U.S. Department of Commerce's National Telecommunications and Information Administration) provides elaborate color coding of 28 radio services, including broadcast, radionavigation, amateur, etc., but has no code for a citizens radio, and the 40-channel citizens band at 27 mc is ominously absent from the chart.

Regulation of the ether can never be absolute. Some governments, like Italy's, have had to abdicate some of their control over broadcasting to independents ("pirates"). Pirate radio and tv flourish where a state radio tries to dominate, and, by the same dynamic, where broadcasting is dominated by a handful of media corporations acting as one, piracy will predictably rise up. (Some people believe in keeping a gun in the house by way of providing for some impending political catastrophe. I'm not a gun person, but I do advocate keeping a transmitter handy. Does the First Amendment guarantee the right to bear transmitters?) The FCC once thought that it controlled CB, but when CB exploded with the advent of inexpensive transceivers made possible by the phase-lock loop frequency synthesizer, the government found it could not enlist the cooperation of all operators in a licensing procedure and threw up its hands. CB may be anarchy, but it still works, and the FCC can't do much about the kilowatt linears anyway.

black-box consumers

There is little encouragement for hams or anybody else to explore radio experimentally. The literature testifies to a time when way opened more easily for the curious and the experimenter. Published between 1900 and 1930 were at least twenty different monthlies for the electrical experimenter. These publications were full of projects, including transmitters and receivers, that one

could build in the basement workshop from parts easily available at independent dealers. Tesla, who published in the popular press, while avoiding the academic, was a star contributor to some of these magazines. The reader was assumed to be an experimenter, a builder, and capable of sustained thought, judging from the prose. Today he is assumed to be, above all, a consumer.

The typical ham through the 1930's built his own station, transmitter and receiver. By the mid-1940's he was still likely to build his own transmitter (though manufactured units were becoming available), but by then he had been persuaded that the manufactured receiver was superior to anything he himself could

DO NOT REMOVE COVER.
NO USER-SERVICABLE PARTS INSIDE.

build. Since the '60's the ham has bought both transmitter and receiver (even most of the kits popular in the '50's are gone), and today he is encouraged to buy, for $800 and up, both units boxed into one solid-state transceiver. Once an experimenter and builder, the ham of today is encouraged to become just another dependent consumer of black-box electronic components, which he himself often cannot even repair. In the case of broadcasting, the FCC prohibits a licensed operator of an AM, FM, or tv station building his own transmitter, and the FCC dictates design, hence cost. Today, among the few who build their own, is the pirate broadcaster, though he is also likely to convert an old ham rig. Many of the radio listeners of yesteryear built their own receiving sets for broadcast AM listening as well as shortwave, but by 1930 this became unfashionable due to the abundance of manufactured units.

With today's integrated circuits, even the do-it-yourself discreet-component builder and experimenter becomes a consumer of tiny black boxes whose concealed workings he may only dimly understand.

Sealing up electronics in black boxes discourages the curious, while it promotes a priesthood, and so does the conventional electronics education and its textbooks. The innocent student, from the first day, is snowed under with mathematical formulae – information that could be useful someday if he were allowed to engineer a circuit, but it cannot tell him how electricity works. (Your author in his checkered past was an editor of a series of those "basic" electronics texts; his Tesla work may be an act of penance.) Tesla, a consummate mathematician, was skeptical of mathematical explanations. He called Relativity "a mass of deceptions wrapped in a beautiful mathematical cloak." Tesla had no good words for the electronics theory that grew out of quantum and Einsteinian physics. He is on record as saying that "there is no such thing as an electron."

low-frequency revival

While conventional histories congratulate the amateurs for turning shortwave into viable radio (the hams invented the shortwave technology the Navy and others would adopt), the allocation of hams to frequencies above 1500 kc meant their exile from superior turf. The banishment of hams from long-wave along with the romancing of the shortwaves has resulted in the almost complete lapse from public memory of low-frequency radio and what it means. This is particularly true in the U.S., for there is some long-wave broadcasting abroad, which, incidentally, can be received here to some extent on both coasts.

But in recent years there has been a revival of longwave. Low Frequency Experimental Radio people (LowFERs) transmit license-free in the 1750-meter band (160-190 kc) with government sanction under Part 15 of the Federal Communications Act, the same little-known part of the law that permits flea-power community broadcasting. The law limits LowFERs to just one watt and to a 50-foot antenna-ground system. Under

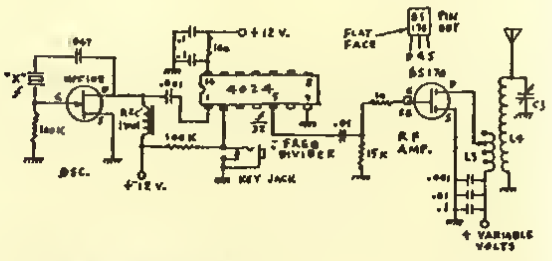

from The Low Frequency Scrapbook by Ken Cornell

low-frequency transmitter (160-190 kc)

ideal conditions, a legal LowFER signal can be heard for up to 1000 miles, testimony to the power of longwave. But there are so many competing disturbances in these frequencies from broadcast harmonics, powerline harmonics, powerline-carried noises from motors and light dimmers and many other inadvertent transmitters, that reception is almost impossible in urban environments. Most LowFERs set up telegraphic beacons, listen for each other, and report reception in their networking newsletters, publications that are in the avant-garde of experimental radio. LowFERs are among the few who build their own. LowFERs remain true to the experimental spirit that marked early radio. They are willing, as one LowFER put it, to "reinvent the wheel." LowFER reception requires the experimenter to go mobile into the boondocks where it's electronically quiet, but even then signals may be overwhelmed by GWEN, a nuclear-doomsday Air Force system having about one hundred sites across the country. GWEN operates in the same band assigned to the one-watt LowFERs and its stations rehearse daily, emitting bursts of heavily encrypted radio teletype. (The same federal spectrum chart that forgets CB assigns a "govemment exclusive" code to all of LowFERland.)

Most LowFERs are resigned to working experimentally within the challenging constraints of the government-mandated one watt, but some are agitating for more practicable levels of power.

Closely allied to the LowFERs are the MedFERs, medium-wave experimenters who operate just above and below the AM band with a 100 milliwatt power limit, the same flea-power limit applied to community broadcasters. The upper MedFER territory has been opened to commercial broadcasters, but these experimenters will continue in the band until displaced. A few broadcasters are already operating in the band; their viability depends upon the manufacture of receivers with extended AM-band coverage.

carrier-current radio

When amateur radio was outlawed in WWII, the only activity open to hams, outside of enlisting in the Wartime Radio Service, was a low-frequency radio propagated over the power lines. Called carrier-current or wired wireless, this little known mode of radio is particularly effective at low frequencies. Line transformers tend to choke out high frequencies, but low frequencies

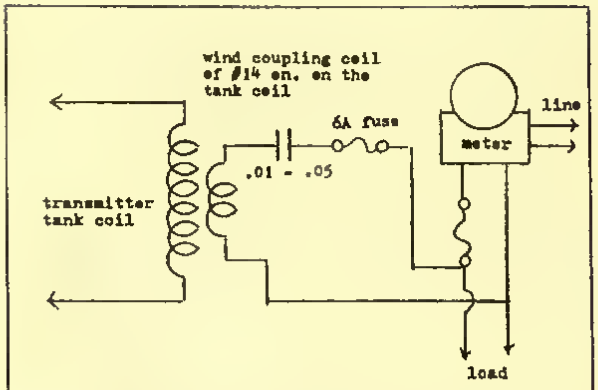

a carrier-current coupling to power lines

conduct through. The WWII hams worked voice and code down at 160 to 200 kc.

Power companies use such a low-frequency system today to transmit information between stations. Powerline carriers are another nuisance to low frequency listeners.

For the independent broadcaster, carrier current is an option. Within flea-power watt restraints, it's even legal under Part 15. Independent and community broadcasters use carrier current for transmitting both AM and FM. Receivers need not be coupled to the lines; even car radios can get the signal from the overhead wires. Though the AM band is five times higher than the frequency a power company or a WWII ham would use, AM probably does some penetrating of transformers. I recall that my college AM carrier-current station did a good job of getting around the entire campus as well as much of the adjoining small town.

open land

Did you know that in the basement of the very crowded, highly controlled radio spectrum, down at 0 - 9000 cycles, there is no government regulation? Thus, this unallocated very low frequency band is open to unlicensed experimenters at any power level. Conceivably, one could set up point-to-point communications using just everyday audio amplifiers. An underwater diver communication system uses 10-watt audio amplifiers. Output is connected to widely spaced submerged electrodes as antennas. The idea might be tempting to audiophiles who would be radiophiles. A problem would

be the noises, both civilized and natural, that abound in this band, particularly the 60-cycle power-line hum and its harmonics. Another problem is that any one voice-modulated signal would consume the entire band within its range for the duration of the transmission.

low-frequency listening

When shortwave came into fashion, the lower frequencies became de-facto off-limits to the listening public. But lately, along with the LowFERs, the low-frequency listener is coming back. There is a growing curiosity about what goes on in the forbidden territory below the AM broadcast band.

To tune in reliably to distant LowFER beacons takes a sophisticated receiver with crystal filters and one kilocycle dial resolution, but I can testify to the enjoyment provided by seeking stronger beacons on my simple, one-transistor, uncalibrated home-built regenerative unit shown later herein. If you own a shortwave receiver, you may want to try a solid-state converter like the one shown above. Beacons are radio-telegraphic lighthouses that repeat slow alphabetic identifiers (good code practice). Called NDB's in LowFER jargon, marine non-directional beacons run only about 25 watts, while the FAA's aeronautic beacons can go to a kilowatt. There are directories that can tell you the location of beacons heard, if you want to take it that far. Also you may hear maritime ship-to-shore telegraph as well as big military transmitters, along with a lot of other strange signals you just have to wonder about. Receiving the megawatt foreign low-frequency broadcast stations is a possibility if you live on either U.S. coast. Any low-frequency listening is subject to suppression by civilized electrical noise and benefits from a nonurban environment. It is in urban listening that the expensive well-filtered receiver pays off.

natural radio

With a very low-frequency receiver (below 30 kc), you can hear the sounds of natural radio: spherics, hisses, pops, chirps, tweaks, whistlers, as well as something called the dawn chorus. Tesla listened to the sounds of VLF radio and conjectured that among the disturbances were signals from Mars. ("A clear suggestion of number and order," he noted; "impossible to think accidental...a purpose was behind these signals.") Experimenters today who tune in to nature's radio use receivers of

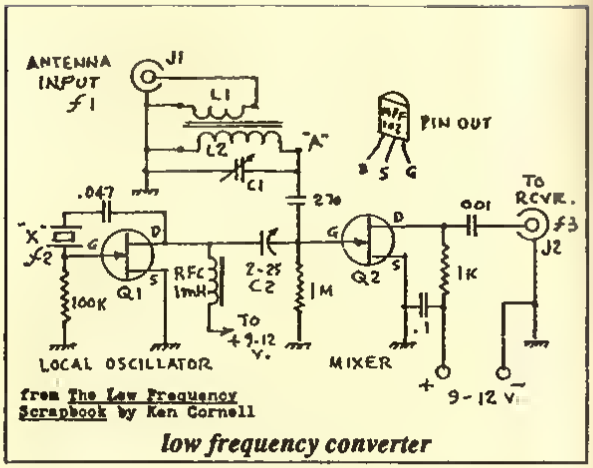

low frequency converter

various degrees of sophistication, but, according to Michael Mideke in his *Sounds of Natural Radio*, "given a large enough antenna, even amplification can be dispensed with; signals can be heard using nothing more than headphones connected between antenna and ground."

for more information

200 Meters and Down, The Story of Amateur radio by Clinton DeSoto, 1936, (ARRL, 225 Main St. Newington, CT 06111). **U.S. Frequency Allocations, The Spectrum** is a full-color wall poster chart (U.S. Govt. Printing Office, Washington D.C. 20422). **High Power Wireless** (1910) and **The 1934 Official Shortwave Manual**, Hugo Gernsbach, ed. (all three from Lindsay). **The Lowdown** is the LowFER and MedFER newsletter, Bill Oliver, ed. (Longwave Club of America, 45 Wildflower Rd., Levitown, PA 19057). **Carrier Current Techniques** by Ernest Wilson (Pan Com, P.O. Box 130, Paradise, CA 95969). **Low and Medium Frequency Scrapbook** by Ken Cornell, the bible of LF tech (225 Baltimore Ave., Point Pleasant Beach, NJ 08742). **Tesla: Contact with Mars** (Rex Research, P.O. Box 19250, Jean NV 89019).

3. Conduction Through the Ground

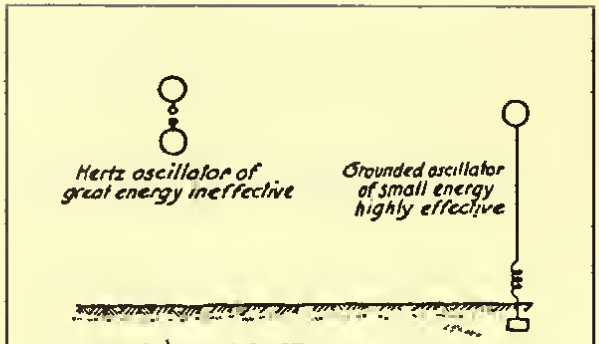

Hertzian vs Tesla radio

The propagation of radio signals and wireless power Tesla saw as a matter of conduction. Tesla's radio-conductive path was not a circuit in the conventional sense but was modelled on the single-wire-without-return principle that he demonstrated in his high-frequency, high-voltage lighting system. Electric researcher Eric Dollard calls this one-way conductive effect "longitudinal electricity."

Tesla's radio-conduction can happen either through the earth or through the sky. Tesla said, "The earth behaves simply as an ordinary conductor." He said the earth was superior conductor; but, pertinent to sky transmission, Tesla is on record in a patent as saying that "transmission through elevated strata encounters possibly less resistance than copper wire."

Conventional theory never hints at radio propagation being anything like conduction but represents it as some kind of radiation. This is more than a textbook convention; a whole science of antenna design is based on this assumption, which Tesla dismissed.

an etheric medium

What is radio, anyway? The texts, like my *Radio Amateur's Handbook,* speak of radio as "radiation." But, at the same time, it is a "wave." Then again, in the same paragraph of the *Handbook,* which is just echoing respectable physics, we are told that it is "traveling electrostatic and electromagnetic fields." Whatever it is, some sort of almost material emanation is presumed to be issuing from the antenna into a void.

Tesla, however, saw radio as a "disturbance of the medium," or a "commotion in the medium." He writes of "transmitting an electrical movement to the environing medium." What is this medium?

In Tesla's time it was an article of faith that there existed a unified field that permeated all being, all matter, including solids, liquids, and even what we call space or vacuum. This pervasive "ether," as it was called, is the medium of radio. The transmitter sets up a disturbance that produces, says Tesla, "alternate compressions and rarefactions in the medium." This suggests some kind of elastic continuum that conducts standing waves.

Coming from this view, all electric phenomena — charge, polarity, oscillation — involve some kind of strain or vibratory disturbance of the equilibrium of the ether.

The etheric perception of radio came naturally to early experimenters. Loomis writes of his aerial telegraphy as "causing electrical vibrations or waves to pass around the world, as upon the surface of some quiet lake one wave circle follows another from the point of disturbance to the farthest shores."

In Tesla's radio, effective transmitting is achieved by setting this elastic medium vibrating with a sudden high-voltage whack, like that created by the discharge of a capacitor.

grounded radio

Hertzian radio has us all conditioned to thinking in terms of aerial radio: "the air waves," "on the air." Extreme importance is placed on the antenna and its

configurations, which can become byzantine. But Tesla's radio is not aerial. It is ground-conduction. The lower end of the energized coil is rooted in the earth. Pure Herzian radio has no such natural load. Modern radio regards earth ground as an electronic toxic waste dump to which noise is conducted. Tesla said radio "should be designed with due regard to the physical properties of the planet and the electrical conditions obtaining in same."

The electrical vibrations of the transmitter are "communicated to the ground," says Tesla. Here they set up standing waves — "outgoing crests and hollows in parallel circles." He said, "The terrestrial conductor is thrown into resonance with the oscillations impressed on it like a wire." Tesla was convinced that the waves were not "electromagnetic" since such waves were not likely to travel through the earth. Tesla's ground wave, unlike Hertz' aerial, does not travel uniformly at the speed of light and can even reach a velocity that is infinite.

Oscillating the entire electrostatic Earth was among Tesla's many ambitions, and he observed that "the planet behaves like a perfectly smooth and polished conductor of inappreciable resistance." He went on to characterize the globe as having "capacity and self-induction uniformly distributed along the axis of sym-

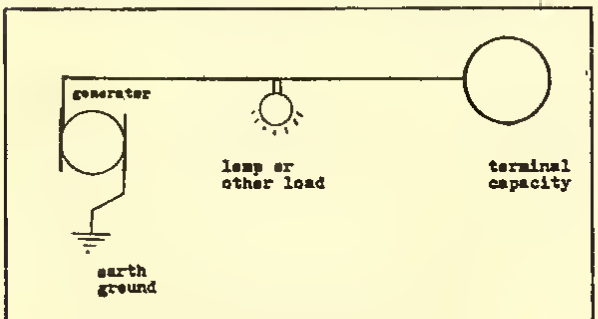

single wire without return

metry of wave propagation." In the same text (a patent applied for in 1902), Tesla added that these standing waves propagate "without attenuation." That is, he is saying they do not diminish in intensity over distance.

no ionosphere

Tesla believed Hertzian aerial radio was a waste of energy. Tesla suggests that there is some radiation

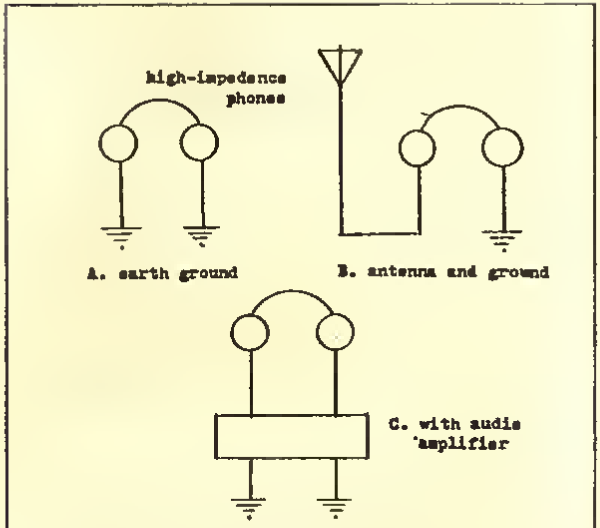

audio-frequency grounded radio

component in a radio transmission but that it is a weak and incidental output. He thought the theory that high-frequency signals travelled long distances by bouncing off some high-altitude, radio-reflective layer called the ionosphere was "an utter impossibility." Tesla was not alone in disputing the existence of the Heavyside Layer, as the ionosphere was called then; it was quite controversial for a time before it was frozen into official science. Tesla said that Hertz wave theory "by its fascinating hold upon the imagination, has stifled creative effort in the wireless art and retarded it for 25 years."

audio radio

In World War I, when field telephones were used that stretched long wires over the surface of the ground, it was discovered that one could eavesdrop on opposing forces' conversations just by connecting headphones to ground rods. This discovered, effective monitoring systems were developed by both sides that consisted of two widely separated ground rods connected to a sensitive audio amplifier. Here was a Tesla-like radio: low-frequency conduction through the earth. There is no reason you cannot use this principle for an audio-frequency radio in the unregulated open land below 10 kc. When you consider that radio can happen in the

audio band, you have to wonder about the term "radio frequency" (rf), as in "rf energy," etc., which seems to imply that radio is a function of frequency.

Disturbances caused by the various electrical happenings in nature, such as lightning-created static crashes, an occasional whistler, and other strange sounds can also be heard using the above system, and it so happens that the WWI eavesdropping apparatus was sometimes totally jammed by such natural activity.

underground radio

A follower of Tesla, James Harris Rogers, patented (1920) a radio system in which both sending and receiving antennas were sunk completely underground or underwater. Rogers had his own doubts about Hertzian radio. He wondered, "If 50 units of power are passed into the aerial, then what becomes of the equal amount of energy which passes into the ground?"

Roger's was working at low frequencies, but nothing in his patents limits his grounded radio to the low band. The Rogers underground achieved superior signal strength. According to accounts, reception was free from atmospheric static, and there was no diminishing of the signal in daytime.

The Navy used the Rogers system secretly in WWI and announced it to the public in 1919. An editorial by

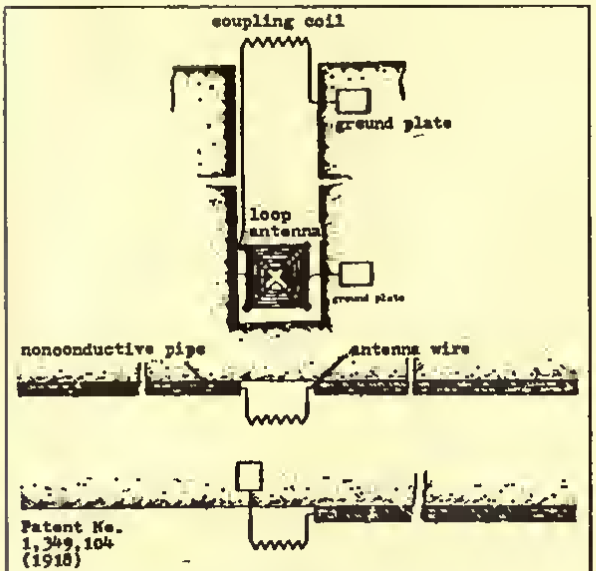

Rogers underground radio

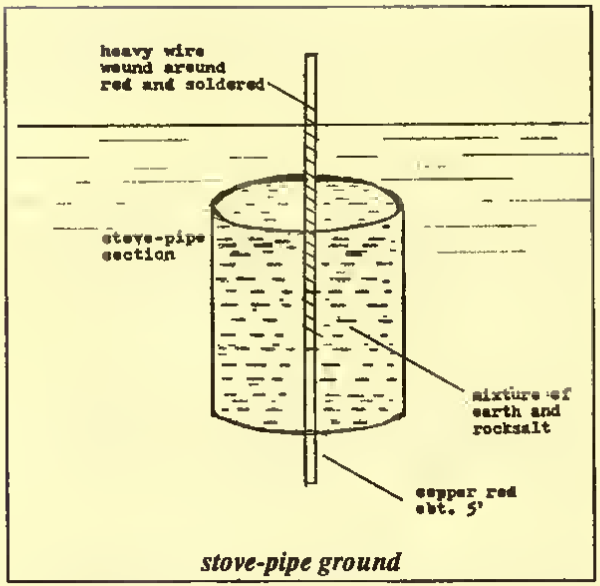

stove-pipe ground

the famous editor Hugo Gernsbach in the March 1919 issue of the *Electrical Experimenter* predicted that "the greatest pride of the radio amateur, the aerial on top of his house...is doomed... As for commercial stations their towers are doomed shortly for the scrap heap." Tesla himself had said, "The great amount of energy which can be conveyed to a [receiving] circuit by conduction through the ground, makes it appear possible that the necessity of elevating terminals...may be dispensed with." Gernsbach, who published much on Tesla in his time, said, "All our pet theories on wireless are thrown into chaos," and he predicted "a war to the knife between our wave-propagation theorists and the new school of ground-impulse savants."

This noted, the Rogers underground vanished from the media, and Rogers' career took a downturn reminiscent of Tesla's.

Stubblefield

In 1902 Nathan Stubblefield demonstrated a grounded wireless-telephone system of his own invention. Sticking iron rods into the ground at the Virginia shore of the Potomac River, Stubblefield communicated with a steamship half a mile away. Stubblefield's grounded radio was powered by the high-frequency output of his Stubblefield battery (patent No. 600,457), a type of space-energy receiver, which shows how the occult

science of free energy nudges up against that of radio, another instance being the free-energy work of T. Henry Moray. Loomis, too, used a power supply that obtained electricity from the atmosphere.

grounding technology

"The ground should be made with great care with the object of reducing its resistance," said Tesla. To ground his Colorado magnifying transmitter, Tesla buried a 20-x-20-inch copper screen 12 feet down in the arid soil. Over the top of the screen he spread a layer of coke. He flowed water over the spot continuously. Beneath Tesla's Wardencliff tower, a shaft descended 120 feet into the earth. Out from the foot of the 12-x-12-foot shaft, side tunnels extended radially. They were carbon-blackened and hence conductive. Situated near the Long Island shore, the giant transmitter was thus grounded to the oceans.

Such solid grounding has become another lost radio art. Until the 1950's even commercial broadcast receivers had a ground terminal on the chassis that one was encouraged to connect to a cold-water pipe or other ground; some houses had a radio ground wired into a wall socket.

A 1930's shortwave magazine recommended a stovepipe ground: a buried stove-pipe section filled with a mixture of soil and rock salt, which attracts moisture. Charcoal can be mixed in, as Tesla used coke. Down the center runs five feet of solid copper rod or galvanized pipe around which is wrapped the heavy lead-in wire.

Any conductor used to connect radio and ground should be as short as possible and with the heaviest conductor, such that an excessively long run of, say, twenty feet is best done with a wire gauge of zero or bigger or maybe with copper tubing or galvanized pipe.

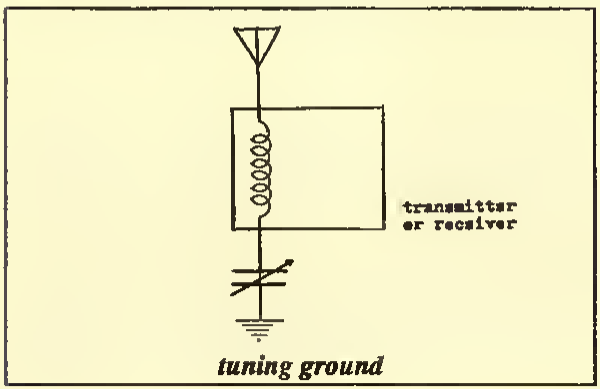

tuning ground

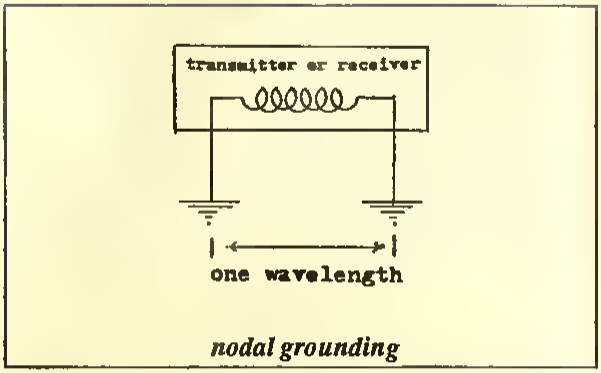

nodal grounding

Clamping securely on to cold-water plumbing near to its ground-entry point is good grounding but this can be supplemented by other grounds, like earth rods or existing fence posts. Any body of water makes a good ground. Connect to a large submerged metal object. Any radio, transmitter or receiver, becomes hyperactive near or connected to a body of water.

Older schematics show a variable capacitor between output coil and ground, comparable to an antenna tuner. I've adopted this practice of tuning ground with good results, including noise control in receiving.

Tesla's radio assumes standing earth waves, and Tesla recommends grounding the two ends of the receiving coil one-half wavelength apart at a wave's nodal points, the location of which one determines experimentally. This arrangement is particularly important for reception of wireless power.

Having established a solid ground, some interesting experiments can be conducted in receiving. Disconnect the antenna. Does the signal vanish? What happens when you connect ground to a receiver's sacred antenna terminal? Will the Hertz police arrest you if you try any of this?

for more information

Underwater Communication, includes some of Rogers patents (Rex Research). **Subsurface Aatennas and the Amateur** by Richard Silberstein, an article in Vol. 1 of *The Antenna Compendium* (ARRL). **The Complex Secret of Dr. T. Henry Moray** by Jorge Resines, radio and TV circuits from 1928 applied to Moray's free-energy discoveries (Borderland).

4. Resonance

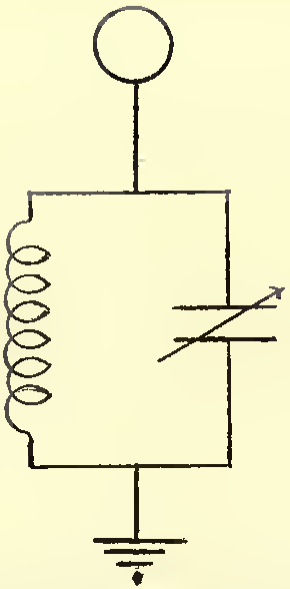

The idea of properly harmonized coils and capacitors vibrating with sympathetic reinforcement and thereby magnifying effects by tremendous ratios is at the heart of Tesla's technology.

Tesla's basic radio tuning "tank" circuit (coil plus capacitor between aerial and ground) is, all by itself, a powerful resonant signal amplifier and a beautifully simple one. Tesla suggests the power of a coil to vorticize energy. But as radio developed over the years, the tank coils in both transmitters and receivers shrank in size, and the result was a loss in gain that was compensated for by the addition of stage after stage of complex amplification circuitry using vacuum tubes.

Tesla watched this development with bewilderment. For transmitting, the resonantly tuned circuits of the tesla coil provided the high electromotive force Tesla thought necessary for long-distance radio-conduction. For receiving, the big loading and tuning coils "magnified effects," as Tesla liked to put it. So why depend on complex, multi-stage circuitry to amplify? It didn't make sense to Tesla. He said, "My plans involved the use of a highly effective and efficient transmitter conveying, at whatever distance, a relatively large amount of energy. The receiver itself is a device of elementary simplicity... In such a system resonant amplification is the only one necessary."

Taking the tank circuit another step out, Tesla conceived of a receiving coil made of glass tubing that was filled with a rarified gas, thus offering almost no impedance to the signal. This superconductivity would, he reasoned, result in tremendous gain.

I've heard tell of a radio experimenter in Portland, Oregon who built the basic crystal set on an obscene scale with a broadcast AM-band tank coil four feet in diameter and and six feet long, wound of copper tubing. Tuned with a big old commercial variable capacitor, the single-stage set, void of amplifier stages, drove an eight-inch loudspeaker with room-filling volume.

earth resonance

Tesla calculated the frequencies and pulsings of his transmitters with an eye to resonating the earth. Earth resonance is fundamental to Tesla's grounded radio and wireless power. Tesla suggested that the electrostatic earth resonated at a particular frequency, and seems to be suggesting that the closer the vibration is to that frequency the greater the magnification of effects.

What is this magical earth-resonant frequency? In his Colorado notes, Tesla says the wavelength is 5200 feet or 1737.7 meters, which works out to about 173 kc. Tesla's Colorado transmitter ranged from 60 kc to 190 kc; 170 kc was a typical operating frequency, according to the *Notes*.

In a 1920 patent, however, Tesla specifies that the frequency should be "smaller than 20 kc, though shorter waves may be practicable." The lowest he would allow would be 6 cycles per second, to which he adds that "paradoxical as it may seem, the effect will be greatest in a region diametrically opposite the transmitter." In another fundamental radio patent, Tesla says he has learned to set up standing waves in the earth. "I found," he says, "their length to vary approximately from 25 to 70 kilometers." This works out to 428 cycles to 12

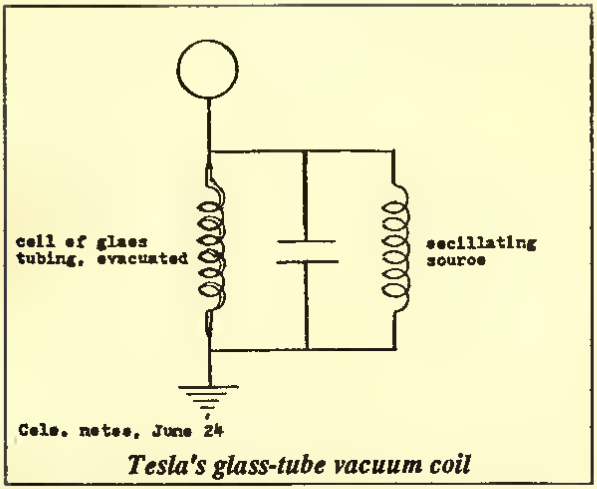

Tesla's glass-tube vacuum coil

kilocycles. If earth resonance happened for Tesla below 60 kc, then he did not achieve it on his Colorado transmitter unless it was by harmonics.

In the 1920 patent Tesla said, "The most essential requirement is...that, irrespective of frequency, the wave or wave-train should continue for a certain interval of time, which I have estimated to be not less than 1/2 or probably .08484 of a second — the time taken in passing to and returning from the opposite pole at a mean velocity of about 471,240 kilometers per second."

Recent thinking on the earth-resonance mystery hypothecates an earth-ionosphere waveguide, a Hertzian notion that would set Tesla spinning in his grave. Tesla spoke only of resonating the earth itself. The Schuman Cavity, as this waveguide is called after its theorist, is said to resonate at exactly 7.83 cycles.

the resonant tank

Of his Colorado transmitter, Tesla wrote, "The vibrating system is formed by a continuously variable and exactly determinable inductance and a capacity standard, or by an inductance standard and a continuously adjustable condenser, or by a system in which both these elements are continuously adjustable."

Modern radio technology has settled on the second of these options for tuning — fixed coil and variable capacitor. This is the arrangement since the 1930's for both transmitters and receivers. But early radio shows a mix of options to accomplish tuning. Sometimes there is no capacitor, and tuning is accomplished with a variable inductance alone. Variable coils include the tapped coil, the slider, and the variometer in which one coil rotates within another. The tradition of the tapped and slider coils is preserved among builders of the crystal set. Almost forgotten is the capacity slider, a section of tubing which encircles the coil except for a narrow slit. There is a revival among LowFERs of the elegant variometer.

Variable capacitors include the familiar rotary plate (also called "air variable" because the dielectric is air), the simply constructed "book" type, (p. 22) and the tubular high-voltage type for transmitting. Old circuits

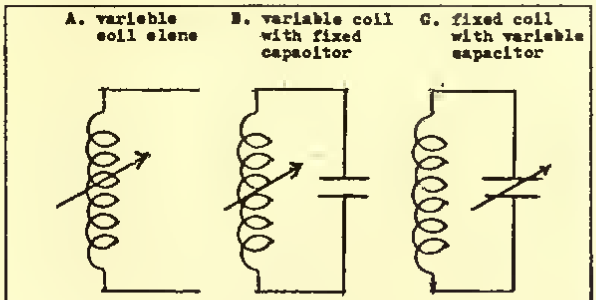

tank options

show variable capacitors consisting simply of a cluster of fixed capacitors and a rotary switch. Tesla's variable capacitor consisted of two opposing conductive disks whose distance apart was adjustable (p. 22). Transmitters sometimes use little neutralizing variables of this design, but I've seen it nowhere else. The book type was manufactured by Crosley in the 1920's. The tubular shows up in the transmitter literature circa 1910.

Even the popular rotary-plate type of variable ca-

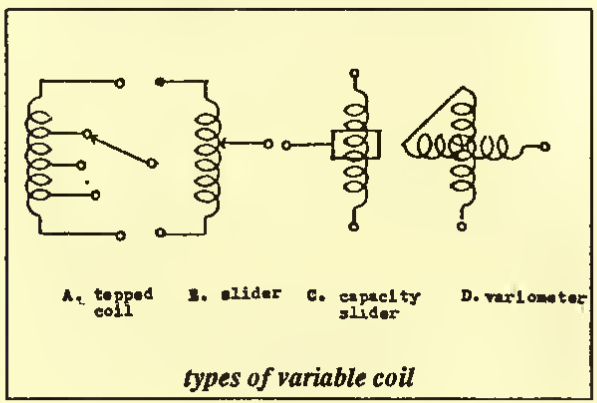

types of variable coil

where L is the coil's inductance, N is the number of turns of wire, and A is the length of the coil winding, B the diameter, both in inches.

Divide the oscillation constant for the frequency you want by the capacitance in microfarads and you'll get the inductance in microhenries that you'll design the coil for. By transposing the coil formula, you can yield the number of turns. By plugging in lengths and diameters, the physical characteristics of a coil with the desired inductance will begin to emerge.

$$N = \sqrt{\frac{L(9A + 10B)}{A}}$$

quarter-wave principle

Tesla advised a simple method of calculating the length of a tuning coil. Just divide the wavelength by four to get the length of the coil wound up. This length includes the length of the entire aerial-ground circuit. Odd multiples of the quarter wave, including, I assume, odd fractions, will also resonate at the frequency.

Tesla stated the rule: "In order to attain the best results it is essential that the length of each wire or circuit, from ground connection to the top, should be equal to one-quarter of the wavelength of the electrical vibration in the wire, or else equal to that length multiplied by an odd number."

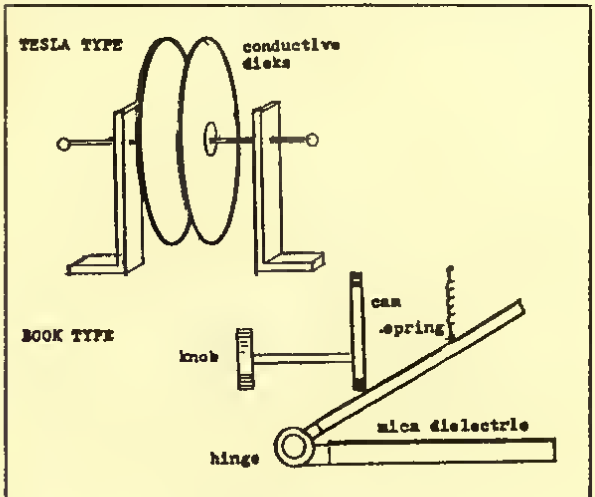

book type variable and Tesla type

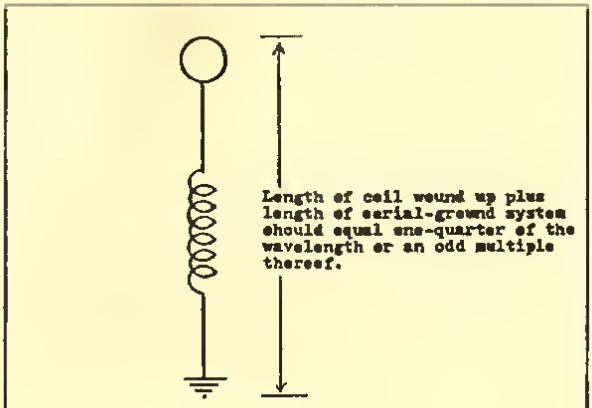

Tesla's quarter wave

Tesla called his quarter-wave principle "the secret of tuning." He said that "without the observation of this rule it is impossible to prevent the interference and insure the privacy of messages."

Tesla's quarter-wave formula is still honored in calculating the length of antenna elements and is still useful in calculating an antenna-loading coil and for tuning circuits that have a coil alone without a capacitor.

building capacitors

If you are building a variable (or any other) capacitor from scratch this formula is useful. It also helps you calculate the value of unmarked variables that you find in surplus electronics stores:

$$C = .224K\,A/d\,(n - 1)$$

C is the capacity in picofarads (pf); A is the area of one plate in square inches; d is the distance between the plates in inches; n is the number of plates. K is the dielectric constant, an index of the insulative (dielectric) power of the material, air being the standard with a K of 1. You can more than double the K of a variable if you are clever enough to find a way to submerge the device in mineral oil, which has a K of 2.2 and you can more than quadruple the K in castor oil (4.7). Oil also ups the voltage-handing ability by a factor of ten or more.

Tesla built a salt-water capacitor for his Colorado magnifying transmitter. It consisted of salt-water in large mineral-water bottles immersed in a tank of salt-water. The "plates" are the salt-water, inside the bottles

and outside. The dielectric is the bottle-glass. Tesla called the bottles "jars" (probably in the tradition of the Leyden jar) and measured capacity by how many jars he connected into the circuit. You can build an adjustable salt-water capacitor out of beer bottles (See *Tesla Coil*.)

World System

When the magnifying transmitter tower at Wardencliff was still under construction (1902), Tesla published a brochure advertising the project as a prototype for a global radio communications corporation. Called the World System in the brochure, it would serve as a multi-frequency wireless traffic center for all existing telephone, telegraph, and stock-ticker services around the planet. Built on Tesla's earth-resonant radio principles, the System would also carry a universal time register, navigation beacons, and even facsimile transmissions. It would also be a global system of broadcasting. Tesla was among the first to suggest broadcasting of news and entertainment to the public; only point-to-point signalling had been experimented with up to then.

Tesla's tower was never completed beyond the rugged framing, and the World System fantasy collapsed when Tesla's backing, from J. P. Morgan, was pulled suddenly from under him. This crushing event signalled the end of Tesla's official career.

Wardencliff tower

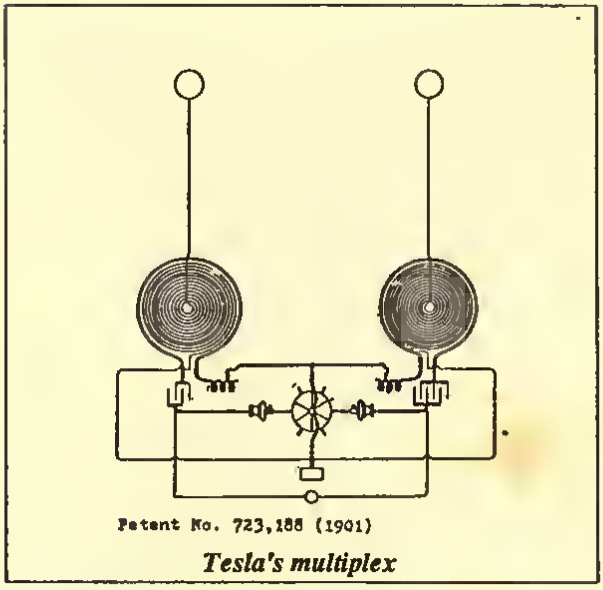

Tesla's multiplex

The system Tesla describes represents a huge jump forward from any radio technology of Tesla's documented in his Colorado notes, his patents, or anywhere else. The brochure suggest the achievement of precisely tunable, high-Q, limitlessly powered transmitting of multiple channels from a single point, transmitting that could be voice-modulated as well.

Little technical detail is given, but the promotional literature suggests that Tesla may have been planning to rely heavily on multiplex techniques to cut through noise. "My individualized system with transmitters emitting a wave complex and receivers comprising separate tuned elements cooperatively associated." He called the technique a "combination lock" and boasted that any degree of safety against statics or other kinds of disturbance can be obtained." The receiver is so designed that it responds "only through the joint action of the tuned elements."

Was Tesla a fascist?

You have to wonder since his World System would have taken radio right off the bat into global centralization, a fantasy of control beyond the dreams even of the U.S. Navy. As it turned out, a quarter century after Tesla proposed his System, broadcast radio, particularly within

the U.S. was still quite diversified with hundreds of AM stations, most only running 100 to 500 watts. National networks were still undeveloped. Stations were owned by entrepreneurs, local newspapers, colleges, churches, retailers. Global radio became the BBC and VOA. Even today, as multinational monopoly media is putting into place a decadent Hertzian equivalent of Tesla's World System using satellites, including direct-satellite tv, the broadcasting of signals across national boundaries is hotly resisted at diplomatic and other levels, though this battle gets no coverage in the mainstream media.

Tesla saw his World System as a civilizing force: "It will be very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions." What did Tesla mean by civilization? He said, "No community can exist and prosper without rigid discipline." He said, "Law and order absolutely require the maintenance of organized force." Tesla said government "should prevent the breeding of the unfit by sterilization and the deliberate guidance of the mating instinct."

Tesla is admired for his technological purism, his insistence that a machine possibility be carried to its logical conclusion. Society, too, was a machine, and it needed perfecting. The World System fitted into Tesla's ideals of social order. His logical conclusion for organizing radio was a system that was centralized, omnipotent, and global.

for more information

Henley's 222 Radio Circuit Designs, 1922 vacuum-tube technology, fascinating (Lindsay) **Tesla's Work with AC and Wireless**, edited by Tesla Researcher Leland Anderson (Twenty First Century Books)

From High Voltage Press

TESLA, The True Wireless edited by George Trinkaus **$7.75**

In Nikola Tesla's own words and in 21 illustrations, this is the inventor's final published statement on how radio, at the radical, really works. What is the true wireless? Tesla says the orthodox Hertzian radio we've been taught is a "fiction." He insists that the amount of energy that can be transmitted is "billions of times greater" than conventional radio would allow. Can we transmit electric power to our homes and workplaces without wires? Can the unsightly and fragile grid come down? Tesla claims his radio can deliver wireless power. This article of 1919 has been completely reset and redesigned for clarity. Includes an introduction by Trinkaus, explanatory notes, and information sources.

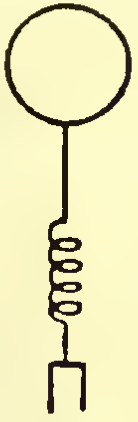

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5. Sensitive Device

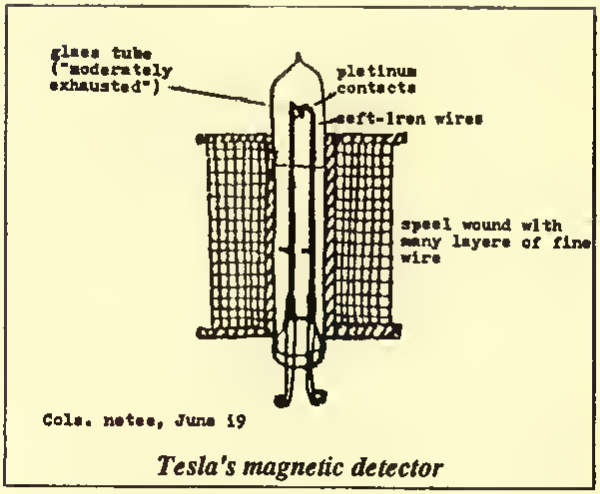

Tesla's magnetic detector

Tesla gave a lot of attention to the development of the ideal apparatus for detecting disturbances in the medium. Tesla let his imagination run free in his quest for the optimal "sensitive device," as he called it.

the coherer

Tesla's detector research was paralleled by many others at the time. The popular detector among radio experimenters was the coherer. This is simply a short glass tube partly filled with small metal chips or filings. Strained to near-conduction by battery voltage, this early semiconductor mysteriously switches on when an oscillating disturbance is present. A tap is needed to reset the coherer back to nonconduction. Breaking the battery circuit also works. Tesla improved the coherer by setting it into constant rotation at about 16 RPM so it would automatically reset. Changing the rate of rotation controls sensitivity. In a patent he also mentions a vibrating coherer. Constant motion suspends the coherer's chips in space, making them more susceptible to disturbances.

The coherer's internal chips or filings are ideally of uniform size. They are cleaned thoroughly in alcohol. Chips are ideally a mixture of nickel and silver, but other conductive materials can be used. Ideally, the chamber is evacuated, but not necessarily.

Until 1902 the coherer was the only detector in wide use. It dropped out of use about 1912. Tesla must have regarded the coherer as a passably reliable sensitive device because he used it in his robot (radio-controlled) boat (patented 1898) and in his Colorado lightning-tracking experiments (1900).

Tesla's detectors

Tesla explored the possibilities of many other sensitive devices. His patents show a rotating rectifier, a precursor to such static rectifying diodes as the crystal detector. Tesla replaced his rotating rectifier with a vacuum-tube diode. This is mentioned in the Colorado notes but there is no patent. I've seen mention of Tesla exhibiting, at the 1893 Chicago World's Fair, a vacuum-tube receiver for voice and music. This must have used for its detector a vacuum diode.

The idea of straining a device to near-conduction, as in the coherer, he applied to a diode vacuum tube and to semiconductors having thin-film dielectrics.

Another Tesla detector, limited to telegraphy, was visual. It used the deposit of a thin film on a glass surface. An iodine solution, upon being stimulated by a radio disturbance, releases a conductive haloid film onto the glass screen. Battery current, conducted through the film, destroys it, thus erasing the screen. A sort of telegraphic tv, this is a precursor of the liquid-crystal display.

Tesla's Colorado notes show a magnetic detector. It consists of a coil of many hundreds of turns of fine wire around glass-enclosed wires of soft iron which are magnetically stimulated by a disturbance. Marconi used a "magnetic detector" that worked on another principle. A pair of horseshoe magnets slowly revolved over an electro-magnet the windings of which were connected

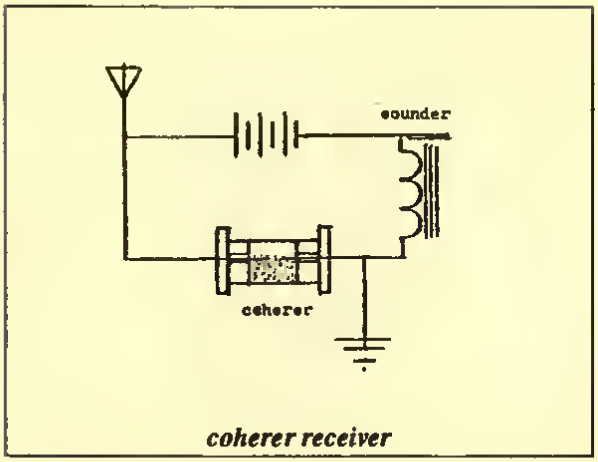

coherer receiver

to earphones. This detector was the immediate successor to the coherer.

Tesla noticed that the megavolt streamers from his Colorado coils were extremely responsive to the slightest changes in etheric conditions and wondered how this phenomenon might be applied to the sensitive device. Later, working with high-voltage, high-frequency currents in vacuum, he discovered the "rotating brush." This is an eerie emanation, a brush discharge, from a spherical conductor exactly centered in a glass bulb. The device resembles the familiar plasma globes, but these contain gases. The result is different in a vacuum. The brush resolves into a rotating ray so sensitive that if you approach it from a few paces it will turn away from you. Tesla found that a small one-inch magnet "will affect it visibly at a distance of two meters, slowing down or accelerating the rotation according to how it's held relative to the brush." There is no information on how Tesla planned to harness the rotating brush as a sensitive device, but he wrote that it was "undoubtedly the most delicate wireless detector known."

Tesla's receivers

Over 50 different receiver circuits are to be found in Tesla's Colorado notes. These are various configurations of sensitive device, tuning coil, capacitor, rotary interrupter, and battery source. If early radio engineers had studied these notes (But how could they have since they were not published until 1978?), they would have found circuits that lay the foundation for two receivers which would dominate the history of radio: the regenerative, and the superhetrodyne.

Most of Tesla's receivers have one or more continuously moving parts, an offensive idea in this age of solid state. Tesla's coherer rotated, and so did his rectifying diode. Central to Tesla's receiver designs is another continously moving part, a rotary "break" or switch used to discharge the capacitor at the proper intervals. The break discharges the capacitor through a sounder. It is a device that magnifies effects.

All the moving parts notwithstanding, Tesla allows for semiconductors to do the job of the mechanical break. "The devices," he says in an 1898 patent, "may consist of merely two stationary electrodes separated by a feeble dielectric layer of minute thickness." Tesla's experience with spark gaps must have attuned him to the possibilities. He writes of thin insulative films serving as dielectrics. The patents offer no drawings or verbal detail. How far Tesla took these thin-film semiconductor ideas experimentally I do not know.

radio-free energy

Central to Tesla's receivers was the use of capacitors to store and release energy and to magnify effects: "However feeble or attenuated the impulses received, enough energy may be accumulated from them by storing up the energy of succeeding impulses for a sufficient interval of time to render the sudden liberation of it highly effective in operating a receiver." By "receiver" here

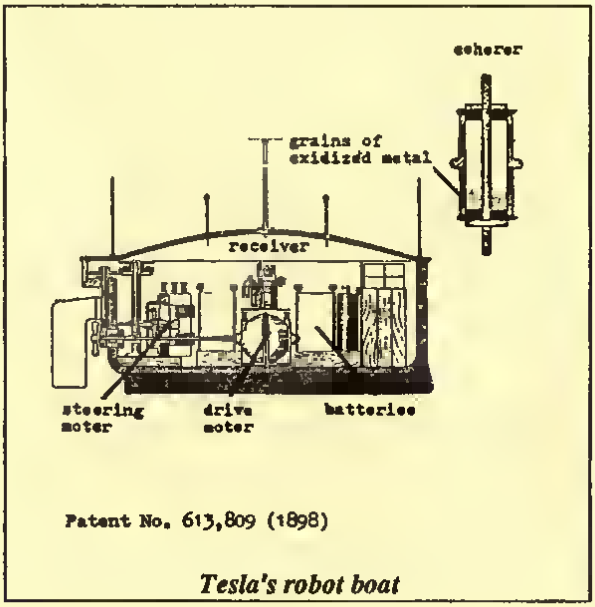

Tesla's robot boat

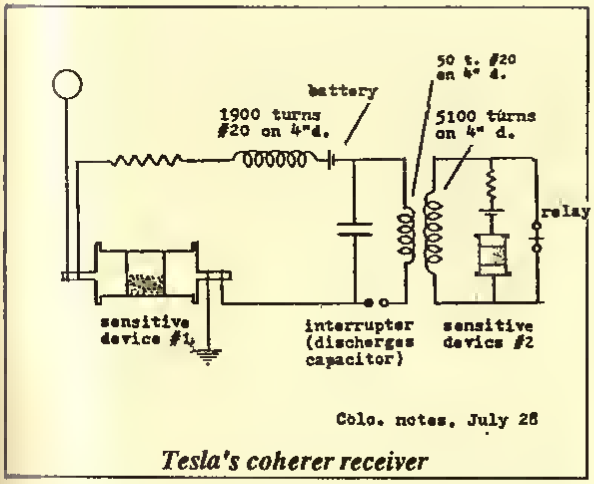

Tesla's coherer receiver

Tesla means sounder. It probably took a fair amount of energy to drive the sounder, especially if what Tesla had in mind was the old magnetic click sounder used in wired telegraphy.

Tesla's free-energy patent (685,957) was filed at about the same time (1901) as a string of his radio receiver patents and is, in fact a kind of radio receiver. As in his radio receiving circuits Tesla is using precisely timed capacitive discharges to magnify effects. Timing is tuning and is critical whether receiving signals or collecting energy at levels sufficient to do work.

The capacitors suitable for energy applications, Tesla says, should be "of considerable electrostatic capacity," and the dielectrics made of "the best quality mica."

The crystal set

The simplest detector diode is the crystal, a sensitive device with a long and illustrious history in radio. It is not clear how close Tesla came to this kind of solid-state rectifying diode; he may have gone from the rotating rectifier to the vacuum diode unaware of the crystal principle, but I doubt it.

The crystal set is the simplest receiver in radio, and the tradition of crystal-set building persists even into this "high tech" era wedded to impressive complexity. You can build a crystal set using an inexpensive diode from Radio Shack. The traditional rock crystal with cat's whisker is still available from Antique Radio Supply, as is the high-impedence headset that enables you to listen to crystal and other elemental receivers without amplification. The cat's-whisker crystal was mass-produced in the Crystal Age enclosed in a glass envelope and with the cat's whisker welded to the active spot. Although germanium became the dominant rectifying material for diodes, similar detectors show up in the literature where the same rectification is accomplished with junction to less exotic materials: an acid solution, an electrolytic solution, a piece of strap iron. Soon after WWII there appeared a "foxhole" radio which used for its detector a safety pin and a razorblade of the no-longer-available blued-steel type. I built one, and it worked.

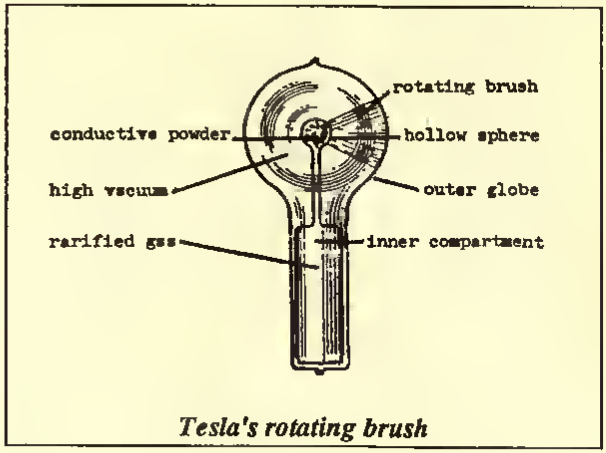

Tesla's rotating brush

The crystal set is the simplest receiver you can build. While a single tuning (tank) circuit might work in the country, in the city one strong station may overwhelm all others unless multiple tuning circuits are used. A crystal set with two or more tuned circuits is the simplest practical radio receiver.

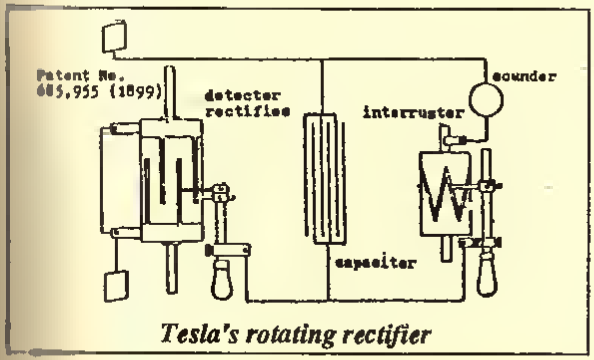

Tesla's rotating rectifier

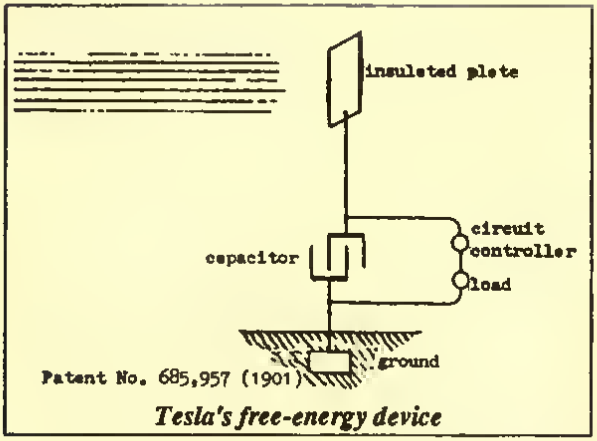

Tesla's free-energy device

the regenerative

Tesla laid the foundation for the regenerative receiver. The vacuum-tube version, credited to Edwin Armstrong, was the receiver that succeeded the crystal set in the development of radio. "Regenerative" refers to the recirculating of the signal vibrating in the coil back into the sensitive device so as to further excite it. This feedback is another of Tesla's strategies for magnifying effects, and he knew about it early on from the self-excitation circuits he used in some of his dynamos.

The regenerative feedback link in Tesla's regenerative is a coil adjacent to the main tuning coil. In the vacuum-tube regens this became known as the "tickler coil." In some regen circuits the feedback link was through a capacitor, which could be a variable. Tesla did not patent the regen but shows many circuit variations of the idea in his Colorado notes, where he observes that it had "many valuable uses since by its means effects too feeble to be recorded in other ways may be rendered sufficiently strong to cause the operation of any suitable device."

The regen is one of the forgotten magical circuits of radio, but only recently forgotten. Familiar to every student of radio at least up through the '60's, it is not to be found in recent editions of *The Radio Amateurs Handbook*.

Though a regen often has a stage or two of amplification, an unamplified, single-stage regen having only a dozen parts is an effective listening tool for a wide range of frequencies from low through short wave. (As in other elemental receivers, high-impedence head phones are used. These differ from other phones in that there are many more turns of finer wire on the electromagnets, a technique to magnify effects, as in Tesla's magnetic detector.) The regen is sensitive and discriminating. As is, without any additional circuitry, a regen can receive code and both AM and single-sideband phone.

In my youth I built a one-tube, 4-band, shortwave

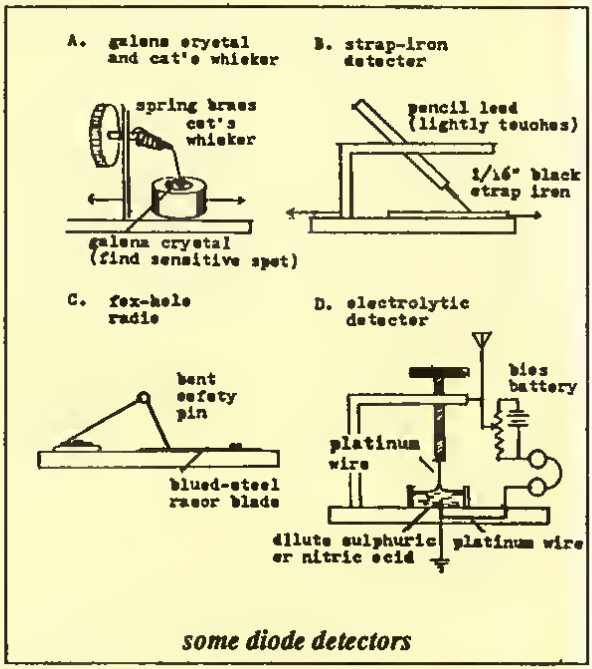

some diode detectors

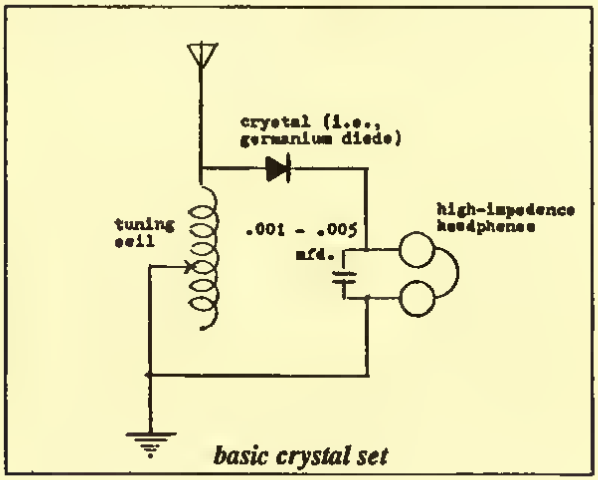

basic crystal set

delicate junctions and tenuous conductors within integrated circuits and other solid-state devices are particularly prone to vaporization. (Vacuum-tube devices are said to be ten-thousand times more resistant.) It's been speculated that a nuke exploded 200 miles above Nebraska would dud all unprotected solid-state circuitry in the continental United States. Particularly vulnerable are components connected to the power grid,

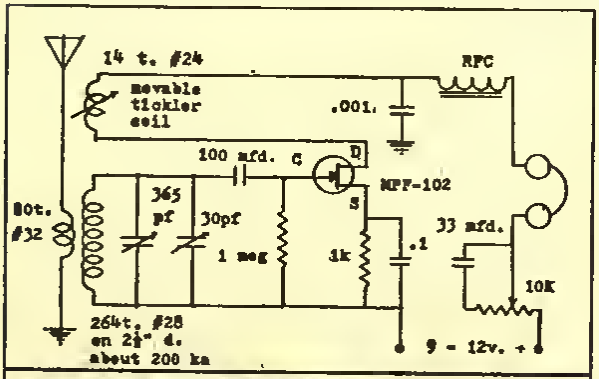

authar's 'low-frequency regenerative

to telephone lines, and to antennas. Magnetic memory could also be erased. While large institutions have been cued to this contingency and are moving ahead with the hardening of computer and communications facilities, the general public is largely oblivious to the fact that the entire "high tech" electronic culture is EMP-cancellable at a stroke.

This same vulnerability of solid-state devices to shock makes them a headache for the builder experimenter. The ability to plug these little items into breadboards is a big step forward in convenience, but, when a circuit fails, the experimenter is left wondering whether his hook-up is flawed or has the IC or transistor blown due to excess heat in soldering, some miniscule excess of current or voltage, from reversed polarity, some

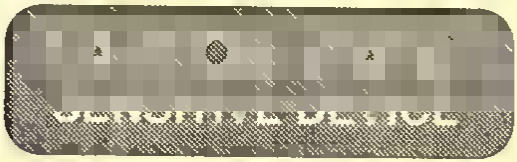

label on Radio Shack IC package

mini-EMP-like static discharge, or kickback from some related high-voltage component.

The same cheap mass production of transistors and IC's that has made possible the world of digital has also encouraged the corruption of the quality of electronic components across the board. Switches, pots, audio transformers, variable capacitors, once built with integrity have become cheaply made mini-junk, and this is often the only stuff readily available to experimenters. Parts suitable for transmitters, tesla coils, and other high-voltage, high-current work, like power transformers, heavy-duty wire-wound pots, chokes, high-watt

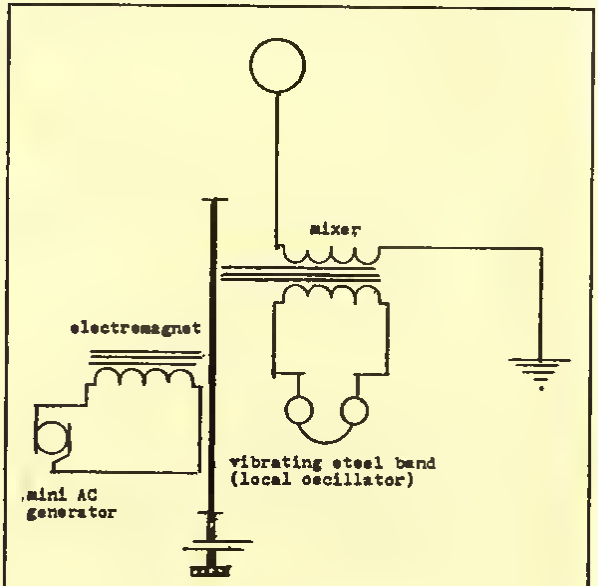

Tesla's beat receptar

resistors, transmitter variables, vacuum tubes, and insulators, must be obtained from surplus sources. For experimenters mini-junk electronics also means tiny, brittle, vexatious, finger-puncturing, eye-straining connection terminals where there used to be hefty lead wires or sturdy posts.

Miniaturization did not become an obsession until the 1950's and the advent of the miniature and "acorn" tubes. The fashion ultimately reduced the size of all components to the minimum, including coils. But formerly, the size of a coil was correlated with its power. "Note the difference in size," said an ad in an *Electrical Experimenter* magazine of 1917. The ad illustrated a 15,000-meter ham antenna-loading coil against a competitor's smaller counterpart. The advertised coil's diameter was 10 inches, its length 32. A typical Tesla receiving coil was 25 inches in diameter. Tesla built with rugged components and on a shameless scale.

for more information

Some coherer technology is to found in **Induction Coils** (Borderland) For Tesla's free-energy patent and other suppressed Tesla technology: **Tesla: The Lost Inventions** by George Trinkaus (High Voltage Press). For crystal set projects **Radios That Work for Free** by K. E. Edwards (Lindsay). **EMP** is from Rex Research. **Antique Radio Supply** is a source of crystal detectors, tubes, variable caps, and more. (P.O. Box 27468, Tempe, AZ 85285). **All Electronics** for all sorts of experimenter stuff. (P.O. Box 567, Van Nuys, CA 91408). A good radio surplus source: **R5D3** (Portland, OR, 503-513-0410).

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6. Aerial Capacity

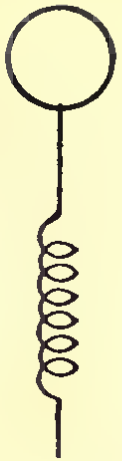

That ball sticking up in the air that is so symbolic of Tesla's radio: What is it? Some sort of antenna? Actually, Tesla never referred to it as an antenna but as an "aerial" or "air capacity" or as an "elevated capacity." Tesla did not see the elevated ball as a radiator, which is how the transmitting antenna of conventional Hertzian radio is construed. The aerial capacity corresponds to the terminal capacitor of a tesla coil. Tesla said that in radio the aerial capacity "heightened the effect" of what is essentially a grounded system. Electrically, in transmitting, it appears to provide a capacitive leverage against which to pump ground. The ball shape also holds high voltage, minimizing coronal discharge and loss.

The ball aerial appears on Tesla's receivers as well as on his transmitters. Tesla understood that a long wire (as in a long-wire antenna) had capacity but he believed the sphere was the efficient geometry. "By using a body of considerable surface...better results are obtained than a wire leading to a height alone... The system is more economical in providing an electrical vibration in the ground." This would be especially true at low frequencies that would require a wire of inordinate length. Tesla's Colorado transmitter when operating at 60 kc would have required a half-wave wire antenna 2500 meters long if modern antenna conventions had been observed.

Tesla also believed that the idea of polarizing, or putting into parallel, transmitting and receiving antennas was nonsense. On his Colorado magnifying trans-

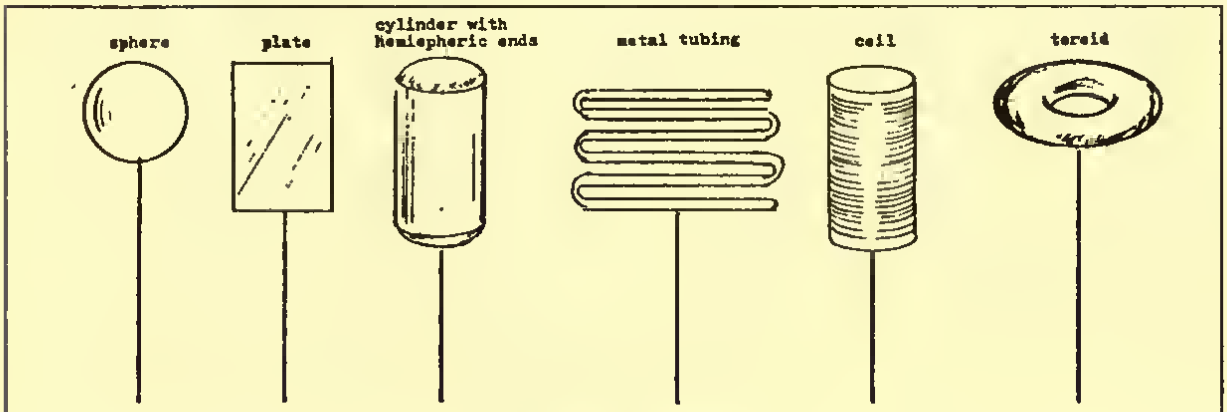

aerial capacity geometries

mitter, Tesla used a hollow copper sphere only 30 inches in diameter. It was thickly coated with rubber insulation. Insulated or not, the ball terminal reduces to a minimum the problem of streamers breaking out at high electrical pressures, since those jump more readily from angular surfaces. Tesla experimented extensively with the effect of the ball's height. An increase in height caused an increase in the effective capacity of the ball, Tesla discovered. (However, of Hertzian radio, Tesla said, "The actions at a distance cannot be proportionate to the height of the antenna or the current in same.")

The ball worked for Tesla but so did other geometries. In Colorado Tesla experimented with a structure of iron pipes as an aerial capacity. He said the aerial

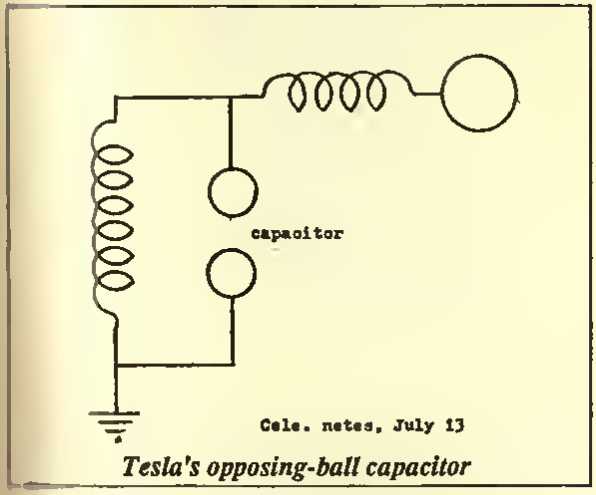

Tesla's opposing-ball capacitor

capacity could be a cylinder with hemispheric ends, or it could be a toroid. Tesla suggested that a coil of insulated wire put aloft would suffice. He said any hollow vessel, like a ball, could be filled with a gas like hydrogen at low pressure for better effect. Some of Tesla's receiver schematics show the aerial capacity as a simple metal plate.

The ball capacitor shows up in other Tesla circuits besides aerial, consisting of a capacitor of two opposing hollow balls.

capacitive antennas

The "capacitive hat" appears as an occasional element in modern antenna design. Although the texts explain it as something that "improves radiating efficiency," it's still in the nomenclature as a "capacitive hat." Capacitive hats appear frequently in low-frequency radio: in the antenna systems of navigational beacons, of LORAN, of GWEN, and among LowFERs. The capacitive hat appears on top of the helical antenna, which, as a coil of wire aloft, might itself qualify as an aerial capacity.

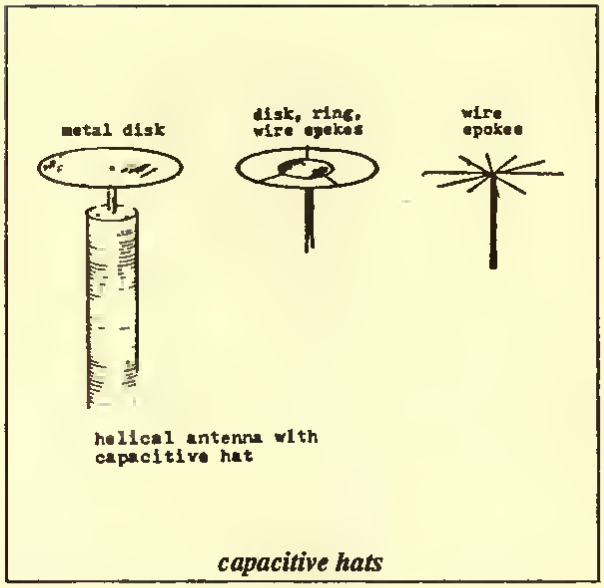

capacitive hats

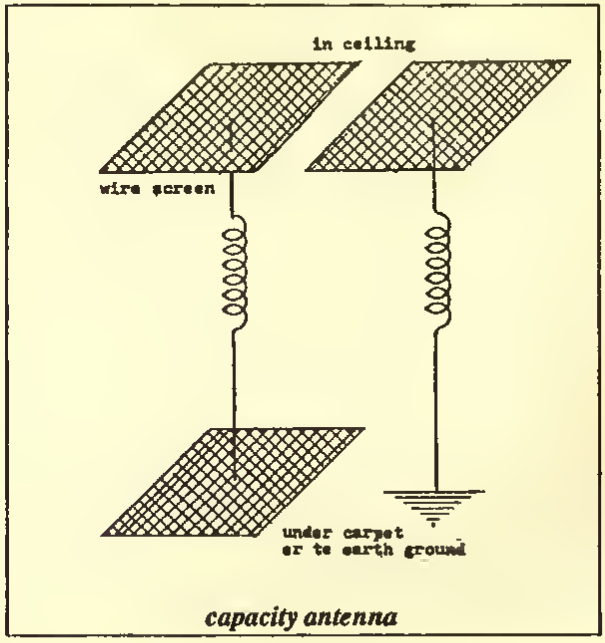

capacity antenna

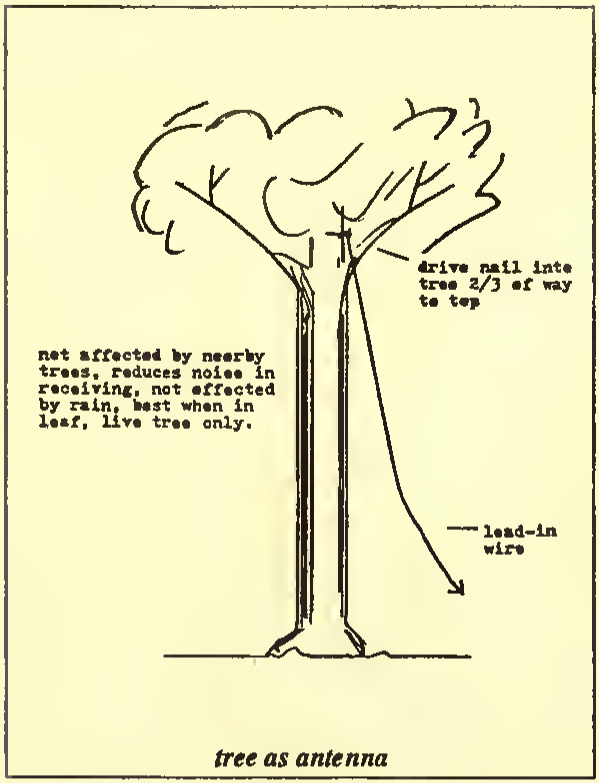

tree as antenna

Is the loading coil on a center- or top-loading whip "seen" as an aerial capacity?

In the radio literature of the 1920's there are references to a "capacitive antenna." This consisted of a sheet of metal or a wire screen aloft or, alternatively, where a ground connection was distant, a sheet of metal or screen aloft and another below, the two separated by 10 to 15 feet. Recommended as an indoor alternative where an outdoor antenna cannot be put up, the upper element could be placed in an attic, the lower, if any, under the carpet.

Hertzian antennas, like the ham array and the CB whip, are flags announcing the presence of a transmitter. Are they necessary?

Loomis sent kites aloft as aerials; they were covered with copper gauze. Loomis also observed that a tree could be used as a receiving antenna, and others have discovered the tree as a transmitting antenna as well. I've seen no mention of frequencies in the tree-as-antenna literature, which comes from the low-frequency era. (I've tried it for receiving, and it works on long-, medium-, and shortwave bands.) Does the transmitter or receiver "see" the tree as a Tesla-style aerial capacity?

loops

Loop antennas abound in radio and suggest Tesla's elevated-coil idea. You can easily build your own using PVC tubing for the structure. For strength, use one-inch schedule 40 tubing instead of the 1/2 inch I used (photo).

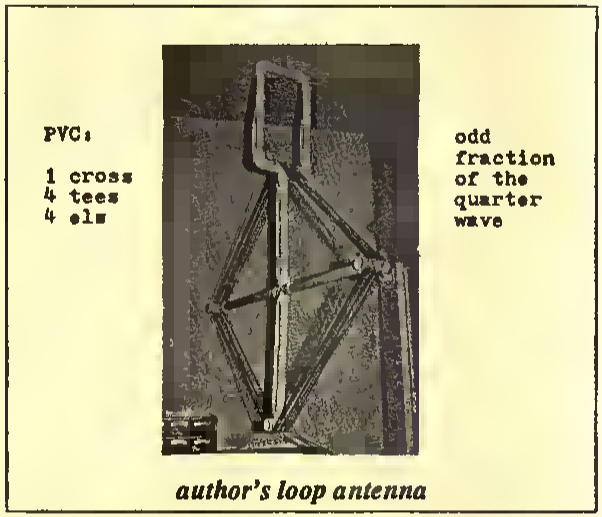

author's loop antenna

The shielded loop appears in the LowFER receiver literature as a noise-reduction strategy. The shielding excludes the magnetic component of disturbances while the loop inside responds only to the electrostatic, ac-

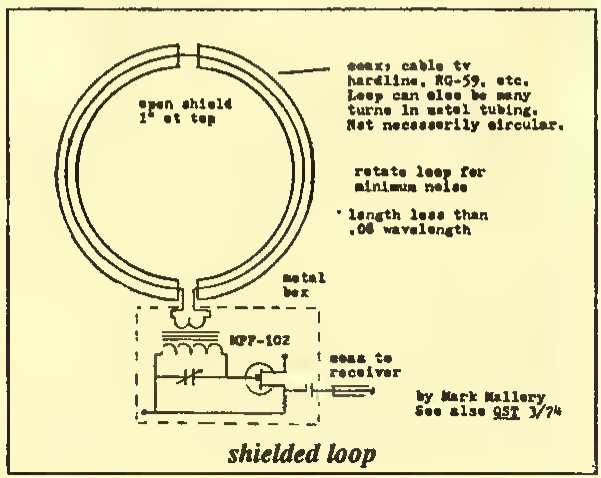

shielded loop

cording to the literature. A preamp is a good idea with any loop.

studded mushroom

Tesla's magnifying transmitter patent shows a toroid-shaped aerial capacity. It is studded with half-spherical metal plates, presumably to enlarge the surface without increasing by much the bulk. The ultimate Tesla aerial capacity is the studded mushroom that topped his Wardencliff tower. Its diameter was 68 feet. The studding may have been parabolic rather than strictly hemispherical. There is not much information about the tower, and Tesla's reasoning behind the strange geometry is not fully understood.

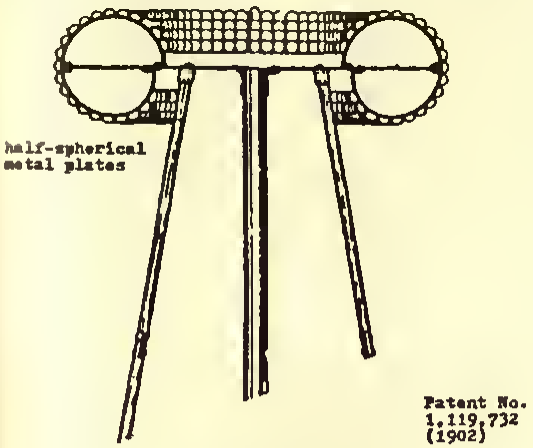

Tesla's magnifying transmitter aerial capacity

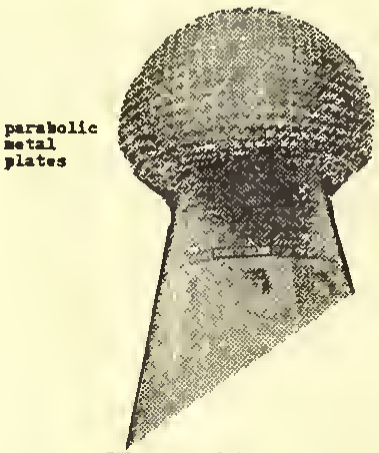

Wardencliff aerial capacity (artist's conception)

The notion of aerial capacity has little currency outside of Tesla-land. What would antennas be like if they were reinvented, not as senders and receivers of Hertzian radiation, but as aerial capacitors?

for more information

Electric Spacecraft Journal, ed. by Charles Yost, has some interesting speculations on Wardencliff's terminal. (P.O. Box 18387, Ashville, NC 28814). **Trees as Antennas** (Rex Research).

WAVELENGTH, FREQUENCY, AND OSCILLATION CONSTANT

Wave-length Meters	Frequency	LC	Wave-length Meters	Frequency	LC
1	300,000,000	.0000003	100	1,579,000	.01016
2	150,000,000	.0000011	195	1,538,000	01071
3	100,000,000	.0000025	200	1,500,000	.01126
4	75,000,000	.0000045	205	1,463,000	.01183
5	80,000,000	.0000070	210	1,429,000	.01241
6	50,000,000	.0000101	215	1,395,000	.01301
7	42,860,000	.0000138	220	1,364,000	.01362
8	37,500,000	.0000180	225	1,333,000	01425
9	33,333,000	.0000228	230	1,304,000	.01489
10	30,000,000	.0000282	235	1,277,000	.01555
15	20,000,000	.0000634	240	1,250,000	.01622
20	15,000,000	.0001126	245	1,225,000	.01690
25	12,000,000	.0001760	250	1,200,000	.01760
30	10,000,000	.0002533	255	1,177,000	01831
35	8,571,000	.0003448	260	1,154,000	.01903
40	7,500,000	.0004503	265	1,132,000	.01977
45	6,667,000	.0005700	270	1,111,000	.02052
50	6,000,000	.0007039	275	1,091,000	02129
55	5,454,000	.0008519	280	1,071,000	.02207
60	5,000,000	.001014	200	1,034,500	02366
65	4,615,000	.001188	295	1,017,000	.02450
70	4,286,000	.001378	300	1,000,000	.02533
75	4,000,000	.001583	310	967,700	.02705
80	3,750,000	.001801	320	937,500	.02883
85	3,529,000	.002034	330	909,100	.03066
90	3,333,000	.002280	340	882,400	.03255
95	3,158,000	.002541	350	857,100	.03448
100	3,000,000	.002816	360	833,300	.03646
105	2,857,000	.003105	370	810,800	.03854
110	2,727,000	.003404	380	789,500	.04005
115	2,609,000	.003721	390	769,200	.04277
120	2,500,000	.004052	400	750,000	.04503
125	2,400,000	.004397	410	731,700	.04733
130	2,308,000	.004757	420	714,300	.04966
135	2,222,000	.005130	430	697,700	.05204
140	2,144,000	.005516	440	681,800	.05446
145	2,069,000	.005919	450	666,700	.05700
150	2,000,000	.006335	460	652,200	.05960
155	1,935,000	.006780	470	638,300	.06219
160	1,875,000	.007204	480	625,000	.06485
165	1,818,000	.007662	490	612,200	.06759
170	1,765,000	.008134	500	600,000	.07039
175	1,714,000	.008620	510	588,200	.07327
180	1,667,000	.009120	520	576,000	.07606
185	1,622,000	009634	530	566,000	.07005

WAVELENGTH, FREQUENCY, AND OSCILLATION CONSTANT—(Continued)

Wave-length Meters	Frequency	LC	Wave-length Meters	Frequency	LC
540	555,800	.08208	900	303,100	.2759
550	545,400	.08519	1,000	300,000	.2816
560	535,700	08836	1,010	297,000	.2870
570	526,300	.09139	1,020	294,100	.2927
580	517,200	09467	1,030	291,300	.2986
500	508,500	.09801	1,040	288,400	.3045
600	800,000	.1014	1,050	285,700	.3105
610	491,800	.1047	1,060	283,600	.3161
620	483,000	.1082	1,070	280,400	.3222
630	476,200	.1117	1,080	277,800	.3283
640	468,700	.1154	1,090	275,200	.3345
650	461,500	.1188	1,100	272,700	.3404
660	454,500	.1225	1,110	270,300	.3467
670	447,800	.1263	1,120	267,000	.3531
680	441,200	.1302	1,130	265,500	.3595
690	434,800	.1341	1,140	263,100	.3660
700	428,600	.1378	1,150	260,900	.3721
710	422,500	.1419	1,160	258,600	.3767
720	410,700	.1459	1,170	256,400	.3853
730	411,000	.1501	1,180	254,200	.3921
740	405,400	.1540	1,100	252,100	.3988
750	400,000	.1583	1,200	250,000	.4052
760	394,800	.1626	1,210	247,900	.4121
770	389,800	.1668	1,220	245,000	.4190
780	384,800	.1712	1,230	243,900	.4260
700	379,800	.1756	1,240	241,900	.4326
800	375,000	.1801	1,250	240,000	.4397
610	370,400	.1847	1,260	238,100	4469
820	365,900	.1893	1,270	236,200	.4541
630	361,400	.1941	1,280	234,400	.4610
840	357,100	.1985	1,290	232,600	.4683
650	352,000	.2034	1,300	230,800	.4757
860	348,800	.2082	1,310	229,000	.4831
670	344,800	.2132	1,320	227,300	.4906
860	340,000	.2179	1,330	225,600	.4978
800	337,100	.2229	1,340	223,900	.5053
000	333,800	.2280	1,350	222,200	.5130
910	329,700	.2332	1,360	220,800	.5206
920	326,100	.2381	1,370	218,900	.5281
930	322,600	.2434	1,380	217,400	.5359
940	319,100	.2487	1,390	215,800	.5438
950	315,000	.2541	1,400	214,300	.5516
960	612,500	.2595	1,410	212,800	.5596
970	309,300	.2647	1,420	211,300	.5674
980	306,100	.2704	1,430	209,800	.5755

tank tables

To calculate the appropriate values for any tank coil and capacitor to resonate at a particular frequency, I find these tables from a 1928 technical-school text clear and useful.. They are also useful for engineering a tesla coil. The column headed "LC" contains numbers representing the "oscillation constant." This is the number you get by multiplying the capacitance in microfarads by the inductance in microhenries. If you know one value, you can get the other by division. The frequency in column two is in cycles; lop off three zeros for kilocycles. See pages 21 –22.

Usually the variable capacitor will be the known and the coil the unknown. Variables are rated in picofarads. Move the decimal point six places to the left to get microfarads.

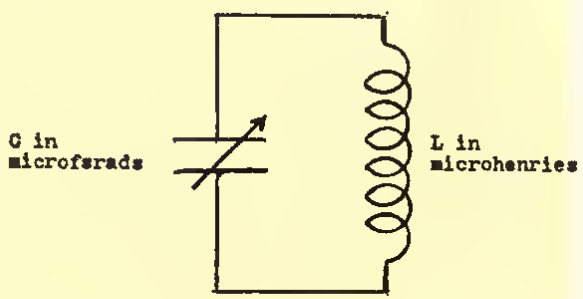

WAVELENGTH, FREQUENCY, AND OSCILLATION CONSTANT—(*Continued*)

Wave-length Meters	Frequency	*LC*	Wave-length Meters	Frequency	*LC*
1,440	208,300	.5837	1,890	158,700	1.006
1,450	206,900	.5919	1,900	157,900	1.016
1,460	205,500	.5998	1,910	157,100	1.027
1,470	204,100	.6081	1,920	156,300	1 038
1,480	202,700	6165	1,930	155,400	1.049
1,490	201.300	.6250	1.940	154,600	1 060
1,500	200,000	.6335	1,950	153,800	1.071
1,510	198,700	.6418	1,960	153,100	1 081
1,520	197,400	.6502	1,970	152,300	1 092
1,530	196,100	6590	1,980	151,500	1.104
1,540	194,800	.6677	1,990	150,800	1.115
1,550	193,600	.8700	2,000	150,000	1.128
1,560	192,300	.6849	2,050	146,300	1.183
1,570	191,100	.6938	2,100	142,900	1.241
1,580	189,900	.7028	2,150	139,500	1.301
1,590	188,700	.7118	2,200	136,400	1.362
1,600	187,500	.7204	2,250	133,300	1.425
1,610	186,300	.7296	2,300	130,400	1.489
1,620	185,200	.7387	2.350	127,700	1.555
1,630	184,100	.7480	2,400	125,000	1.622
1,640	182,900	.7573	2,450	122,500	1.690
1,650	181,800	.7662	2 500	119,000	1.700
1,660	180,700	.7756	2,550	117,700	1.831
1,670	179,600	.7852	2,600	115,400	1.903
1,680	178,600	.7946	2.650	113,200	1 977
1,690	177,500	.8037	2,700	111,100	2 052
1,700	176,500	.8134	2,750	109,100	2 129
1,710	175,400	.8231	2,800	107,100	2.207
1,720	174,400	.8329	2,850	105,300	2.287
1,730	173,400	.8422	2,900	103,500	2.366
1,740	172,400	.8520	2,950	101,700	2.450
1,750	171,400	.8620	3,000	100,000	2.533
1,760	170,500	.8720	3,100	96,770	2 705
1,770	169,400	.8821	3,200	93,750	2 883
1,780	168,500	.8916	3,300	90,910	3.066
1,790	167,600	.0018	3,400	88,240	3 255
1,800	166,700	.9120	3,500	85,910	3.446
1,810	165,700	.9223	3,600	83,330	3.648
1,820	164,800	.9327	3,700	81,080	3.854
1,830	163,900	.9425	3,800	78,950	4.065
1,840	163,000	.9530	3,900	78,920	4.277
1,850	162,200	.9634	4,000	75,000	4.503
1,860	181,300	.9741	4,100	73,170	4.733
1,870	100,400	.9841	4.200	71,430	4.966
1,880	159,600	.9945	4,300	69,770	5.204

WAVELENOTH, FREQUENCY, AND OSCILLATION CONSTANT—(*Continued*)

Wave-length Meters	Frequency	*LC*	Wave-length Meters	Frequency	*LC*
4,400	68,180	5 446	8,800	34,000	21.79
4,500	66,670	5.700	8,900	33,710	22.29
4,600	65,220	5.960	9,000	33,330	22.80
4,700	63,830	6 219	9,100	32,970	23.32
4,800	62,500	6 485	9,200	32,810	23 81
4,900	61,220	6.759	9 300	32,200	24.34
5,000	60,000	7.039	9,400	31,910	24.87
5,100	58,820	7.327	9,500	31,500	25 41
5,200	57,600	7.606	9,600	31,250	25.95
5,300	66,600	7 905	9,700	30,930	26 47
5,400	55,560	8.208	9,800	30,610	27.04
5,500	54,550	8 519	9,900	30,310	27 59
5,600	53,570	8.836	10,000	30,000	28 16
5,700	52,630	9.139	10,500	28,570	31 05
5,800	51,720	9 467	11,000	27,270	34.04
5,900	50.850	9.801	11,500	26,090	37 21
6,000	50,000	10 14	12 000	25,000	40 52
8,100	49,180	10.47	12,500	24,000	43 97
8,200	48,550	10.82	13,000	23,080	47 57
6,300	47,620	11.17	13,500	22,220	51.30
6,400	46,870	11.54	14,000	21,440	55.18
6,500	46,150	11.88	14,500	20,690	59 19
6,600	45,450	12.25	15,000	20,000	63 35
6,700	44,780	12.63	15,500	19,350	87 60
6,800	44,120	13.02	16,000	18,750	72 04
6,900	43,480	13.41	16,500	18,180	76 62
7,000	42,860	13.78	17,000	17,650	81 34
7,100	42.250	14.19	17,500	17,140	86 20
7,200	41,670	14.59	18,000	16,670	91 20
7,300	41,100	15 01	18,500	16,220	96.34
7,400	40,540	15 40	19.000	15,790	101.64
7,500	40,000	15.83	19,300	15,380	107 06
7,600	39,470	16 28	20,000	15.000	112 56
7,700	38,960	16.68	21,000	14,290	124 12
7,800	38,460	17.14	22 000	13,640	136 24
7,900	37,980	17 56	23,000	13,040	148 93
8,000	37,500	18 01	24,000	12,500	162 18
8,100	37,040	18 47	25 000	12,000	175 97
8,200	36,500	18.93	26,000	11,540	190 26
8,300	36,140	19 41	27.000	11,110	205 20
8,400	35,710	19 85	28.000	10,710	220.70
8,500	35,290	20 34	29,000	10,350	236 63
8,600	34,880	20 82	30,000	10.000	253.32
8,700	34,480	21 32			

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Keely's Laws of Being

- on the Nature and Dynamics of Vibration, Oscillation and Toroids

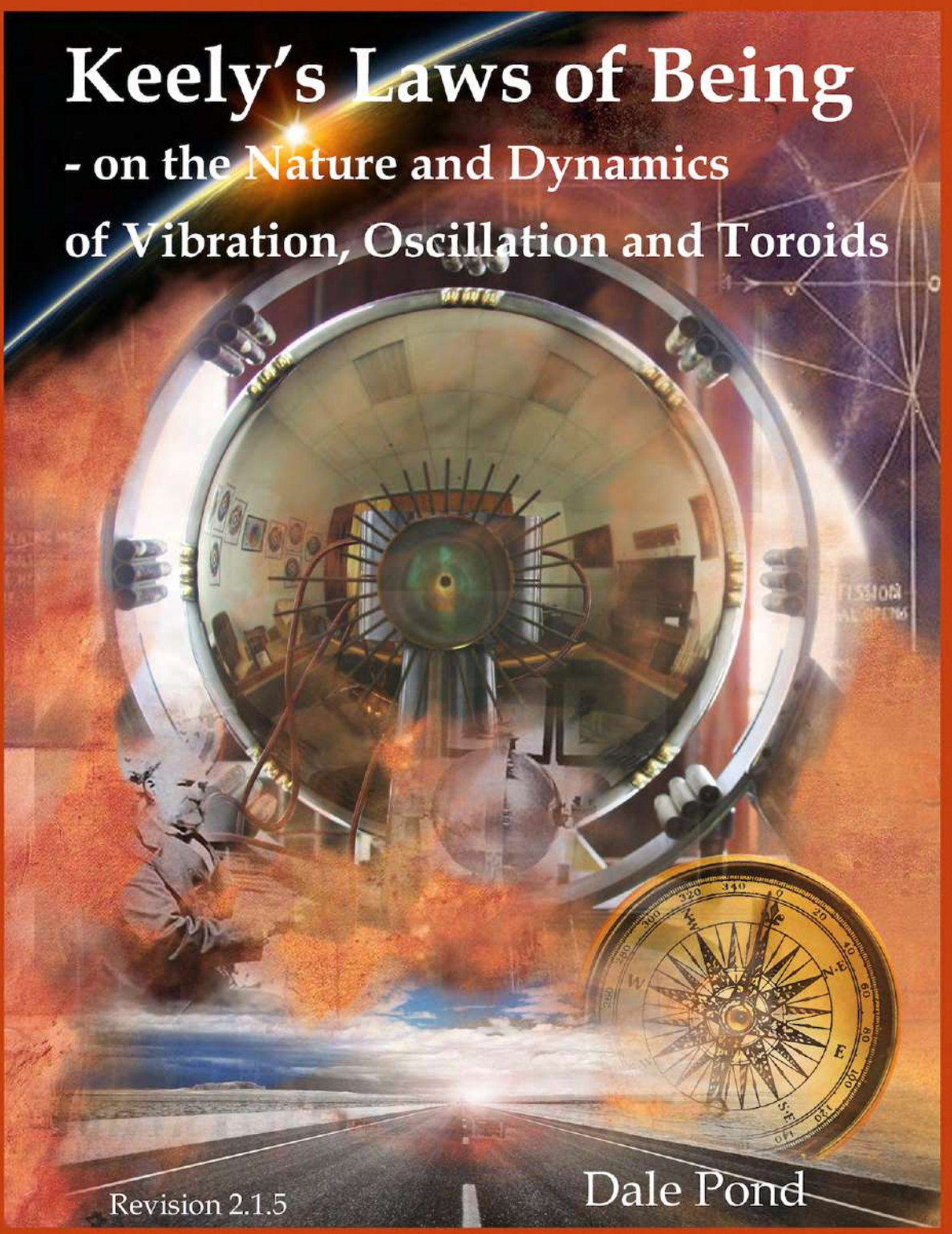

Revision 2.1.5

Dale Pond

Keely's Laws of Being - on the Nature and Dynamics of Vibration, Oscillation and Toroids, version 2.1.5

by Dale Pond
©Dale Pond, 2013, 2014

"*If you only knew the magnificence of the 3, 6 and 9, then you would have a key to the universe.*" Nikola Tesla

What did Tesla consider as "magnificent" about these three numbers? These three numbers represent unseen dynamics and are the very essence of the nature, structure and dynamics of complex periodic motions. This work describes these three unseen (scalar) aliquot components of vibration, oscillation, vortices and toroids (or any periodic motion) as also their relationships and dynamical functions.

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Dedication

This work is dedicated to those rare and courageous individuals who have boundless curiosity in their hearts and minds intensely pursuing a Greater Truth about themselves and the universe in which they live and have their being. They are critical thinking rebels recognizing the status quo does not satisfy their constant and persistent questioning of every thing or idea whether trivial or held as sacred dogma.

"Here's to the crazy ones. The misfits. The rebels. The troublemakers. The round pegs in the square holes. The ones who see things differently. They're not fond of rules. And they have no respect for the status quo. You can quote them, disagree with them, glorify or vilify them. About the only thing you can't do is ignore them. Because they change things. They push the human race forward. And while some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world, are the ones who do." Apple Computers

Forward

"There are times in life when all the stars seem to align for us. This work, for Dale Pond, is one of those moments! Dale has worked to recapture John Keely's fragmented work for over three decades and collate this collection of fragmented footnotes back into John Keely's coherent science called Sympathetic Vibratory Physics [SVP]. I have known Dale personally for twelve years and studied along side him the works of John Keely. It took me many years to understand in a coherent manner what John Keely was saying. A lot of this confusion was due to his works being so fragmented. Dale has completed and is still working on his SVPwiki.com, which integrates so many others' works that support the threads of John Keely. Still one must be deeply committed to the study to pick up the basic corollary concepts to develop a clear image of this new science discipline. "Well, no longer! This new publication of Dale Pond's is surely his greatest work and most fundamental. Here he has laid out basic building blocks of Sympathetic Vibratory Physics in a sequential coherent pattern that helps the reader circumvent years of study to reveal an understanding of this science.

"John Keely was a thousand years ahead of today's quantum physicist understanding of the basic building blocks of the Universe. John Keely saw it as a three dimensional construct of radially vibrating energy systems from centers in proportional progressive values filling all the plenum of the Universe. He understood through repeatable experimentation the character of this primal energy construct and how to manipulate it's present stable resonate fundamental states - known matter into new ones - yet undiscovered by modern man. Also, along the way he discovered many wonderful, what would seem magical, characteristics of these new states of matter and force.

"The possible progression from here as I see it, for Dale Pond, is forward into applied application of this now defined science for humanity's new age."

Jerry Williams

Preface

0.1 What this book is

This book is a culmination of a two year epiphany. In early 2011 I began sensing there is more to the concept and state of *polarity* than previously thought by anyone save Keely. In July of that year I attempted to speak of this new insight at the Extraordinary Science Conference in Albuquerque. That attempt failed.

Then in October of 2013 the idea gelled - I got it! This book then is an expression of that two year epiphany and over a year of writing.

This work attempts to explain the unrecognized nature, construction and dynamics of vibration, oscillation and toroids with their polar dynamics as also to clarify Professor Daniel Brinton's[1] description of Keely's ideas within his article "Laws of Being"[2] revealing Keely's technique for understanding and manipulating the periodic nature of matter and energy[3]. This Brinton article (Chapter 7 - Laws of Being) is central to this document.

Two prior versions of this book have been issued. This version (2.2 or 4th edit) is a rewrite of the previous versions and has been expanded, reorganized and retitled. The chapters coming before Chapter 7 are foundational materials to understanding Chapter 7. The chapters coming after Chapter 7 are consequential to it.

Keely developed what seems to be entire fields of research mostly akin to our non-classical quantum physics and quantum mechanics decades before these fields existed[4]. Keely was splitting the atom in the 1880s[5] working on his own and with few resources fifty years before mainstream science had a clue. Conventional science at that time period considered the atom to be indivisible. Yet here was Keely splitting the atom and releasing its awesome

[1] [Daniel Brinton]
[2] Appendix I and II
[3] see Appendix III - Ultimate Constitution of Matter
[4] [Sympathetic Vibratory Physics]
[5] [Keelys Accomplishments]

powers. Because the scientists and engineers "knew" this was impossible most would not could not believe what Keely was demonstrating to them. Political correctness (dogma and doctrine) didn't work well then either.

It should further be noted Keely worked with the forces and laws that govern matter and energy (non-classical physics). Conventional science and engineering works with things and their motions (classical physics). The distinction between these two very different fields is all important. Most people who have witnessed or read Keely and Russell look at their work from the classical viewpoint and miss everything that was intended. Their first reaction is to condemn Keely and Russell for no other reason than they did not understand - not because Keely and Russell were wrong which they weren't. They were simply too far ahead of their time and everyone else's comprehension.

Unfortunately, or fortunately, Keely's research lab notes, books[6] and publications have not been available wherewith all his work could be studied. Therefore this book is limited to exploring Brinton's paper as also the supporting definitions and explanations required to grasp the subject matter.

0.2 Hindsight is mostly 20/20

Within Keely's philosophy and science are several fundamental concepts substantially different from conventional understandings. It must be remembered Keely developed these ideas years and sometimes decades before similar concepts were imagined or considered by orthodox science. After years of study it has been found these points to be not only essential to understanding Keely's work but they are also more accurate conceptualizations. His work has a consistency, continuity, completeness and homogeneity not seen in other earlier models.

Essentially Keely discovered quantum mechanics and quantum physics decades before these fields were suspected to exist. He further devised means to power and operate mechanical devices[7] with these quantum energy level forces - a feat that has yet to be fully achieved by modern science and engineer-

[6] [Keelys Lost Books]
[7] [Keelys Mechanical Inventions and Instruments]

ing. Keely's focus was primarily on 1) power development and production,[8] whether by pressure from dissociated matter or rotation 2) discovering and harnessing the ultimate Source[9] of all energy 3) demonstrating Mind is that ultimate source and 4) developing and proving out his theories through his many devices.[10]

0.3 Original Concepts

A few of Keely's original concepts that are somewhat different than conventional concepts would be but are not limited to:

- What vibration and oscillation (periodic motion) are.
- Causative (Scalar) constituent components of vibratory motion.
- Dynamical and structural nature of matter and its association with force and energy.
- Mind Force as primordial source of matter and energy.
- Fundamental definitions of basic manifestations of forces and energies such as

1. Electricity
2. Magnetism
3. Gravity
4. Mind / Consciousness
5. Vibration and Oscillation

While many correspondences have been identified between Keely's work and conventional science some like the ones above have no clear correspondence or translation. These are new (for us) concepts and constitutes a new paradigm. It has been found the theories and philosophy of Walter Russell[11] coincides

[8] [Apergy - Power Without Cost]
[9] [Source]
[10] [Keelys Mechanical Inventions and Instruments]
[11] University of Science and Philosophy http://www.philosophy.org

with, compliments and supports in countless ways Keely's ideas. Hence some Russell ideas and artwork are used throughout this book. The few Russell ideas incorporated herein are not all that compliment Keely's work as it would require several volumes to illustrate Russell's work alone. Both their works are vast if not outright encyclopedic in scope. The focus of this work is fairly concentrated and does not attempt to cover the entire gamut of their philosophies and sciences.

0.4 Analog Signal Generators

Keely developed his science and machines in a time before there were electronic or digital instruments such as signal generators, microphones, amplifiers, signal conditioners, synthesizers, transducers, accelerometers, speakers, etc. Therefore he made use of what was at hand - music instruments and simple disk, rod, cavity and string resonators were his signal generators. He invented devices to produce and test for frequencies in the high ranges of etheric and mind vibrations. A violin, zither, harmonica, stretched strings, tube resonators and chladni plates (gongs) among other simple and complex devices supplied his acoustic signals (simple frequencies) and chords (complex wave forms). He also developed precious metal wires and beads[12] that somehow multiplied multiple frequencies and conducted them without resistance. Peppered throughout the literature are many references to his copious use of diverse music instruments employed to excite various responses from his many devices. Below is a picture of one such device using a zither as part of a much more complicated device that also has within it rod, sphere, tube and plate resonators and a simple horn adorning its top.

[12] [Trexar], [Bixar], [Trextrinar]

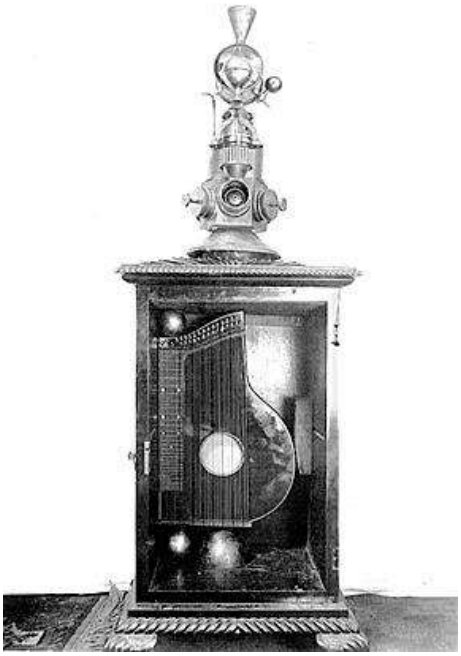

Figure 1: Example of an analog zither as acoustic source
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/zither.jpg

0.5 Music as an Engineering Tool

Music is orderly organized sound. Noise is disorderly unorganized sound. Music allows the intelligent use of simple (notes) and complex tones (chords), time, amplitude, concord and discord (the basis of all vibration), wave form control and how these tools can be used. The study of music science incorporates numbers, arithmetic, geometry, history, philosophy and acoustics. Music is not unlike a shorthand approach to acoustics. Music is of the Whole Mind connecting physical science with higher states of consciousness.

"*It (the study of music) gives (a knowledge of) a rhythm that is as necessary as law, in making any success in a material experience. Some knowledge of music and some knowledge of law are necessary in the experience of every male individual.*" Cayce (903-3,4)

"That was a happy inspiration which led the Quintet Club, of Philadelphia, to pay a visit to the workshop of Keely a few weeks ago. Its members had been told that the illustrious inventor had employed the power of music to develop the wonderful forces of nature, and evolve by a law of sympathetic vibrations a mighty energy through the disintegration of a few drops of water. Naturally they were anxious to go. They were familiar with the claim by Paganini that he could throw down a building if he knew the chord of the mass[13] of masonry, and wanted to know if it were possible that the dreams of the great violinist is realized at last.

"So nearly as can be made out from the mysterious language of the man of many promises, there is a harmony of the universe[14] that is controllable by the strains of music. Each of the molecules composing a mass of matter is in a state of incessant oscillation, and these movements can be so much changed by means of musical vibration that the matter will be disintegrated[15], its constituent molecules fly apart, and a propulsive force be generated similar to that which is evolved by the touching of a match to a single grain of powder stored in a magazine. He holds that matter is nothing but forces held in equilibrium, and that if the equilibrium be once destroyed[16] the most tremendous consequences will ensue.

"According to the report, he proved to the satisfaction of more than one member of the club that he has already discovered the means of calling out this force, and is able to partially control it. In their presence he caused a heavy sphere to rotate rapidly or slowly, according to the notes given by the instrument on which he played. The sphere was so isolated as to prove that it could not be acted on by electricity or in any other way than by the sound waves. He disintegrated water[17] into what he calls "etheric vapor"[18] by means of a tuning fork and a zither. The disintegration of only four drops of water produced a pressure of 27,000 pounds[19] to the square inch, and three drops of

[13] [chord of mass]
[14] see [Sympathy]
[15] [DISINTEGRATION OF MATTER - THREE SYSTEMS]
[16] [Disturbance of Equilibrium]
[17] [THEORY AND FORMULA OF AQUEOUS DISINTEGRATION]
[18] [Etheric Vapor]
[19] [PRESSURES PRODUCED BY VIBRATION]

the harmless liquid fired off a cannon[20] *with a tremendous roar."*[21]

Music incorporates ratio and proportion - the very base constructive elements of vibrations and oscillations.

0.6 A word of warning

It is highly unlikely the reader will grasp the entirety of this material on the first or second read through. One must learn the background ideas, basic or underlying definitions and concepts before the Light dawns in consciousness. This is not unlike learning a new language which does take some time, effort and consequent shifts in consciousness. Do not give up if you don't get SVP within the first five minutes! What you are learning here is PhD level or higher. It takes years of study to earn a PhD - SVP is no different in its level of commitment and materials except that SVP is far more interesting and satisfying.

Do not now or in the future presume what is presented here is the Truth carved in stone. Some is undoubtedly accurate while some not so much. Use your own discernment at all times. This book is my take on these ideas. It is my 'best guess' after years of careful study and deep contemplation. No doubt many will interpret Keely's work differently which is completely OK with me. It will, in my opinion, take many more years if not decades before Keely's work is sorted out, understood and applicable for humanity's benefit. The same goes for Russell's many books and drawings. To do a thorough effort to cover and decipher all that material would take a properly focused and funded team decades of dedicated effort - in my opinion.

0.7 How to use this book

Where terms or phrases are enclosed in brackets ([ ]) the reader is encouraged to look these up within the svpwiki.com. These bracketed terms are mostly in the footnotes at the bottom of each page. If a concept, word or phrase

[20] [Cannon]
[21] [Keely and His Discoveries]

is not understood look it up. A good dictionary resource is onelook.com[22]. Learning Keely is learning a new jargon describing a new paradigm - it takes time to assimilate these new-to-us ideas. On top of that one is obliged to learn the jargons of several fields such as quantum mechanics and physics, chemistry, math, music, acoustics, metaphysics and several others. It then is a hard climb to the peak of understanding but the view will be worth it.

Due to the nature and expense of the printing process, especially color, imbedded images are black and white smaller low resolution facsimiles of the originals to which have been included below each image a link to the original color and/or higher resolution image.

0.8 Generalities and Idealism

The concepts covered herein are mostly generalities. There are some specifics. Usually a general concept is idealized for simplicity's sake. All phenomena are subject to countless influences, some major and some quite subtle all causing some degree of modulation in the simple models presented. A good example covered in 'Chapter 12 - Vortices and Toroids'. A torus is usually presented looking somewhat like a common donut. This is a gross over-simplification as the structural and functional elements in toroids are many, complex and dynamic. The treatment on these complex toroid structures and dynamics takes the basic idea then ventures into a bit more detail. One's lifetime is not enough to cover all the details of all the subjects touched on within Sympathetic Vibratory Physics [SVP][23]. I'll do what I can to provide details as I am able. Other unresolved details are left for later writings and to those so interested and driven to ferret them out.

Dale Pond[24]
La Junta, Colorado

[22] It has been found the older dictionaries are better to understand Keely and the science of that time period than newer dictionaries.
[23] [Sympathetic Vibratory Physics]
[24] [Dale Pond]

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Chapter 1

Ether as a Working Fluid

1.1 Something old something new

Has the Victorian Ether[1] been rediscovered? I believe it has. Science has been brow-beat to never ever use the term "ether" or *else*. Such a threat has perpetuated a clear state of ignorance in direct proportion to holding back true scientific progress. The too often used blanket statement *"Ether does not exist"* is nothing short of dogma and therefore decidedly unscientific. But no one (openly) questions that statement out of reactionary inquisitional fear. Had any questioned it they would have seen the term "ether" is 1) a general concept and not specific and 2) there is obviously 'something' unseen and unacknowledged operating at finer levels of 3) classifications or states of matter and energy. It would require a book-length expose to show not only does the ether exist and has always existed but it is now being seen by conventional science under different eyes because the general catch-all term '*elemental particle*' is being applied to a multitude of new classifications of sub-atomic or quantum entities both elementary and composite. We could take all these 'new' quantum entities or higher classifications of matter and energy states and interactions and lump them under the term "ether" and we would then know what ether is. Ether to SVP is simultaneously a 'classification' or 'state' and depending on context a 'thing'. This puts us into a nice position of understanding what Keely called "Ether", "Etheric Vapor"[2], *etc.* and still be on a solid scientific footing which none could successfully

[1] [Ether]
[2] [Etheric Vapor]

assail.

Quark-Gluon Plasma (QGP) "The strength of the color force means that unlike the gas-like plasma, quark-gluon plasma (QGP) behaves as a near-ideal Fermi liquid, although research on flow characteristics is ongoing. In the quark matter phase diagram, QGP is placed in the high-temperature, high-density regime; whereas, ordinary matter is a cold and rarefied mixture of nuclei and vacuum, and the hypothetical quark stars would consist of relatively cold, but dense quark matter."[3]

Compare the above description to

Liquid Ether *"The atomolic*[4] *substance is what is termed the ether which fills all space and is the transmitting medium for all celestial and terrestrial forces. This is the liquid ether of occult science."* Keely

Both named substance are 1) subatomic entities, 2) liquids and are 3) conducting or transmitting[5] mediums of/for diverse forces. I do not at this point consider QCP as elementary as it is a composite conventionally classified within the "Very high energy state" of matter and energy. It therefore ought to be classified to correlate with Keely's Interetheric subdivision[6]. To ferret out all this "new" information one could begin with the svpwiki.com pages "State" and "Subdivision" then proceed to Wikipedia, States of Matter, *etc.* Again many volumes could be researched and written about this one aspect of SVP correlated to conventional science.

1.2 Energy Levels

For the purposes of this document "Ether" (quantum energy level substances) is considered as a *Working Fluid* not unlike refrigerants in a cooling system where liquid is converted into gas state then back to liquid state by varying pressure and temperature. Molecular substances that can undergo this type of repeating phase change without changing their chemistry are called

[3] Wikipedia/Quark-Gluon Plasma
[4] [etheric]
[5] [Connecting Link]
[6] [Subdivision]

azeotropic fluids of which there are a great variety on the market. The only thing that changes within such a system is the Wave Function[7] (mathematically defined state) of the Working Fluid. In this context Ether, being and viewed as an azeotropic fluid, may be (generally speaking)

Molecular, as in liquid water or water vapor (composed of molecules)

Atomic, as in Hydrogen and Oxygen and (composed of atoms)

Etheric, as in Electrons, Protons, Neutrons, Photons, Quarks and Gluons, etc. of which there are a great variety. (composed of quantum entities)

Hence there are many types and variations of these three main classifications each possessing their own identifying state or Wave Function. These states or Wave Functions are interchangeable according to Keely's Law of Transformation of Forces[8]. The first two above states operate within what is called *classical* physics (sometimes called Newtonian Physics, 3D, materiality, maya, *etc.*) and obey its laws. The third state or classification operates within *non-classical* physics (sometimes referred to as Quantum Physics, Quantum Mechanics, Quantum Electrodynamics, Subtle Energy Physics, Mind Physics, Scalar Physics or Spiritual Physics). As is well known the third state or classification of non-classical physics does not operate according to principles of classical physics even though many foolishly attempt to apply classical physics laws to these subtler (non-classical) states of matter and energy.

1.3 Classification of Energy Levels, States or Phases

SVP establishes a seven-level matter and energy classification having the three main divisions of molecule, atom and ether. The modern classification is not as simple or neat. Modern science has identified multiple classes or types of *associations of quantum entities*. Several of these associative states are theoretical meaning they are hypothesized but not yet "proven". Several

[7] [wavefunction]
[8] [Law of Transformation of Forces]

others are well established and accepted.[9] The modern states that are listed below may be associated with Keely's "Etheric" state or subdivision are (but not limited to)

I - Low Temperature states

1. Superfluid
2. Bose-Einstein condensate
3. Fermionic condensate
4. Rydberg molecule
5. Quantum Hall state
6. Strange matter
7. Photonic matter

II - High-energy states

1. Degenerate matter
2. Quark-gluon matter [10]
3. Color-glass condensate

III - Very high energy states

The High-energy states may be considered in this document as 'states of ether' of which there are countless variations. It is not our intent to delve into the intricate details of these states. If is however our intent to explore and clarify how some aspects of these etheric states associate, behave and have their being. These high energy states as defined as ether or *'atomolic substances*':

"The atomolic substance is what is termed the ether which fills all space and is the transmitting medium for all celestial and terrestrial forces. This

[9] [Wikipedia; States of matter]
[10] [svpwiki.com; Quark-gluon plasma]

is the liquid ether of occult science." Keely

"*For convenience' sake we will use the term atomolic in place of etheric in our subsequent definitions.*" Keely[11]

1.4 Michelson-Morley

Keely's quantum discovery work preceded even the discovery of the electron in the early 1890s[12]. Keely's pioneering work with *splitting the atom* into its constituent quantum elements predates quantum mechanics and quantum physics by decades. This accomplishment[13] predates any officially recognition fields such as these existing within quantum realms of matter and energy - because they didn't exist to victorian science unless it be referred to as *Ether*. In fact the atom was considered as *indivisible* by orthodox science of that day. No scientist or engineer of that time period had a clue what Keely was doing because his ideas were never suspected by science or engineering. In consequence he developed his own terms which worked for him as he applied his findings to design and operate his innovative hybrid quantum/mechanical devices[14][15] of diverse designs and purposes - mostly to prove out his theories as he constructed his paradigm of Sympathetic Vibratory Physics which he sometimes called Vibratory Etheric Physics or simply Vibratory Physics. Of course as there were no other scientists or engineers aware of quantum mechanics and physics in Keely's day there was no one who could understand or verify what he was doing. The best they could do (the honest ones of integrity) was to witness Keely's demonstrations and report what they thought they saw without offering any explanations.[16] The dishonest ones or those who felt threatened by knowledge they knew nothing about (despite their lofty degrees) condemned everything Keely did as fraud or fakery[17].

From the above and with 20/20 hindsight we can see the Michelson-Morley

[11] [Dashed Against the Rock, p. 47]
[12] Depends who you ask.
[13] [Keelys Accomplishments]
[14] etheric or quantum forces powering mechanical machines
[15] [Keelys Mechanical Inventions and Instruments]
[16] [Eye Witness Accounts]
[17] [Was Keely a Fraud]

experiment did not prove the ether did not exist. It simply proved the ether or the now known to exist high-energy states could not be detected or measured with his crude equipment built and operated with their incomplete classical physics paradigm that did not include non-classical physics even though is what they were hoping to verify.

Keely said etheric substances are so tenuous as to pass through seeming solid matter as wind through *"a coarse sieve"*. If his view is correct there was no possibility Michelson and Morley were going to impede or measure any resistance caused by ether.

"The negative sympathetic polar stream is the magnetic flow proper, and it is in sympathetic coincidence[18] *with the second atomic flow, the electric current is the first and second order of atomic vibration, a dual force, the flow of which is too tenuous to displace the molecules. It can no more do so than the flow from a magnet can displace the molecules of a glass plate when it is passed under it. The flow from a magnet is too fine to disturb the plate molecules, but passes as freely between them as a current of air would through a coarse sieve."* (underlines added)[19]

1.5 Etheric or Quantum Carriers

These high-energy states or tenuous substances are *carriers* or conductors of subtle imperceptible forces or disturbances that once excited will manifest as other perceptible detectible phenomena. These streaming forces are Keely's Sympathetic Streams[20]. These fine subtle forces are therefore the unseen and often unsuspected scalar or causative forces manifesting as other lower frequency coarser effects of attraction, repulsion and rotation. This book is about identifying and manipulating these subtle unseen constituent forces that we may be enabled to create desirable effects such as magnetism, electricity, health, gravity effects, rotation and all of their attributes and variations. As carriers of excitation or disturbances[21] they are therefore as connecting

[18] [sympathetic coincidence]
[19] [Keely], [ATTRACTION PROPULSION ETC], [16.21 - Magnetic Flow]
[20] [Sympathetic Streams]
[21] [13.12.1 - Disturbance of Equilibrium]

links[22] between the seven subdivisions[23] of matter and energy states thus affecting transformations or transmutations of these energy states[24] between themselves whether moving into or out of higher or lower energy ranges manifesting as *centralizations* or as more commonly called - *particles.*[25] These unseen and unacknowledged subtler forces are the constructive constituent elements making up the wave function of all known states of matter and energy.

One of the more significant attributes of this Dirac Sea-like[26] substratum of the universe is it's vibratory uniformity and harmony establishing a sympathy between centers or centralizations which modern science now calls *quantum entanglement.* Keely called this ubiquitous harmonic state of being between entities *sympathetic association* and is governed by the Law of Sympathetic Association[27]. The active link between centralizations or particles is their inherent vibrations and oscillations. When these periodic motions form unisons or harmony between secondary and tertiary harmonics are called sympathetic vibration and sympathetic oscillation. It is this sympathy between periodic motions that is the cause and link seen in "action at a distance"[28] phenomena such as quantum entangle[29]ment, remote viewing, mind to mind[30] communication, telepathy, telekinetic actions, *etc.*[31] As we will see another synonym for this universal sympathetic attribute of and between all centralized energy states (centralizations, particles) is Love (as one).

[22] [connecting link]
[23] [Subdivision],[State]
[24] [Law of Transformation of Forces]
[25] [connecting link], [Vibratory Physics - The Connecting Link between Mind and Matter], [The Connecting Link Between Mind and Matter - Keelys Progress - Part 2]
[26] [Dirac Sea]
[27] [Law of Sympathetic Association]
[28] [action at a distance]
[29] [telepathy]
[30] [mind to mind]
[31] [action at a distance]

Chapter 2

Love in Science and Physics

2.1 First and foremost Love is sympathy

First and foremost Love is sympathy or that which connects (entangles) all things to all else. In SVP, sympathy does NOT mean "feeling sorry" but means "feeling the same as", "as one" or "one with". Some might call this "empathy", "harmonization", "resonance", "bonding", "coupling" or "entanglement".[1]

"*Love is the Creative Force of All that Is.*"[2]

2.2 Love in Science and Physics

2.2.1 Sympathy essential

This harmonious high-energy state of matter and energy is everywhere the same. It, by its nature, is that which connects everything to everything else. Without this unity of being the universe would be fragmented, separate and discontinuous. It is a universal bonding agent without discontinuities. Should anything be disturbed everything else responds in like fashion as their essences (constituent elements) are entangled.

[1] [Sympathetic Association], [Law of Sympathetic Association], [Law of Assimilation], [Harmony], [Affinity], [Attraction], [Awareness], [Knowing], [Universal Love], [Christ], [Science], [Truth], [Coupling]

[2] [Dialogue on Awakening], page 160

"Where there is no sympathy there can be no love, for love is sympathy."[3]

2.2.2 The state or condition of Sympathetic Association

The state or condition known as Love is important to science and physics because this state or condition is what underlies and connects all seeming individuated things. Love is a condition or state of vibration that links or entangles all things to all other things everywhere, essentially eliminating Time and Space. Which is to say all things are quantum entangled. This statement appears false as we do not perceive it to be the case when we see every thing as seemingly being separate and distinct. Our perception (opinion) is of the physical or molecular state, form and color of things. For instance, a rock is a molecular mass appearing to have an individual existence all by itself. So we see the mass which we can pick up and move it around and not physically see a connection to any other thing or rock not realizing the rock is a portion of the earth and is resonant to the earth else it would not remain either on the earth or in a molecular state or both. *Should we consider just the electrons and photons making up every thing that is, regardless of location, as being essentially the same, vibratorily speaking, how can they not be entangled?*

2.2.3 Looking at the substance of a rock

Looking at the substance of a rock (for instance)
We know
1 - it is composed of molecules which are composites of atoms.
2 - these atoms are composed of electrons, protons and neutrons.
3 - these elementary entities are composed of photons.
4 - photons are composed of quarks[4].
5 - all these above entities vibrate and oscillate perpetually at given rates and amplitudes and as *modulated by their near and far vibratory environment.*
6 - that individual objects of the same frequencies or chords of frequencies are sympathetically linked or entangled to and with each other. As every type of

[3][Vera Vita the Philosophy of Sympathy]
[4]https://en.wikipedia.org/wiki/Photon_structure_function

quark, photon and electron are essentially the same[5] no matter where they are we can say all these particles are sympathetically linked or entangled to each other to varying degrees or gradients. They have the same or very similar Wave Function[6].[7]

2.2.4 Sympathy Connects Everything

Thus this underlying sympathy that dynamically connects these seeming individual entities is the unseen Connecting Link[8] that connects them all. This Connecting Link functions on the 6th and 7th subdivisions[9] of Matter and Energy and permeates all forms of matter whether in solid or fluid form.

2.2.5 Sympathy is simply another word for Love

Sympathy is simply another word for that state of being known as Love, Harmony, Coupled or Quantum Entanglement.

2.2.6 Sympathy is Attractive

It is this sympathy or sympathetic affinity of vibration or oscillation rates that binds, unites or coheres like entities to one another whether they are quarks, atoms or people individually or in groups. This property of vibratory attraction was demonstrated by Carl Bjerknes[10] in 1881 and is a fundamental dynamic of SVP.[11] Likewise vibratory attraction is the cause of syntropy[12] (negative entropy[13]) another basic and important dynamic of SVP.

[5] notwithstanding near and far, seen and unseen vibratory influences and/or modulations
[6] [Wave Function]
[7] [Entanglement], [Subdivision]
[8] [Connecting Link]
[9] [Subdivision]
[10] [Carl Anton Bjerknes]
[11] [Bjerknes Effect], [Law of Attraction], [Syntropy]
[12] [syntropy]
[13] [negentropy]

2.2.7 Individuated Complex Wave Functions

Having said all that it must be also stated that no two electrons are exactly the same compound chord of frequencies (complex wave function or spectra) at any given moment in Time and location in Space. They do all possess certain 'standard' chord configurations in common else they would be something other than electrons. Each has a slight and ever changing variation dependent upon modulating forces such as local gravity, electric and magnetic influences, pressures, temperatures, *etc.* If these subtle differences were not present then destroying one electron would destroy them all and as we see a continuity happening with the universe we can see this completely entangled sympathy does not occur on the electron subdivision. Some aspects of electrons are fully entangled other aspects not so much. On the other hand should we progress to the next subdivision, the photonic or light, we see a higher degree of sympathy or harmony between the photons than the sympathy that exists between electrons. This is because there are less frequency parameters (simpler chord or signature) to a photon than has a larger group of photons manifesting as an electron. Likewise we can advance to the next higher subdivision of quarks and notice there is again another higher degree or "Q" of sympathy than with the lower grosser photon or electron subdivisions. There is yet another higher level of subdivision which Keely called the Compound Interetheric or Undifferentiated Mind Force and substance. He indicated this level is not differentiated and is wholly sympathetic unto and within itself. A pure (latent) sympathy if you will being of course pure Love or Oneness of vibratory Being. Religions have called this state or condition of total Love or sympathy many names from God, Nirvana, Allah, Jehovah, Heaven, *etc.*

2.2.8 The state of pure Sympathy

This state of pure sympathy acting in a highly sympathetic medium (etheric, quantum subdivisions) means no matter what happens anywhere in this sympathetic medium such is communicated to all of the medium simultaneously and the velocity of communication is near instantaneous.[14] Now, is not this instant awareness or knowing of what is going on regardless of distance (space) an omniscience? Is this not a "Self Awareness" of the underlying universal matrix we call the universe? Does this interconnectedness not account

[14][Quasiparticles carry entanglement to near infinite speeds]

for shared Mind phenomena such as remote viewing, clairvoyance, spooky action at a distance, and telepathy?[15]

This background or ground state sympathy was established when quiescent Divine self-awareness occurred and before active thought or thinking began. This state is not unlike the initiatory Void of Genesis. An undifferentiated state of "perfect continuity without extension". The originating state of neutrality of a Neutral Center cannot change but its effects once disturbed are always changing.

[15][Mind Force the hidden Scalar Force]

Chapter 3

Sympathy

3.1 Sympathy is Love

Sympathy is Love or that which connects (entangles) all things to all else. When the frequency of vibrations are one there is unison and sympathetic resonance[1]. In SVP, sympathy does NOT mean "feeling sorry" but is "feeling the same as", "one with", "as one", concordant, harmonic or entangled with identical or near identical states with near identical wave functions.[2] With this insight we can see Sympathy is a vibratory state of matter and energy with its own waveform, spectra and wave function. It is a real state or condition existing throughout nature and is a condition we can know, understand and engineer[3]. For instance between two tuned tuning forks exists this state of sympathy, sympathetic vibration or sympathetic association. The sympathetic vibrations and oscillations originating from each fork and active between them creating this shared state, can be modified to increase or decrease the state of sympathy existing between them. The fact that they are sympathetic and co-vibrate together is called *resonance* which only occurs within this state or condition of sympathetic association via sympathetic vibrations and oscillations.

[1] [Sympathetic Resonance]

[2] [Concord], [Harmony], [Affinity], [Attraction], [Awareness], [Knowing], [Universal Love], [Christ], [Science], [Truth], [Coupling]

[3] "Engineering with Love", http://svpbookstore.com/

3.1.1 Infinitely Small Centers

The infinitely small strings of the String Theory are a classical physics concept of oscillating physical strings extrapolated to the non-classical quantum realm and is a *non sequiter*. Such is an attempt to apply known or assumed classical oscillation dynamics associated with an oscillating 3D or physical string, which are also poorly understood and in error, as an answer or postulate to address presumed quantum dynamics.[4] Should we replace the hypothetical infinitely small oscillating strings as held in the String Theory with infinitely small constructive (virtual or actively created by virtue of dynamics and purpose) centers that vibrate, pulsate and oscillate like tuning forks it can be seen how every center is sympathetic (in sympathy) with every other center and are therefore quantum entangled; *i.e.*, (sympathetic to one another). All of these centers form One Continuous Continuum of sympathetic (entangled) centers and is everywhere throughout Space permeating every seeming separate or seemingly individualized object. What connects all these sympathetic centers is a state of etheric level high-grade sympathy creating a condition of sympathetic association - one with all others[5]. This would of course imply a single fundamental tone or frequency at the very heart/core of the universe. Keely called these centralizations of orchestrated motion "atomoles"[6]. Therefore what is experienced by one center is to a degree experienced by all other centers regardless of Time and Space. Being mutually responsive to excitation where all are aware of all others we may term this continuum the Whole Undifferentiated Mind of the universe. Mind or Consciousness being synonyms for Keely's Compound Interetheric state. Some over the years have referred to this continuum and its sensitive responsive properties as God and have erroneously anthropomorphized it even though it is the root of Awareness and cognition. Being sympathetic these centers can be stimulated or excited by an appropriate exciter[7]. That exciter being clear focused Mind Force, Thought, Volition or idea.[8] Other different state excitations (stimulations) on coarser molecules and atomic substances could be acoustical, electrical, microwave or physical or similar.

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[4] see 'Chapter 6 - What is Vibration?'
[5] [Law of Assimilation]
[6] [atomoles]
[7] [Exciter]
[8] [What is Sympathy]

3.1.2 Atomoles

Atomoles (atom = unit + mole = power) = Power Unit, are primordial particles (preferably 'centralizations') filling all space.

"Atomoles are elementary units of matter uniform in size and weight, and exist in solid, liquid, gaseous, and isolated forms." (plural 'atomolini')[9]

"The atomoles are made up of atomolini (singular atomolinus); the subdivision of matter from this point is beyond man's power, as at this point it escapes all control of apparatus, passing through glass and hardened steel as a luminous flame without heat, which is hardly seen before it vanishes, - a perpetual flame coldly luminous."[10]

''*The atomolic substance is what is termed the ether which fills all space and is the transmitting medium for all celestial and terrestrial forces. This is the liquid ether of occult science."*[11][12]

3.1.3 Records of Motion are Seeds

Walter Russell refers to these excitable (plastic) centers, when considered as One Continuous Continuum, as points of 4++ (voiding and dispersion) and as "seeds" or "ideas". These seed centers correspond to Keely's Neutral Centers conditions of birth to all seeming things in a progressive evolutionary manner.

"Records of Motion are seeds for repetition of motion. In the seed is desire for manifesting imaged forms of idea. All forms are wave forms. All wave forms unfold from seed records of those wave forms."[13]

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[9] [Keely]
[10] Keely, 1893
[11] Keely, 1893
[12] [Connecting Link]
[13] Russell, [The Secret of Light], page 137

3.2 Neutral Center of the Earth

"In setting the conditions of molecular sympathetic transmission by wire, "writes Keely, "the same law calls for the harmonious adjustment of the thirds, to produce a non-intermittent flow of sympathy. Intermission means failure here. That differential molecular volume is required, in two different mediums of molecular density, to destroy differentiation[14] *of sympathetic flow, seems at first sight to controvert the very law established by the great Creator, which constitutes harmony - a paradoxical position which has heretofore misled physicists who have propounded and set forth most erroneous doctrines, because they have accepted the introductory conditions, discarding their sympathetic surroundings. The volume of the neutral centre of the earth is of no more magnitude than the one of a molecule: the sympathetic conditions of one can be reached in the same time as the other by its coincident chord."*[15]

3.2.1 Force of Sympathy

"There is no force in all creation more real or more powerful that the force of sympathy."[16]

Sympathy may be considered a force because it provides a harmonizing modulation. Where there is discord or enharmonicity Sympathy exerts an influence, of its own accord and nature, converting or transforming that imbalance back to balance or harmony. Discord, entropy or differentiation may be considered as a disturbance of equilibrium which imbalance is restored by Sympathy - harmony or balance being the natural eigenfrequency (wave form and wave function) of the universal matrix - with preponderance of syntropy during growth and a preponderance of entropy during death.

3.2.2 Sympathy is the Essence of Life

"Sympathy, like a human electricity, is the essence of life."[17]

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[14] [differentiation]
[15] [Keely], [Law of Sympathetic Association]
[16] [David Sinclair], [A New Creed the book]
[17] [David Sinclair], [A New Creed the book]

"There is a celestial mind force, a great sympathetic force which is life itself, of which everything is composed."[18] Keely[19]

"Life is creative, and is the manifestation of that energy, that oneness, which may never be WHOLLY discerned or discovered in materiality, and yet is the basis of all motivative forces and influences in the experiences of an individual."[20]

For life or Life Force[21] to be creative it must be syntropic - that building process of assimilating elements its environment - to itself. As this Life Force cannot be discerned strictly in materiality or the 3D classical world it must be of the unseen non-classical scalar forces such as Mind. Hence Keely's use of the term *celestial mind force*[22] also known as *celestial radiation*[23].

3.2.3 Sympathy is as Syntropy and Electricity

"The powers of electricity have not hitherto been observed, nor have the origin and importance of sympathy. The electric marvels of the present day were in electricity thousands of years ago, but there was no practical observer to utilize them. Sympathy is as everlasting and all-powerful as electricity is. Men, in their honest research for human happiness, will put it to the test, and the new insight it will give to life will be more marvelous than the marvels of electricity."[24]

What David Sinclair[25] is saying here is sympathy as a force or state exists and can be engineered. That science has not recognized this state of being existing and operating as an ubiquitous construct of the universe is lamentable. Keely recognized it to such an extent he has able to utilize its properties in his science and incorporated it as a usable function in their dynamics. It is a simple fact that unless a property is acknowledged to exist

[18] [Life]
[19] [Celestial Radiation]
[20] Cayce (2012-1)
[21] [Life Force]
[22] [celestial mind force]
[23] [Celestial Radiation]
[24] [David Sinclair], [A New Creed the book]
[25] [David Sinclair]

it cannot be utilized. We can look at this state of being as a restorative force. Natural systems are in a state of equilibrium. Sympathy, as a pre-existing condition of dynamic systems, will restore that balance or equilibrium should the system be disturbed. This self-acting and self-correcting functional dynamic, unseen by classical and non-classical science and lay alike, is a core functional principle in Sympathetic Vibratory Physics. Taking the metaphor of an undisturbed seesaw quietly sitting in a horizontal position we can see it will tend to re-level itself once disturbed. It will return to its horizontal position. Or a pendulum will come to rest (balance) is moved off center (disturbed out of rest or balance). Likewise we know a given volume of atmosphere is essentially in balance between dry hot expanding air and cold contracting moist air. When a cold wet front approaches a volume hot dry air the localized atmospheric system is then out of balance between the two volumes. The re-balancing occurs when the two volumes come together with the unseen desire[26] to re-balance themselves by one attempting to become the other. This seeming antagonistic action is what Walter Russell called Voiding[27]. This voiding action can be gentle or it can be violent as a tornado depending on Time and polarity or bias difference between the two states or conditions. This desire to void or re-balance (to become *as one*) is born of sympathy and the nature of sympathetic associations where all unlike (seemingly opposite) participant forces or states desire to be alike (in balance or harmony). Hence we see throughout nature seeming opposite poles of electricity voiding against or through each other in a spark or load, opposite poles of a magnetic adhere as one and opposite sexes drawing together and assimilating each other.

[26] [Desire]
[27] [Voiding]

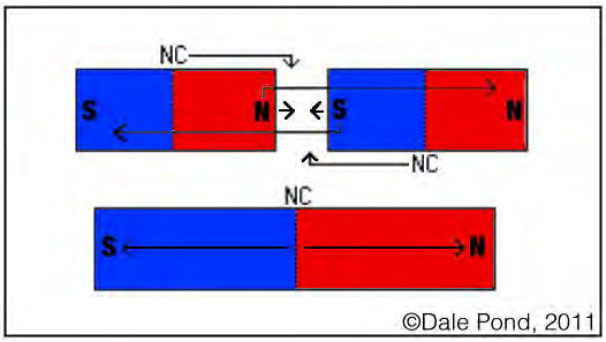

Figure 3.1: Opposite polar forces void/combine as One
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/bar_magnet1.jpg

After voiding (Keely's *neutralization*[28]) or becoming depolar or neutral each pole or participant in the voiding action returns to its original state of unbalance or near so.[29] This return from depolar to polar is of course Time dependent.

3.2.4 The rate of acceleration of Sympathy is enormous

Sympathy exists between all centers. It is as an etheric connecting link[30] stronger and denser than hardened steel. Because transmission or propagation increases with density its rate of extension or propagation is enormous.

"It is a law of falling bodies that they steadily increase their speed, so is it with this great power of sympathy when once it is started. Its rate of acceleration is enormous. A force that is once created can never be destroyed, and there is no force in all creation more real or more powerful than the force of sympathy. It may be stored up and hidden as energy is in fossil vegetable matter. It is a great created power, latent in the hand of the Creator, and at the command of the creature."[31]

[28] [neutralization]
[29] In Figure 3.1 'NC' = [Neutral Center]
[30] [connecting link]
[31] [David Sinclair], [A New Creed the book]

3.2.5 Sympathetic Associative Forces

"*What modern cosmologists would have us believe was evolved by blind chance out of the inherent potentialities of primordial chaos, this glorious system of spiritual physics demonstrates as dependent upon the relationship between mind and matter; showing whence the initial impulse comes which sets in motion machinery of unimagined complexity, on given lines, toward a prescribed end. Chance, as has been said, is in no sense a force, but merely the sway of a balance of forces already in action. Sir Isaac Newton taught that there is such consistency in nature that what lies wholly beneath the region of visibility may be safely inferred to be similar to that which is gross enough to be palpable to sense; and Keely, reasoning on this line, has copied nature in his mechanical work. "I call this indefinable, latent element," he writes, "the soul of the sympathetic elements in which it manifests, itself; and which until now has been locked up in their interstitial embrace. It is the leader of all triple streams, associated with the polar negative envelope of our planet and the one most sympathetically concordant to celestial radiation. In our individual organisms, the latent soul-forces, existing in the cerebral domain, are sympathetically subservient to the celestial radiating force whereby they are stimulated into action in controlling the movements of our bodies. Take away this latent element from the brain and the physical organism becomes an inert, dead mass; on the same order as a mechanical device without an energy to operate it.*

"*The polar negative machine is a mechanical brain, with all the adjuncts associated with it to sympathetically receive and distribute the polar negative force. Its sympathetic transmitter (corresponding to our sun in our planetary system, transmitting all energy from the central sun of the universe) is the medium whereby sympathetic concordance is established between it and polar sympathy. The requisites for polarizing and depolarizing keep up the action of the machine as long as it is associated with the transmitter. The force which operates the mechanical is the same as that which operates the physical brain; purely mental, emanating from celestial outreach. There is nothing in the range of philosophy which so satisfies the intellect as the comprehension of this wondrous system of sympathetic association, planned by the Creator of the celestial and terrestrial universe, for the government of all forms of matter.*

"*Nature cannot rebel against herself. The flowers of spring cannot resist the sympathetic force which calls them into bloom, any more than the latent force in intermolecular spaces can rebel and remain in neutral depths when sympathetic vibration calls it forth.*

"*What is the soul but life in latent suspension? The motion exhibited in matter shows that its soul is ever present; and yet there are men of great learning, as taught in the schools, who, after spending their lives in researching all forms of matter, deny that all living things depend on one everlasting Creator and Ruler, in whom they live and move and have their being through all time, as much as when He first breathed into them the breath of celestial radiation; and to whom they are as closely allied, still, by the workings of the great cosmical law of sympathetic association, as when the evolutionary work of creation commenced.*

"The ancients were far better schooled in spiritual philosophy than are we of the present age. Their mythological records, in their symbolical meaning, prove this fact. They recognized this latent element as the very breath of the Almighty; the sympathetic outflow of the trinity of force, the triple spiritual essence of God Himself. Their conceptions of Deity were greater and truer than our own. From them we learn that when God said 'Let there be light,' He liberated the latent celestial element that illuminates the world: that when He breathed into man the breath of life, He impregnated him with that latent soul-element that made him a living and moving being." [32]

3.2.6 Sympathy is Entanglement

When object A is in sympathy with object B, A is aware (responsive) of what happens to B and B is aware of what happens to A. As there is an innate or natural vibratory sympathy (sympathetic association of vibration and oscillation) between all things or objects all things and objects are aware (responsive) of all that is happening, everywhere and all the time regardless of Time and Space. This property or condition os sympathetic association has been called by many names throughout humanity's long evolution: Entanglement, Omniscience, Coupling, God (and all its variations), non-locality, Mind, Love, Remote Viewing, Clairvoyance, Celestial Sympathetic Radia-

[32] Keely from [The Veil Withdrawn]

tion, Brahma, Cosmic Consciousness, *etc.*[33]

3.3 Sympathy defined

It is important to understand what sympathy is as it plays a tremendous and an all important role in how the universe and all it contains works. Sympathy is a state or condition that occurs between all centers and is an inherent property of these centers.

1 - ‘‘*Where there is no sympathy there can be no love, for love is sympathy.*”[34]

2 - noun: a relation of affinity or harmony between people or things; whatever affects one correspondingly affects the others.[35]

3 - noun: In natural history, a propension of inanimate things to unite, or to act on each other. Thus we say, there is a sympathy between the lodestone and iron.[36]

4 - Sympathy is a Force, as material as Sound, Light and Heat - *“For the sake of being popularly understood, sympathy as a force is here, in a general sense, sometimes spoken of in a kind of figurative way as a message on the telegraph wire, etc. In a more particular way it will now be scientifically explained as a force, as material as sound, light and heat. We speak of the sun’s rays as if each ray were some simple element, and yet easily carry in our minds the fact that each ray is composed of light and heat; so this philosophy speaks of this ether as a mere lineal connecting-rod between the creature and Creator. If the analogy between the sun’s rays and the ether be closely followed, it will be seen that wisdom, truth, and sympathy are the same thing, and travel on the ether lines*[37] *exactly as light and heat do on the sun’s rays.*”[38]

5 - Pertaining to or produced by sympathy.

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[33][Dale Pond], 11/21/10
[34][Vera Vita the Philosophy of Sympathy]
[35][Sympathetic Vibration]
[36]Webster’s 1828 Dictionary
[37][connecting link]
[38][David Sinclair], [Vera Vita the Philosophy of Sympathy]

6 - *"The mutual relation between parts more or less distant, whereby a change in the one has an effect upon the other."*[39]

7 - A real or supposed affinity between certain things, by virtue of which they are similarly or correspondingly affected by the same influence, affect or influence one another (especially in some hidden, unseen way), or attract or tend towards each other.

8 - A relation between two bodily organs or parts (or between two persons or things) such that disorder, or any condition, of the one induces a corresponding condition in the other.

9 - Agreement, accord, harmony, consonance, concord, agreement in qualities, likeness, conformity, correspondence.

10 - Conformity of feelings, inclinations, or temperament, which makes persons agreeable to each other; community of feelings; harmony of disposition.

11 - The quality or state of being affected by the condition of another with a feeling similar or corresponding to that of the other; the fact or capacity of entering into or sharing the feelings of another or others; fellow-feeling. Also, a feeling or frame of mind evoked by and responsive to some external influence.[40]

12 - Sympathy, n.; pl. Sympathies. (F. sympathie, L. sympathia, Gr. ; with + suffering, passion, fr. , to suffer. See Syn-, and Pathos.)

13 - Feeling corresponding to that which another feels; the quality of being affected by the affection of another, with feelings correspondent in kind, if not in degree; fellow-feeling.

14 - An agreement of affections or inclinations, or a conformity of natural temperament, which causes persons to be pleased, or in accord, with one another; as, there is perfect sympathy between them.

[39] Blakiston's New Gould Medical Dictionary. The Blakiston Company, 1949. 1st edition
[40] (source unknown, underline added)

15 - Kindness of feeling toward one who suffers; pity; commiseration; compassion.

16 - (Physiol.) (a) The reciprocal influence exercised by the various organs or parts of the body on one another, as manifested in the transmission of a disease by unknown means from one organ to another quite remote, or in the influence exerted by a diseased condition of one part on another part or organ, as in the vomiting produced by a tumor of the brain. (b) That relation which exists between different persons by which one of them produces in the others a state or condition like that of himself. This is shown in the tendency to yawn which a person often feels on seeing another yawn, or the strong inclination to become hysteric experienced by many women on seeing another person suffering with hysteria.

17 - A tendency of inanimate things to unite, or to act on each other; as, the sympathy between the loadstone and iron.

18 - Similarity of function, use, office, or the like.

3.4 Recommended reading

[David Sinclair], [A New Creed the book]
[David Sinclair], [Vera Vita the Philosophy of Sympathy]

Chapter 4

Neutral Center

4.1 Neutral, Latent Neutral and Neutral Center

Scattered throughout the following pages are the terms "neutral", "latent neutral" and "neutral center". These are central concepts in SVP (Keely's physics) and any study of polarity and its dynamics.

4.2 Neutral means

Neutral means: Where two phases from two vibrations are opposite in polarity and cancel each other out or "sum to zero" is called *phase conjugation* and is one form of neutral. Another form is the balance point between polarities much like a fulcrum under a seesaw. This balance point within a vibration or oscillation is neutral, depolar or potential. The power (potential) in both above cases of the phases or polarities has been equated and becomes latent thus establishing two poles and one neutral - a trinity of states of forces. There are other forms or associative dynamics constituting a neutral state or neutral center and will be discussed later.

"When a force becomes neutral it is inactive, and is no longer a force; consequently the name given is misleading, Keely calls this third element the "latent neutral," which is a better name for it."[1]

[1]Bloomfield-Moore [CJBM], [What Electricity Is - Bloomfield Moore]

Latent means depolar. The other two forces or states are polarized forces dynamic relative to each other. These are the Harmonic (syntropy) and Enharmonic (entropy). There exists a neutral state from which these two polar forces originate and to which they return. This neutral (depolar) state is "latent" or quiescent until stimulated (polarized).

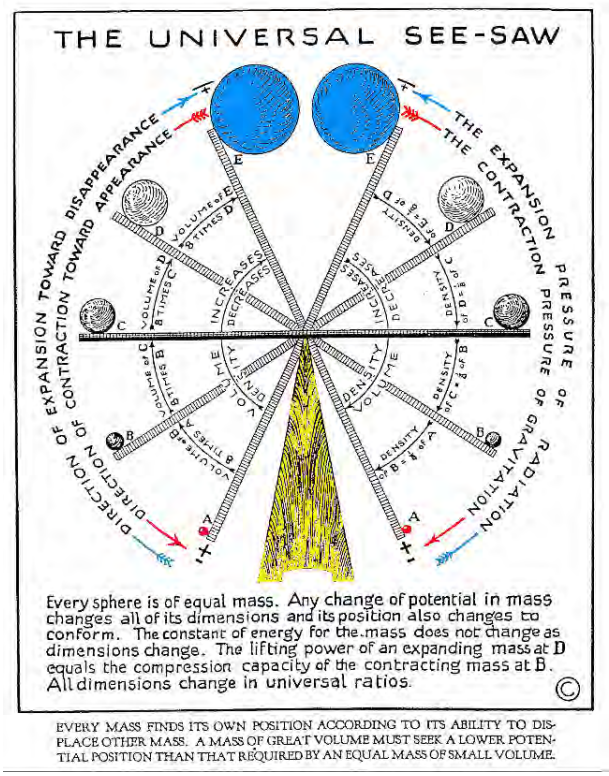

Figure 4.1: Universal Seesaw balancing seeming opposites
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/universal-seesaw.jpg
(courtesy University of Science and Philosophy)

A latent center is a center that has not been stimulated or excited. It is quiescent (depolar). Latent Forces are forces not stimulated (polarized) into motion or activity but held in stable (harmonic) balance. A scalar[2] force is a non-moving non-dynamic latent force or potential - not kinetic.

[2][scalar]

In the above Russell image he uses the phrase "potential position" which is the same as Keely's "level of tenuity". Thus indicating it is the potential or tenuity of relative position that constitutes mass being a relative quantity. The fulcrum is the neutral balance point between two potentials or polarity, bias or bipolar polarities.

Neutral State or condition and Neutral Center are two different things or dynamics. A Neutral State is a condition independent of location. A Neutral Center is a location or foci, relatively speaking. A Neutral State has among other attributes Mutual Affinity between participating streams or conditions, sensitivity to appropriate stimuli, equated polarizations, point or state of equation. There are diverse orders, kinds or types of Neutral Centers. The two sides of the seesaw represent polarization. The fulcrum represents the neutral sustaining point, principle or condition where the polarizations meet by mutual affinity in mutual antagonism. *"All forces are Mind Forces"* meaning all forces originate from Undifferentiated Mind[3] or the Compound Interetheric[4] subdivision. As sections or segments of Undifferentiated Mind are polarized (differentiated) they become forces or energies. The Ultimate Differentiator is thought or idea. These polar forces become neutral or latent by removal of polarization (discords). Keely called this process "harmonization".

4.3 Coordination or coincidence of forces

Consequently when and where various forces meet and cancel (void) or agree there is established a Neutral Center. Sometimes this point may be called a center of neutrality, center of attraction, center of sympathetic attraction, center of sympathetic coincidence, center of association and concentration, center of focalization, nucleal center, Prime Neutral Center and Supreme Neutral Center, depending on its general dynamical state. Some of the types of Neutral Centers are:

- mass - every mass of whatever substance or size has a neutral center.
- molecular - neutral centers in molecules.

[3][Undifferentiated Mind]
[4][Compound Interetheric]

- atomic - neutral centers in atoms.
- etheric neutral centers - neutral centers in quantum/etheric centralizations.
- Prime Neutral Centers - neutral centers that govern and enliven secondary centers not unlike the Sun (primary) and its planets (secondary).
- Supreme Neutral Center - The one Dominant Center that controls all other neutral centers.
- center of centers - an object may have more than one neutral center, this is the coordinated center between them all.
- focalized centers - centers can have more than one center. This idea is what we see in a circle (one foci) and an ellipse (two foci). A focalized center is where all these centers are coincident or focalized together as one center.
- sympathetic concordant focalized neutral center - a focalized center that is concordant (in harmony of parts) that is sympathetic to something else, usually an outside stimulant or exciter or other center(s).
- focalized negative attractive centers - A focalized neutral center that is in the syntropic phase of assimilation, attraction or concentration. It's opposite would be a dispersing positive propulsive center (radiating or radiant). See [Law of Assimilation].
- centers of sympathetic coincidence - A dynamic center where forces that are sympathetic to each other coincide.
- centers of neutrality - a neutral center that is in a quiescent state of neutral latency.
- centers of focalization - centers where forces are mutually attracted or focused to interact.
- centers of distribution - centers where forces are mutually repelled and dispersed.

Centers are intermittently attractive and repulsive or dispersive. When a Neutral Center is disturbed it becomes intermittently attractive and repulsive. When attractive it becomes a center of focalization. When repulsive it becomes a center of propulsion or dispersion. In between one state and its opposite is a moment of pause not unlike the furthest point in the swing of a pendulum or seesaw. This null point or fulcrum can endure both polarities without itself being affected.[5]

The Neutral Centers give birth to quantum centralizations Keely called atomoles. The Neutral Centers are then the cause that give rise to their effects - these atomoles - and are synchronistic meaning "can't have one without the other' (the chicken and egg riddle). On the other hand Keely and Russell both said there is an infinite number of Neutral Centers implying there is an infinitely small space between these centers which makes the universe quite dense (986,000 denser than steel[6]) and births the logical idea matter is more of a tenuous 'bubble' in this dense etheric substratum than the way ego sees matter as more dense than seeming vacuity.

Matter evolves from vacuity of space

"*Pure sympathetic concordants are as antagonistic to negative discordants as the negative is to the positive; but the vast volume the sympathetic holds over the non-sympathetic, in ethereal space, makes is at once the ruling medium and re-adjuster of all opposing conditions if properly brought to bear upon them.*" Again Russell and Keely concur on the origin of matter. Sympathetic streams aggregate at a neutral center about which forms centralized motions; *i.e.*, form or appearance of matter. Non-sympathetic conditions are discordant and dispersive resulting in the appearance of seeming empty space. Solidity devolves towards vacuity through the action of non-sympathetic (discordant) conditions; *i.e.*, entropy. Outer space is the domain of the non-sympathetic or dispersed matter.

In one of many ways Russell describes the dual nature of space (cube) and matter (sphere) he says this about that dynamic state: "*The sphere is the*

[5] See [Philosophers Stone]
[6] [Law of Matter and Force]

result of the concentrative pulsation of Gods thinking which pulls inward from within (syntropy) to focus the light of Gods thinking to a point of stillness, around which a thought body (form or matter) can be formed. This causes that universal effect, which we know as gravitation, and the still point of concentration is a center of gravity. GRAVITATION MULTIPLIES POWER. [See ([Neutral Center])

"*The cube is the result of the decentrative pulsation of Gods thinking which thrusts outward (entropy) from within to the stillness of the cube boundaries to produce the opposite effect which we know as radiation. RADIATION DIVIDES POWER.*

"*Gravitation and radiation are the opposite ends of the piston which motivates the heartbeat of this eternally living dual body of God, which is our dual body. Its continual giving and regiving*[7] *manifests the love principle*[8] *in both the action and reaction not just in one of them.*"[9]

4.4 Neutral Center

Neutral Center = Dominant = Fulcrum = Pure (Undifferentiated) Consciousness = Love = 0 (Russell) = First Cause. There are neutral centers on all seven subdivisions of matter and energy. These Neutral Centers possess differing states; *i.e.*, properties, functions and geometries.[10]

We do not yet know all the properties of the neutral center but Keely does list a few of them. Keely considered his discovery of the Neutral Center to be one of his greatest discoveries as also its control through machinery. Our rediscovery of it will be one of humanity's greatest achievements. Keely's description of the neutral center follows:

"Every molecule, every mass, every moving body in space, every solar system, every stellar system, EVERY ROTATORY SYSTEM, is built about a

[7] [Giving-Regiving]
[8] [Law of Sympathetic Association]
[9] Russell, Home Study Course, GOD CREATED ONLY ONE FORM; see [Cube Sphere]
[10] [Barycenter], [Center], [Center of Gravity], [Center of Mass], [Sympathetic Coincidence], [MINERAL DISINTEGRATION - Snell]

NEUTRAL CENTER."[11]

"The neutral center represents only focalization and distribution of the streams of energy." [12]

Thus there are discrete mass, molecular, atomic and etheric neutral centers as well as Prime Neutral Centers, "center of centers", "focalized centers", "sympathetic concordant focalized neutral center", "focalized negative attractive centers", "centers of sympathetic coincidence", "centers of neutrality" and "centers of focalization", thus defining its state depending on dynamical function, location, association, etc.

"The neutral center is that protean, uncreated, indestructible, forever-existing FIRST CAUSE[13]*. Without hands, without tools, without thought, without emotion, without love, without form, without substance, it, of itself, created all these. All that we see or can see in the objective Universe exists because of and by means of the properties and powers of the NEUTRAL CENTER."*[14][15]

"Where the vibrations under this mode meet, and are maintained in a state of mutual affinity or equilibrium, there is established what is called a "neutral center", or, as otherwise expressed, 'a center of sympathetic coincidence'."[16]

4.4.1 Disturbance of Equilibrium

This is why a meditative state (neutral or undifferentiated) of mind is important (sympathetic) to "knowing" these interlaced concepts. Because they are All One. To be it is to know it. The thinking ego or intellect is differentiated conscious and is highly discordant which is to say it destroys harmony as is present in the meditative or quiet mind. This does not make the intellect thinking an enemy - it is simply discordant, a disturber of the harmony. This

[11] [Keely]
[12] [ROTATION - Snell]
[13] [First Cause]
[14] [Keely]
[15] [First Cause]
[16] [KEELYS PHYSICAL PHILOSOPHY - Snell]

discordance is the Infinite Exciter[17] "*that moulds and makes*"[18] something from seeming nothing thus making humanity as a Creator. We use our crystal clear thinking and focus to create the lives we live. As neutral states are pure unmanifested potential (latent) in perfect harmony it is from where and whence all manifestation of form originates - *"from harmony is generated discord"*[19]. These manifestations become reality when the neutral state is disturbed. This disturbance of equilibrium[20] [21]is a key function in SVP.

Logically, if all three forces are modulated the same degree at the same time there would be imbalance in the equation. Disturbance of equilibrium means the three forces, in an established triune or three-way equilibrium, are thrown out of balance or equation by changing one or two of the three so the equation of harmony becomes one of discord; *i.e.*, thrown into motion which then seeks to re-establish the originating harmony or balance. For instance, this principle is active in spiritual seekers as they are all seeking to return to the original Peace and Harmony with the One (wake up or self realization. Such a disturbance in a molecule being intermittent will cause the molecule to deform in its motions into activity then recede back to its original quiescent state.

The Neutral Center is a point or center of sympathetic coincidence. It has many properties. The creation and perpetuation of the Neutral Center is predicated on the inflow of what some call God/Divine Force (Divine Will or sympathetic celestial streams) or as Keely called it *Celestial Sympathetic Radiation*[22] originating from the Supreme Neutral Center, establishing its progressive evolution, as it were, and through the Principle of Regeneration[23] is radiated outward as refracted or differentiated materiality via the Law of Harmonic Pitch[24], Law of Harmonic Vibrations[25], and Law of Cycles[26]. This process is in other words a ubiquitous (everywhere in all Time and Space) or

[17][Infinite Exciter]
[18][As a Man Thinketh]
[19][8.23 - Law of Cycles]
[20][disturbance of equilibrium]
[21]see [7.26 Disturbance of Equilibrium]
[22][Celestial Sympathetic Radiation]
[23][Principle of Regeneration]
[24][Law of Harmonic Pitch]
[25][Law of Harmonic Vibrations]
[26][Law of Cycles]

non-local "Micro Bang" (syntropic implosion/cavitation) process that then radiates and eventually manifests as what we perceive as matter, *etc.* In a word, the Neutral Center is a Compound Interetheric sympathetic force or state of Undifferentiated Mind (scalar). Therefore it is this inflow of the Divine Will (sympathetic celestial streams, Mind Force) as CAUSE of materiality; I feel this needs to be clearly stated. See Figure 12.8 for an animated graphic showing this spontaneous generation or production of discords that breaks down into dispersion the formative harmony.

4.4.2 Supreme Neutral Center

The Compound Interetheric (Undifferentiated Mind) is outside of Time and Space and is unaffected by either. So one could rightly say the Supreme Neutral Center has always existed and always will exist even though it only exists in the NOW moment like everything else. The physical universe is as a Thought in this Undifferentiated Mind. Thoughts are polar. Expression is polar. Manifestation is polar. All materiality is polar. Non-materiality is depolar (neutral) in relation to materiality. Hence all polar conditions emanate from depolar or neutral latency until stimulated into being by desire, idea or thought.

The egoic intellect creates the ideas of Time and Space. As time is an illusion, a creation of our polar egos, it has not relevance to actuality. There never was a "time" prior to the creation of the "universe". For lack of a better expression the universe has always existed and had no beginning because if time is an illusion then it might be said there never was a past and there is no future. There is only Now. Our fractured egos cannot Know the Undifferentiated Mind Knowing (God's knowing). The countless attempts to anthropomorphize 'creation' and 'God', *etc.* are doomed as feeble attempts at rearranging dream elements (fabrications of the ego). Only our whole undifferentiated minds (Cosmic Consciousness) can know these infinite things, states or conditions which cannot be adequately expressed through finite intellectualism. The Mind of Deity[27] is cause while the universe is the effect of that Cause. A cause and its effects cannot be separated. The connecting link is the etheric domain. As Cause is Undifferentiated Mind then all its effects are polarized (split) mind thinking.

[27] [Mind of God]

Keely indicated there is a single Supreme Prime Neutral Center governing all other neutral centers whether mass, molecular, atomic or etheric regardless of location. Prime Neutral Centers are as the Sun (prime) to its planets (secondaries). As neutral centers are effects as well as cause this Supreme Neutral Center is Dominant and an integral of all neutral centers - they are all one and the same in substance and dynamic with the exception One is sum and source of all others. Russell referred to it as the Universal One[28] from which all else originated. The intellect wants to separate every thing into parts. The universe is one whole acting through what appears to be individuated parts. All the parts are governed by one Supreme Neutral Center, each manifesting as though individual. There is one supreme state of neutrality that permeates every thing. This omnipresent state or condition of Neutrality is perfect concordance or Sympathy (Love) and everywhere present in all things and actions - the Universal One.

Outflow and Inflow

Each Neutral Center has an intermittent outflow and an inflow of sympathetic streams originating from the Supreme Neutral Center redirected from the Prime Neutral Center. These occur according to Russell's Rhythmic Balanced Interchange[29] and Macvicar's Law of Assimilation[30].

There is an outflow: "*..communicates direct by means of its outflow of sympathy, with every planetary mass in the Universe.*"
There is an inflow: "*Through its inflow of sympathy, through the solar intermediate, the sun, it receives the life flow from the Supreme Neutral Center..*"

[28][The Universal One]
[29][Rhythmic Balanced Interchange]
[30][Law of Assimilation]

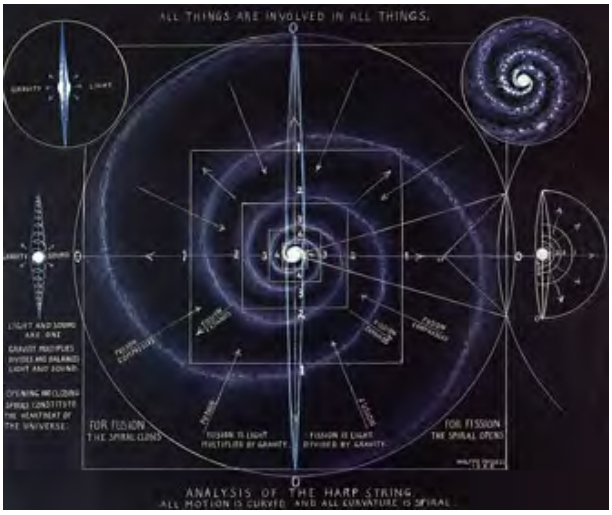

Figure 4.2: From the One comes the many
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/russell-neutral-center2-300.jpg
(courtesy University of Science and Philosophy)

4.4.3 Keely further describes the Neutral Centers

"All the Dominant conditions of nature represent the focal centers towards which like surrounding ones become sympathetically subservient."[31]

The dominant condition of nature is harmony or Sympathy (Love). This harmonic or attractive state has a field of influence (sympathetic outreach) which casts its influence or its controlling effects as a modulation of everything in its reach (its Sympathetic Outreach[32]). Other surrounding Neutral Centers which can be few or countless depending on the chord of the Dominant Neutral Center fall under this influence. Sympathy extents as a state or condition of forces. This extension has harmonizing effects and will modulate any other chord to, in some degree, resemble this originating chord of harmony. This is what and how people "feel" energy around the Dynaspheres. The calming or harmonizing power is extended by sympathetic vibrations and/or oscillations (quantum entanglement) on the sixth and seventh subdivisions. This power and dynamic has been anthropomorphized throughout

[31] [Keely and His Discoveries], pg 179
[32] [Sympathetic Outreach]

history as the"Love of God"[33]. This dynamic is described in Keely's

4.4.4 Law of Transmissive Vibraic Energy

"All oscillating and vibrating coherent aggregates create, in the media in which they are immersed, outwardly propagated concentric waves of alternate condensation and rarefaction, having a period-frequency identical with the pitch of the aggregate."
Scholium: *"All forms of transmissive energy can be focussed, reflected, refracted, diffracted, transformed, and diminished in intensity inversely as the square of the distance from the originating source."*

Which law and its dynamics sets the stage for:

"Neutral centers are the focalized seat of sympathetic concordance for controlling any differentiation that may exist outside, or in the mass that surrounds them."[34]

Every individual "thing" has its own chord of mass. Apparently no two chords of mass are identical. A chord of mass will have numerous frequencies within itself resulting from its own chordal evolutions (overtone series) and as modulated from countless outside FM and AM modulations (summation and difference tones). It is these modulations that cause differentiations[35]. They are the differentiations. One center will control all the neighboring neutral centers being as it is or becomes the Dominant Center. Centers are not entirely individuated in their existence because they are ultimately controlled or governed by sympathetic streams, concurrently arriving to each, from the Supreme Neutral Center which created them and in which they have their being or existence perpetuated.

"Neutral centers are the center of Sympathetic Coincidence."[36]

Which dynamic and conditions establishes Sympathy as being the controlling state or condition over everything in its reach or field of influence.

[33]Law of Sympathetic Association]
[34][Keely and His Discoveries], pg 255
[35][Differentiation]
[36][Keely and His Discoveries], pg 220

‘‘*Pure sympathetic concordants are as antagonistic to negative discordants as the negative is to the positive; but the vast volume the sympathetic holds over the non-sympathetic, in ethereal space, makes it at once the ruling medium and readjuster of all opposing conditions if properly brought to bear upon them.*”[37]

‘‘*The effects of the law of sympathetic association, which Mr. Keely demonstrated as the governing medium of the universe, find illustrations in inanimate nature.*”[38]

“A center of introductory action is necessary in all operations of Nature. All structures require a foundation. This neutral center is the foundation.

“Every molecule, every mass, every moving body in space, every solar system, every stellar system, EVERY ROTATORY SYSTEM, is built about a NEUTRAL CENTER. It is the indestructible unit around which all that we recognize as matter is built. Immovable itself, it moves all things. Indestructible itself throughout infinity of time, it creates all things. It produced and preserves the incalculable energy of motion of the entire Universe. It bears the unthinkable burden of the mass of the Universe. It is the most wonderful thing Man has discovered in the Universe since he discovered fire.

“If we should take a planet of say 20,000 miles diameter and should displace a portion of the interior so as to have a crust of say 5,000 miles thickness, and at the center of the planet, place a billiard ball, that small mass, immeasurably smaller than the bulk of the earth, would bear the entire burden of the mass of the crust 5,000 miles thick and would keep it equidistant from itself. No power, however great, could possibly displace this central mass so as to bring it into contact with the crust. Furthermore, to move this central mass in any direction, would require a force sufficient to move the entire mass of the planet, and in propagating or continuing any such motion the neutral center, this billiard ball, will at all time periods remain still in the exact center, bearing the same equidistant relation to its hollow shell. The mind staggers in contemplating the burden borne by this neutral center, where weight ceases.

[37] [Keely, Chapter 7 of Keely and His Discoveries]
[38] [Bloomfield-Moore, Keely and His Discoveries]

"No less wonderful are other properties of the neutral center.

"It is the cause of the physical Universe. Its attraction condensed that which we recognize as substance. Matter was evolved from the affinity of this neutral center for Sympathetic Streams and since it is immovable, it caused, through negative attraction the formation of nodes in these streams, where the vibrations thereafter continued to meet in a center of Sympathetic Coincidence causing the permanence of form and matter.

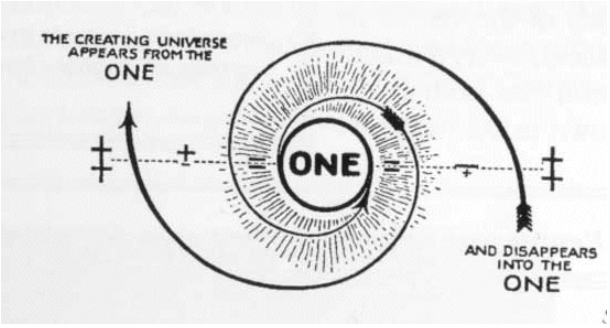

Figure 4.3: Coincidental forces meet at center
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/syntropy-entropy-meet.gif
(courtesy University of Science and Philosophy)

"Every nebula, an embryonic world, is acted upon, created and preserved by this neutral center, and at the termination of its cycle, it is ultimately also destroyed by it, causing its absorption into the Unknown from whence it came."

Every molecule and atom disintegrates into its constituent components and disperses into the vacuity of space - seeking their density coincident or 'level of tenuity' (of density). If they all be depolarized they lose their form and dynamics. They become as 'nothing'; *i.e.*, no 'thing'. Polarity gives form and motion. Depolarity (neutrality) has no form or motion. All form evolves from the vacuity of space (dispersed matter). Neutral Centers do not of themselves exist as a 'thing'. They are dimensionless points of the confluence of forces. How can neutrality have dimension if it has no form? But it does have function not unlike Mind or Consciousness itself.

This latent sympathetic plenum (sympathy) throughout the universe gives rise to all form and motion when disturbed, stimulated or excited. A thought or desire excites this neutrality into a polar condition or state. Polarity causes motion and motion appears as form. Wherever forces synchronize or equate there is established an activated neutral center about which 'matter' may aggregate creating form.

Figure 4.4: Neutral Center - creator of nebula and galaxies
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/ringnebula.jpg

"The actual neutral center of the earth is, in fact, even infinitely smaller than the billiard ball referred to above. It consists of a compound interetheric point in space, so small that were we to magnify a pin head to the size of the sun, and from that substance take a particle of matter the same size, again magnifying it to the size of the sun, the neutral center would still be invisible, even though the structure of this last substance was examined through the highest powered microscope ever created, or to be created. For the neutral center is INDIVISIBLE[39]*. Its attributes do not belong to matter, and pertain in no way to matter, which is but its exterior manifestation.*[40]

[39] How can neutrality (Undifferentiated Mind) have dimension? One cannot divide zero.
[40] [FORM OF THE ATOM]

"Every aggregate mass consists of molecules, each of which has its neutral center where the three modes of vibration, dominant, harmonic, and enharmonic, meet in a center of Sympathetic Coincidence and are equated without cancellation of their energy.[41]

"Neutral centers are the focalized seat of sympathetic concordance.

"The proof of this assumption is that all matter responded to Keely's disintegration process[42] *and must therefore consist of these fundamental modes of vibration.*

Figure 4.5: Keely's Compound Disintegrator
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/compound-disintegrator.jpg

The above Compound Disintegrator,[43][44] later called Liberator[45], is pre-

[41] [Scalar]
[42] disintegrator picture gallery: http://www.svpvril.com/DisPix/Disin1.html
[43] [Compound Disintegrator], [Disintegrator]
[44] more photos http://www.svpvril.com/DisPix/Disin1.html
[45] [Liberator]

sumed to be one of the devices Keely used to progressively dissociate or disintegrate water into etheric vapor (plasma). In modern terms this device would be not unlike a multi-frequency "analog signal generator" in function. See section 7.21 Latent Force. The term 'Liberator' describes its function of liberating the Latent Force held within the confines of the rotating etheric envelopes of the atom. See section 12.12 Etheric Envelopes. In the photo below we see the Liberator connected to the pressure lever for measuring pressure of the liberated etheric vapor[46].

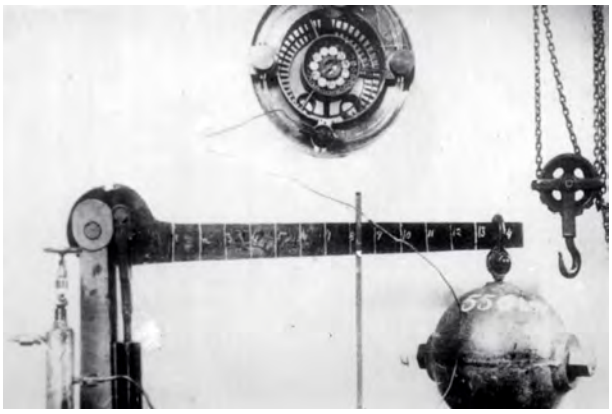

Figure 4.6: Liberating and measuring Etheric Vapor pressures
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/liberating-pressure.jpg

[46][etheric vapor], [Ether Generator Producing High Pressures]

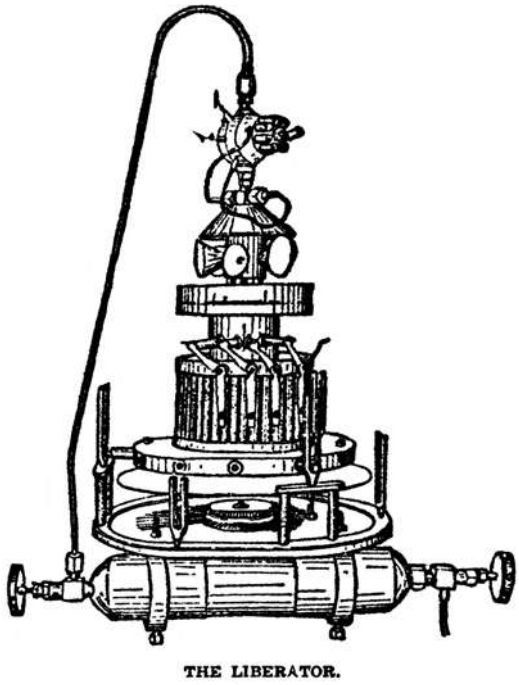

Figure 4.7: An earlier Liberator design
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/liberator1.jpg

4.5 Divine Will - The Wheelwork Source of all Force

"The fixed neutral center of the earth is the concentration or totalized power of all the several molecular neutral centers in the earth's mass. This neutral center, which is absolutely WITHOUT WEIGHT, an interetheric point in space, communicates direct by means of its outflow of sympathy, with every planetary mass in the Universe. Through its inflow of sympathy, through the solar intermediate, the sun, it receives the life flow from the Supreme Neutral Center that enables it to perpetuate its existence. Thus through the outflow from this Supreme Neutral Center that pivoting point of the Universe controls the existence and motion of not only every stellar, solar and planetary mass in space, but also the rotatory vibration, in every individual molecule,

intermolecule, etc. through all the subdivisions of matter, thereby sustaining their existence and motion with the life flow.

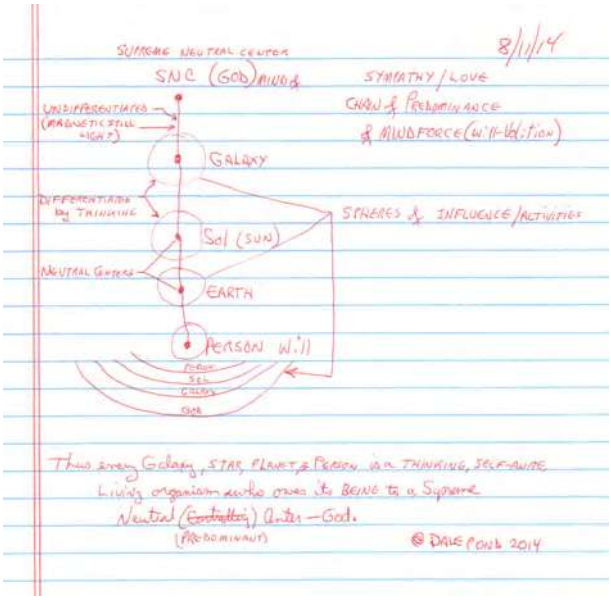

Figure 4.8: Sympathy Links all Centers to all other Centers
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/universal-oneness.jpg

"All foundations must be sufficient to bear their burden. Conceive then the Universe centered upon and resting the burden of is incalculable mass and kinetic energy on a vacuous interetheric point in space, so minute that it is actually INDIVISIBLE. This conception can only be fully comprehended by an infinite mind. Independent of time, because indestructible in its unity, independent in space, because through its properties space itself exists and without it would not exist, independent of matter because its properties in an external direction created all that we know as matter and gave it seeming permanence, the neutral center is that protean, uncreated, indestructible, forever-existing FIRST CAUSE. Without hands, without tools, without thought, without emotion, without love, without form, without substance, it, of itself, created all these. All that we see or can see in the objective Universe exists because of and by means of the properties and powers of the NEUTRAL CENTER.[47]

[47] [God]

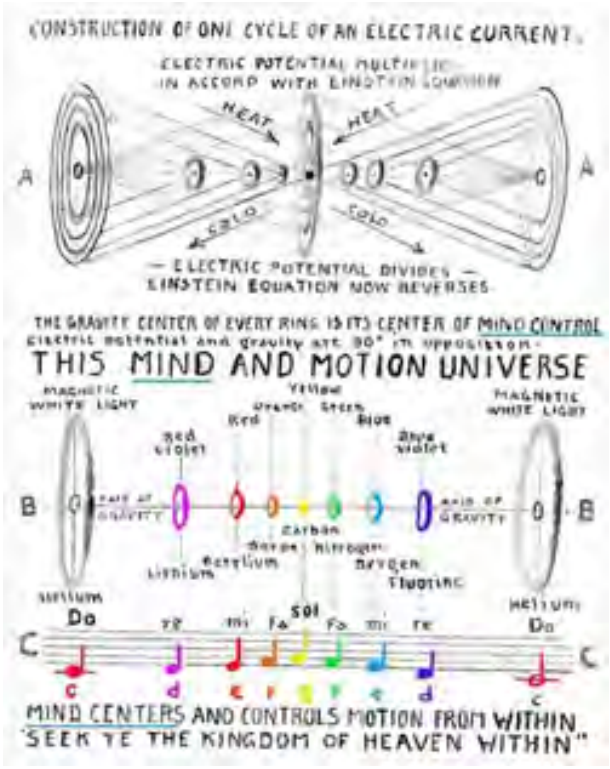

Figure 4.9: Neutral Center is Mind or Consciousness of God
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/mind-motion400.jpg
(courtesy University of Science and Philosophy)

"No machine heretofore constructed has been made with a neutral center. This conception of mechanics has never before dawned on man's thought field. Had this been done, perpetual motion[48] *would have become a demonstrated fact. Were a machine so constructed as to use its properties, an introductory impulse*[49] *would suffice to run it for centuries. However, this would not be a useful mechanical contrivance for no more energy could be obtained from it than was originally given, and its only value would be as a timekeeper.*[50]

"Keely did not seek to invent, nor did he claim to have invented, perpet-

[48] [Perpetual Motion], [Continuous Motion]
[49] [Introductory Impulse]
[50] [Continuous Motion]

ual motion.

"The physicist tells you that "you cannot make something out of nothing;" that "in the economy of nature profit and loss must balance;" that "no matter what the nature of the force may be, its production must necessarily be accompanied by a corresponding expenditure of force in some form or other," etc., etc. But, in the prodigality of nature, this energy flows, without measure and without price, from the great storehouse of the Infinite Will. From the sympathetic portion of the etheric field, all visible aggregations of matter emanate, and on the same order that molecular masses of all living organisms are vitalized by the sympathetic flow from the brain."[51]

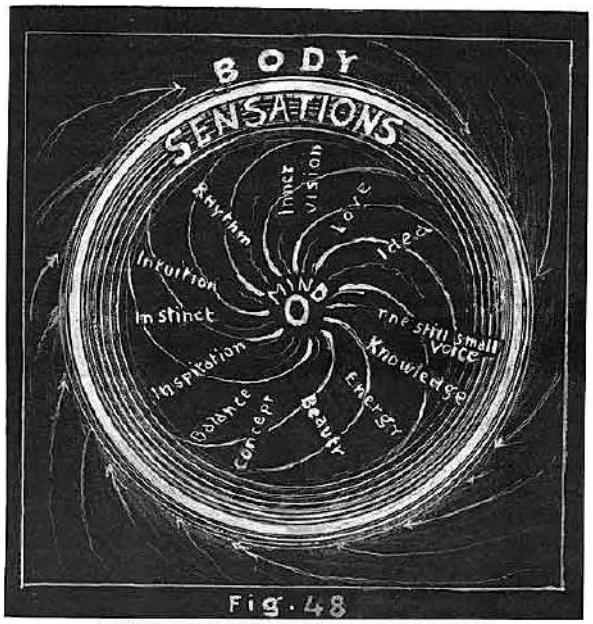

Figure 4.10: Neutral Center is as mind or consciousness
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/ring-of-motion.jpg
(courtesy University of Science and Philosophy)

"When this great scientific and religious truth has been made known, and established by demonstration, all controversy as to the source of energy will

[51] Bloomfield-Moore ([CJBM]) in [Vibratory Sympathetic and Polar Flows]

be for ever silenced. If I am the chosen instrument to develop this knowledge, and to make known the conditions which surround this pure truth, it is only that I may hand the key to those who will use it to enter the doorway that opens into the inaudible, and thus gain an insight into the now invisible region of the operation of Nature's most powerful governing forces, in the control over terrestrial matter by celestial mind."[52]

4.5.1 Center of Sympathetic Attraction

"I find that there is no medium in the range of vibratory philosophic research, that is as unerringly exact, towards the center of sympathetic attraction, as the negative attractive influence of a certain triple association of the metallic masses of gold, silver and platina[53]*. In fact, they are as accurate indicators of the earth's terrestrial sympathetic envelope, and its triple focalized action towards the earth's neutral center, as the magnet is an indicator of the diversion of the attractive flow of the dominant current of the electric stream. Although much has been written on the subject, the conditions attending the continuous flow of the magnet remains a problem that has never been solved by any other theory. Yet the solution is very simple when harmonic vibratory influence is brought to bear upon it.*[54]

4.5.2 Center of Sympathetic Coincidence

"Where the vibrations under this mode meet, and are maintained in a state of mutual affinity or equilibrium, there is established what is called a "neutral center", or, as otherwise expressed, "a center of sympathetic coincidence"."[55]

4.5.3 Center of Association and Concentration

A shared point, point of convergence or center of sympathetic coincidence (Neutral Center) or where syntropic forces meet, coincide, centralize or come together or harmonize.

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[52][Keely] in [Keely and His Discoveries] pg. 365-367

[53][Trexar], [Trextrinar]

[54][Keely], [ANSWERS MADE IN LETTERS FROM MR. KEELY - TO QUESTIONS ASKED OF HIM]

[55][KEELYS PHYSICAL PHILOSOPHY - Snell]

4.5.4 Center of Focalization and Transformation

In the following quote we see the evolution or creation of perceptible light when thought (imperceptible) is directed to a center, undergoes transformation via Law of Cycles, then is manifest as perceptible light.

"Light is induced by electromagnetic percussion emanating from the ether, and in its action represents the plane of magnetism. In fact, it is the plane of magnetism when under polarization. (Platina wires the thickness of a fine hair associated with each of the nine nodal beads, and concentrated towards a general center of focalization, attaching the other end of the wires to the focal center, will determine, by the magnetic conduction, the number of corpuscular oscillations per second induced by a thought[56]*, either positive or negative, in the central centers. These are the only conditions those of magnetic conduction whereby the evolution of a thought can be computed in regard to its force under propagation, as against the amount of latent energy set free to act as induced by such thought on the physical organism.) Some scientific theories of the past have taught us that electricity and magnetism are one and the same thing. Sympathetic vibratory philosophy teaches that they are two distinct forces of one of the triune sympathetic family."*[57]

4.5.5 Nucleal Center

Term used by Russell to denote the point in a wave of maximum polar opposition or the 4++[58] state of polar opposition and when depolar as the Plane of Inertia[59]. Also understood to be the same as Keely's Neutral Center where Keely mentions 'antagonism'[60], *etc.*

In between one state and its opposite is a moment of pause not unlike the furthest point in the swing of a pendulum or seesaw. This null point or fulcrum can endure both polarities without itself being affected. See [Philosopher's Stone] There are in actuality two fulcrum points or points of transformation. The first is the 4++ center position where opposing polarities seek to Void

[56] [Thought Force]
[57] [Keely], [Snell Manuscript - the book], [ELECTROMAGNETIC RADIATION - Snell]
[58] [4plusplus]
[59] [Plane of Inertia]
[60] [antagonism]

at maximum opposition. The other fulcrum or transformation point is what Russell called the Plane of Inertia where polarities are at their least opposition. The sympathetic streams wind or spiral towards the center of 4++ and unwind spiraling away from that center to the six Planes of Inertia.

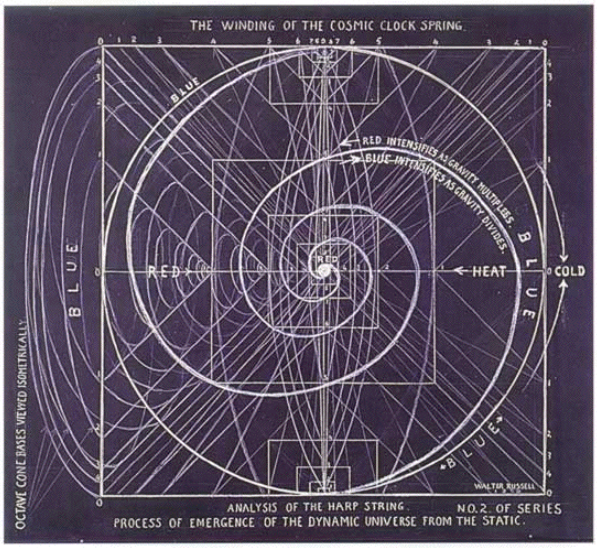

Figure 4.11: Syntropy winding up force to 4++ center
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/67-Winding.GIF
(courtesy University of Science and Philosophy)

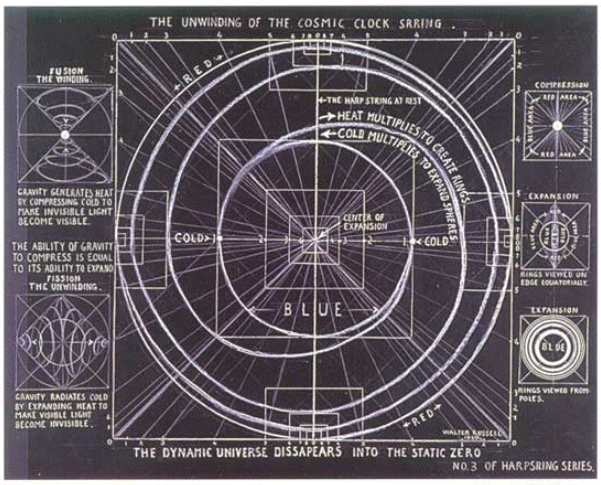

Figure 4.12: Entropy unwinding energy to 0 Plane of Inertia
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/68-unwinding.gif
(courtesy University of Science and Philosophy)

4.5.6 Resistance

Resistance in DC circuits is equivalent to impedance in AC circuits. It is quite clear the concepts of resistance in the writings of Keely and Russell are more akin to AC impedance than DC resistance (as commonly understood). Resistance or antagonism is the presence of discords. As two poles harmonically accumulate force through mutual syntropic assimilation and at the 4++ point of convergence resistance or antagonism is created ultimately resulting in activating the Law of Cycles by way of run-away development of discords.[61] These discords multiply in number and accumulate power until the unifying harmonic forces revert from harmonic assimilation to enharmonic dispersion. No doubt this dynamic is the cause of implosion and cavitation processes and activities.

[61] [overtone series]

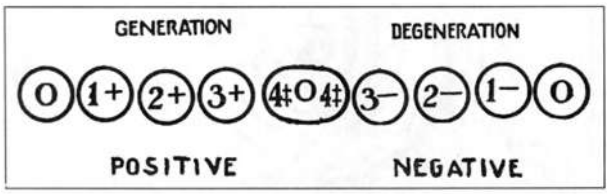

Fig. 68
Two-way journey from zero—through zero—to zero

Figure 4.13: Russell's 4 plus plus center of polar opposition
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/4plusplus2.jpg
(courtesy University of Science and Philosophy)

About resistance Keely says: *"..In crystalline structures, heat, which expands the atoms, by twisting them produces striae*[62]*, increases the resistance, etc."*[63]

[62][striae]
[63]Keely, [Law of Vibrating Atomolic Substances]

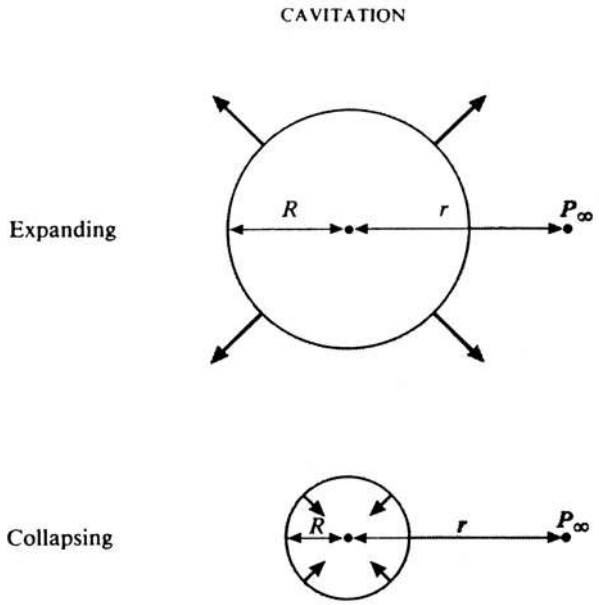

Figure 4.14: Cavitation is an example of the Law of Cycles
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Cavitation_Bubbles.jpg
(courtesy University of Science and Philosophy)

Keely continues: *"The electric current destroys cohesion and chemical tension directly as square of current in amperes, inversely as the resistance in ohms, inversely as the chemical equivalent, and conversely as the coefficient of the difference between the freezing and volatilizing temperature of mass acted upon."*[64]

Russell describing the opposing spirals: *"Positive electricity pulls inward spirally from within against the opposing resistance of negative electricity which thrusts outward spirally from within."*[65]

Russel continues: *"In this electric universe, sensation is the strain of resistance to the separation which exists between all separated masses. All matter is one. Separated particles desire to find that oneness."*[66]

[64]Keely, [Law of Variation of Atomic Oscillation by Electricity]
[65]Russell, [The Secret of Light], page 148
[66]Russell, [The Secret of Light], page 85-86

4.5.7 Prime Neutral Center

Prime Neutral Centers are primary centers about which other subservient secondary neutral centers are attracted and aggregate. In the quote below these Prime Neutral Centers are the neutral centers as stars or suns about which aggregate the secondary neutral centers of their planets. Hence they, the neutral centers are the source of gravity.

"The luminous, etheric, protoplastic element, which is the highest condition[67] *of the ether, fills the regions of infinite space, and in its radiating outreach*[68] *gives birth to the prime neutral centers that carry the planetary worlds through their ranges of motion."*[69]

The actions of Neutral Centers (almost) dictates the existence of rotating shells surrounding centralizing (gravitic) neutral centers. This not unlike so-called electron shells. Hence if every thing or mass has a neutral center and all neutral centers behave according to the same laws then planets would by those same laws (almost) have to be hollow. If it walks like a duck and quacks like a duck then it is a duck. I'm not saying they are but logic points to such a conclusion.

It is not physicality that causes negative attraction but the activated neutral centers that cause negative attraction. It is an illusion of the physical to ascribe causative properties to it when it is in fact nothing more than an effect of the cause - neutral center activity. The neutral centers formed the instant Divine self awareness occurred. It was all created in an instant of no duration and continues to recreate itself as it evolves. *The human intellect has a hard time with the concept of no time.*[70]

4.5.8 Supreme Neutral Center

Every molecule, atom and sub-quantum centralization everywhere existent within the universe has a Neutral Center. All of these neutral centers are sympathetic each to (entangled with or 'as one' with) all others. What keeps

[67] [Interetheric]
[68] [outreach]
[69] [Keely], [Keely and His Discoveries] pg 270
[70] [Time]

all these Neutral Centers "in order" (having one shared state) is subservience to One Supreme Neutral Center of the universe. Some would call this One Supreme Neutral Center, God. Taking out the egocentric anthropomorphic[71] assignments we then have an Intelligence (Consciousness) intimately associated with (in sympathy or entangled with) everything that is. The connecting link[72] between all these centers is Compound Interetheric sympathy which Keely said above '*'fills the regions of infinite space*". These ubiquitous Neutral Centers constitute a state of perfect continuity and living extensions of the One that through progressive evolution[73] or devolution as the case may be manifest as seeming solid matter in all its motions and activities which motion is Life.[74]

It is the nature of neutrality as Undifferentiated Mind Force that fills every thing everywhere. This Undifferentiated Mind Force is everywhere present as "Sympathy" within which, as motion (form), is latent. Being of infinite density and extenuation (although not having dimension) it is ubiquitous and reactive to and action upon every neutral center everywhere without itself being changed. See [Philosophers Stone]. It is the Supreme Prime Neutral state or condition (Cause) governing all else, manifested or not. The state of Neutrality is "perfect continuity without extension". Density and extenuation are dimensions according to Walter Russell so they do not actually exist except in the intellect of Man; *i.e.*, within his definition of matter and energy.

A neutral center is a conjunction of coincidence and focalization of forces. If those centralized forces (molecules, planets, galaxies) cease to exist so too does their controlling neutral center which created them and by which they have their being. They, the cause and its effects, exist concurrently and co-dependently. In other words "can't have one without the other".

"All motion is thought, and all force is mind force."[75]

This then clarifies the adage all, the many, comes from One. The state of the one Supreme Neutral Center does not change yet it births and governs

[71] made in Man's egoic image, anthropomorphizied
[72] [connecting link]
[73] [Progressive Evolution]
[74] [Dale Pond], [Prime Neutral Center]
[75] Keely, [Keely and His Discoveries], pg 252

all else. No state of a material thing is fixed or stable within the universe as everything is in constant compound rhythmical (vibratory) motions. These states of motion are governed by invisible yet knowable principles and laws. It could be said the principles and laws governing these motions are fixed or stable.

"Macvicar[76] foreshadowed the teachings of this new philosophy when he wrote, *"All motion in the universe is rhythmical*[77]*. This is seen in the forward and backward movement of the pendulum, the ebb and the flow of the tides, the succession of day and night, the systolic and diasystolic action of the heart*[78]*, and in the inspiration and expiration of the lungs. Our breathing is a double motion of the universal ether, an active and a reactive movement. This androgyne principle, with its dual motion, is the breath of God*[79] *in man.*" The writings of the ancients teem with these ideas, which have been handed down to us from generation to generation, and are now flashing their light, like torches in the darkness, upon mysteries too long regarded as "*lying outside the domain of physical science*[80]*.*"[81]

How can mind be devoid of thought/awareness? Desire is an aspect of mind, for instance. A quiet mind of knowing contains thought (depolar motionless awareness) but it does not contain egoic or intellectual thinking (polar motion). The physical universe is a recording of thinking dynamics; its existence is manifestation of the originating knowing thought activated by desire. Just as a seesaw contains a fulcrum that does not move it also contains extensions that do move. A seesaw is a trinity of states. Same thing with Divine Mind (the fulcrum or Cause) and everything else (the extensions or effects) in the universe.

[76]Dr. John Gibson [Macvicar] went to the university of St. Andrews in 1814, where he excelled in mathematics and natural philosophy, and thence to Edinburgh, where he studied chemistry, anatomy, and natural history under John Knox's tutelage, together with rhetoric, Hebrew and church history (see Dictionary of National Biography).

[77]same as Russell's [Rhythmic Balanced Interchange]

[78][Universal Heart Beat], [Dynaspheric Force]

[79][breath of life]

[80]classical physics

[81]Bloomfield-Moore ([CJBM]), see [Father-Mother Principle], [Universal Heart Beat]

Chapter 5

Mind and Mind Force

5.1 Mind is Force

Universal Undifferentiated Mind is the One Force from which all other forces are derived. This premise is born out in the writings of many great philosophers, thinkers and sundry historical inspired texts.

"All forces in nature are mind forces: magnetic, electric, galvanic, acoustic, solar, are all governed by the triune streams of celestial infinity; as also the molecular, intermolecular, atomic, and interatomic[1]*. The remote depths of all their acoustic centers become subservient to the third, sixth, and ninth position of the diatonic, harmonic and enharmonic chords; which, when resonantly induced, concentrate concordant harmony*[2]*, by reducing their range of corpuscular motion, drawing them as if towards each other's neutral center of attractive infinity."*[3]

Keely writes *"Luminiferous ether*[4]*, or celestial mind force, a compound interetheric*[5] *element, is the substance of which everything visible is composed. It is the great sympathetic protoplastic element, life*[6] *itself. Consequently, our physical organisms are composed of this element ... its seat in the cerebral*

[1] see [Subdivision]
[2] [Syntropy]
[3] Keely, see [Mind Force the hidden Scalar Force]
[4] [Luminiferous ether]
[5] [compound interetheric]
[6] [life]

convolutions ... This sympathetic outreach[7] *(sympathetic radiation) is mind flow proper, or will force - sympathetic polarization to produce action, sympathetic depolarization to neutralize it. Polar and depolar differentiation*[8] *result in motion. The true protoplastic element ... permeates all forms and conditions of matter, having for its attendants, gravity, electricity and magnetism, the triple conditions born in itself. In fact, it is the soul of matter*[9]*, the element from which all forms of motion*[10] *receive their introductory impulse*[11]*."*[12] (underline added)

"The luminiferous ether the compound interetheric element in other words, celestial mind force[13] *is the substance of which all visible and invisible things are composed."*[14] (underline added)

That Mind Force is a real force has been studied over a 28 year period by the engineering department of Princeton University in their PEAR Proposition project.[15] Their findings were revolutionary with far ranging implications.[16]

"Nearly three decades of intense experimentation leave little doubt that the anomalous physical phenomena appearing in the PEAR studies are valid, and are significantly correlated with such subjective variables as intention, meaning, resonance, and uncertainty."[17]

5.2 Whole vs Split Mind

Mind or Whole Mind means total Awareness unless otherwise specified. The term Mind or Whole Mind does not mean "intellect"[18]. Intellect is of the

[7] [sympathetic outreach]
[8] [Differentiation]
[9] [soul of matter]
[10] [Motion]
[11] [introductory impulse]
[12] [THE NEUTRAL CENTER]
[13] [celestial mind force]
[14] [Ether - Snell]
[15] http://www.princeton.edu/ pear/
[16] http://www.princeton.edu/ pear/implications.html
[17] video http://vimeo.com/4359545
[18] [intellect], [ego]

ego and is a subset of the general Consciousness or Mind and is that limited awareness we have created as our *interpretation* of reality. The term "Mind" as used in SVP means the general Consciousness, Awareness, Whole or Undifferentiated Mind. *Thinking* is of the differentiated intellect, ego or Split Mind while *knowing* is of the Mind, heart or Whole Mind. Whole Mind knowing is knowing with the feeling of the heart while Split Mind thinking or intellect is of the limited duality of the ego.

"*Your ego is a limitation within your Mind. Your ego exists as an expression of limitation.*"[19]

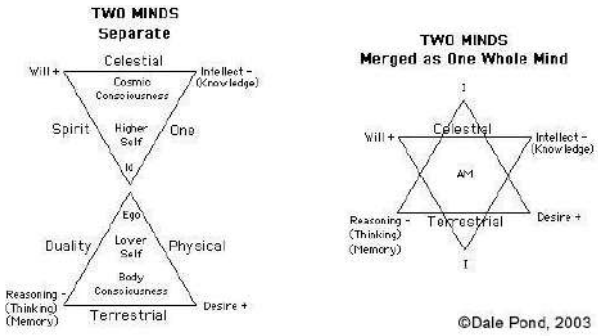

Figure 5.1: Whole and Split Mind
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/two-minds.jpeg

5.3 Mind is of the Sixth and Seventh Subdivisions

Mind is of the Compound Interetheric[20] or seventh subdivision[21] of matter and energy. See Table 5.1. According to Keely's molecular and atomic morphology a molecule may be dissociated into its constituent parts or atoms. Atoms may then be further dissociated into their constituent parts and so forth for all finer subdivisions until the seventh subdivision where the rarefied ubiquitous sympathetic substance of Mind exists.

[19] Tom Carpenter, [Dialogue on Awakening], pg. 29
[20] [Compound Interetheric]
[21] [subdivision]

Dimension	Subdivision	Relation
1	Molecular	separation of air brings us to the first subdivision only.
2	Intermolecular	to the second; see [supercritical fluid]
3	Atomic	to the third;
4	Interatomic	to the fourth;
5	Etheric	to the fifth; and
6	Interetheric	to the sixth subdivision, or positive association with luminiferous ether;
7	Compound Interetheric	as the seventh subdivision.

Table 5.1: Keely's Seven Subdivisions of Matter and Energy

It will be noted these seven states of matter and energy are not unlike the ancient states of matter and energy: Earth, Water, Air and Fire.

5.4 Keely - Substance and Nature of Mind Force

"There is a celestial mind force[22]*, a great sympathetic force which is life itself, of which everything is composed."*[23]

"All motion is thought, and all force is mind force."[24]

"There is no dividing of matter and force into two distinct terms, as they

[22][Mind Force]
[23]Keely
[24]Keely, [Keely and His Discoveries], pg 252

both are ONE. FORCE is liberated matter. MATTER is force in bondage."[25]

The above last two sentences sound like something Albert Einstein would have said roughly twenty years later.

"The mighty forces latent in corpuscular matter, by which we are surrounded, are all held in oscillating vortex action by the Infinite Designer[26] *of workings hidden from us, until the time is ripe for their disclosure. This latent, registered power*[27] *interchanges sympathetically with the celestial radiating streams, whereby light, heat, electricity, magnetism and galvanic action are propagated in their different orders, vitalizing all nature with their life-giving principles.* (underline added)

"When this great scientific and religious truth has been made known, and established by demonstration, all controversy as to the source of energy will be for ever silenced. If I am the chosen instrument to develop this knowledge, and to make known the conditions which surround this pure truth, it is only that I may hand the key to those who will use it to enter the doorway that opens into the inaudible, and thus gain an insight into the now invisible region of the operation of Nature's most powerful governing forces, in the control over terrestrial matter by celestial mind."[28] (underline added)

"The action of the mind itself is a vibratory Etheric evolution, controlling the physical, its negative power being depreciatory in its effects, and its positive influence elevating."[29]

"The substance of the brain[30] *is molecular. The mind which permeates the brain is interetheric in substance; it is the element by which the brain is impregnated. This element, when excited into action, controls all physical motion as long as the necessary sympathetic conditions are maintained. Then conditions are no more immaterial in their character than are light and heat. Electricity, magnetism, gravity, and heat are latent in all aggregations of mat-*

[25] [Keely]
[26] [God]
[27] [Latent Force]
[28] Keely in [Keely and His Discoveries] pg. 365-367
[29] [Keely]
[30] [brain]

ter. They are not obtained from terrestrial influences. Celestial radiation[31] *is the true impregnating medium in all these forces. The brain is the high resonating receptacle where the sympathetic celestial acts, and where molecular and atomic motion are induced, as according to the intensification brought to bear upon it by radiation."*[32]

"The sympathetic conditions that we call mind are no more immaterial in their character than light or electricity. The substance of the brain is molecular, while the substance of the mind that permeates the brain is interetheric and is the element by which the brain is impregnated, exciting it into action and controlling physical motion. In order to trace the successive triple impulses[33]*, taking the introductory one of sympathetic negative outreach*[34]*, towards the cerebral neutrals, which awaken the latent element to action, we find that mind may be considered a specific order of interatomic motion sympathetically influenced by the celestial flow and that it becomes when thus excited by this medium a part and parcel of the celestial itself. The brain is not a laboratory. It is as static as the head of the positive negative attractor*[35]*, until influenced by certain orders of vibration, when it reveals the true character of the outreach so induced. The brain is the high resonating receptacle where the sympathetic celestial acts, and where molecular and atomic motion exhibits itself, as according to the intensification brought to bear upon it by the celestial mind flow. The question arises, Why is this condition of the (luminous) ether always under a state of luminosity of an especial order? Its characteristics are such, from its infinite tenuity and the sympathetic activity with which it is impregnated, that it possesses an order of vibratory, oscillatory velocity, which causes it to evolve its own luminosity. This celestial, latent power, that induces luminosity in this medium, is the same that registers in all aggregated forms of matter, visible and invisible. It is held in the corpuscular embrace until liberated by a compound vibratory negative medium. What does this activity represent, by which luminosity is induced in the high etheric realm, if not to indicate that even this order of ether is bounded by a greater region still beyond? The activity of the corpuscles represents its outflow from the luminiferous track towards the molecular centers of*

[31] [Celestial Radiation]
[32] Keely, [The Operation of the Vibratory Circuit]
[33] [Musical Triplet]
[34] [sympathetic outreach]
[35] [Keelys Mechanical Inventions and Instruments]

neutrality, revealing the connecting link[36] *between mind and matter. These conditions of luminosity have no thermal forces associated with them, although, paradoxically, all thermal conditions emanate from that source. The tenuity of this element accounts for it. It is when the streams come in conflict with crude matter that heat is evolved from its latent state and a different order of light from the etheric luminous is originated, the sun being the intermediate transmitter. All planets and systems are sympathetic intermediates, the whole of one system, connected in sympathy for each other, the Brain of Deity."*[37] See Figure 4.7.

5.5 Russell on Mind and Mind Substance

Keely uses the term 'luminosity' or 'luminiferous ether'[38] which Russell calls 'white still magnetic light of gravity' or simply 'magnetic light'.

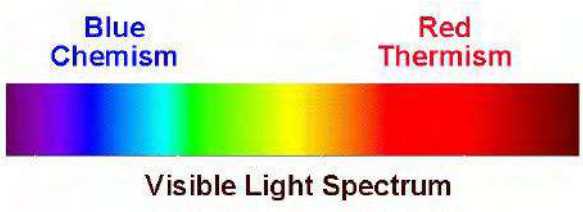

Figure 5.2: Red and Blue halves of the visible light spectrum
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/visible-light-spectrum.jpg

"Electricity is the divider of the invisible white still magnetic light[39] *of gravity - which Mind is - into the red and blue halves of the visible light spectrum for the purpose of creating male and female bodies which alone constitute all matter."*[40]

[36] [connecting link]
[37] Keely, [Dashed Against the Rock]
[38] [7B.09 - Luminiferous Ether or Light]
[39] [Magnetic Still Light]
[40] Walter Russell, notation on chart, 1955

Figure 5.3: Red and Blue halves of Polar states
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/female-male-color.jpg

"This universe of matter in motion is but the electric record of thought."[41]

"Light is the living substance of Mind in action. It is the creating principle of the One substance.

"The One substance is the etheric "spiritual" substance of the One universal Mind.

"The entire "created" universe of all that is, ever has been, or ever will be, is but the One substance in motion, light."[42]

In other words matter is ultimately constituted of the polar concentrated and solidified substance of thought or Mind Force.

5.6 Mind is a Substance

Mind is substance or matter. Mind is a tenuous (ultra-gaseous) matter like ether or plasma (quantum substances). Mind is an etheric (quantum)

[41] Walter Russell, [The Secret of Light]
[42] [Ether - Russell]

substance (ultra-plasma). Mind therefore possesses vibratory, chemical and other knowable and engineerable attributes. As Mind is substance it can be regulated, harnessed and manipulated as any other gaseous substance.

5.7 Mind is also as an aggregate of consciousness

Mind is also as an aggregate of consciousness (self awareness) and is comprised of three distinct subsets:

Compound Interetheric

Superconscious.[43] Also known as Christ Consciousness[44], Cosmic Consciousness[45], Knowing, Wisdom, awareness and science.

Interetheric

Consciousness. Also known as intellect, ego, reason, thinking.

Subconscious. Also known as Soul, body-mind and instinct.

Unconscious. Belief, Habit, Natural Man

Etheric

Tenuous matter that composes the plasma gases of the body actuated (vivified) via our conscious and unconscious thinking and (beliefs, cognized or not).

Interatomic

The liquids and solids composing the body actuated by the etheric or quantum mind forces.

Atomic

Atoms

Molecular

Simple, Compound and Complex Molecules

It is because of this hitherto unsuspected property of mind and consciousness as a form of tenuous matter the link is established between so-called hard science (3D, materiality, classical physics) and so-called sacred science or spiritual fields of study[46] now loosely called non-classical physics. They are

[43] [Superconscious]
[44] [Christ Consciousness]
[45] [Cosmic Consciousness]
[46] [telekinesis], [telepathy]

in fact one field of study when this connection is recognized and admitted.

Chapter 6

What is Vibration?

6.1 Quotes - vibration defined

"Vibration is the rhythmical motion of a body within itself."[1]

"Vibration is a periodic interchange of state."[2]

"Rhythmic Balanced Interchange."[3]

"All force is vibration..." Cayce (900-422) *"So is matter."* Cayce (1861-16)

"All comes from one central vibration - taking different form." Cayce (900-422)

"Everything is vibratory." Cayce (195-54)

"As we see manifest in the electrical forces as used by man. This becoming only an atom in motion, and as the atomic force gathers this, producing such vibration as to create heat, light, and of the various natures, by the kind, class or nature of resistance[4] *met in its passage in the cycle given, reducing or raising the velocity, or better by the class of atomic force it vibrates, either*

[1] Keely, see [Oscillation]
[2] [Dale Pond]
[3] [Russell]
[4] [Law of Vibrating Atomolic Substances]

with or against. These are examples of portions of universal forces."[5]

"Vibration is movement. Movement is activity of a positive and negative force."[6]

"Electricity[7] *or vibration is that same energy, same power, ye call God."*[8]

"Life in its manifestations is vibration. Electricity is vibration. But vibration that is creative is one thing. Vibration that is destructive is another. Yet they may be from the same source. As in the electrical forces in the form or nature prepared even for use in the body. Remember life is vibration. So is mind. So is matter."[9]

6.2 A Vibration Is

A vibration is a rhythmic periodic expansion (entropy/dispersion) and contraction (syntropy/aggregation) change of state; *i.e.*, a periodic inter-exchange of seemingly opposite yet co-joined and inseparable polar states. The two polar states are entropy (expansion) and syntropy (contraction). In each wave or vibration there are two distinct yet related unseen sets of dynamic aliquot parts or constructive currents (when considering a wave train or continuous vibration as a vibratory stream or vibratory flow). One set of aliquot attributes or parameters brings about the periodic concentration or aggregation of the vibrating media while the other set of aliquot attributes or parameters causes periodic expansion or dispersion of the media. If these unseen influences (aliquot or scalar components) were not there and a dynamical constituent of each wave or vibration there could be no delta or change of state as both states or phases would be identical and unchanging. The perceived wave or vibration is then the effect of these unseen causative (scalar) influences, attributes, parameters or currents. The details of these unseen causative (scalar) influences, attributes, parameters or currents are

[5] Cayce (900-17)
[6] Cayce (281-29)
[7] [Law of Vibrating Atomolic Substances]
[8] Cayce (2828-4)
[9] Cayce (1861-16)

the subject of this presentation and are also presented in Laws of Being[10], Laws of Being - Annotated[11], Wavefunction[12] and Part 12 - Russells Locked Potentials[13]. These two states are governed in part by the Law of Harmony[14], Law of Harmonic Pitch[15], Law of Harmonic Vibrations[16] and the Law of Repulsion[17]. See also [Bjerknes Effect] for a mechanical experiment demonstrating these two tendencies of vibratory attraction and repulsion.

Vibrations manifest as three-dimensional (along x, y and z planes) expressions of these unseen creative currents. Vibrations are not well represented by the typical sine wave. The use of the sine wave graphic has become so ubiquitous it is often mistaken for the actual motions of a vibration. These three-dimensional expressions are a periodic expansion and contraction of the elements of the vibrating medium; *i.e.,* the air particles are mutually attractive then mutually repellant according to the Law of Attraction[18] and Law of Repulsion[19]. The contraction is seen as the compressive wave front while the repulsion is seen as the vacuous backside of the compression front. This same dynamic can also be seen as the compressed air at the front of an airfoil and the rarefaction on top of that same airfoil or airplane wing or propeller.

6.2.1 Three Forces action on all Matter and Energy

"All conditions of dispersion and focalization are accompanied by the "celestial mind force" acting upon "terrestrial matter" - (corresponding to the mind force acting on the brain, which is only its molecular instrument.) This force is the first seal of the Book of Vibrational Philosophy - the first stepping stone toward solution of the Source of Life.

"All Nature's forces are mind forces: magnetic, electric, etheric, acoustic,

[10] [Laws of Being]
[11] [Laws of Being - Annotated]
[12] [Wavefunction]
[13] [Part 12 - Russells Locked Potentials]
[14] [Law of Harmony]
[15] [Law of Harmonic Pitch]
[16] [Law of Harmonic Vibrations]
[17] [Law of Repulsion]
[18] [Law of Attraction]
[19] [Law of Repulsion]

solar. Any metallic mass can be so impregnated with certain vibrations that it will assume mental attributes - attraction and repulsion. We must first understand the triune conditions or laws of that sympathetic medium which interconnects matter with matter, the triune conditions or laws of Sympathetic Streams and unites resonance of each of the seven subdivisions before we can understand the induction by means of acoustic generators, of magnetic antagonisms in matter and the different forms of energy thereby liberated."[20]

6.2.2 Law of Attraction (syntropy)

"Juxtaposed coherent aggregates vibrating in unison, or harmonic ratio, are mutually attracted."[21]

6.2.3 Law of Repulsion (entropy)

"Juxtaposed coherent aggregates vibrating in discord are mutually repelled."[22]

6.2.4 Law of the Dominant (Celestial Mind Force)

"All wave propagations, electromagnetic or otherwise by being thus refracted can be measured in regard to the time of their propagation all of which are introductorily subservient to the luminiferous ether."[23]

6.3 Rad-Energy - entropic dispersion

Rad-energy[24] is radiant energy - expanding from a center. Sometimes this energy is referred to as dispersive, entropic or discordant as it is both. According to the Bjerknes Effect[25] radiation or radiant energy disperses (because affected media is mutually repulsive according to the Law of Repulsion[26]) from a center losing its amplitude and degree of discord following the Square

[20][Snell Manuscript]
[21]Keely, [Bjerknes Effect]
[22]Keely
[23]Keely, [Luminiferous Ether]
[24]rad-energy
[25]Bjerknes Effect
[26]Law of Repulsion

Law[27] until it reaches zero amplitude and zero discordant content at Russell's Plane of Inertia[28]. The range of dispersion is dependent upon the Introductory Impulse[29] and conductivity of the media. This dispersive energy effects the media in which it travels through modulation and heterodyning[30]. The overall effects of this process is governed by the Law of Transformation of Forces[31].

6.3.1 Introductory Impulse

The introductory impulse sets the tone so to speak of the acoustic sound mentioned above. The introductory impulse may establish an entropic dispersion or syntropic condition according to its overtone content. When the partials are discords the resultant sound will be entropic dispersion. When the partials are concords the resultant sound will be syntropic concentration. The development of discordant overtones is a simple and low powered occurence. All sounds developing from an introductory impulse will create discords. It appears the more power initiating an introductory impulse the more discords are developed according to the Law of Cycles[32].

6.4 Vibration v Oscillation

These two rhythmic motions of vibration and oscillation are not the same. Without vibration and oscillation made distinct seeming unfathomable paradoxes arise. For these paradoxes to be understood the difference between vibration and oscillation has to be clarified.

"Vibration is the rhythmical motion of a body within itself."[33] Not unlike the rhythmic motions of or within the heart without change in spatial location of the heart.

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[27] Square Law
[28] Plane of Inertia
[29] Introductory Impulse
[30] Heterodyne
[31] Law of Transformation of Forces
[32] Law of Cycles
[33] [Keely]

"Oscillation is a rhythmically recurring translatory movement."[34] Back and forth motion over space not unlike a child's swing or penduluum.

In the ground state, at the moment of inflow of the sympathetic celestial streams or Divine Permeation (spark of Life), vibration is, symbolically, one cps and oscillation is one cps. From that moment on in the process of progressive rhythmic devolution or evolution, due to the Law of Harmonic Pitch[35], Law of Harmonic Vibrations[36], Law of Transformation of Forces[37] and Law of Cycles[38], acting together as one complex or orchestrated law, the One is refracted or differentiated into the multiplicity of materiality (the One becomes the Many) in the natural formation of overtones sometimes called harmonics[39]. These secondary and tertiary overtones are not separate from their source (the fundamental) but are inextricably linked to it as Cause is linked to its Effects. Demonstrating everything-that-is has a common origin or One Source and state of Being (sympathy; *i.e.*, Love or Harmony) regardless of outer appearance (opinion) of separateness and individuality.[40]

6.5 What a Vibration is NOT

A vibration is not a two-dimensional expression as a sine wave. Sine wave patterns are developed from measuring a wave front passing by a measuring device such as a microphone, accelerometer or transducer. As the amplitude changes - at the point of monitoring - a sine wave is traced of the varying amplitude over Time. I spoke about this over simplification in my 1994 SVP presentation in Milwaukee.[41] The sound wave front actually expands simultaneously along all three dimensions (x, y and z). A simple sine wave then is but a trace of what is happening at a given xyz point in space but says next to nothing about what is happening within the three dimensional

[34] [Keely]
[35] [Law of Harmonic Pitch]
[36] [Law of Harmonic Vibrations]
[37] [Law of Transformation of Forces]
[38] [Law of Cycles]
[39] In SVP 'harmonics' are divisible by 2. All other developed secondary and tertiary tones are divisible by other divisors such as 3, 5, 7, etc. and are called 'overtones'. Collectively they are called 'partials'.
[40] [Dale Pond]
[41] see videos on page [Basic Principles]

sound wave as per is originating forces, expanding and contracting dynamics and what is occurring with the periodic or aperiodic motions within the substance of the transmitting medium. The compression portion of the wave front is in actuality the mutual periodic attraction and subsequent concentration between the medium particles due to an increase in syntropic force. Conversely, the less dense (rarefied) wave section is an effect of the entropic forces causing the media particles to be mutually repulsive dispersing them into a relatively rarefied condition. Therefore the amplitude of a wave is predicated on the quantity of syntropy or entropy brought to bear on the vibrating media. The response within the media to an external excitation largely depends on the character (time, duration, condition and location) of the introductory impulse[42] of the excitation. From the above sketch it can be readily seen how Macvicar's Law of Assimilation[43] (Russell's Rhythmic Balanced Interchange[44]) is active in every periodic motion.

6.6 Wave Propagation

In the air the molecular wave front does not actually propagate as a wave. The wave is an effect of subtler causes which when viewed accumulatively have the *appearance* of a wave. Thus we are fooled when relying on our senses. The elements of the molecular medium (air particles) primarily rotate and oscillate about their centers depending on the nature of the disturbance. It is this disturbance that propagates causing periodic expansion and contraction of that which it encounters along the way and before dissipation. The quantum scalar component propagates as a quantum disturbance through the molecular medium. This disturbance is rhythmical; *i.e.*, (polar) intermittently syntropic then entropic in its effects upon the molecular receptive centers. There occurs an increasing compression to the 4++ potential[45] level where a 90° transformation, via the Law of Cycles, converts syntropic influence from syntropic compression into entropic dispersion (gradients of vacuity). Logically then the time it takes for the invisible internal disturbance to become a visible external phenomenon is the apparent propagation rate. This is a periodic disturbance (time to reach the critical 4++ state plus re-

[42] [Introductory Impulse]
[43] [Law of Assimilation]
[44] [Rhythmic Balanced Interchange]
[45] [4plusplus]

laxation time plus reformation time) and takes on the appearance of a wave or vibration. Of course, it should be noted not all rhythmic motions result in a complete 4++ transformation as not all rhythmic motions have sufficient power to achieve transformation. Hence there are low energy waves and vibrations that simply repeat themselves without self-destruction and rebirth in a new energy state.

6.7 Frequency

It can be argued Keely counted frequency as a dual motion of IN then OUT or OUT then IN depending where one begins counting. If this is true then the apparent oscillation of a pendulum is two oscillations from side to side. It is not certain this method of counting carries throughout the Keely materials but it is good to keep this in mind.

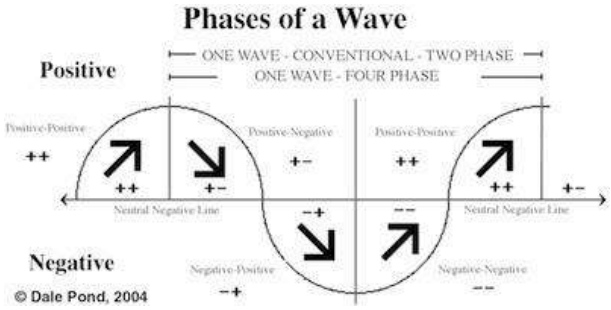

Figure 6.1: Four Phases of a Wave or Oscillation
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/fourphases400.gif

6.8 Law of Cycles

"Coherent aggregates harmonically united constitute centers of vibration bearing relation to the fundamental pitch not multiples of the harmonic pitch, and the production of secondary unions between themselves generate pitches that are discords, either in their unisons, or overtones with the original pitch; from harmony is generated discord, the inevitable cause of perpetual trans-

formation."[46]

[46] [Keely]

Chapter 7

Laws of Being

7.1 Introduction

Professor Daniel Brinton[1], author of the following reviewed article, spent considerable time in Keely's nearby laboratory and workshop. It is believed this article is the clearest attempt to explain the basic concepts Keely discovered, developed and worked with and how he used them. After all, Keely was present to directly answer Brinton's questions. Therefore it behooves us to closely examine this article to discern understanding and hopefully practical use.

The terms and phrases in this article are linked to supporting materials within the svpwiki.com where the bulk of the known Keely materials are located. Comments are given immediately below a Brinton quote. These comments are quite important because they represent a synthesis of years of learning Keely's and Russell's jargons as well as comparative contemporary concepts and research. A careful reader will see an intermingling of materials from various sources that support each other. Most notably is the mutual affinities between the works and ideas of John W. Keely and Walter Russell.

Brinton's words or quotes are preceded by **Roman Numerals in bold type**. Numbers and brackets ([]) contain comments and links about Brinton's writings and Keely's concepts. These terms and phrases in brackets

[1]Daniel Garrison Brinton (May 13, 1837 July 31, 1899) was an American archaeologist and ethnologist at the University of Pennsylvania.

([]) can be searched in www.svpwiki.com. The original unaltered Brinton text can be seen in "Keelys Physical Philosophy - Appendix-I" and "Laws of Being, Appendix-II" at the end of this book or within the svpwiki.com.

7.2 Rhythmical Relations

I. ***"The fundamental conception of the Universe is force manifesting itself in rhythmical relations."*** (continues to II);[2]

7.2.1 Principle of Rhythmic Balanced Interchange

"This principle of rhythmic balanced interchange[3] *between Father*[4] *(syntropy) - Mother*[5] *(entropy) lights of gravitation (syntropy) and radiation (entropy) is fundamental in all creating things."*[6]

In other words the principle of Rhythmic Balanced Interchange[7] is a universal principle[8][9], as Russell repeatedly emphasized, active in all things from molecular to Mind energy subdivisions (states). Rhythmic Balanced Interchange is after all what every vibration and oscillation does that the ubiquitous and over simplified sine wave does not reveal.

7.2.2 Every individualized object assimilates itself

Macvicar[10] writes: *"Every individualized object assimilates itself to itself in successive moments of its existence and all objects tend to assimilate one another."*[11]

---

[2] [Rhythmic Balanced Interchange]
[3] [rhythmic balanced interchange]
[4] [Father]
[5] [Mother]
[6] Russell, [The Secret of Light], page 150; see 'Chapter 6 - What is Vibration?'
[7] [Rhythmic Balanced Interchange]
[8] [Principles]
[9] see Chapter 11
[10] Dr. John Gibson [MacVicar] professor at university of St. Andrews 1830.
[11] [Snell Manuscript], [Three Laws of Being], [Law of Assimilation], [Modes of Vibration - Annotated]

Please note this law as expressed by Macvicar is the same universal law in its essence and dynamic as expressed by Jesus wherein he says:

"Jesus said unto him, Thou shalt love the Lord thy God with all thy heart, and with all thy soul, and with all thy mind. This is the first and great commandment." (Matthew 22:3738).

"And the second (commandment) is like unto it; Thou shalt love thy neighbor as thyself. On these two commandments hang all the law and the prophets." (Matthew 22:3940).

SVP (nor this author) does not subscribe to or promote organized religions but we are interested in universal laws and principles (applicable universally) regardless who revealed them or wherever they may be found.

Love and Sympathy are synonyms for affinity, assimilation or being One With. These same dynamics apply everywhere and with everything thus establishing sympathetic association[12] between all things, everywhere and at all times.

To repeat when the constituent frequencies of A and B are identical A transmits to B and B transmits to A sympathetic association or mutual resonance (Love or Sympathy) occurs. These dynamics are as expressed in the following of Keely's forty laws[13]:

Law of Harmonic Vibrations[14]

"All coherent aggregates are perpetually vibrating at a period-frequency corresponding to some harmonic ratio of the fundamental pitch of the vibrating body; this pitch is a multiple of the pitch of the atomoles[15]*."* See Overtone Series[16].

[12] [sympathetic association], entangled
[13] [Keelys Forty Laws]
[14] [Law of Harmonic Vibrations]
[15] [atomoles]
[16] [Overtone Series]

Law of Transmissive Vibraic Energy[17]

"All oscillating and vibrating coherent aggregates create, in the media in which they are immersed, outwardly propagated concentric waves of alternate condensation and rarefaction, having a period-frequency identical with the pitch of the aggregate."

Scholium: *"All forms of transmissive energy can be focussed, reflected, refracted, diffracted, transformed, and diminished in intensity inversely as the square of the distance from the originating source."* See also Square Law[18].

Law of Sympathetic Oscillation[19]

"Coherent aggregates immersed in a medium pulsating at their natural pitch simultaneously oscillate with the same frequency, whether the pitch of the medium be a unison, or any harmonic of the fundamental pitch of the creative aggregate."

As the atomole is the constructive constituent of all atoms all atoms are therefore in sympathetic association at, by and through these atomoles. All is one at this level or state of being even though at the physical level of our perception everything appears to be separate and individual.

[17][Law of Transmissive Vibraic Energy]
[18][Square Law]
[19][Law of Sympathetic Oscillation]

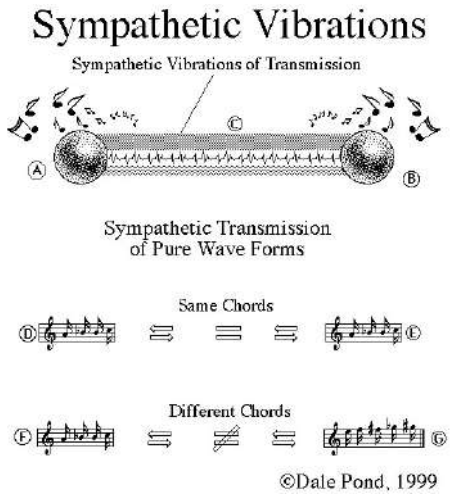

Figure 7.1: Sympathetic Vibration - Entanglement
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/sympathetic-vibrations.jpg

7.2.3 These modes are today much like "phase"

These modes, or periodic change of state, are today much (but not exactly) like what we call "phase" of a wave. Usually conventional 'phase' is undistinguished in construction as to its causative (aliquot/scalar) forces and dynamics being primarily intermittent syntropic and entropic. Phase in modern usage is almost exclusively linked to the positive or negative halves of a sine wave which does not convey all that is occurring in the wave under investigation.[20]

II. ***"This definition [from I] is exhaustive, including both thought[21] and extension[22], mind and matter. The law for the one is the law for the other. The distinction between them is simply relative, i.e., quantitative, not qualitative.***

As above so below - all forms of matter and energy regardless of frequency, subdivision or state are involved in a periodic Rhythmic Balanced Inter-

[20] see chapters 'Chapter 6 - What is Vibration?' and 'Chapter 8 - Modes of Vibration'
[21] [thought]
[22] [Sympathetic Outreach]

change between their polar states where one polar state becomes the other intermittently.

III. *"The rhythmic relations in which force acts are everywhere, under all conditions, and at all times, the same. They are found experimentally to be universally expressible by the mathematical relations of thirds."*[23]

"Rythmic relations" indicates ALL vibratory and oscillatory motions are effects of this periodic interchange of intertwined poles between syntropic contraction or assimilation and entropic expansion or dispersion. This interchange occurs as these two states are in the relative proportion (ratio) of third parts to one another.

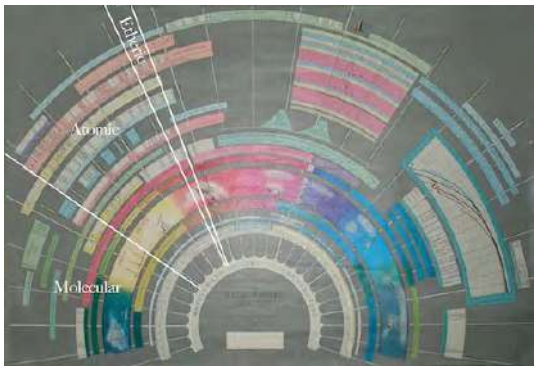

Figure 7.2: Chart showing location of the three mode frequencies.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/electromagneticspectrummodes500.jpg

That three or threeness is fundamental is now seen to be valid in the Rule of Threes[24] re-discovered by Vitaly Efimov and is called the 'Efimov trimer' or 'Efimov state'[25]. Likewise both Keely in the 1880s and Russell in the 1920s clearly comment on the value of threes[26].

"*Rest and action are three. Space and matter are three. Equilibrium and*

[23][14.35.1 - Keely 3 6 and 9] and [Rhythmic Balanced Interchange]
[24][Rule of Threes proven]
[25]Wikipedia/Efimov state
[26][Three]

motion are three. Dimensions and pressures are three. The heartbeat of the universe, and yours, are three. Likewise, its breathings and yours, its temperatures and yours, and all things else of the universe, and you, are three."[27]

7.2.4 'Thirds' is usually a mathematical relationship of proportion

Within this and related SVP documents the concept and use of the term 'thirds' is usually a mathematical relationship of proportion of wave function parameters[28] (of volume, force, density, *etc.*) and not always a musical relation. A given whole being One Whole, has three parts always in varying yet relative proportion to one another. The overall or resultant expression of the One Whole is dependent on the ratios being applied. More syntropy makes the whole more syntropic. The more entropy the more entropic will be the One Whole. Therefore and thereby *polarity is not fundamental but may be modified or manipulated by altering the ratios of these proportions held as thirds or third parts.*[29]

7.3 Threefold Relations

IV. "These threefold relations may be expressed with regard to their results (appearances) as,

I. Assimilative (attractive, aggregating)
II. Individualizing (dispersing, dissociating)
III. Dominant or Resultant (controlling, determining)

[27] Russell, [Atomic Suicide]?, Chapter 5 - Prelude - The Transformation of Man
[28] [Eighteen Attributes or Dimensions]
[29] Chapter 10 - Proportions (Ratios) of Relative Values

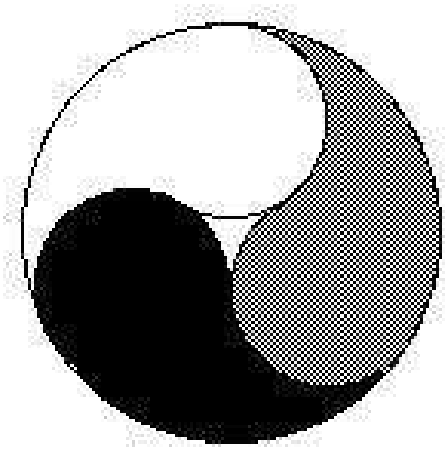

Figure 7.3: Triune Forces/Modes/Proportions combined as One Force
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Triune-Forces.jpg

7.3.1 Each of the above dynamics (IV) is a $\frac{1}{3}$ part or current of a $\frac{3}{3}$ stream

Each of the above dynamics is a $\frac{1}{3}$ portion or current of a $\frac{3}{3}$ stream (rhythmic flow of force or energy[30]). These three-fold relations are resultant dynamics of three-fold relations of these three currents acting *"as one"* - constituting a single compound stream or chord tone; *i.e.*, combined proportions of each with the others. This combination of three entities to make one compound entity works the same way three musical notes may be sounded at one time as a triplet chord, hence Keely's constant use of triplet chord notations throughout his charts. It is further presumed the ratios of the musical notes within a triplet chord on his charts[31] are the same ratios when specifying any other applied proportional value such as frequency, amplitude, *etc. regardless of frequency range or subdivision.*

[30] *"In this system (Sympathetic Vibratory Physics), force and energy are classified as opposites, working in antagonism to each other: Force as a positive power which initiates aggregative motion, and resists separative motion, in three postules, of ponderable matter in the etheric medium; Energy as a negative power, which initiates separative motion, or disintegration, and resists aggregative motion, in three postules of ponderable matter, also of the etheric medium.*" Bloomfield-Moore, [What Electricity Is - Bloomfield Moore]

[31] [Part 25 - Keelys Wonderful Charts of Vibratory Etheric Science]

7.3.2 Ratios of Harmonic and Enharmonic Potentials

It is further assumed (until bench testing shows otherwise) these triplet chords when considered as a singular tone each represents a different degree of concord and discord. Tables would have to be developed from bench testing. These ratios of concord and discord would also parallel in some regards Russell's concepts of Locked Potentials because that is what they are.

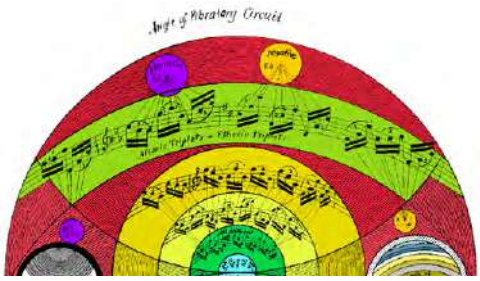

Figure 7.4: Typical Triplet Chords in Keely's charts.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Angles-Segment-500.jpg

7.4 Three Actions and Laws of Being

V. ***"From these three actions are derived the three fundamental LAWS OF BEING:***

I. **Law of Assimilation**: every individualized object assimilates itself to all other objects.[32]

II. **Law of Individualization**: every such object tends to assimilate all other objects to itself.[33]

III. **Law of the Dominant**: every such object is such by virtue of the higher or dominant force which controls these two tendencies.[34]

[32] [Law of Assimilation]
[33] [Law of Individualization]
[34] these three laws act according to and with the [Law of Sympathetic Association] and [Law of the Dominant]

7.4.1 Law of Sympathetic Association

"The effects of the Law of Sympathetic Association[35]*, which Mr. Keely demonstrated as the governing medium of the universe, find illustrations in inanimate nature. What else is the influence which one string of a lute has upon a string of another lute when a stroke upon it causes a proportionable motion and sound in the sympathizing consort, which is distant from it*[36]*, and not perceptibly touched? It has been found that, in a watchmaker's shop, the timepieces, or clocks, connected with the same wall or shelf, have such a sympathetic effect in keeping time, that they stop those which beat in irregular time; and, if any are at rest, set those going which beat accurately. Norman Lockyer*[37] *deals with the Law of Sympathetic Association as follows: - "While in the giving out of light we are dealing with molecular vibration taking place so energetically as to give rise to luminous radiation, absorption phenomena afford no evidence of this motion of the molecules when their vibrations are far less violent." . . ."The molecules are so apt to vibrate each in its own period that they will take up vibrations from light*[38] *which is passing among them, provided always that the light thus passing among them contains the proper vibrations.*[39]*" . . . "Let us try to get a mental image of what goes on. There is an experiment in the world of sound which will help us." . . . "Take two large tuning-forks, mounted on sounding-boxes, and tuned to exact unison. One of the forks is set in active vibration by means of a fiddle-bow, and then brought near to the other one; the open mouths presented to each other. After a few moments, if the fork originally sounded is damped to stop its sound, it will be found that the other fork has taken up the vibration, and is sounding distinctly. If the two forks are not in unison, no amount of bowing of the one will have the slightest effect in producing sound from the other."*[40]

[35][Law of Sympathetic Association]

[36]spooky [action at a distance]

[37]Sir Joseph Norman Lockyer, FRS (17 May 1836 - 16 August 1920), known simply as Norman Lockyer, was an English scientist and astronomer.

[38]etheric [disturbance of equilibrium]

[39][Law of Force]

[40]Clara Bloomfield-Moore([CJBM]), [Keely and His Discoveries], [Tuning Forks], [Sympathy]

7.4.2 Law of Assimilation

The Law of Assimilation[41] acts according to the laws of sympathetic attraction and oscillation as also the Law of Sympathetic Oscillation.[42] - *"this law is to the effect that every individualized object tends to assimilate itself to itself, in successive moments of its existence, and all objects to assimilate one another."*[43]

7.4.3 Law of Attraction

"Juxtaposed[44] *coherent aggregates vibrating in unison, or harmonic ratio, are mutually attracted."*[45]

Here then is the great law of attraction properly explained. When two or more objects are 'vibrating in unison' they are sympathetic to each other and what occurs to one occurs to both. The objects are 'linked' by sympathetic vibration and/or sympathetic oscillation. This phenomenon is recognized today as '*entanglement*' or 'spooky action at a distance'.[46] Where objects are 'equally and uniformly spaced' we see the basis for geometric shapes such as tetrahedrons, *etc.* thought so much of by so many these days. Uniformity of design elements or dimensions (geometry) is therefore an attribute of harmony and therefore attraction or assimilation lacking entropic (discordant) elements of dispersion (numbers and ratios other than those forming unisons or harmonic ratios).

7.4.4 Law of Sympathetic Oscillation

"Coherent aggregates immersed in a medium pulsating at their natural pitch simultaneously oscillate with the same frequency, whether the pitch of the medium be a unison, or any harmonic of the fundamental pitch of the creative aggregate."[47]

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[41] [Law of Assimilation]
[42] [Law of Sympathetic Oscillation]
[43] [Law of Assimilation]
[44] equally and uniformly spaced
[45] Keely, 1894; see [Bjerknes Effect]
[46] [Sympathetic Vibration], [Sympathetic Oscillation], [Entanglement]
[47] Keely, 1894

This coincidental and synchronous action is seen in the coordinated motion of seeming separated clock pendulums all immersed in the common medium of the atmosphere or sharing contact through a wall or shelf. In a similar fashion this is the basis of dissolving foreign materials (aggregates) by solvents in solutions. Curiously it is the same dynamic at work in the Stockholm Syndrome[48]. See II above why this is so.

7.4.5 Infinite neutral Mind centers and controls all motion

Should we replace the non-existent infinitely small strings as held in the String Theory with infinitely small centers[49] to which are applied the above three laws it can be seen how every center is sympathetic (in sympathy) with every other center and are therefore quantum entangled; *i.e.*, sympathetic one to all others and clearly reflects the above three laws and their dynamics. This would of course imply a single fundamental chord at the very heart or core of the universe. This highly sympathetic universal chord could be the *'Cosmic microwave background'*[50] that vibrates and oscillates everything in the universe at a common pitch thus sympathetically connecting (entangling) every seeming individuated thing to all other seeming individuated things regardless of space. At certain subdivision levels it may therefore be presumed all things regardless of location are sympathetically linked and behave as One Thing thus all things may be considered as One yet having individual exist and experience.[51]

Cayce mentions this seeming duality of One yet individual state of affairs as described by the above laws, states and circumstances thusly:

"That it, the entity, may know itself to be itself and part of the Whole; not the Whole but one with the Whole; and thus retaining its individuality, knowing itself to be itself, yet one with the purposes of the First Cause that called it, the entity, into being, into the awareness, into the consciousness of itself. That is the purpose, that is the cause of being."[52](underlines added)

[48]Wikipedia/Stockholm Syndrome
[49][Center Theory]
[50][Cosmic microwave background]
[51][What is Sympathy]
[52]Cayce (826-11)

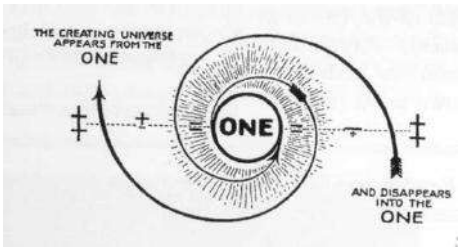

Figure 7.5: From the One comes the many.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/One-Many.jpg
(courtesy University of Science and Philosophy)

And of course this illusion of separateness carries on into the affairs of each individual and hence into society.

As can be seen from the above the totality of the universe is One totality with seeming separate individualizations. Science sees it when it insists on creating experiments isolated from all outside influences. This of course can work in purely mechanical experiments but once the threshold of the atom is breached into the quantum world nothing can be isolated from these higher and finer outside forces and influences. Indeed even the atom is affected by these higher finer forces - we simply do not know how to pay attention to the effects which includes the existence of the atom itself being created and maintained by these unseen forces[53].

How the many forms of matter and substance develop through evolution[54] from the seeming void of Mind or Consciousness is not the topic of this book. Perhaps we'll get around to writing such a book in the future.

7.4.6 One Substance is Mind

There is but One Substance in the universe and that substance is Mind which some have called "Light" as in the Light of Mind. Being of the Light or Etheric order of subdivided being the ancients called it "Luminiferous

[53][7.9 - Ultimate Constitution of Matter and Action of Force Regulating its Phenomena]
[54]svpbookstore.com - Hughes, F.; Harmonies of Tones and Colours - Developed by Evolution

Ether"[55]. Walter Russell expressed it thusly:

"Light units have the appearance of individuality, even as you and I.
"There is no individuality in this universe of Mind. There is but an appearance of individuality.
"This is a universe of the One Thing.
"That One Thing is Mind.
"The substance of thinking Mind in action is light.
"There is but One substance.
"The One substance cannot be divided into many substances, or many parts.
"Individuality is but an appearance, an effect of potential in the periodicity of thinking."[56]

Thus it can be seen Mind centers[57] all things because all things are motions centralized about a common center originating of Mind as Source[58] or the Interetheric realm or subdivision (6th subdivision) of being.

Figure 7.6: Mind centers all motion.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/thought-rings.jpg
(courtesy University of Science and Philosophy)

VI. *"Applying these fundamental laws to an explanation of the universe, as it is brought to human cognition, all manifestations of force may be treated as modes of vibrations."*

Simplistically everything vibrates and oscillates perpetually.[59] But not all

[55][Luminiferous Ether]
[56]Russell, [The Universal One], Book 02 - Chapter 01 - Dynamics of Mind - Concerning Light Units of Matter
[57][Figure 12.06 - Mind Centers and Controls Motion]
[58]very important article by Keely [7.9 - Ultimate Constitution of Matter and Action of Force Regulating its Phenomena]
[59][Law of Harmonic Vibrations]

vibrations and oscillations are equal bringing us to the subject of this book. The great secret to understanding is to see and know the unseen working constituents of vibrations and oscillations such that we can engineer them to create the precise waveforms and effects we want. These periodic motions are not solely about sine, square, sawtooth and pulse shaped waves. Carefully sculpting a waveform synthesizing specific partials and harmonics allows a fine precision in applying these waveforms. Likewise understanding how waves interact with each other, as shown in Keely's forty laws,[60] gives us mastery over such vibrating and oscillating dynamics and media.

7.5 Three Modes of Vibration

VII. ***"The essential differences give rise to three modes of vibration:***

I. **The Radiating**: called also the "Dispersing", the "Propulsive", the "Positive", and the "Enharmonic".[61]

II. **The Focalizing**: called also the "Negative", the "Negative Attractive", the "Polarizing", and the "Harmonic".[62]

III. **The Dominant**: called also the Etheric, or the Celestial.[63]

7.5.1 Polarity, Duality, Bias and Potential

Polarity is usually understood as two seemingly opposing forces or states as in for instance the two poles of magnetism. Neither Keely nor Russell saw polarity in this simplistic manner. To them there are two composite poles and a centering fulcrum or neutral point, neutral center or neutral line. All three states are *effects* of subtler unseen forces united in discrete proportions of three united and manifesting as one. A key here is *preponderance* as in one composite force is preponderant over the other within a triplet configuration

[60] [Keelys Forty Laws]
[61] [Entropic]. [Russell] also calls this '[Mother]' or '[Magnetic]'.
[62] [Syntropic] or [Negentropic]. Russell also calls this '[Father]' or '[Electric]'.
[63] [Mind], [Etheric Elements], [Scalar], [Spirit]

or pole. Each pole then is a result determined by predominance of one composite force over the other two *within each pole.*

7.6 Three Laws of Being

VIII. ***"These, it will be noted, correspond to the three Laws of Being"*** (continues to **IX**.)

Syntropy	**Neutral**	**Entropy**
The Focalizing	**The Dominant**	**The Radiating**
Absorbing	Centering	Emanating
Accumulating	Balancing	Dissipating
Plus	Fulcrum	Minus
Assimilating	Neutralizing	Dispersion
Heating	Zero	Cooling

Table 7.1: Three Polarity States and Effects

6465

7.6.1 Dominant Mode

"By use of the dominant mode, which is allied to the "order" of etheric vibrations, we can induct, "sympathetic negative attraction" or "sympathetic positive propulsion" in any mass, according to its mass chord.[66]

The Dominant mode is of the etheric and interetheric subdivisions that governs the two lower order (molecular and atomic) subdivisions party to the polar triplet.

[66]This quote is from [SYMPATHETIC INDUCTION - Snell]. It says there is a polarity to the etheric (quantum) range of vibrations (row four in the above Table). This also implies the two polar streams are different and therefore must be created and applied as separate streams.

"All the dominant conditions of nature represent the focal centers towards which like surrounding ones become sympathetically subservient."[67]

"By use of the dominant mode, which is allied to the "order" of etheric vibrations, we can induct, "sympathetic negative attraction" or "sympathetic positive propulsion" in any mass, according to its mass chord."[68]

"The magnetic cannot lead the electric, nor the electric the gravital, nor the gravital the magnetic. All are subservient to the dominant, as a train of cars is subservient to the locomotive which pulls it along; the only difference between the two is that one is sympathetic, the other mechanical. Though this is a crude illustration, it conveys a great truth in sympathetic philosophy. All sympathetic flows have this triune condition associated with them, the same as the molecular, atomic and etheric aggregations of all forms of visible matter; the compound etheric, or dominant, being the leader and yet one of the constituents of the molecule itself. The dominant we may call the etheric portion of the molecule; the harmonic, the atomic; and the enharmonic, the molecule itself. The dominant parts of the triune combination of the sympathetic streams are the leaders, toward which all co-ordinate to make up the sympathetic terrestrial envelope of the earth; the cerebral being the high dominant, or compound etheric, the luminiferous proper."[69] (underline added)

[67] [Keely and His Discoveries], page 179
[68] [SYMPATHETIC INDUCTION - Snell]
[69] [Keely and His Discoveries]

7.7 Table of Modes Correspondences

Source	**From Center**[70]	**To Center**[71]	**Balancing** or **Controlling**
Keely / SVP[6]	Enharmonic	Harmonic	Dominant
Modern wave form	Longitudinal[2]	Transverse[3]	Rayleigh[10]
Angle of Incidence	0°- 45°	45°- 90°	<90°
Path/Motion[3]	Straight	Zig-zag	Circular
Keely / SVP	Dispersing	Syntropic	Dominant/Depolar
Keely / SVP	Entropic	Syntropic	Dominant /Depolar
Russell[4]	Plus	Minus	Fulcrum
Russell[4]	Gravitation	Radiation	Balance, Void
Charles Henry[7]	Gravitation	Electromagnetic	Biopsychic
Possible Correspondence[5]	Thirds	Sixths	Ninths

Table 7.2: Table of Mode Correspondences

7.7.1 The above dynamics are to the following effects

Many	to	**One**	to	**Many**
Polar	to	Depolar	to	Polar
Unbalanced	to	Balanced	to	Unbalanced
Split	to	Whole	to	Split
Dispersed	to	Concentrated	to	Dispersed
Differentiated	to	Voided/Undifferentiated	to	Differentiated
Discord	to	Harmony	to	Discord

Table 7.3: Some Mode Effects

7.7.2 Relations of Thirds

Thirds refers to molecular subdivision.	Physical movements, classical physics and mechanics.
Sixths refers to atomic subdivision.	Sympathetic impregnation of electromagnetism in matter. Operations of thermism[72] and low light.
Ninths refers to etheric subdivision.	Sympathetic transfer from the celestial luminous or celestial radiation[73], also chemism.[74]

Table 7.4: Thirds, Sixths and Ninths

[75]

7.8 Three Modes, Currents and Streams

IX. "It is not to be understood that any one of these three modes of vibration can exist independently. Each by itself is called a 'current', and all three must be present in every 'stream' or 'flow' of force. The relations of the currents in every flow are expressible in thirds, and it is experimentally demonstrable that the relation of the three are in the order named: as $33\ \frac{1}{3} : 66\frac{2}{3} : 100$.

7.8.1 Ratios and Proportions of Thirds

The ratios and relations below are logical determinations (best guess) and are not to be taken as established or proven fact. Lots of lab work is needed here.

[75] see 'Chapter 9 - Modes of Vibration' for more details on structure of thirds. See also [Newton of the Mind], [Law of Cycles].

E = 33 $\frac{1}{3}$= Dispersing, Positive, Enharmonic, Depolarizing, Entropic, Mother, Magnetic.

S = 66 $\frac{2}{3}$= Concentrating, Negative, Harmonic, Polarizing, Syntropic, Father, Electric.

D = 100 = Etheric, Celestial, Mind, SpiritWhen defined as proportional parts:

E = 33 $\frac{1}{3}$ = $\frac{1}{3}$ parts of A
S = 66 $\frac{2}{3}$ = $\frac{2}{3}$ parts of A
D = 100 = 100 parts of A.

so if

D = 100 parts then
S = ($\frac{2}{3}$ x A) or 66 $\frac{2}{3}$ parts
and
E = ($\frac{2}{3}$ x A) or 33 $\frac{1}{3}$ parts.
(when applied to vibratory or oscillatory rates)

if

D = 100 cps

then

S = 66 $\frac{2}{3}$ cps
E = 33 $\frac{1}{3}$ cps

Certainly this applies to AMPLITUDE and POWER as well.[76]
These proportions most assuredly apply to "states" of compression (syntropy) and dispers

Where

E = Entropy (dispersion)
S = Syntropy (contraction)
D = Dominant (controlling or regulating)

[76][Potential]

7.9 Evolution of Matter

X. "The evolution of what is called matter from the different modes of vibration is through the action of the second law, that of focalization, or negative attraction, or 'negative affinity'.[77]

Conventionally and generally speaking this assimilating and accumulating into seeming solid matter process would be akin to the forces involved in the formation of bosons and in Bose-Einstein condensation nuclear fusion (BECNF) or boson cluster state nuclear fusion (BCSNF).[78]

7.10 Neutral Center

XI. "Where the vibrations under this mode meet, and are maintained in a state of mutual affinity or equilibrium, there is established what is called a neutral center, or, as otherwise expressed, 'a center of Sympathetic Coincidence'.[79]

[77] [Syntropy], [Negentropy], (Harmonic concentration or aggregation) via [Sympathetic Affinity], [Inverse Square Law] and [Sympathetic Association]

[78] Wikipedia/Bose-Einstein condensation

[79] [KEELYS PHYSICAL PHILOSOPHY - Snell], [Neutral Center], [Center of Sympathetic Attraction]

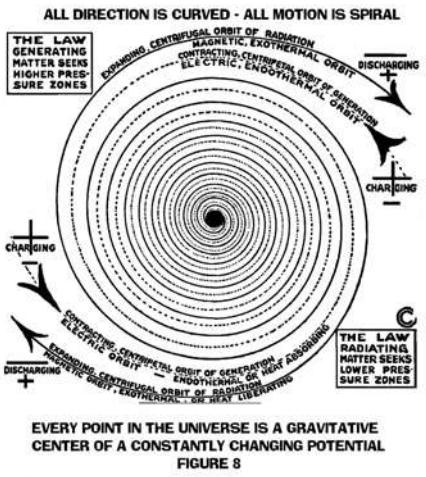

Figure 7.7: Every point in the universe is a gravitative center.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/gravity4.jpg
(courtesy University of Science and Philosophy)

7.10.1 Center of Sympathetic Coincidence or Neutral Center

"The neutral center is that protean, uncreated, indestructible, forever-existing FIRST CAUSE[80]*. Without hands, without tools, without thought, without emotion, without love, without form, without substance, it, of itself, created all these. All that we see or can see in the objective Universe exists because of and by means of the properties and powers of the NEUTRAL CENTER."*[81]

"Neutral centers are the focalized seat of sympathetic concordance for controlling any differentiation[82] *that may exist outside, or in the mass that surrounds them."*[83]

I like to think of the power of the Neutral Center to be much like the power of a conductor wielding control over his orchestra. He sets the tone with

[80][First Cause]
[81]Keely, [First Cause], [Neutral Center]
[82][differentiation]
[83][Keely and His Discoveries], pg 255

his pitch pipe and moderates the time, coordinates activity (harmony) and amplitude of each section and individual within his domain - the orchestra.

"Neutral centers are the center of Sympathetic Coincidence[84]*."*[85]

7.11 Syntropy or Mutual Affinity

XII. "The terms 'neutral attraction', 'neutral affinity', 'negative attraction', or 'polar negative attraction', are employed to express the property of a mode of vibration to direct its components towards such center.[86]

These center directing forces are by definition syntropic derived from mutual affinity itself born of harmony. They are born of harmonic (sympathetic) vibrations as discussed in the Bjerknes Effect[87], Law of Harmonic Vibration, Law of Attraction and Law of Cycles. The etheric or Dominant level frequencies appear to possess a predominant proportion of syntropic (center seeking) forces which increase with velocity. Hence the centralizing power of tornadoes and hurricanes - all vortex motion.

"Taking into consideration even the introductory conditions of the etheric stage, etheric vibration has proved to me that the higher the velocity of its rotating stream the greater is its tendency towards the neutral center or center of sympathetic coincidence. Were it otherwise, how could there ever be any planetary formations or the building up of visible structures? If a billiard ball were rotated to a certain velocity, it would separate in pieces, and the pieces would fly off in a tangent, but if it were a ball of ether, the higher the velocity of rotation, the stronger would be the tendency of its corpuscles to seek its center of neutrality, and to hold together."[88] (underline added)

[84] [Sympathetic Coincidence]
[85] [Keely and His Discoveries], pg 220
[86] [Syntropy], [Negentropy], [Father Forces]
[87] [Bjerknes Effect]
[88] [Keely], [ATTRACTION PROPULSION ETC]

7.12 Subdivisions of Individualized Being

XIII. "As no current or flow of force can be composed of one mode of vibration only, but must always be composed of three modes uniting in varying thirds, we have 1 x 2 x 3 = 6 as the total possible forms of Sympathetic Coincidence, or, to speak in ordinary terms, there can be six; and six only, possible forms of individualized being. These are what Keely calls the six orders of atomic subdivision, or orders of vibratory motion, and he names them as follows:

I. Molecular
II. Intermolecular
III. Atomic
IV. Interatomic
V. Etheric
VI. Interetheric
VII. Compound Interetheric (added by editor)[89]

7.12.1 Table of Subdivisions of Matter and Energy

Subdivision	Keely	Keely Name	Form	Mental	Ancient	Tenuity	Quantum	Bearden	Vedic
7th	Compound Interetheric	Neutral Center	Void	Superconscious	God	Vacuum	Gluon	4-space / Time	
6th	Interetheric	Interetheron	Atomolini	Conscious	Awareness	Vacuum	Quark	4-space / Time	
5th	Etheric	Etheron	Etheron	Mind Activated	Ether	Plasma	Photon	4-space / Time	Akasa
4th	Interatomic	Interatom	Atomole	Electromagnetic	Fire	Gas/Plasma	Electron	3-space	Marut
3rd	Atomic	Atom	Atom	Matter	Air	Gas	Atom	3-space	Tejas
2nd	Intermolecular	Intermolecule	supercritical fluid	Matter	Water	Liquid	Molecule	3-space	Ap
1st	Molecular	Molecule	Solids	Matter	Earth	Solid	Molecule	3-space	Kshiti

Table of Subdivisions of Matter and Energy ©Dale Pond, 2014

Figure 7.8: Table of seven subdivisions or orders.
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/table-of-subdivisions.jpg

[89][Compound Interetheric], [Subdivision], [Etheric Elements], [Magnetic Still Light]

7.13 Arithmetical and Geometric Progressions

XIV. "In this list forms of matter are arranged in the mathematical sequence of the rapidity of the oscillations of their constituent members; the proportion being proved by experiment to be as follows for the molecular orders:[90]

$1 : 3 : 9 : 27 : 81 : 243 ...$
$1 : 3^1 : 3^2 : 3^3 : 3^4 : 3^5 ...$

7.14 Progressions of Orders

XV. "The arithmetical progression changes in the atomic orders to a geometrical progression as follows:

$3 : 9 : 81 : 6561 : 43046721...$
$3^1 : 3^2 : 3^4 : 3^8 : 3^{16} ...$[91]

7.15 Infinite Range of Vibration

XVI. "This same method of progression is believed to hold in all the orders of vibrations above the molecular, and soon passes into mathematical infinity.

[90] [Figure 8.14 - Some Basic Waveforms and their constituent Aliquot Parts]

[91] [Part 12 - Russells Locked Potentials] covering Russell's [Locked Potentials], [Square Law].

Mode	Subdivision	Octave - Hertz	Controlling Law
Enharmonic *Centrifugal*	Molecular Intermolecular	1st - 21st octaves 1 x 10^0 – 2.09715 x 10^6	Law of Oscillating Atomic Substances[92]
Harmonic *Centripetal*	Atomic Interatomic	21st - 42nd octaves 2.09715 x 10^6 – 4.39805 x 10^9	Law of Sonothermity[93]
Dominant *Controlling*	Etheric Interetheric	42nd - 63rd octaves 4.39805 x 10^9 – 9.22337 x 10^9	Law of Oscillating Atoms[94]

Table 7.5: Mode Frequency Ranges

[95]

7.16 Progression Types

7.16.1 Arithmetic and Geometrical Progressions

Arithmetic Progression - In mathematics, an arithmetic progression or arithmetic sequence is a sequence of numbers such that the difference between the consecutive terms is constant.[96]

Geometric Progression - In mathematics, a geometric progression, also known as a geometric sequence, is a sequence of numbers where each term after the first is found by multiplying the previous one by a fixed, non-zero number called the common ratio.[97]

Linear Progression - In music, a linear progression (Auskomponierungszug or Zug, German: train, abbreviated: Zg.) is a passing note elaboration involving stepwise melodic motion in one direction between two harmonic tones.[98]

Melodic Progression may be explored in *"Harmonies of Tones and Colours*

[96] Wikipedia; Arithmetical Progression
[97] Wikipedia; Geometric Progression
[98] Wikipedia; Linear Progression

- *Developed by Evolution*"[99] and *"The Scientific Basis and Build of Music*" by Ramsay[100]

Music (vibrations and oscillations of a string) is linear arithmetic progression[101] while energy expansion and contraction is volumetric with geometric progression[102] as is described in Russell's Scale of Locked Potentials[103], the Square Law and Inverse Square Law.[104]

7.17 Three Major Orders

XVII. "Actually, however, all matter of which we are capable of cognition through the medium of our senses[105] is in one of three forms of aggregation:

I. Molecular
II. Atomic
III. Etheric

7.17.1 The above are not "things"

The above states constitute our sensorial world. They are not solely "things" but are also considered as states, phases, forms or dynamic structures resulting from specific combinations of the dynamic three modes of motion. Each state has a respective combination or proportion of the three modes. The higher three forms of aggregation are not perceptible to our senses and are therefore considered extrasensory, unseen, spiritual, subtle, scalar, nonclassical, *etc.*

[99] svpbookstore.com
[100] svpbookstore.com
[101] [arithmetical progression]
[102] [geometric progression]
[103] [Scale of Locked Potentials]
[104] [Progressive Evolution]
[105] [Sense]

7.18 Controlling Mode

XVIII. "In each of which the controlling mode of vibration is respectively:

I. The Enharmonic (entropy, dispersive) - controls Molecular
II. The Harmonic (syntropy, attractive) - controls Atomic
III. The Dominant (neutral, controlling) - controls Etheric

7.18.1 Modes combine in unique proportions

The above three modes combine in unique proportions to create orthogonal[106] stabilized centralizations of forces that have the appearance of seeming solid matter.

The following table is a supposition about the mixing of mode proportions in the 3rd and 4th columns for each aggregation. They seem reasonable but only bench testing will proven them out.

Aggregation	Governing Mode	Dominant Mode	Subservient Mode
Molecular	100 x Enharmonic	66 $\frac{2}{3}$ Harmonic	33 $\frac{1}{3}$ Dominant
Atomic	100 x Harmonic	66 $\frac{2}{3}$ Enharmonic	33 $\frac{1}{3}$ Dominant
Etheric	100 x Dominant	66 $\frac{2}{3}$ Harmonic	33 $\frac{1}{3}$ Enharmonic
Thirds	3	2	1
Proportion	9	6	3
Portion	Ninths	Sixths	Thirds[107]

Table 7.6: Hypothetical controlling Modes and Proportions

7.19 Modes as actual components

XIX. "But it must be understood that each of these modes is a Positive and real constituent of every atom and molecule.

[106] ideally speaking as is demonstrated in carbon [crystallization].

Considering an atom or molecule as a balanced dynamic of syntropic and entropic forces they must then by definition have these three component modes as essential to their existence. This concept is not unlike Buckminster's Tensegrity[108] idea.

7.20 Foundational Concepts

XX. "It will be seen that as every form of material aggregation is to be considered as a "neutral center of attraction", where the vibratory force of all three orders are held in Sympathetic Coincidence, that is, in balanced activity or harmonized motion, and not by any means cancelled or mutually destroyed, there is no diminution of force, but only temporary suspension of its radiating or propulsive activity or expression.[109] (underline added)

7.20.1 Balance or Equation of Father-Mother Forces

This balance or equation of Father-Mother Forces[110] is not a perfect balance where there is no motion. There is in all seeming solid and still matter a near imperceptibly tiny periodic motions Russell referred to as "Rhythmic Balanced Interchange". Macvicar called this balanced periodic motion the cosmical Law of Assimilation[111]. The range of motion of this periodic motion when considered as stable does not exceed 50% of the molecular dimension.[112] Conventional science refers to this natural residual vibration as vacuum fluctuations, quantum jiggle or Zero-Point Energy. [see **XXV** below]

"If access to the zero-point-energy (ZPE) reservoir is successful, one needn't worry about either depletion of this resource or creating an imbalance in the local environment. It is the electromagnetic equivalent of scooping cupfuls of water out of the ocean, with replacement occurring at the velocity of propagation of electromagnetic waves, the velocity of light. As to the ultimate

[108] Wikipedia/Tensegrity
[109] [Neutralization]
[110] [Father-Mother Principle]
[111] [14.32 - Law of Assimilation]
[112] [AQUEOUS DISINTEGRATION - Snell]

origin of the ZPE, two views are discussed in the physics literature: one, that it is simply part and parcel of the energetic legacy that emerged with the Big Bang, and another that it is an energetic substratum the preceded even the Big Bang, with our universe emerging as the result of a giant vacuum fluctuation.[113] *In any case an argument can be made that it is sustained by a cosmological feedback cycle in which charged particles radiate due to their "quantum jiggle," and the particles "jiggle" due to being caught up in the collective radiation of all the other particles, an electromagnetic equivalent of placing a microphone near a speaker and generating a squeal."*[114]

7.21 Latent Force

XXI "This is the foundation of Keely's doctrine of 'latent force'[115], and of the indefinite power which can be obtained by breaking up the harmonious balance or equation of forces of every mode, which exists in every neutral center, that is to say in every mass of matter."

7.21.1 Matter is the result of three forces or modes of vibration

In SVP every form of matter is the result of three forces or modes of vibration that are balanced or equated to a determinable degree. Disturbing this balance or equation of forces liberates them - not the breaking of a solid appearing atom. Increasing syntropic force, for instance, will instantly evoke the Law of Cycles thereby causing transformation into intense dispersion (emission, radiation). Liberated entropy will instantly disperse. An example of this process of liberation is the well known atomic and nuclear detonations as seen in cavitation or implosion processes.

The use of these principles in atomic weapons is an extreme liberation of

[113] A third view is this persistent periodic motion is that which maintains the physical universe.

[114] H. E. Puthoff, "On the Source of Vacuum Electromagnetic Zero-Point Energy," Phys. Rev. A, vol. 40, p. 4857,1989; Phys. Rev. A vol. 44, p. 3382,1991.

[115] [Latent Force]

the contained latent force within a very short time span. The designers' intent of such weapons is to get the biggest bang possible. In the real world we have no need of such gigantic liberations of energy. It is possible and desirable to perform smaller releases over longer periods of time such as is done with dissociation of water via electrolysis and similar means. In this case it would be prudent to use materials containing less latent energy on the molecular level and perhaps the atomic order. These releases of energy would be more than sufficient for most any application serving humanity's needs. Such liberations would be saner, simpler, safer, non-ionizing and sustainable.

Keely was able to release these forces in a gentle or violent manner depending on the stage of the Law of Cycles progression.

"Sudden unition induces the same effect; but demonstration shows that the concentration of this triple force is as free of percussion as is the breath of an infant against the atmosphere; for the three currents flow together as in one stream, in the mildest sympathetic way, while their discharge after concentration is, in comparison to their accumulation, as the tornado's force to the waft of the butterfly's wing."[116]

Water molecules (Keely's favorite medium for creating his all powerful and useful 'etheric vapor') can be easily dissociated in the molecular order with an electric current (AC or DC), X-rays, cavitation[117], ultrasound[118], microwaves[119], radio waves[120] and even vacuum. This molecular dissociation liberates a gas composed of the atoms of Hydrogen and Oxygen. These as gases constitute the next higher level or order of being - the atomic level of being. This atomic level can be dissociated with an electric spark[121] 'igniting' or rendering (dissociating) the atomic order into the next 'etheric' level or order being plasma; *i.e.*, flame made of ionized gases possessing great pressure as discordant radiating entropy mode preponderates. The process is more complicated than the above but you get the essential points. As humanity

[116] [Keelys Contributions to Science]
[117] [15.12 - Dissociating Water with Acoustic Cavitation]
[118] [15.09 - Dissociating Water with Ultrasonic Vibration - Puharich]
[119] [Dissociating Water with Microwave]
[120] [15.08 - Dissociating Water with X-Rays - Radiolysis]
[121] But then what is a spark if not the electric stream preponderant with the individualizing (syntropic) mode? see [Spark], [Introductory Impulse]

masters these low levels of dissociation the higher levels liberating greater quantities of useful energy may be accessed.

It was this etheric vapor under immense pressure derived from dissociated water that Keely had intended to use to power his original Keely Motor. After designing and building over 120 models and 30 years of effort he gave up on that approach when he discovered the etheric vapor is not the *source* of power but instead is a *carrier*[122] of the force he wished to liberate.

Figure 7.9: Keely Motor activated by slow released etheric vapor
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/keely-motor.jpg

There was one instance where Keely did use this etheric vapor under immense pressure and released or liberated quickly was in his etheric cannon[123]. He demonstrated this cannon on many occasions and once before the US Navy at Sandy Hook Naval Yard, New Jersey. The Navy turned it down because they thought the mechanism "too complex".

[122] [connecting link]
[123] [cannon]

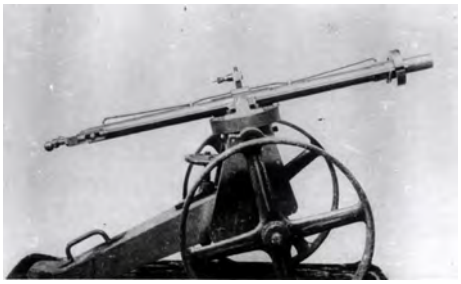

Figure 7.10: Keely's cannon fired by quick release of etheric vapor
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/etheric-cannon.jpg

7.21.2 Latent Force, Keely

"With our present [1880s] knowledge," writes Mr. Keely, *"no definition can be given of this latent force; which, possessing all the conditions of attraction and repulsion associated with it, is free of magnetism. If it is a condition of electricity, robbed of all electrical phenomena, or a magnetic force, rebellant [sic] to the phenomena associated with magnetic development, the only philosophical conclusion I can arrive at is that this indefinable element is the soul of matter*[124]*. Were not every form of matter, even to the cerebral convolutions of the brain, impregnated with this latent element of force, which is sympathetically subservient to celestial radiation, nature would be like a still-born child, or a marble statue - dead to the sympathetic association that induces motion. Matter could not exist without this element, this spiritual essence, this impregnation from the Deity, which is its Soul, any more than a man with an ossified brain could have motion or life."*[125]

This new higher state liberated energy, not having any detectible magnetism or electricity, must by definition be a higher subtler subdivision than the atomic or etheric orders of being both having these two attributes. These new subdivisions then would be the sub-quantum levels of light (photonic) and finer quantum divisions such as quarks, gluons, *etc.*

[124] [Soul of Matter]
[125] [What Electricity Is - Bloomfield Moore]

7.22 Sympathy and Resonance

XXII. "Insomuch as every mass of matter consists thus, in fact, of vibrations in harmonic equilibrium, related by simple proportions of thirds, it follows that every mass of every description stands in harmonic relation to every other mass. This is, in part, what is meant by the sympathy of all forms of matter and of motion (*i.e.*, entanglement, bonding, coupling or love); and it is through the study of the methods of increasing or diminishing[126] this sympathy that we reach practical results in this field of research. At present this is best accomplished by resonance[127]; that is, through the harmonic vibrations created by musical instruments (or signal generators), bringing out the acoustic world as the microscope reveals the hidden visual world.

7.22.1 Attraction and a Repulsion between all things

There exists, by virtue and attributes of harmonic vibrations or sympathy (acoustic entanglement), an attraction and a repulsion between all things. The nature of this attraction and repulsion is discussed in 'Chapter 2 - Love in Science and Physics'. This sympathetic association can be modified at will according to the Law of Sympathetic Association.[128] Keely referred to this process as 'Disturbance of Equilibrium'[129] where he disrupted the harmonic equilibrium thus exciting the dynamics of balanced systems. Centralized forces in a state of coincidental harmony contain Latent Force[130]. The quantity of that Latent Force is determined by the subdivision or order of the material. This force is liberated into an useable force by an outside acoustic disturbance upsetting that balance. This would be not unlike a frequency and amplitude modulation (FM and AM) of existing chordal (complex frequency) patterns.

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[126] [Disturbance of Equilibrium]

[127] established with sympathetic vibration or oscillation, see [Law of Force]

[128] [Bjerknes Effect], [Love in Science and Physics], [Three Laws of Being], [Law of Assimilation]

[129] [Disturbance of Equilibrium]

[130] [Latent Force]

7.23 Matter composed of Molecules

XXIII. "Every visible or tangible mass of matter must be regarded as an aggregation of molecules; the molecules being the true centers of the equated forces of "neutralized attraction".

'Neutralized attraction' is where the two forces of syntropy and entropy are equated to a balanced state or condition. A stable molecule has such a center of neutralization of forces and every molecule, according to Keely, whether singularly or in a larger mass have this distinction. Disturbance of one molecule of such a mass is disturbing all molecules of the mass. Disturbance is accomplished with an 'exciter'[131] being an acoustic pulse[132] possessing certain characteristics such that it is received and re-modulates the molecule into a discordant condition.

7.23.1 Attraction is an effect of Syntropy

We now know that attraction is an effect of syntropy which is an effect of sympathetic association or harmonized frequencies or unisons. Syntropy unopposed is pure active attraction or affinity. "Neutralized Attraction" then would be syntropy balanced by entropy when the rates of vibration or oscillation form an unison with the fundamental or harmonics.[133]

Regarding attraction or bonding as an effect of harmonized vibrations and oscillations is decidedly different than force carrier particles. The first condition is a dynamic condition of the forces involved in the interaction. The second is an isolationist viewpoint requiring an unnecessary additional player on stage. Although a unit measure of attractive force - a quantum (least measure or quantity such as a gluon) of attractive force - could be assigned to these entities for mathematical purposes which I feel is how all this quantum business got started in the first place.

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[131] [Exciter]

[132] or any other frequency within the three main modes

[133] [Law of Attraction], [Bjerknes Effect], [Law of Sympathetic Oscillation], [Law of Force], [Law of Chemical Affinity] and [Voiding]

7.24 Molecules are sensitive to modes

XXIV. "These molecules have been experimentally proved by Keely to be formed of all three modes of vibration; the proof being that they respond to all three modes when subjected to the tests of compound concordant impulses (chords).[134]

An example of a 'compound concordant impulse' would be a musical triplet of say C, E and G sounded together with a sharp attack and little decay within its signature envelope. Logic indicates at least one of those frequencies is concordant with natural tones (eigenfrequencies) of the target molecule. In which case power from the exciter chord is added (sympathetic and syntropic addition) to the molecule thus offsetting its original concordant equation of forces or balance.

7.25 Oscillations of Molecules

XXV. "When in that state of neutral aggregation which we know as matter[11]**, each molecule is in perpetual oscillation, the range of the oscillation being one-third of the molecule, and its rapidity 20,000 oscillations in a second.**[135]

This has always been a curious statement - that all molecules oscillate about their center at a fixed rate of 20,000 Hz. Why hasn't this been found by conventional science? Perhaps it has but I've not found any reference to it (yet). In today's world there are countless types of molecules and many of them are artificial such as are found in plastics and new metal alloys. Does this statement apply to all of them? One would presume - to err on the safe side - that Keely is referring to naturally occurring molecules. That would be a big and perhaps dangerous assumption...[136] Nevertheless it is something to explore. The effort may be well worth it.

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[134] see XXVI, [Law of Force], [Law of Chemical Affinity], [15.18 - Keely's Process for Liberating Ether from Water]

[135] [Molecular Dissociation]

[136] see section '6.5 Frequency' where frequency of oscillation is twice the ordinary count.

7.26 Disturbance of Equilibrium

XXVI. "It is through the disturbance of this oscillatory equilibrium, by means of resonant impulses, that Keely alters the relations of the vibratory impulses which constitute matter[11]. This he does by striking the same chord in three octaves, representing the third, sixth, and ninth of the scale.[137]

The above quote is the beginning of the description of how Keely modulated the eigenfrequency or chord of the mass[138] being acted upon. The following sections give insight into how he approached and did this using the thirds, sixths and ninths of a scale constructed upon the tonic or fundamental of the mass being acted upon using the quantization method[139]. Here lies perhaps one of Keely's greatest secrets - the application of the much verbalized "3, 6 and 9" so often attributed to Tesla[140]. Somewhere I read Tesla stated he had figured our Keely's secret. This may be the secret he referred to. I do not have that quote nor a link to the original material.

In music theory intervals are expressed as ratios. In standard music theory there are Major and Minor Thirds and Keely does not specify which. Normally a Major Third is considered as the quantity 5:4. Translated this quantity is the fundamental frequency divided by 4 which quotient is then multiplied by 5 gives the frequency of a Major Third. A Minor Third is considered as the quantity 6:5. Translated this quantity is the fundamental frequency divided by 5 which quotient is then multiplied by 6. The same treatment applies to all music intervals.

These intervals form a three tone chord (musical triplet) when sounded simultaneously. Multiply each of these frequencies by two and four creates Keely's Triple Triplet[141] of *'same chord in three octaves'*.

[137] [Triple Triplet], [Triple Triplet Flows], [Inversion]
[138] [chord of the mass]
[139] [Quantization - SVP]
[140] [14.35 - Teslas 3 6 and 9]
[141] [Triple Triplet Flows], [Triple Triplet]

Interval	Ratio
Minor Third	6:5
Major Third	5:4
Minor Sixth	8:5
Major Sixth	5:3
Augmented Sixth	125:72
Minor Ninth	32:15
Major Ninth	9:4

Table 7.7: Thirds, Sixths and Ninths Intervals

7.26.1 Disturbance of Equilibrium, Gravity

"Disturbance of equilibrium, like gravity, is inherent, an eternal existing force."[142]

It is possible these two phases, gravity and disturbance of equilibrium, are simply the two opposite poles of matter, the physical Universe, the positive and negative poles of matter, controlled by the third or controlling principle, the Universal Will.

"Unstable equilibrium, like gravity, is a condition born in each neutral center at the time of birth, and thus designed by the Architect as the connective link[143] *between the "dispersing positive"*[144] *and the "attractive negative."*[145] *The action inducing this "link" I call "sympathetic planetary oscillation".*

"The enharmonic portion of the electric current carries the power of propulsion that induces disturbance of negative equilibrium.

"In his (Keely's) experiments of aqueous disintegration[146] *disturbance of equi-*

[142][13.12.1 - Disturbance of Equilibrium]
[143][Connecting Link]
[144][Radiation]
[145][Contraction]
[146][Aqueous Disintegration]

librium was brought about by using mediums of differential gravity in the disintegrator[147]*, air as one, water as the other.*"[148]

Forces are held in a dynamic state of equilibrium, a neutral state, until disturbed by an excitation or stimulation. Adding either harmonic (syntropy) or enharmonic (entropy) excitations will evolve into opposite conditions either attraction or repulsion. This dynamic holds true on all subdivisions. On the lower subdivisions these disturbances must be sympathetic to that being stimulated which is to say acoustic waves or pulses. On the higher etheric subdivisions a sympathetic excitation would be the "infinite exciter" as thought or a form of thought such as desire, intent, etc.

Matter is not directly created by these incoming sympathetic streams. The incoming etheric (celestial) streams impact (bombard) a Neutral Center which differentiates them and matter results from the effects of this impact or antagonism developing summation and difference modulations (tones) during its progressive evolution into being. The incoming excitations need not be all frequencies as countless frequencies may develop during the impact or antagonism. Any tone instantly generates an overtone series. These secondary and tertiary partials or tones spring into existence the instant any tone is sounded. These many tones are effects of the one causative tone and cannot be separated from their cause. They are entangled everywhere experiencing summation and difference modulations (tones) originating from everywhere. Each experience is of course unique because of local influences or modulations.

7.27 Sixths induces Neutral Radiation

XXVII. "Of these, the sixth reduces the range of molecular oscillation, and thus tends to give greater tenuity to the mass. It induces "trajectile velocity" from neutral centers, or "neutral radiation".

[147][disintegrator]
[148][Snell Manuscript]

7.27.1 Seeming Paradox

The first part of the first sentence of XVII appears to contradict the second part of the same sentence thus creating a seeming paradox. However, the two sentences taken together illustrate quite clearly the function and dynamics of the Law of Cycles, said dynamics elsewhere discussed.

"Experiment shows that molecular dissociation does not take place until the molecule attains an oscillation approaching, if not fully reaching two-thirds of its diameter. This can be effected by means of the action of the enharmonic or "radiating" current applied to the mass, after its molecules have been disturbed by an "introductory impulse"; that is, by the musical note[149] *above mentioned.*

7.27.2 Exciting the Molecular Mass

First excite the molecular mass with a strong pulse, then continue this disturbance at resonance with its natural eigenfrequency (chord of mass) until a certain amplitude of oscillation occurs where dissociation takes place. These quantities of applied excitation (amplitude, duration, attack, sustain and decay) could be determined through experiment.

7.28 Third is the Dominant

XXIX. "The third represents the dominant, and when brought under control of a harmonic resonant impulse induces a complete rearrangement of the modes of vibration and oscillation; in other words, will transform the mass either into its component initial forces, or into some other form of matter.

7.28.1 Harmonic Resonant Impulse

"harmonic resonant impulse" means an impulse that is harmonic (in tune with; *i.e.*, sympathetic) not unlike a singer singing the correct pitch that is in synch or establishes a chord of resonance[150] with that of a wine glass to

[149] a musical note is a specific pitch in mathematical relationship with other pitches.
[150] [Chord of Resonance]

be shattered. Also called *"resonant impulse"*.[151]

Of course Brinton/Keely is talking about none other than transmuting the mass being experimented upon whether that be water or some other molecular substance - *'transform the mass either into its component initial forces, or into some other form of matter'*. 'Component initial forces' means liberating these awesome atomic forces whether slowly or instantly. Of course the slower the liberation the better.

"Matter is bound up energy and energy is liberated matter." Keely, 1893

It is astonishing these ideas were first published in 1894 well before orthodox science acknowledged splitting the molecule or atom was even possible. Not only does Keely say this is possible but he says how to do it and that he had been doing it for some years already prior to 1894. Realizing the above it is obvious why no one in Keely's day had any idea what he was doing. In Keely's 'Ultimate Constitution of Matter and Action of Force Regulating its Phenomena'[152] he lays out the basic concepts of matter, force and their interactions such as converting one into the other.

7.29 The Dominant or Etheric Mode

XXX. "It is the study of the dominant[153] to which Keely has devoted his recent researches. He aims to control the power he evolves by altering the dominant or etheric mode of vibration in the triplicate flows of force.

7.29.1 Etheric Current

The etheric (Dominant) current is the controlling medium in the triune flows.[154] It is the switch or regulator that actuates the power of the other two currents or forces thus disturbing the triune balance. The key phrase in the above is '*control the power he evolves*' indicating he doesn't want an all at once release as in a destructive explosion.

[151] [Law of Transformation of Forces], [Transmutation]
[152] [[7.9 - Ultimate Constitution of Matter and Action of Force Regulating its Phenomena.]
[153] [Dominant]
[154] Keely's [Three Modes of Vibration] for range of frequencies of the etheric current, One Universal Controlling Medium

7.30 Centers of Harmonized Vibration

XXXI. "As all molecules and masses are mere centers of harmonized vibrations,[9] temporarily held in suspension by simple Laws[155] identical with those of resonance, it follows that these centers can be broken up or divided by certain orders of vibration impinging upon and disturbing them.[156]

See the above sections and subsections describing this equilibrium and its disturbance. The idea that the control of the forces of a molecule can be addressed via the molecule's center of balanced forces represents a major diversion from conventional thought. It is far easier to modulate this center of balanced forces than any other condition of motion of a molecule be it electrons or atoms forming part of the molecule. The point or center of balance of forces is not unlike that point in a child's swing when the highest or furthest point of motion is reached and all motion stops for an instant then reverses direction. This point coincides with Russell's Zero Plane of Inertia[157]. This instant of depolar non-motion is where the kinetic out swing and in swing are neutralized (conjugated, sum to zero) and energy of the system becomes latent (potential). At this point it is easiest to add additional outside power to maintain or increase motion. It is the optimum point of modulation. Attempting to add power at other points of the swing are either impossible or difficult.

7.31 Sympathetic Outreach (sympathy/resonance field effect)

XXXII. "It is a familiar fact that a cord in vibration tends to produce a similar vibration in a cord placed near it.[158] This property belongs to all vibrations, whether resonant or not, and they exert it in proportion to the order to which they belong. The distance in Space to which this power extends, or can be extended, is what

[155] [Keelys forty laws]
[156] [Disturbance of Equilibrium], [DISTURBANCE OF EQUILIBRIUM - Snell], [13.12.1 - Disturbance of Equilibrium], [7.1 - Matter is centralized motion]
[157] [Plane of Inertia]
[158] [Sympathetic Oscillation], [Tuning Fork]

is called 'the sympathetic outreach'[159] of the current or flow."

Sometimes the effects of this property are referred to as "entrainment" [160] (sometimes as "coupling"[161]) as in the case where multiple oscillating mechanisms will synchronize their motion in and over time. The linking between mechanisms in sympathetic oscillation[162] is referred to as the "connecting link"[163] or the unseen etheric communication mechanism spanning space and time. This connecting link is the purveyor of so-called "spooky action at a distance"[164]. These sympathetic properties can be quantified and therefore engineered. They have for instance an "outreach" or 'field effect' that can likewise be quantified and engineered. This outreach or field effect is an extension of sympathy from the mass and affects other masses within reach of its field effect depending on the degree of sympathetic vibration or oscillation of other nearby masses. Degrees of sympathetic association can be determined by the degree of harmony or discord in their respective chord of mass (vibration or oscillation signature). This property is governed by the Law of Sympathetic Oscillation[165].

7.32 Etheric Outreach

XXXIII. "In this manner we have 'sympathetic negative attraction', and 'sympathetic positive propulsion', with reference to the outreach of the third or dominant current of the stream, which is allied to the order of etheric vibrations."[166]

The effect of this field or outreach can be either attractive or repulsive on nearby objects according to the degree the creative and receptive chords are harmonic or enharmonic with each other.[167] The outreach or field effect of the etheric current is as mentioned above the connecting link between masses.

[159] [Sympathetic Outreach]
[160] [Entrainment]
[161] [Coupling]
[162] [sympathetic oscillation]
[163] [connecting link]
[164] [action at a distance]
[165] [Law of Sympathetic Oscillation]
[166] [Sympathetic Transmission], [Subdivision]
[167] [Law of Force]

This condition of synchronous motions is described in the

7.32.1 Law of Transmissive Vibraic Energy

"All oscillating and vibrating coherent aggregates create, in the media in which they are immersed, outwardly propagated concentric waves of alternate condensation and rarefaction, having a period-frequency identical with the pitch of the aggregate."
Scholium: *"All forms of transmissive energy*[168] *can be focussed, reflected, refracted, diffracted, transformed, and diminished in intensity inversely as the square of the distance from the originating source."*

These "outwardly propagating waves" can be in harmony or discord with other masses creating sympathetic resonance. If the waves from the masses are in tune or harmonic they will be attracted to one another. If they are discords the masses will be repelled. These tendencies and motions of attraction are governed by the laws of attraction[169] and repulsion[170]. If these waves are in harmony the masses are then 'coupled' sympathetically and what occurs to one occurs to the other. They become *as one*.

7.32.2 Etheric vibration is the cause of sympathetic association

Etheric (quantum) vibration is the cause of Sympathetic Association, Sympathetic Vibration and Sympathetic Oscillation also known as Entanglement, Coupling, Quantum Entanglement, *etc.*. This etheric vibratory force[171] can be either syntropy (sympathetic negative attraction) or entropic (sympathetic positive propulsive). This phenomena may also be related to Russell's lens[172] idea.

[168] [Law of Force]
[169] [Law of Attraction]
[170] [Law of Repulsion]
[171] [Etheric Vibration. - The Key Force]
[172] [Figure 3.4 - Focalizing Lenses at nested Cube faces]

7.33 Chord of Mass

XXXIV. "Each molecule of a given mass of matter represents the same harmonic chord or note in its oscillatory motion. The chord of the mass is, therefore, the chord of every molecule of [the] mass."

7.33.1 Qualifiers

The above sentence (XXXIV) contains several qualifiers:

1 - *"Each molecule of a given mass of matter"* - each and every molecule of a specific mass. Therefore a given mass has a single chord being the same as each molecule participating in that mass.

2 - *"same harmonic chord or note in its oscillatory motion"* - to the degree of syntropy the molecule/mass is (*i.e.*, represented by a musical note or pitch) in the mass oscillatory (translation) motion, NOT it's internal vibration.

3 - The chord of mass[173] is of course the vibration or oscillation signature, a collection of the fundamental and all partials resulting from that fundamental as per the Law of Harmonic Pitch.

7.33.2 Law of Harmonic Pitch

"Any aggregate in a state of vibration develops in addition to its fundamental pitch a series of vibration in symmetrical sub-multiple portions of itself, bearing ratios of one, two, three, or more times its fundamental pitch."[174]

7.34 Controlling Chord of Mass

XXXV. "But as the condition of absolutely stable equilibrium is theoretical only, and does not exist in nature, the chord of the mass is constantly changing. Yet we must learn to control this chord of the mass by resonant induction[175], if we would gain command of the molecular forces."

[173] [chord of mass]
[174] Keely, 1894
[175] [resonant induction]

7.34.1 Equilibrium or Balance cannot exist

The states or conditions of equilibrium or balance cannot exist in the material world of seen effects as every thing or force is in perpetual transformation because of the ever present Law of Cycles and the Law of Transformation of Forces. Everything is always in motion as motion is Life activity a resultant of dynamic polarity of force and energy in their perpetual and persistent efforts to void.

7.34.2 Law of Cycles

"Coherent aggregates harmonically united constitute centers of vibration bearing relation to the fundamental pitch not multiples of the harmonic pitch, and the production of secondary unions between themselves generate pitches that are discords, either in their unisons, or overtones with the original pitch; from harmony is generated discord, the inevitable cause of perpetual transformation."[176]

7.34.3 Table of Transformation over Time

Figure 7.11: Table of Transformation of Forces over Time
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Table-of-Transformation300.jpg

[176] Keely, 1894

7.34.4 Law of Transformation of Forces

"All forces are different forms of Universal Energy unlike in their period-frequency, merging into each other by imperceptible increments; each form representing the compass of 21 octaves. Each form or pitch may be transformed into an equivalent quantity of another pitch above or below it in the scale of 105 octaves. The transformation can occur only through its static effect, developing vibrations of harmonic pitches above or below their fundamental vibration, or developing with juxtaposed aggregates, resultant and difference, or third order, as the case may be.
Scholium: *"A table of the intervals and harmonics of the normal harmonic scale will indicate the ratios in which the transformation of forces will occur."*[177]

7.35 Harmonizing Chord of Mass

XXXVI. "Keely believes he has solved this problem, by the invention of a mechanical device which brings the chords of all masses within the conditions of a few simple acoustic tests." [178]

It is not known what this mechanical device is, specifically. It is presumed by this writer this device is the Trexar[179] and similar wires Keely made with specific proportions of specific metals. These wires appear to have the property of superconductivity at room temperature. See section 7.37 below.

7.36 Molecular Oscillation

XXXVII. "The range of molecular oscillation is affected differently in different substances when submitted to the same vibratory impulse, and these ranges can be measured."

Again, more careful bench work is called for to determine these effects or modulations.

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[177] Keely, 1893
[178] [Chord of Mass], [Keelys Mechanical Inventions and Instruments], [MECHANICAL INVENTIONS AND INSTRUMENTS]
[179] [Trexar], [Trexnonar]

7.37 Transmitting Concordant Impulses

XXXVIII. "In the three metals, silver, gold, and platina, we obtain the proportions - 3 : 6 : 9 - As this is the primary relation of the modes of vibration, a wire[8] made of these three metals is peculiarly adapted to transmit concordant impulses; and nodes made of these substances placed upon a wire, transmitting resonant vibrations, indicate, by the different orders of vibration induced in them, the rate of oscillations of the atomic constituents." [180]

The first part of the above concerning transmission of concordant impulses is determined by the

7.37.1 Law of Vibrating Atomolic Substances

"Atoms are capable of vibrating within themselves at a pitch inversely as the Dyne (the local coefficient of Gravity), and as the Atomic volume, directly as the Atomic weight, producing the creative force (Electricity), whose transmissive force is propagated through atomolic solids, liquids, and gases, producing induction and the static effect of magnetism upon other atoms of attraction or repulsion, according to the Law of Harmonic Attraction and Repulsion."
Scholium: *"The phenomenon of Dynamic Electricity through a metallic conductor and of induction are identical. In a metallic conductor, the transmission is from atom to atom, through homologous interstices, filled with ether, presenting small areas in close proximity. In crystalline structures, heat, which expands the atoms, by twisting them produces striae, increases the resistance, etc. Between parallel wires and through air the induction takes place from large areas through a rarefied medium composed of a mixture of substances, whose atoms are separated by waves of repulsion of various pitches, discordant to electric vibrations; the said atoms sympathetically absorb the vibrations and dissipate from themselves, as centers, concentric waves of electric energy which produces heat and gravism*[181] *."* [182]

The second part of the above concerns measuring frequencies. The exact

[180] [Trexar], [Law of Force], [Law of Chemical Affinity], [Disturbance of Equilibrium]
[181] [gravism]
[182] Keely, 1894]

method of this detecting process is not known. Below are some frequencies apparently detected using this or a similar method.

7.37.2 Frequencies of the Modes

"He [Keely] mentions the following frequencies, measured in sound colors[183]:

Molecular frequency
inducted in homexar[184] by harmonic thirds, 100,000,000, [100 MHz]
that inducted by enharmonic sixths, 300,000,000, [300 MHz]
that induced by diatonic ninths, 900,000,000, [900 MHz]
that inducted by dominant etheric sixths, 8,100,000,000, [8.1 GHz (microwave)]
that inducted by interetheric ninths, 24,300,000,000. [24.3 GHz (microwave)]
In the trexar[185] the ''*compounding of the triple triple*[186] *will give a frequency from the ninth node that, set down, would make a string of figures a mile long.*"[187]

7.38 Vibratory Rotation

XXXIX. "The phenomenon of rotation arises from the harmonic interaction of the dominant and enharmonic elements of the flow; in other words, the first and third, the third and ninth, *etc.*; those whose vibrations bear the proportions to each other 33 $\frac{1}{3}$: 100."[188][189]

7.38.1 Microwaved Radiometer

According to the listing of frequencies above (7.37.2) microwaves were part of Keely's vibratory tool box. Today we have ready access to these frequencies.

[183] [music note or sound colors]
[184] [Homexar]
[185] [Trexar]
[186] [Triple Triplet]
[187] from [VIBRATIONAL FREQUENCIES]
[188] see '7.7.2 Relations of Thirds'
[189] see 'Chapter 10 - Proportions (Ratios) of Relative Values'

For instance the effects of these waves can be readily seen by placing an ordinary radiometer or even a typical incandescent light bulb into a typical high power kitchen microwave oven. The radiometer vanes in such an environment and under microwave excitation spin too rapidly to see. The incandescent bulb flashes brilliantly white light. The effects are quite dramatic when these 'dominant' waves interact with the 'enharmonic' or molecular/atomic elements within these bulbs.

Experiment: A microwaved radiometer (with sufficient power) rotates at high velocity, flashes brilliantly and gets very hot very quickly. 'Enharmonic' or molecular/atomic elements are Argon gas, metal of vanes, black and white coatings. Each of these has their own vibration frequency and figure into the process.

7.39 Rotation

7.39.1 Medium for inducing a Neutral Center

"In the conception of any machine heretofore constructed, the medium for inducing a neutral center has never been found. If it had, the difficulties of perpetual motion seekers would have ended, and this problem would have become an established and operating fact. It would only require an introductory impulse[190] *of a few pounds, on such a device, to cause it to run for centuries. In the conception of my vibratory engine*[191]*, I did not seek to attain perpetual motion*[192]*; but a circuit is formed that actually has a neutral center, which is in a condition to be vivified by my vibratory ether*[193]*, and while under operation, by said substance, is really a machine that is virtually independent of the mass (or globe), and it is the wonderful velocity of the vibratory circuit*[194] *which makes it so. Still, with all its perfection, it requires to be fed with the vibratory ether*[195] *to make it an independent motor. . . ."*[196]

[190] [introductory impulse]
[191] [Compound Vibratory Engine]
[192] [perpetual motion]
[193] [etheric vapor]
[194] [The Operation of the Vibratory Circuit]
[195] [Vibratory Ether]
[196] Keely, [Keely and His Discoveries], [More Science]

7.39.2 Keely on Rotation

"Rotation arises from the harmonic interaction of the dominant and enharmonic modes of vibration, which are in the ratio of 3:9." [see **XXXVIII**]

"Harmonic interaction"; where the frequencies of the dominant and enharmonic are harmonized or made coincident.[197]

Keely is here referring to the dynamics operating in and through his globe motor[198] or Dynasphere[199] which was his experimental base or model to demonstrate and prove out his theories on vibratory rotation and power development. It was in this design he first began to use his etheric vapor as a carrier[200] of these higher rotating vibratory forces herein explored.

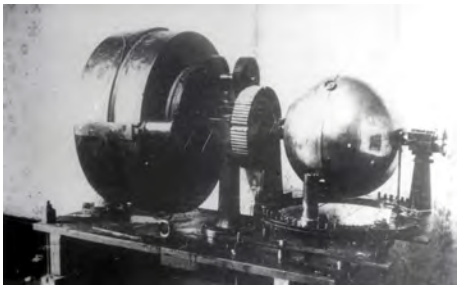

Figure 7.12: Globe motor actuated by rotary vibratory dynamics
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/keely-globe-motor.jpg

[197] [Figure 9.4 - Radiation and Absorption interactions with Neutral Center]
[198] [globe motor]
[199] [Dynasphere]
[200] [connecting link]

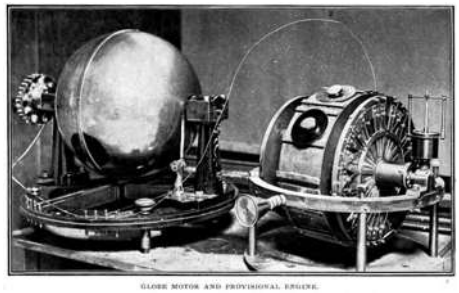

Figure 7.13: Keely's globe motor and provisional engine
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/globe-motor.jpg

Figure 7.14: Keely and his globe motor or dynasphere
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/keelyn.jpg

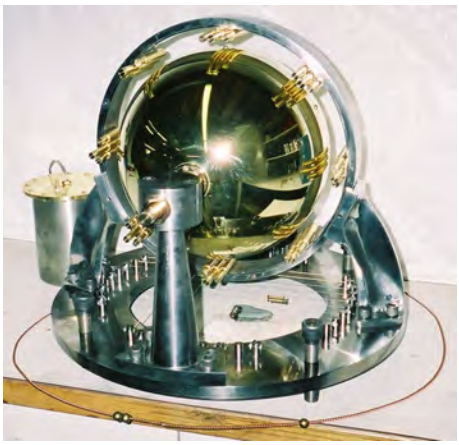

Figure 7.15: Pond's replication of the globe motor or dynasphere
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/altea.jpg

7.39.3 Power of Rotation

"Power of rotation comes on the positive power of negation, arising when the receptive flows become independent of the circular chord of resonation[201] *(set up mechanically or otherwise) breaks up the rotational power. Rotation is caused by the receptive concussion of the positive and negative forces as they come together at the neutral center and as each seeks its "coincident" by harmonic waves, flows or streams."*[202]

I - Two concepts here:

A: Power of Rotation (torque)

"Power of rotation comes on the positive power of negation, arising when the receptive flows become independent of the circular chord of resonation (set up mechanically or otherwise) breaks up the rotational power."

B: Rotation itself. (rotary motion)

[201] [Figure 20.13 - Two Rings - Outer and Inner]
[202] [Keely; [Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]

"Rotation is caused by the receptive concussion of the positive and negative forces as they come together[203] *at the neutral center and as each seeks its 'coincident'*[204] *by harmonic waves, flows or streams."*

7.39.4 Receptive Transmittive Concordance induces Rotation

"Every body capable of rotation is susceptible to the operation of force, which, applied, impels motion. Receptive transmittive concordance[205] *induces rotation. This simply means - the reception of streams of energy by the neutral center, and the transforming of them into radiant outflowing streams of energy causes rotation of the molecule or mass. All the magnets in the world, no matter how differentiated cannot induce rotation, but polar negative attraction*[206] *induces rotation. The earth's rotation is caused and kept in continuance rotation by the action of the positive and negative sympathetic celestial streams*[207]*, that is, by the inflowing celestial*[208] *from the sun and the outflowing radiant celestial dispersing this same energy to all planetary masses in space."*[209][210]

7.39.5 Polar and Depolar Differentiation result in Motion

"Polar and depolar differentiation[211] *result in motion. The compound interetheric or seventh subdivision is the Soul of Matter*[212]*, from which all*

[203] syntropically and [Law of Cycles]
[204] [VIBRATIONAL COINCIDENTS]
[205] [receptive transmittive concordance]
[206] [polar negative attraction]
[207] [sympathetic celestial streams]
[208] [celestial]
[209] [Law of Cycles]
[210] [Keely; [Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]
[211] [differentiation]
[212] [Soul of Matter]

forms of matter receive their introductory impulse.[213] "[214]

Polar and depolar is Keely's way of saying having two poles (as in a magnet or electric circuit) or not.

7.39.6 Neutral Center or fulcrum represents Focalization

"The neutral center (fulcrum) represents focalization (of syntropic forces) and distribution of the streams of (entropic) energy. It is not associated with magnetism. When the radiant elements generated by the focalizing chord are submitted to compound vibration of their mass thirds, those radiant elements become magnetic and rotation ceases. Rotation is induced by submitting the mass to three different orders of vibration simultaneously, giving the majority to the harmonic third."[215]

7.39.7 Rotation of the ether produces condensation

"When we rotate a mass with sufficient rapidity, the particles of that mass ultimately overcome cohesion by dispersing as fragments at a tangent but should we cause rotation of the ether, this would produce condensation, which is opposite in effect. This condensation effect increases with the velocity of rotation of the ether. This is the direct cause of formation of molecules as well as planetary masses.[216]

The above describes the difference between centrifugal (dispersive) and centripetal (attractive) forces. The first belongs to the molecular and atomic domains or orders while the latter is a function of the etheric order or domain. In this we can see when the etheric is the exciter rotation of the molecular results - when proponderance is given the etheric order or third.

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[213] [introductory impulse]

[214] [Keely; [Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]

[215] [Keely; [Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]

[216] [Keely;[Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]

7.39.8 Controlling "negative attractive"

"To control rotational force or produce commercialized energy, we must control through its properties the 'negative attractive' or 'enharmonic' current. This will solve the problem up to any limit of power."[217]

7.39.9 Testing Positive and Negative Rotation

"At the same time Keely was completing his third system[218]*, he was also completing an experimental sphere in which he intended to test the combination of the positive and negative rotation. This experiment was at least entirely successful which showed the explanation of rotation given above, to be correct. The sphere even rotated with physical vibrations from the positive and negative interchange of positive and negative waves - not streams in this case. He had a desperate struggle in seeking to learn these laws of polarization and depolarization*[219]*. It was necessary for him to understand these laws before he could unfailingly secure rotation and control the reversions*[220] *which so often had made wrecks of his machines."*[221]

7.39.10 Russell on rotation

"Mass is an accumulation of the universal constant of energy[222] *into higher potential. The greater the mass the greater the potential. Mass accumulates inductively along the centripetal lines of closing spirals, and is rotated by the impact of genero-active force. Mass dissipates conductively along centrifugal lines of opening spirals, and is rotated by the expulsion of radio-active*[223] *force. These opposite forces are the cause of rotation of mass."*[224]

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[217] [Keely; [Snell Manuscript], PHILOSOPHY OF TRANSMISSION AND ROTATION OF MUSICAL SPHERE]
[218] [Keelys Three Systems]
[219] refers to the Laws of Being herein explained
[220] [reversion]
[221] [Snell Manuscript]
[222] [universal constant of energy]
[223] [radio-active]
[224] Russell, [The Universal One]

7.40 Controlling negative attraction

XL. "A practical example of rotation is a wheel in revolution on its axis. This is force in its commercial or economic aspect. To accomplish this result by molecular vibratory action, we must gain control of the negative attractive[225] or enharmonic current[226] of the triple flow, and the problem is then solved up to any limit of power."

End of Brinton article.

7.41 Notes

[1] Also called Circular wave, Curl, Love Wave, Lamb Wave, Surface wave, Etheric. *"Power of rotation comes on the positive and power of negation, arising when the receptive flows become independent of the circular chord of resonation (set up mechanically or otherwise) breaks up the rotational power."*[227]

[Rayleigh Wave][228]
[Vortex][229]

[2] Also called Compression wave. *"The vibratory velocity governing the magnetic flow ranges from 300,000 to 780,000 per second and comes under the first interatomic. This is the first order above odor and permeates the molecules of glass in the compass cover as air passes through a sieve. Being governed by the full harmonic chord this flow moves in straight lines free from molecular interference.*[230] *... "when free of this differentiation are in straight lines."* see [Discordant]

[Figure 8.3 - Coiled Spring showing Longitudinal Wave]

[225] [negative attractive], [Sympathetic Negative Attraction]
[226] [Enharmonic]
[227] [ROTATION - Snell]
[228] [Rayleigh Wave]
[229] [Vortex]
[230] [MAGNETIC ENGINE - Snell]

[Longitudinal]
[Longitudinal Wave]
[Longitudinal Waves in Vacuum]

[3] *"Discordance in any mass is the result of differentiated groups, induced by antagonistic chords, and the flight or motions of such, when intensified by sound, are very tortuous and zig-zag;"* see [Discordant]
[Figure 8.4 - Transverse Wave]
[transverse]
[Transverse Wave]

[4] Wave Field]
[12.05 - Three Main Parts of a Wave]
[12.09 - The MINUS side]
[12.08 - The PLUS side]
[Figure 2.12.1 - Polarity or Duality]
[Figure 15.03 - Opposing Forces of Gravity and Radiation]
[7B.16 - Polarity], [Principle of Polarity]

[5] Artwork by [Jeremy Pfieffer] et al.

[6] [The Seven Subdivisions of Matter and Energy], [VACUUMS FROM VIBRATORY INDUCTION]

[7] Jose Arguelles, Earth Ascending, page 21; 1996 (3rd edition) [See Binary Triplet]

[8] [Trexar], [Trextrinar], [TREXAR - Snell], [Trexnonar]

[9] [7.1 - Matter is centralized motion]

[10] [Etheric Vibration. - The Key Force]

[11] [7.9 - Ultimate Constitution of Matter and Action of Force Regulating its Phenomena]

Chapter 8

Modes of Vibration

8.1 Two models of three modes

There are three distinct modes of vibration in the standard acoustic model. These are the compression or longitudinal wave, shear or transverse wave and Rayleigh, Lamb or Love wave.

There are three distinct modes of vibration in the Keely/SVP model. These are the

Harmonic,
Enharmonic and
Dominant modes.

Each of these modes have distinct attributes such as

mode of motion,
angle of incidence,
relative frequency or pitch and
creative aliquot component signatures.

The two sets of three modes do not appear to be directly translatable. However they do possess common characteristics.

8.2 Three Modes of Vibration

8.2.1 Compression or Longitudinal Wave or Mode

Longitudinal Wave[1] same as Compression Wave or Sound Wave.

1) A wave incident or normal to a surface of a medium.

2) A vibration moving directly away from a sound source in a straight line.

3) Generally, considered as a motion to and from a center or source.

When harmonic is generally considered syntropic and when enharmonic considered entropic.

"Vibration in which the principal motion is in the direction of the longest dimension."[2]

"A vibrating medium must lengthen and shorten two times per each lateral (transverse) oscillation; so one longitudinal motion equals two lateral or (transverse) motions. Longitudinal frequencies are independent of string tension."[3]

8.3 Three Modes of Vibration

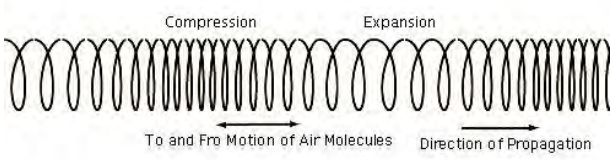

Figure 8.1: Coiled Spring showing Longitudinal Wave
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/longitudinal.jpeg

[1] [Longitudinal Wave]

[2] Rossing, Thomas D. The Science of Sound. Addison-Wesley Publishing Company, 1982

[3] Tyndall, John; Sound; Longmans, Green, and Co., London, 1893

The above and below are but an illustration commonly held of how a longitudinal wave behaves. This is a good working model but it does not explain the complex dynamics in vibrations which dynamics are touched upon in Chapter 6 and 7 where particles in a vibrating medium mutually attract (syntropy) then mutually disperse (entropy) periodically.

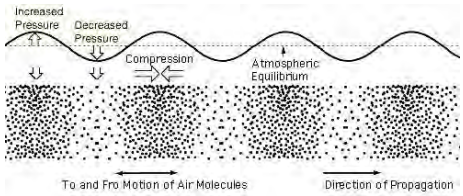

Figure 8.2: Compression and Rarefaction in a Wave
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/compress-wave.jpeg

8.3.1 Transverse or Shear Wave or Mode

Waves 45° and higher to normal incidence.
Waves moving at 90° to the direction of (longitudinal) propagation.

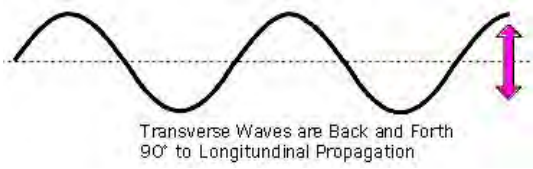

Figure 8.3: Transverse Wave
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/transverse.jpeg

8.3.2 Rayleigh, Lamb or Love Wave or Mode

Rayleigh waves are circular vibrations. They travel along the surface of a vibrating object when the angle of incidence exceeds 90° or nearly parallel to the surface. This behavior is not unlike the idea electrons or electricity travels along the outside surface of a conducting wire and not through the conducting wire. This is the same form and motion of the 'curl' suggested

by Maxwell[4] in 1871 and so often spoken about by Bearden[5]. Thus this circular form and motion would be universal principle of all periodic motion. *With this idea we can say with some confidence power travels longitudinally 'through' the wire, amplitude and polarity forms* 90° *to the longitudinal and the Rayleigh wave is the circulating path (skin effect[6]) around a conducting wire - all three wave forms are* 90° *to each other.* Think about that for awhile.....

Triple axis of the three modes of vibration drawn in reference to a circle and sphere. The three modes working together develop rotation by and through each other's motion - the rotation is the Rayleigh Wave or Surface Wave mode component. The first two modes cause (or are) straight line and zig-zag motions only. The third or Rayleigh Wave travels in a circular motion.

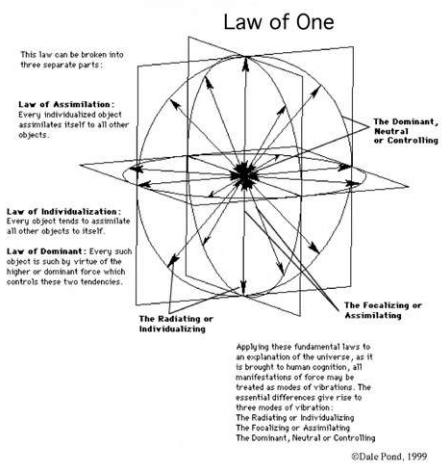

Figure 8.4: Relationship of Three Modes
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Triune-Modes-Motion.jpg

[4]James Clerk Maxwell (13 June 1831 5 November 1879) was a Scottish theoretical physicist and mathematician. See [James Clerk Maxwell]

[5]Thomas E. Bearden, Lieutenant Colonel, U.S. Army (Retired). Born Dec. 17, 1930, Cheniere, Louisiana. See [Bearden]

[6]Wikipedia/skin effect

8.4 Introduction to Keely's Wave Function

Perhaps one of the more interesting aspects of Keely's work is his Wave Function. The Wave Function is comprised of those foundational forces and attributes creating all oscillation and vibration which are seen effects of those unseen modal causes forces and attributes. Fundamentally these forces are in the 3, 6 and 9 proportions discussed in Chapter 7.

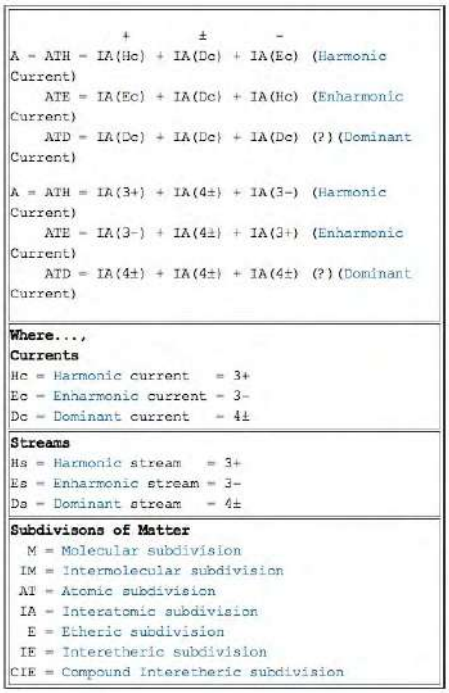

	+	±	-	
A = ATH =	IA(Hc) +	IA(Dc) +	IA(Ec)	(Harmonic Current)
ATE =	IA(Ec) +	IA(Dc) +	IA(Hc)	(Enharmonic Current)
ATD =	IA(Dc) +	IA(Dc) +	IA(Dc)	(?)(Dominant Current)

A = ATH =	IA(3+) +	IA(4±) +	IA(3-)	(Harmonic Current)
ATE =	IA(3-) +	IA(4±) +	IA(3+)	(Enharmonic Current)
ATD =	IA(4±) +	IA(4±) +	IA(4±)	(?)(Dominant Current)

Where...,
Currents
Hc = Harmonic current = 3+
Ec = Enharmonic current = 3-
Dc = Dominant current = 4±

Streams
Hs = Harmonic stream = 3+
Es = Enharmonic stream = 3-
Ds = Dominant stream = 4±

Subdivisons of Matter
M = Molecular subdivision
IM = Intermolecular subdivision
AT = Atomic subdivision
IA = Interatomic subdivision
E = Etheric subdivision
IE = Interetheric subdivision
CIE = Compound Interetheric subdivision

Figure 8.5: Suppositional Math and Symbolic Structure
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/table-13-01.jpg

The above table is an attempt to correlate some of what has been discussed.Elements include the three modes, their combinations, seven subdivisions and Russell's Indig numbers[7]. The following table is another presentation of a portion of the above data.

[7][Indig numbers]

Aggregation	Governing Mode	Dominant Mode	Subservient Mode
Molecular	100 x Enharmonic	66 $\frac{2}{3}$ Harmonic	33 $\frac{1}{3}$ Dominant
Atomic	100 x Harmonic	66 $\frac{2}{3}$ Enharmonic	33 $\frac{1}{3}$ Dominant
Etheric	100 x Dominant	66 $\frac{2}{3}$ Harmonic	33 $\frac{1}{3}$ Enharmonic
Thirds	3	2	1
Proportion	9	6	3
Portion	Ninths	Sixths	Thirds

Table 8.1: Modes of Vibration[8]

8.5 Feynman Morphology

Richard Feynman's morphology[9] from his book, QED: The Strange Theory of Light and Matter[10], depicts Keely's $\frac{1}{3}$ and $\frac{2}{3}$ nested triune structure concept.

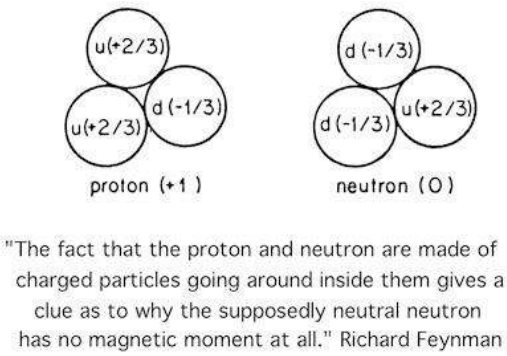

Figure 8.6: Feynman's triplet structures of the proton and neutron
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/feynmandiagram400.jpg

[9][Figure 4.14 - Feynmans Triplet Structures of the Proton and Neutron]
[10]QED: The Strange Theory of Light and Matter; Princeton Science Library, ISBN-10:0691125759

Thus we see again Keely anticipated the quantum world decades before conventional science even had a glimmer of its existence as we also saw in the Rule of Threes (section 7.2.3 the Rule of Threes) and elsewhere.

Range[1]	Octave	cps range (gamut)	Sound Type	Sound Effect	Sound Action	Vibe Type	Governing Law
		Law of Force->	Creative	Transmissive	Static		
Atomolic	65..105	? - ?	Atomolity	Gravism	Gravity	Atoms Oscillate	Law of Oscillating Atomoles
Etheric	43..64	4,398,046,511,104 / 1.8014398509482E+19	Thermism	Rad-energy	Cohesion / Chemism	Atoms Oscillate	Law of Oscillating Atoms
Atomic	21..42	2,097,152 / 4,294,967,296,000	Sono-thermity	Sono-therm	Adhesion / Disintegration	Internal Vibrations	Law of Sono-thermity
Molecular	1..20	1... 1,048,576	Sonity	Sound	Sonism	Atomic Oscillation	Law of Oscillating Atomic Substances

Table 14.03 - Ranges of Forces Vibration Forms Types and Governing Laws

Figure 8.7: Table of ranges of forces, forms and laws
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/table-14-03.jpg

(See Law of Transformation of Forces[11] and subdivision[12] for explanation of the above table)

[11] [Law of Transformation of Forces]
[12] [Subdivision]

Source	**From Center**	**To Center**	**Controlling**
Keely / SVP[6]	Enharmonic	Harmonic	Dominant
Modern wave form	Longitudinal[2]	Transverse[3]	Rayleigh[1]
Angle of Incidence	$0° - 45°$	$45° - 90°$	$> 90°$
Path/Motion[3]	Straight	Zig-zag	Circular
Keely / SVP	Focalizing	Radiating	Dominant
Keely / SVP	Syntropic	Entropic	Dominant
Russell[4]	Plus	Minus	Fulcrum
Russell[4]	Gravitation	Radiation	Balance, Void
Charles Henry[7]	Gravitation	Electromagnetic	Biopsychic
Possible Correspondence[5]	Thirds	Sixths	Ninths

Table 8.2: Table of attributes of the three modes

Mode	**Subdivision**	**Octave** [Hz = 2^{octave}]	**Law**
Enharmonic	Molecular / Intermolecular	1-21	Law of Oscillating Atomic Substances[13]
Harmonic	Atomic / Interatomic	21-42	Law of Sonothermity[14]
Dominant	Etheric / Interetheric	42-63	Law of Oscillating Atoms[15]

Table 8.3: Keely's three modes; subdivision, octave and law

‘‘*By use of the dominant mode, which is allied to the "order" of etheric vibrations, we can induct, "sympathetic negative attraction" or "sympathetic positive propulsion" in any mass, according to its mass chord."*[16]

[16][SYMPATHETIC INDUCTION - Snell]

8.6 Footnotes

[1] Also called Circular wave, Curl, Love Wave, Lamb Wave, Surface wave, Etheric. *"Power of rotation comes on the positive and power of negation, arising when the receptive flows become independent of the circular chord of resonation (set up mechanically or otherwise) breaks up the rotational power."*[17]

[Rayleigh Wave]
[Vortex]

[2] Also called Compression wave. "*The vibratory velocity governing the magnetic flow ranges from 300,000 to 780,000 per second and comes under the first interatomic. This is the first order above odor and permeates the molecules of glass in the compass cover as air passes through a sieve. Being governed by the full harmonic chord*[18] *this flow moves in straight lines free from molecular interference.*[19] *"when free of this differentiation are in straight lines."*[20]

[Figure 8.3 - Coiled Spring showing Longitudinal Wave]
[Longitudinal]
[Longitudinal Wave]
[Longitudinal Waves in Vacuum]

[3] *"Discordance in any mass is the result of differentiated groups, induced by antagonistic chords, and the flight or motions of such, when intensified by sound, are very tortuous and zig-zag;"*[21]

[Figure 8.4 - Transverse Wave]
[transverse]
[Transverse Wave]

[4] See [Wave Field]
[Three Main Parts of a Wave]
[12.09 - The MINUS side]
[12.08 - The PLUS side]

---

[17] [ROTATION - Snell]
[18] [full harmonic chord]
[19] [MAGNETIC ENGINE - Snell]
[20] [Snell Manuscript], [Discordant]
[21] [Keely and His Discoveries, pg 275], [Discordant]

[Figure 2.12.1 - Polarity or Duality]
[Figure 15.03 - Opposing Forces of Gravity and Radiation]
[7B.16 - Polarity, Principle of Polarity]

[5] Artwork by [Jeremy Pfieffer] et al.

[6] [The Seven Subdivisions of Matter and Energy], [VACUUMS FROM VIBRATORY INDUCTION]

[7] Jose Arguelles, Earth Ascending, page 21; 1996 (3rd edition) See [Binary Triplet]
See [MUSICAL CHORDS], [Triplet]

Chapter 9

Keely Wave Function

9.1 Introduction to Keely's Wave Function

One of the keys to Keely's mastery of matter and energy lies in what I call the Keely Wave Function[1] and his ability to manipulate it. A wave function is a mathematical description of the factors involved in a sine-like wave, vibration or oscillation expressed over time. Generally, science considers a wave function of one dimension or within a closed and defined range of frequency (to put it simply) which includes the constructive attributes of amplitude, Time and Space (wave length). In Keely's case the wave function is composite three dimensional wave function that operates within three levels, orders or ranges of frequencies, simultaneously and having additional constructive attributes or aliquot parts within those orders or levels. Thus it is more complicated but also more inclusive of the factors operating naturally within a wave, vibration or oscillation. The Keely Wave Function would include some if not all of the dimensions of the Russell Wave Function[2].

Perhaps one of the more interesting aspects of Keely's work is his Wave Function. The Wave Function is comprised of those creative foundational forces creating all oscillation and vibration which are seen effects of those unseen causes. Fundamentally these forces are in the 3, 6 and 9 proportions discussed in the [Laws of Being - Annotated] and [Modes of Vibration - Annotated] and hinted at by Nikola Tesla and discussed in this book primarily

[1] [Keely WaveFunction]
[2] [Eighteen Attributes or Dimensions]

in Chapter 7 and 8.

The wave function preforms not too unlike complex impedance[3] calculations over time but with more variables or dimensions. The Keely Wave Function operates/is on three levels or orders simultaneously:

Molecular
Atomic
Etheric

Each level or order has three motions/dynamics:

Harmonic = Syntropic
Enharmonic = Entropic
Dominant = Neutral

This table below shows the three main levels or orders plus a fourth level or order and the forces active in each as also the law governing each specific frequency range.

[3][impedance]

Range[1]	Octave	cps range	Sound Type	Sound Effect	Action	Vibe Type	Governing Law
		Law of Force>	**Creative**	**Transmissive**	**Static**		
Atomolic	65-105	?—?	Atomolity	Gravism	Gravity	Atoms Oscillate	Law of Oscillating Atomoles
Etheric	43-64	4,398,046,511,104 - 1.8014398509E+19	Thermism	Radenergy	Cohesion / Chemism	Atoms Oscillate	Law of Oscillating Atoms
Atomic	21-42	2,097,152 - 4,294,967,296,000	Sonothermity	Sonotherm	Adhesion / Disintegration	Internal Vibrations	Law of Sonothermity
Molecular	1-20	1 - 1,048,576	Sonity	Sound	Sonism	Atomic Oscillation	Law of Oscillating Atomic Substances

Table 9.1: Ranges of forces vibration forms types and laws

Table 9.1 shows the break-out into orderly detail the components, activity and functions of Keely's Law of Transformation of Forces[4].

9.1.1 Law of Transformation of Forces

"All forces are different forms of Universal Energy[5] unlike in their period-frequency, merging into each other by imperceptible increments; each form representing the compass of 21 octaves. Each form or pitch may be transformed into an equivalent quantity of another pitch above or below it in the

[4][Law of Transformation of Forces]
[5][12.02 - Universal Energy Unit Constant or Impulse]

scale of 105 octaves[6]*. The transformation can occur only through its static effect, developing vibrations of harmonic pitches above or below their fundamental vibration, or developing with juxtaposed aggregates, resultant and difference, or third order, as the case may be.*

Scholium: *"A table of the intervals and harmonics of the normal harmonic scale will indicate the ratios in which the transformation of forces will occur."*[7]

It is said energy cannot be created or destroyed however energy can be transformed or transmuted into different forms. These vibratory forces, states and conditions have reciprocity and are expressed in ratios of relative values or 'modes' thus they can be changed one into the other under special circumstances as described in Keely's Law of Transformation of Forces.

9.2 Thirds as Ratios within a Whole

In Brinton's "Laws of Being" (Chapter 7) we can see the description of Keely's Thirds, Sixths and Ninths as learned, understood and presented by Professor Brinton during his visits to Keely's laboratory. We can also see these terms are not specifically musical intervals of thirds, sixths or ninths, as considered by musicians, but they are musical in terms of relativity, proportion and value. They are relative proportions within a whole. Flows and currents can be understood by the metaphor of a river or stream. The stream flows as a whole and has within this stream many currents. Herein the syntropic flow to a center is composed of three currents. Each current is a third $\frac{1}{3}$ of the whole flow or stream. These currents are expressed as ratios within a whole of 100; *i.e.*, 33 $\frac{1}{3}$: 100 or 66 $\frac{2}{3}$: 100. The whole wave, flow or stream, regardless of polarity, is 100. Exploring the literature a bit further we find the following relationships:

"Silver represents the third, gold the sixth and platinum the ninth, in their respective relative molecular oscillating ranges. This triune condition will equate thirds in vibratory frequencies, that is, chords in intervals of thirds will set up disturbances in the Trexar and these disturbances will be equated

[6][Scale of the Forces in Octaves]

[7][Keely]; [Law of Cycles], [12.06 - Mid-Tones and Neutral Centers], [Scale of the Forces in Octaves]

so as to be transmitted as thirds from the positive or farthest end of the wire."[8]

[8] [TREXAR - Snell]

Thirds	**Sixths**	**Ninths**
Silver	Gold	Platinum
33 $\frac{1}{3}$	66 $\frac{2}{3}$	100
neutral	depolar	polar
33 $\frac{1}{3}$	>>Attractive - Equation<<	100
<<Repulsive - Equation>>	66 $\frac{2}{3}$	100
neutral	entropic	syntropic
celestial	terrestrial - matter dissolving	terrestrial - matter forming
dominant	individualizing	assimilative
Mind as Intent, Will, Volition, Desire	I want to be One with Everything	I want Everything for myself
Ideals	Service to Others	Service to Self
Fulcrum, Neutral, Balance	Radiating from Center	Contracting to Center
Controller	Dispersing, Dissociating	Concentrating, Associating
Neutral	Minus	Plus
Dominant	Enharmonic	Harmonic
Neutral	Magnetic	Electric
Fulcrum, Void	Mother	Father
Now	Life Reducing (death)	Life Enhancing
Neutral Chords	Dispersing Chords	Assimilating Chords

Table 9.2: Neutral (thirds); energy radiates from center (sixths); force contracts to center (ninths)

The above three levels and three forces acting in each are delineated in the pages listed below, especially within the [Laws of Being - Annotated] and

[Modes of Vibration - Annotated] all subject of this book especially Chapter 7. The action of each mode is determined by their composite proportions or modal preponderance. Hence a mode may have different action in different contexts, use or circumstance.

Chapter 10

Proportions (Ratios) of Relative Values

10.1 Proportion

Proportion is the ratio (relativity) of two or more numbers or quantities to each other as have been presented in the preceding chapters. The same of course applies to notes in a music chord. While the individual frequencies are important they take on a new meaning according to their proportion within the scale, chord and to each other. This gives us an insight into why Keely used music notation to such an extent. On Keely's charts can be seen the following terms of numeric relationship.

Proportion is in three kinds: (1) multiplex. (2) Superparticularis. (3) Superpartiens. Proportio multiplex is when the larger number contains the smaller so many times without a remainder, as

2:1 (dupla)
3:1 (tripla)
4:1 (quadrupla).

Proportio superparticularis is when the larger number exceeds the smaller by one only as

3:2 (sesquialtera)

4:3 (sesquitertia)
5:4 (sesquiquarta).

Proportio superpartiens is when the larger number exceeds the smaller by more than one, as

5:3 (superbipartienstertias)
7:4 (supertripartiensquartas)
9:5 (superquadripartiensquintas).

Thus, it will be understood, that instead of giving simply the ratio between two numbers, early writers on arithmetic and geometry, as well as music, coined a single word to express that ratio; for example, 17:5 was said to be Triplasuperbipartiensquintas, *i.e.*, that the larger number contained the smaller number three times (tripla) with two remainder (bipariens). Again, Triplasupertripartiensquartas proportio, signified that the larger contained the smaller three times and three over, as 15:4, 27:8, *etc.*, the last part of the compound word always pointing out the smaller of the numbers compared, or an exact multiple of it. Lastly, the addition of sub showed that the smaller number was compared to the larger, *e.g.*, 4:15 would be called Subtriplasupertripartiensquartas proportio. This system of proportion was used not only with reference to intervals but also to the comparative length of notes (time).[1]

An excellent booklet on proportion is 'Propositions of Proportions'[2] in the svpbookstore.com online catalog.

10.2 Reciprocating Proportionality

Reciprocating Proportionality means what is added to one side must be simultaneously subtracted from the other. A children's seesaw is a perfect analogy. Whatever quantity or rate of change added to one side must be subtracted from the other. Another good analogy is a mathematical equation where what is added to one side must be subtracted from the other side or where one side is multiplied the other is divided. A dynamic balance

[1] Stainer, John; Barrett, W. A.; A Dictionary of Musical Terms; Novello, Ewer and Co., London, pre-1900

[2] svpbookstore.com

where the whole is always one while the two balanced forces in opposition (*e.g.*; syntropy and entropy) are constantly changing in direct proportion to one another. The Square Law and Inverse Square Law is another good example. This equal and balanced reciprocating dynamic is at the root of Russell's Rhythmic Balanced Interchange[3] and Macvicar's cosmical Law of Assimilation[4].

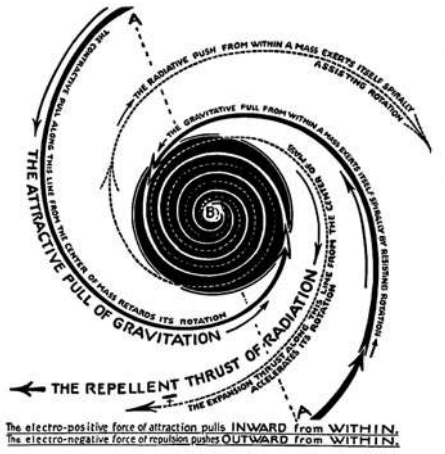

FIGURE 7

Figure 10.1: One Balanced Whole and Two Reciprocating Dynamics
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/reciprocating.jpg
(courtesy University of Science and Philosophy)

10.3 Reciprocating Proportionality

"The underlying law of Creation is RHYTHMIC BALANCED INTERCHANGE in all transactions in Nature. It is the one principle upon which the continuity of the universe depends. Likewise, it is the one principle upon which the continuity of man's transactions, his health and happiness depend. It is the manifestation of God's two opposing desires in all processes of creation.

"BALANCE is the principle of unity, of oneness. In it is the stability which lies in CAUSE. BALANCE is the foundation of the universe.

[3][Rhythmic Balanced Interchange]
[4][Law of Assimilation]

"BALANCED INTERCHANGE simulates oneness by interchange between pairs of opposites. It is the principle of equal giving between all moving pairs of unbalanced opposites which constitute this dual electric universe. In it is the instability of EFFECT. Instability is forever seeking to find stability. It can never find it, but it can simulate it by balancing its instability through equality of interchange.

"RHYTHMIC BALANCED INTERCHANGE is the principle of continuity of EFFECT. Balanced interchange between opposites repeats simulation of stability, and rhythmic balanced interchange continues that repetition."[5]

The degree to which a vibrating or oscillating system is either one polarity or the other can be pictured or expressed in relative and accumulative numbers. Russell used the + sign to indicate accumulating, concentrating (syntropic) quantities and a − sign to indicate dispersive, radiating (entropic) quantities. Russell used his Scale of Locked Potentials[6] to measure degrees of polarity and this author believed Keely similarly used his mysterious thirds, sixths and ninths as part of his referencing method where proportions or parts of a whole were given proportioned or ratioed values.[7]

10.4 Reciprocal Proportion

Increases and decreases (establishing polar preponderance) are in inverse or direct proportion to rate of change or *delta*.

Energy at Plane of Inertia is neutral or depolar. −0 0+.

[5] Russell, [The Secret of Light], page 106-107
[6] [Scale of Locked Potentials]
[7] [3.13 - Reciprocals and Proportions of Motions and Substance]

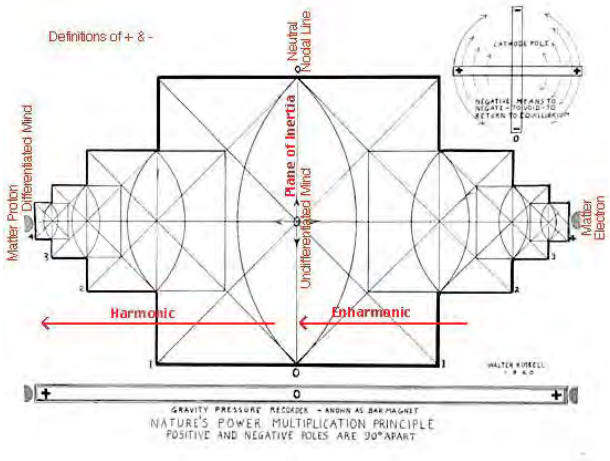

Figure 10.2: Plane of Inertia
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/plane-of-inertia.jpeg
(courtesy University of Science and Philosophy)

Degree of Concord or Discord is determinative anywhere from -0 $0+$ to $4++$[8].

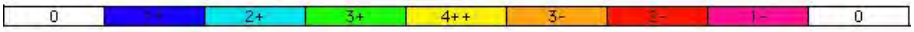

Figure 10.3: Scale of 0 to 4 to 0
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/lockedpotentials.jpeg

When preponderantly harmonic a larger volume -0 $0+$ condenses to smaller volume of -1 $1+$ progressively to $4++$.

When preponderantly enharmonic a smaller volume $4++$ dissociates and expands to larger volume of -3 $3+$ progressively to -0 $0+$[9].

[8] [4plusplus]
[9] [4plusplus]

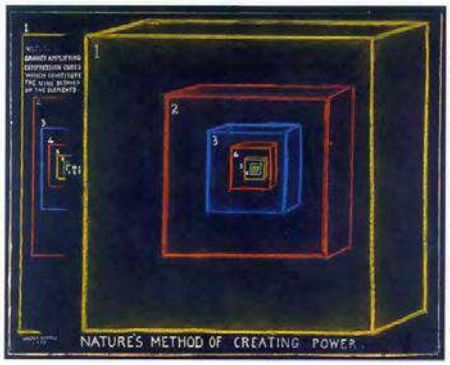

Figure 10.4: Nested cubes or increasing and decreasing proportions
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/nested-cubes.jpg
(courtesy University of Science and Philosophy)

Volume decreases with increased potential.

Volume increases with decreased potential. For numeric details and relationships on the above see [cube-sphere] and [Cubing the Sphere].

Transformations occur at the -0 $0+$ and $4++$ points, states or conditions. The first according to Russell's Principle of Regeneration[10] (Keely's "static effect") and the latter by Keely's Law of Cycles[11]. See Figure 12.8 for an animated graphic show progressive generation of discords until dissociation.

10.5 Reciprocals and Proportions of Motions and Substance

"The following fundamental laws governing mathematical relations will briefly convey the idea of the Principles governing universal ratios which is in every effect of motion the direct and inverse square of the distance, area or time dimensions and the cube of volume or potential dimensions. The direct and the inverse are the two way indicators of direction, the latter belonging to

[10] [Principle of Regeneration Russell], [13.13 - Principle of Regeneration] and [Principle of Regeneration Bearden]

[11] [Law of Cycles]

gravitational and the former to radiational effects."[12]

Notice the reference to the reciprocals Square Law and Inverse Square Law in the above Russell quote. These two laws are reciprocals of each other and reflect the natural ways force and energy[13] interchange in nature when forming pressures, vacuity, rotation, gyroscopic motions, or vortices.

"All dimensions[14] *simultaneously expand and contract in opposite directions of the same ratio."*[15]

10.6 Thirds as Ratios within a Whole

In the above quote we can see the description of Keely's Thirds, Sixths and Ninths as presented by Professor Brinton after his visits to Keely's lab on Chestnut street, Philadelphia. We can also see these terms are not specifically musical intervals of thirds, sixths or ninths, as considered by musicians, but they are musical in terms of relativity, proportion and value. They are proportions within a whole. Flows and currents can be understood by the metaphor of a river. The river flows as a whole stream and has within this flow many currents. Herein the syntropic flow to a center is composed of three currents. Each current is a third ($\frac{1}{3}$) of the whole flow. These currents are expressed as ratios within a whole of 100; i.e., 33 $\frac{1}{3}$: 100 or 66 $\frac{2}{3}$: 100. The whole wave or stream, regardless of polarity, is 100. Exploring the literature a bit further we find the following relationships:

"*Silver represents the third, gold the sixth and platinum the ninth, in their respective relative molecular oscillating ranges. This triune condition will equate thirds in vibratory frequencies, that is, chords in intervals of thirds will set up disturbances in the Trexar*[16] *and these disturbances will be equated so as to be transmitted as thirds from the positive or farthest end of the wire."*[17]

[12] Russell, [Genero-Radiative Concept], part 6b
[13] In SVP [Force] is considered Syntropic while [Energy] is considered Entropic.
[14] [Dimension]
[15] Russell
[16] [Trexar]
[17] [TREXAR - Snell]

Chapter 11

Universal Heart Beat

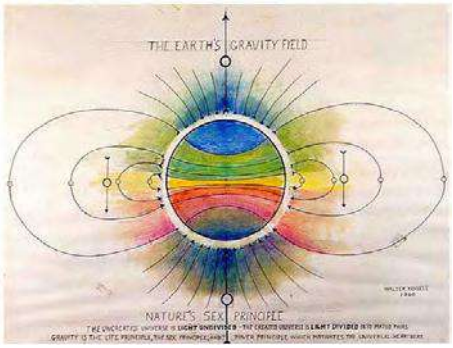

Figure 11.1: Universal Heartbeat
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/heartbeat.jpg
(courtesy University of Science and Philosophy)

Universal Heart Beat =
Dynaspheric Force[1] =
Rhythmic Balanced Interchange[2] =
Triune Polar Flows[3]

"The eternally conscious entity - call it by whatever name we please - moves

[1] [Dynaspheric Force]
[2] [Rhythmic Balanced Interchange]
[3] [Triune Polar Flows], [Figure 13.12 - Triune Polar Stream Characteristics]

in cycles as eternal and infinite as itself; it oscillates and vibrates perpetually."[4]

The universal heartbeat is the periodic flow of a polar system from a preponderance of one pole then to preponderance of its seeming opposite pole. This is the action of all vibration, oscillation and waves no matter what order or level (frequency or media) it is. Russell mentions "*in the wave lies the secret of Creation.*"[5] The secret then of Creation[6] is the unseen dynamics of the wave, vibration or universal heartbeat - the essence of this book. The following are primarily Russell quotes describing this universal dynamic or dance of polarities.

11.1 The Love Cycle

"Energy accumulates during genero-active inhalation by rising potential, and is dissipated during the radio-active[7] *exhalation by lowering potential. The periodicities of inhalation and exhalation in all mass are absolute."*[8]

"All the force of electricity is exerted in the attempt to create the illusions of form and dimension.

"All the force of magnetism is exerted in the attempt to destroy all illusion, all form and all dimension.

"Neither force completely fulfills its desire, for each partially thwarts the other.

"The energy of magnetism is the elastic energy of expansion, a straining energy ever pushing toward the inertial line of equalized pressures which lies between any two masses, while the energy of electricity is ever pulling toward the pulsing heart, the gravitational nucleus of every mass."[9]

[4]Keely's description of that state of being commonly known as God, [Dashed Against the Rock], see [14.30 - Effect of Preponderance] and [14.31 - Preponderance Russell]

[5][In the Wave lies the Secret of Creation]

[6][Creation]

[7][radio-active]

[8]Russell, [The Universal One]

[9]Russell, [The Universal One]

"*To these periodic oscillations, alternating in sequence, is due the revolution and rotation of all mass.*[10]

"*All evolving and devolving mass beats time in accord with its periodic sequences of alternating electro-magnetic oscillations.*

"*All mass beats time in accord with its varying potential.*

"*The electro-magnetic oscillations of the universe are the heart-beats, the life pulsations of the universal One.*"[11]

"*The misconception of gravity as a force of attraction which pulls inward from within. The only force which motivates the heart beat of this universe is the cyclic wave force of gravity which expands and compresses, heats and cools, integrates and disintegrates, centripetally and centrifugally.*"[12]

"*Waves of motion spring from the stillness of the universal equilibrium. They are the universal heartbeat which manifests eternal life and power in God's stillness by eternal repetitions of simulated life and power as expressed in waves of motion.*"[13]

"*Each interchange between the invisible omnipresent universe where motion begins and ends, and the visible transient universe, which multiplies and divides the speed and power of motion, is a cycle. Pulsing cycles constitute the heart beat of this universe, which simulates Mind-Idea through pulsing cycles of two-way motion. Every pulsation of the life principle of multiplying motion creates divided electric male and female bodies, which seek rest in each other from the strains and tensions of their division into pairs of opposites.*"

"*This shows how the heartbeat piston operates between the vacuity of the*

[10][See 7.39.4 Receptive Transmittive Concordance induces Ro- tation]
[11]Russell, [The Universal One], Book 02 - Chapter 03 - New Concepts of Electricity and Magnetism
[12]Russell, [Russells Optic Dynamo-Generator]
[13]Russell, [The Secret of Light], page 115

Creator's Magnetic Light[14] *universe of Mind-energy*[15] *and the potential of the electrically pressured universe to create cycles of two-way motion.*"[16]

"*The sexless Father-Mother Creator is One. His extended sex-conditioned, male and female bodies are the completion of His Trinity.*

"*Rest and action are three. Space and matter are three. Equilibrium and motion are three. Dimensions and pressures are three. The heartbeat of the universe, and yours, are three. Likewise, its breathings and yours, its temperatures and yours, and all things else of the universe, and you, are three.*"[17]

"*To account for this unnatural phenomena The Coulomb Law was adopted, which says that opposites attract, meaning oppositely sexed mates and likes repel, meaning similarly sexed pairs. This law is invalid, for oppositely sexed mates do not attract. They are forced into collision by the electric action of dividing Oneness into unit pairs. The instant that they do collide they use their utmost endeavors to re-attain the sex-divided condition by re-charging their discharged condition. Nature helps in this process by assisting to recharge with every heartbeat, every breathing cycle, and the food one eats.*"[18]

"*By turning on the current it will be found that the spot between the two electrodes is of zero potential, and that many lines of radiation extend from that center and cause a moving electric current to spin around the zero fulcrum center where the ring is located. Not only that but an electrode placed in contact with the ring, will convey current away from it. This effect of electric current extending from a still center to convey its power to the ring, and other outside conductive matter, is identical with the mental example quoted in Fig. 48.*

[14][Magnetic Still Light]
[15][Mind Force]
[16]Russell, [Atomic Suicide]?, Chapter 4 - The True Nature of This Mind and Motion Universe
[17]Russell, [Atomic Suicide]?, Chapter 5 - Prelude - The Transformation of Man
[18]Russell, [Atomic Suicide]?, Chapter 8 - The Oneness of Gravity and Magnetism; see also [PoL - Chapter 9]

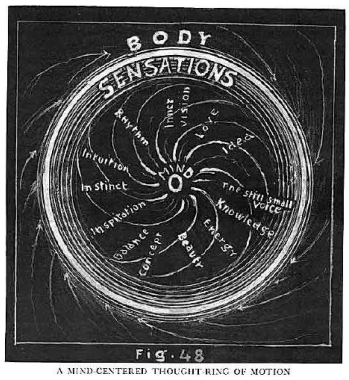

Figure 11.2: Neutral Center 4++ extention to periphery 0
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/ring-of-motion.jpg
(courtesy University of Science and Philosophy)

"*Anyone who may question this fact may not only prove it by this simple experiment but can also move the two electrodes away from the center of the rim so that their centering zero occupies an eccentric position, as the human heart does in relation to the chest, and as the zero center of the heart itself is eccentrically placed in relation to its mass. A different wave pattern will result but the electric qualities will remain the same. There is always a neutral center which centers the birth point of any action. Motion spins around that neutral center, but there is no motion at that center.*"[19]

"*Say also thou to man who thinketh of his heart beat as his own alone - unbound to all things else - that all creating things unfold with the pulse beat of My cyclic thinking. As My thinking is universal, so likewise, is My pulse beat universal.*

"*And furthermore I say that every blade of grass and leaf of oak in mighty forest pulseth with the heart beat of man and all things else, yea even down to microcosmic cells of forming things of earth, and sea, and sky; for even the most minute of these pulse with the electric waves of My cyclic thinking as the mightiest of stars in My heavens likewise pulse.*

"*For I, God of Light, thy Father-Mother God of Love, am the One Whole.*

[19]Russell, [Atomic Suicide]?, Chapter 9 - The Mind Nucleus of the Atom

From Me all unfolding-refolding things extend, and to Me they return for re-extension.

"*All things go from very heart of Me into My imaged universe; and when they disappear from there I also take them back to very heart of Me.*

"*For I am the Soul of art. To him whose Soul would touch My Soul, and feel the heartbeat of its mighty rhythms, I say, in so far as thou knoweth thy Self as Light, thou shalt know Me as Light.*"[20]

"*God has two desires: the desire to unfold His creations to give them form and set them into action; and the other desire is to refold His forms and take them back to Him for rest and resurrection so that they may repeat their action. That is the basis of the entirety of creation - the two desires of God, to act, to create, and to take back for re-creation. That is why God divided everything into pairs of opposites: the desire to express action, the desire to separate from Oneness, God's Oneness desiring to be manifested as many ones - the idea of separation and action; and the desire for return to rest from which that action sprang for the purpose of repeating the action in cycles, countless millions of cycles of action and rest, in-breathing, out-breathing; the pulse beat of the universe; the heartbeat of all things pulsing in all things to manifest life in action and reaction from the stillness of God's One Light in which there is no action and reaction.*"[21]

"*God's universe is entirely composed of microcosmic and macro-cosmic masses of pulsing electric waves, which we call matter. These pulsing waves constitute the universal heartbeat, or universal breath of God's body. God's body continues its manifestation of the life principle by breathing outward and inward sequentially, just as you breathe out and in in balanced sequences to continue your appearance of existence.*

"*Every mass in the universe breathes out and in, rhythmically. There are no exceptions to this law which every nebula, sun, planet or electron of an atom obeys, but in varying frequencies appropriate to their potential. Your breath frequency may be ten cycles per minute while the sun's frequency is*

[20]Russell, [The Message of the Divine Iliad]
[21]Russell, Fifth Kingdom, The Beginning of Man

one cycle in eleven years.

"*The most obvious fact of Nature is its repetition in reverse of every effect of motion in two-way pulsing cycles. It is unaccountably strange that science has never observed this most obvious of all of Nature's characteristics. Every cycle in Nature is a two-way, equal interchange between pairs of opposite conditions. That interchange between the equally balanced anodes and cathodes of this electric wave universe constitute its pulsing heartbeat, which likewise is cyclic, otherwise it would not continue.*"[22]

"*The test for ascertaining the average number of those who are ready for this higher step upward in the unfolding of the man-idea is not a religious one, it is a cultural one. In New York City, for example, about 7,000 people out of 8,000,000 people love the higher inspirational rhythmic creations of the world's great geniuses who interpret the heartbeat of Nature for the Souls of men. These same few shun noisy crowds, shudder at Jazz music, which distresses them acutely, in order to seek aloneness in the forests or oceans shores where they can hear Nature's silent whisperings and rhythmic sounds within their very Souls.*"[23]

"*There is an indescribable glory all along the road which leads from your active thinking to the stillness of deep meditation. If you cannot actually go to the forest or sea, the better to commune with God, go there in your imagination. If some problem demands your thoughts let the imagined tones of the sea drown them out. If you imagine the sea and hear the rhythms of its waves pounding upon the shores as echoes of the heartbeat of the universe resounding within you, or if you hear the breezes whispering in the pines with your inner ears, the glory of that ecstasy will soon drown out dross thoughts of earth.*

"*Earth music is melodic and chains you to earth. The music of the spheres which you hear with inner ears, is deeply tonal, not melodic. The rhythms and tones of Nature's music which sing its octaves in the language of Light have always within them the pulsing rhythms of the universal heartbeat, always the one-two, one-two pulsing of the Father-Mother heartbeat of borning-reborning forms of things, which manifest the Father-Mother pulsing rhythms*

[22]Russell, [Home Study Course], Unit One - Prelude
[23]Russell, [Home Study Course], Unit One - Lesson 1.1

of the Soul's high heavens.

"*Always in your deep meditation the music of the silences from which sounds of earth spring is like unto the aftermath of the great symphonies by cosmic masters, which have refolded from sounds of earth which your ears have heard, into your very Soul, which still hears them in the pulse-beat of your imagining.*"[24]

"*And as love is rhythmically repeated in its givings and regivings to synchronize with the givings of your outward breath to the heavens and their regivings to you, and as such balanced rhythmic interchange between your heartbeat pulsings and all other electric extensions from the stillness of your Soul is LAW - the basic fundamental LAW of all creating things in all this electric universe - your own masterpiece is the measure of how divinely you have conceived it and how worthily you have rendered it in balance with Universal Law.*

"*To the extent that you can extend the beauty of your imagined rhythms to material bodies built in the images of your spiritual conceptions those rhythms which you create are masterpieces of great art. The very measure of the quality of your material interpretation lies in your ability to translate imagined forms and rhythms of the universal heartbeat into bodily forms and rhythms which can reinspire others with the ecstasy of your inspiration.*"[25]

"*Your transcendent genius is the result of your communion with God. By your masterly interpretation of the rhythmic heartbeat of His thinking you have caused others to commune with you and God. Your meditation and theirs are one. You have made them to forget their sensed bodies and dwell in the Mind kingdom of your high heavens with you and all illumined Souls who dwell in God's kingdom of Light.*"[26]

"*Imagine yourself communing with God indirectly, such as listening to the heavenly rhythms of God's heartbeat in a masterly symphony. While thus enraptured by the divine rhythms reaching your very Soul can you possibly*

[24]Russell, [Home Study Course], Unit One - Lesson 1.2
[25]Russell, [Home Study Course], Unit One - Lesson 2.1
[26]Russell, [Home Study Course], Unit One - Lesson 2.2

imagine yourself thinking evil, or thinking sinfully by planning to cheat, or lie, or steal? No - of course you cannot. The reason you cannot is because you are reflecting the love nature of the universe in your spiritual Self in its entirety, and there is no sin in that love nature to reflect."[27]

"*The entirety of Creation is the manifestation of love. Every effect of motion in nature is a manifestation of the nature of God, for Nature gives of its all in every action and regives equally in every reaction. If that were not so the movements of the planets would not be predictable.*

"*The electric heartbeat of Nature expresses love in both halves of each cycle of the universal heartbeat. Nature never takes for God never takes. Nature never gives unequally for God never gives unequally.*

"*God's equally balanced giving for regiving is never violated in Nature. It could not be violated for Nature is an extension of God's nature. For this reason the balance of Nature can never be upset.*

"*You can KNOW music and THINK it without having acquired the technique of expressing it, or without producing sounds to give it a body. Your inner ears can hear the music in the silence of God's eternal rhythms, and you can interpret your moods into the rhythms of the universal heartbeat, as Beethoven interpreted the mood of the moonlight into the rhythms of it without having any teacher but his God-Self.*

"*Consider the life of any great musical genius. What he finally produces in a written composition first begins in his Soul. He must first find aloneness with his Self by getting away from all other people, and even from his own body awareness. He must suppress all outer influences to seek that stillness from within from which the inner ears of his Soul can hear the rhythms of the universal heartbeat of God's creative thinking.*

"*To find that stillness in the Light of knowing he must stop thinking, in order that he can conceive idea from the Light of all-knowing. From the ecstasy of that stillness the inspiration is born in his very Soul. The motive for his symphony gradually takes form through the heartbeat of his thinking*

[27] Russell, [Home Study Course], Unit One - Lesson 3.1

which he extends from the stillness of his Soul, then ceases to extend it to again find the stillness of the Light which is gradually giving him his motive by its inspiring illumining within him."[28]

"*SECOND. Your desire is written upon your heart. It is registered in your Soul. It is no longer your body desire, it is your Soul's desire. You are in communion with God about it - not in words but in Light. You have an increasing sense of joyousness. Your desire is written into the universal heartbeat rhythmically. You are responding to it rhythmically. You are no longer just body - you are Soul - slightly aware of body - slightly aware of earth, and the heavens above, and of creating things. You are not thinking of extraneous things. You cannot think of objective things of earth while in the Spirit.*"[29]

"*The key to that answer is that God's universe is founded upon balance - one balanced condition which He divides into two equal and opposite conditions of His electric thinking. This electric universe of matter is composed entirely of these two equal and opposite conditions.*

"*Every effort of every creating thing is expressed by the motion of interchange between those pairs of opposite conditions, such as matter and space which constantly interchange equally by breathing into and out of each other equally. Without that equality of rhythmically repeated interchange the universe could not continue. That rhythmic interchange constitutes the heartbeat of God's body. Its rhythm and balance are absolute because the division of God's electric thinking is equally balanced.*"[30]

"*Meditation transports one from the transient world of matter to the real world of dreamings, visions, and imaginings where idea is and concepts are born. That is the world where sounds are heard in the silence of your Soul where no sound is where rhythms of symphony and poem are the rhythms of cosmic pulsings of God's thinking manifested in the heartbeat of His universe.*"[31]

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[28]Russell, [Home Study Course], Unit One - Lesson 3.2
[29]Russell, [Home Study Course], Unit One - Lesson 4.1
[30]Russell, [Home Study Course], Unit One - Lesson 4.2
[31]Russell, [Home Study Course], Unit One - Lesson 4.4

"*When you pray for God to show His love for you by giving your field good crops you must yourself give your love to your fields to regive His giving. Your love given to them is God's love given to you for regiving. Your love and God's love are ONE. Its manifestation is TWO in giving and regiving but that TWO is the ONE HEARTBEAT of God's body, even as the swinging of the pendulum is the TWO of the ONE source of their manifestation.*

"*He who knows the Light of love in him does not beseech the Father-Mother of the universe for his next breath, nor for his next heartbeat, for he fully knows that his heartbeat is one with the universal pulse, and that for which he would needlessly ask is already his.*

"*And as there is not a time when God centers you, and an interval elapses in which He again centers and controls your balanced heartbeat to synchronize with His, so is there not a time when you should pray to Him, and another time when you should not.*"[32]

"*The love born symphony is prayer for love fulfilled in the composer and again fulfilled in the hearts of those whose heartbeat feels the ecstasy of God's heartbeat as expressed in those heavenly rhythms.*"[33]

"*I instantly, and timelessly, knew the still magnetic Light which is the fulcrum of life and power, also I knew the heartbeat of the electric universe which manifests love, life and power in matter.*

"*I also instantly and timelessly knew that the magnetic Light of the God of love was all that is - and that the sensed electric wave universe of motion which simulates love, life and power, had no reality whatsoever. I knew it for what it was - God's thinking - God's imagining - pure illusion - simulation - self-voiding forms thrown on the screen of space to manifest changeless idea by setting it in motion to produce the effect of change.*

"*Thus knowing the universal heartbeat I knew the electric wave, or universal pulse, to which all moving, creating things were geared. Thus knowing the wave and its octave pulse beat in cyclic rhythms which spelled their rhythms*

[32]Russell, [Home Study Course], Unit One - Lesson 6.1
[33]Russell, [Home Study Course], Unit One - Lesson 6.2

out for me always as

+zero +one +two +three +four +zero- -four -three -two -one -zero

I then knew all cause and comprehended all effect.

"*There was nothing to know but God's one whole idea of Creation, which is represented in the following diagram by the changeless ZERO of the spiritual Mind universe of REST - and nothing to comprehend but the heartbeat of this pulsing electric wave universe of motion which is represented in the diagram by the NUMBERS.*

THE HEARTBEAT OF THE UNIVERSE	
POSITIVE	NEGATIVE
0 1 2 3 4 0	4 3 2 1 0
GENERATION ENERGY TOWARD LIFE AND GROWTH	DISINTEGRATION ENERGY TOWARD DECAY AND DEATH

Figure 11.3: The basic formula of Creation
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/positive-negative-scale.jpg
(courtesy University of Science and Philosophy)

"*This diagram is given to you now as the first simple step toward your acquisition of all knowledge of CAUSE and all comprehension of EFFECT. During the whole construction of this electric universe in this entire course of study the basic principle above diagramed will never be departed from, or exceeded, for there is nothing in Nature, nor in your own life, nor in your thinking, nor in any action of yours which can vary one whit from this basic formula of Creation.*

"*Nor is there anything the chemist, physicist, metallurgist or engineer can exceed beyond this formula or vary it in their work. Likewise the poet, painter, inventor, musician or architect is limited to this simplicity beyond which he CANNOT GO, and to which HE MUST CONFORM.*

"*Likewise the healthy growth of your body, or the conduct of your friendly or business relations must conform to this principle of BALANCE or else suffer the consequence of whatever unbalanced residue remains from lack of conformity with the heartbeat of the universe.*"

"*The reason why I have been able to do so many things during life, and do them in a masterly manner, was because of my lifetime growing knowledge of the universal heartbeat which fully unfolded in one timeless flash in 1921.*

"*It may not suddenly unfold to you, as it did to me, but you can very greatly accelerate its unfolding if you will open your heart to these lessons and get what I am telling you into your Consciousness instead of just photographing them into your brain.*"[34]

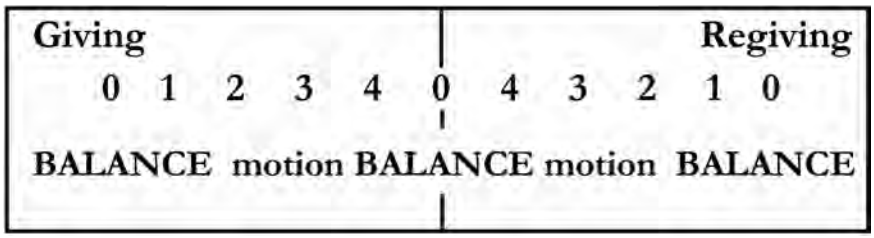

Figure 11.4: Formula of Rhythmic Balanced Interchange
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/giving-regiving.jpg
(courtesy University of Science and Philosophy)

"*As you see I have again used the same formula of rhythmic balanced interchange in all transactions of Nature. I have but used different words to express different ideas.*"[35]

[34]Russell, [Home Study Course], Unit One - Lesson 7.3
[35]Russell, [Home Study Course], Unit One - Lesson 7.4

Chapter 12

Vortices and Toroids

12.1 Vortices

Vortices combine their many complex motions to create compound vortices or toroids composed of several parts and dynamics. In other words a toroid of rotating motion is the effect of vortex dynamics. These dynamics are the combined effects of differential densities[1], temperatures, pressures and tensions. These interactions between differences in density, potential, pressure, temperature and mass are the cause of motion which is the system attempting to regain balance in all its parts. These dynamic systems are in turn governed by simple laws as are discussed in this book. The forces creating vortices are the same forces creating vibration and oscillation but with different parameters.

[1] [differential densities], [2.7 - Differential Densities], [16.13 - Differential Densities], [3.6 - Differential Densities Begin to Form]

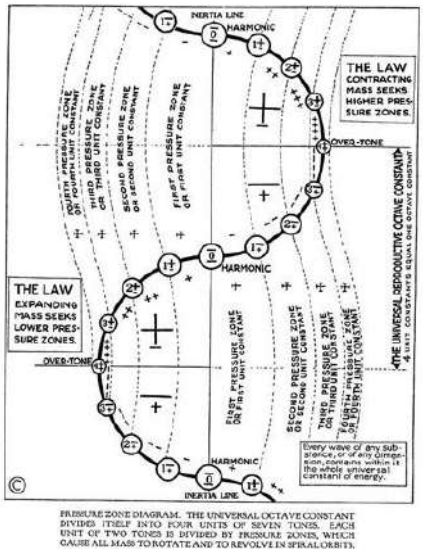

PRESSURE ZONE DIAGRAM. THE UNIVERSAL OCTAVE CONSTANT DIVIDES ITSELF INTO FOUR UNITS OF SEVEN TONES. EACH UNIT OF TWO TONES IS DIVIDED BY PRESSURE ZONES, WHICH CAUSE ALL MASS TO ROTATE AND TO REVOLVE IN SPIRAL ORBITS.

Figure 12.1: Differential densities, pressures and masses
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/differentials.jpg
(courtesy University of Science and Philosophy)

In examining the dynamics of a vortex it is obvious there are many subtle polar dynamics converging to create a typical vortex such as are witnessed in a tornado or hurricane. These polar striations[2] (flows of differing energy states) would include differences in pressure[3], mass, potential, velocities and tensions caused by the differences of these states.

"*...vortex action (is) induced by differential conflict between the low and high tensions...*"[4]

"All such experiments invariably resulted in vortex motion, whether induced sympathetically or otherwise. All corpuscular action in Nature is vortex motion. The undulatory theory[5] *of light is only hypothetical. The conditions of*

[2][striations], [stria]
[3][Figure 3.6.1 - Tornadoes also have a Down Draft caused by its vacuous center], [Figure 3.6 - Tornado Vacuums up Everything for Redistribution]
[4]Keely, [LIGHT - Snell]
[5]wave theory

electro-magnetic radiation, on the same plane of matter as light, disprove the undulatory theory in many particulars. The vortex action induced by differential conflict between the low and high tensions shows conditions analogous to those in the molecular dissociation of water[6] *into hydrogen and oxygen in other words, vortex action of the highest order but peripheral only. Were it otherwise, the ether could not be held suspended or enclosed in the molecular or atomic envelopes*[7]*."*[8]

Figure 12.2: Tornado Vortex
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/tornado-hf.jpg

12.2 Vortex Components

1. Cone
2. Cone Base (large opening)
3. Cone Apex (Gravity Center, Neutral Center)
4. Syntropic Still Magnetic Light, Gravity or Mind Shaft (hollow center)
5. Etheric Vacuous Center
6. Entropic Rotating Periphery (striated with high and low pressures and tensions)
7. Pressure Striations
8. Entropic Equator 90° to formative forces

[6] [Aqueous Disintegration], [Part 15 - Dissociating Water], [AQUEOUS DISINTEGRATION - Snell], [THEORY AND FORMULA OF AQUEOUS DISINTEGRATION]
[7] [rotating envelope]
[8] [LIGHT - Snell]

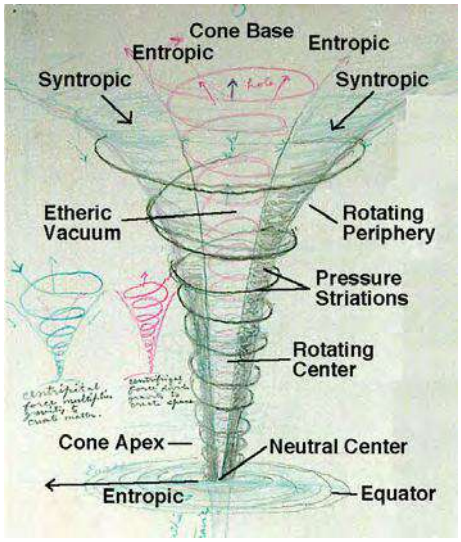

Figure 12.3: Vortex showing a few of its many components
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/vortex-nd.jpg
(courtesy University of Science and Philosophy)

12.3 Vortex Dynamics

Syntropic (Sympathetic) Formative Forces[9] attracting to center.
Entropic (Repellant) Dispersive Forces dispersing from center.
Neutral Center Dynamics (Dominates/controls above two dynamics).

12.4 Vortex Action is rotary

"All such experiments invariably resulted in vortex motion, whether induced sympathetically or otherwise. All corpuscular action in Nature is vortex motion." [Keely]

A vortex rotates on a divided horizontal plane along its extension, length or altitude from the ground to the clouds. The high and low tensions[10] (pressures, temperatures and densities) are in constant conflict seeking balance or

[9] [Figure 4.12 - Keelys Formative Structural Dynamic Morphology]
[10] [antagonism]

voidance through and against each other. This assertive seeking for balance or voidance is the cause of the vortex's violent motions - a sex act if you will allow such term. The base universal state is 'desire for' balance, harmony or equilibrium. Desired because no state of perfect balance can permanently exist. *A system disturbed from this balance of forces will reassert itself in an effort to restore a stable state of balance or harmony (Love or sympathetic association) but such action is like a dog chasing its tail - and never catching it.*

12.5 Vortex Center

A tornado's center is an etheric vacuum having centripetal forces powerful enough to suction asphalt from paved roads[11] or lift cows, people and houses. This central vacuous column has been described as being luminous by those fortunate enough to have seen it and survived to tell about it. Walter Russell referred to this center as the Magnetic Still Light of Mind[12]. It may also be the fabled Luminiferous Ether[13] of the ancients.

"Know thou that God does not extend His Self into his moving universe, for the God-Light is still. Its stillness centers all things and it, likewise, centers the shafts of all motion which turns around it, shafts which are levers of fulcrums and end at poles which measure extensions."[14]

"Electricity (a polar condition) is the divider of the invisible white[15] *still magnetic light of gravity - which Mind is - into the red and blue halves of the visible light spectrum for the purpose of creating male and female bodies (in motion) which alone constitute all matter."*[16]

[11] [Figure 3.6 - Tornado Vacuums up Everything for Redistribution]
[12] [Magnetic Still Light]
[13] [Luminiferous Ether]
[14] [Atomic Suicide]?; Chapter 5 - Prelude - The Transformation of Man, part 2 of 2
[15] In Figure 12.4 the white light is shown as yellow. Hughes in her book "Harmonies of Tones and Colours" considered yellow as the Source from which discord (form) originates and progresses.
[16] Walter Russell, notation on chart, 1955. see [First Cause]

Figure 12.4: The depolar One divides into duality/polarity
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/female-male-color.jpg
(courtesy University of Science and Philosophy)

"The One begat the Two which begat the Three and from the Three all things are made." Lao Tse[17]

The two initial polar states being 1) to separate or be individual and 2) be Unified or One are nothing more than tendencies or desires. Entropy tends in a direction away from the center, under certain circumstances, *in a spiral path.* Syntropy tends to a direction towards the center, under certain circumstances, *in a spiral path.* Interestingly the two opposing states, forces or poles become each other intermittently[18]. Since there are only two states they are initially in seeming perfect equilibrium one against the other. There is no motion or substance with the desire and tendency to direction and motion held latent. In this state of perfect latency on the etheric level there is pure potential waiting to be transformed into motion and matter by introducing idea (desire) or disturbing excitation.[19] But such a static state cannot persist. On the molecular and atomic levels disturbance of this static equilibrium can occur with simple acoustic impulses.

[17]'The Tao te Ching' [http://en.wikiquote.org/wiki/File:8orbitals.jpg]
[18][Law of Assimilation]
[19][2.11 - Beginning as Undifferentiated One]

12.6 Vortex Polar Forces

Russell's reference to - creating male and female bodies - refers to the still magnetic light as dividing itself creating the two seeming polarities - the two seeming opposing forces of entropy and syntropy whose mutual conflict[20] to void or balance results in the motions of the vortex. The two poles' prime objective is to void against/through each other that they may regain the Oneness (balance, harmony or love) from whence they came. These are the dynamics of the Universal Heartbeat, Rhythmic Balanced Interchange or Dynaspheric Force. In the simplest terms *the vortex is comprised of three currents acting as a whole stream or flow* - the same as has been described in Chapter 7 and as shown in Figure 12.5.

Figure 12.5: Triune Forces of a vortex
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/spiral-stria.jpg

12.7 Vortex Periphery

The periphery is molecular rotation governed by centrifugal forces counterbalanced by centripetal forces. In this section of the vortex molecular substances (gases, evacuated debris, *etc.*) *orbit* around the vortex rotating center at high velocities and constitutes the visible form of the vortex.

[20] [antagonsim]

12.8 Vortex Wall

The wall or border condition between the still magnetic light and whirling molecular gases is where centripetal forces (syntropy) are transformed to centrifugal energies (entropy). Obviously this conversion zone is created by a dynamic balance between the inward pulling centripetal or syntropic forces of the vacuous etheric center and the outward flinging centrifugal entropic forces maintained by sufficient velocities.[21]

If we picture three tornadoes rotating at 90° to each other would the combined forces tend enclose themselves to create a sphere much like Keely's description of corpuscles formed via rotating envelopes[22]? Of course they would.

Figure 12.6: Typical idealized torus, toroid or "donut" concept
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/donut-idealized.jpg
(courtesy anonymous web artist)

12.9 Toroid

Idealized toroids are essentially composed of two opposing vortices meeting at their two apices forming a mutual center of neutrality, voidance or transformation. Being resultants of vortex structural components and dynamics they exist by virtue of these defining attributes. Of course, this is a preliminary study and does not include all the myriads of structural and dynamical properties of all the different vortex forms. Please note these dynamics are inherent causative properties and not a mathematical description of phenom-

[21] [Law of Cycles], [Law of Transformation of Forces]
[22] [rotating envelopes]

ena which would be elegant in and of itself[23] yet just a facsimile of what is really taking place.

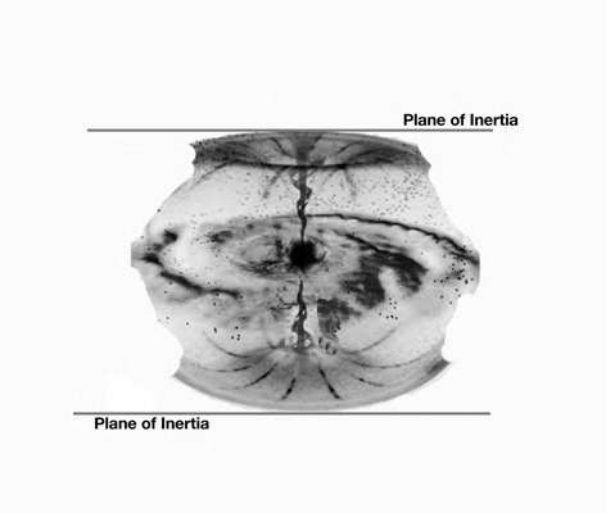

Figure 12.7: Ideally toroids are two vortices meeting apex to apex
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/donut-inverted-mod.jpg

12.9.1 Sympathetic Associative Attraction

The two apices come together by virtue of sympathetic associative attraction or syntropy according to the Law of Harmony. They meet in this fashion at Russell's 4++ wave crest where the Law of Cycles kicks in and the Law of Repulsion assumes preponderance.

[23] for a good example: http://vortexmath.webs.com/

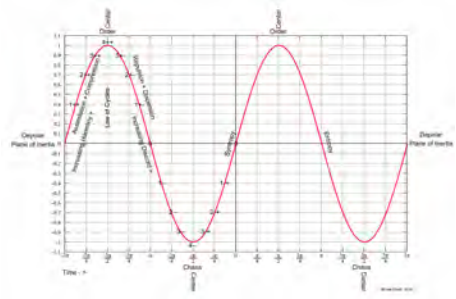

Figure 12.8: Wave elements of Time, Compression and Dispersion
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/sine-indig-wave1.jpg

Figure 12.8 shows an idealized structure of a wave being a sine wave. Some of the functional elements are included for identification purposes. In reality the left upward moving slope is syntropic (Law of Harmony) and will usually be a longer time interval than from upper Center to lower Center (Law of Repulsion) which time may be greatly reduced. This is the time interval when compression (harmony) reverts to dispersion (repulsion) according to the Law of Cycles and may be of negligible duration. Hence the overall sine wave form will become a sawtooth wave as harmonics are generated and synthesized into the wave form according to the same law. An excellent animation of this process can be found on Wikipedia/Sawtooth_wave here:

http://en.wikipedia.org/wiki/Sawtooth_wavemediaviewer/File:Synthesis_sawtooth.gif

12.9.2 Law of Cycle

This sympathetic associative attraction increases until the conditions for the Law of Cycles to assume dominance at which point the sympathetic associative attraction reverts to anti-sympathetic mutually repellant discords[24] of increasing amplitudes. These discords will increase until their power of repulsion exceeds the power of attraction at which point the associating forces become repellant and the center discharges at 90° to the formative sympathetic associative forces. Thus forming the expanding energies outward through the equator. Russell proposed a four step compression to the 4++

[24]By formation of secondary and tertiary pitches not harmonic with the fundamental.

point of transformation discussed in previous chapters[25].

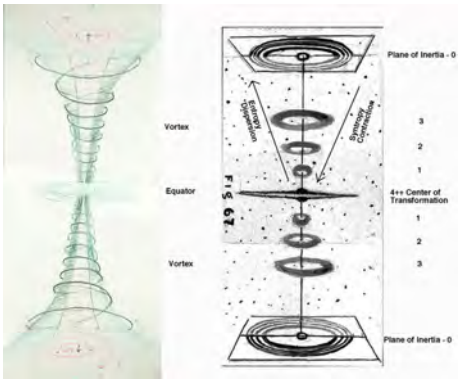

Figure 12.9: Compression to center then equatorial dispersion
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/vortex-side-by-side-sm.jpg
(courtesy University of Science and Philosophy)

12.9.3 Neutral Center Repulsion

The now highly anti-sympathetic (enharmonic) centralized bipolar center goes 'critical' so to speak when the participant substances mutually repel each and all other participant substances as they override the harmonic syntropic forces of attraction and compression. The mutual repulsion occurs 90° to the sympathetic associative forces outwards towards and through the equatorial plane.

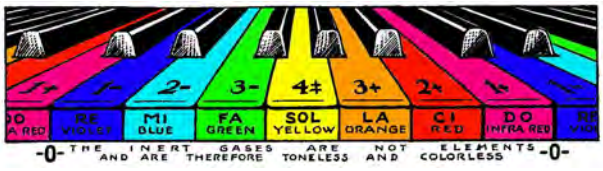

Figure 12.10: 4++ at center of transformation
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/4plusplus.jpeg
(courtesy University of Science and Philosophy)

[25]Figure 10.3: Scale of 0 to 4 to 0

12.9.4 Periphery Neutralization or Depolarization

As these substances move away from the center and nearing the end of influence of sympathetic outreach they begin losing their polar condition or state until such point as they become again depolarized or neutralized. The center represents Russell's 4++ state. The polar substances becoming depolar at the 0th state of Russell's Scale of Locked Potentials.[26] Beginning at the vortex center with 4++ maximum polarization expanding outward (dispersing according to the Square Law) gradually losing polarization until all polarization is lost (depolarization) at the 0th state of Russells Scale of Locked Potentials which he defines as the Cube Wall of Neutrality, Plane of Inertia or the limit of Keely's sympathetic outreach[27]. At this Plane of Inertia a reversion takes place where the depolar state becomes polarized and begins the journey back to the 4++ state or condition.

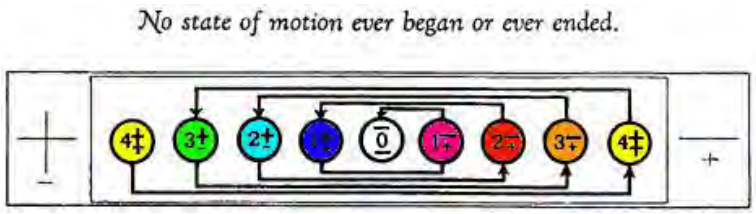

Figure 12.11: Depolar state at plane of inertia
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/0-inertia.jpeg
(courtesy University of Science and Philosophy)

12.10 Plane of Inertia

We can see from photographs of hurricanes the tops are generally flat. These flat tops appear to coincide with Russell's plane of inertia which coincides with the wall of his cube structures. Physically this is a zone where there is no polarity or is depolar. This extending downward as polarity increases to where the maximum (4++) zone is reached at or near the surface of the earth where most polarity occurs and hence the most violent action or motion.

[26] [12.01 - Scale of Locked Potentials]
[27] [sympathetic outreach]

12.11 Free Space

With hurricanes and tornados the plane of inertia is in higher altitudes if not space itself and the vertex at the surface of the earth are mostly molecular structures and are bound by gravity and other terrestrial dynamics. In the case of free forming quantum entities these bounds do not exist as these formations form in etheric space or vacuum. According to Keely and Russell there are two vortices per axis coming together at their mutually attractive centers or vortices making six in number. Do all six have the exact same wave function? No, else they would all be exactly the same which is an impossibility.

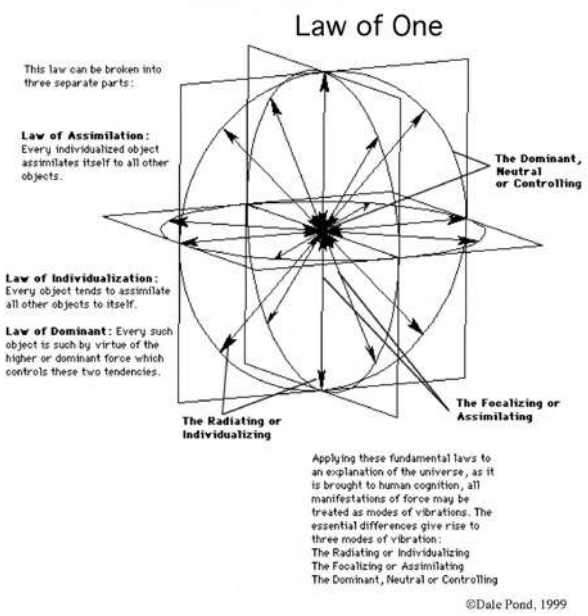

Figure 12.12: Triune polar forces as One Force about a common center
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/triune-modes-motion.jpg

Following the logic of Russell's cosmogony there are virtual 'cubes' in Free Space having six sides. These six sides are the planes of inertia or depolarization. These correspond to Keely's juxtapositioning of atomolic centers of mutual attraction which would be an alignment with the X, Y and Z vectors each forming their own respective virtual cubes as these would align

with the planes of said virtual cubes. Therefore there would be three of these double vortices forming along these vectors, each 90° to the others. Each would possess its own center line of mutual attraction. At the compound center there would therefore be three atomolic (etheric) centers of mutual attraction and six vortices.

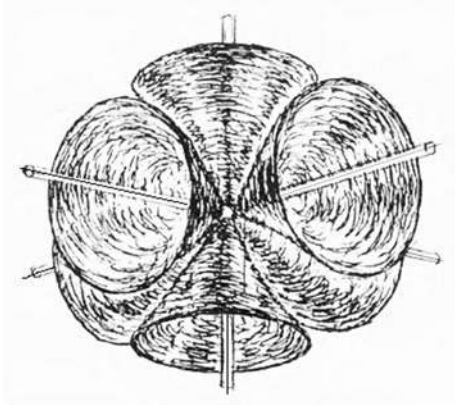

Figure 12.13: Three double vortices
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/3d-vortices.jpeg
(courtesy anonymous web artist)

According to Keely these atomolic centers bear the burden of all structure and motion it controls. Consequently each of the three centers is autonomous and independent of the other two though the three mutually interact to some degree and manner yet to be determined as they mutually occupy the same coordinates at the center of the structure.

Therefore a quantum or etheric torus would have three orthogonal axes each with two mutually attracted vortices. This compound torus would in structure be a compound spheroid with a surface of complex motions or encapsulated rotating envelops[28] so long as their three centers are coincident.[29]

[28] [rotating envelope]

[29] [Etheric Capsule], [AFFINITY OF ETHERIC CAPSULES], [DISINTEGRATION OF ETHERIC CAPSULE], [ROTATION OF THE ETHERIC CAPSULE], [MEASURING THE VELOCITY OF THE ETHERIC CAPSULE]

12.12 Etheric Envelopes

Here is one of the concepts where Keely and Russell diverge in their theories. Russell has the three planes and six vortices. Keely has the three planes as axis where the etheric substance rotates at 90° to the axis resulting in an envelope or shell spinning at tremendous velocities establishing the circumference of the centralization[30]. This results in three envelopes or shells spinning at 90° to each other thus forming the entirety of the corpuscle. Each shell acts together geometrically to fully enclose the corpuscle as they seal each others' non-rotating poles.

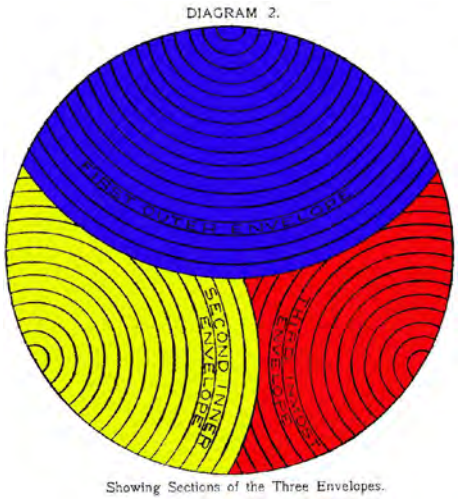

Figure 12.14: Keely's three envelopes or shells
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/envelopes.jpg

[30] [Figure 7.3 - Step 3 - Sphere Forms Orthogonally Triple Compressing Shell Layers]

Figure 12.15: Three overlapping envelopes or shells sealing poles
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/sealedpoles.jpg

This configuration[31] is fundamentally important to Keely's work with splitting the atom or molecule releasing its latent forces bound within. He said the ether (quantum substances) when given sufficient velocity will rotate and centripetally seek its controlling neutral center. The greater the velocity the greater the syntropic force the greater the compression inward and greater the contained latent energy to be liberated. He did this by manipulating these envelopes or shells rupturing them whether instantly or gradually.[32][33][34]

It is not the purpose of this book to go into the details of how Keely manipulated these molecular and atomic envelopes (splitting the atom) to produce his etheric vapor and other forces and quantum substances. To do so would require a doubling or more of its volume (and time to write) and it is already near too much to digest. Perhaps a subsequent volume would be appropriate covering his dissociation and disintegration processes[35] with water and other

[31][Figure 4.12 - Keelys Formative Structural Dynamic Morphology]
[32][15.18 - Keelys Process for Liberating Ether from Water]
[33][Vibratory Physics - True Science]
[34][Etheric Vapor]
[35][Aqueous Disintegration], [THEORY AND FORMULA OF AQUEOUS DISINTEGRATION], [DISINTEGRATION OF ETHERIC CAPSULE], [Disintegration], [Dissoci-

elements.

ation], [DISINTEGRATION OF MATTER - THREE SYSTEMS]

Chapter 13

Electricity and Magnetism

13.1 Electricity is a Polar State Dipole

Contrary to popular belief the common generator of electricity flow or current does not generate electrons then pushes them along a conductor. The generator creates a polarity, potential, dipole or bias between the positive electricity and negative electricity streams where prior to this condition of separation neither pole seemed to exist. This creation of this bias or potential is in fact a differentiation or splitting into three flows of an undifferentiated compound triune flow.

"I believe electricity to be a substance, not a force."[1]

"Electricity is the result of three differentiated sympathetic flows, brought together by combining the celestial flow with the terrestrial flow through a certain degree of "negative attractive assimilation". Electricity is one of Nature's efforts toward restoring "attractive differentiation" for it has the highest degree of assimilative affinity."[2]

13.1.1 Voiding the Dipole or Polarity

Once the two (dipole) electric streams are created, thus creating a potential, they have a natural tendency to re-emerge or assimilate each other through

[1] Keely quoted in [Pittsburg Dispatch April 07-1890]
[2] [Keely in SYMPATHETIC STREAMS - Snell]

voiding as Russell calls it and neutralization or depolarization as Keely calls it. This voiding, neutralization or depolarization is accomplished by providing a conductor and a place or load where the separated streams can and will recombine, re-emerge, unite, assimilate or void the created polarity, dipole or bias - returning back to their natural undifferentiated state. Heat, light and rotation are produced at the point of voiding, neutralization or depolarization by the interaction (antagonism) of these streams against each other.

13.1.2 Conduction

The conduction of the electric current along a conductor is governed by Keely's Law of Electric Conductivity.

13.1.3 Polar and Depolar States

An electric dipole is mutually attractive and will do everything possible to neutralize itself.

A magnetic dipole is mutually repulsive and will retain its polar state.

The difference between these two states of attraction and repulsion is explained in Keely's Law of Attraction and Law of Repulsion - governed by or as explained in the Laws of Being. See also [Bjerknes Effect]

13.2 Keely on Electricity

Should we bring our understanding from previous chapters to bear upon electricity and magnetism a paradigm forms somewhat different than the standard model but which appears to make sense and evidently works as Keely produced electricity from etheric space (vacuum) in 1893.[3]

"Nikola Tesla, for reasons that need not be explained, would not have been able to serve on the committee. It is well known that he is striving to draw power from space by purely scientific methods, which Keely succeeded in doing

[3][Dogmatism of Science], [Keely - Electricity from Space], [Newton of the Mind], [Free Energy], [The Operation of the Vibratory Circuit]

in 1893 by "unscientific methods."[4]

"Electricity is the result of three differentiated sympathetic flows, combining the celestial and terrestrial flows by an order of assimilation negatively attractive in its character. It is one of Nature's efforts to restore attractive differentiation. In analyzing this triple union in its vibratory philosophy, I find the highest order of perfection in this assimilative action of Nature. The whole condition is atomic, and is the introductory one which has an affinity for terrestrial centres, uniting magnetically with the Polar stream; in other words, uniting with the Polar stream by neutral affinity. The magnetic or electric forces of the earth are thus kept in stable equilibrium by this triune force, and the chords of this force may be expressed as 1st, the dominant, 2nd, the harmonic, and 3rd, the enharmonic. The value of each is, one to the other, in the rates of figures, true thirds. E flat - transmissive chord or dominant; A flat - harmonic; A double flat - enharmonic. The unition of the two prime thirds is so rapid, when the negative and the positive conditions reach a certain range of vibratory motion, as to be compared to an explosion. During this action the positive electric stream is liberated and immediately seeks its neutral terrestrial centre, or centre of highest attraction."

[4]Bloomfield-Moore in [Dogmatism of Science], [Keely - Electricity from Space]

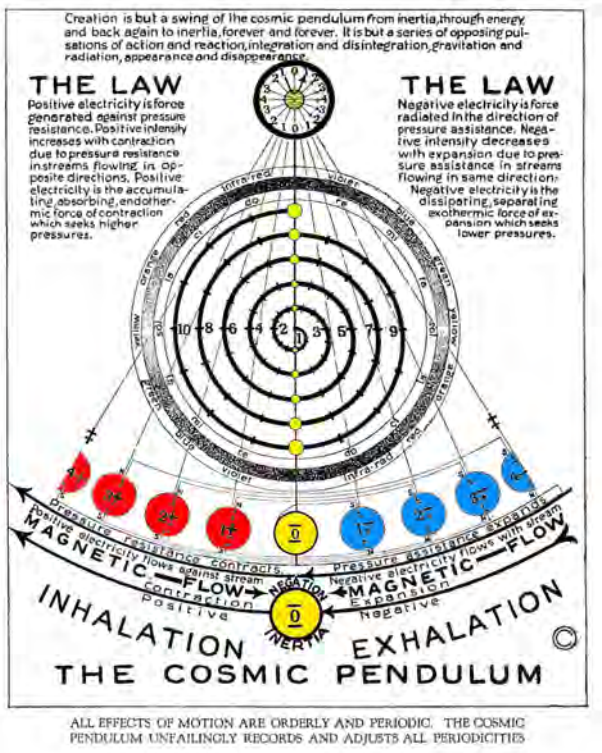

Figure 13.1: Neutral Center governing seeming opposite potential states
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/cosmic-penduluum.jpg
(courtesy University of Science and Philosophy)

"The power of attractive vibration of the solar forces is the great coincident towards which the terrestrial magnetic sympathetic flow is diverted. This force is the celestial current that makes up the prime third of the triple association. It also induces aqueous disintegration[5] *and thermal concentration, the two prime conductors towards this coincident chord of sympathy with itself. Without this aqueous disintegration there would be no connective link*[6] *between the celestial and terrestrial. There would exist nothing but a condition of luminous radiation on the order of the aurora - a reaching out for the concordant without any sympathetic diversion to create unstable equilibrium of terrestrial magnetism. In fact under such a condition, the absence*

[5] [aqueous disintegration]
[6] [connective link]

of the sun on one side, or the absence of water on the other, the magnetic or electric force would remain in a stable state of equilibrium, or the highest order of the chaotic. Disturbance of equilibrium[7] *and sympathetic equation*[8] *constitute the dual power that governs all the varied forms of life and motion which exist terrestrially, of which the electric or magnetic is the prime mover and regulator. All electrical action, no matter of what character, has its sympathetic birth by the intervention of that current of the triune flow, which I call the dominant, with the polar harmonic current; all sympathetic flows being composed of three currents. They become associative one with the other only near the junction of terrestrial interference. The great vacuous field which exists between the planetary ranges holds this portion of the etheric flow free of all antagonism*[9]*, molecularly or otherwise, till the associative point is reached; so wonderfully planned by the Great Creator, for instant electric evolution and assimilation with terrestrial centres of attraction. I call this intervention, atomic intermolecular and molecular density. The combination of the action of the triune sympathetic celestial stream with the same intervening medium induces heat and light as the resultant of these corpuscular confliction with sympathetic celestial and terrestrial focalized centres of neutral radiation. I do not recognize electricity, nor light, nor heat as coming from the sun. These conditions, according to my theories, emanate from atomic and interatomic interference on induced molecular vibration, by sympathetic etheric vibration, the celestial attractive being the prime mover. In my estimation this is not at all phenomenal; it is only phenomenal as far as the knowledge of its action in mechanical physics is concerned. Physicists have been working in the wrong direction to lead them to associate themselves with Nature's sympathetic evolution. The expression "Electricity attracts at a distance" is as bad as, if not worse than, the "microbe of the magnet." Clerk Maxwell seems, when theorizing on sound transmission by an atmospheric medium, not to have taken into consideration the philosophy attending the phenomena of the origination of electric streams in celestial space. Light is one of the prominent evolved mediums in electric action, and is evolved by corpuscular bombardment*[10] *induced by sympathetic streams acting between the neutral centres of planetary masses, all of which are under a condition of unstable equilibrium. These unstable condition were born in them, and were*

[7] [Disturbance of equilibrium]
[8] [sympathetic equation]
[9] [antagonism]
[10] [INTERATOMIC BOMBARDMENT], [bombardment]

thus designed by the Architect of Creation in order to perpetuate the connective link between the dispersing positive and the attractive negative. The action that induces this link I call sympathetic planetary oscillation.[11]

"Light is induced by electromagnetic percussion emanating from the ether, and in its action represents the plane of magnetism. In fact, it is the plane of magnetism when under polarization. (Platina wires the thickness of a fine hair associated with each of the nine nodal beads, and concentrated towards a general center of focalization, attaching the other end of the wires to the focal center, will determine, by the magnetic conduction, the number of corpuscular oscillations per second induced by a thought, either positive or negative, in the central centers. These are the only conditions - those of magnetic conduction - whereby the evolution of a thought can be computed in regard to its force under propagation, as against the amount of latent energy set free to act as induced by such thought on the physical organism.) Some scientific theories of the past have taught us that electricity and magnetism are one and the same thing. Sympathetic vibratory philosophy teaches that they are two distinct forces of one of the triune sympathetic family."[12] (underline added)

"Maxwell's theory[13] *is correct that the plane of polarized light is the plane of magnetic force. The sympathetic vibrations associated with polarized light constitute the pure coincident of the plane of magnetism. Therefore, they both tend to the same path, for both are interatomic, assimilating sympathetically in a given time, to continue the race together, although one precedes the other at the time of experimental evolution. The time is approaching when electromagnetic waves with an outreach of two feet will be produced, having an energy equal to that now shown up on the magnet when it is about to kiss its keeper, and showing a radiating force too stupendous for actual measurement."*[14]

"Professor Fitzgerald's[15] *lecture on electromagnetic radiation shows that sci-*

[11][Vibratory Physics - The Connecting Link between Mind and Matter]
[12]Snell, [Snell Manuscript]
[13][Maxwell Equations]
[14][Snell], [Snell Manuscript]
[15][Professor George Francis Fitzgerald, Irish professor 1851-1901, specializing in electromagnetic theory and physics.]

entific men are beginning to realize and that fairly, the truths appertaining to the new philosophy. The professor admits that electricity and magnetism are of differential character and he is right. The progressive subdivision, induced by molecules by different orders of sympathetic vibration, and the resultant conditions evolved on the intermolecule[16] *and interatom*[17]*, by introductory etheric dispersion, prove that the magnetic flow of itself is a triple one, as is also the electric."*[18]

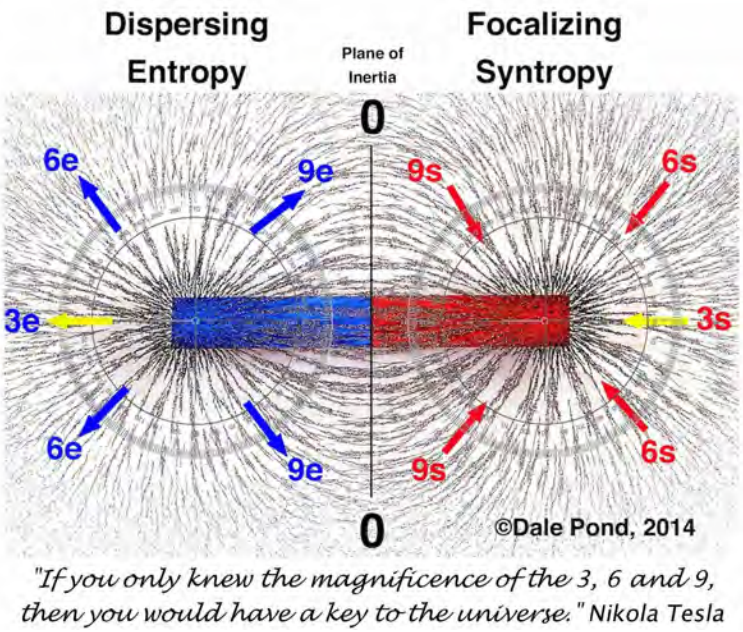

Figure 13.2: Triune Forces of Magnetic Field in Magnet
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/Forces.jpg

Keely says the iron of the magnet has no magnetism of itself. The iron atoms of the magnet diverts a portion of the terrestrial streams. In the above image this diversion is clearly shown where the streams come into the South pole and exit via the North pole. Also shown are the two modes of Syntropy (s), Entropy (e) as also the 3, 6 and 9 modes. His explanation is:

[16] [intermolecule]
[17] [interatom]
[18] [Snell], [Snell Manuscript]

"The explanation of the magnetic flow is very simple. The harmonic attractive chord, thirds, induces nodal interference on the harmonic current in the earth's polar stream, and it moves toward the negative pole to flow out through the positive end. The diversion of the harmonic portion of the stream from the dominant portion causes the magnet to assume its position."[19]

"Again, the professor says that electricity and magnetism would be essentially interchangeable if such a thing existed as magnetic conduction, adding: "It is in this difference that we must look for the difference between electricity and magnetism." Thus you see how plain it is that progressive scientists are approaching true science. The rotation of the magnetic needle[20]*, as produced in my researching experiments, proves conclusively that the interchange spoken of, in Professor Fitzgerald's lecture, is a differentiated vibratory one, in which the dominant and enharmonic forces exchange compliments with each other, in a differential way, thus inducing rotation, in other words polarization and depolarization."*[21]

"In electric lighting, the velocity of the dynamos accumulates only the harmonic current - by atomic and interatomic conflict - transferring one-two hundred thousandth (1/200,000) of the light that the dominant current would give, if it were possible to construct a device whereby it could be concentrated and dispersed."[22]

13.3 Russell on Electricity

"Electricity is the servant of the God-Mind. Electricity expresses the desire in the God-Mind for creative expression by seemingly dividing the One still light into transient waves of spectrum divided positive-negative colors of light."[23]

"Electricity is the motivative force which projects the One Light of Mind two ways to create cycles of light waves for the purpose of expressing thought

[19][POLARIZATION AND DEPOLARIZATION]
[20][4.2.5 - Rotation of Compass Needle], [DISTURBANCE OF MAGNETIC NEEDLE]
[21][Snell], [Snell Manuscript]
[22][Snell], [Snell Manuscript]
[23]Russell, [The Secret of Light], page 50

cycles."[24] (underline added)

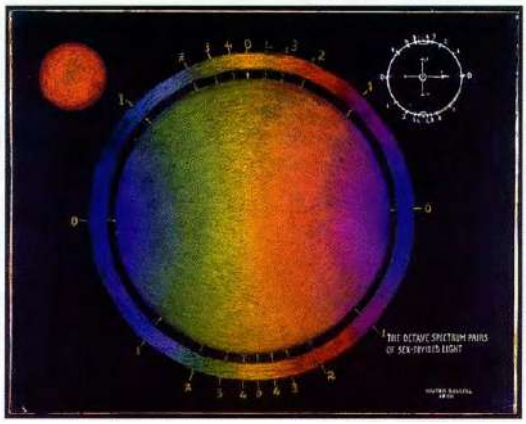

Figure 13.3: White Light of Mind divided into red and blue halves
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/red-blue.jpg
(courtesy University of Science and Philosophy)

"Electricity is the divider of the invisible white still magnetic light of gravity - which Mind is - into the red and blue halves[25] *of the visible light spectrum for the purpose of creating male and female bodies which alone constitute all matter."*[26]

"As servant of Mind, electricity gives moving form to the idea by performing the work necessary to produce it."[27]

"Electricity is forever winding light up into hot spheres, surrounded by cold cube wave-fields of space, and likewise sequentially unwinding them for rewinding. While winding them into compressed light masses, they are simultaneously unwinding to a lesser extent. Conversely, while unwinding they are simultaneously rewinding to a lesser extent."[28]

[24] Russell, [The Secret of Light], page 57
[25] [chemism], [rad-energy]
[26] Walter Russell, notation on chart, 1955.
[27] Russell, [The Secret of Light], page 114
[28] Russell, [The Secret of Light], page 124

"The farther removed from rest, the greater the strain or tension. That which we call high electric potential is merely great strain to maintain a condition which is far from the condition of rest."[29]

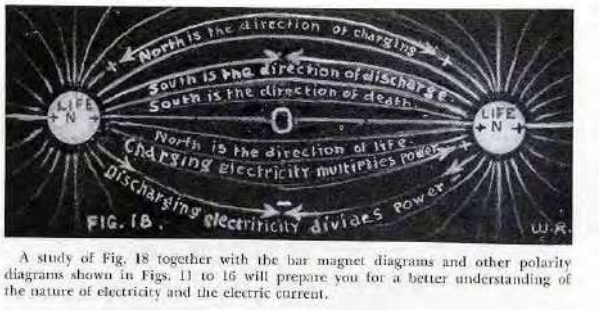

A study of Fig. 18 together with the bar magnet diagrams and other polarity diagrams shown in Figs. 11 to 16 will prepare you for a better understanding of the nature of electricity and the electric current.

Figure 13.4: Attractive (syntropic) power of electricity
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/attractive-electricity.jpg
(courtesy University of Science and Philosophy)

"Electricity is the strain or tension set up by the two opposing desires of universal Mind thinking - the desire for balanced action and the desire for rest."[30]

"Electricity creates Life by dividing stillness into two-way [polar] motion. It creates death by rest (depolar) from motion."[31]

[29]Russell, [The Secret of Light], page 139
[30]Russell, [The Secret of Light], page 139
[31]Russell, [Atomic Suicide]?; Figure 9 and 10, page 88]

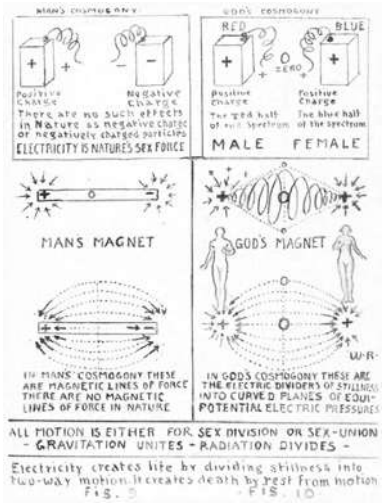

Figure 13.5: Polar dynamics of electricity
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/fig-9-10-88-bw.jpg
(courtesy University of Science and Philosophy)

"Electricity is the strain or tension set up by the two opposing desires of universal Mind thinking - the desire for balanced action and the desire for rest."[32]

"As rest cannot be unbalanced save by illusion, electricity which causes that illusion has no existence."[33]

"Electricity is the servant of Mind. It does all of the work of creating this light-wave universe in unfolding-refolding sequences which Mind desires. The universal Mind has two desires - the desire for creative expression through the action of concentrative (polar) thinking and the desire for rest from action through decentrative (depolar) thinking."[34]

[32]Russell, Walter; [The Secret of Light], page 139
[33]Russell, [The Secret of Light], page 141
[34]Russell, [The Secret of Light], page 144

13.4 Tesla on Electricity

"The day when we shall know exactly what electricity is will chronicle an event probably greater, more important, than any other recorded in the history of the human race."[35]

Below is a quote from William Lyne's book[36] discussing Tesla's ideas about electricity and magnetism. We will see Tesla's ideas were decidedly different than Keely's or Russell's. Incidentally Tesla knew of Keely and he knew Russell personally s mentioned in Russell's 'Atomic Suicide?' book.

In his 1891 A.I.E.E. lecture at Columbia College, Nikola Tesla said in pertinent part: ''*What is electricity, and what is magnetism "...We are now confident that electric and magnetic phenomena are attributable to the ether, and we are perhaps justified in saying that the effects of static electricity are effects of ether in motion". "...we may speak of electricity or of an electric condition, state or effect". "...we must distinguish two such effects, opposite in character neutralizing each other". "...for in a medium of the properties of the ether, we cannot possibly exert a strain, or produce a displacement or motion of any kind, without causing in the surrounding medium an equivalent and opposite effect." "...its condition determines the positive and negative character." "We know that it acts like an incompressible fluid;" "...the electro-magnetic theory of light and all facts observed teach us that electric and ether phenomena are identical." "The puzzling behavior of the ether as a solid to waves of light and heat, and as a fluid to the motion of bodies through it, is certainly explained in the most natural and satisfactory manner by assuming it to be in motion, as Sir William Thomson*[37] *has suggested." "Nor can anyone prove that there are transverse ether waves emitted from an alternate current machine; to such slow disturbances, the ether, if at rest, may behave as a true fluid.*"

In his statements, Nikola Tesla was balancing the various arguments in preparation for his decision: *"...Electricity, therefore, cannot be called ether in the*

[35] [Nikola Tesla]

[36] Summation of Tesla's Dynamic Theory of Gravity; An excerpt from: Occult Ether Physics by William R. Lyne

[37] [William Thomson], 1st Baron Kelvin OM, GCVO, PC, PRS, PRSE, (26 June 1824 - 17 December 1907) was a Belfast-born British mathematical physicist and engineer.

broad sense of the term; but nothing would seem to stand in the way of calling electricity ether associated with matter, or bound ether; or, in other words, that the so-called static charge of the molecule is ether associated in some way with the molecule."

"*...It cannot differ in density, ether being incompressible: it must, therefore, be under some strain or in motion, and the latter is the most probable.*" Nikola Tesla obviously believed in an ether (quantum substances) which was in motion relative to earth, because the earth is in motion.

The thing which Nikola Tesla had realized, was that ether possesses electric charges which are deposited on or contained within atoms. In supporting the "dynamic" ether concept, he was supporting the "stationary ether" concept, since the "motion" he referred to was "apparent" motion of the ether perceived by an observer on earth, relative to a stationary ether.

The importance of cosmic motion to the electromagnetic effects of static charges was brought up by Nikola Tesla in his lecture: *"About fifteen years ago, Professor Rowland*[38] *demonstrated a most interesting and important fact, namely, that a static charge carried around produces the effects of an electric current." "...and conceiving the electrostatically charged molecules in motion, this experimental fact gives us a fair idea of magnetism. We can conceive lines or tubes of force which physically exist, being formed of rows of directed moving molecules; we can see that these lines must be closed, that they must tend to shorten and expand, etc. It likewise explains in a reasonable way, the most puzzling phenomenon of all, permanent magnetism, and, in general, has all the beauties of the Ampere theory without possessing the vital defect of the same, namely, the assumption of molecular currents. Without enlarging further upon the subject, I would say, that I look upon all electrostatic, current and magnetic phenomena as being due to electrostatic molecular forces.*"

In these statements, Nikola Tesla showed he was aware that any "stationary" locale on earth is actually in fantastic motion ("70,000 mph"). The electro-

[38] [Henry Augustus Rowland] (November 27, 1848 April 16, 1901) was a U.S. physicist. Between 1899 and 1901 he served as the first president of the American Physical Society. He is remembered today particularly for the high quality of the diffraction gratings he made and for the work he did with them on the solar spectrum.

static charges "carried around" are currents between atoms and the ether, which produce magnetism. The phenomena of 'permanent magnetism' or 'cosmically induced' magnetism are apparently due to electrostatic charges 'carried around' by cosmic motion, in the universal ether field.

Since no one can hold an atom or molecule perfectly still - because it is in fantastic motion - all atoms and molecules carry currents producing magnetic fields. Since a magnetic field is the product of a current, no one can produce a magnetic field without electricity, moving through or along a conductor, or as electrostatic charges in local or cosmic motion." [39]

"Now, I must tell you of a strange experience which bore fruit in my later life. We had a cold snap observed even drier than before. People walking in the snow left a luminous trail. As I stroked Macak's back, it became a sheet of light and my hand produced a shower of sparks. My father remarked, this is nothing but electricity, the same thing you see on the trees in a storm. My mother seemed alarmed. Stop playing with the cat, she said, he might start a fire. I was thinking abstractly. Is nature a cat? If so, who strokes its back? It can only be God, I concluded. I can not exaggerate the effect of this marvelous sight on my childish imagination. Day after day I asked myself what is electricity and found no answer. Eighty years have gone by since and I still ask the same question, unable to answer it." Tesla [40]

13.4.1 Summary

Keely's definition of electricity in this writer's opinion seems to address the issue best of the three because he details causative forces - when allied with some of Russell's ideas. More research into Tesla's ideas is required. We know ether is quantum and supports electric and magnetic phenomena. To fully understand Keely's definition requires a re-education to more fully grasp his concepts discarding (or at least setting aside) descriptions of phenomena (effects) to the contrary.

[39] Summation of Tesla's Dynamic Theory of Gravity; An excerpt from: Occult Ether Physics by William R. Lyne

[40] Nikola Tesla - Lord of Lightning; by Nikola Tesla , edited by William Kern

Chapter 14

Gravity

14.1 Keely on Gravity

"Gravity is nothing more than an attractive, sympathetic stream[1]*, flowing towards the neutral center of the earth, emanating from molecular centers of neutrality; concordant with the earth's centers of neutrality, and seeking its medium of affinity with a power corresponding to the character of the molecular mass. Gravity, he defines as transmittive interetheric force under immense etheric vibration. He continues: - The action of the mind itself is a vibratory etheric evolution, controlling the physical, its negative power being depreciatory in its effects, and its positive influence elevating."*[2]

"Gravity is transmittive interetheric force under immense etheric vibration."[3]

"Gravity is the mutual attraction of atomoles."[4]

"Gravity is an eternal existing condition in etheric space, from which all visible forms are condensed. It is inherent in all forms of matter, visible and invisible. It is not subject to time or space. It is an established connective link[5] *between all forms of matter from their aggregation. Time is annihilated by it, as it has already traversed space when the neutral centers*

[1] [sympathetic stream]
[2] [Keely and His Discoveries], Chapter 5
[3] Keely
[4] Keely
[5] [connecting link]

of the molecules were established. It is nothing more than an attractive, sympathetic stream, flowing towards the neutral center of the earth, emanating from molecular centers of neutrality, concordant with the earth's centers of neutrality and seeking its medium of affinity with a power corresponding to the character of the molecular mass."[6]

"Nature has established her sympathetic concordants from the birth of the neutral centres of the planets. This is gravity; therefore gravity is fixed, inherent. There is no flight of gravity."[7]

"Gravity is polar propulsion the sympathetic concordant of the ninths and but one of the triune combinations. Magnetism is polar attraction, while gravity is polar propulsion. By proper vibrations, the action of both magnetism and gravity can be intensified or accelerated."[8]

"The sympathetic outreach[9] *of negative attraction*[10] *is the power that holds the planetary masses in their orbital ranges of oscillatory action."*[11]

"Gravity is not subject to time or space. It pervades the universe without reference to time or space, instantaneously and without intermission. It is, however, a sympathetic flow, proceeding from the molecular or mass neutral centers to the earth's neutral center with a power corresponding to the character of each individual molecular mass." He [Keely] believed gravity dependent on the medium of the polar stream, for he says *"If the sympathetic negative polar stream were cut off from the earth the molecular neutral centers would float away into space like a swarm of bees."*

"Under my system the gravital flow comes under the order of the "sympathetic concordant of the ninths" and is that third of the triune combination called the "polar propulsive." Gravity is polar propulsion while magnetism is polar attraction. Both magnetism and gravity can be accelerated by proper

[6] John Worrell Keely circa 1886, [Snell Manuscript]
[7] [Snell Manuscript]
[8] MAGNETIC ENGINE - Snell]
[9] [sympathetic outreach]
[10] [7B.18 - Sympathetic Negative Attraction], [negative attraction], [Neutral Negative Attraction], [polar negative attraction], [Sympathetic Negative Attraction]
[11] Keely, [Snell Manuscript]; [Sympathetic Negative Attraction]

vibrations.

"He believed gravity to be the result of a law which provides for a reversion of attraction in repulsion, and which acts by transmission of force under immense etheric vibration through the "interetheric subdivision." He also showed that gravitation acts "as a lever." MacVicar states "Every individualized object assimilates itself to itself in successive moments of its existence and all objects tend to assimilate one another." Keely says "Gravity is an ever existing eternal force, coexistent with the compound etheric or high luminous (seventh subdivision) since it entered into, and is an inherent property of, all forms of aggregated matter from their birth. It is the source from which all matter originated and each substance-unit or neutral center is a concordant link, attractive and dispersive, to all other neutral centers. Each neutral center is the nucleus of what we recognize as substance and is potentially the nucleus of a planet."[12]

14.2 Keely and anti-gravity

Keely not only had a working theory of what gravity is and how it functions he also developed experimental models which he demonstrated to scientists of his time and an actual heavier-than-air flying craft.[13]

From Dashed Against the Rock - *"A small instrument, having three gyroscopes as a principal part of its construction, is used to demonstrate the facts of aerial navigation*[14]*. These gyroscopes are attached to a heavy, inert mass of metal, weighing about one ton. The other part of the apparatus consists of tubes, enclosed in as small a space as possible, being clustered in a circle. These tubes, represent certain chords, which were coincident to the streams of force acting upon the planet, focalizing and defocalizing upon its neutral center. The action upon the molecular structure of the mass lifted was based upon the fact that each molecule in the mass possessed a north and south pole, - more strictly speaking, a positive and negative pole, - situated through the center, formed by the three atoms which compose it. No mat-*

[12] [GRAVITY - Snell]

[13] [air-ship], [Air-ship model], [Figure 19.17 - Keelys Air-ship], [17.15 - Theory of Vibratory Lift for Air-ships]

[14] [aerial navigation]

ter which way the mass of metal is turned, the poles of the molecule point undeviatingly to the polar center of the earth, acting almost exactly as the dip-needle when uninfluenced by extraneous conditions, electrical and otherwise. The rotation of the discs of the gyroscopes produces an action upon the molecules of the mass to be lifted, reversing their poles, causing repulsion from the earth in the same way as like poles of a magnet repel each other. This repulsion can be diminished and increased according as the mechanical conditions are operated. By operating the three discs, starting them at full speed, then touching two of them, so as to bring them, according to the tone they represented by their rotation, to a certain vibratory ratio, the weight then slowly sways from side to side leaves the floor, rising several feet in the air, remaining in that position, and as the discs gradually decrease their speed of rotation the weight sinks to the floor, settling down as lightly as thistle-down. Where one molecule can be lifted, there need be no limit as to the number in a structure that may be operated upon as easily as one. The vessel in contemplation, the aerial navigator, will be over two hundred feet long, over sixty feet in diameter, tapering at both ends to a point, made of polished steel, and will be capable of being driven under the power of depolar repulsion, at the rate of three hundred miles an hour. It can be far more easily controlled than any instrument now in use for any phase of transit. Another very remarkable feature connected with this system of aerial navigation, is that the vessel is not buoyed up or floated in the air through the medium of the air, so that if there were no atmosphere it would float just as readily; hence, under mechanical conditions most certainly capable of production, involving massive strength of resistance to interstellar vacuity this can be made capable of navigating even the remote depth of space, positions between planets where polarity changes being controlled by other adjuncts of concentration for that purpose.

"Safely enclosed within this structure, a man possessing the chemical knowledge these new laws[15] *give, with sufficient supply of material from which to make oxygen, by the enormously increased rate of speed attained by such navigator where atmospheric friction is avoided, the time occupied in traveling from one planet to another would be amazingly brief, and one can travel to other planets in this system of worlds as easily as the same ship could navigate the depths of the ocean.*

[15] [Keelys Forty Laws]

"The great obstacle hitherto preventing the solution of this problem has been the strength of structure needed under conditions above presented. With this knowledge of matter, the size of structure is unimportant; the heaviest can be as easily controlled as the lightest."[16]

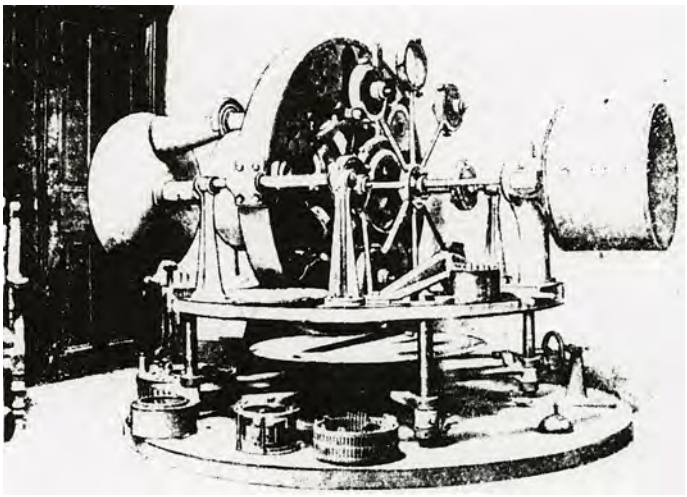

Figure 14.1: Keely's experimental air ship
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/air-ship-photo.jpeg

14.3 Levitation experiments

No less intriguing are Keely's experiments showing principles of levitation.

[16][Levitating Gyroscopes], [Dashed Against the Rock]

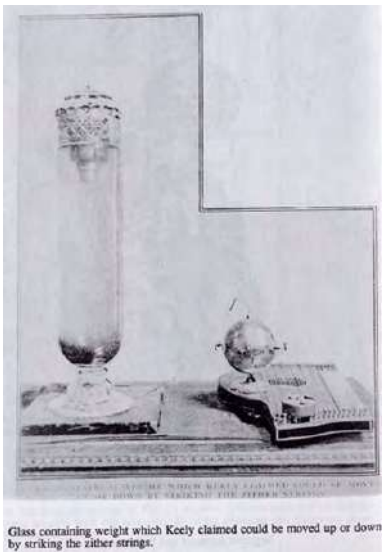

Figure 14.2: Levitating weights
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/anti-gravity-keely.jpg

From Pittsburg Dispatch April 07, 1890 - Mr. Willcox[17] and Dr. Leidy[18] then examined the platinum wire, the metal disk on which the magnetic needles rested, the cupboard, the base of the cupboard and the table on which the disk and needle rested. When asked if there was, in his opinion, any possibility that the force which made the needle revolve[19] was electricity, compressed air or steam, Dr. Leidy looked thoughtful and said he could not see the possibility of any of those forces producing the result attained.

"What you have seen was shown you in order to illustrate the ease with which this force can be made to do work," said Keely.

"Of course the work just done was trifling. But I hope now to show you what will look very differently."

[17]Dr. James M. Wilcox, PhD, [Wilcox]

[18][Joseph Leidy] (September 9, 1823 April 30, 1891) was an American paleontologist. Leidy was professor of anatomy at the University of Pennsylvania, and later was a professor of natural history at Swarthmore College.

[19][4.2.5 - Rotation of Compass Needle], [DISTURBANCE OF MAGNETIC NEEDLE]

He pointed out then two glass jars, such as chemists use, on a table near by. The jars were of the same size, about 40 inches high, and 10 inches in diameter. They were filled with what is said to be, and certainly smelled and tasted like, Schuylkill[20] water. In the bottom of one jar lay a copper globe, cut in half to show, Keely said, just what it was; and filled, in each hollow half, with iron nails.

Another Peculiar Experiment.

In the other jar were three brass balls of different sizes. The copper globe and nails were weighed by Dr. Leidy and found to kick the beam at five pounds and six ounces. The brass balls or eggs they were egg-shaped, weighed less. Everybody sat down alter the weighing and Keely fastened another "platinum silver wire" to the cylinder on the cupboard and, detaching the one already in use from the magnetic needle disk was about to fasten the loose ends of each to the metal disks that covered the tops of the jars when some one asked if the wires were "hollow." The suggestion was followed by a smile from Keely, who at once cut off the end of one of them and handed it around.

"Prof. Rowland, of Baltimore, [had] declared that this was a fraud, because the wires were hollow,' said the woman, *"but Keely asked' him how he could explain what Keely did even on the hypothesis that the wires were hollow and he didn't answer. Then Keely got mad and would not let him cut the wire, as he wanted to do.*"

Dr. Leidy followed everything closely. Keely fastened the loose ends of both wires into the metal caps of the cylinders.

The String an Important Feature.

Again he spun the spindle on his cupboard with the twine string he had used before. Again with his gnarled fingers, the joints of the first two fingers of his right hand being as big as walnuts, be pounded the "harp" in the cupboard and the resonant bars on top of it.

"What are you doing now?" asked Dr. Leidy.

[20] river that passes through Philadelphia

"I am trying" said Keely, "*to get the mass chord of that copper sphere full of nails. Every aggregation of molecules or of matter, I claim, or, in other words, every mass of matter, has a sympathetic chord, through the medium of which I can operate my vibratory force.*"

The chord was not found for some minutes. Again the spindle was spun by the help of the twine, and its whizz [sic]was distinct in the silence of the room. The search for the mass chord continued on the "harp" and the resonant rods. A deep, clear note resounded from both at the same time, and at the instant it broke on the ear the heavy copper globe quivered as it lay at the bottom of the water, rolled over, reluctantly as it were abandoning the ties by which gravity held it to the bottom of the jar, floated at first slowly, and then more swiftly and steadily to the top of the jar, against which it impinged with an audible concussion.

Gravity Easily Overcome.

"Why, there is the force of gravity as plainly overcome and indeed annihilated as it is possible for a human being to imagine," exclaimed the woman.

Dr. Leidy was asked this question: *"Doctor, is it true that this unknown force, or what is here manifested as such, has actually before your eyes overcome the force of gravity with which we are all familiar?*" and the answer, slowly, deliberately, was: *"I see no escape from that conclusion."*[21]

14.4 Russell on Gravity

"Gravitation is the generative force of increasing potential and the regenerative force of decreasing potential.

"Gravitation is the power within the electric force of action to attract the electric force of action.

"Gravitation is the contractive power within electricity to divert the univer-

[21] [Pittsburg Dispatch April 07-1890], [Leidy and Wilcox Visit Keelys Lab], [Figure 17.18 - Keelys Levitation Demonstration], [Eye Witness Accounts]

sal constant of energy into centripetal vortices of closing spirals of increasing speed, thereby attracting similar states of motion into an accumulation of mass, the pressure of which increases toward its center.

"Gravitation is an expression of the power of electricity to accumulate by induction and, by so doing, to force magnetism to increase its resistance to that accumulation.

"Gravitation is the (electric) inductive force."[22]

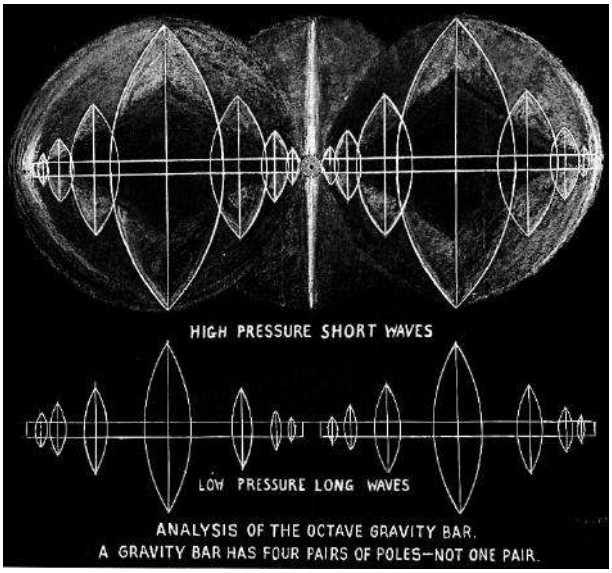

Figure 14.3: Gravity wave bar and poles
Image: http://pondscienceinstitute.on-rev.com/imagesNatDyn/gravitybar.jpg
(courtesy University of Science and Philosophy)

[22]Russell, [The Universal One]

Chapter 15

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" " /Bose-Einstein condensation
" " /Dirac Sea
" " /Efimov state
" " /Geometric Progression
" " /Linear Progression

" " /Quark-gluon plasma
" " /Richard Phillips Feynman
" " /States of matter
" " /Stockholm Syndrome

Appendix A

I - Laws of Being

from 'Keely and His Discoveries', Conclusion

Keely's Physical Philosophy

"Mr. Keely begins with sounds whose vibrations can be known and registered. I presume that the laws of ratio, position, duality, and continuity, all the laws which go to mould the plastic air by plastic bodies into the sweetness of music, will also be found ruling and determining all in the high silence of interior vibrations, which hold together or shake asunder the combinations that we call atoms and ultimate elements."[1]

"What Keely has discovered in physics, I am in some measure credited with discovering in metaphysics: this is nothing strange, according to this philosophy, which shows that many people may divine the same original truth at the same time by means of the etheric element which connects the Deity, the source of all truth, with all His creatures."[2]

Abstract of Keely's Physical Philosophy in its main features up to the point of practical application;

by Professor Daniel G. Brinton, of the Pennsylvania University; subject to

[1] [The Scientific Basis and Build of Music]; [Dougald Carmichael Ramsay]. Edited by the Rev. [John Andrew]. Marcus Ward and Co.

[2] Preface to [Vera Vita; or, The Philosophy of Sympathy]. [David Sinclair]. Author of [A New Creed]. Digby, Long and Co., London.

modifications and additions when Keely has made public his system.

The fundamental conception of the Universe is force manifesting itself in rhythmical relations. This definition is exhaustive, including both thought and extension, matter and mind. The law for the one is the law for the other. The distinction between them is simply relative, i.e. quantitative, not qualitative.
The rhythmical relations in which force acts are everywhere, under all conditions, and at all times, the same. They are found experimentally to be universally expressible by the mathematical relations of thirds.

These threefold relations may be expressed with regard to their results as,-

I. Assimilative
II. Individualizing.
III. Dominant or Resultant.

From these three actions are derived the three fundamental LAWS OF BEING.

I. Law of Assimilation: every individualized object assimilates itself to all other objects.
II. Law of Individualization: every such object tends to assimilate all other objects to itself.
III. Law of the Dominant: every such object is such by virtue of the higher or dominant force which controls these two tendencies.

Applying these fundamental laws to an explanation of the universe, as it is brought to human cognition, all manifestations of force may be treated as modes of vibrations.

The essential differences give rise to three modes of vibration:-

I. The Radiating: called also the “Dispersing,“ the “Propulsive,“ the “Positive,“ and the “Enharmonic.” see entropy
II. The Focalizing: called also the “Negative,“ the “Negative Attractive,“ the “Polarizing,“ and the “Harmonic.” see syntropy
III. The Dominant: called also the “Etheric,“ or the “Celestial.”

These, it will be noted, correspond to the three laws of being. It is not to be understood that any one of these three modes of vibration can exist independently. Each by itself is called a "current," and all three must be present in every "stream" or "flow" of force. The relations of the currents in every flow are expressible in thirds, and it is experimentally demonstrable that the relations of the three are in the order named: as $33\ \frac{1}{3} : 66\ \frac{2}{3} : 100$.

The evolution of what is called "matter" from the different modes of vibration is through the action of the second law, that of focalization, or "negative attraction," or "negative affinity."[3]

Where the vibrations under this mode meet, and are maintained in a state of mutual affinity or equilibrium, there is established what is called a "neutral center," or, as otherwise expressed, "a center of sympathetic coincidence."

The terms "neutral attraction," "neutral affinity," "negative attraction," or "polar negative attraction," are emplyed to express the property of a mode of vibration to direct its components towards such centre. see syntropy

As no current of flow of force can be composed of one mode of vibration only, but must always be composed of three modes uniting in varying thirds, we have 1 x 2 x 3 = 6 as the total possible forms of sympathetic coincidence, or, to speak in ordinary terms, there can be six; and six only, possible forms of individualized being. These are what Keely calls the six orders of atomic subdivision, or orders of vibratory motion, and he names them as follows:

Molecular
Intermolecular
Atomic
Interatomic
Etheric
Interetheric

In this list the forms of matter are arranged in the mathematical sequence of the rapidity of the oscillations of their constituent members; the proportion

[3] see [syntropy]

being proved by experiment to be as follows: for the molecular orders:

1 : 3 : 9 : 27 : 81 : 243.

This arithmetical progression changes in the atomic orders to a geometrical progression as follows:

3 : 9 : 81 : 6561 : 43,046,721; etc.

This same method of progression is believed to hold in all the orders of vibrations above the molecular, and soon passes into mathematical infinity.

Actually, however, all matter of which we are capable of cognition through the medium of our senses is in one of three forms of aggregation:

Molecular
Atomic
Etheric

in each of which the controlling mode of vibration is respectively,

The Enharmonic.
The Harmonic.
The Dominant.

But it must be understood that each of these modes is a positive and real constituent of every atom and molecule.

It will be seen that as every form of material aggregation is to be considered as a "neutral center of attraction," where the vibratory force of all three orders are held in "sympathetic coincidence," that is, in balanced activity or harmonized motion, and not by any means cancelled or mutually destroyed, there is no diminution of force, but only temporary suspension of its radiating or propulsive activity or expression. [4]

This is the foundation of Keely's doctrine of "latent force," and of the indef-

[4] see [Rhythmic Balanced Interchange]

inite power which can be obtained by breaking up the harmonious balance or equation of forces of every mode, which exists in every "neutral center," that is to say in every mass of matter.

Insomuch as every mass of matter consists thus, in fact, of vibrations in harmonic equilibrium, related by simple proportions of thirds, it follows that every mass of every description stands in harmonic relations to every other mass. This is, in part, what is meant by the sympathy of all forms of matter and of motion; and it is through the study of the methods of increasing or diminishing this sympathy that we reach practical results in this field of research. At present this is best accomplished by resonance; that is, through the harmonic vibrations created by musical instruments, bringing out the acoustic world as the microscope reveals the hidden visual world.

Every visible or tangible mass of matter must be regarded as an aggregation of molecules; the molecules being the true centres of the equated forces of "neutralized attraction."

These molecules have been experimentally proved by Keely to be formed of all three modes of vibration; the proof being that they respond to all three modes when subjected to the tests of compound concordant impulses.

When in that state of neutral aggregation which we know as matter, each molecule is in perpetual oscillation, the range of the oscillation being one-third of the molecule, and its rapidity 20,000 oscillations in a second.

It is through the disturbance of this oscillatory equilibrium, by means of resonant impulses, that Keely alters the relations of the vibratory impulses which constitute matter. This he does by striking the same chord in three octaves, representing the third, sixth, and ninth of the scale.

Of these, the sixth reduces the range of molecular vibrations or oscillations; and, by thus bringing nearer to each other the neutral centers, increases solidification.

The ninth extends the range of molecular oscillation, and thus tends to give greater tenuity to the mass. It induces "trajectile velocity" from neutral centers, or "neutral radiation." Experiment shows that molecular dissociation

does not take place until the molecule attains an oscillation approaching, it not fully reaching two-thirds of its diameter. This can be effected by means of the action of the "enharmonic" or "radiating" current applied to the mass, after its molecules have once been disturbed by an "introductory impulse;" that is, by the musical note above mentioned.

The third represents the "dominant," and when brought under control of a harmonic resonant impulse induces a complete rearrangement of the modes of vibration and oscillation; in other words, will transform the mass either into its component initial forces, or into some other form of matter.[5]

It is the study of the dominant to which Keely has devoted his recent researches. He aims to control the power he evolves by altering the dominant or etheric mode of vibration in the triplicate flows of force.

As all molecules and masses are mere centres of harmonized vibrations, temporarily held in suspension by simple laws identical with those of resonance, it follows that these centres can be broken up or divided by certain orders of vibration impinging upon and disturbing them.

It is a familiar fact that a cord in vibration tends to produce a similar vibration in a cord placed near it. This property belongs to all vibrations, whether resonant or not, and they exert it in proportion to the "order" to which they belong. The distance in space to which this power extends, or can be extended, is what is called "the sympathetic outreach" of the current of flow.

In this manner we have "sympathetic negative attraction," and "sympathetic positive propulsion," with reference to the "outreach" of the third or dominant current of the stream, which is allied to the order of etheric vibrations.

Each molecule of a given mass of matter represents the same harmonic chord or note in its oscillatory motion. The "chord of the mass" is, therefore, the chord of every molecule of the mass.

But as the condition of absolutely stable equilibrium is theoretical only, and

[5] see [Law of Transformation of Forces]

does not exist in nature, the chord of the mass is constantly changing. Yet we must learn to control this "chord of the mass" by resonant induction, if we would gain command of the molecular forces.

Keely believes he has solved this problem, by the invention of a mechanical device which brings the chords of all masses within the conditions of a few simple acoustic tests.

The range of molecular oscillation is affected differently in different substances when submitted to the same vibratory impulse, and these ranges can be measured.

In the three metals, silver, gold, and platina, we obtain the proportions - 3 : 6 : 9

As this is the primary relation of the modes of vibration, a wire made of these three metals is peculiarly adapted to transmit concordant impulses: and nodes made of these substances placed upon a wire, transmitting resonant vibrations, indicate, by the different orders of vibration induced in them, the rate of oscillations of the atomic constituents.

The phenomenon of rotation arises from the harmonic inter-action of the dominant and enharmonic elements of the flow: in other words, the first and third, the third and ninth, etc.; those whose vibrations bear the proportions to each other $33\ \frac{1}{3} : 100$.

A practical example of rotation is a wheel in revolution on its axis. This is force in its commercial or economic aspect. To accomplish this result by molecular vibratory action, we must gain control of the "negative attractive" or "enharmonic" current of the triple flow, and the problem is then solved up to any limit of power.

Appendix B

II - Laws of Being

"The brain of an Aristotle was needed to discern and grasp Keely's meaning to interpret and define it. Dr. Brinton never touches a subject without throwing light upon it, and his penetrating mind perceived the ideas to be defined in all their relations. His keen logical acumen separated and classified them in their order, in a true, sound, and scientific manner. In the words of Sir James Crichton Browne, who heard Professor Brinton read this abstract in London, "Professor Brinton's synopsis is an able, lucid and logical paper." [Progressive Science]

Laws of Being

by Professor Daniel Brinton, University of Pennsylvania

Abstract of Keely's Physical Philosophy in its main features up to the point of practical application; by Professor Daniel G. Brinton, of the Pennsylvania University; subject to modifications and additions when Keely has made public his system. [1]

"The fundamental conception of the Universe is force manifesting itself in rhythmical relations.

"This definition is exhaustive, including both thought and extension, mat-

[1] from Keely and His Discoveries, Conclusion, Keelys Physical Philosophy

ter and mind. The law for the one is the law for the other. The distinction between them is simply relative, i.e., quantitative, not qualitative.

"The rhythmic relations in which force acts are everywhere, under all conditions, and at all times, the same. They are found experimentally to be universally expressible by the mathematical relations of thirds.

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"*The evolution of what is called matter from the different modes of vibration is through the action of the second law, that of focalization, or negative attraction, or "negative affinity".*

"*Where the vibrations under this Mode meet, and are maintained in a state of mutual affinity or equilibrium, there is established what is called a neutral center, or, as otherwise expressed, "a center of Sympathetic Coincidence".*

"*The terms "neutral attraction", "neutral affinity", "negative attraction", or "polar negative attraction", are employed to express the property of a Mode of vibration to direct its components towards such center.*

"*As no current or flow of force can be composed of one Mode of vibration only, but must always be composed of three modes uniting in varying thirds, we have 1 x 2 x 3 = 6 as the total possible forms of Sympathetic Coincidence, or, to speak in ordinary terms, there can be six; and six only, possible forms of individualized being. These are what Keely calls the six orders of Atomic subdivision, or orders of vibratory motion, and he names them as follows*:

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VI.	Interetheric

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the rapidity of the oscillations of their constituent members; the proportion being proved by experiment to be as follows for the molecular orders:

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"*The arithmetical progression changes in the atomic orders to a geometrical progression as follows*:

3 : 9 : 81 : 6561 : 43046721, etc.

"This same method of progression is believed to hold in all the orders of vibrations above the molecular, and soon passes into mathematical infinity.

"*Actually, however, all matter of which we are capable of cognition through the medium of our senses is in one of three forms of aggregation*:

I. Molecular
II. Atomic
III. Etheric

"*In each of which the controlling Mode of vibration is respectively*:

I. The Enharmonic
II. The Harmonic
III. The Dominant

"*But it must be understood that each of these modes is a Positive and real constituent of every atom and Molecule.*

"*It will be seen that as every form of material aggregation is to be considered as a "neutral center of attraction", where the vibratory force of all three orders are held in Sympathetic Coincidence, that is, in balanced activity or harmonized motion, and not by any means cancelled or mutually destroyed, there is no diminution of force, but only temporary suspension of its radiating or propulsive activity or expression.*

"*This is the foundation of Keely's doctrine of latent force, and of the indefinite power which can be obtained by breaking up the harmonious balance*

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"*Insomuch as every mass of matter consists thus, in fact, of vibrations in harmonic equilibrium, related by simple proportions of thirds, it follows that every mass of every description stands in harmonic relation to every other mass. This is, in part, what is meant by the sympathy of all forms of matter and of motion; and it is through the study of the methods of increasing or diminishing this sympathy that we reach practical results in this field of research. At present this is best accomplished by resonance; that is, through the harmonic vibrations created by musical instruments, bringing out the acoustic world as the microscope reveals the hidden visual world.*

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"*Each Molecule of a given mass of matter represents the same harmonic chord or note in its oscillatory motion. The chord of the mass is, therefore, the chord of every Molecule of mass.*

"*But as the condition of absolutely stable equilibrium is theoretical only, and does not exist in nature, the chord of the mass is constantly changing. Yet we must learn to control this chord of the mass by resonant induction, if we would gain command of the molecular forces.*

"*Keely believes he has solved this problem, by the invention of a mechanical device which brings the chords of all masses within the conditions of a few simple acoustic tests.*

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Appendix C

III - Ultimate Constitution of Matter

The Ultimate Constitution of Matter and the Action of the Force Regulating its Phenomena

by John W. Keely

First: Matter is capable of infinite subdivision.

Second: In the aggregation of matter, force or energy is stored up or conserved.

Third: In the dissociation of matter, force is liberated.

Fourth: All matter is in a state of perpetual activity, whether the substance under consideration be inanimate or animated, visible or invisible.

Fifth: There is no dividing of matter and force into two distinct terms, as they both are ONE. FORCE is liberated matter. MATTER is force in bondage.

Sixth: All motion is synchronous; no sound or movement can be made but all that moves or sounds does so in harmony with something.

Seventh: All structures, whether crystalline or homogeneous, have for their

unit structures minute bodies called molecules. It is the motion of these molecules with which we have particularly to deal; as in experimental research and demonstration, when we produce an action upon one molecule we do so upon all the molecules constituting the mass operated upon.

Eight: These molecules have an envelope, rotating with inconceivable rapidity, formed of a high tenuous ether, whose place in the order of subdivision ranks third, the three divisions being, - first, molecular; second, atomic; third, atomolic. (Atomolic is the same as Etheric)

Ninth: This atomolic substance has a density approximately 986,000 times that of steel, enabling it to permeate steel as light penetrates glass; this rotating envelope of atomolic substance is in a liquid condition. There are four conditions of matter; viz. solid, liquid, gaseous, and ultra-gaseous. These conditions result from greater or lesser range of oscillation of the composing units individually; this is equally true, whether the units are molecules, atoms, atomoles, planets, or suns. But one LAW governs all matter.

Tenth: This molecular envelope, rotating with such great velocity, holds in its embrace the next subdivision of matter, the atomic. There cannot ever be more or less than three atoms in any molecule. These are placed so as to form a triangle in the interior; they rest in a condition of substance, or matter, we will term intermolecular. In this intermolecular substance we find an enormous energy or force in bondage, held thus by the rotating envelope enclosing it. Were we to rotate a spun brass shell, say nine inches in diameter, at a very much less rate of speed than that at which the molecular envelope rotates, - say nine hundred revolutions per second, - its equator would first bulge out, then form into an oval disk. A solid block of wood subject to such revolution would swiftly fly to pieces. The rotating envelope of a molecule, unlike these, the greater the velocity of rotation, the greater is its compression toward the center of the molecule. The rotation of this envelope is of such a nature as to produce an internal pressure upon every portion from every point of the molecule as a sphere. Were we to consider a rotating envelope as ordinarily understood, it would be one in which the envelope rotated around an equator having poles of no rotation; i.e., the poles would not possess the compressing force of the equator; the result would therefore be a compressed equator, and the intermolecular substance would pass out without resistance at the poles.

Eleventh: If it be possible let us conceive of an envelope with an equator, but destitute of poles, a number of these rotating over the sphere, this atomolic envelope possessing an almost infinite attractive force toward the center of the molecule, pressing in the intermolecular substance, where it is held until this revolving envelope becomes negatized by a certain order of vibration, when the enclosing matter rushes out to its natural condition of concordant tenuity, as in the case of gunpowder, dynamite, and nitroglycerine. This force, we must see, has been held in the embrace of the rotating envelopes of the unit structures, or where does it come from? This force at the time of an explosion was liberated by shock or fire, both being orders of imparted motion or vibration. How much greater the result would be were we to associate a scientific instrument now completed, and shortly to be given to the world, with such an agent as nitroglycerine; one pound of nitroglycerine would have its destructive force augmented beyond all possible control. These instruments are carefully concealed by wise masters from all persons save the few who are already prepared to study their potency with the exclusive end in view of aiding the real scientific progress of humanity; and, furthermore, it may be truly stated that a ferocious sensualist, however powerful his intellect, would be utterly unable to either comprehend or operate one of these marvelous constructions.

Twelfth: Next in order of consideration is the second subdivision of matter - the atomic. The atom has the same rotating envelope as the molecule, governed by the same laws of rotation and compression. The rotating envelope holds in its embrace the interatomic substance and three atomoles resting in it, the atomoles within the atom being constructed after the same pattern as the atom and the molecule, obedient to the same laws; the atomolic being simply the third subdivision of matter. The threefold order is absolutely universal.

Thirteenth: The atomolic substance is what is termed the ether which fills all space and is the transmitting medium for all celestial and terrestrial forces. This is the liquid ether of occult science.

Fourteenth: The atomoles are made up of atomolini (singulara tomolinus); the subdivision of matter from this point is beyond man's power, as at this point it escapes all control of apparatus, passing through glass and hardened

steel as a luminous flame without heat, which is hardly seen before it vanishes, - a perpetual flame coldly luminous.

Fifteenth: (Not in book, may have been a mis-numbering. editor)

Sixteenth: This again, from previous analysis, is made up according to the triple order, and may again be subject to subdivision, even into infinity." [Dashed Against the Rock]

Dale Pond

Author of many books.
Creator of svpwiki.com and
Maker of Dynaspheres.

Keely's Laws of Being

This book describes the unseen (scalar)
components of vibration, oscillation and toroids
as also their relationships and dynamical functions.
This book is a follow-up (volume II) of
The Physics of Love published in 1994.
The forces described in this book are
the 3, 6 and 9 unseen (scalar) forces Keely used
to achieve some of the remarkable feats of
science and engineering accredited to him
yet not understood by the rest of us.

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Musical Numerology

By Don Robertson, 1970 with revisions in 2003

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(First appeared in the book *Kosmon)*

I wrote the article Musical Numerology in 1970 and published it in Denver, Colorado in a book called Kosmon, a book created by myself and two other people. It was in this book that I first published my findings about the duochord and proclaimed that rock and roll music was taking a downward turn.One day, after we had started distributing the book to local bookstores, I received a letter from a young man who lived nearby and wanted to meet the author of this article. I went to see him and looking around the one-bedroom apartment, I saw that everywhere there were large pieces of white paper on which he had been making mathematical calculations: on tables, chairs, and taped to all of the walls. He was ecstatic, "I had to meet the author because I have applied what was stated in the article to every known science and found that the same formula proves itself in every case." I went back a week later to discuss the matter with him more thoroughly , but the apartment was empty and he was gone. Now after 23 years, I have revised the article, and am publishing it again on DoveSong.Com. I hope this information can be as useful to others as it was for this young man and has been for me. I believe that musical scales and harmony are based on alchemical realities that can be proved by math. Math demonstrates the formation of the laws of the universe, and music, color, and all manifestation follow the same laws.

Don Robertson, May, 2003

* *

To our knowledge, there is no religion on the earth that does not incorporate some kind of symbolic use of **the quantities three and seven**.

Our objective is to illustrate some of the mysterious relationships between the quantity three, the quantity **seven**, and what these quantities have in common with the basic physical structure of the universe.

The direct relationship between **three** and **seven** is as follows:

If we have three objects, which we will call 1, 2, and 3, we will observe that the absolute number of different combinations of these 3 objects is 7;

that is, we may arrange them in no more than seven different combinations, regardless of the order in which they are arranged.

Combination 1	**1, 2, 3**
Combination 2	**1, 2**
Combination 3	**1, 3**
Combination 4	**2, 3**
Combination 5	**1**
Combination 6	**2**
Combination 7	**3**

There are **three primary colors** in the color spectrum, plus four more natural colors that are created from the combinations of the three colors similarly to the three objects above.

All colors that exist are either :

a) One of the primary colors, or

b) A resultant mixture of two or three of the primary colors.

The primary colors cannot be created by mixing other colors, so they are rather special.

The three primary colors are **red**, **yellow**, and **blue**.[1]

The ***natural***, or ***secondary*** colors are those colors that are created by mixing equally the three primary colors according to the chart above.

The resultant seven natural colors the colors of the rainbow, a naturally occurring phenomena that can be created using a prism to break down light.

They are arranged in the spectrum as follows:

The Color Spectrum

Red	**1**	**Red**
Orange	**1, 2**	**Red, Yellow**
Yellow	**2**	**Yellow**
Green	**2, 3**	**Yellow, Blue**
Blue	**3**	**Blue**
Indio	**1, 2, 3**	**Red, Yellow, Blue**
Violet	**1, 3**	**Red, Blue**

Thus we see that the color spectrum is based on the relationship between 3 and 7.

There are three primary tones of the musical scale and seven natural tones:

The Musical Scale

C	**1**	**C**
D	**1, 2**	**C, E**
E	**2**	**E**
F	**2, 3**	**E, G**
G	**3**	**G**
A	**1, 2, 3**	**C, E, G**
B	**1, 3**	**C, G**

The notes that correspond to the primary colors are **C, E, G**: the **major triad**, which is **the most important chord in music**, and the groundwork of the scale.

It is important to realize the correspondence between the colors of the spectrum and the notes of the scale, as the musical scale is based on the same principals of nature (the natural overtone series) and it has been adapted in some form or another most all cultures.

There are three root-position triads contained in the **major scale (C,D,E,F,G,A,B).** These are:

The major triad that is based on the correspondence with the primary colors (C, E, G) and **two minor triads, based on three of the natural, or secondary, tones (D, F, A and E,G,B).**

Major and minor triads are the fundamental underpinnings of harmony used in the music of Western cultures.

Three Forces at the heart of Nature

The simplest physical structure in the material universe is the hydrogen atom. It has the least number of forces at work: **three**.

These **three forces** are:

1) At the center of the atom resides the nucleus, composed of a **positive charge** of electricity called a **proton**.

2) Orbiting around this proton in an elliptical orbit is a negative charge of electricity called an **electron**. Since this electron has a negative charge, and since a **negative charge** is attracted to a positive charge, the electron is attracted to the proton.

3) Since the electron is attracted to the proton, there needs to be a force that causes equilibrium between the two, as the electron would collide with the proton if no such force were in place. This force then is the force that governs bodies in motion, causing them to travel in an orbit. It is ***centrifugal force***. In the atom, this is the **neutron**.

Some Aspects of Three

If there is a given object that is fixed in space, this object has, as its location, three coordinates. An example of this would be the relative position of an airplane above the earth. It is calculated by longitude, latitude, and altitude, its three coordinates.

If someone looks into the corner of a room, where the room meets the walls, they will see **three intersecting planes that are considered to extend into infinity**. These are the three dimensions of space.

There are three time zones that man senses, past, present, and future.

If there is space with no motion, then time does not exist, only space. But if there is no motion, then there can be no space, for there has to be space to contain the motion. The motion through space causes sequentially. The earth's orbit around the sun and revolution on its axis causes a time sequence on earth. **Thus we have three aspects: time, space, and motion**.

The Law of Three

The fact that events, laws, and all creation result from three principals is referred to as the "**Law of Three**" or the "**Law of the Triangle**." This law is illustrated by the example that every effect has two causes: **one passive, and one active**.

What does the Russian philosopher Georges Gurdieff have to say about the Law of Three? In the book *In Search of the Miraculous*, PD Ouspensky quotes him as follows:

"This is the **'Law of Three'** or the law of the three principles or the three forces. It consists of the fact that every phenomenon, on whatever scale and in whatever world it may take place, from molecular to cosmic phenomena, is the result of the combination or the meeting of three different and opposing forces.

Contemporary thought realizes the existence of two forces and the necessity of these two forces for the production of a phenomenon: **force and resistance**, **positive and negative magnetism**, **positive and negative electricity, amel and femail cells, and so on**. But it does not observe even these two forces always and everywhere. No question has ever been raised as to the third, or if it has been raised it has scarcely been heard.

"According to real, exact knowledge, once force, or two forces, can never produce a phenomenon. The presence of a third force is necessary, for it is only with the help of a third force that the first two can produce what may be called a phenomenon, no matter in what sphere.

"The teaching of **the three forces is at the root of all ancient systems**. The first force may be called active or positive, the second, passive or negative; the third, neutralizing. But these are merely names, for in reality all three forces are equally active and appear as active, passive and neutralizing, only at their meeting points, that is to say, only in relation to one another at a given moment.

The first two forces are more or less comprehensible to man and the third may sometimes be discovered either at the point of application of the forces, or in the medium, or in the result. But speaking in general, the third forces is not easily accessible to direct observation and understanding.

The reason for this is to be found in the functional limitations of man's ordinary psychological actively and in the fundamental categories of our perception of the phenomenal world, that is, in our sensations of space and time resulting from these limitations. People cannot perceive and observe the third force directly any more than they can spatially perceive the forth dimension.

"The first fundamental law of the universe is the law of three forces,or three principles, or as it is often called, the law of three. According to this law, every action, every phenomenon in all worlds without exception, is the result of a simultaneous action of three forces: the positive, the negative, and the neutralizing. Of this we have already spoken…. The next fundamental law of the universe is the law of seven or the law of octaves.

Some Aspects of Seven

During the late 1700's, some chemists began identifying certain chemical elements. About 1800, they began to determine the atomic weights of some of them. In 1808, John Dalton suggested that atoms were physical objects with specific weights. In 1829, Johann Doebereiner showed that particular elements could be arranged in groups of three. In each group, the elements had similar properties and the weight of the middle atom of the group was close to the average of the other two. These were said to be chemical equivalents to the musical triad.

The Law of Octaves

In 1864, John A. Newlands grouped all the known elements in the order of their atomic weights. He then divided them into groups of seven elements each. He showed that when the atoms were put into order with their weights increasing, there was a repetition in the similarities according to the musical octave, the same found on the keyboard. When he talked to chemists of this time about his newly found law of octaves, they laughed.

But octaves are the substance of the musical scale, the same musical scale that was demonstrated by Pythagoras and used today, with slight modifications according to culture. It is a naturally occurring phenomena. The basis of the musical scale is the *octave*, the repetition of the vibration of the set of seven notes that occurs as the fundamental vibration of the first note, the basic note of that scale, is doubled.

In 1869, Mendeleev compiled a "Periodic Table of the Elements." This table was arranged according to atomic weights. Mendeleev found, as had Newlands, that the chemical properties of the elements reoccur at definite intervals. He concluded that these were the periodic functions of their atomic weights. According to Daniel Morris, in his article *Music of the New Spheres* in the December, 1969 Chemistry Magazine, Mendeleev's arrangement of the elements came to him while listening to a performance of Schumann's exquisite piano quintet. He was seated upon a sofa, apparently mulling over Newland's and Doebereiner's arrangements of the elements, when all of a sudden he jumped up, sat at his desk, and arranged all of the elements accordng to a new plan. Morris' feeling was that there was a definite relationship between the quintet and the periodic table in the repetition and development of the seven-note melody of the quintet.

Vibrations in Different Octaves

It was in 1925 that French scientist Louis Victor Pierre Raymond duc de Broglie discovered that the electron was actually a wave of vibration. These waves properly follow the same property and characteristics of vibration as the vibrating string of a musical instrument, the waves being complete with overtones. (We are familiar with the presence of overtones on the vibrating string from the experiments of Pythagoras and his *monochord* – a single-stringed instrument he built to display how musical scales were produced by the natural overtone series).

An atom such as uranium has more that 90 electrons, each capable of its own harmonies, and all this can be recorded by a spectroscope. From this, one can conclude that all matter is made of waves. Therefore, we, and the world we live in, are vibrations…just as the children of the 1960s discovered while taking large doses of LSD! But this should not be too surprising. Our understanding of the world around us is through perception of the five senses. What we experience is actually taking place in our brain, interpretations of waves of light, taste, smell, feeling, and sound. Are we really living in a world, as we suspect, or is this simply a world created in our brain, similar to that when we dream? And if spectral and aural vibrations obey the same law of octaves that applies to the physical makeup of the universe, then perhaps it is all just a part of one large keyboard of vibrations, with particular sensations and manifestations taking place in particular octave ranges. Light, heat, magnetic and chemical vibration are all subject to the law of octaves.

The ancient Greek philosopher Democritus wrote:

Sweet and bitter
Cold and warm,
As well as all the colors.
All these things exist
But in the opinion
And not in reality.

What really exists
Are unchangeable articles: atoms,
And their motions in empty space.

The great German mathematician Gottfried Wilhelm Leibniz wrote: “I am able to prove that not only light, color, heat, and the like, but motion, shape and extension too are mere apparent qualities.”

Many scientists and philosophers have come to the conclusion that everything exists in the mind: stars, planets, atoms. Einstein showed us that even space and time were forms of intuition.

Georges Gurdjieff, the important Russian spiritual teacher said that the law of octaves was based upon the discontinuity of all vibrations in nature, as they do not develop uniformly, but with periodic accelerations and retardations.

The original impulse becomes alternately stronger and weaker. This could be a phenomenon similar to the AC cycle. This cycle of alternating electrical vibrations can be viewed by means of an oscilloscope or with a computer program such as Sound Forge. Called the duty cycle, it appears as such.

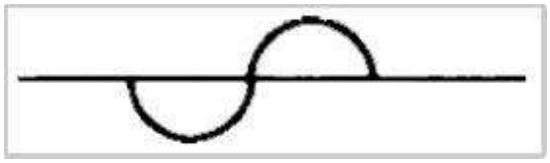

All sounds are made up of these cycles.

The cycles take place in the ***time domain***. By using a brilliant mathematical formula known as the Fourier transform, these cycles can be translated into the frequency domain, where we find that the timber of the sound depends upon the strength of overtones, the higher harmonics of the fundamental tone.

The duty cycle can be equated to a circle broken at its diameter with the bottom half twisted 180 degrees or to the continuous movement of a spiral.

Alternating current (AC) obeys the laws of the duty cycle: energy alternates with no energy.

Home electricity in the United States alternates sixty times per second, thus it is called 60 cycles, or 60 Hertz.

An electric light bulb does not continually burn, but flashes sixty times in one second, faster than our eyes can follow, so we perceive the appearance only of continuous light. This would not be the case when light is powered by a battery, as batteries produce direct current (DC).

Musical tones can be represented using the mathematical symbols of trigonometry, signs and cosigns, and the imaginary numbers of calculus.

Computer systems that generate musical tones, such as synthesizers, do so using these mathematical formulas. All of this is based on the alternation of the duty cycle.

"Shocks"

While teaching in Russia during the first world war, Gurdjieff described something about octaves that had not been publically known before. He stated that there were two places in the octave where retardation of the vibrations takes place.

These places are between the notes **E** and **F** and between the notes **B** and C. These are the two places on the keyboard where there are no sharp or flat note (black) keys between the white keys.

Octaves, according to Gurdjieff, develop according to whether or not these places where retardation of vibrations take place are "filled."

In the right development of these octaves, these places are filled by the energy of octaves that run in parallel to the given octave.

This process of filling in Gurdjieff calls a shock. Processes, institutions, laws and other things all progress through time according to the law of octaves, and therefore these two shocks in the octave are a part of the development process.

Gurdjieff stated that if development continues without the shocks being filled in, then the line of development constantly changes.

The way he described it, if octaves – as a principal of nature – develop unimpeded, the development looks as if it is proceeding along a straight line, but every time one of the two points in the octave is reached where a shock occurs, even though development of the process that the octave represents appears to be progressing forward along a straight line, the development of the process actually jogs a little, causing what would be compared to a jog in the line.

The development continues and after the progress through the series of octaves has gone on for a particular amount of time, what was considered to be development along a straight line has actually turned into a development in the ***opposite direction***! Further continuation will bring the development back to the same direction that it started in. This is actually a full duty cycle, or one full revolution on a spiral.

The law of octaves, with this intrinsic circular motion generating a spiral, governs all activity and shows how organizations, religions, and governments -- if allowed to develop without conscious knowledge concerning the application of the 'filling in' of these shocks -- always develop into something that is opposite to what was originally intended.

The Octave with Two Added Shocks

Gurdjieff explained how an octave of seven 'notes' was transformed into one of nine, the seven notes and the two shocks, by applying the following fascinating bit of arithmetic.

He divided the number **'1'** into seven equal fractions: **1/7, 2/7, 3/7, 4/7, 5/7, 6/7, 7/7**

The decimal equivalents of these seven fractions are arrived at using the time-honored tradition of dividing the numerators by the denominator:

1/7 = .142857
2/7 = .285714
3/7 = .428571
4/7 = .571428
5/7 = .714285
6/7 = .857142

Of course 7/7 equals 1

Studying the numbers that result from our division is a fascinating process.

We find that we have a reoccurring sequence of numbers that is present in every case!

This is the sequence 7142857142857….that continues on and on ad infinitum.

.142857142857142857 etc….
7/1.00000000000000000

(Numerical patterns such as these are very telling.

They describe a situation that is naturally occurring and should be taken seriously by the researcher).

The nature of this pattern is very interesting. It starts with the number **‘7’**, which is the number of the octave, the number that we are dealing with here. Next in line is double that number, **‘14’**.

Following that we have another doubling**: ‘28’**, and after that another doubling: **‘56’**…whoops, not **56**, but **57**, the **‘7’** being the start of another sequence!

It takes some thought about this to fully appreciate the beauty of this sequence and this change from **56** to **57** to start another series. This just really ***breathes*** “cycle,” does it not?

There are other interesting things about this series of numbers. If we add each line in the set of six decimals above, we always get the number **‘28’** as a result.

This is because each of the six decimal sequences is ordered in such a way that when you add downwards, only the six numbers of the sequence appear, there are no duplications.

We have six pieces of the whole **(7/7),** each with a sequence of six numbers, the same sequence in each piece, ordered in the very unique fashion. This is something to contemplate.

Now we will turn to something called horizontal addition. This is a process used in numerology.

Although we don’t endorse the common understanding of what numerology represents, the principles behind manipulation of numbers are simple aspects of natural mathematics, which demonstrate the laws of nature, and this understanding of numbers and what they are all about is the key to understanding nature and what it is all about.

That is why trigonometry and calculus are so important to engineering.

Both these sciences give us an understanding of nature, and hence, an understanding of sound, and the natural laws that govern the use of sound in music…principals that are not arbitrary, but work according to natural law, the law of three, the law of octaves, and now the law of nine (the octave plus the two shocks).

By using horizontal addition on the sequence, we arrive at another number:

1 + 4 + 2 + 8 + 5 + 7 = 27

2 + 7 = 9

Adding the sequence numbers together, we end up with ‘9’. This demonstrates one way that seven ties into nine.

The Periodicity of Nine

The notes of the octave combined with the two shocks show us what is called the ***periodicity of nine****.*

Creating a circle with nine positions and connecting the numbers from our sequence above, we have the figure that Gurdjieff calls the ***enneagram*****.**

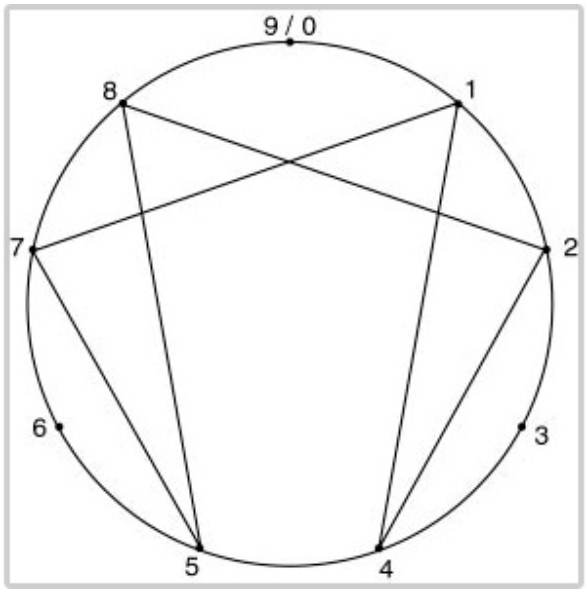

The numbers that are not in the sequence are 3, 6, and 9. When a they are connected, the result is a triangle. The numbers 3 and 6 are the shocks.

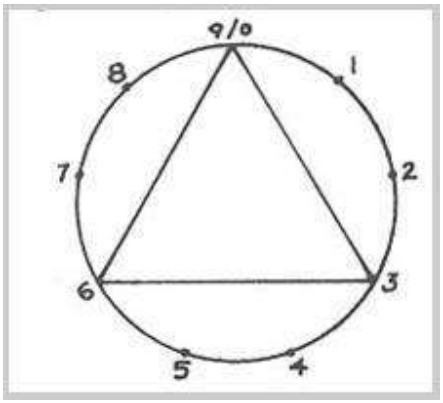

By applying the color spectrum and musical notes to the enneagram, we have the following:

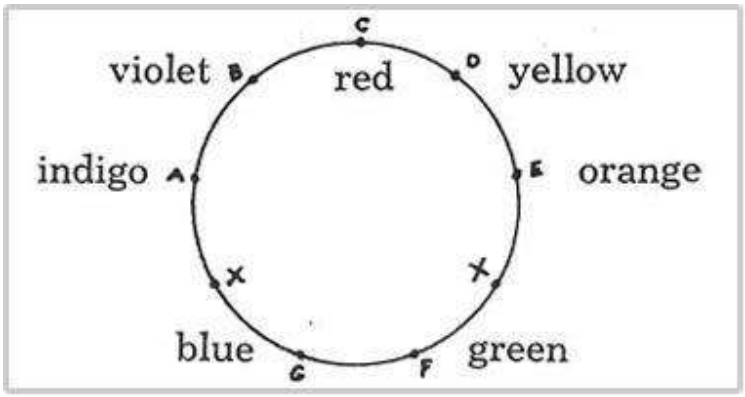

When asked why one shock correctly appeared between the E and the **F**, but the other, instead of appearing between **B** and **C**, appeared between G and **A,** Gurdjieff stated that this demonstrated the nature of the shock that occurred when passing from one octave to the next.

He also said that every completed whole, every organism, is an enneagram, but that each of these enneagrams does not have an inner triangle (**3,6,9**).

142857 is the working of the corporeal scheme, the triangle is the presence of higher elements in the organism. This inner triangle is possessed by plants, for example, from which come our “drugs”: hemp, poppy, hops, tea, coffee, tobacco.

When any number is added to nine, the sum, added horizontally to one significant figure, always equals that same number (also added horizontally to one significant figure).

Examples:

8 + 9 = 17 and 1 + 7 = 8

6 + 9 = 15 and 1 + 5 = 6

36 + 9 = 45 and 4 + 5 = 9 and 3 + 6 = 9

When any number is multiplied by nine, the product added horizontally to one significant figure, always equals nine.

Examples:

9 x 7 = 63 and 6 + 3 = 9

9 x 12 = 108 and 1 + 0 + 8 = 9

Casting Out Nines

Further use of horizontal addition is applied in a mathematical process that is called *casting* ***out nines*****.** The sum of any number added horizontally is equal to the remainder of that same number when it is divided by nine. Thus, to cast out all nines from a number, add it horizontally:

Example: **16,378 = 1 + 6 + 3 + 7 + 8 = 25 = 7**

If you were to divide **16,378 by 9**, you will find that the **remainder is 7.**

The Enneagram with Combinations of Nine

This interesting drawing shows how multiplication of nine by the other single-digit numbers produces a sum that fits nicely into our enneagram. We have equated nine with zero because nine becomes zero when it is cast. Notice how the sums are equal to the two numbers at that level of the drawing (for example, the sums on the first line are **18** and 81, on the second **72** and **27** and so on).

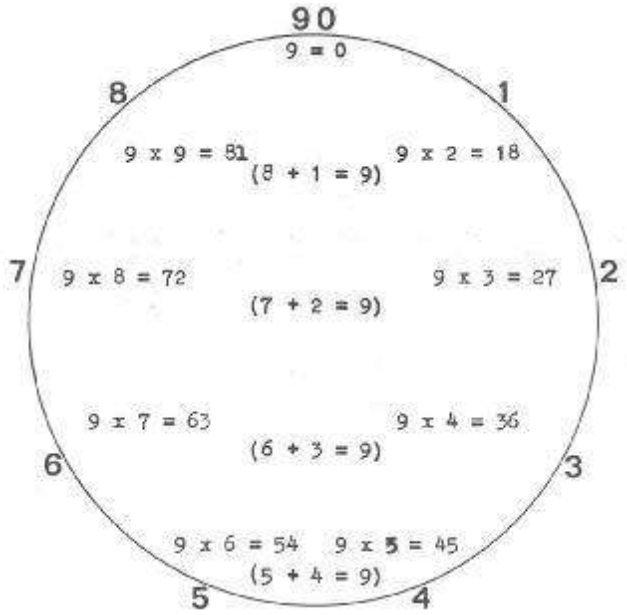

We see that by horizontal addition of the sums, in each case, we always end up with nine. If we now take each number from one to eight and multiply it by numbers **1** through **9** – we will see some interesting numerical patterns develop.

We will start with the first line from the circle above:

8 x 1 = 8
8 x 2 = 7 (16, or 1 + 6 = 7)
8 x 3 = 6 (24, or 2 + 4 = 6, and so on…)
8 x 4 = 5
8 x 5 = 4
8 x 6 = 3
8 x 7 = 2
8 x 8 = 1
8 x 9 = 9

We end up now with a sequence of 876543219.

A similar sequence is produced by doing the same thing with 1.

This sequence is the reverse of the other:

1 x 1 = 1
1 x 2 = 2
1 x 3 = 3
1 x 4 = 4
1 x 5 = 5
1 x 6 = 6
1 x 7 = 7
1 x 8 = 8
1 x 9 = 9

This is how this sequence looks on the circle:

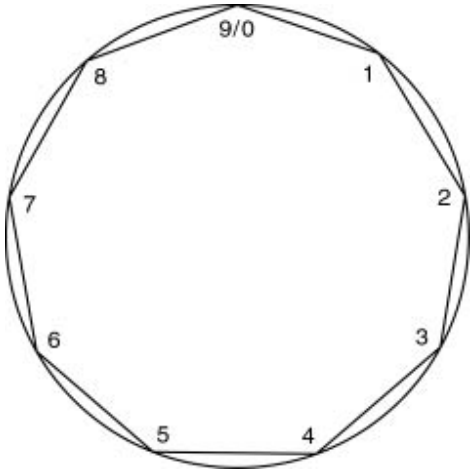

Notice that this sequence was generated by the numbers **8** and **1**, the two numbers at the top of the enneagram.

The number series that resulted from these two was the same, however one series is the reverse of the other. **For 8** we have: **876543219**, and **for 1** we have **12345789**.

To be completely the opposite of each other, the second series would have had to have been **987654321**, but interestingly enough, this isn't the case.

Now we will generate another pair of sequences using seven and two, the next set of numbers in the enneagram.

7 x 1 = 7 **7 x 2 = 5** **7 x 3 = 3** **7 x 4 = 1** **7 x 5 = 8** **7 x 6 = 6** **7 x 7 = 4** **7 x 8 = 2** **7 x 9 = 9**	**2 x 1 = 2** **2 x 2 = 4** **2 x 3 = 6** **2 x 4 = 8** **2 x 5 = 1** **2 x 6 = 3** **2 x 7 = 5** **2 x 8 = 7** **2 x 9 = 9**

This is how this sequence looks on the circle:

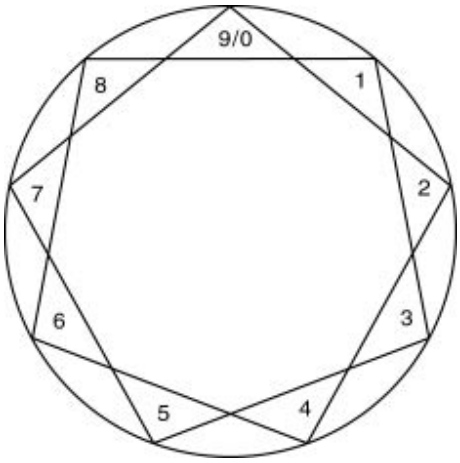

Again we have a resultant series of numbers where one is the opposite of the other.

For 7 we have 753186429, and for 2 we have 246813579.

As is the case **with 8 and 1 above, both series always ends with a 9!**

Also, the reverse series is one number off from the original.

This series of numbers is one that skips every other number.

Now we will generate another pair of sequences using five and four:

5 x 1 = 5 **5 x 2 = 1** **5 x 3 = 6** **5 x 4 = 2** **5 x 5 = 7** **5 x 6 = 3** **5 x 7 = 8** **5 x 8 = 4** **5 x 9 = 9**	**4 x 1 = 4** **4 x 2 = 8** **4 x 3 = 3** **4 x 4 = 7** **4 x 5 = 2** **4 x 6 = 6** **4 x 7 = 1** **4 x 8 = 5** **4 x 9 = 9**

This is how this sequence looks on the circle:

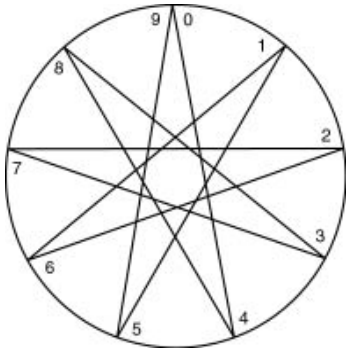

When we look at these, we see again that we have the same kind of pattern where the series from the second set is the opposite of the first, however offset by a single number, and that both end in **9**.

The series **for 5 is 516273849** and the series **for 4 is 483726159**. This series of numbers is one where three numbers is skipped each time.

Finally we will take a look at the sequence generated by the two shock values **three** and **six**:

6 x 1 = 6	**3 x 1 = 3**
6 x 2 = 3	**3 x 2 = 6**
6 x 3 = 9	**3 x 3 = 9**
6 x 4 = 6	**3 x 4 = 3**
6 x 5 = 3	**3 x 5 = 6**
6 x 6 = 9	**3 x 6 = 9**
6 x 7 = 6	**3 x 7 = 3**
6 x 8 = 3	**3 x 8 = 6**
6 x 9 = 9	**3 x 9 = 9**

This is how this sequence looks:

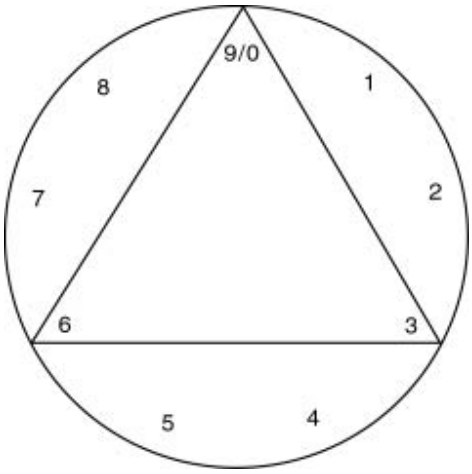

Interestingly enough, **the number 6 yields a series of 639, 639, 639**, and the series from 3 yields the opposite: **369, 369, 369. Who says the universe isn't the result of mathematics!**

We have now horizontally multiplied each number from 1 to 9 by the numbers 1 through 9 and have arrived at a series that is in each case has been illustrated using the enneagram circle, the circle with 9 points.

The numbers **1,2,4,5,7,** and **9** are the numbers found in the period **(142857).** When we look at the tables that we have just created using these numbers (that is the tables for "**8 and 1**", "**7 and 2**", and "**5 and 4**") we can see that a series of numbers has been created in each table.

For example, in the 8 table, the results from horizontally **multiplying 1 through 9 by 8** resulted in a pattern (reading down the sum column) of **876543219** and the results from horizontally **multiplying 7 by 1 through 9 is the sequence 753186429.**

Now, taking the **third**, **sixth**, and **ninth** numbers in each of these series, we discover that we have a repeating sequence of either **639** or **369**. These are the "**inner triangles**" of each one of these sets

8 x 1 = 8 **8 x 2 = 7** **8 x 3 = 6** **8 x 4 = 5** **8 x 5 = 4** **8 x 6 = 3** **8 x 7 = 2** **8 x 8 = 1** **8 x 9 = 9**	**1 x 1 = 1** **1 x 2 = 2** **1 x 3 = 3** **1 x 4 = 4** **1 x 5 = 5** **1 x 6 = 6** **1 x 7 = 7** **1 x 8 = 8** **1 x 9 = 9**	**7 x 1 = 7** **7 x 2 = 5** **7 x 3 = 3** **7 x 4 = 1** **7 x 5 = 8** **7 x 6 = 6** **7 x 7 = 4** **7 x 8 = 2** **7 x 9 = 9**	**2 x 1 = 2** **2 x 2 = 4** **2 x 3 = 6** **2 x 4 = 8** **2 x 5 = 1** **2 x 6 = 3** **2 x 7 = 5** **2 x 8 = 7** **2 x 9 = 9**	**5 x 1 = 5** **5 x 2 = 1** **5 x 3 = 6** **5 x 4 = 2** **5 x 5 = 7** **5 x 6 = 3** **5 x 7 = 8** **5 x 8 = 4** **5 x 9 = 9**	**4 x 1 = 4** **4 x 2 = 8** **4 x 3 = 3** **4 x 4 = 7** **4 x 5 = 2** **4 x 6 = 6** **4 x 7 = 1** **4 x 8 = 5** **4 x 9 = 9**
order: 639	**order: 369**	**order: 369**	**order: 639**	**order: 639**	**order: 369**

We will now show each number and the order of its series.

This order, as you have just seen, was determined by the inner triangle of each series (**the points of 3, 6 and 9 on the circle**) and number present at those point turn out to be either a sequence of **639** or **369**.

639 represents energy moving counter clockwise and **369** is the **energy moving clockwise.**

For purposes of demonstration, we will fix polarity designations to the **639** and **369**.

We will call **369 positive** and **639 negative**.

The numbers **3**, **6** and **9**, not being part of the periods, we will call neutral **(=)**:

Note	Number	Order	Polarity
C	**0**		**=**
D	**1**	**369**	**+**
E	**2**	**639**	**-**
(shock)	**3**		**=**
F	**4**	**369**	**+**
G	**5**	**639**	**-**
(shock)	**6**		**=**
A	**7**	**369**	**+**
B	**8**	**639**	**-**
C	**9**		**=**

We will turning again to the sequences that we created above.

For simplicity sake, we will just use the forward sequence from each set.

These sequences were:

123456789 (from 8-1),
135792468 (from 7-2)
639639639 (from 6-3) and
159483726 (from 5-4).

Applying the polarities we assigned in the chart above to these sequences we get:

8-1	**1 2 3 4 5 6 7 8 9**
	+ - = + - = + - =
7-2	**1 3 5 7 9 2 4 6 8**
	+ = - + = - + = -
6-3	**6 3 9 6 3 9 6 3 9**
	(all neutral)
5-4	**1 5 9 4 8 3 7 2 6**
	+ - = + - = + - =

[1] It is noted that modern theory of colors has adapted new colors to represent the subtractive domain of primary colors, and some writers go so far as to dispute the standard primary colors, but we stand by what we have written: red, yellow and blue are the primary colors.

For more information about modern color theories, see: http://www.goatrance.de/mahak/colors.html
http://www.physicsclassroom.com/Class/light/U12L2d.html

UNIVERSAL LAWS NEVER BEFORE REVEALED: KEELY'S SECRETS

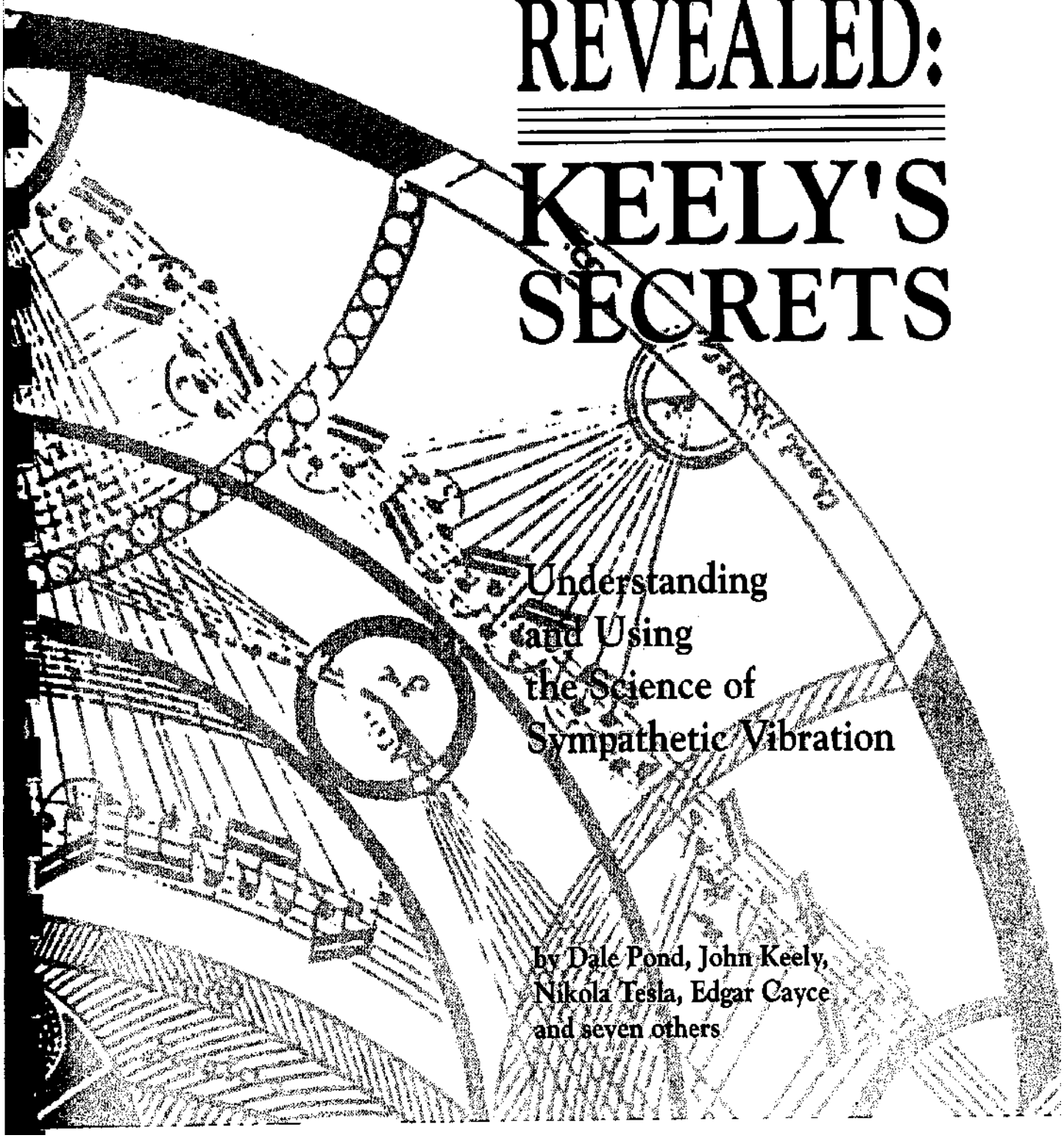

Understanding and Using the Science of Sympathetic Vibration

by Dale Pond, John Keely, Nikola Tesla, Edgar Cayce and seven others

NEW REVISED EDITION

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I wish to thank all those who have helped directly and indirectly in the preparation of this work. Especially those lonely geniuses of old who bore the brunt of derision and ridicule, never faltering in the thankless task of bringing the Light of Understanding to the Minds of Men. With special gratitude to the memory of Mrs. Clara Sophia Jessup Bloomfield-Moore in her courage and strength to stand by such a Man as John Ernst Worrell Keely, even in the face of public scorn, and humiliation. No less thanks go to The Theosophical Society* for their Light-Bearing efforts, The Rosicrucian Order AMORC*, for their centuries of thankless toil and to the Association for Research and Enlightenment and its employees for their support and encouragement. No less do we thank those unnamed ones who have withstood the fury of ignorance of past ages in order that Man may Evolve to his rightful place. It is with truth and humility that "The few carry the many."

This book contains a vast collection of material on Keely and his work. In it has been included all the pictures and charts known to exist as of this date. I have also included all that we have been able to decipher of this wonderful new science and philosophy. There will be more discoveries and these will be published at a later date. The discoveries mentioned here demonstrate that Keely's science of *Sympathetic Vibratory Physics* is a wholistic approach to science and nature and reveals a wonderful order and simplicity.

It is hoped readers will find a number of ideas and methods in these pages which they can apply to their current scientific work and research.

Dale Pond

Author's Note: There has been a great deal of discussion concerning the motives and belief systems of these two organizations. It is taken herein that the *original* intent and purpose of these groups was the preservation and disseminations of *real TRUTH* from the ancient days to the present. We, as human beings, can now more properly partake and use the forces and knowledge contained in their *original* knowledge bases. It is further recognized that these organizations may have more or less "lost their way" during the past two or three centuries. Perhaps the present day motivations and directions being assigned to them are in error – perhaps not. It is not to these I give thanks but to their original intent and accomplishments. For, it is, I believe, through the efforts of these *original* organizations that certain specific and valid information was indeed preserved and brought through the centuries of ignorant persecution that we, through Keely's efforts (and others'), may understand and use same. *Dale Pond*

ABOUT THE AUTHOR/EDITOR

Dale Pond is truly a renaissance man with a diversified background in chemistry, physics, mechanical engineering, computers, mathematics, acoustics, hydrodynamics, geometry, music, and common law.

His vast experience includes technical writing, inventing, lecturing, corporate training, business, manufacturing, publishing and authoring scientific and philosophical journals and books.

At the leading edge of new paradigm thinking, he has been able to show that vibration is the principle underlying all things. Vibration is the link between spirit and matter - the magic key for creating new worlds and universes.

As an internationally renowned lecturer, Dale has presented workshops and seminars at the Swiss Association for Free Energy Conference, the International Keely Conferences, Sound and Vibration Conference, International Symposium on New Science, International Forum on New Energy, United States Psychotronics Association Conference, the Alchemy of Sound Conference and many others.

Other books by Mr. Pond:

Sympathetic Vibratory Physics - A Compendium of Terms and Phrases
Sympathetic Vibratory Physics Certification and Training Course - Level I
Nikola Tesla's Earthquake Machine
HyperVibes (a Hypercard research reference library for SVP)
A History of the American Constitutional or Common Law
Our American Common Law
The Physics of Love
John Keely's Musical Dynasphere

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Disintegration of Stone

1888

A short time ago the mining world in America was seized with an inexplicable excitement. The value of gold mines in particular suddenly rose. Mines long since abandoned on account of the expense of working, awoke, and rubbing their eyes made their way again into the stock list. Presently it leaked out that a syndicate of the longest-headed and wealthiest mining capitalists were quietly buying up all the cheap and apparently worthless gold mines they could hear of, and people at once concluded that something was up. Then everyone of a speculative turn, very knowingly began to buy worthless gold mining shares at ever-increasing prices, and when the little speculators had gorged themselves to the full extent of their financial capacity, they asked: What next? No one knew exactly what he was after; and everyone looked to the Syndicate for the next move; but the Syndicate smilingly put its hands in its pockets and whistled! After the fever came prostration. The small fry had not, like the Syndicate, bought to hold, so they got first uneasy, then alarmed, and finally panic-stricken. The tide of credulity turned and began to run out even more quickly than it had set in, and thousands of the unlucky, but greedy little grudgeon of the Stock Exchange were left stranded in a short time by the receding tide of speculation, kicking and gasping in the mortal agonies of financial asphyxia. The panic is easily accounted for by the general laws that govern the movements of the Stock Exchange; but not so the action of the syndicate. The problem remains: Why did the long-headed millionaires buy up worthless mines? That is the point of interest, and the explanation thereof is as follows:---

A few weeks before the panic occurred, twelve solid men - millionaires - met by appointment in a certain laboratory in Philadelphia to witness an exhibition of the disintegration of quartz by a new method. They were mining magnates, who had a tremendous interest in getting the gold out of quartz rock quickly and cheaply. The inventor obliged them by simply touching some blocks of quartz with a little machine he held in his hand; and as he touched each block it instantly crumbled into atomic dust, in which the specks of gold it had contained stood out like boulders in a bed of sand. Then the twelve solid men solidly said: Mr. Keely, if you will in the same manner disintegrate some quartz for us in its natural place, we will each of us give you a cheque for --- dollars. So off they all went to the Katskill mountains, and there the twelve solid men pointed out a reef of quartz on the side of a mountain, as solid as themselves; and Mr. Keely took out his little machine and said: Gentlemen, please take the time. In eighteen minutes there was a tunnel in that quartz mountain eighteen feet long and four and a half feet in diameter. Then Mr. Keely quietly returned to Philadelphia with his cheques in his pocket, and the twelve solid men went from New York to San Francisco to gather in the seemingly worthless stock of mines long disused because of the working expense, thus producing the disastrous effect upon the mining world, which we have just seen. (All these men bound themselves to secrecy; and this is the first time that this incident has been made public.)

How was the quartz disintegrated?--That is one of Keely's secrets.

The disintegration of the rock is, however, a very small and accidental ef-

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fect of that tremendous force that lies behind the secret. Indeed, that particular application of the force was a chance discovery. One day the inventor was studying the action of currents of ether playing over a floor upon which he had scattered fine sand,---the ether was rolling the sand into ropes,---when a block of granite, which was used for fastening back a door, disintegrated under his eyes. He took the hint, and in a few days he had made a vibratory disintegrater.

Who is this man, and what is this force? to whom, or to which, boring a tunnel into the mountain side is mere child's play? Surely, were such things true, science would long ago have filled the world with the renown of such a man---the man who has discovered a force in nature compared to which all known motor or mechanical forces are like the scratch of a nail, or the breath of a child. Surely the press, the platform, and even the pulpit would have resounded with the glad tidings of so great a victory over the stubborn powers of nature, a victory which goes so far towards making man the master of things in this material plane!

Those who argue like that know little of modern science and its votaries. An Anglican bishop never ignored a dissenting preacher with more dignified grace than the professor of orthodox science ignores the heterodox genius who has the audacity to wander beyond the limitations which received opinion has placed upon the possibilities of nature. The fact is that men of science have persistently ignored, and know absolutely nothing about, the great department of nature into which Keely penetrated years ago, and in which he has now made himself at home. Not long ago a Fellow of the Royal Society of Edinburgh, Major Ricarde-Seaver, went to Philadelphia to convince himself as to the nature of Keely's discovery. He returned, saying that Keely was working with, and had the apparent command over forces, the nature, or even the very existence, of which was absolutely unknown to him, and so far as he is aware, to modern science.

Beyond disintegration lies dispersion, and Keely can just as easily dissolve the atoms of matter as disintegrate its molecules. Dissolve them into what? Well,---into ether, apparently; into the hypothetical substratum which modern scientists have postulated, and about whose nature they know absolutely nothing but what they invent themselves, but which to Keely is not a hypothesis, but a fact as real as his own shoes; and which ether, indeed, seems to be the protoplasm of all things. As to the law of gravity, it appears very like a delusion, in the light of Keely's experiments, or, at least, but one manifestation of a law of very much wider application---a law which provides for the reversion of the process of attraction in the shape of a process of repulsion. One of Keely's little scientific experiments is to put a small wire round an iron cylinder that weighs several hundred weight, and when the force runs through the wire, to lift the cylinder up on one finger and carry it as easily as if it were a piece of cork. Not long ago he moved, single-handed, a 500 horse-power vibratory engine from one part of his shop to another. There was not a scratch on the floor, and astounded engineers declared that they could not have moved it without a derrick, to bring which in operation would have required the removal of the roof of the shop. Of course it is but a step in advance of this to construct a machine which, when polarized with a negative attraction, will rise from the earth and move under the influence of an etheric current at the rate of 500 miles an hour, in any given direction. This is, in fact, Keely's air ship.

Lately, he has applied his force to optics, and by means of three wires placed across the lens of a microscope he makes its magnifying power equal to that of the great telescope in the Lick observatory - the largest in the world. Why don't all astronomers and opticians run to look through Keely's microscope, and to examine into the process? Perhaps if Galileo were alive he might express an opinion!

But, the reader may naturally ex-

claim, how long has this been going on, and we to know nothing about it? Mr. Keely is now over 60 years of age, and he has worked since he was a boy, at times, upon various inventions before his discovery of ether. For the last 18 years he has been constantly employed with experiments upon the ether; for eighteen long years he has worked day and night, with hand and brain, in the face of discouragements that would long ago have killed the owner of a less heroic soul; and he has worked almost single handed. Slander, ridicule, open accusations of fraud, charlatanry, insanity---everything evil that it could enter the head of the knave of the heart of the fool to conceive, every mean insinuation, every malicious lie that prejudice, bigotry, ignorance, self-conceit, vested interests, greed, injustice, dishonesty, and hypocrisy could concoct---these have been the encouragement which, so far, the world has bestowed upon the discoverer of the profoundest truths and laws of nature that have ever been imparted to the profane, or even hinted at, outside of the circle of initiates. And now it has been proved in a hundred ways, and before thousands of persons competent to judge of the merits of his machines, that he has really discovered previously unknown forces in nature, studied them, mastered some of their laws, invented, and almost perfected, apparatus and machinery that will make his discoveries of practical application in a hundred ways---now that he has actually done all this, how does the world treat him? Does Congress come forward with a grant to enable him to complete his marvelous work? Do men of science hail him as a great discoverer, or hold out the hand of fellowship? Do the people do honour to the man whose sole entreaty to them is to receive at his hands a gift a thousand times more precious to them than steam engine or telegraph? It is a literal fact that the world to-day would tear Keely to pieces if it had the power to do so, and if he fell exhausted in the terrible struggle he has so long maintained, his failure to establish his claims would be received with a shout of malignant delight from nearly every lecture hall, pulpit, counting-house, and newspaper office in the so-called civilized world! The world has hardly ever recognized its benefactors, until it has become time to raise a statue to their memory; 'in order to beautify the town.' Jealousy, stupidity, the malignity which is born of conscious inferiority, are at this moment putting in Keely's road every impediment which law and injustice can manufacture. Two hundred years ago he would have been burned, a century since he would have been probably mobbed to death, but thank God we are too civilized, too humane to burn or mob to death those who make great discoveries, who wish to benefit their fellow men, or whose ideas are in advance of their age - we only break their hearts with slander, ridicule, and neglect, and when that fails to drive them to suicide, we bring to bear upon them the ponderous pressure of the law, and heap upon them the peine forte et dure of injunctions, and orders, and suits, to crush them out of a world they have had the impertinence to try to improve and the folly to imagine they could save from suffering without paying in their own persons the inevitable penalty of crucifixion. Had it not been for the obligations incurred by Mr. Keely, writes Mrs. Bloomfield-Moore in the Philadelphia Inquirer, of Jan. 20th of this year, in accepting the aid of the Keely Motor Company - in other words, had scientists, instead of speculators, furnished him with the means necessary to carry on his 'work of Evolution,' the secrets which he has so carefully guarded would now have been public property, so little does he care personally for financial results. As it is, those who have witnessed his beautiful experiments in acoustics and sympathetic vibration were often too ignorant to comprehend their meaning, and, consequently, even after expressing gratification to him, went away from his workshop to denounce him as a Cagliostro, while others, competent to judge, have refused to witness the production of the ether, as Sir William Thomson and Lord Raleigh refused when they were in America a

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few years since. The company here mentioned has been a thorn in the inventor's side ever since it was organized. It has been bulled and beared by greedy speculators, in whose varying interests the American newspapers for years have been worked, the results of which the inventor has had to bear. For many years the Company has contributed nothing towards Mr. Keely's expenses or support, and in the opinion of many lawyers it is virtually dead. How far it is entitled to his gratitude may be gathered from the fact, as stated in Mrs. Bloomfield-Moore's article above quoted, that when Mr. Keely abandoned his old generator of etheric force, baffled in his attempts to wrest from nature one of her most carefully guarded secrets, harassed by his connection with the Keely Motor Company, some of the officers and stockholders of which had instituted law proceedings against him, which threatened him with the indignity of imprisonment, he destroyed many of his marvelous models, and determined that, if taken to prison, it should be his dead body and not himself.

When the history of his discoveries and his inventions come to be written there will be no more pathetic story in the annuals of genius than that of John Worrell Keely. The world hereafter will find it hard to believe that in the last quarter of the 19th century a man with an insight into the secret workings of nature, and a knowledge of her subtler forces, which, whenever it is utilized, will relieve mankind from much of the grinding toil that now makes bitter the existence of the vast majority of mortals, that such a man should have been left to starve, because in all the ranks of Science there was not found one man capable of understanding his colossal work - because in all the ranks of religion there was not found one man able to realize the enlarged conception of Deity immanent in Keely's great thoughts - because in all the ranks of commerce, of speculation, of literature, of art, there was not found one man large enough, generous enough, unselfish enough, to furnish money for a purpose that did not promise an immediate dividend.

It is to a woman, not a man, that the eternal honour is due of having come to Keely's rescue, and saved humanity from once more disgracing itself by doing genius to death with broken-hearted want and neglect. That woman's name will go down the centuries inseparably connected with Keely's discoveries. Probably no more romantic incident ever happened in the history of invention than the connection between this wealthy and large-minded woman and this slandered and persecuted genius, and no stranger one than the way in which she was led, by a series of most unfortuitous events, to offer her aid. From that day this lady has been not only his benefactor, but also his co-worker, trusted friend, and courageous defender. With the exception of his friend, those who have occupied themselves with Keely's discoveries have confined their attention to its commercial value. This was to be expected, for Science now is the hand-maid of trade, and Religion has become the fawning follower of Science. There is, however, a higher aspect to Keely's discoveries, and that their value as contributions to man's knowledge of Nature and natural laws. So far as that is concerned, Keely's success is an accomplished fact. His work, explaining his whole system, is now in the Press, and were he to die tomorrow he will be just as great a figure in the world's history as he would be were a thousand speculators to clear ten million dollars apiece by his inventions. Fancy honouring Copernicus or Galileo because the yelping jackals of speculation, who were their contemporaries, grew fat by feeding on their brains!

Whether Keely's inventions will be commercial success at present is another matter. The force, or, rather forces, which Keely handles, are the same as those known under other names in Occultism, and it is the belief of Occultists that these forces cannot be introduced into the practical life of men, or fully understood by the uninitiated, until the world is fit to receive them with

benefit to itself - until the balance of the good and the evil they work is decidedly on the side of the good. Keely himself is persuaded that the world will derive almost unmixed benefit from his discoveries; but an Occultist would prefer to say that inventions and discoveries are disclosed to man, rather than to credit genius with the elaboration of ideas - disclosed, that is to say, through the brain of the ostensible inventor by one of the higher powers that guide the destinies of humanity. The discoveries of Keely have an occult side, which perhaps he himself may not fully perceive, but it is upon that side that it depends whether those discoveries themselves are fitted, by reason of sympathetic vibration of a still more inner ether than Keely has publicly spoken of, to harmonize with the mass chord of our present civilization, and manifest in the material life of man. Occultists believe that there are intelligent powers behind the visible things and events of life, which powers alone can say So far shalt thou go, and no further; but they do not believe that these powers act as a deus ex machina, for in themselves they are part of the natural order of things, and act in and through material and immaterial nature. We at present in our normal state of consciousness know these powers only as forces and laws, and when we become conscious of them as intelligent entities, we perceive at the same time that they themselves are governed by higher wills and intelligences, which act through them, as they act through us, and are to them their forces and their Laws.

*Occultists see in everything the (to us) eternal action of two opposing powers or principles, which are ever seeking equilibrium, and never find it, for behind them there is a definite tendency towards that which we call progress, which tendency gives the preponderance to one of these powers, and thus prevents the establishment of equilibrium, in other words of stagnation and death. Now all great discoveries are manifestations of one of these powers or forces only, and, however good in themselves, tend to disturb the equilibrium of terrestrial life more than is required for the normal rate of universal progress; and therefore they produce a disproportion of parts, and the opposite power or force gathers strength to resist and check the exaggeration. Already, in the estimation of an ever-growing number of thinking men, the inventions and discoveries of the present century have proved themselves a curse rather than a blessing. The have raised the world's standard of comfort, and at the same time they have lowered the power of purchasing these very comforts, a desire for which they have generated. The advantages that accrue from steam and from machinery have not been distributed, but have become the property of a small minority. Year by year competition is becoming fiercer, and labor more arduous and continual, and men are growing more and more like living machines, and the helpless slaves of machinery and of institutions. An operative, in these days of steam power, has less liberty than a slave ever had, ex-

* Franck, in Die Kabballa, says: We learn, by the last three Sephiroth, that the Universal Providence, that the Supreme Artist, is also Absolute Force, the all-powerful Cause; and that, at the same time, this cause is the generative element of all that is. It is these last Sephiroth that constitute the natural world, or nature in its essence and in its Active principle, Natura naturans. This passage is quoted in Isis Unveiled (Vol.I,p.40), the authoress adding: "This Kabalistic conception is thus proved identical with that of the Hindu philosophy. Whoever reads Plato and his Dialogue Timaeus, will find these ideas as faithfully re-echoed by the great philosopher." They are all, in fact echoes of the archaic Secret Doctrine of the Occultists; and it is somewhat singular (pour le dire en passant) that the newspaper press so persistently refers to Theosophy as a new, or new-fangled, religion or philosophy, whereas the ideas now called theosophical are the oldest in the world, and may be found, more or less disguised or mutilated, and under many different forms and names, in all the great philosophical and religious sytems of antiquity. One is forced to conclude that the complaint, so often heard, that competition now compels young people to earn their bread while they ought still to be at school, applies with a good deal of force to a certain class of writers for the press.

cept in one particular - he has full liberty to starve, or to work himself to death, neither of which privileges an owner would allow him. Keely, however, thinks his discoveries will restore this disturbed equilibrium.

The direct effect of modern discoveries and inventions has been the rise of the commercial and economic system; and the inevitable consequence of that system has been to deepen the gulf between the poor and the rich. The natural effect of this is an antagonism between the two poles of society, which has its roots deep down in human nature and human passions, and this antagonism is becoming better recognized, and growing in intensity, year by year, in so much that it is almost universally felt that the only possible outcome from it is a social overturning, the date of the actual occurrence of which will depend chiefly upon the activity of the schoolboards, and the thoroughness of their work. Hardly a thinking man of the present day but foresees, sooner or later, a great social cataclysm, in which all mere political and financial considerations will be as straws in a whirlwind. Now, it would seem that Keely's discoveries tend to develop power over material nature in the same direction in which that power has been growing during the last hundred years. If it be a power into the exercise of which there enter no moral considerations whatever, then it is applicable alike for good purposes and for evil; and it will be as ready to the hand of the bad man as to that of the good. Were such inventions given to the world in their completeness, the whole of the enormous power they gave over human life and destines would, it would seem, fall into the possession of the same small minority who at present control the power conferred by our present inventions and discoveries - the capitalists. If so, that section of the community would then, under our present institutions, obtain almost absolute power over the great majority - those who depend upon their labor for their support. The capitalists who owned the tremendous powers implied in a monopoly of Keely's inventions would be practically the absolute masters of the people; and obedience to their will would be far more really, than even now, the condition upon which those who were not capitalists also would be allowed the means of continued existence.

Occultists believe that the world is not yet ready for the appearance of such tremendous forces on the stage of human life. Mankind is too selfish, too cruel, too stupid, too pitiless, too animal, to be entrusted with what, in sober reality, are minor divine powers. Such powers could not at present be employed for the benefit of mankind and for the advancement of the race; on the contrary, they would tend to the further brutalization and virtual enslavement of the poor, and also to the further materialization and moral degradation of One the rich. In a word, the human qualities of justice, mercy, love, generosity, unselfishness, have not yet grown strong enough in the race, and the animal qualities of revenge, anger, jealousy, tyranny, hatred, selfishness, are still too powerful in man to make the acquisition of almost absolute power over nature, and over one another, anything but a curse to mankind. It would be less disastrous to give dynamite cartridges to monkeys for playthings.

For this reason Occultists, in general, do not regard Keely's discoveries as likely to succeed in the commercial sense. And at present things have certainly a look that is in accordance with that opinion. The powers that might be expected to intervene in order to prevent Keely's inventions from becoming factors in human life, are, as has been said, through human means, and the stolid stupidity of the scientists in regard to Keely's discoveries, the bovine indifference of theologians, the silly ridicule of the press, the hostility of vested interests, the suicidal greed of some of the largest shareholders, and the paralyzing influence of the law, which apparently lends itself in this case to those whose object is simple robbery. All these things seem very like the operation of the higher controlling powers,

acting with a consciousness other than our consciousness for the attainment of ends that transcend our narrow calculations.

Be this as it may, Keely's discoveries, and Keely's personality also, have a peculiar interest for Theosophists, for the force with which he is working is without doubt the ether of the ancient philosophers, which is one aspect of the Akasa, the underlaying great force in nature, according to the Secret Doctrine, a force whose existence has been recognized from time immemorial under various fanciful names, and whose property is sound, whether audible or inaudible to us; or, in more modern language, whose characteristics are vibration and rhythm. It corresponds to the seven-fold Vach of Hindu Philosophy, and is the raison d'etre of spells and Mantrams. It is the basis of harmony and melody throughout Nature. This force is alluded to many times in Madame Blavatsky's Isis Unveiled. On page 139, vol I., we read: The Akasa is a Sanscrit word which means sky, but it also designates the imponderable and intangible life principles, the astral and celestial lights combined together, and which two form the anima mundi, and constitute the soul and spirit of man; the celestial light forming his nous, pneuma, or divine spirit, and the other his psyche, soul, or astral spirit. The grosser particles of the latter enter into the fabrication of his outward form, the body. The Akasa is connected on the one hand with physical matter and on the other with WILL, that intelligent, intangible, and powerful something which reigns supreme

over all inert matter. Of the Akasa in this respect we read on page 144, vol.I., of Isis Unveiled: The mysterious effects of attraction and repulsion are the unconscious agents of that will; fascination, such as we see exercised by some animals, by serpents over birds, for instance, is a conscious action of it, and the result of thought. Sealing-wax, glass, and amber, when rubbed, *i.e.*, when the latent heat which exists in every substance is awakened, attract light bodies; they exercise unconsciously Will; for inorganic as well as organic matter, however infinitesimally small it may be, possesses a particle of the divine essence in itself... What is, then, this inexplicable power of attraction but an atomical portion of that essence that Scientists and Kabalists equally recognize as the 'principle of life' - the Akasa? Granted that the attraction exercised by such bodies may be blind; but as we ascend higher the scale of organic beings in nature, we find this principle of life developing attributes and faculties which become more determined and marked with every rung of the endless ladder. Man, the most perfect of organized beings on earth, in whom matter and spirit - i.e., Will - are the most developed and powerful, is alone allowed to give a conscious impulse to that principle which emanates from him, and only he can impart to the magnetic fluid opposite and various impulses without limit as to the direction. Isis Unveiled was published nearly eleven years ago; and in her forthcoming work, The Secret Doctrine, the authoress enters more fully into this and other matters only sketched or hinted at in her former volumes.

It is the fact that Keely is working with some of the mysterious forces included under the name Akasa that makes his discoveries interesting to Theosophists. It is the fact that he has shown magnificent courage and fixity of purpose under every kind of opposition, and the fact also that he has been supported all through by the generous belief that his discoveries will be of inestimable benefit to mankind that make his personality of interest. If he can succeed in making his marvelous discoveries pay dividends, science may begin to give attention to them; for men of science, like other men, require a sign before they can accept as truth the things that are beyond their comprehension, and the value of a scientific discovery is now determined by its market value.

R. Harte (Sec. T.P.S.)
July, 1888

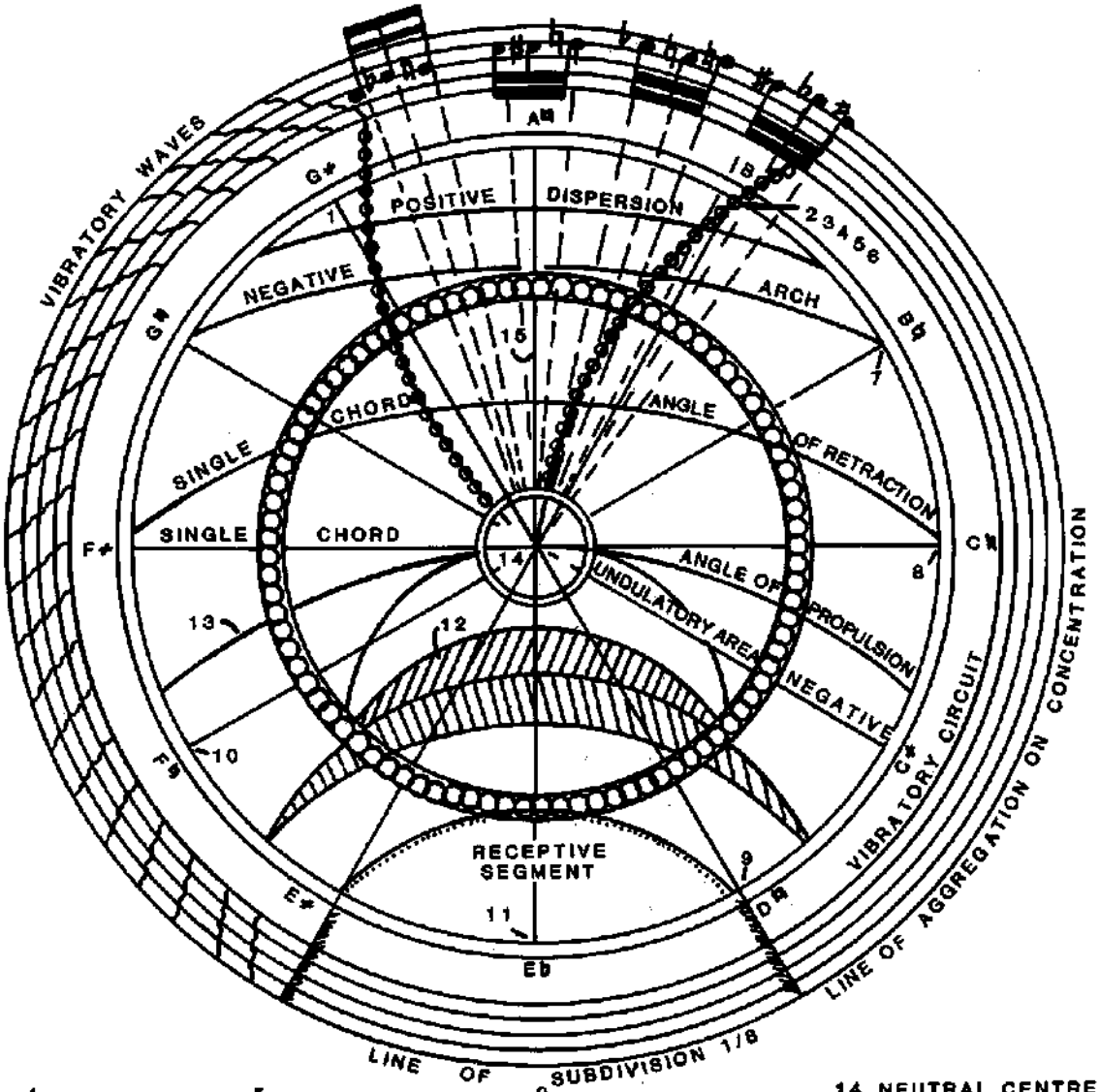

1 CHORD Ab 1st OCTAVE

2 CHORD OF EQUATION 5th OCTAVE

3 QUADROPLE CHORD 3rd OCTAVE

4 CHORD OF RADIATION 1st OCTAVE

5

6 NEUTRAL CHORD ANY OCTAVE

7 MOLECULAR AGGREGATION

8 ETHERIC CHORD 8th OCTAVE

9

10

11 SYMPATHETIC CHORD OF TRANSMISSION

12 HIGH CONCENTRATION DIVERGENCE

13 UNDULATORY AREA POSITIVE

14 NEUTRAL CENTRE

15 VIBRATORY RADIATION

KEY TO VIBRATORY ROTATION

DESIGNED BY

John W. Keely

JANUARY 1886

Etheric Force Identified as Dynaspheric Force

Clara Jessup Bloomfield-Moore

"Science is to know things."

Herodotus.

"Knowledge is developed by experience from innate ideas."

Plato

"Truth is not attained through reflection, but through immediate intuition. We neither originate thought nor its form."

Aryan Teachings

"It may be said that if all things come from only one cause or internal source, acting within itself, then motion and matter must be fundamentally and essentially one and the same, and we look upon matter as being latent force and upon force as being free matter."

Franz Hartmann, M.D.

JOHN WORRELL KEELY---the discoverer of compound inter-etheric force, as operating in the animal organism, man - is a great thinker, and a great student of the capabilities of nature in offering to man's intelligence the means whereby he may discover for himself the secrets she often veils without entirely concealing.

The result of more than twenty years of persistent effort to apply this force to the operation of machinery has, at last, been enabled to produce continuity of motion in his engine; but, up to this time, he has not so mastered this subtle force as to control reversions. The development of his various discoveries has been one uninterrupted work of evolution, reaching, within the last year, he thinks, the sphere of perfect vibratory sympathy, both theoretically and practically. The proof of this is found in the fact that he now transmits vibrations along a wire, connected at one end with the vibratory machine which is the source of power, and at the other end with the engine or cannon, as the case may be, which is operated by such vibratory power. Until recently, comparatively speaking, Keely stored force, as he generated it, in a receiver; and experiments were made by him in the presence of thousands, at various times, for the purpose of testing the operations of this force, liberated in the presence of his audience and stored up in this small receiver. The editor of the Scientific Arena thus describes what took place at one of these exhibitions, when he was present:---"The confined vapor was passed through one of the small flexible tubes to a steel cylinder on another table, in which a vertical piston was fitted so that its upper end bore against the underside of a powerful weighted lever. The superficial area of this piston was equal to one-half of a square inch, and it acted as a movable fulcrum placed close to the hinged end of the short arm of this lever, whose weight alone required a pressure of 1,500 pounds to the square inch against the piston to lift it.

After testing the pressure by several small weights, added to that of the lever itself, in order to determine how much power had already been accumulated in the receiver, the maximum test was made by placing an iron weight of 580 pounds, by means of a differential pulley, on the extreme end of the long arm of the lever. To lift this weight, without that of the lever supporting it, would require a pressure against the piston of 18,900 pounds to the square inch, counting the difference in the length of the two arms and the area of the piston, which we, as well as several others present, accurately calculated. When all was ready, and the crowded gathering had formed as well as possible to see the test, Keely turned the valve-

Universal Laws Never Before Revealed.. Keely's Secrets

wheel leading from the receiver to the flexible tube, and through it into the steel cylinder beneath the piston, and simultaneously with the motion of his hand the weighted lever shot up against its stop, a distance of several inches, as if the great mass of iron had been only a cork. Then, in order to assure ourselves of the full 25,000 pounds to the square inch claimed, we added most of the weight to the arm of the lever without forcing the piston back again.

After repeating this experiment till all expressed themselves satisfied, Keely diverted his etheric gas to the exciting work of firing a cannon, into which he placed a leaden bullet about an inch in diameter. He conveyed the force from the receiver by the same kind of flexible copper tube, attaching at one end of it to the breech of the gun. When all was again in readiness he gave a quick turn to the inlet valve, and a report like that of a small cannon followed, the ball passing through an inch board and flattening itself out to about three inches in diameter, showing the marvelous power and instantaneous action of this strange vapor.

The difficulty encountered by Keely in his old generator of etheric force grew out of the fact, in part, that the vaporic power produced was so humid that he could not, when he attempted to utilize it, obtain its theoretical value in work. This difficulty has been entirely overcome by dispensing with the water which he used in liberating etheric force, by his old generator; and, by this departure, he has attained a success beyond that which we anticipated by himself, when he abandoned his original line of experiment. Ignorant, indeed, of the nature of Keely's work must those men be who accuse him of "abandoning his base" or "principle," each time that he discovers his mistakes:---using them as stepping-stones to approach nearer and still nearer to his goal. Reproaching him, even, for keeping his own counsel, until certainty of success rendered it prudent for him to make known that he had changed his field of experiment from positive attraction to negative attraction, he had succeeded in his efforts to produce continuity of motion. Equally ignorant are those, who would wrench by force his secrets from him before the time is ripe for their disclosure. Let us suppose that Faraday, when he discovered radiant matter in 1816, had formed a "Faraday Phospho-Genetic Radiant Company," to enable him to experiment: fully cognizant of all that Crookes has since discovered, and had taken for his base in experimenting the principle involved in Crookes' discovery. Not succeeding at first, we will suppose that the Company became clamorous for returns, and demanded that his secret principle should be made public. Had he been driven into making known, who would have credited what Crookes is now able to prove? The effect would have been upon the Faraday Company the same as if a balloon were punctured just as it was soaring heavenward. The same with the Keely Motor Company, had Keely obeyed the order of the Court in 1882, and made his marvelous secret public. It would have collapsed. Therefore, he has maintained his secret in the interests of the stockholders of the Keely Motor Company with a firmness worthy of a Christian martyr. The one person to whom alone Keely then disclosed it thought him under a delusion, until he had demonstrated its soundness. When he said, in all solemnity, "Now, I feel as if you and I were the god and goddess of this world," the effect upon the hearer was no more than it would have been had a patient in a hospital for the insane spoken the words. Charles B. Collier, Keely's patent lawyer, writes as follows, concerning the difficulties attendant upon "the supposed duty" of his client's imparting his "secrets," as ordered by the Court to do, some time since:---

If to-day, for the first time in your lives, you saw a harp attuned and being played upon, you would hardly expect, without considerable time and study, to be able to reproduce the harp, attune its strings in proper relation to each other, and to play upon it so as to produce the harmonies which you had listened to. Mr. Keely's work is analogous

to the illustration which I have presented, inasmuch as he is dealing with the subject of sound, or acoustics, but in a much more involved form than as applied simply for the production of harmonies for the delight of the ear. Mr. Keely's engine is analogous to the mechanism of the human ear, in the respect that it is a structure operated upon, and its notion induced by vibration; and to the end of securing and attaining, in and by it, uniformity or regularity of motion, there must be perfect unison or synchronism, as between it and his structure which is the prime source of vibration. To attain this perfect unison or synchronism, has involved unparalleled research and experiment upon his part---experiments that have varied from day to day. No one, in my opinion, who had not stood by his side, as his shadow, watching every experiment, could have kept fully abreast of him. To pursue my simile, I may say that his harp (engine) is not yet perfectly attuned ("graduated"); when it is so, it will produce nothing but harmony (regularity of motion), and his work will be finished.

At such time, I doubt not that he will be able to give to Mr. Boekel, myself or another, the scale with which to reconstruct and attune another apparatus so as to produce like results with it; but to go over the ground that he has gone over, to explore the wilderness in which he has been the pioneer, in other words, the study, to a full understanding of them, of his experiments and researches, as recorded in his writings and illustrated in the beautiful charts which he has produced, will be a work rather for scientists than for mechanicians or engineers

Mr. Keely's "Theoretical Expose'" is in preparation for the press; and, when these volumes are issued, we may look for a change of attitude towards him in all men who hold themselves ready to abandon preconceived notions, however cherished, if they be found to contradict truths; which, Herbert Spencer says, is the first condition of success in scientific research. The Rev. J. J. Smith, M.A., D.D., tells us that the only way the great problem of the universe can ever be scientifically solved is by studying, and arriving at just conclusions with regard to the true nature and character of force. This has been Mr. Keely's life study; and he is able to demonstrate all that he asserts.

The author of No. 5 of the pamphlets issued by The Theosophical Publication Society, "What is Matter and What is Force, " says therein, "The men of science have just found out 'a fourth state of matter,' whereas the occultists have penetrated years ago beyond the sixth, and therefore do not infer, but know of, the existence of the seventh, the last. "This knowledge comprises one of the secrets of Keely's so-called "compound secret." It is already known to many that his secret includes "the augmentation of energy, "the insulation of the ether," and the "adaptation of dynaspheric force to machinery."

Laurence Oliphant writes: Recent scientific research has proved conclusively that all force is atomic --- that electricity consists of files of particles, and that the interstellar spaces contain substances, whether it be called ether or astral fluid (or by any other name), which is composed of atoms, because it is not possible to dissever force from its transmitting medium. The whole universe, therefore, and all that it contains, consists of matter in motion, and is animated by a vital principle which we call God.

"Science has further discovered that these atoms are severally encompassed by an ethereal substance which prevents their touching each other, and to this circumambient, inter-atomic element they have given the name of dynasphere; but, inasmuch as has further been found, that in these dynaspheres there resides a tremendous potency, it is evident that they also must contain atoms, and that these atoms must in their turn be surrounded by dynaspheres, which again contain atoms, and so on *ad infinitum*. Matter thus becomes infinite and indestructible, and the force which pervades it persistent and everlasting.

"This dynaspheric force, which is

also called etheric, is conditioned as to its nature on the quality of the atoms which form its transmitting media; and which are infinite both in variety and in their combinations. They may, however, be broadly divided into two categories; *viz.* the sentient and the non-sentient atoms. Dynaspheric force, composed of non-sentient atoms, is the force that has been already mechanically applied by Mr. Keely to his motor; and which will probably ere long supersede the agencies now used for locomotive, projectile, and other purposes. When the laws which govern it come to be understood, it will produce materially a great commercial and industrial revolution. There is no hard and fast line between the animal and vegetable creation, so there is a graduated scale of atoms, between which although animated by the divine life are not sentient, and those which are as highly developed, relatively to them, as man is to a cabbage."

"The most remarkable illustration of the stupendous energy of atomic vibratory force is to be found in that singular apparatus in Philadelphia --- which for the last fifteen years has excited in turn the amazement, the skepticism, the admiration, and the ridicule of those who have examined it --- called 'Keely's Motor.'" ... "in the practical land of its origin, it has popularly been esteemed a fraud. I have not examined it personally, but I believe it to be based upon a sound principle of dynamics, and to be probably the first of a series of discoveries destined to revolutionize all existing mechanical theories, and many of the principles upon which they are founded. Those who are sufficiently unprejudiced to connect the bearings of this discovery, of what must be dynaspheric force, with phenomena which have hitherto been regarded as supernatural by the ignorant, will perceive how rapidly we are bridging over the chasm which has divided the seen from the unseen, obliterating the distinction between 'matter' and what has most erroneously been called 'spirit.'"

In 1882 a woman, coversing with Mr. Keely, said, "You have opened the door into the spirit world." He answered, "do you think so? I have sometimes though I might be able to discover the origin of life." At this time Mr. Keely had given no attention whatever to the occult bearing of his discovery; and it was only after he had pursued his researches, under the advantages which his small Liberator afforded him for such experiments, that he realized the truth of this women's assertion. It was then, in 1887, that a "bridge of mist" formed itself before him, connecting the laws which govern physical science with the laws which govern spiritual science, and year by year this bridge of mist has solidified, until now he is in a position to stand upon it, and proclaim that its abutments have a solid foundation --- one resting in the material and visible world, and the other in the spiritual and unseen world; or, rather, that no bridge is needed to connect the two worlds, one law governing both in its needed modifications.

"The physical thing," writes a modern scientist, "which energizes and does work in and upon ordinary matter, is a separate form of matter, infinitely refined, and infinitely rapid in its vibrations, and is thus able to penetrate through all ordinary matter, and to make everywhere a fountain of motion, no less real because unseen. It is among the atoms of the crystal and the molecules of living matter; and, whether producing locked effects or free, it is the same cosmic thing, matter in motion, which we conceive as material energy, and with difficulty think of as only a peculiar form of matter in motion."

Oliphant, commenting upon this view of energy, says: "This is nothing more or less than what we have been in the habit of calling 'spirit.'" ... "Mind is also composed of this extraordinary matter; so is will; so is every emotion." Jacob Boehme calls it "heavenly substantiality," and Swendenborg calls it "natural and spiritual atmospheres, composed of discrete substances of a very minute form." Professor Crookes has invented the word "protyle." Professor Cones calls it "soul-stuff," or biogen; while Occultists call it "astral fluid."

Etheric Force Indentified as Dynaspheric Force

To all who are conversant with Mr. Keely's theories a similarity of views will be evident.

The President of the British Association, Sir Henry Roscoe, in his address before that body, said: "In nature there is no such thing as great or small; the structure of the smallest particle, invisible even to our most searching vision, may be as complicated as that of any of the heavenly bodies which circle round our sun." As to the indivisibility of the atom, he asks this question: "Notwithstanding the properties of these elements have been studied, and are now known with a degree of precision formerly undreamt of, have the atoms of our present elements been made to yield?" He continues: "A negative answer must undoubtedly be given, for even the highest of terrestrial temperatures, that of the electric spark, has failed to shake any one of these atoms in two."

This is an error, for it is well known by those who are fully acquainted with the principle involved in Keely's inventions that the intense vibratory action which is induced in his "Liberator" has accomplished what the retort of the chemist has failed to do, what the electric spark has left intact, and what the inconceivably fierce temperature of the sun and the volcanic fires has turned over to us unscathed. The mighty Genii imprisoned within the molecule, thus released from the chains and fetters which Nature forged, has been for years the the tyrant of the one who rashly intruded, without first paving the way with the gold which he has since been accused of using in experiments with reckless and wanton waste! For more than a score of years has Keely been fighting a hand-to-hand fight with this Genii; often beaten back by it, paralyzed at times, even, by its monstrous blows; and only now so approaching its subjugations as to make it safe to harness it for the work that is calling for a power mightier than steam, safer and more uniform in operation than electricity; a power which, by its might and beneficence, will ameliorate the condition of the masses, and reconcile and solve all that now menaces our race; as it was never menaced before, as has been said.

The structure of the air molecule, as believed in by Keely, is as follows: --- Broken up, by vibratory action, he finds it to contain what he calls an atomic triplet. The position of a molecule, on the point of a fine cambric needle sustains the same relation to the point of the needle that a grain of sand sustains to a field of ten acres.

Although, as Sir H. Roscoe has said, "In nature there is no such thing as great or small," the human mind cannot conceive such infinitesimal minuteness. We will, then, imagine a molecule magnified to the size of a billiard ball, and the atomic triplet magnified to the size of three marbles, in the triangular position, within that molecule, at its center; unless acted upon by electricity, when the molecule, the billiard ball, becomes oblate, and the three atoms are ranged in a line within, unless broken up by the mighty force of vibratory action. Nature never gives us a vacuum; consequently, the space within the

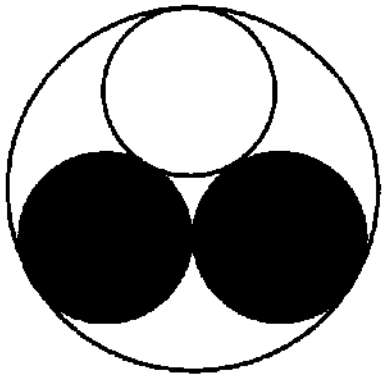

molecule not occupied by the atomic triplet must be filled with something. This is where the Genii- "the all-prevading ether"---has made its secret abode through untold eons, during which our world has been in course of preparation for its release, to fulfill its appointed task in advancing the

Universal Laws Never Before Revealed.. Keely's Secrets

progress of the human race.

Step by step, with patient perseverance which some day the world will honour, this man of genius has made his researches, overcoming the colossal difficulties which have raised up in his path what seemed to be insurmountable barriers to further progress: but never before has the world's index finger so pointed to an hour when all is making ready for the advent of the new form of force that mankind is waiting for. Nature, always reluctant to yield her secrets, is listening to the demands made upon her by her master, necessity. The coal mines of the world cannot long afford the increasing drain made upon them. Steam has reached its utmost limits of power, and does not fulfill the requirements of the age. Electricity holds back, with bated breath, dependent upon the approach of her sister colleague. Air ships are riding at anchor, as it were, waiting for the force which is to make aerial navigation something more than a dream. As easily as men communicate with their offices from their homes by means of the telephone, so will the inhabitants of separate continents talk across the ocean. Imagination is palsied when seeking to foresee the grand results of this marvelous discovery when once it is applied to art and mechanics. In taking the throne which it will force steam to abdicate, dynaspheric force will rule the world with a power so mighty in the interests of civilization, that no finite mind can conjecture the results. Laurence Oliphant, in his preface to "Scientific Religion," says: "A new moral future is dawning upon the human race - one, certainly, of which it stands much in need." In no way could this new moral future be so widely, so universally, commenced as by the utilizing of dynaspheric force to beneficial purposes in life, thus revealing to all men another phase of God's "underlying purpose."

In 1746, when Franklin's attention was drawn to the phenomena of electricity, little more was known on the subject than Thales had announced two thousand years before. Von Kleist in Leyden, Collinson in London, and others in as widely-separated cities in Europe, were experimenting in the same field of research. What our last century has done toward subduing this tyrant which Franklin succeeded in bringing down to earth, from the clouds, the next century will see surpassed beyond man's widest conjectures, should Keely's utilization of this unknown force of nature bestow upon humanity the costless motive power, which he anticipates it will. Reynolds predicted that those who "studied the mysteries of molecular vibration would win the victorious wreaths of successful discovery." After such discoveries as Mr. Keely has made in this field of research, it matters not to him whether he succeeds commercially or not. His work of discovery commenced when, as a boy of twelve, he held the seashells to his ear as he walked the shore and noted that no two gave forth the same tone. From the construction of his first crude instrument, his work of evolution progressed slowly for years; but within the last five years he has made giant strides towards the "Dark Tower" which is his last fortress to take. When he is ready, "Dauntless the slug-horn to his lips" he will set; and the world will hear the blast, and awaken from its slumber into new life.

Molecular vibration is thus seen to be Keely's legitimate field of research; but more than once has he had to tear down portions of the vibratory scaffolding which aided him in the building up of his edifice of philosophy; therefore, he is ever ready to admit that some of the present scaffolding may have to be removed. The charge of "abandoning his base," recently brought against him by one of the editors of The New York Times, could only have been made by one who is utterly ignorant of the subject upon which he writes. Under the heading "A Cool Confession," this editor asserts that Keely has "given up the Keely Motor as a bad job," and that he admits that he is a "bogus inventor" and a "fraud." This is not true.

What Keely does admit is that, baffled in applying vibratory force to me-

chanics, upon his first and second lines of experimental research, he was obliged either to confess a commercial failure, or to try a third departure from his base or principle; seeking success through another channel of experiment. While experimenting upon this third line, until his efforts were crowned with success, he kept his secret from all men; with the approbation of the one who furnished the money for these experiments. There is a time when silence is golden; and the charge made by the same editor that Keely had been "receiving money from the Keely Motor Company on false pretences from the time that he abandoned his original plans," could only have been made by one who knows nothing of the facts of the case: for years have passed away since the Keely Motor Company broke its contract with him, and since it has furnished him with any money for his experiments.

But let Keely speak for himself in reference to his work: --- *"In considering the operation of my engine, the visitor, in order to have even an approximate conception of its modus operandi, must discard all thought of engines that are operated upon the principle of pressure and exhaustion, by the expansion of steam or other analogous gas which impinges upon an abutment, such as the piston of a steam-engine. My engine has neither piston nor eccentrics, nor is there one grain of pressure exerted in the engine, whatever may be the size or capacity of it.*

"My system, in every part and detail, both in the developing of this power and in every branch of its utilization, is based and founded on sympathetic vibration. In no other way would it be possible to awaken or develop this force, and equally impossible would it be to operate my engine upon any other principle.

"All that remains to be done is to secure a uniform speed under different velocities and control reversions. That I shall accomplish this is absolutely certain. Some few years ago, I contemplated using a wire as a connective link between two sympathetic mediums, to evolve this power as also to o[illegible]ate my machinery --- instead of tubular connections as heretofore employed --- I have recently succeeded in accomplishing successfully such change. This, however, is the true system; and henceforth all my operations will be conducted in this manner--that is to say, the power will be generated, my engines run, my cannon operated, through a wire.

"It has been only after years of incessant labour, and the making of almost enumerable experiments, involving not only the construction of a great many most peculiar mechanical structures, and the closest investigation and study of the phenomenal properties of the substance "ether," per se, produced, that I have been able to dispense with complicated mechanism, and to obtain, as I claim, mastery over the subtle and strange force with which I am dealing.

"When my present process of adjustment is completed, the force, the mechanism, and all that pertains to it, will be explained in a theoretical exposition of the subject, with appropriate diagrams, which I shall publish to the world; through the medium, and my patents, when taken out, a knowledge of all that is required for its commercial employment will be more easily acquired than is the necessary skill required to enable one to safely operate a steam-engine.

"My power will be adapted to engines of all sizes and capacities, as well to an engine capable of propelling the largest ship as to one that will operate a sewing machine. Equally well and certain is it that it will be adapted as a projectile force for guns and cannons of all sizes, from the ordinary shoulder-piece to the heaviest artillery."....

When Keely in 1887 obtained continuity of motion (for a time) in his engine he thought that his last difficulty had been overcome: but, up to the present time, he has not succeeded in governing its speed nor in controlling reversions. He has, however, again reduced in size the instrument with which he produces force. From 1882 to 1884 the "Generator" was a structure six feet long and correspondingly wide

Universal Laws Never Before Revealed.. Keely's Secrets

and high; but, failing in his attempt to make an automatic arrangement upon which its usefulness in mechanics depended, Keely found a new standard for research in an experiment often made by himself, but never before successful, which resulted in the production of a machine in 1885 which he named a "Liberator" --- not so large as a lady's small round work-table. Continuing his labor of evolution Keely within one year made such astonishing progress, from experiments with this beautiful piece of vibratory mechanism, as to combine the production of the power, and the operation of the cannon, his engine and his disintegrator in a machine no larger than a dinner plate, and only three or four inches in thickness. This instrument was completed in 1886, up to which time his experiments had been conducted upon a principle of sympathetic vibration, for the purpose of liberating a vapour or etheric product. His later experiments have been confined to another modification of the vibratory sympathy; and the size of the instrument used now, '88, for the same purposes is no larger than an old-fashioned silver watch, such as we see in Museum collections. The raising of a lever with an apparent uplifting expansive force of between 20,000 and 30,000 pounds to the square inch, the running of the engine, the firing of the cannon, are conducted without one ounce of pressure in any part of the apparatus, and without the production or presence of what has been known as Keely's ether. The force is now transmitted along a wire (of platinum and silver), and when the lever is lowered there is no exhaustion, into the atmosphere of the room, of any up-lifting vapor, as was always the case when ether was used in this experiment; nor is there any vapor impinging upon the piston under the lever to raise it.

Mr. Keely has named this new force in nature

been experimenting with, and the phenomena attending them, are the very antithesis of each other. Keely does not feel the shadow of a doubt as to his eventual success in producing engines of varying capacities; small enough, on the one hand, to operate sewing machines with, and large enough, on the other hand, to propel the largest ships that plough the seas. Every fact and feature surrounding the case warrants the belief, notwithstanding the incredulity of all who have not witnessed the progress of Mr. Keely, step by step, that his success will be complete, and his work stand as the most colossal example of the survival of the fittest, in the process of inventive evolution. Cox says: "not one of the great facts which science now accepts as incontrovertible truths but was vehemently denied by the scientists of its time:---declared to be *a priori* impossible, its discoverers and supporters denounced as fools and charlatans, and even investigation of it refused as being a waste of time and thought." "History repeats itself," and Amiel's definition of science gives the key to the incredulity of scientists in reference to Mr. Keely's discovery; for if, as Amiel has said, "science is a lucid madness occupied with tabulating its own hallucinations," it is not strange that men of science should refuse to investigate what they consider the hallucinations of others.

It is an undisputed fact that "too much has been conceded to science, too little to those sublime laws which make science possible." But the one law which regulates creation, and to which

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* A system of pendulums tuned to swing the various ratios of the musical scale, form a "Silent Harp" of extraordinary interest. This "Silent Harp," D.C.Ramsay, of Glasgow, has shown to his students of harmony for many a year. A pen, placed by means of a universal-jointed arrangement between any two pendulums of this "Silent Harp," so as to be moved by a blend of their various motions, writes with all the precision of gravitation, a [illegible] two corresponding

all other laws are made subservient, keeping in harmony the systems upon systems of worlds throughout space, developing sound and colour, animal and vegetable growth, the crystallization of minerals, is the hidden law, which develops every natural science throughout the universe; and which both Kepler and Newton anticipated would be revealed in our age. "You can even trace the poles in sound," writes Mrs. F. J. Hughes, a niece of Darwin, in her work upon the "Evolution of Tones and Colours." The experiments made by Mrs. Watts Hughes, at the annual Reception of the Royal Society, and the Pendulograph* writings by Andrew of Belfast, have a bearing upon Keely's discovery; illustrating the workings of this hidden law of nature.

Of all women Mrs. Hughes approaches nearest to the theories of Mr. Keely. Concerning them she writes to a friend well versed in music, as music is taught: - "From ignorance of the present Science of Musicians, which you know so thoroughly, it is easier for me to grasp his meaning, than for you. I have lately been proving by scriptural types how Nature's laws in the lower creation develop by fifths below and by fourths above the key-note, the two meeting in one harmony: art mingling both, creating discords, and undulating them into harmony. Dr. C. Martin says: - 'Musicians must have discords; the ear is educated to them: but every one must allow that the nearer Art follows nature, the more perfect it is.' Mrs. Hughes adds: "I think Keely must have caught the center where both laws unite, or act upon Nature's law only."

Of the law of periodicity, Hartmann writes: *"Its actions have long ago been known to exist in the vibrations producing light and sound, and it has been recognized in chemistry by experiments tending to prove that all so-called simple elements are only various states of vibration of one primordial element, manifesting itself in seven principal modes of action, each of which may be subdivided into seven again. The difference which exists between so-called single substances appears, therefore, to be no difference of substance or matter, but only a difference of the function of matter in the ratio of its atomic vibration."* It is by changing the vibrations of cosmic ether that Mr. Keely releases this energy, and Dr. Kellner in Austria produces electricity in the same way; while it is said that a chemist in Prague produces magnetism; also Dr. Dupuy, of New York, who has been for years experimenting in this field without meeting with Keely's progressive successes.

Horace Wemyss Smith, in commenting upon the fact that, at the time of Franklin's discovery, men in France, in Belgium, in Holland, and in Germany were pursuing the same line of experiment, says that there is something worthy of observation in the progress of science and human genius, inasmuch as in countries far distant from each other men have fallen into the same tracks, and have made similar and corresponding discoveries, at the same period of time, without the least communications with each other.

Laurence Oliphant's recent works give us the clue to an explanation of this fact; and Lowe, in his Fragments of Physiology, condenses the answer in these words: "Man is not the governor and commander of the created world; and were it not for superhuman influence constantly flowing into created forms, the world would perish in a moment. It is this superhuman influence, felt most by those who have educated the hidden sense (with which all men are born), which inspires all discovery, all invention, all poetry, all of truth, let it take whatever form it may. This sixth sense is as much undeveloped in the mass of mankind as sight would be had we been born with our eye-lid sealed; able to distinguish nothing beyond the period of day-light from the reign of night, and remaining sealed all the years of our life upon earth. We know that some spiritually minded persons seem to possess powers unknown to those who are spoken of in Scripture as the carnal minded ; and it may be that with dim vision they are able to discern as in a glass darkly, without education of this hidden sense, truths which are

hidden from others. Of such are men and women of genius. Again, there are others who possess uncertain, unreliable powers, which often lead astray those who commit themselves to the direction of these powers. What infallible medium of superhuman influence? Spiritualism represents a great truth, behind the spiritism which stands in the same relation toward it that counterfeit coin holds to sterling gold. The operations of our sixth sense are as liable to be deceptive as are the operations of our other senses; and are limited or governed by law in the same way. We cannot see in total darkness, and this hidden power, susceptible of education, can only be brought into use by an illuminated mind; a mind that has studies the laws of evolution and involution, the descent of spirit into matter, and the re-ascension of matter to spirit - laws of the life-impulse beginning in the elemental kingdom and ending in an evolution of man, far beyond the comprehension of man of the present day. Man and woman as units, continues Oliphant, are still so ignorant of the great powers which they themselves inherit that they wholly fail to see them, though they sweep like mighty seas throughout all human nature.

When mankind has become sufficiently spiritualized by the process of evolution laid down in the plan of the great Master, then shall we know ourselves and our powers as we are known to Him. True Science must first open wider the path of religion - a religion of progress, a religion suited to the wants of humanity, as well as a humane religion - the religion, taught by our Holy Master, of love for our fellow-men, of harmony with all that is good - at war only with evil; not with those who, warped by transmitted tendencies, commit evil. An eye for an eye, a tooth for a tooth, is the old Jewish law. Christ's law is the law of love, which is God's law. Do unto others as ye would have others do unto you ; and this is the law which we need to fulfil, in order to purify and regenerate mankind.

Hitherto we have been, in one respect, like the laborer in Tolstoi's Confession, doing the work assigned him, in the space assigned, without understanding where he was, or what the result would be, and unable to judge whether the arrangements for this work were reasonably planned by his master or not. The laborer worked the handle of a pump, he saw the water flow into numerous channels for irrigation of the soil; little by little, shrubs grew and blossomed and bore fruit,, and the laborer passed on to more important work, understanding better and better the arrangement of the establishment, and never doubting that its Lord had planned all for the best. Our race has been pumping water for generations, planting the seed, watching the growth of the plants, the shrubs, and the trees; not always satisfied, however, that the Creator of the universe had planned as well as all might have been planned, or that there was any plan, or any Creator.

There are men in various parts of the world, unknown even by name to each other, who tell us by the sign of the times that the season of harvesting is approaching; the season for gathering the fruit, which has been deferred, century after century, because mankind is yet not ready, in the opinion of many, to share the fruit with one another.

Hyndman says that capitalism has been as necessary as serfdom in the progress of the human race; and its stores will continue to be garnered and used to spread the great net-work of railways, steam navigation, telegraph and telephone lines, which have given bread to millions and millions; encouraging paid labor and bringing nearer and nearer the age of love and harmony, which, it has been predicted that the twentieth century will usher in.

Renan, the French theologian, writing of the advances to be made in science by the discovery of nature's secrets, said that, although he had ceased to look forward to anything very unexpected, he envied those who should live to see the wonders of the twentieth century. For, he added they who live then will see things of which

we have no conception. Already the light of a new dawn is breaking upon the world of science. These foretold advances are heralded by the modifications of force, before alluded to. The instrument invented by Dr. Kellner collects and produces electricity directly from the ether of the atmosphere without any friction of solid corporeal substances and without any chemical agency; the invention of one of the Prague professors, which, it is said, collects and gives out magnetism, seeming to be derived from changing the vibrations of cosmic ether, as in Keely's and Kellner's experiments, and other more recent discoveries.

It has been said that when Keely's vibratory force shall have taken the place of steam-engines, the millions of working men who gain with difficulty their daily bread by the work of their hands, will find themselves without occupation. The same prediction was made in regard to steam, but instead we find the city of Boston giving work to thirty thousand men in one manufactory of boots and shoes by steam, in place of the three thousand shoemakers who were all that were occupied in this branch of labor in that city when the work was done by hand.

Dr. Kellner's colleague, Franz Hartmann, M.D., writing in reference to Keely's discovery, says: I have taken great interest in him ever since I first heard of him in 1882. As gaslight has driven away, in part, the smoky petroleum lamp, and is about to be displaced by electricity, which in the course of time may be supplanted by magnetism, and as the power of steam has caused muscular labor to disappear to a certain extent, and will itself give way before the new vibratory force of Keely, likewise the orthodox medical quackery that now prevails will be dethroned by the employment of the finer forces of nature, such as light, electricity, magnetism, *etc.*

When the time is ripe, these are of the true scientists who will come to the front to lead as Progress leads, men who know how to wait upon God, *viz.*, to work while waiting; and to such the end is, sooner or later, victory! God never hurries. He counts the centuries as we count the seconds, and the nearer we approach to the least comprehension of His underlaying purpose the more we become like Tolstoi's laborer, who knew that the fruit was ripening for him and his fellow-men, trusting implicitly in the superior wisdom of his master.

"Evermore brave feet, in all ages,
Climb the heights that hide the coming day,
Evermore they cry, these seers and sages,
From their cloud, "Our doctrines make no way."
All too high they stand above the nations,
Shouting forth their trumpet-calls sublime,
Shouting downwards their interpretations
Of the wondrous secrets born of time. "

No man, whose spiritual eyes have been opened to "discern the signs of the times," can doubt that we are on the eve of revelations which are to usher in the dawn of a brighter day than our race has yet known; and no prophecy of this brighter day, foretold by prophets, apostles, and inspired poets, was ever made in truer strains than in these glorious lines of Elizabeth Barrett Browning:---

"Verily many thinkers of this age,
Aye, many Christian teachers, half in heaven,
Are wrong in just my sense who understood
Our natural world too insularly, as if
No spiritual counterpart completed it,
Consummating its meaning, rounding a
To justice and perfection, line by line,
Form by form, nothing single nor alone;
The Great Below clenched by the Great Above."

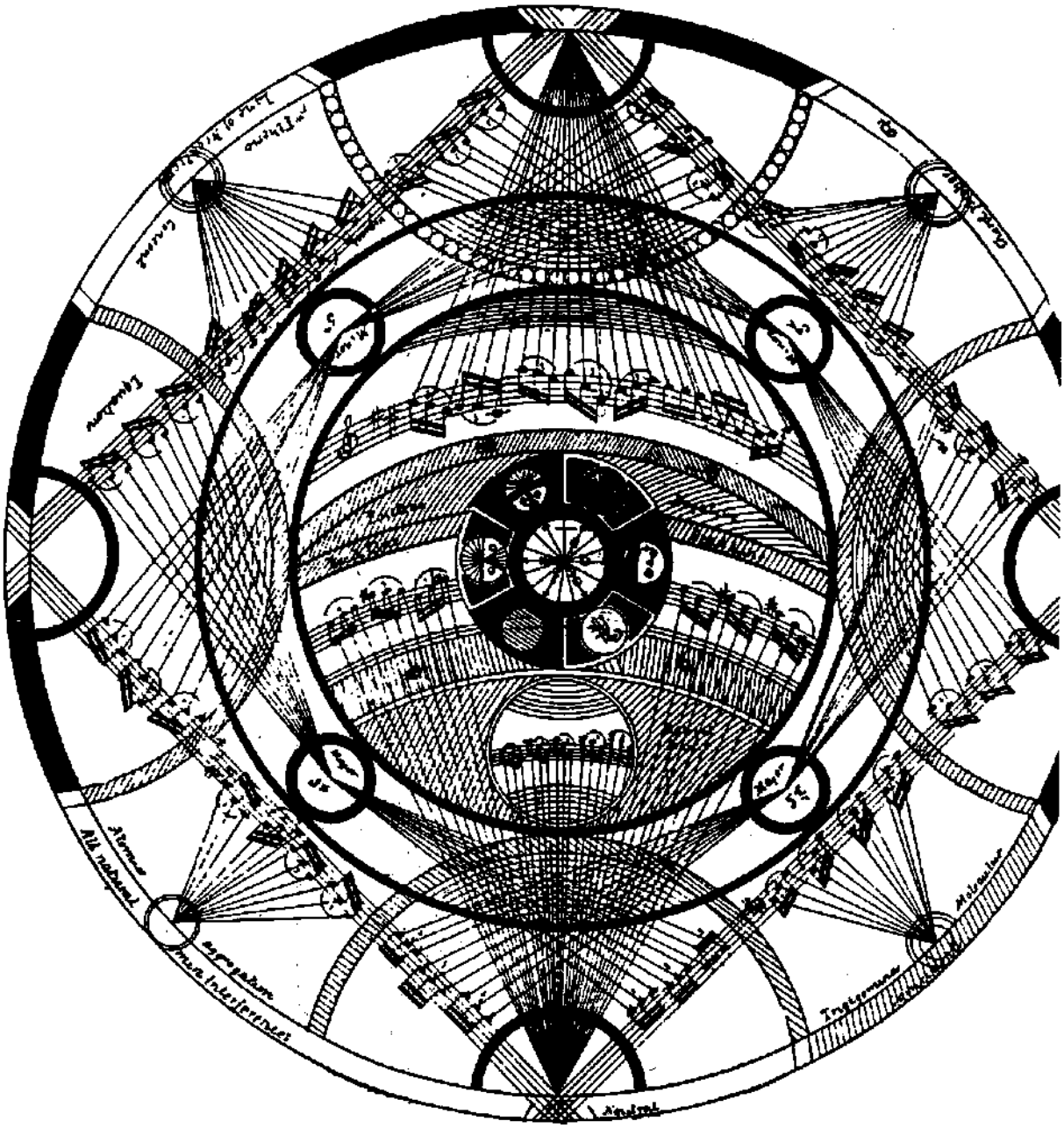

MUSICAL CHART BY WHICH KEELY
CLAIMED TO HAVE DISCOVERED
HIS "ETHERIC" FORCE.

One Phase of Keely's Discovery in Its Relations to the Cure of Disease

Clara Jessup Bloomfield-Moore

"I know medicine is called a science. It is nothing like a science. It is a great humbug! Doctors are mere empirics when they are not charlatans. We are as ignorant as men can be. Who knows anything in the world about medicine? Gentlemen, you have done me the honour to come here to attend my lectures, and I must tell you now, frankly, in the beginning, that I know nothing about medicine, nor do I know anyone who does know anything about it. Nature does a great deal, imagination does a great deal, doctors do devilish little when they do not do harm. Sick people always feel they are neglected, unless they are well drugged, les imbeciles!"

Professor Magendie;
(before the students of his class in The Allopathic College of Paris)

In the year 1871, the writer was sent from Paris to Schwalbach, by Dr. Beylard, and recommended to the care of Dr. Adolph Genth. She said to the physician, I wish for your opinion and your advice, if you can give it to me without giving me any medicine. He replied, With all my heart, madam; and I wish to God there were more women like you, but we should soon lose most of our patients if we did not dose them.

This is a terrible excuse for the use of those agencies which Dr. John Good says have sent more human beings to their graves than war, pestilence and famine combined. Keely holds the opinion that Nature works under the law of Compensation and Equilibrium---the law of Harmony; and that when disease indicates the disturbance of this law Nature at once seeks to banish the disease by restoring equilibrium. He seeks to render assistance on the same plan; replacing grossly material agencies by the finer forces of nature; as has been so successfully done by Dr. Pancoast and Dr. Babbitt in America. It was the intention of Dr. Hartmann to establish a Theosophical Sanatorium at Goritz, in Austria, this summer, where medicine would be dispensed with: but his plans have been interfered with by his visit to America, where he went last March for the purpose of ascertaining Mr. Keely's views in reference to the best manner of conducting experimental research in reference to the restoration of equilibrium in the human system; the disturbance of which occasions local disorders and all disease, according to his ideas. Paracelsus held that *Man is made out of the four elements, and is nourished and sustained by magnetic power, which is the Universal Motor of Nature.* He treated disease in two ways - Sympathetically and Antipathetically; but only a fragmentary trace of his system can now be found. Nature, says Dr. Pancoast, author of The True Science of Light, works by antagonism in all her operations: when one of her forces overdoes its work, disease, or at least a local disorder, is the immediate consequence; now, if we attack this force, and overcome it, the opposite force has a clear field and may re-assert its rights---thus equilibrium is restored, and Equilibrium is health.

The Sympathetic System, instead of attacking the stronger force, sends recruits to the weaker one, and enables it to recover its powers; or, if the disorder be the result of excessive tension of Nerves or Ganglia, a negative remedy may be employed to reduce the tension. Thus, too, equilibrium is restored.

Dr. Hartmann disclosed to me in one of his letters that he knew the most important secret involved in Mr. Keely's compound secret. But he had not in any way connected this so-called secret with Mr. Keely. In one of Dr. Hartmann's letters to me, he writes -

Mr. Keely is perfectly right in saying

that all disease is a disturbance of the equilibrium between positive and negative forces. In my opinion, no doctor ever cured any disease. All he can possibly do is to establish conditions under which the patient (or nature) may cure himself. The universal power which Mr. Keely calls the ether, and, which Dr. Kellner calls transitory element, was known to medieval philosophers as prima materia, will and thought; or, according to Schopenhauer, will and imagination are substance. I recognize only one universal and fundamental power, which I call consciousness, acting within matter by means of thought; and I have no doubt that you already know that we agree all around, although we may not all use the same terms to signify the same objects. In your most important papers, I have found my own sentiments and views reflected; and I have in my books on Magic, Paracelsus, and the Rosicrucians, attempted to explain these identical views. Why will our scientists insist on refusing to see the self-evident fact that all visible material substances, animal organs, etc., are nothing else than the ultimate products of pre-existing psychic (interior and invisible) forces? These facts were all known to the ancient philosophers; while the moderns insist on mistaking the effects for the cause. They reject the idea of God (the primordial cause of all in its highest aspect of spiritual consciousness) because they formed a misconception of that which is intellectually inconceivable; they found that God could not be that which they had imagined, and they logically(?) concluded that there could be no Divine power at all. But this subject is too grand, too sublime, and extensive to be more than alluded to in this letter, and I merely write these remarks to show you that your views, those of Mr. Keely, and my own are all identical, as they, indeed, must be with those who are capable to perceive self-evident truth; for the truth is only one, and all who know it possess that same identical knowledge. Mr. Keely's power seems to be derived by changing the vibrations of cosmic ether. The machine which my friend Dr. Kellner has invented seems to be based upon the same principle, only, while Mr. Keely transforms these vibrations into some force connected with sound, Dr. Kellner's machine transforms them into elctricity. Again, Dr. Hartmann writes: Even to the superficial observer, the fact that the world is becoming more and more spiritualized, from top to bottom, begins to be evident. The crude scientific opinions which were prevailing in the beginning of the century are disappearing before a higher knowledge in regard to the laws of nature; the materialism which flourished twenty years ago, the offspring of animalism and ignorance, has almost disappeared from view, and has to descend to the lowest strata of society to find admirers. The iron rod, with which a self-conceited and arrogant sacerdotalism ruled the people, has been broken, and its remnants exist only in those countries where priestcraft is upheld and abetted by kings and governments.

If you enter the field of therapeutics and medicine, we find a decided fermentation of new ideas; not among the fossil specimens of antediluvian quackery, but among those who are called irregulars, because they have the courage to depart from the tracks trodden out by their predecessors. The more intelligent class of physicians have long ago realized the fact that drugs and medicines are perfectly useless, excepting in cases where diseases can be traced to some mechanical obstruction, in some organ that may be reached by mechanical action. In all other cases our best physicians have become agnostics, leaving nature to have her own way, and observing the expectative method, which, in fact, is no method of cure at all, but merely consists in doing no harm to the patient. Recently, however, light, electricity, and magnetism have been employed; so that even in the medical guild the finer forces of nature are taking the place of grossly material, and therefore injurious substances. The time is probably near when these finer forces will be employed universally. Everywhere the leaven is working, and many are asking, 'What causes it to work?' The answer is 'It is spirit working in matter. But the term 'spirit' is to the majority of man-

One Phase of Keely's Discovery in Its Relations to the Cure of Disease

kind a term without any meaning, a nonentity. Nevertheless, the action of that power which is called cohesion, and which is equally invisible, but which really holds the atoms of all bodies together and prevents them from dissolving into tangible ether, is continually manifested before their eyes. Why should not the opposite form of activity, that which enters between the atoms and separates them, likewise be a reality? The scientist will answer, 'We know this activity, and we call it heat. What has heat to do with spirit?' It has been demonstrated long ago that heat is a mode of motion, and likewise every other form of energy (including spiritual activity) is nothing else but a mode of motion. Motion is that universal agent which is fundamentally and essentially only one, but whose mode of manifestation differs according to the conditions under which it manifests itself. Acting without relative consciousness, it is known as gravitation, attraction, heat, light, sound, electricity, magnetism, etc. In a higher state it is known as life, and becomes endowed with relative consciousness, acting in the highest plane of existence it becomes self-conscious and self-existent, and is called spiritual power. But there is no motion thinkable without a substance to move; we cannot imagine a force without matter, nor matter without energy. There must, therefore, be one original substance, or primordial matter, although of a kind very different from the form in which it appears to us on the externally visible plane. The existence of this primordial substance was known to the spiritual perception of the ancient Rosicrucians, and some of them have, by logical conclusions, arrived at a belief in its existence, and named it Cosmic Ether; while by the Eastern sages it was called Akasa. We therefore see that there is one primordial and universal power , which is Motion: and, likewise, one primordial and universal substance which we may call Ether, or Matter; and that all existing forms can be nothing else but various shapes of that Ether in various states of density, and existing under various conditions, while all forms of energy, from the most grossly material up to the highest spiritual seem to be merely modifications of motion in Ether, manifesting themselves in various conditions and under various circumstances, unconsciously, consciously, and with self-consciousness. Furthermore, it may be said that if there is only one God, that is to say, if all things come from only one cause of internal force acting within itself, then motion and matter must be fundamentally and essentially one and the same, and we may look upon matter as being latent force and upon force as being free matter. Finally, if the great first cause is not to remain eternally in a state of inactivity, or, in other words, if it is to manifest itself as matter and motion, and if motion is to act within matter, then there must be a cause why such an activity takes place, and this cause can be nothing else but the eternally active Great First Cause itself, because there can be only one universal cause and no other. This is a self-evident truth to all who are able to see it. There can be no special name for that cause, because it is in itself the all and cannot be specified, for it is, in itself, everything that exists. It, however, appears to us in manifold aspects, and according to the aspects under which it appears, we may give to it different names. Looked at in its aspect as an universal power, which causes action and reaction, we may call it the will, existing within all forms in an active and latent condition. Whenever it becomes active, it may act unconsciously, consciously, or with self-consciousness, according to the conditions under which it is active.

The great and universal trinity of cause, motion, matter---or, as others call it, will, thought, and manifestation---was known to the ancient Rosicrucians and adepts as prima materia. Paracelsus expressly states that each of the three is also the other two, for nothing can possibly exist without cause, matter, and energy, i.e., spirit, matter, soul, the ultimate cause of existence being that it exists. We may, therefore, look upon all forms of activity as being an action of the universal or Divine will upon the ether...It would be useless for us to speculate about the spiritual pow-

er of the will if acting through the organism of an adept; but we may study the effects of that same will-power when it acts within a more material plane, where it is known to us as causing heat, light, sound, electricity, and magnetism. All these forms of energy may theoretically be transformed one into another, because they all manifest themselves as various rates of vibrations or undulations of the ether which is contained in everything; and if we can change the rate of these vibrations, we may transform one form of energy into another.

For a long time it has been known to modern science that one form of energy can be transformed into another, although with a certain amount of loss; and it was believed impossible that one amount of energy, if transformed into another, would cause more than the same amount to become manifest. The cause of this false conclusion rests in the still prevailing misconception that a form or substance creates or produces an energy, while, in fact, the form is only an instrument through which the universal and pre-existing motion acts....

Worlds and planets are the products of the pre-existing cosmic ether or space, and not the ether the products of the planets! The same fundamental law evidently exists in all departments of nature, manifesting itself differently according to the difference of conditions under which it acts. Universal forces are bound into forms, and the forms dissolved into forces. Every form, on giving up its ghost, renders to the universal storehouse that which has been entombed in the form, but no more; in the same sense as steam, cooled off into water and frozen into an icicle, will, if heated, produce the same amount of heat again. The universal forces exist not merely in the form, but also in the universal storehouse in nature. By means of a glass lens we may collect the heat which exists in the light of the sun's rays and set a piece of wood on fire. No heat exists in the wood; it is merely a certain motion of the ether, which has been latent, and which is rendered free by the process of burning. As in heat, so in sound. No sound exists in a fiddle; it is the ether in the atmosphere which is transformed into vibration of sound by the instrumentality of the fiddle. No light exists in the fire; it is merely the ether which, by the process of combustion, is transformed into certain vibrations which ultimately produce the phenomenon called light. No magnetism exists in iron; but ether, in a certain state of vibration which we call magnetic, acts through the instrumentality of the iron. No life is produced through a vegetable or animal organism; but they are instruments through which the universal element may manifest itself as life. No thought is created with the brain; but the brain is an instrument through which the universal mind operates. No love, will, faith, or any other spiritual power is created by the soul; but the sole is an organism through which these eternal and self-existent powers may become manifest. There is before me a little electrical instrument, invented by a well-known Austrian inventor, which collects and produces electricity directly from the ether of the atmosphere without any friction of solid corporeal substances and without any chemical agency. Moreover, the amount of electricity produced by it is far greater than that produced by a great engine with friction; a continuous stream of electric fire proceeds from it five to seven inches in length. It clearly proves that the electricity does not reside in the substance by means of which it is produced, but in the ether contained in the atmosphere, from which it is collected by means of the instrument and rendered perceptible to our senses. It also shows that electricity(i.e., the ether in that state of atomic vibration which we call electricity; as this is Keely's definition of electricity, it should not be attributed to Hartmann;) is something substantial, for it produces an electric gush of wind similar to the vapour produced by an atomizer; or still more resembling the cold gushes known to spiritualists, and which often occur at the beginning of some so-called spiritual manifestation....If we had any means to induce certain vibrations of ether in the air, or in the ether of space, by producing them in some substance able to

communicate them to the ether of space, we might set the whole atmosphere, or even all the ether of space, into certain vibrations, and exercise a power whose limits cannot be estimated by our present comprehension. On the material plane we can only deal with those powers which we can insulate or store up in a form. We can store up heat, light, electricity, magnetism, and motion; but we cannot store up ether in its original form, because it prevades all known substances. There is nothing which offers any resistance to it. We can, therefore, deal with ether only when it becomes manifest to us through the instrumentality of a substance or for; that is to say, we can deal with it when transformed into heat, electricity, etc. Then it has entered into a state which renders it capable to be insulated by certain substances which offer resistance to it. We must, therefore, conduct our physical experiment with ether stored up in material forms. Everybody knows that a note struck upon an instrument will produce sound in a correspondingly attuned instrument in its vicinity. If connected with a tuning fork, it will produce a corresponding sound in the latter; and if connected with a thousand tuning forks, it will make all the thousand sound, and produce a noise far greater than the original sound, without the latter becoming any weaker for it. Here, then, is an augmentation of multiplication of power, as it has been called by the ancient Rosicrucians, while modern scientists have called it the law of induction. If we had any means to transform sound again into mechanical motion, we would have a thousand-fold multiplication of mechanical motion. It would be presumptuous to say that it will not be as easy for the scientists of the future to transform sound into mechanical motion, as it is for the scientist of the present to transform heat into electricity. Perhaps Mr. Keely has already solved the problem. There is a fair prospect that in the very near future, we shall have, in his ethereal force, a power far surpassing that of steam or electricity. Nor does the idea seem to be Utopian if we remember that modern science heretofore only knew the law of the conservation of energy; while to the scientist of the future the law of the augmentation of energy will be unveiled. As the age which has passed away has been the age of steam, the coming era will be the age of induction. There will be a universal rising up of lower vibrations into higher ones, in the realm of motion, emotion, and thought. Mr. Keely will, perhaps, transform sound into mechanical motion by applying the law of augmentation and multiplication of force known to the ancient Rosicrucians; as we will apply the same law in the realm of thought, and induce people to think. Thus matter will become more subject to the action of the finer forces of nature, and the minds of men will become less gross and easier to be penetrated by the light of Divine wisdom. All this has been predicted eighty-eight years ago, at the beginning of the century.

Mr. Keely, finding in his first interview with Dr. Hartmann about ethereal force, or dynaspheric force, was so well understood by that learned gentlemen, expressed great pleasure in meeting, for the first time, one who comprehended so much more of its nature than any man whom he had ever met; and Dr. Hartmann expressed himself as equally charmed and satisfied with Mr. Keely in this interview; although he gained from him nothing in the way of information that was new to him.

Before the second meeting took place, one of Mr. Keely's papers upon disturbed equilibrium (in the brain) was given to Dr. Hartmann to read with the request that he would limit his next conversation with Mr. Keely to the proper method of re-adjusting opposing conditions in the brain --- or, in other words, ascertaining how the ruling medium could be brought to bear upon these opposing conditions, in the brain, in order to restore equilibrium. Mr. Keely's paper amply treats the cause of disturbance of equilibrium in the brain, producing insanity; and reads as follows:---

Brain Disturbance

"In considering the mental forces as associated with the physical, I find, by my past researches, that the convolutions which exist in the cerebral field are entirely governed by the sympathetic conditions that surround them.

The question arises, what are these aggregations and what do they represent, as being linked with physical impulses? They are simply vibrometric resonators, thoroughly subservient to sympathetic acoustic impulses given to them by their atomic sympathetic surrounding media, all the sympathetic impulses that so entirely govern the physical in their many and perfect impulses (we are now discussing purity of conditions) are not emanations properly inherent in their own composition. They are only media-the acoustic media-for transferring from their vibratory surroundings the conditions necessary to the pure connective link for vitalizing and bringing into action the varied impulses of the physical.

All abnormal discordant aggregations in these resonating convolutions produce differentiation to concordant transmission; and, according as these differentiations exist in volume, so the transmissions are discordantly transferred, producing antagonism to pure physical action.

Thus, in Motor Ataxis, a differentiation of the minor thirds of the posterior parietal lobule produces the same condition between the retractors and extensors of the leg and foot; and thus the control of the proper movements is lost through this differentiation. The same truth can be universally applied to any of the cerebral convolutions that are in a state of differential harmony to the mass of immediate cerebral surroundings. Taking the cerebral condition of the whole mass as one, it is subservient to one general head center, although as many neutrals are represented as there are convolutions.

The introductory minors are controlled by the molecular; the next progressive third by the atomic; and the high third by the Etheric. All these progressive links have their posttive, negative, and neutral position. When we take into consideration the structural condition of the human brain, we ought not to be bewildered by the infinite variety of its sympathetic impulses; inasmuch as it unerringly proves the true philosophy that the mass chords of such structures are governed by vibratory etheric flows---the very material which composes them. There is no structure whatever, animal, vegetable, mineral, that is not built up from the universal cosmic ether. Certain orders of attractive vibration produce certain orders of structure; thus, the infinite variety of effects---more especially in the cerebral organs. The bar of iron or the mass of steel, have, in each, all the qualifications necessary, under certain vibratory impulses, to evolve all the conditions that govern that animal organism---the brain: and it is as possible to differentiate the molecular conditions of a mass of metal of any shape so as to produce what you may express as a crazy piece of iron or a crazy piece of steel; or, vice versa, an intelligent condition in the same.

I find in my researches, as to the condition of molecules under vibration, that discordance cannot exist in the molecule proper; and that it is the highest and most perfect structural condition that exists; providing that all the progressive orders are the same. Discordance in any mass is the result of differentiated groups, induced by antagonistic chords, and the flight or motions of such, when intensified by sound, are very tortuous and zig-zag; but when free of this differentiation are in straight lines. Tortuous lines denote discord, or pain; straight lines denote harmony, or pleasure. Any differentiated mass can be brought to a condition of harmony, or equation, by proper media, and an equated sympathy produced.

There is good reason for believing that insanity is simply a condition of differentiation in the mass chords of the cerebral convolutions, which creates an antagonistic molecular bombardment towards the neutral or attractive centers of such convolutions; which, in turn, produce a morbid irritation in the cortical sensory centers in the substance of idea-

One Phase of Keely's Discovery in Its Relations to the Cure of Disease

tion; accompanied, as a general thing, by sensory hallucinations, ushered in by subjective sensations; such as flashes of light and colour, or confused sounds and disagreeable odours, etc., etc.

There is no condition of the human brain that ought not to be sympathetically coincident to that order of atomic flow to which its position, in the cerebral field, is fitted. Any differentiation in that special organ, or, more plainly, any discordant grouping tends to produce a discordant bombardment---an antagonistic conflict; which means the same disturbance transferred to the physical, producing inharmonic disaster to that portion of the physical field which is controlled by that especial convolution. This unstable aggregation may be compared to a knot on a violin string. As long as this knot remains it is impossible to elicit, from its sympathetic surroundings, the condition which transfers pure concordance to its resonating body. Discordant conditions, i.e., differentiation of mass, produce negatization to coincident action.

The question now arises. What condition is it necessary to bring about in order to bring back normality, or to produce stable equilibrium in the sympathetic centers?

The normal brain is like a harp of many strings strung to perfect harmony. The transmitting conditions being perfect, are ready, at any impulse, to induce pure sympathetic assimilation. The different strings represent the different ventricles and convolutions. The differentiations of any one from its true setting is fatal, to a certain degree, to the harmony of the whole combination.

If the sympathetic condition of any physical organism carries a positive flow of 80 per cent on its whole combination, and a negative one of 20 per cent, it is the medium of perfect assimilation to one of the same ratio, if it is distributed under the same conditions to the mass of the other. If two masses of metal, of any shape whatever, are brought under perfect assimilation, to one another, their unition, when brought into contact, will be instant. If we live in a sympathetic field we become sympathetic, and a tendency from the abnormal to the normal presents itself by an evolution of a purely sympathetic flow towards its attractive centers. It is only under these conditions that differentiation can be broken up, and a pure equation established. The only condition under which equation can never be established is when a differential disaster has taken place, of 66 2/3 against the 100 pure, taking the full volume as one. If this 66 2/3 or even 100 exists in one organ alone, and the surrounding ones are normal, then a condition can be easily brought about to establish the concordant harmony or equation to that organ. It is as rare to find a negative condition of 66 2/3 against the volume of the whole mass, as it is to find a coincident between differentiation; or, more plainly, between two individuals under a state of negative influence. Under this new system, it is as possible to induce negations alike as it is to induce positives alike.

Pure sympathetic concordants are as antagonistic to negative discordants as the negative is to the positive; but the vast volume the sympathetic holds over the non-sympathetic, in ethereal space, makes it at once the ruling medium and re-adjuster of all opposing conditions if properly brought to bear upon them."

(signed) Keely

Until Keely's Theoretical Expose is given to science, there are few who will fathom the full meaning of these views. So little did Dr. Hartmann comprehend the principle involved that he ignored them altogether, and in the more than one hour's conversation with Mr. Keely which followed, instead of keeping to this subject matter as requested, he made no illusion to it whatever, and confined his investigations to the mechanical work of Mr. Keely in its application to machinery. In leaving, Mr. Keely again expressed his great delight in meeting one who knew so much of the hidden working of some of nature's laws; whereas, after his departure, Dr. Hartmann announced it as his opinion that, although Mr. Keely had made the greatest discovery of this or of any other age, he would never be able to utilize the force in mechanics, and that his mission would be to spiritualize the

Universal Laws Never Before Revealed.. Keely's Secrets

world instead of advancing its material progress.

Some days later, when Mr. Keely was asked why it was that Dr. Hartmann no longer believed in the mechanical success of Mr. Keely's inventions, the reply was made that Dr. Hartmann, in disclosing his own views and theories and philosophy, had prevented Mr. Keely from any attempt to point out the errors in these views and theories: feeling, as Mr. Keely did feel, that he would be wanting in humility to dispute with one so learned as Dr. Hartmann, and preferring to wait until the court had removed the injunction placed upon him (Keely), when he would be at liberty to demonstrate to Dr. Hartmann the nature of his errors by the operation of his inventions. However, this delay was not necessary, inasmuch as upon the occasion of Dr. Hartmann's first visit to the workshop, where he saw the old generator, the old Liberator and other machinery, his knowledge that, by means of the vibrations of Ether called Sound, the molecular structure of bodies may be changed, even though these vibrations are not audible to the human ear, caused Dr. Hartmann to confess his error, and to assert that his confidence in Mr. Keely's mechanical success was reestablished and stronger than it had ever been before. Those scientists who, because they could not hear the vibrations of sound, in Mr. Keely's Liberator, denied its operation, saying that one could not make something out of nothing, seem to forget that there are inaudible vibrations of sound as there are invisible rays of light.

Dr. Hartmann knows that everything in nature has its own appropriate 'sound', 'color', and 'number', and can be acted upon as soon as we are in possession of its 'key-note'. This knowledge enabled him to grasp the principle of Mr. Keely's inventions, as soon as the action of the mechanism was explained to him. Although Dr. Hartmann then and there expressed his intention of sacrificing some of his property in order to invest in the new company, in process of organization, it was from no sordid motive that he was so intensely interested in the practical part of Mr. Keely's work; but, having seen such marvelous effects produced in occult experiments, while residing in India, he was inclined to attribute to Mr. Keely natural occult powers which could never be made available in mechanics. Mr. Keely's financial success depends upon the prolongation of his life until his work of evolution is completed. Therefore, the writer of this paper has never advised anyone to invest on such an uncertainty and she requested Dr. Hartmann not to do so.

Mr. Keely's discovery embraces the manner or way of obtaining the key-note, or chord of mass, of mineral, vegetable, and animal substances; therefore, the construction of instruments, or machines, by which this law can be utilized in mechanics, in arts, and in restoration of equilibrium in disease, is only the question of the full understanding of the operation of this law. Herein lies Mr. Keely's work of evolution.

The principal point of difference existing between Mr. Keely and Dr. Hartmann, in their views respecting force, lies in the former attributing the so-called forces of nature to various modes of vibration, as to the length and direction of the vibrations; while the latter attributes all forces to various modes of vibration, as to the number of vibrations in a second. Electricity Mr. Keely defines as a certain form of atomic vibration.

Keely estimates that, after the introductory impulse is given on the harmonic thirds, molecular vibration is increased from 20,000 per second to 100,000,000. On the enharmonic sixths, that the vibration of the intermolecule is increased to 300,000,000.

On the diatonic ninths, that atomic vibration reaches 900,000,000; on the dominant etheric sixths, 8,100,000,000; and on the inter-etheric ninths, 24,300,000,000; all of which can be demonstrated by sound colours.

In such fields of research, Mr. Keely finds little leisure. Those who accuse him of dilly-dallying, of idleness, of always gong to do and never doing, of visionary plans, etc., etc., know nothing of the infinite patience, the persistent energy, which for a quarter of a century

has upheld him in his struggle to attain this end. Still less, if possible, is he understood by those who think he is seeking self-aggrandizement, fame, fortune, or glory.

The time is approaching when all who have sought to defame this discoverer and inventor, all who have stabbed him with unmerited accusations, all who have denounced him as a bogus inventor, a fraud, an impostor, a charlatan, a modern Cagliostro, will be forced to acknowledge that he has done a giant's work for true science, even though he should not live to attain commercial success. But history will not forget that, in the nineteenth century, the story of Prometheus has been repeated, and that the greatest mind of the age, seeking to scale the heavens to bring down the light of truth for mankind, met with Prometheus's reward.

Mrs. Clara F. Bloomfield-Moore
July 1, 1888

NOTE.---Dr. Hartmann, in a report, or condensed statement, in reference to Keely's discovery, writes as follows: He will never invent a machine by which the equilibrium of the living forces in a disordered brain can be restored.

As such a statement would lead the reader of the report to fancy that Keely expected to invent such an instrument, it is better to correct the error that Dr. Hartmann has fallen into. Keely has never dreamed of inventing such an instrument. He hopes, however, to perfect one that he is now at work upon, which will enable the operator to localize the seat of disturbance in the brain in mental disorders. If he succeeds, this will greatly simplify the work of re-adjusting opposing conditions; and will also enable the physician to decide whether the differential disaster has taken place which prevents the possibility of establishing the equation that is necessary to a cure.

According to Keely's theories it is that form of energy known as magnetism - not electricity - which is to be the curative agent of the future, thus reviving a mode of treatment handed down from the time of the earliest records, and made known to the Royal Society of London more than fifty years since by Professor Keil, of Jena, who demonstrated the susceptibility of the nervous system to the influence of the natural magnet, and its efficacy in the cure of certain infirmities, as thousands can testify in our day who are indebted to Parke's Compound Magnets for relief; trying them as the last resort after having suffered much at the hands of many physicians, as St. Paul said. A grandson of Goethe, after calling upon Robert Browning many years since, returned to inquire if he had dropped the magnet there which he was wearing, as he has missed it after leaving the house. The effect of the magnet is one of the effects of the law of sympathetic association, which Keely demonstrates as the governing medium of the universe throughout animate and inanimate nature.

As Cheston Morris, M.D., has well said in his paper on Vital Molecular Vibrations, We are entering upon a new field in biology, pathology, and of course, therapeutics, whose limiits are at present far beyond our ken.

The adaptability of drugs, says Dr. Henry Wood, to heal disease is becoming a matter of doubt, even among many who have not yet studied deeper causation. Materia Medica lacks the exact elements of a science. The just preponderance, for good or ill, of any drug upon the human system is an unsolved prolem, and will so remain ... After centuries of professional research, in order to perfect the art of healing, diseases have steadily grown more subtle and more numerous ... Only when internal, divine forces come to be relied upon, rather than outside reinforcement, will deterioration cease. Said Plato, 'You ought not to attempt to cure the body without the soul.'

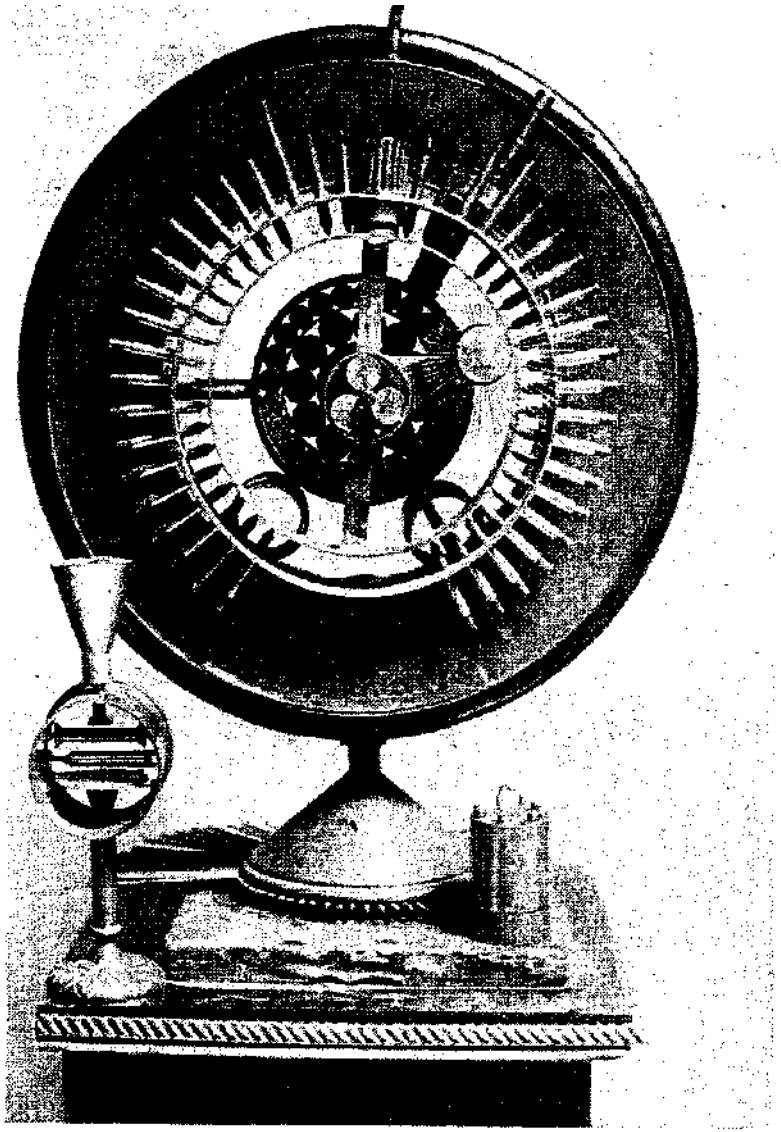

Keely's Compound Disintegrator.

On Dynaspheric Force

by Laurence Oliphant, 1888

Recent scientific research has proved conclusively that all force is atomic. That electricity consists of files of particles, and that the interstellar spaces contain substance, whether it be called ether, or astral fluid, or by any other name, which is composed of atoms, because it is not possible to dissever force from its transmitting medium. The universe, therefore, and all that it contains, consists of matter in motion, and is animated by a vital principle which we call God. Science has further discovered that these atoms are severally encompassed by an ethereal substance which prevents their touching each other, and to this circumambient interatomic element they have given the name dynasphere--- but inasmuch as it has further been found that in these dynaspheres there resides a tremendous potency, it is evident that they also must contain atoms, and that these atoms must in their turn be surrounded by dynaspheres, which again contain atoms, and so on ad infinitum. Matter thus becomes infinite and indestructible, and the force which pervades it, persistent and everlasting.

This dynaspheric force, which is also called etheric, is conditioned as to its nature on the quality of the atoms which form its transmitting media, and which are infinite both in variety and in their combinations and permutations. They may, however, be broadly divided into two categories, the sentient and the non-sentient atoms.

Dynaspheric force, composed of non-sentient atoms, is the force that has been already mechanically applied by Mr. Keely to his motor, and which will probably ere long supersede the agencies now used for locomotives, projectiles and other purposes; when the laws which govern it come to be understood, it will produce materially a great commercial and industrial revolution. There is no hard-and-fast line between the sentient and non-sentient atoms; just as zoophytes are a connecting link between the animal and vegetable creation, so there is a graduated scale of atoms between those which, although animated by the divine life, are not sentient, and those which are as highly developed relatively to them as man is to a cabbage. For the highest class of sentient atoms through which divine force is transmitted are in the perfect human form. They are infinitesimal bi-sexual innocences male and female, two in one. The tradition of fairies is the lingering consciousness, come down from a remote past, of this fact.

Owing to the unhappily debased condition of our planet, this force is not now operant upon it, except to a very limited and imperfect degree - it is struggling, however, to penetrate into the human organism through the channel provided for it, and this channel must, of necessity, partake of the nature of the forces operant within it---in other words, it must be a bi-sexual channel. It was this bi-sexual channel which Christ came to restore by his mission to earth; and thus inaugurate a process by which man should regain his lost bi-une condition. That process has now partially achieved its consummation in the advent of the complementary half of man whom we call the sympneuma. It is only through the sympneuma that the dynaspheric force, consisting of bi-sexual atoms, can be projected into nature. It comes for the healing of the nations, and is all the more necessary now because the conditions of nature have of late years undergone such a change as to render possible the invasion of the human organism by forces

similar in character, with this one difference, that the atoms of which they are composed are not bi-sexual. These forces exhibit themselves in the phenomena of hypnotism, thought-reading, telepathy, mesmeric healing, spiritualistic manifestations, and in divers other ways, and depend for their quality on the source of their projection in the invisible and the human medium through whom they are transmitted---where both are bad, the atoms are in the form of infusoria, or predatory animalculae, who prey upon each other, and work moral and physical malady. Where both are relatively good, they are in the form of separate uni-sexual beings, depending for their quality upon the medium, and partaking of what moral taint his nature may possess. It must be said that the same remark applies to the bi-sexual atoms of the sympneumatic force; but, although imperfect, there is this guarantee for their superior quality, that it is not possible for a human being to enter upon sympneumatic conditions, excepting after a long and arduous discipline and self-sacrifice for his neighbor, and of great sufferings.

The sympneuma visits none who have not been thus prepared, and who do not live exclusively for the service of humanity, to the extinction of private affections, personal ambitions, or worldly considerations of any kind.

A false sympneuma may, however, visit those who are wholly engrossed by self; such are the succabi and incubi---well-known by the Church---and the force acting through them is the most fatal which can operate upon earth.

There are methods, however, not necessary to enter upon here, by which the true can be distinguished from the false with absolute certainty. All human emotion is atomic, and it has never been possible that it should be otherwise. The peculiarity of the atomic force of the present day is, that it has received an immense accession of energy, through changes which have operated in the invisible.

It is these changes which render will-force, and magnetic influence so much more powerful now than they were formerly; and hence it becomes of such transcendent importance that persons who find themselves in possession of this reinforced energy, and able to operate upon others hypnotically or for curative purposes, should realize the character of the agency they are dealing with---for it is quite impossible for them to project this will-force, or magnetic influence, into the organism of another, without projecting the atoms with it. Now, these atoms vary in quality from the predatory animalculae to the human form through an infinite variety of types; none of them pure and good, though some are far purer and better, relatively, than the others---still no magnetiser is so perfect that his magnetism does not convey to his patients the atoms of the vices and defects peculiar to his own nature, of which they may have been comparatively free.

It may thus happen that a magnetiser, while healing the body of a patient, may work irreparable moral injury to his soul, and this while animated with the best intentions, and quite unconsciously to himself. It often happens, moreover, that the progress of the soul can only be achieved by an attenuation of the external structural atoms, thus producing physical disease; to heal a person thus under going moral treatment, directed from the unseen world, by a sudden and premature exercise of will-force in this one, applied to his surface organism, is to render him a fatal service. Again, it may be that the welfare of a person's soul is dependent upon its removal from the body at a certain juncture; here, again, human interference, by the operation of the human will being free, and yet under specific law, that free operation cannot be arbitrarily hindered in defiance of the law under which it acts.

The reason why material remedies of all kinds may be employed with safety and propriety, is because the curative forces they contain are not composed of sentient atoms, and can be controlled from the unseen in quite a different manner from those which are---which may, to a certain extent, be influenced by them, but cannot be controlled. When a person has reached the point, which may be attained after a long

sympneumatic training, and a life passed under the influence of that training, of having no will but that of God operating freely in him, as his own, he may, under a pressure, which he will recognize as a divine impulse, put forth a healing power, but he will have no personal desire connected with it; the healing force will be put through him irrespective of any conscious will he used; the energy he projects will convey bisexual atoms, which may prove a seed sown as a preparation for a sympneumatic descent.

At such moments the operator will hold himself exclusively open to Christ, for it cannot be too earnestly insisted upon, that Christ is the one source and channel of sympneumatic life, and the healing which comes through it, when a person's moral condition renders such physical healing desirable.

In the presence of the rapid development which dynaspheric force is acquiring, and of the great interest which it is attracting, especially among good and earnest truth seekers, who are only investigating it with the object of turning it to account for the benefit of humanity, it has seemed to me necessary to make these remarks. I have done so in the hope that they might serve as a warning and an encouragement---as a warning of the dangers that beset the unwary explorers into these little known and almost untrodden regions; and as an encouragement as indicating the immense potentialities now descending upon the world for its succor in the hour of its approaching need.

If I seem to have written with the certainty of conviction, it is with no desire to impose my authority arbitrarily upon my readers, but in all humility to give them the facts as they have been revealed to me, after an arduous struggle and investigation into the methods of operation of these forces, which has lasted nearly twenty-five years.

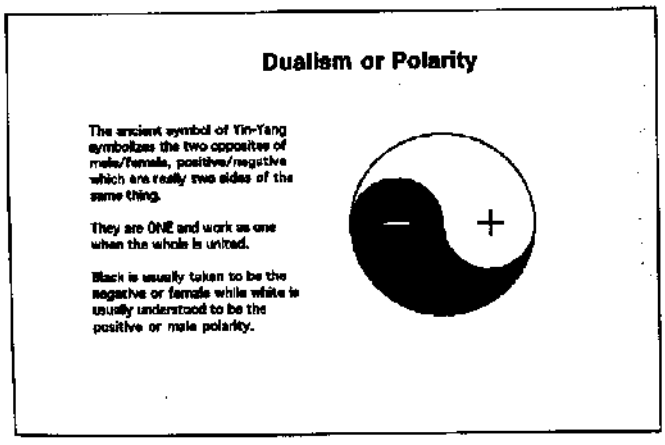

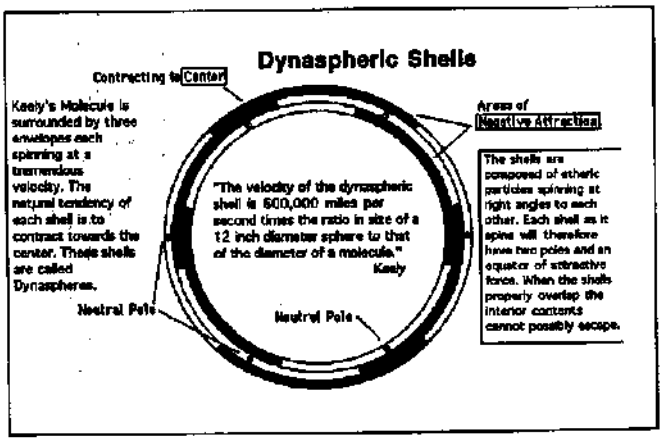

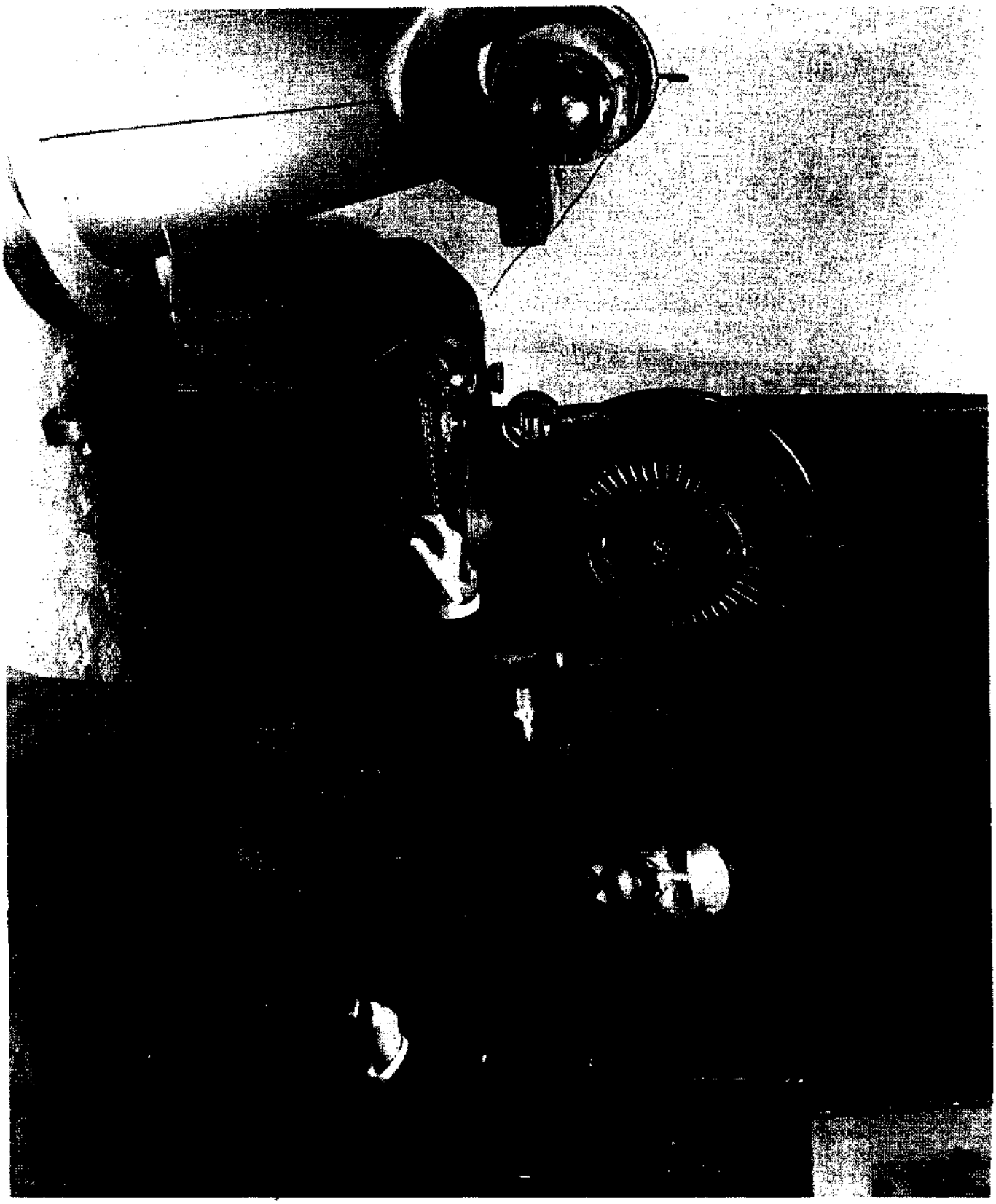

What Is Matter And What Is Force

(from The Theosophist, September, 1888)

[The continual discoveries with which modern science astonishes and bewilders the world create a presumption in the many minds that an article dealing with scientific subjects becomes unreliable when it is a few years old, because most probably superseded by new facts or theories, discovered or formulated in the meantime by the heirophants of the laboratory or the lecture hall, but not yet generally known. Some of these discoveries would in legal phraseology be termed retroactive - they upset theories hitherto upheld as axioms of science or laws of nature; and science that has become out of date is quite as much to be avoided as last year's fashions. This, of course, is a danger which necessarily threatens anyone who, not being in the inner circle of scientists, quotes from even the latest editions of scientific works, and the uncertainty thereby created does much to keep up the unquestioning faith which so many persons feel in the dicta of modern science, paradoxical as that may sound. The reason is plain enough. Men of science stand to the vulgar in the position of revelators. It does not so much matter if they are mistaken today, since they will most likely correct their mistakes tomorrow; and this uncertainty does for the men of science what the constant promise of a new revelation did for Joe Smith and Brigham Young - it creates expectant attention and happy anticipation. This uncertainty of science tends also to discourage undue curiosity and criticism on the part of the public, and to favor the autocratic assumptions of scientific authorities; for naturally there does not seem to be much use for outsiders to spend their time in learning abstruse things that may be discovered, in a few months or years, to have after all been altogether falsely conceived and wrongly explained. In the case of the following article, however, most of the scientific theories and data quoted are still standing, although the article is over five years old; and the occult views of nature it puts forth are true for all time. For this reason it has been thought well to republish it without delay, before the scientific views it deals with have any more time to turn sour or explode. The article, it should be mentioned, was written in answer to some objections raised by a correspondent in a previous number of The Theosophist, as to the designation of electricity as a form of matter; and the writer does not imagine that the question which forms its title is fully answered in the text. There remain several aspects of force almost wholly unnoticed, and it would, of course, be ridiculous to suppose that the subject of Force has been exhausted by dealing with some of its manifestations. Had it been the intention of the article to settle the questions at issue, the writer would not have taken for a title the query, What is Matter and What is Force? but would probably have adopted the usual style of teachers of science, and headed the article, What Matter and Force are. Enough is said in the article, however, to answer its original purpose, namely, of showing that the all-important questions, What is matter? and What is Force? have received no satisfactory answer from modern science, and of proving that no one has any right, in the present state of scientific knowledge, to assert, in the face of the occultists, that electricity is not a form of matter, more especially so since Helmholtz has declared it to be as atomic as ponderable matter itself.]

It is a question of science, which, as such, has to be strictly kept within the boundaries of modern materialistic science. All discussion on the subject, however desirable, would prove, on the whole, unprofitable. Firstly, because science confines herself only to the physical aspect of the conservation of energy or correlation of forces; and, secondly, because, notwithstanding her own frank admission of helpless ignorance as to the ultimate causes of things, judging by the tone of our critic's article, I doubt whether he would be willing to admit the utter inaptness of some of the scientific terms as approved by the Dwija, the twice-born of the Royal Socie-

ty, and obediently accepted by their admirers. The fact that modern science has been pleased to divide and subdivide the atmosphere into a whole host of elements, and to call them so for her own convenience, is no authoritative reason why Occultists should accept that terminology. Science has never yet succeeded in decomposing a single one of the many simple bodies miscalled elementary substances, for which failure, probably, the latter have been named by their elementary. And whether she may yet, or never may, succeed in that direction in time, and thus recognize her error, in the meanwhile, we Occultists permit ourselves maintain that the alleged primordial atoms would be better classified under any other name but that one. With all respect due to the men of science, the terms element and elementary applied to the ultimate atoms and molecules of matter of which they know nothing do not seem in the least justified. It is as though the Royal Society agreed to call every star a Kosmos, because each star was supposed to be a world like our own planet; and then would begin taunting the ancients universe. So far, however, science admits herself that the words element and elementary, unless applied to primordial principles or self-existing essences, out of which the universe was evoluted, are unfortunate terms, and remarks there upon that experimental science deals only with legitimate deductions from the facts of observation, and has nothing to do with any kind of essences except those which it can see, smell, or taste. Professor J.P. Crooke tells us that science leaves all others to the metaphysicians (New Chemistry, 1887). This stern pronunciamento, which shows the men of science refusing to take anything on faith, is immediately followed by a very curious admission made by the same author, Our theory, I grant, may be all wrong, he adds, and there may be no such thing as molecules...The new chemistry assumes as its fundamental postulate that the magnitudes we call molecules are realities, but this is only a postulate. We are thus made suspect that the exact science of chemistry needs to take as well as transcendental metaphysics something on blind faith. Grant her the postulate - and her deductions make of her an exact science; deny it - and exact science falls to pieces! Thus, in this respect, physical science does not stand higher than psychological science, and the Occultists need fear but very little of the thunderbolts of their exact rivals. Both are, to say the least, on a par. The chemist, though carrying his subdivision of molecules further than the physicist, can no more than he experiment on individual molecules. One may even remind both that neither of them has ever seen an individual molecule. Nevertheless, and while priding themselves upon taking nothing on faith, they admit that they cannot often follow the sub-division of molecules with the eye, but can discern it with the intellect. What more, then, do they do than the Occultists, the alchemists, the adepts? While they discern with the intellect, the adept, as he maintains, can as easily discern the sub-division ad infinitum of that which his rival of the exact methods pleases to call an elementary body, and he follows it - with the spiritual in addition to the physical intellect...We must pass to the more important question now, and see how far science is justified in regarding electricity as a force and . . . Eastern Occultists in maintaining that it is still matter. Before we open the discussion I must be allowed to remark that, since a Theosophist wants to be scientifically accurate, he ought to remember that science does not call electricity a force, but only one of the manifestations of the same; a mode of action or motion. Her list of the various kinds of energy which occur in nature is long, and many are the names which she uses to distinguish them. With all that, one of her most eminent adepts, Professor Balfour Stewart - one of the authorities he quotes against our President - warns his readers (see The Forces and Energies of Nature) that their enumeration has nothing absolute or complete about it, representing, as it does, not so much the present state of our knowledge as our want of knowledge, or rather profound ignorance, of the ultimate constitution of matter. So great is that ignor-

ance, indeed, that, treating upon heat, a mode of motion which is supposed to be better understood than electricity, that scientist confess that if heat be not a species of motion, it must necessarily be a species of matter, and adds that the men of science have preferred to consider heat as a species of motion to the alternative of supposing the creation of a peculiar kind of matter. And, if so, what is there to warrant us that science will not yet find out her mistake some day, and recognize and call electricity, in argument with the Occultists, a species of a peculiar kind of matter. Thus, before the dogmatic admirers of modern science take the occultists to task for viewing electricity under one of its aspects - and for maintaining that its basic principle is - matter, they ought first to demonstrate that science errs when she herself, through the mouthpiece of her recognized high priests, confesses her ignorance as to what is properly force and what is matter. For instance, the same Professor of Natural Philosophy, Mr. Balfour Stewart, LL.D., F.R.S., in his lectures on the Conservation of Energy, tells us as follows: - We know nothing or next to nothing of the ultimate structure or properties of matter, whether organic or inorganic, and . . . it is in truth only a convenient classification and nothing more.

Furthermore, one and all, the men of science admit that though they possess a definite knowledge of the general laws, yet they have no knowledge of the individuals in the domains of physical science. For example, they suspect a large number of our diseases to be caused by organic germs; but they have to avow that their ignorance about these germs is complete. And in the chapter What is Energy? the same great naturalist staggers the too-confiding profane by the following admission: - If our knowledge of the nature and habits of organized molecules be so small, our knowledge of the ultimate molecules of inorganic matter is, if possible, still smaller. It thus appears that we know little or nothing about the shape or size of molecules, or about the forces which actuate them. The very largest masses of the universe sharing with the very smallest this property of being beyond the scrutiny of the human senses. Of physical human senses he must mean, since he knows little, if anything, of any other senses. But let us take note of some further admissions, this time by Professor Leconte, in his lecture on the distinction between force and energy is very imperfectly, if not at all, defined in the higher forms of force, and especially in the domain of life. . . Our language cannot be more precise until our ideas in this department are far clearer than now.

Even as regards the familiar liquid - water - science is at a loss to decide whether the oxygen or hydrogen exist as such in water, or whether they are produced by some unknown and unconceived transformation of its substance. It is a question, says Mr. J.P. Crooke, Professor of Chemistry, about which we may speculate, but in regard to which we have no knowledge. Between the qualities of water and the quality of these gases there is not the most distant resemblance. All they know is that water can be decomposed by an electrical current; but why is it so decomposed and then again recombined, or what is the nature of that they call electricity, *etc.*, they do not know. Hydrogen, moreover, was still very lately one of the very few substances which was known only in its aeriform condition. It is the lightest form of matter known.

There is not an atom in nature but contains latent or potential electricity which manifests under known conditions. Science knows that matter generates* what it calls force, the latter manifesting itself under various forms of energy - such as heat, electricity, magnetism, gravitation, *etc.*, - yet that same science has hitherto been unable as we find from her own admissions, as given above, to determine where it is that matter ends and force (or spirit, as some erroneously call it) begins. Sci-

*Using the term generated in the lesser sense of calling forth into manifestation. Force or energy is known to be eternal, and cannot of course be 'generated' in the same sense of being created.

ence, while rejecting metaphysics and relegating it through her mouthpiece, Professor Tyndall, to the domain of poetry and fiction, unbridles as often as many metaphysicians her wild fancy, and allows mere hypotheses to run riot on the field of unproved speculation. All this she does, as in the case of the molecular theory, with no better authority for it than the paradoxical necessity for the philosophy of every science to arbitrarily select and assume imaginary fundamental principles; the only proof offered in the way of demonstrating the actual existence of the latter being a certain harmony of these principles with the observed facts. Thus, when men of science imagine themselves subdividing a grain of sand to the ultimate molecule they call oxide of silicon, they have no real but only an imaginary and purely hypothetical right to suppose that, if they went on dividing it further (which, of course, they cannot), the molecule, separating itself into the chemical constituents of silicon and oxygen, would finally yield that which has to be regarded as two elementary bodies - since the authorities so regard them. Neither an atom of silicon nor an atom of oxygen is capable of any further subdivision into something else, they say. But the only good reason we can find for such a strange belief is because they have tried the experiment and - failed. But how can they tell that a new discovery, some new invention of still finer and more perfect apparatuses and instruments, may not show their error some day? How do they know that those very bodies or molecules, which, when analyzed with still greater minuteness, may show containing in themselves the real primordial elementary globules, the gross encasement of the still finer atom-spark, the spark of life, the source of electricity - matter still! Truly has Henry Kunrath, the greatest of the alchemists and Rosicrucians of the middle ages, shown spirit in man, as in every atom - as a bright flame enclosed within a more or less transparent globule - which he calls soul. And since the men of science confessedly know nothing of (a) the origin of either matter or energy; (b) nor of electricity or life; and (c) that their knowledge of the ultimate molecules of inorganic matter amounts to a cipher. Why, I ask, should any student of Occultism, whose great masters may know, perchance, of essences which the professors of the modern materialistic school can neither see, smell, or taste - why should he be expected to take their definitions as to what is Matter and what is Force as the last word of unerring, infallible science?. . .The term imponderable agents is now regarded as a scientific absurdity. The latest conclusions at which modern chemistry has arrived, it seems, have brought it to reject the word imponderable, and to make away with those text books of premodern science which refer the phenomena of heat and electricity to attenuated forms of matter. Nothing, they hold, can be added to or subtracted from bodies without altering their weight. This was said and written in 1876, by one of the greatest chemists in America. With all that, have they become any wiser for it? Have they been able to replace by a more scientific theory the old and tabooed phlogiston theory of the science of Stahl, Priestley, Scheele, and others? Or, because they have proved, to their own satisfaction, that it is highly unscientific to refer the phenomena of heat and electricity to attenuated forms of matter, have they succeeded at the same time in proving what are really Force, Matter, Energy, Fire, Electricity, Life? The phlogiston of Stahl - a theory of combustion taught by Aristotle and the Greek philosophers - as elaborated by Scheele, the poor Swedish apothecary, a secret student of Occultism, who, as Professor Crooke says of him, added more knowledge to the stock of chemical science in a single year than did Lavoisier in his lifetime, was not a mere fanciful speculation, though Lavoisier was permitted to taboo and upset it. But, indeed, were the high priests of modern science to attach more weight to the essence of things than to mere generalizations, then, perhaps, they would be in a better position to tell the world more of the ultimate structure of matter than they now are. Lavoisier, it is well known, did not add any new fact of prime importance by

upsetting the phlogiston theory, but only added grand generalization. The Occultists are perfectly aware, it need hardly be said, of modern theories of combustion, and fully recognize the part which oxygen plays therein. They prefer, however, to hold to the fundamental theories of ancient sciences, knowing well that a very large balance of real knowledge lies on that side, when the ancient and the modern are compared. No more than the authors of the old theory do they attach to phlogiston - which has its specific name as one of the attributes of Akasa - the idea of weight which the uninitiated generally associate with all matter. And though to us it is a principle, a well defined essence, yet no more than we did they view it as matter in the sense it has for the present men of science. As one of their modern professors put it - Translate the phlogiston by energy, and in Stahl's work on Chemistry and Physics, of 1731, put energy where he wrote phlogiston, and you have . . . our great modern doctrine of conservation of energy. Verily so it is the great modern doctrine, only plus something else, let me add. Hardly a year after these words had been pronounced, the discovery by Professor Crookes of radiant matter - of which farther on - has nigh upset again all their previous theories.

Force, energy, physical agent, are simply different words to express the same idea, observes our critic. I believe he errs. To this day the men of science are unable to agree in giving to electricity a name which would convey a clear and comprehensive definition of this very mysterious agent, as Professor Balfour Stewart calls it. While the latter states that electricity or electrical attraction may probably be regarded as peculiarly allied to that force which we call chemical affinity; and Professor Tyndall calls it only a mode of motion; Professor A. Bain regards electricity as one of the five chief powers or forces of nature:--- One mechanical or molar, the momentum of moving matter, the others molecular, or embodied in the molecules, also supposed(?) in motion - these are heat, light, chemical force, electricity. (The Correlations of Nervous and Mental Forces.) Now, these three definitions would not gain, I am afraid, by being strictly analyzed . . . Light was never regarded as a force. It is, says science, a manifestation of energy, a mode of motion produced by a rapid vibration of the molecules and transmitted by the undulations of ether. The same for heat and sound, the transmission of the latter depending, in addition to the vibrations of ether, on the undulations of an intervening atmosphere. Professor Crookes thought at one time that he had discovered light to be a force, but found out his mistake very soon. The explanation of Thomas Young of the undulatory theory of light, holds now as good as ever in the theories of modern science at least, and according to this explanation that which we call light is simply an impression produced on the retina of the eye by the wave-like motion of the particles of matter. Light, then, like heat - of which it is the crown - is simply the ghost, the shadow of matter in motion! . . The men of science have just found out a fourth state of matter, whereas the Occultists have penetrated years ago beyond the sixth, and, therefore, do not infer, but know of the existence of the seventh, the last. Professor Balfour Stewart, in seeking to show light to be an energy or force, quotes Aristotle, and remarks that the Greek philosopher seems to have entertained the idea that light is not a body, or the emanation of any body (for that, Aristotle says, would be a kind of body), and, that, therefore, light is an energy or act. To this I respectfully demur, and answer that if we cannot conceive of motion without force, we can conceive still less of an energy or act existing in boundless space from the eternity, or even manifesting without some kind of body. Moreover, the conceptions about body and matter of Aristotle and Plato, the founders of the two great rival schools of antiquity, opposed as they were in many things to each other, are nevertheless still more at variance with the conceptions about body and matter of our modern men of science. The Theosophists, old and modern, the Alchemists, and Rosicrucians have ever maintained that there were no such things

per se as light, heat, sound, electricity, least of all could there be a vacuum in nature. And now the results of old and modern investigation fully corroborate what they had always affirmed, namely, that in reality there is no such thing as a chemical ray, a light ray, or a heat ray. As far as can be ascertained by those whose observations and experiments are confined to the material plane, there is nothing but radiant energy; or, as a man of science expresses it in the Scientific American, radiant energy, motion of some kind, causing vibrations across space of something between us and the sun; something which, without understanding fully (verily so!), we call 'ether,' and which exists everywhere, even in the vacuum of a radiometer. The sentence, for being confused, is, none the less for it, the last word of science. Again: We have always one and the same cause, radiant energy, and we give this one thing different names - 'actinism,' 'light,' or 'heat.' And we are told also that the miscalled chemical or actinic rays, as well as those which the eye sees as blue, or green, or red, and those which the thermometer feels, are all one thing, the effects of motion in ether. (The Sun's Radiant Energy, by Professor Langley.)

Now, the sun and ether being beyond dispute material bodies, necessarily every one of their effects - light, heat, electricity, *etc.* - must be, agreeably to the definitions of Aristotle (as accepted, though slightly misconceived, by Professor Balfour Stewart), also a kind of body, ergo - matter.

Now what is in reality matter? We have seen that it is hardly possible to call electricity a force, and yet we are forbidden to call it matter under the penalty of being called unscientific. Electricity has no weight - ergo, it cannot be matter. Well, there is much to be said on both sides. Mallet's experiment, which corroborated that of Pirani (1878), showed that electricity is under the influence of gravitation, and must have, therefore, some weight. A straight copper wire, with its ends bent downwards, suspended at the middle to one of the arms of a delicate balance, while the bent ends dip in mercury. When the current of a strong battery is passed through the wire by the intervention of the mercury, the arm to which the wire is attached, although accurately balanced by a counterpoise, sensibly tends downwards, notwithstanding the resistance produced by the buoyancy of the mercury. Mallet's opponents, who tried at the time to show that gravitation had nothing to do with the fact of the arm of the balance tending downward, but that it was due to the law of attraction of electric currents, and who brought forward to that effect Barlow's theory of electric currents, and Ampere's discovery that electric currents, running in opposite directions, repel one another, and are sometimes driven upwards, only proved that men of science will rarely agree, and that the question is far an open one. This, however, raises a side issue as to what is the law of gravitation. The scientists of the present day assume that gravitation and attraction are quite distinct from one another. But the day may not be far distant when the theory of the Occultists that the law of gravitation is nothing more or less than the law of attraction and repulsion will be proved scientifically correct.

Science may, of course, if it so pleases her, call electricity a force. Only by grouping it together with light and heat, to which the name of force is decidedly refused, she has either to plead guilty of inconsistency, or to tacitly admit that it is a species of matter. But whether electricity has weight or not, no true scientist is prepared to show that there is no matter so light as to be beyond weighing with our present instruments. And this brings us directly to the latest discovery, one of the grandest in science; I mean Mr. Crookes' radiant matter, or, as it is now called, the fourth state of matter. That the three states of matter, the solid, the liquid, and the gaseous, are but so many stages in an unbroken chain of physical continuity, and that the three correlate or are transformed one into the other by insensible gradations, needs no further demonstration, we believe. But what is of far greater importance to us Occultists is the admission made by several great men of science in various articles

upon the discovery of that fourth state of matter. Says one of them in Scientific American:--- 'There is nothing any more improbable in the supposition that these three states of matter do not exhaust the possibilities of material condition than in supposing the possibilities of sound to extend to aerial undulations to which our organs of hearing are insensible, or the possibilities of vision to ethereal undulations too rapid or too slow to affect our eyes as light.

And as Professor Crookes has now succeeded in refining gases to a condition so ethereal as to reach a state of matter fairly describable as ultra-gaseous, and exhibiting an entirely novel set of properties, why should the Occultists be taken to task for affirming that there lie beyond that ultra-gaseous state still other states of matter; state so ultra-refined, even in their grosser manifestations - such as electricity under all its forms - as to have fairly deluded the scientific senses, and let the happy possessors thereof call electricity - a force! They tell us that it is obvious that if the tenuity of some gas is very greatly increased, as in the most perfect vacua attainable, the number of molecules may be so diminished that their collisions under favourable conditions may become so few in comparison with the number of masses that they will cease to have a determining effect upon the physical character of the matter under observation. In other words, they say: The free-flying molecules, if left to obey the laws of kinetic force without mutual interference, will cease to exhibit the properties characteristic of the gaseous state, and take on an entirely new set of properties. This is radiant matter. And still beyond lies the source of electricity - still matter. . . Speaking of his discovery, Professor Crookes justly remarks that the phenomena he has investigated in his exhausted tubes reveal to physical science a new field for explanation, a new world, a world wherein matter exists in a fourth state, where the corpuscular theory of light holds good, and where light does not always move in a straight line, but where we can never enter, and in which we must be content to observe and experiment from without. To this the Occultist might answer: If we can never enter it with the help of our physical senses, we have long since entered and even gone beyond it, carried thither by our spiritual faculties and in our spirit bodies.

And now I will close this too lengthy article with the following reflection. The ancients never invented their myths. One acquainted with the science of occult symbology can always detect a scientific fact under the mask of grotesque fancy. Thus one who would go to the trouble of studying the fable of Electra - one of the seven Atlantides - in the light of occult science, would soon discover the real nature of Electricity, and learn that it signifies little whether we call it force or matter, since it is both, and so far, in the sense given it by modern science, both terms may be regarded as misnomers. Electra, we know, is the wife and daughter of Atlas the Titan, and the son of Asia and of Pleione, the daughter of the Ocean. . . As Professor Leconte well remarks, there are many of the best scientists who ridicule the use of the term vital force or vitality as a remnant of superstition, and yet the same men use the words gravity, magnetic force, physical force, electrical force, *etc.*, and are unable withal to explain what is life, or even electricity; nor are they able to assign any good reason for the well-known fact that when an animal body is killed by lightning, after death the blood does no coagulate. Chemistry, which shows to us every atom, whether organic or inorganic, in nature susceptible to polarization, whether in its atomic mass or as a unit, and inert matter allied with gravity, light with heat, etc., hence as containing latent electricity, that chemistry still persists in making a difference between between organic and inorganic matter though both are due to the same mysterious energy, ever at work by her own occult processes in Nature's laboratory, in the mineral no less than in the vegetable kingdom. Therefore do the Occultists maintain that the philosophical conception of spirit, like the conception of matter, must rest on one and the same basis of phenomena, adding that force and matter, spirit and matter, or

viewed as opposite poles in their respective manifestations, yet they are in essence and in truth but one, and that life is present as much in a dead as in a living body, in inorganic as in organic matter. This is why, while science is searching still, and may go on searching for ever, to solve the problem What is life? the Occultist can afford to refuse taking the trouble, since he claims, with as much good reason as any given to the contrary, that life, whether in its latent or dynamical form, is everywhere, that it is as infinite and indestructible as matter itself, since neither can exist without the other, and that electricity is the very essence and origin of life itself. Purush is non-existent without Prakriti; nor can Prakriti, or plastic matter, have being or exist without Purush, or spirit, vital energy, life. Purush and Prakriti are, in short, the two poles of the one eternal element, and are synonymous and convertible terms. Our bodies as organized tissues are indeed an unstable arrangement of chemical forces, plus a molecular force - as Professor Bain calls electricity - raging in it dynamically during life, tearing asunder its particles at death, to transform itself into a chemical force after the process, and thence again to resurrect as an electrical force or life in every individual atom. Therefore, whether it is called Force or Matter, it will ever remain the omnipresent Proteus of the universe, the one element, Life, Spirit or Force at its negative, Matter at its positive pole; the former the Materio-Spiritual, the latter the Materio-Physical Universe, Nature, Swabhavat or Indestructible Matter.

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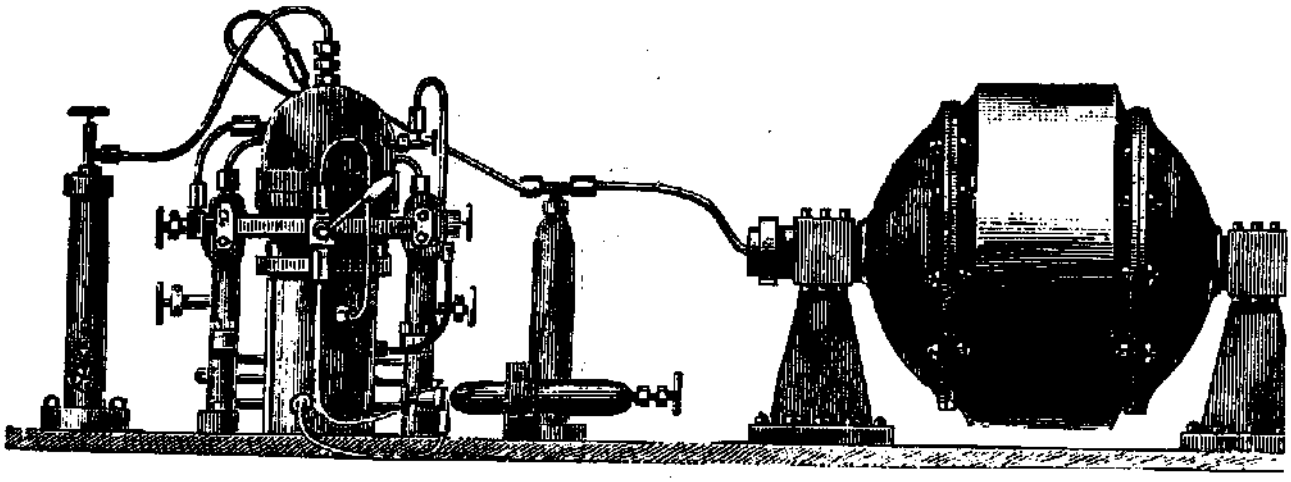

The Astral Light

by Louise A. Off

The Astral Light, as the source of all world phenomena, is a theme of no little importance to the student of occultism. The root of the word Astral is to be found in the Assyrian Istar, signifying star, and was applied to this element by the Kabbalists and later mystics, because they considered the heavenly bodies as the concrete crystallizations of the Astral Light. Some Theosophic writers have confounded the nature of this element with that of Akasa, while in fact the latter comprehends infinitely more both in quality and quantity. Literally the Sanscrit term Akasa means the sky, but occultly the impalpable Ether or the Soul within the Ether. Our most logical authority, The Secret Doctrine, defines it as the immortal spirit, the progenitor of Cosmic life and universal intelligence whose characteristic property is Buddhi. Akasa is the sphere of the pure undifferentiated Monad, the essence of wisdom, while the Astra Light at its opposite pole is the abstract atom of matter, the plane of generation, and the great womb out of which issues all planetary life. Ether, which is the highest vibration of the Astral Light, is but as a vehicle for Akasa, a gross body in comparison. The functions of the Astral Light are as manifold as the expressed universe. Its nature is dual - the highest Ether forming its positive, and the concrete, or differentiated elements, its negative pole. Its cause reaches back to the root of all causes, and its effects involve all our physical and psychical experiences. We deal with its familiar phenomena in every breath and every motion, while the rare and abnormal phases are as strictly subject to its laws. It is not substantially identical with any one of the material elements of Cosmic matter, but is one degree superior to Prakriti (Nature as apprehended by the senses), and it impenetrates and vitalizes each atom. It is itself the one underlying element in which all other known elements have their source and supply. In its physical aspects it includes the Ether of modern scientists, but in the metaphysical sense they scarcely touch its borderland. For while it is the reservoir of Heat, Light, Magnetism, and Electricity - the field of all degrees of vibration - it is also the sphere of all intellectual life, and the ruling agent in the alchemical process which frees the cerebral atom and converts it into thought. Its vibratory rate determines individual mental tendencies, and also establishes our intimate relations in body with the stars. Paracelsus maintains that, as fire passes through an iron stove, so do the stars pass through man with all their properties, and go into him as the rain into the earth, which gives fruit out of that same rain. While the modern spectroscope reveals the identity in substance of infinitesimal man, and the greatest luminiferous body that glides in vast revolutions through space, no instrument has, as yet, been discovered so sensitive as to register the subtle and evanescent fluid which, by its uniform nature, makes astronomical research and thought-transference possible. Keely's Motor has, however, already foreshadowed such a discovery.

The Astral Light is the great record-book upon whose pages every thought and act of differentiated consciousness is engraven, there to be read by the individual who has learnt the secret of exalting his vibrations until they become synchronous with the waves of this finer element. The definition of Memory which has ever been the enigma of science, a function with an inapprehensible cause, is relegated to the domain of

Universal Laws Never Before Revealed.. Keely's Secrets

the occultist, who may briefly define it as the correlative vibration of the cerebral center with the Astral Light. Within this correlation reside all the possibilities of consciousness from the horizon of Maya (illusion) to the zenith of pure Ether of transcendental life. Madame Blavatsky sweepingly states: The psychic forces, the 'ideomotor' and 'electro-biological powers,' latent thought' and even 'unconscious cerebration' theories can be condensed into two words, the Kabbalistic 'Astral Light.' Quesnes treated of it as a universally diffused fluid permeating all things, and differing in action only according to the mobility of the organism by which it is confined.

The differentiated will to live accompanying each primary monad is the sculptor of the astral images which constitute individual experience. An intense power of concentration makes these images subjective, in which case they are realities only to the operator, but under still more acute and intelligent development, these images may assume a concrete objective form with power of duration proportioned to the original impulse or determined purpose of the projector. Determined will, says a fire-philosopher, is a beginning of all magical operations, and the great magician, Abbe Constant, states: To acquire magical power, two things are necessary: to disengage the will from all servitude and to exercise it in control. He alone can become a Master whose physical and psychical organization is attuned to the Astral Key-note - whose self-consciousness has outgrown the limits of personal slavery, and whose will is so cultivated as to act without fear and without desire - intelligent, determined, self-possessed and confident. While the majority of mankind is occupied in mere negative registration of sense-impressions the occultist classifies these, and admits only those most useful to his purpose. Colonel Olcott refers to the manipulation of the Astral Light in his statement, that the efficacy of all words used as charms and spells lies in what the Aryans call the vach, a certain latent power resident in Akasa. Physically we may describe it as the power to set up certain measured vibrations, not in the grosser atmospheric particles whose undulations beget light, sound, heat and electricity, but in the latent spiritual principle or force - about the nature of which modern science knows almost nothing. As an illustration of this we have the word Aum, which, as all students know, has an equilibrating effect which resists the inroad of passion.

The symbol used to express the astral realm by the mystics of all ages is the serpent, or the fiery dragon. It is stated that long before our globe or even our universe became egg-shaped, a long trail of Cosmic dust (or fine mist) moved and writhed like a serpent in space. This was the beginning of our Eternity, exoterically expressed by a serpent with its tail in its mouth, or in the act of incubating the Mundane Egg with its fiery breathe. The Chaldean Oracles refer to the Astral Light as winding in form, which qualification refers to the vibratory motion that characterizes it. The intense rate of its pulsation may be faintly realized in the rapidity with which successive images are recorded in the dreaming or hypnotized state. An illustration is recounted of a student who was making scientific experiments in this psychological field with a friend. While a drop of water was descending down upon his forehead, he closed his eyes and dreamed that he started out from a harbor upon the wide main, soon passing several beautiful islands full of villages, cities, verdant fields and mountains. The sun was beaming generously, but little by little the sky grew darker and heavier, and drifts of black clouds swept upon the scene. A great gal arose. Consternation and horror pervaded the crew. The waves began to rise higher and higher, until finally the heavens and the sea were blended into one dense chaos.

The crises was at hand. The dreamer suddenly felt as though the whole sea had burst asunder and drawn him in - he awoke just as the drop of water touched his skin, fallen from the hand of his friend and held but a few inches above his head. He had registered the full episode of dramatic changes during the instant in which the sensor nerve

flashed its irritation to the brain. Far more remarkable than this are illustrations on record which cover an extent of years and are recorded in an instant of time, experimentally proven to be less than the period required for transmitting a nervous current. The wondrous rapidity with which feeling and thinking may be condensed has also been frequently analyzed in the experience of persons nearly drowned, and as Helmholtz has demonstrated that the period in which a nerve-current may be conducted is a definite one, we have no alternative but to assume that a far subtler element or vehicle is employed in the registering psychic experiences. By the astral current throughout the ayras, around the nerve-centers and nerve-tubes, mind contacts mind, thoughts are flashed in upon us and emotions conveyed. It radiates from the individual man as an impalpable but intelligent aura - the medium of his psychic and intuitional life, by means of which he evinces sympathy and understanding; while in its higher aspect it is the sensitive plane that records Cosmic ideation, and conveys impressions of truth and of universal law to the human mind.

Experiment with trained sensitives has proven that when an intellectual concept is formed, the astral aura photographs it instantaneously, while, when an emotion is evinced, the aura changes in intensity of color, and, on volition becoming manifest, there is a positive increase of vibration. We, therefore, carry with us all we have ever thought and felt - and self is the ever-refining essence of this thought and feeling. From this point of view responsibility assumes enormous proportions, and we perceive why the great Teachers of the world have ever agreed that Man is his own heaven and his own hell.

The great mesmerizer, Du Potet, declares that the faculty of directing this fluid is inherent in certain organizations, that it passes through all bodies, and that everything can be used as a conductor - no chemical or physical forces are able to destroy it. Treating thus with the merest initial of this latent power, who can say where its further unfoldment will lead the collective consciousness of Humanity?

In the present age, our science informs us, we perceive in the main only the lowest vibrations and inferior qualities of the Astral Light, because we are in the lower arc of our present cycle, and the energy of the life-wave is at its ebb. Mme. Blavatsky says of Plato's method of expression that he divides the intellectual progress of the universe during every cycle into fertile and barren periods . . . When those circulations, which Eliphas Levi calls 'currents of the Astral Light' in the universal Ether, . . take place in harmony with the divine spirit, our earth and everything pertaining to it enjoys a fertile period. The occult powers of plants, animals, and minerals magically sympathize with its superior natures, and the divine soul of man is in perfect intelligence with these inferior ones. But during the barren periods the latter lose all their magic sympathy, and the spiritual sight of the majority of mankind is so blinded as to lose every notion of the superior power of its own divine spirit. We are in a barren period. Ignoring our latent inherent forces, we drift in negative submission to the lower laws of Nature, suffer deprivation, want of thought, emotion, and volition, while the precious fluid, in mute anticipation, haunts our dreamless sleep, and awaits the dawning of a higher Consciousness.

Keely's Secrets

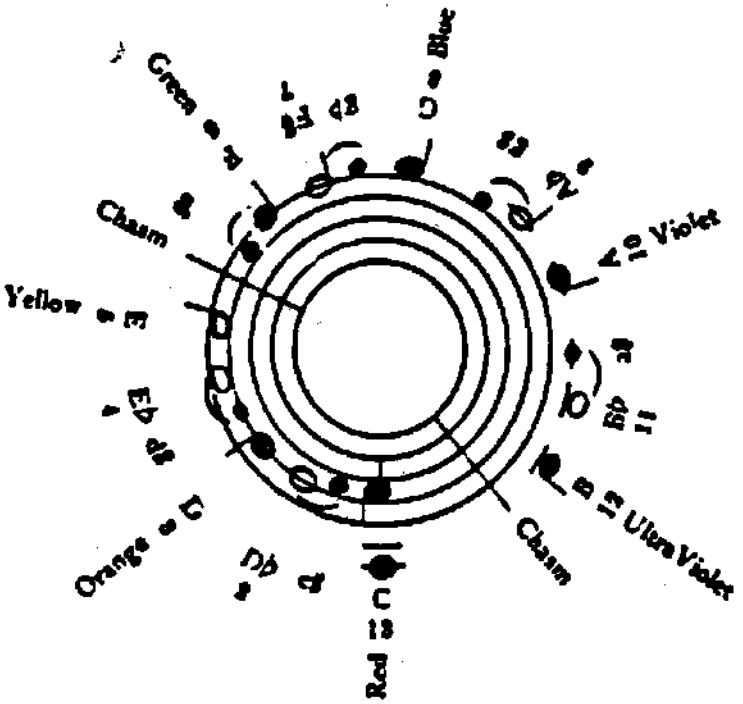

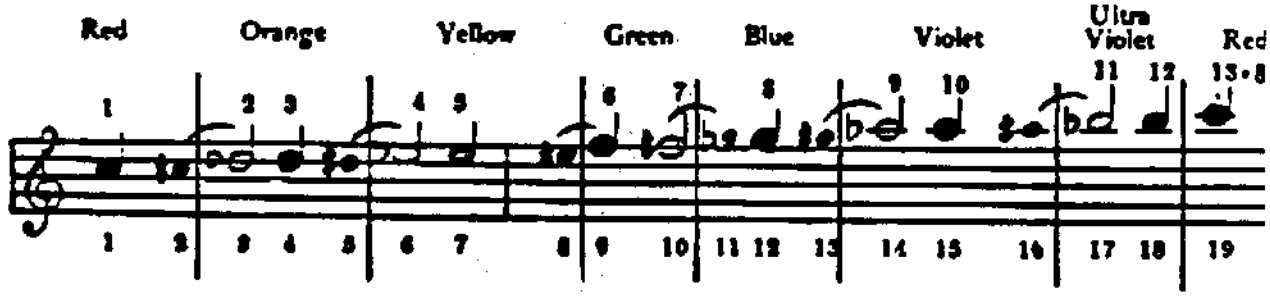

Mr. Plum's Visit to Keely's Laboratory

(sometime in late 1893)
from Dashed Against the Rock

"I have seen a spectacle I would have pronounced impossible according to all accepted theories of physics with which I am familiar. Without apparent exhibition of heat, electricity, or any other form of energy hitherto operated by man, I have seen a strong metallic wheel, weighing seventy-two pounds, in swift and steady revolution by the hour, and absolutely without cost. It is but a subsidiary engine, made and used simply to help equip with similar mysterious capacity of movement the large commercial engine by its side. And that is a most strange and complex mechanism, which perhaps no one but the inventor can even understand at present, and which, but for too frequent previous unauthorized fixing of dates, might be said to give promise of being itself in motion very soon. What is 'very soon' in such an undertaking? Another thirty years of patient, lonely plodding on this labyrinth path would be nothing, if then this explorer could reach his goal. How long after Franklin's kite did the world wait, and how many hundred great experimenters, before a dynamo engine kindled our lamps and whirred our wheels? Yet this solitary pioneer, grown half blind by groping in these dim intricacies so long, again and again hurled aside, broken and almost dieing by the terrific force with which he is seeking to cope, is met with the sneer, 'Why don't you do something?' He has done much, of ignorant, senseless, and cruel abuse. His immortality, however, is sure. For the world at length honors an honorable purpose, persistently pursued in a high undertaking. And he has already so enlarged the domain of human knowledge, he has lifted man into such a new world of facts, the truths his experiments unveil are so novel, suggestive, and inspiring, that whether all this is ever turned to practical account or not, his name will never die. But if he should turn out to be a prophet, if he is a seer, and does really discern a promised land of lightened toil into which mankind will eventually enter, even though he may not live to lead them in, then the world will gratefully build his tomb.

But the world asks, who is the witness that testifies so boldly to these surprising things? Is he competent and worthy of trust? The witness is not a capitalist, and he has no relations with investors, and is free to say that if Keely were to die tomorrow, it might be a hundred years before another mind would arise able to complete his work; if indeed, it is capable of being completed at all, which no one at present knows. Impelled by a life-long interest in the wonders of natural science, and honored by the personal friendship of Keely and a few of his advisers, I have followed the course of this investigator for years with the intensest interest and sincerest admiration. I spent more of my vacation this season in the Philadelphia laboratory, and saw greater wonders there, than in the Chicago Fair.

In whose judgement greater? Is a layman in physical science competent to judge in such matters? Confessedly not, on some questions. To most men the learned physicists speak an unknown tongue. Too profound for the common apprehension are the mathematical formulas, even, with which their works abound, though their theories and arguments are full of interest. And many would confess also that they can no more understand the ground of Keely's assertions concerning the number of millions of oscillations taking place in a given substance each second, nor his fluent discourse upon clustered thirds and introductory ninths, upon nodal transmit-

ters and neutral centers, and upon streams and waves of polar and depolar influence. On these declarations this witness has no testimony to offer. In electrical science the world gladly accepts the terminology and the philosophy by which the specialists creditably seek to gain some practical apprehension of the elusive mystery with which they deal; elusive, for through all their technical terms and fine-spun theories, the futility of their endeavor to gain any exhaustive comprehension of it plainly appears. Experts have their field, but as Mr. Gladstone says of the Hebraist and the scientist in reference to the higher criticism and the scriptural cosmogony, 'their title to speak with authority is confined to their special province, nor are they inerrable there; and if we allow them to go beyond it, and still to claim their authority, when they are what is called at school "out of bounds," we are much to blame, and may suffer for our carelessness.' 'My contention is,' he says, 'that there is a ground which the specialist is not entitled to occupy in his character as a specialist, and on which he has no warrant for entering, except in so far as he is a just observer and reasoner in a much wider field.'

It is into this wider field of fact, where any can go whose general training fits him to be in any wise 'a just observer and reasoner,' that this witness deems it not improper to enter, especially as he follows in the wake of not a few who rank high as experts in mechanical engineering, in chemistry, in electricity, and other departments of superior culture. For, not only has Keely's legal counsellor, Charles B. Collier, an experienced patent lawyer, acute, cultured, and discerning, given him from the first his sincere and hearty support, but numbers of other men of honorable character and position, many of them eminent for scientific attainments, have given their unqualified testimony that Keely is an original and able investigator in an interesting and promising, though wholly novel, field - a wonder-worker, whose work seems to overturn certain accepted theories, and has puzzled and baffled their learned advocates. Yet, partly, perhaps, because Keely is not in the fraternity of college bred men, but has educated himself (though his writings show familiarity with scholarly works), partly because his claims are so astonishing and his methods so incomprehensible, and partly because of premature predictions of a practical issue of his labors, and because also of unfortunate differences reported in respect to the business side of his enterprise, there are comparatively few men of public prominence who seem to be willing to be known as believers in the importance of his investigations, or even in the integrity of the man. At any rate, ridicule and contempt continue to be thrown at him and at the faithful friends who have long and nobly stood by him. Only lately a prominent journal intimated that 'an interruption of Keely's personal freedom' ought to result from what it calls his 'gigantic jugglery.' It is these unworthy flings, together with a sense of the public importance of the whole matter, which have prompted my voluntary and unsolicited testimony in the interest of truth.

For though scores of assemblies, comprising learned scientists, skillful engineers, and men of large success in the practical conduct of affairs, have witnessed various experiments by Keely during the past dozen years, and although their clear and positive statements of the interest and value of his researches have been repeatedly published in leading newspapers, with the names and professional titles of the witnesses given, yet the general public appears either to overlook or forget all these testimonies, and to be rudely impatient of every undertaking that does not immediately issue in commercial success. Seldom does any public journal refer to Keely in terms of appreciation and respect. As his labors have now reached some new results which only a few persons have witnessed, this further testimony is offered as information upon a matter of scientific interest, certainly, and with a possible bearing upon industrial advance.

What, then, is the testimony that the present witness has to give? After some ten years of acquaintance with Keely, and after personally seeing many of his experiments, 'witness deposeth and

of one of the most beneficent revolutions in the history of human progress; a man of wonderful insight and truly amazing fertility of inventive genius in overcoming obstacles and in contriving appliances for attaining his mechanical ends; that he is dealing with and trying to employ in practical mechanics a force absolutely new among all the forces hitherto handled by man, although its presence in nature is affirmed by the theories of scientists, and demonstrated by various observed phenomena; a force of mysterious and awful energy, boundless in extent, and literally costless as the air. Electricity is subtle and powerful and illimitable in supply, but it requires constant and costly expenditure of energy to call it into exercise and keep it at work. This new force, beyond the curious and complicated mechanism which this wonderful wizard has contrived for it to employ, the harness he has fashioned for it to wear, seems to require but a few slight musical sounds, the sonorous vibrations of certain metallic appliances, to set it in motion, and then it will keep in motion - for all that at present appears, in steady, noiseless, and almost resistless motion - till the solid metals of which it is composed wear out.

What! one and all exclaim, is the absurdity of perpetual motion to be revived again? But the physicists tell us there is perpetual motion all around us in nature, intense and all-prevading, and always has been, since the hour 'when the morning stars sang together, and all the sons of God shouted for joy.' Here we touch the robe of the Infinite One, who 'upholdeth all things by the word of his power.' Of him the Unerring One declared, 'My Father worketh hitherto and I work.' Aye, works unceasingly now, in the incessant and intense molecular vibration all the time going on in all matter; in the solid table by which we sit, in the firm granite of the building which encloses us. Action, motion in everything, by everything, everywhere, all the time, and swift, more nimble-footed sometimes than thought almost, but with such a soft and easy pace that no footfall is heard, no movement discerned save as we take observation by the distant heavenly orbs among which we all here on the earth are traveling, hurled along our pathway over a thousand miles a minute. Movement of everything from here to there, and movement in everything while here or there. And so harmonious is the movement, on such delicate anti-friction cushions do the bearings rest, that it is all inaudible, save to that One alone whose ear discerns the music of the spheres - the spheres immensely great and infinitesimally small -

'Forever singing as they shine,
The hand that made us is divine.'

And only now, after thousands of years of unheard song, this great magician arises and strikes the chord of sympathy to which this vibrating force responds, and lo! it comes forth from its secret chambers like the mighty Genius unloosed by the Arabian fishermen from the copper flask, and waits on man to do his bidding, bending its tough sinews and plying its facile fingers to perform his humblest tasks.

And what proof can there be that this dream of poetry and fancy of story is in any degree an accomplished fact? Look and see. Here is a wooden table, sometimes covered by a heavy slab of glass. Standing on the glass or on the wood, and capable of being moved freely upon it, is a metal standard say a foot high, bearing a copper globe about a foot in diameter. Around the base of the standard project horizontally numbers of small metal rods a few inches long, of different sizes and lengths, vibrating like tuning forks when twanged by the fingers. In the hollow globe is a Chladni plate and various metal tubes, the relation which can be altered by turning a projection like a door-knob, on the outside of the globe, at the outer end of a small shaft, round and round to the right or left. This construction is called a 'sympathetic transmitter.' Some two or three feet distant on the table stands a movable metallic cylindrical case, some six inches by eight in size, composed of certain metal resonating tubes, and certain other metal fixtures. You take it all apart and see there is no magnet there. You place on top of this cylinder a small pocket compass, a brass cup of two inches in diameter with its glass face. The

six inches by eight in size, composed of certain metal resonating tubes, and certain other metal fixtures. You take it all apart and see there is no magnet there. You place on top of this cylinder a small pocket compass, a brass cup of two inches in diameter with its glass face. The needle points north. From the periphery of the globe of the 'sympathetic transmitter' extends a wire of the size of a common knitting-needle, made of gold and silver and of platinum. The free end of this wire is now attached to the cylinder. The needle is still true to the pole. Then the vibrating rods are twanged, the knob is turned, and on a rude harmonicon trumpet for a moment or two certain sounds are made, when lo! the needle is invisible, it is whirling on its pivots fast. The operator talks of the variant length of waves and of a continuous stream, and in some instances it is half a minute, sometimes three minutes, before the needle comes to rest, and it has kept in swift revolution for many hours; but when it pauses it points no longer to the north, but to a particular part of the mechanism. You leave it there, and are busy with other wonders for an hour or so. Returning, you find the needle still points to its new master. You lift the compass off, and at once it resumes its normal position. You slowly lower it towards the silent cylinder, and when within an inch or two it obeys the new impulse again, and points as before. So also it veers from the north when you carry it near the knob of the copper globe. As Gladstone says, 'Our hands can lay hold of truths that our arms cannot embrace,' and though it takes a physicist to comprehend this miracle, any careful observer can apprehend it, and, after seeing it repeated many times, if he is measurably well read, is competent to testify that here is a new, subtle, silent, continuous influence, and that it is called into exercise in connection with certain brief musical sounds.

Look again. On this rude harmonicon trumpet this magician blows through a small window into the next room towards a common zither some ten feet distant, held upright on a table by a small standard composed of a group of metal tubes. The two musical instruments have been carefully attuned to each other. Attached to the back of the zither is a common silk thread loosely hanging and extending some eight feet away, where it is tied to a movable framework of half-inch iron rods, supporting and bracing in position, on an isolated table of glass, a metal globe, fifteen inches in diameter, capable of turning freely in either direction, on its axis, which bears inside the globe certain resonant tubes and plates, the table standing at an angle of 45 degrees from the face of the zither. Louder sounds the horn, till in a minute or two the metal globe begins to revolve. The horn stops, the globe stops. Again the horn resounds, again the globe turns, and the stronger and more continuous the blast, the more swiftly whirls the globe. You snip the thread apart with your scissors, and the ear of the globe has grown dull; no sound can awake it to motion again. Does a man need to be an expert in physics after he has seen that marvel repeated a few times, and has moved all that apparatus freely hither and thither, to testify that the rapid revolution of that metal globe was not caused by compressed air, coming in concealed tubes from a hidden reservoir, or that a silk thread is not the highway usually cast up for electricity to travel?

But these are philosophical toys. What about an engine with power to help human toil?

I have in my study a paper weight - a disc, said to be composed of an alloy of three metals. It looks like steel, measures two and a half inches by three-quarters of an inch, weighs about a pound, is enclosed in a brass ring, and exhibits no magnetic power. I am told that shut up in a glass chamber and connected with the wire which seemed to affect the compass, it absorbed some seven pints of hydrogen gas. The story runs that it was also rapidly whirled by a steam engine a certain number of hours, still in connection with the apparatus from which seemed to flow that subtle influence which the needle of the compass obeyed. Whatever may be thought of this, it is a fact that the disc thus 'vitalized in its atomic or molecular constitution' adheres to the under side

of a certain metallic resonant structure as if held there by magnetic attraction, and also supports a weight hung to itself of over two hundred and thirty pounds. Dissociated from the peculiar vibrating apparatus, it falls like any other heavy body, and though that apparatus attracts the disc, even with the attached weights, it is incapable of attracting anything else; it will not support the smallest iron filing. Here then is a strong pulling power in exercise in certain circumstance when two bodies are in contact. Can it pull bodies together which are not in contact?

I see before me on a table a glass jar, ten inches in diameter and forty-eight inches high, filled with water. At the bottom lie three metal balls like the one I hold in my hand, which weighs about two pounds. The jar has a metal cap to which is attached the gold and platinum wire reaching from the copper globe. I am told each ball, like every mass of matter, has its peculiar musical chord. I am reminded of well-known facts of sympathetic vibration; *e.g.*, a large mill trembling in response to the note of a neighboring waterfall, and only quieted and rendered safe by building on an addition, changing its musical chord. And now again the rods are twanged, the knob is turned, the trumpet sounds and keeps sounding till, in a moment or two, I see one ball begin to sway from right to left, then slowly leave the bottom of the jar and rise through the water till with a bump it strikes the metal cap, rebounds a few inches and comes to rest in contact with it on the surface of the water. Still the horn blows, and by this time the second ball responds in like manner, and then the third. Then the music ceases, and we turn to other experiments, but as long as I stayed in the shop that day something made that metal swim. My companion said he had often seen the weights brought slowly down, or held midway, as shown by photographs, by sounding other chords. On the top of the jar lay certain pieces of metal. Keely said, 'Do not remove those. I once did that, and crash went the balls through the bottom of my jar.' Now here was a pulling power acting at a distance of four feet, not capable of lifting the weights through the air, but before all eyes lifting them through water. Can this pulling power turn a wheel?

Here is a wheel of stout metal weighting, as stated, seventy-two pounds, free to move either way on its stationary axis. Its hub is a cylinder containing certain resonant tubes parallel to the axis. It has eight spokes, each carrying one of the 'vitalized discs' at its outer end, the face of the disc at right angles with the spoke. There is no rim to the wheel, but there is a stationary metal rim some six inches wide and thirty-two inches in diameter, within which the wheel turns without touching it. This rim carries on its inner surface nine similar discs, and on the outside, attached to each disc, a resonating cylinder. The requisite amount of the metallic volume of this cylinder is obtained by enclosing in its tubes a few cambric needles, more or less as required, and curiously enough, some of these needles at length become magnetic. Attached to this engine is a gold and platinum wire, some ten feet in length, running through the small window to the copper globe in the other room, where sits the man who has fashioned all this. He twangs the rods of the sympathetic transmitter on the table at his side, he turns its knob, the musical instruments sound for a moment, and peering through the window along the line of the wire his face lights up with a smile of triumph. He settles back in his chair, and all is still. That wheel at the end of the wire is in rapid revolution before your eyes. You turn and look with amazement upon Orpheus returned to earth again and outdoing his fabled exploits of old. For by the enchantment of the subtle harmonies he evokes, too fine for human ear to catch, you see the untamed forces of nature obey his behest; that most constant of all things, the magnetic needle, you see charmed into fickleness by his magic spell; you see balls of iron swim; you see insensate matter - as you thought it, but sensitive now to his call - leap forward into instant rotation, continuous and swift. Long we stand around that flying wheel. The friend who photographed it at rest again levels his camera upon it. In vain; its spokes can-

not tarry long enough to be caught by his snare. It is still as death, and almost as mysterious. We listen to long dissertations upon the reason for the relative position of the eight discs on the wheel and the nine on the stationary rim, and how the adjustment can be so altered that, instead of a revolution, there will be a violent oscillation back and forth. We are shown the corresponding wheel and the rim of the large engine close by, which is to bear the discs not singly, but in groups, the steel resonating drums with their circles of tubes inside, and thirty-five inch Chladni plate underneath the 'sympathetic transmitter' on top; the extra wheel bearing on its spokes cylindrical cases, each filled solid with a hundred thin-carved plates of steel, to get the utmost superficial area, we are told, and it is all so utterly beyond comprehension, that we can see no reason why it should have been made as it is, or how any one can be sure it will ever run. But we turn around and look again on that noiseless wheel, still running rapidly all alone, and confess we should have said the same thing about that. And we are inclined then to trust the word of the inventor when he says the running of the smaller insures the running of the larger; that the wheel you see spinning so fast cannot be stopped by any force except one that would tear it into fragments, unless with thumb and finger you loosen that golden wire along which 'the stream of sympathetic vibration' is said to flow, and that there is no reason why the wheel should not keep in motion till the bearings wear out.

I say nothing now of the wonders of which other witnesses can speak, and which are said to have appeared in the slow progress this incomprehensible man has been making all these years; of a pressure obtained from the disintegration of water by vibration of twenty thousand pounds to the square inch; of a slowly revolving drum which went no slower when winding tightly upon itself a stout inch and a half rope fastened to a beam, and no faster when the rope parted under the strain; of the disintegration of rock into impalpable powder; of raising heavy weights by aid of a 'vibratory lift,' recalling the 'negative gravity' of our modern story-teller.

The engine you have been looking upon requires as part of itself for some mysterious purpose certain heavy tubular copper rings. Skillful artisans failed in various endeavors, by electrical deposit and otherwise, to make them right. The inventor contrived machinery for bending into semicircles sections of copper tube, one and a half inch bore, three-eights of an inch thick, forcing a steel ball through them to keep the tube in shape. To make a ring, he placed two of those half-circles together and joined the ends in some way (without heat), by what he calls sympathetic attraction, so the resonant properties of the ring are satisfactory, and though you see the line of union, the two parts cannot be severed. You see one of these rings, some fifteen inches in diameter, hanging by block and tackle from the ceiling, and lashed to the lower half swings a big iron ball weighing five hundred and fifty pounds, and there it has swung for weeks. Has the man who has done simply that, and done it merely to furnish a subsidiary adjunct to his main contrivance, won no place among the great artificers? Is it worthy business to revile him as a swindling charlatan? The end is not yet. We shall see what we shall see, or some one will. One thing, however, we see clearly now, and that is that John Worrell Keely deserves the esteem and admiration of his fellow-men. Who does not hope that he has solid grounds for the persistent belief which has been his star of hope these many years; that a merciful Providence is about to confer a new boon upon the suffering industries of mankind; that the time at length has come when man is wise enough to fashion and strong enough to handle the beneficent gift of a costless motor to ease the burdens of human toil?

Wise enough and strong enough, perhaps, some may say, but is man trusty? For the question has arisen whether a force of such fearful energy as some of these experiments disclose can safely be entrusted to such a being as man, who can destroy as well as build. But why should man have been set to discover and harness it? 'I take great comfort in God,' said James Russell

Lowell, in one of his recently published letters, 'I think. ... He would not let us get at the match-box as carelessly as he does unless he knew that the frame of his universe was fireproof.'

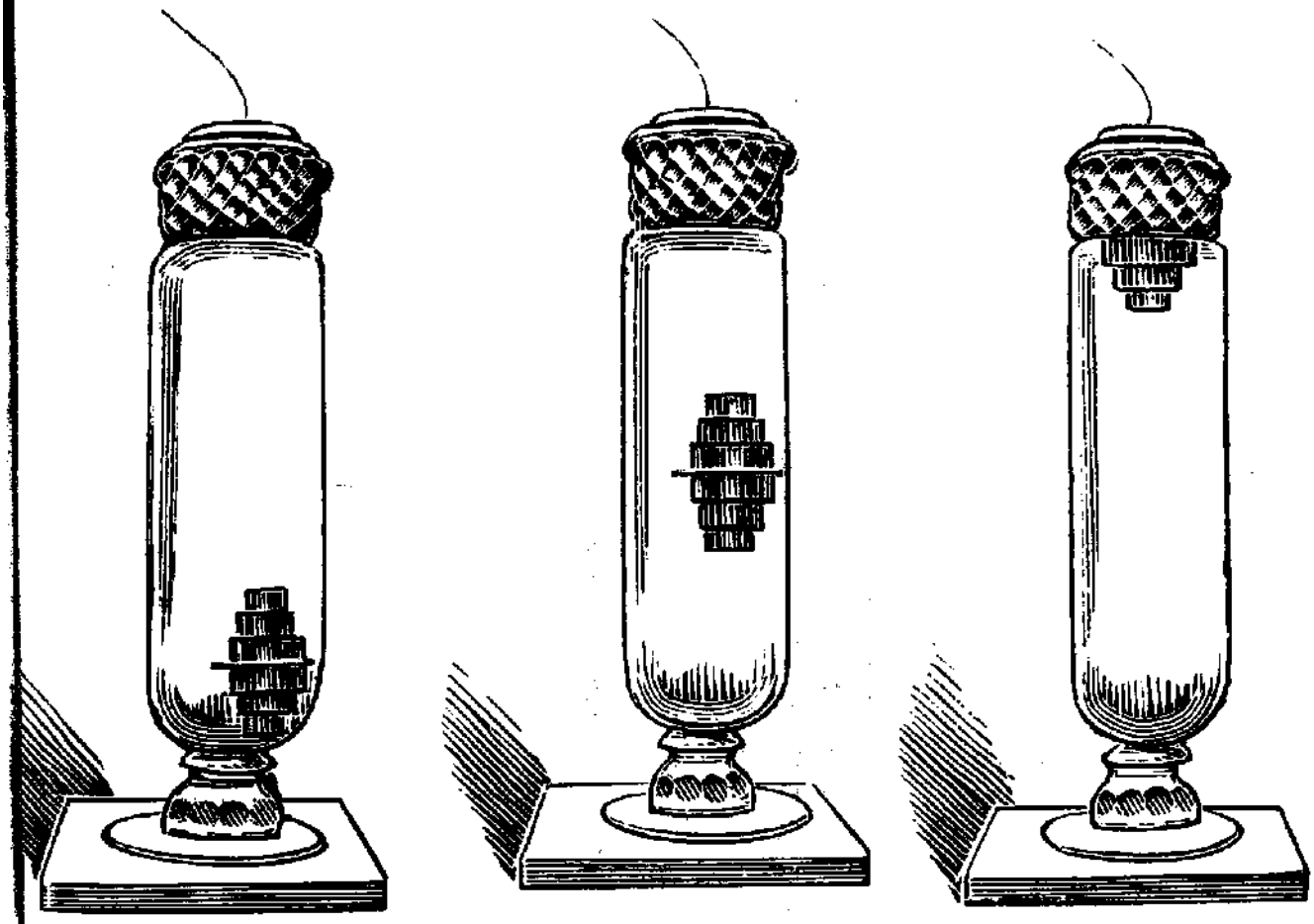

GRAVITY OVERCOME

EXPERIMENTAL MODELS FOR RESEARCHING.

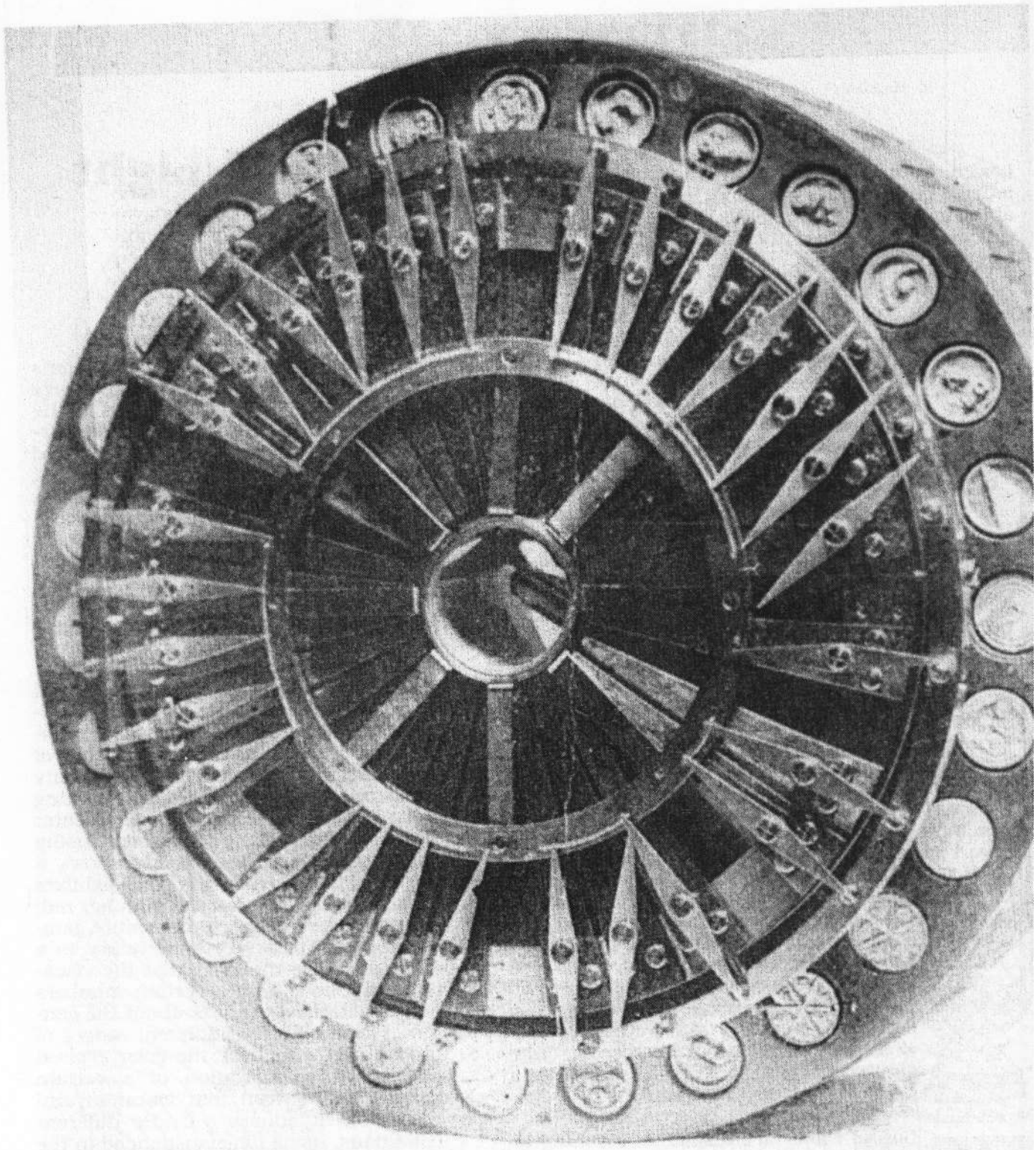

Photo by Collier.

KEELY'S VIBRATORY SWITCH.

No one understands it but himself.

Pyramids, Telescopes and Light

John Ernst Worrell Keely
from Dashed Against the Rock

A building, pyramidal in shape, two hundred feet high, one hundred feet at the base, and having at the apex a disc with a minute aperture in its center, and a triple combination of reflectors, which must concentrate upon one center which must be focalized upon the minute aperture in the disc, - the image being received at the base of the pyramid upon a white surface prepared to receive it, - would yield results beyond the dreams of the most sanguine astronomer of the present day. The distinctness of the image taken would be the most wonderful part of the phenomenon, and the size of the magnification would be limited only to the diameter of the base of the pyramid. This probably explains the great Egyptian pyramid, with its circular opening through its center and cavity at the bottom. The apparatus from its summit has probably been destroyed during some of the many ravages to which the land of strange vicissitudes has so frequently been subjected. The Great Pyramid proves that, among the ancient Egyptians, the knowledge of astronomy was amazingly great, although they need not necessarily have known of the modern telescope to have obtained it. The almost impossible labor of making lenses is done away with in this system, which embraces also a microscope on a similar principle without lenses, far superior to anything now in use.

Vibrations necessary to the production of colors are very high, reaching to millions of vibrations per second. The true relation between the vibration and the color can only be a harmonic one, as colors commence in the millions and end not lower than in trillions of vibrations per second. The conditions essential of this class of phenomena are, first, a condition relating to the structure in which they take place, free from all extraneous vibrations; *the experimenter's presence even influences to a great extent the motions of the molecules* used in the experiments. A bath is employed, arranged so that light rays can be projected upon it at certain angles, and from that upon a screen. The bath must have what are termed centers of association and concentration, and suspended across its surface in such a manner that the centers approach very near the surface of the liquid, which is preferably water, whose surface must be free from all films. Upon this is dropped a single drop of naptha dissolved in ether, which constantly spreads over the surface and gradually evolves most beautiful variations of color. The vibrations are transmitted from an instrument capable of producing vibrations of varying intensity and pitch, across the line of resonating centers, nine in number. The first center shows a *light* straw color, condensing about the center; the second shows a *very dark* straw color; the third exhibits an orange red; the fourth, a bluish red; the fifth is largely green. The entire gamut ranges from a very light yellow to a dark blue. The theory is that the vibrations produced gather certain numbers of the molecules together about the centers, which represent different ranges of motion, and which by the color evolved affords a demonstration of a certain connection between that vibration and the colors it educes. Under different conditions, using films suspended in the air, and light passing through these films under polarization, (polarized light) the vibrations influence the molecules in the film, producing again exhibitions of varying colors when projected upon a screen. Experiments of this kind are most difficult, on account of the unstable conditions found everywhere.

Keely's Secrets

DIAGRAM 1.

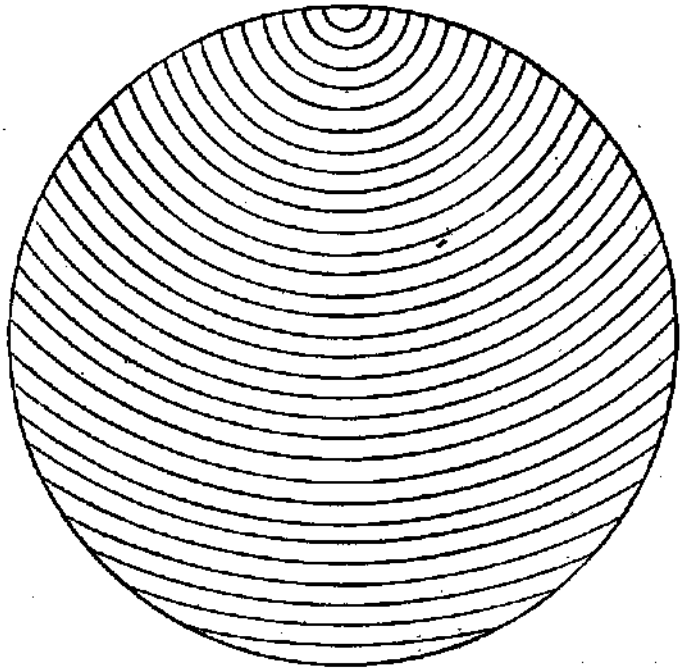

External View of Atom.

DIAGRAM 2.

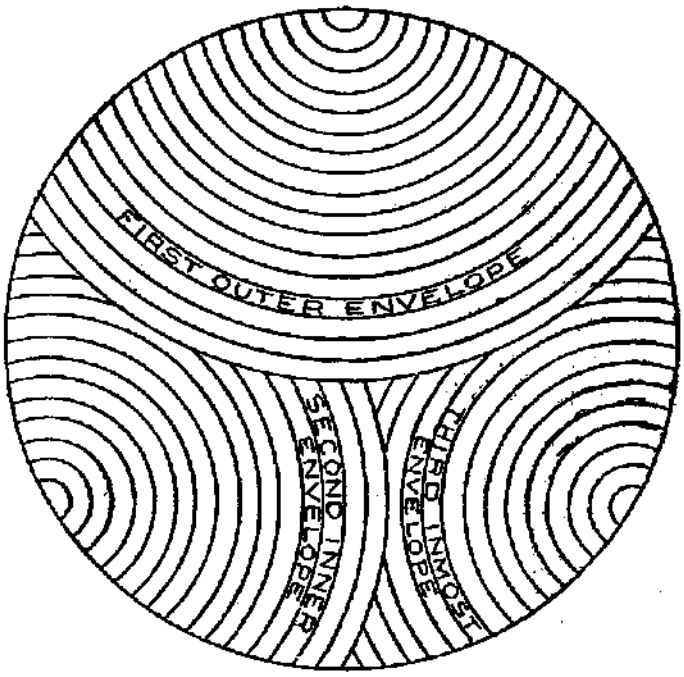

Showing Sections of the Three Envelopes.

DIAGRAM 3.

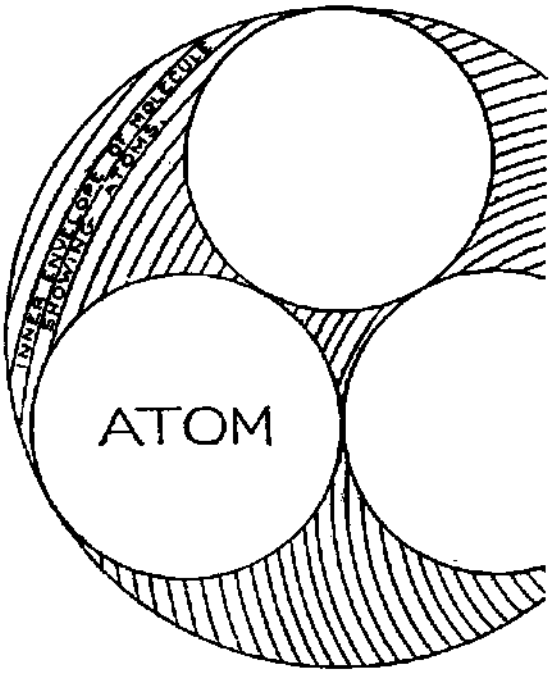

Showing Positions of Atoms in Inner Envelc

DIAGRAM 4.

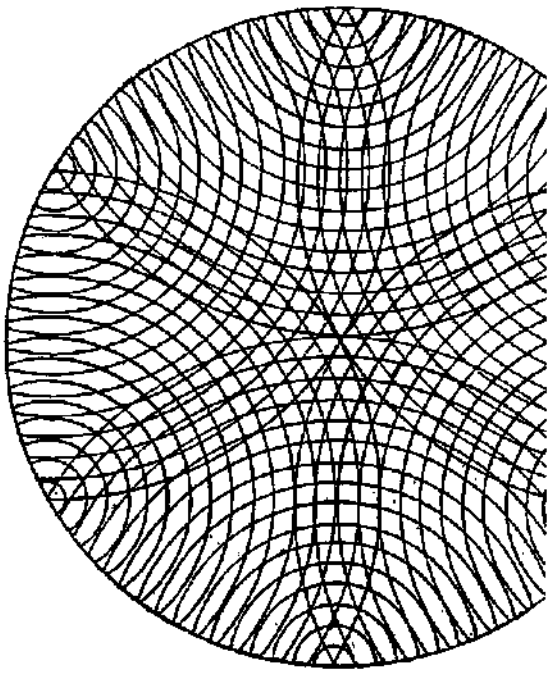

Showing Lines of Interference of Triple Envel

Levitation

John Ernst Worrell Keely
from Dashed Against the Rock

A small instrument, having three gyroscopes as a principal part of its construction, is used to demonstrate the facts of aerial navigation. These gyroscopes are attached to a heavy, inert mass of metal, weighing about one ton. The other part of the apparatus consists of tubes, enclosed in as small a space as possible, being clustered in a circle. These tubes, represent certain chords, which were coincident to the streams of force acting upon the planet, focalizing and defocalizing upon its neutral center. The action upon the molecular structure of the mass lifted was based upon the fact that each molecule in the mass possessed a north and south pole, - more strictly speaking, a positive and negative pole, - situated through the center, formed by the three atoms which compose it. No matter which way the mass of metal is turned, the poles of the molecule point undeviatingly to the polar center of the earth, acting almost exactly as the dip-needle when uninfluenced by extraneous conditions, electrical and otherwise. The rotation of the discs of the gyroscopes produces an action upon the molecules of the mass to be lifted, reversing their poles, causing repulsion from the earth in the same way as like poles of a magnet repel each other. This repulsion can be diminished and increased according as the mechanical conditions are operated. By operating the three discs, starting them at full speed, then touching two of them, so as to bring them, according to the tone they represented by their rotation, to a certain vibratory ratio, the weight then slowly sways from side to side leaves the floor, rising several feet in the air, remaining in that position, and as the discs gradually decrease their speed of rotation the weight sinks to the floor, settling down as lightly as thistle-down. Where one molecule can be lifted, there need be no limit as to the number in a structure that may be operated upon as easily as one. The vessel in contemplation, the aerial navigator, will be over two hundred feet long, over sixty feet in diameter, tapering at both ends to a point, made of polished steel, and will be capable of being driven under the power of depolar repulsion, at the rate of three hundred miles an hour. It can be far more easily controlled than any instrument now in use for any phase of transit. Another very remarkable feature connected with this system of aerial navigation, is that the vessel is not buoyed up or floated in the air through the medium of the air, so that if there were no atmosphere it would float just as readily; hence, under mechanical conditions most certainly capable of production, involving massive strength of resistance to interstellar vacuity this can be made capable of navigating even the remote depth of space, positions between planets where polarity changes being controlled by other adjuncts of concentration for that purpose.

Safely enclosed within this structure, a man possessing the chemical knowledge these new laws give, with sufficient supply of material from which to make oxygen, by the enormously increased rate of speed attained by such navigator where atmospheric friction is avoided, the time occupied in traveling from one planet to another would be amazingly brief, and one can travel to other planets in this system of worlds as easily as the same ship could navigate the depths of the ocean.

The great obstacle hitherto preventing the solution of this problem has been the strength of structure needed under conditions above presented. With this knowledge of matter, the size of structure is unimportant; the heaviest can be as easily controlled as the lightest.

Chart showing the triple
governing the molecule during

condition of the vibratory flow
disruption. 1st order of vibratio

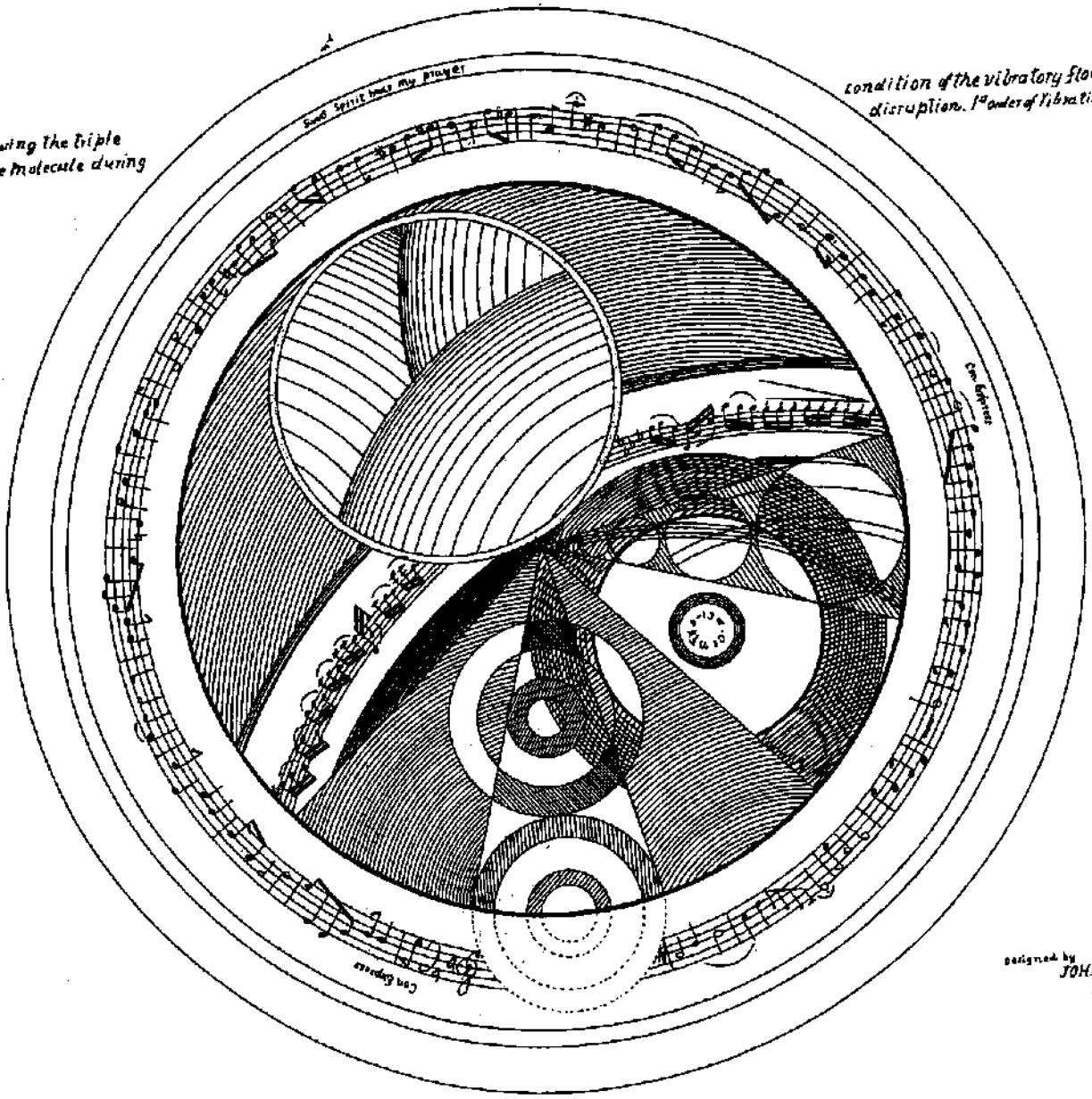

designed by
JOHN

Amplitude of Force

John Ernst Worrell Keely
from Dashed Against the Rock

The amplitude of vibrations is directly increased or diminished by increasing or diminishing the size or number of creative aggregates.

The human EGO, subject to the forces of love or hate, kindness or cruelty, forgiveness or revenge, is according to circumstances ruled or dominated by these forces in proportion to their intensity.

The intensity of a force is precisely proportionate to the number of units vibrating at that particular pitch. For instance, let fear assail one man, and according to its intensity will be the effect; but let a crowd of men experience fear, see the result in the augmentation of fear, though its source be relatively insignificant. A curtain in a theater, for example, takes fire; one or two persons, cowardly at heart, become afraid through the dominance of the purely animal instinct of bodily preservation; there is actually no real danger, but these two or three persons are sufficient to arouse the unreasoning dread which lies latent in every breast, with perhaps a very few remarkable exceptions. The fire burns nobody; but blind fear, which is extremely contagious among people mutually sympathetic, by reason of the rapidity with which etheric waves transmit all feeling, occasions a terrible panic, during which many severe accidents and many instances of fierce cruelty occur, all because of this sympathetic transfer of feeling starting from one or two augmented or intensified fear-centers, each person being a center emanating the feeling of fear. Were there no counteracting centers of influence in an audience, radiating contrary feelings, the result of a panic would be the total bodily extinction of a very large percentage of the assembled multitude.

Thus the human race is immersed in forces whose intensity is vast in proportion to the number of EGOS adding each its quota to the already intense vibration, tending either to love or hate, kindness or cruelty, timidity or bravery. Those who intensify the force of cruelty in the place where they reside, may be strengthening a murder's hand to strike the deadly blow in a distant land. This result is brought about through the agency of etheric waves, which transmit forces with undiminished intensity even to uncalculated distances. This phenomenon may be termed *transympathetic*.

They who feel that force called *love*, which on higher planes is known as *sympathy*, thrill with waves of force which are already strong, augmenting them or increasing their intensity. They who indulge such sentiments and encourage such forces may stop the falling hand on evil sped.

In order to protect ourselves effectually from becoming the dispensers or propagators of deadly force, we must consciously and deliberately relate ourselves by resolute determination, to awaken within us such centers only as are concordantly sympathetic with all force radiating in the interest of universal goodwill, thereby aiding the establishment of universal brotherhood.

All ye who feel a longing for a better life or nobler existence draw to yourselves streams of force which they alone feel who have attuned their bodies to the higher harmonies. For a moment you feel as they who dwell perpetually in communion with higher harmonies, living immersed in that higher force; they are the true heirophants, and you, O neophytes, struggling to attain the goal which they have reached, do not despair though at present you find yourselves unable to maintain this high altitude for

long together. Though you fall many times, be not discouraged, for as yet your organisms and all their centers of resonation are not yet concordant to the focalized vibrations of the higher harmonies; being still related to the mass, you are drawn again and again into the whirlpool of the vibrations which affect the mass, for these you cannot resist. But know that you can change all this rapidly or slowly as your purpose is steadily intense or vacillating.

With the cessation of your lower desires comes the cessation of the action upon you of the lower forces; the resonating centers which formerly distributed this force, no longer active, become latent and are absorbed back to an embryonic condition.

Let him realize fully the transient character of his own personality and contrast therewith his eager longing to know the immortal.

Every man contains, developed or embryonic, all conditions of the Infinite; therefore no height is too great to reach. Impossibility is a meaningless word to the man who apprehends the fathomless contents of his own nature. Thou comest here, O man, with the instrument thou hast graduated in thy many past existences; how few of thy chord-settings, if thou art numbered with the many, respond to the higher harmonies! Universal unity or fraternity has been absorbed to almost embryonic conditions by the prevalence of material self-regard. Charity has been rendered almost latent, that beautiful chord-setting found even in the lowest forms of creation - LOVE, the dominant chord of the cycles. Love has an amplitude of action in the brute which may well make the selfish man ashamed, but until the crust of selfishness is broken through, the beauty of love is obscured, and though it exists all about him, the poor blind egotist has no eye to discern it. The centers of love, brotherhood, charity, voice their music loud and clear, yet the masses will not listen. I do not mean the immortal EGO when I say man will not listen; I refer to the personality which is the resultant of all the ages of action in this, now rapidly closing, cycle.

You who exist to-day, to-morrow would exist no longer in your present personalities did you but dare to yield to these higher harmonies. I say YIELD because it is a *yielding* process for this personality. In a moment your outer life would end, and you, the warrior, would enter peace.

The immortal EGO is an entity of which man can become thoroughly conscious while here on earth, but to arrive at this consciousness necessitates the entire abandonment of all the petty considerations involved in the transient and subordinate EGO, which is the only self of which the unenlightened man is conscious. Let him who desires to reach this inner consciousness enter his inner sanctuary, wherever that sanctuary may be; it matters not whether it be his own chamber, the open field, the mountain top, the seashore, the stately cathedral, or the humble village chapel. Let him realize fully the transient character of his own personality and contrast therewith his eager longing to know the immortal. Let him concentrate his whole consciousness upon his personality, fully arousing all his personal conditions as a distinct individual; then with all the aspiration of which this personality is capable, let him beseech of the immortal EGO - which is eternal and does not incarnate, but overshadows all incarnations, waiting until one is formed capable of illumination, to whom it may reveal itself - to consider him worthy of illumination, and according to his preparedness to receive illumination will it then be granted. He who asks this, knows not what he asks; for were the prayer answered, life henceforth for such an one would be a weary round, as Hamlet says: "to-morrow and to-morrow and to-morrow brings in this weary round of life"; for, having seen the glory of this immortal EGO, all else seems so base, so commonplace and mean, so inglorious, that oftentimes the personality has utterly collapsed when thrown back from the radiant vision of this glorious immortal entity possessed by all alike, though scarcely dreamed of by any save the very few who, discontented with the

ignorance and emptiness of terrene existence, aspire to know the great reality of the supernal. As the incarnations of every entity, passing through certain orders of experience through numerous lives, inevitably culminate in this moment of conscious realization of the immortal entity; the Buddha says: "All shall reach the sunlit snows."

You who through your daily life move on unthinking, not caring, inactive, you shall hear when your supplications reach this high entity, *"Lo! thou didst not even try, knowing that even thy failures were acceptable to me."*

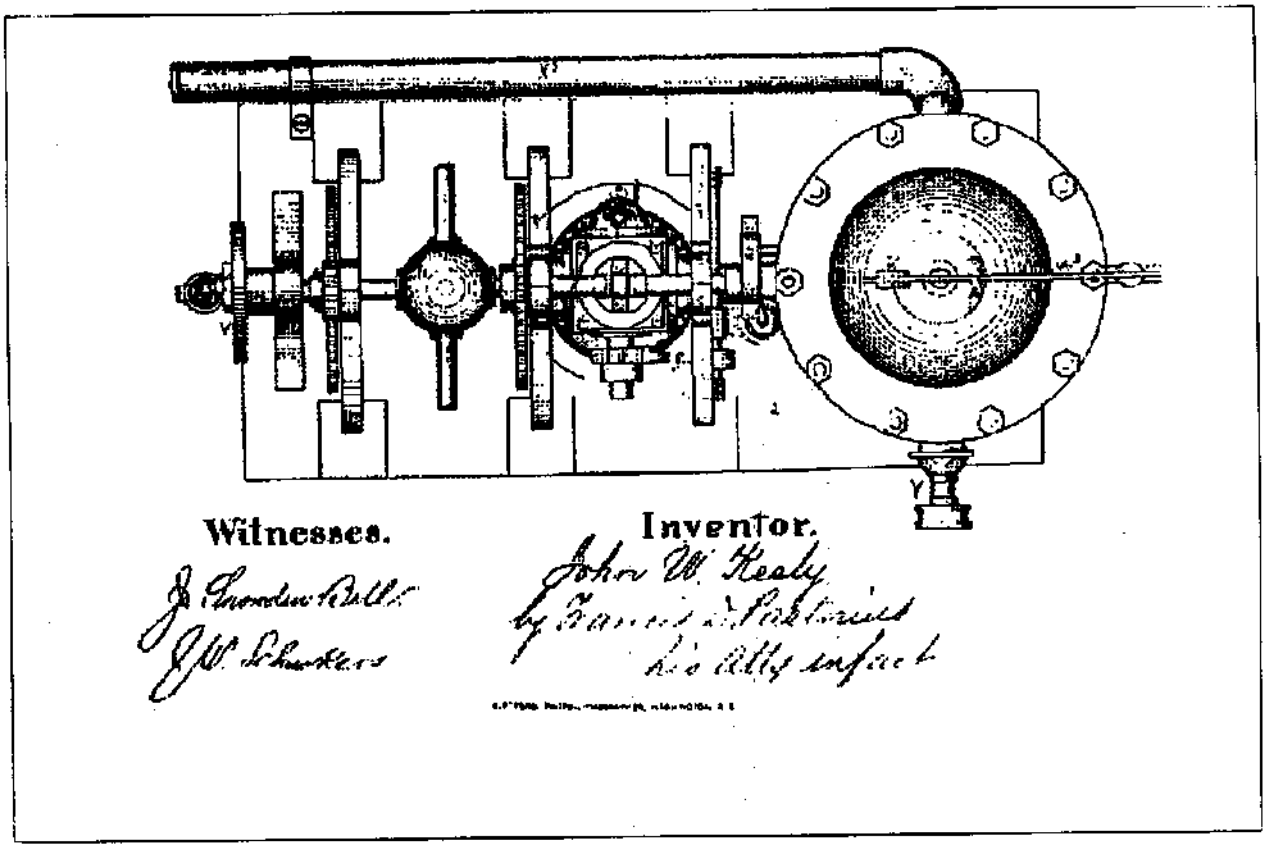

Top view looking down on the original Keely motor.
Scanned image from original patent drawings.

Front view looking straight on the original Keely motor.
Scanned image from original patent drawings.

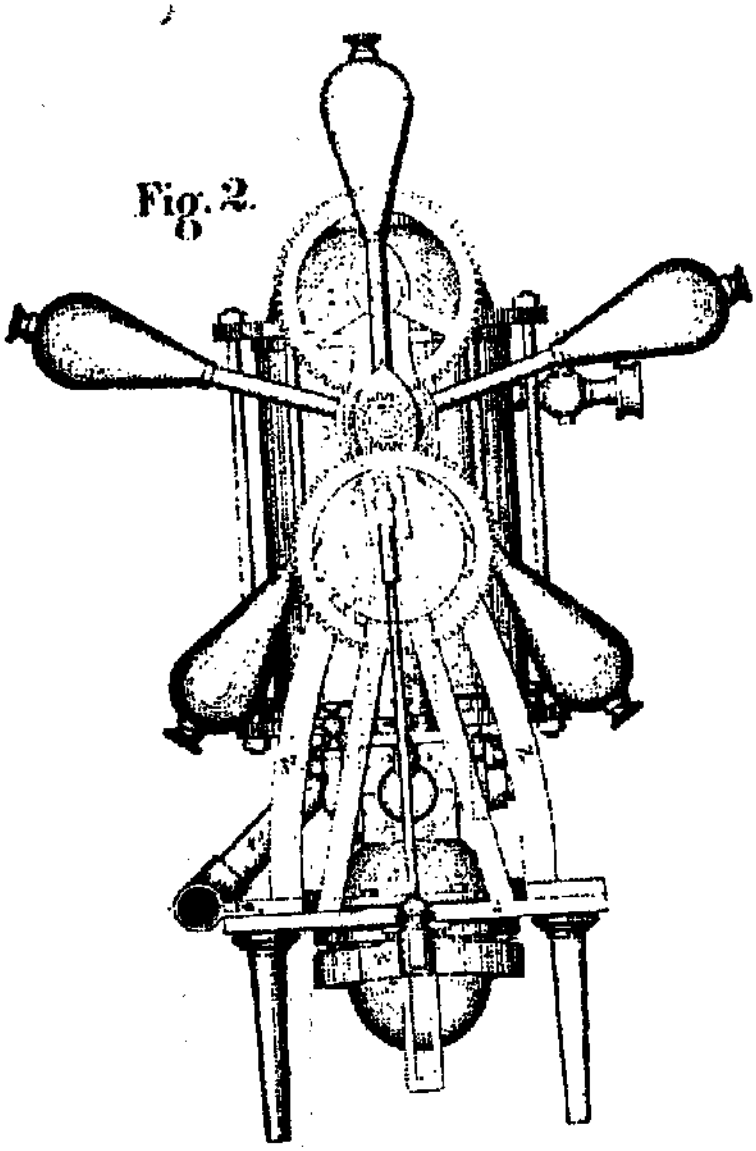

The Chord Settings of Life

John Ernst Worrell Keely
from Dashed Against the Rock

Question: "By what term shall we define that force which, when differentiated, expresses itself on the lower planes of manifestation as charity, self-forgetfulness, compassion, and the tendency of all illuminated ones to association in universal brotherhood?"

Keely's reply: "I hold that ONE SUPREME FORCE, which we may term the incomprehensible, holds within itself all these sublime qualities, as an octave embraces its many tones. This force expressed in the human organism, has what may be termed CONCORDANT CHORDSETTINGS dominated by one or other of the above-named differentiations of this supreme force.

Now let us ask what makes human beings differ the one from the other. The reason we give for this striking natural phenomenon is that in one individual these chord-settings are allowed full amplitude in action, while in others they are suppressed, and by suppression rendered latent. To illustrate: we will picture a beggar asking alms of a richly dressed gentleman, who passes by entirely oblivious of the suppliant's needs; but here the wonderful law of sympathetic action intercedes, making the wealthy individual comprehend the necessitous condition of the pauper.

At this point the *ego* enters the chamber of the ordeal; here, in commonplace life, in everyday surroundings, man is tried; this is *initiation*.

The well-to-do man goes on his way, not caring to stop, hurried perchance by the urgency of worldly affairs; the chord-setting representing that differentiation of infinite force called by us *compassion*, acting upon its concordant chord-setting, loudly proclaims to the *ego* what is right action, and the opportunity passing when it should be seized, powerfully exerts its force against the will of the personality that would suppress its action. Here is where the battle is fought; simple though the illustration may appear, it forcibly sets forth the actual conflict continually waging between divine wisdom and mortal error, carelessness, and ignorance.

The man of wealth and position goes on, perhaps, for some distance, the battle all the while continuing; finally, he stops and turns back, he yields to the dominating influence of that chord-setting; he gives the beggar alms and goes on his way with the skies bright above him; he has won a battle he will not have to fight again. Understand that victory is won, *not by the giving of alms*, but by *yielding to that divine force-differentiation*. If this chord-setting had not retained its dominance, it would only require a few instances of the above type to render it latent, and when latent the person is no longer amenable to influences calculated to arouse compassion. In like manner, other centers may be rendered latent by repeated suppression, until we find a person so dead to all appeals from the various chord-settings that his whole course in life is represented by the sum-total of the antagonisms internally produced; results proving this are seen everyday.

You ask why do people commit such blunders and perform such acts as they do, all the while seemingly unable to help themselves. The reason is that they have rendered latent these centers which otherwise would have given them the power to rightly control their deeds instead of being, as they now are, dominated exclusively by the forces of aggregated matter which we usually call the self-will of the outer personality, as distinquished from the distinctly humane individuality which always responds to

a divine appeal.

It can be readily seen from this example that a man can mould himself practically as he chooses; though he may have to encounter many obstacles erected by himself in past periods of earthly existence, as he comes to earth anew with these chord-settings latent, or developed to the extent they were so, at the conclusion of his earth-embodiment; a man has therefore only to carefully examine the condition of these settings to learn whether they are latent or developed; if latent, he knows well that if he yields to the dominance of the chord-settings of the supreme force - and he needs no monitor other than these to instruct him, their voice being loud-toned, full, strong, deep, and high - to carry him on to the consummation of his highest ideal, their suppression leading him to the lowest condition in which we behold that section of humanity which is dominated by the action of the blind forces inherent in aggregated matter, - forces which are at all times powerfully and intimately associated with everyone who possess a material body.

The work of arousing to activity the latent chord-settings is sometimes equivalent to giving birth to an entirely new condition in the person, the intellect and the imagination having to actively cooperate in the endeavor to produce even the minutest degree of activity.

In such persons their hardest experiences may be the greatest benefit to them, if rightly taken; for it is through certain orders of experience - not unattended with suffering - that these centers are powerfully acted upon. The foregoing illustrations of the merchant and the beggar introduces one in whom the action of the centers is to a certain degree active.

In experiences where the emotions are *intensely* aroused their action is far greater, and we may see the result of the conflict, in the event of a person of hitherto unnoticeable traits being developed either into a person of crabbed, irritable disposition or into one of considerable moral beauty and attractiveness, and all because a center hitherto dormant has been powerfully aroused or more completely suppressed.

Who knows but that all the varieties of disposition we see expressed every hour in the persons of those about us is due to HABIT; in the case of the sweet and lovable, to the habit of constant yielding to the dominance of what we may term super-celestial force, while on the other hand, the sour and morose are but the suffering victims of their own habitual suppression of these same divine centers of radiation, which are continually dispersing the divine energy focalized upon them throughout the eternal ages of unwasting life.

Concerning *circumstance* let it be most emphatically stated that they never need be permitted to suppress the upward tendencies of our nature; that they have, like *all* experiences, and opportunity contained within them, to act either for the more perfect dominance of the celestial or the terrestrial, none need deny; but it rests with every individual to *embrace* or *reject* opportunities as he will, to accept the honors of initiation or undergo the regrets consequent upon failure.

Only the keen, sensitive soul can understand when these opportunities come and go, for only such have won this right by successive victories gained through yielding to these celestial streams of force, and the conqueror over himself is the victor *always*, though he may seem sometimes to yield obedience to a force greater than himself. Let the supreme desire of each one of us ever be that these resonating centers, permanent throughout measureless cycles of time, graduated by the all-wise builders of the universe to perfect concordance with the Divine Force which is in essence incomprehensible, - shall vibrate to fullest amplitude of action; so shall we each escape from the pains, sorrows, and disappointments associated with their suppression and *inevitably* resulting from it."

The Dynamics of Mind

Henry Wood
reprinted from ARENA, #LXIII February, 1895

In the light of recent psychical demonstrations, it has been said that thoughts are things, perhaps a more exact statement would be that they are forces.

In physical science, the present trend of teaching is distinctly from the former accepted atomic basis, which included the solidity and potency of matter, towards a hypothesis in which energy is regarded as the underlying principle of all phenomena. Thus the atom, which has never been discovered, and is not likely to be, is no longer recognized as the real unit in the physical economy, energy being now accepted as the primal starting point.

Manifestations to our senses, which we call light, heat and sound, are only differentiated modes of vibratory forces. Primal energy, unitary in its essence, and always conserved in the aggregate, takes on, to us, one of several qualitative appearances, according to the form of its waves, or rather, perhaps, the rapidity of its vibrations. Under certain circumstances and through the action of laws yet imperfectly understood, these various modes of manifestation are interchangeably transformed in constant repetition.

Modern science has accepted the conclusion that vibration is a universal law, and the recognition of this fact is the key which is unlocking mysteries and solving phenomena hitherto unexplainable. It has furnished an all-comprehensive working hypothesis. Beginning with an inter-molecular rhythm of inconceivable rapidity in all bodies, even those that appear to be solid and at rest, its domain of wave movements extends through all space, and its impulses are coursing in every conceivable direction. They are ceaseless and endless. The cosmos may truly be said to be "all of a quiver."

The basic medium of these enumerable wavy motions is undoubtedly the universal ether, the nature of which can only be dimly conjectured through its multiform manifestations. Who can say that this is not the boundless common meeting ground between the spiritual and the material? Unaccountably enough, the myriads of vibrations of different kinds and velocities that are sweeping through space do not appear to disturb or neutralize each other in the least. There is a clear path for all.

These late developments in physical science, which have only been hinted at in the most general of terms, carry with them necessary inferences and correlations, the scope of which can yet hardly be imagined. The dematerialization, or perhaps what may even be called the *spiritualization of physics*, as a science, is one of the marked logical tendencies. There is also a growing demonstration and conviction of the deceptive and utterly unreliable nature of sensuous appearances. Science, before finally accepting any proposition as proven, has always insisted upon material and mathematical demonstration. This is well in its place but it is not all, in fact it is only the lower and cruder side.

Matter, as formerly regarded, seems to be consciously melting into mind or spirit. It is no longer inert or dead, but instinct with life. Its transformations are ceaseless and mysterious. Can any one explain just how and why a visible solid can take the form of an invisible gas and *vice versa*?

The theoretical boundary line between the immaterial and the material is getting very faint if not actually disappearing. Let us drop our crude, childish materialism and rise easily and reasonably to the grand conception that differ-

entiated forces are being traced back, even through the methods of the physicist to the *One Primal Energy* - INFINITE MIND. The veils which in our infantile development we have hung around external nature are growing so attenuated that we can almost discern with unaided vision the active operation of Supreme Intelligence, Goodness and Beneficence.

All profound discernment and analogy lead back to the grand fundamental premise, that behind all manifestations, energy is One, that it is an Intelligent Energy, and is therefore Omni-present Mind. Monism, or the inherent unity of all things, is the growing inspiration of science. It is thereby confirming the impressions already received through the delicate vision of the unfolded interior faculties. Paul's immortal aphorism, that "in Him we live and move and have our being" has waited long for scientific endorsement, but it is apparently soon to be realized. We behold the universe as soulful and not mechanical. This is no ancient superstitious pantheism resurrected. Rather the Deity is infinitely honored as compared with any and all past human concepts.

If all energy, in its last analysis, be Intelligent Mind, and vibration the universal method, we may reasonably infer that human mind or volition, being in, and a part of the whole, should form no exception in the working plan of its orderly activities. If essential, potential and ideal man be the "offspring," "image" and manifestor of God, nothing unlike it could be normal. As the former ideals of a Deity, localized, personified, changeable and in every way unconsciously limited, are slowly replaced by the transcendent ideal of the unconditioned "All in All," the interrelation of all things, to and in God, is being grasped. When man refines, enlarges and elevates his consciousness of Divinity, he does the same for his own deeper and generic spiritual nature, which though temporarily obscured, is in reality, himself. If God be spirit, man, His reflection and likeness, must also be spirit and not dust. By a traditional and distorted self consciousness he has thought himself to be a poor, sinful, *material* being, and the formative power of his mental specification has externally actualized his model. He *is* mind or spirit, but his physical expression, which should be of ideal quality, outpictures his perverted estimate of himself. Not recognizing his true being, he has drawn a mistaken outline and then naturally filled it out. He has thus unwittingly hidden his own potential and divine forces, though they are still within. The mirror of false consciousness has reflected a doleful image which he has seriously taken for himself.

The purer and higher trend of science is characterized by a gradual refinement and immateriality. The laboratory should become a sanctuary, for in it are gained glimpses of the Eternal. Man himself is being more truly interpreted as the highest expression of divinity. He is a concrete manifestation of the One Mind, finite, but with unlimited possibilities. He is inconceivably great, though ignorantly unaware of it. But a significant indication of his growing consciousness of the possession of supernal power is found in the recent discovery of the dynamic and formative potency of his thought. The Infinite Uncreate is the primal and universal energy, but man is its embodier and manifestor. His mental forces cannot create *de novo*, but they can mould, utilize and express. The unfolded soul having developed a self-consciousness of its transcendent power, intelligently sends out its own vibrations from its own center. Conforming to the divine plan and chord, it becomes a reflection, or secondary radiator of rhythms which are concordant with the Original.

We are logically led to the conclusion that the recent recognition of the potency and utility of the projective vibration of thought, is an unprecedented and immense step in scientific achievement, human unfoldment and spiritual evolution. Man is finding his rightful dominant place in nature, in the arcana of soul force and expression, and in his relation to the Infinite.

Before considering specifically the dynamic relations between mind and mind, it may be well to note briefly these relations as they exist between a human mind and its physical counterpart, Man is mind, and this statement implies that

the physical organism is not man, but only his visible index or expression. To attempt to prove this is like demonstrating an axiom, but yet mankind at large indicate by their action that they do not practically believe it. Nine-tenths of the care, labor, and attention of the world is bestowed upon the body and its gratification, or upon those subordinate mental powers, the product of which will command the greatest commercial value. Most of the prevailing systems of education, so called, have the same end more or less directly in view. The trained intellect, including not only technical and professional attainment, but also the powers of literary, poetic and dramatic ability, eloquence and wit, are largely rated and valued on an economic and material basis. To train, control and uplift the mind, and develop its higher faculties for its own sake, and that of others, is not common. The world is still endeavoring to "live by bread alone."

Prevailing systems of philosophy, science, theology, therapeutics, sociology and charity, including Darwinian evolution, all proceed upon the general hypothesis that man is intrinsically a *material* being. He has an attenuated quality called a soul, dependent upon fleshly brain cells.

The "fall," not historic but continuous, is from the ideal, potential and in mostly actual, into the external of appearances, and this comprises the Adamic consciousness. Men cling to the sensuous Eden until they are started and driven from it by the loud calling of the divine voice within. The beneficent expulsion from that Eden, and the succeeding necessary restlessness, furnish the true and only impetus for voluntary moral and spiritual evolution. The world is still largely peopled with Adams who practically believe that they are made of red earth or dust.

Is man to grasp, mould and rule that little portion of dust that he has temporarily taken on, and which before has often been used to express and embody other qualities of life, or must he believe himself in bondage to it? Shall the shadow, even though real as a shadow, dominate the substance? Not forever, even in what is called this life. So soon as man recognizes the fact that he is a mental and spiritual dynamo he will no longer remain a vassal in his own legitimate kingdom. But the more specific treatment of the relations of mind to body must be reserved for a subsequent paper.

A dominant vibration in the thought-atmosphere is able to arouse a nation, or a continent. Great minds, as well as those of less development, are submerged and swept along by it. Crusades, reformations, revolutions, and reforms, furnish numberless illustrations of psychic upheaval and contagion. *Through sympathetic vibration a vast number of responsive mental strings are stirred into action.* As the rhythmical step of a regiment will powerfully shake a strong bridge, so the concerted energy of mind will generate tidal waves of tremendous import. The result is not merely from a contemporaneous logical process, carried on respectively by many individuals, but from a great immaterial gulf stream, deep and mighty, though silent and unconscious.

Mind, as a *force*, is no more unintelligible or unthinkable than other vibrations of unseen energy. And there lies the tremendous significance of the new psychology or recognition of soul force. Till recently conventional science, as taught in all accepted textbooks, recognized no extension of the dynamics of thought beyond the confines of the physical organism. The mind, with feeble domination, through nerve channels, could transmit its orders to different parts of its visible counterpart, but it was not believed that it could go one inch beyond that limit. Any suggestion that telepathy, or thought transference, could take place at a distance of a thousand miles, or even one mile, would have been pronounced impossible.

We shall waste no time in the mere attempt to prove the fact that thought is, and can be, projected through space, both consciously and unconsciously. No well-informed individual who has given any adequate attention to the subject now questions it. Scores of pages might be filled with examples, now on record, which are entirely beyond collusion or coincidence. Every one of thousands of

hypnotic experiences proves it, and every case of healing through mental treatment attests it. There is no fact in physical science better assured.

And how has the world received this transcendent truth which is transforming in its potency, all-inclusive in its sequences, and divine in its possibilities? Very much as it would a new *curio* or an ingenious toy. The institutional psychologist fondles it, turns it over, weighs and measures its properties in his laboratory, speculates *about* it, and makes a profession of it. But the last thing to be thought of, is to make it useful to mankind. That would be unprofessional. To harness and utilize this force of all forces for the good of humanity would lower it from the select and charmed circle of professional theory and speculation to the broad plane of practical and beneficent agencies.

The average psychical researcher shows much of the same indifference as to any utilization of his favorite principles of pursuits. He is engaged in a never-ending pursuit of phenomena. He will strain his investigative powers, and burn midnight oil in testing, comparing and recording curious manifestations, and in interpreting their methods and laws, but as to their practical application in ethical culture, therapeutic potency or spiritual unfoldment he is as innocent as a child. It has not occurred to him. These reflections are made in no impatient spirit as applied to individuals, but rather to show the negative character of systems of thought into which we have allowed ourselves to become crystallized. How much freedom, originality and progress would at once be manifest if the fear of being called unprofessional and unconventional, which now holds men in bondage, could be eliminated!

Besides the classes already noted there are many excellent people, lovely in character and pure in motive, whose temperamental fondness for the mystical leads them to seek visions, dream dreams, and to cultivate an order of phenomena more dramatic than profitable. Abstract truth and vivid demonstration are well, but the world is hungering for their application to its woes.

If we gained some knowledge of the laws which govern a force inconceivably grander and higher than electricity, may we not dismiss undue sensitiveness as to deviations from traditional scholasticism, and for the sake of humanity, step out of the ruts which have been grooved by the schoolment of the darker and narrower past? All great advances in their earlier aspects have been irrational innovations.

Regarding the fundamental basis of psycho-dynamics, not only as admitted but overwhelming proven, let us now concisely sum up a few of the results which logically should be realized. They are of stupendous significance, but surrounded as we are by the blank walls of our self-imposed and traditional limitations we can hardly picture them even to the imagination.

Thoughts being forces, every mind is a creative center from which rhythms of qualitative energy are going out in all directions. By their impact upon corresponding chords in other minds, these are also swept into active vibration. Throw a pebble into a lake and the placid surface at once becomes vibrant with a series of ever-widening circles which go out to its utmost boundary. They are never quite lost, or neutralized, though we may be unable to trace them to their final destination. So every soul is the seat of a great centrifugal current, which is generated and set free in the simple process of thinking. This is true - though less in degree - of desultory or aimless thought, as well as of that which is concentrated and projected with definite intent. *Every thinker is a battery of positive forces even though he utter never a word.*

The soul - which is the man - is a resonant instrument with innumerable tremulous strings of the most delicate quality. The water in the lake responds to the pebble, but the medium through which thought-waves pass is infinitely more subtle and elastic.

What volumes of potential energy are wasted and far worse, in negative and discordant mental activities! We are not thinking for ourselves but for the world. With the shuttle of thought in the loom of the mind, we are weaving the multicolored fabric of conditions, and these

not merely immaterial but to be outwardly actualized and manifested. If one in his own soul strikes the discordant notes of anger, envy, avarice, selfishness or even those seemingly more harmless ones of simple fear, weakness, grief, pessimism or depression, he is creating and vibrating those conditions far and near, thereby stirring the corresponding chords in other souls into sympathetic activity. The sphere of outward action is limited, while that of thought is boundless. Mere doing makes ephemeral reputation, while quality of thinking determines, or rather *is*, vital character.

Every one's thought-images are being constantly impressed both upon himself and others. His mind is a busy factory where conditions are positively manufactured. He weaves their quality, consciously or unconsciously, into every nerve, muscle and tissue of his own body. His materialistic thought tethers him in a little circle of limitation, while boundless green fields lie beyond waiting for occupation. His mental pictures of evil, disorder and disease, photograph themselves not only upon his own mind and body but upon those of his fellows.

One cannot afford to think much about evil, even for the well-intentioned purpose of its suppression. The true remedy is its displacement. Thought-space given to it confers realism, familiarity and finally dominion. To silence discordant strings in ourselves or others we must vibrate their opposites. To truly sympathize with a friend who is quivering with trouble or sorrow, is not to drop into his rhythm and intensifying it - as is usual - but to lift his consciousness by striking a higher chord in unison. The road to mental and physical invigoration lies through the dynamics of formative thought. Our way to elevate other lives is also through their creative mental energies.

When the art of projecting thought vibrations on a high plane is systematically cultivated, and the concentrative habit developed, potency for good is increased a hundredfold. Force is no longer squandered in worse than useless discordant negations, but intelligently conserved in positive vigor and exuberance. *Purposeful thought ministration, spiritual and pure in quality, accurately and scientifically projected, like an arrow towards a target, will be the great harmonizing and uplifting agency that will transform the world.* Vibrations of love, peace, spirituality, health, sanity and harmony, will be radiated in ever widening circles, striking responsive unisons that are only waiting for a well-directed concordant impulse.

The dynamics of mind, when generally utilized, will be the sovereign balm that with scientific accuracy will heal all the infelicities of society. It will usher in not only reform but regeneration. In its copious fulness it will overflow from the altitude of spiritual development, until the subordinate plains of intellectuality, ethics, therapeutics, sociology, economics and physics are swept purified and uplifted. The highest includes everything below. With the kingdom of heaven - which is subjective harmony - first sought, "all these things" will be added.

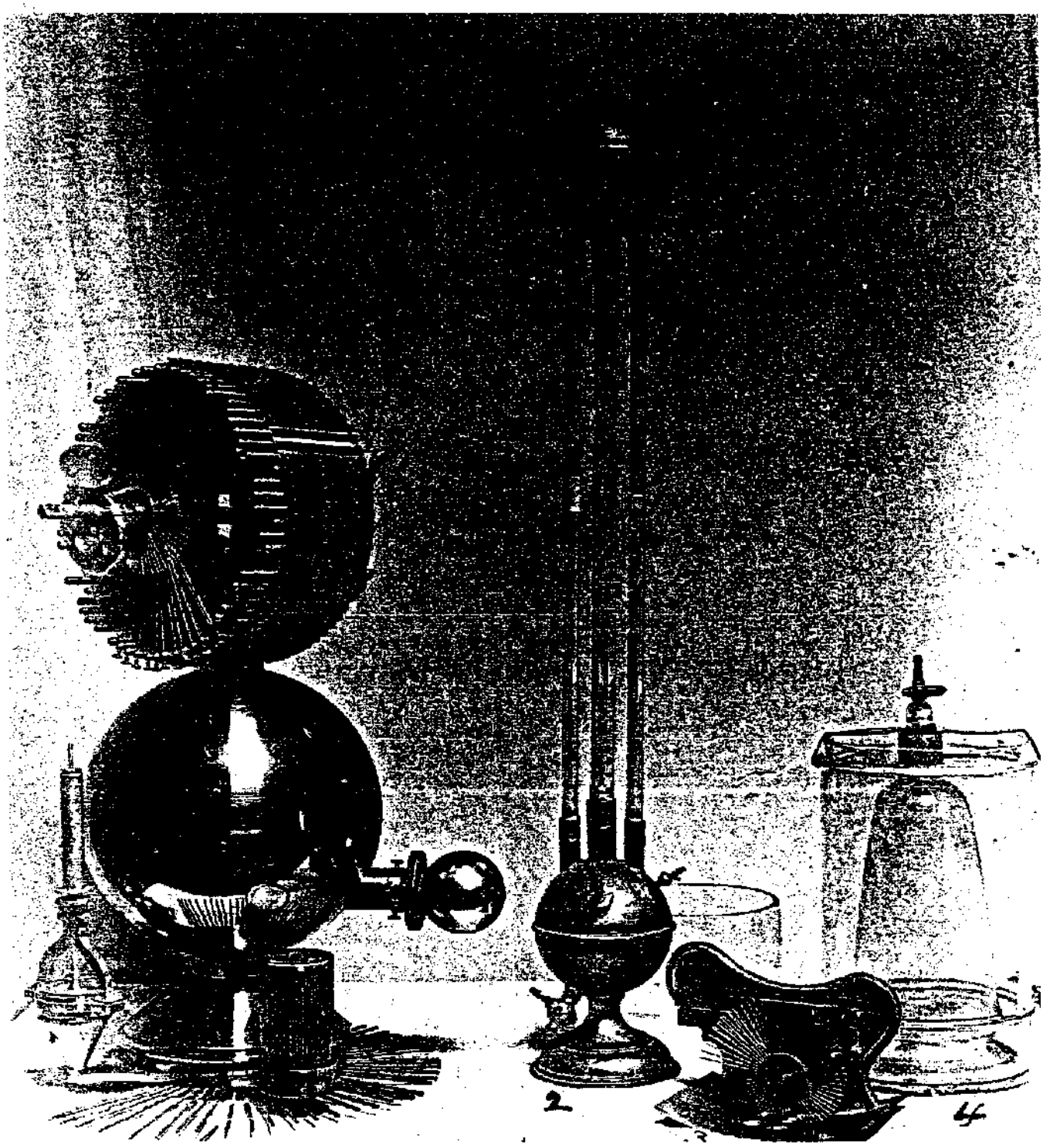

(from left to right) - Sympathetic Negative Transmitter; Triple Column for Measuring Specific Gravity of Gases; Dominat Scale and Resonator; Hydrogen Generator

The Neutral Center

John Ernst Worrell Keely

"A center of introductory action is necessary in all operations of Nature."

All structures require a foundation. This neutral center is the foundation.

"Every molecule, every mass, every moving body in space, every solar system, every stellar system, EVERY ROTATORY SYSTEM, is built about a NEUTRAL CENTER. It is the indestructible unit around which all that we recognize as matter is built. Immovable itself, it moves all things. Indestructible itself throughout infinity of time, it creates all things. It produced and preserves the incalculable energy of motion of the entire Universe. It bears the unthinkable burden of the mass of the Universe. It is the most wonderful thing Man has discovered in the Universe since he discovered fire.

"If we should take a planet of say 20,000 miles diameter and should displace a portion of the interior so as to have a crust of say 5,000 miles thickness, and at the center of the planet, place a billiard ball, that small mass, immeasurably smaller than the bulk of the earth, would bear the entire burden of the mass of the crust 5,000 miles thick and would keep it equidistant from itself. No power, however great, could possibly displace this central mass so as to bring it into contact with the crust. Furthermore, to move this central mass in any direction, would require a force sufficient to move the entire mass of the planet, and in propagating or continuing any such motion the neutral center, this billiard ball, will at all time periods remain still in the exact center, bearing the same equidistant relation to its hollow shell. The mind staggers in contemplating the burden borne by this neutral center, where weight ceases." No less wonderful are other properties of the neutral center.

"It is the cause of the physical Universe. Its attraction condensed that which we recognize as substance. Matter was evolved from the affinity of this neutral center for sympathetic streams and since it is immovable, it caused, through negative attraction the formation of nodes in these streams, where the vibrations thereafter continued to meet in a center of sympathetic coincidence causing the permanence of form and matter. Every nebula, an embryonic world, is acted upon, created and preserved by this neutral center, and at the termination of its cycle, it is ultimately also destroyed by it, causing its absorption into the Unknown from whence it came.

"The actual neutral center of the earth is, in fact, even infinitely smaller than the billiard ball referred to above. It consists of a compound interetheric point in space, so small that were we to magnify a pin head to the size of the sun, and from that substance take a particle of matter the same size, again magnifying it to the size of the sun, the neutral center would still be invisible, even though the structure of this last substance was examined through the highest powered microscope ever created, or to be created. For the neutral center is INDIVISIBLE. Its attributes do not belong to matter, and pertain in no way to matter, which is but its exterior manifestation.

"Every aggregate mass consists of molecules, each of which has its neutral center where the three modes of vibration, dominant, harmonic, and enharmonic, meet in a center of sympathetic coincidence and are equated without cancellation of their energy."

"The fixed neutral center of the earth

Universal Laws Never Before Revealed.. Keely's Secrets

is the concentration or totalized power of all the several molecular neutral centers in the earth's mass. This neutral center, which is absolutely WITHOUT WEIGHT, an interetheric point in space, communicates direct by means of its outflow of sympathy, with every planetary mass in the Universe. Through its inflow of sympathy, through the solar intermediate, the sun, it receives the life flow from the SUPREME NEUTRAL CENTER that enables it to perpetuate its existence. Thus through the outflow from this Supreme Neutral Center that pivoting point of the Universe controls the existence and motion of not only every stellar, solar and planetary mass in space, but also the rotatory vibration, in every individual molecule, intermolecule, etc. through all the subdivisions of matter, thereby sustaining their existence and motion with the life flow.

"All foundations must be sufficient to bear their burden. Conceive then the Universe centered upon and resting the burden of is incalculable mass and kinetic energy on a vacuous interetheric point in space, so minute that it is actually INDIVISIBLE. This conception can only be fully comprehended by an infinite mind. Independent of time, because indestructible in its unity, independent in space, because through its properties space itself exists and without it would not exist, independent of matter because its properties in an external direction created all that we know as matter and gave it seeming permanence, the neutral center is that protean, uncreated, indestructible, forever-existing FIRST CAUSE. Without hands, without tools, without thought, without emotion, without love, without form, without substance, it, of itself, created all these. All that we see or can see in the objective Universe exists because of and by means of the properties and powers of the NEUTRAL CENTER.

"No machine heretofore constructed has been made with a neutral center. This conception of mechanics has never before dawned on man's thought field. Had this been done, perpetual motion would have become a demonstrated fact. Were a machine so constructed as to use its properties, an introductory impulse would suffice to run it for centuries. However, this would not be a useful mechanical contrivance for no more energy could be obtained from it than was originally given, and its only value would be as a timekeeper." Keely did not seek to invent, nor did he claim to have invented, perpetual motion.

"The neutral center is only established when rotation exceeds 100 revolutions per minute, which is sufficient, with the vibratory circuit running at 100,000 per second, to neutralize the influence of gravity on the volume of the neutral third of the sphere." The neutral center controls its sphere of operation, whether that mass controlled by it be homogeneous or complex. All differential mass antagonism is equated on the induction of certain orders of vibration. The structural conditions can be entirely adverse, even of unlike states --- gases with liquids, liquids with solids, solids with gases, its control will be as complete in one case as in the other.

"The condition of unstable equilibrium was born in each neutral center, that by means of this arrangement, the neutral center might become the connective link or controlling tendency, holding these two properties in balance and assuming either phase at will. Between the dispersing positive and the attractive negative it stands, the deciding factor, the Universal Will. "The action that induces this property I call the connective link is sympathetic planetary oscillation."

Theory And Formula Of Aqueous Disintegration

by John Keely

The peculiar conditions as associated with the gaseous elements of which water is composed, as regards the differential volume and gravity of its gases, make it a ready and fit subject of vibratory research. In submitting water to the influence of vibratory transmission, even on simple thirds, the high action induced on the hydrogen as contrasted with the one on the oxygen (under the same vibratory stream) causes the antagonism between these elements that induces dissociation. The differential antagonistic range of motion, so favoring the antagonistic thirds as to become thoroughly repellant. The gaseous element thus induced and registered, shows thousands of times much greater force as regards tenuity and volume than that induced by the chemical disintegration of heat, on the same medium. In all molecular dissociation or disintegration of both simple and compound elements, whether gaseous or solid, a stream of vibratory antagonistic thirds, sixths, or ninths, on their chord mass will compel progressive subdivisions. In the disintegration of water the instrument is set on thirds, sixths, and ninths, to get the best effects. These triple conditions are focalized on the neutral center of said instrument so as to induce perfect harmony or concordance to the chord note of the mass chord of the instruments full combination, after which the diatonic and the enharmonic scale located at the top of the instrument, or ring, is thoroughly harmonized with the scale of ninths which is placed at the base of the vibratory transmitter with the telephone head. The next step is to disturb the harmony on the concentrative thirds, between the transmitter and the disintegrator. This is done by rotating the siren so as to induce a sympathetic communication along the nodal transmitter, or wire, that associates the two instruments. When the note of the siren becomes concordant to the neutral center of the disintegrator, the highest order of sympathetic communication is established. It is now necessary to operate the transferable vibratory negatizer or negative accelerator, which is seated in the center of the diatonic and enharmonic ring, at the top of the disintegrator, and complete disintegration will follow (from the antagonisms induced on the concordants by said adjunct) in triple progression, thus: First thirds: Molecular dissociation resolving the water into a gaseous compound of hydrogen and oxygen. Second: sixths, resolving the hydrogen and oxygen into a new element by second order of dissociation, producing what I call low atomic ether. Third: ninths, the low atomic ether resolved into a new element, which I denominate high or second atomic harmonic. All these transmissions being simultaneous on the disturbance of sympathetic equilibrium by said negative accelerator.

EXAMPLE:

Taking the chord mass of the disintegrator B flat, or any chord mass that may be represented by the combined association of all the mechanical parts of its structure (no two structures being alike in their chord masses) taking B flat, the resonators of said structure are set at B flat first octave, B flat third octave and B flat ninth octave by drawing out the caps of resonators until the harmony of thirds, sixths, and ninths are reached; which is simple movement of the fingers on the diatonic scale, at the head, will determine by the tremulous action which is highly sensible to the touch, on said caps. The caps are then rigidly fixed in their different positions by set screws. The focalization to the neutral center is then established by dampening the steel rods, on the back of the scale, representing the thirds, sixths and ninths, drawing a piece of small gum tube over them, which establishes harmony to the chord mass of the instrument. Concordance is thus effected between the disintegrator and the ninths of the scale at base of transmitters with telephonic head.

This scale has a permanent sympathetic one, set on the ninth of any mass chord that may be represented, on any and all the multiple variations of mechanical combinations. In fact, permanently set for universal accommodations.

The next step is to establish pure harmony between the transmitter and the disintegrator, which is done by spinning the siren disk, then waiting until the sympathetic note is reached, as the siren chord, decreasing in velocity, descends the scale. At this juncture, the negative accelerator must be immediately and rapidly rotated, inducing high disturbance of equilibrium between the transmitter and the disintegrator by triple negative evolution, with the result that a force from five to ten, fifteen, twenty, and thirty thousand pounds to the

square inch is evolved by the focalization of this triple negative stream on the disintegrating cell, or chamber, whether there be one, two, three, five, or ten drops of water enclosed within it."

"When moist air is subdivided by atomic vibration, the hydrogen is dissociated or separated from the oxygen but neither of them pass from the intermolecular state. Not until the intermolecular structure of hydrogen is subdivided by interatomic vibrations can it assimilate with the introductory etheric element."

"The latent force from liquids and gases differs from that liberated in metals in that it results from the breaking up of their rotating etheric envelopes, increasing simultaneously the range of their corpuscular action giving under confinement forces of almost infinite variety of pressures. When liberated from the tube it is confined in it seeks its medium of corresponding tenuity with a velocity exceeding that of light."

"The sympathetic neutral flow (from the molecular neutral centers to the mass neutral center) is the latent power liberated in the disintegration of water. In water this power is dispersive, liberating latent elastic energy, while in metals the latent force manifests itself only in negative attraction and when these vibrations are applied to minerals, there is evolved the primal ether which is dissipated, leaving behind only an impalpable intermolecular dust, in which is contained in virgin form an metals originally in the mineral mass."

A non-intermittent flow of sympathy must flow along the Trexar, consisting of harmoniously adjusted thirds. Differential molecular weight is required, that is, the gas must contain heavy atoms and light atoms. This condition is satisfied by water, which consists of two light atoms of hydrogen and one heavy atom of oxygen. The oxygen atom weighs sixteen times as much as the hydrogen.

It is absolutely necessary to release the molecular ether by reducing the water to the interatomic state, before the atoms within the intermolecules can be released. Also the etheric capsules of the atomic and interatomic must be ruptured before the interatomic force can be produced. The ether from one subdivision is essential to subdividing the next higher.

Keely systemized the proper vibratory chords progressively, from the introductory molecular to the interetheric, embracing seven distinct orders of triple subdivision. He proved to his own satisfaction that progressive subdivision evolves new and distinct elements "too multiple to enumerate."

Water is a ready and fit subject for vibratory research on account of its "differential volume" and gravity of its gases. Even on simple thirds the differential action between hydrogen and oxygen causes antagonism and dissociation. The differential of mass is such that the hydrogen and oxygen become thoroughly repellant and thereby exhibit thousands of times more force than could be induced by heat on the same amount of water. Vibration of antagonistic thirds, sixths and ninths on the mass chord will compel progressive subdivisions and to get the best effect on water, the instrument is set on all of these. First, the focalizing chord of sixths induces perfect harmony to the mass chord. Then the diatonic scale and enharmonic scale at the top of the instrument (or ring) is harmonized with the scale of the ninths at the base of his Trexar with the telephone transmitter. His next procedure was to disturb the harmony between the transmitter and disintegrator on the concentrative thirds or sixths, by rotating a siren. This he used to induce sympathetic communication along the Trexnonar between the vibrator and disintegrator. When the siren concorded to the neutral center it established the highest order of sympathy. He then operated the "transferable vibratory negatizer" or "vibratory accelerator" in the center of the "diatonic and enharmonic ring" at the top of the disintegrator and complete disintegration followed. The thirds first resolved the water molecules into hydrogen and oxygen, then the sixths resolved the hydrogen and oxygen into new elements by dissociation, producing "low atomic ether." Then the ninths resolved the low atomic ether into a new element or "high or second atomic harmonic." All these transmissions were simultaneous on the sympathetic equilibrium being disturbed by the negative accelerator.

Keely's first efforts toward disintegration of the elements of water were successful because of the differential weight of the respective atoms composing its molecules. Subsequently, he discovered that this same method, disintegration by differential mass, may be carried out with any gas, in other words, it must contain heavy atoms and light atoms. The heavy atom or oxygen in water weighs just sixteen times as much as either of the hydrogen atoms to which it is joined by chemical affinity.

"In the dissociation of water, molecular and intermolecular dissociation produces the first order of ozone, which is refreshing and vitalizing to breathe. Atomic and interatomic dissociation produces the second order of ozone, which is too pure to breathe, for it produces insensibility." The third order of ozone, produced by etheric and interetheric dissociation, Keely used in his "carbon

register" to produce a high vibratory circuit to break up cohesion, which he recognized as molecular magnetism. It is possible that this "dissociation" in the "carbon register" depolarized the iron molecules by allowing the corpuscular outreach to return within the molecular embrace. The acceleration of vibration producing these different orders is governed by the introductory impulse and the subsequent chords, as arranged in his Liberator, by which he dissociated water. In molecular dissociation he used one fork of 620, setting chords on the first octave. In atomic separation, he used two forks, one of 620 and one of 630, setting chords on the second octave. In etheric separation he used three forks, one of 620, one of 630 and one of 12,000, setting the chords on the third octave.

"Not until the intermolecular structure of hydrogen is subdivided by interatomic vibrations, can it assimilate with the introductory etheric element."

Certain differential, dual, triple or quadruple chords act as an introductory impulse exciting action on molecular masses (liquid or gaseous) decreasing molecular oscillation. They are then in a receptive state for vibratory disintegration. The diatonic-enharmonic is sounded, increasing molecular oscillation. Molecular subdivision takes place when oscillation exceeds 50% of their diameters. (Molecular or intermolecular?) The gas is now molecularly subdivided and assumes a high velocity of rotation in any confining container, be it sphere or tube and becomes the medium or prepared subject for further disintegration. At this particular time Keely sought to further excite this preparatory medium by the use of an "illuminated revolving prism" a condenser (concave mirror or convex lens) and colored lenses, thereby giving the vibratory frequencies of their respective colors. In his disintegrator a glass tube of sufficient strength to withstand a pressure of 1000 lbs. per square inch was arranged leading to the neutral center and the Trexar was attached to the external end of this glass tube. His use of this tube was probably also to convince the skeptics that the production of his power was genuine and possibly also was used to transmit color vibrations of such frequencies as to release the energy in the neutral center of the sphere.

When the triple introductory impulse or chords in three octaves, are transmitted to the disintegrator it SUBSERVES OR RENDERS NON-OPERATIVE THE MOLECULAR CONCORDANT THIRDS AND ANTAGONIZES WITH DISCORDANT THIRDS, extending their range of oscillation and thereby inducing the highest degree of repellant antagonism or repulsion toward the neutral center of the sphere volume.

The etheric dominant or celestial current induces aqueous disintegration and thermal concentration which two prime conductors display a coincident chord of sympathy with the celestial current. These two prime conductors link the terrestrial to the celestial, without which electricity and magnetism would tend to
become static or stable, all life and motion are governed by a dual power disturbance of equilibrium and sympathetic equation, both of which are in turn moved and regulated by electricity and magnetism.

Progressive molecular and intermolecular dissociation reproduces on a small scale Nature's system of light production and also invariably results in vortex motion. All corpuscular action in Nature is vortex motion. The vortex action between the terrestrial and celestial streams, terrestrial condensation against solar tensions, shows conditions analogous to those displayed in the dissociation of water into hydrogen and oxygen, that is, vortex motion of the highest order, but peripheral only.

EXAMPLE OF DISINTEGRATION

If the mass chord of the disintegrator is B flat, the resonators of that structure are set at B flat first octave, B flat third octave and B flat ninth octave, by drawing out the resonator caps and clamping the set screws. A simple movement of the fingers on the diatonic scale at the head will determine by the tremulous action of the caps when exactly resonant. Neutral focalization is then established by dampening the steel rods on the back of the scale representing thirds, sixths, and ninths, by drawing a piece of small gum tube over them, which establishes harmony to the mass chord of the instrument. This effects concordance between the disintegrator and the ninths of the scale at base of transmitter with telephone head.

This instrument had a universal accommodator for all ninths in all multiple variations. This was possibly his sphere resonator.

Concordant harmony must now be established between the transmitter and the disintegrator by spinning the siren disk and waiting for the sympathetic note as its velocity decreases. As soon as this note sounds, the negative accelerator must be rapidly rotated inducing high disturbance of equilibrium between the disintegrator and the transmitter by triple negative evolution resulting in enormous pressure. By triple negative evolution he doubtless means disintegration to the etheric stage.

"In the beginning was the word"

The neutral negative center

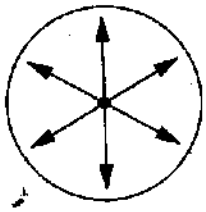

Sensitized - reaching out

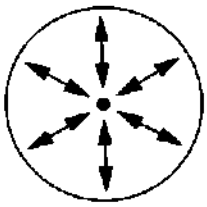

Establishing range of outreach

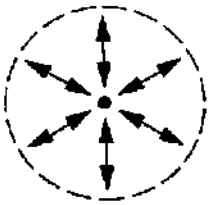

Positive Propulsive
Establishing Resonance

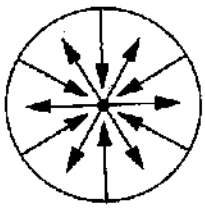

Equilibrium or
Harmony

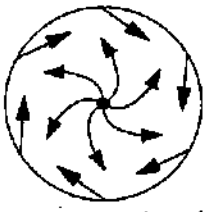

Introductory Impulse
Giving Vortex Motion

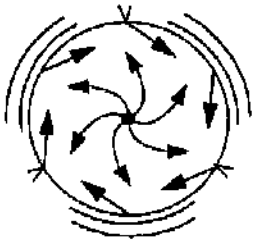

Vibration into
Thirds at Nodes

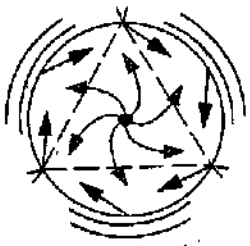

Nodes forming
Tensorial Lines of
Negative Force

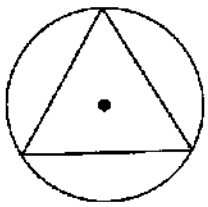

Completed Unit
of Duality

solid matter
in 3 dimensions

Keely's Motor Secret Revealed at Long Last

by Dale Pond

For over 120 years the secret concerning the function and operation of the Keely Hydro-Pneumo-Pulsating-Vacuo motor has baffled all the scientists and engineers who saw it. This mystery of mysteries has been solved.

I had developed a theory of operation over the past several years regarding its secret of operation. What was needed was to rebuild and run the motor to prove the theory.

During the second week of August, Vic Hansen and I resolved to recondition the original Keely motor in his possession. Extraordinary care was taken not to damage any part and all gaskets were replaced and all leaks fixed. We succeeded in recuperating only one of the two pistons as a valve in the second piston was frozen and we loathed to dismember the motor that this second piston would function. We were able to reestablish the functionality in only one piston. This proved to be sufficient for the test. Running on only one cylinder was not sufficient for the motor to run on its own power so we ran water through it in reverse. This was sufficient to prove the principle as we could clearly hear the "pop" of the one live cylinder coinciding with the timing and function of principles. As the piston "popped" the crank and connections responded to the momentary decrease in pressure. Yes, I said decrease in pressure.

This function of this motor represents the female or nightside forces at work. The force is one of implosion or centralization of vibratory forces. It is exactly opposite in function to every known type and manner used to today to derive motive power. This explains, in part, why it has remained a mystery all these years. Because they were looking for expansive force or the male, propulsive type forces, they remained baffled because no such force exists in its function. Two other notable things can be said about its function: one, it uses a lot of water to run, second, there is no heat whatsoever as it operates. The need for so much water can be resolved with better engineering - this should be simple feat as we know Keely eventually generated thousands of psi using but a few drops of water as he improved the design of the motor. The coldness of operation is a boon just the way it is. This means new models can be built of PVC or other plastics.

The importance of this discovery cannot be over stated: 1) It proves Keely wasn't a fraud as some allege. 2) It gives mankind a whole new energy source that is clean, powerful and simple. 3) It uses a plentiful and costless fuel - water. 4) It gets us into the doorway to reach for his greater and more wonderful discoveries based on his etheric vapor. This motor, as simple as it is, led Keely to the discovery and development of his etheric vapor and etheric force. By understanding its prime principle of function, we too, can make this giant step into the far reaches of applied physics.

So, how does it work? Where does the energy come from to propel itself? From cavitation of water. You are no doubt familiar with the phenomenon of water hammer. This is cavitation and is the very same source of energy in the Keely Motor. Water hammer is the development of a negative pressure cell in a flowing stream of water by cutting off its supply quite suddenly. The resulting partial vacuum collapses (implodes) with a force that can reach several thousand pounds per square inch instantly. In his motor this pressure was controlled to around 50 psi which was sufficient to run this little model.

Those of you working with implosion forces will be glad to see this practical application of the phenomenon of cavitation and the resulting implosive force.

Thus, the engineers investigating Keely's Motor were all looking for a male or explosive force and found none. During the collapse of the cavitation bubble formed in the piston chamber the piston was sucked down and not pushed up as in our "modern" engineering concepts.

The design of Keely's motor is so simple and basic that anyone with a modicum of talent can replicate and even improve on his design. He built his machine over 120 years ago and was hindered by not having the convenience we have of modern valves, ready made materials and 120 years of hydraulic engineering as support. Since the motor runs cold and with ordinary water the parts to build a unit can be had at your nearest hardware store. I suggest looking into PVC pipe and automatic valves such as are used in building sprinkler systems. Two valves, one for intake and one for exhaust coupled to a PVC cylinder should be all that is needed.

To go about building your own working model of his motor you should first acquire a copy of the book *Cavitation* by F. Ronald Young, MacMillan and Co. This book is now out of print. This book is the first and hence only book detailing cavitation. The different kinds of cavitation and their technical parameters are explored very thoroughly. The resulting effects of cavitation such as sonoluminescence and sonochemistry are all explored. The book further gives hundreds of references for source materials or previous research and lab work on this most fascinating of subjects. There is also a very good technical description of water hammer on page 249.

How the motor works

Water hammer is caused by a stream of water being shut off quickly. The trailing edge of the water stream (next to the shutoff valve) becomes rarefied (partial vacuum) and forms into a negative pressure area filled with a *sensitized* vapor composed of water, air and any gases that may have been present in the water. This vapor is the first stage or the basic form of Keely's etheric vapor. The negative pressure cell collapses when the water stream bounces back against the shutoff valve. The physics of these actions and reactions is fascinating and promises so much for development that we will all be very busy developing them for years to come.

In the Keely Motor the water is first drawn into the central pulsating vacuum chamber by a light vacuum formed when the pistons pull water into the system. This vacuum chamber maintains a steady negative pressure on the water from this point on. Between the vacuum chamber and the pistons are two valves. The first is a one-way check valve which serves to maintain the vacuum in the central pulsating vacuum chamber yet allows the pistons to pull water into itself as it is needed. The second valve is quite ingenious and simple. Its function is: 1) to allow water into the piston, 2) close for implosion and then 3) to allow drainage of the spent water.

The water then passes directly into the piston during its up (suction) stroke. The valve rotates shutting off the water stream just as the piston reaches its apex and cavitates which brings the piston down again. Instantly the valve rotates a little more opening two exhaust ports and the water is pushed and drained out through the bottom. This is all there is to the Keely motor. It is simple, elegant and functional. Rules of thumb are: 1) the more vacuum the better the cavitation, 2) the greater the velocity of the water the better the cavitation. The book "Cavitation" has more ideas on improving cavitation than we have space here to list.

Editor's Note (June, 1994): Since this article was written much more has been learned about this motor. Please refer to booklet *The Keely Motor* available from Delta Spectrum Research P. O. Box 316 Valentine, Nebraska 69201 (402) 376-1523.

Sympathetic Vibratory Physics

The Science and Technology of John Ernst Worrell Keely

Lecture given by Dale Pond before the
Swiss Association of Free Energy,
October 28, 1989, Einseideln, Switzerland

Mankind has placed himself in a grave situation. He has divorced himself from Nature with his current attitudes towards Science and Religion. The study of Nature is really a study of Science and Religion. Science is man's effort to know about Nature. Religion is man's effort to reconnect with that Nature. Hence through the arts of science and religion Mankind is attempting to know what Nature is in its truest sense and by way of this ever-expanding understanding to establish his kinship with Nature. These two subjects are bound together as a two sided unit. Science on the one side is ever expanding understanding and Religion is the assimilation of himself into this ever growing awareness of all that is around him. This concept is of course the ideal situation. Mankind has rarely attained this ideal state.

In actuality Mankind has separated himself from Nature with his ever increasing materialistic views embodied in both Science and Religion. His Science admits no connection between himself and his experiments. Atheistic attitudes separates him from Nature and natural processes. This is in error and has lead ultimately to the abysmal situation we find on earth today. Pollution is rampant and uncontrolled. Hunger, pain and suffering, and a lack of the basic material necessities plagues people in all countries. In fact, this century has been the bloodiest time in all of Mankind's history with nearly 100 million souls destroyed in all parts of the globe.

It would seem, at first glance, that with all the modernizations and increases in human science and technology, that we are living in the greatest age of history. But this is not so. To those who have perished and those who now suffer this is a terrible time in history. The question remains "why is this so?"

It is an easy thing to point one's finger at the "bad guys" and lay blame at someone else's feet. It is easy to say one political group is evil and one's own political group is innocent. The truth of the matter is these problems were not created by any one or several groups of politically oriented peoples. These problems were created and perpetuated by ignorance. This ignorance is a lack of awareness that all of Mankind is a part of Nature. This materialistic ignorance does not recognize that we are all part of a single natural scheme closely bound together in our actions and circumstances. A concept of Oneness, an idea that Mankind is a valuable part of Nature, has long been held and preserved through the centuries most conspicuously by the religious and metaphysical organizations. Materialistic science has cut off these tried and true ideas at the knees and left man bereft of his common foundation. Materialistic science has left mankind with nowhere to go except along the paths he has established in this century. These paths have lead to more bloodshed, pain and suffering than all previous paths he has ever choosen.

Free energy will not liberate Mankind from these evils. Neither will faster and more powerful machines free him of these self imposed burdens. Certainly more money, more people and more bureaucracies will not help either. We already have cheaper energy, more people, more bureaucracies and have spend vast amounts of human effort towards the solution of these problems

and the net result has been an increase of the same problems. Mankind is on the wrong path.

What is needed is a comprehensive awareness that binds Mankind together within a wholistic knowledge that he is a part, an important part, in the natural processes of Nature in which he finds himself. What one man does has an effect on his neighbor and the natural processes surrounding them both. This dual view of nature is fundamental to science, religion and common sense. It is called the Law of Cause and Effect by science and karma by certain religions. This is an almost impossible law for most science or most religions to accept because it implies responsibility to one's self. It also implies that the perpetrator be charitable. He must concede that his neighbor have as much importance to him as himself. Another false premise of materialistic science is that of insufficiency. The establishment of monopolistic and totalitarian organizations is based on this false idea of there not being enough energy or materialistic substances to go around. With a broader paradigm that concedes the Universal Forces of Nature are limitless mankind can then be charitable. But to even concede this much many are hesitant because it implies their knowledge and power structures are based erroneously on false premises. These ideas of endless abundance implies sharing and most refuse to share because they believe in limited materialities as opposed to limitless potentialities. -- Hence, the exercise of charity has not been one of Mankind's greatest achievements.

My message to you today is that there is a paradigm of both Science and Religion that encompasses the highest of virtues expressible by Man. There is a field of science so powerful that it can build a new and better future for Mankind. There is a philosophy and science so all-encompassing that it can bring Mankind to a realization of his Oneness with his neighbors and with all of Nature. This paradigm has latent within itself, because of its breadth and scope, more than enough material and spiritual benefits for everyone because it recognizes and uses the very foundation principles of Nature itself. Because of its recognition and acceptance of its role in life it does not trample human rights or the rights of Nature and assumes full responsibility for itself within its own scope of possibilities. More than all this, it recognizes the valuable parts of all sciences and religions and merges them into a comprehensive and usable paradigm that has within itself seeds for unlimited growth and expansion. This paradigm of science is called Sympathetic Vibratory Physics.

What is Sympathetic Vibratory Physics? It is the science of Harmony, of Oneness. It holds the concept that all comes from One Source, One Force. It maintains that the fantastic array of things and activities throughout the universe are related in a simple manner. This simple basis of relativity is called vibration. It has been long recognized that everything in the universe vibrates. Thus, a study of vibrations is the study of the very foundation of Nature. For once we grasp the inner functioning of the vibratory Universal Creative Forces as they operate throughout the universe, then, and only then, can we correlate them into a comprehensive paradigm and bring them into practical modes of usefulness for the benefit of mankind. Unlike dogmatic, cold science, Sympathetic Vibratory Physics does not isolate one phenomena from another but accepts and shows the inter-connectivity between all things and forces. This interconnection between all things is vibration and related vibratory phenomena. To understand vibration we must develop a comprehensive organized science of vibration governed by laws and principles. Fortunately a great deal of this development work has already been done. We have a well developed science of music. Music is an organized art and science of vibrations found within the audible range of the infinite Electromagnetic Scale. A major segment of Sympathetic Vibratory Physics is therefore a study of music, its arithmetical and philosophical basis of development and how these may be

United States Patent [19]

Rogers, Sr.

[11] **4,292,804**

[45] **Oct. 6, 1981**

[54] **METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS**

[76] Inventor: **Leroy K. Rogers, Sr.**, #5 Capistrano Ct., Ft. Myers, Fla. 33908

[21] Appl. No.: **158,303**

[22] Filed: **Jun. 10, 1980**

[51] **Int. Cl.**[3] **F15B 11/06**

[52] **U.S. Cl.** **60/407**; 91/187; 91/275

[58] **Field of Search** 60/407, 412; 91/187, 91/275, 364

[56] **References Cited**

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3,885,387	5/1975	Simington	60/407 X
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Primary Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

The present invention relates to a method and apparatus for operating an engine having a cylinder and a piston reciprocable therein on compressed gas. The apparatus comprises a source of compressed gas connected to a distributor which distributes the compressed gas to the cylinder. A valve is provided to selectively admit compressed gas to the cylinder when the piston is in an approximately top dead center position. In one embodiment of the present invention the timing of the opening of the valve is advanced such that the compressed gas is admitted to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases. In a further embodiment of the present invention a valve actuator is provided which increases the length of time over which the valve remains open to admit compressed gas to the cylinder as the speed of the engine increases. A still further embodiment of the present invention relates to an apparatus for adapting a conventional internal combustion engine for operation on compressed gas.

22 Claims, 8 Drawing Figures

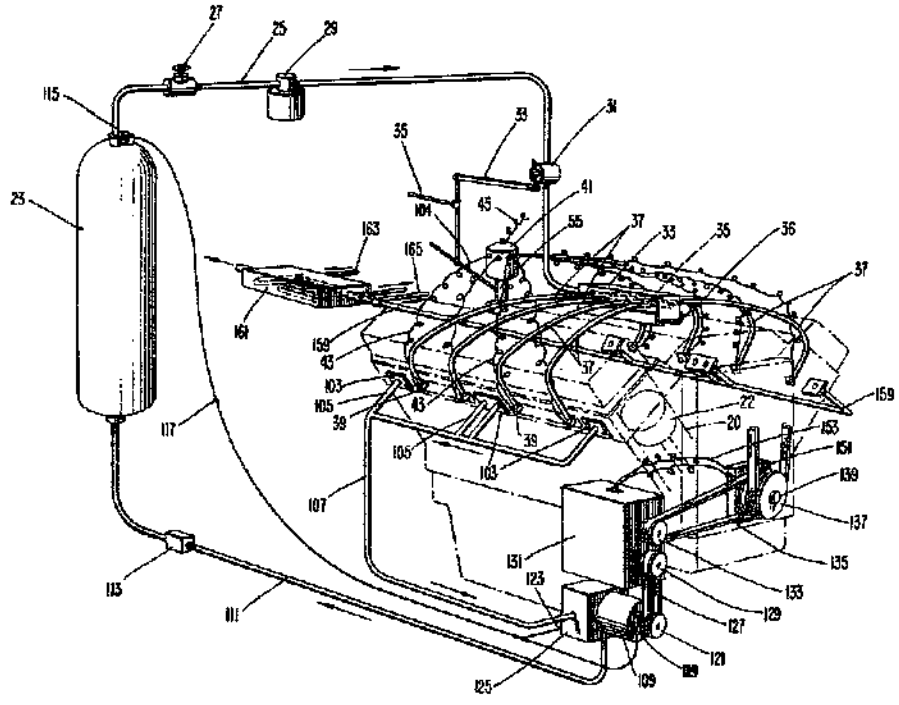

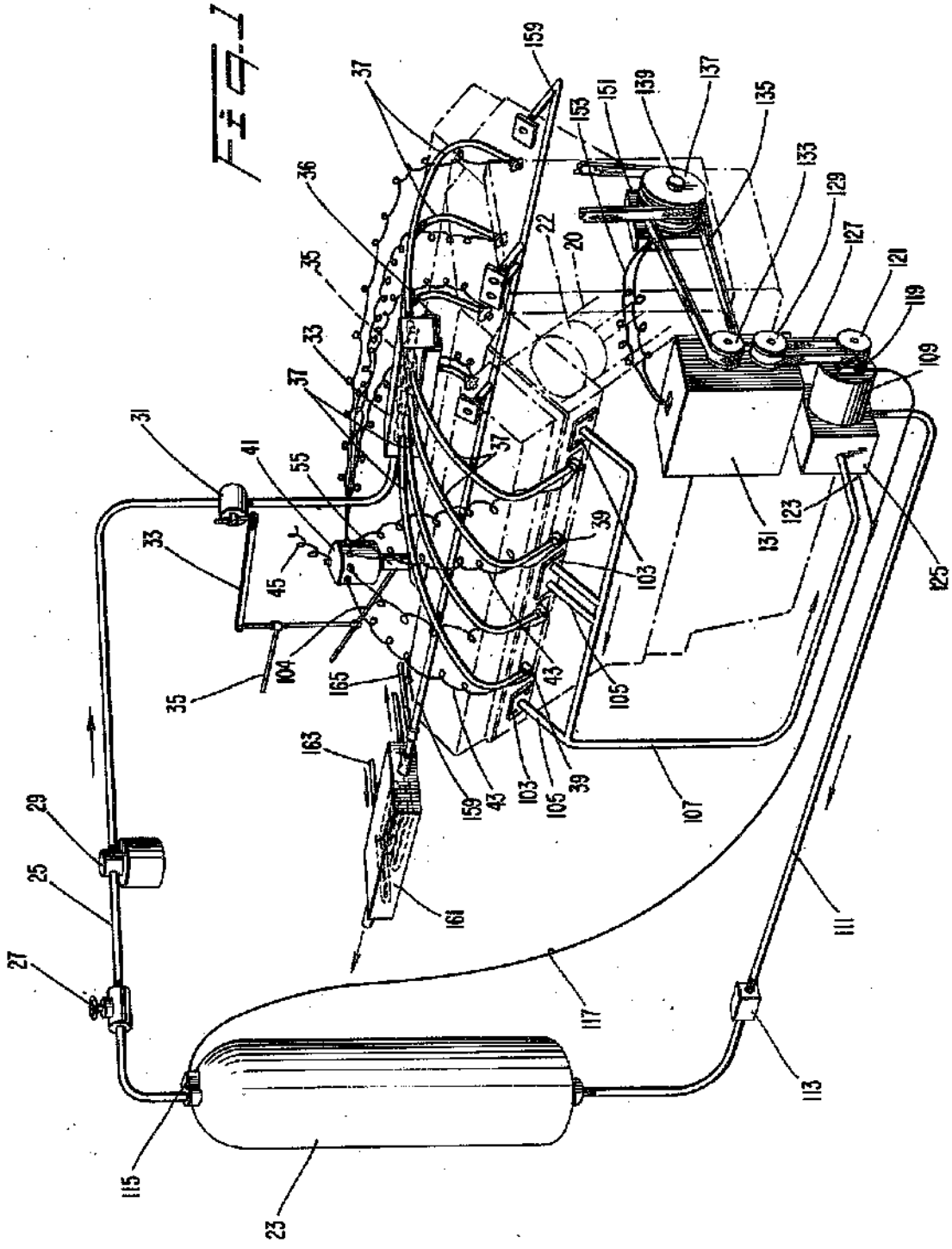
Fig. 1
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Fig. 6

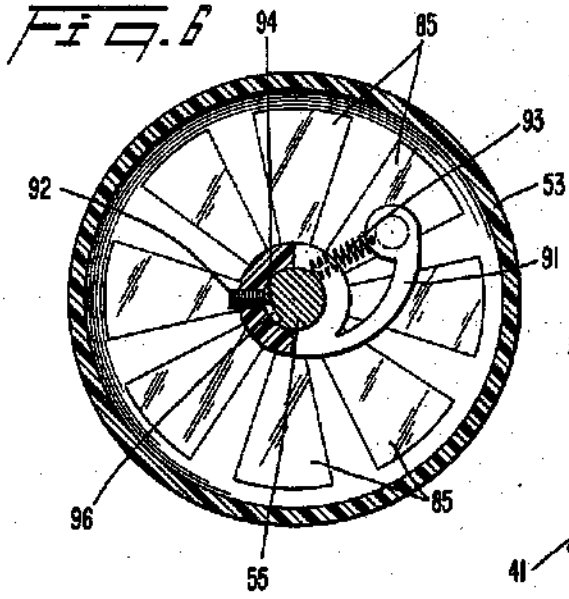

Fig. 7

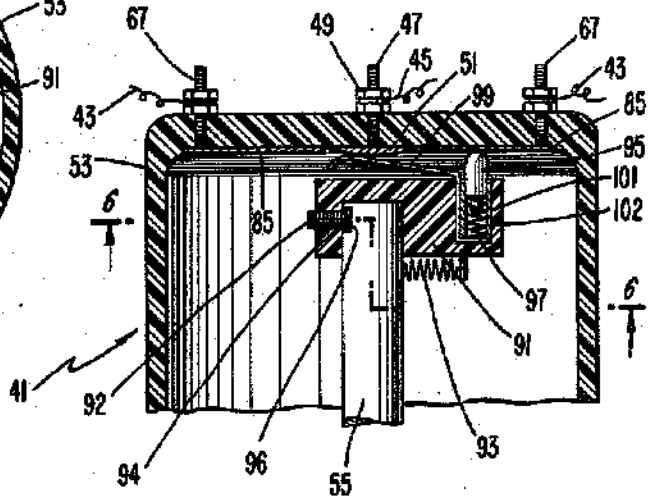

Fig. 3

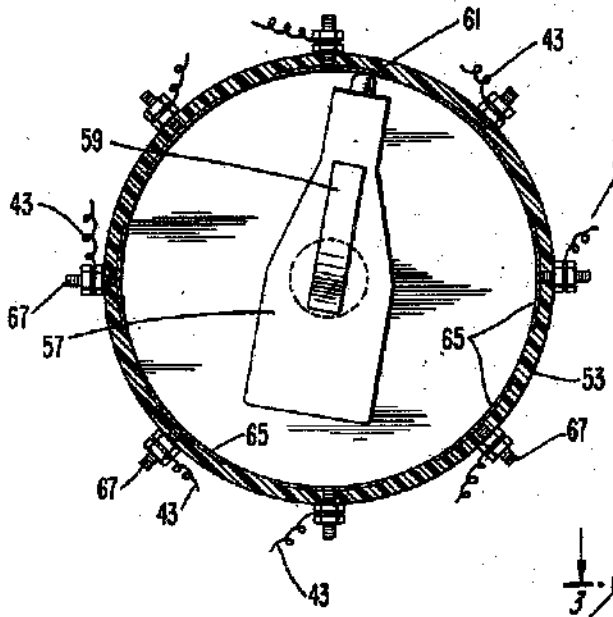

Fig. 2

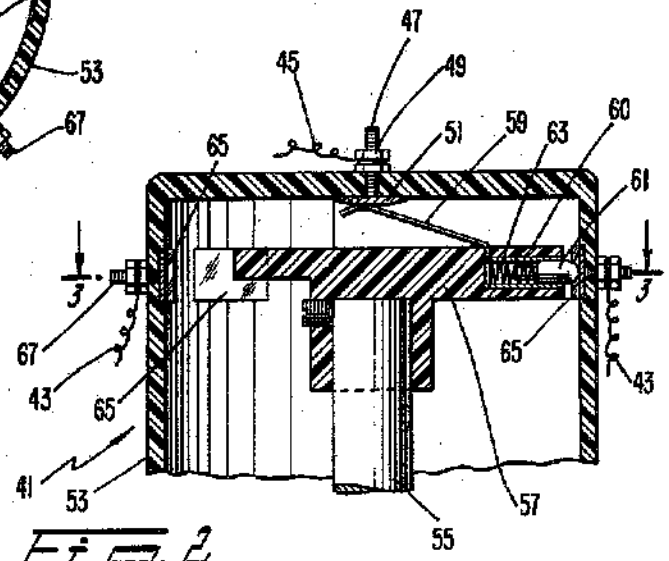

Fig. 3

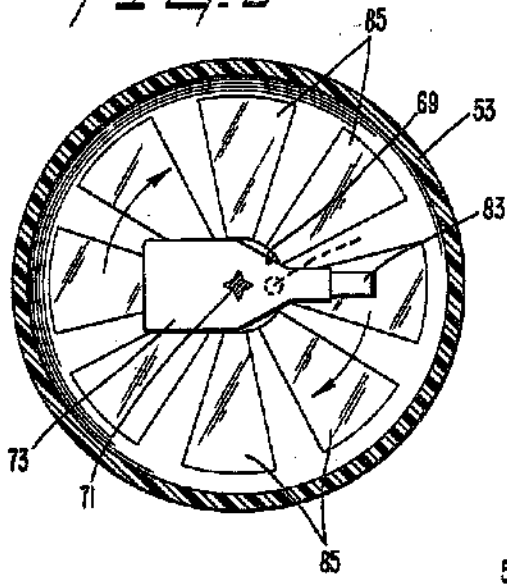

Fig. 4

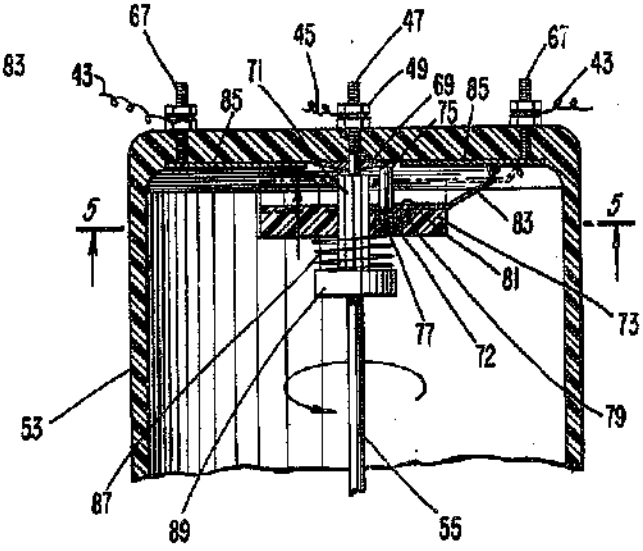

Fig. 8

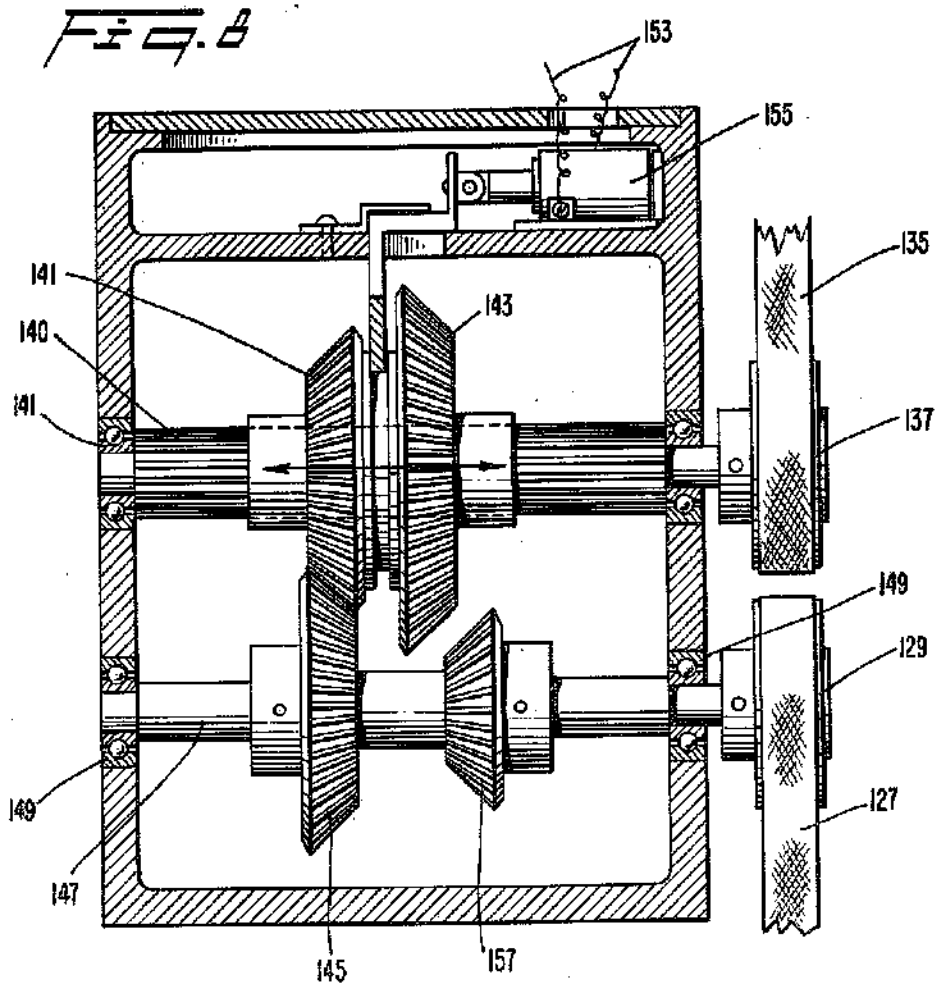

METHOD AND APPARATUS FOR OPERATING AN ENGINE ON COMPRESSED GAS

BACKGROUND AND SUMMARY OF THE PRESENT INVENTION

The present invention relates to a method and apparatus for operating an engine using a compressed gas as the motive fluid. More particularly, the present invention relates to a apparatus for adapting a pre-existing internal combustion engine for operation on a compressed gas.

Air pollution is one of the most serious problems facing the world today. One of the major contributors to air pollution is ordinary internal combustion engine which are used in most motor vehicles today. Various devices, including many items mandated by legislation, have been proposed in an attempt to limit the pollutants which an internal combustion engine exhausts to the air. However, most of these devices have met with limited success and are often both prohibitively expensive and complex. A clean alternative to the internal combustion engine is needed to power vehicles and other machinery.

A compressed gas, preferably air, would provide an ideal motive fluid for a engine since it would eliminate the usual pollutants exhausted from an internal combustion engine. An apparatus for converting an internal combustion engine for operation on compressed air is disclosed in U.S. Pat. No. 3,885,387 issued May 27, 1975 to Simington. The Simington patent discloses an apparatus including a source of compressed air and a rotating valve actuator which opens and closes a plurality of mechanical poppet valves. The valves deliver compressed air in timed sequence to the cylinders of an engine through adapters located in the spark plug holes. However, the output speed of an engine of this type is limited by the speed of the mechanical valves and the fact that the length of time over which each of the valves remains open cannot be varied as the speed of the engine increases.

Another apparatus for converting an internal combustion engine for operation on steam or compressed air is disclosed in U.S. Pat. No. 4,102,130 issued July 25, 1978 to Stricklin. The Stricklin patent discloses a device which changes the valve timing of a conventional four stroke engine such that the intake and exhaust valves open once for every revolution of the engine instead of once every other revolution of the engine. A reversing valve is provided which delivers live steam or compressed air to the intake valves and is subsequently reversed to allow the exhaust valves to deliver the expanded steam or air to the atmosphere. A reversing valve of this type however does not provide a reliable apparatus for varying the amount of motive fluid injected into the cylinders when it is desired to increase the speed of the engine. Further, a device of the type disclosed in the Stricklin patent requires the use of multiple reversing valves if the cylinders in a multi-cylinder engine were to be fired sequentially.

Therefore, it is an object of the present invention to provide a reliable method and apparatus for operating an engine or converting an engine for operation with a compressed gas.

A further object of the present invention is to provide a method and apparatus which is effective to deliver a constantly increasing amount of compressed gas to an engine as the speed of the engine increases.

A still further object of the present invention is to provide a method and apparatus which will operate an engine using compressed gas at a speed sufficient to drive a conventional automobile at highway speeds.

It is still a further object of the present invention to provide a method and apparatus which is readily adaptable to a standard internal combustion engine to convert the internal combustion engine for operation with a compressed gas.

Another object of the invention is to provide a method and apparatus which utilizes cool expanded gas, exhausted from a compressed gas engine, to operate an air conditioning unit and/or an oil cooler.

These and other objects are realized by a method and apparatus according to the present invention for operating an engine having at least one cylinder and a reciprocating piston therein using compressed gas as a motive fluid. The apparatus includes a source of compressed gas and a distributor connected with the source of the compressed gas for distributing the compressed gas to the at least one cylinder. A valve is provided for admitting the compressed gas to the cylinder when the piston is in approximately a top dead center position within the cylinder. An exhaust is provided for exhausting the expanded gas from the cylinder as the piston returns to approximately the top dead center position.

In a preferred embodiment of the present invention a device is provided for varying the duration of each engine cycle over which the valve remains open to admit compressed gas to the cylinder dependent upon the speed of the engine. In a further preferred embodiment of the present invention, an apparatus for advancing the timing of the opening of the valve is arranged to admit the compressed gas to the cylinder progressively further before the top dead center position of the piston as the speed of the engine increases.

Further features of the present invention include a valve for controlling the amount of compressed gas admitted to the distributor. Also, a portion of the gas which has been expanded in the cylinder and exhausted through the exhaust valve is delivered to a compressor to be recompressed and returned to the source of compressed gas. A gear train is selectively engagable to drive the compressor at different operating speed depending upon the pressure maintained at the source of compressed air and/or the speed of the engine. Still further, a second portion of the exhaust gas is used to cool a lubricating fluid for the engine or to operate an air conditioning unit.

In a preferred embodiment of the present invention, the valve for admitting compressed gas to the cylinder is electrically actuated. The device for varying the duration of each engine cycle over which the intake valve remains open as the speed of the engine increase comprises a rotating element whose effective length increases as the speed of the engine increases such that a first contact on the rotating element is electrically connected to a second contact for a longer period of each engine cycle. The second contact actuates the valve whereby the valve remains in an open position for a longer period of each engine cycle as the speed of the engine increases.

Still further features of the present invention include an adaptor plate for supporting the distributor above an intake manifold of a conventional internal combustion engine after a carburetor has been removed to allow air

to enter the cylinders of the engine through the intake manifold and conventional intake valves. Another adaptor plate is arranged over an exhaust passageway of the internal combustion engine to reduce the cross-sectional area of the exhaust passageway.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of a method and apparatus for operating an engine according to the present invention will be described with reference to the accompanying drawings wherein like members bear like reference numerals and wherein:

FIG. 1 is a schematic representation of an apparatus according to the present invention arranged on an engine;

FIG. 2 is a side view of one embodiment of a valve actuator according to the present invention;

FIG. 3 is a cross-sectional view taken along the line 3—3 in FIG. 2;

FIG. 4 is a cross-sectional view of a second embodiment of a valve actuator according to the present invention;

FIG. 5 is a view taken along the line 5—5 in FIG. 4;

FIG. 6 is a cross-sectional view of a third embodiment of a valve actuator according to the present invention;

FIG. 7 is a view taken along the line 7—7 in FIG. 6;

FIG. 8 is a cross-sectional view of a gearing unit to drive a compressor according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, an engine block 21 (shown in phantom) having two banks of cylinders with each bank including cylinders 20 having pistons 22 reciprocable therein (only one of which is shown in phantom) in a conventional manner. While the illustrated engine is a V-8 engine, it will be apparent that the present invention is applicable to an engine having any number of pistons and cylinders with the V-8 engine being utilized for illustration purposes only. A compressed gas tank 23 is provided to store a compressed gas at high pressure. It may also be desirable to include a small electric or gas compressor to provide compressed gas to supplement the compressed gas held in the tank 23. In a preferred embodiment, the compressed gas is air which can be obtained from any suitable source.

A line 25 transports the gas withdrawn from the tank 23 when a conventional shut off valve 27 is open. In addition, a solenoid valve 29 preferably operated by a suitable key operated switch (not shown) for the engine is also arranged in the line 25. In normal operation, the valve 27 is maintained open at all times with the solenoid valve 29 operating as a selective shut off valve to start and stop the engine 21 of the present invention.

A suitable regulating valve 31 is arranged downstream from the solenoid valve 29 and is connected by a linkage 33 to a throttle linkage 35 which is operator actuated by any suitable apparatus such as a foot pedal (not shown). The line 25 enters an end of a distributor 33 and is connected to an end of a pipe 35 which is closed at the other end. A plurality of holes, which are equal to the number of cylinders in the engine 21, are provided on either side of the pipe 35 along the length of the pipe 35.

When the present invention is used to adapt a conventional internal combustion engine for operation on compressed gas, an adaptor plate 36 is provided to support the distributor 33 in spaced relation from the usual intake opening in the intake manifold of the engine after a conventional carburetor has been removed. In this way, air is permitted to enter the internal combustion engine through the usual passageways and to be admitted to the cylinders through suitable intake valves (not shown). The adaptor plate 36 is secured to the engine block 21 and the distributor 33 by any suitable apparatus, e.g., bolts.

Each of the holes in the pipe 35 is connected in fluid-tight manner to a single line 37. Each line 37 carries the compressed gas to a single cylinder 20. In a preferred embodiment, each of the lines 37 is ½ inch high pressure plastic tubing attached through suitable connectors to the distributor 33 and the pipe 35. Each of the lines 37 is connected to a valve 39 which is secured in an opening provided near the top of each of the cylinders 20. In the case of a conversion of a standard internal combustion engine, the valves 39 can be conveniently screwed into a tapped hole in the cylinder 20 typically provided for a spark plug of the internal combustion engine. In a preferred embodiment, the valves 39 are solenoid actuated valves in order to provide a fast and reliable opening and closing of the valves 39.

Each of the valves 39 is energized by a valve actuator 41 through one of a plurality of wires 43. The valve actuator 41 is driven by a shaft of the engine similar to the drive for a conventional distributor of an internal combustion engine. That is, a shaft 55 of the valve actuator 41 is driven in synchronism with the engine 21 at one half the speed of the engine 21.

A first embodiment of the valve actuator 41 (FIGS. 2 and 3) receives electrical power through a wire 45 which is energized in a suitable manner by a battery, and a coil if necessary (not shown) as is conventional in an internal combustion engine. The wire 45 is attached to a central post 47 by a nut 49. The post 47 is connected to a conducting plate 51 arranged within a housing 53 for the valve actuator 41. Within the housing 53, the shaft 55 has an insulating element 57 secured to an end of the shaft 55 for co-rotation therewith when the shaft 55 is driven by the engine 21. A first end of a flexible contact 59 is continuously biased against the conducting plate 51 to receive electricity from the battery or another suitable source. A second end of the contact 59 is connected to a conducting sleeve 60 which is in constant contact with a spring biased contact 61 which is arranged within the sleeve 60. The contact 61 is biased by a spring 63 which urges the contact 61 towards a side wall of the housing 53.

With reference to FIG. 3, a plurality of contacts 65 are spaced from one another and are arranged around the periphery of the housing 53 at the same level as the spring biased contact 61. Each contact 65 is electrically connected to a post 67 which extends outside of the housing 53. The number of contacts 65 is equal to the number of cylinders in the engine 21. One of the wires 43, which actuate the valves 39, is secured to each of the posts 67.

In operation, as the shaft 55 rotates in synchronism with the engine 21, the insulating element 57 rotates and electricity is ultimately delivered to successive ones of the contacts 65 and wires 43 through the spring biased contact 61 and the flexible contact 59. In this way, each of the electrical valves 39 is actuated and opened in the proper timed sequence to admit compressed gas to each of the cylinders 20 to drive the pistons 22 therein on a downward stroke.

The embodiment illustrated in FIGS. 2 and 3 is effective to actuate each of the valves 39 to remain open for a long enough period of time to admit sufficient compressed gas to each of the cylinders 20 of the engine 21 to drive the engine 21. The length of each of the contacts 65 around the periphery of the housing 53 is sufficient to permit the speed of the engine to be increased when desired by the operator by moving the throttle linkage 35 which actuates the linkage 33 to further open the regulating valve 31 to admit more compressed gas from the tank 23 to the distributor 33. However, it has been found that the amount of air admitted by the valves 39 when using the first embodiment of the valve actuator 41 (FIGS. 2 and 3) is substantially more than required to operate the engine 21 at an idling speed. Therefore, it may be desirable to provide a valve actuator 41 which is capable of varying the duration of each engine cycle over which the solenoid valves 39 are actuated, i.e., remain open to admit compressed gas, as the speed of the engine 21 is varied.

A second embodiment of a valve actuator 41 which is capable of varying the duration of each engine cycle over which each of the valves 39 remains open to admit compressed gas to the cylinders 20 dependent upon the speed of the engine 21 will be described with reference to FIGS. 4 and 5 wherein members corresponding to those of FIGS. 2 and 3 bear like reference numerals. The wire 45 from the electrical source is secured to the post 47 by the nut 49. The post 47 has a annular contact ring 69 electrically connected to an end of the post 47 and arranged within the housing 53. The shaft 55 rotates at one half the speed of the engine as in the embodiment of FIGS. 2 and 3.

At an upper end of the shaft 55, a splined section 71 slidably receives an insulating member 73. The splined section 71 of the shaft 55 positively holds the insulating member 73 for co-rotation therewith but permits the insulating member 73 to slide axially along the length of the splined section 71. Near the shaft 55, a conductive sleeve 72 is arranged in a bore 81 in an upper surface of the insulating element 73 generally parallel to the splined section 71. A contact 75, biased towards the annular contact ring 69 by a spring 77, is arranged within the conductive sleeve 72 in contact therewith. The conductive sleeve 72 also contacts a conductor 79 at a base of the bore 81.

The conductor 79 extends to the upper surface of the insulating element 73 near an outer periphery of the insulating element 73 where the conductor 79 is electrically connected to a flexible contact 83. The flexible contact 83 selectively engages a plurality of radial contacts 85 arranged on an upper inside surface of the housing 53. A weak spring 87 arranged around the splined section 71 engages a stop member 89 secured on the shaft 55 and the insulating element 73 to slightly bias the insulating element 73 towards the upper inside surface of the housing 53 to ensure contact between the flexible contact 83 and the upper inside surface of the housing 53. As best seen in FIG. 5, the radial contacts 85 on the upper inside surface of the housing 53 are arranged generally in the form of radial spokes extending from the center of the housing 53 with the number of contacts being equal to the number of cylinders 20 in the engine 21. The number of degrees covered by each of the radial contacts 85 gradually increases as the distance from the center of the upper inside surface of the housing 53 increases.

In operation of the device of FIGS. 4 and 5, as the shaft 55 rotates, electricity flows along a path through the wire 45 down through post 47 to the annular contact member 69 which is in constant contact with the spring biased contact 75. The electrical current passes through the conductive sleeve 72 to the conductor 79 and then to the flexible contact 83. As the flexible contact 83 rotates along with the insulating member 73 and the shaft 55, the tip of the flexible contact 83 successively engages each of the radial contacts 85 on the upper inside of the housing 53. As the speed of the shaft 55 increases, the insulating member 73 and the flexible contact 83 attached thereto move upwardly along the splined section 71 of the shaft 55 due to the radial component of the splines in the direction of rotation under the influence of centrifugal force. As the insulating member 73 moves upwardly, the flexible contact 83 is bent such that the tip of the contact 83 extends further radially outwardly from the center of the housing 53 (as seen in phantom lines in FIG. 4). In other words, the effective length of the flexible contact 83 increases as the speed of the engine 21 increases.

As the flexible contact 83 is bent and the tip of the contact 83 moves outwardly, the tip remains in contact with each of the radial contacts 85 for a longer period of each engine cycle due to the increased angular width of the radial contacts with increasing distance from the center of the housing 53. In this way, the length of time over which each of the valves 39 remains open is increased as the speed of the engine is increased. Thus, a larger quantity of compressed gas or air is injected into the cylinders as the speed increases. Conversely, as the speed decreases and the insulating member 73 moves downwardly along the splined section 71, a minimum quantity of air is injected into the cylinder due to the shorter length of the individual radial contact 85 which is in contact with the flexible contact 83. In this way, the amount of compressed gas that is used during idling of the engine 21 is at a minimum whereas the amount of compressed gas which is required to increase the speed of the engine 21 to a level suitable to drive a vehicle on a highway is readily available.

With reference to FIGS. 6 and 7, a third embodiment of a valve actuator 41 according to the present invention includes an arcuate insulating element 91 having a first end pivotally secured by any suitable device such as screw 92 to the shaft 55 for co-rotation with the shaft 55. The screw 92 is screwed into a tapped hole in the insulating element 91 such that a tab 94 at an end of the screw 92 engages a groove 96 provided in the shaft 55. In this way, the insulating element 91 positively rotates with the shaft 55. However, as the shaft 55 rotates faster, a second end 98 of the insulating element 91 is permitted to pivot outwardly under the influence of centrifugal force because of the groove 96 provided in the shaft 55. A spring 93 connected between the second end 98 of the element 91 and the shaft 55 urges the second end of the element 91 towards the center of the housing 53.

A contact 99 similar to the contact 59 (FIG. 2) is arranged such that one end of the contact 99 is in constant contact with the conducting plate 51 located centrally within the housing 53. The other end of the contact 99 engages a conductive sleeve 101 arranged in bore 102. A contact element 95 is arranged in the conductive sleeve 101 in constant contact with the sleeve 101. The bore 102 is arranged generally parallel to the shaft 55 near the second end of the arcuate insulating

element 91. The contact 95 is biased by a spring 97 towards the upper inside surface of the housing 53 for selective contact with each of the plurality of radial contacts 85 which increase in arc length towards the outer peripheral surface of the housing 53 (FIG. 6).

In operation of the device of FIGS. 6 and 7, as the shaft 55 rotates the arcuate insulating element 91 rotates with the shaft 55 and the second end 98 of the insulating element 91 tends to pivot about the shaft 55 due to centrifugal force. Thus, as the effective length of the contact 95 increases, i.e., as the arcuate insulating element 91 pivots further outwardly, the number of degrees of rotation over which the contact 95 is in contact with each of the radial contacts 85 on the upper inside surface of the housing 53 increases thereby permitting each of the valves 39 to remain open for a longer period of each engine cycle to admit more compressed gas to the respective cylinder 20 to further increase the speed of the engine 21.

With reference to FIG. 1, a mechanical advance linkage 104 which is connected to the throttle linkage 35, advances the initiation of the opening of each valve 39 such that compressed gas is injected into the respective cylinder further before the piston 22 in the respective cylinder 20 reaches a top dead center position as the speed of the engine is increased by moving the throttle linkage 35. The advance linkage 104 is similar to a conventional standard mechanical advance employed on an internal combustion engine. In other words, the linkage 104 varies the relationship between the angular positions of a point on the shaft 55 and a point on the housing 53 containing the contacts. Alternatively, a conventional vacuum advance could also be employed. By advancing the timing of the opening of the valves 39, the speed of the engine can more easily be increased.

The operation of the engine cycle according to the present invention will now be described. The compressed gas injected into each cylinder of the engine 21 drives the respective piston 22 downward to drive a conventional crankshaft (not shown). The movement of the piston downwardly causes the compressed gas to expand rapidly and cool. As the piston 22 begins to move upwardly in the cylinder 20 a suitable exhaust valve (not shown) arranged to close an exhaust passageway is opened by any suitable apparatus. The expanded gas is then expelled through the exhaust passageway. As the piston 22 again begins to move downwardly a suitable intake valve opens to admit ambient air to the cylinder. The intake valve closes and the ambient air is compressed on the subsequent upward movement of the piston until the piston reaches approximately the top dead center position at which time the compressed gas is again injected into the cylinder 20 to drive the piston 22 downward and the cycle begins anew.

In the case of adapting a conventional internal combustion engine for operation on compressed gas, a plurality of plates 103 are preferably arranged over an end of the exhaust passageways in order to reduce the outlet size of the exhaust passageways of the conventional internal combustion engine. In the illustrated embodiment, a single plate having an opening in the center is bolted to the outside exhaust passageway on each bank of the V-8 engine while another single plate having two openings therein is arranged with one opening over each of the interior exhaust passageways on each bank of the V-8 engine. A line 105 is suitably attached to each of the adaptor places to carry the exhaust to an appropriate location. In a preferred embodiment, the exhaust lines 105 are 1½" plastic tubing.

In a preferred embodiment, the exhaust lines 105 of one bank of the V-8 engine are collected in a line 107 and fed to an inlet of a compressor 109. The pressure of the exhaust gas emmanating from the engine 21 according to the present invention is approximately 25 p.s.i. In this way, the compressor 109 does not have to pull the exhaust into the compressor since the gas exhausted from the engine 21 is at a positive pressure. The positive pressure of the incoming fluid increases the efficiency and reduces wear on the compressor 109. The exhaust gas is compressed in the compressor 109 and returned through a line 111 and a check valve 113 to the compressed gas storage tank 23. The check valve 113 prevents the flow of compressed gas stored in the tank 23 back towards the compressor 109.

A suitable pressure sensor 115 is arranged at an upper end of the tank 23 and sends a signal along a line 117 when the pressure exceeds a predetermined level and when the pressure drops below a predetermined level. The line 117 controls an electrically actuated clutch 119 disposed at a front end of the compressor 109. The clutch 119 is operative to engage and disengage the compressor 109 from a drive pulley 121. Also, the signal carried by the line 117 actuates a suitable valve 123 arranged on a compressor housing 125 to exhaust the air entering the compressor housing 125 from the line 107 when the clutch 119 has disengaged the compressor 109 from the drive pully 121.

In a preferred embodiment, when the pressure is the tank 23 reaches approximately 600 p.s.i., the clutch 119 is disengaged and the compressor 109 is deactivated and the valve 123 is opened to exhaust the expanded gas delivered to the compressor 109 from the line 107 to the atmosphere. When the pressure within the tank 23 drops below approximately 500 p.s.i., the sensor 115 sends a signal to engage the clutch 119 and close the valve 123, thereby operating the compressor 109 for supplying the tank 23 with compressed gas.

The pulley 121 which drives the compressor 109 through the clutch 119 is driven by a belt 127 which is driven by a pulley 129 which operates through a gear box 131. With reference to FIGS. 1 and 8, a second pulley 133 on the gear box is driven by a belt 135 from a pulley 137 arranged on a drive shaft 139 of the engine 21. The pulley 137 drives a splined shaft 140 which has a first gear 141 and a second larger gear 143 arranged thereon for rotation with the splined shaft 140. The splined shaft 140 permits axial movement of the gears 141 and 143 along the shaft 140.

In normal operation (as seen in FIG. 8), the first gear 141 engages a third gear 145 arranged on a shaft 147 which drives the pulley 129. The shafts 140 and 147 are arranged in suitable bearings 149 arranged at each end thereof. When the speed of the engine 21 drops below a predetermined level, a suitable sensor 151 responsive to the speed of the drive shaft 139 of the engine 21 generates a signal which is transmitted through a line 153 to a solenoid actuator 155 arranged within the gear box 131. The solenoid actuator 155 moves the first and second gears 141, 143 axially along the splined shaft 140 to the right as seen in FIG. 8 such that the second, larger gear 143 engages a fourth smaller gear 157 which is arranged on the shaft 147. The ratio of the second gear 143 to the fourth gear 157 is preferably approximately 3 to 1.

In this way, when the speed of the engine **21** drops below the predetermined level as sensed by the sensor **151** (which predetermined level is insufficient to drive the compressor **109** at a speed sufficient to generate the 500–600 pounds of pressure which is preferably in the tank **23**), the solenoid actuator **155** is energized to slide the gears **143**, **141** axially along the splined shaft **140** so that the second, larger gear **143** engages the fourth, smaller gear **157** to drive the pulley **129** and hence the compressor **109** at a higher rate of speed to generate the desired pressure. When the speed of the engine increases above the predetermined level, in a preferred embodiment approximately 1500 rpm, the solenoid actuator **155** is deactivated by the sensor **151** thereby moving the gears **143** and **141** to the left as seen in FIG. **8** such that the first gear **141** re-engages with the third gear **145** to effectuate a 1 to 1 ratio between the output shaft **139** of the engine **21** and the pulley **129**.

The other bank of the V-8 engine has its exhaust ports arranged with adapter plates **103** similar to those on the first bank. However, the exhaust from this bank of the engine **21** is not collected and circulated through the compressor **109**. In a preferred embodiment, a portion of the exhaust is collected in a line **159** and fed to an enlarged chamber **161**. A second fluid is fed through a line **163** into the chamber **161** to be cooled by the cool exhaust emmanating from the engine **21** in the line **159**. The second fluid in the line **163** may be either transmission fluid contained in a transmission associated with the engine **21** or a portion of the oil used to lubricate the engine **21**. A second portion of the exhaust from the second bank of the V-8 engine is removed from the line **159** in a line **165** and used as a working fluid in an air conditioning system or for any other suitable use.

It should be noted that the particular arrangement utilized for collecting and distributing the gas exhausted from the engine **21** would be determined by the use for which the engine is employed. In other words, it may be advantageous to rearrange the exhaust tubing such that a larger or smaller percentage of the exhaust is routed through the compressor **109**. It should also be noted that since the exhaust lines **105** are plastic tubing, a rearrangement of the lines for a different purpose is both simple and inexpensive.

In operation of the engine of the present invention, the engine **21** is started by energizing the solenoid valve **29** and any suitable starting device (not shown), e.g., a conventional electric starter as used on an internal combustion engine. Compressed gas from the full tank **23** flows through the line **25** and a variable amount of the compressed gas is admitted to the distributor **33** by controlling the regulator valve **31** through the linkage **33** and the operator actuated throttle linkage **35**. The compressed gas is distributed to each of the lines **37** which lead to the individual cylinders **20**. The compressed gas is admitted to each of the cylinders **20** in timed relationship to the position of the pistons within the cylinders by opening the valves **39** with the valve actuator **41**.

When it is desired to increase the speed of the engine, the operator moves the throttle linkage **35** which simultaneously admits a larger quantity of compressed gas to the distributor **33** from the tank **23** by further opening the regulator valve **31**. The timing of the valve actuator **41** is also advanced through the linkage **104**. Still further, as the speed of the engine **21** increases, the effective length of the rotating contact **83** (FIG. **4**) or **95** (FIG. **6**) increases thereby electrically contacting a wider portion of one of the stationary radial contacts **85** to cause each of the valves **39** to remain open for a longer period of each engine cycle to admit a larger quantity of compressed gas to each of the cylinders **20**.

As can be seen, the combination of the regulating valve **31**, the mechanical advance **104**, and the valve actuator **41**, combine to produce a compressed gas engine which is quickly and efficiently adaptable to various operating speeds. However, all three of the controls need not be employed simultaneously. For example, the mechanical advance **104** could be utilized without the benefit of one of the varying valve actuators **41** but the high speed operation of the engine may not be as efficient. By increasing the duration of each engine cycle over which each of the valves **39** remains open to admit compressed gas to each of the cylinders **20** as the speed increases, conservation of compressed gas during low speed operation and efficient high speed operation are both possible.

After the compressed gas admitted to the cylinder **20** has forced the piston **22** downwardly within the cylinder to drive the shaft **139** of the engine, the piston **22** moves upwardly within the cylinder **20** and forces the expanded gas out through a suitable exhaust valve (not shown) through the adapter plate **103** (if employed) and into the exhaust line **105**. The cool exhaust can then be collected in any suitable arrangement to be compressed and returned to the tank **23** or used for any desired purpose including use as a working fluid in an air conditioning system or as a coolant for oil.

When using the apparatus and method of the present invention to adapt a ordinary internal combustion engine for operation with compressed gas it can be seen that considerable savings in weight are achieved. For example, the ordinary cooling system including a radiator, fan, hoses, etc. can be eliminated since the compressed gas is cooled as it expands in the cylinder. In addition, there are no explosions within the cylinder to generate heat. Further reductions in weight are obtained by employing plastic tubing for the lines which carry the compressed gas between the distributor and the cylinders and for the exhaust lines. Once again, heavy tubing is not required since there is little or no heat generated by the engine of the present invention. In addition, the noise generated by an engine according to the present invention is considerably less than that generated by an ordinary internal combustion engine since there are no explosions taking place within the cylinders.

The principles of preferred embodiments of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. The embodiments are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others without departing from the spirit of the invention. Accordingly, it is expressly intended that all such variations and changes which fall within the spirit and the scope of the present invention as defined in the appended claims be embraced thereby.

What is claimed is:

1. An apparatus for operating an engine having at least one cylinder and a reciprocating piston therein comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

valve means for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder;

altering means for increasing the duration of each engine cycle over which the valve means admits compressed gas to the at least one cylinder as the speed of the engine increases; and

exhaust means for exhausting gas as the piston subsequently approaches approximately the top dead center position.

2. The apparatus of claim 1 further comprising control means for controlling the amount of compressed gas admitted to the distributor means.

3. The apparatus of claim 1 wherein the valve means is a solenoid valve secured in an opening in the cylinder above the level of the piston at the top dead center position.

4. The apparatus of claims 1 or 2 further comprising means for advancing the timing of the valve means as the speed of the engine increases such that compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

5. The apparatus of claim 4 wherein the means for advancing the timing comprises a mechanical linkage connected to an operator actuated accelerator linkage.

6. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is compressed in a compressor driven by an output shaft of the engine and is returned to the source of compressed gas.

7. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is used to cool transmission fluid for a transmission associated with the engine.

8. The apparatus of claim 1 wherein a portion of the gas exhausted through the exhaust means is used as a working fluid in an air conditioning system.

9. The apparatus of claim 6 further comprising first gearing means interposed between the output shaft of the engine and the compressor for increasing the speed at which the compressor is driven.

10. The apparatus of claim 6 further comprising clutch means attached to the compressor both for disengaging the compressor from the output shaft of the engine when a first predetermined pressure at the source of compressed gas is exceeded and for engaging the compressor with the output shaft of the engine when the pressure at the source of compressed gas drops below a second predetermined pressure.

11. The apparatus of claim 9 further comprising means for both disengaging the first gearing means when a predetermined speed of the engine is exceeded and engaging a second gearing means for driving the compressor at a speed slower than the first gearing means when the predetermined speed of the engine is exceeded.

12. The apparatus of claim 1 wherein the valve means is electrically actuated and wherein the altering means comprises:

a rotating member timed with the at least one cylinder and arranged within a housing;

first and second contacts arranged on a first end of the rotating member and on an inside surface of the housing, respectively;

means for increasing the distance of the first contact from the rotational axis of the rotating member as the speed of the engine increases such that the first contact moves radially outwardly within the housing; and

said second contact presenting a longer arc length to the first contact as the distance of the first contact from the rotational axis of the rotating member increases.

13. The apparatus of claim 12 wherein the rotating member comprises an arcuate arm and wherein the means for increasing the distance of the first contact comprises pivotally mounting a second end of the arcuate arm about the axis of rotation of the rotating member and spring means for biasing the first end of the arcuate arm towards a radially inward position whereby the first end of the arcuate arm pivots radially outwardly as the speed of the engine increases.

14. The apparatus of claim 12 wherein the rotating member is axially slidably received on a rotating shaft for co-rotation therewith, said shaft having splines with a radial component in the direction of rotation, and wherein the first contact comprises a flexible contact located on an upper surface of the rotating member, said flexible contact being biased against the inside surface of the housing which carries the second contacts whereby as the speed of the engine increases the rotating member is urged axially along the splined shaft towards the inside surface of the housing such that the flexible contact is forced radially outwardly along the inside surface.

15. The apparatus of claim 12 wherein the second contact comprises of radially extending conductor arranged on an upper inside surface of the housing, said conductor increasing in arc length as the conductor extends radially outwardly from a central portion of the housing.

16. An apparatus for adapting an internal combustion engine for operation with compressed gas, the internal combustion engine having at least one cylinder, a piston reciprocable within the at least one cylinder, intake and exhaust means disposed in the at least one cylinder, and a tapped hole in the at least one cylinder adapted to receive a spark plug, the apparatus comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

valve means arranged in the tapped hole for admitting the compressed gas to the at least one cylinder when the piston is in approximately a top dead center position within the cylinder; and

altering means for increasing the duration of each engine cycle over which the valve means remains open to admit the compressed gas as the speed of the engine increases.

17. An apparatus as in claim 16 further comprising first adapter plate means for supporting the distributor means above an intake manifold of the engine, which adaptor plate means allows ambient air to enter through the intake manifold.

18. The apparatus of claim 16 further comprising second adapter plate means for reducing the exit area of the exhaust means.

19. A method of operating an engine on compressed gas, said engine having at least one cylinder and a piston reciprocable therein comprising the steps of:

delivering compressed gas from a source to a distributor;

distributing the compressed gas to the at least one cylinder;

admitting compressed gas to the at least one cylinder through an intake valve when the piston is at approximately a top dad center position;

increasing the duration of each engine cycle over which compressed gas is admitted to the at least one cylinder as the engine speed increases; and

exhausting the remaining gas when the piston subsequently reaches approximately the top dead center position.

20. The method of claim 19 further comprising the step of controlling the amount of compressed gas which is delivered to the distributor.

21. The method of claim 19 further comprising the step of advancing the timing of the opening of the intake valve as the speed of the engine increases.

22. An apparatus for operating an engine having at least one cylinder and a piston reciprocable therein on compressed gas comprising:

a source of compressed gas;

distributor means connected with the source of compressed gas for distributing the compressed gas to the at least one cylinder;

electrically actuated valve means secured in an opening in the at least one cylinder for selectively admitting compressed gas to the at least one cylinder when the piston is in approximately a top dead center position; and

means for advancing the timing of the valve means as the speed of the engine increases whereby compressed gas is admitted progressively further before the top dead center position as the speed of the engine increases.

* * * * *

PRELIMINARY PLANS TO RUN YOUR CAR ON TAP WATER!

IT ALSO WORKS ON YOUR
TRUCK / RV / MOTORCYCLE / AIRPLANE (ETC)

Will This Work?

These plans were sent to the Spirit of Ma'at anonymously, from someone who does not want his or her name printed (for obvious reasons).
We have had them checked by an expert who believes that they are real.
We also have talked with another individual who has patented a similar device, and we know by personal experience that the technology is sound.
So although we cannot guarantee it, we believe these plans will enable you to build a car that runs on water. If you test it out, though, do as the writer suggests and use an old car that doesn't represent a loss of value if you can't make it work. And leave everything intact so that you can always reconnect back to gas if you have to.

But if you do get it working, please send us your experience for our readers. You could be a national hero and help save our country and our world.

We know for certain that an automobile will run on water. So this could be an interesting project for you mechanical types, with a great reward of never having to purchase gasoline for the rest of your life - and helping humanity at the same time.

Re The Need to Rustproof Your Exhaust System

It is possible to make a hybrid of both gas and water (a system that is being tested now in Mexico), which would eliminate the need to open the head and remove the exhaust system. Just a thought. It takes only a small amount of gas to keep the system dry.

The text sent from the anonymous individual was edited slightly for better reading. The following is his/her words and drawings, which has been given into the public domain.
- Spirit of Ma'at LLC

Introduction

It is suggested you try this out to begin with on a second vehicle you own, one that you don't need to live with everyday, until you perfect this technology.

Do-it-yourself plans allow the individual (that's you and me, folks) to make a difference. This is the easiest and lowest-cost way to convert your car to run on (relatively) free energy.

Now, with existing technology, anyone can stand up and make a difference by reducing the local automotive pollution, eliminate gasoline expenses, help restore our atmosphere, and breathe a little easier.

In putting these plans into operation, you will be making use of your entire existing system except for the fuel tank and the catalytic converter.

The Plan

Build and install a low-cost alternative method for running your vehicle (internal combustion engine) on tap water, using off-the-shelf components.

This is simply an efficient way to convert ordinary tap water into gaseous hydrogen and oxygen, and then burn these vapors in the engine, instead of gasoline.

This "minisystem" runs easily from your existing battery and electrical system, and it plugs into your carburetor with simple off-the-shelf fittings.

You will be installing a plastic water tank, a control circuit, a reaction chamber, a hi-pressure carb/FI fitting, and 3 gauges, and then hooking into your existing carb/FI.

The simplicity comes from its being an "on-demand" system requiring no fancy storage or plumbing. You crank the gas pedal or throttle, and you electrically create more vapor for immediate consumption, on demand; low-high flow rate as needed, from idle to maximum power. The only real change is that you are using tap water as fuel, instead of the traditional petroleum-based fuel.

Given a choice, which way would you choose?

Frequently Asked Questions

Q: Does it really work ?
A: Yes; this is well-established technology dating back to stainless steel. But be sure to follow these instructions using the proper mechanical and electrical assembly techniques, as this plan incorporates the best qualities of several techniques.

Q: How does it qualify as "free energy"?
A: If you're paying someone for the water you use, then it is not strictly free. But the alternative is to keep buying into expen$ive ga$oline and its resultant hydrocarbon pollution.

Q: Is it safe?
A: Technically, it is safer than running on fossil fuel because you are no longer choking on your own emissions (health-wise). In general, it is practically as safe as your current gasoline arrangement. You will be installing a few simple safety devices, using current automotive standards.

Q: What kind of performance can I expect?
A: Properly adjusted, your modified vapor-only fuel system will run cooler, and at a modestly higher power level. The mileage performance expected from this design ranges from 50-300 mpg (of water), depending on your adjusting skills.

Q: Can I do the modification myself?
A: Why not? If you don't have any mechanical skills, and you know someone with basic mechanical and/or electrical skills, you can even delegate some of the construction. If you are using a fuel-injected engine, you may have to get a mechanic's opinion. [There will have to be an adapter inserted into the fuel-injection system, just as you would have to do if you were going to run on propane, hydrogen, or natural gas. Ed.)

Q: What is the environmental impact that my vehicle will have?
A: It will be producing H20 steam (water vapor) and unburnt O2 (Oxygen). Hence, it will be cleaning the environment, rather than dumping nauseous toxins into it. Plus you will be helping to save our dwindling supply of atmospheric oxygen. Any excess vapor in the reaction becomes either steam or oxygen. You can also expect to be receiving more than casual interest from those around you.

Q: Isn't this really a steam engine?
A: No. Really. Exceedingly high temperature and pressure are not used. This is strictly an internal-combustion engine (burning orthohydrogen) with residual steam in the exhaust as a by-product.

There are a few things you should know about gasoline:

Gasoline as a fuel is not necessary; it is optional.

Gasoline versus Water

There is a lot of thermochemical energy in gasoline, but there is even more energy in water. The DOE (Department of Energy) has quoted about 40%, so it is probably much more than that.

Most people are unaware that "internal combustion" is defined as "a thermo-vapor process" - as in "no liquid in the reaction." Most of the gasoline in a standard internal

combustion engine is actually consumed, (cooked, and finally, broken down) in the catalytic converter after the fuel has been not-so-burnt in the engine. Sadly, this means that most of the fuel we use in this way is used only to cool down the combustion process, a pollution-ridden and inefficient means of doing that.

How It Works

Exceedingly simple. Water is pumped as needed to replenish and maintain the liquid level in the chamber. The electrodes are vibrated with a 0.5-5A electrical pulse which breaks 2(H2O) => 2H2 + O2. When the pressure reaches say 30-60 psi, you turn the key and go. You step on the pedal, you send more energy to the electrodes, and thus more vapor to the cylinders; i.e. fuel vapor on demand.

You set the idle max-flow rate to get the most efficient use of power, and you're off to the races.

In the big picture, your free energy is coming from the tap water in an open system, as the latent energy in the water is enough to power the engine and hence drive the alternator and whatever belt-driven accessories. And the alternator is efficient enough to run the various electrical loads (10 - 20 amps), including the additional low current to run this vapor reaction. No extra batteries are required.

STEP BY STEP CONSTRUCTION (Please refer to diagrams at the end of this document)

OVERVIEW - Here is the suggested sequence of steps:

1. Install the CHT (or EGT) gauge and measure your current operating temp range (gasoline), for comparison.

2. Build and test the controller to verify the correct pulse output.

3. Build the reaction chamber and test it with the controller (i.e pressure out).

4. Install the tank, controller, chamber, and pressure fittings.

5. Run engine and adjust the control circuit as necessary for best performance.

6. Install the stainless steel valves and get the pistons/cylinders coated with ceramic.

7. Coat the exhaust system with ceramic without the catalytic converter (or let it rust out and then replace the whole dang thang with stainless steel pipe sections).

YOU WILL NEED

plastic water tank with pump and level sensor.
control circuit, wiring, connectors, and epoxy.
reaction chamber with electrodes and fittings.
3/8" stainless steel flex-tubing, fittings and clamps.
carb/FI vapor-pressure fitting kit. - pressure, CHT (or EGT), & level gauges.
stainless steel valves.
copper mesh junction.
ceramic surface treatment for cylinders & pistons.
stainless steel or ceramic treated exhaust assembly.

BASIC TOOLS

drill, screwdriver and pliers
hole cutter
wire-wrap, solder-iron and clippers
DVM and oscilloscope.

REACTION CHAMBER

Construct as shown in the diagrams. Use a section of 4" PVC waste pipe with a threaded screw-cap fitting on one end and a standard end-cap at the other. Make sure to drill-and-epoxy or tap threads thru the PVC components for all fittings. Set and control the water level in the chamber so that it well submerses the pipe electrodes; yet leave some headroom to build up the hydrogen/oxygen vapor pressure. Use stainless steel wires inside the chamber or otherwise use a protective coating; use insulated wires outside. Ensure that the epoxy perfects the seal, or otherwise lay down a bead of water-proof silicone that can hold pressure.

The screw fitting may require soft silicone sealant, or a gasket; its purpose is to hold pressure and allow periodic inspection of the electrodes. No leaks, no problems. Make sure you get a symmetric 1-5mm gap between the 2 stainless steel pipes. The referenced literature suggests that the closer to 1mm you get, the better. You will want to get your chamber level sensor verified before you epoxy the cap on.

Make your solder connections at the wire/electrode junctions nice, smooth, and solid; then

apply a water-proof coating, e.g. the epoxy you use for joining the pipes to the screw cap. This epoxy must be waterproof and be capable of holding metal to plastic under pressure. You will want to get your chamber level sensor verified before you epoxy the cap on.

CONTROL CIRCUIT

The diagrams show a simple circuit to control and drive this mini-system. You are going to make a 'square-pulse' signal that 'plays' the electrodes like a tuning fork; which you can watch on an oscilloscope. The premise given by the literature is: the faster you want do go down the road, the 'fatter' you make the pulses going into the reaction chamber. Duty cycle will vary with the throttle in the vicinity of 90%MARK 10%SPACE (OFF/ON).

There is nothing sacred about how the pulse waveform is generated; there are many ways to generate pulses, and the attached diagrams show a few. The diagram shows the NE555-circuit approach from the referenced patent. The output switching transistor must be rated for 1-5 amps @ 12VDC (in saturation).

Go with a plan that works for you or your friendly neighborhood technoid or mechanic, and go get all the circuit elements from your local electronics store, such as Radio-Shack or Circuits-R-Us, including the circuit board, IC sockets, and enclosure/box.

DigiKey has better selection, service, and knowledge; plus they have no minimum order. Be sure to use a circuit board with a built-in ground plane, and to accommodate room for mounting 2 or 3 of the gauges. Mounting the reaction chamber in the engine compartment will require running a stub to your pressure gauge where you can watch it.

You can easily make 30-gauge wire-wrap connections between the socket pins and thru-hole discrete components having wire leads. Also make sure to get spec sheets on any IC you use. More details of the best circuits to use will be announced pending prototype testing. You will want to get your chamber level sensor verified before you epoxy the cap on.

Throttle Control

If you have a throttle position sensor, you should be able to access the signal from the sensor itself OR from the computer connector. This signal is input to the circuit as the primary control (i.e. throttle level = pulse width = vapor rate).

If you don't have such a signal available, you will have to rig a rotary POT (variable resistor) to the gas linkage (i.e. coupled to something at the gas pedal or throttle cable running to the carb or FI. If you make the attachment at the carb/FI, be sure to use a POT that can handle the engine temp cycles. Don't use a cheezy-cheapy POT; get one

rated for long life and mechanical wear; mount it securely to something sturdy and stationary that will not fall apart when you step on the gas.

Control Range. The full throttle RANGE (idle-max) MUST control the vapor rate, i.e. pulse-width (duty). The resistor values at the throttle signal must allow the throttle signal voltage, say 1-4 Volt swing, to drive the VAPOR RATE. You will be using this voltage swing to generate a 10% ON 'square' pulse. The patent implies using a 'resonant' pulse in the 10-250 KHz frequency range; but it is not explicitly stated so.

In this circuit, you will simply tune to whatever frequency makes the most efficient vapor conversion. You will have to get into the specs for each IC you use, to insure you connect the right pins to the right wires, to control the frequency and pulse width. You can use spare sockets to try out different discrete component values. Just keep the ones that are spec-compatible in the circuit, and get the job done.

You crank up the throttle signal and put more electrical energy (fatter pulses) into the electrodes; verify you can get 10% duty on the scope (2 - 100 usec on the horizontal time-base). Your averaging DVM will display the 90%-10% DC voltage across the output transistor (Vce or Vds or Output to Ground). Set and connect DVM in the supply current and measure .5 - 5 amps, without blowing the DVM fuse. Now verify that you got everything you wanted.

Verify your wiring connections using your DVM as a continuity detector. Check your wiring 1 at a time and yellow line your final schematic as you go. You can best use board-mount miniature POTs for anything you want to set-and-forget. The LEDs are there to give you a quick visual check of normal vs abnormal operation of your new creation. You will want to get your chamber level sensor verified before you epoxy the cap on.

CARB/FI CONNECTION

The diagram also shows that fittings are required to the carb/FI l. There are ready-made kits (such as by Impco) available for making your pressure fittings to the carburetor or fuel-injector as the case may be. You will necessarily be sealing the built-in vents and making a 1-way air-intake.

The copper mesh comprises the inadvertent backfire' protection for the reaction chamber. Make sure that all vapor/duct junctions are air-tight and holding full pressure without leakage. Your new 'system' is considered successful and properly adjusted when you get the full power range at lower temp and minimum vapor flow without blowing the pressure safety valve.

CHT (or EGT)

Monitor your engine temp with the CHT (cylinder head temp) or EGT (exhaust gas temp) instead of your original engine temp indicator (if any). Your existing gauge is too slow for this application and will not warn you against overheating until after you have burnt something. Make sure that your engine runs no hotter than in the gasoline arrangement. VDO makes a CHT gauge with a platinum sensor that fits under your spark plug against the cylinder head (make sure it is really clean before you re-install your spark plug (as this is also an electrical ground).

ENGINE/EXHAUST TREATMENT

Get the valves replaced with stainless steel ones and get the pistons/cylinders ceramic-treated ASAP when you have successfully converted and run your new creation. Do not delay as these items will rust, either by sheer use or by neglect (i.e. letting it sit). You could make max use of your current exhaust system by using it with your new deal until it rusts through, then have your mechanic or welder friend to fit a stainless steel exhaust pipe (no catalytic converter is required). But it could be easier and cheaper to send your existing exhaust system out for the ceramic treatment, and then simply re-attach it to the exhaust ports.

GENERAL

1. Do not discard or remove any of the old gasoline setup components, e.g. tank, carb/FI, catalytic converter, unless necessary. Better to always leave an easy way to revert back to something that at least runs, just in case. Some people are leaving their gasoline setup completely intact, and switching back and forth at will, just to have a backup plan.

2. Set your throttle circuit so that you get minimum vapor flow at idle, and maximum vapor flow at full power without blowing the pressure relief valve. In this way, you control how 'lean' your mixture is by the strength of the pulse (i.e. “fatness” at the optimum pulse frequency).

3. If you just don't get enough power (at any throttle setting), it means that you need to (1) change the pulse frequency, (2) change the gap between the electrodes, (3) change the size (bigger) electrodes, or (4) make a higher output pulse voltage (last resort). Always use an output transistor, such as a MOSFET, that is rated for the voltage and current you need to get the job done. OK so you might have to play around with it some. Isn't that where all the Fun is anyhow?

4. If you get any engine knock our loud combustions (not compensated by adjusting the timing), it means that you need to install an additional coil in the chamber, and drive the coil with an additional pulse signal (about 19 Hz on the .1sec time base (see diagram). Here,

you will be slowing down the burn rate just enough so that the vapors burn thru out the power stroke of the piston. Be sure to include a board-mount POT to set the correct strength of this 2nd pulse signal into the coil. This is a stainless steel coil of about 1500 turns (thin wire) that you can arrange like a donut around the center pipe (but NOT touching either electrode), directly over the circular 1-5mm gap. You want no knocking at any power/throttle setting; smooth power only, but also no excess hydrogen leftover from the combustion.

5. Build the canister(s) as tall as you can without compromising your ability to mount them conveniently near the dash panel, or in the engine compartment, as the case may be. This way, you can always make the electrodes bigger, if necessary without undue hardship. Remember that anything in the engine compartment should be mounted in a bullet-proof, vibration and temperature tolerant fashion.

6. If you have to drill a thru-hole for wiring or plumbing thru metal, make sure to also install a grommet for protection against chafing. Always watch your chamber pressure range from IDLE (15-25 psi) - FULL POWER (30-60 psi). Set your safety-pressure relief-valve to 75 psi and make sure it's rated for much higher.

7. Shut OFF the power switch and pull over if there is any malfunction of the system. Your engine will last longest when it still develops FULL POWER+ at some minimum temperature that we are sure you can find, by leaning back the Royal Vapor Flow and/or by making use of the water-vapor cooling technique (see diagram). Keep good mpg performance records, and periodic maintenance/inspection. Keep it clean; save some money; clean the air; heal the planet; happy motoring; tell a friend; enjoy your freedom and self-empowerment.

8. There lacks documented material for perfecting this vapor system thru a fuel injector; there may be some details you will discover on your own as working prototypes progress. For example, you may be restricted to inject the hydrogen/oxygen vapor without any water vapor, as it may rust the injectors. If engine temp and CHT is a problem, then you will want to re-think your plan, e.g. ceramic-coating the injectors. There is always "replacing the FI system with a Carb."

9. If you install the water-vapor system (for lower operating temp/stress), you will want to lean the mixture (vapor/air) for minimum vapor flow rate to achieve any given throttle position (idle - max). Make sure that you get a minimum flow for IDLE and a modestly sufficient flow for MAX, that does the cooling job without killing the combustion.

10. If you cannot find stainless steel pipe combinations that yield the 1-5mm gap, you can always regress back to alternating plates of +/- electrodes.

11. If you are concerned about the water freezing in your system, you can (a) add some

98% isopropyl alcohol and re-adjust the pulse frequency accordingly; or (b) install some electric heating coils.

12. Do not let ANYONE ever compromise your dream, your freedom, your independence or your truth.

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CONVERT YOUR ENGINE TO BURN HYDROGEN AND OXYGEN VAPOR FROM WATER..... ON DEMAND + POLLUTION-FREE

FIGURE 1

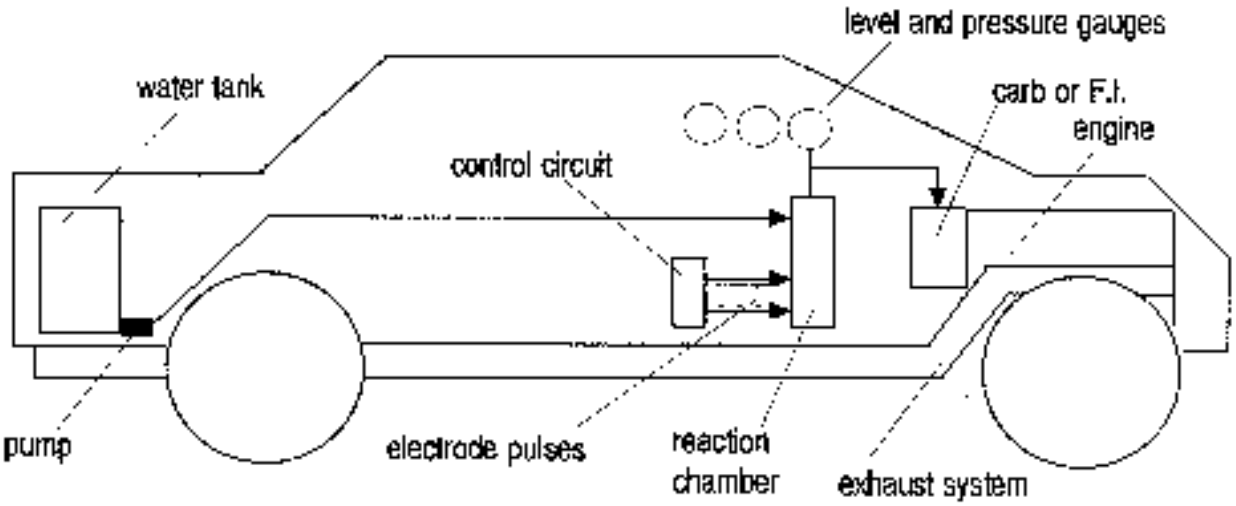

BUILD YOUR OWN WATER VAPOR SYSTEM
CONTROLLER FROM THE-SHELF MATERIALS

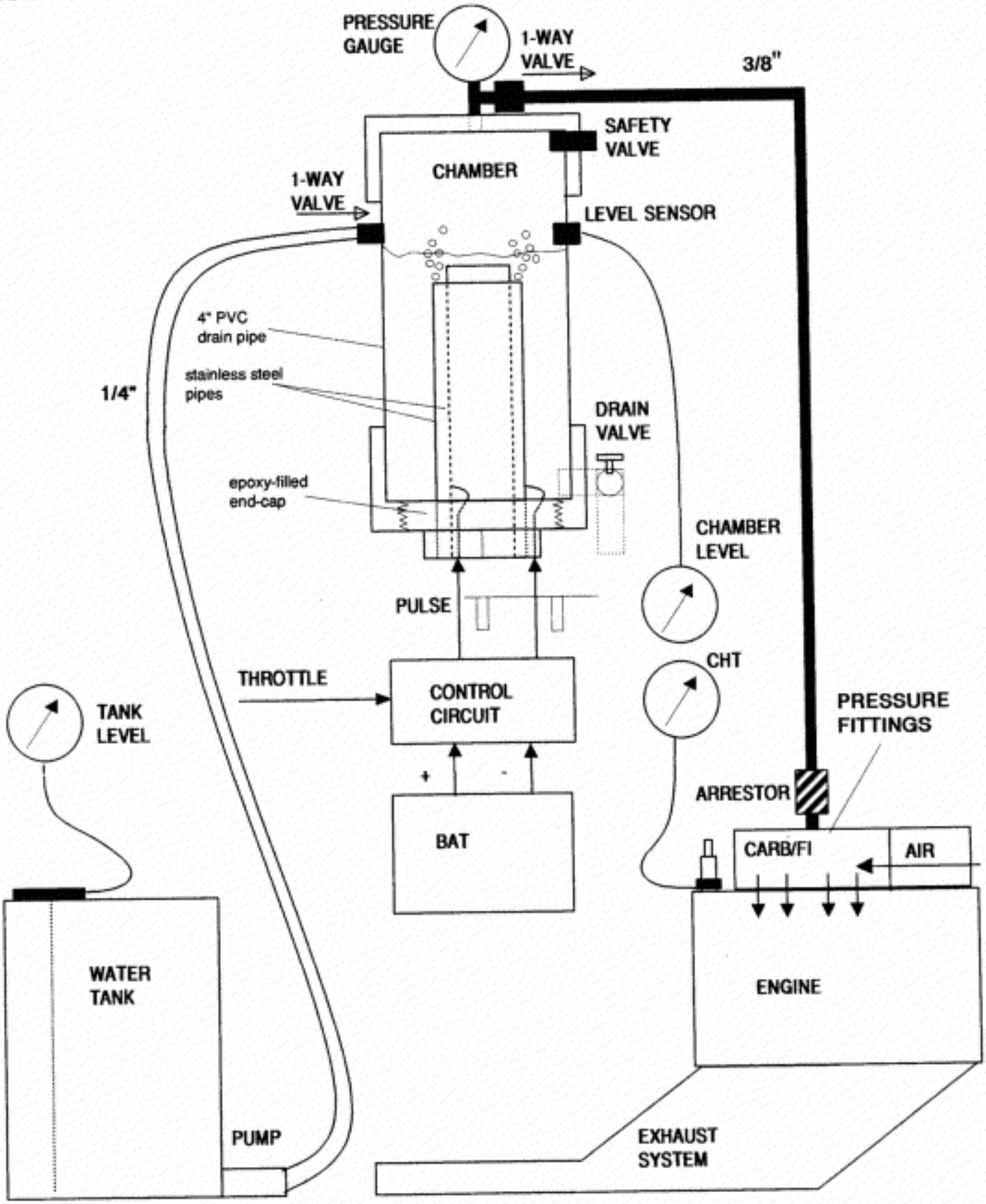

FIGURE 2 BLOC DIAGRAM

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS

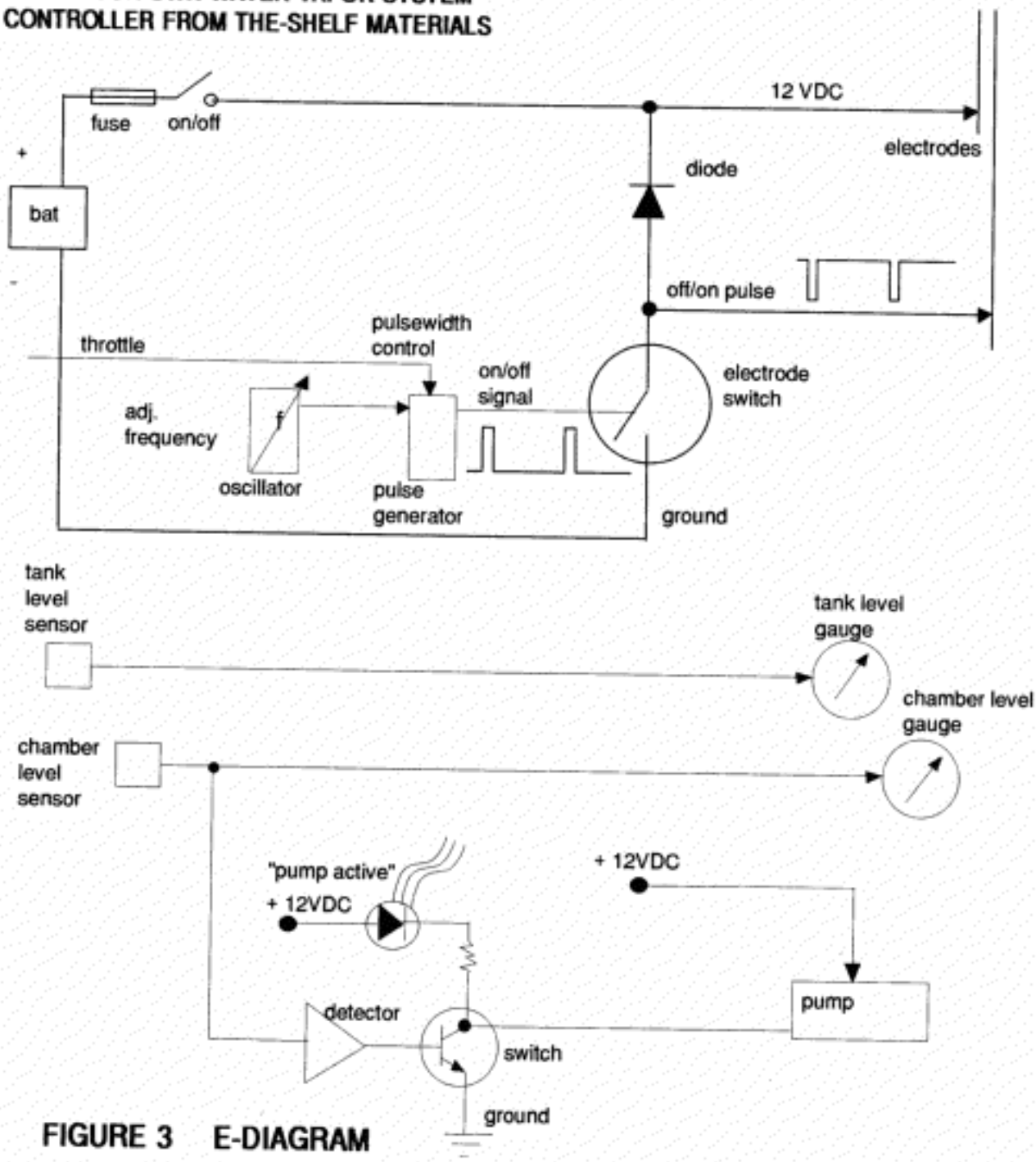

FIGURE 3 E-DIAGRAM

BUILD YOUR OWN WATER VAPOR SYSTEM CONTROLLER FROM THE-SHELF MATERIALS **REV. A**

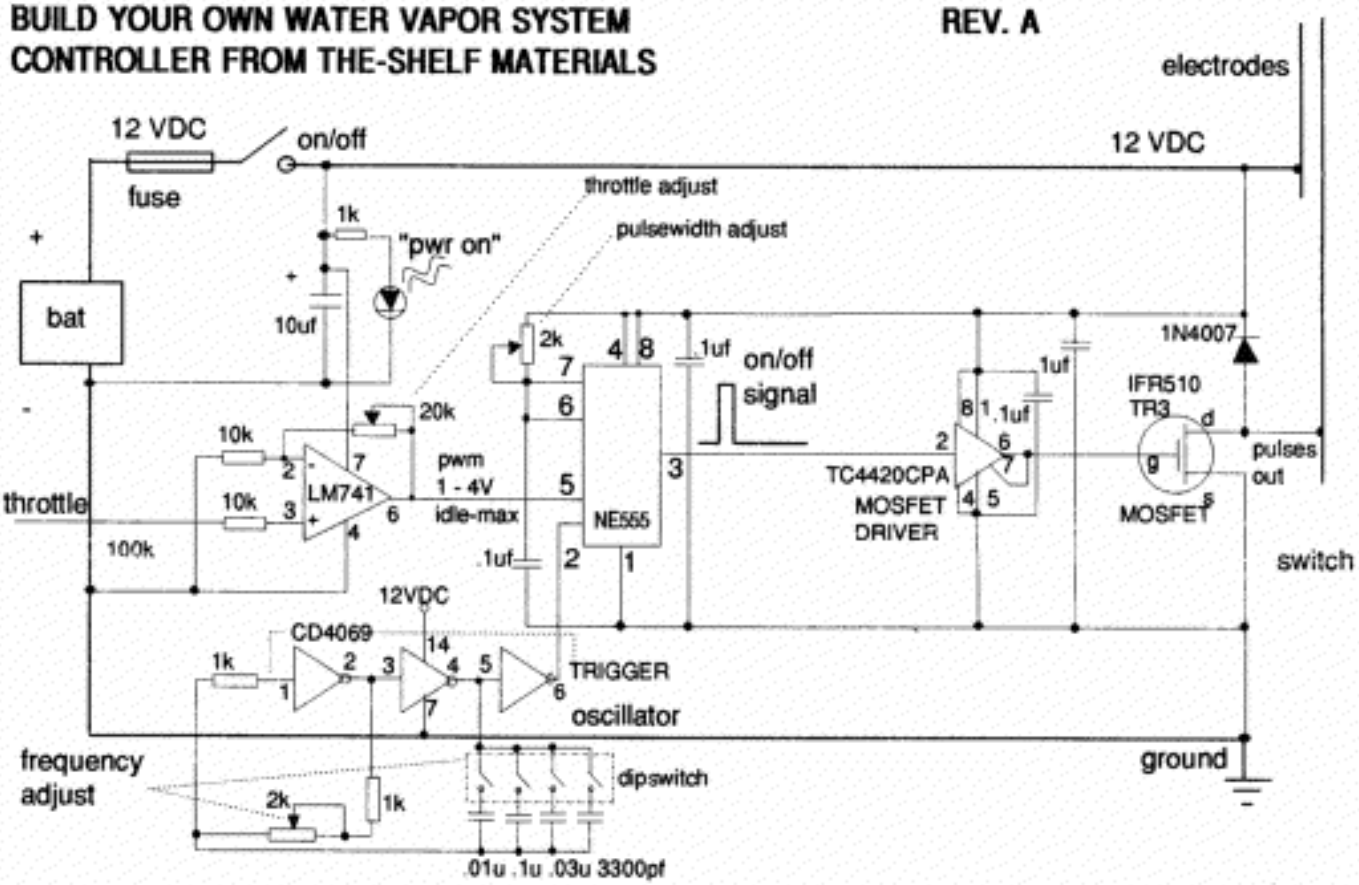

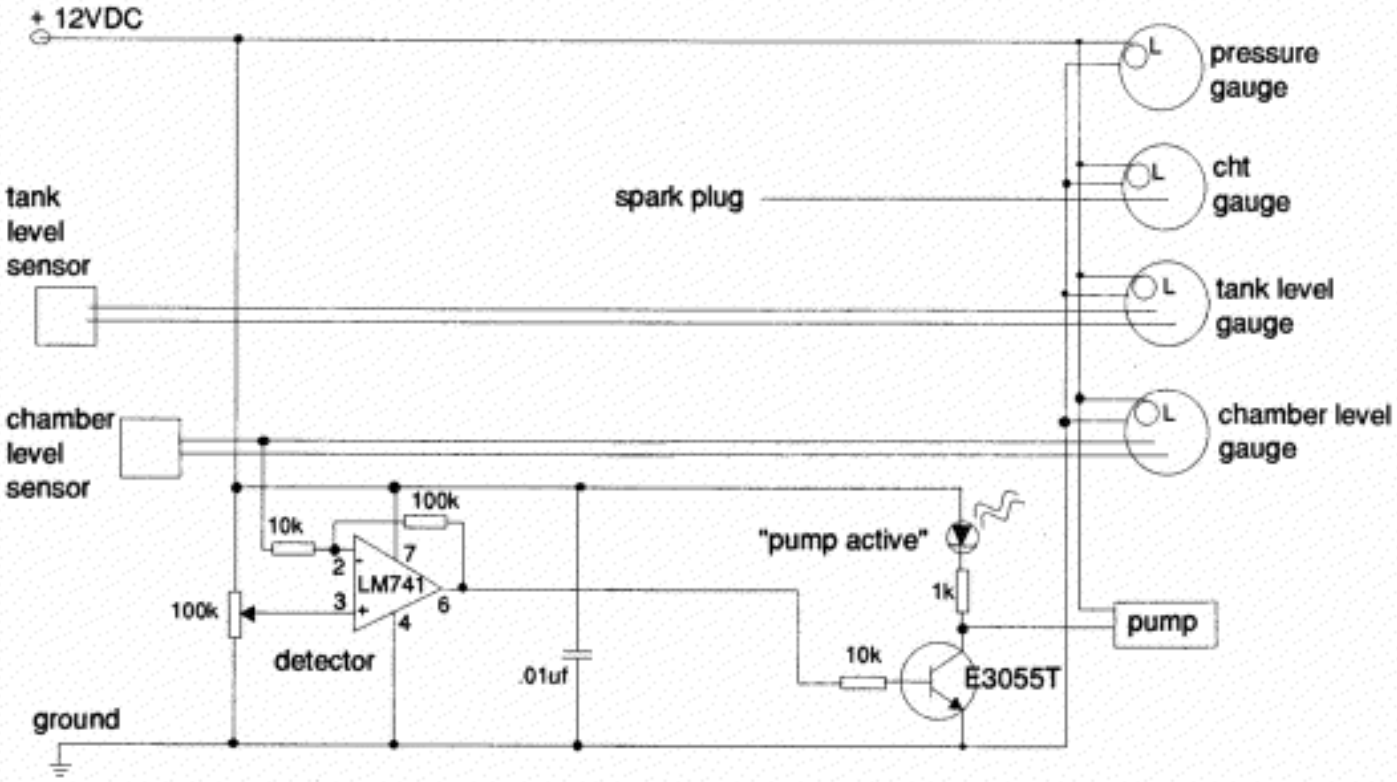

FIGURE 4 E-SCHEMATIC

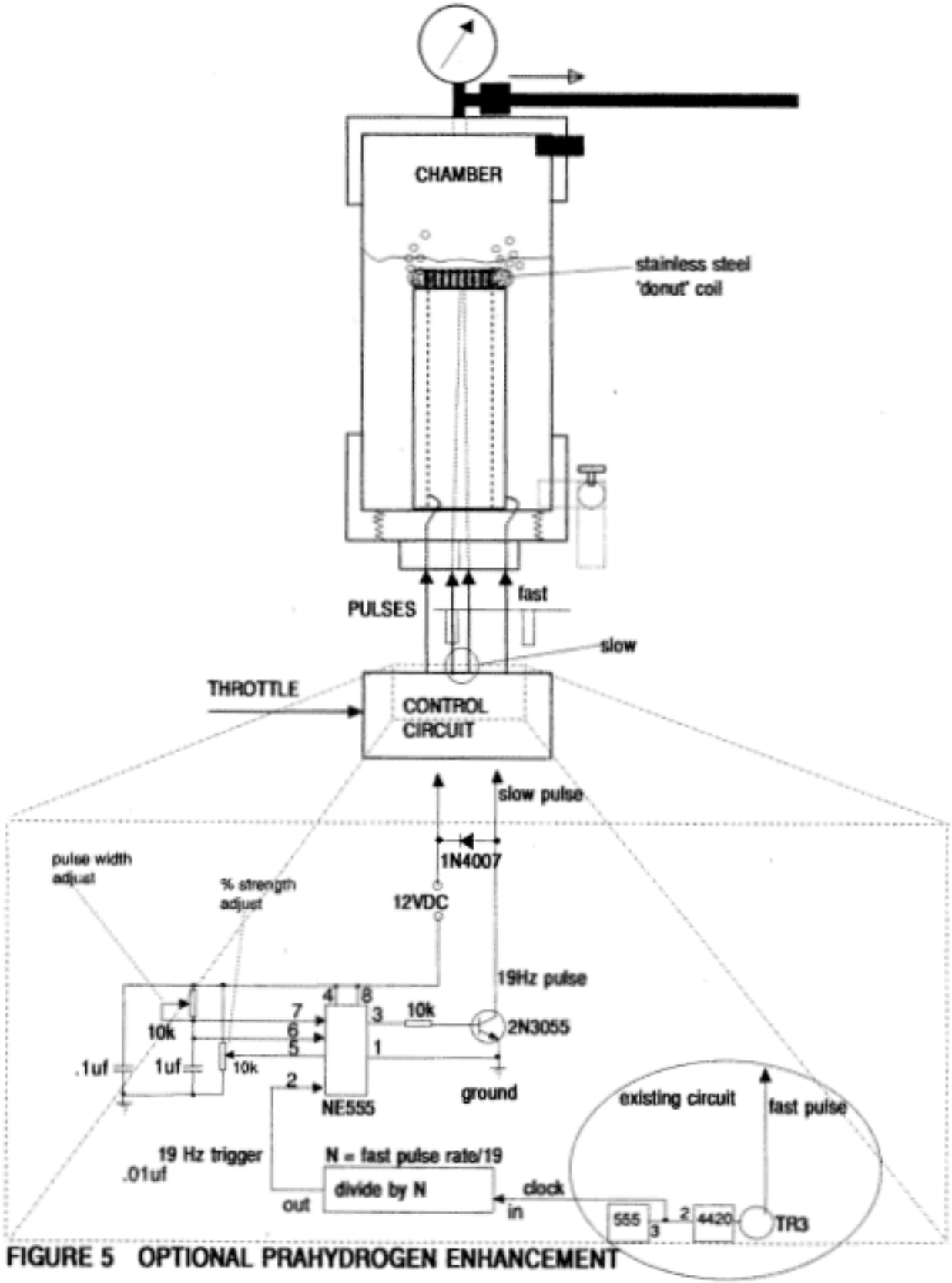

FIGURE 5 OPTIONAL PRAHYDROGEN ENHANCEMENT

BUILD YOUR OWN WATER VAPOR SYSTEM
CONTROLLER FROM THE-SHELF MATERIALS

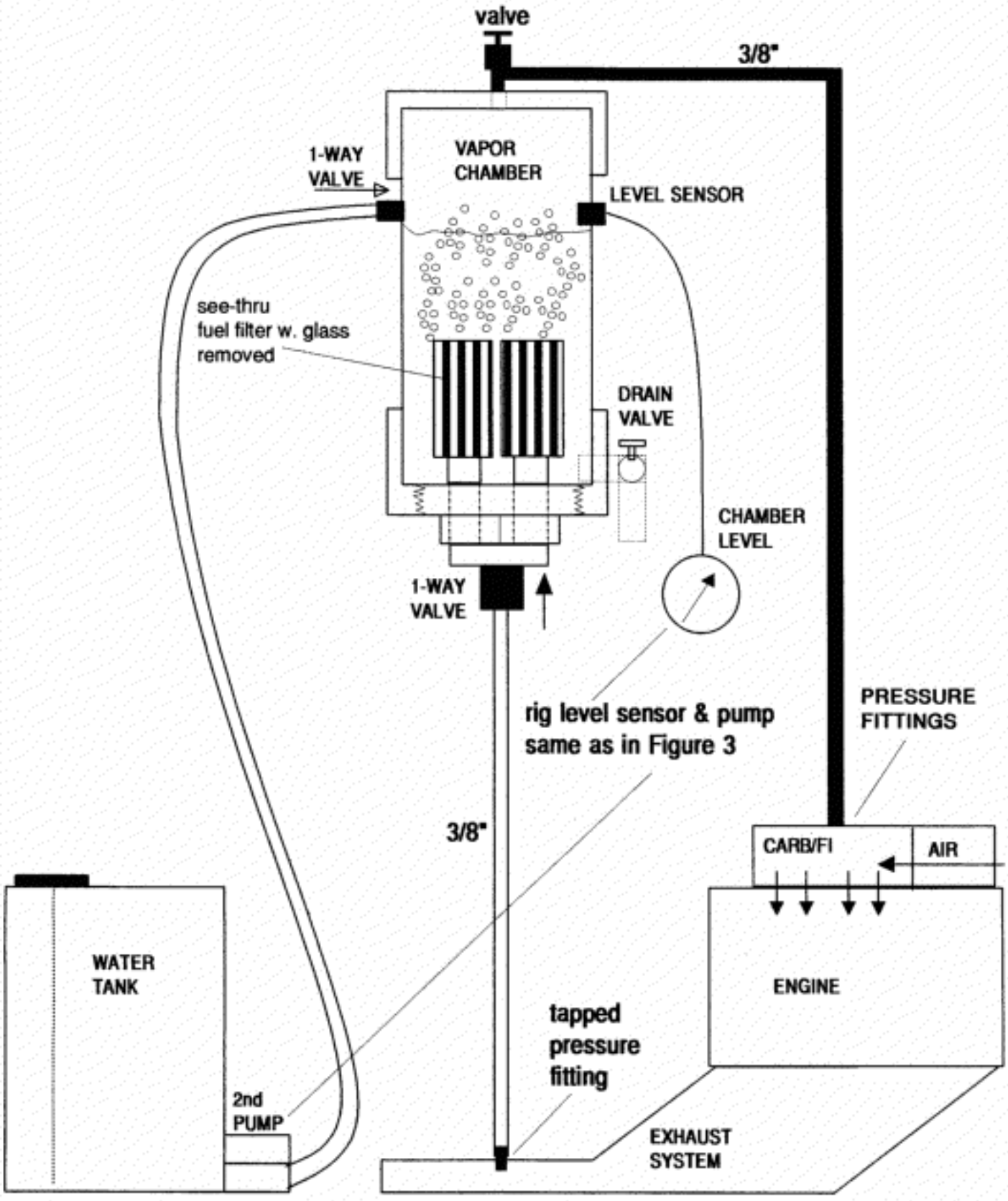

FIGURE 6 OPTIONAL WATER COOLING

An idle telephone line tempts designers to use its 48V potential as a power source. However, Part 68 of the US Federal Communications Commission's telecommunications regulations states that any device that connects to the phone line and is not actively communicating must present a resistance of at least 5 MΩ (**Reference 1**). To meet this requirement, a device's continuous-current drain must not exceed 10 µA. Fortunately, many devices that connect to the phone line do not require continuous power and can remain off for long intervals, awakening only for a short time before relapsing into power-off mode. Providing power for these applications from the phone line presents obvious advantages by eliminating the need for a battery or another power source and the cost of battery maintenance.

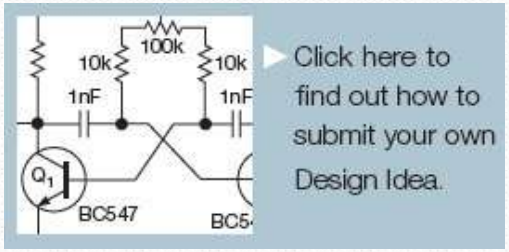

The circuit in **Figure 1** charges a 1.5F supercapacitor, C_1, from the phone line through a diode bridge and a 5.6-MΩ resistor. A **Maxim MAX917** nanopower comparator, IC_1, consumes only 0.75 µA from its power supply. Resistors R_2 and R_3 halve the voltage across C_1 and apply it to IC_1's positive input voltage at Pin 3 for comparison with its built-in 1.245V reference. For voltages across C_1 that do not exceed 2.49V, IC_1's output at Pin 6 remains low. When C_1's voltage reaches 2.5V, Pin 3's voltage exceeds the reference voltage, and IC_1's output goes high, turning on Q_1 and Q_2.

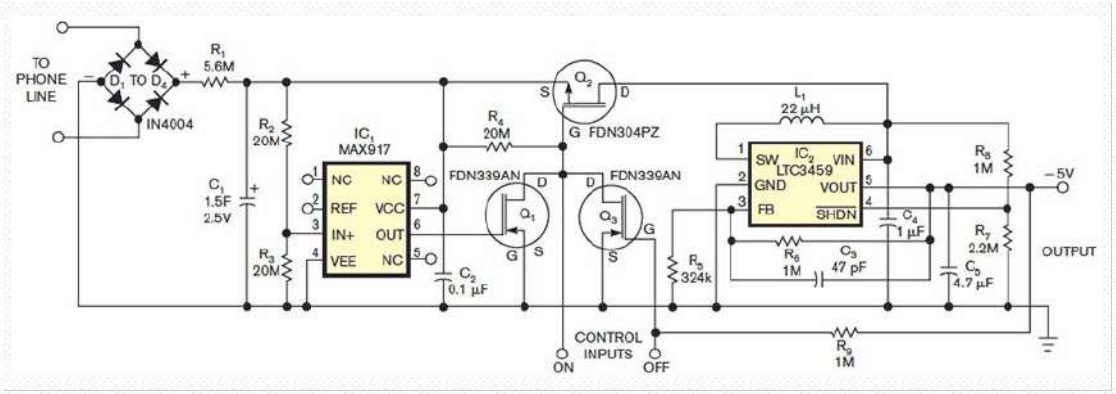

Figure 1 This power-conversion circuit delivers intermittent bursts of regulated voltage from a supercapacitor charged by a trickle of current from a telephone line.

Several days must elapse before C_1 becomes fully charged, given its huge capacitance and a charging current of less than 10 µA. The voltage on C_1 can never exceed 2.5V because, once it reaches 2.49V, Q_1 and Q_2 turn on, connecting C_1 to a switched-mode-power-supply circuit. Because the power-supply current exceeds the charging current, the voltage across C_1 starts to decrease when Q_2 turns on. Transistor Q_3 holds Q_2 on when C_1's decreasing voltage causes Q_1 to turn off.

The switched-mode-power-supply circuit comprises a **Linear Technology LTC3459** micropower boost converter, IC_2, and its associated components, which deliver 5V at 10 mA. A fully charged C_1 can supply power to a 10-mA load for approximately 40 sec. With no load, the circuit can sustain its 5V output for more than 10 hours. For greater output current and shorter operating time, select another boost converter that can operate at a low input voltage.

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Mechanical switches, open-drain MOSFETs, open-collector transistors, or a microcontroller's open-drain output pins can drive two external control inputs to force the circuit on and off. Pulling the On input low forces Q_2 to turn on and deliver power from C_1 to the power converter, and pulling the Off input low turns off Q_2 and removes power from the converter. Note that the power converter's output-return line connects to the telephone line and thus should not connect to an earth ground or to grounded equipment.

Reference

1. "**Part 68**," Federal Communications Commission.

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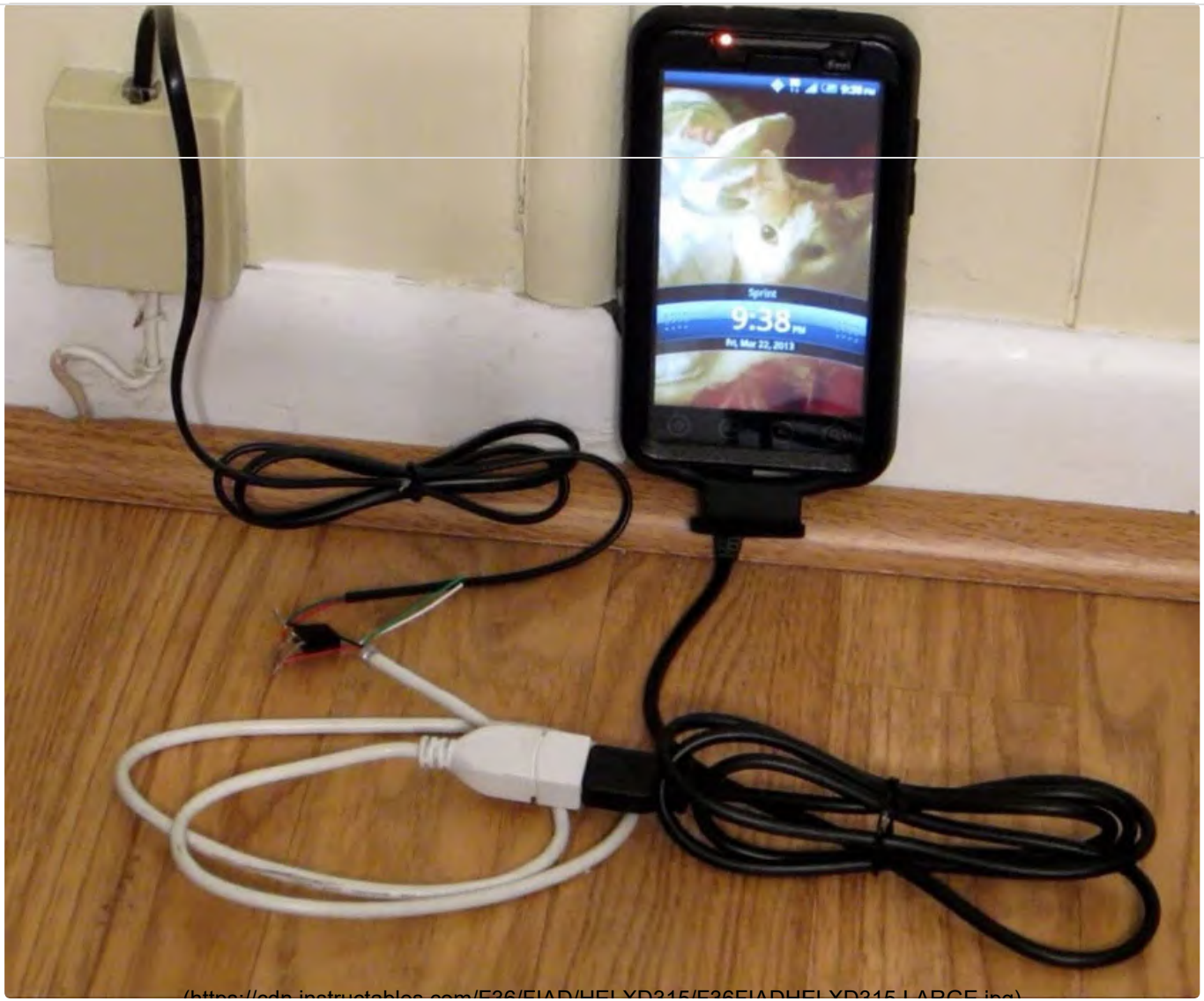

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not in use, this is a constant DC signal (about 50-60 volts). When the phone rings, the signal is a 20 hertz AC signal (about 90 volts). When in use it is a modulated DC signal (between 6 and 12 volts).

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The phones lines even have power during a blackout in most cases. This is because the phone company maintains their own backup power system. Your phone lines may be powered even if you don't have a land line service set up.

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Step 2: Check the Phone Line With a Multimeter

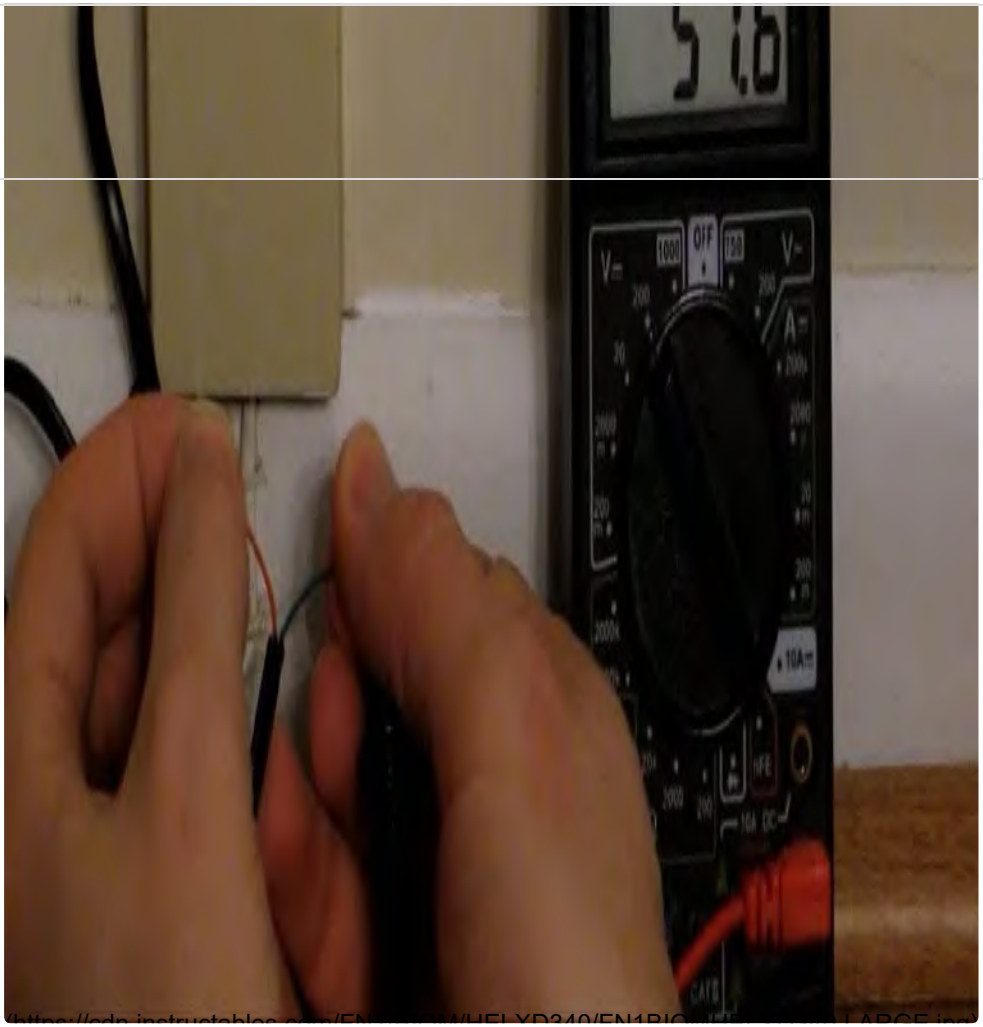

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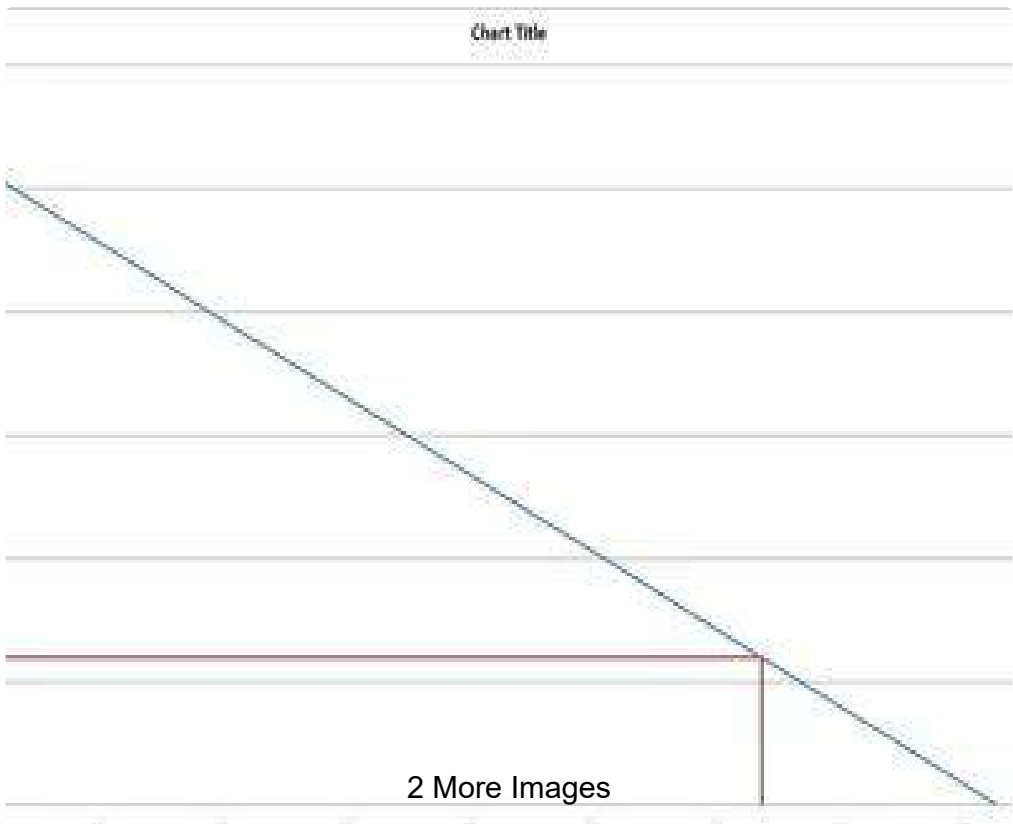

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Before you try to tap into the electricity in the phone line, you should check it with a multimeter to see what you are working with.

Start by cutting open a phone cord and separating the internal wires. In most cases you will have one red wire and one green wire. Strip the insulation off the ends. Then plug the cord into a phone jack and use a multimeter to measure the output voltage. At my house, I measured an open-circuit (no load) voltage (http://en.wikipedia.org/wiki/Open-circuit_voltage) of 52 volts DC.

Then I hooked up various resistors to see what the output would be with different loads. I determined that the supply voltage isn't regulated. This means that the voltage changes depending on the resistance of the circuit that it is powering. After some calculating, I worked out that the base signal coming out of my phone jack pretty closely resembles a 52 Volt DC source (http://en.wikipedia.org/wiki/Voltage_source) with a 628 ohm internal resistance (http://en.wikipedia.org/wiki/Internal_resistance).

Basically this means that I can run a 12V circuit at 64mA, a 9V circuit at 68mA, or a 5V circuit at 75mA. This isn't a lot. But it is enough to charge a cell phone.

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Step 3: Construct a Simple Voltage Regulator Circuit

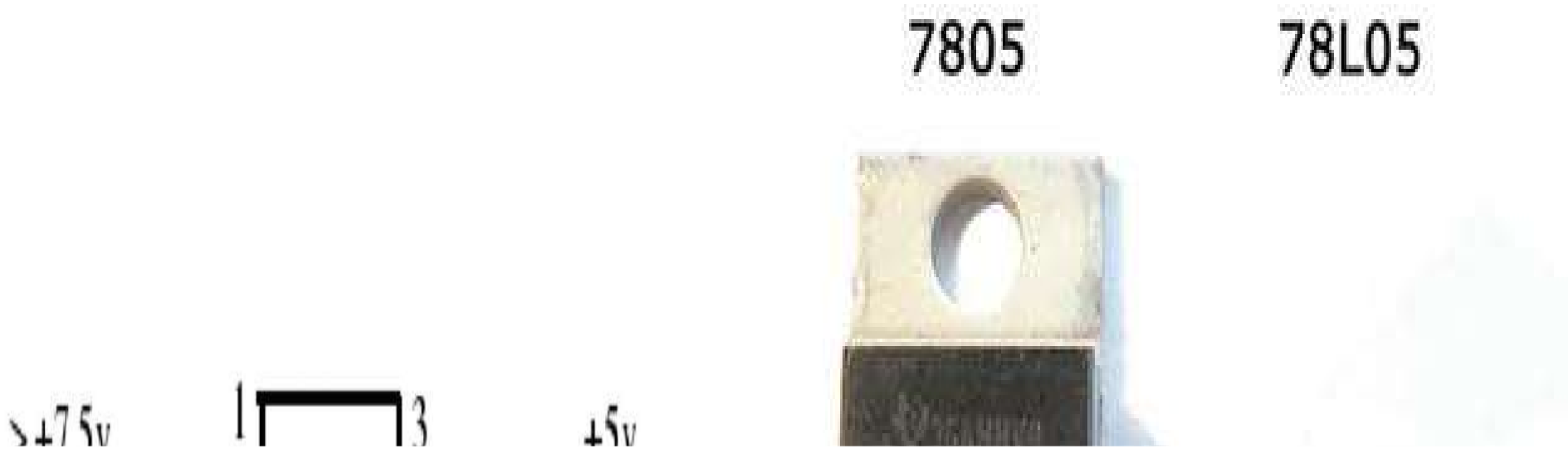

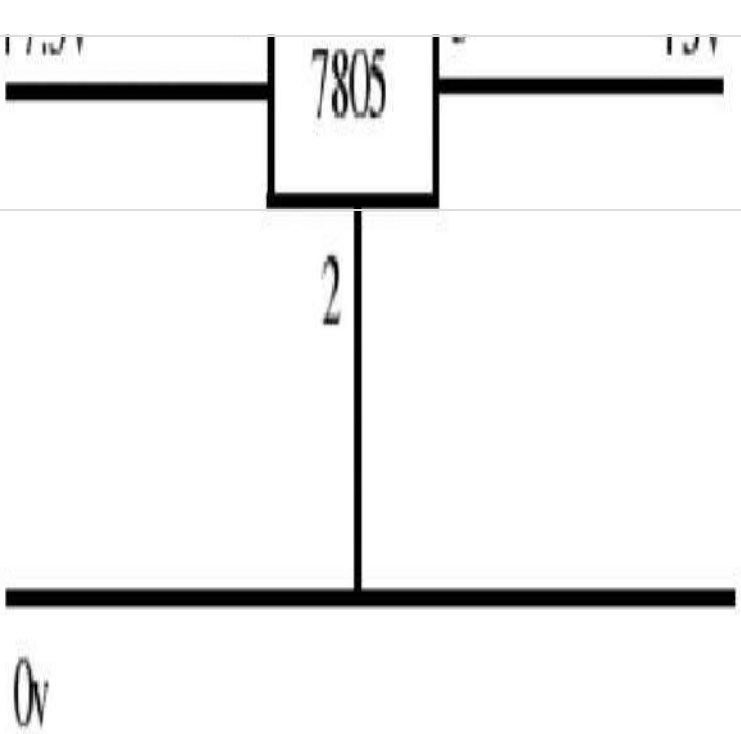

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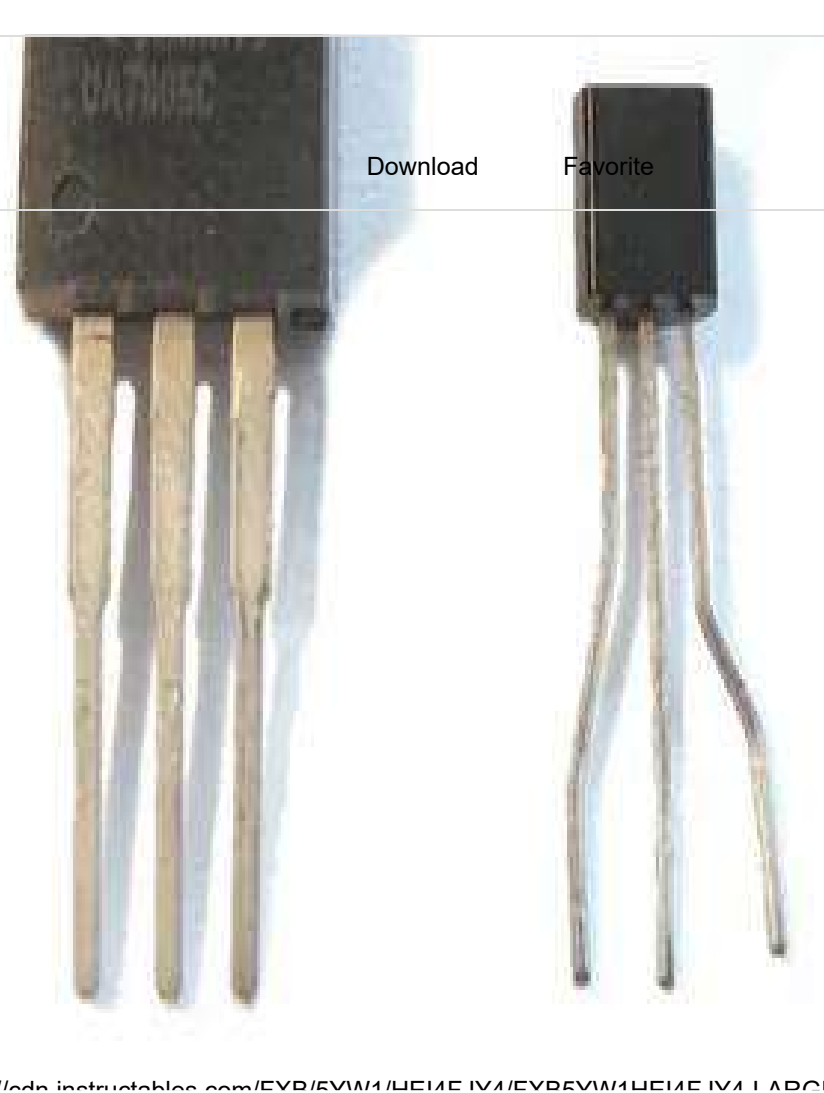

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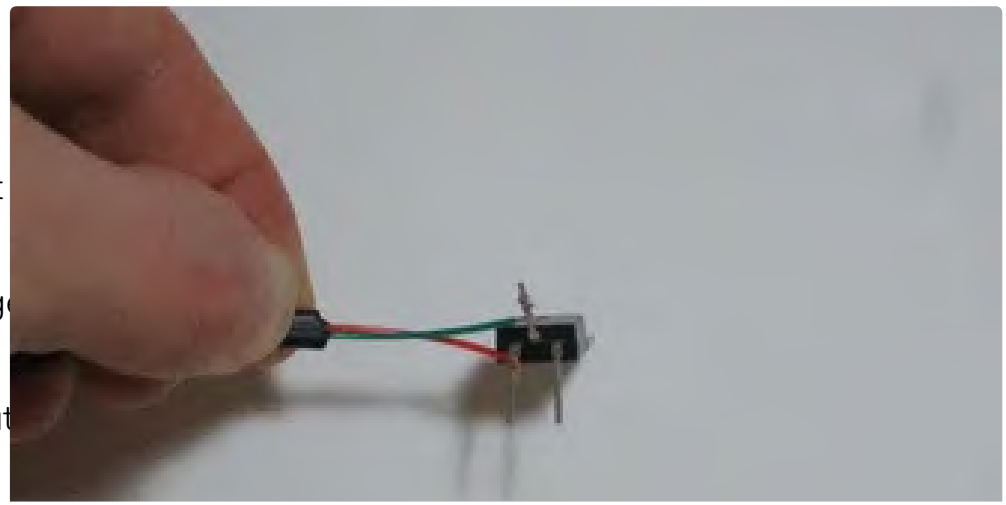

We know that the phone needs 5 volts in order to charge. But much current it draws or it's equivalent load resistance (http://en.wikipedia.org/wiki/Electrical_load). So we can't charg from the phone line. We need to use a voltage regulator (http://en.wikipedia.org/wiki/Voltage_regulator) to bring the out

down to 5 volts and keep it there. A LM7805 5 volt regulator s

To make this simple phone line adapter you will need the phon
been working with, the 5V voltage regulator and a USB connector cable with a female end. Just connect the red wire from the phone line to the first lead on the regulator and connect the green wire from the phone line to the second lead. Then connect the black wire from the USB cable to the second lead on the regulator and connect the red wire from the USB cable to the third lead on the regulator. If you can't solder the wires together (because the power is out), you can just wrap the wires around each lead. If you do this, you should bend the leads of the regulator away from each other. This will help you avoid accidentally crossing the wires.

This simple regulator circuit is able to safely convert the base phone signal into something that can be used to charge your phone. However, many voltage regulators are not able to handle the AC signal that they would receive if the phone rang. So if you are worried that you might receive a call while your regulator is hooked up to the phone line , then you may wish to add a diode between the red wire from the phone line and the first pin on the voltage regulator. This will protect your circuit from problems that may be caused by reverse polarity.

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Step 4: Use Other Regulators for Other Output Voltages

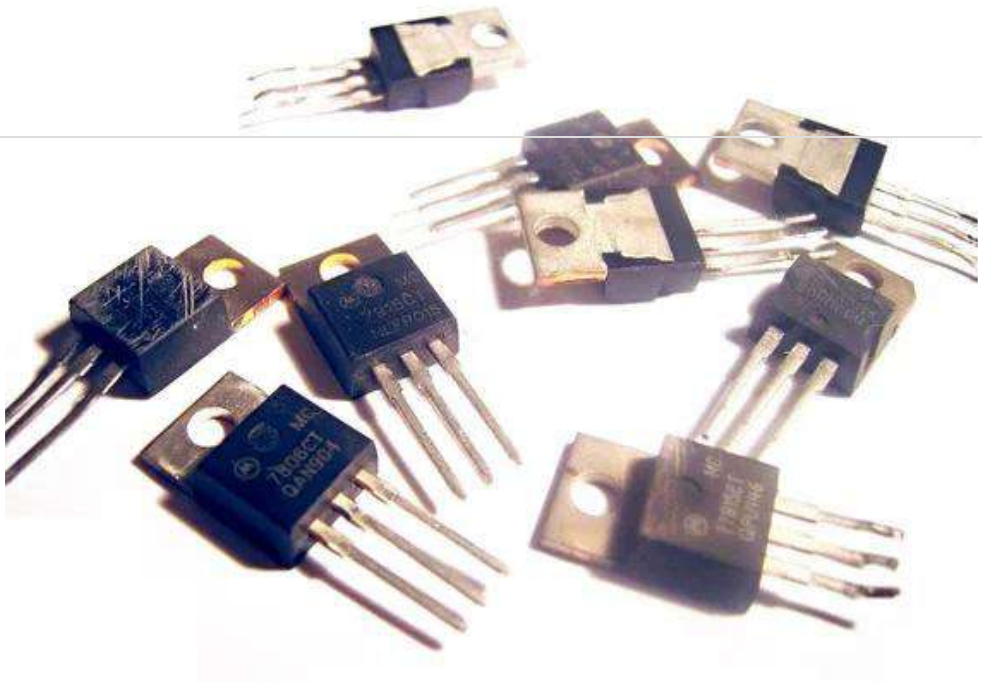

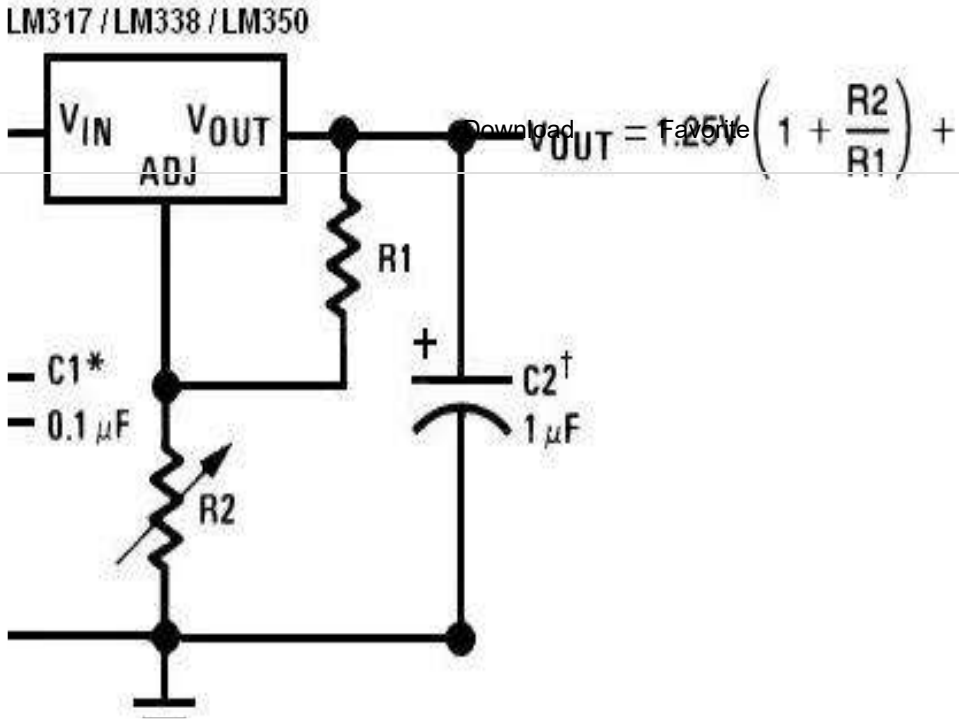

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A 7805 regulator will work if you need an output of 5 volts but other kinds of voltage of voltage regulators are also available. Other voltages in the 78xx series include 6V, 8V, 9V, 10V, 12V, 15V, 18V, and 24V. In addition to these fixed value regulators, there are also variable regulators that let you set the voltage level with the use of a few external components. One such variable voltage regulator is the LM317 (http://www.ti.com/lit/ds/symlink/lm117.pdf). These are what you would use if you needed a different output voltage.

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Step 5: Finished Phone Line Adapter Tool

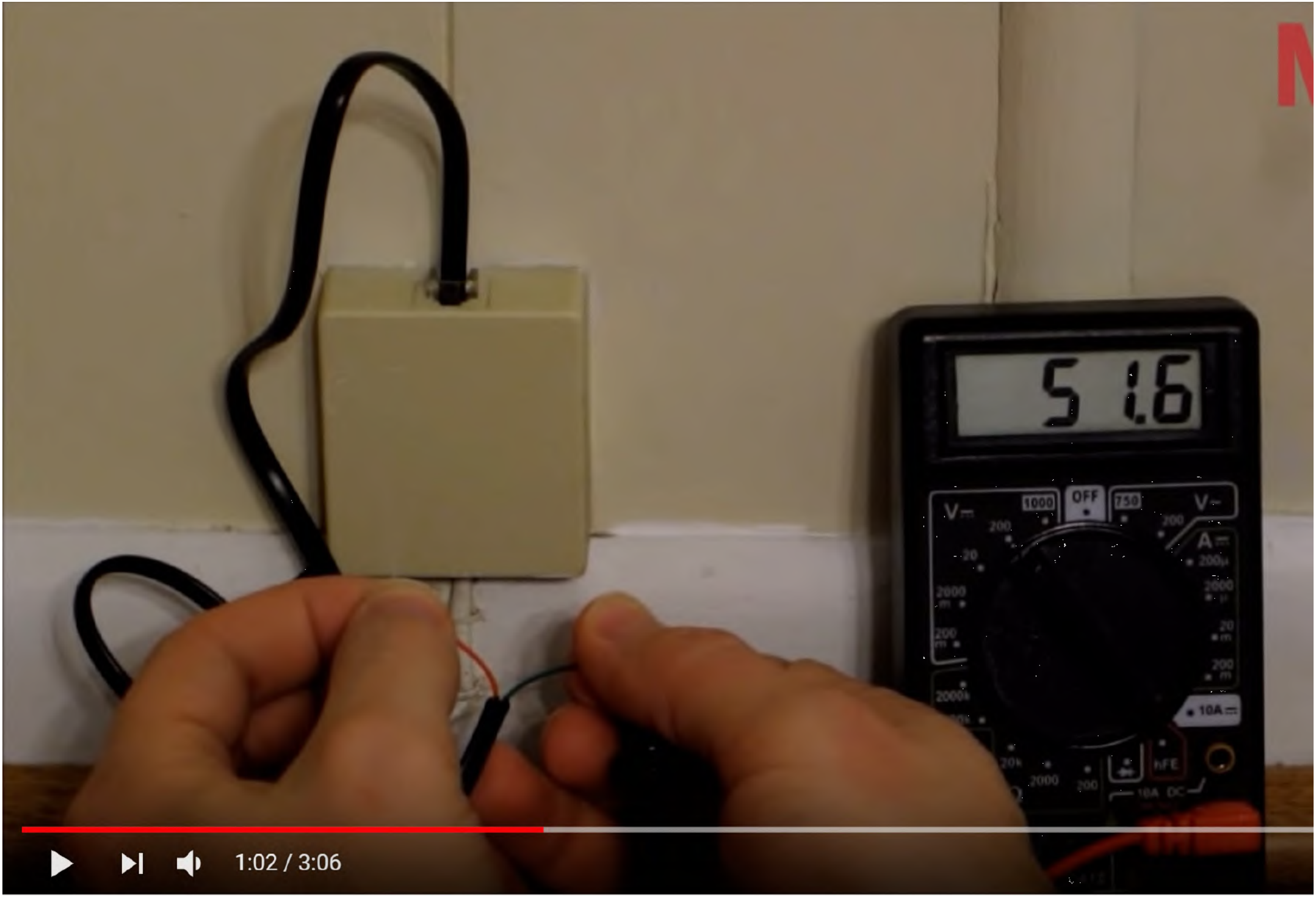
5 1.6
OFF
1000
750
10A
1:02 / 3:06

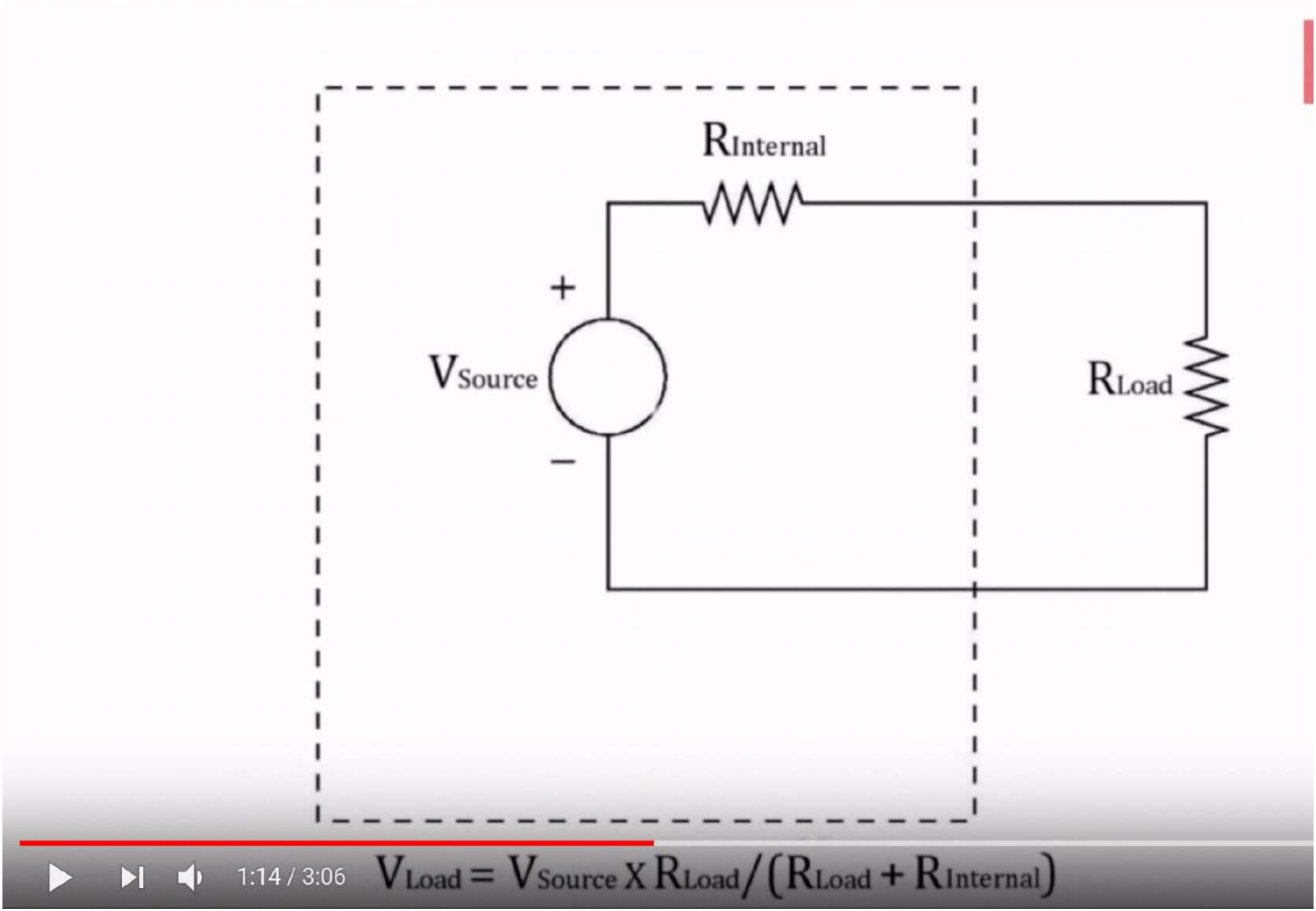
RInternal
+
VSource
−
RLoad
1:14 / 3:06
VLoad = VSource X RLoad/(RLoad + RInternal)

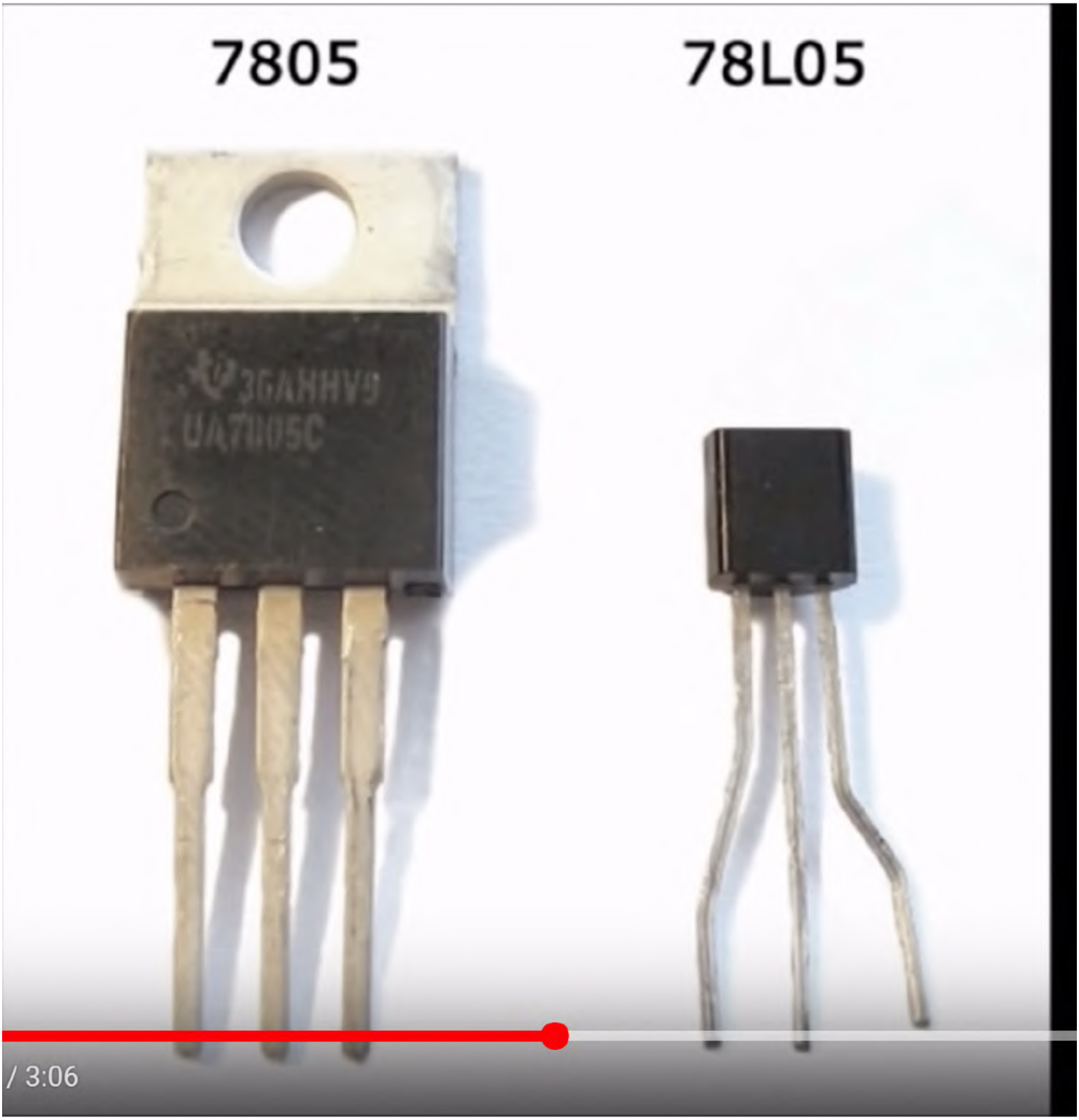
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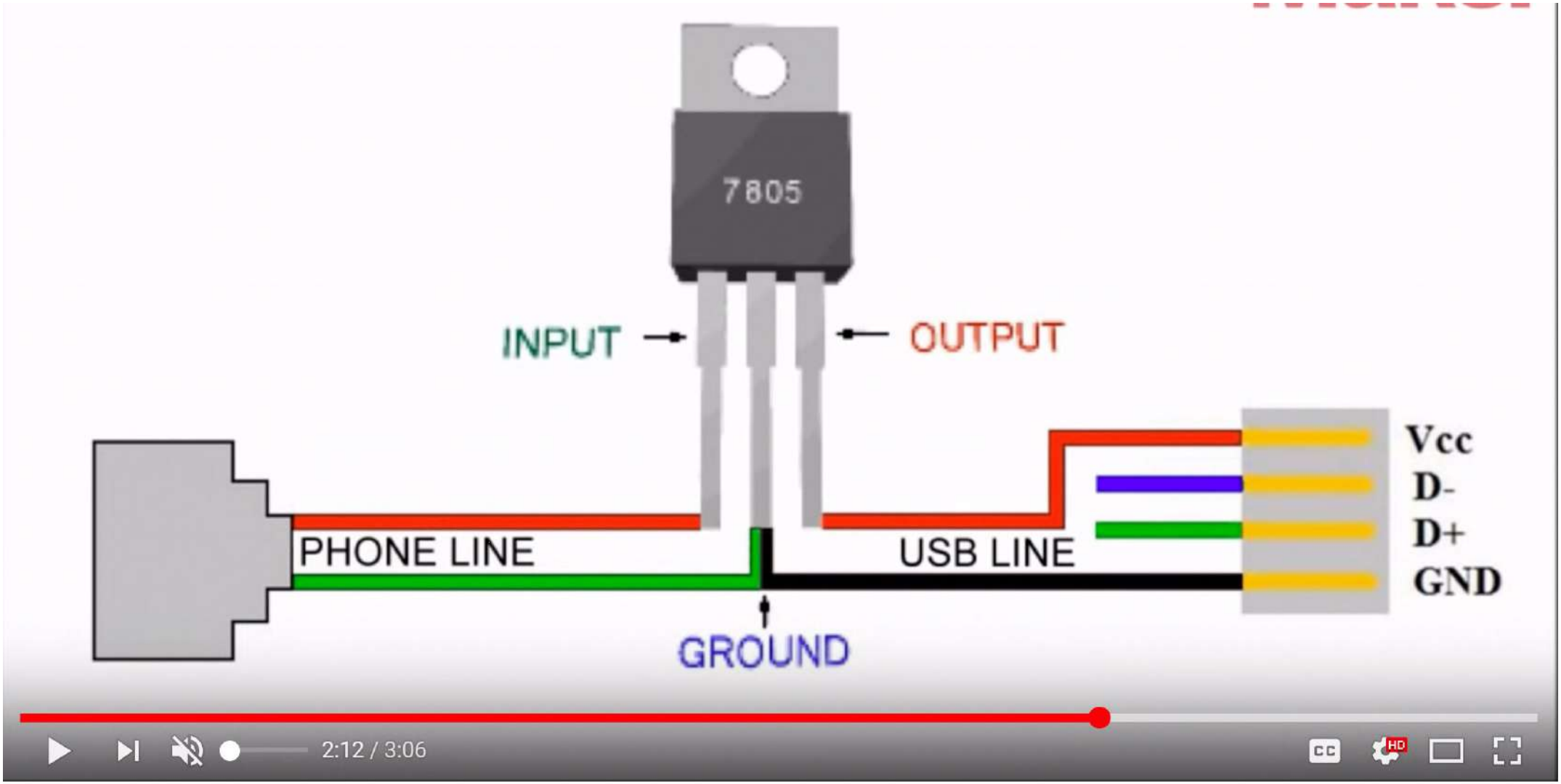
7805
INPUT
OUTPUT
PHONE LINE
USB LINE
GROUND
Vcc
D-
D+
GND
2:12 / 3:06

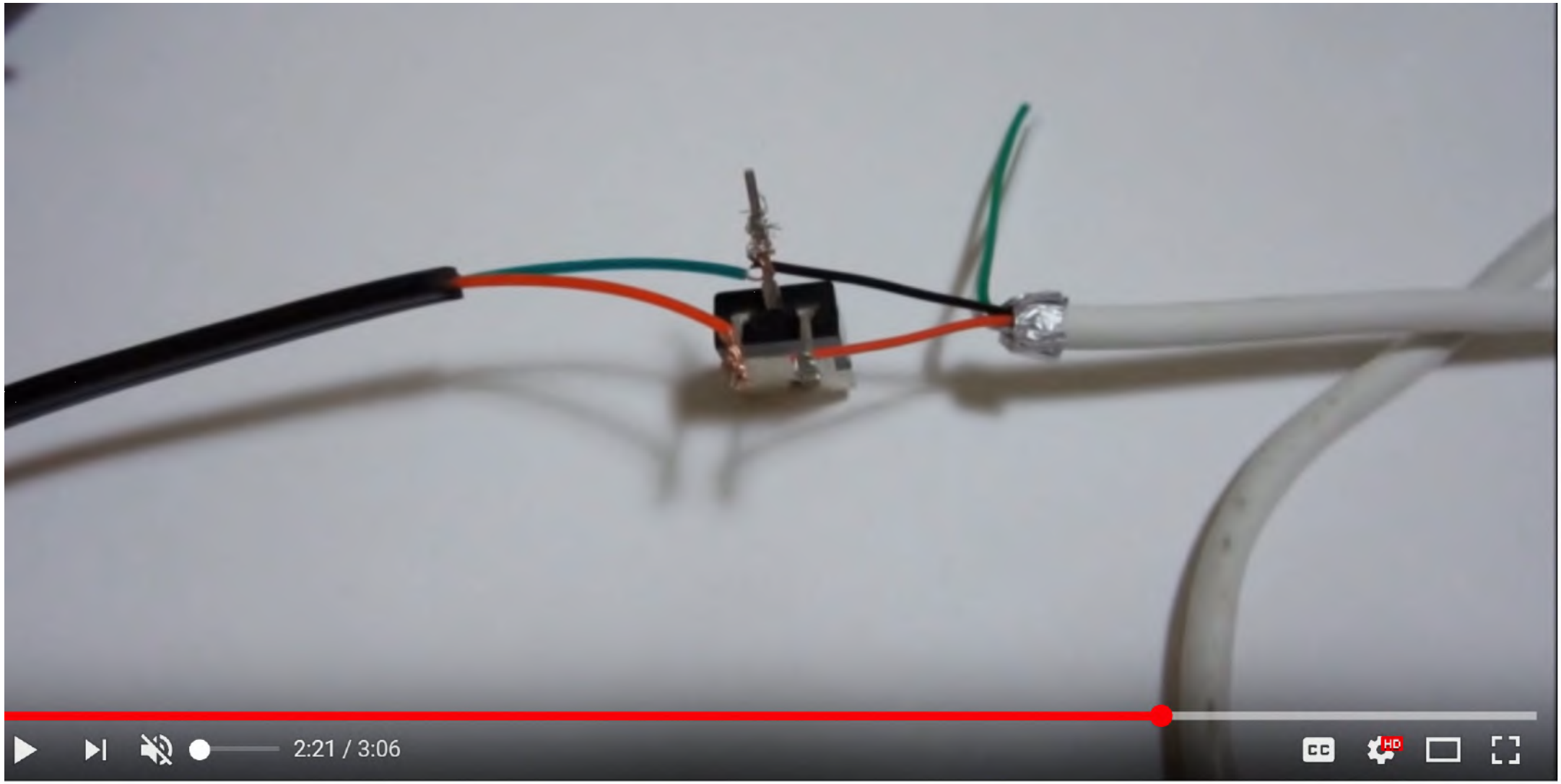
2:21 / 3:06

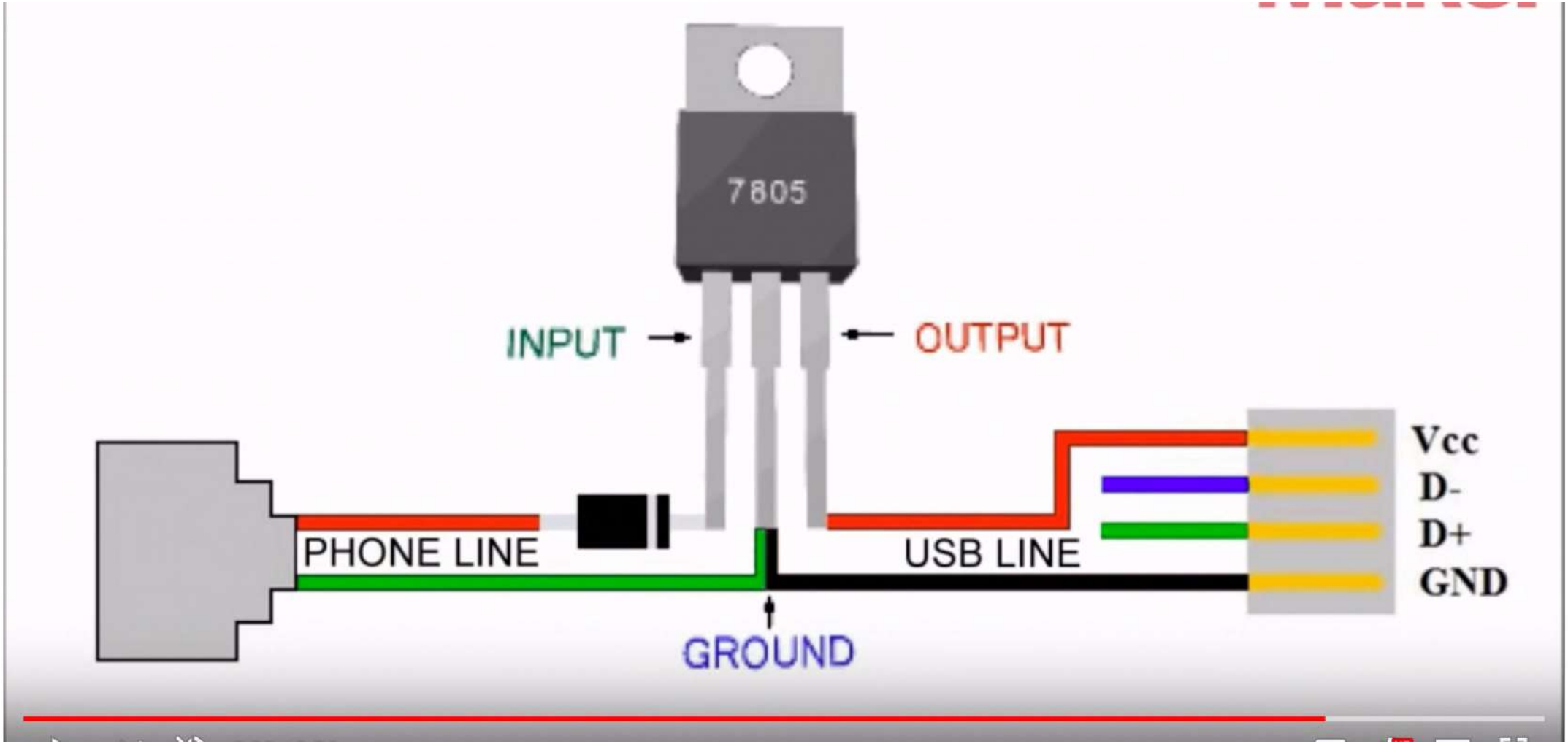
7805
INPUT
OUTPUT
PHONE LINE
USB LINE
GROUND
Vcc
D-
D+
GND

MC
78T05CT
QZA807
2:33 / 3:06

BUILDING A DIY VIDEO TRANSMITTER

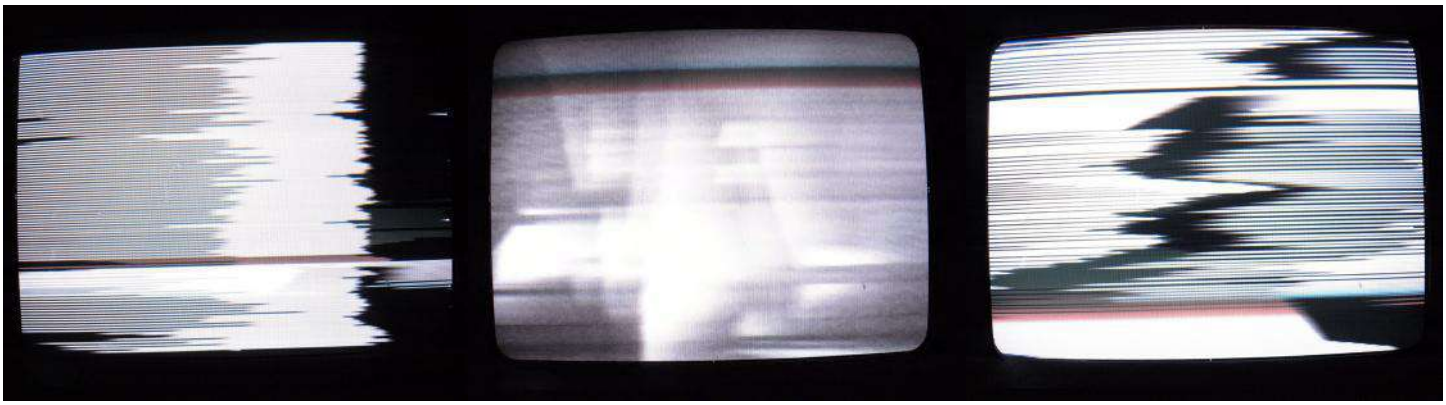

WHAT YOU NEED

- Blank PCB Copper Plate (jameco.com part #169279)
- Capacitors: 2x 0.1uf
  1x 100u
  2x 6-70pf Variable Caps (jameco.com part #32855)
- Resistors: 27kOhm
  10kOh
- Transistor-MPSA18 (jameco.com part #210681)
- 1k potentiometer
- Small amount (~4") of magnet wire 24 AWG or close (jameco.com part #2098419)
- Sand paper
- Stranded hookup wire
- Hacksaw or dremel tool

-Headphones with 1/8" plug (from iPod or MP3 player)

- Hot glue or super glue
- Soldering Iron
- CRT "tube" TV with an antenna (the transmitter won't transmit to newer flat screen TV's)

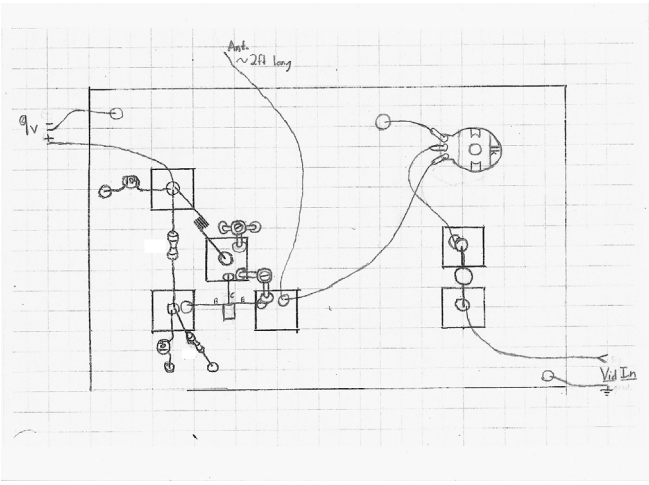

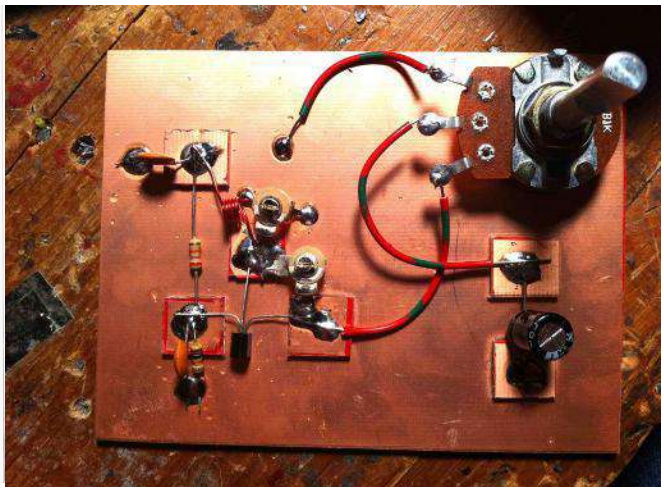

INTRODUCTION

This micro video transmitter was designed by the DIY radio and micro TV artist Tetsuo Kogawa. His website (http://anarchy.translocal.jp/) is full of great info on DIY radio, and all credit for this circuit goes to him.The transmitter can be used to transmit a relatively clear video signal or abstract visualizations, depending on the desired output. It will usually function at a distance of about 20 feet. If you have any previous experience with electronics or circuit building, you will notice that this method of building is different. The circuit is constructed on top of a copper "ground plate" which is common in radio applications. This tutorial uses step-by-step sketches and photos created based on Tetsuo Kogawa's design.

BUILDING THE TRANSMITTER

1. PREPARING THE COPPER PLATE

- Take the bare copper plate and cut off 1inch of material using a dremel tool or hacksaw.
- Use this material to cut out 6 square ½ in. x ½ in. pieces.
- Arrange the 6 pieces on the larger copper plate as shown in the image below…

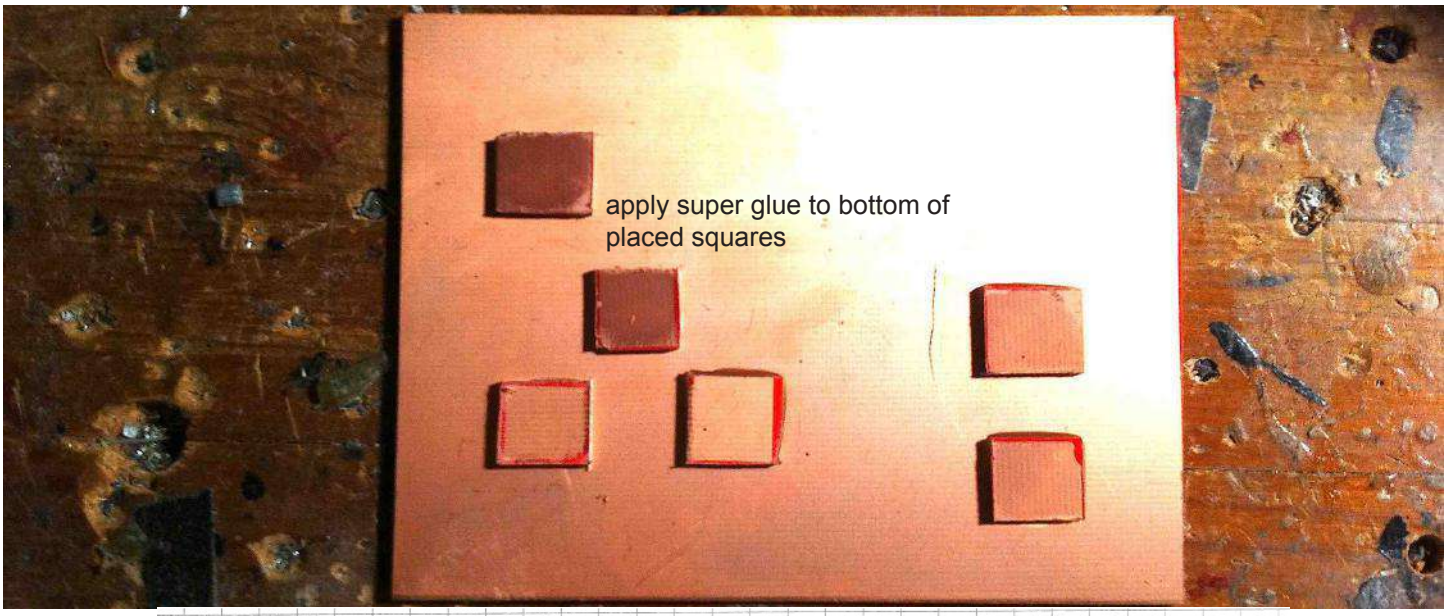

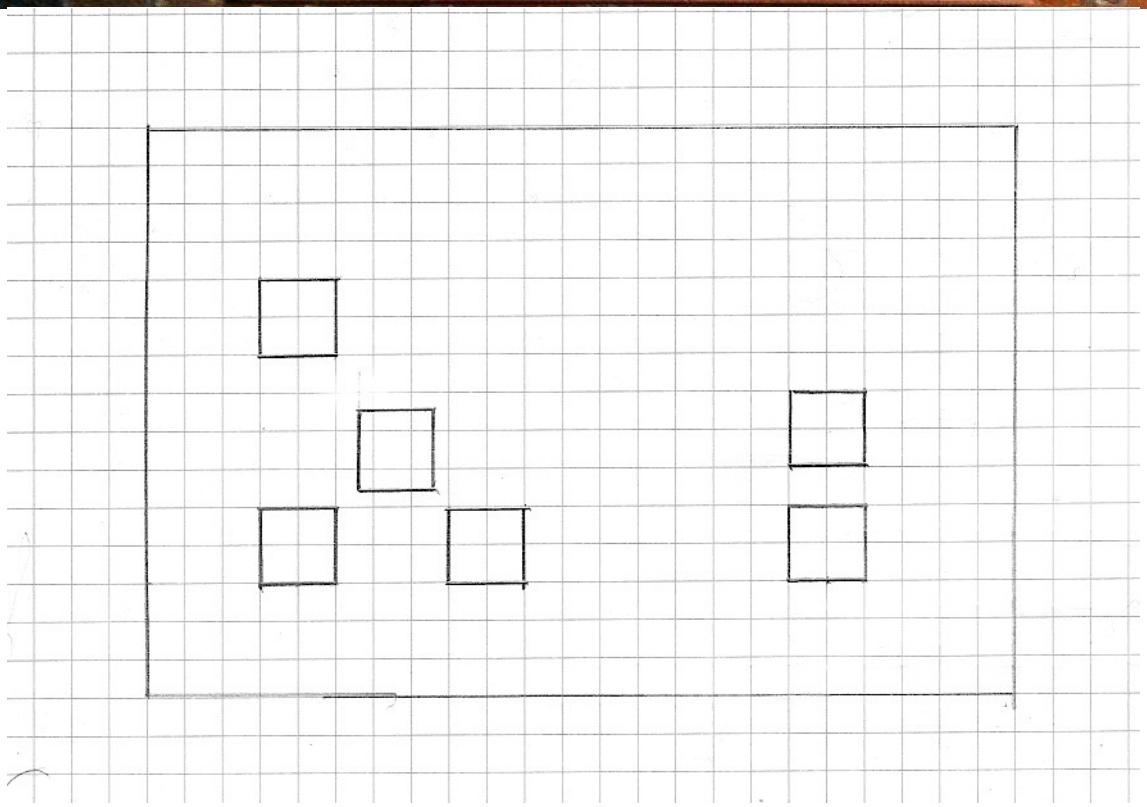

****NOTE**** Be sure to arrange them so that all the component leads will be able to reach the squares. Look ahead to see what components will go where so you know exactly how to space them.

- Once you have them arranged, put a dab of hot or super glue on the bottom of each square and stick them in place on the copper plate.

2. ADDING THE 100uF CAPACITOR (the cylinder with “100uF” written on the side)

- Melt a blob of solder onto the two squares furthest to the right. To do this, apply your iron to each square to transfer heat for an extended period of time until the solder flows onto the surface.

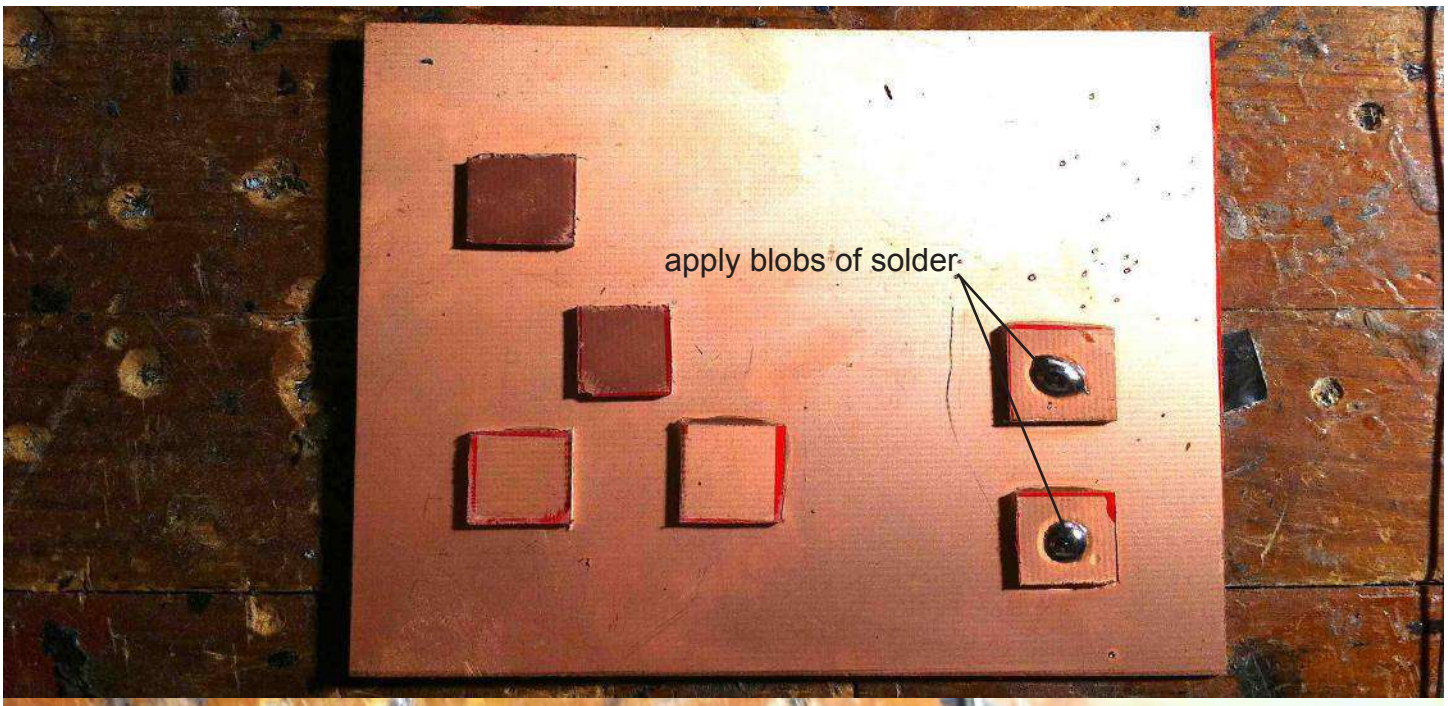

- Bend the legs out of the 100uf capacitor and straddle them between the two squares making sure that the leads are only touching the two small squares (not touching the ground plate).
- Cut the excess off of the leads.
- One at a time, re-heat the solder blobs and place the capacitor leads into them, allowing them to cool down until they stay in place.

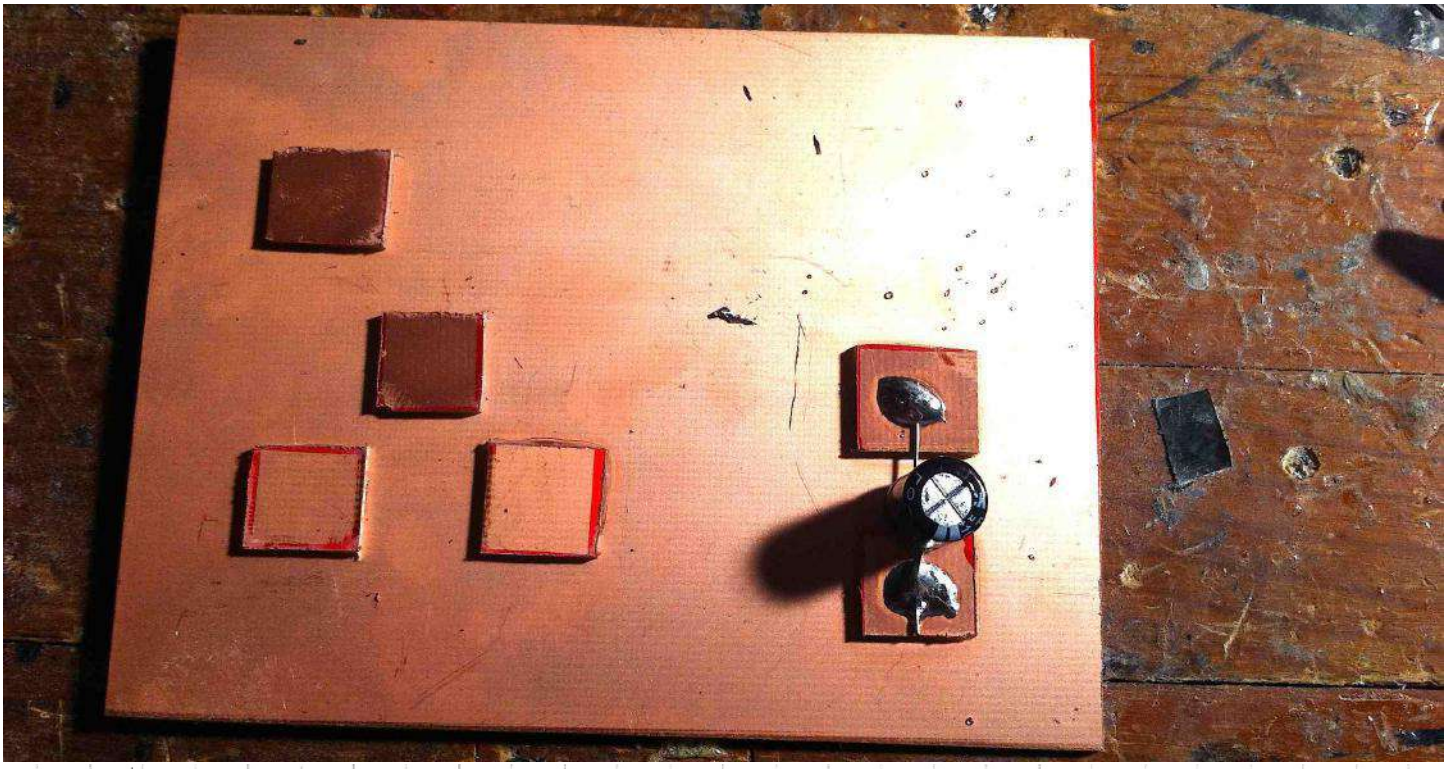

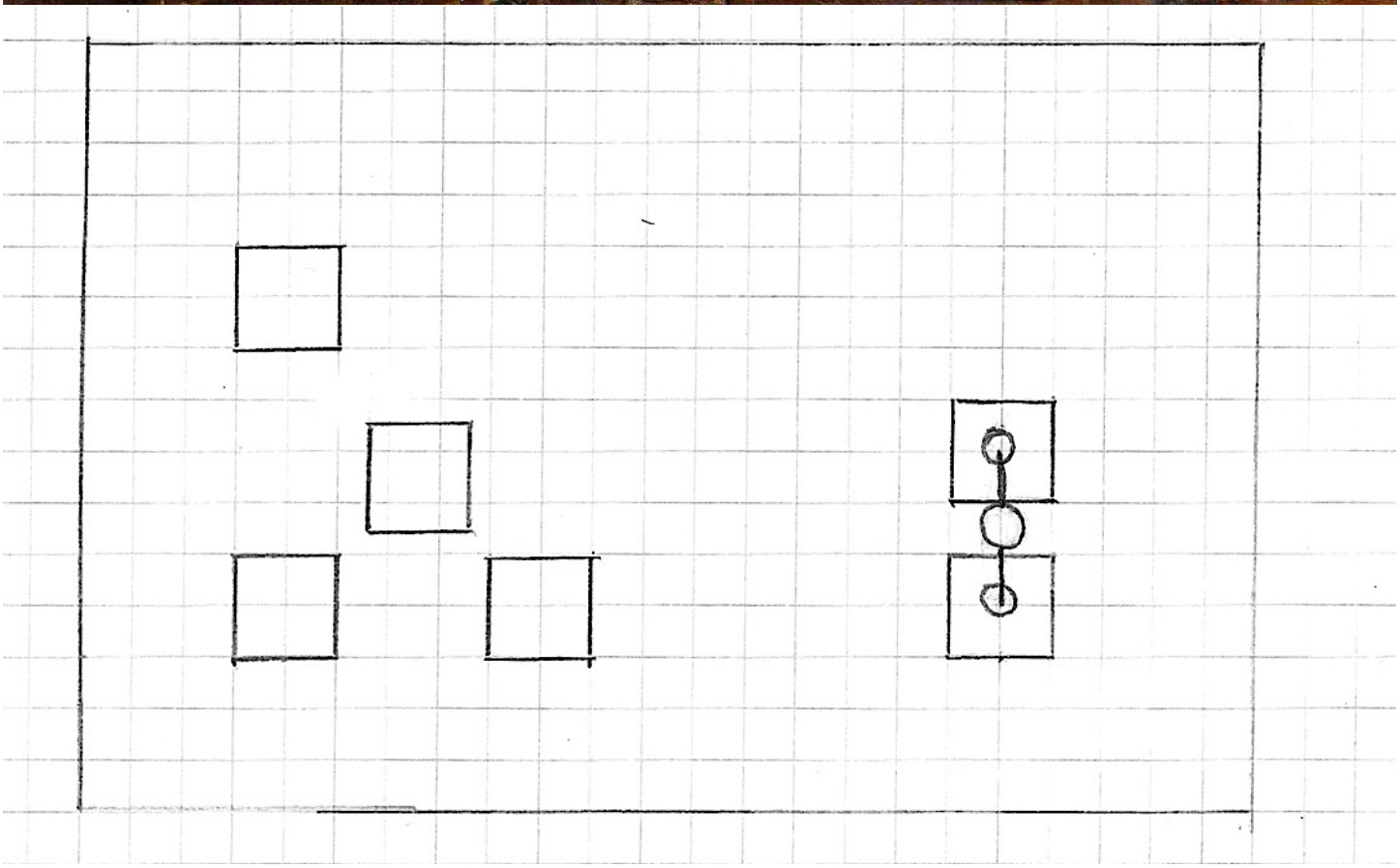

NOTE - This capacitor is polarized meaning that it has to be facing in the appropriate direction. Make sure you solder the NEGATIVE lead to the LOWER of the two squares. The negative side has the shorter lead and a vertical stripe along the side of the capacitor.

3. ADDING THE .1uF CAPACITORS (the two discs with “104” written on them)

- These capacitors will be positioned between the upper and lower left most squares and the ground plate. Melt a blob of solder on these two squares and two blobs on the ground plate beside each. (Reference the pictures for exact positioning).
- Re-heat the blobs and position the capacitors accordingly as in step 2.

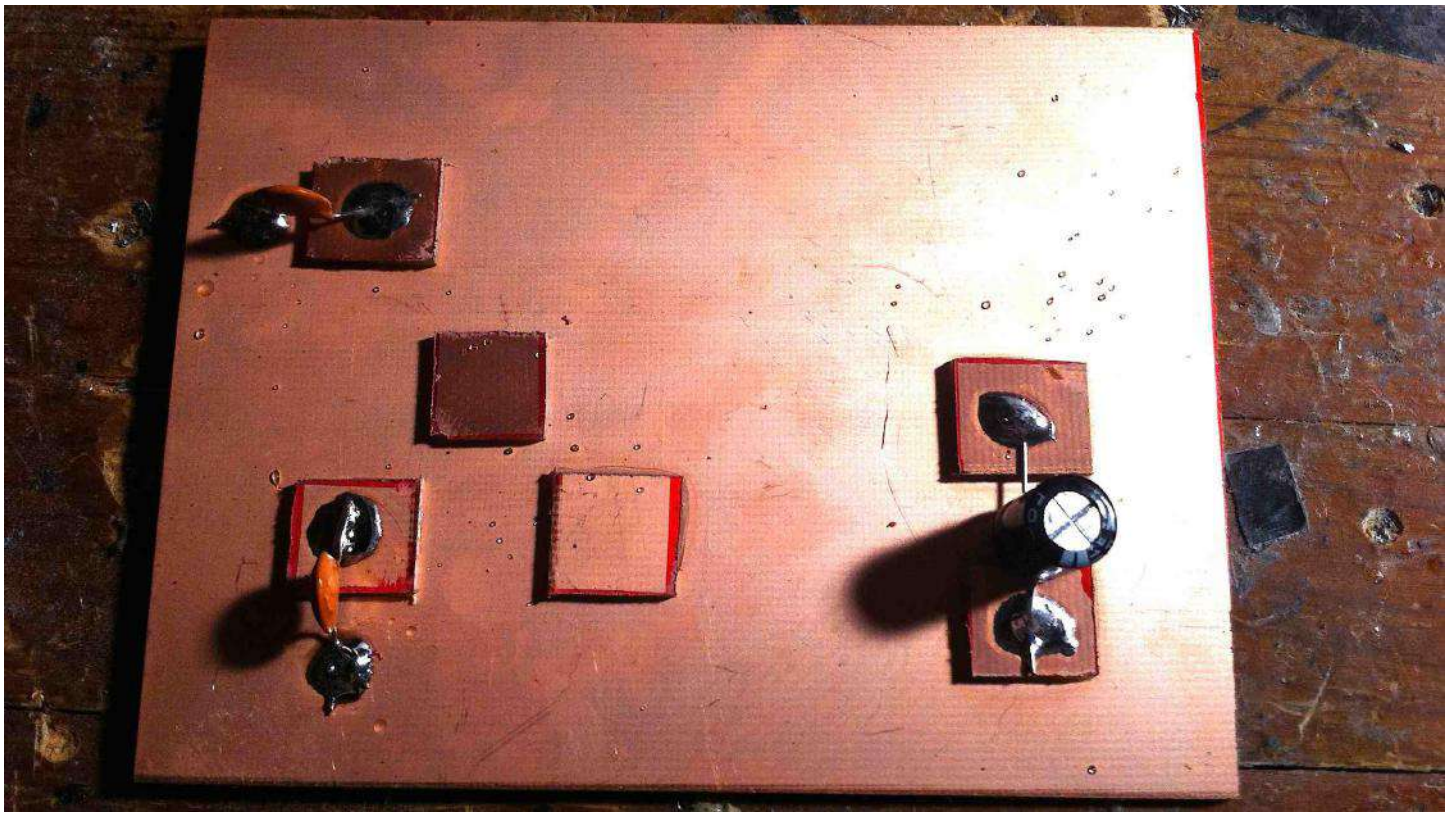

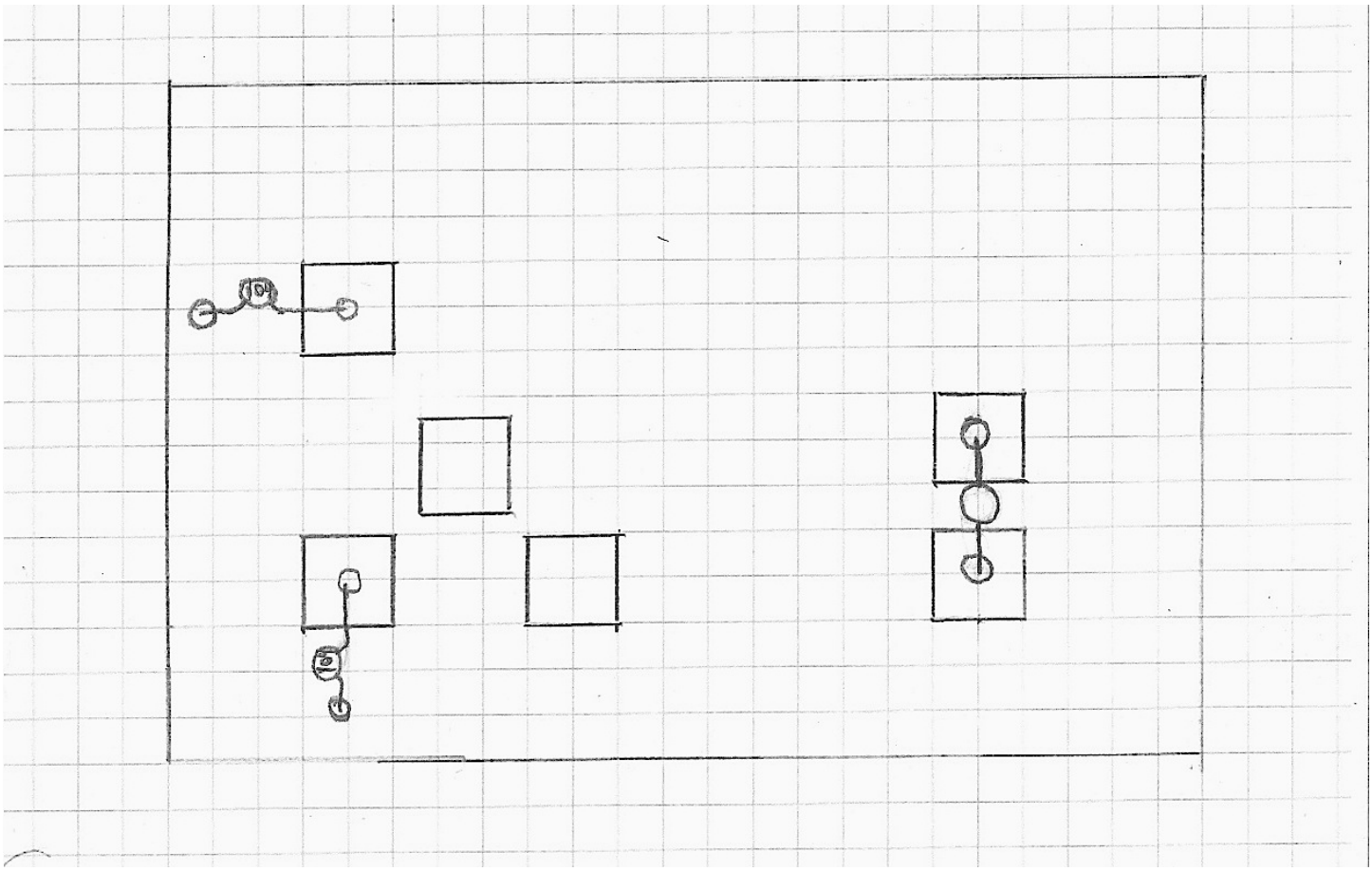

4. ADDING THE RESISTORS (10k and 27k)

- Solder the 10k resistor (brown, black and orange stripes) between the bottom left square and ground.
- Solder the 27k resistor (red, violate and orange stripes) between the two left squares.

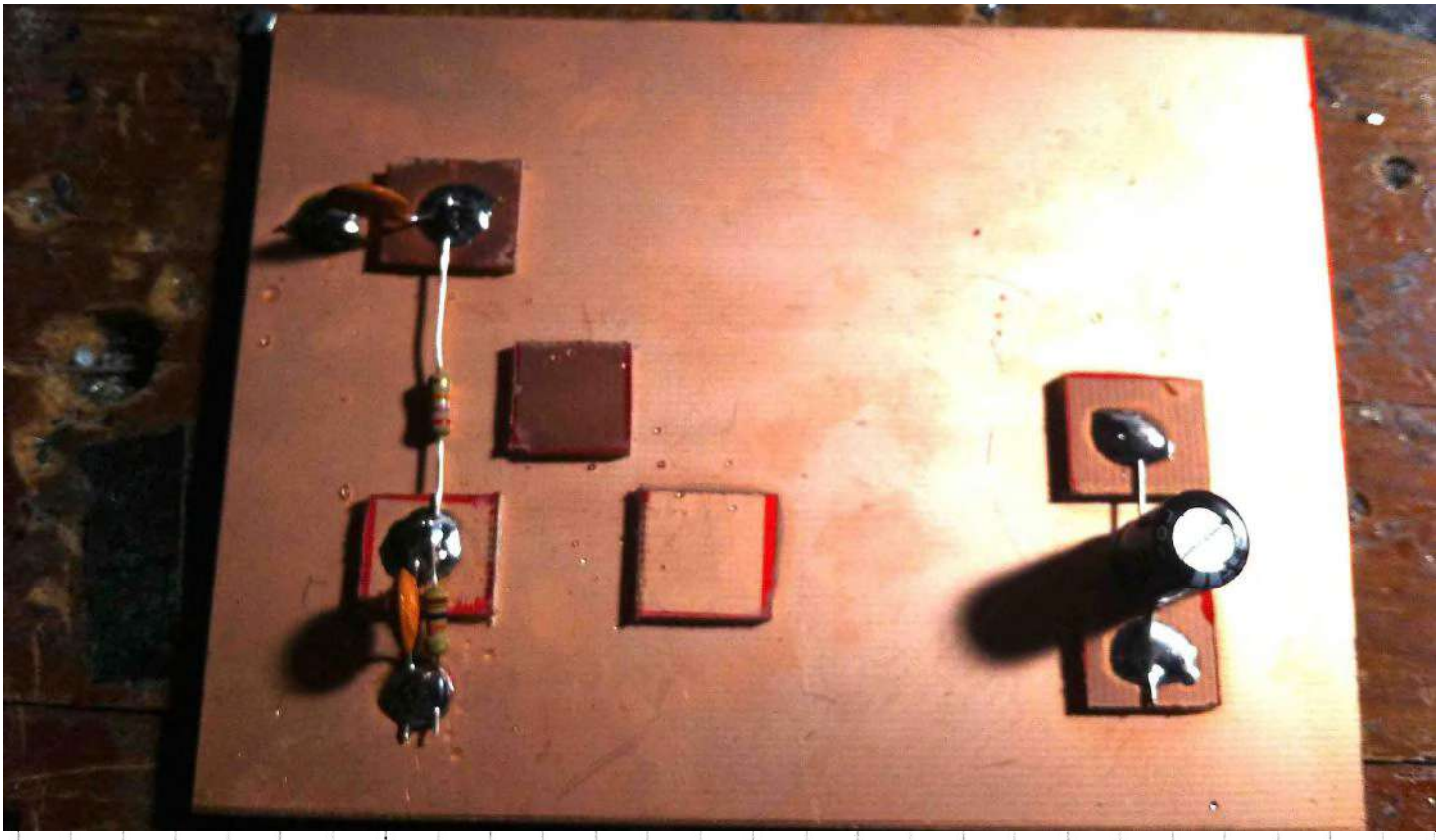

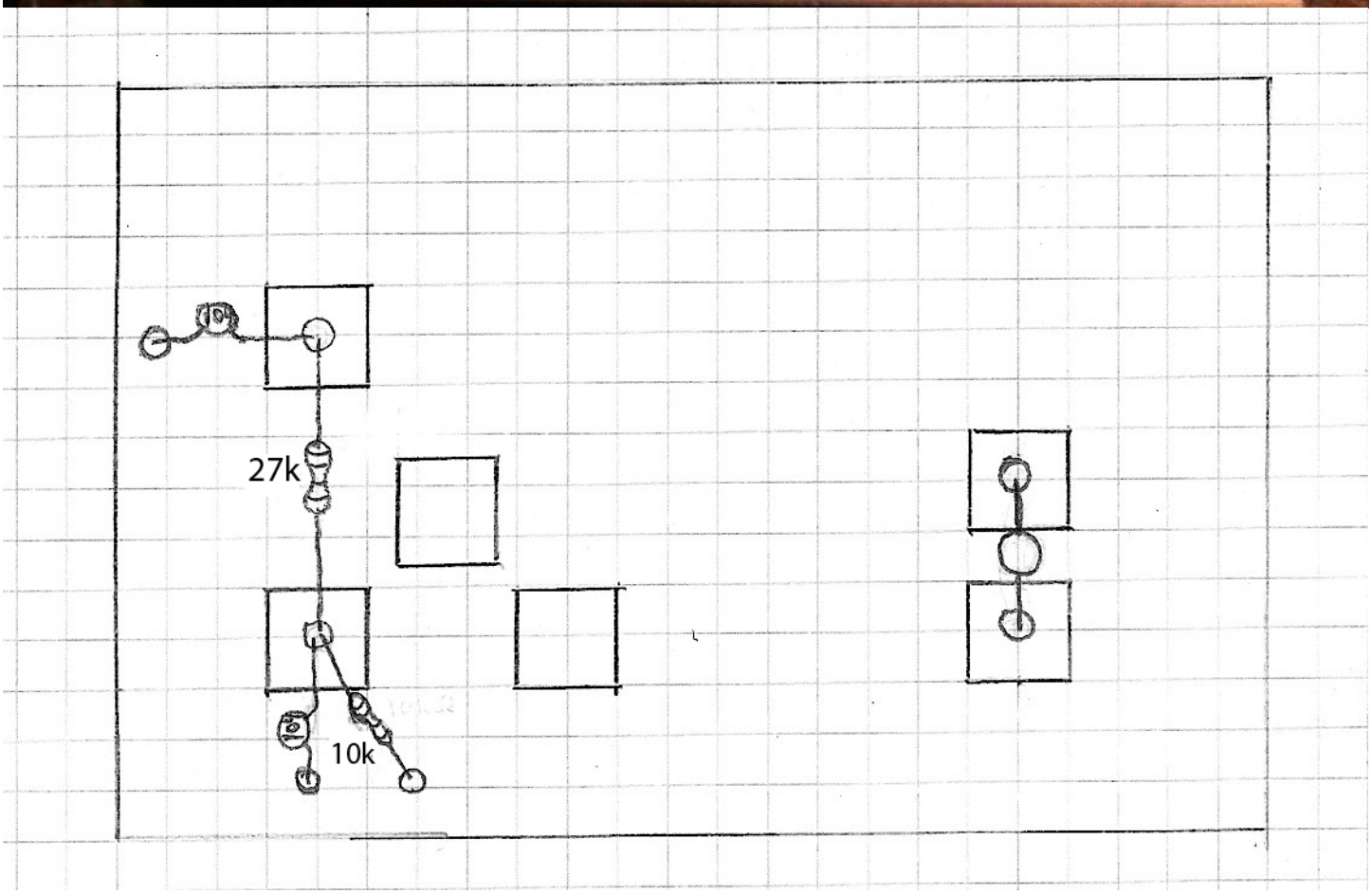

5. ADDING THE COIL

- Cut about 4” of the magnet wire (24 AWG or close)
- Use the plug from your headphones to wrap the wire around. Make 5 turns.

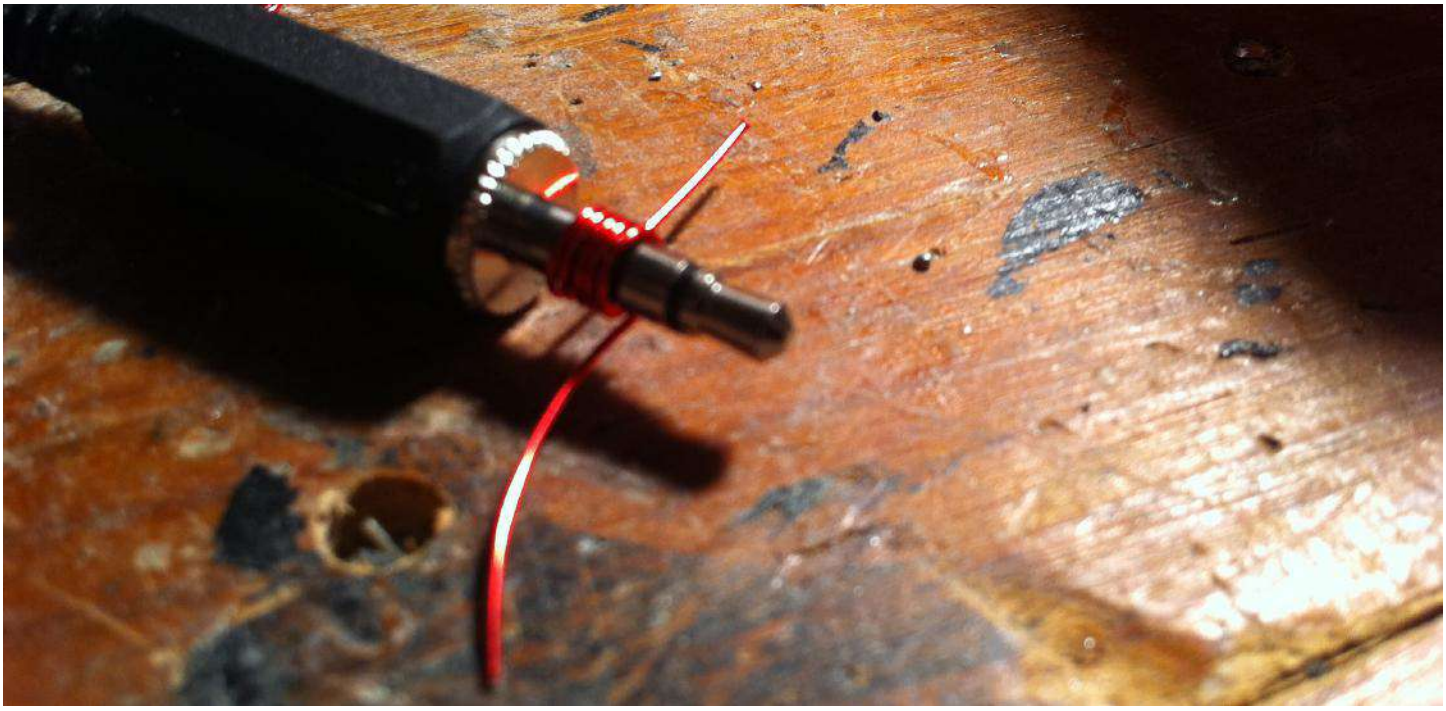

- With the wire still wrapped around the headphone plug, take a small piece of sand paper and rub off the colored insulation of each end until the bare copper is exposed (If the copper is not exposed, you won’t be able to make a connection).

- Solder the coil into place bridging the two squares as seen below

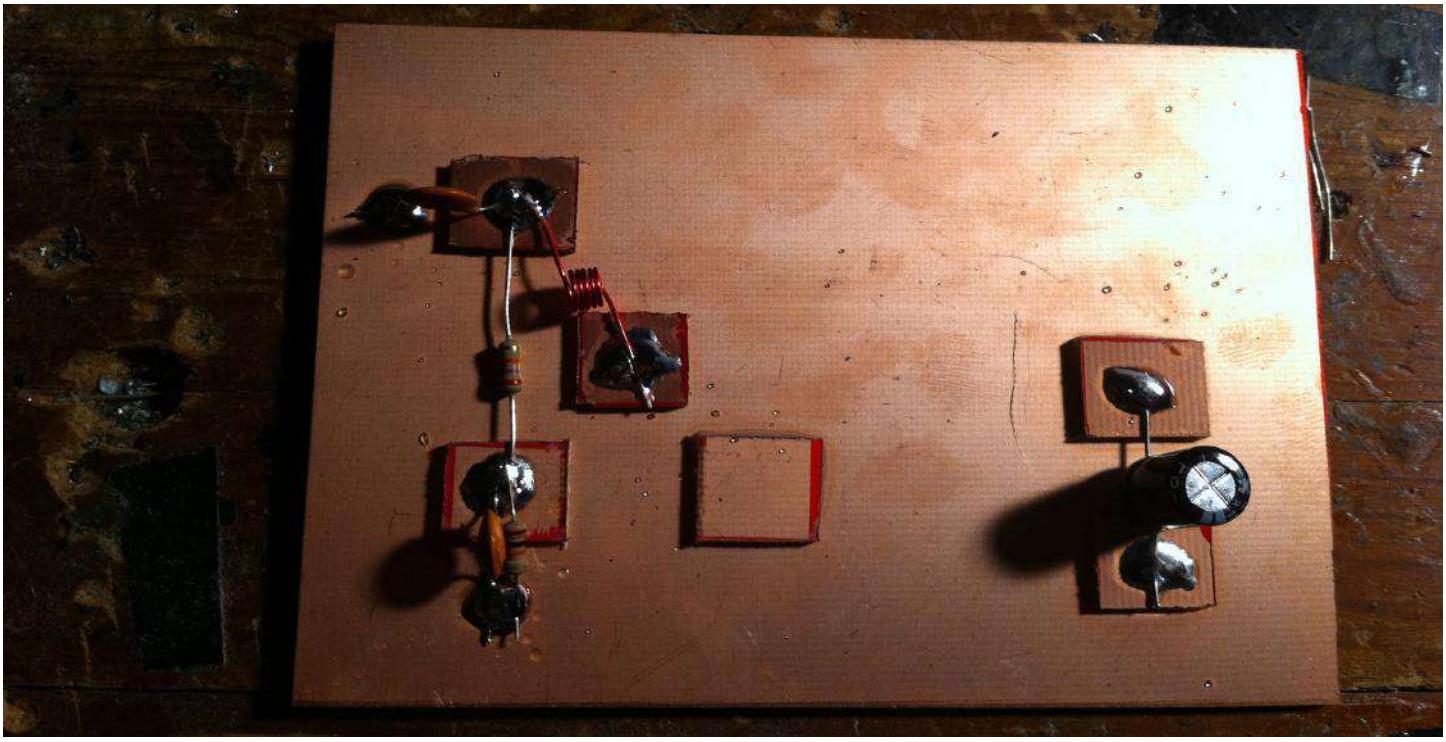

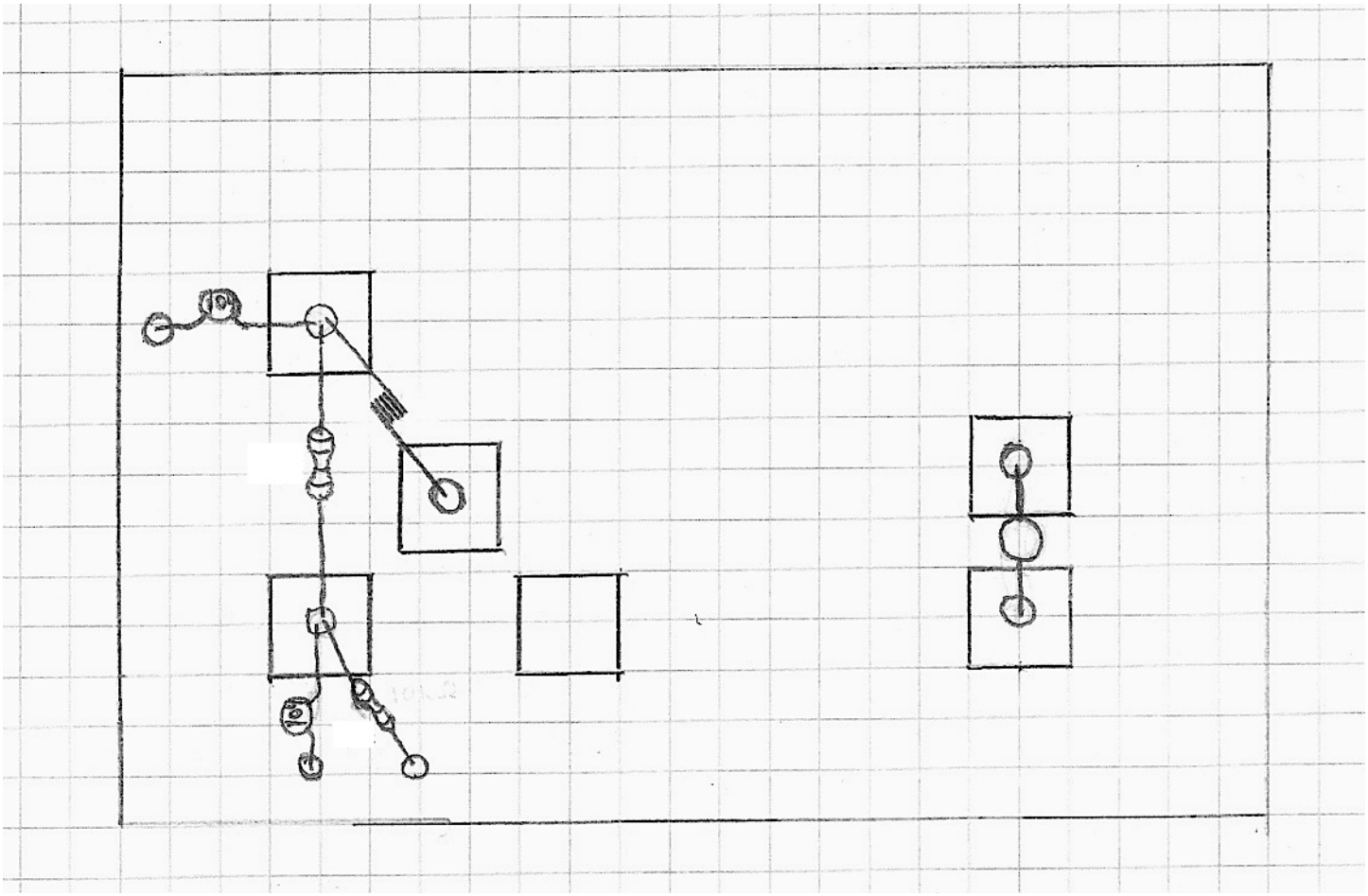

6. ADDING THE VARIABLE CAPACITORS

NOTE Once the component leads start to pile up on each other on each square, it helps to add additional solder.

- The first variable capacitor will be soldered between the top square of the three that make up the bottom triangle and the ground plate.
- Solder the “nose” of the capacitor (the lead that is different from the other two) to the square, and the other two side leads to the ground plate.

NOTE You will have to bend the leads in a certain way in order to get everything positioned properly. Just play around with it till you get it.

- The second variable capacitor will bridge between top and right squares of the triangle. Only two leads are needed here so use your clippers to remove one of the side leads, leaving the nose and only one side. (See the pic below)

The variable capacitors soldered into place…

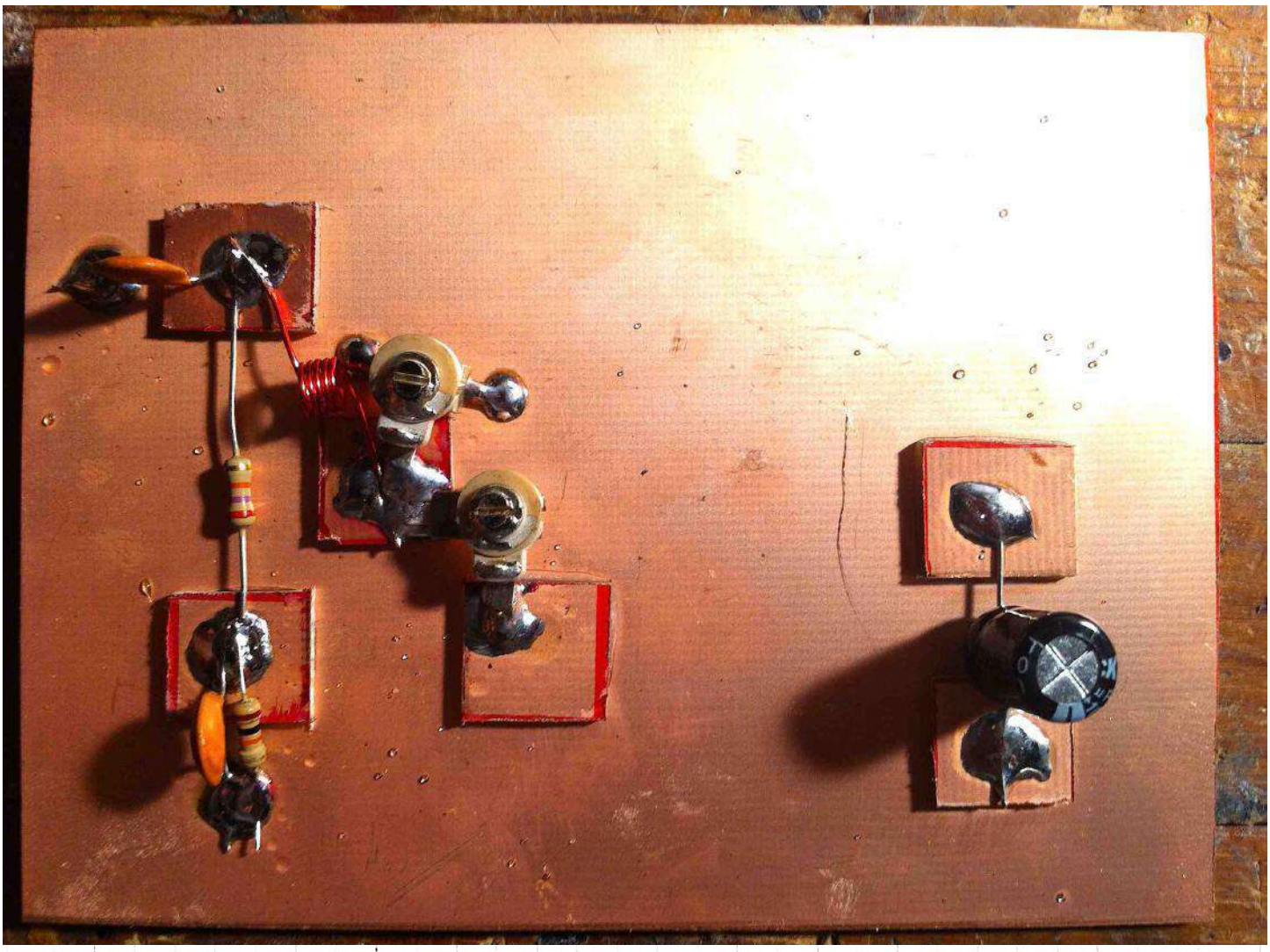

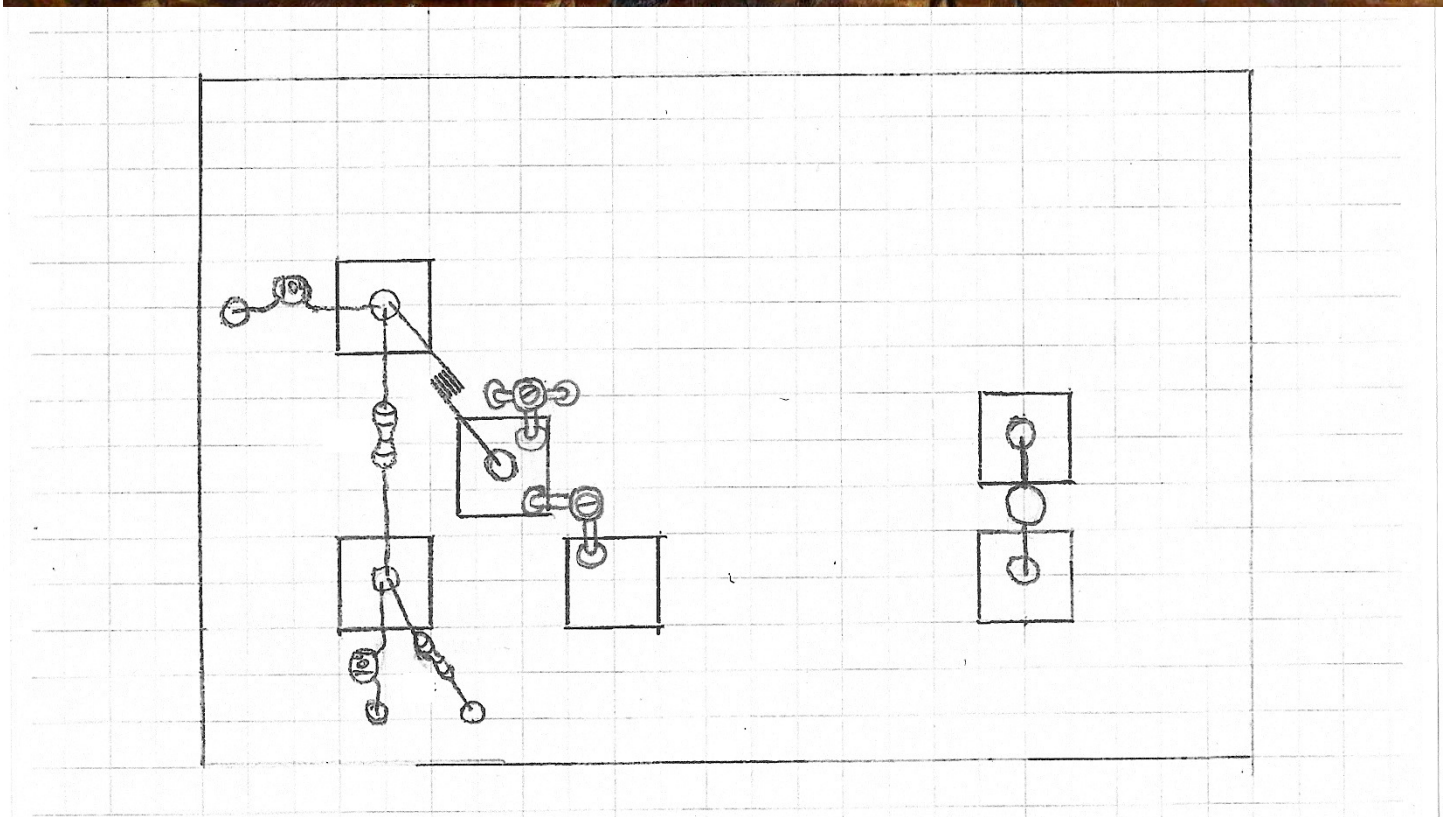

7. ADDING THE TRANSISTOR (MPSA18)

NOTE This transistor is sensitive to heat and can be destroyed by the heat from your iron. Be sure to follow the necessary precautions below. But don't worry if you do kill one, they are only ~$.10 a piece.

- The three leads of the transistor all do specific things and must go to the appropriate places. Here is a pic of the orientation of this transistor…

C=Collector B=Base E=Emitter

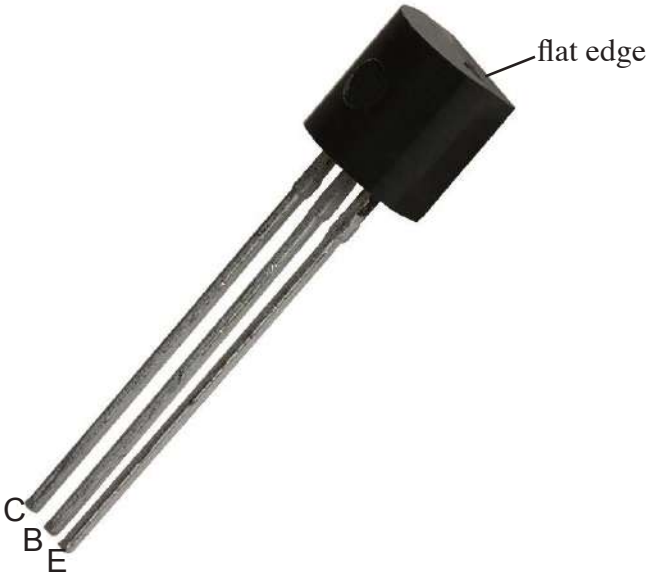

- Each lead from the transistor will be soldered to the three different squares that make up the triangle, so you will have to bend the leads accordingly.
- The B lead (base) goes to the left square of the triangle, the C lead (collector) goes to the top square, and the E lead (emitter) goes to the right square, as in the image below.

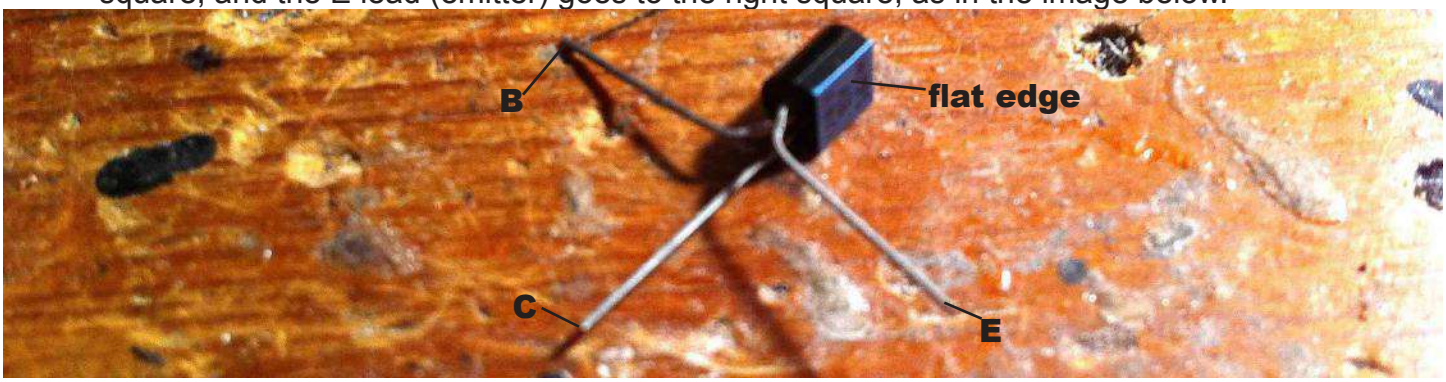

- Before you solder the transistor in place, you need to have a "heat sink" attached to protect it. This will draw some of the heat from the transistor to something else. To do this, simply take an alligator clip and attach it to the lead you are soldering…

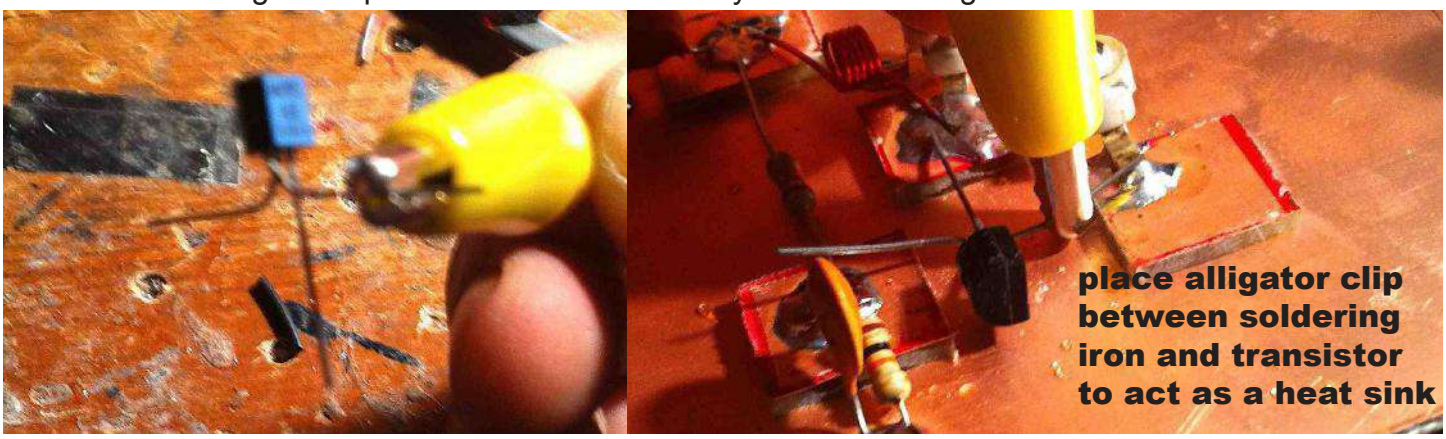

- Solder each lead in place attaching the clip lead to each one before doing so.

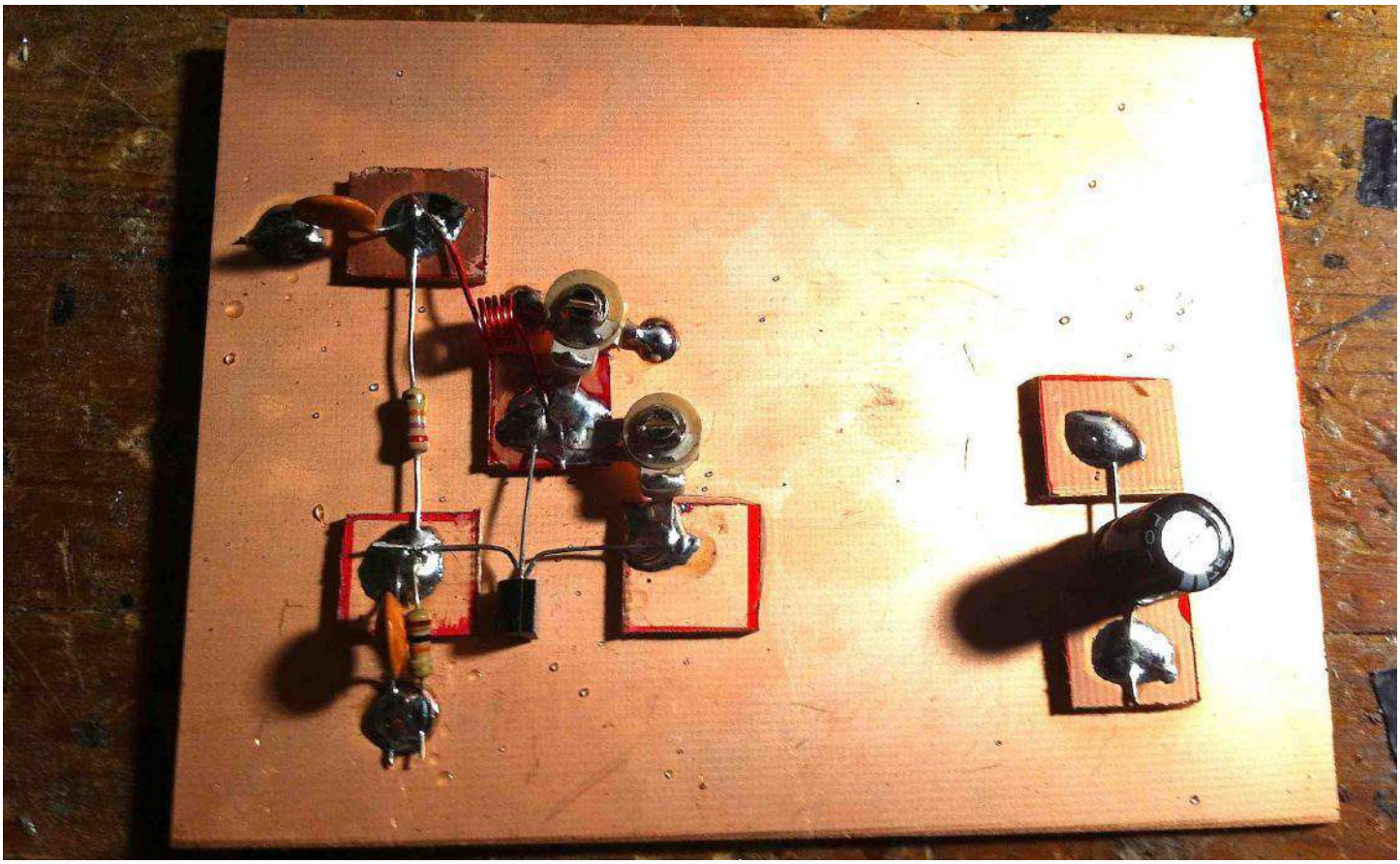

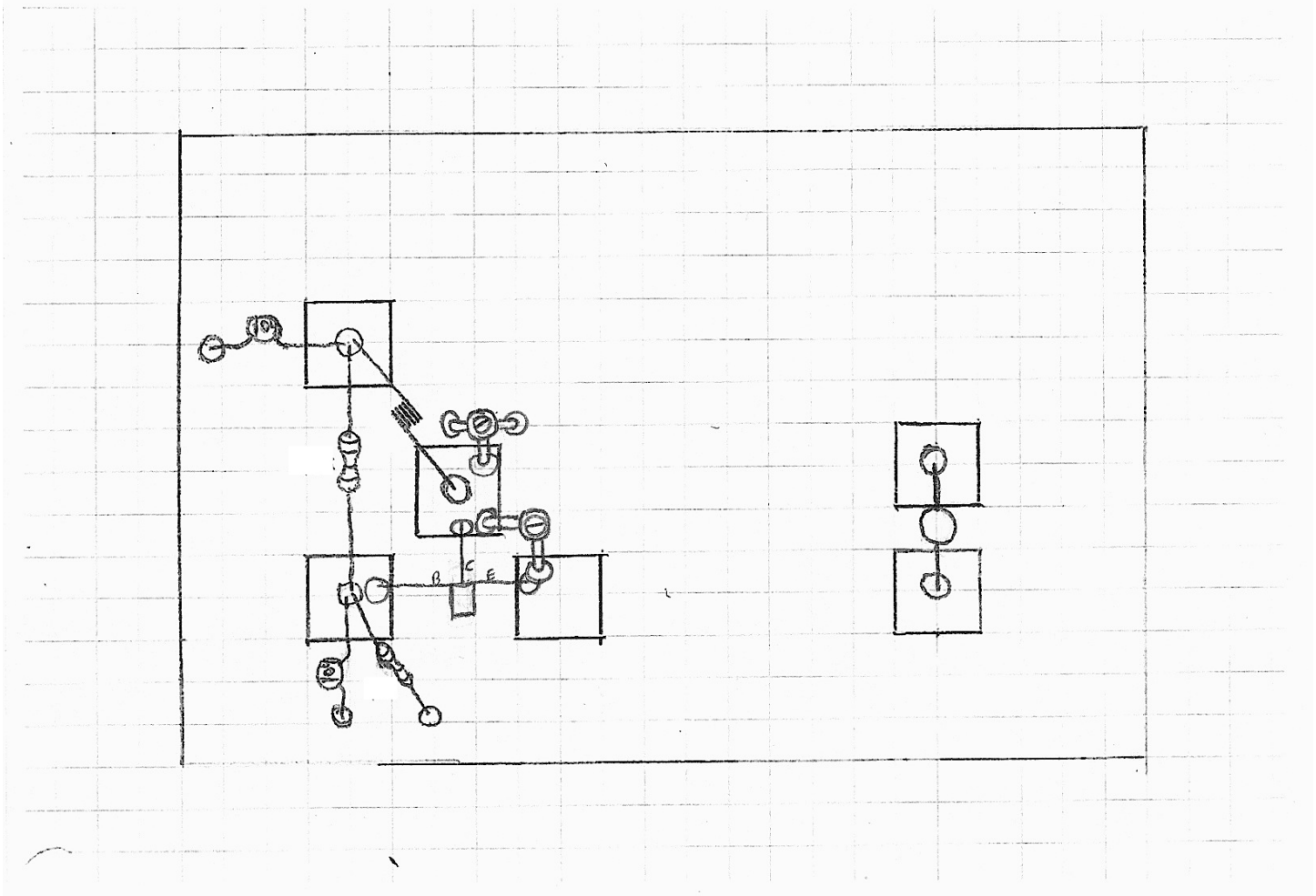

8. ADDING THE 1k POTENTIOMETER

- Put a bit of super glue or hot glue on the bottom of the potentiometer and stick it to the upper right corner with the leads facing towards the left of the plate.
- Take a small amount of stranded hookup wire and strip both ends. Solder one side to the upper most lead and the other side to the ground plate.
- Repeat the process by connecting the middle lead of the potentiometer to the upper most of the two right squares. Then connect the lower lead of the potentiometer to the right most square of the triangle.

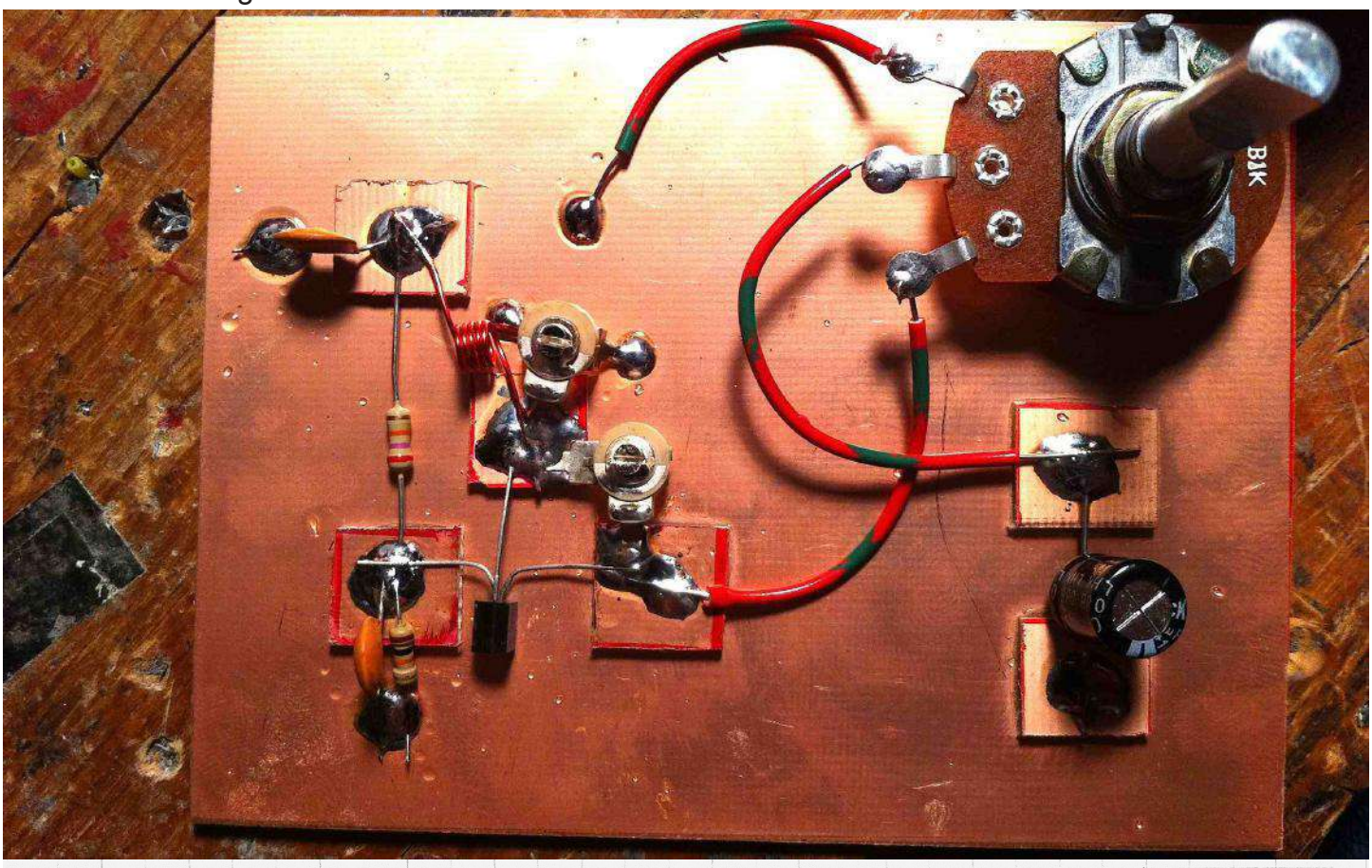

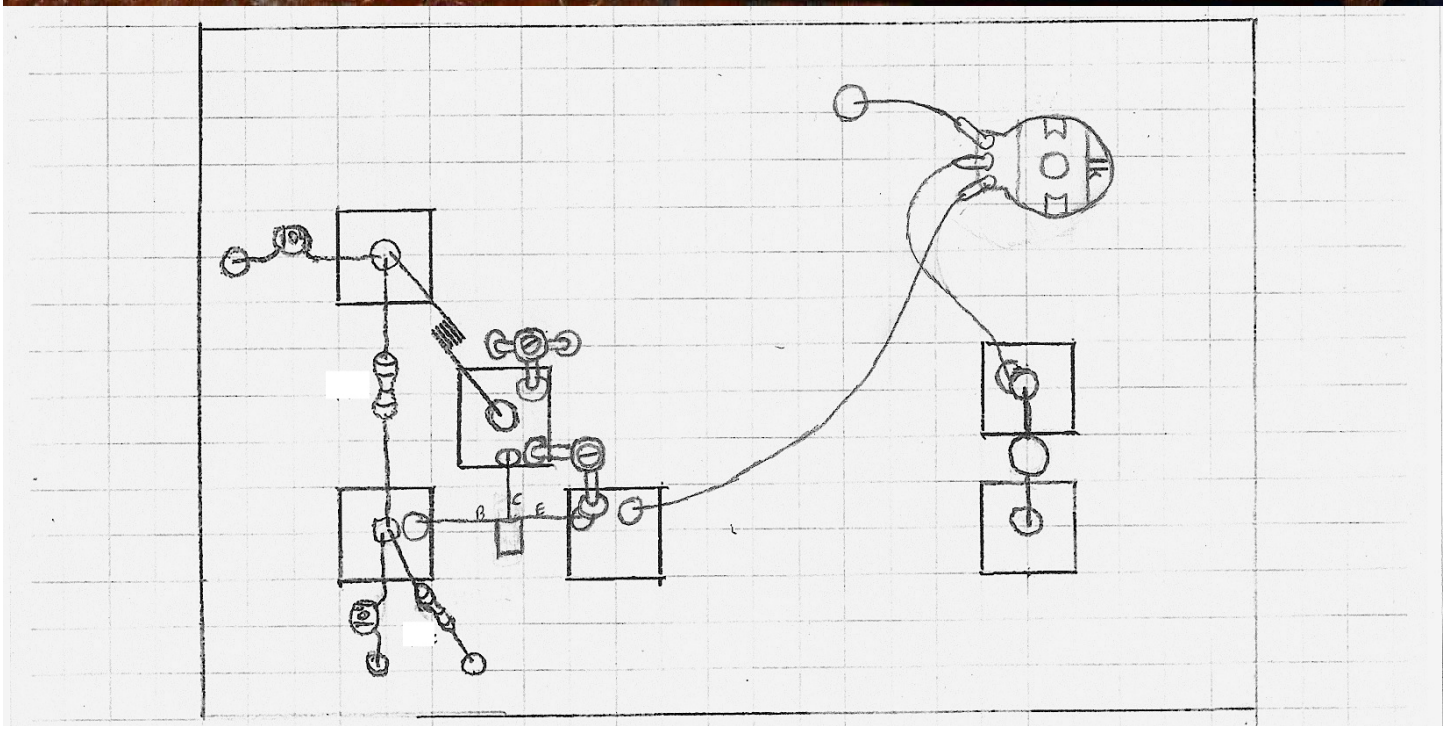

9. ADDING THE INPUT WIRES

- Cut two small lengths (~4-5”) of your stranded wire and strip both sides
- Solder one of the wires to the ground plate (this will be the ground input from your video source)
- Solder the other wire to the bottom square of the two right squares. (This will be the signal input from your video source)

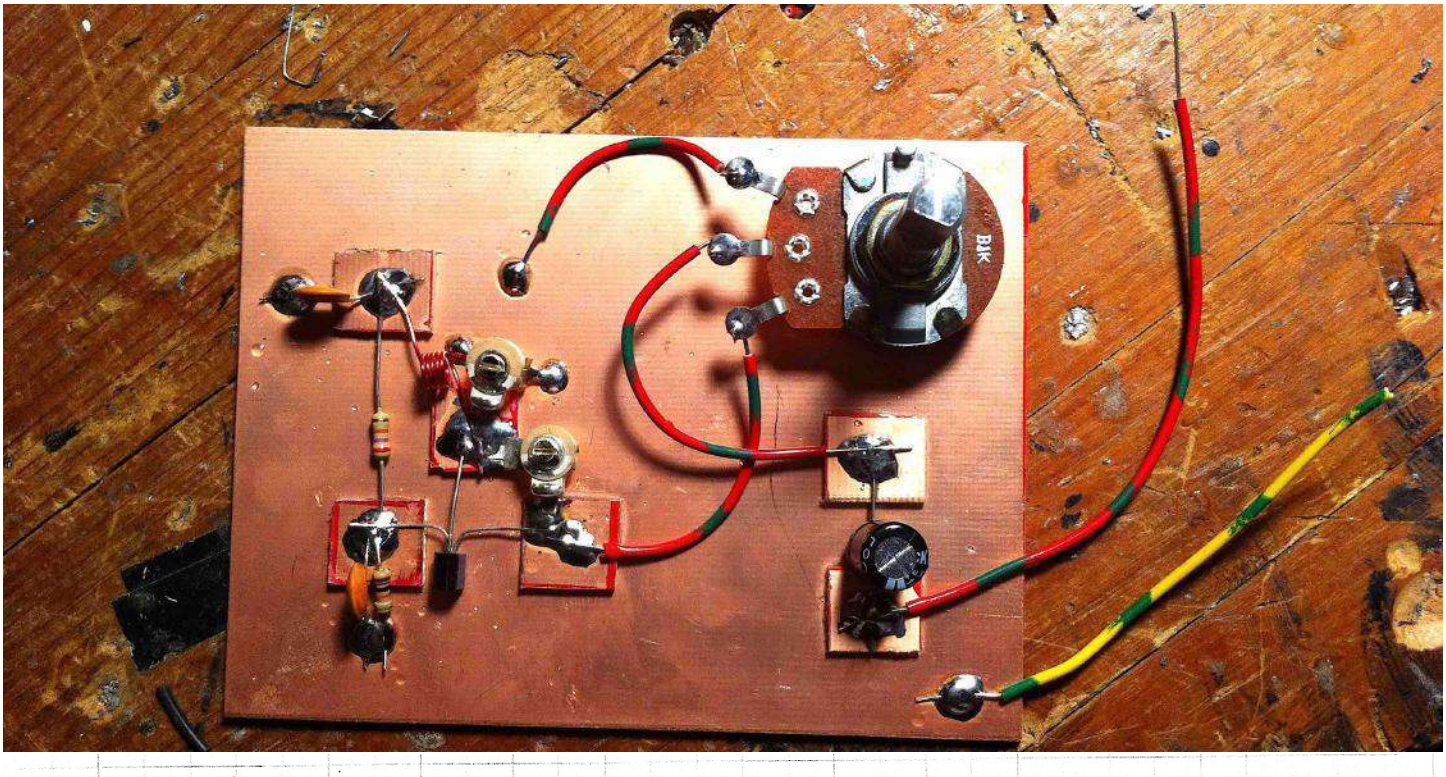

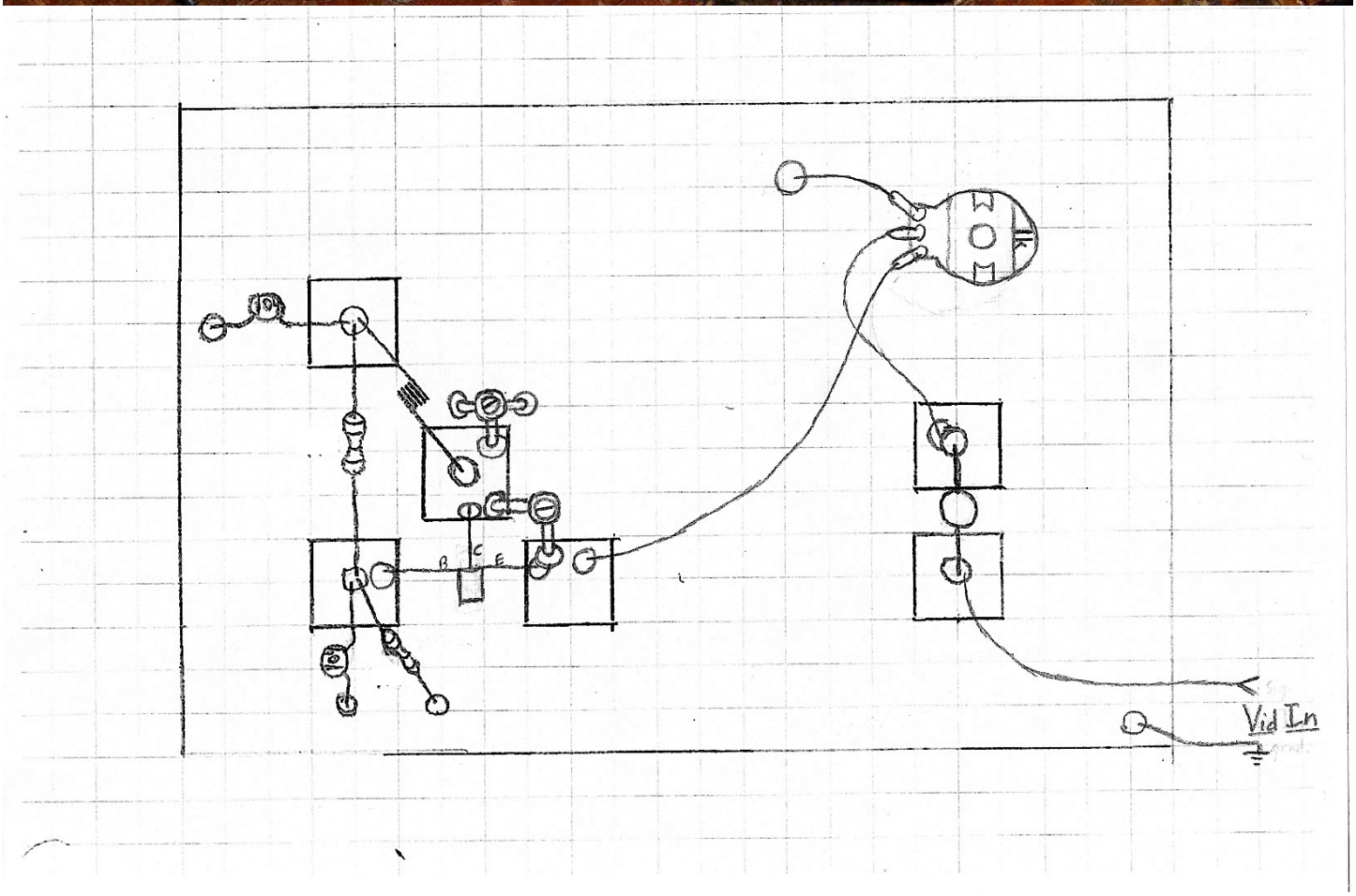

10. ADDING THE BATTERY INPUT WIRES

- Just like the last step, cut two shot pieces of wire and strip both ends.
- Solder one of the wires to the ground plate (this will be the negative input from your 9volt battery).
- Solder the other wire to the upper left square (this will be the positive input from your 9volt battery).

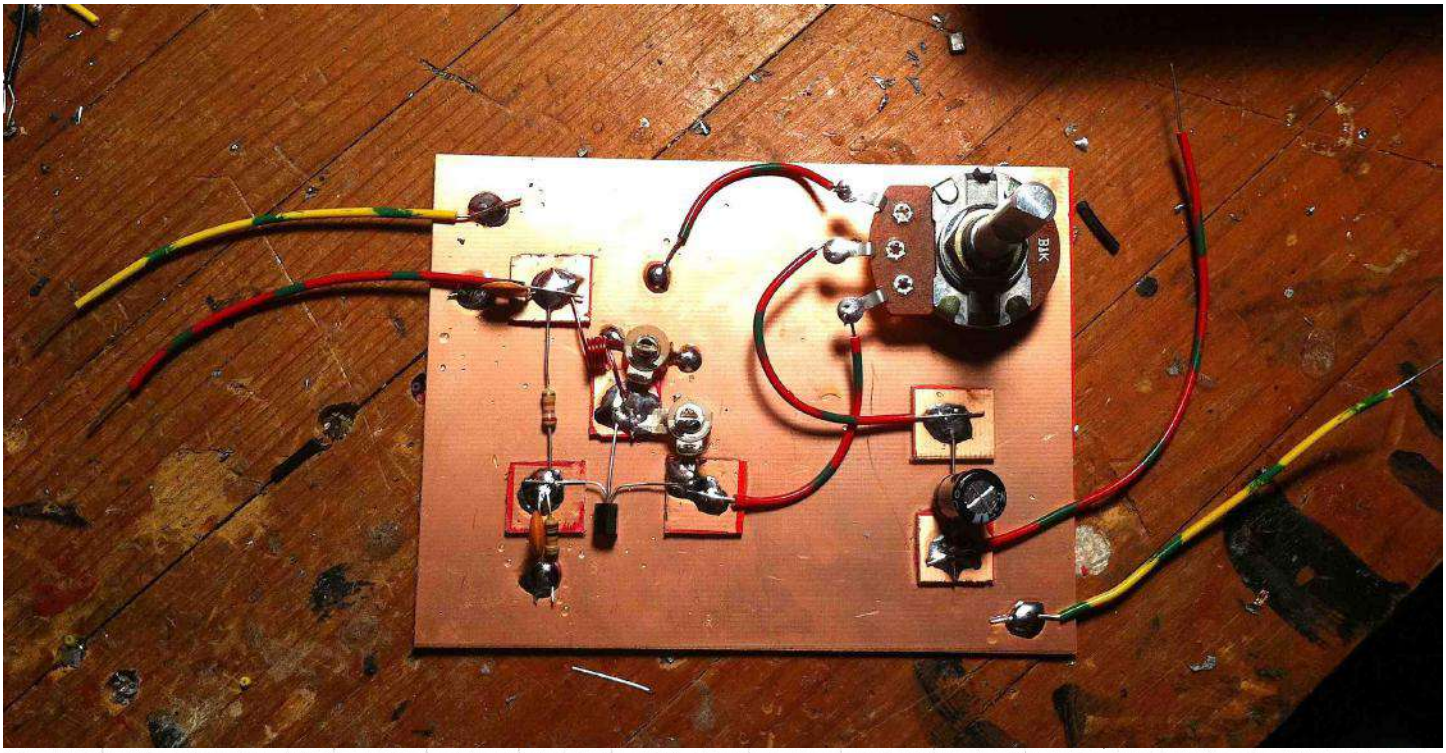

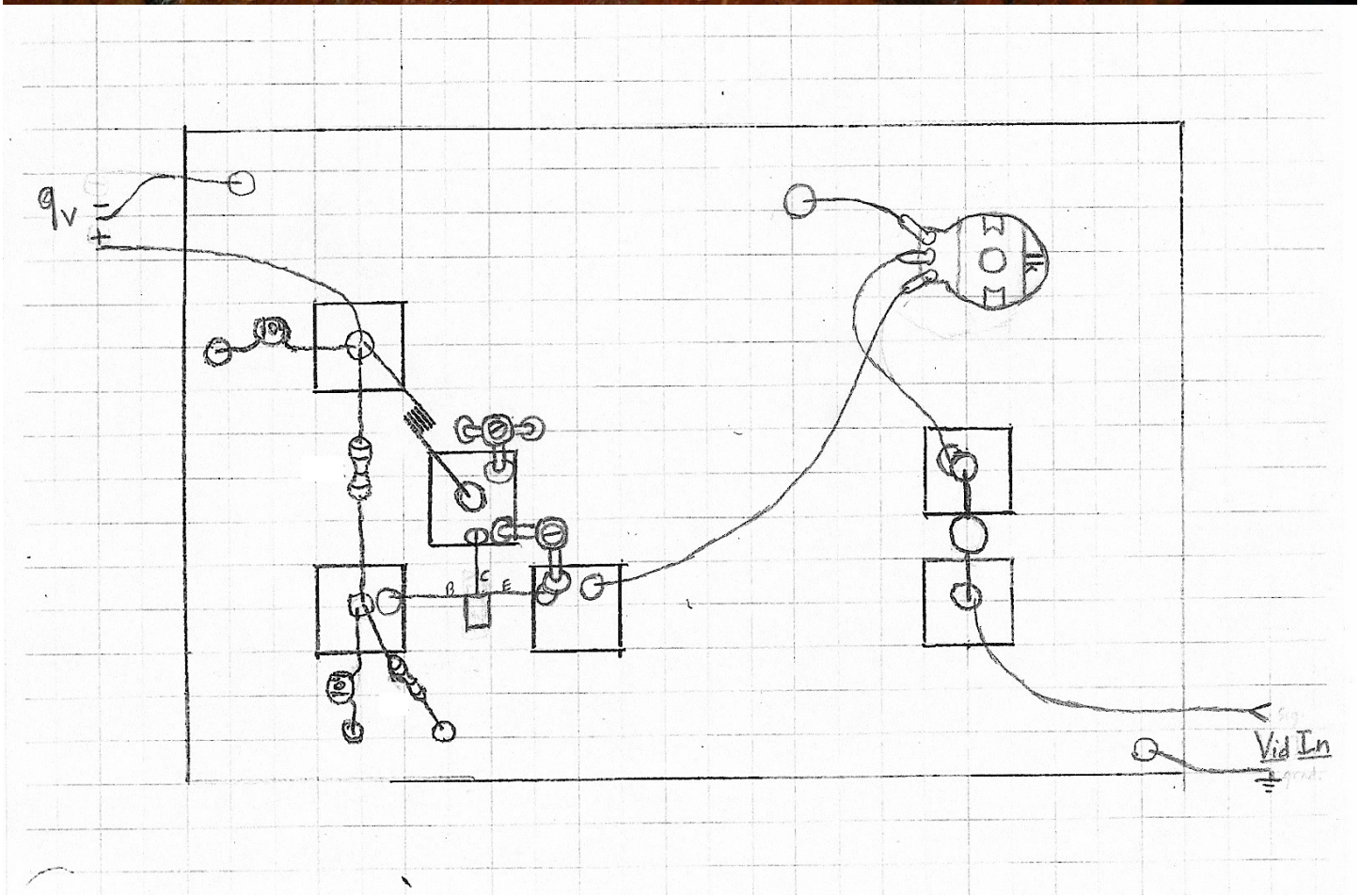

11. ADDING THE ANTENNA

- Cut about 2 feet of wire and strip one end.
- Solder the wire to the right most square of the triangle.

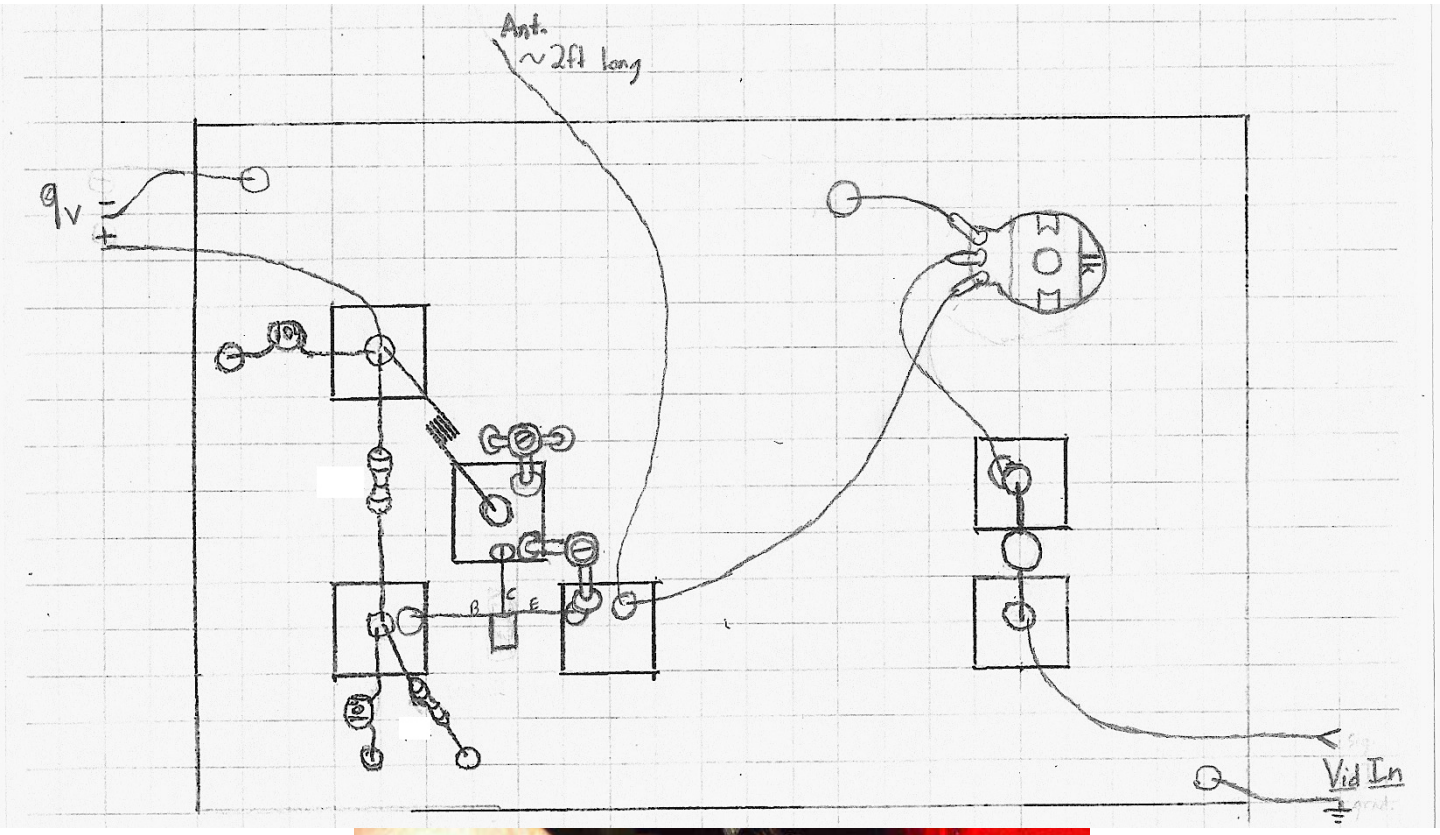

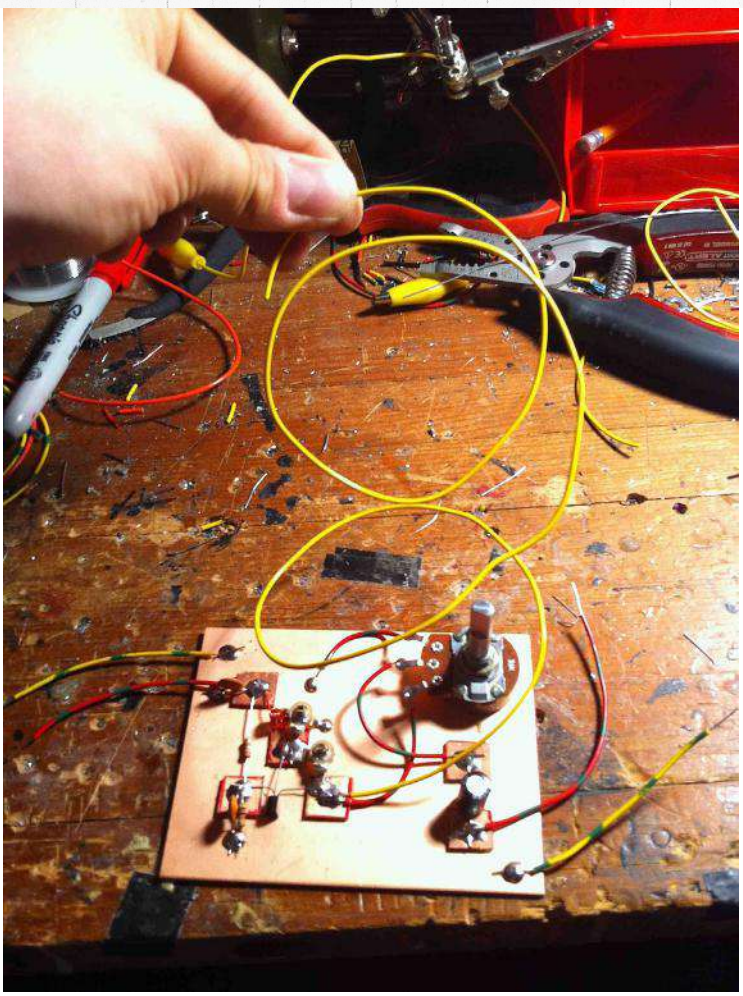

OPERATING

- Find a video source (DVD player, VHS player, iPod etc.) that has a composite video output.
- Use an alligator clip lead to connect the ground from your video source to the ground input of the transmitter. Using another alligator clip lead, attach the signal output from your source to the signal input of the transmitter.
- Use two more alligator clips to connect the positive and negative of a 9v battery to the positive and negative battery inputs of the transmitter.
- Turn on a CRT “tube style” TV and tune it to channel 2 or 3.
- Turn your potentiometer to somewhere around 50%
- Using a small screwdriver, tune the upper most variable cap slowly until you see the TV make a flicker or change.
- Tune the second variable capacitor until you start to see some strong signal coming through
- Tune the potentiometer and the two variable capacitors until you get the imagery you wan

Send any comments, questions or suggestions to yaktronix.online@gmail.com

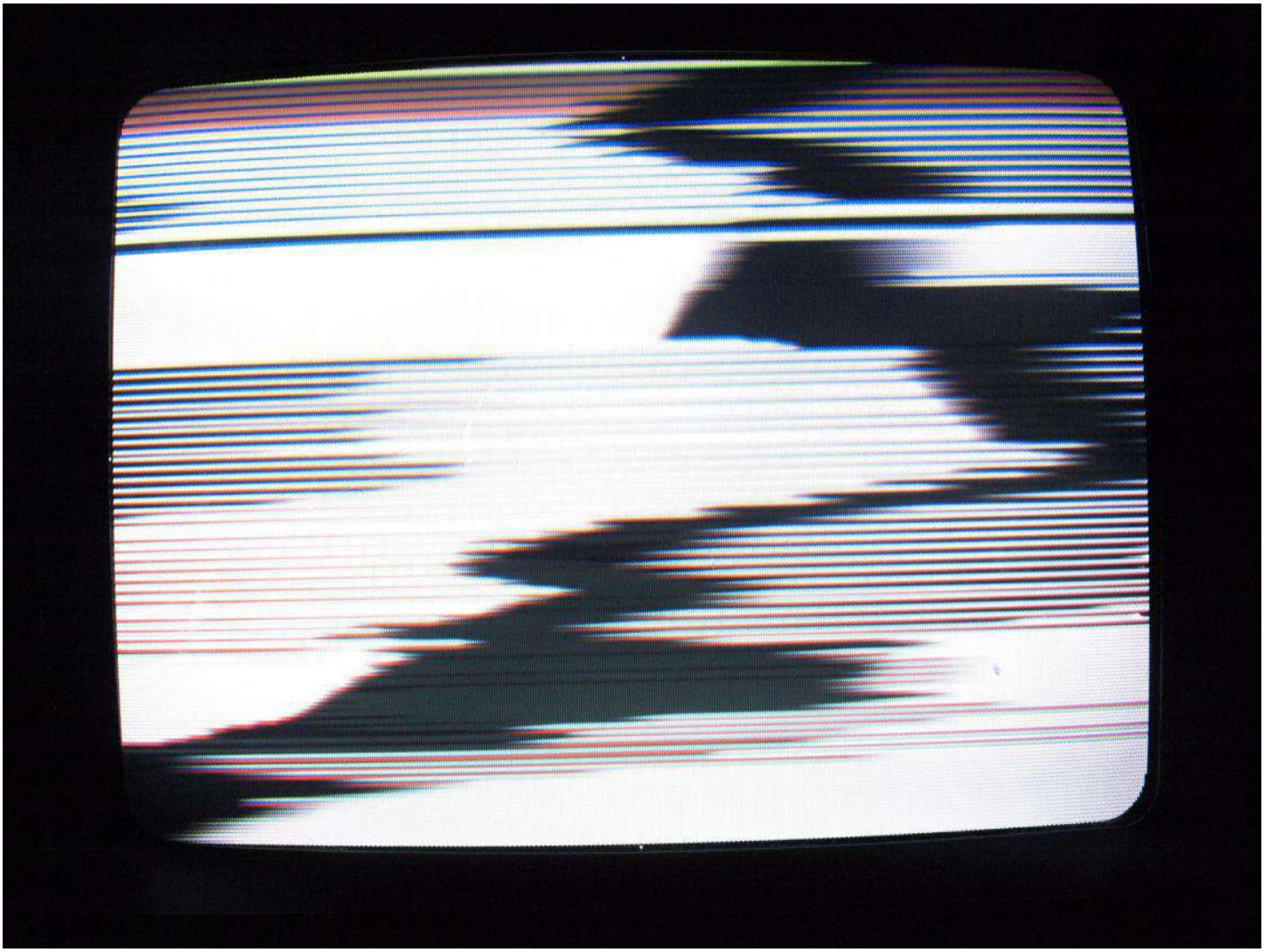

rexresearch.com

Paul BAUMANN

Testatika Generator

Methernitha Group: CH-3517 Linden, Switzerland

Photo Gallery & Videos

Links:

Methernitha ~ http://www.methernitha.com
http://utenti.tripod.it/testatikmachine/
Paul E. Potter ~ http://website.lineone.net/~aarekhu/index.html

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Hans Holzerr: Testatika Demonstration Notes

Paul Potter: Back-Engineered Testatika

P. Potter: Principle Experiment

Anonymous: Believe It or Not --- Here It is!

Cyril Smith: Testatika Generator and Over-Unity

Methernitha: The Research Work of Methernitha in the Field of the so-called Free Energy"

P. Potter: Transcript of Methernitha Testatika Video

Testatika Demonstration (4 August 1999)

Translation by Stefan Hartmann < harti@harti.com > & Hans Holzherr

From: Hans Holzherr
To: Stefan Hartmann

Recently, over 30 technicians and engineers (most of them retired) were allowed to visit the Methernitha group in Linden, Switzerland, where they witnessed a demo of the different Testatika machines.

Here is a report from Hans Holzherr from Switzerland who was present:

Hello Mr. Hartmann,

To your questions: > Have you seen live a machine with a load? If so, what load?

I am referring in the following to the model with the 50-cm diameter disks. This machine was already running when the visitors stepped into the room, and was not halted during the whole time --- we were there for about 1.5 hrs. As a first load a 1000-Watt lamp was connected for approximately 10 seconds whose brightness did NOT diminish --- the corresponding sequence on the Testatika film is just an effect of the camera aperture's automatic adjusting to the sudden brightness! The second load was a U-shaped heating element, that Mr.Baumann handed to me. It became so hot within one second that I had to put it down immediately! What was particularly impressive was that while he pulled back one of the contact wires (that was with the lamp, I believe), a 1-cm long arc appeared between the output electrode and the connecting wire for approximately one second. The apparatus was under a plexiglass hood. Near the base it had two holes which Baumann used to insert the contact wires to touch the output electrodes.

How do you think the high wattage is produced ?

Good question! I'd love to know the answer, too!

Did the disks slow down when a load was placed across the output electrodes ?

I did not notice that (nobody else did), but of course you tend to turn your look to 'where the action is' (the lamp etc.) The disks turned with 15 rpm, which is quite slow. The spin rate was regulated magnetically.

What general impression did you have ?

It was really impressive! One can hardly believe it, with this slow rotation. In any case, this cannot be explained in terms of bare electrostatics in the sense of the Wimshurst machine. The perforated sheets seem to have a key function... Beside the pick-up and the drive electrodes there are a number of small plexiglass blocks with glued-on perforated sheets, whose function is unknown.

As Adolf Schneider already mentioned, my colleague Bernhard XXX and I want to try to copy the principle experiment shown by Baumann --- without much hope to find anything extraordinary, though.

The device consists of a horizontal swiveling plexiglass arm with a small rectangular plexiglass plate at both ends glued to the lower side of the arm. The lower side of the arm is covered with perforated aluminum sheets (square holes), while the bottom of the plates is covered with brass wire mesh. Beneath each plate five additional plates are glued onto the base plate. There is also wire mesh between each pair of plates in the two blocks. From the mesh layer between the lowest plate

and the base a wire goes to the two capacitors, which are connected in parallel . Baumann seized the arm with both hands and turned it about ten times back and forth (a full rotation was not possible, because the capacitors were in the way), then measured the DC voltage with a digital measuring instrument: 60 Volts. Then, as he short-circuited the condensers a loud crack could be heard. I don´t know if that already is an abnormal result...

On my question Baumann replied that with metal foil (instead of wire mesh) the device would not produce that effect.

For more information, Contact: leo@zelator.in-berlin.de

"Back-Engineered Testatika"

by

Paul E. Potter

http://website.lineone.net/~aarekhu/index.html

(Copyright 2000)

That the Swiss Methernitha group's Testatika machine is thought to be based on a Wimshurst electrostatic generator, is only a sparse approximation of the truth --- of the great multitude of electrostatic influence machines developed around the 1900's it more closely follows the charge-separation-and-collection system used by the 1898 Pidgeon machine [note 1] for its electrical circuit.

Its 50-per-disc steel grilles or 'gitter-grilles' are plainly unique to the Methernitha (see fig.1) but in principle follow on from previous research and patents for corrugated sectors which were found to be more efficient charge carriers [note 2] than flat ones, and from a similar example in more recent times of aluminium rods extending out like wheel spokes from an insulating hub of perspex [note 3].

Another unique function of these perforated grilles attached to the discs is how they induce charge from the rotating discs onto the special collecting pads, or 'tasten' antennae keys (which are also perforated --- so as to more readily pick up charge); for in a Wimshurst you had conductive brushes or rails of sharp points which actually touched the discs or were placed very close to them, but in the Methernitha the charge has to be made to traverse a parallel air-gap to the pads and for this purpose the metal gitter-grilles are so designed to create miniature eddy-currents of charged air which circulate in and out of the perforated metal's surface charges, and are more easily bounced out to the collecting pads. This process is categorised as VARIABLE CAPACITANCE electrostatic generation.

Careful note needs to be made of how the Methernitha uses its basically Pidgeon setup with regard to its neutralising rods (that equalise and stabilise the opposite charges --- see fig.2), and how charges are picked up from one area and accumulated at others, so that the polarities of charge are distributed correctly to specific areas on both discs [note 4].

And although there have been some fanciful claims, or misinformation, that it uses all sorts of radioactive materials to achieve its pulsed output I most strongly believe that the auxiliary electromagnetic circuit, that wraps itself around the rotating discs, portrays a simple electronic approach; afterall, who would use radium radioactive emission alongside leyden jar capacitors ! Indeed, the more you look into certain elements of its construction the more they point to three main eras of electronics development, the 1900's, the 1920's and the 1950/60's. The authentic Methernitha

was designed and developed by purists who believed they had discovered a previously unknown electronic phenomenon, but they wanted to keep an integrity to the early pioneering days of the Pidgeon, Wimshurst and Holtz electrostatic machinery; they would not use such modern devices as transistors or IC chips (more's the pity) --- but they do use some pretty uncommon electronic engineering in their circuit [note 5].

Obviously, the electronics are in two parts; one --- the electrostatic generator and its particular technologies of how to direct what charge where, and two --- the very unique auxiliary electromagnetic circuit of inductances, capacitances and rectification that mobilises that 'static' electricity. To understand how they convert static energy into an electromotive force you would do well to go back to the earliest years of radio. From the pages of spark radio you soon appreciate just how important oscillation circuits and their valve rectifiers were, and moreover, how difficult it proved to engineer them. For although radio transmitters and receivers from the 1900's used resonating circuits their oscillations were controlled by sparks between two contacts and, of course, they were relatively inefficient. Not until the 1920's did the first electric current oscillations become an observable controlled phenomenon when someone coupled a rectifier valve, a capacitor, and a resistor together [note 6]. The early 1920's also saw the best era of experimentation and invention for novel devices that turned static energy into useable electromagnetic energy; it was in a 1921 patent that we see a German physicist Hermann Plauson describe in great detail his methods to convert static power, not only from rotary influence machines but also from balloons collecting atmospheric electricity up in the sky; and by using thermionic rectifiers, leyden jar capacitors and inductor coils he proposed a free-energy network that was to power the whole of Germany [note 7] ! The thermionic rectifier valve heralded a new era for radio and high voltage physics, and as it was then subjected to such a broad array of experiments and modifications to improve its efficiency so it paved the way for all sorts of new avenues in electronics. Indeed, with such a technical catalogue of similarities with what we see in the available photographs of Testatika it can be assumed without doubt that the horizontal glass tube which sits on top of the Methernitha machines is exactly what a home-made vacuum thermionic rectifying valve would look like; with its internal anode mesh-plate, surrounded by a coiled copper grid, fed by a glowing (heated) cathode wire running horizontally across its centre and capped by two black end-pieces, which are too big and bulbous to be mere end-caps and must surely be black rubber vacuum seals to seal the glass tube and the input/output wires [note 8].

With such a rectifier, some induction coils, and some leyden jar capacitors you have a circuit that oscillates, and that's what has to happen with a Methernitha, the electromagnetic circuit has to oscillate for it to work, and then the oscillations have to be rectified (or even modulated) so that the resulting single-pole pulses can be channeled through the big cans, which are basically high-efficiency transformers, and outputted as reduced voltage higher current DC pulses (see fig.3).

The precise components used to oscillate the primary oscillating circuit are, I believe, not to be seen in any of the available photographs, but there are various hints for their approximate whereabouts on the machine. Firstly, according to electronic design there should be a capacitor and coil configuration in close proximity to the rectifier. Well, from the picture "3KWREAR" can be seen the two long upright tubes which, according to those who have seen them first-hand, comprise a spirally turned aluminium strip (which indicates they are chokes [note 9]) inside a glass tube, inside the same sort of outer shielding that the big cans have (which indicates they are electrostatic shields), inside yet another glass tube, and are terminated at the top with a brass connecting rod which does a right-angled turn and passes into the side of the tower --- but only two-thirds up the height of the tower. These two assemblies must form a connection to the rectifier, because the rectifier is at the top of the tower, so why don't these electrostatically sensitive tubes extend all the way up to it ? Again, from the photographs of the rear and front of the Methernithas there is a wire that comes out of the tower's side wall at about 4 inches above the upright's brass terminals and this wire then passes through a short black tube and on to the rectifier valve. This, of course, would happen on both sides of the tower, enabling a connection to both ends of the rectifier. But why have

this 4 inch gap of connections at the top of the tower ? Something is placed inside the top of the tower in this intermediate space which is very necessary to the circuit, and I think it must be the location of the capacitor/inductor configuration to oscillate the circuit. This (fig.4) is how I would see the inside of the top of the towers [note 10].

I've seen some of the patented inventions that rotate discs --- by using magnets (i.e., H.Rosenberg's permanent magnet excited rotational machine, US Patent # 3,411,027), and by utilising inscribed metalised discs (US Patent # 3,239,705 for instance), but there simply isn't enough room for these to be located in the Methernitha disc setup --- also, you don't want to interfere with the ES fields that zip around the revolving discs: From the reports of those who have seen the small machines working it appears their discs were rotated by small DC electric motors after they were hand-started, some re-wound with thinner wire (to presumably increase their torque) and powered directly from the discs' generated electricity --- but I have also seen how two discs can continue to rotate simply by careful placement of curved electrodes [note 11] which would act on the charges on the discs --- like the 3kw Testatica Distatica generators.

After reading through the many early accounts of electrostatic rotary machines, and some of the more recent ones, you can't help but be puzzled by the Methernitha's incredibly low rotational speed of just 60 rpm (and in the 1999 engineers report as low 15 rpm !). Most other early experimenters boasted up to 3000 rpm. J.G.Trump in his work on high voltage generation in space [note 12] spun his rotary machine at 10,000 rpm (to produce 433 Watts at 24 KV no less). One reason for this low speed might be to do with the close proximity of the 50 lamellas (gitter-grilles) on the discs at their inner ends, they are very close together, I think too close. Air, normally an insulator, breaks down and conducts at around 25-35 KV (this figure has been fairly constant from day-one of electrostatic machine experiments right through to the present day --- because air has a breakdown field strength of 3x106 volts/metre) and short-circuits the circuit. I feel that because this design of grilles is prone to short-circuiting at high voltages the Methernitha people have limited their rotational speed so as to ensure a low operating voltage --- of what I'd guesstimate to be only 12 to 24KV.

But, is this a waste of extra potential ? Not necessarily, for I don't think that the main power output comes solely from what the two counter-rotating discs supply.

There is, I believe, a far more important power generator --- the electron cascade generator, and the Methernitha has two of them, held inside the two horseshoe magnets, and providing the circuits to the magnets are made to oscillate at the right frequency at a high enough voltage then these metalised-perspex laminated blocks can enmass A MUCH LARGER AMOUNT OF ELECTRICITY THAN WHAT IS PUT INTO THEM.

This, perhaps, is the previously unknown electronic phenomenon that the Methernitha group have so zealously been trying to protect against unscrupulous entrepreneurs. But I would say that this copious supply of free energy is already known to the world --- it is not readily available - and its principles are not fully understood, as yet, but it is known about.

As the descriptions say (on the Testatika website), between the horseshoe magnet legs are four blocks of transparent 'plexiglass' type material alternated with copper and aluminium plates (that may or may not be perforated), in the sequence c-p-a-c-p-a-c-p-a-c-p-a (also see fig.6). And according to the Linden Experiment, where Paul Baumann induces a resonance of about 80-140 MHz in a coiled horseshoe and then has an aluminium-insulator-copper block moved between the horseshoe legs, a voltage could be taken off the plates of the block which measured 700 volts (DC presumably) [note 13]. This incredible phenomenon has never been replicated by any 'outside researcher', and is said to be the basis by which the Methernitha machine could be understood how to work [the clue, possibly, to this Principle Experiment may be variable-capacitance and dielectric-absorpsion].

But what, I hear you say, is an electron cascade... Well, it was only by chance, very recently, that I happened to listen to an audio tape by a Dr. Flanagan about crystal water; when I switched the tape over after the end of side one Dr. Flanagan then began talking about an electronic configuration that applied a high frequency, high voltage alternating field across an insulator --- that created what he called an electron cascade effect --- Yes, I thought, here is the answer to the Methernitha Machine.

The electron cascade or avalanche effect is where air molecules are accelerated to the device at such a high velocity that they collide with other molecules and atoms in the air to liberate new electrons which in turn also collide and liberate even more 'free electrons' from other air molecules (see fig.5), all of which become accelerated by the electric field, and an avalanche of electron-multiplications progresses throughout the whole immediate environment [note 14]. It's a chain reaction, and an entirely safe one, it happens in a more ferocious way in lightning strikes, and is a natural phenomenon. And, as in this case, the environment actually becomes part of the circuit [note 15] because the process is actually negatively-ionising the air surrounding the Methernitha machines, and that is why those who have been near these generators when working say the air around about them is cool and fresh [note 16].

In view of the fact that it's designers have chosen to wind insulated wire (which may or may not be bifilar) around the horseshoe metal it is likely that the horseshoes are used for some form of induction [note 17], it would also be very possible to draw directly from this part of the circuit the extra electric current produced from the electron cascade blocks, with suitable connections that might lead downward into the wooden base (where it is believed that an alternate layering of perforated metal plates and insulating plates - making up a large high-voltage storage capacitor - is located). This power could then be discharged as a pulsed output of high wattage, especially if the final output part of the electronic circuit is configured as a Pulse Forming Network of multiple sections of inductor / capacitor combinations [note 18].

The two big cans at the side, the big capacitors, are probably not highly technical (see fig.7), once the fundamental formula has been decided upon all models of a Testatika generator would follow a similar construction process. The written descriptions are a little contradictory but they seem to suggest a central input rod, or tube, connecting at the bottom of the cans to a stack of inter-linked pancake coils, that are wound secondary-outside primary-inside, fitted around a core of 6 hollow donut-ring magnets stacked in such a way with plastic spacers as to allow air gaps between them, and then finally the output of each can is a connection from the top coil of the secondaries of the pancake coils to a brass ring around the centre of the black plastic top lid --- and from the photographs can be seen a large diameter wire or tube [note 19] connecting that polarity's output terminal to the top lid's brass ring via a brass screw terminal. I would suggest that the ring magnets (of anistropic ferrite perhaps) are gapped in this way to prevent the magnetic flux fields of the pancake primaries co-joining as one sprawling field, because it would be more advantageous, and safer, to have each separate pancake's magnetic flux cut it's own adjoining secondary coil, and divide the secondary output voltage into smaller amounts of potential, thus depending less on complicated insulating procedures that accompany high voltage single primary / single secondary transformers.

The use of aluminium mesh and solid copper sheeting is commonly used in electronic construction; the outer aluminium mesh cylinder would be used to shield stray electrostatic charges, and the solid copper cylinder is to shield the large amount of stray electromagnetic fields produced by the transforming process from high voltage/low current to lower voltage/higher current [note 20]. Obviously they don't want field contamination taking place between the sensitive electrostatic generator and the transformers.

Within these two outside shielding-cylinders are 'grid condensers' which, according to the 1999 report by the 30 engineers, can be as many as 20 layers of perforated sheet (presumably as concentric cylinders) - which I have indicated (in fig.7 for instance) as being electrically connected

BETWEEN each separate secondary winding - in the fashion of an old discovery from the early days of wireless telegraphy and based on the 'disruptive discharge coil' devised by Nikola Tesla, that such a condenser connected in the center of a secondary coil collects the maximum amount of voltage created by that secondary. This configuration of one condenser inside another inside another etc etc, has a striking similarity to the layout of a pulse forming network [see note 18].

In the red wired can the transformer is wired to output negative, and the blue wired can's transformer is wired to output positive polarity. Special note should be made of a similar arrangement for divided primary / secondary windings devised by Van de Graaff in his 'High Voltage Electromagnetic Charged-Particle Accelerator Apparatus Having an Insulating Magnetic Core' [note 21] with respect to magnetic reluctance gaps.

Whilst it has been said that the clear perspex disc was designated the 'cloud' disc, and the (rear) dark disc the 'ground' disc I would think this relates to different types of acrylics or plastics that might become charged to different polarities, as in the triboelectric series, where frictional charging of different plastics --- and then bringing them close together, might cause donation or acceptance from one to the other; I would think from the above that cloud represents a donator (positive charge) and that ground must mean an acceptor (negative charge). Has anyone tried the combination of a teflon disc (extremely negative charge) with a glass disc (highly positive charge) ?

Or discs doped with paramagnetic particles perhaps [note 22] ?

The circuit has to be made to oscillate for it to work, and then the oscillations have to be rectified, so that DC pulses can be channeled through the transformers in the big cans and converted to high-current DC output. The rectifying-diode, together with the coils L1 and L2, and the capacitors C5 and VC4 are one of many configurations that will create the oscillations and rectify them. The rectifier must have a heated filament to provide cathodic electrons, and its efficiency is greatly improved by being inside a vacuum enclosure.

A reed switch is triggered by magnets in the disc rim to provide a timing pulse to indicate the disc's rpm.

What makes this machine 'over unity' is its ability to *magnify* its basic input - and this it does by creating and utilizing an electron cascade effect, which ionizes and polarizes the air in the environment surrounding the two horseshoe-magnet configurations (basically by oscillating the dielectric blocks with high frequency high voltage pulses), the air molecules are accelerated toward the blocks at high speed to cause them to collide with other air molecules to dislodge free-electrons, which are also accelerated to free up more electrons by further collisions, and so on and so forth. The resulting avalanche permeates the surrounding environment.

In each Big Can is a step-down transformer of multiple pancake coil windings especially coupled to a toroid-magnet core so as to intensify the field and produce divided voltage outputs which charge up separate 'condenser-grilles', which build up the charge for output. Electrostatic shielding in the big cans is provided by the outer perforated aluminium cylinder and magnetic shielding is provided by a solid copper cylinder.

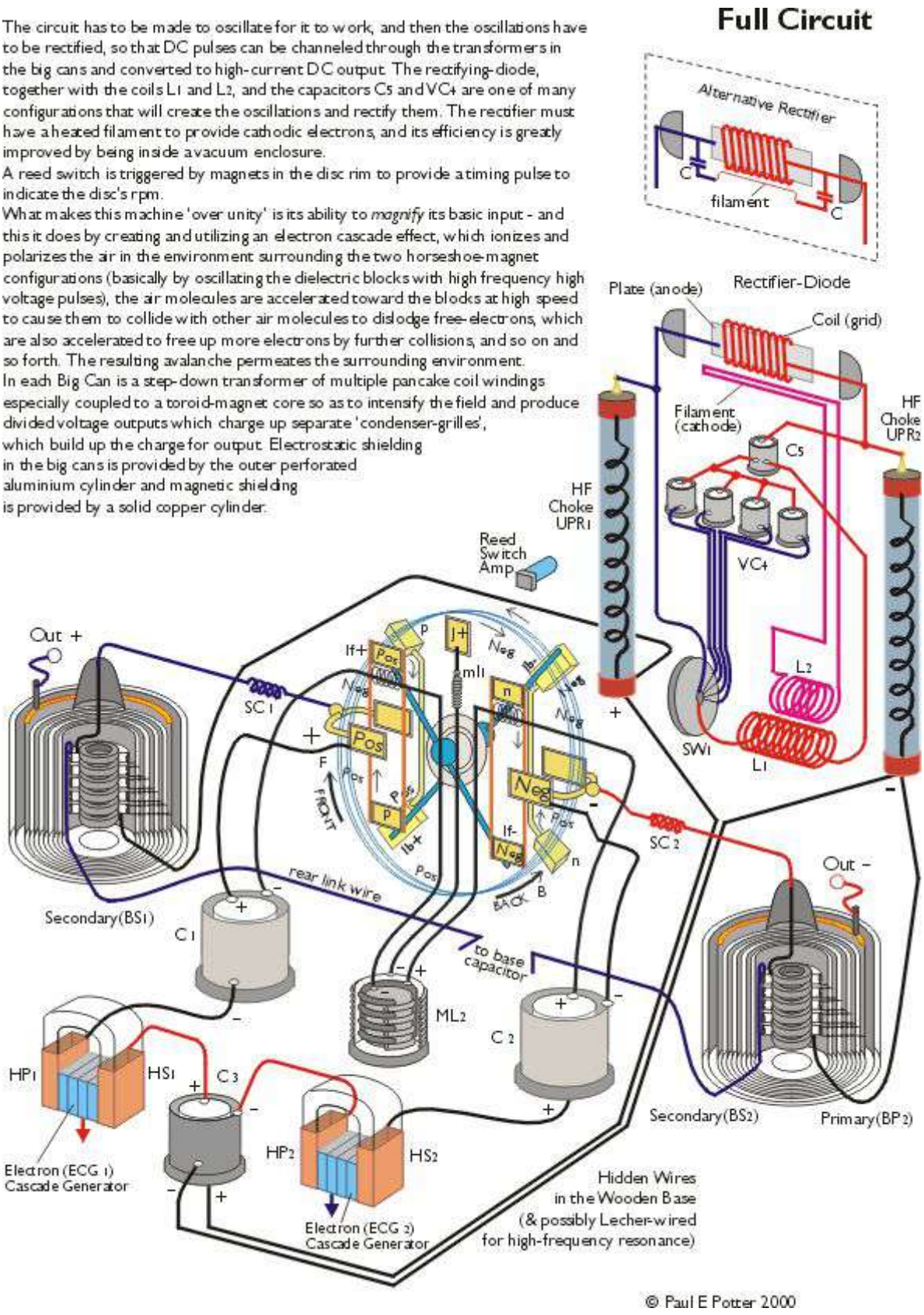

Back-Engineered Methernitha --- Notes

Note 1 --- For more information on the Pidgeon machine see "Electrical Influence Machines" by John Gray, 1903 p. 206 & "Philosophical Magazine" Dec 1898, p. 564, and of course the Pidgeon patents.

Note 2 --- See "Modern High Speed Influence Machines" by V.E. Johnson, 1921, p. 76. Johnson was not only a researcher of electrostatic machines but was also an innovative constructor of them, and as such was keen to try any technique that made his generators more powerful than even the specialised Wommelsdorf multi-disc condenser machines. This book is an absolute must for those who wish to work in this field. Another 'must' is the website of Antonio Carlos M. de Queiroz (http://www.coe.ufrj.br/~acmq/electrostatic.html) which is absolutely full of information about (and with links to) present-day developments in electrostatic machines.

Note 3 --- See "Self-Excited, Alternating, High-Voltage Generation Using A Modified Electrostatic Influence Machine" by M.Zahn, et al., American Journal of Physics, Vol 42 (1974) p. 289.

Note 4 The Methernitha designers have taken a basic Pidgeon electric field system and added a few modifications of their own, partly to lock a certain polarity of charge to a certain area so as to stabilise it, and also to boost certain areas with charge. As in their use, for example, of an extra field plate located at the top-centre in front of the front disc (just under the rectifying valve), note also that this plate, or antennae key, is indirectly coupled to the rest of the circuit, via a coil setup. Much the same occurs with the two plates slightly below it, these plates are connected to a brass terminal which connects to a copper wire that goes down and winds in a coil shape around a hollow plastic tube, and inside the tube will be another wire or small coil that draws off the electric charge. So these three plates are using not direct connection but induction to get their charge.

Note 5 ------- By looking at how each of the photographed machines have been constructed you can see that these are high quality crafted structures. I would think each would start off as sub-assemblies fitted together by pairs or small groups of members, those sub-assemblies of wooden base, big cans, perspex framework, discs with bearings and axles, when completed would be passed on to the electrical engineers of the community who would then fit the wiring connections, vacuum tube rectifier and make sure that not only did they work but that they looked like a work of art.

Note 6 --- The Fleming valve had been around since 1905 and while it progressed to the thermionic valve and audion, by 1922 the ‘Pearson and Anson Effect’ was discovered whereby oscillating currents could be produced with a resistor, capacitor and thermionic valve coupled together.

Note 7 --- See US Patent 1,540,998 (9 June 1925) Conversion of Atmospheric Electric Energy by Hermann Plauson. He also wrote a book of the subject titled "Gewinnung und Verwertung der Atmospharischen Elektrizitat" in 1920 in German (which is currently held in the British Library).

Note 8 --- Whilst some have seen the smaller 300 Watt machine’s discharger/rectifier quite open and not encased in a vacuum tube the vacuum tube models would be much more efficient and would waste less current. Also, the rectifier tube must have a heated filament (which on the 3KW machines can be seen as a glowing line running the whole length of the grid and coil assembly between the two black end caps, and in the films you can see faint flashes coming from behind the rectifier so possibly the filament is wrapped around the other side of the grid/coil assembly as well). Coolridge, back in the 1900’s, discovered that no discharge from the cathode to the anode would occur, even at 100,000 volts, unless the filament was heated (Physics Review, Vol. 2, Dec 1913, p. 418). Aluminium mesh will give off electrons quite readily and can be used as a cold cathode --- but a heated cathode offers the advantage of being able to control the oscillations.

Note 9 --- The two long upright tubes are without doubt choke coil assemblies in precisely the right place to slow down the current where it gets oscillated and rectified. In a choke the higher the flow of current the greater will be its resistance to that current flow. An even better form of choke will have some form of iron core inside it.

Note 10 --- I have come up with 6 different circuits for this oscillation section, some of which include small quartz crystals. (See notes 13 and 16 on frequency of oscillation). The black dial at

the rear of the 3kw machine is most likely to select a variety of capacitances so as to control the oscillations of the circuit, which in turn control disc rotational speed.

Note 11 --- The phenomenon of electrostatic motors has been well researched over the years (see "Electrostatic Motors" O. Jefimenko in "Physics Teacher" Vol. 9, March 1971, p. 121-9, and in "Electrostatics And Its Applications" by A.D. Moore (1973) p. 131-147; "Electrostatic Motors" by B.Bollee in "Philips Tech. Review" Vol 30 (1969), p. 178-194). The Methernitha Testatika generators (see a recent report by 30 engineers) auto-rotate, after they have been started by hand, by the same principles of these ES motors.

Note 12 --- J.G.Trump worked for the US Air Force and pioneered some highly efficient electrostatic machines around the 1960's (see"Electrostatic Sources of Electric Power" in "Elec. Eng." 66:525, June 1947; and "High Voltage Generation in Space:The Parametric Electrostatic Machine" in "Progr. Astronaut. Rocketry" (vol 3 --- Energy Conversion for Space Power) 1961 p745).

Note 13 --- Although the 'Linden Experiment' was thought to register a frequency of 80-140 MHz this does not necessarily mean that the Methernitha generators would oscillate at that rate also. Such a frequency seems unnecessarily high.

Note 14 --- See "Plasma --- The Fourth State of Matter" by D.A. Frank-Kamenetskii (1972) pp10, and Dr.Patrick Flanagan's US patents 4,743,275 (May 10, 1988) and 4,391,773 (Jul 5, 1983).

Note 15 --- The effect is very similar to the converging forces in a non-uniform field, the oscillating perspex blocks become one 'electrode' and the surrounding air in the room becomes the opposite 'electrode', and by the processes of electrophoresis and dielectrophoresis the electrically charged particles in the air (the electrons and negative ions) are drawn toward the central electrode, which in this case is the perspex block assembly (see "Nonuniform Electric Fields" by Herbert A. Pohl in "Scientific American" (Dec 1960) p. 107-8). I am much more inclined to believe that the ingenuity of the design of these types of machines comes from physicists and not electronic engineers.

Note 16 --- Dr. Flanagan actually uses the electron field generator in his own special ionizer (see Method of Purifying Air and Negative Field Generator US Patent 4,391,773).

How does an electron cascade generator work, I would think that while you have an alternating electron movement (and Dr. Flanagan reckons this effect occurs with a high voltage field alternating at above 20 KHz) at the metal electrodes, the perspex blocks sandwiched between them would transfer the electricity not through their mass but around it, as surface charge --- actually in the layer of air right next to the insulator's surface. Its the same principle as dielectric absorption - the perspex blocks don't discharge themselves fast enough to keep up with the alternating voltage and so they accumulate more and more charge --- until it forms as a layer of charge on the insulator's surface. This means that at a high enough frequency the surface-air molecules polarize, with the more mobile electrons separating from the slower bulks of those molecules and while the electrons get thrusted back and forth a secondary layer of (slower) positive air ions develops, and so on, and the process of high voltage high frequency polarization triggers the electron avalanche effect.

In the event that the perspex blocks are indeed ELECTRETS (as free-energy researcher Geoff Egel and others suggest) I would think that they would work in a similar fashion to the above process, of dielectric absorption that charges up the blocks before they produce the cascade-effect. Because in the electret the electrons charged into the perspex/plastic, and the positive ions, would still be manipulated by the reversing electromagnetic field in such a way as to orientate (as with dipoles) back and forth, to eventually reach the point (if the whole circuit is tuned properly) where they would attain resonance with the immediate air surrounding them. And if this effect is similar to an inductance then possibly a back-emf will result also, to increase the output voltage. Either way I believe the effect will still be an electron cascade through the environment and the product of this

oscillating output (at the blocks) could similarly be drawn off and accumulated in the multi-layered base capacitor network.

I would suggest that a test program to find the best type of blocks would be; One --- try different types of plastic/acrylic/ceramic materials for the blocks.
Two --- try different methods of electrifying the plastics (as with electrets). Three --- try plastics doped with semiconducting particles. Four - try plastics doped with paramagnetic particles. Five - try hollow plastic blocks containing an electrolytic fluid. More information on plastics will be found on the Electret vs Dielectric Absorption Page.

Note 17 --- There are several definitions of Bifilar, one where the wires cancel out their magnetic fields, and one where the wires are wound to ensure a tight low-loss magnetic flux coupling, in this case you need all the magnetic flux you can get so it must be the latter --- See "Transformers For Electronic Circuits" by Nathan R. Grossner (1967), p. 224 etc.

Most commonly used magnetic metal is Mumetal, which is an easily saturable magnetic material, routing magnetic flux through it rather than in the surrounding air, so as to enhance the mutual induction between the two coilings of red wire around the horseshoe legs.

Note 18 --- So that the machine's output voltage doesn't drain away when it is connected up to a large load, what is needed here is a Pulse Forming Network (or artificial delay line). "Such a network is an improvement on simple capacitor storage because of the cascading action from one capacitor to the next along the chain. At the beginning, all capacitors are charged to the same voltage but as soon as the first one starts to loose voltage, the one behind it is then free to discharge into it. This topping-up action, which trickles down the network from capacitor to capacitor, is the mechanism by which the voltage across the output terminals tends to hold onto its original level." (see "High Energy Discharge Systems" A.P.Stephenson, Electronics Today International, March 1992, pp. 24-26).

Note 19 --- When voltage of a high potential and high frequency flows along a wire it does so on the outer surface (called the ‘skin effect’) and so the Methernitha would use thick wiring or even 1/8" tubing to connect its circuit.

Note 20 --- Two references for shielding are: "A Shielded Loop" by S. Goldman in "Electronics" Vol 11 (1938), pp. 20-22; and "Measurements in Radio Engineering" by F.E. Terman (1935), p. 218 & p. 341.

Note 21 --- For information on maximum voltage in the center of a secondary coil see "A Handbook of Wireless Telegraphy" by J. Erskine-Murray (1913) p. 42; and an article called "Dielectric Hysteresis at Radio Frequencies" by E.F.W. Alexanderson in "Proc. I.R.E., Vol. 2 (June 1914) p137-157. For Van de Graaff's transformer see US patents 3,323,069 (May 30, 1967) and 3,187,208 (June 1, 1965). These patents were not just for a Van de Graaff high voltage generator, they were for a special system devised by Van de Graaff long after his generator had been in use to convert static electricity into current electricity. This system may be a little too complicated for the Methernitha but, nevertheless, the principles he used for multiple primary / secondary windings may be of some interest.

Note 22 --- Dr. Flanagan modified his insulator blocks, made of resin, by doping them with paramagnetic granules (such as silicon carbide) to enhance even more the electron cascade effect; which is an idea that the physicist Thomas Townsend Brown first experimented with (by using lead oxide granules) in his US Patent 3,187,206 (June 1, 1965) to good effect. The surrounding air could also be ‘enhanced’ in similar fashion to polarise it's electric charge and improve its side of the performance (for those interested in the ‘physics’ of this see an article by W.A.Douglas Rudge "On Some Sources of Disturbance of the Normal Atmospheric Potential Gradient" in Proc. Royal Soc. A, Vol. 90 (1914) pp. 571, etc).

Note 23 --- Some other generators with similarities to the Testatika machine are the "Electrostatic Energy Field Power Generating System" invented by William W. Hyde (US Patent 4,897,592 of Jan 30, 1990) is a rotor/stator variable capacitance machine capable of producing 300 KV. Other such generators are; "Parametric Electric Machine" invented by Ferdinand Cap (US Patent 4,622,510 of Nov 11, 1986) which has a series resonant (LCR) circuit structured into it so that it oscillates --- and indeed operates AT RESONANCE to ensure a high output; "Electrostatic Generator" invented by Dan B. Le May, et al. (US Patent 3,094,653 of Jun 18 1963) is a very ingenious system of variable capacitance; the "Electrostatic Machine" by Noel Felici (US Patent 2,522,106 of Sep 12, 1950) is a good standard which utilizes a valve rectifier; and the "Electrostatic Generator" by William S. Spencer (US Patent 1,415,779 of May 9, 1922) is an early rotor/stator generator which transferred its electric impulses through a transformer to produce a higher current output.

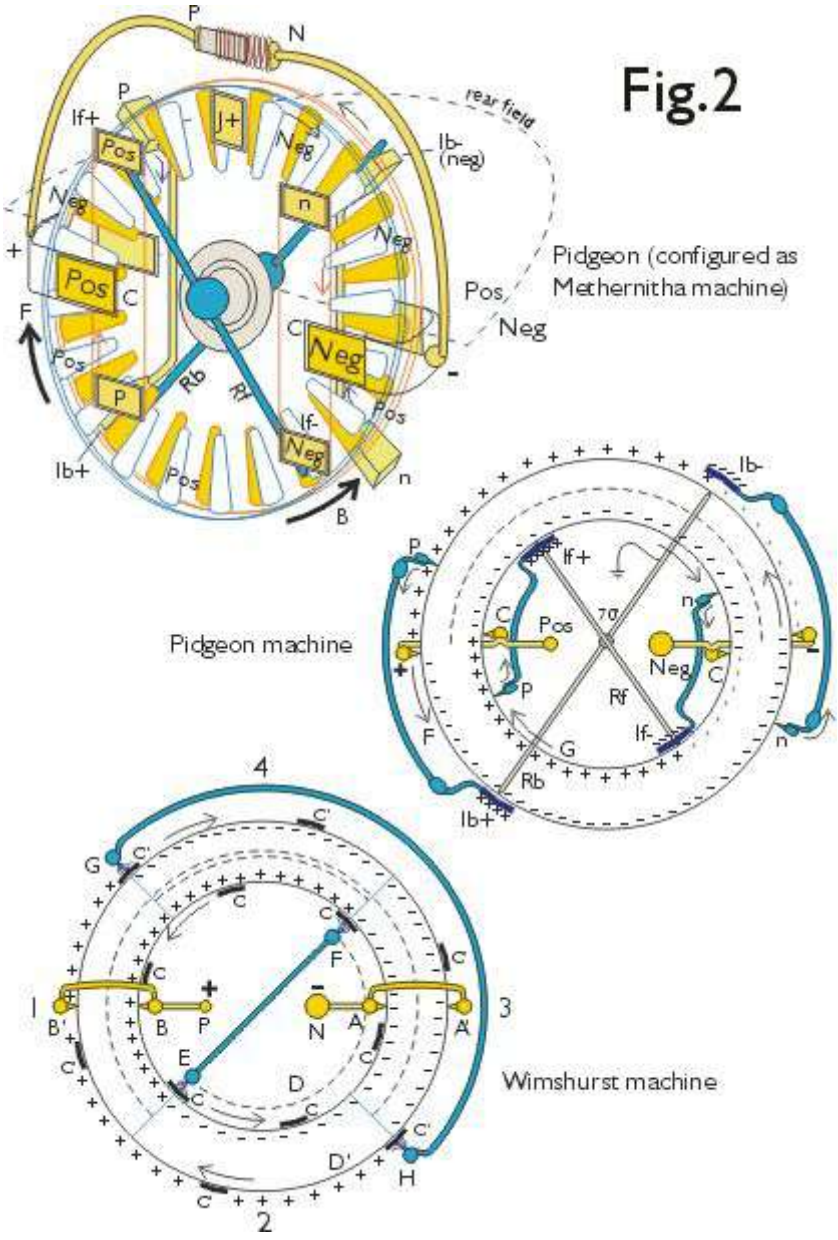

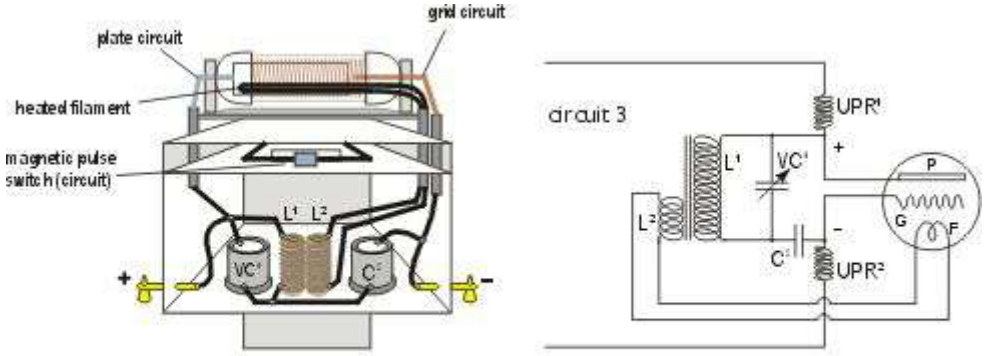

Fig. 4 - Tower Circuits

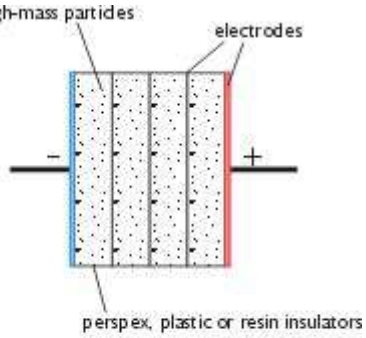

Fig. 6 - ECG Doped

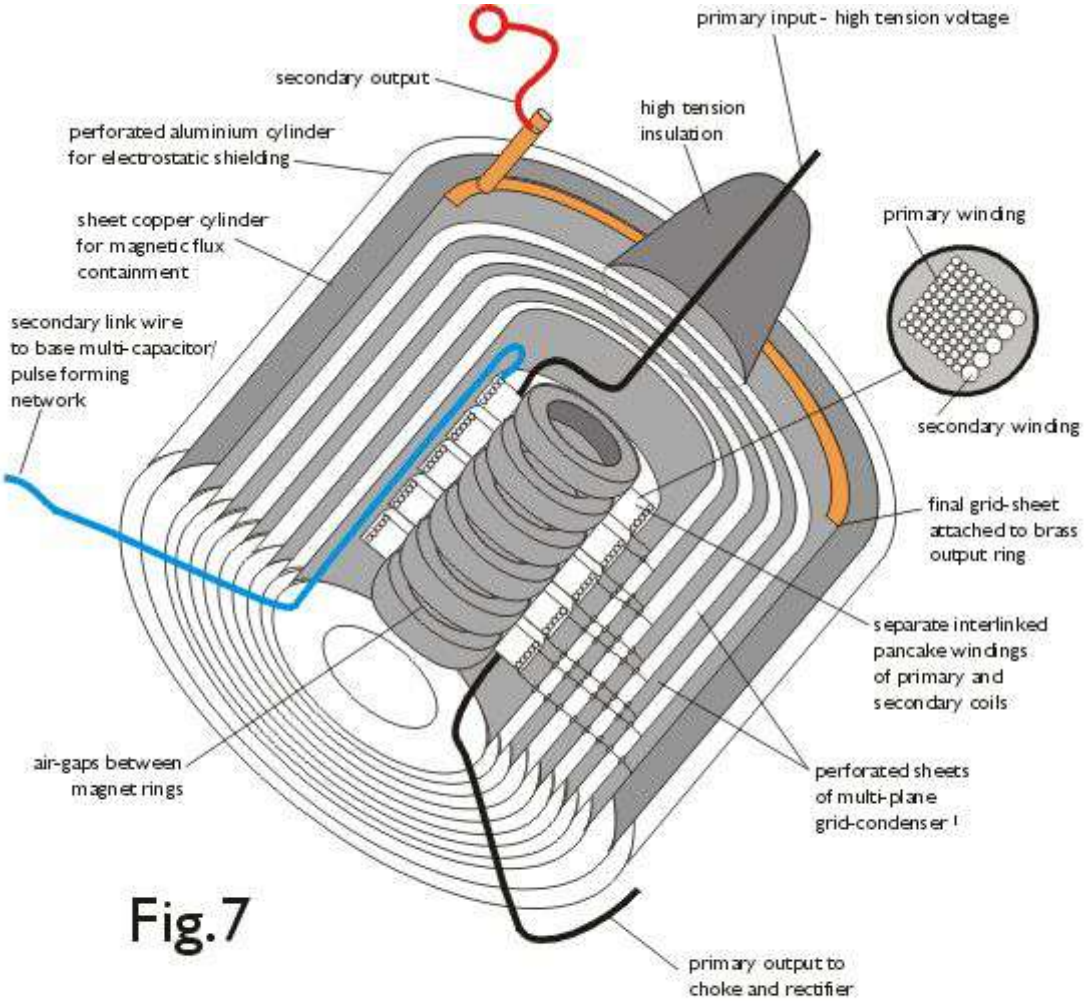

Fig.7

! In the Testatika-Distatica Video it has... "By means of **grid-condensers** the energy is stored and it is then uniformly discharged, at the same time reducing the high-voltage and building up power with additional devices."

"Principle Experiment"

by

Paul E. Potter

With respect to the 30 engineer's report (of 1999) the 'principle experiment' was set up in such a way (see diag 1) that by swivelling the cross-piece over two other plexiglas blocks a current was transferred into two capacitors. Possibly when someone grabs hold of the swivelling cross-piece they transfer some static electricity from their body to the grilles of the cross-piece which, when vigorously turned back and forth will initiate a transfer of electric charge to the two stacks of blocks below them attached to the base. This may either be because anyone walking over a carpet or wearing man-made fibres will already hold thousands of volts of electrostatic charge - which will be enough to 'prime' this apparatus after touching it, to get it to work, much the same as when a rotating influence machine has to be primed with an electric charge before it will work; or, as many researchers have surmised already, that the plexiglas blocks glued to the swivelling cross-piece had been charged up with electricity as an ELECTRET.

The use of mesh around the cross-piece guarantees a variable capacitance to the moving arms --- and as these are moved quickly over the base blocks (again, alternated with mesh and Plexiglas) an amount of electric charge will be transferred to them EACH TIME the arms go backward-and-forward over them. Electronically, you have one variable capacitance acting upon another variable capacitance - which is why Baumann said that if metal foil were used instead of the mesh it would not produce the same effect.

What happens next is called "dielectric absorption", and the following extract, from "Dielectrics" by P.J.Harrop (1972) pp71, will explain;

"When a given dielectric [i.e., plexiglas] has a field put across it, and this field is then removed, the electrodes are briefly shorted out (not enough for all the ions and particles to relapse back) and the device left on open circuit one finds subsequently that it has partially charged up again.

This is due to the slow-moving charge carriers remaining in position. It can be a frightening phenomenon with practical dielectrics since a person who has briefly discharged a charged insulator may subsequently touch it and be severely shocked." Some dielectric materials being more prone to this effect than others, and so obviously some experimentation will be needed to choose the best perspex, plexiglas, plastic, or acrylic materials so as to take the most advantage from this dielectric absorption effect.

Once the blocks are being charged up the electric charge simply flows into the two interconnected capacitors and accumulates.

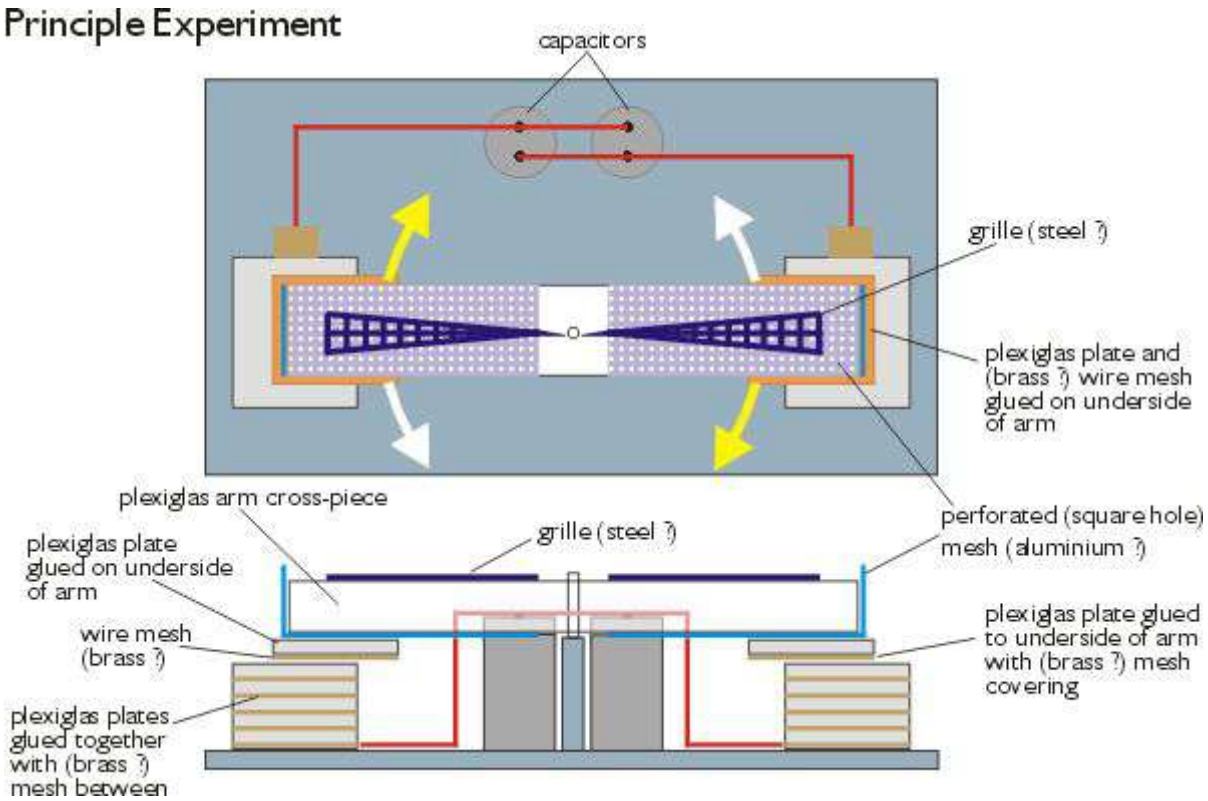

Linden Experiment ~

A look at the only available diagram of the Linden experiment (see diag 2) shows a horseshoe magnet coupled to what seems to be a closed-ended wire. It can also be seen in this diagram that the wire coils around the magnet are sufficiently spaced apart so as to provide capacitance (between each coil of the wire) in the circuit. So, with capacitance, coils (for induction), and magnetic flux, you have all the ingredients needed to make an oscillating circuit --- provided there is a supply of voltage and some sort of interruption mechanism - then you have a circuit that will resonate. And

this leads us back to that oft repeated question --- is the block used in the Linden Experiment an electret. The first person to PUBLISH how they have duplicated this experiment will be the one to answer that question...

But there is something wrong with this diagram --- the resonant frequency of this simple circuit --- depending only on the values of inductance and capacitance included in the circuit would consequently enable it to oscillate at only a few kilohertz at best. No circuit of capacitance/inductance can be made to resonate at such a high frequency as claimed, not even if it included any form of quartz crystal. If, as the diagram says, it resonates at 140 MHz then there must be a Lecher wire system (the running of two conducting wires in a parallel line, about a foot apart or less, for several feet) to make it resonate at such a high frequency. It would seem to me also that a required modification of the Linden Experiment diagram would be to put a different metal into this circuit where the wire is said to be "closed-ended", say for instance a zinc plate, then there will be a contact voltage established between the copper wire and the zinc plate. Such a voltage would start the circuit resonating, for the reasons stated above.

And as with the Tini setup if a block comprising two metal plates separated by a suitable dielectric material (such as plexiglas) is placed in an oscillating electric field the electric charge on the metal plates will permeate into the dielectric, and for the same reasons as detailed above in the Principle Experiment, will temporarily accumulate voltage because of dielectric absorption. As I have already said elsewhere there is a great similarity between the phenomenon of the Testatika horseshoe blocks (and the Tini setup) and the principle behind Patrick Flanagan's Electron Field Generator which energizes an electron cascade mechanism throughout the immediate environment.

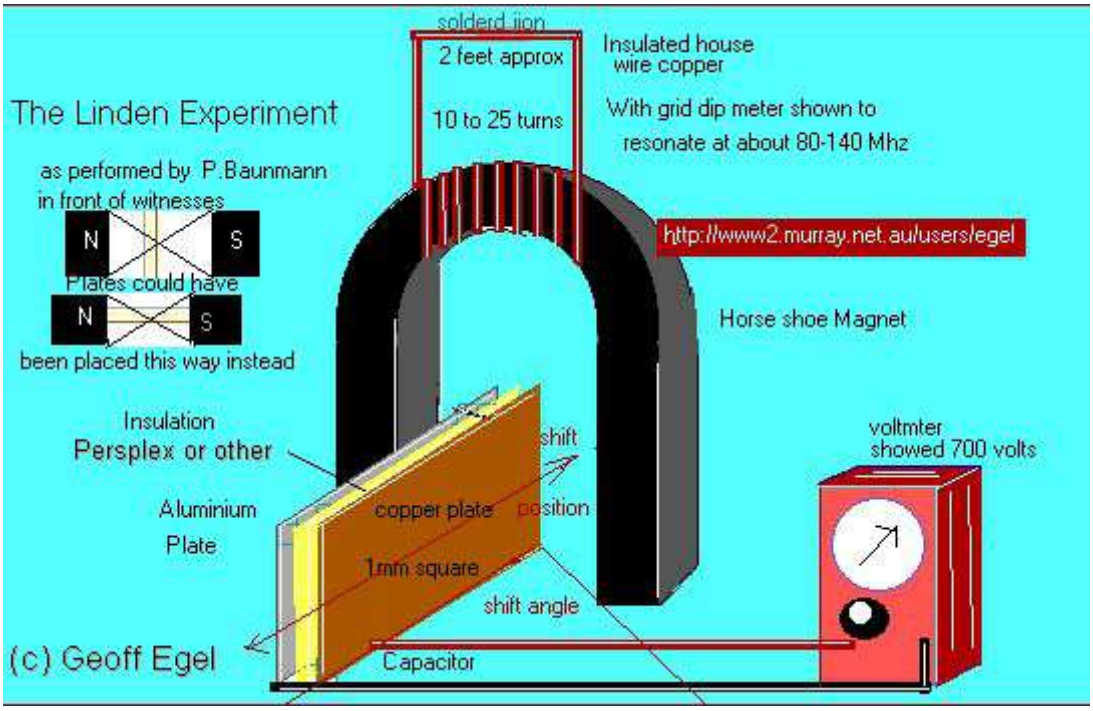

Geoff Egel (1997) --- http://www2.murray.net.au/users/egel ~

Rectifier Circuit ~

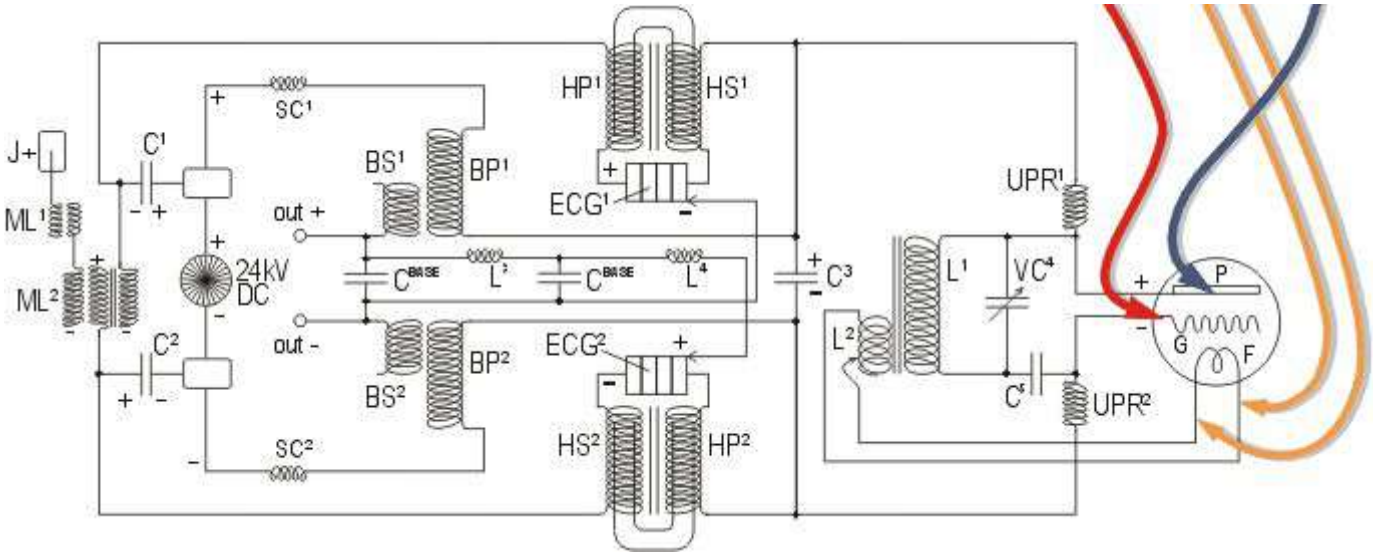

The rectifier forms the basis for Testatika's operation. For whilst the LC circuits L^1, VC^4, UPR^1, UPR^2 and C^5 set up oscillations from the generator's high voltage output the rectifier controls the oscillations to provide positive dc pulses (which are then directed through a step-down transformer BP^1/BS^1 and BP^2/BS^2), to supply power at a higher current rate and lower voltage.

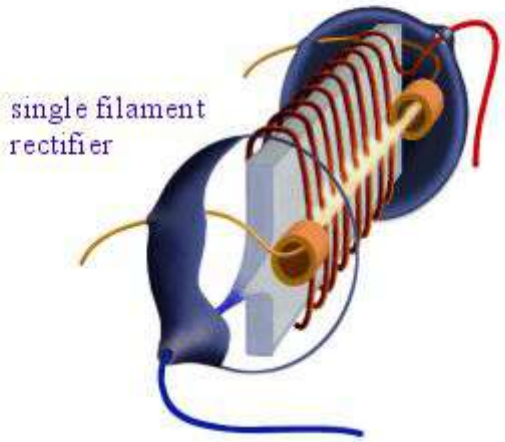

Unidentified European Report ~

"Believe or Not, Here It Is!"

The first really running "free energy" machine coming from Switzerland, Europe. It was developed over a 20 years Research period by a religious group called: METHERNITHA. This group lives in CH-3517 Linden, Switzerland. The inventor of this superb machine, Mr.Paul Baumann claims, its running principle was found by studying the lightning effects from nature.

And here are the facts :

* Testatika is an influence-type Wimhurst machine which runs on it's own energy, once started by counterclock revolving it's 2 dics by hand !!!

* Testatika not only runs on it' own energy, but produces also a huge amount of excess power, at least 3 KWATTS of power! That is enough to supply a one-person apartment with one machine!

* The machine you see during this demo-animation is only about 70 cm wide, 40 cm deep and about 60 cm tall !

* It delivers DC-Voltage ranging from 270 til 320 Volts, only depending on the dryness of the air! At this voltage it can supply at least 10 Amperes of DC-current !

* Testatika is not a perpetuum mobile, but an energy machine that collects it's huge amount of "FREE" energy from the charged and ionized air particles. But there are still some technological tricks implemented to overcome the normal drag-resistance of a conventional Wimhurst machine, which is still the secret of the Methernitha group !!!

When will this technology be available for everyone?

The Testatika machines, (there already exists also some smaller units which only deliver about 200-300 Watts) are not yet mass-production type models! They are still laboratory prototype units, although they are build with a very good craftmansship !

For more info contact directly:

METHERNITHA, CH-3517 LINDEN, Switzerland
TEL.-Nr.: ++ 41 31 97 11 24

The pictures are from some photos and from a video-tape Methernitha sells. It shows the machines (also the smaler ones) and explains also Methernitha's spiritual aims. The tape has a running length of about 40 minutes and is really worth looking at it! It is also available in VHS-NTSC and American language. It also shows Methernitha's earlier research developments like huge wind generators.

With the Testatika there is no fraud, hidden batteries or any other hidden energy source. It is really running! They already have the technology of ten years ahead! No more oil, no more pollution, no more atomic waste products, no more hunger in this world! This is the machine the mankind has dreamed about for centuries. Now it has come true!

More information about the Methernitha machine is also available in the German magazine *RAUM & ZEIT*, issue Nr.40 (8).

Jean L. Naudin Labs (4 February 1998) ~

"Testatika Generator and Over-Unity"

by

Cyril Smith

Having read Nelson Camus' article purporting to "explain" the Testatika over-unity generator (http://members.aol.com/overunity2/nelson/testatic.htm), I am of the opinion that the real explanation is hidden amongst the 19th century electrical mumbo jumbo which makes up much of the machine (Leyden Jars, Horseshoe Magnets, Wimshurst Generator and so on). From the

description of spiral-wound foil capacitors containing radioactive material and placed within current carrying coils it strikes me that perhaps the real energy comes from Beta particles (fast electrons) absorbed into the electrical circuit.

To extract energy from Beta particles it is not just enough to capture them. Clearly this will result in a current flow according to the capture rate, but current by itself is not power. The kinetic energy of the particle must be captured and this will result in potential difference or voltage. If a Beta particle enters a thin foil conductor normal to its surface and is captured, then the potential difference associated with giving up its kinetic energy can be expected to occur across the opposite faces of the foil. If however the Beta particle were turned so as to enter at a shallow grazing angle to the surface, not only would the probability of capture be increased (since the particle will travel further within the material) but the potential difference will occur along the length of the foil. Beta particles travelling even at relavistic velocities can be turned within short distances by relatively weak magnetic fields, so the concept shown in the following Figure suggests itself.

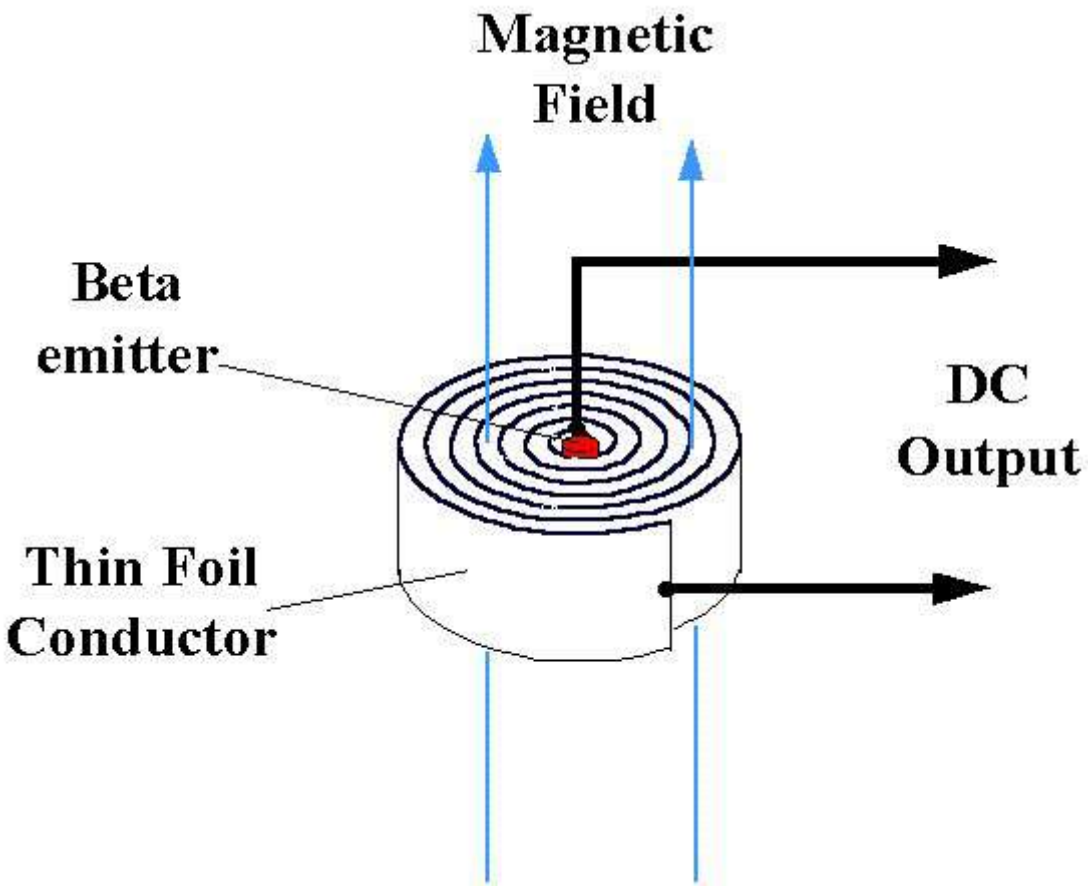

Methernitha Statement of Purpose ~

"The Research Work of Methernitha in the Field of the so-called Free Energy"

Ever since the foundation of Methernitha there existed a department for research, development and electronics, which was concerned with the problem of alternative energy sources, namely with technologies, which were suited to exploit the inherent forces of nature and thus to unlock sources of energy without disturbing natures ecological balance in any negative way. Any technology man invents should serve him in short as well as in long terms, and this condition is not fulfilled as soon as it opposes nature in any way.

This team of research within Methernitha works completely autonomous and is financed out of the co-operatives own resources, without any outside support.

The efficient utilisation of wind energy was one of the first objectives of Methernitha's research program. At the beginning generators with special excitation were developed, which allowed to load the cells of accumulators even at low RPM at times when there are only moderate air movements.

Utilising the kinetic energy of water currents was another field of interest of the development team, but it was pursued more as hobby. The key problem was here to transfer the slow revolutions of the waterwheel to an extent that the excitation threshold of the generator could be surpassed by a minimal loss of energy.

Also solar cells and solar heat collectors attracted the attention of our researchers since a long time. But since in these fields other institutions have attained outstanding results, Methernitha started, and this was already more than 30 years ago, to concentrate its efforts on lesser known and even generally unknown sources of energy. The result of this scientific work is the Thestatica machine.

The question arises: How it comes, that Methernitha, nothing more than a private organisation, could invest so much time, engagement, perseverance and financial resources in this kind of research.

Research and development are integrated parts of the general idealistic concept of Methernitha. To make you understand these ideals and goals, we will now introduce you into the practical sides of this spiritual community Methernitha, as it functions as a co-operative of people, living and working together.

Linden is a calm village of farmers just as dozens of others in the region of the valley called Emmental. However Linden is also the home of a special form of human life, which is capable of attracting more and more people from all over the globe, and which has repeatedly caused astonishment through its excellent functioning, even in extremely difficult situations.

There is no doubt that the formation of Methernitha is also a good part of the life story of Paul Baumann. Through his extraordinary technical capabilities, but also through his astonishing practicable wisdom he opened relations to all kind of people with ideals and in many places, and pretty soon, the idea to form a co-operative enterprise took shape.

"In the name of the God Almighty" people of equal thinking gathered and founded a co-operative, which could serve as the economic basis of this spiritual community.

"We want to be a united group of brothers, and never separate however severe the burden may be", this was the solemn vow.

Renunciation of alcohol and smoking and the will to realise a harmonious community life without dispute and discord like in the original Christian communities were the prerequisites to become a member. For the members Methernitha is an ideal opportunity to lead a fulfilled life by practising charity.

A workshop was erected and soon, one house after the other grew on these premises. Also all construction was done out of own resources and solely with the savings from the common work.

Today Methernitha is a social model proving the quality of its ideals through its well functioning just more than forty years. The people working here are almost without exception members of Methernitha.

Not even the prospering development that took place over the following decades could impair or even suppress the global idealistic aims. On the contrary, everybody works in his own interest with diligence and great joy towards the erection and the support of their new homeland and according to the principle:

One for all and all for one!

With this word one can conquer anything. Also the ancient truths appear again and attain respect.

The people living here feel themselves as members of a family, like a group sitting in the same boat and proud, but also grateful proprietors of their own beautiful homeland, which they may shape exactly as they wish to. Evidently, this form of human social life can function only on the base of idealistic principles.

The question arises, how the realisation of a sincere religious philosophy of life may be brought in harmony with a successful economic management. It is not obvious at all, that this is attainable.

Nowadays there are many amongst us that are caught in the world-wide and dense network of social and economic dependencies and obligations and many also feel the confrontation with its problems.

One member of the economic directory has recently phrased this in the following way:

"The fact that all essential functions of Methernitha are fulfilled without any external force, driven solely through inner conviction, which causes everybody to help and take care of the other, this is for me the most astonishing effect which is produced by this form of living together. It seems to be a miracle."

Another miracle within Methernitha is the Thestatica, which is the result of more than 20 years of research.

This wonder machine is lurked from nature, nothing else. Nature is the greatest source of power as well as knowledge which man has, and it still conceals many secrets, which are only revealed to those, who approach and tie in with them with highest respect and responsibility.

To understand nature and to perceive its voice, man is obliged to experience silence and solitude, and it was there, where the knowledge about this technology was obtained.

For these reasons it was always a great concern of Methernitha to acquire properties, untouched by man as far as possible, be it in valleys or forests, in the mountains or ashore of lakes, where one could study nature, ones own being and the creator of all this universe in silence and concentration and without being disturbed.

The public never understood this properly, rather interpreted it wrongly as an act of seclusion, assuming we had to hide something unclean. We actually had --- and still have --- to take great troubles to realise undisturbed all the things we intended to accomplish.

Such undertaking in research and development necessitate considerable financial expenditures. Therefore we are quite often obliged to construct things with most primitive means and materials. What was thrown away by our affluent society, we collect and possibly set up with it a cornerstone in the discovery of new forces and truth.

We are fortunate in gaining the experience that paradoxically the most beautiful and useful results can be achieved by just using the most simple means. Never did we use any borrowed capital because we want to stay free Swiss citizens and do not want to be hindered or even bound in any way in the pursuance of our aims.

The two conterrotating discs generate an electrostatic charge. One disc represents the earth, the other the cloud. Using grid electrodes the charges are bound. After that they are collected by non-contacting so-called antenna keys and then sorted.

After being initially turned on by hand, the discs rotate by themselves according to the electrostatic laws about attraction and repulsion. A rectifying diode keeps the cycles in steady state. Otherwise the impulses of attraction and repulsion would accumulate and cause the discs to run faster and faster. The correct speed is of great importance and for optimal power generation the discs have to run quite steady and slow.

By means of grid condensers the energy is stored and then uniformly discharged, at the same time reducing the high voltage and building up power with additional devices. Finally the machine supplies a uniform direct current, which varies according to the size of the model. The machine furnishes about 3-4kW permanent output, depending on humidity, whereby the electric potential ranges from 270 to 320Volt. High humidity of the atmosphere prevents the build-up of electric potential. The drier the air, the better.

No doubt, through the so far achieved results one main objective has been reached, namely to prove that it is possible to use Free Energy. Nevertheless the research work is not yet completed.

To the educated physicist many a thing of this machine may seem impossible, maybe even crazy. Maybe he is also offended by the conceptions used to explain the whole. Only partly we could use the concepts of conventional physical terminology to explain and define only approximately the functions and properties of the various parts of the machine.

After all it will be necessary to create some more new concepts like the one we have already used before, when we termed the non-contacting collectors of electric charges as antenna keys.

This machine puts experts, which are just trained in conventional physics to a very hard test, because its mode of action is not explainable with the state of the art of officially accepted physical knowledge, or at the most only partially explainable. However also a trained specialist should remain free and independent in his thinking, and should avoid to be limited by the temporal framework of publicly admitted knowledge in any science.

It has to be remembered that the established science was already many times forced to change or give up some of its very fundamental concepts. Think about Galilee, to name only one example. Our human society almost condemned this man as a sorcerer and magician, just because he investigated and discovered a truth that seemed unacceptable by the established science of the days.

The book knowledge of any times is not wrong, but it is incomplete, and therefore allows to draw wrong conclusions.

We are part of a new area which brings to light many new facts and new knowledge. The clothes of nowadays science have become too tight and should be stripped off, just as the larva of an insect does with its skin. Only this will allow a true metamorphosis to take its course, and finally, at the limits and at the destination of all worldly knowledge, an universal and unlimited spiritual science, radiating and beautiful, just as the completed imago of an insect, may give its blessings and benediction to a renovated humanity.

To ever reach there, a universal development of man has to take place. This however is only possible when man becomes aware of his true role within the whole creation, and again learns to recognise his true tasks, because the whole universe functions within a strict and precisely structured order according to the will and word of the creator. Therefore also man should recognise and realise these universal laws that are valid within the whole and within every part of this creation.

The hard facts rather show how far man has left the divine order through his self willed and authoritarian way of action and that he has become the actual cause of all discord and evil on this planet.

Unfortunately the ruling bodies that should be responsible for the well-being of the people work too often with the target to make life more and more difficult and to render impossible every free spiritual development.

Instead of utilising the achievements of science and technology for the benefit and preservation of all form of life, they are abused carelessly and irresponsibly to destroy and to kill, and thus turn them into a curse upon mankind.

To change all this, the evolution of a new technology is not enough, even if it were the most ecological and ingenious. To change this present status one has to go much deeper down, to the root-cause of all this evil, and this is mans way of thinking, his state of mind.

The ancient divine commandments are still valid today and also show today the way and direction humanity should go, as clearly spoken by the prophet Mica:

God has told you what is good. And what is it that the Lord asks of you? Only to act justly, to love loyalty, to walk wisely before your God.

"Testatika-Distatica Machine"

(Transcribed from the Methernitha Testatika video by Paul E Potter)

"... The efficient utilization of wind energy was one of the first objectives of Methernitha's research program.

At the beginning generators with special excitation were developed which allowed to load the cells of accumulators even at low rpm, at times when there are only moderate movements.

Utilizing the kinetic energy of water currents was another field of interest of the development team, but it was pursued more as hobby. The key problem was here to transfer the slow revolutions of the water-wheel to an extent that the excitation threshold of the generator could be surpassed by a minimal loss of energy. Also solar cells and solar heat collectors attracted the attention of our researchers since a long time. But since in these fields other institutions have obtained outstanding results Methernitha started, and this was already more than 20 years ago [since 1960], to concentrate its efforts on lesser-known and even generally unknown sources of energy, the result of this scientific work is the Testatika machine of which most of you may have heard already.

The two counter-rotating discs generate an electrostatic charge. One disc represents the earth, the other the cloud. Using grid-electrodes* the charges are bound. After that they are collected by non-contacted, so-called, antennae keys** and then sorted [shorted ?].

After being initially turned on by hand the discs rotate by themselves according to the electrostatic laws about attraction and repulsion.

A rectifying-diode keeps the cycles in steady state, otherwise the impulses of attraction and repulsion would accumulate and cause the disc to run faster and faster. The correct speed is of great importance, and for optimum power generation the discs have to run quite steady and slow.

By means of grid-condensers* the energy is stored and it is then uniformly discharged, at the same time reducing the high-voltage and building up power with additional devices.

Finally, the machine supplies a uniform direct current which varies according to size of the model.

The machine furnishes about 3 to 4 Kilo-Watt permanent output, depending on humidity, whereby the electrical potential ranges from 270 to 320 volt. High humidity of the atmosphere prevents the build up of electric potential. The dryer the air the better.

No doubt, through the so-far achieved results, one main objective has been reached, namely, to prove that it is possible to use free energy. Nevertheless, the research work is not yet completed: To finish a model which can be handed out more or less to anybody and without any haphazards, also to non-specialists, much work and also time will still be needed.

Only partly we could use the concepts of conventional physical terminology in order to explain and define only approximately the functions and properties of the various parts of the machine. After all, it will be necessary to create some more new concepts, like the one we have already used before, when we termed the non-contacting collectors of electric charge as antennae keys**. This machine puts experts who are just trained in conventional physics to a very hard test..."

* The German original has gitter-condensers, with gitter defined as wire lattice, grille, grate.

** the original word used is tasten or taster, which means antenna, probe, key.

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Started prototyping receiver to go with Michigan Mighty Mite Transmitter

wandrson Jul '16

In August, there will be two classes where we build a small one transistor morse code radio transmitter. The second class still has four tickets available, so if interested email me to reserve your seat!

August 20th Build a Michigan Mighty Mite Transmitter

Sep 2016

1 / 2
Jul 2016

May 17

In preparation for a couple of classes in September, I started prototyping a matching radio receiver for that transmitter. It will be a very basic direct conversion receiver with crystal control to match the frequency of the transmitter. With luck I will have the prototype completed by the first class on August 3rd

While waiting for some parts, I started assembling the front end to the receiver on some scrap pcb material.

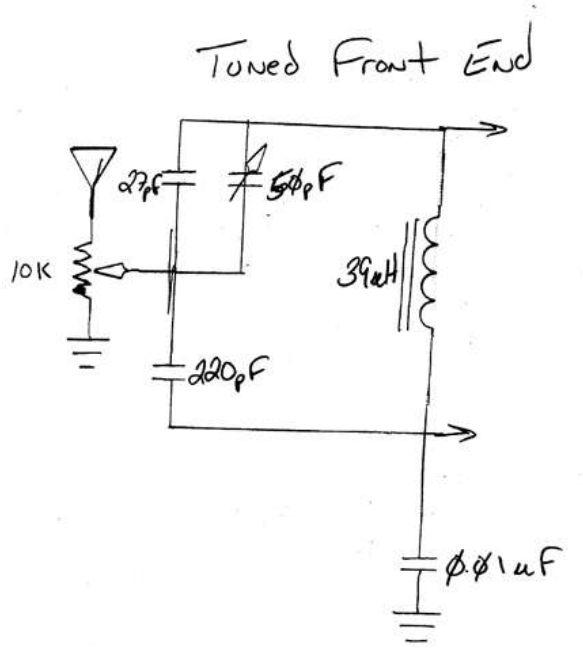

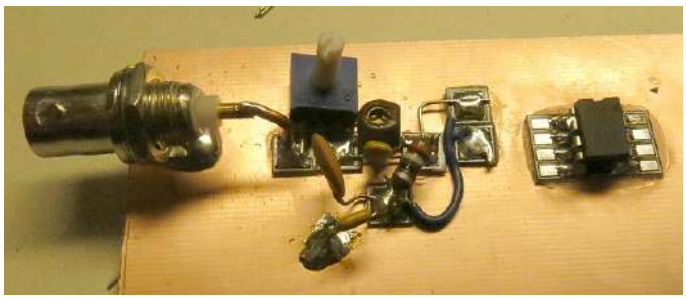

When working with projects like this, it is best to test (and if nescessary) fix the project in stages. So the first stage is a simple tuned front end (inductor-capacitor tank circuit). To ensure I did the math correctly, I plugged one of the crystals into a test oscillator I have and fed that into the antenna input and hooked up my scope to both the input and output of the tuned circuit as shown below.

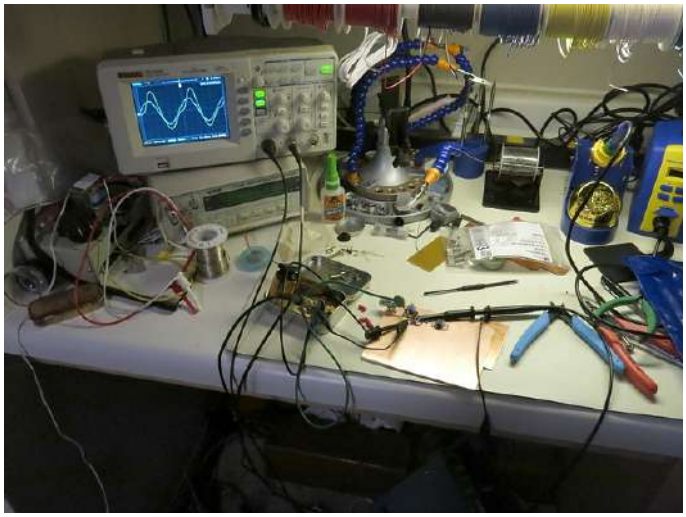

The circuit is aligned by using a non-conductive alignment tool (@artg_dms the Electronics committee could use a couple of sets of these) to rotate the little trimmer capacitor to maximize the amplitude of the output.

Here is a short video demonstrating the process:

If this kind of thing interests you, please sign up for the class (we can/will offer repeats of the transmitter class if there is interest) and come out to our monthly special interest group meetings for the Amateur Radio SIG!

Dallas Makerspace Show and Tell - August 2017

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zmetzing May 17

> wandrson:
>
> If this kind of thing interests you, please sign up for the class (we can/will offer repeats of the transmitter class if there is interest) and come out to our monthly special interest group meetings for the Amateur Radio SIG!

I'm interested. 😉

Another interesting design for a 80m/40m receiver is here:

http://www.schripsema.org/pa3hdf/projects/dc-receiver/dc-rx.html

THE BOY'S BOOK of CRYSTAL SETS

BY

W. J. MAY

BERNARDS (PUBLISHERS) LTD.
THE GRAMPIANS
WESTERN GATE
LONDON W.6

INTRODUCTION

Before any attempt is made to construct a receiver, it is necessary to examine the problems which surround the crystal set, so that the best can be obtained from any of the designs attempted.

Firstly, it must be understood that the crystal set as it is to-day does **not** provide any amplification. It relies entirely on what is fed into it via the aerial and earth system and gives a very faithful replica of the original transmission.

From this it will be obvious that the aerial and earth system must be as efficient as possible if the final results are to be in any way outstanding. This because these are the only means by which the signals are fed to the receiver.

Secondly it is necessary to understand the nature of the transmitted signal, then it will be easy to understand the working of the set and to appreciate the function of each of the components.

When crystal sets first became popular, very little information was generally available, at least, not in a form that school-boys could understand.

We all built sets of all shapes and sizes, with coil designs that had to be seen to be believed, but very few of us had much idea of how they worked.

I well remember the case of a cousin of mine who, in those days acquired a magnificent variable capacitor or condenser as it was then called, this instrument had a most impressively engraved dial of polished ebonite, brass vanes and nickel plated end plates. Having observed similar dials on several highly priced commercial receivers in the town, he at once ripped out the somewhat tattered coil from the family receiver and replaced it with this device. The profound silence which ensued caused considerable amazement and dismay until a better informed adult explained the mysteries of L and C to him. Readers of this manual, however, will be better informed and there is no risk of failure with any of the designs described provided the instructions are carefully followed.

The Signal

To commence, we will assume that an orchestra is playing in a broadcasting studio. Since the principle of radio transmission is electrical it is necessary to change the sound produced by the orchestra into an electrical equivalent. This is carried out by the microphone, which picks up the sound and changes it into minute electric currents.

As they appear at the output of the microphone they are too small to be of use and accordingly are passed through a high power amplifier. These amplified currents could now be transmitted, but unfortunately, as we shall learn, owing to the inherent nature of the signal in this state, transmission over any useful distance would be impractical.

When the music from the orchestra is transformed into electrical currents they are in the form of alternating currents, usually called A.C., that is they rise to a maximum in one direction, fall to a minimum, rise to a maximum in the opposite direction and then fall to minimum again. This process is repeated over and over again. One complete rise and fall in each direction is called a cycle and is drawn in Fig. 1. Every time a note is struck on a piano, vibrations are sent out which reach the ear enabling you to hear it. These vibrations are also spoken of as cycles, they rise and fall in intensity the same way as an alternating current. The number of cycles radiated by any given note over a period of one second are referred to as its frequency. Middle C on the piano sends out 261 cycles every second and is known as having a frequency of 261. The microphone also "hears" the note and in the case of middle C produces minute A.C. at 261 cycles. This can be drawn as in Fig. 2, the only difference between Fig. 1 and 2 is, that the time factor is given so that the frequency can be identified. The higher the pitch of a note the higher the frequency and the lower the pitch the lower the frequency. On a piano the frequency of the top note is 3515 cycles and that of the lower 27 cycles. Those of you who have listened to an organ in a concert hall will have noticed that when a very deep note was played, it sounded like a growl to the ear, but the vibrating fre-

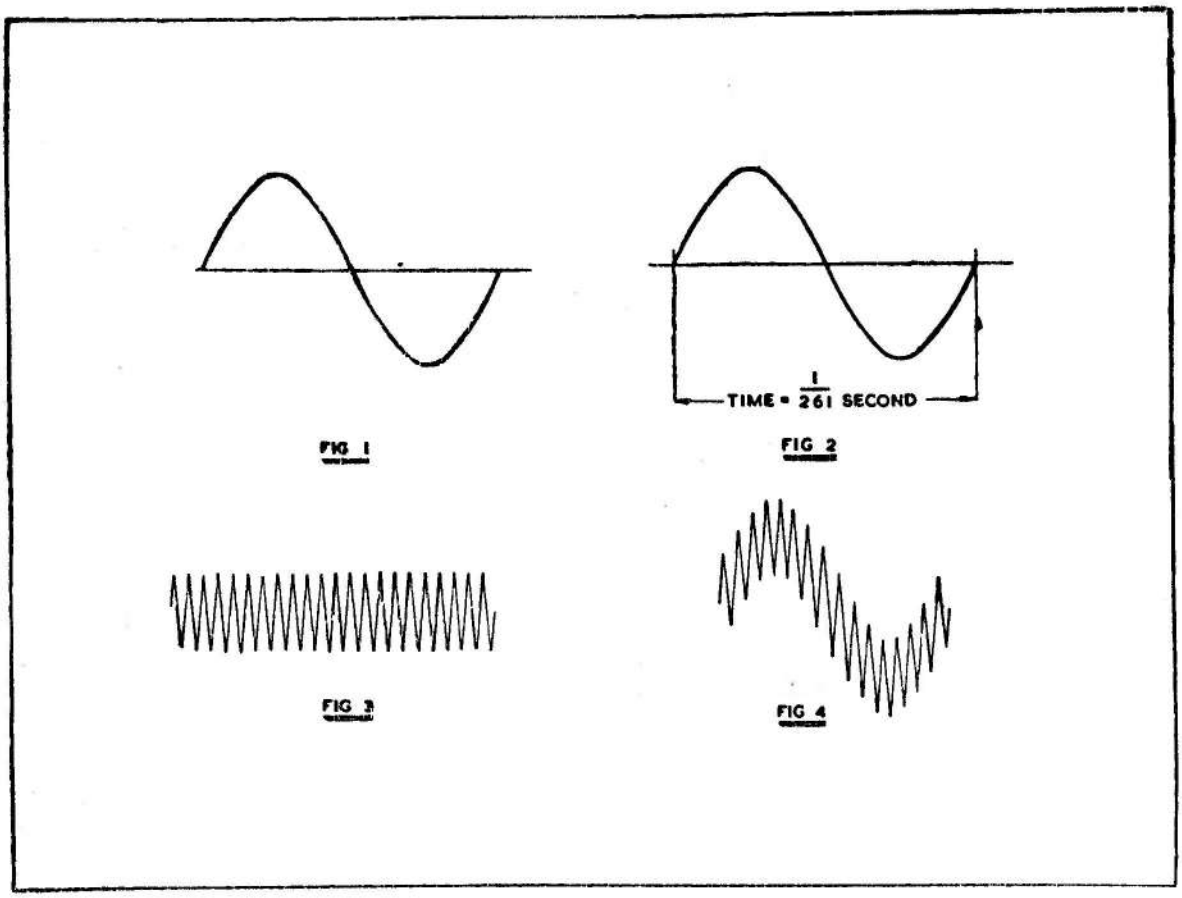

FIG 1

FIG 2

FIG 3

FIG 4

quency could be distinctly felt through the seat. Higher notes have too high a frequency to be observed in this manner.

The range of sounds which can be detected by the human ear are known as audio or low frequencies. From this you will understand that a low frequency amplifier is one which amplifies sound.

So that the transmitter will carry the programme over a useful distance it is necessary to radiate high frequencies. Now, as explained, the programme to be transmitted consists of low frequencies, and to overcome the difficulty, the transmitter generates A.C. of high frequency and combines it with the low frequencies. It will now be understood that the transmitted signal consists essentially of two different parts, a high and a low frequency content.

Fig. 3 gives a representation of the high frequency signal generated by the transmitter. In the case of the London Home Service, the frequency is 908000 cycles.

When referring to a high frequency signal on the medium or long wave-band it is usual to express the frequency in thousands of cycles, thus 908000 cycles becomes 908 kilo-cycles, which in turn may be abbreviated to 908 k/cs. It might at first be thought that by adding the low frequency or L.F. signal to the high frequency or H.F. carrier a form such as in Fig. 4 would result, such a combination is useless, and, so that the original L.F. content can be satisfactorily extracted by the receiver, the L.F. signal must vary the amplitude or output power of the H.F. signal as in Fig. 5.

It is in this form that the signal arrives at the receiving aerial. The aerial in itself is incapable of discriminating between one signal and another, and countless signals will be collected by the aerial at any one time. Many of these are too weak to be of use but the stronger ones must be sorted out since there is no point in receiving several programmes at once.

Fig. 6 shows the basic circuit of the input to a crystal. The coil L possesses a quality known as inductance, and the capacitor C, that of capacitance. If the coil had no capacitance whatever across it, all signals arriving at the aerial would be effectively short circuited to earth. As a matter of interest, it is impossible to obtain this state of affairs since even without any additional capa-

citor any coil **must** contain a certain amount of self capacitance.

By combining a coil and capacitor as in Fig. 6 a peculiar effect is observed, at one particular frequency, the signals are not short circuited to earth, but are developed across the coil. In other words the combined effect of L and C no longer provides a short circuit, **but only at one particular frequency.** If the value of C is altered the effect will be observed at a different frequency; likewise by altering L the frequency at which the effect will take place can be changed. There is a name for this phenomena, the frequency at which it occurs with any given L and C combination is known as the **resonant frequency.**

The values of the coils and capacitors shown in this manual have been carefully chosen so that resonance will be obtained at all frequencies where stations are broadcasting. Broadcasting stations work in bands of frequencies, those of major interest to crystal set constructors are the medium wave-band 1200 k/cs—600 k/cs and the long wave-band 300 kc/s—150 k/cs.

Usually a variable capacitor is used with a fixed inductance to cover one band and an additional coil switched in to increase the inductance to cover the other. In this way the L and C combination can be adjusted to provide resonance at the desired frequency of any given station. In other words you can **select** the station you want by varying C, that is turning the dial of the variable capacitor. This procedure is referred to as tuning. Having selected or tuned the required station it still remains necessary to change the form of the signal back to that of the original transmission. This process is called detection or de-modulation.

Examination of Fig. 5 will show that the signal has been duplicated, in other words, as it rises in one direction it also rises equally in the other. In this form the signal is useless since each half of the signal cancels the other, and if this signal is applied to a pair of headphones silence will result. Obviously some provision must be made to get rid of the unwanted half of the signal, and it is here that the crystal detector must be considered. This device will pass current in one direction only, ignoring any signal in the opposite direction, so that if the signal of Fig. 5 is passed through such a crystal, that of Fig. 7 will result. There is still the H.F. content to be reckoned

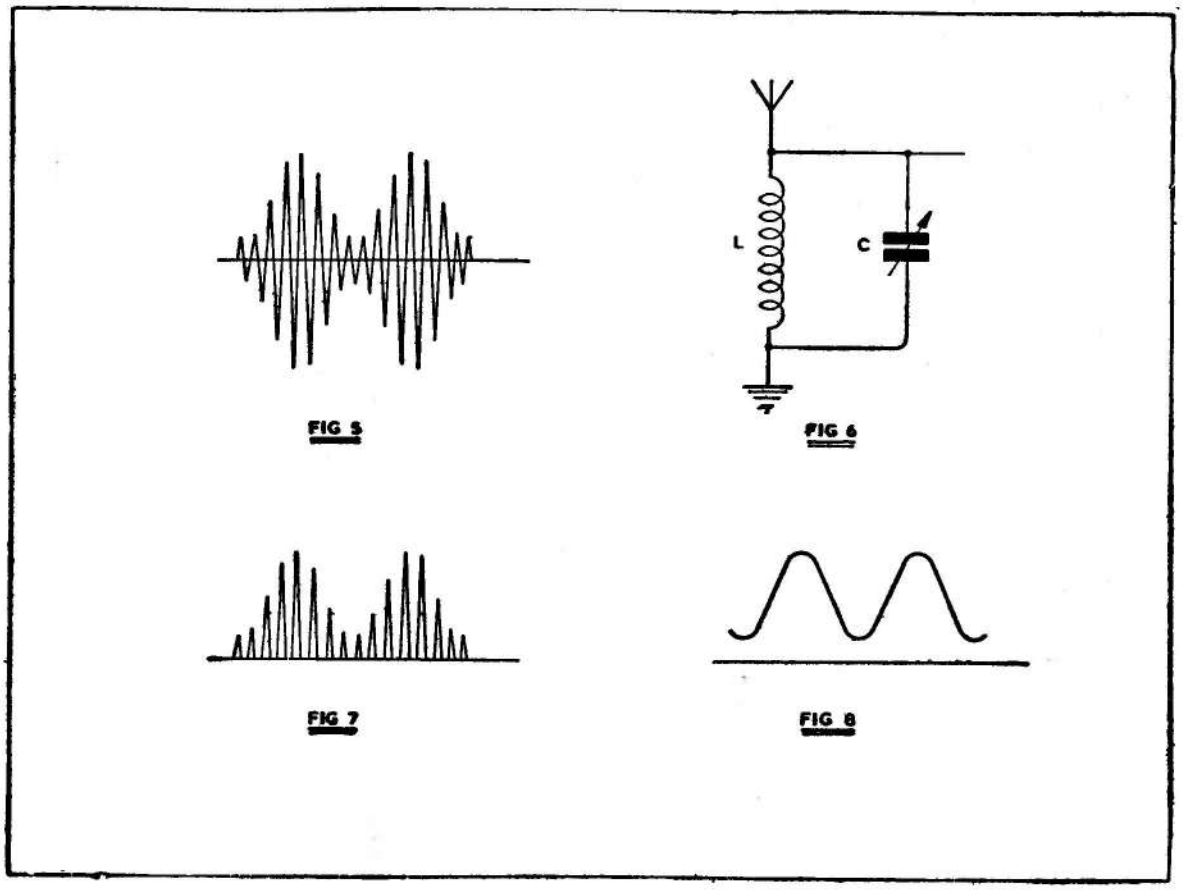

FIG 5

FIG 6

FIG 7

FIG 8

with, fortunately this is easily dealt with, a capacitor connected across the headphone terminals effectively disposes of this, leaving only the audio or L.F. content, as shown in Fig. 8. This audio content, which is a faithful replica of the original transmission is fed to the headphones. These in turn reverse the process of the microphone and transform the electrical currents into sound waves acceptable to the human ear.

Briefly then, your requirements are as follows:—

(1) A good aerial and earth installation, to make the most of the available signals.
(2) A receiver containing:—
  (a) Some form of coil and capacitor (L & C) combination to select or tune in the wanted station.
  (b) A crystal to get rid of the unwanted half of the signal (detection).
  (c) A fixed capacitor across the headphones to get rid of any remaining carrier.
(3) A pair of sensitive high resistance headphones.

Aerials

By this time the intending constructor will be able to appreciate the necessity of a good aerial. It is a point which cannot be over-emphasised. Assuming that you are in the fortunate position of being able to erect an outdoor aerial there are two main considerations, height and length.

One of the best that can be used is the inverted L shown diagramatically in Fig. 9.

It should be erected as high as is practical, every foot counts. The horizontal wire, that is the aerial proper, should have a minimum length of 60′ to which of course the length of the down lead is added. Where it is impossible to erect an aerial with an ideal horizontal length, a compromise must be effected.

Fig. 10 shows a three wire spreader aerial which gives quite a good effective length.

Suitable wire for a receiving aerial will not set any problems, stranded copper about 7/22 gauge is the best. 7/22 means that it consists of 7 strands of 22-gauge wire. This wire may be obtained covered, and for the present purpose is better than the plain or enamelled kind.

Note that insulators are used between the actual aerial wire and its anchoring supports, it is important that these are used, otherwise leakage will occur which will of course spoil its efficiency. Fig. 11 and 12 show how the wire may best be attached to two of the most common types of insulator available. Fig. 11 is of porcelain and is usually referred to as an egg insulator, whereas Fig. 12 shows a more modern (and more expensive) type in glass. If you are using the glass pattern, one is usually sufficient at each end of the aerial, but with the egg type two should be used. No doubt many readers will not be in a position to erect an out-door aerial, and must necessarily be content with an indoor installation.

The next best thing to a good out-door aerial is a replica constructed in a loft. If this form of construction is used, care must be taken when feeding the down lead to avoid close contact with the wall of the house. At the point where the lead feeds under the eaves, a length of rubber tubing can be used to cover the wire. The lead is fed through one of the small spaces left for ventilation purposes. A general idea is given by Fig. 13.

A less elaborate but quite effective aerial can be obtained by using a bed-spring. A length of 7/22 copper insulated wire is connected between the receiver and the spring. The spring should first be cleaned with emery cloth. Remove about 2″ of insulation from the wire and bind it tightly round the prepared spring. The joint may be covered with insulating tape which is obtainable from all electrical stores for a few pence.

Such aerials are quite popular since so many crystal sets are built for bedroom use.

When an aerial is required in the living room, the picture rail can be conveniently used. Insulated screw-eyes are fixed at intervals of about 3 feet along the rail, the wire is firmly anchored to one of them, and stretched right round the room until you arrive back at the starting point. By use of one of the insulated screw-eyes, the wire is secured and the down lead fed to the receiver. The idea is illustrated in Fig. 14.

Soldering

Before leaving the subject of aerials, a few words on soldering will not come amiss. Down leads on outdoor aerials should be soldered, and the same applies to loft types. Apart from aerial leads; earth leads and all the connections in the receiver will require soldering.

For the type of soldering necessary in radio construction an electric iron is the best solution. One of the small types marketed by Adcola or Henleys will be found admirable for the job. These are excellent for actual set construction but are hardly large enough for soldering the down lead to an outdoor type of aerial. Here the heat is dissipated much more quickly and a larger iron is required in order to get the solder to flow.

Ordinary irons which may be heated by a gas flame can be obtained very cheaply from most ironmongers' stores. Assuming the use of such an iron, first heat the iron until the copper bit is giving off a green coloured flame, the iron is now at the correct operating temperature. The bit is now discoloured or oxidised and its tip

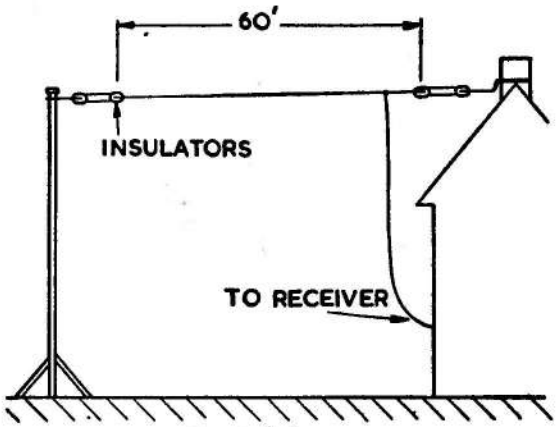

INVERTED 'L' AERIAL

FIG. 9

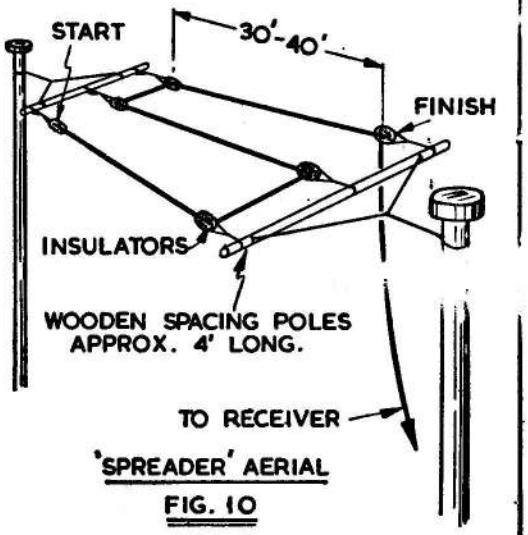

'SPREADER' AERIAL

FIG. 10

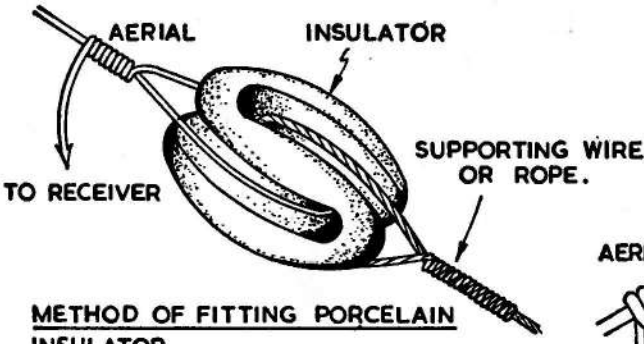

METHOD OF FITTING PORCELAIN INSULATOR

FIG. 11

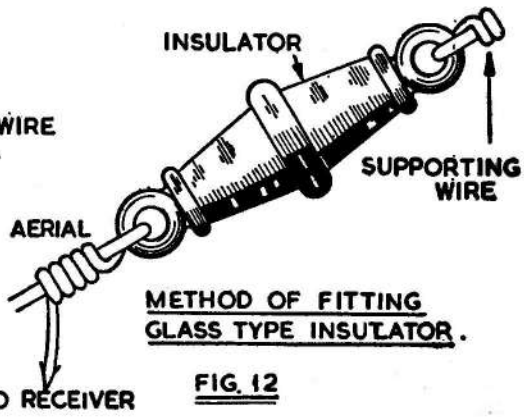

METHOD OF FITTING GLASS TYPE INSULATOR.

FIG. 12

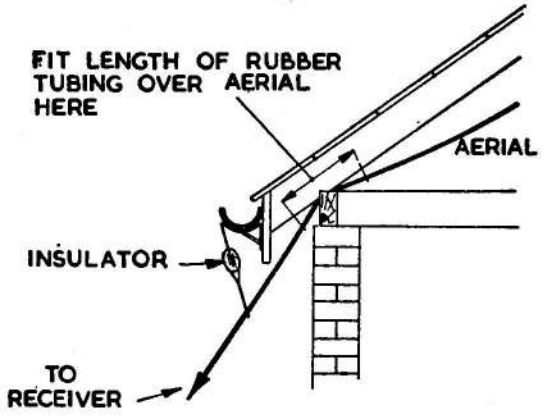

LOFT AERIAL.

FIG. 13

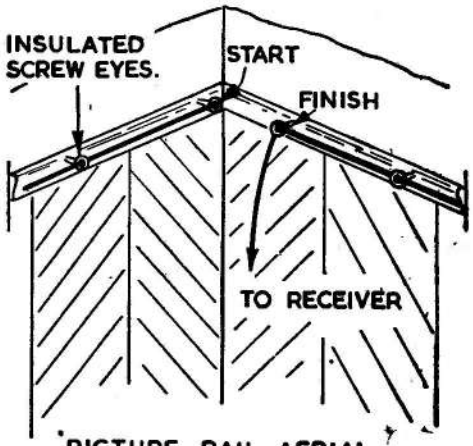

'PICTURE RAIL AERIAL.

FIG. 14

should be quickly cleaned with an **old** file which should be kept specially for the purpose. A better idea is to obtain a small block of sal-ammoniac and rub the tip of the hot iron on it. This will clean the tip of the bit perfectly. Next take a length of cored solder such as Ersin Multicore, and melt a little on to the prepared tip faces, now smooth it evenly over the surface with a piece of old rag (be very careful not to burn your fingers) the iron is now "tinned" and ready for use. When heating the iron, be very careful not to let the bit overheat or get red hot, otherwise the tinned surface will be destroyed and the whole process will have to be gone through again.

An electric iron will not overheat, and the tinning will last much longer than with ordinary types, and since the heat does not deteriorate there is less likelihood of making faulty joints.

Having obtained a tinned iron, the process of soldering joints is remarkably simple and anyone with a little patience can acquire the art in a very short time.

To solder two copper wires together: clean the wire with emery cloth, apply a prepared iron and some cored solder to it, the solder will flow evenly over the wire thus tinning it. Repeat the process with the remaining wire and then twist the two together. Now apply the iron to the joint from the underside and the cored solder to the joint on top. Solder will flow evenly over the joint. Remove both iron and solder and allow to set. The solder will harden or set in a few seconds but during this period the joint must not be touched or moved, as otherwise the joint will be "dry" and quite useless mechanically or electrically. On radio components, tags for soldering are already tinned though if they are old, or discoloured it is best to re-tin them. Normally, however, it is only necessary to twist the connecting wire to it and apply the iron and solder as explained.

Remember: **never** apply the solder to the iron and then the iron to the joint, always apply the iron **and** the solder to the joint. It is however a good thing to apply a little solder to the iron tip even when it is perfectly tinned just before making a new joint.

One final "DON'T," you will have noticed that the solder referred to is "cored," that is, it contains resin and other substances through its centre, plain solder as used by electricians and plumbers will not do, as it is the resin or flux

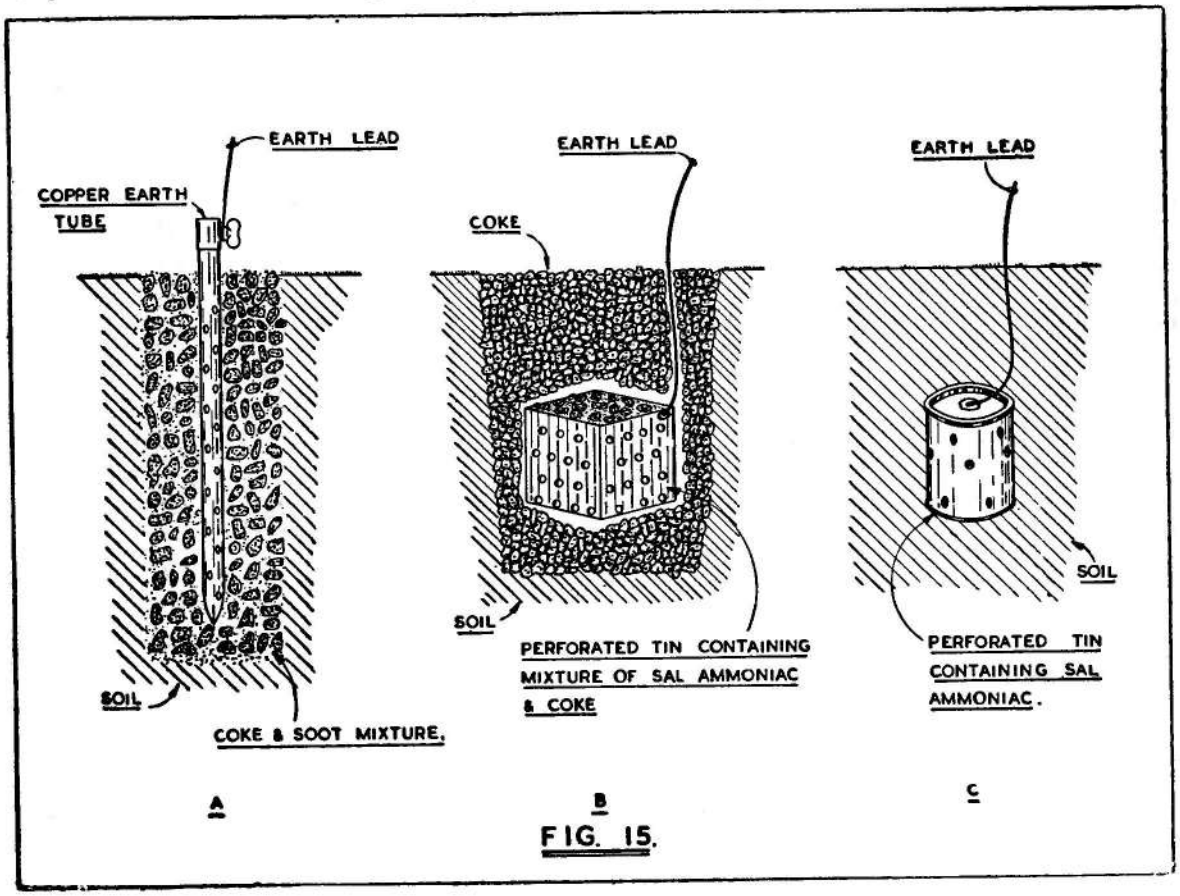

FIG. 15.

as it is called which makes the solder flow evenly and permits a good electrical joint.

Equally important do not attempt to use a separate flux or soldering fluid with plain solder or to "help" the cored solder; since these are almost certain to cause eventual corrosion and will destroy any components that have been contaminated.

Earths

The provision of a good earth is just as important as the rest of the installation.

Much disappointment would be avoided if this fact were not lost sight of, to avoid any slip up in this direction I am proposing to outline several well tried and efficient earth systems.

If it can be obtained, an earth rod, specially designed for the purpose provides the basis of a good earth connection. These were very popular some years ago when the majority of receivers were either crystal or battery operated, but in these days of modern mains driven sets they are not often used and consequently not always readily available.

Fig. 15 shows how it is used. First excavate a hole to a depth of three feet and fill with a mixture of soot and coke. Drive in the earth rod, which is a hollow copper tube, perforated. The lead to the receiver is connected at the top, and should be of covered 7/22 gauge, as used for the aerial system. Though not obvious it is important that this lead-in should be in covered wire, otherwise a number of indifferent earth contacts are likely to be made at various points along its length until it reaches the set. This is very undesirable and will spoil the efficiency of the system. It is essential to keep the soil surrounding the rod moist, which is one reason why the tube is hollow, and care must be taken to pour water into the tube at intervals.

A very efficient earth is the percolative type also popular at one time. Due to the chemicals used, it will extract moisture from its surroundings, thus maintaining a permanently moist earth.

It should be installed as in Fig. 15b.

The container is of copper or zinc, anything else will quickly rust away, again a good quantity of coke is used. Fill the container with a mixture of sal-ammoniac and coke, and then bury in coke as illustrated. This earth will not require further attention. It is possible to use powdered calcium chloride instead of sal-ammoniac but unless a chemist can be persuaded to make some up it is better to stick to sal-ammoniac.

If a zinc container is not available and you do not use or cannot easily get coke, Fig. 15c should be used. This makes a better earth than many so-called "earths" that I have come across. Obtain as large a tin as possible, make a number of holes as shown. Solder the lead in the bottom and fill it with sal-ammoniac. Replace the lid and bury in the ground. The tin will eventually rust away, but the replacement cost is negligible.

If it is quite impossible to make direct contact with the ground, a water pipe must be pressed into service. This should be a main pipe feeding straight to ground and not a hot water pipe or one fed from a tank. Scrape the pipe clean and twist the lead in tightly around it, a copper clip is even better. Do not attempt to solder on to the water pipe; since cold water is flowing through the pipe, it is extremely unlikely that your soldering iron will heat up the water supply sufficiently to allow a sound electrical joint, though you may spring a leak.

No attempt should be made to utilise gas pipes; the possibility of causing a fire is certainly very remote but, they make incredibly bad earth connections due to a number of joints made before true ground is reached. These joints are at best only semi-conductors, at least from an electrical standpoint.

Headphones

Since the late war there have been a large number of head-phone sets available on the surplus market. These may be roughly divided into two types, high-impedance and low-impedance. For the crystal sets detailed in this book high-impedance 'phones are required and the low-impedance pattern will not be suitable unless a matching transformer is used. As this is likely to cost more than the rest of the installation including the set, it will be as well to avoid them.

High-impedance types have an impedance of 2000Ω to 4000Ω whereas the low-impedance types are usually 600Ω.

The remaining consideration is weight; often cheap headphones are very heavy and uncomfortable to wear, every endeavour should be made to obtain 'phones as light in weight as possible.

Crystals

All the sets shown in this book have been designed to work with modern germanium crystals rather than the older galena crystal.

These germanium crystals require no adjustment, which, in itself, removes the main objection to this class of receiver. Suitable crystals are available from the following manufacturers and on the surplus market: Mullard, G.E.C., Brimar, Westinghouse and B.T.H. They are of robust construction, some in glass, others in ceramic or plastic, but must not be subjected to heavy knocks, otherwise the contact point may become dislodged.

From the information given, you should now be able to install an excellent aerial and earth system, and have some idea of how the crystal set works, so it is time to pass on to the actual receiver construction.

CONSTRUCTION 1

If you examine the following circuits you will find that each one is different. In most cases the difference lies in the coil design and/or the method by which the crystal and aerial is tapped into it. Each of these circuits has its own particular advantage to suit different conditions and the ideal circuit in some localities is not necessarily the best in others. It is not just a matter of a given circuit giving louder results than another, if it were there would be no point in showing more than one.

The main problem is to obtain adequate selectivity without reducing the volume level.

A receiver is said to be selective when it tunes sharply, a set with poor selectivity allows the stations to spread over the dial and when used near a transmitter will receive the local stations mixed together, which of course is useless.

Consider Fig. 16a, this is a very simple receiver, with no special attempt to provide any great amount of selectivity. In areas where signal

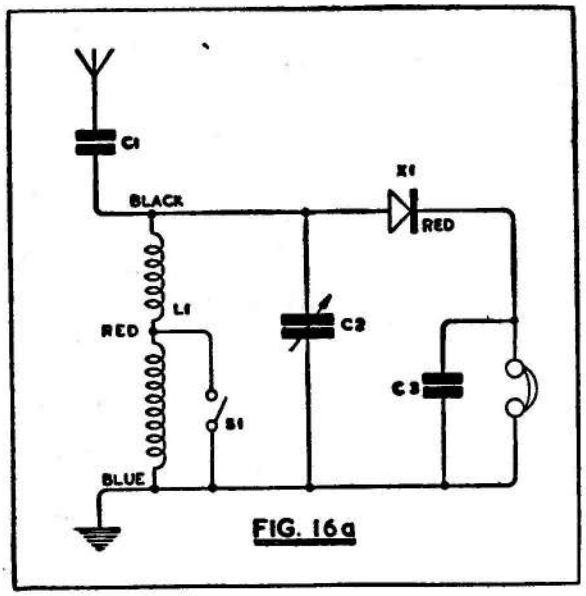

FIG. 16a

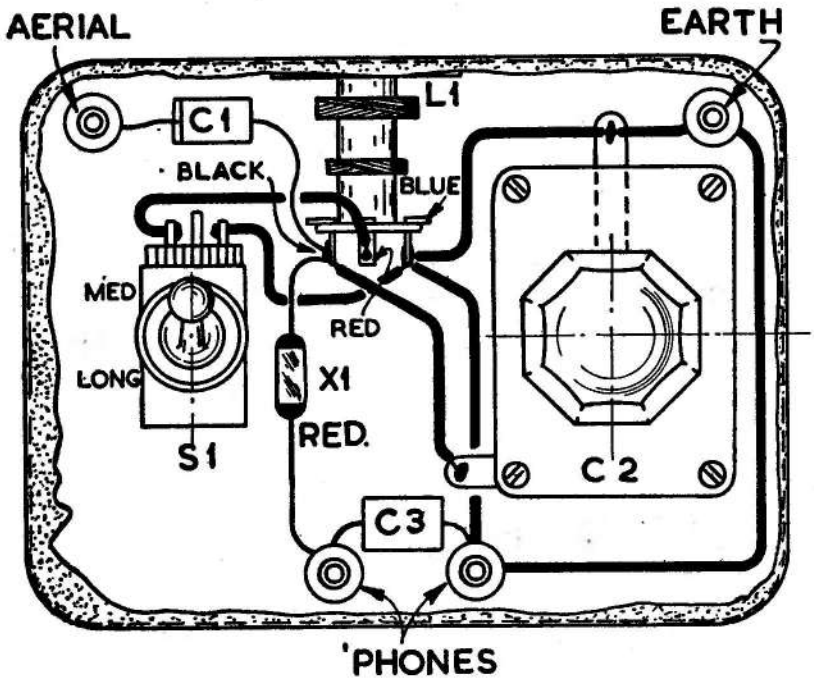

LID SHOWN BROKEN AWAY TO REVEAL POSITION OF COMPONENTS.

FIG 16b

strength is not high, or a short aerial is used, it will probably be ideal.

It would have been quite easy to increase the selectivity by providing a tap on the coil for the aerial as in Fig. 17a, but unfortunately, as the selectivity is increased overall volume is likely to decrease, so that unless you live close enough to the transmitter to have a large signal available and therefore need the selectivity, the circuit of Fig. 16a will be quite satisfactory.

Capacitor C1 is to prevent the aerial damping the circuit too heavily because this would flatten the tuning unnecessarily, however with small aerials it may be better to take the aerial direct to the black tag on L1. The signals are selected or tuned by L1 and C2, X1 is the crystal and C3 the capacitor across the 'phones to prevent unwanted carrier or R.F. reaching the 'phones.

A practical diagram (Fig. 16b) is provided showing the layout and all the wiring. You will require nuts and bolts to fix the coil, about ½", 4BA size will do, the other parts have locking nuts provided. An old 2-oz. tobacco tin makes a very good container and keeps the size down. Note that the metal box is connected to earth. With the exception of AC/DC receivers the metal work on any receiver or amplifier is connected to earth.

When S1 is open as in the diagram, the set will tune in long-wave stations, but when closed the medium wave-band will be received.

Components List, Fig. 16a

C1 100pF mica capacitor.
C2 500pF tuning capacitor, solid dielectric.
C3 1000pF mica capacitor.
X1 Germanium crystal.
L1 Crystal Set Coil. R.E.P.
S1 Single Pole toggle switch.
4 Insulated wander-plug sockets and plugs.
1 2-oz. tobacco tin (or similar container).

Make sure that the wander-plug sockets are of the **insulated** type, otherwise the metal case will join all the sockets together electrically.

Try to follow the theoretical diagram when wiring, a little practice will soon enable you to wire up a set without a practical diagram, which is a great advantage because often only the theoretical diagram is given when circuits are detailed in the technical press.

Fig 28 on page 34 gives a list of symbols used on the theoretical diagrams, so that you can readily identify the components.

2

Fig. 17a circuit is similar in many respects to that of Fig. 16a. The difference is purely one of selectivity, tuning will certainly be sharper, and even with comparatively inefficient aerials the design will put up a very good performance. There is no reason why the construction should not follow the same lines as the previous receiver but, by enlarging the set a little and using an air spaced tuning capacitor, the efficiency is improved. Observe that the colour coding on the coil, an R.E.P. Dual Range (Blue Box) is different from that of the Crystal set coil used on the previous design, and make sure it is correctly wired in.

C1 is a mica compression capacitor, often referred to as a "trimmer" and because it is adjustable, permits the set to be matched to aerials of varying lengths. Construction is carried out on a square panel of bakelite, perspex or wood, as shown in Fig. 17b. Perspex being clear like glass presents a most attractive finish, provided the set is neatly wired. It must be drilled slowly, however, otherwise the generated heat of the drill will make the hole wander, and spoil the panel.

After the set has been wired and tested a small wooden container can be made to house the completed set.

When carrying out reception tests, a little experiment is well worth while, to get the best out of the set. Try removing the germanium crystal

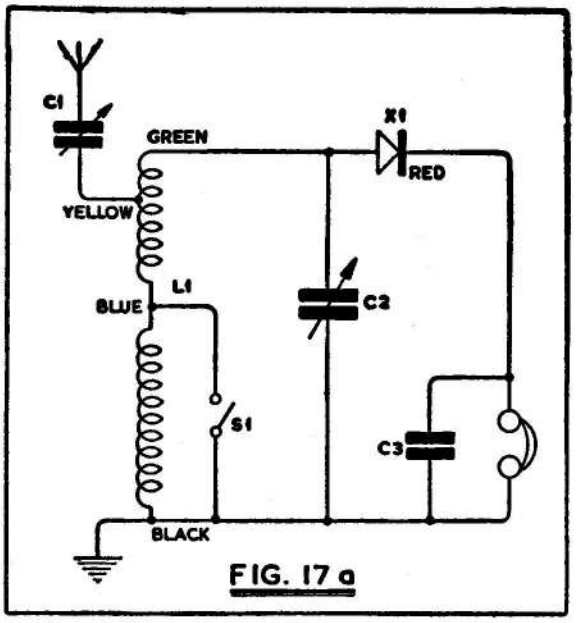

FIG. 17 a

from the green tag on L1 and connecting it to yellow, at the same time removing the lead from C1 to yellow and connecting it to green. Once the best arrangement has been found the wiring

can be left permanently in that position. Note that two tags on the coil are unused, this is intentional because on this circuit the extra winding connected to these tags is not required. With the switch S1 closed, the coil will cover the medium wave-band, and when open, long wave stations can be received. It is customary to abbreviate the expression medium wave-band to M.W. and long wave-band to L.W.

Components List, Fig. 17a

C1	100pF mica trimmer capacitor.
C2	500pF variable capacitor (air spaced).
C3	1000pF mica capacitor.
L1	Dual Range Coil R.E.P. (Blue Box).
S1	Single Pole toggle switch.
X1	Germanium Crystal.
4	Terminals or wander-plugs and sockets. Perspex, bakelite or wood for mounting panel.

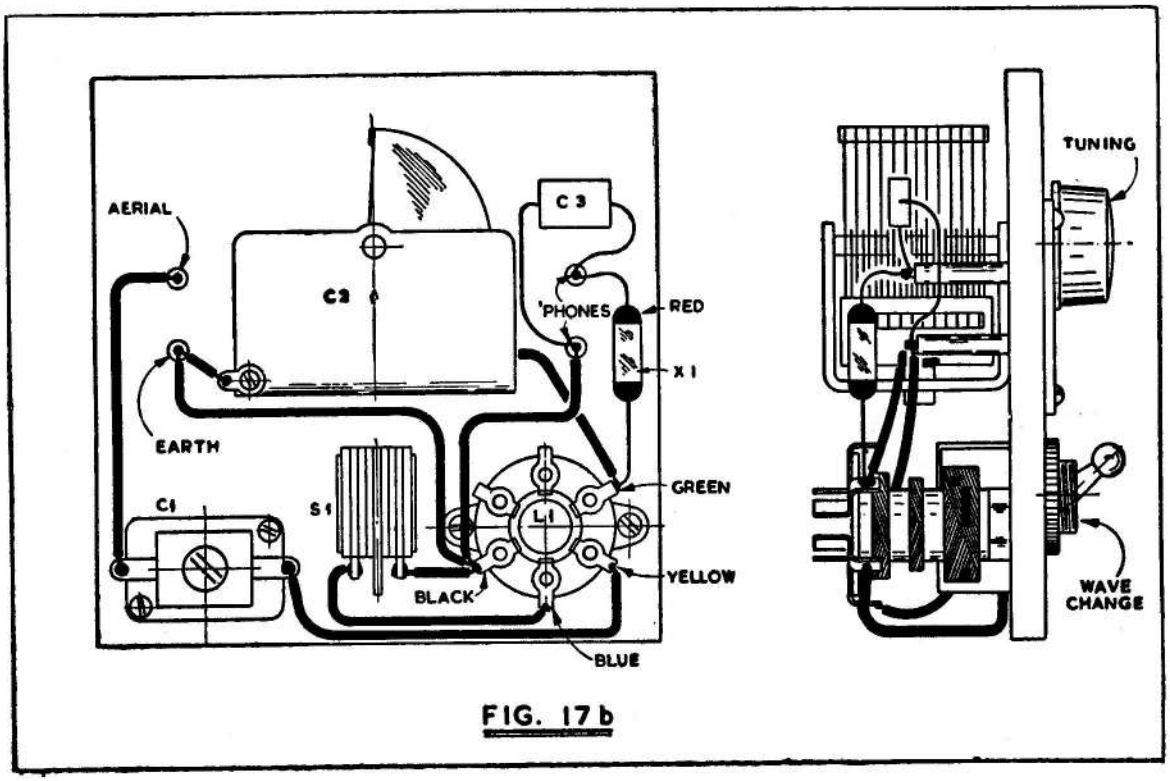

FIG. 17b

3

The design shown in Fig. 18a and 18b is more flexible than either of the preceding sets. That is, it can be varied to suit local conditions to a greater extent than the first two sets. This is made possible by the large number of taps provided on the coil.

You will notice that in this instance the coil is home-constructed on a cardboard former and is much larger than commercially produced coils. Coils wound in this manner are called **solenoids**, the turns are wound on side by side; in this case to a depth of some three inches. The diameter of the coil is made purposely large so as to obtain high efficiency. Modern commercial coils are invariably wave-wound and quite often are litzendraht which is the German for litz wire. This wire is made up of a number of strands of fine copper wire, each strand is enamelled to insulate it from the others, the whole is then silk covered. Litzendraht is more efficient than solid copper wire, and by using this and wave-winding, manufacturers can produce an efficient coil which is also small. Unfortunately wave-wound coils cannot be produced without a complex winding machine and home-constructed coils must take the solenoid form. It would be possible to use litzendraht but it is not easy to obtain by the reel, it is most expensive, and is difficult to handle. This last point is because at termination points, each strand must be cleaned of its enamel before a joint is made, and if one strand is broken, its advantage over plain copper wire is lost. How-

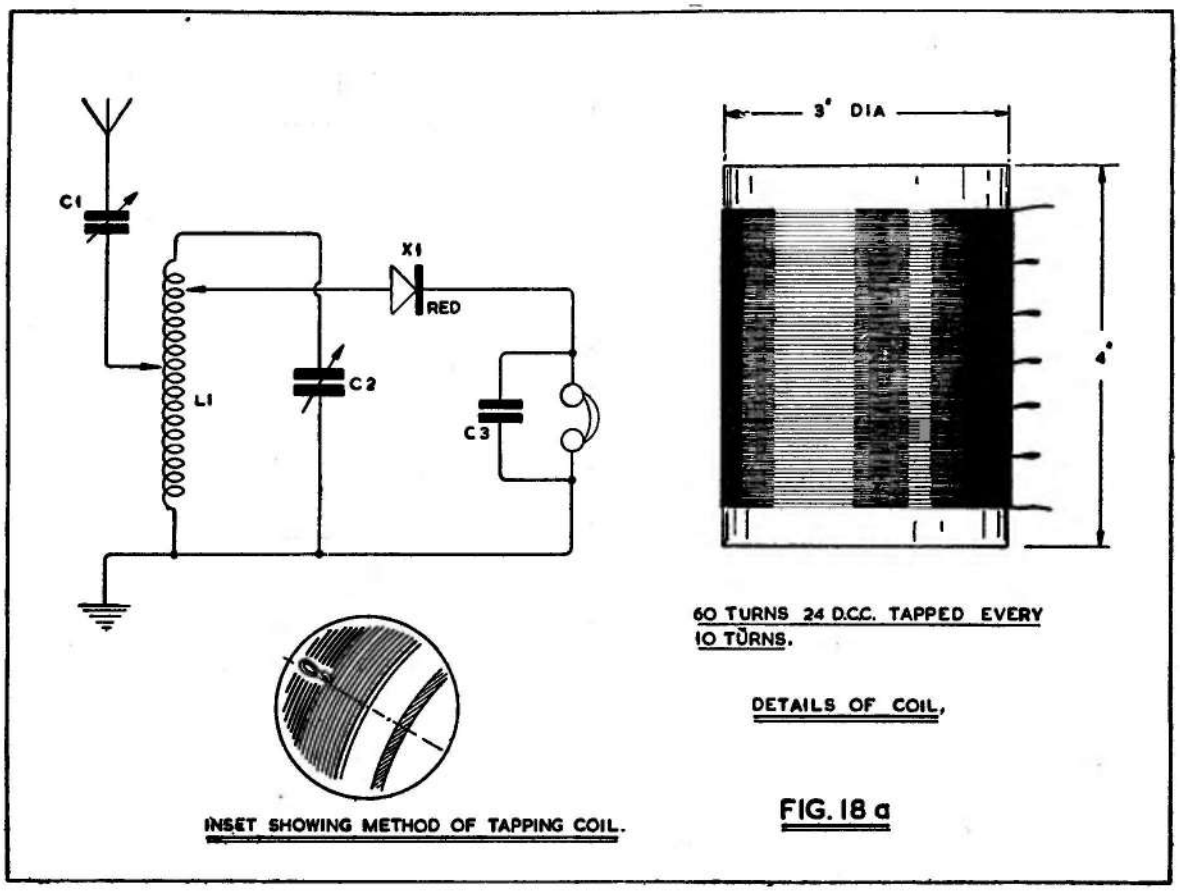

FIG. 18 a

ever, by using a former of reasonably large dimensions an efficient coil can be produced cheaply using ordinary copper wire.

The wire must be firmly secured at the start and finish of the windings. Pierce three small holes about ¼" apart ½" from the end of the former. Pass the wire through the first from the outside, return it through the second and pass it back again through the third. Leave some 6" of wire at the end to make off the connection. It will now be possible to wind the turns on tightly without wire slipping.

Count on ten turns and make a loop 1" long. The method of preparing loops is shown in Fig. 18a, loops or taps should always be made in this manner, never by baring the wire and soldering a further length of wire to it. Carry on with the winding, making off the taps every ten turns as directed until the coil is complete.

Construction is carried out on a wooden base-board and front panel. Secure the coil to the base-board as shown on Fig. 18b, mount the remaining components and proceed with the wiring.

When testing out, it will be found that the further the aerial is tapped down the coil towards the earth end, the greater the selectivity. A position should be found which permits separation of local stations without excessive loss of sensitivity.

The crystal tap is adjusted for best results and different settings of C1 tried out, when choosing the best position for the aerial tap.

Components List, Fig. 18a

C1	450pF padder.
C2	500pF variable capacitor.
C3	1000pF mica capacitor.
L1	See text and Fig. 18a.
X1	Germanium Crystal.
2	Crocodile Clips (to connect leads to coil taps).
4	Wander-plugs and sockets.

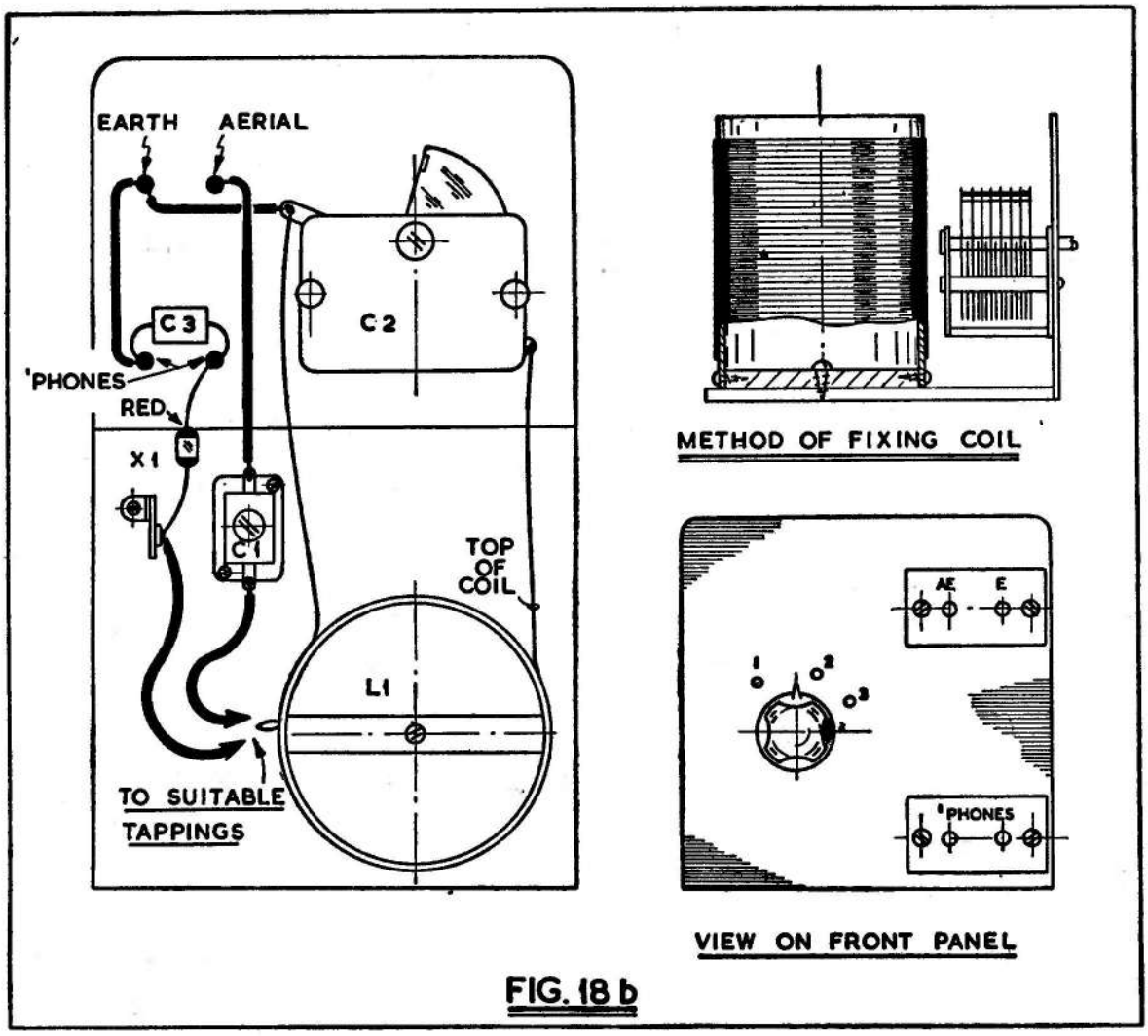

FIG. 18 b

4

A most unusual design is reproduced in Fig. 19a.

It first appeared in America about three years ago, and it certainly does offer some advantage over more conventional sets. The tuning circuits are duplicated and two crystals are used, so the circuit may be described as a full-wave receiver. Signals received will certainly be louder than with simple sets, but care must be taken with the coil winding, as with the other receivers using home-made coils, otherwise results will be disappointing. Be very careful to ensure that all three windings are in the same direction, this is very important.

The distance between each winding should be $\frac{1}{8}$". After the coil has been wound it is a good plan to warm it before a fire and paint the windings with "Durafix." Heating the coils makes the "Durafix" run freely. This substance sets quite hard and there will be no risk of the windings loosening. A small quantity of enamelled wire will cover the requirements of this coil, a 2 oz. reel will provide more than sufficient.

Before wiring in the germanium crystals, examine them carefully, note that one end is coloured red or in some cases marked with a positive sign thus +. You will notice, the sign is the same as the addition symbol used in arithmetic.

It is essential that both the red or positive ends are connected together, note that this is clearly marked on Fig. 19b. The receiver cannot work if

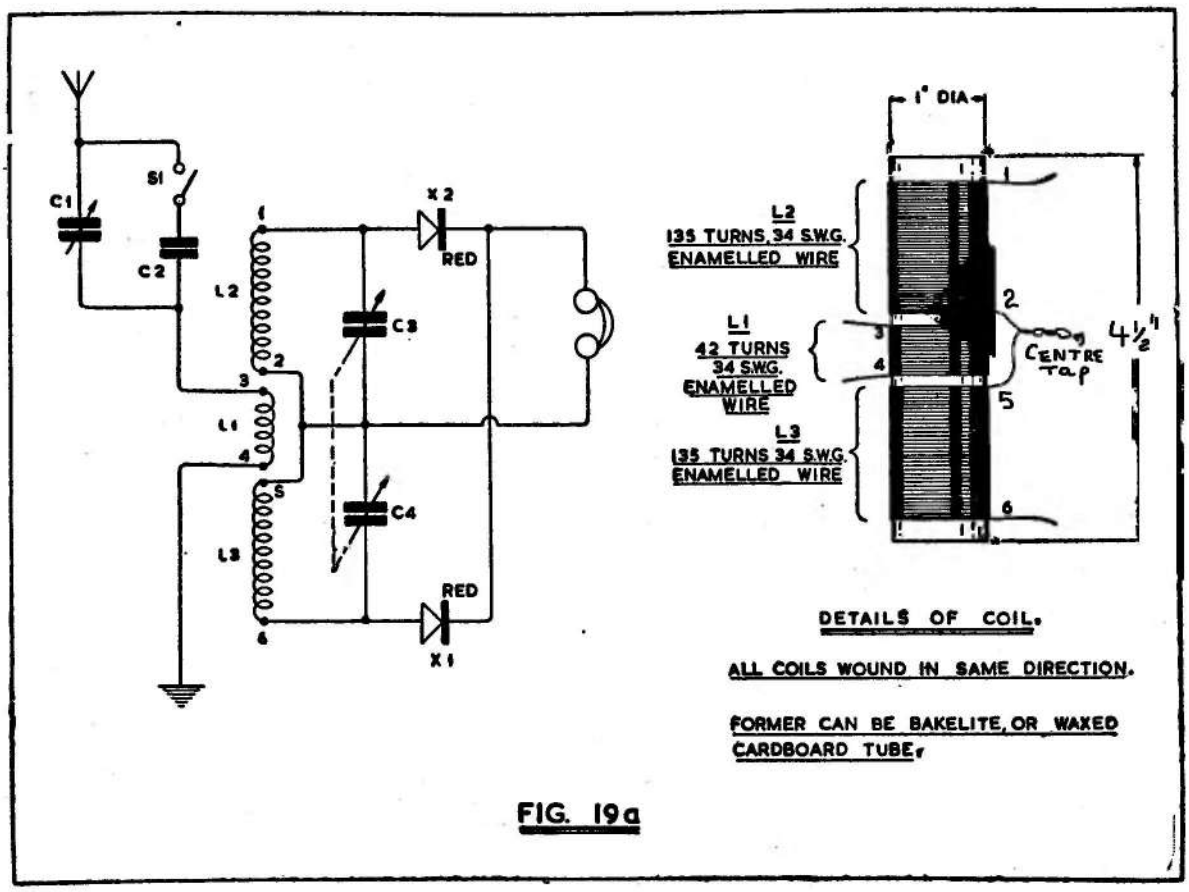

FIG. 19a

one of the crystals is connected the reverse way round.

A baseboard and panel form of assembly is used for this set which looks quite attractive if housed in a small polished cabinet. Dimensions are not at all critical but Fig. 19b gives a general idea of the layout that should be used. To avoid any unnecessary losses the coil should be mounted on perspex.

Obtain two strips of perspex 5½" long by ½" wide, drill fixing holes at both ends of each strip. It is best to clamp the two together when drilling these holes. Place one strip on the board in position, then put the coil and remaining strip over the first one and screw down. The coil will be clamped neatly and rigidly into position.

Twin socket bakelite strips are used to carry the aerial/earth and 'phone connections, if desired terminals mounted on pieces of bakelite could be used. These socket strips can be purchased from most shops selling components. If feet are not provided, drill two holes and screw into the edge of the base-board. Tag-strips are used to anchor some of the wires from the coil, and the germanium crystals. These also can be purchased for a few pence. At least two tags are necessary on one, and three on the other, though if the strips have more tags than required it is of no consequence. C3-C4, the ganged tuning capacitors have trimmers fitted, this should be stipulated when purchasing, and when first operating the set these small trimming capacitances are set about half-way. The idea of these trimmers is, that they compensate for any difference between the self-capacity of the tuning coils. With the switch S.1 open, that is in the OFF position, tune

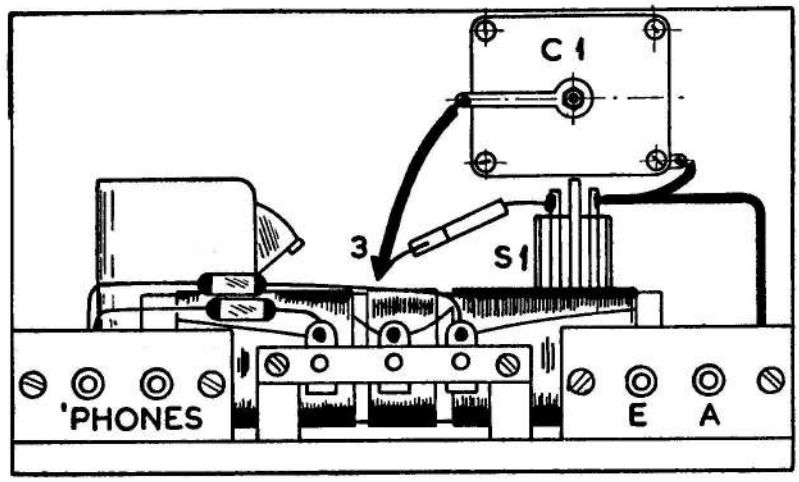
C1
3
S1
'PHONES
E
A

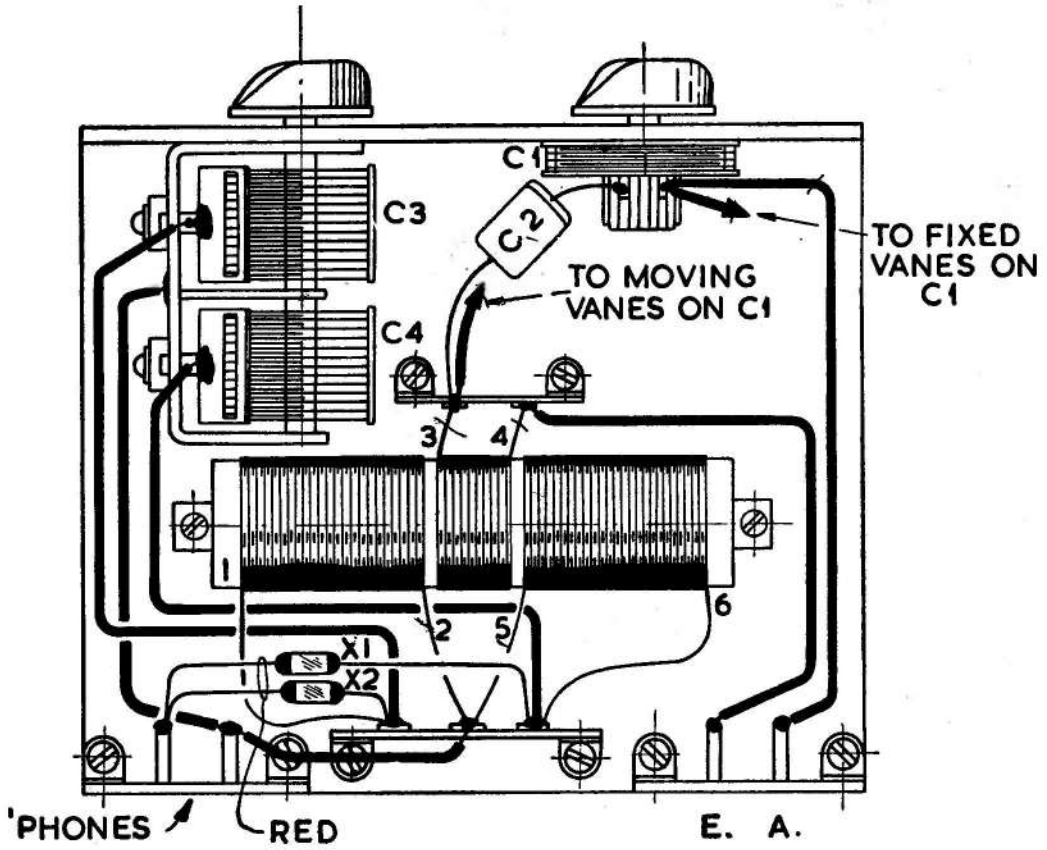
C1
C3
C2
TO FIXED VANES ON C1
TO MOVING VANES ON C1
C4
3
4
1
6
2
5
X1
X2
'PHONES
RED
E. A.

FIG. 19 b

in a station at the high-frequency end of the band, that is with the vanes of C3-C4 towards the disengaged position. Adjust C1 for maximum volume, without interference from other stations. Now adjust the trimmers for loudest headphone strength. It may be necessary to run over the adjustments several times for best results. Once they are correctly set, the trimmers require no further adjustment. The tuning coil covers the M.W. band, 1500 kc/s. to 600 kc/s., as the capacitor C3-C4 is advanced and the vanes start to mesh, the frequency to which the receiver tunes **decreases** so that with the vanes disengaged the set is tuned to 1500 kc/s. approximately and at full mesh, 600 kc/s. Switch S1 is used as follows, for stations **lower** in frequency than 850 kc/s it should be in the ON position with the contact closed, but for stations **higher** in frequency, it is in the OFF position. As an example both the London Home Service and London Light Programme transmitters on the M.W. band operate at a higher frequency than 850 kc/s. If any doubt exists as to the operating frequency of a given station, reference should be made to the Radio Times which quotes both wave-lengths and frequency. If you know the wave-length in metres, it is simple to find the frequency. Divide 300,000 by the wave-length in metres, the dividend equals the frequency in kilocycles, i.e., 300,000 ÷ 300 metres=1,000 kc/s. In the same way, dividing 300,000 by the frequency in kilocycles will produce the wave-length in metres.

To use the receiver, tune in the signal by C3-C4, adjust C1 for maximum volume without allowing stations to overlap.

Components List, Fig. 19a

C1	300pF solid dielectric variable capacitor.
C2	1000pF mica capacitor.
C3-4	500pF twin gang variable capacitor.
L1-2-3	See text and Fig. 19a.
X1-2	Germanium Crystal.
2	Tag-strips.
2	Twin socket strips.
S1	Single Pole toggle switch.

5

Whenever crystal sets are discussed, constructors are apt to think in terms of medium-wave reception. When you consider that at least 98% of published circuits are designed for this band (sometimes with the long-wave band thrown in as an afterthought) it is understandable. However, if you can provide a good outdoor aerial (and an equally good earth) there is a lot of fun to be had listening to the short-wave bands. This receiver is designed specially for short-wave reception.

A metal chassis is used for construction, these can be obtained ready made in aluminium from most good supply houses. It can be quite small and on the original model a 6" x 4" was used. Low loss components are used so as to obtain greatest efficiency on the short wave bands. The coil is a commercial product which plugs into a 4-pin base. Best results were obtained on the 3mc/s to 7mc/s band though coils covering other bands are available.

Note that the tuning capacitor C1 is smaller than normally used and has a maximum capacitance of 140pF.

Coil type 706/R covers the 3mc/s to 7mc/s band, but the set is equally satisfactory on the M.W. band, and to cover this coil type 706P should be used. This coil has an iron dustcore which can be adjusted to make the coil cover the required band. The effect of the core is as if turns were being added or removed from an ordinary coil. When dealing with the short waves it is customary to refer to the frequencies in terms of mega-cycles (mc/s) rather than kilo-cycles. One mega-cycle is equivalent to 1000 kilo-cycles, that is 1,000,000 cycles.

Layout and wiring can be clearly followed from Fig. 20b and a theoretical diagram is shown in Fig. 20a. Care should be taken when arranging a mounting for the aerial terminal. The best plan is to cut a 1" hole in the chassis, mount the aerial terminal on a piece of perspex and screw into the chassis. This avoids any unnecessary losses between aerial and chassis. The earth terminal is screwed directly into the chassis.

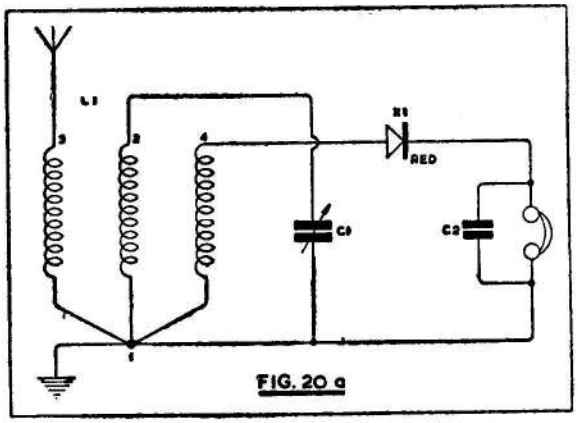

FIG. 20 a

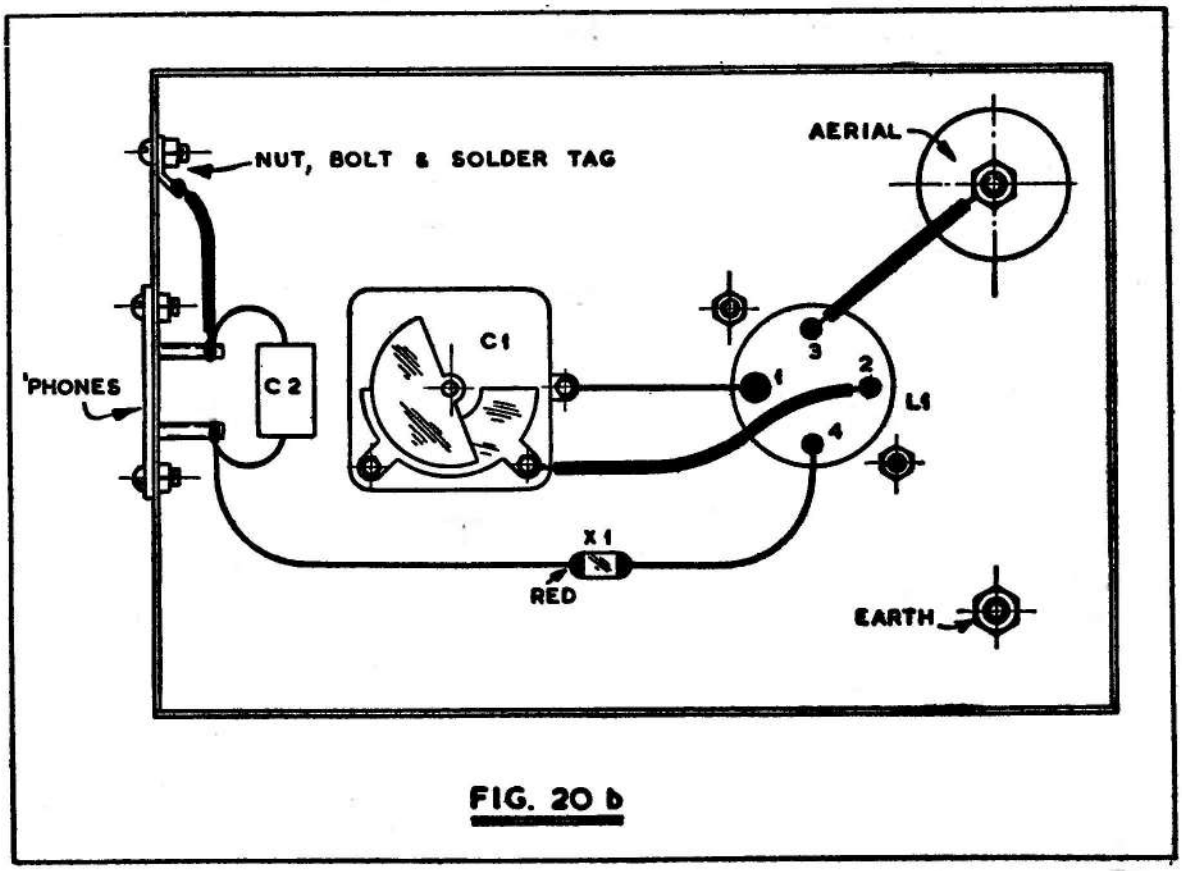

FIG. 20 b

Wiring as shown in Fig. 20a is likely to give the best results, but other arrangements are possible and to get the best out of the set they should be tried.

Refer to Fig. 20a. The aerial is connected to pin 3 on L1, C1 to pin 2 and X1 the crystal to pin 4. If you have a long aerial try this combination—Aerial to pin 4, C1 to pin 2, and the crystal to pin 3. Connections to pin 1 are not altered. In a few cases the following arrangement may prove best. Crystal **and** C1 to pin 2, aerial to pin 3, pin 4 left free and again pin 1 is unaltered.

Tuning on the short-wave bands is more critical than on the medium waves so tune very slowly over the band and remember signal strength is likely to vary from day to day.

Components List, Fig. 20a

C1	140pF variable capacitor Eddystone 586.
C2	1000pF mica capacitor.
1	Coil holder Eddystone 707.
L1	3m/c—7m/c coil Eddystone 706/R.
1	Engraved tuning dial.
1	6"x4"x2½" chassis.
2	Terminals (Aerial-Earth).
1	Twin socket strip ('phones).
X1	Germanium Crystal.

6

Fig. 21a-b is yet another design from America and appeared in Radio Craft some years ago, designed by Mr. W. J. Spain. The original used a silicon crystal which preceded the development of the germanium. Results are certainly very good though of course on the model built here, a germanium crystal was used. Selectivity can be adjusted to suit all conditions and even at short distances from local stations. Good volume can be obtained without the programmes overlapping. Home made coils are used and for best results a 75' outdoor aerial is desirable.

Baseboard and panel construction is used, which can conveniently be housed in a small wooden cabinet.

Operation is a little more complicated than some of the other designs, but the results certainly merit the extra trouble taken. As with the other receivers much of the success obtainable is due to the coils and these must be carefully made otherwise results will be disappointing.

Layout and wiring can be followed quite easily from Fig. 21b and requires no special comment.

First make the coils. L1 is a tapped coil, the taps should be made in the same way as shown in Fig. 18b. It consists of 90 turns of 22 D.C.C. (double cotton covered) copper wire tapped at the following number of turns, 5, 10, 15, 25, 30, 40, 50, 60, 70 and 80. The former used has a diameter of 2". L2 is also wound on a 2" diameter former, this coil however is not tapped, it consists of 110 turns of 38 D.C.C. or enamelled copper wire. Great care must be taken when handling this wire, it is quite fine and in the hands of the inexperienced will easily break.

After wiring has been carried out the set can be put into operation.

Selectivity is controlled by S2, in position B tuning is broad but in position A it can be quite sharp.

When searching for a station switch S2 to B. Tune the station and switch S2 to A. The frequency range is controlled by the position of the tap on L1, a good plan is to start with the 5 turn tap on L1.

Components List, Fig. 21a

C1 500pF variable capacitor.
C2 500pF variable capacitor.
C3 1000pF Mica Capacitor.
X1 Germanium Crystal.
L1 & L2 See text.
S1 Single Pole toggle switch.
S2 Single Pole 2-way toggle switch.
2 Twin socket strips (Aerial/Earth and 'Phones).

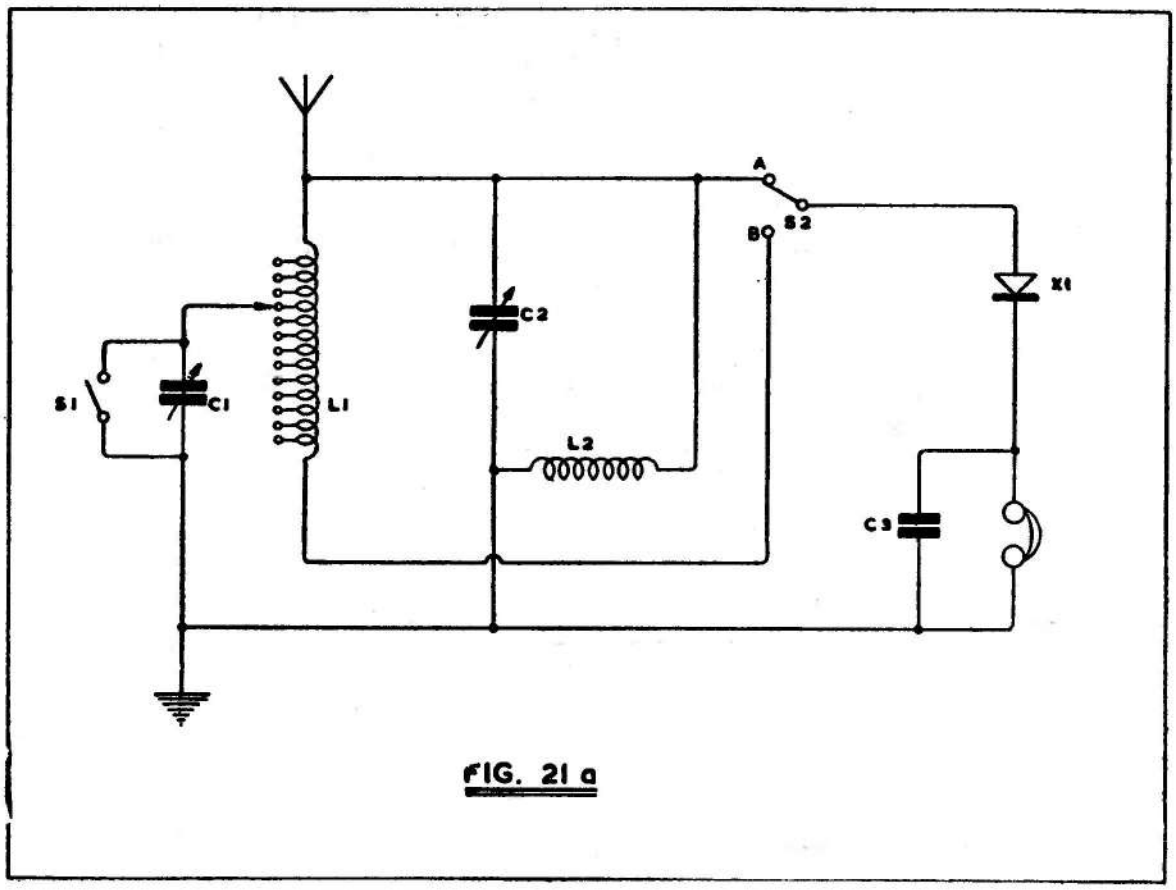

FIG. 21 a

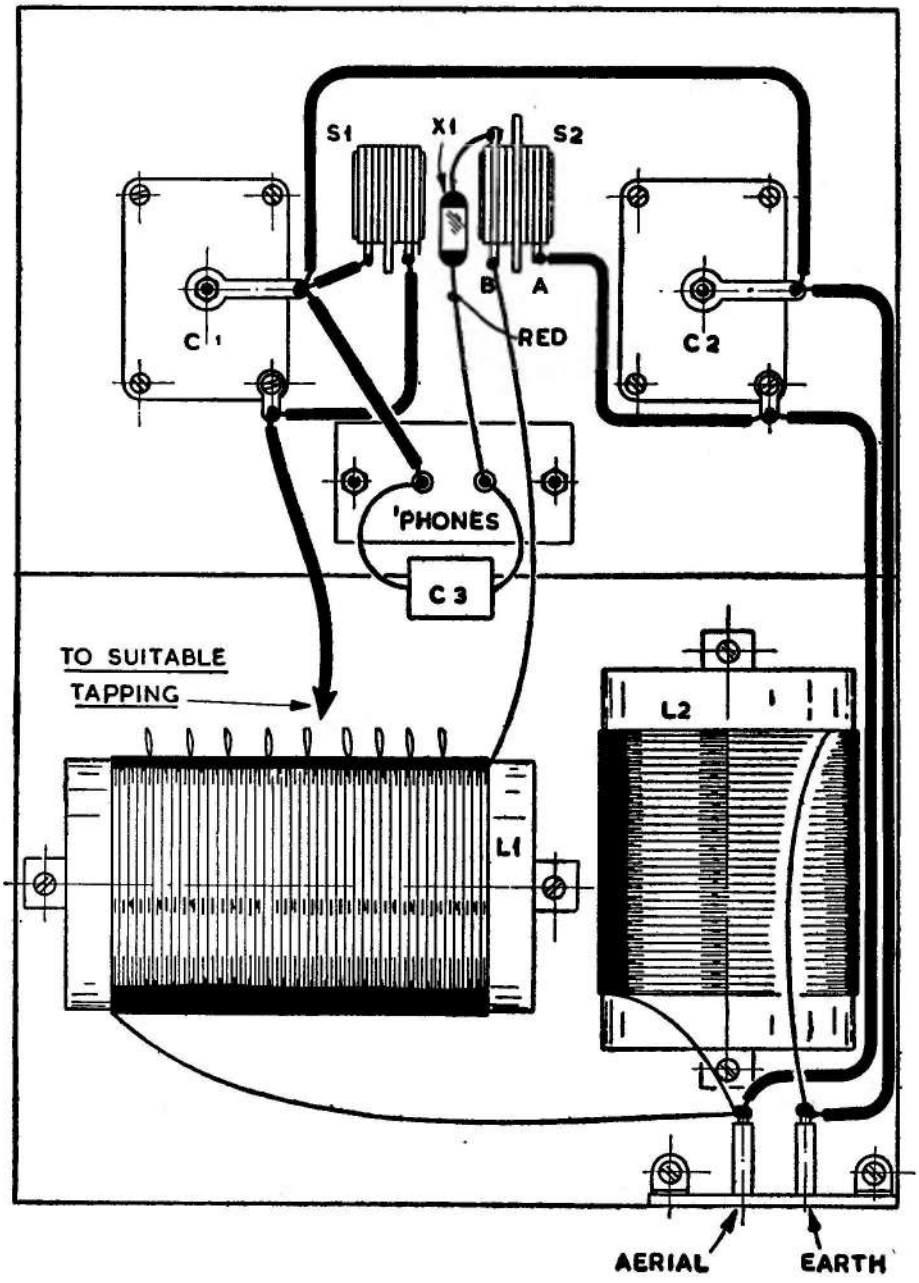
S1
X1
S2
B
A
RED
C1
C2
'PHONES
C3
TO SUITABLE
TAPPING
L1
L2
AERIAL
EARTH

FIG. 21 b

Keep S1 open and C1 for tuning, adjusting the tap on L1 for best results. Very powerful signals are best brought in with S1 closed. When using C1 and adjusting the taps on L1, switch S2 is kept in the A position.

It will be found that C2 acts as a fine control on C1. One division of the tuning dial on C1 is roughly equal to a movement of 20 divisions on C2.

Note that the coils are mounted at right angles to one another and that in this instance wood has been used as far as possible, an aluminium or other metal chassis is not suitable.

7

A very useful receiver for both medium and long-wave reception is possible with the circuit of Fig. 22a-b. A home-made coil is used. On the original a 1¼" diameter former was used but in fact this is not very critical and a 1½" former could be used. An interesting point is the construction of the long-wave coil section. Solenoid coils as used for the medium wave-band are not efficient if the length is too great relative to the diameter. Now as the long-wave section has 300 turns, if wound as a solenoid the winding length would be very great and a lot of efficiency would be lost. To overcome the difficulty the coil is pile wound. If the whole coil were to be wound in one pile it would still be inefficient because of the capacity formed in the winding, but by dividing it into five sections a coil of reasonable efficiency results. The same remarks concerning winding apply to this coil as to all the others in

Components List, Fig. 22a

C1 300pF Mica Capacitor.
C2 500pF Variable Capacitor.
C3 1000 Mica Capacitor.
X1 Germanium Crystal.
L1-2 See Text.
S1 Single Pole Toggle Switch.

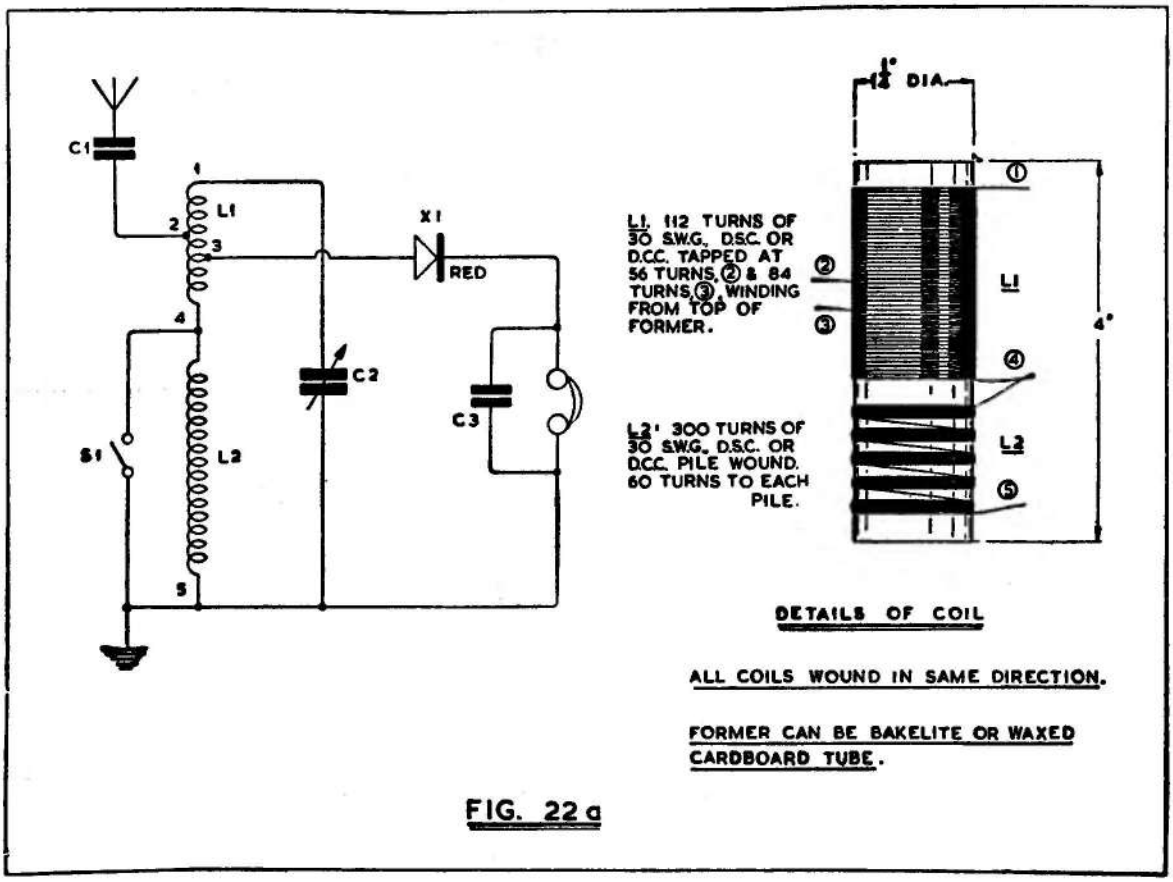

FIG. 22a

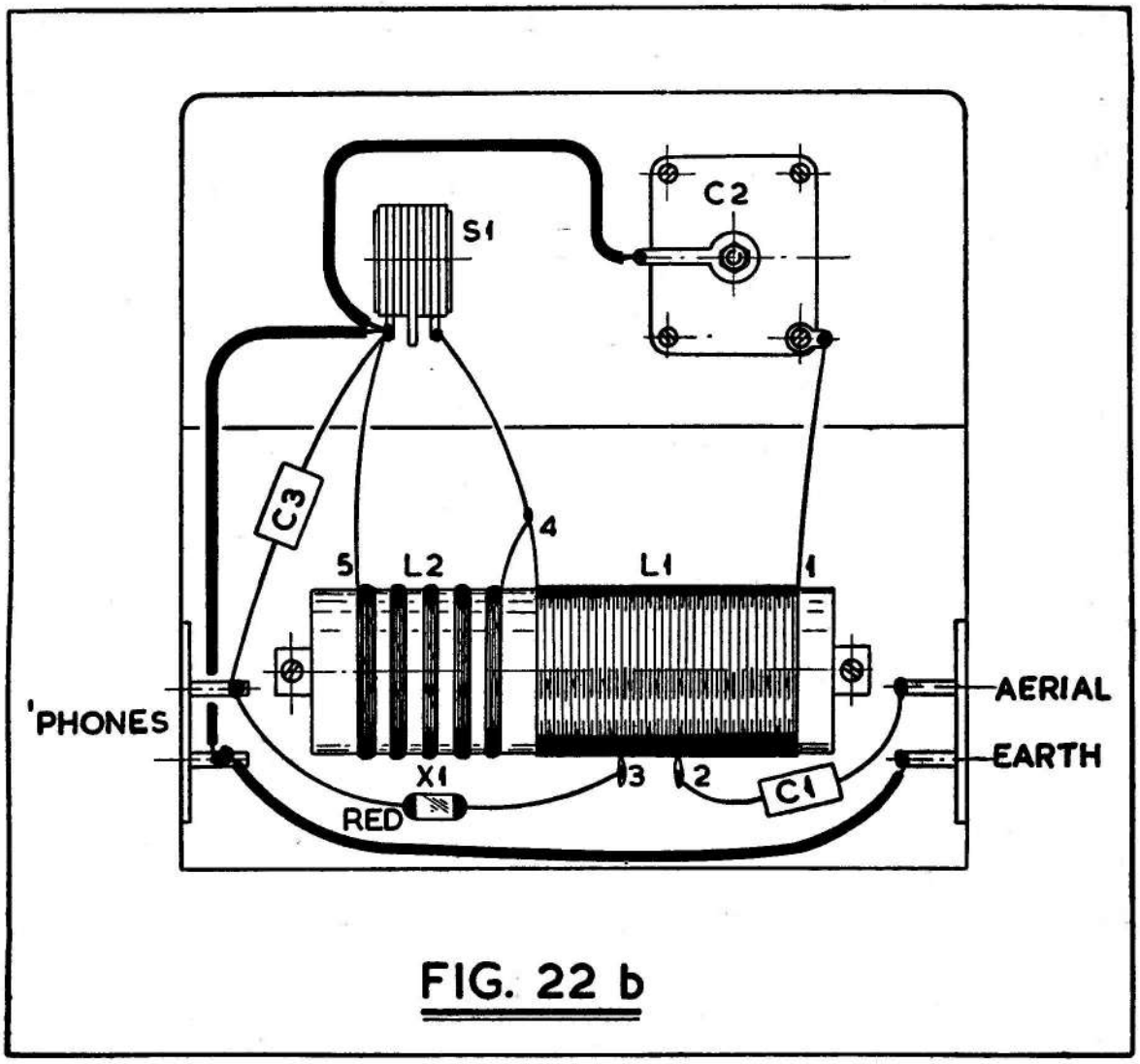

FIG. 22 b

this book, and readers should not, by this time, encounter any difficulties.

The design provides good selectivity with good sensitivity, and provided the set is not required to operate within a few miles of a powerful transmitter, no trouble will be encountered from interference between adjacent stations.

A wooden base-board and front panel is best for this design, and the wiring and layout can be clearly followed from Fig. 22b. Switch S1 is open for long-wave reception and closed for the medium-wave band.

Coil mounting can be on the same principle as for the full-wave design Fig. 19a-b.

8

If you look at all the other circuits shown in this book you will find that in each case the tuning capacitor and tuning coil are in parallel, this is by no means essential and the circuit of Fig. 23a shows a series arrangement that is the tuning capacitor is between the coil and earth instead of being wired up across it. This design also appeared in **Radio Craft** a few years ago.

An interesting point is that the coil is a conversion adapted from another type of component. To make this coil you must obtain an old I.F. transformer as used in superheterodyne receivers.

You will require one designed to work anywhere between 450 and 470 kc/s. Some of the

very early ones worked at 110 kcs/ but these are unsuitable.

The I.F. transformer must also be of the type tuned by an iron dust core at each end.

Dismantle the transformer, remove the parallel capacitors and mounting wires so that you are left with two coil bobbins and their former. Be very careful when un-soldering the wires from the supports because the coils are usually wound in litzendraht and must remain intact. Remove 25% (approximately) of the turns from one coil which we will call the secondary, and completely remove the iron dust slug from this coil, now cut the former in half, and mount as in Fig. 23a. Warm the coils with heat from your soldering iron or from a fire and gently slide the coils into position at the ends of the former as in Fig. 23a. The wax will set again holding the coils in their new position.

Note that the wires from the coils are connected to tags on the mountings. These are pieces of bakelite, and usually the original end pieces used on the I.F. transformer can be used.

A word about soldering litzendraht. Do not attempt to use emery paper. Prepare the end of wire by removing the outer silk covering and dip the end in methylated spirits. Ignite with a match and after about five seconds wipe with a cloth held between finger and thumb. This will quench the flame and will remove all traces of enamel from the wire. It is a good plan to experiment with the odd length of wire removed from the secondary coil. If the coils prove to be constructed of ordinary copper wire, it can of course be prepared with fine emery cloth in the normal manner.

Components List, Fig. 23a

C1 500pF variable capacitor.
X1 Germanium Crystal.
L1 See Text.
4 Plugs and sockets or terminals.

Wiring is straight forward as can be seen from Fig. 23b and requires no explanation.

Operation is as follows, selectivity is controlled by varying the distance between coils with the wing nut, and to an extent by the position of the primary iron dust core. Remember that the aerial and earth installations are as important with this set as with any other crystal receiver. No parallel capacitance appears necessary across the 'phones, the set works quite happily relying on the self-capacitance of the head-phones.

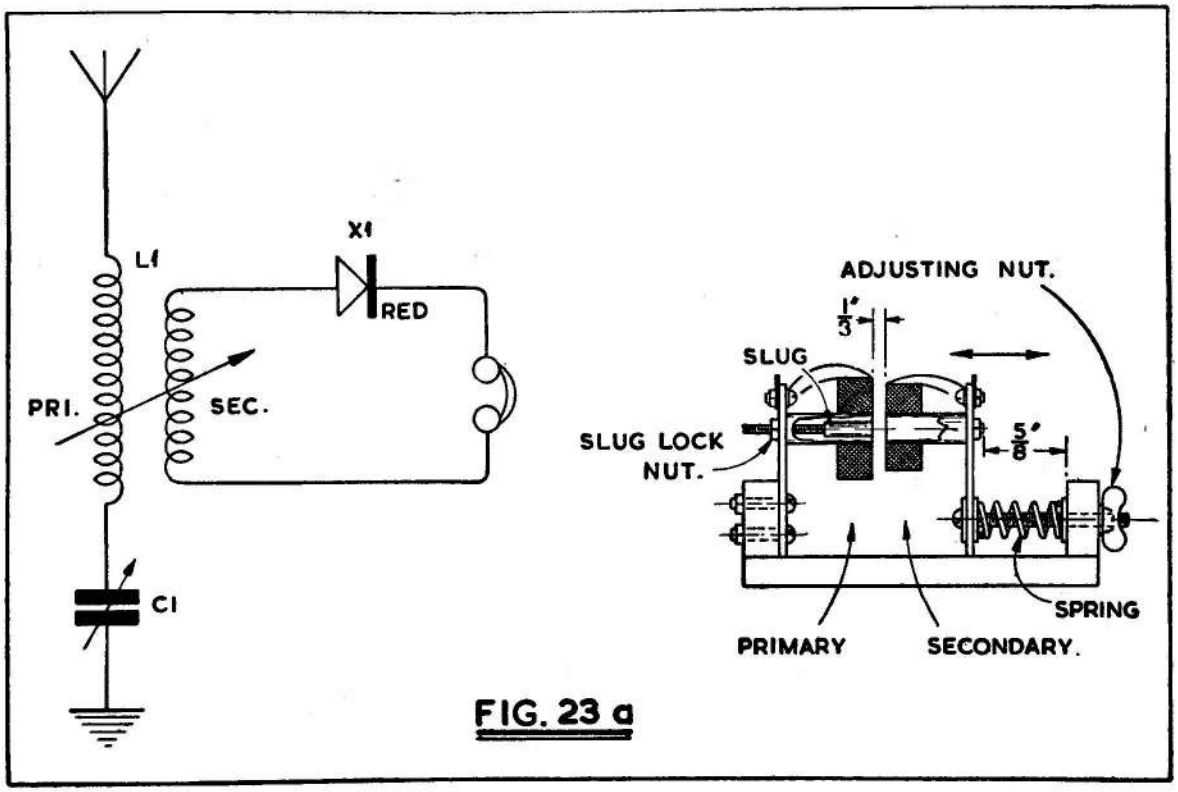

FIG. 23 a

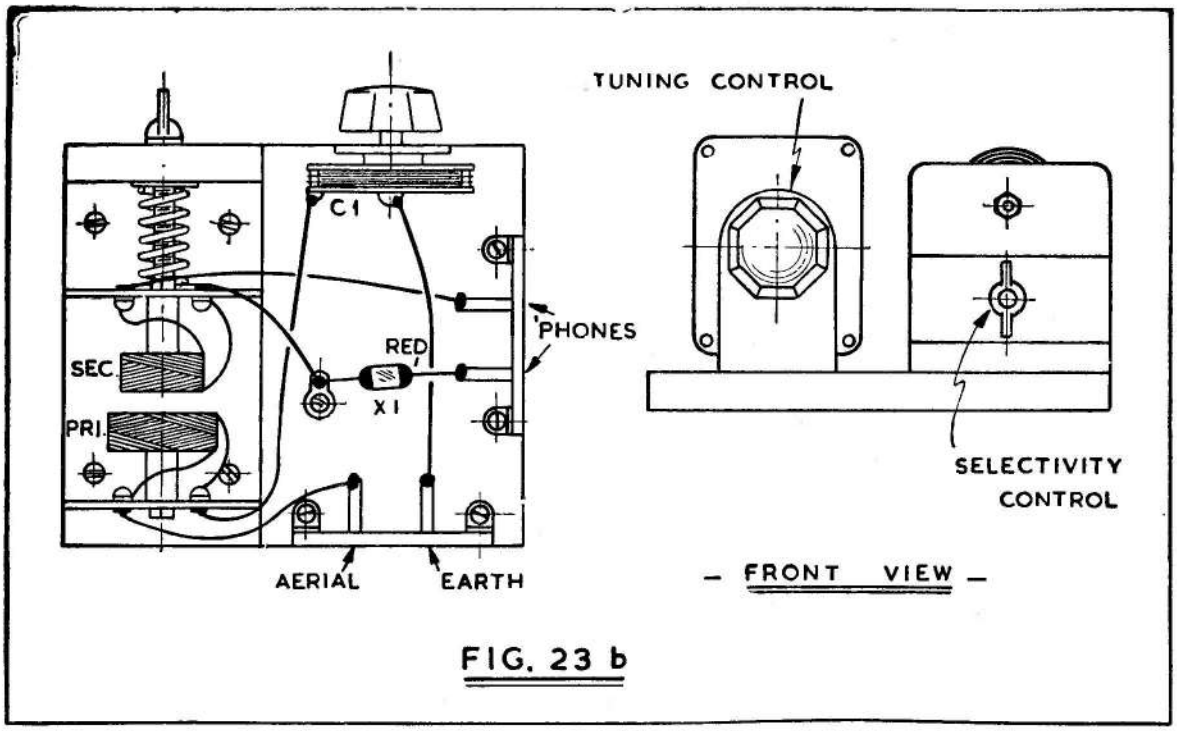

FIG. 23 b

9

So as to give a truly varied selection of circuits, some of the sets have been designed around commercial coils whilst others use coils which must be home-constructed.

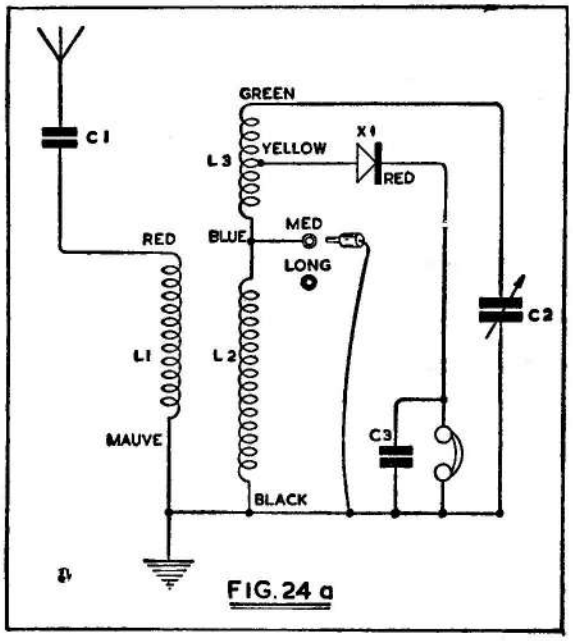

FIG. 24 a

Most enthusiasts like to build their own coils but when it is a question of something really small combined with efficiency a commercial coil is the obvious choice.

Fig. 24a-b uses a tobacco tin or a similar container just as the design shown in Fig. 16a.

This receiver however is a little more selective and is more suitable than the earlier design, if you are near a transmitter or have a very long aerial. Take great care to connect the coil according to the colours shown on the diagrams. Sockets are used for wave-changing, this cheapens the cost a little and they are just as efficient.

Components List, Fig. 24a

C1 100pF Mica capacitor.
C2 500pF variable capacitor solid dielectric.
C3 1000pF Mica capacitor.
X1 Germanium crystal.
L1-2 R.E.P. dual range coil. Blue box.
6 Insulated wander-plug sockets.
5 Wander Plugs.
2oz. Tobacco tin or similar container.

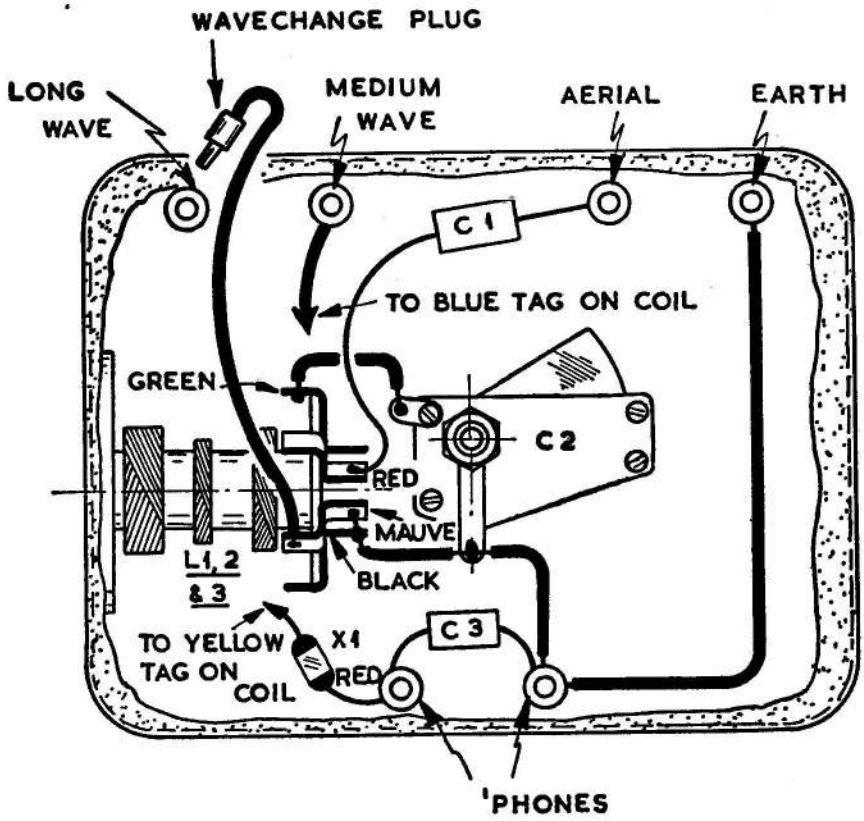

LID SHOWN BROKEN AWAY TO REVEAL POSITION OF COMPONENTS.

FIG. 24 b

10

In certain cases, signals from the local transmitter are too powerful to permit a crystal set with a normal coil to be of much use. I myself live in Hertfordshire a few miles from the London transmitters, and find a more elaborate circuit is necessary. Now in radio circles it is a well-known fact that the greater the number of tuned circuits, the greater the overall selectivity. Look at Fig. 25a, you will see that the usual L and C tuning arrangements have been duplicated. This type of circuit is known as a Band-Pass Filter. There are many kinds of such filters, this particular type is an inductively-coupled filter, note that energy from the first half (L2) is conveyed to L3 by way of two small inductors L1 and L4.

Tuning is quite sharp and the "feel" of the set is quite different from that of single coil designs. A small chassis is ideal for construction. 6"x4"x2½" was used on the original, though it could have been smaller.

Fig. 25b gives the layout and wiring.

Take particular notice that L1-2-3 is mounted horizontally and at right angles to L4-5-6, this is to prevent the coupling from being too "tight" which would ruin the idea of the filter. A good aerial and earth is of course necessary. It may be found on test that the selectivity is too great

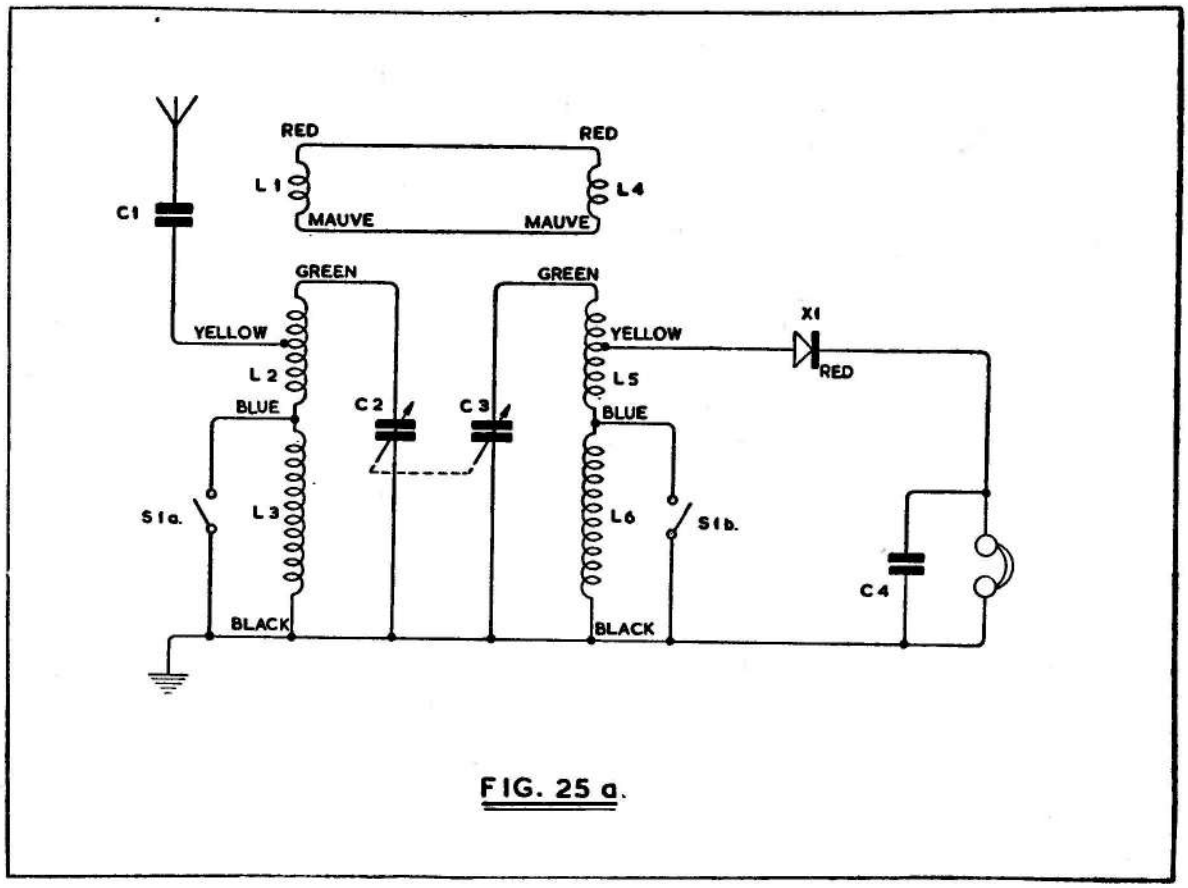

FIG. 25 a.

and that volume has suffered. This can be ingeniously overcome by connecting a very small capacitance between the two Green tags on the coils. The simplest way is to connect it across the fixed vane connections on C2-C3. Values for this extra capacitance are a matter for experiment usually a value between 10pF and 47pF is sufficient. A small 50pF trimmer could be used and adjusted to suit. The ideal setting is to enable powerful adjacent stations to be received just short of overlap so that as much volume as possible is obtained.

There is one point to be observed with the ganged capacitor. It should be of the type fitted with trimmers though of course, there is no reason why you should not fit them yourself. These are to allow for differences between coils to be balanced out, and consist of a small variable capacitance across each main section.

When setting up the receiver, first set each trimmer at half way and tune in a station near the high-frequency end of the band (vanes nearly out) adjust the trimmers for maximum volume. If extra coupling capacity is added as described, try adjusting them further.

Once properly set up, no further adjustment is necessary.

Components List, Fig. 25a

C1 100pF Mica capacitor.
C2-3 2 x 500pF variable capacitor (see text).
C4 1000pF Mica capacitor.
L1-2-3 Dual Range Coil R.E.P. (Blue Box).
L4-5-6 Dual Range Coil R.E.P. (Blue Box).
X1 Germanium Crystal.
S1a-b 2 pole single throw toggle switch.
4 Terminals or plugs and sockets.

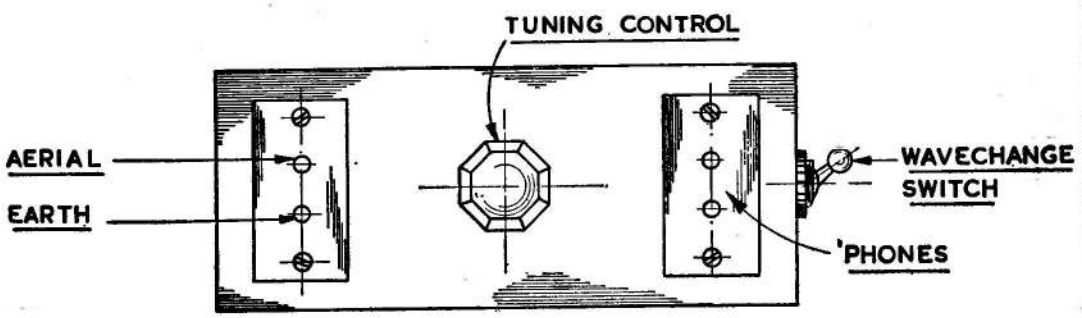

FRONT OF COMPLETED RECEIVER.

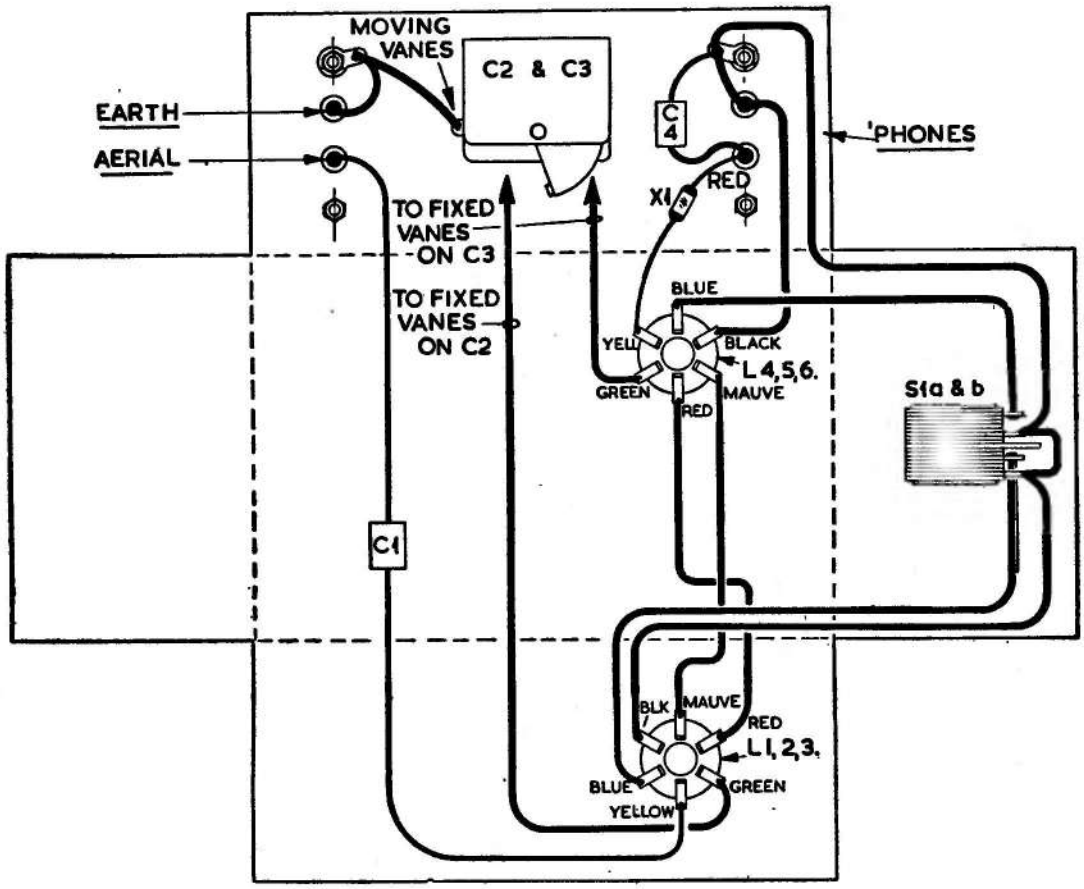

EXPLODED UNDER-CHASSIS VIEW

FIG. 25 b

Another band-pass circuit is shown in Fig. 26a. This time home-made coils are used. This filter is not inductively coupled but entirely capacitive, relying on C3. As in the previous circuit it must be adjusted to give just sufficient " broadness " to the tuning to provide adequate volume without station overlap. To avoid unwanted coupling a screen is mounted between the coils, this is necessary because due to the size of the coils they would be bound to couple quite tightly without it. Such precautions were not necessary with the circuit of Fig. 25a, as the commercial coils are much smaller physically and the risk of unwanted coupling reduced.

The coils for this receiver are for medium wave reception only, this keeps the size down. Coil winding procedure has already been fully explained, and covers all the requirements of these coils. Base-board and panel construction is used, and for more accurate tuning since the coils are home-made, separate tuning capacitors are recommended. Fig. 26b gives the layout and practical wiring.

Components List, Fig. 26a

C1 100pF Mica capacitor.
C2 500pF variable capacitor.
C3 50pF Mica trimmer.
C4 500pF variable capacitor.
C5 1000pF mica capacitor.
L1-2 See text.
X1 Germanium Crystal.
4 Terminals or plugs and sockets.

For those who do not wish to bother with these a ganged capacitor can be used, but tuning may not be as good as with separate ones. The screen mounted between the coils is of aluminium or copper and should be about 1" higher than the coils and the same length as the baseboard depth.

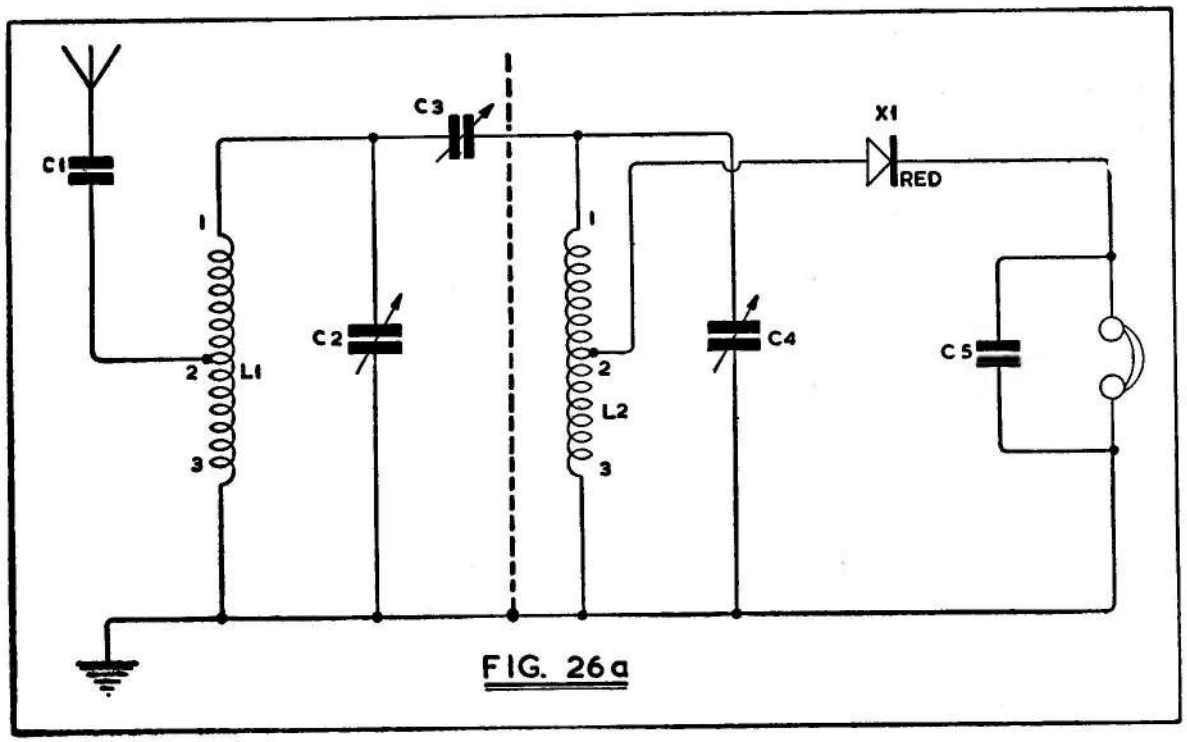

FIG. 26a

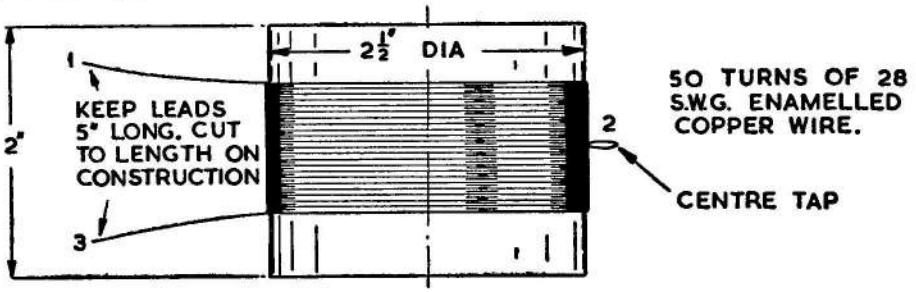

COIL DETAILS.

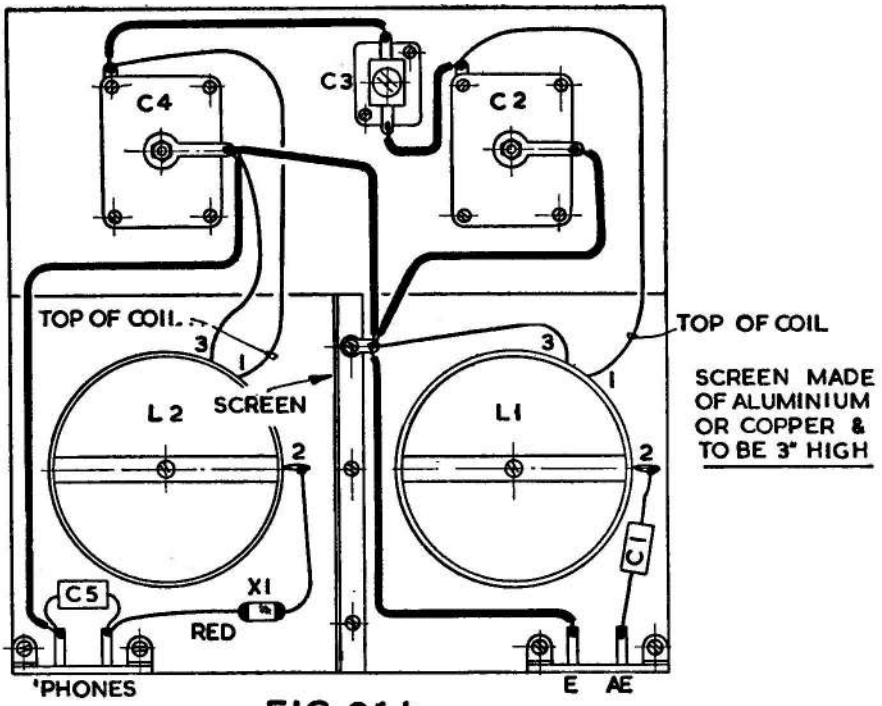

FIG. 26 b

12

Fig. 27a-b uses a band-pass filter for tuning, and the coils are home-constructed.

With this design a ganged capacitor is quite suitable as the coils tune quite accurately. It is essential that the coupling condenser C3 is **non-inductive,** there will be no difficulty in obtaining a new component of this pattern but it is as well to avoid old components which may not employ this form of construction.

Receivers using this type of filter are used to the best advantage when situated a short distance from a powerful transmitter and if selectivity is not important this particular design is not the most suitable.

Both medium-waves and long-waves are catered for: consider L1-2-3, this is the first half of the filter.

L1 is the aerial coupling coil, with S1 closed,

the medium-waves are received. This coil is inductively coupled to L2 and L3. Again with S2 open L2 and L3 combined cover the long-waves and when S2 is closed the medium waves are covered.

Tuning for this half of the filter is by means of the capacitor C1, which is one half of the ganged capacitor. A screen is erected between the two sets of coils comprising the filter, and coupling is effected by C3, an earth return for the coils is provided by R1.

L4 and L5 operated in a similar manner to L2 and L3, tuning is by means of C2, the remaining section of the ganged capacitor. You will realise that the coils must be accurately wound otherwise tuning will not remain constant between the two sections over the band.

The ganged capacitor should be fitted with trimmer capacitors when purchased so that the two circuits can be balanced.

You will have noticed that this circuit uses three sets of switch contacts. A three-pole two-way wafer switch is the best choice otherwise either two or even three separate switches are necessary. All the necessary coil details are given in the diagrams, the tap on L4 is made in the same way as shown for other coils in the manual. One other component used only on this design, is the resistor R1, its size is not important because the current flowing is so small it can be ignored.

A ¼ watt rating is adequate, its precise value is not critical so that a 20% tolerance component is quite suitable.

Resistors are coded by colours and the 1000Ω type you require will bear the following sequence. At one end will be painted three coloured rings.

Components List, Fig. 27a

C1-2 500pF 2 gang, variable capacitor.
C3 0.05mfd. non-inductive paper capacitor.
C4 1000pF mica capacitor.
R1 1000 ohm resistor.
X1 Germanium Crystal.
S1-2-3 3-pole 2-way wafer switch.
L1-2-3 & L4-5 See text.
4 Terminals (Aerial, Earth and 'Phones).
Sheet copper or aluminium for screen.

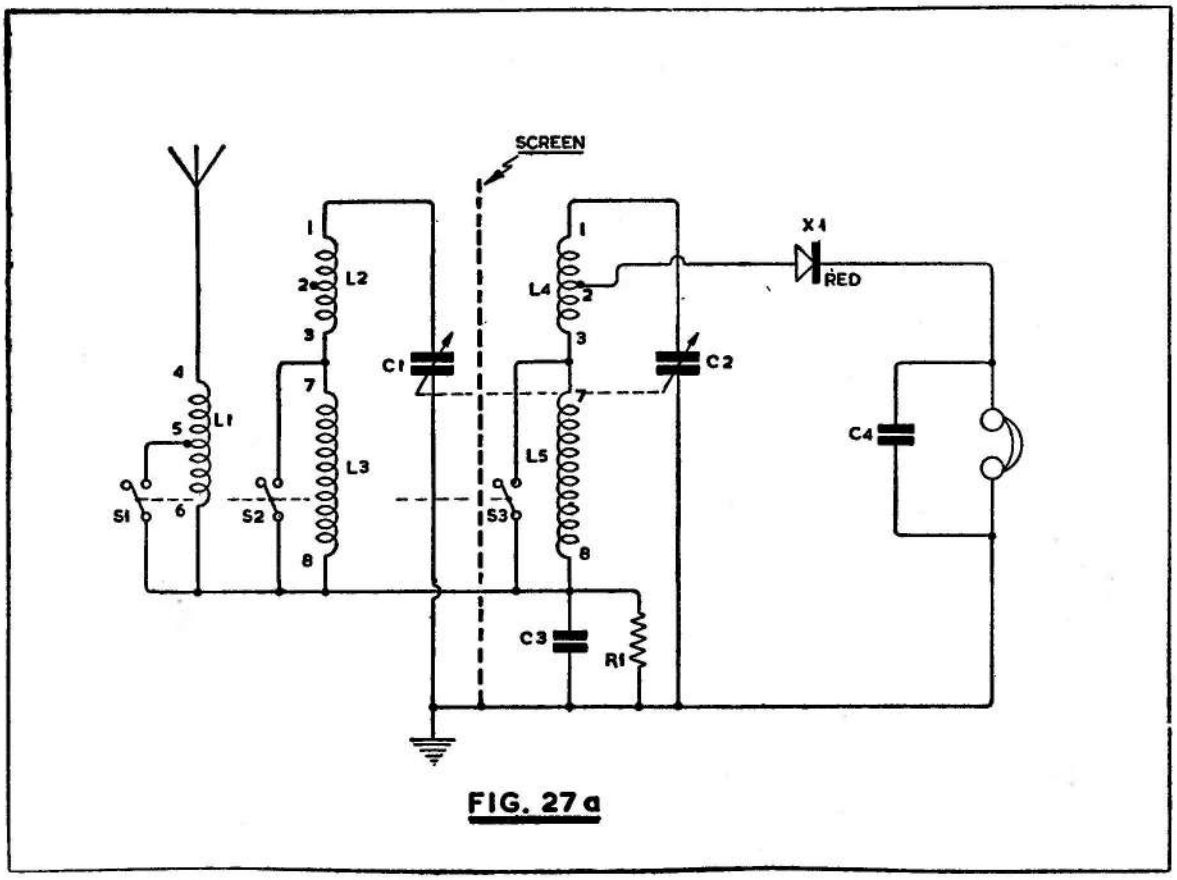

FIG. 27a

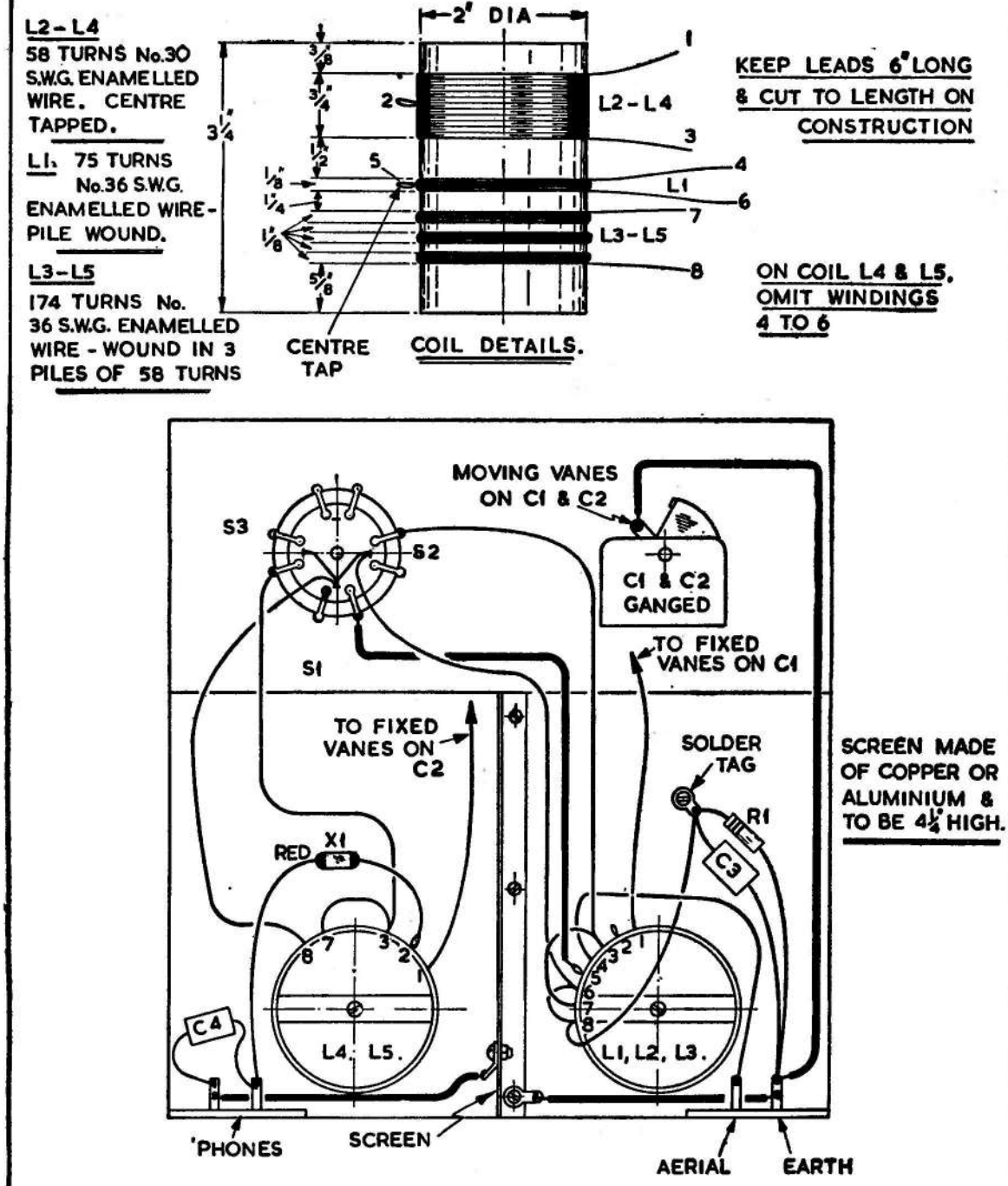
L2 - L4
58 TURNS No.30 S.W.G. ENAMELLED WIRE. CENTRE TAPPED.
L1. 75 TURNS No.36 S.W.G. ENAMELLED WIRE - PILE WOUND.
L3 - L5
174 TURNS No. 36 S.W.G. ENAMELLED WIRE - WOUND IN 3 PILES OF 58 TURNS
2" DIA
3¼"
CENTRE TAP
COIL DETAILS.
KEEP LEADS 6" LONG & CUT TO LENGTH ON CONSTRUCTION
ON COIL L4 & L5, OMIT WINDINGS 4 TO 6
MOVING VANES ON C1 & C2
S3
S2
S1
C1 & C2 GANGED
TO FIXED VANES ON C1
TO FIXED VANES ON C2
SOLDER TAG
R1
C3
RED
X1
C4
L4, L5.
L1, L2, L3.
'PHONES
SCREEN
AERIAL
EARTH
SCREEN MADE OF COPPER OR ALUMINIUM & TO BE 4½" HIGH.

FIG. 27 b

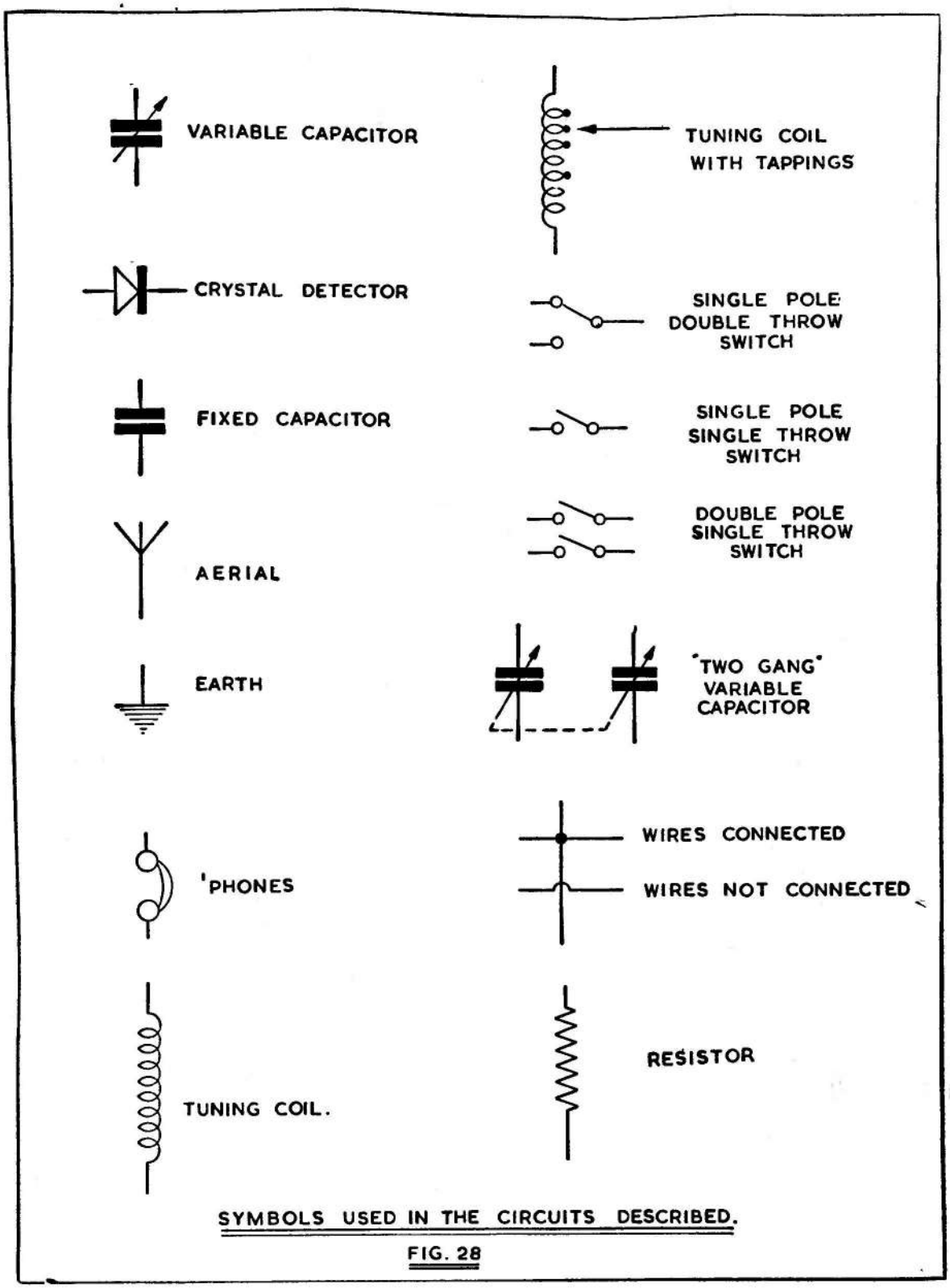

SYMBOLS USED IN THE CIRCUITS DESCRIBED.

FIG. 28

The first one is BROWN which represents 1, the first figure of the value, the second BLACK, this indicates the second numeral is nought, and the third colour is RED which tells us that two further ciphers or noughts are added to give the total value. From this you can see, we have 1 plus a nought equalling 10, plus two further noughts which total 1000. Some earlier types of resistor were painted differently, the whole body colour represented the first figure, one tip was coloured to represent the second figure, and a painted dot in the centre gave the number of ciphers to be added.

There are no other special points regarding construction except perhaps that if a long aerial is used, a small 100pF capacitor might be tried in the aerial lead to prevent damping the first tuned circuit.

When setting up the receiver, tune to a station at the high-frequency end of the M.W. band and set the trimmers for loudest volume, no other adjustments are necessary.

CONCLUSION

The twelve receivers described are representa tive of the best crystal set designs available to-day. Their construction will provide many hours of useful enjoyment, and the results will give lasting pleasure.

A final word about components, if no actual maker is specified, any good class component can be used. Switches, fixed and variable capacitors and crystals, are available from numerous manufacturers all of which are invariably of excellent quality. Where a particular manufacturer's product is called for, the specification should be adhered to. The commercial coils specified are freely available from most supply houses specialising in components for constructors, but in case of difficulty write to Bernards (Publishers) Ltd., The Grampians, Western Gate, London, W.6, who will, on receipt of a S.A.E. be pleased to supply the address of your nearest stockist. Coil formers are not always easy to obtain and in this case advice should be sought from Post Radio Supplies, 395, Queensbridge Road, London, E.8, who will be pleased to help in any way possible.

The HF Current Probe: Theory and Application

KENNETH WYATT
Wyatt Technical Services
Woodland Park, Colorado, USA

This article describes one of the most valuable tools in the EMC engineers "bag of tricks" – the high-frequency current probe. Current probes are invaluable for measuring high-frequency common-mode (or "antenna") currents flowing on wires or cables. Experience has proven that poorly terminated (bonded or filtered) cables are the number-one cause for radiated emissions failures at a test facility. By measuring the common-mode (CM) currents (sometimes referred to as "antenna" currents) on these cables it's possible to troubleshoot and apply fixes to a product right there in your development lab. You can also predict, to a good degree of accuracy, whether a given cable current will pass or fail in the measurement chamber. This will save you tons of time trying to apply fixes at the test facility while the clock is ticking away your test time. I'll also show you several ways to create do-it-yourself (DIY) probes that are quick to make and very useful in a pinch.

COMMON-MODE CURRENTS

Let's consider CM currents and how they are generated, because it is not intuitive as to how current may travel the same direction through both the signal and signal-return wires in a cable or PC board. Referring to Figure 1, note that due to finite impedance in any grounding system (including circuit board signal/power return planes), there will be a voltage difference between any two points within that return plane. This is denoted by V_{GND1} and V_{GND2} in the figure. This difference in potential will drive CM currents through common cabling or circuit traces between circuits or sub-systems. In addition, unbalanced geometries - for example, different lengths or path routings for high-speed differential pairs - can create voltage sources that drive associated CM currents. Finally, routing a high-speed clock trace across a split in the return plane or referencing it to multiple planes, can also be a source of CM current. Because the current phasors in Figure 1 are additive, the resulting radiated phasor may be quite large compared to those generated by differential-mode (DM), or signal currents, which are opposite in direction, and so tend to cancel. Therefore, CM emissions tend to be more of an issue than DM emissions.

CURRENT PROBES: THEORY OF OPERATION

The RF current probe is an "inserted-primary" type of radio frequency current transformer. When the probe is clamped over the conductor or cable in which current is to be measured, the conductor forms the primary winding. The clamp-on feature of this probe enables easy placement around any conductor or cable. This is essentially a broadband high-frequency transformer. High-frequency currents can

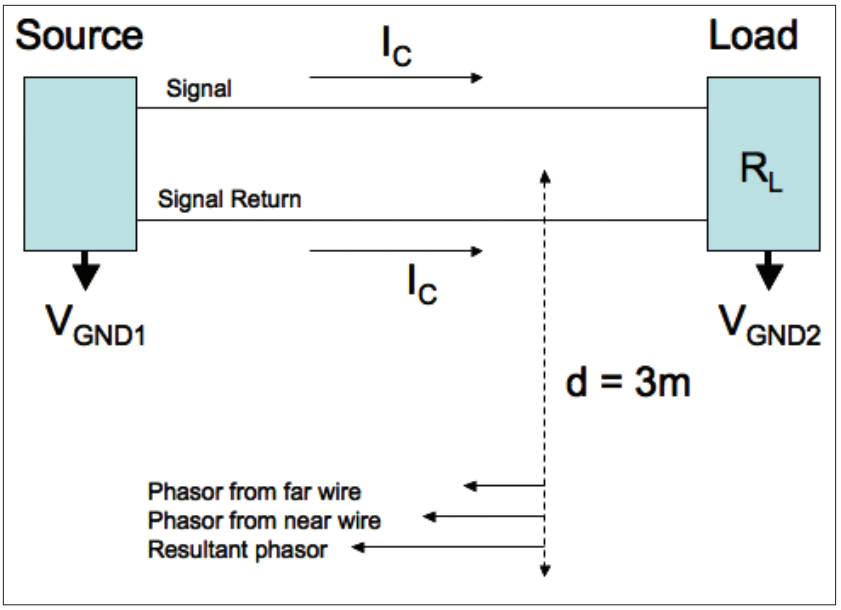

Figure 1. *Common-mode currents in a circuit loop. The source is a digital signal (with harmonics) and we'll assume a resistive load. Because the phasor current in the far wire is in the same direction as the phasor current in the near wire, the resultant phasor is relatively large compared to that produced by differential-mode current phasors. In this case, lowering the harmonic content (by slowing the digital rise/fall-times) or diverting/blocking the CM current is very important in limiting radiated emissions.*

be measured in cables without physically disturbing the circuit.

Since the current probe is intended for "clamp-on" operation, the primary shown in Figure 2 is actually the electrical conductor in which CM currents are to be measured. This primary is considered as one turn since it is assumed that the CM currents flow through the conductor and return to the source via a return conductor such as a frame, common ground plane, or earth. On some current probe models the secondary output terminals are resistively loaded internally to provide substantially constant transfer impedance over a wider frequency range.

COMMERCIAL CURRENT PROBES

While commercial current probes are pricey, the advantage is that they can open up and snap around a cable, rather than having to be threaded onto the cable to be measured. See Figure 3. They are also a lot more rugged and can take a lot of abuse as compared to the "do-it-yourself" (DIY) versions below. Finally, they are also accurately characterized, allowing very precise measurements of cable currents.

DIY CURRENT PROBES

In a pinch, you can make your own current probe. Examples of several DIY probes are shown in Figures 4 and 5. I typically try to find a ferrite toroid or clamp-on core that offers good high-frequency characteristics in the 10 to 1000 MHz range. Winding a few (not too critical) turns and terminating with a coax connector is all you need. Keeping the turns as far apart as possible (as in Figure 4) will reduce inter-winding capacitance and yield better results at the higher frequencies. This is one of the largest drawbacks in performance of the clamp-on ferrites (as in Figure 5).

TRANSFER IMPEDANCE

The CM current (Ic) in microamps in the conductor under test is determined from the reading of the current probe output (V) in microvolts divided by the current probe transfer impedance (Zt).

$$\mathbf{Ic = V/Zt} \quad (1)$$

Or, in dB

$$\mathbf{Ic(dBuA) = V(dBuV) - Zt(dB\Omega)} \quad (2)$$

The typical transfer impedance of the current probe throughout the frequency range is determined by passing a known RF current (Ic) through the primary test conductor and noting the voltage (V) developed across a 50-Ohm load. Then,

$$\mathbf{Zt = V/Ic} \text{ (in standard units)} \quad (3)$$

Or

$$\mathbf{Zt(dB\Omega) = V(dBuV) - Ic(dBuA)} \quad (4)$$

The Fischer F-33-1 probe is a commonly used troubleshooting tool and has a flat frequency response from 2 to 250 MHz (Figure 6). The transfer impedance is about 5Ω (approximately +14 dBΩ on the graph), therefore, a 1 uA current will produce a 5 uV output voltage from the current probe.

PROBE CALIBRATION

The accurate calibration of RF current probes is a complex process. Characterization is a more correct term to use than calibration. The probe must be properly characterized to reflect how the user uses the probe. Probe manufacturers usually sell a calibration fixture that attempts to maintain a 50Ω impedance. A 50Ω load is connected to the output port and a calibrated RF generator (or network analyzer) is connected to the input port. The probe to be characterized is clamped around the fixture and the frequency is swept while measuring

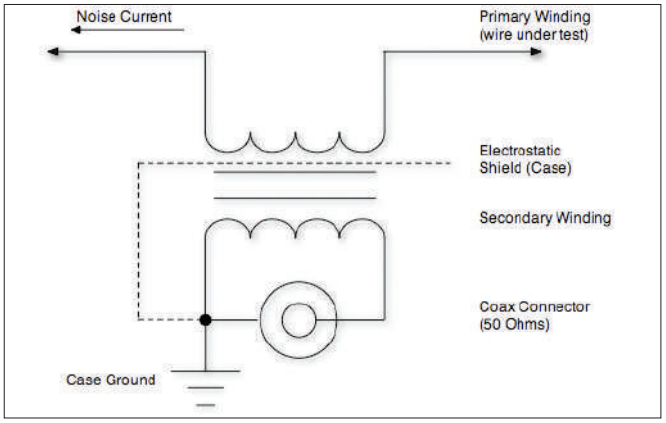

Figure 2. *The basic current probe (high-frequency current transformer).*

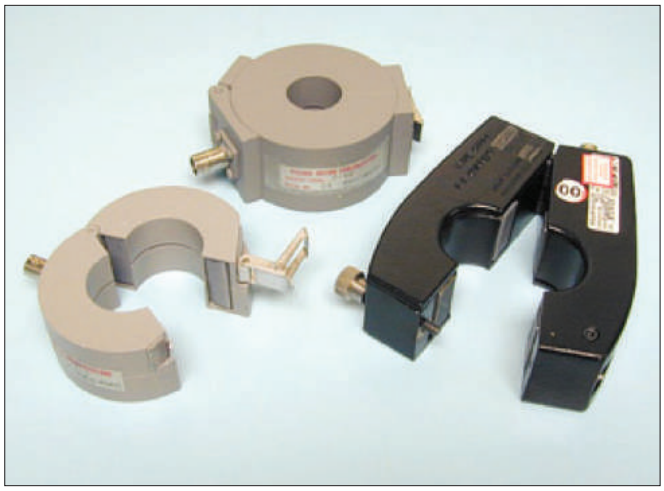

Figure 3. *Examples of commercial current probes.*

Figure 4. *Examples of DIY current probes based on a large toroid core. These photos were taken prior to installing the E-field shield which consists of a layer of copper tape over the windings, leaving a small gap around the inside of the toroid. 14 turns of Teflon-insulated wire wound around a Würth Electronik #74270097 ferrite core (4W620 material) was used, which is useful from 10 to 1000 MHz.*

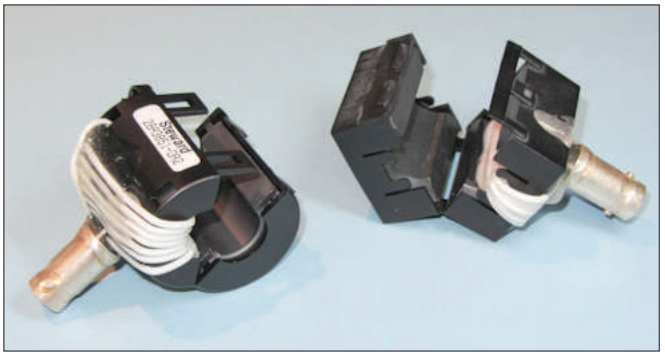

Figure 5. *Examples of DIY current probes based on clamp-on ferrite chokes. I used a couple sample Steward (now a unit of Laird Technologies) chokes – a round one (model 28A3851-0A2) and a square one (model 28A2024-0A2). They each had 7 turns of Teflon-insulated wire wound around one-half and glued down on the inside to hold the windings. I later epoxied a PC board-style BNC connector to the outside, making sure there was enough epoxy to hold the outer turns together. Type 28 material was used, which is useful from 10 to 1000 MHz.*

the probe output.

My test setup was a little more rudimentary (Figure 7), but for troubleshooting purposes, it's good enough. I used a short piece of stiff wire across the output port with a 50Ω resistive load in series. I then adjusted the generator for zero dBm – a convenient amount. This is equivalent to an output voltage of 224 mV (or 73 dBuA of current) into 50Ω. The actual generator output doesn't matter, so long as the resulting probe voltage is large enough to be seen readily in the receiver or spectrum analyzer. I monitored the probe output with a Thurlby Thander TTi PSA2701T handheld spectrum analyzer.

Knowing the current through the wire in dBuA and the probe output in dBuV, the transfer impedance may be plotted graphically by subtracting: V(dBuV) – Ic(dBuA) (expressed in dB). In this case, Z_T(dBΩ) = V(dBuV) – 73. While this may be useful for educational purposes, I wouldn't be too inclined to use the DIY probes to predict "pass/fail", as described further down. However, because they compare favorably to the commercial probes as far as output voltage, I believe (and have proven in practice) that they are completely suited for troubleshooting. You only need to know whether an EMC design fix made the cable current better or worse.

PREDICTING PASS/FAIL

It is possible to predict whether a particular cable will pass or fail radiated emissions by measuring the CM current at the offending frequency, reading off the transfer impedance of the probe, Zt (dBΩ) in Figure 6, and solving for Ic (using Equation 2 above). Plugging Ic(Amps) into Equation 5 will calculate the E-field level in V/m. The length of the cable is L(m) and the offending harmonic frequency is f(Hz). Use a test distance, d, of either 3 or 10m to predict the outcome at those test distances.

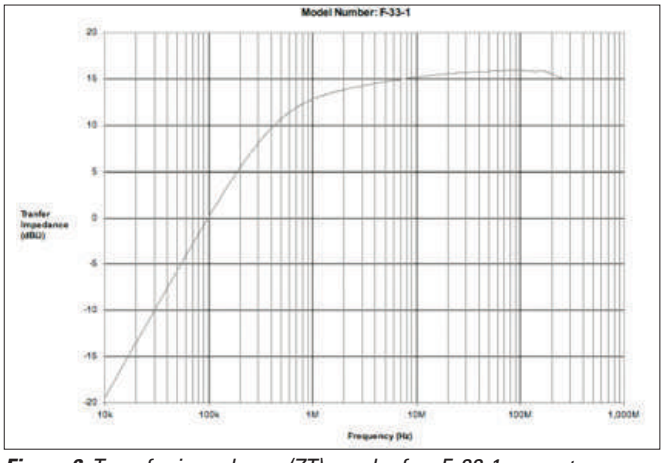

Figure 6. *Transfer impedance (ZT) graph of an F-33-1 current probe (courtesy of Fischer Custom Communications). The x-axis is frequency, while the y-axis is dBΩ. Use this to calculate the value of Ic (Equation 2), given the measured voltage at the probe terminals (V_{dBuV}) and ZT.*

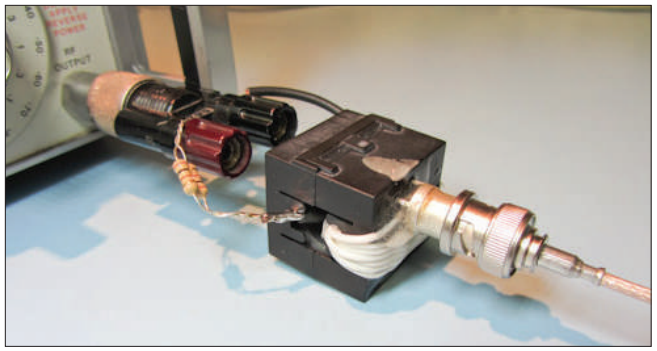

Figure 7. *I used a short wire and 50Ω load (two parallel 100Ω resistors) across the generator output for probe characterization. Obviously, there are shortcomings at higher frequencies, due to the inductance of the wire. In fact, the system impedance starts to go capacitive at 100 MHz and it's difficult to keep a fixed 224 mV across the load resistor with frequency.*

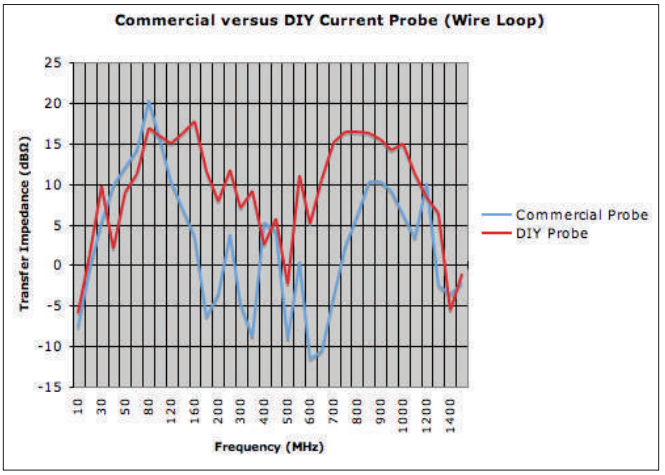

Figure 8 *Transfer impedance (Zt) graph of a commercial current probe versus the DIY toroidal probe. The x-axis is frequency, while the y-axis is dBΩ. Note that the commercial probe is only designed and characterized to 250 MHz, so the data above that, while interesting, is probably not valid. The DIY probe, as well, performs poorly above 200 MHz and frankly, the wire loop used to introduce a "calibrated" current (while as short as possible) affects the measurement, as well.*

$$\left|\hat{E}_{C,\max}\right| = 1.257 \times 10^{-6} \frac{\left|\hat{I}_C\right| f L}{d} \qquad (5)$$

Once you've determined a particular cable has CM currents that may cause a RE failure, you should to examine the connector where the cable is attached to the product enclosure. Very often, I find poor or non-existent bonding between the connector shield and enclosure shield. These points must be bonded well to permit the CM currents to flow back to their source within the product, avoiding associated cable radiation. Please refer to my previous articles on troubleshooting radiated emissions for more information (references below).

REAL-WORLD TROUBLESHOOTING EXAMPLE

As previously mentioned, one of the most common sources of radiated emissions is due to poorly bonded connectors mounted on shielded product enclosures. This occurs especially if the connectors are circuit board mounted and penetrate loosely through the shielded enclosure. Poorly bonded connectors allow internally generated CM currents to leak out and flow on the outside of I/O, mouse or keyboard cables. This will also allow ESD discharges inside the product – more bad news. If these currents are allowed out of the enclosure, the attached cables will act as radiating antennas – often resonating around 300 MHz, due to their typical 1m length.

This was the case for a new digitizing oscilloscope prototype I worked on recently. The I/O connectors were all soldered onto the PC board and the board was fastened to the rear half of the enclosure. The connectors simply poked up through cutouts in the rear metal shield.

While using a current probe to measure the CM current flowing on the outside of the USB cable under test, I simply jammed the screwdriver blade of my Swiss Army knife between the connector bonding fingers and metal chassis enclosure and was able to drop the overall cable currents by 10 to 15 dB.

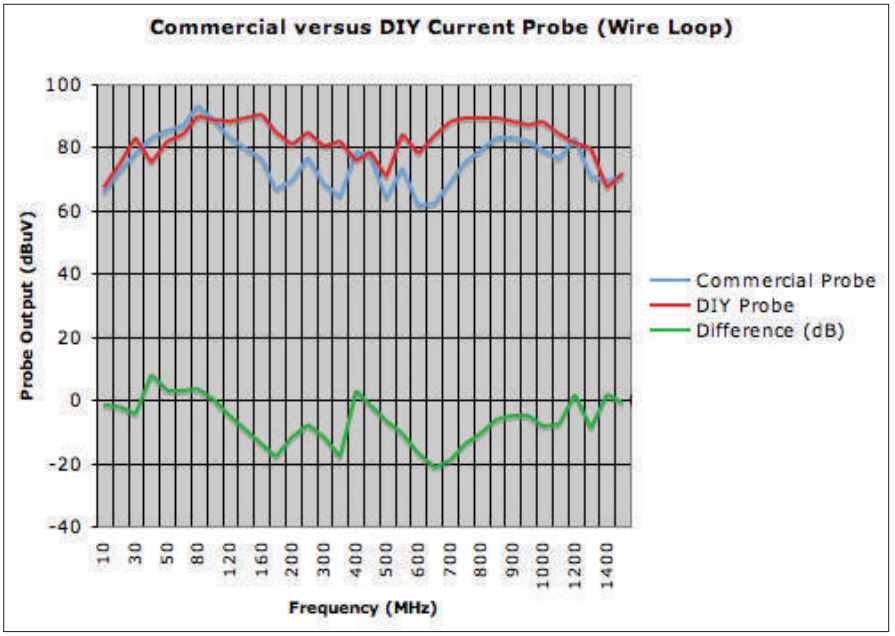

Figure 9. *Probe output voltage (V_{out}) graph of a commercial current probe versus the DIY toroidal probe. The x-axis is frequency, while the y-axis is dBuV. This shows that the probes are very comparable in output voltage versus frequency. For troubleshooting purposes, absolute accuracy is not required - just consistency in measurements. All one really needs to know is, "did the fix I implemented make the CM current go up or down?" The DIY probe works well for this.*

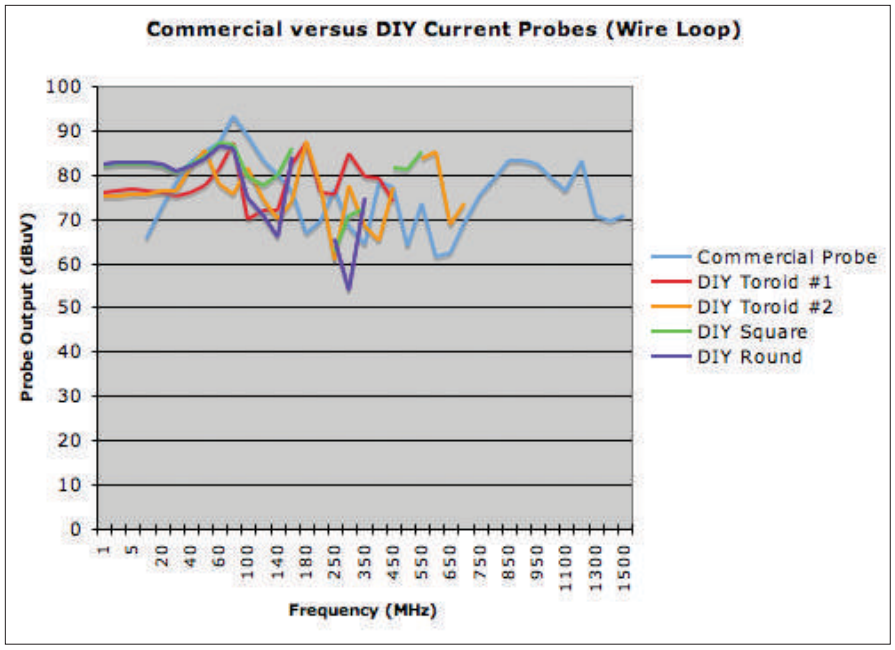

Figure 10. *Probe output voltage (V_{out}) graph of a commercial current probe versus two DIY toroidal probes and two different clamp-on probes. The x-axis is frequency, while the y-axis is dBuV. This shows that all these probes are very comparable in output voltage versus frequency and therefore, useful for troubleshooting purposes. Just don't try using the DIY probes to determine "pass or fail" predictions. Commercial probes are better-suited for that.*

The solution was to fabricate a custom shim with spring-fingers that would slip over all the connectors creating a firm bond between the connector ground shell and inside of the shielded enclosure. More and more low-cost products are relying on PC board mounted I/O connectors as a cost-cutting measure. Any time you see this, be prepared to carefully examine the bonding between the connector ground shell and the shielded enclosure.

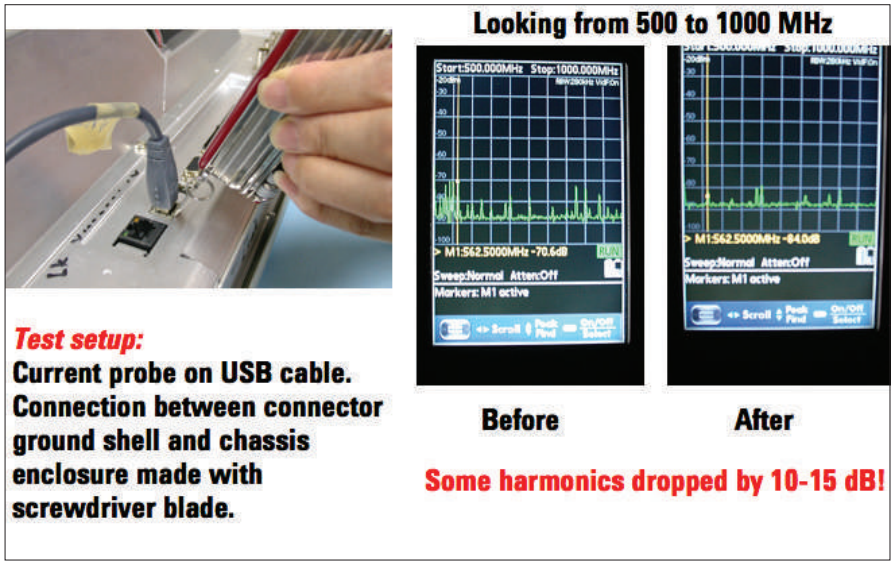

Figure 11. *Cables should be tested individually. Here, I have a current probe clamped around the cable under test and am monitoring the harmonics with a simple hand-held spectrum analyzer. As I ground the connector shell to the chassis with the Swiss Army screwdriver blade, the harmonics were reduced 10-15 dB!*

TROUBLESHOOTING TIPS USING CURRENT PROBES

Here are a few troubleshooting tips using current probes.

1. When evaluating the harmonics on a cable by using a current probe, if sliding the probe back and forth changes the harmonic levels, part of the coupling may be near-field, rather than conducted.

2. When using a pair of current probes; one on each of two cables, if the harmonics are the same in each, the source is in the middle. If one cable has stronger harmonics, then you'll want to work on that side first. See Figure 12 below.

3. Measuring the currents on two suspect legs of a dipole should read the same. Placing the two suspect legs through the same current probe should cause a big decrease due to current cancellation. See Figure 12 below.

4. When measuring video cable currents and large cable movements cause big changes in amplitude, the coupling is likely inductive - otherwise, it's more likely conductive.

5. If you suspect inductive coupling, the phase at the victim will be 180-degrees from the source. This may be observed on an oscilloscope with H-field probes or current probes. Try syncing the scope trigger at the source using a scope probe.

My colleague, Doug Smith, has many more examples on how to use current probes for measuring cable and PC board resonances, injecting pulses for troubleshooting, interpreting the relative phase of common-mode currents and troubleshooting ESD issues. Refer to the references below.

SUMMARY

Use of a current probe is vital during the troubleshooting process. Poorly bonded cable connectors can be readily identified and fixed. The radiated E-field from a product I/O cable may be calculated by measuring the high-frequency common-mode currents flowing in the cable. All this may be performed right at the designer's workbench and without the expense of a third-party test facility or shielded chamber.

REFERENCES - PAPERS

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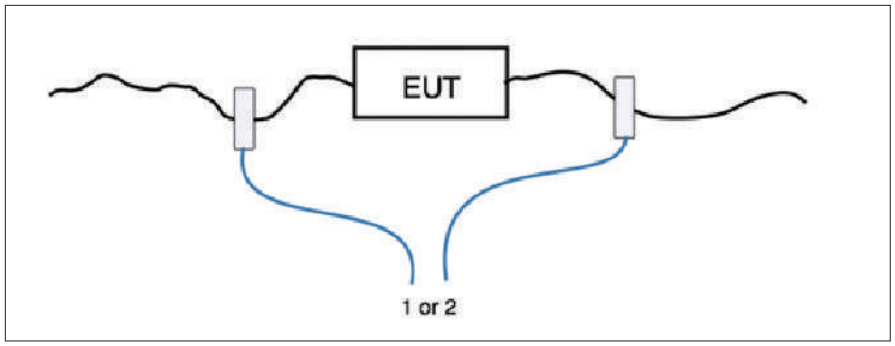

Figure 12. *When measuring two cables from a system and the harmonic currents are approximately the same (point 1 is the same as point 2), the source is at the center (the EUT) and the two cables are acting as a dipole antenna. You may notice a peak in harmonic strength at the half-have length of the two cables combined. If the harmonic currents are larger in one side or the other, then you'll want to troubleshoot just that cable.*

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KENNETH WYATT, SR. *EMC Engineer, Wyatt Technical Services LLC, holds degrees in biology and electronic engineering and has worked as a senior EMC engineer for Hewlett-Packard and Agilent Technologies for 21 years. He also worked as a product development engineer for 10 years at various aerospace firms on projects ranging from DC-DC power converters to RF and microwave systems for shipboard and space systems. A prolific author and presenter, he has written or presented topics including RF amplifier design, RF network analysis software, EMC design of products and EMC troubleshooting techniques. He has been published in magazines such as, RF Design, EMC Design & Test, Electronic Design, InCompliance, Interference Technology, Microwave Journal, HP Journal and several others.*

Wyatt is a senior member of the IEEE and a long time member of the EMC Society where he serves as their official photographer. He is also a member of the dB Society and is a licensed amateur radio operator. Contact Wyatt at ken@emc-seminars.com. His website is www.emc-seminars.com.

No. 96

CRYSTAL SET CONSTRUCTION

SIMPLE INSTRUCTIONS FOR MAKING NINE CRYSTAL SETS

by B. B. BABANI

There is to-day a marked revival of interest in crystal receivers, and this book has been specially prepared to introduce the home constructor to the design and building of the various types. The text is simple and free from technicalities, so that even the young reader may confidently embark on the construction of any of the receivers shown.

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1. AERIALS.
2. EARTHS.
3. CRYSTAL DETECTORS.
4. COILS.
5. THE BEGINNERS' CRYSTAL RECEIVER.
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7. LONG DISTANCE RECEIVER.
8. HIGH GAIN RECEIVER.
9. HIGH SELECTIVITY RECEIVER.
10. BATTERY AIDED CRYSTAL RECEIVER.
11. MEDIUM AND LONG BAND RECEIVER.
12. ULTRA SENSITIVE ALL WAVE RECEIVER.
13. AN ADVANCED CRYSTAL DIODE RECEIVER.

THERE ARE 12 DIAGRAMS

LONDON: BERNARDS (PUBLISHERS) LIMITED

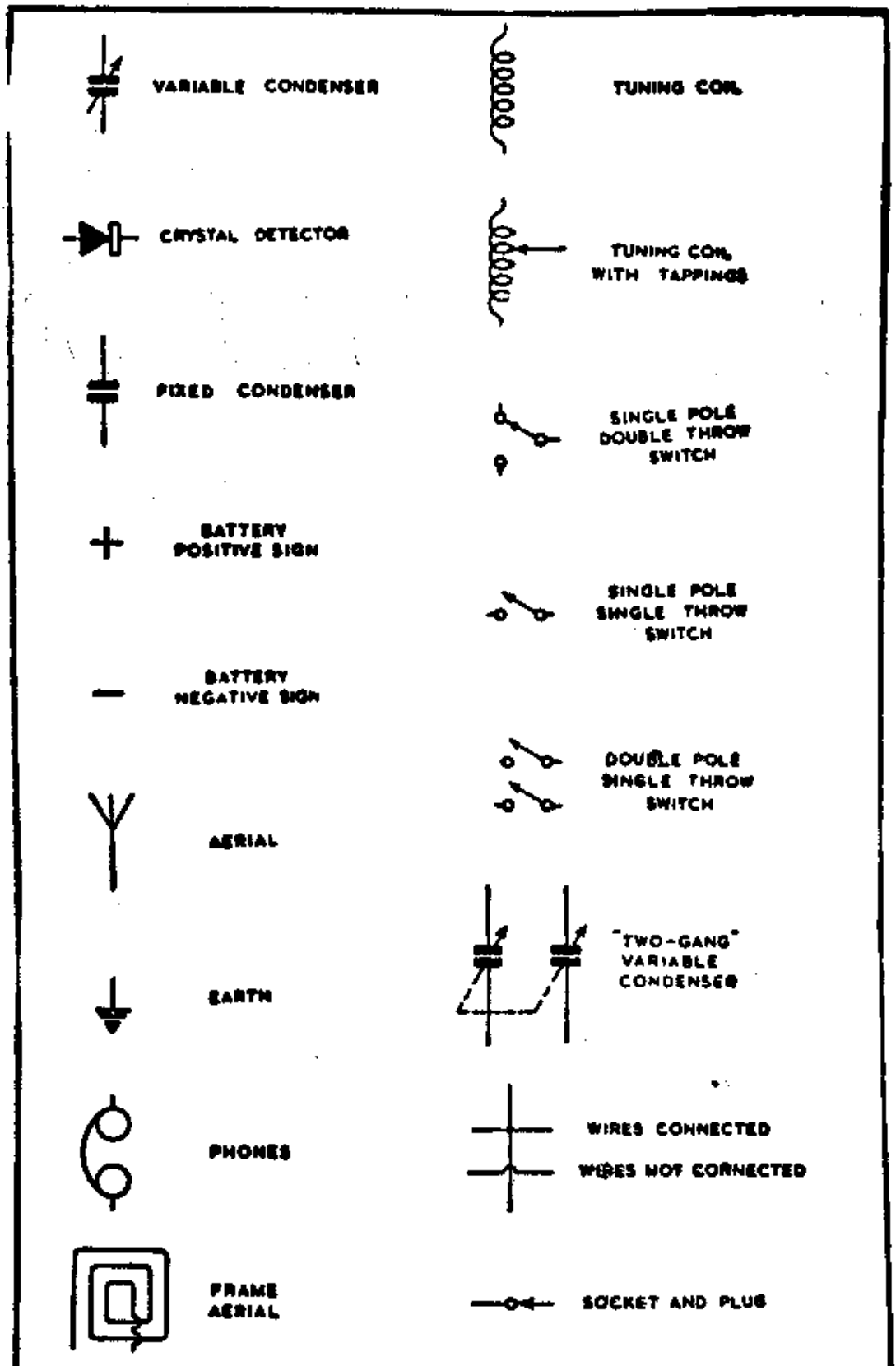

FIG. 1 SYMBOLS USED IN THE CIRCUITS DESCRIBED.

1. Aerials.

One of the essentials for satisfactory reception with crystal sets is an efficient aerial. Four different types are suggested and are shown in Fig. 2.

There are several important points to be noted when erecting an aerial for a crystal set.

(1) See that it is suspended as high as possible and is not screened by tall buildings, obstructions, etc.

(2) The aerial itself and the lead-in from the aerial must be adequately insulated. Be sure that the porcelain or plastic insulators do not permit the aerial or lead-in to touch the building, tree, or post from which they are suspended. The lead-in should be brought into the house through an insulated rod.

(3) It is exceedingly important to use insulated copper wire, either single or multi-stranded, for both the aerial and the lead-in.

2. Earths.

An adequate and efficient earth contributes to the good performance of any well-designed crystal set and Fig. 3 shows the best method of obtaining an efficient earth where there is a garden or patch of ground available at a short distance from the receiver.

Obtain a 3-ft. length of ½-in. galvanised iron pipe and at one end drill a hole right through. Insert a bolt with spring washer and locking nut in the hole. Connect the earth lead-in wire to the bolt; the other end of the lead-in to the earth connection on the receiver. Leave both ends of the pipe open. Insert the end opposite the bolt into the ground vertically until only 3-in. are showing above the surface of the surrounding earth.

It is important to see that the surrounding ground is kept damp, if necessary by occasionally pouring a pint or two of water down the open projecting end of the pipe.

Ready-made copper earthing rods with a pointed end for easy hammering into the earth are sometimes obtainable from radio dealers.

Should a garden not be available, an alternative earth is a cold water pipe coming from a rising main. Simply file very lightly the pipe at the back of the tap and wind the copper wire earth lead-in round the filed part and cover the joint with insulating tape.

In no circumstances should a gas pipe be used for an earth.

3. Crystal Detectors.

Most radio dealers can supply very efficient permanent or semi-permanent crystal detectors of proprietary makes. However, there are always available quite a number of ex-Government surplus units which are called crystal valves and, though these were originally designed for a very different use in service equipment, they are easily adaptable and will give extremely efficient results when used in circuits designed for them. To enable the constructor to purchase suitable types for this purpose—and they cost very little—the following list gives the Government reference numbers.

CV 101, CV 102, CV 103, CV 111, CV 112, CV 113, CV 226, CV 241, CV 246, CV 247, CV 253, CV 291, CV 351, CV 361, CV 364, CV 367, CV 727, CV 749, and CV 1785.

One of the satisfactory proprietary makes of this class of crystal detector is the BTH CS7A, which, incidentally, is the commercial equivalent of the CV 253.

For all these Government types, one connection should be made to each end by arranging a holder to fix them into or by carefully soldering the appropriate connecting wires to each end.

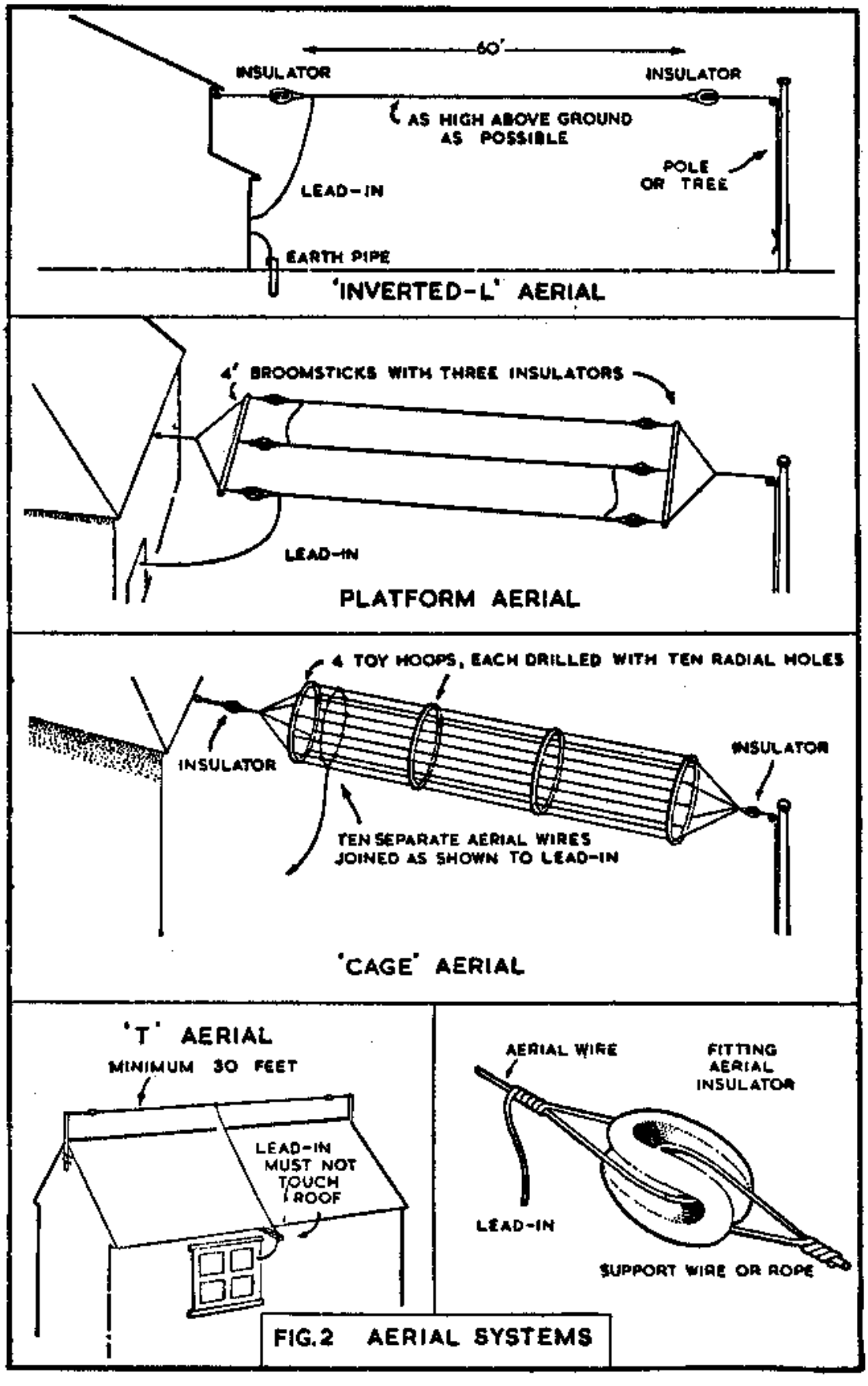

FIG. 2 AERIAL SYSTEMS

4. Coils.

In Fig. 3 two methods are shown of fixing the coil to the chassis. However, the ingenious constructor may evolve another arrangement.

The important thing to remember is that the coil should be fixed so that it is completely insulated from the metal chassis that may be used.

It is also important to remember that if a metal chassis is used, one must see that all components and wiring, with the exception of earth connections, are adequately insulated from this chassis so as to make sure that no short circuits take place. It is recommended that all crystal sets should be built on a panel, and that both panel and chassis should be of bakelite, paxolin or perspex, as these three materials are efficient insulators in themselves.

5. The Beginners' Crystal Receiver.

The popularity of the crystal receiver among beginners is undoubtedly due to the very modest outlay necessary, and the ease with which such receivers may be built. It is not always appreciated that, to obtain worth while results,

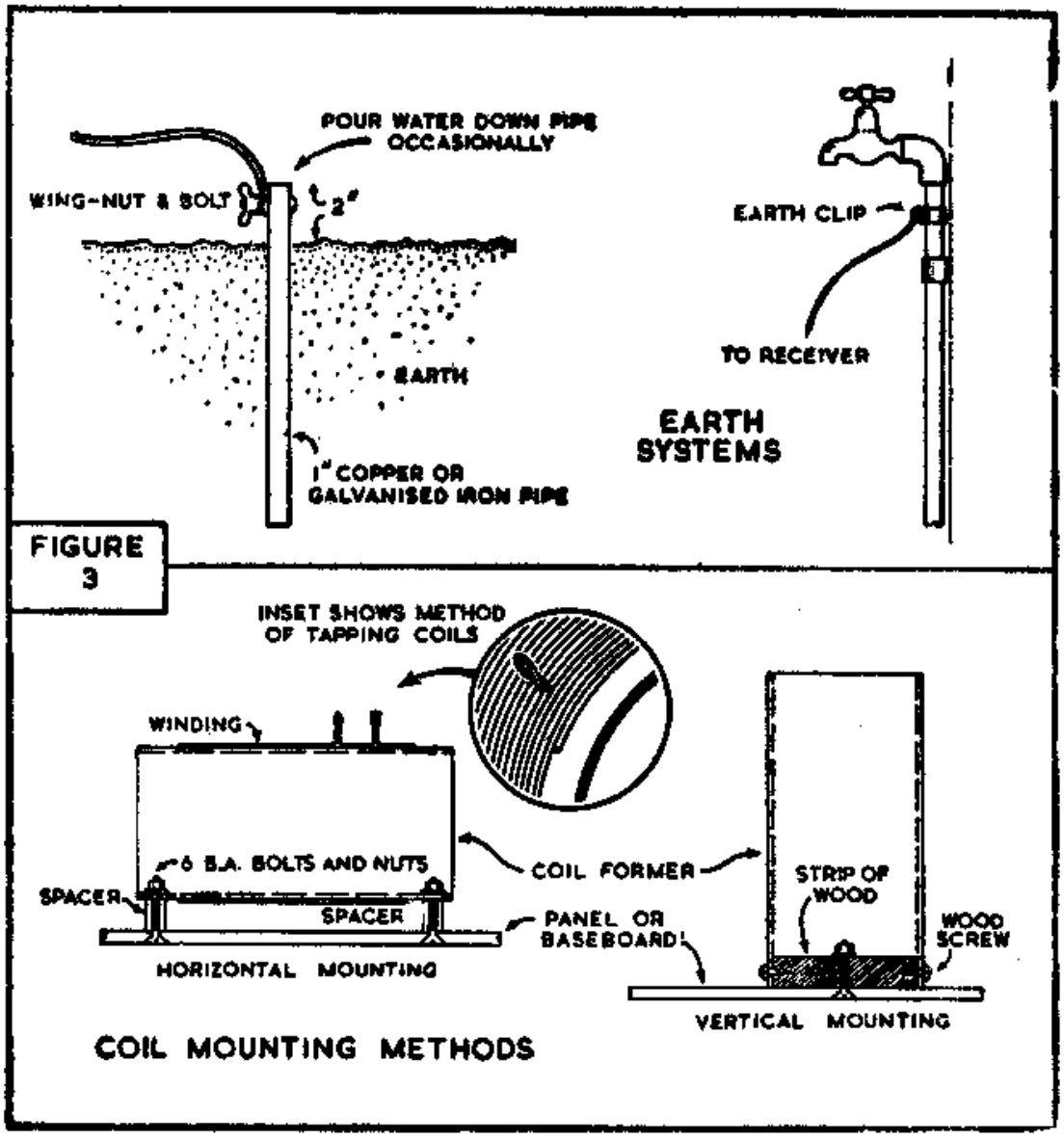

far more care in avoiding losses is necessary than with a three or four valve receiver. One reason for this is the fact that the crystal receiver can offer no help by way of amplification and it is therefore dependent on an efficient aerial/earth system, low loss design within the receiver itself, and the use of sensitive headphones. The experience gained is well worth the time expended since, when more ambitious receivers are attempted, the constructor will remember the benefits gained by efficient construction and installation with the result that each receiver attempted will be an instrument capable of giving a first class performance.

Losses within the receiver itself may be considerably reduced by efficient coil design. Unfortunately, selectivity is a factor which must not be overlooked; it is this factor which governs the sharpness of the tuning and permits the separation of adjacent powerful stations. The greater the selectivity, the greater the ease with which signals may be separated; but at maximum selectivity the received signals are at minimum strength. In Fig. 4, the coil is tapped at four points, which enables the best point between selectivity and sensitivity to be chosen. The nearer the aerial tap to the earth end of the coil, the greater the selectivity. The pre-set condenser C1 also aids selectivity; at minimum capacity the selectivity is high, and *vice versa*.

Used in conjunction with the coil taps, the constructor should have no difficulty in selecting a condenser setting and tapping point which permit the reception of strong signals and at the same time effect the required separation of powerful stations.

The coil is constructed on a former 3-in. diameter × 2-in., and consists of 50 turns 36 S.W.G. enamelled wire close wound and tapped at every tenth turn. These taps are brought out in the form of loops twisted firmly so that there is no actual break in the winding continuity. After completion the winding may be painted with Durafix to prevent any movement, and the taps and two free ends cleaned with emery cloth to remove the enamel. The layout and wiring is shown in Fig. 4. The headphones should have a resistance of some 4,000 ohms or more and should be of reputable manufacture. Any of the aerials previously described are suitable for use with this receiver.

C2 .0005 variable condenser.
C1 .0002 pre-set condenser.
C3 .001 mica condenser.
1 Crystal detector, semi-permanent pattern.
2 oz. 30 S.W.G. enamelled copper wire.
1 Coil former 3-in. dia. × 2-in.
1 Ebonite or Bakelite panel 6-in. × 5-in. × ¼-in.
4 terminals, connecting wire, etc.

6. Frame Aerial Receiver for Local Station use on Medium wave bands.

This receiver was specially designed for constructors who are within 5 to 10 miles of a powerful station and who have no facilities for constructing a good outdoor aerial.

The frame itself consists of two ¾-in. × ¾-in. square section wooden rods each 36-in. in length. These are placed together at their centre line to form a cross; they are fastened by a nut and bolt and these in turn pass through an upright piece of wood ½-in. × 1-in. section 2-ft. in length. This upright support is then screwed into a baseboard 8-in. × 8-in. × 1-in. thick. At each of the arms of the 36-in. cross a 4-in. strip of ½-in. square section wood is placed. Reference to Fig. 5B will give the details of the construction of this aerial quite clearly.

It will be noted that approximately 85-ft. of 20 S.W.G. double cotton-covered wire are required for the inductance to cover the medium wave broadcast band. The wire should be wound around the four crossbars, thereby creating

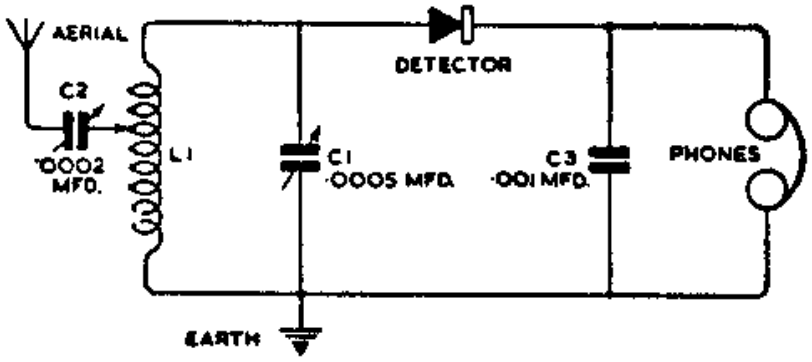

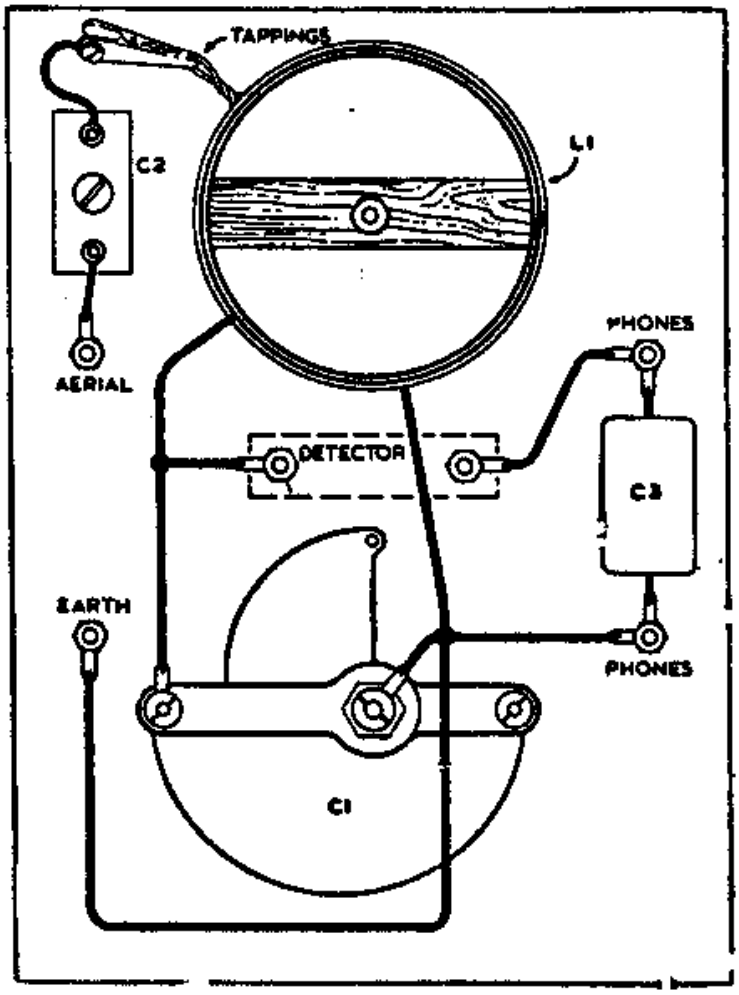

FIG. 4 THE BEGINNER'S CRYSTAL RECEIVER.

a square wire frame, and each turn of the wire should be spaced approximately ½-in. The best way to effect this spacing accurately is to file on the 4-in. crossbars a number of small nicks at ½-in. intervals. The two ends of the wire should then be brought down on the two terminals which may be screwed into the square baseboard and two leads taken from there to the crystal set itself.

The actual set may be constructed on a small ebonite, paxolin or perspex panel 8-in. × 5-in. which may be screwed to one side of this base supporting piece of wood, thereby making the set virtually self-contained except for the earphones. Fig. 5A shows the circuit of the receiver.

To obtain the best results with this receiver, the aerial should be rotated by hand until the signals become loudest.

1 Semi-permanent crystal detector.
C1 1 .0005 mfd. variable condenser.
C2 1 .0005 mfd. fixed condenser.
1 condenser dial marked 0 to 100 or 0 to 180.
1 pair of high sensitivity earphones.
85-ft. to 90-ft. of 20 S.W.G. double cotton covered wire. (8oz.)
Sufficient connecting wire for wiring purposes.

7. Long Distance Receiver.

This receiver has been specially designed to achieve high sensitivity. With a sufficiently good outdoor aerial effective reception has been obtained up to 150 miles.

The circuit is quite straightforward, as can be seen from Fig. 6 and the only special point is in winding the coil L1.

This coil consists of a 2½-in. diameter former on which are wound a total of 51 turns using 24 S.W.G. double cotton wire. Starting at one end, tap every two turns until there are eight taps; wind a further 15 turns and tap; then a further 10 turns and tap; finally, add 10 turns to end the winding. The wire should be close wound, *i.e.*, with turns touching.

To obtain the best results, the two crocodile clips A and B should be tried on the various coil taps until the loudest reception is obtained. It may be found in use that the loudest reception of any particular station causes another station to be heard at the same time; care should, therefore, be taken to select the appropriate tapping point to separate any two powerful stations that may interfere with one another.

4 oz. 24 S.W.G. DCC copper wire.
Coil former 2½-in. dia. × 3-in.
C1-2 single variable condensers .00035 mfd.
2 Condenser dials marked from 0 to 100 or 0 to 180.
1 Permanent crystal detector.
C3 .001 fixed condenser.
1 pair of high sensitivity earphones (preferably between 4,000 ohms and 8,000 ohms impedance).
2 Crocodile clips.

8. High Gain Receiver.

This receiver has been designed to give good reception up to 50 miles distance from any normal power broadcasting station in the medium band. It is a very selective circuit and will therefore enable the user to separate closely situated stations.

It will be noticed in the circuit (Fig. 7) that the variable condenser C1, has an on/off switch S1 to throw it out of circuit if necessary. It is used to increase the selectivity of the receiver and, in operating, it should be tried with this condenser either in or out of circuit on the various tappings on the coil L1.

L1 consists of 90 turns of 22 S.W.G. double cotton covered wire wound on a 2-in. diameter former and tapped every ten turns. L2 separately wound on a 2-in. former, consists of 90 turns of 22 S.W.G. double cotton covered wire, also tapped as L1. The components required are given on page 9

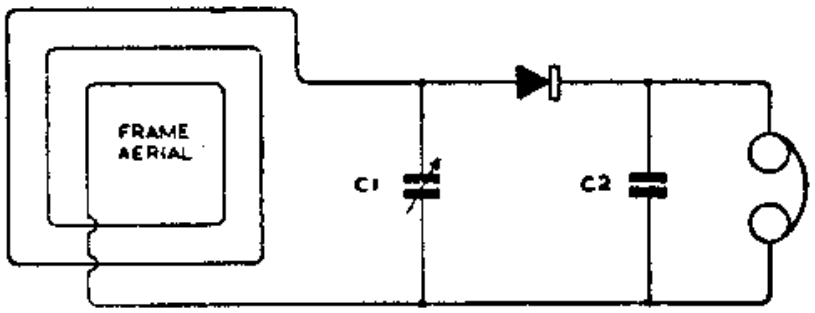

FIG. 5A FRAME AERIAL CRYSTAL RECEIVER

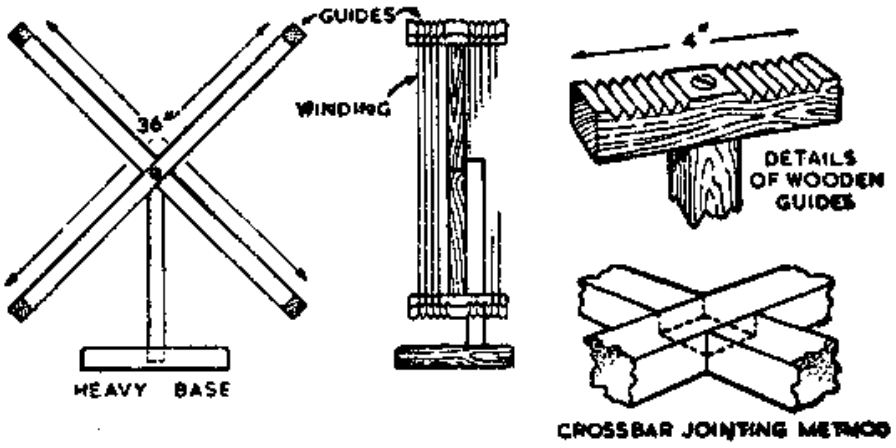

FIG. 5B. DETAILS OF FRAME AERIAL

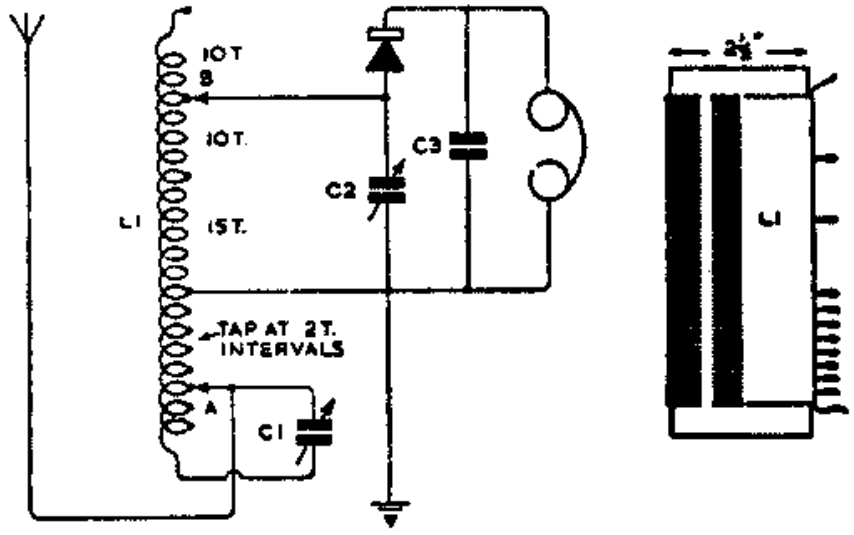

FIG. 6 LONG-DISTANCE CRYSTAL RECEIVER

C1-2 Single variable condensers .00035 mfd.
S1 Single pole single throw switch.
C5 .0001 preset condenser.
1 Permanent crystal detector.
C3-4 .001 mfd. fixed condenser.
1 Pair of high sensitivity earphones.
8 oz. 22 S.W.G. DCC.
2 Dials for variable condenser marked 0 to 100 or 0 to 180.

9. High Selectivity Receiver.

This circuit (see Fig. 8) is for use in high saturation strength areas where it is desired to separate powerful stations. The circuit is not complicated and is extremely effective.

It will be noted that C1 and C2, each .00035 mfd. capacity, are 2 gang unit.

The only special point in this set is the design of coils L1, 2 and 3, which are constructed as follows: L1, 60 turns of 22 S.W.G. double cotton covered wire on a 3 × 4 inches former tapped every five turns; L2, 15 turns of 22 S.W.G. double cotton covered wire on a 3 × 6 former; and L3, 85 turns of 22 S.W.G. double cotton covered wire wound on the same former as L2, the two windings being separated by approximately ¼-in. (see Fig. 8).

Note that the aerial lead is brought down to one of the tappings on wire L1. This should be tried on each of the tappings and the one giving the required selectivity should be used.

C1-2 2-gang variable condenser .00035 mfd.
2 3-in. formers for coils L1-2-3.
8 oz. 22 S.W.G. DCC.
C3 .0005 fixed condenser.
1 Semi-permanent crystal detector.

10. Battery-aided Crystal Receiver.

Fig. 9 shows a design which utilises a 9-volt grid bias battery to improve performance.

The charge built up in the .02 mfd. fixed condenser is changed to a positive current when it passes through the coil L1. This, in turn, is superimposed on the positive charge that is commencing to be rectified by the crystal detector and thereby increases the signal strength.

Coil L1 consists of a 4-in. diameter former wound with 85 turns of 24 S.W.G. double cotton covered wire tapped at 5, 25, 45 and 65 turns from the earth end. The earth end and these four taps are brought out to five small sockets and the connection from the earth is taken to a small socket. The plug should be tried in each of the five positions to find which one gives the greatest signal strength.

The 9-volt battery is connected across the .02 mfd. condenser and special care should be taken to see that the battery is connected correctly, *i.e.*, negative pole to earth.

1 Permanent crystal detector.
1 4-in. dia. × 3-in. former.
8 oz. 20 S.W.G. DCC copper wire.
C1 Variable condenser .0005 mfd.
C2 Fixed condenser .005 mfd.
C3 Fixed condenser .02 mfd.
1 pair of high sensitivity headphones.
1 Clix plug.
5 Clix sockets.
1 9-volt grid bias battery.

11. Medium and Long wave band Receiver.

This set has been designed for reception on two wave bands.

Care must be taken in winding the coils L1, 2, 3 and 4. These are wound on a single 3-in. diameter former. L1 consists of 30 turns of 28 S.W.G. DCC tapped at 8, 16 and 24 turns. L2, 60 turns of 32 S.W.G. DCC. L3, 40 turns of 28 S.W.G. DCC, and L4, 80 turns of 32 S.W.G. DCC. All are close wound and are separated from each other as follows: between L1 and L2, 3/16-in.;

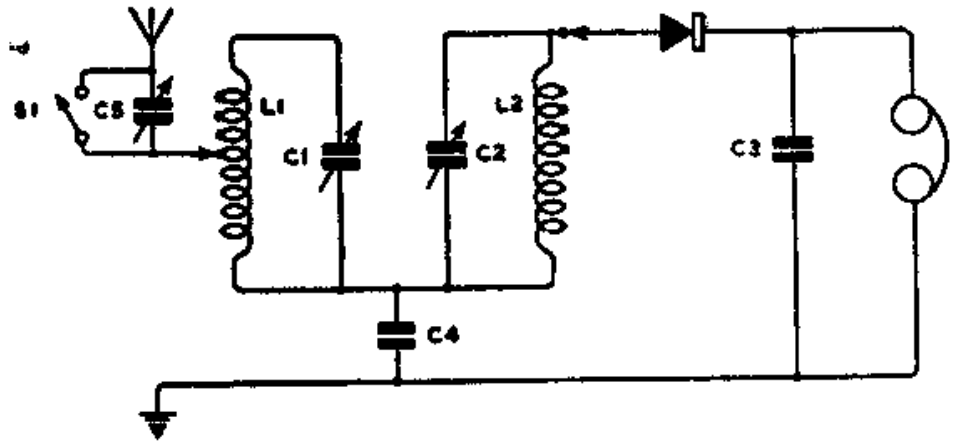

FIG. 7 HIGH-GAIN CRYSTAL RECEIVER

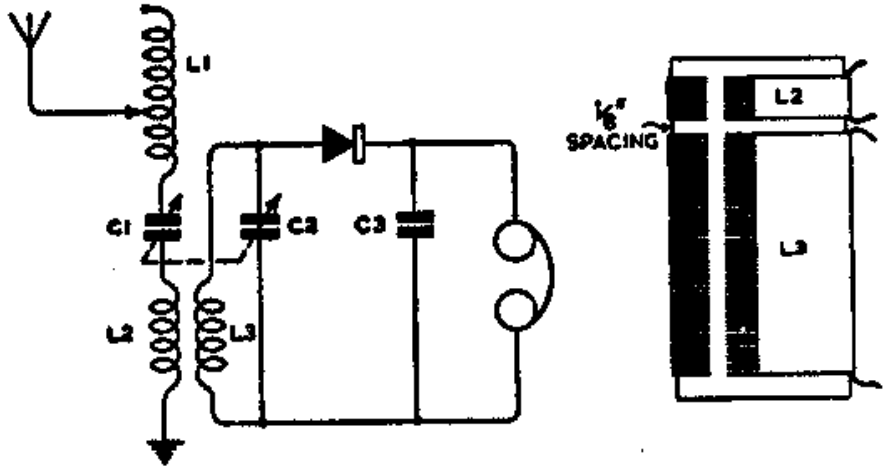

FIG. 8 HIGH SELECTIVITY CRYSTAL RECEIVER

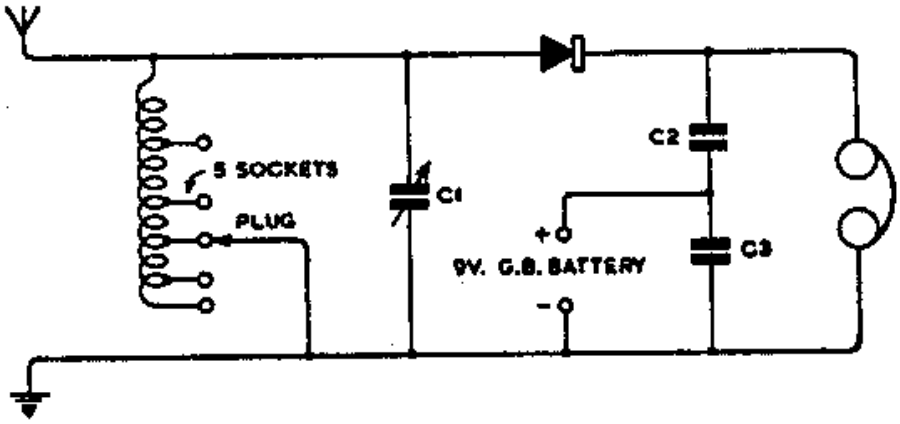

FIG. 9 BATTERY-AIDED CRYSTAL RECEIVER

between L2 and L3, 1-in.; and between L3 and L4, 3/16-in. See Fig. 10.

C1-2 single variable condensers .0005 mfd.
2 Variable condenser dials marked 0 to 100 or 0 to 180.
1 Clix plug.
3 Clix sockets.
S1 Single pole double throw switch.
C3 .001 mfd. fixed condenser.
1 Pair of high sensitivity earphones.
1 3-in. dia. × 8-in. former.
2oz of both 28 and 32 S.W.G. double cotton covered wire to make these 4 coils.
1 Permanent crystal detector.

In use, the plug should be tried in each of the three sockets to find the point which gives the best results. The switch is used as a wave band change switch.

12. Ultra Sensitive All Wave Receiver.

The receiver shown in Fig. 11 is for long distance reception. It is a novel circuit and, though apparently complicated in construction, it is really very simple to assemble with the minimum of tools and labour.

It will be seen from the circuit diagram that there are two banks of sockets, five black and six red. When using this set the appropriate black and red plugs should be inserted in whichever of the similar coloured sockets give the best results. The coil is quite easy to construct and consists of a primary winding which is inserted at the earth end of the secondary winding. For the medium wave band, the secondary winding L2 consists of 54 turns of 20 S.W.G. enamelled or cotton covered wire. This coil has four taps in addition to the starting point and the end connection, and these taps are taken at six turns, 14 turns, 27 turns and 40 turns from the earth end. The taps are taken out and a connection is made to an appropriate socket, as shown in the diagram.

The coil is wound on a 3-in. diameter former which may be a paper tube, bakelite, paxolin or perspex, and spacing is approximately 17 turns to the inch.

For short wave work down to about 30 metres, L2, the secondary coil, will consist of the same diameter former wound with 15 turns of the same gauge wire, the four taps being taken at 3, 6, 9 and 12 turns from the earth end.

L1, the primary coil, is used for both wave bands and consists of 11 turns of similar gauge wire to that used for L2, wound on a 2-in. × 1-in. former, the winding to be spaced the same as L2. The coil is then inserted at the earth end of whichever secondary coil L2 is being used.

The crystal detector may be one of the semi-permanent types freely available to-day; the old-fashioned cat's whisker pattern; or one of the silicon permanent detectors which are sold by many surplus dealers.

The 'phones should be of a standard type 4,000 ohms impedance although 'phones of other values will probably operate quite satisfactorily with this powerful receiver. It should, however, be stressed that the better the headphones used, the more satisfactory the reception.

Coils for other wave bands may be experimentally designed by the constructor, remembering that four tappings are advisable for the secondary coil L2.

A long aerial is very desirable with this receiver, placed as high as possible. It is recommended that a minimum length of 70-ft. be allowed, to include the aerial and lead-in.

The values of the components are shown in the following components list. The constructor should experience no difficulty in obtaining excellent results from this cleverly designed receiver.

C1 .0005 variable condenser.
C2 .002 fixed condenser.
1 semi-permanent crystal detector.
1 coil former 3-in. dia. × 4½-in.
1 coil former 2-in. dia. × 1-in.
½ lb. 20 S.W.G. enamelled or DCC copper wire.
6 red wander plug sockets.
6 black wander plug sockets.
1 red and 1 black wander plug.
Headphones, terminals, connecting wire

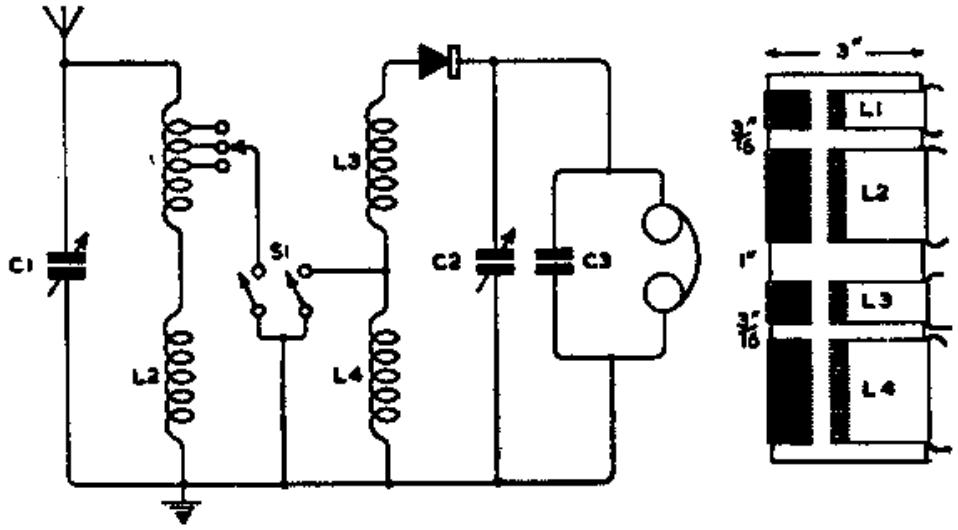

FIG. 10 MEDIUM AND LONG-WAVE CRYSTAL RECEIVER

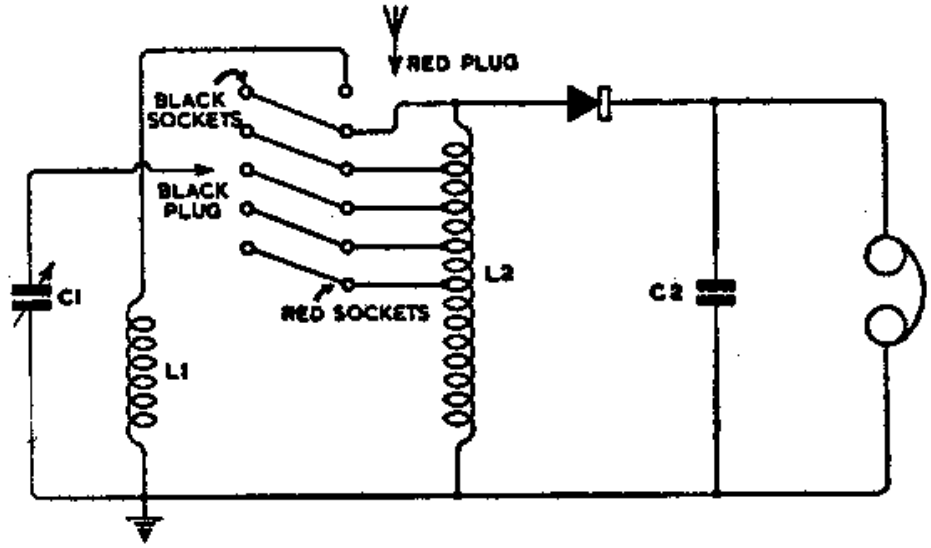

FIG. 11 ULTRA-SENSITIVE ALL-WAVE CRYSTAL RECEIVER

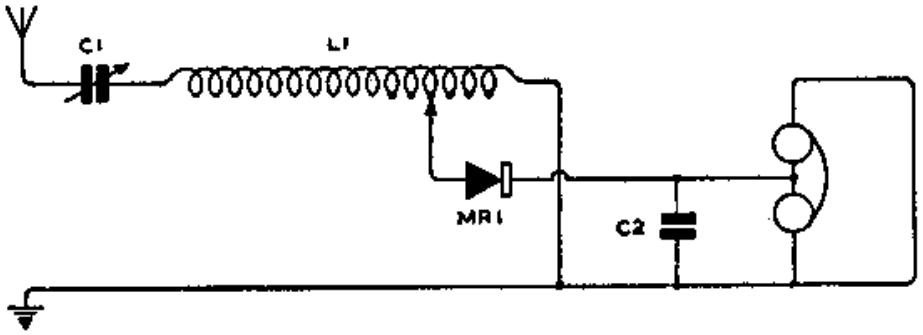

FIG. 12 ADVANCED CRYSTAL DIODE RECEIVER

13. An Advanced Crystal Diode Receiver.

The modern crystal diode of the radar type does not require any adjustment and thus has a distinct advantage over the ordinary crystal detector which needs delicate adjustment—even the semi-permanent type.

Such crystals are now obtainable on both the regular and the surplus markets, and a popular type is the B.T.H. CS7A silicon crystal (also coded as CV 253).

A rather different circuit from the usual crystal set arrangement is needed to suit the characteristics of a crystal diode. The diode must be tapped on to the tuning coil, and it is found that the tuning circuit itself gives best results if a series-tuned acceptor circuit is used. The circuit of a radar crystal receiver is shown in Fig. 12. The type of aerial used with this circuit has a very great bearing on the behaviour of the receiver for, in effect, the tuned circuit, with a series resistance equivalent to the reflected crystal load resistance, is in series with the capacitance of the aerial to earth and the aerial's effective series resistance.

At resonance—when the combination is tuned to any particular signal—the inductance resonates with the capacitances of the tuning condenser and the aerial in series, and the final effect is that the reflected load of the crystal, in series with the coil's R.F. resistance, is paralleled across the aerial's series resistance.

For maximum power transfer, the crystal load resistance must be made equal to the sum of the aerial series resistance and the coil R.F. resistance, and so the method in which the crystal is tapped into the tuning coil, and the exact capacitance required to tune the receiver to any required signal, must depend to a very great extent on the aerial itself.

At the same time the crystal resistance varies with the signal strength, the resistance being high for weak signals and dropping by as much as 50 per cent. and more for strong signals, so that this effect also has a bearing on the correct coil tap. The output impedance of the crystal also varies similarly, affecting the matching of the headphones into the crystal diode, and so for any set of conditions, the receiver requires to be matched up to both the aerial and the signal being received for best results. This would mean a series of coil taps and (theoretically, not practically) a matching transformer between the diode and the headphones; but in practice it will be found that a receiver using standard parts can be built up to give very good results under various conditions.

It has been shown already that the tuning of the receiver depends to a great extent on the characteristics of the aerial, and while a .0005 mfd. variable capacitor is shown in Fig. 12 as the tuner, the constructor must be prepared to experiment with different capacitance values until the required station is tuned in. The range of reception given by the receiver is quite good, if a really long and high aerial, and a good earth connection, are used; but no more than the local station signal can be expected, and the tuning therefore must be adjusted to suit the station frequency.

It must be mentioned that the headphones are shown parallel connected. High resistance headphones of the 4,000 ohm type must be used, and if two of these are connected in parallel rather than in the more usual series method, they will provide a roughly accurate match to the crystal. If more than one pair of headphones are to be connected in, then the pairs of headphones may be left series connected in the usual manner, the sets of headphones being connected in parallel.

The capacitor across the headphone terminals completes the crystal R.F. circuit, and any value between about 0.001 and 0.005 mfd. will serve. The higher capacitance will, of course, by-pass some of the higher audio frequencies, so

that if good steady reception is obtained some experiment with this condenser is also worth while.

C1, .0005 mfd. variable condenser.
C2, .005 mfd. fixed condenser.
M.R.1 CV 253 Crystal diode.
Coil former 1½-in. dia. × 4½-in.
4oz. 26 S.W.G. enamelled copper wire.

Coil details are as follows: 150 turns of 26 S.W.G. tapped at 20, 25, 30, 35, 40 and 45 turns from the earth end. At each tapping-point the wire should be twisted up into a loop and the winding then continued without breaking the wire; when the coil is completed and the ends anchored the tapping loops can be bared.

BERNARDS RADIO BOOKS

No.		Price
56.	Radio Aerial Handbook	2/6
57.	Ultra-Shortwave Handbook	2/6
58.	Radio Hints Manual	2/6
64.	Sound Equipment Manual	2/6
68.	Frequency Modulation Receivers' Manual	2/6
73.	Radio Test Equipment Manual	2/6
83.	Radio Instruments and their Construction	2/6
96.	Crystal Set Construction	1/-
99.	One Valve Receivers	1/6
100.	A Comprehensive Radio Valve Guide, Book 1	5/-
103.	"Radiofolder" A. The Master Colour Code Index for Radio and T.V.	1/6
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147.	Practical Tape Recording Handbook	5/-
148.	Practical Transistor Receivers, Book 1	5/-
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171.	Super Sensitive Transistorised Pocket Set Construction	3/6
172.	International Radio Stations List	2/6
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179.	Transistor Circuits Manual No. 5	5/-
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182.	"At A Glance" Radio Valve & T.V. Tube Equivalents	3/6
183.	How to Receive Foreign T.V. Programmes on your Television Set by simple Modifications	5/-
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	International Radio Tube Encyclopaedia—3rd Edition	63/-

all about CRYSTAL SETS

by
Charles Green

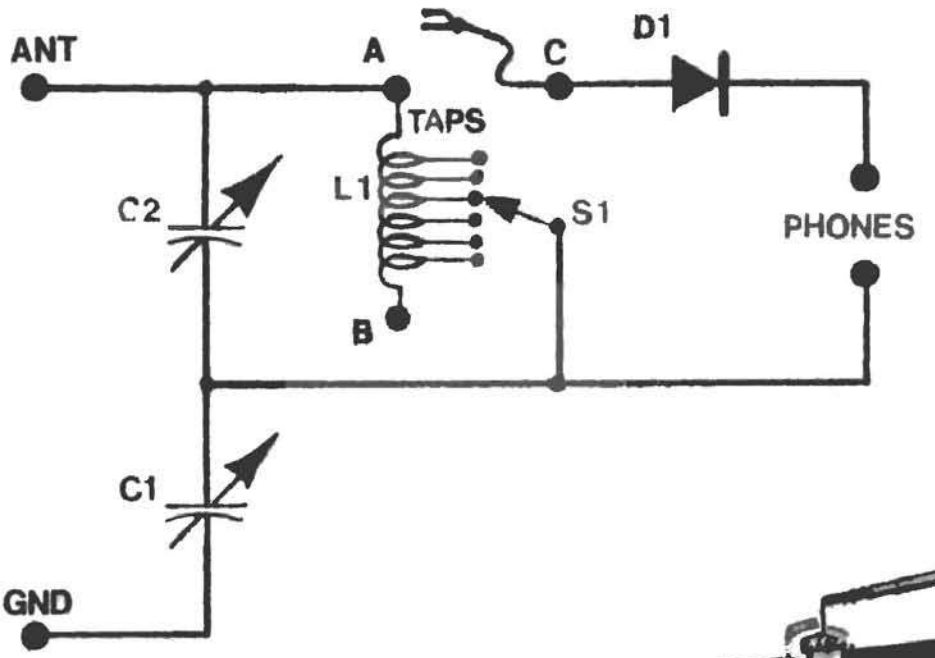

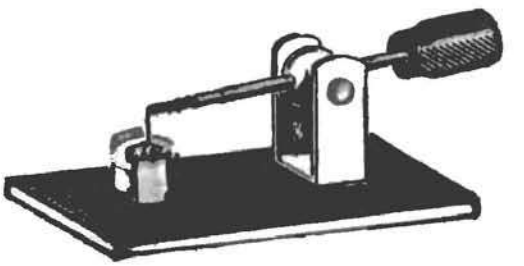

How-To-Build Simple Crystal Set Radios

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all about CRYSTAL SETS

by

Charles Green

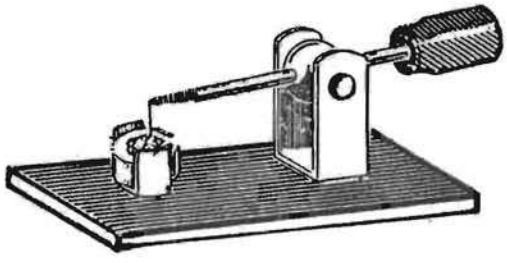

How - To - Build Simple Crystal Set Radios

FIRST EDITION

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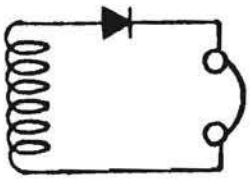

PREFACE

In the beginning of this century, when radio was called "Wireless", most of the early experimenters used a crystal set to receive radio signals.

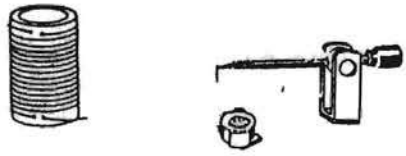

The crystal set is still the simplest type of radio receiver. A catwhisker (made from a thin wire) touching a sensitive spot on a piece of galena or silicon mineral crystal and a tuning coil, form the basic parts of this radio.

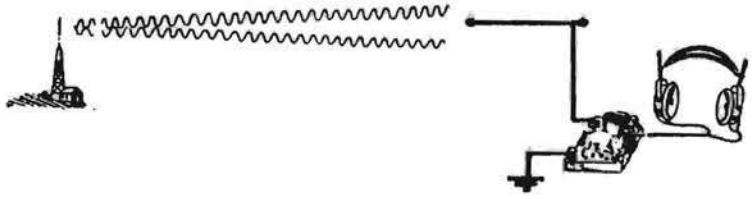

Radio signals from a nearby station are picked up via antenna and ground connections to the crystal set. The galena or silicon crystal detects the signals and the resultant audio is heard with headphones. No battery or electrical power is required.

This book tells you about crystal sets and shows you how to build them.

Charles Green

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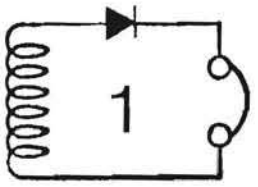

THE CRYSTAL DETECTOR

A crystal detector of radio waves can be either a traditional catwhisker and natural mineral crystal, or a modern semiconductor diode.

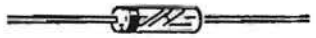

SEMICONDUCTOR DIODE

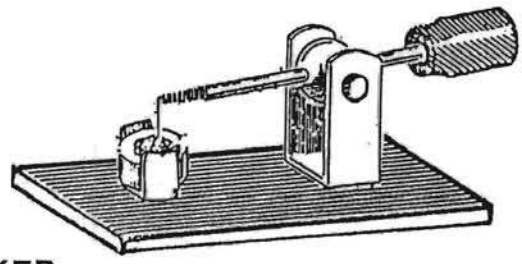

CATWHISKER DETECTOR

Certain natural minerals such as galena (lead sulphide) and silicon have electrically sensitive surface spots. In the beginning of this century, experimenters discovered that electrical current would flow into the sensitive spot on a mineral crystal from a catwhisker, but would not pass readily (high resistance) from the crystal to the catwhisker. This unique feature was used to detect (rectify) radio waves and extract the audio modulation.

HOW-IT-WORKS

There are two general types of crystal detctors;

- Point contact diode
- Junction diode

Both types use semiconductor material such as silicon, germanium, or galena. The basic semiconductor junction diode is made of two portions of the material "doped" in manufacturing by adding controlled amounts of chemicals. The doped portions have opposite electrical properties:

"P" TYPE, with an excess of positive electrical charges (holes).
"N" TYPE, with an excess of negative electrical charges (electrons).

Junction Diode

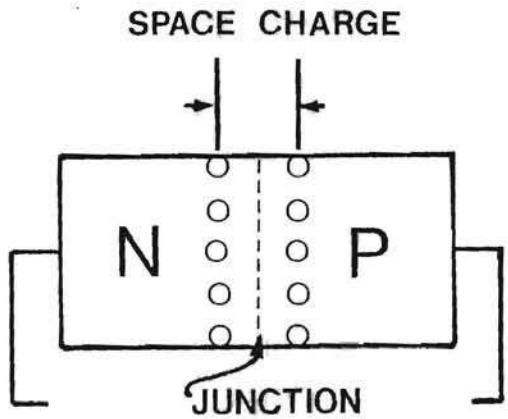

The boundary between the two doped portions is called a PN junction. The area on both sides of the PN junction is called the space charge region. When a positive voltage is applied to the "P" material (and negative voltage to the "N" material), the space charge region becomes narrow and electron current flows through the PN junction.

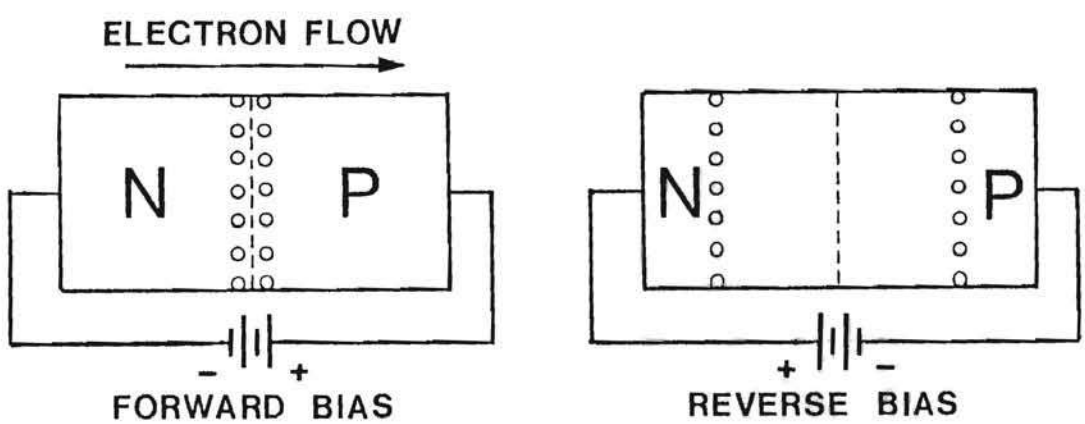

When the voltage polarities are reversed, negative to "P" and positive to "N", the space charge region widens (increasing the effective resistance of the PN junction) and the electron flow is very small (back current). If an ac voltage is applied to the PN junction, it will act as a rectifier (or radio wave detector).

Point Contact Diode

The point contact diode uses a "catwhisker" of thin wire contacting the surface of doped "N" semiconductor material. The pointed end of the wire produces a high intensity electric field in the area of the semiconductor surrounding the wire. When an electric current flows from the wire to the semiconductor material, a small region of "P" material forms around the area of the point contact. Thus a PN junction is formed which operates in the same way as the junction diode.

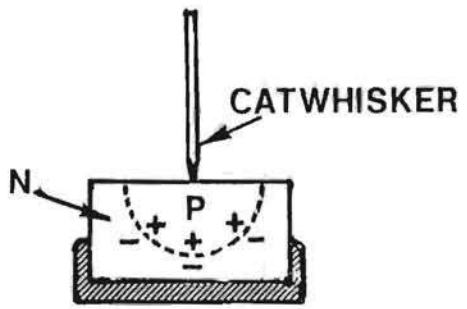

The sensitive spots of galena and silicon crystals used in traditional catwhisker detectors have naturally doped areas of semiconductor material, and operate in the same way as the point contact detector.

DETECTION OF RADIO WAVES

At the transmitting radio station, a microphone converts sound waves into electrical audio signals. The audio signals then modulate the transmitted radio waves.

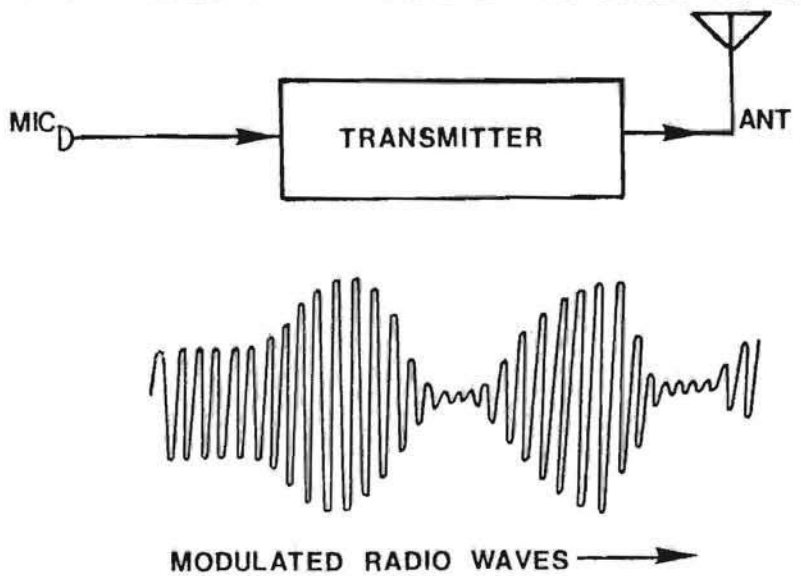

the crystal detector

The transmitted radio waves are intercepted by the receiving antenna and small rf currents are induced in the antenna wire. The rf currents (high frequency ac) flow through the detector to ground. As previously explained, the crystal detector will pass current in only one direction, therefore, pulsating dc voltages (detected audio signals) are developed by the crystal equivalent to the audio modulation of the transmitted radio waves.

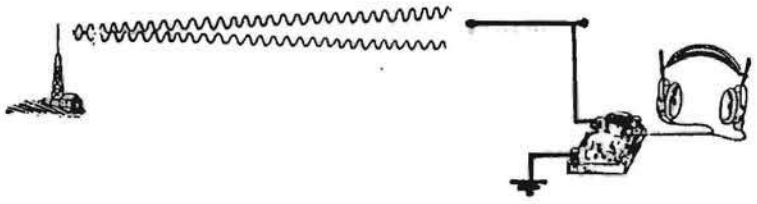

The detected audio signals flow through the headphone coils and affect the intensity of a magnetic field. This causes the steel discs of the headphones to vibrate and produce audible sound waves.

TUNING THE CRYSTAL SET

The antenna intercepts all radio waves in the area, and the signals will be heard jumbled up in the earphones. A nearby radio station may be received with the other stations heard in the background.

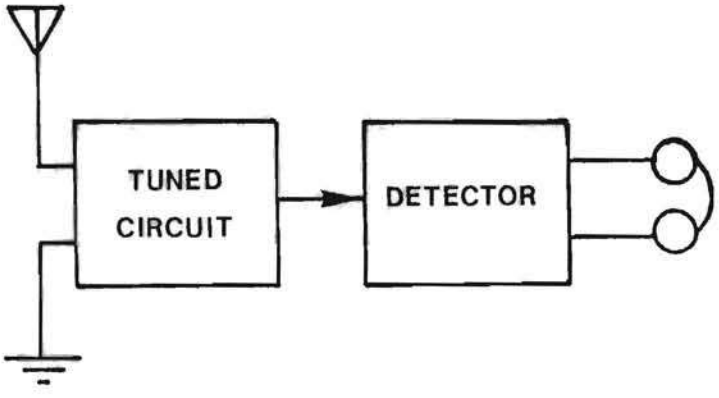

In order to receive a radio station properly, the crystal set must be tuned to the frequency of the transmitter. A tuned circuit composed of an rf coil (inductance) and a capacitor, is connected between the antenna/ground circuit and the detector.

Capacitor

The modern capacitor is evolved from the old Leyden jar. It consists of two or more metal sections separated by a dielectric (air, paper, or plastic). The capacitor stores energy in the form of an electrostatic charge in its dielectric. A variable capacitor (used in a tuned circuit) has movable metal sections that adjust the amount of capacity.

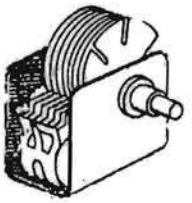

A capacitor will allow pulsating dc current or ac current to flow through it, but will block steady dc current. A capacitor has an oppositon or "reactance" to ac that varies with frequency. The higher the frequency, the lower the reactance of a given value of capacity. Capacity is measured in micro-farads (uF) or micro-micro-farads (picofarads) (uuF or pF).

RF Coil

An rf coil is made of insulated copper wire wound on a plastic or cardboard tube. When electric current flows through the coil, a magnetic field is created. This magnetic field resists any change in electric current flow. This opposition or "reactance" to ac varies with frequency. The higher the frequency, the higher the reactance of a given value of rf coil inductance. Inductance is measured in millihenrys (mH) and microhenrys (uH).

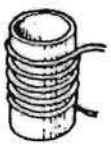

Tuned Circuit

A tuned circuit is composed of a capacitor and an rf coil. As previously described, the reactances of a capacitor and an rf coil change with frequency (but in opposite ways). At a particular frequency, the two reactances will cancel each other out. This condition is called "resonance". The impedance of a parallel tuned circuit is at its highest at resonance. Radio signals at the resonant frequency will be greatly magnified, while signals at other frequencies will be shunted to ground (rejected).

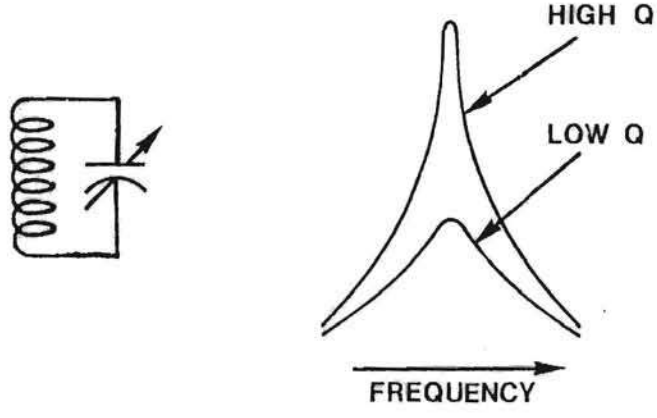

The resonant frequency of a tuned circuit can be changed by adjusting the capacitance (using a variable capacitor),or by varying the inductance (using a slider or taps on the rf coil). A ferrite core can also be used to change the inductance of a coil. The selectivity of a tuned circuit is dependent upon the quality (Q) of the components and the inductance /capacity ratio (L/C ratio). A high-Q tuned circuit is more selective than a low-Q circuit. A tuned circuit with a high L/C ratio (large inductance and small capacity) is more selective than a low L/C ratio circuit.

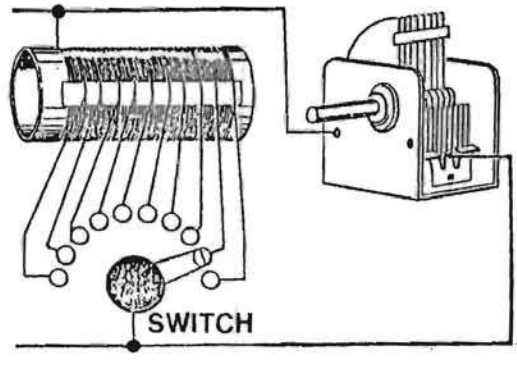

ANTENNA AND GROUND

A simple crystal set depends upon the strength of the radio waves received by the antenna to produce audio in the earphones. If you live in a strong signal area (a nearby radio transmitter), a crystal set can produce loud audio in earphones with only an inside antenna. But in lower signal areas, a good outside antenna with a ground connection is required.

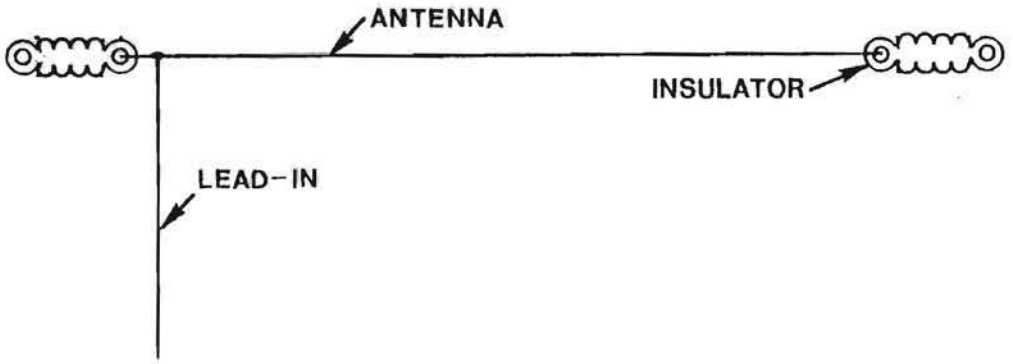

If you are fortunate enough to be able to put up an outside antenna, the basic rule of thumb is the higher, the better reception. Check your local electronics store for an antenna kit. You can construct an antenna using a glass or plastic insulator at each end of a length of copper wire (insulated or bare). Make the antenna as long as possible. It does not have to be in a straight line to work.

CAUTION

ANTENNA INSTALLATION
NEAR ELECTRICAL POWER
LINES IS DANGEROUS.

Make sure that your antenna is far enough away from any power line, so that it will not touch a wire if it falls.

Connect a length of insulated wire between the end of the antenna and your crystal set antenna terminal. This antenna lead-in wire can be fed into your house through a window.

If you can not erect an outside antenna, run a length of insulated wire as long and high as possible through your house or apartment. It will work, but not as well as an outside antenna because of the shielding affect of the house walls.

Connect a ground lead to a cold water pipe. Make sure that it is a metal pipe. Or, you can buy a ground rod from your local electrical supply store and drive it into the ground near your house. Then connect your crystal set ground lead to the rod. For safety install a lightening arrestor between the antenna lead and ground (see the instructions with the device).

HEADPHONES

Headphones (also called earphones, or headset) are required to hear the received audio from a crystal set. The standard headphones are made with dual coils of fine wire connected in series in each phone. Horseshoe magnets are built into each phone case to provide a magnetic field. A disk of thin sheet iron (diaphragm) is mounted near the top of the coils. The phones are connected in series with a set of flexible leads terminated in metal "phone tips".

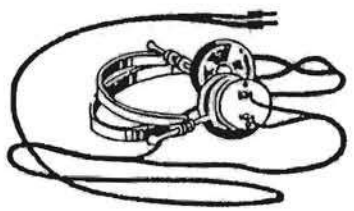

Detected audio signals flow through the coils and affect the intensity of the magnetic field from the horseshoe magnet. This changes the magnetic attraction of the diaphragm, and causes it to vibrate and produce audible sounds.

The total resistance of the series headphone coils is used as a measure of audio sensitivity. A resistance of 2000 ohms is sufficient. More sensitive headphones have a resistance of over 5000 ohms and are used to hear very weak signals.

The 2000 ohm headphones can be obtained at electronic parts mail order houses.

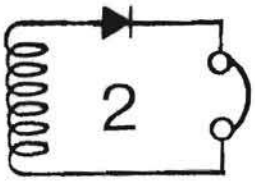

SIMPLE RECEIVER PROJECTS

SIMPLE CRYSTAL SET

Look at the schematic diagram. The crystal set uses a tunable ferrite coil L1, and a crystal diode D1. This type of tuning coil is called a "loopstick". The ferrite core is screwed into the coil form and increases the inductance of L1, thus tuning the receiver to a lower frequency.

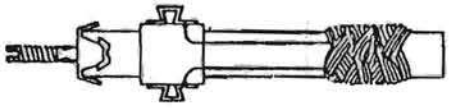

CONSTRUCTION

As shown in the illustration, the crystal set components are mounted on a 5 1/2-inch by 2 1/2-inch by 3/4-inch wood base. Layout and install the crystal set parts in the locations shown. The loopstick L1, is mounted with a metal strip supplied with it. Push the snap-in end of L1 into the large hole of the metal strip. Then bend 1/2-inch of the other end of the strip to form a bracket and mount it on the base with a wood screw. If the metal strip is not available, make one out of sheet metal approximately 2-inches long by 1/2-inch wide. Then drill a hole to fit L1 at one end, and a small hole to fit a wood screw at the other end.

Mount the four fahnestock clips and solder lugs with wood screws in the locations shown in the illustration.

WIRING

Use hookup wire to connect the crystal set components as shown in the schematic and illustration. The loopstick L1 may have three terminals. One of the terminals is a tap, which is not used in this circuit. Make sure that you connect only to the terminals at the start and end of the loopstick coil.

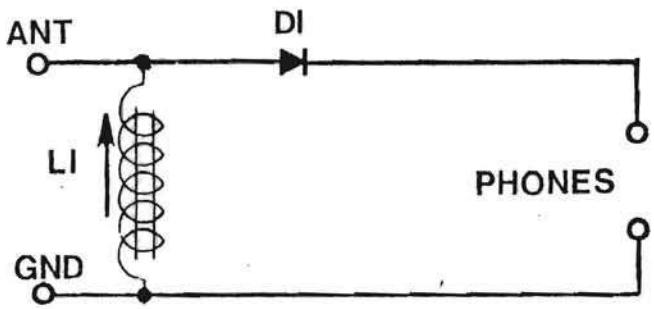

SIMPLE CRYSTAL SET

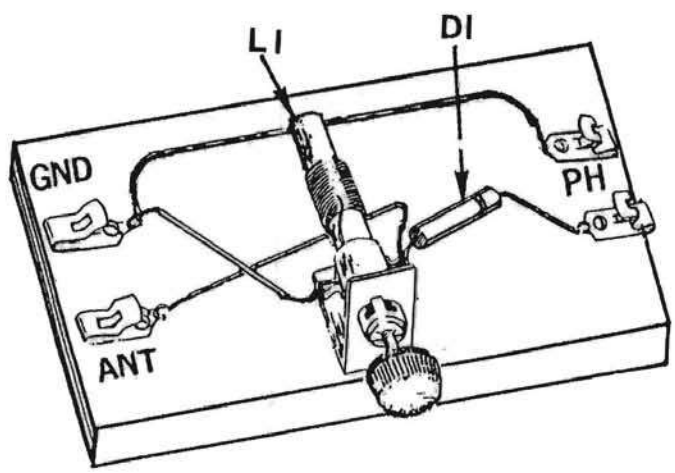

List of Materials

D1 - Germanium diode
(1N34A or equiv.)
L1 - Loopstick
(see text)
4 - Fahnestock clips
BASE - 5 1/2 X 2 1/2 X
3/4-inch wood section
PHONES - 2000-ohm headphones
MISC. - Solder lugs, wood screws,
knob and bracket to fit L1,
hook-up wire.

Install a small knob on the end of the L1 adjustment screw. Make sure that the screw turns freely with the knob. Position the 1N34A diode as shown before soldering the leads.

Experiment 1

Connect the antenna, ground, and 2000-ohm headphones to the crystal set terminals. Rotate the L1 knob counter-clockwise as far as it will go. Do not turn past this point, or you may break the ferrite rod inside the coil form. The ferrite is now outside of the coil winding. This is the highest frequency point of the tuning range of L1.

Slowly turn the L1 knob clockwise and listen for received radio stations. When the L1 knob is turned fully clockwise, the ferrite will be completly inside the coil (increasing the inductance) and it will be at the lowest frequency point of the tuning range.

Experiment 2

Connect capacitors, with values from 50 mmf to 300 mmf, in parallel with L1. Then tune L1 and note how the frequency range has changed.

AMPLIFIER CONNECTION

The simple Crystal Set (and the other receiver projects) can be connected to an amplifier in place of earphones. This amplifier can be a single channel input of your home stereo.

Parts values are not critical; C1 is approximately .005 mfd, and the volume control R1 can be any value from 1000 ohms to 10,000 ohms. Use shielded wire between R1 and the amplifier input jack.

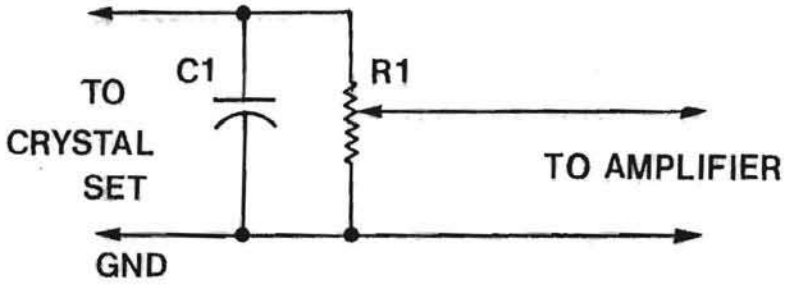

Amplifier Connection

Schematic Symbols

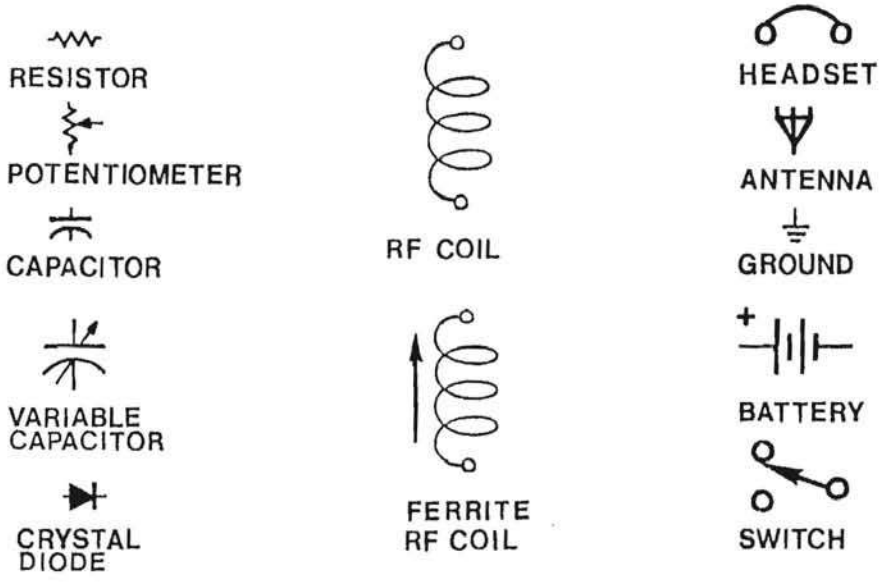

List of Materials

D1 - Germanium diode, type 1N34A, 1N60, 1N82A, or equiv.
L1 - Slider-tuned coil (see text)
4 - Fahnestock clips (terminals)
BASE - 6 x 3 x 1/2-inch section of wood (see text)
PHONES - 2000 ohms headphones
MISC. - Coil form (see text), No. 24 enameled copper wire, 3/32 inch dia. brass rod, brass ball slider (see text), solder lugs, two small brackets, hook-up wire, wood screws, machine screws and nuts.

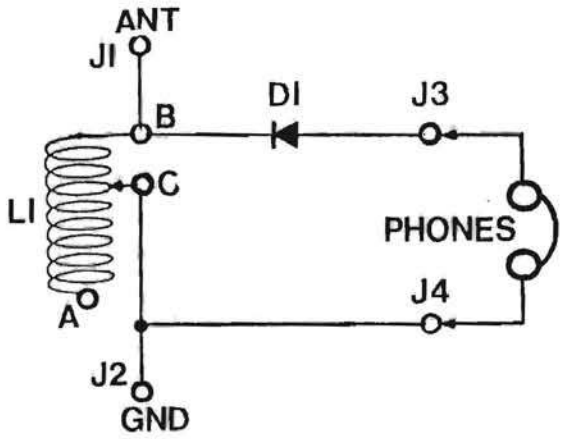

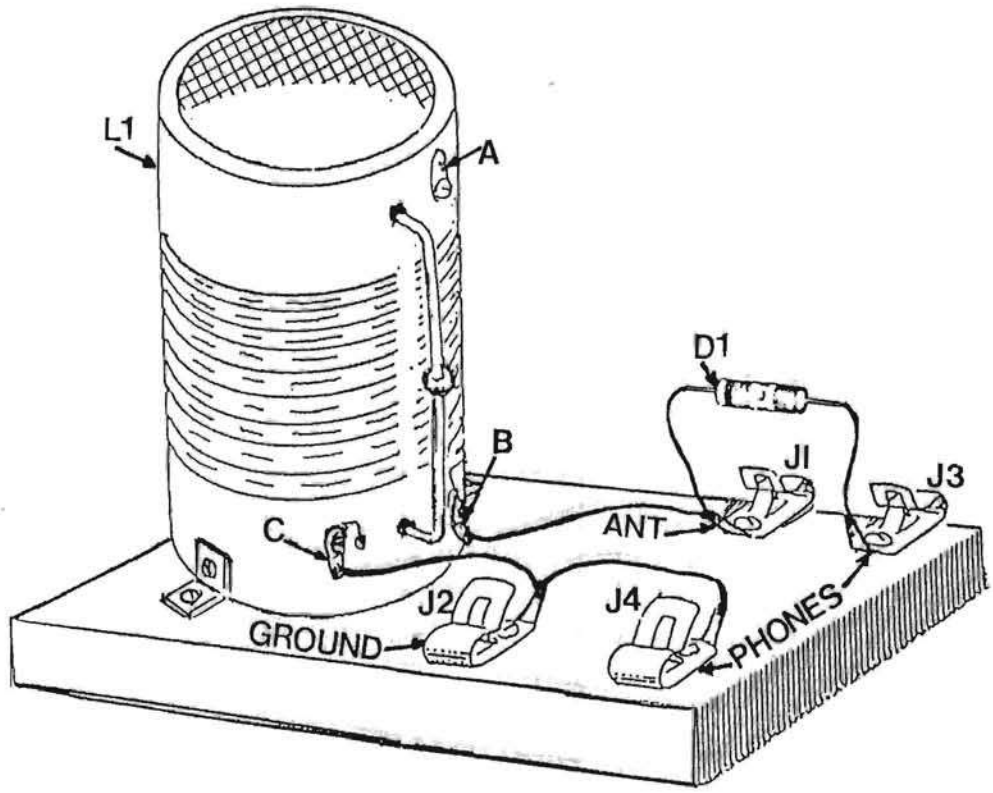

SLIDER TUNED CRYSTAL SET

SLIDER TUNED CRYSTAL SET

In the early days of radio, slider tuned coils were used in crystal sets. This method of tuning the inductance uses an adjustable metal contact (slider) that moves over the coil. The slider makes contact with individual coil wires to tune in the radio stations.

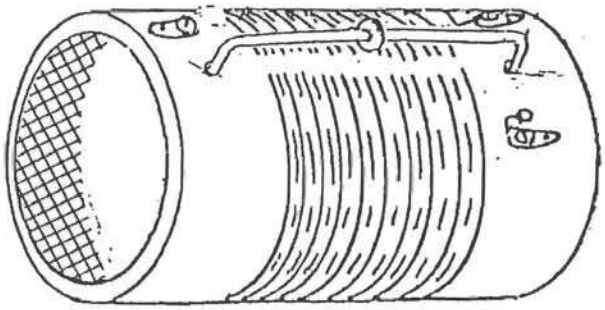

The enamel insulation of the coil wires in the slider path is removed for good electrical contact.

You can experiment with a slider tuned coil by building this crystal set. As shown in the illustration, the coil is mounted upright on a 6-inch by 3 1/2-inch by 1/2-inch wood base. A semiconductor diode is used for a detector.

TUNING COIL CONSTRUCTION

Look at the drawing of the tuning coil L1 construction details on the next page. The tuning coil is wound on a cardboard or plastic mailing tube section, 2 5/8-inches in diameter and 5-inches long. Make sure that you select a rigid, thick-walled tube for a coil form. The tube used in our model has a 3/16-inch wall. The coil form must be rigid to hold the slider ball and rod assembly.

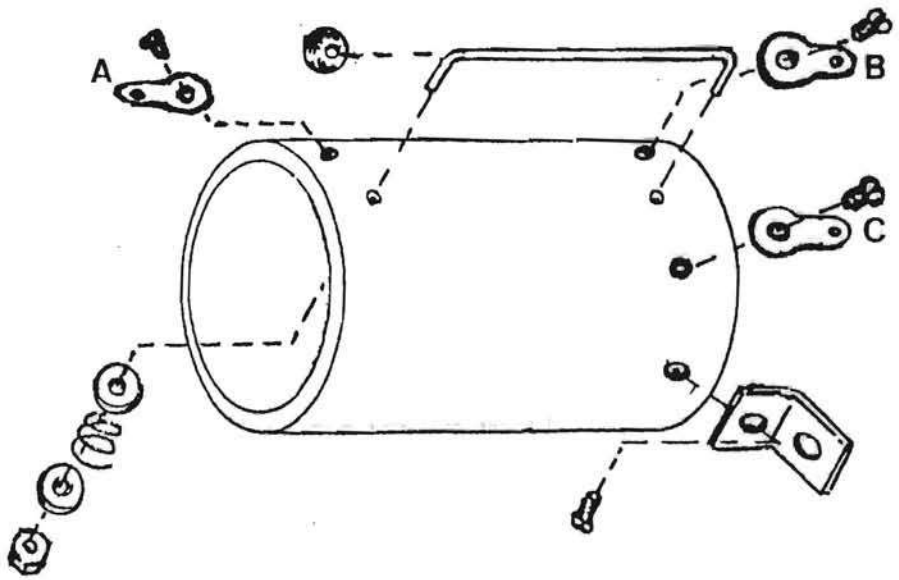

Before winding the coil, drill all the holes in the form as shown in the drawing, and then install the solder lugs. Position the solder lug ends toward the coil form edges.

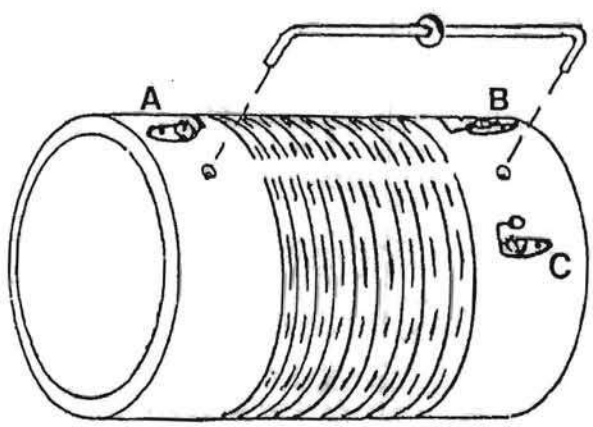

The coil is wound with No. 24 enameled copper wire. Remove the enamel from the wire end with sandpaper and then solder the wire to the lug. Start winding the coil, keeping the turns as tight and close together as possible. Wind the wire to the front of the bottom solder lug B. Remove the enamel and solder the wire end to the lug.

A brass ball approximately 3/8-inches in diameter is used as the moving contact slider. This brass ball can be found at your local electrical supply store. It is a type of ball that is used as a top nut for small table lamps. Drill a hole through the ball so that it will slide over a length of 3/32-inch diameter brass rod. Bend the brass rod at each end (after placing the ball in the center of the rod), to fit through the holes in the coil form as shown in the drawing. Cut the rod 1-inch down from the bend at each end.

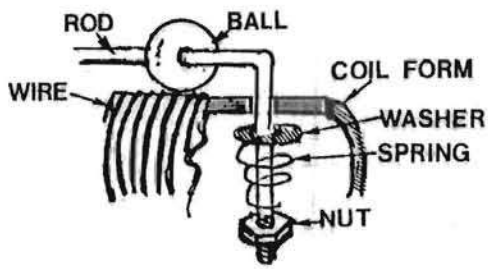

Insert the brass rod with the slider ball into the coil form holes. Then place a small washer and spring on one end of the rod (inside the coil form). Solder a nut on the end of the rod to hold the spring in place. Do the same to the other end of the rod. After soldering, slide the ball over the wires and check that it slides smoothly. Use sandpaper to remove the enamel insulation of the wires in the path of the ball slider. Connect a wire between the soldered nut on the bottom end of the brass rod and the solder lug near the rod.

BASEBOARD

All of the crystal set components are mounted on a wood baseboard as shown in the drawings. Cut the baseboard to size; a 6-inch by 3 1/2-inch section of 1/2-inch thick wood (maple is used in our model). Sand the edges after cutting. It is not necessary to paint or stain the baseboard.

Mount the four terminals and solder lugs as shown in the drawing. Label the four terminals with either rub-on lettering or cemented paper tags. Install two brackets on opposite sides of the bottom of the coil, and mount it on the baseboard with the lugs toward the terminals.

WIRING

Bare No.22 wire was used to wire our model, but any kind of hookup wire can be used. Connect the wires between the solder lugs as shown in the drawing, except do not connect the antenna terminal lug wire to the coil terminal at this time. Connect the crystal diode between the solder lugs as shown.

Experiment 1

This experiment will show how an untuned crystal detector functions.

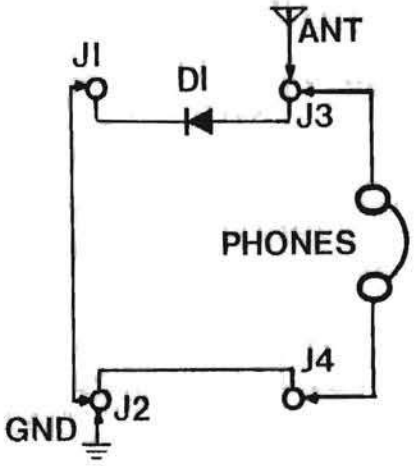

Connect the untuned detector circuit as shown in the drawing, and then hook-up your antenna and ground leads. Connect 2000-ohm headphones to the circuit and listen to the detected radio waves.

You will probably hear a strong local radio station, with other, weaker radio station transmissions all jumbled together.

Experiment 2

Reconnect the baseboard wires to the circuit of the Slider-Tuned Crystal Set as shown in the drawing. Listen to the detected radio waves as you tune the coil by sliding the brass ball over the sanded wire path. You should be able to receive the radio stations much better than the untuned detector circuit of Experiment 1.

LOADING COIL

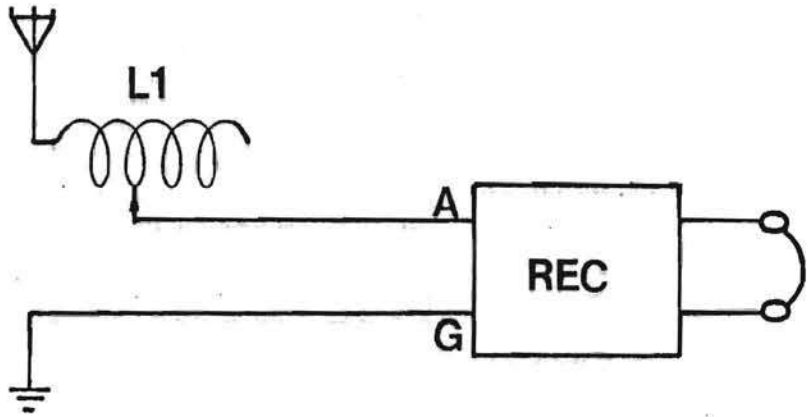

An additional slider tuned coil, L1, can be used as a Loading Coil to increase the electrical length of your antenna. This may allow better reception of the lower broadcast band frequencies. Connect L1 in series with the antenna lead to the receiver, and tune it for best reception.

WAVE TRAP

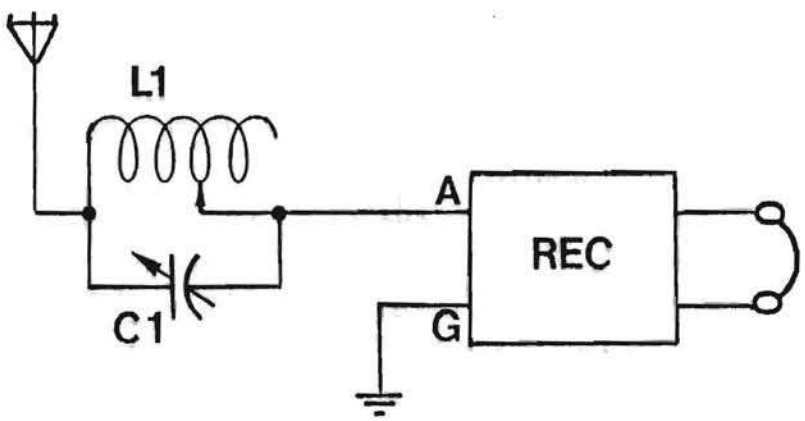

L1 can also be used in a Wave Trap circuit to tune out a strong local signal, and allow easier tuning of weaker stations. C1 is a 365 mmf variable capacitor connected in parallel with L1. Adjust L1 and C1 so that the interfering station is at minimum.

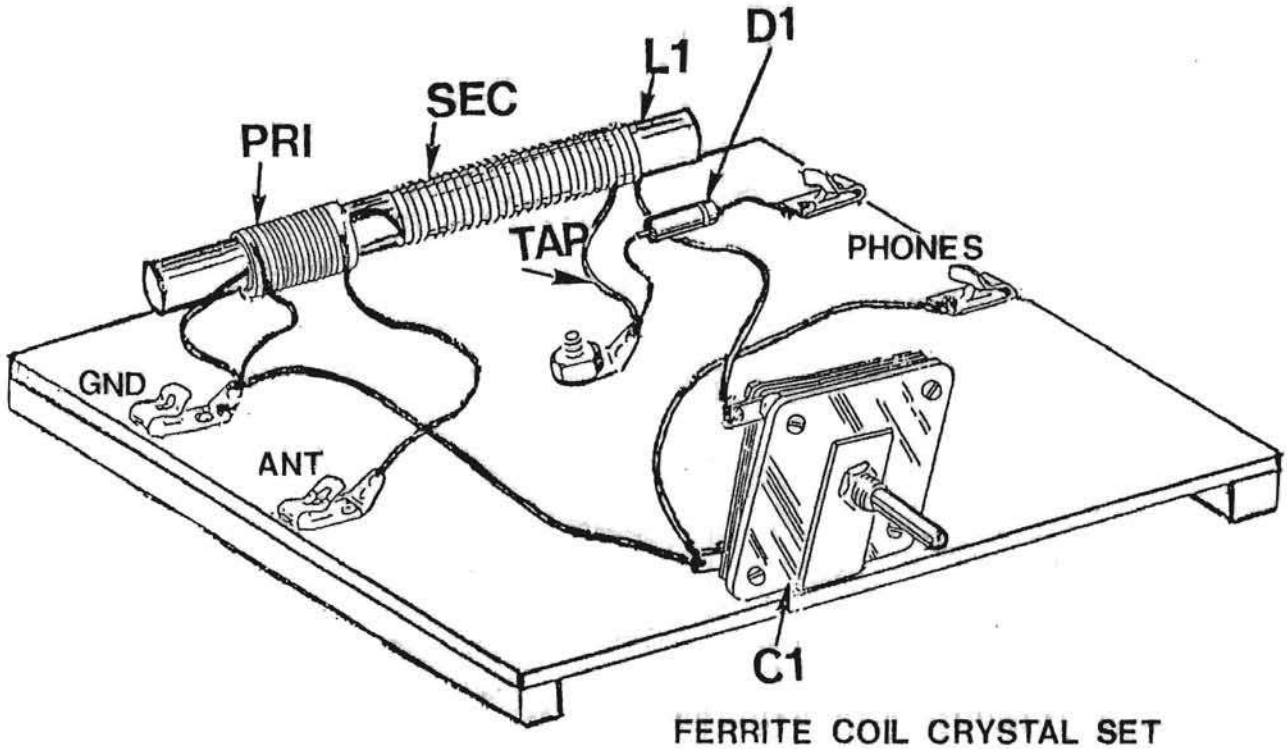

FERRITE COIL CRYSTAL SET

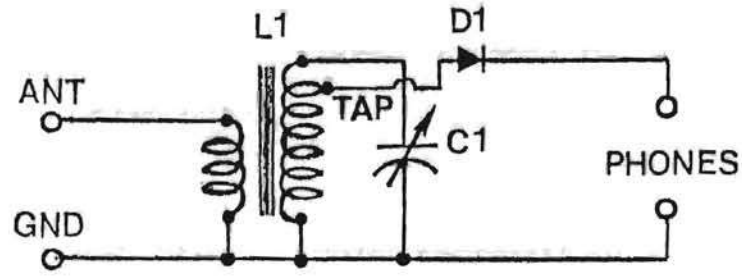

List of Materials

C1 - 365 mmf variable capacitor.
D1 - Germanium diode (1N34A or equiv.).
L1 - Ferrite coil (see text).
4 - Fahnestock clips.
2 - wood sections; 6 X 1/2-inch square (see text).
BASE - 8 1/2 X 6-inch sheet plastic (see text).
PHONES - 2000-ohm headphones
MISC. - plastic tube section for L1 primary winding (see text), solder lugs, machine screws and nuts, wood screws, bracket for C1 (see text), knob for C1, hookup wire.

FERRITE COIL CRYSTAL SET

This crystal set has a large ferrite core coil L1 of a type that is normally used for a built-in antenna in portable radios. This type of coil has a very high "Q" and may be more selective than an air-core coil. As you can see in the schematic, a primary coil is wound around the ferrite coil. The original winding is used as the secondary.

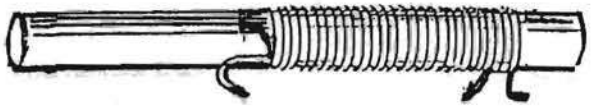

The primary coil (connected to the antenna and ground) can be moved close to, or away from, the secondary (original winding connected to D1). This variable coupling is used to control the selectivity of the crystal set.

PRIMARY COIL

The primary coil is wound on a 1-inch section of plastic tube that can fit loosely over the ferrite rod. A 1/2-inch diameter plastic tube is used on the receiver shown in the illustration. Wind 12-turns of hookup wire evenly over the tube and twist the ends together to prevent movement. Leave 4-inch leads from the primary coil winding. Slide the primary coil over the center of L1.

BASEBOARD

The crystal set components are mounted on a 8 1/2-inch by 6-inch section of sheet plastic. The thickness of the plastic is not critical, but it must be rigid enough to hold the parts without bending. A 6-inch long 1/2-inch square wood section is installed under each end of the baseboard. A section of wood can be used for the baseboard with wood screws to mount the parts, in place of machine screws and nuts.

The model shown uses a plastic variable tuning capacitor, but an air type capacitor can be used for C1 instead. Make a metal bracket approximately 1-inch wide by 1 1/4-inch high and a 1/2-inch right angle mounting foot from sheet aluminum. Drill a hole in the top of the bracket to fit C1 and two holes in the mounting foot to fit small machine screws. Locate the components on the baseboard as shown in the illustration and then drill mounting holes. If you have a cardboard or plastic mounting supplied with ferrite coil L1, you can mount it on the baseboard. If not, L1 can be taped loosely on top of the baseboard. Th ferrite coil L1 in our crystal set was obtained from an old radio. Install the components on the board with solder lugs, machine screws, and nuts.

WIRING

Connect the parts with hookup wire as shown in the illustration. Use the schematic diagram as a guide. Make sure that the ground lead from L1 secondary passes inside the primary coil. Also check that the primary coil slides freely over the L1 winding. Install a knob on the C1 shaft, and mark the terminal designations on the baseboard.

Experiment 1

Hookup the antenna, ground and 2000-ohm headphones to the crystal set terminals. Slide the primary coil over the center of the L1 winding. Tune C1 for radio stations. Then slide the primary coil towards the ground end of L1 while tuning C1. Note the difference in selectivity.

Experiment 2

Change the number of turns of the primary winding and repeat Experiment 1.

Operating Tips

After operating a crystal set for some time, you may notice a difference between day, evening, and night reception of radio stations. This is due to the two ways that radio signals travel between the transmitting antenna and a receiving antenna.

(a) The ground wave; which moves along the surface of the earth.
(b) The sky wave; which travels upward and is reflected by the ionosphere.

The reception of broadcast stations is dependent upon the time of day. During daylight hours, stations are received primarily by ground wave transmission. At night, the broadcast stations will be received via sky wave transmission. Also, some radio stations change to a lower power at night. Reception in the evening may be more difficult as the fading ground wave is interfered with by reflected waves. But later, it may be possible to hear far-away stations transmitted by sky wave.

Your geographical location to radio stations is very important for reception, as a crystal set receiver does not amplifiy signals. It is entirely dependent upon the strength of the radio waves. If you are in a deep valley surrounded by high mountains, reception will be difficult. If you live in a flat plain, with no obstacles to radio transmission, reception may be very good.

An outside antenna is necessary for for best reception. If possible, try erecting an extra antenna at a right angle to the original one, and switch it in to provide a directional effect for increased signal strength. Keeping a log of received stations for a week may be helpful in determining the radio reception conditions in your area.

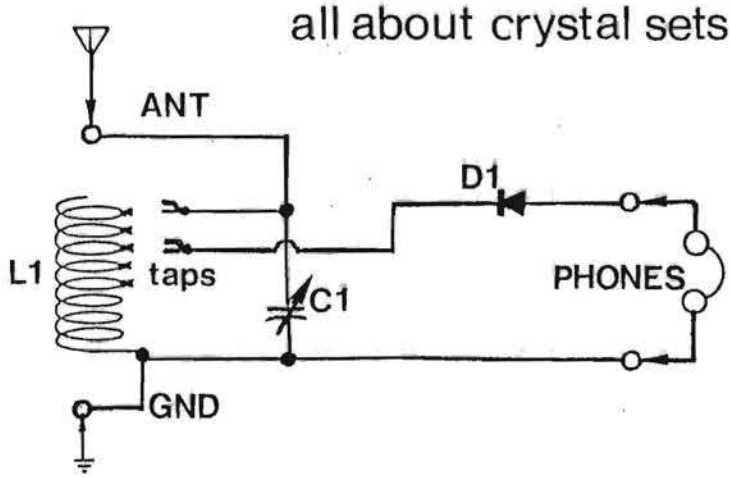

List of Materials

C1 - 365 mmf variable capacitor.
D1 - Catwhisker crystal detector (or 1N34A or equiv. diode).
L1 - Spiderweb coil (see text).
4 - Fahnestock clips.
2 - small alligator clips
BASE - 8 X 6 X 1/2-inch section of wood (see text).
MTG. POST - 5 x 3/4 x 3/8-inch wood section (see text).
PHONES - 2000 ohms headphones.
MISC. - Coil form (see text), No. 22 enameled copper wire, solder lugs, hook-up wire, wood screws, machine screws, and nuts.

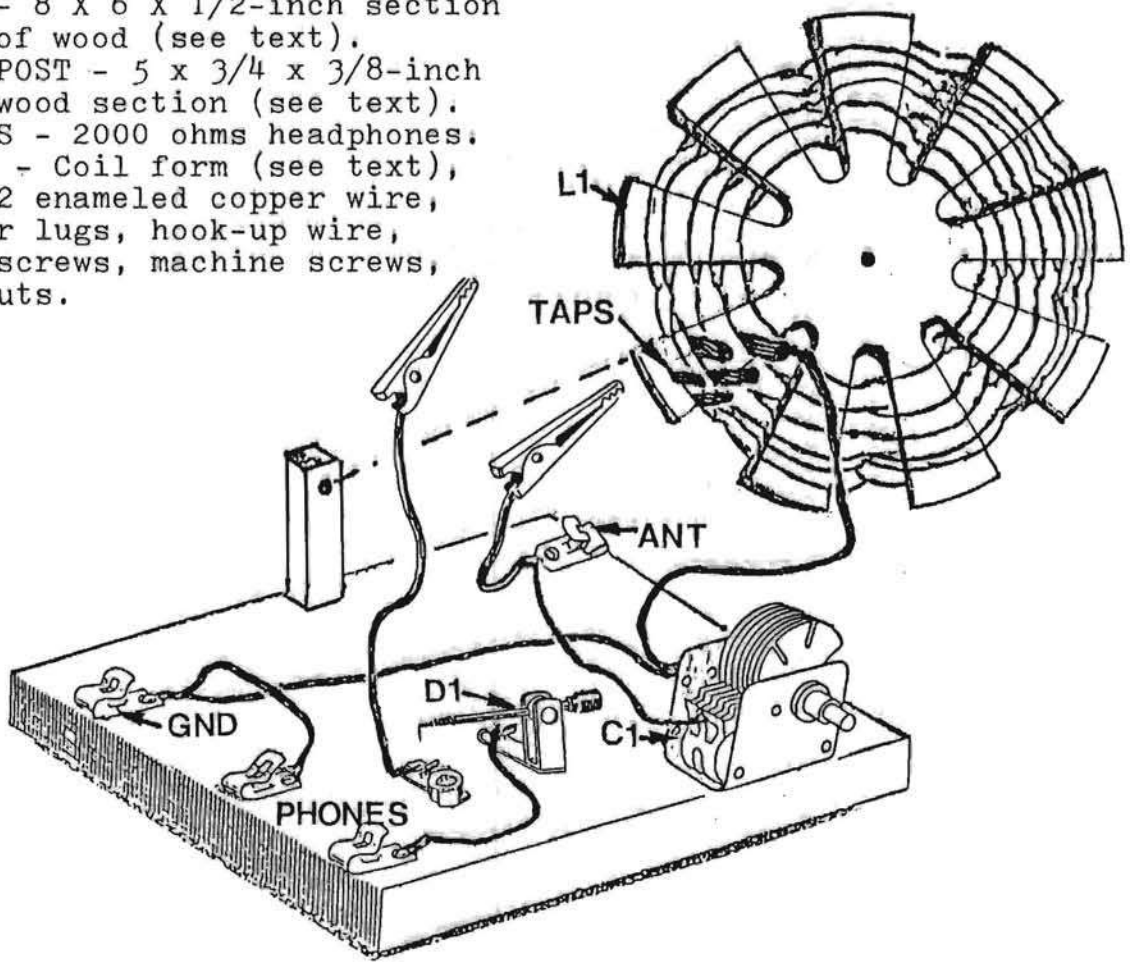

SPIDERWEB COIL CRYSTAL SET

SPIDERWEB COIL CRYSTAL SET

The spiderweb coil is a tuning coil that is wound on a flat wheel form that has an uneven amount of spokes. This type of coil was also used as a loop antenna in early radios.

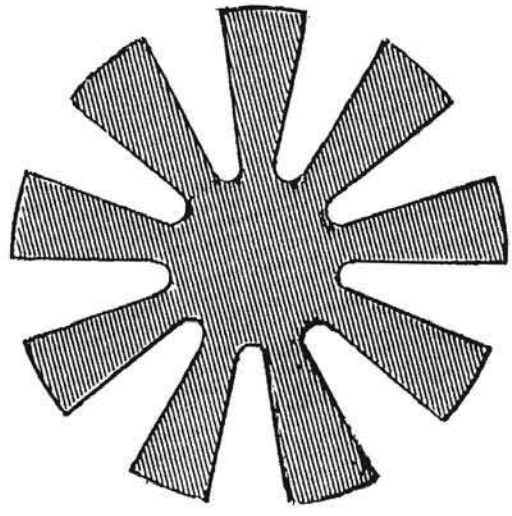

Our receiver uses a tapped spiderweb coil that is tuned by a variable capacitor. As shown in the illustration, the spiderweb coil is mounted at the rear of a 8-inch by 6-inch by 3/4-inch wood base. A catwhisker crystal detector and a variable capacitor are mounted near the front of the wood base.

SPIDERWEB

The spiderweb coil is wound on a 6-inch diameter flat form that has nine vanes. Make a tracing of the spiderweb coil form template on the next page. Then use carbon paper to transfer the tracing to a section of 1/8-inch fibreboard or sheet plastic. Cut the coil form out with a jeweler's saw, and drill a center hole to fit a small wood screw.

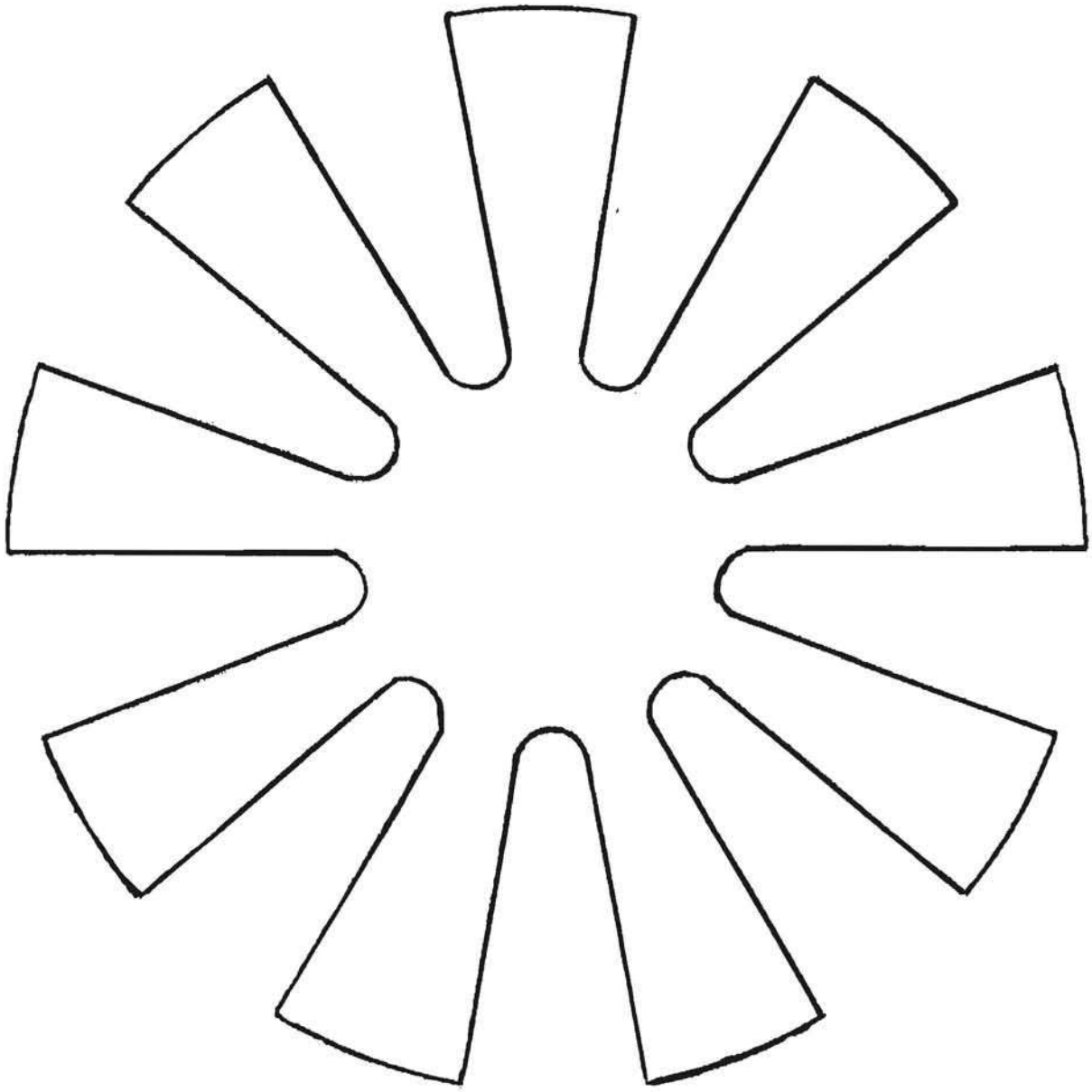

Spiderweb Coil Form Template

Wind the coil with No. 22 enameled copper wire, starting from the center and winding outward. Leave about 5-inches of the starting end of the wire free. It will be used as a connecting lead. Feed the wire behind a vane and over the front of the next vane as you wind. Wind the wire closely and evenly on the form. It is not necessary to count the turns. Wind the wire to about 1/4-inch from the end of a form vane. Then drill a small hole near the vane end, and bend a solder lug through it. Solder the wire end to the lug.

On one of the vanes, count down five wires and then carefully lift it outward. Remove about 1/4-inch of the enamel with a section of sandpaper and then bend the end of a solder lug aound the bared wire. Solder the lug to the wire, then cut off remaining portion of the lug (away from the bentover end). Repeat this every five turns until you have a total of six lug taps on the coil. Stagger the lugs away from each other to keep them from shorting.

BASEBOARD

As shown in the illustration, the Spiderweb Coil Crystal Set parts are mounted on a wood baseboard. Cut the 8-inch by 6-inch baseboard from a section of 1/2-inch thick wood. White pine was used in our model. Sand the surface of the wood after cutting.

Make the spiderweb coil mounting post by cutting out a 5-inch by 3/4-inch by 3/8-inch wood section. Then cut a notch in the center of the rear of the baseboard to fit the wood section. Install the wood section in the notch with small wood screws.

Mount the parts on the baseboard as shown in the illustration with small wood screws. If the mounting holes of the tuning capacitor C1 are on the bottom, drill matching holes in the baseboard and use flathead machine screws to hold the capacitor.

Install solder lugs with the four terminals, and mount the spiderweb coil to the mounting post with a wood screw through a center hole in the coil form. The coil should be positioned with the lugs facing forward (on the left side of the coil form).

WIRING

Connect the crystal set components with hookup wire as shown in the illustration. Use 6-inch lengths of insulated stranded wire to the two small alligator clips.

Experiment 1

Connect antenna, ground, and 2000-ohm headphones to the crystal set. Then connect the D1 alligater clip lead to the antenna terminal. Set the tuning capacitor C1 to minimum capacity (rotor blades all the way out). Connect the antenna clip lead to the tap on L1 near the center of the form.

Adjust the crystal detector D1 catwhisker to a sensitive spot and tune C1 for a radio station. It may be easier to tune for stations if you temporarily connect a crystal diode (1N34A or equiv.) in place of the catwhisker crystal detector.

After a station is heard, you can disconnect the diode and probe for a sensistive spot on the crystal with the catwhisker. Change the antenna clip lead to other L1 taps and continue tuning C1 for radio stations.

Experiment 2

Disconnect the D1 clip lead and reconnect it to a tap on L1 close to the center of the coil. This will load L1 more lightly than if the detector was connected to the top of the coil. Repeat the tuning procedure of Experiment 1 and note the difference in selectivity and volume of the received radio stations. Then tune in a radio station and move the D1 clip lead to other taps on L1. There will be a particular tap point for optimum selectivity and volume for each received station.

STATION LOG

DATE	TIME	DIAL	STATION	NOTES

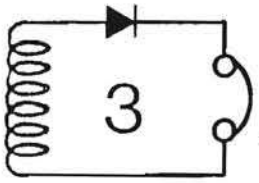

ADVANCED RECEIVER PROJECTS

DUAL TUNED CRYSTAL SET

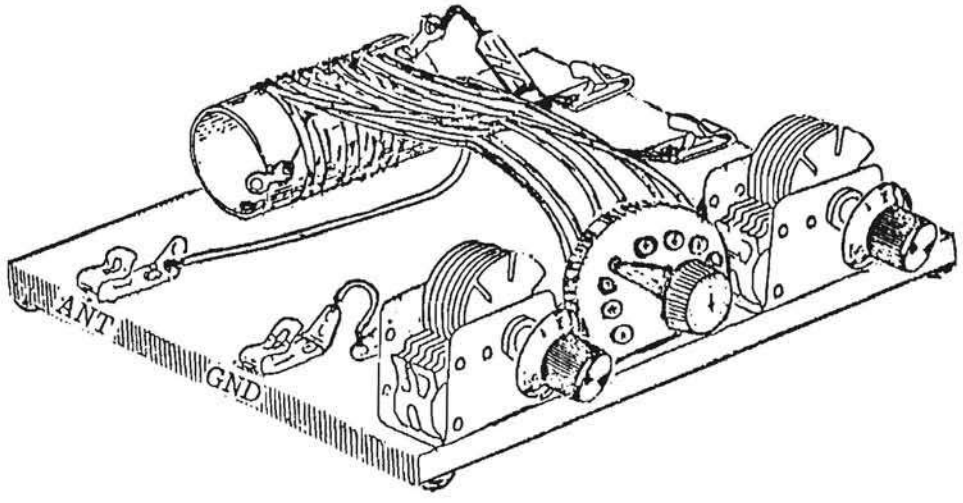

This crystal set circuit uses two variable capacitors C1 and C2. As you can see in the schematic drawing, C1 tunes the ground circuit, and C2 tunes a tapped coil L1. The taps of L1 are connected via the rotary switch S1.

TUNING COIL

Look at the drawing of the coil form construction details on page 34. The tuning coil L1 is wound on a section of 1/8-inch wall plastic tube, 2-inches in diameter, and approximately 4-inches long.

Drill holes in the form and install three solder lugs with machine screws and nuts. Position the solder lug ends towards the coil form ends as shown.

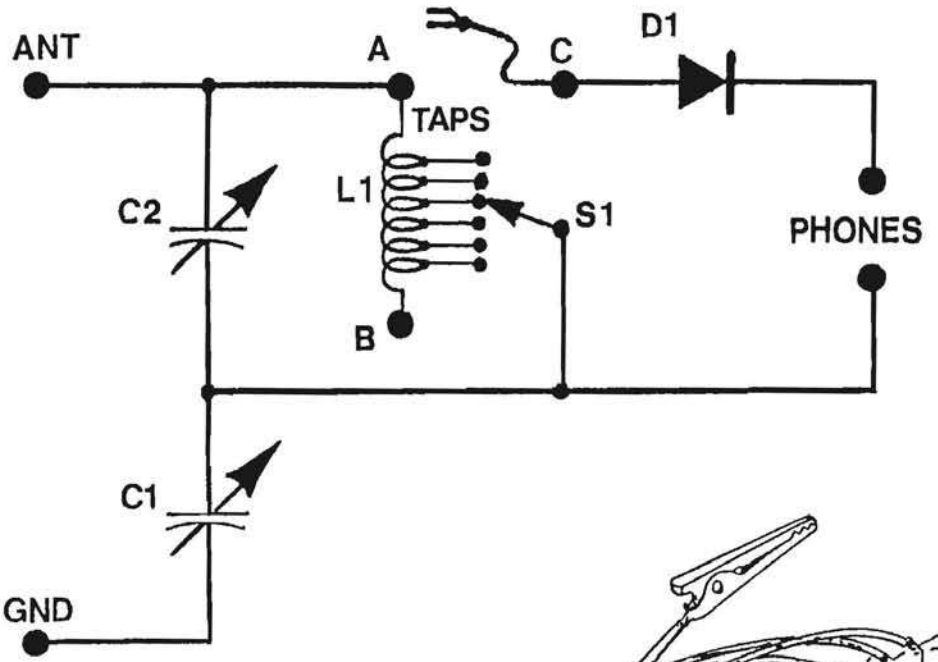

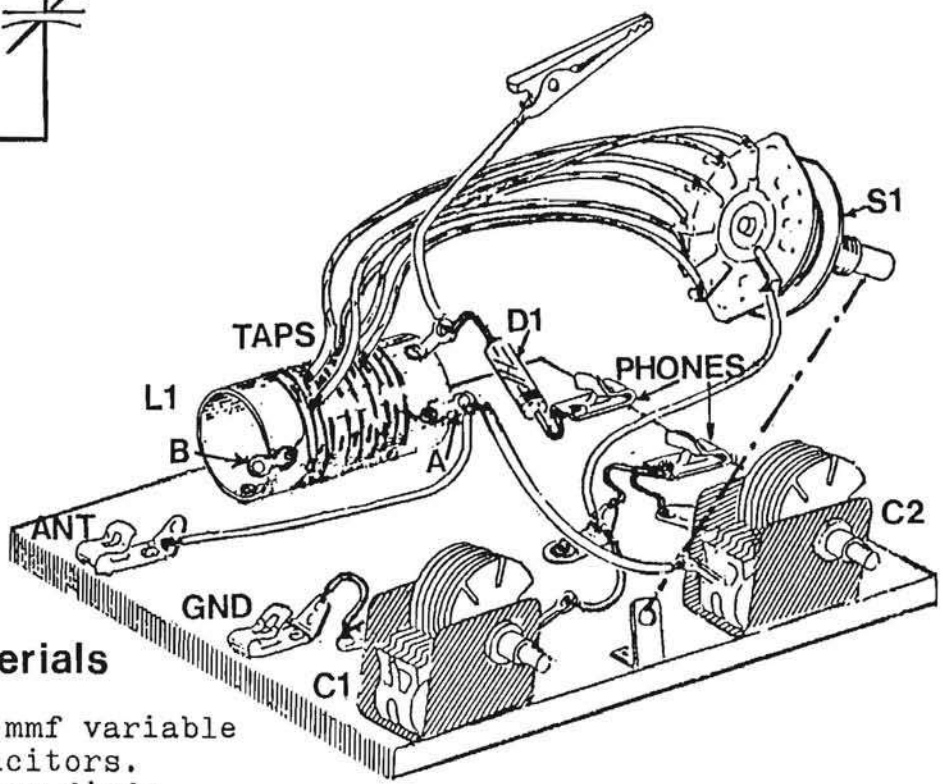

List of Materials

C1,C2 - 365 mmf variable capacitors.
D1 - Germanium diode (1N34A or equiv.).
L1 - Tuning coil (see text).
S1 - 1-pole, 10-position rotary switch (see text).
4 - Fahnestock clips.
1 - Small alligator clip.
BASEBOARD - 5 x 8 x 3/8-inch wood section (see text).
PHONES - 2000-ohm headphones.
MISC. - Coil form (see text), No. 24 enameled copper wire, solder lugs, hook-up wire, wood screws and nuts, knobs, bracket for S1.

DUAL TUNED CRYSTAL SET

The coil L1 is wound with No. 24 enameled copper wire, and is tapped every five turns for a total winding of 75 turns.

Drill a small hole in the coil form approximately 1 1/4-inch from the "A" lug. Remove the enamel from the end of the No. 24 wire and then feed the wire end through the hole. Solder the wire to lug "A".

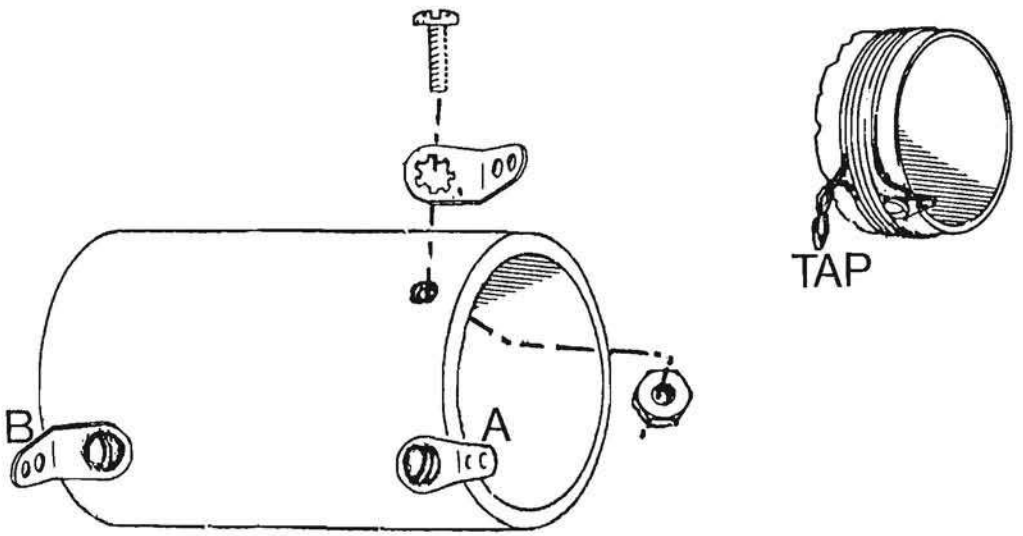

Wind five closely spaced tight turns around the coil form. Then bend back and twist together 1/2-inch of the wire to make a tap. Position the tap outward and then continue winding the coil, keeping the turns as tight and close together as possible. Make a tap every five turns and then drill a small hole in the coil form after the 75th turn. Feed the wire through the hole, remove enamel, and solder the end to lug "B".

BASEBOARD

The Dual-Tuned Crystal Set is built on a wood baseboard as shown in the illustration. Cut the 5-inch by 8-inch baseboard from a section of 1/4-inch thick plywood. Sand the edges and surface of the baseboard to remove any splinters. Drill holes in the baseboard and install the parts with small machine screws and nuts in the locations shown in the illustration. Drill mounting holes at each end of the tuning coil L1 and position it on the rear of the baseboard with the coil taps toward the front. The illustration shows a commercial rotary switch, but a wooden rotary switch can be used for S1 instead. (See page 53 for construction details.)

Install the four fahnestock clips (used as antenna, ground and headphone terminals) with solder lugs. Mount an additional solder lug on the baseboard midway between S1 and L1.

WIRING

Connect the crystal set parts with hookup wire as shown in the pictorial illustration and the schematic diagram. Use the center solder lug as a junction point for leads from C1, C2 and S1 as shown in the illustration. Connect the leads from S1 to the taps on L1 in numerical sequence; every 5 turns for 7 taps. Then connect the last three leads every 10 taps. Insert the lead ends into the taps and hold them with a drop of solder. This will make it easier to move leads to other L1 taps. Use a 5-inch length of stranded hookup wire for the alligator clip lead connected to D1 at solder lug C.

Experiment 1

Connect 2000-ohm headphones, antenna and ground leads, to the crystal set terminals. Then connect the D1 clip lead to the L1 "A" solder lug.

Set S1 to each tap position in turn and tune C1 and C2 for received radio stations. If all of the local stations can not be heard, experiment with different connections to the L1 taps. More turns may have to be added to L1 (with additional five-turn taps) to receive stations at the lower frequency end of the broadcast band.

Experiment 2

Remove the D1 clip lead from "A" and then connect it to the "B" solder lug on L1. Repeat the tuning method of Experiment 1 and note if the crystal set is more selective. This is possible, because L1 is now connected as an rf transformer. You can also connect the D1 clip lead to each of the S1 taps and note if there has been any improvement in reception.

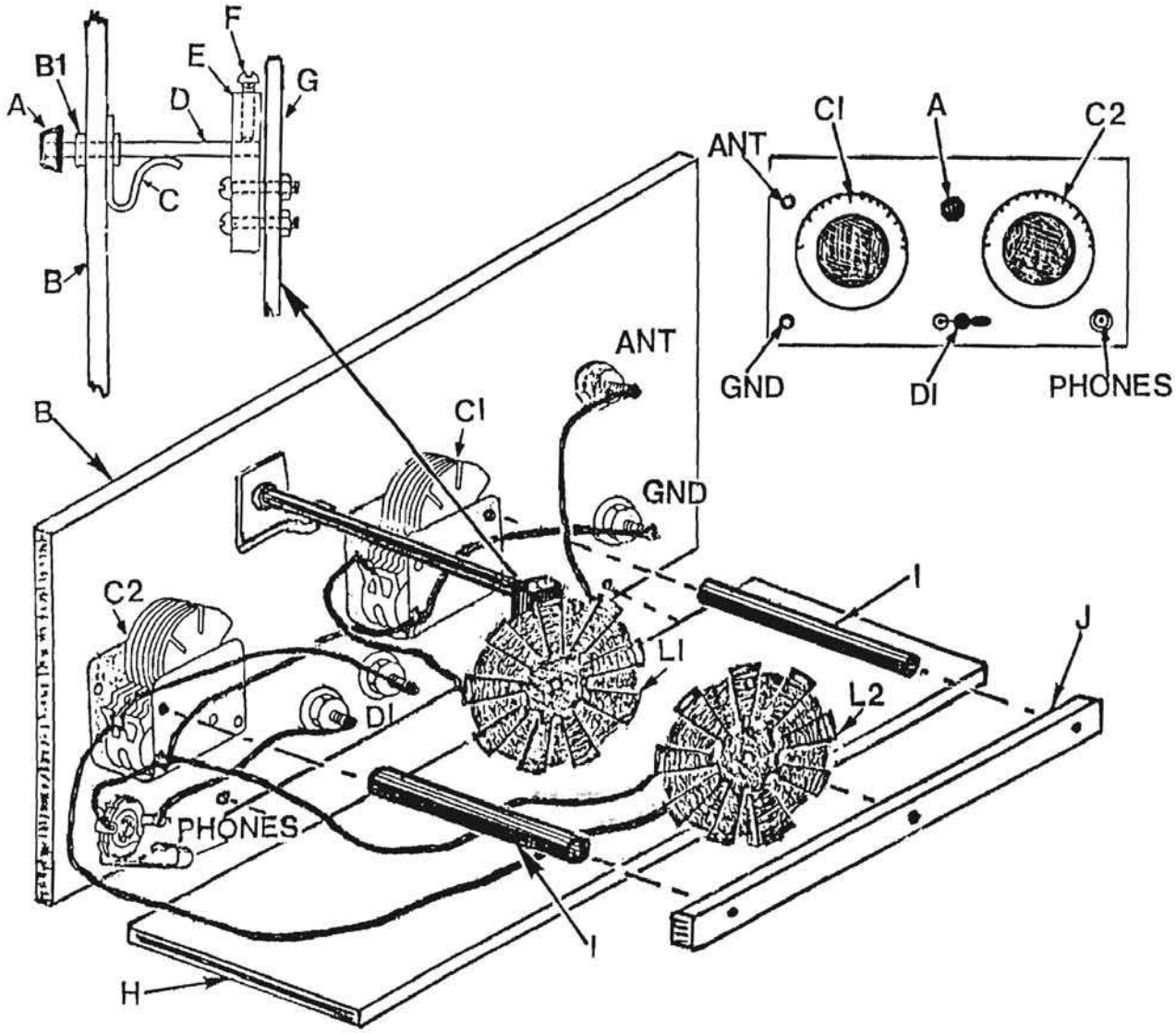

SELECTIVE CRYSTAL SET

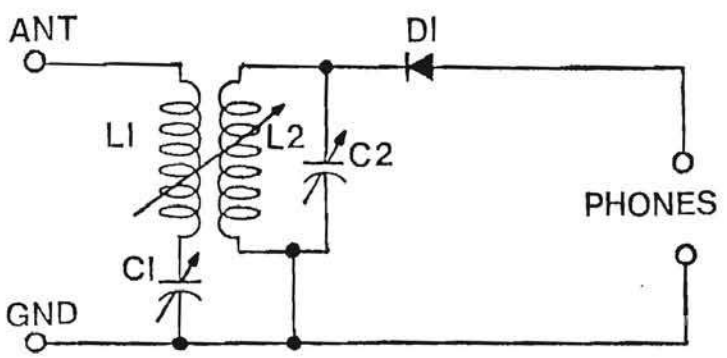

SELECTIVE CRYSTAL SET

This receiver uses two spiderweb coils in a two-circuit tuner for good selectivity and sensitivity. As you can see in the schematic diagram, the antenna-ground rf input circuit is tuned by L1-C1 for maximum signal gain. L1 acts as the primary winding of an rf transformer, with L2-C2 as the tuned secondary. Coupling between L1 and L2 is variable for best selectivity. L2 is connected to a catwhisker crystal detector and the audio signals are fed through the phone jack to 2000-ohm headphones.

As shown in the illustration, the crystal set parts are mounted on the rear of a black plastic panel. This type of layout is similar to the type of construction of the old-time crystal sets.

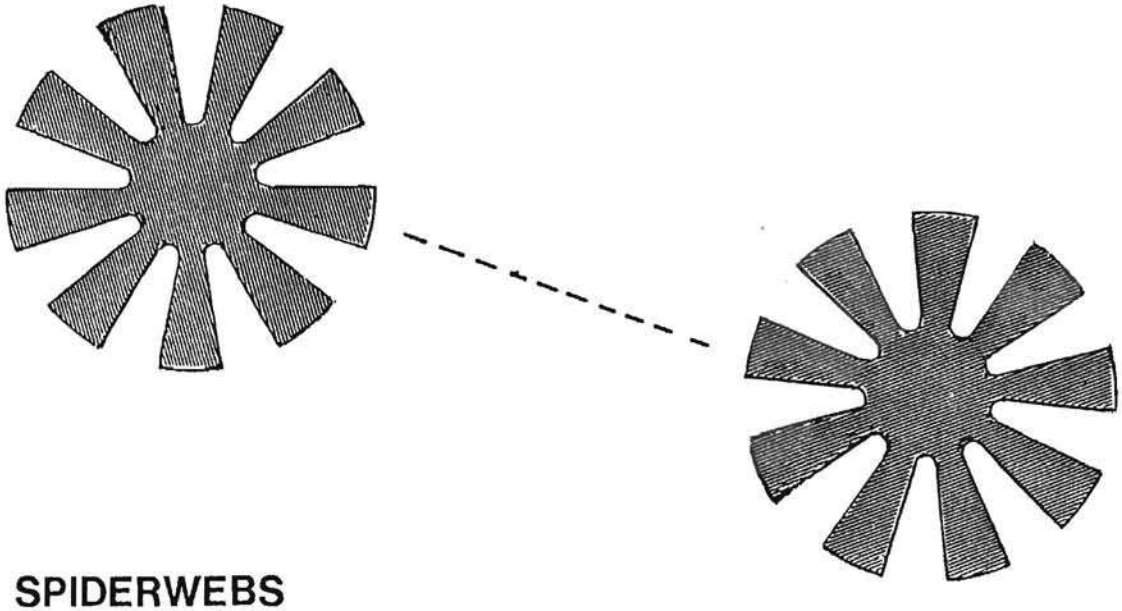

SPIDERWEBS

Both L1 and L2 spiderweb coils are made exactly the same way. L1 and L2 are wound on 17-vane coil forms 3 5/8-inches in diameter. The coil forms in our receiver are made from 1/16-inch sheet plastic of the same type used for printed circuit boards (but without the copper foil). Any kind of rigid sheet plastic should be suitable for the coil forms.

Make a tracing of the spiderweb coil template. Then use carbon paper to transfer the tracing on a section of 1/16-inch thick sheet plastic. Cut out the vanes with a jeweler's saw. Drill two holes as shown, and install the two solder lugs.

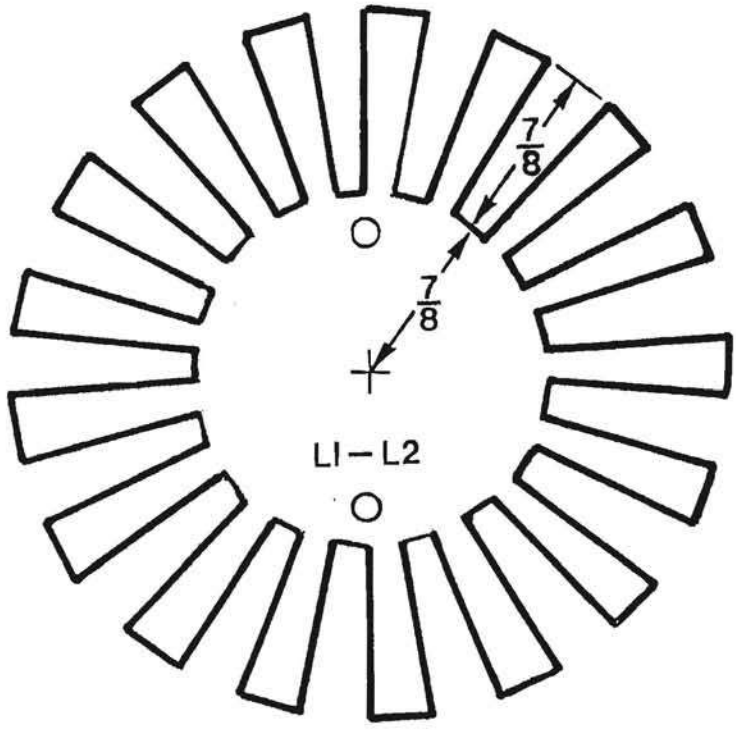

COIL FORM TEMPLATE FOR L1—L2

Wind as much No.22 enameled wire as possible on each coil form. Solder the wire to a solder lug before winding a coil. Then wind the wire over a vane and under the next vane. Wind the wire closely and evenly on the form. It is not necessary to count the turns. Solder the wire end to the remaining solder lug

CONSTRUCTION

The panel used in our receiver is a 7 3/4-inch by 4 1/2-inch section of 1/4-inch thick black acrylic plastic. The size is not critical, but it should be large enough to mount all of the parts as shown in the illustration.

Layout and drill the mounting holes of the components on the panel. Make sure that C1 and C2 are positioned so that the edges of the tuning knob dials are more than 1/2-inch apart. Install the catwhisker crystal detector assembly, antenna and ground terminals, and the phone jack in the locations shown.

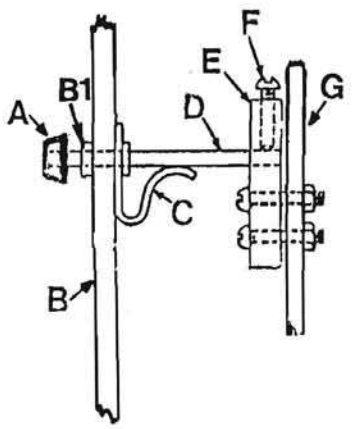

As you can see in the illustration, L1 is installed on the end of a variable coupling metal rod. This 1/4-inch diameter rod is 3-inches long with a flat side. Drill and tap a small hole close to the end of the rod. The rod used in our model came from a discarded volume control. Cut a 2-inch long by 1/2-inch wide by 3/8-inch thick wood section and drill holes to fit the rod, two mounting screws, and a hole for the rod set screw. Locate and mount the wood section in the center of a spiderweb coil L1 so that the rod will be 3/4-inch down from the edge of the top vane.

Hold L1 behind the panel and using the free end of the rod, locate the panel hole. Position L1 midway between C1 and C2, and make sure that the top edge of the coil is below the top of the panel. Drill a hole to fit the rod bushing in the panel hole location. The panel bushing in our model was removed from a discarded volume control.

Drill a hole to fit the bushing in one end of a 2-inch by 1/2-inch section of sheet aluminum. Bend the other end of the section to fit against the flat side of the rod. Install the metal section and the bushing in the panel hole.

Insert the rod into the bushing and make sure that the metal section end fits close to the flat side to prevent rotation of the rod. Install a knob on the rod end and make sure that the rod can be pushed in and out easily. If necessary, put a small amount of grease on the flat side of the rod.

Install the remaining spiderweb coil L2 on a wood section that is mounted on the rear of the panel with two spacers. The spacers should be long enough for L2 to be located 1/4-inch behind L1 with the rod pushed all the way in. The 5 1/2-inch by 1-inch by 1/4-inch wood section in our model is supported with screws installed through 1 1/2-inch metal spacers into tapped holes in the rear of C1 and C2. The screws and bushings can be made longer and mount into panel holes in your receiver.

Install a wood section on the bottom rear of the panel to keep the receiver upright. A 5-inch by 3-inch section of 1/4-inch thick wood is used in our receiver.

SET WIRING

Connect the receiver components with hookup wire as shown in the illustration and schematic diagram. Use flexible stranded wire for connections to L1. Make sure that the L1 leads do not touch any component as the variable coupling rod is moved in and out.

Install knobs on C1, C2, and the variable coupling rod. Then place the crystal in the detector assembly.

OPERATION

Connect antenna and ground leads to the receiver terminals. Plug in a set of 2000-ohm headphones into the panel phone jack. For easier initial operation of the receiver, temporarily connect a germanium diode (1N34A or equivalent) across the D1 connecting lugs. Make sure that the catwhisker is not touching the crystal at this time.

Push the variable coupling rod half way in and tune C1 and C2 for a station. Adjust the variable coupling rod and retune C1-C2 for best reception. Check operation over the entire broadcast band. It may be necessary to add or subtract turns of wire on L1-L2 for complete coverage. After checking operation with the germanium diode, remove it and try using the catwhisker crystal detector.

List of Materials

C1,C2 - 365 mmf variable capacitor.
D1 - Catwhisker crystal detector assembly.
L1,L2 - Spiderweb coils (see text).
2 - Terminals.
1 - Phone jack.
PHONES - 2000-ohm headphones.
MISC.- Plastic sheet for spiderweb coils, solder lugs, machine screws and nuts, wood screws, hookup wire.
CONSTRUCTION MATERIALS (See Text).
A - knob
B - Panel
B1- Bushing
C - Aluminum section
D - Rod
E - Wood section
F - Setscrew
G - L1 coil form
H - Wood section
I - Spacers (2)
J - Wood section

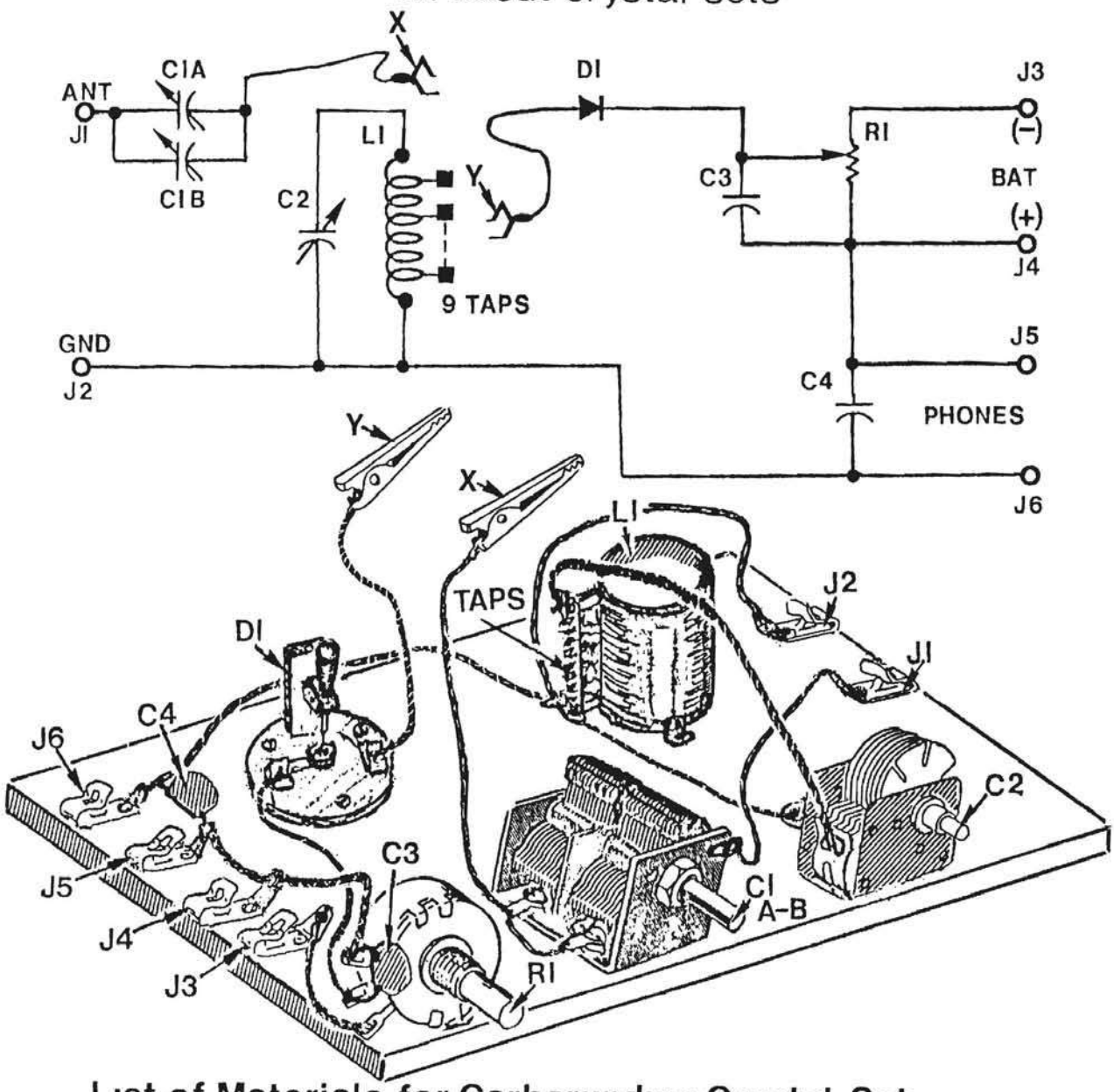

List of Materials for Carborundum Crystal Set

C1A-C1B - Dual 365 mmf variable capacitor.
C2 - 365 mmf variable capacitor.
C3 - 0.1 mf capacitor.
C4 - 1000 mmf capacitor.
D1 - Carborundum crystal and catwhisker detector assembly (see text).
J1 to J6 - Fahnestock clips.
L1 - Tuning coil (see text).
R1 - 5,000-ohm potentiometer (linear taper).
BAT - 6-volt battery
PHONES - 2000-ohm headphones.
MISC. Coil form (see text), No.24 enameled copper wire, 1/2-inch long spacers, perfboard strip (see text), push-in clips, solder lugs, knobs, hook-up wire, 1N34A diode (or equiv.), wood for base and D1 detector assembly (see text), wood screws, machine screws and nuts, alligator clips X-Y, brackets for L1 and R1.

CARBORUNDUM CRYSTAL SET

Materials other than galena, silicon or germanium have the property of detection. In the beginning of radio, carborundum (the name given to a compound of silicon carbide) was also used as a detector. The required heavy catwhisker pressure made it suitable for the early radio stations on ships, as it did not fall out of adjustment. It would also handle the strong signal energy from nearby spark transmitters without burning out. But what makes this type of crystal detector different, is the necessity for a bias battery.

A crystal detector has a high current flow with voltage applied so that it conducts in the forward direction (catwhisker to crystal), and a very low current flow in the reverse direction. The amount of current flow in the forward direction depends upon the characteristics of the crystal material and the applied forward voltage.

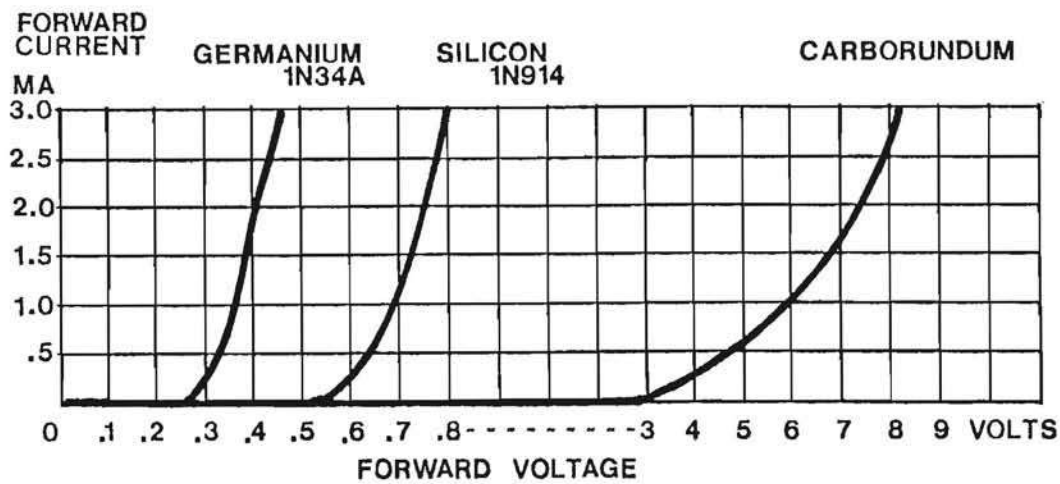

TYPICAL CRYSTAL DIODE CURRENT

The graph compares carborundum with germanium and silicon crystal detectors. Germanium minimum conduction voltage is about 0.3 V. Silicon is 0.6 V, and carborundum is 3 V. The high carborundum minimum conduction voltage is the reason a bias battery is used to move the threshold down so that weak radio signal voltages can be detected.

TUNING COIL

As shown in the illustration, the tuning coil L1 is wound on a cardboard (or plastic) mailing tube section 2-inches in diameter and 2 3/4-inches long.

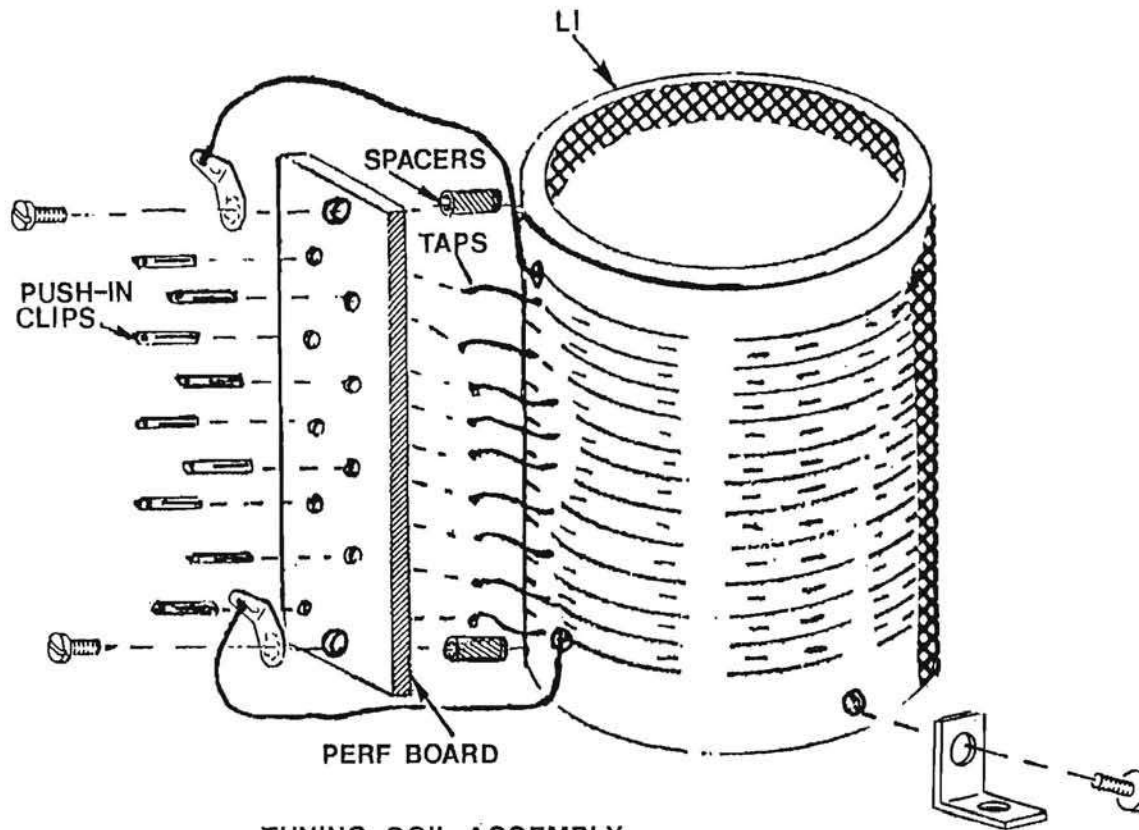

TUNING COIL ASSEMBLY

Locate and drill a hole 1/4-inch from each coil form end for machine screws to fit the two spacers. Also drill holes for two mounting brackets at one end. Then drill a small hole near each spacer hole to feed the wire on the form before you start winding.

Wind the coil with No. 24 enameled copper wire. Tap the coil every 10 turns for a total of 9 taps. An easy way to make the taps is to twist the wire together for a half inch and position the free end out. Make all the coil taps in the area between the two spacer holes. Thread the free end of the wire through the small hole at the end of the form near the spacer hole. Make sure that all of the turns are tightly wound and close together. Use a section of sandpaper to remove the enamel from the tap wire ends. Then tin the ends.

Mount 9 push-in clips in a 1/2-inch by 2 1/4-inch perf board section. Locate and drill holes on the board and install it on the coil form with two solder lugs, 1/2-inch spacers, machine screws, and nuts. Solder the coil taps to the ends of the push-in clips. Connect the coil leads to the solder lugs and mount the two 1/2-inch brackets on the coil form.

DETECTOR

The crystal detector assembly is vertical, (as shown in the illustration) instead of horizontal as in most catwhisker detectors. Begin construction by cutting the 2 1/2-inch diameter base and 2-inch by 4-inch vertical section from 1/4-inch thick wood.

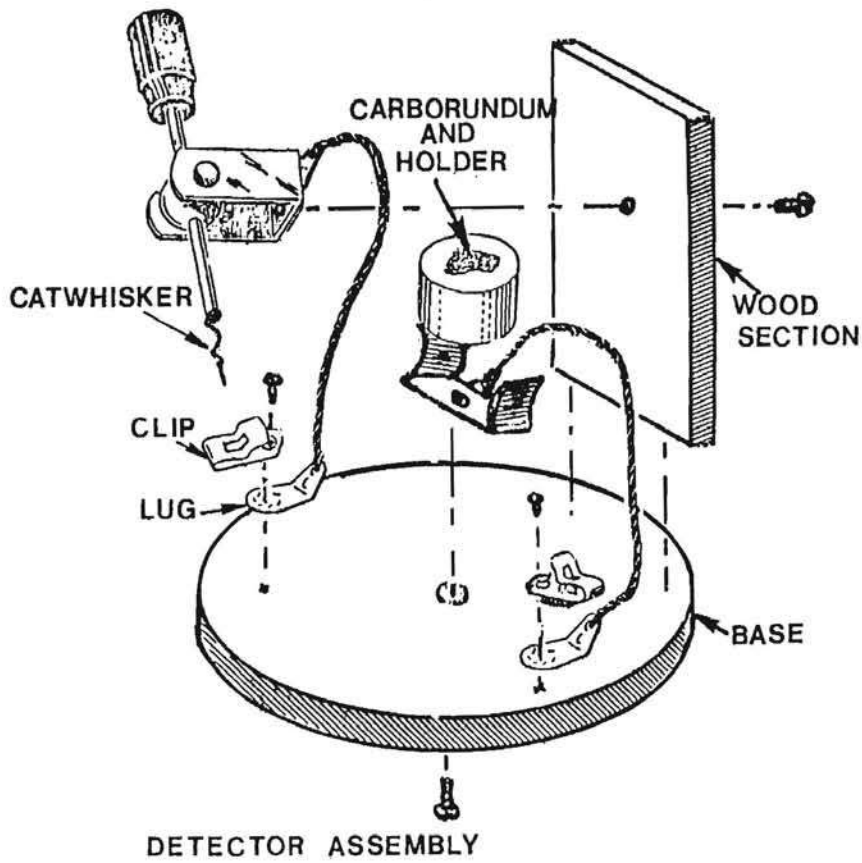

Locate and install the two fahnestock clips on the base with solder lugs and small wood screws. Mount the vertical section on the edge of the base with wood screws (or cement). Locate and install the catwhisker holder with a solder lug, machine screw and nut near the top of the vertical section.

Temporarily position the crystal holder on the base so that the catwhisker will touch the center of the crystal. Locate and mount the crystal holder in this position with a solder lug and machine screw and nut. Connect the detector assembly with hookup wire as shown in the illustration. Solder a short section of coiled steel spring wire to the end of the positioning rod to serve as a catwhisker. Cut the end of the wire diagonally to give it a sharp point.

BASEBOARD

The receiver parts are installed on a 8-inch by 7-inch by 3/4-inch wood base. Wherever poossible, small wood screws are used to hold the components on the base.

Begin construction by laying out and installing the parts in the positions shown in the illustration. It will be necessary to make a metal mounting bracket to fit R1. C1A-B and C2 are mounted with machine screws in the tuning capacitor frames through countersunk holes in the base. Install solder lugs in the rear frame of both tuning capacitors. Also mount solder lugs with all of the terminals. Install knobs on the tuning capacitors and R1.

WIRING

Use hookup wire to connect the crystal set parts as shown in the schematic and illustration. Connect 5-inch leads of flexible stranded insulated wire to each alligator clip. Solder one lead to the stator lugs of C1A-B and connect the other lead to D1. Connect C3 and C4 as shown and keep their leads as short and direct as possible.

Experiment 1

Connect your antenna to J1, ground to J2, and 2000-ohm headphones to J5 and J6. Temporarily connect a germanium diode (1N34A or equiv.) in place of the carborundum crystal detector D1. The diode will make it easier to check out the receiver.

Do not attach the battery to J3-J4 at this time, or the diode may be damaged.

Connect X C1A-B clip lead to the top tap of L1, and Y D1 clip lead to the second tap from the top. Tune in a radio station with C2 and then adjust C1A-B for best volume. Change the position of the clip leads and retune C1A-B and C2 for best reception. Check operation of the receiver over the entire broadcast band.

Experiment 2

Tune the receiver to a radio station and then disconnect the germanium diode. Do not disturb the receiver tuning. Install a carborundum crystal into the D1 assembly. Set R1 to mid range, and connect a 6-volt battery to the receiver; negative lead to J3, positive lead to J4.

Adjust the D1 catwhisker for a sensitive spot on the carborundum crystal. Then set R1 for best volume of received signal. Retune C1A-B and C2 and change the clip leads on the L1 taps as necessary for reception of radio stations.

Note

Carborundum that will work as a detector may be hard to find. Grinding wheels are not suitable as a source, because the carborundum is usually in fine particles mixed with other material. Best bet is to contact collectors of antique radio parts. But you can use this receiver to experiment with minerals for semiconductor operation. See the Workshop Section for information on mounting mineral sections for detector experiments.

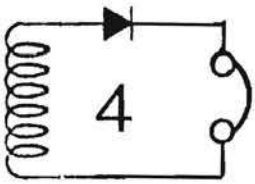

COMPONENT PROJECTS

BOOK TUNING CAPACITOR

During the roaring 20's,the Crosly Radio Corporation used a type of tuning capacitor that had two plates hinged together on one edge. The dielectric was a sheet of mica between the two plates. This type of tuning capacitor was called a Book Condenser.

The tuning capacitor shown in the illustration is similar to the Crosly Book Condenser. It uses aluminum foil plates cemented to fixed and movable wood sections, and a plastic sheet dielectric (cut from thin transparent plastic notebook protector material).

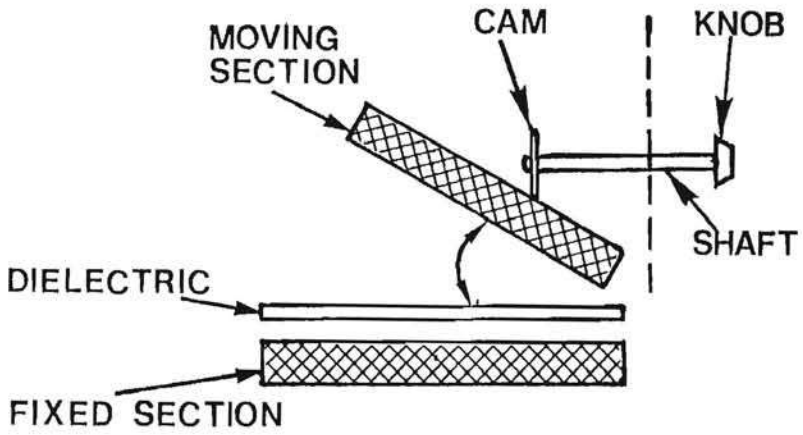

Adjusting the tuning knob causes a metal cam to rotate and control the movement of a spring loaded wood section. This varies the capacity between the two foil plates. As the plates are brought closer together, the capacity increases. As they are separated, the capacity decreases.

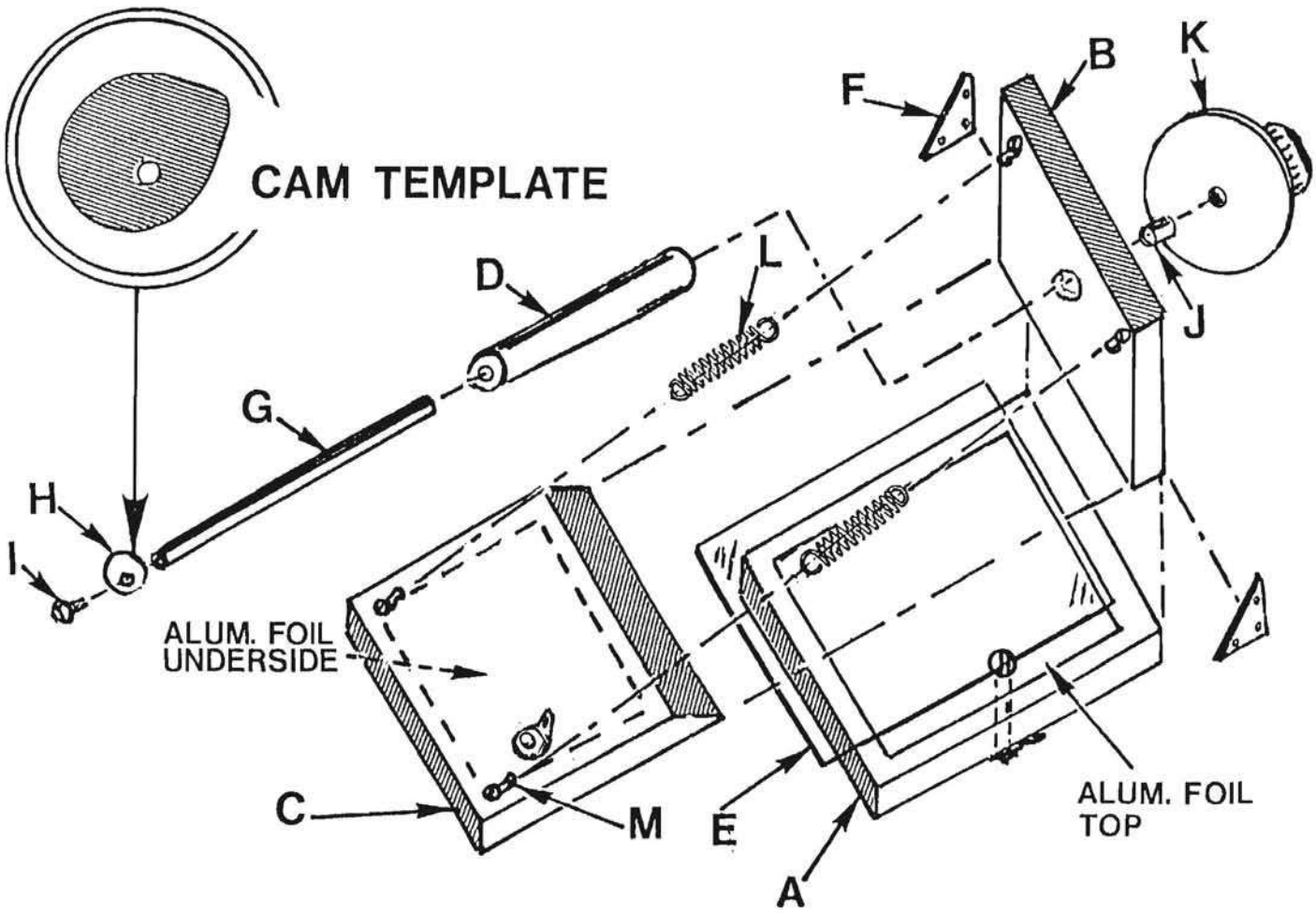

BOOK TUNING CAPACITOR

List of Materials

A - 3 x 3 1/2 X 3/8-inch wood section
B - 3 x 1 3/4 x 3/8-inch wood section
C - 3 x 3 1/8 x 3/8-inch wood section (one end beveled 45 degrees - see text).
D - 3/4 - inch diameter wood dowel, 2 1/4 inches long.
E - 3 1/2 x 3 -inch sheet plastic (See text).
F - 2 triangular 1-inch metal sections
G - 1/4-inch metal rod, 3 -inches long.
H - Metal cam (see text).
I - Machine screw (see text)
J - Bushing 3/8-inch long (to fit rod G).
K - Tuning knob (to fit rod G).
L - 2 springs 1/4-inch diameter by 1 1/4-inch long.
M - 4 solder lugs.
MISC. Small wood screws, nails, aluminum foil, machine screws, nuts, solder lugs and washers.

CONSTRUCTION

Start construction by cutting the wood sections from 3/8-thick wood to the sizes shown in the drawing. Section C has a 45 degree bevel at one end. This acts as a pivot point for the movable section. Drill and countersink a hole to fit a flathead machine screw in the places shown on sections A and C. Do not install the screws at this time.

Cement aluminum foil on the top of section A and on the bottom of section C. Then cut and remove a 1/2-inch strip of foil from the front edge of section A. Cut a 1/8-inch strip from the remaining edges. Also cut away a 1/8-inch strip from all the edges of the foil on section C.

Carefully slit the foil on top of the machine screw hole on section A and press the foil gently inside the hole. Install the flathead machine screw into the hole, making sure that it is in contact with the foil. Fasten the screw with a washer and nut. Make sure that the screw does not turn and rip the foil. Install a solder lug and nut on the free end of the screw. Repeat this operation with section C.

Cut the sheet plastic E to size and place it on top of section A. Then place section B on top of the plastic sheet and install it on the end of section A with wood screws. Install the two metal sections F with small nails.

Saw the metal rod G to size and tap one end to fit a machine screw. Cut the dowel D to size and center drill it to fit the rod G. Cut a flat on one side of the dowel.

Make a tracing of the cam H template and cement it on a section of heavy gauge sheet aluminumm. Cut the cam to size and drill a hole to fit the rod machine screw in the location shown. Install the cam with a lock washer on rod G. Insert the free end of the rod into dowel D. Place section C on top of the plastic sheet E on section A. Then temporarily position dowel D with rod G in the center of section B. Rotate the cam so that its long end touches the top of section C. Mark the placement of the dowel on section B. Drill a hole in section B to fit dowel D. Cement the dowel in place.

Locate and install solder lugs with wood screws on sections A and C as shown in the drawing. Bend over the ends of the solder lugs and install two springs L in the lugs.

Mount tuning knob K and bushing J on the free end of rod G. Adjust the knob and check that section C moves in and out with the cam rotation. changing the capacity between the foil plates.

You may have to experiment with the cam diameter for best operation of section C. File the cam edges in small increments only and recheck the operation often. Use very light springs to keep section C from pressing against the cam and moving it.

Reverse the cam on rod G to alter the direction of capacity (clockwise or counterclockwise). The capacitor can be installed vertically on a receiver project with a small metal bracket mounted on the bottom side of section A.

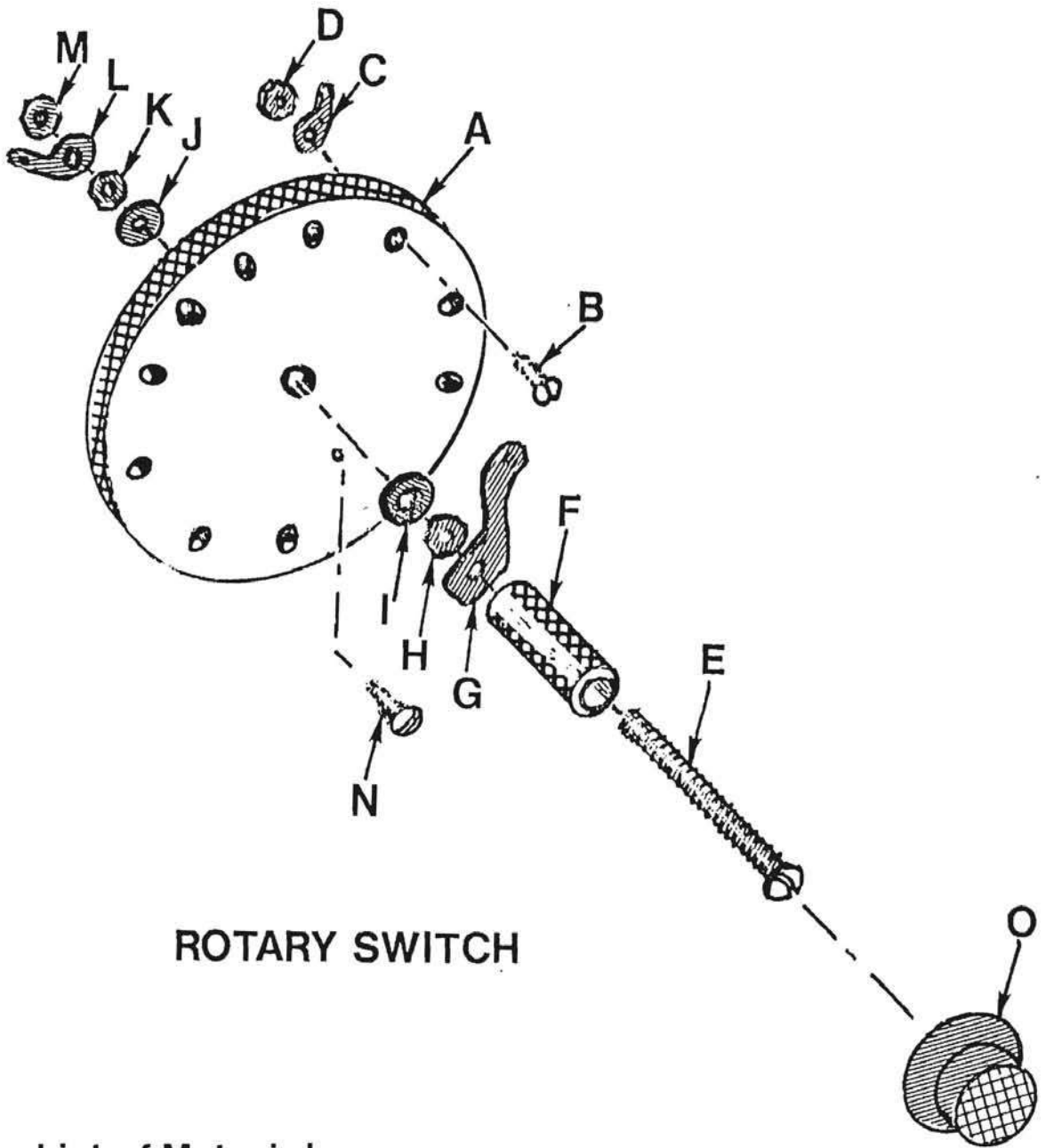

ROTARY SWITCH

List of Materials

A - 2 1/4 diameter x 3/8-inch wood section.
B - Flat head machine screws.
C,L - Solder lugs.
D - Nuts to fit B.
E - Machine screw 1 1/4-inches long.
F - 1/4 diameter x 1/2-inch long bushing (to fit E).
G - Switch arm 1 x 1/4-inch (sheet brass, see text).
H,K,M - Nuts to fit E.
I,J - Washers to fit B.
N - Small woodscrew.

ROTARY SWITCH

In the early days, radio experimenters could not buy parts that are readily available today. They had to build their radio components from wood sections and common hardware.The rotary switch ilustrated is similar to a type constructed for use with tapped coils of crystal sets.

The rotary switch shown uses flat head screws for contact points that are mounted on a wood section. The switch arm is cut from sheet brass and is installed on a machine screw.

CONSTRUCTION

Refer to the drawing of the rotary switch. Begin construction by cutting the 2 1/4-inch diameter section A from 3/8-inch thick wood. Locate, drill,and countersink the holes for the flathead machine screws B. The rotary switch shown has 10 machine screws, but you can space the hole locations for the number of switch contact points desired. Allow a space between the starting and ending contact points for the woodscrew N. This woodscrew is used as a stop for the rotary arm G. Locate and drill a center hole for the machine screw E. Install the screws B in section A with solder lugs C and nuts D. Install the woodscrew N.

Measure and cut the rotary arm G from a section of sheet brass. The arm should be long enough to reach the contacts. Make sure that it is not too wide, or it may short out to a nearby contact. Make a dent or "dimple" on the contact end, and drill a hole for screw E on the other end. Bend the rotary arm as shown in the drawing. Install screw E into bushing F, and arm G, and tighten the assembly with nut H. Place washer I on the screw and install screw E into the center hole of A. loosely fasten the screw with washer J and nut K. Then rotate the bushing F and arm G. Adjust the tightness of nut K as required to allow rotation of G with only a slight "drag". Install solder lug L on screw E with nut M. and bend the lug towards the screw end. Install knob O on bushing F, and recheck operation of the arm G. It should touch all of the contacts B and stop at screw N.

The rotary switch is used as shown in the Dual-Tuned Crystal Set Construction Project. Make sure that extra lead length is allowed for connection to the solder lug L. Bend the lead into a "pig-tail," so that it will not break as the solder lug L is rotated.

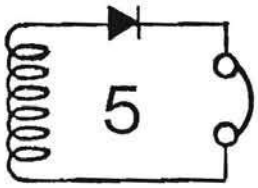

5 WORKSHOP

The construction projects in this book can be built with common hand tools found in an average home workshop.

Useful Hand Tools

Safety glasses or face shield
Steel rule
Square
Hack saw
Wood saw
Screwdrivers
Pliers
Wirecutters
Tin snips
Center punch
Files
Hammer
Soldering Iron

Wear safety glasses or face shield while working. Observe common sense safety precautions.

SOLDERING

Make sure that the part to be soldered is clean. Use only rosin core solder. Prepare the soldering iron tip as follows:

File each surface of the tip to remove oxidation. Plug in the iron and let it heat until you can melt solder on the tip (before the copper tip turns blue or bronze color). Melt enough solder until all sides of the tip are coated. Then wipe off excess solder with a damp sponge or cloth.

Make sure that the bare wire lead to be soldered is free of oxide. It is best to tin it first by melting a bit of rosin core solder on the lead end. Crimp the lead in the part hole to keep it from moving during soldering. Hold the iron tip under the part until it is hot enough to melt solder. Apply only enough rosin core solder to cover the surface of the part. Remove the iron. Do not move the part or wire while it is cooling.

PROJECT CONSTRUCTION TIPS

Tape a sheet of graph paper over a project wood section. Mark locations of the parts on the paper. Center punch mounting hole centers through the paper. Use a compass to draw circles the same size as the holes. Then drill holes through the paper.

Lettering on the projects can be done with a labelmaker that prints on strips of adhesive coated plastic. You can also use decals or dry transfer lettering sheets.

Small metal brackets can be made from heavy gauge sheet aluminum. Layout and drill the mounting holes and then cut it to size with a tin snips. Form the bracket by using a heavy mallet and a vise.

Tuning Capacitors, Knobs, and Dials

Old radios are a good source of components. The radios generally use two tuning capacitor sections ganged together. The receivers previously described will operate with one of the capacitor sections (365 mmf). You can cut out cardboard discs and cement them to radio knobs and use them as dials with the tuning capacitors. Mark the dials with dry transfer lettering, or black drawing ink.

Panels and Cabinets

The layout and construction of crystal sets is not critical. They can be fitted into many different types of wood cabinets. You can use almost any type of non-metallic box, but metal boxes are not recommended as sheet metal close to the tuning coil may lower its "Q". Black sheet plastic used for the front panel with white dry transfer lettering will give your receiver project an antique look.

MOUNTING MINERALS FOR CRYSTAL DETECTORS

Minerals (galena, etc) for experimentation as crystal detectors, will work best when mounted in a metallic base. For temporary mounting (while testing), wrap aluminum foil tightly around the sides and bottom of the mineral. Then place it into a sheet metal ring or cup that will fit into the detector assembly.

After testing, the mineral can be permanently mounted in a metal slug. Drill a shallow hole of a diameter equal to the detector assembly crystal in a block of wood. Fill the hole with melted solder. While the solder is still molten, carefully place your mineral section into the center. Hold the mineral in place with tweezers or long nose pliers until the solder cools. Then pry the metal slug out of the wood. Be sure that the top of the mineral section is free of solder.

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About the Author

Charles Green has been involved in the design and construction of electronic equipment for industry and the U.S. Government for 30 years. Much of his experience has been as a technical writer preparing operation and maintenance manuals. His continuing interest is in constructing radios and he has had over a hundred articles published in hobbyist magazines over the past two decades.

Radio Direction_Finder RDF Projects Joe WB2HOL

Sourse URL: http://home.att.net/~jleggio/projects/rdf/rdf.htm

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SIMPLE Time-Difference-Of-Arrival RDF

Joe Leggio WB2HOL

This T.D.O.A. RDF set is built into a die-cast Pomona box. I built it in October, 1989. As you can see from the photo, it has held up to lots of abuse as it gets knocked around in my RDF bag.

How it works

Time Difference of Arrival RDF sets work by switching your receiver between two antennas at a rapid rate. When both antennas are the same distance from the transmitter, the RF phase received by both antennas will be identical. If the two antennas are different distances from the transmitter the RF will have a different phase at each antenna. If we switch between the antennas 500 times a second, this phase change will be detected by an FM receiver as a 500 Hz tone.

By turning the antennas for a null in the tone, your two antennas will be perpendicular to the transmitter. Unfortunately, you can be facing the transmitter or facing away from the transmitter and get a null in the tone. By using a synchronous detector and processing the phase of the tone, it is possible to drive a center scale meter to indicate which direction to turn to face the transmitter.

If you have a null in the tone and turn slightly right, the meter should point to the left and direct you to turn left to face the transmitter. If instead, it points right as you turn right, you need to continue turning right to face the transmitter; you were facing away from it originally. (in other words, you need to turn 180 degrees around)

When you build this unit you must test it with *your specific receiver.* The audio circuits in a receiver sometimes invert the audio phase and if that is the case, the unit will read opposite of the true direction. If this happens to you simply turn the antenna unit around or reverse the connections to the meter.

If you look closely at the center of the antenna boom in the picture below, you will see my markings on the antenna for one of my HTs. (I used abbreviations, but it says "When using the Ten-Tec HT, this side of the boom should be on the bottom and away from the transmitter")

Circuit Description

This circuit is adapted from an idea which originally was described in QST in an article for a Double Ducky direction finder. It uses a CMOS 4066 as a synchronous detector. I used a CMOS 555 as a square wave oscillator to drive both the antenna switching diodes and the synchronous detector. I also added a stage of audio amplification to help drive a less sensitive meter. This unit was originally designed to be mounted directly on the antenna connector of my HT. This worked fine when I originally built it. Today, I have a Yeasu FT50R. It is smaller than the TDOA unit and has an SMA connector for the antenna. Somehow, I don't think it could support the weight.

Audio is input via a cable connected to the earphone jack of the HT. A small loudspeaker was mounted on the front of the T.D.O.A. RDF unit to allow me to hear the FOX. The loudspeaker is not illustrated in the schematic shown here. The T.D.O.A. RDF unit supplies voltage to the antenna unit through the center conductor of the coax. The voltage alternately causes the diodes connected to the antenna elements to conduct. As the diodes conduct, RF is able to flow from one of the antenna elements to the receiver The switching rate is set by the .01uf capacitor and the 47k resistor connected to pin 2 of the 555. If you would like a different tone, try adjusting the value of the 47k resistor.

This T.D.O.A. RDF unit uses a center scale meter to indicate which direction to turn in order to face the transmitter. I used a surplus meter movement in my TDOA RDF unit. It was not a center zero meter until I took it apart and moved the mechanical zero adjust lever to make it so. I would guess it was a 100 microamp meter movement originally. I think it was a signal strength meter from an old FM broadcast band receiver. A more sensitive meter would allow you to use less volume. I usually look for a 50 to 200 microamp zero center meter when building one of these units and can usually find a bargain at one of the ham radio flea markets I attend. I never spend more than five dollars for a surplus meter. The meter in this unit cost me about a dollar. I would guess that even a 500 microamp meter could be used. I would be less sensitive and require you to use a bit more volume.

The Printed Circuit Board

I used rub-on transfers (available from Radio Shack) to lay out the PC board in this unit. It does not have the audio amplifier stage which is present on the PC layout included on this web page. The amplifier is needed when using less sensitive meter movements.

The PC board layout is shown here looking at the bottom of the board as if you had X-ray eyes and could look through the board and see the parts on top. There is one wire jumper. It is at the lower right side of the PC board. The two transistors are 2N3904 or equivalent. The two diodes across the meter movement are 1N914 or equivalent. The three 25uf capacitors each have two different pads available for their leads. If you can obtain parts small enough to fit the set of pads spaced closer together, use them. There is nothing critical about the value of most of the parts. Anything plus or minus 20 percent of the value indicated will work. (don't add 20% to the 555 or the 4066. I doubt *that* would work!).

All of the resistors are 1/4 watt. The two diodes on the PC board are connected "back-to-back" The PC layout illustrates how the diodes should be mounted. The electrolytic caps should be rated for at least 10 volts. (assuming you are going to use a 9 volt battery). The 1.0 microhenry coil used to couple the output from the 555 to the antenna was fashioned by winding about 20 turns of number 22 AWG wire on a 3/16 inch drill bit. It was then slid off of the drill and mounted on the PC board.

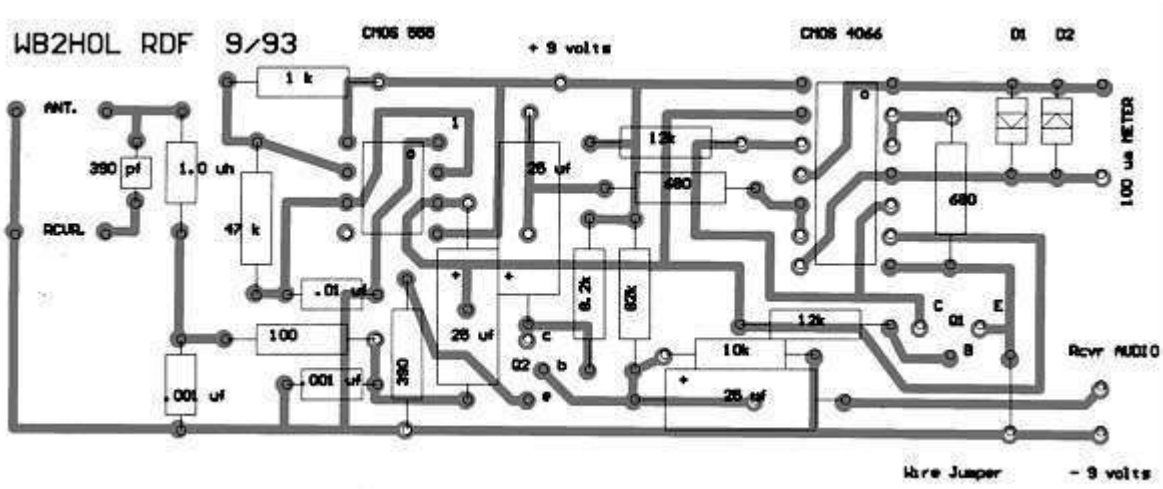

The Antenna Unit

Details of the antenna are shown below. The four antenna elements should be fashioned out of stiff wire or metal rods. One club member recycled a broken TV antenna and used 19 inch segments of its elements. The schematic shows two antennas; you might be wondering why there are four antenna elements. The extra two are connected to the coax shield at the ends of the boom. These form a counterpoise for the two active elements.

The boom of the antenna must be less than 1/2 wavelength long. The longer the boom, (up to 1/2 wavelenngth) the more RF phase difference will be detected. I found that spacing the antennas about 1/4 wavelength apart gave the best results. Further apart resulted in more modulation but at the expense of portability. It also seemed a bit less sensitive to multipath errors when I used the shorter boom. The antenna unit pictured here has a 15 inch long boom.

The antenna must be constructed as symmetrical as possible. The lengths of coax from the center BNC connector must be identical. A difference of 1/2 inch will cause an error of several degrees. If you use 1/2 wavelengths of coax you only need one set of diodes where the coax connects to the BNC connector at the center of the boom. If you find it easier to mount a flange style SO-239 connector on the boom instead of a BNC, use it instead. You will then need a cable with an PL-259 at one end and a BNC connector at the other to connect the antenna to the RDF unit.

I have found that by mounting the antenna on a mast so it is up and in the clear will result in the most accurate bearings.(It is then away from reflections from your body and the ground) Whatever you do, make the unit collapsible so it can be stored when not in use.

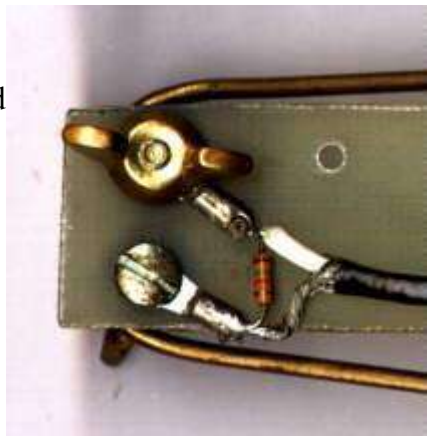

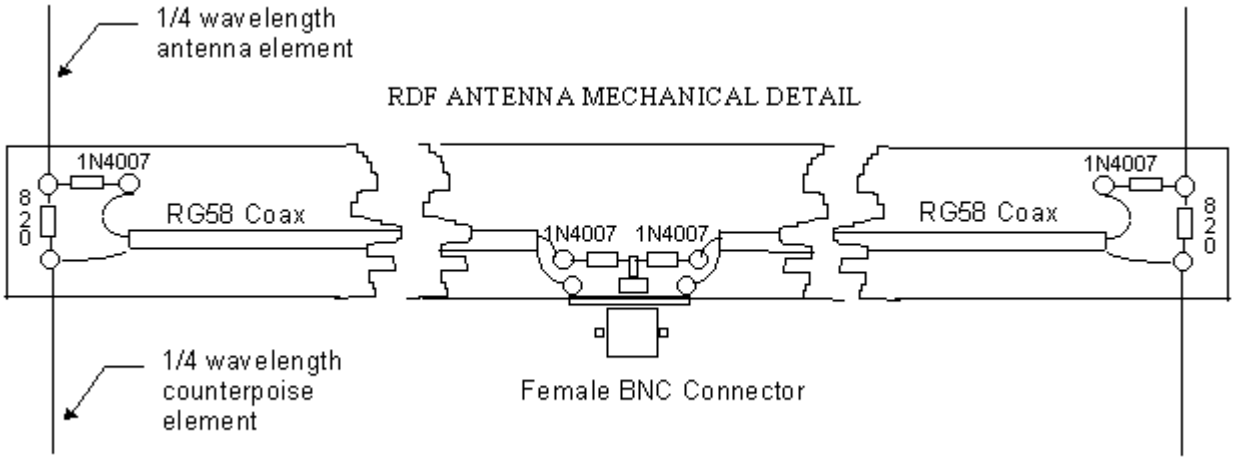

It is very important that the diodes on the antenna be connected as shown on the schematic. Most diodes have a band which shows which end is the cathode. The best diodes for use in the antenna are RF PIN diodes. I used 1SS103 PIN diodes I purchased at a flea market. An equivalent diode is the MPN 3404. In a pinch, you can substitute a 1N4007 power diodes. They have a similar internal diode structure to the PIN diodes and will work almost as well. The MPN 3404 is advertised at Dan's small parts

RDF Antenna Mechanical Details

My antenna unit is designed to fold for storage. Wing nuts are used to secure the elements in position. I used brass brazing rod for the antenna elements on my latest hand-held unit. Earlier units used straightened out coat hanger. On the unit pictured, I used 1/2 wavelength lengths of coax between the center PIN diode and the antenna elements. This allowed me to use only one pair of PIN diodes in the center. I coiled the coax and secured it to the boom mid way between the center BNC connector and the ends. RG-174 coax was used on the unit illustrated here to reduce weight. The resistor in the picture is a 1.5k. The schematic below shows 820 ohms. Remember, in this circuit, few part values are critical.

The antenna boom was made from a piece of scrap glass epoxy circuit board material about 15 inches long and about 1 1/4 inch wide. I peeled the copper from the board, mounted a BNC connector at the center, and used small ring terminals secured by screws as tie points.The PIN diodes are the small rectangular black parts with the red stripe at one end. The picture shows them soldered to the back of a chassis mount BNC connector.

When you build your antenna make sure you mark one side as being the side towards the transmitter. Also mark the TOP. The first time I used this antenna, I started out walking away from the fox instead of towards it because the antenna was being held upside down. (My antenna was visually as well as physically symetrical) What amazed me was the number of other hunters who followed me thinking I knew where I was going. For the second fox hunt, I had marked the antenna. I won that event using this unit.

The Schematic

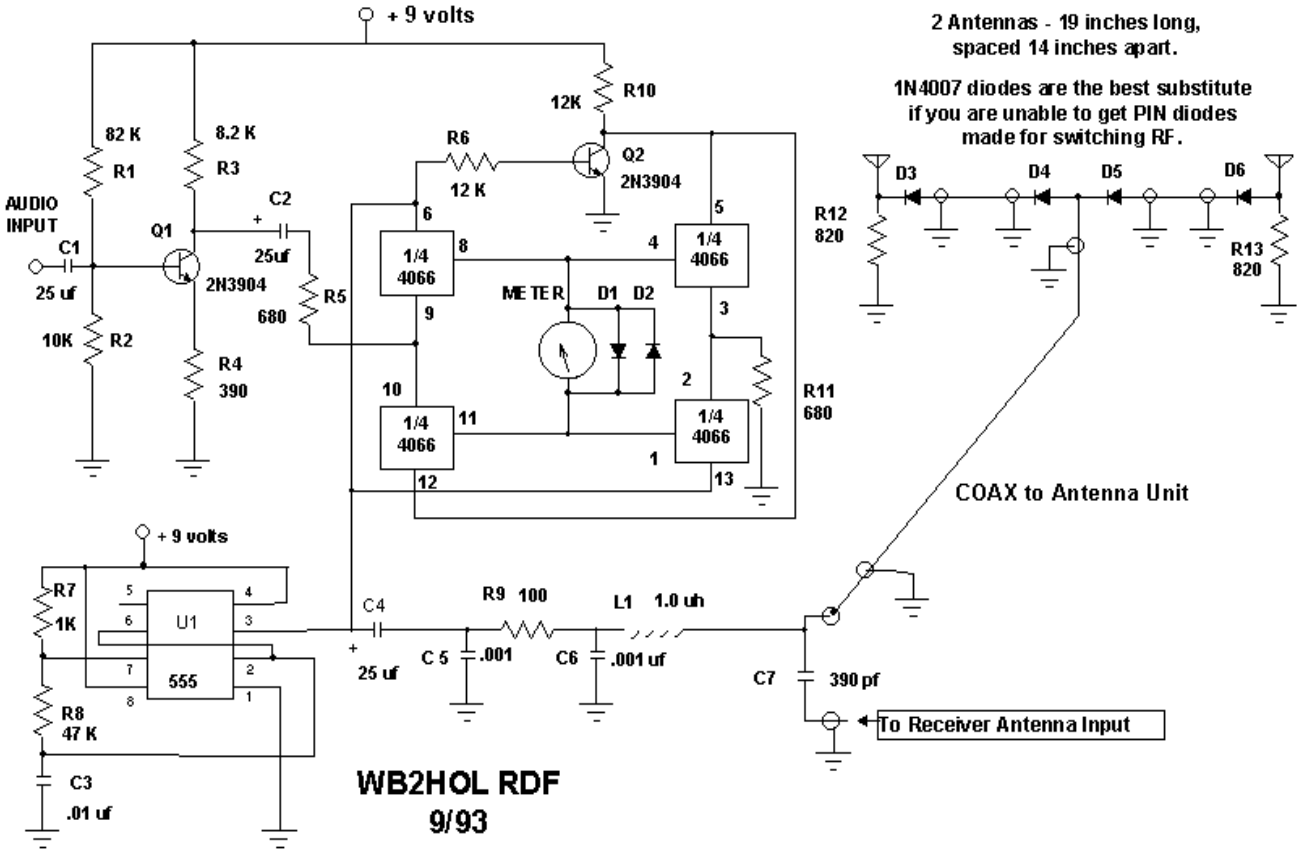

555 Time-Difference-Of-Arrival RDF

by Joe Leggio WB2HOL

This T.D.O.A. RDF set is built on a Radio-Shack experimenters board. It was featured on the cover of the May,June,July 1993 issue of the South Eastern Repeater Association, Inc Repeater Journal.

It uses a single 555 timer wired to produce a square wave output at about 500 Hz. 1N4007 power rectifier diodes were used in place of PIN diodes to switch between two dipole antennas at a 500 Hz rate. If you substitute another lower voltage power rectifier, it will work, just not as well. Of course, if you have RF PIN diodes, use them. (the 1N4007 is the only diode in the 1N400X series to contain a PIN diode structure) Power is supplied by a 9 volt battery.

I mounted the 555 oscillator circuit at the center of a 15 inch long piece of wood which acts as a boom to support two dipoles. The dimensions are not too critical. I used small brass screws as tie points at the ends of the boom and used wing-nuts to allow the dipole elements to fold against the boom when the unit was not in use.

I did not bother to add a power switch. I simply used a rubber band to secure the 9 volt battery to the boom and disconnect the battery from the circuit when I'm not using it.

How it works

Time Difference of Arrival RDF sets work by switching your receiver between two antennas at a rapid rate. When both antennas are the same distance from the transmitter, the RF phase received by both antennas will be identical. If the two antennas are different distances from the transmitter the RF will have a different phase at each antenna. If we switch between the antennas 500 times a second, this phase change will be detected by an FM receiver as a 500 Hz tone.

By turning the antennas for a null in the tone, your two antennas will be perpendicular to the transmitter. Unfortunately, you can be facing the transmitter or facing away from the transmitter and get a null in the tone. This circuit does not give you the ability to know if you are facing the transmitter or facing away from it. You must use triangulation to determine the correct direction. Although I have not tried it, you may also add a switched phasing line to your unit as shown here. This will result in a non-symmetrical receive pattern and allow an indication of which direction to travel.

The best method to tell the front from the back when using a TDOA RDF unit is by using a T.D.O.A. with a synchronous detector and processing the phase of the tone. It is then possible to drive a center scale meter to indicate which direction to turn to face the transmitter.

The Antenna Unit

Details of the antenna are shown below. The four antenna elements should be fashioned out of stiff wire or metal rods. One club member recycled a broken TV antenna and used 19 inch segments of its elements. The schematic shows two antennas; you might be wondering why there are four antenna elements. The extra two are connected to the coax shield at the ends of the boom. These form a counterpoise for the two active elements. I found that 15 inch lengths of wire "coat-hanger" worked well as antenna elements for the unit pictured here. You can experiment to determine the optimal length and distance between the dipole elements. (until you run out of wire hangers, that is)

The boom of the antenna must be less than 1/2 wavelength long. The longer the boom, (up to 1/2 wavelength) the more RF phase difference will be detected. I found that spacing the antennas about 1/4 wavelength apart gave the best results. Further apart resulted in more modulation but at the expense of portability. It also seemed a bit less sensitive to multipath errors when I used the shorter boom. The unit pictured here has a 15 inch long boom.

The antenna must be constructed as symmetrical as possible. The lengths of coax from the center circuit board must be identical. A difference of 1/2 inch will cause an error of several degrees. Note that the layout of the antenna switching diodes on the experimenters PC board is symmetrical.

I have found that by mounting the antenna on a mast so it is up and in the clear will result in the most accurate bearings.(It is then away from reflections from your body and the ground) Whatever you do, make the unit collapsible so it can be stored when not in use. I used wing-nuts on the antenna elements to allow the unit to fold easily.

It is very important that the diodes on the antenna be connected as shown on the schematic. Most diodes have a band which shows which end is the cathode. The best diodes for use in the antenna are RF PIN diodes. I used 1SS103 PIN diodes I purchased at a flea market. An equivalent diode is the MPN-3404. In a pinch, you can substitute a 1N4007 power diodes. They have a similar internal diode structure to the PIN diodes and will work almost as well. The MPN-3404 is advertised at Dan's small parts

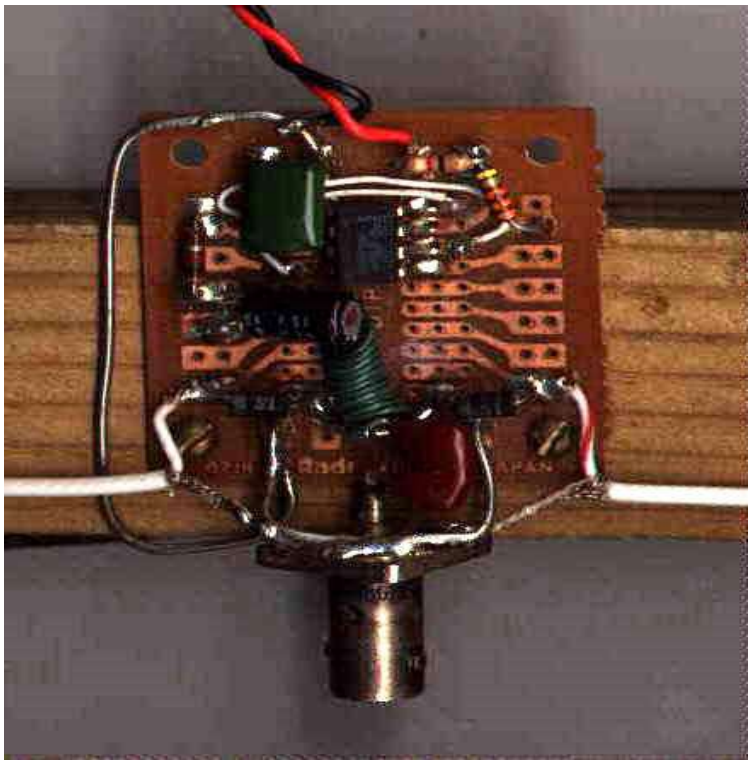

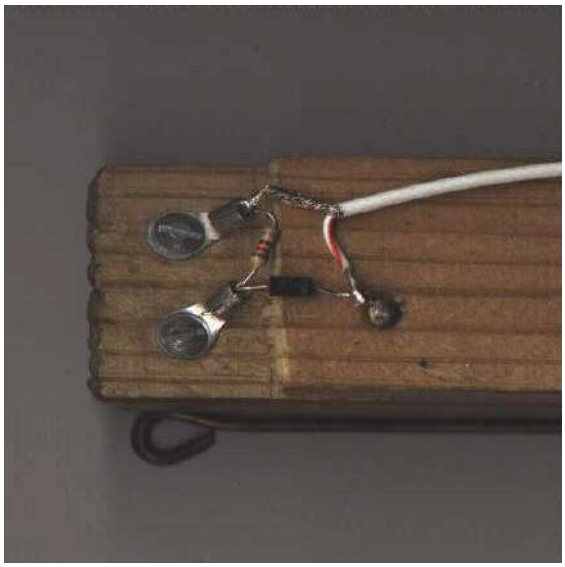

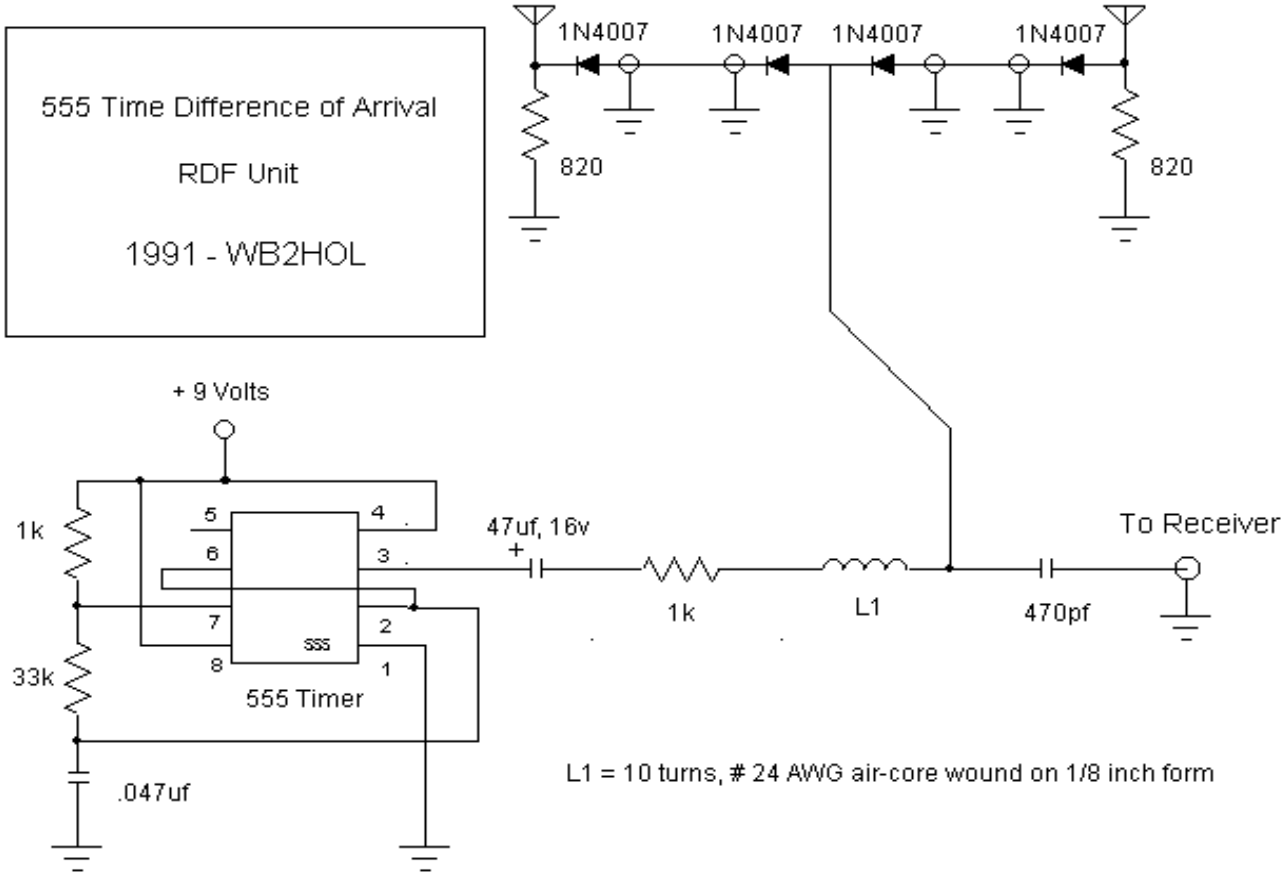
555 Time Difference of Arrival
RDF Unit
1991 - WB2HOL
1N4007
1N4007
1N4007
1N4007
820
820
+ 9 Volts
1k
33k
.047uf
555 Timer
47uf, 16v
1k
L1
470pf
To Receiver
L1 = 10 turns, # 24 AWG air-core wound on 1/8 inch form

TAPE MEASURE BEAM
OPTIMIZED FOR RADIO DIRECTION FINDING

Joe Leggio WB2HOL

Description

This antenna evolved during my search for a beam with a really great front-to-back ratio to use in hidden transmitter hunts. This design exhibits a very clean pattern and is perfect for RDF use. It trades a bit of forward gain in exchange for a very deep notch in the pattern toward the rear. (You could optimize the design for more forward gain, but at the expense of a really good notch in the pattern toward the rear.) It is a design that can be constructed using only simple hand tools (no machine shop needed) and still perform well. It has been duplicated several dozen times by other local hams and has been successfully used as a club construction project.

When I designed this antenna I had one basic idea in mind. It had to be easy to get in and out of the car when hunting for a hidden transmitter. This would be accomplished by the use of steel "tape measure" elements. These elements could fold easily when fitting the antenna into my car and yet still be self supporting. I decided to use three elements to keep the boom from getting too long.

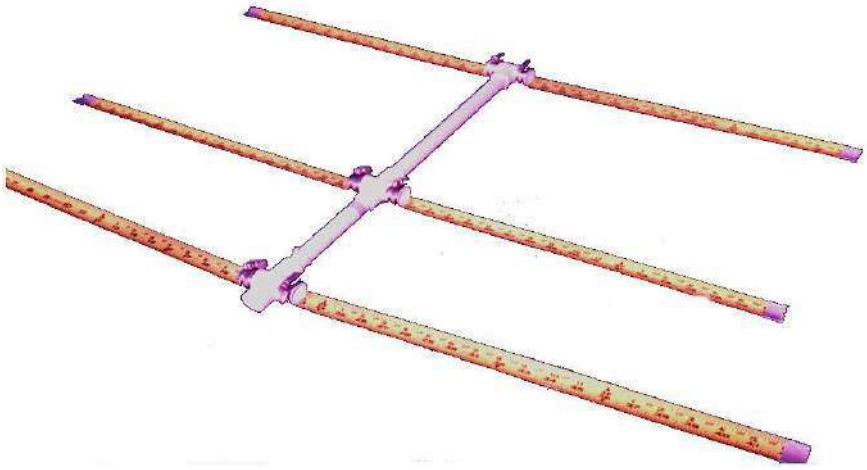

Another of my design goals was to use materials that were easy to obtain. I chose to use Schedule-40 PVC pipe and fittings available at my local hardware store for the boom and element supports. These kept the cost for the antenna very low. The element supports consist of PVC crosses and tees.

Since I had never seen any plans for an antenna using elements made from 1 inch wide steel "tape measure," I had to do the design myself. To assist in the design I used a shareware computer aided yagi design program written by Paul McMahon VK3DIP. It allowed me to optimize the antenna for the cleanest pattern combined with the best front-to-back ratio.

Performance Predicted by YAGI-CAD	
GAIN	7.3 dBd
Front-to-Back Ratio	>50 db
3 db Beamwidth	E = 67.5 degrees
3 db Beamwidth	H = 110 degrees

When I first built this beam I found it needed a matching network of some kind to have a low SWR. My first attempt was a Gamma match. This was unwieldy. The driven element could barely handle the weight and the Gamma match itself was not very flexible. The best matching network turned out to be a "hairpin match." This is simply a 5 inch length of wire that is connected across the feed points of the driven element. The antenna has some capacitive reactance without the matching network. The 5 inch length of wire has just enough inductance to cancel the capacitive reactance. This resulted in a better match than anything else I had tried.

The wire I used for the hairpin match was enamel insulated 18 gauge solid. Other hams who have duplicated this beam have used just about anything they had on hand. 14 gauge house wire works well, so does a length of 22 gauge hookup wire. It does not seem to matter if it is stranded or solid, use whatever you have available. This results in a very good match across the two meter band once you have adjusted the distance between the halves of the driven element for minimum SWR. (1 inch apart on my prototype).

I used a pair of shears to cut the tape measure elements to length. An old pair of scissors will probably do as well. No matter how you cut the elements be very careful. Those edges are very sharp and will inflict a nasty cut if you are careless. Use some sandpaper to remove the really sharp edges and burrs resulting from cutting the elements to size. I put some vinyl electrical tape on the ends of the elements to protect myself from getting cut. I encourage you to do the same. It will probably be best if you round the corners of the elements once you cut them. Wear safety glasses while cutting the elements. Those bits of tape measure can be hazardous.

The RG58 coax feedline is connected directly to the driven element. No matter what method you use to attach the feedline, make sure you scrape or sand the paint off the tape measure element where the feedline is attached. Most tape measures have a very durable paint finish designed to stand up to heavy use. You do not want the paint to insulate your feedline connection.

If you are careful, It is possible to solder the feedline to the element halves. Care must be taken since the steel tape measure does not solder easily and since the PVC supports are easily melted. You might want to tin the tape measure elements before mounting them to the PVC cross.

If you decide not to solder to the tape measure elements, there are two other methods that have been used to attach the feedline. One method employs ring terminals on the end of the feedline. The ring terminals are then secured under self tapping screws which hold the driven element halves. This method does not allow you to tune the antenna by moving the halves of the driven element. 6-32 bolts and nuts could be used if holes are drilled in the elements near the ends. If the bolt heads are placed nearest the PVC fitting, you could secure ring-terminals with nuts and lock washers. Another possibility is to simply slide the ends of the feedline under the driven element hose clamps and tighten the clamps to hold the ends of the coax. I know this is low-tech, but it works just fine.

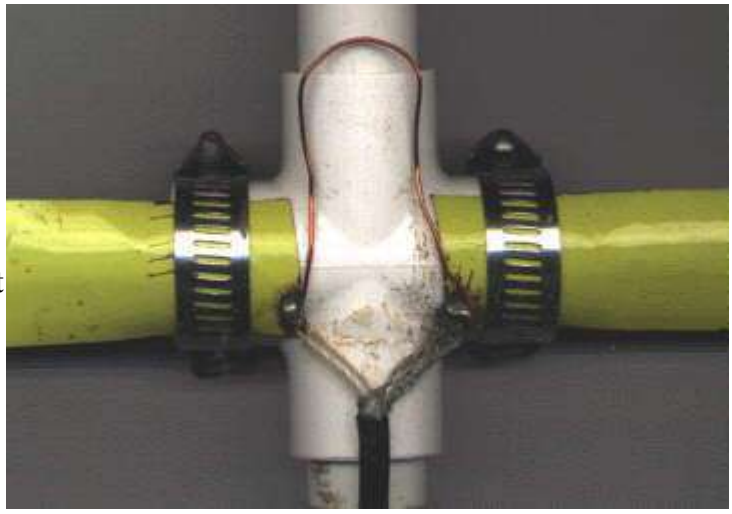

Stainless steel hose clamps are used to attach the driven element halves to the PVC cross which acts as its support. This has the added benefit of allowing you to fine tune your antenna for lowest SWR simply by loosening the hose clamps and sliding the halves of the driven element either closer or further apart. By using the dimensions specified, I found that the SWR was 1:1 at 146.565 Mhz (our Fox-Hunt frequency) when the two elements were spaced approximately 1 inch apart. Figure 1 shows the method used to attach the driven element to the PVC cross.

I used 1 1/2 inch hose clamps to attach all the elements on my prototype beam. Others who have duplicated my design have used self tapping screws to attach the elements to the PVC crosses and tees. Performance is the same using either method. The screws are much less expensive but they do not hold the elements as securely. If you do not use 1/2 inch PVC fittings but instead use 3/4 inch, make sure the hose clamps you buy are large enough to fit.

If you wish a slightly neater looking beam, use the self tapping screws. If you do not mind spending a few more dollars for the hose clamps, use them instead. If I were to build another beam I would use screws for the director and reflector, and hose clamps for the driven element. That would give me the best of both methods.

Rubber faucet washers have been used by some builders between the tape measure element and the PVC fittings on the director and reflector. These allow for the tape to fit the contour of the PVC fitting and will make the antenna look better. Now you know what to do with those washers left over from the assortment you once purchased; You know the ones I mean, the washers that do not fit the faucets you have in your house. If you are an apartment dweller, ask around, these things are stashed in almost every homeowners basement or garage.

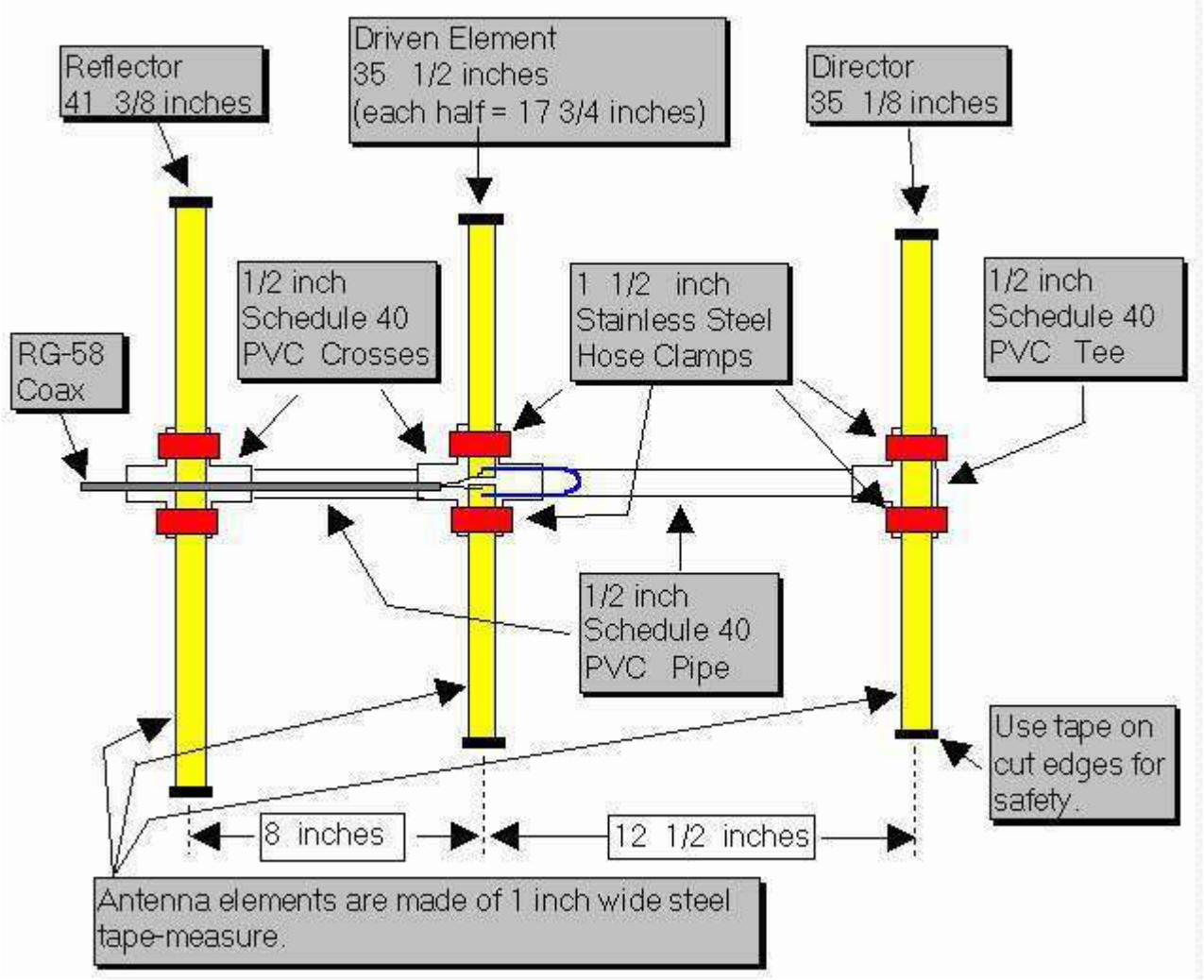

Construction:

Cut a length of tape measure to 41 3/8 inches. It will be the Reflector element. Cut two lengths of tape measure to 17 3/4 inches. These will be used for the Driven element. Cut one length of tape measure to 35 1/8 inches. It will be used for the Director. Once you have cut the tape measure to length, put vinyl tape on the cut ends to protect yourself from the sharp edges. You will want to scrape or sand off the paint from one end of each of the driven element halves so you can make a good electrical connection to the feedline.

If you are planning to solder the feedline to the driven elements it is best to tin the elements first before attaching them to the PVC cross. If you don't, the PVC will melt as you apply heat to the element. It would be a good idea to also take the time to form the wire used for the hairpin match into a "U" shape with the two legs of the "U" about 3/4 inch apart. Tin the ends of the hairpin if you plan on soldering it to the driven element. If you tin 1/4 inch of each end of the hairpin it will leave 4 1/2 inches to shape into the "U".

You will need to cut two lengths of PVC pipe to use as the boom. One should be cut to 11 1/2 inches. It is used to form the boom between the Director and the driven element. The other piece of PVC should be cut to 7 inches. It will be used between the Reflector and the Driven element. Just about any saw will cut through the soft PVC pipe. I used a hacksaw. When we mass produced this antenna as a club project, we marked the pipe and used a portable jig saw to cut the lengths in assembly line fashion. It took longer to measure the pipe than to actually make the cuts. Since the pipe is available in ten foot lengths, you can make a few beams from a single 10 foot length. In any case, you might want to cut a few extras lengths for your friends. They will want to duplicate this once they see your completed antenna.

At this time you can pre-assemble the PVC boom, crosses and tee which will support the tape measure elements. I did not use any cement or glue when I assembled mine. The PVC pipe is secured in the fittings with a friction fit.

The hose clamps I used are stainless steel and have a worm-drive screw which is used to tighten them. They are about 1/2 inch wide and are adjustable from 11/16 inch to 1 1/2 inch diameter. Attach the tape measure elements to the PVC fittings as shown in the accompanying drawing. It is normal for the Reflector and Director elements to buckle a bit as it is tightened to the PVC Tee and Cross. You can eliminate this buckle if you use the washers and self tapping screws to attach these elements instead of the hose clamps. I do not think the beam will withstand as rough a treatment as when hose clamps are used.

How does it perform?

Once you have completed your beam you probably will be interested to see if it performs as well as the computer predicted. The SWR should be less than 2:1 across the entire two meter band. The front-to-back ratio is predicted to be very good with the antenna exhibiting a very deep notch in its pattern towards the rear. The YagiCad 4.1 program produced these antenna pattern graphs showing the pattern you should expect. If you would like to experiment a bit with this program, the yagi specification file for this tape measure beam is available for download here. Simply download the YAGI-CAD program and put the tape measure beam design file in the same directory. You will then be able to experiment with the design.

Note: under Windows95, only the first .yag file will show in the OPEN-FILE menu. You can either move all the other .yag files to a sub-directory or re-start the computer in MS-DOS mode. It works fine there. (I really do not know why this occurs but will blame Microsoft)

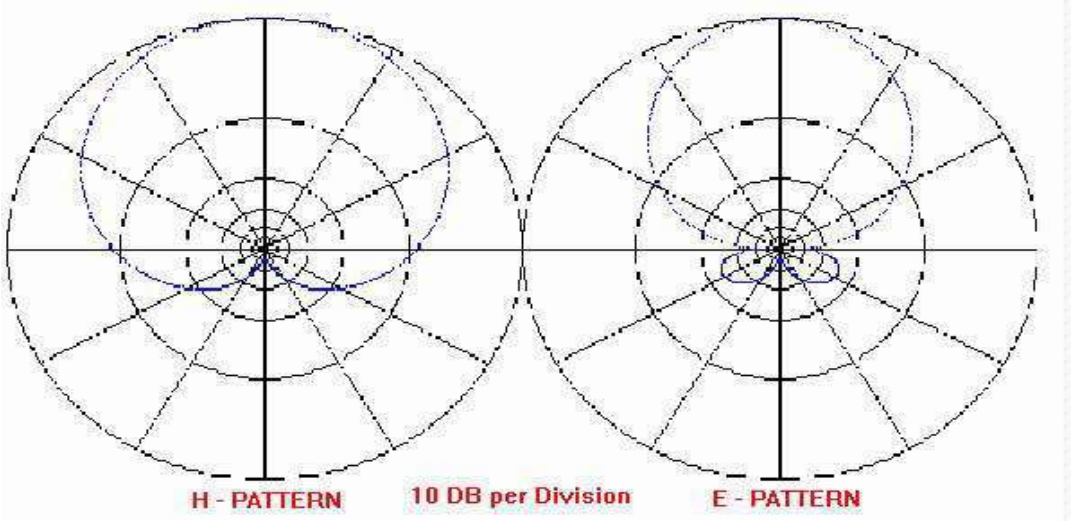

How does the tape measure beam "measure up?"

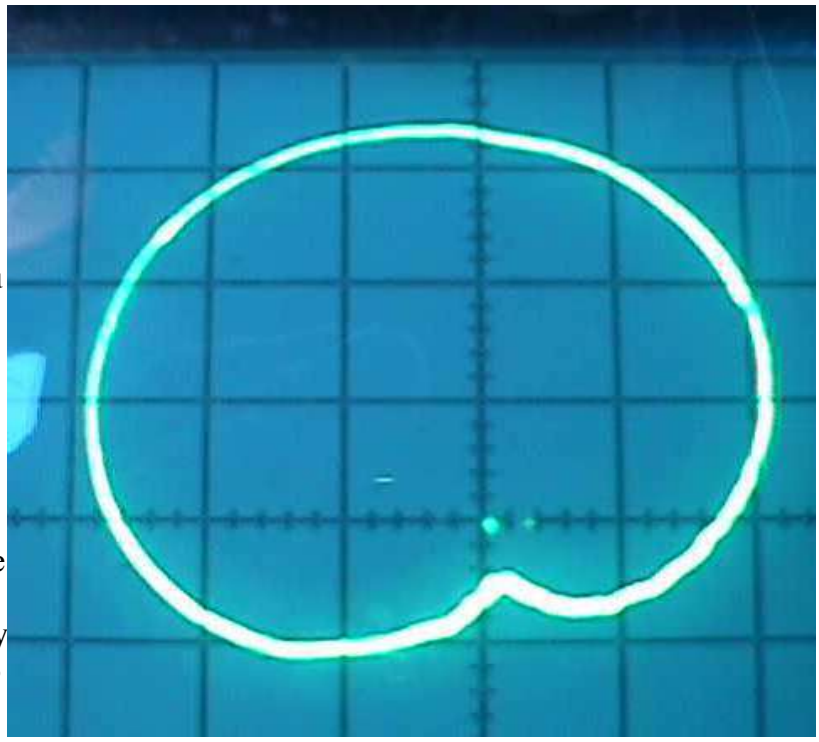

WB4SUV and WA6EZV used a storage scope connected to a copy of this antenna constructed by KC8FQY and provided the following picture of the actual antenna pattern. I am very happy to see that the computer prediction of a clean pattern with a really great front-to-back ratio was accurate. What do you think?

Summary

This beam has been used on Fox-Hunts, on mountain tops, at local public service events, outdoors, indoors in attics, just about everywhere. The SWR is typically very close to 1:1 once adjusted. Front to back performance is exactly as predicted. The null in the rear of the pattern is perfect for transmitter hunts. When tested using a sensitive field strength meter and a low powered fox transmitter, full scale readings were seen from a distance of ten feet. With the same field strength meter I was able to point the antenna away from the transmitter and move the reflector element to within a few inches of the transmitter antenna and still not see a reading. I don't have the facilities to verify a 50 db notch as predicted by the Yagi-Cad software but It sure seems close. The flexible elements have taken a lot of abuse. My antenna has seen a lot of use and has held up quite well. Best of all, when on a fox-hunt, this beam is a breeze to get in or out of the car.

RDF2 YAGI WITH TAPE MEASURE ELEMENTS

Joe Leggio WB2HOL

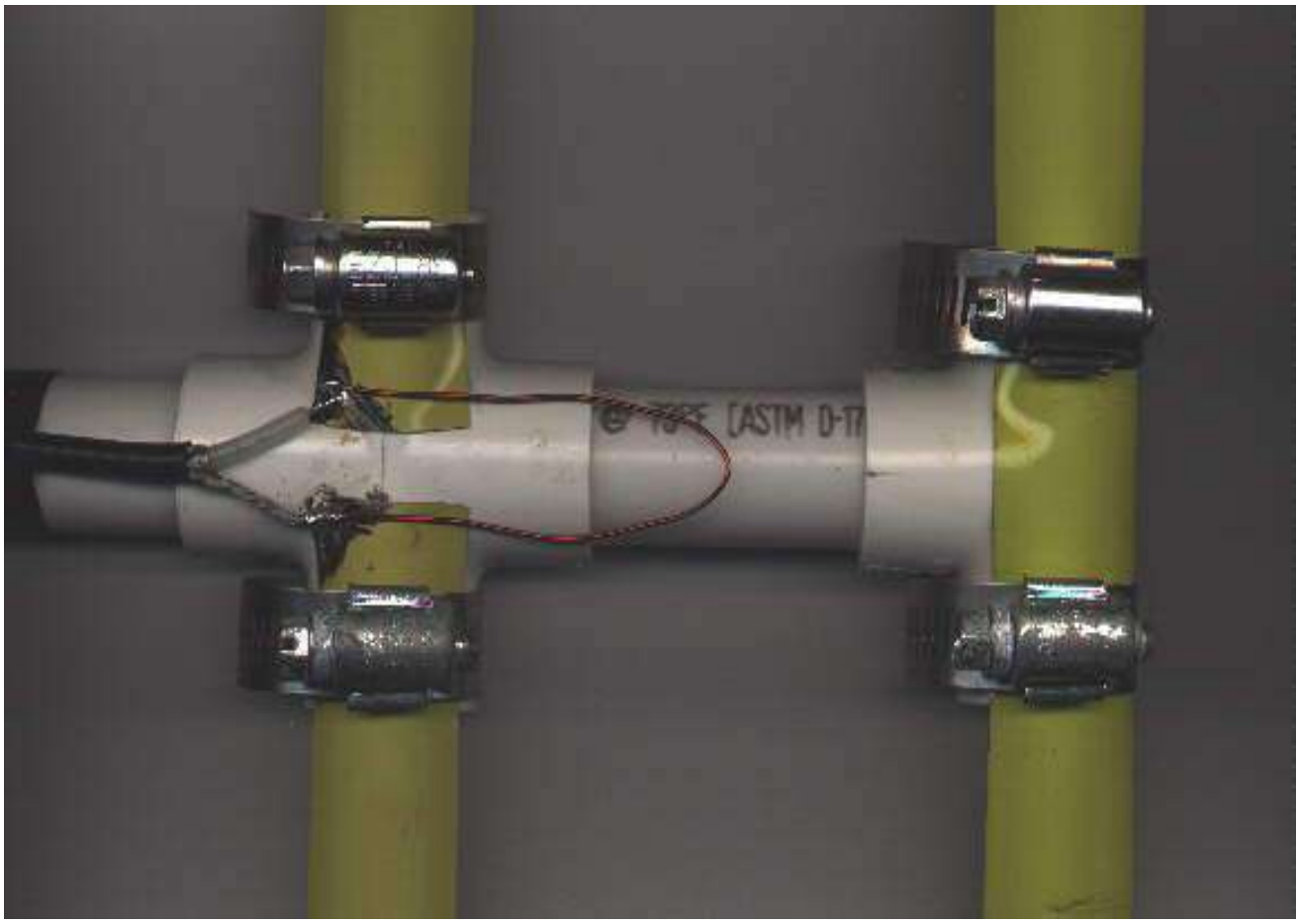

Description

This antenna is an adaptation of the RDF2 two element, close spaced Yagi antenna described in the May, 1996 issue of 73 Amateur Radio Today Magazine.

The original design, developed by N6WZI and featured in the Homing In column of 73, used 1/4 inch solid aluminum rods for antenna elements. If you don't subscribe to 73, find someone who does and ask to see the original article.

My version of the RDF2 antenna uses 1 inch wide steel "tape measure" elements. This is one antenna you can take into the woods without having to worry about Yagi Eating Trees. The flexible elements also make it very easy to get this antenna in and out of the car.

You do not need a machine shop to build this antenna. You only need common hand tools. It is much easier to construct than the original design and can be assembled in about 30 minutes once you gather the needed parts.

Performance Predicted by ELNEC	
GAIN	4.7 dBi
Front-to-Back Ratio	>8 db
3 db Beamwidth	E = 36 degrees
3 db Beamwidth	H = 70 degrees

N6WZI's original design used a "hairpin" matching network made from a length of TV antenna twinlead. I made a similar "hairpin match" but instead used a 5 inch length of wire connected across the feed points of the driven element. The antenna has some capacitive reactance without the matching network. The 5 inch length of wire has just enough inductance to cancel the capacitive reactance.

The wire I used for the hairpin match was enamel insulated 18 gauge solid. This results in a very good match across the two meter band once you have adjusted the distance between the halves of the driven element for minimum SWR at the desired frequency. (3/16 inch apart on my prototype). Experience has shown that the wire guage used for the hairpin match is not very critical. Use what you have on hand. 14 guage house wire works well, probably any insulated wire which will hold its shape will work just fine.

I used a pair of shears to cut the tape measure elements to length. An old pair of scissors will probably do as well. No matter how you cut the elements be very careful. Those edges are very sharp and will inflict a nasty cut if you are careless. Use some sandpaper to remove the really sharp edges and burrs resulting from cutting the elements to size. I put some vinyl electrical tape on the ends of the elements to protect myself from getting cut. I encourage you to do the same. It will probably be best if you round the corners of the elements once you cut them. Wear safety glasses while cutting the elements. Those bits of tape measure can be hazardous.

Replacement tape measure blades are available for reasonable prices at larger hardware stores. I found a 30 foot replacement blade at Sears for less than five dollars. If you use a replacement blade, be very careful when removing it from the package. The blade I purchased had a hard plastic cover which, when twisted, allowed access to the end of the replacement tape measure element. When you twist the cover, make sure you keep your fingers away from the "razor sharp" end of the blade. (I probably could have assembled this antenna in even less time if I didn't have to go upstairs to the medicine chest to get a band-aid. This is experience speaking. The spring steel popped out, inflicting a nasty cut on my thumb. I'll probably heal in a week or so...)

The RG58 coax feedline is connected directly to the driven element. No matter what method you use to attach the feedline, make sure you scrape or sand the paint off the tape measure element where the feedline is attached. Most tape measures have a very durable paint finish designed to stand up to heavy use. You do not want the paint to insulate your feedline connection.

If you are careful, It is possible to solder the feedline to the element halves. Care must be taken since the steel tape measure does not solder easily and since the PVC supports are easily melted. You might want to tin the tape measure elements before mounting them to the PVC cross. I used a bit of rosin flux to help with tinning the element connection points.

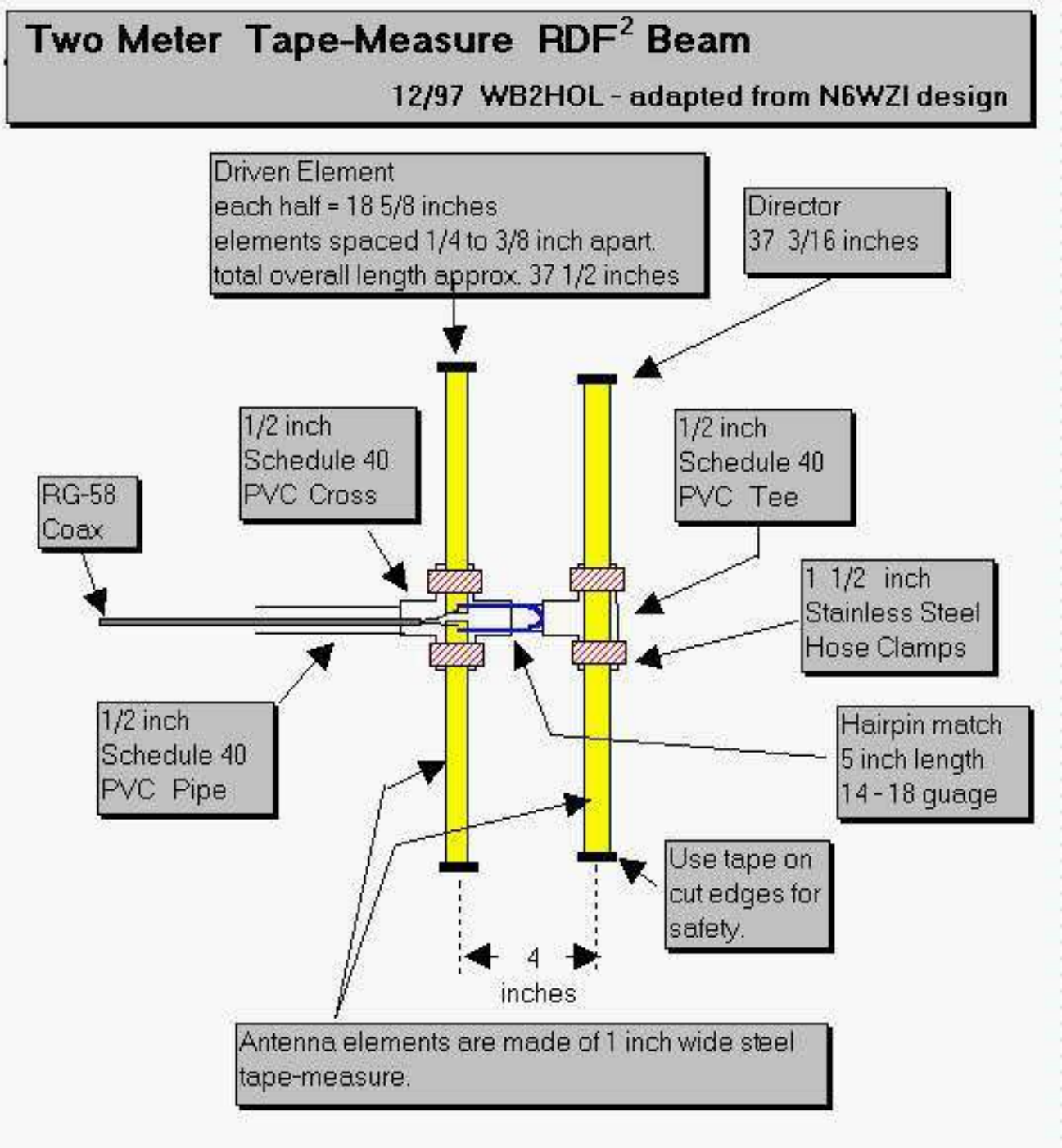

Stainless steel hose clamps are used to attach the driven element halves to the PVC cross which acts as its support. This has the added benefit of allowing you to fine tune your antenna for lowest SWR simply by loosening the hose clamps and sliding the halves of the driven element either closer or further apart. By using the dimensions specified, I found that the SWR was 1:1 at 146.565 Mhz (our Fox-Hunt frequency) when the two elements were spaced approximately 3/16 inch apart. Figure 1 shows the method used to attach the driven element to the PVC cross.

I used 1 1/2 inch hose clamps to attach all the elements on my prototype beam. if you do not use 1/2 inch PVC fittings but instead use 3/4 inch, make sure the hose clamps you buy are large enough to fit. Others who have duplicated my design have used self tapping screws to attach the elements to the PVC crosses and tees. Performance is the same using either method. The screws are much less expensive but they do not hold the elements as securely. In addition, the screws do not allow you to tune the antenna by sliding the halves of the driven element closer or further apart.

If you wish a slightly neater looking beam, use the self tapping screws. If you do not mind spending a few more dollars for the hose clamps, use them instead. If I were to build another beam I would use screws for the director, and hose clamps for the driven element. That would give me the best of both methods.

Construction:

Cut two lengths of tape measure to 18 5/8 inches. These will be used for the Driven element. Cut one length of tape measure to 37 3/16 inches. It will be used for the Director. Once you have cut the tape measure to length, put vinyl tape on the cut ends to protect yourself from the sharp edges. You will want to scrape or sand off the paint from one end of each of the driven element halves so you can make a good electrical connection to the feedline.

It is best to tin the elements first before attaching them to the PVC cross. If you don't, the PVC will melt as you apply heat to the element. It would be a good idea to also take the time to form the wire used for the hairpin match into a "U" shape with the two legs of the "U" about 3/4 inch apart. Tin the ends of the hairpin to make it easier when soldering it to the driven element halves. If you tin 1/4 inch of each end of the hairpin it will leave 4 1/2 inches to shape into the "U".

You will need to cut two lengths of PVC pipe. One should be cut to 3 inches. It is used to form the boom between the Director and the driven element. The other piece of PVC should be cut to 6 1/2 inches. It will be used as a handle so you can hold the antenna from the rear. Just about any saw will cut through the soft PVC pipe. I used a hacksaw. Since the pipe is available in ten foot lengths, you can make a few beams from a single 10 foot length. In any case, you might want to cut a few extras lengths for your friends. They will want to duplicate this once they see your completed antenna.

At this time you can pre-assemble the PVC boom, cross and tee which will support the tape measure elements. I did not use any cement or glue when I assembled mine. The PVC pipe is secured in the fittings with a friction fit. When assembled, the cross and tee will be 4 inches from center to center.

The hose clamps I used are stainless steel and have a worm-drive screw which is used to tighten them. They are about 1/2 inch wide and are adjustable from 11/16 inch to 1 1/2 inch diameter. Attach the tape measure elements to the PVC fittings as shown in the accompanying drawing. It is normal for the Director element to buckle a bit as it is tightened to the PVC Tee. You can eliminate this buckle if you use washers and self tapping screws to attach this element instead of the hose clamps but I do not think the beam will withstand as rough a treatment as when hose clamps are used.

How does it perform?

Once you have completed your beam you probably will be interested to see if it performs as well as the computer predicted. My prototype antenna does seem to have a pretty good front-to-back ratio. It is real easy to get a peak on the "S" meter. It does not hear cross polarized signals very well. This is an advantage as most reflections will not have the same polarization as the original transmitter. Gain seems to be between 3 to 5 dB less than the three element RDF beam I designed. This is probably an advantage when close to the transmitter. You will need a bit less attenuation. The short boom and light weight make this antenna attractive if you have to use it for any length of time. It is light enough for youngsters to carry without tiring. As long as you put vinyl tape on the ends of the elements, this antenna is pretty safe to carry. Descriptions of the N6WZI RDF2 Yagi performance when used on a foxhunt may be found at Jim Elmore's site.

Drawbacks

The curved, airfoil shaped, flexible elements will "flutter" and bend when in high wind situations. (Mobile flutter while stationary?) If you need additional support, you can add short lengths of PVC pipe to the TEE and CROSS and then tape the elements to the PVC pipe. I figure 6 to 12 inches of PVC would add lots of strength to the elements. The short boom does result in less gain than a more conventional Yagi. You may need more gain when starting on a foxhunt and still far from the fox transmitter.

THE FOX - 40 milliwatt transmitter

Joe Leggio WB2HOL

This two transistor 144 MHz transmitter uses a 48 MHz scanner crystal as an oscillator / tripler. A second transistor boosts the power output to 40 milliwatts. A 7-element filter is used to minimize output on the third harmonic. (I did not want it to be easy to RDF this on the 450 MHz third harmonic)

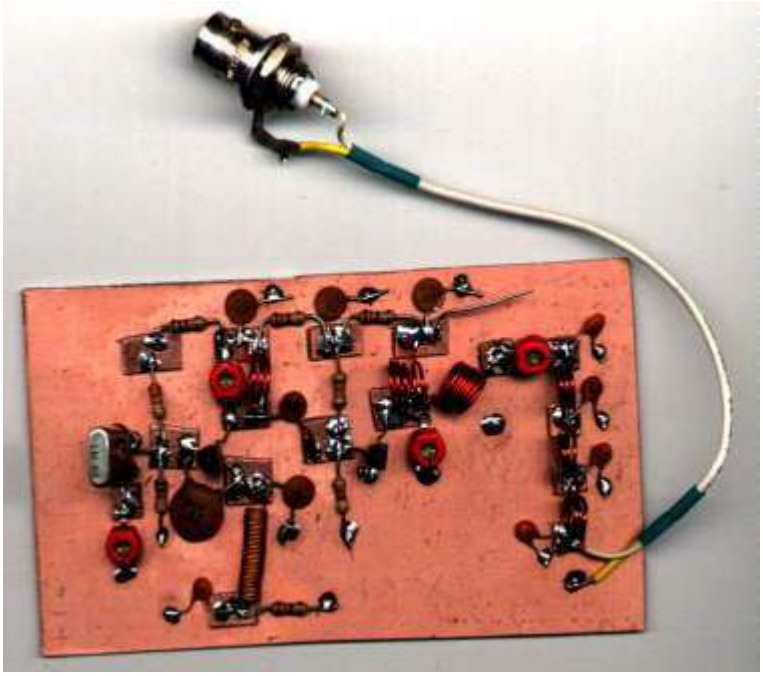

The scanner crystal I used was actually for a receive frequency 10.7 MHz higher than the two meter transmitter output. It was marked 156.21 MHz. (When you subtract the 10.7 MHz IF offset, it resulted in a transmit frequency of 145.51. Since this circuit is not the exact same circuit as the scanner, you may find that the crystal oscillates somewhere close to the marked frequency. The crystal marked as 156.21 MHz I used in this transmitter actually resulted in a signal on 145.53 MHz.)

I did get the salesperson at the local Radio Shack store a bit confused when I asked to look at his box of scanner crystals. The first thing he asked was which service I was trying to listen to... Police, Fire, Ambulance, etc.... When I said that I was looking for something for a homemade project and did not have a specific frequency in mind he understood. I did not try to tell him the crystal was to be used in a transmitter. He probably would have told me that I can't use a "receiver" crystal for a "transmitter."

As I looked at the available crystal selections, I simply took my calculator and subtracted 10.7 MHz from the marked receive frequency. I was lucky; several crystals ended up in places on the two meter band where a fox could transmit without interfering with other users. If you are not lucky, or live in an area where you must put your fox on a specific frequency, you can order a crystal through Radio Shack. Since there are still quite a few crystal controlled scanners out there, the odds are that someone in your town will have something you can use. Be aware, although most scanners use a 10.7 MHz IF, there are some with a 10.8 MHz IF. In that case, you may end up 100 kHz from where you expected.

You will need to wind several coils to build this transmitter. They are all self-supporting air-core coils made from enamel covered wire. If you follow the instructions illustrated here, you should not have any difficulty. The top of my workbench is littered with coils I have wound and tried in various circuits. I specifically avoided tapped coils or multi-winding coils to keep construction as easy as possible.

I use a simple diode detector across a 50-ohm dummy load to measure the power output while tuning up this transmitter. It is reasonably stable. It does not have a tendency to break into spurious oscillations. I did try about 5 or 6 different prototype circuits as I designed this transmitter; many were not stable. Their RF output did not smoothly change as the trimmer capacitors were adjusted but instead jumped as spurious oscillations occurred. I used an oscilloscope to monitor the output waveform and confirm the lack of spurious oscillations. This is not really necessary as you can usually hear the instability if you monitor the output signal with your 2-meter rig.

Style of PC board construction

I built all of the transmitters using copper clad PC board as a ground plane and 1/4 inch squares of PC board as tie points. The tie points were cemented to the ground plane using "crazy-glue." This technique made constructing the transmitter go very fast. It only took a drop of glue to secure the tie points. The glue set up in seconds. It made it easy to experiment with different circuits. In a pinch, a tie point could be removed or relocated by prying upward on its side with a screwdriver. I built three transmitters using this style of construction in the past month. All have worked exactly as expected. I used a pair of shears to cut a number of 1/4 inch squares of PC board material. I then used a wide file to remove any burrs created by the shear. This allowed the square of PC board material to lay flat against the PC ground plane. (Crazy-glue is not designed to fill voids. It works best when the surfaces to be glued fit together well) Be careful as you work with "crazy-glue." It is very effective at gluing fingers together.

I tried to use parts that could be obtained with little difficulty. You will need to wind several coils. I also kept these as simple as possible. The wire I used was recycled from old transformers.

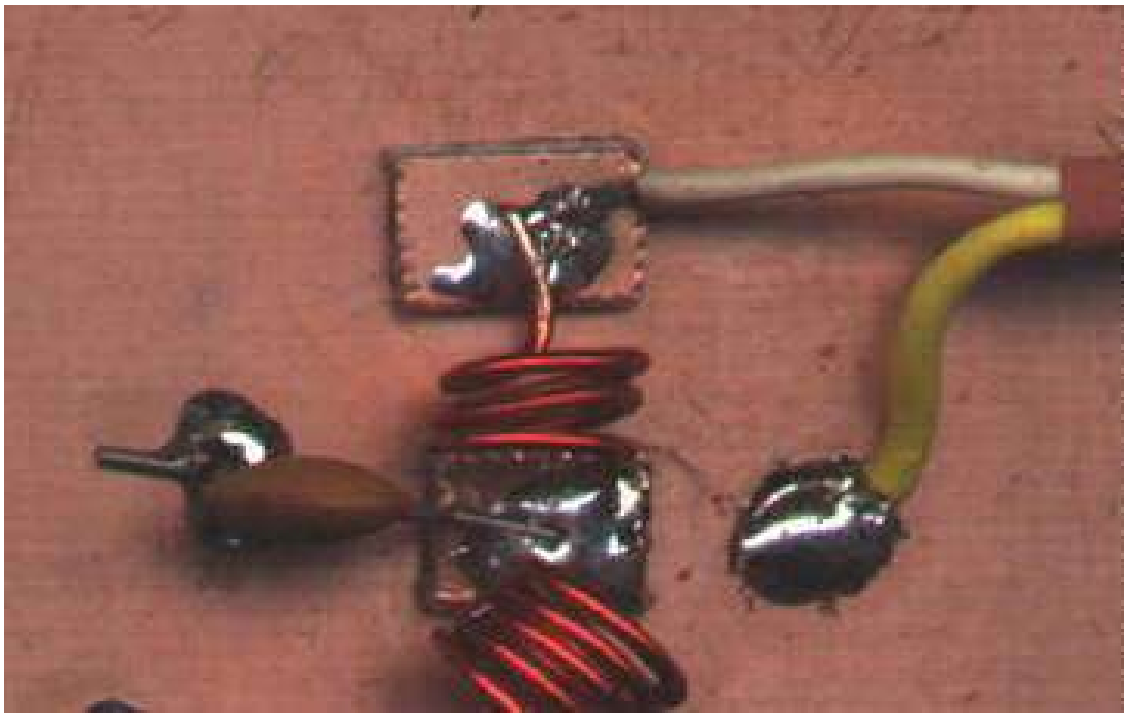

Tie-points are made from 1/4 inch squares of PC board materialglued with "crazy-glue" to a solid ground plane of PC board.

Winding the Coils

Enamel wire is close-wound on a drill bit to form the coils for this transmitter. It is easier to cut the leads to the coil and strip the enamel from the ends prior to removing the coil from the drillbit used as the form.

All the coils are wound in a single layer using a drill bit as a winding form. To help you visualize how to form the coils, I have included an illustration showing how the coils are wound..

All of the coils are "close wound" with "air cores." I used a drill bit as a form and then slipped the coil off of the bit after I had cut the free ends to about 1/4 inch. I used a hobby knife to scrape the enamel paint from the ends of the wire before I removed the coil from the drill bit used as a form. This made the coils easy to solder. With any luck, you too will be able to wind your own coils for this project.

Two different gauges of enamel covered wire are used for the coils in this project. If you have wire reclaimed from an old transformer, or from an old television deflection yoke, you can determine its gauge by winding a single layer on a drill bit. You will be able to fit about 46 turns per inch if the wire is 24 gauge. You will be able to fit about 37 turns per inch if the wire is 22 gauge. If you can't find an old transformer with the correct gauge wire to recycle, the best places I have found to buy enamel covered wire are shops which specialize in rewinding electric motors. In a pinch, if you live in the USA, Radio Shack sells "magnet wire" in both 24 and 22 gauge. You will only need a few feet of each gauge wire for this project.

I used the same transistor for both the oscillator and the amplifier stage. It is important that the transistors you use in your transmitter have sufficient gain at 2 meters. The 2N5770 is one of many I could have used. Please note: a 2N3904 would probably work fine as the oscillator (at 48 MHz), it would not work well as the amplifier as it does not work well at 144 MHz.

The tune-up of this transmitter is easy. Simply adjust each of the trimmer capacitors for maximum RF output to the antenna. (The trimmer in series with the crystal is the only exception, it is used to trim the transmitter frequency, use a frequency counter to adjust it)

I packaged one version of this transmitter in a very well shielded cast aluminum box and powered it with a 9 volt battery. The output power was reduced at the lower voltage to about 25 milliwatts. Even at that power level, it can be heard for miles. As an experiment, I tried voltages as low as 5 volts. The power output was down to below 10 milliwatts but the transmitter stayed on the air! This design works well even as the battery gets weak.

Schematic

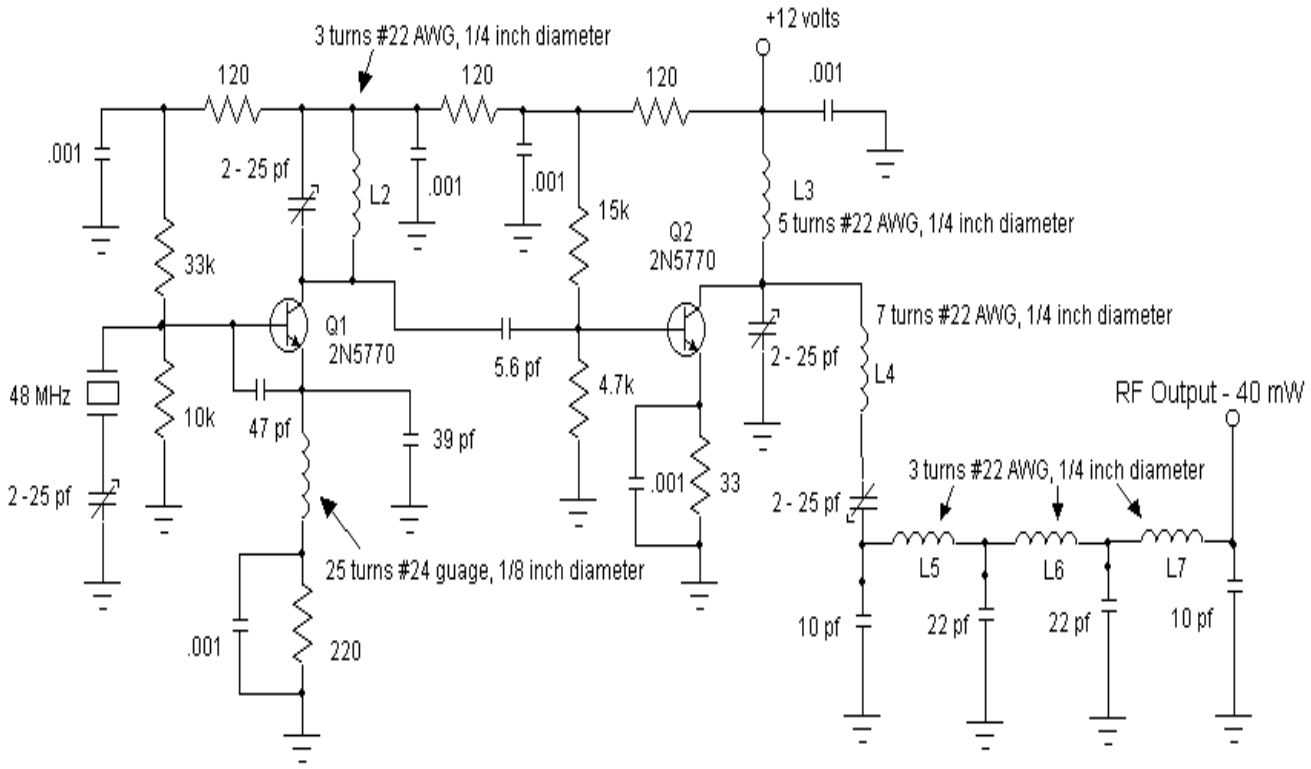

2 Meter - 40 mW FOX TRANSMITTER - 4/98 WB2HOL

THE FOX - 250mw transmitter with TIMER

Joe Leggio WB2HOL

This FOX transmitter is equipped with a timer. It can be set to start transmitting up to 24 hours later.

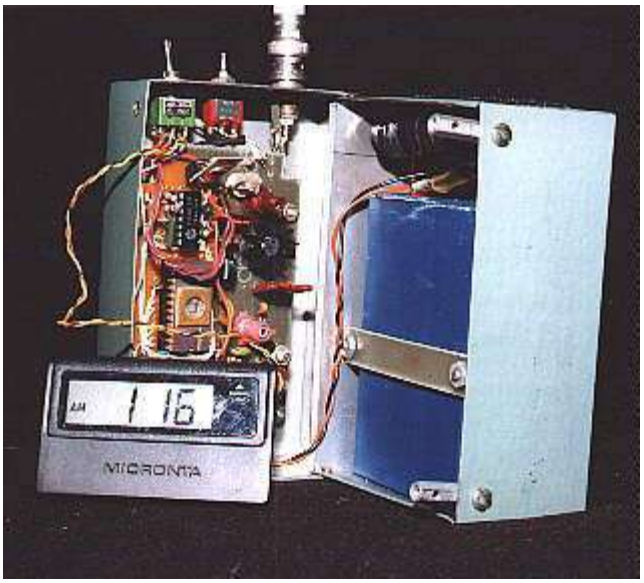

The timer consists of a Radio Shack travel alarm. I disconnected the pizeo-ceramic beeper and used the signal to set a flip-flop built from a CMOS 4011. The output of the flip flop is connected to a switching transistor which supplies voltage to the CW ID. I used an R/C combination on the flip/flop so it would be reset when first powered up. A push button is provided so the flip/flop can be set manually (turning on the transmitter)

The transmitter consists of three stages: a 45 MHz oscillator, a tripler, and a "power" amplifier. I know the heat sink on the final is a bit of overkill at 250 milliwatts output. I used a 6 volt gell cell for power. This thing can go for days.

The CW ID consists of a CMOS 4011 clock and a CMOS 4020 binary counter connected to a 2k EPROM. One bit on the EPROM is used for the CW ID, a second is used to control the switching transistor which supplies power to the transmitter oscillator. It is set up to transmit once every few minutes and stay on the air for about one minute.

Normally, the travel alarm timer is attached to the outside of the 3x5 file card box with velcro. This makes it easy to change the clock battery when needed.

A word of advice. Do not try to take a device like this through the security gate at an airport. It looks too much like something you would see in a "Die Hard" movie. Please make sure it is plainly labeled as an Amateur Radio Transmitter Location Device (or some other official title) and put your name and address on it in case it is discovered by someone not familiar with fox hunting. They *might* think the FOX looks suspicious and call officials to investigate. (You might want to notify officials in advance about your FOX-HUNT. We usually do just to eliminate problems when neighbors call in reporting *strange* people in the neighborhood)

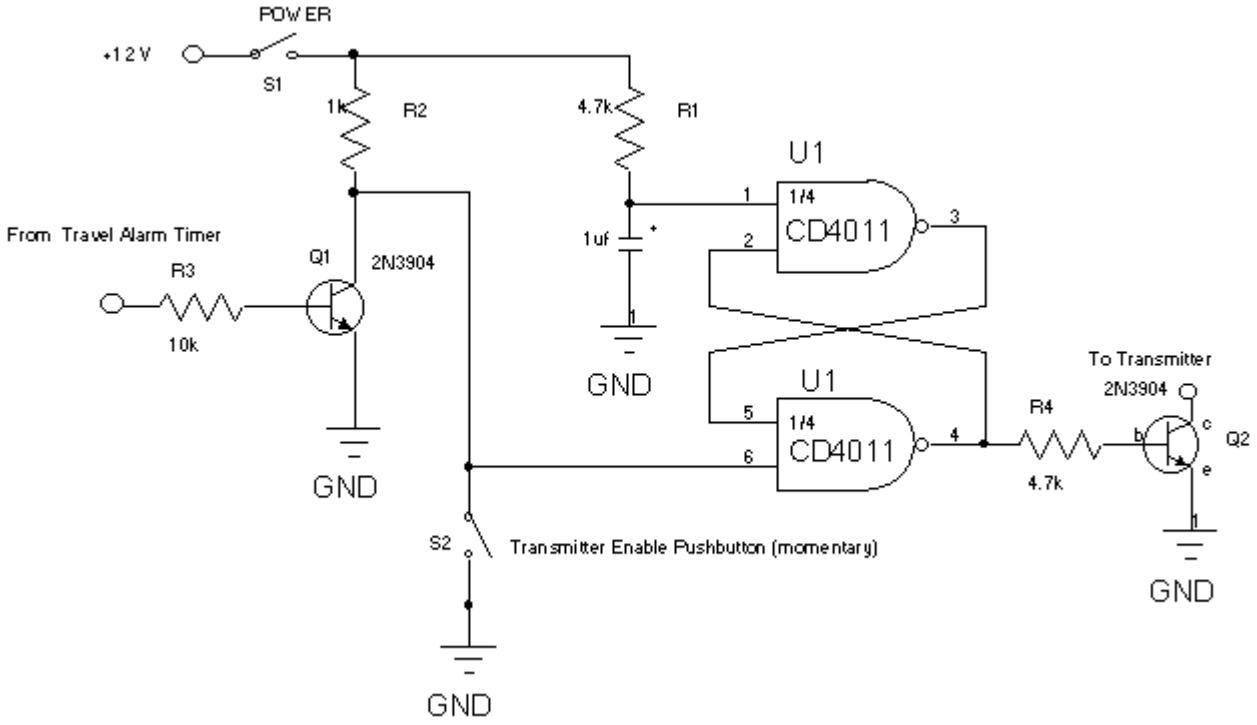
POWER
+12V
S1
1k
R2
4.7k
R1
U1
1/4
CD4011
1
2
3
1uf
GND
From Travel Alarm Timer
R3
10k
Q1
2N3904
GND
U1
1/4
CD4011
5
6
4
R4
4.7k
To Transmitter
2N3904
Q2
b
c
e
GND
S2
Transmitter Enable Pushbutton (momentary)
GND

THE FOX750 - 750 milliwatt transmitter

Joe Leggio WB2HOL

This three transistor 144 MHz transmitter uses a 48 MHz scanner crystal as an oscillator / tripler. A second transistor boosts the signal to 40 milliwatts, a third amplifies the power output to 750 milliwatts.

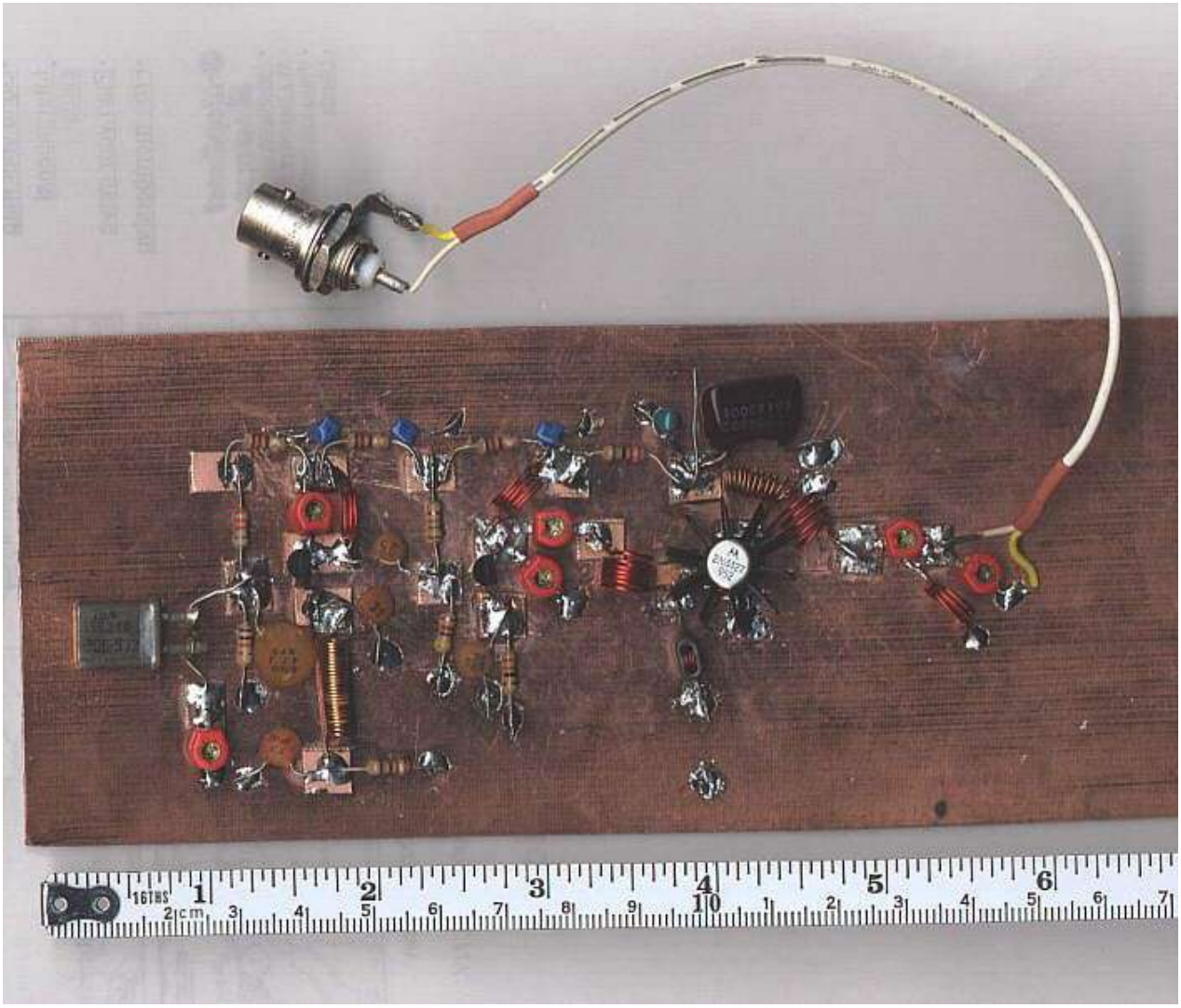

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You will need to wind several coils to build this transmitter. They are all self-supporting air-core coils made from enamel covered wire. If you follow the instructions illustrated here, you should not have any difficulty. The top of my workbench is littered with coils I have wound and tried in various circuits. I specifically avoided tapped coils or multi-winding coils to keep construction as easy as possible.

I use a simple diode detector across a 50-ohm dummy load to measure the power output while tuning up this transmitter. I did try about 5 or 6 different prototype circuits as I designed this transmitter; many were not stable. Their RF output did not smoothly change as the trimmer capacitors were adjusted but instead jumped as spurious oscillations occurred. This design is reasonably stable. It does not have a tendency to break into spurious oscillations. I used an oscilloscope to monitor the output waveform and confirm the lack of spurious oscillations. This is not really necessary as you can usually hear the instability if you monitor the output signal with your 2-meter rig.

Style of PC board construction

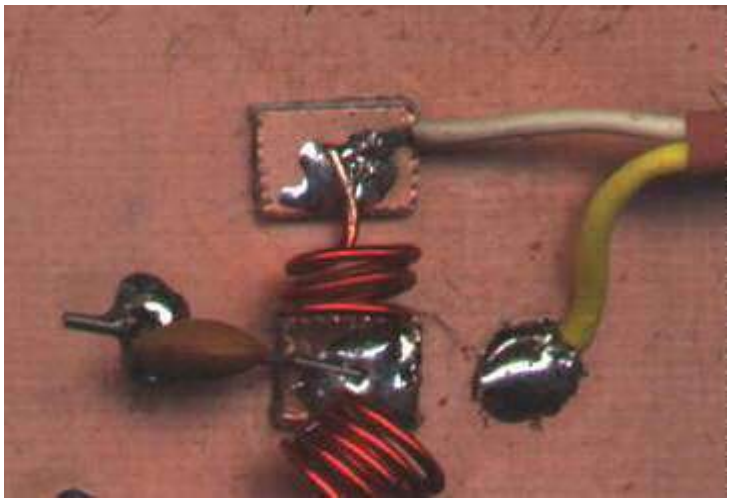

Tie-points are made from 1/4 inch squares of PC board materialglued with "crazy-glue" to a solid ground plane of PC board.

I built all of the transmitters using copper clad PC board as a ground plane and 1/4 inch squares of PC board as tie points. The tie points were cemented to the ground plane using "crazy-glue." This technique made constructing the transmitter go very fast. It only took a drop of glue to secure the tie points. The glue set up in seconds. It made it easy to experiment with different circuits. In a pinch, a tie point could be removed or relocated by prying upward on its side with a screwdriver. I built three transmitters using this style of construction in the past month. All have worked exactly as expected. I used a pair of shears to cut a number of 1/4 inch squares of PC board material. I then used a wide file to remove any burrs created by the shear. This allowed the square of PC board material to lay flat against the PC ground plane. (Crazy-glue is not designed to fill voids. It works best when the surfaces to be glued fit together well) Be careful as you work with "crazy-glue." It is very effective at gluing fingers together.

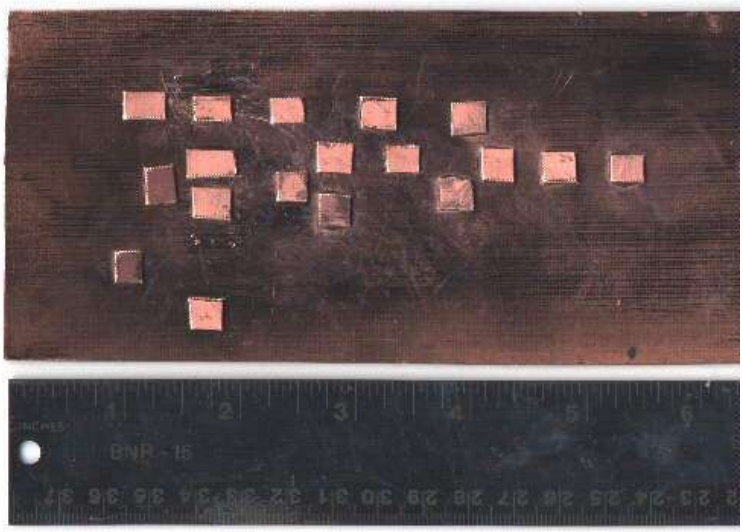

As I had already constructed several low power versions of this transmitter, I first glued squares of PC board material for the first two stages to the PC board ground plane. I then proceeded to add the components. I saved the output stage for last as I had not yet decided upon the interstage and output coupling curcuit design. The design I finally used was a combination of several from the ARRL handbook. I tried to use parts that could be obtained with little difficulty.

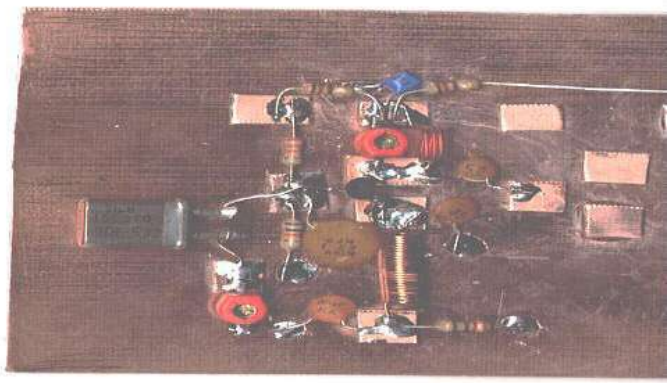

Construction is under way. The oscillator stage was constructed first and tested before proceeding.

Winding Coils

Enamel wire is close-wound on a drill bit to form the coils for this transmitter. It is easier to cut the leads to the coil and strip the enamel from the ends prior to removing the coil from the drillbit used as the form.Winding the Coils

You will need to wind several coils. I kept these as simple as possible. The wire I used was recycled from old transformers. All the coils are wound in a single layer using a drill bit as a winding form. To help you visualize how to form the coils, I have included an illustration showing how the coils are wound..

All of the coils are "close wound" with "air cores." I used a drill bit as a form and then slipped the coil off of the bit after I had cut the free ends to about 1/4 inch. I used a hobby knife to scrape the enamel paint from the ends of the wire before I removed the coil from the drill bit used as a form. This made the coils easy to solder. With any luck, you too will be able to wind your own coils for this project.

Two different gauges of enamel covered wire are used for the coils in this project. If you have wire reclaimed from an old transformer, or from an old television deflection yoke, you can determine its gauge by winding a single layer on a drill bit. You will be able to fit about 46 turns per inch if the wire is 24 gauge. You will be able to fit about 37 turns per inch if the wire is 22 gauge. If you can't find an old transformer with the correct gauge wire to recycle, the best places I have found to buy enamel covered wire are shops which specialize in rewinding electric motors. In a pinch, if you live in the USA, Radio Shack sells "magnet wire" in both 24 and 22 gauge. You will only need a few feet of each gauge wire for this project.

I used the same transistor for both the oscillator and the amplifier stage. It is important that the transistors you use in your transmitter have sufficient gain at 2 meters. The 2N5770 is one of many I could have used. Please note: a 2N3904 would probably work fine as the oscillator (at 48 MHz), it would not work well as the amplifier as it does not work well at 144 MHz.

You will need to use a heat-sink on the output transistor. I used a small press-on style. I gets warm to the touch after transmitting for a few minutes. If it gets very hot, you probably have something mis-tuned or the circuit is oscillating on it own If you follow the layout shown, you probably will not have any difficulty. If you try a different layout, be sure to keep the input and output coils of the various stages away from each other. It is too easy to create an accidental feedback path. If this occurs, the transmitter will be very unstable and almost impossible to tame. If you are experienced with VHF design, you may want to try winding the coils in toriod coil forms. Because toriods are self-shielding, you may be able to try other layouts without as much concern towards stability. Obviously, if you do this, you will have to determine the number of turns needed for the toriods. A grid dip meter would be helpful in that case.

When building the output stage, I realized that I needed to bend the base lead of the output transistor between the emitter and collector in order to install it properly. Although it did not affect performance, it did make soldering the transistor to the PC board pads a bit more difficult. If I build another version of this transmitter, I will lay out the board a bit differently so the transistor will fit better to the pads.

The tune-up of this transmitter is easy. Simply adjust each of the trimmer capacitors for maximum RF output to the antenna. (The trimmer in series with the crystal is the only exception, it is used to trim the transmitter frequency, use a frequency counter to adjust it)

Power output was between 750 milliwats and 900 milliwatts. I will probably add a three terminal voltage regulator so I can vary the output power for any specific hunt. As an experiment, I tried voltages as low as 5 volts. The power output was down to 100 milliwatts but the transmitter stayed on the air! This design works well even as the battery gets weak.

Schematic

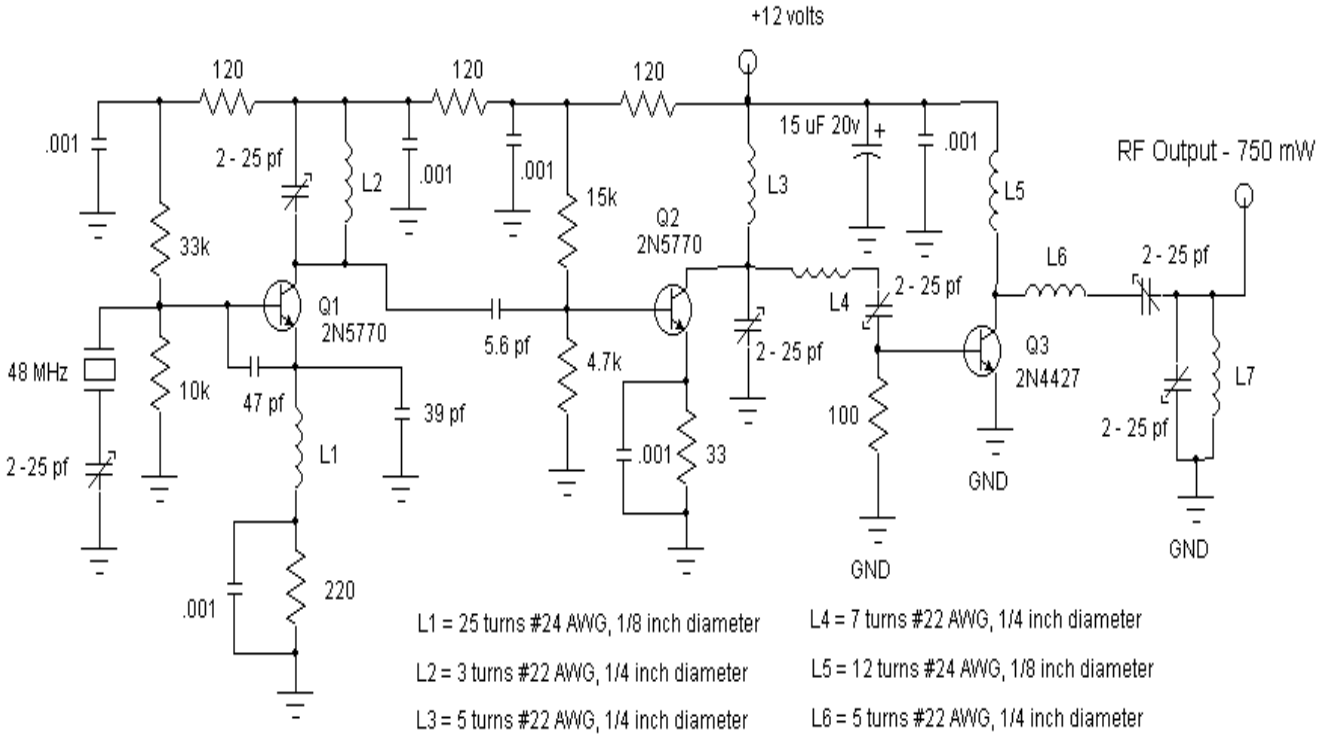

2 Meter - 750 mW FOX TRANSMITTER - 4/98 WB2HOL

SIMPLE ADJUSTABLE PASSIVE ATTENUATOR

Joe Leggio WB2HOL

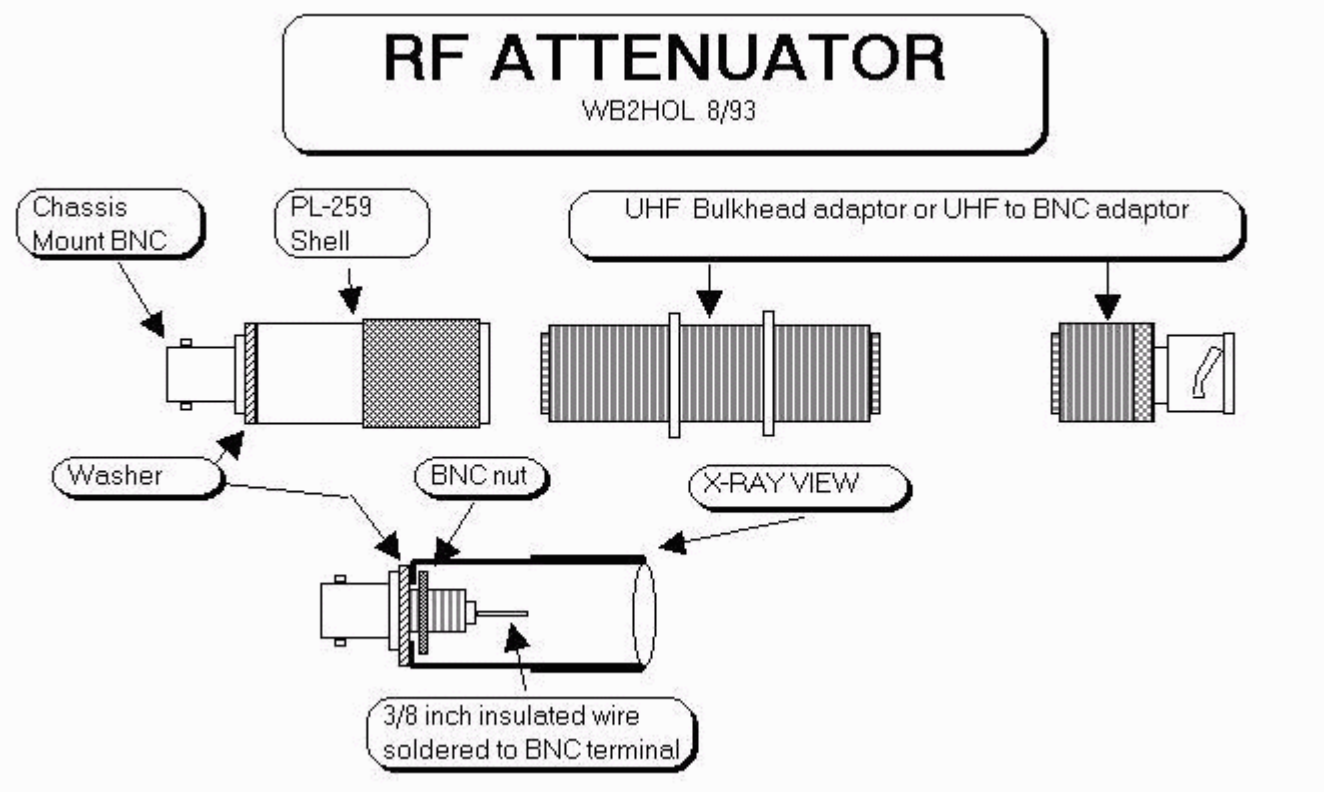

This adjustable passive attenuator works as a "waveguide beyond cutoff." It can be constructed in about ten minutes from parts available locally.

This attenuator was the result of a search for an inexpensive attenuator which could be used on an HT to help beginners equip themselves for a hidden transmitter hunt. The 3/8 inch piece of wire will extend into the center conductor of the bulkhead adaptor forming a small capacitor. The coupling between the two conductors will vary as the PL-259 shell is turned further onto the bulkhead adaptor.

If you are able to find a BNC to UHF adaptor with a long threaded portion, you may use it instead of the bulkhead adaptor.

The maximum attenuation available depends upon the length of the wire soldered to the chassis mount BNC connector. A service monitor measured a loss of up to 36 dB. With the cost so low and construction so simple, many hams have made several with different length wires.

Although 36 dB may sound like a lot of attenuation it will not be suffucient when on most transmitter hunts. This passive attenuator project is aimed at the beginner who is armed with only an HT and is attempting to use the "body-fade" method of Radio Direction Finding. The passive attenuator can be put in-line with the existing rubber-duck antenna and adjusted so the signal no longer is full scale on the S-meter.

Tuning off frequency by 5 or 10 kc, listening for the third harmonic, using a foil wrapped tube as an RF shield around the HT, or even wrapping aluminum foil directly around the HT are all methods which will help to some degree. One or more of these techniques will reduce the signal to where a "S" meter reading peak (or null) gives you a clue to the direction where the transmitter might be found. (If you do wrap aluminum foil around your HT, put some tape over any exposed battery charging contacts. Otherwise, the foil may get a bit warm as it rapidly discharges the battery)

When closer to the fox, more signal will enter the HT through the case than through the antenna. At this point, other methods must be used to locate the fox transmitter. The most effective attenuator in most cases is an "active attenuator." They can offer over 100 dB of attenuation. Plans for one are available here.

Construction Details

This BNC to UHF adapter has a raised knurled portion of the barrel which prevents the PL-259 shell from being tightened completely. (The BNC and insulated wire do not "bottom out" when tightened all the way) You can file that section of the adaptor down and enjoy more range in available attenuation.

Looking in at insulated wire I soldered the wire to the BNC before mounting it in the PL-259 shell. I used a length of wire clipped from a 2 watt resistor. (Use any stiff wire) I then forced a small length of insulation stripped from another piece of wire onto it. By using this method, the insulation does not melt during assembly.

I used a "star" washer. It was just the right size. The washer prevents the BNC connector from falling through the PL-259 shell. The hardest part of the construction is tightening the nut on the BNC connector. I usually wedge a screwdriver in the shell to hold the nut and tighten the BNC from the outside.

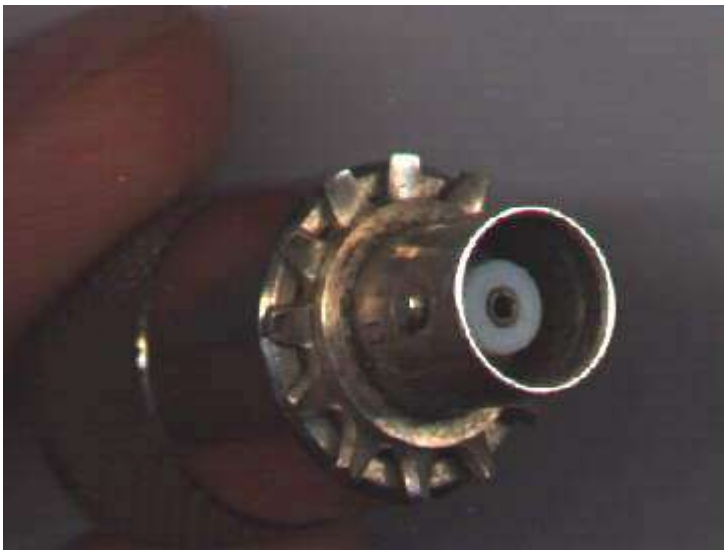

ACTIVE ATTENUATOR

Joe Leggio WB2HOL

How it works

This active attenuator works as a simple mixer. A signal from a 1 MHz oscillator is mixed with the received signal in a 1N914 diode. The 1000 ohm potentiometer adjusts the level of the local oscillator fed to the mixer diode.

It is possible to get over 100 db attenuation using this device. This circuit is a variation of one first described in the November, 1992 issue of QST. That circuit was designed by PA0ZR. It used a L/C tuned 500 KHz oscillator.

I used a 1 MHz crystal oscillator and it made construction even simpler than the original unit.

This attenuator is used by tuning the receiver 1 MHz above or below the frequency of the transmitter. By adjusting the oscillator level fed to the mixer diode, the signal output to the receiver will be attenuated.

Note: You may also tune your reciever 2 MHz above or below the frequency of the transmitter and get even more attenuation. (thanks to VE3EFY for this tip)

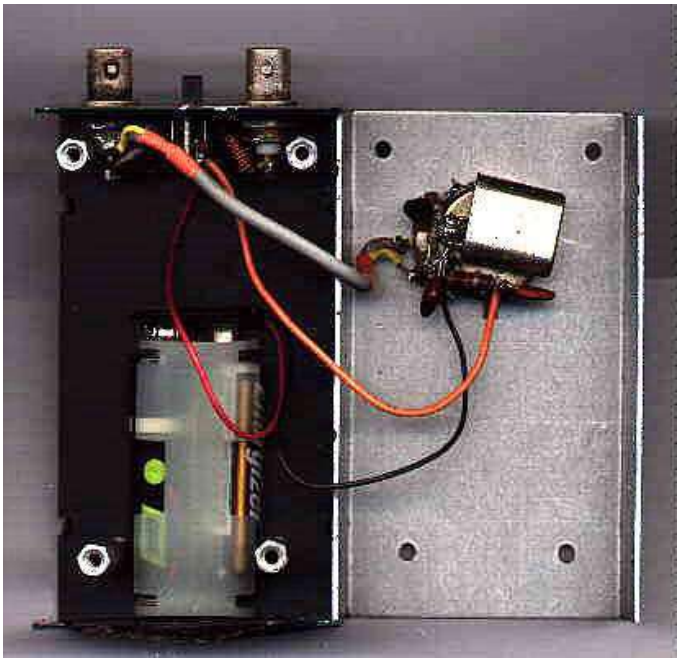

Technical Hints

If you find that this circuit does not oscillate with your crystal you might need to add a small capacitor (anything from 5pf to 25pf) from the gate of the FET to ground. It may also help to reduce the 150pf capicitor connected from the drain to ground to 100pf.

These two capicitors, along with the crystal, provide a 360 degree phase shift from the drain to the gate of the FET. The circuit pictured in the schematic below is a Pierce oscillator and relies upon the gate-to-source capacitance of the FET to form part of its phase shift network. If there is not sufficient stray capacitance to ground from the gate of the FET, you may need to add the additional capicitor. VE3EFY reported that his oscillator would not function below 4.5 volts. He used a 9 volt battery to power his unit. The battery should last a long time, he measured the current drain to be 1.8 mA.

Construction

I built this unit "dead-bug" style. Most of the components were mounted and supported by their own leads on the back of the 1000 ohm potentiometer. The RF Choke connected between the output connector and ground was made by winding about 20 turns of 22 guage wire on a 1/8 inch drill bit. The coil was then slid off of the form and wired in place. If you want to use a commercially available coil, a value of 3.3uh should work just fine. That was the value specified in the original article.

I mounted the 150pf capicitor, the 1N914 diode, and the RF Choke on the inside panel of the attenuator box between the two BNC connectors. I also mounted a slide switch between the BNC connectors so I could conserve the batteries when the unit was not being used on a hunt.

Note: The MPF-102 Field Effect Transistor has an unusual pin-out compared to general purpose transistors. The GATE is not the lead in the center. The pin-out for the MOTOROLA MPF-102 is illustrated below. (The Radio-Shack MPF-102 I used had the same pin-out)

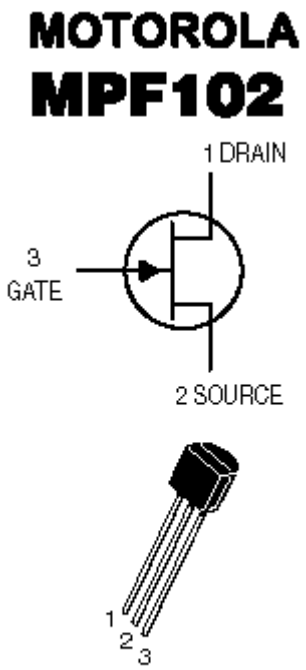

The Schematic

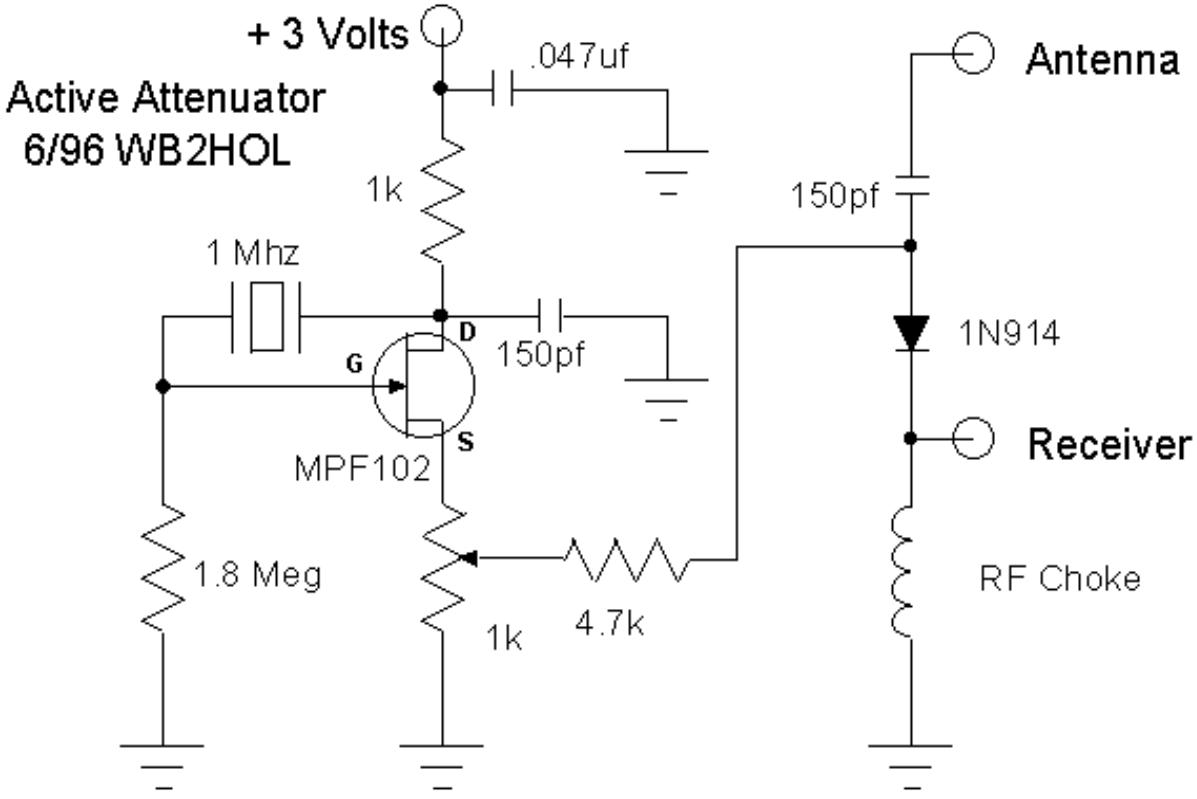

The HANDI-Finder®

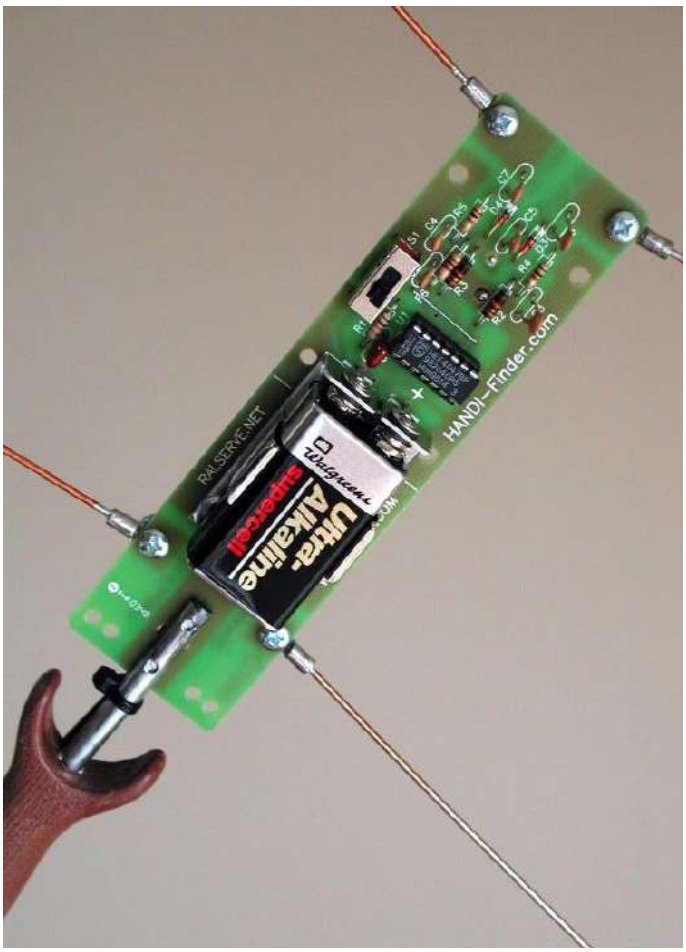

The HANDI-Finder® is a HANdheld DIrection Finder which can be used to localize both AM and FM carrier-based sources using a single connection to the antenna input of an FM receiver tuned to the frequency of interest in the range of 45 to 450 MHz. It has been designed for bare-bone functionality as well as low power consumption, simplicity, and economy!

Because it is both an easy-to-build kit for the beginner and a convenient basis for further experimentation by those with more experience, it makes a great club project! Overall, it is a quick, inexpensive way to implement the concept of direction finding, and provides something relatively compact to keep readily available for locating sources of interference.

Except for adding a handle, fabrication is minimal. Two open-loop antennas are made from coat hanger wire bent into halves of a "bow-tie" shape and mounted directly to the circuit board, as illustrated in the "layout" drawing.

The coax downlead is connected to an FM receiver and detects the carrier regardless of whether the transmission mode is AM or FM. The unit is switched on (UP) and rotated for a null in the audio tone that it adds to the audio coming out the receiver. The signal direction is perpendicular to the plane of the antennas. There is 180-degree ambiguity, but this is not a problem in actual use because multiple "bearings" must be taken anyway in order to establish a "fix" on the location. Once close in, the operator works toward the general sense of the direction, and again the ambiguity is not a problem.

The 3-position switch is moved DOWN to stop the tone but still keeps the antenna activated for monitoring and standby purposes, --or it is moved to the CENTER position to shut off the unit. Refer to the extensive discussion in the manual which describes construction variations, and the concepts behind the design.

"Build the HANDI-Finder" appeared as an article in QST Magazine, May, 1993. All the information in that article and much more is included here! By clicking on the appropriate boxes in this web page, all the drawings and text that come with the kit can be printed out or downloaded from PDF files.

may be obtained by contacting:

Northern Ohio Amateur Radio Development

P. O. Box 271
Brunswick, OH 44212-0271 USA
Tel: 330-225-7373

The HANDI-Finder® Experimenter's Kit

by Bob Leskovec, K8DTS

6th Edition,

The HANDI-Finder® is a HANdheld DIrection Finder which can be used to localize both AM and FM sources using only a single connection to the antenna input of a VHF-FM receiver tuned to the frequency of interest.

The basic HANDI-Finder® when equipped with open-loop wire antennas and a short handle, stores flat and ready-for-use in a briefcase. It works well with just an HT (handy-talky).

The HANDI-Finder® has been designed for low power consumption, simplicity, and economy. The goal was to provide an easy-to-build kit for the beginner and a basis for further experimentation by those with more experience. Overall, it is a quick, inexpensive way to introduce users of FM communications equipment to the principle of direction finding and give them something with which they can help locate sources of malicious interference.

A HANDI-Finder® Experimenter's Kit has been put together to conveniently supply the essential parts necessary to build the control circuit powered by an on-board 9V battery. The user provides the coax, cable connector, and appropriate antennas. By using two open loop antennas made out of coat-hanger wire, the unit can be put into immediate use!

An equally valuable part of the kit is this instruction manual which describes variations in antennas, general construction and detailed discussions of the circuit and components, to encourage experimentation and ideas for improvements.

The HANDI-Finder® first came together in October of 1986, and continued to evolve. A write-up later appeared in May, 1993 QST Magazine, entitled "Build the HANDI-Finder".

TECHNICAL OVERVIEW:

The electronic circuit is based on a design credited to Tom Feierabend SO/CM 03N18 circa 1979 which appeared in a manual published in May, 1980 by Van Field, DCP XVIII, entitled "VHF Radio Direction Finding Manual for Coast Guard Auxiliary Use".

A similar circuit, referred to as the "Double-Ducky" direction finder (DDDF) designed by David Geiser, WA2ANU, is described in July, 1981 QST and reprinted in the 1983 ARRL Antenna Handbook.

The USCG AUX-03N18 version uses an LM555 driving two successive stages of 7404 TTL to provide complementary buffered outputs. Since TTL requires a 5-volt power supply, yet another IC, a 7805 or 78L05 is needed, to regulate the stated 6-30 volt input range.

One problem is that the LM555 does not easily put out a symmetrical square waveform, which is useful in this application. The antenna assembly consists of two vertical ½-wave dipoles (37" long) mounted 8" apart on a boom. This assembly is rather bulky and quite a bit of mechanical fabrication is required.

The QST circuit uses only one IC, the LM567 Phase-Locked-Loop Tone Decoder. This is a complex chip that contains an oscillator and other circuitry, including an output circuit which does put out a symmetrical square wave. However it does not have simultaneous complementary outputs. In the DDDF the single output is connected to the diode switches through a non-polar capacitor, and some adjustment is required to achieve the proper switching level. Data sheet specifications show that the LM567C typically draws 12mA. The antenna assembly consists of two "rubber duckies" mounted 10" apart on a 4.25" X 18.5" ground-plane. While the ground plane requires much less work to fabricate than the USCG-AUX circuit, two "rubber duckies" must be obtained.

The HANDI-Finder® is a good example of integrated simplicity, wherein one simplification contributes to another.

First, it uses a single CD4047B CMOS IC, which contains both an oscillator and a divider flip-flop to automatically provide complementary symmetrical square wave outputs without special adjustments. Only a single resistor and capacitor are needed to set the frequency. While many have not heard of this IC, it continues to be available from standard suppliers like Digi-Key, Mouser, and Jameco.

Second, very little current is used to bias the switching diodes so the total current draw is only 1.7mA at 9V. Good service can therefore be provided by a common alkaline "transistor radio battery" and there is no need for wiring to an external source such as a 12V vehicular supply. This, in turn, eliminates the need for noise filtering. The operation of the circuit is not dependent on battery voltage, so a regulator is not required. Supply voltage for the CD4047 can be anywhere from 3-18 volts. Finally, since all the parts, including the battery are mounted on a single circuit board, the board is designed to also serve as the mounting base for the two open-loop antenna elements easily made out of bent wire. Thus, there are no ground-plane or vertical dipole elements to make, nor "rubber duckies" to buy, and no case to drill, until later if you really want to!

HOW IT WORKS:

All three circuits described above are based on the same principle. An electronic switch alternately connects two antennas to the coax cable downlead going to the antenna input of an FM radio receiver tuned to the frequency of interest. First one antenna is connected, then the other, etc., back and forth with equal intervals. This is done at an audio rate, well within the audio bandpass of the receiver, and usually in the range of 400 to 1500 Hz. A good frequency is 1000Hz.

Of the two antennas, if one is slightly closer to the source, it receives the wave front slightly earlier in time (phase) than the other. There is a phase difference in the signal received by one antenna compared to the other. Since the receiver is being switched between the two antennas, the switching action imposes phase modulation on the incoming signal. This is detected in the FM receiver and is heard at the audio output as a tone equal to the switching frequency. The amplitude of the audio signal corresponds to the deviation, which depends on the physical separation of the two antenna elements, up to ½ wavelength. In other words, if the antennas are farther apart the circuit will impose a higher percentage of modulation or a larger deviation, producing a louder tone, but the modulating frequency will stay the same.

If the antenna is rotated so that the plane of the two elements is perpendicular or broadside to the direction of the signal, both elements receive the signal at the same time (phase) and there is no longer a difference in phase. Hence, the audio tone disappears. This is perceived as a rather sharp null in the audio as the antenna array is rotated into position perpendicular to the direction of the signal.

This type of direction finder has the disadvantage that it exhibits 180-degree ambiguity. However, it has several advantages:

1) It works on a nulling principle rather than a peaking principle. The null is sharp and much easier to detect than the peak from a directional or beam antenna.

2) When you null the superimposed audio, you are not nulling the carrier. This is unlike a conventional loop antenna or cardioid array, which nulls out the carrier. The problem with carrier-null, is that as you get closer to the null, the signal you are trying to hear in order to null out, is getting harder to hear! Also, when you null the superimposed audio, you can still hear the audio coming from the source.

3) Since audio is being nulled, the operator does not have to watch a field-strength meter. He only needs to listen, which is something he can do while driving, riding a bike or walking.

4) Since this method uses phase information, it works well with strong signals, so no attenuator is required. (By comparison, the signal from directional gain antennas must be progressively attenuated to keep the receiver RF within the range of the S-meter.)

REFERENCE INFORMATION:

The HANDI-Finder® is an evolving project which underwent several changes (hopefully for the better) during the early stages. However, the basic circuit remains essentially the same. This manual might be supplied to help you work on an earlier unit, as far back as 1986. If you have a model that does not correspond to the pictorial description in this document, you should be able to identify the components with only minimal tracing of the etched circuit pattern.

Your unit may also have component values that differ from the schematic. If you did not buy a kit, you may have obtained the circuit board and documentation from separate sources that copy and distribute such things and try to make them “public domain”.

The circuit board versions are identified by a prefix letter “A”, a 6-digit date code (YYMMDD), and an optional suffix. (The suffix, if present, indicates very minor changes.) As of this writing, the numbers used are: A861003, A860102, A870122, A890422, A01110, and A031123.

In general, if the board has a date code earlier than the documentation, the component values in the documentation take precedence, provided the integrated circuit type is pin-compatible. If the board has a date code later than the documentation, and/or a different IC pinout, you would do well to send a self-addressed-stamped-envelope (SASE) to the distributor for an update of the layout and parts list. Of course, be sure to furnish the number on your board, so you will be sent the correct information. Please indicate whether the RALTEC® or other trademark is present and we will help you figure it out. Try contacting the author at ral@ralserve.net. (If you have trouble, you can also find the author’s current snail mail and e-mail addresses through the internet Ham-Call database.) For information, try the website handi-finder.com.

CHECKING THE COMPONENTS

If you received this instruction manual as part of a packaged kit along with the circuit board and loose components, unpack all the parts and check the quantities and values against the Component Parts List before you do anything else because some parts have the same value but different mounting positions and lead lengths. Before proceeding with actual construction, it is suggested that you read this manual to see if there are any changes you would rather incorporate right away. Then proceed with "ASSEMBLING THE KIT" which is located at then end of this discussion.

NO PILOT LIGHT:

Considering that a small transistor radio draws about 10mA, it can be seen that the battery will last quite a while if the user remembers to turn it off. Unfortunately a pilot light would be self-defeating, since it would draw 5-10 times the current of the circuit itself!

How many times have you forgotten to turn of your HT? After a while you finally learn to double check. With the HANDI-Finder® it should even be a little easier, because you will probably be disconnecting it from your radio or otherwise storing it at the end of a "DF'ing" session. That action should help remind you to check that the switch is off. Better yet, remove the battery. That's why we have included a top grade battery holder in the bare board version.

ON-OFF SWITCH STATUS INDICATOR:

For models prior to A890422, here are a couple of things to help you tell OFF from ON in the absence of a pilot light. First, the "ON is UP" convention has been followed. This is fairly commonplace on most equipment. Second, you can make a "passive" indicator by using a dot of bright paint, for example, typewriter correction fluid such as "whiteout". Push the slider to the ON position, then paint a small dot on the lower part of the slider that is now exposed. Let the paint dry thoroughly so it doesn't rub off. When you slide the switch to OFF, the painted part should be hidden; when ON, it should be visible. On Model A890422 and later the switch has 3-positions: OFF is in the center, UP is for DF'ing, and DOWN is for straight receiving or Standby. (Notice the design date is embedded in this code as YYMMDD.)

ON-OFF SWITCH MECHANICAL VARIATION:

There are a couple of subminiature slide switches available from "experimenter" sources such as Mouser and Digi-Key, but they differ slightly in the spacing and style of the connector pins. Circuit boards A861003 and A860102 used the CW Industries switch available from Digi-Key as SW103-ND.

Starting with circuit board A870122, the switch pads were made larger and the spacing changed to use the Mouser 10SM007 or 10SP001. The larger pads allow larger holes to be drilled to allow for the wider flat pins. If the switch you have does not go right in, do not force it. Study the problem and carefully enlarge the holes only where necessary. A small modeling file is handy for this purpose. Don't make the holes any larger than necessary, or you will have trouble bridging the gap and getting a good flow joint when soldering. When you do solder it into position, use ample solder and heat it enough so the solder surrounding each terminal flows evenly into a nice even form similar to an "Indian tepee." A890422 and later use a DP3T switch with 6 pins, which will not fit the previous models, but that gave the ability to add the "standby" position which is very useful.

BATTERY HOLDER:

The 9-volt battery holder is fastened at one end by soldering the two terminal tabs that pass through the board. The other end of the frame can best be fastened by using 1/8" diameter "pop-rivets", but you may alternatively try hot-melt glue, epoxy, small screws, etc. However, make sure that whatever you use won't protrude and prevent the battery from seating in the clip.

QUICK HANDLE:

The bottom area of the circuit board contains an area where the handle is attached. The unit can be mounted on either a short handle or directly to a mast, whatever you desire. To get going quickly, take any convenient piece of wood or metal, lay the end against the board, mark the holes, drill them through the handle, and attach with screws. If you use a round handle, you will either have to make a flat cutout along one side, or cut a slot in the end so that the board can slide in. A round handle is best. The most utilitarian handle is described next. .

PAINT-ROLLER HANDLE:

Find an inexpensive paint roller, but one with a handle which is threaded for an extension pole. (Home supply stores sell them typically for $1.39). Study how the handle is attached and determine the best way to remove it or otherwise adapt it so the HANDI-Finder® can be mounted on it.

Most of the handles available these days are plastic, force-fit directly to the metal roller rod. Use a hacksaw and cut off the roller assembly rod so that about 3" of rod is left protruding from the handle. File the rod enough to have a flat area, center punch, then drill two #6 holes to match up with the circuit board, and attach. The flat side should of course go against the board.

Next, shop around for your choice of a wood or metal paint roller extension pole, preferably the type which is made of 3 sections which screw together. You will thus have a very flexible system. You can use the unit with just the handle alone, or screw on up to three lengths of additional "mast". You may even wish to obtain a second extension to have more lengths available. Be aware that some extension handles have different threads in the sections than they have at the roller end. In any event, the pieces are easily stored when disassembled.

UTILITY-DUSTER HANDLE:

There is a homemaker's utility duster on the market called a WEBSTER® which can be found for as little as $4 in discount stores. Unfortunately, only a small percentage of stores seem to stock it. However, this is an amazing value for our purposes because it contains not only a 6-inch detachable handle, but includes a removable, telescoping, extension pole!

The dusting head consists of an 8-inch diameter half-spherical array of bristles embedded in the end of the short handle. This end is easily sawed off to allow for the HANDI-Finder®. The extension pole is about 36" in the collapsed position and 60" when extended.

HANDLE, CAUTIONARY NOTE:

Mount the handle against the component side and put the screws through with the heads on the solder side, to keep a low profile for the coax cable which will come down the solder side

The HANDI-Finder® works best when the first ¼ wavelength of coaxial cable downlead to the receiver is kept vertical or parallel to the center line of the circuit board. (Measure the ¼-wave from the bottom antenna terminal.) If it waves around, it can throw off the bearing. Therefore, when using the unit with a short handle, make sure to hold it straight and high so that the cable hangs straight down. When using the unit with a long handle it is preferable to attach the coax to the mast for the first ¼ wavelength. Use tape, nylon cable ties, etc.

RESISTORS vs. INDUCTORS:

The HANDI-Finder® was designed mainly out of the need to inexpensively provide Radio Amateurs with something they could use to help locate interference on the 2-meter repeaters. But the unit operates over a much wider range of frequencies because the chokes "traditionally" used in such RF circuits have been replaced by resistors.

Inductors are usually used to feed direct current into some point in a circuit where it is desired to allow an alternating current signal to pass without attenuation. At radio frequencies these are called "RF chokes". Circuits which operate in the 150MHz range, for example, usually use small coils with a value of 1.0 to 1.2 microHenries. Using the expression Xc = 2(3.14)fL, where "f" is the frequency in MHz and L is the inductance in microHenries, the corresponding reactance works out to about 1000 Ohms. At 1/3 the frequency, or 50 Mhz, this same inductor would have a reactance of only 333 Ohms. At UHF this inductance would mathematically exhibit a proportionately higher reactance, but other difficulties arise. Certain assumptions about the construction of the coil are no longer valid and the math becomes more complicated. Factors like the "capacitance between turns" and the length of the connecting leads can no longer be ignored. At some frequencies the coil looks like a high impedance, but at others it may look like a short circuit!

Thus, the frequency band over which the circuit can operate is limited by the chokes. Different sets have to be installed to operate over different ranges of frequencies. Normally it is necessary to use chokes because they have a comparatively low resistance at d.c. so there won't be any significant voltage drop. The key word here is "significant".

In this circuit, the switching diodes are biased by current. As long as enough current is supplied to do the job, it doesn't matter if a little voltage drop occurs across the connecting element. The chokes can simply be replaced by 1000 Ohm resistors. The currents are so small that the voltage drop is negligible. Further, for all the complications involved with determining how chokes will act at different frequencies, it is no less risky, and a great deal easier, to assume that a resistor will exhibit the same resistance over a much wider frequency range.

In this circuit R4, R5, and R6 would have "traditionally" been specified as 1.0uH chokes for operation in the 150 MHz region. As you can see, by using 1K resistors, operation at 150 MHz should not be affected, and operation over a wider range of frequencies should now be possible. The value of the resistors is not that critical. Values in the range of 1K-1.3K will do, but make them all the same value. Using carbon-film resistors, we also get some useful inductance, but since the resistance is high and distributed with resistance, these are inherently free of self resonance, and broadband becaue they are low Q.

However, if you wish to experiment with inductors, you can either make them or buy them. According to the USCG AUX article, you can make these with one layer of #28 close wound on a 1 Meg ½-watt carbon composition resistor. Actually there is nothing magical about the 1 Meg value, it is the physical size and shape that is more important. The intention is that the resistance be at least a factor of 100 times greater than the inductive reactance. Therefore any value above 100k is acceptable.

Mouser Electronics has a line of good quality subminiature RF chokes that are quite reasonably priced, roughly $.23 each. Consult their catalog for the "43LQ" series. The 1uH value is part number 43LQ106. Keep in mind they probably will not fit on the HANDI-Finder circuit board supplied with the kit.

WIDEBAND OPERATION:

The HANDI-Finder® should work over a wider range when resistors are used in place of inductors, but there will still be problems with resonances (series LC) and anti-resonances (parallel LC) for any given set of antennas. However, ignoring those effects, let us discuss the effect of antenna spacing. Remember, you want the vertical members of the two antennas as far apart as practical to get maximum modulation.

This will make it easier to tune for a null.

For a given set of antennas, the upper frequency limit should be that which corresponds to a ½ wavelength equal to the widest spacing of the vertical members.

If the usual wavelength formula is multiplied by 12 inches/ft, a new "constant" factor is obtained: dividing 5616 by the frequency in MHz will give the ½ wavelength in inches. For the open-loop antennas you will be instructed to make elsewhere in this manual, the spacing between opposing vertical sections is typically 17.5 inches. Turning our formula around, and dividing 5616 by 17.5 gives 321 MHz, which is also the frequency at which maximum deviation would be available. Some have reported operation to include the 70cm Ham Band.

Moving to 1/10 that frequency or 32 MHz, only 1/10 the modulation would be available, but the units should still function. So it would appear that operation over a 10:1 range might be possible.

COUPLING CAPACITORS:

At the lowest limit, it is important that the coupling capacitors have a reactance of 50 Ohms or less so as not to attenuate the signal by more than 3dB. If we choose that limit to be 27MHz the value of capacitance having 50-Ohm reactance is 117pF. Values of .001uF, or 1000pf will be one tenth that or 5 Ohms, and work just fine.

SCREW TERMINALS:

Antenna connections to the board are made using screw terminals. On early units, these are formed by installing a clip-type "tinnerman nut" which is slipped onto the circuit board edge at each designated point, and then threading in a 6-32 x 3/8" or ½" binder head machine screw. Only four are needed for any given configuration. Later units use regular hex nuts, serrated lock washers, and flat washers against the board to keep the lock washers from tearing up the copper foil.

When fastening small diameter or stranded wires to these, it is suggested that you first install crimp-on spade lugs or ring lugs on the end of the wire. If you must wrap the wire around the screw, do it under a washer and wrap it in the direction that the screw tightens (clockwise).

BE CAREFUL NOT TO OVERTIGHTEN. If you experiment a lot, the tinnerman nuts will strip and wear out. If you need to have things very tight, you can use 6-32 screws with regular hex nuts. However, do not put serrated lock washers against the surface of the board since they really dig in and cause problems. It is better to use a slightly longer screw with flat washers to protect the surfaces. If you are tempted to just solder directly to the board, don't do it! The heavy heat may cause the foil to delaminate. Further, if the antennas are bumped, the foil may be pulled off the board. If you want to have some sort of "rounded off" nut on the thread end, inquire about "acorn nuts" in the screw specialty section of most hardware stores.

ANTENNAS:

The HANDI-Finder® is quite versatile in the way it can be used with different kinds of antennas. First of all, you can get it running immediately without extensive fabrication because two simple wire antennas can be attached directly at the circuit board. For 150 MHz, take two EQUAL lengths of stiff wire about 19 to 20 inches long and bend each one into a neat square "U" shape. The bottom of the "U" should be about 6". Form the ends into a hook and fasten them to the screw terminals on the circuit board. Looking at the component side of the board, you will see there are three terminals along the left side and three along the right side. Fasten one end of one antenna to the very top terminal on the right side. Fasten the other end of that same antenna to very bottom terminal on the same side. Then repeat this procedure for the left side.

Note that the bottom terminals are merely mounting points. They are electrically isolated. On some board designs there are circuit pads to allow installation of a grounding jumper. DO NOT INSTALL THIS JUMPER! It is desired that the antennas be open loops. If you ground the bottom of the loop, you will create a closed loop that will cause a carrier null in the direction of the signal. This is not desirable. On later circuit boards provisions for grounding was eliminated to avoid confusion.

The wire you use should be thick enough to provide desired rigidity, but thin enough to allow fastening under the screw terminals. If it is too thick, you might be better to first solder on some spade lugs or similar terminations. Of course, it helps if the wire is a good conductor, but steel coat-hanger wire or welding rod will work satisfactorily. A better choice would be brass rod or brazing rod, between 1/16" to 3/32" thick. If you wish, you can make the loops even larger.

Note the ACTIVE ELEMENT of each antenna in this application is the vertical part of the open loop supported in space by the horizontal part. A greater separation of the vertical elements will produce a larger deviation and more audio. However, the longer a vertical element is, the more signal it will receive, provided there isn't some gross impedance mismatch. This shows up as more carrier, better quieting, or a stronger S-meter reading. Of course, when that vertical section is maintained in space by an unshielded horizontal section, determining the resonance or tuning gets very complicated. Also consider that the horizontal part does receive some signal, and this degrades the intended signal. Therefor, larger loops may work worse. Feel free to experiment; that is the whole object of this project!

Alternatively, the circuit board is designed to accommodate connections by coax cable to other kinds of antenna arrays. Just below the top antenna mounting screw on each side, is a ground screw. This is not used with the open loop antennas, but is used for the coax shield. Thus, if you do wish to make a "Double-Ducky" direction finder as described in the ARRL Antenna Handbook, you can connect the two equal-length coax cables to the HANDI-Finder® circuit board. Similarly, you can fabricate the dual half-wave vertical dipole array described in the Coast Guard Auxiliary Manual and run it with the HANDI-Finder® board.

One suggestion for a more extravagant system is to position two multi-element Yagi antennas with vertical orientation at opposite ends of a horizontal boom. Support the boom at its center on a vertical mast so that it can be rotated. Use equal lengths of coax from each beam and connect them to the HANDI-Finder® board which should be mounted in a protective enclosure at the center of the boom. The beams will give greater forward gain and reduce the 180-degree ambiguity. It is just a little hard to use with the mobile!

Since the antennas have no path to ground, there is no need for DC blocking capacitors. On A890422, the positions of C6 and C7 are jumpered out with board foils. If an application is encountered which requires DC blocking, slit each foil at each end carefully with a sharp hobby knife, then heat the center section with a soldering iron and peel it off the board with the knife. Holes are provided to install the capacitors. Refer to parts list. Later boards don't have this connection, and come with capacitors. Check the board. If you don't have the capacitors, then be sure to insert some jumpers.

NO ENCLOSURE

As you can now appreciate from these discussions, there are many ways you may end up using the circuit board and enclose it accordingly.

In its simplest "quick & dirty" constructed form, the unit can be put to immediate use. The long narrow profile was purposely selected to minimize wind resistance for the benefit of a vehicle operator who may be trying to hold on to the unit mounted on a narrow mast protruding through the drivers window.

You will discover that an enclosure will only increase the drag and may not be worth the effort! With only minimal care, these units have rattled around in many trunks and back seats without anything getting shorted out. The battery in one of the demo lasted over three years, even though it had been left "ON" for several weekends during that time!

However, you might want to consider that numerous sharp edges from component leads could snag cloth upholstery, or scratch leather and vinyl.

Where you really need to, the circuit board can be mounted to surfaces on standoffs using 6-32 screws through existing holes.

MOUNTING IN AN ENCLOSURE:

Model A890422 and later are designed so that it can be more easily modified to fit into a case. This is somewhat irreversible since it requires that the bottom part of the board be cut off, unless you can find a really long, flat plastic case. Some have come and gone off the market, so it is there is no particular model case that can be recommended. It is strongly suggested that the circuit be completely built up on the existing board and thoroughly checked out. After you are familiar with the unit's operation, you may NOT wish to put it in a case.

TRYING IT OUT:

It is best to start off with a "test" situation where you know the location of the source, and experiment with "getting a feel" for the null. The null itself is fairly sharp, but it does not always manifest itself as a total null in the audio tone. Sometimes, you will observe instead, a jump in tone one octave up or down. (Refer to the ARRL Antenna Handbook article for more discussion.)

At other times, you may hear a "buzz" or a fast "twiddle". This is usually due to multipath, so moving just a few feet may help clear up the null. Also, if there is a strong transmitter in the area, such as a 1kw paging system, 3 or 4 MHz away, you may experience more "de-sense" than normal when the HANDI-Finder® is switched on in the DF-ing mode. The sharp edges of the diode switching waveform cause it to be rich in harmonics, all of which modulate that strong RF source and cause it to broaden its normal spectrum at the input of your receiver. (These are the same problems that bother the more complex "DOPSCANs" that switch 4 or 8 antennas.)

Using the unit with a synthesized scanner or one of the new extended-coverage HT's will not only allow you to work in the Ham bands, but other frequencies as well. The prototypes were tried over the range of 49 MHz to 450 MHz and worked well even though the 450 MHz test was well above the suspected ½-wave limit frequency of 321 MHz calculated previously. As you get considerably above or below the 150 MHz design frequency you may find that your unit has a "null" point which is no longer perpendicular to the plane of the circuit board. However this also sometimes occurs due to multi-path in high reflection areas, especially indoors. (Don't try to do anything meaningful indoors!) In any event, don't jump to conclusions. Take several measurements at different locations a few feet apart, and consider your findings carefully before deciding whether the problem is due to the location or a characteristic of the way you have set up your particular unit.

When driving through neighborhoods it is interesting to scan the bands and see what sort of frequencies are in use. For example, one of our experimenters found several homes with 49 MHz "baby monitor" intercoms. You may also hear cordless phones near that frequency.

Another application is to drive around and look for Cable-TV leakage on 145.250 MHz. You will quite easily pinpoint hotspots on poles and at the lawn boxes used for underground installations.

Perhaps you can promote some Ham Radio good will by helping local law enforcement officials find mobiles with "stuck mikes." Such a "free" service can help educate personnel about Amateur Radio and keep you from getting "pulled over" when you are out hunting.

If you are an avid radio-controlled model airplane enthusiast, and have had a plane get away from you and get lost in the woods, this could save you time. Put a low-power transmitter and "crash switch" in your plane. Then if it gets away or crashes in the woods, you can track it down!

Some areas have rather extensive park reserves or other situations where naturalists “tag” wild animals with radio transmitters to track their migration.

They are quite interested in reports on these animals, and will give out the frequencies to individuals with a genuine interest in helping. Invite your local naturalist to speak to your club and demonstrate how you can help. But keep in mind they DO NOT put radio collars on deer and turkey just to make it easy for game hunters to track and kill them!

CHECKING DIRECTION CALIBRATION:

A round handle is best, because it allows a calibration mark at any angle. You would do well to try your unit outdoors in an open field by walking in a circle around a central source. A person keying an HT held up at arm’s reach is easiest, but caution him to hold still. The null should always occur perpendicular to the plane of the antennas, but your radio or other factors may be introducing phase shift. If the error is totally consistent as you walk around the circle, then you will want to mark the true direction on the handle.

If such is the case, expect this calibration to change at different RF frequencies, or if you change the CD4047 oscillator frequency. If the error is not consistent, and changes as you walk around the source, you are experiencing (multi-path) reflections from the surroundings. Try reducing the power of the source. For example, if a 100 mW HT is too strong, remove the antenna and substitute a 51 Ohm, 2 watt carbon resistor. If you still get erratic readings you will have to go to another location.

Once you have established the calibration mark, fasten the cable along the side of the handle or mast so it runs over the mark. That way you can feel it in the dark. Now you are ready to do some serious DF-ing or Fox Hunting.

Notes:

1. The abbreviation “uF” is used throughout this text to denote “micro-Farads”.

2. Bob Leskovec, K8DTS, has been licensed since 1957 and promises not to change his call letters so you can always locate his mailing address via the Ham database!

3. A less detailed description of this project appeared as “Build the HANDI-Finder!” QST Magazine, May, 1993.

4. HANDI-Finder® and RALTEC® are Registered Trademarks.

The HANDI-Finder® Experimenter’s Kit

ASSEMBLING THE KIT: (Please read the whole manual before assembling)

1) Check the circuit board and make sure all the holes are drilled and it is otherwise finished and ready to accept the parts.

2) Having read the discussions about the ON/OFF switch, locate that item and make sure that the type you have does indeed fit the hole pattern on the circuit board. Do not install it yet.

3) Locate the integrated circuit socket, carefully straighten the pins, and insert it onto the component side of the board with the proper orientation. You may have to study the IC socket to determine how its design denotes the position of pin 1. Some sockets have a beveled corner at pin 1. Others have an indentation at the end between pins 1 & 14, some are not clear!

Note, for packing purposes, the IC may have been installed in the socket. It is NOT necessary to remove it, unless you can see it has been inserted in the socket incorrectly. The IC will incur much less handling and there will be less chance of damaging it if you just leave it in place when you solder the socket onto the board. Make sure the socket is properly oriented and seated flat against the board when you do the final soldering.

4) In the following order, mount the diodes, resistors, and capacitors, starting with the smallest parts first. If you have only one capacitor with long leads, SAVE that, and use the precut ones first. There is one location that needs the capacitor to be formed with longer leads.

5) Examine the ON/OFF switch and make sure that the terminals are clean and not tarnished, before soldering. If needed, carefully scrape them with a small hobby blade. Then mount the switch and solder it in position. The 6-pin switch also requires that the two diagonal frame tabs be soldered as well. NOTE: if you later use a solvent to remove flux from the board, be especially careful not to get any into the switch. Some literally melt. Some have four frame mounting pins. Carefully clip off only the two diagonal pins that prevent insertion.

6) Refer back to the discussion about the battery holder and mount that item.

7) Prepare the end of a length of RG-58/U or the miniature RG-174/U and attach it to the board. Note that the hole for the shield should be 1/8" so that the shield can fit through. The excess braid is cut off so that only about 3/16" lies flat against the circuit foil where it is soldered down. Install a nylon cable tie through the holes provided in the circuit board. Pull it tight so that it anchors the coax securely against the board to prevent flexing at the cable end. This is known as a "strain relief." Clip off the excess. Depending on what type of handle you use, you will need to figure out how to route the coax so that it crosses to the center and comes down the handle equidistant from the two antennas for best symmetry. Later circuit board layouts have the coax routed down the centerline in the solder side of the board on the side opposite where the handles should be attached.

8) Slide on "tinnerman" nuts (if such nuts have been supplied) at the four points used to attach the open loop antennas. These are the two top-most and two bottom-most locations.

9) Fashion two open-loop antennas according to the instructions described previously and attach them to the board using the 6-32 x ½" screw hardware. That's it! Refer to the section "TRYING IT OUT".

The manual includes discussions of several other options and variations in the way the unit can be wired.

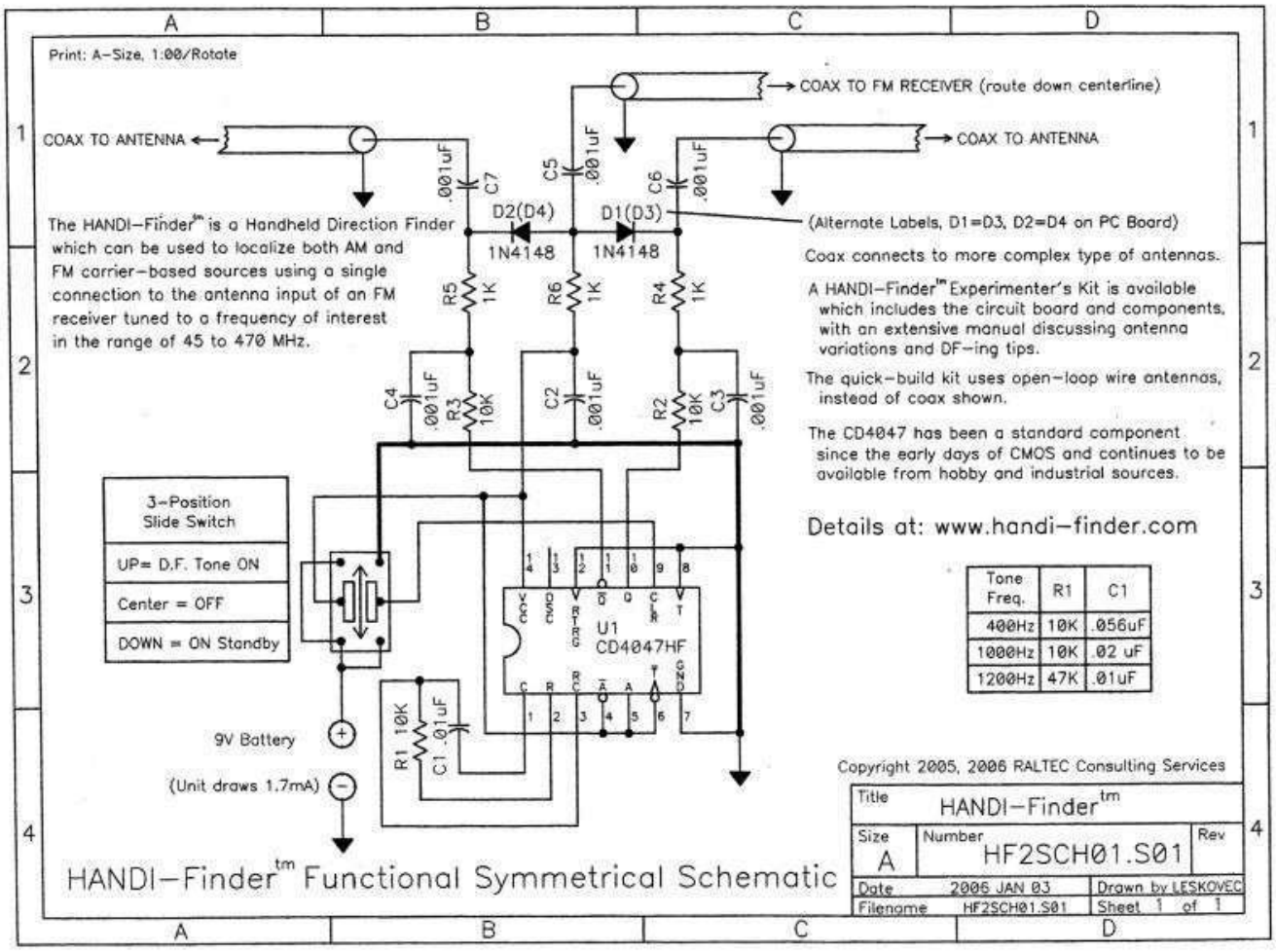
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COAX TO FM RECEIVER (route down centerline)
COAX TO ANTENNA
COAX TO ANTENNA
The HANDI-Finder™ is a Handheld Direction Finder which can be used to localize both AM and FM carrier-based sources using a single connection to the antenna input of an FM receiver tuned to a frequency of interest in the range of 45 to 470 MHz.
D2(D4)
D1(D3)
1N4148
1N4148
(Alternate Labels, D1=D3, D2=D4 on PC Board)
Coax connects to more complex type of antennas.
A HANDI-Finder™ Experimenter's Kit is available which includes the circuit board and components, with an extensive manual discussing antenna variations and DF-ing tips.
The quick-build kit uses open-loop wire antennas, instead of coax shown.
The CD4047 has been a standard component since the early days of CMOS and continues to be available from hobby and industrial sources.
Details at: www.handi-finder.com
3-Position Slide Switch
UP= D.F. Tone ON
Center = OFF
DOWN = ON Standby
U1 CD4047HF
9V Battery
(Unit draws 1.7mA)
Tone Freq. | R1 | C1
400Hz | 10K | .056uF
1000Hz | 10K | .02 uF
1200Hz | 47K | .01uF
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Title HANDI-Finder™
Size A
Number HF2SCH01.S01
Rev
Date 2006 JAN 03
Drawn by LESKOVEC
Filename HF2SCH01.S01
Sheet 1 of 1
HANDI-Finder™ Functional Symmetrical Schematic

Sense The Right Way To Go With The HANDI-Finder®

by Joe Moell KØOV
ARRL Technical Advisor

The following was submitted to the Technical Correspondence column in QST Magazine for October 1993 in response to the HANDI-Finder construction project in a previous QST issue. The original HANDI-Finder was created by Bob Leskovec K8DTS. It is documented at the HANDI-Finder Web site. A kit of parts is sold by the North Olmsted Amateur Radio Depot. "Clones" of the bow-tie bidirectional HANDI-Finder are being or have been offered for sale by some other companies and individuals. The KØOV unidirectional pattern modification and antenna improvements described below are applicable to all of these bow-tie sets.

Hats off to QST for its recent promotion of foxhunting and radio direction finding (RDF) activities. Simple RDF gear in the hands of a large number of hams will provide important preparedness for emergency searches and malicious interference location.

The HANDI-Finder® by K8DTS[1] holds promise for this purpose, but its bidirectional peaks and nulls limit it to short range "sniffing" in situations where time-to-locate is of little concern. Its 180-degree ambiguity makes it unsuitable for long-range or high-speed work.

If you were shopping for a compass to use on a hike, what would you think of one with an indicator that points either north or south, with no way of determining which? You probably wouldn't buy it, even if it was priced much lower than other compasses in the store. It's the same way with foxhunt equipment.

A bidirectional RDF set such as the basic HANDI-Finder presents a 50-50 chance of leading you away from the fox instead of toward it. So it's worthwhile only for occasions when boundaries are small, such as on-foot foxhunts in a small park. Fortunately, it's a simple matter to incorporate a second mode into your HANDI-Finder to resolve the ambiguity.

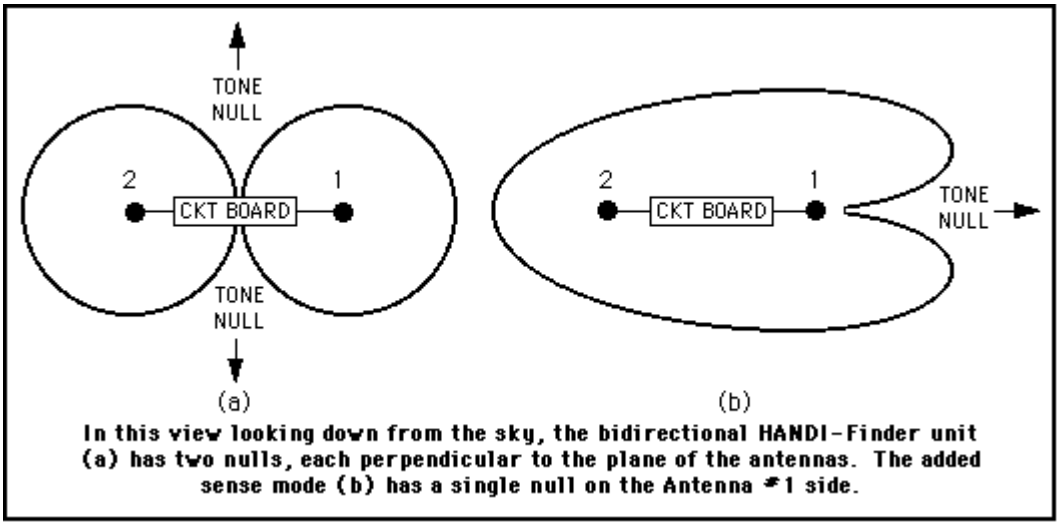

In this view looking down from the sky, the bidirectional HANDI-Finder unit (a) has two nulls, each perpendicular to the plane of the antennas. The added sense mode (b) has a single null on the Antenna #1 side.

Add a Sense Mode

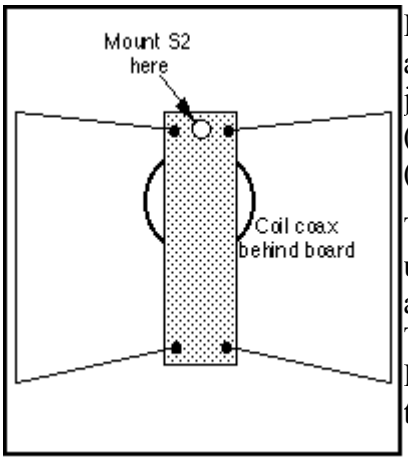

By adding time delay to the signal from one of the two HANDI-Finder antennas, the peak/null tone pattern of the unit is modified. If you add just the right amount of delay, the pattern changes from bidirectional (figure-8) with nulls perpendicular to the antenna plane to cardioid (heart-shaped) with a single null off one end.

This two-pattern technique forms the basis of the Handy Tracker, a RDF unit that I designed in 1989.[2] The cardioid pattern concept came from an unpublished 1980 project by Russ Andrews K6BMG. The Handy Tracker sense mode scheme can be applied to the K8DTS HANDI-Finder with the simple addition of a switch and a length of coaxial cable to provide delay.

As K8DTS points out, the bidirectional HANDI-Finder indication is independent of frequency. This is not true of the added sense mode. A delay line of a given length produces a precise cardioid pattern at only one frequency. A useful pattern is obtained over a frequency range of several per cent, however, so one delay line will provide ambiguity resolution over one full VHF amateur band.

Modification Details

The modification adds a DPDT micro-mini toggle switch without center-off (Radio Shack 275-626) and a precisely trimmed coax delay line. Mount the switch in the etch-free area of the circuit board between the two antennas.

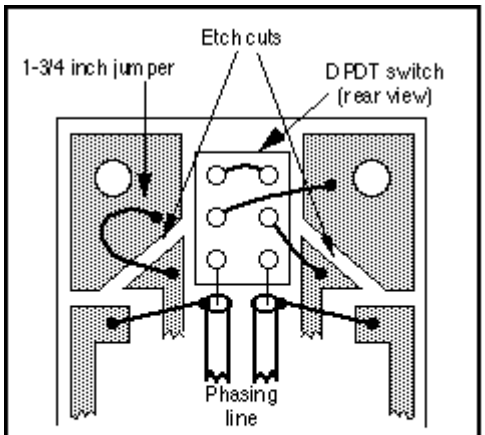

Rear view of modified board showing trace cuts and added switch wiring. Note loop of wire on left; this compensates for switch-lead lengths that would otherwise unbalance the system.

On the rear side, cut the traces where C6 and C7 connect to the antenna terminals per the drawing. On the Antenna #2 side, wire the antenna connection through the switch per the schematic. On the Antenna #1 side, install an unshielded wire jumper 1-3/4 inches long, to compensate for the added switch wiring on the Antenna #2 side. This jumper is important, since one inch of difference in feed length to one antenna will cause 6.5 degrees bearing error in the figure-8 mode.

Cut the delay line according to the following formula:

$$l = (11808-df)v/f$$

where l = length of coax in inches, v = velocity factor of coax as a fraction, f = frequency in MHz, and d = spacing between the vertical antennas in inches. For example, assume we are adding the sense mode to a HANDI-Finder with "bow tie" open loop antennas for two meters. The vertical sections of the two loops are 15 inches apart. We are using RG-174 coax, which has velocity factor of 65.9 per cent. Computed for the center of the band (146 MHz), delay line length is

$$(11808-(15)(146))(0.659)/146 = 43.4 \text{ inches.}$$

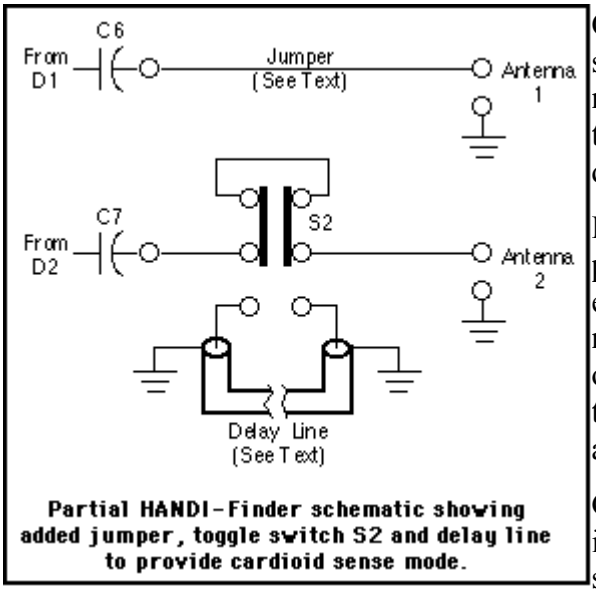

Partial HANDI-Finder schematic showing added jumper, toggle switch S2 and delay line to provide cardioid sense mode.

Coil up the coax and lace it to the board. Miniature coax such as RG-174 is best for the delay line because it makes a compact coil. Whatever coax you use, make sure to determine its characteristic velocity factor. It is different for foam and non-foam type cables.

Because of environmental multipath and stray coupling, a perfect cardioid tone pattern may not be achieved. The end null may not be complete or there may be a double null on one end. This doesn't matter, because the purpose of the sense mode is merely to determine which of the two figure-8 nulls to follow. There is plenty of peak/null amplitude difference for that.

Getting RDF bearings with the modified HANDI-Finder is a simple two-step process. In a clear location, with S2 set for normal (bidirectional) mode, listen for the tone nulls in the receiver to obtain a line of bearing as described by K8DTS. Next, switch S2 to the cardioid pattern mode and turn the unit 90 degrees so that one end points along your line of bearing. Note the tone level. Rotate the unit 180 degrees and note the tone level again. It should be distinctly different. The lower amplitude tone will occur when Antenna #1 is closest to the signal source. To help you remember, mark the peak/null directions on the board.

Other Observations

In the K8DTS QST article photo, the receiver feedline passes over the open end of one antenna loop. This unbalances the antenna pair and can cause major bearing errors on two meters and above. The coax should be routed away from the loop.

The horizontal sections of the bow tie antennas severely degrade RDF performance. Properly spaced coax-fed vertical dipoles are far better for serious use with this type of RDF set. Such an antenna set is easy to make with inexpensive whip antennas and PVC plumbing parts.

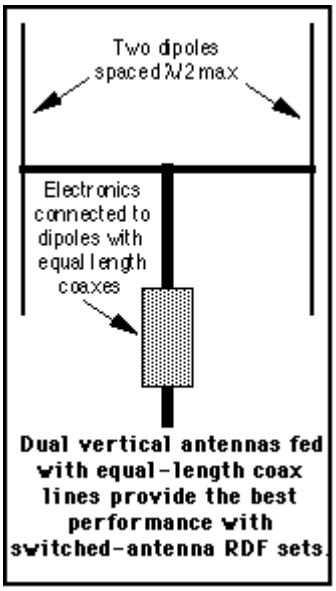

Dual vertical antennas fed with equal-length coax lines provide the best performance with switched-antenna RDF sets.

The two antennas should be spaced as widely as possible for maximum audible df tone, but spacing must not exceed one half free-space wavelength at the receiving frequency. Approximately 24 inch spacing is practical for both two meters and 125 cm. Coax cables from the HANDI-Finder board to each of the two vertical dipoles must be exactly equal in length.

Wide antenna spacing gives better performance, but it may increase the received tone deviation to the point that the receiver "squelches out." If this occurs, reduce the tone oscillator frequency to 400 Hz or lower by increasing the value of R1 and/or C1.

Footnotes:

[1] Leskovec, "Build the HANDI-Finder!" QST, May 1993, pp 35-38.

[2] Moell, "Homing In," 73 Amateur Radio, September 1989, pp 58-59 and November 1989, pp 52-53.

The spelling and form of HANDI-Finder constitutes a trademark registered to K8DTS.

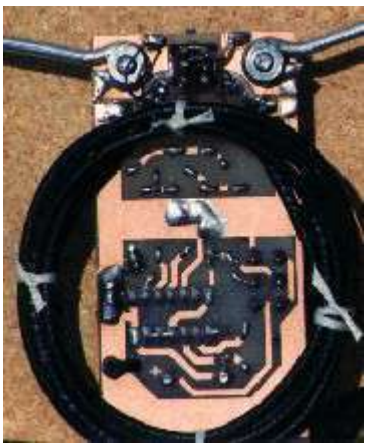

The added coax delay line is tied to the rear of the circuit board.

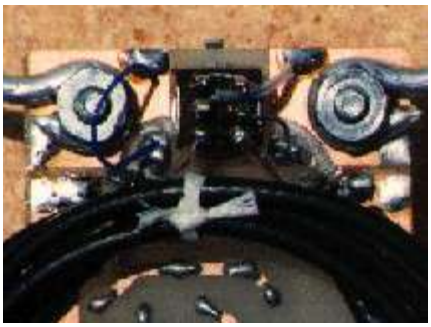

Close-up of top area of board, showing added DPST switch and wire jumper to provide equal signal paths in bidirectional mode.

Frequently Asked Questions and Answers About T-hunting and RDF

by Joe Moell KØOV

Over 98% of reader response to my articles is via e-mail. The 80-20 rule (or is it 90-10?) definitely applies, because the vast majority of questions are the same. Here they are, along with the answers. Now maybe I can spend more time building and T-hunting!

- Part 1 - Questions about Dopplers (scroll down)
- Part 2 - Questions about Other RDF Equipment
- Part 3 - Questions About Transmitters and and Covert Tracking
- Part 4 - Miscellaneous Questions

Part 1 - Questions About Dopplers

Q: What is a Doppler? What is a Roanoke Doppler?

A: Nineteenth Century physicist Christian Doppler is credited with creating equations that describe the apparent frequency shifts that result from the relative motion of the sender and receiver of a wave. The Doppler principle is now used for many applications, including dating the universe and catching highway speeders. In radio direction finding, a simulated rotating antenna can be used to determine the direction of an incoming signal using this principle.

When transmitter hunters speak of Dopplers, they usually mean a device with an electronically rotating array of 3 to 8 vertically oriented whips or dipoles and a circular display of 8 to 50 light-emitting diodes. These Doppler add-ons work with VHF and UHF narrowband FM receivers. There are other RDF devices with similar antenna sets and displays that are used with AM receivers (e.g Watson-Watt), but these are not Doppler sets.

The Roanoke Doppler was first published in my book "TRANSMITTER HUNTING---Radio Direction Finding Simplified" (THRDFS), along with an extensive writeup of the theory of operation. The Roanoke Doppler has become the most popular Doppler RDF home construction project. Originated by Chuck Tavaris N4FQ, then improved and documented by Joe Moell KØOV and Thomas Curlee WB6UZZ, the design was named by KØOV to honor the transmitter hunters of Roanoke, Virginia, where N4FQ tested his prototype. This Homing In site is the official support site of the Roanoke Doppler project:

- Three suppliers of circuit boards and parts for the Roanoke Doppler are listed on the Hardware Sources page.
- Updates to the THRDFS documentation of the Roanoke Doppler are in the THRDFS Update page.
- An improved multiband antenna switcher is fully described in the Wide-Range Antenna Array page.

There are other home-construction Doppler projects, but only the ones built from the design in THRDFS and this Web site are Roanoke Dopplers.

Q: I can't locate any 75492 ICs for the Roanoke Doppler display. What shall I do?

A: An improved 16-LED display circuit is in the THRDFS Update page at this site. The 75492 ICs have been eliminated. If you already have a circuit board for this project, you can still use it.

Q: The WA2EBY Doppler circuit in a recent ham magazine looks very much like the Roanoke Doppler. Is it an improvement?

A: That author has utilized many of the design attributes of the Roanoke Doppler, but his unit has no new functions or operating features.

Q: The WA2EBY article states that ECG-555 PIN diodes give poor UHF performance and that ordinary 1N4148 diodes are just as good for a Doppler antenna. Is that true?

A: First, The ECG-555 is an older PIN diode, with unspecified RF series resistance. Newer PIN diode types listed on the Hardware Sources page of this site should perform better. Second, the switcher circuit of the WA2EBY Doppler is not optimized for PIN diodes. For best isolation, RF diodes should be reverse-biased when OFF, not just at zero DC current. That's because the series capacitance of PIN diodes drops dramatically as OFF (reverse) bias goes from 0 to 4 volts. (Examples: HP 5082-3080 goes from 1.1 to 0.4 pF. MPN3404 goes from 2.5 to 1.4 pF.) The lower the capacitance, the less RF gets through (better isolation). The Wide-Range Roanoke Antenna at this Homing In site reverse-biases the OFF diodes, which is an important reason why it performs better than the original Roanoke antenna. The WA2EBY Doppler circuit does not reverse-bias the OFF diodes. I believe that the results of the WA2EBY's loss/isolation tests would have been quite different if it did.

I discuss PIN versus switching/rectifier diodes for Dopplers on page 128 of THRDFS. PIN diodes provide significantly less insertion loss when ON, if biased properly, meaning that a PIN switcher will generally have less loss. More importantly, stray RF rectification is much less likely with PINs. I encountered significant cross-modulation problems using a Doppler with non-PINs, especially when driving near strong RF sources. WA2EBY did not test for cross-modulation when he evaluated diodes. I would welcome input from anyone who has done such tests.

Q: Will the Roanoke Doppler find aircraft Emergency Locator Transmitters (ELTs)?

A: The Roanoke and other ring-antenna Doppler RDF sets can readily track signals in the 120 and 240 MHz aircraft bands, provided that a suitable receiver is used. The Doppler modulation produced by switched whips in a Doppler array is FM, not AM. Therefore, the receiver must have an FM detector to properly process it. I use a venerable Regency MX-7000 scanner for this purpose. Just tune it to the proper frequency (121.5 or 243.0 MHz for ELTs, 121.6 MHz for tests) and set the receiver to the Narrowband FM mode.

The new Wide-Range Antenna Array should be used with the Roanoke Doppler processor for greatest sensitivity and best rejection of multipath distortion. Whips for 121.5 MHz should be 22 inches long, spaced in a square pattern 21 inches on each side. Whip lengths and spacings should be halved for 243.0 MHz operation. The Doppler is intended for vehicle or fixed station use only, not for on-foot operation.

Some high-end scanning receivers (including Icom R1, R10, R100, R7100-2, AOR AR-3000A, AR-8000, Radio Shack Pro-60 and others) can be operated in the Narrowband FM mode on 121.5 MHz. Specification changes may occur, so check to be sure before purchasing. Another idea for experimenters is to install crystals for 121.5 and 121.6 into an old crystal-controlled FM scanner. Everybody wants synthesized scanners nowadays, so "rockbound" sets are cheap and plentiful at swap meets and yard sales. Retune the RF stages as necessary for best sensitivity, because these sets were usually designed for receiving 146 MHz and up.

While a Doppler may be useful in some ELT tracking situations (such as a false alarms from aircraft on an airport runway), it is not a universal tool. ELT signals from actual crashes are usually very weak and of mixed wave polarization. Experienced Civil Air Patrol (CAP) volunteers in my area prefer cubical quads and phased arrays (such as the L-Per) instead of a Doppler when in such weak-signal situations. The photo shows a dual frequency (121.5 and 243.0 MHz) stiff-wire quad built by Bob Miller N6ZHZ, Commander of Brackett Composite Squadron 64 in La Verne, California. He says, "With the quad, I am able to pick up a 243 MHz ELT two to five miles miles before the L-Per's antenna will hear it. When there are two or three ELTs chirping simultaneously in hangers at an airport, I use a high-gain quad to track one at a time, listening to the differences in tone sweep rate of each one."

An RF attenuator should be used with an RDF quad to allow S-meter bearing readout and to help determine how close you are to the ELT. Plans for suitable quads are in THRDFS. For more on CAP and tales of searches for ELTs, see Homing In for April 1994.

Q: Can I use the Roanoke (or other) Doppler on the 10-meter ham band and/or the 11-meter Citizens Band?

A: It could be done if:

- The receiver is in FM detection mode (not SSB or AM)
- Switcher inductors and capacitors are optimized for this frequency range
- Antennas are 8-foot whips in a square pattern 8 feet by 8 feet

Of course this is not practical on a car, but could be considered for a fixed installation. Remember, Dopplers need carrier-type signals, so you can track amplitude-modulated signals (in FM mode) but not SSB signals. I have experimented with the Roanoke Doppler on 6 meter (50 MHz) FM signals, using resonant whips spaced in a four-foot square. They fit on the roof of the van, but there wasn't enough ground plane area around the whips, and the whips were so tall that they waved around too much while driving. Compared to baseline two-meter performance, this didn't work very well, especially in motion.

Q: I'm thinking of mounting a Doppler RDF antenna on top of my home ham station tower. Any suggestions?

A: One problem with remote operation of the array will be rf losses in the coax. You will probably not have problems with long control lines, although some added protection from lightning-induced transients is in order. For tower mounting, I recommend using four vertical dipoles (which would look like the marine DF antenna photo in THRDFS) instead of whips on a ground plane. This will give better performance by minimizing mutual coupling between the whips.

Q: OK, how about putting the Doppler at our mountaintop repeater site to find jammers on the input?

A: There are many pitfalls in the way of remote mountaintop RDF systems. I get letters regularly from hams who tell me about the wonderful linked RDF systems at repeater sites that they'll be putting on line "real soon now." I encourage them to send me all the details of their results, with photos, so I can tell the world via Homing In. Then I never hear from them again.

You'll probably discover, as they do, that you won't be able to successfully operate a Doppler DF at your repeater site. Here's why:

1. The commutating antenna system, "moving" at an audio rate, will induce the annoying Doppler tone into your repeater receiver and probably into most other receivers at the site, even those on widely different frequencies. This will occur even if you use a separate receiver for the Doppler antenna. Note that this phenomenon is not caused by digital switching noise in the commutating antenna. It is a parasitic RF effect and can occur even if no digital switching noise exists.
2. The cross-modulation products caused by stong signals from your repeater transmitter and other VHF/UHF transmitters at the site into the switched antenna system will make the Doppler insensitive and prone to unreliable indications.

Fast-switched dual-antenna RDF sets such as TDOA's will probably have similar problems. You might consider a slowly rotating beam with some sort of direction indication through the repeater---this was done by the Happy Flyers organization many years ago.

I know of only one successful remote repeater-connected RDF system now in operation, and it is not a Doppler. (If you know of others, please enlighten me.) This system uses a phased array which is switched very slowly (every second or so) to avoid the problems mentioned above. That slow switching is OK in the user's application, because it is intended to track continuously-transmitting ELTs, not ham-band kerchunkers.

So if you want to use Dopplers for remote RDF, put them at sites that are not associated with repeaters or other VHF/UHF radio systems.

Q: I have read several articles on 2-meter Dopplers and they all specify different antenna element spacings. What is the best?

A: No matter how many whips or vertical dipole elements in a Doppler array, the adjacent elements must not be more than 1/2 free-space wavelength apart, to avoid ambiguous bearings due to phase steps of greater than 180 degrees. Furthermore, adjacent element spacings of greater than 1/4 wavelength will produce phase steps of more than 90 degrees, lowering the level of the recovered audio tone and worsening the signal-to-noise ratio. With that in mind, an optimum adjacent-whip spacing for a 4-whip mobile array for VHF or UHF is slightly less than 1/4 wavelength at the highest frequency to be used. Plans for the 4-whip Roanoke Doppler in THRDFS call for 18-inch whip-to-whip spacing, which is 0.22 wavelength.

The array doesn't have to be this big, but don't make it too small, either. Deviation of the recovered Doppler tone is a function of antenna size and speed of rotation, as given by the formula on page 121 of THRDFS. This works out to about 0.5 KHz deviation for the Roanoke Doppler 2-meter antenna, which is a good value. A super-small array such as the 0.07 wavelength-on-a-side mentioned in the Dick Smith literature won't work well, because the recovered Doppler tone out of the receiver would be only 0.1 KHz. It could be readily overpowered by modulation audio and noise.

If you use a mag-mount implementation, remember to place the whips in a perfect square pattern. Measure spacing carefully or make a template. A slightly rectangular or trapezoidal pattern will introduce significant bearing errors at some angles.

Q: What about the spacing if I use more than four whips?

A: Going to 6, 8, 12 or more whips, as provided for in some Doppler sets, provides little improvement if the array size (radius of rotation) is the same as for 4 whips. The Doppler tone deviation is unchanged, though there are fewer high-order harmonics in the recovered audio. (That's unimportant if a very narrow passband filter is used, as in the Roanoke Doppler). Furthermore, the closer element spacing of a same-size-more-whips array increases inter-whip RF coupling, which degrades performance in multipath.

To fully realize the advantages of more whips, the array size must be increased. Consider a two-meter 8-whip array in an octagon pattern of 18 inches per side (i.e. the same adjacent whip spacing as the Roanoke Doppler). Radius of rotation is more than double that of the 4-whip Roanoke, giving over 1 KHz Doppler tone deviation at the same rotation rate. The array aperture is more than doubled, which improves performance in multipath.

However, an array with a diameter of almost 4-1/2 feet won't fit on most vehicles, especially when you remember that you would need 7-1/2 feet total diameter to provide ground plane under the whips. A similar size (in wavelengths) array for the 70 cm band (450 MHz) would be only 2-1/2 feet diameter, which is practical.

Q: Why doesn't the Roanoke Doppler use RF preamps and/or "soft switching" in the antenna system to give more sensitivity and less noise?

A: Questions like this indicate three assumptions:

- Assumption #1: Soft switching eliminates noise
- Assumption #2: Monolithic amps provide increased system sensitivity
- Assumption #3: A Doppler with switched preamps provides the same directional performance as one using PIN diodes.

I disagree with all three assumptions. Here's why:

1. Any Doppler antenna commutation, whether "hard" or "soft," produces additional spectral components in the RF signal to the receiver. It is true that rectangular-wave switching can create some broadband noise, but if the noise is really bad in your system, it's probably because the diodes are biased or driven improperly. Wide-bandwidth receivers such as scanners and handi-talkies are much more susceptible to this problem than mobile radios with good input RF filtering (such as helical resonators). You may find that changing your receiver or adding a helical filter between antenna and receiver improves the performance of your Doppler markedly.

2. Monolithic preamps have gain, which can overcome the small amount of loss in the coax from antenna to receiver. But they usually have a poor noise figure, much worse than most receivers. RF gain ahead of the receiver will worsen any receiver overload and cross-modulation problems. Strong signals can also overload the preamps, distorting the incoming signal phase and degrading the bearing accuracy. (Long-time T-hunter Mike Musick NØQBF has observed this even on signals from one or two miles away!) So unless you are using a very insensitive receiver, antenna preamps will probably do more harm than good. In addition, some Doppler sets hard-switch the preamp supply voltages. This causes the same broadband noise problems in a wideband receiver that improperly biasing the PIN diodes does.
3. As I explained in detail in my Homing In of April 1995 and August 2003, the impedance match (or mismatch) presented to switched-off whips in a Doppler array determines the multipath performance of the system. Preamps usually "look like" 50 ohms, which is undesirable in this application.

In summary, I believe that a properly designed PIN-diode switcher (with correct ON and OFF biasing), when used with a sensitive narrow-range receiver, gives as good or better overall Doppler performance (in both sensitivity and multipath accuracy) than any preamp-based design does, whether hard or soft-switched.

Q: Our club wants to set up some RDF sites to automatically find jammers and display their locations on the Internet. How do we do it?

A: First, understand that you won't be able to use such a system to positively identify RF coming from a specific house or apartment at a distance. Let's say you set up a RDF system with three sites to cover a typical urban area of 20 X 20 miles. For good coverage of the area, the sites will have to be on the perimeter. Assume that you can find enough quiet sites and link them. Now assume that the jammer is right in the middle of the triangle of sites (best case). The intersection of your bearings and their uncertainties will create a polygon with an area of about 4 square miles! That certainly won't be good enough evidence for the FCC. There are about 10 hams per square mile in my city, probably the same as where you live. So you'll still have to do plenty of close-in DFing to verify the actual perpetrator's site and get eyewitness evidence.

Why the large polygon? Because the inherent uncertainty of a bearing from a typical VHF 4-whip Doppler in an urban environment is about +/- 5 degrees, even if you have 10-bit readout precision. Sometimes, the bearing error is even greater, especially at fixed sites. (See Chapter 18 of THRDFS.)

This is not intended to discourage you, just to add a healthy dose of reality. If you want to link up RDF stations, consider using APRS, which allows packet interconnection of a limitless number, both fixed and mobile, close-in or far away, each one displaying their own and everyone else's bearings. Bearings and station locations can be input to APRS either manually or automatically, so even base stations with beams can help out. For more info, see my Homing In columns in 73 Magazine for October 1994, January 1995, and February 1995.

Q: How can I interface my Doppler to APRS?

A: Any of the popular homebrew or kit-built Doppler RDF sets with 8, 16, or 32 LED indicators can be connected to computers using a circuit developed by Robert Swain N7LUE. This includes the popular Roanoke Doppler and the DoppleScAnt from QST in the 70's. Robert's circuit takes the binary information from the LED drivers and outputs a serial RS232 data stream of ASCII characters representing directions. For details, see Doppler-to-APRS interface at this Web site and Homing In for August 1995. A microcontroller-based serial interface that outputs in "Agrelo" format is described on the Web pages of Bob Simmons WB6EYV. He also sells the PicoDopp, a Doppler add-on that includes serial interface, in semi-kit form.

Some sets made by Doppler Systems Incorporated feature RS232 serial output consisting of 3-digit numerical readout of bearing in degrees. Doppler Systems sets in the 3000, 4000, and 5000 series can also be used with N7LUE's interface.

The MicroFinder Doppler set by AHHA! Solutions has serial output of bearing information in "Agrelo" format.

Q: Why are there only 16 LEDs on the Roanoke Doppler?

A: The Roanoke Doppler was designed for the best combination of simplicity and performance. A 16 LED display is usually quite adequate for tracking signals when mobile in urban areas. It gives a rapid indication of which way to drive when time is of essence. I still use my 16-LED unit on the local hunts with good results. When I need higher accuracy for triangulation, I switch to a beam.

Finer resolution is possible with some circuit changes. Tom Curlee WB6UZZ has designed a version with digital readout to the nearest degree. But the basic bearing accuracy of VHF Dopplers on vehicles is typically +/- 5 degrees, so such a display gives a false sense of accuracy. And all these improvements require more complexity. That means more parts to find and greater cost. We have found that most hams want maximum simplicity in projects they have to build themselves. (On the other hand, when they buy a ready-to-use piece of gear, they want maximum bells and whistles.)

Part 2 - Questions About Other RDF Equipment

Q: Can you help me get my (choose one) Agrelo, Ramsey, Dick Smith, or "bow-tie" RDF equipment (not in THRDFS) to work?

A: Mail about these units is so frequent that I have posted details at this site.

- Agrelo DFjr Doppler
- Ramsey SlyFox and Foxhound
- Dick Smith Doppler
- "Bow-tie" sets by K8DTS and others

Q: I can't get my Shrunken Quad to work. What's wrong?

A: Most likely you are using the wrong piston trimmers, but it could also be an improperly built balun. Go to More on the Shrunken Quad to find out.

Q: Are there any updates/corrections to _____ (fill in your favorite project in TRANSMITTER HUNTING---Radio Direction Finding Simplified)?

A: Click here to get the latest updates to THRDFS.

Q: Where can I find boards/kits/parts for your projects?

A: I try to locate inexpensive sources for uncommon parts and include them in all my project articles. For updates and additional parts/boards info, jump to the Hardware Resources page at this site.

Part 3 - Questions About Transmitters and Covert Tracking

Q: My club wants to start transmitter hunting but first we need a hidden transmitter. What is available?

A: No problem! The transmitting part of T-hunting is easy if you give it a little thought. Keep in mind that no transmitting setup is perfect for all hiding situations. Hiders use a wide variety of equipment, with power output and antenna type depending on the distance to the start point and the level of intended difficulty. You need to determine, for instance, whether you want to do short range on-foot hunting, longer range hunting on bicycles, or still longer range mobile hunts.

For your first mobile hunts, just have someone stay with the transmitter and and key it up at appropriate intervals. The hider can read into the mike from a book, or from the club newsletter, or just make comments and urge the hunters on, as NØQEC and KBØIEK of the Lincoln (Nebraska) Amateur Radio Club are doing in the photo at left.

After a few hunts, you may want to put together an unattended transmitting setup, so the hider doesn't have to stay with the rig. For starters, connect your two-meter hand-held or mobile transceiver to a tape recorder playing an endless loop answering machine cassette with an appropriate message and ID. Some hiders like to use a dual-band hand-held and activate it on the subband from another transmitter. Later on, after you gain some experience and have a better idea what suits your needs, consider a dedicated home-built or commercial "foxbox" with tones and a cycling timer for hiding. See the Hardware Resources page at this site for transmitter controller ideas.

For short-range on-foot hunts in parks, consider complete mini-transmitters like the SquawkBox by Bob Simmons WB6EYV (photo at right). It records and sends short voice messages at adjustable periodic intervals.

More about transmitting gear for on-foot hunts can be found in the Equipment Ideas for Radio-Orienteering page of this site. And of course there is a complete chapter of clever transmitter hiding ideas in THRDFS.

Q: I need a miniature transmitter to put on my prized possession (sports car, TV set, motorcycle, coonhound) to find it after it wanders away or is stolen/abducted. What is available?

A: Yes, I have actually had inquiries about tracking devices for each of the above examples, and many more! Unfortunately, it is still true that you get what you pay for, and no matter what you pay, there's no assurance of success.

In the under-$40 category are "experimenter" micro-transmitters such as the TT7-K "Tracking Transmitter Homing Beacon" sold by Amazing Devices. Several miniature transmitter models are available from ElectroKits. These "bugs" typically use the 88-108 MHz FM broadcast band, where low-power unlicensed transmitters are permitted by FCC Part 15. Manufacturers sometimes claim range of three miles or more for these FM micro-transmitters. But that range assumes high-gain antennas on both transmitter and receiver. A practical antenna on a stealth radio tag will seldom be large and efficient enough for that. Furthermore, if one were to actually achieve three-mile range with such a transmitter, that fact would demonstrate that the field strength is in excess of that allowed by FCC Part 15 rules for unlicensed devices in the USA. In other words, it would be illegal operation of a radio transmitter in the eyes of the law.

Some of these experimenter FM-band transmitters use simple L-C tuning, so the transmitter tends shift frequency due to temperature changes, battery voltage droop or proximity to other objects. Futhermore, the FM broadcast band is not suitable for covert operations, as the tag can be tuned in on every home and car radio within range. Usable tracking range is severely limited by interference from powerful broadcast stations. The high level of audio FM deviation (+/-75 KHz) used by transmitters and receivers in the FM broadcast band is not compatible with narrowband Doppler RDF techniques. Have I convinced you that this is not a good option for most applications?

Also available for about $40 are micro VHF transmitters for the two-meter ham radio band, such as the MR6 Model Rocket Tracking Transmitter Kit by Ramsey Electronics. A similar postage-stamp sized transmitter project was detailed in Homing In for May and September 1993 (photo at left). At about 10 milliwatts, such transmitters are perfect for short-range ham radio transmitter hunts (see previous question). But two-meter frequencies may be used only by licensed ham radio operators, with proper transmitter identification, in accordance with FCC regulations. Plenty of ham radio T-hunters are ready and eager to track down intruders on these frequencies, and they won't be amused if they discover that a non-ham is using their spectrum space to keep track of his cat. There are restrictions and license requirements for the use of other VHF and UHF frequencies at these power levels as well.

A much better choice would be the tiny transmitters and tracking receivers made specifically for tracking mammals, reptiles, birds, fish and even insects. See my RDF links page for commercial suppliers of transmitters and receivers that are popular with two market groups: wildlife researchers and the owners of prize hounds. A good example is Communications Specialists of Orange, California, which sells waterproof tracking transmitters that are about the size of a stack of six quarters (photo at right). They may operate unlicensed under FCC Part 15 rules and are powered by a lithium-ion "coin-cell" battery that lasts about a month. Com-Spec is expanding the market for these radio tags by selling them as the LoCATor Pet Tracking System, the Radio Controlled Airplane ELT System, and the Law Enforcement Tracking System. Range of Part 15 compliant transmitters is a few blocks in the city and up to a mile in open terrain with transmitter and receiver elevated. For official law enforcement use, more powerful transmitters certified to FCC Part 95 are available for greater range.

To save battery life, these critter-tracking transmitters are pulsed for a few tens of milliseconds, every second or so. Their low-power signals are so weak at long range that dual-antenna sets and Dopplers are at a disadvantage. Sensitive narrowband receivers and beam or phased-array antennas work best. Professional grade tracking receivers are quite expensive, but the 30-channel Com-Spec Model PR-30 215 MHz range set with Moxon type directional antenna (photo at right) is a bargain at about $200. Another option is a consumer-type scanner. It must be multi-mode model such as the Icom IC-R10, Trident TR2400 or Sony ICF-PRO80, which include CW/SSB (BFO) modes. For a tracking antenna, you could build a small cubical quad from plans in THRDFS.

If money is no object, consider the complete RDF tracking systems manufactured by law-enforcement suppliers such as Tracking Products, Inc. Also at the high end of the cost range are "hostage tracking" systems sold by "spy market" distributors such as Surveillance Equipment Group and Airtight Investigations. Note that even with their high prices, there are practical limits on range and battery life. All advertising claims must be taken with more than a grain of salt. None of these providers offer any guarantees that you will locate whatever you're tracking or even that you will hear a trackable signal.

For vehicles, don't overlook LoJack and other commercial tracking systems. LoJack transmitters are installed in an undisclosed place in your vehicle or other important asset and activated automatically when it's reported stolen to the police. Then the signal is received and RDF-tracked by police and sheriff cruisers and aircraft (over 400 in the Los Angeles area alone). Ask the LoJack salesman if the guarantee of your car's return is still offered.

There are also non-RDF vehicle tracking systems such as the new GPS-based CyntrX by Enhanced Vehicle Applications of Wisconsin. It is sold by TechWholesale in Ohio. (Reports from users wanted, please let me know your experiences by e-mail.)

Q: What about a pager-sized tracking device to put on toddlers? Parents would carry a pocket-sized receiver so that they could locate the child in case he/she became lost.

A: As you can imagine, the tracking of children is a much more serious and difficult matter than the tracking of cats and sports cars. Here are just some of the many factors that must be considered if direction-finding technology is to be used:

- Size - For sufficient transmitter power and antenna size for tracking over a wide area, the child's device must be bigger and heavier than most people desire.
- Tracker - An effective tracker needs a "wide aperture" antenna for sensitivity and accuracy, so it cannot be pocket-sized. But parents won't want to haul around a big tracker on every trip to the amusement park.
- Battery Life - The longer the battery must last, the bigger and heavier the transmitter on the child must be.
- Antenna - How do you put an effective antenna next to a child's body without detuning it?
- RF Radiation - Is it safe to have a transmitting antenna next to a child's body?
- Liability - Will the maker be sued if parents cannot quickly find their child with the device?
- Security - How do you keep criminals from tracking lost children, too? What happens if a potential kidnapper finds the lost child before the parents do?

Companies such as Xmark Systems make "perimeter protection" systems that sound an alarm if a tag-wearing individual wanders or is taken out of a protected area. These systems are marketed to health care facilities as alarms to provide early notification of wandering Alzheimers or mental patients, or of infant abductions. They are based on RFID technologies (see next question), so they don't have any direction-finding capabilities. The protected perimeter is non-portable, and the tags can't be used to help find the person once he or she is outside the protected area. Care Trak, Incorporated sells a system of wrist/ankle transmitters that combines perimeter alarm and short-range (up to one mile) RDF tracking. In some localities, RDF-proficient volunteers assist authorities in tracking wandering patients under Project Lifesaver.

Some startup "personal tracking" companies, such as Protect Me Toys (now defunct?), eWorldTrack, Wherify Wireless, and Digital Angel (also defunct?) have received considerable press (and resulting investor attention) for their claims of long-range positioning and tracking. None of their systems use traditional direction finding (i.e. beacon transmitter and human-carried RDF gear). Instead, they are based on wearable Global Positioning Receivers with radio transmitters that beacon the GPS data to trackers directly or via cell/PCS phone systems. Currently available models are relatively large, have short battery life, and require a clear view of the sky for accurate positioning. A savvy child abductor would quickly remove such a device from the child or shield it to render it inoperative.

Other RDF-based systems now on the market for tracking children and adults include the medium- and high-end solutions described in my answer to the previous question, with the usual power, range, and battery limitation. If you have personal experience with any of these products, good or bad, or if you discover any other suitable (or unsuitable) systems, please let me know the details by e-mail.

Q: Our construction company is losing small tools, either by accident (falling into holes) or theft. Can a transmitter be inserted into items like wrenches, drills or grinders, with a RDF unit capable of detecting them inside a car trunk?

A: Radio Direction Finding (RDF) technology is typically done at considerable distance (from yards to miles and beyond). To do that, transmitters require long-term power sources (such as batteries) and antennas. They're usually too large to be placed on or in a hand tool. In addition, the transmitted signal can be detected by anyone with a receiver tuned to the proper frequency, so these systems are not covert.

RFID technology at the jobsite exit is probably more appropriate for this tool-detection application. RFID systems track property and objects at relatively close range with unique codes. For instance, chips (also called tags or transponders) can be implanted in pets to provide positive proof of ownership if the pet strays into the pound or is stolen. A reader device, passed over the chip, detects it and reads out the chip's unique ID code. Similar RFID systems sound an alarm when non-paid-for merchandise passes through the doors of a store. RFID done at greater distance in automatic toll collection systems on and elsewhere. At one time, the FasTrack transponders for southern California toll roads could even be used to quickly pay for a McDonald's burger at the offramp. (This feature was discontinued because so many transponders were being stolen out of cars and then used for this purpose!)

In an ideal situation, the chips are "passive," meaning that they don't require battery power. They usually cannot be detected with conventional receivers, but only by a reader or polling device designed to be used with them.

Part 4 - Miscellaneous Questions

Q: I'm ready to go on a mobile T-hunt. How do I find one?

A: If you live in southern California, see the Southern California T-Hunts for Beginners page at this site for monthly mobile T-hunts in the Los Angeles and Orange County area where first-timers are especially welcomed and encouraged. Web sites about other Los Angeles area Saturday night hunts and the southern California All-Day hunts are on the Links page of this site. That page also has links to Web sites and Homing In Correspondents who can tell you about hunts all over the USA, and in some other countries, too. If there are no hunts in your area now, get together with your local ham club members and start them!

Q: My friends and I chat on the local two-meter repeater. Somebody on there transmits beeps and mocks us. We can all hear him on the input of the repeater. Please listen with your direction finding equipment. We need to stop him.

(Believe it or not, requests for me to listen on VHF/UHF have come from hams that are hundreds of miles away from me!) You and your friends need to put some RDF gear on your vehicles and track down the offender yourselves. That's why I have this site and my book --- to help hams like you become proficient at RDF. It's not hard. Once you find him or her, a little friendly persuasion may be all that it takes to eliminate the problem. If not, the chapter on solving malicious interference problems in THRDFS may be helpful in developing a strategy.

You should also find out if the Amateur Auxiliary and Official Observer programs of the American Radio Relay League are active in your area. If so, join them now. Your ARRL Section Manager has more information.

Q: Is it true that transmitters can be "fingerprinted" for positive identification without the user being aware?

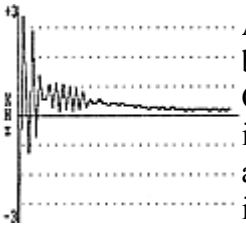

A: The concept of transmitter fingerprinting was invented and patented decades ago by Phil Farrell K7PF of Seattle. He licensed his patent/technique to The Boeing Company and to Motron Electronics, which sells equipment for it. The Motron implementation (called TxID) consists of a card that plugs into the expansion slot of a PC, plus software running under DOS. The asking price is higher than most individuals are willing to pay, but it is affordable for repeater clubs. I tested and reviewed the system in Homing In for November 1994. The review explains the principles of fingerprinting and shows good and bad points, including comparison of some same-model transmitters. Since then, Motron has added features such as receiver frequency control and readout for remote operation. TxID will control a tape recorder for evidentiary purposes.

A few hams have developed similar fingerprinting systems. The first was "XMIT_ID" by Richard Rager KB8RLN. It used PC software and an 8-bit Soundblaster card. I have lost contact with Richard and don't know the current status of this project.

"Sherlock" by Malcolm Mallette WA9BVS also runs on a PC and uses its sound card with commercial oscilloscope software. The newest version of Sherlock, which works with Windows XP and Vista, was detailed in a feature article by WA9BVS in the Winter 2006 issue of CQ VHF magazine. Click to download this article in PDF format (7 MB), courtesy of WA9BVS.

XMIT_ID and Sherlock are intended for home experimentation only. Commercial production of any fingerprinting system based on the turn-on frequency changes of a transmitter may infringe on US patent 5,005,210.

Q: What is a Crenshaw Factor and why do I need one?

A: The Crenshaw Factor has been used for many years in southern California T-hunts to normalize mileages and account for odometer differences between various vehicles. Your vehicle's Crenshaw Factor is the odometer mileage you get when you drive a standardized course that runs along Crenshaw Boulevard for about 9 miles. The course was chosen because it is relatively straight and goes up to the start point of the All-day hunts. This makes it easy for hunters to check their factors regularly on the way to a hunt.

A big problem right now is that the landmarks at the start of the Crenshaw have changed. The official start point is in front of a now-gone telephone booth in front of a now-gone Winchell's Doughnut shop on the southwest corner of Artesia Boulevard and Crenshaw. If you can find this point, then all you do is record your odo reading and drive in the left-hand lane along Crenshaw to the stop sign at Crest Road in Rancho Palos Verdes. Your elapsed mileage to that point is your Crenshaw Factor.

Nobody knows exactly what this distance is, but it doesn't matter. To normalize mileages on a T-hunt, each vehicle's elapsed odometer mileage is divided by its Crenshaw factor. The result is in "Crenshaw Units." The team with minimum Crenshaw Units wins.

Example: Say your odometer mileage on the hunt is 35.7 and your Crenshaw factor is 8.8. Your Crenshaw Units are 4.057. You think you won, but another hunter has odo mileage of 36.8 and Crenshaw factor of 9.3. That means his odo reads higher than yours for the same distance traveled. His Crenshaw Units are 3.957, so he beat you.

It is commonplace for two or more hunters to have low mileages within a few tenths of one another. Crenshaw Factors are needed to determine winners on many of our milege hunts, so it is important for every hunter to have one.

Q: Why has your book's price increased to $24.95?

A: I don't know. It was done by the new publisher in recent printing runs, without notice to the authors. There are no changes in these print runs, so look for previous-printing books at lower prices, if you can find them.

Q: I have a ham store and would like to carry your book. Do I have to get it from ARRL?

A: Retailers and dealers should get books directly from the publisher. Call McGraw-Hill Trade Order Desk at (800) 722-4726 to place quantity (5 or more) orders.

Q: Is there any difference between ISBN number 007-1560068 and ISBN number 0-8306-2701-4 for your book?

A: The book has two ISBN numbers because one was assigned to it by TAB Books originally, and the second was assigned by McGraw-Hill when McGraw-Hill acquired TAB Books. Booksellers might show stock in either ISBN number, depending on when they ordered the book and put it into their computer system. Sorry for the confusion, but I have had no control over this process.

Q: Why don't you sell copies of old Homing In columns or post them here on the Web?

A: For logistic and contractual reasons, I don't mail out or sell copies of magazine articles I have written. Furthermore, they cannot be posted here or on any other Web site, with only a few exceptions. Your fastest source for back issues of ham magazines is probably a visit to your local library. A nearby ham radio store may also have recent issues in stock. Many ham clubs maintain ham magazine libraries for their members.

Q: Can I make and sell kits and boards for projects in your books and articles?

A: Since Tom Curlee and I don't have the time to get into the board/kit business, we welcome other enterprising hams supplying these products. However, our publishers insist that we protect the copyrighted material appearing in the book and my magazine columns. Kit/board suppliers must not duplicate, sell, or give away any of the TAB/McGraw-Hill or 73 documentation of the projects. Kit/board buyers should be urged to purchase THRDFS for the tune-up, calibration, installation, and operating details. This works out well, because some of our kit suppliers are making extra money by retailing the book! To purchase books wholesale (5 or more copies), call the "trade order" desk at TAB/Mc-Graw-Hill. Please note that Tom and I support the circuits in our book, but we accept no responsibility for performance of third-party boards and products.

Hardware Resources for RDF Home Builders

Sources for the Roanoke Doppler project

Complete construction plans for the Roanoke Doppler are in Transmitter Hunting---Radio Direction Finding Simplified (THRDFS). The following are sources of printed circuit boards for the display unit. Some may also offer critical parts, complete kits, and/or wired/tested units.

- Directional Systems: Jim Sorenson KA4IIA, PO Box 81881, Conyers, GA 30094, ka4iia@radio.org
- FAR Circuits: Fred Reimers KF9GX, 18N640 Field Court, Dundee, IL 60118, farcir@ais.net or http://www.farcircuits.net (847) 836-9148. Users have reported errors on older versions of the display boards. They have been corrected in display boards now being shipped. FAR Circuits also has a circuit board for the Wide-Range Antenna Array. There is a minor correction to the marking on this board. Click here for more information.
- Stephen Douglas K6HZT of Sacramento, CA, k6hzt@arrl.net or http://www.marshwildman.com/doppler.htm. Please note the board errata information on his site.

Disclaimer: The information above, and elsewhere on this page, is provided for the convenience of readers only. These suppliers are independent entities. They have no business association with Joe Moell or Tab/McGraw-Hill. A listing on this page does not constitute endorsement of products. Contact these suppliers directly for offers and prices.

Boards are no longer available from Ed Greany KB6DOL or Tom Lewis AB5CK.

Sources for RF attenuator projects

Resistive RF attenuators are best suited for mobile HF and VHF T-hunting with directional antennas such as loops, yagis and quads. Pete Ostapchuk N9SFX sells parts for resistive attenuators, including a 6-section enclosure machined from 6061-T6 aluminum bar stock and engraved with attenuation values. Also available from him are switches, resistors and connectors. Plans for his project are in QST Magazine for May 1998. Send e-mail to n9sfx@aol.com for details and prices. The above disclaimer applies.

Another source of resistive RF attenuators is National RF, Incorporated (formerly Radio Engineers) of San Diego, CA.

For on-foot VHF/UHF "sniffing" and international-style foxhunting with a beam and handi-talkie or scanner, an "offset" or "active" attenuator is better because it eliminates the problem of signal leakage directly into the receiver's case. Plans for an active attenuator are at this Homing In site, click here.

Sources for fox-boxes

Hidden transmitter controllers, sometimes called "fox-boxes" are units that provide audio and timed key-up/key-down (push-to-talk) outputs. A fox-box turns an ordinary handi-talkie or mobile transceiver into a cycling hidden T. Here are four fox-box projects for home construction:

1. The Un-Music Box by KØOV is an easy-to-build project using common easy-to-obtain CMOS ICs. No microprocessor programming is required. Provides on-off cycling or continuous transmissions. Callsign is hand-programmed using two switches; shift register memory has battery backup. Complete plans in the book TRANSMITTER HUNTING---Radio Direction Finding Simplified. You can remote control the Un-Music Box with a surplus pager receiver using plans in Homing In for December 1990.
2. PicCon by Byon Garrabrant N6BG uses a Microchip PIC microcontroller and has a variety of programmed on/off modes and tone sequences for mobile T-hunts as well as IARU-standard MOE/MOI/MOS audio, timing and synchronization for international-style radio-orienteering. DTMF remote control and programming with your HT or external receiver. Delayed turn-on and turn-off timers. Callsign and programming info are held in EEPROM when power is removed. Reviewed in Homing In for March 1997. Complete kit is available from N6BG.
3. TBOX by Ron Seese N6MBR uses an 80C51 microprocessor to provide three programmed tone sequences and/or a CW message. User-programmable on and off times in intervals from seconds to hours. Programmed via RS-232 serial port using commands similar to packet TNCs. Non-volatile memory (EEPROM) holds programming and message when powered down. Optional SmartWatch clock turns fox on automatically at programmed time. Plans for basic unit are in Homing In for October 1991. Assembly, object and binary files for the microcontroller program (10K total) are available at this Homing In site. Contact N6MBR regarding availability of kits and critical parts.
4. Francois Tremblay VE2JX and Jacques Brodeur VE2EMM of Montreal have designed a new PIC-based foxbox for international-style hunts with MOE/MOI/MOS audio, synchronization of 2 to 7 foxes, delayed start of up to 3-1/2 hours in 1/2-hour increments, and automatic shutoff after four hours of operation. Callsign is held in non-volatile flash memory. Callsign changes and mode setup are easily done with dipswitches. This project is fully described in Homing In for April 1998.

Sources of PIN type RF diodes

For maximum receiving sensitivity and minimum problems with cross-modulation, good RF PIN diodes must be used in hard-switched dopplers such as the Roanoke Doppler. Breakdown voltage and power rating of the PIN diodes are not important in low-level receiving circuits. (You aren't going to transmit through the switcher, are you?) For low loss and good sensitivity, the diodes should have low RF resistance (Rs) at the expected forward DC bias current (7.5 mA for the wideband switcher). They should have low capacitance (Ct) at the reverse bias off-state voltage. Effective carrier lifetime and reverse recovery time (Trr) should be short. (PIN diodes with long carrier lifetime are ideal for current-controlled RF attenuators, but that's not what we want in this application.) Keep the diode leads very short to minimize inductance and make sure signal path lengths, including diodes, are equal for all elements in the array.

Suitable PIN diodes include:

- Narda KS3542 -- DO-34 package, click for data sheet. A ham with a supply of these diodes has offered to make them available in small quantities to home builders of RDF equipment. Send e-mail to me for more information.

  Philips NTE555 or ECG555 -- "Replacement" type semiconductor available at local electronics parts houses all over the country. Even some giant computer stores such as Fry's Electronics carry NTE parts. Priced $1.50 to $2.00 each. This is an older part with tab leads and unspecified series RF resistance.

- Agilent Technologies (formerly Hewlett-Packard) surface-mount PIN diodes -- Surface-mount parts are best if you're building a doppler for UHF (400 MHz and up). Three types used to be easy to get from RadioShack.com but are apparently no longer available there. Try Arrow Electronics, a major parts distributor in in Melville, New York. The Agilent HSMP-3892 or HSMP-3893 are good choices for a series doppler switcher such as the wideband array on this Web site. On the other hand, the HSMP-3820 is optimized for a shunt switcher such as the one in THRDFS.

- Motorola MPN3404 -- In TO92-style plastic package. 50 cents each or ten for $4.50 at Circuit Specialists, 220 S. Country Club Dr. #2, Mesa, AZ 85210 (800) 528-1417. $1.00 each from Debco Electronics, 4025 Edwards Road, Cincinnati, OH 45209 (513) 531-4499. Advertised price is 60 cents each at Dan's Small Parts and Kits, Box 3634, Missoula, MT 59806-3634 (406) 258-2782.

- TRW A5S303 -- Axial lead device formerly available from Tanner Electronics in Carrollton, TX (214) 242-8702. Does anyone have a new source?

- Agilent Technologies 5082-3077 -- Axial-lead low-Rs device available from Newark Electronics. Newark also carries Agilent 5082-3081 and 5082-3080, which are long-carrier-lifetime parts intended for variable RF attenuators and thus not suitable for doppler switches.

- Motorola MMBV3401LT1 -- Surface-mount replacement for the now-discontinued MPN3401. Available from Motorola industrial distributors. Not suitable for perf-board construction.

After I bought some Motorola PIN diodes from Debco Electronics, I mentioned their availability in Homing In for April 1995. A reader wrote to me after publication to say that Debco was astonished at the response. The order-taker said that they hadn't sold a PIN diode for over a year and then after the article came out they began selling like hotcakes. Who says hams don't build nowadays?

Other Sources of RF Parts

Hard-to-find RF parts such as air variable capacitors for tuning HF loop antennas can sometimes be found at dealers of "overstocked" or "industrial surplus" components. Here are three to try:

- Bogdan Electronic Research & Development (Jim & Carolyn), PO Box 62, Lakewood, CA 90712, (562) 634-0911. They sell RF parts by mail and are often at southern California swap meets, too. Note: Jim says that the margin on small quantities of RF parts is so low that it's not cost-effective for him to return calls. (I know the problem!) Therefore, please use e-mail or call back to catch him or Carolyn "live" on the phone if you get a recording when you call.
- All Electronics, PO Box 567, Van Nuys, CA 91408.
- Alltronics, 2300 Zanker Road, San Jose, CA 95131, (408) 943-9773.

For more information about sealed RF "piston" trimmer capacitors and sources, see the Shrunken Quad page at this site.

Ferrite beads and cores for the dual-polarization quad (see Homing In for February 1997) and other RF projects are available by mail order from Amidon Associates. Locals can save shipping charges by picking up orders at 240 Briggs Avenue, Costa Mesa, California, during normal business hours. Call in advance to 800-898-1883 or 714-850-4660.

ByteMark Corporation, 7714 Trent Street Orlando, FL 32807 (407) 679-3184 also carries Amidon ferrite components and has technical information about Amidon ferrite and iron powder products on its Web site. In addition, ByteMark sells a Windows-based program for calculating the turns for coils on various Amidon cores.

The Philmore line of packaged electronic parts includes unusual items such as Amidon T50-6 cores (used in the ATX80 80-meter fox transmitter), International Rectifier HEXFETs, MPF-102 JFETs, etc. Unfortunately the Philmore Web site does not have a complete product list, but it does include a list of local distributors of these parts.

Crystals for 80-meter foxboxes are available from Brian Carling AF4K in Sanford, FL. He also sells some crystal-can oscillators that may be suitable for building offset attenuators.

Jerry Boyd WB8WFK provides this feedback on ON7YD's Fox Transmitter for 80 meters (ATX80), which was featured in 73 Magazine for November 2000: "Motorola MC14001B Quad-NOR ICs from Radio Shack (part number 276-2401) didn't work. The oscillator would not start properly. I tried 6 different ones and they all acted the same. I put in an old Fairchild CD4001B Quad-NOR and now it works with no problem. I downloaded data sheets from the manufacturers' Web sites and the internal schematics are indeed different." Fairchild ICs are available from many suppliers, including Digi-Key. KØOV's six transmitters use Signetics (Philips) CD4001B's packaged by Jim-Pak and sold by local parts suppliers nationwide -- they all work fine.

Sources for building polar-plot bearing readouts

I have many requests for sources of unusual electromechanical parts used in two-dimensional bearing indicators such as the KK6CU motorized quad, the WB8WFK and KD6IFZ computer displays, and the NØMKJ Foxcopter. (See the Homing In Index page at this site for articles describing these RDF systems.)

For (relatively) inexpensive surplus sine-cosine potentiometers as used in the KK6CU motorized quad, try Servo Systems Company, 115 Main Road, PO Box 97, Montville, NJ 07045, (201) 335-1007, in USA (800) 922-1103. The last catalog I received from this company included sin-cos pots by Litton, Duncan, N.E.I., Samarius, and Gamewell. There were continuous turning and single-turn models with prices from US$18.50 to $69.50.

For a "Cadillac" system, check out these contactless sin-cos resolvers using internal magnets and Hall effect sensors, designed to be rotated at up to 10,000 RPM: Elweco Incorporated, PO Box 909, Painesville, OH 44077-0909, (440) 254-1716.

Small industrial rotary joints (slip rings) in the $30 price class are suitable for low-voltage uses. NØMKJ used one of these for the two-meter coax feed in his Foxcopter. They are available from McMaster-Carr Supply Company, PO Box 54960, Los Angeles, CA 90054-0960, (310) 692-5911.

Another promising source of rotary joints is Mercotac, Incorporated, 6195 Corte del Cedro #100, Carlsbad, CA 92009, (619) 431-7723. Unfortunately the Web site does not list prices. If you use one of these products in your RDF system, please let me know how it works and what it costs.

Inexpensive electronic compasses with digital output (Vector 2X series) are manufactured by Precision Navigation Incorporated, 1235 Pear Avenue, Suite 111, Mountain View, CA 94043 (415) 962-8777. They are sold by Jameco Electronic Components, 1355 Shoreway Road, Belmont, CA 94002, (415) 592-8097, in USA (800) 831-4242. They are also sold by JDR Microdevices, 1850 South 10th Street, San Jose, CA 95112, (408) 494-1400, in USA (800) 538-5000.

From Peter PB2RDF comes this suggestion for a source of obsolete and out-of-stock electronic components for replacement or for older designs: 1-Source Electronic Components, 591-B Bicycle Path, Port Jefferson Station, NY 11776 (800) 966-8826 or (631) 642-2479.

RF Sniffer with Tone Output

Here is a neat Sniffer designed by Don, KF6GQ. It produces an audible tone which rises in frequency as the signal gets stronger. It uses 5 transistors and a 555 timer IC.

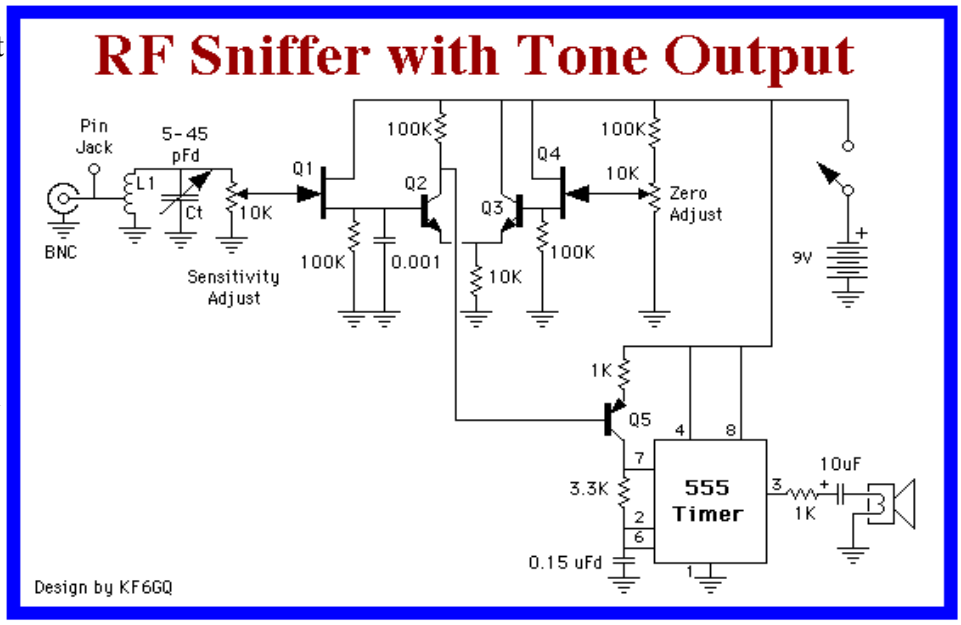

For a 1 Watt transmitter, sniffing range is about 225 feet using a 3 element Quad beam, or about 100 feet with a 1/4 wave spike antenna.

The Zero Adjust pot is used to set the tone frequency when there is no RF. With knob, field adjustable.

The Sensitivity Adjustment pot is used to control how much signal is required to produce the maximum tone frequency. With knob, field adjustable.

Parts Not Given on Schematic

L1 = 5 turns, 1/4 inch form tapped at 1.5 turns. (For 2 meters)
Ct = Small RF trimmer capacitor, adjustable over about 5 to 45 pFd. Not critical. Screwdriver adjustment is fine.
Q1 & Q4 = 2N5457 (silicon J-FET)
Q2 & Q3 = 2N3904 (silicon NPN)
Q5 = 2N3906 (silicon PNP)
NOTE: Just about any small-signal silicon transistor of the same general type as specified should work.

Contact Information

George (Russ) Andrews, K6BMG
BMG Engineering, Inc.
9935 Garibaldi Avenue
Temple City, CA 91780 USA
Phone: 1(626)285-6963
FAX: 1(626)285-1684 (dedicated line, automatic)
Web: http://members.aol.com/bmgenginc

Audible S-Meter

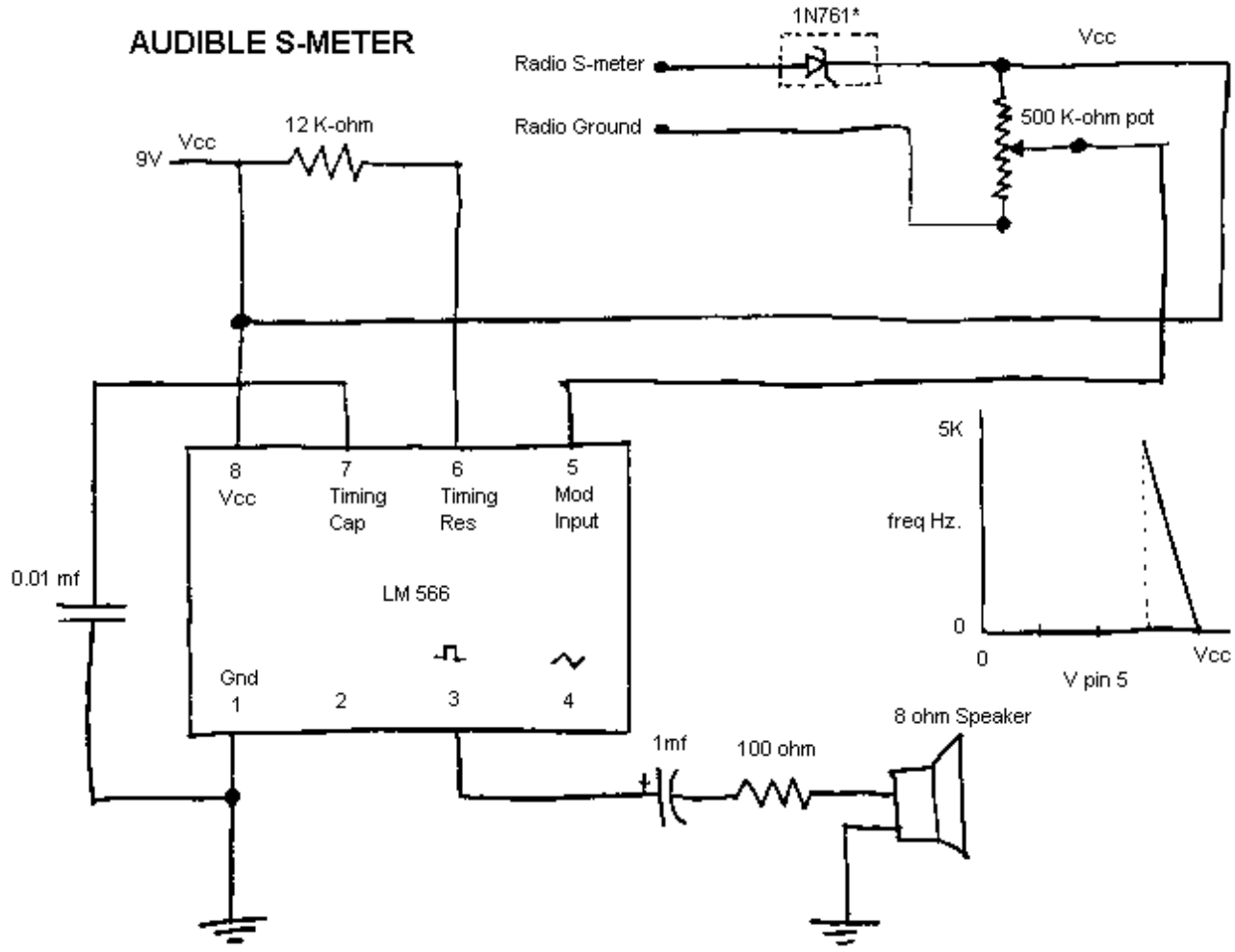

The Montreal Audio FS-Meter

PARTS LIST, 27 JULY 99

R1 = 2M7 1/4 W (2.7 mohms)
R2 = 47R 1/4 W (47 ohms)
R3 = 100K 1/4 W
R4 = 10K 1/4 W
R5 = 10K 1/4 W
R6 = 1K0 1/4 W or 1K0 trimm pot DK# D4AA12-ND for volume adjustment
if needed (1 kohm)

RV1 = 1M0 to 5M0 POTENTIOMETER (GAIN) (1 to 5 mohms)
RV2 = 10K 1T TRIMM POT, DK# D4AA14-ND

C1 = 2-20 pF RED TRIMMING CAP DK# SG20015-ND
C2 = .001 uF CER
C3, C4 = .1uF CER
C5 = 1 uF ELECTROLITIC 16V
C6 = 100 uF ELECTROLITIC 16V, Mount laying down on the board
C7 = .01 uF CER

D1 = 1N34, 1N60 ETC GERMANIUM DIODE
IC1 = MAXIM MAX495CPA RAIL TO RAIL SINGLE SUPPLY OP-AMP, DK# MAX495CPA-ND
IC2 = MICROCHIP PIC12C671/JW, UPGRADABLE, DK# PIC12C671/JW-ND
OR FOR LOWER COST, PIC12C671-04/P, NOT UPGRADABLE, DK# PIC12C671-04/P

L1 = 2T, 1/4" ID ON COLD END OF L1 #20
L2 = 5T, 1/4" ID AIR WOUND #20

SW1 = SPST MINIATURE SWITCH

MISC:

3 = AAA BATTERY HOLDER
1 = 18 pins IC socket or 2 = 8 pins IC sockets
1/8" EARPHONE JACK MONO
SINGLE EARPHONE
BNC CHASSIS JACK
PUNCH BOARD OR PCB
METAL BOX for shielding

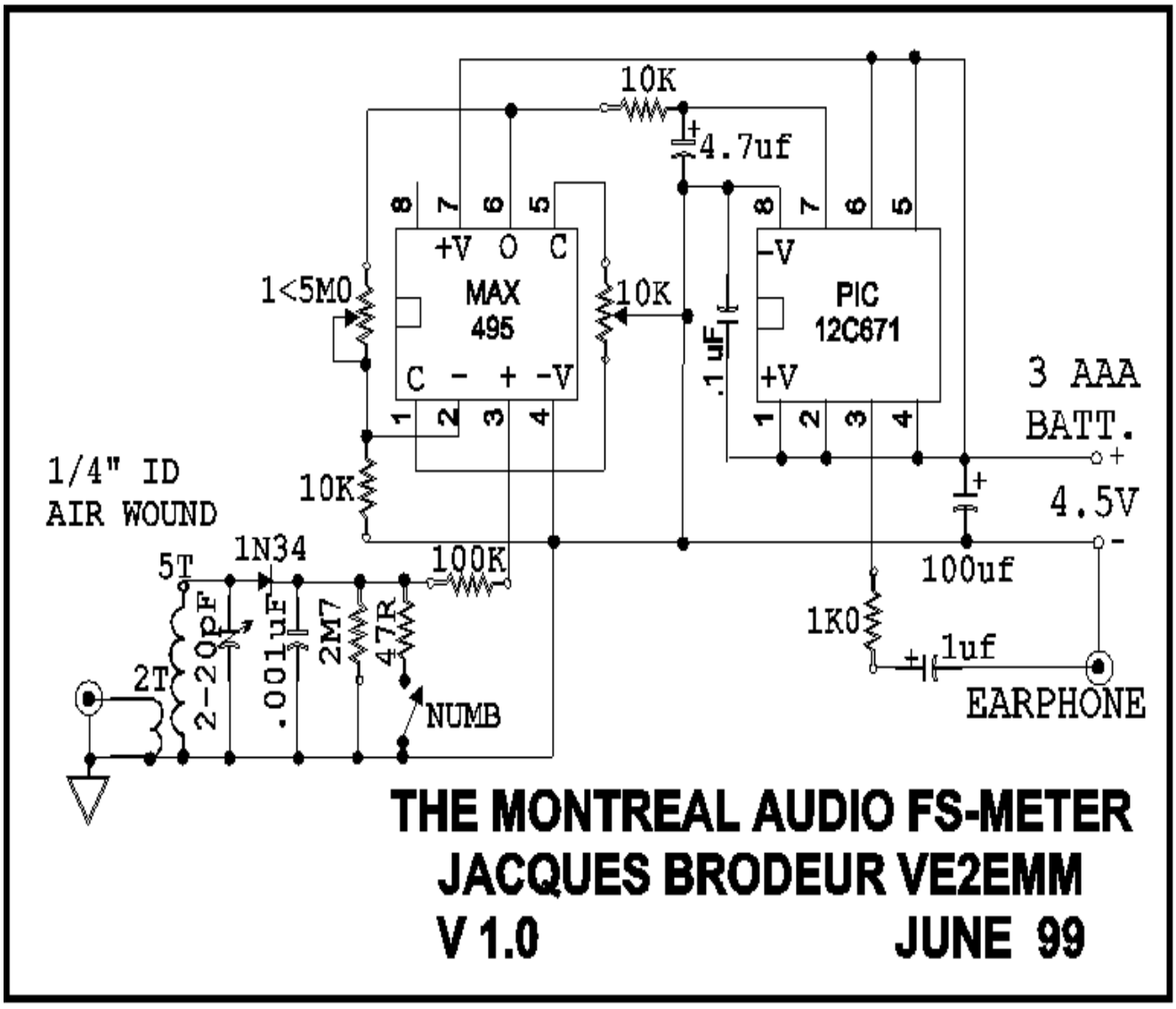
10K
4.7uf
+V O C
MAX
495
C - + -V
1<5M0
10K
.1 uF
-V
PIC
12C671
+V
3 AAA
BATT.
4.5V
1/4" ID
AIR WOUND
10K
1N34
5T
100K
100uf
1K0
1uf
2T
2-20pF
.001uF
2M7
47R
NUMB
EARPHONE
THE MONTREAL AUDIO FS-METER
JACQUES BRODEUR VE2EMM
V 1.0
JUNE 99

A Simple Crystal Radio Set

Whether you are a beginner or a seasoned expert, you would probably agree that there is nothing quite like using this simple design to make a crystal radio and enjoying it, listening to stations both near and far. Add to this the "something for nothing" advantage of not having to power this set with batteries or AC line and you can see why this simple design will be used and enjoyed for a long time to come. Almost like magic... Let' build one!

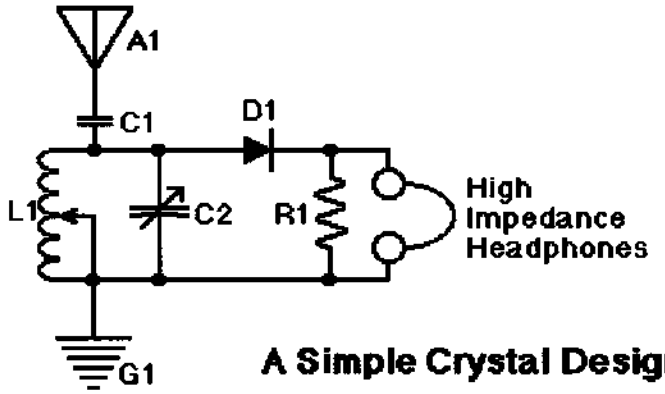

A Simple Crystal Design

Components:

- **A1- 50-100 foot longwire antenna**
- **C1 - 50 pf ceramic capacitor OSE p/n CD-5**
- **C2 - 365 pf variable capacitor OSE p/n BC14400**
- **D1 - 1N34A diode OSE p/n 1N34A**
- **G1 - Ground (see instructions below)**
- **L1 - 100 turns of #20 AWG enamel coated copper wire OSE p/n MW20, adjustable tap (see instrctions below)**
- **R1 - a 100k ohm resistor OSE p/n RQ100K**
- **Crystal Earphones OSE p/n CE748**
- **Fahnestock clips OSE p/n 2090**

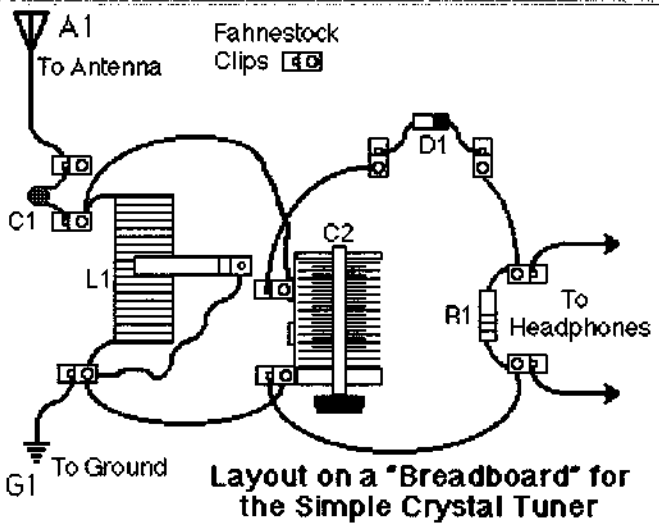

Layout on a "Breadboard" for the Simple Crystal Tuner

CHAPTER THREE

Crystal Sets

Crystal sets are simple to build and cheap! With six feet of aerial this set will pick up the BBC programmes at good strength; with fifty feet of aerial the volume is really loud. Build the set with care, remembering that reception depends entirely upon aerial and earth.

These crystal set designs are chosen as the first in our constructional series because of their simplicity and cheapness. The most popular receiver for years was the 'crystal set', the theoretical design of which was precisely the same, in effect, as that shown in Fig. 7, our first design. Those old crystal sets, however, used large coils of thick wire and detectors consisting of a piece of crystalline substance 'tickled' by a small cat's whisker, which was only a piece of thin wire wound up into a small spring. Today we use a miniature coil and a germanium diode detector.

Germanium is one of the modern metals which have been developed for industrial purposes in recent years. A small flake of it is sealed into a tiny glass tube, with its cat's-whisker contact cemented permanently into place (Fig. 6).

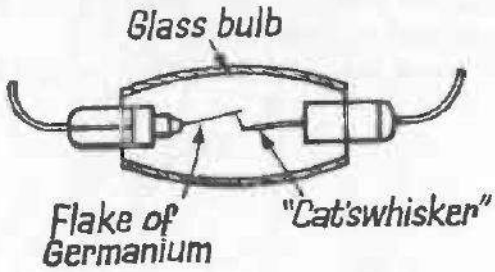

Figure 6 The Germanium Diode Detector

A crystal set has no power to amplify the signals which it receives via the aerial and the crystal detector merely converts the radio signals into currents capable of actuating the diaphragms of our headphones and producing sounds thereby.

It follows, therefore, that the strength of the sound we receive in the headphones depends on the size of the aerial we have – a larger aerial picking up 'bigger' signals – and the efficiency of the detector in converting them ('rectifying' them is the proper term) into 'sound' signals.

The germanium diode is much better as a detector in every way than the old

crystal detector and is completely stable in use. The modern crystal set, therefore, must not be confused with that of fifty years ago; it is best to discard the term 'crystal set' really in favour of 'germanium diode receiver'. The receiver in the Fig. 7 circuit is small and compact and very simple to make. With a good aerial it will give an extremely loud headphone signal from two or, possibly, three stations. It is essential to have a good aerial with a crystal set, and a good earth as well if this is possible. In North London, I could receive both the BBC Radio 2 (Light) and Radio 4 (Home) services with about 6 feet of wire. With 50 feet of aerial in the loft I could obtain Radio 1, 2, 3 and 4, with Radio 2 and 4 at extremely loud volume. The trouble then is that it is difficult to separate Radio 2 from Radio 4, and each programme has a slight background of the other.

From this you see that on medium and long waves *small aerials mean good selectivity (i.e. power to separate stations) but small signals*, whereas large aerials give large signals but poor station separation. If you live in a country district a long way

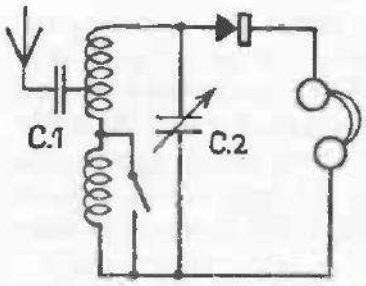

Figure 7 Crystal Set Theoretical Diagram

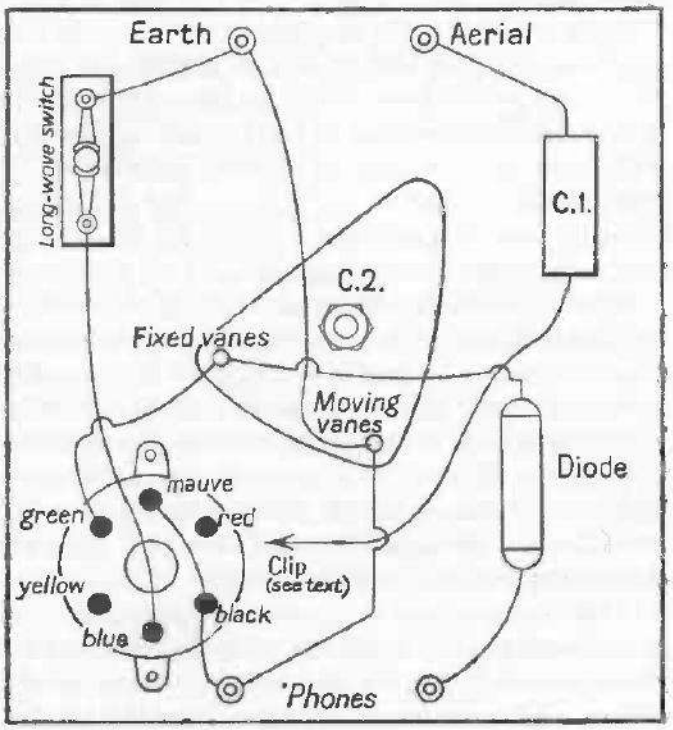

Figure 8 Crystal set Wiring Diagram

Components required:

·0005 mfd. solid dielectric variable capacitor (C.2)
On-off switch
DRR2 coil (Repanco)
·0002-mfd. fixed capacitor (C,1)
Germanium diode (Osram GEX 35 or Mullard OA 81)
4 terminals or 2 double mounts
Crocodile clip
Wood, wire, etc.
Tuning knob

from a BBC transmitter, and can erect a large aerial in the open air, you will probably get good results from the simple receiver; but if you live under twenty miles from a station for best results you need a more selective set.

Firstly, then, to build the set shown theoretically in Fig. 7 with a wiring diagram in Fig. 8, you need a piece of three-ply wood about 2½ inches square. If you have a particular box or cabinet to build the set into, and this requires a slightly larger size, it does not matter at all. You must drill holes for those components which are mounted on the panel; and these are the tuning capacitor in the centre, above and below it the 'A/E' and 'phones' terminals or terminal mounts. If you use the latter, the terminals affixed to them must protrude through holes to the other side, but terminals will automatically pass their shanks through the panel. The particular coil specified has a long-wave section and this requires an 'on-off' switch to short-circuit the long-wave section of the coil when medium waves only are required. As some of the holes may be a little larger than the drill you have available, an easy way to make them is to drill them out as large as possible and then 'reamer' them to size with the tang of a file or other tool.

After mounting those parts which require fixing to the panel, the soldering-up can be started; it will be found that remaining small items can be soldered into place and held into position by the wiring. Earlier remarks on soldering and wire to use may be referred to here, particularly the importance of clean joints made with a hot iron. Avoid 'dry joints' which look good but can be pulled apart quite easily and beware of applying a hot soldering iron for too long to the tags of components. In particular, do not let the iron get too near to the diode or remain too long on its connecting wires.

When soldering to the coil, be careful that the heat of the iron does not unsolder the wires already connected to the tags. Once the wiring has been completed and checked over, the headphones may be joined to the appropriate terminals, with aerial and earth also connected to their correct points.

Headphones must be of the 'high-resistance' type, i.e. 2000 or 4000 ohms impedance. If you have a pair of headphones which are low-resistance type, or yours are marked LR or 120 ohms, you can use them by interposing a special transformer (obtainable quite cheaply) between the set and the phones. Most dealers have these transformers.

After connecting the external apparatus, make sure the switch indicates the waveband required, that is, points *short-circuited*, cutting out the long waveband, if you want to receive on medium waves, and *open* if you want the whole coil in circuit for long-wave reception. Turn the knob slowly and you should pick up the stations available. A push-pull switch may not be available but any small on-off switch will do.

The coil specified is a Repanco DRR 2 and is really a coil with a reaction winding which is normally used in a one-valve or two-valve receiver. I have specified it for the crystal set because, in accordance with our promise of progressive set-building, it can be used for the receiver described in Chapter 4. In the design as given, using the DRR 2 coil, the 'reaction' winding is wired up so that it may be used as an aperiodic aerial winding which will give you a variation in selectivity. For this reason the lead from the aerial (through C.1) terminates in a crocodile clip.

This may be attached either to 'yellow' on the coil or 'red', in order to give the best position for the aerial in use. Try also fixing the diode to 'yellow' instead of to 'fixed vanes'.

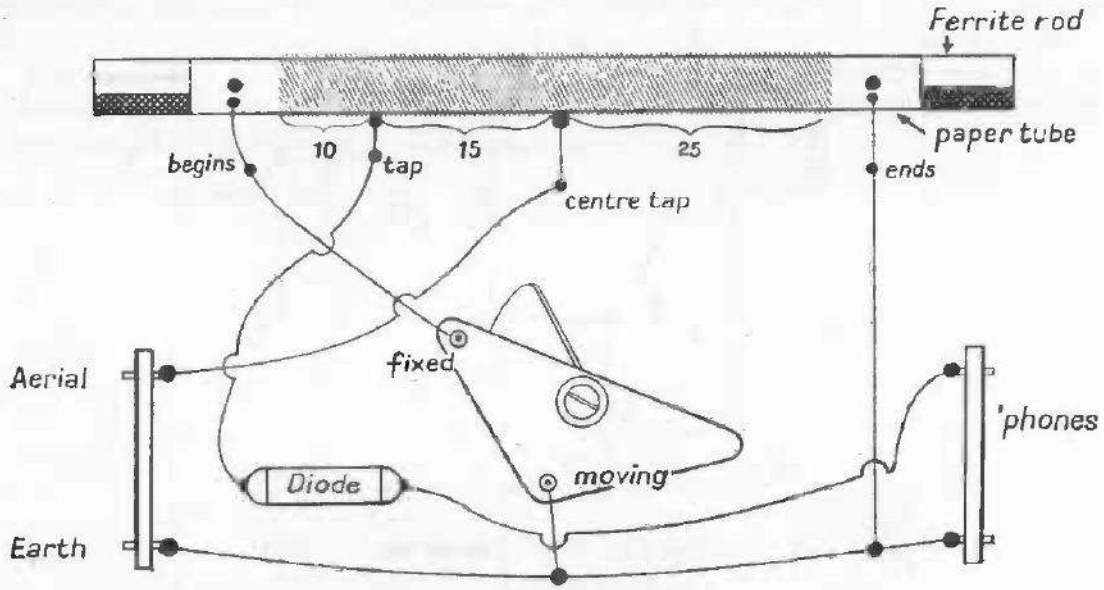

Figure 9 Crystal Set Wiring Diagram (home-made coil)

The second crystal receiver is very cheap and simple to make and uses the *BOP* coil which I first made up for use in two transistor receivers described in *Boy's Own Paper* in 1963. It is very easily wound on a ferrite rod which is 4 inches long and ¼ inch in diameter. At the end of this chapter I repeat the instructions which we gave in *BOP* for winding it. The receiver in Fig. 9 can be put together easily in any handy box and will tune medium waves only, so that if you must get your Light programme on long waves, you would do better to make the design in Fig. 8. Components for this ferrite-rod coil design should be the same as those listed below Fig. 8 except for the coil, of course, which will not be required, nor will the on-off wavechange switch or the crocodile clip. The ·0002 mfd. condenser (capacitor) will help selectivity if it is wired between the aerial terminal and centre-tap on coil. By the way, use two thicknesses of good writing paper or very thin card for making the coil. The wire should not be too close to the ferrite rod itself. You can experiment with this coil quite a lot, if you wish, by putting different windings on it. Readers have told me they have even been using it for short-wave reception in a transistor receiver by using fewer turns and adding a reaction winding. For this crystal receiver, it might be found better to use a tuning condenser of only 200 pf (i.e. ·0002 mfd.) instead of the ·0005 mfd. one specified.

If you build these crystal sets, remember that reception is *entirely* dependent upon the aerial and earth in use. If these are poor, good signals cannot be expected. *Poor signals cannot be amplified or adjusted to make them louder*. A crystal set connected to an amplifier such as the 'small high fidelity' described later makes a very satisfactory arrangement for local station reception. For 'reaching out' and

for louder signals a valve detector is required. Do not take your crystal set to pieces unless you have no alternative. The next design shown in Fig. 10 uses the large home-made coil of Fig. 4.

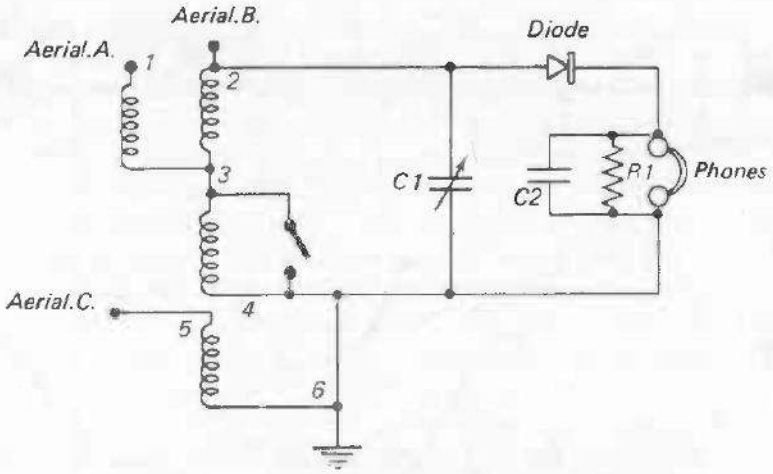

Figure 10 Diode 'Crystal Set'

Components required:
Coil: see text (home made type)
C.1. ·0005 mfd variable capacitor
C.2. ·001 mfd fixed capacitor
Diode: any suitable of good quality
R.1.: 1000 ohm resistor
Phones, wire, wood, etc.

The crystal set shown in Fig. 10 is very simple to make. Fix your coil on a small piece of wood in the manner shown. On one side of that piece of wood fix a small panel on which are mounted the tuning capacitor and two small terminals or a socket strip for phones. Also required will be a small on-off switch for wavechanging. Connect 2 on the coil to one side of diode and fixed plates on the tuning capacitor. Other side of diode to phones. Other side of phones to 4 on coil and 4 on coil also goes to one side of on-off switch plus 6 on coil and moving plates on capacitor. Other side of on-off switch to 3 on coil. Across the phones terminals connect a ·001 mfd. capacitor and if you are using a crystal earpiece you will also need a 1kΩ resistor there. For ordinary headphones (high-resistance) no resistor is needed. The aerial can be attached to a 'crocodile' clip and tried for best results on 1, 2 or 5 on coil. Earth can be clipped to 4 or 6, or you can add two more terminals to the panel for A & E. Your set should now work well and, having fixed a small knob to the shaft of the capacitor, you can tune in the available stations.

Figures 11 and 12 are rather special crystal set designs and I am indebted to Messrs Reparco Ltd, whose copyright designs they are, for allowing me to use them here. The coil featured is the DRR2 which they make and the first circuit is for a headphone crystal receiver which uses 2 diodes and 1½ volt cell. It is rather

CHAPTER 2

Crystal Sets

Crystal sets are simple to build and *cheap! With six feet of aerial this set will pick up the BBC programmes at good strength; with fifty feet of aerial the volume is really loud. Build the set with care, remembering that reception depends* entirely *upon aerial and earth.*

THESE Crystal Set designs are chosen as the first in our constructional series because of their simplicity and cheapness. The most popular receiver for years was the 'crystal set', the theoretical design of which was precisely the same, in effect, as that shown in Fig 4, our first design. Those old crystal sets, however, used large coils of thick wire and detectors consisting of a piece of crystalline substance 'tickled' by a small cat's-whisker, which was only a piece of thin wire wound up into a small spring. To-day we use a miniature coil with a dust-iron core and a germanium diode detector.

Germanium is one of the modern metals which have been developed for industrial purposes in recent years, and is actually processed from soot-scrapings obtained from certain factory chimneys! A small flake of it is sealed into a tiny glass tube with its cat's-whisker contact cemented permanently into place (Fig. 3).

A crystal set has no power to amplify

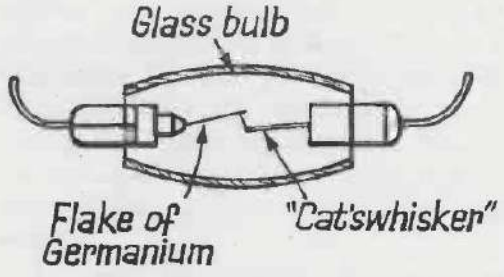

Fig. 3. The Germanium Diode Detector

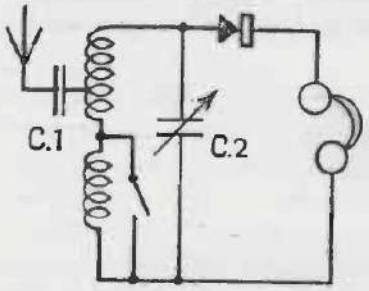

Fig. 4 Crystal Set Theoretical Diagram

the signals which it receives via the aerial and the crystal detector merely converts the radio signals into currents capable of actuating the diaphragms of our headphones and producing sounds thereby.

It follows, therefore, that the strength of the sound we receive in the headphones depends on the size of the aerial we have—a larger aerial picking up 'bigger' signals—and the efficiency of the detector in converting them ('rectifying' them is the proper term) into 'sound' signals.

The germanium diode is much better as a detector in every way than the old crystal detector and is completely stable in use. The modern crystal set, therefore, must not be confused with that of thirty years ago; it is best to discard the term 'crystal set' really in favour of 'germanium diode receiver'. The receiver in Fig. 4 circuit is small and compact and very simple to make. With a good aerial it will give an extremely loud headphone signal from two or, possibly, three stations. It is

essential to have a good aerial with a crystal set, and a good earth as well if this is possible. At my own home, which is ten miles from the BBC (Brookmans Park) transmitters in North London, I can receive both the BBC Home and Light service with about 6 feet of wire. With 50 feet of aerial in the loft I can obtain Home, Light and Third, the first two at extremely loud volume. The trouble then is that it is difficult to separate Home from Light, and each programme has a slight background of the other.

* * *

From this you see that on medium and long waves *small aerials mean good selectivity* (*i.e. power to separate stations*) *but small signals,* whereas large aerials give large signals but poor station separation. If you live in a country district a long way from a BBC transmitter, and can erect a large aerial in the open air, you will probably get good results from the simple receiver; but, if, like me, you live under twenty miles from a station, for best results you need the more selective set shown in our second design.

Firstly, then, to build the set shown theoretically in Fig. 4 with a wiring diagram in Fig. 5, you need a piece of three-ply wood about 2½ inches square. If you have a particular box or cabinet to build the set into, and this requires a slightly larger size, it does not matter at all. You must drill holes for those components which are mounted on the panel; and these are the tuning capacitor in the centre, above and below it the 'A/E' and 'Phones' terminals or terminal mounts. If you use the latter the terminals affixed to them must protrude through holes to the other side, but terminals will automatically pass their shanks through the panel. The particular coil specified has a long-wave section and this requires an 'on-off' switch to

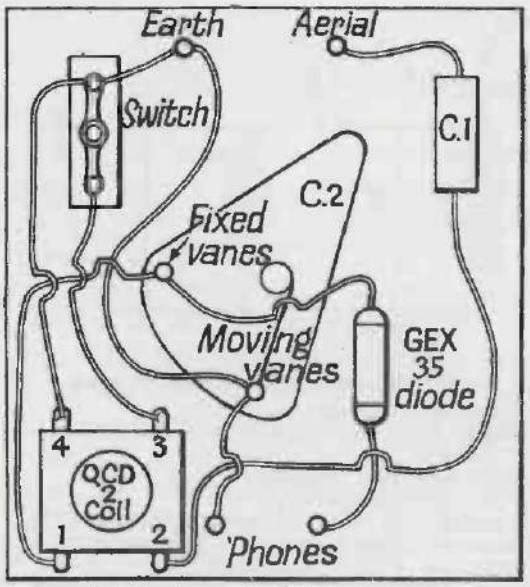

Fig. 5. Crystal Set Wiring Diagram

Components required:
·0005 mfd. solid dielectric variable capacitor (C.2)
On-off switch
QCD 2 Coil (Osmor)
·0002 mfd. fixed capacitor (C.1.)
Germanium diode (Osram GEX 35 or Mullard OA 60)
4 terminals or 2 double mounts
Wood, wire, etc.
Tuning knob
For better selectivity Teletron HAX coil can be used. Connections are given with coil.

short-circuit the long-wave section of the coil when medium waves only are required. As some of the holes may be a little larger than the drill you have available an easy way to make them is to drill them out as large as possible and then 'reamer' them to size with the tang of a file or other tool.

After mounting those parts which require fixing to the panel, the soldering-up can be started; it will be found that remaining small items can be soldered into place and held into position by the wiring. Earlier remarks on soldering and wire to use may be referred to here, particularly the importance of clean joints made with a hot iron. Avoid 'dry' joints which look good but can be pulled apart quite easily and beware of applying a hot soldering iron for too long to the tags of components. In particular do not let the iron get too

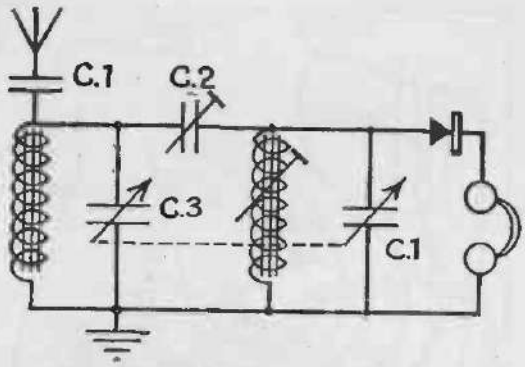

Fig. 6 Crystal Set Theoretical Diagram

Components required:
Midget ·0005 mfd. variable capacitor (C.3/4) dual gang
·00005 mfd. fixed capacitor (C.1)
2 Teletron Coils type BA 2
50 mmfd. (i.e., ·00005 mf.) variable trimmer (C.2)
Germanium diode (Osram GEX 35 or Mullard OA 60)
4 terminals or 2 terminal mounts
Knob or small dial

near to the diode or remain too long on its connecting wires.

When soldering to the coil be careful that the heat of the iron does not un-solder the wires already connected to the tags. Once the wiring has been completed and checked over, the headphones may be joined to the appropriate terminals, with aerial and earth also connected to their correct points.

Headphones must be of the 'high resistance' type, i.e. 2000 or 4000 ohms impedance. If you have bought a pair of Government surplus 'phones which are low-resistance type, or yours are marked LR or 120 ohms, you can use them by interposing a special transformer (obtainable quite cheaply) between the set and the 'phones. Most dealers have these transformers.

After connecting the external apparatus, make sure the switch indicates the waveband required, that is, points *short-circuited*, cutting out the long waveband, if you want to receive on medium waves, and *open* if you want the whole coil in circuit for long-wave reception. Turn the knob slowly and you should pick up the stations available.

The selective receiver in my next design is shown theoretically in Fig. 6, and fully wired in Fig. 7. It costs a little more than the set just described, but if a large aerial is available is well worth having because of the large signal the aerial brings in, which

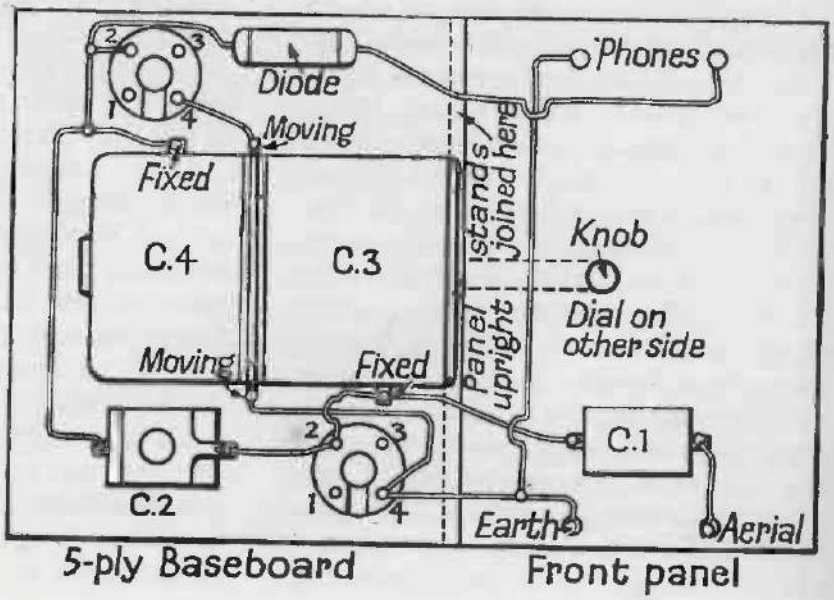

Fig. 7 Crystal Set Wiring Diagram

FREE-POWER AM RECEIVER (P,E)

This project uses a strange way to get its power. It uses power "extracted" from the tuned station to give to the amplifier transistor. With a reasonably strong applied modulation envelope, this type of detector produces a strong demodulated output.

Naturally, the closer you are to a strong station, the more current your radio will be able to supply.

For best results, you must do everything possible to deliver a strong signal to the transistor detector. We recommend a good antenna and ground, the latter preferably being made to a water pipe or solid external ground composed of a pipe driven at least 5 feet into moist earth. This is important for ensuring maximum signal pickup.

If you have plenty of space available, the longer the antenna (up to about 100 feet), the better the results.

Figure 1 shows the schematic diagram of the Free-Power AM receiver. Observe that the heart of the circuit is a germanium transistor that works as a detector and audio amplifier.

Components placement on a terminal strip used as a chassis is shown in ***Figure 2.*** The terminal strip can be fixed on an experiment board that can be constructed using some common tools and materials.

Q1 is any germanium transistor, such as GE-2 or 2N107. You can find germanium transistors in old nonworking AM transistor radio receivers. Nonworking AM radios can also supply the variable capacitor and the loopstick (ferrite rod).

Earphone must be a high-impedance crystal type. Low-impedance earphones don't function in this circuit.

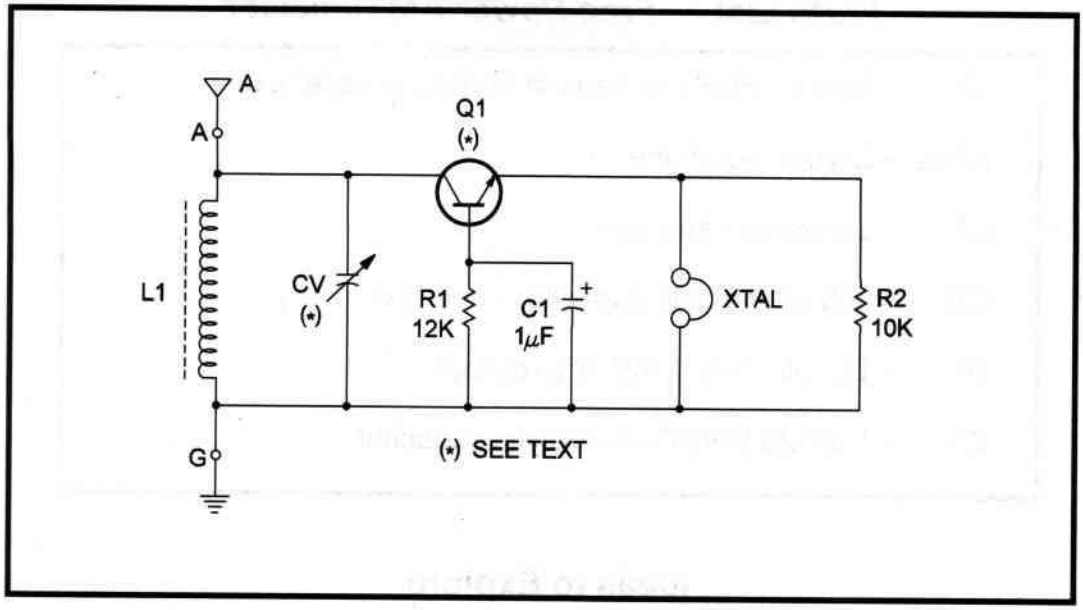

Figure 1

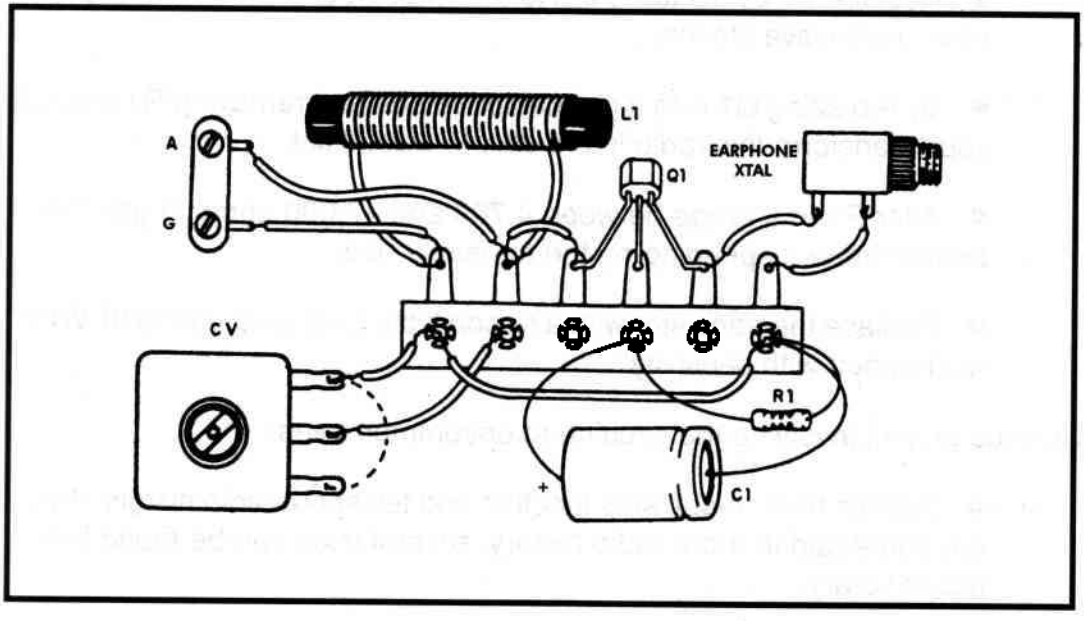

Figure 2

Parts List — Free-Power AM Receiver

Q1	- NPN or PNP germanium transistor - see text
XTAL	- Crystal earphone
L1	- Loopstick - see text
CV	- 365 pF variable capacitor - see text
R1	- 12,000 ohm, 1/4W, 5% resistor
C1	- 1 uF, 25 WVDC electrolytic capacitor

Ideas to Explore

To learn more about the circuit:

- Replace L1 by 15 turns of No. 28 wire, wound on a ferrite rod, to tune short-wave stations.
- By replacing Q1 with a germanium diode and removing R1 and C1 you'll transform this radio into a simple crystal set.
- Alter R1 in a range between 4,700 and 47,000 ohms to get better performance, depending on the transistor used.
- Replace the transistor with a silicon type, such as the BC548. What will happen with sensivity?

Science project involving the circuit and uncommon uses:

- Explain how crystal sets function and tell about radio history. If you are interested in more radio history, several texts can be found in the public library.
- If you want to learn more about radio receivers, try to find information about heterodyne and super-hereterodyne types.

Benjamin and David Goldenberg's Very-Fine Old-time Crystal Radio

Parts List:

Item	Qty.
PVC pipe, 1" outside diameter (3/4” size) x 4" long	1
Aluminum or steel sheet metal, 0.5” wide x 5” long	1
Coil wire (#24 magnet wire)	36 ft
Hook-up wire (#22)	25 ft
Crystal earphone (GC electronics, cat. no. 30-5302)	1
Jack for the earphone plug	1
Crystal diode (1N34A)	1
Capacitor, 470 picofarad	1
#8 sheet metal screws	8
8-32 machine screw, 1" long	1
8-32 nuts	2
flat washers	6
Ring terminal	1
Board, 3/4" thick, approximately 7" x 9"	1

What else you need:

Vise-Grip pliers
Wire cutters
Soldering iron and solder
Drill, with 1/8", 3/16” and 3/8” bits
File or motorized grinder (e.g. Moto-Tool)
Screwdriver
Scotch tape

Instructions

I. CONSTRUCTION OF SPECIAL PARTS.

The following steps involve making a few special parts for the radio. Some of these steps are most easily performed using power tools and some involve soldering. This work should be done by someone old enough and knowledgeable enough to handle these tools safely. Once these parts are made, however, the rest of the project requires only hand tools and can be completed by nearly anyone.

1. Coil Form

The coil form is a piece of PVC pipe, 1” in diameter (outside) and 4” long. (For reasons fully understood only by plumbers, pipe of this diameter is referred to as 3/4”.)

To facilitate mounting the coil to the board, drill two sets of holes, on opposite sides of the form. On one side of the form, drill two holes, 3/16" in diameter and 3/8" from the ends. Directly opposite from these holes, drill two more holes 3/8" in diameter. Screws will be placed through the smaller holes, while the larger ones make it easy to reach the screws with a screwdriver.

2. Slider

Drill two 3/16" holes in the piece of sheet metal, each 1/4" from an end. After the holes are drilled, place a bend in the metal 3/4" from each end, as shown in the figure on page 3. Use a vise or pliers to bend the metal. Use a file to smooth all of the edges and corners of the metal.

CAUTION: Drilling sheet metal can be very dangerous! If the bit catches on the metal, you can have a very sharp edge flying through your hands. Hold the metal firmly with a pair of pliers (preferably Vice-Grip type), not with your hands! Also, place a piece of wood under the metal as you drill. This will help keep the metal from tearing and grabbing the bit as the passes through.

3. Pointed screw for slider

Using either a file or a grinder, grind a point on the 8-32 machine screw. The point doesn't need to be very sharp; about like the tip of a medium ball-point pen is ideal.

4. Earphone jack with wires.

Cut two pieces of hook-up wire 2" long. Remove 1/4" of insulation form one end of each wire and solder the wires to the terminals of the earphone jack. Remove 1/2" of insulation from the other ends of the wires.

Note: Headphone jacks often have more than two terminals. Make sure that the terminals you solder to are the ones that will be connected to the tip and side of the plug when it is inserted.

5. Ring terminal with two wires.

Cut two pieces of hook-up wire, one 7" long and the other 2". Remove 1/4" of insulation from one end of each wire. Solder the two wires to the ring terminal. Remove 1/2" of insulation from the other ends of the wires.

6. Board

Tape the layout template (the last page of this document) to a board, approximately 7" x 9", and drill a 1/8" hole at each position marked with a cross.

II. ASSEMBLY

1. Wind the coil.

The coil is made by wrapping the #24 magnet wire onto the coil form, which is made from a piece of PVC pipe. The magnet wire is the wire that looks like it has no plastic insulation on it. But, it is actually coated with a thin layer of enamel. This coating must be removed from the ends of the wire before making any connections.

The best way to wind the coil is with two people, one to hold the wire taught (the holder) and the other to wind it onto the coil form (the wrapper). First, thread the end of the coil wire from the outside of the form through one of the large holes and out the end of the form. Leave about 4" of wire going out the end. Hold onto the other end of the wire and begin wrapping it around the form, starting right next to the hole. After you have wound a few turns on, push the wire together so it is nice and neat and put a piece of Scotch tape over it. The coil should look like this:

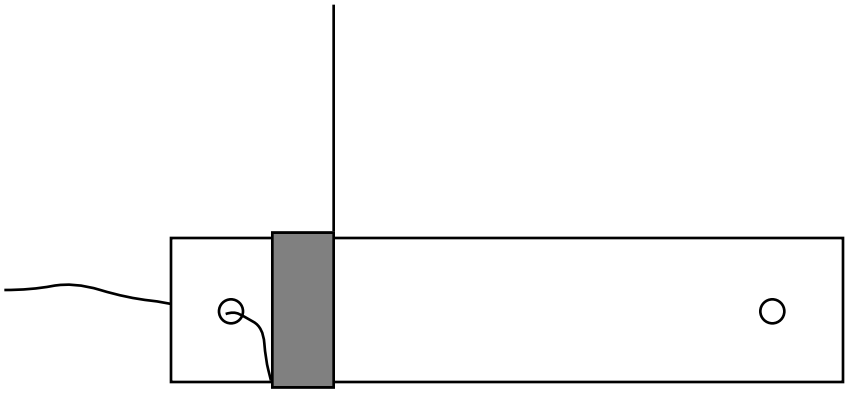

Now, the "holder" should hold the spool of wire loosely while the "wrapper" walks across the room unwinding the wire. Then, the holder should hold the spool very tightly so that the wrapper can wind the wire onto the pipe evenly. Each turn should be wrapped on right next to the previous turn, but shouldn't overlap. As the wire is wrapped on, the wrapper slowly walks across the room keeping the wire tight. When the wrapper reaches the holder, hold the wire that has been wrapped onto the form tightly, while the holder lets the wire on the spool unwrap. The wrapper then walks back across the room unwinding the wire from the spool, and the same procedure is repeated.

When the coil is within about 1/8" of the holes at the other end of the coil, stop winding. Put a piece of Scotch tape on the end of the wrapping, and cut the wire a few inches from the end of the coil. Thread the end of the wire through the large hole in the form.

2. Attach the coil to the board.

Use two of the #8 sheet metal screws to attach the coil to the board, using holes B and C that you drilled. Place the screws through the small holes in the coil form from the inside. You can then use the large holes on the other side of the form to reach the screws with a screwdriver. Make sure the coil is attached snugly to the board.

3. Assemble the slider.

Find the slider, the 8-32 screw and the two 8-32 nuts. Thread one of the nuts onto the screw until it is about 3/8" from the head of the screw. Put the screw through one of the holes in the slider and thread the other nut on, so that the slider looks like this from the side:

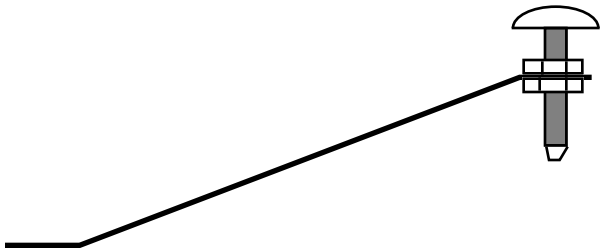

Tighten the second nut against the slider and the first nut with a wrench.

4. Attach the slider to the board.

Find a sheet metal screw, a washer and the ring terminal with two wires attached to it. Put the screw through the ring terminal, the washer and finally the open hole in the slider assembly (from the top of the slider as shown above). Attach the entire assembly to the board with the screw at hole E. Tighten the screw so that it is snug but still allows the slider to move back and forth. The pointed end of the machine screw at the other end of the slider should press firmly against the wire on the coil. If necessary bend the slider so that it makes firm contact with the coil but can still move.

Move the slider back and forth on the coil to scrape the enamel insulation from the coil wire where the pointed end of the machine screw touches it. The screw should be able to make an electrical contact with the coil wire at any position along the length of the coil.

5. Put the remaining screws in the board.

Screw the remaining sheet metal screws into holes A, D, F, G and H, with a washer on each screw. Do not tighten the screws yet.

6. Wire the components of the radio together.

Use the circuit drawing as a guide. For each connection, make sure that the insulation is removed from the end of the wire. Wrap the bare ends of the wires around the screw between the screw head and the washer underneath.

a. Wrap the two wires from the earphone jack around screws F and H. Do not tighten these screws yet.

b. Take the short wire from the slider and wrap the bare end around screw F (which should already be attached to one of the earphone jack wires). Do not tighten the screw yet.

c. Take the long wire from the slider and wrap the bare end around screw A. Do not tighten this screw yet.

d. Find the crystal diode, the small cylinder with two bare wires attached to it. Wrap one of the wires around screw H (attached to the other earphone jack wire), and tighten the screw.

e. Take the other wire from the diode and wrap it around screw G. Do not tighten this screw yet.

f. Find the capacitor, the small disc with two bare wires attached to it. Wrap one of the wires around screw F and tighten the screw.

g. Wrap the other wire from the capacitor around screw G, but do not tighten this screw yet.

h. Cut a piece of hook up wire about 6" long and remove about 1/2" of insulation from each end. Wrap one end around screw G and tighten the screw. Wrap the other end of the wire around screw D, but do not tighten this screw yet.

i. Take the wire from the right hand end of the coil and remove the insulation from about 1/2" from the end of the wire. To remove the insulation, either lightly scrape the wire with a knife or use a small piece of sandpaper. Wrap the bare end of the wire around screw D, but do not tighten the screw yet.

7. Connect the radio to ground.

In order to work, the crystal radio must be wired to a good ground connection. Often, the easiest way to make a ground connection is to use the grounding circuit for the house's electrical system. Cut a piece of hook-up wire long enough to reach from the radio to a nearby electrical outlet. Remove 1/2" of insulation from each end of the wire. Wrap one end around screw A of the radio and tighten the screw. On the electrical outlet, loosen the screw that holds the plate on the box. Wrap the other end of the wire around this screw and tighten it.

CAUTION: Be sure not to let the wire or anything else touch the 120 V socket!

Alternatively, you can use a cold water pipe to connect the radio to ground. Remove a few inches of insulation from the wire from screw A of the radio and wrap the bare end around a cold water pipe.

8. Connect an antenna to the radio.

Use the rest of the hook-up wire to make an antenna. Remove 1/2" of insulation from one end of the wire and wrap it around screw D. Tighten the screw. Unwind the wire from the spool and try to place it as high as possible in the room.

In areas with many powerful radio stations nearby, an inside antenna should be adequate to receive a few stations. If you have trouble hearing anything, it may help to

set up a long outside antenna. Radio Shack sells a kit with the necessary wire and other parts (cat. no. 278-758).

9. Try the radio!

Plug the earphone into the jack. Listen to the earphone and slowly move the slider across the coil. Try to find the position where a station is loudest. You should be able to hear a few different stations with the slider at different positions.

10. If the radio doesn't work, check the following:

a. Make sure all of the connections are correct and that the insulation has been removed from the wires where they are wrapped around screws. Also check that there aren't any short circuits between the screws or bare wires.

b. Make sure that you scraped the insulation from the coil wire with the slider so that the slider can make good contact with the coil.

c. Make sure that you have a good ground connection. Try a different electrical outlet or a cold water pipe.

d. Place the antenna higher up or try a longer wire.

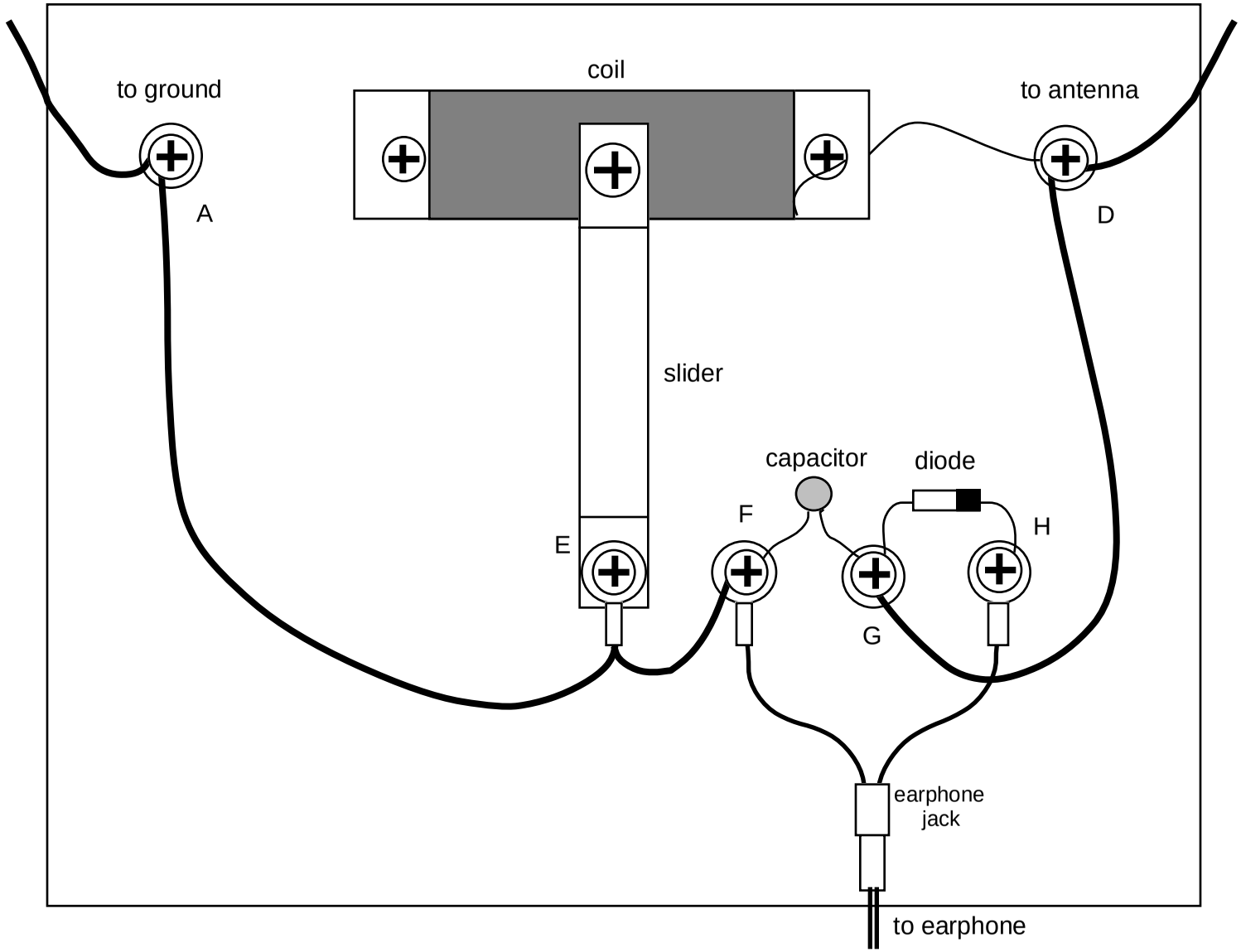
to ground
A
coil
to antenna
D
slider
E
capacitor
diode
F
H
G
earphone
jack
to earphone

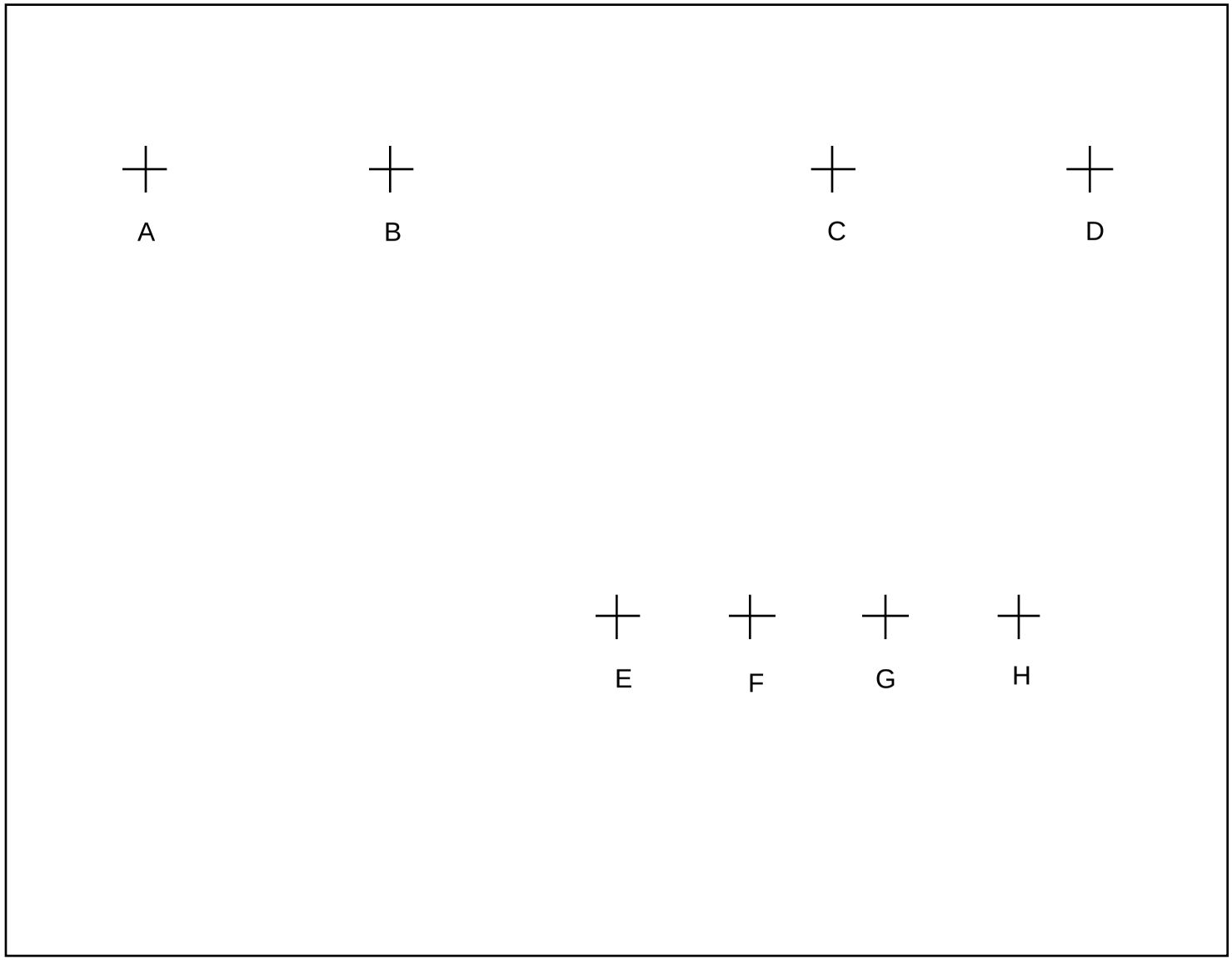
A
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C
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H

Electronic Projects for Beginners

F. G. RAYER, T.Eng. (CEI), Assoc. IERE

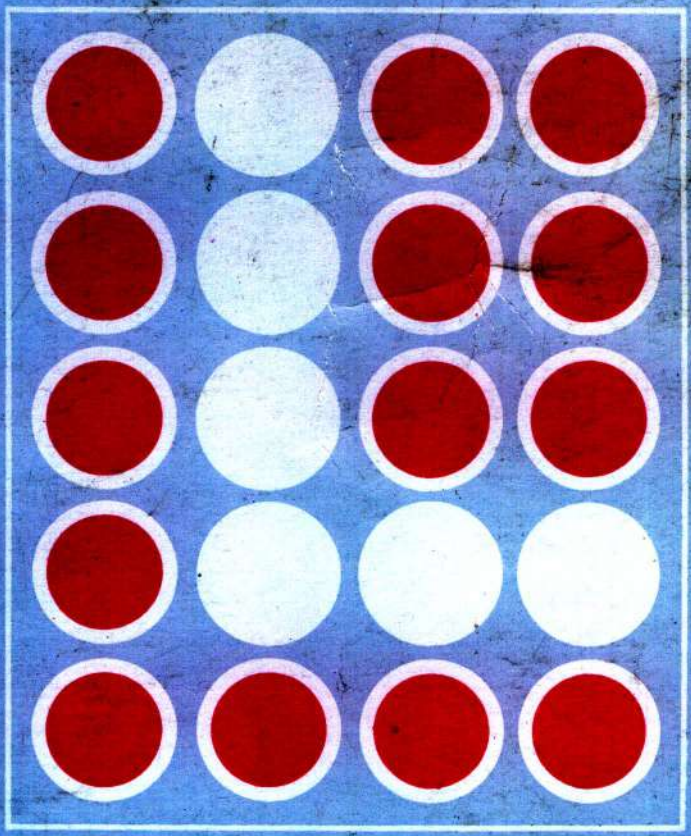

speaker SP2. SP1 then acts as a microphone, and sounds are reproduced in SP2.

With the switch in the opposite position, S1A selects SP2 as microphone, and amplified signals pass via S1B to SP1, so that speech can be in the other direction.

The switch, amplifier, battery and SP2 are assembled as the master control unit, and twin leads run to SP1. The person at SP1 should say "Over" so that the other person can operate the switch, and he in turn should say "Over" to signify that SP1 is again acting as microphone.

A simplified home-made change over switch is shown in Fig. 5. This is two strips of metal, pivoted so that they can be swung from side to side, and bearing on two of the three round-headed screws. A strip of insulating material is fitted so that both strips move together. In Fig. 5, this switch is in its "Off" position.

Ready made 2-pole 2-way switches can be obtained and used instead (see Fig. 49). Spring-loaded push switches are also available, and can be wired to provide "press to talk". A switch without a central "Off" position can also be used, a single pole on-off switch then being added in one battery connection.

The master unit can call SP1 by switching to speak, and allowing SP2 to be used as microphone. If calling in the other direction is required, a third connection, with bell push, battery and buzzer can be used. (An alternative, requiring more circuitry, but avoiding the need for a third wire, will be found in "Two Transistor Electronic Projects", (BP30, Babani Press.)

Fig. 5B shows assembly of the intercom in a wooden case. A 3½ inch speaker is suitable, so the whole can be quite a compact unit. The home-constructed switch, using the bolts below the speaker, can be replaced by a ready-made switch, as described, if preferred.

Best results are obtained with speaker units of quite high impedance – say 45 ohm to 75 ohm or so. The few other components are assembled on a small insulated board, as for earlier circuits.

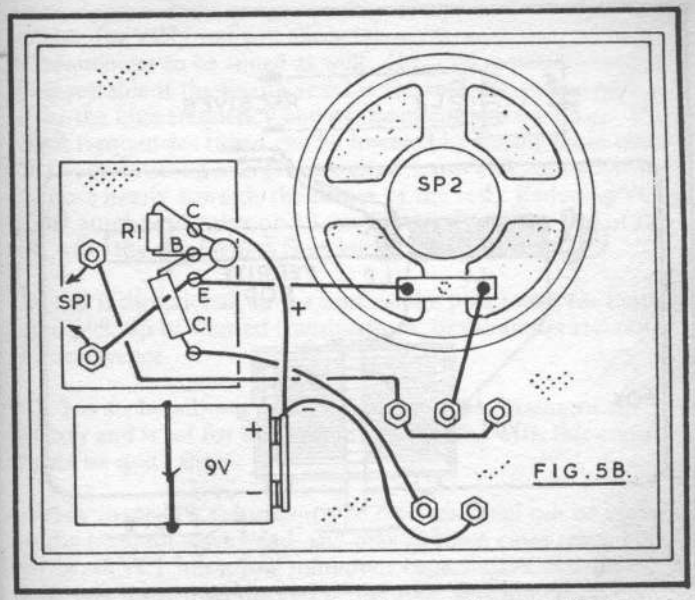

FIG.5B.

The speaker at the remote point also requires a small case. Dimensions are not important, and it is possible to utilise plastic boxes of suitable type for each unit. Connections between units are by twin bell wire, or any similar twin conductor. With a transistor of other than the type shown, the value of R1 can be chosen to give maximum amplification.

Tuned Ferrite Aerial

This simple device will allow "portable" reception with the old type of receiver which normally requires an external aerial, and it can also give improved reception in terms of freedom from interference on the 160 metre amateur band and adjacent frequencies. As shown in Fig. 6, it consists of a tuned circuit with ferrite rod, and a coupling winding to connect to the receiver aerial and earth sockets. It will be found very useful with a communications type receiver, where a long extended outdoor or similar aerial results in a high level of noise and interference.

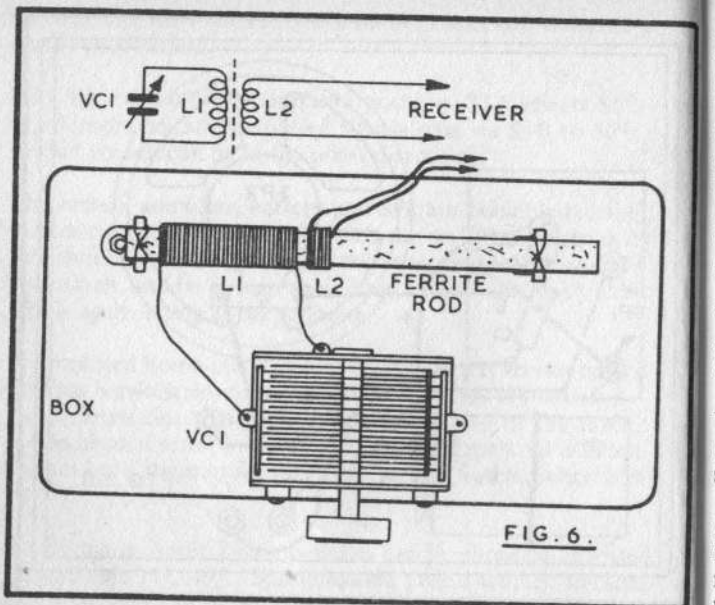

FIG. 6.

The device is constructed in a plastic lunch box about 6 x 4 x 4 inch or other *insulated* case. Some boxes of this kind, though strong, are of brittle material. These must be drilled without too much pressure, or they may crack. Drill points should also be sharp.

The rod is 6 inch long and 3/8 inch in diameter, and it is supported by two strips of insulating material, which are fixed with brackets. Each strip has a V-shaped notch, so that the rod can be held with thin string. L1 is the tuned winding, and it had sixty turns of 24 swg enamelled wire, side by side. Connections can be made to the frame (moving plates) and fixed plates of the capacitor VC1 by means of small bolts, or may be lightly twisted.

L2 is the coupling winding. Many communications type receivers have a low impedance input circuit, and twelve turns will be adequate for L2. The same wire can be used as for L1. With other receivers it may be worth while to experiment with the number of turns on L2, for best reception.

An air-spaced single gang capacitor of about 315pF is most suitable for VC1, and will allow the usual medium wave band of frequencies to be tuned as well. However, a smaller capacitor is suitable if the ferrite aerial is for 160m reception only, or for the high frequency end of the medium wave band. The actual frequencies tuned can be lowered by having more turns for L1, or by using a larger capacitance for VC1, or by having L1 more nearly towards the centre of the rod. Reducing VC1, or the number of turns on L1, or moving L1 to the end of the rod, will raise the highest frequency tuned.

The rod is directional, so the unit can be positioned for best signal pick up of wanted transmissions, or minimum reception of interference.

VC1 has to be adjusted in conjunction with tuning of the receiver and is set for best reception. Tuning with this control should be quite sharp.

A ready made MW transistor type receiver aerial can be useful for the medium wave band, and may in some cases reach 160 metres, if VC1 has a low minimum capacitance, and the winding is quite near the end of the rod. But should tuning not reach a high enough frequency, some turns will have to be removed.

Diode Radio

A lot of interest can be obtained from a diode radio receiver. It requires few components, no battery or other supply, and can give good headphone reception of a few of the more powerful transmitters. It can also be used as a tuner, as shown later, and will provide excellent audio quality for local station reception.

The circuit in Fig. 7 is intended for medium wave reception. That is, from about 200 metres to 500 metres, or 1500 kilohertz to 600 kilohertz.

The coil L1 is tuned by the variable capacitor VC1. At resonance with the wanted transmission, a signal voltage is developed across the coil. Detection or demodulation by the diode D1 allows the audio component of the signal to be

recovered, and taken to the phones or to an amplifier. Such "crystal sets" were used in very many homes, in the early days of radio.

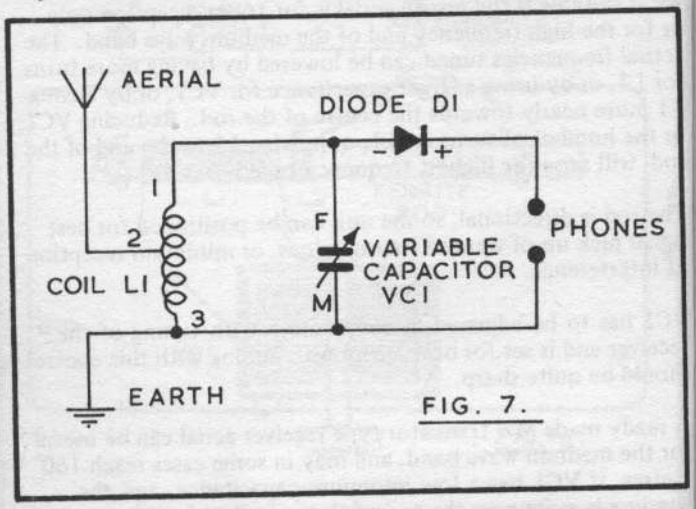

FIG. 7.

Fig. 7B shows the practical layout. It is convenient to use an insulated board larger than necessary, so that a transistor amplifier can be added later. A board about 5 x 8 inch is suggested, and it can be supported on 1 inch high runners (strips of wood) so that there is clearance for screws or terminals.

Coil L1 is wound with 26swg or similar wire, and has seventy turns, side by side. Secure the wire by passing it through two small holes, wind on about thirty five turns, and form a loop. Continue to wind in the same direction for a further thirty five turns, cut off the wire, and secure the end through two holes. The tube used can be 1½ inch to 2 inch in diameter, and can be paxolin, or can be made by winding thin card round a suitable object, smearing a little adhesive on to form a tube.

Point 1, the beginning of the coil, is taken to the fixed plates tag F of the variable capacitor, which is also connected to diode D1. The tapping 2 goes to the aerial terminal. End 3 is

taken to the moving plates connection or metal frame of the capacitor. Ends 1 and 2, and loop 3, are left long enough to reach these points, and the insulation is carefully scraped off the wire where connections are to be made. The capacitor VC1 can best be about 500pF, but this exact value is not essential.

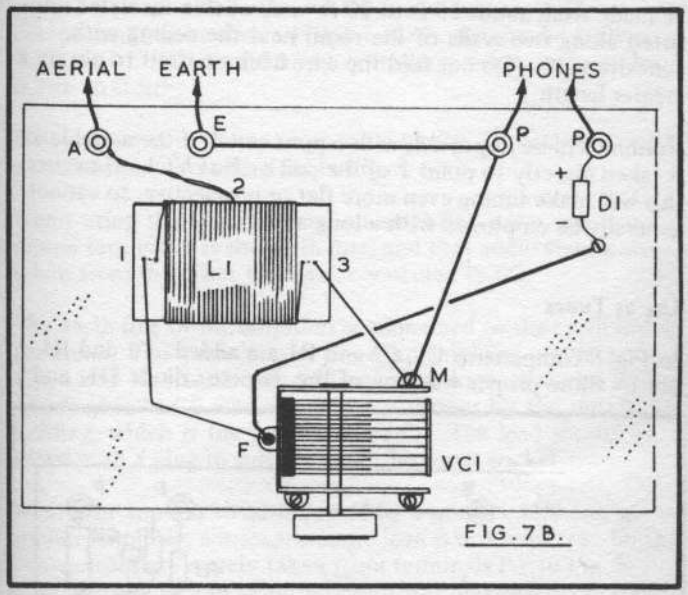

FIG. 7B.

Four terminals, for Aerial, Earth, and Phones, will complete the receiver. Best results will be had by connecting a good headset, of about 500 ohm to 2,000 ohm. Very low impedance earpieces, such as are employed with some transistor receivers, are not suitable here.

With a simple receiver of this kind it is necessary to employ a reasonably effective aerial and earth. Only in some circumstances will volume be great enough with no earth, or with a short aerial. The earth connection can be taken to a metal spike in the ground, or to a metal object buried in soil, or to any other available earth other than a mains circuit earth. (No connection must be made to any mains plug or other mains circuit.) A cold water pipe may provide a good earth. Gas pipes should not be used.

For the aerial, a length of aerial wire some 30 ft to 75 ft or so in all may form the aerial itself and lead-in. If this can be suspended quite high, and clear of buildings or earthed objects, signal strength will be improved. However, satisfactory reception may be obtained from an indoor aerial, or shorter aerial, if a good earth is present. A simple indoor aerial can be made from about 15 ft to 20 ft or so of thin insulated wire, fitted along two walls of the room near the ceiling with adhesive tape. (Do not fold the wire back on itself to obtain a greater length.)

Volume will be improved, with a poor aerial, if the aerial lead is taken directly to point 1 of the coil or F at VC1. However, this will make tuning even more flat or unselective, so cannot generally be employed with a long aerial.

Use as Tuner

In Fig. 8 components C1, C2 and R1 are added. C1 and R1 are to allow proper working of the detector diode D1, and

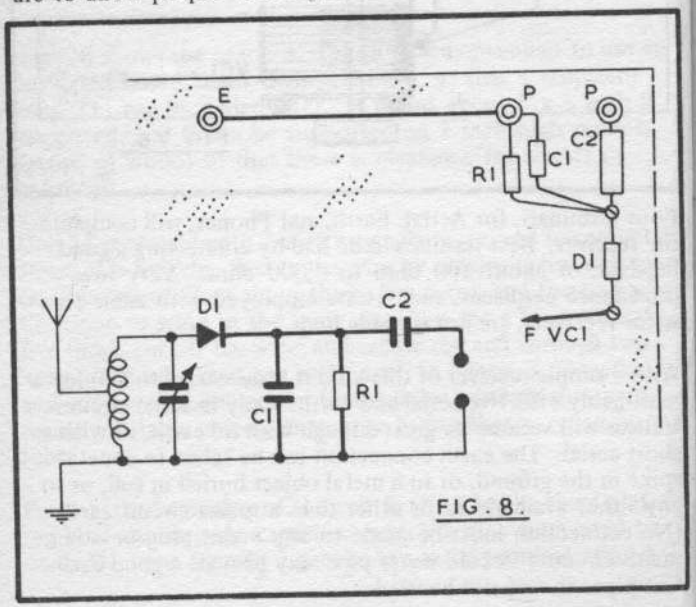

FIG. 8.

may be considered as replacing the headphones. C2 is a coupling capacitor passing audio signals to the following amplifier.

As with the previous circuit, any general purpose detection type diode is satisfactory for D1, such as the OA91 and many similar devices. The value of C1 is not critical, and this component can be about 470pF or 1nF. R1 can be 100k to 220k or so. C2 should be of quite large value, and can be 0.1μF to 0.5μF.

D1 can be moved from the position in Fig. 7B, and the few extra components added, as in Fig. 8.

When using the tuner to feed an amplifier, note that one phone terminal P is the earth line, and that audio signals are taken from the other terminal, connected to C2.

The earth line of the amplifier is connected to the earth line of the tuner. For a sensitive or powerful amplifier, a screened audio lead is recommended. This has an inner screened lead, which goes to C2, and a conductor former by the outer brading, which is the ground or earth. The lead should be fitted with a plug to suit the amplifier input socket.

Where the tuner is to be followed by a small headphone or similar amplifier, a screened audio lead is not required. So then connections are merely taken from terminals P-P in Fig. 8, remembering to join amplifier earth and tuner earth circuits as explained.

Medium and Long Wave

The addition of long wave coverage is worthwhile in some areas, and the coil can be modified as in Fig. 9 so that both MW and LW can be tuned.

A tube about 3 inch long and approximately 1½ inch in diameter will be necessary. The section L1 is wound as before. L2 consists of about two hundred turns of 34swg or 36swg wire, in two compact piles of one hundred turns each. All turns throughout are in the same direction. The junction of L1 and L2 goes to the waveband switch S1. The second

switch terminal goes to 4 and earth line. MW tuning is obtained with S1 closed, and LW tuning with S1 open.

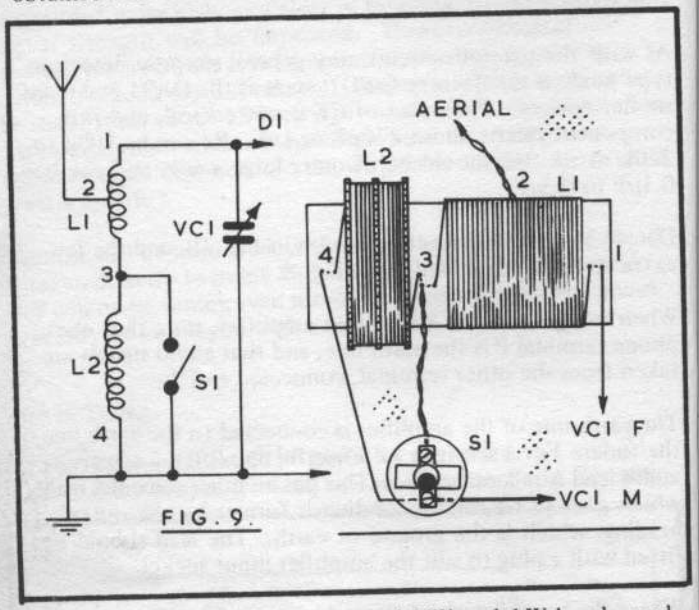

FIG. 9.

For accurate coverage of the usual MW and LW bands, and using a 1¼ inch diameter tube, L1 can be eighty-four turns of 32swg enamelled wire, with tapping 2 sixty turns from point 1. Leave a space of 5/8 inch and glue on a card disc cut to fit the tube. Also glue on two further discs, leaving spaces of ¼ inch between them. L2 is wound with 32swg double cotton covered wire, with one hundred and twenty turns in each slot (making 240 in all for L2). The coil can be fixed with two screws or small bolts, with spacers or extra nuts to hold it a little clear of the board. The windings should not be varnished, covered with adhesive, or wax.

With circuits of this kind there is no ganged tuning, or need for exact tuning of a particular frequency band. This means that coil winding details (wire gauge and covering, and diameter, or number of turns) can be varied to suit materials to hand. Ready-made coils can also be tried. Some commercially made coils with cores can give a slightly better

performance than the air-cored home made type of coil. Coils can also be wound in a similar way to that in Fig. 6.

One Transistor Amplifier

Headphone volume obtained from the crystal diode receiver can be considerably boosted by adding a single transistor audio amplifier. Space for this can be found on the circuit board.

In Fig. 10, resistor R2 and the transistor have been added, with a switch S2 for on-off switching of the battery. R1, C1, D1 and C2 are already present, as shown in Fig. 8.

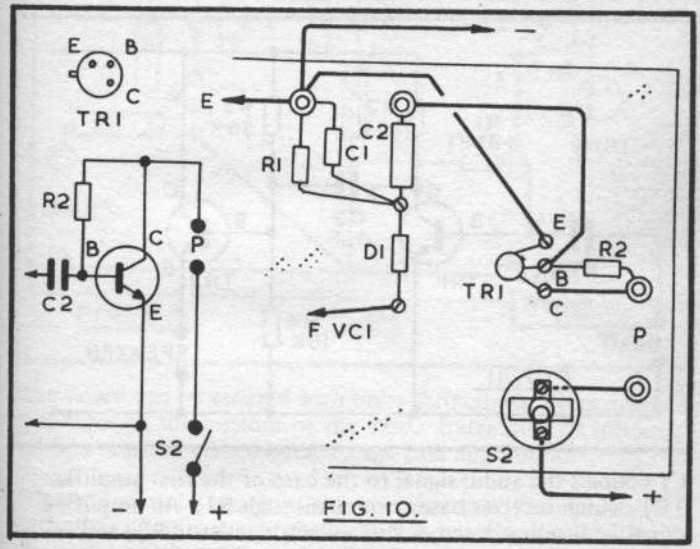

FIG. 10.

TR1, R2 and S2 are connected as shown. For TR1, a BC108, 2N706, or similar general purpose NPN transistor will be satisfactory. R2 can generally be 1 megohm with satisfactory results, but it can be worth while trying values from about 100k to 2.2 megohm here, as performance depends on the transistor, phones, and battery voltage.

Medium and high impedance phones, such as a 600 ohm DC headset, will be most suitable. The battery can be 4.5v to 9v.

If the phones are first connected to terminals P-P in Fig. 8, then taken to terminals P in Fig. 10, a very considerable increase in volume should be obtained.

If a PNP transistor is to be tried in this circuit, the polarity of the battery *must* be reversed.

Two Transistor Amplifier

Fig. 11 is the circuit for an easily made 2-transistor amplifier which can provide reasonable loudspeaker volume. The audio signal is taken to the input terminals, battery negative being the grounded side of this circuit.

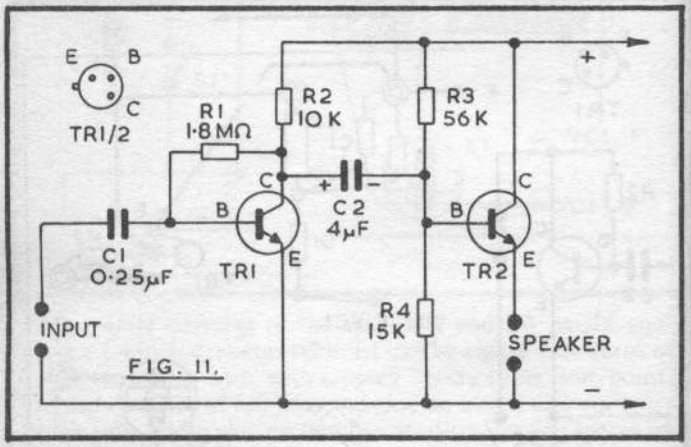

C1 couples the audio signal to the base of the first amplifier TR1, which receives base current through R1. An amplified signal is developed across the collector resistor R2, and is coupled to the base of the following amplifier TR2 by means of C2.

The two resistors R3 and R4 set the base operating conditions for TR2, and the output is taken from TR2 emitter.

Fig. 11B shows assembly of the components on a small insulated board. If preferred, connections between components can be on the underside of the board, in the way shown for

later circuits. Fit red and black flexible leads for battery connections. The amplifier, with its battery, can be fixed in an insulated box or metal case. Sockets can then be used for input and output circuits, and an on-off switch can be placed in one battery lead.

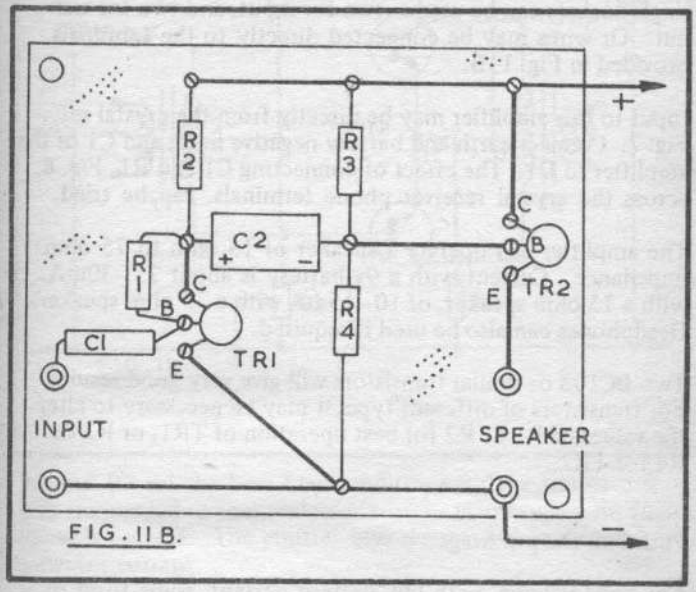

The board can be secured with bolts through its fixing holes, and through the bottom of the case. Extra nuts or other spacers must be placed between the case and board.

Whenever a metal box is used, remember that all connections and other circuits except the earth line must be insulated from the metal. The metal case itself is normally connected to the earth line, and a lead can be put under one of the fixing screws for this purpose. In Fig. 11, both input and speaker are returned to the earth line. So 3.5mm jack sockets of the type in which the outer or sleeve contact is common to the fixing bush could be used, as these points will be connected to battery negative and the earth line and metal box. But with some circuits it is necessary to use an insulated jack socket, or to insulate this from the metal. An example of this would

arise if the speaker were placed in the collector circuit of TR2, as the outer or sleeve circuit would then need to go to battery positive.

Instead of the type of socket which takes a jack plug, ordinary single sockets can be used – two for input, and two for output. Or wires may be connected directly to the terminals provided in Fig. 11B.

Input to this amplifier may be directly from the crystal set, Fig. 7. Connect earth and battery negative lines; and C1 of the amplifier to D1. The effect of connecting C1 and R1, Fig. 8, across the crystal receiver phone terminals, can be tried.

The amplifier can operate a speaker of 15 ohm to 75 ohm impedance. Current with a 9v battery is about 25–30mA with a 15 ohm speaker, or 10–15mA with a 75 ohm speaker. Headphones can also be used if required.

Two BC108 or similar transistors will give very good results. For transistors of different type, it may be necessary to alter the values of R1 or R2 for best operation of TR1, or R3 or R4 for TR2.

Push-Pull Output Stage

For good volume, with low battery current, some form of push-pull output stage is generally used. This has two transistors, and each amplifies one half of the audio signal. Base bias conditions of the two transistors are so arranged that only a low current flows during silent intervals. Overall battery drain is thus much lower than if a single transistor were used to obtain a similar level of volume.

Fig. 12 is a typical push-pull output stage. T1 is the input or driver transformer, and an audio signal is taken to its primary P. The secondary S is centre tapped. So for one half of the audio cycle one transistor base is driven positive and the other transistor base is driven negative, this being reversed for the remaining half cycle. Thus each transistor conducts alternately, and the centre-tapped output transformer T2 combines the collector currents, to operate the speaker connected to the secondary S.

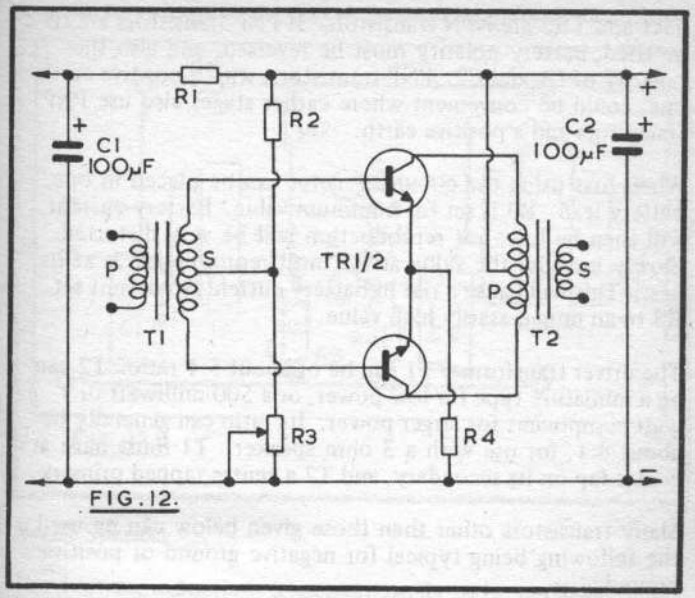

R2 and R3 set the base bias conditions for the transistors. Bias is arranged so that collector current is low, when no audio signal is present. The emitter bias resistor R4 limits peak collector current.

If R3 is a pre-set resistor, as in Fig. 12, operating conditions can be arranged to suit the transistors fitted. For best results TR1 and TR2 should be a matched pair. This means that they will have similar gain and current characteristics. However, two transistors of the same type number will generally be satisfactory.

It is assumed that the same battery will supply earlier stages of the amplifier, and current for this purpose is taken from C1 and R1. R1 and C1 prevent audio signals present in the positive line passing back to earlier amplifier stages. The by-pass capacitor C2 also helps in this respect. With simple circuits not giving much overall amplification, or small power outputs, R1, C1 and C2 might all be omitted.

TR1 and TR2 are NPN transistors. If PNP transistors are to be tried, battery polarity must be reversed, and also the polarity of C1 and C2. PNP transistors, with a positive earth line, could be convenient where earlier stages also use PNP transistors and a positive earth.

When first using the circuit, a meter can be placed in one battery lead. R3 is set for minimum value. Battery current will then be low, but reproduction will be very distorted. Slowly increase the value at R3 until reproduction is at its best. This will cause a rise in battery current, so do not set R3 to an unnecessarily high value.

The driver transformer T1 can be of about 5:1 ratio. T2 can be a miniature type for low power, or a 500 milliwatt or 1 watt component for larger power. Its ratio can generally be about 8:1, for use with a 3 ohm speaker. T1 must have a centre tap on its secondary, and T2 a centre tapped primary.

Many transistors other than those given below can be used, the following being typical for negative ground or positive ground.

Negative earth (NPN transistors). 2 x BC108. R1 1.2k. R3 100 ohm fixed or 250 ohm pre-set. R4 4.7 ohm.

Positive earth (PNP transistors). 2 x AC128 or 2 x AC142. R2 4.7k. R3 82 ohm or 250 ohm pre-set. R4 4.7 ohm.

R1 will generally be 1k to 2.2k, depending on the earlier amplifier. The primary of T1 can be connected to terminals P in Fig. 10; or alternatively to any audio source where a reasonably strong signal is present.

Where signals are too strong, an audio gain control needs to be fitted. In Fig. 8 this can be done by omitting R1, and disconnecting C2 from D1. Connect the outer tags of a 100k volume control or log pot from D1 to earth line. Take C2 to the centre tag or slider of the potentiometer. Any required audio level can then be taken off by adjusting the control knob.

Fig. 12B shows the board layout.

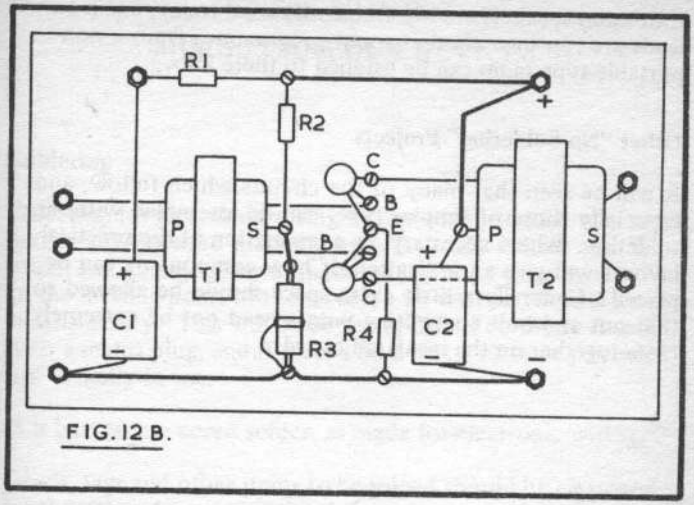

FIG. 12 B.

Boost Speaker

For best reproduction, a speaker needs to be enclosed in a cabinet or fitted to a baffle board. A cabinet can be made from wood, and can be about 6 x 10 inch and 4 inch deep, or as required for the speaker unit. Cut an aperture in the cabinet front to match the cone diameter, and glue thin fabric behind this opening. The speaker can be fixed with nuts and bolts, or short woodscrews driven in from behind.

Connect flexible leads, with separate plugs or a jack plug, to suit the equipment.

Small pocket receivers, which have a miniature speaker, can give much improved volume and reproduction when used with a larger speaker. If a headphone socket, operated from the receiver output stage, is present, it is only necessary to plug the speaker into this. A fairly large speaker, of sensitive type, will give best results. A unit 5 inch to 6 inch in diameter, or about 4 x 7 inch, will be convenient. The speaker has to be of approximately the correct impedance, which should be found in the receiver operating instructions. Where the speaker impedance is wrong, a matching transformer has to be employed between receiver and speaker.

Extension speakers are less frequently used today, but if two leads are run into another room programmes from a non-portable type radio can be listened to there also.

Other "No Soldering" Projects

It will be seen that many of the circuits which follow, and especially those of simpler type, can be assembled without soldering. Where necessary, an examination of the practical layouts will give an indication of how components can be placed. Generally a little extra space should be allowed so that nut and bolt connecting points need not be extremely close together on the insulated board.

SECTION 2
MISCELLANEOUS DEVICES

Soldering

Soldering for electronic wiring will be found to be a very easy and straightforward matter. An electrically heated iron is usual, and as large areas of metal do not have to be raised to the melting point of the solder, a 20 watt to 25 watt iron is satisfactory. This will be perfectly safe if correctly fitted with a mains plug, and if placed on a metal plate or tray when not actually in use.

It is best to use cored solder, as made for electronic wiring.

Leads, tags and other items to be joined should be clean and bright. They have to be raised in temperature to the melting point of the solder at the actual points where a joint is to be made, and the active core of the solder, or flux, must be present here when the joint is being made.

The iron should be tinned – that is, have melted solder on its tip – and have reached its correct temperature. Leads can be hooked or looped into position. The joint is then heated with the iron, and the solder is simultaneously applied to the joint, so that it melts and flows over the surfaces to be soldered. This usually takes place in a second or two. The solder and iron should be removed at once, as excessive heating may damage some components, and especially transistors or other semiconductors. The joint cools in a few seconds, and should be rigid, and solder having flown onto the items to be joined.

A probable cause of poor joints is insufficient heating of items to be soldered, or carrying solder to the joint on the iron, so that the activity of the flux is wasted.

Electronic items such as tags and the wire ends of components are generally designed for easy soldering. They will be copper, tinned copper, and similar metals and alloys which solder readily. For this reason, difficulties are unusual.

Some metals do not solder readily, or need special methods. Aluminium is one of these, and it is not used where popular cored solders intended for copper or general wiring are employed.

Make sure that heat from the iron does not damage furniture or other items, and keep the flexible cord away from the heated tip. Always switch the iron off at once when the work in progress is to be left.

One Transistor Audio Oscillator

This can be used instead of a bell or buzzer warning, or for code practice and similar purposes. It needs very few components, Fig. 13, and can be made to work satisfactorily with a wide range of transistors.

In Fig. 13, an NPN transistor is shown in the theoretical circuit, so battery polarity is as indicated, with negative to emitter. If a PNP transistor is fitted, battery polarity must be reversed.

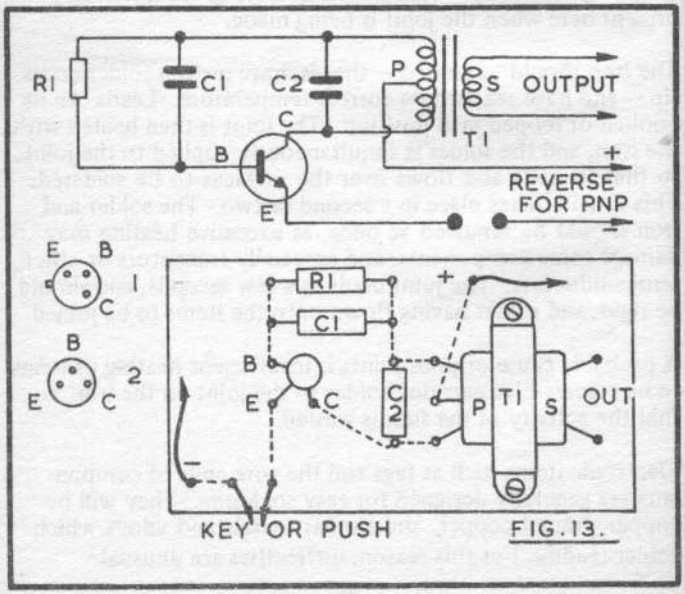

FIG.13.

(1) shows leads from a typical NPN transistor, such as the BC108, 2N706, and similar types. (2) is the base of the PNP AC128 transistor.

T1 can be a small speaker matching transformer, as used for push-pull stages. A centre tapped primary is necessary. The secondary S can be taken to a loudspeaker or headphones.

The values of R1, C1 and C2 can be varied considerably. C1 can be 0.1μF or so. R1 determines to some extent the power obtained, and can be about 22k, increased to 47k or 100k for lower power. The value of C2 has considerable influence on the note, or frequency of oscillation. Increasing the value of C2 lowers the pitch. C2 can be about 47nF to 4.7nF or thereabouts. A 9v battery can be used. Changes to the supply voltage will influence the note produced.

Fig. 13 also shows a layout for components, using either a fully perforated board, or a panel drilled to suit. Transformer T1 is fixed by screws. Small transformers of this type are usually wire ended, or have pins which pass down through holes in the board.

The wire ends of the resistors and capacitors are passed down through suitable holes, and bent over. The board is then turned so that the underside wiring can be carried out. In most places the wire ends of the components will be long enough to reach connecting points. Elsewhere, 24swg tinned copper wire, or similar connecting wire, will be used. Make the soldered joints as described, and snip off unwanted ends of wire. It is as well to leave the transistor to last, as this avoids heating it unnecessarily when soldering other items. Lengths of flex, anchored at holes in the board, are used for battery, key (or push) and speaker connections.

Multivibrator

Fig. 14 is the circuit of the multivibrator assembled in Fig. 2. Reference to Fig. 14B will show how this can also be prepared on a tag board.

The tag board has two rows of tags fitted to an insulated

board, and it is five tags long in Fig. 14B. Boards of this type can be obtained in many sizes. It is also easy to cut a section from a long tag board, to suit the needs of the item to be assembled. Such boards are very handy indeed for electronic assemblies, as the tags support resistors, capacitors and other items, and a neat layout is readily achieved.

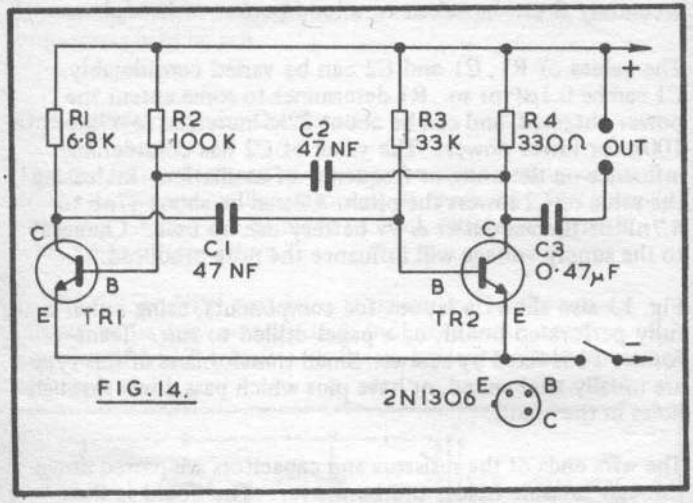

FIG.14.

Tag strips are also useful for projects, and may have any number of tags required. Long tag strips can be cut down as necessary. Short tag strips have one tag for mounting the strip, longer strips having two tags formed as brackets for this purpose.

Place the components approximately as in Fig. 14B, and solder the wires to the tags. If any component values may be changed, do not twist the leads tightly round the tags before soldering, or removal will be difficult.

Wires which cross can be kept clear of each other, and then no insulated sleeving will be necessary. The transistors can be soldered on last, and can readily be changed without disturbing other parts.

The same layout can be used for the next project, though the component values are different.

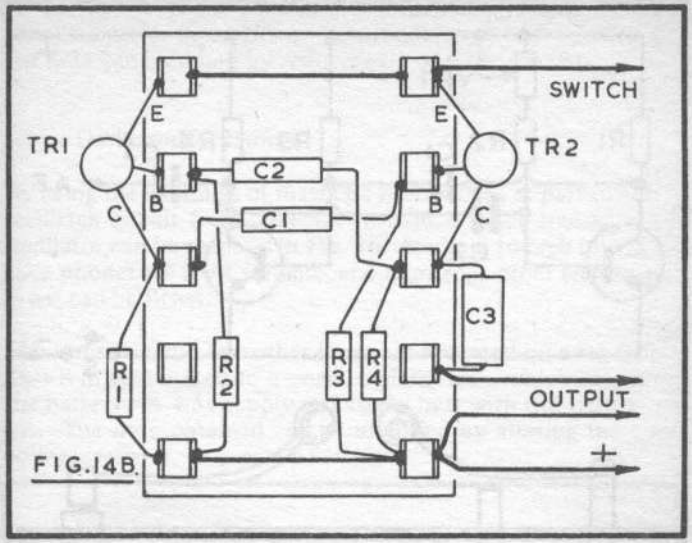

FIG.14B.

Glissade

This device will produce swooping, rising and falling tones, for "effects" purposes, or can with additional skill be used to obtain musical notes through several octaves. The circuit is shown in Fig. 15, and reference can be made to Fig. 14B for a practical layout on a tag board.

In Fig. 15, suitable component values are:

R1	10k	C1	22nF
R2	12k	C2	22nF
R3	100k	C3	22nF
R4	10k	VR1	100k linear pot.

Transistors: 2 x BC108 or similar types.

The circuit is a wide frequency audio oscillator, in which the pitch can be controlled by VR1, and "on" switching is obtained by S. The oscillator is placed in a box, so that switch S and VR1 can be mounted on the top. The switch is a strip of springy metal, fitted with a spacer and bolt, so that it is just clear of a further bolt. A small downwards movement of the arm or knob completes the circuit.

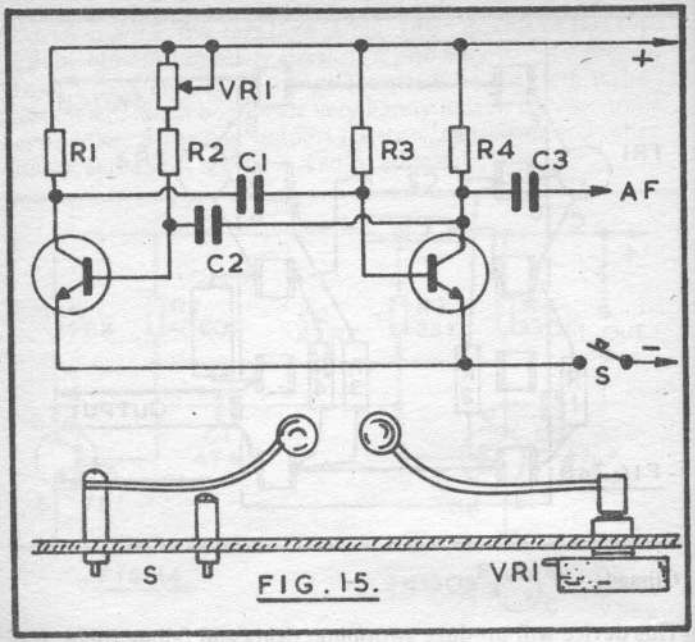

FIG. 15.

VR1 has a ¼ inch shaft coupler, into which is screwed a length of 4ba threaded rod. A knob is also fitted to the end of this rod. It can be swung backwards or forwards, to change the resistance of VR1. Connect VR1 so that movement of the knob towards the right raises the pitch.

Output from C3 can go to high resistance headphones, for amusement, but should be taken to an audio amplifier. Gain of the amplifier will have to be turned back somewhat, as the output from the glissade is at a quite high level.

Swooping tones are produced by holding down the switch S and swinging the control knob attached to VR1 from side to side. For notes which do not swoop to frequency, switch S must be released while VR1 is rotated. A slight quivering motion of the hand controlling VR1 will produce a vibrate effect. It is useful to have an ordinary switch in parallel with the knob control S, and to have the amplifier audio gain control near the left hand, so that fading effects can be produced as well.

About 4.5v to 9v can be used, this influencing volume. Should other transistor types give an unsuitable range of frequencies, the note can be raised by reducing C1 or C2 (or both).

Morse Oscillator for Phones

By using the windings of magnetic headphones as part of the feedback circuit from collector to base, a single transistor oscillator can be made as in Fig. 16. Medium to high impedance phones are most suitable, and numerous other transistor types can be fitted.

The transistor and few other items are mounted on a tag strip. This is in turn bolted to a small insulated box, which can carry the battery. A 4.5v supply was found best with this oscillator. The note obtained can be modified by altering the voltage, resistor, or capacitor values.

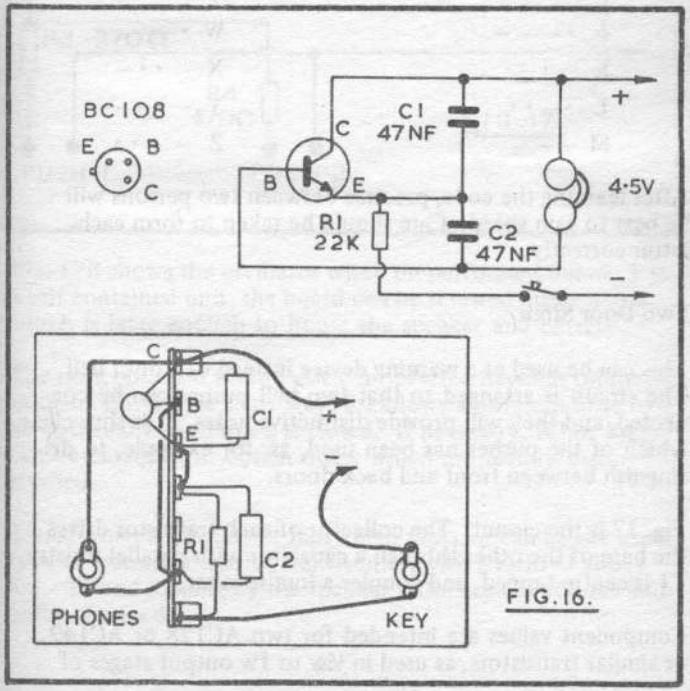

FIG. 16.

For serious code practice a good Morse key is required. It is adjusted so that only a small movement of the wrist is needed to operate it. Each letter consists of short and long sounds, shown as (·) and (–). The (–) has three times the length of the (·)

A	·–	N	–·
B	–···	O	–––
C	–·–·	P	·––·
D	–··	Q	––·–
E	·	R	·–·
F	··–·	S	···
G	––·	T	–
H	····	U	··–
I	··	V	···–
J	·–––	W	·––
K	–·–	X	–··–
L	·–··	Y	–·––
M	––	Z	––··

After learning the code, practice between two persons will be best to gain speed. Care should be taken to form each letter correctly.

Two Door Siren

This can be used as a warning device instead of a door bell. The circuit is arranged so that two bell pushes can be connected, and they will provide distinctive notes. It is thus clear which of the pushes has been used, as, for example, to distinguish between front and back doors.

Fig. 17 is the circuit. The collector of each transistor drives the base of the other through a capacitor with parallel resistor. T1 is centre tapped, and couples a loudspeaker.

Component values are intended for two AC128 or AC142, or similar transistors, as used in ½w to 1w output stages of

receivers and small amplifiers. Other transistors will of course operate in this circuit. The pitch obtained can be modified by changing C3. The circuit shown is for PNP transistors, and battery polarity has to be reversed for NPN transistors.

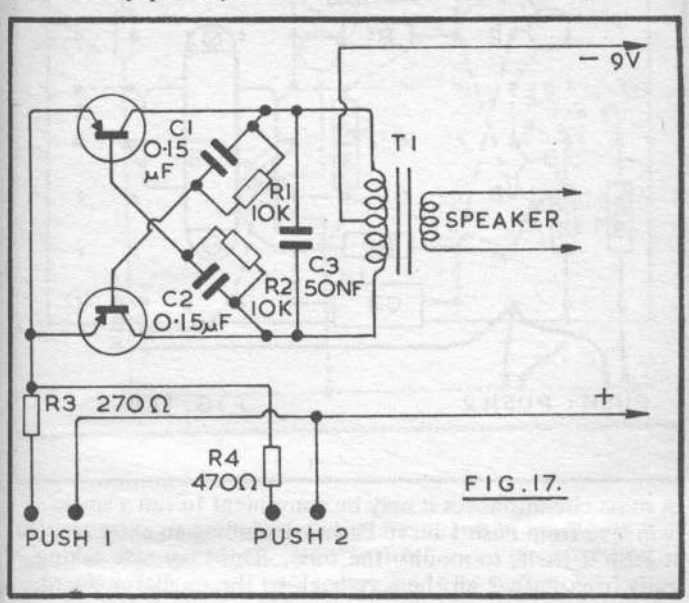

FIG. 17.

Fig. 17B shows the oscillator wired on perforated board. For a self contained unit, the board can be screwed inside a case which is large enough to house the speaker and battery.

The note obtained when Push 1 is operated depends on the value of R3. In the same way, R4 allows a different note to be obtained when Push 2 is closed. If necessary, R3 or R4 can be changed, to obtain notes which are readily distinguished.

Transformer T1 is best of fairly high ratio, or can be the usual type of transistor output transformer, with a ratio of about 8:1. T1 and loading by the speaker influence the volume and notes obtained.

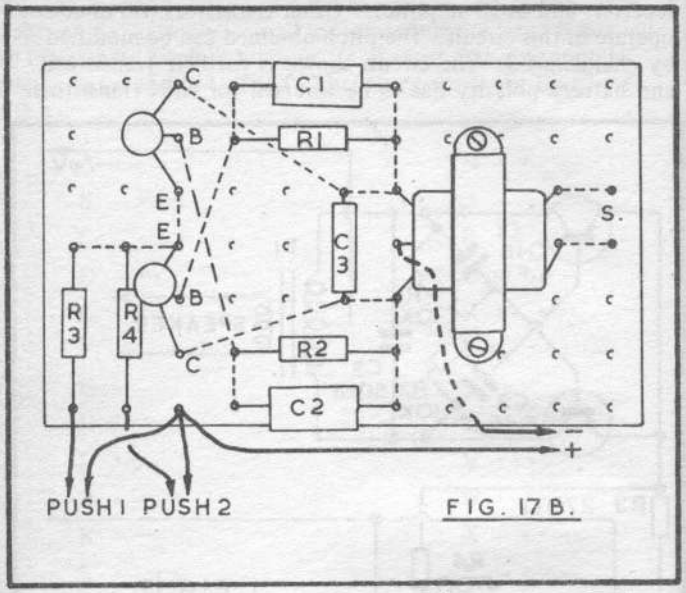

FIG. 17B.

In some circumstances it may be convenient to run a single twin lead from Push 1 on to Push 2, including an extra resistor at Push 2 itself, to modify the tone. This may save taking leads from Push 2 all the way back to the oscillator board.

UJT Oscillator

The uni-junction transistor is a device having emitter, Base 1, and Base 2, Fig. 18. B2 receives positive bias, in this case through the headphones. When forward bias on the emitter E is reached the UJT conducts.

In Fig. 18, the emitter potential rises as C1 charges through the resistor R1. When the UJT conducts, C1 is discharged, and the process is repeated. This can take place over a very wide range of frequencies, depending on the values used for R1 and C1. Here, these are chosen to produce an audio tone.

A battery supply of 3v to 9v will be convenient. For use of the UJT oscillator during code practice, place the key in one battery lead.

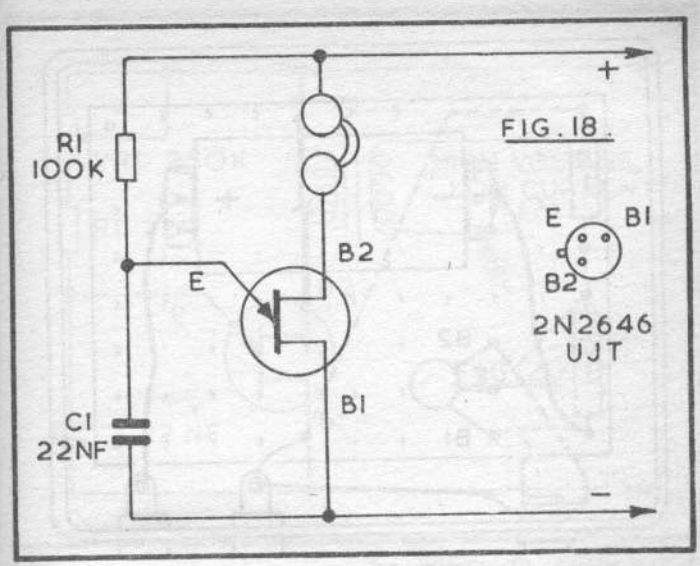

FIG. 18.

UJT Continuity Tester

Fig. 19 shows actual assembly of the circuit in Fig. 18 on a small perforated board. This is fitted in an insulated box, which carries a phone jack socket, and two sockets for Morse key or test leads. A 9v battery is used, secured with string or elastic.

For continuity tests, take prods or clips on the test leads to the suspected item. If the circuit is in order, the UJT oscillator will produce an audio tone. Oscillation will be obtained with a series resistance between the prods of up to 20k or more, so various components can also be tested, and some idea of the resistance in circuit can be gained from the sound obtained. The tester can also be used to check bulbs, lamps, fuses, extension and other leads, and similar items – these must of course be removed or disconnected from the equipment, before being tested.

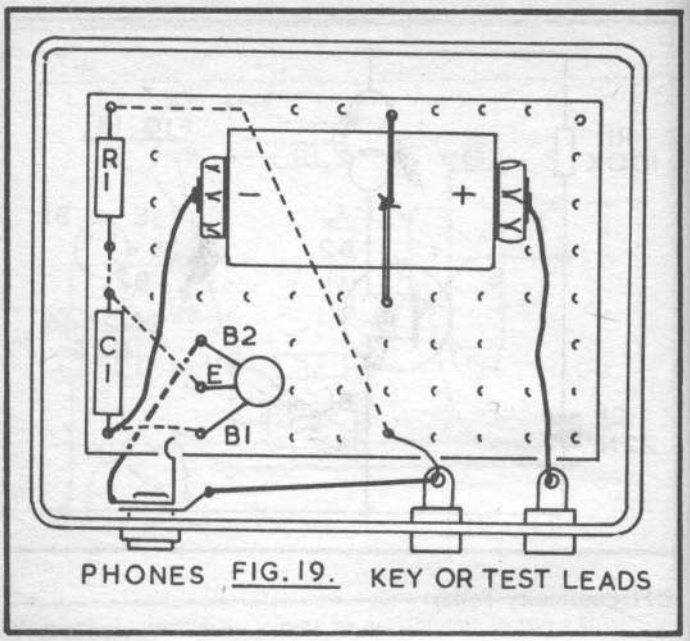

FIG. 19.

UJT High Voltage Producer

The UJT oscillator can be used to produce a high voltage, at very low current, by connecting a transformer as in Fig. 20. A loudspeaker transformer, as would be used in valve equipment, is suitable, and will have a ratio of about 45:1 or so. The usual secondary, or low-resistance winding, is connected to B2 and positive, so that a step-up of voltage is obtained. This should be found to light a small neon lamp.

VR1 is fitted to allow some adjustment, to find the most suitable frequency of oscillation. For maximum possible high voltage output, if required, operating voltage and current should be raised. No rating of the UJT must be exceeded. For the 2N2646, the supply should not exceed 30v, emitter current should not be over 50mA, and dissipation of power in the device should not be more than 300 milliwatts. (Dissipation can be found from Voltage x Current.)

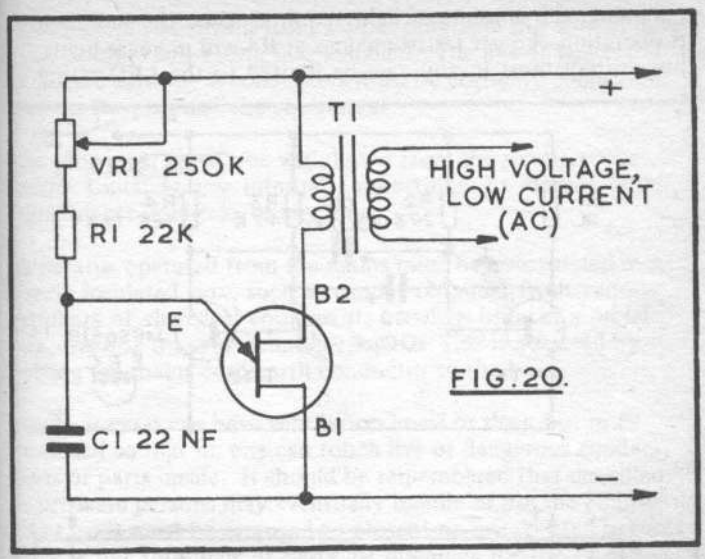

FIG. 20.

A small mains transformer can be used for T1, with a low voltage winding, such as that for a 6.3v heater circuit, as primary, and the 200/250v winding as secondary. The high voltage output is alternating current.

Signal Blinker

Fig. 21 is a multivibrator in which the feedback capacitors C1 and C2 are of high value, so that conduction alternates between TR1 and TR2 at a low rate. A light emitting diode is placed in the collector circuit of TR2, and so flashes on and off.

This device can be used for various instruments and other equipment, and a flashing indicator draws attention to a greater extent than does one continuously illuminated. The LED can be located at any required point, with leads running to it.

Transistors other than the types shown can be utilised. R4 can usually be about 150 ohm for a 3v supply, 470 ohm to 1.2k for 6v, or 680 ohm to 1.5k for 9v. This depends to some

extent on the amount of light required when the indicator is operating. Lower resistor values at R4 will increase light, but current must in any case be limited to the LED rating.

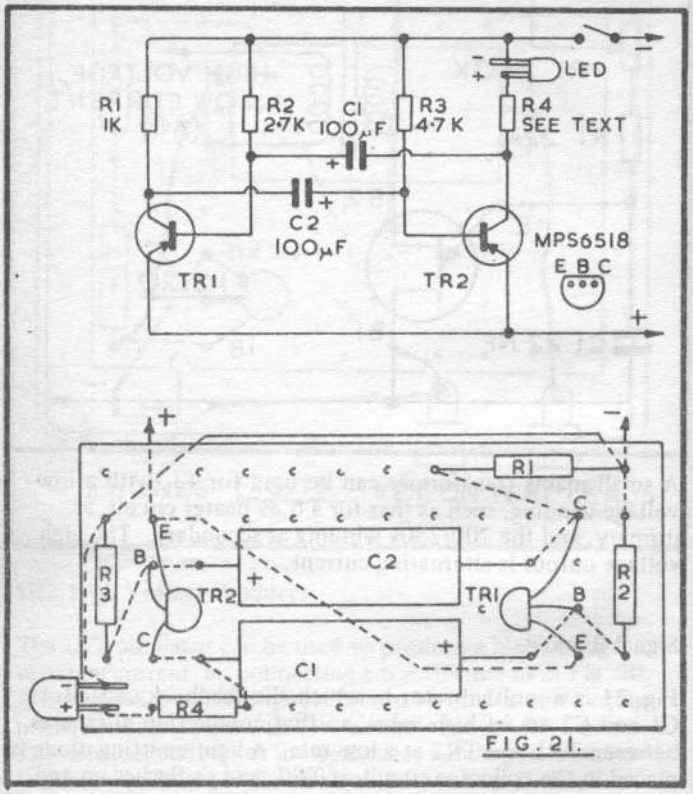

FIG. 21.

C1 and C2 need only be 6.4v working, and the device can be assembled on a very small perforated board. See p.61 for LED polarity.

Mains Wiring

All the devices described so far have operated from low voltage batteries, so than no shock hazard exists with them. However, it is necessary to employ mains power for some units, and proper care must then be taken to avoid any danger.

Power should be drawn from a 3-pin plug, and this should have a 3A or other low rating fuse installed. The live or L, neutral or N, and earth or E conductors must be correctly connected, both at the plug and the equipment.

The plug must always be withdrawn from the supply socket, before touching any internal connections, or making any adjustments or checks of any kind.

Apparatus operated from the mains must be constructed in a strong insulated box, such as can be obtained from various suppliers of electrical equipment; or when built in a metal box, the box must be soundly earthed. This is achieved by bolting the mains cord earth conductor to the box.

Boxes or cases can have ventilation holes or slots, but must be closed so that no one can touch live or dangerous connections or parts inside. It should be remembered that unskilled or unaware persons may eventually handle or use the equipment, so it must be arranged to present no unexpected hazards such as live terminals or parts, or openings for the fingers.

If these points are remembered, mains operated equipment can be safe to use and handle. No switch or other means of interrupting the circuit is put in the earth conductor, and any switch or equivalent device is placed in the live or L conductor. This leaves both earth and neutral permanently connected, for maximum safety.

Dimmer/Heat Control

It is often convenient to dim a filament lamp, or reduce the heat of a soldering iron to be left on for long periods, or the power of a low wattage heater. The silicon controlled rectifier circuit in Fig. 22 can be used for these purposes.

When the switch marked "Full" is closed, current for the load passes through this, so that full power is obtained.

When this switch is opened, current passes through the SCR. This device conducts only when the gate has been triggered, and the instantaneous point in the alternating current cycle

where this arises is determined by the setting of the potentiometer VR1. Triggering is advanced as the wiper of VR1 is moved towards R1. The average power supplied to the load can thus be adjusted between wide limits. Since the device is operating as a half wave controller, full power is not obtained with VR1 at maximum, so the switch is closed as described.

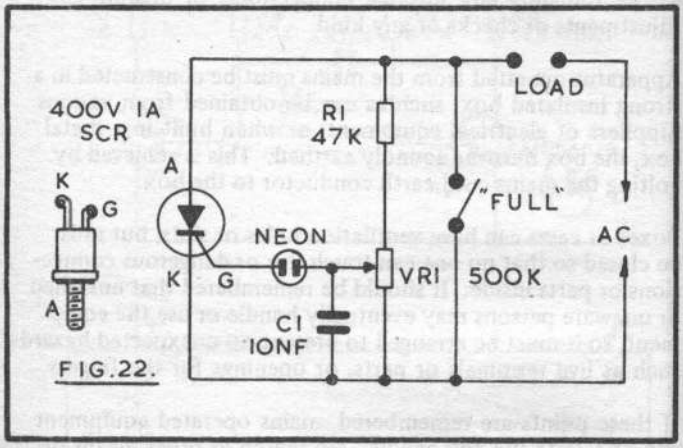

FIG.22.

Fig. 22B shows construction of the SCR controller in a metal box. The front of this carries a socket outlet, and the mains cord has a 3-pin plug, wired as explained earlier. It is thus easy to plug the controller into an outlet, and insert the plug of the lamp or other item to be used in the new outlet.

The mains cord is secured with a clamp, and passes through an insulated grommet. The tag strip supporting the small items is mounted by an unused tag. A strip of metal is cut to clamp round the body of the SCR, and is soldered to one tag, as shown. Run earth and neutral leads from the cord up through a hole, and connect them to the E and N terminals of the socket outlet. Also earth the case, at E. A well insulated wire runs from the L terminal of the outlet, to the "Full" switch. The outlet can be secured with bolts and nuts.

R1 should be 1 watt, and C1 is a 500v capacitor. The neon is a small type as used for indicators, etc.

After checking that the controller operates correctly, the back

of the box should be screwed in place. A suitable size is about 4 x 5 x 2 inch deep.

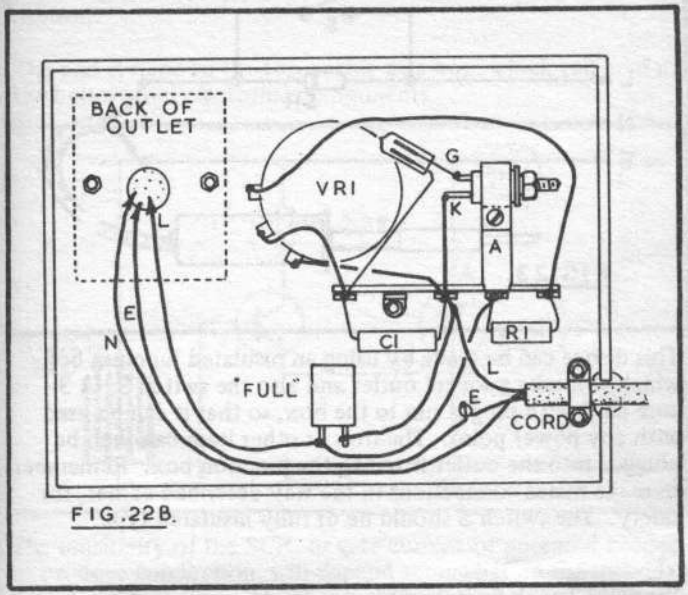

FIG.22B.

If a fully insulated box is used instead, then the bush of VR1 and of the switch should both be earthed by wires, except when these items are constructed wholly with insulated material. (This precaution is necessary to avoid any chance of metal parts outside the box becoming "live".)

Two Power

A circuit which will allow half or full power can be useful to reduce the heat of a soldering iron, or for dimming a filament lamp.

Fig. 23 is an easy circuit of this type. Full power is obtained when the switch S is closed. With S open, the silicon rectifier allows current to flow in one direction only, so that power is approximately halved. A 600v 1A or 1000v 1A rectifier is suitable.

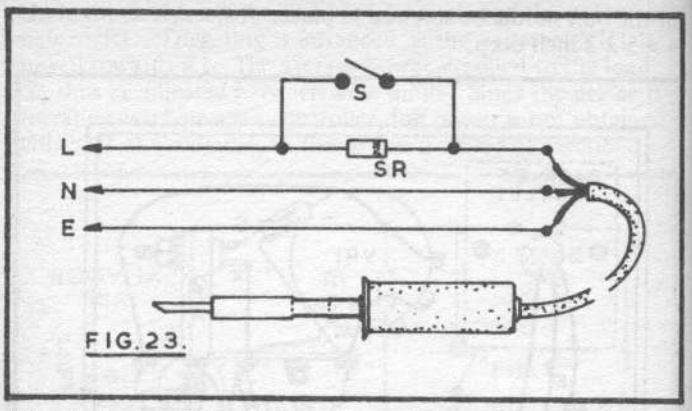

FIG. 23.

This device can be made by using an insulated junction box which will take a socket outlet and also the switch S. A 3-core cord with plug is run to the box, so that it can be used with any power point. The iron or other item can then be plugged into the outlet fitted to the junction box. Remember to make mains connections in the way described earlier, for safety. The switch S should be of fully insulated type.

Sensitive Touch Switch

In Fig. 24, finger contact with the touch pad switches on a low voltage bulb. This circuit is suitable for a battery operated portable bedside light, and for some other devices.

Normally the silicon controlled rectifier is not conducting, so the lamp is extinguished. Finger contact with the pad provides positive base bias for the transistor so that it conducts. This moves the transistor emitter and SCR gate positive, triggering the SCR. Current then flows from cathode K to anode A, and through the bulb. The SCR remains in the conducting condition until the battery circuit is interrupted by opening the switch. A push switch, normally closed, is most suitable here. Pressing it then switches off the bulb.

This touch pad is easily made from a piece of circuit board with foil strips. It can be about 2 x 1 inch, or of any convenient size. Join together alternate foils – e.g., 1, 3, 5 and 7 – by

soldering a connecting wire through the holes. This will provide one connection to the pad. The other foils – 2, 4 and 6 – are similarly joined together for the other pad connection.

The pad is fixed to the top or side of a box, which can contain the battery and electronic components.

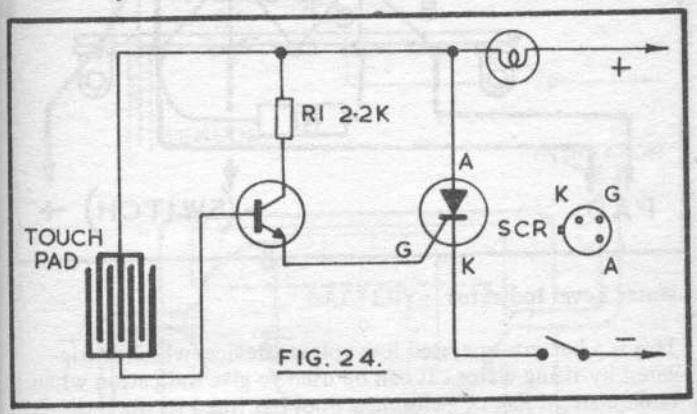

FIG. 24.

The sensitivity of the SCR, or gate current or potential needed to produce conduction, will depend somewhat on the individual device, while the gain of individual transistors will also be different. Numerous NPN types are suitable. If it is found that the switch is too sensitive, this can be corrected by placing a resistor from transistor base to SCR cathode or negative line. This resistor can be about 470k to 1 megohm or so. Excessive sensitivity will be apparent if the circuit is switched on by dust, damp air, or similar effects. The pad should be kept clean by wiping it with a dry cloth.

Fig. 24B shows assembly of the components on a tag strip. A small 50v 1A SCR is more than adequate. The bulb can be a screw in type, and can be 6.3v 0.15A, or 6.3v 0.3A. A 6v 3W (0.5A) bulb is also suitable, provided the battery is fairly large.

It is convenient to make a wooden box which will take the battery, and leave a little space for the tag strip assembly.

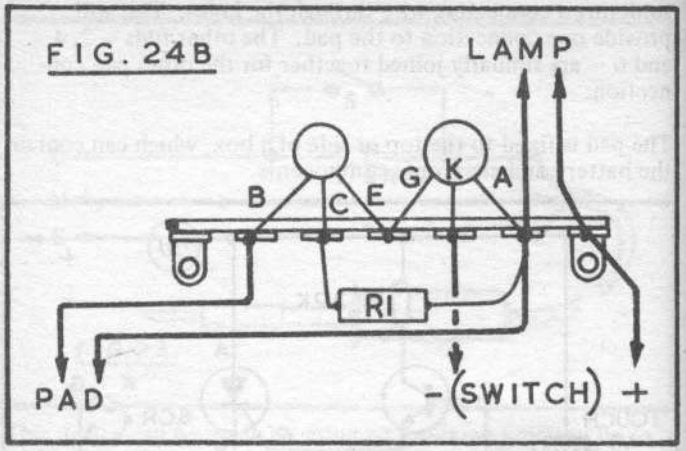

Water Level Indicator

This is a battery operated low voltage device, which is triggered by rising water. It can be used to give indication when a tank, cistern, fish or swimming pool has filled to the required level.

Fig. 25 shows the circuit, and also assembly on an insulated board. This also carries the battery, and it is fitted in a metal or plastic box.

In use, the base normally has no positive bias, as the sensor passes no current. When water reaches the sensor, it conducts, and the transistor passes collector current, to operate the indicator. R1 limits base current.

This circuit will operate satisfactorily with a wide range of PNP or NPN transistors, but battery polarity must be reversed for the PNP types.

The indicating or warning device can be one of the multivibrator or other audio oscillators shown earlier. These will give an audible warning, and will draw only a small current, so that a large transistor is not required.

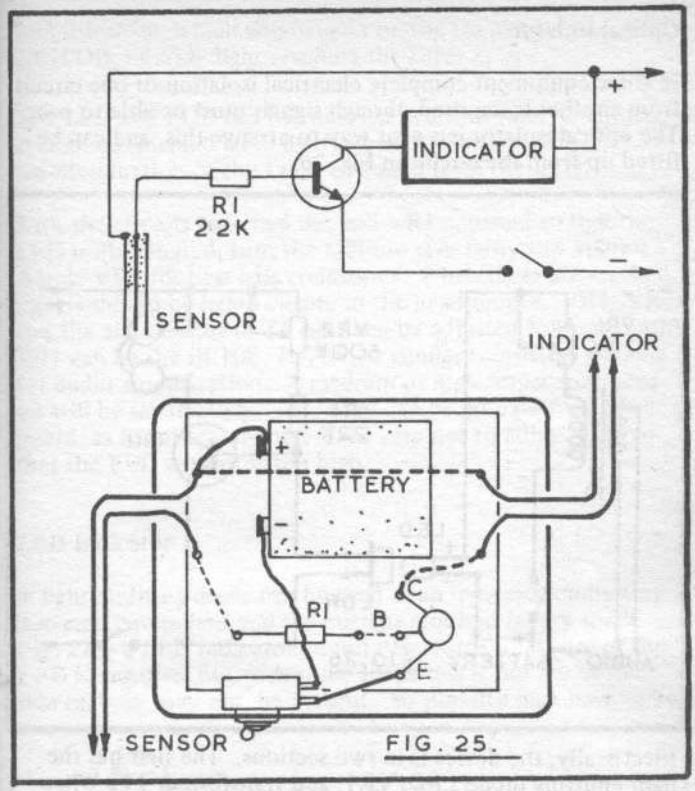

For indoor use or in a location protected from rain, the sensor can be two bare wires, about ¼ inch apart, bolted to a strip of insulated material. Where rain could operate the device, it needs to be covered. Alternatively, it can be made from a piece of metal tube, with a central wire, as in Fig. 25. The wire is bound with insulating tape for about half its length, to fit tightly in the tube. Flexible leads are soldered on, and the joints covered with tape. The sensor can be suspended inside the tank or pool, with its bottom at the required water level.

If the transistor is a high gain one, so that damp operates the indicator, sensitivity can be reduced by connecting a 100k resistor from base to emitter.

Optical Isolator

In some equipment complete electrical isolation of one circuit from another is required, though signals must be able to pass. The optical isolator is a neat way to arrange this, and can be fitted up from the circuit in Fig. 26.

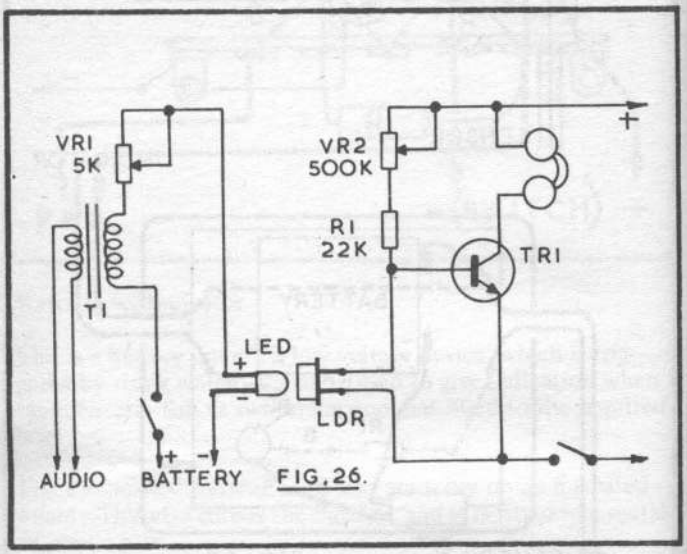

Electrically, the device is in two sections. The first has the light emitting diode LED, VR1, and transformer T1. When the battery is switched on, current flowing through the LED is adjusted by VR1, so that the LED glows dimly. A signal voltage in the secondary of T1 then modulates the LED light intensity.

To operate this circuit from a radio having a 2/3 ohm or similar speaker, a speaker matching transformer with a ratio of about 45:1 can be used. (The actual ratio is not very important.) Connect the usual transformer secondary to the radio speaker, so that T1 provides a step up effect.

The second part of the equipment has the light dependent resistor LDR, forming part of the network providing TR1 with base bias. VR2 allows adjustment of conditions for best

amplification, which will depend on the transistor, and also the LDR, or stray light reaching the latter.

The LED and LDR can be enclosed in a card tube, or should at least be shielded from light, which will swamp the modulated illumination of the LDR, obtained from the LED.

With the circuits switched on, and VR1 adjusted so that the LED is illuminated, turn the radio to give fairly low volume. Adjust VR2 for best bias conditions. When these are reached, signals should be heard clearly in the headphones. VR1, VR2 and the audio input to T1 can then be adjusted for best results. TR1 can be the BC108, 2N706, or similar transistors suitable for audio amplification. A medium or high impedance headset will be satisfactory. Assembly can be on a perforated board, as for other circuits. Take care not to adjust VR1 so that the LED current is too high.

LED Indicator

A light emitting diode can be used as an indicator on battery powered equipment and the current required is very small. Fig. 27 is a LED indicator circuit. Here, the long wire of the LED is negative, but with some LEDs this is not so. A flat side may, or may not, be present. So polarity may have to be

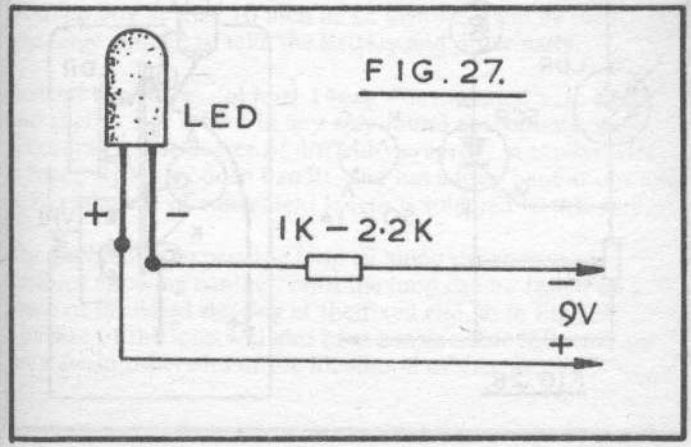

found by trial – the correct connections are those allowing the LED to light. The series resistor may be about 150 ohm to 1k or more, depending on the actual voltage, and brightness required. Current drawn varies with different LEDs, and with voltage and series resistance, but can be about 5mA or less, without reducing the brightness too far.

The LED indicator with resistor is connected to the circuit where voltage is present when the equipment is on. LEDs are available in red, yellow, green and other colours, with grommets or clips for panel mounting. Different circuits may be identified by a range of colours.

"Magic Candle"

The triggering of a silicon controlled rectifier can be used for slave photoflash and similar purposes. In Fig. 28 it is employed to switch on a light when a match or lighter is brought near. Sensitivity is best in somewhat subdued light, and it will then be found that striking a match at some distance can bring on the light.

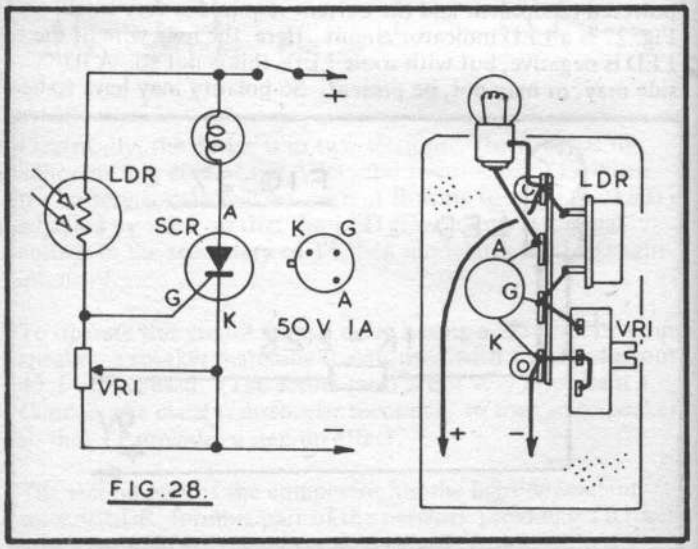

FIG.28.

The LDR has a high resistance when in darkness or subdued light, so that the gate potential of the SCR is not sufficiently high to trigger this device. When light reaches the LDR, its resistance falls, and the SCR gate voltage rises. The SCR then moves into its conducting condition, so that current flows through the bulb. The sensitivity of the circuit, or level of illumination needed to trigger the SCR, is set by VR1.

Components can be assembled on a small tag strip. This, with a battery, can occupy a tubular case, with the lamp on top. An opening is necessary opposite the LDR, and a hole is also made so that VR1 can be adjusted with a screwdriver. Here, a miniature pre-set 50k or 100k linear potentiometer is most suitable. It is necessary to have a small push switch to interrupt the battery current, as the SCR remains in the conducting condition until the circuit is momentarily broken. A 6V battery and bulb can be used. SCRs may fail to operate at all if attempts are made to use them with extremely low voltages, such as a single 1.5v cell.

"Nerve Tester"

This device tests the nerve, concentration, and steadiness of hand, and always provides amusement.

Connections and construction will be seen from Fig. 29. A wooden box at least 10 inch or 12 inch long will be used, and large enough to take the battery and other parts.

A stout bare wire – at least 14swg – is mounted with a bolt and spacer, and is bent in any way found appropriate, and according to the degree of difficulty wanted. A similar wire is fitted with a wooden handle, and has a loop bent at one end. A flexible lead of convenient length is soldered to this wire.

The problem is to pass the loop all along the shaped wire, without allowing contact, until the loop can be rested on a piece of insulated sleeving at the fixed end, as in Fig. 29. The size of the loop will also have considerable influence on the ease or otherwise of the likelihood of success.

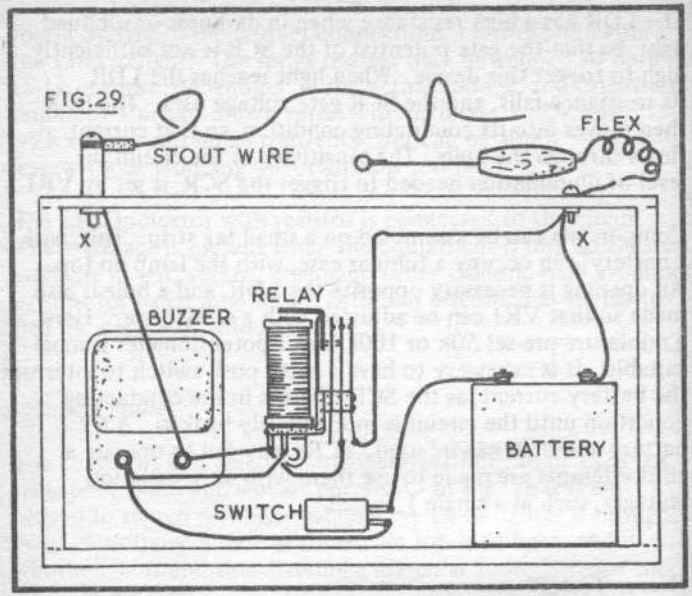

If loop and wire touch, current flows from the battery to the buzzer, which sounds. Current also flows to the relay winding, so that the relay contacts close. Even a momentary contact between loop and wire will thus cause the buzzer to sound until the switch is used to break the circuit.

Any 4.5v, 6v or similar battery and buzzer will be satisfactory, with a relay which operates on a similar voltage. Connections are to the relay contacts which remain open until the relay is energised.

In use, the device can stand upright. A back is attached with small screws.

Burglar Alarm

The same circuit arrangement as in Fig. 29 will provide a burglar alarm operated by pressure mats. The latter are available in various sizes, and consist of a thin pad which can be placed under a carpet or ordinary mat.

Leads from the mat or mats will run to the terminals at X–X. The buzzer should be changed for a bell, which need not be fitted in the box, but can be situated where it is best heard. Momentary weight on any of the mats will then switch on the bell, which will be locked on by the relay as described, and will ring until the unit is switched off.

Transistor Tester

A very useful check of transistors can be made with the aid of a multi-range test meter, with a selection of base resistors to provide base current, as in Fig. 30. This method does not give an exact indication of transistor gain, but it does allow defective transistors to be eliminated, and provides a good idea of the performance to be obtained from surplus or other unknown transistors.

A 6-way switch allows the base to be open circuit, or to receive current through one of the resistors R1 to R5. These values are R1 330k, R2 110k, R3 33k, R4 11k and R5 3.3k. After allowing for the base-emitter potential, switch positions and corresponding base currents are near the following: 1, zero; 2, 10μA; 3, 30μA; 4, 100μA; 5, 0.3mA, and 6, 1mA.

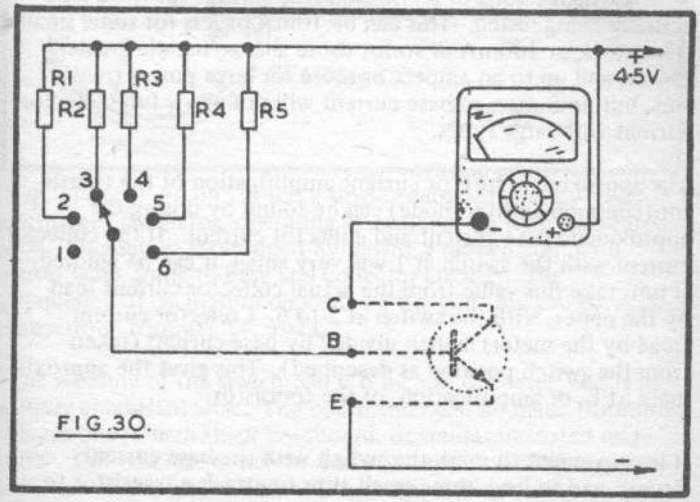

FIG.30.

Polarity is shown for NPN transistors. Reverse polarity of both meter and battery for PNP transistors.

For all tests, initially set the switch to 1, and the meter to its highest range (say 1 ampere). Afterwards, switch the meter to a lower range, after adjustment of the 6-way switch, as may prove to be necessary to obtain an easy reading.

With the switch at 1, a high reading on the meter shows that the transistor has a short circuit from emitter to collector, and is defective.

With germanium transistors, collector current (with the switch at 1) may be 0.1mA or so up to perhaps 0.5mA for small types, and up to some milliamperes for larger types. This small leakage current does not show that the transistor is defective.

In the case of silicon transistors, the leakage current (with switch at 1) will be zero or extremely small, if the device is in good condition.

The switch is then turned to one of the positions 2 to 6. If collector current does not rise, the transistor is defective. If current rises at each step, do not go beyond the switch setting which results in a safe collector current for the device actually being tested. This can be 10mA or less for some small transistors, or 100mA or so for those able to handle greater power, and up to an ampere or more for large power transistors, but limitation of base current will not allow full collector current with large types.

The approximate hFE or current amplification of the transistor (common emitter mode) can be found by noting the approximate base current and collector current. If the collector current with the switch at 1 was very small, it can be ignored. If not, take this value from the actual collector current read by the meter, with the switch at 2 to 6. Collector current (read by the meter) is then divided by base current (taken from the switch position as described). This gives the approximate hFE, or amplification, of the transistor.

It is convenient to mark the switch with the base current figures, and to have three small clips to attach a transistor to

the circuit. Switch, clips, and battery can all be fitted to a small box. A development of the circuit would be to include a current meter, with switch and shunts, to replace the external general purpose test instrument.

Treasure Locator

This locator is among the simplest that can be constructed, as it uses an ordinary small portable radio as part of the detection circuitry. No modifications or connections to the radio are needed.

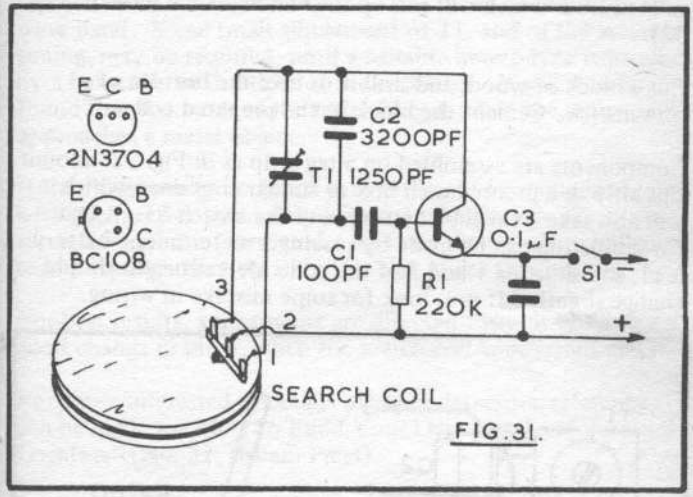

Fig. 31 is the circuit. It has a single transistor as a low radio-frequency oscillator, operating in conjunction with the search coil. Oscillation is obtained by having a tapped coil, with outer leads going to base and collector circuits. The frequency of oscillation depends on the coil, and the parallel capacitors, trimmer T1, and C2.

The winding of the search coil is 6 inch in diameter, and is of 34swg enamelled wire. The coil former can be made from three pieces of 1/8 inch thick hardboard, or similar insulated material. Cut one disc 6 inch in diameter, and two others about 6½ inch in diameter. Smooth the edges with glasspaper, and

cement them securely together, with the small disc between the larger discs. This provides a former with a channel to take the winding. The adhesive should be allowed to dry with the discs under pressure, so that there is no gap into which turns can fall. The former should also be varnished, and allowed to dry, before winding.

The wire is passed up through a small hole, this being point 1. Wind on fifteen turns. Make a loop and pass this up through a hole, for point 2. Wind a further twenty-five turns in the same direction, finishing off at point 3. These leads are scraped and soldered to a small tag strip. This is an anchor point for insulated leads which will run up the handle of the locator (Fig. 32).

Cut a block of wood, and drill it to take the bottom of a broomstick. Cement the block to the prepared coil.

Components are assembled on a tag strip as in Fig. 32. Mount this strip in a plastic lunch box or similar container, which will also take a small 9v battery, and the switch S1. A test for oscillation can be made by placing a meter in one battery lead, and shorting 1 and 3 of the coil. Meter current should change slightly. If not, look for some mistake in wiring.

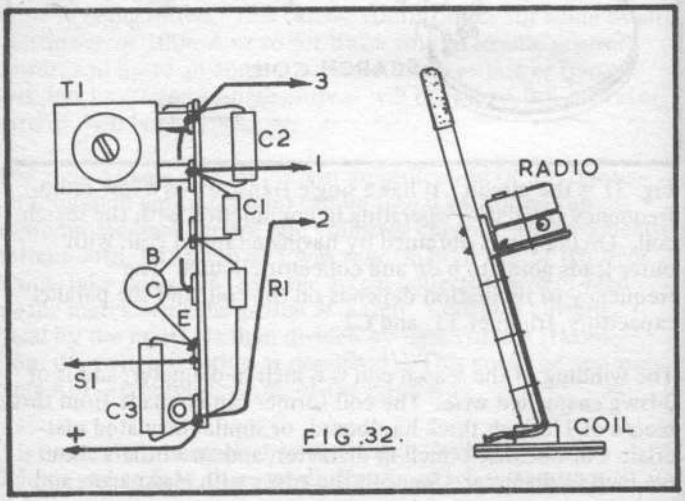

FIG.32.

A shelf is bolted to the handle, and the detector rests on this, with connections passing down to the search coil. A few loops of tape or string will secure these to the handle.

Operation in Great Britain can be on frequencies under 100kHz. Initially tune the radio receiver to 200kHz on long wave, and place it near the coil. Adjust T1 until a strong whistle is heard in the receiver speaker. This is the 2nd harmonic of the oscillator. T1 is then screwed down very slightly from this position.

The small portable radio is placed on top of the locator box, and can be held here with elastic. It is tuned to the medium wave band. Some small adjustment of T1, and of the receiver tuning, may be required, until a suitable heterodyne is produced by a harmonic or multiple of the oscillator. It will then be found that the pitch of the note changes when the search coil approaches a metal object.

It should generally be found that sufficient coupling is obtained with the receiver when they are situated as in Fig. 32. If not, run a few inches of insulated wire from the transistor collector tag up through the box and place this under the receiver.

For best results, adjustments are directed towards obtaining a good change in pitch, when the search coil approaches metal.

For those interested in details of other detectors, reference can be made to "How to Build Your Own Metal and Treasure Locators" (No. 32, Babani Press).

SECTION 3
RADIO AND AUDIO FREQUENCY

MW Booster

This unit can be employed in conjunction with any ordinary portable having a ferrite rod aerial, and will provide a considerable increase in range and sensitivity to weak signals. It has two functions – to allow the use of an external aerial and earth, and to amplify and couple signals to the portable receiver.

Tuning coverage is for medium waves. That is, about 200–550 metres, or 1500–550kHz. Many overseas and other stations can be picked up on this band, and distant reception can be particularly common on the higher frequencies, during the hours of darkness.

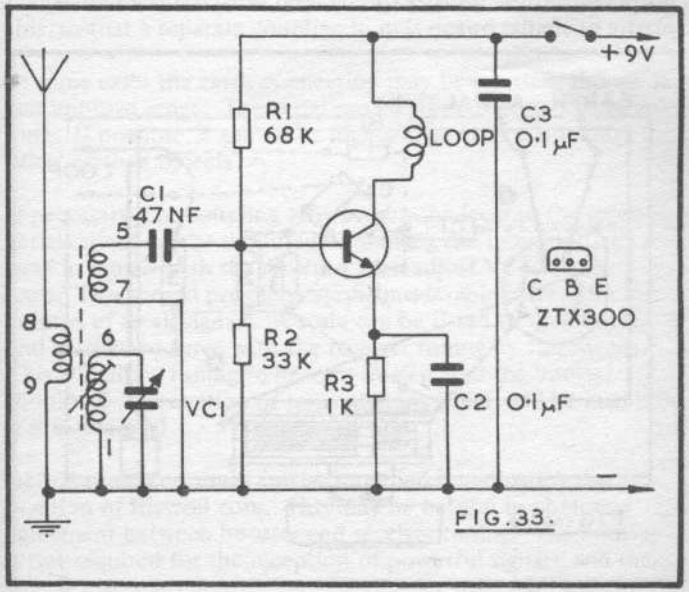

FIG.33.

Fig. 33 is the circuit, and it uses a cored tuning coil with aerial coupling winding 8–9, tuned winding 6–1, and base coupling coil 5–7. These numbers are for the pins of the Denco (Clacton) "Blue" Range 2 component. It will be apparent that other coils, or surplus or home-wound inductors, can be substituted.

For the coil mentioned, VC1 is 315pF. However, this value is not too critical, provided the capacitor fitted allows tuning the wanted frequencies. A solid dielectric capacitor can be used, though the air spaced type is likely to be a little more efficient.

Coupling to the base is by C1, and resistors R1 and R2 set the base bias conditions, with R3 for emitter bias. These values will suit numerous RF transistors.

Fig. 33B shows assembly of the components on an insulated board. The coil is mounted by its threaded bush. When the board has been wired, it can be mounted by means of bolts with extra nuts. The case is preferably metal, for screening purposes, but the booster can be used satisfactorily with a plastic or similar box.

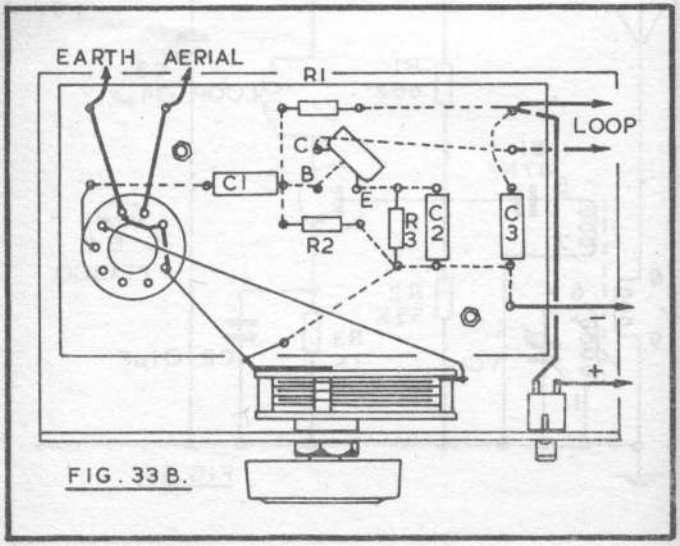

FIG. 33 B.

Fit a small slide switch to the box front, and aerial and earth sockets to the back, near the coil. A 9v battery is accommodated in the case.

Coupling to the transistor receiver is by means of a loop which is placed on the receiver ferrite rod, or near the rod. The loop can be about twenty turns of thin insulated wire, about ½ inch in diameter, and bound with cotton to keep the turns together The ends can be left long enough to reach the two connecting points in Fig. 33B.

If the case is metal, the booster and receiver can be near each other, so the loop leads will only need to be a few inches long. But when an insulated case is used, coupling from the receiver ferrite aerial or other circuits, to the booster coil, may cause instability. This will become apparent as whistles accompanying most signals. If this arises, the booster and receiver should be moved some inches apart. The aerial lead must not run near the loop connections.

Some receivers have an internal winding which is intended to couple an external aerial, and it may be possible to connect to this, so that a separate coupling loop is not required.

In some cases the earth connection may be omitted, though it can improve range. The aerial can be some 20ft to 40ft or so long. If possible, it should be high and clear of walls and other earthed objects.

If necessary, the coupling afforded by the loop to the receiver aerial circuit can be modified by moving the loop. Initially, tune in signals with the receiver, then adjust VC1 for resonance. This should provide a very considerable increase in the volume of weak signals. A scale can be fitted to the booster, and marked to agree with the receiver tuning by this means. This will allow tuning to be kept in step, and the booster should allow reception of transmissions which will be inaudible if it is removed.

Actual tuning coverage can be modified by adjusting the position of the coil core. This may be helpful in obtaining agreement between booster and receiver tuning. The booster is not required for the reception of powerful signals, and the

receiver automatic gain control circuit will tend to mask any increase in signal strength obtained with such transmissions.

Midget MW Diode Radio/Tuner

A small, compact tuner can be of utility in allowing radio reception through an amplifier, and a diode receiver can give excellent quality of reception. Such a unit can also be employed alone, with headphones, for personal listening.

Fig. 34 is a receiver/tuner which can be built in a very small plastic or other insulated box. VC1 is a compression type trimmer, fitted with a small knob for adjustment by hand. To do this, it is necessary to remove the short screw (generally 6ba) and replace this with a longer one, which projects to take the knob. The latter can be a terminal head, or the cap from an empty tube of adhesive, secured with lock nuts.

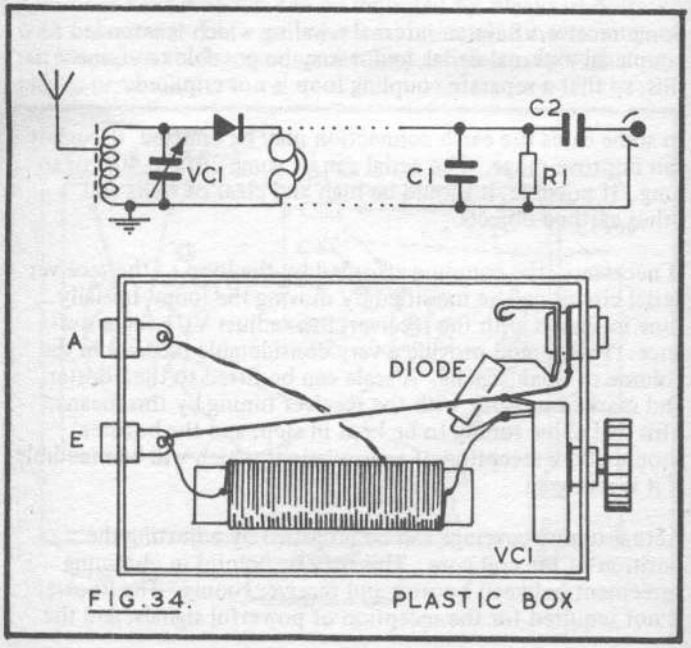

FIG.34.

For best efficiency and small size, the tuning coil is wound on a piece of ferrite rod. It consists of seventy turns of 24swg or similar enamelled wire, on a rod about 1½ inch long and 3/8 inch in diameter. Actual details will not be critical. A piece can be obtained from a longer rod by cutting a notch round the rod with a file and snapping at this point with the fingers. A few touches of adhesive will hold the ends of the winding secure. The loop for the aerial connection is about one-third the total number of turns from the diode end of the coil. (Moving this tapping towards the earthed end of the coil will increase selectivity or sharpness of tuning, but reduce volume.)

Aerial and earth sockets, and a 3.5mm jack outlet, complete the receiver. Headphones can be plugged directly in here.

The aerial and earth can be provided as explained for the diode radio in Fig. 7.

To use the radio as a tuner, C1, R1 and C2 may be added. Suitable values are C1 470pF, R1 220k, and C2 0.25μF. A screened lead with jack plug should be made up to connect the tuner to the amplifier input socket.

One Transistor VHF Receiver/Converter

The super-regenerative receiver is well known for its great sensitivity, which equals that of a multi-stage superhet. It has no alignment difficulties, and few components, so is an interesting project. Its main disadvantages are its background hiss, but this ceases when a signal is tuned in, and its lack of selectivity. The latter is however relatively unimportant on the VHF bands. The circuit here is particularly intended for 2m reception, but is easily modified. It is not intended for FM signals.

In Fig. 35 the detector is a VHF FET, and the field effect transistor will be found very satisfactory in circuits of this kind. T1 is the pre-set tuning capacitor, which allows adjustment over a fairly wide band of frequencies. Tuning is by VC1, which does not require a reduction drive.

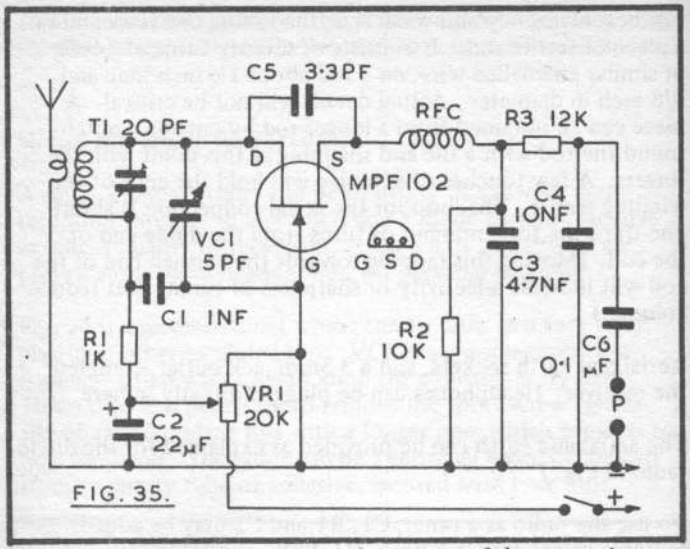

Control of super-regeneration is by means of the potentiometer VR1, which adjusts the FET drain potential. The value of VR1 is not very important, but a linear potentiometer is necessary.

C5 provides feedback from source to drain, for regeneration. R3 and the associated components form the quench network, with C6 feeding headphones, or an audio amplifier.

For best results, VR1 should enable the transistor to go smoothly into super-regeneration, which is shown by the hiss mentioned. Achieving this depends somewhat on the transistor, value of C5, adjustment of T1, and aerial loading. However, matters are not too critical.

Transistors unsuitable for VHF cannot be used. Individual FETs of the same type will also differ somewhat, so that in some cases it might be necessary to omit C5, or change the value. Alternatively, a small pre-set (not over 10pF) may be fitted. It will be found that a very small capacitance is required.

Another cause of failing to obtain super-regeneration is too tight aerial coupling, and this is easily corrected by moving the aerial coupling winding a little further from the larger winding.

The RF choke can be a VHF type, or can consist of seventy five turns of 36swg enamelled wire, side by side on a ¼ inch diameter insulated rod. Touches of adhesive may hold the end turns only.

Short leads are essential, and assembly on a tag board is shown in Fig. 35B. The variable capacitor is fitted first, and it can later attach the finished board to a panel, by means of an extra nut.

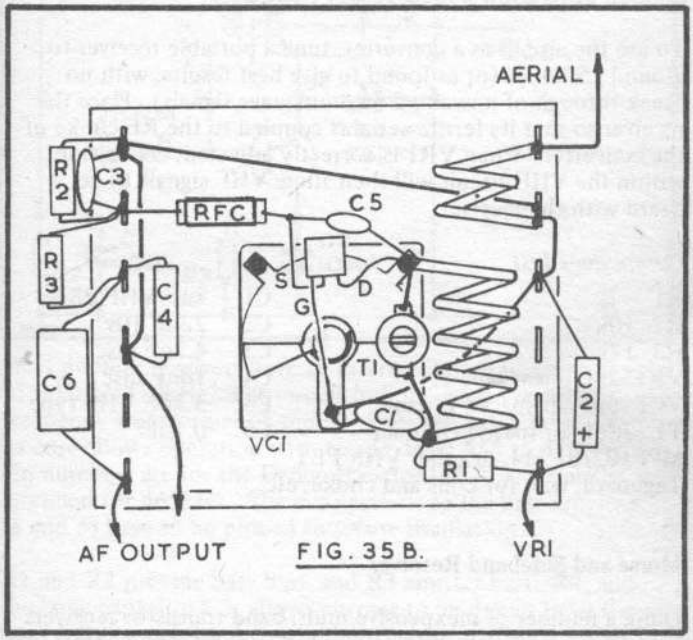

The larger coil has five turns of 18swg wire, and is ½ inch in diameter and ¾ inch long. The smaller coil has two turns. Wiring to VC1, T1, C5, the coil and C1 must be as short as can be arranged. Connections elsewhere are reasonably direct. A ceramic disc capacitor may be used at C1. T1 should be a low loss trimmer.

The board can be fitted in a case which will carry VR1, and large enough for the battery and on-off switch. The case can be used to support a telescopic aerial, some 30 inch or so when extended.

Frequencies tuned by VC1 can be raised by unscrewing T1, or by stretching the larger coil to separate the turns more, or by using a coil with fewer turns, or of smaller diameter. The receiver is most suitable for use over the 70MHz to 200MHz range.

For the single transistor alone, a sensitive pair of medium or high resistance phones will be needed. Audio ouptut from C6 can be taken to an amplifier, for more powerful reception with phones, or to allow a loudspeaker to be used.

To use the circuit as a converter, tune a portable receiver to around 1500kHz (or as found to give best results, with no break through of unwanted medium wave signals). Place the receiver so that its ferrite aerial is coupled to the RF choke of the converter. When VR1 is correctly adjusted, conversion within the VHF circuit will then allow VHF signals to be heard with the receiver.

Component List

R1	1k	C1	1nF VHF disc
R2	10k	C2	22µF 10v
R3	12k	C3	4.7nF disc
VR1	20k linear pot.	C4	10nF disc
VC1	5pF air-spaced variable	C5	3.3pF VHF type
T1	20pF air spaced trimmer	C5	0.1µF

MPF102/BF244, or other VHF FET
Tagboard, wire for coils and choke, etc.

Morse and Sideband Resolver

Quite a number of inexpensive multi-band transistor receivers have frequency coverage which includes one or more Amateur bands. That is, 1.8, 3.5, 7, 14, 21, or 28MHz. On these bands transmissions are often in Morse code or CW, or single sideband. CW or SSB can be resolved by the specialised Amateur receivers and transceivers, but not with the general purpose home receiver. To receive CW or SSB with the latter type of radio, it is necessary to add an oscillator. This either generates a heterodyne or beat note for code reception, or replaces the carrier which was eliminated from the single sideband transmission.

The circuit in Fig. 36 may be used for these purposes. It generates a carrier of about the same frequency as that used in the intermediate frequency stages of the receiver, exact adjustment of frequency being by VC1,

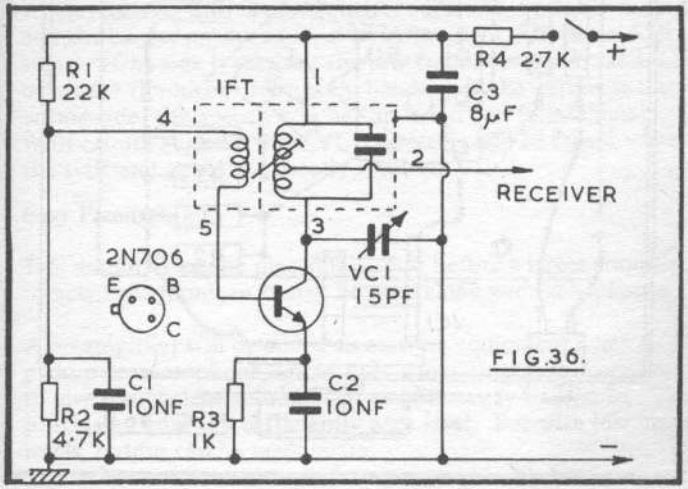

FIG.36.

Most popular receivers have an intermediate frequency of about 455kHz to 470kHz. The circuit in Fig. 36 uses an intermediate frequency transformer of similar type, and adjustment of its core allows operation with any IF from 455 to 470kHz. Pin numbers are for the Denco (Clacton) IFT13, normally intended for 465kHz. The connections to the base winding (4 and 5) have to be phased to secure oscillation.

R1 and R2 provide base bias, and R3 emitter bias. R4, and the large capacitor C3, allows current to be drawn from the same battery as is used to run the receiver, if wished. Alternatively, a separate 9v battery may be employed here.

Fig. 36B shows the practical layout of components, and wiring to them, using a perforated board. Connections and joints are kept close against the underside of the board. When wiring is finished, the board is mounted in a metal box, using ½ inch bolts with extra nuts for clearance.

VC1 can best have a dial with a central zero mark, this showing when the plates are half meshed.

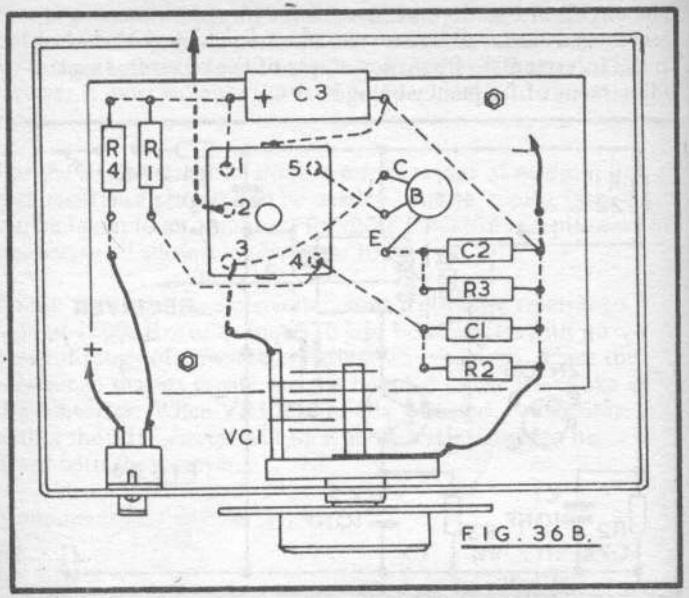

FIG. 36B.

An insulated lead is run from 2 on the IFT, and is placed near the receiver. This lead may be so positioned as to give best coupling into the IF stages of the receiver. If coupling is too weak, the signal from the CW/SSB Resolver will be inadequate. On the other hand, tight coupling will allow the carrier to swamp weak signals tuned in on the receiver. Fortunately the degree of coupling is not at all critical.

To set up the oscillator, first of all tune in any normal broadcast with the receiver. Set VC1 half closed and switch on. The core of the IFT should now be slowly adjusted until a loud heterodyne or beat note is heard accompanying the signal received. Set the core so that this note falls to about zero, or to a low pitch. It will then be possible to rotate VC1 either way from this central zero beat position, in each case producing a note which rises in frequency as VC1 is rotated.

To receive CW or Morse code, it is only necessary to tune in the code signal with the receiver, and then to adjust VC1 to

obtain a note of the most suitable pitch. VC1 can be rotated either way from its central or zero beat position, to obtain best freedom from interference.

When receiving SSB, a more critical adjustment of VC1 is needed and the carrier produced must be at the right side of the SSB signal. (One side is used for the low frequency bands, and the other for the higher frequency bands.) If the carrier is the wrong side, the speech will be "inverted" or unintelligible. With careful adjustment of VC1, a setting will be found where the sideband signal is correctly resolved.

Easy Preamplifier

This amplifier can be placed in circuit before a larger amplifier, to boost the input, or it may be used alone with headphones.

A preamplifier will be added to existing equipment when a pickup or microphone having only a low output has been found to give insufficient volume. An amplifier may be able to provide a signal at a sufficiently high level. But with low input levels, output can be inadequate.

The stage in Fig. 37 can provide considerable gain. Audio input is to C1, and R1 provides base current for the transistor. Amplified signals are obtained across R2, and pass to the main amplifier (or phones) via the isolating capacitor C2.

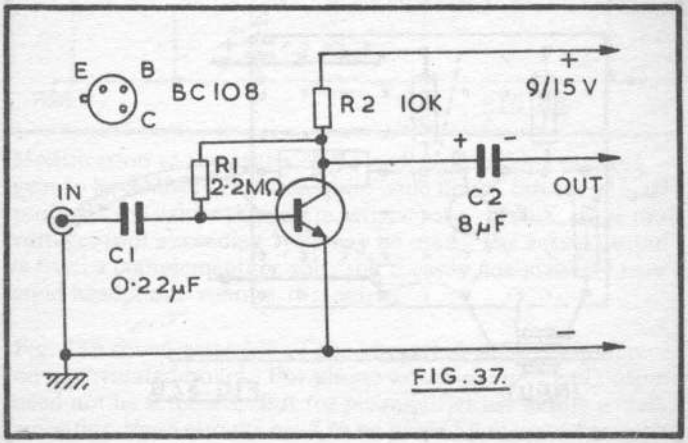

FIG. 37.

With a BC108 or similar transistor, the supply can be about 9v to 15v. Numerous NPN transistors, intended for preamplifier use and of low noise type, will perform well. Current may be from a separate battery. Or it may in many cases be drawn from the main amplifier. To avoid instability or similar troubles, the positive supply should be from a well decoupled and smoothed point in the main amplifier. If this is not available, connect a 220μF capacitor from positive to negative in Fig. 37, and draw the positive supply through a 1k resistor. Negative is returned to the negative line of the main amplifier.

Should the main amplifier have a positive earth line, then the transistor can be a PNP type, R1 and R2 being changed to suit.

Fig. 37B shows assembly on a perforated board. When the circuit provides input to a main amplifier, it should generally be in a metal case. Input is by a screened lead, and a screened lead is also fitted for the audio circuit to the main amplifier. The case should be earthed to the negative line. This can be by means of one of the bolts securing the board.

Screening to avoid hum or instability will generally prove to be unnecessary when using the stage to operate headphones. So two sockets, or a jack socket, will be more convenient for the phone circuit.

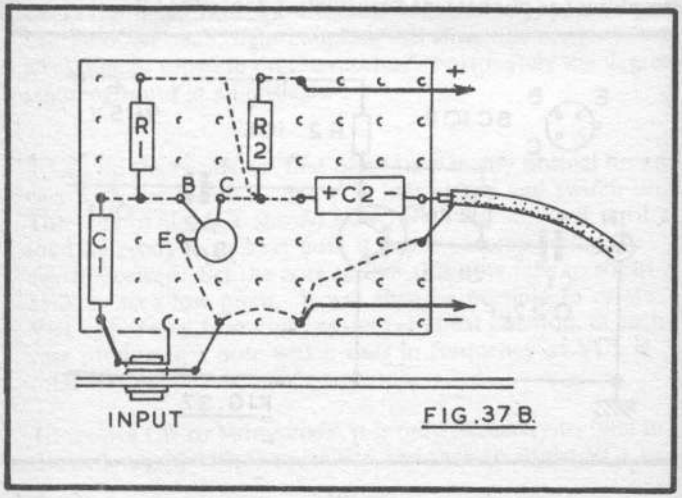

FIG.37B.

741 Preamplifier

Integrated circuits have several stages of amplification, formed as a single chip and enclosed in a small case. The 741 is an easily obtained audio IC which can be used in many circuits. The uA741CE or metal can 741 is convenient, as its leads may be spaced to suit any ready perforated board. The dual in line 741 is electrically similar.

Fig. 38 shows a preamplifier using the metal can 741. Input is via C1 to 3. As shown, 7 and 4 are positive and negative, while output is from 6. Negative feedback is applied to 2, via R4. C3 is an isolating capacitor.

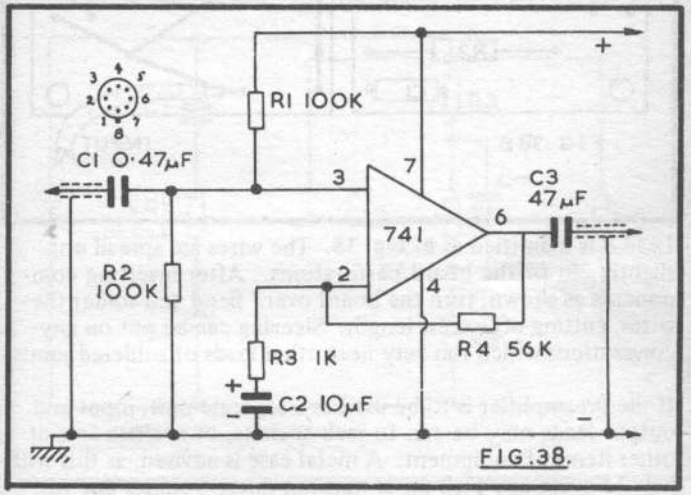

FIG.38.

Modification to the values of R3 or R4 allow feedback and gain to be adjusted between quite wide limits, but for general purposes the values shown are satisfactory. A wide range of voltages (not exceeding 36v) may be used. The actual output is from a complementary pair, and is easily adequate for very good headphone volume, if required.

Fig. 38B shows assembly of the integrated circuit amplifier on a perforated board. For phone working, input and output need not be screened. But for preamplifier use before a main amplifier, these circuits need to be made by means of screened leads.

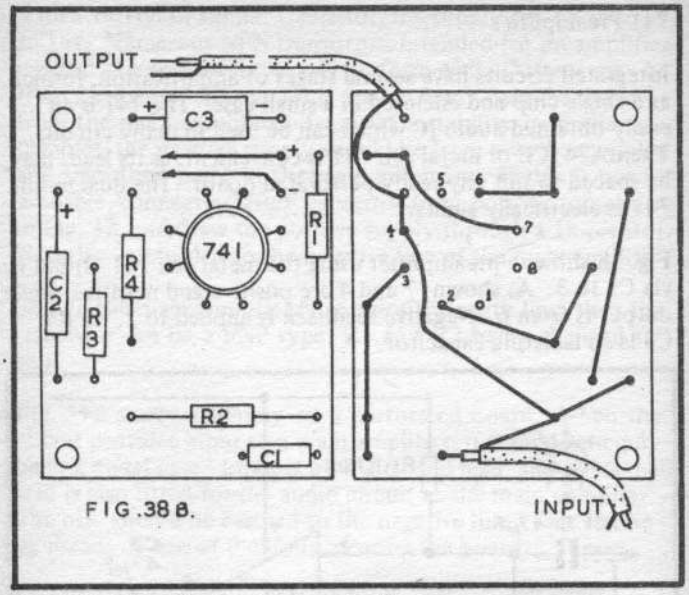

FIG.38B.

Lead 8 is identified as in Fig. 38. The wires are spread out slightly, to fit the board perforations. After inserting components as shown, turn the board over. Bend and solder the wires, cutting off excess length. Sleeving can be put on any connections which run very near other leads or soldered joints.

If the preamplifier is to be used as a separate unit, input and output leads may be run to jack sockets, or sockets to suit other items of equipment. A metal case is advised, as this will help to avoid any pick up of hum, or other troubles due to coupling to the board wiring. The board can be secured to the metal box or case with ½ inch 6ba bolts, and extra nuts to give a little clearance.

The amplifier may be run from its own battery; or from a supply used with a main amplifier. For the latter, it is wise to provide a decoupled point, in a similar manner to that described for the transistor preamplifier. This consists of a quite large capacitor (say 220μF to 470μF) from positive to negative across the preamplifier supply circuit, and a resistor of 1k to 2.2k or so from preamplifier positive to positive on the main amplifier.

Tone Control for Your Discs Etc.

The preamplifiers shown have a substantially flat response. That is, they do not purposely emphasize bass or treble, or have similar effects in modifying the audio frequencies present. In some circumstances it is necessary to boost treble or bass, or reduce the emphasis of these frequencies, in order to obtain the most satisfactory reproduction.

This may be achieved by making a fully adjustable tone control, and Fig. 39 is a suitable circuit. A volume control is also incorporated, as this has not been present in the preamplifiers.

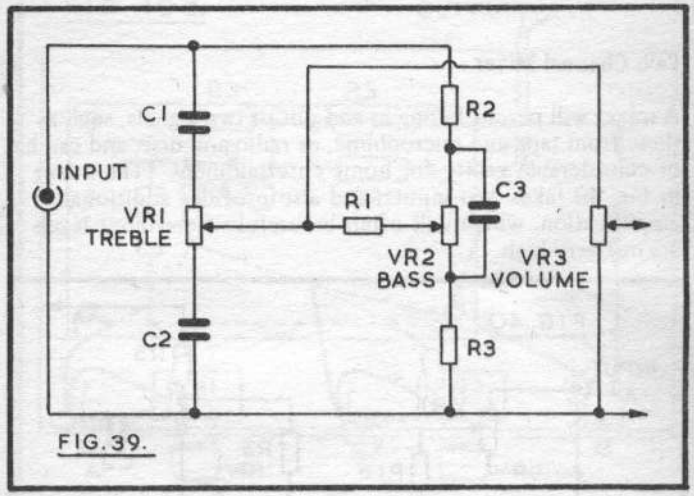

FIG.39.

The tone control is a passive circuit, needing no battery, and it can be placed between the source of audio signals (generally a microphone, pick-up, or radio tuner) and the amplifier or preamplifier. It may also be located between preamplifier and main amplifier, if wished.

Results are substantially flat with the treble control VR1 and base control VR2 in their central positions. Adjustment of VR1 and VR2 will provide separate boost or cut of treble, or boost or cut of bass frequencies. VR3 is the volume control.

The degree of control afforded by circuits of this type may be adjusted by alterations to the component values. In practice, it will be found that there is little point in having extreme levels of adjustment, which will never be required. The following values may be used: C1 and C2, 270pF; R1, 390k; R2 and R3, 100k; C3 680pF; VR1 and VR2, 2 megohm linear potentiometers; VR3, 2 megohm log potentiometer.

Components should be assembled in a metal case, for screening. The case is grounded to the earth line. Input and output sockets can be near the ends of the case, with VR1, VR2 and VR3 between. Components can be soldered directly to the potentiometer tags.

Two Channel Mixer

A mixer will permit fading in and out of two signals, such as these from tape and microphone, or radio and disc, and can be of considerable utility for home entertainment. The mixer in Fig. 40 takes two inputs, and also provides additional amplification, which will often be useful where input levels are not very high.

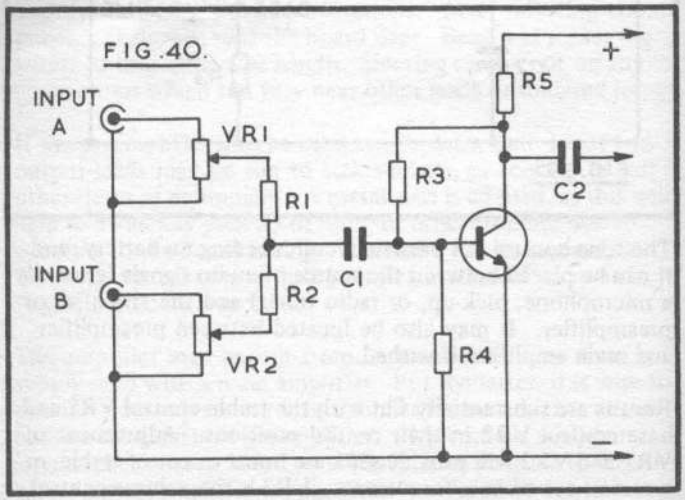

Input A has its individual volume control VR1, and Input B is similarly provided with VR2. Resistors R1 and R2 prevent short circuiting one input when the other potentiometer is set at zero. Coupling to the transistor base is by C1. R3 and R4 set base bias conditions, with R5 as the collector load and audio output from C2.

Component values are not very critical, though R3, R4 and R5 need to be selected to suit the transistor fitted. The mixer is connected and used in a similar way to that explained for the preamplifiers.

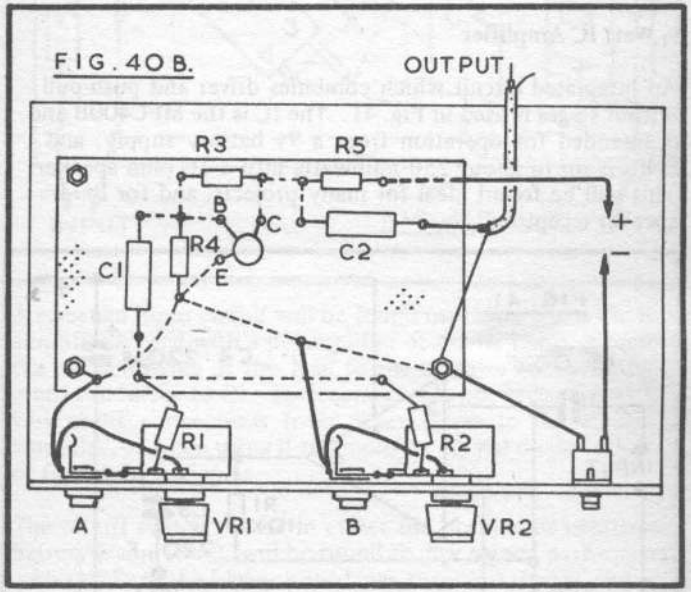

Fig. 40B is the layout, using a metal case or box. A screened output lead is provided. Input sockets A and B may be chosen to suit the type of plugs on existing equipment. The on-off switch is separate from the potentiometers, so that these can be left at pre-set levels if wished.

Component values may be chosen to suit low or high impedance inputs, if wished. Or the following may be used for general purposes:

Components List:

VR1, VR2, 1 megohm log potentiometers.
R1, R2, 200k
C1 0.5μF — C2 0.5μF
R3 330k — BC109
R4 22k
R5 10k

This is when using a 9v supply.

¼ Watt IC Amplifier

An integrated circuit which combines driver and push-pull output stages is used in Fig. 41. The IC is the MFC400B and is intended for operation from a 9v battery supply, and delivers up to about 250 milliwatts into a 16 ohm speaker. This will be found ideal for many projects, and for loudspeaker reception.

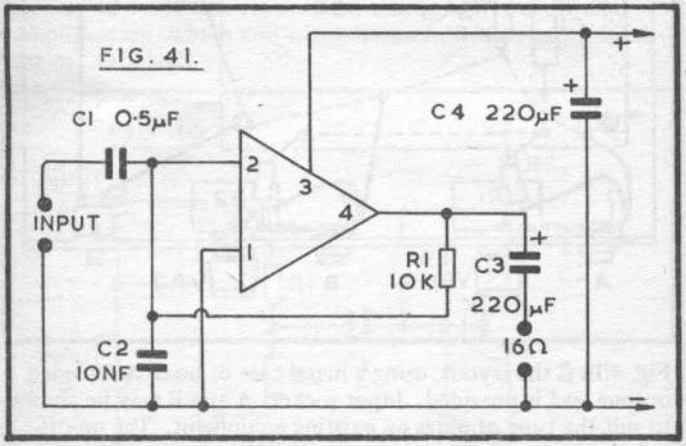

Audio input is to 2 of the IC, from the isolating capacitor C1. C2 is a by-pass capacitor to maintain stability. The IC has only four connections, 1 going to the negative line, and 3 to the positive supply. Audio output is from 4, and to the loudspeaker via C3. R1 provides negative feedback and bias to point 2.

The assembly of this amplifier on 0.15 inch matrix board is shown in Fig. 41B. Pin numbering is when looking at the top of the IC and the component side of the board.

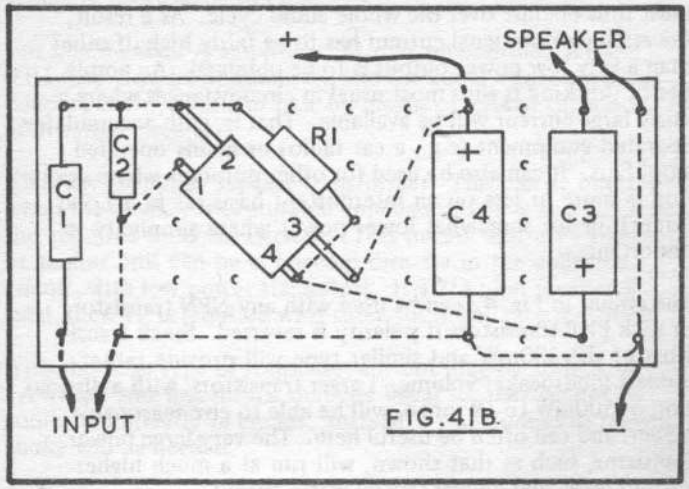

A screened input circuit will be found necessary when the IC amplifier is used with a preamplifier or similar items. Connect the outer brading of this lead to the negative line, and the inner conductor to C1. Such screening is not necessary with very short connections from other stages to the IC amplifier, or when using it to amplify a crystal diode radio, or for similar purposes.

The on-off switch can be in either the positive or negative battery lead. The IC will be found to give a good performance with speakers of a higher impedance than that shown, and up to 75 ohm may be used (with some small loss in output). Units of lower impedance than 16 ohms should not be fitted.

The small size of this IC and the few extra components needed make is very suitable for miniature apparatus, probably with a 2½ inch speaker. It will also operate a large speaker well (see "Boost Speaker") and at a volume level adequate for many purposes.

Class A Amplifier

A Class A amplifier uses a single transistor, Fig. 42, which must thus operate over the whole audio cycle. As a result, the resting or no-signal current has to be fairly high, if other than a very low power output is to be obtained. An amplifier of this kind is thus most usual in circumstances where a fairly large current will be available. That is, with accumulator operated equipment (e.g., a car radio) or mains operated amplifiers. It can also be used for other purposes where operation is more or less on an intermittent basis (as in a Loud Hailer), or for somewhat lower power where simplicity is important.

The circuit in Fig. 42 can be used with any NPN transistor, or with PNP transistors if polarity is reversed. Small transistors of the 300mW and similar type will provide rather modest loudspeaker volume. Larger transistors, with a dissipation of 500mW to 1W or so, will be able to give reasonable power, and can often be useful here. The very large power transistor, such as that shown, will run at a much higher current level, and deliver several watts output.

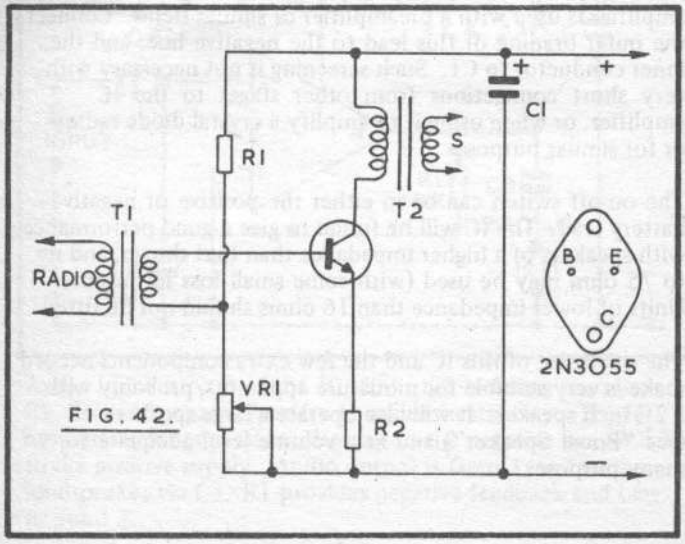

FIG. 42.

T1 is the coupling or driver transformer, which may receive audio signals from a radio receiver, smaller amplifier, or other equipment. A step down ratio of about 5:1 to 10:1 will generally prove to be suitable.

For smaller Class A amplifiers, T1 may be omitted. R1 and VR1 may then be of about 1k, and the audio signal can be coupled to the transistor base by means of a fixed capacitor, as in earlier circuits.

T2 is the output or speaker transformer. This can be omitted when the speaker is of suitable impedance, and is able to carry the required collector current. This means that a 75 ohm or similar unit can be connected directly in the collector circuit, with low power transistors. If a 2/3 ohm speaker is used, then T2 is required with these for impedance matching.

With the large type of transistor, current may be 500mA to 1A or so, and this means that the usual speaker cannot be connected directly in circuit. Instead, a transformer or tapped choke will be needed.

The circuit is often operated from 12v (a vehicle supply) but can be used with 9v, or more than 12v.

R1 and VR1 set bias conditions, and R2 limits peak collector current. For the 2N3055, R2 may be 1 ohm. R1 can be 100 ohm, and VR1 25 ohm. T2 can be 2:1 for a 3.5 ohm speaker. C1 is 3200μF. Begin with VR1 at minimum value, slowly increasing this until reproduction is satisfactory. (This will set collector current at about ½ ampere.)

With other transistors, adjustment can be made in the same way, by slowly increasing the base bias until best results are secured. Raising the value of VR1 in Fig. 42, or reducing the value of R1, will increase collector current, and thus raise the power which can be handled. However, current is limited by the power handling capacity of the transistor, so a meter should be put in one battery lead, and a check made that the power dissipation of the transistor is not exceeded. With small transistors, current can be limited to 50mA or so.

Fig. 42B shows assembly of the circuit in Fig. 42. The power

transistor is mounted on an aluminium plate, which acts as a heat sink to carry away heat from the transistor itself. Note that this plate is common to the collector. Base and Emitter pins pass through clearance holes. Smooth off any burr round the fixing and clearance holes, so that the transistor can rest flat on the metal. Where it is awkward to have the plate or case common to the collector, the usual insulation set can be fitted. This consists of bushes for the fixing bolts, and a thin mica washer to go under the transistor, so that electrical isolation is obtained.

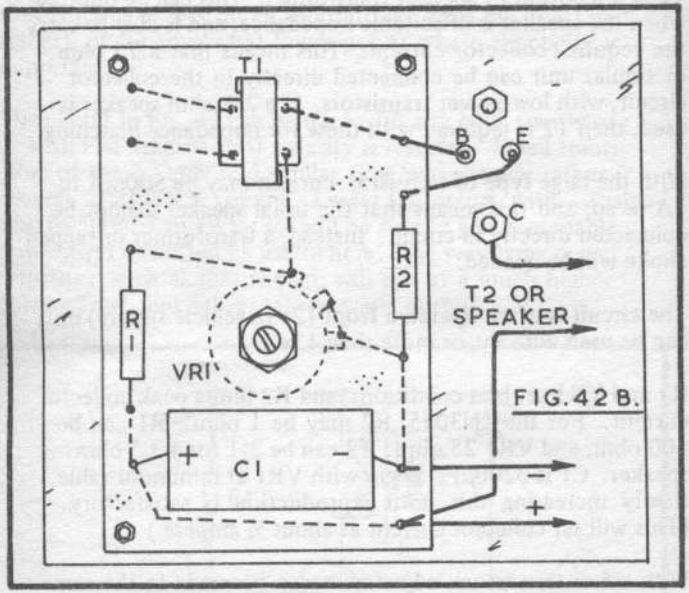

The insulated board carrying the other components is mounted by long bolts with extra nuts. A large Class A stage transistor of this type will grow very warm to the touch, if run at anything like maximum power rating. This does not indicate any defect.

Two Stage Amplifier

The circuit of a 2-stage amplifier is shown in Fig. 43, and this can be used for loudspeaker reproduction. Input to the driver

stage is by the isolating capacitor C1. Operating conditions in this stage depend largely on the values of R2, R3, and the emitter bias resistor R5.

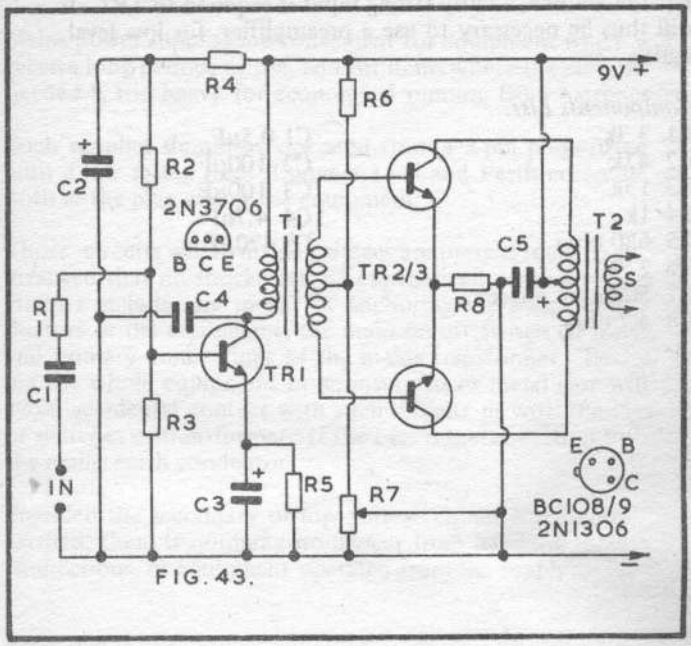

T1 is the driver transformer, with centre tapped secondary, so that TR2/3 may be operated in push-pull (see Fig. 12). T2 couples output to a 2/3 ohm speaker.

With the values shown, a BC109 will give very good results in the TR1 position, with 2 x BC108s for the output stage. R7 is set so that battery current is around 10mA, with no signal present. Current rises from 20mA to 60mA or so, according to volume, when the amplifier is driven.

A pair of 2N1306 transistors may be used for the output stage. Other transistors are also possible here, as operating conditions can be adjusted by R7.

The 2N3706 will operate in the TR1 position, though with

lower gain than the BC109. Numerous other small audio transistors can also be used here.

For full volume, a fairly strong input is required to TR1. It will thus be necessary to use a preamplifier, for low level signals.

Components List:

R1 3.3k
R2 47k
R3 15k
R4 1k
R5 680 ohm
R6 2.7k
R7 500 ohm pre-set
R8 4.7 ohm

C1 0.5μF
C2 100μF
C3 100μF
C4 4.7nF
C5 470μF

SECTION 4
POWER SUPPLIES

Mains power supplies are convenient for equipment which will receive long periods of use, and for items where the current needed is too heavy for economical running from batteries.

Such supplies should be operated from a 3-pin plug, fitted with a low rating fuse. Connect L, N and Earth correctly, both at the plug and at the equipment.

Those circuits where mains voltages are present must be so arranged that no shocks can be experienced. Mains voltage circuits include any means of anchoring the mains conductors in the equipment, the main on-off switch (if used), and primary connections of the mains transformer. Enclosing the whole equipment in an insulated or metal case will avoid accidental contact with such circuits or with the tags of switches or transformer. If the case is metal, earth it by the mains earth conductor.

Provided the secondary or low voltage circuit is correctly earthed, there is normally no danger from handling these connections, or equipment operated from the supply.

Easy PSU

A useful power supply suitable for many purposes can use the circuit in Fig. 44. Mains L (live) and N (neutral) conductors go to the primary P of the transforer. A switch is placed in the L circuit.

The secondary S can delivery any wanted low voltage, and also give isolation from the mains.

Almost all equipment will need direct current. The four separate rectifiers, or an equivalent single device, produce pulsating DC. The reservoir capacitor C1 smoothes this. Resistor R1, with the second capacitor C2, gives additional smoothing. Output from the supply is then substantially smooth DC, as would be obtained from a battery.

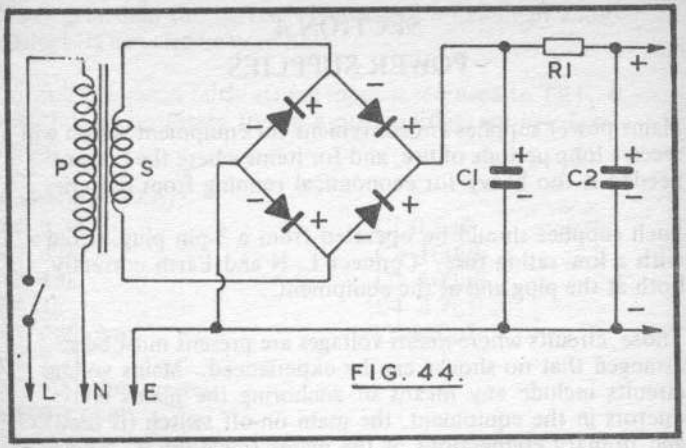

FIG. 44.

Sometimes R1 and C2 are omitted. Should hum accompany reproduction from an amplifier, this shows that smoothing is probably inadequate, and if so the cure is to add R1 and C2.

Any wanted voltage can be obtained by using a transformer with an appropriate secondary, with rectifiers and capacitors to suit.

C1 may charge up to approximately 1.4 times the RMS or usual voltage rating of the secondary S. Thus, if S were a 6.3v winding, about 8.8v would be expected across C1. But should R1 be present, a voltage drop will arise in it, the figure depending on the resistance value of R1, and current flowing.

For these reasons, the actual output may not be exactly the figure expected. This will often be unimportant, and such power supplies are largely used for all sorts of equipment.

For apparatus generally operated from a 9v or similar battery, a bell transformer with 3v, 5v and 8v output tappings is suitable. If R1 is 22 ohm, this will give around 9v at 100mA, with the 8v tap in use.

It is convenient to use 50v or 100v rectifiers, and the rating can be 1 ampere, with a 1 ampere transformer secondary. Four individual wire ended rectifiers can be mounted on a

tag strip, and connected as in Fig. 44. A combined rectifier will have AC, positive, and negative tags (see Fig. 45) and can be fitted instead.

The capacitors need to be of large value, and have a voltage rating higher than the actual voltage which will be present. The 12v capacitors could be fitted in the circuit described. C1 can be 2500μF or larger, and C2 can be of similar value.

Easy Regulated PSU

With the circuit in Fig. 44, the exact voltage will depend on the current drawn, rising when current is low. To avoid this, some means of regulation may be employed.

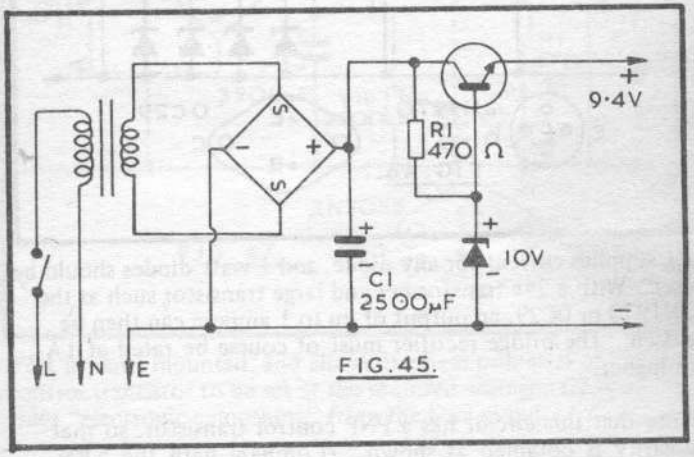

FIG. 45.

Fig. 45 shows a typical regulation circuit, giving an output of approximately 9.4v. The output from the rectifier needs to be of somewhat higher voltage than required at the output, and a transformer with a 10v secondary is suitable. Current through R1 supplies the Zener diode, which holds the base of the transistor at virtually the same voltage for all current loads. Some voltage is lost in the transistor, so the output is nearly the same, for any current load. For up to about 200mA, a BFY51 or equivalent transistor is adequate, so this will do well for many purposes.

Multi-Voltage Regulated PSU

Fig. 46 is a somewhat similar circuit, but it has a switch, to select any one of the four Zener diodes. These may be chosen so that 6v, 9v, 12v and 15v will be available.

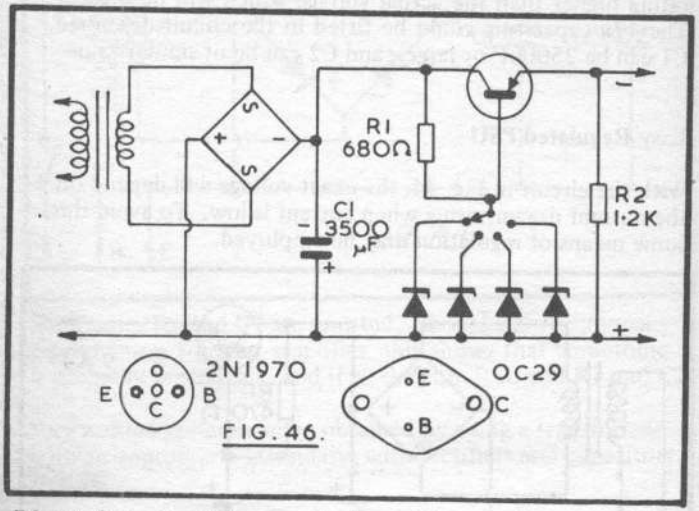

FIG. 46.

R1 supplies current for any diode, and 1 watt diodes should be used. With a 24v transformer and large transistor such as the 2N1970 or 0C29, an output of up to 1 ampere can then be drawn. The bridge rectifier must of course be rated at 1A or higher.

Note that this circuit has a PNP control transistor, so that polarity is obtained as shown. (Compare with the NPN transistor in the previous circuit.) However, either positive or negative can be grounded, and a separate earth terminal can be provided to allow this. A flying lead is placed between earth terminal and positive, or earth and negative, as required. The permanent negative earth connection shown in Fig. 45 must of course then be omitted.

More details of actual construction will be found later.

One Transistor Adjustable PSU

Fig. 47 is the circuit of a simple power supply unit which can be set to provide any output from zero to 12 volts. The transformer has a 17v secondary, rated at 1 ampere or higher. After rectification, DC is obtained from the reservoir capacitor C1.

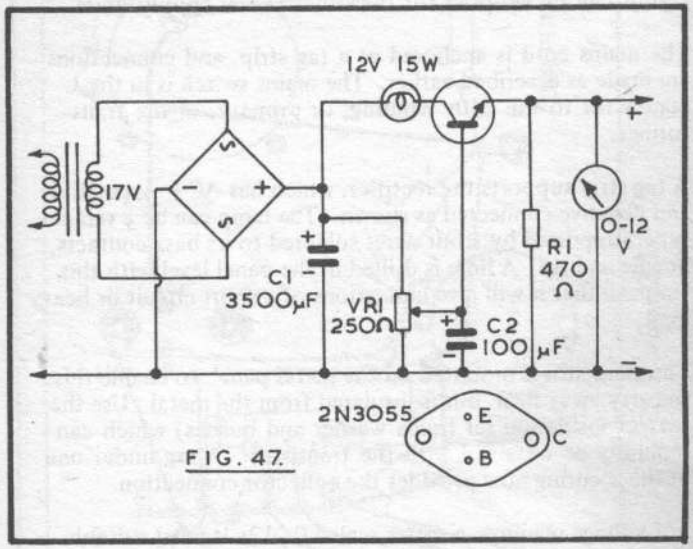

FIG. 47.

VR1 is panel mounted, and allows the base potential of the control transistor to be set at the required voltage. C2 provides "electronic smoothing" from the base circuit.

The 12 volt 15 watt bulb is for short circuit protection. With relatively low currents, little voltage is lost here. But if a short circuit arises in the output circuit, current is limited to a little over 1A by the bulb. This reduces the chances of any damage due to temporary shorts in leads or equipment.

R1 is a bleeder resistor, drawing some current even when no external load is connected. The meter is the usual high resistance type, scaled from zero to 12v. VR1 is adjusted until this instrument shows the wanted voltage.

The regulation of this supply is not so good as that of supplies using a number of transistors. But it will be found suitable for all ordinary purposes, and to supply power for circuits in this book, as only a small change in voltage arises, with changes to the load, or current drawn.

Fig. 47B shows practical construction of this PSU. A similar layout can be adopted for the other power supply units.

The mains cord is anchored at a tag strip, and connections are made as described earlier. The mains switch is in the L conductor to the 240v winding, or primary, of the transformer.

A tag strip supports the rectifier, which has AC (~), positive and negative connected as shown. The lamp can be a vehicle type, supported by stout wires soldered to its base contacts, or side and tip. A hole is drilled in the panel level with this lamp, so that it will give indications of a short circuit or heavy load.

The transistor is mounted on the metal panel, to enable this to carry away heat, but is insulated from the metal. Use the correct insulation set (mica washer and bushes) which can generally be obtained with the transistor. A tag under one of the securing nuts provides the collector connection.

For voltage readings, a meter scaled 0–12v is most suitable. Or a 1mA meter, with 12k 1% series resistor, may be used. If so, a new scale, marked 0–12, can be drawn for it.

A 3 watt linear potentiometer is used. Earth and negative are connected to the metal panel, for equipment with a negative ground line. The positive output terminal or socket is insulated from the metal.

The case can be metal, or wood. It should have a few ventilation holes. The transistor can be expected to run quite warm, at maximum current. Heating here rises as the output voltage is reduced by VR1, as in these circumstances more voltage is dropped in the transistor.

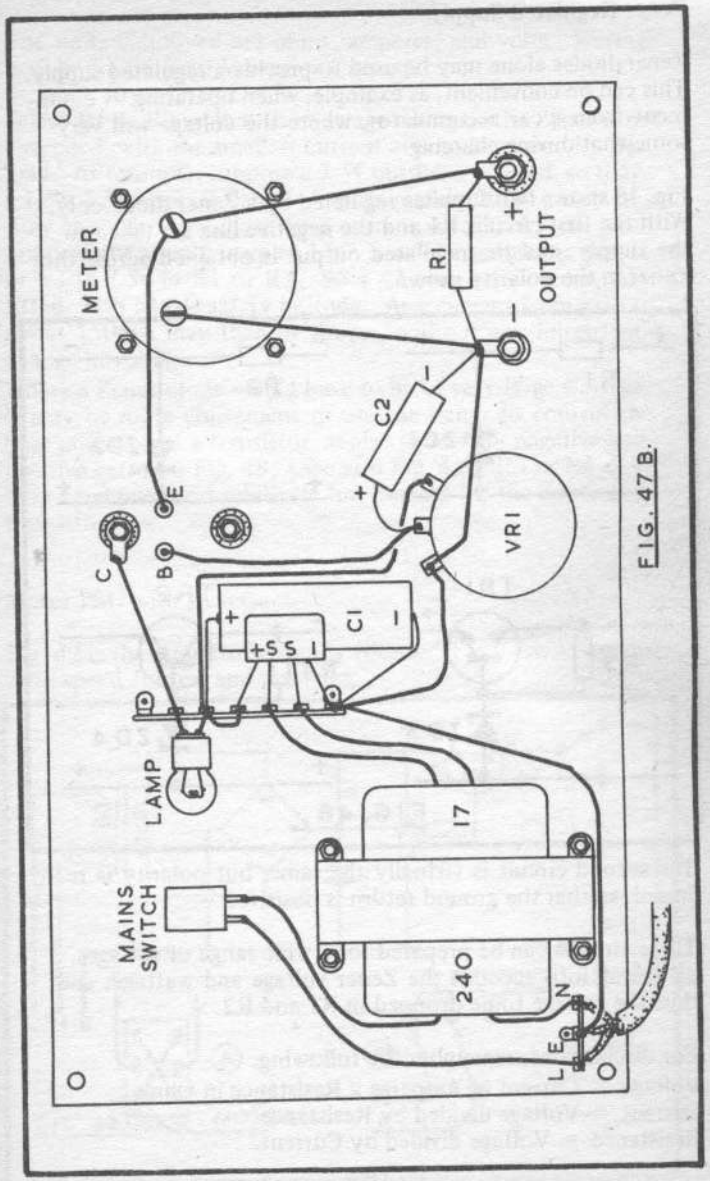

FIG. 47B.

Zener Regulated Supply

Zener diodes alone may be used to provide a regulated supply. This can be convenient, as example, when operating 9v equipment from a car accumulator, where the voltage will vary somewhat during charging.

Fig. 48 shows two supplies regulated by a Zener diode only. With the first circuit, R1 and the negative line are taken to the supply, and the regulated output is obtained across the Zener in the polarity shown.

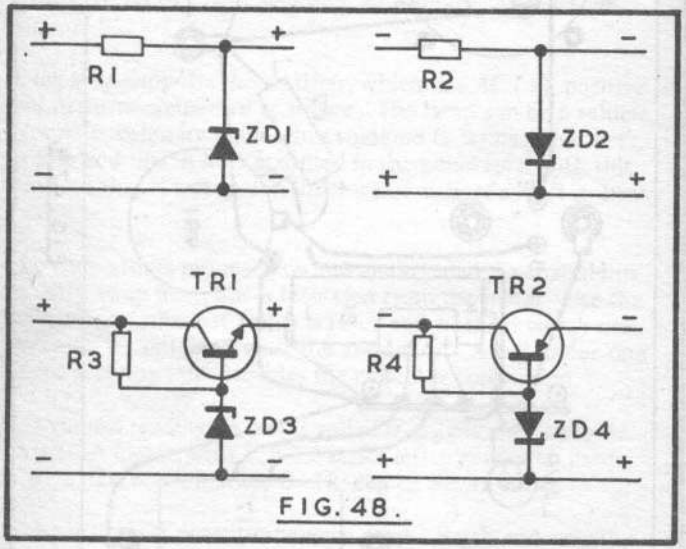

FIG. 48.

The second circuit is virtually the same, but polarity is reversed, so that the ground return is positive.

These circuits can be prepared for a wide range of voltages, by taking into account the Zener voltage and wattage, and thus the voltage to be dropped in R1 and R2.

For calculations, remember the following:
Voltage = Current in Amperes x Resistance in Ohms.
Current = Voltage divided by Resistance.
Resistance = Voltage divided by Current.

The units employed are ohms, amperes, and volts. Wattage may be found from Voltage x Current.

Select R1 or R2 so that the wattage rating of the Zener is not exceeded, with the smallest current ever to be drawn by the load. As example, suppose a 7.5v output is wanted, so that a 1½w 7.5v Zener is fitted. Approximately 200mA may thus flow through the Zener, if no current is taken by the load. Suppose the supply is up to 15v. It will be necessary to drop or waste 7.5v in R1 or R2. So a 42 ohm resistor may be fitted, with a little safety latitude. Any current from zero to about 150mA may then be drawn, without any important change in voltage.

Where a Zener diode would have to be of very large wattage, it may be more convenient to use the Zener to control the base potential of a transistor, as also shown for negative and positive earths in Fig. 48. (See also Fig. 45.) R3 or R4 then only need provide a relatively low current for the Zener and transistor base.

Motor PSU with Reverse

Fig. 49 is the circuit of a supply for model motors, and giving both speed control and reversing.

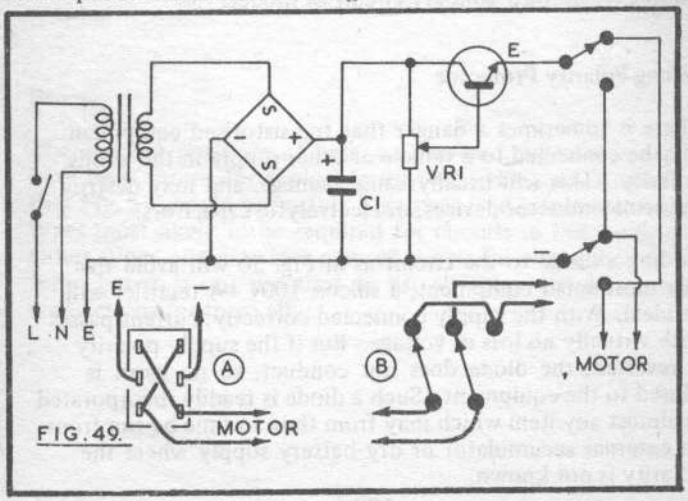

FIG. 49.

A transformer with a 12v secondary will be suitable for the usual model requiring up to 12v. The circuit is similar to that of the supply in Fig. 47. The potentiometer VR1 gives speed control. C1 can be around 2,000μF.

"A" is one type of ready-made switch, and it can be obtained with a central off position. "B" shows a home-built switch, similar to that described in Fig. 5. The switch must not short circuit the supply when changing over polarity, and one with central off is recommended.

Motors reversed in this way must be of the permanent magnet type, in which a change of polarity causes the armature to run in the opposite direction. Train and many other model motors are of this construction. Motors with a wound field will not be reversed by changing the polarity of supply.

A controller of this kind should be constructed as shown earlier, so that it is safe to use, and so that no joints in the mains circuits can be touched.

Earthing can only be omitted when a double-insulated transformer, of the type specifically made to avoid any need for earthing, has been used. The whole controller should be so constructed that, even if a fault develops, mains voltages cannot reach the secondary circuit or model.

Wrong Polarity Protector

There is sometimes a danger that transistorised equipment may be connected to a vehicle or other supply in the wrong polarity. This will usually cause damage, and may destroy the semiconductor devices, or electrolytic capacitors.

Adding a diode to the circuit as in Fig. 50 will avoid this. For most small equipment, a silicon 100v 1A rectifier will be ideal. With the supply connected correctly, current passes with virtually no loss of voltage. But if the supply polarity is reversed, the diode does not conduct, so no harm is caused to the equipment. Such a diode is readily incorporated in almost any item which may from time to time be run from an external accumulator or dry battery supply where the polarity is not known.

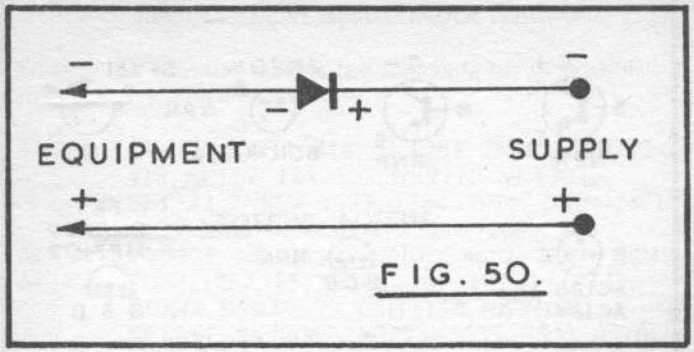

FIG. 50.

Component Tolerances

For circuits in this book, exact component values are generally not too important. Capacitor values such as 47nF (0.047μF) and 0.05μF may be regarded as interchangeable. In the same way, a 125μF capacitor may replace 100μF, or 200μF can be used instead of 220μF, and so on.

Resistors will generally be the standard 5% tolerance types. In some circuits exact resistor values are not at all critical. In others, and especially base, emitter and collector circuits, the values which provide best results can have much less latitude.

Bases

The lead-out positions of base, emitter and collector wires have been shown for typical transistors. However, it is felt that Fig. 51 should be useful. This gives lead information for types most likely to be required for circuits in this book. Other types of transistors may of course be used successfully, but it is not practical to list all these, or show connections for them all.

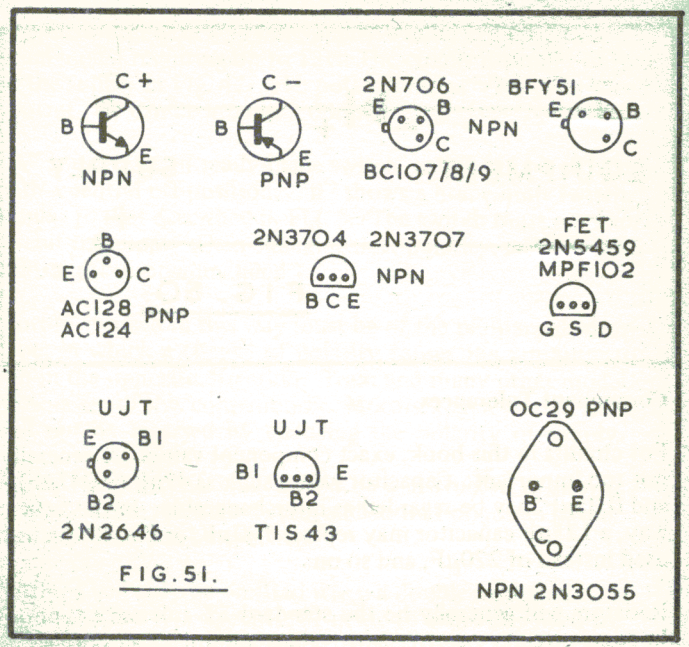

FIG. 51.

EQUIVALENT SEMICONDUCTORS

To help our overseas readers the following list of possible equivalents is shown below: –

AC128	CV9778, OC74–318, NKT281, 2N467, 2SB222–415, AC117–124–153, GET110, NKT302, SFT232, 2N659–1373–1384–1926–2001–2431–4106, 2SB370, SK3004, RS276–2005.
ACY39	CV9475, NKT243, ACZ10, 2N652–2303–2801.
AF117	2N642, 2SA155, AF102–105–127–133–137, BFX48, BSW19–73, GM1213B, NKT603F, SFT354, SK3006, 2N2273–2635–3324–4916–5354, RS276–2003.
BC107	CV9780, AM251, BC147–167–207–317, MPS6566, SK3020–3122, ZTX107, TT107, RS276–2009.
BC108	CV10541, AM252, BC148–168–208–318, MPS6520, SK3020, ZTX108, TT108, RS276–2009.
BC109	CV10769–10806, AM253, BC149–169–209–319, MPS6521, SK3020, ZTX109, TT109, RS276–2009.
BC147	BC171–182/L–207–317, MPS6566, SK3020, RS276–2013,
BC148	BC172–183/L–208–318, MPS6520, SK3020, BS276–2009.
BC149	BC184/L–209–173–319, MPS6521, SK3020, RS276–2009.
BF200	BF162–173–225–271–311–314, SE5020/1/2/3/4, SK3018, 2N616–2708–3288–3693, RS276–2011.
BFY51	CV7723–7726–10827–11238, BFX51–68A, BFR19, BSX45/X, BSY46–85, SK3024, 40347, 2SC708, ME6102 2N2193/4–2218–2410 -3053–3252–4046, RS276–2009.
BSY95A	CV7648–9379, BC108A, BSX51–73–91, BFX96, BSY20–58–62, ME9022, SK3122, 2SC321, 2N744–914–1708–2218–2369–5187, RS276–2011.
MPF102	E305, SK3116.
OA81	AA117–118–132–144, AAZ15, OA91–95–161, SD38, 1N38–56–476–618, 1S33.
OC26	CV8560, NKT452, 2N257–297–458–553–1021, 2SB3, AD130–131–138–140–149, OC28, SK3009, TF80, T1156–3027, 2N174–1073–2870–RS276–2006.

OC29	CV7083–8356, NKT402, 2N457, 2SB86–425, AD150, ASZ16, AUY21, OC28–35–36, SK3009, T13028, 2N174–1073–2870, RS276–2006.
OC44	CV5710–7003, OC170–171–410–613, 2N1303, 2SA15, AF101–117–126, ASY55, AC191, BC126, NKT211, SKT358, SK3005, 2N36–1191/2–1352–1373–1384, RS276–2003.
OC70	CV5457, OC303–602, NKT214, 2N279–1305, 2SB75, AC122–125–151–163, ACY27–34, ASY27, BC213–206A, BSX36, SK3003, 2N1193–1352–1375–2429, RS276–2004.
OC71	CV5712–7005–8344, OC70–304–604, NKT214, 2N280–1305, 2SB77, AC122–125–151–163, ACY35, BSX36, OC3041, SK3003, 2N1193–1352–1375–1384–2429, RS276–2004.
OC72	AC122/3–125/6–131–151 IV–152–162–191, BC126–213–206A, NKT211, SFT353, 2N282–1190–1352–1371–1384–1991–2431, CV5713–7006–8440, RS276–2005.
OC76	CV8314, OC307–6025, 2N284–1305, NKT212, 2SB89, AC128–131–151–152, ACY28, ASY58–76, BC126–213–260A, SK3004, 2N394–1191–1352–1371–1384–1991, RS276–2004.
ORP12	RS276–116, LDR03, RPY25.
1N4001	BY127, EM502, RS276–1101/1135, 1S100.
1N4002	BY127, EM502, RS276–1102/1136, 1S100.
2N1306	CV7350–10686, NKT736, 2N634–635–636–1891–1993–1994–1995, ASY26–29, BSX19–20, RS276–2001.
2N1613	CV7440–8843, BFY33–34–67, BSY44, 2N698–699–717–1711–1889–1890–1893, BFY41, BSX45/6, BSY53, MPS6530, 2SC708, 2N2101.

N.B.: Although equivalent semiconductors may have similar electrical properties, physical dimensions may be different and this must be born in mind if space is tight and for mounting details.
Remember polarities if replacing PNP with NPN types and vice versa. If in doubt always be advised by your dealer for suitable equivalent semiconductors.

Notes

by Peter J. Bertini, radioconnection@juno.com

Building An FM Crystal Receiver!

Our earlier crystal receiver projects proved popular, so here's another crystal receiver with an odd twist: it's intended to intercept stations on the 88- to 108-MHz FM band! With some modification, it'll also copy nearby VHF AM aviation band traffic, just the ticket for eavesdropping while watching the activity at your local airfield! FM crystal receiver projects aren't new; this project is based on material from an article that ran back in the 1950s, but with some modern refinements to improve performance. Most of the parts you'll need to build this project can be found in your junkbox, but I'll also provide some mail-order sources for those of you who don't have goodies hoarded away!

Monitoring FM signals is more challenging than tuning in your local AM stations with a simple crystal set. There are two reasons: AM signals are readily detected by a crystal-diode detector, and a simple longwire antenna will usually suffice in providing enough signal level so you can hear at least a few of the local stations. FM is a different animal. A crystal detector recovers both a DC and audio signal from an AM carrier, a simple diode detector will only produce a DC signal component when monitoring a FM signal. Since there are no AM sidebands to mix with the carrier in the detector, none of the audible information is recovered.

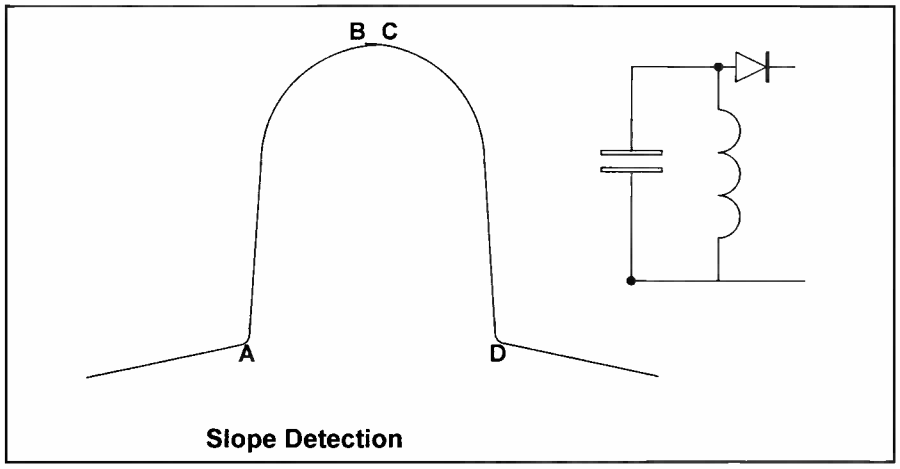

Figure 1. Here's a representative tuning curve for an LC tuned circuit as found in our FM Crystal Set. Slope detection occurs when the FM carrier straddles either side of the tuning curve between points A and B or C and D. An AM carrier would be centered between points B and C for best AM detection.

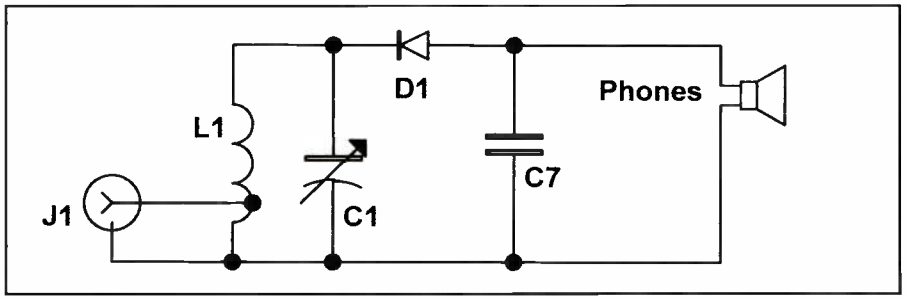

Figure 2. Here's the schematic for the simple and basic FM crystal receiver. FM performance is about 20 dB down from AM signals in the same tuning range. It makes a good companion at the local airfield to monitor AM aircraft and tower traffic in the 120-MHz region.

Slope Detection

So, how's it possible to make a working FM crystal radio? Good question. The answer lies in using a technique called "Slope Detection." FM is simply a carrier being shifted in frequency at an audible rate. The rate of shift corresponds to the frequency of the audio signal while the excursion, or carrier deviation, represents the audio signal level, or amplitude. U.S. FM broadcasters are allowed a deviation of ± 75 kHz, or 150 kHz total. This means we can hear FM signals on a simple crystal radio, providing the tuned circuit has enough Q for the recovered audio to be great enough to drive a pair of headphones. Whereas a crystal detector will detect AM signals without tuned circuits, the FM set relies on a very sharply tuned high-Q circuit to work. If we tune the FM station so it falls on either side of the slope, the modulated FM carrier will be converted to AM since its signal amplitude will vary depending on where it falls on the tuning slope at any given instant.

Many early 2-meter amateur FM repeater operators used AM transceivers, modified with simple external FM modulators, while using slope detection to hear the FM repeaters. Most of these early AM receivers were 15 or 30 kHz wide; the IF bandpass curves easily recovered the ± 5-kHz FM deviation! The trick was to tune to one side of the signal or the other, carefully centering the FM carrier on the center of the tuning skirt, not dead on at the peak! In short: The steeper the slope, the greater the recovered audio for a given deviation.

Figure 1 illustrates how slope detection works. The curve on the drawing represents a typical, but not exact, representation of how a tuned circuit responds as it is tuned across a carrier. Points A and D denote the bandwidth of the tuned LC circuit. The areas between points A and B and C and D represent the slopes of the tuning curve. Ideally, an AM signal would be tuned so its carrier is at the apex, or center, of the tuning curve. If we center the carrier frequency of the FM transmitter to the same spot, the carrier will swing over both slopes, and any recovered audio would be canceled. Instead, the "sweet spot" is where the FM carrier falls near the midpoint of the slope between A and B, or likewise on the slope of the curve between points C and D. The AM detector output will then swing in correspondence with the aural information carried on the FM carrier.

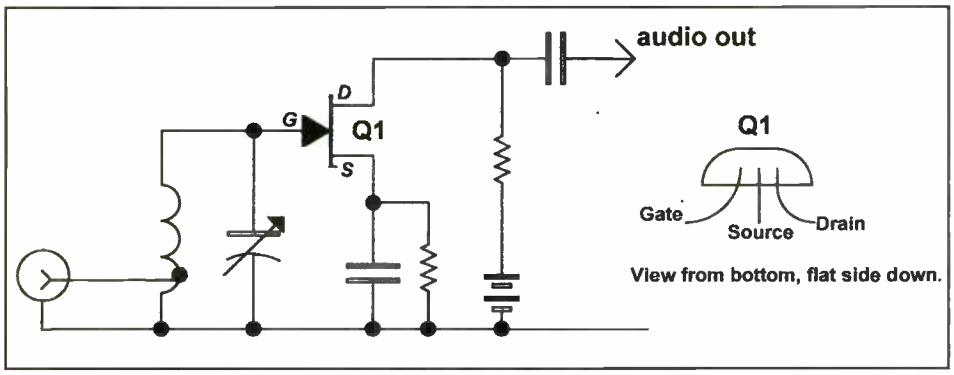

Figure 3. The infinite-impedance detector offers several advantages over a germanium diode detector. It has gain, doesn't load the tuned circuit, and it features better weak-signal detection.

Ideally, for maximum audio recovery, the FM deviation will "sweep" over the largest area of one side of the slope as is possible. It's hard to match the tuning curve to the FM deviation, and also any non-linearity in the slope along the rise or fall on the curve (a straight line, like a saw tooth, is ideal) will cause distortion. Too wide a slope and the FM deviation will fall on a very small area on the slope, giving very poor recovered audio. Too much deviation, where the carrier swings beyond the cutoff and into the opposing slope, yields large amounts of distortion on the recovered audio. In practice, these sets do work, but don't expect anything approaching high-fidelity reception!

The Simplest Receiver

There are several key elements needed for this project to work, most importantly, having a very strong local FM station or two or listen to. Most urban locations are so blessed. You'll also probably need a good outdoor FM or TV antenna to capture enough signal for the set to work, and it's a big plus if your system includes an inline VHF/FM preamplifier.

Let's get started by looking at **Figure 2**, the starting point for our project. It closely resembles the primitive FM crystal set projects shown in those early magazines. The heart of the receiver is the high-quality tuning capacitor and inductor. The tuning capacitor can be salvaged from an old FM tuner or converter, if need be. The tuning capacitor (C1 in the drawings) is a 35-pF capacitor with a built in 3:1 vernier dial reduction, and was salvaged from my junkbox. Any capacitor with a maximum capacity of 25 to 45 pF will work.

The set tunes rather broadly, thus the vernier tuning isn't a necessity, but it is nice to have. One source for the cap is Fair Radio; its 3G-25 variable cap has a vernier drive and three sections with 4-25, 4-20, and 3-17 pF. Two of these sections could be paralleled to yield a larger tuning range. The inductor (L1 in all drawings) is wound from a length of #8 copper ground wire, available from any hardware store. You can substitute a smaller gauge if necessary. The circuit Q could be improved by silver-plating the coil—if you have a means to do so try it. Otherwise, I suggest polishing the copper to a sheen, followed by applying a coat of clear Krylon to prevent tarnishing. The coil consists of six turns; I used a half-inch wood dowel as a form to wind the coil. The antenna tap is made at one-half turn above ground on the coil. **Photo A** shows the tap point and also the tuning capacitor. **Table 1** lists the parts values and sources for all the components used in three versions of the receiver shown in this month's column.

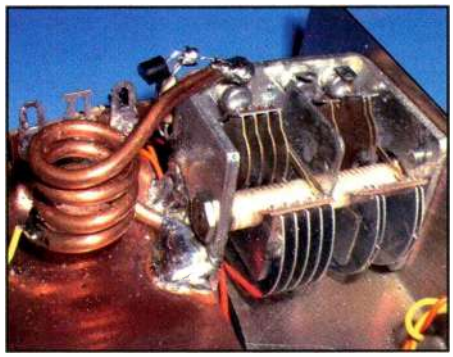

Photo A. The tuning capacitor and coil form the heart of the crystal set. The Q of these parts determines the tuning slope, and ultimately audio recovery on FM signals. The capacitor should be the best quality available. Often military surplus capacitors with ceramic insulation are available on the surplus market or at hamfests. If you can find one, use it. The tap point for the antenna is visible. Use a short lead between the tap and J1 connector.

Photo B. Here's the Millen Grid Dip Meter in action! When tuned to the resonant frequency of the capacitor and coil, the meter on the Millen will dip to a lower value. Fifty or 60 years ago, every ham owned one of these useful pieces of test equipment. That was a time when hams built their own gear. Now using one has become an archaic art.

I know finding parts can be difficult. I listed a few resources in **Table 1**, including one for a basic kit, sans headphones, for building the basic FM crystal set. This five-dollar postpaid kit can serve as the nucleus for the more advanced versions shown here as well.

Checking The Tuning Range

A grid-dip meter is the easiest way to check the tuning range of your coil and tuning capacitor combination. A ham friend who is also a builder is a likely candidate to have one of these units in his workshop. **Photo B** shows my venerable James Miller *'dipper* being used to check that my set will tune the entire FM band. These devices are variable oscillators with calibrated tuning ranges. A set of companion plug-in coils allows covering from the broadcast band up through 300 MHz. When the *'dipper's* coil is held near a tuned circuit, and the grid dipper is tuned to that frequency, the grid current in the *'dipper* will drop (or "dip"), as shown on the *'dipper's* built-in meter.

Alternately, a signal generator would also do for checking the tuning range. Compressing or expanding the coil slightly will shift the range: squeezing the coil will allow lower frequency tuning, while

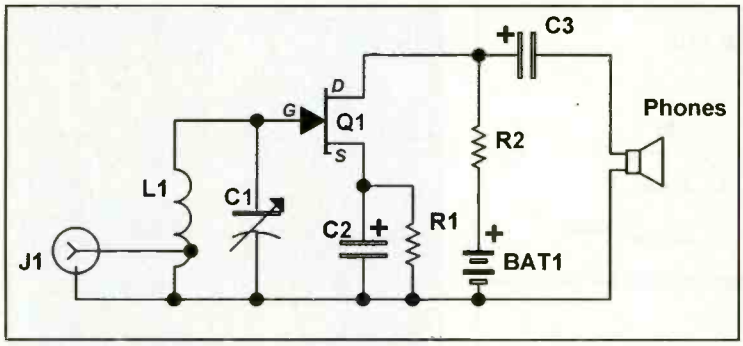

Figure 4. Adding the infinite-impedance detector to the basic FM crystal receiver might make the difference between hearing a station or not!

Photo C. The leads for the infinite-impedance detector should be kept short and direct for VHF. The J-FET leads and associated parts are mounted to the capacitor terminals and frame. ⟶

Table 1. Parts List And Recommended Suppliers

L1	#8 copper wire, see text
C1	variable capacitor, 5 to 50 pF max. with knob
D1	1N34A germanium diode, or equivalent
J1	RCA phono jack or suitable RF connector for antenna
C2	10 µfd @ 16 volts electrolytic
C3	10 µfd @16 volts electrolytic
C4	10 µfd @ 16 volts electrolytic
C5	0.1-mfd ceramic capacitor @ 16 volts
C6	220 to 470 µfd @ 16 volts electrolytic
C7	500-pF ceramic disc or silver mica capacitor
R1	47k-ohm 1/4-watt resistor
R2	47k-ohm 1/4-watt resistor
R3	10k-ohm variable potentiometer, audio taper/with knob
BAT1	9-volt transistor battery with battery clip
Phones	2000-ohm vintage headset or crystal earpiece
Speaker	8-ohm speaker in enclosure
Q1	J-FET, type J-310
U1	LM-386 DIP package 8-pin audio IC

Resources

• Dan's Small Parts, PO Box 3634, Missoula, MO 59806-3634, (406) 258-2782, www.danssmallpartsandkits.net

This is an excellent resource for all components (ICs, FETs, small parts, and variable caps). Dan's features low prices and is set up to deal with home experimenters. Dan's offers an online catalog and ordering system. Minimum order might apply, check with seller.

• Bill Turner, 1117 Pike Street, St. Charles, MO 63301, (636) 949-2210, www.dialcover.com

Bill offers a kit and copy of the original vintage magazine article for the FM Crystal receiver for $5 postpaid. No frills or headphones, just the basic parts. No minimum order.

• Fair Radio Sales, 2935 St. Johns Road, PO Box 1105, Lima, OH, (419) 227-6573, www.fairradio.com

Surplus stalwart Fair Radio has a nice three-section variable (catalog #3G-25) that will work well. Price is $6. They also offer some high-Q ceramic military versions, but these are more expensive. Minimum orders might apply, check with seller.

expanding the coil will increase the higher end of the tuning range. A 40-pF variable capacitor should tune from 80 MHz through at least 130 MHz into the aircraft band. At worst, you may have to wind a new coil with a turn added or removed before you're able to tune the desired range. Adding a full or partial turn will lower the frequency. **Photo B** shows my Millen dip meter in action.

Improving The Detector

Crystal diodes make poor detectors. Germanium diode detectors don't work well on weak signals; for a weak enough signal they act more like resistors than diodes. **Figure 3** shows a circuit for a neat device called an Infinite Impedance Detector. This detector offers some gain and doesn't load the tuned circuit as much as a diode detector would; hence the Q and selectivity are also improved. The J-FET gate adds some capacity to the tuned circuit, and this can reduce the high-frequency tuning by several MHz.

Photo C shows how the J-FET and associated parts for the infinite-impedance detector are mounted using short leads. The gate is tied directly to the tuning capacitor stator terminal, and the FET's *source* lead bypass caps and biasing resistor are tied directly to the capacitor frame for good VHF performance.

Figure 4 shows how the infinite-impedance detector is incorporated in the FM crystal receiver. Parts values are given in **Table 1**. The detector will drive a pair of vintage high-impedance headphones (2000 ohms or better) directly. I use a pair of military sound-powered headphones with a matching transformer. Adding the

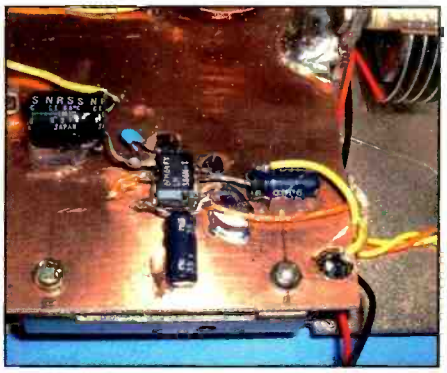

Photo D. The audio amp IC is mounted using "dead bug" construction techniques. The larger parts are glued to the pc board to alleviate stress on the IC leads.

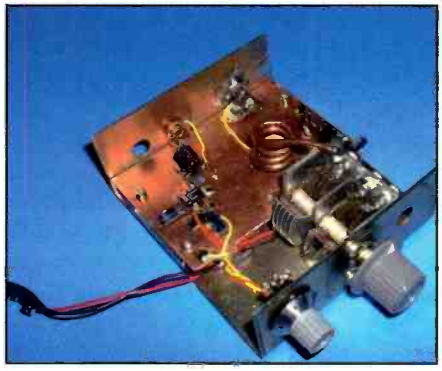

Photo E. Here's a top view of the completed receiver. Ugly, but it works—and it was intended as an experimental prototype to begin with.

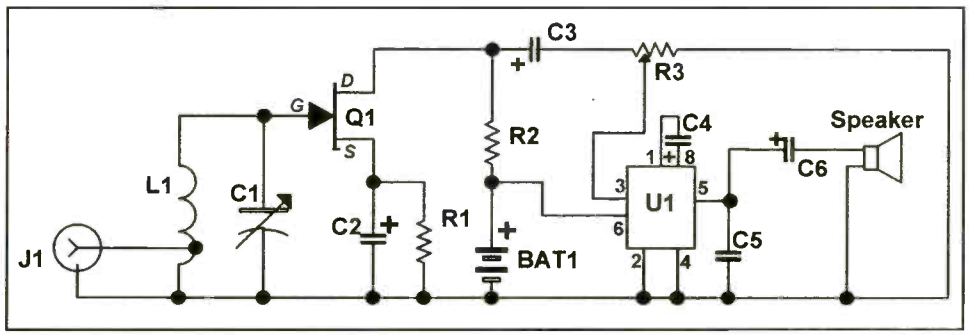

Figure 5. Adding the high-gain audio stage gives loudspeaker volume on strong stations.

Photo F. This is my 6S321 Stars-and-Bars Zenith! Sorry for the mix up! As you can see, this cabinet needs a bit of work. I'd started scraping the old lacquer off the top when the photo was taken. Chemical strippers risk damaging the photo-etched lacquered patterns on the front, which I intend to restore and save.

infinite-impedance detector allowed me to hear some FM stations from my rural home when using some high-gain tower-mounted VHF antennas.

You might want to try this detector on your AM BCB crystal sets; it makes a big improvement!

Adding An Audio Amplifier

Figure 5 shows the final phase of the FM crystal receiver. A small 8-pin LM-386 audio IC gives enough gain for loudspeaker level volume, or to drive more contemporary low-impedance headphones. I mounted the IC and supporting parts "dead bug" fashion on the pc board. If you're not familiar with this breadboarding technique, the parts are soldered directly to the copper side of an unetched pc board for ground, and are self-supporting or glued in place as needed. (ICs were sometimes mounted on their backs, looking like little dead bugs; hence the name.)

It's not very pretty, as shown in **Photo D**, but it works and is good for quickly prototyping circuits on the fly. I think some builders call this technique *Ugly Board* construction. Hot glue assisted in mounting and supporting the IC and larger components to the board. **Photo E** shows an overall view of the entire receiver. Again, it isn't pretty, since I considered this to be an experimental project. An off/on switch is needed to preserve battery life.

An Apology

Our opening photograph in the July 2004 issue purportedly showed the deplorable condition of my Zenith 6S321 cabinet. What accidentally got forwarded for publication was a photo of a nicely restored example from the webpages of Mike Urban's Internet site at www.urban-antiqueradio.com. I had saved his photo as an example to follow when restoring my Zenith. Hopefully **Photo F** is the correct photo. Anyway, visit Mike's website to see some nicely restored radios in his collection, and to check out a few he's offering for sale.

Well, that's it for this month. If you build one of these sets, I'd like to hear about it, and photos would be great! Let me hear about your other projects, as well. Until next month, keep those soldering irons warm and those letters coming in! ■

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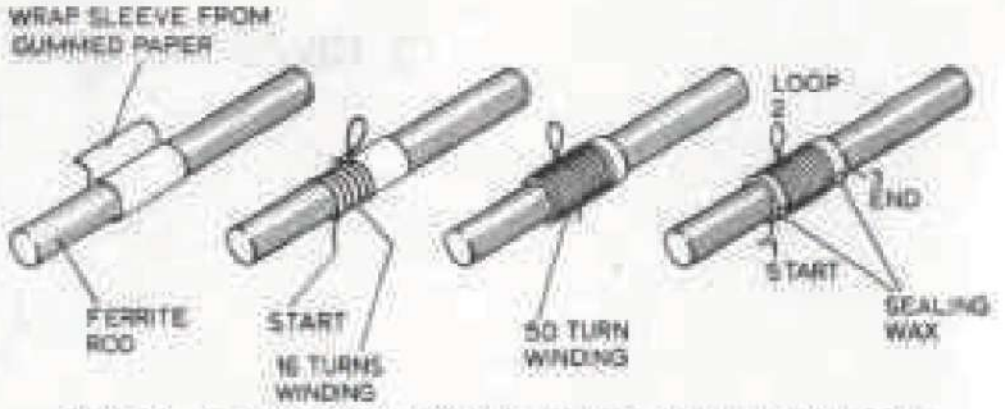

Fig. 3.1 Aerial tuning coil wound from 38-s.w.g. wire on a $\frac{5}{16}$-in. diameter ferrite rod.

Fig. 3.1 details the construction of a suitable coil for a tuned circuit, matched to a ferrite rod of $\frac{5}{16}$ in. diameter and about 4 in. long (see Chapter 4 for alternative coil windings on different rod sizes). If a rod is purchased longer than 4 in., it can be used as it is, or cut down by marking around with a file and then breaking off the surplus length.

Cut seven 1-in. lengths of gumstrip. Moisten one and wrap around the rod gummed side up. Now add about another half a dozen wrappings of similar length over the first, this time with gummed side *down* to form a reasonably rigid tube. Make sure that the paper tube is a *sliding* fit on the ferrite rod and leave to dry thoroughly (preferably removed from the rod so that it cannot become stuck to it).

When the paper tube is quite dry it should be rigid, when the coil windings can be applied. The wire to be used is 38-s.w.g. enamelled copper wire, the number 38 referring to the actual diameter of the wire according to the standard wire gauge (s.w.g.).*

Starting about $\frac{1}{4}$ in. in from one end of the paper tube, wind the wire carefully round the tube, with each turn tight against the one before it, until sixteen full turns have been completed. Then make a loop in the wire, as shown, and carry on winding, with succeeding turns touching, until fifty turns in all have been completed. The two loose ends of the coil (the start and finish) can be secured with a dab of sealing wax whilst the projecting loop can be twisted together (e.g. by putting a pencil through the loop and twisting up). Cut off the loop, leaving about $\frac{1}{2}$ in. protruding from the main coil, bare the wire ends and solder together. This forms point 2 on the coil; the start is point 1, and the end point 3—see Fig. 3.1. It will be easy to remember these

* American wire gauge (AWG) is about two sizes smaller than the British standard wire gauge (s.w.g.). For example, 38 s.w.g. is approximately the same as 36 AWG.

without marking since the loop or tapping point (2) comes much closer one end (1) than the other (3).

Cut a panel of *Paxolin sheet* to about the size shown in Fig. 3.2, using a hacksaw.* On this secure a *tag strip*, as shown, and drill a hole to mount a miniature or small-size 500 pF *variable capacitor*.

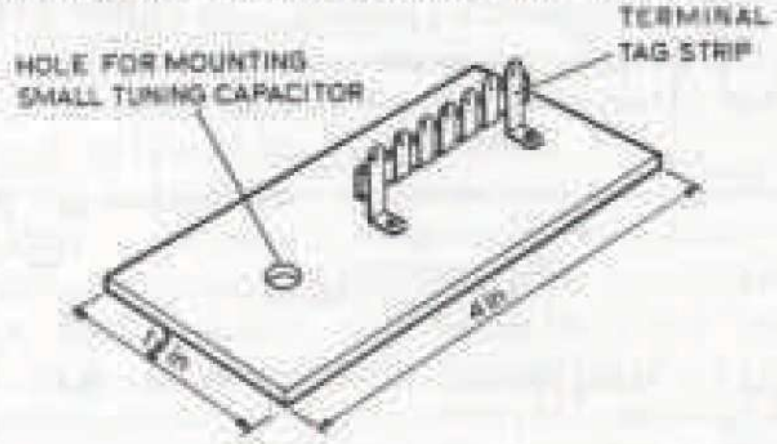

Fig. 3.2 Paxolin panel and tag strip for crystal set circuits.

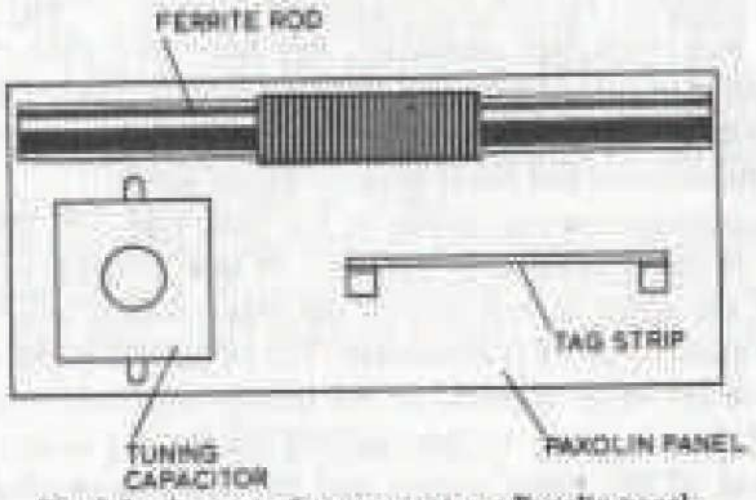

Fig. 3.3 Layout of components on Paxolin panel.

The aerial coil is then mounted on the panel as shown in Fig. 3.3, gluing the coil on to the Paxolin with two or three dabs of sealing wax, or some other suitable adhesive. *Note:* the ferrite rod must be free to slide in the paper tube for 'tuning' adjustments.

Virtually any miniature germanium or silicon diode will be suitable for the detector. Recommended types, which are readily available, are 1N34 and 1N914.

Earphones must be of *high-impedance* type, which need not be expensive to buy, and the higher the impedance the better the reception.

* A phenolic or fiberglass sheet may also be used.

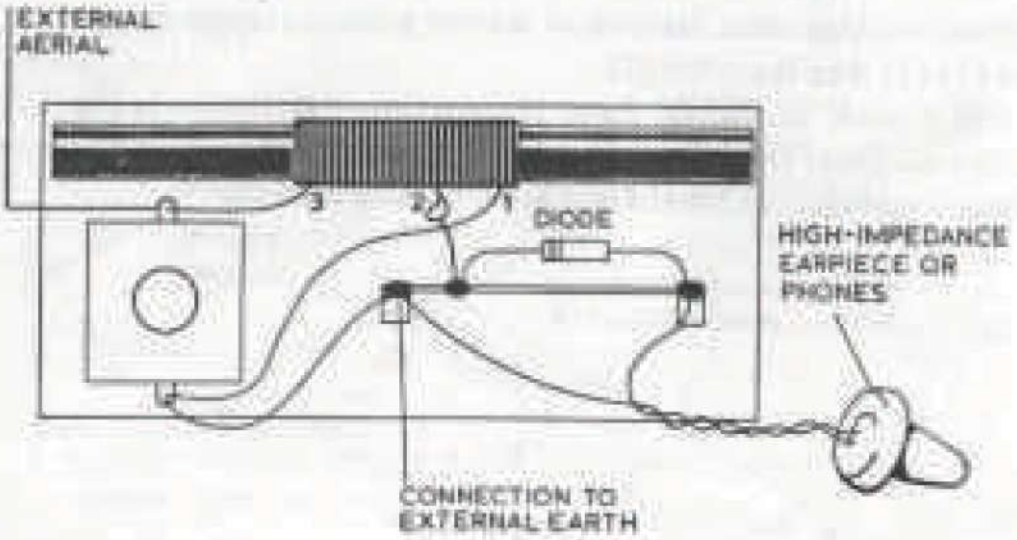

Fig. 3.4 Wiring connections to complete the crystal set.

Alternatively a deaf-aid type earpiece can be used; this will not give the same volume or quality of reproduction as headphones, but is a less expensive component. This should preferably be of the *high-impedance magnetic* type, with high sensitivity. Any high-impedance earpiece will suffice, but if of crystal type will require a resistor, connected across it, to complete the circuit. This will reduce the amount of current flowing through the earpiece and lower the strength of signal.

Wiring connections are shown in Fig. 3.4. End 3 of the aerial coil (the end of the 50-turn coil) connects to one terminal of the tuning capacitor, the aerial or 'hot' end of the tuned circuit, and the point to which an external aerial is connected. The other end of the coil (end 1) connects to the other terminal of the tuning capacitor, from which an additional wire is taken to the first tag on the tag strip. This is the 'earthy' end of the tuned circuit, and the point to which an external earth is connected. Leave plenty of slack wire between the coil and tuning capacitor.

The other connections are then as follows:

(i) Tapping point of the coil wire bared and connected to the second tag.

(ii) The diode also soldered to this same tag, and to any other free tag.

(iii) Headphone (or earpiece) leads to the 'earthing' tag, and to the 'free' tag to which the above diode has been connected. All connections should be made with *soldered* joints.

The wiring-up can be checked against the *circuit diagram* shown in Fig. 3.5 (ignoring the components shown with broken lines). The set should now be 'working'.

In areas of strong signal strength, no external aerial or earth connections should be necessary. Performance will, however, be improved in any area by attaching an aerial wire (which can be any thin wire, e.g. using the same wire as for the coil winding), of up to 160 feet. The longer the aerial the better the reception, provided it is led away from the receiver to as *high* a point as possible.

An earth connection may further improve aerial performance; by this we mean a connection to some conductor positively in contact with the ground (preferably buried), an excellent example being a metal water-pipe. Thus, if an earth connection is found to be necessary (or you want to try one to see how performance is affected), connect a wire from the 'earthing' tag on the receiver to a convenient water-pipe.

This question of obtaining a *good* aerial and earth is a most important one in areas of poor signal strength. Linking up to a television aerial is often a good plan, since TV aerials are also usually mounted as high as possible. If bare wire is used, it is also important that the upper (free) end of the aerial is not made fast to something which could produce an earth connection (e.g. a damp tree), or at least is suitably insulated from such a support. String is not an efficient insulator; that, too, can conduct when wet.

Quite good results are often obtained by using the springs of a bed as an aerial, in which case an earth connection is usually not necessary. Sometimes, too, when other attempts to yield a good signal strength in

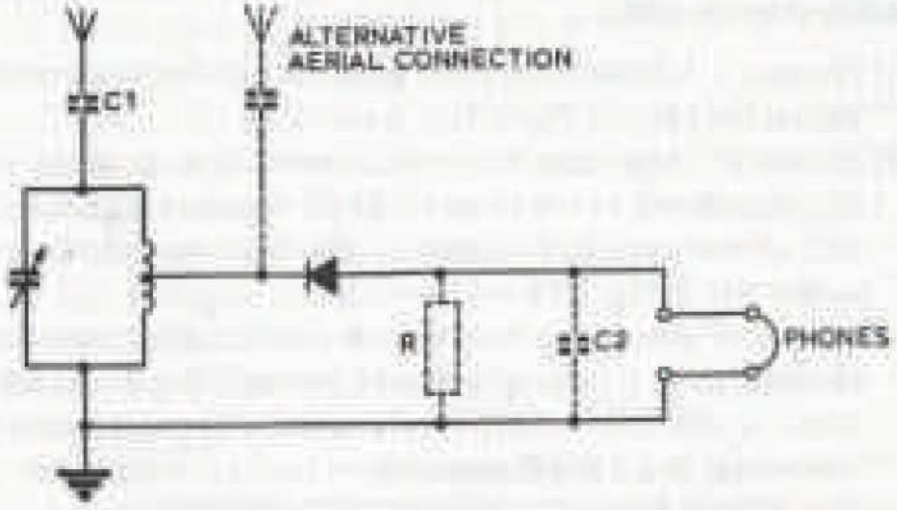

Fig. 3.5 *Circuit I.* Circuit diagram of basic crystal set.

the aerial have failed, connecting the *aerial* side of the tuning coil to a *good earth* (a water-pipe) can produce better results, the normal earth connection being left off.

Tuning

The receiver is adjusted as follows. Turn the tuning capacitor to fully close the vanes, then open about half a turn on the spindle or knob. (If you are using a trimmer as a tuning capacitor, screw right down and then open half a turn.)

The tuning coil should now be slid up and down the ferrite rod (the coil leads were left a fairly long time to give the necessary freedom of movement) until BBC Radio 3 is heard.*

It may be necessary to slightly alter the adjustment of the variable condenser to tune in to this programme. Also, because of the ferrite-rod aerial the set will be directional, that is, the signal strength received will depend to some extent on the direction in which the aerial rod is pointing, so position the set to pick up the maximum volume.

Having established the best position of the tuning coil on the rod to receive BBC Radio 3, fix permanently with a dab of sealing wax. You should then find it possible to tune in to further stations by altering the setting of the variable capacitor—e.g. typically Radio 4 in about the middle of the capacitor travel and Radio 1 towards the other end.

Any reception you get will almost certainly be very weak and (unless you live close to a broadcast station) you can really feel satisfied if you get any station at all at audible strength. But it is surprising how, sometimes, even quite distant stations can be heard. Also you can often improve the reception and listening strength by quite simple modifications. Try these in order:

(i) Connect a 1,000-pF capacitor across the headphone (earpiece) connections (C2 in Fig. 3.5).

(ii) Instead of connecting the external aerial directly to the tuned circuit, connect one lead to a 220-pF capacitor, and the other end of the capacitor circuit to the 'hot' end of the tuned circuit (C1 in Fig. 3.5).

(iii) Instead of connecting the external aerial to the tuned circuit, connect to the tapping point of the coil (tag to which the diode is also connected). Try a direct connection, and also connecting in a 220-pF capacitor.

* Tune to an AM broadcast station near the lower end of the dial—close to 550 kHz.

(iv) Try connecting a 1.2-k resistor (or higher value) across the phone connection (R in Fig. 3.5). You may be using the wrong type of phones or earpiece, which do not provide a proper load or complete the circuit.

If there is a complete lack of response, check for faulty wiring-up. A more likely cause, however, is lack of an external aerial or earth connection in an area where these are strictly necessary for adequate reception; or an inefficient aerial (too short) or poor earth connection (bad electrical contact to a good earth point, or connection to a bad earth point).

Another possible cause of apparent failure may be too much outside noise entering the ear so that it is impossible to detect the very weak radio signal as it is being tuned in. Headphones are better than a single deaf-aid type of earpiece in this respect but, in any case, a really quiet room is virtually essential for initial setting up and tuning adjustments. Also, if your adjustment of the tuning control is too coarse, you may completely miss the setting for the station you are looking for, without realizing it.

Reception will also tend to vary with weather conditions. Some days it may be so poor that what was normally a strong station is hardly heard at all. The simple basic receiver has many limitations but, since it costs very little to construct and nothing at all to operate, this must be regarded as inevitable.

Providing you can hear something—even if too weak a signal to distinguish properly—you can certainly improve the performance of your basic set by further experimentation with tuned circuits (see Chapter 4) and/or the addition of amplification to the circuit. You can also try other types of basic crystal set, as described in the following projects.

Circuit 2 (Fig. 3.6) is identical to *Circuit 1* except that, instead of a diode, a transistor is used as a detector. Only two of the transistor leads are connected—the emitter (*e*) connection to the tapping part of the coil, and the base (*b*) to the 'earthy' end of the circuit. The collector lead of the transistor is ignored (bend it out of the way so that it cannot accidentally short out the other leads).

You can try almost any type of low-cost AF transistor; recommended types are OC42 2N370, 2N2925, 2N5088.

With the addition of two more components, Circuit 2 can be modified to work the transistor both as a detector and an amplifier, to give stronger signals through the headphones. Using the same transistor type

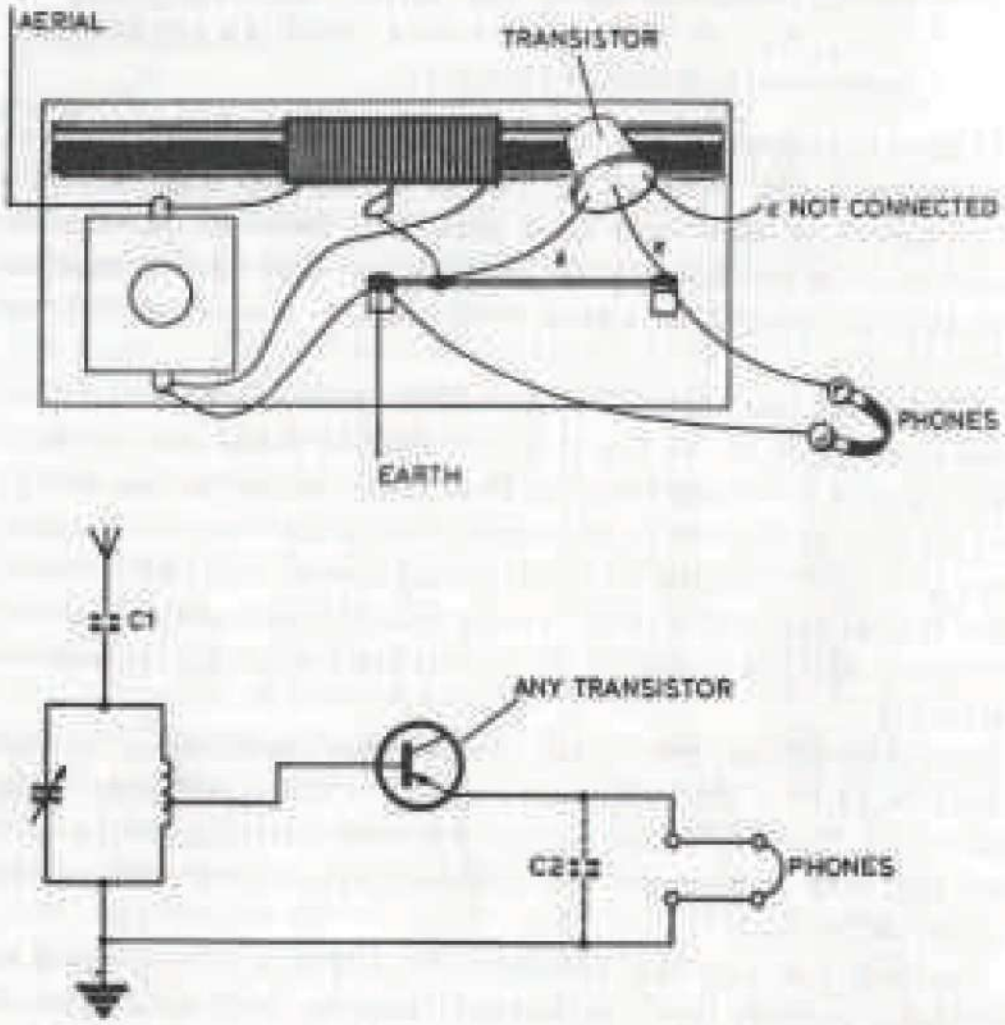

Fig. 3.6 *Circuit 2.* Crystal set using transistor instead of a diode.

as above (or near-equivalent) resistor R should be 15 k and capacitor C3 1 μF or higher.

This time a battery is also required to supply power for the transistor to work as an amplifier. This can be from 1.5 V up to 9 V. Remember the rules for polarity of connection: those shown in Fig. 3.7 are for a p-n-p transistor; an n-p-n transistor would need the battery connected the opposite way round. Battery polarity also affects the connections of capacitor C3 (if an electrolytic or polarized type).

Experiment further by trying the effect of using additional capacitors in the circuit, e.g. C1, 220 pF; C2, 0.001 μF (try other values as well); C4, 0.001 μF (try other values as well).

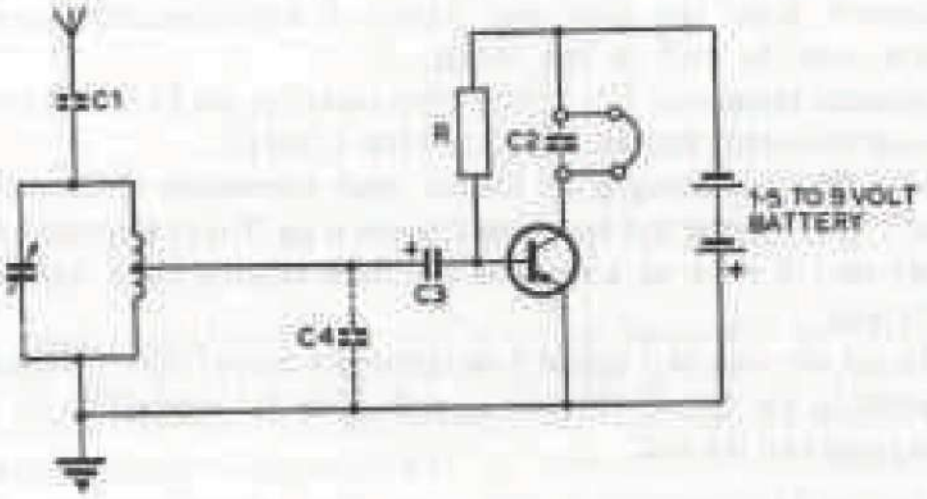

Fig. 3.7 *Circuit 3.* Crystal set with amplification.

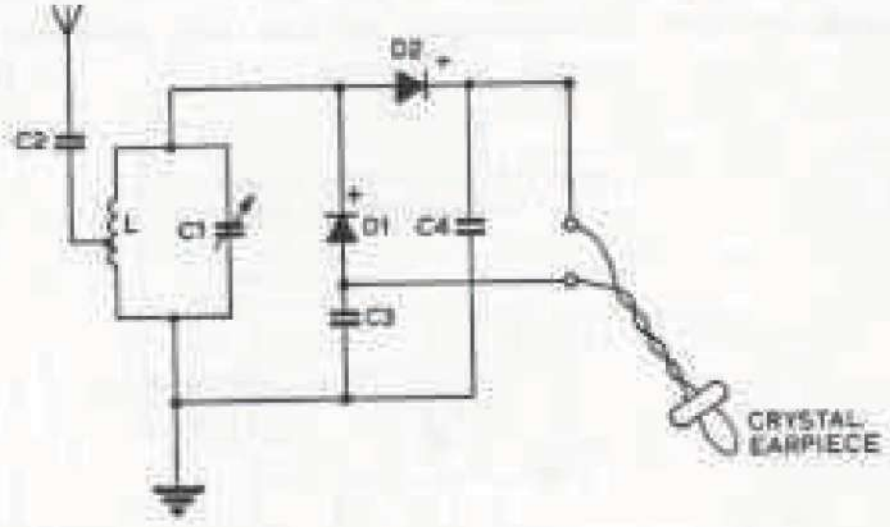

Fig. 3.8 *Circuit 4.* Double diode crystal set.

This circuit incorporates 'voltage doubling' to improve the signal volume and should give better performance than a single diode circuit. L and C1 are the usual tuned circuit, but an unusual feature is that the *aerial* is connected to the coil tapping point. Any type of germanium diodes can be used (they should preferably be the same), making sure to connect them the right way round. A high-impedance *crystal* earpiece must be used in this circuit.

Capacitor values are: C2, 220 pF (this capacitor can be omitted—try with and without in the circuit); C3 and C4, 1,000 pF.

The optimum tapping point for the aerial connection to the coil L is best found by trial and error (see Chapter 4 on 'Tuned Circuits'), but the set should work at a nominal one-third tapping point from the 'earthy' end.

This set can also be tried with conventional tuned-circuit coupling—i.e. aerial to the top of the coil L, and diode D2 connection to the tapping point on the coil.

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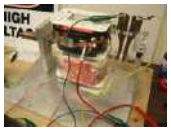

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Question: Is there enough useable energy from my phone line to light a 100 watt light bulb?

Answer: Yes, but only for a short time. If you are looking for a way to light up your home then build our fuelless engine.(see our web site at: www.fuellesspower.com or write us for a catalog.) This engine is powerful enough to run a 10 kw 120 vac 60 hz generator which can run your home.

You can still use your incoming phone line as a useful light source. You can get enough light to light up a room or two by using a diode and a large 100 volt capacitor bank to collect the 50 vdc. What you then want to do, is to use a high efficient lighting source, such as ultra bright white diodes, White neon lighting or flouresent bulbs. (great for emergancy lighting in any storm.)

The 50 vdc current you have collected will not light Neon or Flourescent bulbs until the voltage is much higher. 300 to 5,000 vac, You can buy a 15,000 volt neon transformer and pulse the 50 vdc into the primary using a wind up spring pulse switch (food timers) or build a low milliamp transistor type pulse generator, this will turn the DC to AC which you can then collect from the secondary out put of your transformer. You can also build our #363-a step up DC (No amperage loss! 100% eff. Using Photo caps) Or just for a quick fun experiment charge 20 - 50 volt capacitors, with each capacitor having about 4700 uf (micro farads), simply fully charge each capacitor by hand then connect them in series using Radio Shack allegator clips (wire), just like batteries, Negative to Positive, **Warning! Use rubber gloves when working with High Volatge, High Voltage can kill!**

Once you are done with connecting them in series, use a small low amp (Miliamp) isolation transformer which you can buy from any electronic supplier or Radio Shack store. (Search for Electronic Suppliers on web search engine) connect the negative to the primary and the positive you will need to pulse the + on and off very quikly! the faster the pulse the better the output of energy! Connect the secondary leads from the isolation transformer to the ends of a neon or flourescent light bulb, as you pulse the positive to the primary of the transformer the bulb will light very brightly!

15,000 v Neon Transformer

Or you can pulse this homemade Tesla Coil to light a bulb!

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Again, there are many ways to get free electricity from your phone lines. (also great for out door lighting.)

Updated 2004: The below method seems to be the best way so far to collect and store the 50 vdc energy. This method should be done at night or when the phone line is not in use.

To obtain 1 amp at 15 vdc we use a 10 volt capacitor to step down the 50 VDC that is coming from the lines. This capacitor is a very special capacitor, try to get the same type if they still sell them. I think it was made in Japan. I wish we had them in stock we would sell them. Photo caps are very special and might work as well.

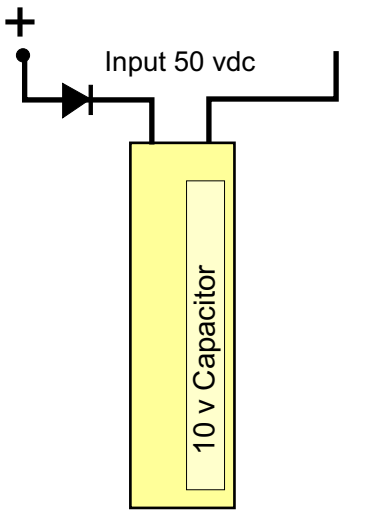

Electrolytic Capacitor
10 v x 1000 uf 105 C
Made by Elna part # 8643

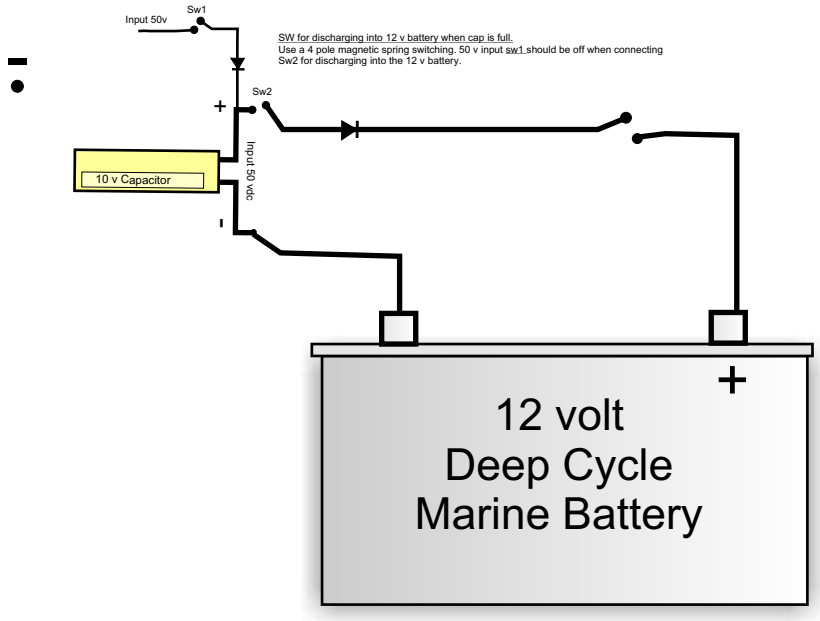

Power diode works best!

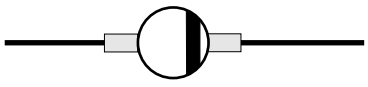

G1 G4g

Let cap charge every 4 to 6 seconds, you may want to use a spring wind up timer for switching or use transistors as dc pulser to control 4 pdt relays which all can be powered from free energy from the earth method, *(See our free energy from the earth plans #459 $29.95 plus $3.95 shipping.)* Or you can use small magnetic reed switches (about 10) placed and glued around a kitchen timer. Glue a small 1/4 diameter neodymium magnet to the rotating handle.

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High Voltage Care

Be careful, high voltage or even low voltage with high amperage can kill you. Do not attempt to work on this project unless you are a trained professional in high and low - high amperage..

Remember to wear RUBBER GLOVES and RUBBER SOLE SHOES. Using rubber platex gloves from a dollar store or such, work good for up to 50 volts, any higher voltage you should wear a thicker rubber pair of gloves....

WARNING: discharge all capacitors before you touch and work on them or around them.. If you do not know what a electrolytic capacitor is then we suggest you buy a beginners book in electronics that you can get from from any Radio Shack or electronic store or book store.

You can also use the earth ground to gain more electrical energy into your capacitor by using one leg (the Negative) from the the telephone out put! A diode in the right direction of this leg will do wonders. it's that easy.

The following information is confidential and has copyright and patent pending: Capacitors store and discharge free energy! Radiant energy is stored in between the capacitors plates and the electrons rest on the metal plates themselves. Radiant energy is also created at discharge, but in reality is taking the energy from a very special place that we do not want to disclose at this time.

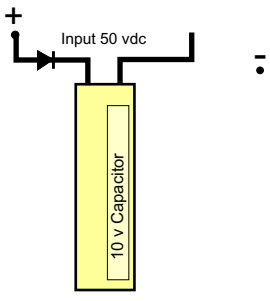

Electrolytic Capacitor
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Power diode works best!

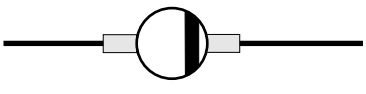

G1 G4g

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Part 2

We are going to show you several different methods that you can use to get free electricity from your phone line.

The amount of electricity will vary and depend on which set up you use. most of these set ups can be used at night time while your phone is not in use. using it this way will be the strongest.... by using these methods it will keep the phone 1/2 way off the hook ? (hard to explain)

One of the methods that we will explain is a bit crude....
If you should get an incoming phone call in the middle of the night or day it will charge the capacitors faster and with more amperage input, but with one disadvantage, the phone will not ring! But we have discovered a way past this, but with a slight amperage loss. By using what we invented called a ceramic permanent magnet capacitor blocker filter.. you will see the drawings on the following pages.

I'm sure there are much better ways to charge and gain more voltage and amperage from your phone line than what we have shown you here. but I am sure you will understand that our time is limited, it's a fun project, but we have been developing and researching much better technology than this! If you find a better way then please contact us so we can put it in our plans and share it to the world, we can mentionyour name as being the inventor if you like.

(Timer Switching 4 PDT relays)

The Electricity you will get can be constant when hooked up to multible capacitor banks (Differant caps than the one shown on page 2). Using one 9 volt battery capacitor timer switches, to fire each cap bank at it's proper time. or by using earth energy. (use 2 - 63 v x 4700 uf electrolytic capacitors)

We have actually lit a 100 watt 115 volt AC light Bulb with this set up. 2 caps connected in series. Charge each cap by hand, then connect together in series. But the main purpose is to use this system as a 12 volt deep cycle battery charger that will run a DC to AC 115 volt inverter to use as usable household energy to power a light bulb, an ac motor, TV, VCR etc...

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You can Produce up to 3 amps every 30 seconds by charging a 35 volt x 4,700 uF electrolytic capacitor bank. Connecting large uf capacitors in parallel increases the amperage but slows down the charge time. You can also use them in series to step up the voltage to get 100 volts or 150 vdc if you use three fully charged caps connected in series. The Fuelless engine can be designed as a small 2 hp electric motor and made to run on .05 ma x 300 input and can run from the phone line using our Com /SW method, (See Our Plans) you would need six fully charged caps 50 to 63 v x 4700 uf caps, to run this type of High Effiecient free energy motor. the output will be greater than the input!

You can also use a DC to AC inverter (not the type to run your home)right from the phone wall outlet and then by using a step down transformer you can get 12 volts ac which you will then need to change to dc using a one way diode. The amperage will be greater and can charge a 12 volt marine battery.

Notice:

Be sure to be neat! Put all Components in a safe and convenient plastic box. Use PC board, make it professional looking don't be sloppy! You must keep it safe were Kids as well as some Adults will not get shocked or hurt.

IS IT LEGAL?

We don't Know?
When we first put it in our catalog we were confident that it was. Now we are not so sure? But, it's your phone and you are paying for it! Once it passes into your home it should be yours, as long as you hook it up right and it does not kick back up into the phone line and cause any harm to the phone companies generator lines or breaker boxes etc... that's why we use one way diodes. We have knocked out our phone lines for about an hour or so. when pulsing into the earth you sometimes get a kick back of more current and voltage than what is being collected or inputed.

Remember: it's your phone service! you pay for it every month. The electric you pay for is used to run your telephone, if you wish to use it for something else there should be no law against it.... WE HOPE!!!!????

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OBJECTIVE;

All the methods described in these plans are ways to get cheap Free energy for your home, (#359 is not intended for your entire home).

There are millions of poor people all around the world who can't afford electricity but may have a phone, (this system is much better than using candles). It's fast and cheap to put together for emergancy low light conditions. If one can afford it, we recomend building our Fuelless engine to run a car altntr, or 10 kw home generator system and stop paying a high electric bill, our system can pay for itself. Someday I hope we will be allowed to manufacture our free energy motors then you can simply go down to your local hardware store and buy a free energy motor and generator to power your entire home, but that may not be soon. The only way the open public is going to be able to get a hold of a free energy electric motor is to build one for thereself. It's really not that hard! The cost to build our 2 hp (Fuelless) Free Energy Electric Motor is only about $195. You can use the 2 hp to run a 80 amp car alternator to charge a 12 volt marine deep cycle battery system connected to a 500 to 5000 watt inverter (Which you can buy or make, see our #579 plans $40) to run your lighting, fans, VCR, TV, Refrig, Microwave etc...

Collecting Free Energy from your phone line is also a fun science project! Your friends will love it. Most people do not even know they have 50 vdc running to there phone line, and when the phone rings it sends 3 times more amperage to your charging system. Set your phone up were it will ring itself every 2 minutes for one hour or until your batteries are fully charged. It's basically free! The phone company is not going to charge you extra for it.

Use 4 - 12 v deep cycle marine batteries, (car batteries will not work) and connect them in parralel to increase your amp hr. then connect your inverter or inverters to your fully charged battery bank and enjoy free lighting, free electricity etc... Notice: Do not let your batteries go under a 25% charge, the batteries will last years if you take care of them by not under charging or over charging them. Use a digital volt meter. If you need more amperage, again use our Fuelless Engine or our free energy from the earth.

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Use a DC Volt meter to find the negative and the positive. WARNING! Do not ground the positive to the earth, it will knock out your phone line for about 1 hr!

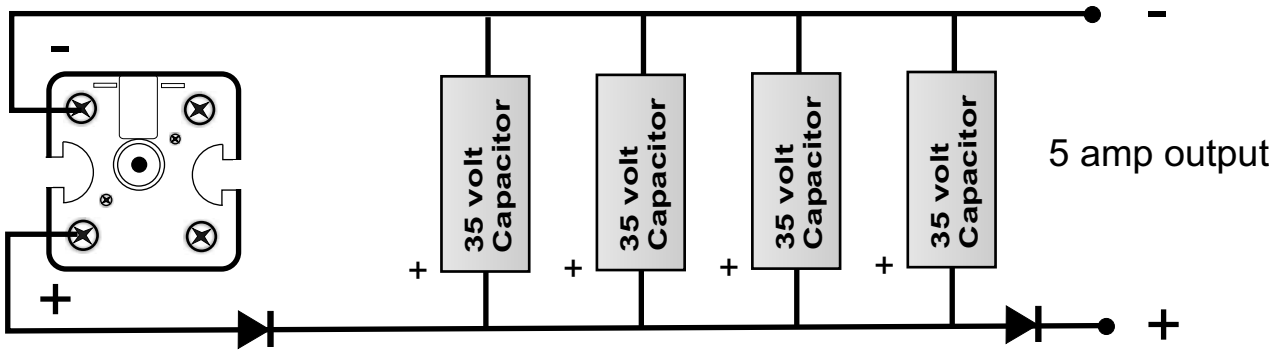

Using both the negative and the positive of the phone line seems to work best. Use 4 - 35 v x 4700 uf electrolytic capacitors. This can be used as a battery charger using the diode as shown or a com / sw switching method as seen in our Fuelless Engine plans or you can simply use a hand wind timer with a strong magnet glued or taped to the handle and using multiple reed switches. Or power a low volt, low milliamp 4 PDT relay using the earth power (see plans #459 $29.95) or our #396 homemade batteries $16.95

Many homes have 2 phone lines, you can use both lines to get 100 vdc with double the amperage output! Use 4 - 150 v x 4700 uf capacitors instead, you can then light a 100 watt bulb, or pulse the 100 volts into a 15,000 volt neon transformer to get a 14,000 vac out put to power several neon bulb tubes or flourescent bulbs.

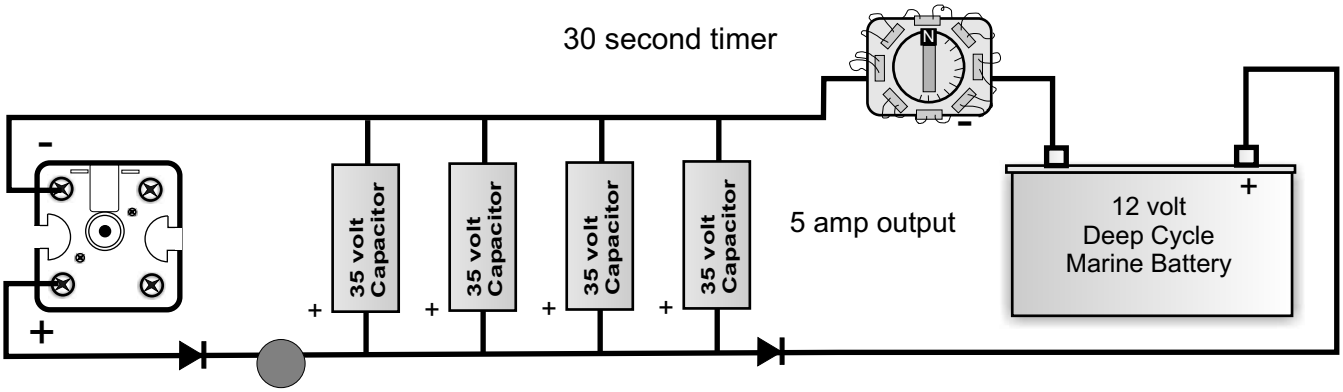

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Grounding to Earth

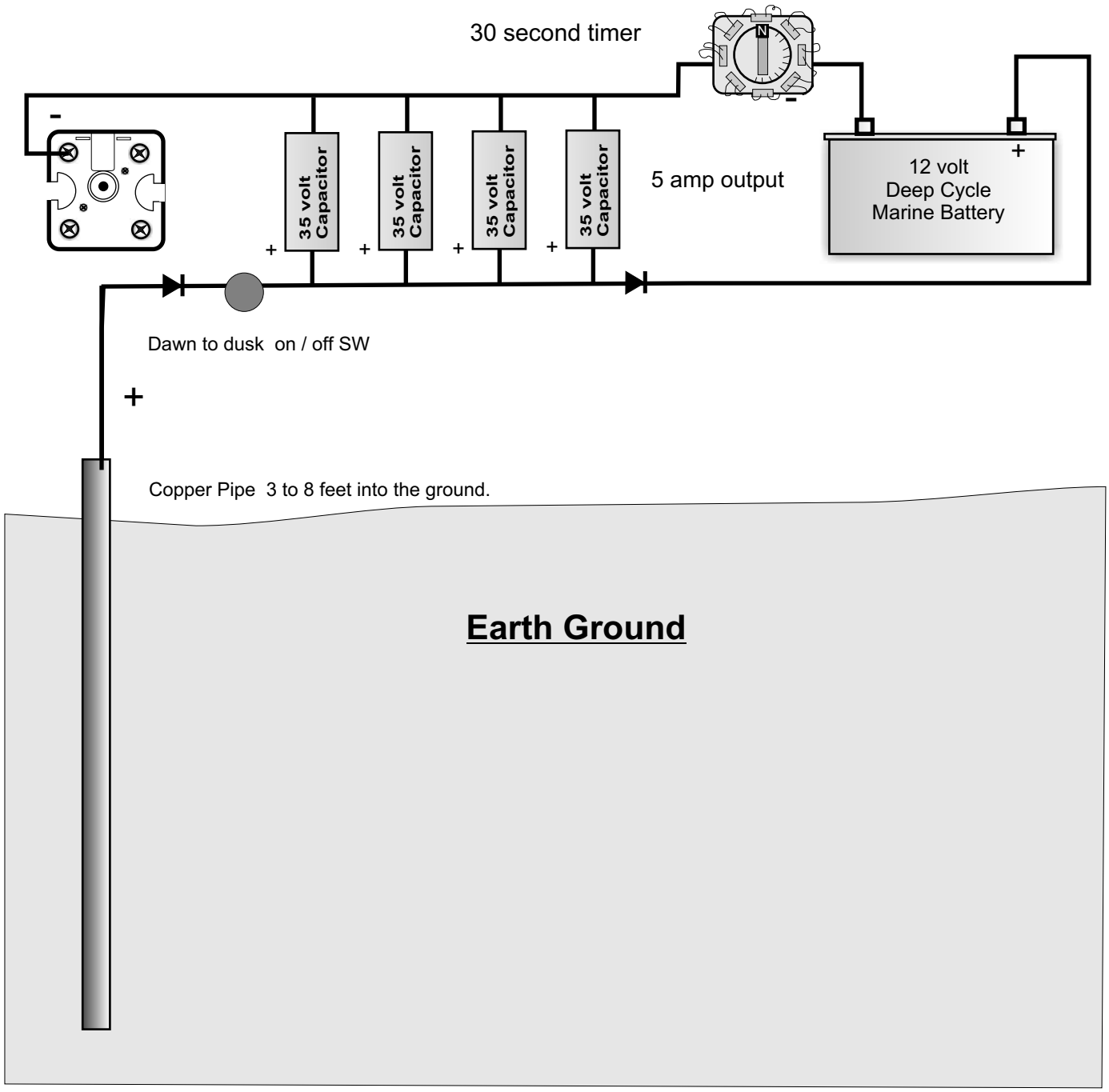

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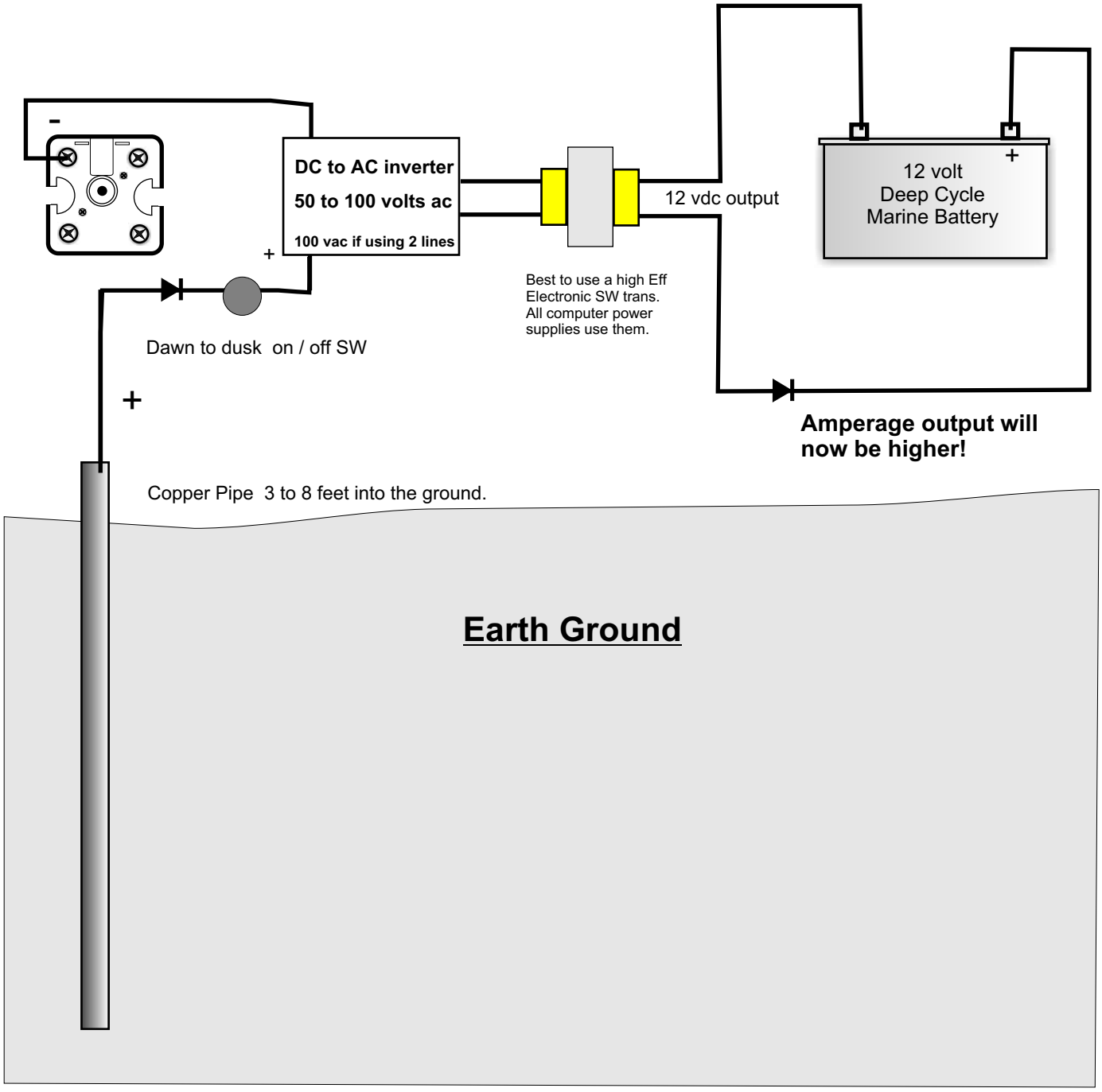

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The 50 vdc must be changed to ac voltage current or it will not work (step up voltage) into a step up transformer or diode / capacitor step up multiplier circuit.

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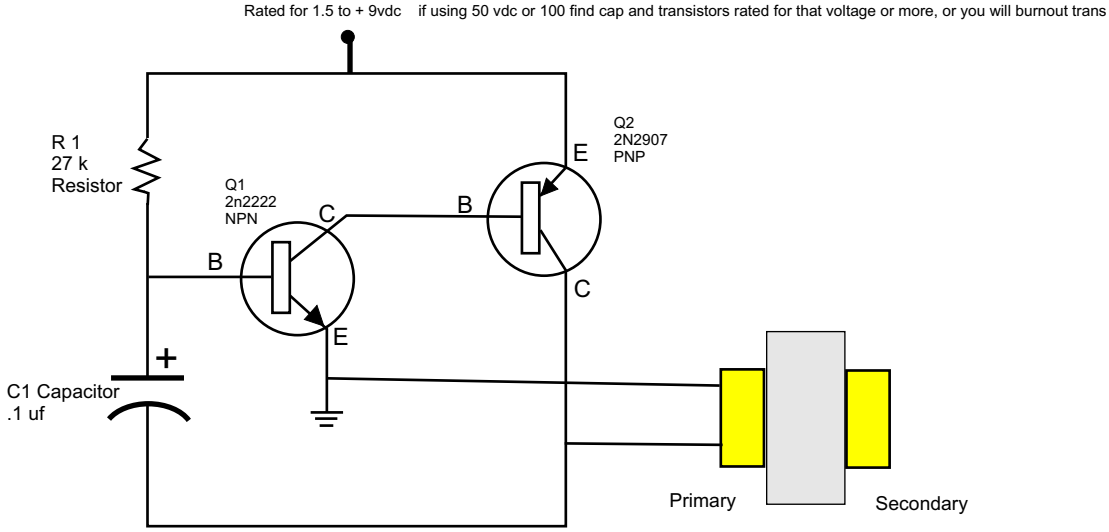

T1 = 6.3 v x 120v transformer This circuit will produce about 220 volts. Use a 1m resisitor for higher volatges.

We found this cicuit in an old electronics book, it is for low voltages but you can replace the parts with higher rated parts so they will work on higher amperages or higher voltages.

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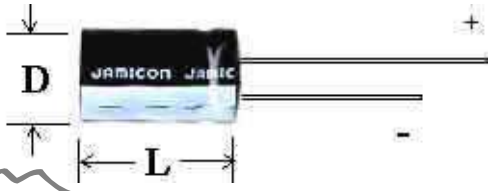

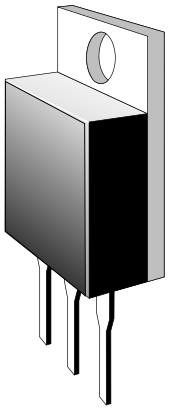

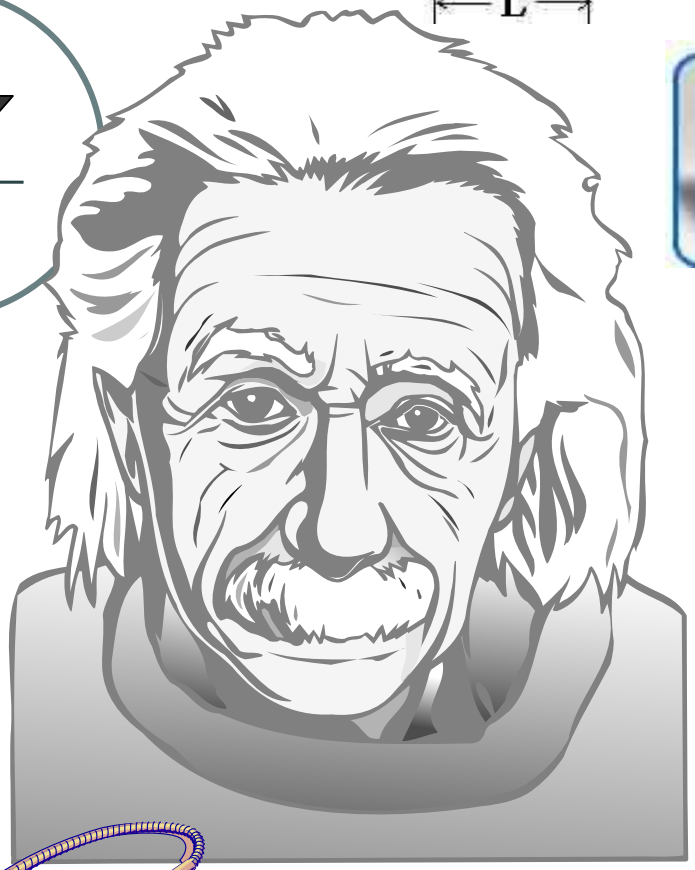

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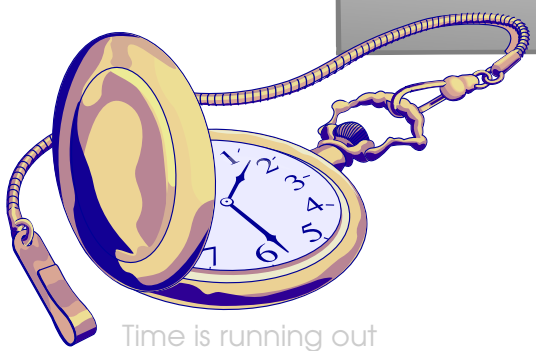

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Thank you
David Waggoner

David Waggoner

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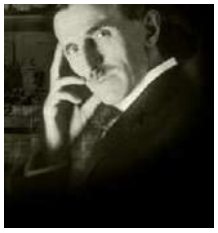

Nikola Tesla

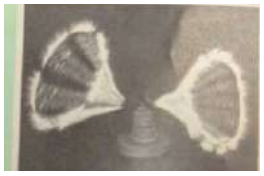

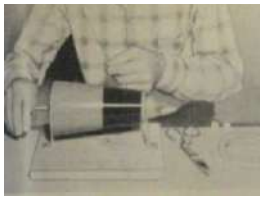

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The Fuelless Engine

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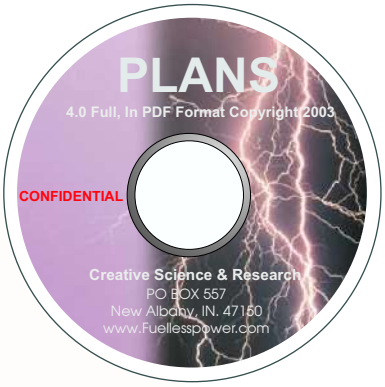

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Radio Receivers, *from crystal set to stereo*

author: Miomir Filipovic

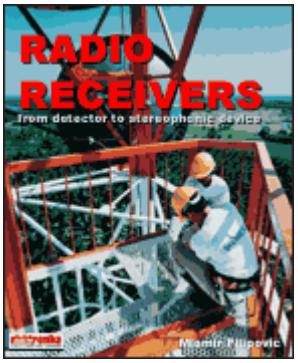

It is hard to imagine what would the modern world look like without the permanent exchange of huge quantity of information. It is being transferred by various means (newspapers, telephone, the Internet etc.), however, the fastest way of doing it, and sometimes the only one, is by radio, where transfer is being done by electromagnetic waves, traveling at the speed of light. This book covers the history and principles of radio transmission and an array of different radio receivers...

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2.2. FM Transmitter
2.3. Wavebands

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CHAPTER 1 Introduction

It is hard to imagine what the modern world would look like without the constant exchange of a huge quantity of information. It is currently disseminated by various means such as newspapers, telephone and the Internet. However the fastest way, and sometimes the only way, is by radio. This is where the transfer is by electromagnetic waves, traveling at the speed of light. In radio communication, a radio transmitter comprises one side of the link and a radio receiver on the other. No conductor of any kind is needed between them, and that's how the expression **Wireless Link** came into being.
In the early days of radio engineering the terms **Wireless Telegraph** and **Wireless Telephone** were also used, but were quickly replaced with **Radio Communication**, or just **Radio**.

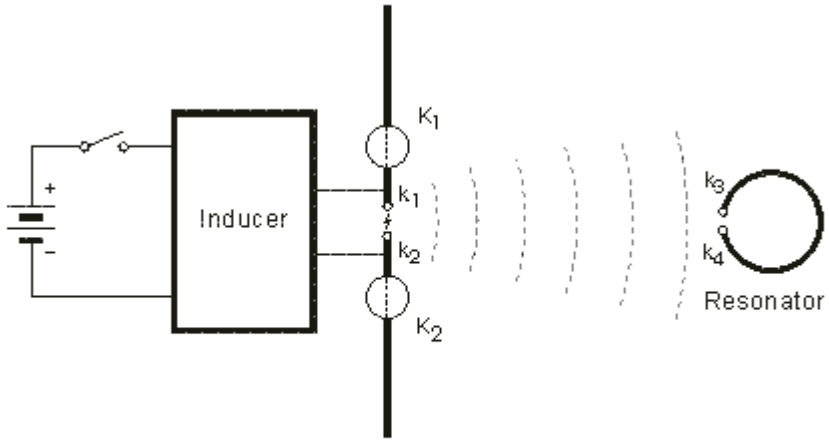

Pic.1.1. Electrical diagram of Hertz's transmitter/receiver

Radio communication is created by means of electromagnetic waves, of which the existence and features were theoretically described and predicted by James Maxwell, in 1864.
First experimental proof of this theory was given by Heinrich Hertz in 1888, ten years after Maxwell's death.
It was already known at that time that electric current exists in oscillatory circuits made of a capacitor of capacity **C** and coil of inductance **L**. It was Thomson, back in 1853 that determined the frequency of this arrangement to be:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Hertz used an oscillatory circuit with a capacitor made of two bowls, K1 and K2 (Pic. 1.1), and the "coil" was made of two straight conductors. The bowls could be moved along the conductors. In this way the capacitance of the circuit could be altered, and also its resonance frequency. With every interruption from the battery, a high voltage was produced at the output of the inductor, creating a spark between the narrow placed balls k1 and k2. According to Maxwell's theory, as long as there was a spark, i.e. alternating current in the circuitry, there was an electromagnetic field surrounding the conductors, spreading itself through the surrounding space. A few metres away from this device Hertz placed a bent conductor with metal balls k3, k4 placed on the ends, positioned very close to each other.
This also was an oscillatory circuit, called the resonator.

According to Maxwell's theory, voltage induced by the electromagnetic waves should be created in the resonator. Voltage existence would be shown by a spark between the balls k3 and k4.
And that's the way it was: Whenever there was a spark in the oscillator between the balls k1 and k2, a spark would also be produced by the resonator, between balls k3 and k4.
With various forms of the arrangement in Pic. 1.1, Hertz proved that electromagnetic waves behave as light since they could also be reflected and refracted.
It was also shown that light is of electromagnetic nature, as stated by Maxwell.
Hertz, however, did not believe in the practical value of his electromagnetic waves experiments. The range of the link was no further than a few meters. The transmitted signal was very weak, therefore the signal in the receiver had a very small amplitude and it wasn't possible to detect it at a greater distance. The possibility of amplifying the signal in the receiver did not exist at the time.
Besides the short range, another shortcoming of the link was noted: If another similar transmitter was working nearby, a receiver detected all the signals at the same time. It did not have the ability of isolation.
However crude and simple these experiments were at the time, they represented the birth of a new scientific branch - **Radio Engineering**.
The pioneers of radio were Popov and Marconi, but the place of honor belongs to Nikola Tesla, who demonstrated wireless broadcasting in 1893, at the Franklin Institute.
Pic.1.2 shows the arrangement of this broadcast system.
Tesla's idea was to produce electromagnetic waves by means of oscillatory circuits and transmit them over an antenna. A receiver would then receive the waves with another antenna and oscillatory circuit being in resonance with the oscillatory circuit of the transmitter. This represented the groundwork of today's radio communications.
In 1904 John Flemming created the diode, and in 1907 Lee De Forest invented the triode. That year can be considered the birth of electronics, with the triode being the first electronic component used in a circuit for signal amplification.

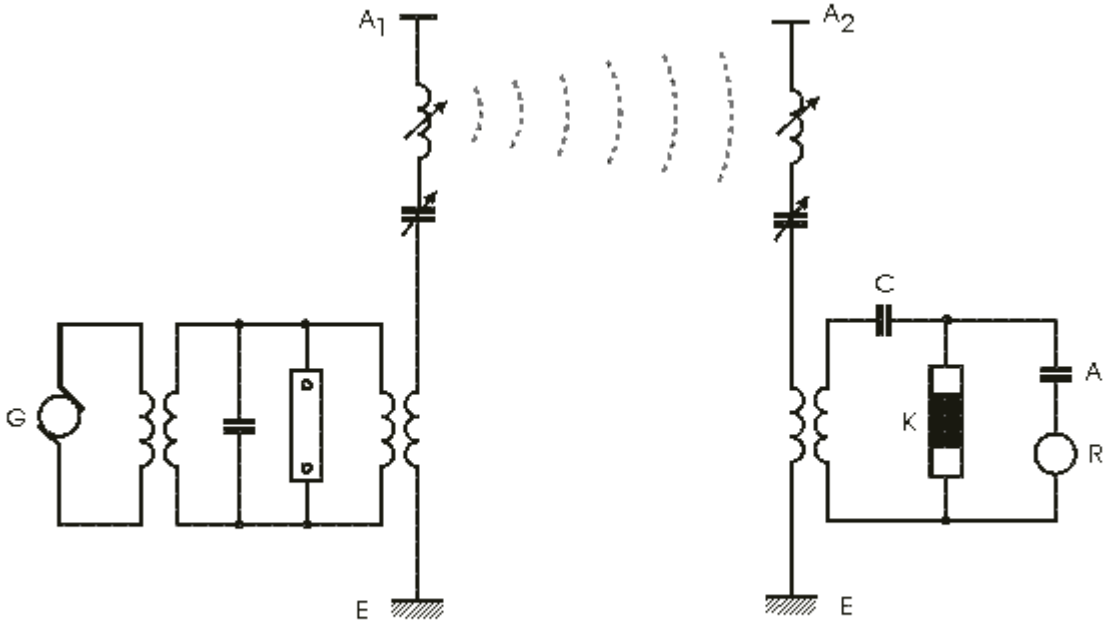

Pic. 1.2. Electrical diagram of Tesla's radio transmitter & receiver from 1893.

Rapid development of radio engineering over the ensuing years produced many innovations and after the First

World War a huge number of radio stations emerged.
At that time TRF (Tuned Radio Frequency) receivers were used. Compared to modern receivers they had both poor selectivity and sensitivity, but back then they fulfilled the demands. The number of radio stations was much less than today and their transmitting power was much smaller. The majority of listeners were satisfied with the reception of only local stations. However as the number of stations increased, as well as their transmitting power, the problem of selecting one station out of the jumble of stations, was becoming increasingly more difficult.

It was partially solved with an increase in the number of oscillatory circuits in the receiver and the introduction of positive feedback, but the true solution was the invention of the **superheterodyne receiver**. This was accomplished by Lewy (1917), and improved by E.H. Armstrong (1918).
An enormous impact on the world of radio was the invention of the transistor by Bardeen, Bretten & Schockley, in 1948. This reduced the size of the radio receiver and made truly portable sets a reality.
This was followed by the introduction of the integrated circuit, enabling the construction of devices that not only proved better in every way than those using values, but also new designs.
Radio amateurs' contribution to radio engineering should also be emphasized.
In the beginning, radio communication was being conducted in the LW and MW bands. But achieving long-distance reception required very powerful transmitters. The SW band was considered to be useless for radio broadcast on long distances and was given to radio amateurs.
The were banned from using LW and MW bands by commercial radio stations.
However, something unexpected happened: Amateurs were able to accomplish extremely long distance transmissions (thousands of kilometres), by using very low-power transmitters. This was later explained by the influence of the ionosphere layer, the existence of which was also predicted by Tesla.
Modern radio receivers differ greatly from the "classical" types, however the working principles are the same.

The only significant difference is in the way the receiver is tuned to a station. Classical devices used a variable capacitor, coil or varicap diode, with the frequency read from a scale with movable pointer. In modern devices, the adjustment is done with a frequency synthesizer controlled by a microprocessor and the reading is displayed on an optical readout.

The inclusion of a microprocessor enables any one of a large number of pre-tuned stations to be selected and displayed and the use of a remote control makes the receiver even more user friendly.

Chapter 2 Principles of radio transmission

2.1. AM Transmitter
2.2. FM Transmitter
2.3. Wavebands

Transfer of information (speech, music, image, computer data etc.) by radio can be presented in its simplest form with block - diagram as on Pic.2.1. That is a transmission realized by amplitude - modulated signal. Since, in our example, the information being transferred is the sound, the first step of such transmission is converting the sound into electrical signal, this being accomplished by a microphone. The low - frequency (LF) voltage at microphone output (Pic.2.1-a), that represents the electrical "image" of the sound being transferred, is being taken into the transmitter. There, under the effect of LF signal, the procedure called amplitude modulation is

being carried out, and on its output high - frequency (HF) voltage is generated, its amplitude changing according to the current LF signal value. HF voltage creates HF current in the antenna, thus generating electromagnetic field around it. This field spreads through the ambient space, being symbolically shown on Pic.2.1 with dashed circles. Traveling at the speed of light (c=300 000 km/s), the electromagnetic field gets to the reception place, inducing the voltage in the reception antenna, as shown on Pic.2.1-c. This voltage has the same profile as the one on Pic.2.1-b, except it has much smaller amplitude. In the receiver, the amplification and detection are carried out first, resulting with the LF voltage on its output, that has the same profile as the one on Pic.2.1-a. This voltage is then transformed into sound by loudspeaker, that sound being exactly the same as the sound that acted upon the microphone. This, naturally, is the way it would be in ideal case. Back to reality, due to device imperfection as well as the influence of various disturbances, the sound being generated by the loudspeaker differs from the one that acts upon the microphone membrane. The block - diagram on Pic.2.1 (excluding the HF signal shape) is also applicable in case of radio transmission being carried out by frequency modulation. In that case frequency modulation is being carried out in the transmitter, under the effect of LF signal coming from the microphone, therefore HF signals on Pics.2.1-b and 2.1-c having constant amplitude, and their frequency being changed in accordance with the actual value of LF signal from the microphone. In fact, all types of radio transmission can be presented with Pic.2.1. First, the information being sent is always transformed into electrical signal through the appropriate converter. In telegraphy this converter is the pushbutton, in radiophony it's a microphone, in television engineering an image analysis cathode ray tube (CRT) etc. Then, with this "electrical image" of information, the modulation is being done. The modulated HF signal is being transferred into antenna and transmitted. On the reception place, the modulated signal from the reception antenna is being amplified and detected and then, again with the appropriate converter (pen recorder, loudspeaker, TV CRT etc.), the information is transformed back into its original form.

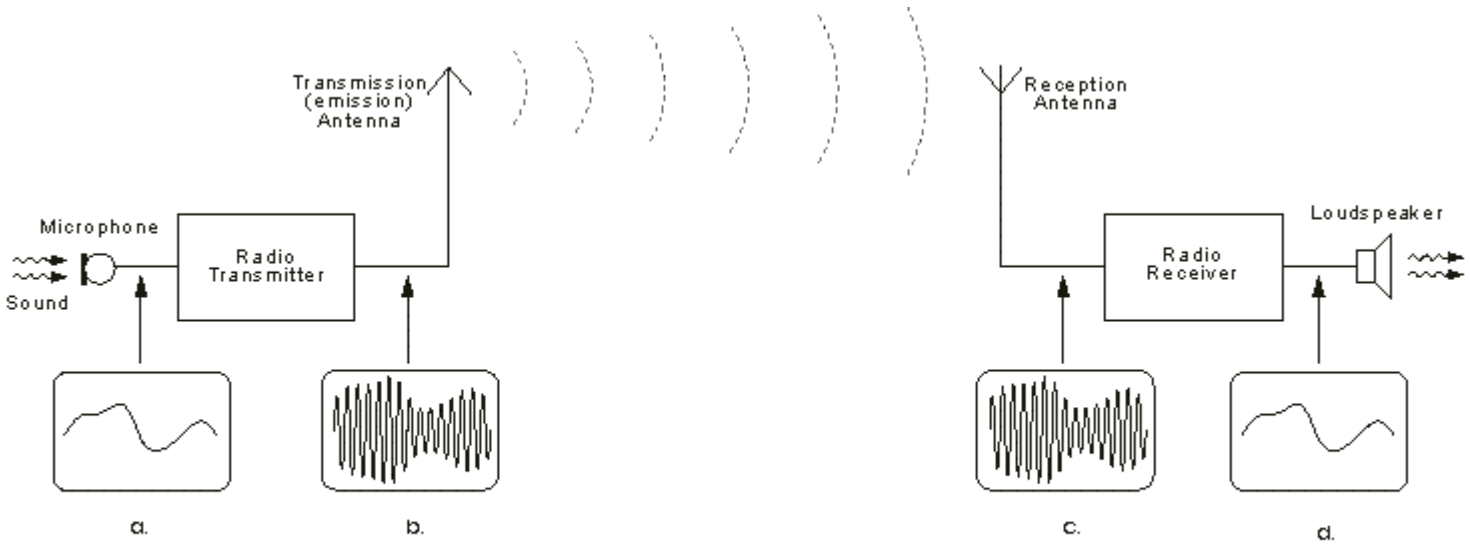

Pic.2.1. Radio Transmission Block-Diagram

2.1 AM Transmitter

In order to better understand the way the radio transmitter works, block - diagram of a simple AM (amplitude modulated) signal transmitter is shown on Pic.2.2. The amplitude modulation is being performed in a stage called the modulator. Two signals are entering it: high frequency signal called the carrier (or the signal carrier), being created into the HF oscillator and amplified in the HF amplifier to the required signal level, and the low frequency (modulating) signal coming from the microphone or some other LF signal source (cassette player, record player, CD player etc.), being amplified in the LF amplifier. On modulator's output the amplitude

modulated signal UAM is acquired. This signal is then amplified in the power amplifier, and then led to the emission antenna.

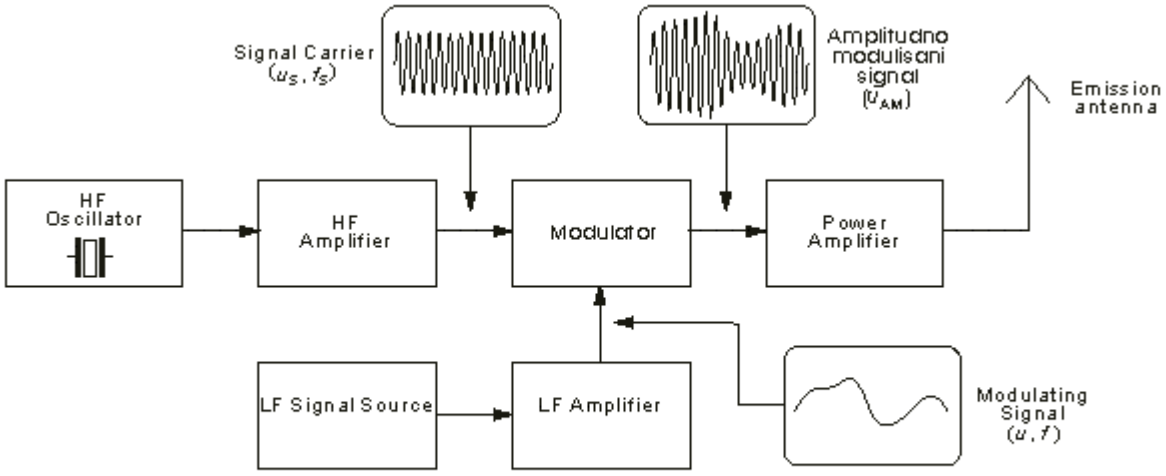

Pic. 2.2. AM Transmitter Block Diagram

The shape and characteristics of the AM carrier, being taken from the HF amplifier into the modulator, are shown on Pic.2.3-a. As you can see, it is a HF voltage of constant amplitude US and frequency fS. On Pic.2.3-b the LF signal that appears at the input of the modulator at the moment t0 is shown. With this signal the modulation of the carrier's amplitude is being performed, therefore it is being called the modulating signal. The shape of the AM signal exiting the modulator is shown on Pic.2.3-c. From the point t0 this voltage has the same shape as that on Pic.2.3-a. From the moment t0 the amplitude of AM signal is being changed in accordance with the current value of the modulating signal, in such a way that the signal envelope (fictive line connecting the voltage peaks) has the same shape as the modulating signal.
Let's take a look at a practical example. Let the LF signal on Pic.2.3-b be, say, an electrical image of the tone being created by some musical instrument, and that the time gap between the points t0 and t2 is 1 ms. Suppose that carrier frequency is fS=1 MHz (approximately the frequency of radio Kladovo, exact value is 999 kHz). In that case, in period from t0 till t2 signals us on Pic.2.3-1 and uAM on 2.3-c should make a thousand oscillations and not just eighteen, as shown in the picture. Then It is clear that it isn't possible to draw a realistic picture, since all the lines would connect into a dark spot. The true picture of AM signal from this example is given on Pic.2.3-d. That is the picture that appears on screen of the oscilloscope, connected on the output of the modulator: light coloured lines representing the AM signal have interconnected, since they are thicker than the gap between them.
Block - diagram on Pic 2.2 is a simplified schematic of an AM transmitter. In reality there are some additional stages in professional transmitters that provide the necessary work stability, transmitter power supply, cooling for certain stages etc. For simple use, however, even simpler block diagrams exist, making the completion of an ordinary AM transmitter possible with just a few electronic components.

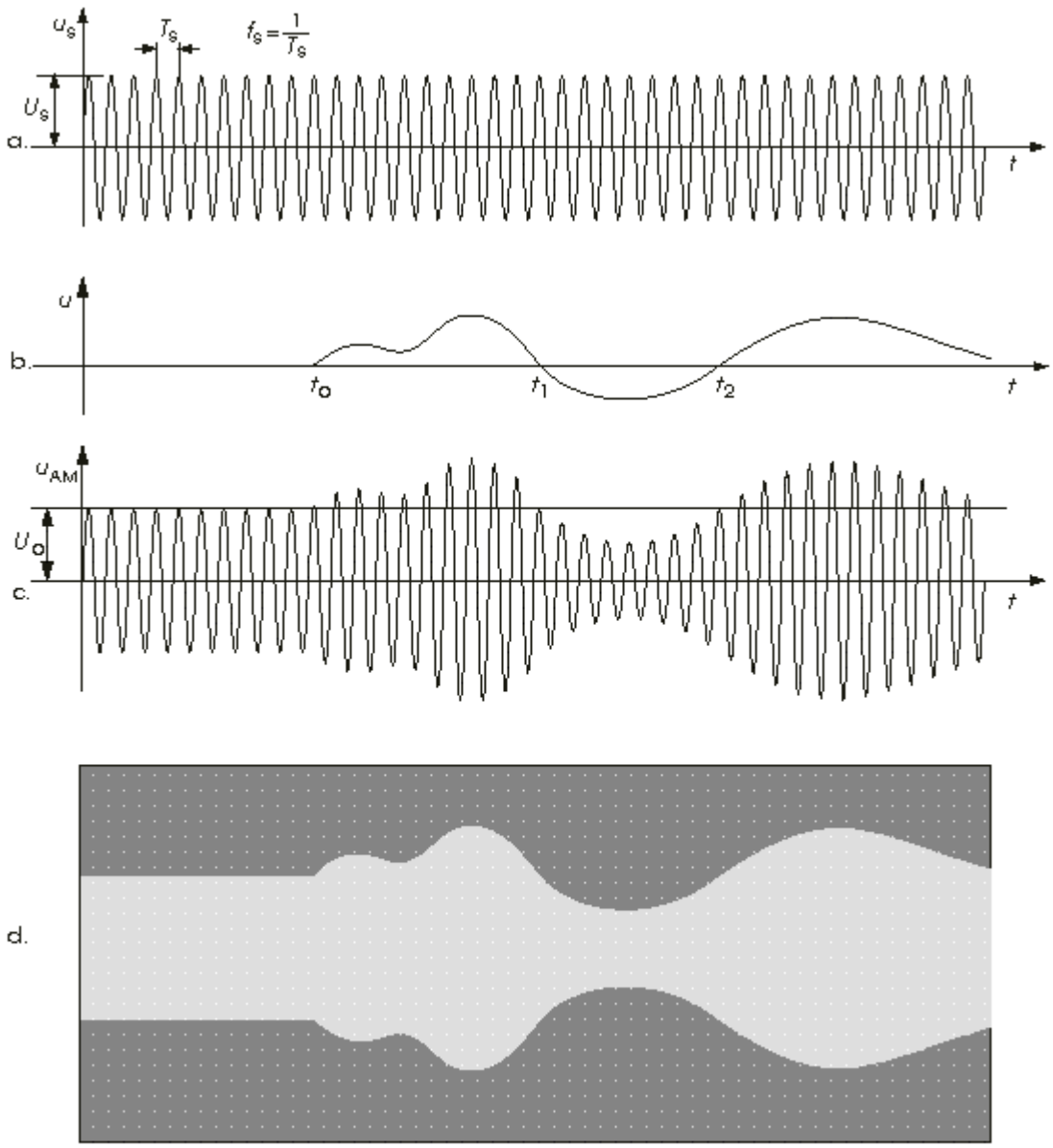

Pic.2.3. Voltage wave envelopes of an AM signal: a- The (signal) Carrier, b- The Modulating Signal (LF signal being transferred), c- AM (amplitude - modulated) signal, d- true look of the AM signal.

2.2. FM Transmitter

Block diagram of an FM (frequency modulated) transmitter is given on Pic.2.4. Information being transferred, i.e. the modulating signal, is a signal from some LF source. it is being amplified in LF amplifier and then led into the HF oscillator, where the carrier signal is being created. The carrier is a HF voltage of constant amplitude, whose frequency is, in the absence of modulating signal, equal to the transmitter's carrier frequency fS. In the oscillatory circuit of the HF oscillator a varicap (capacitive) diode is located. It is a diode whose capacitance depends upon the voltage between its ends, so when being exposed to LF voltage, its capacitance is changing in accordance with this voltage. Due to that frequency of the oscillator is also changing, i.e. the frequency

modulation is being obtained. The FM signal from the HF oscillator is being proceeded to the power amplifier that provides the necessary output power of the transmission signal.
Voltage shapes in FM transmitter are given on Pic.2.5. Pic.2.5-a shows the LF modulating signal. The frequency modulation begins at moment t0 and the transmission frequency begins to change, as shown on Pic.2.5-b: Whilst current value of the LF signal is raising so is the trasmitter frequency, and when it is falling the frequency is also falling. As seen on Pic.2.5-c, the information (LF signal) is being implied in frequency change of the carrier.
The carrier frequencies of the radio difusion FM transmitters (that emmit the program for "broad audience") are placed in the waveband from 88 MHz til 108 MHz, the maximum frequency shift of the transmitter (during the modulation) being ±75 kHz. Because of that the FM signal should be drawn much "thicker", but it would result in a black-square-shaped picture.

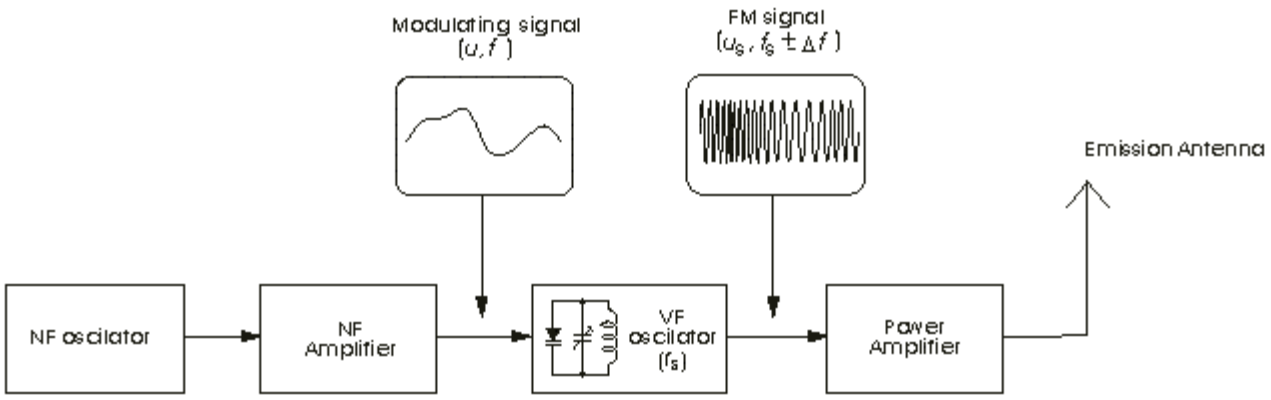

Picture 2.4. FM transmmiter Block diagram

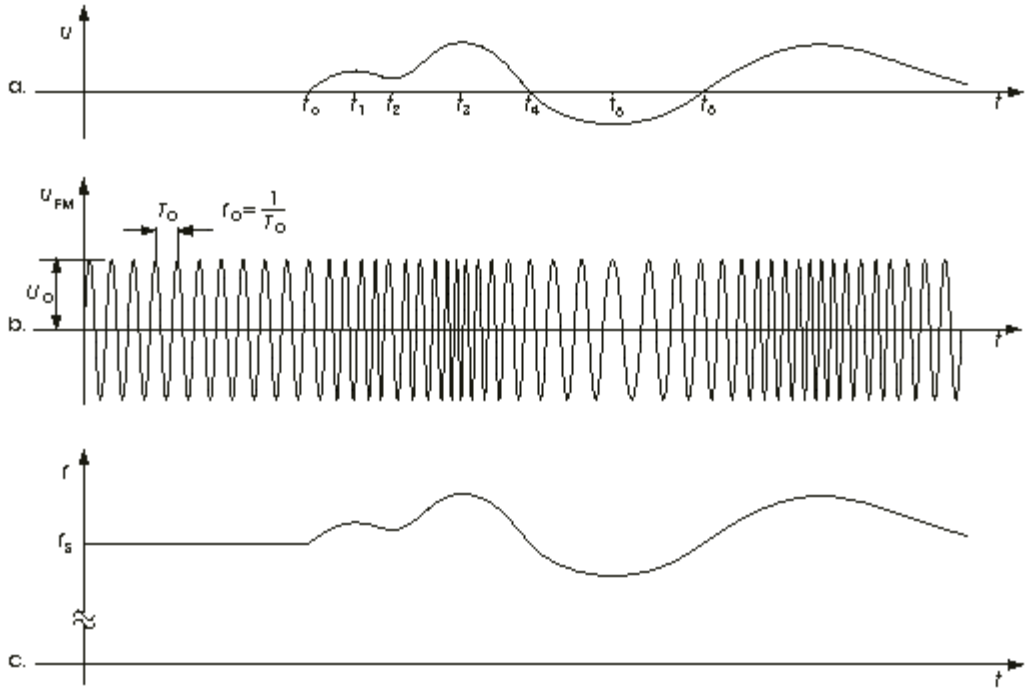

2.3. Wavebands

While considering problems related to the realization of the long - distance radio links, significant differences between the electromagnetic waves of various frequencies must be kept in mind. For example, low frequency waves (below 500 kHz) can bend themselves following Earth's curvature, while the HF waves are moving in streamlines, just as light. Some waves can be reverberated from the ionosphere, others are passing through it etc. According to characteristics of their outspread, radio waves can be classified into several groups or ranges: long, mid, short and ultra-short. Limits between the wavebands are not precise, with the raise of their frequency the waves are gradually losing some features while gaining some others. This division is shown in Table 1.

Table No.1

Range	Frequency	Wavelength
Long waves (LF*)	30 - 300 kHz	10 km - 1 km
Mid waves (MF*)	300 - 3000 kHz	100 m - 100 m
Short waves (HF*)	3 - 30 MHz	100 m - 10 m
Ultra short waves:		
a. Metre range (VHF*)	30 - 300 MHz	10 m - 1 m
b. Decimetre range (UHF*)	300 - 3000MHz	100 cm - 1 cm
c. Centimetre range (SHF*)	3 - 30 GHz	10 cm - 1 cm
d. Millimetre range (EHF*)	30 - 300 GHz	10 mm - 1 mm

* LF low frequencies, MF mid frequencies, HF high frequencies, VHF very high frequencies, UHF ultra high frequencies, SHF super high frequencies, EHF extra high frequencies. Waves with wavelength smaller than 30 cm are also called the microwaves.

In the third table column the wavelengths are given. Wavelength (ë) is distance that the wave passes moving at the speed of light (c=3*103 m/s), during the period that is equal to its oscillating period (T): ë=c*T. Having in mind that the wave frequency is f=1/T, one can easily get to the well known expression that gives the relation between the wavelength and the frequency:

$$\lambda = \frac{c}{f}$$

Using this formula one can calculate the wavelength knowing the frequency and vice versa. For example, wavelength of an FM transmitter emitting at f=100 MHz frequency is L=3*108/100*106=3 m. Similar to that, wavelength of Radio Belgrade 1 is L=439 m, which makes its frequency equal to f=3*108/439=684 kHz. Radio diffusion is being performed in certain parts of the wavebands given in Table 1, their boundary frequencies are (rounded values):

LW (long waves) 150 kHz (2km) 300 kHz (1 km)
MW (mid waves) 500 kHz (600 m) 1500 kHz (200 m)
SW (short waves) 6 MHz (50 m) 20 MHz (15 m)
FM (ultra short waves) 88 MHz (3.4 m) 108 MHz (2.78 m)

In LW, MW and SW the amplitude modulation is used, while in FM range it is the frequency modulation.

Here are the frequencies (in kHz) of some radio transmitters from the MW range, that can serve for tuning of the radio receivers being described in this issue: Timisoara 630, Belgrade1 684, Bucharest 855 .

3.1. The Simplest Radio Receiver

Each radio receiver must have a reception antenna. It is an electrical conductor, where voltages of various frequencies and amplitudes are being induced, under the influence of electromagnetic fields from various radio transmitters. Besides these voltages, those induced by EM fields that are created by various disturbance sources (such as electrical motors, various household appliances spark-plugs of an automobile and all other devices where electrical current is being switched on/off during work) are also present in the antenna, as well as those from fields originating from outer space or the Earth's atmosphere. Basic roles that a radio receiver has are:
a. To separate the signal (voltage) of the radio station that it is tuned at from the multitude of other voltages, whilst suppressing (weakening) all other signals as much as possible,
b. amplifies the extrapolated signal and take out information from it and
c. reproduces that information, i.e. restores it into its' original shape.
Even the simplest radio, the one we are discussing in this chapter, must be able to accomplish all these tasks. The electronic diagram of one such device is given on Pic.3.1. It is the famous (years ago) Detector Radio Receiver or shortly, Detector. The signal selection (separation) and voltage amplification are performed in the oscillatory circuit that is

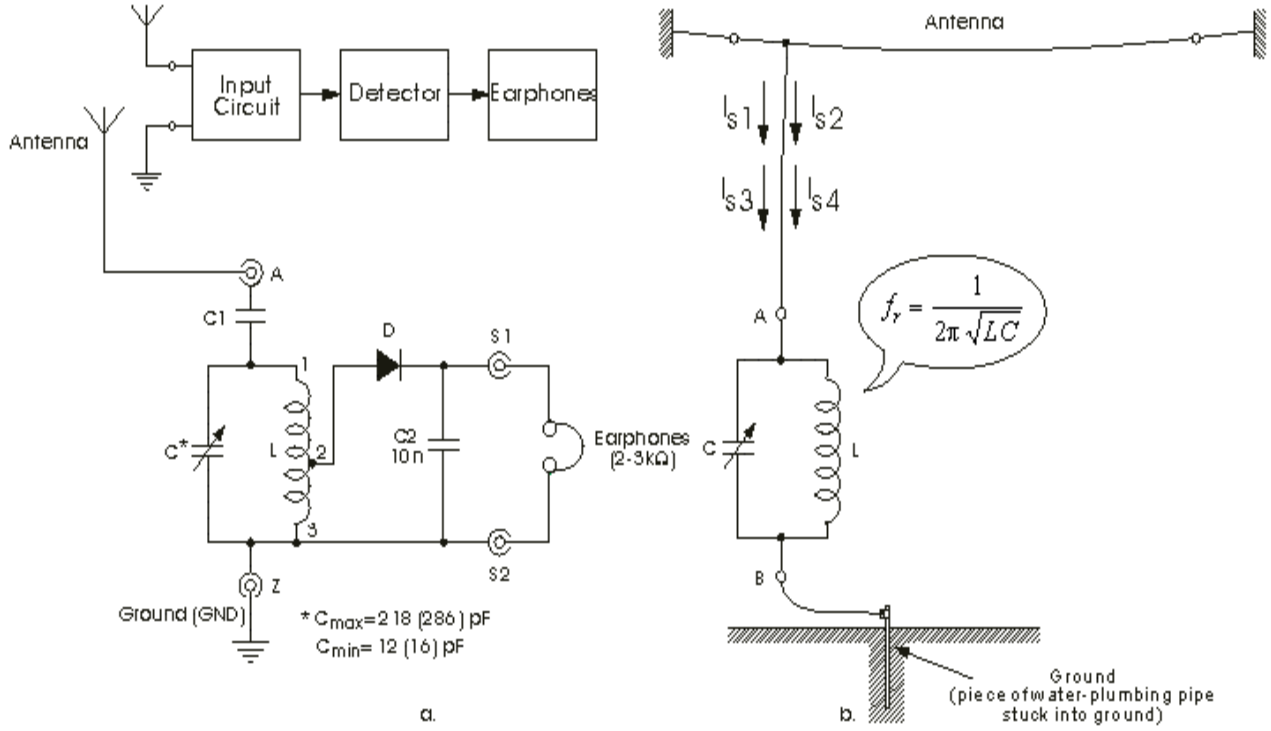

Pic.3.1- a-Block diagram and electronic diagram of a detector radio receiver, b-operating principle of input circuit

made of the capacitor C and coil L, the separation of information (speech or music) from the AM station signal in the detector that comprises the diode D, capacitor C2 and resistance of the headphones, and information restoring in the very headphones.
Main advantages of this device lie in its extreme simplicity and the fact that it requires no additional energy sources for its' operation. All the energy required it draws from the antenna, which therefore has to be at least a dosen metres long for proper operation. It is also useful to have a good ground. One can do without it but the reception with it is truly better, especially considering the distant and small-power transmitters.

3.1.1. Input Circuit

The capacitor that takes the signal from the antenna (so-called coupling capacitor) C1, variable capacitor C and coil L form the input circuit of the radio receiver. Its main role is to separate the signal of station the receiver is tuned at from multitude of voltages (having various frequencies and amplitudes) existing in the antenna, amplify that signal and turns it over to the detector.
In order to better understand the requests that are to be fulfilled during the practical realization of input circuit, it is necessary to know basic characteristics of circuit made of capacitor C and coil L. It is called 'The oscillatory circuit' and is shown on pic.3.2-a. The amount of its impedance (resistance to AC current) between points A and B, which is marked with , depends on the frequency, as it is shown on the diagram on pic.3.2-b. The most important characteristic of this circuit is its resonance frequency, being given by the Thomson's formula:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

As one may notice, the resonance frequency depends on the capacitance of the capacitor C and inductivity of coil L, and changes if one of them change. In our receiver, a variable capacitor is used, that can change its capacitance from Cmax to Cmin, therefore changing the resonance frequency in boundaries from

$$f_d = \frac{1}{2\pi\sqrt{LC_{max}}} \quad \text{to} \quad f_g = \frac{1}{2\pi\sqrt{LC_{min}}}$$

The area between fd (lower boundary frequency) and fg (upper boundary frequency) is the reception area of the input circuit, as shown on pic.3.2-b. On this picture, carrier frequencies of four radio transmitters are being marked with fs1, fs2, fs3 and fs4. The resonance frequency of the oscillatory circuit is set (by means of C) to be equal to the carrier frequency of the second station: fs2. In that case, the impedance ZAB - frequency dependance is shown in continuous line. As one can see, the impedance ZAB for all received signals whose carriers have frequencies less than fs1 and greater than fs3 is less than 20 kOhms, while for the station that is tuned it is equal to 200 kOhms. Let us now imagine that the parallel oscillatory circuit is connected with the antenna and ground, as shown on pic.3.1-b. Imagine, also, that there are (only) four voltages in the antenna, that have the same amplitude and are created by four radio

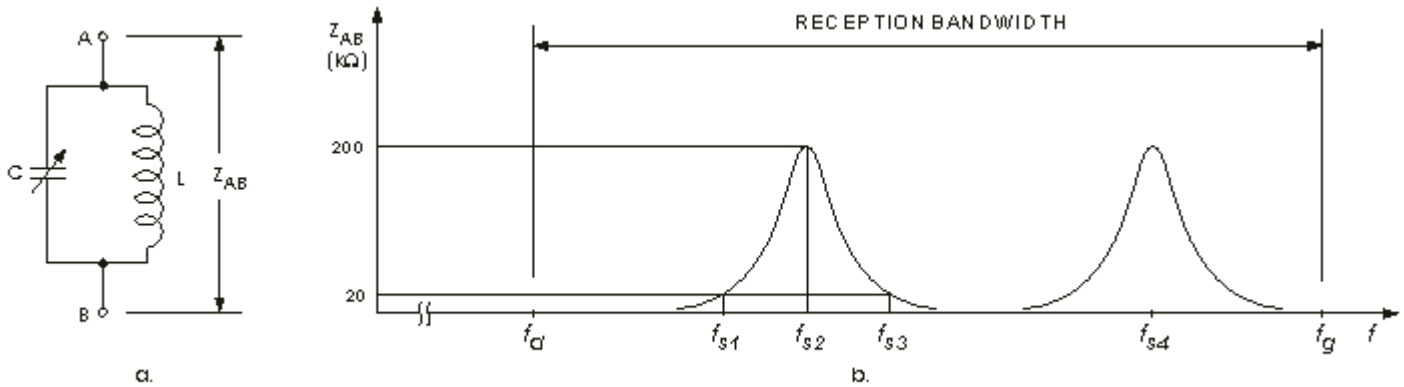

Pic.3.2 a-parallel oscillatory circuit, b-ipedance - frequency dependence of the parallel oscillatory circuit

transmitters, having carrier frequencies of fs1, fs2, fs2 and fs4. Since these voltages spread between the antenna and the ground, four currents will flow through the oscillatory circuit: Is1, Is2, Is3 and Is4. The voltages that are created by them in the oscillatory circuit, between points A and B, are equal, acc. to Ohm's Law, to the product of current and impedance: UAB=I*ZAB. Acc. to pic.3.2-b, for Is2, impedance of the circuit is ZAB=200 kOhms, and for currents Is1 and Is3 it is 10x smaller. That means that the voltage that is being created in the oscillatory circuit by the station that transmits on frequency fs2 will be ten times greater than the voltages being created by stations transmitting on frequencies fs1 and fs3. This is how selection of one station is performed, by means of the oscillatory circuit. Transition to some other station is performed by changing the capacitance of capacitor C, as long as the resonance frequency of the oscillatory circuit does not become equal to the carrier frequency of that station. If its frequency happens to be fs4 (acc. to pic.3.2-b), the impedance of the oscillatory circuit for that case is shown in dashed line, which causes that on the circuit output voltage of the station that transmits on frequency fs4 is acquired, while other stations' signals are suppressed.

At first glance, everything is just the way it should be: Parallel oscillatory circuit extrapolates one and suppresses all other stations. Unfortunately, the reality isn't so simple. First of all, radio transmitters operate with various output (emission) powers and on various geographic distances from the receiver, therefore making the voltages that their signals create in the reception antenna very different in amplitude. It is clear that stronger signals will "cover" the weak ones, thus disabling their reception. E.g. if radio transmitter that emits on the frequency fs1 is geographically much closer to our radio receiver that the transmitter operating on fs2, the voltage the former creates in the reception antenna can be even 200 times greater than the one created by the latter. The oscillatory circuit will do its job as previously described, but on its ends the voltage of the first transmitter will still be greater (20x) than that of the transmitter the receiver is tuned at, and normal reception won't be possible. There are also other problems whose solving will not be discussed herein, and readers that are interested in those can read a book "Radio Receivers", written by Momir Filipovic, issued by the National Textbook Publishing Company from Belgrade, Yugoslavia.

To conclude this chapter, we may say that the simplest radio receiver can cover only signals of the local and powerful radio transmitters.

3.1.2. The Antenna

Extremely important factor for good work of simple radio receivers is the outside antennaTHAT HAS to be long enough, and in which voltages induced by the radio transmitters will be high enough. At first sight, one can think of using instead some modest antenna made of a piece of wire, compensating that with supplying the receiver with amplifier strong enough to give the end result as if much better antenna have been used. That, of course, is not the case, since every amplifier creates noise that makes the reception worse, if not impossible. This fact is the cause for a radio-amateur saying that "Antenna is the best HF amplifier." The external (outside) antenna is being made of copper wire, thick enough to resist strong wind conditions. In the sense of mechanical strength, the best thing is to use the litz wire (cable), i.e. a cable made of huge number of thin threaded copper wires. There is no need to remove the wire isolation if it exists since it doesn't represent an obstacle for the electromagnetic waves. The length of antenna is being determined in accordance with the "TLTB" law (The Longer, The Better). The antenna that we have been using for testing the receivers described herein was 6 metres long (the length of the Radio Receivers Lab at "Tesla" highschool, where it was spread), but if you are in position, you should make it even longer (the author has a friend whose antenna is about 30 metres long). It should be moved away from the sources of electrical disturbances (public electricity cables, various household electrical devices, cars, electric motors etc.). Considering this, the best place for your antenna should be the building roof. The wire can be crossed between two chimneys (Pic.3.3), between a chimney and some pillar, between two purposefully built pillars, between two buildings, a building and a pole in the yard etc. You should, however, always keep in mind that the wire, however strong it may be, can snap during some big storm and, in case that happens, under

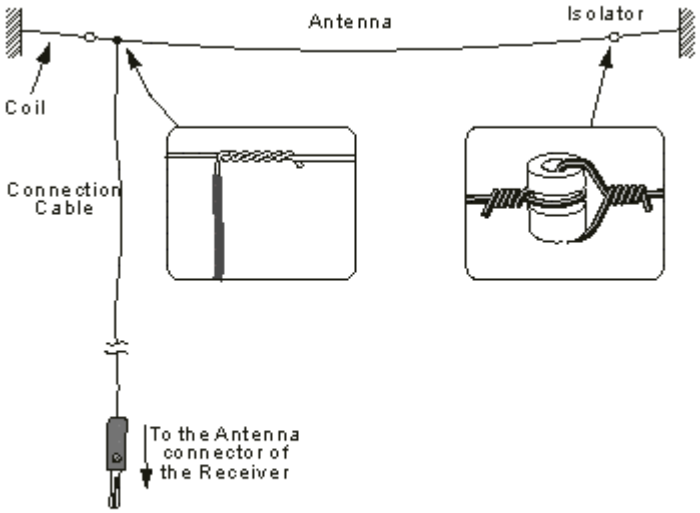

Pic.3.3. Outside Antenna

NO CIRCUMSTANCES it should fall onto electrical network cables, telephone leads and similar, or to cause some other damage. if your roof cover is not covered with tin, the attic could also be a good place for the antenna. You can also stretch it between two stronger laths attached to two opposite window frames of your apartment. If you have no other options, you can put your antenna between the walls in your room.
The antenna must be electrically isolated from the carriers being attached to. In amateur conditions, one can make the isolators of a piece of thick wall plastic pipe where, acc. to Pic.3.3, an indent should be made with the round rasp, in order for the wire not to slip away.
The antenna lead is another piece of wire which carries the signals from antenna into the receiver. It should be isolated and placed in such a way not to touch the walls, to be as far from metal parts as possible (gutters, city grounding etc.).

At the end of this chapter, let's just say that in mobile receivers ferrite antennas are being used, which we are going to talk about later.

3.1.3. The Ground

As all other sorts of ground, the ground for the radio receivers is being accomplished by connecting the receiver ground (point Z on Pic.3.1) to Earth over a coper wire. You can live without the ground but the reception is much better with it though, especially considering simple devices, such as one at the Pic.3.1-a. Water plumbing is an excellent ground (central heating pipes are not), but it is most often inappropriate for use. There is no housewife that would agree to have some dreadful wire stretched across the house, from bathroom to the living room! House electrical installation's ground is excellent, but it should be used under NO circumstances, since life-threatenning danger from electrical shock exists. If you live on a ground floor, and there's plain soil beneath your window you can make your own ground by sticking a piece of water plumbing in it, acc. to Pic.3.4. The pipe should be about 80 cm long, and on its end you should connect the receiver ground, attaching it with a metal ring and a screw with the nut.

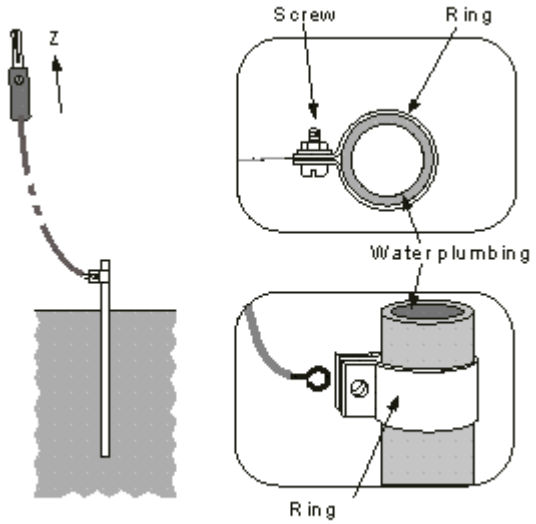

Pic.3.4. The Ground

3.1.4. Other Components

a. On Pic.3.1-a with letters A, Z, S1 and S2 the hubs where one can connect the antenna (A), ground (Z) and the headphones (S1 and S2) are labelled. Since the cabinet for our radio receiver(s) is being made of material that is the electrical isolator (plywood, plastics etc.), the simplest metal hubs can be used, although hubs with isolation plates (for metal plate mounting) can be found in shops more easily, but are significantly more expensive.
b. C1 capacitor is the so-called coupled capacitor, through it the signals from the antenna being led into the oscillatory circuit. Its capacitance depends upon the length of the antenna, and it lies within the limits of few pF (antenna longer than 10 m), up to few dozens pF (a couple of metres long antenna), the optimal value is to be found through experimenting. Every reception antenna behaves as a voltage generator, having its own internal resistance and capacitance. Antenna's resistance damps the oscillatory circuit and reduces its selectivity (which manifests as the "mixing" of stations) and sensitivity (which exerts as signal strength reduction), and antenna's capacitance reduces the reception bandwidth. More precise, antenna's capacitance reduces the upper bound frequency of the reception bandwith (Pic.3.2), making reception of the stations laying close to this frequency impossible. Both these features are undesirable and manifest themselves as

less as the capacitance C1 is smaller. On the other hand, the smaller the capacitance C1, the weaker the signal that goes through it from the antenna, the reception therefore getting weaker. As you can see, the compromise solution is a thing to go for, i.e. one must find the capacitance at which the signals from the antenna won't be much weakened while simultaneously keeping the selectivity and the bandwidth big enough. You can start with C1 being about 30 pF. Then,

using C, tune yourself to some radio stations you can receive. If all the stations that interest you are there, and the strongest one of them still does not jam the reception of other stations all's well. Try then with some bigger capacitance for the capacitor C1. The reception will be getting louder, so do continue increasing C1 as long as it is still possible, by changing C, to receive all the stations of your interest that can be heard in your place, without the interference of some strong or local station. If, however, reception of some nearby station isn't possible, smaller C1 should be tried out. In this manner the biggest capacitance for C1 should be found, that allows optimal reception both regarding selectivity and bandwidth. The simplest solution is using variable capacitor for C1, its capacitance ranging from few picofarads to few dozens pF, adjusting it to obtain optimal reception for each station individually. During this, whenever C1 is being changed, the receiver must be re-tuned to the station using C.
c. The coil is one of the components that cannot be bought, therefore it has to be manufactured. Its main property is the inductance L. As an example, we are going to take a look at how to build a coil for the MW receiver with band range from fd=540 kHz til fg=1620 kHz. The inductance is being calculated using the Thomson formula (being solved by L):

$$L = \frac{1}{4\pi^2 f_g^{\,2}\,(C_{\min} + C_x)}$$

Where Cx denotes the so-called parasite capacitance. It comprises the capacitance of the trimmer capacitor (its average value) that is connected parallel to the variable capacitor C, input capacitance of the next stage of the receiver (where the signal from the input circuit is being lead), antenna capacitance, coil capacitance and capacitance of the connections between the components of the input circuitry. The amount of this capacitance is not known in advance, therefore must be assumed. Taking that value, the coil inductance is calculated and the appropriate coil is made, together with the input circuit. The error being made with the assumption of the capacitance Cx is then compensated with the abovementioned trimmer capacitor. In all our projects this capacitor had minimum capacity Cmin=12 pF. We assumed Cx=15 pF, and therefore:

$$L = \frac{1}{40 \cdot 1{,}62^2 \cdot 10^{12} \cdot (12 \cdot 10^{-12} + 15 \cdot 10^{-12})} = 353\ \mu H$$

We made this coil, conented it with other components from Pic.3.1 and, after some experimenting and measurement, came upon the conclusion that its inductance should be somewhat smaller. We uncoiled a few reels, re-checked the bandwidth, then uncoiled some more, re-checked again, and after several tries came up with the solution. With variable capacitor that will be described in the following chapter, the abovementioned bandwidth is achieved with the coil of inductance L=330 ìH (microhenries).
The coil body i.e. the body where the coil is being reeled is a cylindrically shaped isolation material. For this purpose we have been using the carton core of the household aluminium foil package, its diameter being 3.2 cm. The number of bends required and wire diameter are calculated acc. to the formulas from Pic.3.5.

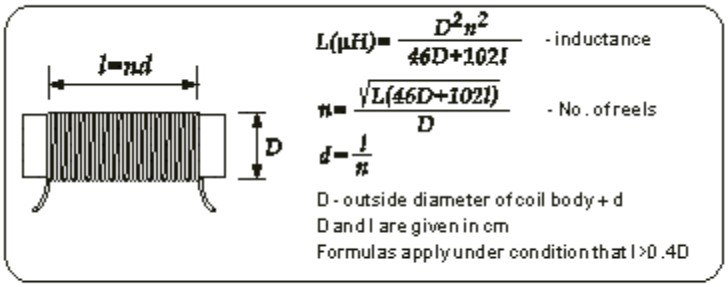

Pic.3.5. Formulas to calculate the coil inductance and number of reels

In order to use these expressions coil length must be assumed first. If this length later proves to be incorrect because the wire is too thick or thin, new length is adopted and the calculation is repeated. Let us assume that coil length is l=4 cm. The number of reels and coil diameter are:

$$n=\frac{\sqrt{330\cdot(46\cdot 3{,}2+102\cdot 4)}}{3{,}2}=134$$

$$d=\frac{40\,mm}{134}=0{,}298\,mm$$

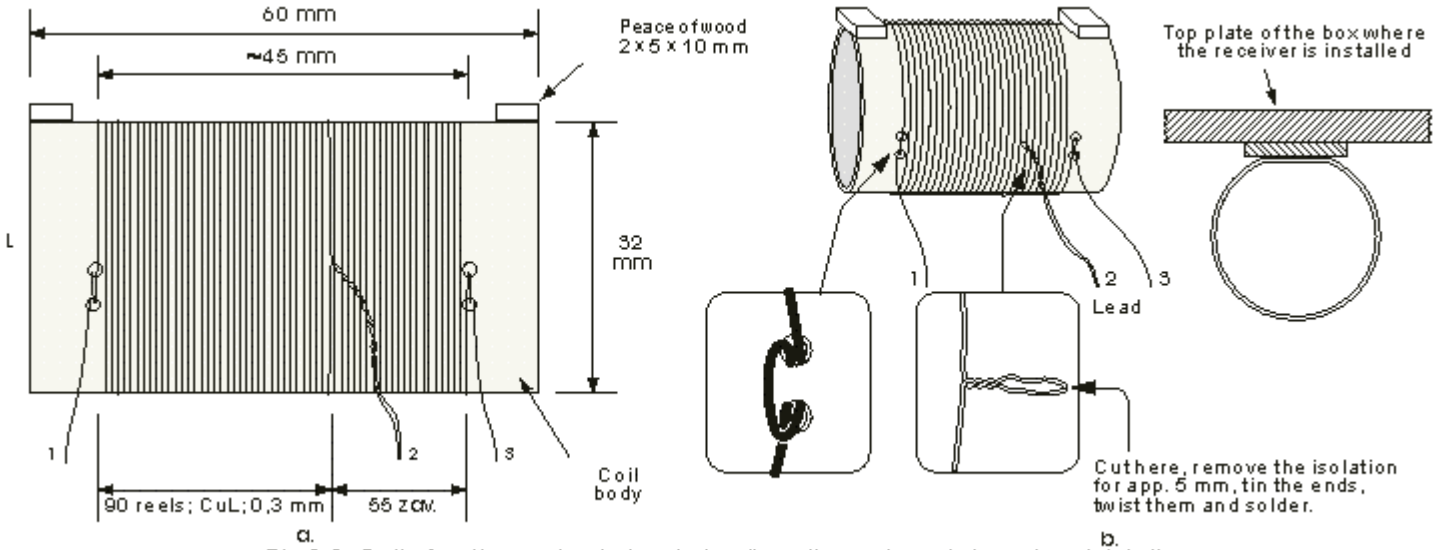

Pic.3.6. Coil of radio receiver's input circuit: a-dimensions, b-layout and details

Since there is no wire of such diameter, we adopt the closest existing value, d=0.3 mm. In that case the length l will be somewhat bigger, and so will be the number of reels. After a few iterations in calculus and later inductance check of the finished coil, we came upon the n=144 reels of lacquered copper wire (the

mark for such wire is CuL), its diameter being d=0.3 mm.

This coil is shown on Pic.3.6. As you can see, two holes are made in coil body (with a bodkin) and through them the wire origin is being threaded twice. After that 90 reels are made, then a leg, then another 55 reels and finally the wire end is again threaded twice, through the other two holes. The leg is made by multiple twisting the wire. It is then cut, and from these new ends about 5 mm of isolation is removed, after which they are tinned, twisted around each other and finally, soldered (the easiest way to remove the isolation is by burning it with lighter, then carefully scrapping it with the pocket knife or similar). Two small pieces of wood are then glued onto coil's ends. When the coil is being mounted into the box, they are pasted onto its top panel, as shown in the rightmost part of Pic.3.6-b.

If you are using a coil of different diameter, you should keep in mind that the necessary inductance for the coil which measures more than 3.2 cm in diameter will be obtained with number of reels less than 144 and vice versa, if the coil body is less than 3.2 cm you will need more than 144 reels.
d. Variable capacitor C is hard to find in stores, therby we have been using in all our receivers the one that we took from a disused commercial pocket size MW radio receiver, the one shown on Pic.3.7. On Pic.3.7-a you can see it together with the reel with numbers that represent the frequencies, divided by 100, on which that receiver was able to be tuned at. On Pic.3.7-b you can see the front, side and rear views of this capacitor. Electrical diagram is given on Pic.3.7-c. As one may notice, there are actually two variable capacitors under the same cover, Co and Ca, and two trimmer capacitors connected parallel to them, Cto and Cta. The dashed line shows symbolically that the rotating plates of the variable capacitors are connected on a common shaft, so that by turning the reel their capacitances are being changed simultaneously. For our use, all four capacitors are parallel connected, by joining the legs O and A. The trimmers are set to minimal capacitance. In such way the variable capacitor is attained with capacitance ranging from Cmin=12 pF til Cmax=218 pF.

In commercial radios that can receive both stations from AM and FM ranges, variable capacitor shown on Pic.3.8 is being used. Four variable and four trimmer capacitors are placed under the same cover. If you wish to use capacitor like this in the receiver from Pic.3.1 (and in most of the receivers described in this book), you should then connect in parallel Cto, Co, Ca and Cta, after which you shall obtain a variable capacitor ranging from Cmin=16 pF til Cmax=286 pF. Other capacitors from this block are not being used.
In all input circuits (more about them soon to come), one end of the variable capacitor is always connected to the device ground. For capacitors shown on Pics.3.7 and 3.8 that is the middle leg, marked as G.
During the dismounting of the capacitor from the old radio, you should pay attention not to loose the screw for the reel attachment, and two screws for mounting the capacitor onto the PCB, since they are very hard to provide separately.

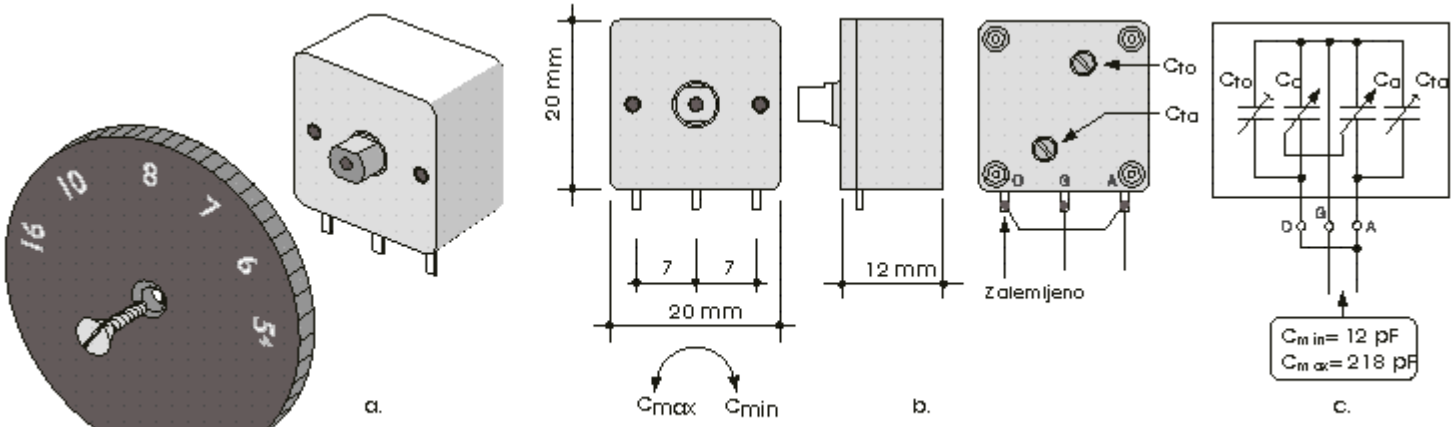

Pic.3.7. Variable capacitor of the input circuit of an AM receiver: a-layout, b-dimensions, c-capacitance

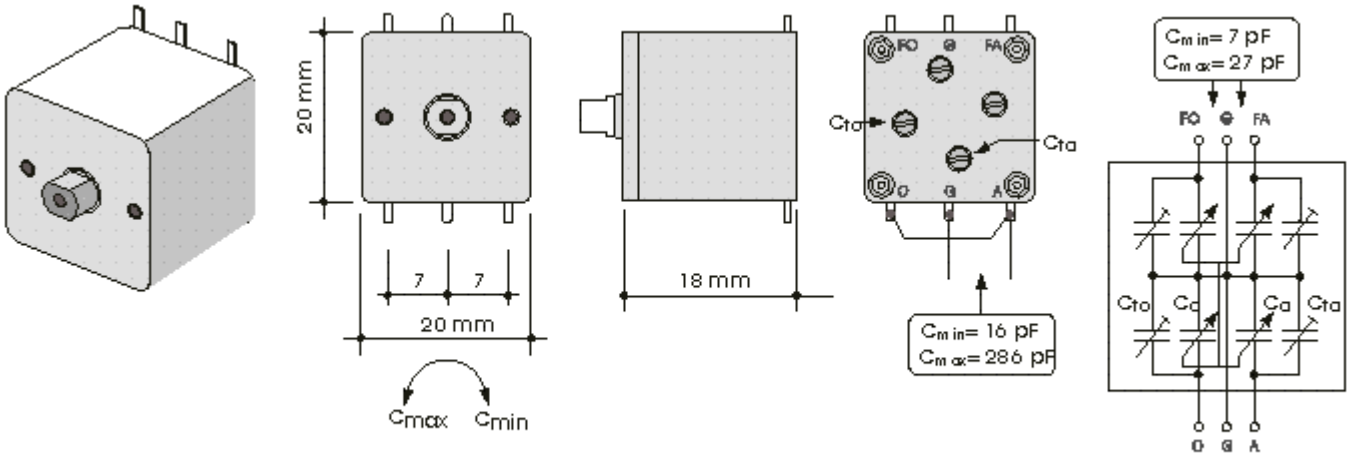

Pic.3.8. Variable capacitor of the input circuit of an AM/FM receiver: a-layout, b-dimensions, c-capacitance

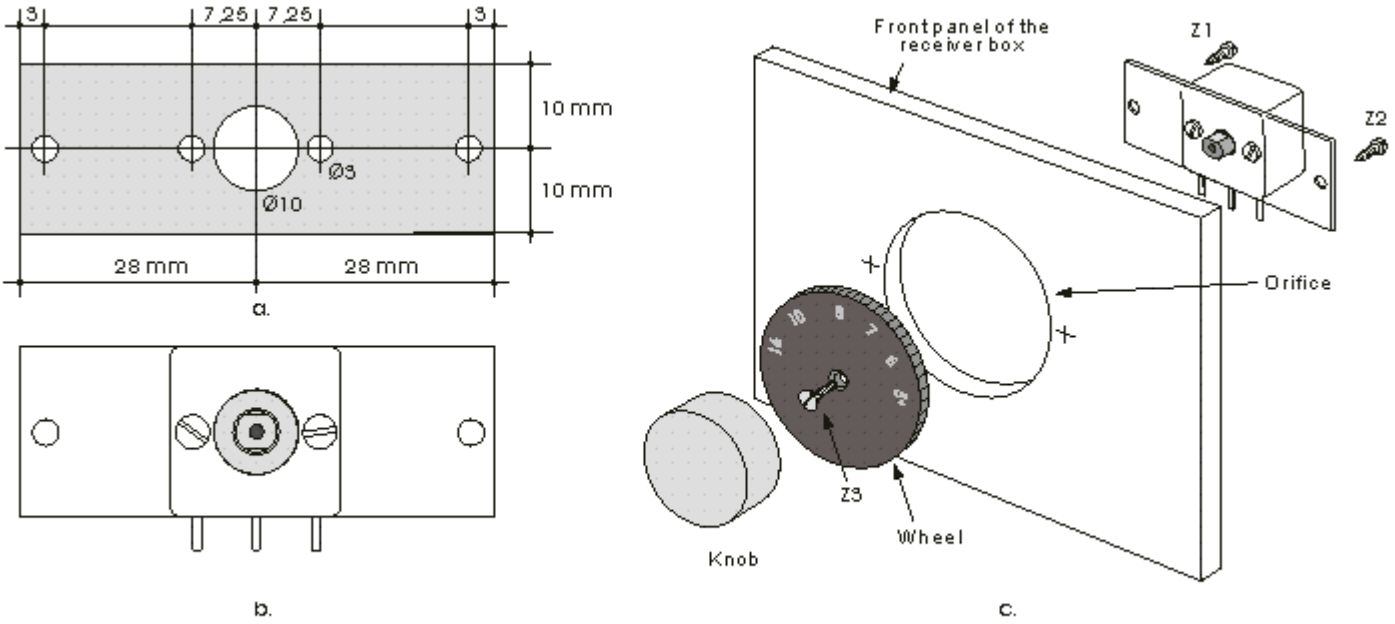

Pic.3.9. Variable capacitor assembly: a-plate dimensions, b-capacitor on plate, c-assemblage on the front receiver panel

If the reciever is being put into the box whose front pannel is made of isolating material not thicker than 1 mm, then one 10 mm hole should be drilled on it, followed by two 3 mm holes, as shown on Pic.3.9-a. Having thicker front panel does represent a problem, the shaft of the capacitor being too short to mounting the reel. In that case you will have to make the auxiliary plate about 1 mm thick as shown on Pic.3.9-1 and then mount the capacitor on it , acc. to Pic.3.9-b. On the front panel a round eye should be made, its diameter being a little bit bigger than the reel. The auxiliary plate with the capacitor should then be tightened onto this front panel with two small screws Z1 and Z2, and the reel on the capacitor shaft with the screw Z3 (While tightening this screw you should hold the reel with your other hand, and not the capacitor housing). Finally, a button made of a thick plywood can be glued to the reel. This is not necessary, but gives the device a more sophisticated looks.
Different variable capacitors than the ones described here can also be used, for example, an air variable capacitor described in the first issue of Practical Electronics. The important thing for it is to have a big max/min capacitance ratio, at least 15, i.e. Cmax/Cmin>15. While connecting the capacitor, care should be taken to connect its rotor with the ground (as on Pic.3.1), labeled Z, and its stator with the point 1 of the coil.
e. The diode D, capacitor C2 and headphones' resistance comprise the AM signal detector, also called the serial diode detector. When the AM signal of the station the receiver is tuned at is brought on its input, NF signal is obtained on the output, its shape being the same as the envelope of the AM signal. An example of this is given on Pic.3.10. When voltage uul is present on the input of the detector, the voltage uizl appears on its output. It is useful to notify that on the output, besides the LF voltage (speak, music etc.), DC voltage Uo is also present.
The detection diode D must be of low-power GERMANIUM type, such as AA112, AA116, AA121, 1N21, 1N34, 1N54, 1N78 etc.

Product of the capacitance C and resistance R (on Pic.3.1. R is the headphones resistance) should be approx. equal to 50 ìs (microseconds). That means that if you're using the bigger resistor (which is advisable, since the detector then damps less the oscillatory circuit), the capacitor should then be smaller. For example, if

R=500 kÙ then C=100 pF, and if R=10 kÙ, C=5 nF, etc.

f. The headphones are the electro acoustic convertor that transforms electrical signal into the sound. We have been using old fashioned electromagnetic headphones with 1.5 kÙ resistance that were serially connected, giving the total resistance of 3 kÙ. The receiver from Pic.3.1 will be working as better as headphones' resistance is bigger. if you're using the crystal headphones, parallel to them you should add a resistor of couple of hundreds of kiloOhms. There's a very simple way of testing the high resistance headphones: Hold one end of their cable between your fingers while rubbing the other over the surface of a big metal object, say, the radiator. If snapping can be heard from them they are, most likely, satisfactory.

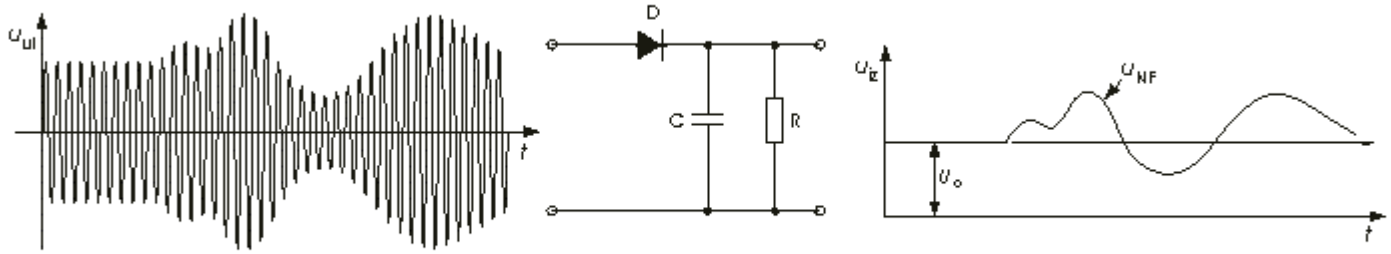

Pic.3.1. Input and output voltage at the serial diode detector

All the components of the receiver from Pic.3.1 should be placed into some kind of a box. That can be any box made of an isolation material (plastics, wood etc.), big enough to receive all the components. As an example, a receiver is shown in scale 1:1 on Pic.3.11, being placed in a box made of plywood. The top, bottom and side panes are made of plywood that is 5 10 mm thick. The front and the rear side are being made of some thinner material, that allows for simple mounting of the variable capacitor. One can notice straightaway that the box is at least twice as big as it could be. That has been done for the sake of better visibility, and for the box to be big enough to accept the devices that will be described later in this book.

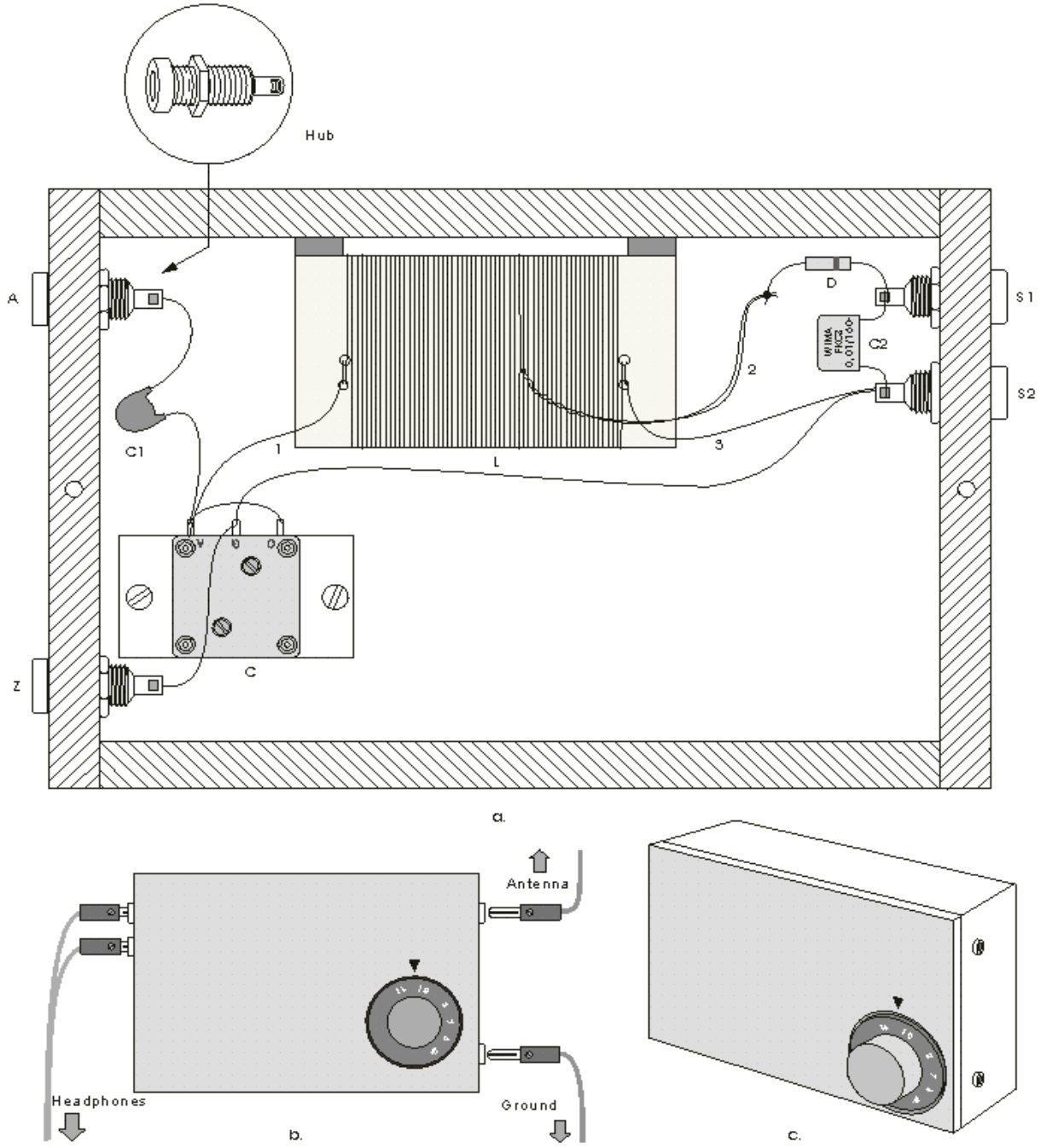

Pic.3.11. Practical realization of the Detector Receiver from pic.3.1-a: a-component layout in the box, b-front panel view, c-3D view

Component joining is being done by soldering. Performing soldering onto the hubs can represent a small problem. In order to complete this operation successfully, you should turn the box for the part of hub where cables are being soldered pointing upwards. Put a piece of the tinol wire through the eye on the hub, put the soldering iron top onto the eye from upwards and hold it like that a while, for the tinol to melt. Then add some more tinol, until the eye is completely covered with the solder. After that, push the wire end into the melted solder while holding it with pencers, until it hardens and cools itself a little. The pencers remove the heat and prevent its transfer onto the component that is being soldered.

3.2. The Simplest Amplified Radio Receiver

The most obvious shortcoming of the receiver described in the previous chapter is that it can perform the sound reproduction loud enough only in case when the programme from some local or very powerful radio transmitter is being received, which can create very strong signal in the reception antenna. The reception of signals from other transmitters is too weak. The only thing that can be done is either to increase the length of the antenna, which, of course, does have its limits, or to insert an amplifying stage into the receiver. The simplest way to perform the latter is to add a LF amplifying stage behind the detector in the detection receiver, Pic.3.1. The electrical diagram of one such receiver is given on Pic.3.12. The electrical load in the detection stage are no longer headphones, but an ordinary resistor R1. An NF signal is obtained on its ends, which is then being lead into the LF amplifier with the transistor T, over the coupling capacitor C3. The electrical load in the collector circuit of the transistor are the headphones, which transform the amplified LF signal into sound. The voltage negative feedback is being obtained with the capacitor C4, and the current negative feedback with the resistor R3. They enhance the characteristics of the amplifier (increase its stability, reduce distortion, widen the reception band), but they also reduce the amplification. The capacitor C5 prevents the AM signal carrier which, although very weak, also appears on the detector output, from entering the headphones. These 3 components however, can be omitted in most cases, for the sake of simplifying the device. C4 and C5 can be simply removed, and a piece of wire should be soldered instead of R3. Transistor operation point where the optimal reproduction (the biggest amplification, the smallest distortion) is being set by adjusting the resistence value of the resistor R2. The simplest way to do it is to connect the trimmer of couple of MÙ instead of the resistor, set the receiver on some station, then change the resistence until the optimal reception is being reached. The trimmer is then put out, its resistence measured, and a resistor of similar resistivity is then soldered on its place. The transistor T is any universal NPN - type.

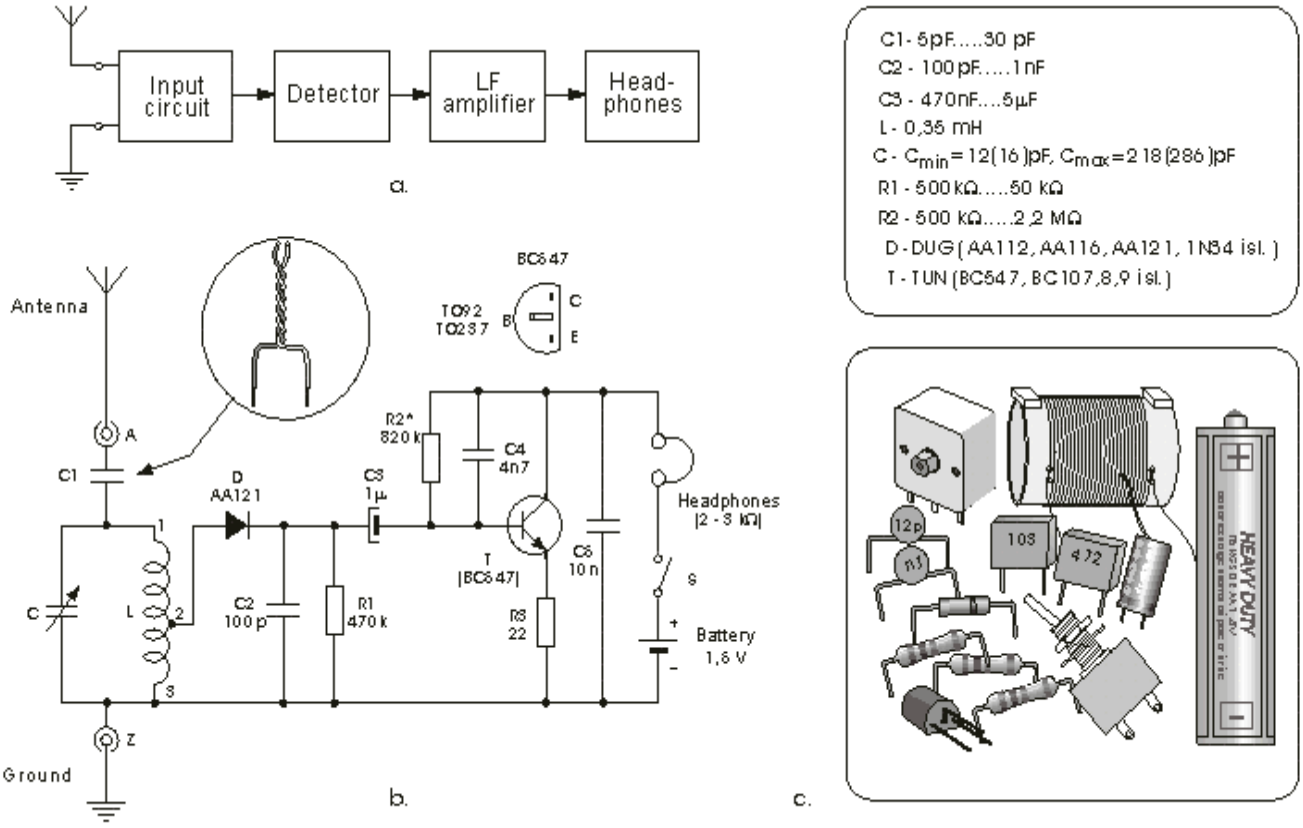

Pic.3.12. Detection receiver with simple amplifier: a-block diagram, b-electronic diagram, c-components

Please note that in the case of a very long antenna, when C1 of very small capacitance is being used, a hand made trimmer capacitor can be used. It is made by twisting two isolated wires, and its capacitance is changed simply by removing some wire from the ends.
The component data is given on the electrical diagram and in table on the rightmost side of Pic.3.12. If you don't have a 100 pF capacitor (C2) you can put some of bigger capacitance, but you should then use smaller R1.
The PCB layout is given on Pic.3.13. On 3.13-a is a picture that should be copied with the thin alcohol marker onto well cleaned copper side of the pertinax plate. Etching is to be performed then, as well as drilling the 0.8 mm holes, in the way that has been described in detail in PE2 issue (Practical realization of electronic devices). The component layout is given on Pic.3.13-b. The printed circuit is also visible on this picture, and that can be achieved by using vitroplast plate instead of pertinax. The look of board upon completion is on 3.13-c. Before soldering the wires that connect the variable capacitor, battery, switch etc. with the board, put some tin on the wire ends, using the calofonium or the tinol wire. You should by all means do this, especially if you 're not using the wire that is not pre tinned, in order to avoid cold solders, very unpleasant surprises that are hard to detect and locate.
The layout of the entire receiver is given on Pic.3.14, in a scale 1:1. As in the previous receiver example, the coil is being glued to the top side of the box, over two small pieces of wood. The board is being tightened with a screw, that is screwed into a piece of wood being glued to the front end box plate. The battery is attached with a rubber band for the pieces of wood glued at the back plate of the box. We did this, however, only for the sake of having a clear and understandable drawing. Battery can be put inside the box in the same way as before, or some other way.

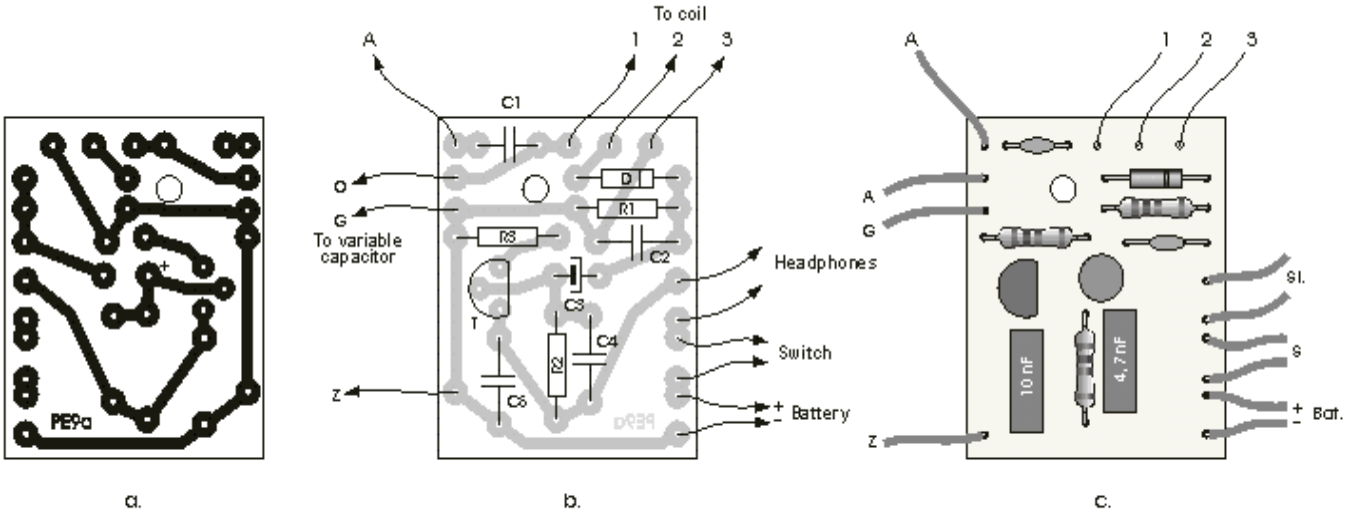

Pic.3.13. PCB for the receiver from pic.3.12: a-soldering side view, b-component side view, c-component layout

3.3. Simple Radio Receiver with TDA7050 IC

Readers that were able to browse through book 4 and, especially, book 5 of Practical Electronics edition, were able to convince themselves that there's a huge number of various audio amplifiers built with IC's, therefore amplifiers in discrete technique are practically no more being made. If we add on this the fact that integrated amplifiers outreach their discrete competition both by price and quality, it is then clear why we are going to use them in this book.
Electronic diagram of a simple radio receiver with LF stage built around the TDA7050 IC, where reproduction is being made through modern-type headphones, resistance being 32 or 64 Ù, is given on Pic.3.15. In book 5 of Practical Electronics you have acquainted yourself in more detail with this IC. Let us just repeat that it can be purchased both in 8-pin DIL package that we have been using, and in SO package, suitable for surface mount. Its label in the latter case is TDA7050T and it can also be used without any problems whatsoever. In that case changes on the PCB should be made considering that it is being mounted on the copper side of the board, and that drilling is now obsolete, since the pins are being soldered directly onto the copper foil. You can read the text that follows Pics.4.16 and 4.17 about soldering SMD components. Supply voltage for the IC is in range from 1.6 to 6 V. Idle current is 3 mA on 3 V supply voltage. Voltage amplification is 32 dB (40 x) on 6 V supply voltage and 32 Ù headphones resistance. Maximum output power is 150 mW, more than enough for the headphones amplifier device.
Regarding the Pic.3.15, both input and detection circuit described in two previous projects can be used, We have decided instead, to show you how to use the coil with multiple legs, since it offers more possibilities for experimenting in order to achieve optimal reception. The picture of such coil is given on Pic.3.16, the legs being made as previously described in this book. The first leg (numerated 6) is made after the 15-th quirk, the second (5) after 30-th, the third (4) after 45-th and the last one (2) after 55-th. Number of quirks between the legs isn't critical, you can have even more legs, being arranged more closely to each other. As seen on Pic.3.15, both the antenna and the detector are connected over these legs. Legs No. 4 and 5 have been used, but that is not a must. The closer the legwhere antenna is connected is to the ground (point Z), the less it damps the oscillatory circuit (therefore increasing the receiver's selectivity), and less it reduces the reception bandwidth. However,

the signal that exits the antenna is then also smaller. The similar thing is with the leg where the diode (its anode end) is connected: The closer it is to the ground, the less the detector damps and tunes out the input circuit, but the signal being transferred to the detector is also smaller. It is clear now that a compromise must be made: Experimenting with various coil legs, those providing the optimal reception should be found.

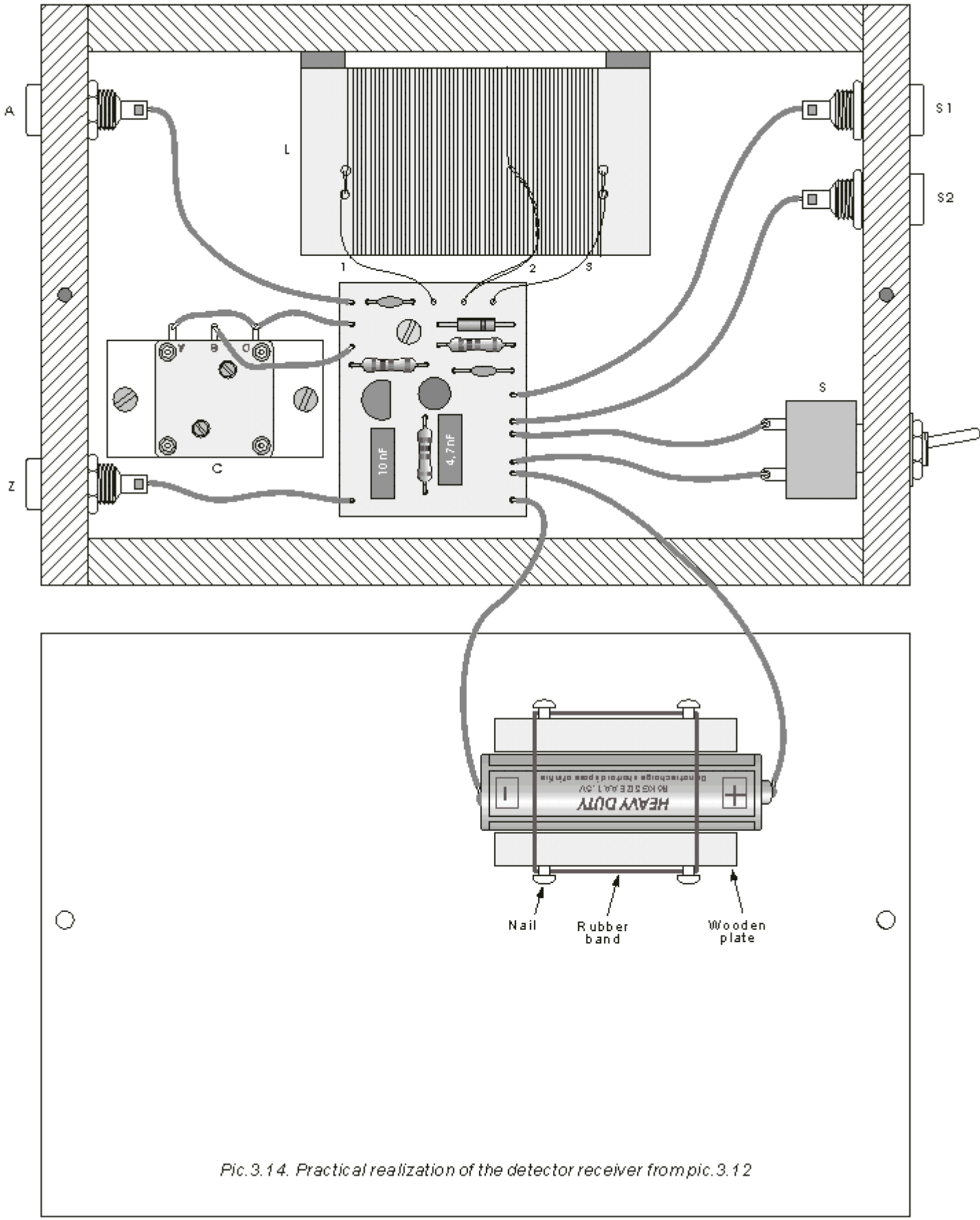

Pic.3.14. Practical realization of the detector receiver from pic.3.12

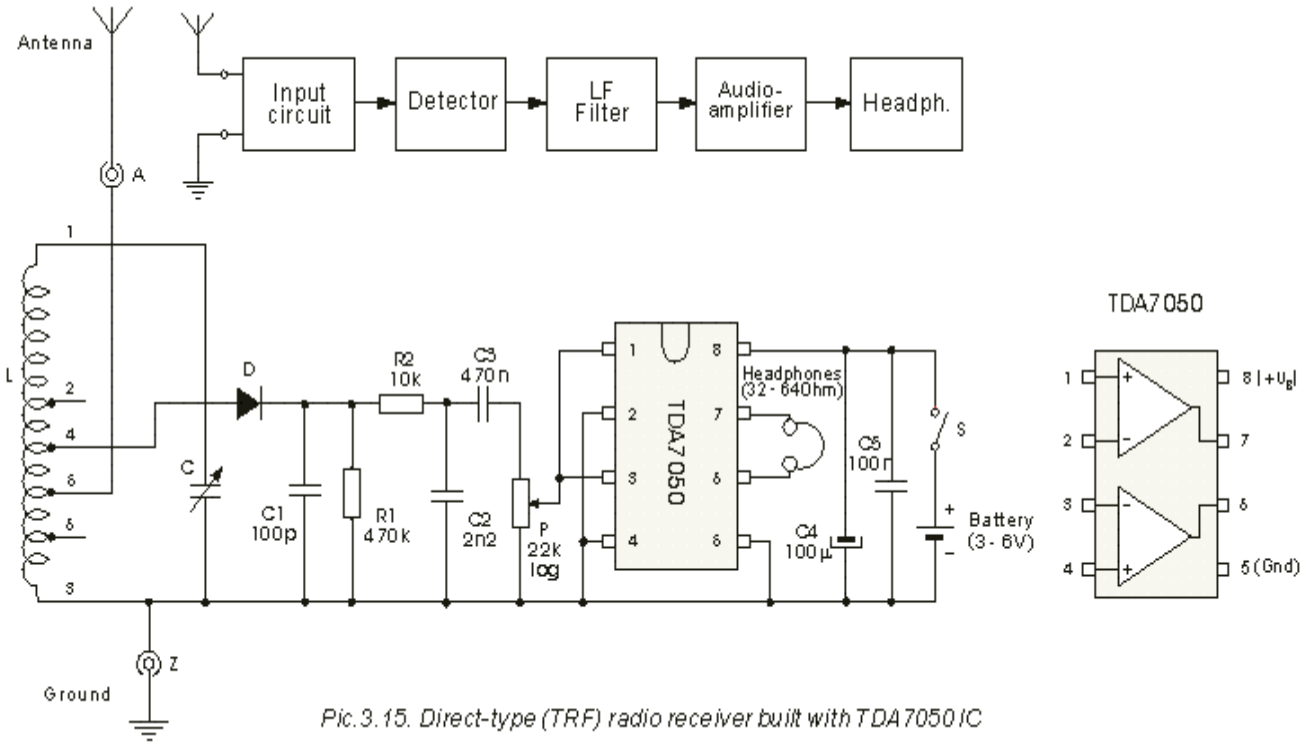

Pic.3.15. Direct-type (TRF) radio receiver built with TDA7050 IC

Let us finally add that the antenna can also be connected to point 1, over the coupling capacitor (C1 on Pic.3.1), and the detector on one of the coil legs, or you can connect both the antenna and the diode's anode on the same leg, to connect the anode to point 1, etc. You should try various combinations out, observing their influence on the reception. You should certainly re-tune the resonance of the oscillating circuit after every change, with the aid of the variable capacitor C.

The resistor R2 and capacitor C2 create an LF filter, whose role is to pass through at the next stage the LF signal being detected, preventing simultaneously the HF voltage do the same (this voltage originates from the AM signal carrier). This filter circuit affects the LF signal tone colour. If you don't like it, you should alter the capacitance C2 in order to change it.

PCB for this device is shown on Pic.3.17. The receiver can be put in a box just as on Pic.3.14. The only significant difference is that a 4.5 V battery pack must be used instead of 1.5 V battery, but there's plenty of room for it.

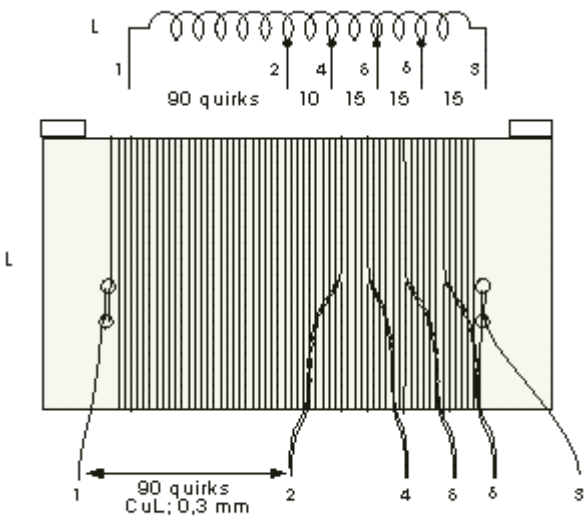

Pic.3.16. a-Multiple-leg coil for MW, for the receiver from pic.3.15

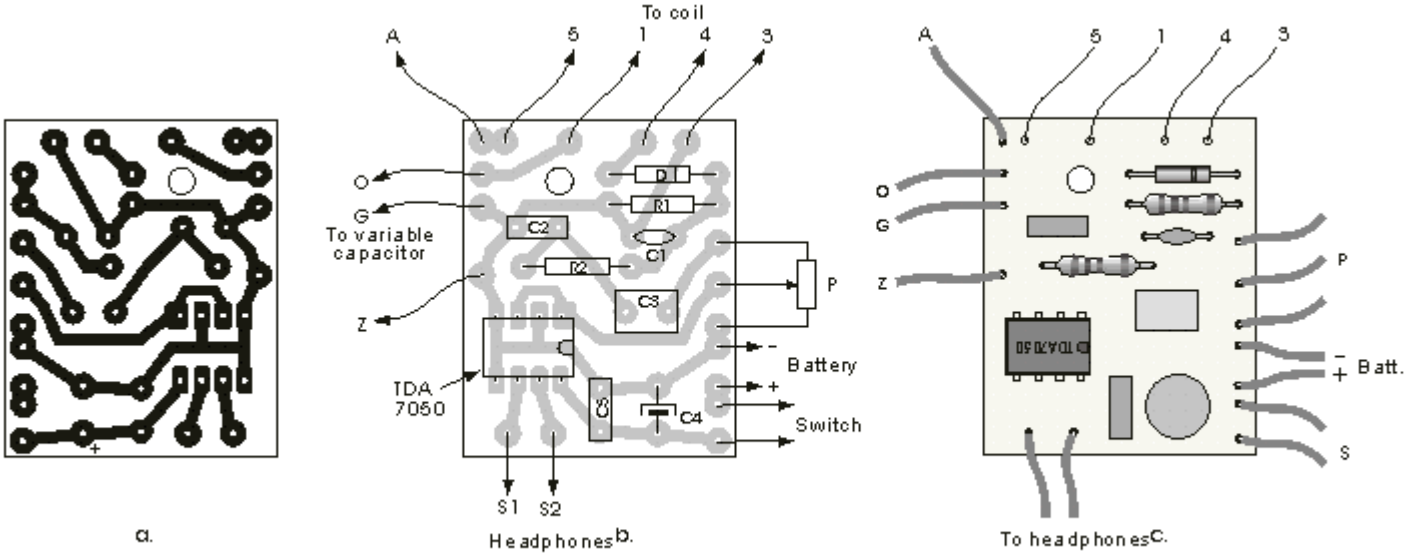

Pic.3.17. PCB for the receiver from pic.3.15: a-soldering side view, b-component side view, c-photo-view

3.4. Simple Radio Receiver with LM386 IC

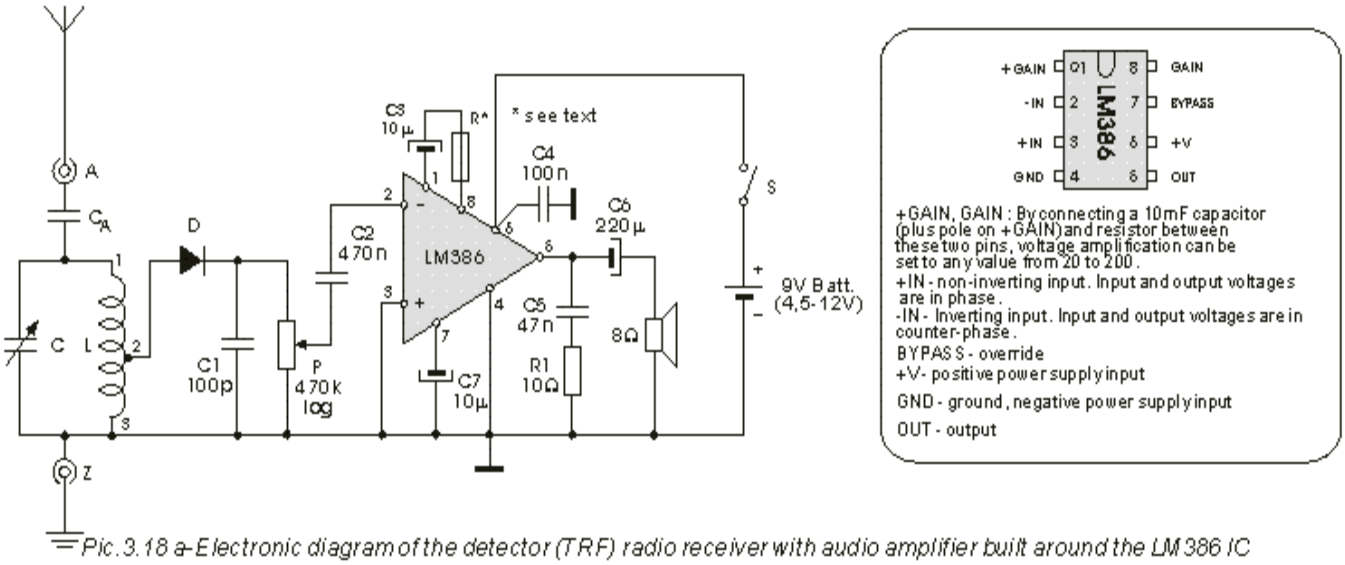

Pic.3.18 a-Electronic diagram of the detector (TRF) radio receiver with audio amplifier built around the LM386 IC

Listening the programme over the headphones has its advantages, but the true radio receiver is certainly the one that with the loudspeaker. In this project the simplest such receiver is being described, consisting of input circuit, diode detector and audio amplifier with LM386 IC, that allows the loudspeaker reproduction to be performed.

The author has firstly met with the LM386 circuit over twenty years ago, and has ever since been using it very successfully in various devices. The fact that this IC has survived at the market for such a long time is a considerable proof of its quality, however, its most significant advantage remaining extremely low price. The readers can find more information on this circuit in book 4 of PE. Purchasing this IC, one must have in mind that it is being manufactured in several versions, marked as LM386, LM386N-1, LM386N-3 and LM386N-4, that differ themselves by the supply voltage values and the output power. In case the supply voltage being no greater than 12 V, any of these can be used in this receiver.

Electronic diagram of the direct radio receiver that has a LM386 IC in its LF stage is given on Pic.3.18. The resistor in the detection circuit is the log type 470 kOhms potentiometer. The LF voltage is being led over its moving end and the coupling capacitor C2 onto the inverting input (leg No.2) of the LM386. Other, non inverting input (leg No.3) is connected to the ground. The output is on the leg No.5. On this leg the load (i.e. 8 Ohm impedance loudspeaker) is being placed, connected over the C6 capacitor to the ground. With smaller battery power supply voltages a 4 Ohm impedance loudspeaker can also be used. If there's nothing in between the legs 1 and 8, the voltage amplification of the IC is Au=20, in which case the capacitor C7 can be omitted. If, however, a 10 ìF electrolytic capacitor is connected between legs 1 and 8 (+ end on leg 1) as shown on Pic.3.18, the amplification is Au=200. Adding a resistor in line with the abovementioned capacitor, any amount of amplification between 20 and 200 can be achieved. This resistor is shown in dashed line on Pic.3.18 and is being marked with "*" sign.

The PCB and components layout for the receiver shown on Pic.3.18 are given on Pic.3.19. Miniature loudspeakers from the pocket-size radio receivers should be avoided, since their

efficiency and sound quality are poor, especially in the low frequencies area. On Pic.3.19 a 1W loudspeaker is being shown, whose membrane is 8 cm in diameter. That isn't such a bad solution, but even better would be using the loudspeaker with greater power and membrane diameter (During the testing the 3 W , 8 Ohm loudspeaker has also been used, and the sound quality was much better than with the one that is shown on the picture). As you can see, the cables connecting the loudspeaker with the PCB are firmly twisted around each other. This is a must, especially for the cables being longer than a dozen centimetres. The same has to be done with cables that connect PCB with the battery and the main switch Z.

Significantly louder reception, with bandwith being narrower in the area of the lower bound frequency, can be accomplished with the coil that has smaller inductivity and the coupling capacitor CA with greater capacitance. For example, if you are interested in radio stations that emits the signal in the MW area from 750 kHz to 1700 kHz, you could use the coil that has been previously described, by using only its' part between the legs 1 and 2, as shown on Pic.3.20. For the antenna that is about 6 m long use the CA=33 pF, and the reception is going to get better. Try increasing the CA capacitance (47 pF, 100 pF, 200 pF), the reception is going to get louder and louder, but the reception bandwidth will be getting smaller and smaller, some stations will not be heard any more, others will start to "mix" etc. it is up to you to find an optimum that suits you best. If using very short antenna, you should omit CA, and connect the antenna directly to the oscillatory circuit (at pt. 1).

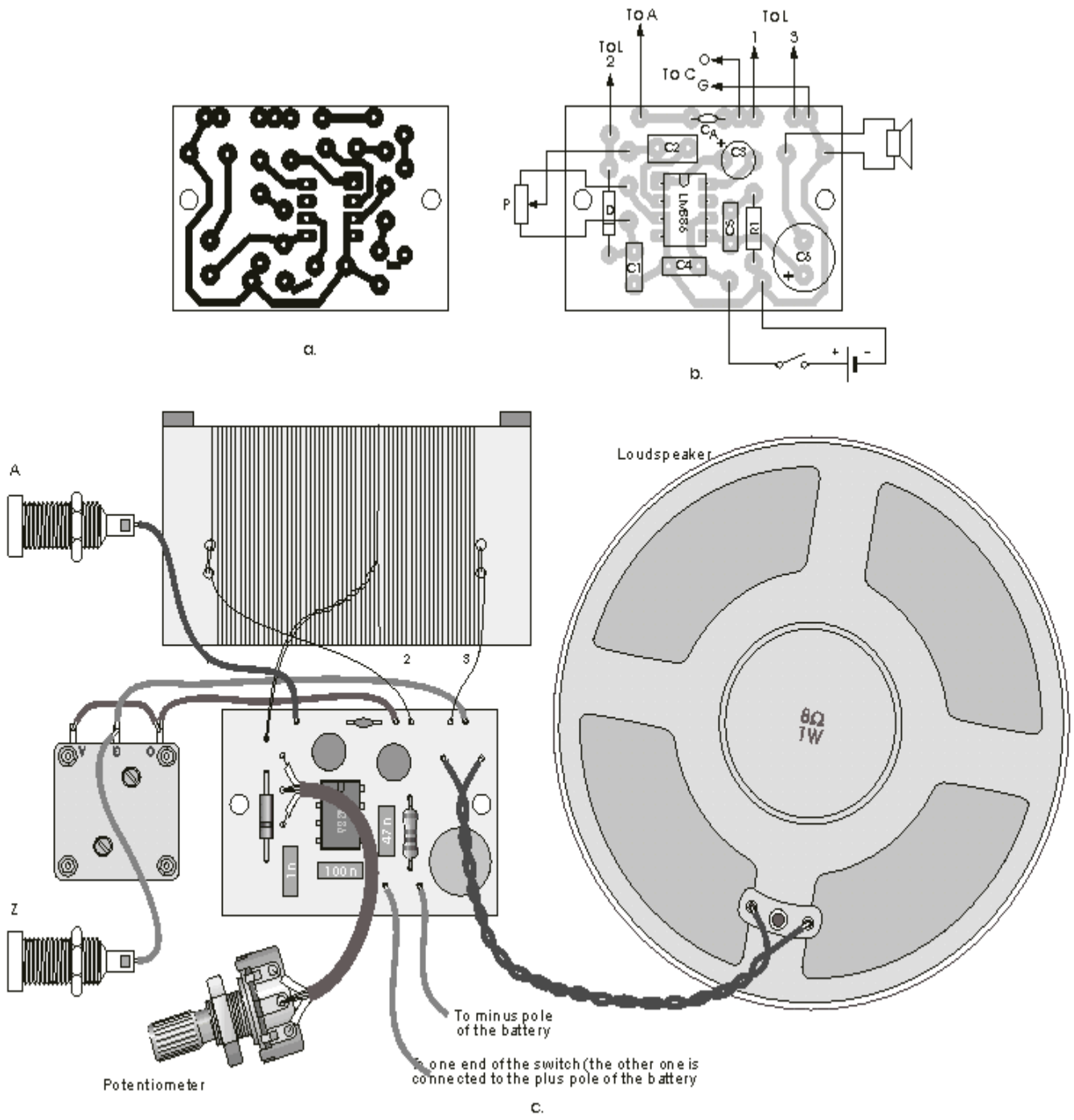

Pic.3.19. Practical realization of radio receiver from pic.3.18: a-PCB, b-component layout, c-connecting the board with other components

3.5. Radio Receiver with Increased Sensitivity Audio Amplifier

If you cannot obtain the signal reception that is loud enough with receiver from the previous project, the sensitivity of the LF part of the device must be increased. The simplest way to manage this is adding a transistor pre-amplifier, as shown on pic.3.21. Please note that all the components except C1, C and L are located on the PCB, which allows you to use the input circuit from pics.3.15 and 3.20. The receiver is supplied from the 4.5 V battery but, if you intend to use an adaptor, the supply voltage can be bigger, its maximum value being from 12 V (for the LM386) till 18 V (for the LM386-4).
The optimal value for R3 resistor (obtaining the greatest amplification, minimal distortion etc.) depends upon the kind of transistor that is being used. The easiest way to finding it is by experimenting, with a few MOhms' trimmer resistor, in the way it has already been described in chapter 3.2.

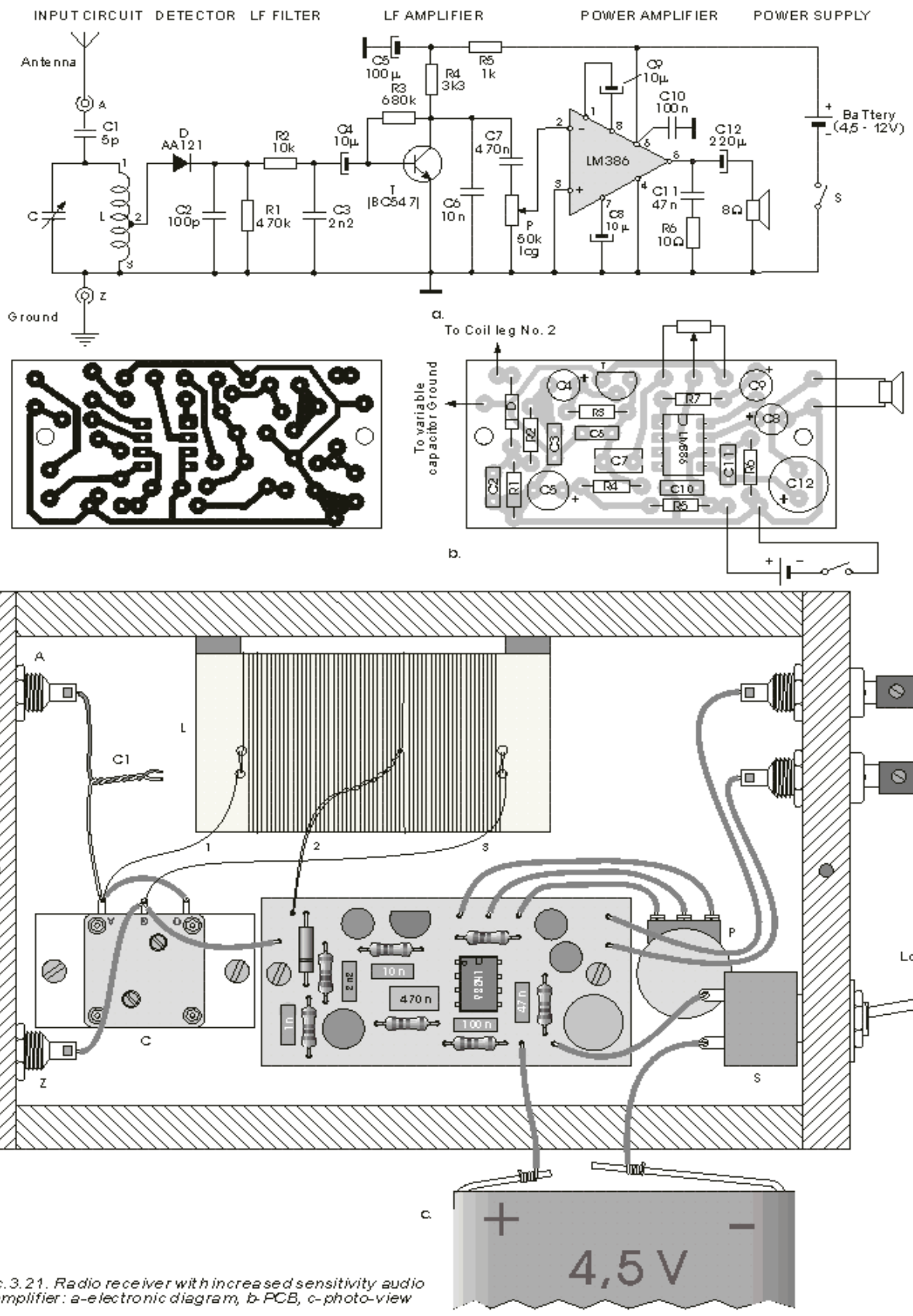

Pic. 3.21. Radio receiver with increased sensitivity audio amplifier: a-electronic diagram, b-PCB, c-photo-view

3.6. Universal Audio Amplifier

In majority of the receivers described so far, as well as in many those that will be described further, an audio amplifier is being used. This makes it useful to build an universal amplifier that would be used during testing of all receivers. That can be the circuit from pic.3.21 (from C4 inclusive to the right), but it can be something else, too, e.g. the one from the pic.3.22. Two IC's are used in it: operational amplifier TLO71 as the pre-amplifier, and LM386 as the power amplifier. The TLO741 is exactly the same as the more famous 741, the only difference laying in fact that TLO71 has the FET on its input, and 741 - the bipolar transistor. Since inverting input is being used in the operational amplifier, its voltage amplification is given by Au=RP/R1, where RP stands for the potentiometer resistance from the sliding contact to its left end. When the slider is at its rightmost position, it is then RP=470 kOhms, yielding Au=470, and when it's at its leftmost position the RP=0, therefore Au=0. As you can see, moving the slider changes the amplification from 0 to 470. That's what theory says, the practice is, of course, somewhat different. When capacitors are being connected between the input and ground, maximum amplification gets lower than 470 but is still more than enough for our needs.

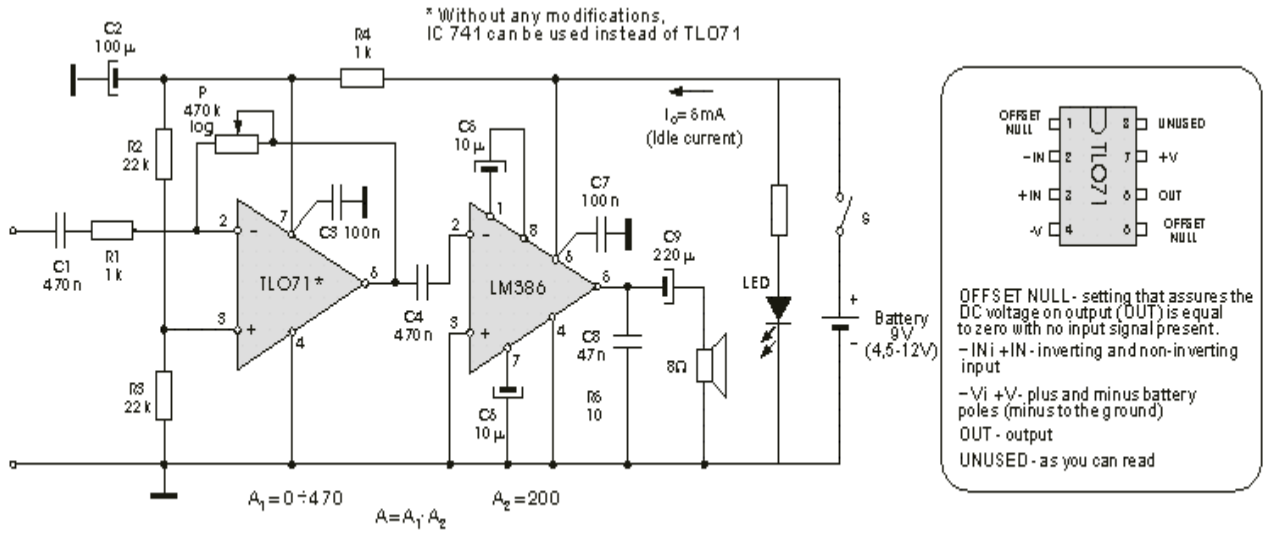

Pic.3.22. Audio amplifier built with TLO71 and LM386

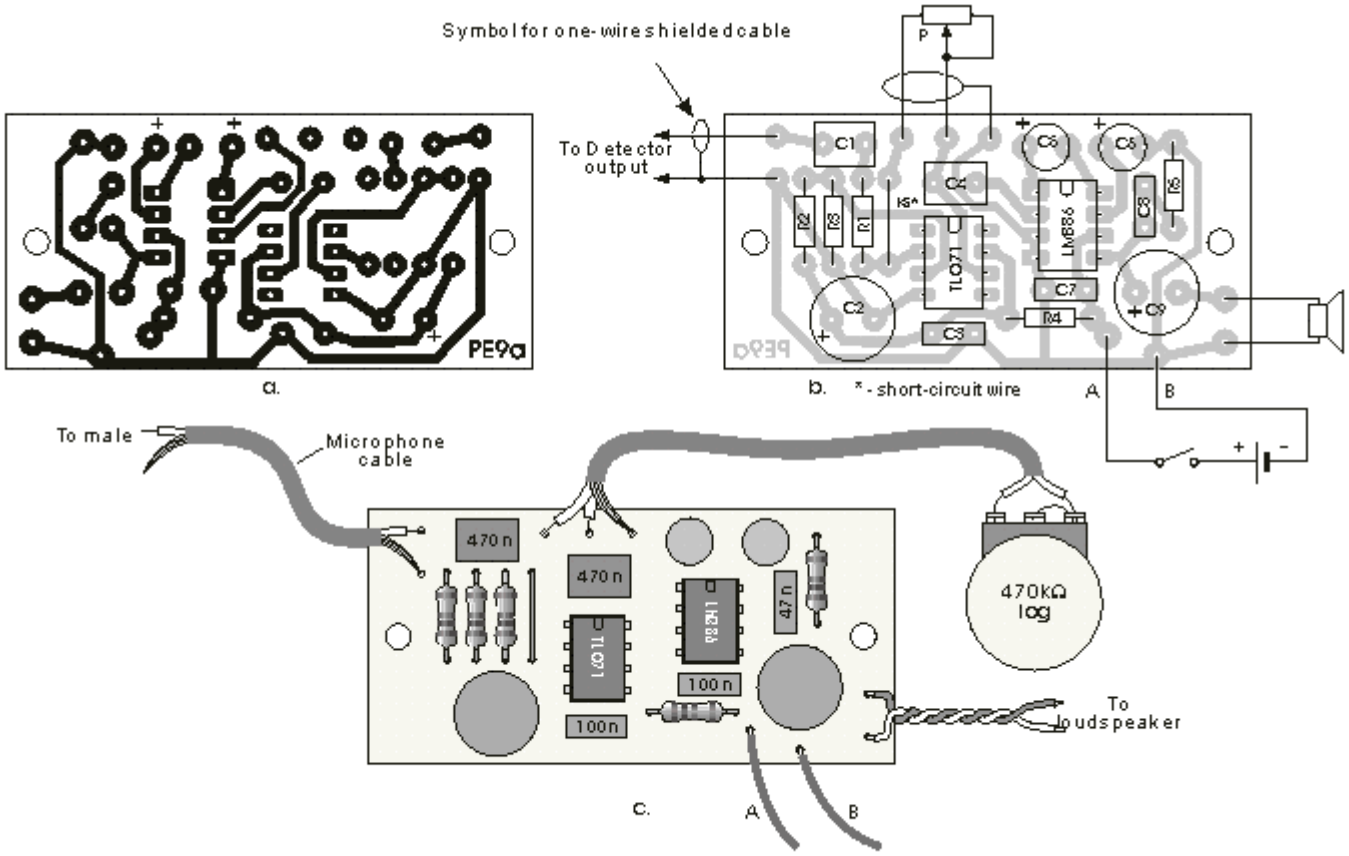

Pic.3.23. PCB for the amplifier from pic.3.22: a-print side view, b-component side view, c-"photographic" view

* All the receivers that have been described so far, as well as all those to come, can be tested with this universal amplifier. That is done by taking the signal from the Detector output (through two wires as short as possible or through the microphone cable that can be significantly longer) to the amplifier input (between left end of C1 and Ground). If the antenna, input circuit (and other stages, if exist) are OK, you will be able to hear the tuned station program from the loudspeaker. The sound volume can be adjusted by moving the slider of the potentiometer P. PCB and component layout are given on pic.3.23.

* KS marks the short-circuit wire. It's a piece of wire which ends are taken through the holes on the plate and soldered. It can be omitted, but then the left end of potentiometer is to be soldered in such a way to be connected to the bottom end of R1.

* To connect the potentiometer with the PCB, as well as the male, a shielded cable should be used. The shield (outside conductor) is connected to the Ground. If cables are shorter than app. 10 cm, the ordinary wires can be used instead.

* The amplifier, the loudspeaker and the battery (or adapter) are put in the common box, on whose front plate the potentiometer, the switch and some simple plug (the chinch will do) are mounted. If the device is powered from the adapter, it is useful to also mount a LED. With these parts you have made yourself the so-called "active loudspeaker", which is a

very useful gadget for every electronics lover.

* Just before you start mounting and soldering the components, clean well the PCB copper conductors with a piece of wet sponge dipped in some cleaning powder. Components should be mounted and soldered in the following order: short-circuits, resistors, IC's, capacitors (all except C4), connecting wires and microphone cables (if used). The last component to be mounted is the C4 capacitor, but first you have to check whether the amplifier operates correctly.

Connect the loudspeaker, and the wire marked as "B" on pic.3.23-c connect to the minus battery pole. The other end of the wire marked as "A" should be connected to one probe of the multimeter, which is to be set to measure DC current. Contact the plus battery pole with second instrument probe, and it will measure the idle current of the amplifier, which should be app. 5 mA. If this is OK, touch the pin No.2 of the LM386 with finger, and if everything is fine you will hear the 50 Hz hum from the loudspeaker. The power amplifier is OK. You can now solder C4. Touch the left end of the wire that is connected to the C1 with your finger, the hum should be heard again from the loudspeaker, its loudness depending upon the position of the slider of the potentiometer P. (If you don't possess an instrument, connect the battery on the wires "A" and "B" and do the touching described. If you hear the hum, the amplifier is OK).
If the Idle current is zero or is significantly bigger than 5 mA, something is wrong. If it's zero, check out whether you have connected your instrument properly and whether it is functioning. Remove the instrument and connect the battery directly to the wires A and B. Touch the pin No.2 of LM386 with your finger, if you hear the hum - your instrument is malfunctioning. However, if the instrument is OK, you should check the DC voltages. Set your multimeter to measure DC voltages, connect one probe (the one marked with the ground sign) to the amplifier ground (minus battery pole) and with second probe touch the plus battery pole first, and then pin No.6 of LM386. These two voltages should be equal to the battery (supply) voltage. Contact then pin No.7 of the TLO71. This voltage should be slightly smaller than the supply voltage. Voltages at pin No.5 of LM386 and No.7 of the TLO71 should be app. equal to the one half of the supply (battery) voltage.
Try to locate the malfunction based on your measurements. Check out if there are some discontinued copper lines on the print, or if two adjacent lines are connected (by themselves or by a small piece of tin that you dropped from the iron during soldering), whether all junctions are the way they should be, if you happened to mount some electrolytic capacitors or IC's upside-down, etc.
When you make sure that everything is fine, un-solder the potentiometer and the loudspeaker and put them on the front box panel. Also mount the plug and the switch, the LED (if used) etc. Tighten the plate with two small wood screws to the side pane, placing the LM386 on top (above the TLO71). Two distant-rings are to be mounted between the plate and the wood, making the distance between them a few (say, 5) mm. (These rings can be cut from some small plastic pipe). The screws are first to be put through the plate holes, then the rings and then screwed in the panel. After all this you can connect the loudspeaker, the switch, the battery, etc.

3.7. Receiver with the HF Amplifier

In HF amplifier the signal coming from the radio station is being amplified in its original form. In our case, this means that AM signal is led at input of the HF amplifier, and on its output the same shaped signal is obtained, only with bigger amplitude. This device got its name because it is used to amplify HF signals, although more precise term for it is the Selective Voltage Amplifier (that's how it is called in professional books).
Electrical diagram of a direct receiver consisting of HF amplifier, diode detector and LF (audio) amplifier is presented on Pic.3.24. This receiver does not have a selective input circuit. It would be better that way, the selectivity of the receiver would be better, but "technical reasons" made us not to include it: the double variable capacitor (like the one in the first issue of PE) i.e. the one consisting of two equal variable capacitors connected onto the common shaft, is very hard to find these days. The active element of the HF amplifier from Pic.3.24 is the transistor BC557 that operates in the common base junction. The station signal that is being amplified is led onto the emitter (i.e. between the emitter and ground), and the amplified signal is taken from the collector (i.e. between it and ground). Working principle is similar to the one of the input circuit explained with the Pic. 3.1-b. To refresh your memory: we have been considering an example where four signals of equal amplitudes but different frequencies, were present in the antenna: fs1, fs2, fs3 and fs4. They were causing four different currents to flow through the LC oscillatory circuit: Is1, Is2, Is3, and Is4. All these currents were creating some voltage on the ends of the LC circuit, but the one caused by the current Is2 was significantly (about 20 times) bigger, due to the oscillatory circuit being set to its frequency. The parallel oscillatory circuit that is on Pic.3.24 as the collector .....is exactly the same as the the one on pic.3.1.

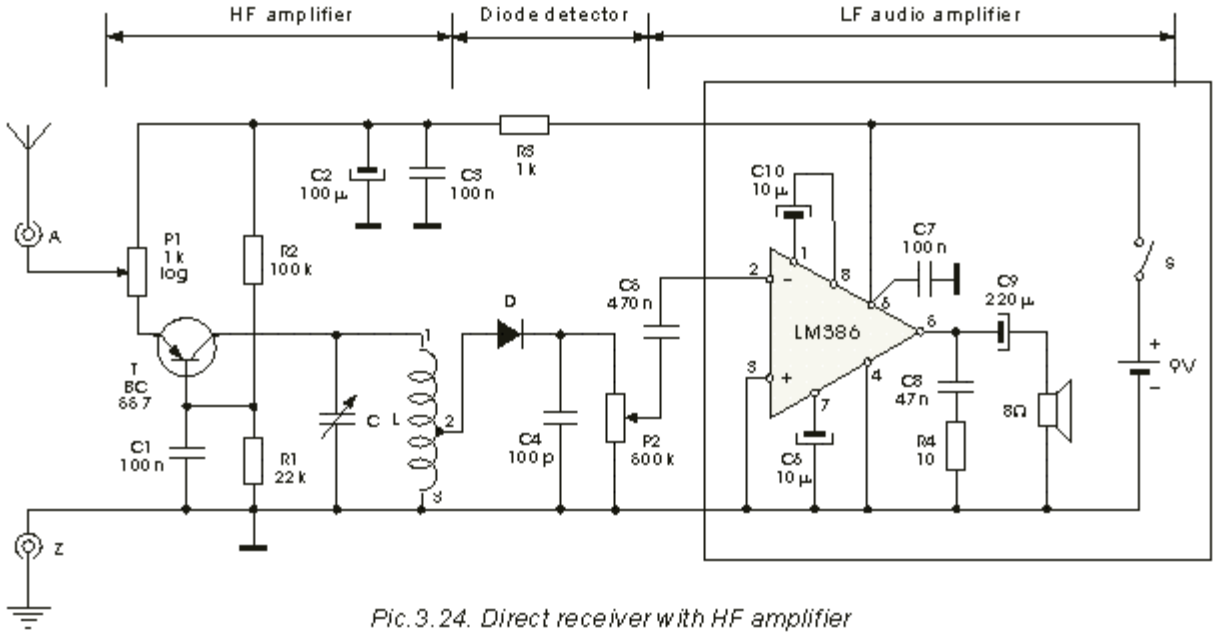

Pic.3.24. Direct receiver with HF amplifier

It also has the same role, therefore HF amplifier from pic.3.24 having the same selectivity as the input circuit in all the receivers described so far, with addition of extra amplification. This is being accomplished in the following manner: under the simultaneous load of 4 voltages that are coming to emitter from the antenna, their frequencies being fS1, fS2, fS3 and fS4, four currents flow simultaneously through the transistor. They share the same circuit: from positive battery pole, through P1, then transistor (in direction emitter-collector), over the LC circuit to the minus battery pole. All of them therefore flow

simultaneously through the LC circuit as well. The resonance frequency of this circuit is set (by C) to be equal to the frequency of one of the currents and it acts upon it as a huge resistor (200 kOhms, as on pic.3.2-b). According to Ohm's Law, this current creates voltage on the oscillatory circuit. For other 3 currents the circuit acts as a resistor with much smaller resistance (less than 20 kOhms, as on pic.3.2-b) and they create much smaller voltage in the circuitry (10x smaller, as in our example). The important difference in operation of circuits from pics. 3.1 and 3.24 is that all currents are much smaller in the latter case (because of the amplifying effect of transistor), therefore the voltages on the LC circuit being much bigger.

* With P1 potentiometer the signal amplitude from antenna to the input of HF amplifier is regulated. If, on your device, you find the slider for all stations to be in rightmost position, put a resistor instead of potentiometer, and connect the antenna with emitter.

* As with all input circuits, when connecting the capacitor C care should be taken to connect the rotor to the ground (G-point on pic.3.7-a).

* The R3 resistor comprises with C2 and C3 capacitors the LF filter which prevents the feedback (that would lead to unstable operation) between the LF circuitry and HF amplifier. If the feedback still occurs, the R3 resistance should be increased.

* In LF part of the receiver the audio amplifier with LM386 IC is used. That is by no means necessary, any audio receiver will do.

* There is also a better variation of HF amplifier, with increased selectivity. Its electronic diagram is shown on pic.3.29-b.

3.8. The Audion - Direct Receiver with Drain Detector

During the experiments with this receiver, the Author had decided to name this chapter "The BEST Direct (TRF) Receiver", which he gave up on later, having in mind the old Latin saying: DE GUSTIBUS NON DISPUTANDUM EST (Tastes should not be discussed). It is, however, very hard to make something better with so little components. Anyway, the Author leaves to the readers of this chapter to name their own Best Receiver candidates, picking one of these described in this book, having in mind their own criteria for concepts of the beautiful, simple, cheap and useful. You can mail your voices to me on the address: ETŠ "Nikola Tesla" (Praktièna ELEKTRONIKA), Narodnog Fronta 31, Beograd, or by E-mail: tesla@drenik.net, Subject: Pe9.
On Pic.3.25 you can see the electrical diagram of this, however, anyway, nevertheless... Device. The signal of the tuned-in station is lead to the Gate of the BF256 transistor. Please notify that the signal is being taken from the upper end of the coil, and not from its leg, as it has been in previous projects. This is possible due to big input resistance of the FET (bigger than MegaOhm), compared to the one of the bipolar transistor (couple of kiloOhms). Why is this so important? Pic.3.26 shows the voltage - frequency curve of the parallel oscillatory circuit that is made of the coil L and capacitor C, while being tuned to the station whose frequency is fs2. In case the circuit is not loaded (the next stage of the device is not connected to it), this curve is shown in solid line and, as previously explained, the voltage

(measured at the ends of the osc. circuit) of the station with carrier frequency fs2 is significantly bigger than the voltages of the stations with frequencies fs1 and fs3, although all of them have the same size in the antenna. However, when the next stage, containing the bipolar transistor as, for example, the one on the Pic.3.12, is connected, is small input resistance is damping the circuit and the bandpass curve has

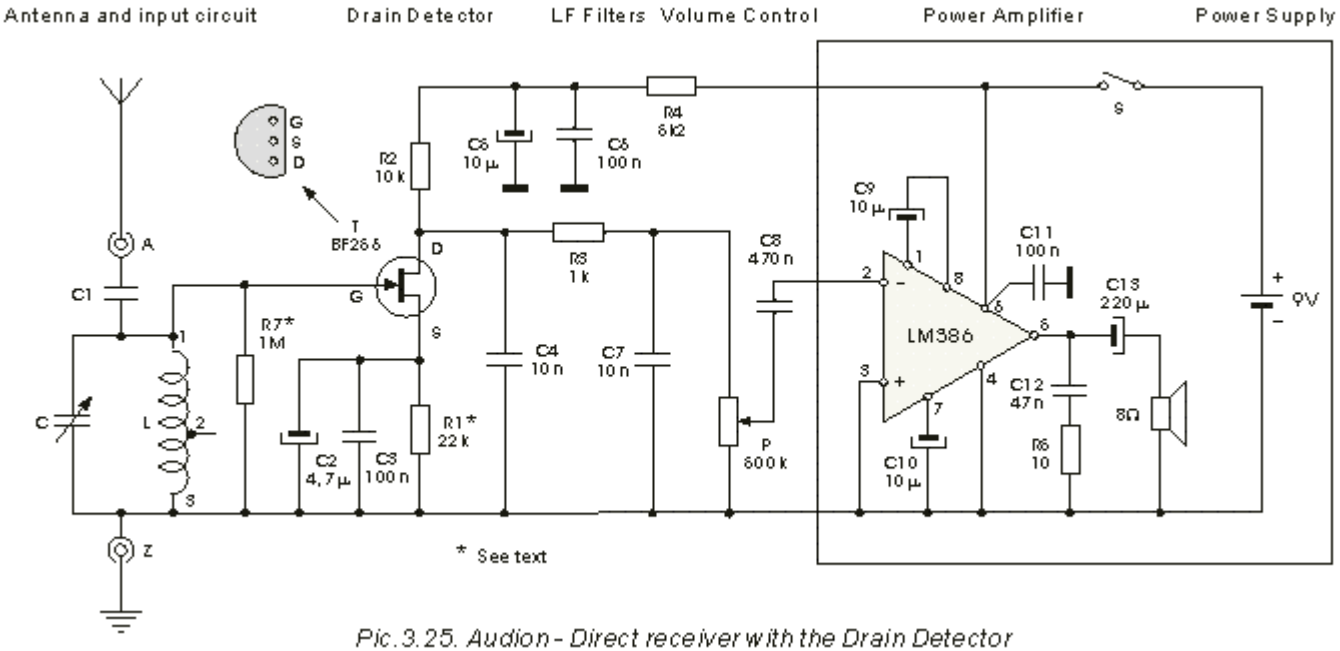

Pic.3.25. Audion - Direct receiver with the Drain Detector

he shape shown with the dashed line, marked as Q2.When the FET is connected to the oscillatory circuit (as on Pic.3.25) there is practically no damping, and the bandpass curve remains as shown in solid line. This is, clearly, much better, since all the other station voltages are more suppressed (reduced), comparing to the voltage of the tuned station. Considering the curve marked as Q3, we will be discussing it more in context with the Pic.3.29-a.

It has been earlier noticed that the most important characteristic of a parallel oscillatory circuit being used in a receiver is its resonance frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Its second most important feature is the Goodness Factor of the receiver, which is most often being marked with the letter Q, and is therefore also known as the Q-Factor. A loaded circuit has smaller Q-factor than the non-loaded one, as shown on Pic.3.26, consequently being Q1>Q2.For example, the goodness factor of the circuit from Pic.3.6 is Q=95. Since it is not loaded, the oscillatory circuit on Pic.3.25 has smaller (narrower) bandpass and therefore better selectivity. Additionally, since the whole signal from the circuit is led in the next stage (instead partly, when getting the signal from the coil's leg), the receiver has got bigger sensitivity (it's capable of receiving weaker signals).

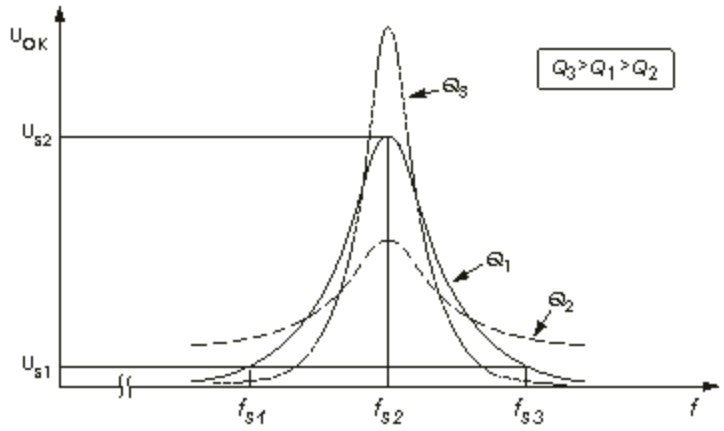

Pic. 3. 27. Bandpass curves of a parallel LC circuit

The FET, together with R1, R2, C2, C3 and C4 forms the so-called Drain Detector (its analogous circuit with bipolar transistors is the Collector Detector, and with the electronic tubes - the Anode Detector. The popular name for the anode detector was - the Audion). The LF signal being detected is received on the drain (D). It has the same shape as the LF signal obtained on the output of the diode detector, but is significantly bigger than it, since the drain detector also amplifies the signal. The LF signal is then led on the volume regulation potentiometer, over the filter that is used to suppress the remains of the HF signal carrier (R3 and C7). After that it goes to the audio - receiver.

* The R7 resistor can be omitted. If you do that you should switch off the battery (over the switch S) every time you are removing the coil from the circuitry (during experiments). If you fail to do so, the oscillation in the circuitry will occur, and loud hum will be heard from the loudspeaker.

* Since FETs have very different characteristics compared to each other, it might be necessary to change the value of R1 resistor. The simplest way to do it is to place a 50 kOhm variable resistor instead, tune the receiver to some radio station and then achieve the best possible reception by moving the slider. The resistor is then removed from the circuit, its resistance measured, and the (fixed value) resistor of similar resistivity soldered in the circuit. The same goes for R2.

* The filter (R3 and C7) used to suppress the remains of the signal carrier affects the colour of the tone of the LF signal. If you wish more bass tones you should increase the C7 capacitance. Similarly, if you wish more high pitch tones, C7 should then be decreased.

* The receiver will not start operating the very same moment the switch S is engaged. That is due to a fact that the FET doesn't work under small supply voltages. Its supply voltage is the one on the C5 capacitor and the detector won't work until C5 doesn't fill. This is being achieved through R4. Since this resistance is quite big and so is the capacitance of C5, the filling time is rather long. If, however, you just need the receiver that will have a "late

start", you should be increasing the capacitance and the resistance until reaching the desired delay time.

* This receiver works well also with the ferrite antenna. On Pic.3.27-a you can see the symbol for it, and on Pic.3.27-b its shape and dimensions are given. The simplest thing to do isusing the antenna from an old pocket radio, probably the same one you took the variable capacitor from. During the dismount, you should by no means cut the coil ends or shorten them later. Instead, you should carefully un-solder and unhook them from the PCB (the coil is made of the "litz wire", consisting of a dozen very thin lacquer - isolated copper wires, wrapped together with the thread. If you cut this cable, you will find very hard to re-solder it, since it is difficult to remove the lacquer from all the wires without damaging (some of) them). Such an antenna, as seen on picture, has four ends. We shall be using the coil L, therefore only significant ends for us are those marked as 1 and 2. The end No.1 is easy to identify, it is the single one, which is not the case with the end No.2. To detect it in the group of three you will need an ohm-meter of some other conductivity tester, which you should connect to the end No.1, and then search for No.2 by touching those 3 remaining ends.

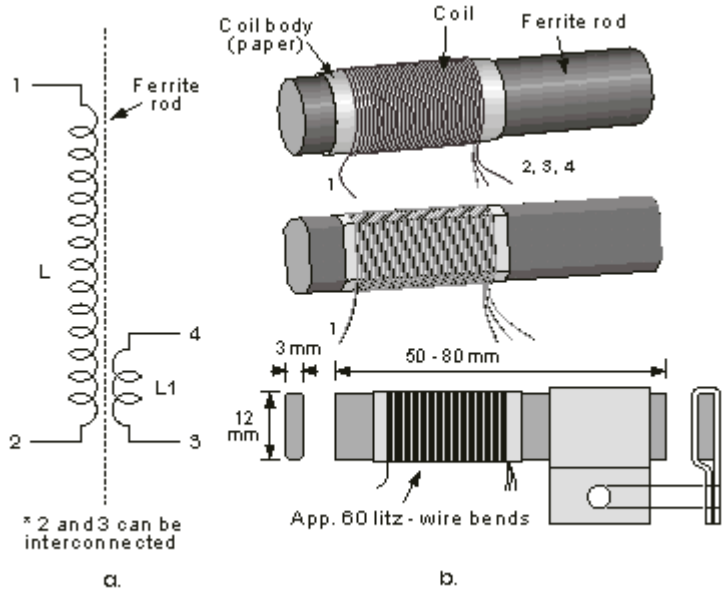

Pic.3.27. The Ferrite Antenna: a - symbol, b- appearance

In the lower right corner of Pic.3.27-b you can see means of attachment of such an antenna to the PCB. The envelope being shown is made of carton. It is wrapped around the ferrite core, and then glued to it. The screw is mounted through the hole and the antenna is then attached to the PCB. Instead of screw and nut, the antenna can also be glued onto the board. If the ferrite rod is longer than 6 cm, the envelopes should be mounted on both rod ends.

* C6 is the block-type capacitor that (together with R4) prevents the receiver from working in an unstable regime. If such a thing occurs, its capacitance should be increased. If that doesn't help either, or if the detector is working improperly, you should try increasing R1

and R4.

* With this receiver the reception of the SW band stations can also be achieved. All that is to be done is making a new coil. For these purposes we utilized a piece of carton cylinder already used for building our coil L (described in previous projects). On it, we bended tightly 6 bends of 0.6 mm copper wire. The wire diameter isn't critical, practically any can be used. This coil is shown on Pic.3.28-a, together with attachment plates. This coil should replace the coil L, as seen on Pic.3.25. With 6 m long antenna and the antenna capacitor C1=12 pF, the reception bandwidth should be app. from fd=7 MHz till fg=10 MHz. This can be changed by changing the number of bends on the coil and /or C1 capacitance. I such a way you can "take a peek" what's happening in the civil area, what are the radio - amateurs doing, some professional links etc. You can even make a multiple - legged coil, such as on Pic.3.28-b (number of bends isn't critical, it may be useful trying out some other values, too), and to be able to choose SW1, SW2, SW3 with a selector switch. Please do have in mind that the reception quality of the SW stations isn't the same during the day. It is good in the afternoon hours, during the night and in the morning, the weakest reception quality is around noon. But, that isn't all. It also depends on the season, solar activity etc. Anyway, you should see it for yourself.
There's also a possibility of receiving professional stations working on considerably higher frequencies. The coil, which is then also an antenna, is given on Pic.3.28-c. It is made of stronger, thicker wire or an metal band, being circularly shaped and then attached to the wooden plate with two screws. With same screws cables connecting the antenna with the variable capacitor C are affixed. The antenna diameter varies from couple of cm till few dozens cm, the real value being found by experiments. It is a directive antenna, which means that the amount of voltage being induced in it depends also upon the direction where the waves are coming from. This gives you the opportunity of achieving the optimum reception of the desired station and simultaneous suppression of others by rotating the antenna. Similar antennas are used in radio - location (searching for whereabouts of an unknown radio transmitter).

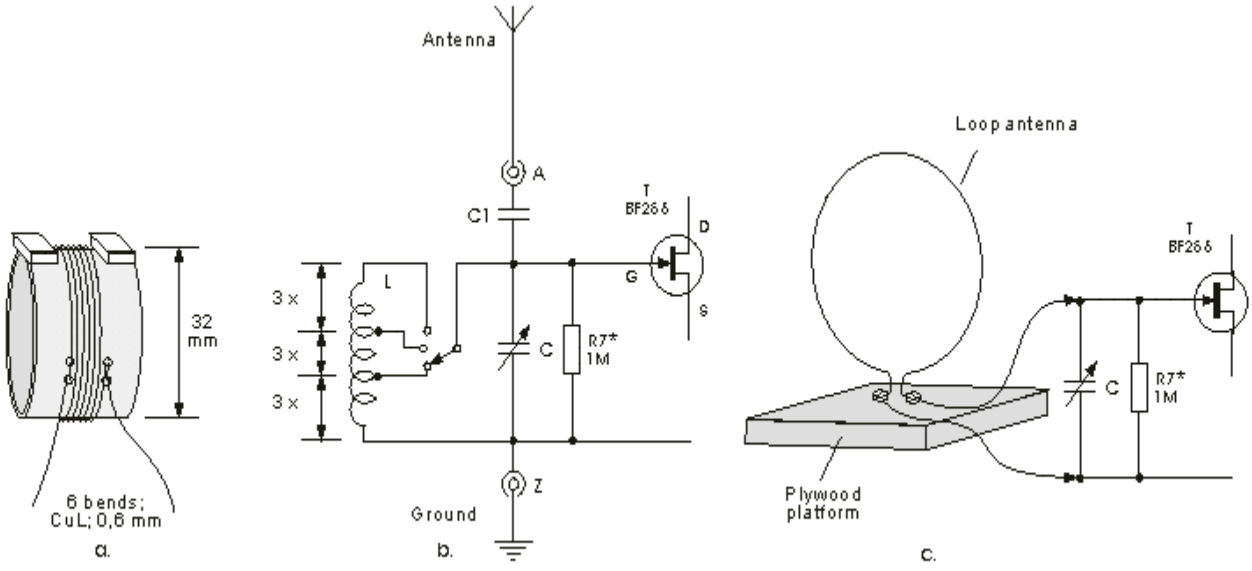

Pic.3.28 a - SW band coil; b- Input circuit with 3 SW bands; c - Coil for VHF & UHF bands

3.9-a Reaction - type Receiver

In the previous project, in the context of Pic.3.26, we have seen how important it its for an oscillatory circuit of the receiver to have as big Q- factor as possible. The bigger it is, the receiver gets more selective, i.e. capable to separate the signal of the station the oscillatory circuit is tuned at from the multitude of signals in the reception antenna, at the same time suppressing other signals. There is yet another important thing to be emphasized: the voltage in the oscillatory circuit is Q times bigger than the voltage that is being led to it from the antenna. If Q=95 and the voltage in the antenna is, say, 1 mV, the voltage exiting the circuit is then 95 mV. It is then clear that the Q- factor should be as big as possible. Some improvements can be made by using the silver - coated wire instead of the plain copper one, of using ceramic material for the coil body instead of carton etc. These improvements, however, are not significant. The solution for this was, eventually, found: It was the process known as the "regeneration", many scientists had been working on it simultaneously, A. Meissner being one of the more important ones. The complete process was patented in 1913 by the American radio - pioneer Edwin H. Armstrong, two months before his 23rd. Birthday. He discovered that the Q- factor could be extremely increased (even by couple of tens of times), if the signal from the inlet circuit would be amplified with the triode and then the small part of this amplified voltage adequately returned into the inlet circuit. The radio station signal could therefore be amplified to much greater extent, and the reception of very far stations became possible, the thing that wasn't even thought of, until then. From an average listener's point of view, the main mishap of this regenerative, or, here better known as reactive, receiver was the fact that optimal tuning required somewhat more skill and basic knowledge of the working principles. Much easier tuning was that of the superheterodyne receiver (invented also by Armstrong), which was reduced to turning only one reel, and it contributed, to a great extent, to its final victory. The battle between the two concepts lasted for almost half a century, but the reactive receiver did not retreat itself completely. Even nowadays an electrical diagram of some younger and more modern brother, or rather a grand-grandson of once famous reactive receiver, appears in some popular electronics magazine. One such diagram, where the triode is replaced by a MOSFET, is given on Pic.3.29-a.

Radio engineering enthusiasts know that, as soon as the signal from the input circuit is led on the gate (G1) and that the source (S) isn't connected to the ground but to the coil leg (point No.3), they have a diagram of the Hartley's oscillator in front of them and that connecting the source to the leg No.3, the so-called positive feedback (positive reaction)is achieved. But, the abovementioned labourers also know that the oscillator shall oscillate only if the leg No.3 is made on the right spot, and the P1, TP1 and TP2 variable resistors are set on the right values. Let us imagine that everything is OK: the coil leg is right where it should be, the slider of the variable resistor P1 is in the middle of the range, and trimmers TP1 and TP2 are set in such a manner that the oscillator is really oscillating. It behaves then as the generator, that creates the sinusoidally - shaped AC voltage, whose amplitude is a couple of volts. Theoretically speaking, the Q- factor is now infinitely big . All this shall produce a very strong whistling sound in the loudspeaker. The slider of P1 should now be carefully moved downwards. The transistor amplification is hereby reduced and the oscillating stops. The Q-factor is being reduced too, it is no longer infinite but is still very big. The receiver is now tuned on the desired station. If the station signal is weak, everything should be OK and the programme should be heard. The reception can then be made better, by carefully operating with P1's slider. If the whistling emerges again, the slider should be moved backwards until it stops. If we come upon some stronger station the whistling will start immediately, in which case the slider P2 should be carefully moved downwards until it stops and the station programme is heard, loud and clear. As one may notice, every time this receiver is being attuned to optimal receipt the whistling is being heard for a short while. This is why it has been named "The Whistler", here in Yugoslavia .

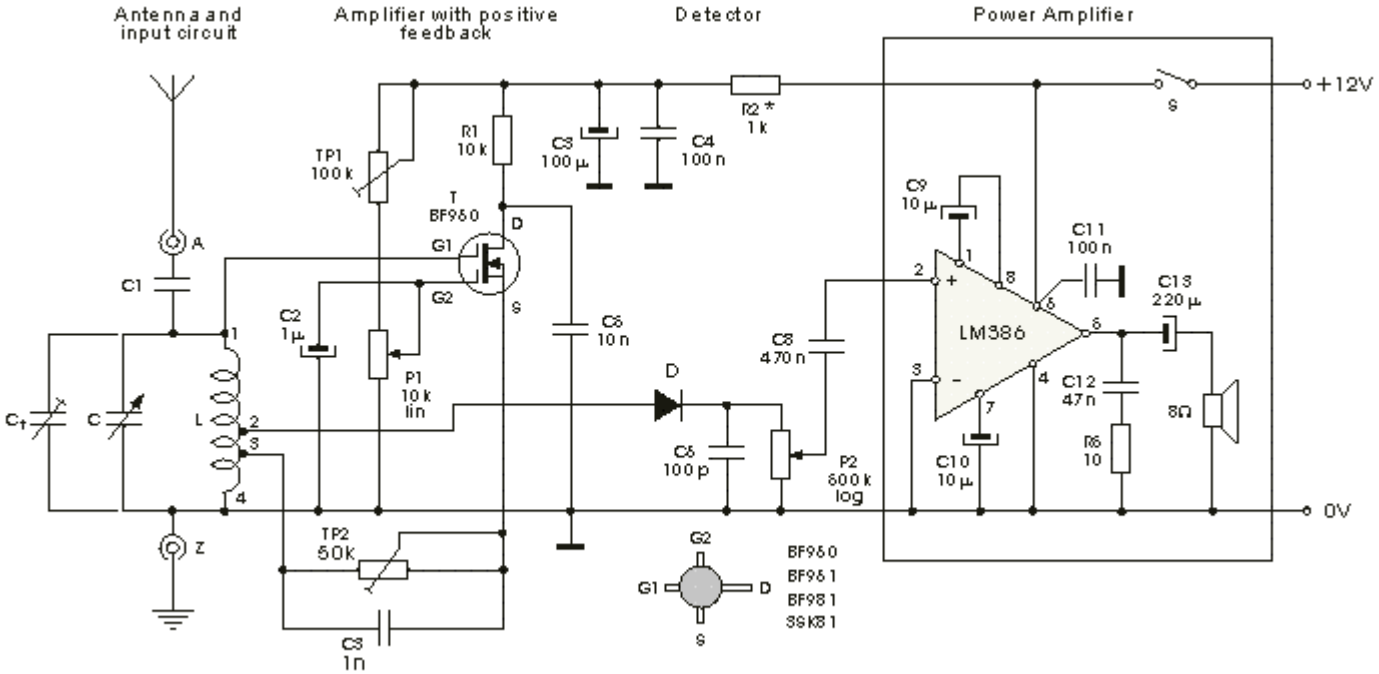

Pic.3.29-a. Reactive Receiver with double-gate MOSFET.

The amount of the reaction (feedback, regeneration) is controlled with P1 potentiometer, which sets the magnitude of DC voltage on the gate G2 of the MOSFET, changing therewith the amount of its amplification. The range of this control is being determined with TP1 trimmer, G2 is connected to the AC signal's ground over C2 simultaneously eliminating the noise coming from the potentiometer, and the FET is de-coupled from the supply line (and therefore all other stages of the device by the LF filter made of C3, C4 and R2.

The receiver is being tuned as follows: Put the slider of P2 in mid position and later, after tuning, you can set the volume as you wish. Set the P2 at minimum resistance (slider full down), and P2 on maximum (slider full right), connect the antenna and close the switch S. Start moving the slider P1 upwards, the reaction gets stronger and stronger, and you can hear the typical hiss or some radio programme from the loudspeaker. Move the variable capacitor C and tune the receiver to various stations. If the whistling starts, put the slider P1 back down.

Set the capacitor is minimum capacitance position (see Pic.3.7), put the slider P1 fully upwards and start carefully increasing the resistance TP2 until the whistling stops. Measure the TP2 and insert in the device the ordinary resistor of similar resistance. The TP1 trimmer should be set in such a way to have as big resistance as possible, keeping at the same time the reaction effective throughout the entire reception bandwidth of the receiver.

* During every station change (with C), a maximum amount of reaction should be set (with P1). Move the slider upwards until the oscillating occurs, then put it back down a little.
* While receiving very strong signal (local transmitter), an overload can occur. If that happens, you should insert a 1 MOhm potentiometer between the antenna (A) and the upper end of C1 capacitor; it should be connected as the rheostat (like TP1 and TP2), then you can set the optimum reception with slider.
* SW - band stations can also be received with this device, with a different coil. In this case it would be very useful to add a trimmer capacitor in parallel to the variable capacitor, being marked as Ct on Pic.3.29-a. With it the so-called "range yielding" can be done (the initial, approximate setting is done with C, and fine tuning between closely placed stations with Ct). It should be mounted on the front panel, as close to C as possible. Another type of capacitor can be used as Ct, see more about it in the Appendix. The SSB (Single Side Band) technique transmissions are also being placed in the SW band area. These signals cannot be received with the earlier described receivers, but they can with this one. In that case the slider P1 should be moved a bit more upwards, so that oscillating can occur. The reception becomes clear, before that it was unrecognizable.

* If the local radio station still corrupts the reception of other stations, you should insert the circuit that will suppress its signal. You can read more about it also in the Appendix.

3.9-b Direct SW Receiver for AM, AM-SSB & CW Signals

SSB stands for Single Side Band, which signifies the amplitude - modulated signal which gets its signal carrier and one sideband suppressed in the transmitter. Carrier suppressing gives huge savings in transmission power (the power necessary to accomplish the desired reach of the signal is significantly smaller than in the conventional - type transmitters), and cancellation of one sideband makes the signal have its spectrum two times narrower, allowing twice as many transmitters as usual to be placed into the same bandwidth.
CW is for Continuous Wave, which determines the radio link where the Morse Code is being transmitted by cutting the oscillator work in the transmitter.
SSB and CW signals are impossible to accomplish with the receivers that use the ordinary diode - type detector (earlier described AM receivers). The receipt can be done only by bringing another signal into the detector, the HF signal from the oscillator, known as the BFO (Beat Frequency Oscillator). Simpler solutions, however, do exist. These are the reaction - type receivers, i.e. receivers with positive feedback.

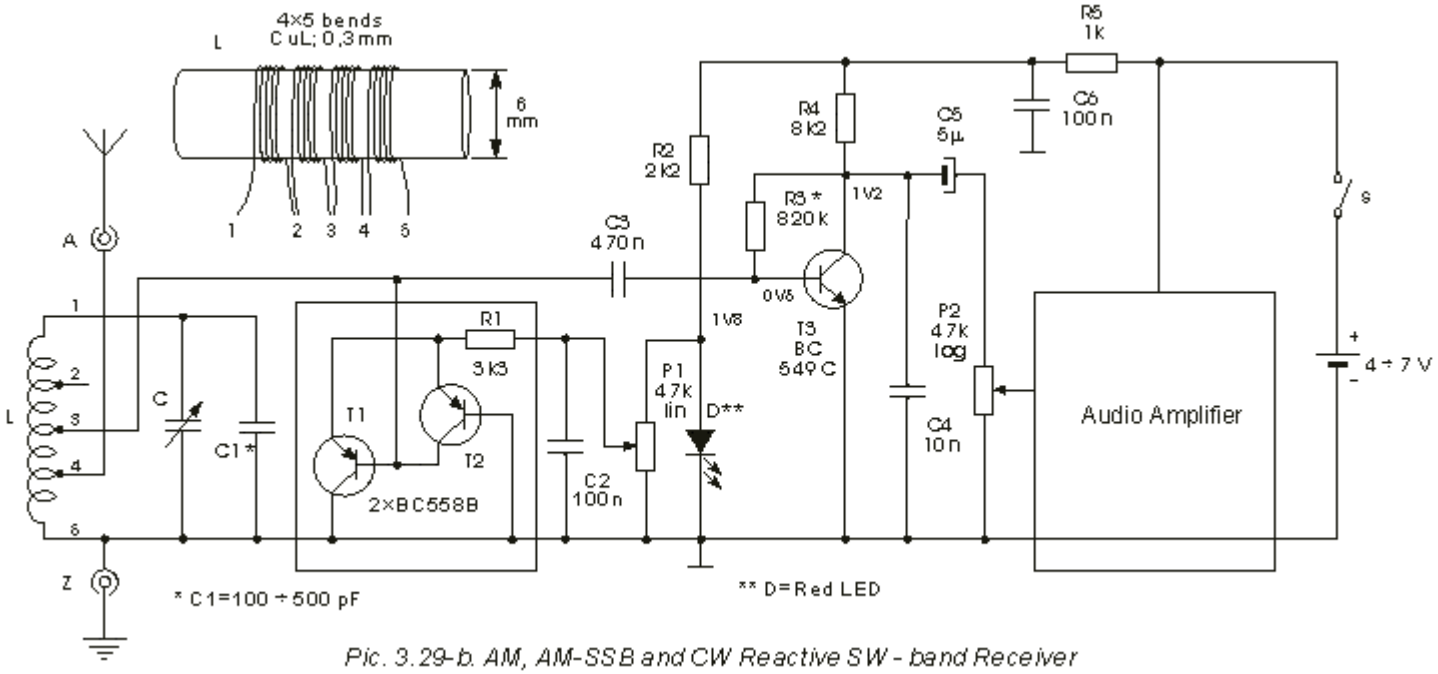

Pic. 3.29-b. AM, AM-SSB and CW Reactive SW - band Receiver

You have been able to see one of them in the previous project (3.29-a), and here we'll take a look at another one, which works so nice that we were sometimes having the impression it beats up much more sophisticated, modern supereterodyne receivers. Its electrical diagram is shown on Pic.3.29-b.
The coil L and capacitors C and C1 form a parallel oscillatory circuit whose role is to separate and amplify the signal of the tuned station, and to suppress all others. It doesn't entirely succeed in that, however. The reason for this is small Q- factor of the oscillatory circuit, being such because of big energy losses in the circuitry. There are many kinds (reasons) of these losses, but we can imagine in first approximation that there's a resistor RG in the circuit which represents these losses, its resistance being such that the oscillating current transforms itself into heat dissipation energy on it, its amount being the sum of all the (actual) losses in the circuit. We could, furthermore, solve the problem of these losses if connecting serially to RG a resistor RG', whose resistance would be negative and equal to the value of RG by its absolute value. The overall resistance would then be zero, there would be no energy losses and the Q- factor would become infinite. The oscillatory circuit would, together with the components that create this negative resistance, become an oscillator capable of receiving SSB and CW

signals.
We don't really need an infinite Q- factor while receiving usual (conventional) AM RG by its absolute value. The resistances would not cancel each other completely, but the losses would be made very small, the Q- factor therefore becoming very big therefor increasing both the selectivity and sensitivity of the oscillatory circuit.
Transistors T1 and T2 constitute, together with resistor R3, a two-stage amplifier with strong positive feedback that has a negative dynamic input resistance. This negative resistance is connected between the leg No.3 on the coil and the ground, therefore superimposing itself with the resistance representing losses of the circuit. The quantity of this negative resistance depends on the amount of the DC current flowing through the transistors, which is being regulated by altering the DC voltage on the right end of the R3 resistor (by moving the slider of the P1 potentiometer).
The red LED D and the resistor R2 comprise a simple voltage stabilizer, obtaining 1.8 V of stabilized voltage on the P1. That means that the voltage on the right end of R3 shifts between 0 and 1.8 V while moving the slider of P1. The current flowing through the transistors thereat also changes, causing the voltage on the left end of R3 to vary between 0 and 0.6 V.
The signal of the station is being led from the leg No.3 of the coil into the collector-type detector made of T3, R3, R4 and C4. That is an AM signal detector that performs both signal detection and its amplification. Its name is the Audion. The LF signal is then, from the collector of T3, over the coupling capacitor C5, being led onto the sound volume potentiometer P2 and the audio amplifier. For the latter any of the earlier described devices can be used.
Tuning this receiver on the desired station requires both some knowledge and patience (that's what finally "buried" this kind of receivers). Put the slider P1 in the upmost position. If strong whistling is heard that means the oscillating began. Move the slider carefully downwards until the oscillating stops. Then start slowly turning the rotor of the capacitor C until you come upon some station. If the whistling re-appears, move the slider of the potentiometer very little downwards, the whistling should stop and you should be able to hear the radio - station programme from the loudspeaker (loud and clear). For the next station tune yourself with C, then move the slider P1 upwards until the whistling appears, then put the slider back until it stops etc. All this may seem rather complex at first, but with a little practice and with two hands all will go quick and smooth.
The abovementioned method is for the signal reception of ordinary, broadcast stations. If you wish to receive the SSB and CW signals you should move the P1 slider upwards until the oscillating is achieved, so that articulate speech (SSB) or Morse code signs (CW) can be heard from the loudspeaker.
* The coil L is being made on the cylindrically - shaped body 6 mm in diameter, about 25 mm long. The plastic - made body taken from an old device is the best, like the one shown on Pic.5.14-b. The screw-shaped core allows the setup of the inductance, adjusting therewith the reception bandwidth of the device. If you cannot find such coil body, any plastic- or carton- made cylinder can be used instead. If you don't have even that, then make yourself one. Cut the paper band to be 25 mm wide and about 150 mm long and reel it around the flat part of the 4 mm drill, adding every now and then some glue (UHU or similar). When the glue gets dry, remove the coil body off the drill.

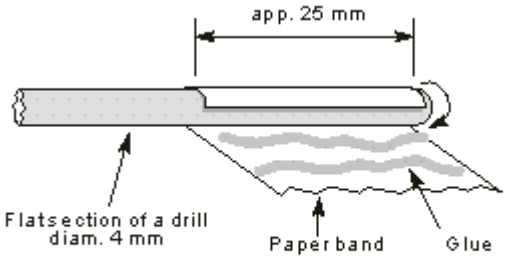

Pic.3.29-c. Spooling the coil body

The coil L has the total of 20 quirks of the lacquer - isolated copper wire, having 0.3 to 0.5 mm in diameter. A leg should be made on every fifth quirk. Latching of the wire ends (with small holes made in the coil body), as

well as leg making (by making wire loops) can be done acc. to the instructions given with Pic.3.6. It can also be accomplished differently, as shown on Pic.3.29-b. First, 4 separate coils, each one made of 5 wire rings, are made side-by-side on the coil body. The starts and ends are fixed with scotch tape. The isolation is then removed from all coil ends, about 5 mm in length, after which they are tinned. On the PCB the legs are being soldered in pairs, the end of one coil with the beginning of the next (they are put together in the same hole on the PCB). For example, the end of the second and the beginning of the third coil should be connected on the same line where contact for the left end of C3 capacitor is, thus creating the leg No.3 of the coil. Putting two wires through one hole is not a very professional solution. The "real thing" are separate junctions, one for each wire, as shown on Pic.3.29-d-c.

* The feedback may happen to be not big enough, causing that there's no oscillating even when the P1 slider is in the rightmost position. In that case, leg No.2 of the coil should be used instead of No.3. Switching between the legs can be done in many ways, the nicest (?) one given on Pic.3.29-d, made with factory-made contact pins and jumpers. On Pic.3.29-d-c you can see a detail of the PCB for the receiver shown on Pic.3.29-b. In the contacts marked as x, y and z (distance between them is 1/10 inch) the contact pins are soldered. The jumper is in position marked with dashed line, therefore making contacts x and y short-circuited. When it is moved in vertical position, the x and z contacts are in junction. In former case the coil leg No.3 is used, and in the latter it is No.2. In factory-made devices, these

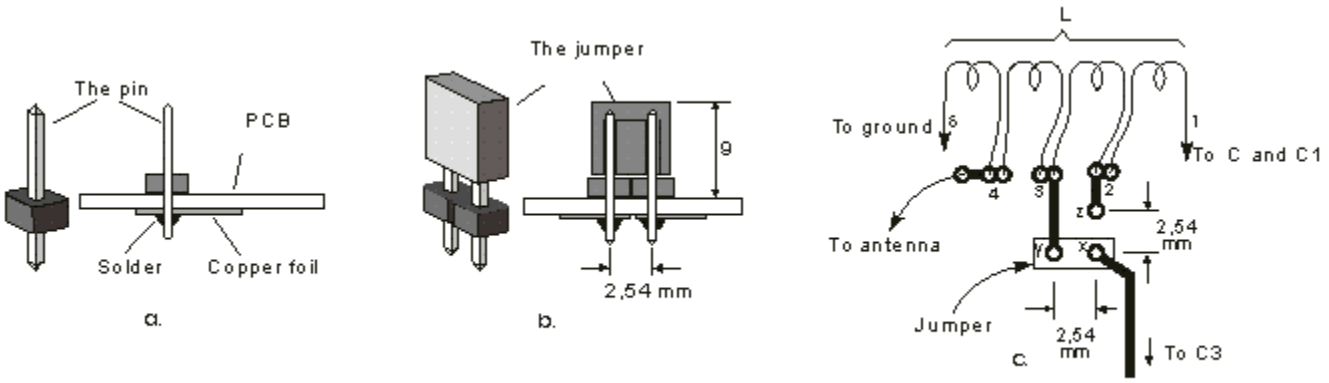

Pic.3.29-d. A- connector pin, b- pins with jumper, c- detail of the PCB from Pic.3.29-b

jumpers and contacts are used, together with appropriate connectors, to connect the PCB to the loudspeaker, power supply, variable capacitors, various switches etc.

* Setting the collector-type detector circuit to optimum operation is done by changing the R3 resistance, until voltage on the collector of BC549C is 1.2 V.

* The antenna can be a piece of copper wire no longer than 50 cm, but with longer (few metres), external antenna, the results will be much better.

* This receiver is scheduled for the reception of SW stations from 6 MHz till 9 MHz, which is accomplished with C1 value of about 400 pF. The exact value for C1 is being determined experimentally and can be significantly different. Going down to the amateur range (about 3.75 MHz) is performed with bigger C1 capacitance.

3.10. Miniature Receiver with ZN414 (ZN414Z) IC

The receiver from Pic.3.25 can be made portable (without an external antenna) if ferrite antenna is used instead of the carton-body coil, right? Well, not exactly. The ferrite antenna is a directional - type antenna, meaning that it does matter where are the waves made by transmitter coming from. The voltage being induced in it under the effect of EM field is the biggest if the ferrite rod is in horizontal position, aimed in such a manner that its axis is perpendicular to the direction of spread of the waves (i.e. perpendicular to the direction towards the transmitter). If the rod is being turned (in horizontal plane), the voltage decreases and gets to minimum when the rod is turned for 90 degrees, i.e. When the rod axis is parallel to the direction pointing towards the transmitter. That means that when the receiver from Pic.3.25 (with the ferrite antenna) is tuned to some station, the reception can be additionally improved by simply rotating it. The directional feature of the antenna is useful here. This, however, can be bad if the receiver is used in motion, since the volume would be constantly changing, and the receiver should be constantly turned towards the transmitter. It would clearly prove itself useful to have an electronic circuit in the receiver that would be automatically changing the amplification of the receiver, in such a manner that it would be increased when the signal in the antenna weakens and vice versa. This would even be convenient in the stationary - type receivers, since it would provide the constant sound strength in the loudspeaker during the reception of signals of various power. Such circuit does exist in modern receivers, and is called the Automatic Amplification Regulation circuit (AAR).
AAR circuit could be added to some of the receivers described in previous projects. The mishap is that electrical diagrams would then become significantly more complex, which would reflect itself both on the price and the realizability. The solution, however, does exist, and is rather simple: it's the ZN414 IC, being promoted as an "AM Receiver". Its block diagram is given on the Pic.3.30. The signal from the input

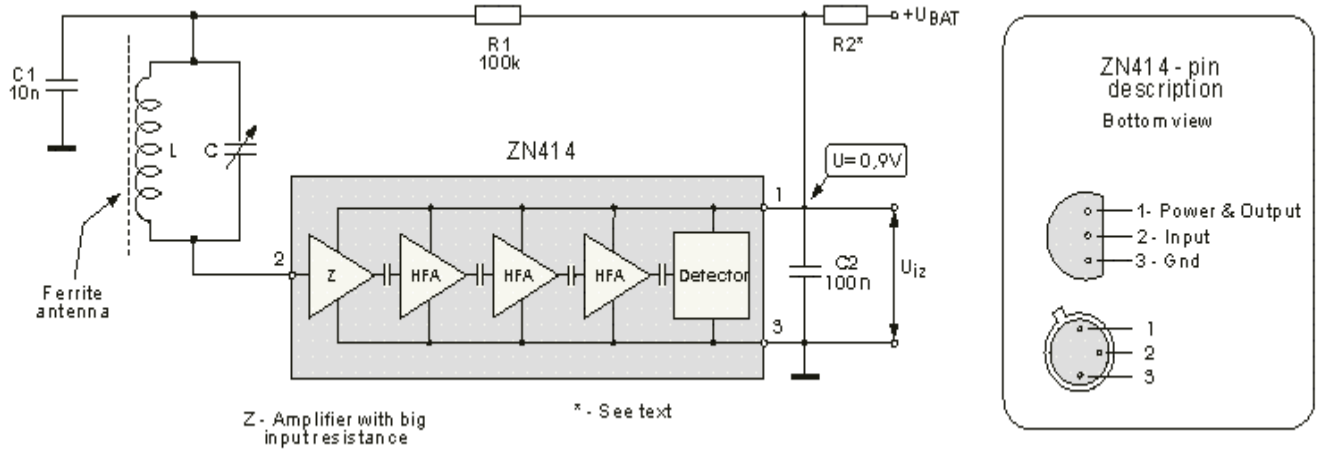

Pic.3.30. HF part of an AM radio receiver realized with the Zn414 IC

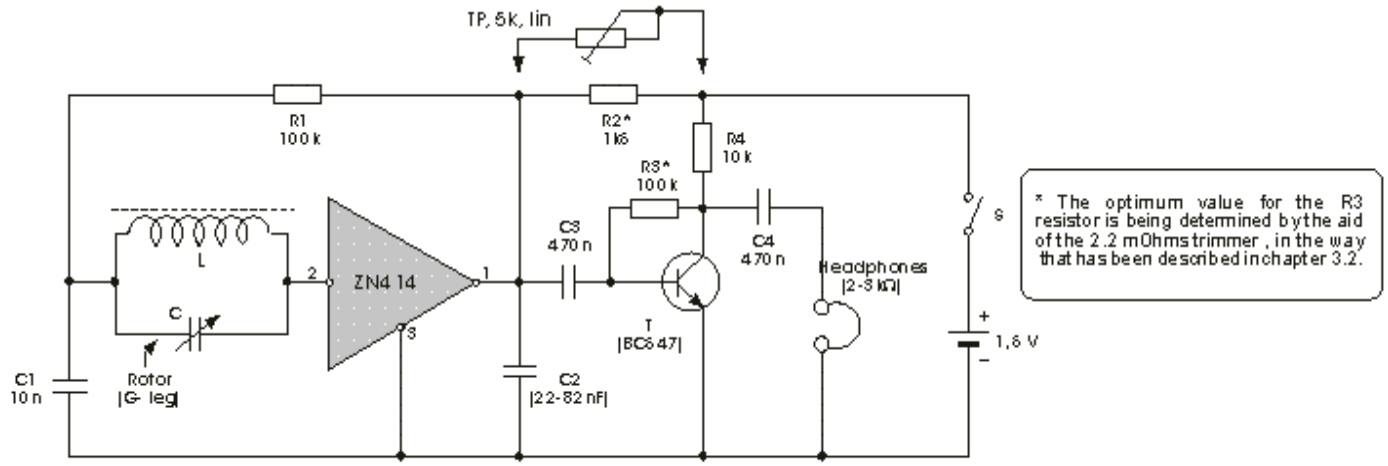

Pic.3.31. AM radio receiver with ZN414 IC

circuit (with ferrite antenna) is led on pin 2 of the IC, which is the input of the amplifier (Z) that has very big input impedance (about 4 MOhms). This is very significant, since such amplifier does not load the oscillatory circuit and doesn't reduce its Q- factor. The signal is then being amplified through 3-stage HF amplifier (HFA) and demodulated in the detector, thereby exiting the IC as an LF signal (music, speech...). In the right part of the Pic.3.30 the pin description of the ZN414 is given. As you can see, it is placed in a housing usually used for small-power transistors, either plastic (on top, like BC547) or metal (bottom, like BC107).
One end of the oscillatory circuit is connected to the ground over the C1 capacitor (for AC voltages), since input into the amplifier Z is between pin 2 and the ground, where the input signal is to be brought.
The automatic amplification regulation (control) is achieved by returning the DC component of the detected signal from the output to the input of the IC, over the R1 resistor. This DC voltage is being created on R2 resistor. It is substantial for the correct operation of ZN414, its resistance must be such that DC voltage on the pin 1 (to the ground) when no station is being received, is equal to 0.9 V. While calculating the R2 one must have in mind that the idle current of the IC goes through it, its typical value being 0.3 mA, and maximum 0.5 mA (more data about ZN414 can be found in table on Pic.3.36).

The electrical diagram of a small portable MW radio receiver, reproduction being done over the headphones, is given on Pic.3.31. The LF signal is led from the ZN414 output over the coupling capacitor C3 to simple amplifier made with BC547 transistor (or similar), which we discussed about before. This can even be done without the LF amplifier. If you have high-resistance headphones that are sensitive enough connect them between the right end of C3 and the ground, and omit the transistor, R3 R4 and C4.

The 1.5V battery is being used in this device, therefore the necessary 0.6V voltage drop is done with R2=1.5 kOhms. You should, just in case, connect first a 5 kOhms trimmer instead of R2, put its slider in the mid position, turn on the receiver and set it on an empty place on the scale, where no signal can be heard. Connect the voltmeter between the pin1 and ground, and carefully move the slider until the instrument shows 0.9V. If you have no instrument, tune the receiver to some station and move the slider carefully until you reach an optimum receipt. Then turn the variable capacitor's knob across the entire scale, to

ensure that receiver is working well throughout the entire reception range. If everything is OK turn off the receiver, disconnect the trimmer, measure its resistance and solder an appropriate resistor on the PCB. While experimenting with R2 please have in mind that its resistance should be in any case no less than 600 Ohms.

On Pic.3.32 the PCB, ferrite antenna and look of entire device are shown.
If you plan to make a different PCB, since the device works on high frequencies, you have to obey certain rules in order to have a reliable and stable operation:

a. The splitting capacitor C2 has to be mounted as close as possible to the pin 1 of the ZN414. Its capacitance affects both the amplification (which increases with increase of C2) and the limit frequency of the LF signal (which decreases with increase of C2), so the compromise has to be found. You may put for start C2=82 nF (or even 100 nF), and if the reproduction quality pleases you - everything is in order. You could try with smaller capacitance, the amplification will decrease but the reproduction will be better, etc.

b. All the connections, especially those near the ZN414, must be kept as short as possible.

c. The ferrite antenna and variable capacitor should be placed as far away from the battery, loudspeaker (if existing) and the cables connecting them to the PCB.

d. The rotor (G- leg) of the variable capacitor must be connected with the junction of R1 and C1.
Regarding the ferrite antenna, the best thing would be using some that is retrieved from some disused conventional receiver, more on this was told in the project No.3.8. If you can't find one, or it is unsuitable for some reason, you can make it according to Pic.3.32-c. The length of the ferrite rod is 42 mm. If you have a longer rod, cut it down to size. This cannot be done with the saw, but a groove must be made with the rasp all around, after which the rod can be simply broken in two. The coil body is, again, made of paper tape that is spooled and glued onto the rod. Before you start with spooling, several pieces of 0.5 mm wire (3 on the picture) should be inserted between the rod and the paper. The coil has got 80 quirks of lacquer -isolated copper wire, its diameter being app. 0.2 mm. The beginning and the end of the coil are fixed with the scotch tape (the starting quirks are pressed on the coil body and fixed with several reels of 3 mm tape. The same is done with the ending ones). When the body is finished, the wires are removed. It is thus achieved that the coil body doesn't lay firmly on the rod, which can now be moved side-to-side, changing thereby the inductance of the coil, so that its optimum value can be established. If you still decide not to use the ferrite antenna, you can use our coil from Pic.3.6. In that case, the leg should be kept "in air", i.e. it is not used.

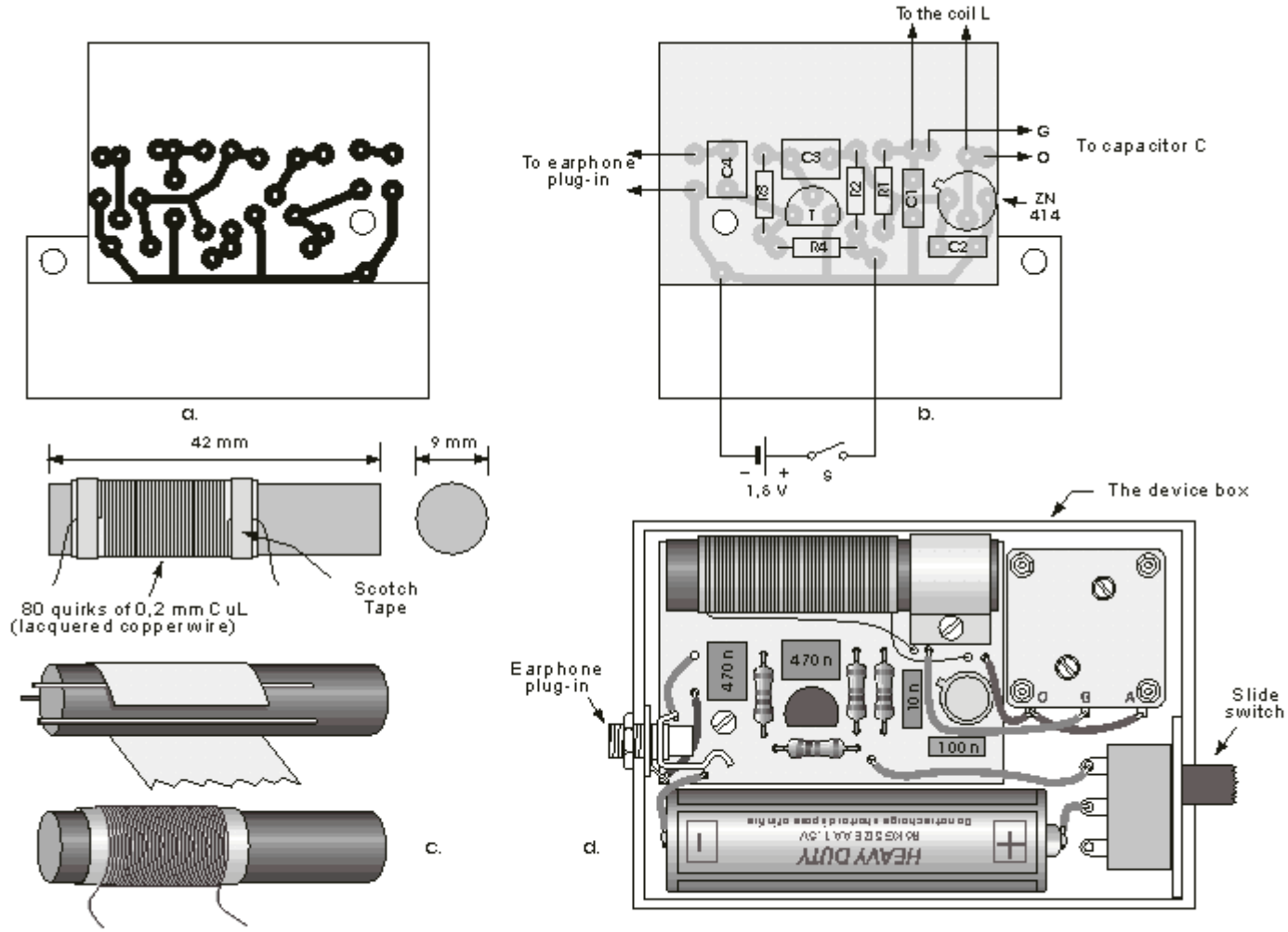

Pic.3.32. Practical implementation of the Radio Receiver from Pic.3.31-a: a- PCB (soldering side), b- PCB (component side), c- ferrite antenna making, d- complete device

* The battery can be connected to the PCB with two pieces of wire that are soldered to it. This solution is fine if you are skilled in soldering and can easily un-solder the old battery and attach the new one. But if you intend to give the receiver to someone, and he/she is not a soldering-lover, you'll have to find another solution. The simplest thing to do is take the battery housing from an old receiver, do the necessary adjustments and connect it with the PCB with two pieces of flexible (litz) wire. If you cannot do the former, make two battery platforms of brass, as shown on Pic.3.33 and solder them on two copper areas on PCB that are big enough to support them. If you accept this solution, your PCB must be bigger (The additional part is shown in dashed line, on Pic.3.32-a). The board now also contains the holes for the screws, which are fixing it onto the device box. On the platform that supports negative (-) battery pole, a small spring can be attached, to provide a good contact. If you don't have such a spring, bend the platforms inwards a little, to keep the battery firmly in place.
If you are using a power source whose voltage is greater than 1.5 V, the R2 resistance should be increased. The exact value for it is best to find as previously described, by using the 50 kOhms trimmer. Even better solution is using one of the circuits from the Pic.3.34. Which one should it be? The one on the Pic.3.34-d gives the best operating performance.

The setting is done with the TP trimmer. The slider is put in the lowest position, and then is slowly moved upwards until the voltage on the pin 1 doesn't reach the level required. However, this circuit applies a big load onto the battery, surging from it the current I=(9V-3V)/680Ohm=8.8 mA.

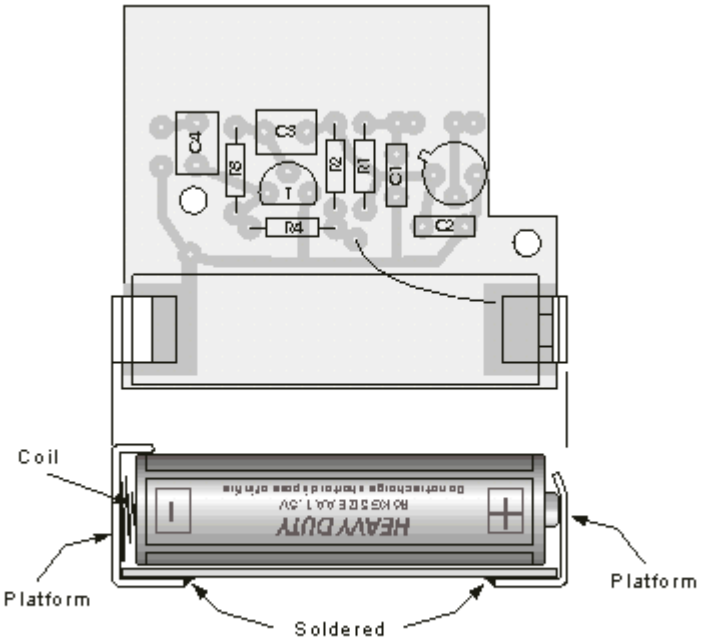

Pic. 3.33. Battery mounting on the PCB

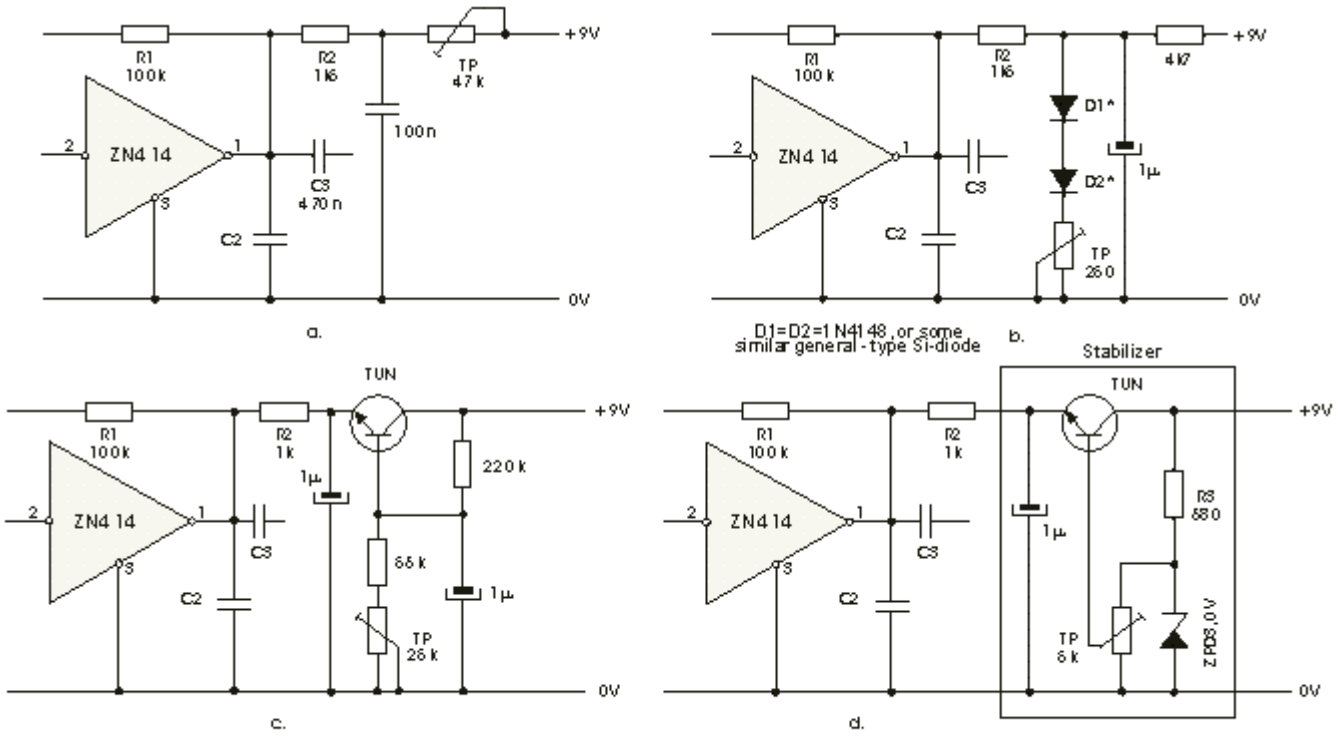

Pic.3.34. Power supplying the ZN414 from the 9V battery: a- with the resistor divider, b- with a two-diode stabilizer, c- with the transistor voltage attenuator, d- with the stabilizer with a transistor and the Zener - diode

3.11. Pocket Receiver with ZN414 & LM386 IC's

The author was taking notes in his lab while testing the receivers being described herein, and used them later to write this book. One remark about the receiver whose electrical diagram is given on Pic.3.35 was: "Works EXCELLENT". The reader will probably ask himself: Isn't this the aforementioned "The Best Receiver"? No, it isn't, just remember: DE GUSTIBUS... If, however, you consider it to be "The One", please send your vote on E-mail: tesla@drenik.net;

This device is very similar to the one being described in the previous project. The most important difference is that the LF signal exiting the ZN414 does not go to the transistor amplifier but to the power amplifier built around the LM386, which was used in some previous projects. Any other audio amplifier can be used instead, e.g. those on Pics. 3.15, 3.21 and 3.22.

With this receiver, special care should be taken regarding the voltage on pin No.1. As you did in previous project, put the potentiometer's slider in mid-position, turn the receiver on and tune it to some station. Move the slider carefully, until you reach the optimum reception. Start changing the capacitance of the variable capacitor, covering its entire scope, to make sure that receiver works well in its entire operating range. If a problem occurs, re-position the slider again. When everything gets OK, turn the receiver off, disconnect the potentiometer, measure its resistance, and solder the resistor of such resistance on the board. The R2 resistance must be no less than 600 Ohms.

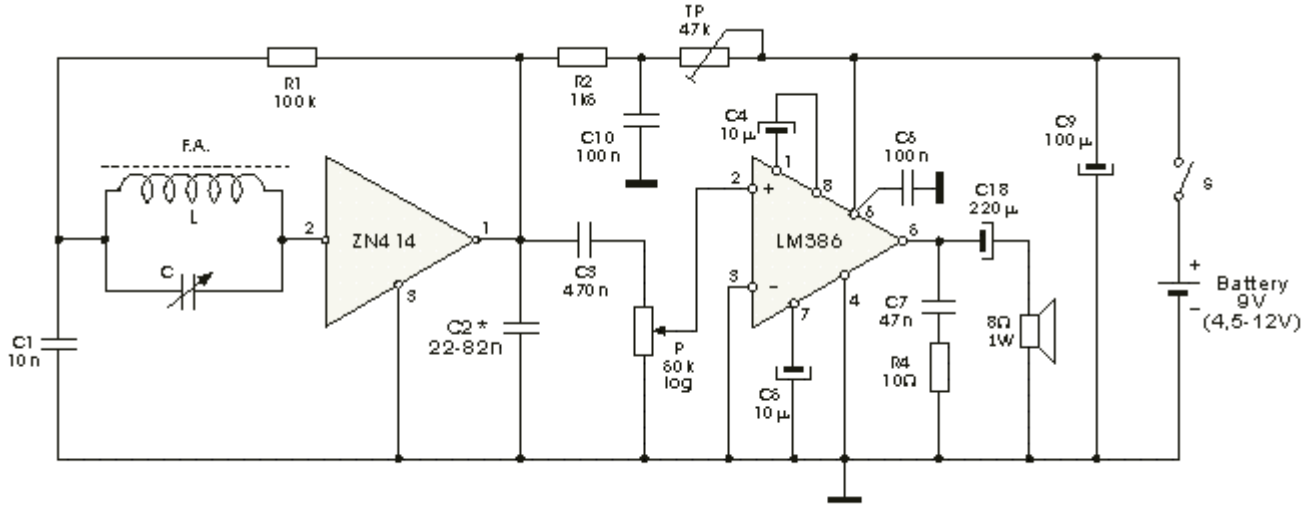

Pic.3.35. The AM Radio Receiver with ZN414 and LM386 IC's

3.12. Miniature Receiver with ZN415E (ZN416E) IC

The ZN415 IC, being promoted as "The World's smallest radio" by its manufacturer (FERRANTI), is an improved version of ZN414. As seen on the Pic.3.36-a (IC's block diagram), the 8-pin DIL package contains ZN414 IC with R1 and R2 resistors, an amplifier with T1 transistor and the separation stage performed with T2 transistor. All the necessary resistors are comprised in the IC. Someone will, perhaps, wonder why there are no capacitors integrated inside, so that the externally mounted parts would then be only the battery and the headphones? The answer is fairly simple: It isn't yet possible to make the capacitors that would have enough big capacitance, in the monolithic IC's manufacturing process. Regardless of this "problem", the receiver built around the ZN415 is, really, extremely simple.
As described in project 3.10, the LF signal exits the ZN414. Through the coupling capacitor C3 it is led on the base of T1, and the amplified signal is obtained on its collector pin, and is taken directly on the base pin of T2. The remains of the HF signal are led to the ground over the C4 capacitor. The separation stage allows us to connect small - resistance (64 Ohms) headphones, which are mass - produced these days and are the easiest ones to obtain.
The 1.5 V battery is used for the power supply of the circuit, and is being connected between the pins 6 and 4. Having in mind the previous experience gained with the ZN414 IC, the author recommends to the readers to try improving the signal reception by adding the R2* resistor (helping themselves with linear 1-5 kOhms potentiometer), which is shown in dashed line on the picture.
In the upper end of the Pic.3.37 the table with basic data about ZN415 circuit is given. All these apply on the ZN414 as well, except for the last line. The smaller table given below it contains the data about the DC voltages on the pins of the IC. If something is wrong, the first thing to do is check these voltages and if they are (approximately) as those given in the table, the IC is OK and the error is therefore to be searched in the printings, the contacts, junctions, etc.
Everything that is said about the ferrite antenna in the previous projects applies here as well.

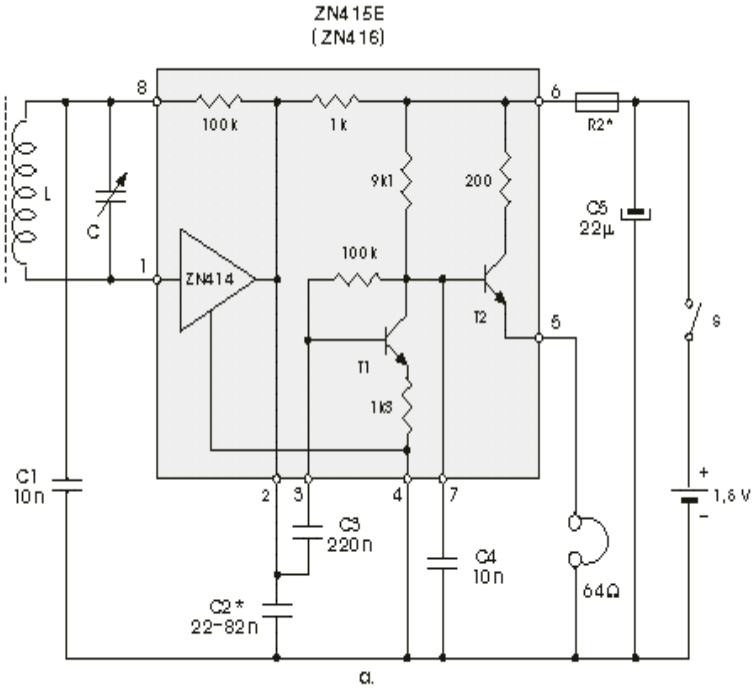

Pic.3.36 Miniature AM receiver with ZN415E IC

The ZN415E (ZN414Z) features

Parameter	min.	tip.	max.	unit
Supply voltage	1,1	1,3	1,6	V
Current consumption		4 (0,3)	5 (0,5)	mA
Frequency range	150		3000	kHz
Input resistance		4		MOhm
HF power amplification		72		dB
LF voltage amplification		18		dB

* Data in the parenthesis are for ZN414Z

Pin	U(V)
1	0,75
2	1,1
3	0,7
4	0
5	0,2
6	1,5
7	0,9
8	0,75

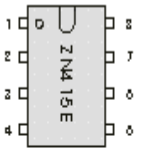

The DC voltages on ZN415E pins

b.

Pic.3.37. ZN... IC's data

3.13. AM Receiver with ZN415E & LM386 IC's

This FRT AM receiver combines the features of two magnificent IC's, ZN416E (HF amplifier, detector and the pre-amplifier) and LM386 (audio power amplifier). Add a power supply based on 7809 voltage stabilizer IC, use a loudspeaker with membrane diameter being about 15 cm, put all this in one of the boxes described in the Appendix, and you will have a new and improved silicone - based model of an old - fashioned radio receiver, built somewhat less than 100 years ago.

The electrical diagram of this device is given on Pic.3.38. The voltage reduction (and stabilization) from 9V to 1.5V, as needed by ZN415, is being done over the R2 resistor and D1 and D2 diodes, although any circuit given on Pic.3.34 can be used instead. Universal - type diodes 1N4148 are used here, but any other low-power silicon diodes will do. With 250 Ohms trimmer TP the fine - tuning of the voltage on the pin 6 is being done (the receiver is set to some station in the upper part of the reception bandwidth (app. 1500 kHz), and the slider of the TP is then used to obtain the optimum reception). After that, the receiver is switched off, the trimmer is disconnected, its resistance measured and an equivalent resistor soldered in the circuitry. On the PCB, this resistor is marked as R3.

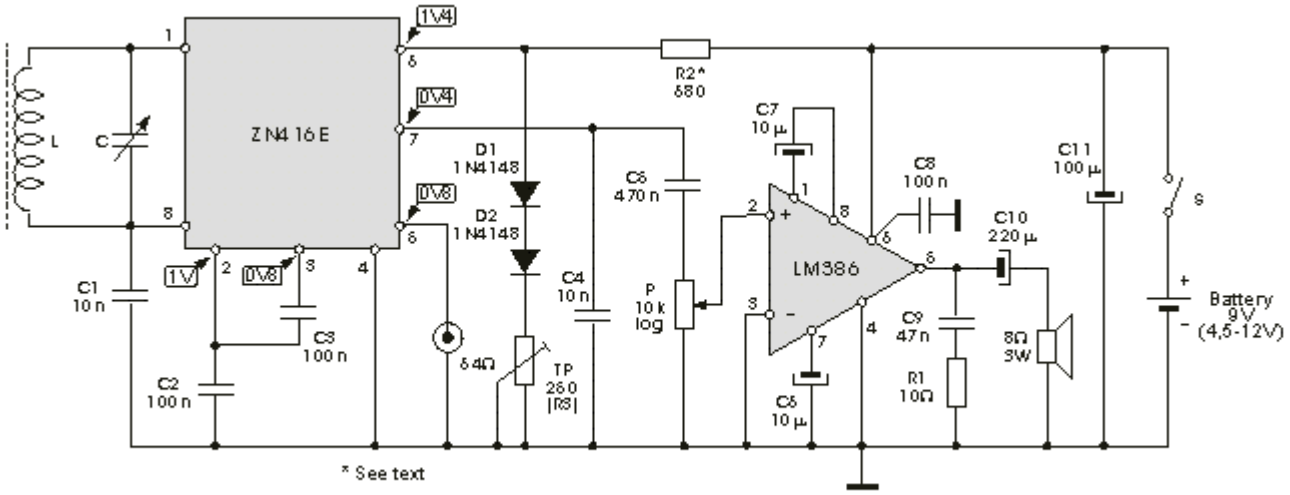

Pic.3.38. AM radio receiver with ZN415E & LM386

The PCB, component layout and connections with other parts of the device ar shown on Pic.3.39. If the receiver is made for the household use, you should certainly put it into some bigger box where bigger loudspeaker (~15 cm) can be installed. The ferrite antenna should be mounted on the rear or side panel, as far from the loudspeaker as possible. All the conductors, especially those that connect the capacitor to the board, should be as short as possible. The wires that connect the loudspeaker and the adapter to the PCB have to be firmly twisted, as shown on picture for the loudspeaker. The potentiometer is to be connected with the shielded microphone cable, if it is more then 10 cm away from the board.

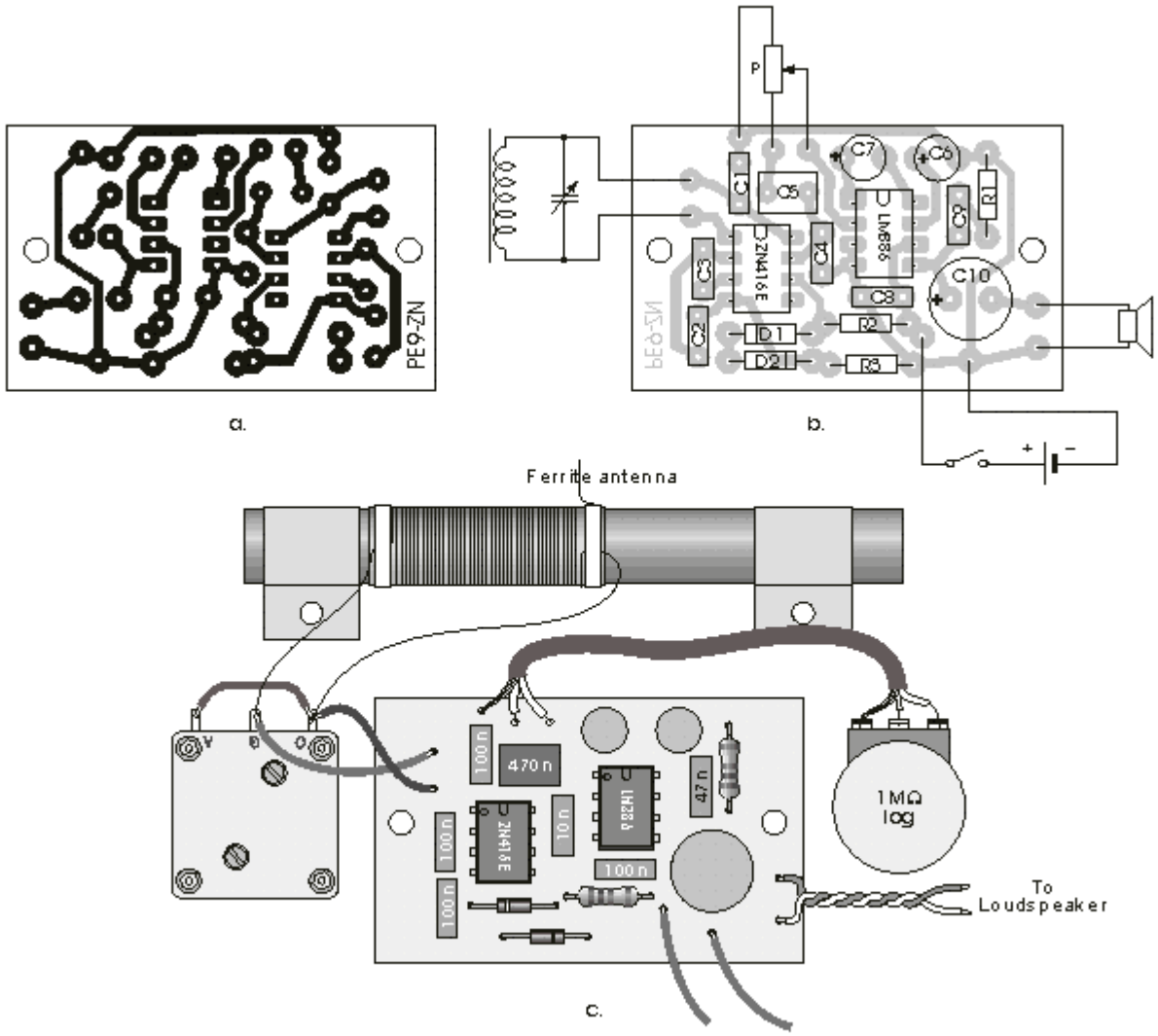

Pic.3.39. Practical implementation of the receiver from Pic.3.38: a- PCB (solder side), b- PCB (component side), c- "Real" layout

A connector for 64-Ohm headphones can also be mounted on the box. It is then connected to the PCB via a microphone cable, connecting its "live" end directly on pin No.5, and the shield wire to the closest ground. Headphones can also be used instead of loudspeaker, in which case such connector must be chosen, that will switch off the loudspeaker when headphones are plugged in.

* Some more modern IC, other than LM386, can also be used in this device. The author recommends TDA7052A. Its main features are:

1. Extremely stable operation
2. Implemented output short-circuit protection
3. No cooler necessary
4. Small power consumption, IO=4 mA
5. No "clicking" during switching ON/OFF
6. Voltage amplification is 39 dB
7. Output power Piz=1.2 W (3x bigger than LM386)
8. The 220 mF capacitor isn't needed if the power rectifier that has an electrolytic capacitor on its output is used, and the cables connecting it with the device are short. In that case the

amplifier is practically made without the external components, if we exclude the (inevitable) 100 nF capacitor, which is in every way great advantage.

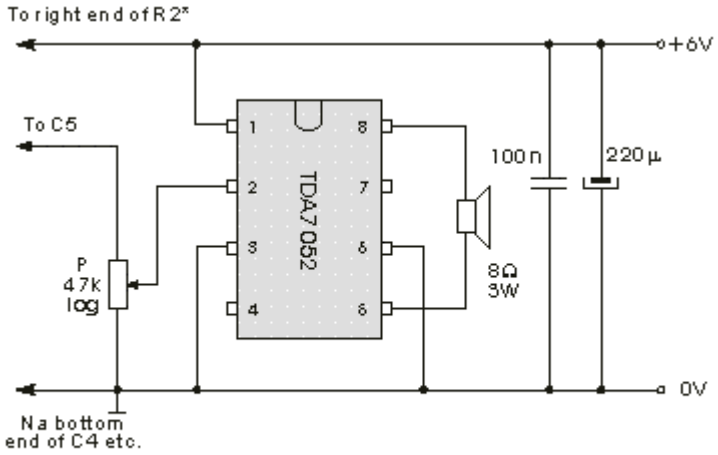

Pic.3.40. LF part of the receiver from pic.3.38.

3.14. Miniature receiver with ZN415E & TDA7052 IC's

The 9 V battery is not so popular nowadays as it used to be, probably for its quite big price/capacity ratio, so it is almost never used in the pocket-type receivers today. Much more frequently utilized these days are the cylindrically shaped 1.5 V AA type batteries. Electrical diagram of one pocket-type AM receiver that uses two of these for power supply is given on Pic.3.41. Two IC's, ZN415 and TDA7050 are being used in it. The DC supply voltage for TDA7050 must be exclusively 3 V, and should be no bigger than 4 V. The voltage being supplied from the batteries gets smaller during the use, but the IC operates properly as long as it doesn't drop below 1.6 V. Besides this nice feature, this IC has very small dimensions, very low idle current (4 mA), all the external components it requires are two capacitors (C8 and C9), which makes it ideal for usage in the mobile-type devices (radios, wakmans, etc.), the purpose that is originally designated to it by its manufacturer (Philips).
* Caution must be expressed with the power supply, since this two-batteries power supply cannot be simply replaced with some common-type 3V adaptor. If you wish to use such adaptor, the pin 6 of ZN414 must be connected, over the R2 resistor and one of the circuits from Pic.3.35, to the pin 8 of the TDA7050, and the adaptor is then to be connected between the pin 8 and the ground.
* The R2* resistor, shown in dashed line on the picture, should be added only if the receiver does not operate stable. Determining its exact value is explained in several previous projects.
* The 64 Ohm headphones are connected onto the output of the ZN415 (between pin 5 and Gnd), or instead of the loudspeaker (in which case the reproduction can be much louder).
* The PCB and components layout is shown on the Pic.3.42. Connecting other components is being done in the similar manner as in the previous project. In the left corner the batteries are shown, placed in some convenient holder taken from some old device. Between the plus pole of the left and the minus pole of the right battery the tin plate is inserted, with one of 3 cables connecting the supply to the PCB soldered to it.

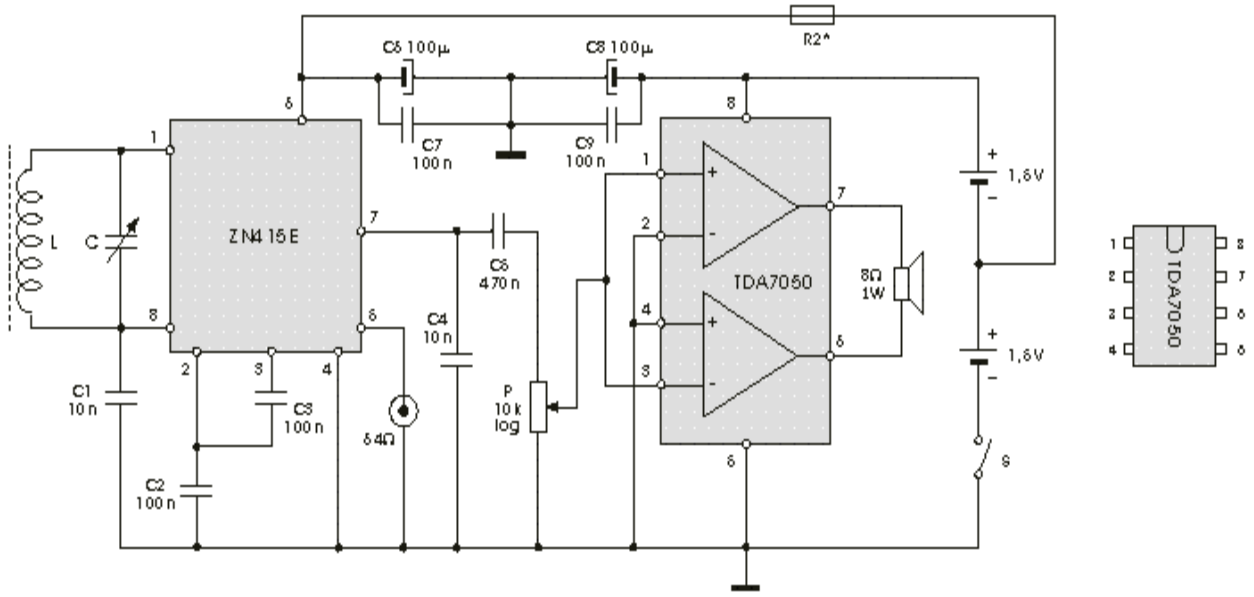

Pic.3.41. AM receiver with ZN415E i TDA7050

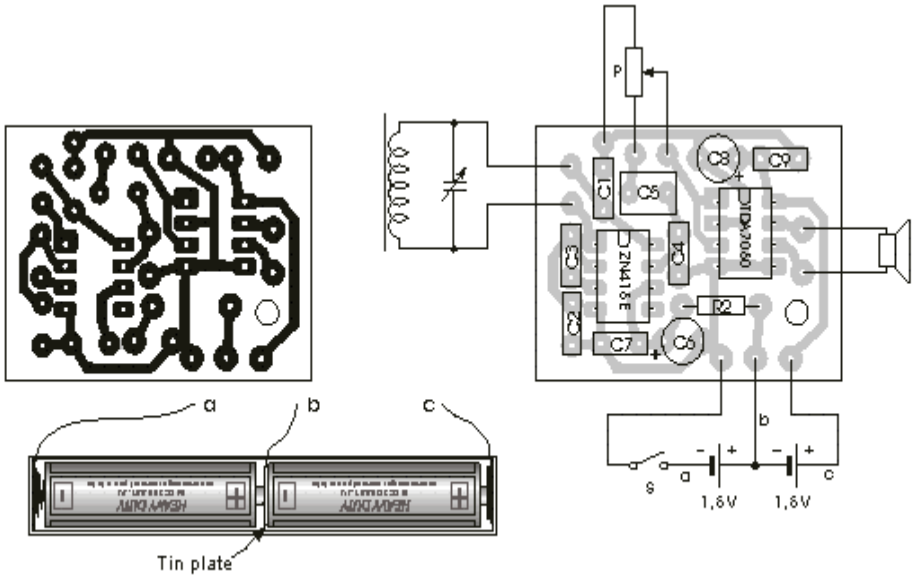

Pic.3.42. The PCB for the device from pic.3.41

3.15. Direct (TRF) FM Receivers

Frequency modulation is used in radio broadcast in the bandwidth range from 88 MHz til 108 MHz. This range is being marked as "FM" on the band scales of the radio receivers, and the devices that are able to receive such signals are called the FM receivers.
Radio broadcast transmitters are using the amplitude modulation on LW, MW and SW bandwidths. According to international treaties, each of the transmitters has a 9 kHz wide broadcasting channel, therefore making maximum frequency of the information being transferred fNFmax=4.5 kHz, according to the characteristics of the AM signal. To put it

more simple, the highest frequency of the sound that can be heard from the loudspeaker of an AM receiver is 4.5 kHz, all above it will be simply truncated in the circuitry. Considering the speech itself, this isn't so important since the most important components are located below these 4.5 kHz (during the telephone transfer, all the components above 3.2 kHz are being cut, and nobody is complaining). Things stand different, however, for the transfer of music. Music has much more sound components, with their frequencies spreading up to 15 kHz, so truncating them above 4.5 kHz does deteriorate the transmission quality.
The radio-broadcast FM transmitter has a 250 kHz wide channel on its disposal, therefore allowing for the maximum frequency of the information (acc. to the characteristics of the FM signal) to be fNFmax=15 kHz. That means that music is being fully transferred and its quality is significantly better than in the case of the AM transfer. The FM transfer has some other advantages, perhaps the most significant of them being the possibility of eliminating various disturbances that are manifesting themselves as snapping, squeaking etc. The main disadvantage, however, is not the result of the frequency modulation itself, but rather of the fact that this method is being used on high frequencies, and that high-frequency electromagnetic waves behave themself as light, spreading themselves in straight line, not reflecting from the ionosphere etc. This is why obtaining this kind of radio-link requires optical visibility between the transmission and reception antennas, which is not the case for the links obtained on frequencies which are less than 40 MHz. In practical terms, it is possible to receive the SW signal from anywhere on Earth, whilst the range of an UHF link is limited to the horizon. Or, as Hamlet would say: "The quality or the range, that is the question!"
Can we have it both, somehow? Yes we can, and it is already being done, over the satellite links, using the same equipment as for the TV signal receipt and an audio amplifier connected to the audio output of the satellite receiver. For now, in the earthly conditions, those that are interested in the worldwide news will make and use the AM receivers, and music lovers will stick to the FM's. And what can those interested in both do? Well, they make AM-FM receivers :)
The direct-type (TRF) FM receivers have never been produced, the industry started right away with the superheterodynes, made acc. to the block diagram on Pic.4.6, which will later be discussed. In amateur life, however, the direct FM receivers do exist, having very simple electronic diagrams and being easy to manufacture. These receivers have very strong positive feedback, making the intermittent oscillations in it, and are therefore being called the super-reaction receivers.

3.15.1. The Simplest FM Receiver

On Pic.3.43 you can se the electronic circuit of an extremely simple direct FM receiver. The T2 transistor together with the R1 resistor, the coil L the variable capacitor C and internal capacitances of the T1 transistor, comprises the so-called Kolpitz oscillator. The resonance frequency of this oscillator is being set by C to correspond to the one of the station that we wish to hear (meaning it has to be altered between 88 and 108 MHz). The signal, i.e. the information being used in the transmitter to perform the modulation, is extracted on the R1 resistor, and being led from it to the high-resistance headphones, over the coupling capacitor C1.

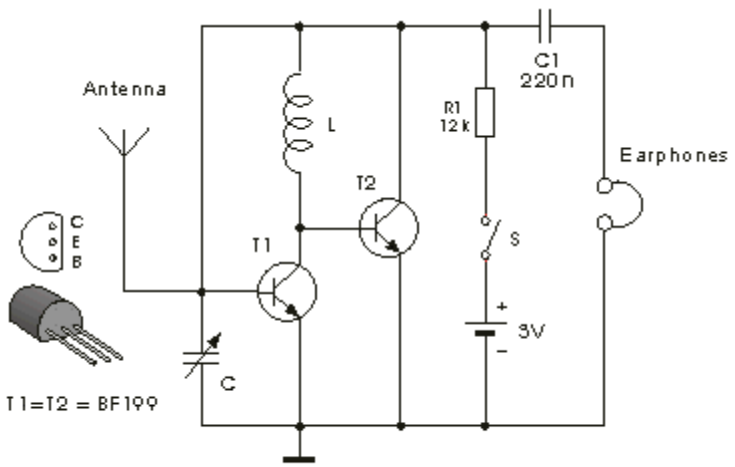

Pic.3.43. The simplest FM receiver

* The capacitance of the variable capacitor should be able to change from a couple of pF (Cmin) to app. 20 pF. During the testing off this device, we were using the capacitor from Pic.3.8. The legs marked as FO and G were used, the G leg being connected to the ground. When all the trimmers from the circuit on the Pic.3.8 are set to minimum capacitance, the capacitance between the FO and G legs should be adjustable between 7 and 27 pF.
* The coil L has 4 quirks of lacquer-isolated copper wire (CuL), bended to have a 4 mm internal diameter. The practical realization of this coil is explained in text connected with Pic.3.45. During the setup of the bandwidth, the inductance of the coil can be altered by changing the distance between the quirks. If the coil is stretched the inductance decreases, and vice versa. If this cannot give the desired results, new coil must be made.
* The telescopic antenna taken from a disused device can be used. If you can't find one, you obtain very good results with a piece of isolated copper wire, about 60 cm long (the optimum length to be found experimentally).

3.15.2. The Simplest FM Receiver with Audio Amplifier

The radio-broadcast FM transmitters operate with output power that is much smaller than that of the AM transmitters. That is why the LF signal coming from the device on Pic.3.43 is rather small, urging the use of very sensitive headphones. They are much more expensive than the "ordinary" ones, making it better to use the cheap headphones in connection with audio amplifier. One such solution where TDA7050 IC is used is given on the Pic.3.44. The R3 resistor and capacitors C5 and C6 are to be added only if the operation of the device is unstable. There optimum values are to be found experimentally, starting with those shown in the picture.
For loudspeaker reproduction any of the previously described amplifiers can be used, e.g. that from Pic.3.21 (which we have been using, very successfully), or one of the devices described in P.E.4 and P.E.5. Since in these amplifiers a battery with voltage bigger than 3 V is used, using of R3 and C5 is obligatory. The R3 is counted from the formula

$$R_3 = \frac{U_{BAT} - 3}{0,235}\,[k\Omega]$$

where UBAT is battery voltage, and 0.235 mA is the current through R1, that supplies T1 and T2. E.g. if UBAT=9 V, it is then and the nearest existing resistor is used.

$$R_3 = \frac{9-3}{0{,}235} = 25{,}5\,k\Omega$$

Capacitors C5 and C6 comprise, together with R3, a pass-filter for very low frequencies, which is used to separate the HF and LF parts of the receiver.

The battery itself acts as a short-circuit for the AC currents. But when it ages its resistance increases and there is no more short-circuit. That is why C3 and C4 are added, to accomplish it.

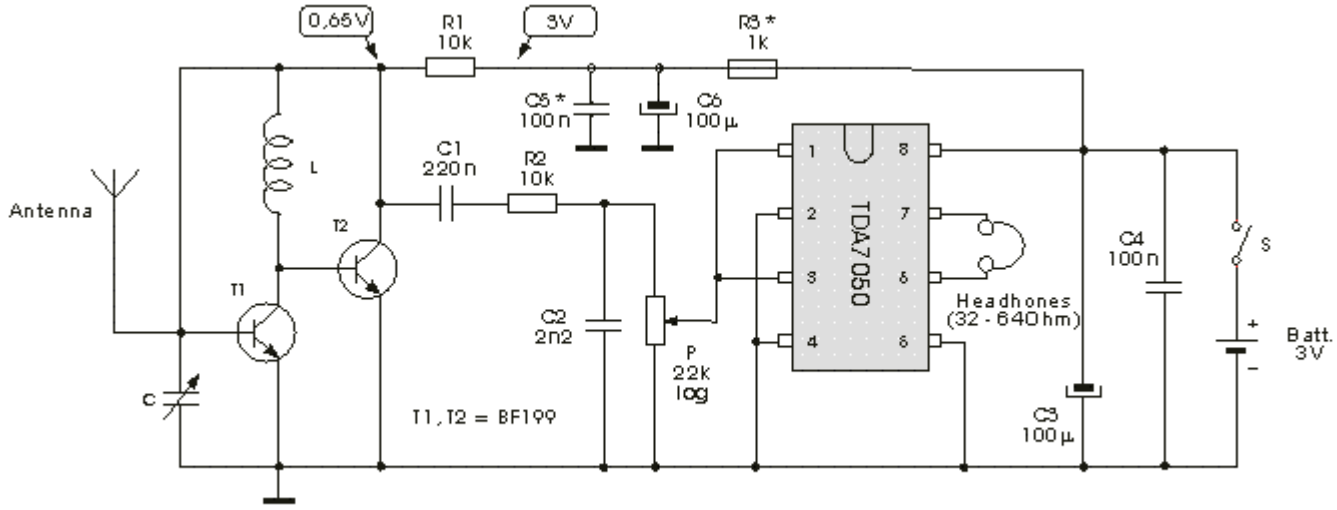

Pic.3.44. The simplest FM receiver with audio amplifier

3.15.3. FM Receiver with one Transistor and Audio Amplifier

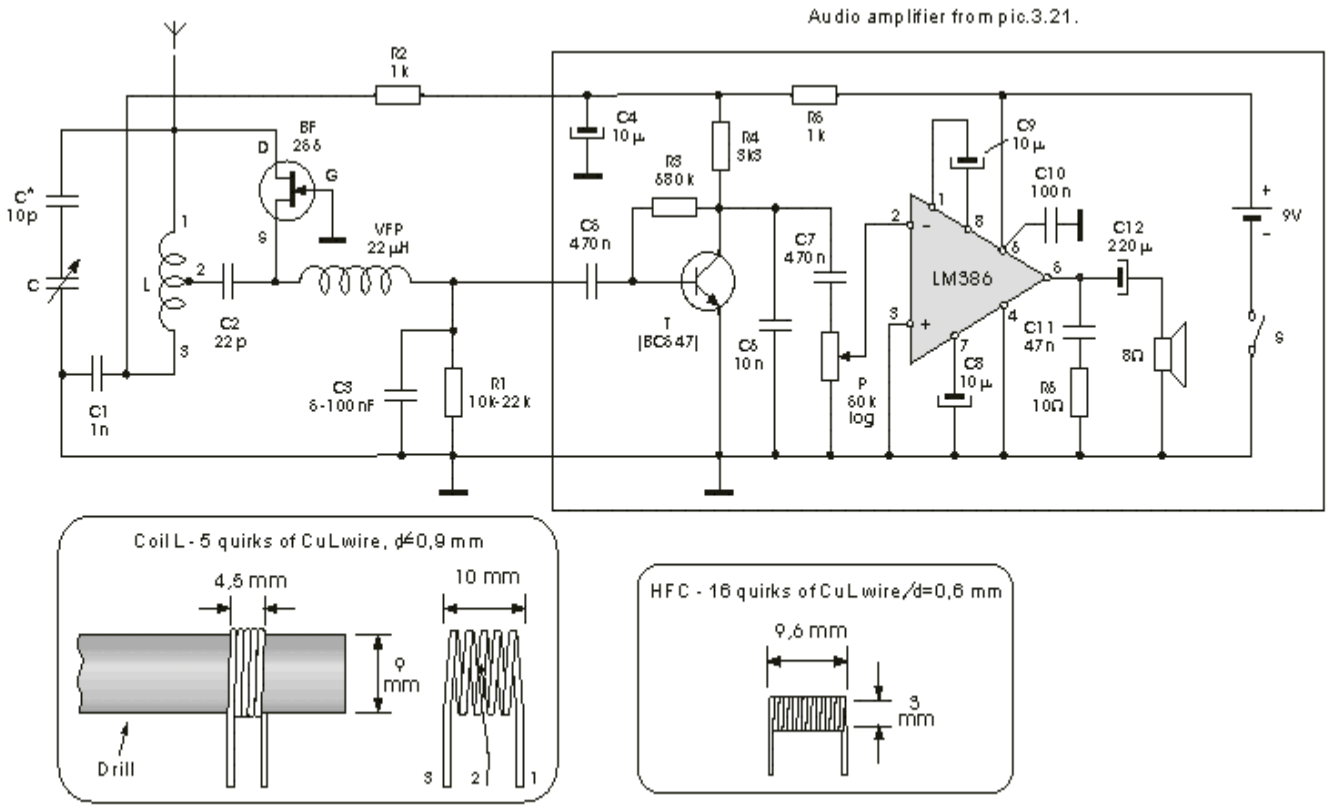

Pic.3.45. FM radio receiver with audio amplifier

We have made this receiver on the experimental plate, and it was playing for days in our lab. Its electronic diagram is given on Pic.3.46. Regretfully we had to disassemble it, since we needed the plate for one of the devices described later in this book. This, too, is a reaction-type receiver, where the BF256 transistor, coil L and capacitors C, C* and C2 form the Hartley oscillator. Its frequency is being adjusted by means of the variable capacitor C to be equal to the frequency of the station that we wish to listen to. The LF signal is being taken from the R1 resistor, and led into the audio amplifier.

* The coil L is self-supporting (doesn't have the body), made of 5 quirks of CuL wire, its diameter being from 0.8 to 1 mm. It is spooled on some cylindrical object (pencil, pen etc., the best thing is the round part of a 9 mm drill), in one layer, quirks put tight to each other, as shown in the left, framed part of the picture. When the coil is finished, it is taken off the cylinder and stretched a little, so that the quirks do not touch each other. Its final length should be about 10 mm. The mid coil leg, which is to be connected to the left end of the C3 capacitor, is made by taking off couple of millimetres of the lacquer from the wire, approximately in the middle of the coil. This place is then tinned and a piece of thin wire is soldered to it. The other end of this wire is soldered onto the PCB, on its place, to be connected to the left end of C2.

* For the variable capacitor C the one from the Pic.3.8 (legs FO and G, G goes to Gnd). If you are using some other capacitor, that has bigger capacitance, and you cannot achieve the reception of the full FM bandwidth (88 til 108 MHz), try changing the value of the C*. Its capacitance is to be determined experimentally, usually being about a dozen pF.

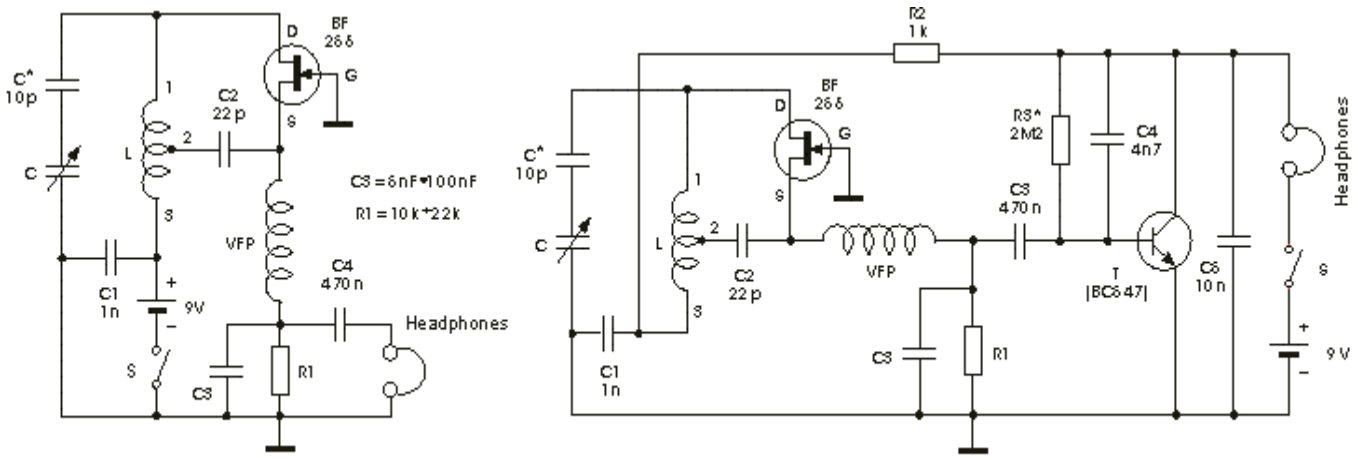

Pic.3.46. FM receivers with headphones

* HFC is the high-frequency choke. Together with C2, it makes a filter that prevents the HF current to flow through the R1, simultaneously allowing for DC and LF current to go through. The muffler is, in fact, a coil that has 16 quirks of 0.6 mm CuL wire, spooled on a round part of a 3 mm drill.

* This receiver works well even without the external antenna. It can, of course, be connected to it, as shown in dashed line. Instead of antenna, a 50 mm piece of wire can also be used.

3.15.4. FM Receiver with (just) one Transistor

On the left side of the Pic.3.46 you can see the diagram of another very simple FM receiver, that has only one transistor as the active element. That is, as one can see, the HF part of the receiver from Pic.3.45, where the reproduction is being accomplished over the high-resistance headphones. But, as previously noticed, they are pretty expensive, therefore making it better to use the "regular" headphones and a simple amplifier, as shown on the right side of the Pic.3.46.

Chapter 4 Superheterodyne Radio Receivers

4.1.Superheterodyne AM Receivers
4.1.1. The Simplest AM Superheterodyne Receiver (worldwide)
4.1.2. The Fully (not exactly 100%) superheterodyne AM Receiver No.1
4.1.3. The Fully (not exactly 100%) superheterodyne AM Receiver No.2
4.2. Superheterodyne FM Receivers
4.2.1. FM Receiver with TDA7000
4.2.2. FM Receivers with TDA7088T
4.2.2.1. Miniature FM Receiver
4.2.2.2. Stereophonic Receiver

As far as the professional manufacturers are concerned, the direct (TRF) receiver has "played out his tune". After half-century struggle on the market, it has been replaced by the

superheterodyne receiver, that was patented in 1918 by Edwin Armstrong. In that time, commercially speaking, its main advantage was its substantially easier tuning to the station. It requires only one button for this, comparing to the TRF receiver that needs two buttons to be intermittently adjusted for optimal reception, and also it requires much of the knowledge, skill and patience, which the average buyer does not have. The superheterodyne receiver is, however, also more complex than the TRF, and setting of its stages during its production requires some special instruments, that the average radio amateur does not possess. Nevertheless, it is not impossible to build such device in the amateur environment, and when the operating principles are known, the necessary adjustments can be done "by hearing".

4.1. Superheterodyne AM Receivers

On Pic.4.1 you can see the block diagram of a radio-broadcast superheterodyne receiver
The input circuit (UK) refines the signal of the tuned station from all the voltages created in the antenna (A) by various radio transmitters and sources of disturbances. In our example, it's an AM signal that has the carrier frequency fs, and is modulated by a single tone, as seen in the rectangle above its label. This signal is being led into the stage called the mixer. Another voltage is also led into it, the voltage from the local oscillator that has the frequency of f0, and a constant amplitude. Under the effect of these two signals, the phenomenon called the outbreak takes place in the mixer, and an AM signal appears on its output, its frequency being fm=455kHz. This signal is called the inter-frequency (IF) signal, and its frequency fm the interfrequency. The IF signal has the same envelope as the station signal entering the mixer. That means, that the information from the transmitter to the mixer is carried by the signal frequency fs, and in the mixer it is being assumed by a new carrier, that has the frequency fm. When transferring to another station, the user changes the capacitance of the variable capacitor C by turning the knob, setting up the resonance frequency of the input circuit to be equal to that station's one. Another variable capacitor, Co, is located on the same shaft as C, so its capacitance changes simultaneously to that of C. This capacitor is located in the local oscillator and that is how it gets the new oscillating frequency, having such value that the difference of the oscillator and station frequencies is again equal to the inter-frequency value.
Here's one numerical example. The interfrequency is being adopted by the constructor of the device, and it is mostly fm=455 kHz. When the receiver is set to the station that has the frequency of fm=684 kHz, the frequency of the local oscillator shall be fO=1139 kHz, therefore making there difference be
1139 kHz-684 kHz=455 kHz=fm.
When tuning to a station that operates on the frequency of fS=1008 kHz, the listener will change the capacitances of the two capacitors until the resonant frequency of the input circuit becomes fS=1008 kHz, and the oscillator frequency fO=1463 kHz, therefore yielding 1463 kHz-1008 kHz=455 kHz=fm.
If the receiver has more wavebands (LW, MW, SW1, SW2…) it is being constructed to have the same inter-frequency value for all of them.
What do we gain with this change of the carrier frequency? So far we haven't mentioned one very important thing, that is that the input circuit can never be selective enough, to extrapolate only the signal of the tuned station, from all the signals that exist in the antenna. On the output of this circuit, besides the station signal, also signals of strong and local transmitters are obtained, especially the signals from the neighbouring channels (their frequency being very close to the one of the tuned station). All these signals are receiving new signal carriers in the mixing stage, with their frequencies deviating fm as much as their carrying frequencies differ from fS. E.g., if the input circuit is set on the station whose frequency is 1008 kHz, another two signals from the neighbouring channels can also emerge on its exit.

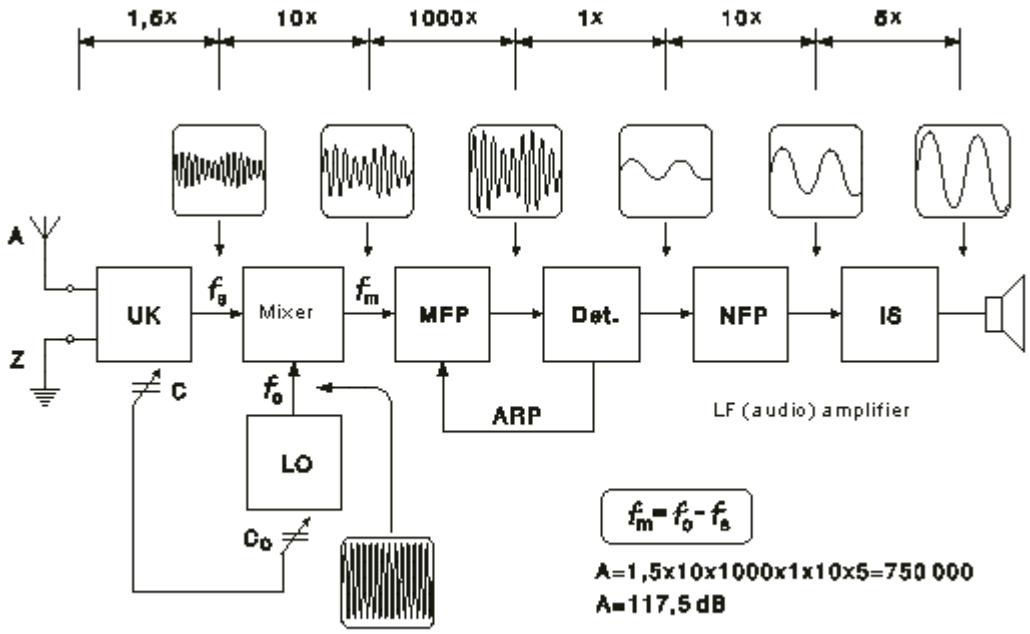

Pic.4.1. Block diagram of a superheterodyne AM receiver

Their frequencies would be 999 kHz and 1017 kHz. The ordinary TRF receiver would in this case be totally incapable of suppressing those signals, which is not the case with the superheterodyne receiver. These 3 signals are entering the mixer, which gets the 1463 kHz voltage from the oscillator. The outbreak occurs, and 3 AM signals are exiting the stage, their frequencies being 455 kHz, 464 kHz and 446 kHz. All 3 signals go to the IF amplifier (MFP), which has several amplifying stages with oscillatory circuits set to 455 kHz, making it very selective, so it amplifies only the 455 kHz signal and suppresses the others enough not to disturb the reception.
the signal exiting the IF amplifier is led onto the detector (Det.), the LF voltage amplifier (NFP) and the output stage (IS), the circuits we spoke about in the previous projects.
The ARP signifies the circuit that turns back the DC component of the detected signal into the IF amplifier, to obtain the automatic amplification regulation.
Above every block on the picture you can see the signal shape exiting that block, as seen on the oscilloscope, in case the modulation in the transmitter is done by the single, sinusoidally-shaped tone. The upper part of the picture contains the average voltage amplifications for each block, for the mass-production devices. Total voltage amplification, which is the ratio of the voltage on the loudspeaker to the voltage in the antenna is A=750000. The amplification in decibels is therefore: A(dB)=20logA=117.5

4.1.1. The Simplest Superheterodyne AM Receiver

The author presumes that most of the readers, especially those just entering the world of radio with this book, are somewhat scared by the block diagram from Pic.4.1. Their question probably is: Can an amateur build such a receiver? Yes, he can. The author has a friend that succeeded in this some 40 years ago, when all had been done with the electronic tubes, making the practical realization of a receiver much harder than it is today, with semiconductors (its radio amateur call sign is YT1FA, and those who doubt it may contact him). However, he was doing this in the premises of YU1EXY Radio Club, in the attic of the Electrotechnical Faculty in Belgrade, using the club (more less trophy) instruments and, more important, he had help of Sasa Piosijan, Radivoje Karakasevic and Kiro Stojcevski,

who knew all about the radios, especially Sasa.
The main problem in making a superheterodyne device is not the circuitry complexity but its setup, which requires lot of practical experience and some special instruments, that our readers probably don't possess. But they are much better than the TRF receivers, both regarding the sensitivity and selectivity, so we made simpler devices that are simple to set, with no instruments necessary than your ears. They are realized around the NE612 IC, whose pin description, block diagram and main features are given on Pics.4.2-a & b.
This IC comprises the critical stages of an AM superheterodyne receiver, the mixer and local oscillator. the station signal is led either on pin 1 or on pin 2 (or on both of them, in case of symmetrical coupling with the previous stage), and the IF signal is obtained on the pin 4 or 5 (or on both of them, in case of symmetrical coupling with the next stage). An oscillatory circuit, that determines the frequency of the local oscillator and the positive feedback circuit are connected between the pins No.6 and 7. Pin 3 is connected to Gnd, i.e. the minus pole of the DC supply voltage. Pin 8 receives a positive DC supply voltage which can, acc. to the table given on Pic.4.2, vary between 4.5 V to 8 V. The value of this voltage is not critical, but it is extremely important for normal operation of the receiver that this voltage is stable, therefore urging for it to be separately stabilized (with special care), as seen in some projects in this chapter and in the Appendix, that involve the NE612.
In the text that follows 3 simple superheterodyne receivers made with NE612 will be described.

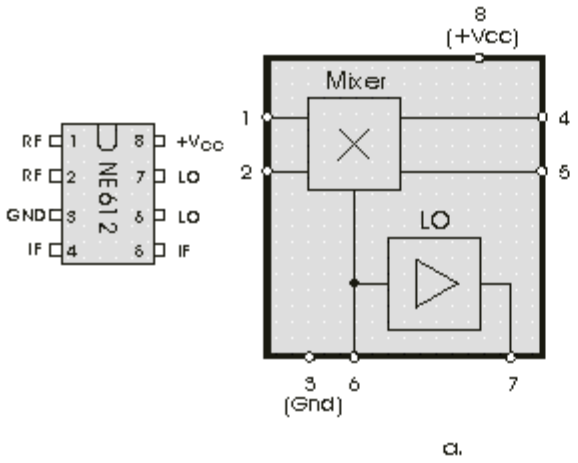

a.

NE612 IC Characteristics (NE602, SA612, SA602)

Parameter	Symbol	Range	Unit
Supply Voltage	V_{CC}	4,5 ··· 8	V
Supply Current	I_{CO}	2,4 ··· 3	mA
Input resistance (between 1&2 & Gnd)	R_{in}	1,5	kΩ
Output resistance (between 4&5 & Gnd)	R_{out}	1,5	kΩ
Mixer amplification	A_{mix}	14 ··· 17	dB
Maximum oscillator frequency	f_{omax}	200	MHz
Maximum mixer frequency	f_{Mmax}	500	MHz
Outside oscillator votage	U_O	200	mV

b.

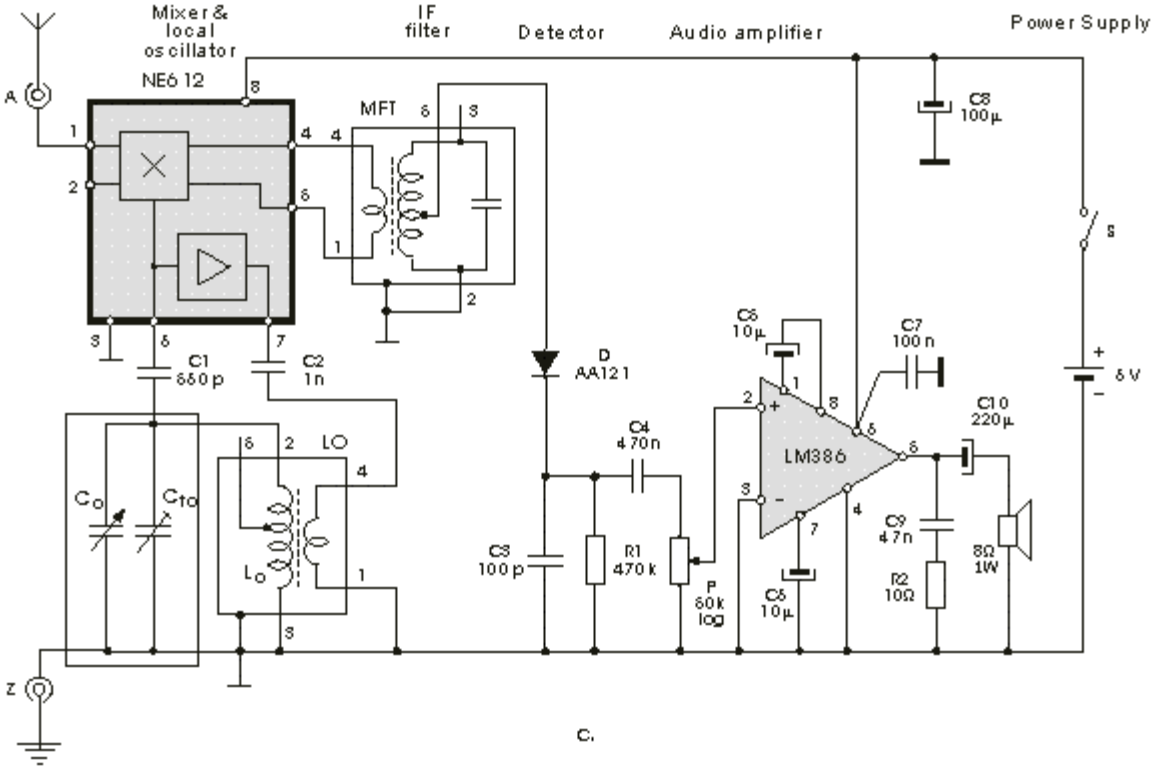

c.

Pic.4.2. The simplest superheterodyne AM receiver: a-pin layout and block diagram of the NE612, b-IC technical data, c-electronic diagram of the receiver

More will be discussed in the chapter dedicated to NE612 IC, and the reader should pick one of these, or make the receiver that suits him best by combining these diagrams with earlier described HF amplifiers and input circuits.

The electronic diagram of the simplest superheterodyne AM receiver in the world, with reproduction over the loudspeaker, is shown on Pic.4.2-c. The device has got only one oscillatory circuit in the IF amplifier (being marked as MFT), whose frequency does not need to be set to some specific value (meaning the receiver will work OK even if its frequency is bigger or smaller than standard 455 kHz). Further simplification was done by omitting the

input circuit, therefore avoiding the problems with quite complex adjustments between the input circuit and the local oscillator. All these simplifications do have their price: this device is less sensitive and selective than the complete superheterodyne, and is also more prone to disturbances. Even so, it has better both the selectivity and sensitivity than the TRF.
Signals of all the stations are being led directly from the antenna onto the pin no.1, i.e. the mixer. On the other hand, the mixer also receives the HF voltage from the local oscillator, whose frequency is equal to the resonance frequency of the parallel oscillatory circuit made of CO, CtO, and LO. This frequency, if neglecting the parasite capacitances, is:

$$f_o = \frac{1}{2\pi\sqrt{L_o(C_o + C_{to})}}$$

On the mixer exit the signals from all the stations are obtained, but now they have new carrier frequencies, that are equal to the difference of the oscillator frequency and their original one. Nevertheless, only one of these signals will have the frequency that is equal to the resonance frequency of the MFT, and it will be the only one to appear on the ends of this oscillatory circuit. Here's a numerical example.

Let us assume that we have (only) 3 MW signals in the antenna, having the frequencies of fS1=711 kHz (Nis), fS2=855 kHz (Bucharest) and fS3=1008 kHz (Belgrade 2). The IF transformer frequency could be fm=455 kHz. If we set the frequency of our oscillator on fm=1166 kHz (with CO), the following signals, modulated by the radio stations' programs, will exit the mixer:

fm1=f0-fS1=1166-711=455 kHz,
fm2=f0-fS2=1166-855=311 kHz and
fm3=f0-fS3=1166-1008=158 kHz.

Since the oscillatory circuit on the mixer exit (MFT) is set to 455 kHz, we will have Radio Nis's signal from it, others will be suppressed. If we wish to hear Bucharest, the oscillator frequency should be set to 1310 kHz, and for Belgrade 2 1463 kHz. Of course that the listener doesn't need to know all these frequencies, he will just turn the knob of CO until hearing the desired station's broadcast.
The IF signal is led from the pin 3 to the detector with AA121 diode. The LF signal is taken from the R1 resistor and over the capacitor C4 it is led to the volume potentiometer P and the audio amplifier.

* the MFT is also being called the inter-frequency transformer. It is a special type component that is hard to find in the ordinary electronic shops, therefore the radio amateurs are usually obtaining them from disused factory-made devices. The IF transformer is shown on Pics.4.3-a,b,c & d. As you can see it on 4.3-a, the MFT is, in fact, a parallel oscillatory circuit with a leg on its coil. The coil body has a ferrite core (symbolically shown with single upward straight dashed line) that can be moved (with screwdriver), which allows for the setting of the resonance frequency of the circuit, being mostly fm=455 kHz. The same body contains another coil, with less quirks in it. Together with the bigger one it comprises the HF transformer that takes the signal from the oscillatory circuit into the next stage of the receiver. Both the coil and the capacitor C are placed in the square-shaped metal housing that measures 10x10x11 mm (Pic.4.3-b). From the bottom side of the

housing you can see 5 pins emerging from the plastic stopper, that link the MFT to the PCB, being connected inside the MFT as on Pic.4.3-a. Besides them, there are also two noses located on the bottom side, that are to be soldered and connected with the device ground. Japanese MFT's have the capacitor C placed in the cavity of the plastic stopper, as shown on Pic.4.3-c. The part of the core that can be moved with the screwdriver can be seen through the eye on the top side of the housing, Pic.4.3-d. This part is coloured in order to distinguish the MFT's between themselves, since there are usually at least 3 of them in an AM receiver. The colours are white, yellow and black (the coil of the local oscillator is also being placed in such housing, but is being painted in red, to distinguish it from the MFT).
Un-soldering the MFT isn't that simple and is to be performed very carefully. The iron is not to be kept leaned too long on the pins, since there's danger of melting the plastic stopper. All the tin from the pins and noses has to be removed first, by the aid of the iron and the vacuum pump (or a piece of wire stripped from the antenna coaxial cable). You can then safely remove the MFT from its original PCB.

* Pics.4.3-a, b, c & d almost fully apply for the oscillator coil as well (LO). The only difference is that LO doesn't have the capacitor C. looking from the outside, LO and MFT can be distinguished only by the marking colour, until they're lifted from the PCB.

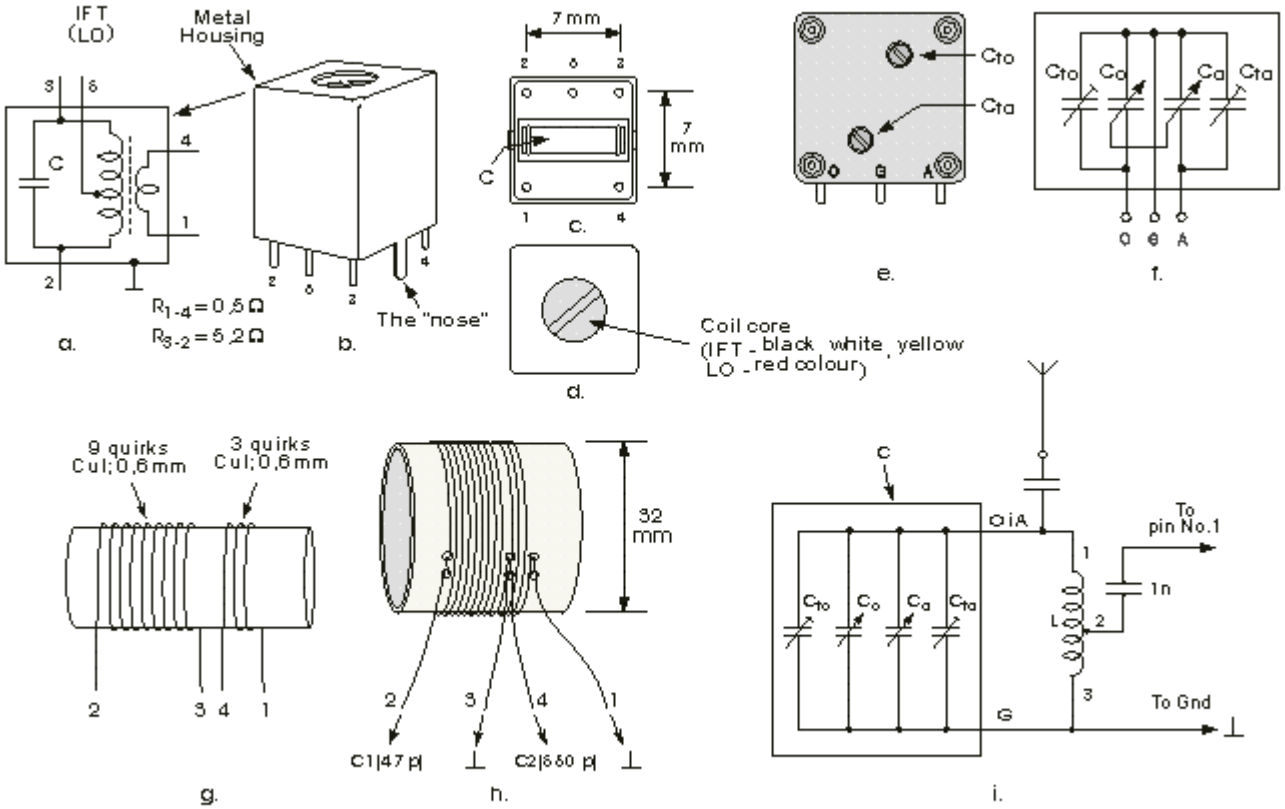

Pic. 4.3. Components of the receiver from pic.4.2: a,b,c,d-IFT and LO; e,f-variable and trimmer capacitors of the local oscillator, g,h-SW oscillator coil; i-independent input circuit

LO's have red colour, while MFT's (IFT's) are white, black or yellow. During the PCB design, absolute care must be taken that pins 1 & 4, as well as 2 & 3, do not permute. If that would

happen, the feedback would be negative (instead of positive) and the oscillator wouldn't function. However, if you conclude during the design phase that it would be more convenient to connect pin 4 to Gnd (instead of pin 1), do have in mind that it can be done only if you connect also pin 2 to Gnd (instead of pin 3).

* Fine tuning (if necessary) of the LO's and MFT's inductance values is done by adjusting the position of the ferrite core with screwdriver.

* With CO and CtO, variable capacitor and the trimmer capacitor in the oscillator are labelled. Acc. to Pic.4.3-e & f, which shows the capacitor we spoke about in the connection with Pic.3.7, the abovementioned capacitors are connected with the circuitry over the legs O and G (Ca and Cta are not used), with G connected to Gnd.

* The receiver from Pic.4.2 can be utilized for the reception of AM stations in the SW waveband. All there is to be done is to make a new oscillator coil, acc. to Pic.4.3-g & h. It is being made of 0.4 mm CuL wire (a thicker one can also be used), on the 32 mm diam. carton body, the same one used for making coils on Pics.3.6 & 3.28. Number of quirks on the picture is 9, but other combinations should also be tried, say, 12 quirks, or somewhat less than 9. The feedback coil has 3 quirks and is spooled along the oscillator coil (as shown on picture), or over it. If you have already accomplished the reception of SW stations with some of the previously described TRF devices, you will be surprised with much bigger selectivity of the receiver from Pic.4.2. in the evening hours you'll be able to perform the receipt of huge number of stations on the radio-broadcast, professional and amateur wavebands.
For the reception of SW stations smaller capacitances for C1 should also be tested, say, C1=33 pF and similar, since it affects the oscillator frequency.

* In the previous numerical example we saw that tuning is done by setting up the frequency of the local oscillator and that fm=455 kHz, Radio Nis will be heard when the oscillator frequency is fO=1166 kHz. The story is not over, though: What will happen if there is a station that operates on 1621 kHz? Mixing its signal with the voltage from the local oscillator the modified signal is made, its frequency being
1621 kHz-1166 kHz=455 kHz.
We now have two signals on the MFT. They both have the same carrier frequency (455 kHz), one of them is program of Radio Nis, and the other comprehends the program of the station transmitting on 1621 kHz. Both of them are being heard in the loudspeaker, the interference occurs. Speaking in expert language, the obstruction because of the symmetrical station occurred. That is a station whose frequency fSS iz greater than fm for the value of the oscillator frequency:
fSS=fO+fm
Suppressing the symmetrical station signal must be done before the mixing stage. In the radio-broadcast receivers this is being done over the input circuit, and in the professional devices, by input circuitry and the HF amplifier. If you have experienced disturbances while using the receiver from Pic.4.2 (mixing of stations or, more common, whistling or squeaking tone) try changing the MFT's oscillation frequency (by turning the ferrite coil), then re-tune the receiver.

* If the receiver from Pic.4.2 is power-supplied from the battery (or adaptor) whose voltage is over 6 V, a voltage stabilizer should be inserted in the plus (+) line of the power supply for NE612, as it was done with the receivers on Pics. 4.4, 5.7 and 5.9.
If you cannot receive the signal of some station transmitting on 1500 kHz, not even with the capacitor CO knob in the rightmost position, start reducing the CtO capacitance (turning the trimmer with screwdriver) until you hear the signal. similarly, if you can't hear some station you're fond of, that transmits on 500 kHz (e.g. Radio Budapest), try increasing the LO inductance (by turning the core towards inside with screwdriver). If this doesn't succeed, change a little the MFT frequency, then try again.

* The reception can be significantly improved if input circuit (UK) is added to the receiver. In order to avoid problems with attuning the UK and the LO, the UK with special variable capacitor can be used, as on Pic.4.3-i. It is "our" capacitor from Pic.3.7, with all the capacitors connected in parallel, and "our" coil from Pic.3.6. Station tuning is now being done with two buttons, which isn't "a job for everyone". The receiver is first roughly tuned to the station using these two buttons, and then the optimum reception is carefully searched.

* If you omit the amplifier with 386 IC on the Pic.4.2, and connect high-resistance headphones instead of R1, it is the truly the simplest superheterodyne receiver in the world.

4.1.2. The Fully (not exactly 100%) Superheterodyne AM Receiver No.1

Its electrical diagram is given on Pic.4.4. It is easily being noticed that this is the receiver from Pic.4.2 with inter-frequency (IF) amplifier with ZN415E added.
By adding ZN415 IC multiple enhancements are performed. Thanks to its huge input resistance, the MFT's oscillatory circuit is not choked, resulting in better selectivity. The sensitivity of the device is extremely increased since this IC has big amplification and the AAR (automatic amplification regulation) is also accomplished, making the usage of this device easier and more comfortable.
* It is very important to obtain the necessary value of the DC voltage in pin 6 of the ZN415 for its proper operation. Acc. to the table on Pic.3.36 it has to be about 1.3 V, and its setting is done via the TP1 trimmer. The receiver is set to some weaker station, the sound volume is made very low with potentiometer P, and the slider of the TP1 is carefully moved until the best reception is made. If that doesn't work, one should try changing the value of R5 resistor; this is to be done also if the supply voltage being used is other than 12 V. In case of voltage on the pin being much bigger than 1.3 V, and cannot be reduced on the trimmer, short-circuit one of the diodes.
* The voltage stabilizer with 78L06 isn't needed if the receiver is supplied from the 6 V battery.
* The receiver from Pic.4.2 needs input circuit to be 100% complete. That can be an independent input circuit from Pic.4.3-i, or input circuit and the HF amplifier that are described in the Appendix (Pic.5.10). If the former circuit is used, station tuning is being accomplished with 2 knobs, as explained in the previous chapter.

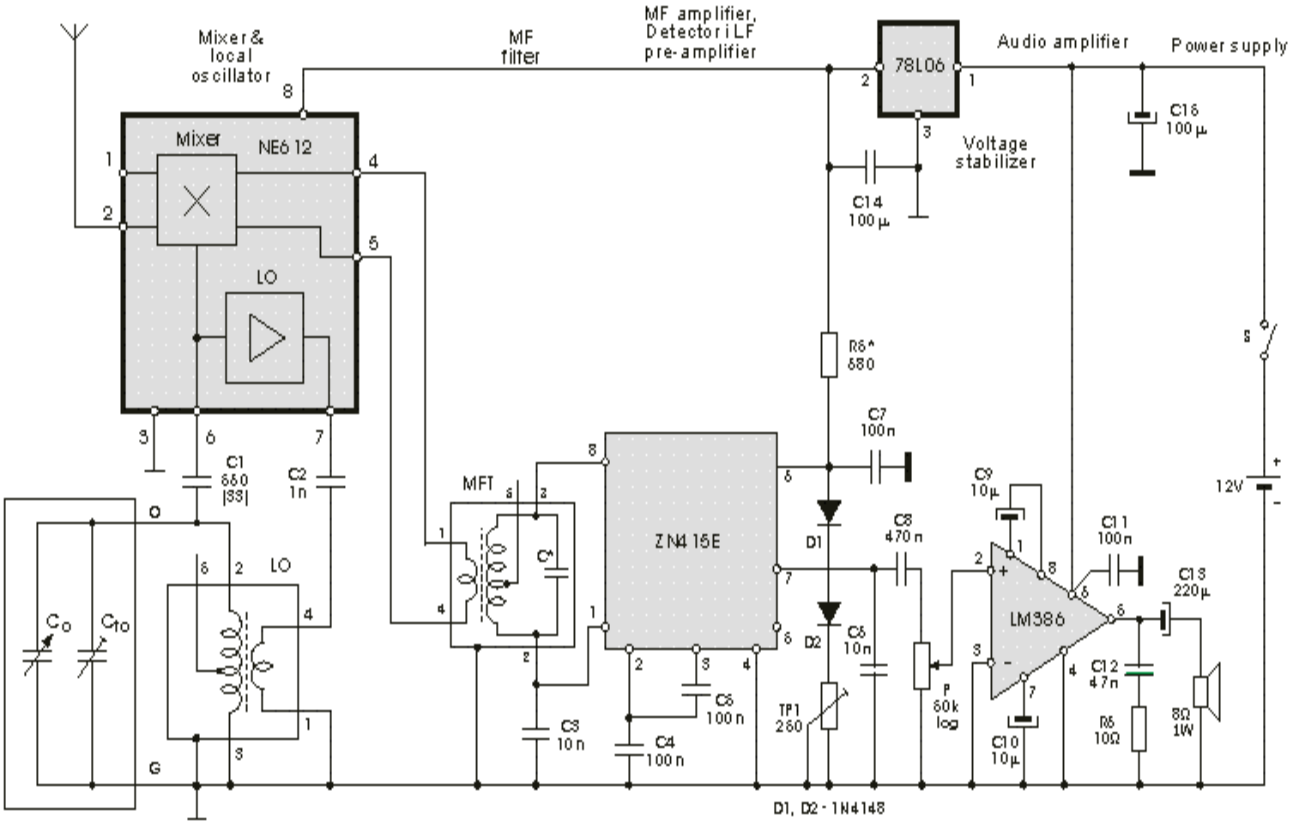

Pic.4.4. Superheterodyne AM receiver with NE612, ZN415E & LM386

4.1.3. Fully (not exactly 100%) Superheterodyne AM Receiver No.2

All the receivers we made with NE612 IC were tested in our lab, except the one from the previous project, since we didn't have ZN415 "with us". We found, however, a ZN414 IC, so we tested the receiver from Pic.4.5 with it. The receiver was working great, from the amateur's point of view. He played us for long time, until we didn't require the board to test one of the receivers from previous projects afterwards, when we regretfully had to disassemble it.

* The diagram is very similar to that on Pic.4.4, so most of the things said about that receivers stands for this one, too.
* DC voltage setting on pin 1 of ZN414 is done with the trimmer TP. Its slider is put in mid position, the receiver is tuned to some weaker station close to the upper bound of the bandwidth. While making the reproduction very quiet (slider of P as low as possible), the trimmer slider is moved until reaching optimum reception. After that the trimmer is disconnected, its resistance measured and the ordinary resistor of similar value is put into circuit.
* The device operates nicely with the outside antenna made of a piece of wire measuring only half metres in length.
* The reception would certainly become better if an input circuit would be added, which we spoke about in the previous project.
* The receivers from pics. 4.4 and 4.5 can, with appropriate coils in the oscillator, accomplish the reception of AM stations from all the bandwidths from 70 kHz till 200 MHz.

4.2. Superheterodyne FM Receivers

The FM receivers being described in chapter 3.15 are the amateur solutions. These are extremely simple devices, that cannot perform the noiseless tuning, automatic oscillator frequency regulation and other features that ensure very high quality of the reproduction, being expected from an UHF FM receiver. The true solution is the superheterodyne FM receiver, whose block-diagram is given on Pic.4.6.
Station signals are taken from the dipole antenna and led through the appropriate cable into the input circuit (UK). Inside it, the signal selection is performed, of station whose frequency is fS, this signal is then amplified in the HF amplifier and led into the mixer. As in the case of earlier described AM receiver, the inter-frequency signal is obtained at the mixer output, whose carrier frequency is fm=10.7 MHz (this is the standard value, used in all radio-broadcast FM receivers). The IF signal is being amplified in the IF amplifier and led on the amplitude limiter (Ogr.). In this stage the signal whose amplitude exceeds certain level is being cut off, accomplishing with this the elimination of the parasite amplitude modulation, which is performed by various noise sources during the transmission (atmospheric charges, various electrical devices etc.), which significantly improves the signal quality. The signal then goes to the FM signal detector, where the information being modulated in the transmitter is extrapolated from the signal, followed by the LF part of the receiver. With AFC the circuit that performs the automatic frequency regulation of the local oscillator is labelled.

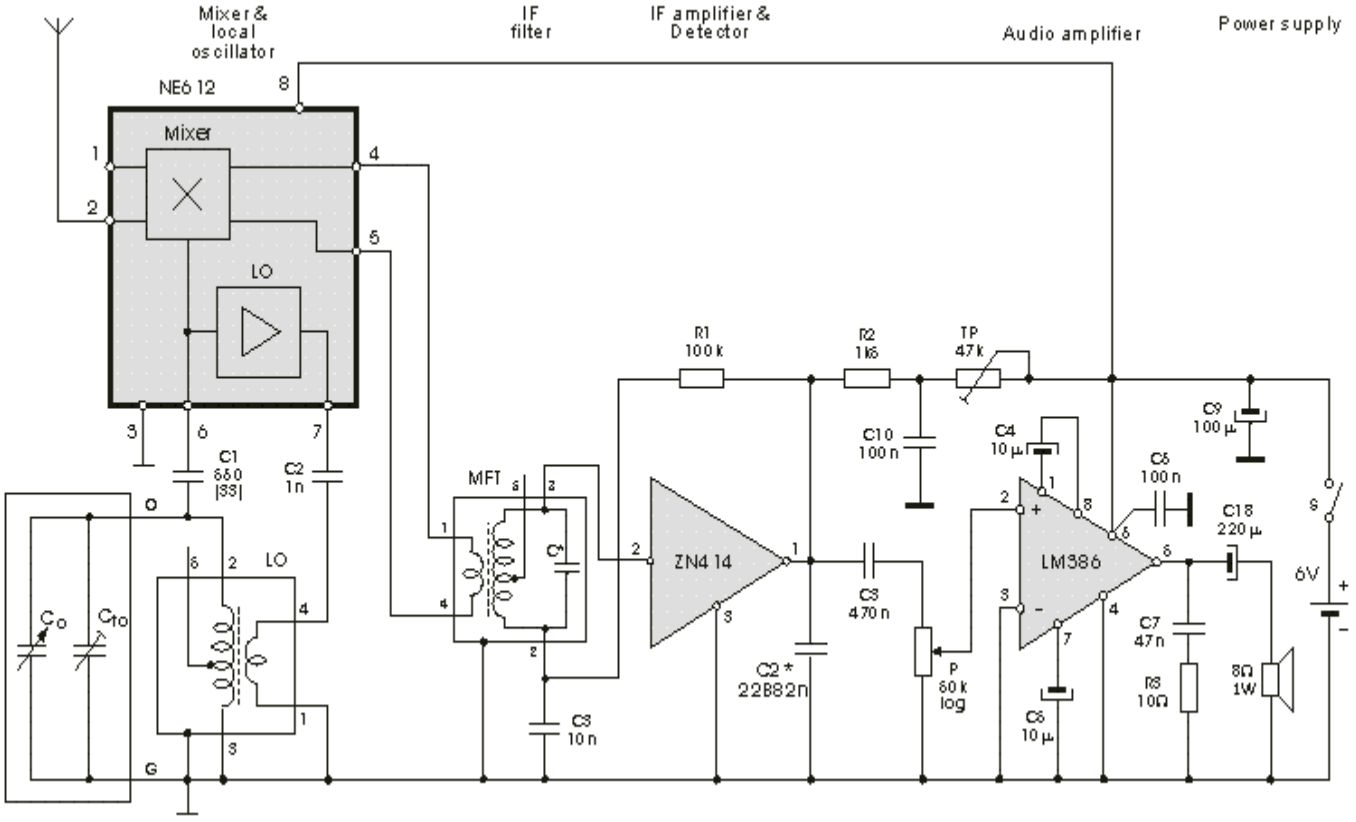

Pic.4.5. Superheterodyne AM receiver with NE612, ZN414 & LM386

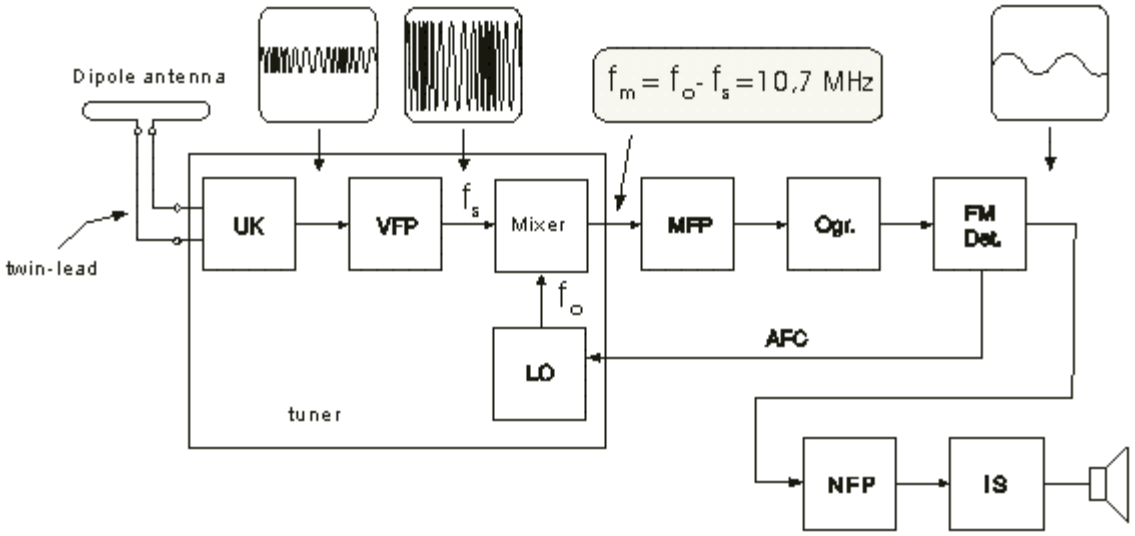

Pic.4.6. Block diagram of the monophonic superheterodyne FM receiver

4.2.1. FM Receiver with TDA7000

The face that FM receivers operate on pretty high frequencies makes their practical realization somewhat difficult, but most of the problems, as in many other amateur builds, originates from building the coils, except the self-bearing, small-inductance coils (without the coil body), which are easy to make, especially if there aren't many of them in the device and if no special instruments are required for setting up their proper inductance value. The coils used in this FM receiver are just like this, and there are only two of them, making the practical realization much easier.
The basic data about the famous Philips' IC used in this project, TDA7000, are given in the following table.

Supply Voltage	2,7 ÷ 10	V
Current Consumption (U_s=4,5V)	8	mA
Frequency Bandwidth	1,5 ÷ 100	MHz
Sensitivity	1,5	mV
LF signal on pin 2	75	mV
Package - DIL-18 ;SOT102-1	-	-

Electronic diagram of the HF part of the device (from antenna to the LF output) built with TDA7000 is shown on Pic.4.7. As one can see, it is a simple device, made with relatively small number of components. The IC contains all the stages of the superheterodine receiver: the mixer, the oscillator, the IF amplifier, the amplitude limiter, the FM detector and few others. More about them will be told in the next project which contains the description for a receiver with TDA7088T IC, which is the improved version of TDA7000.
The station signal is from the (telescopic) antenna led to the input circuit that consists of L2, C13, C12 and C14. It is a parallel oscillatory circuit damped with R3 resistor, which has the

reception bandwidth from 88 MHz till 108 MHz (it admits all the UHF signals on the pin 13, and weakens te signals outside the reception bandwidth). Inside the IC the signals are led into the mixer, where they are being given new carrier frequencies. The IF amplifier then follows, amplifying only one of those signals, the one whose frequency is equal to the inter-frequency, followed by the limiter, the FM detector, mute circuit and LF pre-amplifier. The output from the last stage is on the pin 2 (R2 is the collector load of the last transistor in the LF pre-amplifier). The oscillatory circuit of the local oscillator (L1, Cp, Cs, C and C5) is connected between pins 5 and 6.
Pic.4.8-a shows the PCB of the device from Pic.4.7, while Pic.4.8-b contains the component layout (on the PCB). The complete device can be seen on Pic.4.8-c. The variable capacitor from Pic.3.8 is used as the only variable capacitor here since the input circuit is aperiodic, the legs marked with FO and G. This capacitor serves us to tune the receiver to stations. In the LF part of the receiver, the amplifier made with LM386 from Pic.3.19 is utilized (the components left from the potentiometer are omitted).
* L1 and L2 are the self-bearing coils (without the core). They have few quirks and are made of relatively thick wire, therefore they don't need a body of any kind, that is why they are called "self-bearing". Their appearance is shown on Pic.4.9, and the calculus for them is done acc. to the table from Pic.3.5. They both have 6 quirks of the CuL wire, 0.6 mm in diameter, being spooled on the flat part of the 3 mm drill. In order to be able to solder the coil onto the PCB, the couple of mm of isolation has to be removed from the wire ends with sharp knife, and they have to be tinned afterwards. There must be a small gap between the adjacent quirks. The inductance of the coil is set by its shrinking (the inductance increases) or stretching (the inductance decreases). Stretching can be nicely done by inserting the screwdriver between the quirks and then turning it along the coil.
* The TDA7000 also contains the mute circuit (for noiseless tuning). It is being active when the S2 switch is open. Pocket-type receivers usually do not have S2 and R1 elements.
* The part of the receiver that requires biggest care during build is the oscillatory circuit of the local oscillator, which is connected between the pins 5 and 6. When changing the capacitance of C, its resonance frequency must change from 88 MHz (C=Cmax) till 108 MHz (C=Cmin). If that cannot be accomplished (not all the stations can be heard) some experimenting is required with capacitances of Cp and Cs. For start, you should omit the Cp. If the problem persists,

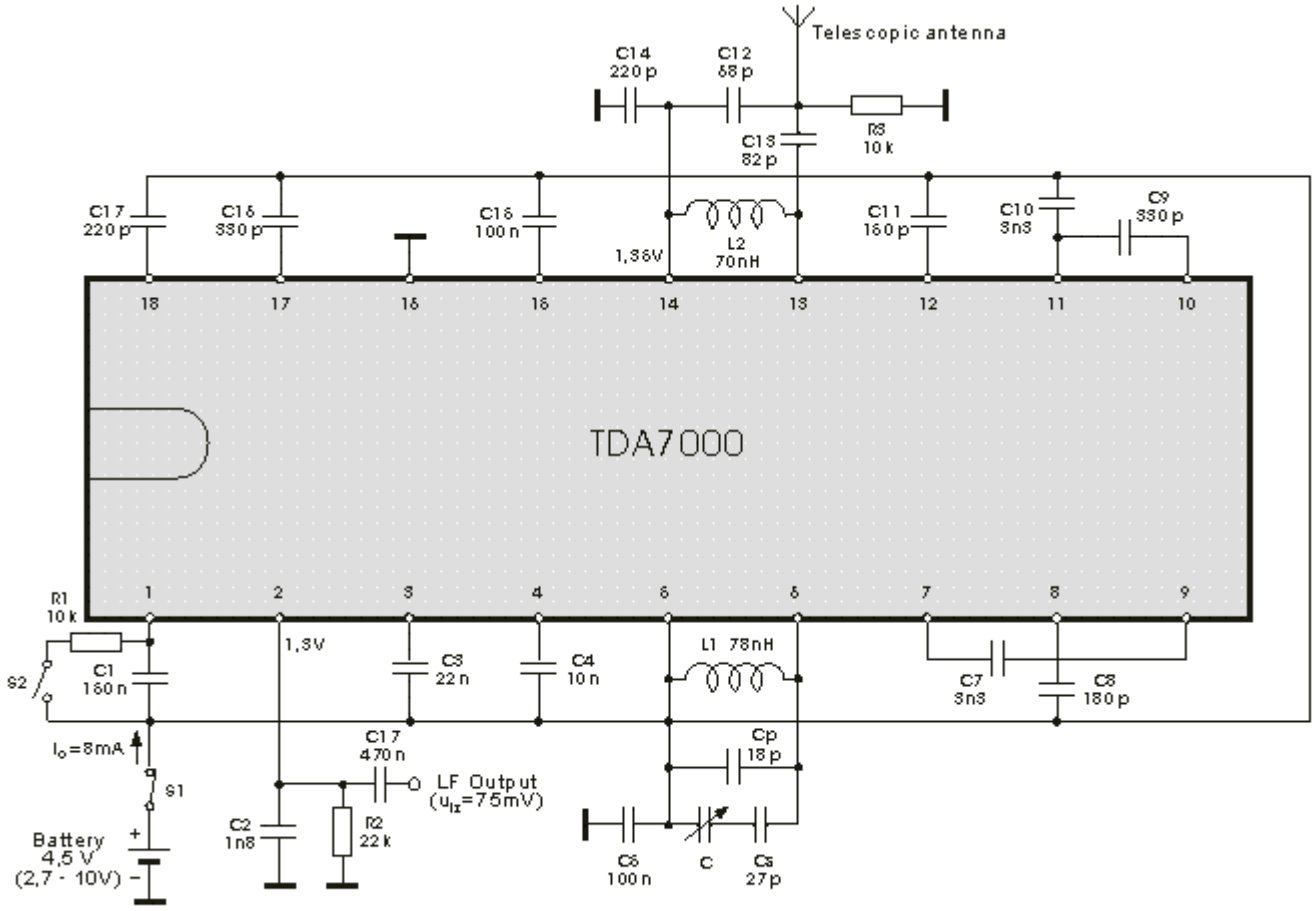

Pic. 4.7. FM radio receiver with TDA7000

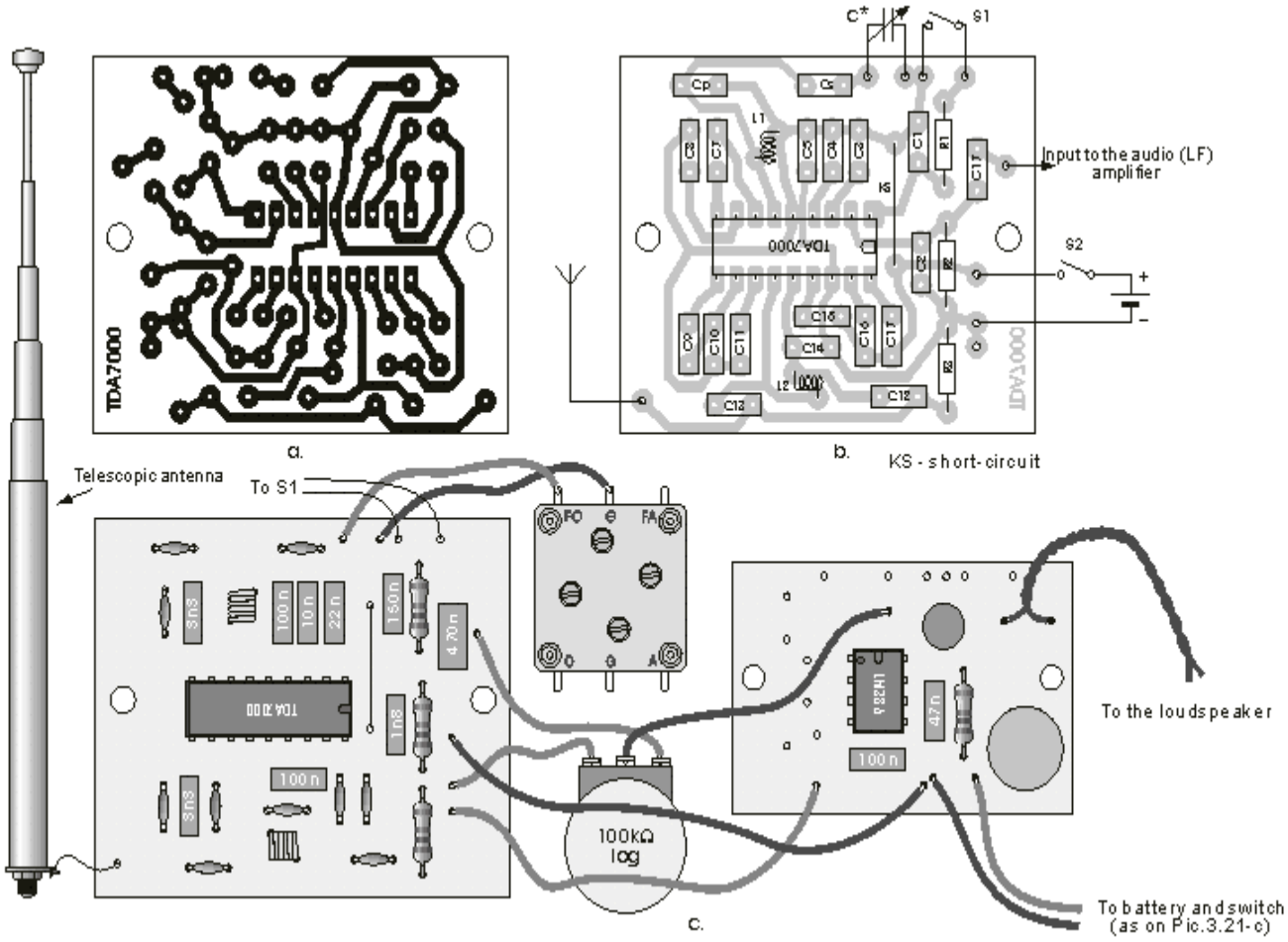

Pic.4.8 Practical realization of the receiver from Pic.4.7: a-PCB, b-component layout, c-complete device

capacitance of Cs should be reduced (to 15 pF, 10 pF etc.), or it should be short-circuited. You can also try compressing or stretching the L1 coil, etc. The setup of the oscillatory circuit is completed when with C=Cmax some station that operates on app. 88 MHz can be heard, and with C=Cmin the one that works on 108 MHz.
The input circuit setup (it is connected between pins 13 and 14), is performed by tuning the receiver to some mid-range station (about 98 MHz). Then, the best possible reception is searched, by changing capacitances C13 and C12 and inductance L2.

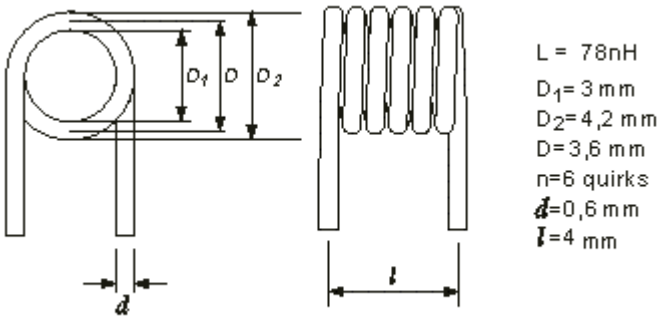

Pic.4.9. Coils for the receiver from Pic.4.7

4.2.2. FM Receiver with TDA7088T IC

The receiver described in the last project has two IC's, one variable capacitor, two small coils and fairly small few other components, so it can be put into some small box, by carefully placing the components. Further miniaturization can be accomplished by using the SMD components. These are the resistors, capacitors, transistors, IC's and other components, whose dimensions are significantly smaller than these of "classical" components. They are mounted on the copper side of the PCB, therefore it isn't necessary to drill the holes on the board. TDA7088T is also an SMD component. Its drawing is shown on Pic.4.10.
This IC is the successor of the famous TDA7000, i.e. it is an improved model of TDA7000, that allows to implement both monophonic and stereophonic FM receiver. The basic features of TDA7088T are given in the following table.

Supply Voltage	1,8 ÷ 5	V
Consumption current (U_s=4,5V)	4,2 ÷ 6,6	mA
Frequency bandwidth	0,5 ÷ 110	MHz
Sensitivity	3	mV
LF signal on pin 2	85	mV
Package - DIL-18 ;SOT102-1	-	-

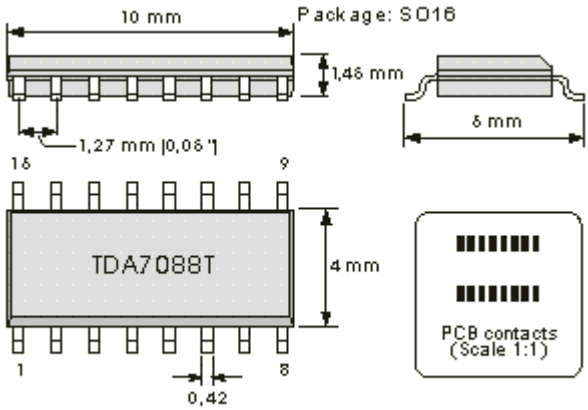

Pic.4.10. TDA7088T IC Layout

The electronic diagram of the HF part of the monophonic FM receiver made with TDA7088T IC is given on Pic.4.11. The IC contains all the parts of the classic superheterodyne receiver: the local oscillator, IF amplifier and FM detector, but also some other circuits that extend the possibilities and improve the features of this IC.
As far as practical use is concerned, the most significant novelty is the auto-tuning circuitry. No variable capacitor is necessary for tuning, as it was in all the previous projects, the BB910 varicap diode is used instead. Its capacitance is being changed by varying the DC voltage supplied to its anode over the 5k6 resistor. This is how the tuning is performed: When the user press and releases the pushbutton marked with "RUN", the positive voltage impulse is released to the S(et) input of the SEARCH TUNING circuit. The 100 nF capacitor then starts chargingl and the voltage on the pin 16 increases. This voltage is then

transferred, over the 5k6, to the anode of the BB910, causing its capacitance to decrease, which increases the frequency of the local oscillator (VCO). The VCO voltage is led into the mixer (MIXER) which also receives, over pin 11, the signals of all the other FM stations. The mixer outputs the FM signals whose frequencies are equal to the differences of the oscillator and the original station frequency. The only signal that can reach the demodulator (FM detector) is the one whose carrier frequency is equal to the inter-frequency, i.e. fm=73 kHz (selectivity is being accomplished by two active filters whose components are the capacitors connected to pins 6, 7, 8, 9 and 10). Therefore, the oscillator frequency increases until it gets the condition fO-fS=73 kHz is accomplished. When this happens, the charging of the capacitor is halted by the command that is sent into the SEARCH TUNING circuit by two detectors (diode-blocks) located in the MUTE circuit. The AFC (Automatic Frequency Control) circuit now gets its role and prevents the voltage on pin 16 to be changed, until the RUN button is pushed again (this voltage can vary from 0 V til 1.8 V during the tuning).
When the RESET button is pushed, the 100 nF capacitor is discharged, the voltage on pin 16 drops down to zero, and the receiver is set to the low end of the reception bandwidth, i.e. 88 MHz.
Let us get back to the mixer. On its output, the 73 kHz FM signal is obtained, and it is modulated by the programme of the first station that is found after the RUN button is pushed. This signal then passes the active filters, gets amplified in the IF amplifier (IF LIMITER) and passed onto the input of the demodulator. By connecting the demodulator exit, over the LOOP FILTER, the adder (+) and resistor, to the VCO, the so-called FFL (Frequency Feedback Loop) circuit is accomplished, reducing the deviations of the signal being received from ±75 kHz to ±15 kHz.
The LF (AF) signal is led from the demodulator, over the LOOP FILTER stage, the invertor (-1) and MUTE circuit onto the pin 2. The detectors (diode-blocks) control the operation of the MUTE circuit, preventing the LF (AF) signal to reach the output pin (2) until the tuning on the station that creates the signal in the antenna that is strong enough for quality reception is obtained.

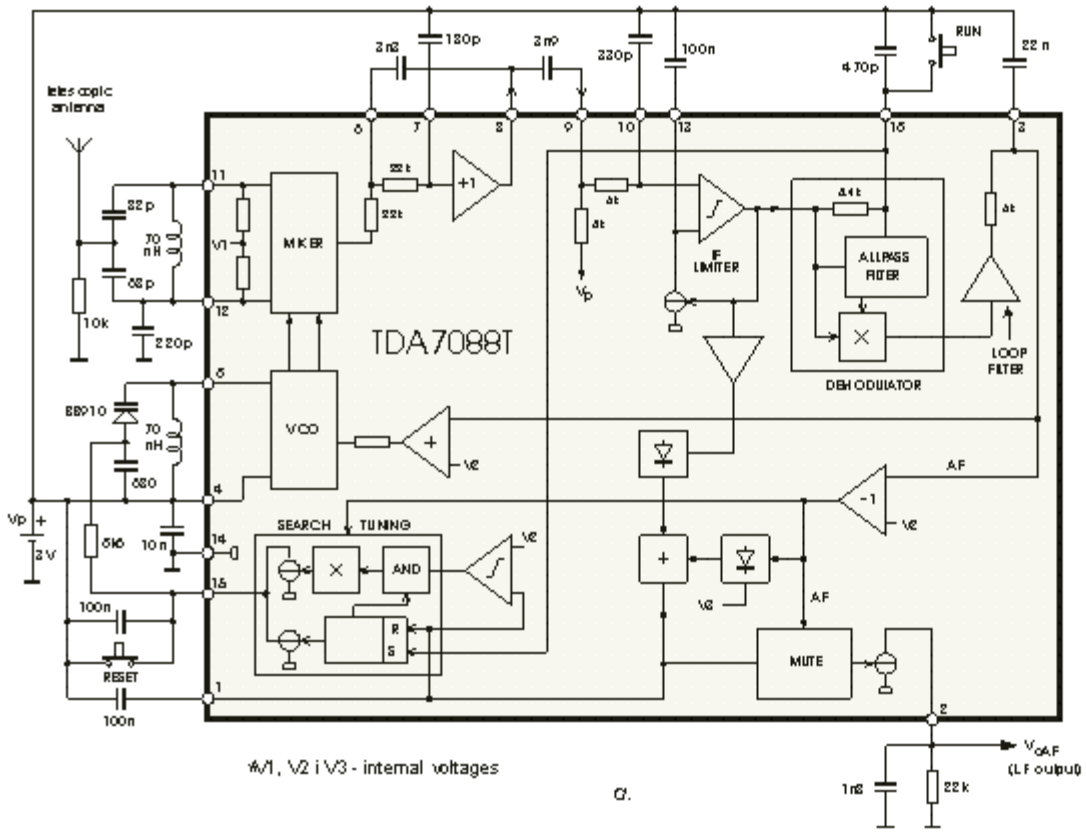

MUTE - output from the circuit for noiseless tuning
$V_{o\,AF}$ - output LF signal
LOOP - AF LOOP FILTER output
V_p - positive end of the battery (+3 V)
OSC - connection to the oscillatory circuit
IF FB - feedback
C_{LP1} - 180pF - LF filter capacitor
$V_{o\,IF}$ - output from +1 dB amplifier
$V_{I\,IF}$ - input to IF amplifier
C_{LP2} - 330pF LF filter capacitor
V_{IRF} - mixer input
C_{LIM} - capacitor of the limiter offset voltage
GND - ground, minus battery pole (0V)
C_{AP} - 470p F capacitor of the ALLPASS FILTER; input to the SEARCH TUNING circuit
TUNE - electronic tuning; AFC output

V1, V2 i V3 - internal voltages

Pic.4.11. TDA7088T: a- block diagram, b-pin layout

4.2.2.1 Mini FM Receiver

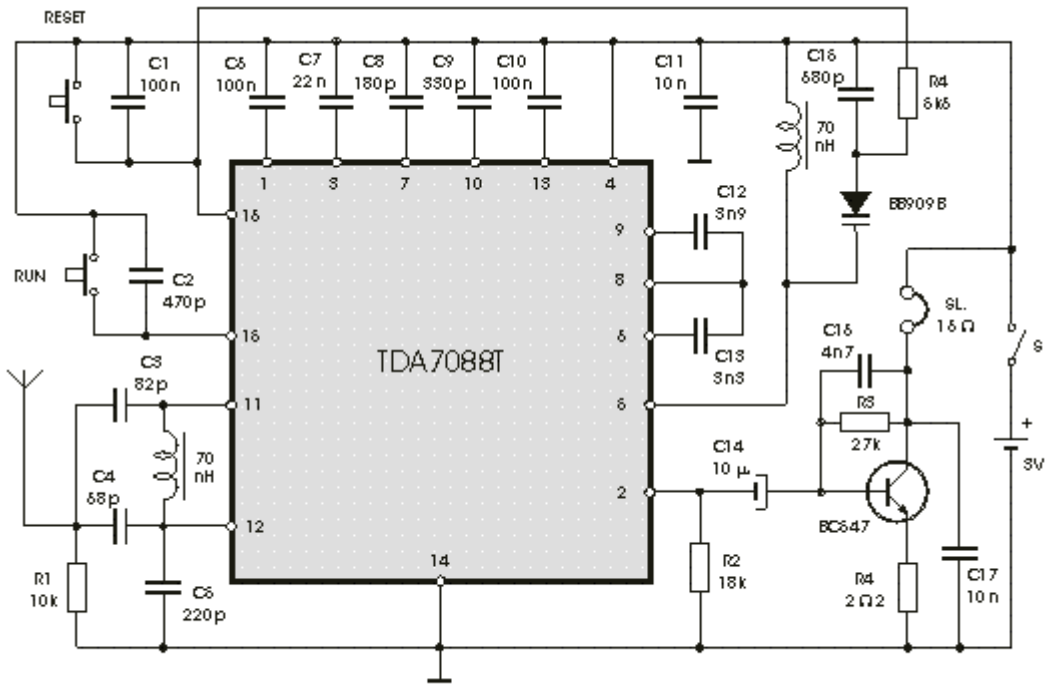

Pic.4.12. Electronic diagram of the monophonic FM radio receiver with electronic tuning

The electronic diagram of the monophonic FM receiver made with TDA7088T is shown on Pic.4.12. If built with SMD components it can be placed in a matchbox, altogether with two button-type batteries. The operating principle of this device is given in the previous chapter. The only thing new is a very simple audio amplifier made with BC547 transistor, which is loaded by cheap 16-Ohm headphones. The telescopic antenna is used, as on Pic.4.8.
Small mishap of this receiver is that it has no indication of station tuning. This problem can be solved by adding a small voltmeter in parallel to the BB909, whose scale is graduated in MHz, as described in the Appendix. This solution is not appropriate for the miniature receiver, since the voltmeter that has the scale that is big enough takes too much space. It is in this case better using a manual tuning instead of automatic. Such solution is given on Pic.4.13.
The tuning is done via the variable capacitor C with numbers written on its button, similar to that on Pic.3.11. It is most simple to use numbers from 1 to 10. The variable capacitor is like the one on Pic.4.8. Some experimenting is to be done with capacitances of Cx and Cy, in order to cover the entire reception bandwidth, from 88 till 108 MHz.

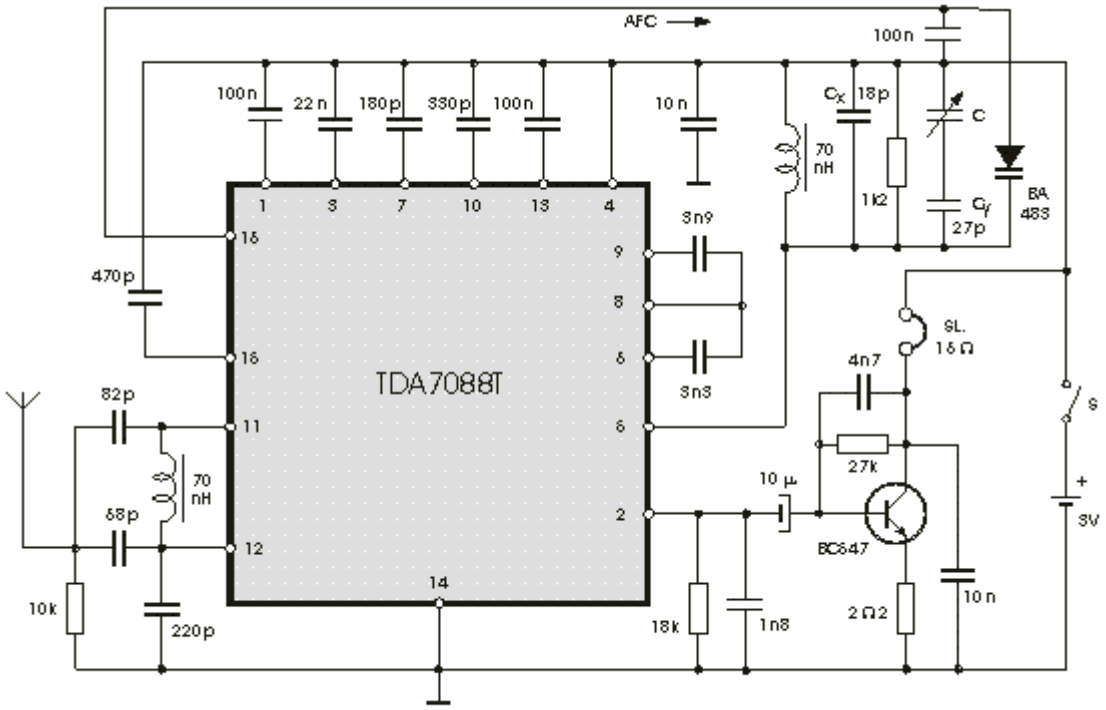

Pic.4.13. Electronic diagram of the monophonic FM radio receiver with manual tuning

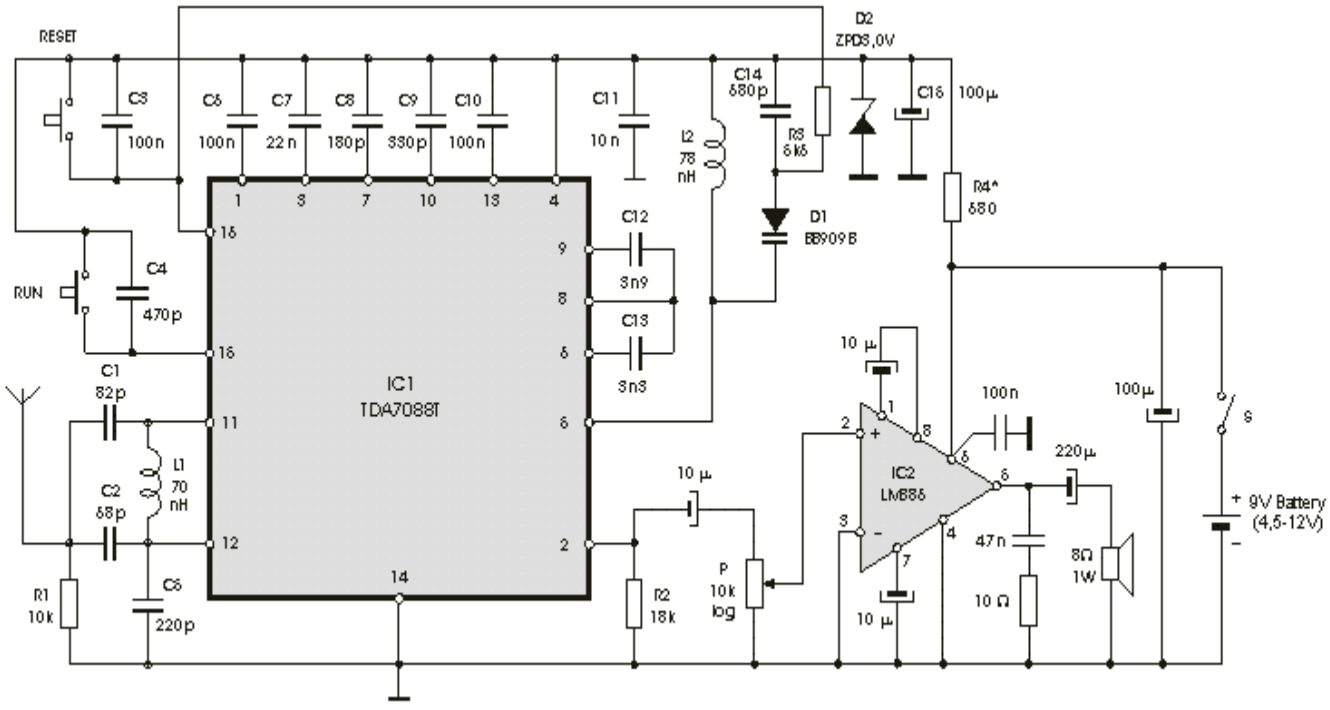

Pic.4.14. Electronic diagram of the monophonic FM radio receiver with TDA7088T and LM386

The AFC (Automatic Frequency Control) of the local oscillator is accomplished with BA483 diode, obtaining that station's position on scale does not "walk" over the scale.
The complete radio receiver should still have a loudspeaker. Electronic diagram of such

receiver made with TDA7088T is given on Pic.4.14. As one can see, that is a receiver from Pic.4.12 with an audio receiver made with LM386 IC.
Maximum value of the DC supply voltage for the TDA7088T is 5V, therefore if using a 4.5 V battery the LM386 will work with reduced output power, the D2 diode and C15 capacitor should be omitted, and R4 should be short-circuited.

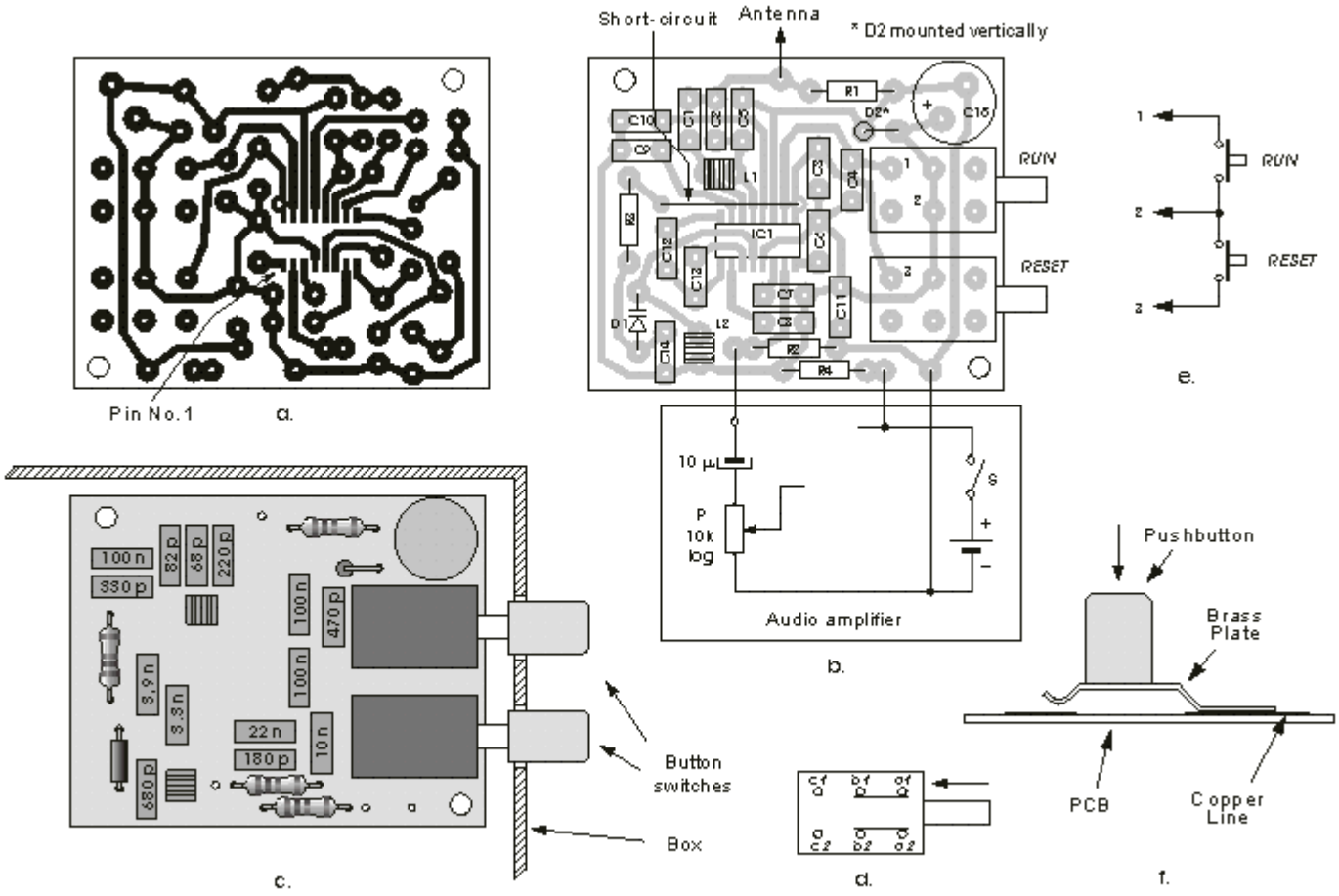

Pic.4.15. Practical realization of the receiver from Pic.4.14.: a- PCB copper side, b- PCB component side, c- board layout with components, d- switch for PCB mounting, e- connecting the switches that are mounted on the device box

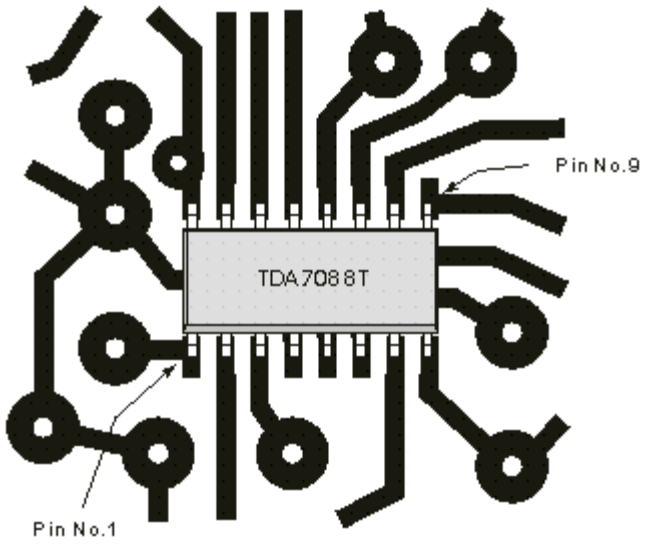

Pic.4.16. Position of the TDA7088T on the PCB

If higher voltage battery is used, the voltage stabilizer, comprised by the aforementioned components, has to be activated. D2 is a Zener diode with 3 V Zener voltage. The optimum value of R4 is found experimentally: in order to make the power consumption as low as possible it should have the resistance as big as possible, while simultaneously keeping the voltage on Pin 4 about 3 V and the device working well within the entire reception bandwidth (One should start with, say, R4=1.5 kOhm, and if the receiver operates well bigger resistance should be tried out, and if not smaller one, until the optimum value is found).

Pic.4.15. shows the PCB for the HF part of the receiver with TDA7088T, that is realized with ordinary components, instead of the SMD's. Pic.4.15-a shows the board layout from the soldering (copper) side. All the components apart from TDA7088T are mounted on the opposite side of the board, their pins are put through the holes and soldered through the holes. The TDA is soldered on the copper side, directly onto the copper contacts. That is why it is being drawn in dashed line on pic.4.15-b, where the board layout on the component side is given.

* Pic.4.16-a shows 3x enlarged picture of the IC and the surrounding lines. The soldering procedure for SMD is as follows:
A thin tin layer is applied on the copper contacts where IC legs are to be soldered to. The firs legs to be soldered are the diagonally opposite ones, in this case No.1 and 9. A small cushion-shaped amount of tin (not profuse) is applied on the contacts where these pins are to be soldered (pic.4.17-a). The IC is placed in its position, with all the pins properly laid. Pin No.1 is pressed against the tin pillow with a top of a bodkin, with iron head simultaneously touching both the tin and the pin end. The tin gets melted, and the pin lies down on its place with the aid of the bodkin, and gets soldered.
It is now time to check out the positioning of the chip. If it needs to be corrected, the tin surrounding the pin No.1 is melted with iron tip and the chip position is quickly and carefully adjusted, in order not to overheat the pin. Soldering the pin No.9 is shown on Pic.4.17-b. First, the iron tip is simultaneously put on the top of the leg and the copper below it, so that

both of them are heated. After app. half a second, the iron is slightly removed from the leg but remains on the copper contact. The tip of the tinol wire is then approached to touch the iron, the pin top and the copper contact at the same time. The wire gets melted and adheres to the copper and the pin, so it has to be constantly moved downwards. When enough tin is applied, the tinol wire is removed first, then the iron, and the pin No.9 is soldered. Once again you have to check whether all the pins are properly placed, and then they too are soldered as it was just described. The solders are OK if they look app. as on Pic.4.17-c.

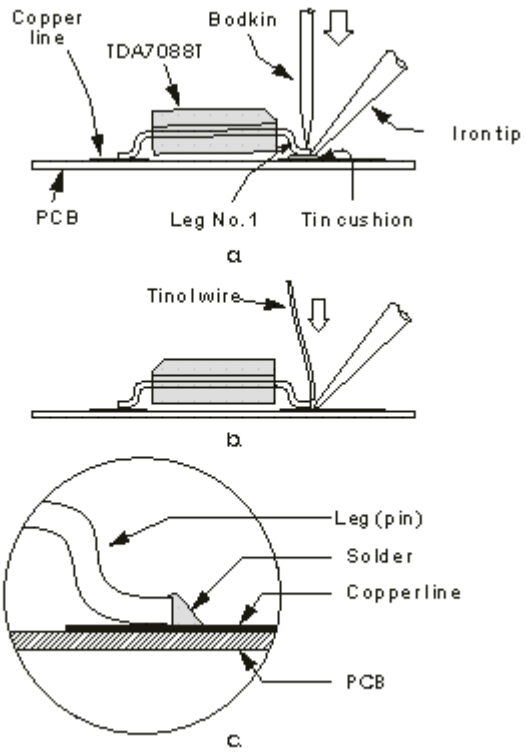

Pic.4.17. Soldering of the leg of TDA7088T: a-soldering the leg No.1, b-soldering the leg No.9, c-proper solder look

* Pic.4.15-b contains the PCB component side layout. The pushbuttons we used here are Siemens, type BO2AMAP-2. The common housing contains, as one can see, two button switches, one of which is being used by this device. Any other pushbutton switches can also be used. In that case small modifications on the PCB lines would probably be necessary. The board is mounted fairly close to the box edge, so that the switch shafts are passing through the panel, and that the buttons can be mounted on the outside. The panel-mount switches can also be used, in which case they are connected to the board by wires (pic.4.15-e).

* Any audio amplifier described so far can be used, e.g. the one with LM386, as on pic.4.8.

* Instead of the antenna, a 20 cm piece of wire can also be utilized.

4.2.2.2. Stereophonic Receiver Built with TDA7088T

Stereophonic radio broadcast is performed in the ultra short waveband, from 88 MHz till 108 MHz. All radio transmitters operating in this range are stereophonic, but their signal is designed so that monophonic receivers can also read it, performing the compatibility. The readers that wish to get acquainted in more details with the stereophonic broadcast basics can refer to the "Radio Receivers" textbook, for the IV grade of the Electrotechnical Highschool.

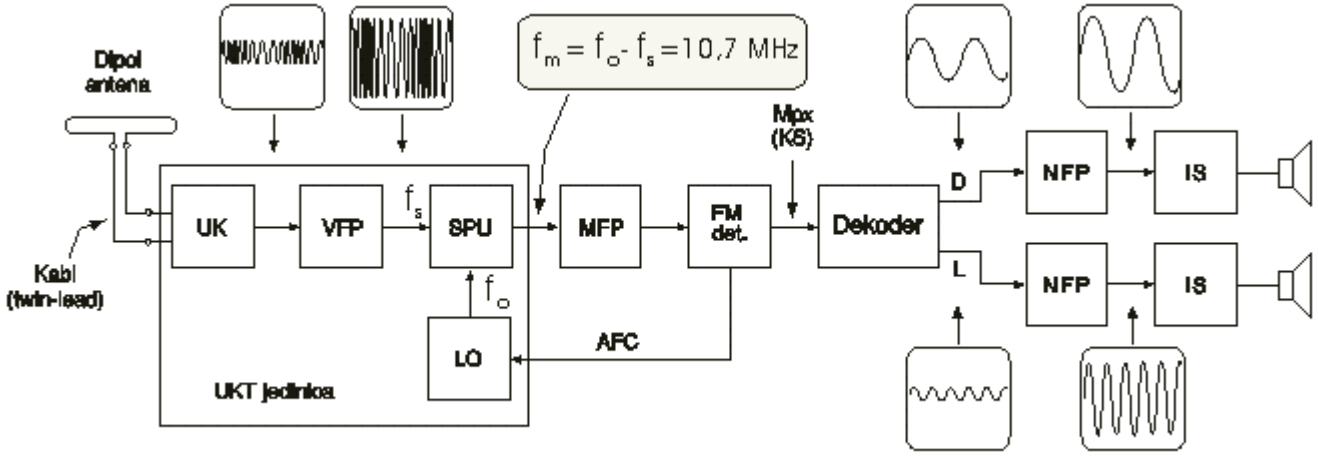

Pic.4.18. Block diagram of a stereophonic FM receiver

Making an introduction to this part, a operating principle of the stereophonic radio receiver shall be considered, its block diagram shown on pic.4.18. Comparing this diagram with the one of the monophonic receiver given on pic.4.6, one may notice that they are identical, up to the block called "The Decoder". It means that, as already described, exiting the FM detector the LF signal is obtained, i.e. the information that was used to perform the frequency modulation in the transmitter. However, this is not an ordinary LF signal, but the one, called the "composed" (KS) or "multiplexed" (Mpx) signal. Besides the full-scale LF signal used by the monophonic receiver,

it also contains the so-called auxiliary signal which allows the separation of left (L) and right (R) channels in the stereophonic receiver. E.g. if a direct broadcast of some band music is performed, the left part of performers is being recorded with one microphone (the signal marked as L), whilst the right side is recorded with the other one (it's a R signal). These two

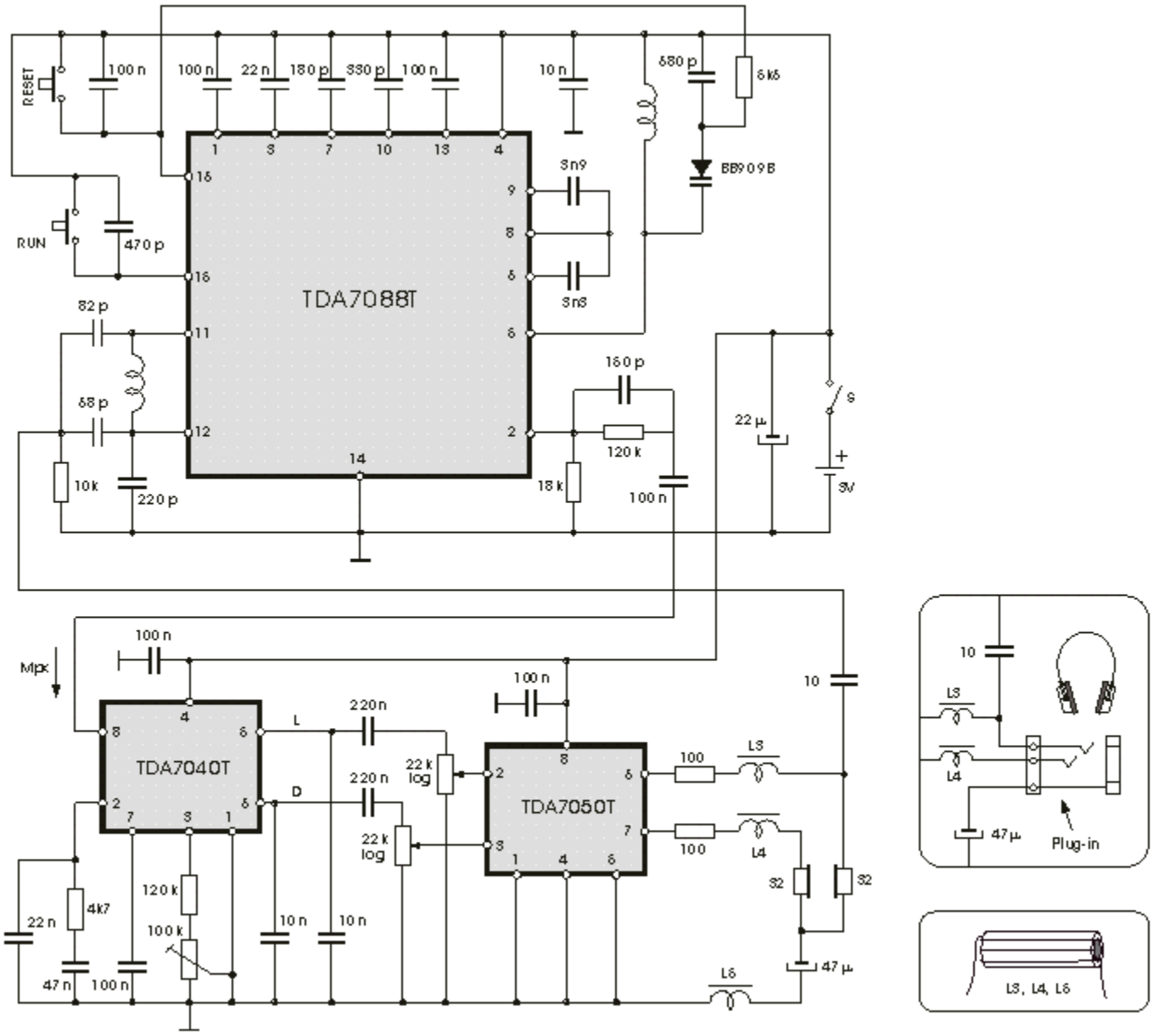

Pic.4.19. Electronic diagram of the stereophonic radio receiver built with TDA7088T (HF deo), TDA7040T (decoder) i TDA7050T (audio-amplifier)

signals are being led in the FM transmitter in the stage called "the coder". Exiting the coder we have the multiplexed signal Mpx which contains, in an indirect manner, both left (L) and right (R) signal. Frequency modulation of the transmitter is being performed with the Mpx signal. In the receiver, Mpx signal is obtained on the output of the FM Detector and is then led to the decoder. This stage plays a role complementary to the one of the coder in the transmitter, therefore two signals are exiting it, the L and D signal. They are being amplified

over two identical audio amplifiers, then reproduced over two same loudspeakers. The listener can now hear the left half of the performers from the loudspeaker placed on its left, and the right half from the loudspeaker that is placed on its right. The performers that are situated in the middle of the orchestra are being equally reproduced from both loudspeakers, making an impression to the listener as if there's a third loudspeaker, located in the middle, between the left and right one. Based on all this, the listener has a picture about the layout of the performers in space, which significantly improves the total musical impression.
Electronic circuit of a portable stereophonic radio receiver with headphones reproduction, made with TDA7088T is shown on pic.4.19. It is a receiver whose practical realization was described in the previous project, with decoder with TDA7040T and dual audio amplifier with TDA7050T blocks added, the latter was discussed in PE5.
* L3, L4 and L5 are HF chokes that allow for the headphones cable to be used as a reception antenna. This is accomplished by connecting one of the headphones' contacts from the plug-in, over the 10 pF capacitor, to the point where, acc. to pic.4.14, the outside antenna is connected. The coils represent big resistance to the station signals, preventing them to "go to ground" over the 47 mF capacitor or over the TDA7050T output. Each coil has 3 quirks of the 0.2 mm CuL wire, threaded through ferrite pearls, as shown on detail in the right corner of the pic.4.19. If telescopic antenna is to be used, these coils should be omitted.

Chapter V Appendix

5.1. Making PCB's
5.2. Computer - Aided Radio Receiver Control
5.3. Receivers with NE612 IC
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5.3.2. AM Receiver with Synchro - Detector
5.3.3. Input Circuits for the Receivers with NE612
5.4. Universal Audio Receiver
5.5. Additional Circuits
5.5.1. Fine Tuning
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5.5.3. Signal Suppressing of Local Radio Transmitter(s)
5.5.4. Dual Tuning
5.5.5. Separation of Stages - Preventing the Oscillation
5.6. The Boxes
5.7. Bimboard, Protoboard
5.8. Universal PCB Plates
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5.1. Making PCB's

Design and manufacturing of the PCB's has been explained in detail in the second issue of P.E. Here, we'll consider how to make a PCB whose drawing is already done. As an example, we'll take a drawing of the board of the receiver from pic.3.19, which measures 45 mm x 30 mm.
a. The PCB is being made of pertinax or vitroplast, i.e. a thin plate (about 1.5 mm) made of isolation material, which has a lean layer of copper put on one side. From the plate you buy in some electronic components' shop, a 45 mm x 30 mm piece should be cut. In amateur conditions, this means refracting. First, points A and B are marked on the non-copper side of the plate, acc. to pic.5.1-b. A ruler is placed over them and a groove is made by pressing

with a screwdriver or a bodkin along it. Its depth should be about 0.5 mm (on picture it is shown in dashed line). When this is done, the plate is placed on the edge of the table, with copper facing downwards. With one hand the plate is pressed firmly to the table, and with the other, the piece that has to be refracted. And - it cracks just along the groove.
On the refracted piece, a new groove, measuring 30 mm from the edge, is made, and the procedure is repeated. In this way we finally have our 45 mm x 30 mm plate.
b. All of the copper has to be clean and shiny, since only in this case the etching and, later, soldering is performed quick and easy and well. If it seems to you that the copper you have just bought is clean enough, you're probably wrong. The plate must have spent some time in the shop, and the copper surface is certainly more-less corroded. The cleaning is most efficiently done with some abrasive powder (VIM or similar) which is otherwise used for cleaning of the cookers, bathrooms etc, but also the sodium bicarbonate, laundry detergent and even plain salt can well serve the purpose. Take a piece of cloth, wipe it with water, extract the water well and muss it to be ball-shaped. Dip it then in the powder, and scrub the copper until it "shines like the shiny sun". After that rinse the plate, and pay attention not to touch the copper with your fingers, since that will make it dirty again.
c. Put the plate, facing the copper up, beneath the sheet that contains the PCB layout, right under this drawing. In our example, that would be the one on the pic.5.2-a. With the pike of a bodkin the holes are made through the centers of all the contacts, and in the centers of two bigger holes that are placed sidewise, taking care not to move the plate. The bodkin has to be pressed firmly, in order to obtain good prods on the copper. When this is finished, the plate should look as on pic.5.2-b. i.e. it has to contain as much prods as there are contacts, plus two. If the drawing contains many contacts, the plate can be easily dislocated, and the procedure is to be done all over again. It is better practice then to make a copy of the picture, cut it out, and attach it to the plate with two pieces of scotch tape.
d. Drawing the contacts and lines on the plate is done with the acid-resistant marker paintstick. It can be recognized by its characteristic "alcohol smell", and is being sold in bookstores as a marker for "writing on glass". You can test it: write in the store (it will be later afterwards) something on the glass, piece of plastic and similar, wait for a couple of seconds, then try to wipe it out with your fingertip. If the paint remains - the marker is OK. Nevertheless, this test isn't 100% certain, it is much better to buy the marker in the electronic components store (you have to accent to the salesman that you need a marker for drawing lines on PCB's). With the tip of the marker draw a circle around every prod (except those two that are for bigger holes), measuring 2-3 mm in diameter. Move the marker slowly, in order to leave a thick layer of paint on the plate. Take care to leave a small copper isle around every hole. Then,

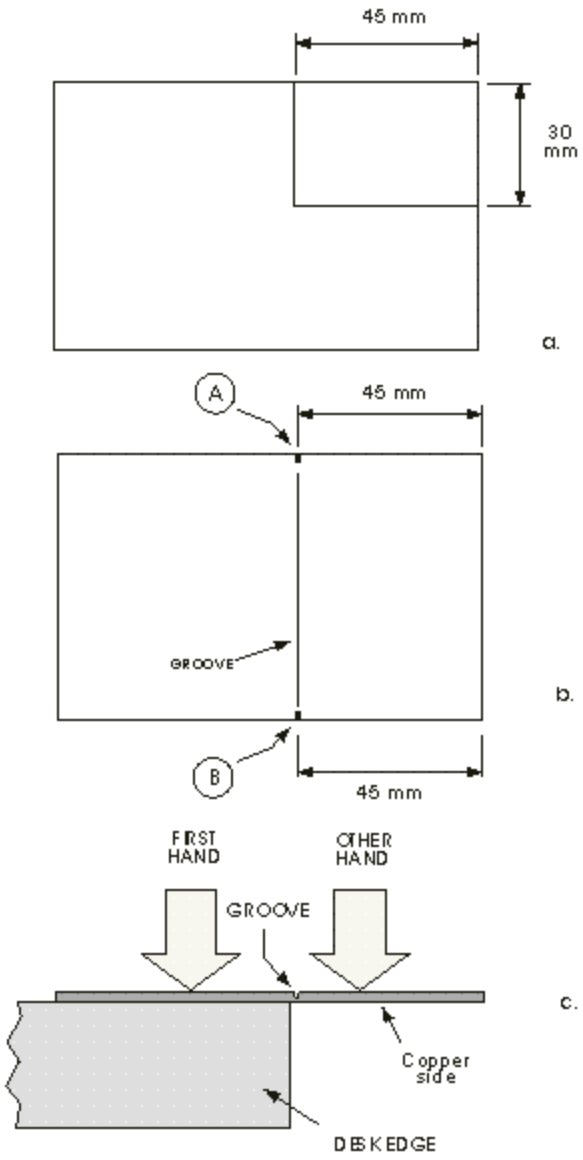

Pic.5.1. "Cutting" of the plate: a-pertinax plate, b-marking, c-cracking

you should, carefully and slowly, draw all the lines, by looking at the pic.5.2-a. They do not need to have the same shape as on the picture, especially they don't have to be that "chamfered". Line thickness should be about 1 mm, but that either is not obligatory, they can be somewhat thinner or a lot thicker (where applicable). The important thing is not to connect the nearby lines or contacts during the drawing, i.e. not to make junctions that do not exist on the drawing. If that happens anyhow, remove the paint surplus with a razor or a small, sharp screwdriver. Pic.5.2-c shows the beginning of drawing, several contacts and 3 lines are drawn. The drawing is finished when you have a pic.5.2-a on the copper foil.
e. Next step is etching, i.e. removing the copper that is not covered with marker paint. For this purpose, a mixture of hydrochloric acid (HCl), hydrogen peroxide (H2O2) and water (H2O). Pure hydrochloric acid is not used, but its 35% solution, that is being sold as a household cleaning agent. Hydrogen peroxide is being sold in drug stores and cosmetic

stores. It is being sold as 30% solution, or even more diluted, 8-12%.
Hydrochloric acid and hydrogen peroxide are very aggressive media, especially for the eyes and skin, therefore care should be exercised when working with them. It would be the best for you to work with them in the bathroom, or some other place close to the running water supply. If some of these liquids spills on your skin, metal tool or clothing, wash them down with water immediately.

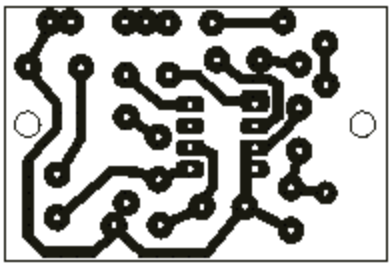

a.

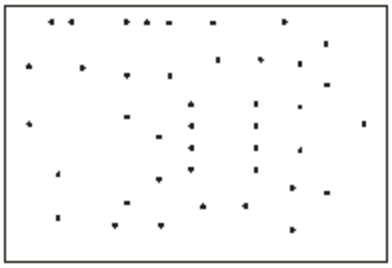

b.

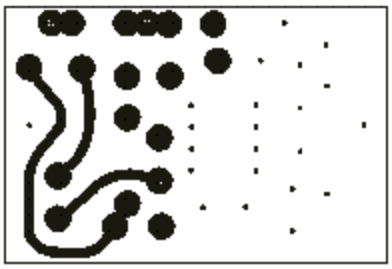

c.

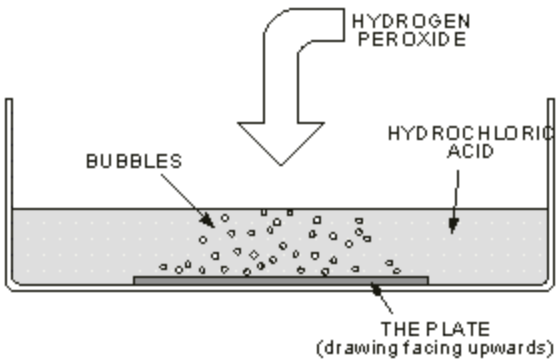

d.

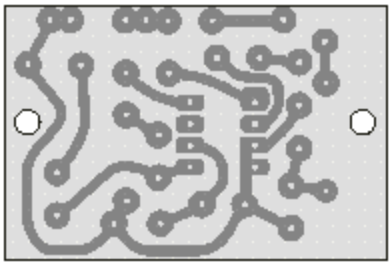

e.

Pic.5.2. Making a PCB: a-drawing, b-plate with bodkin prods, c-drawing contacts and lines, d-etching in the hydrochloric acid while adding the hydrogen peroxide, e-finished plate

The etching mixture is being made directly before the etching, and is CERTAINLY being disposed of, right after the process. The plate is put at the bottom of a plastic, glass or porcelain dish, with copper facing upwards, and the acid is poured, in quantity enough to fully cover the plate (pic.5.2-d). Hydrogen peroxide is then added, being poured from the container directly over the plate. The amount of peroxide depends on its concentration, as well as on the concentration of the acid. So, put some peroxide, raise a little left end of the dish, then the right one, to allow a liquids to mix, and observe the plate. The mixture is transparent, and if the copper starts changing the colour after a dozen seconds - the etching has begun. During this process, the bubbles are formed in the mixture, in the amount somewhat more than in a glass of mineral water. If too little bubbles are present, add some more peroxide. Be careful, however, not to exaggerate, since if you happen to have too much bubbles, the mixture is going to heat up and the marker paint can be destroyed. From time to time, you should raise one end of a plate with a pointed wooden or plastic stick, in order to remove the old liquid from its surface, and allow for fresh mixture to take its place.
Etching is finished when there is no more uncovered copper on the plate. Raise one plate end with the stick, wait for the liquid to decant, take a plate with a laundry clip and wash it thoroughly in a jet of running water. You can then remove the paint by scrubbing, as previously described, with a wet cloth dipped in some powder. The copper contacts and lines will emerge on the plate.
f. If you were careful enough to leave a uncovered isle of copper in the centre of every contact, after etching this will be a small cavity, in the centre of the contact. Through these cavities, that will guide your drill, a 1 mm holes should be drilled (it is better if the holes are 0.8 mm in diameter, but such drills are harder to find, and a lot easier to break). Two holes for the fixing screws are usually about 3 mm in diameter. While drilling, a piece of thicker plywood or some flat hard-wood plank (beech, oak) should be put beneath the plate, and not a piece of polystyrene or something similar. Do not press the drill too hard, since the tool will be plucking tiny pieces of plastic on the other side of the plate.

5.2. Computer-Aided Radio Receiver Control

In Book 7/8 of Practical ELECTRONICS methods for simple control of various electrical devices by computer were discussed. Practical realization of various interface circuits and sensors was described, by which the computer is being connected with the outside world, so that it can turn on/off the heater, light, fan, TV set or some other electrical device at the desired moment, based on data comprising temperature, light intensity, humidity etc. In this chapter we shall present, in short terms, one of the projects from the aforementioned book, that deals with simple computer-aided turning on/off of the radio receiver at the desired moment.
The radio is connected with the computer via parallel port, the one where the printer is also being plugged. It is a 25-pin female connector, called Sub D-25, which is given on Pic.5.3. With appropriate programme, logical ones (voltage +3.6 V) and zeroes (0 V) can be sent to the outputs marked as DI-1, DI-2,...DI-8, that are located on the legs marked with numbers 2 to 9. Electrical devices that are being controlled are connected to these outputs over the interface circuit that is given on Pic.5.4. Two connected devices are shown on the picture, their maximum number is 8.
Pic.5.5-a shows the electronic diagram of an extremely simple interface circuit, which can serve to connect to computer the radio receiver, that can then be switched on or off at certain time, with adequate programme. The low-power transistor BC547 can be used for the consumers that use the current from the battery that is not greater than 100 mA. In case you have bigger power consumers, some stronger transistor or two transistors in Darlington junction can be used instead of BC547. The transistor bas is connected to the pin No.9 of the mail Sub D-25 connector over the R1 resistor, while the emitter and minus pole

of the battery are connected to the pin No.25, i.e. to the computer ground. As long as there's a logical zero on the DI-8 output, the base voltage is zero and the transistor is locked and no current runs through it, therefore also through the consumer. When a logical one emerges on the DI-8, the transistor goes to the saturation regime, the voltage between collector and emitter becomes very small (practically zero) and the transistor behaves as if the collector and emitter are short-circuited. In that way almost the entire battery voltage is available on the receiver power supply input.
The PCB layout is shown on Pic.5.5-b: The component side is in the upper part, and the soldering side in lower part of the picture.
Pic.5.5-c shows how a small transistor radio receiver, powered by a 9 V battery, is connected to the parallel port, over the interface from pic.5.5-a. The plate is connected with clamps via the cables A and B, and with the battery over C and D.

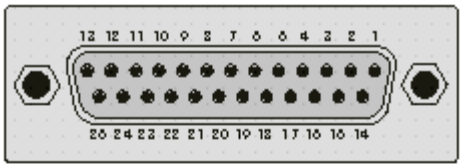

a - Sub-D-25 Connector
located on the computer housing back plate,
female type, front view

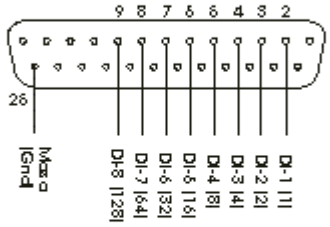

b- Pin marking on the Sub-D-25 Connector

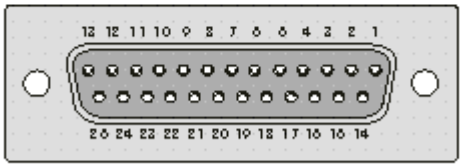

c-Sub-D-25 connector,
male type, watched from behind,
from the side where the
soldering legs are

Pic.5.3. Parallel Port

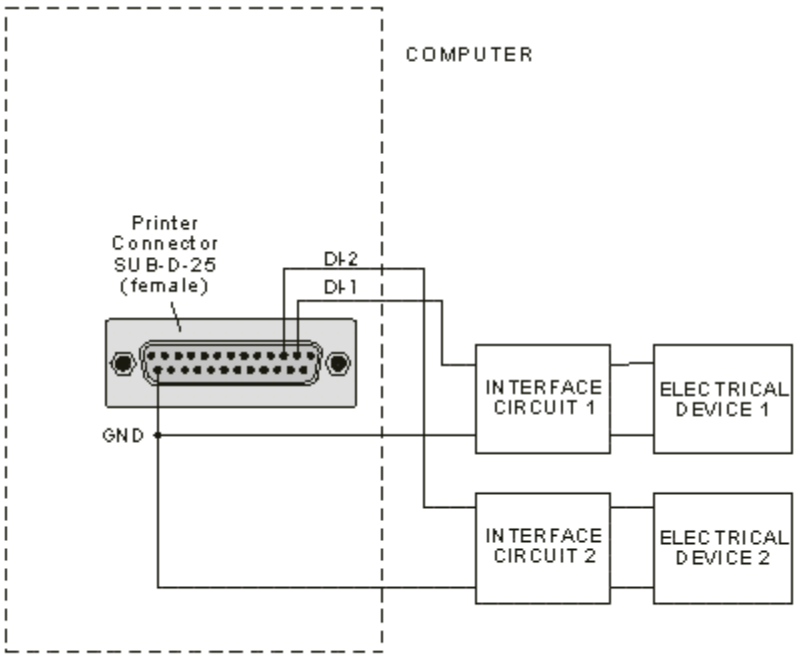

Pic.5.4. Connecting electrical devices onto the parallel port

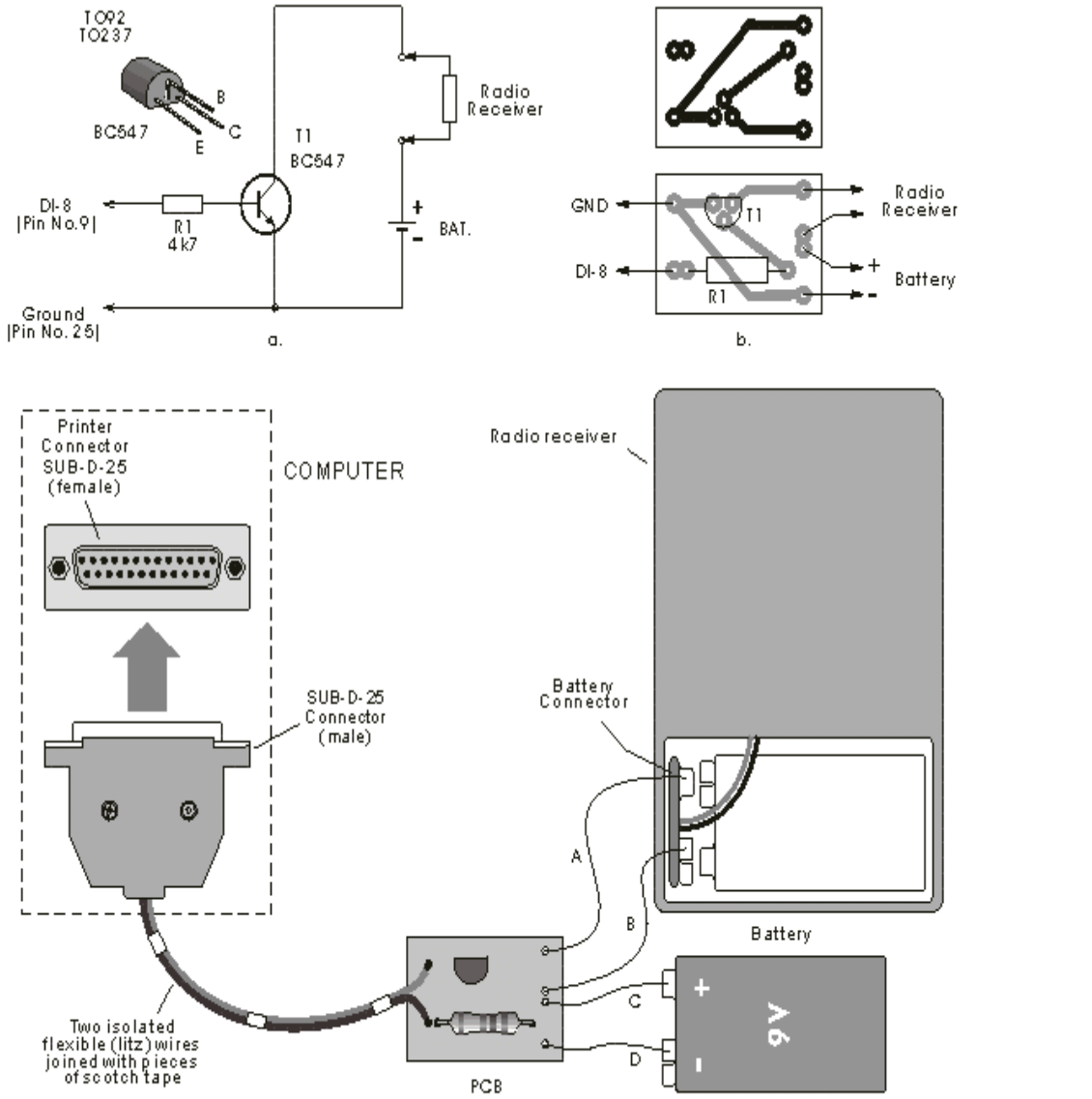

Pic.5.5. Connecting the Radio Receiver to the Parallel Port: a-Ellectronic diagram of the Interface Circuit, b-PCB, c-Connecting the Computer, Interface Circuit, Receiver and the Battery

5.3. NE612

5.3.1. Synchrodyne AM Receiver

If the author remembers well an article that he read in a professional magazine many years ago, the synchrodyne receiver is the ancestor of the superheterodyne receiver. Sometime at the beginning of the 20th century this device was called the Heterodyne receiver, and it was first constructed by Levvy. Armstrong improved it and gave new name to the new device, by adding the prefix SUPER to the old name.
The electronic diagram of this device is given on Pic.5.7. This receiver, as well as that on pic.4.2 has got the local oscillator with oscillatory circuit connected between pins 6 and 7. However, frequency of this oscillator is

not greater for the value of fm, but is in fact equal to the frequency of the station we wish to listen to: fm=fS. Because of that, the important design difference compared to the diagram from pic.4.2 is that on pic.5.7 capacitors Co and Cto are not used, but the capacitor C which is obtained by connecting the legs O and A, acc. to pic.3.7. Its capacitance can be changed from 12 pF till 218 pF, so that the oscillator frequency, in case of MW reception, goes between 500 kHz to 1500 kHz. The oscillator voltage is emanated in the mixer by the signals from all stations coming from the antenna. The result of emanation with signal of the station whose frequency is equal to the oscillator frequency is the LF signal (speech, music, Morse Code etc.) that serves for performing the modulation in the transmitter. This signal is obtained on pin No.4, from which it is then led, over the 1 ìF capacitor, to the volume potentiometer and audio amplifier. Products of mixing the oscillator voltage with other stations' signals are also obtained on that pin.

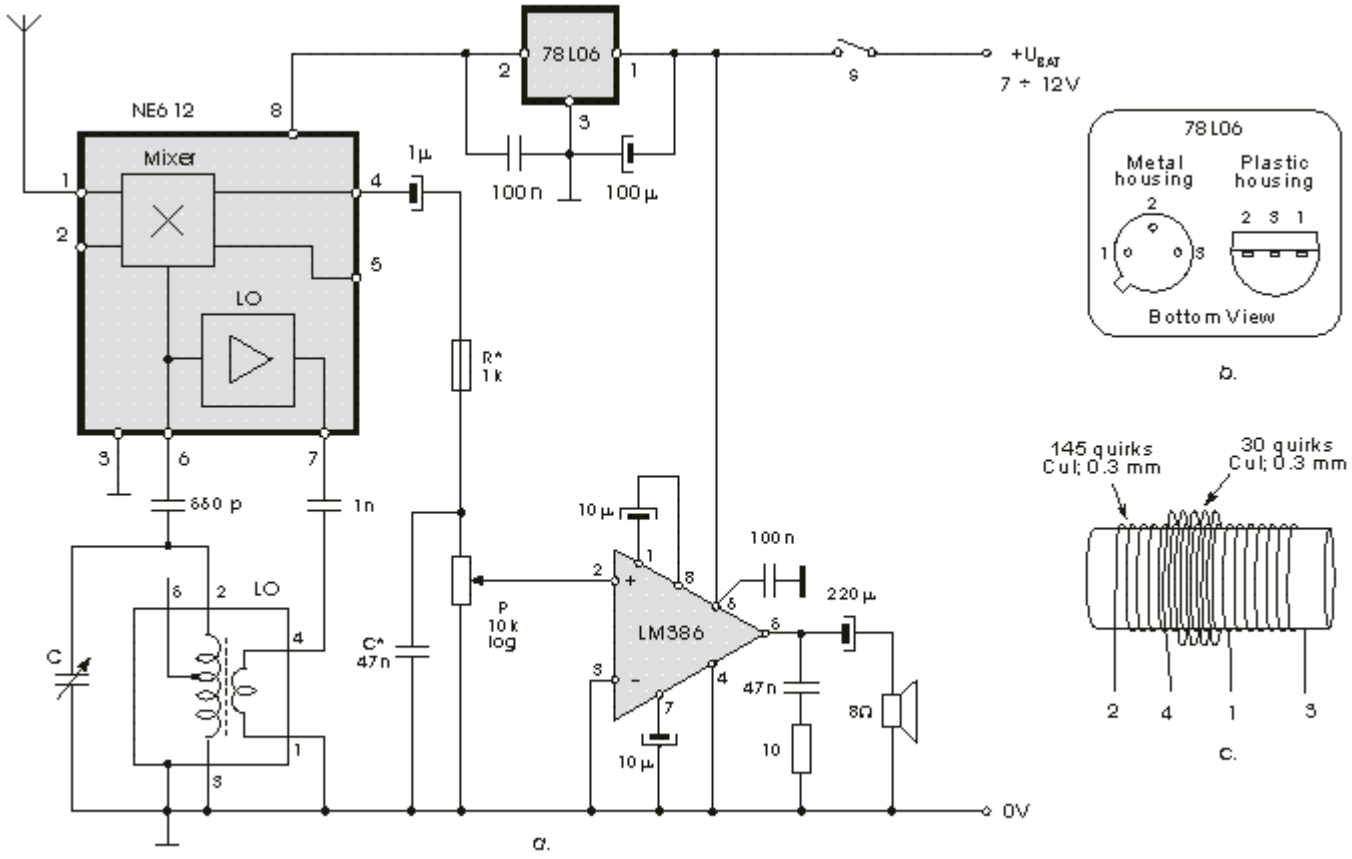

Pic.5.7. Synchrodyne AM Receiver: a-Electronic diagram, b-Pin layout for 78L06, c-Oscillator coil

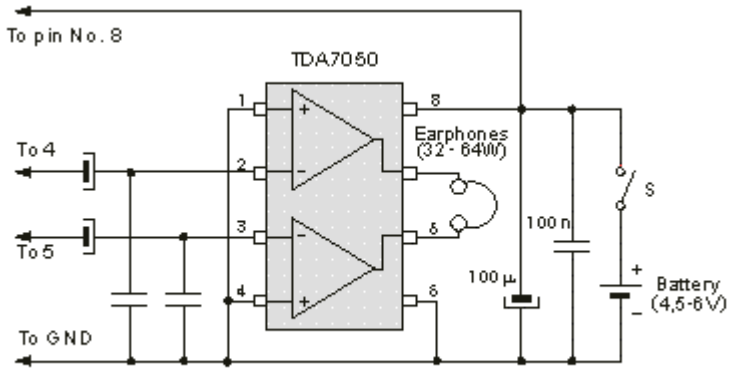

Pic.5.8. LF part of the Receiver from pic.5.7

They are being suppressed by the LF filter that comprises the R* resistor and C* capacitor. The device we were testing did not, however, contain R*. It is to be installed if some disturbances occur (whistling or similar), and its optimum value is to be found experimentally. If necessary, greater capacitance of C* is also to be tried out.

* As mentioned earlier, it is very important for the supply voltage of the NE612 to be stable. This values even more for the synchrodyne then the superheterodyne receiver. The voltage control is done by the stabilizer, made with 78L06 IC. It is being placed in the low-power transistor package, either metal (as for BC107) or plastic (as for BC547), and its maximum current is about 100 mA (pic.5.7-b). A simpler stabilizer, made with the Zener diode, can be used instead, as on pic.5.9.

* Instead of factory-made coil LO, the self-made one can also be used. The simplest solution is to use the one from pic.3.6, in which case the mid leg is not used. Over this coil, the feedback coil should be winded, acc. to pic.5.7-c (its ends are marked with 4 and 1). When connecting with capacitor C and pins 1 and 7 of NE612, care should be taken to join properly: coil ends 1 and 3 with ground, 2 with capacitors C and 560 pF, and 4 with 1 nF capacitor. It is, of course, possible to use smaller coil, wound on a smaller body, with more quirks of thinner wire. Its inductance should be about 350 mH, and the number of quirks required is to be found by testing. The feedback coil (4-1) has app. 3x fewer quirks than the oscillatory circuit coil (2-3).

* On the pin 5 of the NE612 the LF signal is also obtained. It is the same as the one on pin 4, but has a 180° phase shift compared to it (in simple words, while one signal increases, the other one decreases, and vice versa). That gives us the opportunity to use the dual audio amplifier in the LF part, that has two amplifiers, with inverting and non-inverting inputs. As shown on pic.5.8, the counter-phase LF signals from NE612 are led onto the same inputs. The output signal has 2x greater amplitude, therefore making the output power 4x greater than when only one input is used (as on pic.5.79).

5.3.2. AM Receiver with Synchro Detector

In previous project, the NE612 was in fact used as the AM signal detector. The LF signal exiting the mixer is product of the simultaneous (synchronous) action of the station signal and voltage from the local oscillator upon it. That is how the term "Synchro Detector" emerged. There's also a possibility to use a station carrier instead of local oscillator's voltage, so that the station signal gets beaten by itself, however strange this may sound. Electronic diagram of one such device is given on pic.5.9.
The station signal, which the input circuit (C, L) is tuned at, is led to the regulating Gate of the BF960 MOSFET.

Under the effect of this voltage, the AC current that creates voltage drops on resistors R2 and R3 runs through the transistor. These two voltages, taken between the S and ground and D and ground, are mutually shifted in phase for 180°, and are being led over the coupling capacitors C2 and C3 to pins 1 and 2 of the NE612, i.e. on one input of the mixer. On the other mixer input the Drain signal is brought, over C4, and beating occurs in the mixer, the result of which is the LF signal on pin 4. This signal is, over C8, being led onto the volume regulation potentiometer and the audio amplifier.
* The unwanted (and parasite) products of mixing, that are manifested as whistling, squeaking etc. are being suppressed by the C7 capacitor. If the obstructions still exist, the capacitance of C7 is to be increased and/or the R* resistor added.
* The voltage stabilization of the DC voltage on pin 8 is performed by the ZPD6.2V Zener diode and resistor R5. A diode with smaller voltage is also possible to be used, say, 6.2 V and similar. If the supply voltage is less than 12 V, the resistance of R5 should be decreased.

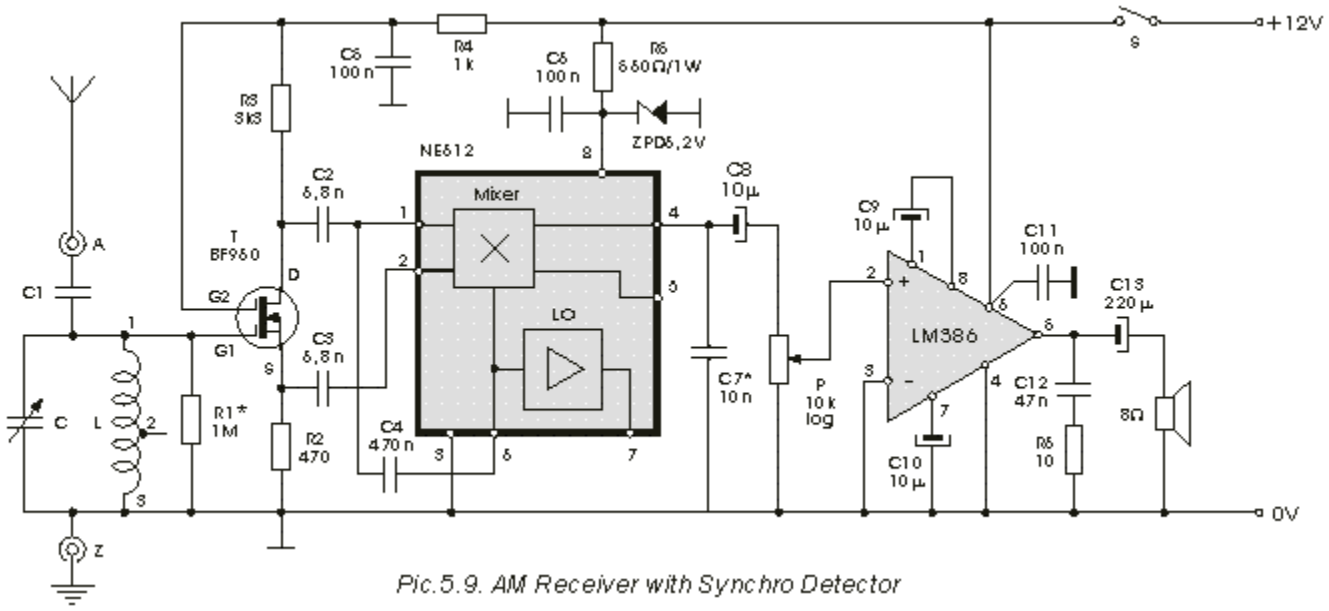

Pic.5.9. AM Receiver with Synchro Detector

5.3.3. Input Circuits for Receivers with the NE612 IC

All the receivers with NE612 that are described here work better, especially considering suppressing the noise in case of the symmetrical station, if the proper input circuitry is added to them. Pic.5.10 shows two examples of the MW receivers that use the ferrite antenna. In both cases, the antenna taken from an old commercial radio is being used.

5.4. The Universal Audio Amplifier

We already spoke about the universal amplifier in the text connected with pic.3.22. Pic.5.11 contains the diagram of another such device, where the transistor amplifier with BC547 is used as the pre-amplifier, instead of that with TLO71 IC. It can be used for practical check of all the earlier mentioned radio receivers. The LF signal is being taken from the detector in the HF part of the receiver to the hubs marked as In and Gnd (if the links aren't too long the ordinary wires are used, otherwise - the microphone cable). On the third hub the DC voltage is outputted, which is used in some HF circuits for their operation (such as e.g. those on pics.3.24, 3.25, 3.29 etc.).
* The LED (and the appropriate resistor) are added if the amplifier is being supplied from the adapter connected to the household voltage installation. It can also be used if the amplifier is power supplied from the battery, but this is not recommendable, since its power consumption is fairly big, which significantly shortens the battery life.

* The amplifier can be put in a box of any kind, one of the possible solutions shown on pic.5.11-b.
* A very useful solution can be to place the adapter also in the box, with the ability to control its output voltage from few volts to 12 V. In that case, you have both the amplifier and adapter in the same box, which can be used for power supply and check-out of various electronic devices, and not just radio receivers.

5.5. Additional Circuitry

5.5.1. Fine Tuning

During the tuning of the receiver to some station at the SW band with the variable capacitor, a problem occurs. In simple terms, the station frequencies are too close to each other, so the capacitor's shaft should be turned for an extremely small angle in order to change station, which is practically impossible. It would certainly be useful if we could somehow stretch (a popular term for this) the part of the band near the frequency to which the receiver is tuned at. For the direct type (TRF) receivers that were described in the previous chapters, this can be accomplished if, acc. to pic.5.12, another variable

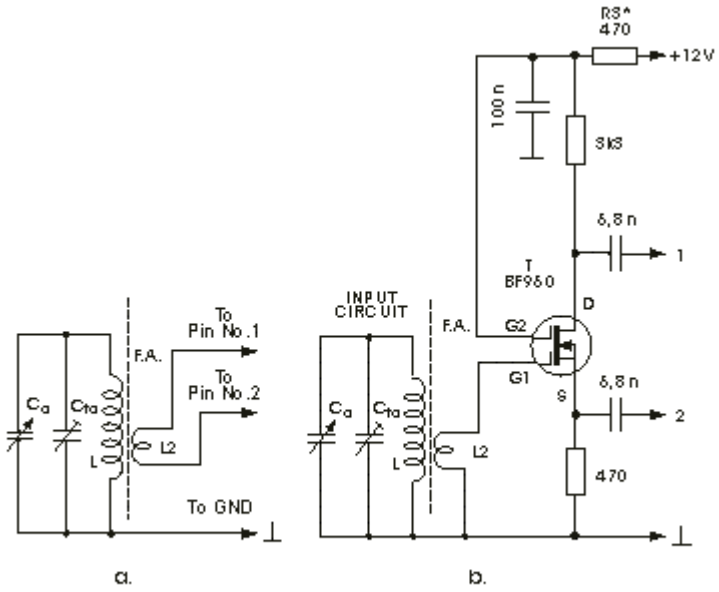

Pic.5.10. a-Input Circuit for the Receiver from pic 5.9, b-Iput Circuit & HF Amplifier for the Receiver from pic.4.2

capacitor (CR) is added in parallel to the variable capacitor at the input circuit. Its capacitance should vary at substantially smaller scale than that of C, meaning from a few pF til about 20 pF. The tuning is accomplished by setting the receiver, by means of C, approx. at the middle of the band we are interested in, then tuning by means of CR to some station in that area. E.g. if the stations we want to receive are located in the part of the SW band from 6.1 MHz till 6.2 MHz (it's a well-known 49-metre band), first we tune ourselves with C to approx. 6.15 MHz, and then we pick with CR some of the stations located in that area. The same applies for the famous Magic Band (at about 50 MHz).
The CR capacitor is mounted close to C in order for their knobs to be near each other at the front plate.
* As CR, some air-type trimmer capacitor can be utilized, with adjustment knob mounted on its shaft. Also, one of the sections of the variable capacitor from pic.3.8 can be used, as shown on the right part of pic.5.12.
* The problem of the station "adjacency" at the SW band also exists at the superheterodyne receivers. It is being solved by adding the CR in parallel to the variable capacitor in the local oscillator circuit. The reason for this is that, at supereterodynes, the station is chosen over the local oscillator. The important thing for the

oscillator is to have the exact frequency, that is greater from the station frequency for the amount of the interfrequency. If the resonance frequency of the input circuit isn't equal to the station frequency, it won't significantly affect the reception. Because of all this, in the receiver on pic.4.5, CR is attached between the pins 2 and 3 of the LO circuit.

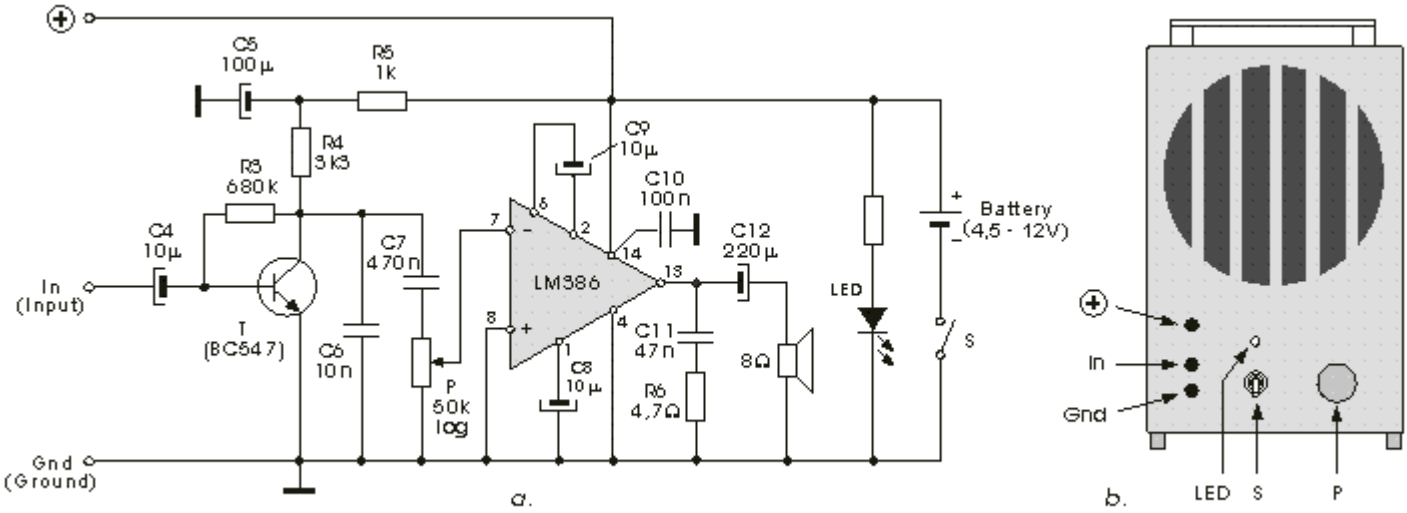

Pic.5.11. Universal Audio Receiver: a-Electronic Circuit, b-Box

5.5.2. Electronic Tuning

Instead of the capacitor CR, that was used for fine tuning in the previous project, a capacitive (varicap) diode can be used. It's a special HF diode which is polarized by exposing it to DC voltage in order to be non-permeable (+ to the anode, - to cathode). By changing the voltage diode's capacitance also changes, which allows for it to be utilized as variable capacitor. If, acc. to pic.5.13-a, the DC voltage between the cathode and anode (UAK) varies from U1 to U2, diode's capacitance goes from Cmax till Cmin.
The electronic diagram for the electronic fine tuning circuitry is given on pic.5.13-b. Diode capacitance is changed by moving the slider of the P1 potentiometer. By means of trimmer TP the necessary Cmax is set, and when this is done TP can be replaced by an ordinary resistor. All the components are mounted on the PCB, together with other parts of the receiver, except the P1. It is mounted on the front panel, and connected to the PCB with 3 ordinary wires.
* The variable capacitors that were used for tuning in all the receivers described so far are solid, lasting, reliable

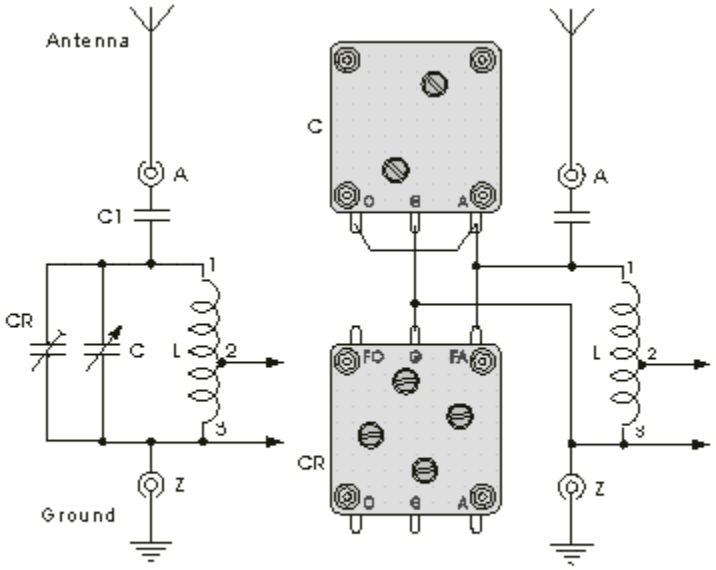

Pic.5.12. Fine Tuning
(stretching a part of the bandwidth)

components. Their mishap is they are hard to purchase, they are quite robust (compared to other device components), and their mounting isn't simple because the shaft for the knob must go through the front plate of the device box. That is why varicap diodes are also replacing them. With the diode that has Cmax/Cmin ratio that is big enough, say, Cmax/Cmin>15, the circuit form pic.5.13 can be used as the variable capacitor (C is simply omitted). In that case, some bigger knob with an arrow is mounted on the P1 handle, and numbers from 1 to 10 are written on the panel, as shown on pic.5.13. This scale allows the listeners to see what station is the receiver tuned at. Of course, for the MW band, the numbers as those on pic.3.7 can also be written.

* In case of SW band, the P2 potentiometer is added for fine tuning.

The optical indication of the tuning, with and knob with arrow is the simplest solution possible. More prettier one is using a small movable-coil instrument (V), such as those used as battery indicators in industrial devices, or for tuning indication and similar. The connecting is done acc. to the diagram on the left part of the pic.5.13-c. In series with the instrument, the TP potentiometer is attached. Its resistance depends on the maximum instrument current, and can be found experimentally. For start, you may use a 1 MOhm linear trimmer, with its slider at lowest position (so that its resistance is maximum). Put the P1 slider also at the lowest position. Turn on the receiver. Start moving the P1slider upwards, and observe the instrument needle. if it soon goes to the end, you'll have to take a trimmer with greater resistance or to add another resistor in series with it, so that when the P1 slider gets to its rightmost position, the needle goes somewhere around the middle of the full scale. If the needle, with P1 in topmost position, moves too little, you'll need a smaller resistance trimmer. When you succeed in having the needle in the middle of the scale with P1 in topmost position, start moving the TP slider until the needle reaches the end of scale. The circuit is well adjusted if the needle goes from zero to full scale while P1 slider is moved from bottommost to topmost position. The instrument can have any shape, but the most appropriate (and cheapest) is square, like the one on the picture.

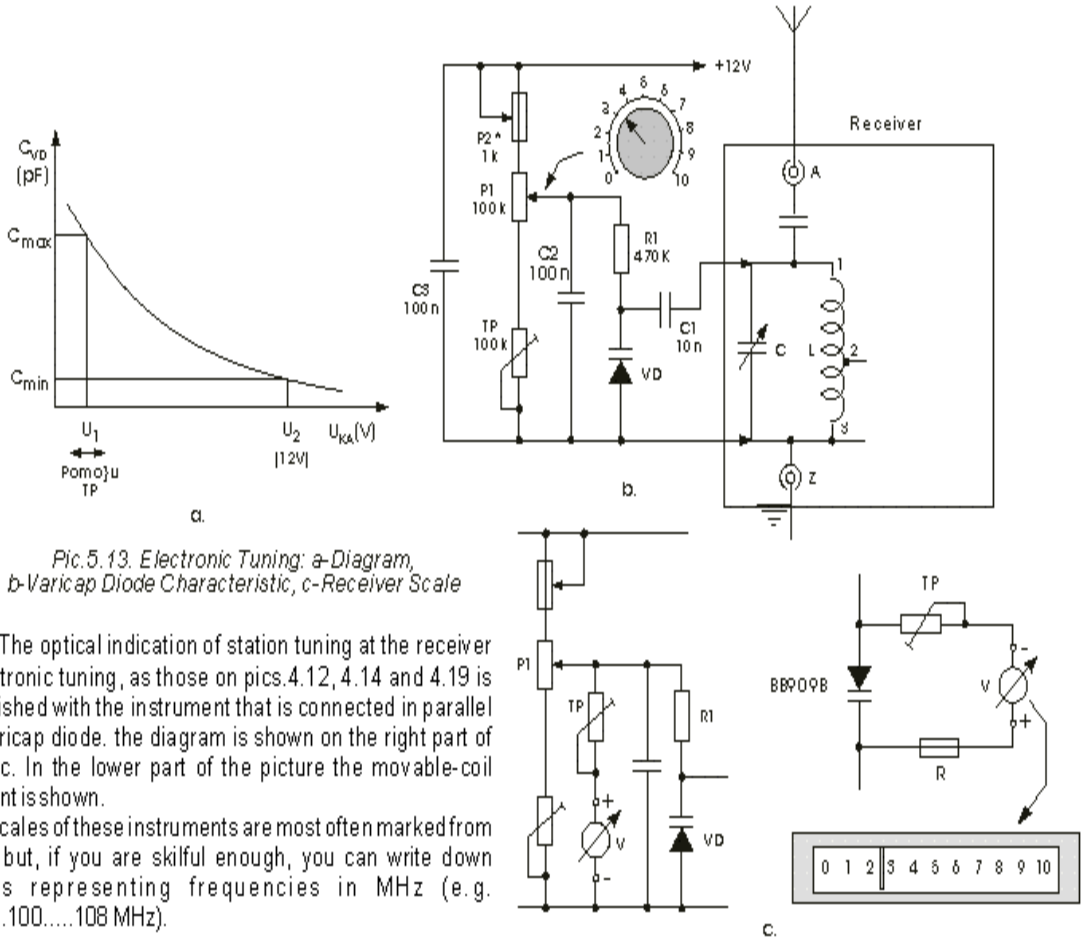

Pic.5.13. Electronic Tuning: a-Diagram, b-Varicap Diode Characteristic, c-Receiver Scale

* The optical indication of station tuning at the receiver with electronic tuning, as those on pics.4.12, 4.14 and 4.19 is accomplished with the instrument that is connected in parallel to the varicap diode. the diagram is shown on the right part of pic.5.13-c. In the lower part of the picture the movable-coil instrument is shown.

Scales of these instruments are most often marked from 1 to 10, but, if you are skilful enough, you can write down numbers representing frequencies in MHz (e.g. 88...96....100.....108 MHz).

5.5.3. Suppressing the Signal of the Local Transmitter

From all the signals in the reception antenna, the one that is created by the local transmitter is by far the strongest one, due to the fact that it is hundreds, sometimes even thousands times closer than other radio transmitters. That signal can be so strong that it can jam normal reception of other stations. In case of simpler receivers its programme is heard,more or less, in all the positions of the variable capacitor. The solution for this problem is the so-called seal circuit, which serves to weaken the signal of the local transmitter, so that it doesn't interfere (but is still strong enough for normal reception, when the receiver is tuned at it).

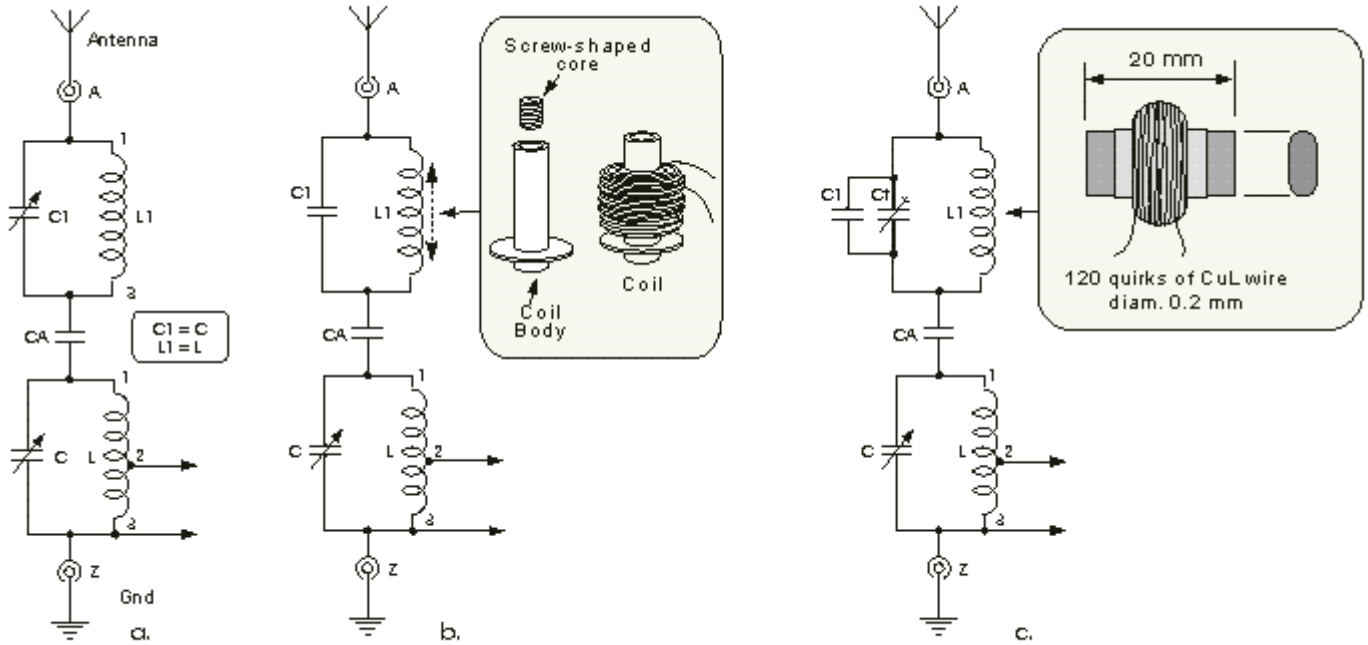

Pic.5.14 . Suppressing the Signal of the Local Transmitter

The seal circuit is a parallel oscillatory circuit which comprises the coil L1 and capacitor C1, as shown on pic.5.14-a. By means of C1 the resonance frequency of the circuit is set so that it corresponds to the carrier frequency of the local station. On that frequency, this circuit behaves as a huge resistor (see pic.3.2-b) and decreases the current that is created by the local transmitter signal. For other signals it has very small resistance and practically has no effect on them. The setup is done by tuning the receiver on the local station, and the reception is weakened enough by turning the C1. If the decay is too strong, a resistor should be added in parallel to C1.

Using a variable capacitor in the seal circuit (pic.5.14-a) isn't an economical solution. It is much better, considering both economy and space, the solution given on pic.5.14-b. A block capacitor C1 and a variable inductance coil are used in the seal circuit. As shown on the framed part of picture, the coil is wound on the plastic body, with ferrite core. The number of quirks is found experimentally about couple of hundreds of quirks made with as thin copper wire as possible). The capacitance for C1 is also found experimentally (couple of hundreds of pF). The earlier mentioned IF transformer can also be used as a coil. With labelling acc. to pic.4.3-a, legs No.2 and 3 are used, the others are "hanging" (they are not soldered). C1 capacitance is also found experimentally. It is also possible to wind the coil on a piece of ferrite rod, as shown on pic.5.14-b, and setup to be done with trimmer Ct

5.5.4. Dual Tuning

The author of this book, as great radio techniqe lover (amateur, in French), owns great collection of over 150 pieces of various old-timer radio receivers. There is one among them that is over 60 years old, at which the tuning is being done by two knobs. With first one the

receiver is set roughly to the desired station, which is usually barely heard at that moment. The second knob is then turned until the optimum reception is achieved, which is significantly better than before, and in case of weak stations - extremely better.
The selectivity of simple receivers that were described in previous chapters can be significantly increased by using the aforementioned dual tuning. The electronic diagram is shown on pic.5.15-a. Another oscillatory circuit, made of L1 and C1 connected in series, is inserted between the antenna connector and input circuit of the receiver (it can be any of the earlier described AM receivers). As with the earlier mentioned parallel oscillatory circuit, the resonance frequency of the serial circuit is given by the Thompson pattern:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

The serial oscillatory circuit has very small impedance (compared to the parallel circuit whose impedance is very big on the resonance frequency). The dependance of the impedance (”resistance”) of the serial oscillatory circuit from the frequency is shown on the diagram on pic.5.15. As you can see, the serial circuit acts as a resistor of very small impedance only for the station that it’s tuned at. For all other stations, it behaves as a huge resistor (impedance). All in all, from all the signals in the antenna, the biggest current, and therefore the biggest voltage on the input circuit is created by the transmitter that both serial and parallel oscillatory circuits are set to. The tuning is done as it has already been described, first with C (so-so), then with C1 (much better).

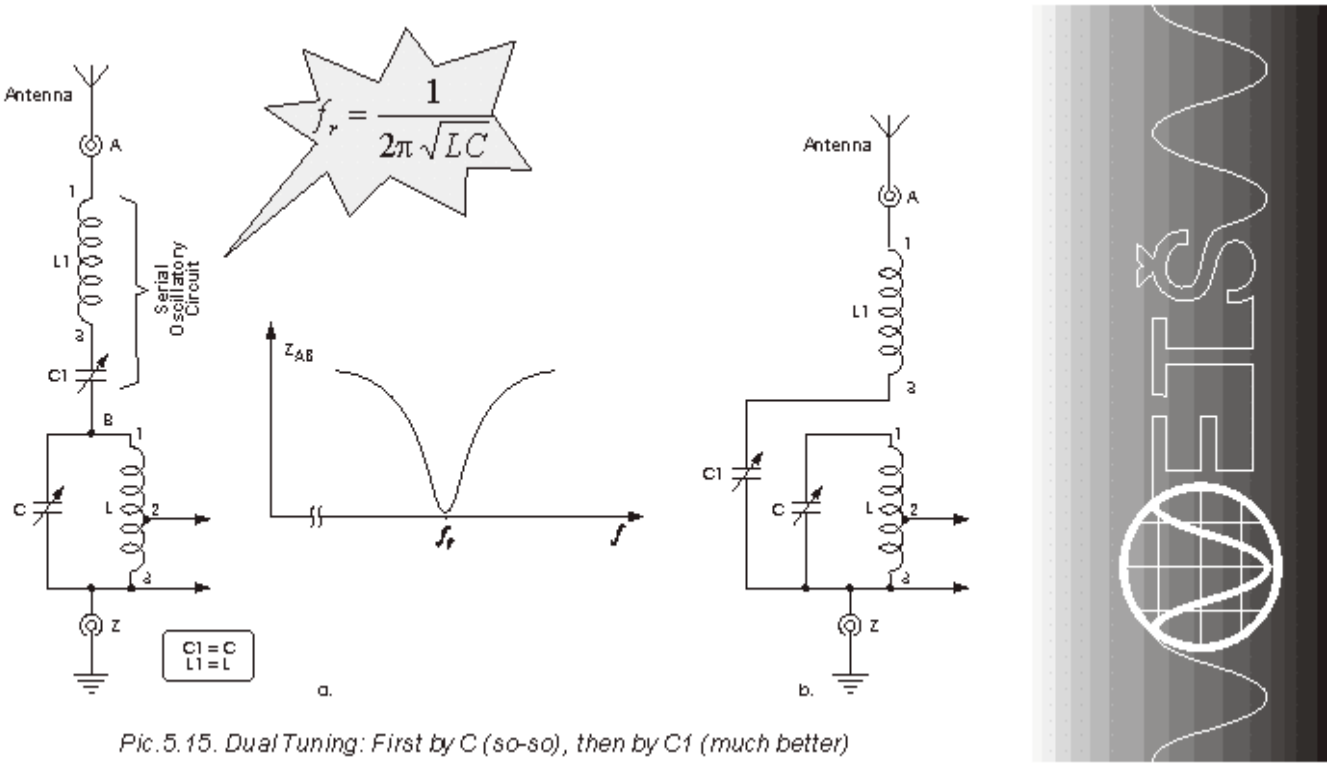

Pic.5.15. Dual Tuning: First by C (so-so), then by C1 (much better)

* Between the coils L1 and L a magnetic coupling should be prevented. This is accomplished by mounting the coils to be as far from each other as possible, and to position their axes mutually perpendicular.

* Greater experimenting opportunities with dual tuning provides the diagram on pic.5.15-b. Once again, it's the serial resonance (in circuit L1, C1), and parallel resonance (in circuit L, C), that are being used. The coils are placed side-by-side, in order to generate magnetic coupling between them. The tuning is done as previously explained, but now we also have a possibility of changing the amount of magnetic coupling between the coils by moving them closer or farther, which affects the antenna's influence on the L, C oscillatory circuit, therefore changing its selectivity and sensitivity.

5.5.5. Separation of Stages - Preventing the Oscillation

On of the significant problems that occur at devices that comprise more cascade-linked amplifying stages is the occurrence of the feedback over the conductors that connect those stages with the positive pole of the battery, or the power supply. By the way, the feedback is a phenomenon when part of the signal exiting an amplifier gets on its input. Under certain conditions, this feedback causes the oscillation of the stage, which in devices that have the loudspeaker on output, manifests itself as strong whistling, squeaking and similar.
On of the ways to prevent this feedback is given on pic.5.16, where a block-diagram of a radio receiver that has four amplifying stages with active components (transistors or IC's) that require the battery supply is shown. Separation of stages for the AC current (preventing the feedback) is accomplished by the LF filters with resistors and capacitors. Resistors are from couple of hundreds of Ohms to 1 kOhm. Capacitances of C1 and C2 are from couple of tenths till couple of hundreds of nF, and of C3 from couple of hundreds of nF to about 100 mF. The stage PCBs should be designed in such way to make the contact where right end of the capacitor is soldered as close to the contact where the positive end of the power supply voltage is brought (e.g. on pic.5.9, the right contact for C6 should be as close as possible to the contact where pin 8 of NE612 is soldered).
In the devices supplied from the battery, the C5 capacitor, which has capacitance of couple of hundreds of micro Farads, serves to take the role of the battery when it gets emptied a little bit, and strong tones have to be reproduced at the loudspeaker (in simple terms, C5 acts as a small accumulator that helps the worn-out battery to give enough power to the power amplifier, when necessary. When its help isn't needed, the capacitor is refilled). This capacitor is not needed when the receiver is supplied from the adaptor that already has an electrolytic capacitor on its output, and when the wires that connect the adaptor to the receiver are not longer than about 15 cm.

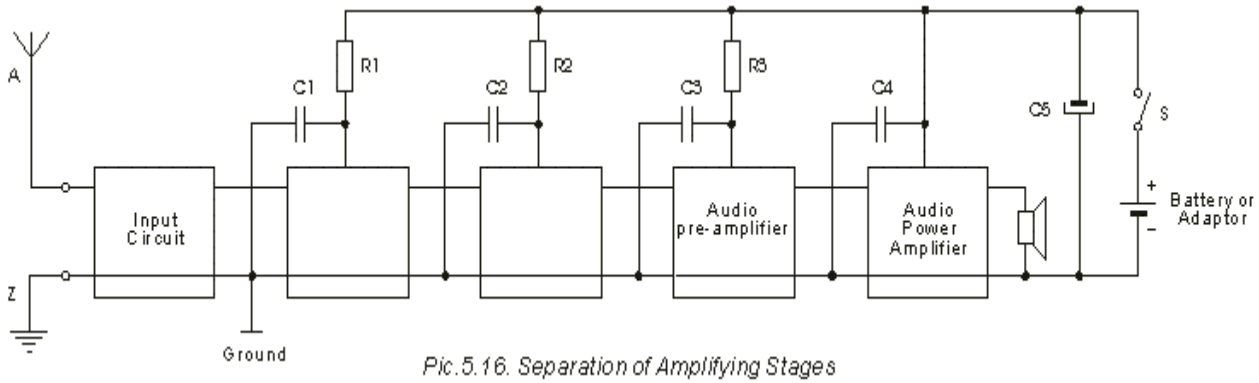

Pic.5.16. Separation of Amplifying Stages

5.6. The Boxes

For all lovers of the electronics, the box where their device is to be put is the famous "production weak link". The finished boxes are either impossible to purchase, or they can be bought but their dimensions or shape is inappropriate, or they are too expensive, or... In cases like this one should be quick-witted enough to find some square-shaped box that is being used at household, or some packaging box or similar. That is how it's done in the "whole white world". Two years ago, in the famous electrotechnical magazine ETI TOP PROJECTS the article named "TIC TAC RADIO" was printed, where a receiver with ZN414 that is placed in the transparent plastic box of TIC TAC mints (In the abstract, it was written that making this device serves well as an excuse for buying candies, which is probably meant for the readers that are on a diet for aesthetic reasons).
However, the "finishing touch" is of great importance for everything. The majority of your friends will be more impressed by a lovely box where the receiver is placed, than the reproduction quality, type of modulation and other technical characteristics. And a nice, appropriate box cannot be bought, it is up to you to make it. It can be something as on pic.3.11 or similar. The idea can be also found in some catalogue of radio receivers' manufacturers, or you can think of something of your own. As far as the author of these lines is concerned, he likes best the wooden boxes from the 20's and 30's of the previous century, from the times of the charleston, E. H. Armstrong and Al Capone. They looked something like those on the pic.5.17 and can serve you as an inspiration for your personal design.

The mid button is for the variable capacitor for station tuning, the right one is for the potentiometer for volume regulation. The button on the left can be a rotary switch for turning on/off (S). It can also be a tone regulation button, and for the reaction-type receivers it can be a button of the potentiometer that regulates the magnitude of the reaction. In the last two cases, the on/off switch (S) is located on the regulation potentiometer. The outside antenna and ground hubs are located at the rear panel of the box. The wires connecting the hubs with the PCB should be isolated, flexible and long enough to be able to open the panel and put it at upright position.
If the receiver is power supplied from the outside net, a green LED should also be added, as the power indicator. The good place for it is just above the variable capacitor's button, instead of the triangle-shaped marker.
Pic.5.18 shows the parts for the first box from pic.5.17. For the front and rear side two pieces of 5 cm thick plywood, measuring 22 cm x 15 cm are needed; for the side panels, two pieces of 10 cm thick plywood, 15 cm x 9 cm, and for the bottom side - one piece of 10 cm thick plywood, measuring 13 cm x 9 cm. The best way to cut these parts is to be done by the carpenter on the special machine, since only then will they be of strictly rectangular shape, and bottom and side panels will have exactly the same width, which is very important during assembling. On the front side, the circle and the arc are drawn with the aid of the sector, and the cutting is done with the carving saw. The part that is cut from the back panel will serve as a closure. When it is cut it isn't necessary to treat it with emery, since it will fit nicely in the hole on the rear panel even if it isn't cut evenly. On the inner side of the rear panel two plywood lattices measuring about 2 cm x 13 cm should be nailed. Four wood screws will be screwed in them later (the holes are shown as four dots), which will serve to tighten the closure. Connecting of the pieces is done with the wood glue and small nails. Before you start hammering, it is very useful to drill a few holes for the nails in the front and rear panel with 1 mm drill. The nails are partially hammered into the panels, the edges are then covered with glue, and the nailing can then be done. When all this is finished, the box should look as the drawing at the right end art of the pic.5.18 *vertical stripes over the loudspeaker opening are not shown. They can be omitted, and you can nail in a few thin lattices, when the box is finished, as shown on the last drawing on the

pic.5.17). The semicircle part is made of 5 mm x 5 mm lattices, or similar, which are put side by side on the upper edges of the front and rear panels, that are covered with glue (the picture shows only one of these lattices). When the last one is fitted, the space between them is filled with "putty" that is made by mixing the fine wooden chips with the wood glue, with the aid of a steel plate. After that, the lattices are tightened to the panels' edges by two pieces of strong scotch tape, which are shown in dashed lines, and everything is left to dry well. When drying is, after about 10 hours, finished, all the edges and lattice parts that protrude are well flattened with emery. All the remaining holes are filled with the fast-drying putty, and everything is abraded once again, and the putty is applied again, and abraded again, etc., until the upper part is semicircle-shaped, all the sides smooth and the edges correct.

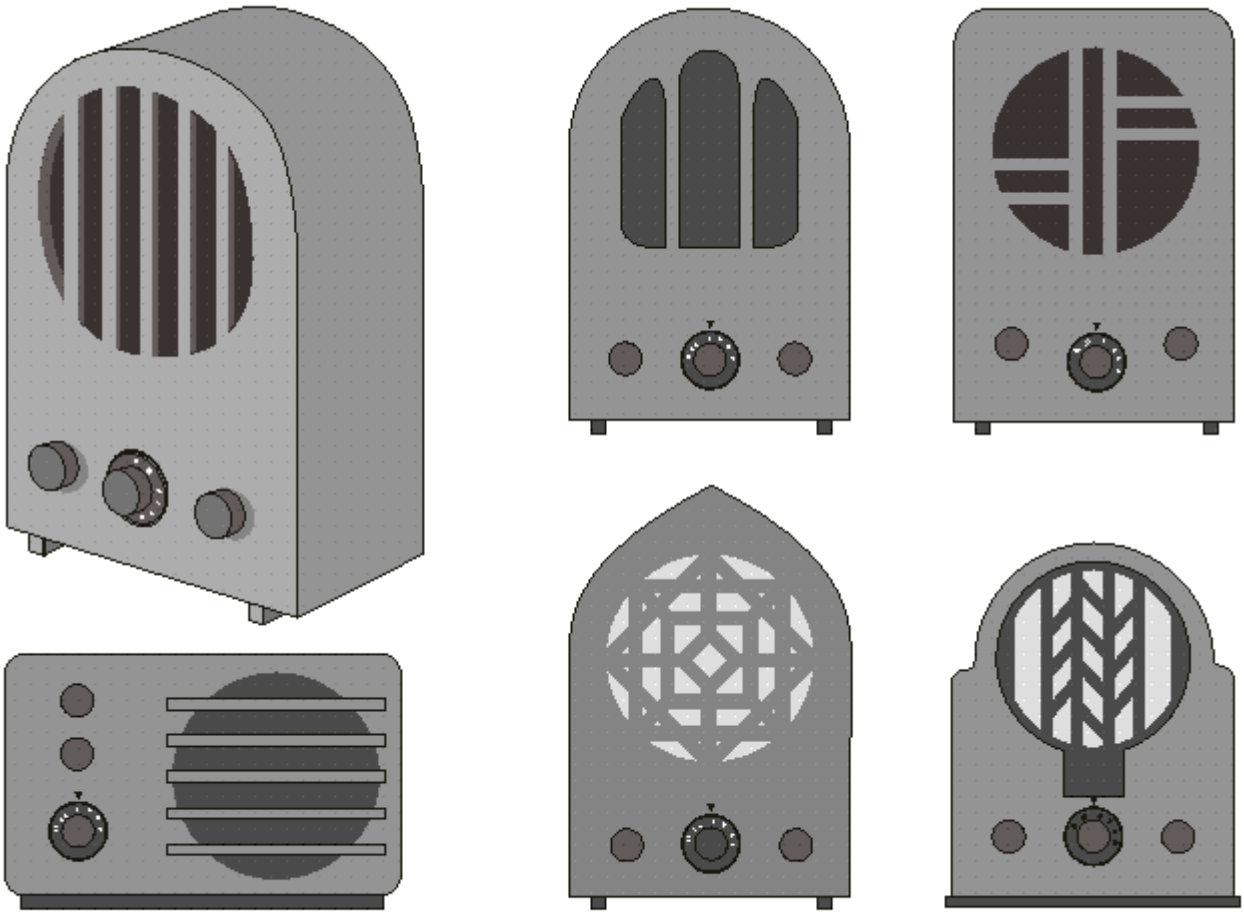

Pic.5.17. Radio Receiver Boxes

* Before the loudspeaker is attached with screws, a piece of decorating cloth should be placed between the panel and the loudspeaker, which will protect it and contribute to better looking box.

* Perhaps some of the readers will seem that there's a lot of exaggeration in previous lines, and even too much pedantry. There's a Latin proverb, that says: AGE QUOD AGIS - Do the

things you do, which, in our case, can be interpreted as: You should either make the box properly or not making it at all.

* This box is relatively small, it is predicted for the loudspeaker that is about 12 cm wide. If you have bigger loudspeaker, and it will certainly play both louder and better, you should make a bigger box. The dimensions calculation is done by dividing the diameter of the bigger opening, that will suit bigger loudspeaker, in centimetres, by 11, and all the measures on pic.5.18 are multiplied with the number attained. E.g. if the diameter for the new, bigger hole is 15 cm, new dimensions are obtained by multiplying the old ones by 1.36.

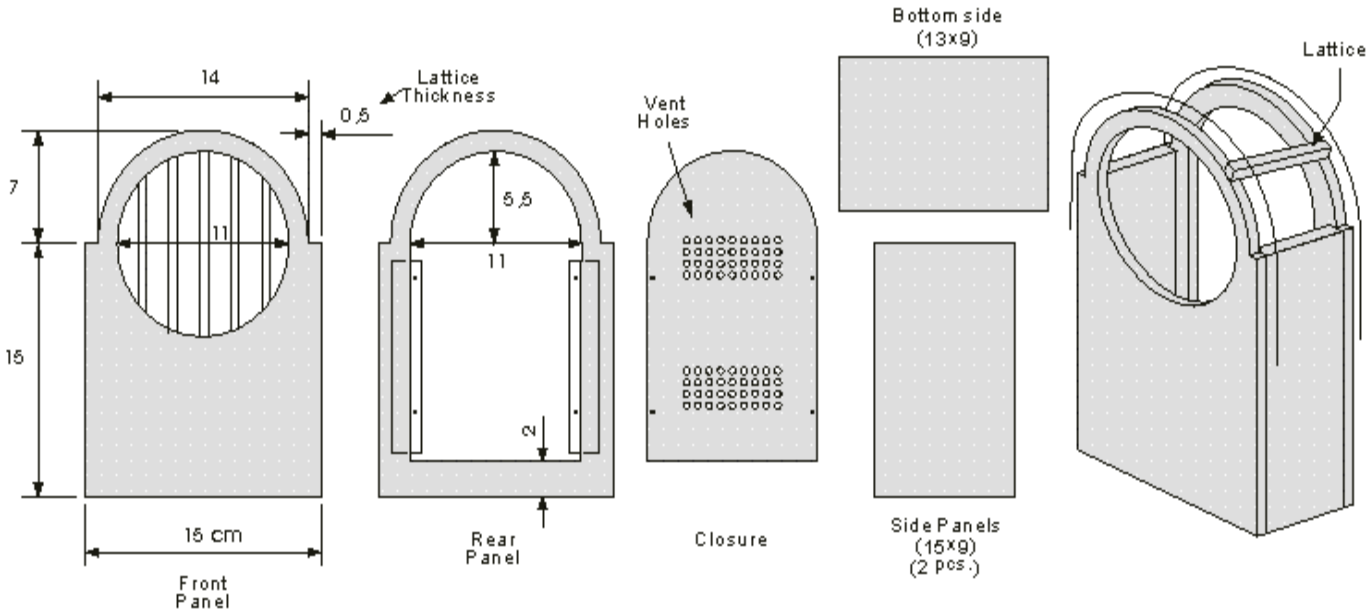

Pic.5.18. Parts of an old-fashioned Radio Receiver's Box

5.7. Bimboard, Protoboard . . .

The readers that have carefully studied all the radio receiver projects that are described here, have possibly noted that the author referred to experimenting either with values of some components or with entire circuits, and all that was in order to practically find the optimal solution. When small changes are discussed, such as finding the optimum value for some resistor, that can be done on the previously made PCB. In case of bigger changes that of course is not convenient, and sometimes it is almost impossible. For all kind of electrical diagrams check-outs as well as various experimenting with all electronic devices, including radios, it is the best to use a special experimental board, which can be purchased under various trade names: protoboard, bimboard, matador, steckplatine, steckboard etc. All of them have in common that component connecting is done without soldering, by simply inserting the legs into the small holes on the plate.
As an example, pic.5.19 shows a full-scale experimental board that can be purchased in one of the Belgrade electronic shops. It has 630 vertically aligned holes, connected internally in 126 groups of 5 holes each, and another 100 holes placed in two topmost lines, connected in two horizontal groups by 50 holes each. The connections between the holes are inside the board and cannot be seen, they are shown on picture in dashed lines. The two topmost

parts are used fo bring the supply voltage, and the battery or the adaptor is connected to them. One of them, most often the one that has minus pole connected to it (in all the devices described herein), also serves as the device Ground. The holes contain miniature metal hubs that are elastic, so when a leg is popped in, a reliable mechanical and electrical junction is accomplished. The distance between the adjacent holes is 2.54 mm (1/10 inch), which allows for connecting the vast majority of electronic components, which are being produced with inter-leg distance that is equal to a hole number multiplied with 2.54 mm (in the producers and sellers' catalogues the 2.54 mm distance is marked as R, which stands for raster, and the components that have their legs horizontally and vertically distanced to 2.54 mm multiplied by some whole number are said to have their legs in raster).
The necessary electrical junctions between the hole groups are accomplished with connecting wires that can be bought at Conrad, but are more often self-made from plastic-isolated 0.5 mm or 0.6 mm copper wire. These pieces vary in their length and can be bent as the biggest piece in the lower left part of the pic.3.19, although it is better and nicer to use regular pieces, shaped as the cyrillic letter P.
Pic.5.19 also shows an example of practical usage of one such board. The radio-receiver from pic.3.15 is made on it. As can be seen, the coil ends are stuck into the holes whose coordinates are j,37; j,39; i,45; i,47, the diode in holes i,39 and i,45, the pin No.1 of the IC in e,54, etc. With the connecting wires the legs No.1 and 3 are connected, the ones that are connected with the potentiometer slider, and legs No.2 and 4 are connected to the ground by means of 4 connecting wires (the minus pole of the battery), etc.
It is now clear that experimenting is done in a very simple manner. E.g. if you are interested how does a capacitance of C2 affect the tone colour in the headphones, all you should do is remove it and insert a capacitor of greater or smaller capacitance, etc.

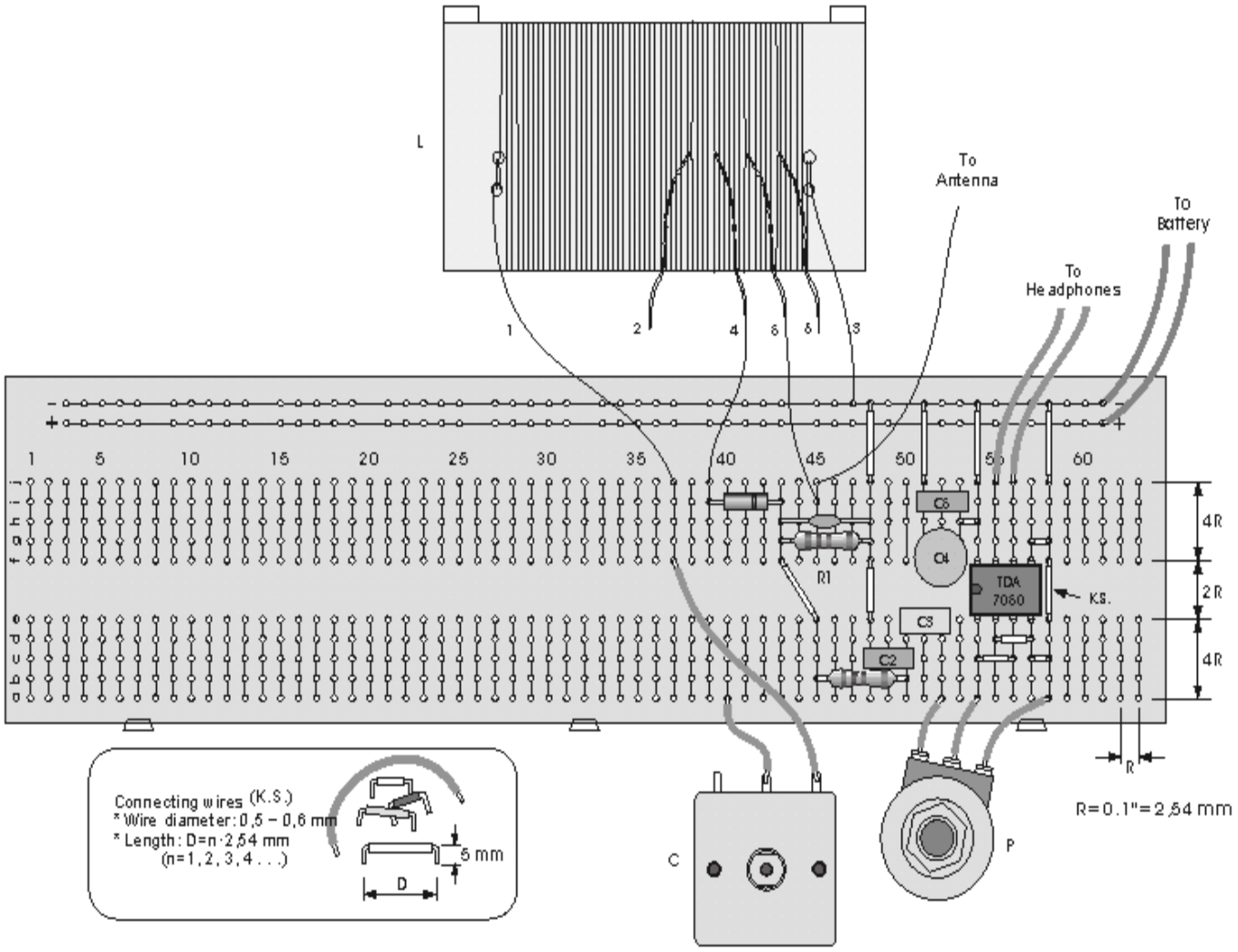

Pic.5.19. The Receiver from pic.3.15 Mounted on the Protoboard

* The hubs on the board are elastic, so that conductors of various diameters can be easily inserted. No wires much thicker than 0.6 mm should be inserted, since the hubs will deform. The components whose legs are too thick as the variable capacitors, potentiometers, transformers and similar, are connected over pieces of wire that are soldered to them.

* It is useful for the connecting wires to be made with isolations of various colours, so that red ones could be used e.g. for connecting with the + battery pole, the black ones with Gnd, the yellow ones for the signal etc.

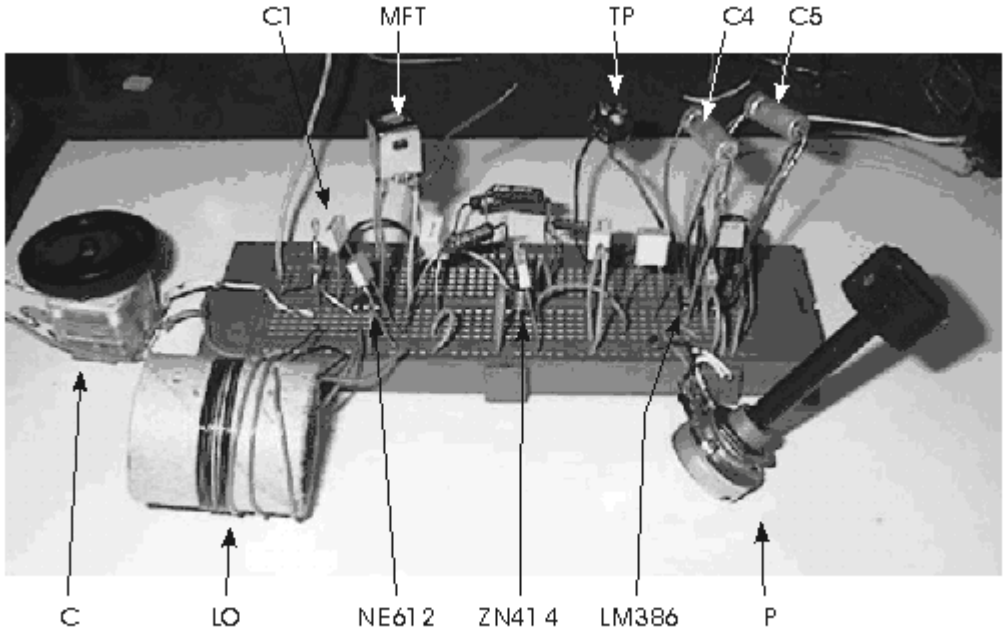

Pic.5.19-b The Receiver from pic.4.5, with the SW Coil, mounted on the Bimboard

5.8. Universal PCB

Practical realization of simple radio receivers, as well as other simple electronic devices, can be done in many ways, as it was discussed in PE No.2. One of those is shown also in this number. That is construction of the detector receiver from pic.3.11, where some of the components are mounted onto the box walls (the variable capacitor, coil and the hubs), while other (the diode and two block-capacitors) are placed between them. With some skills, and by the aid of few smaller nails nailed from the inside of the front panel, a more complex device could be made, say, that from pic.3.12. But this solution would start looking as "the dead cockroach technique", which will be discussed in the "Funniest Electronics". The real solution is the PCB that can be made from the drawings that are given, or those you will draw yourself, together with the instructions given in chapter 5.1.
There's another option for practical realization. It is a universal PCB, that can be bought in the electronic components' stores. There are more sorts of these PCB's, and all of them have in common that the holes on them are drilled on the distance of 1/10 inch (R=2.54 mm).
One of the universal PCB's is shown on pic.5.27. It consists from a huge number of round copper isles, with hole in the middle. The components are being soldered first (resistors, diodes, IC's, capacitors...), and then the component pins are connected by pieces of isolated copper wire, on the soldering side.
As an example, pic.5.28 contains the photograph of the receiver from pic.3.21-a that is made with the universal PCB from pic.5.27. It can be placed into a box as on pic.3.21-c, except the box should be bigger, in order for the loudspeaker to.

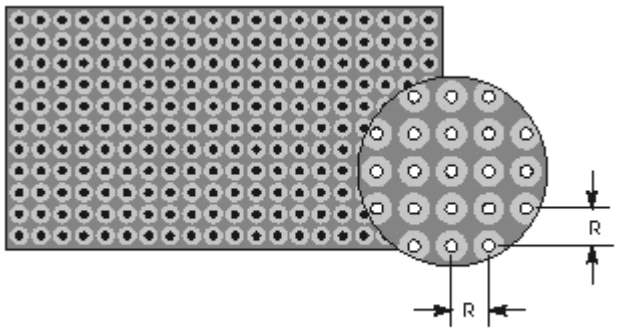

Pic.5.20 The Universal PCB

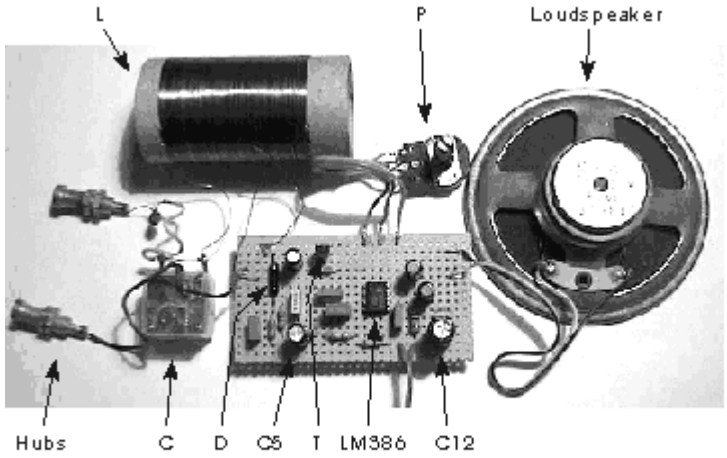

Pic.5.21 The Receiver from pic.3.21-a, mounted on the universal PCB

5.9. A Modern Oldtimer

The receiver on pic.5.22 is designed for the readers that wish to make a semi-conductor model of a complete direct radio receiver that was being produced many years ago, with electronic tubes. It had a total of 3 tubes, one of the contained the HF pentode (utilized in the HF amplifier) and the diode (used in detector), the other one had a triode (pre-amplifier) and powerful pentode (power amplifier), whilst the third one contained the duo-diode (the rectifier).

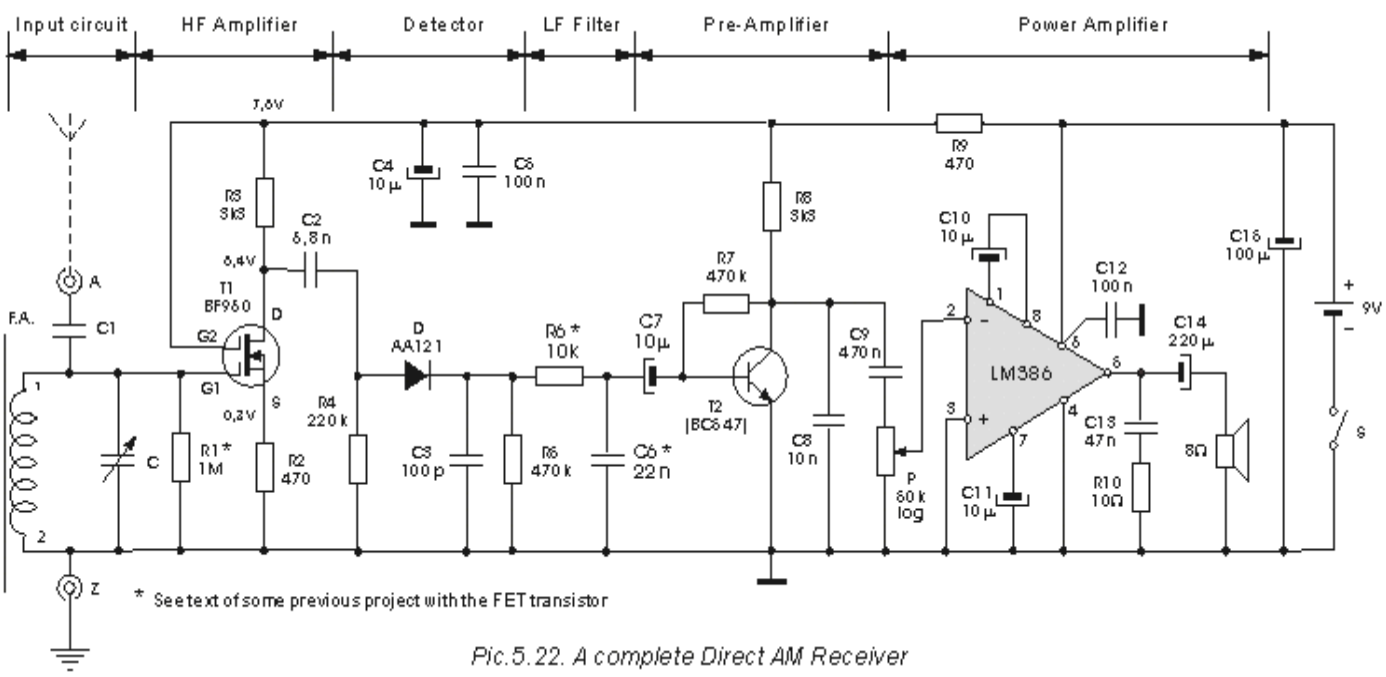

Pic.5.22. A complete Direct AM Receiver

THE END

Visual inspection

What are we looking for during this inspection? In general terms we are inspecting the installation with regard to:

S afety
A ge
D eterioration
C orrosion
O verload
W ear and tear

An easy way to remember this is to use the acronym SADCOW.

Suitability and external influence should also be included. At this point it is a good idea to get from the client any documentation that is relevant to the installation. These documents could include:

- Plans
- Drawings
- Previous test results and certification
- Fuse charts

You should also make it clear that you will require access to all parts of the building and that the electricity supply will need to be turned off at some point. It is also a good idea to ask the client if they are aware of any alterations that have been carried out, as this information may be useful to you during inspection.

The visual inspection of any installation is as important as any testing that is carried out on an installation; if you are not familiar with the building it is also a good opportunity to find your way around first.

The first part of a visual inspection is to ensure that the system is safe to test and that you have enough information to be able to carry out the test safely. Generally, a good place to start would be the supply intake; this will give a reasonable indication of the age, type and size of the installation.

Things to look for at the supply intake before removal of any covers would be:

- The type of supply system – is it TT, TNS or TNCS?
- Is it old or modern?

- Are the conductors imperial or metric?
- What type of protection is there for the final circuits?
- Is documentation available for the original installation?
- Is the consumer's unit labelled correctly?
- Is the earthing conductor in place?
- What size is the earthing conductor?
- Is the earthing conductor green or green and yellow?
- Are all of the circuits in one consumer's unit or are there two or three units that need combining?
- Is there any evidence of equipotential bonding? Remember! It must start at the main earthing terminal.
- What size is the equipotential bonding? Is it large enough?
- Is there a residual current device (RCD)? If so has it a label attached? Is it a voltage or current operated type?
- Do the enclosures meet required IP codes? (Regulation 412-03-01)
- If alterations have been carried out is there documentation available for them, along with test results?
- Where alterations have been carried out since January 2005, has a warning notice been fitted on or near to the distribution board to indicate that new colours have been used? (Regulation 514-14-01)
- What size is the supply fuse? Is it large enough for the required load?
- Are the meter tails large enough?
- Are the seals broken on supply equipment? If they are it could indicate that the system has been tampered with since it was first installed and perhaps closer investigation is required.
- Have any alterations or additions been made?
- Would any alterations or additions affect the required disconnection time for the circuit concerned?

This list is not exhaustive and installation conditions may require more.

When the visual inspection of the supply intake area is complete, that is a good time to look around the building to make sure that there are no very obvious faults. All of this should be carried out before removal of any covers.

Things to look for:

- Are accessories fixed to the wall properly? Are they missing or damaged?
- Are the accessories old with wooden back plates?
- Are the socket outlets round pin or square? Is there a mixture of both?
- Have cables been installed in vulnerable situations?
- Have cables, enclosures and accessories been fixed securely?

- Have ceiling roses got perished flexes? (Particular attention should be given to the old braided and rubber type flexes.)
- Are any socket outlets likely to be used outside? If they are then they should be RCD protected. If they have been installed before the late 1990s, then it is not a requirement that they are, but an RCD should be listed as a recommendation.
- Are earthing clamps to BS 951 standards and correctly labelled?
- If gas, water is bonded using the same conductor, ensure that the conductor is continuous and not cut at the clamp.
- Is the supplementary bonding in place in bathroom? (See Figure 4 of the On-Site Guide.)
- Is the correct equipment for the correct zones in bath/shower room? (See 601 BS 7671)
- Has the bedroom had a shower installed? If so, are the socket outlets 3 metres from the shower and RCD protected?
- Is there any evidence of mutual detrimental influence; are there any cables fixed to water, gas or any other non-electrical services? (*The cables need to be far enough away to avoid damage if the non-electrical services are worked on.*)
- Are the cables of different voltage bands segregated? Low voltage, separated extra low voltage (SELV), telephone cables or television aerials should not be fixed together (*although they are permitted to cross*).

Whilst these items are being checked, look in any cupboards for sockets or lights. If your customer is uncomfortable with this it is vitally important that you document any areas that cannot be investigated in the extent and limitation section on the Periodic Inspection Report. During this purely visual part of the inspection you will gain some idea of the condition of the installation, and indeed any alterations which have been carried out by a qualified tradesman or by a cowboy/girl.

Clearly, if it is an old installation, an electrical installation certificate must be completed and some of the items listed above will apply. However, if it is a new installation, access to all areas must be secure; if this is not possible then the certificate should not be issued. Again, this list is not exhaustive but will not require removal of any fittings, etc.

Providing that you are happy that the installation is safe to tamper with, a more detailed visual inspection can be carried out and the dreaded but necessary form filling can be started.

Once again begin at the consumer unit. Before you start, this must be isolated. The Electricity at Work Regulations 1989 states that it is an offence

to work live. Once you remove a cover you will be working live if you do not isolate it first. Having carried out the safe isolation procedure, remove the cover of the consumer unit.

- Your first impression will be important – has care been taken over the terminations of cables (*neat and not too much exposed conductor*)?
- Are all cables terminated and all connections tight (*no loose ends*)?
- Are there any signs of overheating?
- Is there a mixture of protective devices?
- Are there any rubber cables?
- Are there any damaged cables (*perished or cut*)?
- Have all circuits got Circuit Protective Conductors (CPCs)?
- Are all earthing conductors sleeved?
- On a photocopy of a Schedule of Test Results record circuits, protective devices and cable sizes.
- Look to see if the protective devices seem suitable for the size cables that they are protecting.
- Note any type D or 4 circuit breakers – these will require further investigation.
- Are all barriers in place?
- Have all of the circuit conductors been connected in sequence, with phase, neutral and CPC from circuit number 1 being in terminal number 1 – preferably the highest current nearest the main switch?
- Have any protective devices got multiple conductors in them, are they the correct size (*all the same*)?
- Is there only one set of tails or has another board been connected to the original board by joining at the terminals?

Having had a detailed look at the consumer unit, and with the installation still isolated, carry out a more detailed investigation of the rest of the installation.

It may be that you have agreed with your client that only 10% of the installation is to be inspected. This would mean 10% of each circuit. There would be little point in inspecting 10% of the circuits. If the period between inspections was 10 years it could be many years before a circuit was eventually inspected and the exercise would be pointless.

During your preliminary walk around, you will have identified any areas of immediate concern, and these must be addressed as your inspection progresses. There is no reason why you should not start your dead testing at this point, as you progress through your visual inspection.

On radial circuits this would be a good time to carry out CPC continuity, $R_1 + R_2$, insulation resistance and polarity tests as you work your way round. Start at circuit number 1 and work your way through the circuits one at a time.

But first what are you looking for? Let's look at a selection of circuits.

Shower circuit

- Is isolation provided, if so is it within prescribed zones?
- Has the correct size cable/protective device been selected?
- Is it bonded?
- Are connections tight?
- Has earth sleeving been fitted?
- Is the shower secure?
- Is there any evidence of water ingress?
- Is the shower in a bedroom?

Cooker circuit

- Is the switch within 2 metres of the cooker or hob?
- Has the cooker switch got a socket outlet? If so it requires a 0.4 second disconnection time.
- Green and yellow sleeving fitted.
- If it has a metal faceplate has it got an earth tail to the flush box?
- Is the cable the correct size for protective device?
- Are there any signs of overheating around the terminations?
- Is the cooker outlet too close to the sink? Building regulations require any outlets installed after January 2005 should be at least 300 mm from the sink.

Socket outlets

- Is there correct coordination between protective devices and conductors?
- Green and yellow sleeving fitted.
- Do any metal sockets have an earthing tail back to the socket box?
- Radial circuit not serving too large an area (*see Table 8A of the On-Site Guide*).
- Secure connections.
- Are cables throughout the circuit the same size?
- Are there any sockets outside? Are they waterproof? Are they 30 mA RCD protected?
- Are there any outlets in the bathroom? If there is, are they SELV?

- Are there socket outlets within 3 metres of a shower installed in a bedroom? If there is, are they 30 mA RCD protected?
- Will the protective device for the circuit provide 0.4 seconds disconnection time?

Fused connection units and other outlets

- As above but could be 5 second disconnection time.
- Does it supply fixed equipment in bathrooms? Are they in the correct zones?
- Do they require RCD protection? (*Regulation 601-09-02 and 601-09-03*)
- Permanently connected equipment must be protected locally by a plug or fused connection unit or comply with (*Regulation 476-03-04*).

Immersion heater circuits

- Is there correct coordination between the protective device and live conductors?
- Has the CPC been sleeved?
- Is the immersion the only equipment connected to this circuit? (*Any water heater with a capacity of 15 litres or more must have its own circuit*.) *On-Site Guide*, Appendix 8. Often you will find that the central heating controls are supplied through the immersion heater circuit.
- Is the immersion heater connected with heat resistant cord?
- The immersion heater switch should be a cord outlet type; not a socket outlet and plug.
- If the supplementary bonding for the bathroom is carried out in the cylinder cupboard, does the supplementary bonding include the immersion heater switch? (It should.)

Lighting circuits

- Is there correct coordination between the protective device and the live conductors?
- How many points are there on the circuit? A rating of 100 watts minimum must be allowed for each lighting outlet. Shaver points, clock points and bell transformers may be neglected for the purpose of load calculation. As a general rule, ten outlets per circuit is about right. Also remember that fluorescent fittings and discharge lamps are rated by their output, and the output must be multiplied by a factor of 1.8 if exact information is not available (*Table 1A of the On-Site Guide*).
- Are the switch returns colour identified at both ends?
- Have the switch drops got CPCs? If they have, are they sleeved with green and yellow?
- Are the CPCs correctly terminated?

- Are the switch boxes made of box wood or metal?
- Are ceiling roses suitable for the mass hanging from them?
- Only one flexible cord should come out of each ceiling rose unless they are designed for multiple cords.
- Light fittings in bathrooms must be suitable for the zones in which they are fitted.
- Circuits supplying luminaries fitted outside must have a 0.4 second disconnection time (*Regulation 471-08-03*).
- Is the phase conductor to ES lampholders connected to the centre pin? This does not apply to E14 and E27 lampholders (*Regulation 553-03-04*).

Three phase circuit/systems

These circuits should be inspected for the same defects that you could find in other circuits. In addition to this:

- Are warning labels fitted where the voltage will be higher than expected? For example, a lighting switch with two phases in it, or perhaps where sockets close to each other are on different phases.
- Are conductors in the correct sequence?
- Remember PFC should be double the phase to neutral fault current.

Occasionally other types of circuit will be found, but the same type of inspection should be carried out using common sense.

Always remember that the reason for this inspection is to ensure safety

Periodic testing

The level of testing will usually be far less for periodic testing than it is for initial verification; this is providing that previous test results are available. If they are not, then it will be necessary for the full survey and the complete range of tests to be carried out on the installation, to provide a comprehensive set of results.

The level of testing will depend largely on what the inspector discovers during the visual inspection, and the value of results obtained while carrying out sample testing. If any tests show significantly different results, then further testing may be required.

In some cases, up to 100% of the installation will need to be tested. Periodic testing can be dangerous, and due consideration should be given to safety.

Persons carrying out the testing must be competent and experienced in the type of installation being tested and the test instruments being used.

There is no set sequence for the testing which may be required for the completion of the periodic inspection report. The sequence and type of tests which are to be carried out are left to the person carrying out the test to decide upon. Where tests are required, the recommendations for these tests would be:

	Recommended tests
Continuity of protective conductors	Between the distribution board earth terminal and exposed conductive parts of current using equipment. Earth terminals of socket outlets (test to the fixing screw of outlet for convenience).
Continuity of bonding conductors	All main bonding and supplementary bonding conductors.
Ring circuit continuity	Only required where alterations or additions have been made to the ring circuit.
Insulation resistance	Only between live conductors joined and earthed. Or between live conductors with the functional switch open if testing lighting circuit.
Polarity	Live polarity tested at the origin of the installation. Socket outlets. At the end of radial circuits. Distribution boards.
Earth electrode resistance	Isolate installation and remove earthing conductor to avoid parallel paths.
Earth fault loop impedance	At the origin of the installation for Z_e. Distribution boards for the Z_e of that board. Socket outlets and at the end of radial circuits for Z_S.
Functional tests	RCD tests and manual operation of isolators, protective devices and switches.

Voltage drop in conductors

It is part of the inspection process to ensure that installed conductors have been correctly selected for current carrying capacity and voltage drop.
To check the suitability of the current carrying capacity it is simply a matter of looking at the installation method, and then checking on the current carrying capacity tables for the cable in Appendix 4 of BS 7671.

To ensure that the cable meets the voltage drop requirements is slightly more complex. A simple method is to measure the voltage at the origin of the circuit, and then measure the voltage at the end of the circuit with the load connected and switched on. The difference between the two measurements will be the volt drop.

If the first method is impractical, then a resistance test should be carried out between the phase and neutral of the circuit. This test is carried out using the same method as the $R_1 + R_2$ test although, instead of the test being between phase and CPC, it is between the phase and neutral for the circuit. Once the resistance $R_1 + R_n$ of the circuit has been measured it should be multiplied by the current that will flow in the circuit. This will give you the volt drop for the circuit.

Example

A circuit is wired in 2.5 mm^2 and is 25 metres in length. The current in the circuit is 18 amps.

The measured value of resistance is 0.37 Ω

$$\textit{Voltage drop} = I \times R = V$$
$$18 \times 0.37 = 6.66 \textit{ volts.}$$

This is the voltage drop for the circuit.

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3 Testing of electrical installations

Safe isolation

It cannot be over-emphasized how important it is that isolation of electrical circuits is carried out in a set sequence, and that this sequence is repeated each time a circuit or complete installation is to be isolated.

If the same procedure is followed each time isolation is carried out, it will soon become a habit, which can only be a good thing as it may save your life.

It is vital that the correct test equipment is used for isolation and that it complies with the Health and Safety Executive document GS 38. This document gives guidance on the use of test equipment, particularly leads and probes.

The GS 38 document is not a statutory document but if the guidance given in the document is followed, it will normally be enough to comply with the Health and Safety at Work Act 1974, the Electricity at Work Regulations 1989 and any other statutory requirements that may apply. The items of equipment that should be available to persons carrying out the safe isolation procedure are:

- A proving unit

- An approval voltage indicator (left) and test Lamp (right)

- Warning notices

- Locking devices

Another useful piece of equipment is:

- An R_1 and R_2 box. This will not only be useful for the safe isolation of socket outlets, it can also be used for ring circuit testing and the $R_1 + R_2$ testing of radial circuits incorporating a socket or socket outlets without having to remove them from the wall.

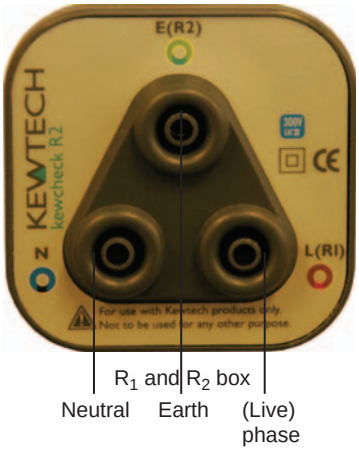

The leads should be:

- Flexible and long enough, but not too long.
- Insulated to suit the voltage at which they are to be used.
- Coloured where it is necessary to identify one lead from the other.
- Undamaged and sheathed to protect them against mechanical damage.

The probes should:

- Have a maximum of 4 mm exposed tip (preferably 2 mm).
- Be fused at 500 mA or have current limiting resistors.
- Have finger guards (*to stop fingers slipping on to live terminals*).
- Be colour identified.

Isolation procedure

It is very important to ensure that the circuit that you want to isolate is live before you start. To check this, a voltage indicator/test lamp or a piece of equipment that is already connected to the circuit should be used. If it appears that the circuit is already dead, you need to know why.

- Is somebody else working on it?
- Is the circuit faulty?
- Is it connected?
- Has there been a power cut?

You must make absolutely certain that you and you alone are in control of the circuit to be worked on. Providing the circuit is live you can proceed as follows:

STEP 1

Ensure voltage indicator/test lamp is working correctly.

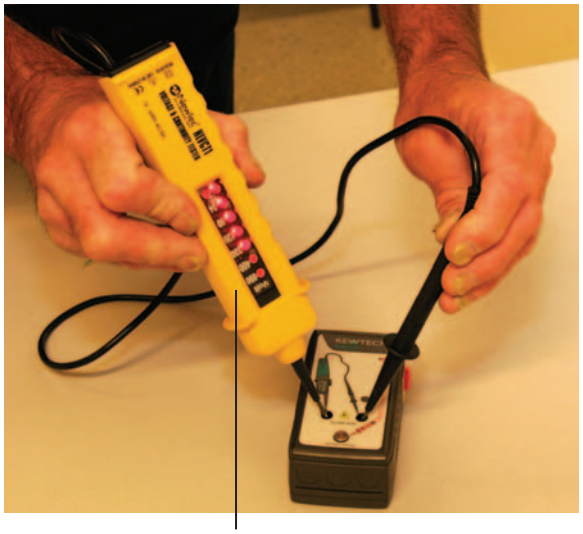

Voltage lights lit

STEP 2

Test between all live conductors and live conductors and earth.

Voltage lights lit

STEP 3

Locate the point of isolation. Isolate and lock off.

Place warning notice (**DANGER ELECTRICIAN AT WORK**) at the point of isolation.

STEP 4

Test circuit to prove that it is the correct circuit that you have isolated.

Be careful! Most test lamps will trip an RCD when testing between live and earth, it is better to use an approved voltage indicator to GS 38 as most of these do not trip RCDs

STEP 5

Check that the voltage indicator is working by testing it on a proving unit or a known live supply.

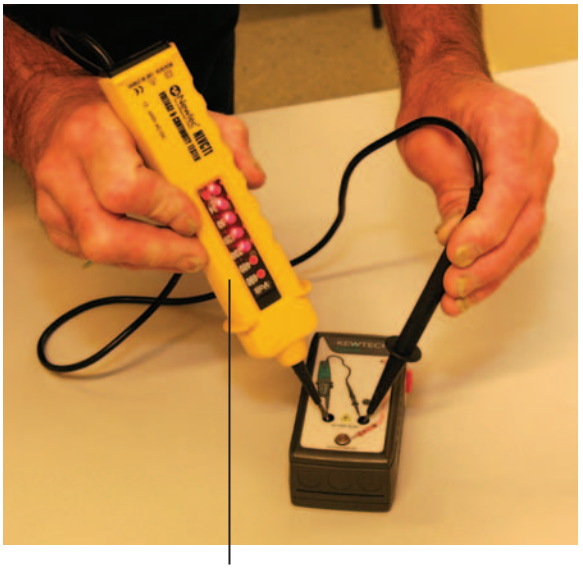

Voltage lights lit

When carrying out the safe isolation procedure never assume anything, always follow the same procedure

It is now safe to begin work.

If the circuit which has been isolated is going to be disconnected at the consumer's unit or distribution board, **REMEMBER** the distribution board should also be isolated. The Electricity at Work Regulations 1989 do not permit live working.

Testing for continuity of protective conductors

Main equipotential bonding

This test is carried out to ensure that the equipotential bonding conductors are unbroken, and have a resistance low enough to ensure that, under fault conditions, a dangerous potential will not occur between earthed metalwork (*exposed conductive parts*) and other metalwork (*extraneous conductive parts*) in a building.

It is not the purpose of this test to ensure a good earth fault path but to ensure that, in the event of a fault, all exposed and extraneous conductive parts will be live at the same potential, hence EQUIPOTENTIAL bonding. In order to achieve this, it is recommended that the resistance of the bonding conductors does not exceed 0.05 Ω.

Table 54H of the *On-Site Guide* and Regulation 547-02-02 in BS 7671 cover the requirements of equipotential bonding. Table 10A of the *On-Site Guide* is also useful. Maximum lengths of copper bonding conductors before 0.05 Ω is exceeded.

Size mm^2	Length in metres
10	27
16	43
25	68
35	95

The test is carried out with a **Low Resistance Ohm meter** and often can only be carried out on the initial verification; this is because one end of the bonding conductor must be disconnected to avoid parallel paths. When disconnecting a bonding conductor, it is important that the installation is isolated from the supply. On larger installations it is often impossible to isolate the installation and, therefore, the conductor must remain in place. The instrument should be set on the lowest value of Ω possible.

STEP 1

Isolate supply (as safe isolation procedure)

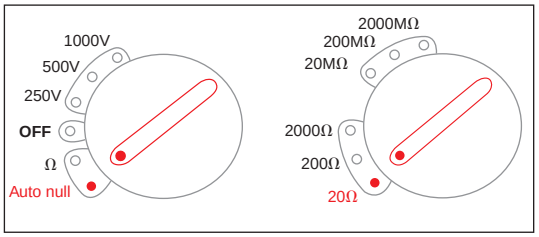

STEP 2

Disconnect one end of the conductor (*if possible, disconnect the conductor at the consumers unit, and test from the disconnected end and the metalwork close to the bonding conductor. This will test the integrity of the bonding clamp*).

Test leads

STEP 3

Measure the resistance of test leads or null leads (*these may be long as the only way that we can measure a bonding conductor is from end to end*).

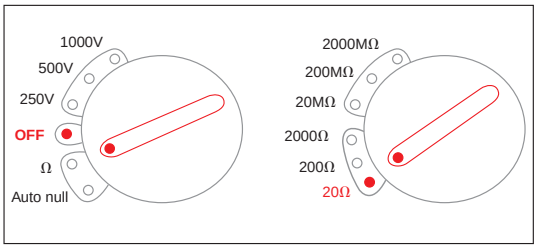

Nulled leads

STEP 4

Connect one test lead to the disconnected conductor at the consumer's unit.

Note: Safety notice removed for clarity.

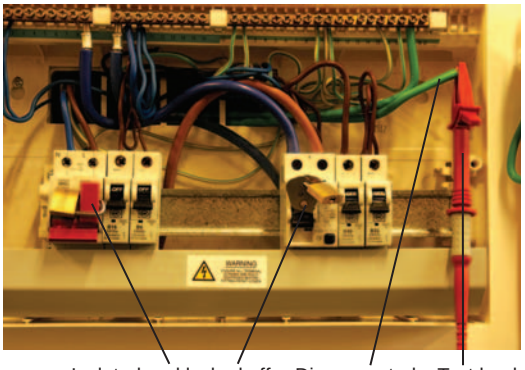

STEP 5

Connect the other end of the test lead to the metalwork that has been bonded (connecting the lead to the metalwork and not the bonding clamp will prove the integrity of the clamp).

STEP 6

If the instrument is not nulled remember to subtract the resistance of the test leads from the total resistance. This will give you the resistance of the bonding conductor. If the meter you are using has been nulled, the reading shown will be the resistance of the conductor.

STEP 7

Ensure that the bonding conductor is reconnected on completion of the test.

Whilst carrying out this test a visual inspection can be made to ensure that the correct type of BS 951 earth clamp, complete with label is present, and that the bonding conductor has not been cut if it is bonding more than one service.

If the installation cannot be isolated on a periodic inspection and test, it is still a good idea to carry out the test; the resistance should be a maximum of 0.05Ω as any parallel paths will make the resistance lower. If the resistance is greater than 0.05Ω the bonding should be reported as unsatisfactory and requires improvement.

In some instances the equipotential bonding conductor will be visible for its entire length; if this is the case, a visual inspection would be acceptable, although consideration must be given to its length.

For recording purposes on inspection and test certificates no value is required but verification of its size and suitability is.

Items to be bonded would include any incoming services, such as: water main, gas main, oil supply pipe, LPG supply pipe. Also included would be structural steel work, central heating system, air conditioning, and lightning conductors within an installation (*before bonding a lightning conductor it is advisable to seek advice from a specialist*).

This is not a concise list and consideration should be given to bonding any metalwork that could introduce a potential within a building.

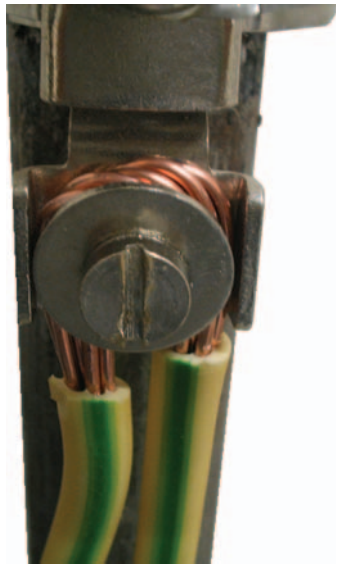

✓ Correct

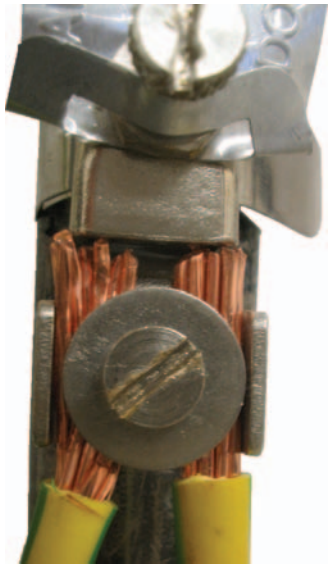

✗ Incorrect

Continuity of supplementary bonding

There are two general reasons for carrying out supplementary equipotential bonding.

Supplementary bonding 1

This is required when there is an increased risk of electric shock (Regulation 471-08-01).

BS 7671 states that supplementary bonding must be installed in bathrooms/shower rooms and swimming pools.

It should be remembered that, although Regulation 601-04-01 requires that we must bond the exposed and extraneous conductive parts in bathrooms, this Regulation applies only to zones 1, 2, and 3.

Due consideration must be given to other areas where there is an increased risk of electric shock. There is no specific requirement to carry out supplementary bonding in Kitchens. However, if it is thought by the installer that there is an increased risk of electric shock, there is no reason why bonding could not be carried out, it will do no harm providing it is carried out correctly.

On occasions it is often useful to carry out supplementary bonding, particularly under Kitchen sinks. This may not be for electrical reasons, more for visual purposes – bonding is not well understood by many people. A possible scenario might be where you may have travelled 20/30 miles to fit a Kitchen and completed everything to comply with the required regulations. A few days later, before you have been paid for the work you receive a phone call from your customer, informing you that his next door neighbour has spotted that you have not bonded the sink. Of course your customer will believe his neighbour is right and that you have forgotten something or tried to save a bit of money. The choice is now yours, do you try and convince your customer that his neighbour is wrong or do you travel back to the job to carry out the bonding to ensure payment? Perhaps for the sake of a couple of earth clamps and a short length of 4 mm^2, it would have been cheaper just to bond it in the first place.

Where complimentary supplementary bonding is used in this instance a test must be carried out to ensure that the resistance between exposed and extraneous conductive parts is in place and has a resistance of less than 0.05 Ω. The instrument to be used is a low resistance ohm meter.

Probe on solid metal part of tap

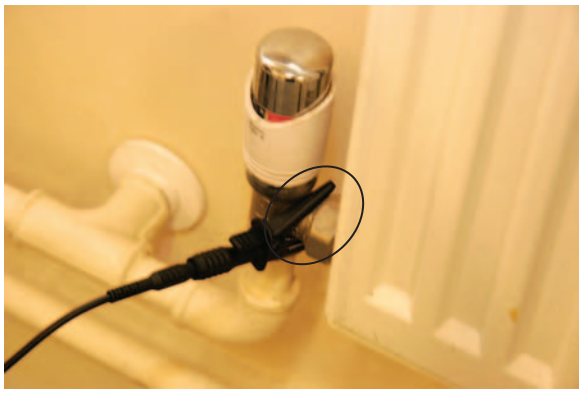

Probe on unpainted metal work

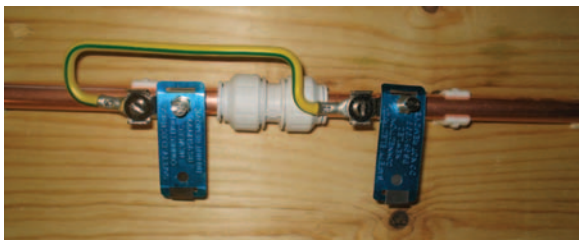

Bonding conductor

A visual check must be made to ensure that the correct earth clamps have been used and that they have the correct labels attached.

It is perfectly acceptable to use the pipe work and structural steelwork within the area as a bonding conductor, and bonding can be carried out adjacent to the area providing that the integrity of the pipe work/steelwork can be assured. An airing cupboard would be a good example of a suitable place to bond.

If it is necessary for the lighting point or electric shower in a bathroom (*remember if they are not within zones 1, 2, or 3 no bonding is required*), there is no reason why the bonding conductor could not be simply attached to a pipe within the roof space, which is bonded elsewhere and passes near the item which requires bonding. The correct bonding clamps and labels should always be used.

If using pipe work of plumbing and heating systems as bonding, continuity of the pipe work must be verified. The resistance values are the same as if copper cables were used. Tests must be made between exposed and extraneous conductive parts to ensure that the resistance does not exceed 0.05Ω. This is a simple test carried out using a low resistance ohm meter. A probe of one lead should be placed on one metal part and the probe of the other lead placed on an adjacent metal part. The resistance must be no greater than 0.05Ω.

Problems can arise if the pipe work is altered and plastic push fittings are used. Clearly these will not conduct and the bonding continuity could be compromised. If ever a plastic plumbing fitting is used on copper pipe work, consideration should be given to the installation of a bonding conductor installed across the fitting.

It is a common belief that water in pipe work will conduct; in fact, the current that would flow through water in a 15 mm diameter pipe which has a plastic joint in it is very small.

To find out just how much, I set up a simple controlled experiment, two short lengths of 15 mm pipe were joined using a 15 mm plastic push fit coupler. The pipe was then filled with water and the two ends of the joined pipe were connected to a 230 volt supply. The current flowing was measured to be 0.003 Amperes (3 mA). The current flow would increase if the water had central heating additives in it, but not considerably.

In bathrooms/shower rooms where the plumbing has been carried out using plastic pipe, the pipe work does not need supplementary bonding; however, it should be remembered that electrical appliances and any extraneous/exposed conductive parts within zones 1, 2 and 3 must still be bonded. Figure 4d and 4e in section 4 of the *On-Site Guide* are good places of reference for this.

For the sizing of supplementary bonding Table 10b in Appendix 10 of the *On-Site Guide* should be used. As a general rule, supplementary bonding within a bathroom should be 2.5 mm^2 if mechanically protected or 4 mm^2 if not. It is usually easier to use 4 mm^2 to save the trouble of mechanically protecting the bonding conductor (see Regulation 547-03 of BS 7671).

Supplementary bonding 2

Used where, due to various circumstances, the required disconnection time cannot be met by conventional methods, and where it is not desirable to use a residual current device. Supplementary equipotential bonding may be used as a means of compliance (Regulation 413-02-04 (i)).

Wherever supplementary bonding is used in this instance it must be tested to ensure that the resistance between two parts is less than the value R obtained by the following formulae:

$$R = \frac{50}{I_a}$$

R = maximum resistance of bonding conductor; 50 = the safe touch voltage (*this may be 25 volts in special locations*); I_a = fault current needed to operate the protective device within 5 seconds (Regulation 413-02-28).

If the circuit is protected by a Residual current device I_a may be substituted by $I\Delta_n$.

The fault current can be found in Appendix 3 in BS 7671 or by using the calculation:

$$I_a = \frac{U_{OC}}{Z_S}$$

U_{OC} = open circuit voltage of supply transformer; Z_S = maximum earth loop impedance for the protective device.

The test should be carried out between exposed and extraneous conductive parts, using a low resistance ohm meter with long leads to find out the resistance between them. If the resistance is higher than that required, then supplementary bonding is required.

Exposed conductive parts

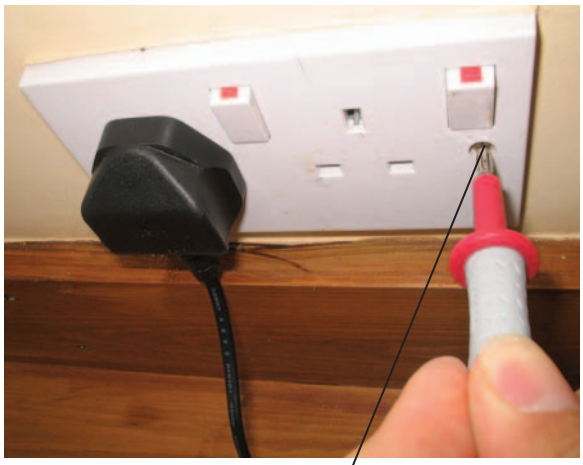

Screw fixings are earthed

Extraneous conductive parts

Unpainted metal work

Example 1

A circuit on a TN system is to be altered. The current carrying capacity and the volt drop of the cable are adequate for the load. However, the Z_S value is too high for the 20A BS 1361 protective device which is being used to protect the circuit.

The maximum resistance permissible between exposed and extraneous conductive parts must be calculated.

The first step is to find the current that would cause automatic disconnection of the supply.

$$I_a = \frac{U_{OC}}{Z_S}$$

$$I_a = \frac{240}{2.93} = 81.91\,amps$$

This value can also be found in Figure 3.1 of Appendix 3 of BS 7671 (it is rounded up to 82 amps).

The maximum permissible resistance between conductive parts can now be found by:

$$R = \frac{50}{I_a}$$

$$R = \frac{50}{82} = 0.6\Omega$$

Supplementary bonding is installed where there is a risk of simultaneous contact with any extraneous and exposed conductive parts. Its purpose is to ensure that the potential between any of these parts does not rise above a safe value. In most cases, this value is 50 volts, although some chapters in Part 6 of BS 7671 require a maximum potential of only 25 volts.

Determining if a part is extraneous, or just a piece of metal

A test should be made using an insulation resistance tester set on mΩ, supplying 500 volts.

Connect one test lead to the metal part and the other lead to a known earth. If the resistance value is 0.02 mΩ (20,000 Ω) or greater, no supplementary bonding is required. If less than 0.02 mΩ, supplementary bonding should be carried out.

If we use Ohm's law we can see how this works:

$$\frac{V}{R} = I: \qquad \frac{500}{20{,}000} = 0.025\ A$$

This shows that a current of 25 mA would flow between the conductive parts; this would of course only be 0.012 amp if the fault was on a single phase 230 volt supply. This current is unlikely to give a fatal electrical shock.

The test must not be confused with a continuity test. It is important that an insulation resistance tester is used.

Continuity of circuit protective conductors

This test is carried out to ensure that the CPC of radial circuits are intact and connected throughout the circuit. The instrument used for this test is a **low resistance ohm meter** set on the lowest value possible.

This is a dead test and must be carried out on an isolated circuit.

Testing can be carried out using two methods.

Method one

STEP 1

Using a short lead with a crocodile clip on each end, bridge phase and CPC together at one end of the circuit (*it does not matter which end, although it is often easier to connect at the distribution board as this will certainly be one end of the circuit*).

The resistance of this lead plus the resistance of the test leads should be subtracted, or the instrument nulled before the $R_1 + R_2$ reading is recorded.

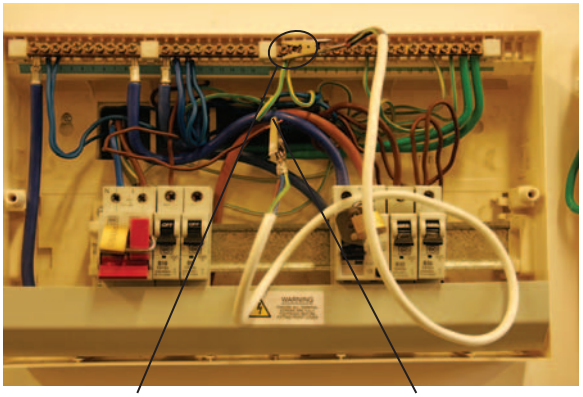

STEP 2

At **each** point on the circuit test between phase and CPC.

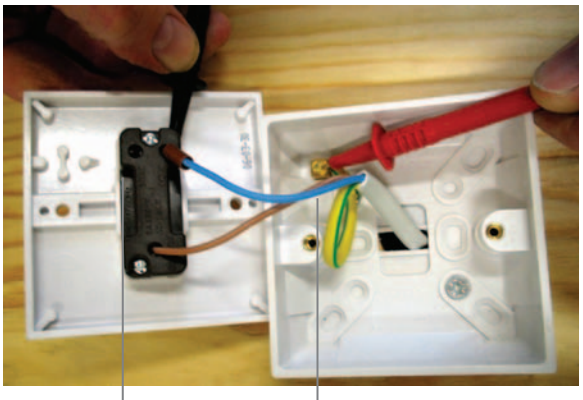

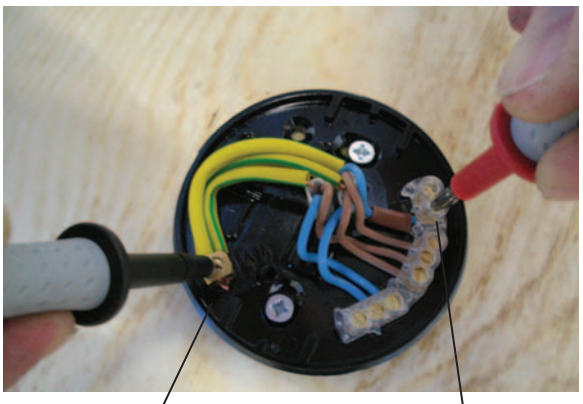

Keep a note of the readings as you carry out the test, they should increase as you move further from the connected ends. The highest reading obtained should be at the furthest end of the circuit and will be the $R_1 + R_2$ of the circuit. This value should be recorded on the schedule of test results. If the highest reading is obtained at a point which is not the furthest from the circuit, further investigation should be carried out as it may indicate a loose connection (high resistance joint).

In some instances only the value of R_2 may be required. Where the phase conductor is the same size as the CPC the total measured resistance can be divided by 2 as the phase and CPC resistance will be the same. If the phase and CPC are of different sizes (this is usual in twin and earth thermoplastic cable) the R_2 value can be calculated using the following formula:

$$R_2 = R_1 + R_2 \times \frac{A\ phase}{A\ CPC + A\ phase}$$

R_2 = resistance of CPC in ohms; $R_1 + R_2$ = measured value of resistance in ohms; *A phase* = Area of phase conductor in mm^2; *A CPC* = Area of CPC mm^2.

Example 2

A radial circuit is wired in 2.5 mm^2 phase and 1.5 mm^2 CPC. The test resistance of $R_1 + R_2$ is 0.37 Ω.

To calculate the resistance of the CPC on its own:

$$R_2 = 0.37 \times \frac{2.5}{2.5 + 1.5}$$
$$R_2 = 0.37 \times 0.625 = 0.23\Omega$$

If the CPC is smaller than the phase conductor, the resistance of the CPC conductor will always be greater than the phase conductor as it has a smaller cross-sectional area.

Another method of determining R_2 is described in the ring circuit test.

Method two

This method will prove CPC continuity and is usually only used where the circuit is wired in steel enclosures where parallel paths to the CPC may be present and the $R_1 + R_2$ value would not be a true value. Or where the CPC resistance is required for use with Table 41C of the Wiring Regulations.

This method uses a long lead. One end is connected to the earth terminal of the distribution board, and the other connected to a **low resistance ohm meter**. The short lead of the ohm meter is then touched onto each fitting to ensure that it is connected to the CPC. The highest reading minus the resistance of the leads can be recorded as the R_2 reading.

If the furthest point of the circuit is known, and no parallel paths exist, the $R_1 + R_2$ reading can be carried out first using **Method one**, and then a test between earthed metal at each point can be made to ensure that the CPC is connected to each point on the circuit, using **Method two**. This method is particularly useful where there are a lot of enclosed metal fittings and dismantling them would be impractical.

Ring final circuit test

The purpose of this test is to ensure that:

- The cables form a complete ring.
- There are no interconnections.
- The polarity is correct on all socket outlets.

When this test is carried out correctly it also gives you the R_1 and R_2 value of the ring and identifies spurs.

Table 8A in the *On-Site Guide* provides information on final circuits for socket outlets. This table states that a ring circuit is to be wired in 2.5 mm^2 phase conductor and 1.5 mm^2 CPC as a minimum size. This type of circuit is an A1 ring and should be protected by a 30/32 amp overcurrent protective device.

Complete ring circuit

A test must be carried out on the conductors to verify that they form a complete loop. If it is found that they do not, overloading of the cables could occur. In installations where more than one ring circuit has been installed, it is possible for the ends of the ring to become muddled, resulting in the circuits being supplied through two protective devices.

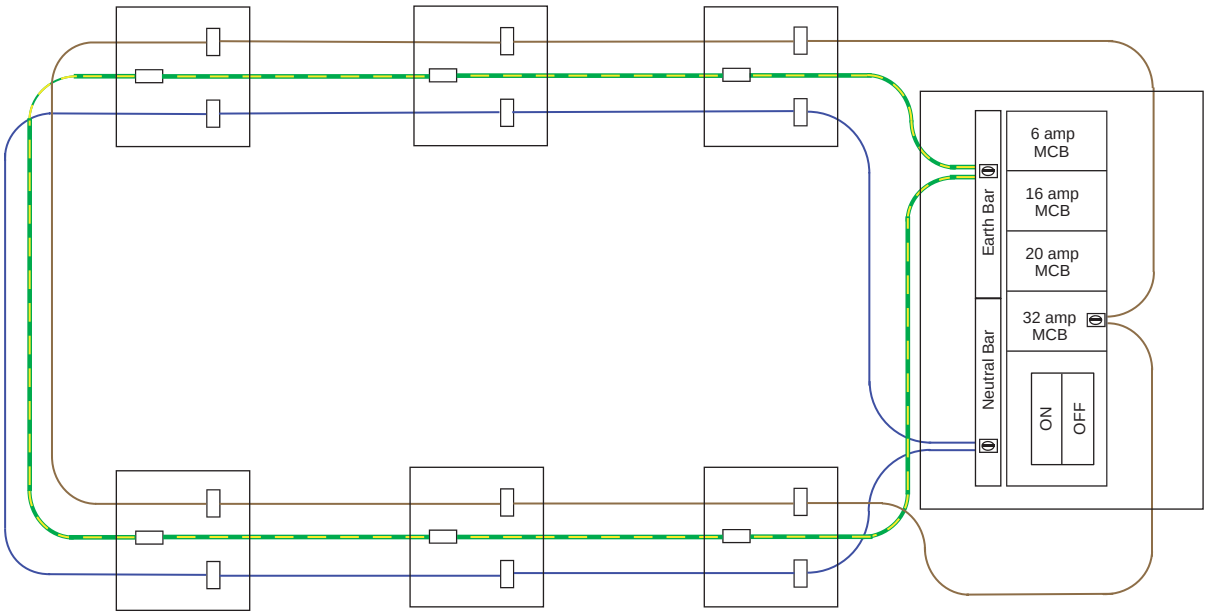

Complete ring circuit

The whole point of a ring circuit is that it can be wired in small CSA cables but carry a reasonably high current, this is because we have two 2.5 mm^2 cables wired in parallel (*Regulation 473-01-06*). If we look at Table 4D5A in BS 7671, the value of current that 2.5 mm^2 cable can carry is 20 amps in the worst type of conditions.

If we use two of these conductors in parallel, we will have a total current carrying capacity of 40 amps. As one of the jobs of the protective device is to protect the cable, this situation will be fine because the protective device is smaller than the total current carrying capacity of the cables in parallel.

Broken ring circuit

If, however, we found the ring to be broken, the protective device could not do its job as it is rated at 32amps and the cable is rated only at 20amps. Hence overloading!

Interconnections

Occasionally a situation will be found where there is a ring within a ring, in other words the ring is interconnected.

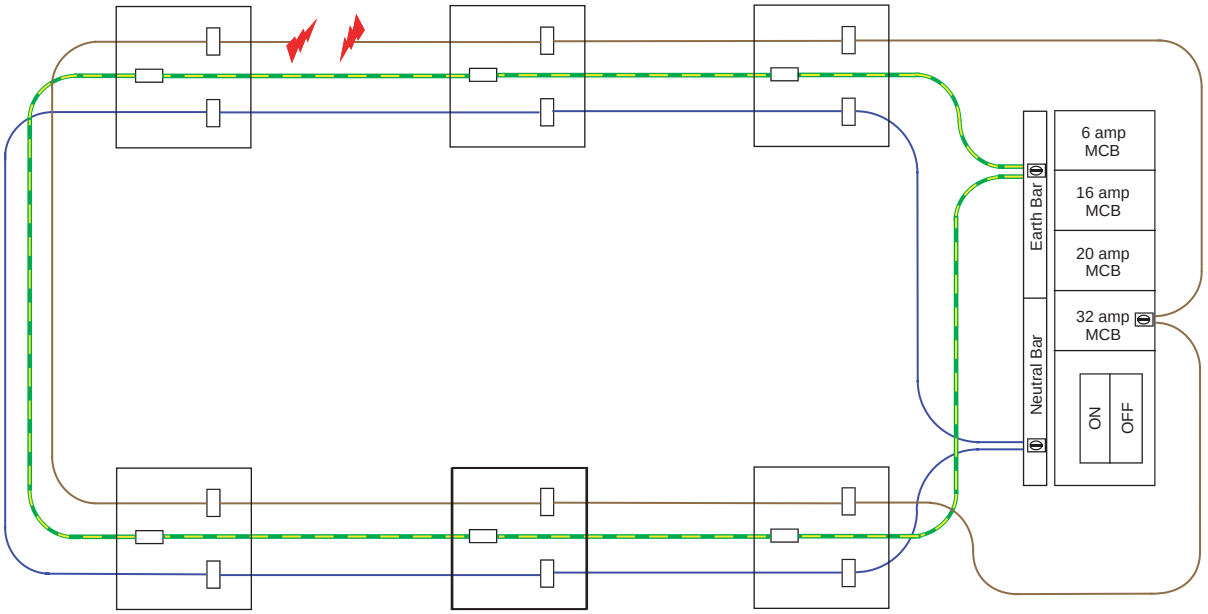

Broken ring circuit

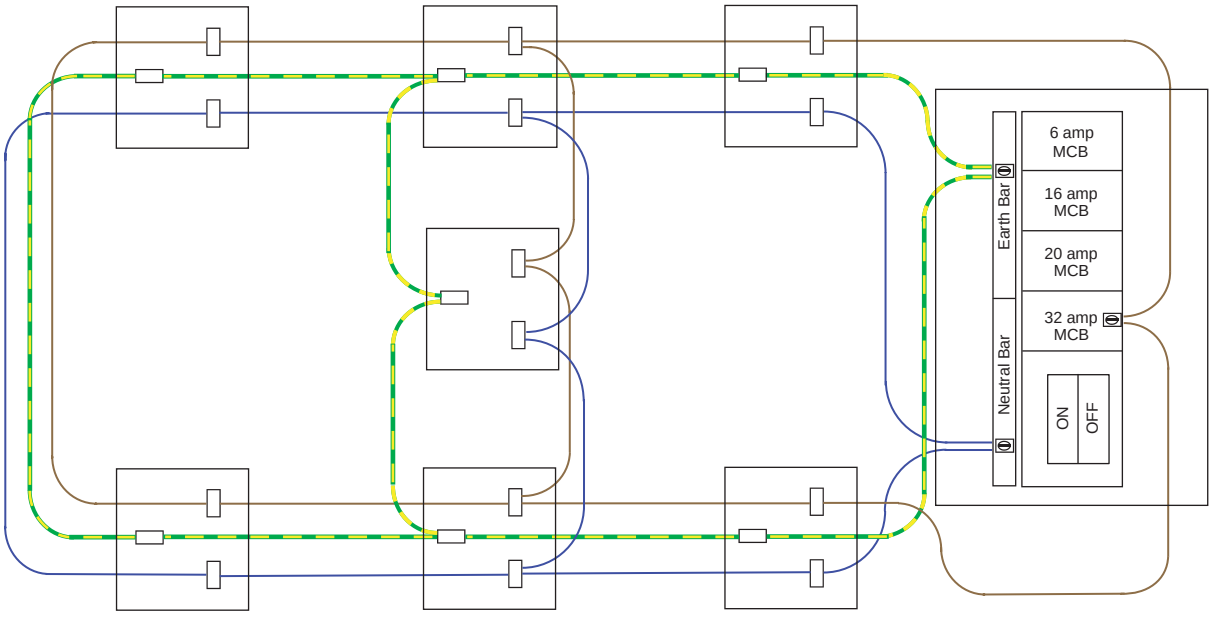

Interconnected ring circuit

This situation, as it is, will not present a danger. However, it will make it very difficult for a ring final circuit test to be carried out as, even if the correct ends of the ring are connected together, different values will be found at various points of the ring. If one loop is broken, a test at the consumer's unit will still show a complete ring. It will not be until further tests are performed that the interconnection/broken loop will be found.

Polarity

Each socket outlet must be checked to ensure that the conductors are connected into the correct terminals. Clearly if they are not, serious danger could occur when appliances are plugged in.

It could be that phase and neutral are the wrong polarity; the result of this is that the neutral would be switched in any piece of equipment with a single pole operating switch.

If the live conductors and CPC are connected with reverse polarity, then the case of any Class 1 equipment could become live and result in a fatal electric shock.

Performing the test

The instrument required is a low resistance ohm meter set on the lowest scale, typically 20Ω. Be sure to zero the instrument or subtract the resistance of the leads each time you take a reading.

This is a dead test! Safe isolation must be carried out before working on this circuit

STEP 1

Isolate circuit to be tested.

STEP 2

Identify legs of ring.

STEP 3

Test between ends of phase conductor and note the resistance value.

Instrument set to Ω for whole test.

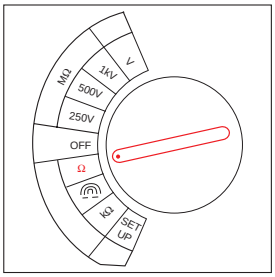

Ends of phase conductor

STEP 4

Test between ends of neutral conductor. This value should be the same as the phase conductor resistance as the conductor must be the same size (*see Note 1*).

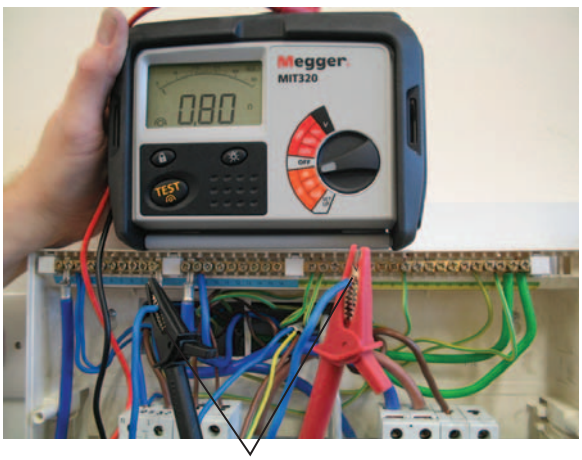

Ends of neutral conductor

STEP 5

Test between the ends of the CPCs. If the conductor size is smaller than the live conductors (*as is usually the case when using twin and earth cable*), the resistance value will be higher (*see Note 2*); make a note of this reading.

Ends of CPCs

STEP 6

Join P of leg 1 to N of leg 2.

Test between N of leg 1 and P of leg 2. The measured resistance should be double that of the phase conductor.

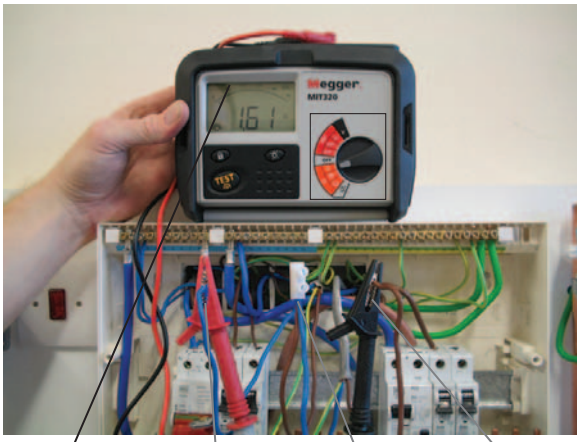

Resistance double that of phase conductor

P2

P1 joined to N2

N1

STEP 7

Join N of leg 1 to P of leg 2 together (*leaving N2 and P1 joined*).

Test between joined ends.

The measured value should be $\frac{1}{4}$ of test between N of leg 1 and P of leg 2.

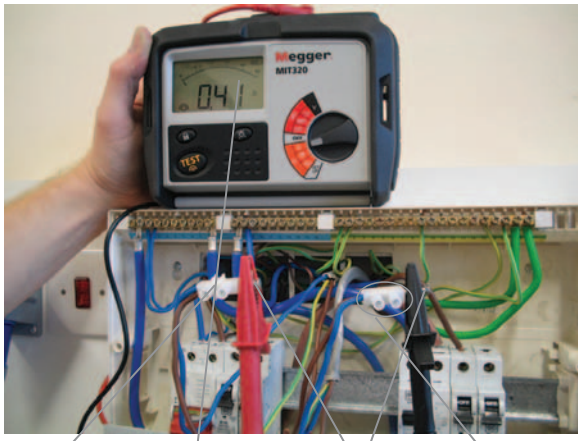

P2 joined to N1 | Resistance 1/4 of that tested between N1 and P2 | Test between joined ends | P1 still joined to N2

STEP 8

Leave the ends joined.

Test between P and N at each socket outlet, the resistance should be the same at each socket (*see Note 1*).

A higher reading should be investigated, although it will probably be a spur it should be checked as it may be a loose connection (*high resistance joint*).

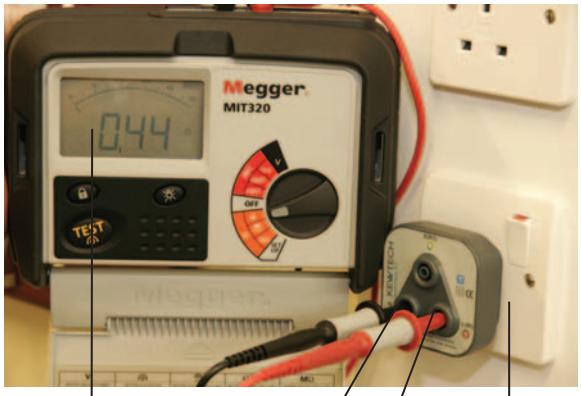

Resistance value the same at each socket | N | P | Test at each socket outlet

STEP 9

Disconnect the ends and repeat the test using phase and CPC conductors (*see Note 3*).

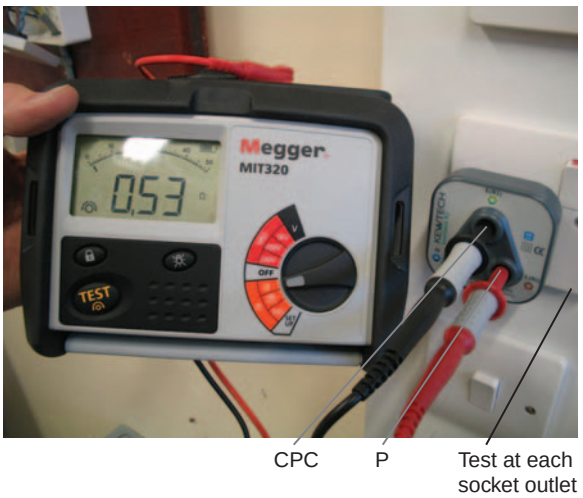

The highest value (*which will be the spur*) will be the R_1 and R_2 value for this circuit.

Notes

1. If with ends connected (P1/N2 and P2/N1) a substantially different resistance value is measured at each socket outlet, check that the correct ends of ring are connected. A difference of 0.05 Ω higher or lower would be acceptable.
2. In a twin and earth cable the CPC will usually have a resistance of 1.67 times that of the phase conductor as it has a smaller cross-sectional area.
3. When phase and CPC conductors are not the same size a higher resistance value will be measured between Phase and CPC than Phase and neutral. It will also alter **slightly** as the measurement is taken around the ring, the resistance will be lower nearer the joined ends and will increase towards the centre of the ring. The centre socket of the ring will have the same resistance value as the test between the joined ends.
4. If the circuit is contained in steel conduit or trunking parallel paths may be present, this would result in much lower $R_1 + R_2$ resistance values.
5. Some certificates may require r_n to be documented. This is the resistance of the neutral loop measured from end to end.

Example 3

Let's use a 2.5/1.5 mm^2 twin and earth cable 22 metres long. If we look at Table 9A in the *On-Site Guide* we will see that the resistance of a copper 2.5 mm^2 conductor has a resistance of 7.41 mΩ per metre.

The resistance of the phase conductor will be:

$$\frac{7.41 \times 22}{1000} = 0.163\Omega$$

Divide the largest conductor by the smallest to find the ratio of the conductors (how much bigger is the larger conductor?).

$$\frac{2.5}{1.5} = 1.67$$

The 2.5 mm^2 conductor is 1.67 × larger than the 1.5 mm^2 conductor; therefore, it must have 1.67 × less resistance than the 1.5 mm^2 conductor.

If we now multiply the resistance of the phase conductor by 1.67:
$0.163 \times 1.67 = 0.27\Omega$ this is the resistance of the 1.5 mm^2 conductor.

We can check this by looking at Table 9A of the On-Site Guide once again, and we can see that the resistance of 1.5 mm^2 copper is 12.10 $m\Omega$ per metre. Therefore, 22 metres of 1.5 mm^2 copper will be:

$$\frac{22 \times 12.10}{1000} = 0.266\Omega$$

As a final check, if we look at Table 9A of the On-Site Guide for the resistance of a 2.5 mm^2/1.5 mm^2 cable, we will see that it has a resistance of 19.51 $m\Omega$ per metre, and that 22 metres of it will have a resistance of:

$$\frac{22 \times 19.51}{1000} = 0.429\Omega$$

The resistance value of the 2.5 mm^2 is 0.163Ω; and the resistance value of the 1.5 mm^2 is 0.266Ω.

If we add them together: 0.163Ω + 0.266Ω = 0.429Ω. Finally, 0.429Ω is the resistance of our 2.5 mm^2/1.5 mm^2 measured as one cable.

Insulation resistance test

This is a test that can be carried out on a complete installation or a single circuit, whichever is suitable or required. The test is necessary to find out if there is likely to be any leakage of current through the insulated parts of the installation. A leakage could occur for various reasons.

A good way to think of this test is to relate it to a pressure test – we know that voltage is the pressure where the current is located in a cable. On a low voltage circuit, the expected voltage would be around 230 V a.c. The voltage used in an insulation test on a 230 V circuit is 500 V, which is more than double the normal circuit voltage. Therefore, it can be seen as a pressure test similar to a plumber pressure testing the central heating pipes.

Low insulation resistance

Cable insulation could deteriorate through age. A low insulation resistance caused through age will often be found in installations where rubber-insulated cables have been used. Cables which are crushed under floor boards, clipped on edge, or worn thin where pulled through holes in joists next to other cables, can give a very low reading.

Low insulation resistance could be found if a building has been unused for a period of time, due to the installation being affected by dampness in the accessories. Low insulation resistance readings will also often be found where a building has been recently plastered. In theory, long lengths of cables or circuits in parallel could give low readings due to the amount of insulation (*the longer the circuit or the more circuits, the more insulation there will be for leakage to occur*).

The instrument used to carry out this test is an **insulation resistance tester**. To comply with the requirements of the Health and Safety Executive the instrument must be capable of delivering a current of 1 mA when a voltage of 500 V.d.c is applied to a resistance of 0.5 MΩ. Table 71A in BS 7671 gives the test voltages and minimum acceptable resistance values.

The values are shown here:

	Circuits between 0 V and 50 V a.c.	Circuits between 50 V a.c. and 500 V a.c.	Circuits between 500 V and 1000 V a.c.
Required test voltage	250 V d.c.	500 V d.c.	1000 V d.c.
Minimum acceptable	0.25 MΩ	0.5 MΩ	1 MΩ
In 17th Edition of the Wiring Regulations	(0.5 MΩ)	(1 MΩ)	(2 MΩ)

Domestic installations

Remember that testing should be carried out from the day the installation commences (Regulation 711-01-01).

Testing a whole installation

In new domestic installations it is often easier to carry out insulation resistance testing on the whole of the installation from the meter tails before they are connected to the supply. If this is the preferred choice the test should be carried out as follows:

- Safe isolation must be carried out before commencing this test.
- Inform any occupants of the building that testing is to be carried out.
- Ensure that all protective devices are in place and switched on.
- Remove all lamps from fittings where accessible.
- If the lamps are not accessible or if a luminaire with control gear (fluorescent) is connected, open the switch controlling the luminaire (*Note 6*).

The same applies to extra low voltage transformers.

- Where dimmer switches are fitted it is important that they are either removed and the switch wires joined, or that the switch is bypassed (*Note 7*).
- Any accessories with indicator lamps are switched off (*Note 8*).
- Passive infra red detectors (PIRs) are removed or bypassed (*Note 9*).
- All fixed equipment such as cookers, immersion heaters, boilers and television amplifiers are isolated.
- Shaver sockets are disconnected or isolated (*Note 9*).
- Items of portable equipment are unplugged.

Great care must be taken as, during this test, 500 V will be passed through any electrical equipment which is left connected. This could damage the equipment or, at the very least, cause low readings to be obtained during the test. Once all precautions have been taken proceed with the test as follows:

Notes

1. The control equipment within discharge lamps will cause very low readings. It is quite acceptable to isolate the fitting by turning off the switch. This is more desirable than disconnecting the fitting. After the test between live conductors is completed the control switch for the luminaire should be closed before carrying out the test between live conductors and CPC. This is to ensure that all live conductors are tested for insulation resistance to earth.
2. Most dimmer switches have electronic components in them and these could be damaged if 500 V were to be applied to them. It is important that wherever possible the dimmer switches are removed and the phase and switch return are joined together for the test.
3. Neon indicator lamps will be recognized as a load by the test instrument and will give a very low insulation value. All that is required is for the switch on the accessory to be turned off.
4. Passive infra red detectors will give very low readings and may be damaged by the test voltage. Either disconnect it or test between live conductors and earth only on circuits containing PIRs. The same applies to shaver sockets.

STEP 1 Set insulation resistance tester to 500 V.

Some instruments have settings for Meg ohms and some are self ranging. If yours requires setting then 200 MΩ or higher is the setting to use.

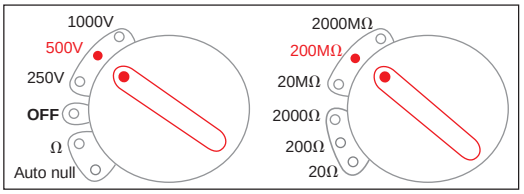

STEP 2

To ensure that the test results are accurate it is important to ensure correct operation of instrument and the integrity of the leads. Push the test button with the leads disconnected. The resistance shown on screen should be the highest that the instrument can measure.

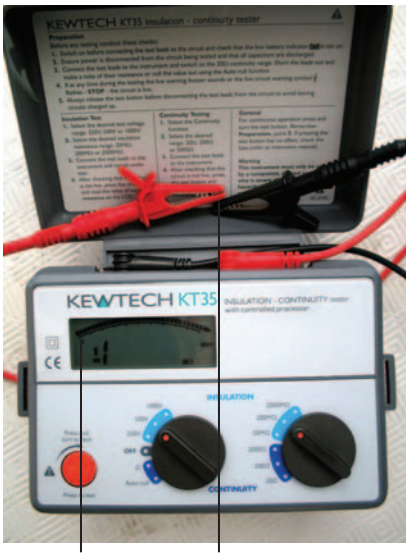

STEP 3

Join leads and operate instrument again, the resistance shown on screen should be the lowest value possible (0.0 mΩ) in all cases.

STEP 4

When testing the whole installation from the disconnected tails, it is important that the main switch is in the on position and that the protective devices are in place. If they are circuit breakers they must be in the 'on' position.

Test between live conductors (tails) and operate any two-way and intermediate switching. This is to ensure that all switch wires and strappers are tested and that the switch returns have been correctly identified and connected (*no neutrals in the switches*).

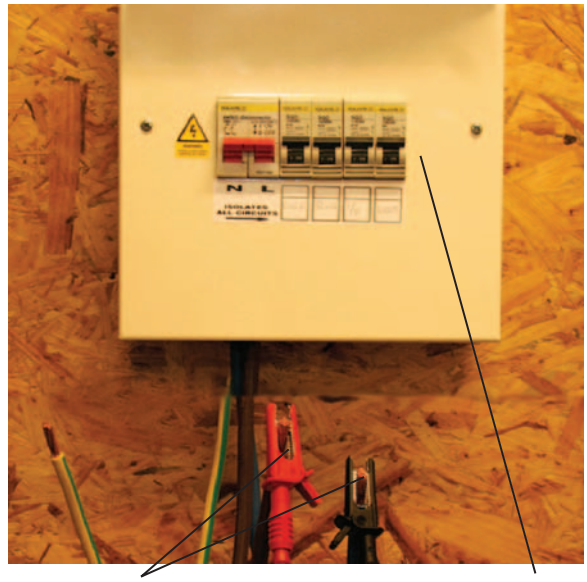

STEP 5

Join live conductors (tails) together, connect IR tester leads, one on live conductors and the other on the earthing conductor, carry out the test and again operate all two-way and intermediate switching.

Table 71A of BS 7671 give the acceptable insulation resistance as 0.5 MΩ. This is for a single circuit or a complete installation. *Guidance Note 3* in BS 7671 recommends that any circuit under 2 MΩ should be investigated, as such a low insulation resistance value could indicate a latent defect. Although these values will comply with the requirements of BS 7671, they are very low values for the majority of domestic circuits and installations.

Depending on the type of circuit it may be wise to carry out further investigation on the circuit with the lower reading. It would be very rare that an insulation resistance value of between 0.5 MΩ and 2 MΩ would be acceptable. There would have to be a very good reason for this, and it would need to be monitored to ensure that there was not continued deterioration.

A low value would possibly be acceptable if, for instance, a building had been empty and unused for a period of time, or perhaps an underground cable which had been unused for some time was to be reconnected to supply an outbuilding, or any other outdoor circuit. It could be that, after a period of continued use, the insulation resistance rises; only regular testing would show this.

Example 4

An installation consisting of five circuits is tested as a whole, and the insulation resistance value between live conductors and earth is found to be less than 2 MΩ.

The installation is split into individual circuits and each circuit is tested again, all circuits are found to be greater than 200 MΩ except a mineral insulated cable serving electrically opening gates 30 metres from the building. This circuit is found to have an insulation resistance value of 2 MΩ. In this instance, the value would be compared to previous results to see if any deterioration had occurred since the last test. In the likely event that previous results are not available, the result could be recorded for future reference.

If, however, the low value circuit was a new circuit wired in PVC thermoplastic cable, 6 metres long further investigation should be carried out as the insulation resistance for this circuit should be beyond the scale of the test instrument; in this case $>$ *200 MΩ.*

When testing is carried out on any installations it is important that the results are thought about and not just recorded. As shown in the example above, an

element of careful thought and sensible judgement has to be included in the testing process.

If a high insulation resistance value for a complete installation is measured, it is permissible to enter this value for all circuits on the schedule of test results.

Testing of individual circuits

If it is necessary to test individual circuits, the same process can be applied to new and existing circuits; and the same safety precautions must be taken.

Ensure that safe isolation of the circuit to be tested is carried out. It is preferable for safety reasons to isolate the whole of the distribution board if possible. If not, each circuit can be isolated individually by removing the fuse or turning off and locking off the circuit breaker.

It will be necessary to disconnect the neutral or CPC of the circuit to be tested. This is because the neutrals for all of the circuits will be connected to a common neutral bar and the CPCs for all circuits will be connected to a common earth bar.

Check that equipment vulnerable to testing, or any equipment that could produce a low insulation resistance reading is disconnected or isolated.

Carry out a test between live conductors. And then live conductors and earth.

If there was an insulation fault between any neutral and CPC in the system it would show up as a fault on all circuits, disconnection of the neutral or CPC will stop this happening.

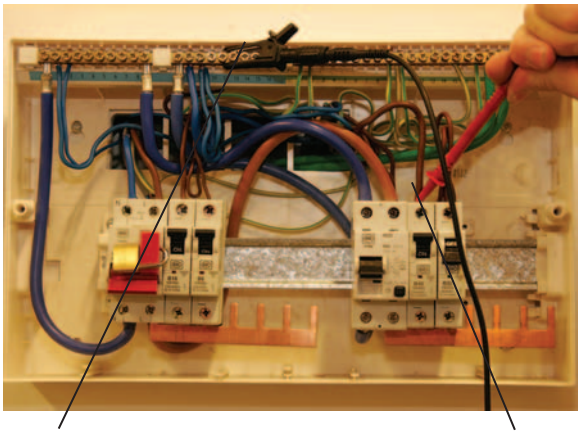

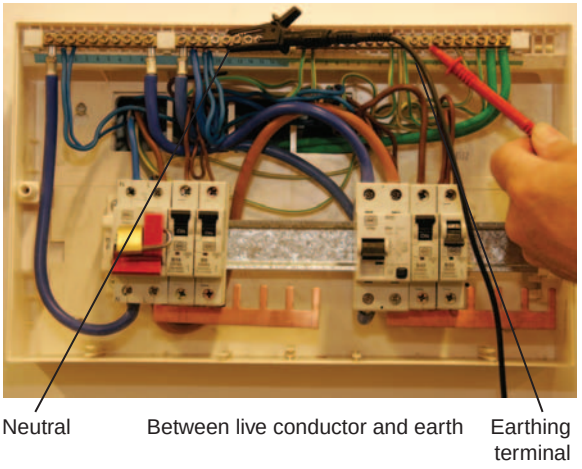

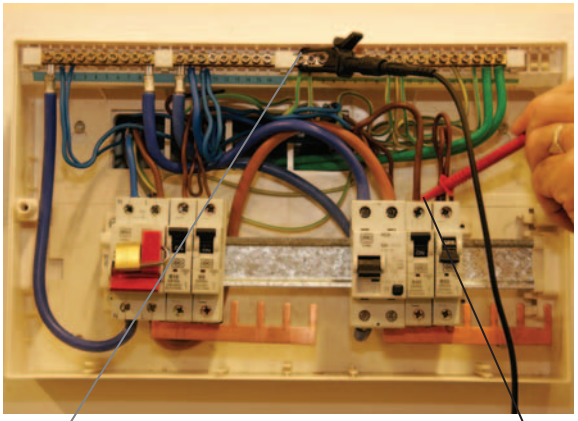

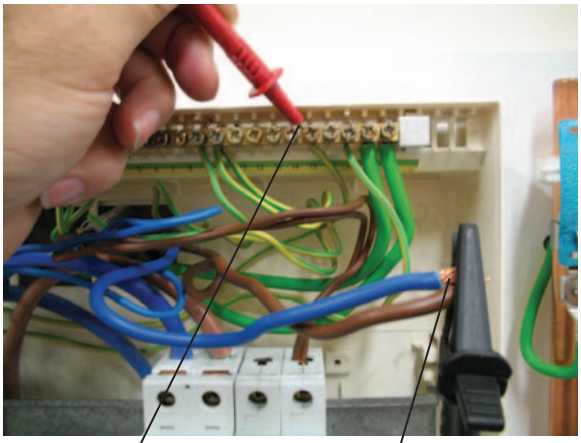

Where testing between live conductors and earth the live conductors can be joined and then tested to earth. Alternately, they can be tested separately, whichever is the easiest.

If, for some reason, there is a piece of equipment connected to the system that cannot be isolated from the circuit under test, do not carry out the test between live conductors – only test between live conductors and earth. This is to avoid poor readings and possible damage to equipment. This test should only be carried out on individual circuits, not whole installations, as it is important to test as much of the installation as possible.

Testing of 3 phase installations

When testing 3 phase and neutral (TP&N) installations or circuits the same safety precautions apply as when testing single phase installations or circuits.

The test for the whole installation can be carried out on the isolated side of the main switch. If this is the chosen method it is important to ensure that all of the protective devices are in the 'on' position. Safe isolation must be carried out before commencing this test.

STEP 1

The instrument should be set on 500 volts DC.

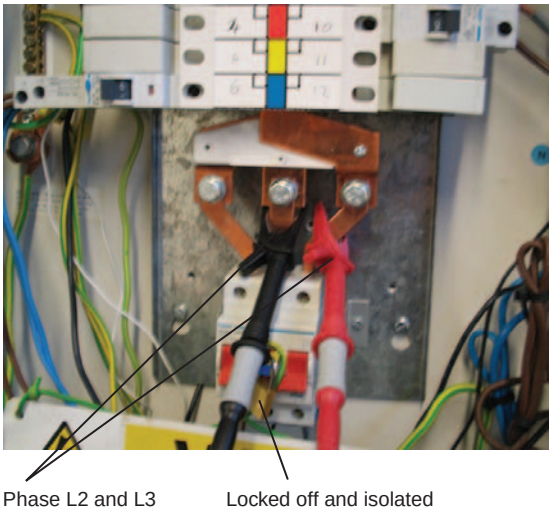

STEP 2 Test between all phase conductors.

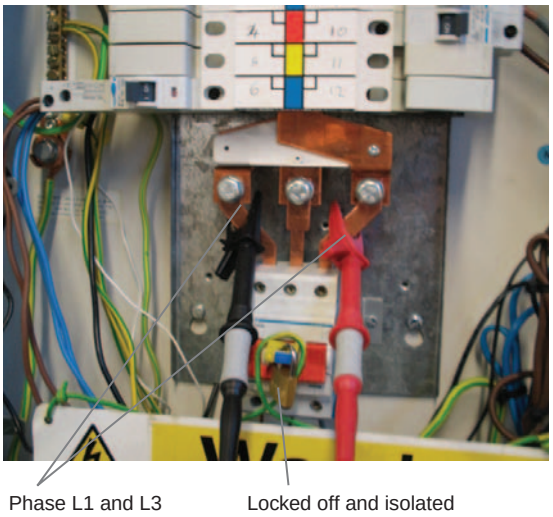

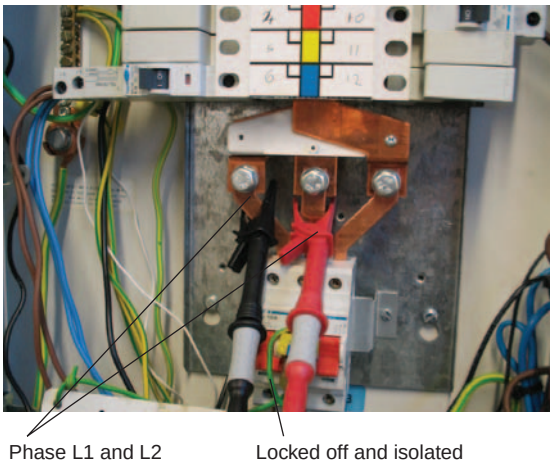

STEP 3

Test between all phase conductors and neutral, the phase conductors can be joined together for this test to save time.

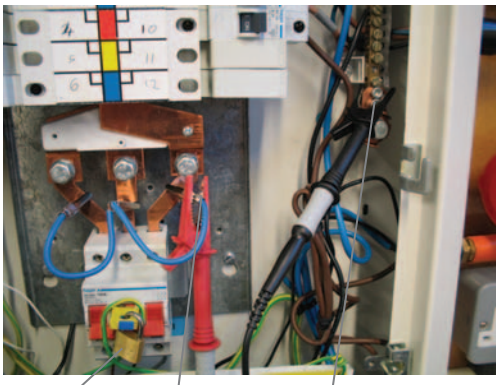

STEP 4

Test between all phase conductors and earth. The phase and neutral conductors can be joined to save time.

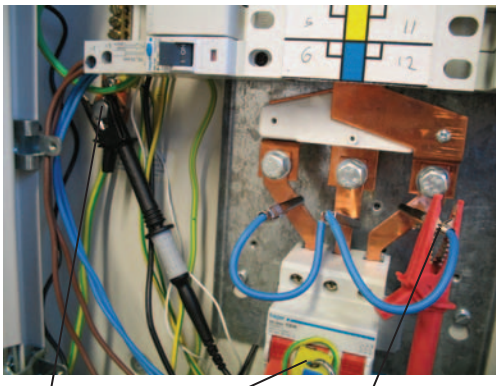

STEP 5

Test between neutral and earth.

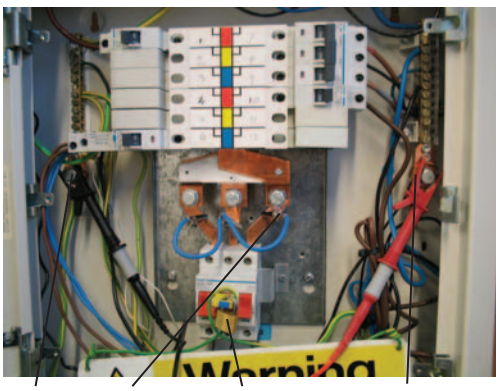

STEP 6 The resistance values should be 2 MΩ or greater for each circuit and the whole installation must have an insulation resistance of greater than 0.5 MΩ.

STEP 7 If a circuit is found to have an insulation resistance of less than 2 MΩ it should be investigated.

STEP 8 Ensure that any links used for testing are removed prior to the switching on of the supply.

Be aware that if the live conductors are joined and then tested to earth, theoretically the insulation resistance value may be lower due to the conductors being in parallel.

Example 5

A three-phase sub-main is tested and the results are as follows:

L1 to earth is 130 MΩ
L2 to earth is 80 MΩ
L3 to earth is 50 MΩ
N to earth is 100 MΩ

If these conductors were now joined and tested to earth the value would be as given below.

Calculation is:

$$\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4} = \frac{1}{Rt}$$

Put in the values:

$$\frac{1}{130} + \frac{1}{80} + \frac{1}{50} + \frac{1}{100} + \frac{1}{0.05} = 19.92\,M\Omega$$

Enter it this way into a calculator:

$$130X^{-1} + 80X^{-1} + 50X^{-1} = X^{-1}\ Answer\ is\ 19.92\,M\Omega$$

This value is still acceptable but lower because the conductors are in parallel.

When completing a Schedule of Test Results, it is important that you document exactly which insulation tests have been carried out. If it is not possible to carry out a test between any conductors a note of this should be made in the remarks column of the schedule.

Testing of site applied insulation

This type of testing is only required where insulation is applied during the erection of equipment on site. It is not required to be carried out on site built assemblies where pre-tested equipment is built on site.

The test is carried out by wrapping metallic foil around all surfaces which has been insulated. Then joining all live conductors together and applying a voltage of 3750 V a.c. between the foil and the conductors for a duration of 60 seconds. The insulation is satisfactory if a breakdown of the insulation does not occur within this time. The instrument used to carry out this test is an applied voltage tester.

Further information on this type of test can be found in the IEE *Guidance Note 3* in BS 7671).

Polarity tests

This is a test carried out to ensure that:

- Protective devices are connected to the phase conductors of the circuits which they are protecting.
- Switches in circuits are in the phase conductor.
- ES lampholders have the centre pin connected to the phase conductor (except for E14 and E27 lampholders complying with BSEN 60238) (Regulation 553-03-04).
- Accessories such as fused connection units, cooker outlets and the like are correctly connected.

Remember! If you are working on a consumer unit or a distribution board, the whole board should be isolated.

In many cases this test can be carried out at the same time as the CPC continuity test. The instrument required is a low resistance ohm meter.

Ensure that the circuit that is to be tested has been isolated.

Polarity test on a radial circuit such as a cooker or immersion heater circuit

STEP 1

At the origin of the circuit, link the phase and CPC using a short lead with crocodile clips at each end. Whilst connecting the lead visually check that the phase conductor is colour identified and connected into the protective device.

STEP 2

At the furthest point of the circuit remove the cooker or immersion heater switch, visually check that the phase conductor is identified and connected into the correct terminal.

Remember to null the leads of the instrument if the value is to be used for $R_1 + R_2$.

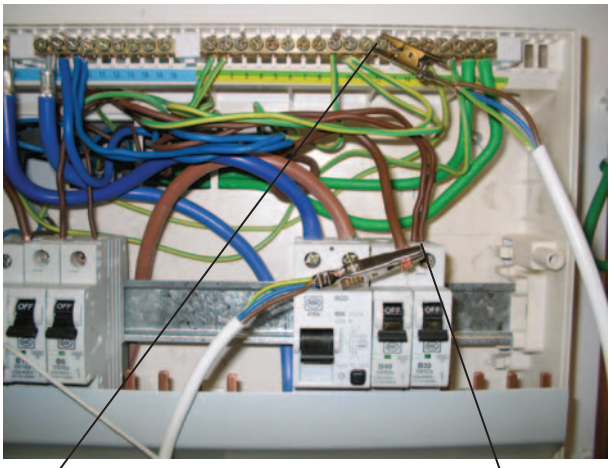

STEP 3

Connect the leads of the test instrument to the incoming phase and CPC terminals at the switch. Test to ensure continuity. The instrument should show a very low reading. This will also be the $R_1 + R_2$ for the circuit.

STEP 4

Remove the lead at the consumer unit and test again. The circuit this time should be open and the instrument reading will be high. This will prove that the correct circuit is being tested.

Polarity test on a lighting circuit

STEP 1

At the origin of the circuit connect the phase and CPC, this can be done with a short lead with crocodile clips at each end.

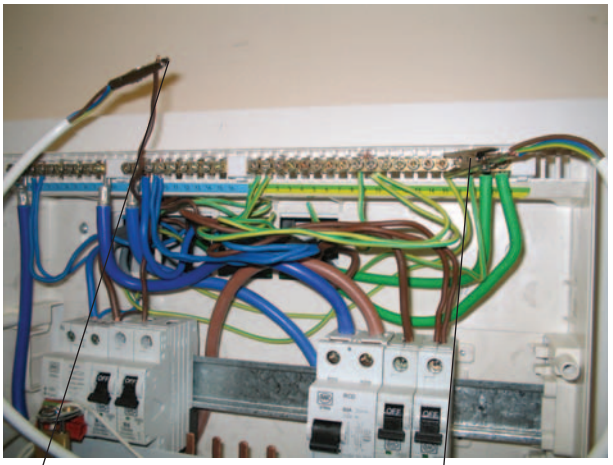

STEP 2

At the ceiling rose or light fitting place the probes of the instrument on to the earthing terminal and the switched live.

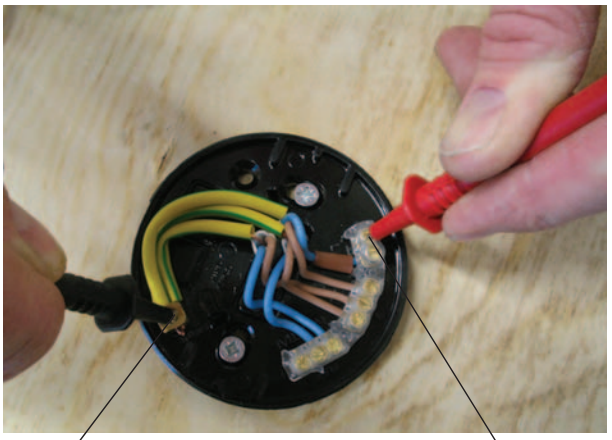

STEP 3 Close the switch controlling the light and the instrument should read a very low resistance (this will also be the R_1 and R_2 reading for the circuit). When the switch is opened the instrument reading should be very high.

This test can also be carried out at the switch if required:

STEP 1

Place a link between the phase and CPC of the circuit.

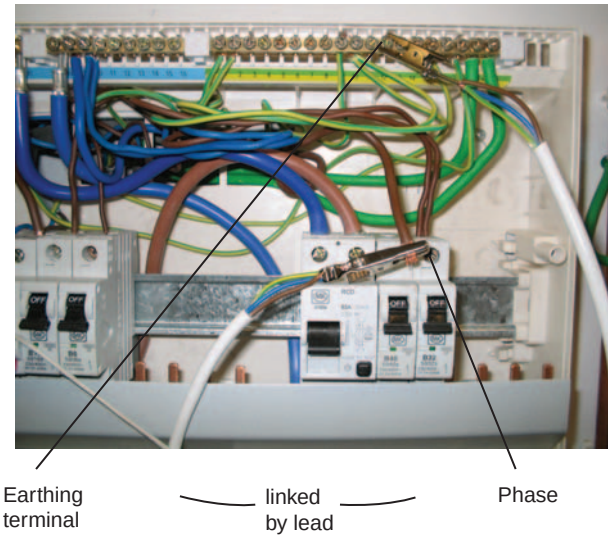

STEP 2

Place the probes of the test instrument on the earth terminal at the switch and the switch return terminal.

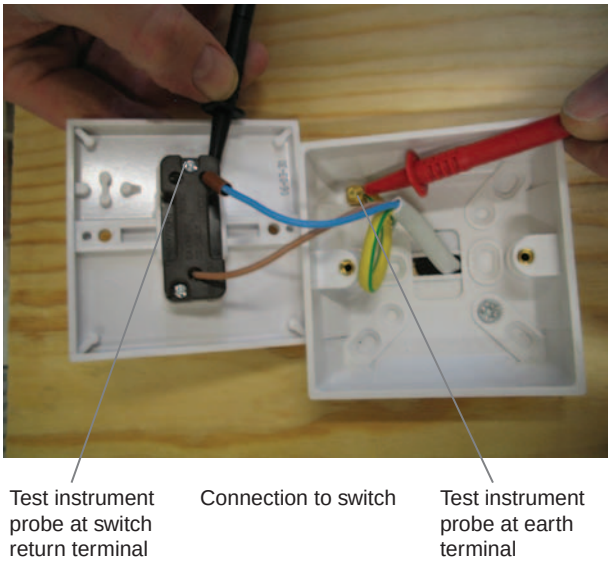

STEP 3

Close the switch and a low resistance reading should be shown on the instrument.

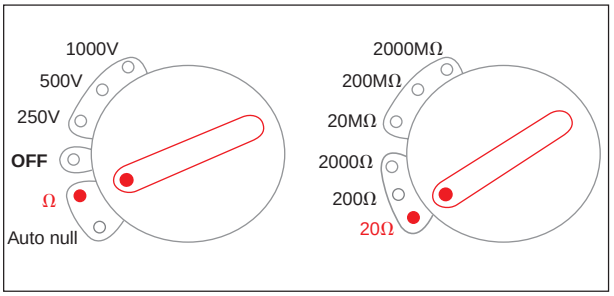

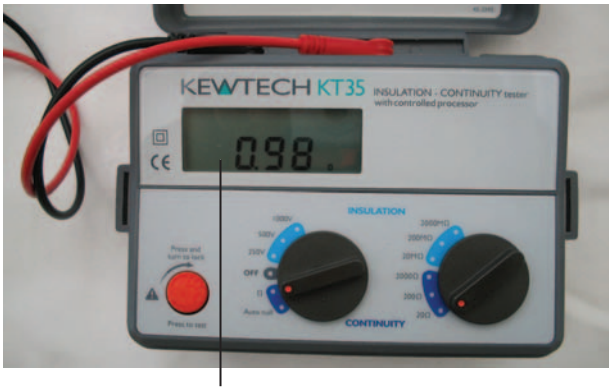

Low resistance reading

STEP 4

Open the switch and the instrument reading will show over range as the circuit should be open circuit.

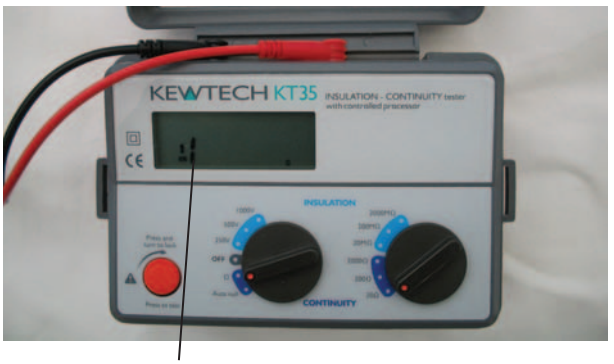

Over range

Live polarity test

This test is usually carried out at the origin of the installation before it is energized to ensure that the supply is being delivered to the installation at the correct polarity.

The instrument to be used is an approved voltage indicator or test lamp that complies with HSE document GS 38. It is acceptable for an earth loop impedance meter to be used as these instruments also show polarity.

Great care must be taken whilst carrying out this test as it is a live test.

STEP 1

Place the probes of the voltage indicator onto the phase and neutral terminal of the incoming supply at the main switch. The device should indicate a live supply.

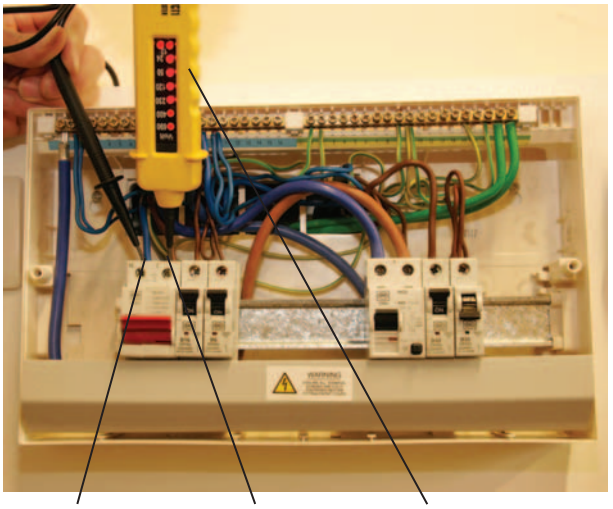

STEP 2

Place the probes of the voltage indicator onto the phase and earth terminal of incoming supply at the main switch. The device should indicate a live supply.

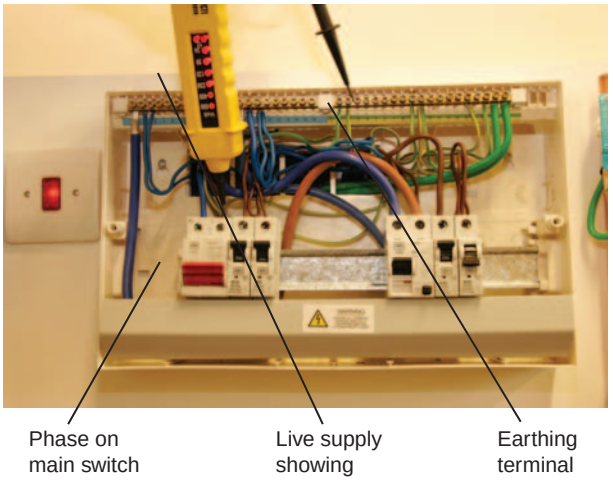

STEP 3

Place the probes of the voltage indicator onto the earthing terminal and the neutral terminal at the main switch. The device should indicate no supply.

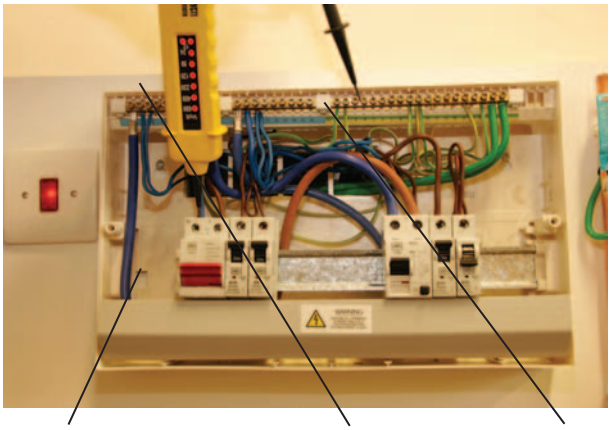

Earth electrode testing

Earth fault loop impedance tester

For many installations the resistance of the earth electrode can be measured using an earth fault loop impedance test instrument. It is perfectly acceptable to use this type of instrument on a TT system where reasonably high resistance values could be expected.

The test is performed in exactly the same way as the external earth fault loop Z_e test.

STEP 1 Isolate the installation.

STEP 2 Ensure that the earthing conductor is correctly terminated at the earth electrode.

STEP 3 Disconnect the earthing conductor from the main earthing terminal.

STEP 4 Connect a lead of the earth fault loop meter to the disconnected earthing terminal.

STEP 5 Place the probe of the other lead on to the incoming phase conductor at the supply side of the main switch and carry out the test.

STEP 6 Record the result.

STEP 7 Reconnect the earthing conductor and leave the installation in safe working condition.

If a three lead test instrument is used, read the instrument instructions before carrying out the test. It may be that the leads must be connected on to the phase, neutral and earthing terminals, or possibly the neutral and earth lead of the test instrument, should be joined together.

Regulation 413-02-16 from BS 7671 tells us that the maximum permissible resistance value of the earth electrode must be no greater than 50/IΔn. This is to ensure that any exposed metalwork does not rise to a potential of greater than 50 volts.

50 is the maximum voltage
IΔn is the trip rating of the residual current device
Z_S is the earth fault loop impedance

If the rating of the device is 100 mA the calculation is:

$$\frac{50}{0.1} = 500\ \Omega$$

The maximum permissible value to comply with the regulations using this calculation is 500 Ω. Although this value would be deemed acceptable, it may not be reliable as it could rise to an unacceptable value if the soil dries out.

An acceptable value for RCDs up to 100 mA is stated as a maximum of 200 Ω. If the resistance is above this it should not be accepted under most circumstances. The installation of an additional or larger electrode may bring the resistance value down to an acceptable value.

The maximum calculated values for earth electrodes are:

Operating current of the RCD	Electrode resistance in ohms
100 mA	500
300 mA	160
500 mA	100

For special locations where the maximum touch voltage is 25 V the electrode resistance should be halved. Electrode tests should be carried out in the worst possible conditions. The worst condition for an earth electrode is when the soil is **dry**. Where lower values of earth electrode resistances are required, an earth electrode tester should be used.

Measurement using an earth electrode test instrument

This test requires the use of three electrodes: the earthing electrode under test, a current electrode and a potential electrode.

STEP 1 The earthing electrode (E) should be driven into the ground in the position that it is to be used. Attention should be paid to the length of the electrode which is in the ground.

STEP 2 The current electrode (C^2 spike) should be pushed into the ground at a distance of ten times the depth of the electrode under test away from it.

STEP 3 The potential electrode (P^2) should be pushed into the ground midway between E and C^2.

STEP 4 The leads of the test instrument should be connected to the appropriate electrodes.

STEP 5 Measure the value of resistance.

STEP 6 Move P^2 10% closer to C^2.

STEP 7 Measure the value of resistance.

STEP 8 Move P^2 back to 10% closer to E than the mid-point.

STEP 9 Measure the value of the resistance.

A calculation must now be carried out to find the percentage deviation of the resistance values.

Example 6

Three measurements are taken: 0.8 ohms, 0.86 ohms and 0.78 ohms. These must now be added together and an average value calculated.

Total value of three readings = 2.44

Find the average:

$$\frac{2.44}{3} = 0.81$$

The average value is 0.81 ohms.

Now find the highest difference between the average value and the measured values. In this case it will be 0.86 − 0.81 = 0.05.

The percentage of this value to the average value must now be found:

$$\frac{0.05}{0.81} \times 100 = 6.1\%$$

This value is higher than 5% of the average value and it is not advisable to accept, it as a percentage deviation of greater than 5% is deemed to be inaccurate. To overcome this, the distance between the electrode under test (E) and the current spike (C^2) should now be increased and the first three tests repeated to obtain a more accurate reading.

If the required resistance value cannot be obtained by the use of a single electrode, additional electrodes may be added at a distance from the first electrode equal to its depth.

Earth fault loop impedance Z_e

This is a live test and great care must be taken

Z_e is a measurement of the external earth fault impedance (resistance) of the installation. In other words, it is the measured resistance of the supply transformer winding, the supply phase conductor, and the earth return path of the supply. It is measured in ohms.

Earth fault path for a TT system

This system uses the mass of earth for the fault return path.

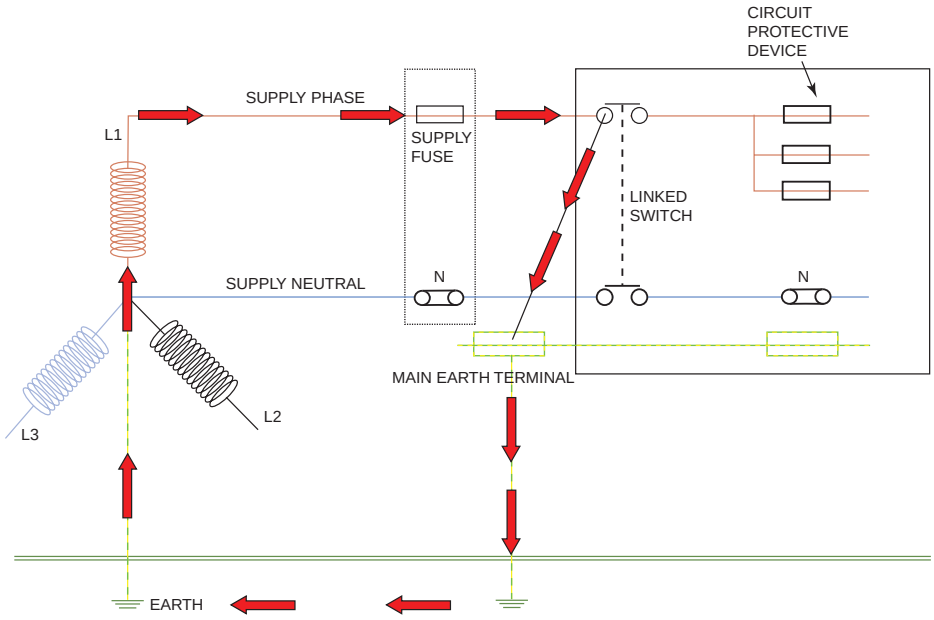

Earth fault path for a TNS system

This system uses the sheath of the supply cable for the earth fault return path.

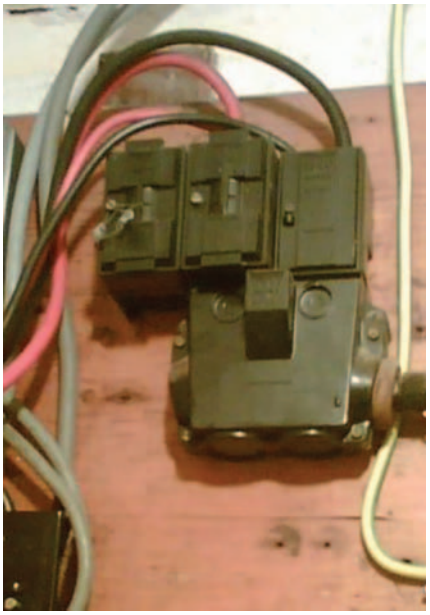

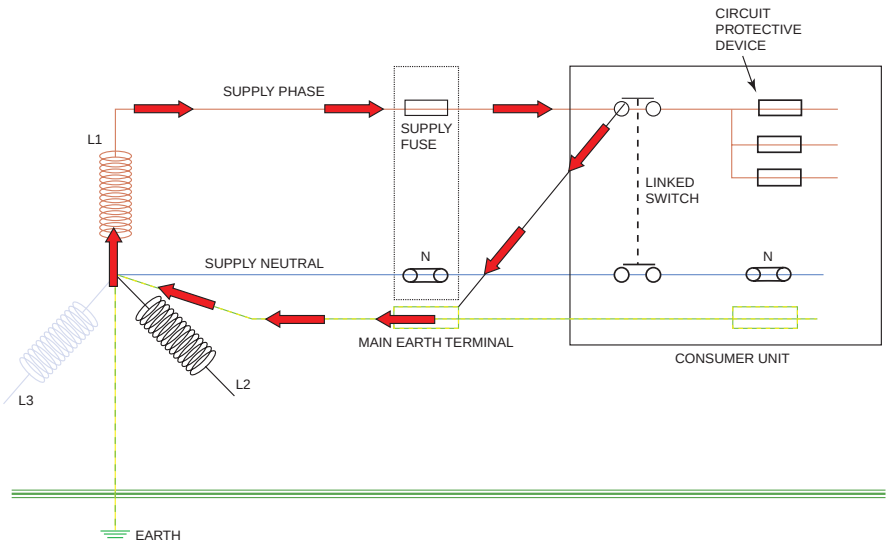

Earth fault path for a TNCS system

This system uses the neutral (PEN) conductor of the supply for its earth fault return path.

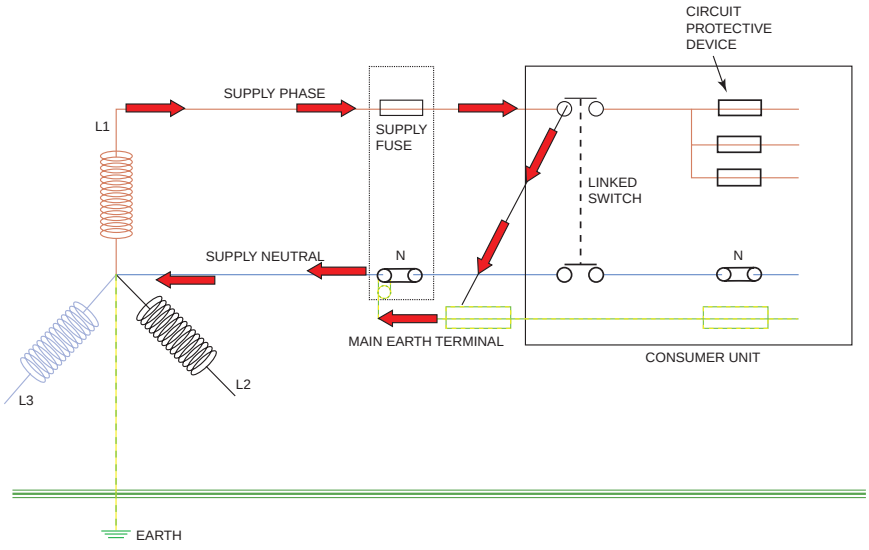

To carry out this test correctly the installation should be isolated from the supply and the main earth disconnected from the main earth terminal (MET). This is to avoid the possibility of parallel paths through any earthed metalwork within the installation.

Often in industrial and commercial installations – where isolation may be impossible due to the building being in use – the only time that this test can be carried out with the main earthing conductor disconnected, is during the initial verification. It is important that the Z_e with the earthing conductor is disconnected during the initial verification as this will give a reference value for the life of the installation. If, during subsequent tests, the earthing conductor cannot be disconnected, a test can still be carried out but the parallel paths should give a lower impedance value. If a higher value is recorded it will indicate a deterioration of the supply earth.

The instrument used for this test is an earth fault loop impedance meter, and it is important that the person using the instrument has read and understood the operating instructions. There are many types of test instruments on the market and they all have their own characteristics.

Some instruments have three leads which must be connected to enable this test to be carried out correctly. Some instruments require that the leads are connected to the phase, neutral and earth of the circuit to be tested. Other instruments require the phase lead to be connected to the phase conductor and the earth and neutral leads to be connected to the earthing conductor of the circuit to be tested (*it is important to read the instructions of the instrument being used*).

If using a two-lead instrument it should be set on Z_e. One lead should be connected to the main earthing conductor and the other to the incoming phase on the supply side of the main switch.

Probes can be used for this providing they meet the requirements of GS 38, i.e.:

- Insulated
- Fused
- Finger guards
- Maximum of 4 mm exposed tips or retractable shrouds
- Long enough to carry out test safely
- Undamaged

Performing the test

This is a live test and care should be taken when carrying it out

STEP 1 Isolate the supply.

STEP 2 Disconnect the earthing conductor.

STEP 3 Set the instrument to loop test.

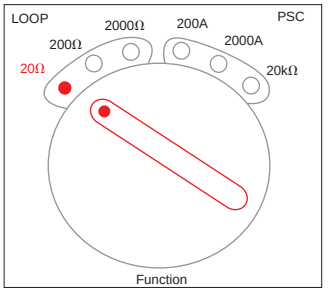

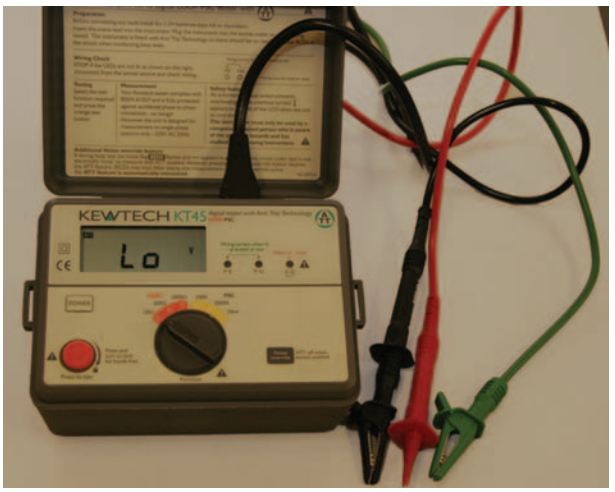

STEP 4 If you are using a two-lead instrument the leads should be connected as in the figures below. If you are using a three lead instrument, then the leads should be connected as shown here.

Connections for 2-lead instrument

Disconnected earthing conductor

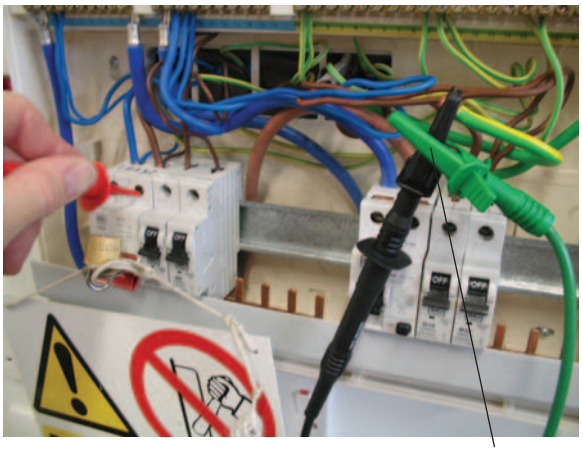

Connections for 3-lead instrument

Leads joined

STEP 5 The measurement obtained is Z_e and can be entered on the test certificates in the appropriate place.

STEP 6 Reconnect earthing conductor.

It is important that the instructions for the test instruments are read and fully understood before carrying out this test.

Care should be taken to reset time clocks, programmers, etc. when the supply is reinstated.

Circuit earth fault loop impedance

This is a live test and great care must be taken

Z_S is the value of the earth loop impedance (resistance) of a final circuit including the supply cable.

The earth fault loop (Z_S) path for a TT system.

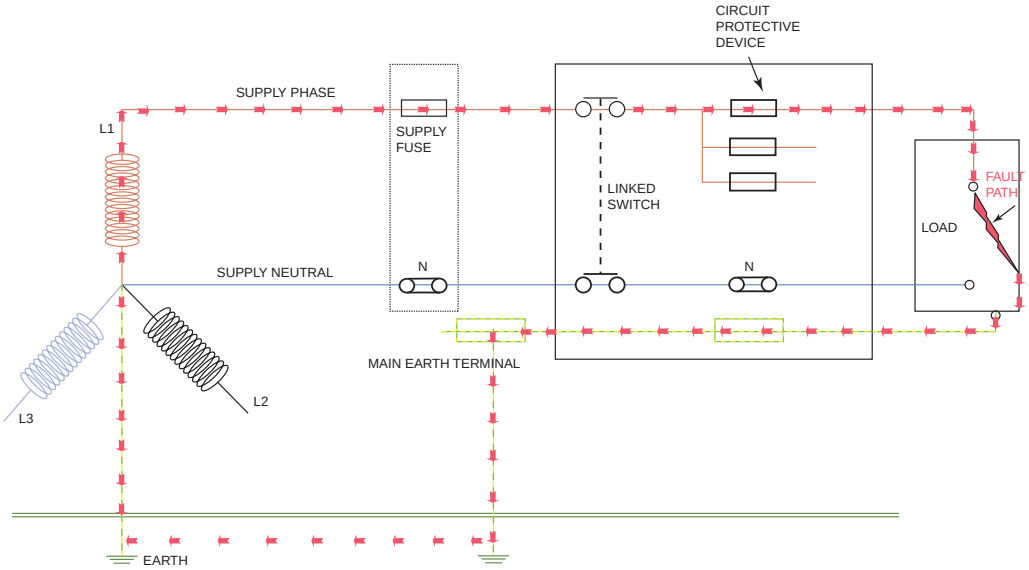

The earth fault loop (Z_S) path for a TNS system.

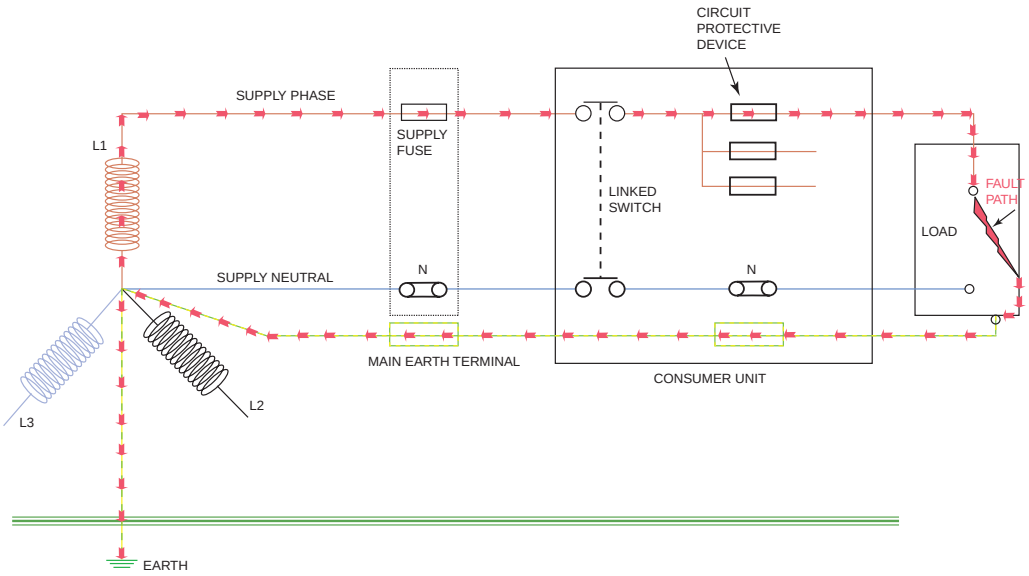

The earth fault loop (Z_S) path for a TNCS system.

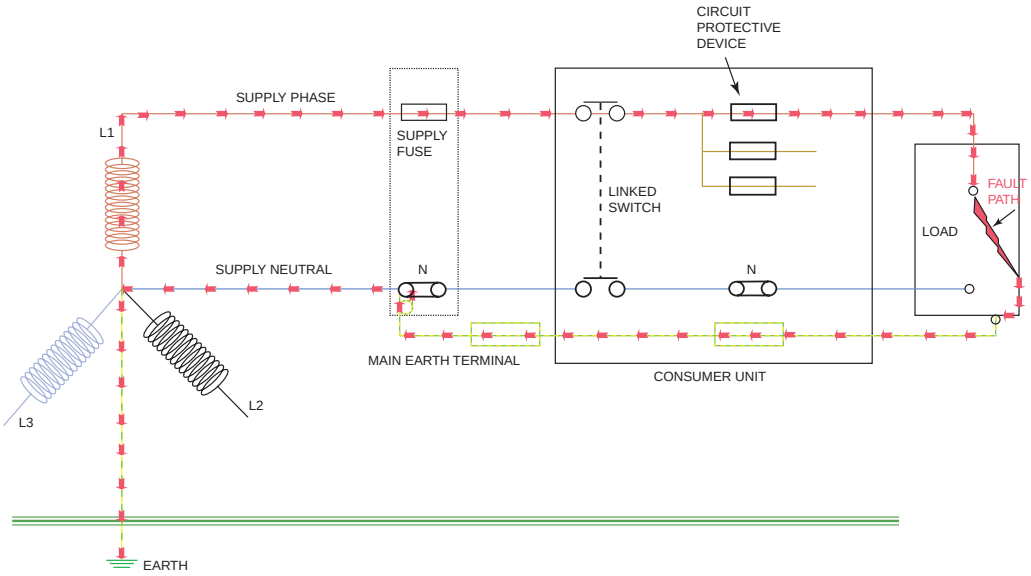

To obtain Z_S, the Z_e value should now be added to the $R_1 + R_2$ values that were obtained when carrying out the CPC continuity tests for each individual circuit.

The total value $Z_e + R_1 + R_2$ will be Z_S (earth loop impedance for the circuit).

This value (Z_S) should now be compared with the maximum values of Z_S given in BS 7671, Chapter 41, to verify that the protective device will operate in the correct time.

Unfortunately, it is not quite as simple as it seems. This is because the values Z_S have been measured when the conductors were at room temperature and the maximum Z_S values given in BS 7671 are at the conductor operating temperature of 70°C. This is the maximum temperature that the conductor could be operating at in a sound circuit. There are two methods.

Accurate test instruments must be used for these tests.

Method one

Measure the ambient temperature of the room and use the values from Table 9B in the *On-Site Guide* as dividers. (**DO NOT USE THEM AS MULTIPLIERS**)

This is because Table 9B is to correct the conductor resistances in Table 9A from 20°C to room temperature.

When they are used as dividers they will correct the cable from room temperature resistance, to the resistance that it would be at 20°C.

Example 7

$$\frac{R_1 + R_2}{\text{Temp factor}}$$

Measured $R_1 + R_2 = 0.84\,\Omega$ @ 25°C

Factor from Table 9b for 25°C = 1.02.

$$\frac{0.84}{1.02} = 0.82$$

Values at 20°C is 0.82 Ω.

Having corrected the measured values to 20°C the next step is to calculate what the resistance of the cable would be at its operating temperature.

As the resistance of copper changes by 2% for each 5°C the conductor resistance will rise by 20% if its temperature rises to 70°C.

Multiplying the resistance by 1.2 will increase its value by 20%, this value can now be added to Z_e to give Z_S.

Resistance value at operating temperature would be:

$$0.82\,\Omega \times 1.2 = 0.98\,\Omega$$

Example 8

The Z_e of an installation is 0.6 Ω. A circuit has been installed using twin and CPC 70°C thermoplastic (pvc) cable. The room temperature is 25°C and the measured $R_1 + R_2$ value is 0.48Ω. The circuit is protected by a BS EN 60898 16A type B device.

Correct the cable resistance to 20°C by using factor from Table 9B *On-Site Guide.*

$$\frac{0.48}{1.02} = 0.47\,\Omega$$

Adjust this value to conductor operating temperature by increasing it by 20%.

$$0.47 \times 1.2 = 0.56\,\Omega$$

Add this value to installation Z_e to find Z_S.

$$0.56 + 0.6 = 1.16\,\Omega$$

This value can now be compared directly with the maximum value Z_S for a 16A type B protective device. This value is 3Ω and can be found in Table 41B2 in BS 7671.

To comply with the regulations the actual value 1.16 Ω is acceptable as it is less than 3 Ω.

Method two

Measure the resistance of earth fault loop impedance at the furthest point of the circuit using the correct instrument (*remember the furthest point is the end of the circuit, not necessarily the furthest distance from the distribution board*). Record the value obtained onto the test result schedule.

This measurement cannot be compared directly with the values from BS 7671 because the operating temperature of the conductors and the ambient temperature of the room are unknown.

This method is useful for a periodic test where existing test results are available. If the measured value is higher than previous results it will indicate that there is a possible deterioration of the earth loop impedance of the circuit.

The usual method to check that the measured Z_S is acceptable is to use the rule of thumb method.

First look in the correct table in Chapter 41 of BS 7671 for the maximum permissible Z_S of the protective device for the circuit being tested.

Use three-quarters of this value and compare it with the measured value. Providing the measured value is the lowest the circuit will comply.

More information on this can be found in Chapter 5 (Protective devices).

Performing the tests

This is a live test and great care must be taken

A circuit incorporating a socket outlet on a ring or a radial

STEP 1 Use an earth fault loop impedance instrument. Set it onto 20Ω (unless you have a self ranging instrument).

STEP 2 Ensure all earthing and bonding is connected.

STEP 3 Plug in the instrument and record the reading.

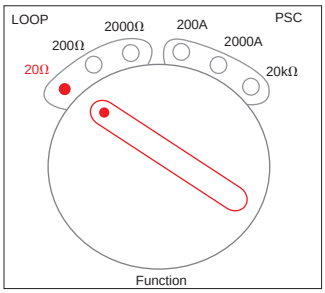

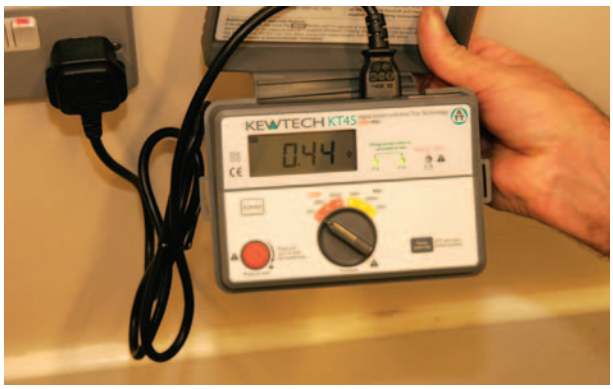

Performing the test on a radial circuit other than a socket outlet

STEP 1

Ensure earthing and bonding is connected.

STEP 2

Isolate circuit to be tested.

STEP 3

Remove accessory at the extremity of the circuit to be tested.

STEP 4

Use an earth fault loop impedance instrument with fly leads.

Place the leads on correct terminals. If you are using a two-lead instrument as connected here; if you are using a three-lead instrument as connected here (always read the instrument manufacturers instructions).

STEP 5

Energize the circuit.

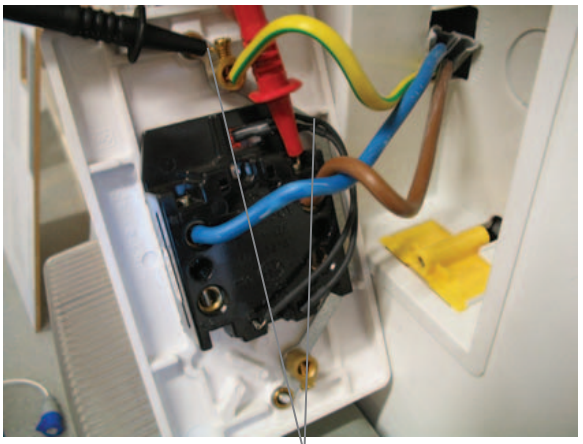

Probes on phase and earthing terminals for 2-lead instrument

Two-lead instrument as connected here

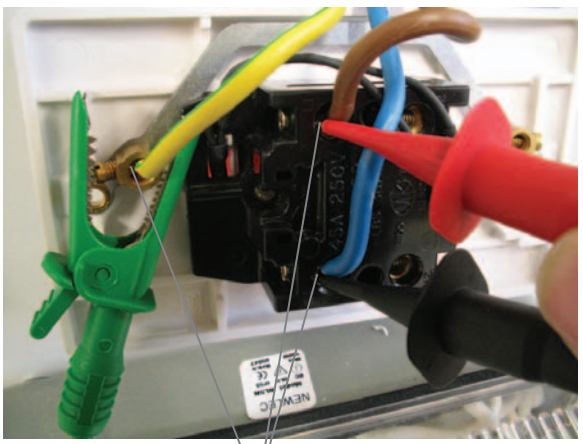

Probes on phase and neutral terminals, clip on earthing terminal for 3-lead instrument

Three-lead instrumented as connected here

STEP 6

Perform the test on a lighting circuit at the ceiling rose or at the switch.

If you are using a two-lead instrument, place the probes as shown on the left, this will also prove polarity if the switch is operated whilst carrying out the test (*this may be easier with two people*).

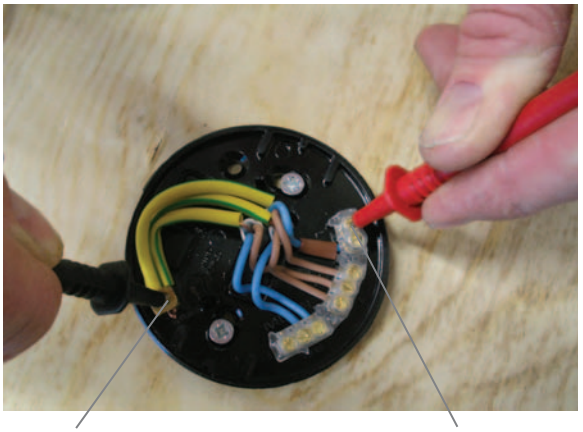

Connection to light-fitting place for 2-lead instrument

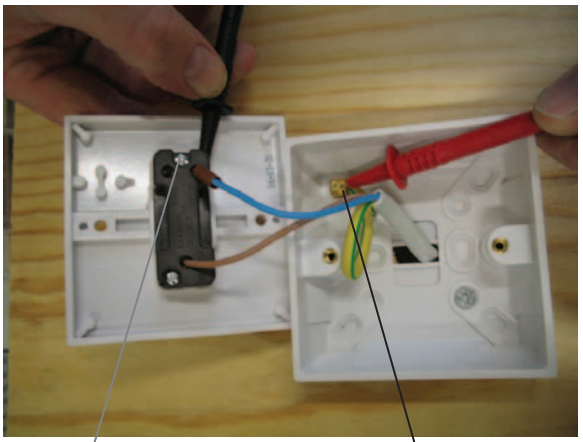

Connection to switch for 2-lead instrument

If you are using a three-lead instrument then connect the probes as shown here (always read the instrument's instructions).

STEP 7 Isolate the circuit and remove the leads.

STEP 8 Replace accessory and energize circuit.

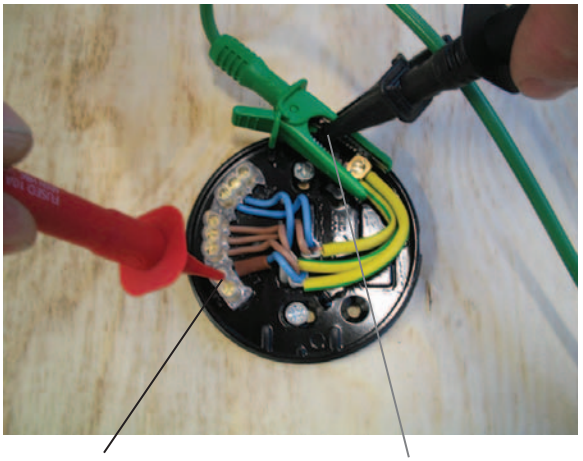

Connection to light-fitting place for 3-lead instrument

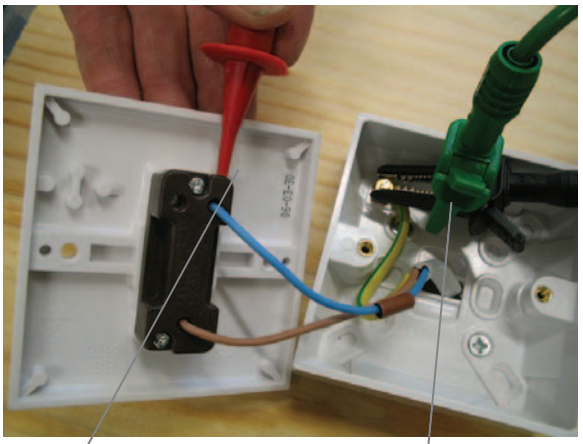

Connection to switch for 3-lead instrument

Example 9

A ring final circuit is protected by a 30A BS3036 semi-enclosed rewirable fuse and the measured Z_S is 0.96 Ω.

As this is a ring final circuit, the disconnection time has to be 0.4 seconds. From Table 41B1 in BS 7671 the maximum Z_S for a 30A rewirable fuse is 1.14 Ω.

Three-quarters of this value must now be calculated, this can be achieved by multiplying it by 0.75.

$$1.14 \times 0.75 = 0.85\,\Omega$$

The measured value for the circuit must now be lower than the corrected value if it is to comply with BS 7671.

Measured value	*0.96 Ω*
Corrected value	*0.85 Ω*

The measured value of Z_S is higher; therefore, the circuit will ***not*** *comply.*

Option one is the preferred method because it will give an accurate value whereas the test in Option two will include parallel paths and because of this will often give lower readings.

Option one should always be used for an initial verification as the first reading will be used as a benchmark to be compared with results taken in future periodic tests.

If, on a periodic inspection using Option two, a higher test result is obtained than on the initial verification, this would indicate that the circuit is deteriorating and that further investigation would be required.

The methods described here must be fully understood by anyone who is intending to sit the City and Guilds 2391 exam on inspection and testing of electrical installations.

However! Providing that the ambient temperature is between 10°C and 20°C there is a much simpler way to check the results when you are actually working on site testing. The *On-Site Guide* and *Guidance Note 3* information contain tables which are already corrected for conductor operating current

and ambient temperature. In the *On-Site Guide* these tables can be found in Appendix 2 (Table 2A to Table 2D). These tables can also be used where the CPC is of a different cross-sectional area than the live conductors.

These values are slightly more favourable than the rule-of-thumb method, as they are at approximately 80% of values given in BS 7671 and are perfectly acceptable (*remember, however, that the previous methods described must also be understood*).

Example 10

A circuit supplying a fixed load is protected by a 20A BS 3036 fuse and the measured Z_S is 2.32 Ω. The circuit CPC is 1.5 mm^2.

As this circuit is supplying a fixed load the maximum permitted disconnection time is 5 seconds.

The table that should be used is 2A(ii) from the On-Site Guide. Using this table it can be seen that for a 20A device protecting a circuit with a 1.5 mm^2 CPC the maximum permissible Z_S is 3.2 Ω. As the measured Z_S is lower than the maximum permitted, the circuit complies with the Regulations.

Example 11

A circuit supplying a cooker outlet which incorporates a socket outlet protected by a 45A BS 1361 fuse, has a measured Z_S of 0.4 Ω. The CPC is 4 mm^2.

As this circuit has a socket outlet on it, the disconnection time would be 0.4 seconds.

The table to use for this circuit is 2C(i) from the On-Site Guide and the maximum permitted Z_S is 0.48 Ω. This circuit will comply.

Example 12

A circuit supplying a lighting circuit protected by a 6A type C BS 60898 protective device has a measured Z_S of 2.9 Ω.

It should be remembered that miniature circuit breakers will operate at 0.1 seconds providing that the measured Z_S is equal to or lower than the values given in the tables. We do not have to worry about 0.4 or 5 second disconnection times for these devices.

The table to use for this example is 2D in the On-Site Guide, the maximum permitted Z_S is 3.2 Ω. The measured value of 2.9 Ω is lower than the maximum permitted, therefore, this circuit would comply.

Remember that the values in GN3 and the *On-Site Guide* are corrected for temperatures between 10°C and 20°C and no other calculation is required providing the ambient temperature is between these values.

If the ambient temperature is below 10°C or above 20°C then correction factors from Table 2E of the *On-Site Guide* must be used as follows.

Using Example 9, a circuit supplying a fixed load is protected by a 20A BS 3036 fuse and the measured Z_S is 2.32 Ω. The circuit CPC is 1.5 mm^2, and the **ambient temperature is 23°C.**

As this circuit is supplying a fixed load, the maximum permitted disconnection time is 5 seconds.

The table that should be used is 2A(ii) from the *On-Site Guide*. Using the table it can be seen that for a 20A device protecting a circuit with a 1.5 mm^2 CPC, the maximum permitted Z_S is 3.20 Ω.

Now the temperature has to be taken into account.

Using Table 2E from Appendix 2 of the *On-Site Guide* it can be seen that the nearest value to the temperature which was measured (23°) is 25°C (*always round up to be on the safe side*). The correction factor for 25°C is 1.06.

This value (1.06) is now used as a multiplier to the maximum permitted Z_S (3.20 Ω) to calculate the maximum Z_S for the circuit at 25°C

$$3.20 \times 1.06 = 3.39\,\Omega$$

This is the maximum measured Z_S permissible for the circuit at 25°C.

Prospective fault current test

This is a live test and great care must be taken

A prospective fault current test instrument is normally combined with an earth loop impedance test instrument, the measured value is normally shown in kA (kilo amps).

Regulations 434-02-01 and 713-12-01 require that the prospective short circuit current and the prospective earth fault current are determined. Once determined, the highest value must of course be recorded.

A prospective short circuit current is the maximum current that could flow between phase and neutral on a single-phase supply or between phase conductors on a three-phase supply.

A prospective earth fault current is the maximum current that could flow between live conductors and earth.

The higher of these values is known as prospective fault current.

The highest prospective fault current will be at the origin of the installation and must be measured as close to the meter position as possible, usually at the main switch for the installation. It is measured between phase and neutral.

This can be done by:

- Enquiry to the supplier
- Calculation
- Measurement

Enquiry

This is a matter of a phone call to the electricity supplier of the installation. They will tell you the maximum PFC. Usually this is a lot higher than the value will actually be, but if you use this value you will be on the safe side.

Calculation

The PFC can only be calculated on a TNCS system. This is because the neutral of the supply is used as a Protective earth and neutral (PEN) conductor.

When the earth fault loop impedance is measured, the value measured is in ohms. To convert this value to prospective short circuit current we must use the following equation:

$$PSCC = \frac{V}{Z_e} = I$$

It is important to remember that the open circuit voltage of the supply transformer is used U_{OC} 240 V (BS 7671, Appendix 3).

Example 13

Z_e is measured at 0.28 Ω

$$\frac{240}{0.28} = 857\ amps$$

A useful tip is that when you have measured Z_e on a TNCS system, set your instrument to PFC and repeat the test. This will give you the value for PFC and save you doing the calculation.

Measurement

This is carried out using a prospective fault current tester. As with all tests it is important that you have read the instructions for the instrument which you are going to use.

If you are using a two-lead instrument with leads and probes to GS 38:

STEP 1

Set instrument to PFC.

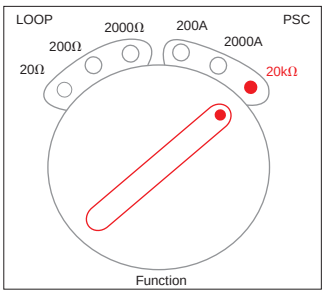

STEP 2

Place the probes on the phase and neutral terminals at supply side of the main switch.

STEP 3

Operate the test button and record the reading.

When carrying out the test using a three-lead instrument with leads to GS 38, it is important that the instrument instructions are read and fully understood before carrying out this test.

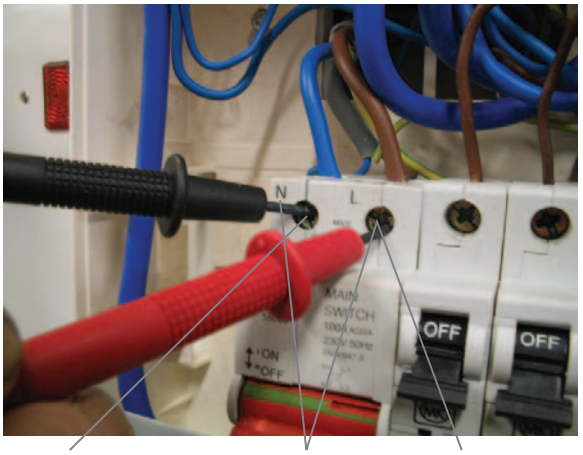

Probe at neutral at supply side of main switch

Insulated tips

Probe at phase at supply side of main switch

Connection for 2-lead instrument

STEP 1

Place the phase lead on the supply side of the main switch and the neutral and earthing probes/clips onto the earthing terminal.

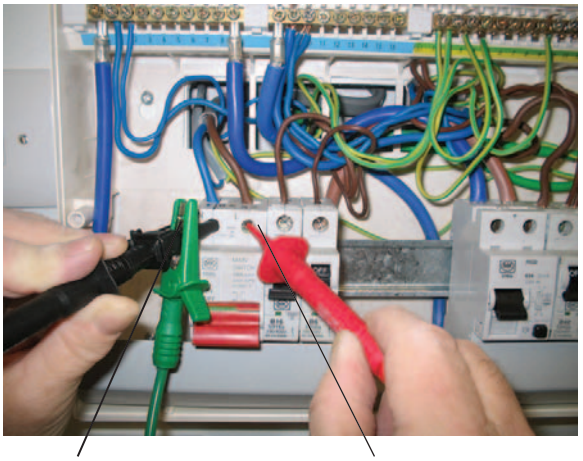

Joined leads at neutral at supply side of main switch

Probe at phase at supply side of main switch

Connection for 3-lead instrument

STEP 2 Operate the test button and record the reading.

If the supply system is a three-phase and neutral system then the highest current that could flow in it will be between phases. Some instruments will not be able to measure the high current that would flow under these circumstances.

Under these circumstances the measurement should be made between any phase and neutral at the main switch and the measured value should be **doubled**.

For your personal safety and the protection of your test equipment it is important to read and fully understand the instructions of your test instrument before commencing this test.

Some PSCC (protective short-circuit current) instruments give the measured value in ohms, not kA. If this is the case, a simple calculation, using ohms law is all that is required.

Example 14

Measured value is 0.08 Ω.

Remember to use U_{OC} in this calculation (240 V)

$$PSCC = \frac{240}{0.08} = 3000\ A$$

It is important that the short circuit capacity of any protective devices fitted exceeds the maximum current that could flow at the point at which they are fitted.

When a measurement of PFC is taken as close to the supply intake as possible, and all protective devices fitted in the installation have a short circuit capacity that is higher than the measured value, then Regulation 432-02-01 will be satisfied.

In a large installation where sub mains are used to supply distribution boards it can be cost effective to measure the PFC at each board. The PFC will be smaller and could allow the use of a protective device with a lower short circuit rating. These will usually be less expensive.

Table 7.2A in the *On-Site Guide* gives rated short circuit capacities for devices. These values can also be obtained from manufacturer's literature.

Examples	Rated short circuit capacity
Semi-enclosed BS 3036	1 kA to 4 kA depending on type
BS 1361 Type 1	16.5 kA
Type 2	33 kA
BS 88-2.1	50 kA at 415 volts
BS 88-6	16.5 kA at 240 volts
	80 kA at 415 volts

Circuit breakers to BS 3871 are marked with values M1 to M9 the number indicates the maximum value of kA that they are rated at.

Circuit breakers to BS EN 60898 and RCBOs to BS EN 61009 show two values in boxes, usually on the front of the device.

Circuit breaches to BS EN 60898

The square box will indicate the maximum current that the device could interrupt and still be reset 3. This is the Ics rating. The rectangular box will indicate the maximum current that the device can interrupt safely 6000. This is the Icn rating.

If a value of fault current above the rated Isc rating of the device were to flow in the circuit, the device will no longer be serviceable and will have to be replaced. A value of fault current above the Icn rating would be very dangerous and possibly result in an explosion causing major damage to the distribution board/consumer's unit.

Functional testing

All equipment must be tested to ensure that it operates correctly. All switches, isolators and circuit breakers must be manually operated to ensure that they function correctly, also that they have been correctly installed and adjusted where adjustment is required.

Residual current device (RCD)

The instrument used for this test is an RCD tester, and it measures the time it takes for the RCD to interrupt the supply of current flowing through it. The value of measurement is either in seconds or milliseconds.

Before we get on to testing, let's consider what types of RCDs there are, what they are used for, and where they should be used.

Types of RCD

Voltage operated

Voltage operated earth leakage current breakers (ELCBs) are not uncommon in older installations. This type of device became obsolete in the early 1980s and must not be installed in a new installation or alteration as they are no longer recognized by BS 7671.

They are easily recognized as they have two earth connections, one for the earth electrode and the other for the installation earthing conductor. The major problem with voltage operated devices is that a parallel path in the system will probably stop it from operating.

These types of devices would normally have been used as earth fault protection in a TT system.

Although the Electrical Wiring Regulations BS 7671 cannot insist that all of these devices are changed, if you have to carry out work on a system which has one it must be replaced to enable certification to be carried out correctly. If, however, a voltage operated device is found while preparing a periodic inspection report, a recommendation that it should be replaced would be the correct way of dealing with it.

BS 4293 General purpose device

These RCDs are very common in installations although they ceased to be used in the early 1990s. They have been replaced by BS EN 61008-1, BS EN 61008-2-1 and BS EN 61008-2-2.

They are used as standalone devices or main switches fitted in consumers' units/distribution boards.

This type of device provides protection against earth fault current. They will commonly be found in TT systems 15 or more years old, although they may be found in TNS systems where greater protection was required.

A typical voltage – operated earth leakage current breaker (ELCB) – now obsolete

A typical general purpose RCD to BS4293 – now obsolete

If this type of device is fitted to a TT system which is being extended or altered, it is quite safe to leave it in the system. If the system supplies socket outlets which could be used to supply portable equipment used outside, it must have a tripping current of no more than 30 mA. This includes socket outlets that could serve extension leads passed through open windows or doors.

The problem with using a low tripping current device as the main switch is that nuisance tripping could occur. The modern way of tackling this is explained later in this chapter.

BS 4293 Type S

These are time delayed RCDs and are used to give good discrimination with other RCDs.

BS EN 61008-1 General purpose device

This is the current standard for a residual current circuit breaker (RCCB) and provides protection against earth fault current. These devices are generally used as main switches in consumers' units/distribution boards.

Three-phase devices are also very common.

A typical 2-phase RCCB to BS EN 61008-1

BS 7288

This is the current standard for RCD-protected socket outlets and provides protection against earth fault currents. These socket outlets would be used in areas where there is an increased risk of electric shock, such as common areas of schools and colleges. It is also a requirement that any socket outlet used for portable equipment outdoors must have supplementary protection provided by an RCD (*Regulation 471-16-02*). Where the socket outlets are sited outside, waterproof BS 7288 outlets are used to IP 56.

A typical 3-phase RCCB to BS EN 61008-1

BS EN 61009-1

This is the standard for a residual current circuit breaker with overload (RCCBO) protection.

These devices are generally used to provide single circuits with earth fault protection, overload protection and short circuit protection. They are fitted in place of miniature circuit breakers and the correct type should be used (types B, C or D).

BS EN 61008-1 Type S

These are time delayed RCDs and are used to give good discrimination with other RCDs.

Section 3 of the *On-Site Guide* gives good examples of how these devices should be used within an installation.

RCDs and supply systems

TT system

If the installation is a TT system and it is possible for any of the sockets to supply portable equipment outdoors or RCD protection is required for other

A typical RCCBO to BS EN 61009-1

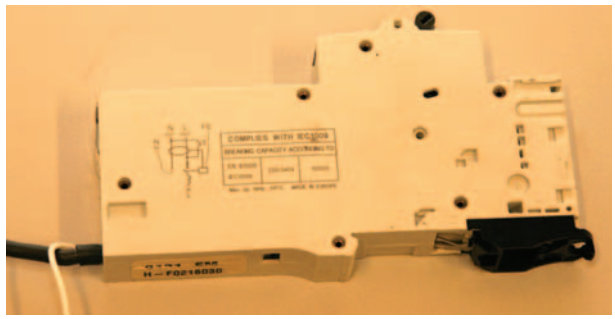

Side view of a typical RCCBC to BS EN 61009-1

reasons (*protection for fixed equipment in zones 1-3 in bathrooms, for instance*), there are various options available. While all will be safe, they will vary in cost.

Option 1 Use a 100 mA S-Type RCD (*BS EN 610081*) as the main switch and RCD protection for all circuits. Then use a 30 mA RCBO (*BS EN 61009*) as a circuit protective device for the circuit which requires protection. In this case, the 100 mA RCD must be labelled 'Main Switch'.

Option 2 Use a split board with 100 mA S-Type RCD (*BS EN 61008*) as a main switch and a 30 mA RCD (*BS EN61008*). All circuits require supplementary protection. This method is useful if more than one circuit requires 30 mA protection.

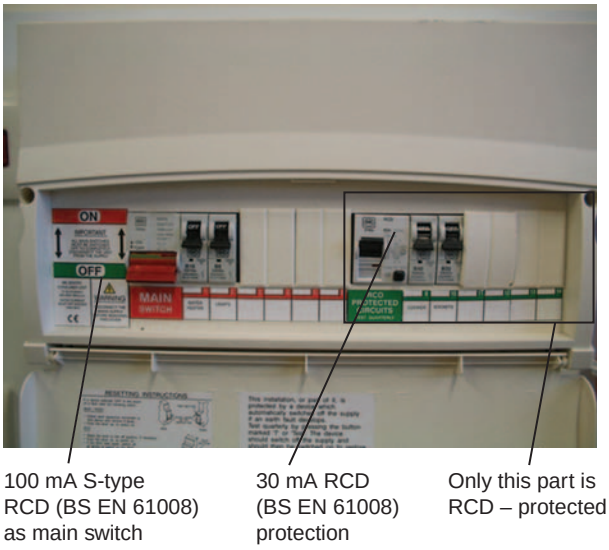

Option 3 Use a split board with a 100 mA RCD for fixed equipment and lighting with a 30 mA RCD for the circuits requiring supplementary bonding. This option would require a separate main switch.

Option 4 Another method would be to use a consumer unit with a main switch to BSEN 60947-3 and RCBOs to BS EN 610091 as protective devices for all circuits. This option is perfectly satisfactory but can work out a little expensive!

TNS and TNCS systems

If the supply system was TNS or TNCS, Options 1 and 2 could be used. But instead of using a 100 mA S-Type RCD as a main switch, it could be substituted for a main switch to BS EN 60947-3.

Option 4 will remain pretty much the same but BS EN 60898 devices could be used where RCD protection is not required.

Testing of RCDs

Remember that these are live tests and care should be taken whilst carrying them out

The instrument to be used to carry out this test is an RCD tester, with leads to comply with GS 38.

Before carrying out the tests ensure that all loads are removed; failure to do this may result in the readings being inaccurate.

Voltage operated (ELCBs)

No test required as they should now be replaced.

BS 4293 RCDs

If this type of RCD is found on TT systems or other systems where there is a high value of earth fault impedance (Z_e), the RCD tester should be plugged into the nearest socket or connected as close as possible to the RCD. The tester should then be set at the rated tripping current of the RCD ($I\Delta n$); for example, at 30 mA (*be careful and do not mistake the tripping current for the current rating of the device*).

STEP 1

The test instrument must then be set at 50% of the tripping current (15 mA).

STEP 2

Push the test button of the instrument, the RCD should not trip.

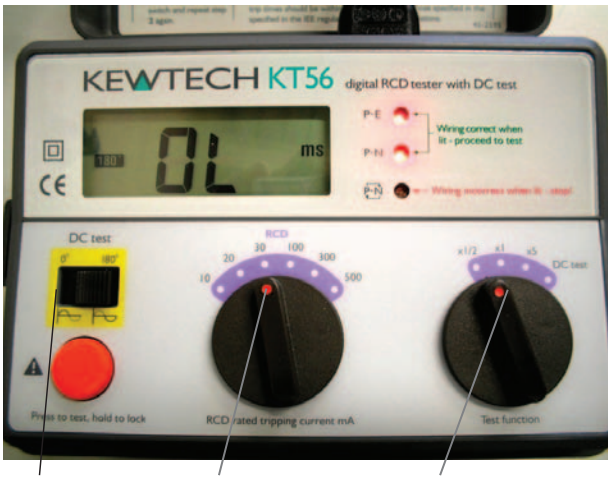

STEP 3

The test instrument will have a switch on it which will enable the instrument to test the other side of the waveform 0°~180°. This switch must be moved to the opposite side and the test repeated. Again the RCD should not trip.

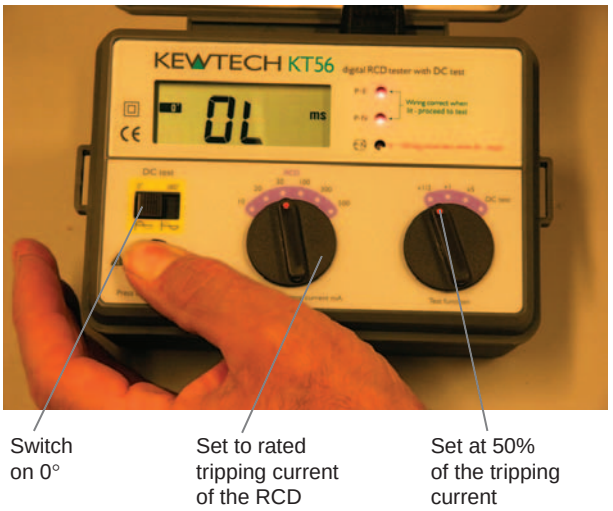

If, while testing an RCD it trips during the 50% test, do not automatically assume that the RCD is at fault.

Consider the possibility that there is a small earth leakage on the circuit or system. Switch all circuits off and test RCD on the load side at 50% using fly leads. If it still trips, then the RCD should be replaced.

If the RDC does not trip, then turn each circuit on one at a time, carrying out a 50% test each time a circuit has been turned on. When the RCD does trip, switch off all circuits except the last one which was switched on. Test again. If the RCD trips carry out an insulation test on this circuit as it probably has a low insulation resistance. If, however, the RCD does not trip it could be an accumulation of earth leakage from several circuits and they should all be tested for insulation resistance.

STEP 4

Now set the test current to the rated tripping current (30 mA)

STEP 5

Push the test button, and the RCD should trip within 200 milliseconds.

STEP 6

Reset the RCD.

STEP 7

Move the waveform switch to the opposite side, and repeat the test. Again it must trip within 200 milliseconds.

STEP 8

Reset the RCD and the slowest time in which it trips should be entered on to the test result schedule.

If the RCD is used to provide supplementary protection against direct contact, or for socket outlets used to supply portable equipment outdoors – fixed equipment in zone 1 or other current using equipment in zone 3 of a bathroom, the following test should be performed.

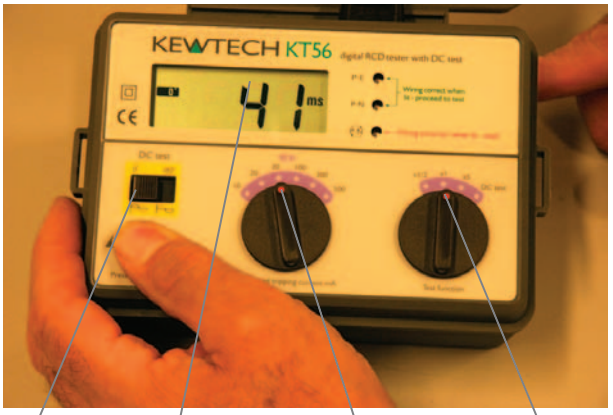

Switch on 0° | Tripping time <200 ms | Set to rated tripping current of the RCD | Set to 100% of the tripping current

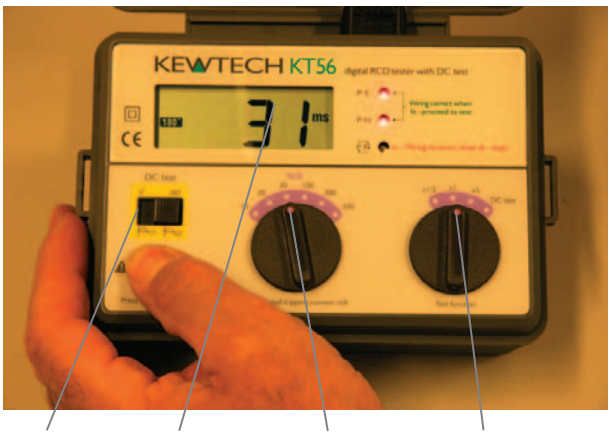

Switch on 180° | Tripping time <200 ms | Set to rated tripping current of the RCD | Set to 100% of the tripping current

STEP 9

Set the test current to 5 times the rated tripping current (150 mA).

STEP 10

Push the test button and the RCD should trip within 40 milliseconds.

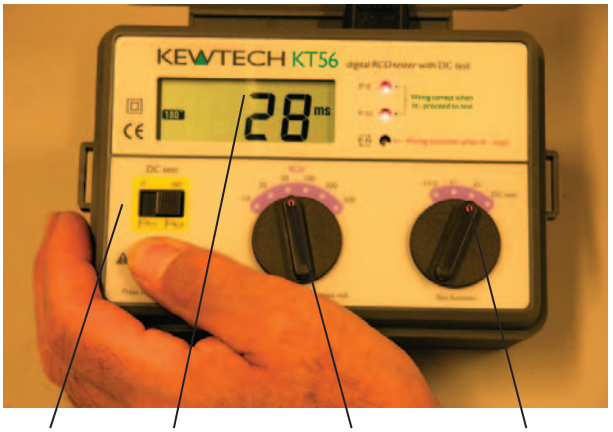

STEP 11

Move the waveform switch to the opposite side, and repeat the test. Again it must trip within 40 milliseconds (five times faster than the times 1 test).

After completion of the instrument tests

STEP 12

Push integral test button on RCD to verify that the mechanical parts are working correctly.

STEP 13

Ensure that a label is in place to inform the user of the necessity to use the test button quarterly.

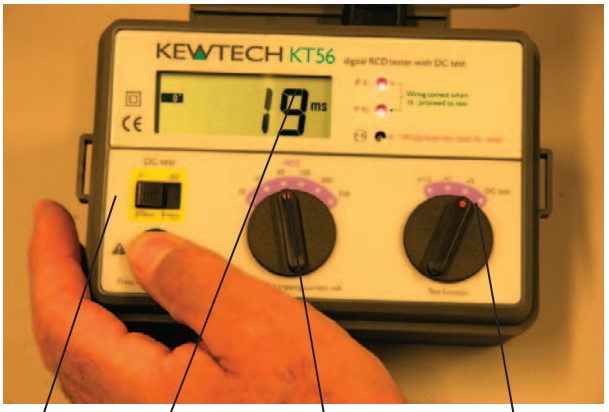

BS EN 610081

These devices should be tested in exactly the same manner as BS 4293 using the same test instrument. However, the difference is that, when carrying out the 100% test, the tripping time is increased to 300 milliseconds.

BS 4293 Type S

This device has a built in time delay. The simple way to think about this is that it does not recognize a fault for 200 milliseconds, and they must trip within 200 milliseconds after that.

The 5 times test must only be carried out on RCDs with trip ratings (IΔn) up to 30 mA.

STEP 1 Plug in or connect an RCD as close as possible to the RCD to be tested.

STEP 2 Set the instrument on the trip current of the RCD and ensure that it is set for 'S' type.

STEP 3 Test at 50% and the device should not trip.

STEP 4 Repeat the test on the opposite waveform.

STEP 5 Set test instrument on 100% and carry out test. The RCD should trip within 400 milliseconds (200 *ms time delay and 200 ms fault*).

STEP 6 Repeat on the opposite wave form.

Always ensure that it is safe to carry out these tests. Remember to remove any loads, ensure that the disconnecting of the supply due to the test will not effect any equipment or cause damage. If any people are within the building ensure that they are aware of testing being carried out, and that a loss of supply is likely.

The slowest operating time at the 100% test should be recorded, as should the fact that it is an 'S' type.

BS EN 61008 Type S

This device has a time delay of 200 milliseconds and a tripping time of 300 milliseconds, making a maximum tripping time of 500 milliseconds.

The test should be carried out as the BS 4293 Type S but remember the different tripping time.

BS 7288 RCD protected socket

This device should be tested the same as for a BS 4293 and the tripping times are the same.

Consideration should be given to whether the socket will supply portable equipment outdoors. If it can it should be tested at 5 times its rating.

BS EN 61009 RCBOs

These devices should be tested as for BS 4239 RCDs but the disconnection times are:

- 50% test on both sides of waveform, no trip.
- 100% test on both sides of waveform; must trip within 300 milliseconds.
- If used as supplementary protection, the 5 times test must also be carried out; it must trip within 40 milliseconds.

5 Safety in electrical testing

Correct selection of protective devices

(***While protective devices are mentioned throughout this book, this chapter brings all of the information together for reference***)

When carrying out an inspection and test on any electrical installation it is important to ensure that the correct size and type of device has been installed.

To do this we must have a good knowledge of the selection of protective devices and the type of circuits that they are protecting.

Why are they installed?

Protective devices are installed to protect the cable of the circuit from damage – this could be caused by overload, overcurrent and fault current.

The definition for overload given in Part 2 of BS 7671:2004 is: *Overcurrent occurring in a circuit which is electrically sound.* This is when the circuit is installed correctly and the equipment connected to it is drawing too much current. For instance:

An electric motor connected to the circuit is used on too heavy a load, leading to an overload of the circuit. Provided that the correct size of protective device was installed, the device will operate and interrupt the supply preventing the cable from overloading.

If additional luminaries were installed on an existing circuit which was already fully loaded, the protective device should operate and protect the cable of the circuit.

Overcurrent is a current flow in a circuit which is greater than the rated current carrying capacity of the cables. This would normally be due to a fault on the circuit or incorrect cable selection. For example:

If a 20 amp cable protected by a 32 amp circuit breaker was loaded by 25 A, the cable would overheat and the device would continue to allow current to flow – this could damage the cable.

A fault current is a current which is flowing in a circuit due to a fault. For example:

A nail is driven through a cable causing an earth fault or a short circuit fault. This would cause a very high current to flow through the circuit, which must be interrupted before the conductors reach a temperature that could damage the insulation or even the conductors.

So what are we looking for with regard to protective devices during an inspection?

What type of device is it? Is it a fuse or circuit breaker?

A fuse has an element which melts when too much current is passed through it, whether by overload or fault current.

Fuses in common use are:

BS 3036 semi-rewirable fuse
BS 88 cartridge fuse
BS 1361 cartridge fuse

A circuit breaker is really two devices in one unit. The overload part of the device is a thermal bi metal strip, which heats up when a current of a higher value than the nominal current rating (I_n) of the device passes through it.

Also incorporated within the device is a magnetic trip, which operates and causes the device to trip when a fault current flows through it. For the device to operate correctly it must operate within 0.1 seconds. The current which has to flow to operate the device in the required time has the symbol (I_a).

Circuit breakers in common use are:

- BS 3871 types 1, 2 and 3
- BS EN types B, C and D (*A is not used, this is to avoid confusion with Amps*)

Is the device being used for protection against indirect contact?

In most instances this will be the case.

What type of circuit is the device protecting, is it supplying fixed equipment only, or could it supply handheld equipment?

If the circuit supplies fixed equipment only, the device must operate on fault current within 5 seconds. If it supplies socket outlets it must operate within 0.4 seconds (*see BS 7671, Regulations 413-02-08 and 413-02-09*).

When using circuit breakers to BS 3871 and BS EN 60898 these times can be disregarded. Providing the correct Z_S values are met, they will operate in 0.1 seconds or less.

If it is a circuit breaker is it the correct type?

Table 7.2b of the *On-Site Guide* provides a good reference for this.

Types 1 and B should be used on circuits having only resistive loads (*have you ever plugged in your 110 v site transformer and found that it operated the circuit breaker? If you have it will be because it was a type 1 or B*).

Types 2, C and 3 should be used for inductive loads such as fluorescent lighting, small electric motors and other circuits, where surges could occur.

Types 4 and D should be used on circuits supplying large transformers or any circuits where high inrush currents could occur.

Will the device be able to safely interrupt the prospective fault current which could flow in the event of a fault?

Table 7.2A or the manufacturer's literature will provide information on the rated short circuit capacity of protective devices.

Is the device correctly coordinated with the load and the cable?

Correct coordination is:

> Current carrying capacity of the cable under its installed conditions must be equal to or greater than the rated current of the protective device (I_z).

The rated current carrying capacity of the protective device (I_n) must be equal to or greater than the design current of the load (I_b).

In short, $I_z > I_n > I_b$ (*Appendix 4. item 4 BS 7671 or Appendix 6 On-Site Guide*).

Additional information regarding circuit breakers

Overload current

The symbol for the current required to cause a protective device to operate within the required time on overload is (I_2).

Circuit breakers with nominal ratings up to 60 amps must operate within 1 hour at 1.45 × their nominal rating (I_n).

Circuit breakers with nominal ratings above 60 amps must operate within 2 hours at 1.45 × its rating (I_n).

At 2.55 times the nominal rating (I_n), circuit breakers up to 32 amps must operate within 1 minute; and circuit breakers above 32 amps, must operate within 2 minutes.

They must <u>not</u> trip within 1 hour at up to 1.13 their nominal rating (I_n).

Maximum earth fault loop impedance values (Z_S) for circuit breakers

These values can be found in Table 41B2 in BS 7671, they can also be found in Sections 604 and 605 of BS 7671.

Because these devices are required to operate within 0.1 of a second, they will satisfy the requirements of BS 7671 with regard to disconnection times in all areas. Therefore, the Z_S values for these devices are the same wherever they are to be used (this only applies to circuit breakers) even in special locations where the disconnection time must be 0.2 seconds.

Calculation of the Maximum Z_S of circuit breakers

It is often useful to be able to calculate the maximum Z_S value for circuit breakers without the use of tables. This is quite a simple process for BS 3871 and BS EN 60898 devices. Let's use a 20A BS EN 60898 device as an example:

Table 7.2b shows that a type B device must operate within a window of 3 to 5 times its rating. As electricians we always look at the worst case scenario. Therefore, we must assume that the device will not operate until a current

equal to 5 times its rating flows through it (I_a). For a 20 A type B device this will be 5 × 20 A = 100 A.

If we use a supply voltage of 240 volts – which is the assumed open circuit voltage (U_{OC}) of the supply (Appendix 3, BS 7671) – Ohm's law can be used to calculate the maximum Z_S.

$$Z_S = \frac{U_{OC}}{I_a}$$

$$Z_S = \frac{240}{100} = 2.4\ \Omega$$

And to check this, we look in Table 41B2 of BS 7671, we will see that the value Z_S for a 20 A type B device is 2.4 Ω.

Now let's use the same procedure for a 20 A type C device. Table 7.2b shows us that a type C device must operate at a maximum of 10 times its rating (I_n).

$$10 \times 20 = 200\ \text{A}$$

$$\frac{240}{200} = 1.2\ \Omega$$

If we check again in Table 41B2, we will see that the maximum Z_S for a 20 A type C device is 1.2 Ω.

A type C circuit breaker with a nominal operating current (I_n) must operate at a maximum of 20 times its rating:

$$20 \times 20 = 400\ \text{A}$$

$$\frac{240}{400} = 0.6\ \Omega$$

Again, if we check in Table 41B2 we will see that the Z_S value is 0.6 Ω.

We can see that the maximum Z_S values for a type C are 50% of the Z_S value of a type B device, and that the Z_S value for a type D are 50% of the Z_S value of a type C device.

Maximum earth loop impedance (Z_S) for fuses

Fuses have to operate at 0.4 or 5 seconds depending on the type of circuit which they are protecting. To find the maximum permissible Z_S value for a fuse, the current curves in Appendix 3 of BS 7671 will have to be looked at.

Example

Find the maximum permissible Z_S for a BS 1361 fuse with a rating of 20 amps with a required disconnection time of 0.4 seconds.

Look in Appendix 3, Figure 3.1. The left-hand side of the grid represents the disconnection time.

From the bottom left-hand corner, follow the line upwards until the horizontal line representing 0.4 seconds is found. Now follow the horizontal line across to the right until the bold line for a 20 amp fuse is found, from where the horizontal line touches the bold line move vertically down the page until you meet the bottom line of the grid. The bottom line represents the automatic operating current for the fuse. It can be seen that the current required is around 130 amps.

The table in the right-hand top corner of the page will show this value to be 135 amps.

The calculation is:

$$Z_S = \frac{U_{OC}}{I_a}$$

$$Z_S = \frac{240}{135}$$

$$Z_S = 1.777\ \Omega$$

Rounded up, this is 1.77Ω. As a check, look in BS 7671, part 4, chapter 1, Table 41B1 and you will see that the Z_S for a BS 1361 20 amp fuse is 1.77Ω.

Do not forget to correct this value for the conductor operating temperature and ambient temperature, if required.

This calculation can be used for any type of protective device. But remember that the disconnection time for a circuit breaker will always need to be 0.1 seconds, and that for some special locations it will be 0.2 seconds.

Comparing maximum Z_S and measured Z_S

Unfortunately, we cannot compare this value directly to any measured Z_S values that we have. This is because the values given in BS 7671 for Z_S are for when the circuit conductors are at their operating temperature (generally 70°C).

However, we can use a simple calculation which is called the rule-of-thumb (Section 2.7.14 of *Guidance note 3*). This calculation will allow us to compare our measured values with the values from BS 7671.

The values given in the Table below are the worst case values. In these types of calculations we must always use the worst case values to ensure a safe installation.

From this table below, it can be seen that types D, 3 and 4 will have very low maximum permitted Z_S values. This will often result in the use of an RCD.

Circuit breaker type		Worst case tripping current	Typical uses
BS EN 60898	B	5 times its rating	General purpose with very small surge currents (i.e. small amounts needed for fluorescent lighting). Mainly domestic
	C	10 times its rating	Inductive loads. Generally commercial or industrial where higher switching surges would be found (i.e. large amounts of fluorescent lighting or motor starting)
	D	20 times its rating	Only to be used where equipment with very high inrush currents would be found
BS 3871	1	4 times its rating	As for type B
	2	7 times its rating	As for type C
	3	10 times its rating	As for type C but slightly higher inrush currents
	4	50 times its rating	As for type D

Example

Let's assume that we have a circuit protected by a 32A BS EN 60898 type B device. The measured value of Z_S is 0.98 Ω.

Following the procedure described previously:

$$5 \times 32 = 160 \ A$$

$$\frac{240}{160} = 1.5 \ \Omega$$

The maximum Z_S at 70°C for the circuit is 1.5 Ω.

To find $^{3}/_{4}$ of 1.5 we can multiply it by 0.75.

$$1.5 \times 0.75 = 1.125 \Omega$$

So, 1.125 Ω now becomes our maximum value, and we can compare our measured value directly to it without having to consider the ambient temperature or the conductor operating temperature. Our measured value must be less than the corrected maximum value; in this case it is, and the 32 amp type B device would be safe to use.

This type of calculation must be understood by any student studying for the City and Guilds 2391 inspecting and testing course

Test equipment

It is important that the test equipment you choose is suitable for your needs. Some electricians prefer to use individual items of equipment for each test; others like to use multi-function instruments.

Any test instruments used for testing in areas such as petrol filling stations, or areas where there are banks of storage batteries, etc. In fact, anywhere there is a risk of explosion, must be intrinsically safe for the purpose.

Most electricians are aware that electrical test instruments must comply with BS standards. However, students studying for Part P and City and Guilds 2391 exams, an understanding of the basic operational requirement for the most common types of test instrument is very important.

Whichever instrument you choose it must be suitable for the use to which it is to be put and be manufactured to the required British standard. It is also vital that you fully understand how to operate it before you start testing.

Instruments required

Low resistance ohm meter

Used to measure the resistance and verify the continuity of conductors. This instrument must produce a test voltage of between 4 and 24 volts and a current of not less than 200 mA. The range required is 0.02 to 2 ohms although most modern instruments are self ranging and will measure higher values if required.

Insulation resistance tester

Used to measure the insulation resistance between live conductors and live conductors and earth. This test is a pressure test of conductor insulation. The instrument must deliver a current of 1 mA on a resistance of 0.5 MΩ. At 250 volts d.c. for extra low voltage circuits, 500 volts d.c. for low voltage circuits up to 500 volts a.c. and 1000 volts d.c. for circuits between 500 and 1000 volts d.c.

This instrument is sometimes called a high resistance tester as it measures values in megohms.

Earth fault loop impedance tester

This instrument allows a current of up to 25 amps to flow around the earth fault loop path. It measures the current flow and by doing so can calculate the resistance of the earth fault loop path. The values given are in ohms.

As a current of 25 amps will trip RCDs and some smaller circuit breakers, it is useful to have an instrument that can carry out low current testing where required. Use of this type of instrument will avoid the tripping of devices during testing.

Prospective short circuit current test instrument

This instrument measures the current that would flow between live conductors in the event of a short circuit. It is usually incorporated in the earth loop impedance tester and normally gives a value in kA. Some instruments give the value in ohms which then needs to be converted to amps by using Ohm's law (*use 240 volts*).

Most instruments will measure the value between phase and neutral and not between phases; to find the value between phases it is simply a matter of doubling the phase to neutral value.

Earth electrode resistance tester

This is normally a battery operated 3 or 4 terminal instrument with a current and potential spike. The values given are in ohms and the instrument instructions should be fully understood before using it. The instrument would be used where low and very accurate earth electrode resistance values are required such as for generators or transformers.

Residual current device tester

This instrument measures the tripping times of RCDs in seconds or milliseconds.

Phase rotation

This instrument is used to ensure the correct phase rotation of 3 phase supplies.

Calibration of test instruments

To carry out any kind of test properly your instruments have to be accurate. If they were not then the whole point of carrying out the test would be lost. While it is not a requirement to have instruments calibrated on an annual basis, a record must be kept to show that the instruments are regularly checked for accuracy.

Instrument accuracy can be tested using various methods. For an earth loop impedance tester all that is required is a dedicated socket outlet. Use your earth fault loop impedance instrument to measure the value of the socket outlet. This value can then be used as a reference to test the accuracy of the instrument at a later date. You can also test any other earth fault loop instrument on the dedicated outlet to check its accuracy. The loop impedance values of the socket outlet should not change.

For an insulation resistance tester, or a low resistance ohm meter, the accuracy can be checked quite simply by using various values of resistors. The instruments could even be checked against values given by another instrument. If the values given are not the same when testing against another instrument, this will indicate that one of the instruments is inaccurate and further investigation using resistors should be undertaken.

An RCD test instrument accuracy is a little more difficult to check and often the best way is to check it against another instrument. However, if you do check it in this way do not expect exactly the same values as the trip time could be slightly different each time you test it due to the instrument increasing slightly in temperature.

It is also possible to purchase a calibration instrument which will check the accuracy of all electrical test instruments. When it is found that an instrument is not accurate, then it must be returned to the manufacturer or specialist for re-calibration. This is not a job that can normally be carried out by the owner of the instrument.

Calibration instrument

Calibration instrument

If, for any reason, your instrument does require re-calibration, it should be returned to the instrument manufacturer or a calibration specialist.

Recordkeeping for accuracy testing of the instrument is quite a simple but important process. A record showing the instrument model, serial number and the date of the test along with the recorded values is all that is required and will satisfy most regulatory bodies. Records can be kept in a ledger, on a computer. Alternatively, calibration registers can be purchased to make life a little easier.

Electric shock

An electric shock is caused by current flowing through a body. A very small amount – between 50 and 80 mA is considered to be lethal to most human beings, although this would of course depend on the person's health and other circumstances. In livestock the lethal current would be considerably less.

The electrical regulations are set out to provide for the safety of persons and livestock. An electric shock is one risk of injury; others are:

- Excessive temperatures likely to cause burns, fire and other injurious effects.
- Mechanical movement of electrically actuated equipment, in so far as such injury is intended to be prevented by electrical emergency switching or by switching for mechanical maintenance of non-electrical parts of such equipment.
- Explosion.

This can be found in Chapter 13 of BS 7671 (Regulation 130-01-01).

Regulation 130-02-01 tells us that persons and livestock shall be protected so far as is reasonably practical against dangers that may arise from contact with live parts of the installation. This protection can be achieved by one of the following methods.

For direct or indirect contact:

- Preventing current passing through the body of any person or livestock.
- Limiting the current which can pass through a body to a value lower than the shock current.

For indirect contact:

- Automatic disconnection of the supply in a determined time on the occurrence of a fault likely to cause a current to flow through a body in contact with exposed conductive parts, where the value of that current is equal to or greater than the shock current.

The regulations quoted mention **Direct** and **Indirect** contact.

Direct contact is electric shock received by touching a known live part which is intended to be live.

Indirect contact is electric shock received when touching exposed conductive parts made live due to a fault.

Protection can be achieved by various methods which can be found in Chapters 41 and 47 of BS 7671. The most common methods used for protection against direct contact within electrical installations are: the use of insulation, and enclosures.

Protection from electric shock from indirect contact can be by many methods. The most common method used within a normal electrical installation is by the use of Earthed Equipotential Bonding and the Automatic Disconnection of the supply (EEBADs). Class 2 equipment (double insulated) and electrical separation (shaver socket) are also very common methods.

In a single phase system, current flow is achieved by creating a difference in potential.

If we were to fill a tank with water and raise the tank a metre or so, then connect a pipe with a tap on one end of it to the tank, when we open the tap the water will flow from the tank to the open end of the pipe. This is because there is no pressure outside of the pipe – the higher we raise the tank the greater the pressure of water and therefore the greater the flow of water.

Current flow is very similar to this. If we think of voltage as pressure, then to get current to flow we have to find a way of creating a difference in pressure. This pressure in an electrical circuit is called **potential difference** and it is

achieved in a single phase system by pegging the star point of the supply transformer to earth. The potential of earth is known to be at 0 volts.

If we place a load between a known voltage and earth, the current will flow from the higher voltage through the load to earth. If we increase the voltage, then more current will flow, just as more water would flow if we increased the height of the water tank.

The problem we have with electricity is that if we use our body to provide the current with a path to earth it will use it, and possibly electrocute us at the same time.

Current will not flow unless it has somewhere to flow to – that is, from a high pressure to a lower pressure, possibly zero volts but not always. It is also possible in some instances to get different voltages in an installation, particularly during a fault where volt drops may occur due to loose connections, high resistance joints and different sizes of conductors. We must also remember that during a fault it will not only be the conductors that are live, but any metalwork connected to the earthing and bonding system, either directly or indirectly. It is highly likely that a shock by indirect contact could be received between pipe work at different voltages.

In any installation, protection must be in place to prevent electric shock. The protection we use against direct contact is self-explanatory and we can only prevent unintentional touching of live parts – if a person is intent on touching a live conductor, we can only make it difficult for them, not impossible.

Protection against indirect contact is a different problem altogether and we can achieve it by different methods. Firstly, if there is a fault to earth all of the metal work connected to the earthing system, whether directly or indirectly, would become live. In the first instance we need to ensure that enough current will flow through the protective device to earth to operate the protective device very quickly. This is achieved by selecting the correct type of protective device, and ensuring that the earth fault loop path has a low enough impedance to allow enough current to flow and operate the device in the required time. On its own this is not enough and that is where the equipotential and supplementary bonding is used. The basic principle is that, if one piece of metal work becomes live, any other parts that could introduce a potential (voltage) difference also become live at the same potential. If everything within the building is at the same potential, current cannot possibly flow from one part to another via a person or livestock.

Testing transformers

It is a requirement to test isolation and SELV transformers to ensure the user's safety. It is also useful to be able to test them to ensure that they are working correctly.

Step up or down double wound transformer

Use a low reading ohm meter to test between to primary (*cable that connects to the main supply*) side. The resistance should be quite high – this will of course depend on the size of the transformer. It may be that the resistance is so high that a multi meter set on its highest resistance value will have to be used. If this is the case, then set the instrument to the highest value possible and turn it down until a reading is given. If the winding is open circuit then the transformer is faulty. Repeat this test on the secondary winding.

Now join the ends of the primary winding together and join the ends of the secondary winding together. Use an insulation resistance meter set on 500 V d.c. to test between the joined ends. Then test between the joined ends and earth. The maximum insulation value permissible in both cases is 0.5 MΩ. If the resistance is less, then the transformer is faulty.

Isolation transformer

Carry out the test in the same manner as the double wound transformer and the values for insulation resistance are the same, 0.5 MΩ.

Separated Extra Low Voltage transformers (SELV)

These transformers are tested using the same procedure as for the step up or down transformer. The insulation resistance test values are different for this test. If the SELV circuits from the secondary side of the transformer are being tested, then the test voltage must be 250 V d.c. and the maximum resistance value is 0.25 MΩ – although this would be considered a very low value and any value below 5 MΩ must be investigated.

The test voltage is increased to 500 V d.c. for a test between the actual transformer windings. The minimum insulation resistance value is 0.5 MΩ although any value below 5 Ω must be investigated.

Testing a 3 phase induction motor

There are many types of 3 phase motors but by far the most common is the induction motor. It is quite useful to be able to test them for serviceability.

Before carrying out electrical tests it is a good idea to ensure that the rotor turns freely. This may involve disconnecting any mechanical loads. The rotor should rotate easily and you should not be able to hear any rumbling from the motor bearings. Next, if the motor has a fan on the outside of it, check that it is clear of any debris which may have been sucked in to it. Also check that any air vents into the motor are not blocked.

Generally, if the motor windings are burnt out there will be an unmistakable smell of burnt varnish. However, it is still a good idea to test the windings as the smell could be from the motor being overloaded. Three phase motors are made up of three separate windings – in the terminal box there will be six terminals as each motor winding will have two ends. The ends of the motor windings will usually be identified as W1, W2; U1, U2; or V1, V2. The first part of the test is carried out using a low resistance ohm meter. Test each winding end to end (W1 to W2, U1 to U2 and V1 to V2). The resistance of each winding should be approximately the same and the resistance value will depend on the size of the motor. If the resistance values are different, then the motor will not be electrically balanced and it should be sent for rewinding. If resistance values are the same, then the next test is carried out using an insulation resistance tester. Join W1 and W2 together, U1 and U2 together and V1 and V2 together. Carry out an insulation resistance test between the joined ends, i.e. W to U then W to V and then between U and V. Then repeat the test between joined ends and the case, or the earthing terminal of the motor (*these tests can be in any order to suit you*). Providing the insulation resistance is 2 MΩ or greater then the motor is fine. If the insulation resistance is above 0.5 MΩ this could be due to dampness and it is often a good idea to run the motor for a while before carrying out the insulation test again as the motor may dry out with use.

To reconnect the motor windings in star, join W2, U2 and V2 together and connect the 3 phase motor supply to W1, U1 and V1. If the motor rotates in the wrong direction, swap two of the phases of the motor supply.

To reconnect the motor windings in delta, join W1 to U2, U1 to V2 and V1 to W2 and then connect the 3 phase motor supply one to each of the joined ends. If the motor rotates in the wrong direction, swap two phases of the motor supply.

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Updated 4th Edition

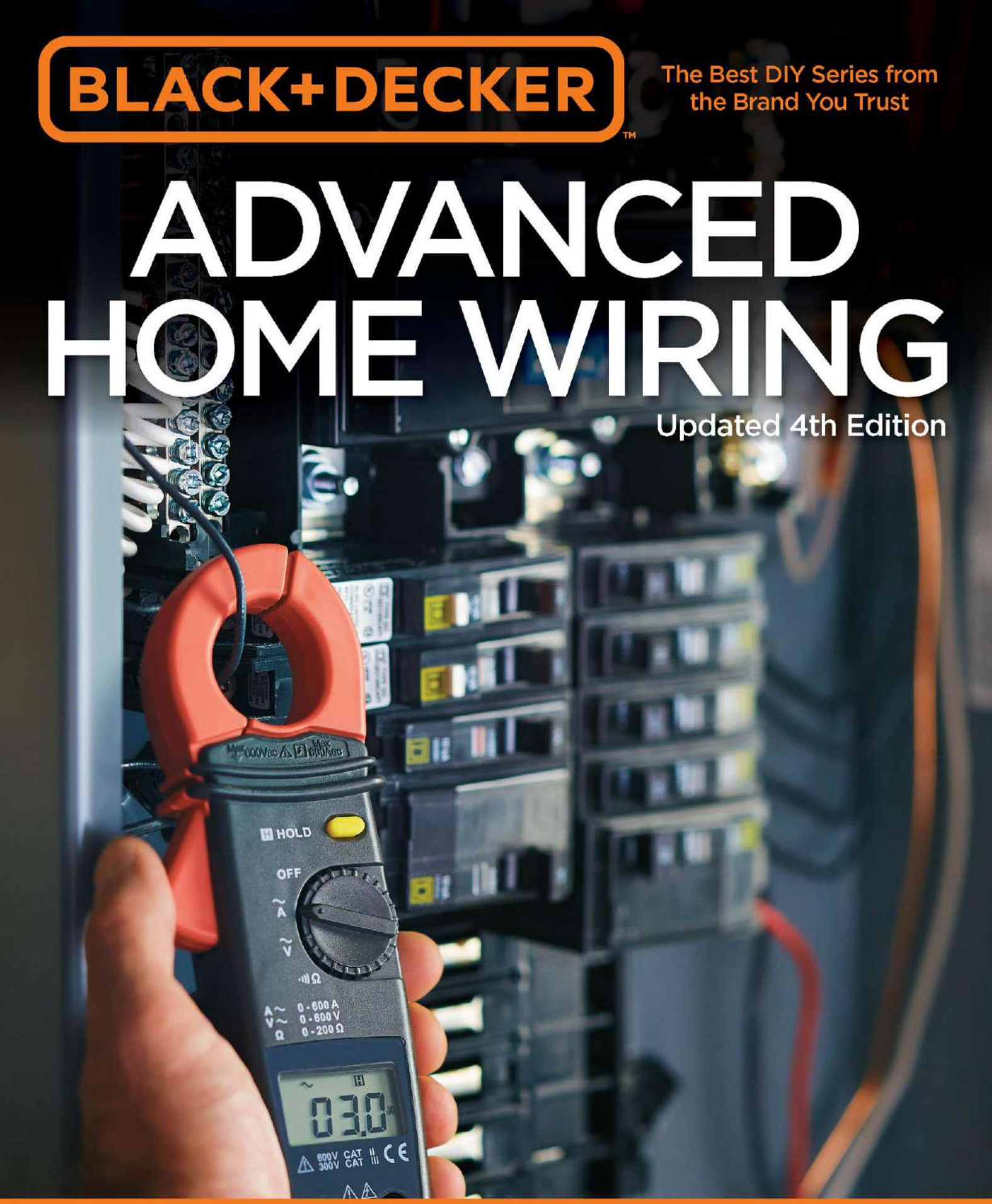

DC Circuits • Transfer Switches
Panel Upgrades • Circuit Maps • More

Introduction

Experienced home electricians understand the need to keep up with changes in the world of wiring. Wiring projects, and more advanced projects in particular, almost always require a permit from your municipality and typically an on-site inspection or two as well. If you aren't up-to-date with wiring codes, there is a likelihood that your project will not pass inspection. But beyond the practicality of passing inspections, the codes that govern wiring practices are updated for good reason: they improve safety. And when you're talking about your own home and family, that's worth paying attention to.

This newest edition of BLACK+DECKER *Advanced Home Wiring* has been reviewed and revised to reflect the many changes to wiring code published in the 2014 edition of the National Electrical Code (NEC), which is updated every three years. And this time around there were an unusually high number of changes. They include the requirement that an available neutral wire be present in every switch box, expansion of the types of circuits that require AFCI protection, a new prohibition on tying into a garage receptacle, and more. Several of these changes are reflected in the updated information you'll find here.

Almost all of the advanced wiring projects featured in this book involve new circuitry, panel upgrades, or troubleshooting with diagnostic equipment. Among the high-level projects: making a direct-current, solar-electric circuit; upgrading the grounding and bonding on your new 200-amp or larger home circuit; installing an automatic transfer switch for your backup power supply; wiring a room addition; and using a multimeter to precisely locate an open neutral in a home circuit.

Because the projects found in this book are advanced in nature, do not attempt any of them unless you are confident in your abilities. Consult a professional electrician if you have any concerns—in many cases your best solution might be to do some of the work yourself, such as pulling new sheathed cable through walls, and to have the electrical contractor do the other work, such as making the connections. But do keep in mind that home wiring can be a fun and fascinating pursuit, and successfully accomplishing a major project is personally gratifying and can also save you substantial amounts of money.

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Wiring Safety

Safety should be the primary concern of anyone working with electricity. Although most household electrical repairs are simple and straightforward, always use caution and good judgment when working with electrical wiring or devices. Common sense can prevent accidents.

The basic rule of electrical safety is: Always turn off power to the area or device you are working on. At the main service panel, remove the fuse or shut off the circuit breaker that controls the circuit you are servicing. Then check to make sure the power is off by testing for power with a voltage tester. *Tip: Test a live circuit with the voltage tester to verify that it is working before you rely on it.* Restore power only when the repair or replacement project is complete.

Follow the safety tips shown on these pages. Never attempt an electrical project beyond your skill or confidence level.

Shut power OFF at the main service panel or the main fuse box before beginning any work.

Create a circuit index and affix it to the inside of the door to your main service panel. Update it as needed.

Confirm power is OFF by testing at the outlet, switch, or fixture with a voltage tester.

Use only UL-approved electrical parts or devices. These devices have been tested for safety by Underwriters Laboratories.

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Wear rubber-soled shoes while working on electrical projects. On damp floors, stand on a rubber mat or dry wooden boards.

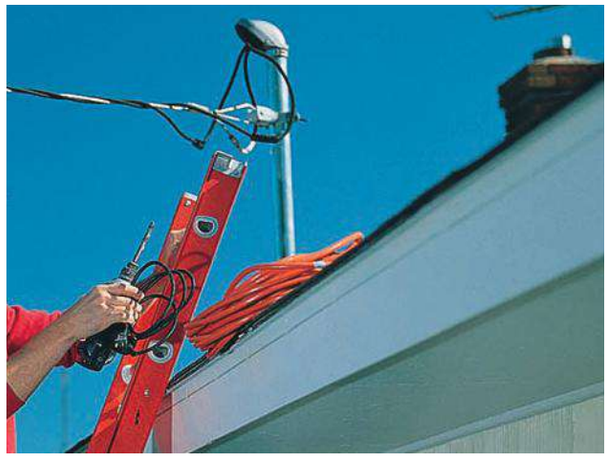

Use fiberglass or wood ladders when making routine household repairs near the service mast.

Extension cords are for temporary use only. Cords must be rated for the intended usage.

Breakers and fuses must be compatible with the panel manufacturer and match the circuit capacity.

Never alter the prongs of a plug to fit a receptacle. If possible, install a new grounded receptacle.

Do not penetrate walls or ceilings without first shutting off electrical power to the circuits that may be hidden.

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Planning Your Project

Careful planning of a wiring project ensures you will have plenty of power for present and future needs. Whether you are adding circuits in a room addition, wiring a remodeled kitchen, or adding an outdoor circuit, consider all possible ways the space might be used, and plan for enough electrical service to meet peak needs.

For example, when wiring a room addition, remember that the way a room is used can change. In a room used as a spare bedroom, a single 15-amp circuit provides plenty of power, but if you ever choose to convert the same room to a family recreation space, you will need additional circuits.

When wiring a remodeled kitchen, it is a good idea to install circuits for an electric oven and countertop range, even if you do not have these electric appliances. Installing these circuits now makes it easy to convert from gas to electric appliances at a later date.

A large wiring project adds a considerable load to your main electrical service. In about 25 percent of all homes, some type of service upgrade is needed before new wiring can be installed. For example, many homeowners will need to replace an older 60-amp electrical service with a new service rated for 100 amps or more. This is a job for a licensed electrician but is well worth the investment. In other cases, the existing main service provides adequate power, but the main circuit breaker panel is too full to hold any new circuit breakers. In this case it is necessary to install a circuit breaker subpanel to provide room for hooking up added circuits. Installing a subpanel is a job most homeowners can do themselves (see pages 65 to 67).

This chapter gives an easy five-step method for determining your electrical needs and planning new circuits.

Five Steps for Planning a Wiring Project

1

Examine your main service panel (see page 10). The amp rating of the electrical service and the size of the circuit breaker panel will help you determine if a service upgrade is needed.

2

Learn about codes (see pages 11 to 13). The National Electrical Code (NEC), and local electrical codes and building codes, provide guidelines for determining how much power and how many circuits your home needs. Your local electrical inspector can tell you which regulations apply to your job.

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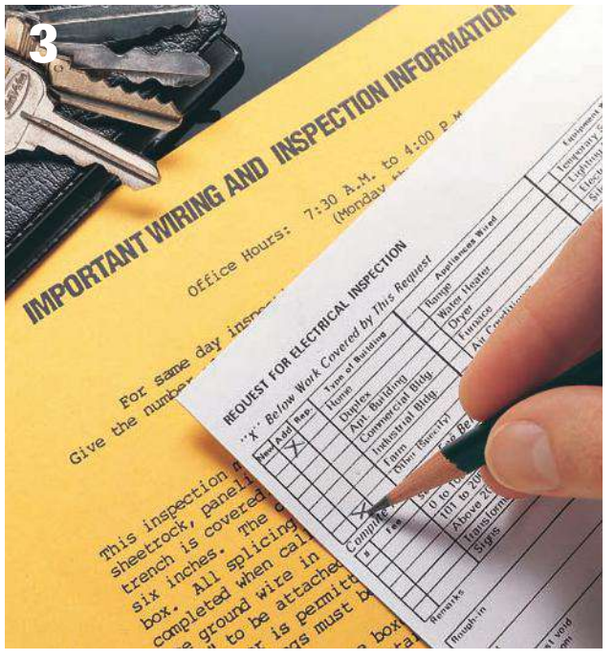

Prepare for inspections (see pages 14 to 15). Remember that your work must be reviewed by your local electrical inspector. When planning your wiring project, always follow the inspector's guidelines for quality workmanship.

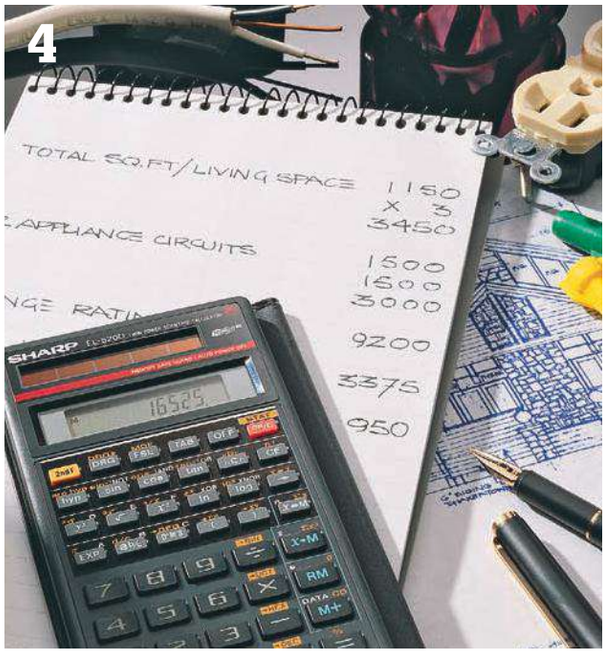

Evaluate electrical loads (see pages 16 to 19). New circuits put an added load on your electrical service. Make sure that the total load of the existing wiring and the planned new circuits does not exceed the service capacity or the capacity of the panel.

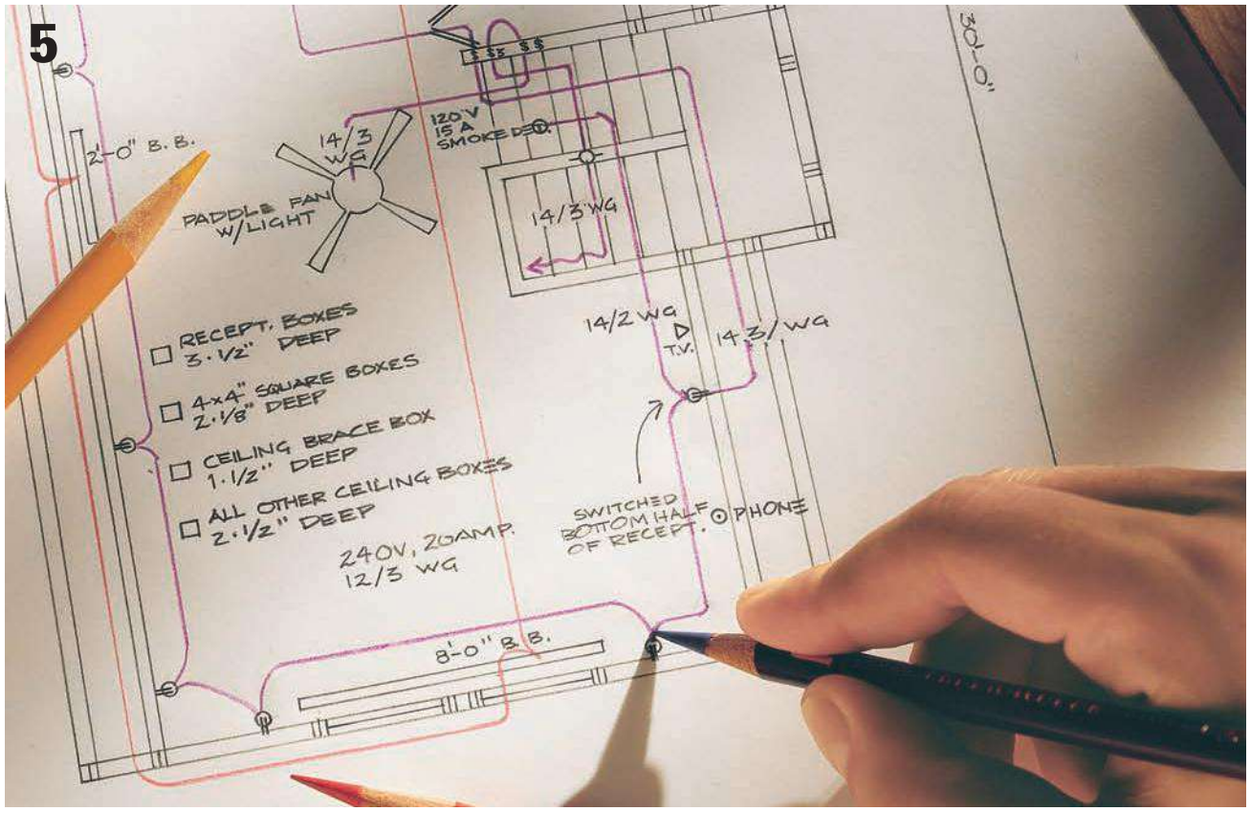

Draw a wiring diagram and get a permit (see pages 20 to 21). This wiring plan will help you organize your work.

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Examine Your Main Service Panel

The first step in planning a new wiring project is to look in your main circuit breaker panel and find the size of the service by reading the amperage rating on the main circuit breaker. As you plan new circuits and evaluate electrical loads, knowing the size of the main service helps you determine if you need a service upgrade.

Also look for open circuit breaker slots in the panel. The number of open slots will determine if you need to add a circuit breaker subpanel.

Find the service size by opening the main service panel and reading the amp rating printed on the main circuit breaker. In most cases, 100-amp service provides enough power to handle the added loads of projects such as the ones shown in this book. A service rated for 60 amps or less should be upgraded. Note: In some homes the main circuit breaker is located in a separate box.

Older service panels use fuses instead of circuit breakers. Have an electrician replace this type of panel with a circuit breaker panel that provides enough power and enough open breaker slots for the new circuits you are planning.

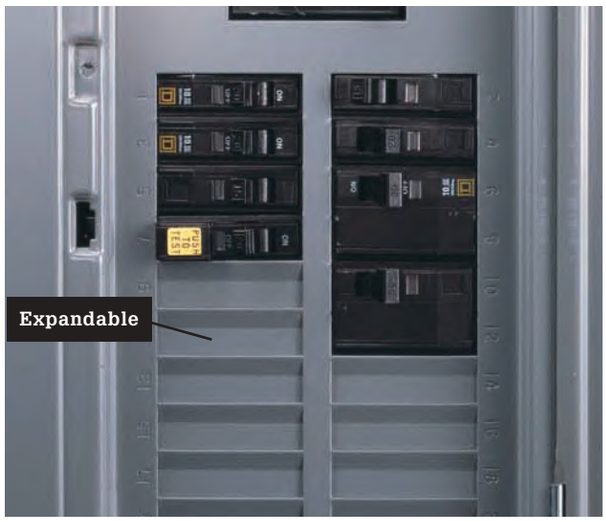

Look for open circuit breaker slots in the main circuit breaker panel or in a circuit breaker subpanel, if your home already has one. You will need one open slot for each 120-volt circuit you plan to install and two slots for each 240-volt circuit. If your main circuit breaker panel has no open breaker slots, install a subpanel (see pages 65 to 67) to provide room for connecting new circuits.

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Learn About Codes

To ensure public safety, your community requires that you get a permit to install new wiring and have the work reviewed by an inspector. Electrical inspectors use the National Electrical Code (NEC) as the primary authority for evaluating wiring, but they also follow the local building code and electrical code standards.

Most communities use a version of the NEC that is not the most current version. Also, many communities make amendments to the NEC, and these amendments may affect your work.

As you begin planning new circuits, call or visit your local electrical inspector and discuss the project with him or her. The inspector can tell you which of the national and local code requirements apply to your job and may give you a packet of information summarizing these regulations. Later, when you apply to the inspector for a work permit, he or she will expect you to understand the local guidelines as well as a few basic NEC requirements.

The NEC is a set of standards that provides minimum safety requirements for wiring installations. It is revised every three years. The national code requirements for the projects shown in this book are thoroughly explained on the following pages. For more information, you can find copies of the current NEC, as well as a number of excellent handbooks based on the NEC, at libraries and bookstores.

In addition to being the final authority of code requirements, inspectors are electrical professionals with years of experience. Although they have busy schedules, most inspectors are happy to answer questions and help you design well-planned circuits.

Basic Electrical Code Requirements

Electrical code requirements for living areas: Living areas need at least one 15-amp or 20-amp basic lighting/receptacle circuit for each 600 sq. ft. of living space and should have a dedicated circuit for each type of permanent appliance, such as an air conditioner, or a group of baseboard heaters. Receptacles on basic lighting/receptacle circuits should be spaced no more than 12 ft. apart. Many electricians and electrical inspectors recommend even closer spacing. Any wall more than 24" wide also needs a receptacle. Every room should have a wall switch at the point of entry to control either a ceiling or wall-mounted light or plug-in lamp. Kitchens and bathrooms must have a ceiling or wall-mounted light fixture.

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Highlights of the National Electrical Code ▸

BY MATERIAL

Panels

- Maintain a minimum 30" wide by 36" deep of clearance in front of the panel.
- Match the amperage rating of the circuit when replacing fuses.
- Use handle ties on all 240-volt breakers and on 120-volt breakers protecting multi-wire branch circuits.
- Close all unused panel openings.
- Label each fuse and breaker clearly on the panel.

Electrical Boxes

- Use boxes that are large enough to accommodate the number of wires and devices in the box.
- Install all junction boxes so they remain accessible.
- Leave no gaps greater than ⅛" between wallboard and the front of electrical boxes.
- Place receptacle boxes flush with combustible surfaces.
- Leave a minimum of 3" of usable cable or wire extending past the front of the electrical box.

Wires & Cables

- Use wires that are large enough for the amperage rating of the circuit.
- Drill holes at least 2" from the edges of joists. Do not attach cables to the bottom edge of joists.
- Do not run cables diagonally between framing members.
- Use nail plates to protect cable that is run through holes drilled or cut into studs less than 1¼" from the front edge of a stud.
- Do not crimp cables sharply.
- Contain spliced wires or connections entirely in a plastic or metal electrical box.
- Use wire connectors to join wires.
- Use staples to fasten cables within 8" of an electrical box and every 54" along its run.
- Leave a minimum ¼" (maximum 1") of sheathing where cables enter an electrical box.
- Clamp cables and wires to electrical boxes with approved clamps. No clamp is necessary for one-gang plastic boxes if cables are stapled within 8".
- Connect only a single wire to a single screw terminal. Use pigtails to join more than one wire to a screw terminal.

Switches

- Use a switch-controlled receptacle in rooms without a built-in light fixture operated by a wall switch.
- Use three-way switches at the top and bottom on stairways with six risers or more.
- Use switches with grounding screws with plastic electrical boxes.
- Locate all wall switches within easy reach of the room entrance and not behind the door.
- Install a neutral wire in switch boxes.
- Use black or red wires to supply power to switched devices.

Receptacles

- Install receptacles on all walls 24" wide or greater.
- Install receptacles so a 6-ft. cord can be plugged in from any point along a wall or every 12 ft. along a wall.
- Include receptacles in any hallway that is 10 ft. long or longer.
- Use three-slot, grounded receptacles for all 15- or 20-amp, 120-volt branch circuits.
- Include a switch-controlled receptacle in rooms without a built-in light fixture operated by a wall switch.
- Install GFCI-protected circuits in bathrooms, kitchens, garages, crawl spaces, unfinished basements, and outdoor receptacle locations.

Light Fixtures

- Use mounting straps that are anchored to the electrical boxes to mount ceiling fixtures.
- Keep non-IC-rated recessed light fixtures 3" from insulation and ½" from combustibles.
- Include at least one switch-operated lighting outlet in every room.

Grounding

- Ground receptacles by connecting receptacle grounding screws to the circuit grounding wires.
- Use switches with grounding screws whenever possible. Always ground switches installed in plastic electrical boxes and all switches in kitchens, bathrooms, and basements.

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BY ROOM

Kitchens/Dining Rooms

- Install at least two 20-amp small appliance receptacle circuits.
- Install dedicated 15-amp, 120-volt circuits for dishwashers and food disposals (required by many local codes).
- Install GFCI protection for all countertop receptacles; receptacles behind fixed appliances do not need to be GFCI protected.
- Position receptacles for appliances that will be installed within cabinets, such as microwaves or food disposals, according to the manufacturer's instructions.
- Include receptacles on all counters wider than 12".
- Space receptacles a maximum of 48" apart above countertops and closer together in areas where many appliances will be used.
- Locate receptacles on the wall above the countertop not more than 20" above the countertop.
- Install at least one receptacle not more than 12" below the countertop on islands and peninsulas that are 12" × 24" or greater.
- Do not connect lights to the small appliance receptacle circuits.
- Install at least one wall or ceiling-mounted light fixture.

Bathrooms

- Install a separate 20-amp GFCI-protected circuit only for bathroom receptacles.
- Ground switches in bathrooms.
- Install at least one receptacle not more than 36" from each sink.
- Install at least one ceiling- or wall-mounted light fixture.

Utility/Laundry Rooms

- Install a separate 20-amp circuit for a washing machine.
- Install approved conduit for wiring in unfinished rooms.
- Use GFCI-protected circuits for 120-volt receptacles within 6 feet from a sink (including the washing machine receptacle).

Living, Entertainment, Bedrooms

- Install at least one 15- or 20-amp lighting/receptacle circuit for each 600 sq. ft. of living space.
- Install a dedicated circuit for each permanent appliance, such as an air conditioner or group of electric baseboard heaters.
- Use electrical boxes listed and labeled to support ceiling fans.
- Include receptacles on walls 24" wide or more.
- Space receptacles on walls in living and sleeping rooms a maximum of 12 ft. apart.
- Check with your local electrical inspector about requirements for installing smoke and carbon monoxide alarms during remodeling.

Outdoors

- Check for underground utilities before digging.
- Use UF cable or other wiring approved for wet locations for outdoor wiring.
- Run cable and wires in schedule 80 PVC plastic and other approved conduit, as required by local code.
- Install in-use rated weatherproof receptacle covers.
- Bury cables and wires run in conduit at least 18" deep; cable not in conduit must be buried at least 24" deep.
- Use weatherproof electrical boxes with watertight covers.
- Install GFCI-protected circuits for receptacles.
- Support boxes that are not attached to a building and that contain switches or receptacles using at least two pieces of conduit. Secure the conduit not more than 18 feet from the box. Locate the box at least 12" above the ground.

Stairs/Hallways

- Use three-way switches at the top and bottom on stairways with six risers or more.
- Include receptacles in any hallway that is 10 ft. long or longer.
- Position stairway lights so each step and landing is illuminated.

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Prepare for Inspections

Electrical inspectors who issue the work permit for your wiring project will also visit your home to review the work. Make sure to allow time for these inspections as you plan the project. For most projects, inspectors make two visits.

The first inspection, called the rough-in, is done after the cables are run between the boxes but before the insulation, wallboard, switches, and fixtures are installed. The second inspection, called the final, is done after the walls and ceilings are finished and all electrical connections are made.

When preparing for the rough-in inspection, make sure the area is neat. Sweep up sawdust and clean up any pieces of scrap wire or cable insulation. Before inspecting the boxes and cables, inspectors will check to make sure all plumbing and other mechanical work is completed. Some electrical inspectors will ask to see your building and plumbing permits.

At the final inspection, inspectors check random boxes to make sure the wire connections are correct. If they see good workmanship at the selected boxes, the inspection will be over quickly. However, if they spot a problem, inspectors may choose to inspect every connection.

Inspectors have busy schedules, so it is a good idea to arrange for an inspection several days in advance. In addition to basic compliance with code, inspectors expect your work to meet their own standards for quality. When you apply for a work permit, make sure you understand what the inspectors will look for during inspections.

You cannot put new circuits into use legally until an inspector approves them at the final inspection. If you have planned carefully and done your work well, electrical inspections are routine visits that give you confidence in your own skills.

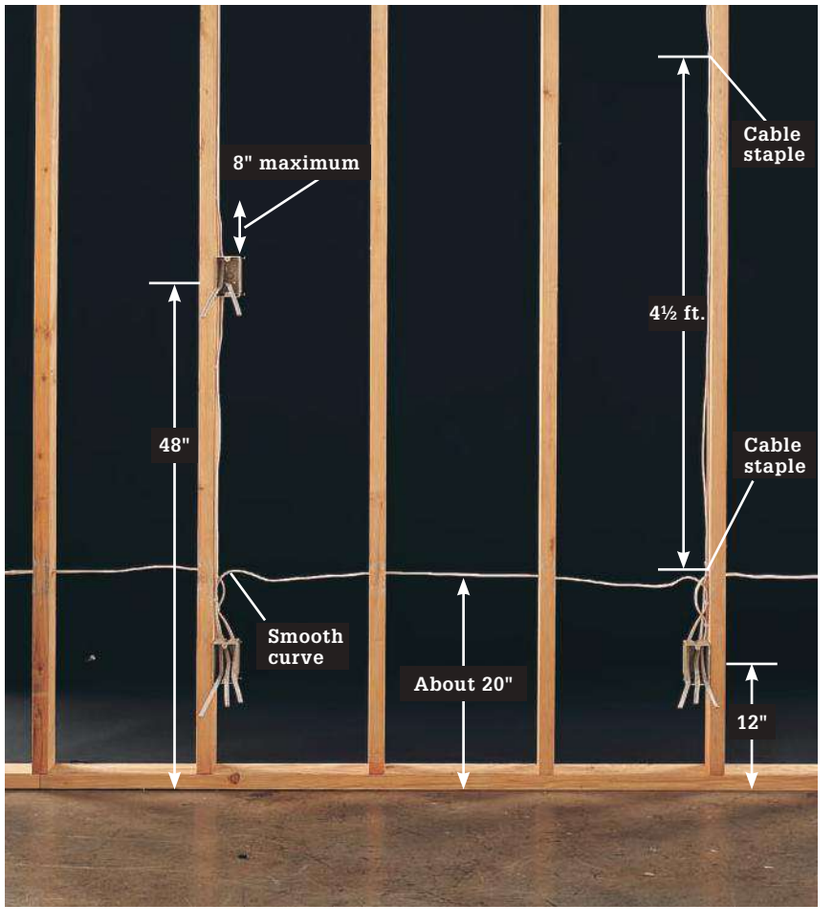

Inspectors may measure to see that electrical boxes are mounted at consistent heights. Height may not be dictated by code, but consistency is a sign of good workmanship. Measured from the center of the boxes, receptacles in living areas typically are located 12" above the finished floor and switches at 48". For special circumstances, inspectors allow you to alter these measurements. For example, you can install switches at 36" above the floor in a child's bedroom, or set receptacles at 24" to make them more convenient for someone using a wheelchair.

Inspectors will check cables to see that they are anchored by cable staples driven within 8" of each box and every 4½ ft. thereafter when they run along studs. When bending cables, form the wire in a smooth curve. Do not crimp cables sharply or install them diagonally between framing members. Some inspectors specify that cables running between receptacle boxes should be about 20" above the floor.

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What Inspectors Look for

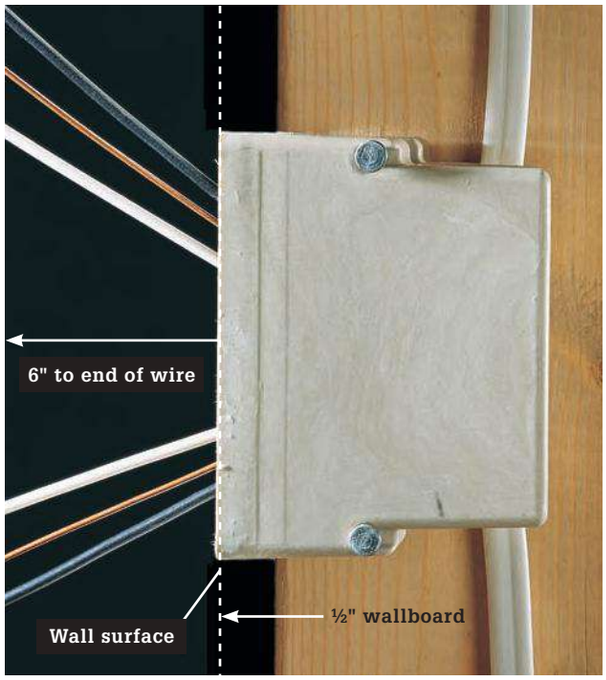

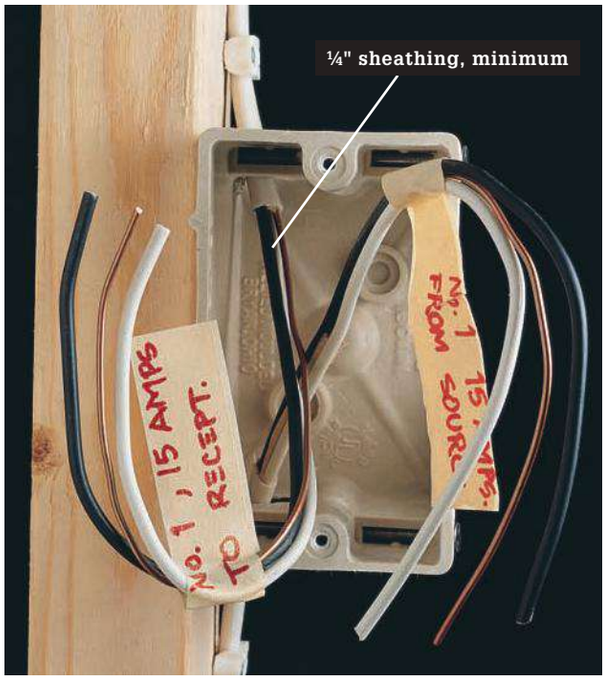

Electrical box faces should extend past the front of framing members so the boxes will be flush with finished walls (left). Inspectors will check to see that all boxes are large enough for the wires they contain. Cables should be cut and stripped back so that at least 3" of usable length extends past the front of the box and so that at least ¼" of sheathing reaches into the box (right). Label all cables to show which circuits they serve: inspectors recognize this as a mark of careful work. The labels also simplify the final hookups after the wallboard is installed.

Is your Receptacle Spacing Correct?

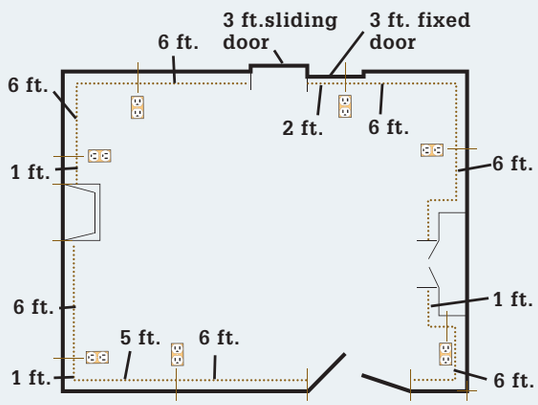

Example of receptacle spacing requirements in a typical room. Measure receptacle spacing distance along the wall line. Install receptacles along partial height walls and along balcony guards in lofts and similar areas.

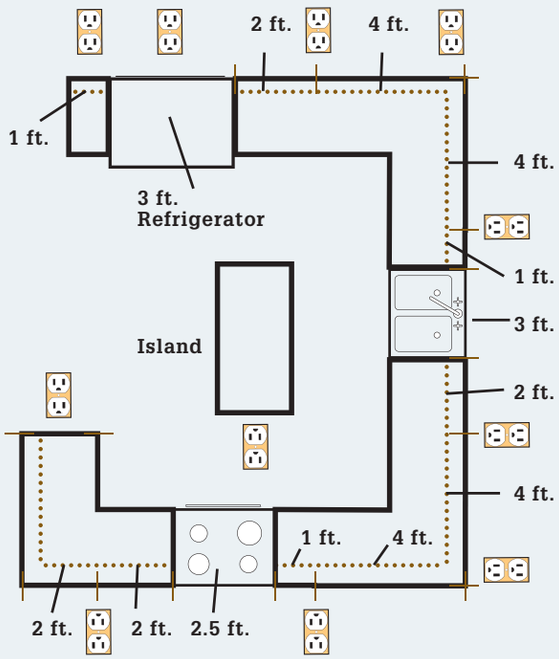

Example of countertop receptacle spacing in a typical kitchen (right).

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Evaluate Electrical Loads

Before drawing a plan and applying for a work permit, make sure your home's electrical service provides enough power to handle the added load of the new circuits. In a safe wiring system, the current drawn by fixtures and appliances never exceeds the main service capacity.

To evaluate electrical loads, use whatever evaluation method is recommended by your electrical inspector. Include the load for all existing wiring as well as that for proposed new wiring when making your evaluation.

Most of the light fixtures and plug-in appliances in your home are evaluated as part of general allowances for basic lighting/receptacle circuits and small-appliance circuits. However, appliances that are permanently installed require their own dedicated circuits. The electrical loads for these appliances are added in separately when evaluating wiring.

If your evaluation shows that the load exceeds the main service capacity, you must have an electrician upgrade the main service before you can install new wiring. An electrical service upgrade is a worthwhile investment that improves the value of your home and provides plenty of power for present and future wiring projects.

Amperage ▸

Amperage rating can be used to find the wattage of an appliance. Multiply the amperage by the voltage of the circuit. For example, a 13-amp, 120-volt circular saw is rated for 1,560 watts.

AMPS × VOLTS	TOTAL CAPACITY	SAFE CAPACITY
15 A × 120 V =	1,800 watts	1,440 watts
20 A × 120 V =	2,400 watts	1,920 watts
25 A × 120 V =	3,000 watts	2,400 watts
30 A × 120 V =	3,600 watts	2,880 watts
20 A × 240 V =	4,800 watts	3,840 watts
30 A × 240 V =	7,200 watts	5,760 watts

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Calculating Loads

Add 1,500 watts for each small appliance circuit required by the local electrical code. In most communities, three such circuits are required—two in the kitchen and one for the laundry—for a total of 4,500 watts. No further calculations are needed for appliances that plug into small-appliance or basic lighting/receptacle circuits.

If the nameplate gives the rating in kilowatts, find the watts by multiplying kilowatts times 1,000. If an appliance lists only amps, find watts by multiplying the amps times the voltage—either 120 or 240 volts.

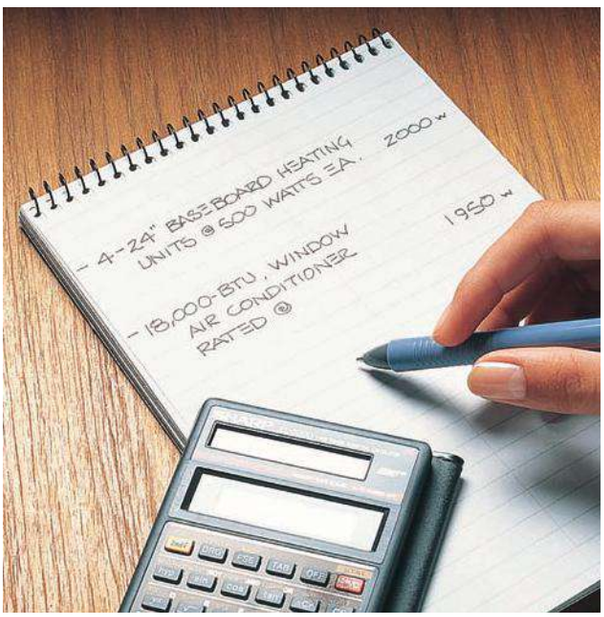

Air-conditioning and heating appliances are not used at the same time, so figure in only the larger of these two numbers when evaluating your home's electrical load.

Fixed Devices ▸

Do not connect one or more fixed devices that in total exceed 50 percent of a multiple outlet branch circuit's amperage rating. Fixed devices do not include light fixtures. This means that that all fixed devices (such as a permanently wired disposal or hot water circulating pump) on a multiple outlet branch circuit may not exceed 7.5 amps (about 900 watts) on a 15-amp multiple outlet branch circuit and may not exceed 10 amps (about 1,200 watts) on a 20-amp multiple outlet branch circuit.

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Locating Wattage

Light bulb wattage ratings are printed on the top of the bulb. If a light fixture has more than one bulb, remember to add the wattages of all the bulbs to find the total wattage of the fixture.

Electric water heaters are permanent appliances that require their own dedicated 30-amp, 240-volt circuits. Most water heaters are rated between 3,500 and 4,500 watts. If the nameplate lists several wattage ratings, use the one labeled "Total Connected Wattage" when figuring electrical loads.

Food disposers are considered permanent appliances and may require their own dedicated 15-amp, 120-volt circuits. Most disposers are rated between 500 and 900 watts.

Dishwashers installed permanently under a countertop may need a dedicated 15-amp, 120-volt circuits. Dishwasher ratings are usually between 1,000 and 1,500 watts. Portable dishwashers are regarded as part of small appliance circuits and are not added in when figuring loads.

Electric ranges can be rated for as little as 3,000 watts or as much as 12,000 watts. They require dedicated 120/240-volt circuits. Find the exact wattage rating by reading the nameplate found inside the oven door or on the back of the unit.

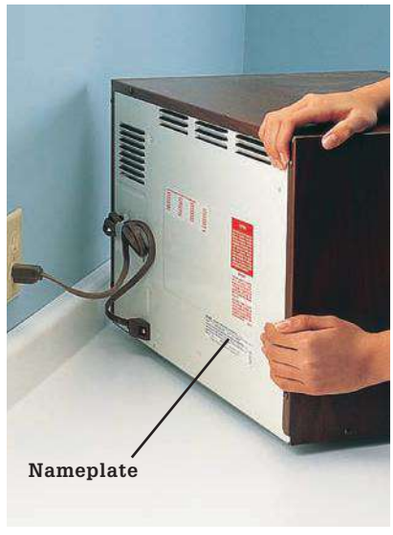

Microwave ovens are regarded as permanent appliances. Add in its wattage rating when calculating loads. The nameplate is found on the back of the cabinet or inside the front door. Most microwave ovens are rated between 500 and 1,200 watts.

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Freezers are permanent appliances that may need a dedicated 15- or 20-amp, 120-volt circuits. Freezer ratings are usually between 240 and 480 watts. But combination refrigerator-freezers rated for 1,000 watts or less are plugged into small appliance circuits and do not need their own dedicated circuits. The nameplate for a freezer is found inside the door or on the back of the unit, just below the door seal.

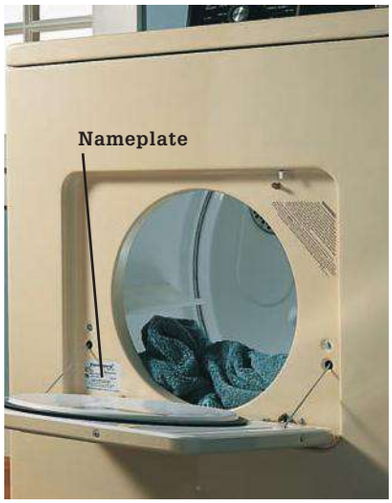

Electric clothes dryers are permanent appliances that need dedicated 30-amp, 120/240-volt circuits. The wattage rating is printed on the nameplate inside the dryer door. Use 5,000 watts as a minimum, regardless of the printed rating. Washing machines and gas-heat clothes dryers with electric tumbler motors do not need dedicated circuits. They plug into the 20-amp small-appliance circuit in the laundry room.

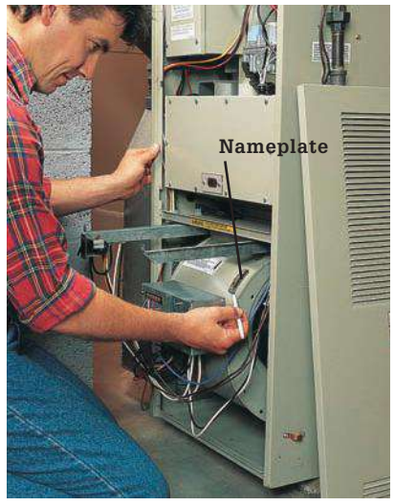

Forced-air furnaces and heat pump air handlers have electric fans and are considered permanent appliances. They require dedicated 15-amp, 120-volt circuits. Include the fan wattage rating, printed on a nameplate inside the control panel, when figuring wattage loads for heating. You should also include the wattage rating for heat pump backup heating coils.

A central air conditioner requires a dedicated 240-volt circuit. Estimate its wattage rating by adding the numbers labeled RLA and FLA on the air conditioner's metal plate. Multiply the RLA+FLA by 240.

Window air conditioners, both 120-volt and 240-volt types, are permanent appliances that require dedicated circuits. The wattage rating, which can range from 500 to 2,000 watts, is found on the nameplate located inside the front grill. Make sure to include all window air conditioners in your evaluation.

Electric room heaters that are permanently installed require a dedicated circuit and must be figured into the load calculations. Use the maximum wattage rating printed inside the cover. In general, 240-volt baseboard-type heaters are rated for 180 to 250 watts for each linear foot.

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GFCI & AFCI Breakers

Understanding the difference between GFCI (ground-fault circuit interrupter) and AFCI (arc fault circuit interrupter) is tricky for most homeowners. Essentially it comes down to this: Arc-fault interrupters keep your house from burning down; ground-fault interrupters keep people from being electrocuted.

The National Electric Code (NEC) requires that an AFCI breaker be installed on most branch circuits that supply outlets or fixtures in newly constructed homes. The NEC also requires adding AFCI protection to these circuits when you add new circuits and modify or extend existing circuits. They're a prudent precaution in any home, especially if it has older wiring. AFCI breakers will not interfere with the operation of GFCI receptacles, so it is safe to install an AFCI breaker on a circuit that contains GFCI receptacles. For a discussion on codes that concern AFCI and GFCI breakers see pages 120 to 121.

GROUND-FAULT CIRCUIT-INTERRUPTERS

A GFCI is an important safety device that disconnects a circuit in the event of a ground fault (when current takes a path other than the neutral back to the panel).

On new construction, GFCI protection is required for receptacles in these locations: kitchen counter tops, bathrooms, garages, unfinished basements, crawlspaces, outdoors, within six feet of sinks, and in unfinished accessory buildings such as storage and work sheds. In general it is a good practice to protect all receptacle and fixture locations that could encounter damp or wet circumstances.

Tools & Materials ▸

- Insulated screwdriver
- Circuit tester
- Combination tool
- AFCI or GFCI breaker

ARC-FAULT CIRCUIT INTERRUPTERS

AFCIs detect arcing (sparks) that can cause fires between and along damaged wires. AFCI protection is required for 15- and 20-amp, 120-volt circuits that serve living rooms, family rooms, dens, parlors, libraries, dining rooms, bedrooms, sun rooms, kitchens, laundry areas, closets, and hallways. AFCI protection is not required for circuits serving bathrooms, garages, the exterior of the home, appliances such as furnaces and air handlers.

The easiest way to provide AFCI protection for a circuit is to install an AFCI circuit breaker labeled as a "combination" device in the electrical panel. The 2014 NEC allows several alternate methods of providing AFCI protection, but you should consult an electrician before using these alternate methods. You should install combination AFCI circuit breakers when installing new circuits that require AFCI protection. You should install either combination AFCI circuit breakers or AFCI receptacles when you modify, replace, or extend an existing circuit that requires AFCI protection.

AFCI breakers (left) are similar in appearance to GFCI breakers (right), but they function differently. AFCI breakers trip when they sense an arc fault. GFCI breakers trip when they sense fault between the hot wire and the ground.

An AFCI-protected receptacle

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How to Install an AFCI or GFCI Breaker

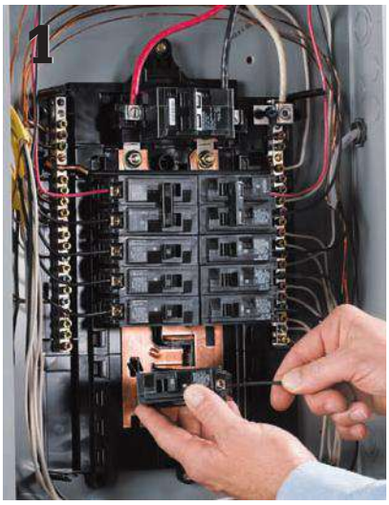

Locate the breaker for the circuit you'd like to protect. Turn off the main circuit breaker. Remove the cover from the panel, and test to ensure that power is off. Remove the breaker you want to replace from the panel. Remove the black wire from the LOAD terminal of the breaker.

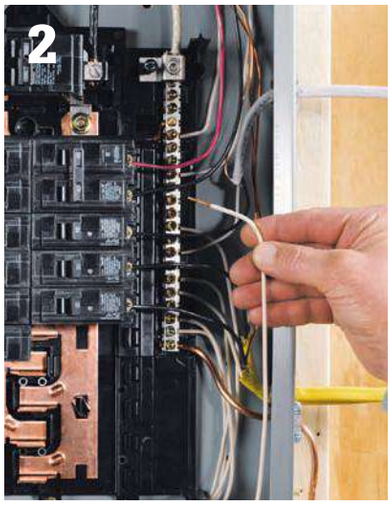

Find the white wire on the circuit you want to protect, and remove it from the neutral bus bar.

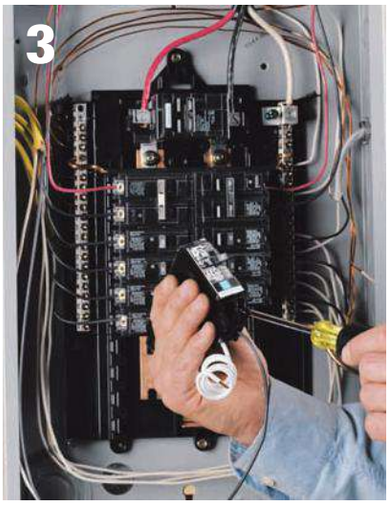

Flip the handle of the new AFCI or GFCI breaker to OFF. Loosen both of the breaker's terminal screws. Connect the white circuit wire to the breaker terminal labeled PANEL NEUTRAL. Connect the black circuit wire to the breaker terminal labeled LOAD POWER.

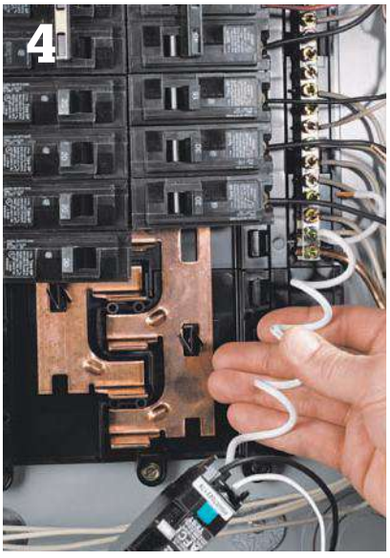

Connect the new breaker's coiled white wire to the neutral bus bar on the service panel.

Make sure all the connections are tight. Snap the new breaker into the bus bar.

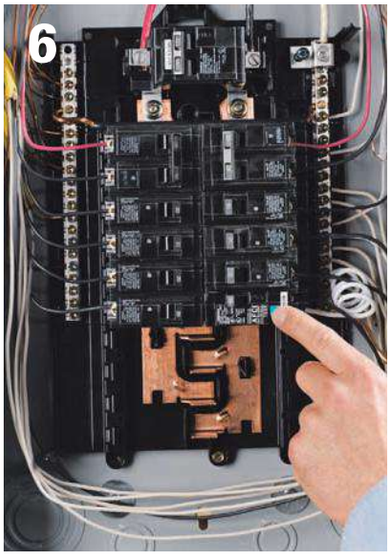

Turn the main breaker on. Turn off and unplug all fixtures and appliances on the AFCI or GFCI breaker circuit. Turn the AFCI or GFCI breaker on. Press the test button. If the breaker is wired correctly, the breaker trips open. If it doesn't trip, check all connections or consult an electrician. Replace the panel cover.

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Replacing a Service Panel

Only a generation ago, fuse boxes were commonplace. But as our demands for power increased, homeowners replaced the 60-amp boxes with larger, safer, and more reliable circuit breaker panels. Typical new homes were built with perfectly adequate 100-amp load centers. But today, as average home size has risen to more than 2,500 sq. ft. and the number of home electronics has risen exponentially, 100 amps is often inadequate service. As a result, many homeowners have upgraded to 200-amp service, and new single-family homes often include 250 amps or even 400 amp service.

Upgrading your electrical service panel from 100 amps to 200 amps is an ambitious project that requires a lot of forethought. The first step is to obtain a permit. When you are ready to begin, you will need to have your utility company disconnect your house from electrical service at the transformer that feeds your house. When you schedule this, talk to your utility company about the size of your service drop or lateral. That may need to be upgraded too. Not only does this involve working them into your schedule, it means you will have no power during the project. You can rent a portable generator to provide a circuit or two, or you can run a couple extension cords from a friendly neighbor. But unless you are a very fast worker, plan on being without power for at least one to two days while the project is in process.

Also check with your utility company to make sure you know what equipment is theirs and what belongs to you. In most cases, the electric meter and everything on the street side belongs to the power company, and the meter base and everything on the house side is yours. Be aware that if you tamper with the sealed meter in any way, you likely will be fined. Utility companies will not re-energize your system without approval from your inspecting agency.

Upgrading a service panel is a major project. Do not hesitate to call for help at any point if you're unsure what to do.

Tools & Materials

- 200-amp load center (service panel)
- 200-amp bypass meter base
- Circuit breakers (AFCI if required by local code)
- Schedule 80 or RMC conduit and fittings
- Weatherhead
- Service cable
- Circuit wires
- Plywood backer board
- Screwdrivers
- Drill/driver
- Tape
- Allen wrench
- Circuit tester
- Multimeter

Modern homeowners consume more power than our forebears, and it is often necessary to upgrade the electrical service to keep pace. While homeowners are not allowed to make the final electrical service connections, removing the old panel and installing the new panel and meter base yourself can save you hundreds or even thousands of dollars.

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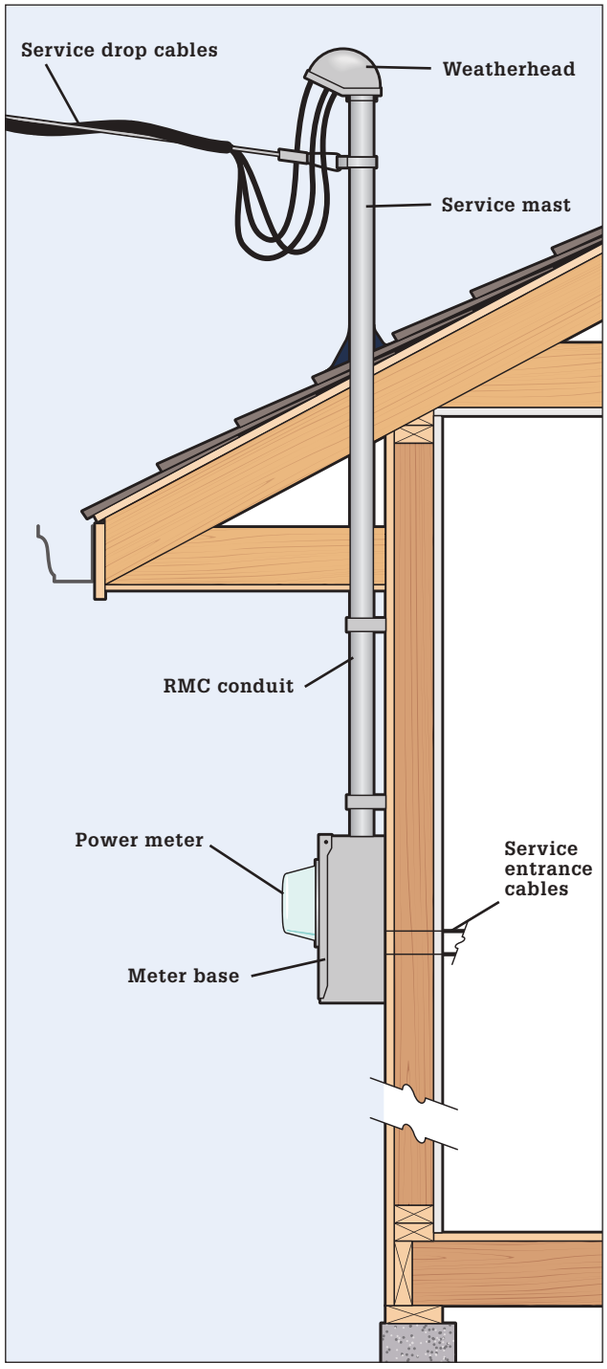

Aboveground service drop. In this common configuration, the service cables from the closest transformer (called the service drop) connect to service entrance wires near the weatherhead. This connection is called the service point and is where your property usually begins. The service entrance wires from the weatherhead are routed to a power meter that's owned by your utility company but is housed in a base that's considered your property. From the meter the service entrance wires enter your house through the wall and are routed to the main service panel, where they are connected to the main circuit breaker.

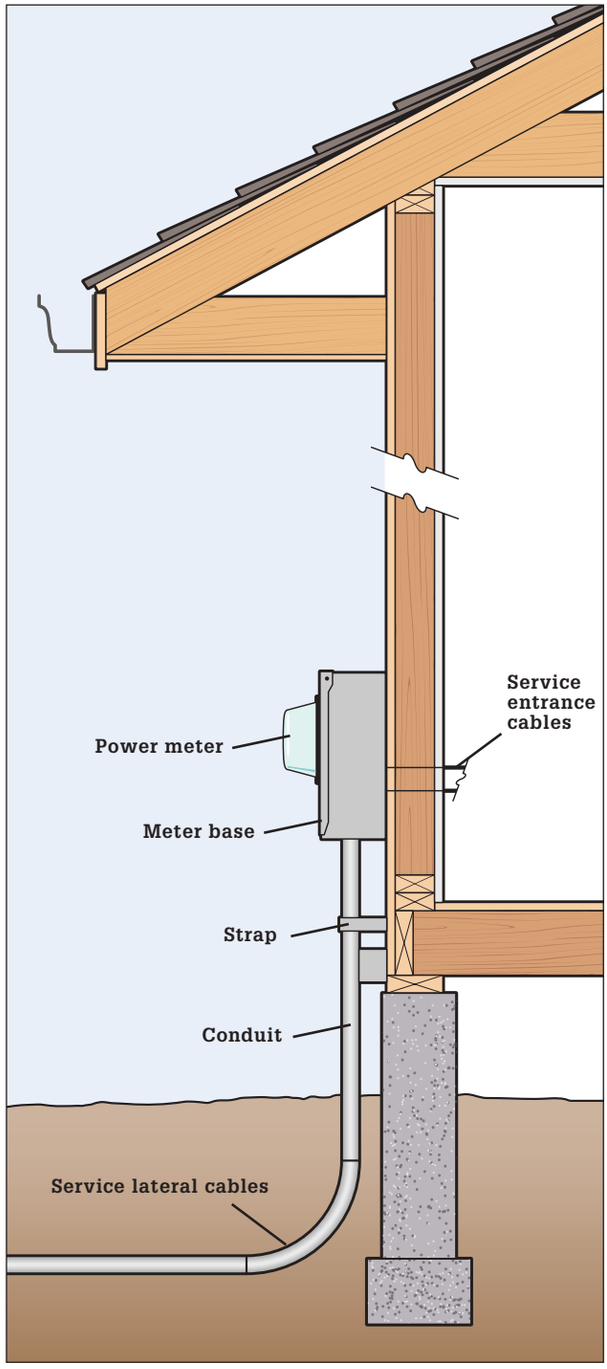

Underground service lateral. Increasingly, homebuilders are choosing to have power supplied to their new homes underground instead of an overhead service drop. Running the cables in the ground eliminates problems with power outages caused by ice accumulation or fallen trees, but it entails a completely different set of cable and conduit requirements. For the homeowner, however, the differences are minimal, because the hookups are identical once the power service reaches the meter.

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Locating Your New Panel

Local codes dictate where the main service panel may be placed relative to other parts of your home. Although the codes vary (and always take precedence), national codes stipulate that a service panel (or any other distribution panel) may not be located near flammable materials, in a bathroom, clothes closet or other area designated for storage, above stairway steps, or directly above a workbench or other permanent work station or appliance. The panel also can't be located in a crawl space. If you are installing a new service entry hookup, there are many regulations regarding height of the service drop and the meter. Contact your local inspections office for specific regulations.

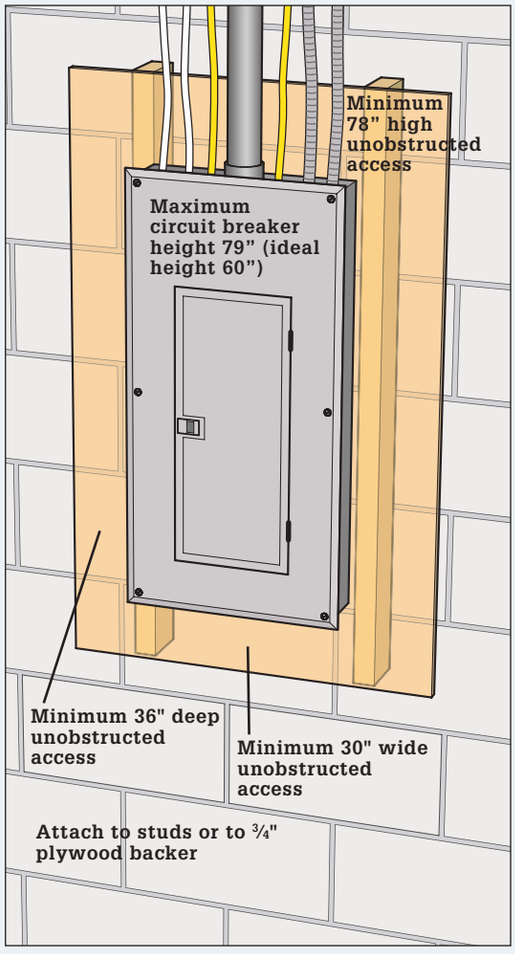

All the equipment you'll need to upgrade your main panel is sold at most larger building centers. It includes (A) a new 200-amp panel; (B) a 200-amp bypass meter base (also called a socket); (C) individual circuit breakers (if your new panel is the same brand as your old one you may be able to reuse the old breakers); (D) new, THW, THHW, THWN-2. RHW, RHW-2, XHHW (2/0 copper seen here); (E) 2" dia. rigid metallic conduit; (F) weatherhead shroud for mast.

The main circuit breaker (called the service equipment) may need to be located outside next to the electric meter if your main panel is too far away from the point where the service cable enters your house. The maximum distance allowed varies widely, from as little as 3 ft. to more than 10 ft. Wiring the service cable through the shutoff has the effect of transforming your main panel into a subpanel, which will impact how the neutral and ground wires are attached (see Subpanels, pages 64 to 65).

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How to Replace a Main Panel

Shut off power to the house at the transformer. This must be done by a technician who is certified by your utility company. Also have the utility worker remove the old meter from the base. It is against the law for a homeowner to break the seal on the meter.

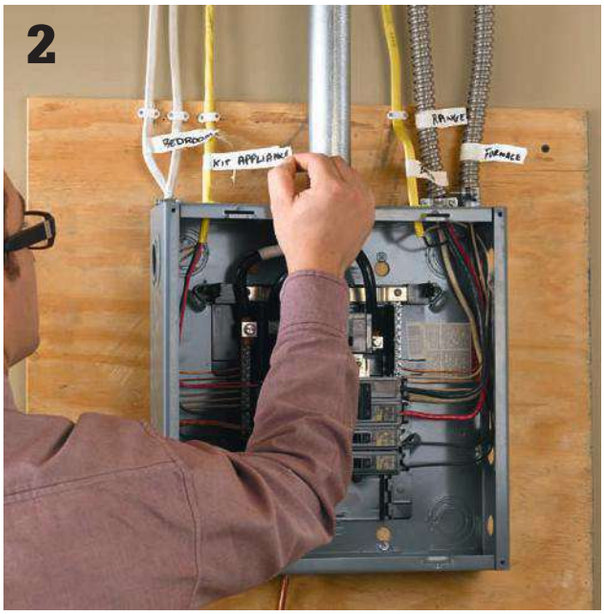

Label all incoming circuit wires before disconnecting them. Labels should be written clearly on tape that is attached to the cables outside of the existing service panel. Test the circuits before starting to make sure they are labeled correctly.

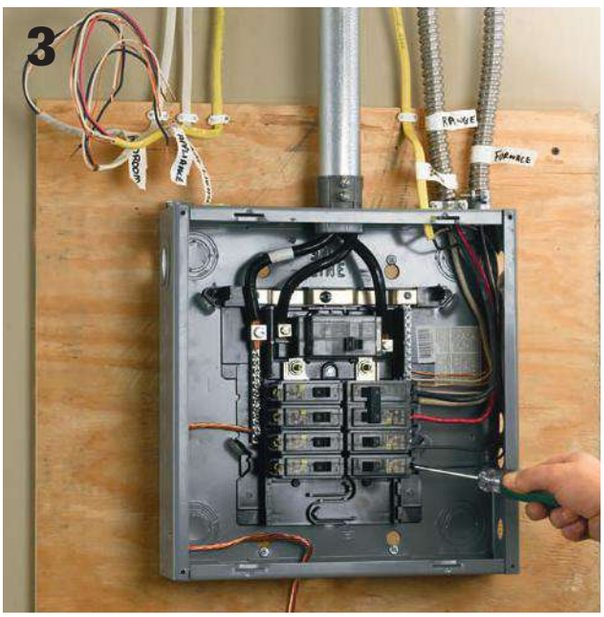

Disconnect incoming circuit wires from breakers, grounding bar, and neutral bus bar. Also disconnect cable clamps at the knockouts on the panel box. Retract all circuit wires from the service panel and coil it up neatly, with the labels clearly visible.

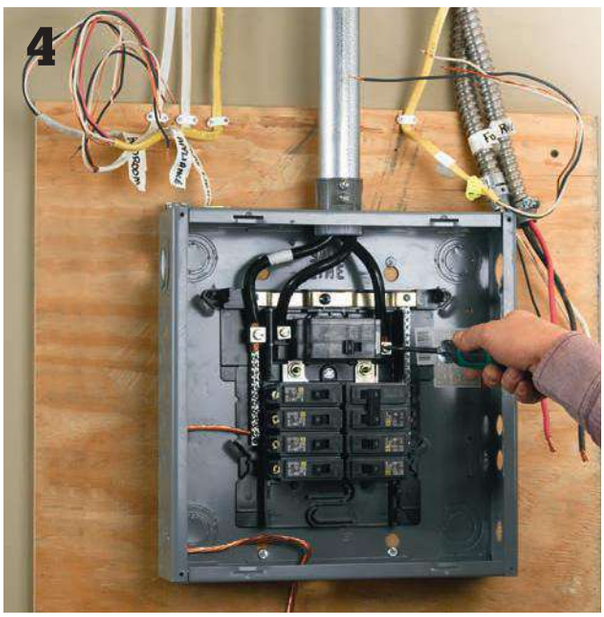

Unscrew the lugs securing the service entry cables at the top of the panel. For 240-volt service you will find two heavy-gauge SE cables, probably with black sheathing. Each cable carries 120 volts of electricity. A neutral service cable, usually of smaller gauge than the SE cables, will be attached to the neutral bus bar. This cable returns current to the source.

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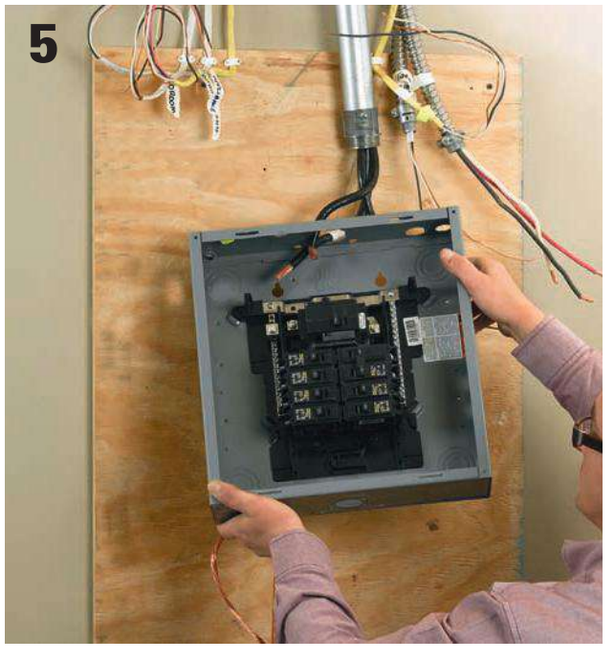

Remove the old service panel box. Boxes are rated for a maximum current capacity; and if you are upgrading, the components in the old box will be undersized for the new service levels. The new box will have a greater number of circuit slots as well.

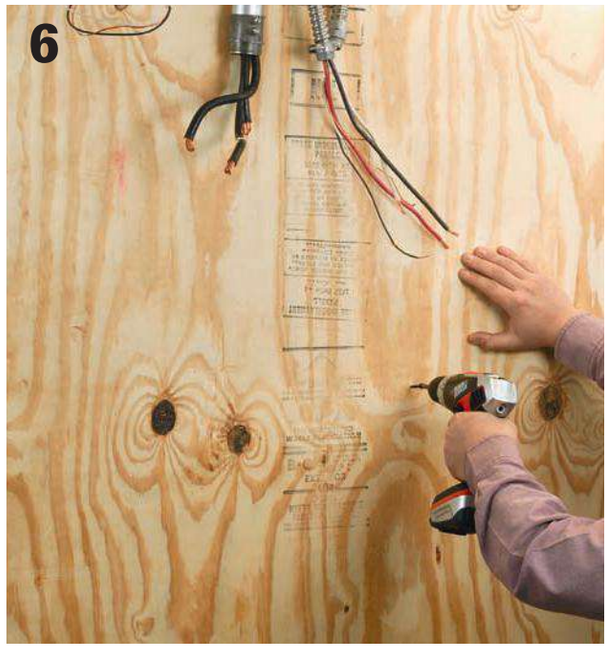

Replace the old panel backer board with a larger board in the installation area (see sidebar, page 52). A piece of ¾" plywood is typical. Make sure the board is well secured at wall framing members.

Attach the new service panel box to the backer board, making sure that at least two screws are driven through the backer and into wall studs. Drill clearance holes in the back of the box at stud locations if necessary. Use roundhead screws that do not have tapered shanks so the screwhead seats flat against the panel.

Attach properly sized cable clamps to the box at the knockout holes. Install one cable per knockout in this type of installation and plan carefully to avoid removing knockouts that you do not need to remove (if you do make a mistake, you can fill the knockout hole with a plug).

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Splicing in the Box ▸

Some wiring codes allow you to make splices inside the panel box if the circuit wire is too short. Use the correct wire cap and wind electrical tape over the conductors where they enter the cap. If your municipality does not allow splices in the panel box, you'll have to rectify a short cable by splicing it in a junction box before it reaches the panel and then replacing the cable with a longer section for the end of the run. Make sure each circuit line has at least 12" of slack.

Attach the white neutral from each circuit cable to the neutral bus bar. Most panels have a preinstalled neutral bus bar, but in some cases you may need to purchase the bar separately and attach it to the panel back. The panel should also have a separate grounding bar that you also may need to purchase separately. Attach the grounds as well.

Attach the hot lead wire to the terminal on the circuit breaker, and then snap the breaker into an empty slot. When loading slots, start at the top of the panel and work your way downward. It is important that you balance the circuits as you go to equalize the amperage. For example, do not install all the 15-amp circuits on one side and all the 20-amp circuits on the other.

Create an accurate circuit index and affix it to the inside of the service panel door. List all loads that are on the circuit as well as the amperage. Once you have restored power to the new service panel (see step 18), test out each circuit to make sure you don't have any surprises. With the main breakers on, shut off all individual circuit breakers, and then flip each one on by itself. Walk through your house and test every switch and receptacle to confirm the loads on that circuit.

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Install grounding conductors (see pages 58 to 59). Local codes are very specific about how the grounding and bonding needs to be accomplished. For example, some require multiple rods driven at least 6 ft. apart. Discuss your grounding requirements thoroughly with your inspector or an electrician before making your plan.

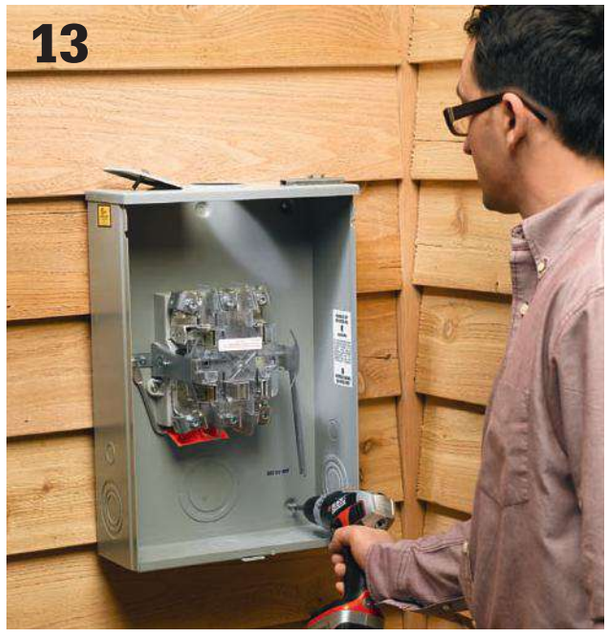

Replace the old meter base (have the utility company remove the meter when they shut off power to the house, step 1). Remove the old meter base, also called a socket, and install a new base that's rated for the amperage of your new power service. Here, a 200-amp bypass meter base is being installed.

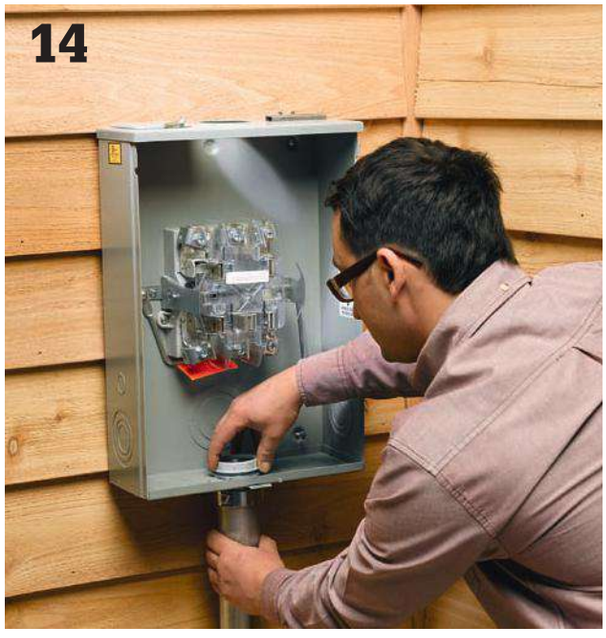

Update the conduit that runs from your house to the bottom of the meter base. This should be 2" rigid conduit in good repair. Attach the conduit to the base and wall with the correct fittings. Rigid metal conduit is a good option, but Schedule 80 PVC is probably the best choice for housing the service entrance wires.

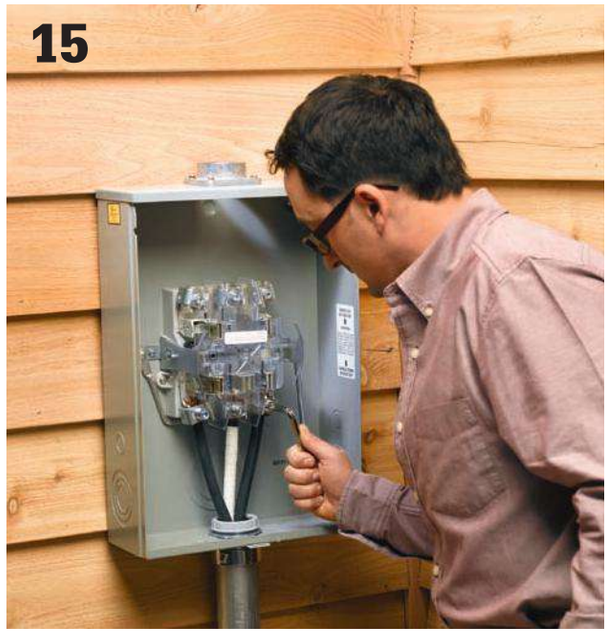

Install new service entrance wires. Each wire carries 120 volts from the meter to the service wire lugs at the top of your service panel. Code is very specific about how these connections are made. In most cases, you'll need to tighten the terminal nuts with a specific amount of torque that requires a torque wrench to measure. Also attach the sheathed neutral wire to the neutral/grounding lug.

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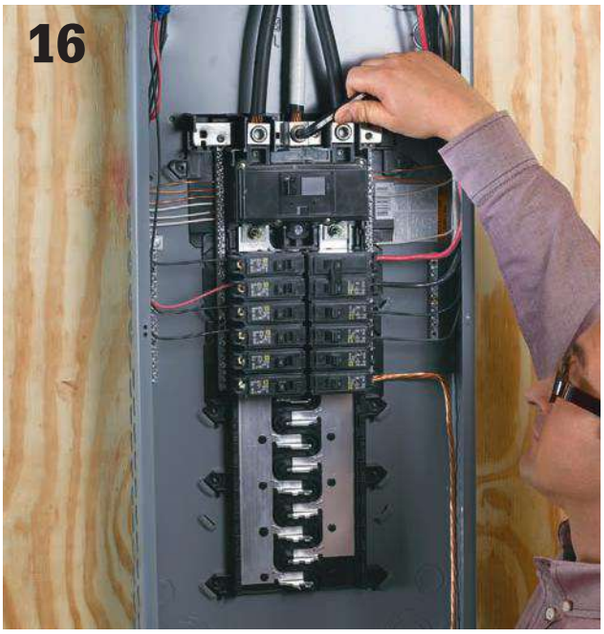

Attach the SE wires to the lugs connected to the main breakers at the top of your service entry panel. Do not remove too much insulation on the wires—leaving the wires exposed is a safety hazard. The neutral service entry wire is attached either directly to the neutral bus bar or to a metal bridge that is connected to the neutral bonding bus bar. Install the green grounding screw provided with the panel.

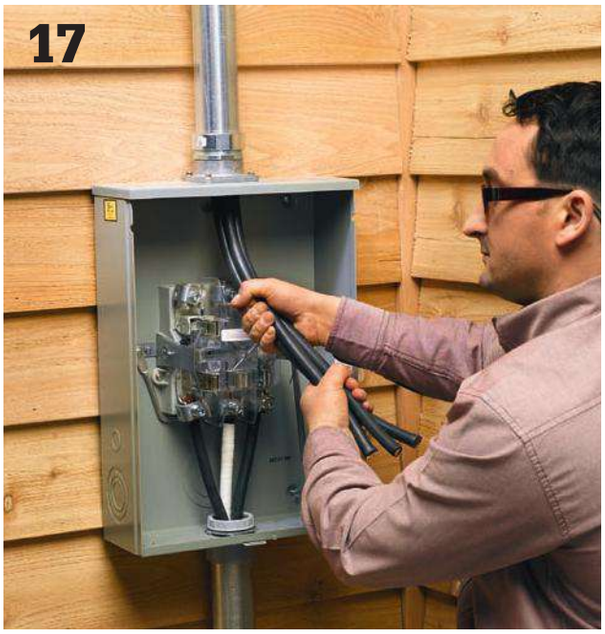

Install service entrance wires from the meter to the weatherhead, where the connections to the service drop wires are made. Only an agent for your public utility company may make the hookup at the weatherhead.

Tall Mast, Short Roof ▸

The service drop must occur at least 10 ft. above ground level, and as much as 14 ft. in some cases. Occasionally, this means that you must run the conduit for the service mast up through the eave of your roof and seal the roof penetration with a boot.

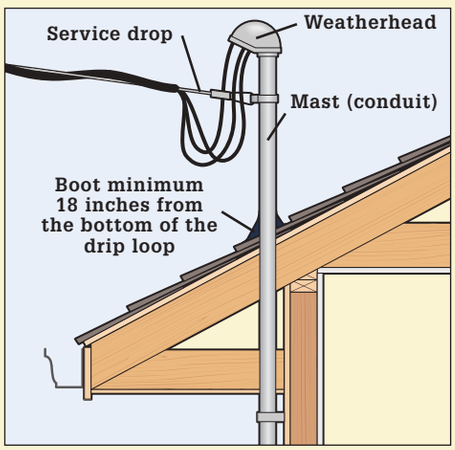

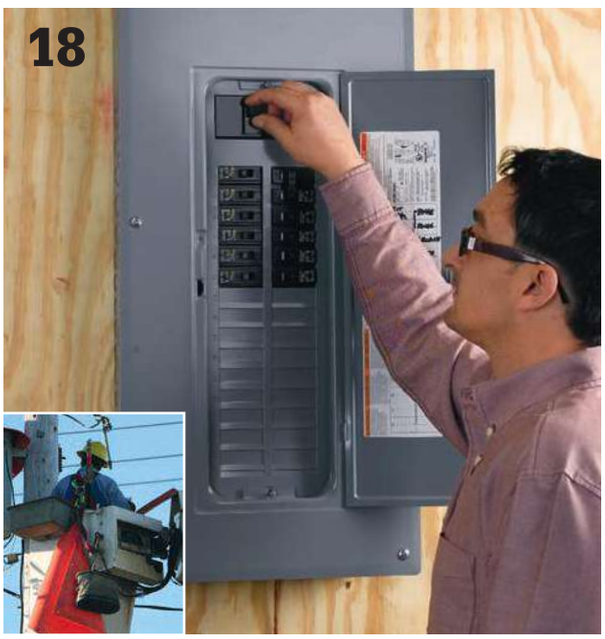

Have the panel and all connections inspected and approved by your local building department, and then contact the public utility company to make the connections at the power drop. Once the connections are made, turn the main breakers on and test all circuits.

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Grounding & Bonding a Wiring System

All home electrical systems must be bonded and grounded according to code standards. This entails two tasks: the metal water and gas pipes must be connected electrically to create a continuous low resistance path back to the main electrical panel; and the main electrical panel must be grounded to a grounding electrode such as a ground rod or rods driven into the earth near the foundation of your house. Although the piping system is bonded to the ground through your main electrical service panel, the panel grounding and the piping bonding are unrelated when it comes to function. The grounding wire that runs from your electrical panel to grounding electrode helps even out voltage increases that often occur because of lightning and other causes. The wires that bond your metal piping are preventative, and they only become important in the unlikely event that an electrical conductor energizes the pipe. In that case, correct bonding of the piping system will ensure that the current does not remain in the system, where it could electrocute anyone who touches a part of the system, such as a faucet handle. Bonding is done relatively efficiently at the water heater, as the gas piping and water piping generally there.

Gas pipe in older homes is usually steel or copper. The bonding connection point for these pipes can be at any accessible location, such as at the water heater or at the gas meter. Gas pipe in some new homes is a flexible material called corrugated stainless steel tubing (CSST). The bonding point for CSST must be at the first piece of steel or copper pipe where the gas service enters the home. This is because lightning can blow holes in CSST, causing a gas leak.

Tools & Materials

- Hammer
- Straight edge screwdriver
- Drill
- ½" drill bit
- A length of ground wire
- Some wire staples
- 3 pipe ground clamps
- Eye and ear protection
- Work gloves
- Grounding rods
- 5-lb. maul
- Caulk

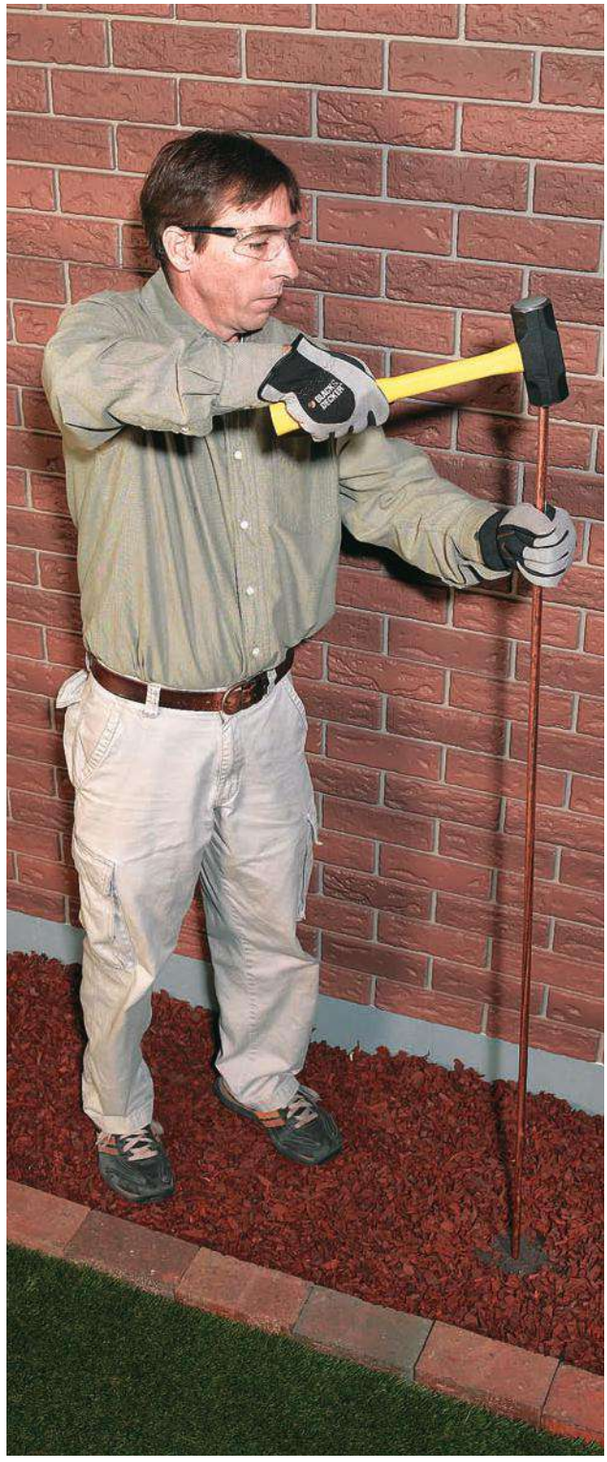

A pair of 8-ft.-long metal ground rods are driven into the earth next to your house to provide a path to ground for your home wiring system.

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How to Bond Metallic Piping

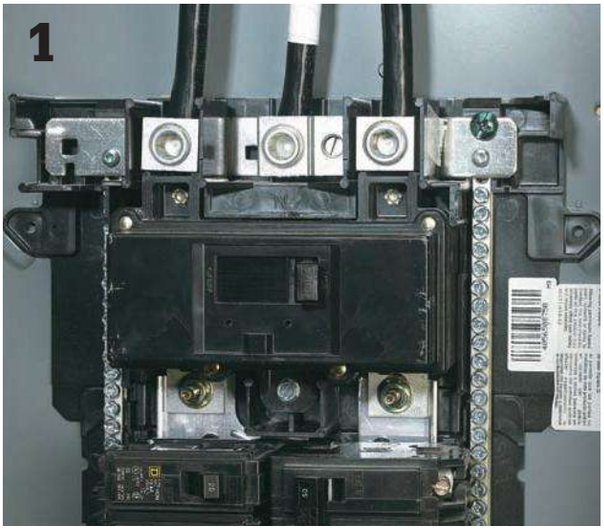

Determine the amperage rating of your electrical service by looking at your main breakers. The system amperage (usually 100 or 200 amps) determines the required gauge of the bonding wire you need. #4 copper wire is sufficient for service not exceeding 200 amps. Smaller, less expensive copper wire is allowed for services between 100 and 175 amps. Check with your electrical inspector if you want to use wire smaller than #4.

Run the bonding wire from a point near your water heater (a convenient spot if you have a gas-fueled water heater) to an exit point where the wire can be bonded to the grounding wire that leads to the exterior grounding electrodes. This is frequently done at the service panel. Run this wire as you would any other cable, leaving approximately 6 to 8 ft. of wire at the water heater. If you are running this wire through the ceiling joists, drill a ½" hole as close to the center as possible to not weaken the joist. Staple the wire every 2 ft. if running it parallel to the joists.

Install pipe ground clamps on each pipe (hot water supply, cold water supply, gas), roughly a foot above the water heater. Do not install clamps near a union or elbow because the tightening of the clamps could break or weaken soldered joints. Also make sure the pipes are free and clear of any paint, rust, or any other contaminant that may inhibit a good clean connection. Do not overtighten the clamps. Use clamps that are compatible with the pipe so that corrosion will not occur. Use copper or brass clamps on copper pipe. Use brass or steel clamps on steel pipe.

Route the ground wire through each clamp wire hole and then tighten the clamps onto the wire. Do not cut or splice the wire: The same wire should run through all clamps.

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At the panel, turn off the main breaker. Open the cover by removing the screws, and set the cover aside. Route the ground wire through a small ⅜" hole provided towards the rear of the panel on the top or bottom. You will usually have to knock the plug out of this hole by placing a screwdriver on it from the outside and tapping with a hammer. Make sure the ground wire will not come into contact with the bus bars in the middle of the panel or any of the load terminals on the breakers.

Locate an open hole on your ground and neutral bus and insert the ground wire. These holes are large enough to accommodate up to a #4 awg wire, but it may be difficult at times. If you're having trouble pushing the wire in, trim a little wire off the end and try with a clean cut piece. Secure the set screw at the lug. Replace the panel cover and turn the main breaker back on.

Tips for Grounding the Main Service Panel

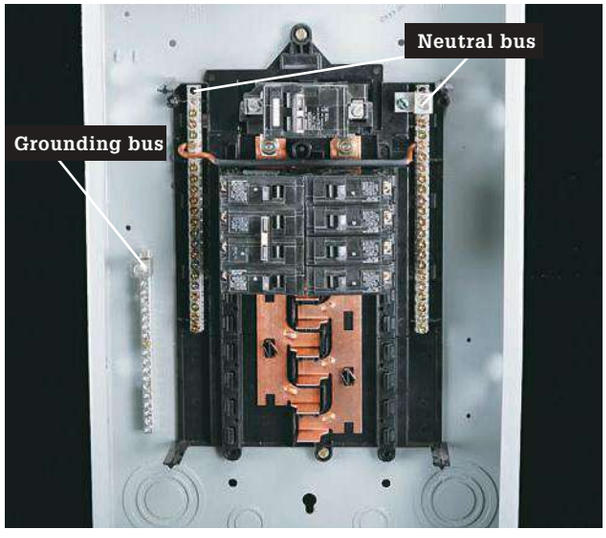

The neutral and grounding wires should not be connected to the same bus in most subpanels. The grounding bus should be bonded to the subpanel cabinet. The neutral bus should not be bonded to the subpanel cabinet.

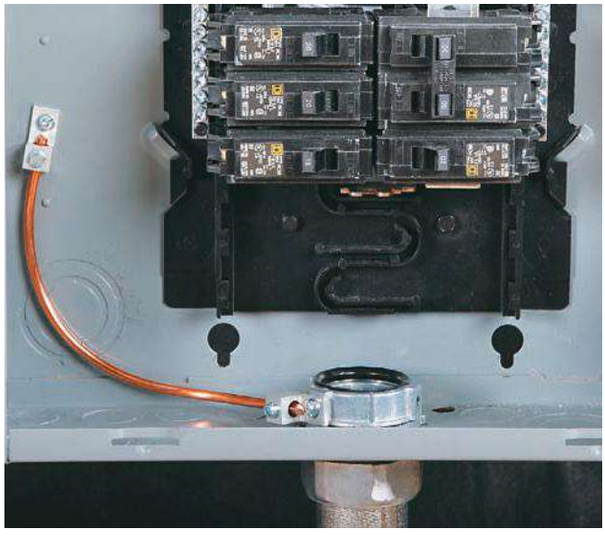

Metallic conduit must be physically and electrically connected to panel cabinets. A bonding bushing may be required in some cases, where not all of a knockout is removed.

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Ground Rod Installation

The ground rod is an essential part of the grounding system. Its primary function is to create a path to ground for electrical current, such as lightning, line surges, and unintentional contact with high voltage lines. If you upgrade your electrical service you likely will need to upgrade your grounding wire and rods to meet code.

Note: Different municipalities have different requirements for grounding, so be sure to check with the AHJ (Authority Having Jurisdiction) first before attempting to do this yourself.

Call before you dig! Make sure the area where you will be installing the ground rods is free and clear from any underground utilities.

Exercise Your Breakers ▸

Your breakers (including the main) should be "exercised" once a year to ensure proper mechanical function. Simply turn them off and then back on. A convenient time to perform the exercise is at daylight savings time, when you'll need to reset all of your clocks anyway.

How to Install a Grounding Electrode System

Begin by purchasing two copper-coated steel ground rods 5/8" diameter by 8' long. Grounding rods have a driving point on one end and a striking face on the other end.

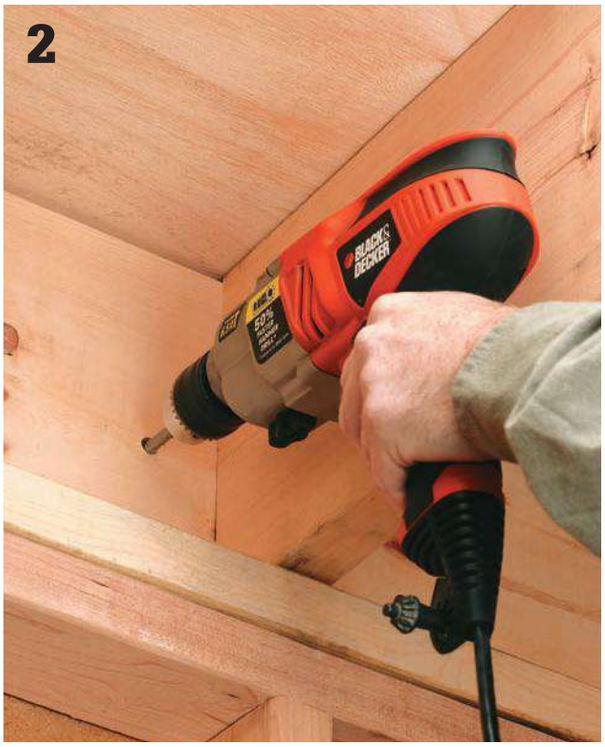

Drill a 5/16" hole in the rim joist of your house, as close as practical to the main service panel to the outside of the house above the ground level at least 6".

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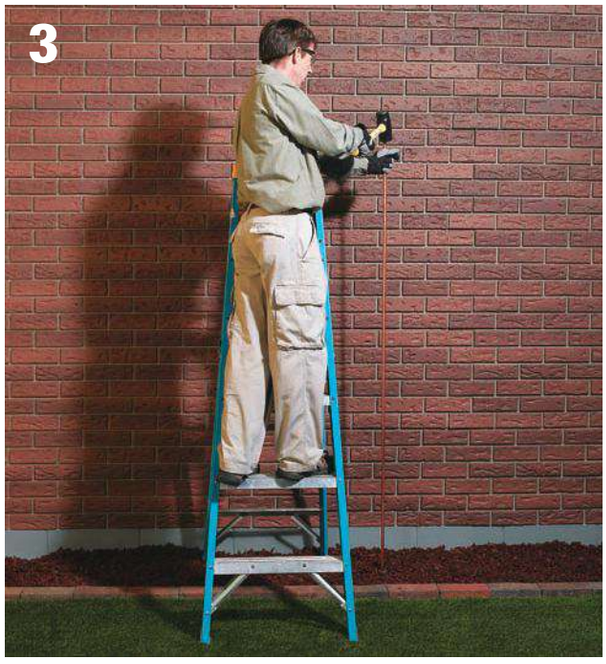

About a foot from the foundation of the house, pound one ground rod into the earth with a five-pound maul. If you encounter a rock or other obstruction, you can pound the ground rod at an angle as long as it does not exceed 45°. Drive until only 3" or 4" of the rod is above ground. Measure at least 6 ft. from the first ground rod and pound in another one.

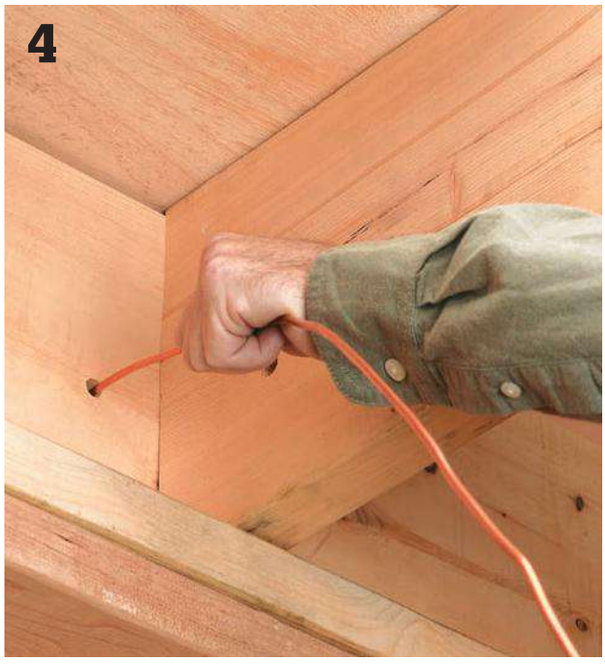

Run uninsulated #4 copper wire from the ground bus in your main service panel through the hole in the rim joist and to the exterior of the house, leaving enough wire to connect the two ground rods together.

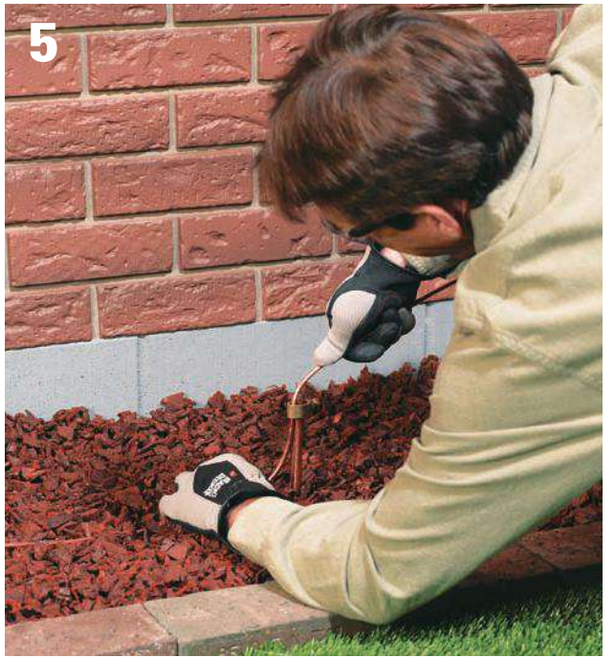

Using a brass clamp commonly referred to as an acorn, connect the wire to the first ground rod, pulling the wire taut so no slack exists. Continue pulling the wire to reach the second grounding rod, creating a continuous connection.

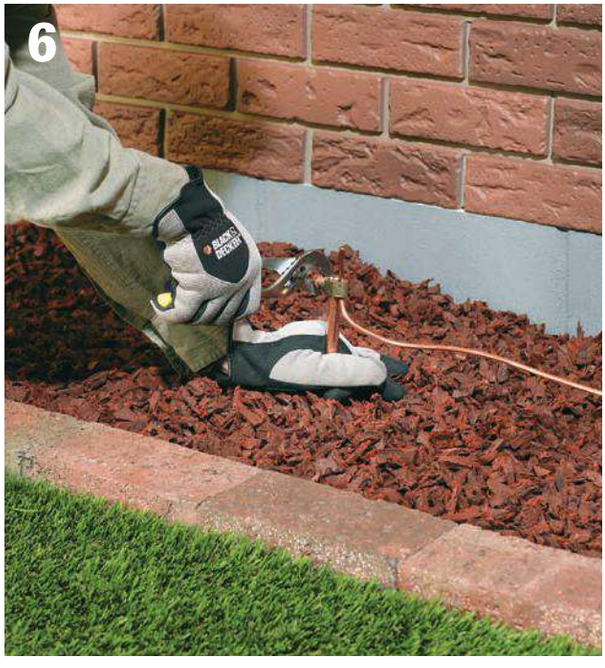

Connect the second ground rod with another acorn to the uncut grounding wire previously pulled through the first acorn. Trim the excess wire.

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Dig out a few inches around each rod to create clearance for the five-pound maul. Creating a shallow trench beneath the grounding wire between the rods is also a good idea. Drive each rod with the maul until the top of the rod is a few inches below grade.

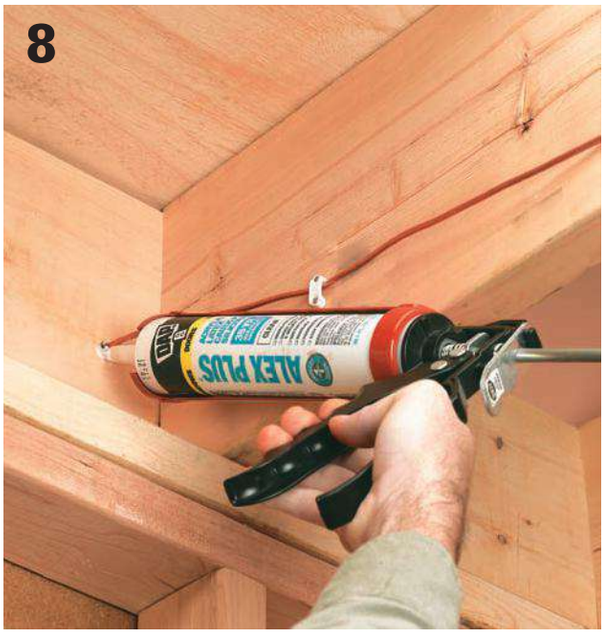

Inject caulk into the hole in the rim joist on both the interior and exterior side.

Tips for Grounding

A listed metal strap may be used to ground indoor communication wires such as telephone and cable TV if an intersystem bonding terminal is not available.

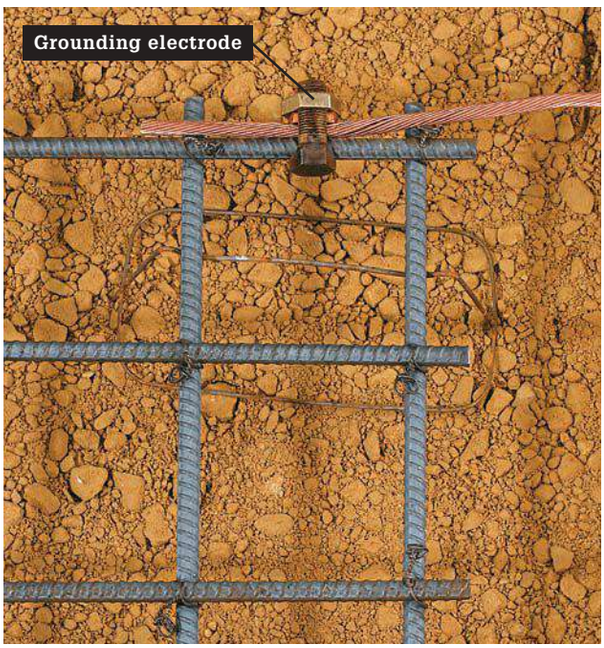

A piece of reinforcing bar encased in a concrete footing is a common grounding electrode in new construction. Called an ufer, the electrode must be No. 4 or larger rebar and at least 20 ft. long. (Shown prior to pouring concrete.)

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Installing a Subpanel

Install circuit breaker subpanels if the main circuit breaker panel does not have enough open breaker slots for the new circuits you are planning. Subpanels serve as a second distribution center for connecting circuits. They receive power from a double-pole circuit breaker you install in the main circuit breaker panel.

If the main service panel is so full that there is no room for the double-pole subpanel breaker, you can reconnect some of the existing 120-volt circuits to special slimline breakers (photos below).

Plan your subpanel installation carefully, making sure your electrical service supplies enough power to support the extra load of the new subpanel circuits. Assuming your main service is adequate, consider installing an oversized subpanel breaker in the main panel to provide enough extra amps to meet the needs of future wiring projects.

Also consider the physical size of the subpanel, and choose one that has enough extra slots to hold circuits you may want to install later. The smallest panels have room for up to six single-pole breakers (or three double-pole breakers), while the largest models can hold 20 single-pole breakers or more.

Subpanels often are mounted near the main circuit breaker panel. Or, for convenience, they can be installed close to the areas they serve, such as in a new room addition or a garage. In a finished room, a subpanel can be painted or housed in a decorative cabinet so it is less of a visual distraction. If it is covered, make sure the subpanel is easily accessible and clearly identified.

Tools & Materials

Hammer	Cable clamps
Screwdriver	Three-wire NM cable
Circuit tester	Cable staples
Cable ripper	Double-pole circuit breaker
Combination tool	Circuit breaker subpanel
Screws	Slimline circuit breakers

Before

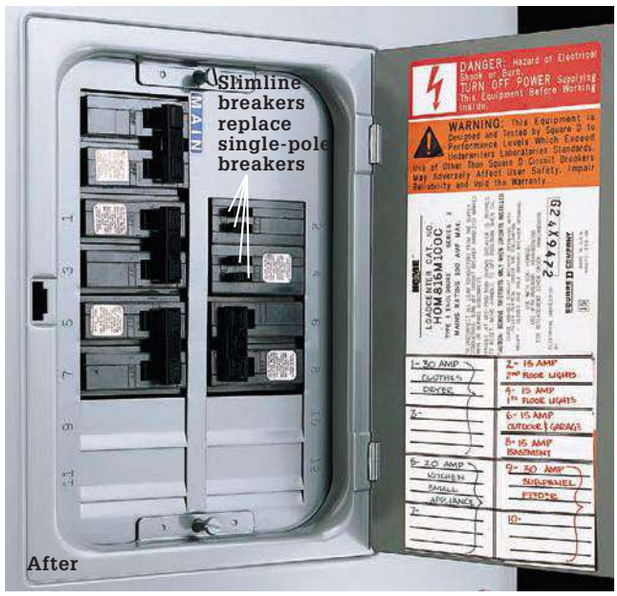

After

To conserve space in a service panel, you can replace single-pole breakers with slimline breakers. Slimline breakers take up half the space of standard breakers, allowing you to fit two circuits into one single slot on the service panel. In the service panel shown above, four single-pole 120-volt breakers were replaced with slimline breakers to provide the double opening needed for a 30-amp, 240-volt subpanel feeder breaker. Use slimline breakers (if your municipality allows them) with the same amp rating as the standard single-pole breakers you are removing, and make sure they are approved for use in your panel. If your municipality and panel allow slimline breakers, there may be restrictions on the quantity and location where they may be installed on the panel.

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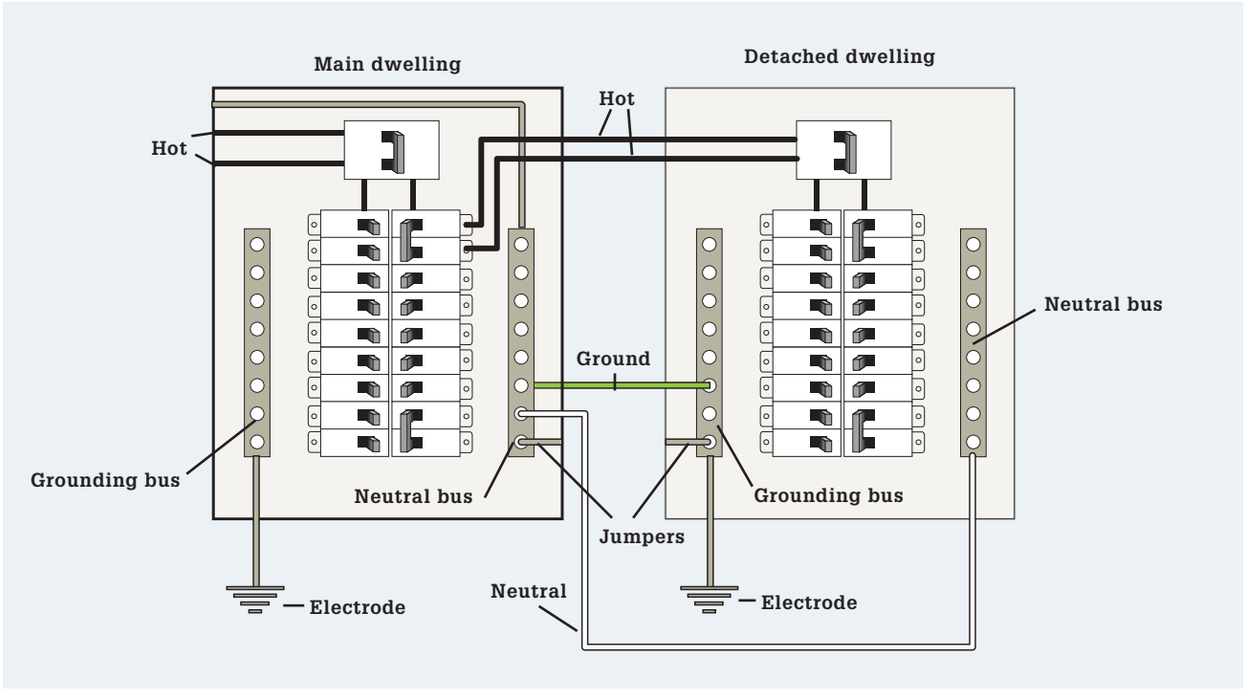

Wiring diagram for wiring a feeder from the main service panel to a subpanel in a separate building.

How to Install a Subpanel

Subpanels are subject to the same installation and clearance rules as service panels. The subpanel can be mounted to the sides of studs or to plywood attached between two studs. The panel shown here extends ½" past the face of studs so it will be flush with the finished wall surface.

Open a knockout in the subpanel using a screwdriver and hammer. Run the feeder cable from the main circuit breaker panel to the subpanel, leaving about 2 ft. of excess cable at each end.

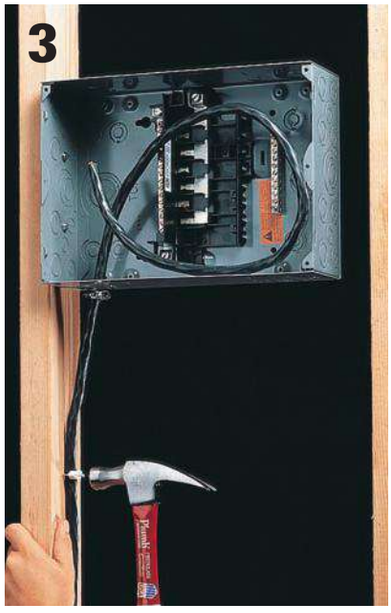

Attach a cable clamp to the knockout in the subpanel. Insert the cable into the subpanel, and then anchor it to framing members within 8" of each panel and every 54" thereafter.

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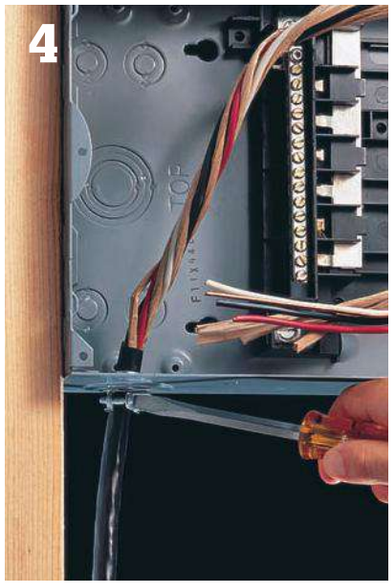

Strip away outer sheathing from the feeder cable using a cable ripper. Leave at least ¼" of sheathing extending into the subpanel. Tighten the cable clamp screws so the cable is held securely, but not so tightly that the wire sheathing is crushed.

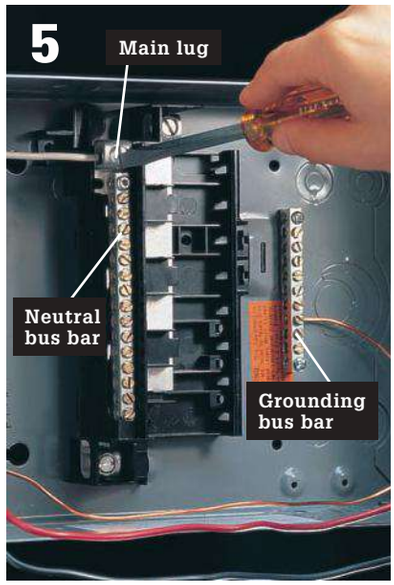

Strip ½" of insulation from the white neutral feeder wire, and attach it to the main lug on the subpanel neutral bus bar. Connect the grounding wire to a setscrew terminal on the grounding bus bar. Fold excess wire around the inside edge of the subpanel.

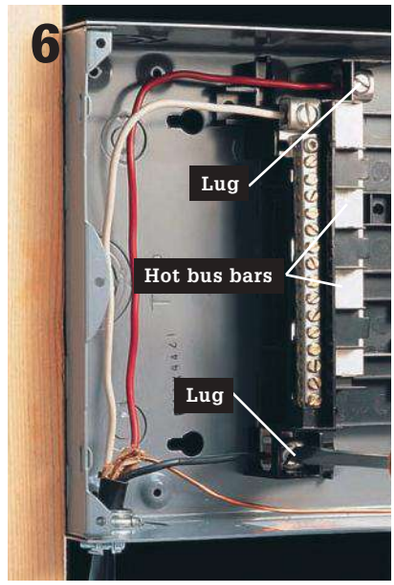

Strip away ½" of insulation from the red and the black feeder wires. Attach one wire to the main lug on each of the hot bus bars. Fold excess wire around the inside edge of the subpanel.

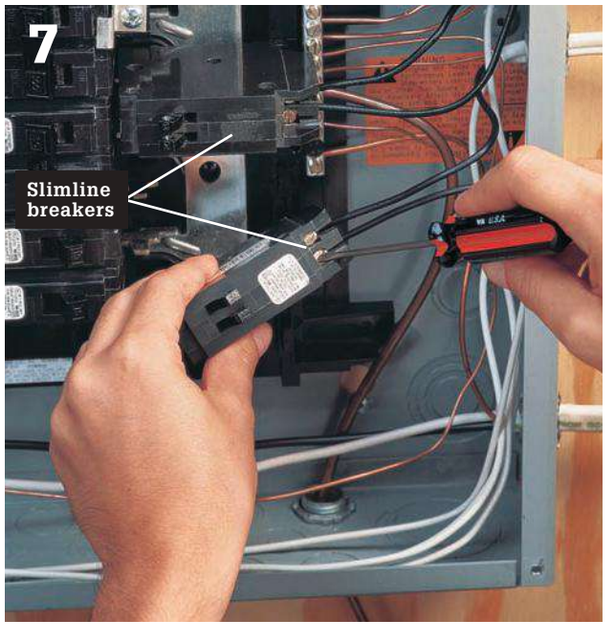

At the main circuit breaker panel, shut off the main circuit breaker, and then remove the coverplate and test for power. If necessary, make room for the double-pole feeder breaker by removing single-pole breakers and reconnecting the wires to slimline circuit breakers. Open a knockout for the feeder cable using a hammer and screwdriver. Note: some panels do not allow slimline breakers and some restrict where slimline breakers can be installed. Read the instructions on the panel cover.

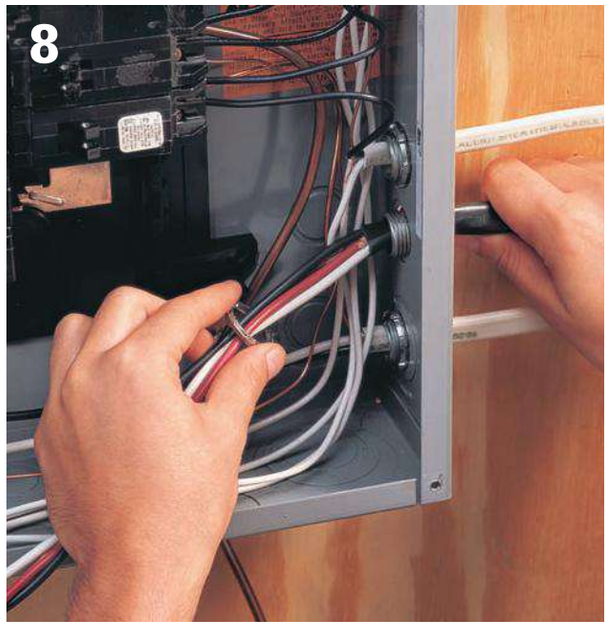

Strip away the outer sheathing from the feeder cable so that at least ¼" of sheathing will reach into the main service panel. Attach a cable clamp to the cable, and then insert the cable into the knockout, and anchor it by threading a locknut onto the clamp. Tighten the locknut by driving a screwdriver against the lugs. Tighten the clamp screws so the cable is held securely, but not so tightly that the cable sheathing is crushed.

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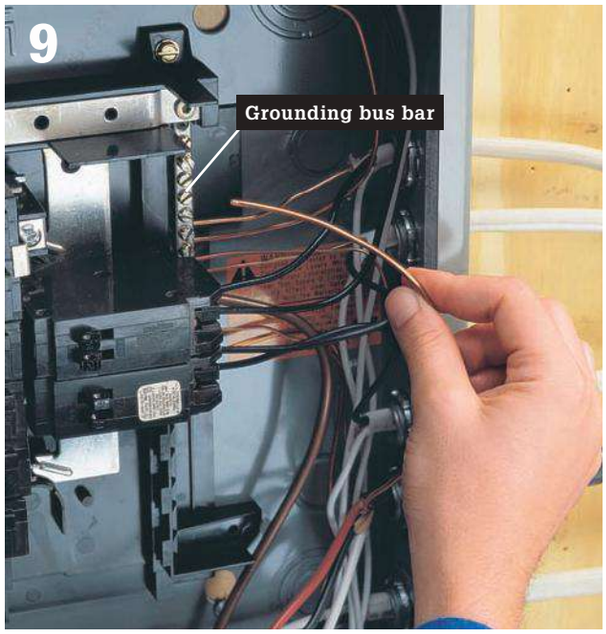

Bend the bare copper wire from the feeder cable around the inside edge of the main circuit breaker panel, and connect it to one of the setscrew terminals on the grounding bus bar.

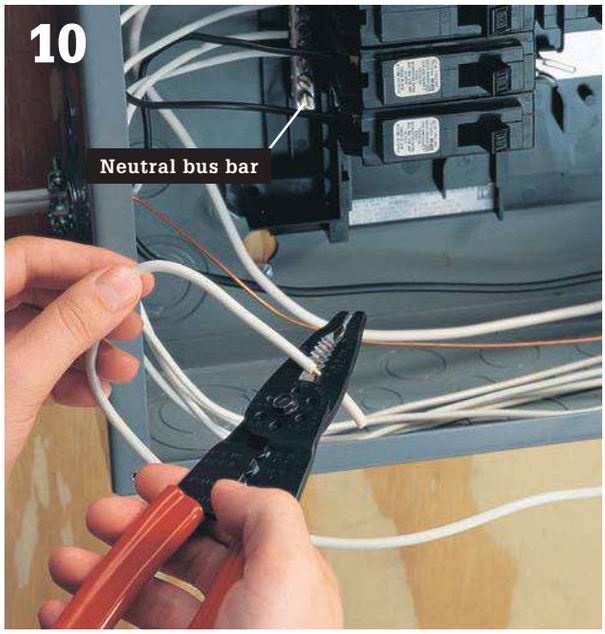

Strip away ½" of insulation from the white feeder wire. Attach the wire to one of the setscrew terminals on the neutral bus bar. Fold excess wire around the inside edge of the service panel.

Strip ½" of insulation from the red and the black feeder wires. Attach one wire to each of the setscrew terminals on the double-pole feeder breaker. *Note: If your subpanel arrived with a preinstalled grounding screw in the panel back, remove and discard it.*

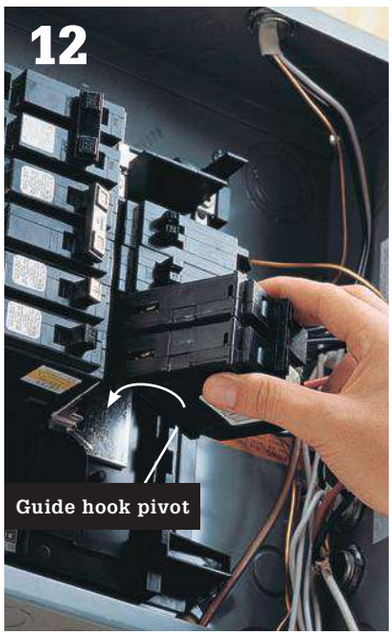

Hook the end of the feeder circuit breaker over the guide hooks on the panel, and then push the other end forward until the breaker snaps onto the hot bus bars (follow manufacturer's directions). Fold excess wire around the inside edge of the circuit breaker panel.

If necessary, open two tabs where the double-pole feeder breaker will fit, and then reattach the cover plate. Label the feeder breaker on the circuit index. Turn the main breaker on, but leave the feeder breaker off until all subpanel circuits have been connected and inspected.

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Baseboard Heaters

Baseboard heaters are a popular way to provide additional heating for an existing room or primary heat to a converted attic or basement.

Heaters are generally wired on a dedicated 240-volt circuit controlled by a thermostat. Several heaters can be wired in parallel and controlled by a single thermostat (see circuit map 15, page 39).

Baseboard heaters are generally surface-mounted without boxes, so in a remodeling situation, you only need to run cables before installing wallboard. Be sure to mark cable locations on the floor before installing drywall. Retrofit installations are also not difficult. You can remove existing baseboard and run new cable in the space behind. Baseboard heaters (and other heating equipment) get very hot and can ignite nearby combustible materials. Maintain the manufacturers recommended distance between the heater and materials such as curtains, blinds, and wood.

Tools & Materials

Drill/driver
Wire stripper
Cable ripper
Wallboard saw
Baseboard heater or heaters
240-thermostat (in-heater or in-wall)
12/2 NM cable
Electrical tape
Basic wiring supplies

Baseboard heaters can provide primary or supplemental heat for existing rooms or additions. Install heaters with clear space between the heater and the floor.

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Baseboard Thermostats

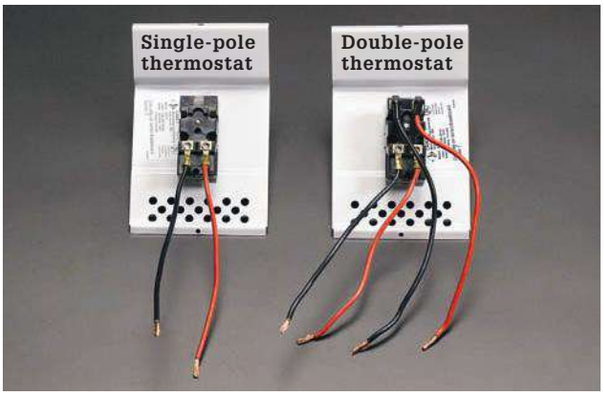

Single-pole and double-pole thermostats work in a similar manner, but double-pole models are safer. The single-pole model will open the circuit (causing shutoff) in only one leg of the power service. Double-pole models have two sets of wires to open both legs, lessening the chance that a person servicing the heater will contact a live wire.

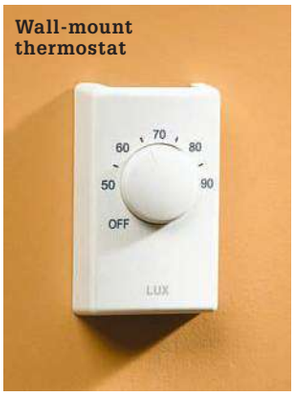

In-heater and wall-mount are the two types of baseboard thermostats you can choose from. If you are installing multiple heaters, a single wall-mount thermostat is more convenient. Individual in-heater thermostats give you more zone control, which can result in energy savings.

How Much Heater Do You Need?

If you don't mind doing a little math, determining how many lineal feet of baseboard heater a room requires is not hard.

1. Measure the area of the room in square feet (length × width): _____
2. Multiply the area by 10 to get the baseline minimum wattage: _____
3. Add 5% for each newer window or 10% for each older window: _____
4. Add 10% for each exterior wall in the room: _____
5. Add 10% for each exterior door: _____
6. Add 10% if the space below is not insulated: _____
7. Add 20% if the space above is not well insulated: _____
8. Add 10% if ceiling is more than 8 ft. high: _____
9. Total of the baseline wattage plus all additions: _____
10. Divide this number by 250 (the wattage produced per foot of standard baseboard heater): _____
11. Round up to a whole number. This is the minimum number of feet of heater you need. _____

Note: It is much better to have more feet of heater than is required than fewer. Having more footage of heater does not consume more energy; it does allow the heaters to work more efficiently.

Planning Tips for Baseboard Heaters

- Baseboard heaters require a dedicated circuit. A 20-amp, 240-volt circuit of 12-gauge copper wire will power up to 16 ft. of heater.
- Do not install a heater beneath a wall receptacle. Cords hanging down from the receptacle are a fire hazard.
- Do not mount heaters directly on the floor. You should maintain at least 1" of clear space between the baseboard heater and the floor covering.
- Installing heaters directly beneath windows is a good practice.
- Locate wall thermostats on interior walls only, and do not install directly above a heat source.

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How to Install a 240-Volt Baseboard Heater

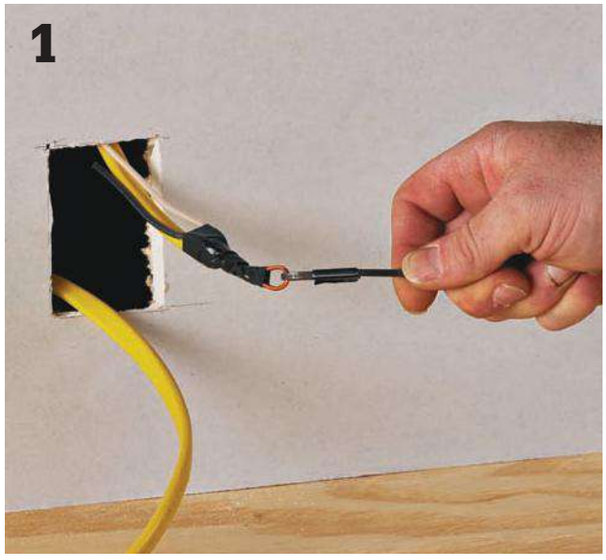

At the heater locations, cut a small hole in the drywall 3" to 4" above the floor. Pull 12/2 NM cables through the first hole: one from the thermostat, the other to the next heater. Pull all the cables for subsequent heaters. Middle-of-run heaters will have two cables, while end-of-run heaters have only one cable. (See also circuit map 15, page 39.)

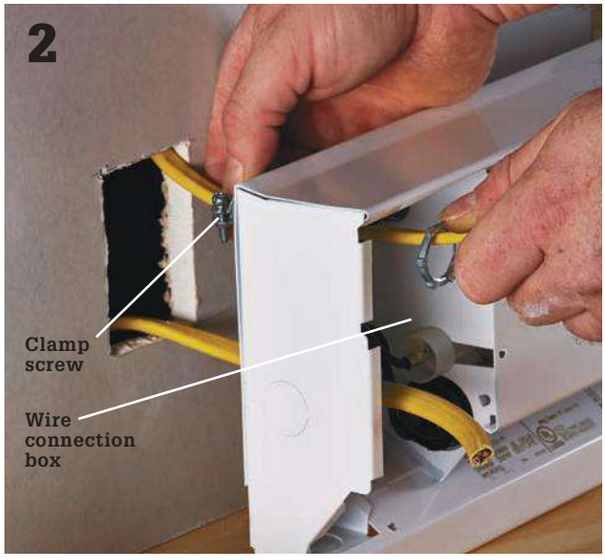

Remove the cover on the wire connection box. Open a knockout for each cable that will enter the box, and then feed the cables through the cable clamps and into the wire connection box. Attach the clamps to the wire connection box, and tighten the clamp screws until the cables are gripped firmly.

Anchor the heater against wall about 1" off floor by driving flathead screws through the back of the housing and into studs. Strip away cable sheathing so at least ½" of sheathing extends into the heater. Strip ¾" of insulation from each wire using a combination tool.

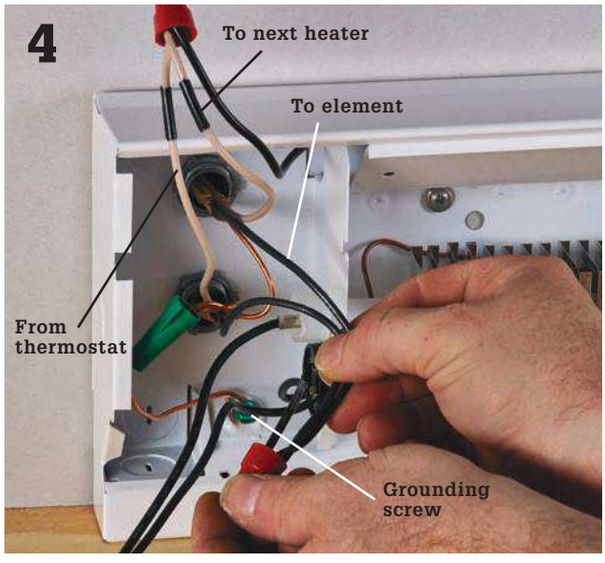

Make connections to the heating element if the power wires are coming from a thermostat or another heater controlled by a thermostat. See the next page for other wiring schemes. Connect the white circuit wires to one of the wire leads on the heater. Tag white wires with black tape to indicate they are hot. Connect the black circuit wires to the other wire lead. Connect a grounding pigtail to the green grounding screw in the box, and then join all grounding wires with a wire connector. Reattach the cover.

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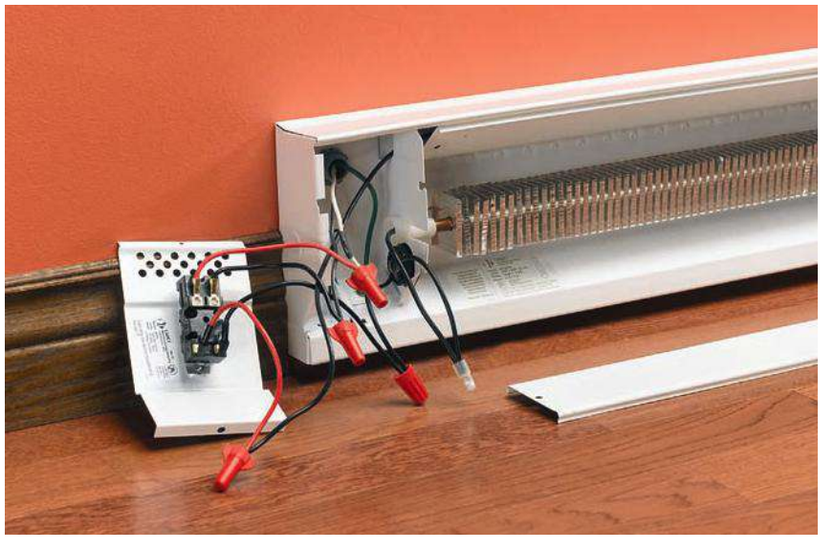

One heater with end-cap thermostat. Run both power leads (black plus tagged neutral) into the connection box at either end of the heater. If installing a single-pole thermostat, connect one power lead to one thermostat wire and connect the other thermostat wire, to one of the heater leads. Connect the other hot LINE wire to the other heater lead. If you are installing a double-pole thermostat, make connections with both legs of the power supply.

Multiple heaters. At the first heater, join both hot wires from the thermostat to the wires leading to the second heater in line. Be sure to tag all white neutrals hot. Twist copper ground wires together and pigtail them to the grounding screw in the baseboard heater junction box. This parallel wiring configuration ensures that power flow will not be interrupted to the downstream heaters if an upstream heater fails.

Wall-mounted thermostat. If installing a wall-mounted thermostat, the power leads should enter the thermostat first and then be wired to the individual heaters singly or in series. Hookups at the heater are made as shown in step 4. Be sure to tag the white neutral as hot in the thermostat box as well as in the heater box.

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Wall Heaters

Installing a wall heater is an easy way to provide supplemental heat to a converted attic or basement without expanding an existing HVAC system.

Wall heaters are easy to install during a remodel (most have a separate can assembly that you attach to the framing before the drywall is installed). They can also be retrofitted.

Most models available at home centers use 120-volt current (shown below), but 240-volt models are also available.

Tools & Materials

- Drywall saw
- Drill
- Fish tape
- Combination tool
- Screwdrivers
- 12/2 NM cable
- Wire connectors
- Wall heater
- Thermostat (optional)
- Wallboard saw

Wall heaters are an easy-to-install way to provide supplemental heat. Some models have built-in thermostats, while others can be controlled by a remote thermostat.

How to Install a Wall Heater in a Finished Wall

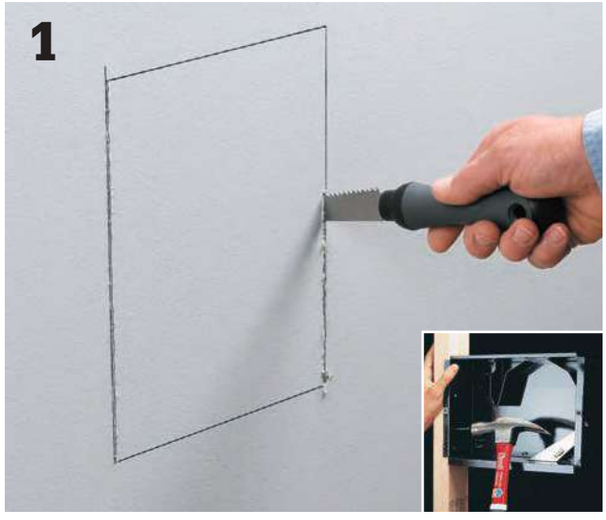

Make an opening in the wall for the heater. Use a stud finder to locate a stud in the area where you want to install the heater. Mark the opening for the heater according to the manufacturer's guidelines so that one side of the heater sits flush with a stud. Pay attention to clearance requirements. Cut the opening with a wallboard saw. If the wall is open, install the heater can before hanging drywall (inset).

Turn power off, and test for power. Pull 12/2 NM cable from the main panel to the wall opening. If the heater is controlled by a separate thermostat, pull cable to the thermostat, and then run another cable from the thermostat to the heater location.

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Disconnect and remove the motor unit from the heater can. Remove a knockout from the can, and route the cable into the can.

Install the can in the opening. Secure the cable with a clamp, leaving 8" to 12" of cable exposed. Attach the can to the framing as directed by the manufacturer.

Wire the heater. Connect the black circuit wire to one of the black heater leads. Connect the white circuit wire to the other lead. Connect the grounds.

Secure the heater unit in the can as directed by the manufacturer. Reconnect the motor if necessary. Attach the grill and thermostat knob as directed. Connect the new circuit breaker at the main panel.

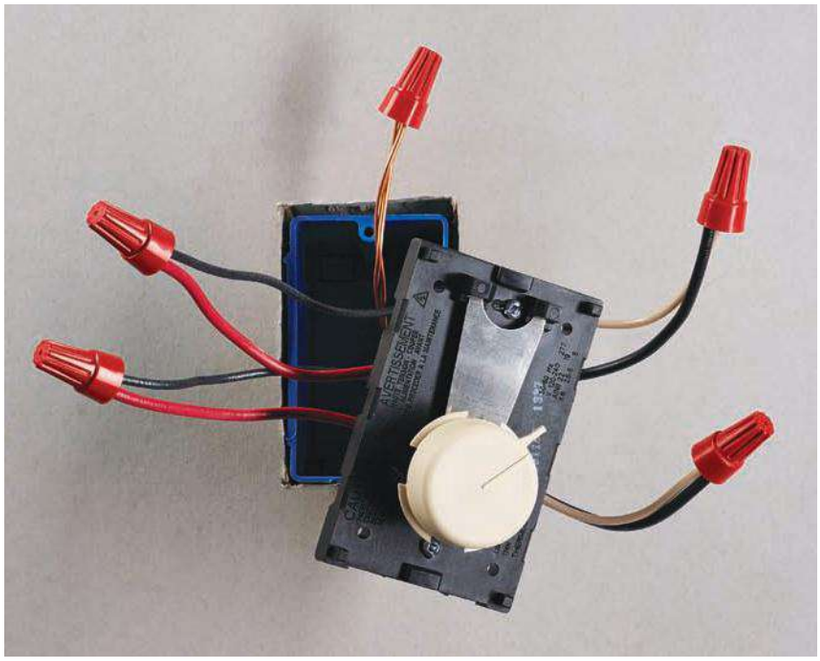

Variation: Connect a thermostat to control a wall heater. Some wall heaters do not use built-in thermostats. Install a thermostat in the heater circuit before the wall heater. Connect the black and the white wires coming from the main panel to the red leads on the thermostat. Connect the wires going to the heater to the black leads on the thermostat. Connect the grounds.

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Backup Power Supply

Installing a backup generator is an invaluable way to prepare your family for emergencies. The simplest backup power system is a portable gas-powered generator and an extension cord or two. A big benefit of this approach is that you can run a refrigerator and a few worklights during a power outage with a tool that can also be transported to remote job sites or on camping trips when it's not doing emergency backup duty. This is also the least expensive way to provide some backup power for your home. You can purchase a generator at most home centers and be up and running in a matter of hours. If you take this approach, it is critically important that you make certain any loads being run by your generator are disconnected from the utility power source.

The next step up is to incorporate a manual transfer switch for your portable generator. Transfer switches are permanently hardwired to your service panel. They are mounted on either the interior or the exterior of your house between the generator and the service panel. You provide a power feed from the generator into the switch. The switch is wired to selected essential circuits in your house, allowing you to power lights, furnace blowers, and other loads that can't easily be run with an extension cord. But perhaps the most important job a transfer switch performs is to disconnect the utility power. If the inactive utility power line is attached to the service panel, "backfeed" of power from your generator to the utility line can occur when the generator kicks in. This condition could be fatal to line workers who are trying to restore power. The potential for backfeed is the main reason many municipalities insist that only a licensed electrician hook up a transfer switch. Using a transfer switch not installed by a professional may also void the warranty of the switch and the generator.

Automatic transfer switches turn on the generator and switch off the utility supply when they detect a significant drop in line voltage. They may be installed with portable generators, provided the generator is equipped with an electric starter.

Large standby generators that resemble central air conditioners are the top of the line in backup power supply systems. Often fueled by home natural gas lines or propane tanks that offer a bottomless fuel source, standby generators are made in sizes with as much as 20 to 40 kilowatts of output—enough to supply all of the power needs of a 5,000-sq.-ft. home.

Generators have a range of uses. Large hard-wired models can provide instant emergency power for a whole house. Smaller models (below) are convenient for occasional short-term backup as well as job sites or camping trips.

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Options for Backup Generators

A 2,000- to 5,000-watt gas-powered generator and a few extension cords can power lamps and an appliance or two during shorter-term power outages. Appliances must not be connected to household wiring and the generator simultaneously. Never plug a generator into an outlet. Never operate a generator indoors. Run extension cords through a garage door.

A permanent transfer switch patches electricity from a large portable generator through to selected household circuits via an inlet at your service panel (inset), allowing you to power hardwired fixtures and appliances with the generator.

For full, on-demand backup service, install a large standby generator wired through to an automatic transfer panel. In the event of a power outage, the household system instantly switches to the generator.

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A Typical Backup System

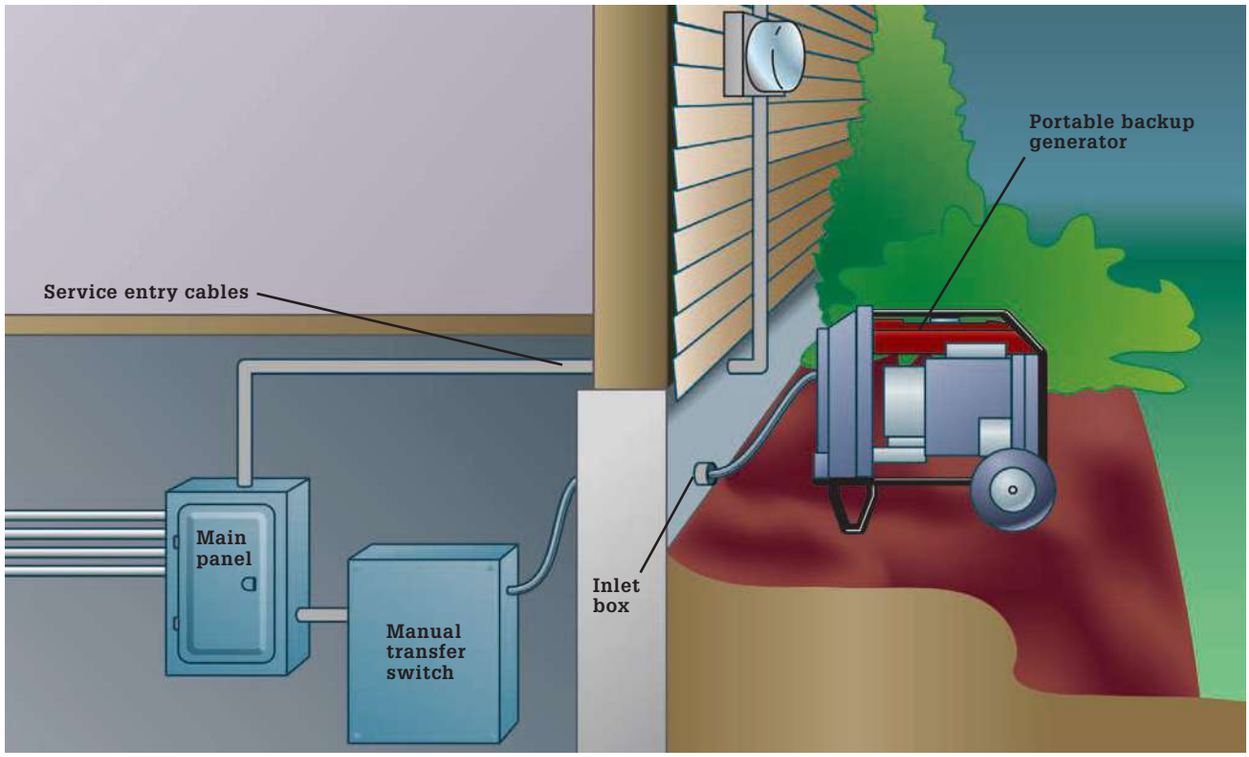

Backup generators supply power to a manual transfer switch, which disconnects the house from the main service wires and routes power from the generator through selected household circuits.

Choosing a Generator

Choosing a generator for your home's needs requires a few calculations. The chart below gives an estimate of the size of generator typically recommended for a house of a certain size. You can get a more accurate number by adding up the power consumption (the watts) of all the circuits or devices to be powered by a generator. It's also important to keep in mind that, for most electrical appliances, the amount of power required at the moment you flip the ON switch is greater than the number of watts required to keep the device running. For instance, though an air conditioner may run on 15,000 watts of power, it will require a surge of 30,000 watts at startup (the power range required to operate an appliance is usually listed somewhere on the device itself). These two numbers are called run watts and surge watts. Generators are typically sold according to run watts (a 5,000-watt generator can sustain 5,000 watts). They are also rated for a certain number of surge watts (a 5,000-watt generator may be able to produce a surge of 10,000 watts). If the surge watts aren't listed, ask, or check the manual. Some generators can't develop many more surge watts than run watts; others can produce twice as much surge as run wattage.

It's not necessary to buy a generator large enough to match the surge potential of all your circuits (you won't be turning everything on simultaneously), but surge watts should factor in your purchasing decision. If you will be operating the generator at or near capacity, it is also a wise practice to stagger startups for appliances.

SIZE OF HOUSE (IN SQUARE FEET)	RECOMMENDED GENERATOR SIZE (IN KILOWATTS)
Up to 2,700	5–11
2,701–3,700	14–16
3,701–4,700	20
4,701–7,000	42–47

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Types of Transfer Switches

Cord-connected transfer switches (shown above) are hard-wired to the service panel (in some cases they're installed after the service panel and operate only selected circuits). These switches contain a male receptacle for a power supply cord connected to the generator. Automatic transfer switches (not shown) detect voltage drop-off in the main power line and switch over to the emergency power source.

When using a cord-connected switch, consider mounting an inlet box to the exterior wall. This will allow you to connect a generator without running a cord into the house.

Generator Tips ▸

If you'll need to run sensitive electronics such as computers or home theater equipment, look for a generator with power inverter technology that dispenses "clean power" with a stable sine wave pattern.

A generator that will output 240-volt service is required to run most central air conditioners. If your generator has variable output (120/240) make sure the switch is set to the correct output voltage.

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Running & Maintaining a Backup System

Even with a fully automatic standby generator system fueled by natural gas or propane, you will need to conduct some regular maintenance and testing to make sure all systems are ready in the event of power loss. If you're depending on a portable generator and extension cords or a standby generator with a manual transfer switch, you'll also need to know the correct sequence of steps to follow in a power emergency. Switches and panels also need to be tested on a regular basis, as directed in your owner's manual. And be sure that all switches (both interior and exterior) are housed in an approved enclosure box.

Smaller portable generators often use pull-cords instead of electric starters.

ANATOMY OF A PORTABLE BACKUP GENERATOR

Portable generators use small gasoline engines to generate power. A built-in electronics panel sets current to AC or DC and the correct voltage. Most models will also include a built-in circuit breaker to protect the generator from damage in the event it is connected to too many loads. Better models include features like built-in GFCI protection. Larger portable generators may also feature electric starter motors and batteries for push-button starts.

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Operating a Manual System During an Outage

Plug the generator in at the inlet box. Make sure the other end of the generator's outlet cord is plugged into the appropriate outlet on the generator (120-volt or 120/240-volt AC) and the generator is switched to the appropriate voltage setting.

Start the generator with the pull-cord or electric starter (if your generator has one). Let the generator run for several minutes before flipping the transfer switch.

Flip the manual transfer switch. Begin turning on loads one at a time by flipping breakers on, starting with the ones that power essential equipment. Do not overload the generator or the switch, and do not run the generator at or near full capacity for more than 30 minutes at a time.

Maintaining & Operating an Automatic Standby Generator

If you choose to spend the money and install a dedicated standby generator of 10,000 watts or more and operate it through an automatic transfer switch or panel, you won't need to lift a hand when your utility power goes out. The system kicks in by itself. However, you should follow the manufacturer's instructions for testing the system, changing the oil, and running the motor periodically.

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Installing a Transfer Switch

A transfer switch is installed next to the main service panel to override the normal electrical service with power from a backup generator during a power outage. Manual transfer switches require an operator to change the power source, while automatic switches detect the loss of power, start the back-up generator, and switch over to the backup power feed. Because the amount of electricity created by a backup generator is not adequate to power all of the electrical circuits in your house, you'll need to designate a few selected circuits to get backup current (see page 81).

A manual transfer switch connects emergency circuits in your main panel to a standby generator.

Tools & Materials

- Circuit tester
- Drill/driver
- Screwdrivers
- Hammer
- Wire cutters
- Cable ripper
- Wire strippers
- Level
- Manual transfer switch
- Screws
- Wire connectors (yellow)
- Standby power generator

One flip of a switch reassigns the power source for each critical circuit so your backup generator can keep your refrigerator, freezer, and important lights running during an outage of utility power.

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Selecting Backup Circuits

Before you purchase a backup generator, determine which loads you will want to power from your generator in the event of a power loss. Generally you will want to power your refrigerator, freezer, and maybe a few lights. Add up the running wattage ratings of the appliances you will power up to determine how large your backup generator needs to be. Because the startup wattage of many appliances is higher than the running wattage, avoid starting all circuits at the same time—it can cause an overload situation with your generator. Here are some approximate running wattage guidelines (see page 132 to 137 for more information on calculating electrical loads):

- Refrigerator: 750 watts
- Forced air furnace: 1,100 to 1,500 watts
- Incandescent lights: 60 watts per bulb (CFL and LED lights use less wattage)
- Sump pump: 800 to 1,000 watts
- Garage door opener: 550 to 1,100 watts
- Television: 300 watts

Add the wattage values of all the loads you want to power, and multiply the sum by 1.25. This will give you the minimum wattage your generator must produce. Portable standby generators typically output 5,000 to 7,500 watts. Most larger, stationary generators can output 10,000 to 20,000 watts (10 to 20 kilowatts).

How to Install a Manual Transfer Switch

Turn off the main power breaker in your electrical service panel. CAUTION: The terminals where power enters the main breakers will still be energized.

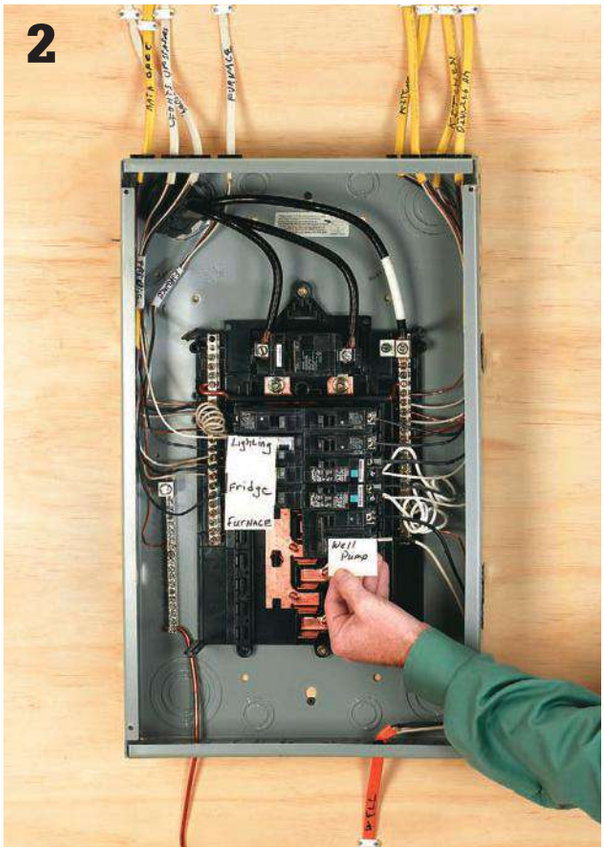

Determine which household circuits are critical for emergency usage during a power outage. Typically this will include the refrigerator, freezer, furnace, and at least one light or small appliance circuit.

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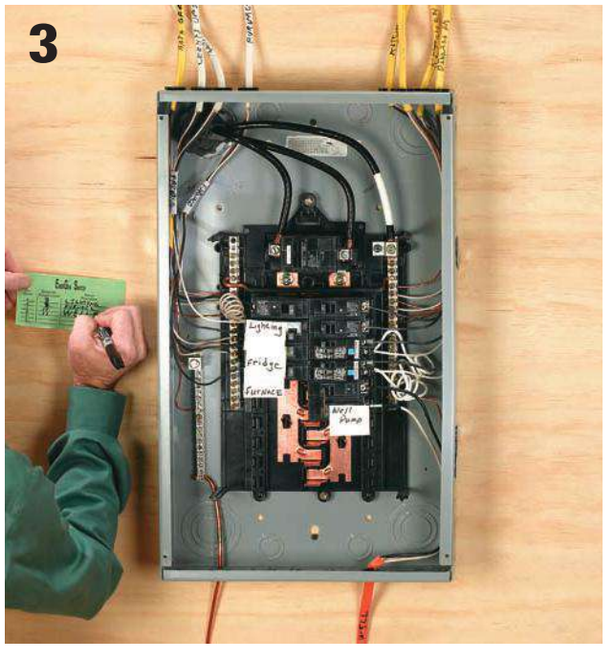

Match your critical circuits with circuit inlet on your pre-wired transfer switch. Try to balance the load as best you can in the transfer switch: For example, if your refrigerator is on the leftmost switch circuit, connect your freezer to the circuit farthest to the right. Double-pole (240-volt) circuits will require two 120-volt circuit connections. Also make sure that 15-amp and 20-amp circuits are not mismatched with one another.

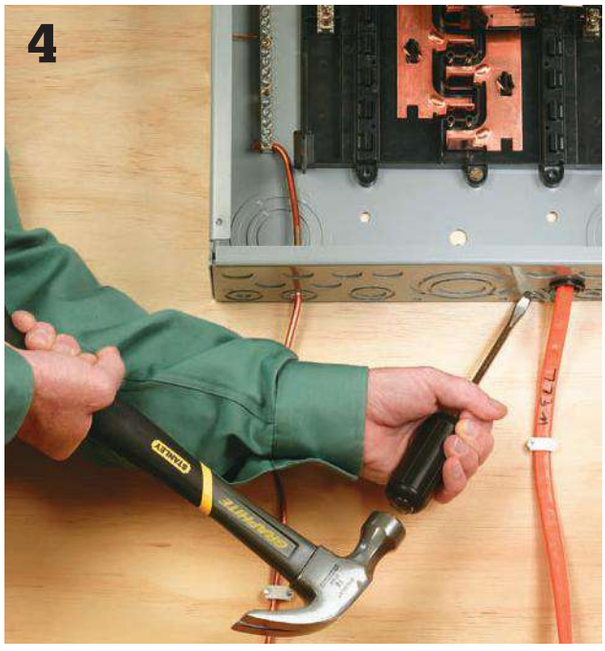

Select and remove a knockout at the bottom of the main service panel box. Make sure to choose a knockout that is sized to match the connector on the flexible conduit coming from the transfer switch.

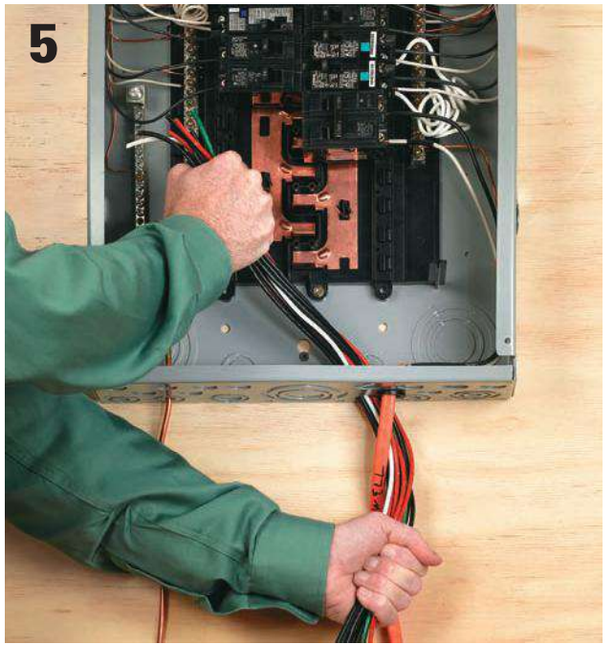

Feed the wires from the transfer switch into the knockout hole, taking care not to damage the insulation. You will note that each wire is labeled according to which circuit in the switch box it feeds.

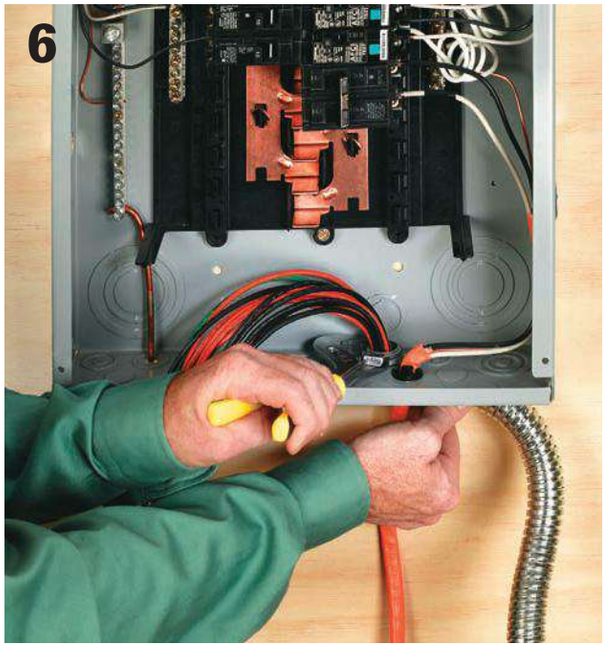

Secure the flexible conduit from the switch box to the main service panel using a locknut and a bushing where required.

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Attach the transfer switch box to the wall so the closer edge is about 18" away from the center of the main service panel. Use whichever connectors make sense for your wall type.

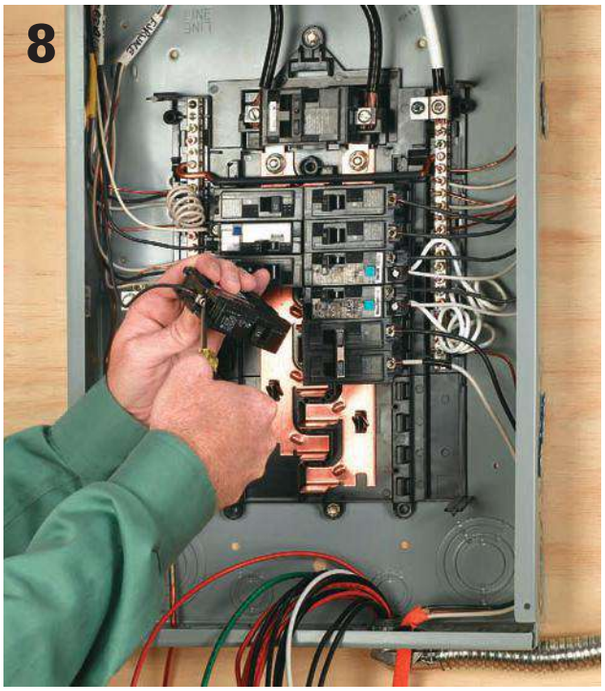

Remove the breaker for the first critical circuit from the main service panel box, and disconnect the hot wire lead from the lug on the breaker.

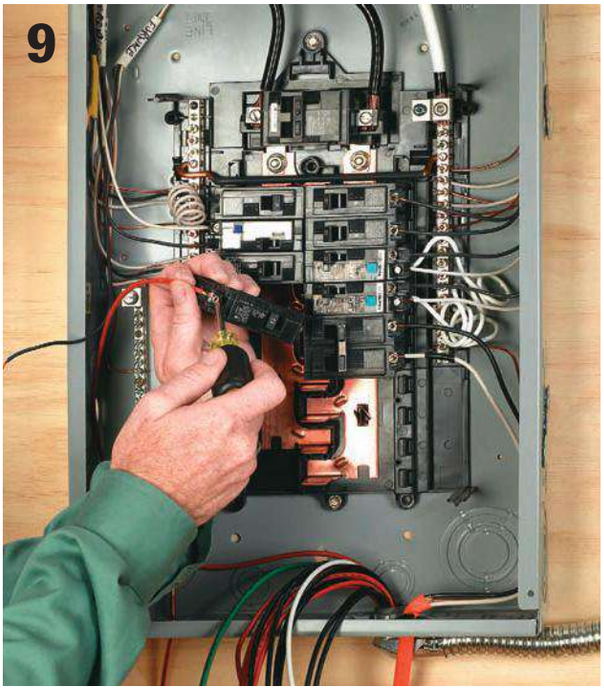

Locate the red wire for the switch box circuit that corresponds to the circuit you've disconnected. Attach the red wire to the breaker you've just removed, and then reinstall the breaker.

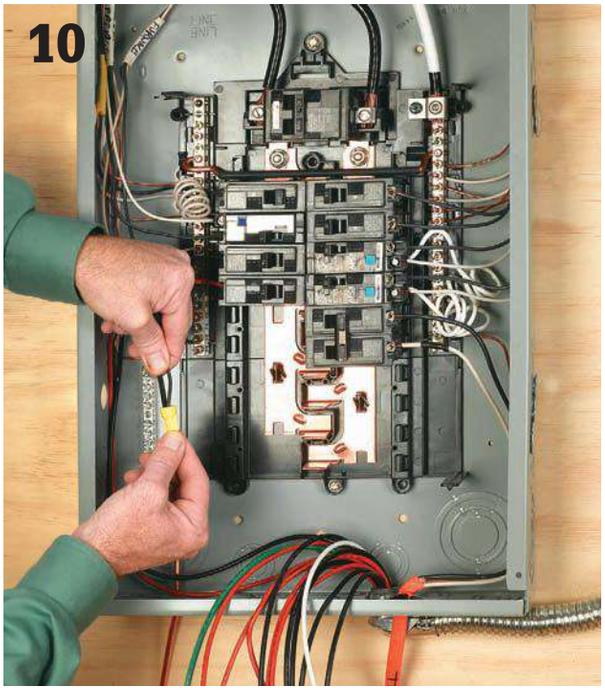

Locate the black wire from the same transfer switch circuit, and twist it together with the old feed wire, using a yellow wire connector. Tuck the wires neatly out of the way at the edges of the box. Proceed to the next circuit, and repeat the process.

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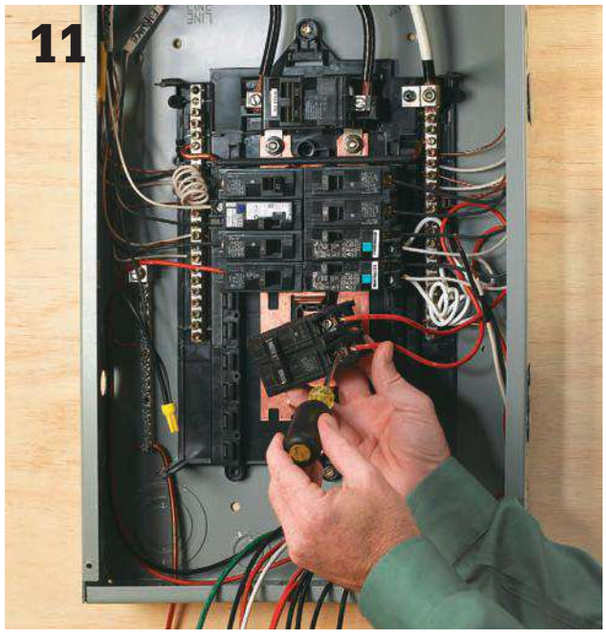

If any of your critical circuits are 240-volt circuits, attach the red leads from the two transfer switch circuits to the double-pole breaker. The two circuits originating in the transfer switch should be next to one another, and their switches should be connected with a handle tie. If you have no 240-volt circuits you may remove the preattached handle tie and use the circuits individually.

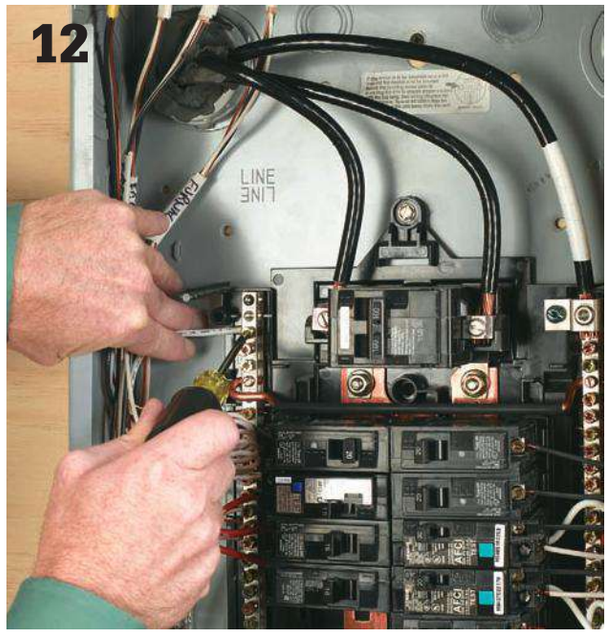

Once you have made all circuit connections, attach the white neutral wire from the transfer switch to an opening in the neutral bus bar of the main service panel.

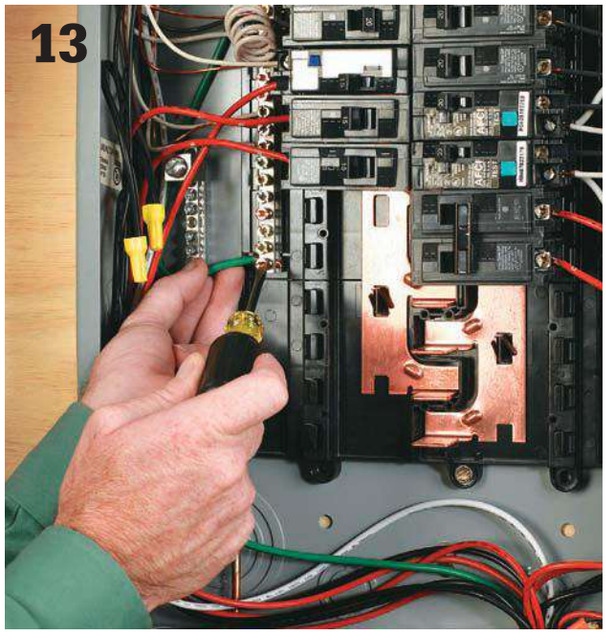

Attach the green ground wire from the transfer switch to an open port on the grounding bar in your main service panel. This should complete the installation of the transfer switch. Replace the cover on the service panel box, and make sure to fill in the circuit map on your switch box.

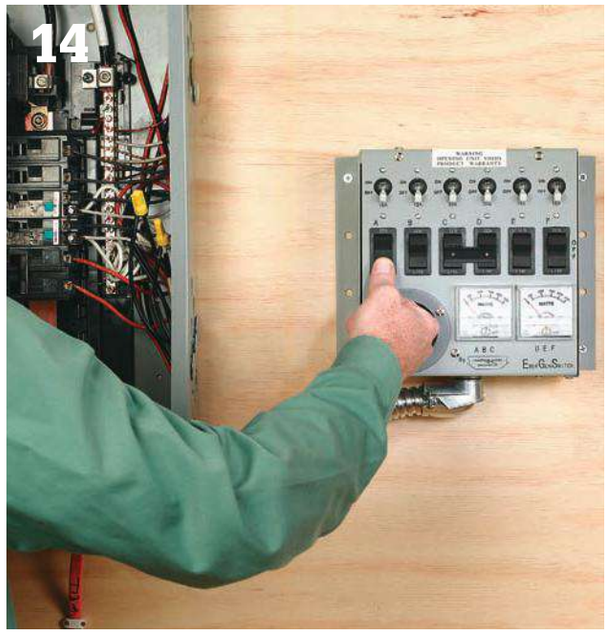

Begin testing the transfer switch by making sure all of the switches on it are set to the LINE setting. The power should still be OFF at the main panel breakers.

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Standby Generators ▸

Make sure your standby generator is operating properly and has been installed professionally. See page 76 for information on choosing a generator that is sized appropriately for your needs.

Before turning your generator on, attach the power cord from the generator to the switch box. Never attach or detach a generator cord with the generator running. Turn your standby power generator on, and let it run for a minute or two.

Flip each circuit switch on the transfer switch box to GEN, one at a time. Try to maintain balance by moving back and forth from circuits on the left and right side. Do not turn all circuits on at the same time. Observe the onboard wattage meters as you engage each circuit, and try to keep the wattage levels in balance. When you have completed testing the switch, turn the switches back to LINE, and then shut off your generator.

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Outbuildings

Nothing improves the convenience and usefulness of an outbuilding more than electrifying it. Running a new underground circuit from your house to an outbuilding lets you add receptacles and light fixtures both inside the outbuilding and on its exterior. If you run power to an outbuilding, you are required to install at least one receptacle.

Adding one or two 120-volt circuits is not complicated, but every aspect of the project is strictly governed by local building codes. Therefore, once you've mapped out the job and have a good idea of what's involved, visit your local building department to discuss your plans and obtain a permit for the work.

This project demonstrates standard techniques for running a circuit cable from the house exterior to a shed, plus the wiring and installation of devices inside the shed. To add a new breaker and make the final circuit connections to your home's main service panel, see page 52. If you run power to an outbuilding, you are required to install at least one receptacle.

First, determine how much current you will need. For basic electrical needs, such as powering a standard light fixture and small appliances or power tools, a 120-volt, 15-amp circuit should be sufficient. A small workshop may require one or two 120-volt, 20-amp circuits. If you need any 240-volt circuits or more than two 120-volt, 20-amp circuits, you will need to install at least a 60-amp subpanel with appropriate feeder wires. Installing a subpanel in an outbuilding is similar to installing one inside your home, but there are some important differences.

You may use #14 copper wire for one 120-volt, 15-amp circuit or #12 copper wire for one 120-volt, 20-amp circuit. Use #10 copper wire for two 120-volt, 20 amp circuits. Also, if the shed is more than 150 ft. away from the house, you may need heavier-gauge cable to account for voltage drop.

Most importantly, don't forget to call before you dig. Have all utility and service lines on your property marked even before you make serious project plans. This is critical for your safety of course, and it may affect where you can run the circuit cable.

Adding an electrical circuit to an outbuilding such as this shed greatly expands the activities the building will support and is also a great benefit for home security.

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Tools & Materials ▸

- Spray paint
- Trenching shovel (4" wide blade)
- 4" metal junction box
- Metal L-fittings (2) and conduit nipple for conduit
- Wood screws
- Conduit with watertight threaded and compression fittings
- Wrenches
- Hacksaw
- 90° sweeps for conduit (2)
- Plastic conduit bushings (2)
- Pipe straps
- Silicone caulk and caulk gun
- Double-gang boxes, metal (2)
- One exterior receptacle box (with cover)
- Single-pole switches (2)
- Interior ceiling light fixture and metal fixture box
- Exterior motion-detector fixture and plastic fixture box
- EMT metal conduit and fittings for inside the shed
- Utility knife
- UF two-wire cable (12 gauge)
- THNN wire (12 gauge)
- 20-amp GFCI-protected circuit breaker
- Wire stripper
- Pliers
- Screwdrivers
- Wire connectors
- Hand tamper
- Schedule 80 conduit
- Eye protection

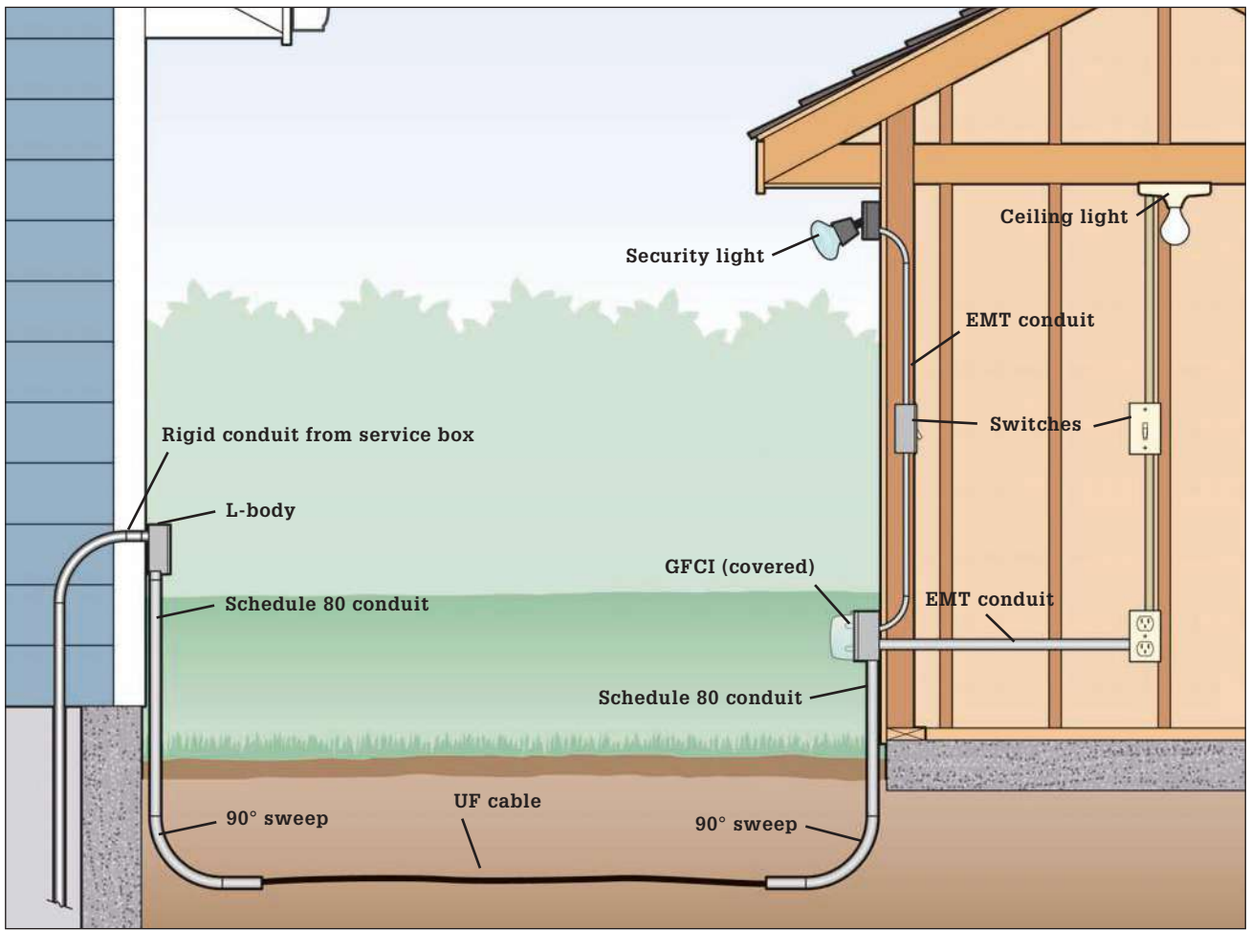

A basic outdoor circuit starts with a waterproof fitting at the house wall connected to a junction box inside. The underground circuit cable—rated UF (underground feeder)—runs in a 24"-deep trench and is protected from exposure at both ends by metal or PVC conduit. Inside the shed, standard NM cable runs through metal conduit to protect it from damage (not necessary if you will be adding interior wallcoverings). All receptacles in the shed must be GFCI protected.

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How to Wire an Outbuilding

Identify the circuit's exit point at the house and entry point at the shed and mark them. Mark the path of the trench between the exit and entry points using spray paint. Make the route as direct as possible. Dig the trench to the depth required by local code (24") using a narrow trenching shovel.

From outside, drill a hole through the exterior wall and the rim joist at the exit point for the cable (you'll probably need to install a bit extender or an extra-long bit in your drill). Make the hole just large enough to accommodate the L-body conduit fitting and conduit nipple.

Assemble the conduit and junction box fittings that will penetrate the wall. Here, we attached a 12" piece of ¾" IMC (intermediate metallic conduit) and a sweep to a metal junction box with a compression fitting and then inserted the conduit into the hole drilled in the rim joist. The junction box is attached to the floor joist.

From outside, seal the hole around the conduit with expandable spray foam or caulk, and then attach the free end of the conduit to the back of a waterproof L-body fitting. Mount the L-body fitting to the house exterior with the open end facing downward.

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Cut a length of IMC to extend from the L-fitting down into the trench using a hacksaw. Deburr the cut edges of the conduit. Secure the conduit to the L-fitting, and then attach a 90° sweep to the bottom end of the conduit using compression fittings. Add a bushing to the end of the sweep to protect the circuit cable. Anchor the conduit to the wall with a corrosion-resistant pipe strap.

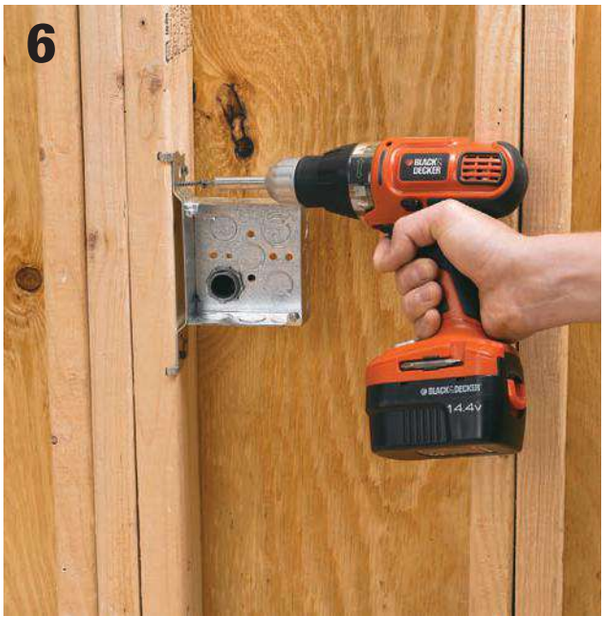

Inside the shed, drill a ¾" dia. hole in the shed wall. On the interior of the shed, mount a junction box with a knock-out removed to allow the cable to enter through the hole. On the exterior side directly above the end of the UF trench, mount an exterior-rated receptacle box with cover. The plan (and your plan may differ) is to bring power into the shed through the hole in the wall behind the exterior receptacle.

Run conduit from the exterior box down into the trench. Fasten the conduit to the building with a strap. Add a 90° sweep and bushing, as before. Secure the conduit to the box with an offset fitting. Anchor the conduit with pipe straps, and seal the entry hole with caulk.

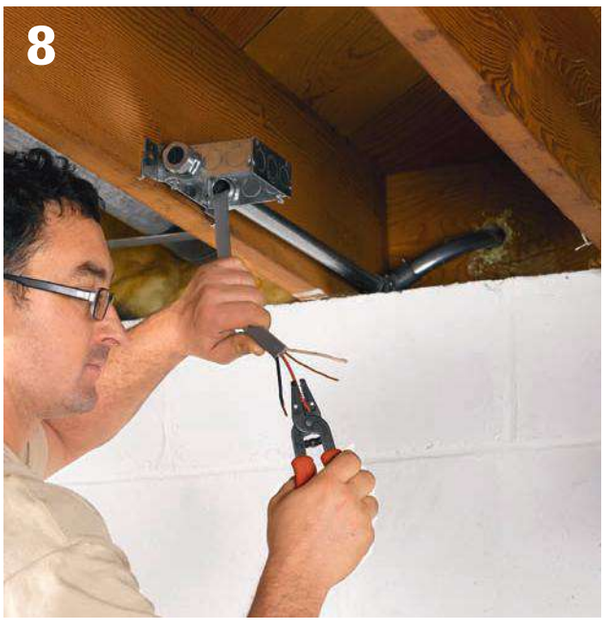

Run UF cable from the house to the outbuilding. Feed one end of the UF circuit cable up through the sweep and conduit and into the L-fitting at the house (the back or side of the fitting is removable to facilitate cabling). Run the cable through the wall and into the junction box, leaving at least 12" of extra cable at the end.

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Lay the UF cable into the trench, making sure it is not twisted and will not contact any sharp objects. Roll out the cable, and then feed the other end of the cable up through the conduit and into the receptacle box in the shed, leaving 12" of slack.

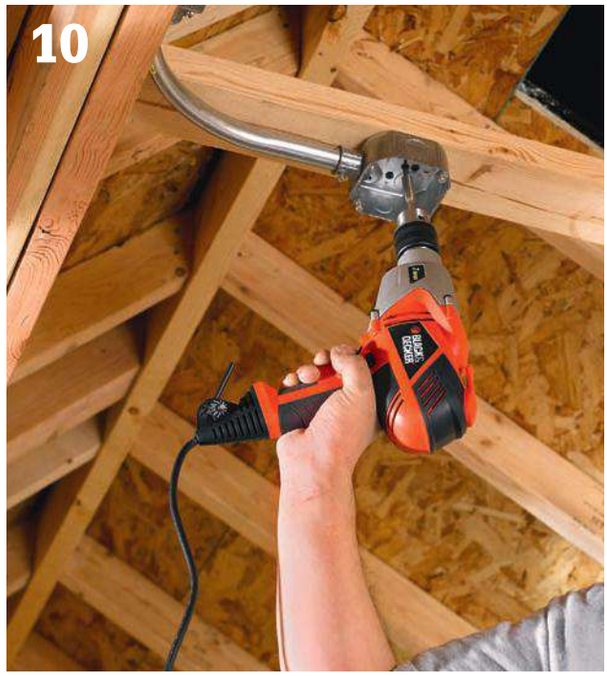

Inside the outbuilding, install the remaining boxes for the other switches, receptacles, and lights. With the exception of plastic receptacle boxes for exterior exposure, use metal boxes if you will be connecting the boxes with metal conduit.

Connect the electrical boxes with conduit and fittings. Inside the outbuilding, you may use inexpensive EMT to connect receptacle, switch, and fixture boxes. Once you've planned your circuit routes, start by attaching couplings to all of the boxes.

Cut a length of conduit to fit between the coupling and the next box or fitting in the run. If necessary, drill holes for the conduit through the centers of the wall studs. Attach the conduit to the fitting that you attached to the first box.

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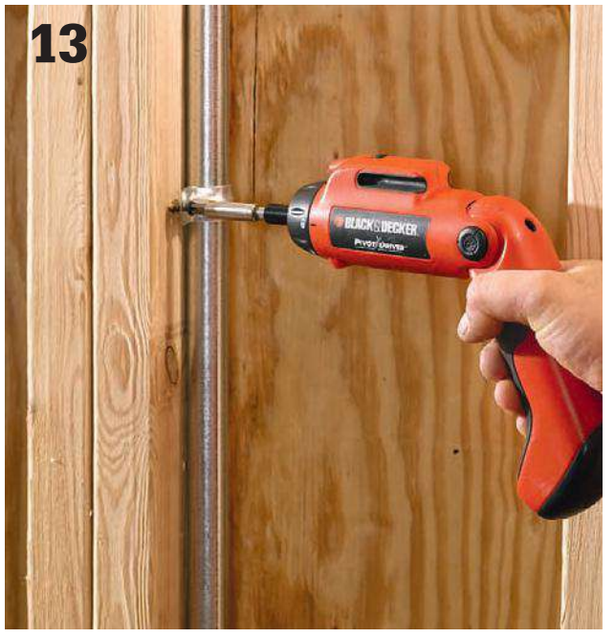

If you are surface-mounting the conduit or running it up or down next to wall studs, secure it with straps no more than 3 ft. apart. Use elbow fittings for 90° turns and setscrew couplings for joining straight lengths as needed. Make holes through the wall studs only as large as necessary to feed the conduit through.

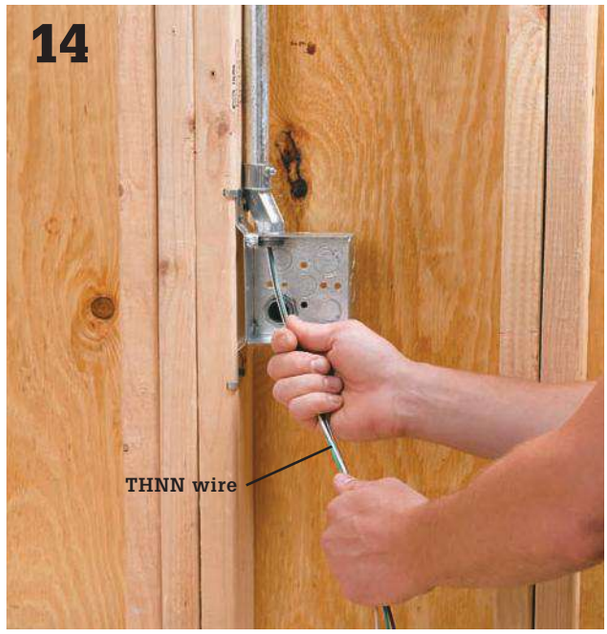

Measure to find how much wire you'll need for each run, and cut pieces that are a foot or two longer. Before making L-turns with the conduit, feed the wire through the first conduit run.

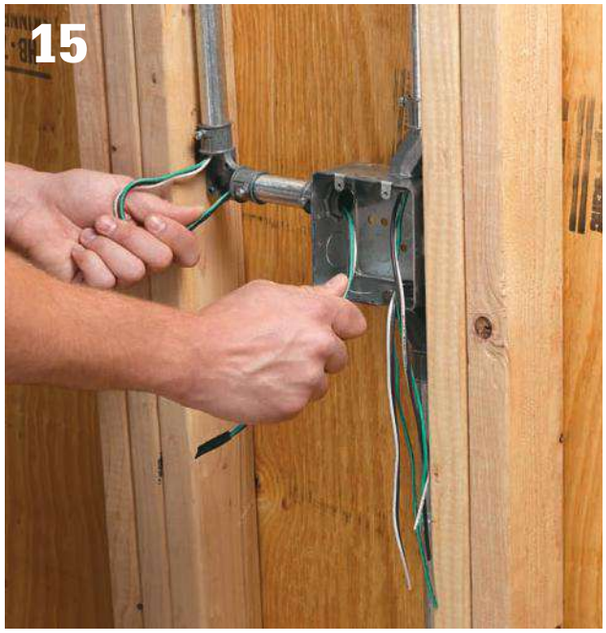

Feed the other ends of the wires into the next box or fitting in line. It is much easier to feed wire into 45° and 90° elbows if they have not been attached to the conduit yet. Continue feeding wire into the conduit and fitting until you have reached the next box in line.

Once you've reached the next box in line, coil the ends of the wires and repeat the process with new wire for the next run. Keep working until all of the wire is run and all of the conduit and fittings are installed and secured. If you are running multiple feed wires into a single box, write the origin or destination on a piece of masking tape and stick it to each wire end.

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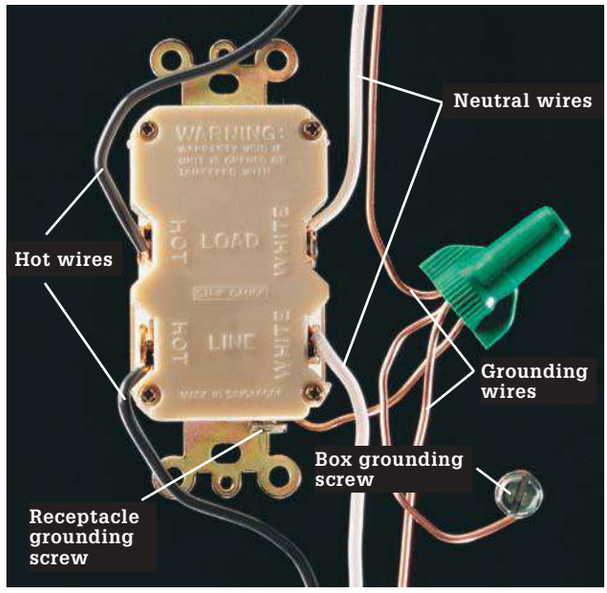

Make the wiring connections at the receptacles. Strip ¾" of insulation from the circuit wires using a wire stripper. Connect the white (neutral) wire and black (hot) wire of the UF cable to the LINE screw terminals on the receptacle. Connect the white (neutral) and black (hot) wires from the NM cable to the LOAD terminals. Pigtail the bare copper ground wires and connect them to the receptacle ground terminal and the metal box. Install the receptacle and cover plate.

Variation: Installing a GFCI-protected breaker for the new circuit at the main service panel is the best way to protect the circuit and allows you to use regular receptacles in the building, but an alternative that is allowed in many areas is to run the service into a GFCI-protected receptacle and then wire the other devices on the circuit in series. If you use this approach, only the initial receptacle needs to be a GFCI receptacle.

Continue installing receptacles in the circuit run, and then run service from the last receptacle to the switch box for the light fixture or fixtures. (If you anticipate a lot of load on the circuit, you should probably run a separate circuit for the lights). Twist the white neutral leads and grounding leads together and cap them. Attach the black wires to the appropriate switches. Install the switches and cover plate.

Install the light fixtures. For this shed, we installed a caged ceiling light inside the shed and a motion-detector security light on the exterior side.

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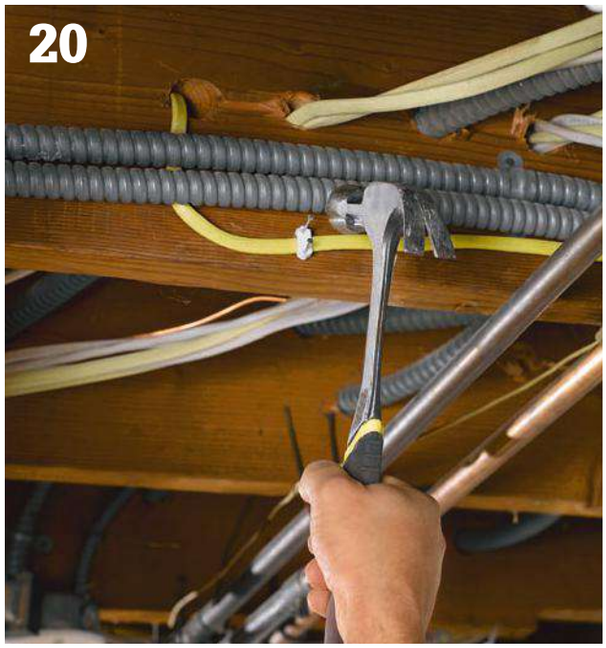

Run NM cable from the electrical box in the house at the start of the new circuit to the main service panel. Use cable staples if you are running the cable in floor joist cavities. If the cable is mounted to the bottom of the floor joists or will be exposed, run it through conduit.

At the service panel, feed the NM cable in through a cable clamp. Arrange for your final electrical inspection before you install the breaker. Then attach the wires to a new circuit breaker, and install the breaker in an empty slot. Label the new circuit on the circuit map.

Turn on the new circuit, and test all of the receptacles and fixtures. Depress the Test button and then the Reset button if you installed a GFCI receptacle. If any of the fixtures or receptacles is not getting power, check the connections first, and then test the receptacle or switch for continuity with a multimeter. Backfill the trench.

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Standalone Solar Lighting System

A self-contained electrical circuit with dedicated loads, usually 12-volt light fixtures, is one of the most useful solar amenities you can install. A standalone system is not tied into your power grid, which greatly reduces the danger of installing the components yourself. Plus, the fact that your light fixtures are independent of the main power source means that even during a power outage you will have functioning emergency and security lights.

Installing a single solar-powered circuit is relatively simple, but don't take the dangers for granted. Your work will require permits and inspections in most jurisdictions, and you can't expect to pass if the work is not done to the exact specifications required.

Solar panels that convert the sun's energy into electricity are called photovoltaic (PV) panels, and they produce direct current (DC) power. PV solar panel systems can be small and designed to accomplish a specific task, or they can be large enough to provide power or supplementary power to an entire house. Before you make the leap into a large system, it's a good idea to familiarize yourself with the mechanics of solar power. The small system demonstrated in this project is relatively simple and is a great first step into the world of solar. The fact that the collector, battery, and lights are a standalone system makes this a very easy project to accomplish. By contrast, installing panels that provide direct supplementary power through your main electrical service panel is a difficult wiring job that should be done by professional electricians only.

This 60-watt solar panel is mounted on a garage roof and powers a self-contained home security lighting system. Not only does this save energy costs, it keeps the security lights working even during power outages.

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Schematic Diagram for an Off-the-Grid Solar Lighting System

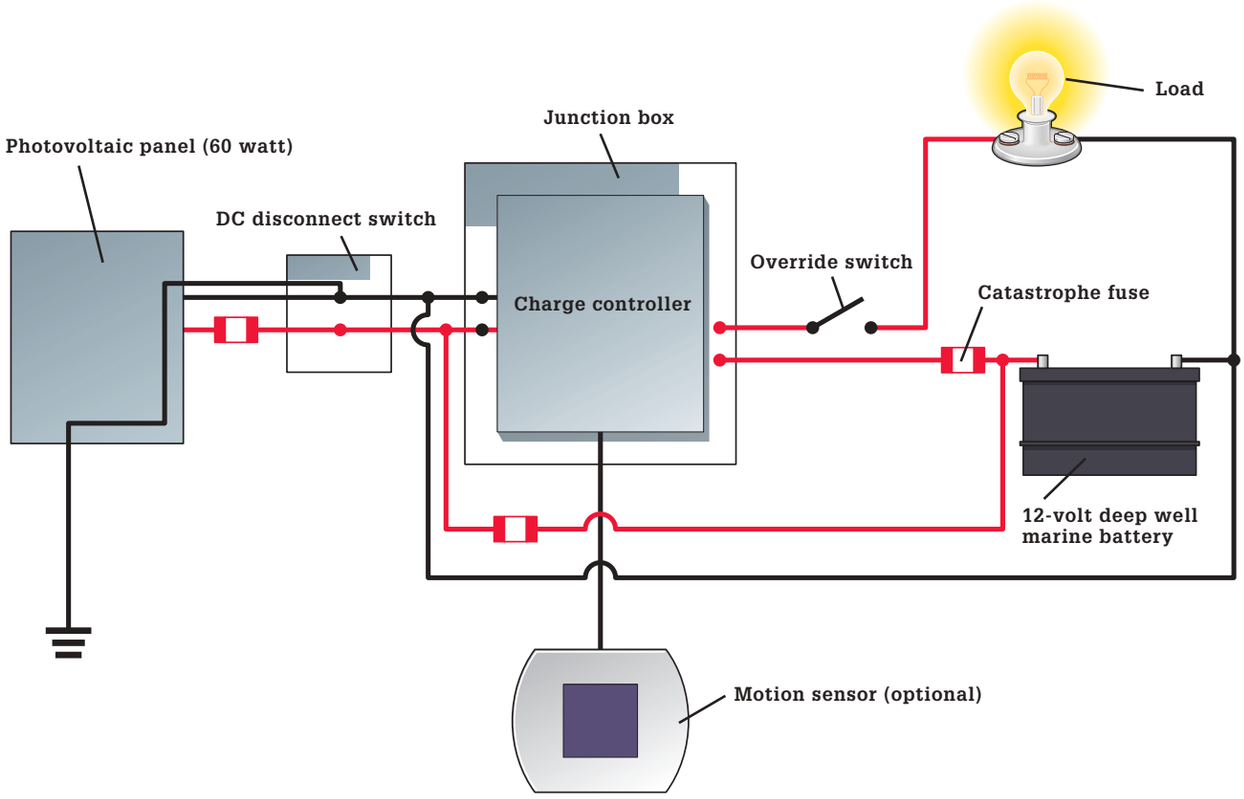

Tools & Materials

Tape measure
Drill/driver with bits
Caulk gun
Crimping tool
Wiring tools
Metal-cutting saw
Photovoltaic panel (50 to 80 watts)
Charge controller
Catastrophe fuse
Battery sized for 3 day autonomy
Battery case
Battery cables
12-volt LED lights including motion-sensor light
Additional 12-volt light fixtures as desired
20 ft. Unistrut 1⅞" thick U-channel (See Resources, page 125)
(4) 45° Unistrut connectors
(2) 90° Unistrut angle brackets
(4) Unistrut hold down clamps
(12) ⅜" spring nuts
(12) ⅜"-dia. × 1"-long hex-head bolts with washers
DC-rated disconnect or double throw snap switch
6" length of ½"-dia. liquid-tight flexible metallic conduit
(2) ½" liquid tight connectors
(2) Lay-in grounding lugs
(2) Insulated terminal bars to accept one 2-gauge wire and 4 12-gauge wires
(2) Cord cap connectors for ½"-dia. cable
½" ground rod and clamp
Copper wire (6, 12-gauge)
Green ground screws
½" Flexible metallic conduit or Greenfield
½" Greenfield connectors
(4) 11⁄16" junction boxes with covers
(4) square boxes with covers
PVC 6"× 6" junction box with cover
14/2 UF wire
¼" × 20 nuts and bolts with lock washers
Roof flashing boot
Roof cement
Silicon caulk
Eye protection

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Mounting PV Panels

The mounting stand for the PV panel is constructed from metal U-channel (a product called Unistrut is seen here. See Resources page 125) and pre-bent fasteners. Position the solar panel where it will receive the greatest amount of sunlight for the longest period of time each day—typically the south-facing side of a roof or wall. For a circuit with a battery reserve that powers two to four 12-volt lights, a collection panel rated between 40 and 80 watts of output should suffice. These panels can range from $200 to $600 in price, depending on the output and the overall quality.

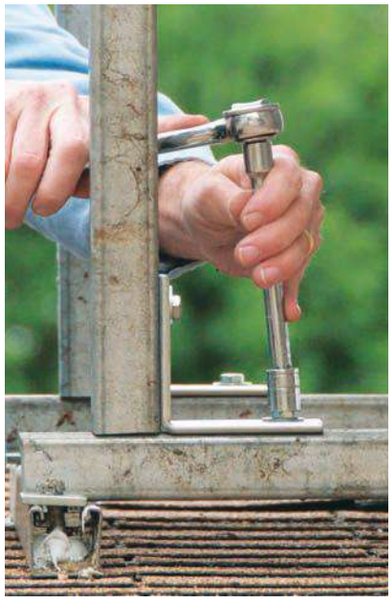

The stand components are held together with bolts and spring-loaded fasteners. The 45° and 90° connectors are manufactured specifically for use with this Unistrut system.

Connections for the feed wires that carry current from the collector are made inside an electrical box mounted on the back of the collector panel.

An EPDM rubber boot seals off the opening where the PVC conduit carrying the feed wires penetrates the roof.

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How to Wire a DC Lighting Circuit

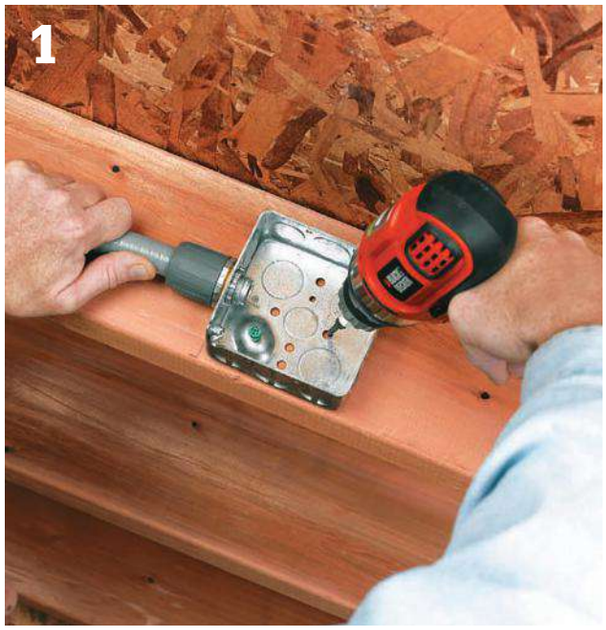

Mount a junction box inside the building where the conduit and wiring enter from the power source. Secure the box to the conduit with appropriate connectors. Run two #14 awg wires through the conduit and connect them to the positive and negative terminals on the panel (see previous page).

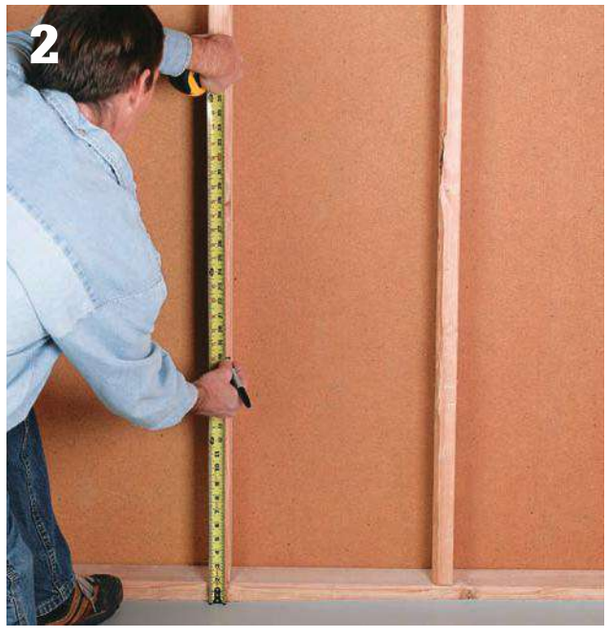

Plan the system layout. Determine the placement of the battery, and then decide where you will position the charge controller and DC disconnect. The battery should be placed at least 18" off the floor, in a well-ventilated area where it won't be agitated by everyday activity. Mark locations directly on the wall.

Attach a junction box for enclosing the DC disconnect, which is a heavy-duty switch, to a wall stud near the battery and charge controller location. Use a metal single-gang box with mounting flanges.

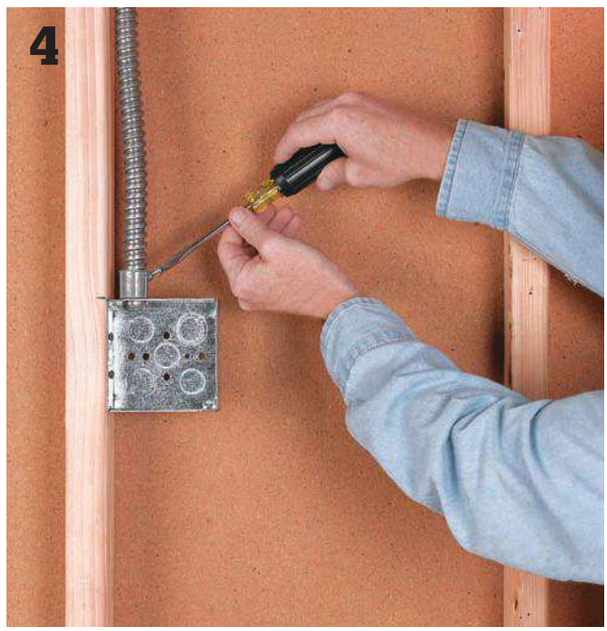

Run flexible metal conduit from the entry point at the power source to the junction box for the DC disconnect box. Use hangers rated for flexible conduit.

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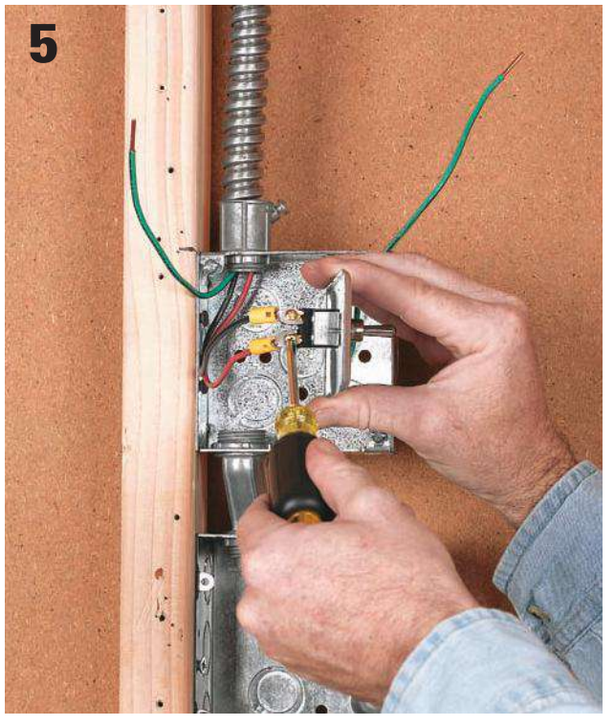

Attach the DC disconnect switch to the wire leads from the power source.

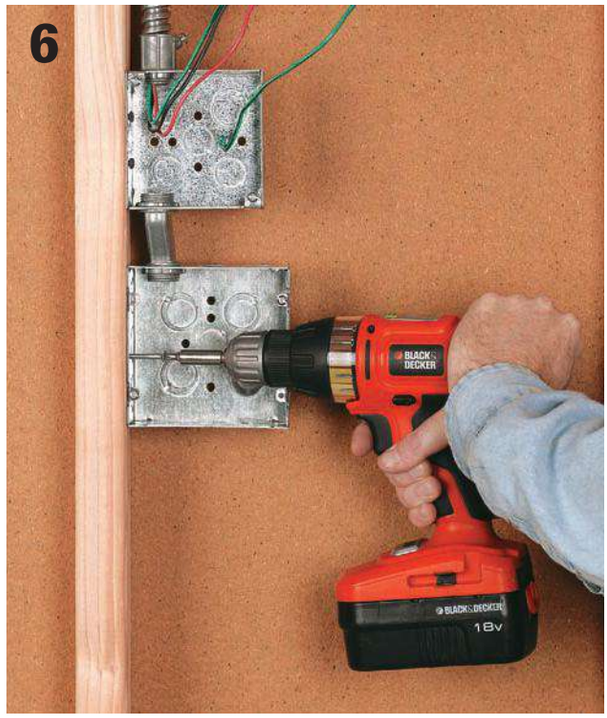

Attach a double gang metal junction box to the building's frame beneath the DC disconnect box to enclose the charge controller.

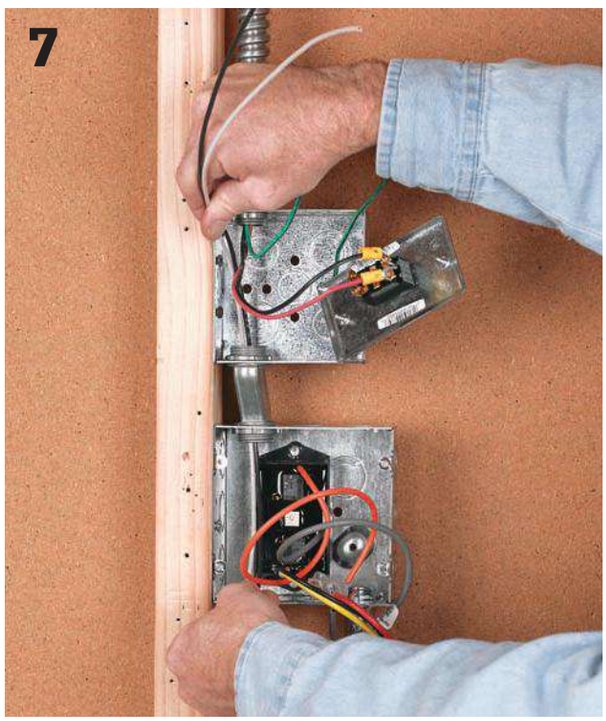

Install the charge controller inside the box. Run flexible conduit with connectors and conductors from the disconnect box and to the charge controller box.

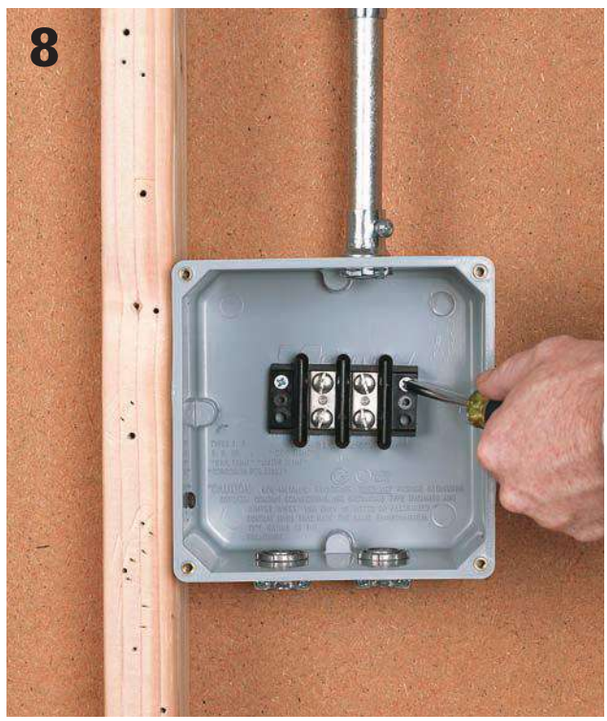

Mount a PVC junction box for the battery controller about 2 ft. above the battery location, and install two insulated terminal bars within the box.

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Build a support shelf for the battery using 2 × 4s. The shelf should be at least 18" above ground. Set the battery on the shelf in a sturdy plastic case.

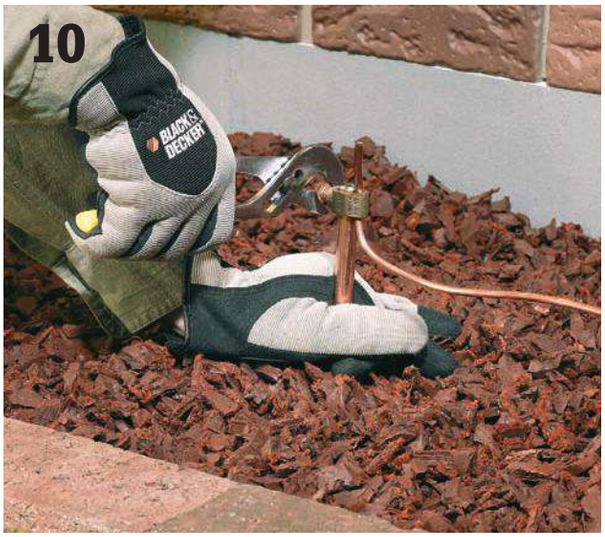

Set up grounding protection. Pound an 8-ft. long, ½"-dia. ground rod into the ground outside the building, about 1 ft. from the wall on the opposite side of the charge controller. Leave about 2" of the rod sticking out of the ground. Attach a ground rod clamp to the top of the rod. Drill a 5/16" hole through the garage wall (underneath a shake or siding piece) and run the #6-gauge THWN wire to the ground rod. This ground will facilitate lightning protection. See pages 58 to 63 for more information on grounding the system.

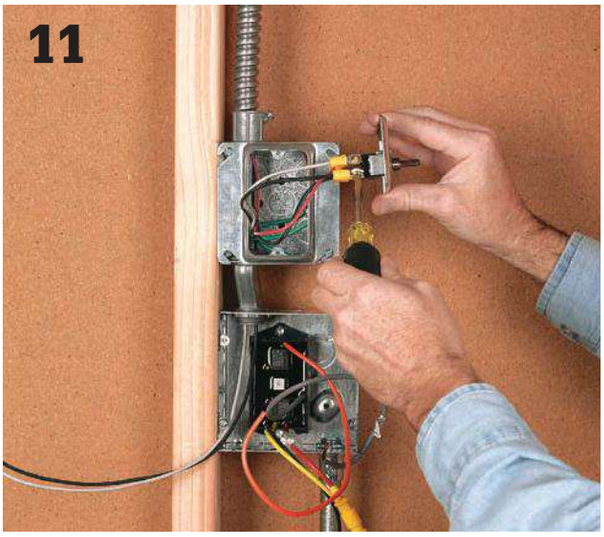

Wire the DC disconnect. Attach the two #14-gauge wires to the two terminals labeled "line" on the top of the DC disconnect switch.

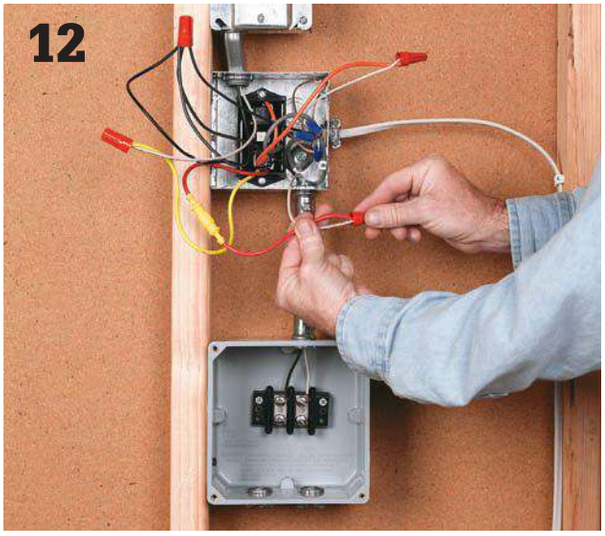

Wire the charge controller. Route two more #14-gauge wires from the bottom of the DC disconnect terminals into the 4" × 1 1/16" junction box and connect to the "Solar Panel In" terminals on the charge controller. The black wire should connect to the negative terminal in the PVC box and the red to the positive lead on the charge controller. Finish wiring of the charge controller according to the line diagram provided with the type of controller purchased. Generally the load wires connect to the orange lead, and the red wire gets tied to the battery through a fuse.

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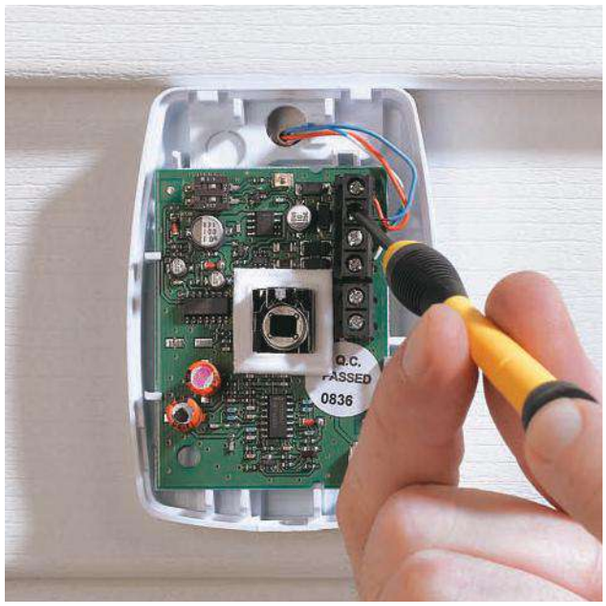

OPTION: Attach a motion sensor. Some charge controllers come equipped with a motion sensor to maximize the efficiency of your lighting system—these are especially effective when used with security lighting. The motion sensor is typically mounted to a bell box outside and wired directly to the charge controller with an 18-gauge × 3-conductor insulated cable. A system like this can support up to three motion sensors. Follow the manufacturer's directions for installing and wiring the motion sensor.

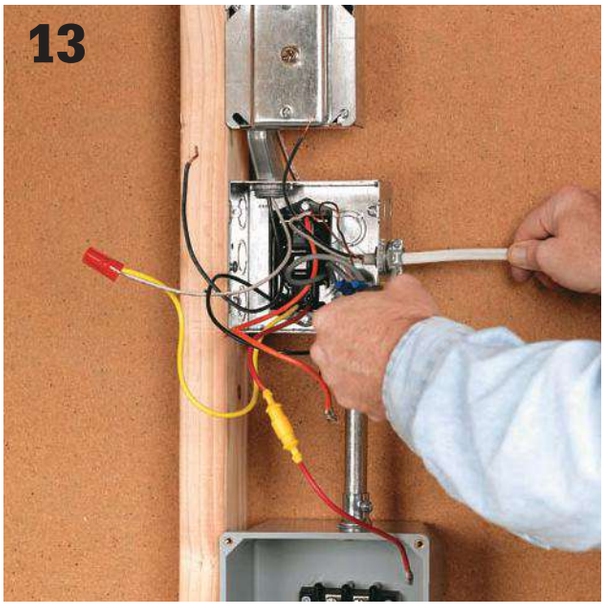

Run wiring to the loads (exterior DC lighting fixtures in this case) from the charge controller. DC light fixtures (12-volt) with LED bulbs can be purchased at marine and RV stores if you can't find them in your home center or electrical supply store.

Install the battery. Here, a deep-cell 12-volt marine battery is used. First, cut and strip each of the two battery cables at one end and install into the battery control junction box through cord cap connectors. Terminate these wires on two separate, firmly mounted insulated terminal blocks.

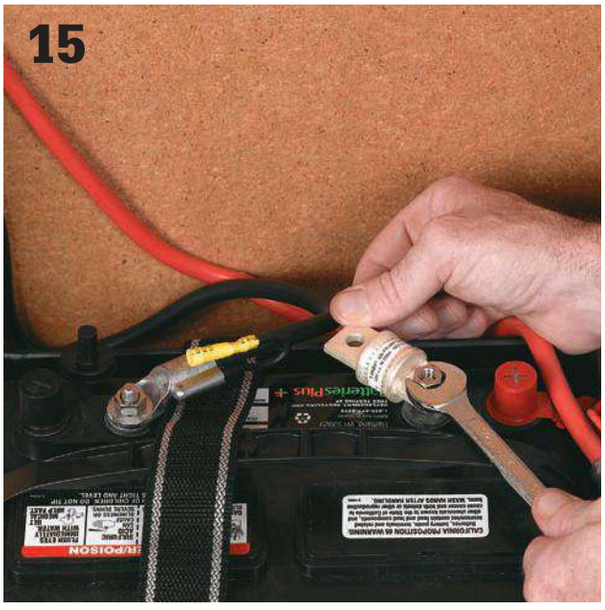

Install the catastrophe fuse onto the positive terminal using nuts and bolts provided with the battery cables. Connect the battery cables to the battery while paying close attention to the polarity (red to positive and black to negative). Make sure all connections have been made and double checked.

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Troubleshooting & Repairs

Running new circuits and hooking up new fixtures are fairly predictable projects when it comes to estimating time and expense. This is less true with repairing problems in your system and fixtures. In some cases, a repair is as simple as opening an electrical box, spotting a loose wire connector and remaking the connection. But there are also times when fixing a dead circuit or device is a highly frustrating proposition. Such cases are almost always caused by tricky diagnostic challenges. Wires are hidden behind walls and there very often are no visual clues to system breakdowns. So essentially, minimizing repair frustration boils down to learning to deploy logical, systematic diagnostics. Educated troubleshooting, you could say.

In this project you'll learn how to use the most important diagnostic tool in any electrician's toolkit: the multimeter. These handy devices come in a dizzying array of types and qualities, but for diagnostic purposes they are used to take readings for current (amperage), voltage and continuity (whether an electrical path is open or closed). Once you learn the basics of operating a multimeter, you can enlist it in a logical, deductive manner to track down the source of a wiring problem. Once located, correcting the problem is usually very simple.

Diagnostic tools for home wiring use include: Touchless circuit tester (A) to safely check wires for current and confirm that circuits are dead; Plug-in tester (B) to check receptacles for correct polarity, grounding and circuit protection; Multimeter (C) to measure AC/DC voltage, AC/DC current, resistance, capacitance, frequency and duty cycle (model shown is an auto-ranging digital multimeter with clamp-on jaws that measure through sheathing and wire insulation).

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Multimeters

Multimeters are nearly indispensible diagnostic tools for doing intermediate to advanced level electrical work (as well as automotive and electronics repair). They are used to measure voltage, current (amperage) and a few other conditions such as continuity, capacitance and frequency. For your home electrical system, by far the most used feature of a multimeter is testing voltage and current, although there are occasions where testing for resistance is needed. Among professional electricians, the most common and widely used multimeters have a clamp-on ammeter that measures current through the wire insulation so you don't have to disconnect the circuit and expose bare wire. Most clamp-on multimeters also are fitted with insertible probes with which you can measure voltage and continuity in the traditional way. An example of a clamp-on multimeter can be seen on the next page. Among homeowners, however, the most common multimeters these days are digital, auto-ranging tools that use probes or alligator clamps at the ends of wire leads for diagnostic work. Older multimeters that do not have autoranging capability must be pre-set to estimated calibration levels before use. Non-digital multimeters or ammeters usually have a dial gauge that gives readouts. These tools are somewhat more difficult to use and are less precise. Considering that digital, autoranging multimeters can be found for just a few dollars (the top of the line models cost over $100) there is really no good reason not to replace your old device with one that resembles the tools seen on these pages.

Time to Replace that Neon Tester ▸

Neon circuit testers are inexpensive and easy to use (if the light glows the circuit is hot), but they are less sensitive than multimeters and can be unsafe. In some cases, neon testers won't detect the presence of lower voltage in a circuit. This can lead you to believe that a circuit is shut off when it is not—a dangerous mistake. The small probes on a neon circuit tester also force you to get too close to live terminals and wires. For the most reliable readings, buy and learn to use a multimeter. At the very least, switch to a touchless tester like the one on page 107, Step 1.

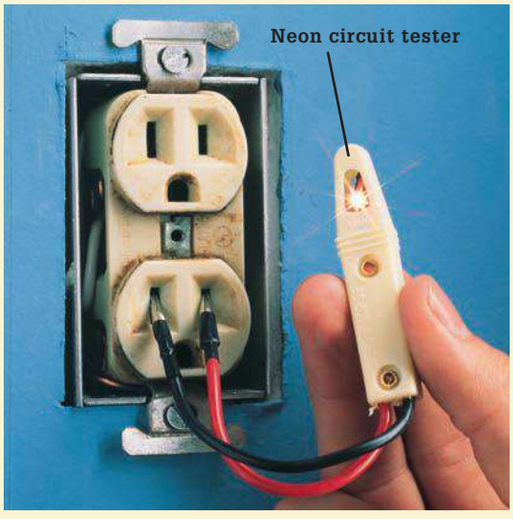

A digital, autoranging multimeter must be adjusted to the proper setting for the reading you want to take. The probe leads also must be inserted into the correct inlet at the bottom of the tool. Inserting the red lead into the incorrect inlet can cause the tool to trip an internal fuse. Study your owner's manual carefully before using any tool.

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How to Measure Current

Create access to the wires you need to test. In most cases this requires that you remove the cover to an electrical service panel or an electrical box (inset).

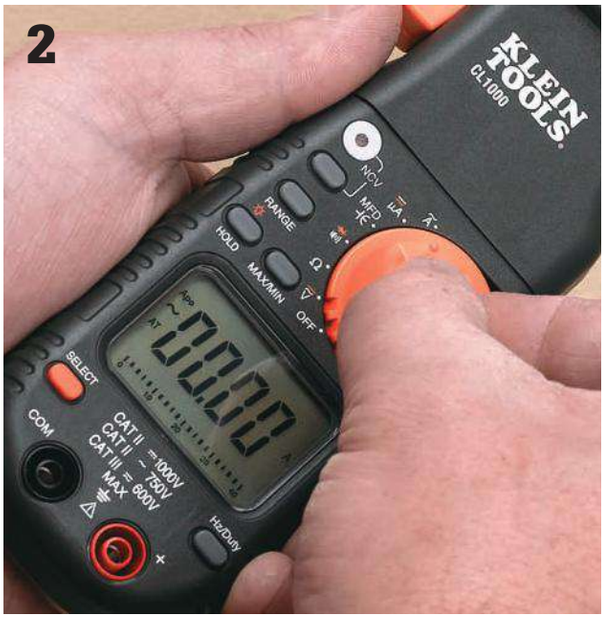

Set the multimeter to test for amperage (current is measured in amperes or amps). On some multimeters you need to select between amperage settings that are above or below 40 amps. Use the rated amperage of the circuit as a guide (amperage is printed on the circuit breaker switch).

Clamp the jaws of a clamp-on multimeter onto the conductor or one of the conductors (if more than one) leading to a circuit breaker. If you are using a non-clamping multimeter, touch one probe to the screw terminal where the hot lead is attached to the breaker and touch the other probe to the metal panel box. The readout on your meter is the amount of current flowing in that circuit.

Taking Measurements at a Receptacle ▸

You may use a multimeter to measure for voltage at a wall receptacle. Regardless of whether the outlet is in service, if it is live you will get a voltage reading in the approximate range of the receptacle rating—here, 120 volts. To detect live current, measured in amps, the receptacle must be in use, with an appliance drawing from it. Taking an amperage reading in such an instance will only yield the amount of current being drawn, which is a factor of the appliance, not the circuit capacity.

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How to Measure Voltage

To measure voltage using the multimeter, you will have to use the two probes provided with the multimeter and have access to a live terminal or slot as well as a grounded terminal or slot. If your meter has probe holders at the top, snap the probes into them. They are like extra hands.

Turn the multimeter to the VAC setting to measure AC voltage that is found in your house. Set the multimeter to VDC if measuring DC voltage, such as in a car or a battery-fed device. On some multimeters, like the one above, you select "V" for voltage then change between AC and DC with the"FUNC" button.

To measure the AC voltage, place one probe on a grounded surface, such as the metallic junction box or the bare ground wire. Place the other probe on the hot screw terminal or into the receptacle slot associated with the hot wire. The voltage readout should be in the range of 120 volts, plus or minus 5 volts (usually 120 volts in a residence in the US).

240 VOLTS. You can also measure voltage across the two hot leads to determine if you have 240 volts. This can be done at your range receptacle, dryer receptacle, or any other 240-volt receptacle. Place one probe in one of the small slots and the other probe in the other slot directly across from it. The voltage should read 240 volts, plus or minus 5 volts.

DC Voltage. When testing DC voltage, such as in a car battery, you can measure exactly the same way as for AC as long as the meter is set to the DC function. For more accurate results, test the voltage while the battery is in use.

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How to Test for Continuity

Continuity is a condition in a circuit where the conductors form an unbroken pathway through which current may flow. When measuring for continuity, always make sure there is no power present on the circuit you are testing or damage may occur to the meter. You can also measure the resistance in this mode as well.

The setting for continuity is an "audible" or diode symbol display on the dial. Select this setting.

Verify that the continuity tester is functional by touching the two probes together. You should hear an alert sound and/or see a reading of zero ohms (Ohms is a value of the resistance to current flow).

To test a circuit, touch one probe to one of the wires on a given circuit and the other to the second wire of the circuit. If you hear an audible sound or read a value of resistance other than zero, you have a complete or unbroken path for current to flow.

How to Test a 3-way Switch

Remove the switch from the circuit and place one of the probes onto the common terminal and the other probe onto one of the other two terminals used for the traveler wires. If the meter indicates infinity ohms or there is no sound, flip the switch and if it is in working order the meter should read zero ohms or emit an audible sound. It should only work in one direction or the other, not both.

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Troubleshooting an Open Neutral

An open neutral is an electrical problem where the circuit is broken on the return path wire or neutral (white wire). When this situation occurs anything plugged into or connected to this circuit can experience low or high voltage, which could damage voltage sensitive electronics such as a computer or flat screen TV. The lights will be dim or not work at all, depending upon where the problem lies within the circuit.

Possible Symptoms of an Open Neutral ▸

1. When a whole circuit does not work and the breaker associated with that circuit is operating normally.
2. When the neutral or white wire registers as a hot wire by using a non contact voltage tester when the circuit breaker is on. This most likely indicates a problem between the main service panel and the utility transformer. The condition should be readable on other receptacles as well.
3. If you register a voltage lower than 110 volts between the hot and neutral.
4. When the incandescent lights work, but are very dim.
5. When the fluorescent lights are barely lit and are flickering.
6. Discoloration of the wires or exposed copper turning green under the wirenut holding the neutral wires together.

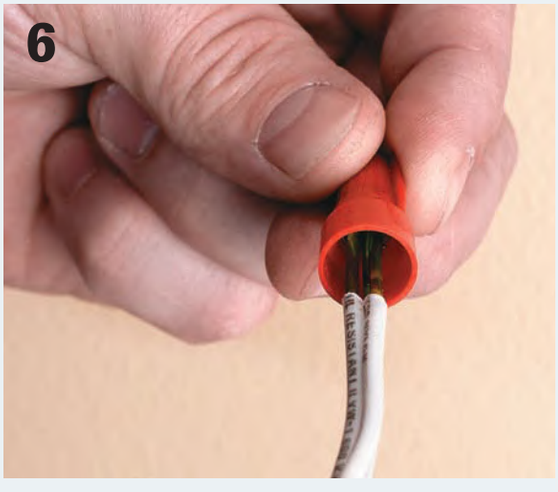

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How to Troubleshoot an Open Neutral

Verify which lights and receptacles are on the circuit by turning the breaker off and by checking for power with a non-contact voltage tester. It is helpful to either draw a map of the house or place some tape on every affected opening.

Start at the outlet nearest to the panel. With the breaker off and using a multimeter, check for continuity between the neutral (white wire) and the ground (bare or green wire). These two wires land at the same point electrically in your electrical panel. If there is an indication of continuity between these two wires, the neutral and ground connections are sound and you should proceed to the next outlet as you move away from the panel.

When you encounter a point at which you read infinity ohms or there is no continuity between the neutral and ground wires, the problem lies within the connections in that box or the box just upstream (toward) the panel from the one you are checking. Sometimes you will see evidence of arcing on the wire cap containing the connection which may include discoloration, or a blackish char near the copper.

When you have found the problem connection, remove the wire cap and, if it is possible, cut the damaged portions of the wires off and restrip the wires to expose new copper. Line the wire ends up and twist on a new wire cap.

Turn the circuit breaker back on and verify the proper voltage is present at your receptacles by measuring with a multimeter.

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Troubleshooting a Short Circuit

Short circuits are a direct connection between the hot or power wire (black or red) and to either the neutral (white) or ground (bare) wire. This connection between the two will cause your circuit breaker or fuse to blow, which should interrupt power to the affected circuit.

Short circuits are a common problem and can usually be solved by taking the following steps. The idea behind electrical troubleshooting is to simplify the circuit by checking it at certain points, in order to narrow down the problem point by process of elimination. Generally, the problem is that there is a bare ground wire touching a hot terminal within a switch or an outlet box. There will usually be a black scorched mark or some sign of an electrical arc where the problem lies.

How to Troubleshoot a Short Circuit

Turn the power off at the affected breaker and verify with a non-contact voltage tester that there is no power present. Unplug everything from the receptacles and turn the lights off on the circuit that is affected.

Using a multimeter set to the ohms or continuity setting, check the wires at the panel. Touch one of the probes to the hot or black wire and the other probe to the ground or bare wire. If the meter rings or indicates a low resistance value, you have a direct short to ground. If the meter does not ring or indicates a high resistance value the circuit is clear. If the meter does not ring, start by turning the switches on one-by-one and re-testing to verify the resistance value. If the meter indicates a low resistance value or a short circuit, the problem is downstream from the switch or within the light fixture itself.

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If the meter consistently rings or indicates a low resistive value, you will need to find the electrical box that contains the affected circuit. Choose a box that is convenient to open and preferably in the middle of the run, such as a receptacle. Verify there is no power present by touching all of the wires within the box with a non-contact voltage tester.

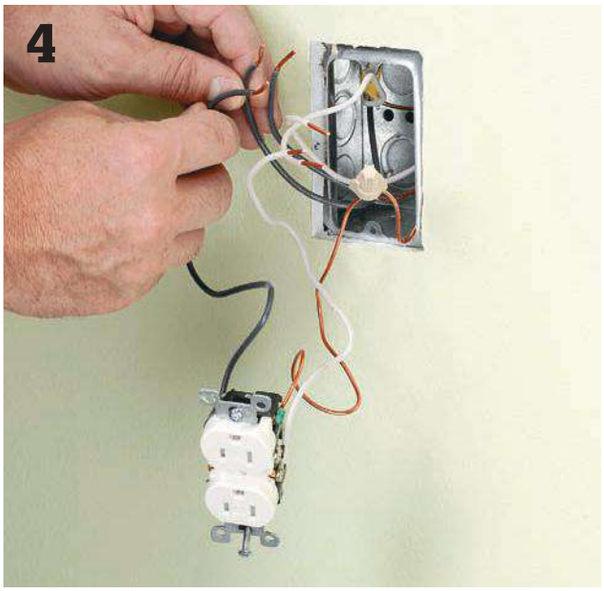

If the box you have chosen is in fact in the middle of the run, it will contain at least two cables. Remove the receptacle from the two cables and separate all of the wires.

Check the resistance between the black and the ground on both sets of cables. One of the cables should cause the continuity alert to ring and the other should not. Mark the affected one with a piece of black tape and place wire caps over the exposed ends of the black wires.

Check the wires at the panel to see if the short has cleared. If the short is clear, the problem lies down stream from the opened box and it is now safe to turn the breaker back on to help eliminate further problem points. If the short is still present, the problem lies between the opened electrical box and the panel.

Choose another box in the middle of the affected circuit, there by narrowing down the possible problem areas until the short circuit can be positively identified and corrected. When you have discovered the short circuit, verify the wires are still in good shape and repair the connection.

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Types of Wall Switches

Wall switches are available in three general types. To re-connect or replace a switch, it is important to identify its type.

Single-pole switches are used to control a set of lights from one location. Three-way switches are used to control a set of lights from two different locations and are always installed in pairs. Four-way switches are used in combination with a pair of three-way switches to control a set of lights from three or more locations.

Identify switch types by counting the screw terminals. Single-pole switches have two screw terminals, three-way switches have three screw terminals, and four-way switches have four. Most switches include a grounding screw terminal, which is identified by its green color.

When replacing a switch, choose a new switch that has the same number of screw terminals as the old one. The location of the screws on the switch body varies depending on the manufacturer, but these differences will not affect the switch operation.

Whenever possible, connect switches using the screw terminals rather than push-in fittings. Some specialty switches (pages 118 to 119) have wire leads instead of screw terminals. They are connected to circuit wires with wire connectors.

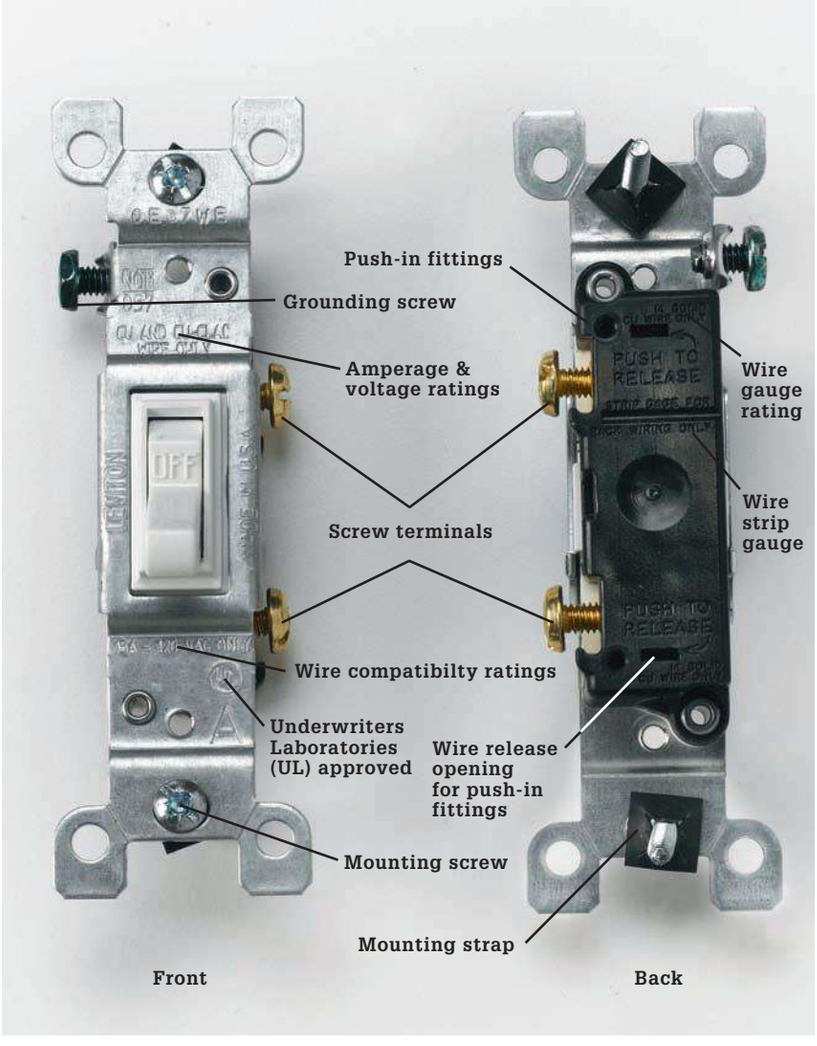

A wall switch is connected to circuit wires with screw terminals or with push-in fittings on the back of the switch. A switch may have a stamped strip gauge that indicates how much insulation must be stripped from the circuit wires to make the connections.

The switch body is attached to a metal mounting strap that allows it to be mounted in an electrical box. Several rating stamps are found on the strap and on the back of the switch. The abbreviation UL or UND. LAB. INC. LIST means that the switch meets the safety standards of the Underwriters Laboratories. Switches also are stamped with maximum voltage and amperage ratings. Standard wall switches are rated 15A or 125V. Voltage ratings of 110, 120, and 125 are considered to be identical for purposes of identification.

For standard wall switch installations, choose a switch that has a wire gauge rating of #12 or #14. For wire systems with solid-core copper wiring, use only switches marked COPPER, CU, or CO/ALR. For aluminum wiring, use only switches marked CO/ALR. Note that while CO/ALR switches and receptacles are approved by the National Electrical Code for use with aluminum wiring, the Consumer Products Safety Commission does not recommend using these. Switches and receptacles marked AL/CU can no longer be used with aluminum wiring, according to the National Electrical Code.

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Single-Pole Wall Switches

A single-pole switch is the most common type of wall switch. It has ON-OFF markings on the switch lever and is used to control a set of lights, an appliance, or a receptacle from a single location. A single-pole switch has two screw terminals and a grounding screw. When installing a single-pole switch, check to make sure the ON marking shows when the switch lever is in the up position.

In a correctly wired single-pole switch, a hot circuit wire is attached to each screw terminal. However, the color and number of wires inside the switch box will vary, depending on the location of the switch along the electrical circuit.

If two cables enter the box, then the switch lies in the middle of the circuit. In this installation, both of the hot wires attached to the switch are black.

If only one cable enters the box, then the switch lies at the end of the circuit. In this installation (sometimes called a switch loop), one of the hot wires is black, but the other hot wire usually is white. A white hot wire should be coded with black tape or paint.

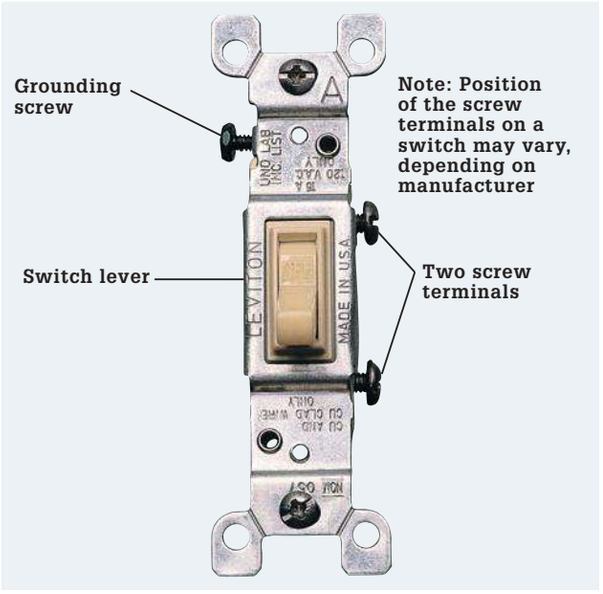

A single-pole switch is essentially an interruption in the black power supply wire that is opened or closed with the toggle. Single-pole switches are the simplest of all home wiring switches.

Typical Single-Pole Switch Installations

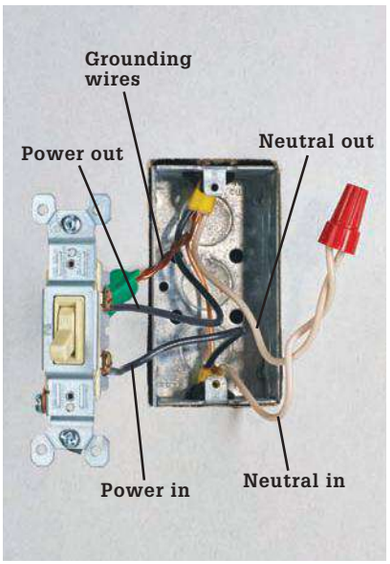

Two cables enter the box when a switch is located in the middle of a circuit. Each cable has a white and a black insulated wire, plus a bare copper grounding wire. The black wires are hot and are connected to the screw terminals on the switch. The white wires are neutral and are joined together with a wire connector. Grounding wires are pigtailed to the switch.

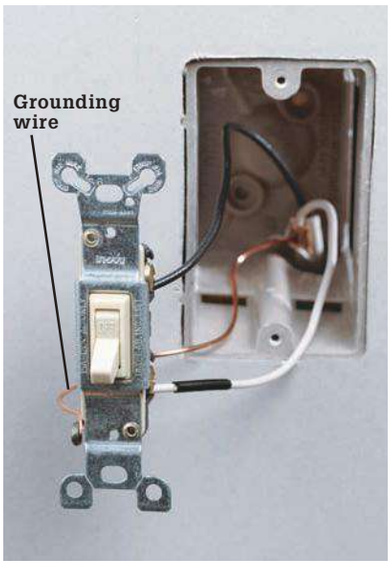

Old method: One cable enters the box when a switch is located at the end of a circuit. In this installation, both of the insulated wires are hot. The white wire should be labeled with black tape or paint to identify it as a hot wire. The grounding wire is connected to the switch grounding screw.

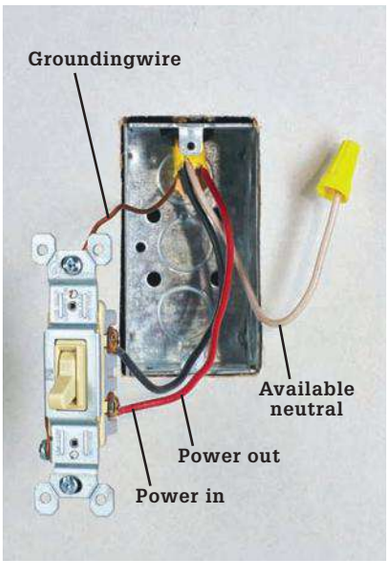

Code change: In new switch wiring, the white wire should not supply current to the switched device and a separate neutral wire should be available in the switch box.

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Three-Way Wall Switches

Three-way switches have three screw terminals and do not have ON-OFF markings. Three-way switches are always installed in pairs and are used to control a set of lights from two locations.

One of the screw terminals on a three-way switch is darker than the others. This screw is the common screw terminal. The position of the common screw terminal on the switch body may vary, depending on the manufacturer. Before disconnecting a three-way switch, always label the wire that is connected to the common screw terminal. It must be reconnected to the common screw terminal on the new switch.

The two lighter-colored screw terminals on a three-way switch are called the traveler screw terminals. The traveler terminals are interchangeable, so there is no need to label the wires attached to them.

Because three-way switches are installed in pairs, it sometimes is difficult to determine which of the switches is causing a problem. The switch that receives greater use is more likely to fail, but you may need to inspect both switches to find the source of the problem.

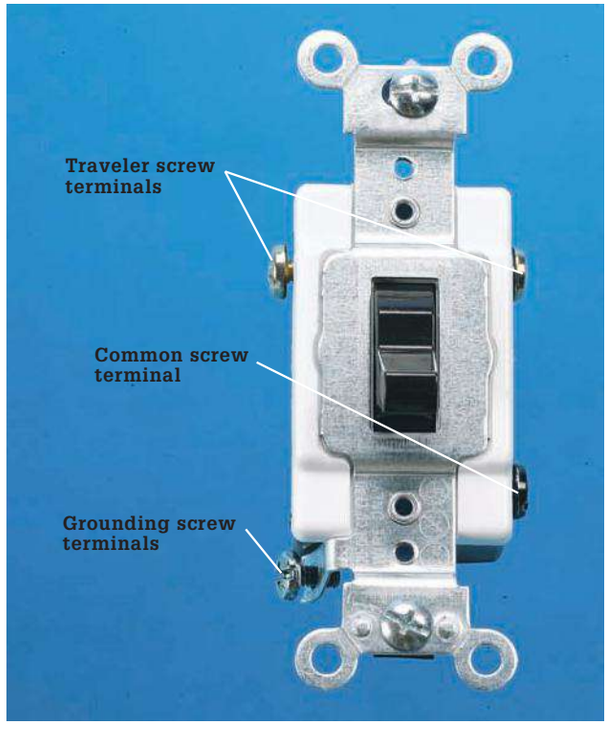

Typical Three-Way Switch Installation

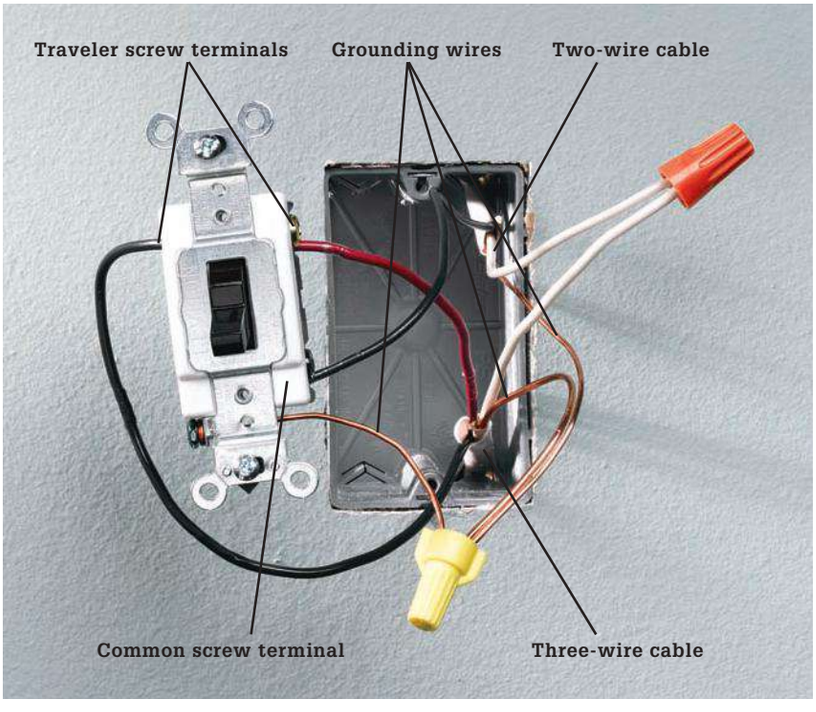

Two cables enter the box: one cable has two wires, plus a bare copper grounding wire; the other cable has three wires, plus a ground. The black wire from the two-wire cable is connected to the dark common screw terminal. The red and black wires from the three-wire cable are connected to the traveler screw terminals. The white neutral wires are joined together with a wire connector, and the grounding wires are pigtailed to the grounded metal box.

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How to Replace a Three-Way Wall Switch

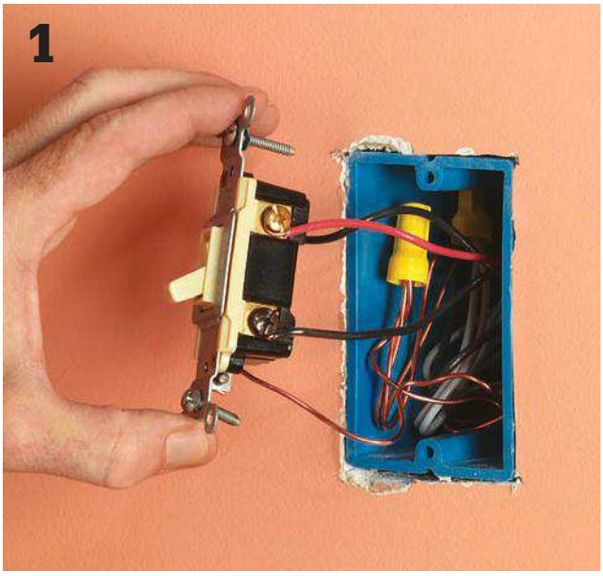

Turn off the power to the switch at the panel, and then remove the switch cover plate and mounting screws. Holding the mounting strap carefully, pull the switch from the box. Be careful not to touch the bare wires or screw terminals until they have been tested for power. *Note: If you are installing a new switch circuit, you must provide a neutral conductor at the switch.*

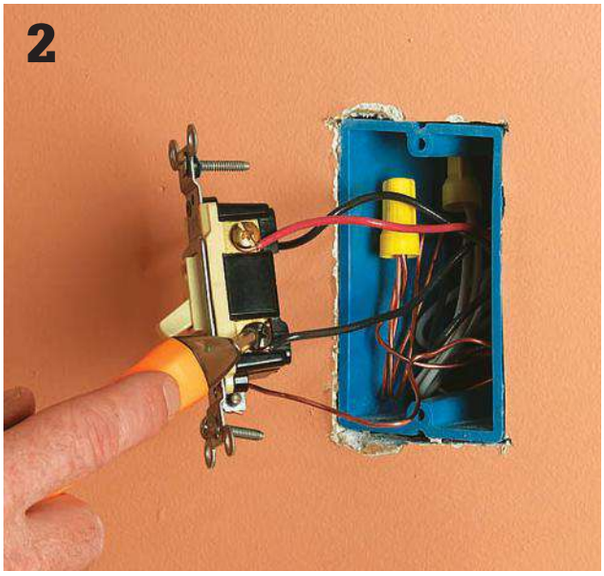

Test for power by touching one probe of the circuit tester to the grounded metal box or to the bare copper grounding wire and touching the other probe to each screw terminal. Tester should not glow. If it does, there is still power entering the box. Return to the panel, and turn off the correct circuit.

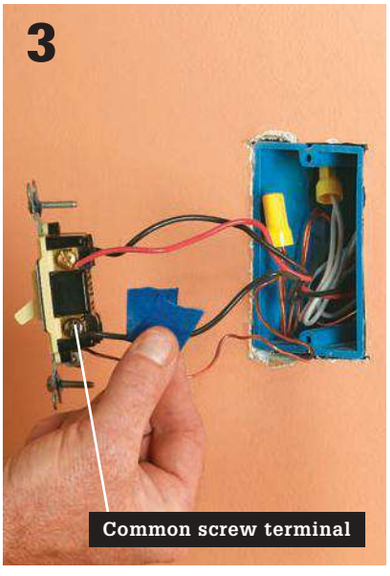

Locate the dark common screw terminal, and use masking tape to label the "common" wire attached to it. Disconnect wires and remove switch. Test the switch for continuity. If it tests faulty, buy a replacement. Inspect wires for nicks and scratches. If necessary, clip damaged wires and strip them.

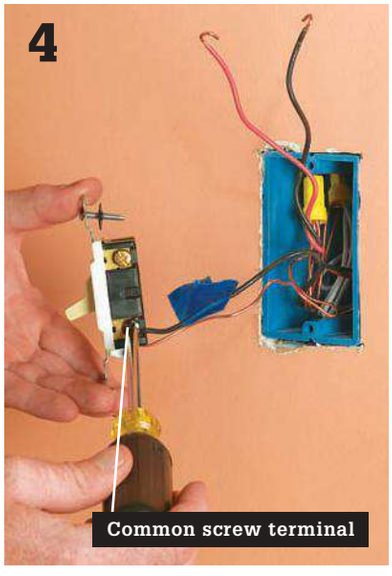

Connect the common wire to the dark common screw terminal on the switch. On most three-way switches, the common screw terminal is black. Or it may be labeled with the word COMMON stamped on the back of the switch. Reconnect the grounding screw, and connect it to the circuit grounding wires with a pigtail.

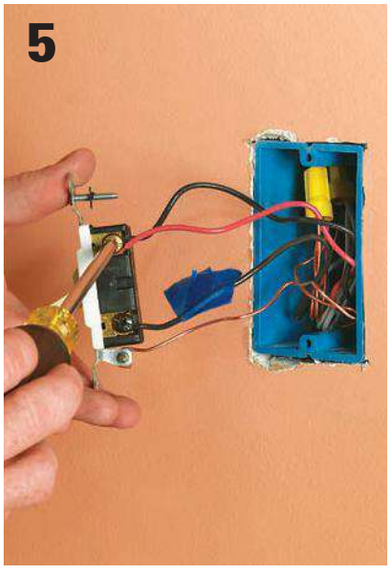

Connect the remaining two circuit wires to the screw terminals. These wires are interchangeable and can be connected to either screw terminal. Carefully tuck the wires into the box. Remount the switch, and attach the cover plate. Turn on the power at the panel.

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Four-Way Wall Switches

Four-way switches have four screw terminals and do not have ON-OFF markings. Four-way switches are always installed between a pair of three-way switches. This switch combination makes it possible to control a set of lights from three or more locations. Four-way switches are common in homes where large rooms contain multiple living areas, such as a kitchen opening into a dining room. Switch problems in a four-way installation can be caused by loose connections or worn parts in a four-way switch or in one of the three-way switches (facing page).

In a typical installation, there will be a pair of three-wire cables that enter the box for the four-way switch. With most switches, the white and red wires from one cable should be attached to the bottom or top pair of screw terminals, and the white and red wires from the other cable should be attached to the remaining pair of screw terminals. However, not all switches are configured the same way, and wiring configurations in the box may vary, so always study the wiring diagram that comes with the switch.

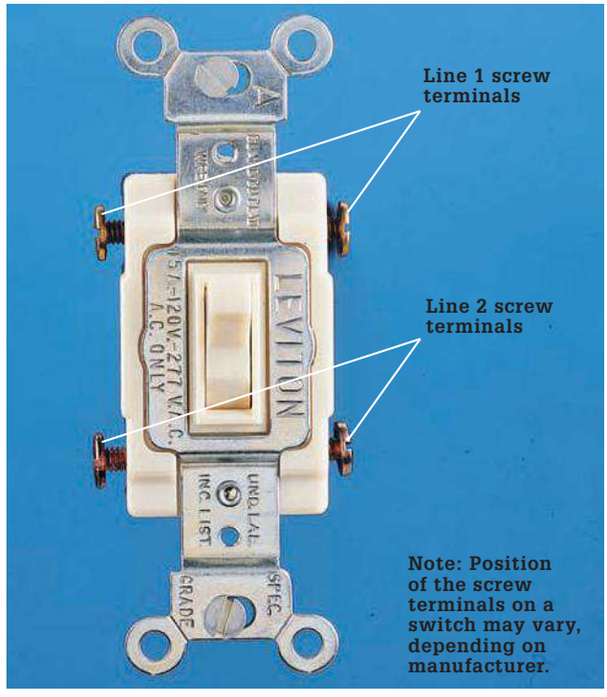

Typical Four-Way Switch Installation

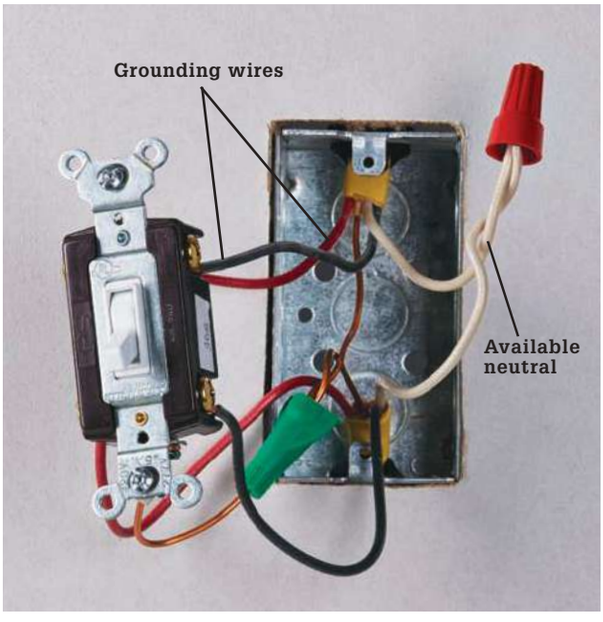

Four wires are connected to a four-way switch. The red and white wires from one cable are attached to the top pair of screw terminals, while the red and white wires from the other cable are attached to the bottom screw terminals. In new switch wiring, the white wire should not supply current to the switched device, and a separate neutral wire should be available in the switch box.

Switch variation: Some four-way switches have a wiring guide stamped on the back to help simplify installation. For the switch shown above, one pair of color-matched circuit wires will be connected to the screw terminals marked LINE 1, while the other pair of wires will be attached to the screw terminals marked LINE 2.

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How to Replace a Four-Way Wall Switch

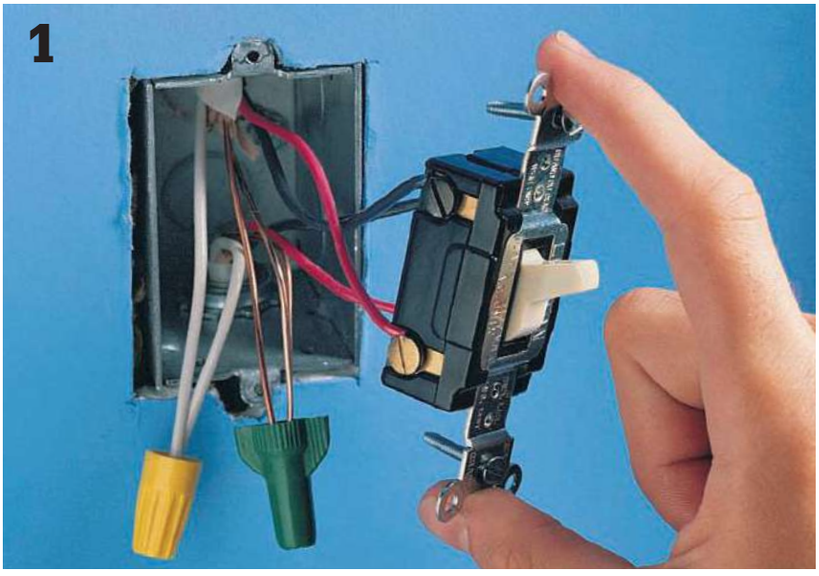

Turn off the power to the switch at the panel, and then remove the switch cover plate and mounting screws. Holding the mounting strap carefully, pull the switch from the box. Be careful not to touch any bare wires or screw terminals until they have been tested for power. Test for power by touching one probe of the neon circuit tester to the grounded metal box or bare copper grounding wire and touching the other probe to each of the screw terminals. The tester should not glow. If it does, there is still power entering the box. Return to the panel, and turn off the correct circuit.

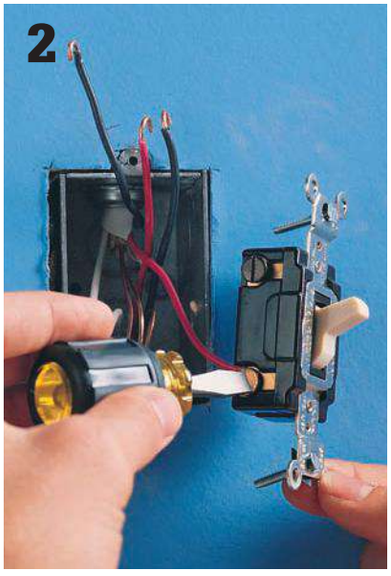

Disconnect the wires and inspect them for nicks and scratches. If necessary, clip damaged wires and strip them. Test the switch for continuity. Buy a replacement if the switch tests faulty.

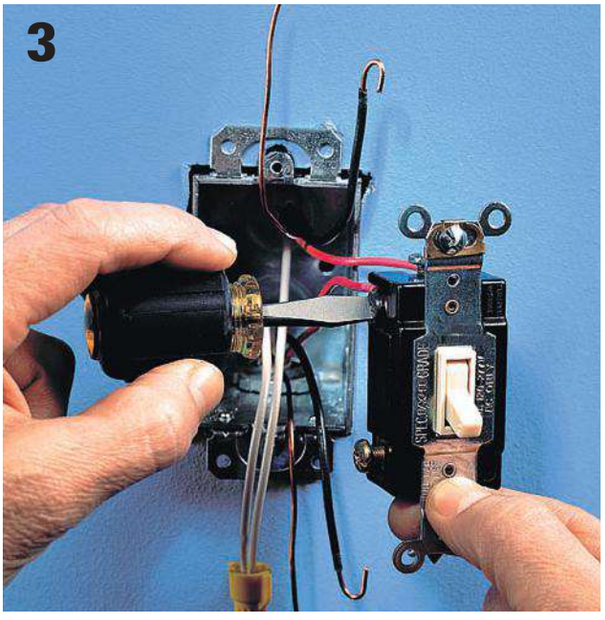

Connect two wires from one incoming cable to the top set of screw terminals.

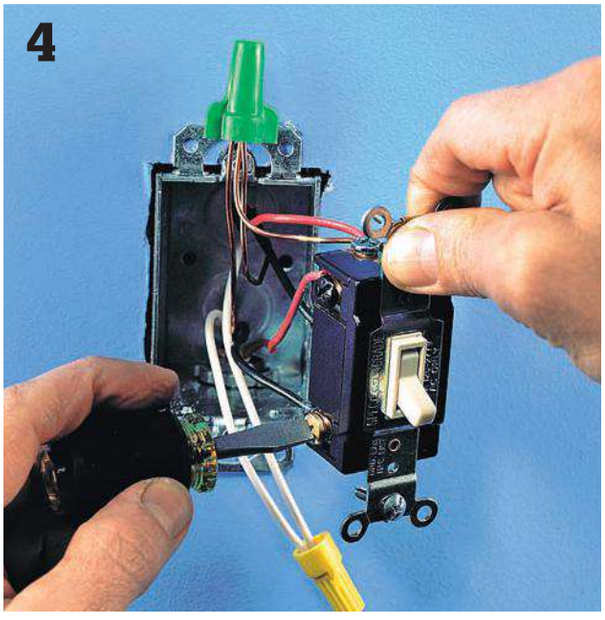

Attach remaining wires to the other set of screw terminals. Pigtail the grounding wires to the grounding screw. Carefully tuck the wires inside the switch box, and then remount the switch and cover plate. Turn on power at the panel.

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Double Switches

A double switch has two switch levers in a single housing. It is used to control two light fixtures or appliances from the same switch box.

In most installations, both halves of the switch are powered by the same circuit. In these single-circuit installations, three wires are connected to the double switch. One wire, called the feed wire (which is hot), supplies power to both halves of the switch. The other wires, called the switch leg, carry power out to the individual light fixtures or appliances.

In rare installations, each half of the switch is powered by a separate circuit. In these separate-circuit installations, four wires are connected to the switch, and the metal connecting tab joining two of the screw terminals is removed (see photo below).

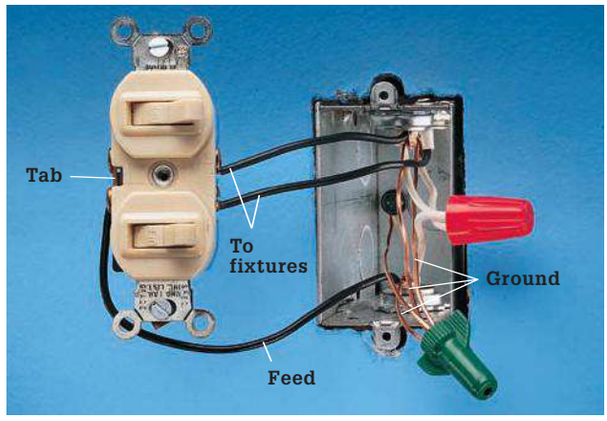

Single-circuit wiring: Three black wires are attached to the switch. The black feed wire bringing power into the box is connected to the side of the switch that has a connecting tab. The wires carrying power out to the light fixtures or appliances are connected to the side of the switch that does not have a connecting tab. The white neutral wires are connected together with a wire connector.

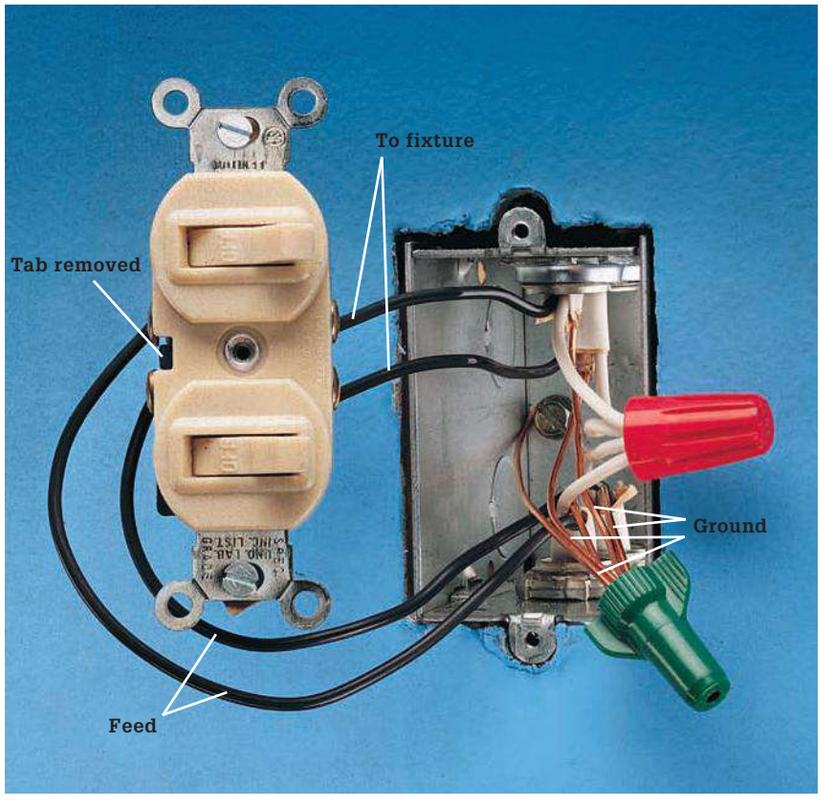

Separate-circuit wiring: Four black wires are attached to the switch. Feed wires from the power source are attached to the side of the switch that has a connecting tab, and the connecting tab is removed (photo, right). Wires carrying power from the switch to light fixtures or appliances are connected to the side of the switch that does not have a connecting tab. White neutral wires are connected together with a wire connector.

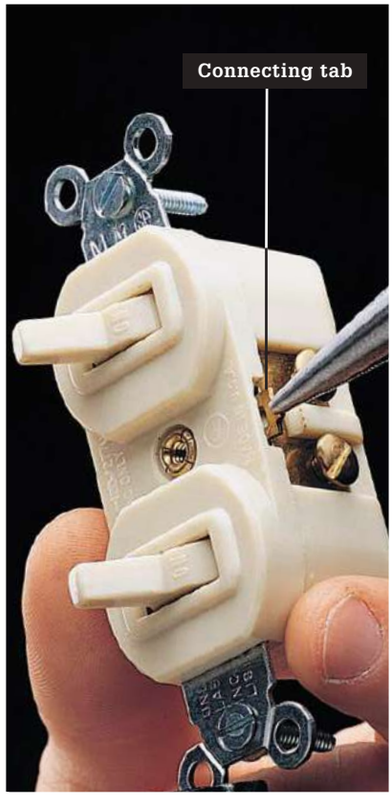

Remove the connecting tab on a double switch when wired in a separate-circuit installation. The tab can be removed with needlenose pliers or a screwdriver.

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Pilot-Light Switches

A pilot-light switch has a built-in bulb that glows when power flows through the switch to a light fixture or appliance. Pilot-light switches often are installed for convenience if a light fixture or appliance cannot be seen from the switch location. Basement lights, garage lights, and attic exhaust fans frequently are controlled by pilot-light switches.

A pilot-light switch requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a pilot-light switch.

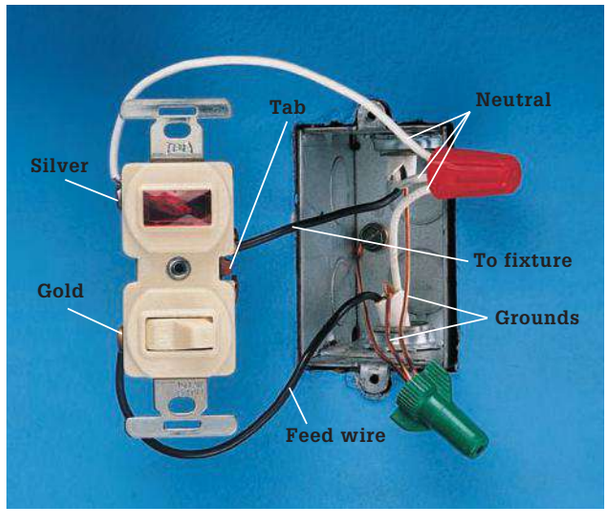

Pilot-light switch wiring: Three wires are connected to the switch. One black wire is the feed wire that brings power into the box. It is connected to the brass (gold) screw terminal on the side of the switch that does not have a connecting tab. The white neutral wires are pigtailed to the silver screw terminal. The black wire carrying power out to a light fixture or appliance is connected to the screw terminal on the side of the switch that has a connecting tab.

Switch/Receptacles

A switch/receptacle combines a grounded receptacle with a single-pole wall switch. In a room that does not have enough wall receptacles, electrical service can be improved by replacing a single-pole switch with a switch/receptacle.

A switch/receptacle requires a neutral wire connection. A switch box that contains a single two-wire cable has only hot wires and cannot be fitted with a switch/receptacle.

A switch/receptacle can be installed in one of two ways. In the most common installations, the receptacle is hot even when the switch is off (photo, right).

In rare installations, a switch/receptacle is wired so the receptacle is hot only when the switch is on. In this installation, the hot wires are reversed, so that the feed wire is attached to the brass screw terminal on the side of the switch that does not have a connecting tab.

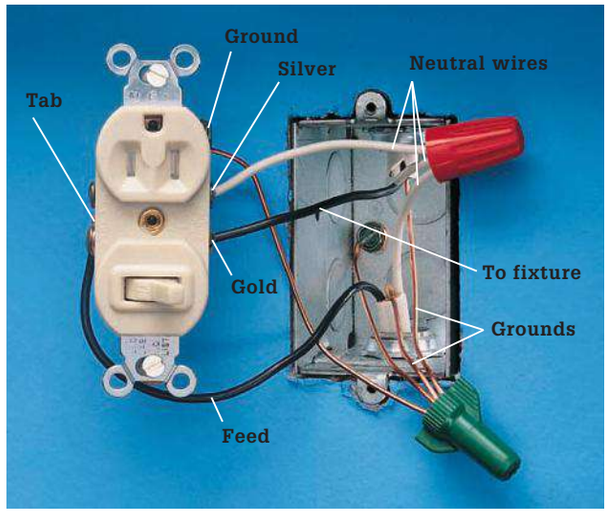

Switch/receptacle wiring: Three wires are connected to the switch/receptacle. One of the hot wires is the feed wire that brings power into the box. It is connected to the side of the switch that has a connecting tab. The other hot wire carries power out to the light fixture or appliance. It is connected to the brass screw terminal on the side that does not have a connecting tab. The white neutral wire is pigtailed to the silver screw terminal. The grounding wires must be pigtailed to the green grounding screw on the switch/receptacle and to the grounded metal box.

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Specialty Switches

Your house may have several types of specialty switches. Dimmer switches (pages 96 to 97) are used frequently to control light intensity in dining and recreation areas. Timer switches and time-delay switches (below) are used to control light fixtures and exhaust fans automatically. Electronic switches provide added convenience and home security, and they are easy to install. Electronic switches are durable, and they rarely need replacement.

Most specialty switches have preattached wire leads instead of screw terminals and are connected to circuit wires with wire connectors. Some motor-driven timer switches require a neutral wire connection and cannot be installed in switch boxes that have only one cable with two hot wires. It is precisely due to the rise in popularity of "smart" switches that the NEC Code was changed in 2014 to require an available neutral wire in newly-installed switch boxes.

If a specialty switch is not operating correctly, you may be able to test it with a continuity tester. Timer switches and time-delay switches can be tested for continuity, but dimmer switches cannot be tested. With electronic switches, the manual switch can be tested for continuity, but the automatic features cannot be tested.

Timer Switches

Countdown timer switches can be set to turn lights or fans on and off automatically once each day. They are commonly used to control outdoor light fixtures.

Timer switches have three preattached wire leads. The black wire lead is connected to the hot feed wire that brings power into the box, and the red lead is connected to the wire carrying power out to the light fixture. The remaining wire lead is the neutral lead. It must be connected to any neutral circuit wires. A switch box that contains only one cable has no neutral wires, so it cannot be fitted with a timer switch.

After a power failure, the dial on a timer switch must be reset to the proper time.

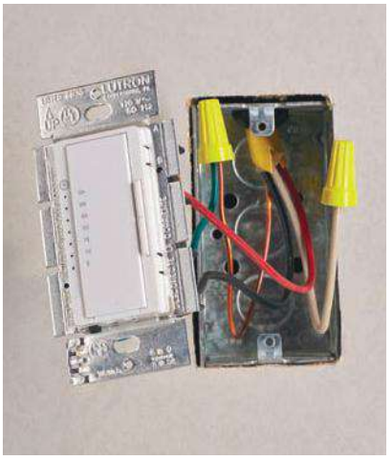

Countdown timer switch. This rocker-type switch gives you the option to easily program the switch to shut off after a specified time: from 5 to 60 minutes. Garage lights or basement lights are good applications: anywhere you want the light to stay on long enough to allow you to exit, but not to stay on indefinitely. These switches often are used to control vent fans.

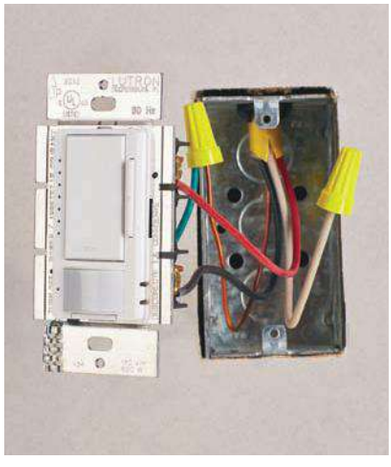

Occupancy sensor. Many smart switches incorporate a motion detector that will switch the lights on if they sense movement in the room and will also shut them off when no movement is detected for a period of time. The model shown above also has a dimmer function for further energy savings.

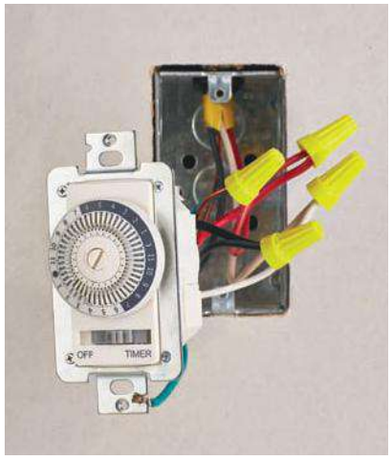

Programmable timer switch. A dial-type timer allows you to program the switch to turn on for specific time periods at designated times of day within a 24-hour cycle. Security lights, space heaters, towel warmers, and radiant floors are typical applications.

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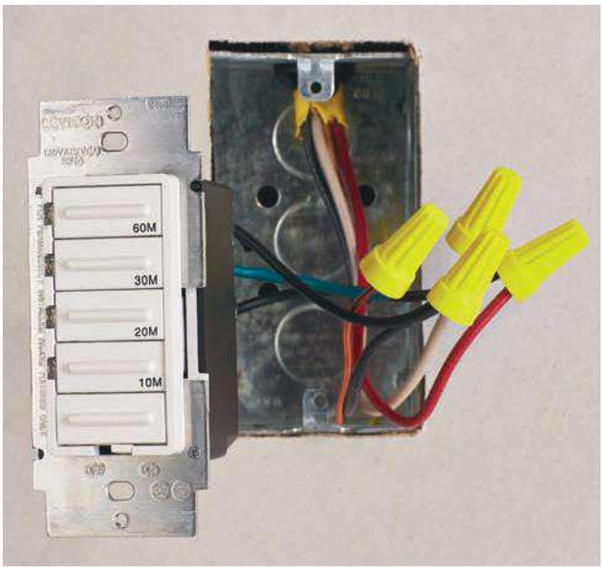

Preset timer switch. This lets you turn on lights, heat lamps, and other loads for a designated amount of time (10 to 60 minutes) with one easy push of a button. The green LED at the bottom of this unit provides a readout of how much time is left before the switch shuts off. The model shown is not compatible with fluorescent ballasts.

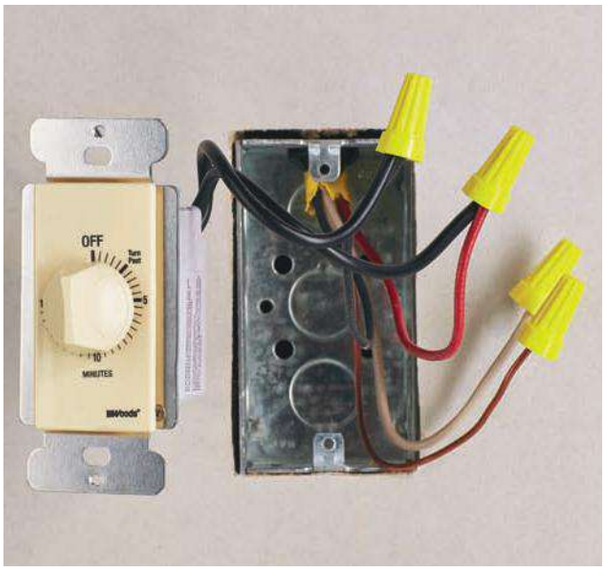

Spring-wound timer switch. A relatively simple device, this timer switch functions exactly like a kitchen timer, employing a hand-turned dial to and spring mechanism to shut the switch off in increments up to 15 minutes.

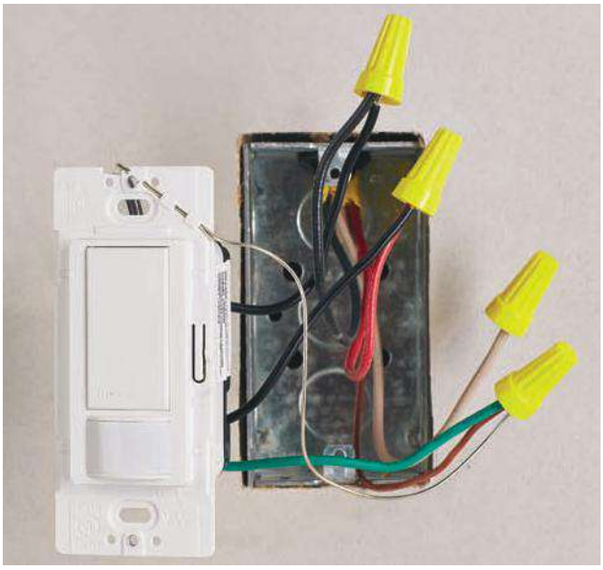

Daylight sensor switch. This switch automatically turns on when light levels drop below a proscribed level. It can also be programmed as an occupancy sensor to shut off when the room is vacant and turn on when the room is entered.

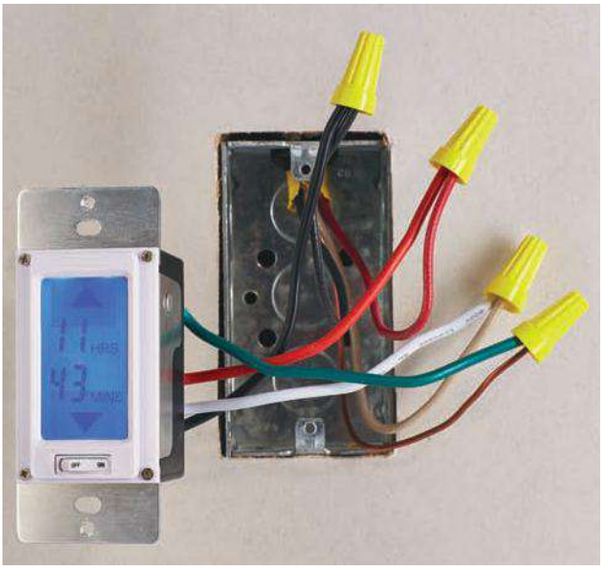

Backlit countdown timer. This digital switch lets you program lights or other devices to stay on for up to 24 hours and then shut off automatically. The backlit, LED readout gives a countdown, in minutes, of the amount of time left in the "on" cycle. Up and down buttons let you raise or lower the remaining time easily, and a manual override button will shut off the switch until it is turned back on.

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Ground-fault (GFCI) & Arc-fault (AFCI) Protection

GROUND-FAULT LOCATION REQUIREMENTS

1. Kitchen receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles that serve kitchen countertops. This does not include receptacles under the kitchen sink receptacles located on kitchen walls that do not serve the countertop and receptacles that are not within six feet of a sink.
2. Kitchen. Install ground-fault circuit interrupt (GFCI) protection on the outlets that supply dishwashing machines.
3. Bathroom receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located in bathrooms. This applies to all receptacles regardless of where they are located in the bathroom and includes receptacles located at countertops, inside cabinets, and along bathroom walls. This also applies to bathtubs and shower stalls that are not located in a bathroom. Install ground-fault circuit interrupt (GFCI) protection on all circuits serving electrically heated floors in bathrooms, kitchens, and around whirlpool tubs, spas, and hot tubs.
4. Garage and Accessory Building receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located in garages and grade-level areas of unfinished accessory buildings.
5. Exterior receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located outdoors. This does not apply to receptacles that are dedicated for deicing equipment and are located under the eaves. This applies to holiday lighting receptacles located under the eaves.
6. Basement receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located in unfinished basements. An unfinished basement is not intended as habitable space and is limited to storage and work space.
7. Crawl space receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located in crawl spaces. Receptacles in crawl spaces are not required unless equipment requiring service is located there.
8. Sink receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles that are located within six feet of the outside edge of a sink. This includes wall, floor, and countertop receptacles.
9. Boathouse receptacles. Install ground-fault circuit interrupt (GFCI) protection on all 120-volt receptacles located in boathouses.

Ground-fault receptacles and circuit breakers detect unwanted current running between an energized wire and a grounded wire.

A combination ARC-fault circuit breaker detects sparking (arcing) faults along damaged energized wires and detects these faults between wires. A branch ARC-fault circuit breaker only detects arcing faults between wires.

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10. Spas, tubs, and other circuits requiring ground-fault protection. Install ground-fault circuit interrupt (GFCI) protection on all circuits serving spa tubs, whirlpool tubs, hot tubs, and similar equipment. Refer to the general codes for more information about receptacles serving these components.
11. Install GFCI circuit breakers and receptacles so that they are readily accessible.

ARC-FAULT LOCATION REQUIREMENTS

1. Install a combination type or an outlet (receptacle) type arc-fault circuit interrupter (AFCI) on all 15- and 20-amp, 120-volt branch circuits serving sleeping, family, dining, living, sun, and recreation rooms, kitchens, laundry areas, and parlors, libraries, dens, hallways, closets, and similar rooms and areas. This means that 15-and 20-amp, 120-volt branch circuits serving most interior spaces in a home are required to have AFCI protection. Note that garages, basements, utility and mechanical rooms, and exterior branch circuits are not included in this list, although local building officials may include these areas by interpretation.
2. You may provide AFCI protection for the entire branch circuit by installing a combination-type AFCI circuit breaker in the electrical panel where the branch circuit originates.
3. You may provide AFCI protection to a branch circuit using several different combinations of branch-circuit type AFCI circuit breakers and branch-circuit type AFCI receptacles. Refer to general codes or your local building inspector for details about these alternate methods.
4. Provide AFCI for branch circuits that are modified, replaced, or extended. You may use either of the following methods: (a) install a combination-type AFCI circuit breaker in the electrical panel where the branch circuit originates, or (b) install a branch-circuit type AFCI receptacle at the first receptacle in the existing branch circuit.
5. Install AFCI circuit breakers and receptacles so that they are readily accessible.

Receptacles for whirlpool tubs must be GFCI protected.

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Junction Boxes, Device Boxes & Enclosures

All electrical boxes are available in different depths. A box must be deep enough so a switch or receptacle can be removed or installed easily without crimping and damaging the circuit wires. Replace an undersized box with a larger box using the Electrical Box Fill Chart (see page 124) as a guide. **The NEC also says that all electrical boxes must remain accessible. Never cover an electrical box with drywall, paneling, or wall coverings.**

NONMETALLIC BOX INSTALLATION

1. Use nonmetallic boxes only with NM type cable or with nonmetallic conduit or tubing. You may use nonmetallic boxes with metallic conduit or tubing if you maintain the electrical continuity of the metallic conduit or tubing by installing a bonding jumper through the box. In many situations it is easier to use a metallic box with metallic conduit or tubing.
2. Extend NM cable sheathing at least ¼ inch into a nonmetallic box knockout opening.
3. Secure NM cable, conduit, and tubing to each box. You may secure NM cable with cable clamps inside the box or with compression tabs provided where the cable enters the box. You do not need to secure NM cable to a standard single-gang box (2¼ by 4 inches) mounted in a wall or ceiling if you fasten the cable not more than eight inches from the box and if the sheathing enters the box at least ¼ inch. Measure the eight inches along the length of the sheathing, not from the outside of the box.

LIGHT FIXTURE BOX INSTALLATION

1. Use boxes designed for mounting light fixtures if a light fixture is to be mounted to the box. These boxes are usually four-inch round or octagonal.
2. You may use other boxes to mount light fixtures on walls if the fixture weighs less than 6 pounds and if the fixture is secured to the box using at least #6 screws.
3. Support light fixtures weighing at least 50 pounds independently from the light fixture box. You may use the light fixture box to support light fixtures weighing less than 50 pounds. Note that ceiling fans are not light fixtures.

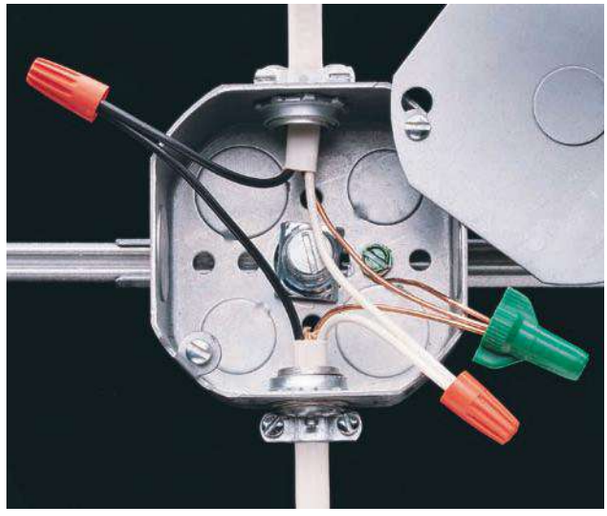

Box shape is directly related to function, as electrical fixtures are created to fit on boxes of a particular shape. Octagonal and round boxes generally are designed for ceiling mounting, while square and rectangular boxes are sized for single-pole, duplex, and other standard switch and receptacle sizes.

Do not support heavy light fixtures using only the light fixture electrical box. The eye hook supporting this chandelier is driven into the same ceiling joist to which the electrical box is mounted.

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BOX CONTENTS LIMITATIONS

1. Limit the number of wires, devices (such as switches and receptacles), and fittings in a box. This limitation is primarily based on the heat generated by the wires and devices in the box. The actual size of the box relative to its contents is a secondary consideration.
2. Use the cubic inch volume printed on the box or provided in the box manufacturer's instructions to determine box volume. Do not attempt to measure the box volume. Do not estimate box volume from the volume of similar size boxes. You will probably not get the same volume as provided by the manufacturer.
3. Use table "Wire Volume Unit" to determine the volume units required by wires, devices, and fittings in a box.

BOX INSTALLATION TOLERANCES

1. Install boxes in non-combustible material, such as masonry, so that the front edge is not more than ¼ inch from the finished surface.
2. Install boxes in walls and ceilings made of wood or other combustible material so that the front edge is flush with the finished surface or projects from the finished surface.
3. Cut openings for boxes in drywall and plaster so that the opening is not more than ⅛ inch from the perimeter of the box.

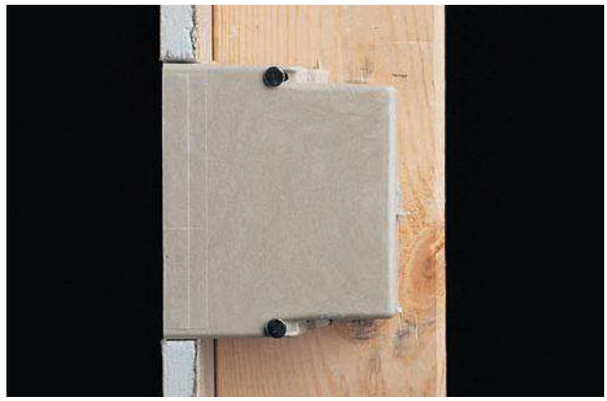

Boxes must be installed so the front edges are flush with the finished wall surface, and the gap between the box and the wall covering is not more than ⅛".

Wire Volume Unit ▸

WIRE SIZE (AWG)	WIRE VOLUME
14	2.00 in.^{3}
12	2.25 in.^{3}
10	2.50 in.^{3}
8	3.00 in.^{3}
6	5.00 in.^{3}

Volume Units ▸

Calculate the volume units required by wires, devices, and fittings based on the following definitions:

Volume units for current-carrying wires. Allow one volume unit for each individual hot (ungrounded) and neutral (grounded) wire in the box. Use Table 47 to determine the volume units of common wire sizes. Example: two pieces of #14/2 NM are in a box. Each piece of this cable contains one hot (ungrounded) and one neutral (grounded) wire and one grounding wire. From table "Wire Volume Unit", each #14 wire uses 2.00 cubic inches in the box. The total volume units required by the hot (ungrounded) and neutral (grounded) wires is eight cubic inches.

Volume units for devices. Allow two volume units for each device (switch or receptacle) in the box. Base the volume units on the largest hot (ungrounded) or neutral (grounded) wire in the box. Example: NM cable size #14 and #12 are in a box. From Table 47, #14 wire uses 2.00 cubic inches and #12 wire uses 2.25 cubic inches. Allow 4.5 cubic inches volume units (2 × 2.25 cubic inches) for each switch or receptacle in the box based on the volume of the larger #12 NM cable.

Volume units for grounding wires. Allow one volume unit for all grounding wires in the box. Base the volume unit on the largest hot (ungrounded) or neutral (grounded) wire in the box.

Volume units for clamps. Allow one volume unit for all internal cable clamps in the box, if any. Base the volume unit on the largest hot (ungrounded) or neutral (grounded) wire in the box.

Volume units for fittings. Allow one volume unit for all fittings in the box, if any. Base the volume unit on the largest hot (ungrounded) or neutral (grounded) wire in the box.

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Electrical Box Fill Chart

BOX SIZE AND SHAPE (If volume not labeled by manufacturer)	MAXIMUM NUMBER OF VOLUME UNITS PERMITTED (SEE NOTES BELOW) 14 AWG	12 AWG	10 AWG	8 AWG
JUNCTION BOXES				
4 × 1¼" R or O	6	5	5	4
4 × 1½" R or O	7	6	6	5
4 × 2⅛" R or O	10	9	8	7
4 × 1¼" S	9	8	7	6
4 × 1½" S	10	9	8	7
4 × 2⅛" S	15	13	12	10
4 11/16 × 1¼" S	12	11	10	8
4 11/16 × 1½" S	14	13	11	9
4 11/16 × 2⅛" S	21	18	16	14
DEVICE BOXES				
3 × 2 × 1½"	3	3	3	2
3 × 2 × 2"	5	4	4	3
3 × 2 × 2¼"	5	4	4	3
3 × 2 × 2½"	6	5	5	4
3 × 2 × 2¾"	7	6	6	4
3 × 2 × 3½"	9	8	7	6
4 × 2⅛ × 1½"	5	4	4	3
4 × 2⅛ × 1⅞"	6	5	5	4
4 × 2⅛ × 2⅛"	7	6	5	4

Notes:

- R = Round; O = Octagonal; S = Square or rectangular
- Each hot or neutral wire entering the box is counted as one volume unit
- Grounding wires are counted as one volume unit in total—do not count each one individually.
- Raceway fittings and external cable clamps do not count. Internal cable connectors and straps count as one volume unit.
- Devices (switches and receptacles mainly) each count as two volume units.
- When calculating total volume units, any non-wire components should be assigned the gauge of the largest wire in the box.
- For wire gauges not shown here, contact your local electrical inspections office.

BOX SUPPORT IN WALLS, CEILINGS & FLOORS

1. Provide support for boxes that rigidly and securely fasten them in place. You may use nails or screws to support these boxes.
2. Protect screws inside boxes so that the threads will not damage the wires.
3. Wood braces used to support boxes must be at least one by two inches.
4. Use "cut-in" or "old work" retrofit boxes only if they have approved clamps or anchors that are identified for the location where they are installed.

DAMP LOCATIONS

1. Install a receptacle box cover that is weatherproof when the cover is closed and a plug is not inserted into a receptacle located in a damp location. This applies to 15-amp and 20-amp receptacles. A damp area is protected from direct contact with water. Refer to the definition of damp location. You may use a receptacle cover suitable for wet locations in a damp location.
2. Install a watertight seal between a flush-mounted receptacle and its faceplate. This will require a gasket or sealant between the finished surface (such as stucco, brick, or siding) and the faceplate.

WET LOCATIONS

1. Install a receptacle box cover that is weatherproof when the cover is closed on any receptacle located in a wet location. This applies to 15-amp and 20-amp receptacles in any indoor or outdoor wet location. This applies regardless of whether or not a plug is inserted into the receptacle.
2. Install a watertight seal between a flush-mounted receptacle and its faceplate. This will require a gasket or sealant between the finished surface (such as stucco, brick, or siding) and the faceplate.

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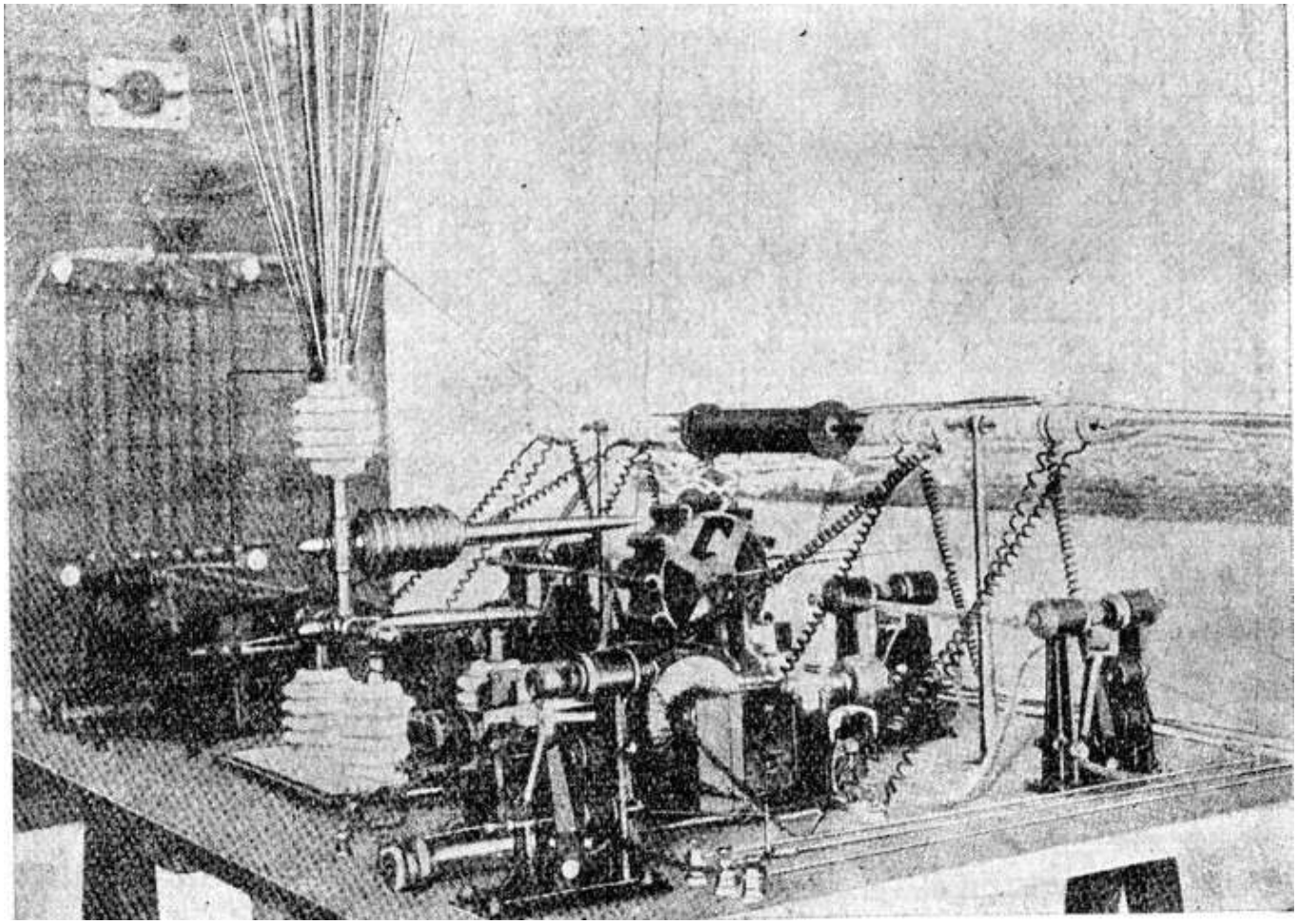

Shared by L. Cozma (Thanks !) --

The Guillot device generated about 2.5-3 Kilowatts with antenna height of ~ 20 meters. Power depends on the total collector surface and height of the vertical antenna. The apparatus in the photo produced ~300 watts with a collector 2 meters tall.

"Practical Utilization of Atmospheric Electricity"

by

Gillbert Darida

in *The Invention Encyclopedia,* pp. 204-207 (1930, Geo. Constantinescu, Ed.)

"The Earth has its own negative electricity, in the soil, and the atmosphere which surrounds the Earth is charged with positive electricity. The electric potential (the voltage) increases with the altitude, so we can say that the electric force is proportional to the atmospheric altitude (after Franklin, Quetelet, Lord Kelvin, Mascart, Joubert and other scientists).

The recent observations demonstrate that the air at 6000-7000 meters in altitude, is very highly charged with positive electricity, which could be explained by the friction between the external photosphere and the upper atmosphere of Earth, which rotates at a speed of more than 100,000 Kilometer per hour.

In that way, the Earth works like an electrostatic generator with electric charging by influence --- the upper atmosphere is positively charged by influence and the Earth crust obtains the negative polarity.

Between the two environments, the air and the soil, and inside the low atmosphere, in conditions of good weather, there are sbout 800 positive ions and also, 680 negative ion (and electrons) in just one square-centimeter of normal ionised air.

The Earth behaves like an huge electric armature negatively charged, which repels the electrons and attracts the positive ions. That positive ions' attraction determinates an electric current, also called "convective current". That's like an invisible continous bombardment, subject to daily and seasonal variations, which could be aproximated at **3 x 10 ^ -16 Amperes per square-centimeter,** and that is a total value of 1500 Amperes for the entire surface of the Earth.
The question is --- how does this current always maintains the same direction ? We can suppose that the natural radioactive emissions of the soil is responsable for this. We also know that radioactive emissions of the Earth works usually near the soil surface, and that explains the ionisation phenomenona inside caves.

The ionisation of the low atmosphere could also be the effect of the radioactive emissions of the Earth, especially when the X radiation works. Also, the Earth atmosphere is ionisated by the external radiation proceeding from the Sun and from the space environment, especially the action of ultraviolet radiation and the electron fascicles emitted by the Sun surface, at the temperature of 6000 deg. Celsius.

The capture of atmosphere electricity has been used in France, with aerial cables mounted on the Mont Blanc, and also in Germany --- with conductive cables carried by the captive baloons.

The atmosphere electricity collect system invented by eng. Jules Guillot is most ingenious and it relies on "the **electric siphon**" [*m.n. --- the discharging devices or spark-gap used today from the protection of aerial electric cables against the atmospheric electricity ; Jules Guillot has thought to recuperate and to use that electricity*].

His method consisted in the direct "pumping" of the atmosphere electricity using a collecting device which had two antennae and several collecting rods.

One antenna is **vertical** and it has a lot of **rods** scattered like an opened **fan**, with the tips against the **zenith**, for collecting the **negative** electricity which comes from the air ; the **horizontal** antenna is orientated against the **South** and its role is to collect the **positive** electricity.

The air electricity seems to have the double-polarity, as we can see at two electrised clouds when between them apears the electric discharge. The air could have different electric charging and the ionisation processus of atmosphere is very heterogenous. The inventor Guillot used **two separated and insulated armatures with the positive armature against the South** (more precisely, against the **Equator**...) and the **negative** armature against the **zenith**.

We can see in the scheme :

1,- the device P is the "**collector apparatus**" having **15-20 meters height** ; it also has a lot of **rods** which are scattered **fan**-like, all this on top of an **iron pillar** ; and also an **horizontal antenna** S oriented against the **South** ; the two antennae are disposed at **90 deg. angle** forming the two armatures where the electrical tension must apear. As the **height** of the pillar **increases**, the **voltage** increases more and more ;

2,- a system of **lightning-rods** (p1, p2, p3) for protection against discharges of atmospheric electricity during storms;

3,- the regulator system (**voltage regulator**, etc) R ;

4,- the electric **resistors** (Cn) for absorbing the parasite currents ;

5,- the "electric siphons" which have the role of making a magnetic field as a good environment for the transport of the ionized fluid, absorbing the electricity from the air ; the E1 and E2 are their regulator devices ;

6,- an **auxilliary continous current power supply** which send the current against an special **excitation coil**, used as starting device ; it works only when the system is starting.
This collector device works very good for lighting and heating. The device made by Guillot had **20 meters height** on the total surface of **3 square-meters**. Also, J.Guillot used and electrical transformer for the industrial utilization of this "collector" --- as power supply for industrial electric engines."

French Patent # 551,882

Apparatus for Capture of Electric Currents in the Atmosphere

16 April 1923

Considering the terrestrial globe like the inductor of a dynamo, where the extraterrestrial ether is the inductor of electric currents circulating in the atmosphere; the apparatus of the invention described here selects through the device described below two perfectly distinct currents and eliminates others.

The device includes:

1, The air sensor; 2, a series of lightning rods; 3, vacuum; 4, an array of resistances; 5, vacuum; 6, witnesses.

1. An aerial sensor mounted on a pole is composed of **magnetic steel** fixed and sealed by a porcelain **insulator**, and surrounded a base by a **bronze ring** which are screwed **32 points of soft iron**, all forming antenna a pole. level beside it and isolated from the first, forming the 2nd pole, is fixed a sharp point of magnetic steel fixed in the horizontal position and directed towards the south and **movable to an angle of 45** is sealed in a porcelain insulator. This point is also circled a **ring of copper** notches figure. 1.

2. A series of 6 lightning surge arrestors at corners between each pole and the earth and the various gauges.

3. A first **regulator** form of a device similar absolutely similar to the aerial amtenna, but the two poles are superposed and opposed to the vertical point, and a **copper disk connects to ground**. Opposite the horizontal point, a **ring of tin** to which are welded tubes alternatively **16 tubes** composed each composed of **copper-lead** and **iron-lead** . The ring connects to the **ground** as shown in figure. 2.

A second regulator form of **automatic breakers** balanced on 3 poles and two poles also equally balanced.

4. A panel of **resistances** composed of **wire mesh** in bunches from different sections of **glass tubes** containing **copper** dust, **coal** and flowers of **sulfur**.

Vacuum cleaners consists of a **wooden box** on each pole, containing a **porcelain vase** in which **layers** isolated with **mica** is made up of **mercury, tin, coal, copper** and **sulfur**, all contaied in a **copper tube**.

6. The witnesses are comprised of ordinary incandescent lamps.

Resume

By the point at the zenith and the point to the south we channel two currents forming the two poles. We also protect from lightning. It regularizes the flow by a regulator and similar devices by a controlling each devise of adequate strength of the current harmful nature of these devices do not have loads. The refined current is conducted by ordinary copper wires**.**

French Patent # 565,395

Combined Apparatus for Capture of Atmospheric Electric Currents with Immediate Implementation

25 January 1924

We know that earth with its constitution, its rotation and movement in space, provides the electricity in the atmosphere. The electrical currents escape into space or largely accumulate towards the equator, as a result of the greater periphery of the globe.

In the atmosphere, there are two clearly distinct poles, i.e., clouds that can be electrically positive or negative; everything in nature shows this, otherwise it would be difficult to explain the lightning that occurs between the clouds and which are none other than contrary cloud electrical charges discharged by too close proximity.

The invention relates to a set of devices capable of capturing the atmospheric electricity.

So far, all searches made for this purpose has been to capture the atmosphere, i.e., that brought together into one system to capture two poles and opposes effect has been to destroy or cancel each other leaving the amount as the difference of the strongest to weakest.

It is therefore easy to understand why, considering the two poles of air as about equal, it is almost impossible to measure some potential with the land, the highest on the lowest remaining which can be positive or negative, copper being the strongest of one or other of these polarities.

It is on this basis that all research until now have been made, and that is why we must consider that all the time, between the two poles captured in the atmosphere and not in any mixture of systems uptake, it is possible to obtain tension and intensity, a considerable and measurable power captured separately between the two poles and remaining isolated from one another until their utilization .

In accordance with this invention, this collection is made by attraction of primary electrical currents in teh atmosphere, either positively or negatively charged, by an antenna that has two points absolutely isolated from one another, where one points to the zenith to attract negative electricity, and the other turned south, toward the equator to draws in the masses grouped in this area.

This shows and proves the existence of atmospheric electrical currents, and that it is possible to capture them with specially designed equipment primarily acting as regulators, as the persistent difficulty encountered so far in realizing their capture lies with large variations of tension in which the current atmosphere is present in space, for each of the poles, and an overload could inevitably fatal.

The patent in its present form of presentation does not cover the regulators or devices that are anticipated in the system, because they can be designed in different ways and give the same result, but covers the application and grouping of equipment operating as automatic relays with variable influence to limit current tension to that chosen for utilization.

These devices have a role associated with an overflow reservoir outside carrying excess liquid; these regulators will divert the excess voltage flows to ground.

We can still absorb these regulators having filters because they have the sole purpose of diverting the post being used , currents that are not yet known but likely that we will call for simplicity, abnormal currents. [sic...]

The patent also covers systems for regulating currents, applied to each of the poles because it is recognized that the shape and tension of the currents of the two poles are not equivalent.

The method of capture is by special antenna has directed two points in the atmosphere, as will be stated after this, with Boot ecoulement prior to the current atmosphere is also of great importance.

Finally, the current atmospheric reception is adequate even with the installation of a post, which can be expected at any location without the need for special altitude, as has been attempted in previous efforts.

We refer to the attached drawings:.

Figure 1 represents in elevation and side view an antenna that only has two points, to overcome an elevation ;

Figure 2 is the end of one of the peaks, the horizontal:

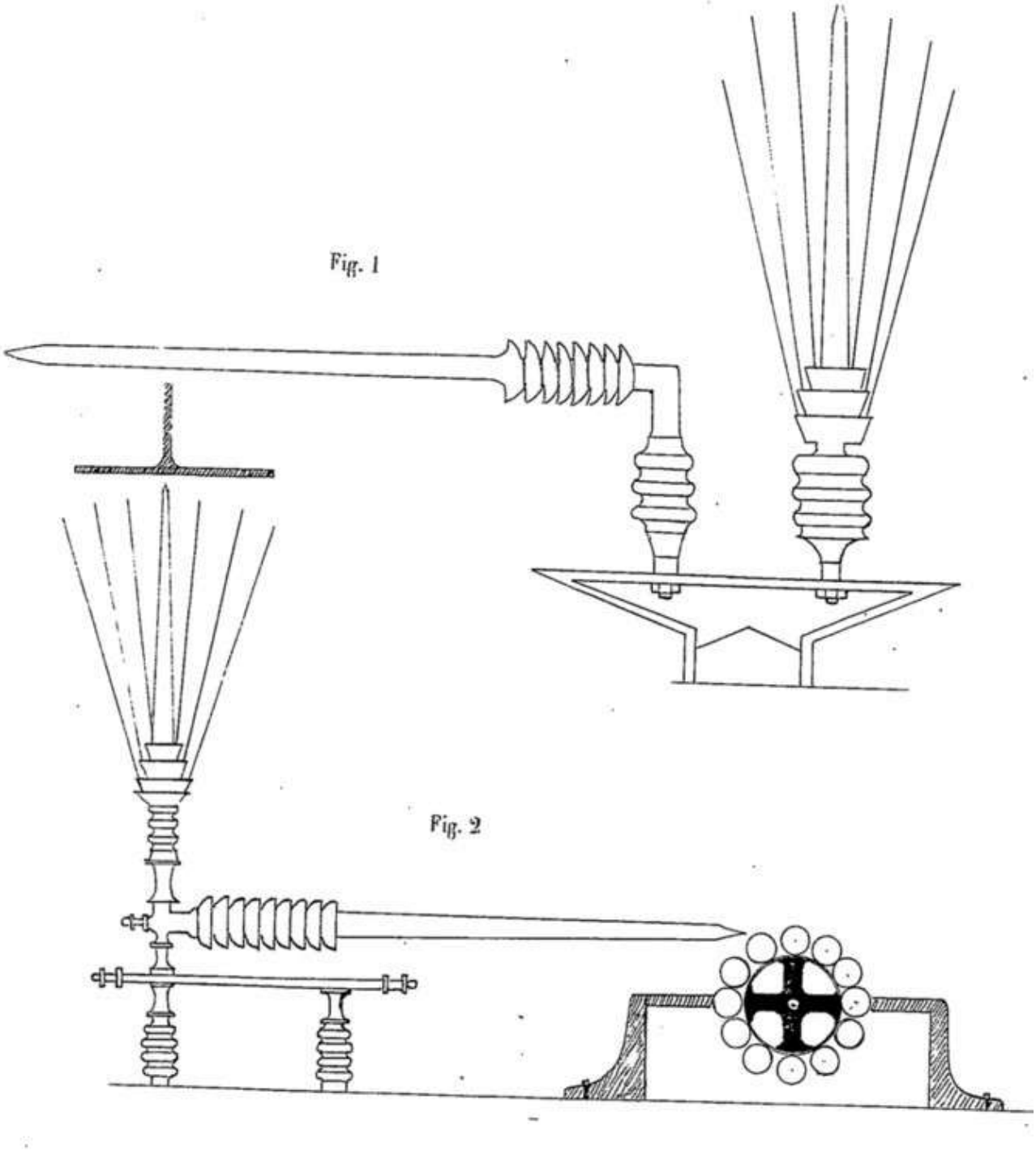

Figure 3 shows schematically the table on which are mounted various devices or accessories that act as regulators of current tensions.

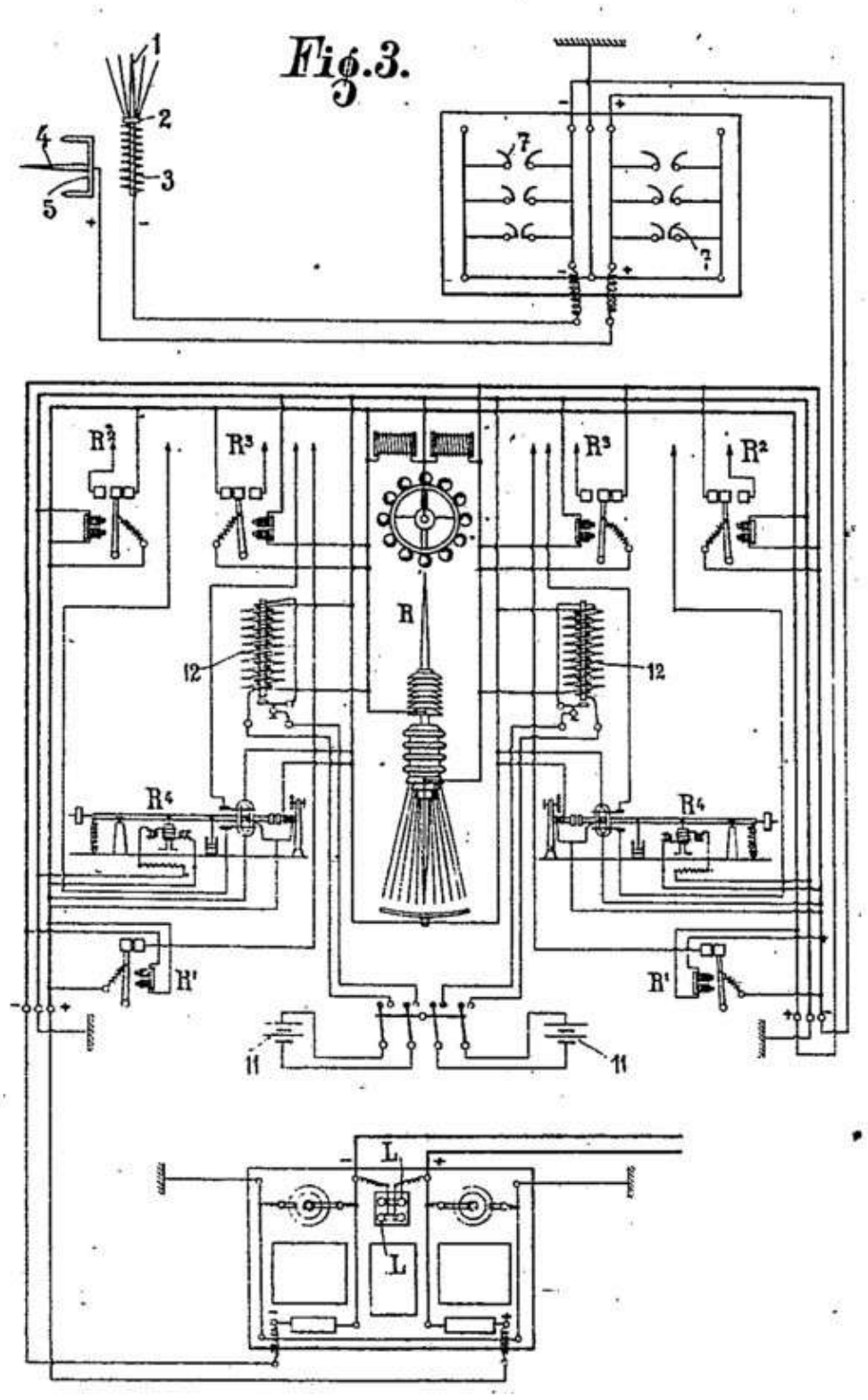

Figure 4 is a scheme of surge arrestors, and

Figure 5 a table of resistances.

Fig. 4.

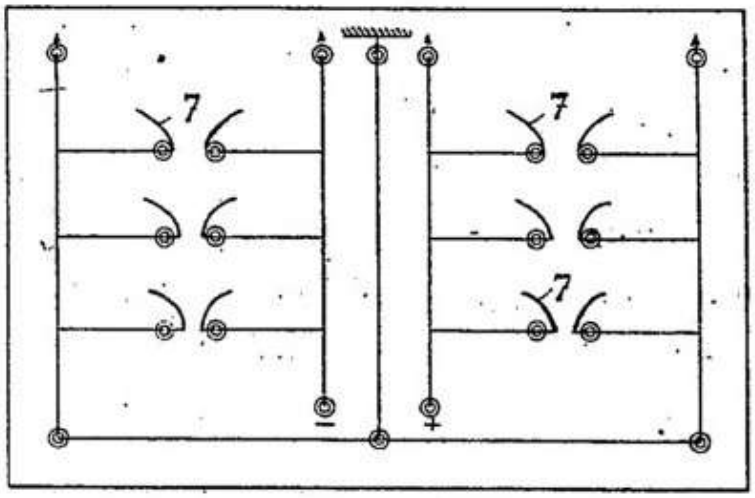

Fig. 5.

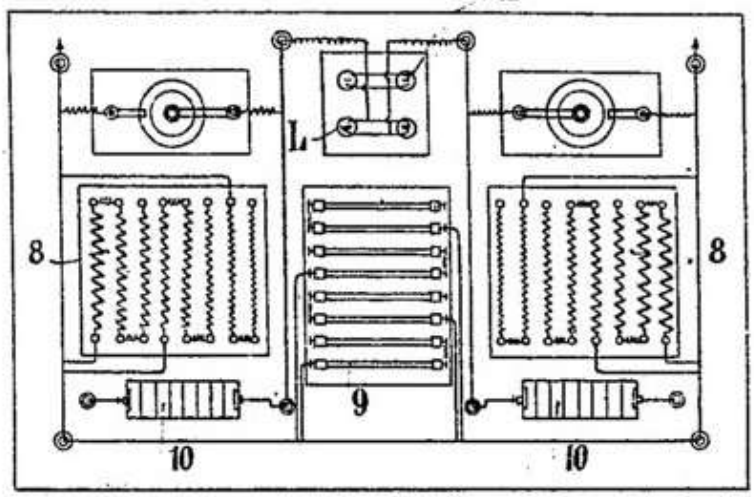

The necessary arrangements to capture atmospheric current form is as follows:

1. The **antenna** in figure 1 is formed with two peaks: the 1 is **steel**, supported by a **bronze ring** 2, surrounded by a **spiral form** 3; this point is oriented for attracting the **zenith** layers of **negative electricity** and the other edge 4 contains **copper coils** 6, and is oriented **south** to the **equator** to draw in the masses grouped in this area. To use this antenna it suffices to be raised on a mast or **pole** to a height a little higher than that of surrounding houses.

2. On the table **lightning arrestors**, contained 4, forms of 7 **copper horns** used to absorb large atmospheric discharges by certain time, as it would be dangerous to allow movement in the devices regulators.

3. On a table of **two** symmetrical systems **regulators**, Figure 3, one for each pole, to obtain and allow a regularization of large excesses in the current tensions, by automatically absorbing surges before passing over the surfacea chosen for the desired use. These regulators are represented on the drawing by the references R, R1, R2, R3, R4.

4. In the **resistance** panel in communication with regulators, these resistances are formed as **spiral coils or screens** 8, **tubes 9 of glass filled with fine coal dust , aluminum powder, sulfur and fine copper dust**. Finally, **two** special 10 **processors** and constitutes **layers** of metal forming an **absorbant** for harmful or abnormal currents.

5. As a source of energy formed **auxiliary batteries** 11 and **Ruhmkorff coils** 12 to get into the antenna sufficient attraction by means of an adjustment of intensity, which once it begins, allows the constant flow of atmospheric current in the system.

In considering Figure 3, which represents a sort of an installation scheme of the device, the reception of atmospheric electrical current will, as set out above, producing a priming of these currents. This boot is made in launching the system which is double to answer each of the poles, the current batteries 11 through 12 and reels going to the antenna.

This boot will continue until the disposal of electrical current atmosphere is evident by the one or more table lamps L of resistance shown in Figure 5.

Once the lights illuminate it is advisable to charge the batteries to boot. Natural flow and constant currents will be captured by the regulators , Figure 3; they will regularize in tension and in amperage and then directed to use in table lamps.

It has been said above that regulators R, etc., are intended and designed to automatically eliminate earth surge currents capture and abnormal currents that cannot yet be level but that these regulators could be replaced by devices with the same function.

There is therefore no need to describe in detail and especially the claims. We only specify that these regulators must be proper protection for the purposes described above.

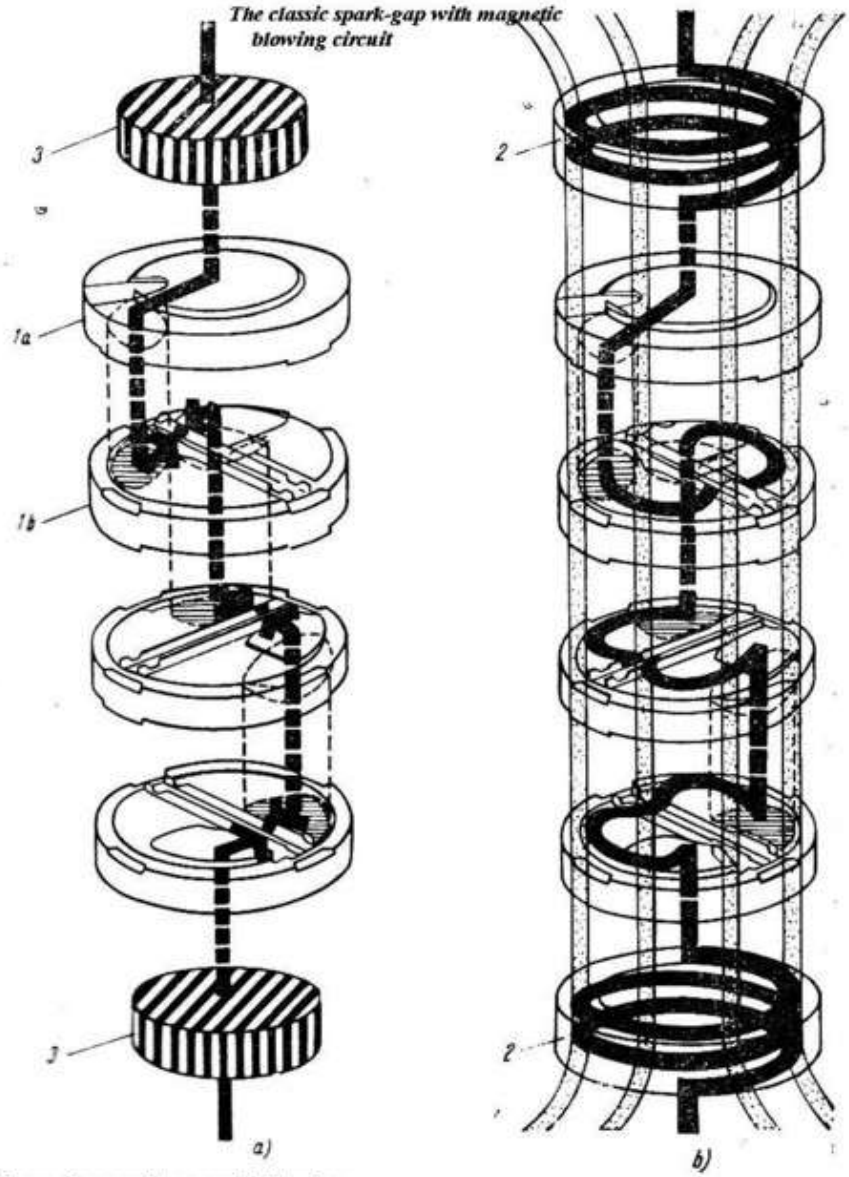

The spark-gap with magnetic blowing :
a,- the initial stage ; the impulse current send in soil through the shunt-resistences 3, because the coils 2 have an impedance too big for the impulse of 10/20 µs ;
the spark-gap 1 has two elements disc-shaped 1a and 1b, the inferior disc have one electrode and the upper disc the other electrode of the spark-gap circuit.
b,- the second stage ; the accompanying current discharge - after the impulse current ;
this accompanying current pass through the coils 2 which produce the magnetic field with the role to extend the electric arc into the slit between insulator discs 1a and 1b ; the thickness of this slit is smaller and smaller in accord with the extension of the electric arc, in this manner producing the magnifing of its electric resistance and finally, the electric arc extinction.

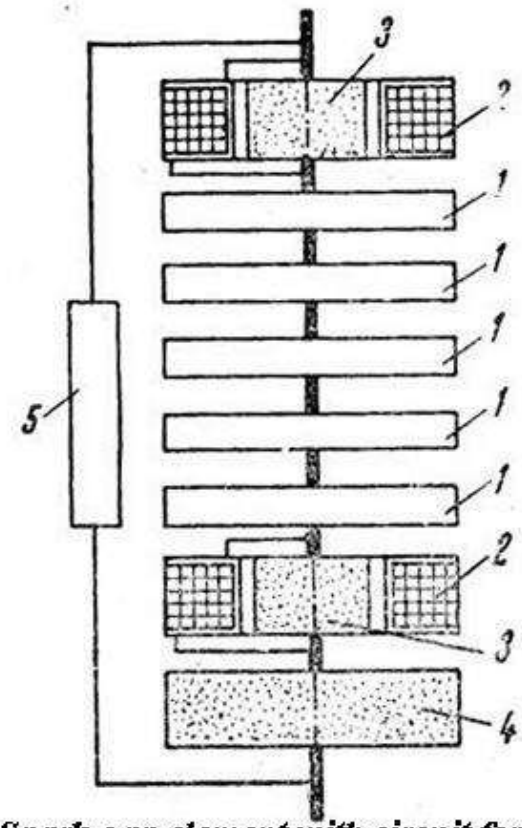

1,- the spark-gap individual devices which work in the manner to extend the electric arc of the accompanying electric current ;
2,- the coils which produce the magnetic field for the magnetic blowing ;
3,- the electric shunt-resistances in parallel connection on the blowing coils, with the role of reducing the current inside this coils
4,- the disc with unlinear resistance ;
5,- electrical resistance for the homogenous distribution of the electric field in all the elements of the spark-gap.

In Jules Guillot scheme, that kind of device could be used for leading the current.

Spark-gap element with circuit for the magnetic blowing of the electric fascicle

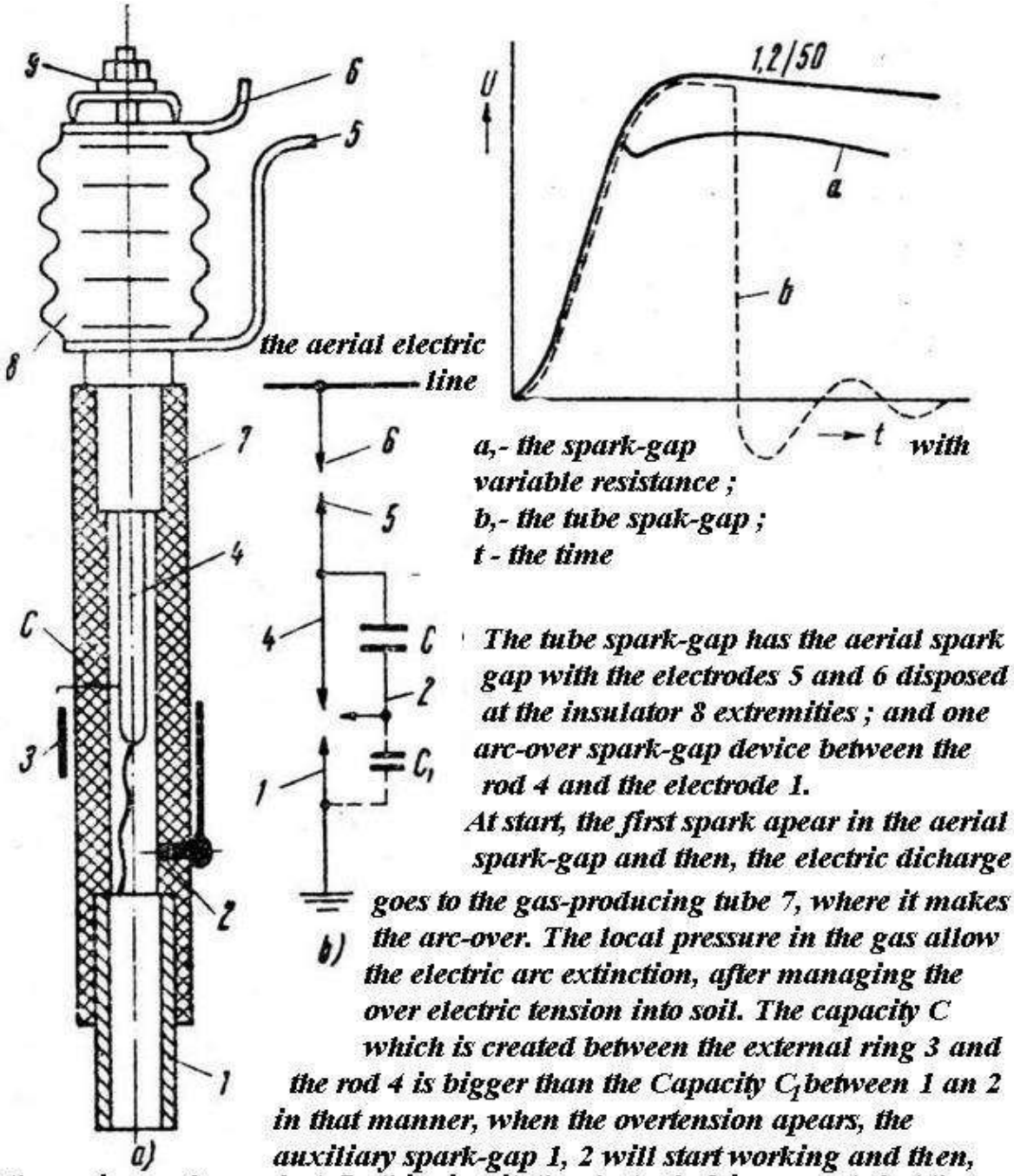

The tube spark-gap has the aerial spark gap with the electrodes 5 and 6 disposed at the insulator 8 extremities ; and one arc-over spark-gap device between the rod 4 and the electrode 1.

At start, the first spark apear in the aerial spark-gap and then, the electric dicharge goes to the gas-producing tube 7, where it makes the arc-over. The local pressure in the gas allow the electric arc extinction, after managing the over electric tension into soil. The capacity C which is created between the external ring 3 and the rod 4 is bigger than the Capacity C_1 between 1 an 2 in that manner, when the overtension apears, the auxiliary spark-gap 1, 2 will start working and then, the main spark-gap 1, 4. In this circuit, the electrode 9 is connected at the aerial electric line and the electrode 1 at the Earth.

In the image above, it is an classic tube spark-gap used for the protection of aerial electric cables. The atmospheric electricity is discharged in soil and lost... The Guillot's inventions used that kind of devices for leading and absorbing of the atmospheric electricity.

DARIDA, Gillbert : "Practical Utilization of Atmospheric Electricity";
(in *The Invention Encyclopedia,* pp. 204-207 ; 1930, Geo. Constantinescu, Ed.) --

Utilizarea practică a electricităţii atmosferice

Pământul ca şi celelalte astre, posedă o electricitate proprie negativă în interior, iar aerul care-l înconjoară este pozitiv. Potenţialul sau tensiunea electrică a aerului se măreşte pe măsură ce ne ridicăm în înălţime, astfel că putem spune că intensitatea electrică este proporţională cu înălţimea (după lucrările remarcabile ale lui Franklin, Quetelet, Lord Kelvin, Mascart, Joubert şi a altor mari savanţi fizicieni).

Observaţiile făcute recent, au arătat că aerul regiunilor înalte dela 6000—7000 m este foarte încărcat cu electricitate pozitivă, a cărei explicaţie se datoreşte frecării fotosferei sau atmosferei terestre, prin învârtirea pământului în jurul soarelui cu mai mult de o sută de mii de km pe oră. Această frecare directă în fluidul eteric ambiant, face ca aerul să se încarce cu electricitate pozitivă prin influenţă, iar pământul să se încarce negativ.

Intre cele două medii, fluidic (aerul) şi (pământul) materie, ştiinţa ne spune, că în partea de jos a atmosferei, pe timp frumos un centimetru cub de aer ionizat, conţine circa 800 particule cu ioni pozitivi şi 680 ioni negativi (electroni).

Pământul se comportă ca un enorm conductor încărcat negativ, respingând electroni şi atrăgând ionii pozitivi. Această atracţie a ionilor pozitivi determină un curent electric, zis şi curent de convenţiune. E un fel de bombardament invizibil supus variaţiunilor zilei şi a sezoanelor, putându-l evalua aproximativ la o densitate mijlocie remarcabilă, dela 3×10^{16} sau a 30 quatrilionime de amper pe cm cub, ceea ce dă pentru întreagă suprafaţă a pământului un curent formidabil, de 1500 de amperi.

Se pune întrebarea cum un astfel de curent poate să-şi întreţie mereu acelaşi sens? Aceasta este enigma pe care ne-o punem, studiind curenţii naturali ai atmosferei noastre, presupunem că poate să fie o legătură a acţiunii emanaţiunilor radioactive. Aceste

emanaţiuni fiind din gaze radioactive grele, se găsesc de obiceiu în mare abundenţă aproape de pământ ceea ce ne explică marea ionizare observată în general în grote şi caverne.

Ionizarea atmosferică poate de asemenea fi produsă în parte, de acţiunea razelor X, foarte pătrunzătoare şi de diferite substanţe radioactive închise în subsolul pământului. De asemenea poate să mai fie, ţinând seama de acţiunea «Calei Lactee» şi de ionizarea luminei solare, foarte bogată în radiaţiuni ultraviolete

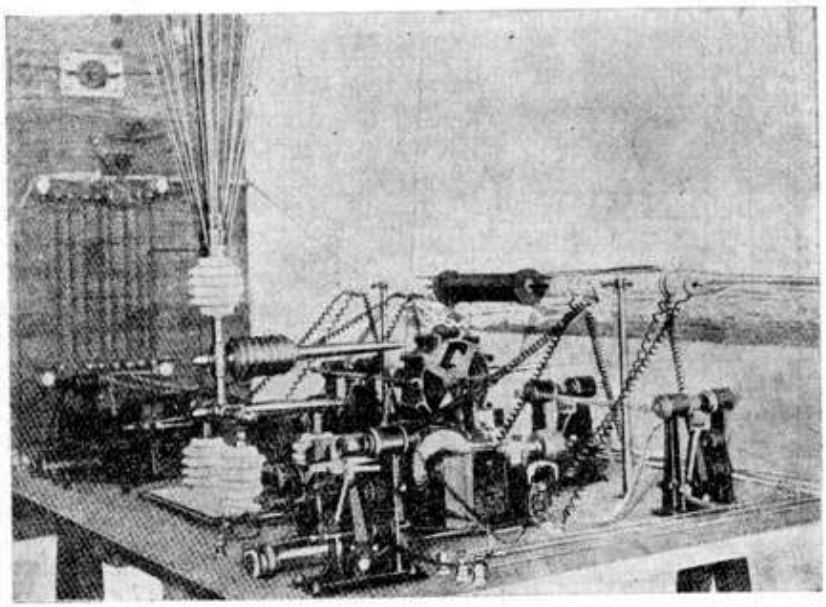

Fig. 108

precum şi a electronilor emişi direct din radierea căldurii solare de circa 6000 de grade.

Captarea electricităţii atmosferice a fost utilizată în Franţa prin cabluri aeriene montate pe Mont Blank, iar în Germania prin cabluri susţinute de baloane captive.

Sunt mai multe sisteme, vom da pe scurt pe cel mai ingenios procedeu, inventat de ing. Jules Guillot, bazat pe sifonul electric. Procedeul consistă de a pompa direct din atmosferă, electricitate

prin ajutorul unui aparat de captare, format din 2 antene aeriene şi o serie de bobine după cum se vede în fig. 108. Una din antene este verticală în formă de evantaiu dirijată cu vârfurile către zenit, pentru a capta electricitatea negativă din atmosferă; cea care este orizontală, este dirijată către Sud, pentru a capta electricitate pozitivă.

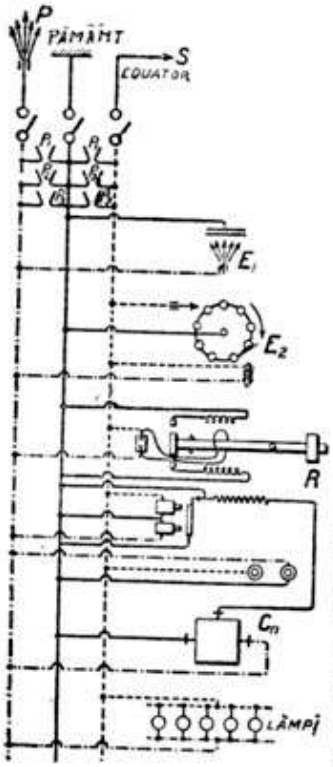

Fig. 109

Electricitatea în aer pare să fie cu dublă polaritate, după cum se vede la 2 nori electrizaţi, cari deplasându-se în sens contrar, dau naştere unei scântei (fulger) când distanţa respectivă poate să fie străbătută de puternica lor diferenţă de potenţial. Straturile de aer de densităţi diferite, nu sunt toate antrenate de aceeaşi viteză prin rotaţia pământului, ele se electrizează deci prin frecarea decalajului lor respectiv.

Aceste sunt consideraţiunile ce l-au făcut pe inventator să aşeze în atmosferă doi poli complet distincţi şi perfect izolaţi, al cărui pol pozitiv *S* (fig. 109) poate fi dirijat în direcţiunea Sudului, şi a celuilalt negativ *P*, în direcţiunea zenitului. Fig. 109 arată schema montajului şi a conexiunilor compuse după cum urmează: 1. dintr'o antenă dublă aeriană, montată pe stâlpi de 15—20 m înălţime. Această parte care se mai numeşte şi aparat de captat, este format din vârfurile *P*, dispuse în evantai în vârful unei tije de oţel dirijate către zenit, pentru a capta curenţii negativi ai atmosferei şi dintr'o altă antenă orizontală a cărei săgeată este îndreptată către sud *S*, adică către equator, pentru a recepta curenţii pozitivi. Aceste două părţi dispuse în unghiu de 90°, formează cei doi poli al curentului aerian, a cărei diferenţă de potenţial este suficientă pentru a permite utilizarea electricităţii atmosferice.

French Patent # 551,882

Appareil Capteur de Courants Electriques dans L'Atmosphere

No. 674,427. Patented May 21, 1901.

A. PALENCSÁR.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

(Application filed July 10, 1900.)

(No Model.) 3 Sheets—Sheet 1.

Fig. 1.

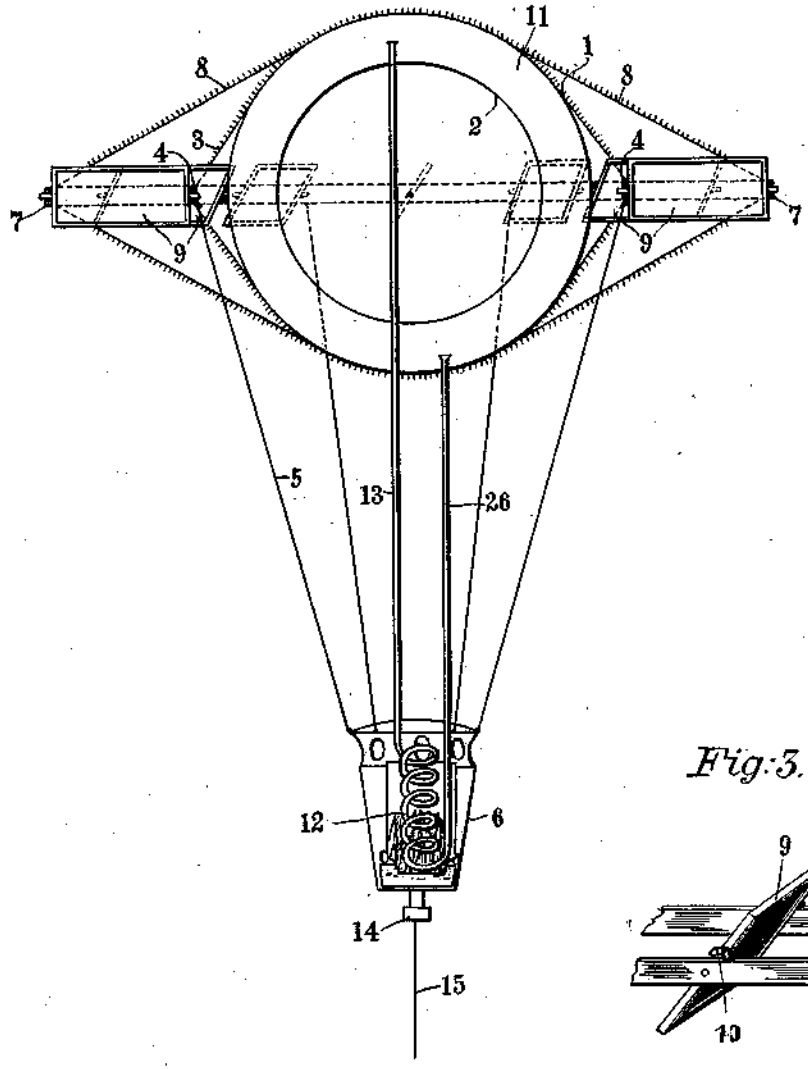

Fig. 3.

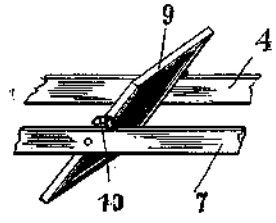

WITNESSES:

Ella L. Giles

Otto Munn

INVENTOR

Andor Palencsár

By Richards & Co.

ATTORNEYS

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 674,427. Patented May 21, 1901.

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APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

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(No Model.) 3 Sheets—Sheet 2.

Fig. 2.

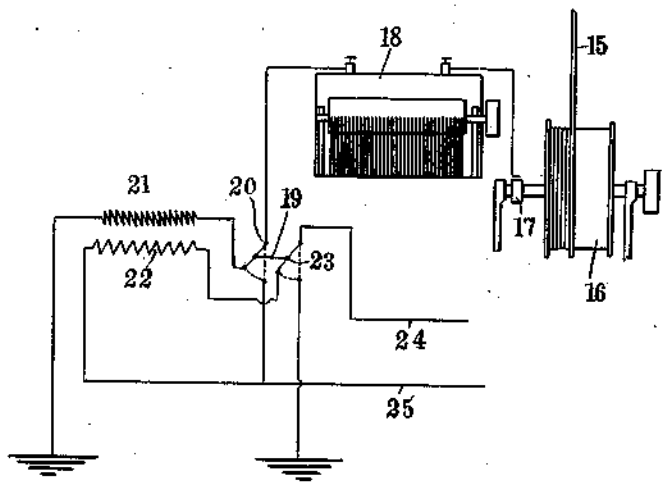

WITNESSES:
Ella L. Giles
Otto Munk

INVENTOR
Andor Palencsár
BY
Richards & Co
ATTORNEYS

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(No Model.) 3 Sheets—Sheet 3.

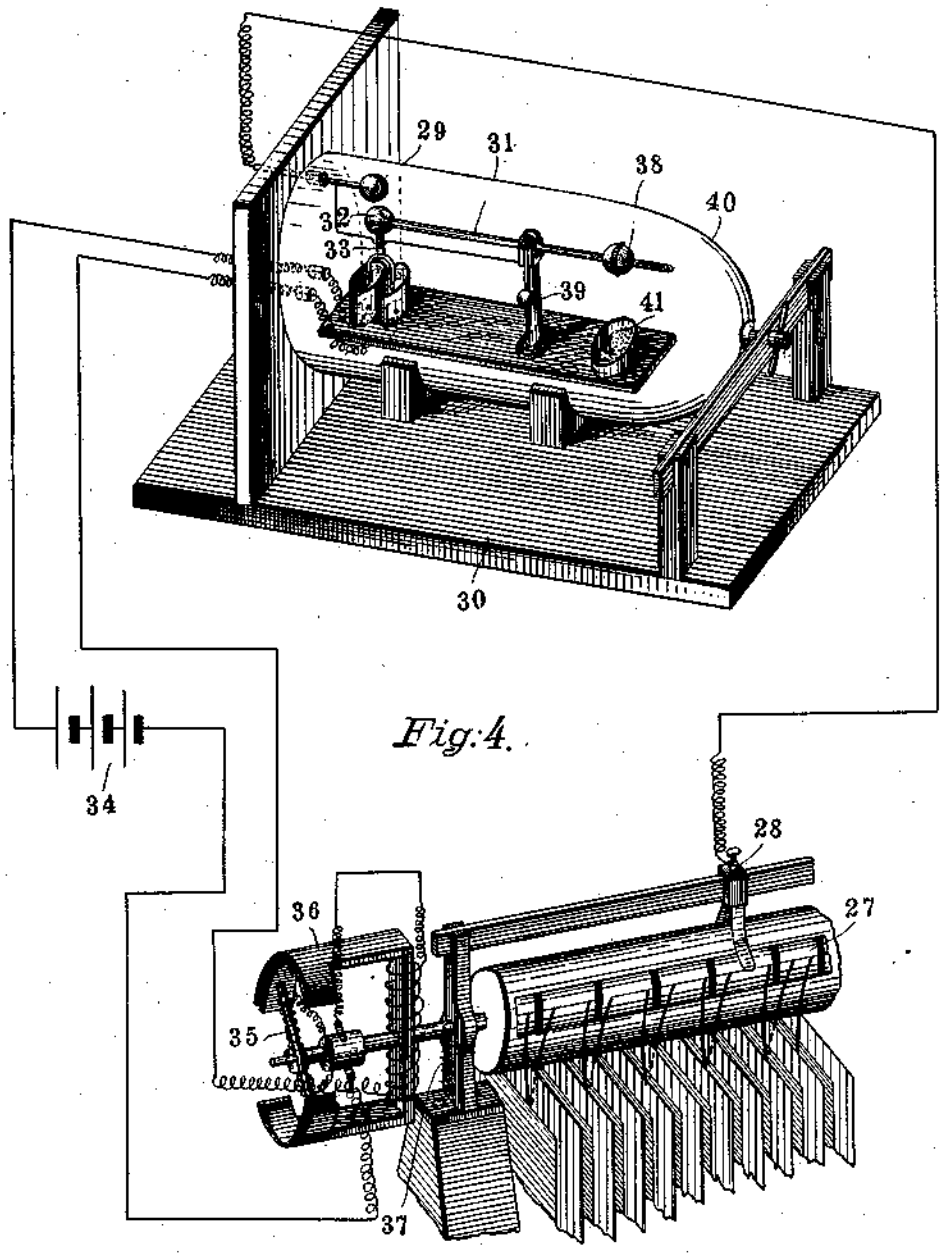

Fig. 4.

WITNESSES:
Ella L. Giles
Attorney

INVENTOR
Andor Palencsár
BY
Richards & Co
ATTORNEYS

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

ANDOR PALENCSÁR, OF BUDA-PESTH, AUSTRIA-HUNGARY.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

SPECIFICATION forming part of Letters Patent No. 674,427, dated May 21, 1901.

Application filed July 10, 1900. Serial No. 23,102. (No model.)

To all whom it may concern:

Be it known that I, ANDOR PALENCSÁR, a subject of the King of Hungary, residing at Buda-Pesth, Austria-Hungary, have invented a certain new and useful Apparatus for Collecting Atmospherical Electricity, of which the following is a full, clear, and exact specification.

The present invention concerns an apparatus for collecting and driving or conducting atmospherical electricity which renders it practicable to obtain material quantities of the same in serviceable form.

The experiments made hitherto have been limited to deviating or conducting the electricity by simple lightning-rods without making allowance for the progress of the theory of atmospherical electricity. It is obvious that only extremely small quantities of electricity can be collected in this manner, and, moreover, it was obtained in a form which entirely precluded its utilization. It is evident that a source of electricity of irregular yield can only be utilized by means of accumulators and for charging accumulators only a current of constant potential can be employed. The potential of electricity derived or deviated by means of a lightning-rod varies within wide limits, and, moreover, it is so high that it cannot be used at all for charging accumulators. All these drawbacks are remedied by the present invention, by which the atmospheric electricity is obtained in larger quantities with as low and constant a potential as may be desired.

The idea underlying the invention is based on the modern theory of atmospheric electricity, according to which it is produced by the condensation of steam or aqueous vapors, and that the increase of potential is effected by the concentration of the small drops of water into larger ones, as the proportion of the surface of the drops to the volume of same is materially reduced thereby. According to this theory the water-droplets floating in the layers of air are considered as vehicles or carriers of the electricity, and a rational system of the deviation of the atmospheric electricity must derive it from the water-drops. This is attained by the present invention in the following manner: A collecting-body of as large a surface as possible is provided with sharp needles. This is moved in the higher layers of air, while being continually heated by a suitable heating device. Owing to the heat the water-drops immediately ambient to the collecting-body will be evaporated, their capacity is gradually reduced, while the potential of the charge grows until it reaches an infinite height with infinite smallness of the drops. It is readily apparent that the whole charge of the drops as soon as they have been evaporated will have passed to the collector or collecting-body, from which it can be conducted. For the purpose of replacing the evaporated drops, which have been deprived of their charge by new-charged drops, the collector is moved in relation to the ambient air.

One way of carrying out the invention is represented in diagram in the accompanying drawings, in which—

Figure 1 is a longitudinal section of the collecting-balloon. Fig. 2 shows the deviating and conversion device, and Fig. 3 a detail. Fig. 4 is a diagrammatic perspective view of a form of automatic regulator for the rheostatic machine.

The apparatus consists of a balloon having two walls and covered with a light wire net, preferably of aluminium wire, said net being studded with needles. Besides, the balloon carries the net 3, on which the ring 4, made of a solid but light material, (wood, cane, &c.,) is fixed. This ring carries the basket 6 by means of the cords or ropes 5. On a level with the ring 4 is the ring 7, which is kept spread by the blades or wings 9, which are journaled in a manner to rotate easily. The ring 7 is kept fixedly in position by the cords or ropes 8. The blades or wings consist of a frame covered with light material, and their rotation in either direction is limited by the stops or ledges 10. The blades or wings form advantageously an angle of sixty to seventy degrees with the vertical line.

All wire nets, ropes, rings, and blades or wings may be covered with small metal needles which are electrically connected with each other.

From the space 11, formed between the double walls of the balloon, the pipe 26 leads from the lowest point of the same to the serpentine 12, arranged in the basket 6, which in turn is

connected with the pipe 13, ending in the upper part of the space 11 between the two walls 1 2. The serpentine is heated by means of a suitable source of heat, whereby a warm current of gas or air circulates continually between the double walls of the balloon.

Under the basket the ball-bearing 14 is arranged in electrical connection with the wire nets, and its stud is electrically connected with the carefully-insulated light though sufficiently strong cable 15.

On the earth's surface is a winch 16, Fig. 2, by means of which the balloon can be made to ascend or descend as soon as the interior space of the balloon is filled with illuminating gas or hydrogen.

The end of the cable-core is soldered to a collector arranged upon and insulated from the axle of the winch, and the electricity is conducted from this collector by means of a sliding contact. The collecting of the electricity takes place by moving the balloon continuously up and down by means of the winch. In this movement the balloon is turned by means of the wings or blades 9, which are adapted to turn the balloon always in the same direction whether ascending or descending, as in the change from ascending into descending of the balloon, or vice versa, the blades are turned over by the aerial resistance, and thus impart the rotating motion to the balloon in the same direction. In order to avoid torsion of the cable, the ball-bearing 14 is provided. This up-and-down motion and rotating of the balloon accomplishes the purpose of bringing it into contact with as many water particles floating in the air as possible.

As the electricity conducted from the collector-wing 17 possesses a much too high and varying potential for making its direct application practicable, and as it is usual with an irregular source of electricity to first charge accumulators and to further utilize the easily-regulated current of the same only, it becomes necessary to seek to maintain the electricity conducted from the collector 17 for the charging of the accumulators at a constant potential and convert the potential to a much lower one; but as we deal in this case with a direct current ordinary converters cannot be used for this purpose. Moreover, the electricity possesses in this case a much too high potential, so that with the employment of ordinary converters the greatest part of the collected electricity would be lost again. The only practical method for this purpose is the converting by means of the Planté rheostatic machine, by which this high-voltage electricity can be transformed almost without any loss whatever. Thus the question of conversion would be solved, and only the question of maintenance of constant potential remains. This is obtained in the following manner: The rheostatic machine 18 or only a part of the plates is connected with an electrometer of any construction, the movable part of which closes a contact which eventually actuates an electromagnet which effects the switching or reversion of the rheostatic machine. After the switching of the rheostatic machine it is discharged, the potential falls to zero, (*nil*,) and the electrometer resumes its initial position, whereby the current of the electromagnet which effects the reversion is interrupted and the plates of the rheostatic machine are reconnected to potential. The machine is then ready for renewed charge and is again discharged when the determined potential is reached. This action is continually repeated as long as the apparatus is in operation.

A form of the automatic regulator for the rheostatic machine is represented in Fig. 4. 27 is the contact-cylinder of the rheostatic machine, on which, for clearness sake, only the contacts for the charging position of the condenser-plates are shown, while the contacts for the discharging position, which come into action after the contact-cylinder has been turned, are omitted. The coating of the condenser-plates is connected in electrical circuit with the stationary ball 29 and the movable ball 32 of the charge-meter 30. When the charge of the rheostatic machine rises, the ball 32, arranged on the one extremity of the lever 31, is repelled and at a certain stroke actuated by means of the fork 33, which is fastened on the ball 32, and by dipping into a mercury-cup it closes the circuit of the source of current 34. This current passes through the windings of the anchor or armature 35, fixed on the shaft of the contact-cylinder, and it also passes through the electromagnet 36. Thereby the contact-cylinder is turned by a certain angle and the rheostatic machine is thus reversed. Then if the tension decreases by discharge and the repulsion of the balls 29 32 declines so far that the contact is interrupted at 33 the spring 37 turns the contact-cylinder into its normal position and the rheostatic machine is again switched to tension. The regulation of the electrometer is effected by the adjustable weights 38 39. When larger quantities of electricity shall be derived or deviated, two rheostatic machines may operate alternately so, that while the one is being discharged the other can be charged. It is readily apparent that if the capacity of the rheostatic machine is not changed the switching or reversion by the electrometer will always take place at the same potential of the rheostatic machine, and as the number of plates, and hence the proportion of conversion, remains the same the current impulses derived or deviated from the rheostatic machine will also have the same potential.

The irregularities of the source of electricity change the interval of time in which the charges follow each other; but as long as the potential remains constant this has no injurious effect on the charge of the accumulators. The current derived or deviated from the

rheostatic machine can be further transformed by an ordinary converter 21 22, and whenever it is sufficiently constant it can be utilized without the intervention of the accumulators. The converters can be connected or disconnected by means of the double switch 19 20 23.

24 and 25 are the conducting-wires, which run either directly to the place of consumption or to an accumulator-battery.

Having now described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. An apparatus for collecting atmospheric electricity comprising a collecting-body adapted to be kept in motion, heating means for said body, and a rheostatic machine and a converter connected with the said body electrically, substantially as described.

2. An apparatus for collecting atmospheric electricity for storage comprising a collecting-body adapted to be kept in motion in the ambient air, heating means for said body, a conductor leading from said body, a rheostatic machine connected with the said conductor, an electrometer connected with said rheostatic machine electrically, a contact controlled by the electrometer, and an electromagnet controlled by said contact, said electromagnet controlling the reversing of the rheostatic machine, substantially as described.

3. In combination, the balloon-like collecting-body, having the collecting-points, means for heating the interior space of said body, a conductor leading from the balloon-like body, and electrical devices for receiving the current therefrom, substantially as described.

4. In combination, the balloon-like collecting-body, means for turning the same constantly in one direction in both ascending and descending, conducting means leading from the balloon and electrical devices for receiving the current therefrom, substantially as described.

In witness whereof I have hereunto set my hand in presence of two witnesses.

ANDOR PALENCSÁR.

Witnesses:
EUGÈNE HARRÄNJO,
PAUL BÖLESKEY.

June 9, 1925. 1,540,998

H. PLAUSON

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

Filed Jan. 13, 1921 12 Sheets-Sheet 1

Fig. 1.

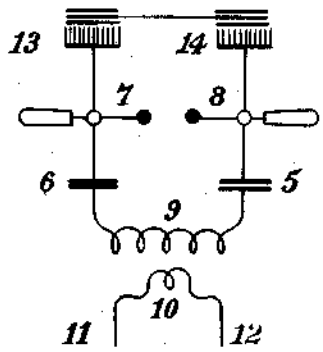

Fig. 2.

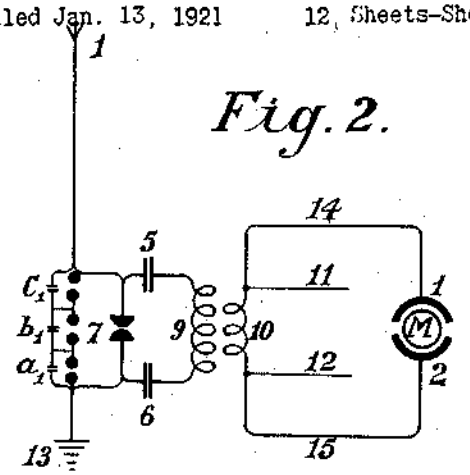

Fig. 3.

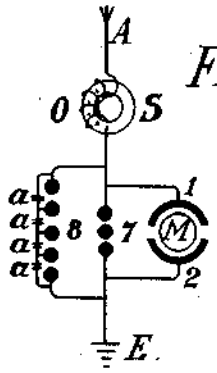

Fig. 4.

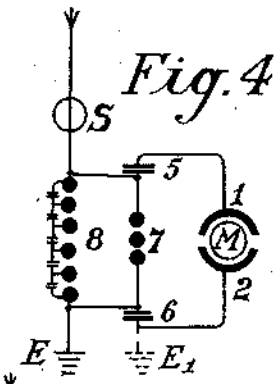

Fig. 5.

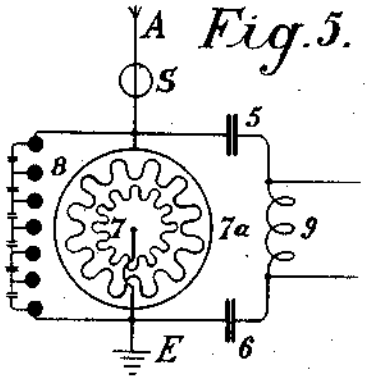

Fig. 6

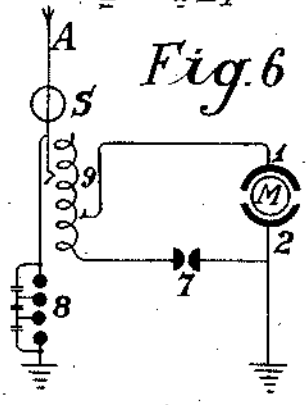

Inventor

Hermann Plauson

by Knight Bros

Attorneys

June 9, 1925. 1,540,998

H. PLAUSON

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

Filed Jan. 13, 1921 12 Sheets-Sheet 2

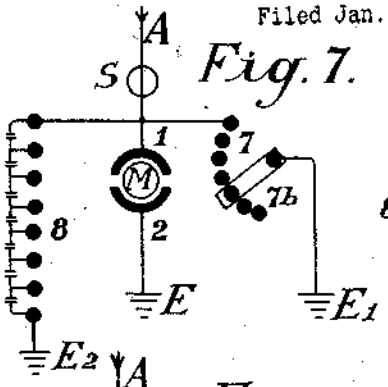

Fig. 7.

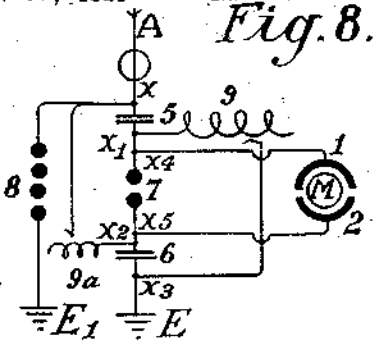

Fig. 8.

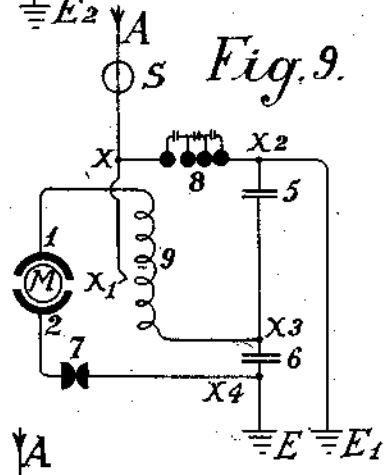

Fig. 9.

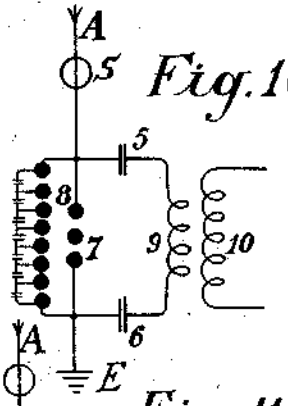

Fig. 10.

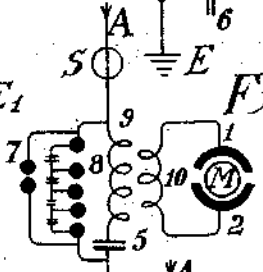

Fig. 11.

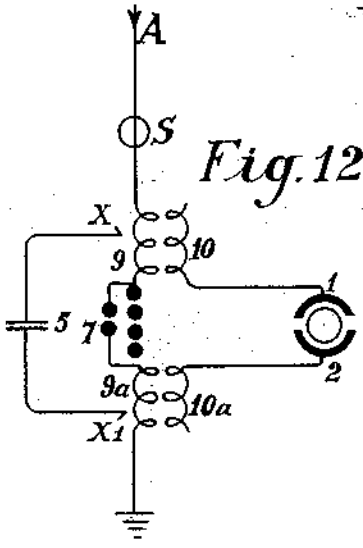

Fig. 12.

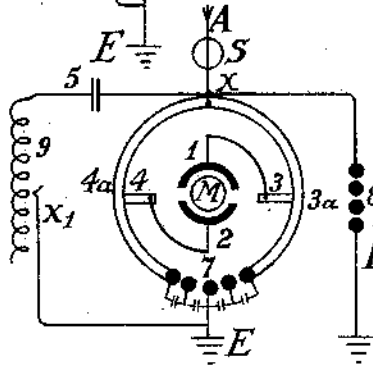

Fig. 13.

Inventor

Normann Plauson

by Knight Bros

Attorneys

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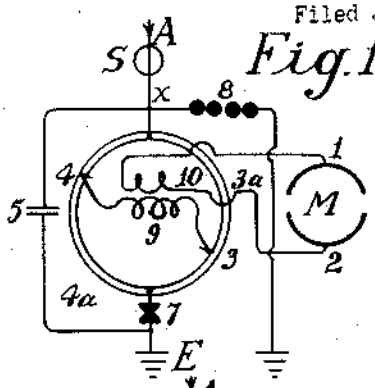

Fig. 14.

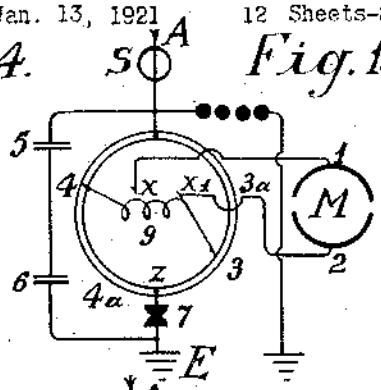

Fig. 15.

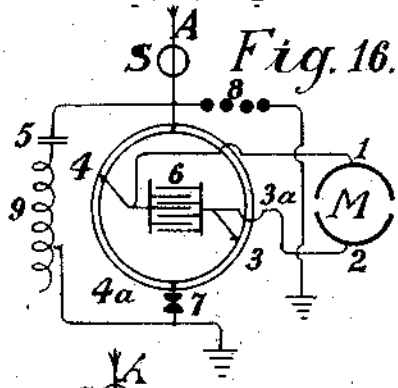

Fig. 16.

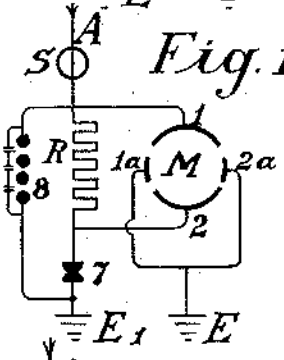

Fig. 17.

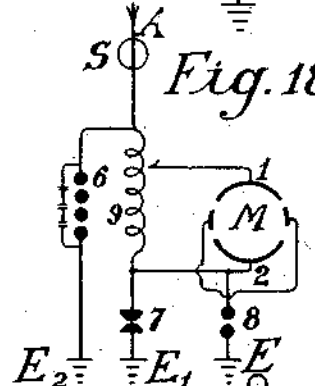

Fig. 18.

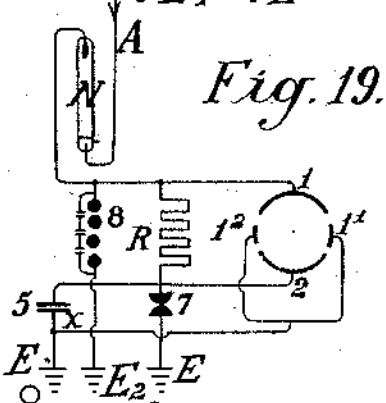

Fig. 19.

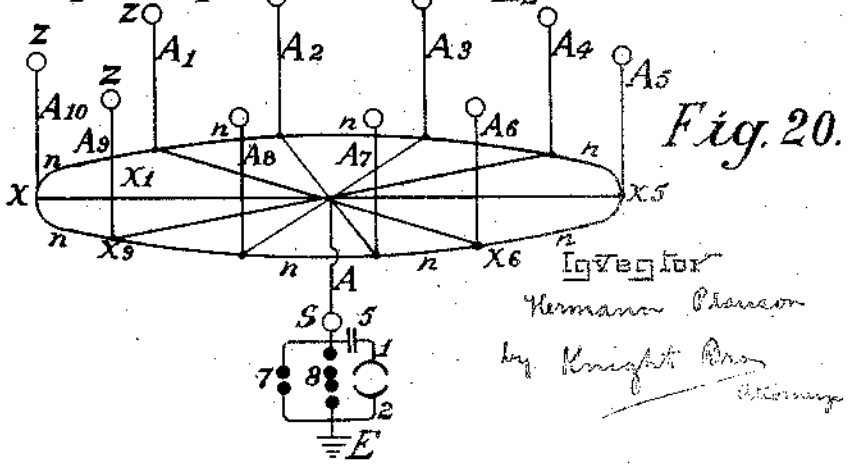

Fig. 20.

Inventor
Hermann Plauson
by Knight Bros
Attorneys

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Fig. 22.

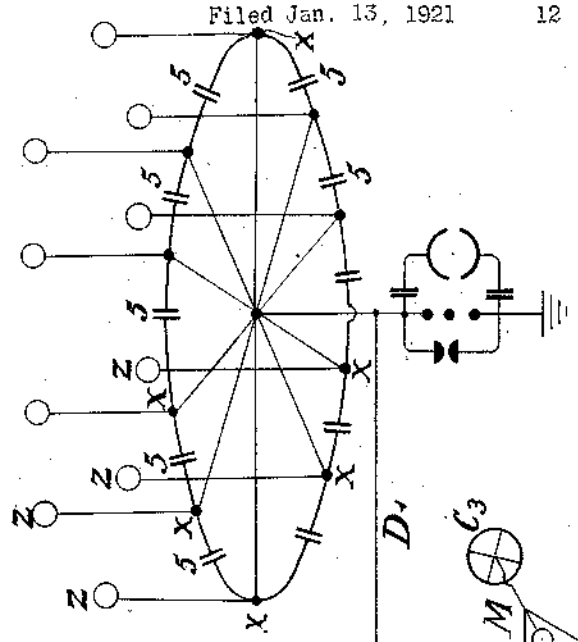

Fig. 23.

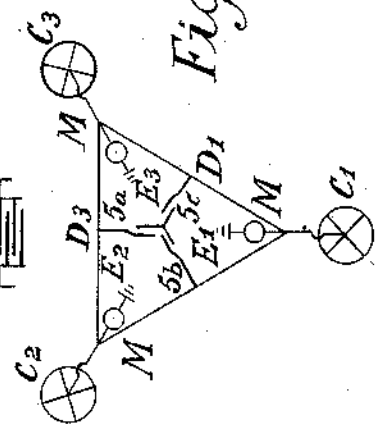

Fig. 21.

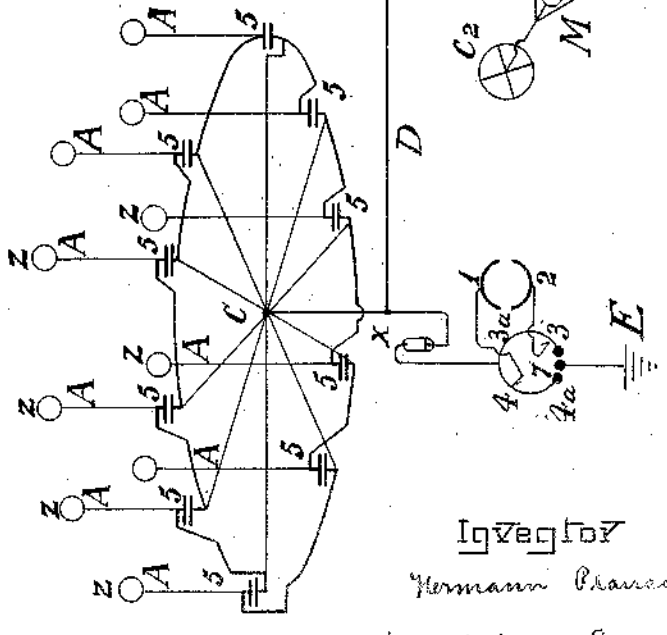

Inventor

Hermann Plauson

by Knight Bros

Attorneys

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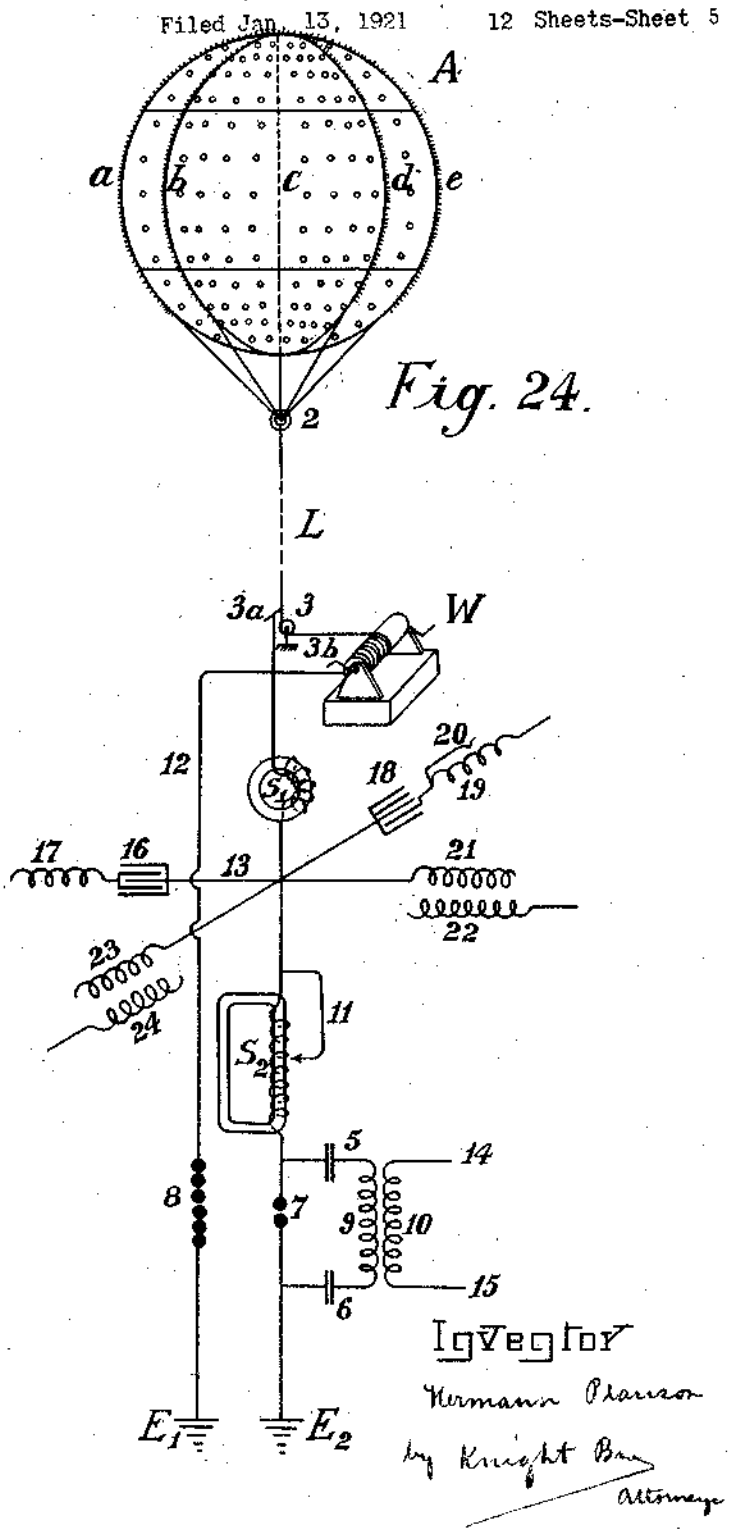

Fig. 24.

Inventor

Hermann Plauson

by Knight Bros

Attorneys

June 9, 1925. 1,540,998

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Fig. 25.

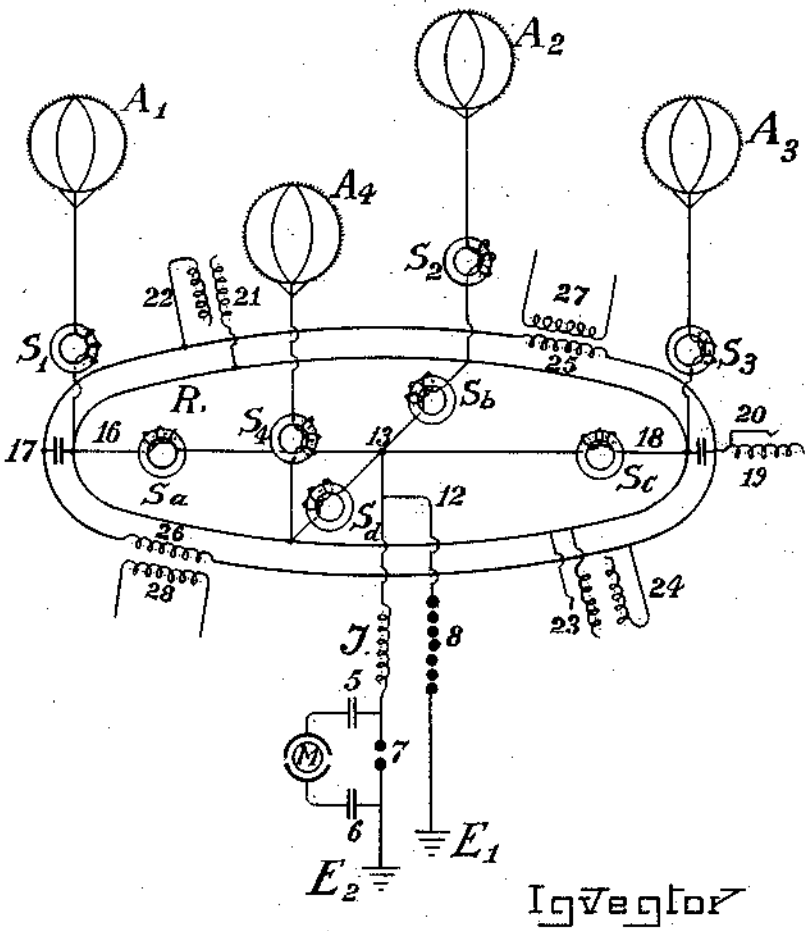

Inventor

Hermann Plauson

by Knight Bros

attorneys

June 9, 1925. 1,540,998

H. PLAUSON

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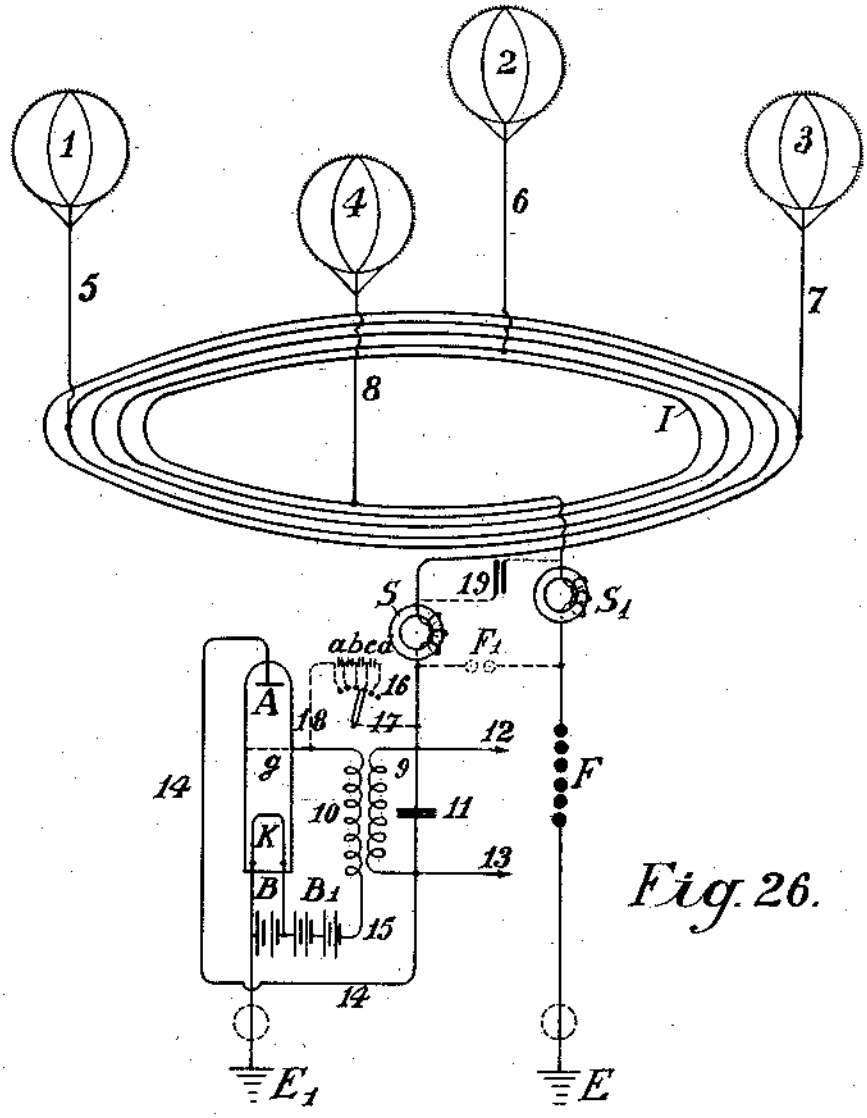

Fig. 26.

Inventor
Hermann Plauson
by Knight Bros
Attorneys

June 9, 1925. 1,540,998

H. PLAUSON

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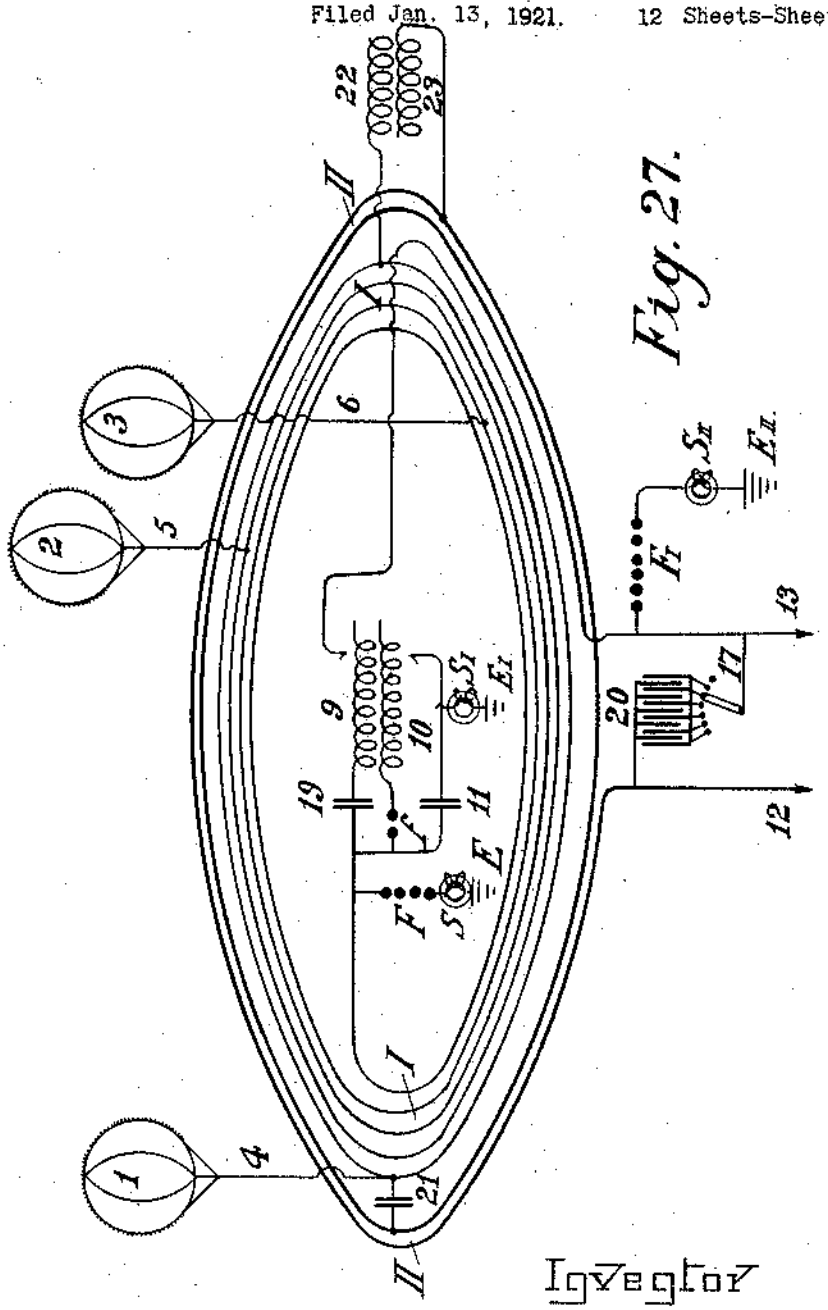

Fig. 27.

Inventor

Hermann Plauson

by Knight Bros

attorneys

June 9, 1925. 1,540,998

H. PLAUSON

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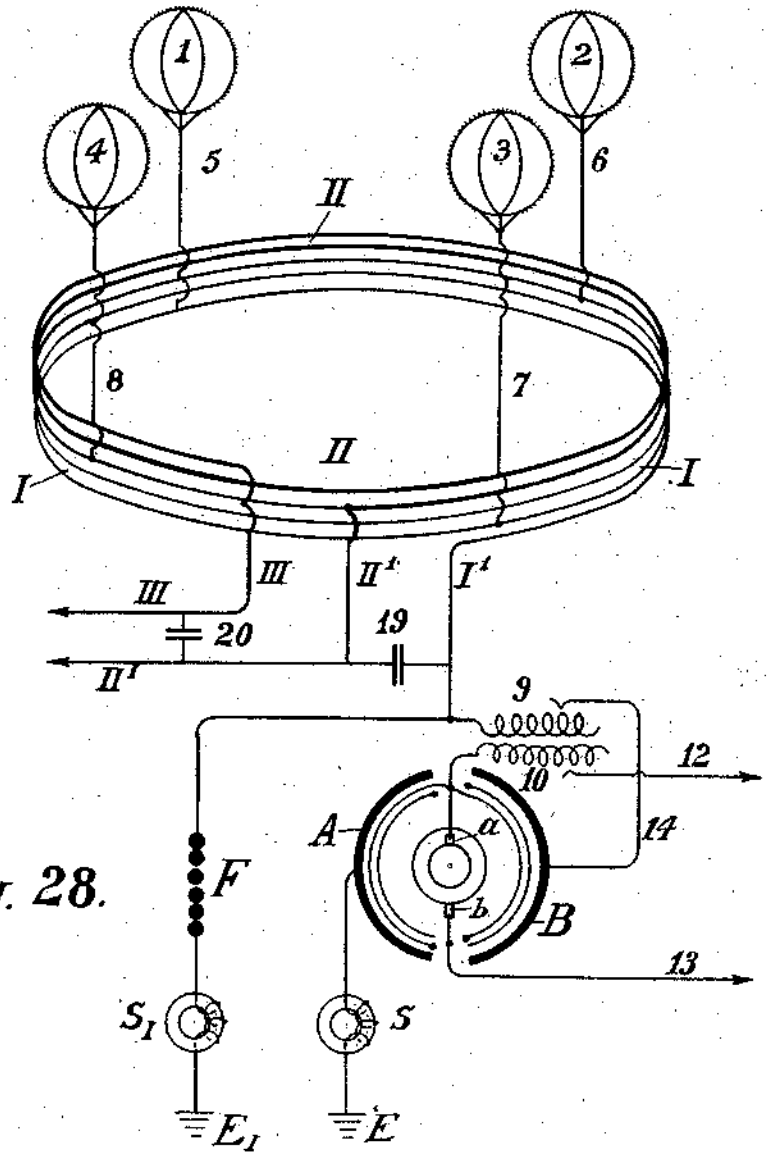

Fig. 28.

Inventor

Hermann Plauson

by Knight Bros

attorneys

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H. PLAUSON

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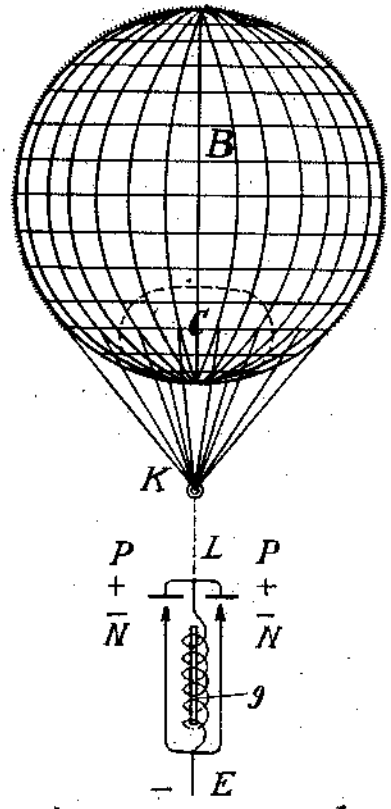

Fig. 29.

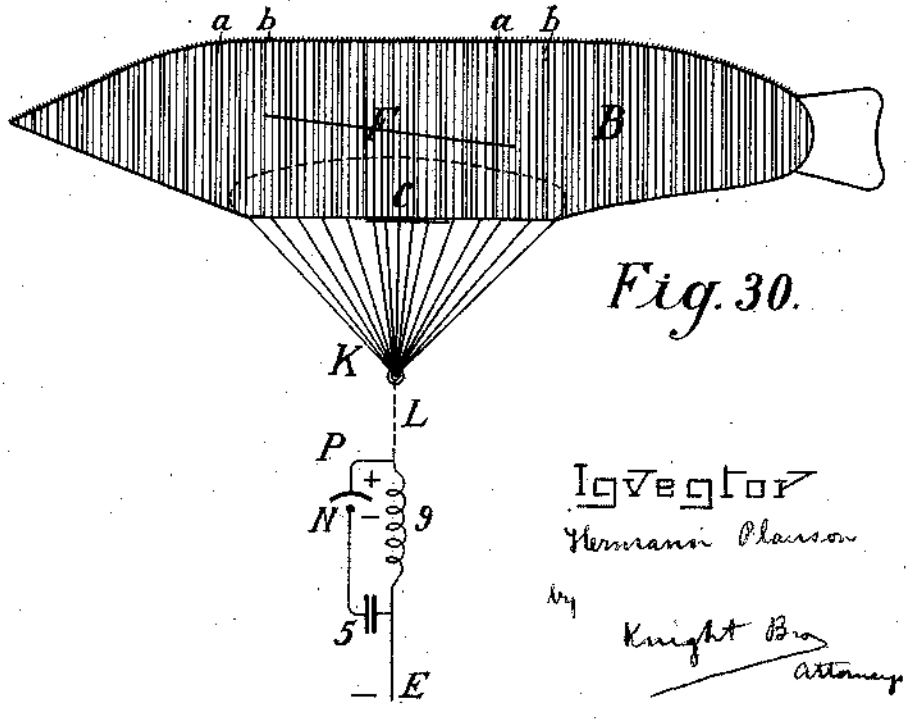

Fig. 30.

Inventor
Hermann Plauson
by
Knight Bros
Attorneys

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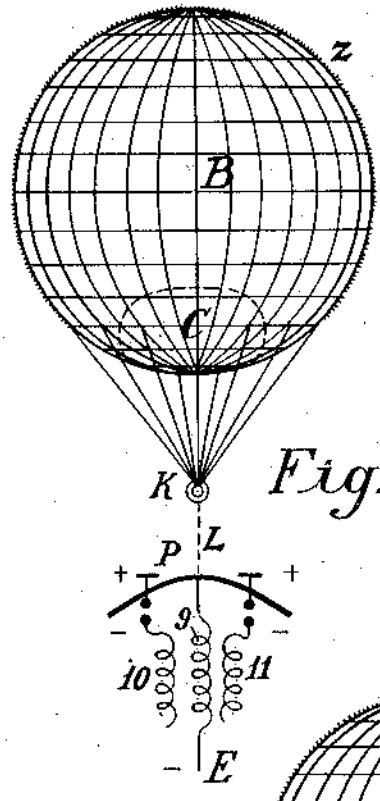

Fig. 31.

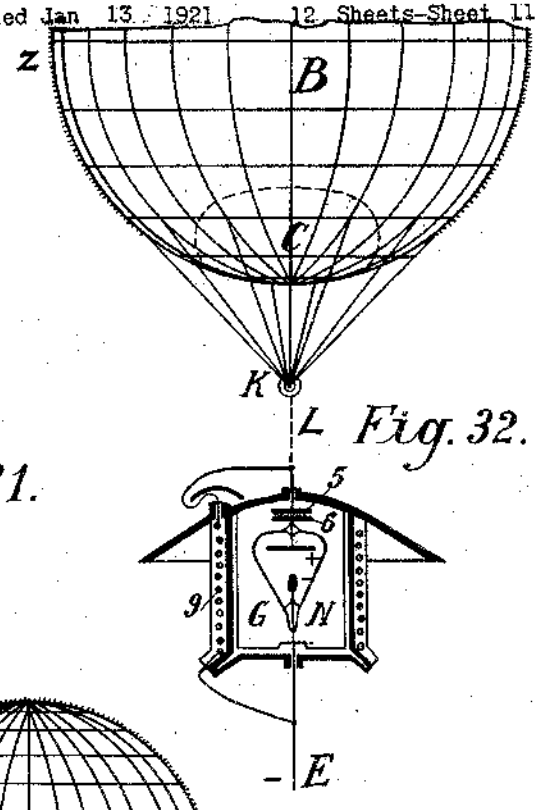

Fig. 32.

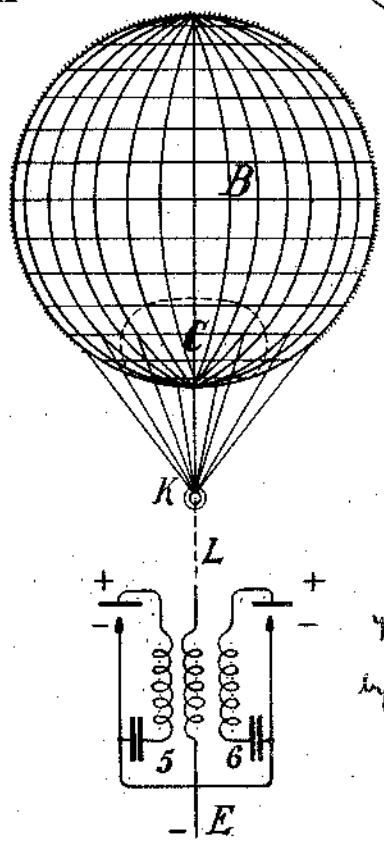

Fig. 33.

Inventor
Hermann Plauson
by Knight Bros
Attorneys

June 9, 1925. 1,540,998

H. PLAUSON

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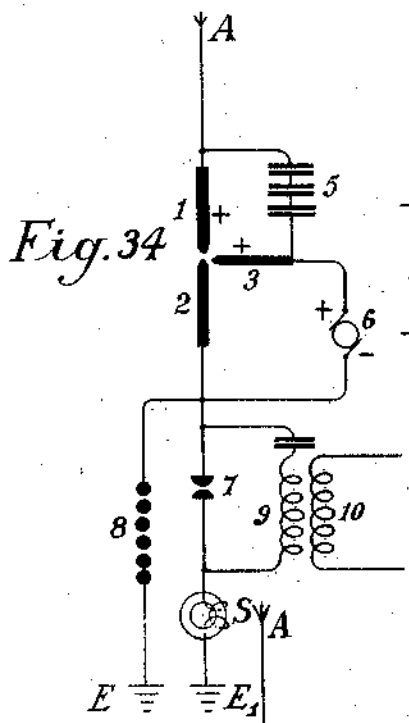

Fig. 34

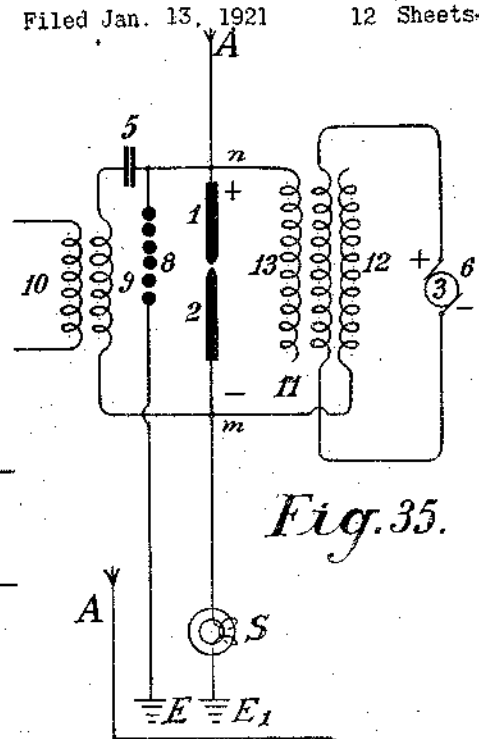

Fig. 35.

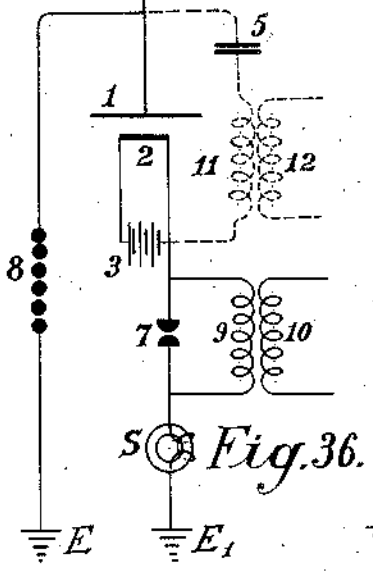

Fig. 36.

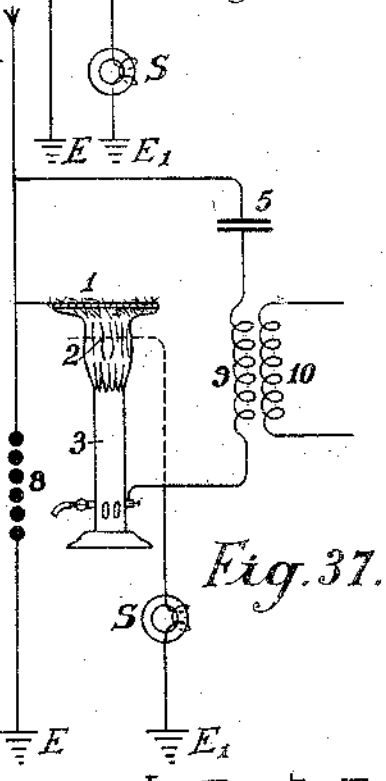

Fig. 37.

Inventor

Hermann Plauson

by Knight Bros

Attorneys

Patented June 9, 1925. 1,540,998

UNITED STATES PATENT OFFICE.

HERMANN PLAUSON, OF HAMBURG, GERMANY.

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY.

Application filed January 13, 1921. Serial No. 437,107.

To all whom it may concern:

Be it known that I, HERMANN PLAUSON, Esthonian subject, residing in Hamburg, Germany, have invented certain new and useful Improvements in the Conversion of Atmospheric Electric Energy, of which the following is a specification.

Methods of obtaining atmospheric electricity by means of metallic nettings set with spikes which are held by means of ordinary or anchored kite balloons made of fabrics and filled with hydrogen, are in theory already known. Atmospheric electricity obtained in this way has been suggested to be used in the form of direct current for the charging of accumulators. This knowledge however is at present only theoretical as the conversion in practice has hitherto been a failure. No means are known of protecting the apparatus from destruction by lightning. The balloons used for collecting the charge must also be made of very large size in order to be able to support the weight of the metallic netting and the heavy cable connections.

Instead of using heavy metallic netting as collectors attached to single air balloons of non-conducting materials which are liable to be torn and are permeable to the gas, it is proposed to use metallic balloon collectors which have the following important advantages—

(*a*) The metallic cases are impenetrable to helium and hydrogen; they also represent large metallic weather-proof collecting surfaces.

(*b*) Radio active means and the like may be easily applied internally or externally; whereby the ionization is considerably increased and therewith also the quantity of atmospheric electricity capable of being collected.

(*c*) Such balloon collectors of light metal do not require to be of large size as they have to carry only their own moderate weight, and that of the conducting cable or wire.

(*d*) The entire system therefore offers little surface for the action of storm and wind and is resistant and stable.

(*e*) Each balloon can be easily raised and lowered by means of a winch so that all repairs, recharging and the like can be carried out without danger during the operation.

It is further proposed to use a collecting aerial network of several separate collectors spread out in the air above the earth, which collectors are interconnected by electrical conductors.

According to this invention charges of atmospheric electricity are not directly converted into mechanical energy, and this forms the main difference from previous inventions, but the static electricity which runs to earth through aerial conductors in the form of direct current of very high voltage and low current strength is converted into electro-dynamic energy in the form of high frequency vibrations. Many advantages are thereby obtained and all disadvantages avoided.

The very high voltage of static electricity of a low current strength can be converted by this invention to voltages more suitable for technical purposes and of greater current strength. By the use of closed oscillatory circuits it is possible to obtain electro-magnetic waves of various amplitude and thereby to increase the degree of resonance of such current. Such resonance allows various values of inductance to be chosen whereby again the governing of the starting and stopping of machines driven thereby by simply tuning the resonance between coils of the machine and the transformer circuit forming the resonance can easily be obtained. Further, such currents have the property of being directly available for various uses, even without employing them for driving motors, of which there may be particularly mentioned, lighting, production of heat and use in electro-chemistry.

Further, with such currents a series of apparatus may be fed without direct current supply through conductors and also the electro-magnetic high frequency currents may be converted by means of special motors adapted for electro-magnetic oscillations into mechanical energy, or finally converted by special machines into alternating current of low frequency or even into direct current of high potential.

The invention is more particularly described with reference to the accompanying diagrams in which:—

Figure 1 is an explanatory figure.

Figure 2 is a diagrammatic view of the simplest form.

Figure 3 shows a method of converting atmospheric electrical energy for use with motors.

Figure 4 is a diagram showing the use of protective means.

Figure 5 is a diagram of an arrangement for converting large current strengths.

Figure 6 is a diagram of an arrangement including controlling means.

Figure 7 shows means whereby the spark gap length can be adjusted.

Figure 8 shows a unipolar connection for the motor.

Figure 9 shows a weak coupled system suitable for use with small power motors.

Figures 10, 11 and 12 show modified arrangements.

Figure 13 shows a form of inductive coupling for the motor circuit.

Figure 14 is a modified form of Figure 13 with inductive coupling.

Figure 15 is an arrangement with non-inductive motor.

Figure 16 is an arrangement with coupling by condenser.

Figures 17, 18 and 19 are diagrams of further modifications.

Figure 20 shows a simple form in which the aerial network is combined with special collectors.

Figure 21 shows diagrammatically an arrangement suitable for collecting large quantities of energy.

Figure 22 is a modified arrangement having two rings of collectors.

Figure 23 shows the connections for three rings of collectors.

Figure 24 shows a collecting balloon and diagram of its connection of condenser batteries.

Figures 25 and 26 show modified collector balloon arrangements.

Figure 27 shows a second method of connecting conductor for the balloon aerials.

Figure 28 shows an auto-transformer method of connection.

Figure 29 shows the simplest form of construction with incandescent cathode.

Figure 30 shows a form with cigar shaped balloon.

Figure 31 is a modified arrangement.

Figure 32 shows a form with cathode and electrode enclosed in a vacuum chamber.

Figure 33 is a modified form of Figure 32.

Figure 34 shows an arc light collector.

Figure 35 shows such an arrangement for alternating current.

Figure 36 shows an incandescent collector with Nernst lamp.

Figure 37 shows a form with a gas flame.

Figure 1 illustrates a simple diagram for converting static electricity into dynamic energy of a high number of oscillations. For the sake of clearness in the drawings an influence machine is assumed to be employed and not an aerial antenna. 13 and 14 are combs for collecting the static electricity of the influence machine. 7 and 8 are spark discharging electrodes, 6 and 5 condensers, 9 an inductive primary coil, 10 secondary coil, 11 and 12 ends of conductors of the secondary coil 10. When the disc of the static influence machine is rotated by mechanical means, the combs collect the electric charges one the positive and the other the negative, and charge the condensers 5 and 6 until such a high potential is formed across the spark gap 7—8, that the spark gap is jumped. As the spark gap 7—8 forms a closed circuit with condensers 6 and 5, and inductive resistance 9, as is well known, waves of high frequency electromagnetic oscillations will pass in this circuit.

The high frequency of the oscillations produced in the primary circuit induces waves of the same periodicity in the secondary circuit. Thus in the primary circuit electromagnetic oscillations are formed by the passage of the spark over the spark gap and these waves are maintained by fresh charges of static electricity.

By suitably selecting the ratio between the number of the coils in the primary and secondary circuits with regard to a correct application of the co-efficients of resonance (capacity, inductance, and resistance) the high voltage of the primary circuit may be suitably converted into low voltage and high current strength.

When the oscillatory discharges in the primary circuit becomes weaker or entirely cease, the condensers are charged again by the static electricity until the accumulated charge again breaks down the spark gap. All this is repeated as long as electricity is produced by the static machine by employing mechanical energy.

An elementary form of the invention is shown in Figure 2 in which two spark gaps in parallel are used one of which may be termed the working gap 7 in Figure 2, whilst the second serves as a safety device for excess voltage and consists of a larger number of spark gaps than the working section, which gaps are arranged in series and are bridged by very small capacities as is illustrated in a_1, b_1, c_1, Figure 2 which allow of uniform sparking in the safety section.

In Figure 2 A is the aerial antenna for collecting charges of atmospheric electricity. 13 is the earth connection of the second part of the spark gap, 5 and 6 are condensers, 9 a primary coil. Now when through the aerial A the positive atmospheric electricity seeks to combine with the negative charge to earth, this is prevented by (the air gap between) the spark gaps. The resistance of the spark gap 7 is, as shown in the drawings, lower than that of the other safety section which consists of three spark gaps connected in

series, and consequently a three times greater air resistance is offered by the latter.

So long therefore, as the resistance of the spark gap 7 is not overloaded, so that the other spark gaps have an equal resistance with it the discharges take place only over spark gap 7. Should however the voltage be increased by any influences so that it might be dangerous for charging the condensers 5 and 6 or for the coil insulation 9 and 10 in consequence of break down, by a correct regulation of this spark gap the second spark gap can discharge free from inductive effects direct to earth without endangering the machine.

Without this second spark gap, arranged in parallel having a higher resistance than the working spark gap it is impossible to collect and render available large quantities of electrical energy.

The action of this closed oscillation circuit consisting of spark gap 7, two condensers 5 and 6, primary coil 9, and also secondary coil 10 is exactly the same as the one described in Figure 1 with the arrangement of the static induction machine with the only difference that here the second spark gap is provided. The electromagnetic high frequency alternating current obtained can be tapped off from the conductors 11 and 12 for lighting and heating purposes. Special kinds of motors adapted for working with these peculiar electrical charges may be connected at 14 and 15 which can work with static electricity charges or with high frequency oscillations.

In addition to the use of spark gaps in parallel a second measure of security is also necessary for taking off the current. This precaution consists according to this invention, in the introduction of and method of connecting certain protective electromagnets or choking coils in the aerial circuit as shown by S in Figure 3.

A single electromagnet only having a core of the thinnest possible separate laminations is connected with the aerial.

In the case of high voltages in the aerial network or at places where there are frequent thunder storms, several such magnets may however be connected in series.

In the case of large units or plants several electromagnets can be employed in parallel or in series parallel.

The windings of these electromagnets may be simply connected in series with the aerials. In this case the winding preferably consists of several thin parallel wires, which make up together, the necessary section.

The winding may be made of primary and secondary windings in the form of a transformer. The primary winding will be then connected in series with the aerial network, and the secondary winding more or less short-circuited over a regulating resistance or an induction coil. In the latter case it is possible to regulate to a certain extent the effect of the choking coils. In the further description of the connecting and constructional diagrams the aerial electromagnet choke coil is indicated by a simple ring S.

Figure 3 shows the simplest way of converting atmospheric electricity into electromagnetic wave energy by the use of special motors adapted for high oscillatory currents or static charges of electrical energy. Recent improvements in motors for working with static charges and motors working by resonance, that is to say, having groups of tuned electromagnetic cooperating circuits render this possible but such do not form part of the present invention.

A motor adapted to operate with static charges will for the sake of simplicity be diagrammatically indicated by two semicircles 1 and 2 and the rotor of the motor by a ring M. (Figure 3.) A is a vertical aerial or aerial network. S the safety choke or electromagnet with coil O as may be seen is connected with the aerial A. Adjacent the electromagnet S the aerial conductor is divided into three circuits, the circuit 8 giving the safety spark gap, the circuit 7 with the working spark gap, and then a circuit including the stator terminal 1, the rotor and stator terminal 2 at which a connection is made to the earth wire. The two spark gaps are also connected metallically with the earth wire. The method of working these diagrams is as follows:

The positive atmospheric electric charge collected tends to combine with the negative electricity (or earth electricity) connected with the earth wire. It travels along the aerial A through the electromagnet S without being checked as it flows in the same direction as the direct current. Further, its progress is arrested by two sparks gaps placed in the way and the stator condenser surfaces. The stator condenser surfaces are charged until the charge is greater than the resistance of the spark gap 7, whereupon a spark springs over the spark gap 7 and an oscillatory charge is obtained as by means of the motor M, stator surfaces 1 and 2, and spark gap 7, a closed oscillation circuit is obtained for producing the electromagnetic oscillations. The motor here forms the capacity and the necessary inductance and resistance, which, as is well known, are necessary for converting static electricity into electromagnetic wave energy.

The discharges formed are converted into mechanical energy in special motors and can not reach the aerial network by reason of the electromagnet or choke. If, however, when a spark springs over the spark gap 7 a greater quantity of atmospheric electricity tends to flow to earth, a counter voltage is

induced in the electromagnet, which is greater the more rapidly and strongly the flow of current direct to the earth is. By the formation of this opposing voltage a sufficiently high resistance is offered to the flow of atmospheric electricity direct to earth to prevent a short circuit with the earth.

The circuit containing spark gap 8 having a different wave length which is not in resonance with the natural frequency of the motor, does not endanger the motor and serves as security against excess voltage, which, as practical experiments have shown, may still arise in certain cases, but can be conducted direct to earth through this spark gap.

In the diagram illustrated in Figure 4 the spark gap 7 is shunted across condensers 5 and 6 from the motor M. This construction affords mainly a better insulation of the motor against excess voltage and a uniform excitation through the spark gap 7.

In Figure 5 a diagram is illustrated for transforming large current strengths which may be employed direct without motors, for example, for lighting or heating purposes. The main difference is that here the spark gap consists of a star shaped disc 7 which can rotate on its own axis and is rotated by a motor opposite similarly fitted electrodes 7^a. When separate points of stars face one another, discharges take place, thus forming an oscillation circuit over condensers 5 and 6 and inductance 9 for oscillatory discharges. It is evident that a motor may also be directly connected to the ends of the spiral 9.

The construction of the diagram shown in Figure 6 permits of the oscillation circuit of the motor being connected with an induction coil. Here a regulating inductive resistance is introduced for counter-acting excess voltages in the motor. By cutting the separate coils 9 (coupled inductively to the aerial) in or out the inductive action on the motor may be more or less increased or variable aerial action may be exerted on the oscillation circuit.

In Figure 7 the oscillation circuit is closed through the earth (E and E_1). The spark gap 7 may be prolonged or shortened by more or fewer spark gaps being successively connected by means of a contact arm 7^b.

Diagram 8 shows a unipolar connection of the motor with the aerial network. Here two oscillation circuits are closed through the same motor. The first oscillation circuit passes from aerial A through electromagnet S, point x, inductance 9^a to the earth condenser 6 and further, over spark gap 7 to the aerial condenser 5 and back to x. The second oscillation circuit starts from the aerial condenser 5 at the point x^1 over the inductance 9 to the earth condenser 6 at the point x^2 and through the condenser 6 over the spark gap 7 back to x^1. The motor itself is inserted between the two points of the spark gap 7. From this arrangement slightly damped oscillation wave currents are produced.

In the diagram illustrated in Figure 9 a loosely coupled system of connections is illustrated which is assumed to be for small motors for measuring purposes. A indicates the aerial conductor, S the electromagnet in the aerial conductor, 9 the inductance, 7 the spark gap, 5 and 6 condensers, E the earth, M the motor, and 1 and 2 stator connections of the motor. The motor is directly metallically connected with the oscillation circuit.

In Figure 10 a purely inductive coupling is employed for the motor circuit. The motor is connected with the secondary wire 10 as may be seen in Figure 11 in a somewhat modified diagram connection. The same applies to the diagram of Figure 12.

The diagrams hitherto described preferably allow of motors of small and medium strength to be operated. For large aggregates, however, they are too inconvenient as the construction of two or more oscillation circuits for large amounts of energy is difficult; the governing is still more difficult and the danger in switching on or off is greater.

A means of overcoming such difficulties is shown in Figure 13. The oscillation circuit here runs starting from the point x over condenser 5, variable inductance 9, spark gap 7 and the two segments (3^a and 4^a) forming arms of a Wheatstone bridge, back to x. If the motor is connected by brushes 3 and 4 transversely to the two arms of the bridge as shown in the drawings, electromagnetic oscillations of equal sign are induced in the stator surfaces 1 and 2 and the motor does not revolve. If however, the brushes 3 and 4 are moved in common with the conducting wires 1 and 2 which connect the brushes with the stator poles a certain alteration or displacement of the polarity is obtained and the motor commences to revolve.

The maximum action will result if one brush 3 comes on the central sparking contact 7 and the other brush 4 on the part x. They are however, usually in practice not brought on to the central contact 7 but only held in the path of the bridge segments 4^a and 3^a in order not to connect the spark gaps with the motor oscillation circuit.

As however, the entire oscillation energy can thereby not act on the motor it is better to carry out the same system according to the diagram 14. The diagram 14 differs from the foregoing only by the motor not being directly metallically connected with the segments of the commutator, but only a primary coil 9 which induces in a secondary coil 10, current which feeds the motor M and takes the place of the rotor. By this

arrangement a good transforming action is obtained, a loose coupling and also an oscillation circuit without a spark gap.

In Figure 15 the motor is not purely inductively as in 14, but directly metallically branched off from the primary coil (at x and x^1) after the principle of the auto-transformer.

In Figure 16 instead of an inductance a condenser 6 is in similar manner, and for the same object inserted between the segments 3^a and 4^a. This has the advantage that the segments 3^a and 4^a need not be made of solid metal but may consist of spiral coils whereby a more exact regulation is possible and further motors of high inductance may be employed.

The arrangements of Figures 17, 18 and 19 may be employed for use with resonance and particularly with induction condenser motors; between the large stator induction condenser surfaces, small reversing pole condensers are connected, which, as may be seen from Figures 17, 18 and 19 are led together to earth. Such reversing poles have the advantage that with large quantities of electrical energy the spark formation between the separate oscillation circuits ceases.

Figure 19 shows a further method which prevents electromagnetic oscillations of high number of alternations formed in the oscillation circuit striking back to the aerial conductor. It is based on the well known principle that a mercury lamp, one electrode of which is formed of mercury, the other of solid metal such as steel allows an electric charge to pass in only one direction from the mercury to the steel and not vice versa. The mercury electrode of the vacuum tube N is therefore connected with the aerial conductor and the steel electrode with the oscillation circuit. From this it results that charges can pass only from the aerial through the vacuum tube to the oscillation circuit, but not vice versa. Oscillations which are formed on being transformed in the oscillation circuit cannot pass to the aerial conductor.

In practice these vacuum tubes must be connected behind an electromagnet as the latter alone affords no protection against the danger of lightning.

As regards the use of spark gaps, all arrangements as used for wireless telegraphy may be used. Of course the spark gaps in large machines must have a sufficiently large surface. In very large stations they are cooled in liquid carbonic acid or better still in liquid nitrogen or hydrogen; in most cases the cooling may also take place by means of liquefied low homologues of the metal series or by means of hydrocarbons the freezing point of which lies at between −90° C. and −40° C. The spark gap casing must also be insulated and be of sufficient strength to be able to resist any pressure which may arise. Any undesirable excess super-pressure which may be formed must be automatically let off. I have employed with very good results mercury electrodes which were frozen in liquid carbonic acid, the cooling being maintained during the operation from the outside through the walls.

Figure 20 is one of the simplest forms of construction of an aerial network in combination with collectors, transformers and the like illustrated diagrammatically. E is here the earth wire, 8 the safety spark gap, 7 the working spark gap, 1 and 2 the stator surfaces of the motor, 5 a condenser battery, S the protective magnet which is connected with the coil in the aerial conductor, A^1 to A^{10} aerial antennæ with collecting balloons, N horizontal collecting or connecting wires from which, to the centre a number of connections run.

The actual collectors consist of metal sheaths preferably made of an aluminium magnesium alloy, and are filled with hydrogen or helium and are attached to copper plated steel wires. The size of the balloon is selected so that the actual weight of the balloon and the weight of the conducting wire is supported thereby. On the top of the balloon aluminium spikes, made and gilded in a special manner hereinafter described, are arranged in order to produce a conductor action. Small quantities of radium preparations, more particularly polonium-ionium or mesothorium preparations considerably increase the ionization, and therewith the action of these collectors.

In addition to metal balloons, fabric balloons which are superficially metal coated according to Schoop's metal spraying process, may however also be employed. A metallic surface may also be produced by lacquering with metallic bronzes, preferably according to Schoop's spraying process or lacquering with metallic bronze powders in two electrical series of widely different metals, because thereby the collecting effect is considerably increased.

Instead of the ordinary round balloons, elongated cigar shaped ones may be employed. In order also to utilize the frictional energy of the wind, patches or strips of non-conducting substances which produce electricity by friction, may be attached to the metallized balloon surfaces. The wind will impart a portion of its energy in the form of frictional electricity, to the balloon casing, and thereby the collecting effect is substantially increased.

In practice however, very high towers (up to 300 metres is fully admissible) may be employed as antennæ. In these towers copper tubes rise freely further above the top of the tower. A gas lamp secured

against the wind is then lit at the point of the copper tube and a netting is secured to the copper tube over the flame of this lamp to form a collector. The gas is conveyed through the interior of the tube up to the summit. The copper tube must be absolutely protected from moisture at the place at which it enters the tower and also rain must be prevented running down the walls of the tower which might lead to a bad catastrophe. This is done by bell shaped enlargements which expand downwards, being arranged in the tower in the form of high voltage insulators of Siamese pagodas.

Special attention must be devoted to the foundations of such towers. They must be well insulated from the ground, which may be obtained by first embedding a layer of concrete in a box form to a sufficient depth in the ground and inserting in this an asphalt lining and then glass bricks cast about 1 or 2 metres in thickness. Over this in turn there is a ferro-concrete layer in which alone the metal foot of the tube is secured. This concrete block must be at least 2 metres from the ground and be fully protected at the sides by a wooden covering, from moisture. In the lower part of the tower a wood or glass house for the large condenser batteries or for the motors may be constructed. In order to lead the earth connection to the ground water, a well insulated pit constructed of vitreous bricks, must be provided. Several such towers are erected at equal distances apart and connected with a horizontal conductor. The horizontal connecting wires may either run directly from tower to tower or be carried on bell shaped insulators similar to those in use for high voltage conductors. The width of the network may be of any suitable size and the connection of the motors can take place at any suitable places.

In order to collect large quantities of electricity with few aerials it is well to provide the aerial conductor with batteries of condensers as shown in two methods of construction in Figures 21 and 22. In Figure 21 the batteries of condensers 5 are connected on the one hand with the aerial electricity collectors Z by the aerial conductor A, and on the other hand interconnected in series with an annular conductor from which horizontal conductors run to the connecting points C to which the earth wire is connected.

Figure 22 shows a similar arrangement. Should two such series of antennæ rings be shown by a voltmeter to have a large difference of potential (for example, one in the mountains and one in the plain) or even of different polarity these differences may be compensated for by connecting sufficiently large condenser batteries (5, 5^a, 5^b) by means of Maji star conductors D and D^1. In Figure 23 a connection of three such rings of collectors to form a triangle with a central condenser battery is illustrated.

The condenser batteries of such large installations must be embedded in liquefied gases or in liquids freezing at very low temperatures. In such cases a portion of the atmospheric energy must be employed for liquefying these gases. It is also preferable to employ pressure. By this means the condenser surfaces may be diminished, and still allow for large quantities of energy to be stored, secure against breakdown. For smaller installations the immersing of the condensers in well insulated oil or the like, suffices. Solid substances on the other hand cannot be employed as insulators.

The arrangement in the diagrams hitherto described was always such that the condenser batteries were connected with both poles directly to the aerial conductors. An improved diagram of the connections for obtaining atmospheric electricity for the condenser batteries has however, been found to be very advantageous, this arrangement consists in that they are connected by only one pole (unipolar) to the collecting network. Such a method of arrangement is very important, as by means of it a constant current and an increase of the normal working pressure or voltage is obtained. If for example a collecting balloon aerial which is allowed to rise to a height of 300 metres, shows 40,000 volts above earth voltage, in practice it has been found that the working voltage (with a withdrawal of the power according to the method hereinbefore described by means of oscillating spark gaps and the like) is only about 400 volts. If however, the capacity of the condenser surfaces be increased, which capacity in the above mentioned case was equal to that of the collecting surface of the balloon aerials, to double the amount, by connecting the condenser batteries with only one pole, the voltage rises under an equal withdrawal of current up to and beyond 500 volts. This can only be ascribed to the favourable action of the connecting method.

In addition to this substantial improvement it has also been found preferable to insert double inductances with electromagnets and to place the capacities preferably between two such electromagnets. It has also been found that the useful action of such condensers can be further increased if an induction coil be connected as inductive resistance to the unconnected pole of the condenser, or still better if the condenser itself be made as an induction condenser. Such a condenser may be compared with a spring which when compressed carries in itself accumulated force, which it again gives off when released. In charging, a charge with reversed sign is formed at the

other free condenser pole, and if through the spark gap a short circuit results, the accumulated energy is again given back since now new quantities of energy are induced at the condenser pole connected with the conductor network, which in fact charges with opposite signs to that at the free condenser pole. The new induced charges have of course the same sign as the collector network. The whole voltage energy in the aerial is thereby however increased. In the same space of time larger quantities of energy are accumulated than is the case without such inserted condenser batteries.

In Figures 24 and 25 two different diagrams of connections are more exactly illustrated, Figure 24 shows a collecting balloon and the diagram of the connections to earth. Figure 25 four collecting balloons and the parallel connection of the condenser batteries belonging thereto.

A is the collecting balloon made of an aluminium magnesium alloy (electron metal, magnalium) of a specific gravity of 1.8 and a thickness of plate 0.1 to 0.2 mm. Inside there are eight strong vertical ribs of T shaped section about 10 to 20 mm. in height and about 3 mm. in thickness with the projecting part directed inwards (indicated by *a*, *b*, *c*, *d* and so forth); they are riveted together to form a firm skeleton and are stiffened in a horizontal direction by two cross ribs. The ribs are further connected with one another internally and transversely by means of thin steel wires, whereby the balloon obtains great power of resistance and elasticity. Rolled plates of 0.1 to 0.2 mm. in thickness made of magnalium alloy are then either soldered or riveted on this skeleton so that a fully metallic casing with smooth external surface is obtained. Well silvered or coppered aluminium plated steel wires run from each rib to the fastening ring 2. Further, the coppered steel hawser L preferably twisted out of separate thin wires (shown in dotted lines in Figure 24) and which must be long enough to allow the balloon to rise in the desired height, leads to a metal roller or pulley 3 and from thence to a winch W, well insulated from the earth. By means of this winch, the balloon, which is filled with hydrogen, or helium, can be allowed to rise to a suitable height (300 to 5,000 metres) and brought to the ground for recharging or repairs.

The actual current is taken directly through a friction contact from the metal roller 3 or from the wire, or even from the winch or simultaneously from all three by means of brushes (3, 3^a and 3^b). Beyond the brushes the conductor is divided, the paths being:—firstly over 12 to the safety spark gap 8, from thence to the earth conductor E^1, and secondly over electromagnet S^1, point 13, to a second loose electromagnet having an adjustable coil S^2, then to the spark gap 7 and to the second earth conductor E^2. The actual working circuit is formed through the spark gap 7, condensers 5 and 6, and through the primary coil 9; here the static electricity formed by oscillatory discharges is accumulated and converted into high frequency electromagnetic oscillations. Between the electromagnets S^1 and S^2 at the crossing point 13, four condenser batteries are introduced which are only indicated diagrammatically in the drawings each by one condenser. Two of these batteries (16 and 18) are made as plate condensers and prolonged by regulating induction coils or spirals 17 and 19 while the two others (21 and 23) are induction condensers. As may be seen from the drawings each of the four condenser batteries 16, 18, 21, 23 is connected only by one pole to the aerial or to the collector conductor. The second poles 17, 19, 22, 24 are open. In the case of plate condensers having no inductive resistance an induction coil is inserted. The object of such a spiral or coil is the displacement of phase of the induction current by ¼ periods, whilst the charging current of the condenser poles which lie free in the air, works back to the collector aerial. The consequence of this is that in discharges in the collector aerial the back inductive action of the free poles allows a higher voltage to be maintained in the aerial collecting conductor than would otherwise be the case. It has also been found that such a back action has an extremely favourable effect on the wear of the contacts. Of course the inductive effect may be regulated at will within the limits of the size of the induction coil, the length of the coil in action being adjustable by means of wire connection without induction (see Fig. 24, No. 20).

S^1 and S^2 may also be provided with such regulating devices in the case of S^2 (illustrated by 11). If excess voltage be formed it is conducted to earth through the wire 12 and spark gap 8 or through any other suitable apparatus, since this formation would be dangerous for the other apparatus.

The action of these condenser batteries has already been hereinbefore described.

The small circles on the collector balloon indicate places at which zinc amalgam or gold amalgam or other photoelectric acting metals in the form of small patches in extremely thin layers (.01 to .05 mm. in thickness) are applied to the balloon casing of light metal. Such metallic patches may also be applied to the entire balloon as well as in greater thickness to the conducting network. The capacity of the collector is thereby considerably strengthened at the surface. The greatest possible effect in collecting may be obtained by polonium amalgams and the like. On the surface of the

collector balloon metal points or spikes are also fixed along the ribs, which spikes serve particularly for collecting the collector charge. Since it is well known that the resistance of the spikes is less the sharper the spike is, for this purpose it is therefore extremely important to employ as sharp spikes as possible. Experiments made as regards these have shown that the formation of the body of the spike or point also plays a large part. for example, spikes made of bars or rollers with smooth surfaces, have a many times greater point resistance as collector accumulator spikes than those with rough surfaces. Various kinds of spike bodies have been experimented with for the collector balloons hereinbefore mentioned. The best results were given by spikes which were made in the following way. Fine points made of steel, copper, nickel, or copper and nickel alloys, were fastened together in bundles and then placed as anode with the points in a suitable electrolyte (preferably in hydrochloric acid or muriate of iron solutions) and so treated with weak current at 2 to 3 volts pressure. After 2 to 3 hours according to the thickness of the spikes or pins the points become extremely sharp and the bodies of the spikes have a rough surface. The bundle can then be removed and the acid washed off with water. The spikes are then placed as cathode in a bath consisting of solution of gold, platinum, iridium, paladium or wolfram salts or their compounds and coated at the cathode galvanically with a thin layer of precious metal, which must however be sufficiently firm to protect them from atmospheric oxidation.

Such spikes act at a 20 fold lower voltage almost as well as the best and finest points made by mechanical means. Still better results are obtained if polonium or radium salts are added to the galvanic bath when forming the protective layer or coating. Such pins have a low resistance at their points and even at one volt and still lower pressures have an excellent collector action.

In Figure 24 the three unconnected poles are not connected with one another in parallel. That is quite possible in practice without altering the principle of the free pole. It is also preferable to interconnect in parallel to a common collector network, a series of collecting aerials.

Figure 25 shows a diagram for such an installation. A^1. A^2, A^3, A^4 are four metal collector balloons with gold or platinum coated spikes which are electrolytically made in the presence of polonium emanations or radium salts, which spikes or needles are connected over four electro-magnets S^1, S^2, S^3, S^4, through an annular conductor R. From this annular conductor four wires run over four further electromagnets S^a, S^b, S^c, S^d, to the connecting point 13. There the conductor is divided, one branch passing over 12 and the safety spark gap 8 to the earth at E^1, the other over inductive resistance J and working spark gap 7 to the earth at E^2. The working circuit, consisting of the condenser 5 and 6 and a resonance motor or a condenser motor M, such as hereinbefore described, is connected in proximity round the sparking gap section 7.

Instead of directly connecting the condenser motor of course the primary circuit for high frequency oscillatory current may also be inserted.

The condenser batteries are connected by one pole to the annular conductor R and can be either inductionless (16 and 18) or made as induction condensers as shown by 21 and 23. The free poles of the inductionless condensers are indicated by 17 and 19, those of the induction condensers by 22 and 24. As may be seen from the drawings all these poles 17, 22, 19, 24 may be interconnected in parallel through a second annular conductor without any fear that thereby the principle of the free pole connection will be injured. In addition to the advantages already set forth the parallel connection also allows of an equalization of the working pressure in the entire collector network. Suitably constructed and calculated induction coils 25 and 26 may also be inserted in the annular conductor of the free poles, by means of which a circuit may be formed in the secondary coils 27 and 28 which allows current produced in this annular conductor by fluctuations of the charges or the like appearances to be measured or otherwise utilized.

According to what has been hereinbefore stated separate collector balloons may be connected at equidistant stations distributed over the entire country, either connected directly with one another metallically or by means of intermediate suitably connected condenser batteries through high voltage conductors insulated from earth. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations and may in such form be coupled as a source of energy by means of a suitable method of connecting, various precautions being observed and with special regulations. The wires leading from the collector balloons have hitherto been connected through an annular conductor without this endless connection, which can be regarded as an endless induction coil, being able to exert any action on the whole conductor system.

It has now been found that if the network conductor connecting the aerial collector balloons with one another is not made as a simple annular conductor, but preferably short circuited in the form of coils over a

condenser battery or spark gap or through thermionic tubes or valves or audions, then the total collecting network exhibits quite new properties. The collection of atmospheric electricity is thereby not only increased but an alternating field may be easily produced in the collector network. Further, the atmospheric electrical forces showing themselves in the higher regions may also be directly obtained by induction. In Figures 26 and 28 a form of construction is shown on the basis of which the further foundations of the method will be more particularly explained.

In Figure 26 1, 2, 3, 4 are metal collector balloons, 5, 6, 7, 8 their metallic aerial conductors and I the actual collector network. This consists of five coils and is mounted on high voltage insulators in the air, on high voltage masts (or with a suitable construction of cable embedded in the earth). One coil has a diameter of 1 to 100 km. or more. S and S^1 are two protective electromagnets, F the second safety section against excess voltage, E its earth conductor and E^1 the earth conductor of the working section. When an absorption of static atmospheric electricity is effected through the four balloon collectors, the current in order to reach the earth connection E^1 must flow spirally through the collector network over the electromagnet S, primary induction coil 9, conductor 14, anode A of the audion tube, incandescent cathode K, as the way over the electromagnet and safety spark gap F offers considerably greater resistance. Owing to the fact that the accumulated current flows in one direction, an electromagnetic alternating field is produced in the interior of the collector network coil, whereby the whole free electrons are directed more or less into the interior of the coil. An increased ionization of the atmosphere is therefore produced. In consequence of this the points mounted on the collector balloon show a considerably reduced resistance and therefore increased static charges between the points on the balloon and the surrounding atmosphere are produced. The result of this is a considerably increased collector effect.

A second effect which could not be obtained otherwise is obtained by the electromagnetic alternating field which running parallel to the earth surface, acts more or less with a diminishing or increasing effect on the earth magnetic field, whereby in the case of fluctuations in the current a return induction current of reversed sign is always produced in the collector coil by earth magnetism. Now if, however, a constantly pulsating continuous alternating field is produced as stated in the above collector network I, an alternating current of the same periodicity is produced also in the collecting network coil. As the same alternating field is further transmitted to the aerial balloon, the resistance of its points is thereby considerably reduced, whilst the collector action is considerably increased. A further advantage is that positive electrons which collect on the metal surfaces during the conversion into dynamic current produce a so-called drop of potential of the collector area. As an alternating field is present, the negative ions surrounding the collector surfaces, when discharge of the collector surfaces takes place produce by the law of induction, an induction of reversed sign on the collector surface and so forth (that is to say again a positive charge). In addition to the advantages hereinbefore set forth, the construction of connecting conductors in coil form when of sufficiently large diameter, allows of a utilization of energy arising in higher regions also in the simplest way. As is well known electric discharges frequently take place at very great elevations which may be observed, such as St. Elmo's fires or northern lights. These energy quantities have not been able to be utilized up to now. By this invention all these kinds of energy, as they are of an electromagnetic nature and the direction of the axis of the collector coils stands at right angles to the earth's surface, can be more or less absorbed in the same way as a receiver in wireless telegraphy absorbs waves coming from a far distance. With a large diameter of the spiral it is possible to connect large surfaces and thereby to take up also large quantities of energy.

It is well known that large wireless stations in the summer months, and also in the tropics are very frequently unable to receive the signals in consequence of interruptions which are caused by atmospheric electricity, and this takes place with vertical coils of only 40 to 100 m. diameter. If on the contrary horizontal coils of 1 to 100 km. diameter be employed very strong currents may be obtained through discharges which are constantly taking place in the atmosphere. Particularly in the tropics or still better in the polar regions where the northern lights are constantly present, large quantities of energy may probably be obtained in this way. A coil with several windings should act the best. In similar manner any alteration of the earth magnetism should act inductively on such a coil.

It is not at all unlikely that earthquakes and spots on the sun will also produce an induction in such collector coils of sufficient size. In similar manner this collector conductor will react on earth currents more particularly when they are near the surface of the earth or even embedded in the earth. By combining the previous kind of current collectors so far as they are adapted for

the improved system with the improved possibilities of obtaining current the quantities of free natural energy which are to be obtained in the form of electricity are considerably increased.

In order to produce in the improved collector coil uniform current oscillations of an undamped nature so-called audion high vacuum or thermionic tubes of suitable connection are employed instead of the previously known spark gaps (Fig. 26, Nos. 9–18). The main aerial current flows through electromagnet S (which in the case of a high number of alternations is not connected here but in the earth conductor E^1) and may be conveyed over the primary coils in the induction winding through wire 14 to the anode A of the high vacuum grid tube. Parallel with the induction resistance 9 a regulating capacity of suitable size, such as condenser 11 is inserted. In the lower part of the vacuum grid tube is arranged the incandescent filament or the cathode K which is fed through a battery B. From the battery B two branches run, one to the earth conductor E^1 and the other through battery B^1 and secondary coil 10 to the grid anode *g* in the vacuum tube. By the method of connections shown in dotted lines, a desired voltage at the grid electrode *g* may also be produced through the wire 17 which is branched off from the main current conductor through switches 16 and some small condensers (*a*, *b*, *c*, *d*) connected in series, and conductor 18, without the battery B^1 being required.

The action of the entire system is somewhat as follows:—

On the connecting conductor of the aerial collector network being short circuited to earth, the condenser pole 11 is charged and slightly damped oscillations are formed in the short circuited existing oscillation circuit formed of the condenser 11 and self inductance 9. In consequence of the coupling through coil 10, fluctuations of voltage take place in the grid circuit 15 with the same frequency, which, fluctuations in turn influence the strength of the electrode current passing through the high vacuum amplyfying tube and thus produce current fluctuations of the same frequency in the anode circuit. A permanent supply of energy to the oscillation circuits 9 and 10 consequently takes place, until a condition of balance is set up, in which the consumed oscillation energy is equal to that absorbed. Thereby constant undamped oscillations are now produced in the oscillation circuits 9–11.

For regular working of such oscillation producers high vacuum strengthening tubes are necessary and it is also necessary that the grid and anode voltages shall have a phase difference of 180° so that if the grid is negatively charged, then the anode is positively charged and vice versa. This necessary difference of phase may be obtained by most varied connections, for example, by placing the oscillation circuit in the grid circuit or by separating the oscillation circuit and inductive coupling from the anodes and the grid circuit and so forth.

A second important factor in this way of converting static atmospheric electricity into undamped oscillations is that care must be taken that the grid and anode voltages have a certain relation to one another; the latter may be obtained by altering the coupling and a suitable selection of the self induction in the grid circuit, or as shown by dotted lines 18, 17, 16 by means of a larger or smaller number of condensers of suitable size connected in series; in this case the battery B^1 may be omitted. With a suitable selection of the grid potential a glow discharge takes place between the grid *g* and the anode A, and accordingly at the grid there is a cathode drop and a dark space is formed. The size of this cathode drop is influenced by the ions which are emitted in the lower space in consequence of shock ionization of the incandescent cathodes K and pass through the grid in the upper space. On the other hand the number of the ions passing through the grid is dependent on the voltage between the grid and the cathode. Thus if the grid voltage undergos periodic fluctuations (as in the present case) the amount of the cathode drop at the grid fluctuates and consequently the internal resistance of the tube correspondingly fluctuates, so that when a back coupling of the feed circuit with the grid circuit takes place, the necessary means are afforded for producing undamped oscillations and of taking current, according to requirements from the collecting conductor.

The frequency of the undamped oscillations produced is with a suitably loose coupling equal to the self frequency of the oscillation circuits 9 and 10. By a suitable selection of the self induction of the coil 9 and capacity 11 it is possible to extend from frequencies which produce electromagnetic oscillations of only a few metres wave length down to the lowest practical alternating current frequency. For large installations a suitable number of frequency producing tubes in the form of the well known high vacuum transmission tubes of .5 to 2 kw. in size may be connected in parallel so that in this respect no difficulty exists.

The use of such tubes for producing undamped oscillations, and also the construction and method of inserting such transmission tubes in an accumulator or dynamo circuit is known and also that such oscillation producing tubes only work well at voltages of 1,000 up to 4,000 volts, so that on the contrary their use at lower voltages is

considerably more difficult. By the use of high voltage static electricity this method of producing undamped oscillations as compared with that through spark gaps must be regarded as an ideal solution particularly for small installations of outputs of from 1 to 100 kw.

By the application of safety spark gaps, with interpolation of electro-magnets, not only is short circuiting avoided but also the taking up of current is regulated. Oscillation producers inserted in the above way form a constantly acting electromagnetic alternating field in the collector coil, whereby as already stated, a considerable accumulating effect takes place. The withdrawal wire or working wire is connected at 12 and 13, but current may be taken by means of a secondary coil which is firmly or movably mounted in any suitable way inside the large collector coil, i. e. in its electromagnetic alternating field, so long as the direction of its axis runs parallel with that of the main current collecting coil.

In producing undamped oscillations of a high frequency (50,000 per second and more) in the oscillation circuits 9 and 11, electromagnets S and S^1 must be inserted if the high frequency oscillations are not to penetrate the collector coil, between the oscillation producers and the collector coil. In all other cases they are connected shortly before the earthing (as in Figs. 27 and 28).

In Figure 27 a second method of construction of the connecting conductor of the balloon aerials is illustrated in the form of a coil. The main difference consists in that in addition to the connecting conductor I another annular conductor II is inserted parallel to the former on the high voltage masts in the air (or embedded as a cable in the earth) but both in the form of a coil. The connecting wire of the balloon aerials is indicated as a primary conductor and also as a current producing network; the other is the consumption network and is not in unipolar connection with the current producing network.

In Figure 27 the current producing network I is shown with three balloon collectors 1, 2, 3 and aerial conductors 4, 5, 6; it is short circuited through condenser 19 and inductance 9. The oscillation forming circuit consists in this diagram of spark gap *f*, inductance 10, and condenser 11; the earth wire E, is connected to earth over electromagnet S^1. F is the safety spark gap which is also connected to earth through a second electromagnet S at E. On connecting up the condenser circuit 11 this is charged over the spark gap *f* whereby an oscillatory discharge is formed. This discharging current acts through inductance 10 on the inductively coupled secondary 9, whereby in the producing network a modification of the potential of the condenser 19 is produced. The consequence of this is that oscillations arise in the coil shaped producer network. These oscillations induce a current in the secondary circuit II, which has a smaller number of windings and a less resistance, the voltage of which, according to the proportion of the number of windings and of the ohmic resistance, is considerably lower whilst the current strength is greater.

In order to convert the current thus obtained into current of an undamped character, and to tune its wave lengths, a sufficiently large regulatable capacity 20 is inserted between the ends 12 and 13 of the secondary conductor II. Here also current may be taken without an earth conductor, but it is advisable to insert a safety spark gap E^1 and to connect this with the earth over an electromagnet S^2.

The producer network may be connected with the working network II over an inductionless condenser 21 or over an induction condenser 22, 23. In this case the secondary conductor is unipolarly connected with the energy conductor.

In Figure 28 the connecting conductor between the separate accumulator balloons is carried out according to the autotransformer principle. The collecting coil connects four aerial balloons 1, 2, 3, 4, the windings of which are not made side by side but one above the other. In Figure 28 the collector coil I is shown with a thin line, the metallically connected prolongation coils II with a thick line. Between the ends I^1 and II^1 of the energy network I a regulating capacity 19 is inserted. The wire I^1 is connected with the output wire and with the spark gap F.

As transformer of the atmospheric electricity an arrangement is employed which consists in using rotary pairs of condensers in which the one stator surface B is connected with the main current, whilst the other A is connected with the earth pole. Between these pairs of short circuited condensers are caused to rotate from which the converted current can be taken by means of two collector rings and brushes, in the form of an alternating current, the frequency of which is dependent on the number of balloons and the revolutions of the rotor. As the alternating current formed in the rotor can act, in this improved method of connection described in this invention, through coils 10 on the inductance 9, an increase or diminution of the feed current in I can be obtained according to the direction of the current by back induction. Current oscillations of uniform rhythm thereby result in the coil shaped windings of the producer net-work.

As the ends of this conductor are short cir-

cuited through the regulatable condenser 19 these rhythms produce short circuited undamped oscillations in the energy conductor, the periodicity and wave lengths of which oscillations can be adjusted according to desire by altering the capacity 19 to a given wave length and therewith also to a given frequency. These currents may also be employed in this form directly as working current through the conductors II¹ and III. By inserting the condenser 20 a connection between these conductors may also be made, whereby harmonic oscillations of desired wave length are formed. By this means quite new effects as regards current distribution are obtained. The withdrawal of current can even take place without direct wire connection if, at a suitable point in the interior of the producing network (quite immaterially whether this has a diameter of 1 or 100 km.) a coil tuned to these wave lengths and of the desired capacity is firmly or movably mounted in the aerial conductor in such a way that its axial direction is in parallel with that of the collector coil. In this case a current is induced in the producing network, the size of which is dependent on the total capacity and resistance and also on the periodicity employed. A possibility is thereby afforded in future, of taking energy from the producer network by wireless means. As thereby in addition to atmospheric electricity also magnetic earth currents and the energy from the higher atmosphere (at least partially) may be simultaneously obtained, this last system for collecting the atmospheric energy is of particular importance for the future.

Of course everywhere instead of spark gaps suitable grid vacuum tubes may be employed as producers for undamped oscillations. The separate coils of the producer net-work with large diameters may be connected with one another through separate conductors all in parallel or all in series or in groups in series. By regulating the number of oscillations and also the extent of the voltage more or less large collector coils of this kind may be employed. The coils may also be divided spirally over the entire section. The coils may be carried out in annular form or also in triangular, quadrangular, hexagonal or octagonal form.

Of course wires may be carried from a suitable place to the centre or also laterally which serve the current waves as guides. This is necessary when the currents have to be conducted over mountains and valleys and so forth. In all these cases the current must be converted into a current of suitable periodicity.

As already hereinbefore mentioned separate collecting balloons may be directly metallically interconnected at equidistant stations distributed over the entire country or may be connected by interpolation of suitable condenser batteries by means of high voltage conductors. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations, and could then in such form, with a suitable arrangement of the connections, observing various measures of precaution, be employed as source of energy after separate or special regulation.

According to this invention in order to increase the collecting effect of the balloon in the aerial collector conductor or in the earth wire, radiating collectors are employed. These consist either of incandescent metal or oxide electrodes in the form of vacuum grid tubes, or electric arcs (mercury and the like electrodes) Nernst lamps, or finally flames of various kinds may be simply connected with the respective conductor.

It is well known that energy can be drawn off from a cathode consisting of an incandescent body opposite an anode charged with positive electricity (vacuum grid tube). Hitherto however, a cathode was always first directly placed opposite an anode, and secondly the system always consisted of a closed circuit.

Now if we dispense with the ordinary ideas in forming light or flame arcs in which a cathode must always stand directly opposite an anode, and if we place an incandescent cathode opposite an anode charged to a high potential or another body freely floating in the air, or regard the incandescent cathode only as a source of unipolar discharge (which represent group and point discharges in electro-static machines similar to unipolar discharges), it may be ascertained that incandescent cathodes and less perfectly all incandescent radiators, flames and the like admit of relatively large current densities and allow large quantities of electric energy to radiate into the open space in the form of electron streams as transmitters.

The object of this invention is as described below, if such incandescent oxide electrodes or other incandescent radiators or flames are not freely suspended in space but connected metallically with the earth so that they can be charged with negative terrestrial electricity, these radiators possess the property of absorbing the free positive electrical charges contained in the air space surrounding them (that is to say of collecting them and conducting them to earth). They can therefore, serve as collectors and have, in comparison to the action of the spikes, or points, a very large radius of action R; the effective capacity of these collector is much greater than the geometrical capacity (R_o–) calculated in an electro-static sense.

Now as our earth is surrounded as is well

known, with an electro-static field and the difference of potential

$$\frac{\delta V}{\delta h}$$

of the earth field according to the latest investigations, is in summer about 60 to 100 volts and in winter 300 to 500 volts per metre of difference in height (δh), a simple calculation gives the result that when such a radiation collector or flame collector is arranged for example on the ground, and a second one is mounted vertically over it at a distance of 2,000 metres and both are connected by a conducting cable, there is a difference of potential in summer of about 2,000,000 volts and in winter even of 6,000,000 volts and more.

According to Stefan Boltzmann's law of radiation, the quantity of energy which an incandescent surface (temperature T) of 1 sq. cm. radiates in a unit of time into the open air (temperature T_o) is expressed by the following formula:

$$S = \sigma (T^4 - T_o^4) \text{ watt/sq. cm.}$$

and the universal radiation constant σ is according to the latest researches of Ferry (Annales de Chimie et de physique 17 page 267 (1909)) equal to 6.30×10^{-12} watt/sq. cm.

Now if an incandescent surface of 1 sq. cm. shows, as compared with the surrounding space a periodic fall of potential δV it radiates (independent of the current direction, that is to say of the sign) in accordance with the above formula, for example at a temperature of 3725° C. an energy of 1.6 kw. per sq. cm. per second. As for the radiation the same value can be calculated for the collection of energy, but reversed. Now as carbon electrodes at the temperature of the electric arc support on the current basis a current density up to from 60 to 65 amperes per sq. cm. no difficulties will result in this direction in employing radiating collectors as accumulators.

If the earth be regarded as a cosmically insulated condenser in the sense of geometrical electro-statics x there results from the geometric (compare Ewald Rasch, "das elektrische Bogenlicht" (The electric arc light) page 169) capacity of the earth according to Chwolson:

For negative charging 1.3×10^6 Coulomb
For negative potential $V = 10 \times 10^8$ volts.
From this there results however, $EJT \cong 24.7 \times 10^{24}$ watt/Sec. Now if it is desired to make a theoretic short circuit through an earthed flame collector this would represent an electric total work of about 79,500 10^{10} kilowatt years. As the earth must be regarded as a rotating mechanism which is thermo-dynamically, electromagnetically, and also kinematically coupled with the sun and stars system by cosmic radiations and gravitation a diminution of the electric energy of the earth field is not to be feared. The energies which the incandescent collectors would withdraw from the earth field can only cause by the withdrawal of motor work a lowering of the earth temperature (temperature $T_E = 300$) and reduce this to that of the world space ($T = O$) by using the entire energy. This is however not the case as the earth does not represent a cosmically entirely insulated system. On the contrary there is conveyed to the same according to the recent value corrected by Ferry for the solar constants through the radiation from the sun an energy of 18,500 $\times 10^{10}$ kw. Accordingly any lowering of the earth temperature (T_E) without a simultaneous lowering of the sun's temperature (T_S) would contradict Stefan Boltzmann's law of radiation.

$$S = \sigma (T_S^4 - T_E^4).$$

From this it must be concluded that if the earth temperature (T_E) sinks, the total radiation S absorbed by the earth increases, and further also that the secular speed of cooling of the earth is directly dependent on that of the sun and the other radiators cosmically coupled with the sun and is connected most closely with these.

The incandescent radiation collectors may, according to this invention, be employed for collecting atmospheric electricity if they (1) are charged with the negative earth electricity (that is to say when they are directly connected by means of a metallic conductor with the earth) and (2) if large capacities (metal surfaces) charged with electricity are mounted opposite them as positive poles in the air. This is regarded as the main feature of the present invention as without these inventive ideas it would not be possible to collect with an incandescent collector, sufficiently large quantities of the electrical charges contained in the atmosphere as technology requires; the radius of action of the flame collectors would also be too small, especially if it be considered that the very small surface density (energy density) (σ about $= 2 \times 7 \cdot 10^9$ St. E. per sq. cm.) does not allow of large quantities of charge being absorbed from the atmosphere.

x) Calculated according to Poisson's calculation;

$\Delta V = -4\pi\delta$; as here the alteration of the potential or potential gradients only takes place in the direction of the normal, this calculation assumes the simple form

$$\delta = \frac{1}{4\pi} \times \frac{\delta^2 V}{\delta n^2}$$

It has indeed already been proposed to employ flame collectors for collecting atmospheric electricity and it is known that

their collecting effect is substantially greater opposite the points. It is however, not known that the quantities of current which could hitherto be obtained are too small for technical purposes. According to my experiments the reason for this is to be found in the too small capacities of the collector conductor poles. If such flame or radiating collectors have no or only small positive surfaces, their radius of action for large technical purposes is too small. If the incandescent collectors be constantly kept in movement in the air they may collect more according to the speed of the movement, but this is again not capable of being carried out in practice.

By this invention the collector effect is considerably increased by a body charged with a positive potential and of the best possible capacity being also held floating (without direct earth connection) opposite such an incandescent collector which is held floating in the air at a desired height. If for example, a collecting balloon of sheet metal or of metalized balloon fabric be caused to mount to 300 up to 3,000 metres in the air and as positive pole it is brought opposite such a radiating collector connected by a conductor to earth, quite different results are obtained.

The metallic balloon shell (with a large surface) is charged to a high potential by the atmospheric electricity. This potential is greater the higher the collecting balloon is above the incandescent collector. The positive electricity acts concentratedly on the anode floating in the air as it is attracted through the radiation shock ionization, proceeding from the incandescent cathode. The consequence of this is that the radius of action of the incandescent cathode collector is considerably increased and thereby also the collecting effect of the collecting balloon surface. Further the large capacity of the anode floating in the air plays therefore an important part because it allows of the taking of large charges, and thereby a more uniform current is obtained even when there is a large consumption; this cannot be the case with small surfaces.

In the present case the metallic collecting balloon is a positive anode floating in the air and the end of the earth conductor of this balloon serves as positive pole surface opposite the surface of the radiating incandescent cathode, which in turn is charged with negative earth electricity being conductingly connected to earth.

The process may be carried out by two such contacts (negative incandescent cathode and anode end of a capacity floating in the air) a condenser and an inductive resistance being switched on in parallel, whereby simultaneously undamped oscillations may be formed.

In very large installations it is advisable to connect two such radiating collectors in series. Thus an arc light incandescent cathode may be placed below on the open ground and an incandescent cathode which is heated by special electro-magnetic currents be located high in the air. Of course for this the special vacuum Liebig tubes with or without grids may also be employed. An ordinary arc lamp with oxide electrodes may be introduced on the ground and the positive pole is not directly connected with the collecting balloon, but through the upper incandescent cathode or over a condenser. The method of connecting the incandescent cathode floating in the air may be seen in Figs. 29–33.

B is the air balloon, K a Cardan ring (connection with the hawser) C the balloon, L a good conducting cable, P a positive pole, N negative incandescent cathode, and E earth conductor.

Fig. 29 represents the simplest form of construction. If electric oscillations are produced below on the ground by means of a carbon arc lamp or in other suitable way a considerably greater electric resistance is opposed to that in the direct way by inserting an electrical inductive resistance 9. Consequently between P and N a voltage is formed, and as, over N and P only an inductionless ohmic resistance is present, a spark will spring over so long as the separate induction co-efficients and the like are correctly calculated. The consequence of this is that the oxide electrode (carbon or the like) is rendered incandescent and then shows as incandescent cathode an increased collecting effect. The positive poles must be substantially larger than the negative in order that they may not also become incandescent. As they are further connected with the large balloon area which has a large capacity and is charged at high voltage, an incandescent body which is held floating in the air and a positive pole which can collect large capacities is thereby obtained in the simplest way. The incandescent cathode is first caused to become incandescent by means of separate energy produced on the earth, and then maintained by the energy collected from the atmosphere.

Fig. 30 only shows the difference that instead of a round balloon a cigar shaped one (of metal or metalized fabric) may be employed and also a condenser 5 is inserted between the incandescent cathode and the earth conductor so that a short circuited oscillation circuit over P. N 5 and 9 is obtained. This has the advantage that quite small quantities of electricity cause the cathode to become incandescent and much larger cathode bodies may be rendered incandescent.

In this form of construction both the in-

candescent cathode and also the positive electrode may be enclosed in a vacuum chamber as may be seen in Fig. 32. A cable L is carried well insulated through the cover of a vessel and ends in a condenser disc 5. The cover is arched in order to keep off the rain. The vessel is entirely or partially made of magnetic metal and well insulated inside and outside. Opposite the disc 5 another disc 6 and on this again a metallic positive pole of the vacuum tube *g* with the incandescent cathode (oxide electrode) N is arranged. The negative electrode is on the one hand connected with the earth conductor E, and on the other hand with the inductive resistance 9 which is also connected with the cable L with the positive pole and wound round the vessel in coils. The action is exactly the same as that in Fig. 29 only instead of an open incandescent cathode one enclosed in vacuo is employed. As in such collectors only small bodies can be brought to incandescence in large installations a plurality of such vacuum tubes must be inserted in proximity to one another. According to the previous constructions Figs. 31 and 33 are quite self evident without further explanations.

Figs. 34–37 represent further diagrams of connections over radiating and flame collectors, and in fact, how they are to be arranged on the ground.

Fig. 34 shows an arc light collector with oxide electrodes for direct current and its connection; Fig. 35 a similar one for alternating current, Fig. 36 an incandescent collector with a Nernst lamp and Fig. 37 a similar one with a gas flame.

The positive pole 1 of the radiating collectors is always directly connected to the aerial collecting conductor A. In Fig. 34 this is further connected over the condenser battery 5 with a second positive electrode 3. The direct current dynamo *b* produces current which flows over between the electrodes 3 and 2 as an arc light. On the formation of an arc the negative incandescent electrode 2 absorbs electricity from the positive poles standing opposite it and highly charged with atmospheric electricity and conveys the same to the working circuit. The spark gap 7, inductive resistance 9 and induction coil 10 are like the ones previously described. The protective electromagnet S guards the installation against earth circuiting, the safety spark gap 8 from excess voltage or overcharging.

In Fig. 35 the connection is so far altered that the alternating current dynamo feeds the exciting coil 11 of the induction condenser. 12 is its negative and 13 its positive pole; if the coil 3 on the magnet core of the dynamo is correctly calculated and the periodicity of the alternating current is sufficiently high an arc light can be formed between the two poles 1 and 2. As the cathode 2 is connected with the negatively charged earth, and therefore always acts as a negative pole, a form of rectification of the alternating current produced by the dynamo 3 is obtained, the second half of the period is always suppressed. The working circuit may be carried out in the same way as in Fig. 34; the working spark gap 7 may however be dispensed with, and instead thereof between the points *n* and *m* a condenser 5 and an induction resistance 9 may be inserted from which the current is taken inductively.

Fig. 36 represents a form of construction similar to Fig. 34 only that here instead of an arc lamp a Nernst incandescent body is employed. The Nernst lamp is fed through the battery 3. The working section is connected with the negative pole, the safety spark gap with the + poles. The working spark gap 7 may also be dispensed with and the current for it taken at 12 over the oscillation circuit 5, 11 (shown in dotted lines).

Flame collectors (Fig. 37) may also be employed according to this invention. The wire network 1 is connected with the aerial collector conductor A and the burner with the earth. At the upper end of the latter, long points are provided which project into the flame. The positive electrode is connected with the negative over a condenser 5 and the induction coil 9 with the earth.

The novelty in this invention is firstly, the use of incandescent cathodes opposite positive poles which are connected with large metallic capacities as automatic collecting surfaces, (2) the connection of the incandescent cathodes with the earth whereby, in addition to the electricity conveyed to them from the battery or machine which causes the incandescing, also the negative charge of the earth potential is conveyed, and (3) the connection of the positive and negative poles of the radiating collectors over a condenser circuit alone or with the introduction of a suitable inductive resistance, whereby simultaneously an oscillatory oscillation circuit may be obtained. The collecting effect is by these methods quite considerably increased.

I declare that what I claim is:—

1. An electrical energy generating system, comprising a conducting surface for static charges, means to support same at a distance above the earth, a conductor leading to the earth level, a spark gap associated with said conductor to convert electrostatic charges into electromagnetic high frequency oscillations means to supply said electromagnetic energy to a net work, and a spark gap of greatly increased relative resistance in parallel therewith.

2. An electrical energy generating system

comprising a conductor, means to support same above the earth level, an inductance therein, a spark gap associated with said conductor, a second spark gap of much higher relative resistance in parallel therewith and an energy receiving circuit coupled with the spark gap of lesser resistance.

3. An electrical energy generating system comprising a collecting surface, means to support same above the earth level, a conductor connecting said collecting surface with the earth level, a choke in said conductor, an electromagnetic resistance converting electrostatic energy to electromagnetic energy, a safety higher resistance in parallel therewith and a net work coupled with the conversion resistance of lesser value.

4. An electrical energy generating system comprising electric conductors spaced above the earth to form electromagnetic oscillating circuits, conductors connecting to earth level, electrostatic to electromagnetic energy conversion means therein, a safety high electrostatic resistance in parallel therewith and means to alter the electromagnetic characteristic of the circuits.

5. An electrical energy generating system comprising in combination a static collecting surface arranged above the earth, conductors connecting to earth level, a pair of spark gaps in parallel of different electrostatic resistance, a utilization net work shunted across the spark gap of lesser resistance and an electromagnetic choke in said conductors.

6. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance, connected thereto and a closed electric oscillation circuit in shunt across the gap of lesser resistance.

7. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance connected thereto, a closed electric oscillation circuit in shunt across the gap of lesser resistance, a plurality of electrostatic collecting surfaces, means to connect said collecting surfaces in parallel in groups and means to connect said groups symmetrically with said aerial.

In witness whereof, I have hereunto signed my name this 30 day of Dec., 1920, in the presence of two subscribing witnesses.

HERMANN PLAUSON.

Witnesses:
H. F. ARMSTRONG,
W. H. BEESTON.

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(54) **METHOD AND APPARATUS FOR EXTRACTING AND CONVEYING ELECTRICAL ENERGY FROM THE EARTH'S IONOSPHERE CAVITY**

(71) Applicant: **Earth Energies, Inc.**, Johns Creek, GA (US)

(72) Inventors: **John Dinwiddie**, Cary, NC (US); **Terry L. Wright**, Suwanee, GA (US)

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CPC ***H01F 38/14*** (2013.01); *H01F 2038/146* (2013.01)

(57) **ABSTRACT**

The system and apparatus of one or more embodiments of the present invention extracts, conditions, and conveys electric power from the earth ionosphere cavity through the integrated and collaborative operation of the system and apparatus consisting of a capacitively-coupled insulated elevated terminal (coupled capacitor upper plate), an evacuated spark gap, an integrated step-down transformer and resonant capacitor, and a ground terminal (coupled capacitor lower plate). The architecture governing exemplary embodiments of the system and apparatus of the present invention emulates the natural architecture governing the interaction of living trees with the electrical energy resident in the earth ionosphere cavity. The implementation of such exemplary embodiments of the present invention utilizes standard and customized components appropriate for their function within the system and apparatus.

The extracted electric power from the earth ionosphere cavity manifests in the form of broadband electromagnetic waves in the 0 to 200 Hz frequency range. Electric energy from these waves produce magnetic fields inside the integrated step-down transformer which are added together by the primary coil of the integrated step-down transformer, and delivered as 60 Hz 120/240 VAC to an electric load via the secondary coil of the integrated step-down transformer resonating at 60 Hz due to the influence of the integrated resonant capacitor.

The system and apparatus of exemplary embodiments of the present invention extracts, conditions, and conveys ionosphere cavity-resident electric power in alternating current and direct current realms.

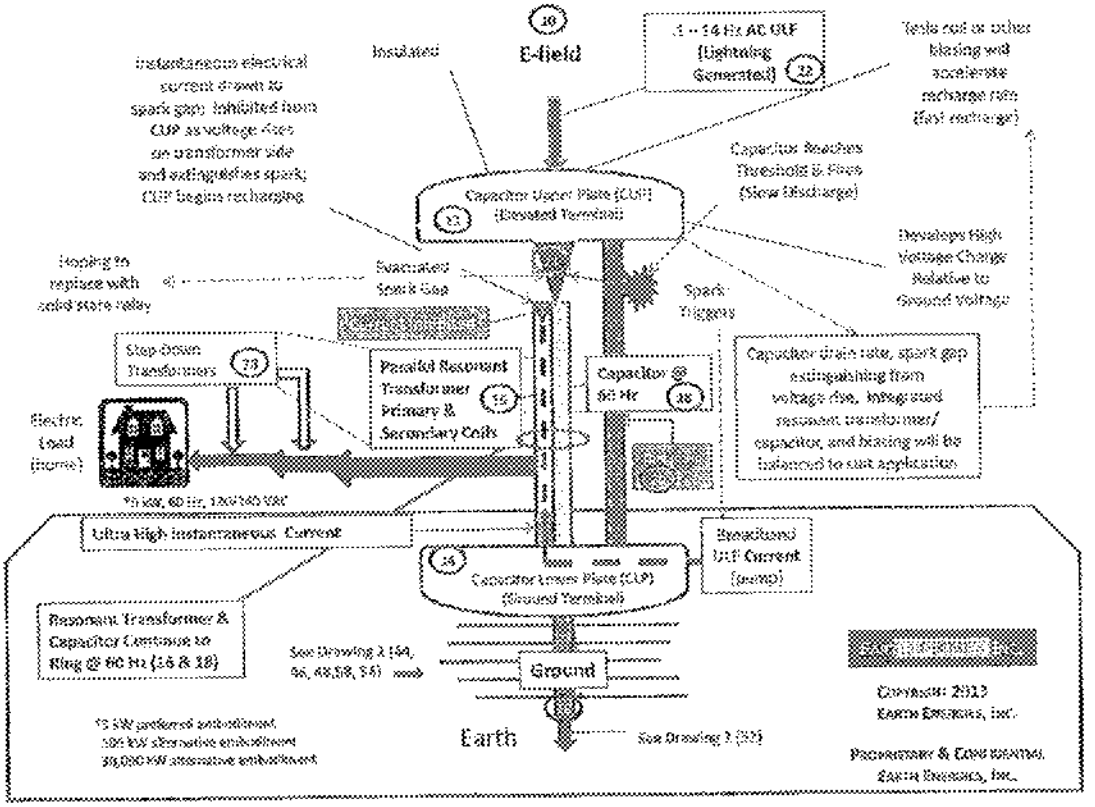

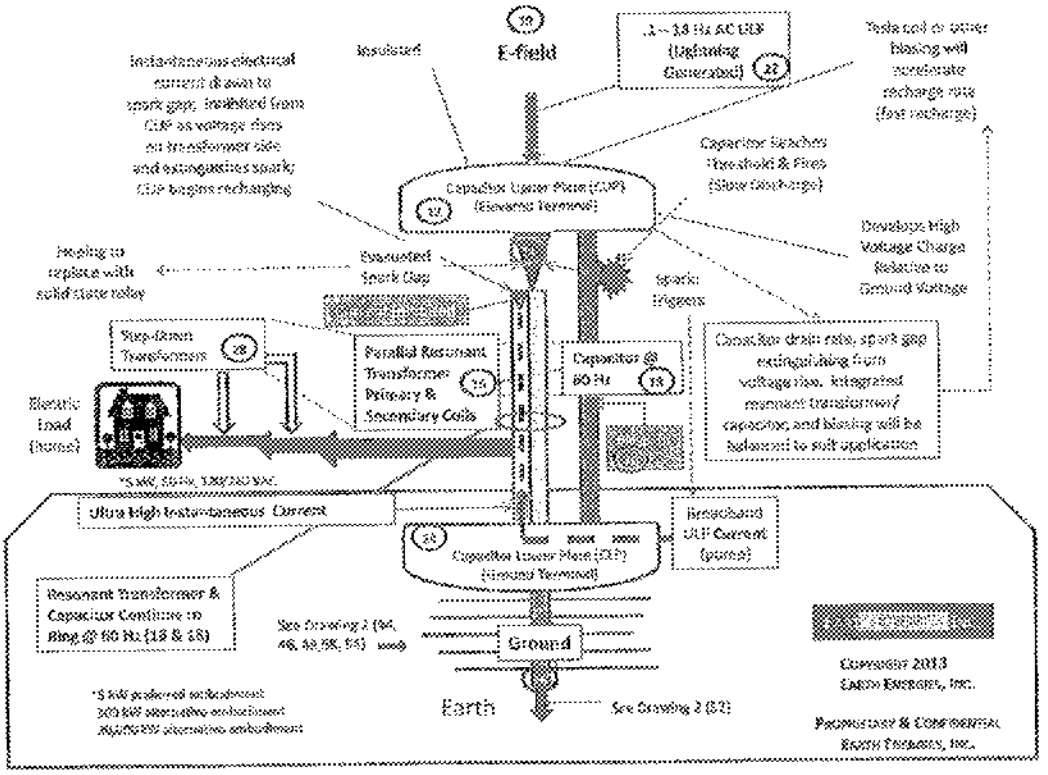
E-field
Insulated
Step-down Transformer
Parallel Resonant Transformer Primary & Secondary Coils
Capacitor @ 60 Hz
Electric Load (home)
Ultra High Instantaneous Current
Resonant Transformer & Capacitor Continue to Ring @ 60 Hz (18 & 28)
Ground
Earth
Spark Triggers
Breakdown ULF Current (pulse)
Capacitor Lower Plate (CLP) (Ground Terminal)
Capacitor Upper Plate (CUP) (Elevated Terminal)
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FIG. 1

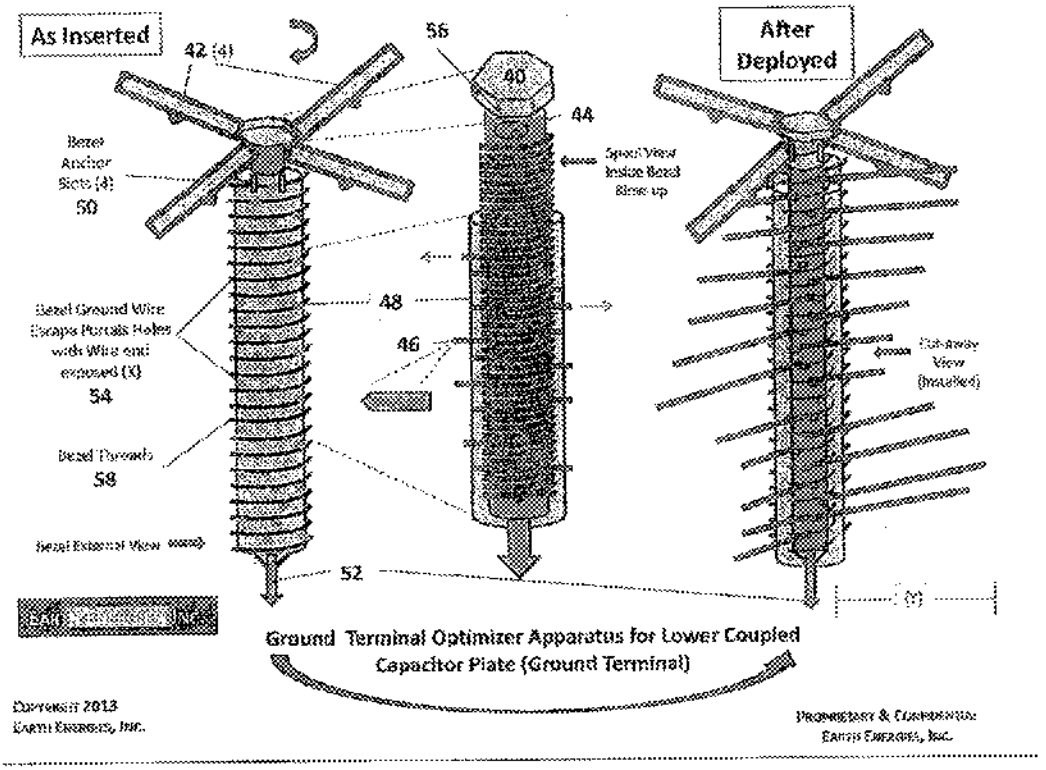
As Inserted
After Deployed
42 (4)
56
40
44
Bezel Anchor Slots (4)
50
48
46
Bezel Ground Wire Escape Portals Holes with Wire end exposed (X)
54
Bezel Pyramids
58
52
Ground Terminal Optimizer Apparatus for Lower Coupled Capacitor Plate (Ground Terminal)

FIG. 2

METHOD AND APPARATUS FOR EXTRACTING AND CONVEYING ELECTRICAL ENERGY FROM THE EARTH'S IONOSPHERE CAVITY

[0001] This application claims benefit of U.S. Provisional Application No. 61/889894, filed 11 Oct. 2013, titled, "Method and Apparatus for Extracting and Conveying Electrical Energy From the Earth's Ionosphere Cavity," the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] A portion of the disclosure of this patent document contains material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by any-one of the patent document or the patent disclosure, as it appears in the Patent and Trademark Office patent file or records, but otherwise reserves all copyright whatsoever.

[0003] The invention is an apparatus and methodology for extracting electric power manifesting as a broadband collection of electric field oscillations in the 0 to 200 Hz frequency range within the Earth's ionosphere cavity, through the use of an elevated biased hemispherical or other curved surface capacitor coupling the ionosphere cavity and Earth, and then conveying this electrical energy at the proper frequency, amperage, and voltage to existing homes and buildings where it is delivered for consumption over existing home or building wiring.

DESCRIPTION OF THE RELATED ART

[0004] The current state of the art in this field is focused on the bending of radio frequency waves in the Earth's ionosphere cavity for the purpose of distorting (through reflection) the resident cavity's magnetic field to physically direct the stimulating electrical energy to targeted locations within the Earth's ionosphere cavity and/or coordinates on the Earth's surface at specific energy levels appropriate to specific applications. The regenerative feedback was done by Sutton's active antenna.

[0005] Nikola Tesla attempted to transmit wireless power in the "natural medium"; however, Tesla bad no description of a device to receive natural oscillations as described in the present disclosure.

[0006] There is no known prior art in the field of electric energy extraction from the ionosphere cavity and conveyance to other terminals within the cavity for delivery of usable electric power.

SUMMARY OF THE INVENTION

[0007] In one exemplary embodiment of the present invention, a properly-scaled electric power extraction/conveyance apparatus is installed at a typical consumer residential home to deliver 60 Hz 120/240 VAC electric power, sufficient to convey the equivalent of 5 kW of continuous electricity, to the home's existing electric service entry component to power electrical appliances in the home over existing home electric wiring.

[0008] In another exemplary embodiment of the present invention, a properly-scaled electric power extraction/conveyance apparatus is installed at an appropriate location within an industrial park or neighborhood to deliver 60 Hz 120/240 V AC electric power, sufficient to convey the equivalent of 300 kW of continuous electricity, to the service entry components of industrial buildings or neighborhood homes to power electrical devices and appliances over existing building or home electric wiring.

[0009] Alternative exemplary embodiments of the present invention will extract direct current electric power from the Earth ionosphere cavity, generated by the earth's rotating magnetosphere, and convey in the form of conditioned direct current to direct current load sources, or convert to alternating current and convey in the form of conditioned alternating current to alternating current load sources.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A disclosure embodiments of the present invention, is set forth more particularly in the remainder of the specification, which makes reference to the accompanying figures, in which:

[0011] FIG. **1** provides an example of an electric power extraction and conveyance apparatus for one residential-scale embodiment of the present invention. Certain additional example embodiments of the present invention utilize similar fundamental technologies, but differ in the scale (size) of the components and characteristics of the electricity conveyed for consumption; and

[0012] FIG. **2** is a schematic illustration of ground terminals for use with embodiments of the present invention.

DETAILED DESCRIPTION

[0013] Applicant has discovered that trees extract and use electric power from the Earth ionosphere cavity. The present invention emulates the architecture of electric power extraction and usage methodology inherent in the natural operation of living trees, but uses standard and customized components, common in the field, for its implementation. The natural electric power extraction and use of electric power by trees leverages the shape and physical composition of trees as instances of large electrical capacitors coupled to the ionosphere cavity. The canopy of trees (upper limbs and leaf structures) emulates the upper plates of a coupled capacitor, the trunks of trees emulate a combined dielectric and resonant transformer/capacitor, and the root systems of trees emulate ground terminals (lower coupled capacitor plates). The extraction of electric power from the ionosphere cavity by trees is in the form of ultra-low frequency broadband waves (oscillations) in the frequency range of 0.1 to 14 Hertz (ULF). Inherent tree physical composition and control structure (i.e., DNA/RNA) govern the use of the extracted electric power to accomplish tree growth, seasonal metabolic adjustments, and reproductive processes. Any excess extracted electric power by trees is returned to the ionosphere cavity. The present invention is an exemplary instance of this same natural architecture using standard and customized components that facilitate extraction and conveyance of ionosphere cavity-resident broadband electric power at useful scales sufficient to provide continuous electrical power for electrical devices used by people.

[0014] One preferred exemplary embodiment of the present invention is in the form shown in Drawing **1** above and will deliver continuous 60 Hz 120/240 V AC electric power to consumer residences (and other structures with similar electricity conditioning and consumption requirements) equivalent to electric power capacity of 5 kilowatts.

[0015] A secondary exemplary embodiment of the present invention is also in the form shown in FIG. **1**, appropriately scaled for larger electrical power demands and related conveyance capacity, and will deliver continuous 60 Hz 120/240 V AC electric power to larger buildings or electrical distribution facilities for commercial office parks with electric power capacity of 300 kilowatts.

[0016] A third exemplary embodiment of the present invention is also in the form shown in FIG. **1**, appropriately scaled for larger electrical power capacity, and will deliver continuous 60 Hz 120/240 VAC electric power to utility substations with electric power capacity of 30,000 kilowatts (or higher).

[0017] The following system, power sources, and component descriptions provide additional details of the present invention in various embodiments.

[0018] Earth's ionosphere cavity (**10**) is a reservoir of continuously-generated electrical energy (E-Field) in both direct current (DC) and alternating current (AC) realms. The DC electric energy is created by the constant rotation of the Earth's magnetosphere exposed to the solar wind. Earth's perpetually moving magnetic fields create the DC electric power in the ionosphere cavity E-Field per the equations in James Clerk Maxwell's fundamental theory of electromagnetism. AC electrical energy in the ionosphere cavity is generated from the persistent E-Field disturbances (i. e., oscillations) caused by lightning discharges. The present invention includes the direct extraction of AC electric power from the ionosphere cavity, and the direct extraction of DC electric power from the ionosphere cavity which is converted to AC electric power before conveyance. Optional operational configurations of the present invention will also enable conveyance of extracted DC electric power for potential scenarios where the conveyance of conditioned DC electricity is required.

[0019] Electric-field oscillations (**22**) are induced by lightning and encapsulated in the earth-ionosphere cavity, creating a continuous source of renewable electrical energy. The frequency of lightning occurrences in the ionosphere cavity averages thirty (30) strikes per second, with each strike representing approximately one (1) terawatt (TW) of instantaneous energy. Assuming an average energy dissipation rate for each lightning strike of fifteen (15) microseconds (μsec), i. e., the time involved for one (1) terawatt of instantaneous energy to dissipate to zero (0) energy, these lightning-induced electric field oscillations are sufficient to provide 4,500 times the entire electric energy consumption on planet Earth at the projected consumption rate for the year 2100 (55.3 TWh annually). Lightning-induced E-Field oscillations vary between 0.1 and 14 Hertz with wavelengths exceeding the practicality of an electromagnetic antenna for collecting the energy. The present invention utilizes capacitive coupling to overcome this obstacle.

[0020] An insulated upper capacitor plate (terminal) (12) elevated above the influence of the ground floor collects E-Field oscillations from the ionosphere cavity. This insulated elevated terminal, capacitively-coupled to the E-Field bounded by the earth-ionosphere cavity, is arranged in a surface of large radii of curvature, supporting maximum surface connection to the E-Field without leaking the high voltage charge applied to the elevated terminal. The capacitance and resistance of the elevated terminal are responsive to the reception of broadband electric-field frequencies in the 0 to 200 hertz range. The elevated terminal is subject to high voltage alternating current biasing used to collect electric-field oscillations generated by lightning impulses in the earth-ionosphere cavity.

[0021] An evacuated spark gap (**24**) connected to the elevated terminal (**12**) prevents electrical discharge occurring between the elevated terminal and the ionosphere cavity. As the high voltage alternating current approaches peak voltage the spark gap energizes and a large voltage is applied to the step-down transformer primary coil (**16**). The high voltage pumps high current from the ground terminal (**14**, **26**) converting the electric-field to a magnetic field within the transformer (**16**). The step-down transformer is connected to a 60 hertz resonant capacitor (**18**), the secondary side of the transformer resonating at 60 hertz will supply a 60 hertz 120/240 VAC power to the load. Filter circuits will condition the power. The evacuated spark gap function may be accomplished by solid state circuitry in the implementation of the present invention.

[0022] The resonant transformer (**16**) is integrated with a parallel resonant capacitor across the transformer where the integrated combination resonates at 60 hertz supplying power to the electricity consuming structure (home or business). Various step-down transformers (**28**) are utilized to condition the conveyed electricity to accommodate the requirements of the receiving station for various embodiments of the present invention.

[0023] Ground (**26**) is the source of electric current for the present invention. A ground terminal, connected to the soil, is arranged in a surface of large radii of curvature to permit instantaneous sourcing of high currents from earth ground without temperature and voltage rise inhibiting the ground terminal collection of current. The capacitance and resistance of the ground terminal to earth is minimized to promote on demand current sourcing. Drawing **2** illustrates an exemplary apparatus of the present invention that optimizes ground connection quality by maximizing the penetration extent and resulting surface area of the ground terminal's extension into the soil.

[0024] Step-down transformers (**28**) are scaled to transform the electrical current and voltage into structured and conditioned electricity that is compatible with the electric power needs of the load sources for various embodiments of the present invention.

[0025] A mechanical nut (**40**) solidly attached to shaft **44** to facilitate extension, when turned, of large gauge copper wire extrusions (**46**).

[0026] A downward pointed anchor flat shaft (**42**) attached to the bezel **50** via a T-slot in bezel.

[0027] A copper (or other highly-conductive metal) spool base (**44**) sourcing "X" independently attached large gauge pointed copper wires (**46**) of length "Y", where "X" is equal to the number of escape portals in bezel (**50**), and "Y" is the length determined to yield optimum surface area of wires of type **46** for high quality connectivity to soil. The spool can freely rotate inside the bezel (**48**) and emulates the primary root structure of a living tree.

[0028] Sharpened large gauge (reinforced) copper wires (**46**), quantity "X", of length "Y" emulating the root structure of living trees.

[0029] Threaded bezel (spool-housing sleeve) (**48**) with drilled escape portal holes with end of copper wires (**46**) protruding through holes ½ inch.

[0030] Bezel anchor slots (**50**) of twice the height of anchor flat shafts (**42**) and T-slotted to accommodate anchor flat shafts.

[0031] Extended pointed end (**52**) of inner spool base shaft.

[0032] Escape portals (**54**) in bezel to allow for large gauge copper wire (**46**) extension into soil.

[0033] Connector port (**56**) for connection to ground terminal (**14**) in Drawing **1**.

[0034] Bezel threads (**58**).

[0035] Various embodiments of the present invention will include one or more of the following characteristics in various combinations. These descriptions are provided for purposes of example. Not all of the following characteristics will be required for any given exemplary embodiment.

[0036] Characteristic 1, The form (shape), physical composition, size, insulation, location altitude, discharge capacitive threshold and discharge rate, and the strength of AC or DC biasing applied to the (CUP) upper coupled capacitor plate (**12**: elevated terminal) all form an integrated whole, the purpose of which is to extract and temporarily store DC or AC electric power from the Earth's ionosphere cavity (**10**) at high voltage, and to trigger the energizing of the evacuated spark gap (**24**).

[0037] Characteristic 2, The elevated terminal (**12**) is capacitively coupled to the E-Field (**10**) bounded by the earth ionosphere cavity, and arranged in a surface of large radii of curvature, supporting maximum surface connection to the E-Field without leaking the high voltage charge applied to the elevated terminal (**12**).

[0038] Characteristic 3, The capacitance and resistance of the elevated terminal (**12**) are responsive to the reception of broadband electric-field frequencies in the 0 to 200 hertz range.

[0039] Characteristic 4, The elevated terminal (**12**) is subject to high voltage alternating current biasing used to collect E-Field oscillations generated by lightning impulses in the earth-ionosphere cavity.

[0040] Characteristic 5, An alternative instantiation of elevated terminal (**12**) is subject to high voltage direct current biasing used to collect E-Field direct current generated by the Earth's rotating magnetosphere.

[0041] Characteristic 6, The evacuated spark gap (**24**) may be in the form of a cohesive physical spark ignition or an operational emulation of this function through solid state circuitry.

[0042] Characteristic 7, The evacuated spark gap (**24**) connected to the elevated terminal (**12**) prevents electrical discharge occurring between the elevated terminal and the ionosphere cavity.

[0043] Characteristic 8, The high voltage alternating current from the E-Field, induced into the elevated terminal (**12**), approaches peak voltage and causes the evacuated spark gap (**24**) to energize and a large voltage is applied to the step-down transformer primary coil (**16**).

[0044] Characteristic 9, The high voltage alternating current impulse from the elevated terminal (**12**), which causes the evacuated spark gap (**24**) to energize, manifests as alternating current on broadband frequencies between 0.1 and 200 Hz.

[0045] Characteristic 10, In an alternative instantiation of the elevated terminal (**12**) the stored high voltage direct current, which causes the evacuated spark gap (**24**) to energize, manifests as direct current on broadband frequencies between 0 and 200 Hz.

[0046] Characteristic 11, The high voltage applied to the step-down transformer primary coil (**16**) pumps high current from the ground terminal (**14**), converting the electric-field to a magnetic field within the transformer (**16**).

[0047] Characteristic 12, The high current pumped from the ground terminal (**14**), caused by high voltage applied to the step-down transformer primary coil (**16**), will attempt to normalize the field and extinguish the evacuated spark gap (**24**).

[0048] Characteristic 13, The transformer's (**16**) magnetic field expands in response to the high current electric-field inrush from the ground terminal (**14**).

[0049] Characteristic 14, The primary winding inside the step-down transformer (**16**) will add the energy from each broadband frequency together into a single magnetic field, where it will become a 60 Hz frequency at the secondary winding of the transformer (**16**).

[0050] Characteristic 15, The step-down transformer (**16**) is connected to a 60 Hertz resonant capacitor (**18**).

[0051] Characteristic 16, The secondary (coil) side of the step-down transformer (**16**), resonating at 60 hertz, will supply a 60 hertz 120/240 VAC power to the electric load.

[0052] Characteristic 17, Filter circuits within the step-down transformer will condition the power according to the electric power needs of the electric load.

[0053] Characteristic 18, Electric-field lines exist (within the Earth's ionosphere cavity) that are horizontal to the surface of the Earth and extend to heights above 30,000 feet, with voltage gradients typically 100 Volts per vertical meter.

[0054] Characteristic 19, Lightning impulses create global broadband oscillations in the Earth ionosphere cavity electric-field between 0.1 and 14 Hertz.

[0055] Characteristic 20, Rotation of the Earth's magnetosphere creates global electric field oscillations in the Earth ionosphere cavity that manifest as electromagnetic waves in the 0 to 200 Hertz frequency range.

[0056] Characteristic 21, Global broadband oscillations in the Earth ionosphere cavity electric-field can be used for wireless energy transmission without harm to people, plants, or trees.

[0057] Characteristic 22, A maximum quality ground connection is achieved by expanding the surface area of the ground connection (**48** and **44**) through extension of high-conductor large gauge copper wires (**46**) horizontally through bezel (**48**) escape portals (**54**) along depth of source spool (**44**) and bezel (**48**).

[0058] Characteristic 23, The technique described in Characteristic 22 effectively expands the diameter of the ground source spool (**44**) with regard to quality of ground connection.

[0059] Characteristic 24, Bezel threads (**58**) expand surface area of bezel (**48**) touching earth, enhancing ground connection quality.

[0060] Characteristic 25, Bezel threads (**58**) enhance ground connection quality of bezel (**48**), source spool (**44**), and high conductor large gauge copper wires (**46**) through rotational insertion and resulting friction hold v. other (direct drive) insertion methods which can result in corruption of ground hole integrity caused by imprecise angle and/or vibration during insertion.

[0061] While one or more embodiments of the present invention have been described above, it should be understood that any and all equivalent realizations of the present invention are included within the scope and spirit thereof. Thus, the embodiments presented herein are by way of example only

and are not intended as limitations of the present invention. Therefore, it is contemplated that any and all such embodiments are included in the present invention.

What is claimed is:

1. A power receiver for extracting electrical energy from the earth's electric field, said power receiver comprising:

a resonant transformer connected between a ground terminal disposed below the surface of the earth and an elevated terminal;

impulse generator for generating and applying a high voltage electrical impulse to a primary winding of the resonant transformer to induce current flow from the ground terminal through the primary winding of the transformer; and

a power conversion circuit connected to a secondary winding of the resonant transformer to convert electrical current flowing through the secondary winding to a desired form.

2. The power receiver of claim **1** wherein a resonant frequency of the resonant transformer is below 200 Hz.

3. The power receiver of claim **1** wherein the elevated terminal comprises an upper capacitive plate coupled to the earth's ionosphere cavity.

4. The power receiver of claim **3** wherein the impulse generator comprises:

the upper capacitive plate;

a pair of electrodes separated by a spark gap, said electrodes connected between the upper capacitive plate and the primary winding of the resonant transformer and configured to generate a spark when a voltage difference between the electrodes reaches a predetermined level.

5. The power receiver of claim **1** further comprising a lower capacitive plate coupled to the ground terminal.

6. The power receiver of claim **1** wherein the resonant transformer comprises a capacitor connected in parallel with a primary winding of the resonant transformer.

* * * * *

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Information Big Brother & the Oil Companies do not want you to know!

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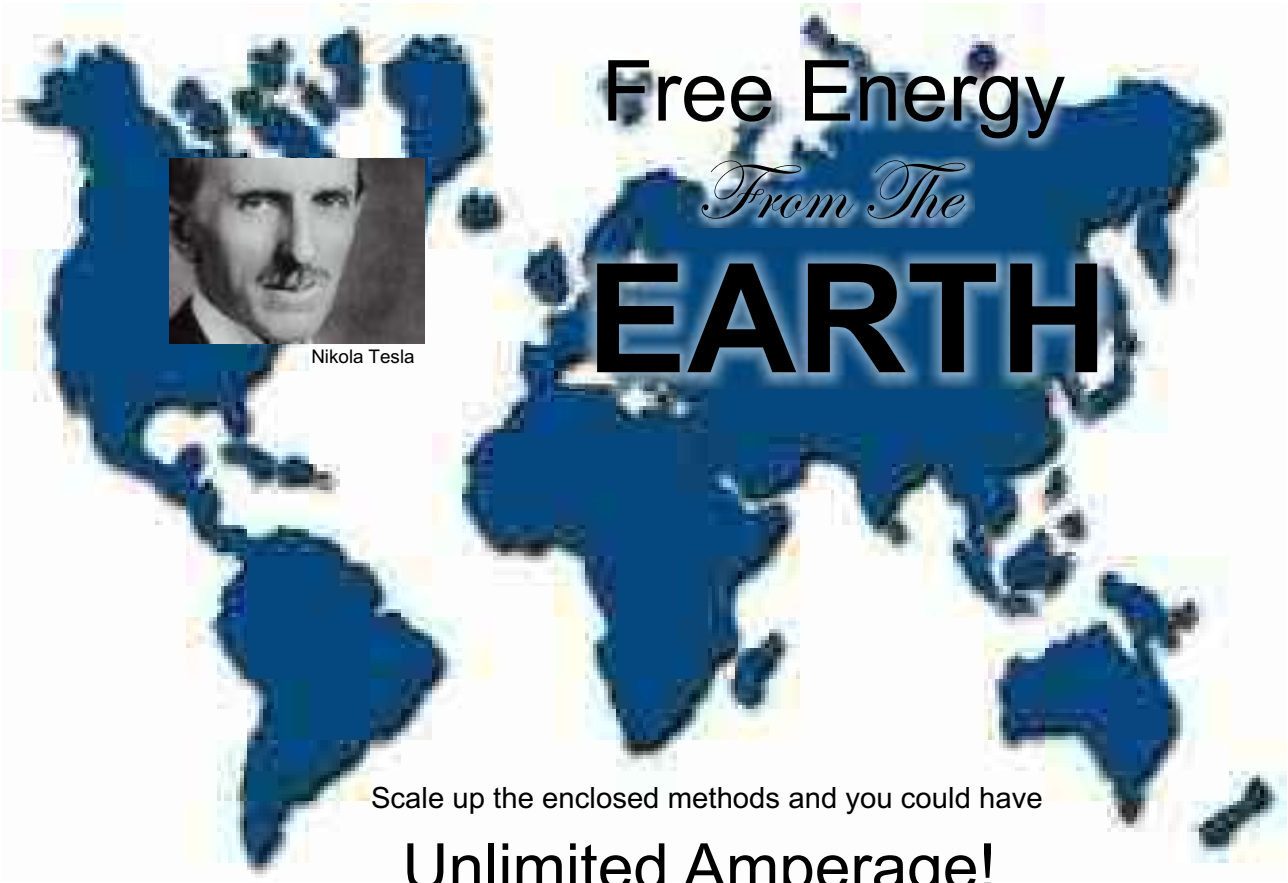

Free Energy

From The

EARTH

Nikola Tesla

Scale up the enclosed methods and you could have

Unlimited Amperage!

By Unlimited we mean you can keep adding more earth cells to your earth power station as you can afford it year by year adding more and more amp power.

Aluminum

Copper

There are many ways to pick up on the free energy in the earth, Just a few are described in these plans. These devices if made right will pick up earth energy that many call ether or static currents as well as acting as high efficient earth battery's. Ether travels through plastic wood etc... Study and research these plans closely there is more to these plans than what you may think. You can learn to get enough power to run your home!

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Learning The basic's of our invention

Experiment #1 How to assemble a 12 vdc system

1. You will have 12- 4" 3/4" copper piping, or If you did not purchase the kit then cut your copper to this size. KIT: take each piece of copper and tape the tops with 1" masking tape.

2. Now using RED LACQUER spray paint (Which you can buy at any hardware store), Paint the outside of the copper all around. (DO NOT PAINT THE INSIDE.) let air dry for 24 hrs. Now remove 1" masking tape.

3. Take the copper pipe outside to the area that you are going to use. use a hammer and hammer each one Into the ground up to the 1" copper exposed top. do not let the exposed copper touch the earth in the final placement. Dirt should be moist. Not real dry.

4. Now remove each pipe and place a thick piece of plastic on bottom of copper pipe to cap it. LET IT BE LOSE, DO NOT TAPE IT. YOU WANT RAIN WATER TO BE ABLE TO ESCAPE FROM EACH PIPE, Do not let exposed outside copper touch the earth.

5. Now hammer each pipe back Into the same holes. place each 2" piece of zinc rod (or a long bolt, most bolts are zinc plated) into the center of each pipe. The zinc Is the NEGATIVE and the copper is the + POSITIVE.

6. Now connect them in series to get 12 volts, use clip wire or solder them. If you are going to leave It outside for a long time then make sure connections are soldered and then painted to protect them from the weather. The rain will replenish your earth batteries. Top get more amaperage with this type simply add more copper and zinc rod cells USE 3' PIECES OF COPPER PIPE INSTEAD OF 4" PIPE. THEN CONNECT EVERY ROW OF 12 PIPES IN PARALLEL.. ADD AS MANY ROWS AS YOU NEED UNTIL YOU GET THE DESIRED AMPERAGE YOU WANT. **(THINK BIG!)** This can be a very powerful free energy system for your home or other. Not only will you get an earth battery effect, but you will also be collecting earth currents from ether /static and under ground radio waves as well.

7. The deeper you go with the copper pipe, the more amperage and voltage you can get.

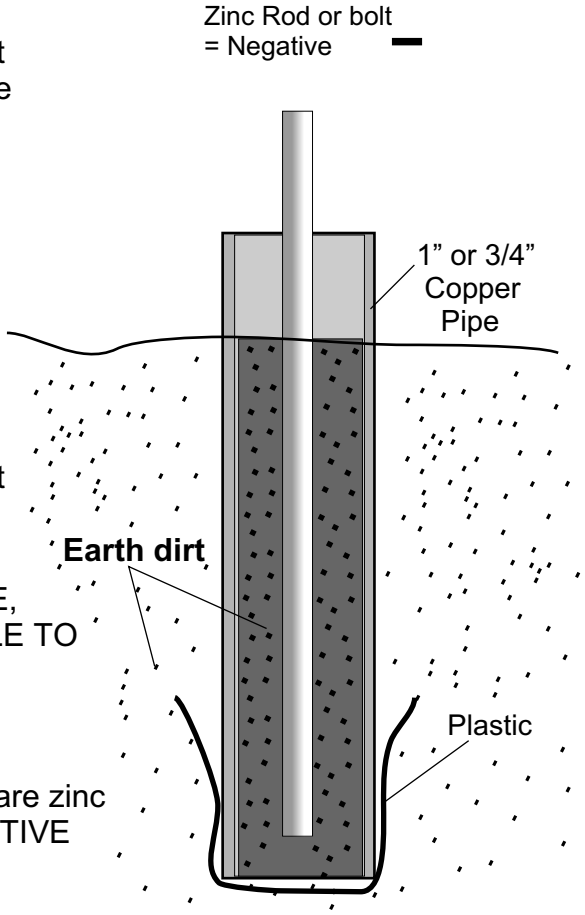

1" Copper = +
Positive 1.5 vdc
each cell you make

This represents one cell. A qty of 12 to 14 will give you 12 - 14 volts dc when connected in series.

Cut 12 - 4" L x 3/4" copper pipe

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Learning The basic's of our invention

Experiment #2 How to assemble a 12 vdc system

This is just an example to go by and is not the best way but is low in efficiency! See our capacitor earth cells, coil type or flat sheet type. They produce far more amperage and voltages than this type.

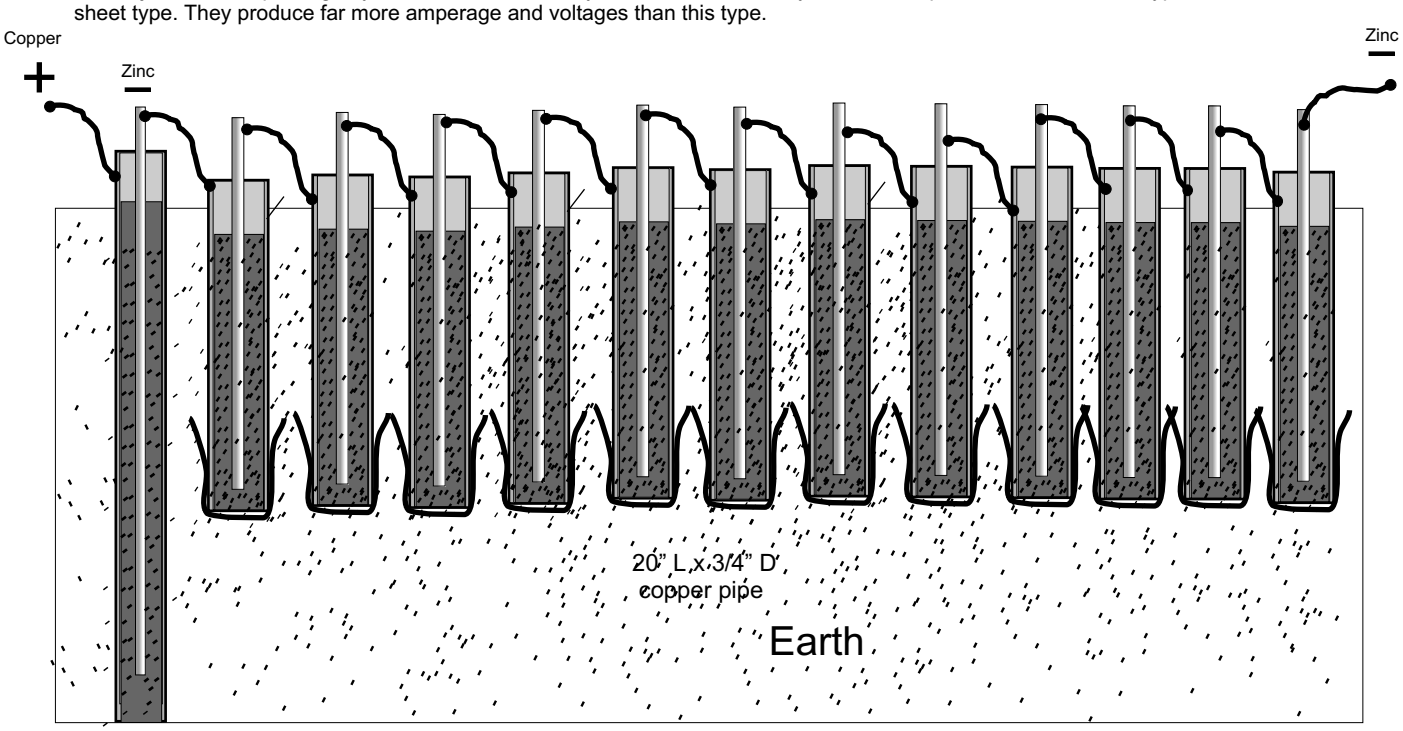

= 1 - 12vdc array

NOTICE: Do not paint the 10 foot copper cell. Keep all copper exposed to the earth. The more exposed copper the better. For higher amperage output, use a zinc or aluminum rod 10/16" Diameter which will leave a space of more than 1/16" to the copper.

Advantages of earth powered batteries

1. Free Energy
2. Long Life
3. The collection of aether energy.
4. Cells are also replenished by outside weather. Rain as well as lightning charges.

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You can purchase Zinc rods or zinc plated bolts at any hardware store, most all nuts and bolts they sell are zinc coated and will work just fine. They also carry aluminum sheeting. Most hardware stores can order you copper sheeting as well.

Experiment #3 How to assemble a 12 vdc system

This is a simple way to produce more amperage but is not practical, we are only showing you this to educate you. The closer the zinc rod is to the copper the more amperage you will get as well as going deeper into the earth. If you do decide to build this basic set up. It is suggested that you solder all leads very well and dig deep enough into the earth to hide the tops of each cell. By covering the tops with dirt the cells can short out so what you want to do is to paint the exposed tops with lacquer or enamel paint then cover with plastic, cover with dirt and allow both the negative and the positive leads to stick out of the ground. But like I said this is not practical, what your goal should be is to make a very strong uf earth capacitor / battery, This will allow you to pick up and collect earth radiant waves of energy as well as lighting energy during storms, the energy you can collect in a strong lighting storm will amaze you! You must use an antenna on the zinc rod or copper rod. **WARNING! Be careful when collecting lighting it can kill you, be sure the positive and negative wires are not coming into your home. During a storm it is advised to have the lead wires going into a large uf cap bank via a one way diode on the positive lead to the positive of the cap or battery. The earth battery's can be dangerous at times and must be completely buried in the earth so a child, adult or animal can not touch or get to. Our earth capacitor batteries can store and hold thousands of volts. So be careful. Use rubber gloves and clothing to protect yourself. We are not responsible for anything in these plans you build at your own risk.**

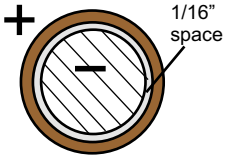

Example of a perfect Zinc rod copper pipe cell

Top view of a 12 volt dc array high amp system

Connect the series arrays in parallel to each other as shown. Or for a high voltage system connect all in series! Pulse the dc into a 10x step up transformer, 15,000 v Neon transf.

Zinc rod can be replaced by using rolled up aluminum sheeting or Zinc sheeting, Use 100% cotton cloth wrapped around the rolled sheeting or rod to give a small space in between the aluminum sheet and copper.

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Learning The basic's of our invention

Experiment #4 The 6 foot spacing method (old way)

There are many US Patents that were Issued back in the 1800's, one of them was issued to a Mr. Deckman. Deckman found that if you take several small pieces of Zinc and Carbon rod and stick them into the ground next to each other and connect them in series (much like a battery) you get very liittle gain at all.

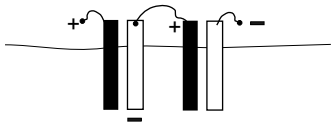

But if you put them 6 feet apart you will get a gain In voltage and they will not cancel one another out. so by doing this you can put them In series to increase your voltage and your volt amps. The theory is that there Is some sort of natural energy VORTEX that takes up about that much space for each unit or cell.

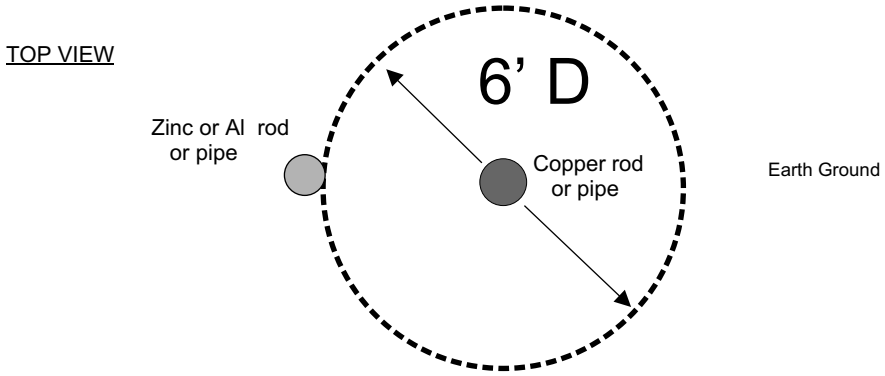

By using this method it will take a lot of ground space, ground space that many people just do not have with the exception of farmers. If you do have the space then think BIG! dig deep and have as many cells as you can get up to 2 to 4 acres. There are much better ways - vs - the old method as you will see. but by using Deckmans old way or our new methods, you can get as much free energy as you want with voltages or amperages as high as you want or desire. The higher the desired amperage the more costly it can get. We are always working to better our inventions to keep the cost down.

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By using our new system you can get as much voltage or amperage as you want. Just size It to meet your needs or your budget.

How to get AC current for house hold use.

You can convert the incoming dc current to ac by using a home made inverter (which we sell the plans to, **5 kw inverter plans $40 order #579**) or you can purchase a 12 v to 115 vac inverter from a store or solar panel supply house.. If you are planing to make a 115 VAC system this Is the only way you can do it. You can not get AC current from the ground. You must use our system to charge a deep cycle 12 v marine battery, and then connect our 5,000 watt 120 vdc to ac inverter to the battery to run your home. (we do not sell kits or inverters assembled, we only sell the plans at this time.)

More on the basic pipe method

Please note: the dirt level inside each pipe should be up to 1/4" from the top. each pipe should be tightly fliied with dirt. Which will automatically happen when you hammer the pipe into the ground the first time.

Each copper pipe (or cell) should be spaced 1 Inch to 1 1/2 inch apart. Doing this will give you more amperage and voltage.

How to dig a simple deep hole for 8' pipe: There are many ways in which you can do this. you can rent a ground drill bit and rig it up with a electric 2 hp motor or you can use 1" copper pipe.

First: prepare the ground with water to make it moist but not muddy, 2nd: hammer a 1" x 5' copper pipe into the moist ground about 5 inches deep/ then remove it from the ground and take a stick or a water hose to remove the dirt from inside the pipe. Then just repeat the process over and over until you get the desired depth that you want. you can get about 10 feet or more using this method.

WARNINGI BE CAREFUL OF ELECTIC POWER LINES WHEN YOU PLACE OR PULL THE COPPER PIPE FROM THE GROUND, IT WILL KILL YOU IF YOU TOUCH A POWER LINE WITH THE END OF THE COPPER PIPE.

We are dealing with a new type of energy as well as conventional energy < Ether energy can go through rubber/ plastic. Iron, etc....

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What is ether or Radiant energy?

The understanding comes from a very deep study of etheric or static forces, this energy that we are getting out of the ground is what some call LIGHT ETHER, when you separate the light ether from the warm ether you can get these superconductive events. It appears like electricity but it has no heat events related to It.

The point is that the best polarity's of things to get a differential in the light ether is to have a silvered coloured metal and then something that is totally absorbitive/ Like black Carbon.

So now you have something that's the perfect reflector and something that is the perfect absorber, and once you understand what your pulling out of the ground (and that it Is not classic electricity as we get out of a normal type of chemical battery), then your going to be farther down the road to understanding how to get much more power out of this stuff.....

There are researchers now that are getting 1 /2 volt to 2 volts dc on a "Quote" volt meter, but it will shock you through an inch of rubber shoes this is not normal electricity!

Q: Is this energy coming from the sun and being absorbed In the earth or from the center of the earth?

A: Yes, but the primary source of light ether is the sun light, yes the earth does have an economy of light ether which does follow the sun around. BUT IT IS ALSO IN THE GROUND! AND ITS IN THE AIR!

Q: Did NokolaTesla know about this in the 1900's?

A: Yes, if you read into his writings he was always saying things like, there is more energy moving than just the electricity in this stuff.

Example: If you take a large Tesla coil and fire it up, and you drive it with a van de graph generator and you put the output of that into a Tesla coil. you can throw sparks across the room! What these electrostatic machines are gathering is light ether.

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A Very Strange and New Discovery!

While working outside on another experiment I discovered a very strange generator effect, much to my surprise, I found that by using 2 aluminum 8” disks connected to my DC volt meter and by placing both disks in a vertical position while touching the bare earth dirt, and moving one of the disks and allowing the other to be stationary I get a dc voltage positive output! This effect works with any size or shape of aluminum, we used 8” diameter disk x 1/8” thick, we found that size to work best. Also by stacking them like a capacitor you will find that the current output is far greater, For Example: see figure 1, Disk A would have 4 more disks connected in parallel of the same size separated by paper die electrics. The same goes for Disk B .

First find a spot any where on the ground where there is no grass (best when wet). Please note, it's not just creating an acid battery effect, you are also getting a good contact with the ground as a conductor to pick up ether energy.

Now place the disks side by side, attach your DC voltmeter probes onto the disks, one negative and one positive. DC meter should be on the lowest setting, now place both disks on the ground very softly and move **disk B** and **do not move disk A** (positive.) You will notice you are getting a small amount of voltage and amperage. Now Move **disk A** and do not move **disk B.** **THE POLARITY CHANGES**.

The rule here is; The disk that moves is always positive. since we can get a polarity change just by moving the disks at opposite times. You can make a very simple mechanical device to get AC current from on top of the earth. Again, this is not just a chemical reaction we have done many test to prove this. You can also get a small voltage reading in dry dirt. The reason for the smaller voltage in using dry dirt is because a low conductance resistance is taking place here, keeping the system from being in contact with the earth and collecting the earth **ether energy.**

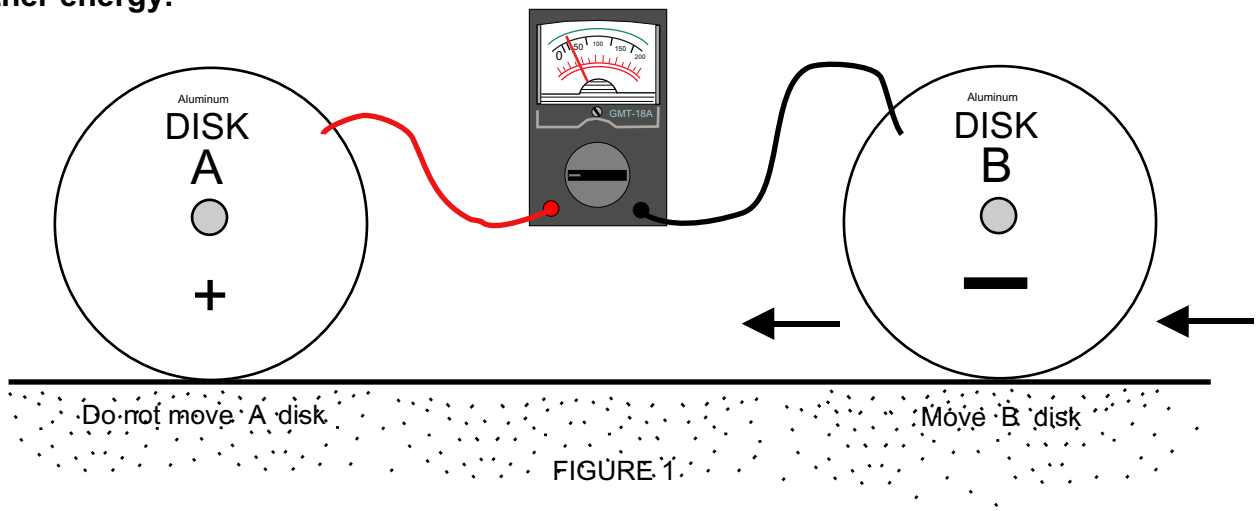

FIGURE 1

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Capacitor Sheet Method

This method is far better than using pipes or rods. By using copper and zinc or aluminum foil sheets you will get much more amperage out of your system!

The amperage you will be collecting will be coming from 3 different sources,

1. **The acid in the ground and water**
2. **Energy that is being transmitted from the earth itself**
3. **Energy that is being transmitted from the sky and space.**

This may all seem unbelievable but it's true and is a fact! The more plates that you add the more power you will get! The copper sheet(s) is the positive, it must be facing down toward the earth. The aluminum or zinc sheet(s) is the negative and must be facing toward the sky! Between each sheet place 1- cotton or course screen printing mesh or other plastic course mesh cloth material. you can use a hole puncher to punch exact holes in each sheet, use 2 holes per sheet copper and aluminum. Use a 8 1/2" x 11" paper puncher one that is adjustable. next use a 3/4 wood base and drill hole for wood dowel rods to fit to the holes you punched in the sheets, you will have a total of 4 wood dowel rods, 2 on the right for the copper sheets and 2 on the left for the aluminum sheets to fit over, cloth die electric can be done the same. You then need to assemble dry and use another 3/4" wood board for top holding plate, which will fit over the wood dowel rods on top, sandwhich and press the assembly together and tape in place with duct tape, drill 2 long bolt holding holes on bottom wood base and top wood base then attach long bolts and nuts and tighten down. Remove tape. and attach wires, water the entire capacitor assembly and bury in the ground.

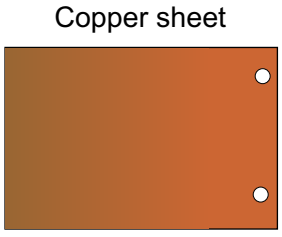

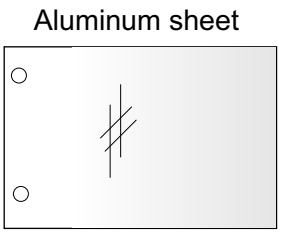

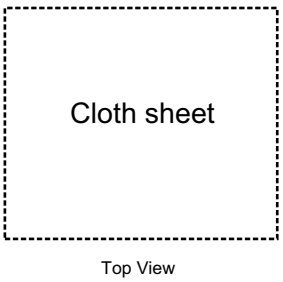

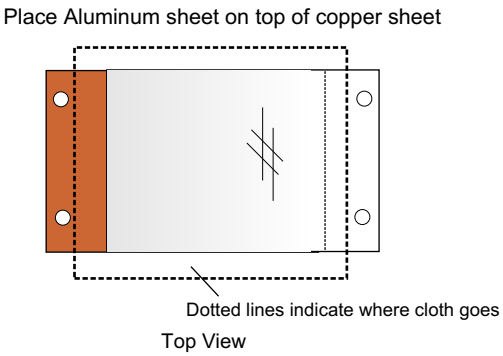

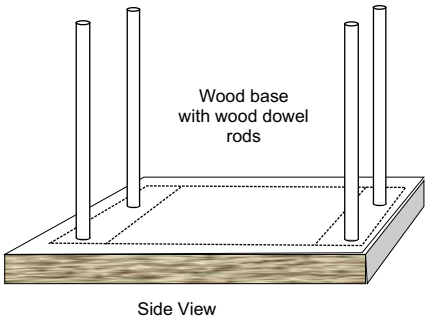

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Capacitor Sheet Method

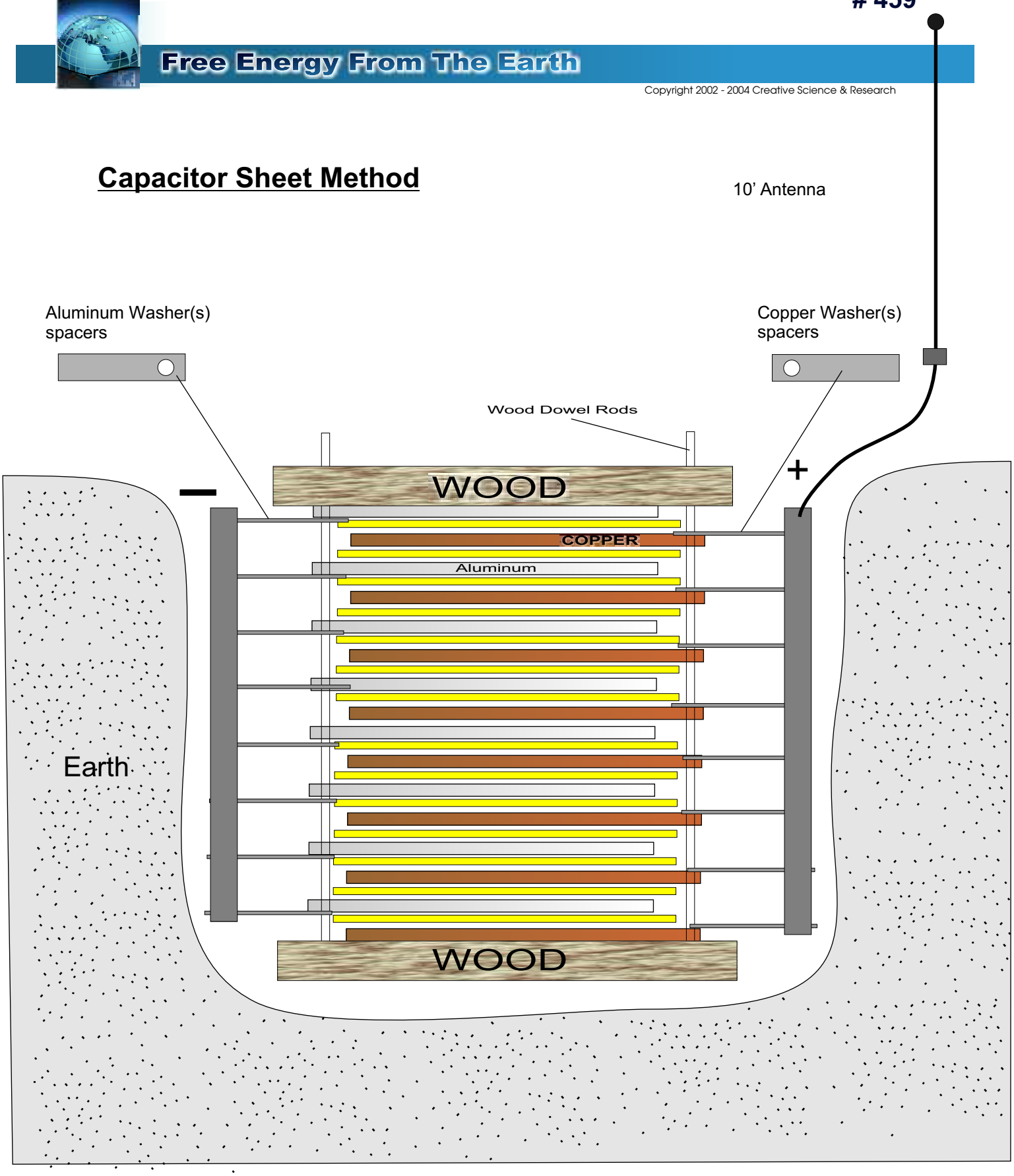

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Capacitor Sheet Method

Again, the more plate sheets of metal you add (or cells) the more power you will get! Remember it's all about capacitance. You are collecting more than just simple battery type power. The copper plate sheet is the Positive + and the Aluminum sheet is the negative. There are many ways in which one can build this type of earth energy collector, below is simply an example of another shape and form. In this type we use water holes. water holes must all be in exact spots.

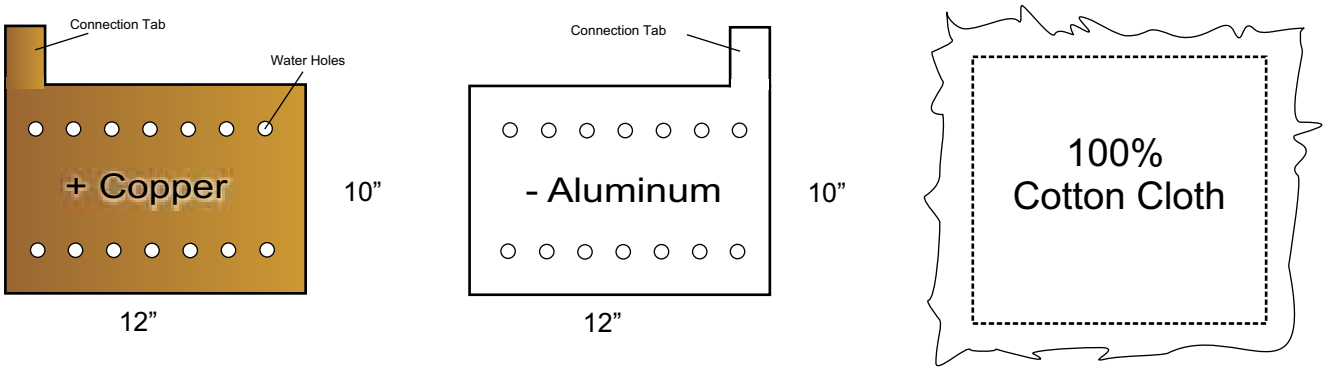

Figure #1 Top View of separate pieces

Figure #1 Side View

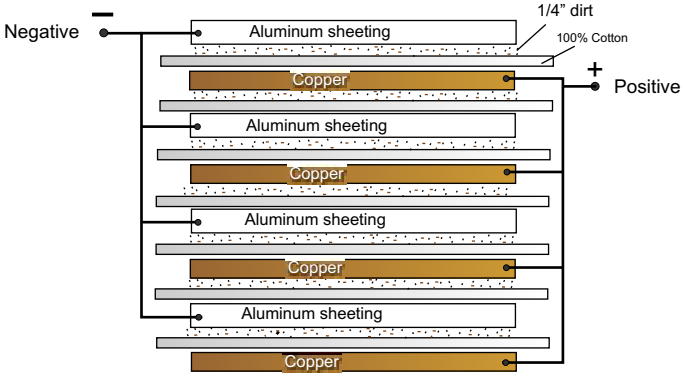

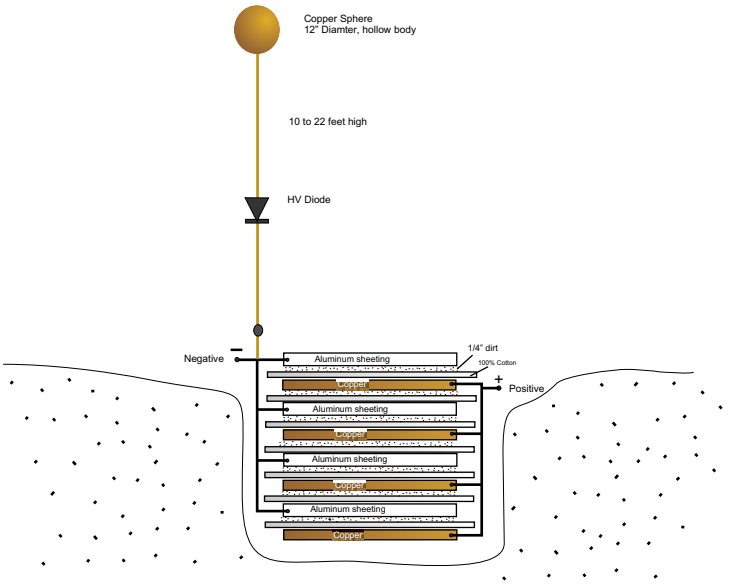

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

To collect more ether earth energy atoms, build the following **Earth Energy Coil Capacitor**, **Designed & Created by Creative Science & Research.** This is far better than anything we have found yet! Much more power and is easier to build.

Start with our EECC Model #1, Take a 5/16" zinc rod or aluminum rod, cut to 7.5" long. Now use #27 bare copper wire, secure it in a drill press (which you will then turn by hand). Cover zinc rod with paper one layer, use very tiny bits of tape to secure. Now apply the copper wire over the paper, remember to use copper that is not coated! Tape one end of the copper wire to the end of the zinc or aluminum rod and begin to slowly wind. Each wind must be perfectly fitted side by side, paper should be 5.5" long, total length of winds should be 4" long centered on paper. Once you are done with the first layer, apply another piece of paper to the top layer of the first copper layer, do not use to much tape to secure paper in place! Now begin your 2nd layer, repeat this same process until you have about 10 layers, (the more layers the better!) Copper must not touch the zinc or aluminum. When done hot glue or epoxy a small end piece of the copper wire so it will not come unwound. This is one complete cell, keep in mind this is a small test version, to get more power you have to THINK BIG! Build larger cells, using larger size copper. Then place them in salt water to test, 2 cells can be connected in series, after that you must connect them by use of capacitors, diodes and electronic or hand wound spring switches. If you build 20 of these and try to connect them all in series without a cap/ diode switching method, the cells will cancel each other out. Keep in mind you want water to get to each layer as well as the zinc or aluminum. You can also use Aluminum or zinc pipe.

Now concerning the paper Die Electric, Paper will not last very long, test and find a water absorbing plastic die electric,(mesh type). We suggest that you use Plastic screen mesh that you can buy at any hardware store, if all you are interested in is collecting small voltages then use one layer in between each layer of copper, if you are interested in collecting higher voltages such as lightning charges then you must use more layers of plastic screen mesh to thicken the die electric so the higher voltages will not short out your system. Paper may not last longer than 1 year, Plastic screen mesh or polyester screen printing mesh will last for many years.

EECC Model #2 Same as #1, but different. In this design we use #27 copper COATED wire, instead of bare wire. since the copper wire is coated and not bare, each layer must be sanded, that is, the top portion of the copper coated layer must be sanded off so it will be exposed to the water and acid, a die electric should still be used in this case. This type makes for a very high efficient earth cap!

EECC Model #3 Same as #1 but reversed! You will use aluminum wire and a copper rod or pipe. Use a 3/4" copper pipe and wind the die electric paper or plastic mesh and Aluminum bare wire around the copper pipe as explained in Model #1

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

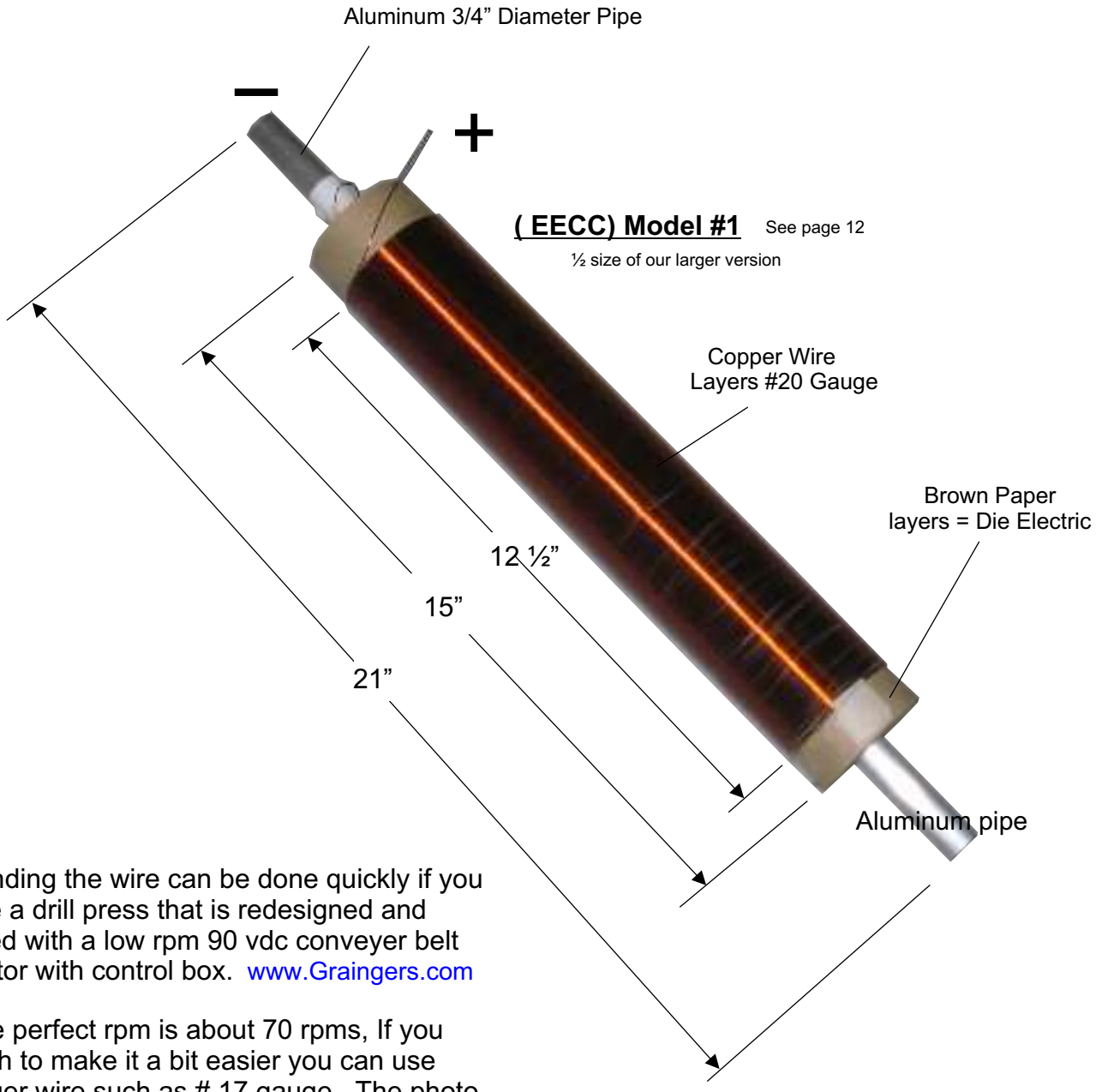

Winding the wire can be done quickly if you use a drill press that is redesigned and fitted with a low rpm 90 vdc conveyer belt motor with control box. www.Graingers.com

The perfect rpm is about 70 rpms, If you wish to make it a bit easier you can use larger wire such as # 17 gauge. The photo is an example of a mid size cell and can be very powerful! This is ½ size of a large cell.

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OUR MORE ADVANCED EARTH CAPACITOR!

(EECC) Earth Energy Coil Capacitor!

Our small test model #1, we used #22 bare copper wire wrapped around a zinc rod, each layer had a paper die electric, tested in tap water. 5 layers.
Output = 89 vdc x 3.5 ma, this is low.
more layers will = more capacitance which =’s more amperage and voltage.

Small Drill press turned into a Coil Winder

The more layers, the more free earth energy you can collect!

Small Drill press turned into a Coil Winder. We turned this by hand.
Larger coils is best to use low rpm motor at about 70 rpms, In this picture you see that we wound each wind side by side, this makes for a more high efficient earth cap.
You can wild wind if you like if you use smaller wire like #31 to #34.

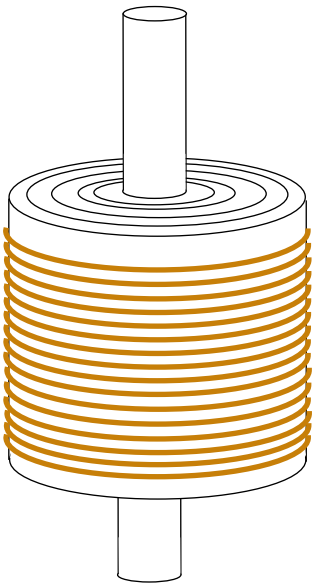

Side View
Ideal size for experimenting

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(EECC) Earth Energy Coil Capacitor!

Rolled Earth Capacitor

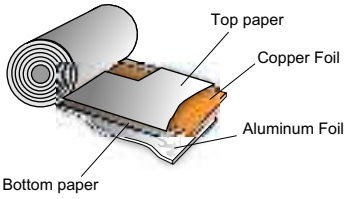

MODEL #4 Rolled Earth Capacitor

Copper foil is placed between 2 pieces of paper strips and Aluminum is placed on bottom. Use 400 foot strips 2" wide. This method is very hard to do. But is very high eff.

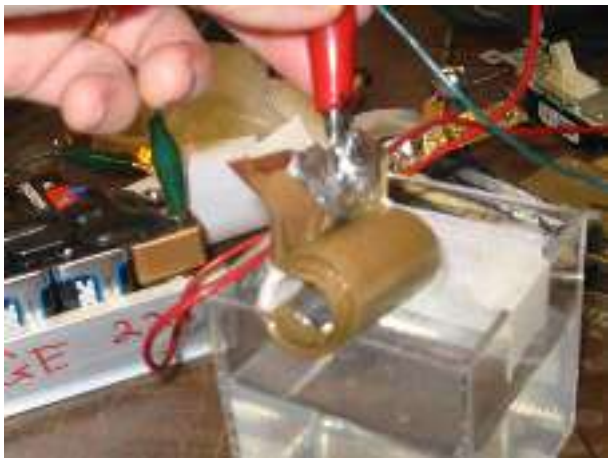

We used salt water to test rolled caps before placing them in the ground.

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(EECC) Earth Energy Coil Capacitor!

MODEL #4 Rolled Earth Capacitor

Rolled Earth Capacitor

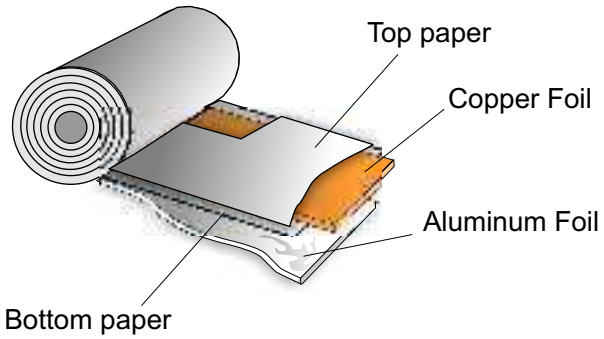

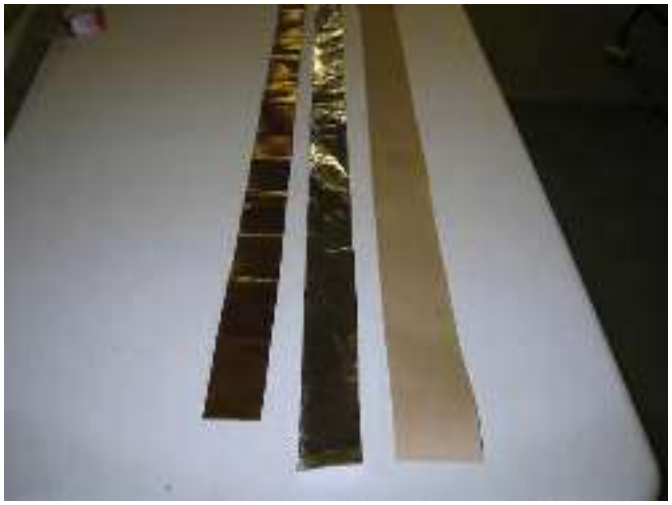

Again rolling this type of earth capacitor is very hard, Everything must be kept straight and inline with one another, Manufacturers of rolled electrolytic capacitors use computers and machinery. I am sure a simple home made roller with pin registration could be designed very easily. This type of earth battery is very high efficient. Paper is not a good die electric for high voltages! If you are wanting to collect earth and storm HV Currents you must use a thicker die electric. Metals must be spaced properly for storing high voltage.

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(EECC) Earth Energy Coil Capacitor!

Rolling a capacitor is the best way but not the easiest,
Which makes this pipe coil model much more desirable to build

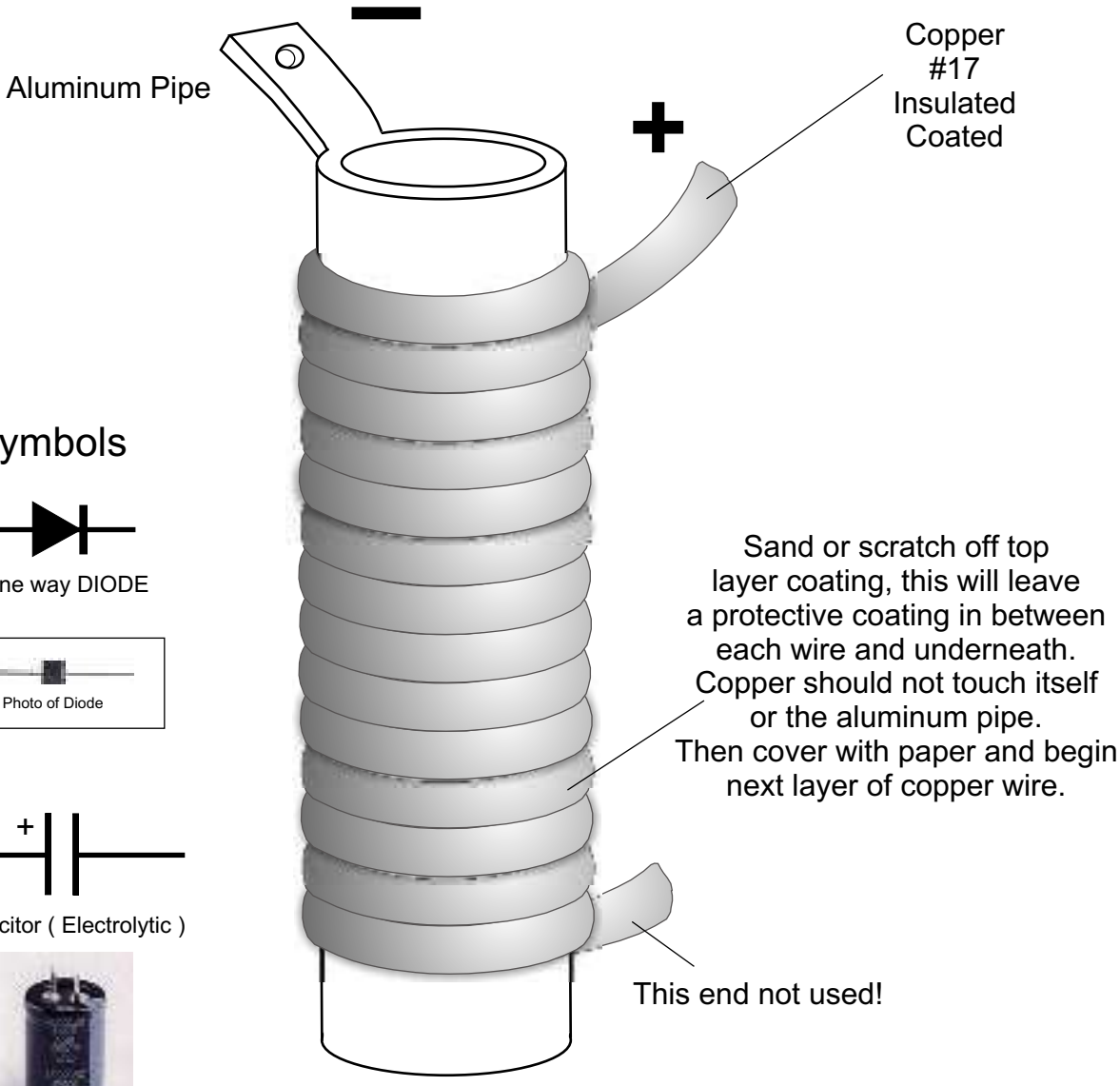

Symbols

= One way DIODE

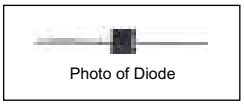

Photo of Diode

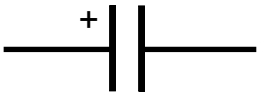

Capacitor (Electrolytic)

Photo of one type
of Capacitor

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CONNECTING THE CELLS IN SERIES

How to connect the cells in series to increase the output voltage without allowing the cells to cancel each other out. Figure **A** The Copper pipe and zinc rod method without the use of plastic on bottom of pipe. **Figure B** is the coil earth cap method.

Figure A

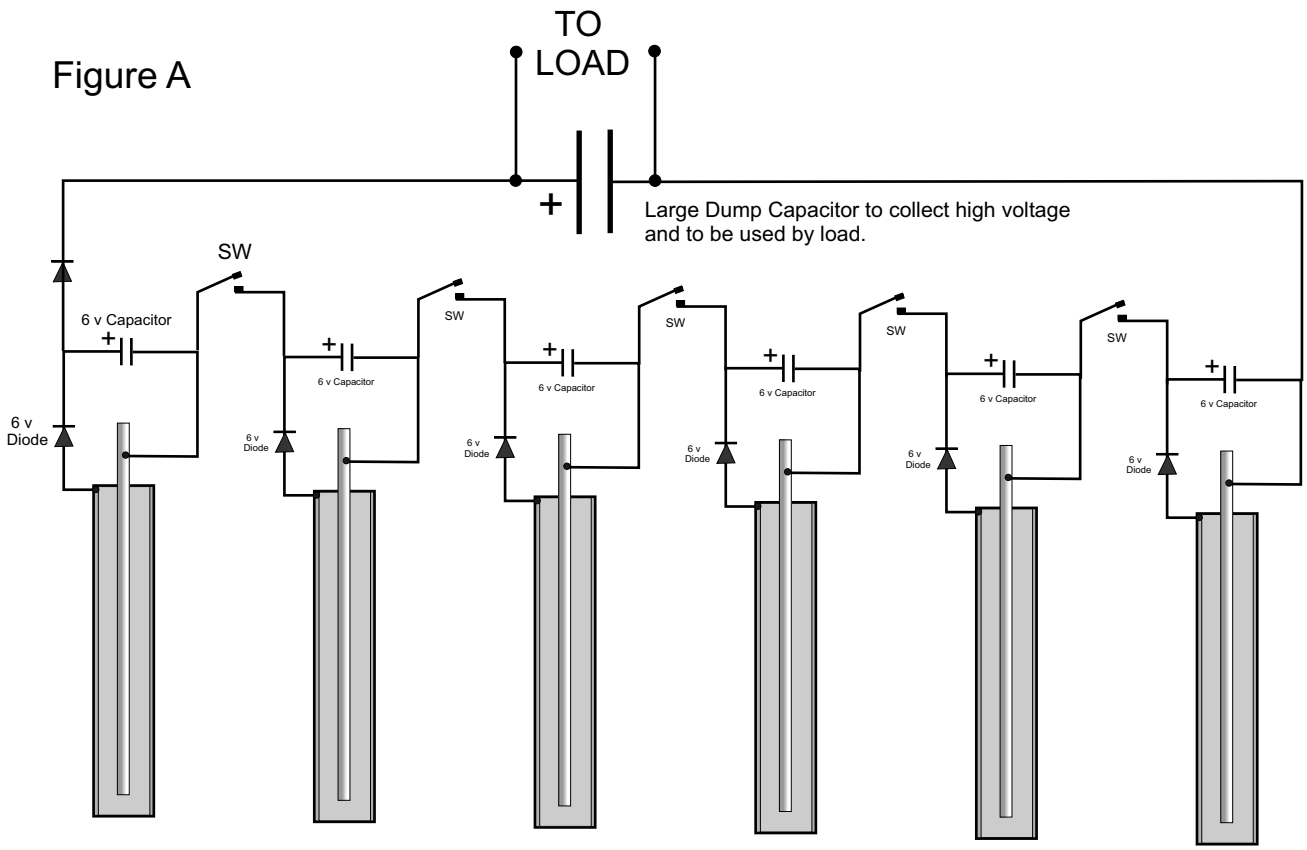

Use electrolytic capacitors to store the charge coming from each cell, then connect them in series using Commutator Sw's connected to a small rotor shaft, connected to a milliamp solar cell hobby motor or build a small fuelless engine electric motor to run on and off switch's. You can also build a very low milliamp electronic switching circuit and use the earth energy to power it. Or another more simple way would be to use a hand spring type device (timer type) glue small magnets on a long rotating rotor arm connected to the inner spring. Then place small reed relay magnetic switches, on each timing magnet ON position. should have multi reed sw's, as the unit turns if gives time for the caps to charge and then comes around and connects caps all in series which in turn discharges into main cap dump.

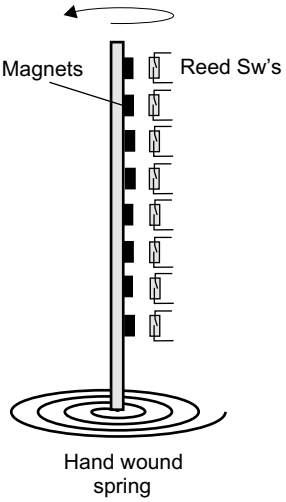

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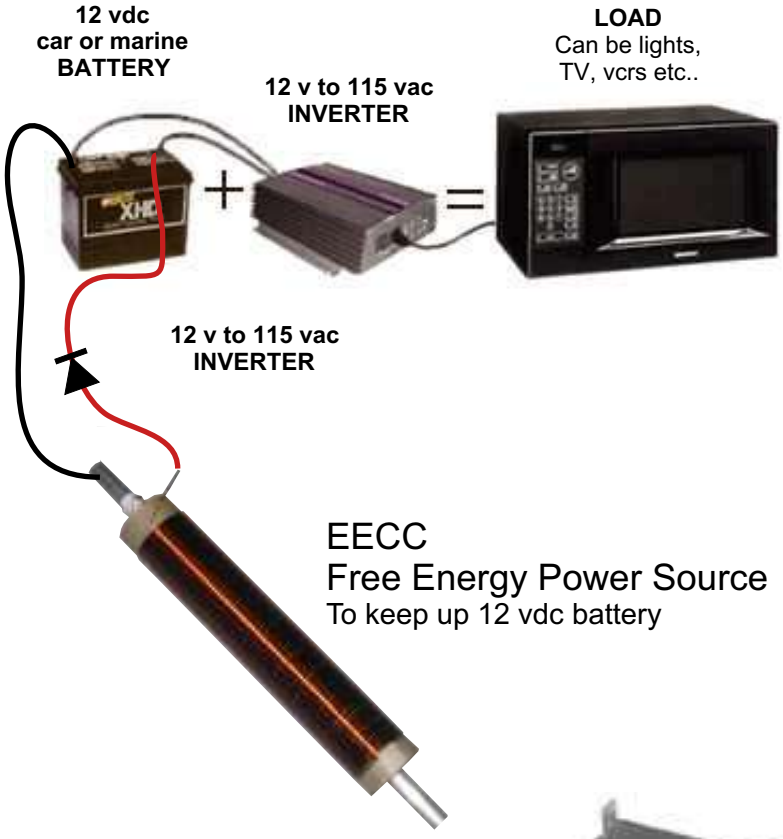

EECC
Free Energy Power Source
To keep up 12 vdc battery

Copper

Symbols

= One way DIODE

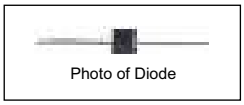

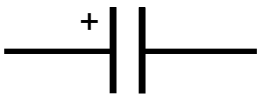

Capacitor (Electrolytic)

Photo of one type
of Capacitor

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Suppliers List

Free News

Google

Copper Foil Search

See www.google.com

1. Http://www.delphiglass.com/

   Use there search engine to find copper foil tape

2. http://www.glassmart.com/foil_menu.htm

3. http://www.globalsources.com

Search Google.com for:

1. Copper flashing
2. Inverters
3. Batteries
4. Copper coated wire
5. Copper wire
6. Electronic parts and supplies
7. Diodes
8. Capacitors
9. Free energy from the earth
10. Zinc rods

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EECC update

Step One

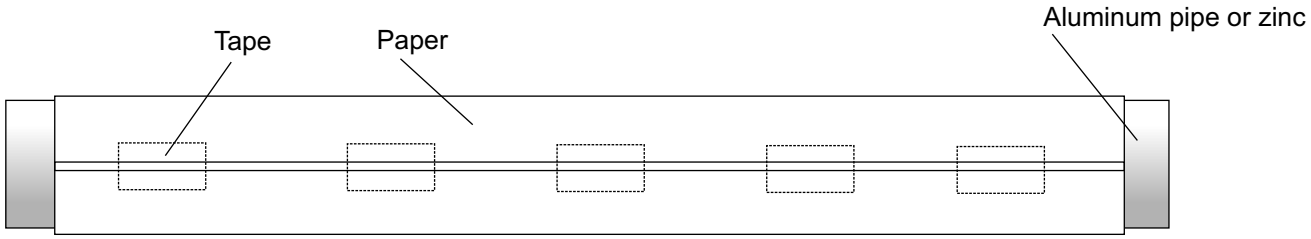

Step two

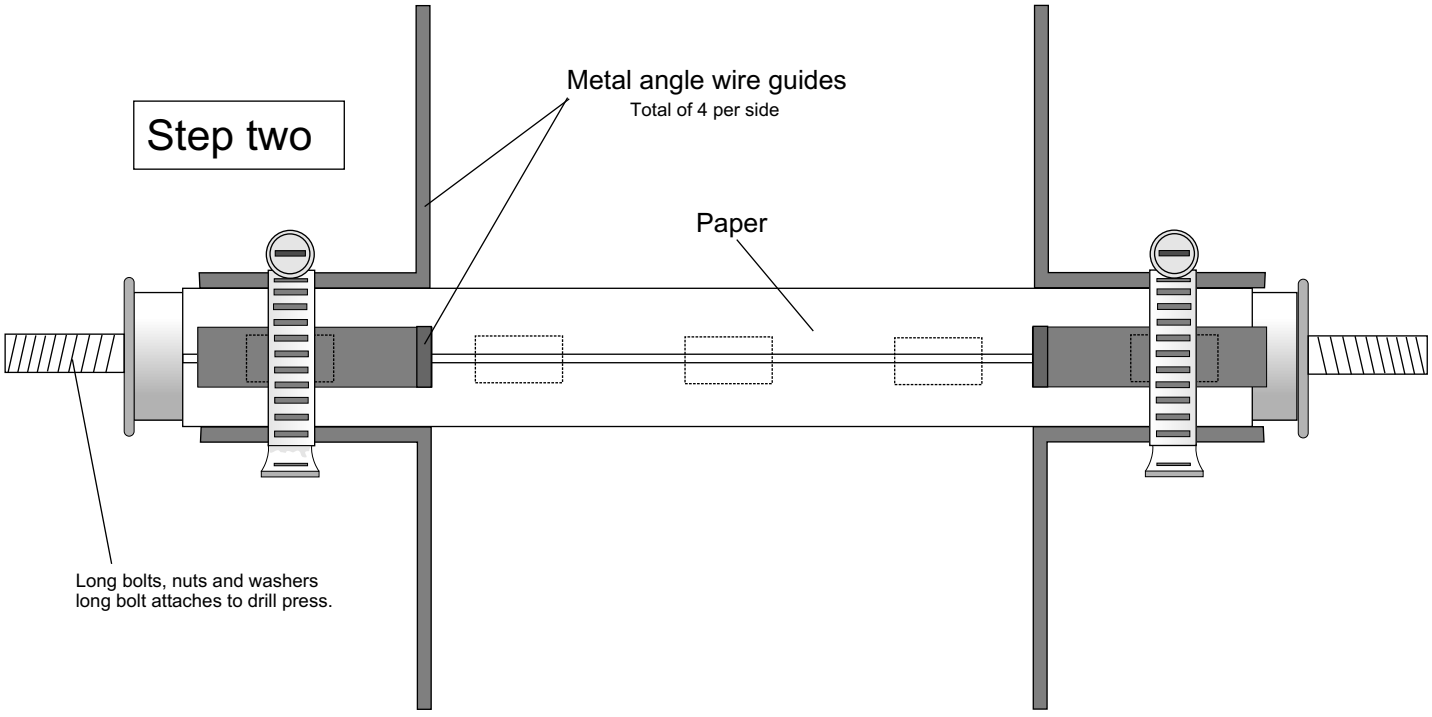

Apply first layer of wire, remove, metal wire guides, apply more paper, then repeat over and over again until you have about a 5 to 6 inch diameter roll of wire and paper. Makes a very powerful earth capacitor!

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EECC update

These are just a few extra idea's that we threw together. I hope they are helpful to you. Let us know how you like these plans. Send us photo's of what you have done we love to hear from our customers. If you got any new free energy idea's let us know we can research them for you. Many customers do not have the extra research time that we have.

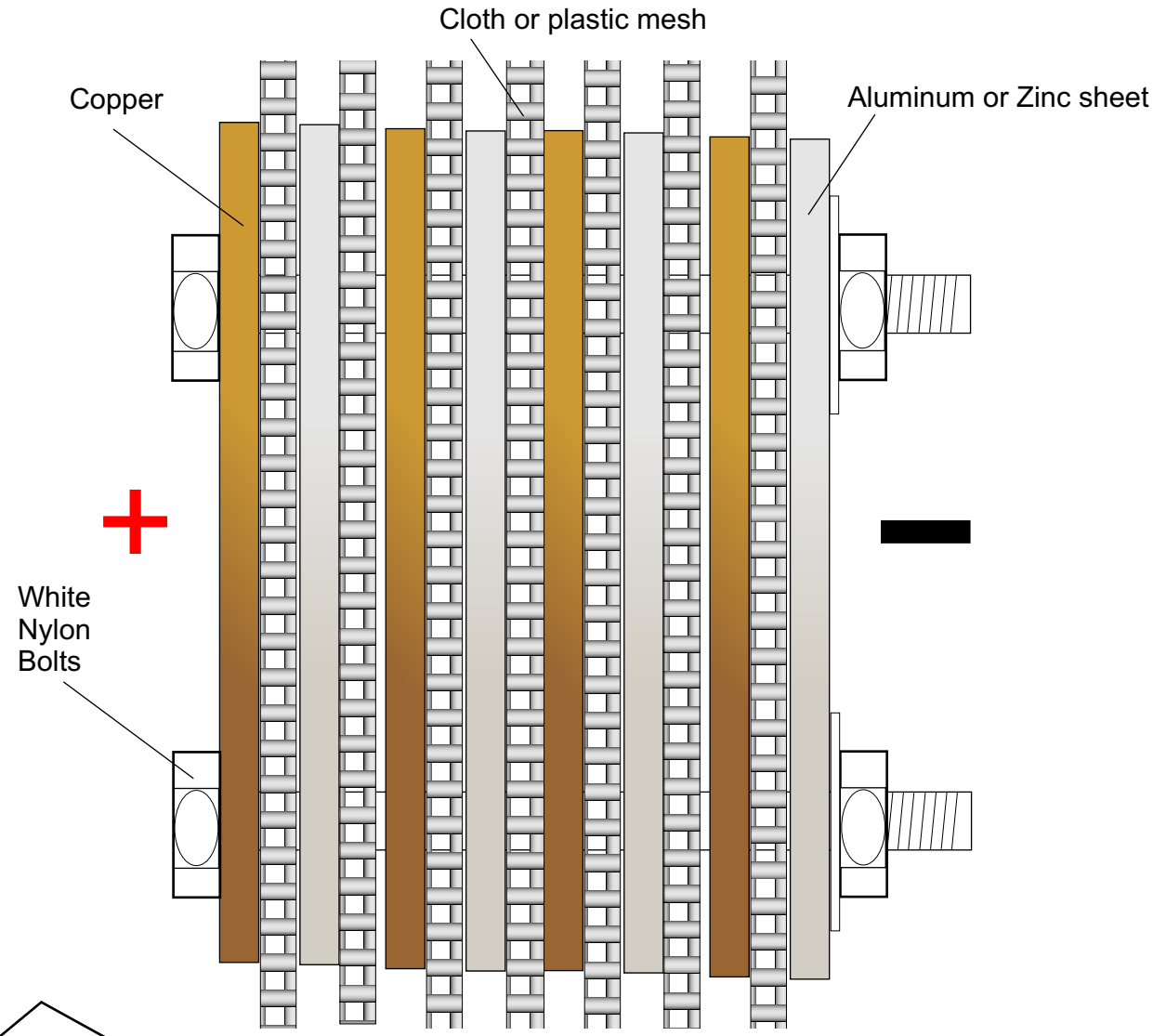

Metal sheet type earth battery

Fighting the pollution by public radio broadcast antennas

Un texte en français :	La pollution radio par les émetteurs FM
Een tekst in het Nederlands:	De radiovervuiling door FM-stralen
A petition:	www.petition-electrosmog.be

The electromagnetic pollution has now reached such a level that not only hypersensitive persons are being harmed. The debate most often focuses on cell phones, their relay antennas, Wi-Fi routers and similar technologies. It is often pointed out that domestic appliances like power saving lamps and cheap electronic devices, are harmful too. Recently, I came to the conclusion that I too had problems with electromagnetic radiations. Yet after a few months investigating, I was surprised to find out that far out the main cause of my problems was nothing I had heard about. A 100 MHz FM public radio broadcast antenna is located atop a local hospital and burns the whole city with an astounding force of 2 V/m (pike value).

I found other persons that are harmed. For example people who develop severe headaches or tiredness after a few hours working in a given place. They have no problems in other places, that are less exposed to the FM radio waves. It seems to me that people who live in strongly exposed habitations often develop psychiatric problems. My guess is that probably several thousand persons in the city are severely affected. Maybe tens of thousands are affected but without getting obviously sick.

Most puzzling is the fact that this hammering by radio waves is completely useless. It wouldn't change anything to the quality of the reception by the listeners in the city, if the force of the radio waves was divided by 100 or preferably 1,000. The purpose of those antennas is to emit far away in the countryside. That's why they are located atop hills or tall buildings and they have a huge power. But, due to their rudimentary construction, quite much of that power is wasted and hits the nearby city.

It is legal to hit the ground with such force. Whether I measure in rooms or in the open, it is at worst a little below the norms. Hence the problem is with the norms. They keep being too high, despite the efforts of many scholars and health organizations. The situation is catastrophic. If the people did understand the harm that is done to their children, revolts would break open.

Below is a picture of a cheap calculator that I transformed. It contains no more battery nor solar power cell. Instead it draws its energy from a 1 meter long antenna. Anyplace in the city center, in direct view of the emitter, the power of the radio waves is strong enough to feed the device. I made this because nobody was frightened by the figures I was reporting, except some friends that are into electronics. Everybody knows that a car can kill even at 30 km/h speed but almost nobody has any knowledge about radio waves figures. When I showed the calculator, everybody understood and some whitened. (The calculator also works in some classrooms where I tried it out. The emitter was visible through the windows... Should I warn the parents of the students that failed their exams?)

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This didn't help anyway, so I invented another device: the "snake". The picture below shows six of them, an early version.

You just hang the snake in the flux of radio waves and the LED lamp at one end will bright up, clearly visible in daytime and enough to light and read a text at night.

The snake is less impressive than the calculator but it is much cheaper and easier to make and it can be sent in an envelope. I made tens of them and sent them to politicians, newspapers, universities... I gave some to local people, together with a user guide on a sheet of paper. Just like the calculator, the snake contains no battery. The lamp lights up solely on the power of the radio waves. The picture below shows a later version, that can be rolled up in an envelope that fits the conditions to be sent with only one stamp.

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However mad it is to send such power on a city, nothing has been done yet against this. It's like an 19th century chemical plant sending its pollutants all around. Some complain but others argue that closing the factory would mean people laid off. Some then reply that being employed to feed children that die from ugly sicknesses may be nonsense... And so on, except for the fact that the chemical factory indeed had a purpose while the strength of the radio waves we're talking about, has no serious purpose at all.

Something common to all heavy sources of electromagnetic pollution is that it wouldn't cost much to make them harmless. For example, high tension power lines can be made harmless by feeding them DC current instead of AC current. This requires some more heavy electronics at the input and the output but the price of it is a detail in the whole. I studied the schematics of power saving lamps and simply noticed that they were conceived by people who do not understand the propagation of radio waves. Adding the necessary components to make the lamps radio-silent would almost not increase their prices. Enforcing proper norms will not change our way of life, it will just stop to favor the sociopathics amongst the industrials and lobbyists.

So, what can I do to help people understand the situation? They need to appropriate the scientific knowledge involved. Most assume that the necessary studies will be made by labs and then the governments will adapt the laws accordingly... That would be OK if it wasn't for the trillions of money involved. A minister in Belgium tried to prevent sugar dispensers in schools, she immediately got a made-up scandal on her shoulders. All she ultimately managed to get was to have some health advice notices glued on the sacred dispensers...

Flows of observations are now available, showing the effects of radio waves that match the norms: brains of rats destroyed, people unable to work, eggs that don't hatch, quarreling birds, increased risk of cancer, cows aging abnormally... I myself had seeds germinate and saw them die quicker when closer to a power saving lamp. Their strategy to cope with this is simple: "OK, there does exist scientific evidence of some danger... but there also does exist evidence that there is no danger at all! So let's balance the whole..." The norms are lowered but kept above what cell phone operators need for the current systems. The fact in itself of making a balance between scientific evidence is nonsense. Either a study proves a given danger and it can be verified, or bust. But anyway, what are those studies that tend to prove that there would be no danger? Lots of them are simply payed for by the cell phone industry... Yet some are perfectly serious, for example those concluding that radiations within the norms will not heat the brain or the body abnormally. This is perfectly true. There is no problem of scientific fairness involved with these studies. But, is a bullet harmless because it only very slightly heats your bones? A more sophisticated approach is to pick out studies that have borderline conclusions: "there may be a problem but it is not clear..." The study will be assumed to conclude that there is no problem at all, while it just was an inconclusive experiment like many are in science.

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(When I'm exposed, I tend to compulsively perform simple tasks. What if a study examines if being exposed hampers the ability to perform that kind of tasks?)

Then, there is the problem that I'm going to make people sick. Indeed, electromagnetic hypersensitivity has a psychological component. Once people understand that they are victim to the radio waves and what symptoms the radio waves cause, they can overreact and become very sick when they start feeling the symptoms or just when they know there is a strong radiation force around. The radio waves induce a physiological stress, that hampers the proper functioning of the brain. When you add a psychological stress, due to the awareness of the problem, the summation of the two multiplies... Therapies for hypersensitive persons imply to dislearn them to overreact. Some friends of mine just refuse to start talking about electromagnetic sensitivity because they don't want to embark in the sickness. They do so with everything, meanwhile they eat very good food and have lots of pleasure in life. It works... with people with a strong health and a tad of selfishness.

When you are in a cold wind and you feel a pain in the neck, you know it is due to the wind and you take cover. Almost nobody can do this with the symptoms of an exposition to strong radio waves. You feel tired, some brain fog, like if your head was in a clamp, a headache, or simply you make stupid errors... You will blame yourself or the location, possibly the noisy people around... while in fact you are mainly undergoing electromagnetic sensitivity. The home of a friend is strongly exposed. After about twenty minutes I can nor more find my words and speak correctly, unless I wrap my head in aluminum foil. There is a fair chance that a while ago, I would have blamed my friend for being annoying (he is) to the point of making me speechless. There also is a fair chance that my friend is annoying because he hangs in that electromagnetic pollution everyday. Since he lives there, he became an alcoholic, lost his job, manages to keep no girlfriend... (Everything I mention here can have other causes. Quite often, such causes just add up. For example, the person blaming the noisy people around, would maybe have felt nothing if the noisy people weren't there. Like you don't feel your bad knee when you carry no bag.)

The impact of the electromagnetic pollution is severe. It is a far too heavy, and pointless, contribution to our burdens and losses. But how do you establish, scientifically, be it as an amateur, that there indeed is a problem? My initial approach can be an illustration of this. As my home is uninhabitable, I spend most of the day working in local libraries. I noticed that I could work quite well at some places and not at all at other places. Then I saw an article taped on a board, about the effects of cell phone and Wi-Fi radiations. Okay... I made a spreadsheet, with a row for each location and a note from 0 to 10 according to my ability to work there. Although I knew it was a weak approach, I then filled in each row the strength of the closest Wi-Fi router, as listed by my laptop. There was no correlation... but this proved not at all that the Wi-Fi was innocent. Weeks later I made a nonsensical but working little assembly that made the variability of the radio waves hearable. This time I got a correlation. Mild, but obvious. The ability to work is horizontally while the intensity of the radio signals is vertically:

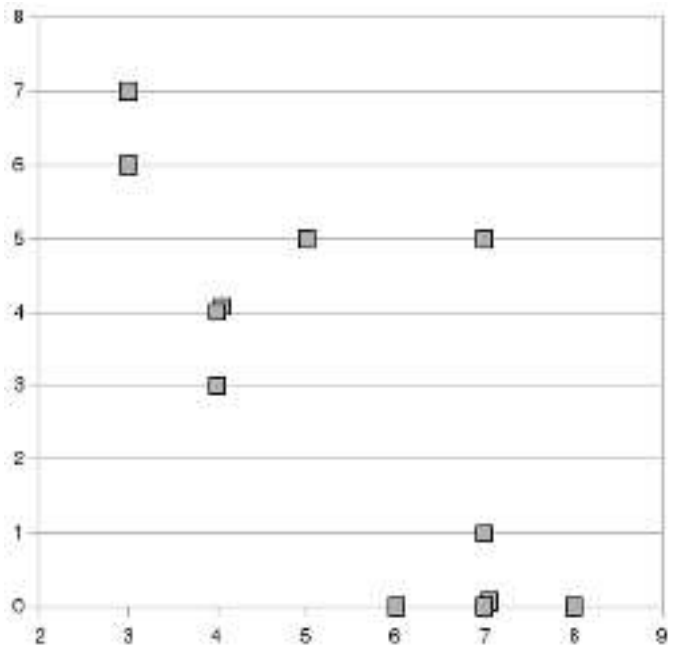

It quickly became obvious that I was measuring no strong signal in the GHz bands. I had no doubt that there were cell phone and Wi-Fi emissions coming from all directions and echoing all around but their strength was obviously

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weak. The problem was with lower frequencies. I accused the fluorescent lamps for a while, till I finally understood that there was only one strong source, hitting me everywhere; those 100 MHz public radio broadcasts. The picture below shows the final correlation. Only one dot disagrees with the theory:

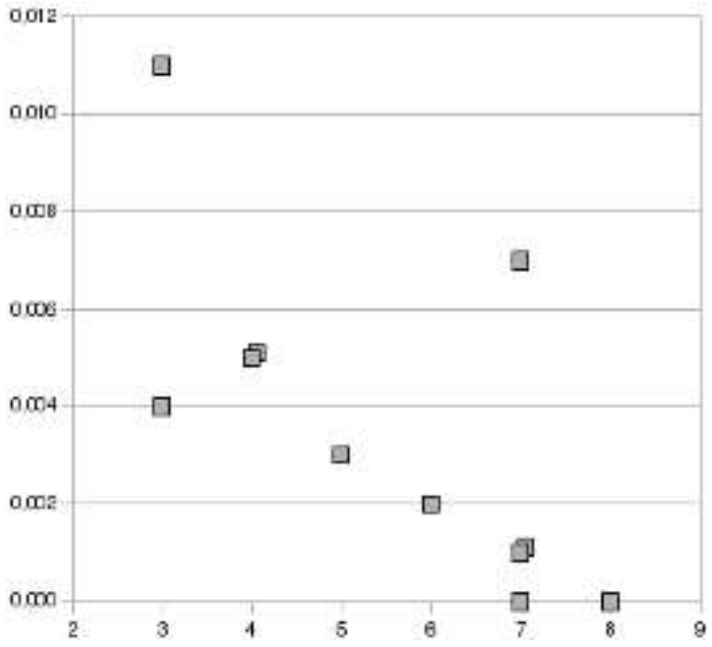

I was heavily disturbed by the radio waves, simply unable to work, long before I started puzzling on the subject. This is a strong proof that the matter is not just psychological. Reciprocally, once I understood the psychological component, I tried to use it positively, to counterbalance the effects of the electrosmog. I did get some results but I was never able to work correctly in the most exposed places. It is by no means "just psychological". It is useless "to be willing to make a small effort". I did efforts that frightened other people. One thing that does clearly help is eating a lot of sugar (Organic jam on rice bread...) (by the way, is that why sugar dispensers are placed everywhere kids are supposed to think and learn, to counterbalance the effects of the nearby cell phone relay antennas?) Alcohol does also help and I'm afraid this is why people seem to become alcoholics in exposed habitations.

Also, it does sometimes happen that I feel like undergoing strong radio waves but when I pop out my measuring device, I measure nothing serious. I have a natural tendency to be knocked-out... The radio waves are far out my heaviest problem but they are not always responsible.

I started studying other sources of radio pollution. I had an obvious benefit of removing every power saving lamp in my home. I put ferrite cores on most power chords. On one power chord that I sometimes use to feed my laptop inside my shielded tent, I had to put ten ferrites till I felt no more direct effect. Something very interesting is that till then I had no problem when using my cell phone. You guessed correctly: I started having problems, to the point that I never more hold it against my ear. I always use an earplug linked to the cell phone by a wire with two ferrite cores. I suppose that since I started avoiding the exposure to strong radio waves (which significantly improved my life and ability to work), my brains are no more constantly knocked out. So they get knocked out if I hold my cell phone against my head. And I feel it. This is one more synergy between the public broadcasts emitters and the cell phone industry: one hides the other away. 'Want to prove that inhabitants close to a relay antenna are no worse than those further away? Do the experiment in a city that is strongly exposed to public broadcasts...

So: buy a measuring tool or have a friend assemble one for you. And start comparing your problems and those of the people around you, with the level of electromagnetic pollution. If you can, make large-scale experiments with tens of persons, under advice of somebody with knowledge in statistics (to build an expressive statistic yet completely false, is *easy*). We need many such experiments, till it becomes unbearable for local interlocutors to negate the problem and not to dim the emissions. Step by step, we need to conquer our world back. Some enterprises and some countries have already set their norms at responsible levels.

One very important parameter is the rate at which the problems build up and then disappear, when exposed. Some people claim that they instantly feel when their cell phone is going to ring. I never could verify this. A friend claims that his cat reacts when he is going to get a text message on his cell phone. I tried several times to see the cat change

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behavior while making my cell phone emit close to him but I got nothing. So I suppose that the cat reacts to the tone of the cell phone and my friend brain-confuses the timing. (I don't pretend nobody can feel a text message arriving, I'm just saying that I never could verify.) What I'm sure about is that my problems need minutes to build up, most often some ten or twenty minutes, the problem possibly becoming really painful after an hour. Once the problem built up, it needs much more time to diminish, maybe four times more. I often had to sleep a whole night on it. One day I "burned" my brains by holding a very polluting power saving lamp about 3 decimeters away from my head. I only noticed the problem after half an hour. But then it was horrible, like if a flame had been sweeping inside my head. Really just like the ache of a burn wound. I had a strong nausea and headache, that calmed down only hours later. I identified a few persons whose problems are obviously due to the electromagnetic pollution, in all cases the same applies: it needs time to build up. This means you cannot simply walk in and out of an exposed zone and claim you feel no difference. Also, you cannot get into a safe zone and claim you feel no better. If you were already poisoned, you will stay that way a long while. The only sure approach is to stay really long in a safe zone, preferably spend the night there, then go working in a polluted area. Try to be aware of what happens to you. The next day go working in a safe zone and try to see the difference. (This is a goldmine to build inconclusive studies.)

Everybody is sensitive to electromagnetic waves. The question is about the level of the sensibility. That's why people who get seriously sick with the current levels of exposition are called "hypersensitive". They are more sensitive than the average, sometimes with very painful and debilitating consequences.

There is a whole ladder of symptoms. This is roughly the ladder for me, exposed to the 100 MHz FM broadcasts:

0.01	V/m	No problem
0.1	V/m	No more able to concentrate and work
1	V/m	head in a clamp, maybe difficulties to talk
10	V/m	Tried it once for 2 hours, had to stay the whole next day in bed with an awful headache.

The serious problems begin for me at 0.1 V/m. Yet I know some people that wouldn't be called hypersensitive and that get problems similar to mine at about 0.3 V/m. A friend spent with me the two hours under the 10 V/m radiation and claimed he endured no problem... but he made surprising errors on the way back. It is very difficult for me, in my city, to find locations where the force is around 0.01 V/m. Values between 0.1 and 0.3 are common. It is easy to find building with rooms reaching 1 V/m. The force is quite predictable, according to the location and the orientation of the building, how much it emerges out of other buildings... So, because many people are being affected and because the radiation is reasonably easy to measure or to estimate, making statistics linking common health problems with the level of exposition is quite doable.

Hypersensitive persons would be 1% of the population. The need to protect this minority is enough to stop those powerful broadcasts from reaching the ground. I don't understand why I have to add that everybody is being harmed, be it to a lesser degree. I met official people whose job is to help hypersensitive persons. They've seen their pain and anguish by themselves... but they feel clueless as to how to stop the emissions. It's a very strange situation, when even the people close to the steer and convinced of a problem, can't do anything to stop it.

It has been claimed that the hypersensitivity of some persons is caused by an accumulation of toxic metals or organic pollutants. In such cases, antioxidants can be of immediate help and detoxifications would greatly help. (Note that common medical analysis like looking for mercury and the like in samples of blood, urine or hair, will reveal nothing even under severe intoxication, because blood and hair renew constantly. Only a sudden intoxication can be revealed by such analysis. The toxics slowly accumulated in standing body cells like the brain... Best method seem to be to take a well-tuned quantity of chelating molecules and then perform an analysis of the blood or urine.)

Cell phone and Wi-Fi radiations are different, for several reasons: they don't spread the same way in the body, they are pulsated and their frequency make they will not target the same macromolecules in the body. It would seem that you need 3 times more force of FM broadcast waves than cell phone or Wi-Fi waves, to have a same global impact...

I was frightened when I understood that under those 2 V/m force of radiation, an electric current in the order of 1 mA oscillates through the body. Such a current at a high frequency of 100 MHz will interact with the body quite differently than a DC or low frequency AC current. You cannot make direct comparisons... Anyway, 100 mA of DC current can be enough to kill a person by electrocution. 1 mA of low frequency current is enough to feel the current as a tickle. What are the consequences of such a current on the chemical reactions in the liver, on the production of

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hormones by glands everywhere in the body? What if the person being exposed is a pregnant woman, with the baby just at the worst place in the flux of current? The length of an "antenna" matters much to allow it to build up current. Teenagers have the "optimal" length for 100 MHz radio waves... One thing I'm sure about is that if the government decided that from now on the school kids will be latched electrodes on the body and a current of 1 mA send through several hours a day, whatever the frequency, the parents will not accept. But this *is* happening, through radio waves, and I could feel the neuroleptic-like effect of it. (By the way, this implies that those experiments that show brains of rats destroyed by cell phones waves within the norms, apply only to a lesser degree to human brains, because of the difference in size. Rats are close to the optimal length to be harmed by cell phone waves... The optimal wavelength to dammage teenagers is that of those 100 MHz public broadcasts...)

The radiations harm me more inside buildings than outside. I may get more sick under 0.2 V/m in a room than under 2 V/m directly exposed to an antenna. I don't know exactly why. Here are four possibilities:

- The roofs atop buildings act like prisms and send the waves towards the inhabitants beneath. Radio waves coming from above would be more harmful than when coming from aside.
- The radio waves resonate and echo inside the building and build up in metallic structures. This creates halos of proximity that will inject more power inside nearby living bodies. For example, while simply wrapping aluminum foil around my head, it is obvious that some designs of shielding will make me even more sick than using no aluminum at all. The same way, when some parts of the shielding of my tent wear off and stop to be conducting, I can get serious problems till I replace or complement the faulty area.
- Buildings contain their own sources of electromagnetic pollution. They add their effects to those of the pollution from the outside...
- Close to metallic structures, the electromagnetic field can become rotating. This because waves with equivalent strength come from different directions with different phase shifts.

Again, the four possibilities mentioned above are potentially very suitable to build experiments that demonstrate there is no problem. Perform the experiment in an anechoic place with the waves coming from aside and no other radiation than the one from the experiment... Just the opposite from real world situations but you can claim to be serious at avoiding parasitic variables...

If you want to find the FM emitters somewhere, fmscan.org is the reference I used till now.

This is the schematic of the "snake":

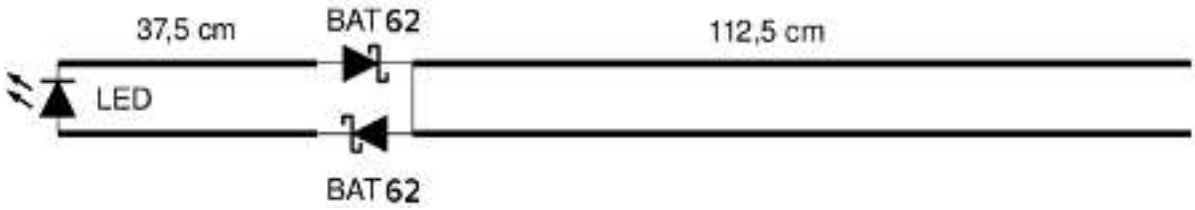

BAT62 detection diodes are no more produced. **BAT15** diodes work fine but they wear out; after a few months they stop functioning. **SMS7630** diodes are great but very little and mechanically fragile. **MMSD701T1G** diodes are sturdy and powerful; an excellent choice for a beginner. Such SMD diodes do also work for cell phone frequencies, which allows to test out a snake with a calling cell phone pushed against it. But any detection diodes that can manage 100 MHz will do.

The LED I'm currently using is the **L-7113SEC-H** . It lights up with a low tension and a very low current (the bluer a LED, the more tension it needs). Its color is red yet close to orange hence it is easily seen by the human eye (the eye is most sensitive to green, yellow and orange). The beam is quite narrow so when the LED is directed towards somebody's eyes it will appear quite bright.

For the lengths of 37.5 and 112.5 centimeters, any electric wire with two copper conductors will do. Audio signal wire is a practical solution. Use the shielding as one of the two conductors. The lengths of the two segments must not be precise. What matters is that the total length of the snake be 1.5 meters. Do not hesitate to try out if a little

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longer or shorter snake gives better results.

A schematic of my current probes, that I connect to a standard multimeter, measuring Volts DC. The measure displayed by the multimeter must be multiplied by 10. When using a 200.0 mV scale, just read while forgetting the dot:

This is a picture of a device that tries to pack the whole in a neat gadget. The electronic circuit is a €7 digital Volts display with a scale of 200.0 mV. I soldered away the jumper that makes the dot be displayed. The antenna is only 7 cm long, so an RMS value is displayed (for roughly steady radio waves). The whole cost about €12. Hold the antenna perpendicular to the direction the waves come from and try to hold the device away from conducting objects like your body or metallic objects. You cannot closely trust such simple device yet it is very handy and adequate to compare the radiation level in different places:

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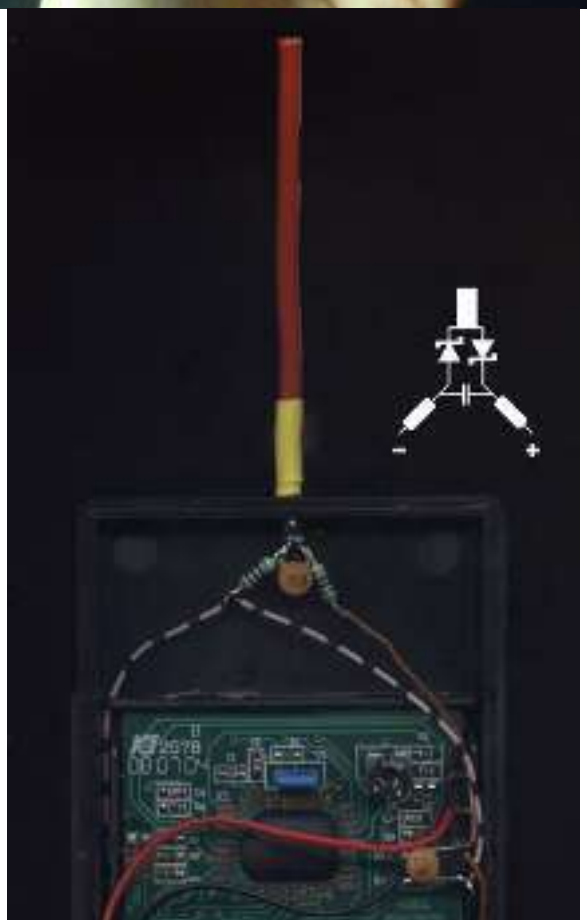

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Those probes and device, quite easily allow to know the direction some 100 MHz radiation come from. Hold the thing at some decimeters from your body, roughly at the height of the belly. Your body and the device form a directional antenna... When the device is towards the emitter, it will display up to twice the value, while when it is hidden from the emitter by your body, the measure will be very low.

If you measure something strong, yet by turning in different directions the device always shows approximately the same value, then you are probably undergoing low-frequency radio waves like short wave broadcasts.

If the emitter is close, like a power saving lamp or a wrongly build power supply, converge towards it simply using the fact that the closer you get, the stronger the measure.

Such measuring tools are handy to find out power chords and appliances that pollute, yet then the measure displayed doesn't mean much. Once you are really close to an emitter, the measuring device and the emitter interact and the power flowing through the measuring device can be tremendous even though the device is only weakly polluting. You are in the "halo of proximity" of the device... Best example is most quality laptops, which emit almost no radio waves. I never could notice a problem while using my laptop when it is plugged to nothing... Yet if I hold a measuring tool against the screen I get frightening data... A few decimeters further, where my head can be, the measuring tool tells there is nothing... So, the high figures close to the laptop indeed tell that strong currents flow through it, but competent people made things such that those currents harm nobody...

If you want a global measure, away from the effects of your body, hold the device above your head. Or place it on some plastic or cardboard box and walk some distance away.

The windows are a common entry point of radio waves and electric wires can be awfull ducts, yet in some cases I noticed that metallic structures unrelated with electricity, like the copper tubes of water heating radiators, were the main ducts of radio pollution towards a room.

Below is a device I assembled to focus on 1.8 GHz cell phone radio waves. Close to the nearby cell phone relay antenna, in direct view of it, I could not measure much more than 0.1 V/m (pike value). While this is still too much, it is by no means comparable to the frightening 2 V/m intensity of the FM broadcasts. I also went measuring in places where people complain about problems similar to mine. They thought the reason was the nearby cell phone relay antennas. But I could measure no significant intensity of cell phone radio waves at all, while the force of the FM broadcasts was above 0.2 V/m...

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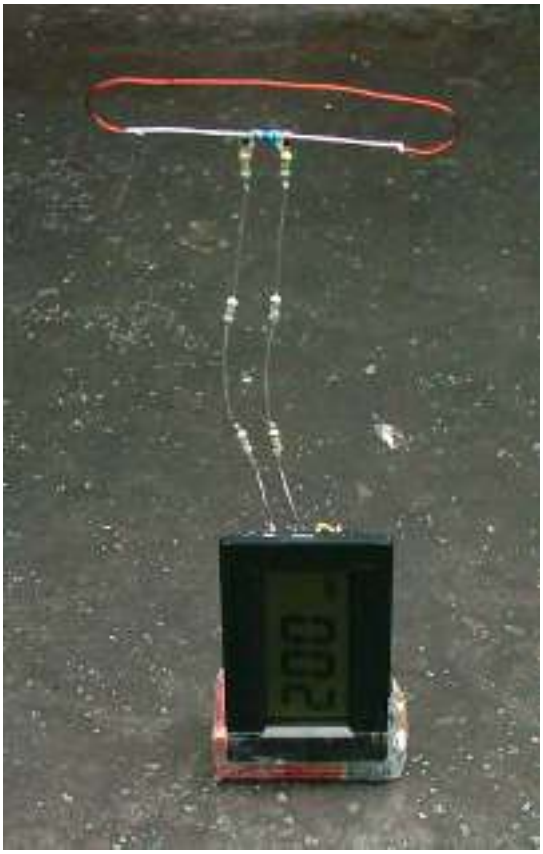

After about a year experimenting, the most simple protection I could come up with against 100 MHz broadcasts is a headband of aluminum, much the shape and size of a sweatband. I hide it inside a bonnet. I have no idea as to how and why it helps, aside from the general fact that any conducting structure will change something to the propagation of high frequency currents. Don't make it too high, a 3 to 4 centimeters height is OK. To try this out, you can just fold in a circle a 1 meter long wrap of aluminum and compress it to a flattened ring that fits your head. If you intent to re-use it, then you must strengthen it with lengths of tape before (inside) and after (outside) the ring is constituted. Make sure the tape does not hamper a perfect electric contact all around the ring. This protection is not perfect but it really helps.
When the field strength is above 0.1 V/m, I need a complementary vertical band in order to be able to work.
This also is a cheap way to make statistics. Compare days with the headband to days without the headband. In order to be scientific, you must ask somebody else to put the headband inside your bonnet every morning, at random. Every morning, the other person writes down if there was a conducting headband inside the bonnet or not. Every evening, you write a comment down to how your day was (headache? brain fog? errors? doomed day?) Then after a while you compare the two. At worst, if you have to do it alone, buy two identical bonnets, push a plastic headband inside one and an aluminum headband inside the other, and spend each day without knowing which one you picked. At the end of the day, write your appreciation down before checking and writing down which bonnet you picked.

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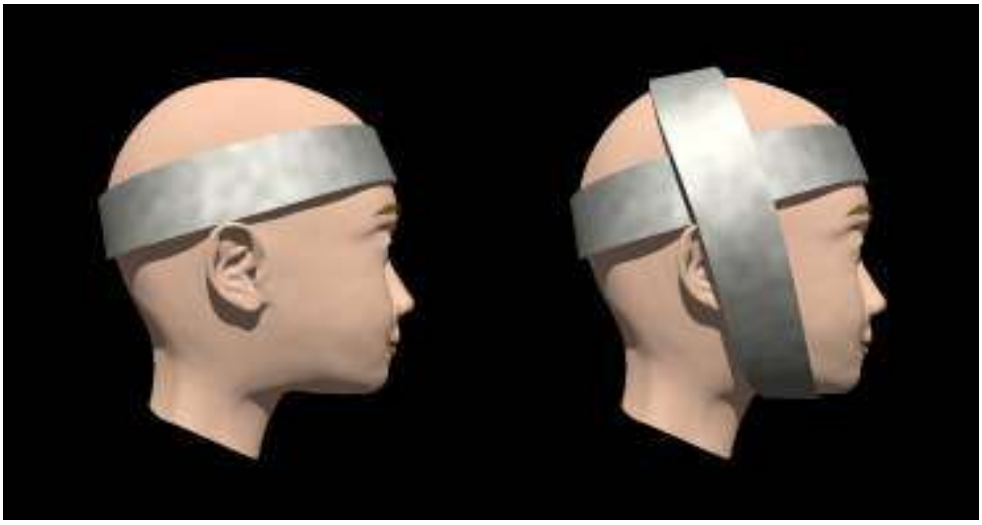

A friend who is a physician points out that in many administrations, be they public or private, the employees are being persecuted. (That often happens when the work done by the administration is mostly useless and only serves to justify the social position and the salaries of a few people.) A statistic about the health impact of radio waves in such administrations could be of few significance, because the people have all kinds of health problems due to the harassment. The addition to this by the radio waves may be comparatively negligible. (Yet another way to build a statistic that shows few or no impact of the radio waves: perform it in a place where people bow under humilations...)

I was quite frightened to discover that the symptoms caused by radio waves, as I see them around me, are very close to those of "radiation poisoning". This is part of nuclear medicine. When a victim is exposed to a short and strong burst of radioactivity or any other ionizing radiation, its body will quickly react like if it had been poisoned. A "low" poisoning by radiations yields headaches, tiredness, difficulties to think... while stronger poisoning can lead to the person die in a few days like if it was heavily burn. The exposure to ionizing radiations is measured in "Gray". 1 Gy leads to a low poisoning. So I computed out how much energy a person gets from the local FM emitter, like the person I know that get sick at their desk. The result is 0.01 Gy for 8 hours of exposition, which is quite close.

Radio waves can induce all the typical problems caused by that ionisinig radiations but the energy levels involved can be quite different. For example, ionizing radiations cause burns without increasing the temperature of the body, while radio waves can only burn if they are powerful enough to heat the body. Radio waves can induce cancer but again the energy required is ways higher, like spending ten years using a cell phone against the head, several hours a day.

Body cells can be attacked by all kinds of means. Ionizing radiations lead to direct damage of the cell membrane. Radio waves disturb the molecular cell gates operate. The cell will always react the same way, as for poisoning: it will close the cell gates, to try to shun itself from the outside world and from the harm. This has many consequences. The cell is less able to fulfill its purpose inside the body. It uses resources to try to protect its internal parts. It will accumulate waste. That's why people get tired, less efficient or even sick. When the aggression made to the cell is deemed too strong, the cell will auto-destruct. That's the way radiations and chemicals can be used against cancer, making the cancer cell suicide.

The cells can be helped to better recover from the state of shock. Also they can be made to go less likely into the state of shock. Medication and health advice can be helpful for this.

A link has been proposed between autism and radio pollution. The growth of the human brain is very complex, with cells traveling from one side of the brain towards the other to find their place. This involves a tremendous amount of communication and coordination between the cells. What if those cells are too often put into a state of shock?

These are two scientific publications about the link between autism and radio waves :

http://www.ncbi.nlm.nih.gov/pubmed/16530334

http://www.ncbi.nlm.nih.gov/pubmed/14962625

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Publications about how radio waves disturb cells :

http://www.ncbi.nlm.nih.gov/pubmed/10860806

http://www.ncbi.nlm.nih.gov/pubmed/12379225

Links

http://www.teslabel.be
http://www.clag.be
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http://www.criirem.org
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http://www.stopumts.nl

A petition: www.petition-electrosmog.be

Eric Brasseur - October 3 2009 till October 16 2015

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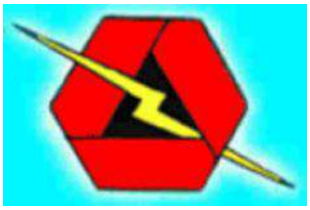

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C. Edholm: "Picks Power from Air" (*Technology World Magazine*, 1912 ?)
Dr L. Hirshberg: "Electricity from Air New Great Discovery (*Modern Electrics*, 1914 ?)
Roy J. Meyers: British Patent # 1098 (1913) --- Improvements in and Relating to Apparatus for Producing Electricity (PDF Format, requires Adobe Reader)
R. J. Meyers: British Patent # 1098 (1913) --- Transcription w/ enlarged figures
Notes & Comments
R. J. Meyers: British Patent # 1098 (1913) --- JPG version

***Technology World Magazine*, p. 279-281 (Year unknown, apparently circa 1912; another article about Meyers appeared in the November 1912 issue of *Electronic World*)**

"Picks Power from the Air"

by
Charlton Lawrence Edholm

A remarkable scene took place in the legislature of Arizona this spring when the lawmakers

enthusiastically voted for the parole of a certain convict in the State penitentiary, granting him a leave of absence for 30 days and by means of private contributions raising a fund to defray his expenses to Washington DC and return.

The prisoner, Roy J. Meyers, is serving a 3-1/2 year sentence, but in spite of the fact that he bears the stigma of a convicted lawbreaker, he has demonstrated that a convict can be a useful member of society. During his imprisonment he perfected an electrical device of such original character as to arouse feelings of wonder and skepticism until experts had seen it in actual operation. It is a device to draw electricity from the atmosphere for light and power, and the 30-day parole was granted in order that the inventor might protect his rights through the patent office at Washington.

With the acquiescence of the legislature, Governor Hunt granted the parole and the prisoner was allowed to go free without any guard or any assurance but his word of honor that he would return. Two days before the period had elapsed, Meyer again presented himself before the governor, having accomplished his mission, and then returned to the penitentiary at Florence, where he continues to serve his sentence.

This, in brief, is the picturesque story which has called attention of the civilized world to a newly discovered electrical genius, and to another feature of the case which is of equal importance and human interest; namely, the enlightened policy pursued by our youngest State in its treatment of convicts...

Before entering the prison, Meyer had already applied for various patents, among them one for an improved trolley wheel head which prevents the trolley wheel from jumping the wire. Meyers had a conference with Superintendent Sims and Parole Clerk Sanders, and it was to these gentlemen that the inventor first explained the principles of his new device for securing electrical energy from the air. The officials were willing to give the man the opportunity to develop his plan and a little wooden building outside the walls was turned over to Meyers and was fitted up as a workshop and a laboratory. The first demonstration of the new apparatus was made shortly thereafter, the electricity drawn from the atmosphere being used to spark the gas engines of the pump house, and although the device was crude yet it did the work, and removed the doubts of his friends. Furtter development of the "absorber" followed, and his second model was constructed, and developed 8 volts. The machine came to the attention of the remarkable woman who brought his name before the legislature.

This was Miss Kate Barnard, State Commissioner of Charities and Corrections of Oklahoma, who was a guest of Mr. Sims, while studying prison conditions. She saw the machine at work, became familiar with the facts of Meyers' case, and was impressed by his rather blunt and unaffected personality, for Meyers has nothing of the polish or glibness of the poseur. He is a simple, earnest student of mechanical problems and not the sort of man to make a sentimental appeal for sympathy because of any grace of person or manner. Therefore it was the value of Meyers' invention, together with his essential integrity (in spite of his lapse) which so strongly impressed Miss Barnard that when she appeared before the Arizona legislature not long afterwards, addressing that body on the need of enlightened legislature along the line of her own work, she told the story of Roy Meyers and his epoch-making invention.

So, early in May, Meyers set out for Washington, unaccompanied.

In his own words: "When I arrived in Washington and laid my plans before the patent office experts, they merely smiled and told me that I would have to build a model and demonstrate my claims --- that it seemed strange that I, unknown as I am in the electrical world, should have accomplished the things for which Edison, Tesla and other experts have been striving for years.

"They could grasp the meaning of my drawings nor the explanation I tried to make to them. There was little time to spare, as I had only 20 days left of my leave, but I set to work in a few days was able to take a crude model around to the patent office to make a demonstration.

"Arriving at the patent office I telephoned to a friend who had been so kind as to introduce me and aid me in reaching the proper officials. The absorber was hoisted on two short poles and made to work. While they were as yet unable to understand the principles involved and hardly willing to believe their eyes, they were forced to admit that I had something new and different, and they told me that there would be no further objection; that I might file my application without further delay.

"I hope to construct my first large machine right here in Phoenix. I feel grateful; to Governor Hunt and others for what they have done for me and to the help they have given in securing protection I might not otherwise have had, and I am desirous of demonstrating this gratitude. I am going back to Florence today to resume the serving of my sentence, which will expire in 10 months. Then, here in Phoenix, I will begin the work of making my machines."

While there are some details of the device which the inventor refuses to make public, yet there are many general features that may be explained. It is planned that the machine, to be set up in Phoenix, will generate sufficient power to light the city, and will consist of a 200 foot tower upon which is placed the "absorber". The latter consists of a series of magnetized steel plates set in a circle (the manner of preparing them is kept secret) and this mechanism attracts the electricity from the atmosphere. This is carried by wires to a transformer in the engine house below and thence is applied to produce either power or light after the usual manner.

In an authorized statement Meyers says: "The flow of electricity is constant. When it emerges into the transformer it is in the form of a direct current. It will absorb the electricity day and night and will work whenever the wireless will work. I can put up a plant to supply such a building as the Adams Hotel for about $1500, and one of the principal items of the expense is the cost of the towers, the wires, the magnetizing of one set of plates, which is part of the secret of the treatment which makes it respond to the accumulations of the atmosphere.

"For use in the case of an electrical storm I have made what I call a modified form of circuit breaker, such as is commonly used as a lightning arrester on telegraph lines. In case of a storm the accumulator would suddenly become overcharged, possibly, and as the electricity would not of itself flow back into the air, the result might be disastrous. So I send it down into the ground, whenever the voltage rises above a certain amount."

Roy J. Meyers & the "Absorber"

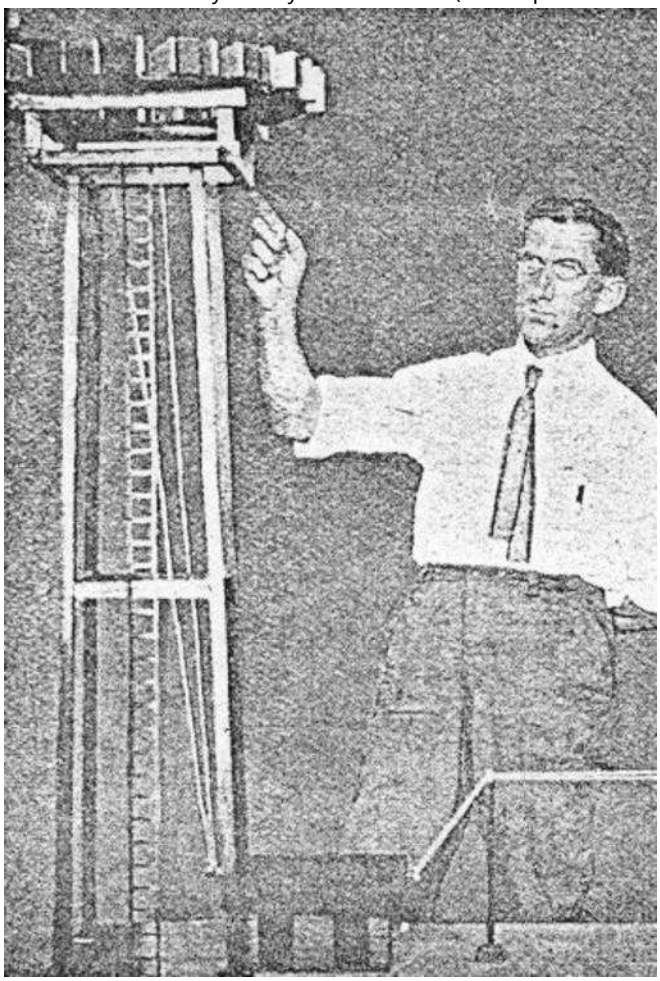

Modern Electronics **(1914 ?)**

Electricity From Air New Great Discovery

by

Dr Leonard Keene Hirshberg

Working quietly in the heart of Baltimore for weeks on an invention which some critics say will revolutionize the method of converting electricity to practical use has been Roy J. Meyers, who like Benjamin Franklin, extracts the electric current from the air.

Mr Meyers invention was made last summer while he was confined in the penitentiary at Florence, Arizona. His first finished apparatus was made in Baltimore.

A practical, unlettered electrician, Mr Meyers, while in Arizona, was arrested on a comparatively minor charge and sent to the penitentiary. There he was placed in charge of the prison electrical plant, and there he says he made his discovery that the current which the civilized world is beginning to use most extensively for light and power could be transformed from the atmosphere without the

aid of moving machines or batteries.

Miss Kate Barnard, Commissioner of Charities and Corrections, of Oklahoma, hearing of Meyers' invention and of his desire to have it patented, appeared before the Arizona Legislature to make an appeal in behalf of the young convict. As a result a special bill was passed which granted Meyers a month's leave of absence on parole. He went unaccompanied to Washington, filed his patent applications and returned to the penitentiary. Since then he has been indefinitely paroled.

He came to Baltimore as the place where he could easily obtain the mechanical parts needed to make a more nearly perfect machine than the crude model he has fashioned in the penitentiary workshop, and is making his headquarters here while working on his invention. With him is W.E. Chenot, who has been his assistant in assembling and testing the machine and who says that he has bought Meyers' patent rights for Germany.

They have proved beyond doubt that the invention is practical and that when finally brought to a state of perfection it will introduce a new epoch in the industrial use of electricity. By Westinghouse meters they tested the strength of the current gathered from the air, and with the use of only two of the four rectifying transformers the voltmeter recorded four and one-half volts, and the ammeter, which had the capacity of recording 75 amperes, was broken by the force of the current.

The machine itself is simple. It is in reality a transformer, which is familiar to anyone knowing anything at all about electricity in its practical uses. On a high tripod, which resembles somewhat the framework of a windmill tower, is the transformer, which Mr Meyers calls his 'absorber'. It is made up of an iron core, wrapped with copper wire. The secret of the invention is the manner in which the disks composing this 'absorber' are magnetized, and this secret Meyers says he found by accident while at work in prison.

What the machine, when finally perfected, will do is yet to be seen. Its inventor claims that it will greatly reduce the cost of making electricity. No batteries of any kind are needed, he says, and not a part of the machine turns upon the other. It is as durable, apparently, as an electric light pole. One of these machines, says Meyers, when perfected may be placed on a vehicle and transform enough electricity to give motive power, be that vehicle a locomotive or an automobile. He declared it can be placed on a building to furnish electric lights or power, and that the only wear will be upon the machinery which its current runs.

Meyers is 34 years old and he gained his knowledge of electricity by working in shops along the Pacific Coast. The depths of the mysteries of electricity he has not explored, but he is certain that he has found the means of absorbing it from the air and of converting it to the use of mankind.

British (GB) Patent # 191301098

Improvements in and Relating to Apparatus for Producing Electricity.

1-14-1914

Roy Jerome Meyers

Classification: - international: H05F7/00; H05F7/00; - european: H05F7/00
Application number: GBD191301098 19130114
Priority number(s): GBT191301098 19130114
Abstract ~ Vapour apparatus, arrangements of. - A rectifier for use with apparatus for producing electricity from the earth consists of mercury- vapour lamps constructed and arranged as shown in Fig. 4. Each lamp comprises two wires 6<1>, 7<1> wound around a steel tube 15 surrounding a

mercury tube 11 preferably of copper. The coil 6<1> is connected between the electrode 14 and the terminal 18, and the coil 7<1> between the terminals 19, 5. The coils 6<1>, 7<1> are preferably composed of soft iron. Reference has been directed by the Comp- troller to Specifications 16,709/87, 14,033/99, and 5457/11, [all in Class 53, Galvanic batteries], and 15,412/06.

British Patent # 1098

(January 14, 1913)

Improvements in and Relating to Apparatus for Producing Electricity

Roy Jerome Meyers

This invention relates to improvements in apparatus for the production of electrical currents, and the primary object in view is the production of a commercially serviceable electrical current without the employment of mechanical or chemical action. To this end the invention comprises means for producing what I believe to be dynamic electricity from the earth and its ambient elements.

I am, of course aware that it has been proposed to obtain static charges from upper strata of the atmosphere, but such charges are recognized as of widely variant potential and have thus far proved of no practical commercial value, and the present invention is distinguished from all such apparatus as has heretofore been employed for attracting static charges by the fact that this improved apparatus is not designed or employed to produce or generate irregular, fluctuating or other electrical charges which lack constancy, but on the other hand I have by actual test been able to produce from a very small apparatus at comparatively low elevation, say about 50 or 60 feet above the earth's surface, a substantially constant current at a commercially usable voltage and amperage. This current I ascertained by repeated tests is capable of being readily increased by additions of the unit elements in the apparatus hereinafter set forth, and I am convinced from the constancy of the current obtained and its comparatively low potential that the current is dynamic and not static, although, of course, it is not impossible that certain static discharges occur and, in fact, I have found occasion to provide against the damage which might result from such discharge by the provision of lightning arresters and cut-out apparatus which assist in rendering the obtained current stable by eliminating sudden fluctuations which sometimes occur during conditions of high humidity from what I consider static discharges. The nature of my invention is obviously such that I have been unable to establish authoritatively all of the principles involved, and some of the theories herein expressed may possibly prove erroneous, but I do know and am able to demonstrate that the apparatus which I have discovered does produce, generate, or otherwise acquire a difference of potential representing a current amperage above stated, or varied therefrom at the will of the operator according to the uses which the current is to be subjected.

The invention comprises generically means for producing electrical currents of serviceable potential substantially without the employment of mechanical or chemical action, and in this connection I have been able to observe no chemical action whatever on the parts utilized although deterioration may possibly occur in some of the parts, but so far as I am able to determine such deterioration does not add to the current supply but is merely incidental to the effect of climatic action.

The invention more specifically comprises the employment of a magnet or magnets and a co-operating element, such as zinc disposed adjacent to the magnet or magnets and connected in such manner and arranged relative to the earth so as to produce current, my observation being that current is produced only when such magnets have their poles facing substantially to the north and

south and the zincs are disposed substantially along the magnets.

The invention also comprehends other details of construction, combinations and arrangements of parts as will hereinafter be fully set forth and claimed.

In the accompanying drawings:

Figure 1 is a top plan view of an apparatus embodying the features of the present invention, the arrow accompanying the figure indicating substantially the geographical north, parts of the figure being diagrammatic for condensing the showing.

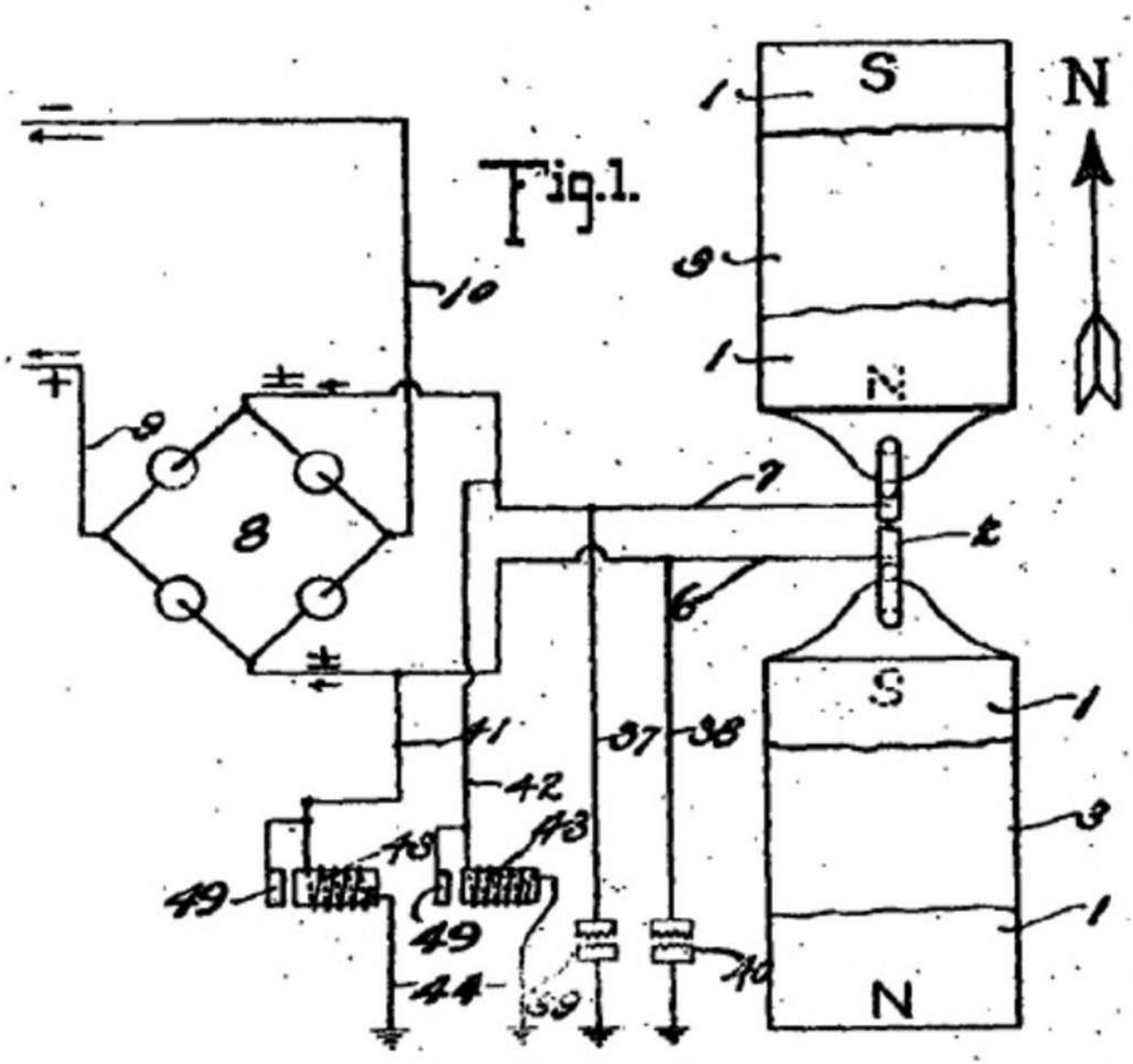

Figure 2 is a view is side elevation of the parts seen in plan in Figure 1.

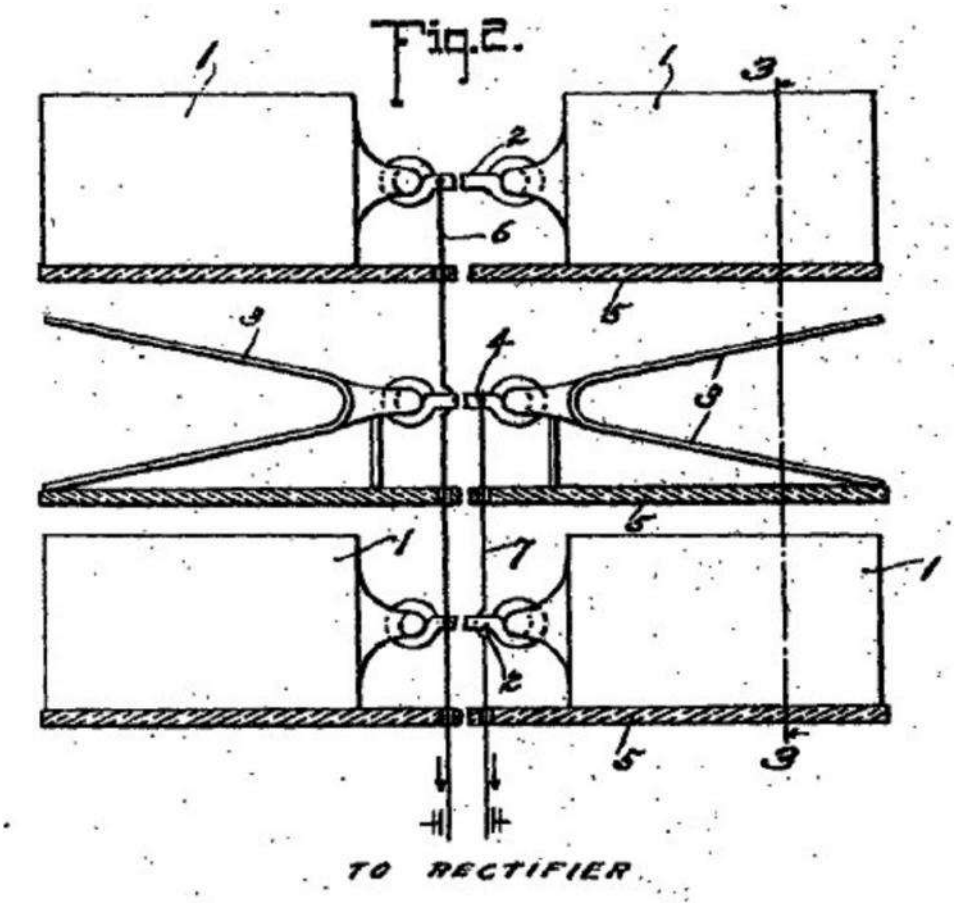

Figure 3 is a vertical section taken on the plane indicated by the line 3-3 of Figure 2 and looking in the direction indicated by the arrow.

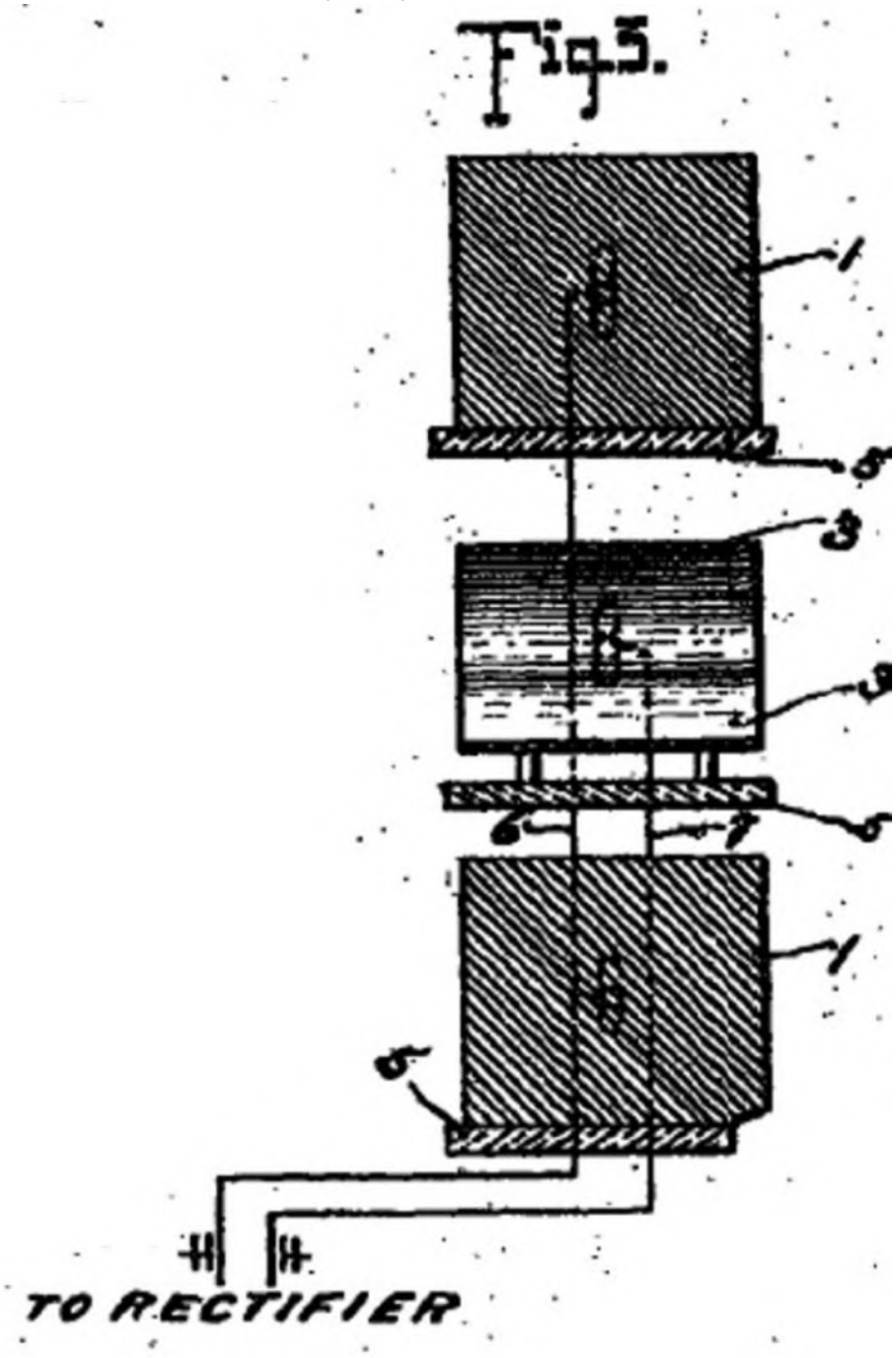

Figure 4 is a detail view partly in elevation and partly in section showing the detail connections of the converter and intensifier.

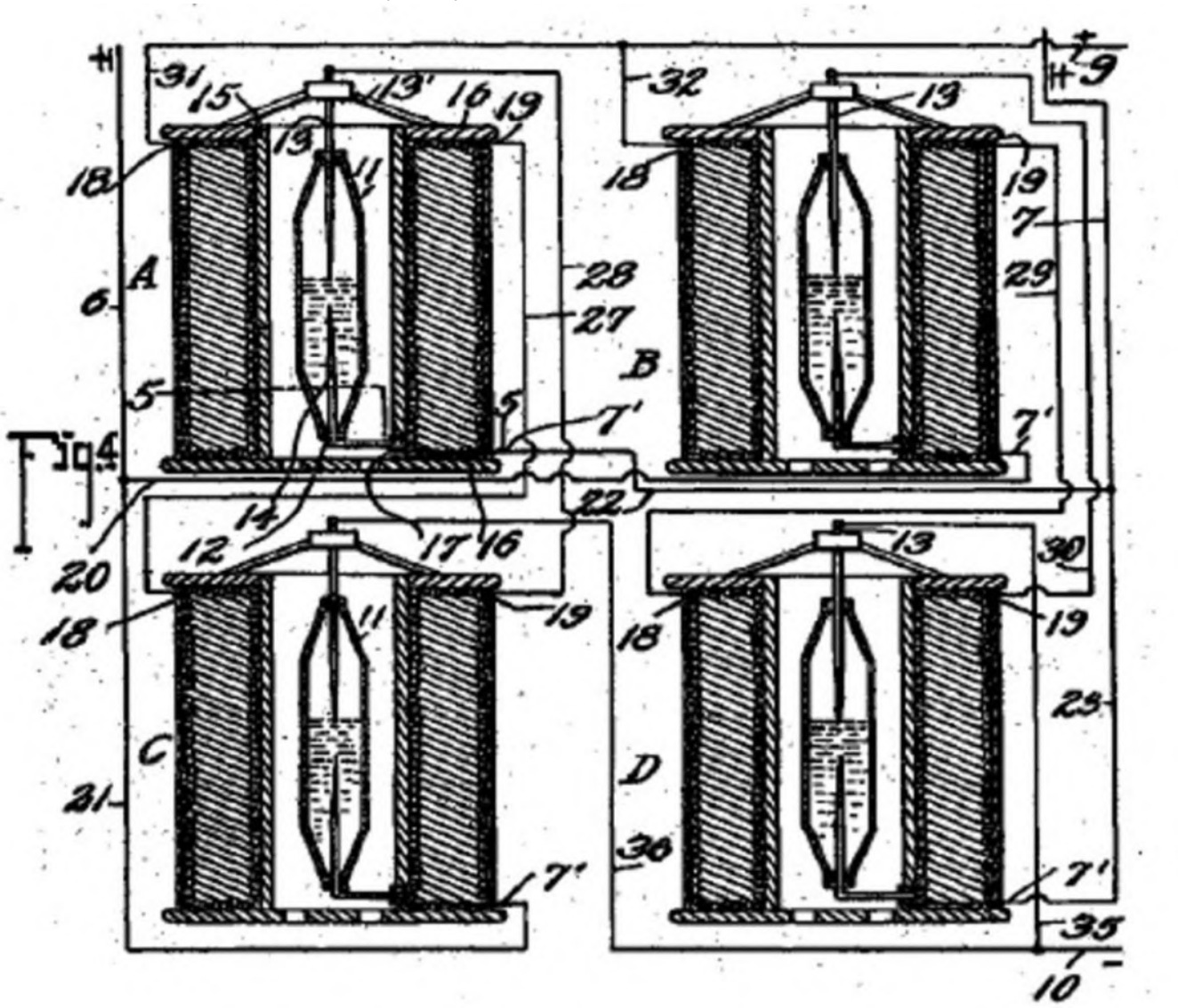

Figure 5 is a transverse section taken on the planes indicated by line 5-5 of Figure 4 and looking downwardly.

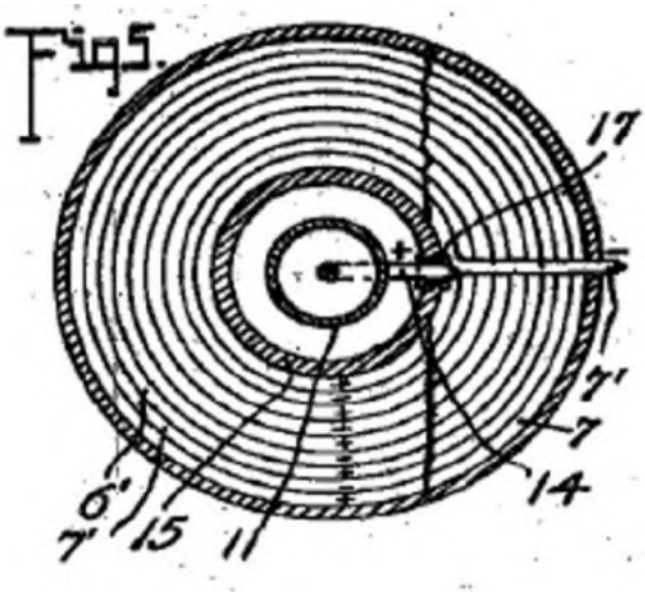

Figure 6 is an enlarged detail fragmentary section illustrating the parts at the juncture of the

conductors and one of the intensifiers.

Figure 7 is an enlarged detail view partly in elevation and partly in section of one of the automatic cut-outs and

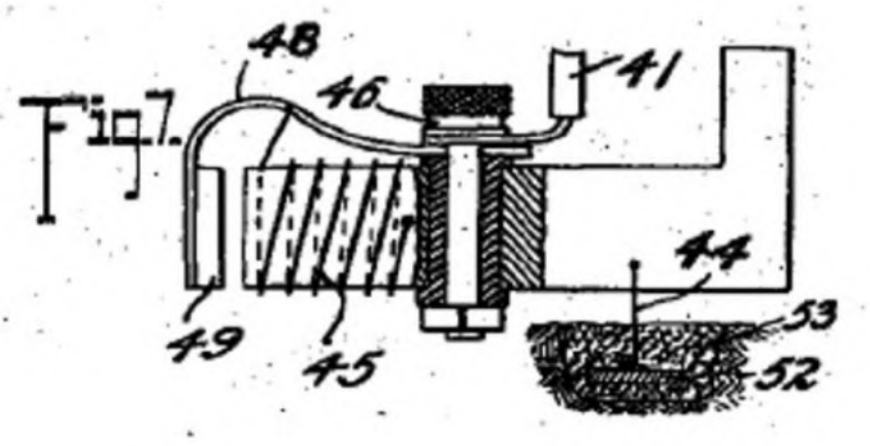

Figure 8 is a diagrammatic view of one of the simplest forms of embodiment of the invention.

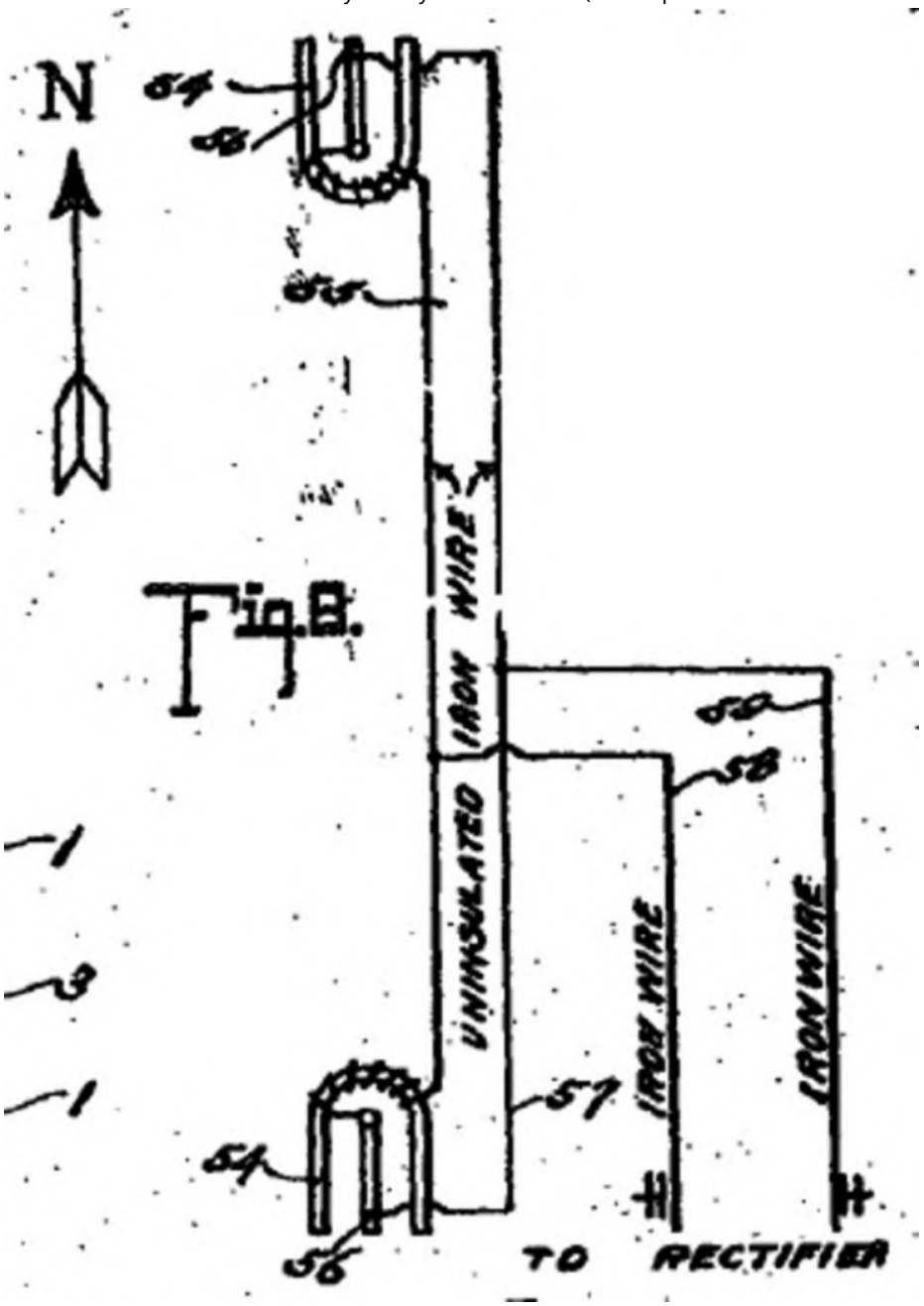

Referring to the drawing by numerals, 1,1 indicates magnets connected by a magnetic substance 2, preferably an iron wire. The magnets 1 are arranged in pairs, one pair being spaced beneath the other, and interposed between the magnets are zinc plates 3,3 connected by an iron wire conductor 4. Suitable insulating supports 5 are arranged for sustaining the respective magnets 1 and plates 3,3. Each plate 3 is preferably bent substantially into V form, as clearly seen in Figure 1, and the V1 of one of the plates opens or faces toward the north and the V of the other plate to the South. I have determined by experimentation that it is essential that the plates 3 be disposed substantially north and south with their flat faces approximately parallel to the adjacent faces of the co-operating magnets, although by experience I have not discovered any material difference in the current obtained when the plates are disposed slightly to one side of north and south, as for instance when the plates are disposed slightly to one side of north and south, as for instance when disposed in the line of the magnetic polarity of the earth. The same is true with respect to the magnets 1, the said magnets being disposed substantially north and south for operative purposes, although I find that it is immaterial whether the north pole of one of the magnets is disposed to the north and the south pole to the south, or vice versa, and it is my conviction from experience that it is essential to have the magnets of each pair connected by magnetic material so that the magnets substantially become

one with a pole exposed to the north and a pole exposed to the north. In Figure 1, I have indicated in full lines by the letters 8 and N the respective polarities of the magnets 1, and have indicated in dotted lines the other pole of those magnets when the connection 2 is severed. I have found that the magnets and zinc plates operate to produce, whether by collection or generation I am not certain, electrical currents when disposed substantially north and south, but when disposed substantially east and west no such currents are produced. I also find that the question of elevation is by no means vital, but it is true that more efficient results are obtained by placing the zincs and magnets on elevated supports. I furthermore find from tests that it is possible to obtain currents from the apparatus with the zincs and magnets disposed in a building or otherwise enclosed, although more efficient results are obtained by having the said elements arranged in the open.

While in Figures 1, 2, and 3, I have shown the magnets and the zinc plates as superimposed, it will be apparent, as hereinafter fully set forth, that these elements may be juxtaposed in horizontal planes, and substantially the same results will be secured. Furthermore, the magnets 1 with the interposed zincs 3, as shown in Figures 1, 2 and 3 merely represent a unit which may be repeated either horizontally or vertically for increasing the current supply, and when the unit is repeated the zinc plates are arranged alternating with the magnets throughout the entire series as hereinafter indicated.

A conductor 6 is connected in multiple with the conductors 2 and a conductor 7 is connected with conductor 4, the conductor 6 extending to one terminal of a rectifier which I have indicated by the general reference character 8, and the conductor 7 extending to the other terminal of said rectifier. The rectifier as seen in diagram in Figure 1 may assume any of several well known embodiments of the electrical valve type and may consist of four asymmetric cells or Cooper-Hewitt mercury vapor lamps connected as indicated in Figure 1 for permitting communication of the positive impulses from the conductor 6 only to the line conductor 9 and the negative impulses from conductor 6 on only to the line conductor 10. The current from this rectifier may be delivered through the conductors 9 and 10 to any suitable source for consumption.

While the said rectifier 8 may consist of any of the known types, as above outlined, it preferably consists of a specially constructed rectifier which also has the capacity of intensifying the current and comprises specifically the elements shown in detail in Figures 4, 5, and 6 wherein I have disclosed the detail wiring of the rectifier when composed of four of the rectifying and intensify in elements instead of asymmetric cells or simple mercury vapor valves. As each of these structures is an exact embodiment of all the others, one only will be described, and the description will apply to all. The rectifying element of each construction consists of a mercury tube 11 which is preferably formed of glass or other suitable material, and comprises a cylinder having its end portions tapered and each terminating in an insulating plug or stopper 12. Through the upper stopper 12 is extended the electrode 13 which extends well into the tube and preferably substantially one-half the length thereof to a point adjacent the inner end of an opposing electrode 14 which latter electrode extends thence downwardly through the insulation 12 at the lower end of the tube. The tube 11 is supplied with mercury and is adapted to operate on the principle of the mercury vapor lamp, serving to rectify current by checking back impulses of one sign and permitting passage of impulses of the other. To avoid the necessity for utilizing a starter, as is common with the lamp type of electrical valve, the supply of mercury within the tube may be sufficient to contact with the lower end of the electrode 13 when current is not being supplied, so that as soon as current is passed from one electrode to the other sufficiently for volatilizing that portion of the mercury immediately adjacent the lower end of electrode 13, the structure begins its operation as a rectifier. The tube 11 is surrounded by a tube 15 which is preferably spaced from tube 11 sufficiently for allowing atmospheric or other cooling circulation to pass the tube 11. In some instances, it may be desirable to cool the tube 11 by a surrounding body of liquid, as hereinafter indicated. The tube 15 may be of insulating material but I find efficient results attained by the employment of a steel tube, and fixed to the ends of the of the

tube are insulating disks 16, 16 forming a spool on which are wound twin wires 6^1 and 7^1, the wire 6^1 being connected at the inner helix of the coil with the outer end of the electrode 14, the lower portion of said electrode being extended to one side of the tube 11 and passed through an insulating sleeve 17 extending through the tube 15, and at its outer end merging into the adjacent end of the wire 6^1. The wire 7^1 extends directly from the outer portion of the spool through the several helices to a point adjacent the juncture of the electrode 14 with wire 6^1 and thence extends in mechanical parallelism with the wire throughout the coil, the wire 6^1 ending in a terminal 18 and the wire 7^1 ending in a terminal 19. For the sake of convenience of description and of tracing the circuits, each of the apparatus just above described and herein known as an intensifier and rectifier will be mentioned as A, B, C and D, respectively. Conductor 6 is formed with branches 20 and 21 and conductor 7 is formed with similar branches 22 and 23. Branch 20 from conductor 6 connects with conductor 7^1 of intensifier B and branch 21 of conductor 6 connects with the conductor 7^1 of intensifier C, while branch 22 of conductor 7 of intensifier C, while branch 22 of conductor 7 connects with conductor 7^1 of intensifier D. A conductor 27 is connected with terminal 19 of intensifier A and extends to and is connected with the terminal 18 of intensifier C, and a conductor 7 connects with conductor 7^1 of intensifier D. A conductor 27 is connected with terminal 19 of intensifier A. and extends to and is connected with terminal 18 of intensifier C, and a conductor 28 is connected with the terminal 19 of intensifier C and extends from the terminal 19 of intensifier B to the terminal 18 of intensifier D to electrode 13 of intensifier B. Each electrode 13 is supported on a spider 13^1 resting on the upper disk 16 of the respective intensifier. Conductors 31 and 32 are connected with the terminals 18 of intensifiers A and B and are united to form the positive line wire 9 which co-operates with the negative line wire 10 and extends to any suitable point of consumption. The line wire 10 is provided with branches 35 and 36 extending to the electrodes 13 of intensifiers C and D for completing the negative side of the circuit.

Thus it will be seen that alternating currents produced in the wires 6 and 7 will be rectified and delivered in the form of a direct current through the line wires 9 and 10, and I find by experiment that the wires 6 and 7 should be of iron, preferably soft, and may of course be insulated, the other wiring not specified as iron being of copper or other suitable material.

In carrying out the operation as stated, the circuits may be traced as follows: A positive impulse starting at the zincs 3 is directed along conductor 7 to branch 23 to conductor 7^1 and the winding of the rectifier of intensifier B through said rectifier to the conductor 6^1, through the winding thereof to the contact 18, conductor 32 and to the line wire 9. The next or negative impulse directed along conductor 7 cannot find its way along branch 23 and the circuit just above traced because it cannot pass across the rectifier of intensifier B but instead the negative impulse passes along conductor 22 to conductor 7 of intensifier A and the winding thereof to the contact 19 and to conductor 27 to contact 18 of intensifier C, to the winding of the wire 6^1 thereof to the electrode 14 through the rectifier to the of the electrode 13 and conductor of intensifier A, electrode 14 thereof and conductor 6^1 to contact 18 and wire 31 to line wire 9. Obviously the positive impulse cannot pass along the wire 20 because of its inverse approach to the rectifier of intensifier B. The next impulse or negative impulse delivered to conductor 6 cannot pass along conductor 21 because of its connection with electrode 13 of the rectifier of intensifier A, but instead passes along conductor 20 to the wire 7^1 and its winding forming part of intensifier B to the contact 19 and conductor 29 to contact 18 and the winding of wire 6^1 of intensifier D to the electrode 14 and through the rectifier to the electrode 13 and conductor 35 to line wire 10. Thus the current is rectified and all positive impulses directed along one line and all negative impulses along the other lie s that the potential difference between the two lines will be maximum for the given current of the alternating circuit. It is, of course, apparent that a less number of intensifiers with their accompanying rectifier elements may be employed with a sacrifice of the impulses which are checked back from a lack of ability to pass the respective rectifier elements, and in fact I have secured efficient results by the use of a single intensifier with its rectifier elements, as hereinafter set

forth.

Grounding conductors 37 and 38 are connected respectively with the conductors 6 and 7 and are provided with the ordinary lightning arresters 39 and 40 respectively for protecting the circuit against high tension static charges.

Conductors 41 and 42 are connected respectively with the conductors 6 and 7 and each connects with an automatic cutout 43 which is grounded as at 4. Each of said automatic cutouts is exactly like the other and one of the same is shown in detail in Figure 7 and comprises the inductive resistance 45 provided with an insulated binding post 46 wit which the respective conductor 6 or 7 is connected, said post also supporting a spring 48 which sustains an armature 49 adjacent to the core of the resistance 45. The helix of resistance 45 is connected preferably through the spring to the binding post at one end and at the other end is grounded on the core of the resistance, the said core being grounded by ground conductor 44 which extends to the metallic plate 52 embedded in moist carbon or other inductive material buried in the earth. Each of the conductors 41, 42 and 44 is of iron, and in this connection I wish it understood that where I state the specific substance I am able to verify the accuracy of the statement by the results of tests which I have made, but of course I wish to include along with such substances al equivalents, as for instance, where iron is mentioned its byproducts, such as steel, and its equivalents such as nickel and other magnetic substances are intended to be comprehended. The cutout apparatus seen in detail in Figure 7 is employed particularly for insuring against high tension currents, it being obvious from the structure shown that when potential rises beyond the limit established by the tension of the spring sustaining the armature 40, the armature will be moved to a position contacting with the core of the cutout device and thereby directly close the ground connection for line wire 41 with conductor 44, eliminating the resistance of winding 45 and allowing the high tension current to be discharged to the ground. Immediately upon such discharge the winding 45 losing its current will allow the core to become demagnetized and release the armature 49 whereby the ground connection is substantially broken leaving only the connection through the winding 45 the resistance of which is sufficient for insuring against loss of low tension current.

In Figure 8 I have illustrated an apparatus which though apparently primitive in construction and arrangement comprehends the first successful embodiment which I produced in the course of discovery of the present invention, and it will be observed that the essential features of the invention are therein disclosed. The structure delineated in said figure consists of horseshoe magnets 54, 55, one facing north and the other south, that is, each opening in the respective directions indicated and the two being connected by an iron wire 55 which is uninsulated and wrapped about the respective magnets each end portion of the wire 55 being extended from the respective magnets to and connected with, as by being soldered to, a zinc plate 56, there being a plate 56 for each magnet and each plate being arranged longitudinally substantially parallel with the legs of the magnet and with the faces of the plate exposed toward the respective legs of the magnet, the plate being thus arranged endwise toward the north and south. An iron wire 57 connects the plates 56, the ends of the wire being preferably connected adjacent the outer ends of the plates but from experiment I find that the wire may be connected at practically any point to the plate. Lead wires 58 and 59 are connected respectively with the wires 55 and 57 and supply an alternating current at a comparatively low tension, and to control such current the wires 58 and 59 may be extended to a rectifier or combined rectifier and intensifier, as above set forth.

The tests which I have found successful with the apparatus seen in Figure 8 were carried out by the employment first of horseshoe magnets approximately 4 inches in length, the bar comprising the horseshoe being about one inch square, the zincs being dimensioned proportionately and from this apparatus with the employment of a single intensifier and rectifier, as above stated, I was able to obtain a constant current of 8 volts.

It should be obvious that the magnets forming one of the electrodes of this apparatus may be permanent or may be electromagnets, or a combination of the two.

While the magnets mentioned throughout the above may be formed of any magnetic substance, I find the best results obtained by the employment of the nickel chrome steel.

While the successful operation of the various devices which I have constructed embodying the present invention have not enabled me to arrive definitely and positively at fixed conclusion relative to the principles and theories of operation and the source from which current is supplied, I wish it to be understood that I consider myself as the first inventor of the general type hereinbefore described capable of producing commercially serviceable electricity, for which reason my claims hereinafter appended contemplate that I may utilize a wide range of equivalents so far as concerns details of construction suggested as preferably employed.

The current which I am able to obtain is dynamic in the sense that it is not static and its production is accomplished without chemical or mechanical action either incident to the actual chemical or mechanical motion or incident to changing caloric conditions so that the elimination of necessity for the use of chemical or mechanical action is to be considered as including the elimination of the necessity for the use of heat or varying degrees thereof.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is: --- [Claims not included here]

NOTES & COMMENTS

From the Article in *Tech. World Mag*.:

1. First demo model was powerful enough to spark a gas engine.
2. Second model developed 8 volts.
3. Demo model at Patent Office was elevated on short poles.
4. The model planned to power Phoenix AZ would be elevated 200 feet.
5. The Absorber "consists of a series of magnetized steel plates set in a circle (the manner of preparing them is kept secret)".
6. "[T]he magnetizing of one set of plates... is part of the secret of the treatment which makes it respond to the accumulations of the atmosphere".

From British Patent # 1098 (1913):

"I have been able... to produce from a very small apparatus at comparatively low elevation, say about 50 or 60 feet above the earth's surface, a substantially constant current at a commercially useable voltage and amperage".

"This current... is capable of being readily increased by additions of the unit elements in the apparatus".

Fig. 1 and Fig. 2 show the magnet poles are connected N-S by a thick iron rod (thick compared to the lines used for wires in the drawings).

No angle is specified for the V-shaped zinc plates. The article (but not the patent) states that the plates are magnetized (obviously not zinc). Zinc-galvanized steel? Will a thin film of Zn work? Or, powdered Zn in a binder (more surface area)? Or, zinc-galvanized iron wire in a coil?

The Palmer Craig device (www.rexresearch.com/craig/craig.htm) is powered by the terrestrial

magnetic field, and employs a thin film of bismuth to capture the energy as diamagnetism. Perhaps this can be integrated with Meyers' device.

Figure 8 (the demonstration of principle) show uninsulated iron wire being used to connect the plates and magnets. The wire is wound around the Bloch wall area of the horseshoe magnets. Perhaps Coler-type windings around the poles could be used here (See: www.rexresearch.com/coler/coler.htm). Coler used copper plates as "condensers" in his device. Could copper plates be used for the Meyers device? Perhaps flat (Tesla non-inductive) coils could be integrated here.

"It is essential that the plates 3 be disposed substantially N and S with their flat faces approximately parallel to the adjacent faces of the co-operating magnets....

"I find that it is immaterial whether the N pole of one of the magnets is disposed to the N and the S pole to the S, or vice versa".

"[T]he magnets and zinc plates... produce electrical currents when disposed... N and S, but when disposed... E and W no such currents are produced".

"[E]levation is by no means vital, but... more efficient results are obtained by placing the zincs and magnets on elevated supports".

"The elements may be disposed in horizontal planes [or vertically]...".

The "zinc plate 56... [is] arranged longitudinally substantially parallel with the legs of the magnet and with the faces of the plate exposed toward the respective legs of the magnet, the plate being thus arranged endwise toward the north and south".

The first model used "horseshoe magnets approximately 4 inches in length, the bar comprising the horseshoe being about one inch square, the zincs being dimensioned proportionately and from this apparatus with the employment of a single intensifier and rectifier, as above stated, I was able to obtain a constant current of 8 volts... [T]he magnets... may be permanent or may be electromagnets, or a combination of the two... I find the best results obtained by... nickel chrome steel".

Comments & Questions:

The rectifier is described as a preferred embodiment, but other designs also work. The Ed Gray capacitor design comes to mind (www.rexresearch.com/evgray/1gray.htm). The Tate Ambient Power Module also might apply (www.rexresearch/tate/tate.htm).

Would non-ferrous magnets work? Is there a frequency involved (oscilloscope tests)? Coler found that ferromagnetism has a resonant frequency about 180 KHz. Can the components be made adjustable for RLC-resonance?

N° 1098 A.D. 1913

Date of Application, 14th Jan., 1913—Accepted, 14th Jan., 1914

COMPLETE SPECIFICATION.

Improvements in and relating to Apparatus for Producing Electricity.

I, ROY JEROME MEYERS, of Hotel Altamont, Baltimore, in the State of Maryland, United States of America, Electrician, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to improvements in apparatus for the production of electrical currents, and the primary object in view is the production of a commercially serviceable electrical current without the employment of mechanical or chemical action. To this end the invention comprises means for producing what I believe to be dynamic electricity from the earth and its ambient elements.

I am, of course, aware that it has been proposed to obtain static charges from upper strata of the atmosphere, but such charges are recognized as of widely variant potential and have thus far proved of no practical commercial value, and the present invention is distinguished from all such apparatus as has heretofore been employed for attracting static charges by the fact that this improved apparatus is not designed or employed to produce or generate irregular, fluctuating or other electrical charges which lack constancy, but on the other hand I have by actual test been able to produce from a very small apparatus at comparatively low elevation, say about fifty or sixty feet above the earth's surface, a substantially constant current at a commercially usable voltage and amperage. This current I ascertained by repeated tests is capable of being readily increased by additions of the unit elements in the apparatus hereinafter set forth, and I am convinced from the constancy of the current obtained and its comparatively low potential that the current is dynamic and not static, although, of course, it is not impossible that certain static discharges occur and, in fact, I have found occasion to provide against the damage which might result from such discharge by the provision of lightning arresters and cut-out apparatus which assist in rendering the obtained current stable by eliminating sudden fluctuations which sometimes occur during conditions of high humidity from what I consider static discharges. The nature of my invention is obviously such that I have been unable to establish authoritatively all of the principles involved, and some of the theories herein expressed may possibly prove erroneous, but I do know and am able to demonstrate that the apparatus which I have discovered does produce, generate, or otherwise acquire a difference of potential representing a current value which is commercially serviceable and may be delivered at the voltage and amperage above stated, or varied therefrom at the will of the operator according to the uses to which the current is to be subjected.

The invention comprises generically means for producing electrical currents of serviceable potential substantially without the employment of mechanical or chemical action, and in this connection I have been able to observe no chemical action whatever on the parts utilized although deterioration may possibly occur in some of the parts, but so far as I am able to determine such deterioration does not add to the current supply but is merely incidental to the effect of climatic action.

The invention more specifically comprises the employment of a magnet or

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magnets and a co-operating element, such as zinc disposed adjacent to the magnet or magnets and connected in such manner and arranged relative to the earth so as to produce current, my observation being that current is produced only when such magnets have their poles facing substantially to the north and south and the zincs are disposed substantially along the magnets.

The invention also comprehends other details of construction, combinations and arrangements of parts as will hereinafter be fully set forth and claimed.

In the accompanying drawings:

Figure 1 is a top plan view of an apparatus embodying the features of the present invention, the arrow accompanying the figure indicating substantially the geographical north, parts of the figure being diagrammatic for condensing the showing.

Figure 2 is a view in side elevation of the parts seen in plan in Figure 1.

Figure 3 is a vertical section taken on the plane indicated by the line 3—3 of Figure 2 and looking in the direction indicated by the arrow.

Figure 4 is a detail view partly in elevation and partly in section showing the detail connections of the converter and intensifier.

Figure 5 is a transverse section taken on the planes indicated by line 5—5 of Figure 4 and looking downwardly.

Figure 6 is an enlarged detail fragmentary section illustrating the parts at the juncture of the conductors and one of the intensifiers.

Figure 7 is an enlarged detail view partly in elevation and partly in section of one of the automatic cut-outs and

Figure 8 is a diagrammatic view of one of the simplest forms of embodiments of the invention.

Referring to the drawing by numerals, 1, 1 indicates magnets connected by a magnetic substance 2, preferably an iron wire. The magnets 1 are arranged in pairs, one pair being spaced beneath the other, and interposed between the magnets are zinc plates 3, 3 connected by an iron wire conductor 4. Suitable insulating supports 5 are arranged for sustaining the respective magnets 1 and plates 3, 3. Each plate 3 is preferably bent substantially into V form, as clearly seen in Figure 1, and the V of one of the plates opens or faces toward the north and the V of the other plate to the south. I have determined by experimentation that it is essential that the plates 3 be disposed substantially north and south with their flat faces approximately parallel to the adjacent faces of the co-operating magnets, although by experience I have not discovered any material difference in the current obtained when the plates are disposed slightly to one side of north and south, as for instance when disposed in the line of the magnetic polarity of the earth. The same is true with respect to the magnets 1, the said magnets being disposed substantially north and south for operative purposes, although I find that it is immaterial whether the north pole of one of the magnets is disposed to the north and the south pole to the south, or *vice versa*, and it is my conviction from experience that it is essential to have the magnets of each pair connected by magnetic material so that the magnets substantially become one with a pole exposed to the north and a pole exposed to the south. In Figure 1, I have indicated in full lines by the letters S and N the respective polarities of the magnets 1, and have indicated in dotted lines the other poles of those magnets when the connection 2 is severed. I have found that the magnets and zinc plates operate to produce, whether by collection or generation I am not certain, electrical currents when disposed substantially north and south, but when disposed substantially east and west no such currents are produced. I also find that the question of elevation is by no means vital, but it is true that more efficient results are obtained by placing the zincs and magnets on elevated supports. I furthermore find from tests that it is possible to obtain currents from the apparatus with the zincs and magnets disposed in a building or otherwise enclosed, although more efficient results are obtained by having the said elements arranged in the open.

While in Figures 1, 2 and 3, I have shown the magnets and the zinc plates as superimposed, it will be apparent, as hereinafter fully set forth, that these elements may be juxtaposed in horizontal planes, and substantially the same results will be secured. Furthermore, the magnets 1 with the interposed zincs 3, as shown in Figures 1, 2 and 3 merely represent a unit which may be repeated either horizontally or vertically for increasing the current supply, and when the unit is repeated the zinc plates are arranged alternating with the magnets throughout the entire series as hereinafter indicated.

A conductor 6 is connected in multiple with the conductors 2 and a conductor 7 is connected with conductor 4, the conductor 6 extending to one terminal of a rectifier which I have indicated by the general reference character 8, and the conductor 7 extending to the other terminal of said rectifier. The rectifier as seen in diagram in Figure 1 may assume any of several well known embodiments of the electrical valve type and may consist of four assymmetric cells or Cooper-Hewitt mercury vapor lamps connected as indicated in Figure 1 for permitting communication of the positive impulses from conductor 7 only to the line conductor 9 and the negative impulses from the conductor 7 only to the line conductor 10, and permitting the positive impulses from the conductor 6 only to the line conductor 9 and the negative impulses from conductor 6 only to the line conductor 10. The current from this rectifier may be delivered through the conductors 9 and 10 to any suitable source for consumption.

While the said rectifier 8 may consist of any of the known types, as above outlined, it preferably consists of a specially constructed rectifier which also has the capacity of intensifying the current and comprises specifically the elements shown in detail in Figures 4, 5 and 6 wherein I have disclosed the detail wiring of the rectifier when composed of four of the rectifying and intensifying elements instead of assymmetric cells or simple mercury vapor valves. As each of these structures is an exact embodiment of all the others, one only will be described, and the description will apply to all. The rectifying element of each construction consists of a mercury tube 11 which is preferably formed of copper but may be formed of glass or other suitable material, and comprises a cylinder having its end portions tapered and each terminating in an insulating plug or stopper 12. Through the upper stopper 12 is extended the electrode 13 which extends well into the tube and preferably substantially one-half the length thereof to a point adjacent the inner end of an opposing electrode 14 which latter electrode extends thence downwardly through the insulation 12 at the lower end of the tube. The tube 11 is supplied with mercury and is adapted to operate on the principle of the mercury vapor lamp, serving to rectify current by checking back impulses of one sign and permitting passage of impulses of the other. To avoid the necessity for utilizing a starter, as is common with the lamp type of electrical valve, the supply of mercury within the tube may be sufficient to contact with the lower end of the electrode 13 when current is not being supplied, so that as soon as current is passed from one electrode to the other sufficiently for volatilizing that portion of the mercury immediately adjacent the lower end of electrode 13, the structure begins its operation as a rectifier. The tube 11 is surrounded by a tube 15 which is preferably spaced from tube 11 sufficiently for allowing atmospheric or other cooling circulation to pass the tube 11. In some instances, it may be desirable to cool the tube 11 by a surrounding body of liquid, as hereinafter indicated. The tube 15 may be of insulating material but I find efficient results attained by the employment of a steel tube, and fixed to the ends of the tube are insulating disks 16, 16 forming a spool on which are wound twin wires 6^1 and 7^1, the wire 6^1 being connected at the inner helix of the coil with the outer end of the electrode 14, the lower portion of said electrode being extended to one side of the tube 11 and passed through an insulating sleeve 17 extending through the tube 15, and at its outer end merging into the adjacent end of the wire 6^1. The wire 7^1 extends directly from the outer portion of the spool through the

several helices to a point adjacent the juncture of the electrode 14 with wire 6^1 and thence extends in mechanical parallelism with the wire throughout the coil, the wire 6^1 ending in a terminal 18 and the wire 7^1 ending in a terminal 19. For the sake of convenience of description and of tracing the circuits, each of the apparatus just above described and herein known as an intensifier and rectifier will be mentioned as A, B, C and D, respectively. Conductor 6 is formed with branches 20 and 21 and conductor 7 is formed with similar branches 22 and 23. Branch 20 from conductor 6 connects with conductor 7^1 of intensifier B and branch 21 of conductor 6 connects with the conductor 7^1 of intensifier C, while branch 22 of conductor 7 connects with conductor 7^1 of intensifier A and branch 23 of conductor 7 connects with conductor 7^1 of intensifier D. A conductor 27 is connected with terminal 19 of intensifier A and extends to and is connected with terminal 18 of intensifier C, and a conductor 28 is connected with the terminal 19 of intensifier C and extends to and is connected with electrode 13 of intensifier A. A conductor 29 extends from the terminal 19 of intensifier B to the terminal 18 of intensifier D and a conductor 30 extends from the terminal 19 of intensifier D to electrode 13 of intensifier B. Each electrode 13 is supported on a spider 13^1 resting on the upper disk 16 of the respective intensifier. Conductors 31 and 32 are connected with the terminals 18 of intensifiers A and B and are united to form the positive line wire 9 which co-operates with the negative line wire 10 and extends to any suitable point of consumption. The line wire 10 is provided with branches 35 and 36 extending to the electrodes 13 of intensifiers C and D for completing the negative side of the circuit.

Thus it will be seen that alternating currents produced in the wires 6 and 7 will be rectified and delivered in the form of a direct current through the line wires 9 and 10, and I find by experiment that the wires 6 and 7 should be of iron, preferably soft, and may of course be insulated, the other wiring not specified as iron being of copper or other suitable material.

In carrying out the operation as stated, the circuits may be traced as follows: A positive impulse starting at the zincs 3 is directed along conductor 7 to branch 23 to conductor 7^1 and the winding of intensifier D to terminal 19 through conductor 30 to electrode 13 of the rectifier of intensifier B through said rectifier to the conductor 6^1, through the winding thereof to the contact 18, conductor 32 and to the line wire 9. The next or negative impulse directed along conductor 7 cannot find its way along branch 23 and the circuit just above traced because it cannot pass across the rectifier of intensifier B but instead the negative impulse passes along conductor 22 to conductor 7 of intensifier A and the winding thereof to the contact 19 to conductor 27 to contact 18 of intensifier C, to the winding of the wire 6^1 thereof to the electrode 14 through the rectifier to the electrode 13 and conductor 36 to the line wire 10. A positive impulse delivered to wire 6 passes along the said wire to the branch 21 to the conductor 7^1 of intensifier C and the winding thereof to the contact 19, conductor 28, electrode 13 of the rectifier of intensifier A, electrode 14 thereof and conductor 6^1 to contact 18 and wire 31 to line wire 9. Obviously the positive impulse cannot pass along the wire 20 because of its inverse approach to the rectifier of intensifier B. The next impulse or negative impulse delivered to conductor 6 cannot pass along conductor 21 because of its connection with electrode 13 of the rectifier of intensifier A, but instead passes along conductor 20 to the wire 7^1 and its winding forming part of intensifier B to the contact 19 and conductor 29 to contact 18 and the winding of wire 6^1 of intensifier D to the electrode 14 and through the rectifier to the electrode 13 and conductor 35 to line wire 10. Thus the current is rectified and all positive impulses directed along one line and all negative impulses along the other line so that the potential difference between the two lines will be maximum for the given current of the alternating circuit. It is, of course, apparent that a less number of intensifiers with their accompanying rectifier elements may be

employed with a sacrifice of the impulses which are checked back from a lack of ability to pass the respective rectifier elements, and in fact I have secured efficient results by the use of a single intensifier with its rectifier elements, as hereinafter set forth.

Grounding conductors 37 and 38 are connected respectively with the conductors 6 and 7 and are provided with the ordinary lightning arresters 39 and 40 respectively for protecting the circuit against high tension static charges.

Conductors 41 and 42 are connected respectively with the conductors 6 and 7 and each connects with an automatic cut-out 43 which is grounded as at 44. Each of said automatic cut-outs is exactly like the other and one of the same is shown in detail in Figure 7 and comprises the inductive resistance 45 provided with an insulated binding post 46 with which the respective conductor 6 or 7 is connected, said post also supporting a spring 48 which sustains an armature 49 adjacent the core of the resistance 45. The helix of resistance 45 is connected preferably through the spring to the binding post at one end and at the other end is grounded on the core of the resistance, the said core being grounded by ground conductor 44 which extends to the metallic plate 52 imbedded in moist carbon or other inductive material 53 buried in the earth. Each of the conductors 41, 42 and 44 is of iron, and in this connection I wish it understood that where I state the specific substance I am able to verify the accuracy of the statement by the results of tests which I have made, but of course I wish to include along with such substance all equivalents, as for instance, where iron is mentioned its by-products, such as steel, and its equivalents such as nicked and other magnetic substances are intended to be comprehended. The cut-out apparatus seen in detail in Figure 7 is employed particularly for insuring against high tension currents it being obvious from the structure shown that when potential rises beyond the limit established by the tension of the spring sustaining the armature 49, the armature will be moved to a position contacting with the core of the cut-out device and thereby directly close the ground connection for line wire 41 with conductor 44, eliminating the resistance of winding 45 and allowing the high tension current to be discharged to the ground. Immediately upon such discharge the winding 45 losing its current will allow the core to become demagnetized and release the armature 49 whereby the ground connection is substantially broken leaving only the connection through the winding 45 the resistance of which is sufficient for insuring against loss of low tension current.

In Figure 8 I have illustrated an apparatus which though apparently primitive in construction and arrangement comprehends the first successful embodiment which I produced in the course of the discovery of the present invention, and it will be observed that the essential features of the invention are therein disclosed. The structure delineated in said figure consists of horse shoe magnets 54, 54, one facing north and the other south, that is, each opening in the respective directions indicated and the two being connected by an iron wire 55 which is uninsulated and wrapped about the respective magnets at or adjacent the neutral zone thereof, and the wire 55 is preferably soldered to the respective magnets each end portion of the wire 55 being extended from the respective magnet to and connected with, as by being soldered to, a zinc plate 56, there being a plate 56 for each magnet and each plate being arranged longitudinally substantially parallel with the legs of the magnet and with the faces of the plate exposed toward the respective legs of the magnet, the plate being thus arranged endwise toward the north and south. An iron wire 57 connects the plates 56, the ends of the wire being preferably connected adjacent the outer ends of the plates but from experiment I find that the wire may be connected at practically any point to the plate. Lead wires 58 and 59 are connected respectively with the wires 55 and 57 and supply an alternating current ordinarily at a comparatively low tension, and to control such current the wires 58 and 59 may be extended to a rectifier or combined rectifier and intensifier, as above set forth.

The tests which I have found successful with the apparatus seen in Figure 8 were carried out by the employment first of horse shoe magnets approximately four inches in length, the bar comprising the horse shoe being about one inch square, the zincs being dimensioned proportionately and from this apparatus with the employment of a single intensifier and rectifier, as above stated, I was able to obtain a constant current of 8 volts.

It should be obvious that the magnets forming one of the electrodes of this apparatus may be permanent or may be electro-magnets, or a combination of the two.

While the magnets mentioned throughout the above may be formed of any magnetic substance, I find the best results obtained by the employment of the nickel chrome steel.

While the successful operation of the various devices which I have constructed embodying the present invention have not enabled me to arrive definitely and positively at fixed conclusions relative to the principles and theories of operation and the source from which current is supplied, I wish it to be understood that I consider myself as the first inventor of an apparatus of the general type hereinbefore described capable of producing commercially serviceable electricity, for which reason my claims hereinafter appended contemplate that I may utilize a wide range of equivalents so far as concerns details of construction suggested as preferably employed.

The current which I am able to obtain is dynamic in the sense that it is not static and its production is accomplished without chemical or mechanical action either incident to the actual chemical or mechanical motion or incident to changing calorific conditions so that the elimination of necessity for the use of chemical or mechanical action is to be considered as including the elimination of the necessity for the use of heat or varying degrees thereof.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. Means for producing dynamic electricity without mechanical or chemical action.

2. Electricity producing means as claimed in Claim 1, characterized in that said means is capable of producing low tension current.

3. Electricity producing means as claimed in Claim 1, characterized in that said means comprises a magnet, and means co-operating with the latter.

4. Means as set forth in Claim 3, characterized in that the parts are stationary.

5. Means as claimed in Claim 3, characterized in that the magnet is disposed substantially north and south.

6. Means as claimed in Claims 1, 3 and 5, wherein the means coacting with the magnet is a metal and said parts are disposed substantially north and south.

7. Means as claimed in Claims 1, 3 and 6, in which the metal is zinc, and combined with conductors connected with the co-operating parts to deliver current therefrom.

8. Means as set forth in Claim 1, characterized in that said means comprises spaced magnets with an adjacent co-operating zinc, and an iron wire connecting the magnets, and means to deliver electrical current from said parts.

9. Means as set forth in Claim 8, characterized in that the current delivery means comprises an intensifier and rectifier.

10. Means as set forth in Claim 8, characterized in that the current delivery means comprises wires connected with the magnets and zinc, an electrical valve connected with one of said wires, and independent helices surrounding said valve, one of said helices being connected with the terminal of the valve at the opposite side from the contact of said wire and the other of said helices being connected with the other wire, the electrical valve comprising a mercury vapor rectifier.

11. The process of producing electricity comprising exposing a magnet and

co-operating means disposed substantially north and south and taking off current therefrom.

12. The process of producing electricity comprising disposing stationary elements in co-operative relation in respect to each other and with respect to the earth for giving off relatively low tension electrical current, substantially without chemical action.

13. Electricity producing means constructed and operating substantially as described with reference to the accompanying drawings.

Dated this 13th day of January, 1913.

W. P. THOMPSON & Co.,
6, Lord Street, Liverpool, and at
Bradford & London,
Agents for the Applicant.

Reference has been directed, in pursuance of Section 7, Sub-section 4, of the Patents and Designs Act, 1907, to Specifications No. 16,709 of 1887, No. 14,033 of 1899, No. 15,412 of 1906, and No. 5457 of 1911.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1914.

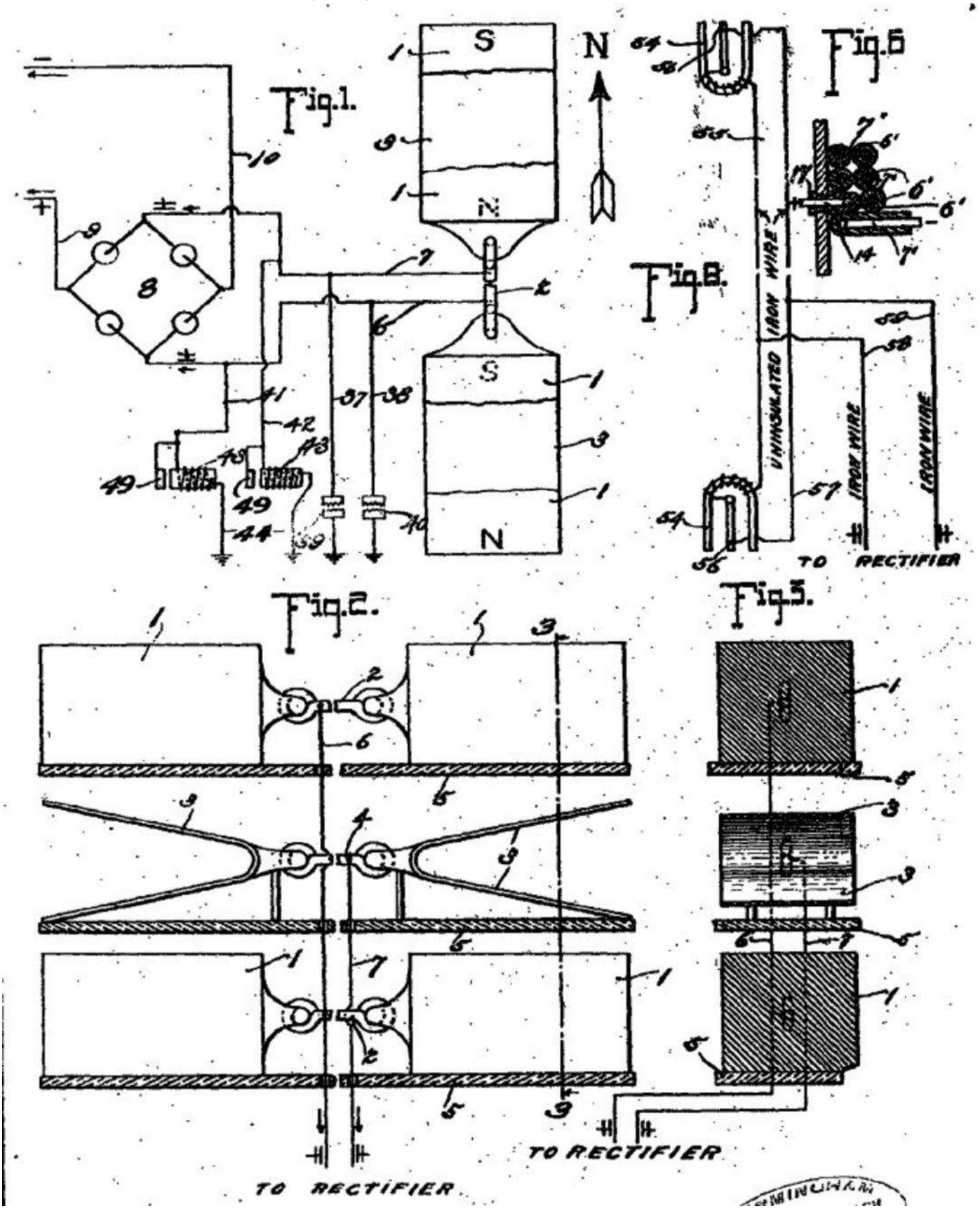
Fig.1.
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Fig.6
UNINSULATED IRON WIRE
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Fig.8.
Fig.2.
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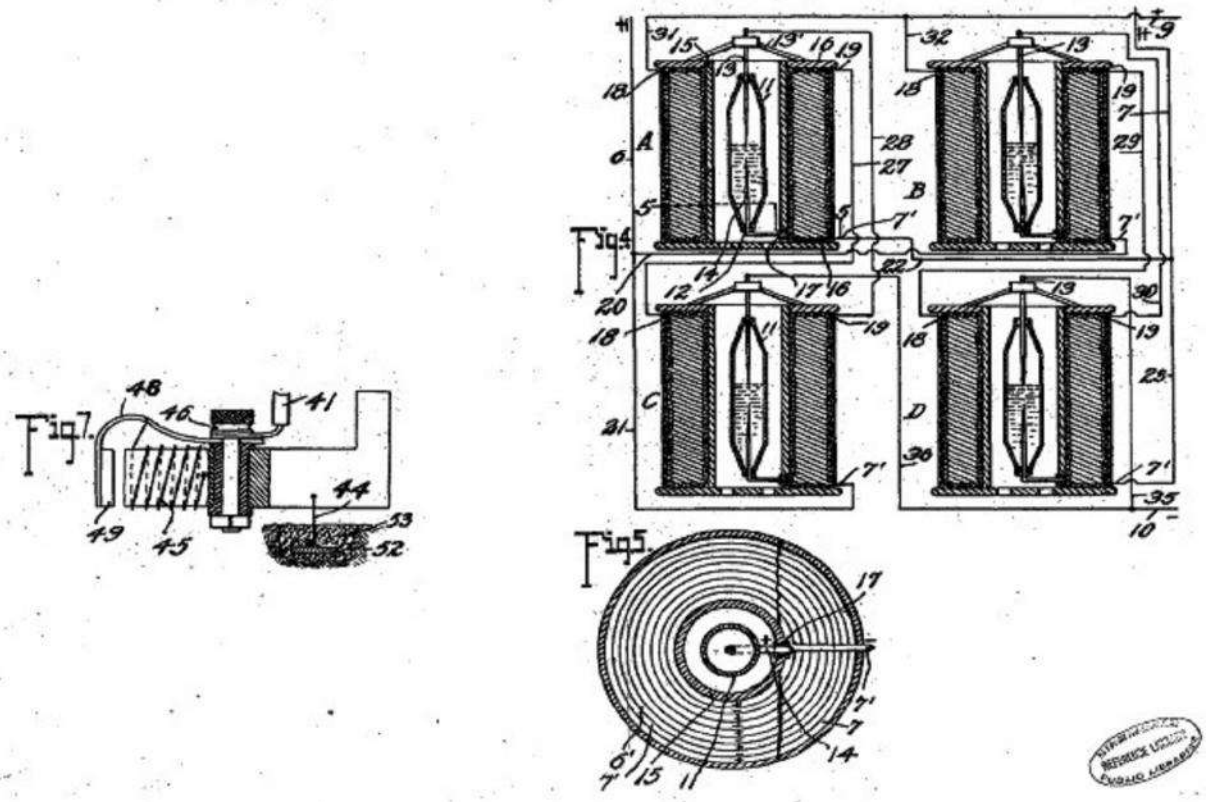

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Roy J. Meyers Absorber, GB Patent 191301098.

This device was brought to my attention by Grumage. Here is my take on why it worked.

In its simplest form the device consists of two horseshoe magnets, some zinc plates and some uninsulated iron wire. The iron wire is wound around the curved ends of the horseshoe magnet and connected to the zinc plates as shown in figure 1. The system has to be aligned with the earth's magnetic field.

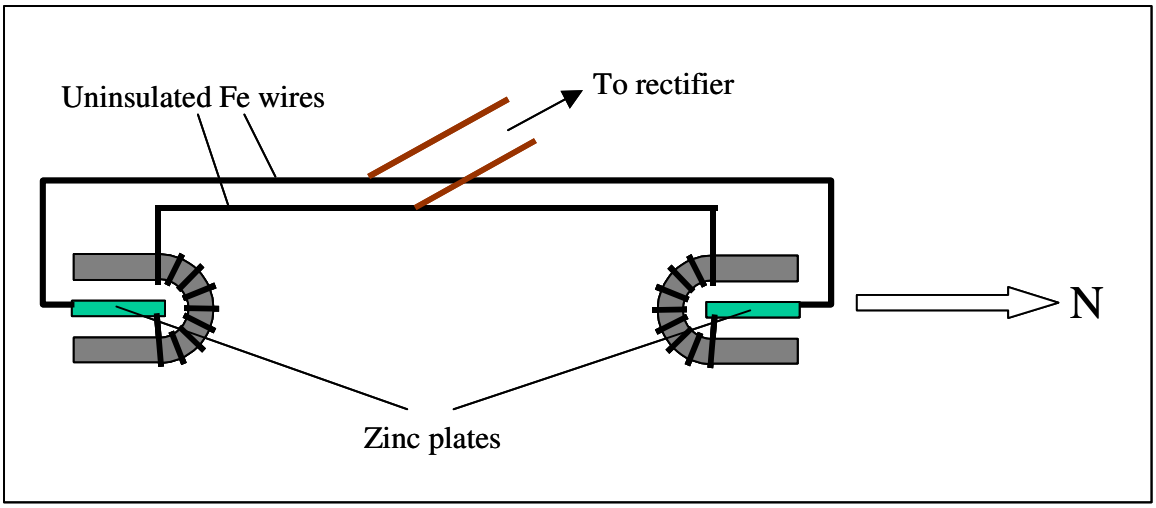

Figure 1. Simple Scheme reported to supply alternating current at low voltage

At first sight this seems incapable of providing alternating voltage but here is a possible explanation. If you follow the magnetization axis of each horseshoe it is seen that the earth's field supplies a magnetic gradient around the curved section, hence spin polarized conduction electrons therein will be dragged along thus creating a tiny potential difference between the two legs of each magnet. The iron wires wound over that curved end do nothing except create contact points at the ends of each curvature. We can discount any galvanic potential between iron wire and magnet since the magnets used were of magnetized steel. However we cannot ignore the galvanic potential between the zinc and the iron connection, or indeed the solder used for the connection. Although the two connections to the zinc would normally result in a zero overall potential, there exists a difference in the magnetic field at each end of the zinc, which could result in a significant (but low) voltage present. This magneto-Seebeck effect is a fairly new phenomenon and would not have been known in 1913 when the patent application was made. Also unknown at that time was the presence of spin-polarized conduction electrons.

This all predicts the presence of DC voltage, so how could this become AC? Well the magneto-Seebeck effect can result in a positive or a negative potential, and it also changes with temperature. In fact there can be a crossover temperature where it changes from positive to negative. Hence the DC current flowing around the closed loop of iron wire could heat the thin zinc plates to take it through that crossover temperature, whereupon the current decreases, the zinc cools down then the whole process repeats itself. This would result in a very low frequency AC voltage being observed.

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JENNINGS

(54) **ATMOSPHERIC TRANSDUCTION SYSTEM**

(71) Applicant: **JAMES EDWARD JENNINGS**, SUPERIOR, CO (US)

(72) Inventor: **JAMES EDWARD JENNINGS**, SUPERIOR, CO (US)

(21) Appl. No.: **13/692,121**

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CPC ***H02N 11/002*** (2013.01); ***F03D 9/003*** (2013.01)

USPC **290/55**; 310/308

(57) **ABSTRACT**

Atmospheric Transduction System including a Power Frequency broadcast station, a receiver, and a network. The Power Frequency broadcast station includes a transmitter and a computer server. The receiver is in communication with the Power Frequency broadcast transmitter and also includes a user interface for receiving user input commands comprising a request for information from the Power Frequency broadcast station. The receiver is configured to establish a two-way communication path between the receiver and the Power Frequency broadcast transmitter. The network is in communication with the transducer, controller and the receiver for exchanging information therebetween. In response to oscillation translation and/or rotation of the electronic transducer, portions of forces induced by the mass are transferred to the piezoelectric elements. Electrical energy output by these piezoelectric elements is received in a power controller and can be applied to the battery as self charging. The piezoelectric transducer includes a conductive rotor and bearings, at least one of them incorporating a vibrator of mechanical oscillation, having a piezoelectric transducer converting mechanical vibrations into electric power.

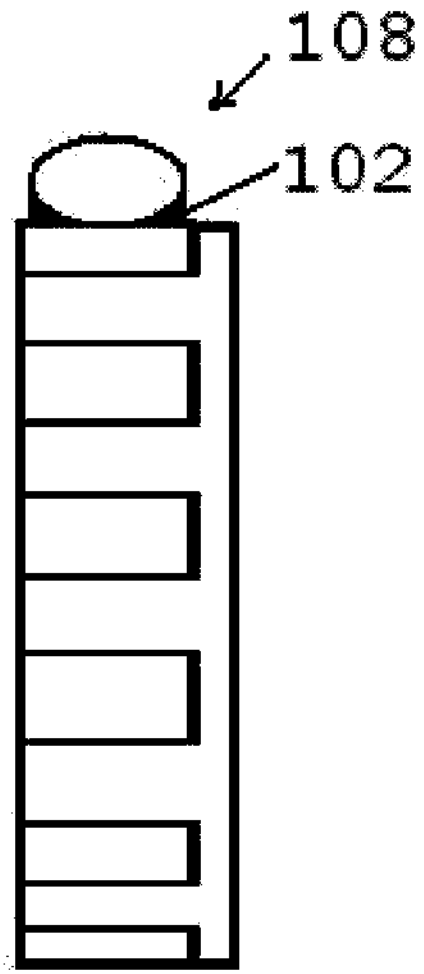

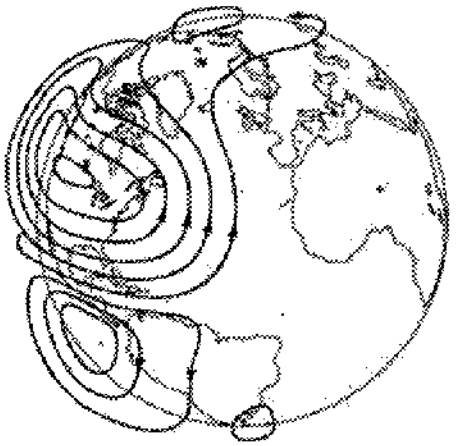

FIG.1

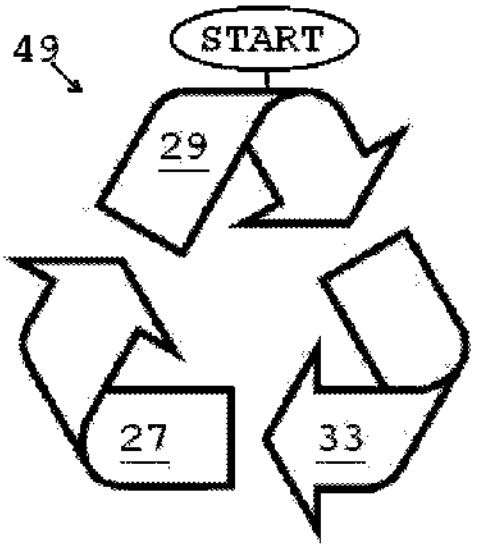

FIG.2

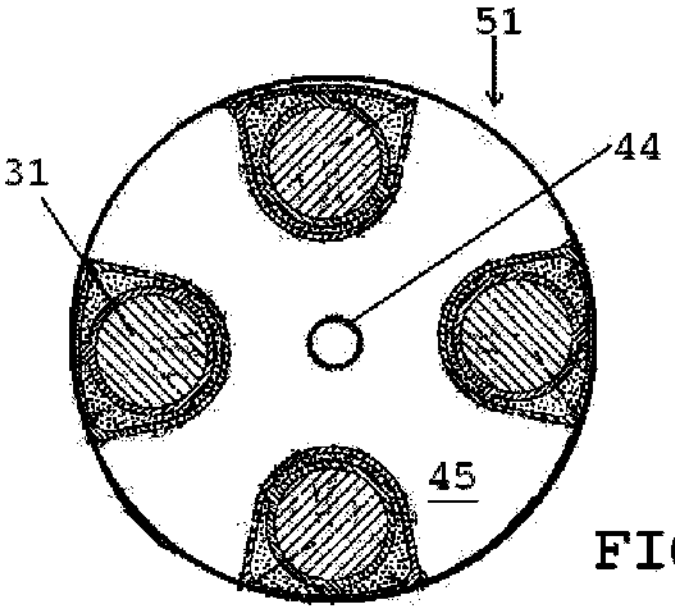

FIG.3

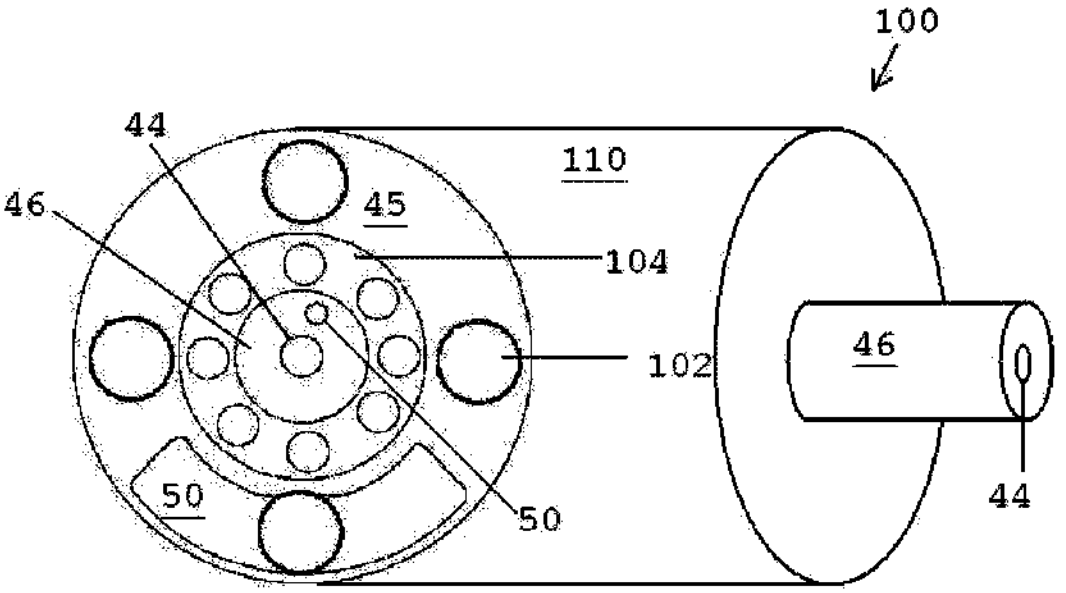

FIG. 4

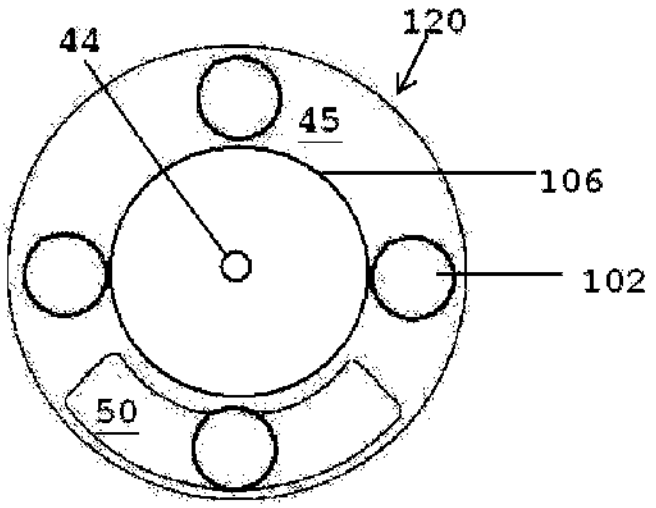

FIG. 5

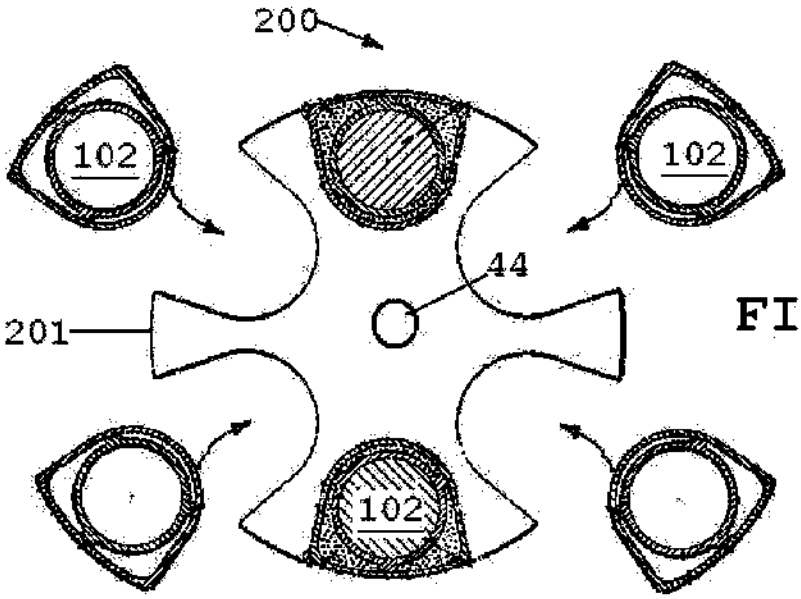

FIG. 6

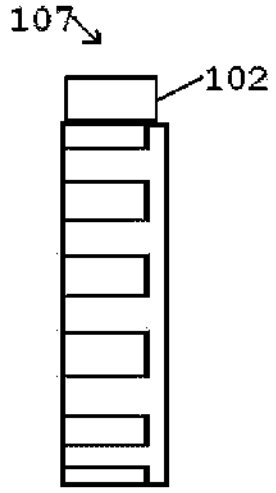

FIG. 7

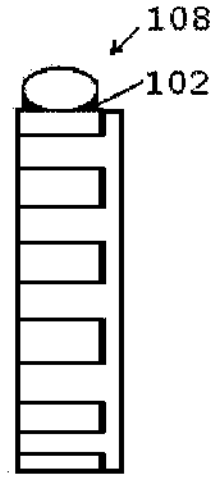

FIG. 8

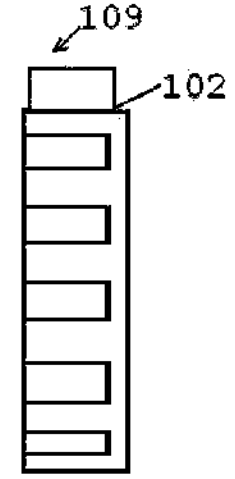

FIG. 9

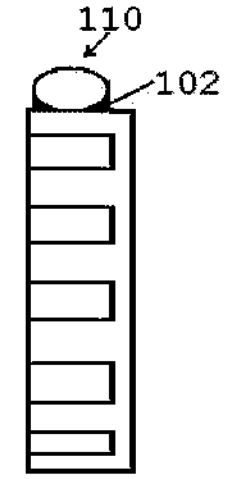

FIG. 10

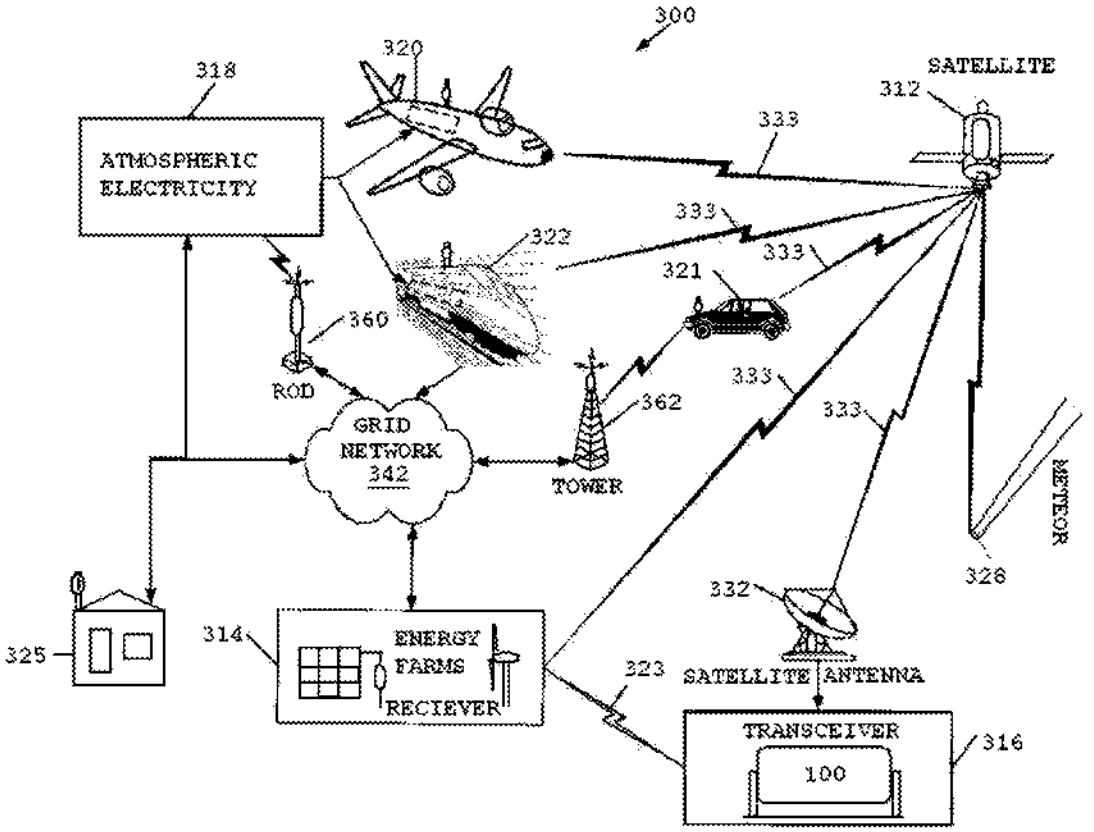
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312
ATMOSPHERIC ELECTRICITY
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333
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ROD
GRID NETWORK 342
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TOWER
333
333
METEOR
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332
325
314
ENERGY FARMS
RECIEVER
323
SATELLITE ANTENNA
TRANSCEIVER
100
316

FIG.11

FIG.12

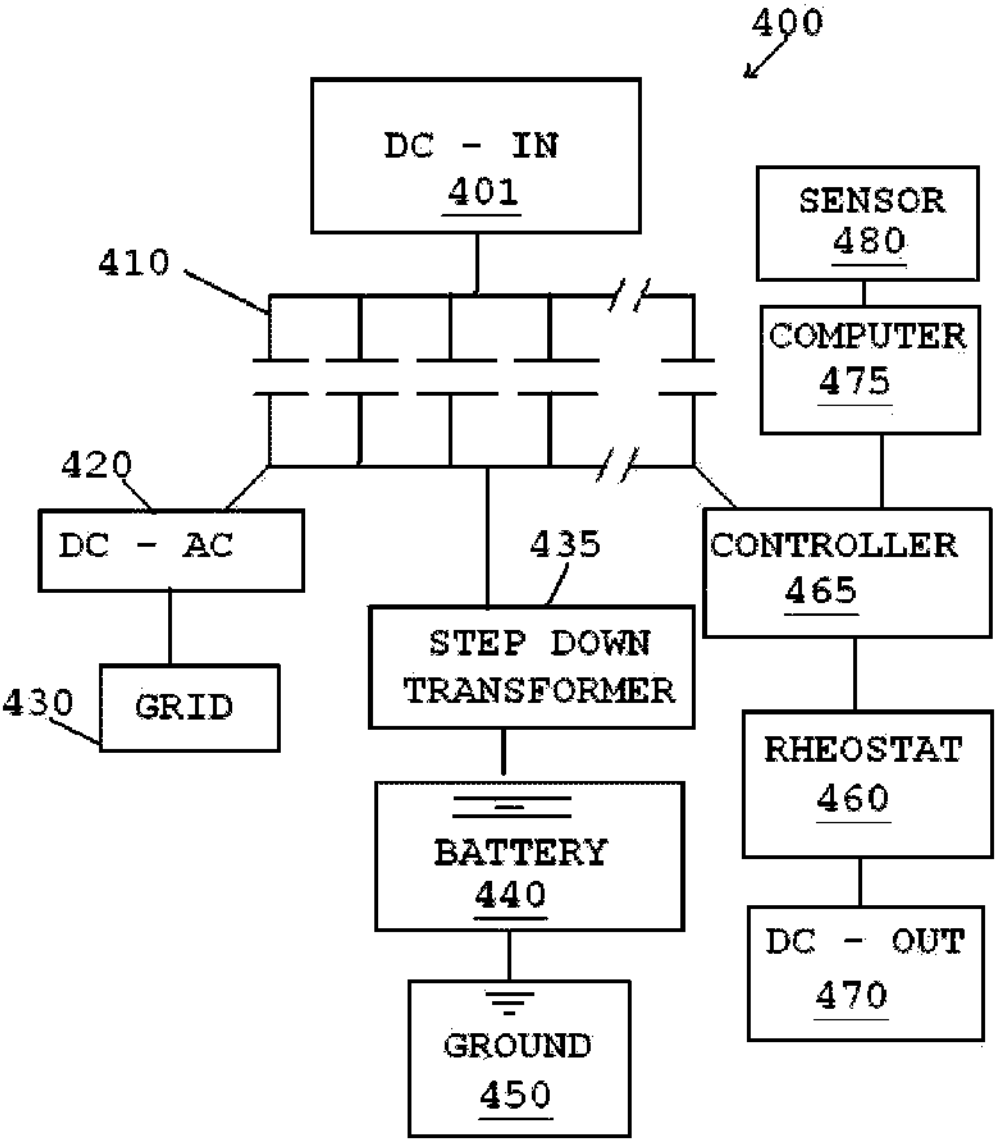
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GRID
RHEOSTAT
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BATTERY
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DC - OUT
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GROUND
450

FIG.13

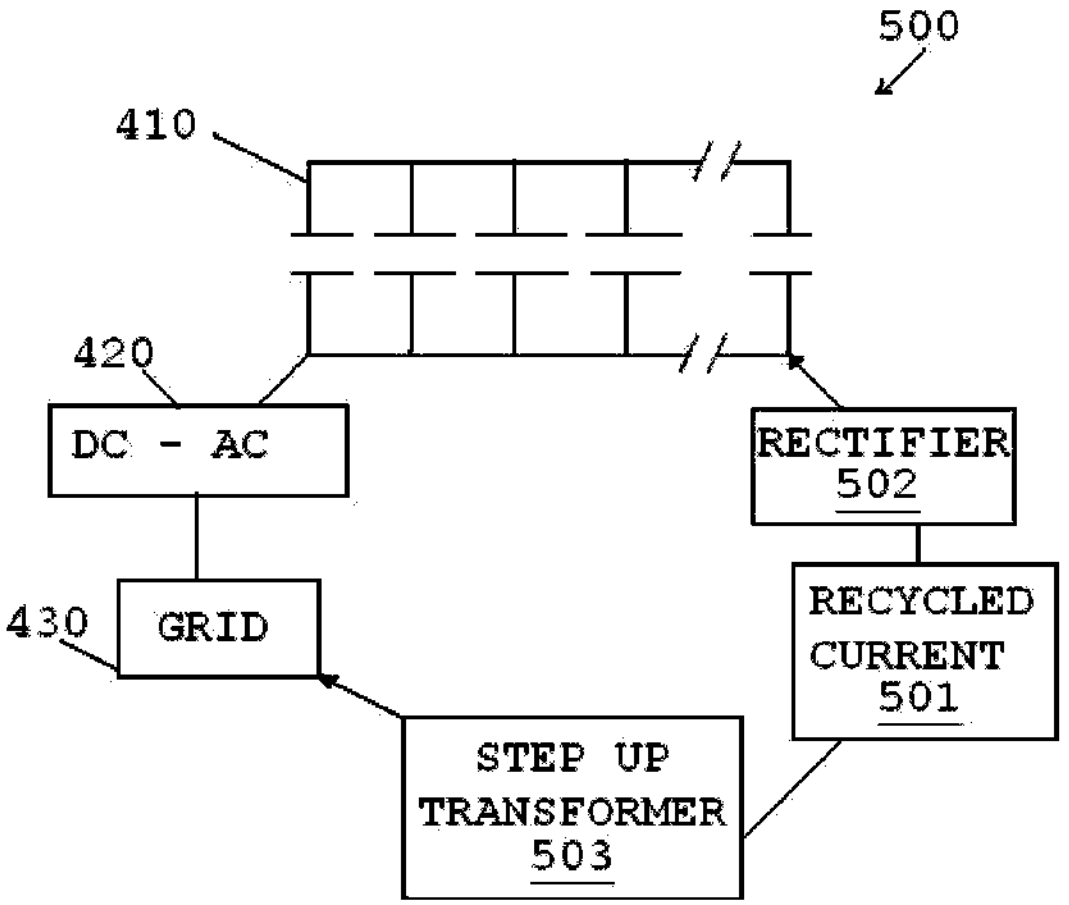
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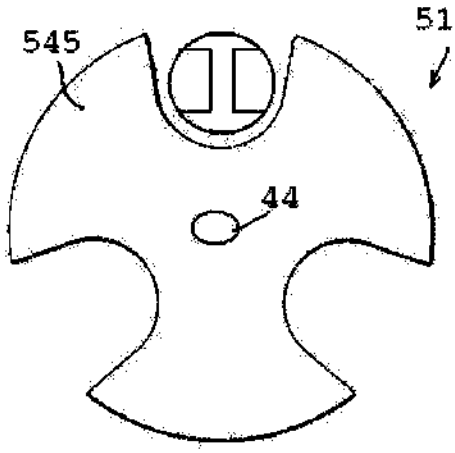

FIG.14

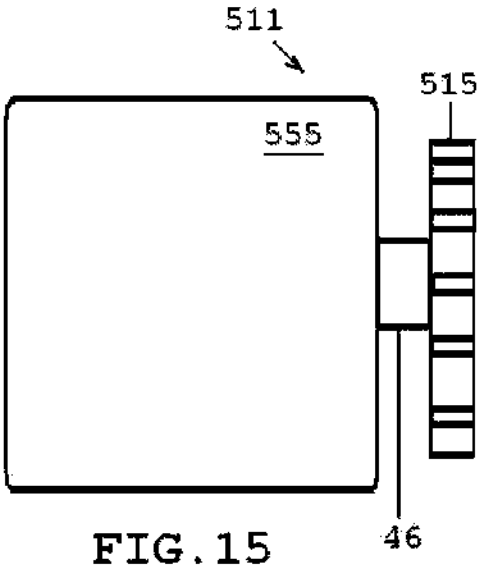

FIG.15

FIG.16

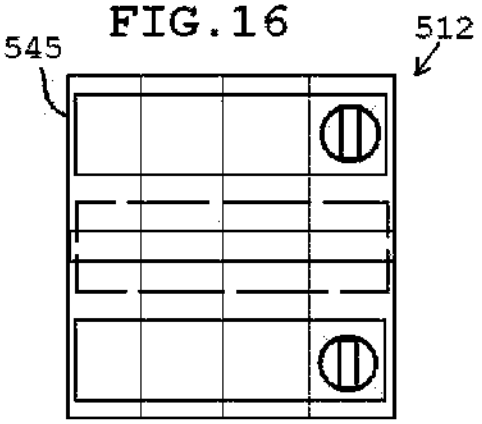

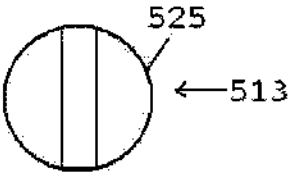

FIG.17

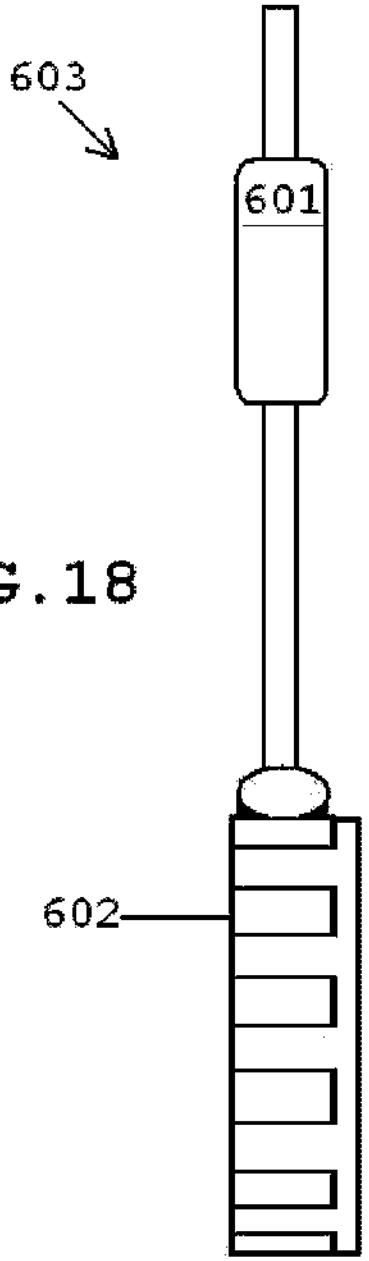

FIG.18

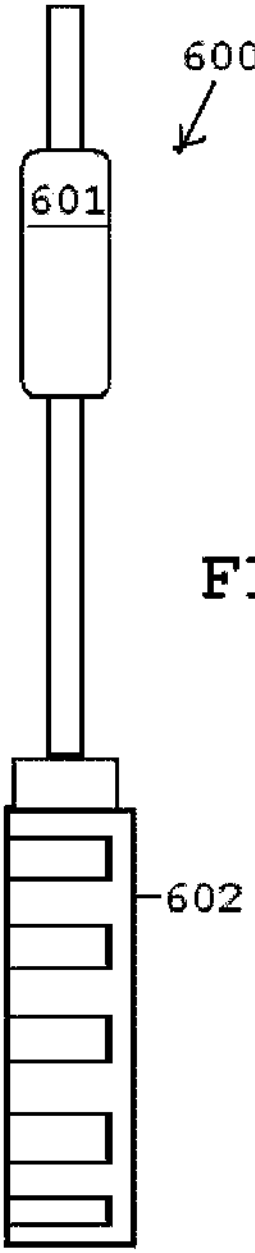

FIG.19

FIG.20

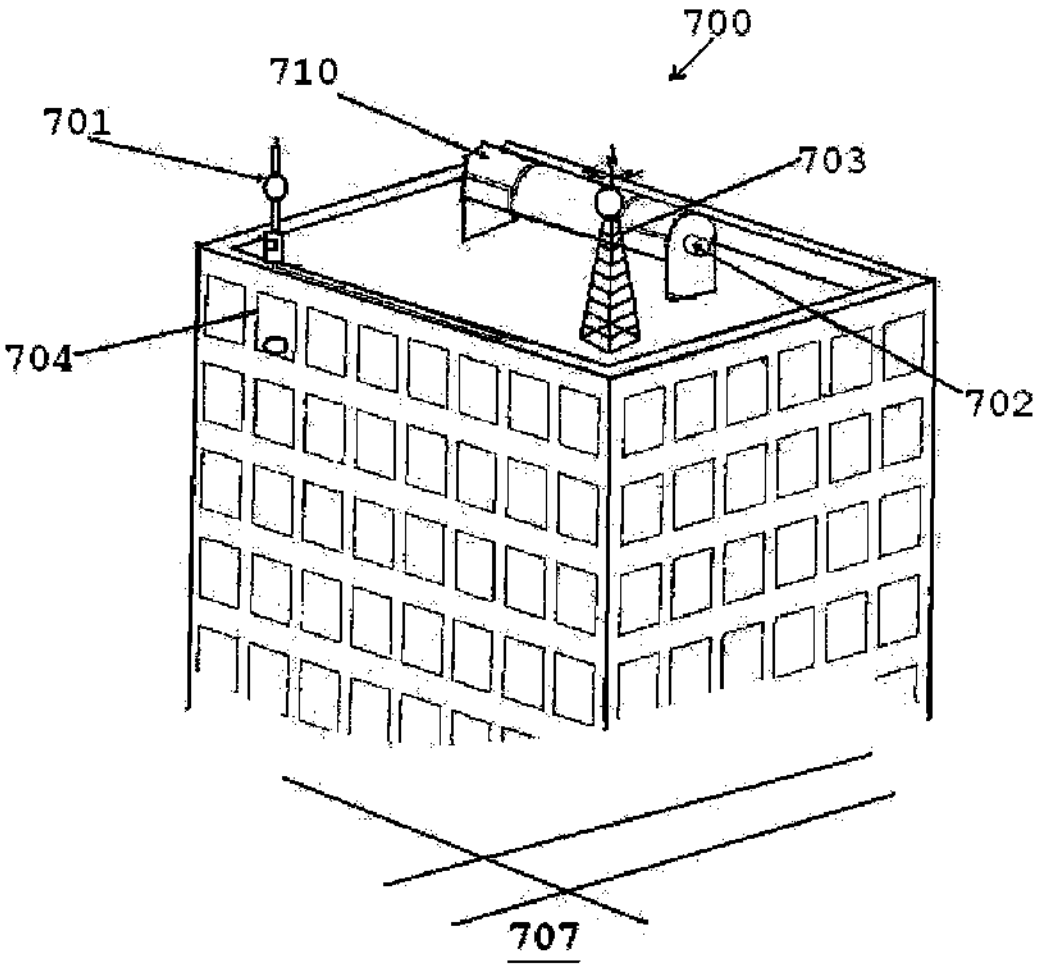

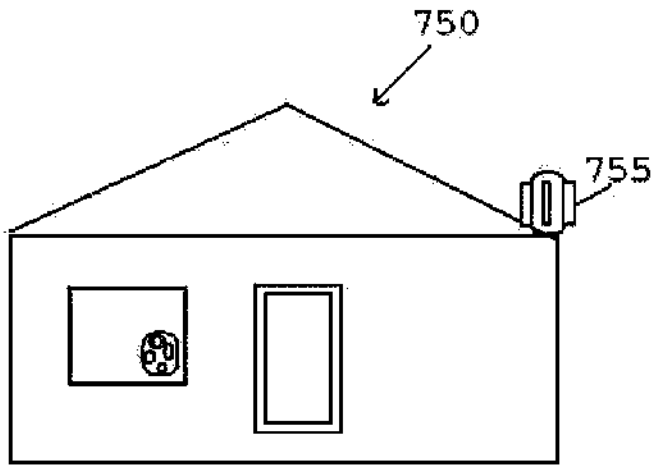

FIG.21

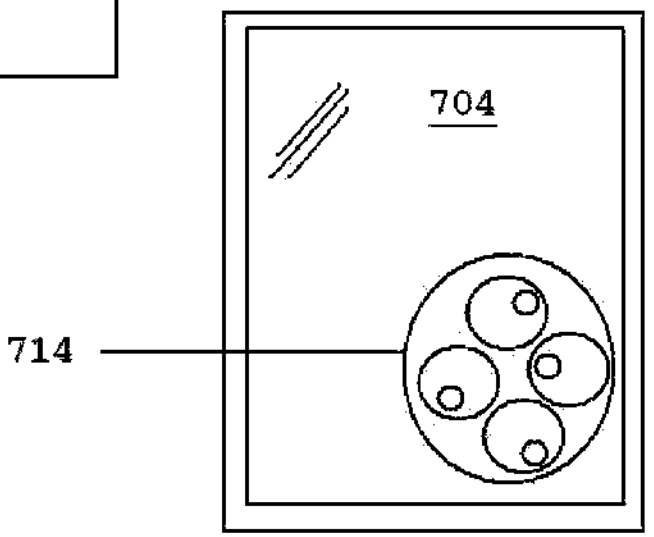

FIG.22

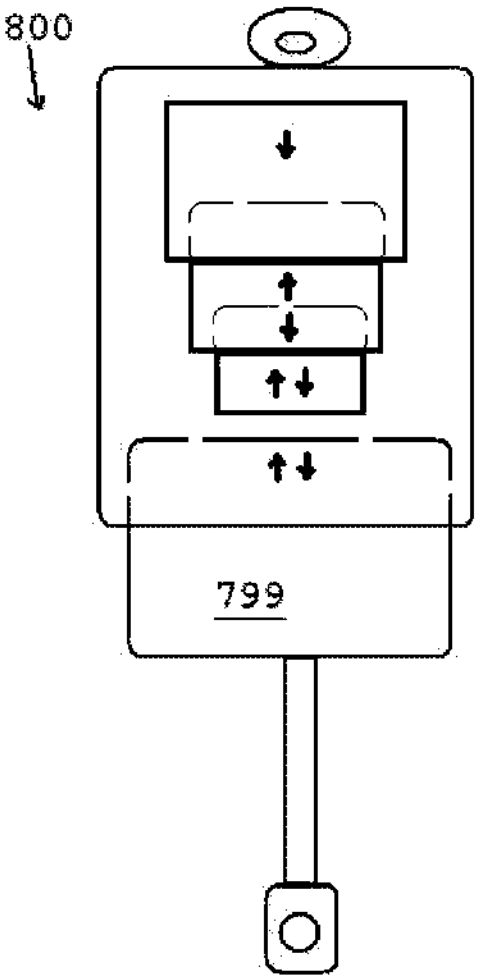

FIG.23

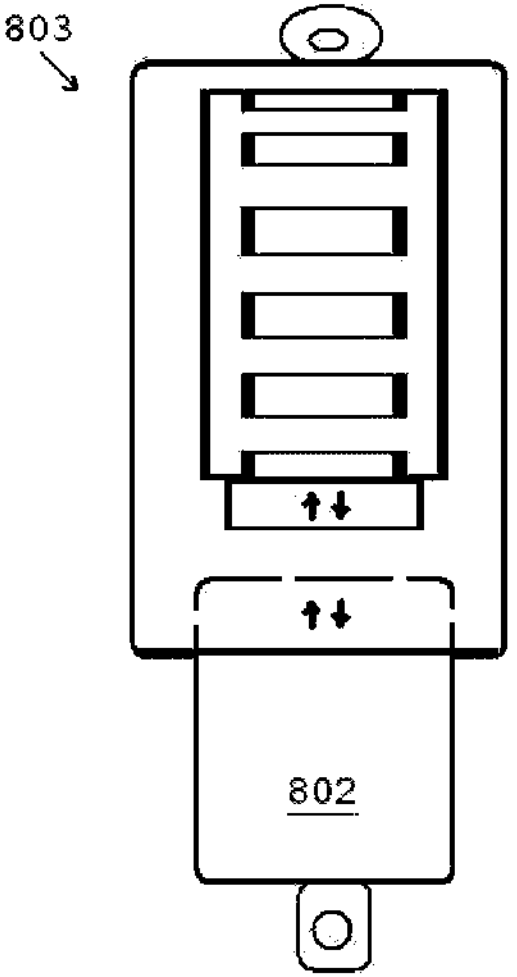

FIG.24

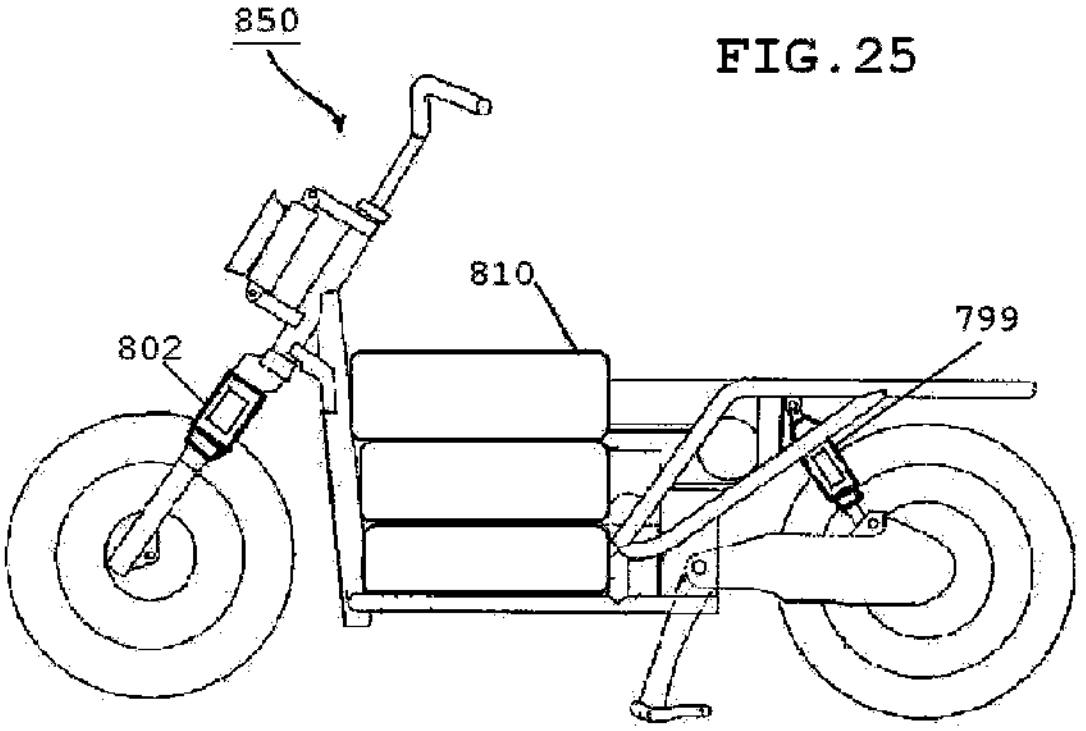

FIG. 25

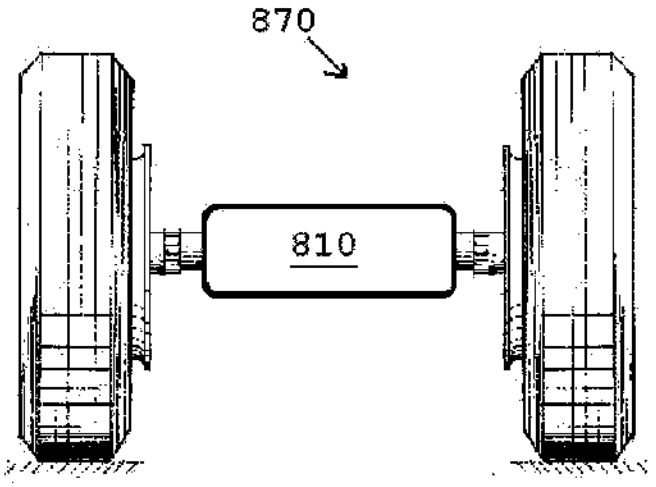

FIG. 26

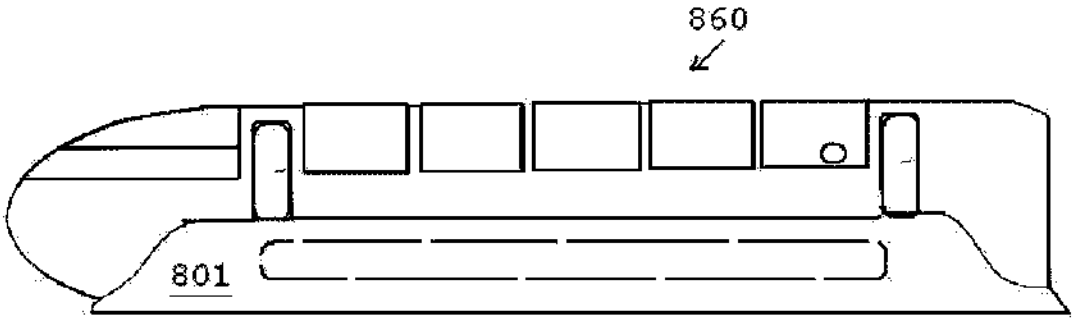

FIG. 27

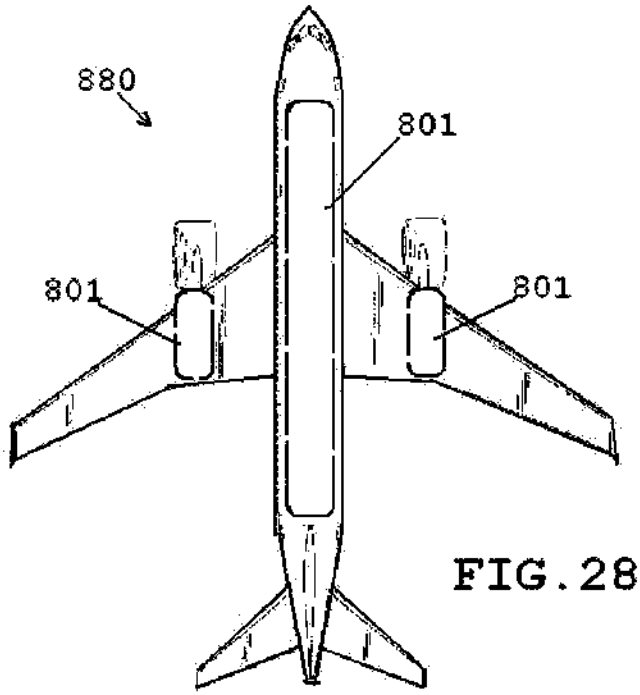

FIG. 28

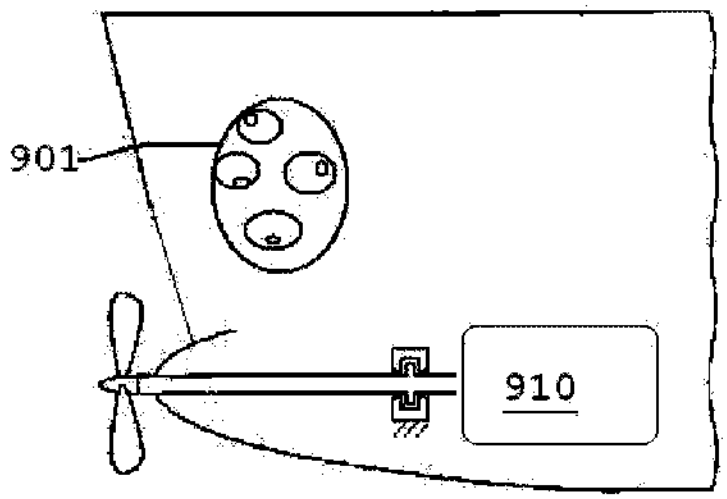

FIG. 29

FIG. 30

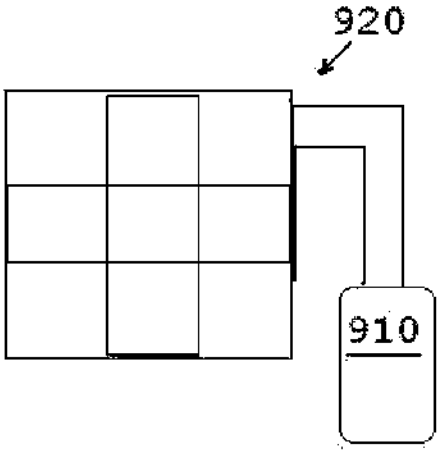

FIG. 31

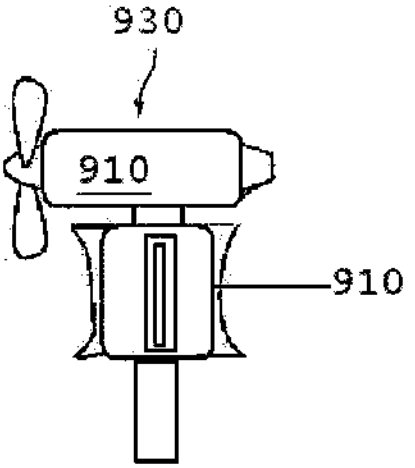

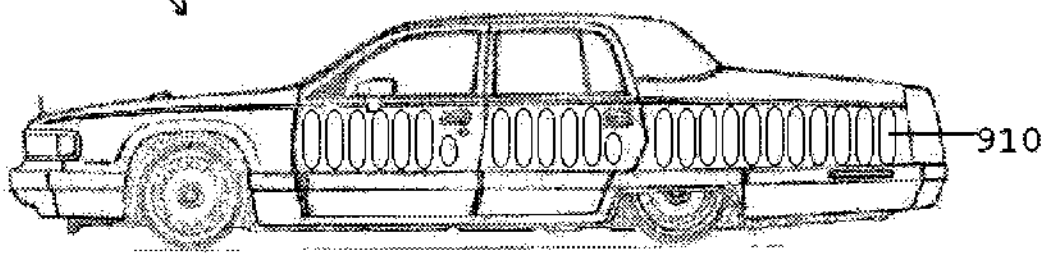

FIG. 32

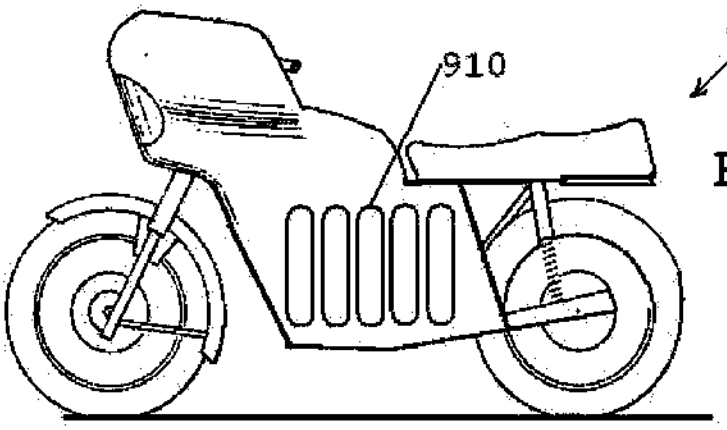

FIG. 33

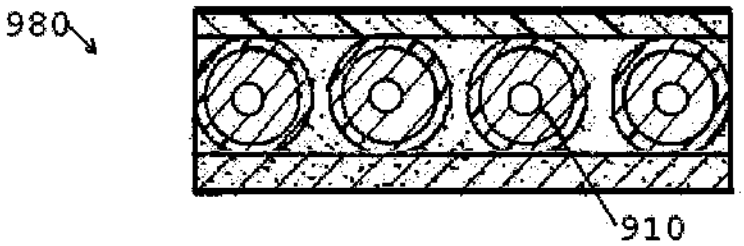

FIG. 34

ATMOSPHERIC TRANSDUCTION SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] NONE

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Self-propelled travel is a type of recreational adventure travel using human powered transport. This includes non-motorized machines such as a bicycle or skateboard. It is in contrast to traveling in a powered vehicle (such as an automobile) as in that case it is the vehicle which powers itself. Self-propelled travel is used to travel short distances or even for much longer distances such as bicycle touring. Self propelled describes something that moves, progresses or acts on its own power without needing outside help. Leonardo da Vinci's 1478 Self-Propelled Car: It was more than 500 years ago, however—sometime around the year 1478 to be more or less specific—when Leonardo drew out his plans for the world's first self-propelled vehicle. Experts originally believed two leaf springs, the simplest form of the spring typically used for automotive suspensions, somehow powered the vehicle. Closer inspection eventually revealed the power came from bigger, coiled springs located in tambours, cylindrical drum-like casings, inside the car's frame. The machine works like a robot or a wind-up toy simply by rotating the wheels opposite of their intended direction, which winds up the springs inside and gives it power. Self propulsion (of a vehicle) provided with its own source of tractive power rather than requiring an external means of propulsion.

[0003] In the middle of the 18th century, Benjamin Franklin's experiments showed that electrical phenomena of the atmosphere were not fundamentally different from those produced in the laboratory. By 1749, Franklin observed lightning to possess almost all the properties observable in electrical machines.

[0004] In July 1750, Franklin hypothesized that electricity could be taken from clouds via a tall metal aerial with a sharp point. Before Franklin could carry out his experiment, in 1752 Thomas-Francois Dalibard erected a 40-foot (12 m) iron rod at Marly-la-Ville, near Paris, drawing sparks from a passing cloud. With ground-insulated aerials, an experimenter could bring a grounded lead with an insulated wax handle close to the aerial, and observe a spark discharge from the aerial to the grounding wire. In May 1752, Dalibard affirmed that Franklin's theory was correct.

Piezoelectric Motor

[0005] A piezoelectric motor or piezo motor is a type of electric motor based upon the change in shape of a piezoelectric material when an electric field is applied. Piezoelectric motors make use of the converse piezoelectric effect whereby the material produces acoustic or ultrasonic vibrations in order to produce a linear or rotary motion. In one mechanism, the elongation in a single plane is used to make a series stretches and position holds, similar to the way a caterpillar moves. A transducer is a device that converts one form of energy to another. Energy types include (but are not limited to) electrical, mechanical, electromagnetic (including light), chemical, acoustic or thermal energy. While the term transducer commonly implies the use of a sensor/detector, any device which converts energy can be considered a transducer. Transducers are widely used in measuring instruments. Piezoelectric materials can also be used to harvest low levels of mechanical energy into electrical energy suitable for powering wireless sensors, low power microprocessors or charging batteries. Rotary Uses include rotating machines such as fans, turbines, drills, the wheels on electric cars, locomotives and conveyor belts. Also, in many vibrating or oscillating machines, an electric motor spins an unbalanced mass, causing the motor (and its mounting structure) to vibrate.

Atmospheric Electricity

[0006] There is always free electricity in the air and in the clouds, which acts by induction on the earth and electromagnetic devices. Experiments have shown that there is always free electricity in the atmosphere, which is sometimes negative and sometimes positive, but most generally positive, and the intensity of this free electricity is greater in the middle of the day than at morning or night and is greater in winter than in summer. In fine weather, the potential increases with altitude at about 30 volts per foot (100 V/m).

Atmospheric Layers

[0007] The electrical conductivity of the atmosphere increases exponentially with altitude. The amplitudes of the electric and magnetic components depend on season, latitude, and height above the sea level. The greater the altitude the more atmospheric electricity abounds. The exosphere is the uppermost layer of the atmosphere and is estimated to be 500 km to 1000 km above the Earth's surface, and its upper boundary at about 10,000 km. The thermosphere (upper atmosphere) is the layer of the Earth's atmosphere directly above the mesosphere and directly below the exosphere. Within this layer, ultraviolet radiation causes ionization. Theories that have been proposed to explain the phenomenon of the polar aurora, but it has been demonstrated by experiments that it is due to currents of positive electricity passing from the higher regions of the atmosphere to the earth.

[0008] The mesosphere (middle atmosphere) is the layer of the Earth's atmosphere that is directly above the stratosphere and directly below the thermosphere. The mesosphere is located about 50-80/85 km above Earth's surface. The stratosphere (middle atmosphere) is a layer of Earth's atmosphere that is stratified in temperature and is situated between about 10 km and 50 km altitude above the surface at moderate latitudes, while at the poles it starts at about 8 km altitude. The stratosphere sits directly above the troposphere and directly below the mesosphere. The troposphere (lower atmosphere) is the densest layer of the atmosphere.

[0009] The planetary boundary layer (PBL), also known as the atmospheric boundary layer (ABL), is the lowest part of the atmosphere and its behavior is directly influenced by its contact with the planetary surface. It is also known as the "exchange layer". (see also: p-n junction.)

[0010] There is a potential gradient at ground level ("Atmosphere ground layer") and this vertical field corresponds to the negative charge in and near the Earth's surface. The negative potential gradient falls rapidly as altitude increases from the ground. Most of this potential gradient is in the first few kilometers. The positive potential gradient rises rapidly as altitude increases from the ground. Volta, over two centuries before the 21st century, discovered with some degree of exactitude that the proportions of the ordinates of the curve or

gradient of electric potential increased as the distance from the earth increases, and, more recently, Engel has provided data to calculate the increase (Image to the right).

Drum-Type Generator

[0011] A drum-type homopolar generator has a magnetic field (B) that radiates radially from the center of the drum and induces voltage (V) down the length of the drum. A conducting drum spun from above in the field of a "loudspeaker" type of magnet that has one pole in the center of the drum and the other pole surrounding the drum could use conducting ball bearings at the top and bottom of the drum to pick up the generated current.

Astrophysical Unipolar Inductors

[0012] Unipolar inductors occur in astrophysics where a conductor rotates through a magnetic field, for example, the movement of the highly conductive plasma in a cosmic body's ionosphere through its magnetic field. In their book, Cosmical Electrodynamics, Hannes Alfvén and Carl-Gunne Fälthammar write:

[0013] "Since cosmical clouds of ionized gas are generally magnetized, their motion produces induced electric fields [. . .] For example the motion of the magnetized interplanetary plasma produces electric fields that are essential for the production of aurora and magnetic storms" [. . .]

[0014] " . . . the rotation of a conductor in a magnetic field produces an electric field in the system at rest.

[0015] This phenomenon is well known from laboratory experiments and is usually called 'homopolar' or 'unipolar' induction.

The Faraday Disc

[0016] The homopolar generator was developed first by Michael Faraday during his experiments in 1831. It is frequently called the Faraday disc in his honor. It was the beginning of modern dynamos—that is, electrical generators which operate using a magnetic field. It was very inefficient and was not used as a practical power source, but it showed the possibility of generating electric power using magnetism, and led the way for commutated direct current dynamos and then alternating current alternators.

Boeing 737-800

[0017] The Boeing Fuel Cell Demonstrator Airplane has a Proton Exchange Membrane (PEM) fuel cell/lithium-ion battery hybrid system to power an electric motor, which is coupled to a conventional propeller. The fuel cell provides all power for the cruise phase of flight. During takeoff and climb, the flight segment that requires the most power, the system draws on lightweight lithium-ion batteries.

[0018] The demonstrator aircraft is a Dimona motor glider, built by Diamond Aircraft Industries of Austria, which also carried out structural modifications to the aircraft. With a wing span of 16.3 meters (53.5 feet), the airplane will be able to cruise at approximately 100 kilometers per hour (62 miles per hour) on power from the fuel cell.

[0019] Nikola Tesla explored the wireless transmission of energy through his work with radio and microwaves and his creation of the Tesla coil and the magnifying transmitter. In 1898, Tesla demonstrated his radio-controlled boat, which he was able to control remotely. In the 1930s, Tesla claimed to have invented a particle beam weapon, or, as some called it, a "peace ray." The device was, in theory, capable of generating an intense, targeted beam of energy and sending it across great distances to demolish warplanes, foreign armies, or anything else you'd rather didn't exist.

[0020] "Roy J. Meyers, British Patent Number 1098"

[0021] This invention relates to improvements in apparatus for the production of electrical currents, and the primary object in view is the production of a commercially serviceable electrical current without the employment of mechanical or chemical action. To this end the invention comprises means for producing what I believe to be dynamic electricity from the earth and its ambient elements.

[0022] Edward Leedskalnin: Magnetic Current—

[0023] The Perpetual Motion Holder is primarily a teaching device but it has many functions including an electromagnet, this is easy enough to see; it is a generator—spin a magnet between the coils it will generate electricity; it functions as a transformer; it demonstrates how permanent magnets are made, and is a holder of perpetual motion.

Strategic Defense Initiative

[0024] The Strategic Defense Initiative (SDI) was proposed to use ground and space-based systems to protect the United States from attack by strategic nuclear ballistic missiles.

Description of the Related Art

[0025] The present invention relates to a ball bearing assembly structure, an electromagnetic clutch having the ball bearing assembly structure, and a gas compressor equipped with the electromagnetic clutch.

[0026] When operating the gas compressor, the electromagnet of the electromagnetic clutch is energized to attract or adsorb the follower armature plate to an end surface of the prime-mover pulley and join the prime-mover pulley and the rotor shaft, thereby rotating the rotor shaft.

[0027] The ball bearing of the electromagnetic clutch conventionally has used one having an even number of balls per row. Generally, the ball bearing causes vibration and noise due to rotation. In the case of the ball bearing rotating while undergoing a radial load due to a tension of the belt, vibration and noise considerably occur. Particularly when other vibration and noise levels are lowered during engine idling, the vibration and noise of the ball bearing transmitted to the vehicular compartment is not negligible.

[0028] The inventor has conducted various experiments and discovered that the one factor of high vibration and noise level is an even number of balls of the ball bearing. In the ball bearing having an even number of balls per one row, the balls are in a facing relation to have linear-symmetry arrangement between the inner race and the outer race. The deformation and vibration at a regular particular frequency is caused in the inner and outer races. It is to be considered that the vibration as a source also increases noise.

[0029] The present invention relates generally and in various embodiments to piezoelectric mechanical systems. More specifically, the present invention relates generally and in various embodiments to atmospheric oscillation transducer apparatuses, systems, and methods.

[0030] Although various implementations of the present invention, among many, may be described herein with reference to the specific illustrative embodiments related to particular applications, those skilled in the art will understand that the invention is not in any way intended to be limited to

such embodiments and/or applications. Those having ordinary skill in the art and reference to the description of the embodiments herein will recognize additional modifications, applications, and other embodiments falling within the scope of the claimed invention and additional fields in which the present invention may be practiced.

[0031] Digital Radio (also known as Satellite Radio or Satellite Digital Audio Radio Service (SDARS)) is a subscriber-based digital radio service that is broadcast via satellites. Digital radio service provides compact-disc (CD) quality programming that may be digitally transmitted via one or more satellites and/or space stations to one or more Earth-based (terrestrial) digital radio stations, receivers, and/or repeaters. In satellite-based direct-broadcast radio services, digitally-encoded audio program material may be broadcast to terrestrial fixed or mobile digital radio receivers. Fixed receivers may include, for example, stand alone digital radio receivers or digital radio receivers connected via computer networks, including for example, the Internet. Mobile receivers may include, for example, digital radio receivers located in automobiles, aircrafts, watercrafts, and the like.

[0032] Satellite-based digital audio radio services such as SDARS, for example, may be broadcast to one or more digital radio receivers either directly from an orbiting satellite, or indirectly from one or more repeater stations. Such repeater stations may be useful where the digital radio receiver is located in a shielded location or where there is no direct line of sight between the radio and the satellite. In other digital audio radio services systems, the audio programs also may be transmitted in digital form by one or more space stations directly to fixed, mobile, and/or portable radio stations. Such systems may comprise, for example, orbiting satellites, complementary repeating terrestrial transmitters, telemetry, tracking, and control facilities.

[0033] Combinations of mechanical devices U.S. Pat. Nos. 4,019,073, 6,615,968 and atmospheric system interaction are disclosed in U.S. Pat. Nos. 1,119,732, 787,412, 6,902,513 to Nikola Tesla; 28,793 to Charles Vion; and U.S. Pat. No. 1,540,998 to Herman Plauson. Lastly, U.S. Pat. No. 8,102,078 and US2008/0009240. Agnoff discloses an Oscillating watch winder in U.S. Pat. No. 6,543,929, Jennings further discloses an oscillating smart device in application No. 13,572,679.

[0034] As illustrated by a large body of prior art, including the above-noted patents, and a large number of commercial devices, efforts are continuously being made in an attempt to improve helmets, headsets and their methods of fabrication. Nothing in the prior art, however, suggests the present inventive combination of materials and method steps as herein described and claimed. The present invention achieves its purposes, objects and advantages over the prior art through a new, useful and unobvious combination of components and method steps which improve safety, comfort and noise abatement performance.

[0035] Therefore, it is an object of this invention to provide Effectively, the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their own needs . . . . Sustainable Energy has two key components: renewable energy and energy efficiency.

[0036] It is still a further objection of this invention to promote Dynamic harmony between equitable availability of energy-intensive goods and services to all people and the preservation of the earth for future generations." And, "the solution will lie in finding sustainable energy sources and more efficient means of converting and utilizing energy.

[0037] It is a further object of the present invention to produce Green Power Energy: is energy that can be extracted, generated, and/or consumed without any significant negative impact to the environment, green power; as electricity produced from solar, wind, geothermal, biogas, biomass, and low-impact small hydroelectric sources.

[0038] Thus, there is a need for a clean energy system that uses atmospheric electricity.

Prior Art

[0039] Quartz crystals have been in regular use for many years to give an accurate frequency for all radio transmitters, radio receivers and computers. Their accuracy comes from an amazing set of coincidences: Quartz—which is silicon dioxide like most sand—is unaffected by most solvents and remains crystalline to hundreds of degrees Fahrenheit. The property that makes it an electronic miracle is the fact that, when compressed or bent, it generates a charge or voltage on its surface. This is a fairly common phenomenon called the Piezoelectric effect. In the same way, if a voltage is applied, quartz will bend or change its shape very slightly.

[0040] If a bell were shaped by grinding a single crystal of quartz, it would ring for minutes after being tapped. Almost no energy is lost in the material. A quartz bell—if shaped in the right direction to the crystalline axis—will have an oscillating voltage on its surface, and the rate of oscillation is unaffected by temperature. If the surface voltage on the crystal is picked off with plated electrodes and amplified by a transistor or integrated circuit, it can be re-applied to the bell to keep it ringing.

[0041] The electronics of the watch initially amplifies noise at the crystal frequency. This builds or regenerates into oscillation—it starts the crystal ringing. The output of the watch crystal oscillator is then converted to pulses suitable for the digital circuits.

Polymers

[0042] Polyvinylidene fluoride (PVDF): PVDF exhibits piezoelectricity several times greater than quartz. Unlike ceramics, where the crystal structure of the material creates the piezoelectric effect, in polymers the intertwined long-chain molecules attract and repel each other when an electric field is applied.

Near Space

[0043] Solar particles become trapped within the Earth's magnetic field and form radiation belts. The Van Allen radiation belt is a torus of energetic charged particles (i.e. a plasma) around Earth, trapped by Earth's magnetic field.

[0044] At elevations above the clouds, atmospheric electricity forms a continuous and distinct element (called the electrosphere) in which the Earth is surrounded. The electrosphere layer (from tens of kilometers above the surface of the earth to the ionosphere) has a high electrical conductivity and is essentially at a constant electric potential. The ionosphere is the inner edge of the magnetosphere and is the part of the atmosphere that is ionized by solar radiation. (Photoionisation is a physical process in which a photon is incident on an atom, ion or molecule, resulting in the ejection of one or more electrons.)

Advantages/Disadvantages

[0045] Energy in electronic elements: Electric potential energy, or electrostatic potential energy, is a potential energy (measured in joules) that results from conservative Coulomb forces and is associated with the configuration of a particular set of point charges within a defined system. The term "electric potential energy" is used to describe the potential energy in systems with time-variant electric fields, while the term "electrostatic potential energy" is used to describe the potential energy in systems with time-invariant electric fields.

[0046] Capacitance is the ability of a body to store an electrical charge. Any body or structure that is capable of being charged, either with static electricity or by an electric current, exhibits capacitance. A common form of energy storage device is a parallel-plate capacitor. In a parallel plate capacitor, capacitance is directly proportional to the surface area of the conductor plates and inversely proportional to the separation distance between the plates. If the charges on the plates are +q and −q, and V gives the voltage between the plates, then the capacitance C is given by

$$C=q/V$$

[0047] The capacitance is a function only of the physical dimensions (geometry) of the conductors and the permittivity of the dielectric. It is independent of the potential difference between the conductors and the total charge on them.

[0048] Piezoelectricity is the combined effect of the electrical behavior of the material:

$$D=\in E$$

where D is the electric charge density displacement (electric displacement), $\in$ is permittivity and E is electric field strength, and

$$\text{Hooke's Law: } S=sT$$

where S is strain, s is compliance and T is stress.

[0049] Polyvinylidene fluoride, or polyvinylidene difluoride (PVDF) is a highly non-reactive and pure thermoplastic fluoropolymer produced by the polymerization of vinylidene difluoride. PVDF is a specialty plastic material in the fluoropolymer family; it is used generally in applications requiring the highest purity, strength, and resistance to solvents, acids, bases and heat and low smoke generation during a fire event. Compared to other fluoropolymers, it has an easier melt process because of its relatively low melting point of around 177° C.

[0050] It has a low density (1.78) and low cost compared to the other fluoropolymers. It is available as piping products, sheet, tubing, films, plate and an insulator for premium wire. It can be injected, molded or welded and is commonly used in the chemical, semiconductor, medical and defense industries, as well as in lithium ion batteries. It is also available as a crosslinked closed cell foam, used increasingly in aviation and aerospace. PVDF has a glass transition temperature (Tg) of about −35° C. and is typically 50-60% crystalline. To give the material its piezoelectric properties, it is mechanically stretched to orient the molecular chains and then poled under tension. PVDF exists in several forms: alpha (TGTG'), beta (TTTT), and gamma (TTTGTTTG') phases, depending on the chain conformations as trans (T) or gauche (G) linkages. When poled, PVDF is a ferroelectric polymer, exhibiting efficient piezoelectric and pyroelectric properties. These characteristics make it useful in sensor and battery applications. Thin films of PVDF are used in some newer thermal camera sensors.

[0051] Copolymers: Copolymers of PVDF are also used in piezoelectric and electrostrictive applications. One of the most commonly-used copolymers is P(VDF-trifluoroethylene), usually available in ratios of about 50:50 wt % and 65:35 wt % (equivalent to about 56:44 mol % and 70:30 mol %). Another one is P(VDF-tetrafluoroethylene). They improve the piezoelectric response by improving the crystallinity of the material.

[0052] While the copolymers' unit structures are less polar than that of pure PVDF, the copolymers typically have a much higher crystallinity. This results in a larger piezoelectric response: d33 values for P(VDF-TrFE) have been recorded to be as high as −38 pC/N versus −33 pC/N in pure PVDF.

[0053] Applications:

[0054] The piezoelectric properties of PVDF are used to advantage to manufacture tactile sensor arrays, inexpensive strain gauges and lightweight audio transducers. Piezoelectric panels made of PVDF are used on the Venetia Burney Student Dust Counter, a scientific instrument of the New Horizons space probe that measures dust density in the outer solar system. PVDF is the standard binder material used in the production of composite electrodes for lithium ion batteries. 1-2% weight solution of PVDF dissolved in N-Methyl-2-pyrrolidone (NMP) is mixed with an active lithium storage material such as graphite, silicon, tin, LiCoO2, LiMn2O4, or LiFePO4 and a conductive additive such as carbon black or carbon nanofibers. This slurry is cast onto a metallic current collector and the NMP is evaporated to form a composite or paste electrode. PVDF is used because it is chemically inert over the potential range used and does not react with the electrolyte or lithium. Piezoelectric elements can be used in laser mirror alignment, where their ability to move a large mass (the mirror mount) over microscopic distances is exploited to electronically align some laser mirrors. By precisely controlling the distance between mirrors, the laser electronics can accurately maintain optical conditions inside the laser cavity to optimize the beam output. Piezoelectric sensors especially are used with high frequency sound in ultrasonic transducers for medical imaging and also industrial nondestructive testing (NDT).

[0055] For many sensing techniques, the sensor can act as both a sensor and an actuator—often the term transducer is preferred when the device acts in this dual capacity, but most piezo devices have this property of reversibility whether it is used or not. Ultrasonic transducers, for example, can inject ultrasound waves into the body, receive the returned wave, and convert it to an electrical signal (a voltage). Most medical ultrasound transducers are piezoelectric.

[0056] Advantageously,

[0057] Sustainable energy is the sustainable provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Technologies that promote sustainable energy include renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, and tidal power, and also technologies designed to improve energy efficiency.

[0058] This sequence of oscillations causes the rotor within the watch to spin rapidly thereby winding the watch in a manner closely simulating the spinning of the rotor that occurs during normal winding of the watch when the watch is

worn by a user. Due to the forces that are exerted, the rotor spins around the watch shaft during the oscillations, as opposed to the partial rotation observed in prior art mechanisms. Therefore, the time required to wind the watch, and the energy required, is substantially reduced. Moreover, since the rotor is spinning about the shaft, as opposed to merely being held in a downward position while the watch is rotated, winding more closely approximating the design mechanism is achieved, thereby putting less wear on the watch.

[0059] This invention relates to satellite communications systems using multiple spot beams from a geosynchronous earth orbit satellite to provide selective coverage of the continental United States and, more particularly, relates to a system having a satellite receiving hub in every spot beam that allows for asynchronous communications between each hub and the satellite for maximizing frequency re-use.

[0060] These purposes, objects and advantages should be construed as merely illustrative of some of the more prominent features and applications of the present invention. Many other beneficial results can be obtained by applying the disclosed invention in a different manner or by modifying the invention within the scope of the disclosure. Accordingly, other purposes, objects and advantages as well as a fuller understanding of the invention may be had by referring to the summary herein mentioned and detailed description describing the preferred embodiments of the invention, in addition to the scope of the invention, as defined by the claims, taken in conjunction with the accompanying drawings.

SUMMARY OF THE INVENTION

[0061] In one general respect, an embodiment of the present invention is directed to a system. The system includes a Power Frequency broadcast station, a receiver, and a network. The Power Frequency broadcast station includes a transmitter and a server. The receiver is in communication with the Power Frequency broadcast transmitter and also includes a user interface for receiving user input commands comprising a request for information from the Power Frequency broadcast station.

[0062] The receiver is configured to establish a two-way communication path between the receiver and the Power Frequency broadcast transmitter. The network is in communication with the server and the receiver for exchanging information therebetween. The request for information is provided to the server via the network and the server is configured to receive the request and transmit a response message to the receiver in accordance with the request.

Continuously Outboard Recharged Electric Vehicle (COREY)

[0063] Given suitable infrastructure, permissions and vehicles, BEVs (battery electric vehicles) can be recharged while the user drives. The BEV establishes contact with an electrified rail, plate or overhead wires on the highway via an attached conducting wheel or other similar mechanism (see Conduit current collection). The BEV's batteries are recharged by this process—on the highway—and can then be used normally on other roads until the battery is discharged. Some of battery-electric locomotives used for maintenance trains on the London Underground are capable of this mode of operation. Power is picked up from the electrified rails where possible, switching to battery power where the electricity supply is disconnected.

[0064] The present invention is directed to overcome the disadvantages of the prior art. The invention is a mechanism which taps into the naturally occurring static electricity in the atmosphere. Whereas heretofore, the attempt to garner electricity from the atmosphere has focused exclusively on capturing lightning, the present invention syphons off the static electricity which is generated from any agitated air and voids lightning.

[0065] Lightning is only the final discharge of the static electricity, whether that lightning is intra-cloud lightning, cloud-to-ground lightning, or inter-cloud lightning. Other types of final discharges are known as heat lightning, summer lightning, sheet lightning, ribbon lightning, silent lightning, ball lightning, bead lightning, elves, jets, and sprites. Well before these discharges are observed, as the atmosphere becomes agitated by wind or thermal, static electricity is being generated. The present invention recognizes that this static electricity is being formed and creates a mechanism to capture it.

[0066] In the preferred embodiment, a sensor array is used to monitor the activities both at the base unit (such as electrical flow within the conductor) and in the surrounding locale. A sensor monitoring the electrical flow (i.e. voltage and/or current) within the conductor is used to monitor the electrical activity within the conductor.

[0067] In the preferred embodiment, a lightning sensor monitors for lightning activity within the locale. As noted earlier, the electrical characteristic of lightning is so extreme that ideally this discharge is avoided as it might damage the mechanism of this invention. The sensor array is utilized by a controller, such as microprocessor, programmed to operate the mechanism as outlined herein.

[0068] The controller operates the winch motor to extend or withdraw the conductive line and by extension the altitude of the balloon. The controller is programmed to operate the winch by monitoring the electrical characteristics of the conductor and adjusting the balloon's altitude to maintain these characteristics within the conductor within a preset range.

[0069] This preset range is established either in the base programming of the controller or is established by an operator of the system. As example, by controlling the amount of current being withdrawn from the atmosphere, the mechanism operates within a safe range and also provides a relatively stable current flow from which a variety of activities can take place (such as DC-AC conversion).

[0070] The controller also utilizes the lightning sensor to protect the mechanism from a lightning strike. Should lightning be detected within a pre-determined range (as established by the software or defined by an operator), then the balloon is pulled down to minimize the risk of damage from a lightning strike.

[0071] Another aspect of the invention relates to the electrical system which accepts the fluctuating atmospheric charge and changes it into an acceptable configuration for either the desired load or for the existing power grid.

[0072] Power grids in the United States operate with a frequency of 60 hertz in an alternating current arrangement. While this basic configuration seems to be universally accepted, the voltage within the grid varies dramatically, such as 15 kv, 34 kv, 69 kv, and even 112 kv.

[0073] Each atmospheric generator is placed proximate to or within easy access to a specific grid; this establishes the required electrical output configuration (i.e. that which is accepted by the power grid). As example, one of the atmo-

spheric electrical collector units as described above collects the atmospheric electrical power as direct current and then supplies the appropriate power grid a specific flow (as example, AC, 60 hertz, at 69 kv).

[0074] The difficulty lies the fact that the DC current being garnered from the atmosphere varies depending on the actual agitation being generated in the atmosphere. This means that the source of DC current is fluctuating.

[0075] The present invention uses a monitoring system which checks the input DC voltage. Depending on the actual voltage being received, the appropriate converter is connected to the input DC voltage so that the desired output is obtained.

[0076] As example, suppose the DC input voltage is 1500 volts, the monitoring system, sensing this input, closes the switch connecting the DC voltage to a converter which accepts DC voltage in the range of 1000-2000 volts which then delivers an AC, 60 hertz 69 kv signal to the power grid. If the DC input voltage increases to 2100 volts, then the monitoring system opens the switch to the first converter (1000-2000 volts) and closes the switch to a second converter (such as 2000-4000 volts) to deliver the desired output of AC (60 hertz, 69 kv) for the power grid.

[0077] In this manner, regardless of the fluctuating input DC voltage, the electrical grid is supplied with a fully configured electrical input conforming to the needs of that specific electrical grid.

[0078] Another aspect of the present invention is the use of a tower or permanent structure instead of an aircraft. In this embodiment, the building or tower is electrically isolated from the ground and a rod (similar to a lightning rod) is extended into the atmosphere. The rod collects the atmospheric charge which is conveyed via an electrical conduit (ideally insulated) where the collected DC charge is reconfigured to meets the need of the locale.

[0079] In this context, for one embodiment of the invention, a tower is placed onto the top of a building. The tower is electrically isolated from the building using such mechanisms well known to those of ordinary skill in the art such as rubber mats. A rod ideally extends from the top of the tower to facilitate the collection of the DC electrical energy.

[0080] Piezoelectricity is a material property that is manifested when voltage is produced by applying mechanical forces, and vice versa, the effect has been described as direct and converse. Piezoelectricity has been described as coupling between a quasi-static electric field and dynamic mechanical motion.

[0081] A piezoelectricity converter mechanism such as described above, is connected to the tower to flow the DC electricity to a converter which modifies the DC current for the specific application. In one application, the DC current is converted to the electrical needs of the building, thereby providing at least some of the electrical requirements of the building itself.

[0082] As noted earlier, the dynamic converter system of the present invention allows a power generator to address a variable voltage in an efficient manner. This makes the dynamic converter system ideal for a variety of alternative energy sources such as the above described atmospheric electrical generator and other alternative energy sources such as wind and wave powered systems. In these systems, the energy being generated must be converted to a proper electrical configuration for a identified load. This may be a particular motor or connection to the power grid which act as a load to the power generating mechanism.

[0083] For these energy generating systems, the converter assembly of this invention utilizes multiple converters. Each converter is configured to accept a unique range of voltages and from these voltages, create the desired electrical configuration. By using multiple converters, a full range is available, from a minimum voltage input to a maximum voltage input.

[0084] The present invention can include systems and methods for integrating sensors for tracking atmospheric transducer system performance metrics into media devices and accessories therefor, thereby reducing or eliminating the need for additional independent monitoring devices. In one embodiment of the present invention.

[0085] It also is known to provide such transducers with connectors to allow their rechargeable batteries to be charged. In some cases, the connector is a Universal Serial Bus (USB) connector, allowing the transducer to be charged by plugging it into the USB port of a computer, grid circuit or other device.

[0086] These and other objects and advantages of the invention will appear more clearly from the following description in which the preferred embodiment of the invention has been set forth in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0087] FIG. **1** Prior Art depicts perspective view of Electric currents created in sunward ionosphere;

[0088] FIG. **2** is a box flow chart of the propulsion cycle systems present invention;

[0089] FIG. **3** is an top view of the piezoelectric disk cylinder orb of the present invention;

[0090] FIG. **4** is a longitudinal sectional view showing an embodiment of this invention;

[0091] FIG. **5** is a top view of the (ATS) slip rotor piezoelectric chamber of the present invention;

[0092] FIG. **6** is an alternate top view of the piezoelectric cylinder orb of the present invention;

[0093] FIG. **7-10** elevation views of spine piezo stacks embodiments of the present invention;

[0094] FIG. **11** illustrates one embodiment of a power service (ATS) system architecture;

[0095] FIG. **12** is a block diagram of the ATS charge schematics systems of the present invention;

[0096] FIG. **13** is a block diagram of an ATS charge and recycle schematics of the present invention;

[0097] FIG. **14** is a view of the piezoelectric ball race cylinder of the present invention;

[0098] FIG. **15** is a view of the piezoelectric housing and gear of the present invention;

[0099] FIG. **16** is a view of a multiple piezoelectric ball race cylinder of the present invention;

[0100] FIG. **17** is another embodiment of the piezoelectric stack ball of the present invention;

[0101] FIGS. **18** & **19** are antenna rod transmit device embodiments of the (ATS) present invention;

[0102] FIG. **20** illustrates substation embodiment of the power service (ATS) system architecture;

[0103] FIG. **21** illustrates a home embodiment of the power service (ATS) system architecture;

[0104] FIG. **22** illustrates a window embodiment of the power service (ATS) system architecture;

[0105] FIG. **23** is (ATS) shock device in accordance with an embodiment of the present invention;

[0106] FIG. **24** is (ATS) shock device in accordance with an embodiment of the present invention;

[0107] FIG. **25** is (ATS) motorcycle device embodiment of the present invention;

[0108] FIG. **26** is (ATS) axle device in accordance with an embodiment of the present invention;

[0109] FIG. **27** is (ATS) train device in accordance with an embodiment of the present invention;

[0110] FIG. **28** is (ATS) plane device in accordance with an embodiment of the present invention;

[0111] FIG. **29** is (ATS) boat device in accordance with an embodiment of the present invention;

[0112] FIG. **30** is (ATS) solar device in accordance with an embodiment of the present invention;

[0113] FIG. **31** a (ATS) turbine device in accordance with an embodiment of the present invention;

[0114] FIG. **32** is (ATS) auto body panel device embodiment of the present invention;

[0115] FIG. **33** is (ATS) motorcycle body fairing panel device in of the present invention; and

[0116] FIG. **34** is (ATS) cross section view of body embed panel device of the present invention.

DETAILED DESCRIPTION

[0117] This sequence of oscillations causes the conductive rotor within piezoelectric molded housing device to spin rapidly thereby winding the mechanism in a manner closely simulating the spinning of the conductive rotor that occurs during normal electric activity when the device is activated. Due to the forces that are exerted, the conductive rotor spins around the piezoelectric cylinder device shaft during the oscillations, as opposed to the partial rotation observed in prior art mechanisms. Therefore, the time required to charge the Atmospheric Transduction System (ATS) device, and the energy required, is substantially reduced. Moreover, since the rotor is spinning about the shaft, as opposed to merely being held in a downward position while the ATS device is rotated, recharging more closely approximating the design mechanism is achieved, thereby putting less wear on the ATS chamber device Innovative Piezoelectric housing and ball bearing, coupler and book spine stacks. There relies the notion of negative ground electricity and positive aerial electricity which is in abundance. This invention substantiates land vehicles recycle recharge by reverse oscillation. Aerial vehicles recycle recharge by forward oscillation in accumulation of environmental positive and negative electricity. These aforementioned activities are integral or synchronous with frequency.

[0118] Prior Art FIG. **1**

[0119] Electric currents created in sunward ionosphere. FIG. **2** is a recycle box flow chart **49** of a self propulsion unit consisting of a battery **27**, engine **29** and piezoelectric transducer **33** unit. FIG. **3** is a multiple disk **31** load part **51** about a 360 degree cylinder **45** and shaft **44**. FIG. **4** is a piezoelectric molded device **100** housing **110** containing a ball bearing race **104**, disk stacks capacitor **102** and conductive rotor **46**. FIG. **5** is a piezoelectric chamber **120** configuration including a counterweights **50**, shaft **44**, conductive slip rotor **106**. FIG. **6** is an alternate part **200** chamber cylinder **201** embodiment containing piezoelectric spine disk stack capacitors **102**. FIG. **7-10** are variations of spine **107**,**108**,**109**,**110** case piezoelectric stack capacitor **102** with plate and ball heads. FIG. **11** Various embodiments of the present invention, among others, will now be described with reference to the accompanying drawings. Accordingly, FIG. **11** illustrates an embodiment of a Atmospheric Transduction (ATS) System **300** architecture. The system **300** may include, for example, a satellite broadcast station **318** that transmits signals **333** containing frequency content from a geostationary satellite **312** by way of airplane antenna **326**. In turn, the satellite **312** transmits line-of-sight (LOS) signals **333** to one or more ATS terrestrial frequency power receiver farms **314**. The system **300** also may include one or more terrestrial repeaters **316** which receive and retransmit the satellite signals **333** as repeater signals **323** to facilitate reliable reception in geographic areas where LOS reception from the satellite **312** is obstructed by tall buildings, hills, tunnels, and other similar impediments to the signals **333**. The ATS receivers **314** maybe designed to receive one or more signals **333** from the satellite **312** and/or from the terrestrial repeater transceiver **316**. In operation, such ATS receivers **314** may receive both the satellite signals **333** and the repeater signals **323**. The receivers **314** also may be located in mobile environments **320**, **321**, **322** which include, but are not limited to, land vehicles **321**, **322**, aircraft **320**, watercraft **900**, and handheld devices, among others. The receivers **314** also may be fixed in stationary units for residential use (e.g., home **325**,**750** entertainment, etc.) or commercial **314**, **328**,**360** use (e.g., business **314**, office **700**, security **328**, etc.). The power frequency broadcast station **318** also may be in communication with a grid network **342**. Two-way communication between the ATS receivers **314** and the power frequency broadcast station **318** may occur via the network **342**. Furthermore, information feedback from the power frequency broadcast station **318** may be transmitted to the ATS receiver **314** both by way of the network **342** as well as via the satellite **312**. Information also may be transmitted to the power broadcast station **318** wirelessly via a wireless network **342**,**707** by way of transducer tower **360**.

[0120] Further disclosed in FIG. **12** and FIG. **13** (in block diagrams **400**, **500**) are electrical schematics for handling the static charge from the atmosphere. By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **12**, and **13** illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations which will serve the same function.

[0121] Referencing FIG. **12**, Direct Current In (DC IN) **401** is buffered by a gang of capacitors **410** before being communicated to a DC/AC converter **420**. The DC/AC converter **420** converts the direct current into a an alternating current suitable for placement over an existing electrical grid **430** such as normally found from a power-plant. FIG. **12** Also illustrates an electrical arrangement suitable for use in charging a battery **440**. DC IN **401** is buffered by capacitor **410** bank before entering into a step down transformer **435**. Step down transformer **435** reduces the voltage so that the voltage can safely be introduced into battery **440** which is connected to ground **450** at the battery's other pole. In FIG. **12**, DC IN **401** is fed into an adjustable rheostat **460** which is controlled by the controller **465** so that the DC OUT **470** falls within a computer **475** monitored and sensor **480** specified range. FIG. **13** Hypothetically, unused energy may be recycled current **501** and/or recaptured by reversing the oscillated spin rotation of devices **51**, **100**, **120** with the use of a rectifier **502** and Step up transformer **503**, returned to grid **430** capacitor **410**. This theory lends itself to the concept of positive and negative frequency. FIG. **14-17** Self charging propulsion embodiment of the invention where Da Vinci's ball race **510**,**512** is com-

bined with a disk cylinder **45** and **513** stack balls **525**, conductive rotor **46**, **511** tooth gear **515** and piezoelectric molded housing **555**. FIGS. **18** & **19** Improvement structures Franklin's lightening rod **600**,**603** and a molded vibration transducer **601** quasi replicating Vion's tubes and piezoelectric spine stacks capacitor **602** improving Tesla's Atmospheric transmit device. FIG. **20** is an atmospheric receiving building sub station **700** where energy is consumed and excess rendered to the grid **707** by conductive rotor **702** transducer **710**, tower transducer **703**, antenna rod **701** and transducer windows **704**.

[0122] FIG. **12** and FIG. **2** flowchart illustration also includes battery **440**. Battery **440** may provide electrical power to components of ATS devices within FIG. **11**. Charging circuitry may also be provided to charge battery **440** when an external power supply is connected to an ATS device **100**. FIG. **14-17** eliminates one or more steps by presenting a self charge retaining transducer **510-513** may be configured with an accelerator sensor **480** controller **465** and gears **515**, provide reciprocal power incorporated within piezoelectric molded and ceramic housing **555** along with stack balls **525** and cylinder **545**. This assembly more resembles a motor by characteristics given power with application.

[0123] In operation, as illustrated in FIGS. **2-20** and FIGS. **21-34**, is periodically energized by movement to rotate Orb in either a clockwise or counterclockwise direction. The length of time or activity is energized, and the length of time between the period when the capacitor **31**, **102** battery is energized, will depend on the particular ATS device design. As the Orb rotates, the outer end of the disk moves along a 360° circular pathway to push against with forward and rearwardly spinning. Upon engagement of the Orb, ATS device disk is rotated until carried to the apex or top of the circular pathway. Upon reaching the apex, the gravitational and vibrational force or counterweight **50** promotes additional oscillation. ATS device movement rapidly rotate on Orb at a rotational speed greater than the speed of rotation of Orb. Counterweight **50** is then carried beyond the bottom or lowest point of the pathway by its momentum to a point near the apex on the opposite side of the pathway. The cycle is repeated through multiple increasing oscillations of the ATS device until counterweight **50** stops at the bottom position, or until once again engages to again move counterweight to the top of its circular pathway.

[0124] FIG. **2** is a flow chart showing generation of energy using a rotor according to one or more of the above-described embodiments. First, battery **27** starts the engine **29** and/or mobile transducer **33** is oscillated. In response to this acceleration, forces are imposed on one or more rotation piezoelectric devices. In response to those forces, the piezoelectric devices output electrical energy, which energy is extracted at a power controller **465**. The power controller **465** sensor **480** then makes this energy available to recharge a capacitor **410** battery **440** and/or to electronic components of the mobile terminal. Although FIG. **2** shows a serial flow of events, it is to be appreciated that the events of blocks **33**, **27** and **29** occur substantially instantaneously upon acceleration of the mobile terminal.

Preferred Alternate Embodiments

[0125] The present invention (ATS) device in accordance with an embodiment of the present invention overcomes the foregoing problem in the conventional art and provides an electro energy vibration and alternative to gas, oil or fossil fuel consumption in FIG. **21** homes **750** transducer **755**, FIG. **28** airplane **880** transducer **801**, FIG. **27** train **860** transducer **801**, FIG. **32** auto **950** transducer **910**, FIG. **25** and FIG. **33** motorcycles **960**,**850** transducers **799**, **802**, **810**, **910** and FIG. **29** boat **900** transducers **901**,**910**.

[0126] In order to solve the foregoing problems in the conventional art, the present invention provides an electro transducer having a ball bearing assembly which is compatible with FIG. **26** axle shaft **44** transducer **810** wheel **870** assembly. In order to solve the foregoing problems in the conventional art, the present invention provides an electro transducer having an FIG. **34** housing panel **980** transducer **910** assembly which is compatible with an exterior body assembly. Thereby, an Atmospheric transducer device may be shock **800** integrated as within the FIG. **23** coupler **802**, and FIG. **24** ladder **799**, (vertical friction) piezoelectric absorbers assemblies. In order to solve the foregoing problems in the conventional art, the present invention provides an electro transducer having a capable flat assembly which is compatible with FIG. **22** window **704** disk **31** plate transducer **714**, FIG. **30** solar panel **920** transducer **910**, FIG. **31** wind turbine **930** transducer **910** assembly. This invention provided FIG. **3** piezoelectric plate disks **31**, FIG. **7-10** spine piezoelectric disks stacks **107-110** capacitor **102**, FIG. **17** piezoelectric stack balls **525** capacitor, the arrangement of balls **525** will not be in a facing relation. The deformation in the inner and outer races during rotation of the ball bearing while undergoing a radial load is made irregular and complicated. The spine eliminates the deformation and vibration level increased by a combination of ceramic and molded piezoelectric materials at a regular predetermined frequency thereby multiplying the level of vibration and noise reduction.

[0127] Certain modifications and improvements will occur to those skilled in the art upon a reading of the foregoing description. It should be understood that all such modifications and improvements have been deleted herein for the sake of conciseness and readability but are properly within the scope of the following claims.

[0128] Thus it is seen that an atmospheric transducer device may be integrated and/or provided. It will be understood that the foregoing is only illustrative of the principles of the invention, and that various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention, and the present invention is limited only by the claims that follow.

1-3. (canceled)

4. An atmospheric transduction system comprising:

means for recycle recharge by oscillation and frequency in accumulation of environmental positive and negative electricity, maintaining the voltage being collected in a prescribed range, providing an electrical conversion broadcast network; and

means for collecting the atmospheric electrical power as direct current and then supplies the appropriate power grid, transceiver and capacitates a charge; and

means for self charging propulsion provides motor characteristics, and frequency engine.

5. The atmospheric transduction system in accordance with claim **1**, wherein said means for recycle recharge by oscillation and frequency in accumulation of environmental positive and negative electricity, maintaining the voltage being collected in a prescribed range, an electrical conversion broadcast network comprises piezoelectric transducer molded device(s), rotor, stack ball bearing, coupler, book spine stacks and antenna rod stacks;

wherein said means for collecting the atmospheric electrical power as direct current and then supplies the appropriate power grid and capacitates a charge comprises a piezoelectric network, piezoelectric grid, piezoelectric spine stack antenna, piezoelectric transmitters, piezoelectric receivers, piezoelectric devices, piezoelectric cylinders and orbs, power frequency broadcast;

wherein said means for charging providing motor characteristics, said power frequency engine comprises a sensor accelerator, rotor/gear, battery/capacitor, antenna, controller, for propulsion.

6. An atmospheric transduction system comprising:

a piezoelectric transducer molded device(s), rotor, spine ball bearing, coupler and book spine stack transducers, for recycle recharge by oscillation and frequency in accumulation of environmental positive and negative electricity, maintaining the voltage being collected in a prescribed range, providing an electrical conversion broadcast server network; and

a piezoelectric network, piezoelectric grid, piezoelectric spine stack antenna, piezoelectric transmitters, piezoelectric receivers, piezoelectric devices, piezoelectric cylinders and disc orbs, stack rods, power frequency broadcast, for collecting the atmospheric electrical power as direct current and then supplies the appropriate power grid, transceiver and capacitates a charge; and

a sensor accelerator, rotor/gear, battery/capacitor, controller, antenna, means for self charge propulsion providing motor characteristics, thereby an engine of power frequency.

* * * * *

(No Model.)

M. W. DEWEY.

METHOD OF UTILIZING NATURAL ELECTRIC ENERGY.

No. 414,943. Patented Nov. 12, 1889.

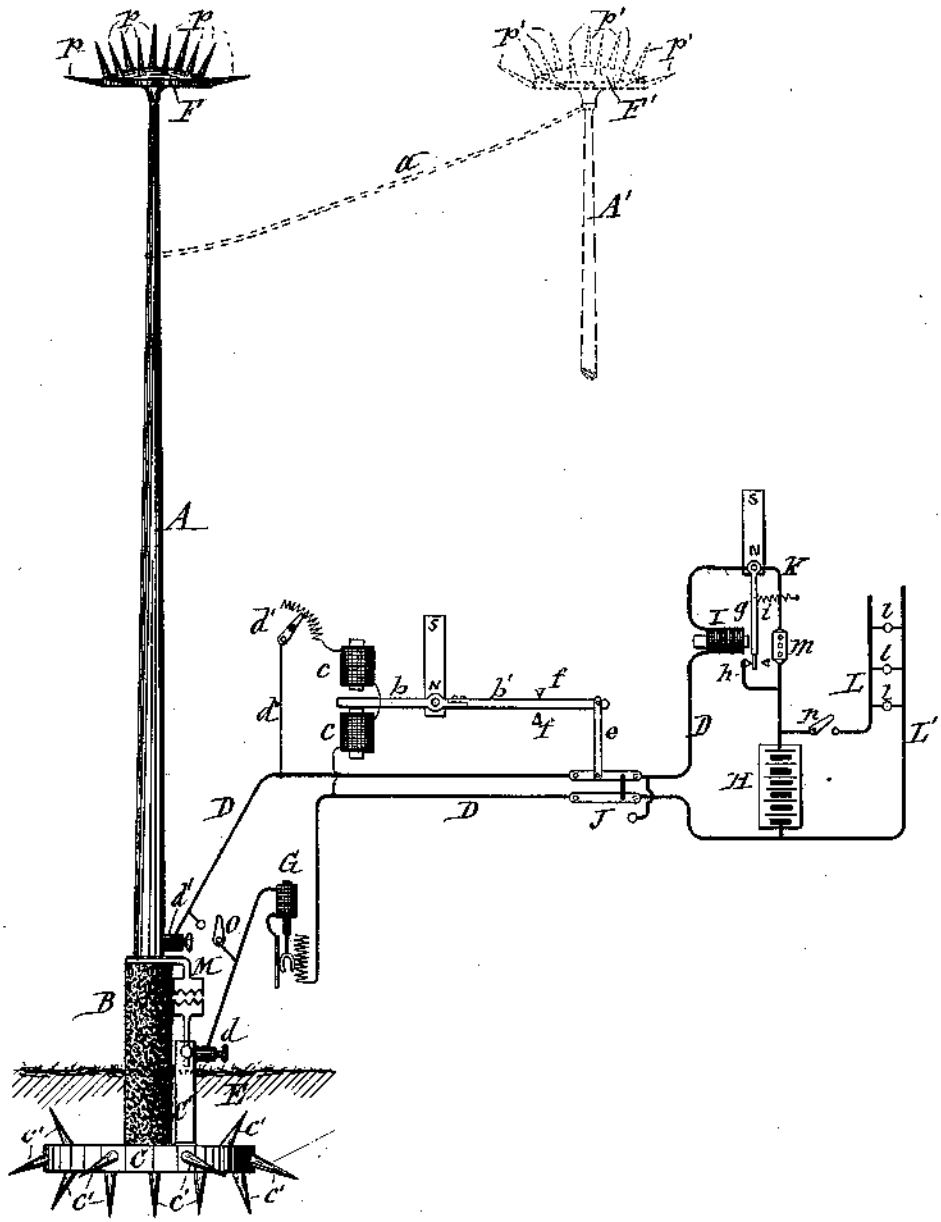

WITNESSES:

C. L. Bendixon

A. F. Walz.

INVENTOR

Mark W. Dewey

BY

Dull, Lacey & Dull

ATTORNEYS

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

MARK W. DEWEY, OF SYRACUSE, NEW YORK, ASSIGNOR TO THE DEWEY CORPORATION, OF SAME PLACE.

METHOD OF UTILIZING NATURAL ELECTRIC ENERGY.

SPECIFICATION forming part of Letters Patent No. 414,943, dated November 12, 1889.

Application filed May 1, 1889. Serial No. 309,171. (No model.)

To all whom it may concern:

Be it known that I, MARK W. DEWEY, of Syracuse, in the county of Onondaga, in the State of New York, have invented new and useful Improvements in the Method of Utilizing Natural Electric Energy, of which the following, taken in connection with the accompanying drawings, is a full, clear, and exact description.

The object of this invention is to provide a method whereby natural electrical energy—such as the so-called "atmospheric electrical energy," or electrical energy that may be derived from the difference of potential existing between two points, one being the earth and the other the atmosphere at an elevation above the earth—may be collected or utilized for the various uses to which electricity is applied.

It has been found that the presence of electricity in the upper regions of the atmosphere is not confined to thunder-clouds, but can be detected at all times and often in great quantities in different conditions of the atmosphere. In fine weather this electricity is mostly positive; but in showery or stormy weather negative electricity is as frequently met with as positive, and it is in such weather that the indications of electricity, whether positive or negative, are usually the strongest. It has also been found that as we proceed farther from the earth's surface, whether upward from a level plane thereof or horizontally from an elevation, the potential of points in the air becomes more and more different from that of the earth, the difference being, in a broad sense, simply proportional to the distance; hence we can infer that there is electricity residing on the surface of the earth, the density of which at any moment in the locality of observation is measured by the difference of potential found to exist between the earth and a given point in the air near it. The results of observations show that the variations of the electricity residing in the atmosphere is the main cause of the variations of the electricity on the surface of the earth. A charged cloud or body of air induces electricity of the opposite kind to its own on the parts of the earth's surface over which it passes and produces such variations. The difference of potential in increasing the distance from the earth is due to electricity induced on the surface of the earth by opposite electricity in the air overhead, and the air being a non-conductor the electricities are unable to combine. As electrical density is greater on projecting parts of a surface than on those which are plane or concave, stronger indications are obtained on hills than in valleys, if the collecting apparatus be at the same distance from the ground in both cases. The average difference of potential is greater in the winter than in the summer. Little or no effects can be obtained within inclosures or under trees, as they tend to screen the apparatus.

Inasmuch as electricity travels in preference through the best conductors, it follows that if a path of low resistance is formed (such as the erection of a metal pole) to a sufficient elevation above the earth the electricities in the atmosphere and that on the surface of the earth will tend to combine and travel through the said path in a current or currents, and if this pole terminates in a metal point or a number of such points the earth and clouds exchange their opposite electricities without a disruptive discharge—as the lightning—but in a slow and gradual way through convection. Besides supplying the top of the pole with points, a metal plate to which the said points are fixed attracts the opposite electricity in the atmosphere. In order to obtain a greater and increased effect, a large metal plate is buried at the foot of the pole and electrically connected therewith, and is provided with points or branches extending in different directions in the ground. The plate and branches may be surrounded by metallic refuse, coke, or other good conducting substance. The metallic points on the top of the pole should be sharp, and preferably of copper, and may be platinized, gilded, or galvanized to prevent corrosion. It having been ascertained by practical experiments that either a flame or dropping water at an elevation above the surface of the earth produces convection of electricity, it is obvious that such means may be employed in place of the points hereinbefore referred to. As the electricity in the atmosphere is some-

times positive and other times negative, the direction of the currents is not always the same—that is, the atmospheric electrical energy is composed of a current of an alternating character, flowing in one direction on an average about as much of the time as in the opposite direction, but the length of the current in a certain direction, or the lengths of time between reversals or changes in the direction of its flow, is greatly varied. This and also the varied strength of the currents have prevented the utilization of atmospheric electrical energy in commercial quantities for the various purposes for which electricity is generally employed. In order to utilize such a current or currents, they should be transformed into a continuous direct current of uniform strength. The apparatus for accomplishing the transformation of atmospheric electricity into a direct current of uniform strength is susceptible of being greatly modified. The preferred form of apparatus, however, for carrying the invention practically into effect I will now proceed to describe to show that the method is capable of actual performance. Said apparatus is illustrated in the diagram accompanying this specification.

Referring specifically to said diagram, A represents a metallic pole, which is shown bare, but may be enveloped in suitable insulating material, if desirable. B is the base of the aforesaid pole, which base is of insulating material set in the ground E. C is a large metal plate beneath the said base, and has points or branches c' extending therefrom in different directions in the ground. C′ is a metallic post extending from the said plate above the surface of the ground and having a terminal d of the circuit D. On the top of said pole is mounted a metallic cap F, consisting, preferably, of a convex disk provided with sharp iron or copper points p, which project in all directions from the same. As before mentioned, the said points may be plated with a suitable metal that forms a good conductor and prevents corrosion. Similar caps F′ may be placed on other insulated poles, as A′, in the vicinity, and connected with the main pole A by an electric conductor a, for increasing the effect. The pole A′ may be of wood, and the pole A may also be of the same material if provided with a metal conductor within or on the outside, extending from the cap to the other terminal d' of the circuit D. The said circuit D leads from the terminal d through an automatic variable resistance G, thence to one of the poles of a secondary or storage battery H, and from the other pole of said battery through an automatic current-regulator to the terminal d'. An automatic current-reverser or pole-changer J is located in the said circuit for reversing the current whenever there is a change in its direction, so that it may be rectified or straightened during transit and caused to travel at all times whether its direction is toward or from the earth in one and the same direction through a portion of the circuit containing the secondary battery. The reversals are accomplished automatically by means of a pivoted polarized armature b, located between two electro-magnets $c\,c$, having their coils included in a shunt-circuit between the leads of the circuit D. The magnets are wound so that a north pole will be presented to the armature on one side and a south pole on the other. When the current is flowing in a certain direction, the said polarized armature will be repelled by one magnet and attracted by the other, and thereby moved to one side. When the current changes its direction through the magnets, the poles of the said magnets are reversed and the armature is both repelled and attracted to the other side. An arm b', of diamagnetic material, is fixed to and extends from the armature and is moved by the same. Between a movable end of the arm and the said current-reverser is a pivoted connection or link e, by which the motion of the arm is conveyed to the reverser. Stops f are provided for limiting the movement of the said arm, and an adjustable resistance d' is included in the shunt d'' to regulate the current through the same.

The current-regulator hereinbefore referred to prevents short-circuiting or the rapid discharge of the secondary battery into the air and ground when the strength of said battery-current becomes greater than that passing to the battery. Said regulator is composed of an electro-magnet I, having its coil in the circuit D. A pivoted polarized armature g is connected at its pivot to one terminal of the coil of said magnet, and when the current is flowing to the battery said armature is attracted by the magnet I and held in contact with the stop h, to which the terminal of the secondary battery is connected. In the aforesaid condition a free or low-resistance path for the current is provided to the battery; but when the battery-current exceeds the charging-current the magnet-poles are reversed and the armature is repelled by the magnet, and the free path of the circuit is broken between the armature g and stop h. In order to maintain the armature in the latter position until the charging-current has been increased in strength above that of the battery-current or discharging-current, and so that the said regulator will automatically operate, a shunt path K of high resistance is provided around the armature g and stop h. The high resistance of the said shunt is obtained by including a rheostat m. This shunt path or circuit K, with the resistance, permits a small but sufficient amount of current to flow through the magnet I to hold the armature away from the stop h until the current is reversed, and then move the armature back to stop h to close the free or low-resistance path. A spring i is provided to assist the movement of the armature from the magnet when it is repelled by the same.

The electric current may be directly con-

ducted to translating devices—such as lamps or electromotors; but, as hereinbefore stated, said current is preferably employed to charge one or more cells of the secondary battery H, and this battery stores or accumulates the electrical energy and supplies the said translating devices. To illustrate the latter feature, leads or wires L and L′ are extended from the poles or electrodes of said battery, and translating devices, in the shape of incandescent lamps *l*, are connected with the said wires in multiple arc. In the wire L is a common circuit maker and breaker *n* to close and open the circuit to the lamps. The said battery may be charged in series or parallel.

The automatic variable resistance G maintains the current flowing through the circuit D approximately uniform by increasing the resistance therein upon an increase of strength. Said resistance is not absolutely necessary and may be dispensed with.

The lightning-arrester M is to short-circuit a very heavy current to prevent the same from passing through the other parts of the apparatus and injuring it. A low-resistance shunt O, with a circuit maker and breaker therein, is connected between the leads of the circuit D, near the terminals *d* and *d′*, to completely short-circuit the apparatus when desired.

Having described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The method of utilizing atmospheric electrical energy, consisting in conducting the electric current or currents between the earth and a point in the atmosphere at an elevation above the earth, rectifying or straightening the currents during transit, and storing or accumulating the electrical energy of said rectified current or currents.

2. As preliminary steps in the method of utilizing atmospheric electrical energy, conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, maintaining an approximately uniform strength of current and rectifying or straightening the same during transit.

3. As preliminary steps in the method of utilizing atmospheric electrical energy, conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, and rectifying or straightening said currents during transit.

4. The method of utilizing atmospheric electrical energy or deriving energy from the difference of electrical potential existing between the earth and a point or points in the atmosphere at an elevation above the earth, consisting in conducting the current or currents between the two points through a path of low resistance, rectifying or straightening the said currents in a portion of the path during transit, and storing or accumulating the electrical energy thereof.

5. The method of utilizing atmospheric electrical energy or deriving energy from the difference of electrical potential existing between the earth and a point or points in the atmosphere at an elevation above the earth, consisting in conducting the current or currents between the two points through a path of low resistance, maintaining an approximately uniform strength of current, rectifying or straightening the said currents in a portion of the path during transit, and storing or accumulating the electrical energy.

6. The method of utilizing atmospheric electrical energy composed of a current of a varied alternating character, consisting in conducting the electric current or currents through a path of low resistance between the earth and the atmosphere at an elevation above the earth, and then accumulating the electrical energy of said current or currents while flowing in both directions in one or more cells of a secondary or storage battery, as described.

In testimony whereof I have hereunto signed my name this 29th day of April, 1889.

MARK W. DEWEY. [L. S.]

Witnesses:
C. H. DUELL,
C. L. BENDIXON.

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719.

Patented Jan. 16, 1912.

2 SHEETS—SHEET 1.

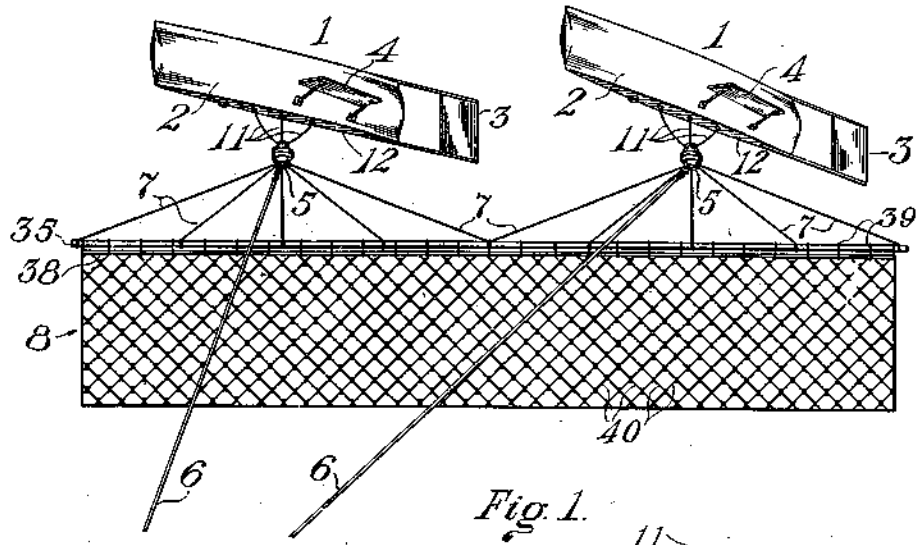

Fig. 1.

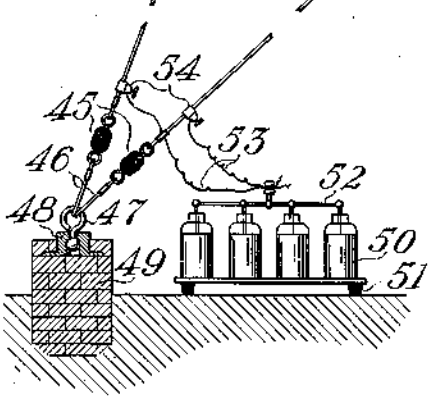

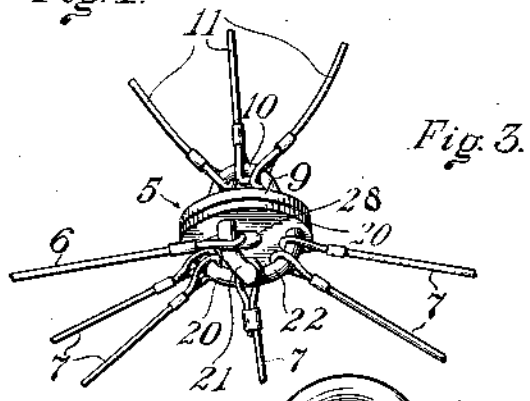

Fig. 3.

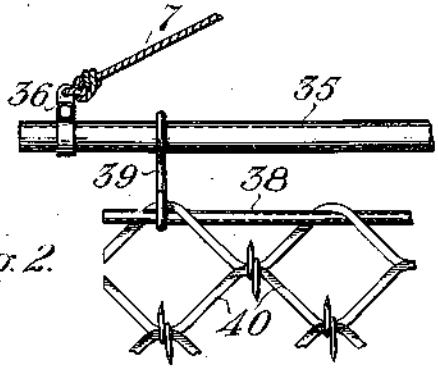

Fig. 2.

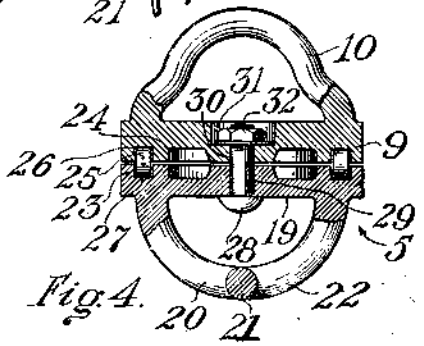

Fig. 4.

INVENTOR

Walter I. Pennock.

WITNESSES

Elizabeth L. Smith

J. Stuart Freeman.

BY

ATTORNEY

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719.

Patented Jan. 16, 1912.

2 SHEETS—SHEET 2.

Fig. 5.

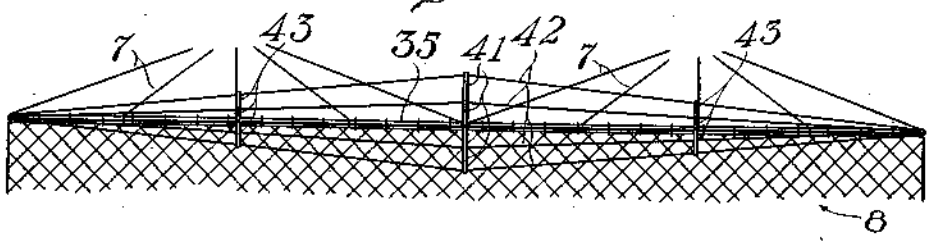

Fig. 6.
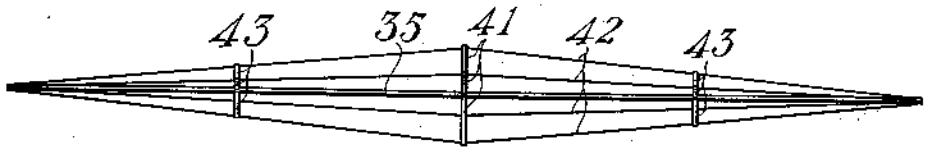
Fig. 7.

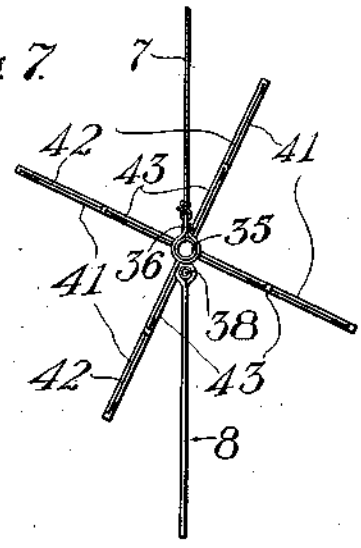

INVENTOR

Walter I. Pennock.

WITNESSES

Elizabeth L. Smith,

J. Stuart Freeman,

BY

Munn & Co.

ATTORNEY

UNITED STATES PATENT OFFICE.

WALTER I. PENNOCK, OF PHILADELPHIA, PENNSYLVANIA.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

1,014,719. Specification of Letters Patent. Patented Jan. 16, 1912.

Application filed January 4, 1911. Serial No. 600,777.

To all whom it may concern:

Be it known that I, WALTER I. PENNOCK, a citizen of the United States, residing at Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Electrical Energy, of which the following is a full, clear, and exact disclosure.

The present invention relates to an improved means for collecting the charges of electricity from the upper atmosphere and more particularly to that form which consists in one or more captive balloons from which is suspended a suitable form of metallic conductor.

The principal objects of the device are: to provide a collector for atmospheric and static electricity, which when in operative position will present a large surface to currents of air, but which will offer comparatively little resistance thereto, to provide a collector of such material and construction as will be more efficient in its operation than any previously constructed for a similar purpose, to provide a means for maintaining such a collector suspended in the air and at right angles to opposing currents thereof, and to provide a suitable anchorage for holding said means captive.

With these principal objects in view, the present invention consists in further advantages which are brought out in the following specification and accompanying drawings, in both of which like numerals refer to like parts, and in which drawings—

Figure 1 is a perspective view of the complete device in operative position, Fig. 2 is an enlarged detail view of the wire mesh and the manner in which it is attached to the supporting balloons, Fig. 3 is a detail of the manner of securing the collector-supporting and anchor cables to the balloons, Fig. 4 is an enlarged cross section of the swivel connection shown in Fig. 3, Fig. 5 is top plan view of the reinforcing braces on the screen, Fig. 6 is an elevation of the same and Fig. 7 is an end view of the structure shown in Figs. 5 and 6.

Referring to the drawings, in Fig. 1 thereof, a plurality of balloons 1 of any suitable type is shown, each of which embodies hollow metallic elongated gas tanks 2, extending from the rear of which are single, rigidly affixed rudders 3, while on the sides of the tanks are secured stationary lifting planes 4.

To the bottom and slightly to the rear of the center of the tanks 2 is secured a suitable swivel 5, by which the anchor ropes 6 and the suspension ropes 7 for the metallic conductor 8 are secured to the balloons 1. A suitable form of swivel joint is illustrated in Figs. 3 and 4, but any type can be used that embodies the essential features shown therein.

The swivel joint illustrated consists in the base plate 9 having a looped portion 10 integral therewith and projecting from the upper face thereof. Secured to the loop 10 is a set of three light electrically conductive supporting ropes or cables 11 which extend upwardly and are secured at intervals to the bottom 12 of the balloon above.

The lower or revoluble member 19 of the swivel joint preferably comprises three upwardly directed curved arms, 20, 21, and 22, respectively, forming at their junction a T-shape as shown, said arms at their upper extremities being integral with the plate 23. The member 19 is revoluble below and concentric with the plate 9, and the two members are lightened in weight by opposed concentric grooves as shown at 24. Contact between said members is made through the roller bearings 25, which are carried in the opposed concentric grooves 26 and 27 of the respective upper and lower plates. Furthermore, said plates are maintained in coöperative relation with each other by means of a bolt 28 passing through centrally drilled holes 29 and 30 in the respective lower and upper plates, the drilled hole 30 opening upwardly into an enlarged recess 31, in which is sunken the nut 32 on the bolt 28. Two of the arms 20 and 22 of the lower revoluble member 19 extend in diametrical alinement, while from the central point thereof extends the third arm 21 at right angles thereto, and upward to the plate 23.

Suspended below the plurality of balloons is a hollow rod 35, of any suitable material, connected at regular intervals such as at points 36, by metallic ropes 7, to the alined arms 20 and 22 of the swivel joint 5. Below and parallel to the rod 35 is a similar but smaller rod 38 suspended therefrom by means of suitable couplings 39. From the rod 38 hangs a wire mesh 40 of any suitable form, such as can be extended over a considerable area and which will offer comparatively little resistance to the passage of air therethrough. The metal in such a screen is preferably rough, sharp or jagged and a convenient form embodying these characteristics is expanded sheet metal such as is used for lathing and for reinforcing concrete construction. Instead of the single hollow rod 35 alone, applicant contemplates the use of reinforcing means to prevent the buckling of the rod in a stiff wind, such, for instance, as the arrangement of wire bracing shown in Figs. 5, 6 and 7 in which cross rods 41, secured to the rod 35 at the center thereof are attached to the ends thereof by means of stretched wires 42. Between the rods 41 and the ends of the rod 35 are secured sets of cross rods 43 which support the wires 42 and strengthen the rod 35 at as many points as they may be placed.

For the purpose of maintaining the balloons and apparatus suspended therefrom captive, the light metallic cables 6 terminating downwardly in insulators 45 are employed. These insulators in turn are connected by means of short sections of rope 46 to the eye 47 of a suitable swivel 48, embedded in the anchorage 49.

When the balloons with the metallic screen suspended therefrom are allowed to rise into one of the higher altitudes, the entire apparatus being of metallic construction and uninsulated will become energized by contact with the surrounding natural charges of electricity. From the above description it is evident then that, while the screen 8, on account of its great extent, will be the greatest collecting agent, it will be seen that the balloons themselves and the suspending wires will also coöperate as one large collector, since no parts of which are insulated from any of the neighboring parts thereof. Consequently, when the apparatus described has reached an altitude or strata of the atmosphere abounding in static charges of electricity, an amount of the said charges proportionate to the surface area of the metal exposed will collect upon the apparatus as a whole and will be conducted downwardly toward the earth by means of the various anchor ropes 6, but will not pass into the ground on account of the interposition of the insulators 45.

To use the electrical charges thus acquired, a plurality of Leyden jars 50, or other suitable collectors are supported above the surface of the earth and insulated therefrom by any suitable means as represented by the blocks 51. Either the inner or outer conducting surfaces of the jars may be connected together and energized by the accumulated charge. In the present instance, the inner surfaces of the accumulators are shown to be connected, and the connecting means 52 is in turn connected to the ropes 6 by means of wires 53. These wires are secured to the ropes mentioned by means of suitable binding posts 54.

In the device described the anchor ropes 6 are of substantially the same length, and when the apparatus is raised to the desired altitude and is being blown by the currents of air, the balloons are turned by means of the vanes 3 to parallel relation with each other, and furthermore, from the manner in which the device is held captive and the collecting net 40 is suspended from the balloons, it is obvious that said net will at all times readily swing into a plane substantially perpendicular to any current of air acting upon the balloons above. The purpose of the swivel joint shown in Figs. 3 and 4 is principally for allowing the balloons to readily aline themselves with any new direction of the wind before the apparatus, including the suspended screen, can swing about the swivel 48, and said joint will also prevent the twisting of the ropes 7, when any rapid shifting of the air currents may occur.

While applicant has shown a set of Leyden jars as the accumulators in the accompanying drawings, it is obvious that any other suitable form may be used, and furthermore, that although not illustrated, any suitable apparatus may be run thereby, such as for instance, wireless telegraphic instruments.

Furthermore, although but one embodiment of the invention has been described, it is to be understood that various modifications may be made therein, and in fact several are contemplated by applicant that are of such structure as fall well within the scope of the appended claim.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States, is:

A collector for charges of electricity, comprising a plurality of supporting means, a metallic gauze sustained thereby to lie in a plane and substantially equidistant from each of said supporting means, anchoring means emanating from a common point to each of said supporting means, means operative to maintain said supporting means

in their normal positions, and means between each of said supporting means and said gauze to permit each of said supporting means to readily and independently aline itself to accord with any alteration in the direction of opposing air currents.

In witness whereof I have hereunto set my hand this 28 day of December, A. D. 1910.

WALTER I. PENNOCK.

Witnesses:
MILDRED S. TEMPLE,
E. EUGENIA PENNOCK.

US007439712B2

(12) **United States Patent**
McCowen

(10) **Patent No.: US 7,439,712 B2**
(45) **Date of Patent: Oct. 21, 2008**

(54) **ENERGY COLLECTION**

(76) Inventor: **Clint McCowen**, 1902 Rue La Fontaine, Navarre, FL (US) 32566

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 509 days.

(21) Appl. No.: **11/358,264**

(22) Filed: **Feb. 21, 2006**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H02N 1/00 (2006.01)

(52) **U.S. Cl.** ..... **322/2 A**; 307/149; 361/225; 361/117; 174/2; 320/101

(58) **Field of Classification Search** ..... 361/220, 361/117, 212, 233, 221, 222, 225; 322/2 A, 322/2 R; 307/149; 174/2, 3; 320/101
See application file for complete search history.

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Primary Examiner—Mark T Le
(74) *Attorney, Agent, or Firm*—Thomas, Kayden, Horstemeyer & Risley, LLP

(57) **ABSTRACT**

An energy collection system may collect and use the energy generated by an electric field. Collection fibers are suspended from a support wire system supported by poles. The support wire system is electrically connected to a load by a connecting wire. The collection fibers may be made of any conducting material, but carbon and graphite are preferred. Diodes may be used to restrict the backflow or loss of energy.

28 Claims, 10 Drawing Sheets

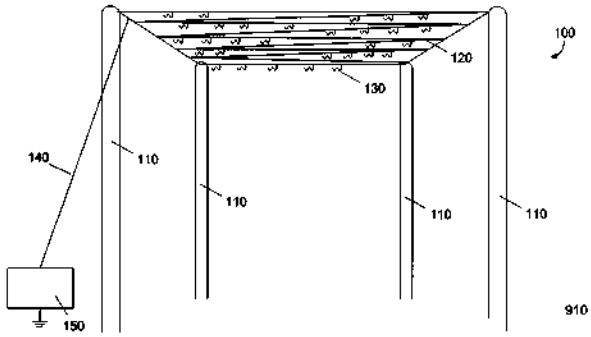

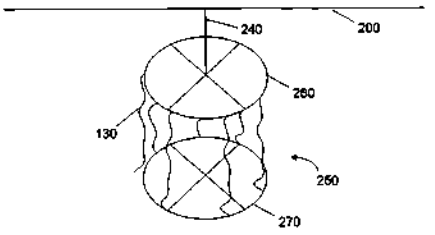

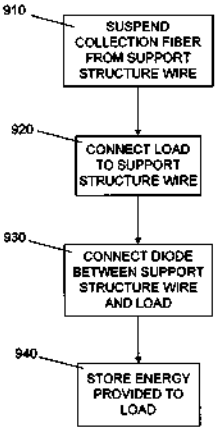

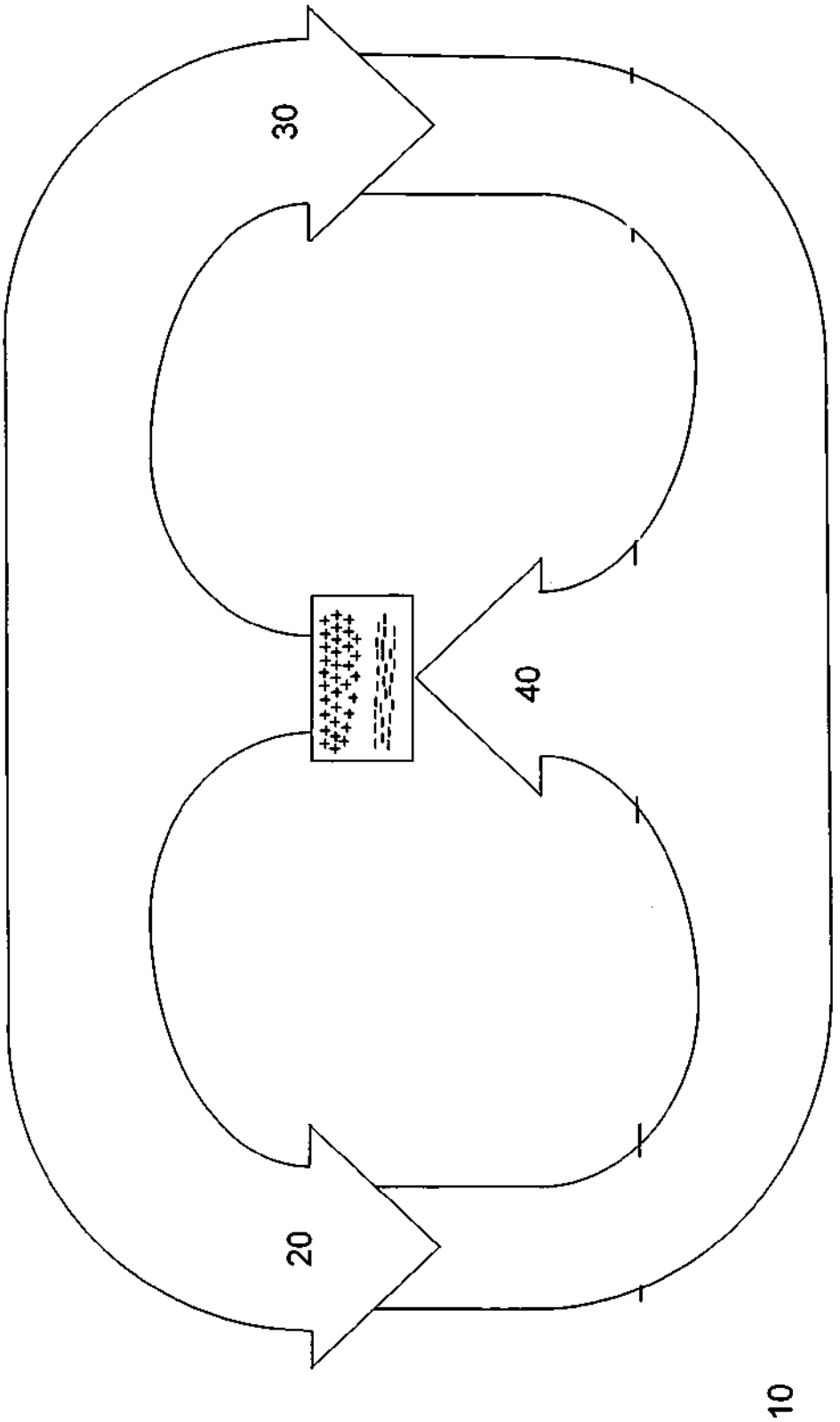

FIGURE 1

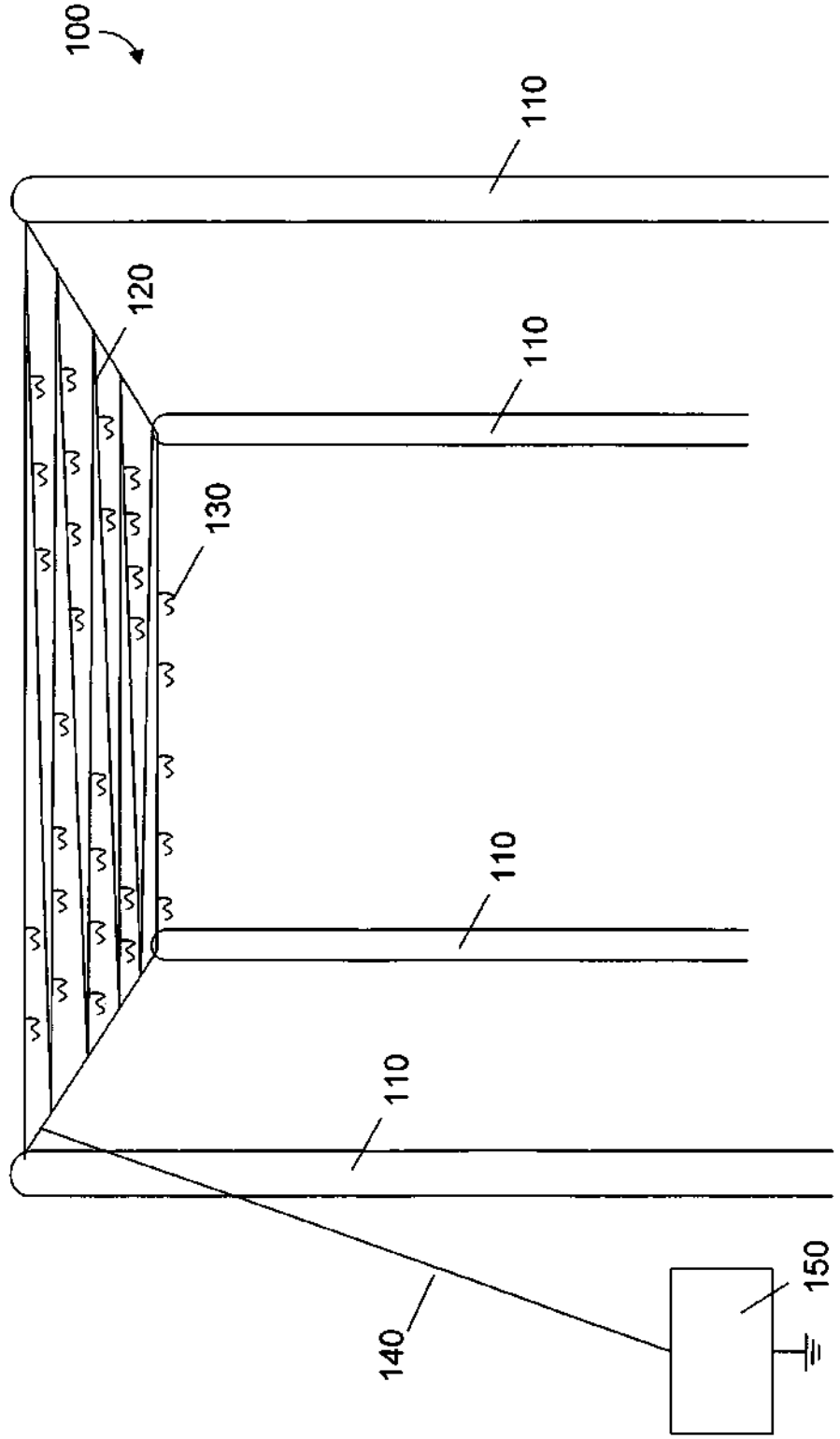

FIGURE 2

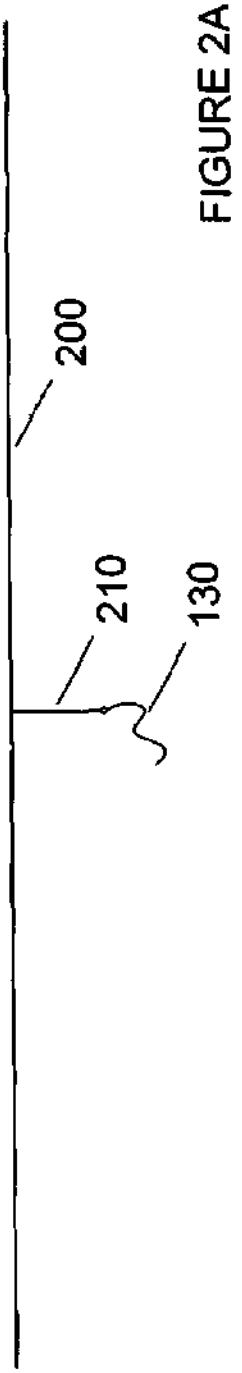

FIGURE 2A

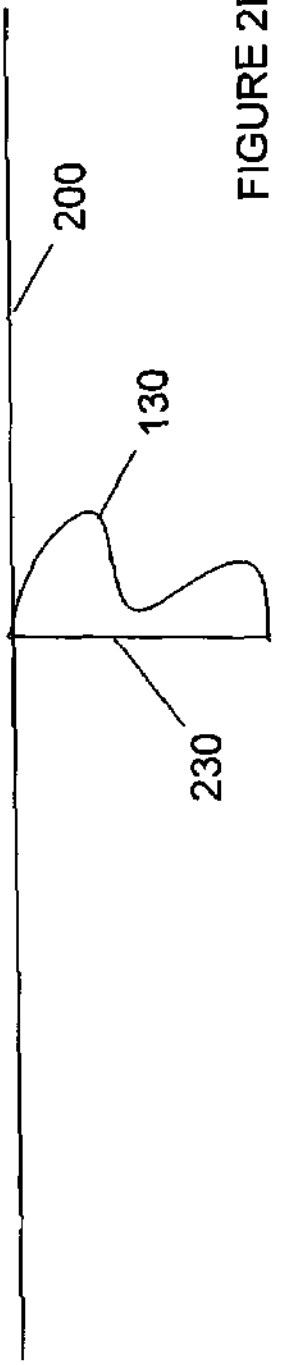

FIGURE 2B

FIGURE 2C

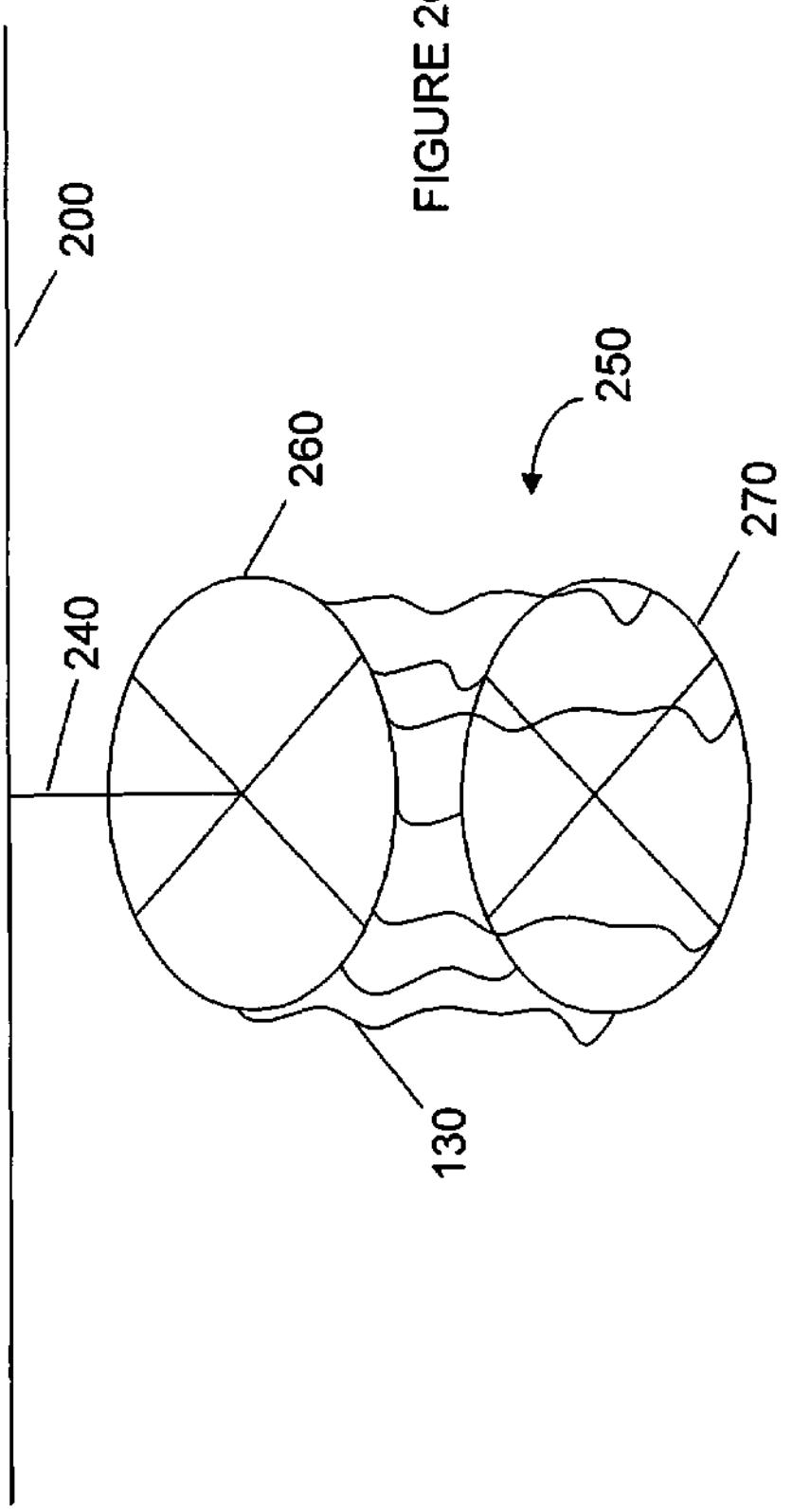

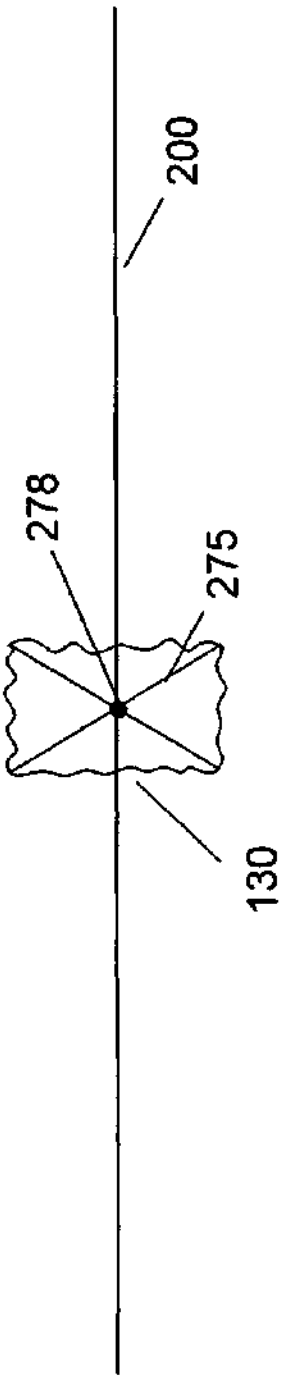

FIGURE 2D

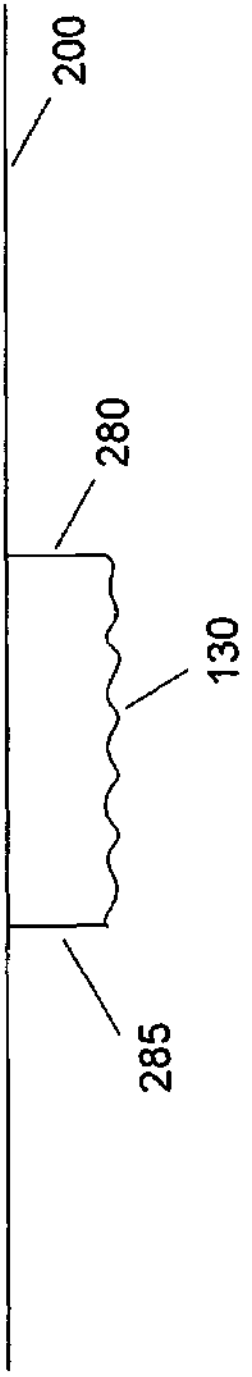

FIGURE 2E

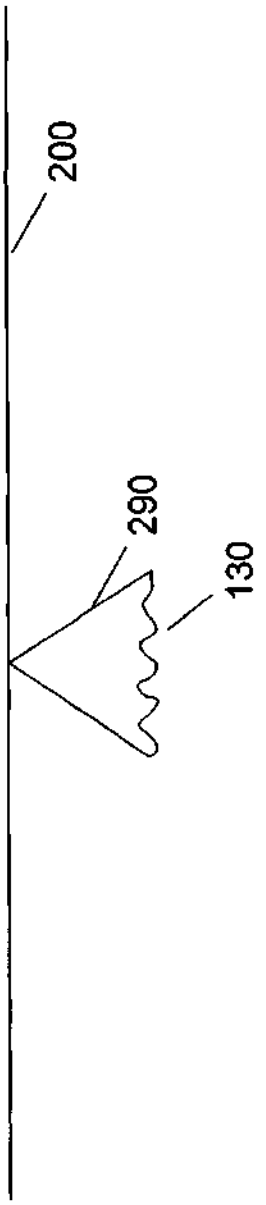

FIGURE 2F

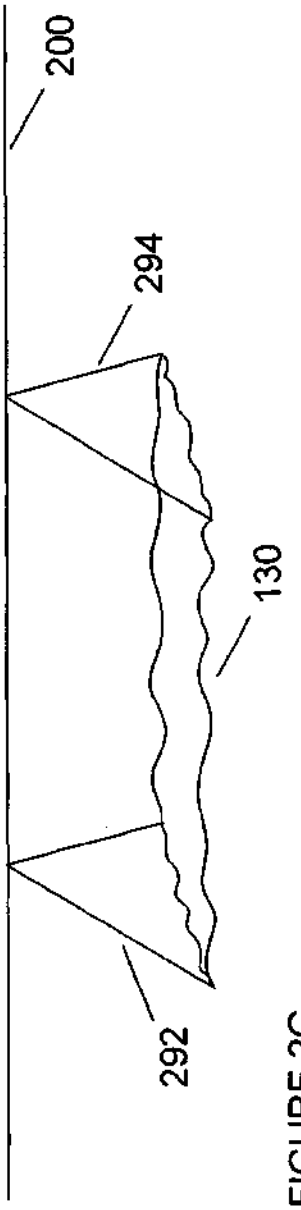

FIGURE 2G

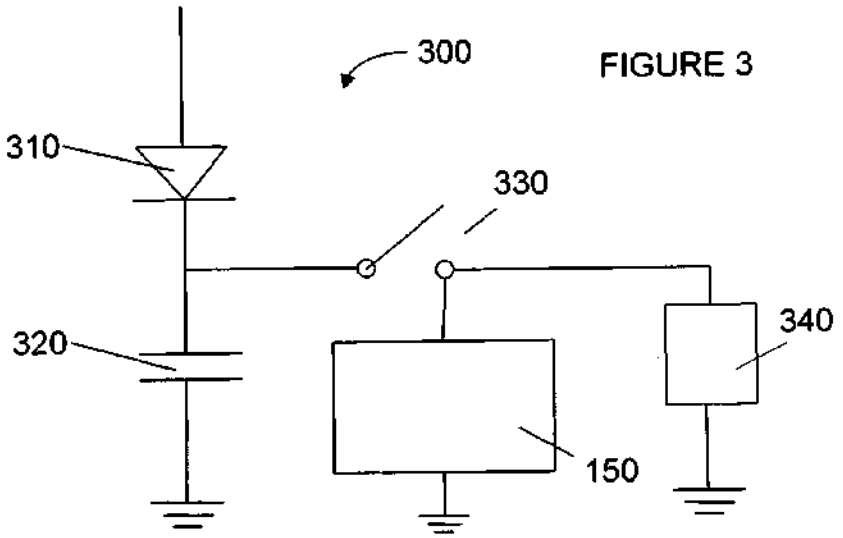

FIGURE 3

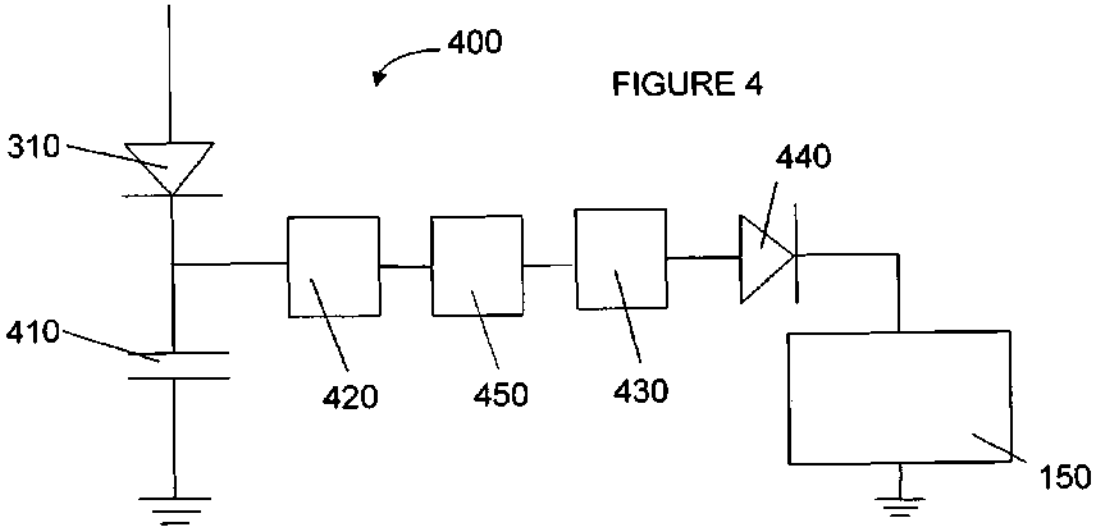

FIGURE 4

FIGURE 5

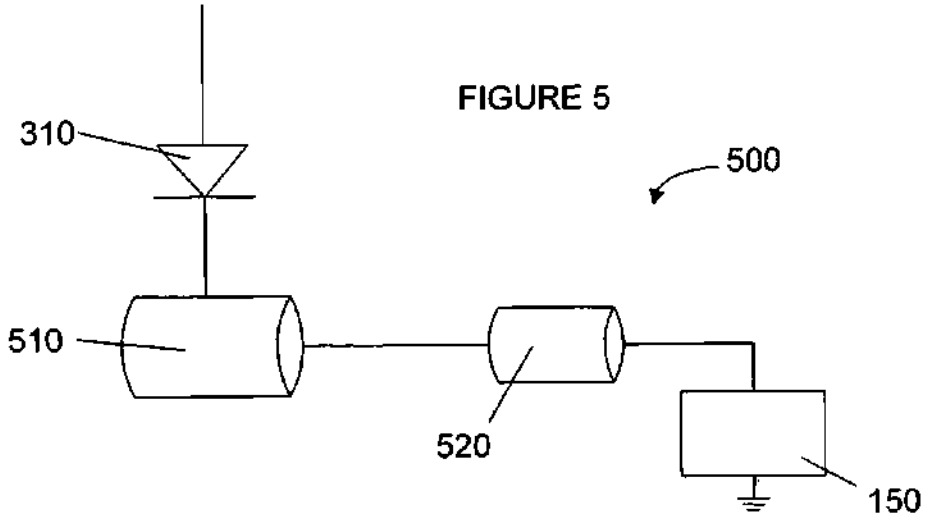

FIGURE 6

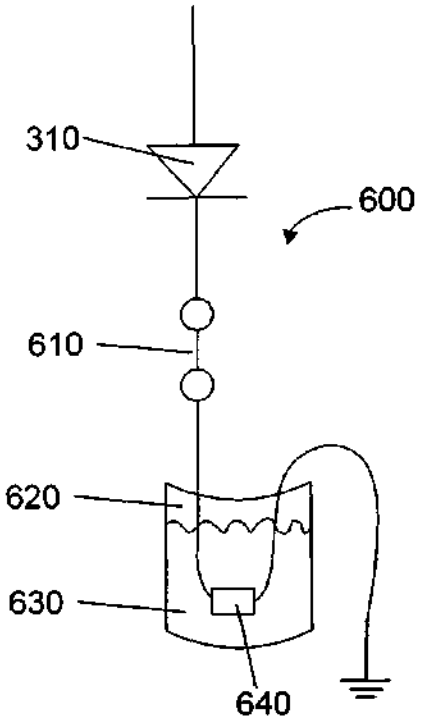

FIGURE 7

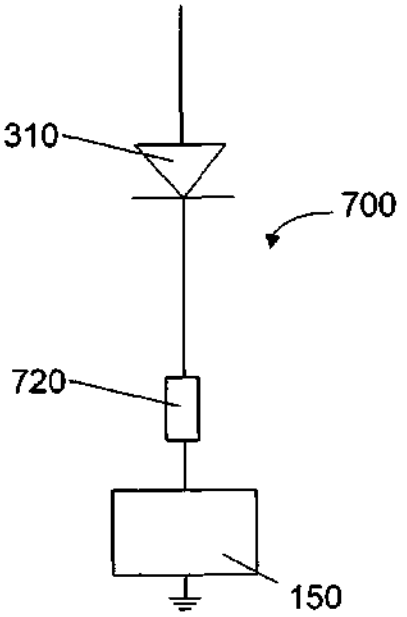

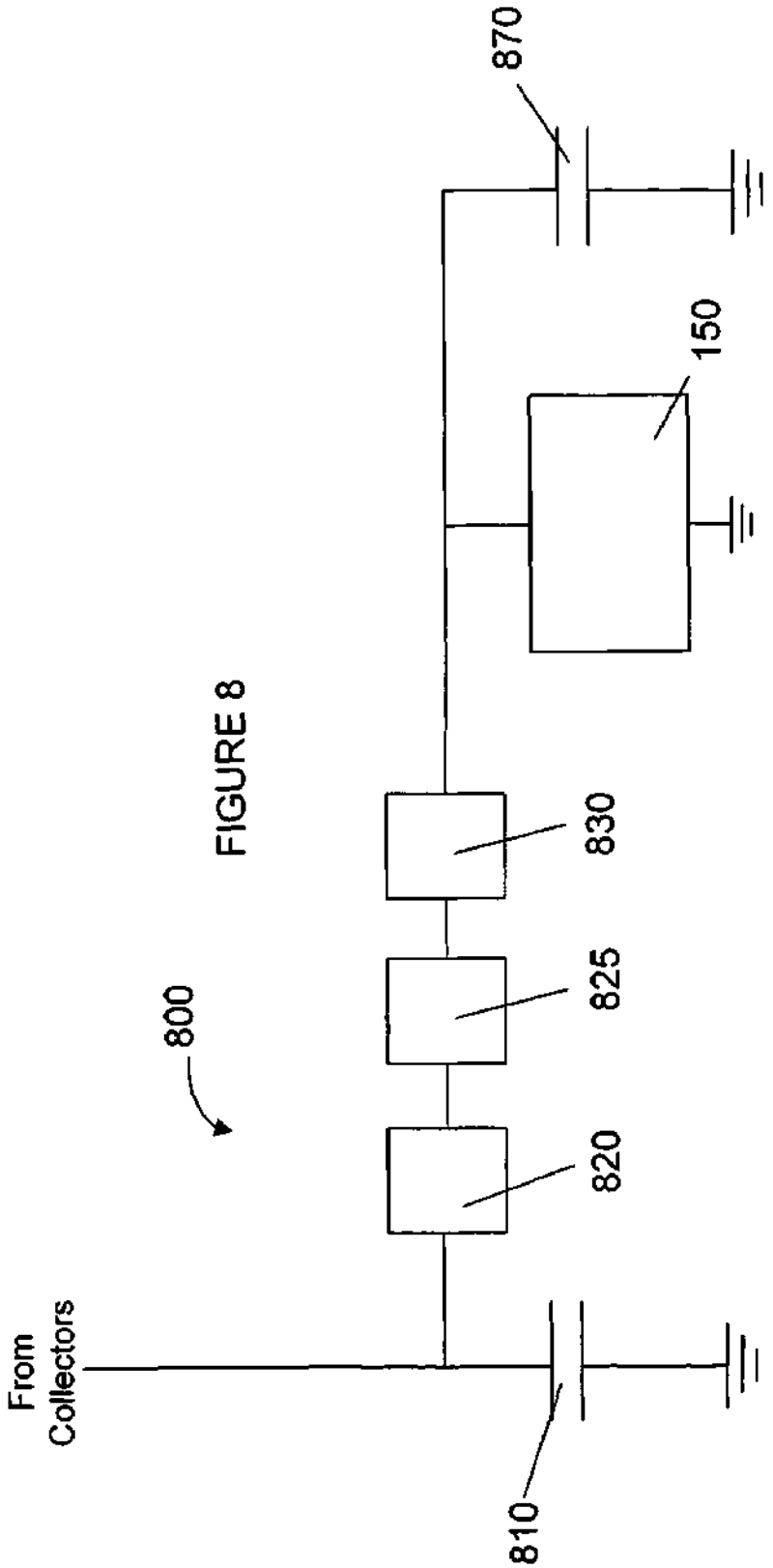

FIGURE 8

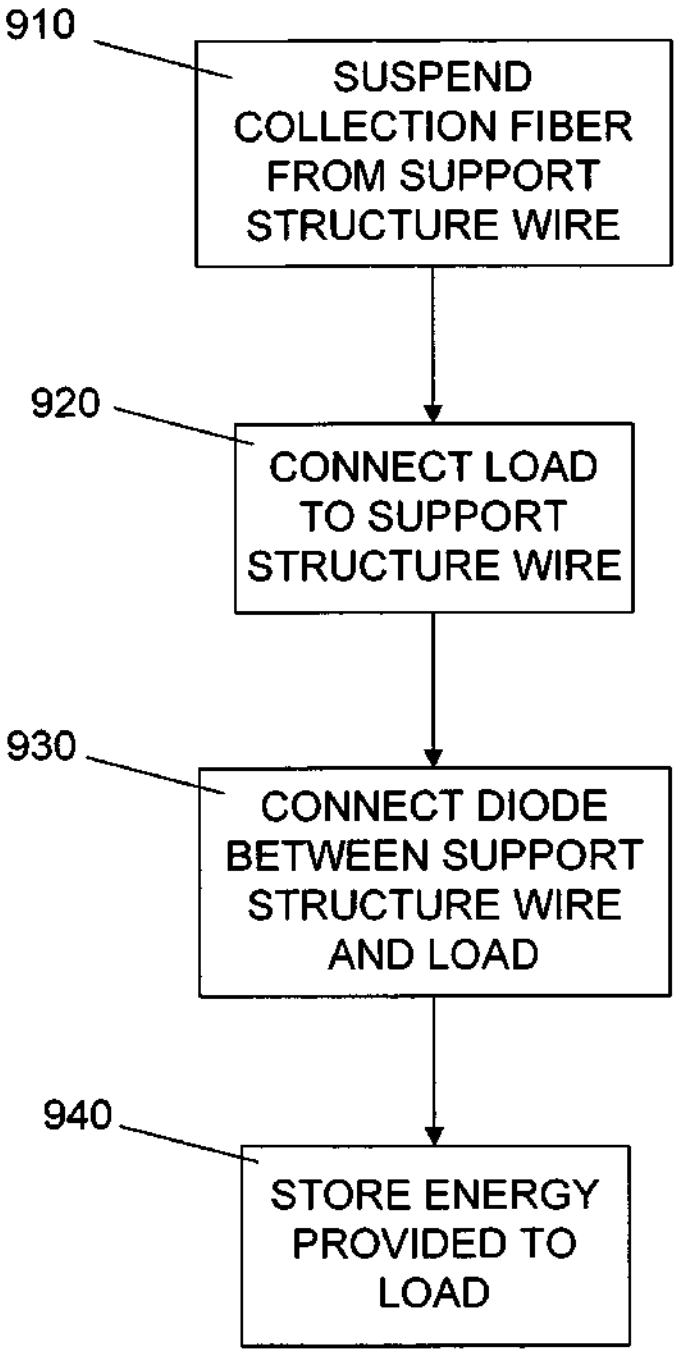
910
SUSPEND COLLECTION FIBER FROM SUPPORT STRUCTURE WIRE
920
CONNECT LOAD TO SUPPORT STRUCTURE WIRE
930
CONNECT DIODE BETWEEN SUPPORT STRUCTURE WIRE AND LOAD
940
STORE ENERGY PROVIDED TO LOAD

FIGURE 9

ENERGY COLLECTION

TECHNICAL FIELD

The present disclosure is generally related to energy and, more particularly, is related to systems and methods for collecting energy.

BACKGROUND

The concept of fair weather electricity deals with the electric field and the electric current in the atmosphere propagated by the conductivity of the air. Clear, calm air carries an electrical current, which is the return path for thousands of lightening storms simultaneously occurring at any given moment around the earth. For simplicity, this energy may be referred to as static electricity or static energy. FIG. **1** illustrates a weather circuit for returning the current from lightning, for example, back to ground **10**. Weather currents **20**, **30** return the cloud to ground current **40**.

In a lightening storm, an electrical charge is built up, and electrons arc across a gas, ionizing it and producing the lightening flash. As one of ordinary skill in the art understands, the complete circuit requires a return path for the lightening flash. The atmosphere is the return path for the circuit. The electric field due to the atmospheric return path is relatively weak at any given point because the energy of thousands of electrical storms across the planet are diffused over the atmosphere of the entire Earth during both fair and stormy weather. Other contributing factors to electric current being present in the atmosphere may include cosmic rays penetrating and interacting with the earth's atmosphere, and also the migration of ions, as well as other effects yet to be fully studied.

Some of the ionization in the lower atmosphere is caused by airborne radioactive substances, primarily radon. In most places of the world, ions are formed at a rate of 5-10 pairs per cubic centimeter per second at sea level. With increasing altitude, cosmic radiation causes the ion production rate to increase. In areas with high radon exhalation from the soil (or building materials), the rate may be much higher.

Alpha-active materials are primarily responsible for the atmospheric ionization. Each alpha particle (for instance, from a decaying radon atom) will, over its range of some centimeters, create approximately 150,000-200,000 ion pairs.

While there is a large amount of usable energy available in the atmosphere, a method or apparatus for efficiently collecting that energy has not been forthcoming. Therefore, a heretofore unaddressed need exists in the industry to address the aforementioned deficiencies and inadequacies.

SUMMARY

Embodiments of the present disclosure provide systems and methods for collecting energy. Briefly described in architecture, one embodiment of the system, among others, can be implemented by a support structure wire elevated above a ground level, at least one collection fiber electrically connected to the support structure wire; a load electrically connected to the support structure wire; and a diode electrically connected between the load and at least one collection fiber.

Embodiments of the present disclosure can also be viewed as providing methods for collecting energy. In this regard, one embodiment of such a method, among others, can be broadly summarized by the following steps: suspending at least one collection fiber from a support structure wire elevated above ground level, the fiber electrically connected to the support structure wire; providing a load with an electrical connection to the support structure wire to draw current; and providing a diode electrically connected between the collection fiber and the load.

Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a circuit diagram of a weather energy circuit.

FIG. **2** is a perspective view of an exemplary embodiment of many energy collectors elevated above ground by a structure.

FIG. **2A** is a side view of an energy collection fiber suspended from a support wire.

FIG. **2B** is a side view of an exemplary embodiment of an energy collection fiber suspended from a support wire and with an additional support member.

FIG. **2C** is a perspective view of a support structure for multiple energy collection fibers.

FIG. **2D** is a side view of an exemplary embodiment of a support structure for multiple energy collection fibers.

FIG. **2E** is a side view of a support structure for an energy collection fiber.

FIG. **2F** is a side view of an exemplary embodiment of a support structure for an energy collection fiber.

FIG. **2G** is a side view of a support structure for multiple energy collection fibers.

FIG. **3** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **4** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **5** is a circuit diagram of an exemplary embodiment of an energy collection circuit for powering a generator and motor.

FIG. **6** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy and using it for the production of hydrogen and oxygen.

FIG. **7** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy, and using it for driving a fuel cell.

FIG. **8** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy.

FIG. **9** is a flow diagram of an exemplary embodiment of collecting energy with a collection fiber.

DETAILED DESCRIPTION

Electric charges on conductors reside entirely on the external surface of the conductors, and tend to concentrate more around sharp points and edges than on flat surfaces. Therefore, an electric field received by a sharp conductive point may be much stronger than a field received by the same charge residing on a large smooth conductive shell. An exemplary embodiment of this disclosure takes advantage of this

property, among others, to collect and use the energy generated by an electric field in the atmosphere. Referring to collection system **100** presented in FIG. **2**, at least one collection device **130** may be suspended from a support wire system **120** supported by poles **110**. Collection device **130** may comprise a diode or a collection fiber individually, or the combination of a diode and a collection fiber. Support wire system **120** may be electrically connected to load **150** by connecting wire **140**. Supporting wire system **120** may be any shape or pattern. Also, conducting wire **140** may be one wire or multiple wires. The collection device **130** in the form of a fiber may comprise any conducting or non-conducting material, including carbon, graphite, Teflon, and metal. An exemplary embodiment utilizes carbon or graphite fibers for static electricity collection. Support wire system **120** and connecting wire **140** can be made of any conducting material, including aluminum or steel, but most notably, copper. Teflon may be added to said conductor as well, such as non-limiting examples of a Teflon impregnated wire, a wire with a Teflon coating, or Teflon strips hanging from a wire. Conducting wire **120**, **140**, and **200** may be bare wire, or coated with insulation as a non-limiting example. Wires **120** and **140** are a means of transporting the energy collected by collection device **130**.

An exemplary embodiment of the collection fibers as collection device **130** includes graphite or carbon fibers. Graphite and carbon fibers, at a microscopic level, can have hundreds of thousands of points. Atmospheric electricity may be attracted to these points. If atmospheric electricity can follow two paths where one is a flat surface and the other is a pointy, conductive surface, the electrical charge will be attracted to the pointy, conductive surface. Generally, the more points that are present, the higher energy that can be gathered. Therefore, carbon, or graphite fibers are examples that demonstrate exemplary collection ability.

In at least one exemplary embodiment, the height of support wire **120** may be an important factor. The higher that collection device **130** is from ground, the larger the voltage potential between collection device **130** and electrical ground. The electric field may be more than **100** volts per meter under some conditions. When support wire **120** is suspended in the air at a particular altitude, wire **120** will itself collect a very small charge from ambient voltage. When collection device **130** is connected to support wire **120**, collection device **130** becomes energized and transfers the energy to support wire **120**.

A diode, not shown in FIG. **2**, may be connected in several positions in collection system **100**. A diode is a component that restricts the direction of movement of charge carriers. It allows an electric current to flow in one direction, but essentially blocks it in the opposite direction. A diode can be thought of as the electrical version of a check valve. The diode may be used to prevent the collected energy from discharging into the atmosphere through the collection fiber embodiment of collection device **130**. An exemplary embodiment of the collection device comprises the diode with no collection fiber. A preferred embodiment, however, includes a diode at the connection point of a collection fiber to support system **120** such that the diode is elevated above ground. Multiple diodes may be used between collection device **130** and load **150**. Additionally, in an embodiment with multiple fibers, the diodes restricts energy that may be collected through one fiber from escaping through another fiber.

Collection device **130** may be connected and arranged in relation to support wire system **120** by many means. Some non-limiting examples are provided in FIGS. **2A-2G** using a collection fiber embodiment. FIG. **2A** presents support wire **200** with connecting member **210** for collection device **130**. Connection member **210** may be any conducting material allowing for the flow of electricity from connection device **130** to support wire **200**. Then, as shown in FIG. **2**, the support wire **200** of support system **120** may be electrically connected through conducting wire **140** to load **150**. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at an elevated position at the connection point between a collection fiber embodiment of collection device **130** and connection member **210**.

Likewise, FIG. **2B** shows collection fiber **130** electrically connected to support wire **200** and also connected to support member **230**. Support member **230** may be connected to collection fiber **130** on either side. Support member **230** holds the fiber steady on both ends instead of letting it move freely. Support member **230** may be conducting or non-conducting. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at elevated position at the connection point between collection fiber **130** and support wire **200** or between fiber **130**, support member **230**, and support wire **200**.

FIG. **2C** presents multiple collection fibers in a squirrel cage arrangement with top and bottom support members. Support structure **250** may be connected to support structure wire **200** by support member **240**. Structure **250** has a top **260** and a bottom **270** and each of the multiple collection fibers **130** are connected on one end to top **260** and on the other end to bottom **270**. A plurality of diodes may be placed at any position on support structure **250**. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support structure wire **200**.

FIG. **2D** presents another exemplary embodiment of a support structure with support members **275** in an x-shape connected to support structure wire **200** at intersection **278** with collection fibers **130** connected between ends of support members **275**. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2E** provides another exemplary embodiment for supporting collection fiber **130**. Collection fiber **130** may be connected on one side to support member **285**, which may be connected to support structure wire **200** in a first location and on the other side to support member **280**, which may be connected to support structure wire **200** in a second location on support structure wire **200**. The first and second locations may be the same location, or they may be different locations, even on different support wires. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support wire **200**.

FIG. **2F** presents another exemplary embodiment of a support for a collection fiber. Two support members **290** may support either side of a collection fiber and are connected to support wire **200** in a single point. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2G** provides two supports as provided in FIG. **2F** such that at least two support members **292**, **294** may be connected to support structure wire **200** in multiple locations and collection fibers **130** may be connected between each end of the support structures. Collection fibers **130** may be connected between each end of a single support structure and between multiple support structures. A plurality of diodes may be

placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support structure wire **200**.

FIG. **3** provides a schematic diagram of storing circuit **300** for storing energy collected by one or more collection devices (**130** from FIG. **2**). Load **150** induces current flow. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. A plurality of diodes may be placed at any position in the circuit. Switch **330** may be electrically connected between load **150** and at least one collection device (**130** from FIG. **2**) to connect and disconnect the load.

Capacitor **320** may be connected in parallel to the switch **330** and load **150** to store energy when switch **330** is open for delivery to load **150** when switch **330** is closed. Rectifier **340** may be electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. Rectifier **340** may be a full-wave or a half-wave rectifier. Rectifier **340** may include a diode electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. The direction of the diode of rectifier **340** is optional.

In an exemplary embodiment provided in FIG. **4**, storage circuit **400** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **410**. If charging capacitor **410** is not used, then the connection to ground shown at capacitor **410** is eliminated. A plurality of diodes may be placed at any position in the circuit. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. Diode **440** may be placed in series with load **150**. The voltage from capacitor **410** can be used to charge spark gap **420** when it reaches sufficient voltage. Spark gap **420** may comprise one or more spark gaps in parallel. Non-limiting examples of spark gap **420** include mercury-reed switches and mercury-wetted reed switches. When spark gap **420** arcs, energy will arc from one end of the spark gap **420** to the receiving end of the spark gap **420**. The output of spark gap **420** may be electrically connected in series to rectifier **450**. Rectifier **450** may be a full-wave or a half-wave rectifier. Rectifier **450** may include a diode electrically connected in parallel to transformer **430** and load **150**, between the receiving end of spark gap **420** and ground.

The direction of the diode of rectifier **450** is optional. The output of rectifier **450** is connected to transformer **430** to drive load **150**.

FIG. **5** presents motor driver circuit **500**. One or more collection devices (**130** from FIG. **2**) are electrically connected to static electricity motor **510**, which powers generator **520** to drive load **150**. A plurality of diodes may be placed at any position in the circuit. Motor **510** may also be directly connected to load **150** to drive it directly.

FIG. **6** demonstrates a circuit **600** for producing hydrogen. A plurality of diodes may be placed at any position in the circuit. One or more collection devices (**130** from FIG. **2**) are electrically connected to primary spark gap **610**, which may be connected to secondary spark gap **640**. Non-limiting examples of spark gaps **610**, **640** include mercury-reed switches and mercury-wetted reed switches. Secondary spark gap **640** may be immersed in water **630** within container **620**. When secondary spark gap **640** immersed in water **630** is energized, spark gap **640** may produce bubbles of hydrogen and oxygen, which may be collected to be used as fuel.

FIG. **7** presents circuit **700** for driving a fuel cell. A plurality of diodes may be placed at any position in the circuit. Collection devices (**130** from FIG. **2**) provide energy to fuel cell **720** which drives load **150**. Fuel cell **720** may produce hydrogen and oxygen.

FIG. **8** presents exemplary circuit **800** for the collection of energy. Storage circuit **800** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **810**. If charging capacitor **810** is not used, then the connection to ground shown at capacitor **810** is eliminated. A plurality of diodes may be placed at any position in the circuit. The voltage from capacitor **810** can be used to charge spark gap **820** when it reaches sufficient voltage. Spark gap **820** may comprise one or more spark gaps in parallel or in series. Non-limiting examples of spark gap **820** include mercury-reed switches and mercury-wetted reed switches. When spark gap **820** arcs, energy will arc from one end of spark gap **820** to the receiving end of spark gap **820**. The output of spark gap **820** may be electrically connected in series to rectifier **825**. Rectifier **825** may be a full-wave or a half-wave rectifier. Rectifier **825** may include a diode electrically connected in parallel to inductor **830** and load **150**, between the receiving end of spark gap **820** and ground. The direction of the diode of rectifier **825** is optional. The output of rectifier **825** is connected to inductor **830**. Inductor **830** may be a fixed value inductor or a variable inductor. Capacitor **870** may be placed in parallel with load **150**.

FIG. **9** presents a flow diagram of a method for collecting energy. In block **910**, one or more collection devices may be suspended from a support structure wire. In block **920**, a load may be electrically connected to the support structure wire to draw current. In block **930** a diode may be electrically connected between the support structure wire and the electrical connection to the load. In block **940**, energy provided to the load may be stored or otherwise utilized.

Any process descriptions or blocks in flow charts should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred embodiment of the present disclosure in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure.

It should be emphasized that the above-described embodiments of the present disclosure, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present disclosure and protected by the following claims.

Therefore, at least the following is claimed:

1. A method of collecting energy comprising:

suspending at least one collection device from a plurality of support structure wires elevated above a ground level, the collection device including a carbon or graphite fiber that collects electrical enemy from the air and is electrically connected to the support structure wire; and

providing a load with an electrical connection to the plurality of support structure wires to draw current.

2. The method of claim **1**, wherein the collection device comprises a diode.

3. The method of claim 1, wherein the collection device comprises a diode electrically connected between the fiber and the load.

4. The method of claim 1, further comprising storing energy provided to the load.

5. The method of claim 4, wherein storing energy provided to the load comprises storing energy in a capacitor or an inductor.

6. The method of claim 2, wherein the diode is elevated relative to the ground level.

7. A system of energy collection comprising:

a plurality of support structure wires elevated above ground level; at least one collection device including at least one carbon or graphite fiber that collects electrical enemy from the air and is electrically connected to the plurality of support structure wires; and

a load electrically connected to the plurality of support structure wires.

8. The system of claim 7, wherein the collection device comprises a diode.

9. The system of claim 7, wherein the collection device comprises a diode electrically connected between the load and the fiber.

10. The system of claim 8, wherein the diode is elevated relative to the ground level.

11. The system of claim 7, further comprising a diode electrically connected between the at least one collection device and the plurality of support structure wires.

12. The system of claim 7, wherein the fiber comprises a first end and a second opposing end, and wherein the system further comprises a support structure connected to both ends of the fiber.

13. The system of claim 7, comprising:

said at least one fiber including a plurality of collection fibers; a support frame having a top side and a bottom side; and a conducting connecting wire between the plurality of support structure wires and the support frame, wherein one end of each of a plurality of collection fibers is connected to the top side of the support frame, and the opposing end of each of a plurality of collection fibers is connected to the bottom side of the support frame.

14. The system of claim 7, further comprising a rigid structure, the rigid structure comprising multiple supports extending outward from a single point of the support structure, wherein each end of the fiber is connected to an end of the multiple supports.

15. The system of claim 7, further comprising a rigid structure, the rigid structure comprising multiple supports extending outward from multiple points of the support structure, wherein each end of the fiber is connected to an end of the multiple supports.

16. The system of claim 14, further comprising a plurality of rigid structures wherein said at least one fiber includes collection fibers connected between a plurality of the rigid structures.

17. The system of claim 7, further comprising:

a switch connected in series between the plurality of support structure wires and the load; and

a capacitor connected in parallel with the switch and the load.

18. The system of claim 17, wherein the switch comprises an interrupter connected between the plurality of support structure wires and the load.

19. The system of claim 18, wherein the interrupter comprises one of a fluorescent tube, a neon bulb, an AC light, or a spark gap.

20. The system of claim 18, further comprising a transformer connected between the interrupter and the load.

21. The system of claim 7, further comprising:

a motor for providing power the motor connected between the plurality of support structure wires and the load; and

a generator powered by the motor.

22. The system of claim 7, wherein the load comprises a spark gap in a container of fluid, and the load is used to produce a chemical reaction.

23. The system of claim 22, wherein the fluid comprises water and the chemical reaction comprises the production of hydrogen and oxygen.

24. The system of claim 7, further comprising a fuel cell between the plurality of support structure wires and the load.

25. The system of claim 7, wherein the load comprises a fuel cell.

26. The system of claim 24, wherein the fuel cell produces hydrogen and oxygen.

27. The system of claim 24, further comprising a diode connected between the plurality of support structure wires and the fuel cell.

28. A system of collecting energy comprising:

means for suspending carbon or graphite collection fibers, the means elevated above a ground level, the collection fibers collecting electrical enemy from the air and electrically connected to the means for suspending collection fibers;

means for inducing current flow, the means for inducing current flow electrically connected to the means for suspending collection fibers; and

means for restricting the backflow of charge carriers, the means for restricting the backflow of charge carriers electrically connected between the collection fibers and the means for inducing current flow.

* * * * *

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McCowen

(10) Patent No.: US 8,686,575 B2
(45) Date of Patent: Apr. 1, 2014

(54) **ENERGY COLLECTION**

(75) Inventor: **Clint McCowen**, Navarre, FL (US)

(73) Assignee: **Ion Power Group, LLC**, Navarre, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/255,130**

(22) Filed: **Oct. 21, 2008**

(65) **Prior Publication Data**

US 2009/0040680 A1 Feb. 12, 2009

Related U.S. Application Data

(63) Continuation of application No. 11/358,264, filed on Feb. 21, 2006, now Pat. No. 7,439,712.

(51) **Int. Cl.**

F02B 63/04	(2006.01)
F03G 7/08	(2006.01)
H02K 7/18	(2006.01)
H02N 1/00	(2006.01)

(52) **U.S. Cl.**

USPC ..... **290/1 R**; 322/2 A

(58) **Field of Classification Search**

USPC ..... 290/1 R; 322/2 A; 126/660; 60/641.8, 60/641.11, 641.12, 659, 698; 244/158.2

See application file for complete search history.

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Primary Examiner — Pedro J Cuevas

(74) *Attorney, Agent, or Firm* — Benjamin A. Balser; Balser & Grell IP Law

(57) **ABSTRACT**

An energy collection system may collect and use the energy generated by an electric field. Collection fibers are suspended from a support wire system supported by poles. The support wire system is electrically connected to a load by a connecting wire. The collection fibers may be made of any conducting material, but carbon and graphite are preferred. Diodes may be used to restrict the backflow or loss of energy.

25 Claims, 10 Drawing Sheets

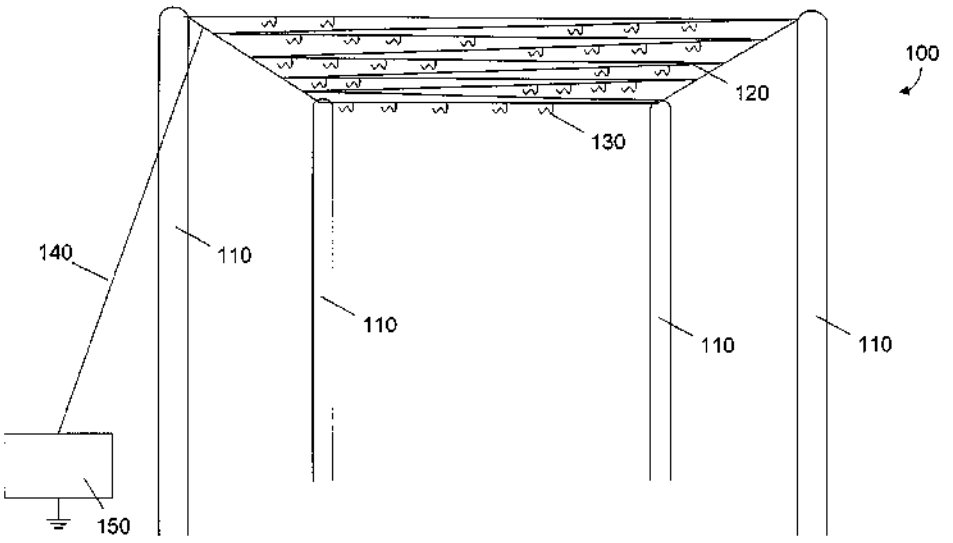

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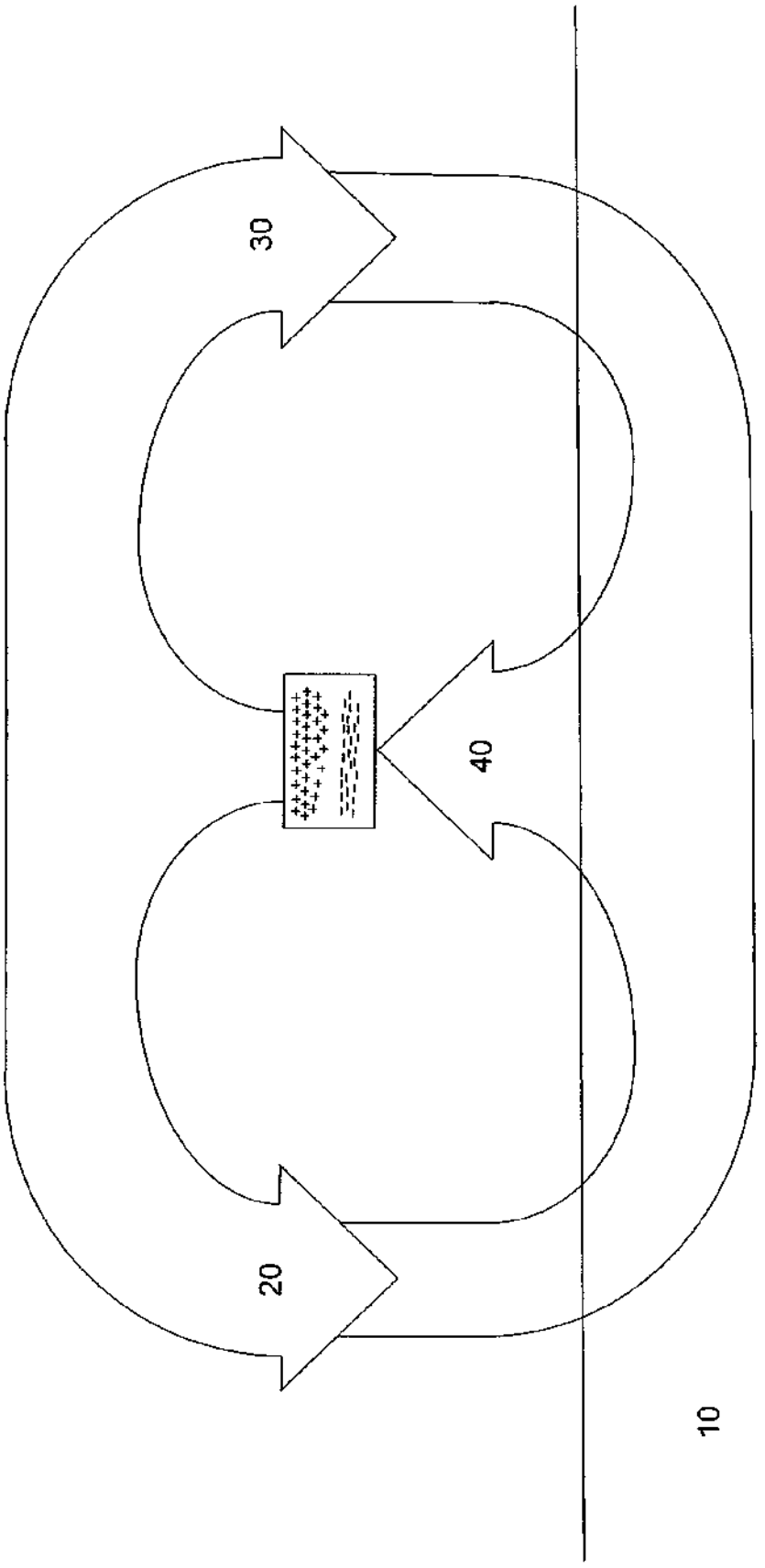

FIGURE 1

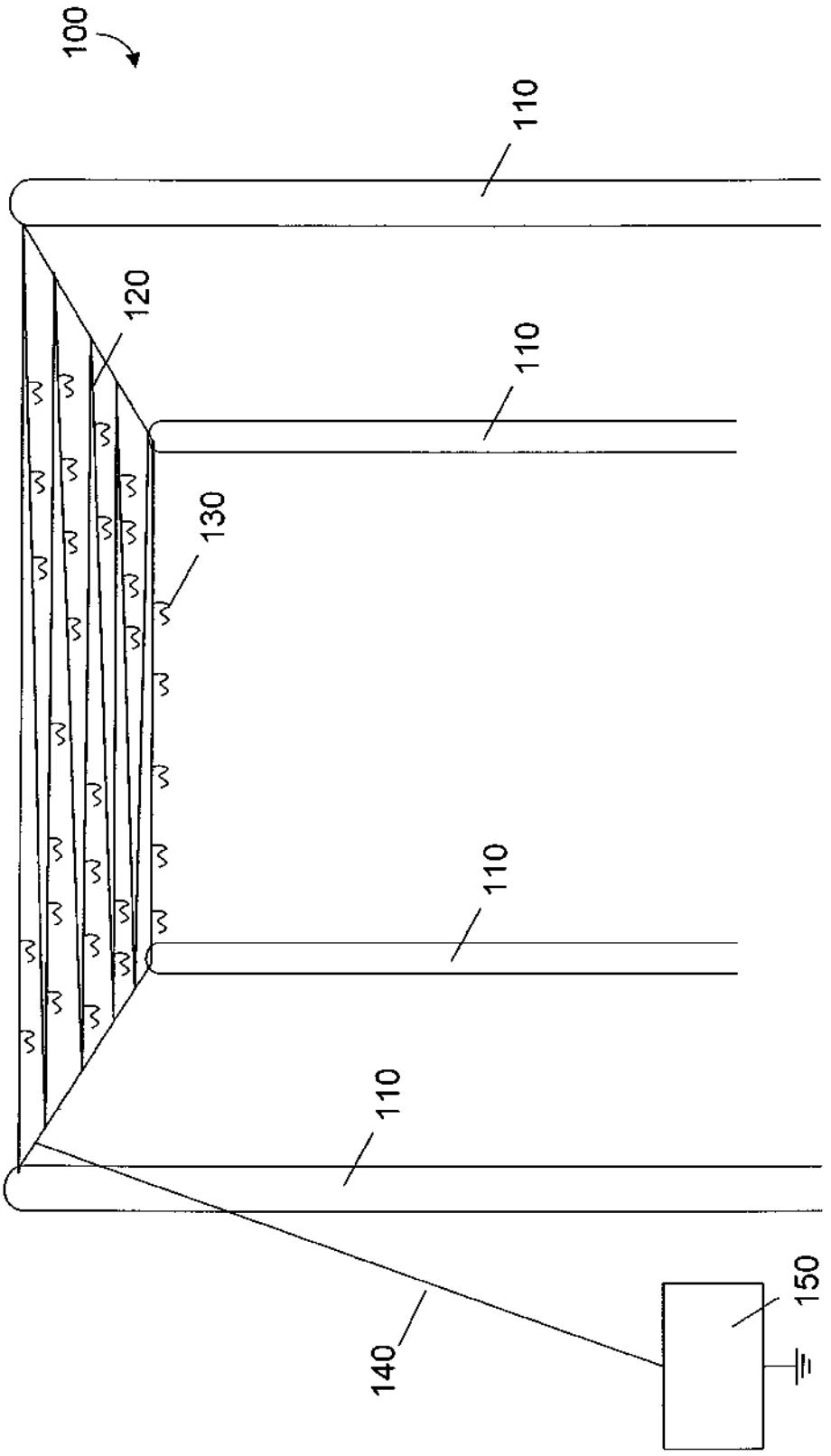

FIGURE 2

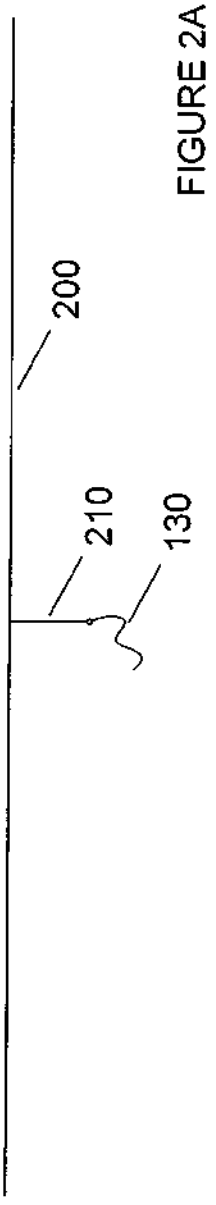

FIGURE 2A

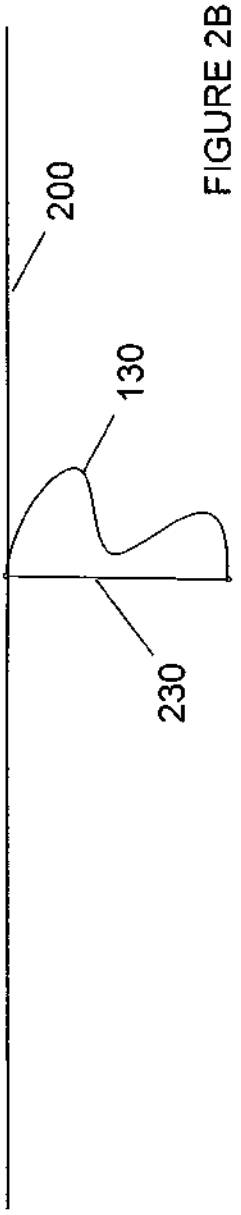

FIGURE 2B

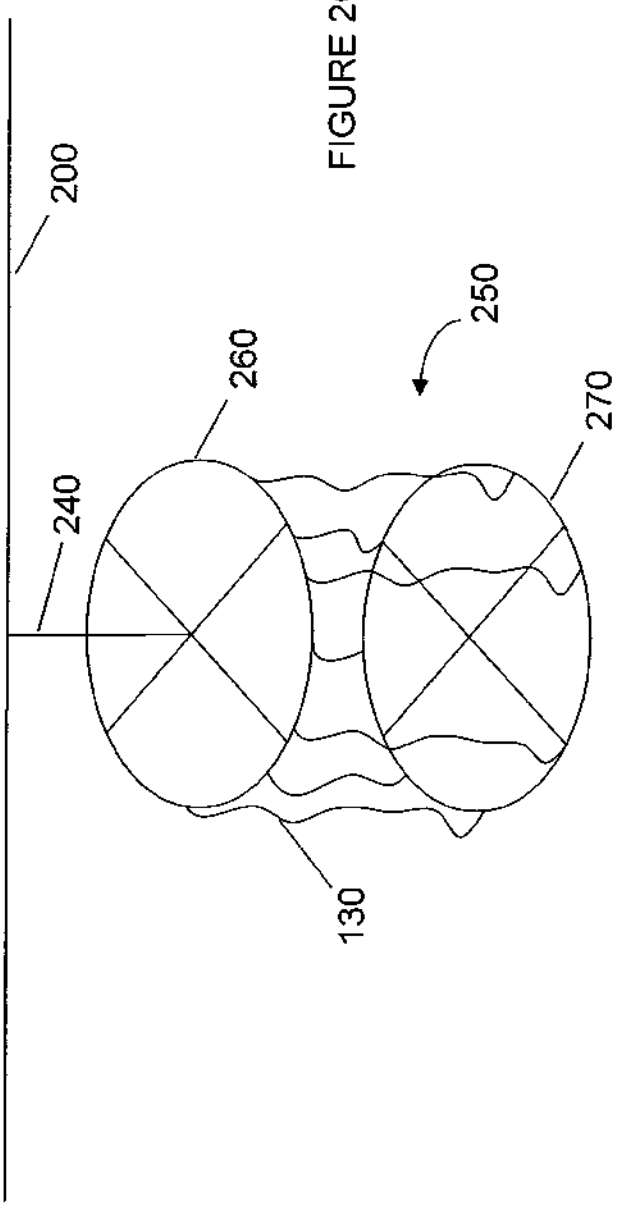

FIGURE 2C

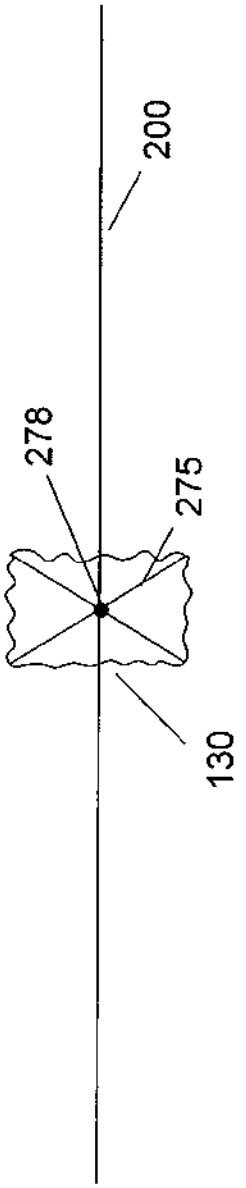

FIGURE 2D

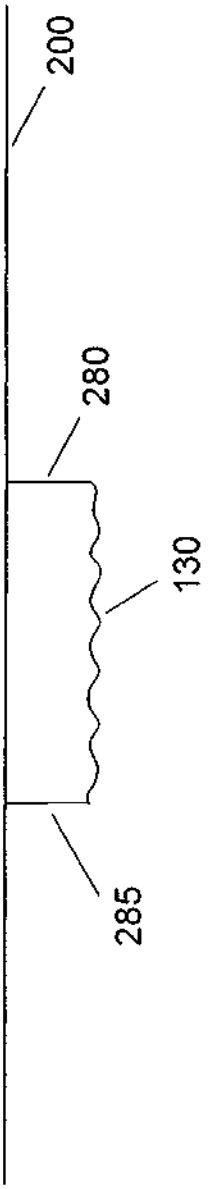

FIGURE 2E

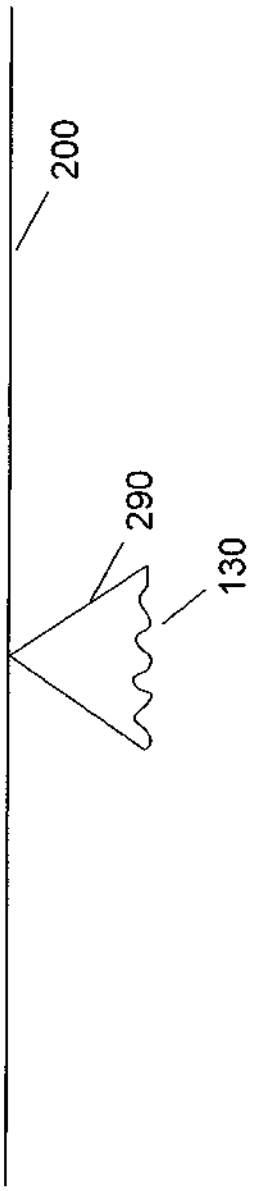

FIGURE 2F

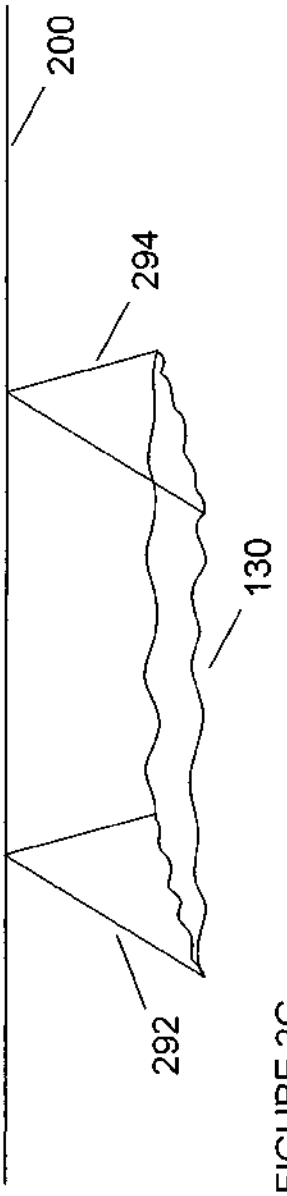

FIGURE 2G

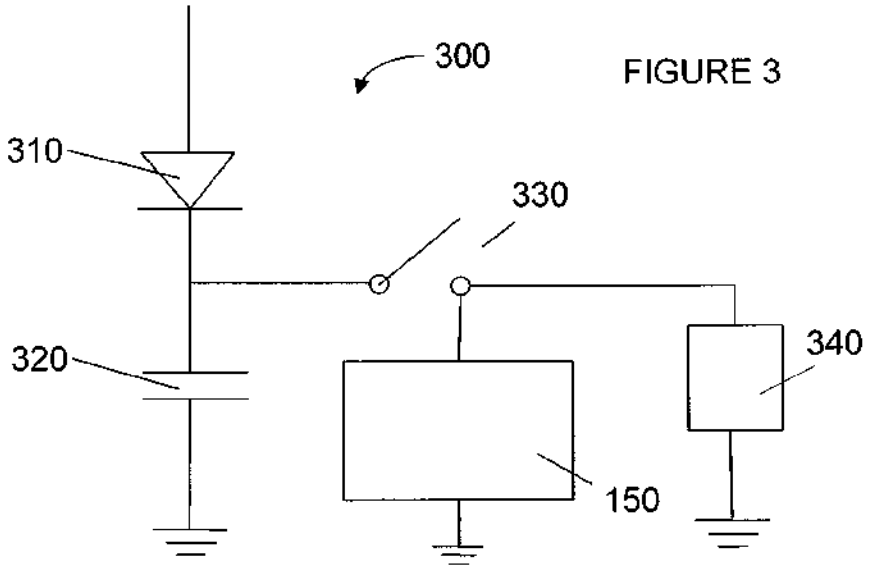

FIGURE 3

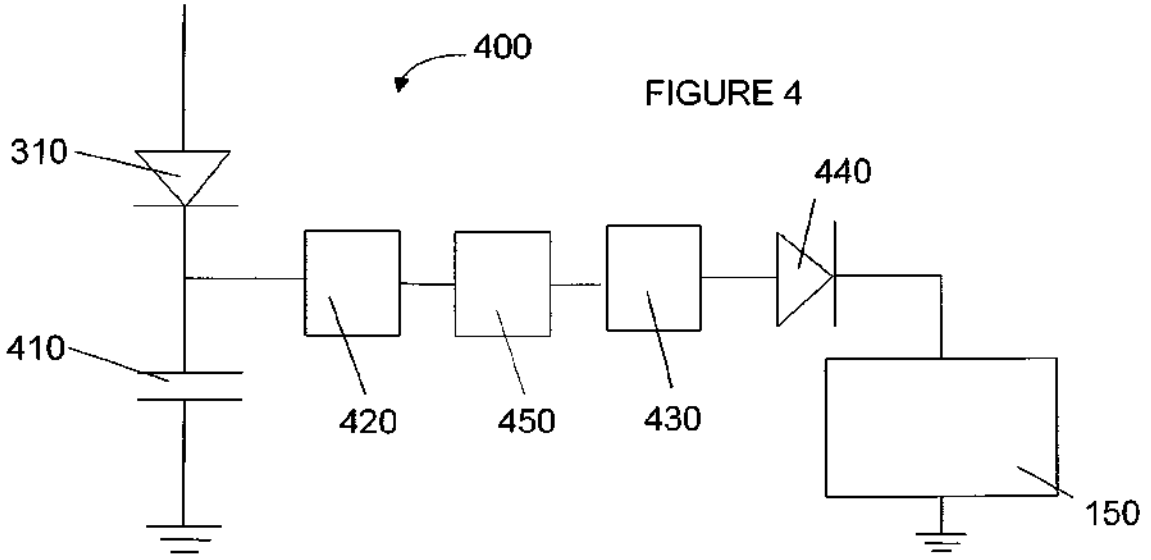

FIGURE 4

FIGURE 5

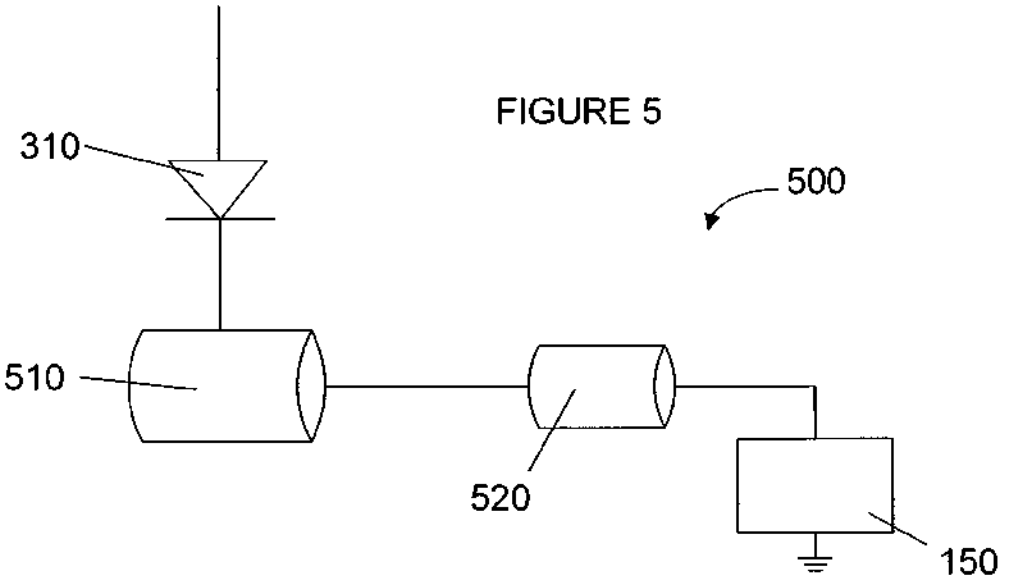

FIGURE 6

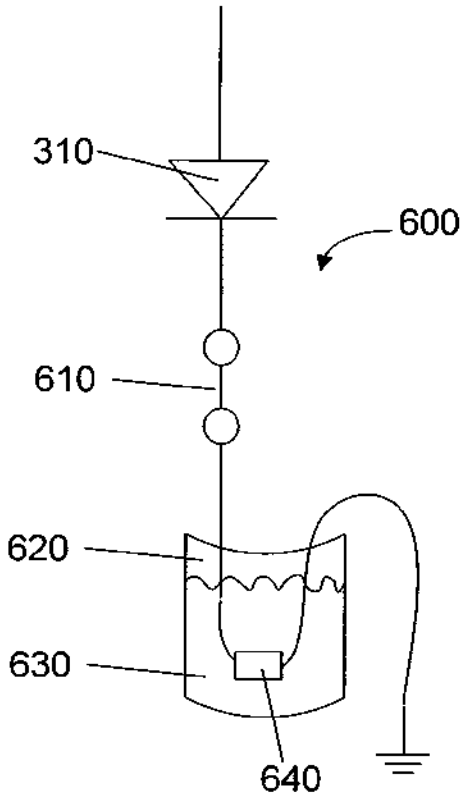

FIGURE 7

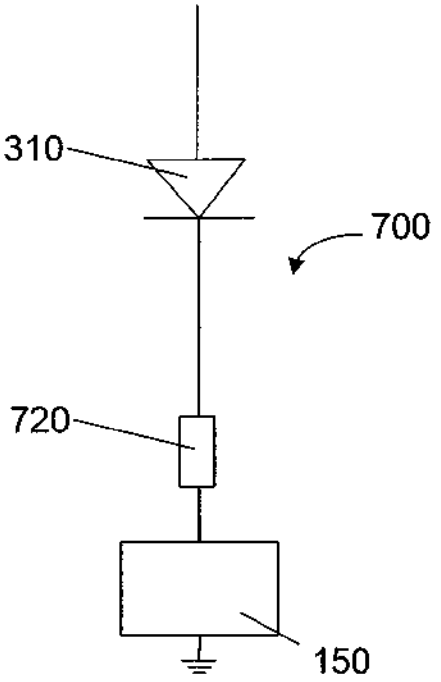

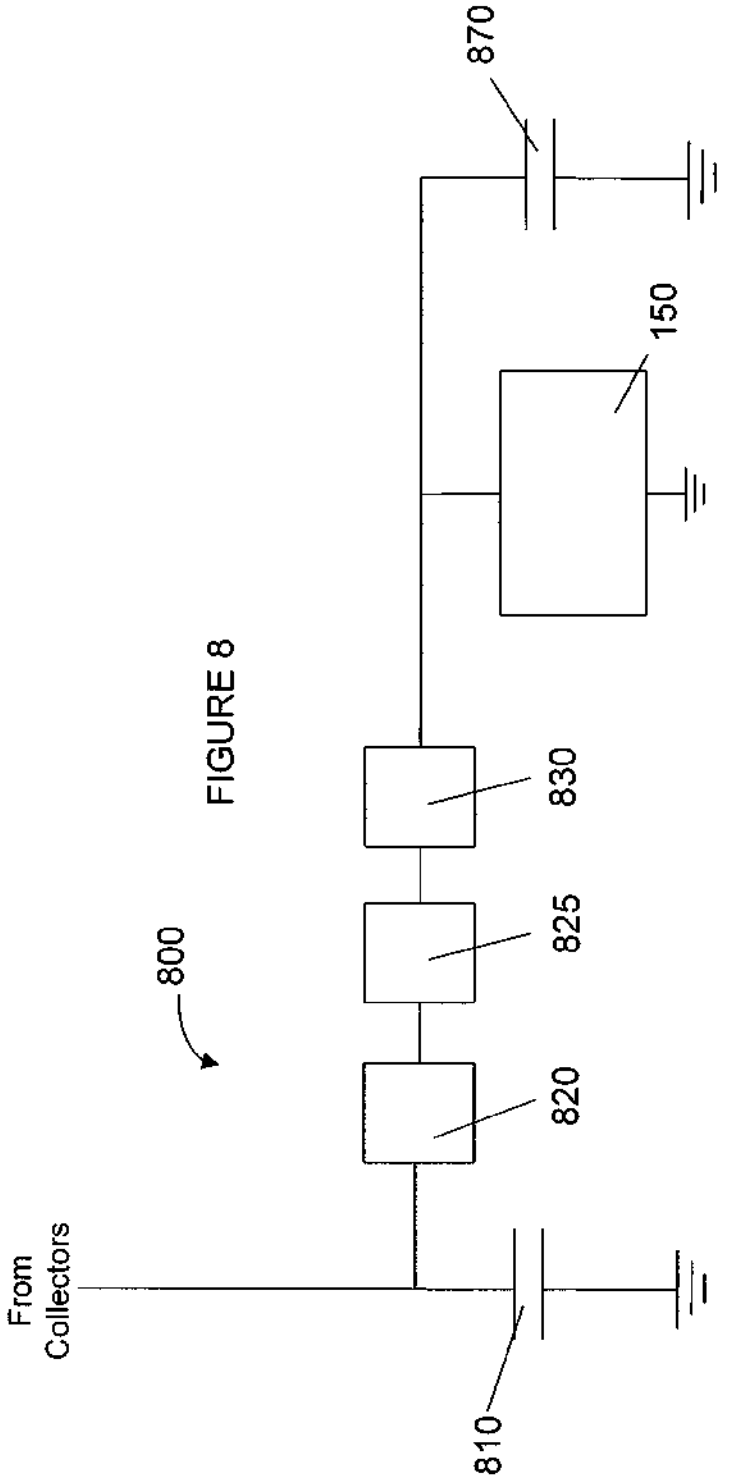

FIGURE 8

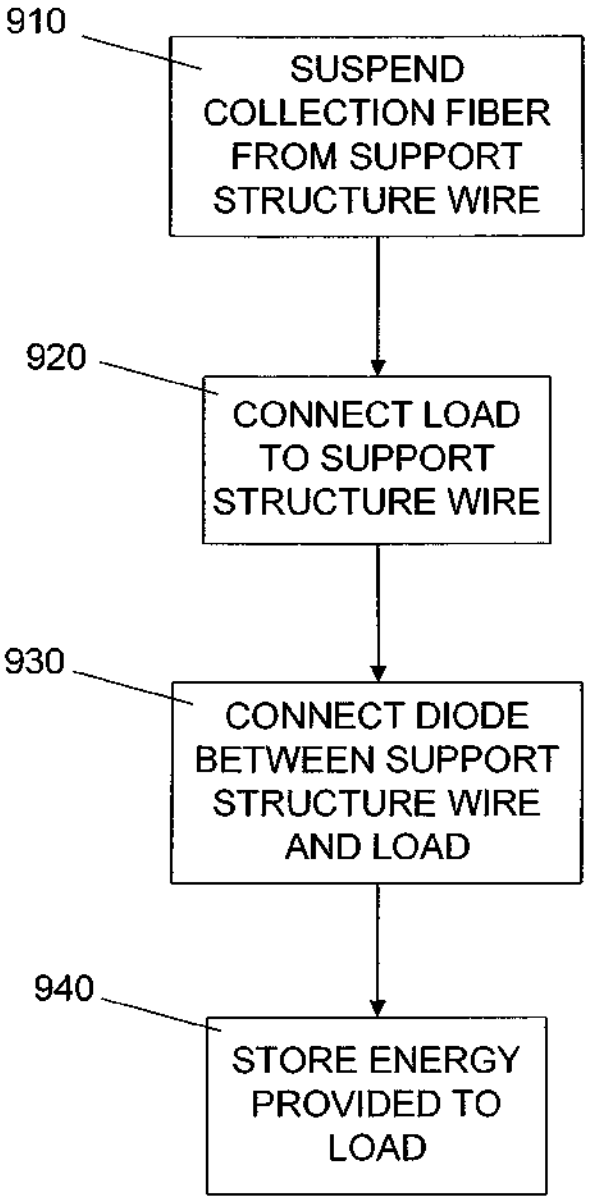
910
SUSPEND COLLECTION FIBER FROM SUPPORT STRUCTURE WIRE
920
CONNECT LOAD TO SUPPORT STRUCTURE WIRE
930
CONNECT DIODE BETWEEN SUPPORT STRUCTURE WIRE AND LOAD
940
STORE ENERGY PROVIDED TO LOAD

FIGURE 9

ENERGY COLLECTION

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation application of U.S. patent application Ser. No. 11/358,264, filed on Feb. 21, 2006, which is incorporated by reference herein.

TECHNICAL FIELD

The present disclosure is generally related to energy and, more particularly, is related to systems and methods for collecting energy.

BACKGROUND

The concept of fair weather electricity deals with the electric field and the electric current in the atmosphere propagated by the conductivity of the air. Clear, calm air carries an electrical current, which is the return path for thousands of lightening storms simultaneously occurring at any given moment around the earth. For simplicity, this energy may be referred to as static electricity or static energy. FIG. **1** illustrates a weather circuit for returning the current from lightning, for example, back to ground **10**. Weather currents **20**, **30** return the cloud to ground current **40**.

In a lightening storm, an electrical charge is built up, and electrons arc across a gas, ionizing it and producing the lightening flash. As one of ordinary skill in the art understands, the complete circuit requires a return path for the lightening flash. The atmosphere is the return path for the circuit. The electric field due to the atmospheric return path is relatively weak at any given point because the energy of thousands of electrical storms across the planet are diffused over the atmosphere of the entire Earth during both fair and stormy weather. Other contributing factors to electric current being present in the atmosphere may include cosmic rays penetrating and interacting with the earth's atmosphere, and also the migration of ions, as well as other effects yet to be fully studied.

Some of the ionization in the lower atmosphere is caused by airborne radioactive substances, primarily radon. In most places of the world, ions are formed at a rate of 5-10 pairs per cubic centimeter per second at sea level. With increasing altitude, cosmic radiation causes the ion production rate to increase. In areas with high radon exhalation from the soil (or building materials), the rate may be much higher.

Alpha-active materials are primarily responsible for the atmospheric ionization. Each alpha particle (for instance, from a decaying radon atom) will, over its range of some centimeters, create approximately 150,000-200,000 ion pairs.

While there is a large amount of usable energy available in the atmosphere, a method or apparatus for efficiently collecting that energy has not been forthcoming. Therefore, a heretofore unaddressed need exists in the industry to address the aforementioned deficiencies and inadequacies.

SUMMARY

Embodiments of the present disclosure provide systems and methods for collecting energy. Briefly described in architecture, one embodiment of the system, among others, can be implemented by a support structure wire elevated above a ground level, at least one collection fiber electrically connected to the support structure wire; a load electrically connected to the support structure wire; and a diode electrically connected between the load and at least one collection fiber.

Embodiments of the present disclosure can also be viewed as providing methods for collecting energy. In this regard, one embodiment of such a method, among others, can be broadly summarized by the following steps: suspending at least one collection fiber from a support structure wire elevated above ground level, the fiber electrically connected to the support structure wire; providing a load with an electrical connection to the support structure wire to draw current; and providing a diode electrically connected between the collection fiber and the load.

Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a circuit diagram of a weather energy circuit.

FIG. **2** is a perspective view of an exemplary embodiment of many energy collectors elevated above ground by a structure.

FIG. **2A** is a side view of an energy collection fiber suspended from a support wire.

FIG. **2B** is a side view of an exemplary embodiment of an energy collection fiber suspended from a support wire and with an additional support member.

FIG. **2C** is a perspective view of a support structure for multiple energy collection fibers.

FIG. **2D** is a side view of an exemplary embodiment of a support structure for multiple energy collection fibers.

FIG. **2E** is a side view of a support structure for an energy collection fiber.

FIG. **2F** is a side view of an exemplary embodiment of a support structure for an energy collection fiber.

FIG. **2G** is a side view of a support structure for multiple energy collection fibers.

FIG. **3** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **4** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **5** is a circuit diagram of an exemplary embodiment of an energy collection circuit for powering a generator and motor.

FIG. **6** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy and using it for the production of hydrogen and oxygen.

FIG. **7** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy, and using it for driving a fuel cell.

FIG. **8** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy.

FIG. **9** is a flow diagram of an exemplary embodiment of collecting energy with a collection fiber.

DETAILED DESCRIPTION

Electric charges on conductors reside entirely on the external surface of the conductors, and tend to concentrate more

around sharp points and edges than on flat surfaces. Therefore, an electric field received by a sharp conductive point may be much stronger than a field received by the same charge residing on a large smooth conductive shell. An exemplary embodiment of this disclosure takes advantage of this property, among others, to collect and use the energy generated by an electric field in the atmosphere. Referring to collection system **100** presented in FIG. **2**, at least one collection device **130** may be suspended from a support wire system **120** supported by poles **110**. Collection device **130** may comprise a diode or a collection fiber individually, or the combination of a diode and a collection fiber. Support wire system **120** may be electrically connected to load **150** by connecting wire **140**. Supporting wire system **120** may be any shape or pattern. Also, conducting wire **140** may be one wire or multiple wires. The collection device **130** in the form of a fiber may comprise any conducting or non-conducting material, including carbon, graphite, Teflon, and metal. An exemplary embodiment utilizes carbon or graphite fibers for static electricity collection. Support wire system **120** and connecting wire **140** can be made of any conducting material, including aluminum or steel, but most notably, copper. Teflon may be added to said conductor as well, such as non-limiting examples of a Teflon impregnated wire, a wire with a Teflon coating, or Teflon strips hanging from a wire. Conducting wire **120**, **140**, and **200** may be bare wire, or coated with insulation as a non-limiting example. Wires **120** and **140** are a means of transporting the energy collected by collection device **130**.

An exemplary embodiment of the collection fibers as collection device **130** includes graphite or carbon fibers. Graphite and carbon fibers, at a microscopic level, can have hundreds of thousands of points. Atmospheric electricity may be attracted to these points. If atmospheric electricity can follow two paths where one is a flat surface and the other is a pointy, conductive surface, the electrical charge will be attracted to the pointy, conductive surface. Generally, the more points that are present, the higher energy that can be gathered. Therefore, carbon, or graphite fibers are examples that demonstrate exemplary collection ability.

In at least one exemplary embodiment, the height of support wire **120** may be an important factor. The higher that collection device **130** is from ground, the larger the voltage potential between collection device **130** and electrical ground. The electric field may be more than 100 volts per meter under some conditions. When support wire **120** is suspended in the air at a particular altitude, wire **120** will itself collect a very small charge from ambient voltage. When collection device **130** is connected to support wire **120**, collection device **130** becomes energized and transfers the energy to support wire **120**.

A diode, not shown in FIG. **2**, may be connected in several positions in collection system **100**. A diode is a component that restricts the direction of movement of charge carriers. It allows an electric current to flow in one direction, but essentially blocks it in the opposite direction. A diode can be thought of as the electrical version of a check valve. The diode may be used to prevent the collected energy from discharging into the atmosphere through the collection fiber embodiment of collection device **130**. An exemplary embodiment of the collection device comprises the diode with no collection fiber. A preferred embodiment, however, includes a diode at the connection point of a collection fiber to support system **120** such that the diode is elevated above ground. Multiple diodes may be used between collection device **130** and load **150**. Additionally, in an embodiment with multiple fibers, the diodes restricts energy that may be collected through one fiber from escaping through another fiber.

Collection device **130** may be connected and arranged in relation to support wire system **120** by many means. Some non-limiting examples are provided in FIGS. **2A-2G** using a collection fiber embodiment. FIG. **2A** presents support wire **200** with connecting member **210** for collection device **130**. Connection member **210** may be any conducting material allowing for the flow of electricity from connection device **130** to support wire **200**. Then, as shown in FIG. **2**, the support wire **200** of support system **120** may be electrically connected through conducting wire **140** to load **150**. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at an elevated position at the connection point between a collection fiber embodiment of collection device **130** and connection member **210**.

Likewise, FIG. **2B** shows collection fiber **130** electrically connected to support wire **200** and also connected to support member **230**. Support member **230** may be connected to collection fiber **130** on either side. Support member **230** holds the fiber steady on both ends instead of letting it move freely. Support member **230** may be conducting or non-conducting. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at elevated position at the connection point between collection fiber **130** and support wire **200** or between fiber **130**, support member **230**, and support wire **200**.

FIG. **2C** presents multiple collection fibers in a squirrel cage arrangement with top and bottom support members. Support structure **250** may be connected to support structure wire **200** by support member **240**. Structure **250** has a top **260** and a bottom **270** and each of the multiple collection fibers **130** are connected on one end to top **260** and on the other end to bottom **270**. A plurality of diodes may be placed at any position on support structure **250**. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support structure wire **200**.

FIG. **2D** presents another exemplary embodiment of a support structure with support members **275** in an x-shape connected to support structure wire **200** at intersection **278** with collection fibers **130** connected between ends of support members **275**. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2E** provides another exemplary embodiment for supporting collection fiber **130**. Collection fiber **130** may be connected on one side to support member **285**, which may be connected to support structure wire **200** in a first location and on the other side to support member **280**, which may be connected to support structure wire **200** in a second location on support structure wire **200**. The first and second locations may be the same location, or they may be different locations, even on different support wires. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support wire **200**.

FIG. **2F** presents another exemplary embodiment of a support for a collection fiber. Two support members **290** may support either side of a collection fiber and are connected to support wire **200** in a single point. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2G** provides two supports as provided in FIG. **2F** such that at least two support members **292**, **294** may be connected

to support structure wire **200** in multiple locations and collection fibers **130** may be connected between each end of the support structures. Collection fibers **130** may be connected between each end of a single support structure and between multiple support structures. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support structure wire **200**.

FIG. **3** provides a schematic diagram of storing circuit **300** for storing energy collected by one or more collection devices (**130** from FIG. **2**). Load **150** induces current flow. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. A plurality of diodes may be placed at any position in the circuit. Switch **330** may be electrically connected between load **150** and at least one collection device (**130** from FIG. **2**) to connect and disconnect the load. Capacitor **320** may be connected in parallel to the switch **330** and load **150** to store energy when switch **330** is open for delivery to load **150** when switch **330** is closed. Rectifier **340** may be electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. Rectifier **340** may be a full-wave or a half-wave rectifier. Rectifier **340** may include a diode electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. The direction of the diode of rectifier **340** is optional.

In an exemplary embodiment provided in FIG. **4**, storage circuit **400** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **410**. If charging capacitor **410** is not used, then the connection to ground shown at capacitor **410** is eliminated. A plurality of diodes may be placed at any position in the circuit. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. Diode **440** may be placed in series with load **150**. The voltage from capacitor **410** can be used to charge spark gap **420** when it reaches sufficient voltage. Spark gap **420** may comprise one or more spark gaps in parallel. Non-limiting examples of spark gap **420** include mercury-reed switches and mercury-wetted reed switches. When spark gap **420** arcs, energy will arc from one end of the spark gap **420** to the receiving end of the spark gap **420**. The output of spark gap **420** may be electrically connected in series to rectifier **450**. Rectifier **450** may be a full-wave or a half-wave rectifier. Rectifier **450** may include a diode electrically connected in parallel to transformer **430** and load **150**, between the receiving end of spark gap **420** and ground. The direction of the diode of rectifier **450** is optional. The output of rectifier **450** is connected to transformer **430** to drive load **150**.

FIG. **5** presents motor driver circuit **500**. One or more collection devices (**130** from FIG. **2**) are electrically connected to static electricity motor **510**, which powers generator **520** to drive load **150**. A plurality of diodes may be placed at any position in the circuit. Motor **510** may also be directly connected to load **150** to drive it directly.

FIG. **6** demonstrates a circuit **600** for producing hydrogen. A plurality of diodes may be placed at any position in the circuit. One or more collection devices (**130** from FIG. **2**) are electrically connected to primary spark gap **610**, which may be connected to secondary spark gap **640**. Non-limiting examples of spark gaps **610**, **640** include mercury-reed switches and mercury-wetted reed switches. Secondary spark gap **640** may be immersed in water **630** within container **620**. When secondary spark gap **640** immersed in water **630** is energized, spark gap **640** may produce bubbles of hydrogen and oxygen, which may be collected to be used as fuel.

FIG. **7** presents circuit **700** for driving a fuel cell. A plurality of diodes may be placed at any position in the circuit. Collection devices (**130** from FIG. **2**) provide energy to fuel cell **720** which drives load **150**. Fuel cell **720** may produce hydrogen and oxygen.

FIG. **8** presents exemplary circuit **800** for the collection of energy. Storage circuit **800** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **810**. If charging capacitor **810** is not used, then the connection to ground shown at capacitor **810** is eliminated. A plurality of diodes may be placed at any position in the circuit. The voltage from capacitor **810** can be used to charge spark gap **820** when it reaches sufficient voltage. Spark gap **820** may comprise one or more spark gaps in parallel or in series. Non-limiting examples of spark gap **820** include mercury-reed switches and mercury-wetted reed switches. When spark gap **820** arcs, energy will arc from one end of spark gap **820** to the receiving end of spark gap **820**. The output of spark gap **820** may be electrically connected in series to rectifier **825**. Rectifier **825** may be a full-wave or a half-wave rectifier. Rectifier **825** may include a diode electrically connected in parallel to inductor **830** and load **150**, between the receiving end of spark gap **820** and ground. The direction of the diode of rectifier **825** is optional. The output of rectifier **825** is connected to inductor **830**. Inductor **830** may be a fixed value inductor or a variable inductor. Capacitor **870** may be placed in parallel with load **150**.

FIG. **9** presents a flow diagram of a method for collecting energy. In block **910**, one or more collection devices may be suspended from a support structure wire. In block **920**, a load may be electrically connected to the support structure wire to draw current. In block **930** a diode may be electrically connected between the support structure wire and the electrical connection to the load. In block **940**, energy provided to the load may be stored or otherwise utilized.

Any process descriptions or blocks in flow charts should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred embodiment of the present disclosure in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure.

It should be emphasized that the above-described embodiments of the present disclosure, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present disclosure and protected by the following claims.

Therefore, at least the following is claimed:

1. A method of collecting energy comprising:

suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to the support structure;

providing a load with an electrical connection to the at least one collection device to passively draw current; and

powering a fuel cell between the support structure and the load, the powering performed with energy collected from the at least one collection device.

2. The method of claim **1**, wherein the collection device comprises a diode.

3. The method of claim **1**, wherein the collection device comprises a collection fiber.

4. The method of claim **1**, wherein the collection device comprises a diode and a collection fiber and the diode is electrically connected between the collection fiber and the load.

5. The method of claim **1**, further comprising storing energy provided to the load.

6. The method of claim **5**, wherein storing energy provided to the load comprises storing energy in a capacitor or an inductor.

7. The method of claim **3**, wherein the collection fiber comprises carbon fiber or graphite fiber.

8. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the collection device electrically connected to and suspended from the support structure, the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a diode electrically connected between the at least one collection device and the support structure.

9. The system of claim **8**, wherein the collection device comprises a diode.

10. The system of claim **8**, wherein the collection device comprises a collection fiber.

11. The system of claim **8**, wherein the collection device comprises a collection fiber and a diode electrically connected between the load and the collection fiber.

12. The system of claim **9**, wherein the diode is elevated relative to the ground level.

13. The system of claim **10**, wherein the collection fiber comprises a carbon fiber or a graphite fiber.

14. The system of claim **8**, further comprising:

a switch connected in series between the at least one collection device and the load; and

a capacitor connected in parallel with the switch and the load.

15. The system of claim **14**, wherein the switch comprises an interrupter connected between the at least one collection device and the load, and wherein the interrupter comprises at least one of a fluorescent tube, a neon bulb, an AC light, and a spark gap.

16. The system of claim **15**, further comprising a transformer connected between the interrupter and the load.

17. The system of claim **8**, further comprising:

a motor for providing power, the motor connected between the at least one collection device and the load; and

a generator powered by the motor.

18. The system of claim **8**, further comprising a fuel cell between the support structure and the load.

19. The system of claim **18**, wherein the fuel cell produces hydrogen and oxygen.

20. A system of collecting energy comprising:

means for suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to the means for suspending;

means for passively inducing current flow, the means for inducing current flow electrically connected to the means for suspending; and

means for restricting the backflow of charge carriers, the means for restricting the backflow of charge carriers electrically connected between the at least one collection device and the means for inducing current flow.

21. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the collection device electrically connected to and suspended from the support structure, the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a switch connected in series between the at least one collection device and the load, the switch comprising an interrupter connected between the at least one collection device and the load, and wherein the interrupter comprises at least one of a fluorescent tube, a neon bulb, an AC light, and a spark gap.

22. The system of claim **21**, further comprising a transformer connected between the interrupter and the load.

23. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to and suspended from the support structure, the collection device configured to passively draw current;

a load electrically connected to the at least one collection device;

a motor for providing power, the motor connected between the at least one collection device and the load; and

a generator powered by the motor.

24. A system of energy collection comprising:

a support structure;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment, the at least one collection device electrically connected to and suspended from the support structure the at least one collection device configured to passively draw current;

a load electrically connected to the at least one collection device; and

a fuel cell between the support structure and the load.

25. The system of claim **24**, wherein the fuel cell produces hydrogen and oxygen.

* * * * *

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(54) **ENERGY COLLECTION**

(75) Inventor: **Clint McCowen**, Navarre, FL (US)

(73) Assignee: **Ion Power Group, LLC**, Navarre, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **13/569,133**

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Related U.S. Application Data

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(51) **Int. Cl.**

F02B 63/04	(2006.01)
F03G 7/08	(2006.01)
H02K 7/18	(2006.01)
F03D 9/00	(2006.01)
H02P 9/04	(2006.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

CPC Y02E 10/721; Y02E 10/70; Y02E 10/722; B32B 2262/101; C01B 31/00

USPC ..... 290/1 R, 44, 55

See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Benjamin A. Balser; Balser & Grell IP Law

(57) **ABSTRACT**

An energy collection system may collect and use the energy generated by an electric field. Collection fibers are suspended from a support wire system supported by poles. The support wire system is electrically connected to a load by a connecting wire. The collection fibers may be made of any conducting material, but carbon and graphite are preferred. Diodes may be used to restrict the backflow or loss of energy.

20 Claims, 11 Drawing Sheets

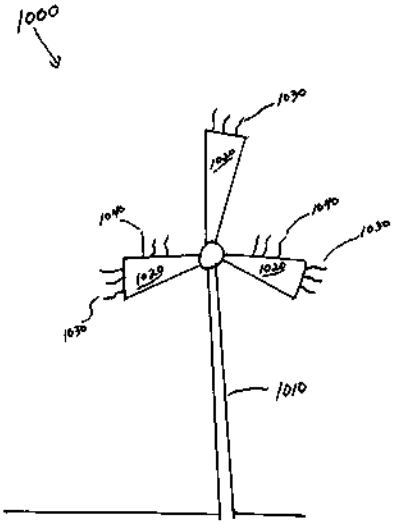

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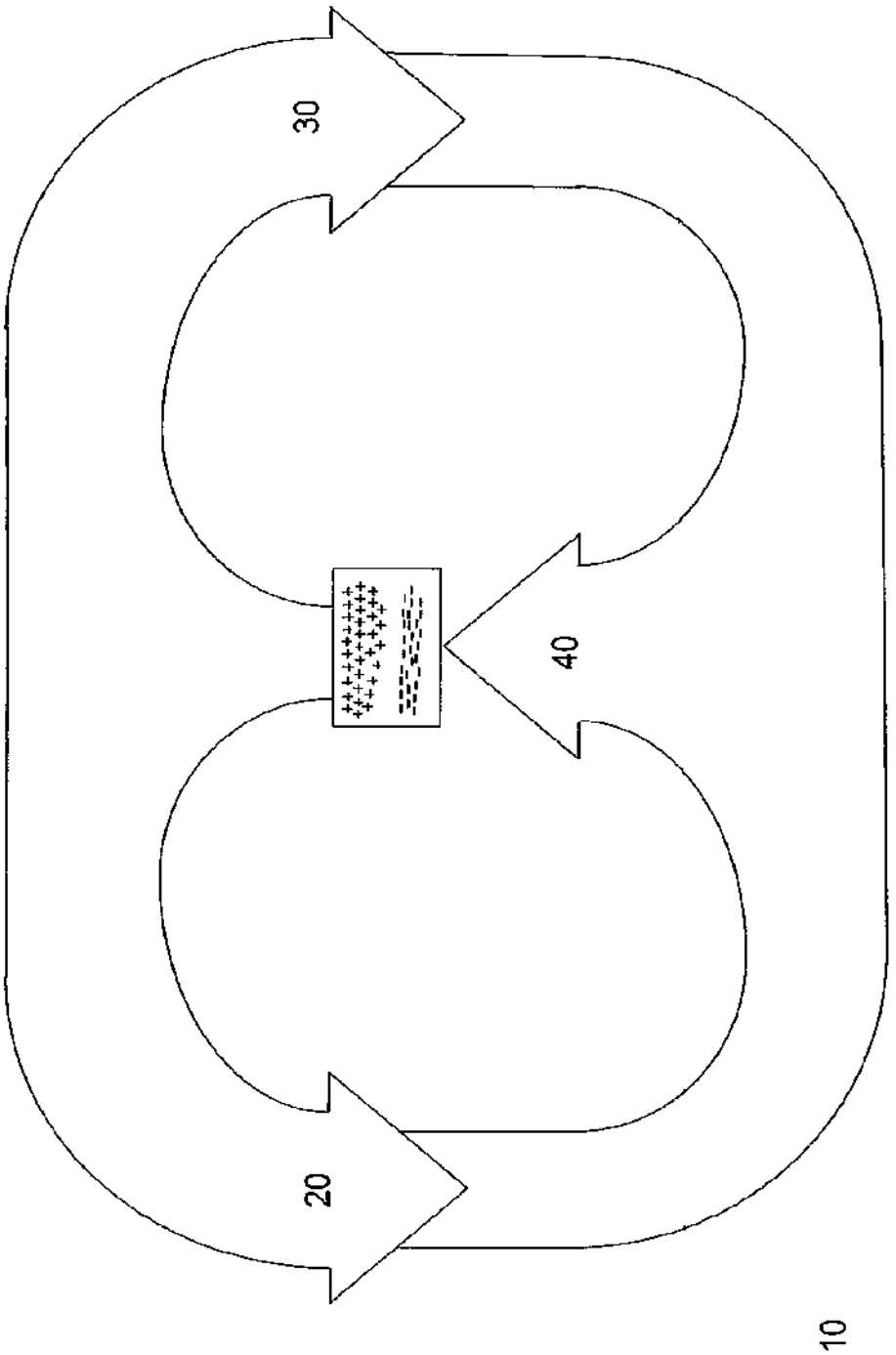

FIGURE 1

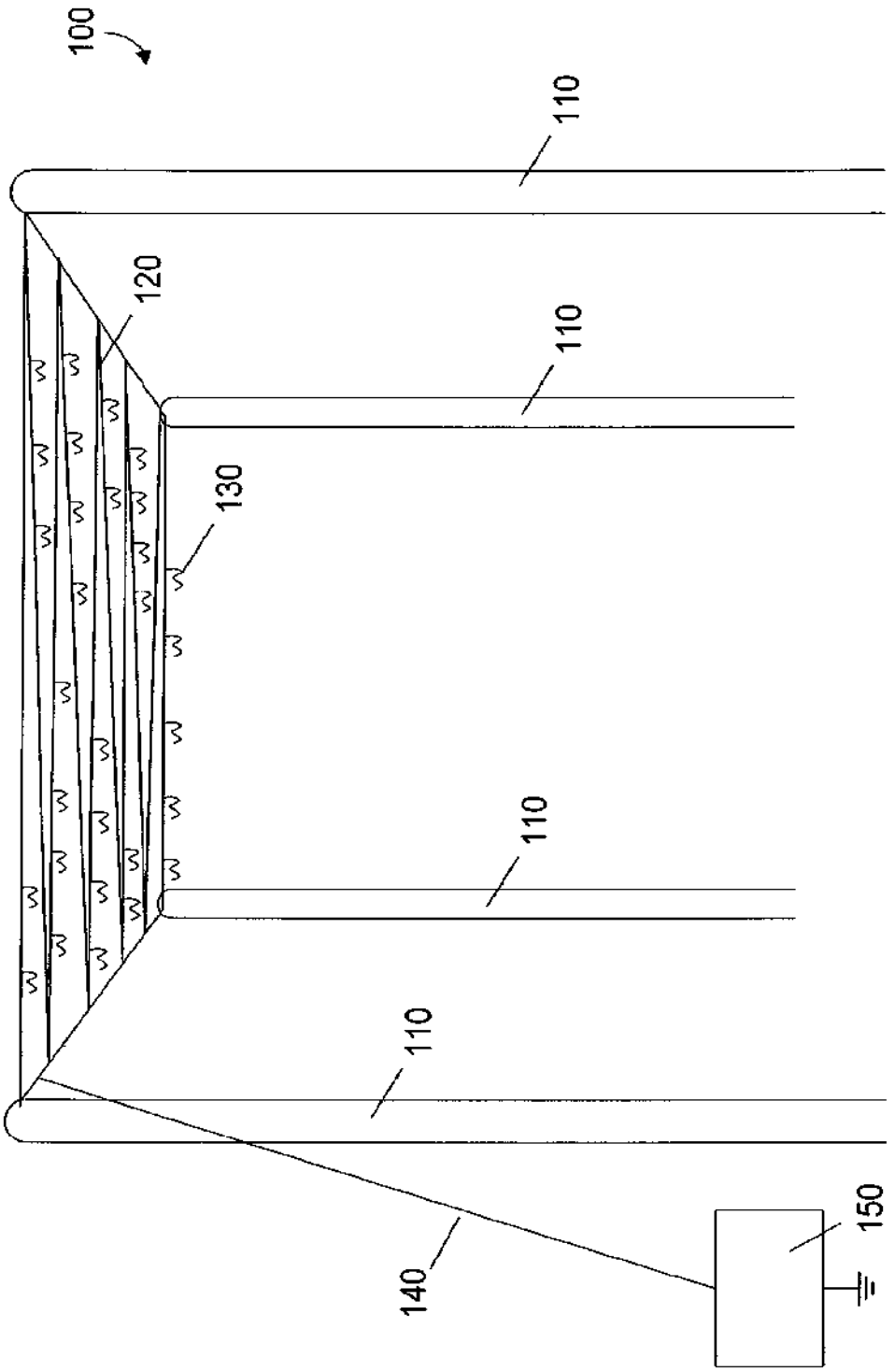

FIGURE 2

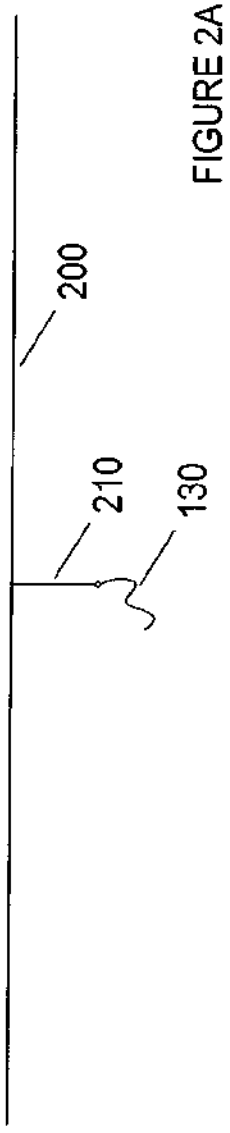

FIGURE 2A

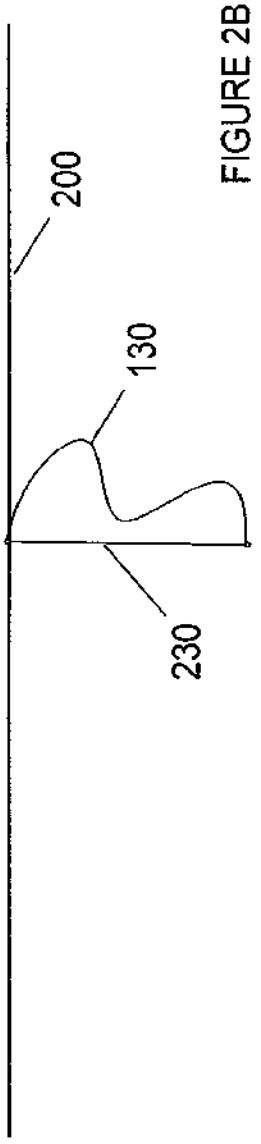

FIGURE 2B

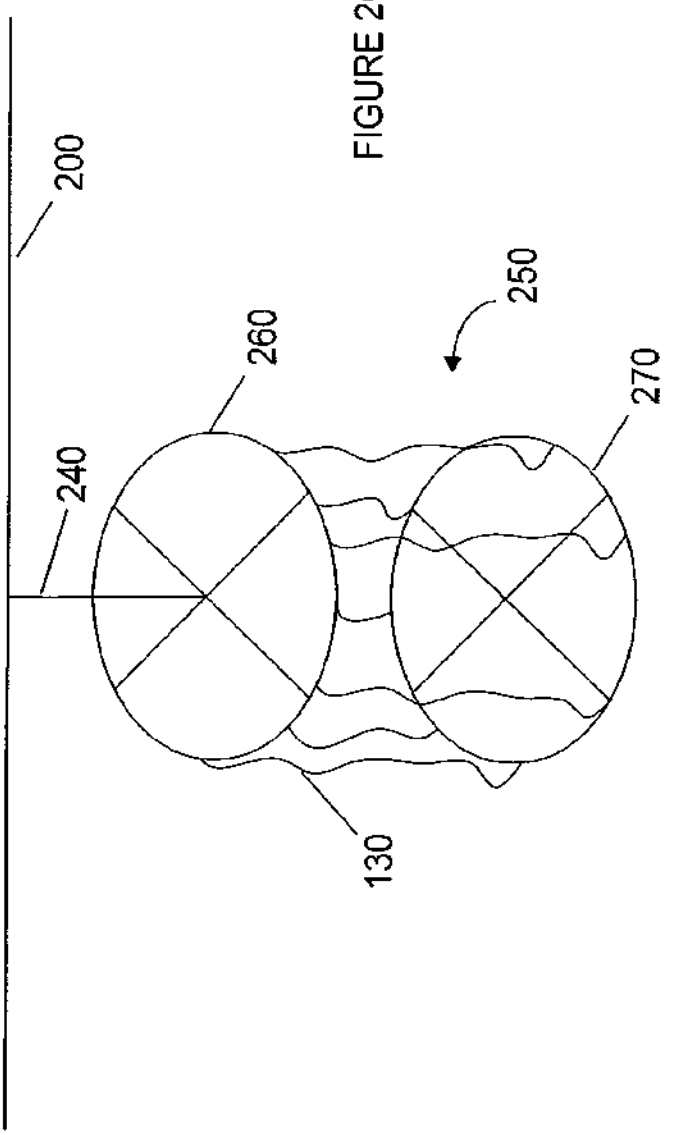

FIGURE 2C

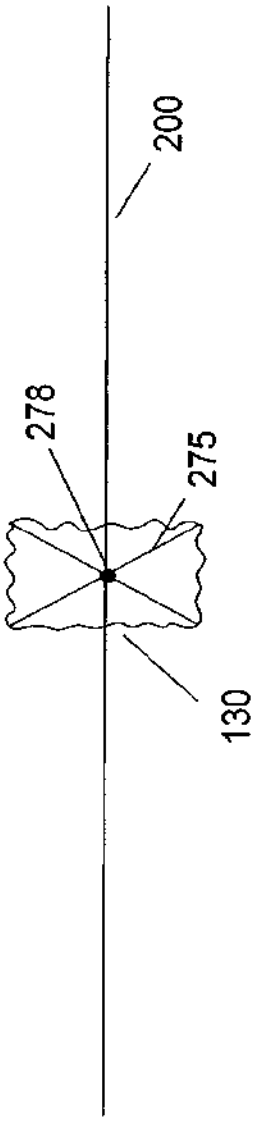

FIGURE 2D

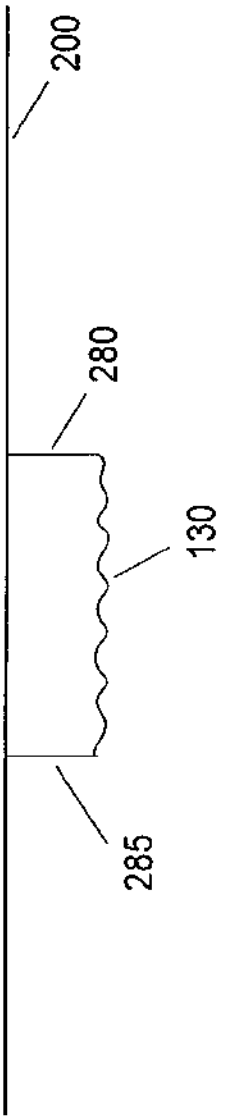

FIGURE 2E

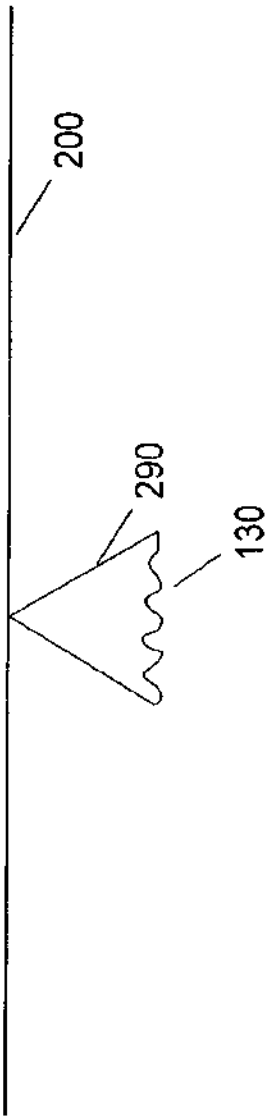

FIGURE 2F

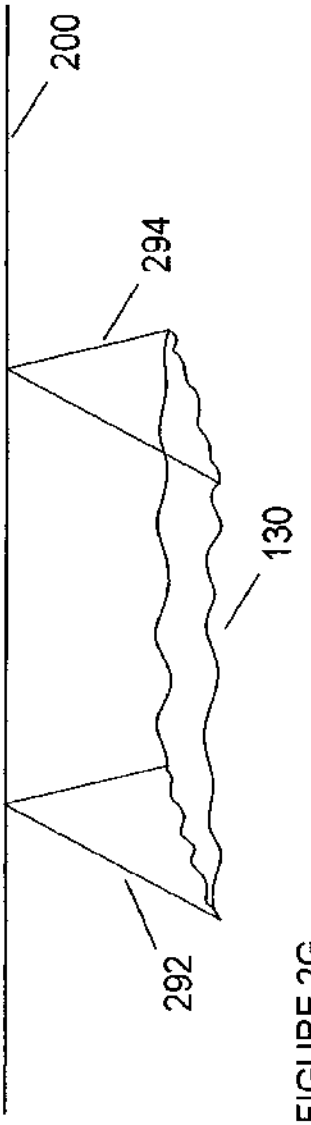

FIGURE 2G

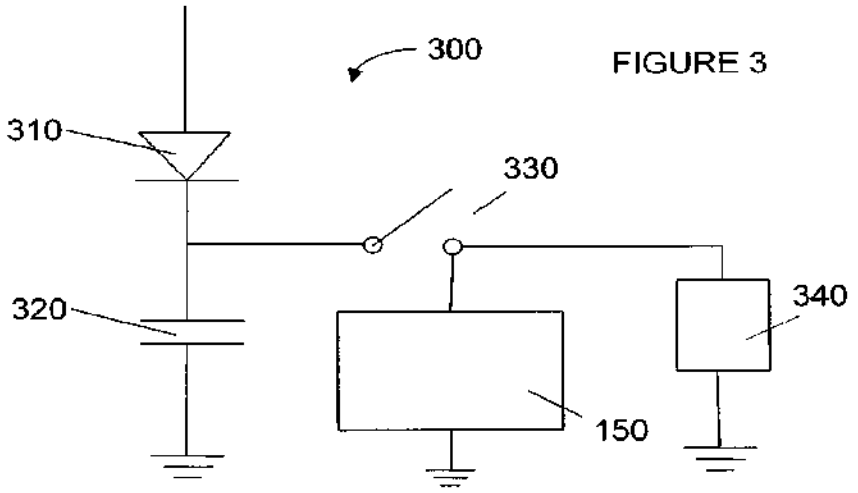

FIGURE 3

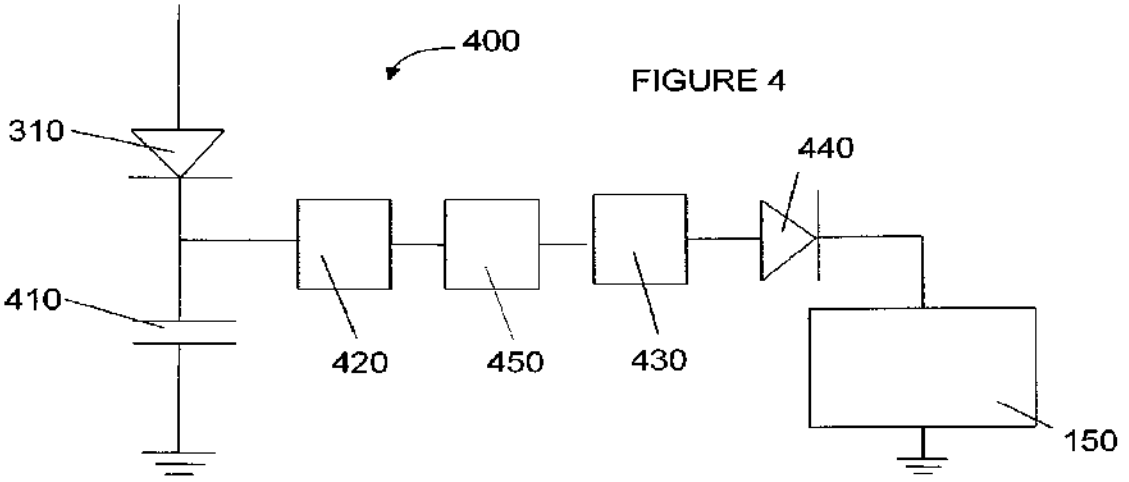

FIGURE 4

FIGURE 5

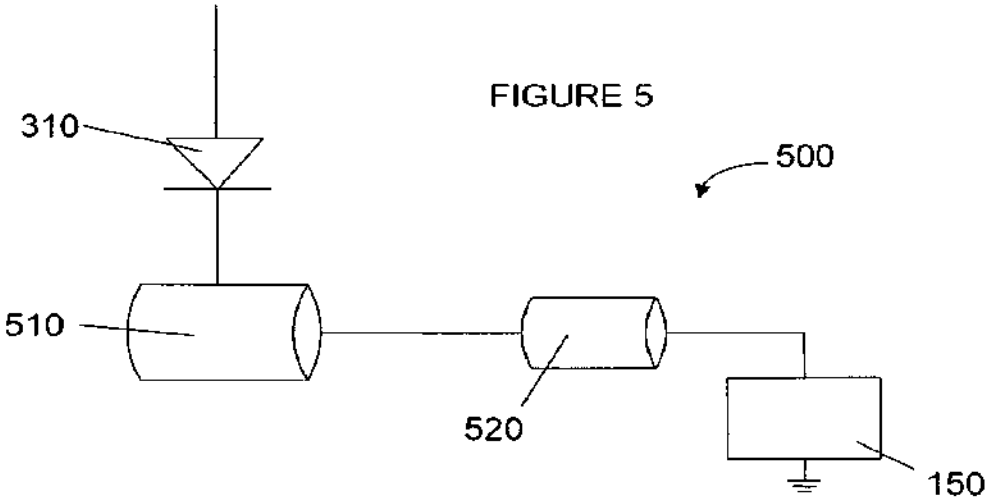

FIGURE 6

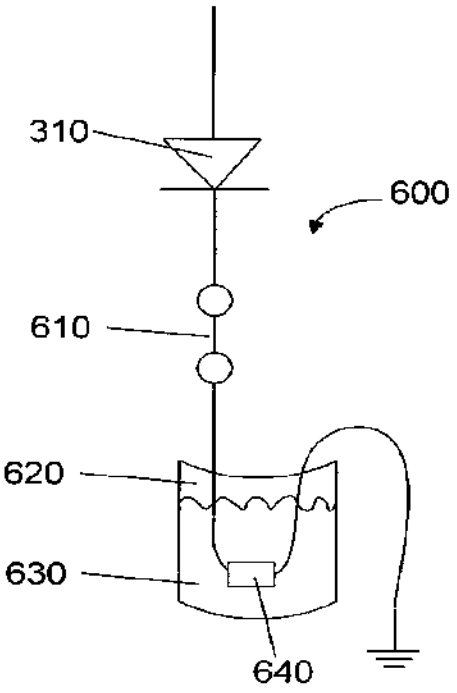

FIGURE 7

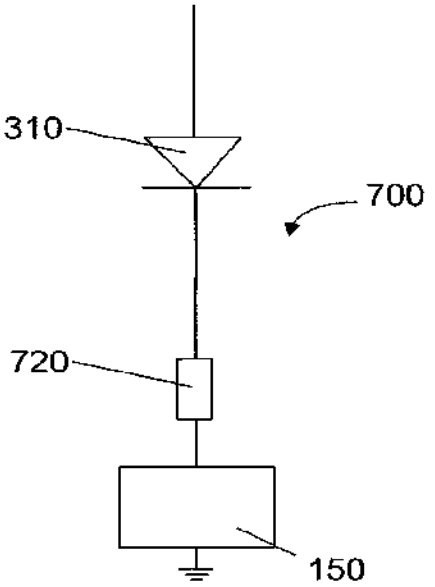

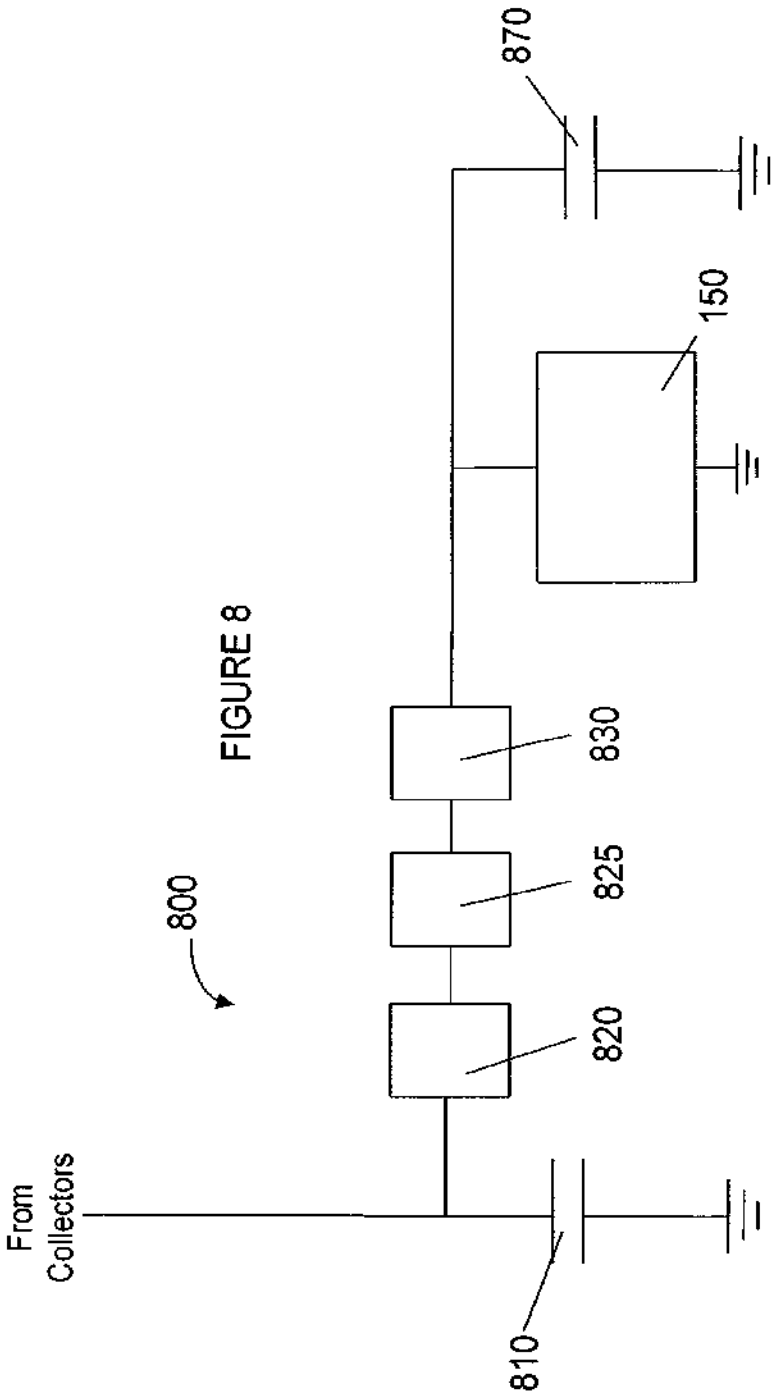

FIGURE 8

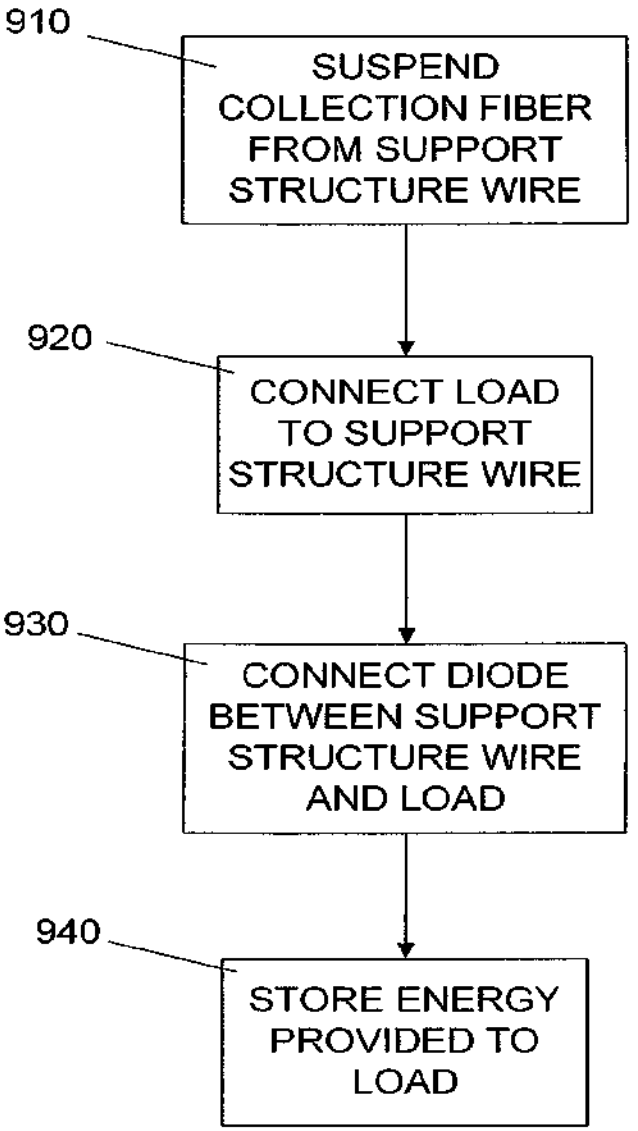
910
SUSPEND COLLECTION FIBER FROM SUPPORT STRUCTURE WIRE
920
CONNECT LOAD TO SUPPORT STRUCTURE WIRE
930
CONNECT DIODE BETWEEN SUPPORT STRUCTURE WIRE AND LOAD
940
STORE ENERGY PROVIDED TO LOAD

FIGURE 9

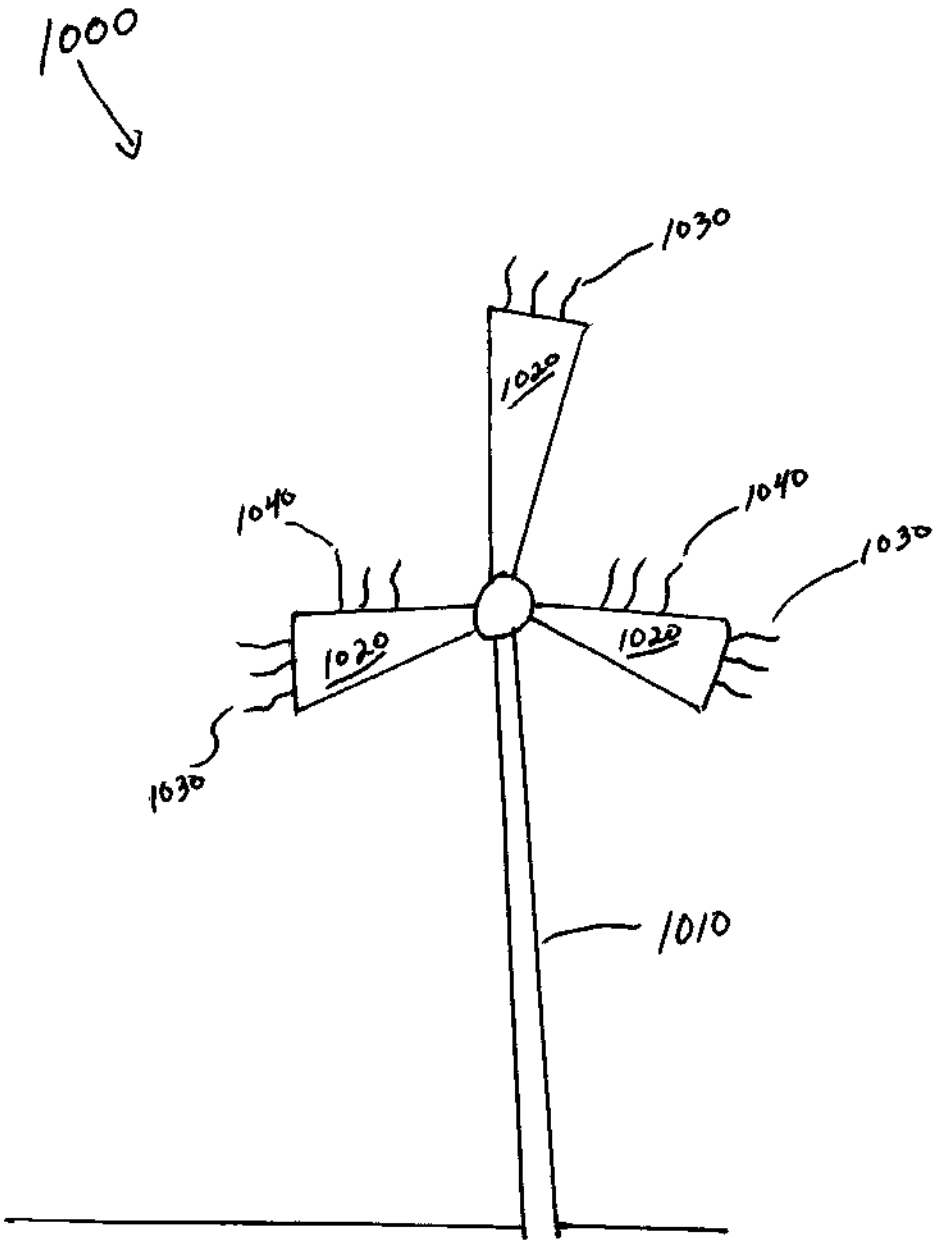

FIG. 10

ENERGY COLLECTION

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation in part application of U.S. patent application Ser. No. 12/255,130 filed on Oct. 21, 2008, which is a continuation application of U.S. patent application Ser. No. 11/358,264, filed on Feb. 21, 2006, which are both incorporated by reference herein.

TECHNICAL FIELD

The present disclosure is generally related to energy and, more particularly, is related to systems and methods for collecting energy.

BACKGROUND

The concept of fair weather electricity deals with the electric field and the electric current in the atmosphere propagated by the conductivity of the air. Clear, calm air carries an electrical current, which is the return path for thousands of lightening storms simultaneously occurring at any given moment around the earth. For simplicity, this energy may be referred to as static electricity or static energy. FIG. **1** illustrates a weather circuit for returning the current from lightning, for example, back to ground **10**. Weather currents **20**, **30** return the cloud to ground current **40**.

In a lightening storm, an electrical charge is built up, and electrons arc across a gas, ionizing it and producing the lightening flash. As one of ordinary skill in the art understands, the complete circuit requires a return path for the lightening flash. The atmosphere is the return path for the circuit. The electric field due to the atmospheric return path is relatively weak at any given point because the energy of thousands of electrical storms across the planet are diffused over the atmosphere of the entire Earth during both fair and stormy weather. Other contributing factors to electric current being present in the atmosphere may include cosmic rays penetrating and interacting with the earth's atmosphere, and also the migration of ions, as well as other effects yet to be fully studied.

Some of the ionization in the lower atmosphere is caused by airborne radioactive substances, primarily radon. In most places of the world, ions are formed at a rate of 5-10 pairs per cubic centimeter per second at sea level. With increasing altitude, cosmic radiation causes the ion production rate to increase. In areas with high radon exhalation from the soil (or building materials), the rate may be much higher.

Alpha-active materials are primarily responsible for the atmospheric ionization. Each alpha particle (for instance, from a decaying radon atom) will, over its range of some centimeters, create approximately 150,000-200,000 ion pairs.

While there is a large amount of usable energy available in the atmosphere, a method or apparatus for efficiently collecting that energy has not been forthcoming. Therefore, a heretofore unaddressed need exists in the industry to address the aforementioned deficiencies and inadequacies.

SUMMARY

Embodiments of the present disclosure provide systems and methods for collecting energy. Briefly described in architecture, one embodiment of the system, among others, can be implemented by a support structure wire elevated above a ground level, at least one collection fiber electrically connected to the support structure wire; a load electrically connected to the support structure wire; and a diode electrically connected between the load and at least one collection fiber.

Embodiments of the present disclosure can also be viewed as providing methods for collecting energy. In this regard, one embodiment of such a method, among others, can be broadly summarized by the following steps: suspending at least one collection fiber from a support structure wire elevated above ground level, the fiber electrically connected to the support structure wire; providing a load with an electrical connection to the support structure wire to draw current; and providing a diode electrically connected between the collection fiber and the load.

Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a circuit diagram of a weather energy circuit.

FIG. **2** is a perspective view of an exemplary embodiment of many energy collectors elevated above ground by a structure.

FIG. **2A** is a side view of an energy collection fiber suspended from a support wire.

FIG. **2B** is a side view of an exemplary embodiment of an energy collection fiber suspended from a support wire and with an additional support member.

FIG. **2C** is a perspective view of a support structure for multiple energy collection fibers.

FIG. **2D** is a side view of an exemplary embodiment of a support structure for multiple energy collection fibers.

FIG. **2E** is a side view of a support structure for an energy collection fiber.

FIG. **2F** is a side view of an exemplary embodiment of a support structure for an energy collection fiber.

FIG. **2G** is a side view of a support structure for multiple energy collection fibers.

FIG. **3** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **4** is a circuit diagram of an exemplary embodiment of a circuit for the collection of energy.

FIG. **5** is a circuit diagram of an exemplary embodiment of an energy collection circuit for powering a generator and motor.

FIG. **6** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy and using it for the production of hydrogen and oxygen.

FIG. **7** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy, and using it for driving a fuel cell.

FIG. **8** is a circuit diagram of an exemplary embodiment of a circuit for collecting energy.

FIG. **9** is a flow diagram of an exemplary embodiment of collecting energy with a collection fiber.

FIG. **10** is a system diagram of an exemplary embodiment of a windmill with energy collectors.

DETAILED DESCRIPTION

Electric charges on conductors reside entirely on the external surface of the conductors, and tend to concentrate more around sharp points and edges than on flat surfaces. Therefore, an electric field received by a sharp conductive point may be much stronger than a field received by the same charge residing on a large smooth conductive shell. An exemplary embodiment of this disclosure takes advantage of this property, among others, to collect and use the energy generated by an electric field in the atmosphere. Referring to collection system **100** presented in FIG. **2**, at least one collection device **130** may be suspended from a support wire system **120** supported by poles **110**. Collection device **130** may comprise a diode or a collection fiber individually, or the combination of a diode and a collection fiber. Support wire system **120** may be electrically connected to load **150** by connecting wire **140**. Supporting wire system **120** may be any shape or pattern. Also, conducting wire **140** may be one wire or multiple wires. The collection device **130** in the form of a fiber may comprise any conducting or non-conducting material, including carbon, graphite, Teflon, and metal. An exemplary embodiment utilizes carbon or graphite fibers for static electricity collection. Support wire system **120** and connecting wire **140** can be made of any conducting material, including aluminum or steel, but most notably, copper. Teflon may be added to said conductor as well, such as non-limiting examples of a Teflon impregnated wire, a wire with a Teflon coating, or Teflon strips hanging from a wire. Conducting wire **120**, **140**, and **200** may be bare wire, or coated with insulation as a non-limiting example. Wires **120** and **140** are a means of transporting the energy collected by collection device **130**.

An exemplary embodiment of the collection fibers as collection device **130** includes graphite or carbon fibers. Graphite and carbon fibers, at a microscopic level, can have hundreds of thousands of points. Atmospheric electricity may be attracted to these points. If atmospheric electricity can follow two paths where one is a flat surface and the other is a pointy, conductive surface, the electrical charge will be attracted to the pointy, conductive surface. Generally, the more points that are present, the higher energy that can be gathered. Therefore, carbon, or graphite fibers are examples that demonstrate exemplary collection ability.

In at least one exemplary embodiment, the height of support wire **120** may be an important factor. The higher that collection device **130** is from ground, the larger the voltage potential between collection device **130** and electrical ground. The electric field may be more than 100 volts per meter under some conditions. When support wire **120** is suspended in the air at a particular altitude, wire **120** will itself collect a very small charge from ambient voltage. When collection device **130** is connected to support wire **120**, collection device **130** becomes energized and transfers the energy to support wire **120**.

A diode, not shown in FIG. **2**, may be connected in several positions in collection system **100**. A diode is a component that restricts the direction of movement of charge carriers. It allows an electric current to flow in one direction, but essentially blocks it in the opposite direction. A diode can be thought of as the electrical version of a check valve. The diode may be used to prevent the collected energy from discharging into the atmosphere through the collection fiber embodiment of collection device **130**. An exemplary embodiment of the collection device comprises the diode with no collection fiber. A preferred embodiment, however, includes a diode at the connection point of a collection fiber to support system **120** such that the diode is elevated above ground. Multiple diodes may be used between collection device **130** and load **150**. Additionally, in an embodiment with multiple fibers, the diodes restricts energy that may be collected through one fiber from escaping through another fiber.

Collection device **130** may be connected and arranged in relation to support wire system **120** by many means. Some non-limiting examples are provided in FIGS. **2A-2G** using a collection fiber embodiment. FIG. **2A** presents support wire **200** with connecting member **210** for collection device **130**. Connection member **210** may be any conducting material allowing for the flow of electricity from connection device **130** to support wire **200**. Then, as shown in FIG. **2**, the support wire **200** of support system **120** may be electrically connected through conducting wire **140** to load **150**. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at an elevated position at the connection point between a collection fiber embodiment of collection device **130** and connection member **210**.

Likewise, FIG. **2B** shows collection fiber **130** electrically connected to support wire **200** and also connected to support member **230**. Support member **230** may be connected to collection fiber **130** on either side. Support member **230** holds the fiber steady on both ends instead of letting it move freely. Support member **230** may be conducting or non-conducting. A plurality of diodes may be placed at any position on the support structure wire. A preferred embodiment places a diode at elevated position at the connection point between collection fiber **130** and support wire **200** or between fiber **130**, support member **230**, and support wire **200**.

FIG. **2C** presents multiple collection fibers in a squirrel cage arrangement with top and bottom support members. Support structure **250** may be connected to support structure wire **200** by support member **240**. Structure **250** has a top **260** and a bottom **270** and each of the multiple collection fibers **130** are connected on one end to top **260** and on the other end to bottom **270**. A plurality of diodes may be placed at any position on support structure **250**. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support structure wire **200**.

FIG. **2D** presents another exemplary embodiment of a support structure with support members **275** in an x-shape connected to support structure wire **200** at intersection **278** with collection fibers **130** connected between ends of support members **275**. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. **2E** provides another exemplary embodiment for supporting collection fiber **130**. Collection fiber **130** may be connected on one side to support member **285**, which may be connected to support structure wire **200** in a first location and on the other side to support member **280**, which may be connected to support structure wire **200** in a second location on support structure wire **200**. The first and second locations may be the same location, or they may be different locations, even on different support wires. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support wire **200**.

FIG. **2F** presents another exemplary embodiment of a support for a collection fiber. Two support members **290** may support either side of a collection fiber and are connected to

support wire **200** in a single point. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places a diode at an elevated position at the connection point between collection fiber **130** and support wire **200**.

FIG. 2G provides two supports as provided in FIG. 2F such that at least two support members **292**, **294** may be connected to support structure wire **200** in multiple locations and collection fibers **130** may be connected between each end of the support structures. Collection fibers **130** may be connected between each end of a single support structure and between multiple support structures. A plurality of diodes may be placed at any position on the support structure. A preferred embodiment places one or more diodes at elevated positions at the connection point(s) between collection fiber **130** and support structure wire **200**.

FIG. **3** provides a schematic diagram of storing circuit **300** for storing energy collected by one or more collection devices (**130** from FIG. **2**). Load **150** induces current flow. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. A plurality of diodes may be placed at any position in the circuit. Switch **330** may be electrically connected between load **150** and at least one collection device (**130** from FIG. **2**) to connect and disconnect the load. Capacitor **320** maybe connected in parallel to the switch **330** and load **150** to store energy when switch **330** is open for delivery to load **150** when switch **330** is closed. Rectifier **340** may be electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. Rectifier **340** may be a full-wave or a half-wave rectifier. Rectifier **340** may include a diode electrically connected in parallel to load **150**, between the receiving end of switch **330** and ground. The direction of the diode of rectifier **340** is optional.

In an exemplary embodiment provided in FIG. **4**, storage circuit **400** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **410**. If charging capacitor **410** is not used, then the connection to ground shown at capacitor **410** is eliminated. A plurality of diodes may be placed at any position in the circuit. Diode **310** may be electrically connected in series between one or more collection devices (**130** from FIG. **2**) and load **150**. Diode **440** may be placed in series with load **150**. The voltage from capacitor **410** can be used to charge spark gap **420** when it reaches sufficient voltage. Spark gap **420** may comprise one or more spark gaps in parallel. Non-limiting examples of spark gap **420** include mercury-reed switches and mercury-wetted reed switches. When spark gap **420** arcs, energy will arc from one end of the spark gap **420** to the receiving end of the spark gap **420**. The output of spark gap **420** may be electrically connected in series to rectifier **450**. Rectifier **450** may be a full-wave or a half-wave rectifier. Rectifier **450** may include a diode electrically connected in parallel to transformer **430** and load **150**, between the receiving end of spark gap **420** and ground. The direction of the diode of rectifier **450** is optional. The output of rectifier **450** is connected to transformer **430** to drive load **150**.

FIG. **5** presents motor driver circuit **500**. One or more collection devices (**130** from FIG. **2**) are electrically connected to static electricity motor **510**, which powers generator **520** to drive load **150**. A plurality of diodes may be placed at any position in the circuit. Motor **510** may also be directly connected to load **150** to drive it directly.

FIG. **6** demonstrates a circuit **600** for producing hydrogen. A plurality of diodes maybe placed at any position in the circuit. One or more collection devices (**130** from FIG. **2**) are electrically connected to primary spark gap **610**, which may be connected to secondary spark gap **640**. Non-limiting examples of spark gaps **610**, **640** include mercury-reed switches and mercury-wetted reed switches. Secondary spark gap **640** may be immersed in water **630** within container **620**. When secondary spark gap **640** immersed in water **630** is energized, spark gap **640** may produce bubbles of hydrogen and oxygen, which may be collected to be used as fuel.

FIG. **7** presents circuit **700** for driving a fuel cell. A plurality of diodes may be placed at any position in the circuit. Collection devices (**130** from FIG. **2**) provide energy to fuel cell **720** which drives load **150**. Fuel cell **720** may produce hydrogen and oxygen.

FIG. **8** presents exemplary circuit **800** for the collection of energy. Storage circuit **800** stores energy from one or more collection devices (**130** from FIG. **2**) by charging capacitor **810**. If charging capacitor **810** is not used, then the connection to ground shown at capacitor **810** is eliminated. A plurality of diodes may be placed at any position in the circuit. The voltage from capacitor **810** can be used to charge spark gap **820** when it reaches sufficient voltage. Spark gap **820** may comprise one or more spark gaps in parallel or in series. Non-limiting examples of spark gap **820** include mercury-reed switches and mercury-wetted reed switches. When spark gap **820** arcs, energy will arc from one end of spark gap **820** to the receiving end of spark gap **820**. The output of spark gap **820** may be electrically connected in series to rectifier **825**. Rectifier **825** may be a full-wave or a half-wave rectifier. Rectifier **825** may include a diode electrically connected in parallel to inductor **830** and load **150**, between the receiving end of spark gap **820** and ground. The direction of the diode of rectifier **825** is optional. The output of rectifier **825** is connected to inductor **830**. Inductor **830** may be a fixed value inductor or a variable inductor. Capacitor **870** may be placed in parallel with load **150**.

FIG. **9** presents a flow diagram of a method for collecting energy. In block **910**, one or more collection devices may be suspended from a support structure wire. In block **920**, a load may be electrically connected to the support structure wire to draw current. In block **930** a diode may be electrically connected between the support structure wire and the electrical connection to the load. In block **940**, energy provided to the load may be stored or otherwise utilized.

A windmill is an engine powered by the energy of wind to produce alternative forms of energy. They may, for example, be implemented as small tower mounted wind engines used to pump water on farms. The modern wind power machines used for generating electricity are more properly called wind turbines. Common applications of windmills are grain milling, water pumping, threshing, and saw mills. Over the ages, windmills have evolved into more sophisticated and efficient wind-powered water pumps and electric power generators. In an example embodiment, as provided in FIG. **10**, windmill tower **1000** of suitable height and/or propeller **1020** of windmill tower **1000** may be equipped with energy collecting fibers **1030**, **1040**. Collecting fibers **1030**, **1040** may turn windmill **1000** into a power producing asset even when there is not enough wind to turn propellers **1020**. During periods when there is enough wind to turn propellers **1020**, collecting fibers **1030**, **1040** may supplement/boost the amount of energy the windmill produces.

Windmill **1000**, properly equipped with ion collectors **1030**, **1040**, such as non-limiting example carbon fibers, can produce electricity: 1) by virtue of providing altitude to the carbon fiber to harvest ions, and 2) while the propeller is turning, by virtue of wind blowing over the carbon fiber producing electricity, among other reasons, via the triboelec-

tric effect (however, it is also possible for the triboelectric effect to occur, producing electricity, in winds too weak to turn the propeller).

There are at least two ways that energy collectors may be employed on or in a windmill propeller to harvest energy. Propellers **1020** may be equipped with energy collectors **1030**, **1040** attached to, or supported by, propeller **1020** with wires (or metal embedded in, or on propeller **1020**) electrically connecting energy collectors **1030**, **1040** to a load or power conversion circuit. There may be a requirement to electrically isolate energy collectors **1030**, **1040**, which is added to propeller **1020**, from electrical ground, so that the energy collected does not short to ground through propeller **1020** itself or through support tower **1010**, but rather is conveyed to the load or power conversion circuit. Energy collectors may be connected to the end of propellers **1020** such as collectors **1030**. Alternatively, energy collectors may be connected to the sides of propellers **1020** such as collectors **1040**.

Alternatively, propeller **1020** may be constructed of carbon fiber or other suitable material, with wires (or the structural metal supporting propeller **1020** may be used) electrically connecting to a load or power conversion circuit. In the case of propeller **1020** itself being constructed of carbon fiber, for example, the fiber may be 'rough finished' in selected areas so that the fiber is "fuzzy." For example, small portions of it may protrude into the air as a means of enhancing collection efficiency. The fuzzy parts of collectors **1030**, **1040** may do much of the collecting. There may be a requirement to electrically isolate carbon fiber propeller **1020** from electrical ground, so that the energy it collects does not short to ground through metal support tower **1010**, but rather is conveyed to the load or power conversion circuit. Diodes may be implemented within the circuit to prevent the backflow of energy, although diodes may not be necessary in some applications.

In an alternative embodiment, windmill **1000** may be used as a base on which to secure an even higher extension tower to support the energy collectors and/or horizontal supports extending out from tower **1010** to support the energy collectors. Electrical energy may be generated via ion collection due to altitude and also when a breeze or wind blows over the collectors supported by tower **1010**.

Any process descriptions or blocks in flow charts should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred embodiment of the present disclosure in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure.

It should be emphasized that the above-described embodiments of the present disclosure, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) of the disclosure without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present disclosure and protected by the following claims.

Therefore, at least the following is claimed:

1. A method of collecting energy comprising:

suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment from a windmill, the at least one collection device electrically connected to the windmill; and

providing a load with an electrical connection to the at least one collection device to draw current.

2. The method of claim **1**, wherein the collection device collects energy by triboelectric effect.

3. The method of claim **1**, wherein the collection device comprises a collection fiber.

4. The method of claim **1**, wherein the collection device comprises a diode and a collection fiber and the diode is electrically connected between the collection fiber and the load.

5. The method of claim **1**, further comprising storing energy provided to the load.

6. The method of claim **5**, wherein storing energy provided to the load comprises storing energy in a capacitor or an inductor.

7. The method of claim **3**, wherein the collection fiber comprises carbon fiber or graphite fiber.

8. A system of energy collection comprising:

a windmill;

at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment electrically connected to the windmill; and

a load electrically connected to the at least one collection device.

9. The system of claim **8**, wherein the collection device collects energy by triboelectric effect.

10. The system of claim **8**, wherein the collection device comprises a collection fiber.

11. The system of claim **8**, wherein the collection device comprises a collection fiber and a diode electrically connected between the load and the collection fiber.

12. The system of claim **9**, wherein the diode is elevated relative to the ground level.

13. The system of claim **10**, wherein the collection fiber comprises a carbon fiber or a graphite fiber.

14. The system of claim **8**, further comprising a diode electrically connected between the at least one collection device and the support structure.

15. The system of claim **8**, further comprising: a switch connected in series between the at least one collection device and the load; and a capacitor connected in parallel with the switch and the load.

16. The system of claim **15**, wherein the switch comprises an interrupter connected between the plurality at least one collection device, and wherein the interrupter comprises at least one of a fluorescent tube, a neon bulb, an AC light, and a spark gap.

17. The system of claim **8**, further comprising: a motor for providing power, the motor connected between the at least one collection device and the load; and a generator powered by the motor.

18. The system of claim **8**, further comprising a fuel cell between the support structure and the load.

19. The system of claim **18**, wherein the fuel cell produces hydrogen and oxygen.

20. A system of collecting energy comprising:

means for suspending at least one collection device with, in operation, microscopic points of a cross-section of the collection device exposed to the environment from a windmill structure, the at least one collection device electrically connected to the means for suspending;

means for inducing current flow, the means for inducing current flow electrically connected to the means for suspending; and

means for restricting the backflow of charge carriers, the means for restricting the backflow of charge carriers electrically connected between the at least one collection device and the means for inducing current flow.

* * * * *

US 20120286623A1

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(43) **Pub. Date: Nov. 15, 2012**

Ogram

(54) **ATMOSPHERIC ENERGY COLLECTION**

(75) Inventor: **Mark E. Ogram**, Tucson, AZ (US)

(73) Assignee: **Sefe, Inc.**, Tempe, AZ (US)

(21) Appl. No.: **13/103,963**

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Publication Classification

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H02N 3/00 (2006.01)

(52) **U.S. Cl.** **310/309**

(57) **ABSTRACT**

The subject matter described herein is an atmospheric energy collector. The atmospheric energy collector includes of a windsock arrangement that has a large up-wind opening on one side and that tapers from the larger up-wind opening on the one side to a small down-wind opening on the other side. The up-wind side is secured to a tether such that an electrically conducting material (e.g. metal) included in construction of the atmospheric energy collector is connected to the tether. The windsock arrangement is extended outwards by wind and the like atmospheric conditions such that the electrically conducting material collects the atmospheric energy and transfers the collected energy to the tether.

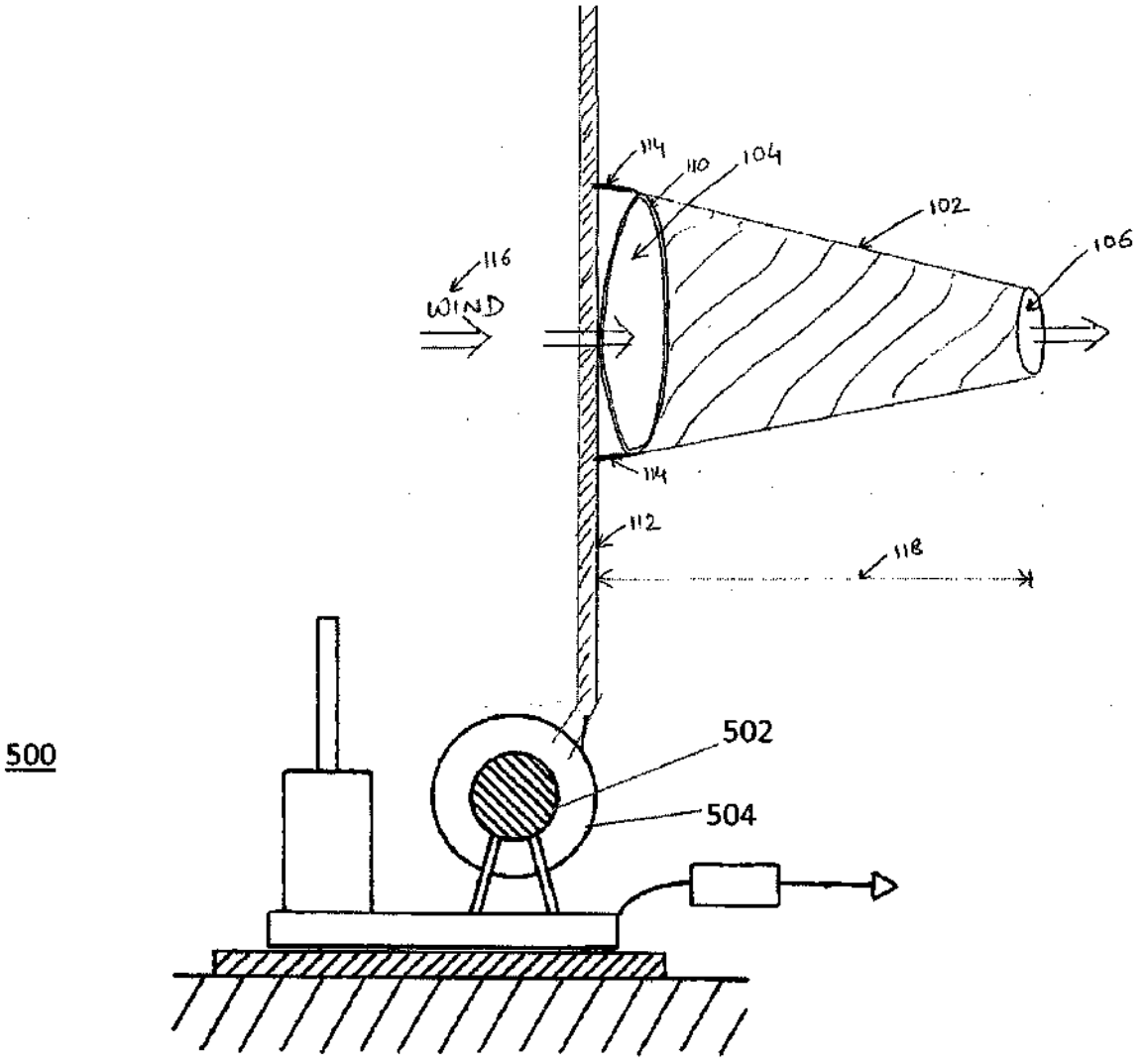

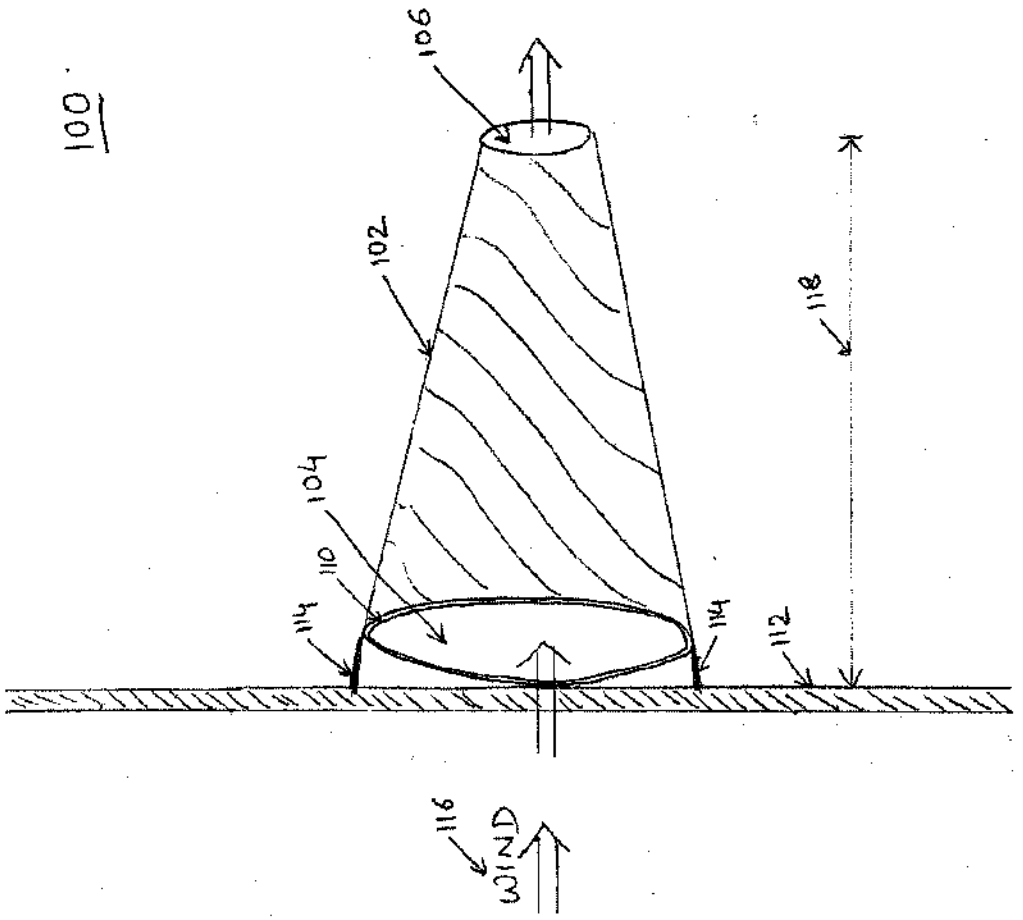

FIG. 1A

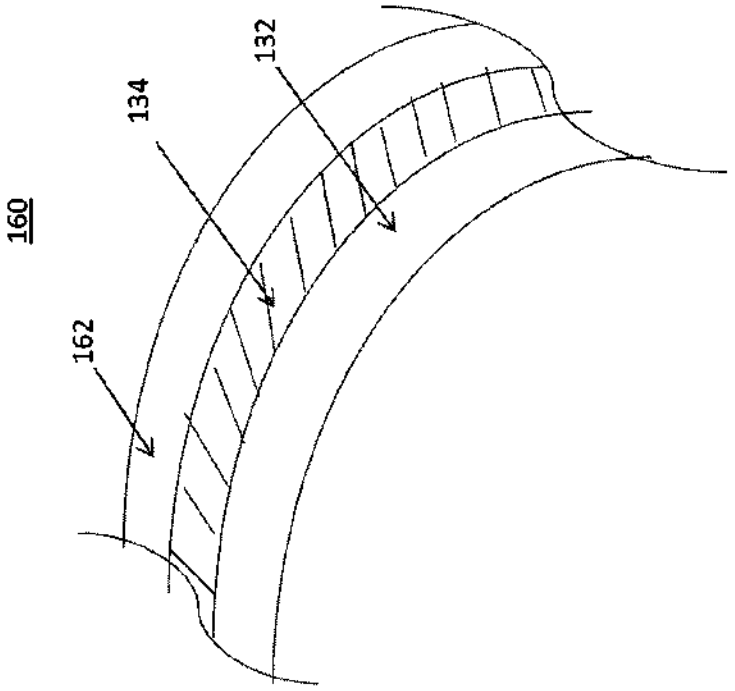

FIG. 1C

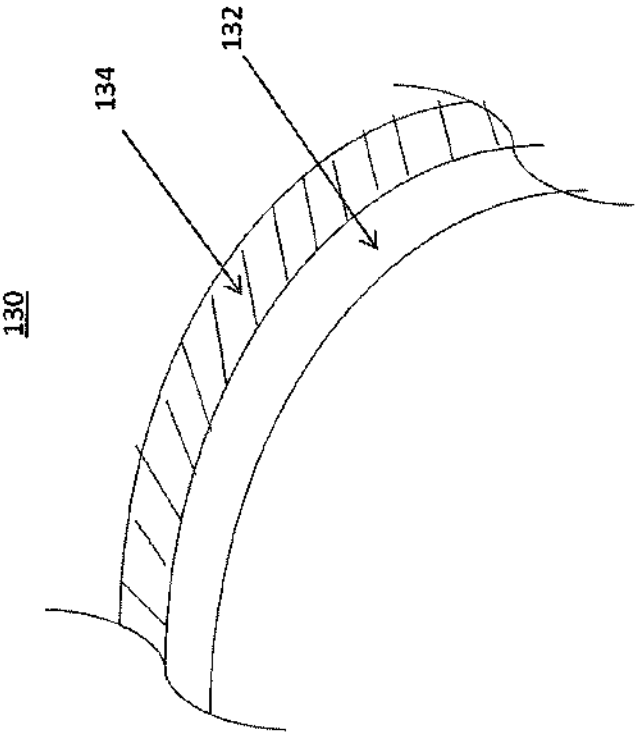

FIG. 1B

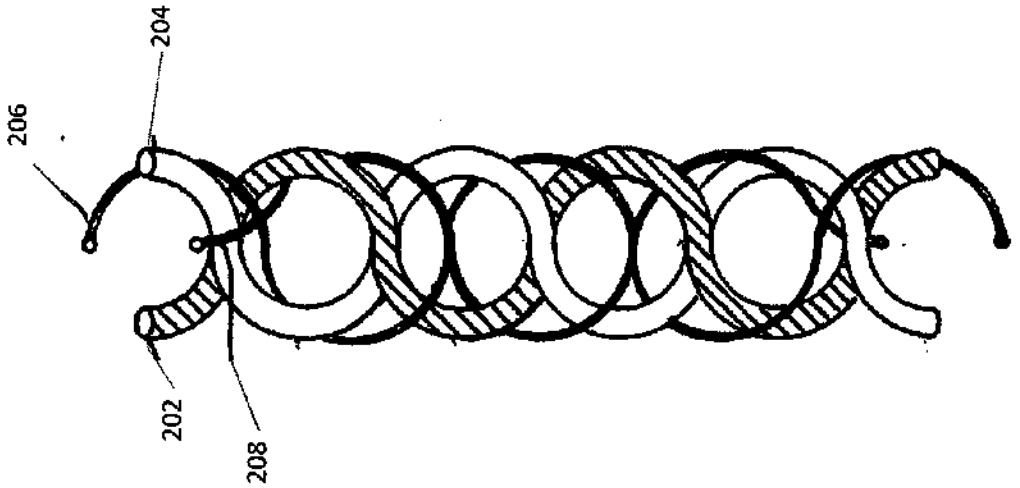

FIG. 2

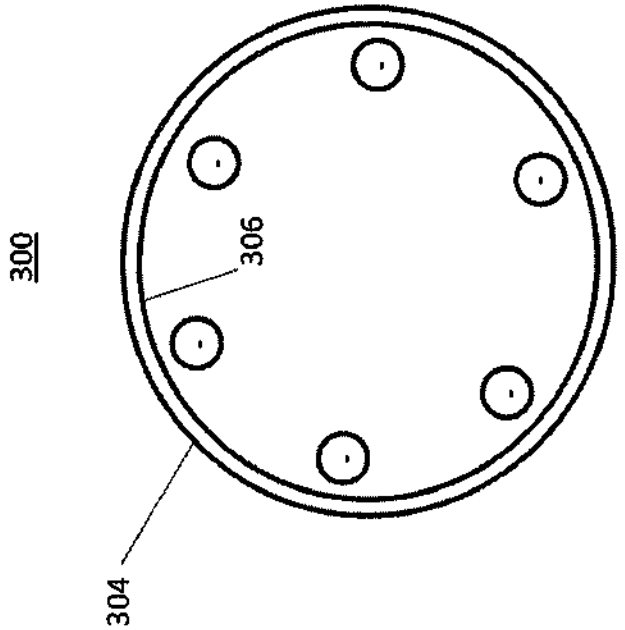

FIG. 3B

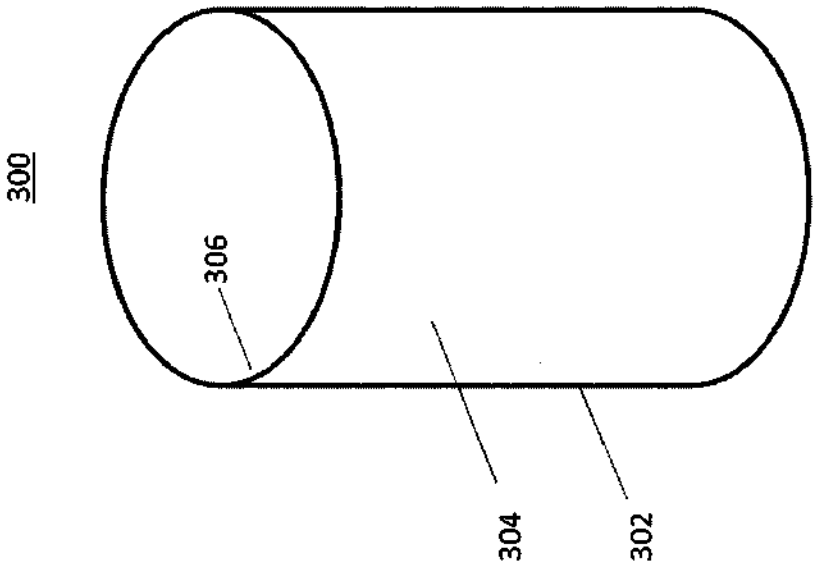

FIG. 3A

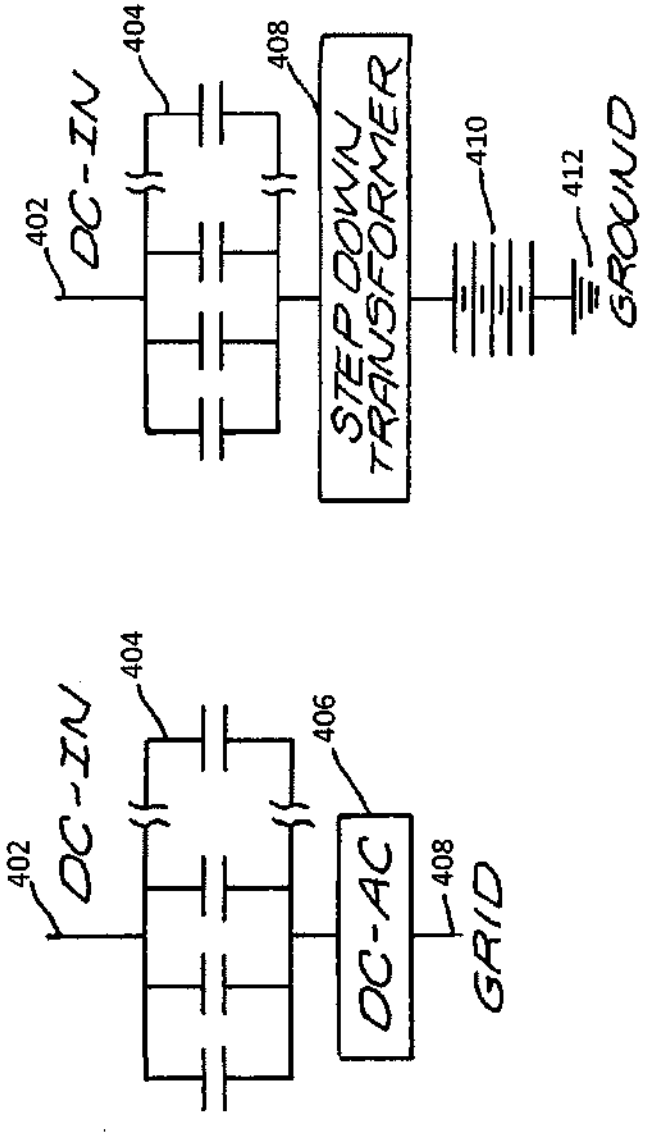

FIG. 4A

FIG. 4B

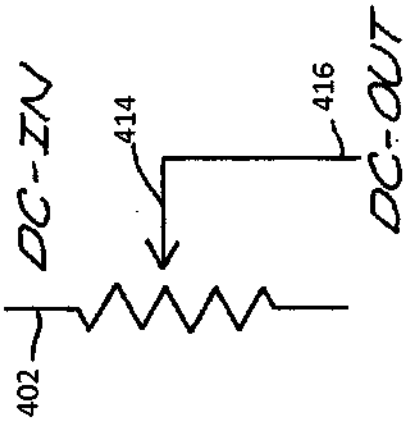

FIG. 4C

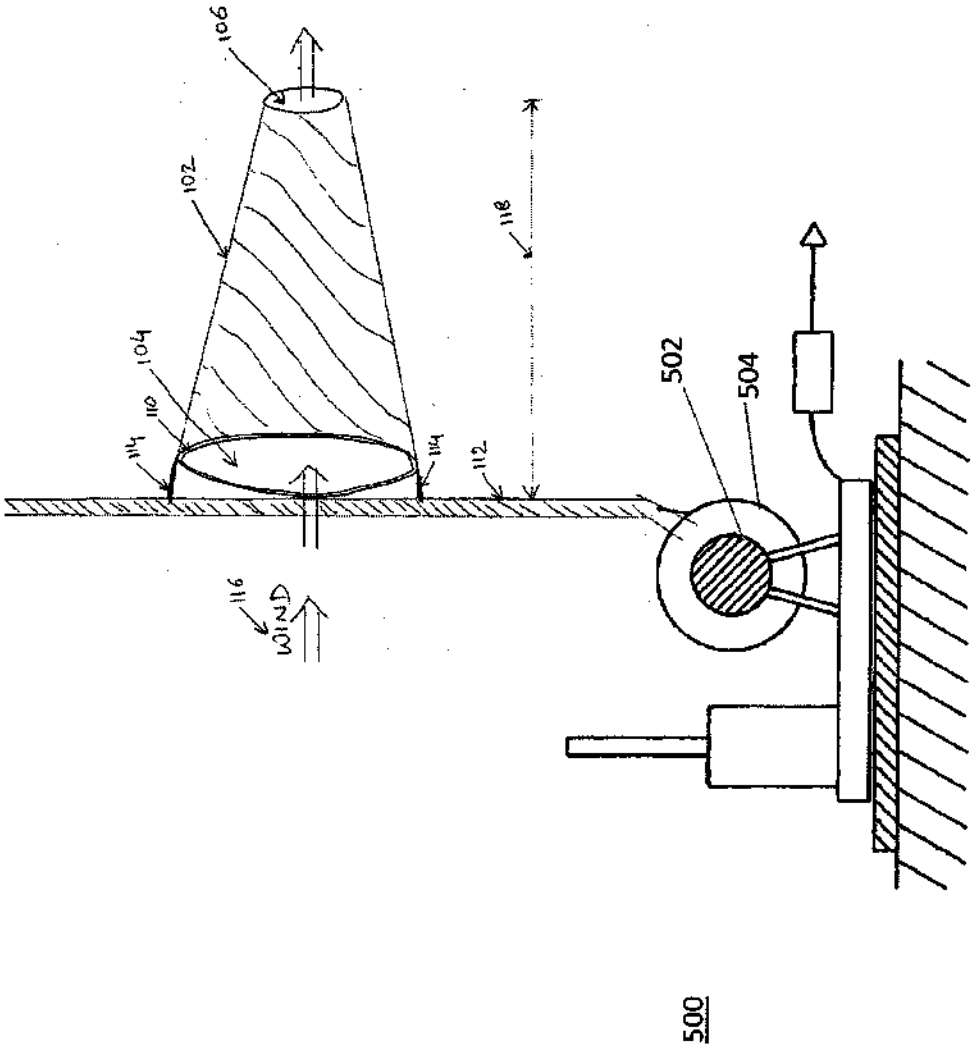

FIG. 5

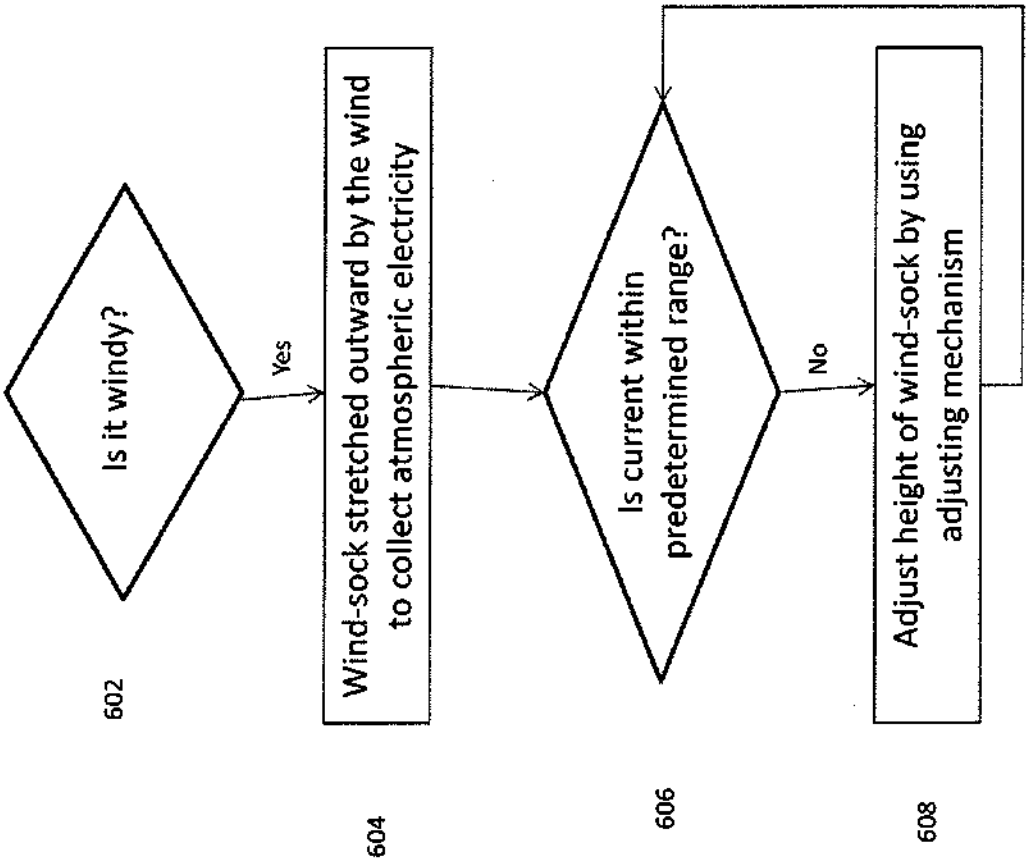
Is it windy?
602
Yes
Wind-sock stretched outward by the wind to collect atmospheric electricity
604
Is current within predetermined range?
606
No
Adjust height of wind-sock by using adjusting mechanism
608

FIG. 6

ATMOSPHERIC ENERGY COLLECTION

TECHNICAL FIELD

[0001] The subject matter described herein relates to a light-weight, extendible electricity collecting windsock arrangement comprising an enhanced collection surface for atmospheric electrical energy collection.

BACKGROUND

[0002] The atmosphere above the earth is known to include electrical charge. The earth's surface is negatively charged, while the air above it is positively charged. All atmospheric effects are a result of an interplay between these two huge areas of opposite electrical energy. The potential difference between the positively charged atmosphere and the negatively charged earth surface causes atmospheric electrical energy to be developed. Some of this atmospheric electrical energy may be experienced through thunderstorms.

[0003] Even though there is a huge amount of atmospheric electrical energy in the atmosphere, collection of the atmospheric electrical energy still remains a problem. Due to high voltage and low current conditions, there is a need for large collection surfaces for maximizing the collection of atmospheric electrical energy. Note that the terms atmospheric electricity, atmospheric energy, and atmospheric electrical energy have been used interchangeably in this specification.

[0004] The problem of low current is compounded by a heavy weight of the collectors of atmospheric electrical energy. The heavy weight of the collectors increases payload requirements of a lift mechanism, which may be used to lift the collectors to an appropriate height or altitude so that the collection of atmospheric electrical energy is maximized. Thus, a need exists for large yet light-weight collectors such that payload requirements for the lift mechanism remain reasonable.

SUMMARY

[0005] The subject matter described herein relates to an atmospheric energy collector. The atmospheric energy collector includes an electricity collecting windsock arrangement that has a large up-wind opening on one side and that tapers from the larger up-wind opening on the one side to a small down-wind opening on the other side. The up-wind side is secured to a tether such that an electrically conducting material (e.g. metal) included in construction of the atmospheric energy collector is connected to the tether. The electricity collecting windsock arrangement is extended outwards by wind and the like atmospheric conditions such that the electrically conducting material collects the atmospheric energy and transfers the collected energy to the tether. Further, the electricity collecting windsock includes light-weight collectors such that payload requirements for the lift mechanism remain reasonable (i.e. remain within a predetermined value).

[0006] In one aspect, an electricity collection apparatus includes a tether and a windsock. The windsock is formed of an insulation material with a metal deposited on at least a portion of the insulation material. The metal of the windsock is electrically connected to the tether. The windsock extends in a direction of ambient wind to provide a surface area based on the ambient wind, and the surface area provides the metal to collect electrical energy from the ambient wind, the collected electrical energy being transferred to the tether.

[0007] In another aspect, an electricity collection apparatus includes a windsock formed of an insulation material the windsock to extend in a direction of ambient wind to provide a surface area based on the ambient wind. The apparatus further includes one or more electrical conductors provided on at least a portion of the insulation material to collect electrical energy from the ambient wind. The apparatus further includes an electrically conductive tether connected with windsock to anchor the windsock in the direction of the ambient wind, the electrically conductive tether being electrically connected to the one or more electrical conductors provided on at least a portion of the insulation material to transfer the collected electrical energy from the one or more electrical conductors to an electrical storage.

[0008] The subject matter described herein provides many advantages. For example, large collection surfaces allow a maximized collection of atmospheric energy. Moreover, the light-weight collectors allow payload requirements for the lift mechanism to remain reasonable (i.e. remain within a predetermined value).

[0009] The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Other features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0010] The accompanying drawings, which are incorporated in and constitute a part of this specification, show certain aspects of the subject matter disclosed herein and, together with the description, help explain some of the principles associated with the disclosed implementations. In the drawings,

[0011] FIG. **1**A illustrates extendible electricity collecting windsock arrangement that is used for collection of atmospheric electrical energy in accordance with implementations of the current subject matter;

[0012] FIG. **1**B illustrates a cross-section of one implementation of the electrically conducting windsock in accordance with implementations of the current subject matter;

[0013] FIG. **1**C illustrates a cross-section of another implementation of the electricity collecting windsock in accordance with implementations of the current subject matter;

[0014] FIG. **2** illustrates an exemplary conductive line in accordance with implementations of the current subject matter;

[0015] FIG. **3**A illustrates a front view of a conductive line in accordance with implementations of the current subject matter;

[0016] FIG. **3**B illustrates a top view of the conductive line shown in FIG. **3** in accordance with implementations of the current subject matter;

[0017] FIGS. **4**A, **4**B, and **4**C illustrate electrical schematics for handling the static charge from the atmosphere in accordance with implementations of the current subject matter;

[0018] FIG. **5** illustrates an adjusting apparatus (winch motor and spool) that enables adjustment of location/height of the electricity collecting windsock arrangement in accordance with implementations of the current subject matter; and

[0019] FIG. **6** is a process flow diagram illustrating aspects of a method in accordance with implementations of the current subject matter.

[0020] When practical, similar reference numbers denote similar structures, features, or elements.

DETAILED DESCRIPTION

[0021] To address these and potentially other issues with currently available solutions, one or more implementations of the current subject matter provide methods, systems, articles or manufacture, and the like that can, among other possible advantages, provide an energy collector formed as a windsock and having an enhanced collection surface for atmospheric electrical energy collection. In preferred implementations, an electricity collecting windsock is formed as a flexible cylinder, a truncated cone, or a cone with a metal surface, and is mounted to a mast or other tether so as to capture ambient wind which extends the windsock outward from the mast, in turn forming the largest possible surface area for the wind conditions to enable the metal surface to collect atmospheric amperage. The collected amperage is transferred from the metal surface of the electricity collecting windsock to the mast or tether, and eventually to an electricity storage device. Although implementations in which windsock arrangements having one windsock each are discussed below, those or ordinary skill in the art understand that a windsock arrangement may include two or more windsocks for enhanced atmospheric electricity collection.

[0022] FIG. **1**A illustrates an implementation of electricity collecting windsock arrangement **100** that is used to collect atmospheric electrical energy. The electricity collecting windsock arrangement **100** includes an extendible electricity collecting windsock **102**. The extendible electricity collecting windsock **102** is made of a material that has a high tensile strength and provides electrical insulation. This electrically insulating material **134** (discussed below with respect to FIG. **1**B) may be a plastic or a flexible glass, such as polyester like polyethylene terephthalate (PET) or biaxially-oriented polyethylene terephthalate (BoPET). BoPET is known in the industry by different trade names, some of which are Mylar, Melinex and Hostaphan.

[0023] As is described later with respect to FIGS. **1**B and **1**C, which illustrate cross-sections of implementations of electricity collecting windsock **102**, a thin coat of an electrically conducting material **132**, **162** is deposited on the electrically insulating material **134**. The deposited electrically conducting material **132**, **162** is a good conductor of electricity, and helps electricity collecting windsock **102** to tap atmospheric electrical energy. The electrically conducting material may be any one of a metal or a suitable alloy, such as one of or a combination of one or more of gold, silver, copper, aluminum, and the like.

[0024] The electricity collecting windsock **102** has a large up-wind opening up-wind opening **104** on one side. The electricity collecting windsock **102** tapers from the large up-wind opening **104** on the one side to a small down-wind opening **106** on the other side of the electricity collecting windsock **102**. The up-wind opening **104** has a metal loop **110** on the circumference of the up-wind opening **104**. The metal loop **110** is attached to a tether **112** using an attachment mechanism **114**. The attachment mechanism **114** may include a soldering mechanism. In some implementations, other attachment mechanisms **114** are also known to be used, such as nut and bolt mechanism, threading mechanism, gluing mechanism, and the like. The electricity collecting windsock **102** is extended outwards by wind **116** and/or like atmospheric conditions such that the electrically conducting material (e.g. metal) collects the atmospheric electrical energy and transfers the collected energy to the tether **112**.

[0025] The tether **112** includes a conductive line that is isolated from the ground. The conductive line is used to transfer the collected atmospheric electrical energy from the electricity collecting windsock **102** to an electricity storage device (not shown) where the collected atmospheric charge may be gathered for later or simultaneous use.

[0026] When wind **116** strikes against the electricity collecting windsock arrangement **100** in the direction illustrated, the electricity collecting windsock **102** extends outward, thus allowing the electrically conducting material **132** (discussed below with respect to FIG. **1**B) to collect maximum possible atmospheric electricity. In one implementation, the outward extension **118** is fifty feet or more. When there is no wind, the electricity collecting windsock **102** may be in a relatively compressed state such that the length of the electricity collecting windsock **102** is less than the outward extension **118** caused by windy conditions or like atmospheric conditions. The collected atmospheric electrical energy is communicated to the tether **112**.

[0027] FIG. **1**B illustrates a cross-section **130** of one implementation of the electrically conducting windsock **102**. The cross-section **130** illustrates the electrically conducting material **132** deposited on the inner surface of the electrically insulating material **134**. The electricity collecting windsock **102** includes the electrically conducting material **132** and the electrically insulating material **134** such that the electrically conducting material **132** forms the inner surface of the electricity collecting windsock **102**. When the wind **116** strikes the electricity collecting windsock arrangement, the electricity collecting windsock **102** extends outward, thus allowing the electrically conducting material **132** to collect maximum possible atmospheric electricity. The electrically conducting material **132** may include multiple collectors that are spaced apart such that the collection surface is greatly enhanced. The multiple collectors may be spaced apart in patterns, such as spaced apart lines, squares, rectangles, circles, and the like, or any other pattern that may maximize the collection of the atmospheric electrical energy. As noted above, the electrically insulating material **134** may be a plastic or a flexible glass, such as polyester like polyethylene terephthalate (PET) or biaxially-oriented polyethylene terephthalate (BoPET). The electrically conducting material **132** may be a metal or alloy, such as one of or a combination of one or more of gold, silver, copper, aluminum, and the like.

[0028] FIG. **1**C illustrates a cross-section **160** of another implementation of the electricity collecting windsock **102**. The electrically conducting material (e.g. metal deposit) **132**, **162** may be placed on both sides of the electrically insulating material **134** such that the collection ability is increased even further. Multiple collectors are implemented and are spaced apart on electrically conducting material **132**, **162** such that the collection surface is greatly enhanced. The multiple collectors may form one or more patterns, as noted above with respect to FIG. **1**B. Furthermore, the electrically insulating material **134** (e.g. mylar) used in the electricity collecting windsock **102** is light, thereby minimizing the overall weight of the electricity collecting windsock **102** and reducing the weight for payload calculations. The electrically conducting materials **132**, **162** may be an electrically conducting metal or alloy, such as one of or a combination of at least one of gold, copper, aluminum, silver, and the like. The electrically con-

ducting materials **132**, **162** may be made of the same metal/alloy or a different metal/alloy.

[0029] The electrically conducting materials **132**, **162** may be attached to the electrically insulating material **134** by a gluing mechanism. In some implementations, other attachment mechanisms are known to be implemented, such as paint coating mechanism, a threading mechanism, a nut and bolt mechanism, soldering mechanism, and the like. The attachment mechanism between the electrically conducting material **132** and the electrically insulating material **134** may or may not be the same as the attachment mechanism between the electrically conducting material **162** and the electrically insulating material **134**.

[0030] FIG. **2** illustrates an exemplary conductive line in accordance with one implementation. This type of conductive line is commonly referred to as poly-wire. The conductive line consists of multiple interwoven strands of plastic **202** and **204** woven into a cord or rope arrangement having intertwined therein exposed metal wires **206** and **208**. Although FIG. **2** illustrates two plastic strands and two metal wires, any number of possible combinations of plastic strands and metal wires is possible. The exposed metal wires **206** and **208** attract the atmospheric static charge and transmit the charge down to the electricity storage device (not shown).

[0031] FIG. **3**A illustrates a front view of a conductive line **300** in accordance with another implementation. FIG. **3**B illustrates a top view of the conductive line **300** illustrated in FIG. **3**. The conductive line **300** creates an ionized pathway for the flow of the static charges from the atmosphere to the electricity storage device via the electricity collecting windsock arrangement **100**. This conductive line utilizes a tube **302** having an outer layer **304** of PET Film (Biaxially-oriented polyethylene terephtalate polyester film). The tube **302** provides exceptionally high tensile strength and is chemically and dimensionally stable. In one implementation, the tube **302** may have an ideal diameter of between two and three inches. An interior metal coating **306** provides an initial conduit for the flow of static charge. The static charge through the metal may force the tube **302** to expand due to the repulsion experienced by like charges. Further, the flow of electricity causes the interior of the tube **302** to become ionized to provide an additional pathway for the atmospheric static charges to the electricity storage device (not shown).

[0032] FIGS. **4**A, **4**B, and **4**C illustrate electrical schematics for handling the static charge from the atmosphere. By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **4**A, **4**B, and **4**C illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations that may serve the same function.

[0033] Referencing FIG. **4**A, Direct Current In (DC IN) **402** is buffered by a gang of capacitors **404** before being communicated to a DC/AC converter **406**. The DC/AC converter converts the direct current into alternating current suitable for placement over an existing electrical grid **408** such as normally found from a power-plant. Those of ordinary skill in the art readily recognize a variety of DC/AC converters that may work in this capacity.

[0034] FIG. **4**B illustrates an electrical arrangement suitable for use in charging a battery. DC IN **402** is buffered by capacitor bank **404** before entering into a step down transformer **408**. Step down transformer **408** reduces the voltage so that the voltage can safely be introduced into battery **410**, which is connected to ground **412** at the battery's other pole. Those of ordinary skill in the art readily recognize a variety of batteries that may work in this capacity.

[0035] In FIG. **4**C, DC IN **402** is fed into an adjustable rheostat **414**, which is controlled by the controller so that the DC OUT **416** falls within a specified range.

[0036] FIG. **5** illustrates an adjusting apparatus **500** that enables adjustment of height of the electricity collecting windsock arrangement **100** in accordance with one implementation. As per one implementation, the height of the electricity collecting windsock **102** can be adjusted using a winch motor **502** and a spool **504**. The winch motor **502** and the spool **504** can release or withdraw the tether **112** to adjust the height of the electricity collecting windsock **102** that is connected to the tether **112**. In one implementation, this release and the withdrawal may be performed manually. In another implementation, this release and the withdrawal may be performed automatically based on information obtained from a sensor system that measures atmospheric electrical energy being collected per unit time. If the sensor indicates that a current flow is diminishing, then the tether **112** is released/extended from the spool **504** to increase the altitude of the electricity collecting windsock **102** such that more static charge from the atmosphere is gathered. If the sensor indicates that collected atmospheric electrical energy exceeds a preset level per unit time, the tether **112** is withdrawn onto the spool **504** to decrease the static charge being collected from the atmosphere.

[0037] FIG. **6** is a process flow diagram illustrating aspects of a method consistent with implementations of the current subject matter. At step **602**, the functioning of the electricity collecting windsock arrangement **100** depends on whether atmospheric conditions are windy. If the atmospheric conditions are windy, the wind **116** stretches/extends outward the electricity collecting windsock **102**—Step **604**. Next, it is determined whether the atmospheric electrical energy (atmospheric current) that is collected is in a predetermined range—Step **606**. If the collected atmospheric electrical energy is in the predetermined range, the flow goes back to step **604**. If the current is not in the predetermined range, the height of the electricity collecting windsock **102** may be adjusted using adjusting apparatus **500**, such as the winch motor **502** and spool **504**. One skilled in the art understands that other implementations may include any other adjusting apparatus **500**, such as a pulley, a wheel mechanism, or the like.

[0038] The implementations set forth in the foregoing description do not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Although a few variations have been described in detail herein, other modifications or additions are possible. In particular, further features and/or variations can be provided in addition to those set forth herein. For example, the implementations described above can be directed to various combinations and sub-combinations of the disclosed features and/or combinations and sub-combinations of one or more features further to those disclosed herein. In addition, the logic flows depicted in the accompanying figures and/or described herein do not necessarily require the particular order shown, or sequential order, to achieve desirable results. The scope of the following claims may include other implementations or embodiments.

What is claimed is:

1. An electricity collection apparatus comprising:

a tether; and

a windsock formed of an insulation material with a metal deposited on at least a portion of the insulation material, the metal of the windsock being electrically connected to the tether, the windsock to extend in a direction of ambient wind to provide a surface area based on the ambient wind, the surface area providing the metal to collect electrical energy from the ambient wind, the collected electrical energy being transferred to the tether.

2. The apparatus in accordance with claim **1**, wherein the metal is deposited on at least one of opposite sides of the insulation material.

3. The apparatus in accordance with claim **2**, wherein the metal is a metal selected from a group of metals comprising gold, silver, copper and aluminum.

4. The apparatus in accordance with claim **1**, wherein the insulation material is a polyester film.

5. The apparatus in accordance with claim **1**, wherein the transferred electrical energy at the tether is further transferred from the tether to an electricity storage device.

6. The apparatus in accordance with claim **1**, wherein the metal comprises conductors that are light-weight thereby allowing payload requirements for adjusting the windsock to an optimum location to be within a predetermined value, the optimum location comprising a height of the windsock from ground level.

7. The apparatus in accordance with claim **6**, wherein the deposited metal conductors form a pattern that maximizes the collection of the electrical energy at the optimum location.

8. An electricity collection apparatus comprising:

a windsock formed of an insulation material having a metal deposited on at least a portion of the insulation material, the windsock to extend in a direction of ambient wind to provide a surface area based on the ambient wind, the surface area providing the metal to collect electrical energy from the ambient wind; and

an electrically conductive tether connected with windsock to anchor the windsock in the direction of the ambient wind, the electrically conductive tether being electrically connected to the metal of the insulation material, the collected electrical energy being transferred to the tether.

9. The apparatus in accordance with claim **8**, wherein the metal is deposited on at least one of opposite sides of the insulation material.

10. The apparatus in accordance with claim **9**, wherein the metal is a metal selected from a group of metals comprising gold, silver, copper and aluminum.

11. The apparatus in accordance with claim **8**, wherein the insulation material is a polyester film.

12. The apparatus in accordance with claim **8**, wherein the transferred electrical energy at the tether is further transferred from the tether to an electricity storage device.

13. The apparatus in accordance with claim **8**, wherein the metal comprises conductors that are light-weight thereby allowing payload requirements for adjusting the windsock to an optimum location to be within a predetermined value, the optimum location comprising a height of the windsock from ground level.

14. The apparatus in accordance with claim **13**, wherein the metal conductors form a pattern that maximizes the collection of the electrical energy at the optimum location.

15. An electricity collection apparatus comprising:

a windsock formed of an insulation material the windsock to extend in a direction of ambient wind to provide a surface area based on the ambient wind;

one or more electrical conductors provided on at least a portion of the insulation material to collect electrical energy from the ambient wind; and

an electrically conductive tether connected with windsock to anchor the windsock in the direction of the ambient wind, the electrically conductive tether being electrically connected to the one or more electrical conductors provided on at least a portion of the insulation material to transfer the collected electrical energy from the one or more electrical conductors to an electrical storage.

* * * * *

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(19) **United States**

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Dinwiddie et al. (43) **Pub. Date: Apr. 27, 2017**

(54) **POWER RECEIVER FOR EXTRACTING POWER FROM ELECTRIC FIELD ENERGY IN THE EARTH**

(71) Applicant: **Earth Energies, Inc.**, Johns Creek, GA (US)

(72) Inventors: **John Dinwiddie**, Cary, NC (US); **Terry L. Wright**, Suwanee, GA (US); **David R. Ames**, Johns Creek, GA (US)

(21) Appl. No.: **15/397,281**

(22) Filed: **Jan. 3, 2017**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/509,772, filed on Oct. 8, 2014, now Pat. No. 9,564,268.

(60) Provisional application No. 61/889,894, filed on Oct. 11, 2013.

Publication Classification

(51) **Int. Cl.**

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H02J 7/35	(2006.01)
H02J 3/38	(2006.01)

(52) **U.S. Cl.**

CPC ***H02J 4/00*** (2013.01); ***H02J 3/385*** (2013.01); ***H02J 7/35*** (2013.01)

(57) **ABSTRACT**

A resonant transformer connected between a ground terminal and elevated terminal draws current from the earth's electric field through a primary winding of the transformer. An impulse generator applies a high voltage impulse to the primary winding of the resonant transformer to cause current to flow from the ground terminal through the primary winding. The flow of current through the primary winding of the resonant transformer induces a current in the secondary winding, which may be converted and filtered to a usable form, e.g. 60 Hz AC or DC.

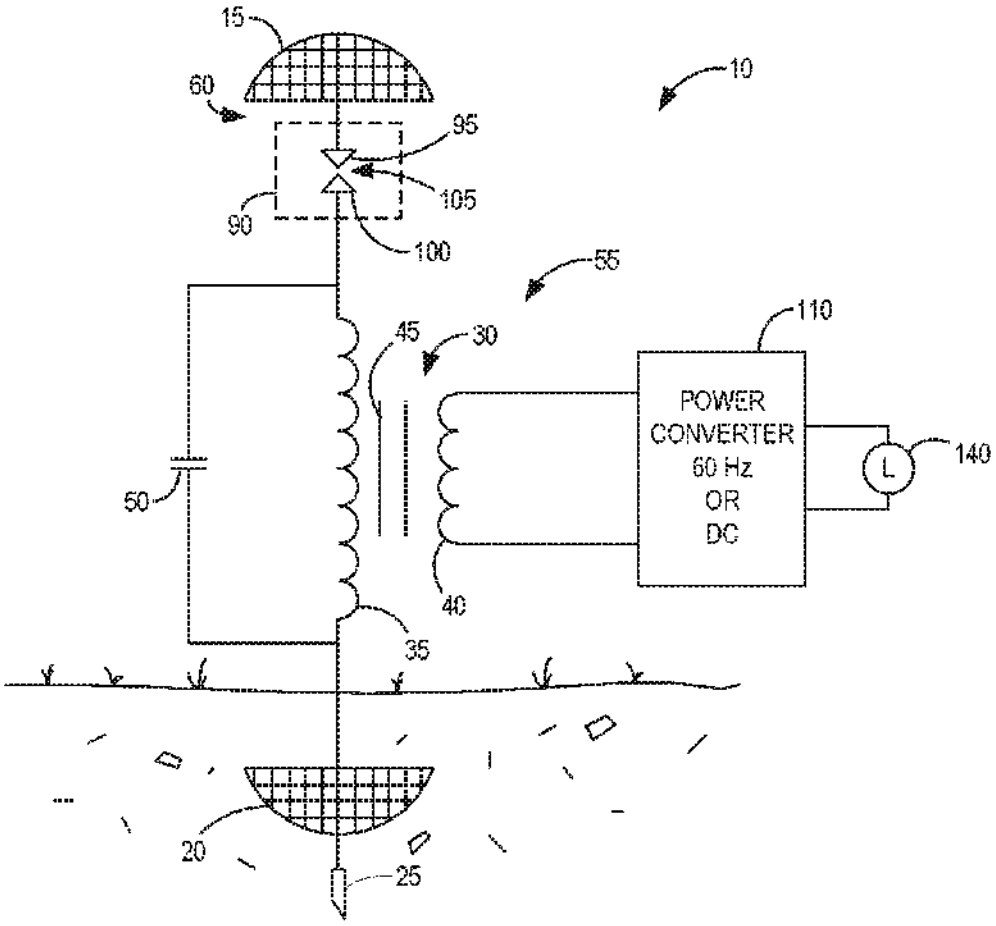

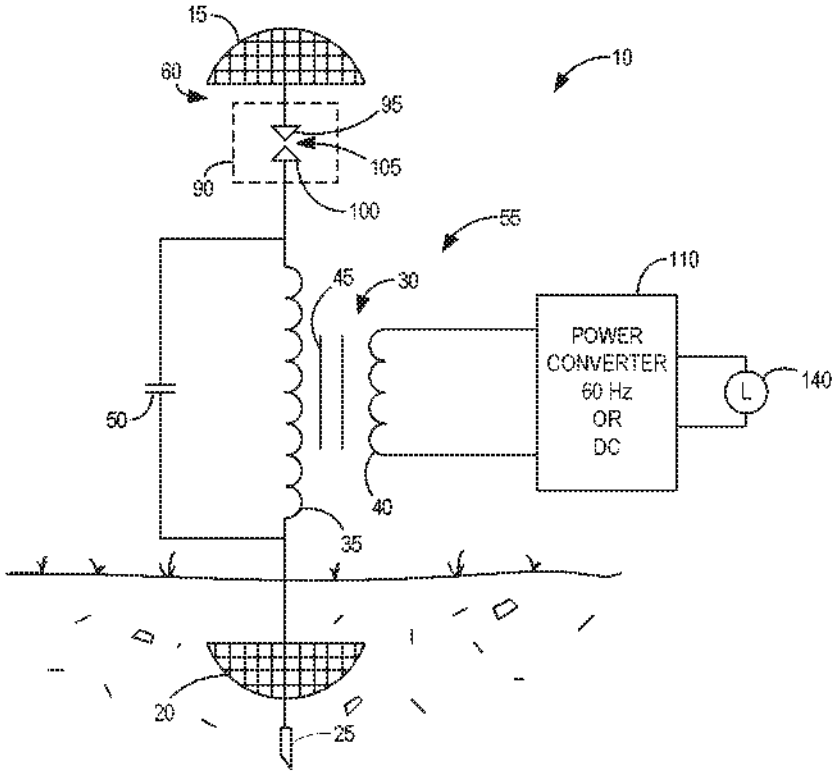
15
60
10
95
105
90
100
55
110
45
30
POWER
CONVERTER
60 Hz
OR
DC
140
L
50
40
35
20
25

FIG 1

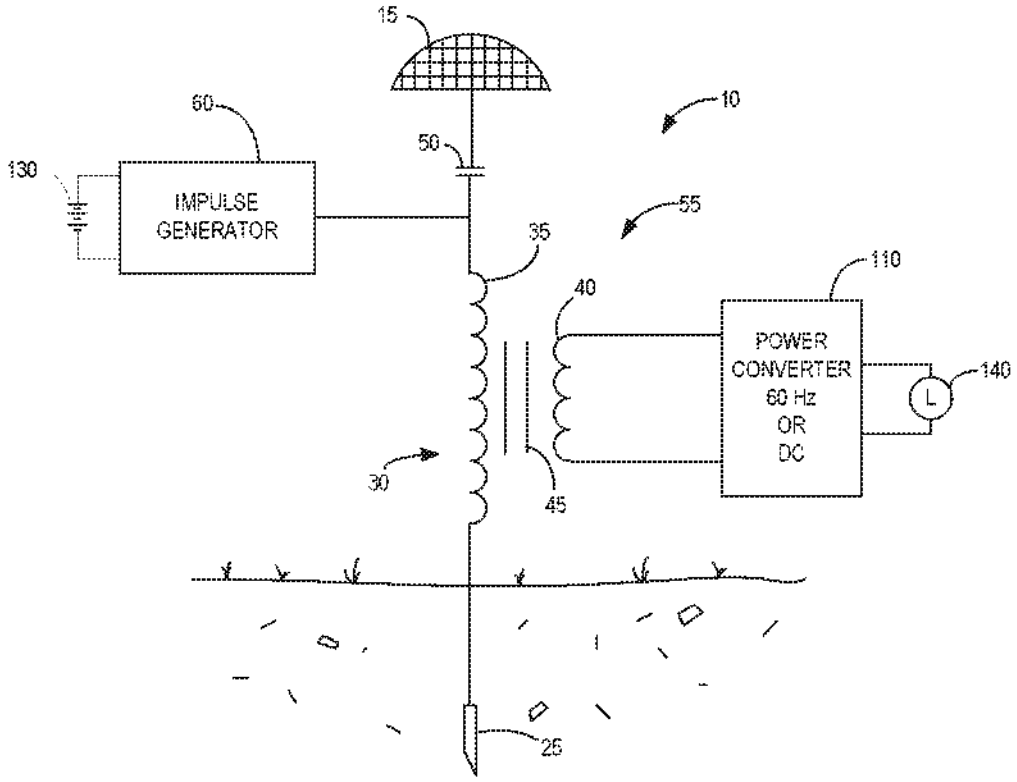
15
60
10
50
130
IMPULSE
GENERATOR
55
35
110
40
POWER
CONVERTER
60 Hz
OR
DC
140
L
30
45
25

FIG 2

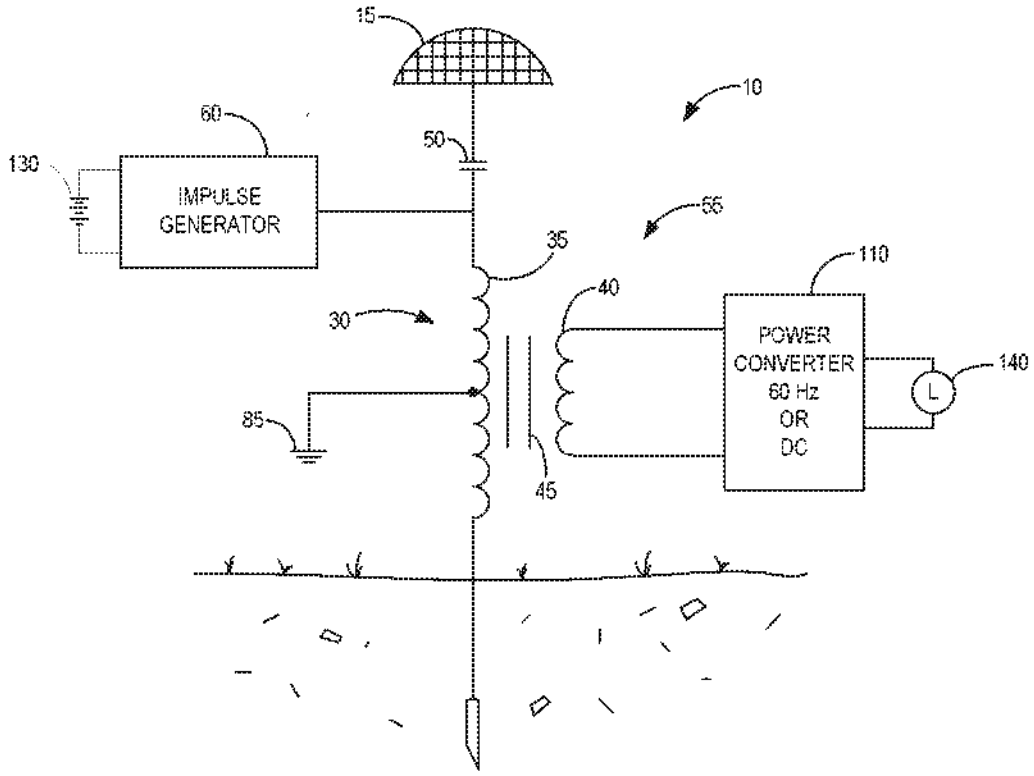
15
10
60
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130
IMPULSE
GENERATOR
55
35
110
40
30
POWER
CONVERTER
60 Hz
OR
DC
140
L
85
45

FIG 3

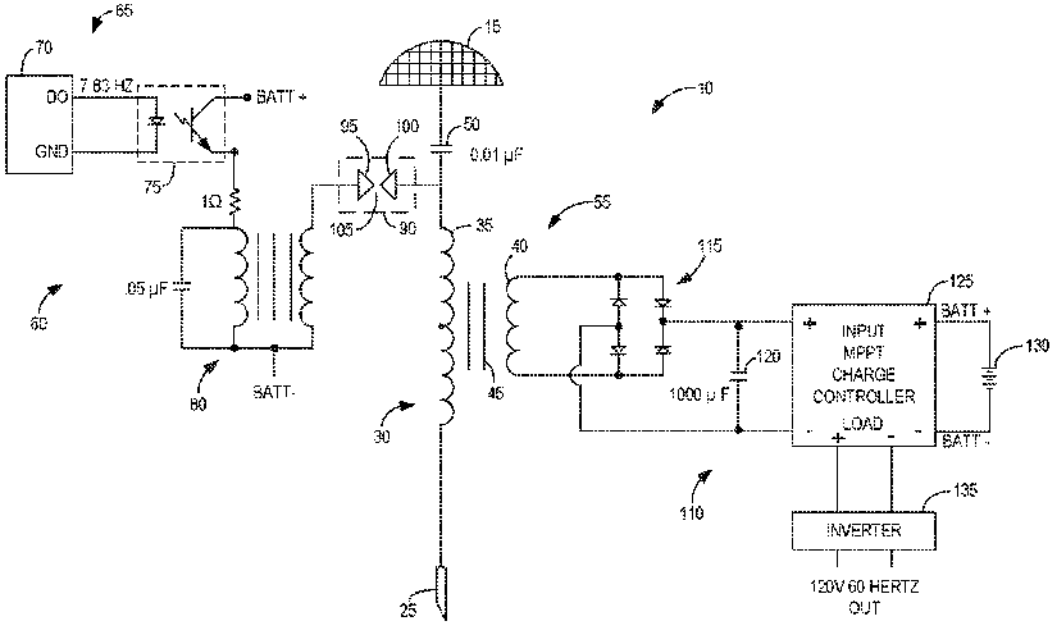
65
70
DO
GND
7.83 HZ
BATT +
75
1Ω
.05 µF
60
80
SATT-
95
100
105
90
50
0.01 µF
35
30
25
15
10
55
40
45
115
120
1000 µ F
125
BATT +
INPUT
MPPT
CHARGE
CONTROLLER
LOAD
BATT -
130
110
135
INVERTER
120V 60 HERTZ
OUT

FIG 4

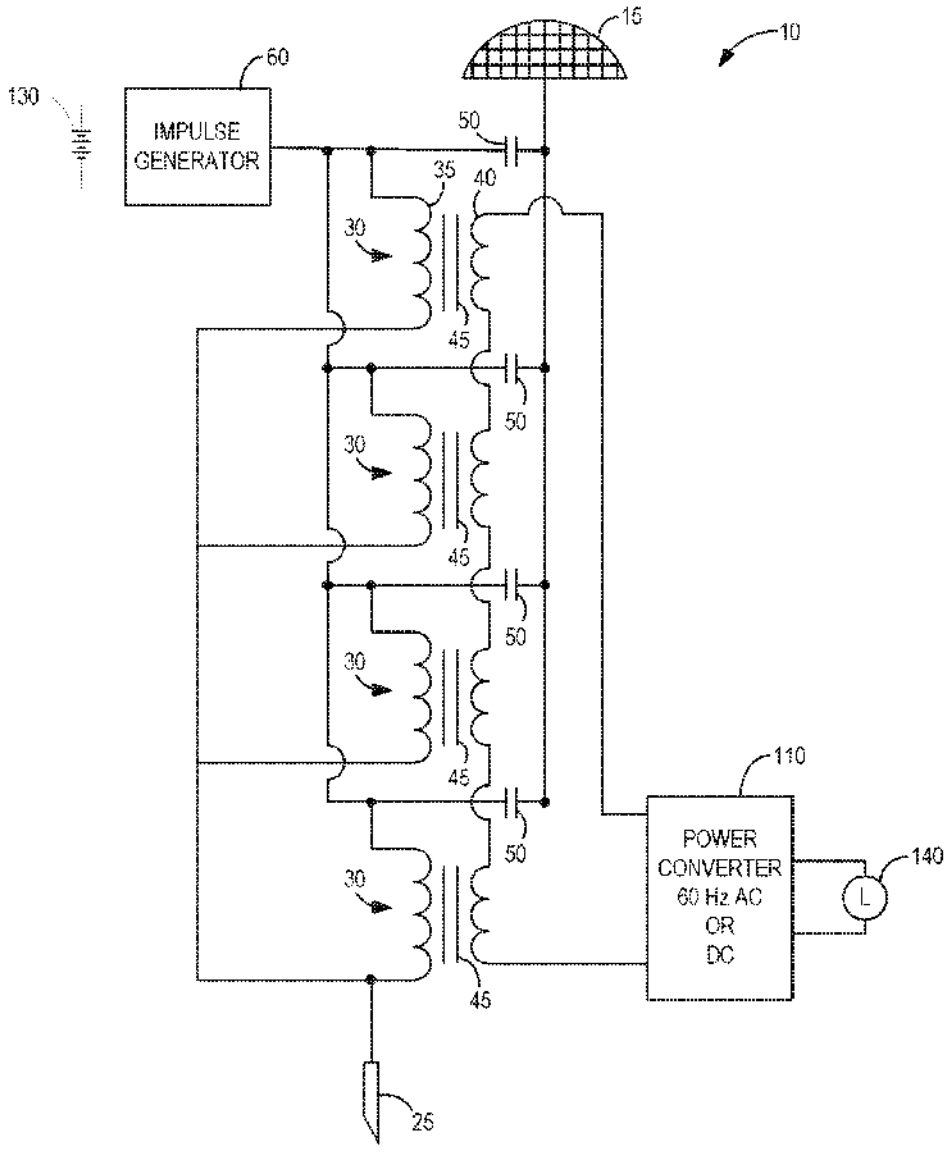
15
10
60
130
IMPULSE GENERATOR
50
35
40
30
45
50
30
45
50
30
45
50
30
45
110
POWER CONVERTER 60 Hz AC OR DC
140
L
25

FIG 5

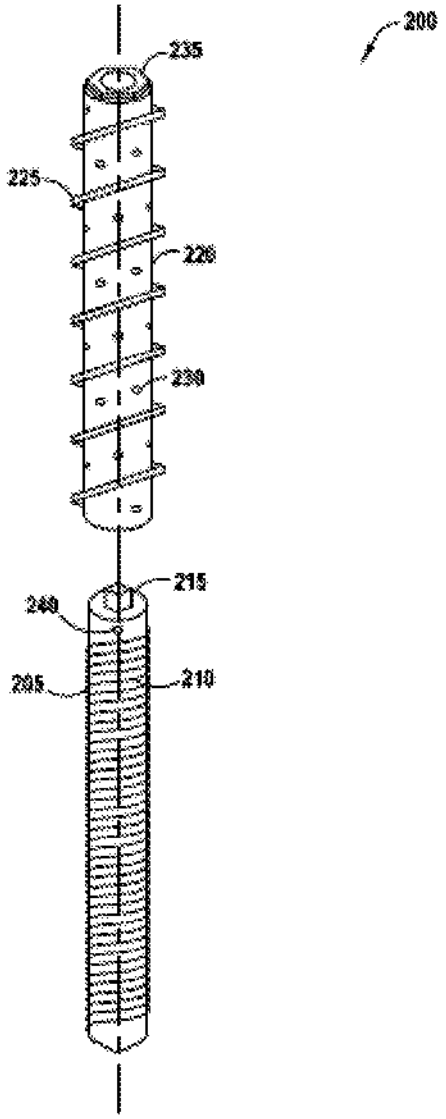

FIG 6A

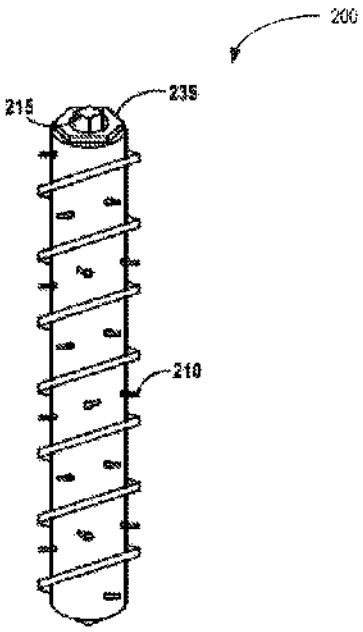

FIG 6B

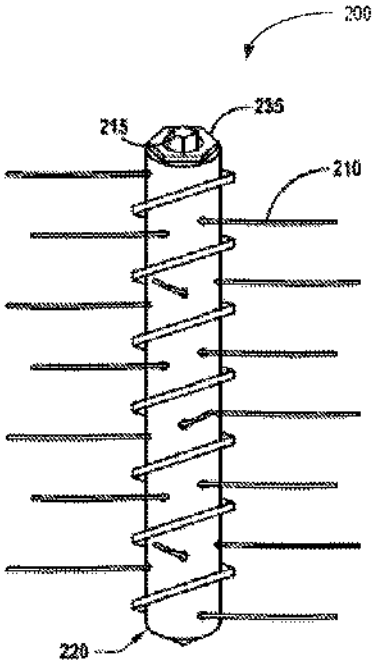

FIG 6C

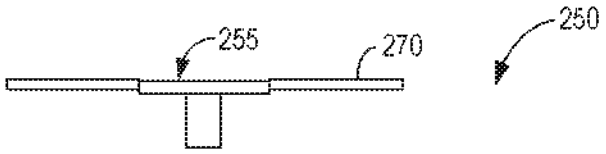

FIG 7A

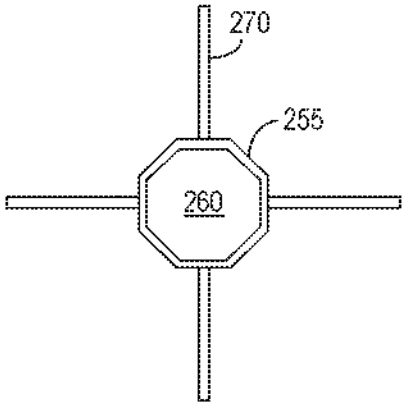

FIG 7B

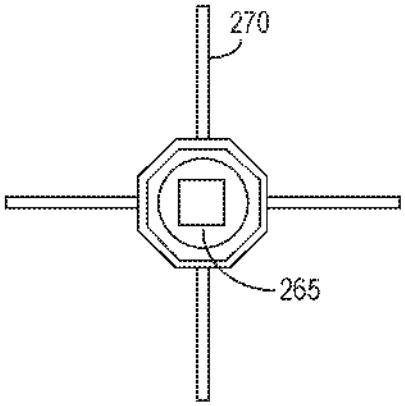

FIG 7C

POWER RECEIVER FOR EXTRACTING POWER FROM ELECTRIC FIELD ENERGY IN THE EARTH

[0001] This application is a continuation-in-part of prior U.S. application Ser. No. 14/509772 filed 8 Oct. 2014 which claims the benefit of U.S. Provisional Application No. 61/889894 filed 11 Oct. 2013, the disclosures of all of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The present invention relates generally to renewable energy, and more particularly to methods and apparatus for extracting energy from subsurface electrical fields beneath the earth's surface.

BACKGROUND

[0003] The earth and the ionosphere cavity may be viewed as a global electric circuit. Electrical currents are constantly flowing within the earth and its atmosphere. Within the earth, the majority of the earth's energy is carried by extremely low frequency (ELF) and ultralow frequency (ULF) waves in the 0-200 Hz frequency range. The earth's rotating magnetic field and positive lightning are two energy sources that sustain the ELF/ULF waves within the earth and the atmosphere.

[0004] A great deal of research has been devoted to studying the electric field present in the earth's ionosphere cavity. Joseph M. Crawley, the "Fair Weather Atmosphere as a Power Source", Proceedings ESA Annual Meeting on Electrostatics 2011; O. Jefimenko, "Operation of Electric Motors from Atmospheric Electric Field," American Journal of Physics, Vol. 39, Pgs. 776-779, 1971; M. L. Breuer, "Usability of Tapping Atmospheric Charge as a Power Source," Renewable Energy, Vol. 28, Pgs. 1121-1127, 2003. Numerous attempts have been made in the past to extract electrical energy from the earth's atmosphere. For example, U.S. Pat. No. 1,540,998 to Plauson describes a system for converting atmospheric electrical energy into usable power. These past attempts have been successful in producing only small amounts of power from the electrical field in the earth's ionosphere cavity. The modest success of these experiments compared to results from other renewable energy sources, such as solar and wind, has tempered further research and prevented widespread use of the electric field in the ionosphere cavity as an energy source.

SUMMARY

[0005] The present invention relates to a power receiver for extracting power from electric fields beneath the earth's surface. In embodiments of the present disclosure, a resonant transformer connected to a ground terminal draws current from the earth's electric field through the primary winding of the transformer. Current flow through the resonant transformer is induced by applying a high voltage impulse to the primary winding. The flow of current through the primary winding of the resonant transformer induces a current in the secondary winding, which may be converted and filtered to a usable form, e.g. 60 Hz AC or DC.

[0006] In some embodiments of the power receiver, the resonant frequency of the resonant transformers is below 200 Hz.

[0007] In some embodiments of the power receiver, the resonant transformer comprises a ferro-resonant transformer.

[0008] In some embodiments, the power receiver further comprises an elevated terminal.

[0009] In some embodiments of the power receiver, the primary winding of the resonant transformer is connected between the ground terminal and elevated terminal.

[0010] In some embodiments of the power receiver, the elevated terminal comprises an upper capacitive plate coupled to the earth's ionosphere cavity.

[0011] In some embodiments of the power receiver, the impulse generator comprises the upper capacitive plate and a spark gap connected between the upper capacitive plate and the primary winding of the resonant transformer. The spark gap comprises a pair of electrodes separated by a gap and configured to generate a spark when a voltage difference between the electrodes reaches a predetermined level.

[0012] In some embodiments of the power receiver, the impulse generator comprises a pulse generator for generating low voltage pulses, a step-up transformer for converting the low voltage pulses provided by the pulse generator to high voltage impulses, and a spark gap connected between the step-up transformer and the primary winding of the resonant transformer to generate a spark responsive to the high voltage impulses from the step-up transformer.

[0013] In some embodiments of the power receiver, the impulse generator comprises a pulse generator for generating low voltage pulses, and a step-up transformer connected to the primary winding of the resonant transformer for converting the low voltage pulses provided by the pulse generator to high voltage impulses.

[0014] In some embodiments of the power receiver, the impulse generator comprises a solid state spark generator.

[0015] In some embodiments of the power receiver, the resonant transformer includes a capacitor connected in parallel with the primary winding.

[0016] In some embodiments of the power receiver, the resonant transformer includes a capacitor connected in series with the primary winding between the impulse generator and the elevated terminal.

[0017] In some embodiments, the power receiver comprises multiple resonant transformers having primary windings connected in parallel between the ground terminal and the elevated terminal.

[0018] In some embodiments of the power receiver, the resonant transformers have different resonant frequencies.

[0019] In some embodiments of the power receiver, the resonant frequencies of the resonant transformers are all below 200 Hz.

[0020] In some embodiments of the power receiver, the resonant frequencies of the resonant transformers are matched to respective Schumann resonances.

[0021] Another embodiment of the power receiver comprises a resonant circuit connected to a ground terminal disposed below the surface of the earth, an impulse generator for generating and applying a high voltage electrical impulse to the resonant circuit to induce current flow from the ground terminal through the resonant circuit, and a power conversion circuit connected to the resonant circuit to convert electrical current flowing through the resonant circuit to a desired form. The resonant circuit has a resonant frequency below 200 Hertz.

[0022] In some embodiments of the power receiver, the resonant circuit comprises a resonant transformer having a primary winding, a secondary winding, and resonant capacitor connected in series with the primary winding.

[0023] In some embodiments of the power receiver, the resonant circuit comprises multiple resonant transformers having primary windings connected in parallel to the ground terminal.

[0024] In some embodiments of the power receiver, the resonant transformers have different resonant frequencies.

[0025] In some embodiments of the power receiver, the resonant frequencies of the resonant transformers are all below 200 Hz.

[0026] In some embodiments of the power receiver, the resonant frequencies of the resonant transformers are matched to respective Schumann resonances.

[0027] Other embodiments of the disclosure comprise a ground terminal for a power receiver. In one embodiment, the ground terminal comprises a ground shaft configured for insertion beneath the surface of the earth, a hollow cylinder surrounding the ground shaft and having a plurality of openings, and a plurality of ground wires connected at one end to the ground shaft. The ground wires are wound around the ground shaft and have free ends protruding through respective openings in the hollow shaft so that rotation of the ground shaft relative to the hollow cylinder causes the ground wires to extend radially into the earth.

[0028] Other embodiments of the disclosure comprise methods of extracting power from the earth. In one embodiment, the method comprises applying a high voltage impulse to resonant circuit coupled to a ground terminal disposed beneath the surface of the earth to initiate resonance in the resonant circuit and induce the flow of current from the ground terminal to the resonant circuit, and converting the current flowing from the ground terminal into the resonant circuit into a useful form.

[0029] In some embodiments of the method, the resonant circuit comprises a resonant transformer including a primary winding coupled to the ground terminal and a second winding coupled to a power converter, and applying a high voltage impulse to resonant circuit comprises applying a high voltage impulse to the primary winding of the resonant transformer.

[0030] In some embodiments of the method, applying a high voltage impulse to the primary winding of the resonant transformer comprises applying an impulse in the range to 10,000 to 40,000 volts to primary winding of the transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. **1** illustrates a first exemplary embodiment of a power receiver.

[0032] FIG. **2** illustrates a second exemplary embodiment of a power receiver.

[0033] FIG. **3** illustrates a third exemplary embodiment of a power receiver.

[0034] FIG. **4** illustrates a fourth exemplary embodiment of a power receiver.

[0035] FIG. **5** illustrates a fifth exemplary embodiment of a power receiver.

[0036] FIG. **6**A is an exploded perspective view of an exemplary ground antenna array for the power receiver.

[0037] FIG. **6**B is a perspective view of an assembled ground antenna array before being deployed.

[0038] FIG. **6**C is a perspective view of an assembled ground antenna array after being deployed.

[0039] FIG. **7**A is a side view of an insertion tool for installing the ground antenna array.

[0040] FIG. **7**B is a top view of the insertion tool for installing the ground antenna array.

[0041] FIG. **7**C is a bottom view of the insertion tool for installing the ground antenna array.

DETAILED DESCRIPTION

[0042] Referring now to the drawings, a power receiver for extracting energy from the earth's electric field are illustrated and indicated generally by the numeral **10**. Various embodiments of the power receiver **10** are described and similar reference numbers are used throughout the description to indicate similar components.

[0043] The power receiver **10** converts energy in the ELF/ULF waves to useful form, e.g. 60 Hz AC or DC. The power receiver **10** is essentially a resonance circuit that resonates at the natural resonance frequencies in the earth's electric field. These resonance frequencies, known as Schumann resonance frequencies, occur at 7.83 Hz, 14.3 Hz, 20.8 Hz, 27.3 Hz, and 33.8 Hz. A high voltage impulse initiates resonance within the power receiver **10**. In the resonant mode, the impedance of the power receiver **10** is reduced to near zero thus inducing ground currents to flow into the power receiver **10** where the ground currents are converted to useful form.

[0044] FIG. **1** illustrates a first embodiment of the power receiver **10**. The power receiver **10** comprises a resonant transformer **30** connected between an elevated terminal **15** and ground terminal **25**. In this embodiment, the elevated terminal **15** is capacitively coupled to electric fields within the earth's ionosphere cavity and functions as an upper capacitive plate. A lower capacitive plate **20** is connected to the ground terminal **25** beneath the surface of the earth.

[0045] The resonant transformer **30** comprises a primary winding **35**, secondary winding **40**, ferromagnetic core **45**, and capacitor **50**. One end of the primary winding **35** is connected to the lower capacitive plate **20** and ground terminal **25**. The opposite end of the primary winding **35** is connected via a spark gap **90** to the elevated terminal **15**. The capacitor **50** is connected in parallel with the primary winding **35** of the resonant transformer **30** to form an LC circuit **55** with a resonance frequency range of between about 0.1 and 200 Hz. In a preferred embodiment, the resonant transformer has a Q of about 10 or greater and resonance frequency in the range of about 0.1-200 Hertz. For example, the resonant transformer **30** may have a resonance frequency of about 7.83 Hz, the fundamental Schumann resonance frequency. The secondary winding **40** of the resonant transformer **30** is connected to a power converter **110** as will be hereinafter described in greater detail. The power converter **110** converts the energy extracted from the earth's electric field by the power receiver **10** into a usable form for driving a load **140**.

[0046] The elevated terminal/upper capacitive plate **15** comprises an insulated, dish-shaped plate with a large radius of curvature. The capacitance and resistance of the elevated terminal is chosen for receiving broadband electric field frequencies in the 0-200 Hz range. The upper capacitive plate **15** is sized to maximize to the extent practical coupling with the electric field in the earth's ionosphere cavity.

[0047] The lower capacitive plate **20** is also a dish-shaped plate with a large radius of curvature. One function of the lower capacitive plate **20** is to collect charge from the earth's ground currents and provide an instantaneous source of current as hereinafter described. The capacitance and resistance of the lower capacitive plate **20** is selected to promote the flow of current from the ground with minimal losses.

[0048] The spark gap **90** connected between the elevated terminal **15** and resonant transformer **30** comprises a pair of electrodes **95**, **100** separated by an evacuated air gap **105**. Electrode **95** is connected to the upper capacitive plate **15**. Electrode **100** is connected to the resonant transformer **30**. The spark gap **105** prevents electrical discharge from the upper capacitive plate **15** to the earth's ionosphere cavity. The spark gap **90** in combination with the elevated terminal **15** function as an impulse generator that applies a high voltage impulse of about 10,000-40,000 volts to the primary winding **35** to initiate resonance in the transformer **30**.

[0049] In operation, the capacitive coupling of the upper capacitive plate **15** induces a high voltage operating current in the upper capacitive plate **15**. The upper capacitive plate is connected to a first electrode **95** to the spark gap **90**. When the voltage difference between the electrodes **95** and **100** reaches a threshold, a spark forms across the electrodes **95**, **100** and a high voltage impulse is applied to the primary winding **35** of the resonant transformer **30**. This high voltage impulse initiates resonance within the transformer **30**.

[0050] In resonant mode, the impedance of the resonance transformer is reduced to nearly zero allowing current to flow from the capacitive plate **20** and ground terminal **25** through the primary winding **35** of the transformer **30**, which in turn induces current in the secondary winding **40**. Power converter **110** converts the current flowing through the secondary winding **40** into a usable form for driving a load **140**. The transformer **30** will continue to resonate for a short period of time. By providing high voltage impulses to the primary winding **35** of the resonant transformer **30** at periodic intervals, it is possible to maintain a continuous flow of current from the earth into the resonant transformer **30**, thus producing a continuous supply of power.

[0051] FIG. **2** discloses a second embodiment of the primary receiver **10**. This embodiment includes a resonant transformer **30** connected between an elevated terminal **15** and ground terminal **25**. The resonant transformer **30** comprises a primary winding **35**, secondary winding **40**, ferromagnetic core **45** and a high voltage capacitor **50**. One end of the primary winding **35** is connected to the ground terminal **25**. The opposite end of the primary winding **35** is connected to the elevated terminal **15**. The capacitor **50** has a capacitance of about 0.01 micro-farads. In contrast to the previous embodiment, capacitor **50** is connected in series with the primary winding **35** and elevated terminal **15** and forms a LC circuit **55** with a Q of about 10 or greater and a resonance frequency in the range of about 0.1 to 200 Hz. In a preferred embodiment, the resonance frequency of the transformer **30** is 7.83 Hz, the fundamental Schumann resonance frequency. An impulse generator **60** is connected between the primary winding **35** of the resonant transformer **30** and the series capacitor **50** and applies a high voltage impulse to the primary winding **35** of the resonant transformer **30**. A battery **130** or other external power source supplies power to the impulse generator **60**. As previously described, the high voltage impulse applied by the impulse generator **60** initiates resonance within the resonant transformer **30** inducing current flow from the ground terminal **25** into the primary winding **35** of the resonant transformer **30**. The flow of current from the ground terminal **25** through the primary winding **35** induces current in the secondary winding **40**. Power converter **110** converts the electrical energy in the current flowing through the primary winding **40** into a usable form.

[0052] In contrast to the first embodiment, it is not required to capacitively couple the elevated terminal **15** in the second embodiment to the earth's ionosphere cavity. Rather, the elevated terminal **15** in this embodiment provides lightning protection and dissipates some of the energy flowing into the power receiver **10** to the earth's ionosphere cavity. Also, in contrast to the first embodiment, the capacitor **50** is connected in series between the primary winding **35** of the transformer **30** and the elevated terminal **15**. Those skilled in the art will appreciate that the capacitor **50** could also be connected in parallel rather than series with the primary winding **35** as shown in FIG. **1**. Another difference is that the impulse generator **60** has an external power source. The amount of energy generated by the power receiver **10**, however, is far greater than the energy needed to generate high voltage impulses. The first embodiment does not require an external power source to generate high voltage impulses.

[0053] FIG. **3** illustrates a third embodiment of the power receiver **10**. This embodiment is essentially the same as the embodiment shown in FIG. **2**. The main difference is that a center tap of the primary winding **35** in the resonant transformer **30** is connected to an electrical ground **85**. It should be appreciated that the electrical ground **85** may be different than the earth ground. When the center tap of the resonant transformer **30** is grounded at a distance away from the ground terminal **25** (e.g. 50 ft to 100 ft), the power receiver **10** becomes a transmitter via the ground loop formed.

[0054] FIG. **4** illustrates the power receiver **10** of FIG. **2** in greater detail. The power receiver includes a resonant transformer **30** connected between a ground terminal **25** and an elevated terminal **15**. The ground terminal **25** may comprise a ⅝-inch×8-foot copper ground rod, such as the ERICO 615880UPC. The elevated terminal **15** may comprise a 90% copper mesh formed into a hemisphere with a radius of about 9 inches. The elevated terminal **15** may be elevated at a height of approximately 6 feet above the ground.

[0055] The resonant transformer **30** includes a primary winding **35**, secondary winding **40**, ferromagnetic core **45** and series capacitor **50** configured as previously described. The resonant transformer **30** may have a Q of about 10 and a resonance frequency in the range of about 0.1 to 200 Hz. The resonant transformer **30** may be made using an Allanson transformer (part #1530BP120R) connected in series with a 0.01 micro-farad capacitor, such as the Condensor Products high voltage capacitor (part #TC 103-17-125). The resonant transformer **30** is used in a step-down configuration. The center tap of the resonant transformer **30** may optionally be connected to a ground.

[0056] An impulse generator **60** is connected between the primary winding **35** of the resonant transformer **30** and the series capacitor **50** and applies a high voltage impulse in the range of about 10,000 to 40,000 volts to the primary winding of the transformer **30**. A battery **130** or other external power source supplies power to the impulse generator **60**. The power converter **110** connects to the secondary winding **40**

of the resonant transformer **30** for converting current in the secondary winding of the transformer to a useful form.

[0057] The impulse generator **60** comprises a pulse generator **65** for generating low voltage pulses, a step-up transformer **80** for converting the low voltage pulses from the pulse generator **65** to high voltage pulses, and a spark gap **90** for generating sparks responsive to the high voltage pulses from the step-up transformer **80**.

[0058] The pulse generator **65** comprises a square wave generator **70**, such as a Sinometer VC2002 function signal generator, and solid state relay **75**. The square wave generator **70** generates a digital pulse stream. In one embodiment, the digital pulse stream generates a square waveform with a frequency of about 7.83 Hz. The frequency of the digital pulse stream is selected to match the resonance frequency of the transformer **30**, though such is not necessarily required. The pulse stream output from the square wave generator **70** is applied to the solid state relay **75**. The solid state relay **75** is connected between a battery or other power source and a first winding of the step-up transformer **80**. The battery may comprise a 12 V, 7.0 A/H sealed lead acid battery, such as the ELB 1270A by Lithonia Lighting. The solid state relay **75** functions as a switch that is activated responsive to the waveform from the square wave generator **70** to provide a continuous stream of low voltage pulses from the battery to the first winding of the step-up transformer **80**. A 1 ohm resistor is connected between the solid state relay **75** and step-up transformer **80**.

[0059] The step-up transformer **80** may comprise a Transco 15 kV, 30 mA neon sign transformer (part #S15612). The step-up transformer **80** converts the low voltage pulses from the pulse generator **65** to high voltage pulses that are applied to the spark gap **90**. The step-up transformer has a 0.5 micro-farad capacitor connected in parallel with the primary winding of the step-up transformer **80**. The step-up transformer produces pulses at the output of about 30,000 to 40,000 volts.

[0060] The spark gap **90** comprises a pair of electrodes **95**, **100** separated by an air gap **105**. A suitable spark gap electrode pair is the Information Unlimited SPARK05 ¼-inch×1-inch tungsten electrodes. As previously described, when the voltage potential between the electrodes **95**, **100** reaches a threshold, a spark forms between the electrodes **95**, **100** and supplies a nearly instantaneous, high voltage impulse to the primary winding **35** of the resonant transformer **30**. This high voltage impulse initiates resonance in the resonant transformer **30** inducing current flow from the ground terminal **25** through the primary winding **35** of the resonant transformer **30**.

[0061] The power converter **110** comprises a bridge rectifier **115**, filter capacitor **120**, charge controller **125**, and inverter **135**. A suitable rectifier is the Micro Commercial Components 10 amp, 1000 volt bridge rectifier (Part #GBJL 1010). The bridge rectifier **115** converts the AC current flowing through the secondary winding **40** of the resonant transformer to a DC current. A filter capacitor **120** removes unwanted frequencies from the DC current. A suitable capacitor **120** is Cornell Dubilier 1000uF 450VDC capacitor (part #383LX102M450N082). The filter capacitor **120** has a capacitance of about 1000 micro-farads. The DC current is input to the charge controller **125**. The charge controller **125** may, for example, comprise a maximum power point tracking (MPPT) charge controller, such as a Tracer 4215 BN MPPT Solar Charge Controller, which is commonly used in solar power generating systems. The charge controller **125** applies a small amount of energy to a battery **30** to charge the battery **130**. As previously noted, the battery **130** serves as a power source for the impulse generator **60**. The remaining current is supplied to an inverter **135**, which converts the DC current to an AC current with a desired voltage and frequency, e.g., 120 volts/60 Hz AC. A suitable inverter **135** is the 1500 W Pure Sine power inverter (AIMS) (part #PWRI1500125).The power converter **110** as shown in FIG. **4** may be utilized in the embodiment shown in FIGS. **1**, **2** and **3**.

[0062] FIG. **5** illustrates a power receiver **10** according to another embodiment. The power receiver **10** comprises a plurality of resonant transformers **30** connected between a ground terminal **25** and elevated terminal **15**. Each of the resonant transformers **30** comprises a primary winding **35**, secondary winding **40**, ferromagnetic core **45** and series capacitor **50**. The primary windings **35** of the resonant transformers **30** are connected in parallel. The secondary windings **40** are connected in series with the power converter **110**. An impulse generator **60** applies a high voltage impulse to the primary windings **35** of the resonant transformers **30**. A battery **130** or other external power source supplies power to the impulse generator **60**. The power converter **110** converts the current in the power converter circuit to a usable form for driving a load **140**.

[0063] In one embodiment, each of the resonant transformers **30** shown in FIG. **5** is configured to have a different resonant frequency. In one embodiment, the resonant transformers **30** are configured to resonate at frequencies of 7.83 Hz, 14.8 Hz, 20.3 Hz and 26.8 Hz respectively. Additional resonant transformers **30** could be added to operate at other resonance frequencies.

[0064] FIGS. **6**A-**6**C illustrate a high quality ground antenna array **200** which may be used as a ground terminal **25**. The ground antenna array **200** comprises a generally cylindrical ground shaft **205** disposed with a hollow cylinder **220** and a plurality of reinforced, heavy gauge ground wires **210** attached at one end to the ground shaft **205**. The ground shaft **205** and ground wires **210** should be highly conductive and have low resistance to supply current from the ground to the power receiver **10**. In one embodiment, the ground wires **210** may be copper or other highly-conductive metal. The end of the ground shaft may be pointed to facilitate insertion into the earth. A connection port on the ground shaft **220** is provided to electrically connect the ground antenna array **220** to the resonant transformer **30**.

[0065] The hollow cylinder **220** has external threads **25** to facilitate insertion into the ground. A rotator nut **235** is fixedly secured to the top end of the hollow shaft **220**. A square shaft **215** protrudes from the top end of the ground shaft **205** into the opening in the rotator nut **235**. FIG. **6**B. A tool **250**, shown in FIG. **7**, engages with the rotator nut **235** and square shaft **215** during insertion of the ground antennas array **200** into the ground as will be hereinafter described.

[0066] The insertion tool **250** is shown in FIG. **7**. The insertion tool **250** includes a tool body **255** having a first socket **260** on one side to fit the rotator nut **235** on the hollow cylinder **220** and a second socket **265** on the other side to fit the square shaft **215** on the ground shaft **205**. Arms **270** extend from the outer periphery of the tool body **255** for manually or mechanically turning the insertion tool **250**.

[0067] Before the antenna array **200** is deployed, the ground wires **210** are wound around the ground shaft **205** with the free ends protruding slightly from respective openings **230** in the hollow cylinder **220** to a distance not to exceed one half (½) the depth of the external threads **225** on the hollow cylinder **220**. FIG. **6**B illustrates the ground antenna array **200** before deployment. FIG. **6**C illustrates the ground antenna array in a deployed configuration.

[0068] Installation of the ground antenna array **200** is performed in two stages. In the first stage, a hole slightly smaller in diameter than the threads **235** of the hollow cylinder **220** is drilled into the Earth to a depth matching the length of the hollow cylinder **220** or slightly longer. The hole is filled with water and the water is allowed to soak into the soil. After the ground is softened, the hollow cylinder **220** is rotated using the insertion tool **250** to insert the ground antenna array **200** into the ground. The first socket **260** of the insertion tool **250** is engaged with the rotator nut **230** and the insertion tool **250** is turned by hand or a mechanized rotating shaft fitted and attached to the tool arms **270** to thread the ground assembly into the hole. During the initial insertion of the ground antenna array **200**, the ground shaft **205** is fixed to the hollow shaft **220** and rotates with the hollow shaft. The hollow cylinder **220** is rotated until it reaches the full depth of the hole.

[0069] Once the ground antenna array **200** has been fully inserted into the earth, the insertion tool **250** is flipped over and the second socket **265** of the insertion tool **250** is engaged with the square shaft **215**. The insertion tool **250** is turned by hand or a mechanized rotating shaft fitted and attached to the tool arms **270** to rotate the ground shaft **205**. During the second phase, the ground shaft **205** rotates freely inside the hollow cylinder **220**. Rotation of the ground shaft **205** causes the reinforced ground wires **210** to extend radially into the earth. The ground shaft **220** is rotated until the ground wires are fully extended. The ends of the ground wires may be sharpened to aid in the extension of the ground wires during the second phase.

[0070] After the ground antenna array **200** is deployed, a connection cable **280** is attached to a connection port **240** on the ground shaft **220** to electrically connect the ground antenna array **220** to the resonant transformer **30** in the power receiver **10**.

What is claimed is:

1. A power receiver for extracting electrical energy from the earth's electric field, said power receiver comprising:

a resonant transformer connected to a ground terminal disposed below the surface of the earth;

an impulse generator for generating and applying a high voltage electrical impulse to a primary winding of the resonant transformer to induce current flow from the ground terminal through the primary winding of the transformer; and

a power conversion circuit connected to a secondary winding of the resonant transformer to convert electrical current flowing through the secondary winding to a desired form.

2. The power receiver of claim **1** wherein a resonant frequency of the resonant transformers is below 200 Hz.

3. The power receiver of claim **1** wherein the resonant transformer comprises a ferro-resonant transformer.

4. The power receiver of claim **1** further comprising an elevated terminal, and wherein the primary winding of the resonant transformer is connected between the ground terminal and elevated terminal.

5. The power receiver of claim **1** wherein the impulse generator comprises:

a pulse generator for generating low voltage pulses;

a step-up transformer for converting the low voltage pulses provided by the pulse generator to high voltage impulses;

a spark gap connected between the step-up transformer and the primary winding of the resonant transformer to generate a spark responsive to the high voltage impulses from the step-up transformer.

6. The power receiver of claim **1** wherein the impulse generator comprises a solid state spark generator.

7. The power receiver of claim **1** wherein said resonant transformer includes a capacitor connected in parallel with the primary winding.

8. The power receiver of claim **1** wherein said resonant transformer includes a capacitor connected in series with the primary winding between the impulse generator and the elevated terminal.

9. The power receiver of claim **1** comprising multiple resonant transformers having primary windings connected in parallel between the ground terminal and the elevated terminal.

10. The power receiver of claim **9** wherein the resonant transformers have different resonant frequencies.

11. The power receiver of claim **10** wherein the resonant frequencies of the resonant transformers are matched to respective Schumann resonances.

12. A power receiver for extracting electrical energy from the earth's electric field, said power receiver comprising:

a resonant circuit connected to a ground terminal disposed below the surface of the earth, said resonant circuit having a resonant frequency below 200 Hertz

an impulse generator for generating and applying a high voltage electrical impulse to the resonant circuit to induce current flow from the ground terminal through the resonant circuit; and

a power conversion circuit connected to the resonant circuit to convert electrical current flowing through the resonant circuit to a desired form.

13. The power receiver of claim **12** wherein the impulse generator comprises:

a pulse generator for generating low voltage pulses;

a step-up transformer for converting the low voltage pulses provided by the pulse generator to high voltage impulses;

a spark gap connected between the step-up transformer and resonant circuit to generate a spark responsive to the high voltage impulses from the step-up transformer.

14. The power receiver of claim **12** wherein the resonant circuit comprises a resonant transformer having a primary winding, a secondary winding, and resonant capacitor connected in parallel with the primary winding.

15. The power receiver of claim **12** wherein the resonant circuit comprises a resonant transformer having a primary winding, a secondary winding, and resonant capacitor connected in series with the primary winding.

16. The power receiver of claim **12** wherein the resonant circuit comprises multiple resonant transformers having primary windings connected in parallel to the ground terminal.

17. The power receiver of claim **16** wherein the resonant transformers have different resonant frequencies.

18. The power receiver of claim **17** wherein the resonant frequencies of the resonant transformers are matched to respective Schumann resonances.

* * * * *

Capacitors we used are electrolytic rated at 400 volts x 47 uF put in series to equal 6,000 volts, the diodes we used were silicon 1000 volt 2 amp placed in series to equal 6,000 volts..... Ground was connected to laboratory wall out let ground.

If you decide to try Tesla's experiment by pumping DC into the ground be careful, I tried this and it does work but is very dangerous to you or your neighbors. If someone is taking a shower or using water they can get killed or shocked. do this experiment far away from humans and animals. you can get far more energy out than you put in. I will not tell you much more because it is such a dangerous experiment.

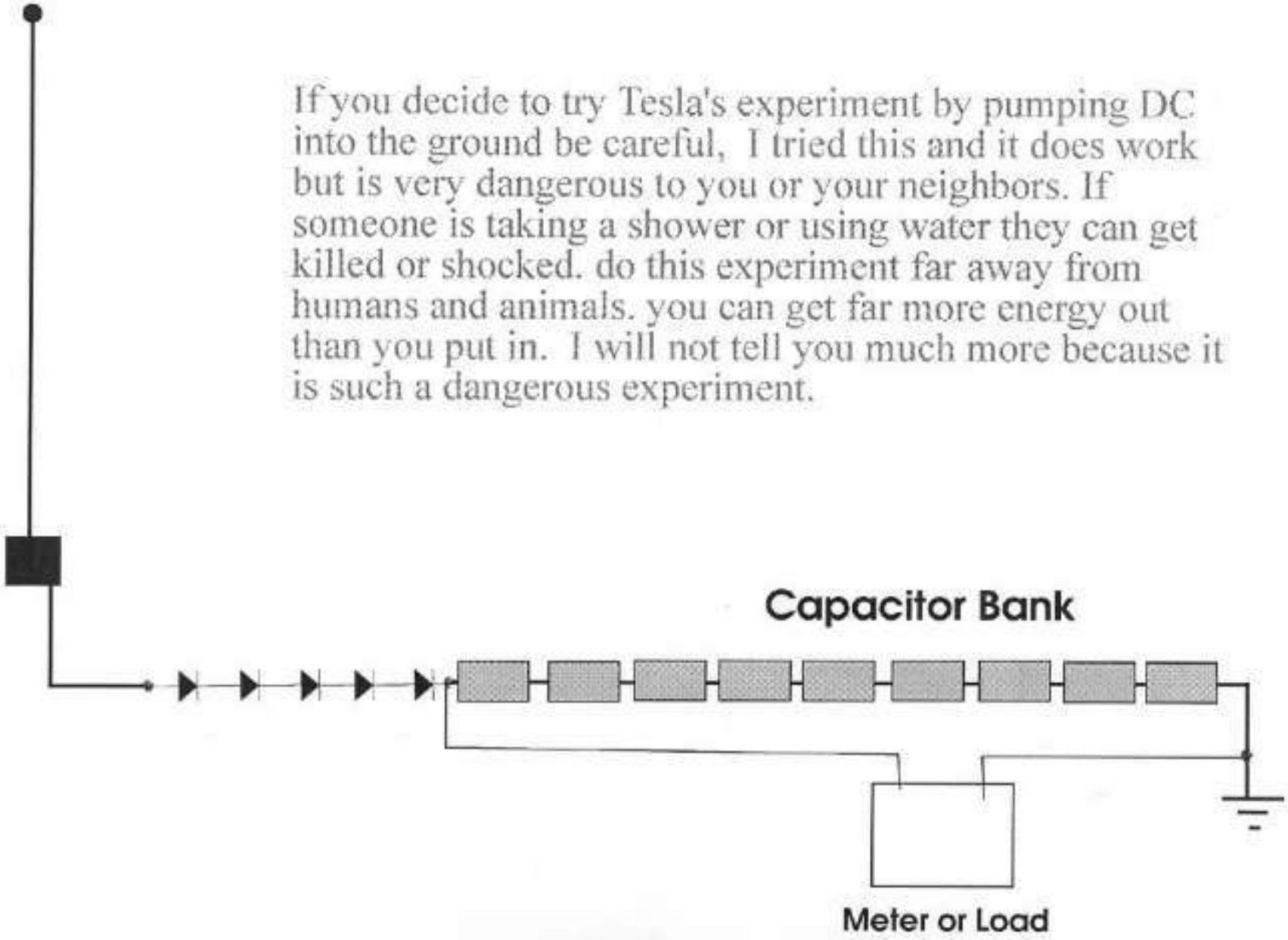

Energy Projects
Electrodynamic Tether Photos

Deployment of the Tether Satellite

Boom Deploy

Initial Deploy

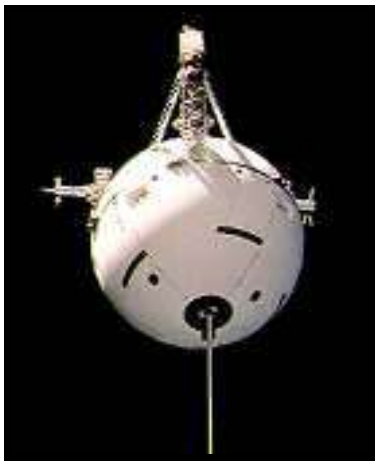

Satellite Deployed

Closeup of boom showing tether

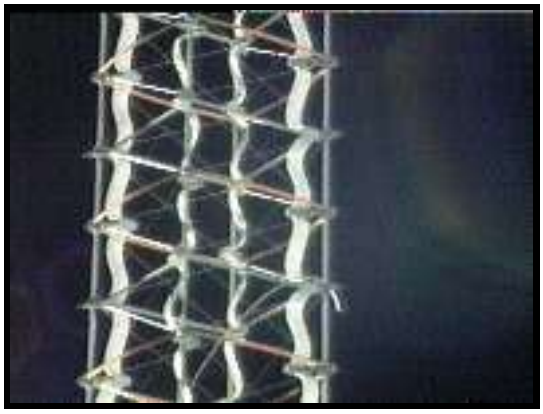

Close up of end of boom

Tether Break

The tether deployed to one mile

Shortly after the breakreak

The tether coils as it moves away from the Shuttle

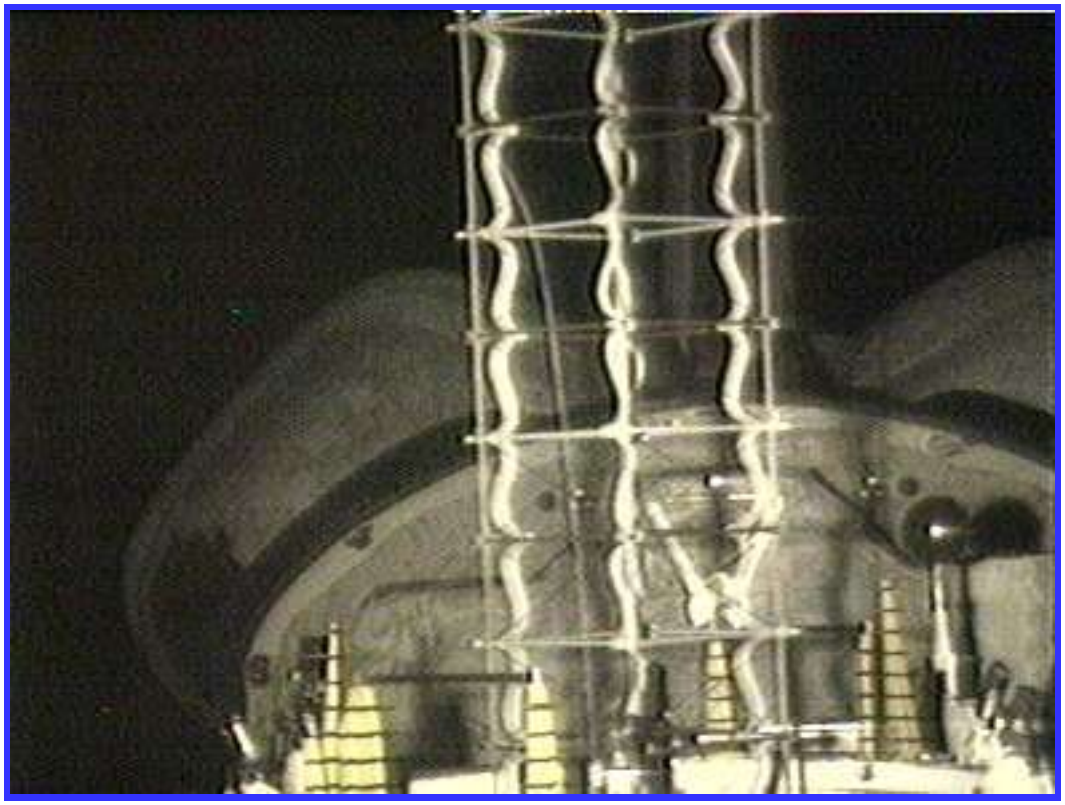

The base of the tether boom. The area looks more like a Tesla Laboratory than the space shuttle hanger bay.

After the Break

The following three images are those displayed for the public showing the white specks that appearall around the tether after it has broken free. NASA calls these "dust and debris" particles, though Mission control in the audio portion of the videos state that they see a "lot of stuff swimming around" and that the tether is wider than expected.

If you compare these images to the ones we captured from a hard to find high resolution copy of the video on this page you will see a remarkale difference. The video is a must see.

Video Clip
STS-75 'The Tether Incident' Feb 1996
Editors Note: This video has been removed several times by Youtube. Currently it is available again. If it does get removed again, email me and I can send you a copy as we have it on disk now. Contact me at webmaster
This one is from the hand held Infrared Camera and is not as clear as the other one was STS-75 Alternate Copy

Comments:

What is most interesting to note is that most of the video clips above are taken from this video, yet NASA does not show the video itself. The copy on Youtube is a transmission intercept copy. However the fact that the NASA info site DOES use those clips gives credibility to the video that it is indeed a NASA film - Zorgon

Tethered Satellite System (TSS-1R)
Source of Clips: NASA STS-75 Mission Pictures

Kennedy Space Center STS-75 Mission Fact Sheet

"Critters" from STS-75

The Report After the Fact

NASA/TP—2003-21228
Low Earth Orbit Spacecraft Charging Design Guidelines

Below are a few keynote excerpts from the PDF file. The entire 367 page document is available below for those with technically savy who want to read the entire paper...

Excerpt 1:

In the case of the TSS-1R tether, its 20 km length produced a maximum of about 3500 V potential between its most positive and negative ends, since it wasn?t oriented perfectly perpendicular to the velocity vector and the Earth?s magnetic field. A satellite at its upper end collected electrons, and an electron gun at the lower end emitted electrons to complete the circuit. When the electron gun was not in operation, a large resistance prevented the Shuttle from being biased thousands of volts negative of its surrounding plasma. However, there remained a large voltage between the tether lower end and the Shuttle orbiter. This enormous bias eventually led to a continuous arc on the tether (see The Continuous Arc, section 4.2.3.1 below), which broke, freeing the satellite and ending the experiment. During the arc, the satellite collected over 1 Amp of electron current to keep the arc going. Probe theory (Cohen et al, 19870010625 N) is usually used to calculate the total current collected by a wire with distributed potentials. However, before the break, TSS-1R demonstrated that a satellite at a high positive potential could collect an anomalously large electron current. See Zhang, et al (20000110580), Stone and Raitt (19990084046 and 20000025437), and Stone, et al (19980202347)

Excerpt 2:

Sustained arcs (continuous arcs) - These are the events that have been attributed with the destruction of on-orbit solar arrays. Generally, the process begins with a fast transient (a so-called trigger arc). Under some conditions, the transient develops into an arc that is fed directly by the entire array, effectively becoming a short-circuit. Such events invariably involve large quantities of energy and can be severely damaging to cells, interconnects or power traces.

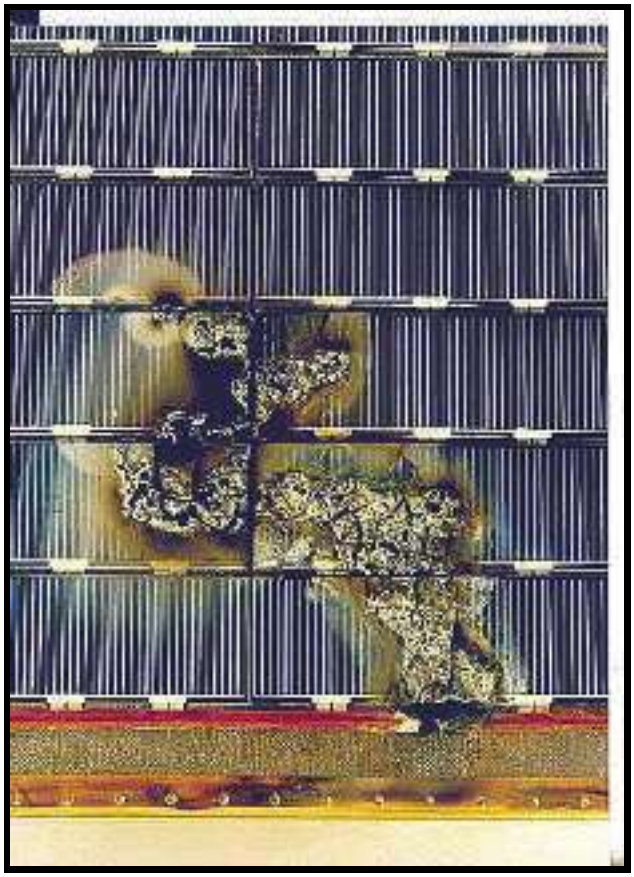

Excerpt 3:
When the structure or array capacitance electrically connected to the arc site is sufficiently large, the initial transient arcs themselves can be large enough to produce significant damage. In Figure 9, we see an anodized aluminum plate that has undergone repeated arcing in the laboratory with the ISS structure capacitance attached. Its thermal properties have been completely destroyed, along with most of the insulating surface layer of aluminum oxide.

Excerpt 4:

The most famous sustained arc event of all led to the breakage of the TSS-1R electrodynamic tether, and the loss of the attached satellite. The image below shows the burned, frayed and broken tether end still attached to the Shuttle after the break.

Incidentally, the tether continued arcing long after it and its satellite were drifting free, until finally it went into night conditions where the electron density was insufficient to sustain the arc. Noel Sargent (2002) has investigated whether the TSS-1R arc was seen to disrupt Shuttle communications. Although he has found no record of disturbed communications during the event, for most of the time the arc was shielded by metallic structures from the communications antennas, and when the tether broke, the arc was many meters from the receiving antennas. It remains to be seen whether sustained arcs produce radio noise severe enough to be a communications problem.

Comments:

This is official confirmation that the tether continued to produce plasma energy long after it broke free, accounting for the "fluorescent bulb" glowing effect viewed after. We believe this concentrated collection of plasma energy is what attracted the "swarm" of "critters" to a "feeding frenzy"

To get the full PDF file you can download LEO_Charging_Guidelines_v1.3.1.zip

Tether Optical Phenomena Experiment (TOP)

Using a hand-held camera system with image intensifiers and special filters, the TOP investigation will provide visual data that may allow scientists to answer a variety of questions concerning tether dynamics and optical effects generated by TSS-1R. In particular, this experiment will examine the high-voltage plasma sheath surrounding the satellite...

In one mode of operation, the current developed in the Tethered Satellite System is closed by using electron accelerators to return electrons to the plasma surrounding the orbiter. The interaction between these electron beams and the plasma is not well understood...

Associate Investigator: Stephen Mende, Lockheed Martin

SOURCE

The Report After the Fact

The most famous sustained arc event of all led to the breakage of the TSS-1R electrodynamic tether, and the loss of the attached satellite. Figure 8 shows the burned, frayed and broken tether end still attached to the Shuttle after the break. Incidentally, the tether continued arcing long after it and its satellite were drifting free, until finally it went into night conditions where the electron density was insufficient to sustain the arc.

Figure 8 – The end of the remaining TSS-1R tether

...

It is thus possible that an astronaut, grounded to ISS by his tether or conductive tools, could undergo an arc at only –50 V. A sneak circuit analysis showed that such arcs could put 1 Amp of current through an astronaut's heart. Since 0.1 Amp is enough to cause heart stoppage, it is imperative that if the ISS plasma contactors are inoperable during astronaut EVAs, a method be used to prevent ISS astronaut workplaces from floating more than 50 V negative.

...

For many ISS surfaces, peak arc strengths of hundreds of Amps have been calculated. Arcs this strong will melt the arc site and spew molten metal through space. Plasma chamber tests of this kind of arcing are spectacular indeed! Arcs on one anodized surface have been seen to trigger arcs on nearby line-of-sight surfaces.

...

Finally, an arc on an electrodynamic tether may become continuous. The infamous arc on the TSS-1R tether that led to its break and the loss of the satellite was a continuous (sustained) arc with its power supplied by the tether.

...

Had TSS-1R used a tether of greater resistance, the threshold arc current could not have been maintained. For example, a total tether resistance of ten thousand ohms would have limited the arc current to less than 0.4 Amps, less than the sustained arc threshold. Alternatively, if the satellite electron collection capability had been limited to less than ½ Amp, the arc could not have been sustained. Of course, these measures would have severely restricted the power or propulsion that could be obtained by tether operation and could not be tolerated on an experiment that was not just a proof-of-concept. An arc detection circuit could have also been used to shut the tether down at the satellite end when very large currents were first detected. One should never assume that a high voltage power system will not arc.

...

Ionized gases can be emitted by plasma sources such as hollow cathode plasma contactors or from neutral gas sources at high positive potentials. Locally, the plasma density can be greater than the ambient plasma density and similar plasma interactions can occur with high voltage components. On ISS, the Plasma Contacting Units (PCUs), when operating, produce a local xenon plasma of much greater density than ambient. It has been estimated that the invisible plasma ball produced is some eight meters in radius before its density decreases below the ambient plasma density in LEO. Arcing and current collection from such a plasma could occur in much the same way as with an ambient plasma, implying that solar arrays and other active sites should be kept out of induced plasma plumes.

...

Electrodynamic Tethers ~ Menu
Critters ~ Critters 01 ~ Critters 02 ~ Critters 03

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Menu

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STS 75 TETHER INCIDENT

•

Tether Deployed

Tether Satellite being deployed from the Shuttle Bay of STS-75

••

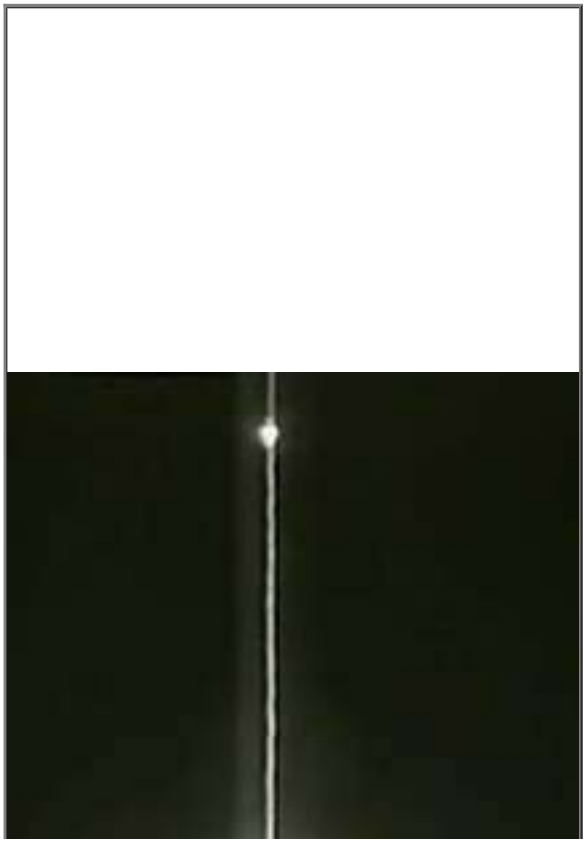

Tether Activated

Tether Satellite begins to glow as it gathers electricity from the Ionosphere

..

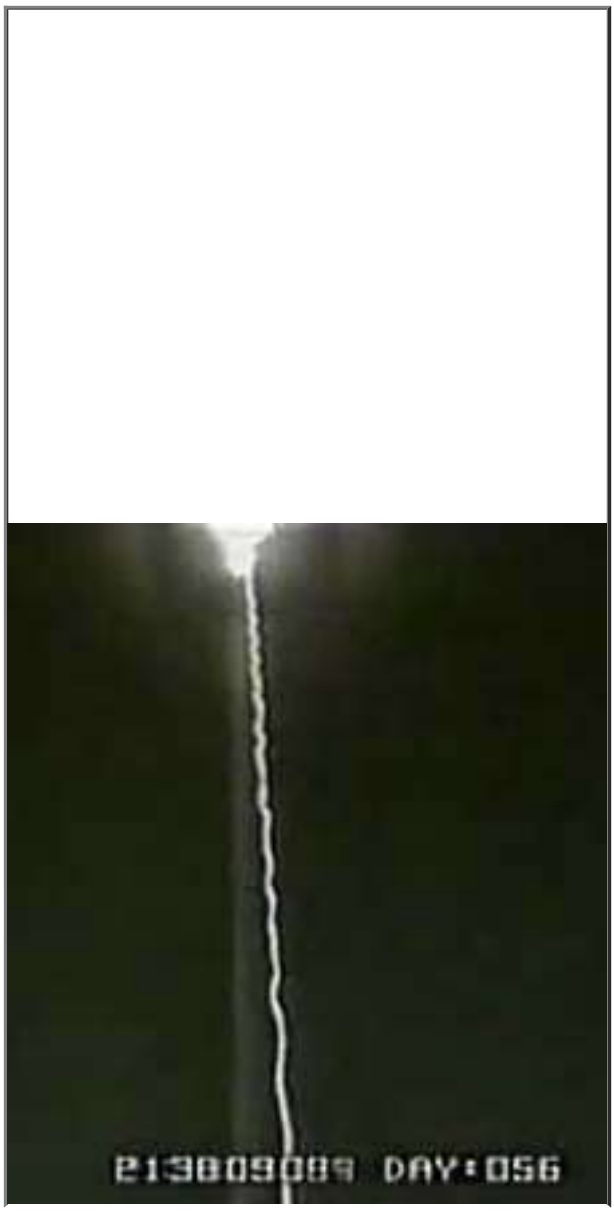

Tether Breaks Free

Tether Satellite cable fries the connection and breaks free... still producing energy. The glow increases and the cable gets wider. (More on this later)

•

Tether Broke Free

Tether Satellite worth 100 million has overloaded the circuits within minutes of being activated because the NASA Scientists under estimated the potential. The tether in just a few moments of operation produced 10 times the anticipated power and they forgot to install a circuit breaker.

•

NOTES:
Add "Critter" Portion
Add Video
Add FLV Viewer

TETHER BROKEN FREE AND DRIFTING AWAY

••

Source: Original Image NASA Cassini/ Huygens N00008771.jpg

~ MENU ~

US006116544A

United States Patent [19]

Forward et al.

[11] **Patent Number: 6,116,544**

[45] **Date of Patent: Sep. 12, 2000**

[54] **ELECTRODYNAMIC TETHER AND METHOD OF USE**

[75] Inventors: **Robert L. Forward**, Houston, Tex.; **Robert P. Hoyt**, Seattle, Wash.

[73] Assignee: **Tethers Unlimited, Inc.**, Seattle, Wash.

[21] Appl. No.: **08/929,271**

[22] Filed: **Sep. 12, 1997**

[51] **Int. Cl.**[7] **B64G 1/00**

[52] **U.S. Cl.** ..... **244/158 R**; 244/166; 244/172

[58] **Field of Search** ..... 244/158 R, 164, 244/166, 172

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,097,010	6/1978	Colombo et al.	244/158 R
4,824,051	4/1989	Engelking	244/158 R
4,923,151	5/1990	Roberts	244/158 R

OTHER PUBLICATIONS

"Tethers Open New Space Options" by Ivan Bekey, *Astronautics & Aeronautics*, 1983.

Primary Examiner—J. Woodrow Eldred
Attorney, Agent, or Firm—Arthur M. Dula

[57] **ABSTRACT**

The present invention comprises an electrodynamic tether structure and a method of use. The structure of the tether taught by the present invention is a short, wide, interconnected multiwire (compared to the long, narrow single wires of the prior art) conductive tether whose area maximizes electrodynamic drag while simultaneously minimizing the Area-Time-Product swept by the tether during its operating life. The preferred tether length is two kilometers to five kilometers. The preferred tether mass is one percent to five percent of the spacecraft mass. The method of operation comprises orienting the tether structure at an angle to the local vertical to maximize electrodynamic drag on the host spacecraft and minimize tether instability. The angle of 35.26 degrees is preferred.

26 Claims, 12 Drawing Sheets

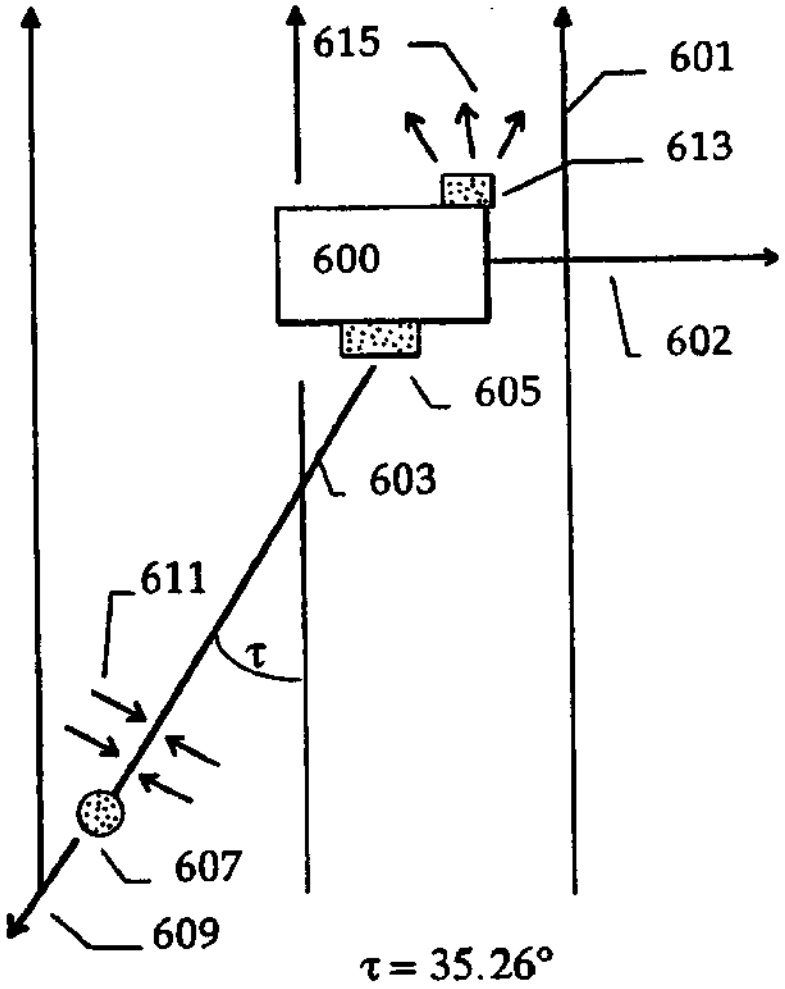

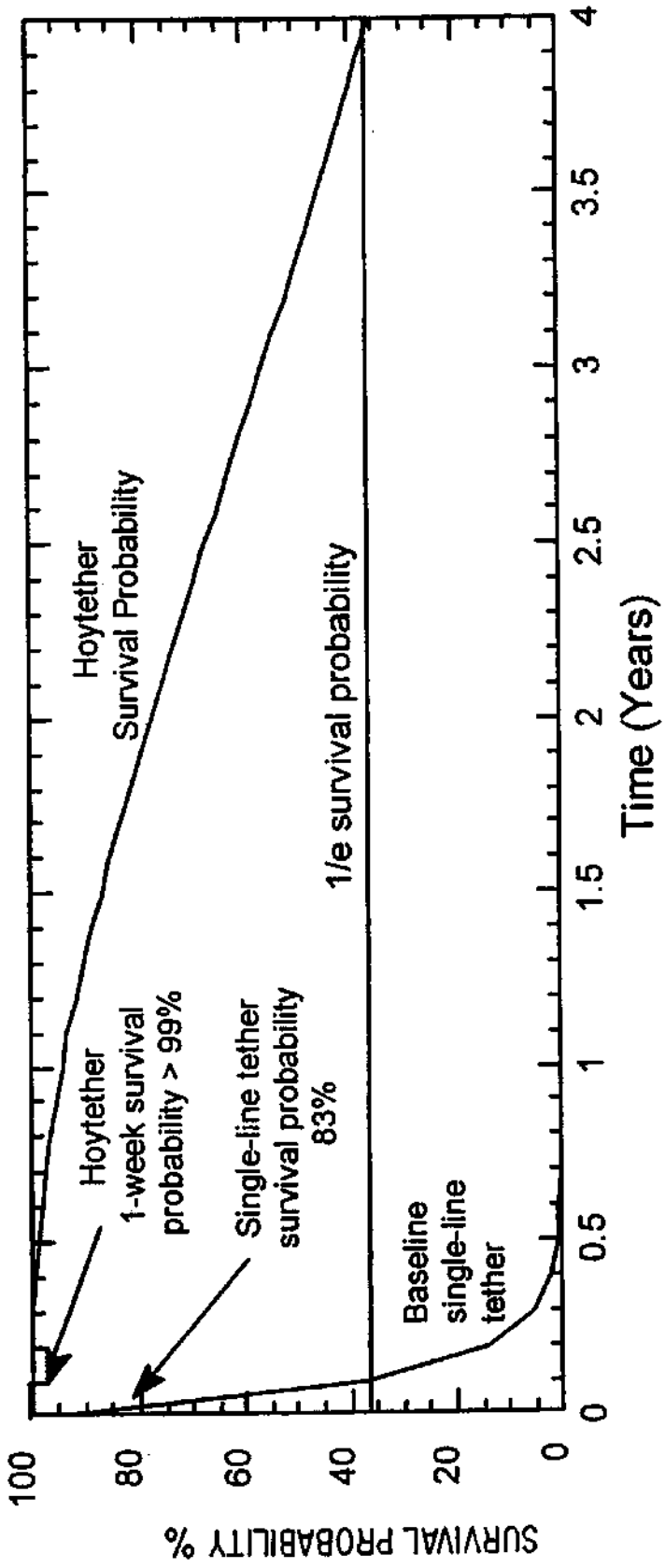
SURVIVAL PROBABILITY %
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (Years)
Hoytether
Survival Probability
1/e survival probability
Hoytether
1-week survival
probability > 99%
Single-line tether
survival probability
83%
Baseline
single-line
tether

FIG. 1a

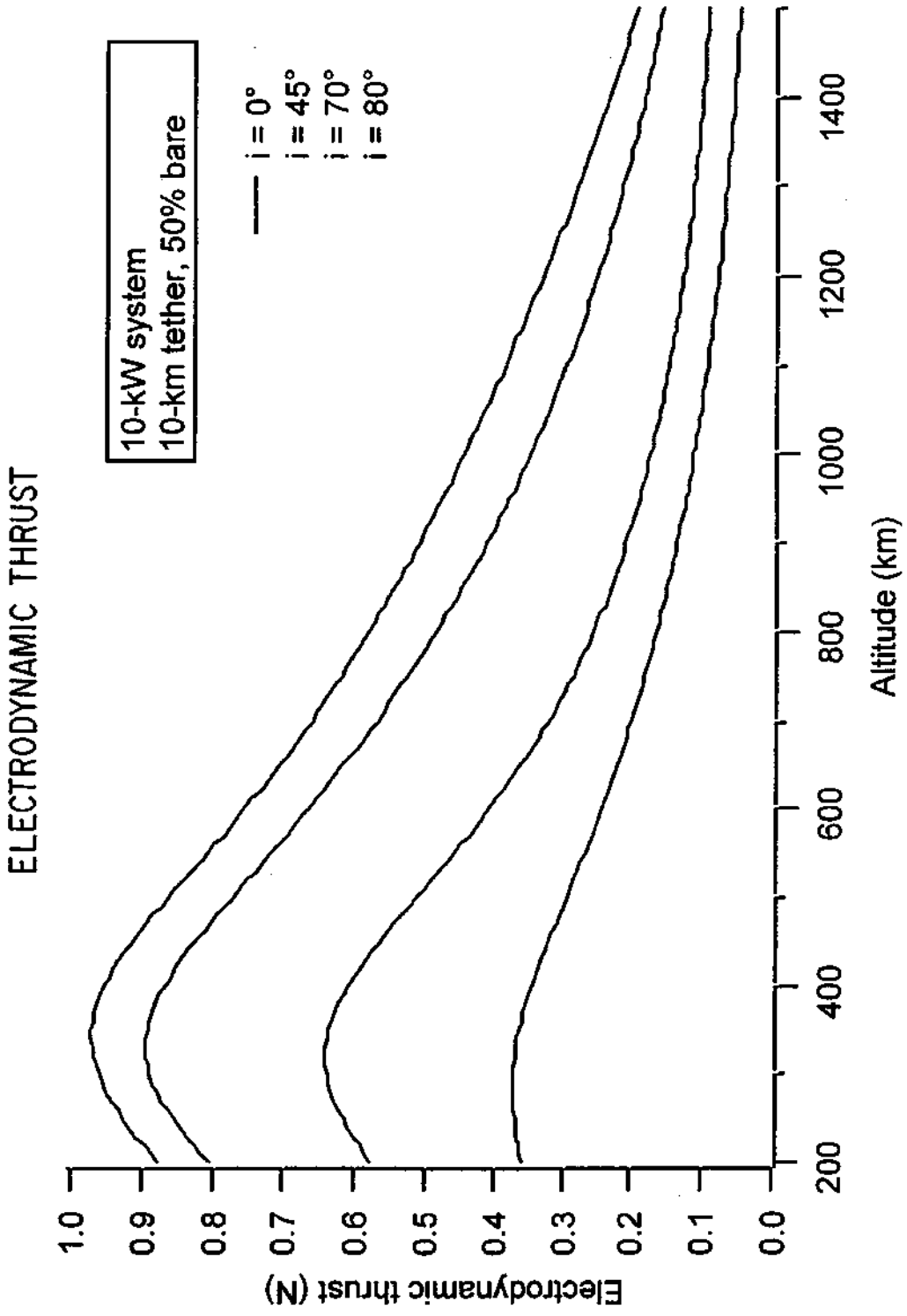
ELECTRODYNAMIC THRUST
10-kW system
10-km tether, 50% bare
i = 0°
i = 45°
i = 70°
i = 80°
Electrodynamic thrust (N)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
200
400
600
800
1000
1200
1400
Altitude (km)

FIG. 1b

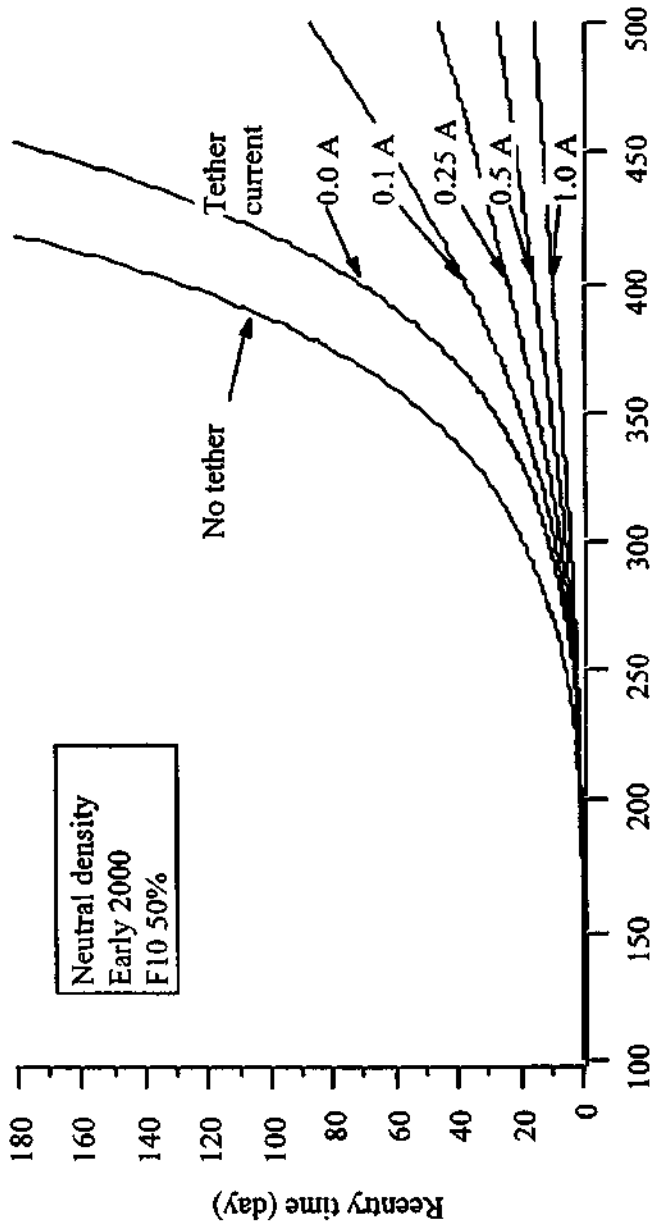

Enrico Lorenzini, SAO, NASA ProSEDS Mission (July 1997), NASA/MSFC Grant NAG8-1303

FIG. 1c

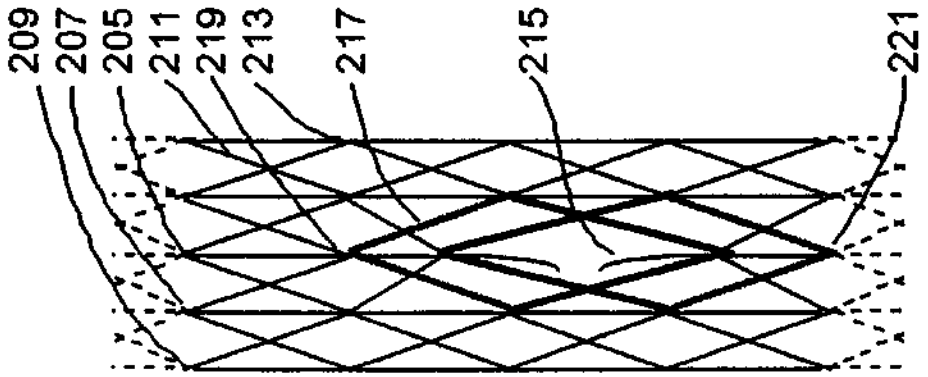

FIG. 2c

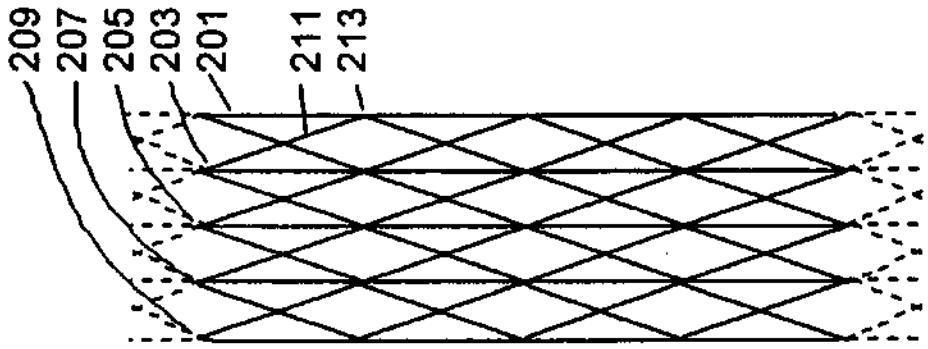

FIG. 2b

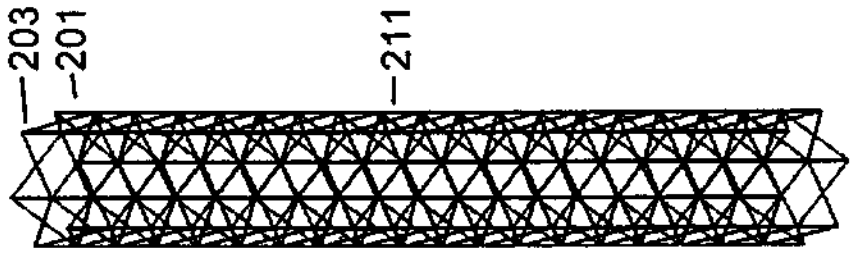

FIG. 2a

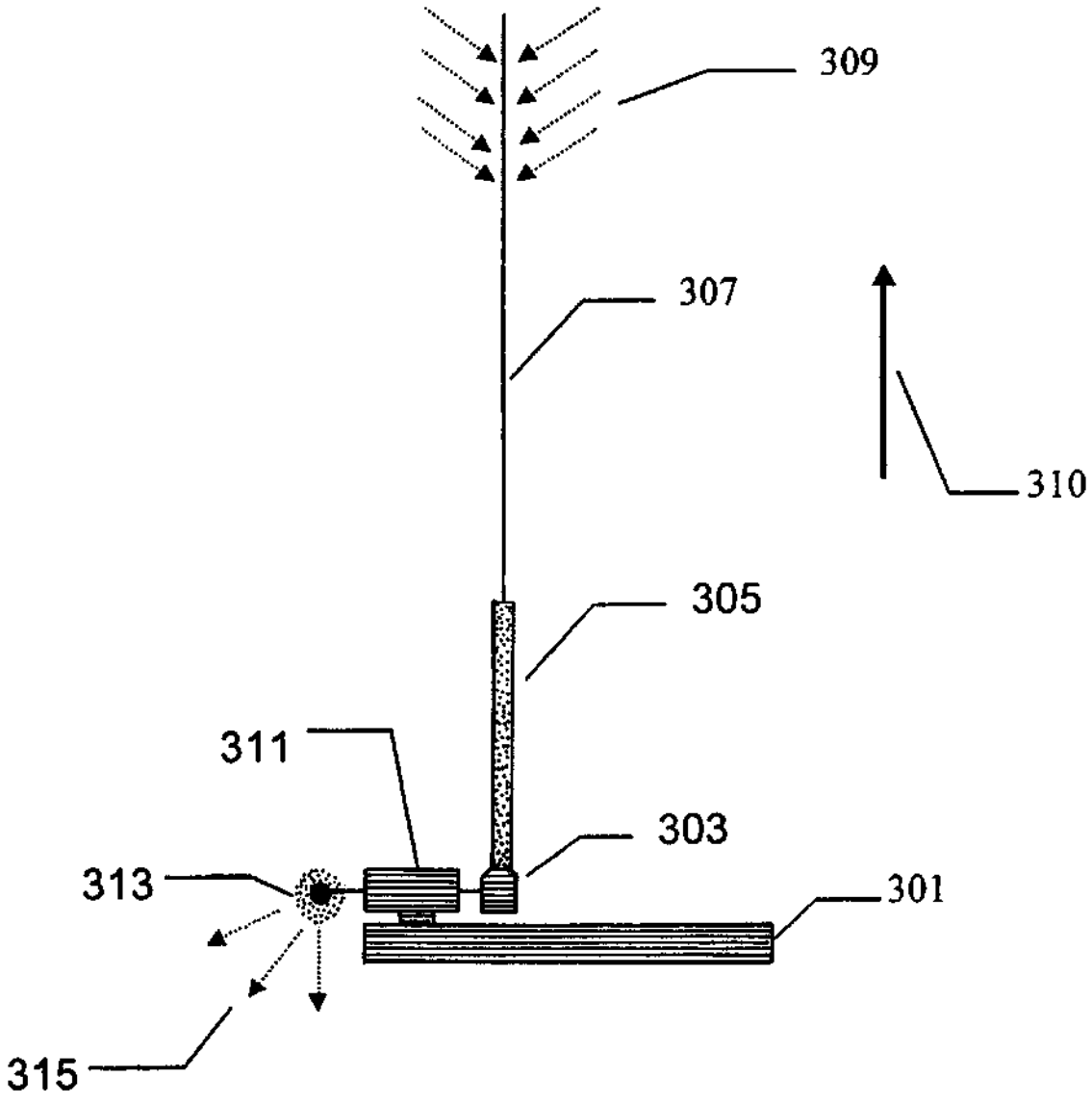

FIG. 3

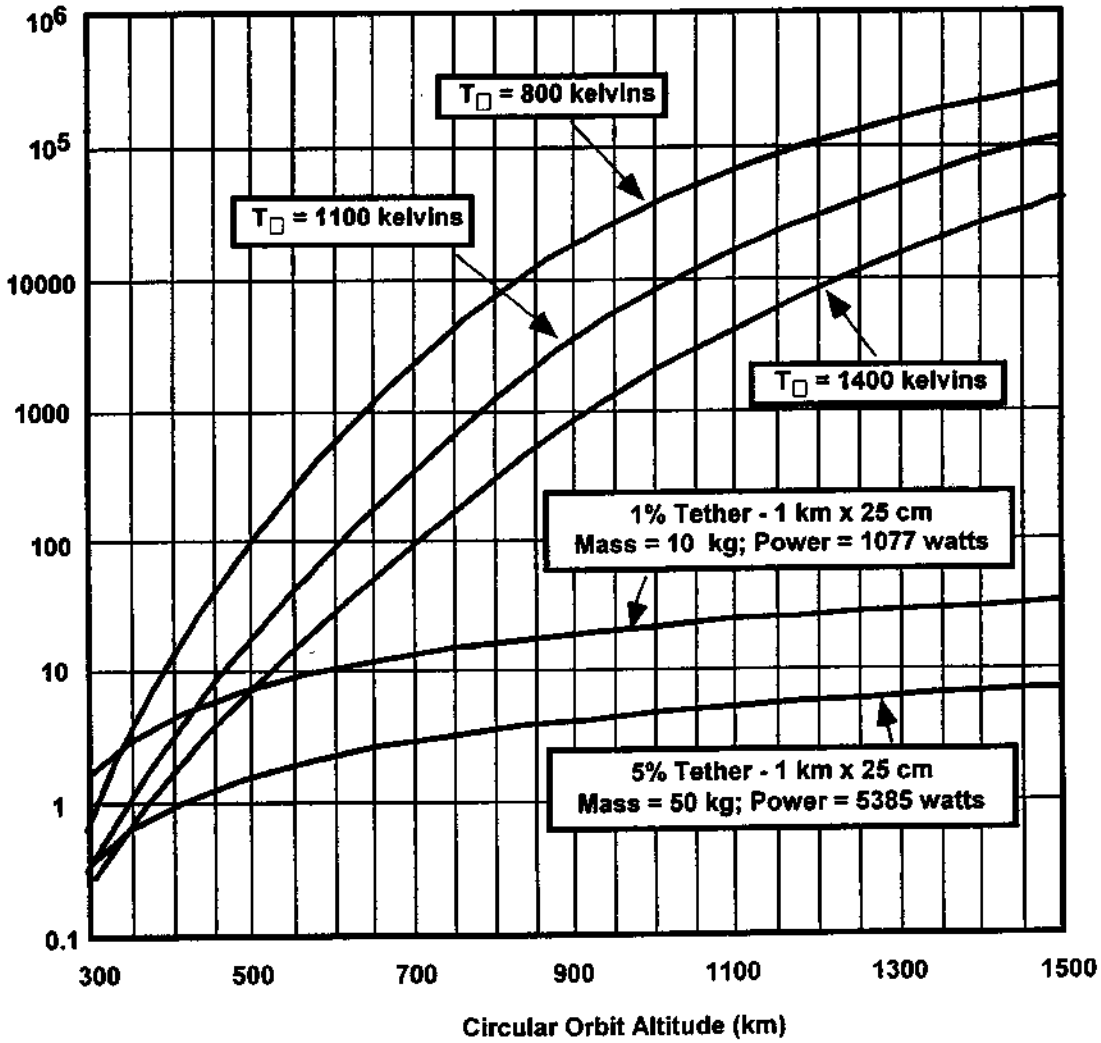

Area-Time Product for Mean and Extremes of Exospheric Temperature

(m = 1000 kg, Cd = 2.0 ; 1% Tether, 1 km x 25 cm; power = 1077 watts)

(5% Tether, 1 km x 25 cm; power =5385 watts)

FIG. 4

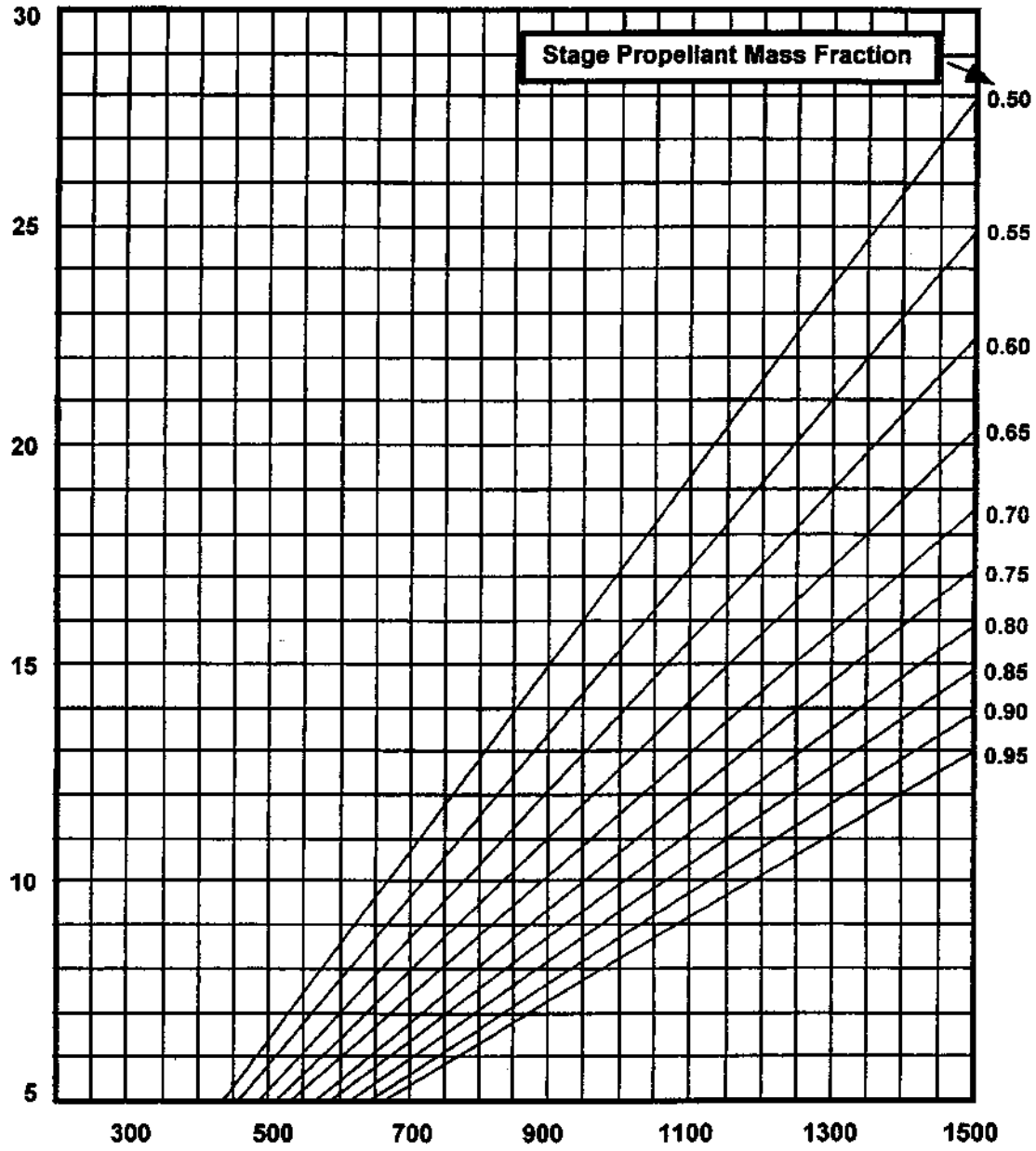

Conventional Solid Rocket Motor System

Percent Increase in Orbital Mass vs. Altitude and I' (Isp = 288 sec)

FIG. 5

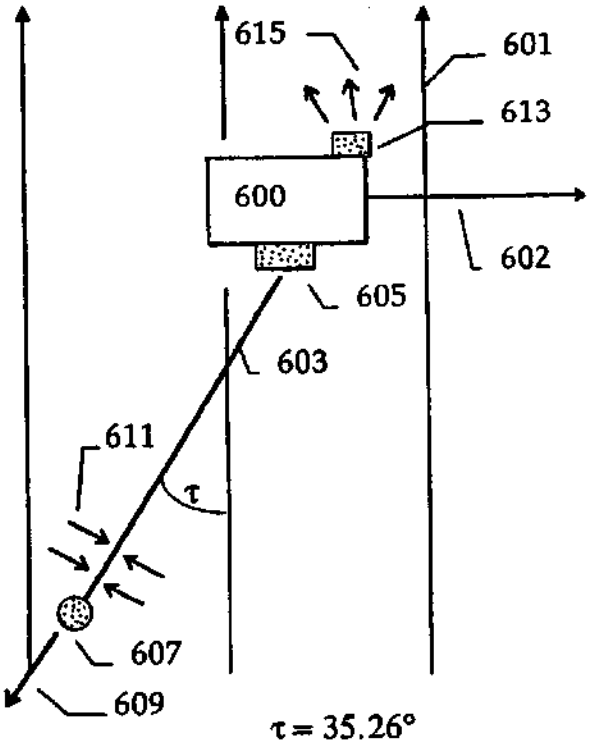
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τ
607
609
τ = 35.26°

FIG. 6

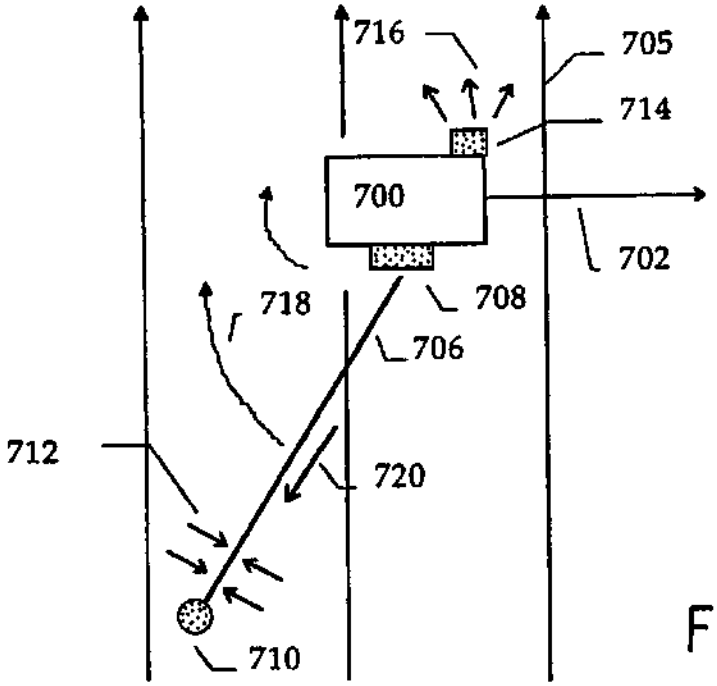
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FIG. 7

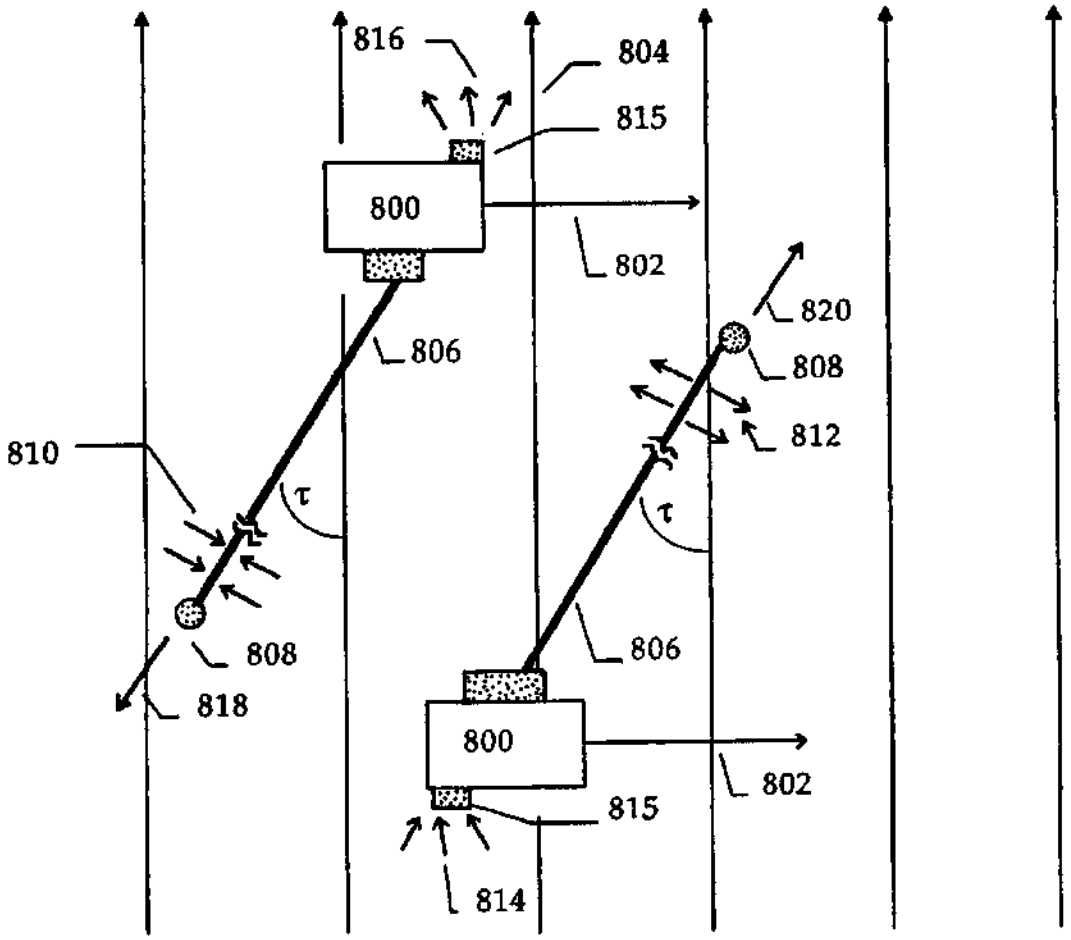
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FIG.8

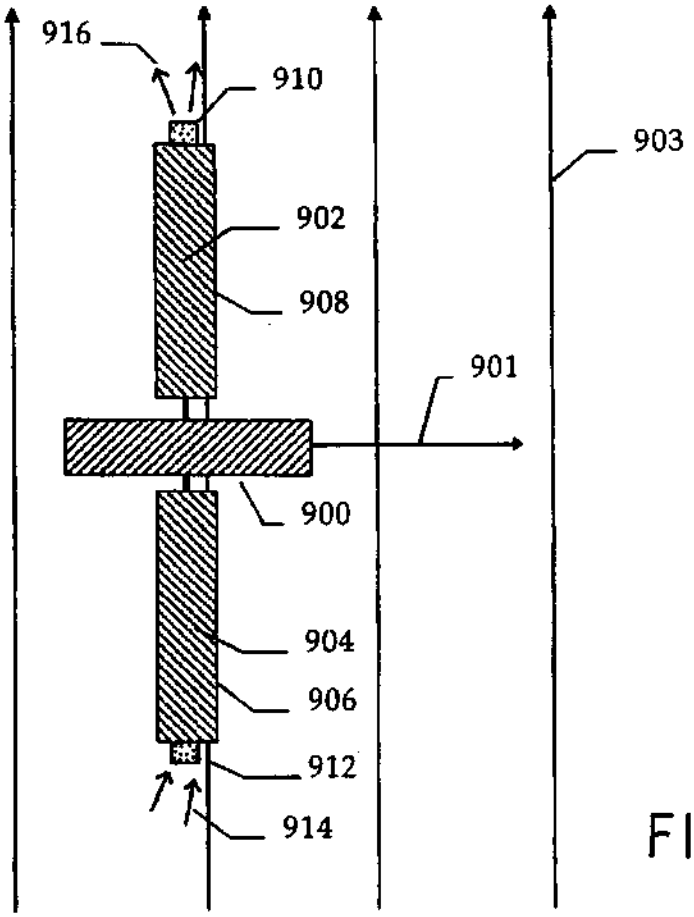
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FIG. 9

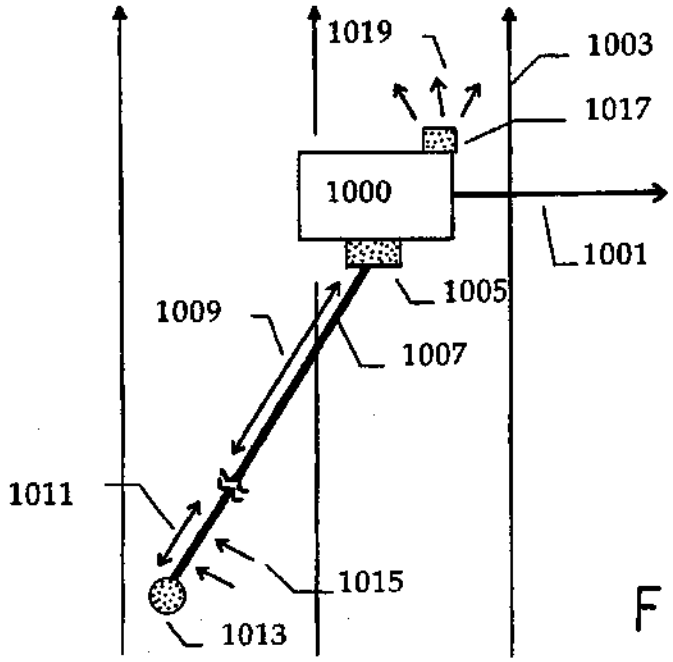
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1013

FIG. 10

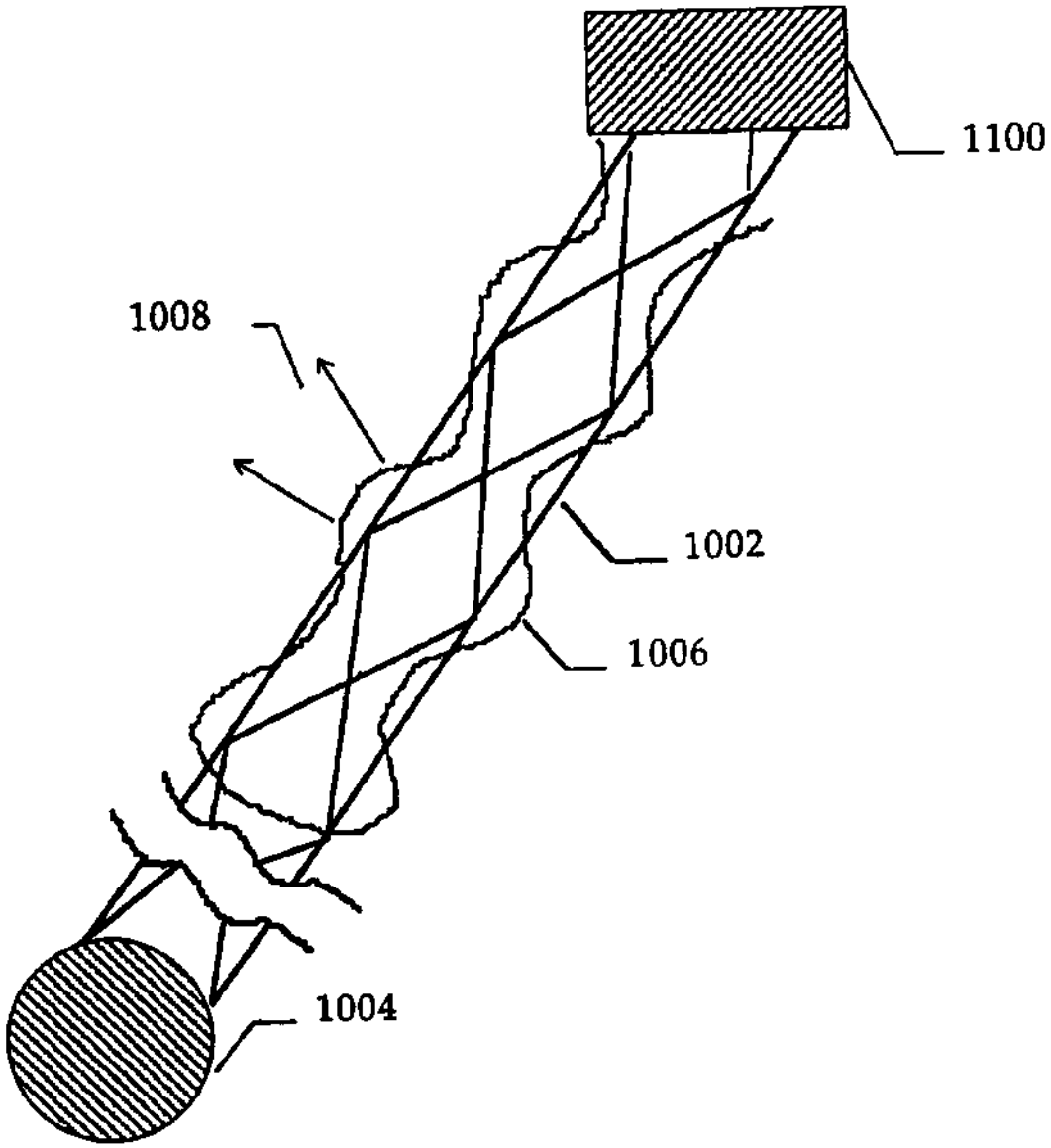

FIG. 11

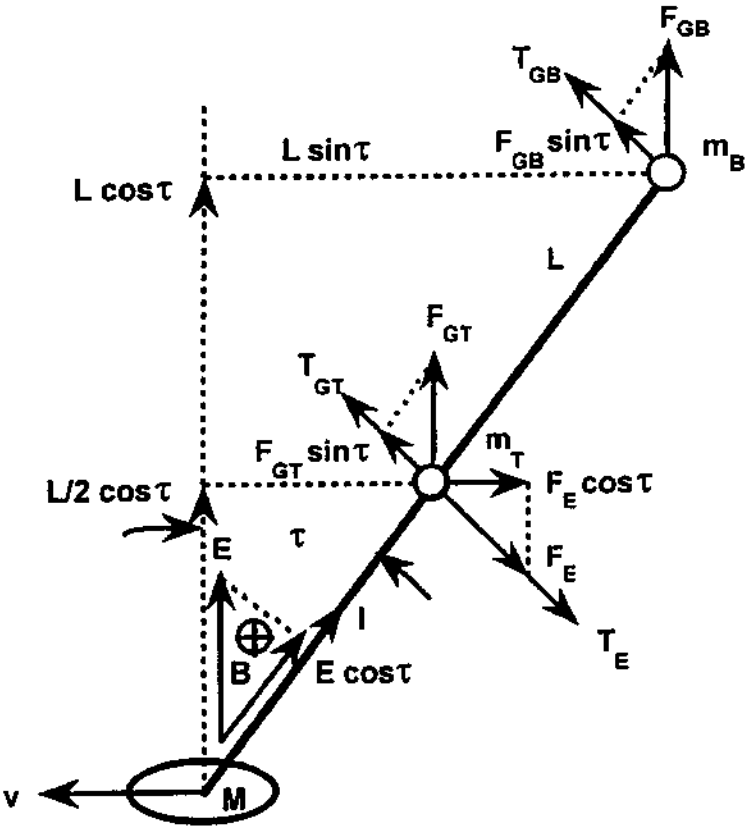

FORCES AND TORQUES ON AN UPWARD DEPLOYED CONDUCTING TETHER DUE TO THE MOTION OF THE HOST SPACECRAFT THROUGH THE MAGNETIC FIELD OF THE EARTH.

FIG. 12

ELECTRODYNAMIC TETHER AND METHOD OF USE

TECHNICAL FIELD

This invention relates generally to apparatus and methods useful for changing the state vector of a space object when the space object is moving relative to a magnetic field. More specifically, the present invention relates to an apparatus and method of using a conducting tether to produce an electrodynamic force to deorbit a satellite from its orbit around a celestial body, such as the Earth, which has an associated magnetic field.

RESERVATION OF RIGHTS

This application is subject to certain rights of the U.S. government as a result of contracts between the U.S. government and the inventors.

BACKGROUND ART

The present invention has its principal utility in outer space, primarily for deorbiting satellites at the end of their useful life to mitigate the harm and reduce the liability created by the proliferation of space debris. In order to obtain a better understanding of the present invention it is helpful to understand the prior art of space tethers, especially tether dynamics and tether electrodynamics. The present invention may be more readily understood through a review of the experimental prior art and a mathematical analysis of electrodynamic space tethers.

Prior Art Tethers:

A tether was originally a rope or chain used to fasten an animal so that it grazed only within certain limits. Tethers have been used for decades in space to attach astronauts to their spacecraft.

In 1974 Professor Guiseppe Colombo, holder of the Galileo chair of astronomy at the University of Padua in Italy, proposed using a long tether to support a satellite from an orbiting platform. U.S. Pat. No. 4,097,010, which issued to Professor Colombo and Mario Grossi on Jun. 27, 1978, teaches a satellite connected by means of a long tether to a powered spacecraft. Colombo actively pursued the design of a tethered satellite system.

Several NASA experiments, such as the two Small Expendable Deployer System (SEDS 1 & 2) experiments and the Plasma Motor Generator (PMG) experiment used tethers in space. SEDS used a nonconducting tether. The PMG used a 500-meter conducting tether. The Tethered Satellite System flights in 1992 and 1996 (TSS-1 & 1R) used a 20,000-meter conducting tether.

On the TSS-1 mission the tether deployed only 260 meters (853 feet) before the deployer failed. On the TSS-1R the tether was deployed 19,500 meters. In the SEDS-2 flight, a 0.8-mm diameter, 20,000-meter long braided single-line tether was deployed to study tether dynamics and lifetime. Orbital debris or a meteoroid severed this tether in less than four days.

In the TSS-1R flight, the conducting single-line tether was severed after five hours of deployment. This failure was caused by an electric arc produced by the 3,500 volts of electric potential generated by the conductive tether's movement through the Earth's magnetic field.

The Tether Physics and Survivability (TiPS) satellite consists of two end masses connected by a 4,000-meter long non-conducting tether. This satellite was deployed on Jun. 20, 1996 at an altitude of 1,022 kilometers (552 nautical miles). Its tether is an outer layer of Spectra™ 1000 braid

over a core of acrylic yarn. The yarn will "puff" its outer braid to two millimeters to "give it a larger cross section to improve its resistance to debris and small micrometeoroids", according to the National Reconnaissance Office (NRO), which is a sponsor of the TiPS mission. As of Jun. 21, 1997 the TiPS tether had survived one year.

References:

1. Joseph A. Carroll, "SEDS Deployer Design and Flight Performance", paper WSEDSA-1 at the 4th International Conference on Tethers in Space, Washington, D.C., April 1995.
2. James E. McCoy, et. al. "Plasma Motor-Generator (PMG) Flight Experiment Results", pp.57–84, Proceedings of the 4th International conference on Tethers in Space, Washington, D.C., April 1995.
3. W. John Raitt, et. al. "The NASA.ASI-TSS-1 Mission, Summary of Results and Reflight Plans, pp. 107–118, Proceedings of the 4th International conference on Tethers in Space, Washington, D.C., April 1995.
4. Joseph C. Anselmo, "NRO Orbiting Spacecraft Studies Tether Survivability", Aviation Week, page 24, Jul. 1, 1996.

These experiments all used single line tethers.

The following reference is illustrative of the current state of the art in space tethers: Paul A. Penzo and Paul W. Ammann. Tethers in Space Handbook—Second Edition. NASA Office of Space Flight, NASA Headquarters, Washington, D.C. 20546. See also the hundreds of references in the 33 page bibliography at the end of the handbook.

The "Hoytether"™, an Improved, High-Reliability Tether:

In 1991, one of the present inventors, Robert Hoyt, invented a lightweight net-like structure that provides many redundant load-bearing paths. A number of primary load bearing lines running the length of the structure are connected periodically by diagonal secondary lines. The disclosed embodiment of this invention has the secondary lines firmly connected by knots to the primary lines. The secondary lines are connected only to the primary lines. At either end of the disclosed structure, a support ring enforces the cylindrical spacing between the primary lines. The secondary lines are designed with a small amount of slack. These secondary lines are only put under load if a primary line fails. This specific tether structure was disclosed to the public in 1992 (Forward, R. L., "Failsafe Multistrand Tether Structures for Space Propulsion", AIAA paper 92–3214, 28th Joint Propulsion Conference, Nashville, Tenn., 1992 (hereinafter "1992 Hoytether structure"). This structure was named a "Hoytether". The term "Hoytether" is used throughout the remainder of this specification for this type of tether structure.

The present invention uses an improved Hoytether, which was invented by the same inventors as the present invention. This improved Hoytether is the subject of a copending PCT application. The Hoytether is discussed briefly in this specification to aid understanding of the present invention.

The 1992 Hoytether design teaches that the normally slack secondary lines have half the cross-section (0.707 the diameter) of the primary lines. There are twice as many secondary lines as primary lines, thus the mass of the secondary lines is equal to the mass of the primary lines. In an undamaged Hoytether, the primary lines carry the entire load, while none of the secondary lines are under load.

While the survival probability of a single-line tether decreases exponentially with time, the Hoytether can maintain a high, i.e. greater than 99 percent, survival probability

for periods of months or years (forward and Hoyt, "Failsafe Multiline Hoythther Lifetimes", Paper AIAA 95–2890, 31st Joint Propulsion Conference, July 1995).

References:

1. Robert L. Forward, Failsafe Multistrand Tethers for Space Propulsion, Forward Unlimited, P.O. Box 2783, Malibu, Calif. 90265, July 1992, Final Report on NASA Contract NAS8-39318 SBIR 91-1 Phase I.
2. Robert L. Forward and Robert P. Hoyt, Failsafe Multistrand Tether SEDS Technology Demonstration, Final Report on NAS8-40545 with NASA/MSFC (Jun. 14, 1995).
3. Robert L. Forward and Robert P. Hoyt, "High Strength-to-Weight Tapered Hoytether for LEO to GEO Payload Transfer" Final Report on contract number NAS8-40690 with NASA/MSFC (Jul. 10, 1996).

The Hoytether is essentially a tri-axial net structure, with 'primary' lines running along the length of the tether and two sets of 'secondary' lines connecting these primaries diagonally. They can be made by hand and connected with knots as is taught by the 1992 Hoytether structure. Because knotted connections severely limit the strength of a structure, it is desirable to use a knotless fabrication technique to achieve interconnections that have strengths approaching the limits of the constituent material. As these tethers may be many kilometers long; fast and inexpensive mechanical methods are required for their practical fabrication.

Hoytethers may be made by mechanical braiding, i.e. three-dimensional braiding, such as 3-D rotation braiding using braiding machines such as those developed by the Herzog Company in Germany (August Herzog Maschinenfabrik GmbH & Co., Postfach 2260.26012, Oldenburg, Germany. The specialized loom developed by the Nichimo Company of Japan (Nichimo Company Ltd., 2-6-2 Ohtemachi, Chiyoda-Ku, Tokyo, Japan) is used to produce "Ultracross" knotless fishing nets in which the individual strands are braided as a 4-braid line, and the strands are interbraided where they cross. This produces netting that has slipless interconnections that are very strong, approaching the maximum capability of the fiber. Such a loom could, with some modifications, produce the present invention's structure. Only two such machines exist, one in Japan, the other in Washington State. Unfortunately neither can work with the small line diameters needed to practice the preferred embodiment of the present invention. See generally, Ko, F. K., "Braiding", in *Engineered Materials Handbook, Vol.* 1., *Composites*. ASM International, Metals Park, Ohio, 1957. Pp. 519–528.

The most common 3-dimensional braiding machines are 4-step braiders based upon the designs of Maistre (German Patent P230-16986, issued 1973) and Forentine (U.S. Pat. No. 4,312,261, issued 1982). Braiding is accomplished by using pneumatics or solenoids to push the parts of the braiding machine to the proper positions. This is a slow process and making a Hoytether kilometers long with these machines would be very time consuming and expensive. The composites division of Albany International (Albany International Research Company, 777 West Street, Mansfield, Mass.) also produces a 3-D braiding machine. This machine uses modular braiding components that are assembled breadboard fashion on a large wall.

Although braiding is the preferred technique, alternate fabrication methods such as Raschel knitting and crocheting can be used successfully. Multikilometer long Hoyththers are presently being produced for the inventors by the vendors Culzean Fabrics and Flemings Textiles using an electronically controlled crochet machine produced by Comez in Italy.

Space Tether Systems:

The prior art teaches the use of tethers in space applications. U.S. Pat. No. 5,163,641, issued on Apr. 9, 1990 to Yasaka, teaches the use of a powered spacecraft connected by a tether to a satellite. This tether is disconnected to change the state vector of the satellite. The state of the art of energy and momentum transfer using space tethers is discussed in Ivan Beckey's article "Tethering, a new Technique for Payload Deployment", Aerospace America, March 1997, at pages 36–40. Beckey concludes, "Tethers can perform the same functions as propulsive upper stages of direct payload injection, but at lower weight and cost per pound." U.S. Pat. No. 4,923,151, issued Mar. 1, 1988 to Roberts, Wilknson and Webster, teaches a tether power generator for earth orbiting satellites. U.S. Pat. No. 4,580,747, issued Mar. 15, 1983 to Pearson, teaches use of a long tether extending downward into the atmosphere from a satellite. The state vector of the satellite is changed by forces acting on a lifting body connected to the end of the tether. U.S. Pat. No. 4,824,051, issued Jan. 12, 1987 to Engelking, teaches passing an electric current through a conductive tether attached to a satellite to provide propulsive force to alter the orbit of the satellite. U.S. Pat. No. 5,082,211, issued Jan. 21, 1992 to Werka, teaches use of a tether to deorbit space debris. U.S. Pat. No. 4,727,373, issued Mar. 31, 1986 to Hoover, teaches an orbiting stereo imaging radar system having two spacecraft in synchronous parallel orbits connected by a tether.

Tether Dynamics:

In order to understand the forces that cause a tethered satellite to move upward and away from an orbiting satellite, for example, it is first necessary to explain briefly how a satellite remains in orbit. An orbiting satellite is acted on by the force of gravity which pulls it toward Earth, and by a centrifugal force, which pushes it away from Earth. The centrifugal force" (actually inertia) results from the motion of the satellite around its circular orbit. This is the same force that one can experience by swinging a ball around on the end of a string. A satellite is maintained in its orbit when it travels at the natural speed for its altitude and, as a result, the centrifugal force is equal to the gravitational force.

At the typical orbital altitude of 250 kilometers for a low-Earth orbit satellite, for example, a speed of approximately 7.6-km per second is required to create sufficient centrifugal force to balance gravitational attraction on the satellite. If the altitude is changed, the two opposing forces will no longer be in balance unless the satellite also changes its speed. A higher orbital altitude requires a slightly lower speed so the satellite will take longer to complete an orbit. Because of this, if two free-flying satellites are in orbits at different altitudes, the lower satellite will circle the Earth in less time than the satellite in the higher orbit.

If two satellites, at different altitudes, are connected to each other by a tether, they are forced to travel around their orbits together—in the same period of time, which is longer than the natural period of the lower satellite but shorter than that of the upper satellite. The lower satellite will, therefore, slow down below the natural speed for its orbit and will tend to fall to a lower orbit because the centrifugal force will now be less than the gravitational attraction of the Earth. An upward force in the tether that makes up the difference between centrifugal and gravitational forces holds it in place, however.

Correspondingly, the upper satellite will be accelerated above its natural orbiting speed (increasing its centrifugal force above the gravitational attraction) and will tend to move to a higher orbit. It, too, is held in place by an additional force (downward) in the tether. In other words,

the net force downward on the lower satellite is balanced, through the tether, by the net force upward on the upper satellite. The effect of unbalanced forces on the two satellites is, therefore, to create tension in the tether. During the TSS-1 & 1R experiments, the inertia of the tethered satellite causes the satellite to rise above the orbiter as the tether is reeled out. Very close to the orbiter, there is little difference in the two orbits, and the tension force is insufficient to overcome friction in the deployer mechanism; therefore, until the satellite reaches a separation of approximately 1000-meters, the tension is augmented by small tether-aligned thrusters on the satellite. Beyond this point, the tension in the tether is the only force required.

By experimenting with a ball hung on a piece of elastic cord (a paddleball, for example) it is possible to simulate all the different types of oscillations that are possible on a space-based tether system. The elastic cord, representing the tether, may compress and stretch, causing the ball to bounce up and down (longitudinal oscillation). It also may move in a circular (skip-rope) motion or may develop wave-like motions (transverse oscillations). Even if the string itself remains straight, it is possible to get the ball swinging back and forth about its attachment point on the paddle like a child on a swing rope (pendulous motion).

Each type of motion occurs with a particular frequency, which depends on the length and tension of the tether. When the frequencies are different, the motions do not interact; however, at some tether lengths, the frequencies of two or more types of oscillation can become very close. At this point, energy can be transferred from one type of motion to another, a phenomenon known as resonance. For instance, the transverse oscillations in the tether may cause the satellite to swing back and forth in pendulous motion.

Many different factors may cause oscillations; the movements of the satellite or Shuttle are but two of these. For an electrodynamic tether, the skip-rope and pendulous oscillations are of particular interest. If a current is passed through a tether, the current will interact with Earth's magnetic field, resulting in a force that may produce skip-rope and pendulous oscillations. Because it is necessary to maintain control of the satellite, much study has gone into identifying the different types of possible motions and the methods used to control them.

One way to control the magnitude of those motions that cause a change in tension or transverse motion at the end of the tether is to have an end mass connected to the Hoytether that maintains a controlled tension on the tether, working much like a spring-loaded 'dog leash'. This may be as simple as a coiled spring, or as complex as an active control system that measures the tension and transverse forces on the tether and adjusts the applied tension according to a local or remotely operating algorithm.

Electrodynamic Effects of Conductive Tethers:

Electric potential is generated across a conductive tether by its motion through the Earth's magnetic field. Electromagnetic forces acting on a conductive tether in orbit can make the tether system behave like an electric motor or generator, thereby exerting a useful force to alter the state vector of the tether and any mass attached to it.

Electrodynamic tether propulsion is unlike most other types of space propulsion in use or being developed for space application today—there is no hot gas expelled to provide thrust. Instead, the environment of near-Earth space is being utilized to propel a spacecraft or upper stage via electrodynamic interactions.

A charged particle moving in a magnetic field experiences a force that is perpendicular to its direction of motion and the direction of the field. When a current flows through a long, conducting tether the electrons flowing through the tether experience this force due to the fact that they are moving along the wire in the presence of Earth's magnetic field. This force is transferred to the tether and to whatever the tether is attached (like a spacecraft, satellite, space station or upper stage). It can be an orbit-raising thrust force or orbit-lowering drag force, depending upon the direction of current flow. Operation in one mode allows boost from LEO to higher orbit while reversing the current flow provides negative thrust for deboost. The principle is much the same for an electric motor; reverse its operation and it acts as a generator. The current passing through the tether is returned through the ionosphere to complete the current loop with collection and emission occurring on opposite ends of the tether.

The PMG experiment demonstrated that a conducting tether can be used as both a motor and a generator. The TSS experiments, especially TSS-1R showed that very large voltages (about 3500 volts) can be generated by a sufficiently long tether.

Uses of an electrodynamic tether as an orbit raising and lower propulsion system has many advantages over competing systems:

a. It is nearly propellantless. Most other systems expel hot gases and require extensive resupply. To emit current, the electrodynamic tether propulsion system may use plasma contactors developed as a part of the International Space Station Program. These contactors consume less than 20 kg of xenon gas per year with a 50% duty cycle. The electrodynamic tether propulsion system can also use field emitter arrays, which emit electrons without the use of any gas.

b. It can change both altitude and inclination. The Earth's magnetic field is non-uniform and can therefore provide both in- and out-of-plane forces for inclination changes as well as altitude changes. This is of particular interest to payloads requiring polar orbits in that they can be launched on a small launch vehicle into a lower inclination orbit and have it raised in space by the proper phasing of current through the tether.

A demonstration of the propulsive capabilities of electrodynamic tethers was recently approved for a flight test in 1999. The Propulsive SEDS or ProSEDS mission, will fly as a secondary payload on a Delta II launch vehicle and deploy a 5-km conducting tether using the existing SEDS deployer concept. The ProSEDS experiment will be followed by the Electrodynamic Tether Upper Stage (EDTUS) experiment that will demonstrated the use of electrodynamic forces to change both the altitude and inclination of the experimental spacecraft. FIGS. 1B and 1C show the calculated electrodynamic thrust at several inclinations and the reentry time sensitivity of the ProSEDS tether, respectively.

One application for long-life conducting electrodynamic tethers is as a "Terminator Tether™" for removing from orbit unwanted Earth orbiting spacecraft at the end of their useful lives. When the mission of the satellite is completed, the Terminator Tether™, weighing a small fraction of the mass of the satellite, would be deployed. The electrodynamic interaction of the conducting tether with the Earth's magnetic field will induce current flow in the tether conductor. The resulting energy loss from the heat generated by the current flowing through the ohmic resistance in the conducting tether will remove energy from the spacecraft, eventually causing it to deorbit, thus reducing the amount of orbital space debris that must be coped with in the future.

In the following analysis, it is shown that the amount of energy loss generated by an electrodynamic tether is essen-

tially independent of its length or area, and instead is primarily proportional to the tether mass and the physical properties of the conductor metal chosen. In the typical example calculated, a 1000-kg spacecraft can be deorbited from a 1000-km high Earth orbit by a 10-kg mass tether in a month, while a 1-kg tether can deorbit a 1000-kg spacecraft in less than a year.

To the knowledge of the inventors, Joseph P. Loftus of NASA/JSC first proposed the general concept of using an electrodynamic tether to deorbit spent satellites. (Joseph P. Loftus <JLoftus@ems.jsc.nasa.gov>, personal communication via email to Robert Forward, Monday Jun. 10, 1996 15:50:10.) In order to show that the Loftus deorbit concept was not obvious to those skilled in the art of electrodynamic tethers, Forward contacted the leading expert, Joseph Carroll, of Chula Vista, Calif., who built and participated in the flight test of the PMG. After being told of the Loftus concept in a telephone conversation, his reply in an Email message dated Aug. 5, 1996, was "such a system would be feasible . . . by it is still not obvious to me that it would be useful . . . "

Loftus was considering the use of electrodynamic drag from a conducting tether to achieve this goal of bringing the unwanted spacecraft down from its high orbit (where atmospheric drag is negligible) to a 200-km orbit, where atmospheric drag would rapidly finish off the task of removing the unwanted spacecraft from orbit. The tether Loftus was considering was a single-line, conducting tether, typically 1-mm in diameter, 1-km long, and, if made of aluminum, 2-kg in mass. He would include means at the ends of the tether to contact the ambient space plasma around the Earth to complete the current loop.

Unfortunately it is probable that space impactors would sever the 1-mm diameter, 1-km long single-line tether proposed by loftus within a 1/e lifetime of four months. This would produce orbital debris rather than removing it. The motivation for this work is the NASA Safety Standard NSS 1740.14 "(Guidelines and Assessment Procedures for Limiting Orbital Debris." The relevant portion of the Standard starts on page 6-3: General Policy Objective-Postmission Disposal of Space Structures. Item 6-1: "Disposal for final mission orbits passing through LEO: A spacecraft or upper stage with perigee altitude below 2000 km in its final orbit will be disposed of by one of three methods." The method of interest is the atmospheric reentry option, Option a: "Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause the spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit."

The NASA standard applies only to NASA spacecraft and even then only to completely new spacecraft designs. New versions of existing designs are to make a "best effort" to meet the standard, but will not be required to change their design to do so. The Department of Defense has adopted the NASA standard with the same provisos. An Interagency Group report has recommended that the NASA standard be taken as a starting point for a national standard. It is NASA's recommendation to the Interagency Group that the safety requirement be phased in only as spacefaring nations reach consensus internationally, which is being done through the International Debris Coordination Working Group whose members are Russia, China, Japan, ESA, UK, India, France, Italy, and the US.

Thus, although the NASA Safety Standard in its present form is not the "Law", the existence of the standard means that some time in the future a similar requirement may be imposed on all spacecraft. This could result in major growth in future space tether business, with a sale to every non-geostationary spacecraft being "mandated" by government safety regulations, somewhat as the sale of seat belts and airbags for every car are mandated.

In fact, three of the companies planning to set up "constellations" of low to medium orbit communications: Teledesic, Iridium and Odessey have committed their companies to abide by the spirit of NASA Safety Standard 1740.14 by using one means or another to deorbit their spacecraft before they reach end of life.

Problems with Prior Art Tethers:

All electrodynamic tether designs proposed by the prior art teach that the tether should be operated at a right angle to the magnetic field through which the tether is moving. This is a problem because the electrodynamic force acting on the tether causes the tether to align itself with the magnetic field force lines. To overcome this problem the prior art teaches the use of a large ballast mass attached to the end of the tether and/or use of a very long (tens to hundreds of kilometers) tether. The large ballast mass is expensive to take to orbit because it replaces useful payload. The long tether sweeps a larger Area-Time-Product during its useful life and thus is more likely to impact other space objects, either debris or another spacecraft.

Another problem common to all proposed prior art tethers is tether instability. If the tether produces a large electrodynamic drag force, which is desirable because a large drag force will cause the satellite to deorbit quickly, then the tether will be dynamically unstable. This instability can cause the tether to lose its effectiveness, act uncontrollably and even wrap around the satellite or otherwise malfunction. Experts skilled in the art of tether design have opined that this dynamic instability is inherently unavoidable in any electrodynamic tether system. The prior art solution, such as that presently being used in the ProSEDS experiment, has been to use a large ballast mass to increase the stabilizing gravity-gradient force and/or to limit the electrodynamic drag of the tether to less that the maximum that could be produced. In the ProSEDS experiment, the conducting electrodynamic tether is five kilometers long. To insure stability, it will be augmented by a 20–35 kilometer long non-conducting tether, which to further have stability will have a 40 kilogram ballast end mass.

Yet another problem of all proposed prior art electrodynamic tether systems is how to radiate away the energy produced by the tether's operation. A satellite moving at an orbital velocity of 18,000 miles per hour has a kinetic energy of over 10,000 calories per gram. To put this amount of energy in an understandable perspective, it may be noted that when nitroglycerine explodes it produces about 1,500 calories per gram. Prior art designs of electrodynamic drag tethers teach the use of the electrical energy generated by the tether to charge batteries or operate electronics, with the excess energy being converted into heat by a resistive load. This excess heat must be radiated to the space environment or it will melt the resistive load. Thus the resistive load, and/or its associated radiator structures, must be massive and replace useful payload.

DISCLOSURE OF THE INVENTION

The present invention comprises an electrodynamic tether structure and a method of use. The principal industrial utility of the present invention is to deorbit satellites in Earth orbit

at the end of their useful life. This embodiment of the present invention is sometimes referred to in this specification as a "Terminator Tether™" because it terminates the orbital lifetime of the host spacecraft. The structure of the tether taught by the present invention is a short, wide, interconnected-multiwire (compared to the long single wires of the prior art) conductive Hoytether whose area maximizes electrodynamic drag while simultaneously minimizing the Area-Time-Product swept by the tether during its operating life. The preferred tether length is two to five kilometers. The preferred tether mass is one to five percent (1%–5%) of the spacecraft mass. The method of operation comprises orienting the tether structure at a 35.26-degree trailing angle to the local vertical to maximize electrodynamic force on the tether while avoiding tether instability and allowing use of a small tether end mass.

The present invention also teaches that the satellite-tether system may be rotated around its common center of mass to centrifugally produce tension force in the tether structure to oppose forces causing tether instability. The angle of the conductive tether structure of the present invention with respect to the velocity vector of the host spacecraft may be controlled by the method of the present invention so it interacts with the encountered magnetic field to induce a maximum current flow in the tether. This produces maximum electrodynamic drag. All or a portion of this electric power may be stored and then controllably applied to the conductive tether to produce an induced electrodynamic force. This induced electrodynamic force may by used to enhance the drag force, to rotate the tether-satellite system and/or to provide satellite propulsion, i.e. to change the state vector of the satellite for any useful purpose, e.g. to avoid collision or to change the host spacecraft's orbit to an orbit more favorable for more rapid deorbiting.

The present invention also teaches a tether structure that also functions as a thermal radiator and/or plasma contactor. An embodiment of the present invention using conducting elements of the satellite, e.g. the solar arrays, as electrodynamic tether structures is also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood with reference to the following drawings:

FIG. **1***a* is a graph comparing the survival probability of a single line tether as taught by the prior art to the Hoytether used by the present invention.

FIG. **1***b* is a graph showing the level of electrodynamic thrust for a 10 kilometer, 10 kilowatt tether at various altitudes and inclinations.

FIG. **1***c* is a graph showing reentry time sensitivity of a five kilometer ProSEDS tether for several conditions of current flow in the electrodynamic tether.

FIGS. **2***a*, **2***b* and **2***c* show the Hoytether structure used by the preferred embodiment of the present invention.

FIG. **2***d* shows the Hoytape structure used by the preferred embodiment of the present invention.

FIG. **3** is a block electrical diagram of an electrodynamic tether system.

FIG. **4** is a graph showing a graph of the Area-Time product for three separate levels of exospheric temperature (for neutral drag calculations) and for two separate assumptions regarding tether mass and power drawn from the ambient plasma (for the Terminator Tether™ calculations).

FIG. **5** is the percent additional mass required in orbit to drop the perigee of a circular orbit at altitude, at, to a value of 200 kilometers using standard chemical rocket as taught by the prior art for deorbiting unwanted spacecraft.

FIG. **6** is a deorbit tether system shown operating with its electrodynamic tether at a trailing 35.26-degree angle to the encountered magnetic field, as is taught by the preferred embodiment of the present invention.

FIG. **7** shows an embodiment of the present invention in which the electrodynamic tether—satellite system is rotated about its center of mass to avoid tether instability.

FIG. **8** shows an embodiment of the present invention wherein the tether is powered to provide induced electrodynamic force.

FIG. **9** shows an embodiment of the present invention wherein the solar power system structure of the satellite is used as an electrodynamic tether.

FIG. **10** shows the use of a portion of the tether structure as a thermal radiator and plasma contactor.

FIG. **11** shows the braiding of an ohmic resistive load into the tether structure.

FIG. **12** is a force diagram showing the forces and torques on an upward deployed conducting tether due to the motion of the host spacecraft through the magnetic field of the Earth.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The principal industrial utility of the present invention is the deorbiting of satellites in Earth orbit, which necessarily can happen only in outer space. Until the present invention is reduced to actual practice by use with satellites in outer space and a body of practical experience is thereby obtained, the present invention can only be constructively reduced to practice, such as by this written specification and its associated drawings, diagrams and graphs and by reference to electric measurements made on conducting tethers in space by the PMG and TSS experiments. The inventors provide herein a detailed discussion of the theory of the present invention to help those skilled in the art of aerospace and tether engineering to understand the present invention and to make and use the best embodiment of the present invention known to the inventors at the time this specification was prepared, without undue experimentation.

Although the present invention is discussed in this specification in its preferred embodiment as a means of deorbiting satellites, it must be emphasized that discussion of this specific use in no way limits the broad scope of the present invention. The present invention can be used to change the direction and speed, i.e. the state vector, of any space object providing that object is in motion relative to any magnetic field. This magnetic field may be that of the Earth or of any other celestial body, for example Jupiter or the sun.

In this specification the material forming the structure of the electrodynamic tether is specified as being a conductor. For example, a metal, such as copper or aluminum wire could be used. Likewise, nonmetallic conductor, such as carbon nanotubes, or a conductive polymer could form the conductive structure of the tether.

FIG. **1***a* shows the survival curve for a Hoytether as used by the present invention vs. the survival curve of a prior art single line tether. The survival probability curve of the Hoytether as a function of time does not conform to the well known "1/e decay" shape of a single-line tether. The Hoytether can maintain a high level of survival probability, about 99 percent, until it nears its 'lifetime'. Its survival probability then drops rapidly to zero. A detailed mathemati-

cal analysis of the difference between Hoytether and single tether survival probabilities is given in Appendix E "Small Impactor Survival Probabilities of Hoytethers" and Appendix F "Large Orbital Debris Survival Probabilities of Hoytethers", both contained in the Final Report of NASA Contract NAS8-40545. The resulting cut probability with time for the Hoytether has a "bingo curve" shapes. In a bingo game, at least five numbers must be called before anyone can win, and usually many numbers have to be called before one of the bingo cards gets five in a row. In the Hoytether at least four cuts must happen at the same level before any failure occurs, and many cuts have to be made before any one of the levels has all four lines cut. The bingo curve has the property that the probability of survival stays very high for periods short compared to the lifetime. The probability of survival is greater than 99% for periods shorter than 10% of the lifetime. This is much better performance than the 1/e curve of a single line tether, where the probability of survival is only 90% at 10% of the 1/e lifetime.

FIG. **1***b* shows the calculated level of electrodynamic thrust, in Newtons, produced by a ten kilowatt, ten kilometer single conductor tether at altitudes between 200 and 1400 kilometers and at orbital inclinations between zero degrees and eighty degrees.

FIG. **1***c* is a graph showing the reentry time sensitivity calculated for a five kilometer ProSEDS single conductor tether at altitudes between 200 and 500 kilometers with current flow in the tether between on flow and one ampere.

FIGS. **1***b* and **1***c* are the work of Enrico Lorenzini of the Smithsonian Astrophysical Observatory from his study "Performance Evaluation of the Electrodynamic Tether Tug", NASA/MSFC Grant NAG8-1303 (Nov. 12, 1966). They show that experts in the field believe that the present invention will have industrial utility, as the current flow of one ampere in FIG. **1***c* decreases the deorbit time for the calculated case from more than 180 days to less than 20 days.

FIG. **2***a* is an isometric drawing showing the generally cylindrical structure of the Hoytether. In FIG. **2***a*, primary lines **201** and **203** are shown connected via secondary lines **211**. In FIG. **2***b*, which is a schematic illustration of the structure shown in FIG. **2***a*, primary lines **201**, **203**, **205**, **207** and **209** are connected, each to their respective adjacent primary lines, by a plurality of secondary lines **221**. These connections, for example as shown at interconnection **213**, are made by knotless, slipless interconnections, such as Soutache braiding of twisted connections.

FIG. **2***c* shows the Hoytether structure of FIG. **2***b* but with a severed primary line **205** at breakpoint **215**. The second level of secondary lines **217**, shown as bold lines in FIG. **2***c*, redistribute the load from the severed primary line **215** at point **217** back to line **215** at points **219** and **221**, above and below the break, respectively.

For the electrodynamic tether, a preferred embodiment would be to unroll the tubular Hoytetherr™ into a flat Hoytape™ as shown in FIG. **2***d*.

FIG. **3** generally shows the arrangement of functional elements of an electrodynamic tether system. Of course such a system must have a means of attachment to the spacecraft, a deployer, the tether itself, some form of space plasma cathode contactor, some form of space plasma anode contactor, a power dissipation system, and a communication and control system. Each of these individual elements are known in some form to those skilled in the art of aerospace engineering. Thus the present inventors do not feel it is necessary to describe them in detail in this specification.

In FIG. **3**, a space object **301**, i.e. a satellite in Earth orbit, or any other space object either natural or man made, is physically connected to the tether system. The tether system comprises a deployer **303** from which a conductive Hoytether **305** having a bare segment **307** extends upward from space object **301**. The positively biased anode end **309** of tether **305** collects electrons from the ionosphere as space object **301** moves in direction **310** across the Earth's magnetic field. These electrons flow through the conductive structure of the Hoytether to the power system interface **311**, where it supplies power to an associated load, not shown. The electrons then flow to the negatively biased cathode **313** where electrons are ejected into the space plasma **315**, thus completing the electric circuit.

In order to allow those skilled in the art to better appreciate the broad scope of the present invention, the inventors will now provide an example using specific tether and system values to compare the Terminator Tether™ to prior art means, ie a rocket, for deorbiting a satellite.

Terminator Tethers™:

When an Earth orbiting conducting space tether moves through the magnetic field of the Earth, an electric field is generated in the tether that is proportional to the velocity of the conductor, the magnetic field strength of the Earth, and the angle between the conducting tether and the magnetic field lines. From data obtained during the various electrodynamic experiments that have been conducted in space to date, such as the PMG, TSS-1, and TSS-1R experiments, a typical value of the generated emf per unit length of tether of E=100–200 Volts/kilometer can be assumed. The electric potential V developed at the ends of a tether of length L is then V=EL. For a tether of length L=10 km, the electric potential developed is V=1000 V. For calibration, the 20-km long TSS-1R tether, at the moment of failure, was developing a potential of 3500 volts, which is 175 volts/km.

The mass of a conducting tether of length L, cross-sectional area A, and densin, d is given by m=dLA. Typical values for the density are d=2700 kg per cubic meter for aluminum and 8900-kg per cubic meter for copper. For a typical aluminum tether of mass m=10 kg and length L=10 km, the cross-sectional area will be A=0.37 mm squared. If this were a solid-wire single-line tether, the diameter of the wire would be D=0.69 mm (21.5 gauge). If this were an 18 line tubular Hoytether, the diameter of the lines in the Hoytether would be D=0.16 mm (34 gauge).

The resistance of a conducting tether of length L and cross-sectional area A is given by R=rL/A, where r is the resistivity of the conductor in nano-ohm-meters (nΩ-m). Typical values for the resistivity are r=27.4nΩ-m for aluminum and 17.0 -nΩ-m for copper. For the m=10 kg aluminum tether of length L=10 km and cross-sectional area A=0.37 mm squared at 20 degrees C, the end-to-end resistance is 750 Ω. This value of resistance is the essentially the same whether the conductor area is concentrated into a single-line tether or divided up into many lines as in a multiline Hoytether.

The current I generated in the conducting tether by the electric potential V between the ends of the tether applied across the tether resistance R is I=V/R. For the 10 kg mass aluminum tether of length L=10 km, electric potential V=EL=1000 volts, and resistance R=750 Ω the current is I=V/R=1.33 Amps. Currents near these values were measured in the TSS-1R experiment at the time of failure. At the time of failure of the TSS-1R tether, none of the plasma contactors on the Space Shuttle or the Italian Satellite were operating. Thus the current was being collected by the conductive surface area of the Space Shuttle and the Italian

Satellite at the two ends of the tether. The Space Shuttle area is quite large, so it was not the limiting factor in current collection. The diameter of the Italian Satellite was 1.6 m, which would give it an effective plasma contact area of about 8 square meters. This shows that, if the plasma contact area of the ends of a conductive space tether can be make large enough, then ampere level currents can be extracted from the ambient space plasma without the use of space plasma contactors.

The power dissipated as ohmic heating in the tether is given by P=IE. For an aluminum tether of mass m=10 kg, resistivity r=27 nΩ-m, and density d=2700 kg/cubic meter, subjected to an electric field of E=100 V/m, the power dissipated in the ohmic losses of the conductor is P=IV=1330 Watts. For a 1 kg mass tether, it would be still a considerable 133 Watts of dissipation.

There will no doubt be additional dissipation of energy in plasma ohmic losses, plasma wave generation, and plasma ion acceleration, but the ohmic losses in the conducting tether alone are sufficient for the task of deorbiting an unwanted spacecraft massing 100 to 1000 times more than the tether.

The decay time of a metric ton spacecraft moving from a 1000 km altitude orbit to a 200 km altitude orbit with an energy difference of dU=3.3GJ, when its energy is being dissipated at a power of P=1330 W by an aluminum tether massing just 10 kg, or 1% the mass of the spacecraft, is about one month. This is a remarkably short time, and indicates that the concept of using a conductive tether to deorbit a spacecraft is indeed feasible. If the aluminum tether massed only 1 kg, or 1/1000th the mass of the spacecraft it was deorbiting, then the decay time would rise to 10 months, still a reasonable value.

In reality, of course, the actual decay time will be longer than this. If the electrodynamic drag force is very large, and becomes larger than the gravity gradient forces pulling on the ends of the tether (which force is proportional to the mass of the tether), then the tether will tend to align itself along the magnetic field lines instead of across them, and the drag force will decrease because of the small angle between the conductor length and the magnetic field lines. The tether will then settle into an angle determined by the balance between these two forces.

Is the Terminator Tether™ theoretically a better means than atmospheric drag or a rocket engine for deorbiting satellites at the end of their useful life?

In the formula for da/dt (change in altitude per change in time), using the assumptions of near-circular spiral trajectories, the Area-Time-Product (Z), the criteria by which NASA judges compliance with Safety Standard 1740.14, is given by:

$$Z = A\int dt = -\frac{m}{C_D}\int \frac{da}{\rho(a)\sqrt{\mu a}},$$

where ρ(a) is simply the density as a function of semi-major axis. Thus, for a static atmosphere, the problem of area-time product is reduced to quadrature. Note that the area-time product depends only on the density profile and the ratio of spacecraft mass to drag-coefficient and is linearly related to that ratio.

The basic altitude-dependence of the atmospheric density, represented here by ρ(a) can be expressed in a low-order power series of ln(density)=f(ln(altitude)), so that it will be possible to develop a representation of the log—log relationship between altitude and density. The three static levels of atmospheric density are modeled as 5th order polynomials in the natural log of the altitude and are representative of well known atmosphere models, for example, Jacchia, L. G., "Thermospheric Temperature, Density, and Composition: New Model," SAO Special Report 375, March 1977. 2. Anon., Marshall Space Flight Center, "Long-Range Statistical Solar Activity Estimation," Atmospheric Sciences Division, 1989.) The values of exospheric temperature are reasonable (about 2-sigma) high and low solar activity values of 1400 and 800 kelvins respectively. The mean value is taken to be 1100 kevins.

FIG. 4 shows a graph of the Area-Time product for three separate levels of exospheric temperature (for neutral drag calculations) and for two separate assumptions regarding tether mass and power drawn from the ambient plasma (for the Terminator Tether™ calculations). The density profiles for the three values of exospheric temperature represent the extremes and mean values to be expected during the next several decades. The exospheric temperature goes through a cycle of about an 11 year period with maximum about 1400 kelvins and minimum about 800 kelvins.

The tether calculations include an inherent assumption that the Terminator Tether™ transfers all the energy extracted from the ambient space plasma into drag that decreases the orbital energy of the spacecraft at a rate given by the power drawn by the tether. Thus, the change in energy for a spacecraft of mass m at an initial altitude h is given by the expression:

$$\Delta E = -m\left\{\frac{\mu}{2(R_e+h)} - \frac{\mu}{2(R_e+250)}\right\},$$

and the time required to effect this change in energy of the mass, m, is just

$$\Delta t = \Delta E/P,$$

where P is the power drawn by the tether from the ambient plasma charge.

The curves for 1% and 5% tethers do not include the effects of atmospheric drag because the electrodynamic drag is orders of magnitude greater than the neutral atmospheric drag. At altitudes greater than about 700 km, the electrodynamic drag is 200 to 3000 times greater than the neutral drag forces.

It is clear, from FIG. 4 that the Terminator Tether™ concept is far superior to neutral drag in removing spacecraft from orbit, no matter how much additional area is added to the passive spacecraft to increase the atmospheric drag. The analyst should note that FIG. 4 is proportional to mass; that is, the Area-Time-Product values should be multiplied by the mass of the spacecraft and divided by 1000 kg. This is true for the neutral drag and Terminator Tether™ curves alike. The power levels assumed for the 1% and 5% tethers are only 80% of their theoretical values. This is done to provide a 20% margin on the power available from the ambient plasma and electrodynamic gradient.

Conventional rocket mechanisms can remove spacecraft from orbit, but this mechanism is apparently not viable from mass considerations when these factors are compared with the capabilities of the Terminator Tether™. A satellite owner may decide to satisfy the NASA safety requirements by adding a small solid motor and the associated hardware, software, sensors and structure to make the package independent, to be used to deorbit the spacecraft in case the main spacecraft power, attitude, or propulsion system fails.

The requirements of such a rocket motor system are more stringent than those attributed to ordinary spacecraft. The

rocket motor deorbit system must operate when some or all other systems of the spacecraft have failed. These more stringent requirements are balanced by lesser requirements of performance. The backup system must simply deorbit the spacecraft; it does not have to perform all the other duties of the spacecraft. But the backup system must know when to fire under all kinds of anomalous situations, including tumbling, offset of center of mass (because of loss of parts due to collisions), and lack of knowledge of the orbital position.

FIG. **5** shows the percent additional mass required by the rocket motor system to drop the perigee of a circular orbit at some initial perigee altitude to a value of 200 km. The atmospheric drag at this 200 km perigee altitude will remove any spacecraft (in the range considered) from orbit in a few revolutions. The contours of constant stage propellant mass fraction, λ, range from low values of 0.5 through reasonable values of 0.65 to 0.7, up to the values associated with the best solid motors ($\lambda \nabla 0.93$) without adding any extra hardware to the emergency stage. An effective, independent stage to provide a retro deltaV of from 50 to 325 m/s will almost certainly have a λ of the order of 0.6 to 0.75. If the emergency stage is required to perform its own attitude determination, the stage propellant mass fraction may be as low as 0.55 or 0.50. Note that the additional mass, shown in FIG. **5**, must also be lofted to orbit in the first place, to provide the mass on orbit for the originally intended service. The stage propellant mass fraction, λ, is a key stage performance parameter that describes the ratio of the mass of propellant to the mass of the stage. That is $\lambda = m_p/(m_p+m_I)$, where m_p is the mass of the propellant and m_I is the mass of everything else in the stage (not including the payload or any stages above or below the stage being considered). Typical independent small rocket stages have values of λ from 0.60 to 0.75. The curves of stage propellant mass fraction are shown as straight lines (a minor approximation) and are included only from 0.5 to 0.95, the extremes of reasonable design practice.

These calculations that show, beyond any reasonable doubt, that the Terminator Tether™ concept is far superior to conventional mechanisms such as drag enhancement devices or small rocket deorbit propulsion systems. The superiority is measured in terms of Area-Time-Product, NASA's measure of the likelihood of collision with other spacecraft in the path of the descending spent member of a constellation. Tether calculations were made using conservative assumptions that the power extractable from the ambient plasma and electrodynamic gradient is only 80% of the theoretical power available to a perfect tether crossing the magnetic field lines at a right angle, i.e. normally.

The following analysis is presented by the inventors to help those skilled in the art to better understand the present invention when it is used as a Terminator Tether™ for removing from orbit unwanted non-geostationary Earth-orbiting spacecraft at the end their useful lives. The primary result of that analysis is that the electrical power P in the tether that is converted into heat by the resistance of the tether and radiated away into space will remove energy from the spacecraft, causing it to rapidly deorbit, thus reducing the amount of orbital space debris that must be coped with in outer space. Tether electric power P is given by:

$$P=(vB)^2m/2rd$$

where m is the mass of the conducting tether, r and d are the resistivity and density of the conducting material, and v is the velocity of the spacecraft's motion through the Earth's magnetic field B. For a m=10 kg tether of aluminum with resistivity of r=27.4 nΩ-m and density d=2700 kg/m^3, moving at a velocity v=7037 m/s relative to the Earth's horizontal magnetic field B=26.5 μT, the power dissipated is P=2350 W! This energy loss in the form of heat must necessarily come out of the kinetic energy of the host spacecraft. For a typical example, a 1000 kg spacecraft in a 1000 km high orbit subjected to an energy loss of 2350 J/s from a 10 kg tether (1% the mass of the host spacecraft) will be deorbited in a few weeks.

Power levels of the magnitude estimated in the previous paragraph have been measured in a real orbital space experiment, the TSS-1R mission carried out on the Shuttle Orbiter in 1995. In that experiment, a large Italian spacecraft, 1.6 m in diameter, was deployed upward from the Shuttle Orbiter at the end of a conducting copper wire tether covered with electrical insulation. As the tether was slowly deployed upwards, a series of measurements were made of the open circuit voltage induced in the tether by its motion through the Earth's magnetic field. The voltage between the end of the tether and the Orbiter ground varied from zero volts at the start to 3500 V when the amount of tether deployed approached its maximum length of 20 km. Periodically, the end of the tether was connected either to one of two different electron guns, which supplied contact to the surrounding space plasma, or to the Orbiter ground. The bare surfaces of the Shuttle Orbiter proved to be a surprisingly good plasma contactor via a combination of ton collection and secondary electron emission. The current flow through the tether was deliberately limited by control circuits and the current capacity of the electron guns to about 0.5 amperes, but power levels of 1800 Watts were reached.

The tether was intended to have a fully deployed length of 20 km, but at a deployed length of 19.5 km, when about 3500 V was being induced at the end of the tether inside the Orbiter reel mechanism, a flaw in the insulation allowed an electrical spark to jump in an uncontrolled manner from the tether to the Orbiter ground. With no control circuits to keep the current level down to 0.5 amperes, the current flow jumped to 1.1 amperes, and the total power generated was P=3850 Watts Most of this energy went into the electrical arc, which burned through the tether, causing it to break and halting the experiment. This experiment showed that large areas of bare conducting material, such as that provided by the 8 square meter area of the Italian spacecraft at one end of the tether and the very large surface area of the Shuttle Orbiter spacecraft at the other end of the tether, can collect and emit amperes of current, while thousands of volts of potential can be generated by sufficiently long tethers moving at orbital speeds.

Thus, both theory and experimental data collected in the space environment indicate that significant amounts of electrodynamic drag force can be obtained from a low mass conducting tether attached to a host spacecraft, provided the ends of the conductor can exchange sufficient numbers of electrons with the surrounding space plasma.

Experimental data from the TSS-1R data also produced the amazing result that the efficiency of a bare metal surface in "contacting" the space plasma is many times better than the standard theory would predict. The 8 square meters of bare surface area of the Italian spacecraft were sufficient to collect the 1.1 A of electron current. This amount of area is easily replicated by a few hundred meters of bare wire, considering that the effective collection diameter around the wire is the Debye length, which is a few centimeters at the typical values for space plasma density and temperature.

Because of this result, that a bare wire can easily collect electrons, Les Johnson, Nobie Stone, Chris Rupp, and others

at NASA Marshall Space Flight Center have formed a team, which includes the present inventors, which is embarked on a new flight experiment. The experiment is scheduled for a piggy-back flight on a Delta II launch of an AF Global Positioning Satellite in early 2000. The goal of the experiment is to demonstrate that electrodynamic drag from a wire moving at orbital speeds through the Earth's magnetic field will create a large enough electrodynamic drag force to deorbit the Delta II second stage, whose mass is greater than 1000 kilograms, in a few weeks. This is essentially a demonstration of the Loftus electrodynamic drag deorbit concept and the first step in the development of a Terminator Tether™.

The ProSEDS (Propulsion Small Expendable-tether Deployer System) mission will use a 5 km long copper wire conductive tether massing 18 kg connected to a 20–35 km long nonconducting tether, which is in turn connected to a 25–40 kg ballast mass. The total of 25–40 km of tether length and the 25–40 kg ballast mass on the end will provide enough gravity gradient force to keep the tether aligned near the zenith, so that the direction of the current in the tether is at right angles to both the direction of the spacecraft motion in the nominal EW direction and the Earth's near-equatorial magnetic field in the nominal NS direction.

An important feature of the ProSEDS experiment is that it is designed to be completely self-powered. It uses a battery to initiate deployment and to power up the plasma contactor, but once current is flowing through the tether, some of the power is tapped off and used to recharge the battery. The battery, in turn, powers the current control electronics, the telemetry, system, and the plasma contactor. The ProSEDS mission will not be designed to allow ground control changes in operation, primarily because of the increase in complexity and cost associated with that option.

The present invention is the use of a small, low-mass deployer/controller package containing a large collecting area, short length, multiline space tether, such as a Hoytape mesh made of aluminum wire, as a "Terminator Tether™" for a constellation spacecraft. The Terminator Tether™ would be deployed when the host spacecraft is no longer working or no longer wanted. The electrodynamic drag from the Terminator Tether™ would rapidly remove the unwanted spacecraft from the constellation and a few weeks later complete the deorbit of the host spacecraft from space by burnup in the upper atmosphere of the Earth. For a Terminator Tether™ to be of maximum usefulness for constellation spacecraft, it would be desirable to minmize the mass and the length of the tether. A lower added mass means more mass for revenue producing transponders, while a shorter tether length means a lower collision cross-section Area-Time Product during deorbit.

FIG. 6 shows a spacecraft **600** having a state vector **602** that causes the spacecraft to move across magnetic field lines **601**. Spacecraft **600** has a conductive tether **603** attached to it by tether deployer and control system **605**. The outer end of tether **603** is attached to tether end mass **607**. Spacecraft **600** also has an attached electron emitter means **613**.

In FIG. **6**, spacecraft **600** has a velocity and direction defined by state vector **602**. As spacecraft **600** moves it causes conductive tether **603** to cut magnetic field lines **601**. As this happens the distal end of the conductive tether collects electrons, shown as arrows **611**, from the space plasma. Electrons **611** move through the conductive tether **603**, are passed through a resistive load, not shown, in control system **605**, and are emitted back into the space plasma as electrons **615** from electron emitter **613**. This produces an electrodynamic drag in the direction shown by arrow **609**.

As is discussed in detail in the electrodynamic drag analysis below, especially in that sections of the analysis titled "Optimization of Tether Angle", the maximum electrodynamic drag of the tether is achieved when the angle, shown as the Greek letter τ in FIG. **6**, is 35.26 degrees, trailing, to the direction of the magnetic field lines. This angle may be maintained by a feedback control circuit that maximizes the electrodynamic drag of the tether system, as is discussed in detail below. The tether structure **603** is a Hoytether having a length of about 2 to 5 kilometers. The use of the 35.26 degree angle to the magnetic field reduces the tether instability, allowing the use of a short tether which will have a small Area-Time-Product. This will minmize the possibility that the tether will impact another space object during its use.

In FIG. **7**, spacecraft **700** has a state vector **702** across magnetic field lines **704**. Conductive tether **706** is attached to spacecraft **700** by tether deployer and control system **708**. The distal end of tether **706** is attached to a tether end mass **710**. Spacecraft **700** has an electron emitter means **714**.

Functionally, electrons **712** flow from the space plasma into conductive tether **706**, are passed through a resistive load in control unit **708** and are emitted into the space plasma by electron emitter **714** as free electrons **716**. As is discussed in detail in the analysis below, this produces an electrodynamic drag on satellite **700**, which causes it to deorbit.

In FIG. **7**, spacecraft **700** is rotating with an angular velocity indicated by arrow **718**. This rotation causes a centrifugal force **720** to place tension on conductive tether **706**. This force **720** places tension on the tether **706** in a direction that counters tether instability. The Tether **706** may be at any angle to the magnetic field while the rotation of the tether-satellite system is producing this useful tension. FIG. **7** shows the angle to be 35.26 degrees, which is optimum, but any angle will work.

FIGS. **8***a* and **8***b* show a powered Terminator Tether™. In FIG. **8***a* the spacecraft **800** has a state vector **802** that causes it and its associated conductive tether **806** to move across magnetic field **804**. Tether **806** has an end mass **808** that is proximate a plasma contactor **810**. Just as was discussed in the embodiment of the present invention shown in FIG. **6** and FIG. **7**, an electric current moves through the circuit formed by the space plasma, the plasma contactor **810**, the conductive tether **806**, and the electron emitter **815**, thence back into the space plasma as electrons **816**. This creates an electrodynamic drag on the tether in the direction shown by arrow **818**.

In FIG. **8***b*, similar numbers indicate similar structures. In FIG. **8***b*, however, an electric power source, not shown, in spacecraft **800** provides electrons to conductive tether **806**. The electrons are emitted from the end **812** of the tether **806**. Electrons are collected to from the space plasma **814** by contactor **815**, thus completing the electric circuit. The result is an electrodynamic force on tether **806**, and therefore on spacecraft **800**, in the direction show by arrow **820**.

Spacecraft **800** in FIG. **8***b* may be rotated as is taught in the embodiment of the invention shown in FIG. **7**, above, to allow the control system to time the application of electric current to the tether **806** to cause force **820** to be exert force in any desired direction along the circle made by the rotating tether. This allows the state vector of the spacecraft to be modified to raise or lower the spacecraft's orbital altitude, or to otherwise usefully change its orbital elements.

FIG. **9** show an embodiment of the present invention wherein the conductive structure of a satellite is used as the tether. In FIG. **9**, a spacecraft **900** which has a state vector

901 and is moving across magnetic field 903, has two attached solar panels, 902 and 904. Solar panels 902 and 904 have conductive aluminum frames 908 and 906, respectively. Frame 906 is electrically and mechanically connected to plasma contactor 912. Frame 908 is electrically and mechanically connected to electron emitter 910. As spacecraft 900 moves across magnetic field 903, electrons from the space plasma 914 flow through contactor 912 and frame 906 to the body of spacecraft 900, where the current flows through a resistive load, not shown, and then into frame 908 and electron emitter 910 to the space plasma 916, thus completing the circuit. This creates an electrodynamic drag on spacecraft 900. If the power output from solar panels 902 and 904 was directed to flow into the frames, 906 and 908, then the electrodynamic interaction with the space plasma would cause a useful force to be impressed on spacecraft 900, as was discussed in connection with FIG. 8 above. The spacecraft may be rotated and/or oriented to a desired angle with the magnetic field lines, as was also discussed above.

FIG. 10 shows an embodiment of the present invention wherein the plasma contactor and the resistive load are structurally part of the conductive tether. In FIG. 10 spacecraft 1000 has a state vector 1001 that causes it to pass through magnetic field 1003. Spacecraft 1000 has a tether control and deployment system 1005 that is connected to a conductive tether 1007 having an end mass 1013. A contactor portion 1015 of the conductive tether 1007 near end mass 1013 is adapted to contact the space plasma so as to receive or emit electrons. This may be the bare wire strands of a wide Hoytether, or it may be any other plasma contactor means that can be conveniently made electrically part of the Hoytether structure, such as points or metal fuzz. A second resistive portion 1009 of tether structure 1007 is adapted to be a resistive load. This may be done by making a portion of the tether structure from a material, such as nichrome steel wire, that has suitable electrical resistance The large surface area of the Hoytether provides an excellent radiator structure into the three degree Kelvin radiation sink of outer space.

FIG. 11 shows an alternative embodiment of the load resistance/radiator structure of the present invention. In FIG. 11, a biline Hoytether 1002 is attached to its control and deployer system 1100 on a spacecraft, not shown, and to a tether end mass 1004. A resistive load, 1006 is woven into the Hoytether structure, whereby this load 1006 and the section of the Hoytether 1002 into which it is woven act together as a thermal radiator allowing photons 1008 to radiate into the thermal sink of outer space.

The following detailed analysis of the present invention will help those skilled in the art to better understand and use the present invention.

Electrodynamic Drag Analysis:

The following is an optimization analysis of the electrodynamic drag produced by a conducting tether deployed from a host spacecraft that it is to deorbit. The force and torque diagram used in the analysis is shown in FIG. 12, which shows the forces and torques on an upward deployed conducting tether due to the motion of the host spacecraft through the magnetic field of the Earth.

Physical Constants and Assumptions:

The analysis that follows will use the following physical constants and assumptions:

Newton's gravitational constant $G=6.67\times10^{-11}$ $m^3/kg\text{-}s^2$.

Mass of Earth $M_e=5.976\times10^{24}$ kg.

Radius of Earth near equator $R_e=6378$ km.

Assumed host spacecraft altitude h=622 km.

Assumed host spacecraft orbital radius a=7000 km.

Host spacecraft orbital velocity $w=\omega a=[GM_e/a]^{1/2}=7546$ m/s.

Vertical gravity gradient at spacecraft $2\Gamma=2GM_e/a^3=2.32\times10^{-6}$ s^{-2}.

Centrifugal gradient at spacecraft $\omega^2=GM_e/a^3=1.16\times10^{-6}$ s^{-2}.

Combined gradient at spacecraft $3\Gamma=3GM_e/a^3=3\omega^2=3.49\times10^{-6}$ s^{-2}.

Magnetic field of Earth (tilted dipole approximation):

Magnitude $B_o=35$ μT=0.35 gauss.

Angle between magnetic pole and spin pole 11.5°.

Field components at spacecraft with altitude a and angle β between radius vector of spacecraft and magnetic equatorial plane.

Horizontal $B_H=B_o(R_e/a)^3\cos\beta=26.5$ μT $\cos\beta$.

Vertical $B_V=2B_o(R_e/a)^3\sin\beta=52.9$ μT $\sin\beta$.

Electrodynamic Tether Constants and Assumptions:

The electrodynamic tether is assumed to be made of a conducting metal, and have a length L, density d, resistivity r, and cross-sectional area A that is constant along the length of the tether. If the tether is a single round wire of diameter D, then the cross-sectional area is $A=\pi D^2/4$. Because of the micrometeorite and space debris hazard, however, it is likely the tether will be made up of redundantly interconnected multiple lines whose individual cross-sectional areas add up to A. Given these assumptions, the tether mass is then $m_T=dLA$, while the end-to-end tether resistance is $R_T=rL/A=rdL^2/m_T$.

Specific Conductivity Parameter:

The choice of the metal conductor to be used in a space tether is determined by a combination of low resistivity (high conductivity) and low density, with cost, strength, and melting point as secondary considerations for certain applications. Copper has a resistivity r=17.0 nΩ-m, a density d=8933 kg/m, and a "specific conductivity" of 1/rd=6,585 m^2/Ω-kg. Aluminum has a resistivity r=27.4 nΩ-m, which is significantly greater than that of copper, but it has a much lower density of d=2700 kg/m^3. As a result, aluminum's "specific conductivity" of 1/rd=13,500 m^2/Ω-kg is twice the conductivity per unit mass of copper. Silver, because of its higher density and higher cost, is not competitive as an electrodynamic space tether even though its resistivity of 16.1 nΩ-m is slightly better than that of copper. An alternate candidate material would be beryllium, with a resistivity r=32.5 nΩ-m, density d=1850 kg/m^3, and a "specific conductivity" of 1/rd=16,630 m^2/Ω-kg, slightly better than that of the much cheaper aluminum. Beryllium also has a higher melting point at 1551 K than aluminum at 933 K, so some of its alloys may be a preferred material for some electrodynamic applications despite its higher materials cost. Unfortunately, despite decades of metallurgical research by the nuclear power industry, highly ductile alloys of beryllium have not been found, so it is difficult to pull beryllium into wire. As a result, because of its high specific conductivity, low cost, and ready availability in ductile wire form, it will be assumed for this analysis that the electrodynamic tether will be made of aluminum wire.

Typical Resistance Values:

To be economically competitive, the mass of the tether needs to be a small fraction of the mass of the host spacecraft it is required to deorbit. Since a typical constellation spacecraft has a mass of about 1000 kg, a typical Terminator Tether™ with a mass that is 2% of the host spacecraft mass would consist of a deployer/controller package with a mass $m_D=10$ kg, containing an aluminum tether with a mass $m_T=10$ kg with a volume of $LA=m_T/d=3.70\times10^{-3}$ m^3. If this 10 kg of aluminum were formed into a tether with a length

of L=2 km and a cross-sectional area of A=1.85 mm^2, then the end-to-end resistance of the tether would be $R=rL/A=rdL^2/m_T=29.6\ \Omega$ A longer tether would have a proportionately smaller cross-sectional area and a higher resistance; for example, a 5 km long tether with the same mass would have a resistance of 185 Ω.

Orbit Inclination Assumption:

In order to make the remainder of the analysis mathematically tractable, it will be assumed that the orbit of the host spacecraft is circular and above the magnetic equator, so that the angle between the radius vector to the spacecraft and the magnetic equatorial plane is β=0 degrees. In this orbit, the velocity v of the spacecraft with respect to the magnetic field is the orbital velocity w less the rotational velocity of the magnetic field at the orbital radius a due to the once per day rotation of the Earth, or:

$$v=W-2\pi a/1day=(7546-509)m/s=7037m/s$$

This equation also shows why electrodynamic drag will not be useful for removing geostationary spacecraft from orbit. At the geostationary orbital radius of a=42,200 km, the relative velocity of the spacecraft and the rotating magnetic field of the Earth is zero.

With this assumption of an orbit above the magnetic equator, the vertical component of the Earth's magnetic field is zero and the horizontal component of the Earth's magnetic field is at right angles to both the local vertical and the direction of motion of the spacecraft. The total magnetic field seen by the host spacecraft and its Terminator Tether™ is then orthogonally horizontal and has the magnitude:

$$B=B_H=B_e[R_e/a]^3\cos\beta=26.5\mu T.$$

Where for simplicity the subscript H will be dropped for the remainder of this analysis.

This orbit, with its inclination of 11.5° with respect to the spin equator, will not stay in the plane of the magnetic equator, but will vary ±11.5° above and below it as the Earth rotates, causing a variation in magnetic field strength of ±0.5 μT, as well as a slight variation in angle. This 2% variation is negligible in terms of the other uncertainties in this analysis. It is not until the orbital inclination of the host spacecraft orbit reaches 60°, where cos 60°=0.5, that there is a significant drop in the expected magnitude of the electrodynamic drag forces calculated in this analysis.

Electromagnetic Drag Effects in Polar Orbit:

In many medium Earth orbit communication satellite constellations, there are a significant number of spacecraft at high inclinations and in nearly polar orbits. The high inclination spacecraft, with inclinations between 60° and 78.5°, will all have orbits that stay between the magnetic poles. Although the amount of electrodynamic drag will be significantly less than that experienced by spacecraft with orbits at lower inclinations, the direction of the induced electric fields in the tether will always be in the proper direction. If the tether is vertically upward, the outer tip of the tether will be positively charged and the bare wire in the tether will pull electrons out of the surrounding space plasma, while the electron emitter at the host spacecraft end will eject the electrons back into the space plasma to complete the circuit.

For spacecraft in near polar orbits with inclinations between 78.5° and 90°, however, there will be much more drastic variations. First of all, for a spacecraft in a 90° orbit that happens to pass directly over the magnetic poles, there is no horizontal component of the magnetic field when it is passing over one of the magnetic poles, so no voltage is generated in the tether during that part of the orbit, while the horizontal component of the magnetic field near the magnetic equator, while strong in magnitude, is along the spacecraft velocity vector, so no voltage is generated in the tether in that part of the orbit either. As a result, there will be negligible electrodynamic drag experienced by the host spacecraft during that particular orbit. The Earth is rotating, however, and the magnetic pole is rotating with it. A few orbits later, the host spacecraft will be passing over the Earth's spin pole at a point where the horizontal component of the magnetic field is exactly at right angles to the direction of motion of the spacecraft, so the full voltage is generated in the tether. When passing over the spin pole, the spacecraft radius vector is at an angle of 11.5° from the magnetic pole and at an angle β=78.5° away from the magnetic equatorial plane. With these assumptions, the magnitude of the horizontal component of the magnetic field at the Earth's spin pole is a respectable:

$$B=B_e[R_e/a]^3\cos 78.5°=5.28\mu T$$

or 20% of the maximum value experiences by spacecraft orbiting above the magnetic equator. This value will drop slightly as the orbit continues, then build back up as the spacecraft passes over the opposite pole. As the Earth continues to rotate, bringing the magnetic pole again under the orbit, and the interaction of the tether with the horizontal component of the magnetic field again drops to zero. The average coupling of a tether to the Earth's magnetic field over all polar trajectories has been calculated to be 12.3 percent.

A problem experienced only by spacecraft with orbit inclinations greater than 78.5°:

The spacecraft will no longer be traveling from west to east with respect to the magnetic field axis, but will have a retrograde motion as it moves through the magnetic field. As a result, the voltage generated by the motion of the tether through the Earth's magnetic field will switch direction. The outer tip will be negatively charged and will attempt to collect ions, which is a much less efficient process than collecting electrons.

There are a number of solutions to this problem. The first is to increase the mass and length of the tether supplied to a spacecraft assigned to a polar orbit, so that higher voltages, currents, and drag are generated during the limited times the spacecraft is passing over the poles in the right direction. The second is to supply a tether with plasma contactors at both ends that can emit electrons from either end, allowing the current to flow either way, depending upon which direction the spacecraft is passing around the magnetic pole. The third is to utilize the first number of passes to torque the orbit of the spacecraft until the orbit inclination has been shifted below 60°, then turn on the electrodynamic drag full time to deorbit the spacecraft from this more favorable orbit inclination. This orbit torqueing maneuver is accomplished by activating the electrodynamic drag mechanism only when the magnetic field orientation is such that a strong out-of-plane component of force is created. This orbit torqueing maneuver can be augmented by switching to a propulsion mode, where power saved in the batteries during the drag force mode is pumped back into the tether when the magnetic field is in the opposite direction, applying electrodynamic propulsion to torque the orbit even further. With the tether at a large and stable trailing orientation, the coupling to the magnetic field can be significant to a vertical tether.

In summary, spacecraft in near-polar orbits might take longer to bring down, and might have to utilize specially designed Terminator Tethers™ that might cost and mass

more than the simpler Terminator Tethers™ usable in lower inclination orbits, but a Terminator Tether™ can still remove a spacecraft from a polar orbit when desired.

The inventors now present a detailed analysis and optimization of a typical Terminator Tether™ attached to a typical host spacecraft in a typical low inclination orbit.

Electromotive Generation of Voltage and Current in the Tether:

When an object is moved at a velocity v through a magnetic field B, an electric field is generated in the frame of reference of the moving object given by:

$$E=v\times B=vB$$

where the magnetic field B of the Earth, being mostly tangent to the Earth's surface in the north-south direction, is at right angles to the velocity vector v of the spacecraft, assumed to be orbiting in a generally west-east direction. The direction of the electric field E will be at right angles to both v and B, or along the local vertical. It should be noted that this electric field exists in the moving frame of reference because a moving magnetic field creates an electric field. No object actually has to be there, but if it is, then the relative motion of the magnetic field of the Earth will not only apply magnetic forces to whatever material the object is made out of, but electric forces too.

Note also that the velocity used in this equation is the relative velocity between the object and the magnetic field. Because the Earth's magnetic field rotates with the Earth, the motion of the magnetic field must be subtracted from the orbital velocity of the object to obtain the relative velocity.

Voltage generation in a Conducting Tether:

If the moving object is a long conducting wire of length L, the electric field E, generated in the wire produces a voltage V between the opposite ends of the wire given by:

$$V=E\cdot L=EL\cos\tau=vBL\cos\tau$$

where τ is the angle between the length vector L of the tether and the electric field vector E, assumed to be in the vertical direction at right angles to the velocity vector v in the plane of FIG. **12** and the magnetic field vector B out of the plane of FIG. **12**. A typical value for the voltage level built up in a vertically oriented tether with length L=5 km and τ=0, moving at a velocity of v=7037 m/s through the Earth's horizontal magnetic field of strength 26.5 μT, is 932 V, or 0.186 V/m. Spacecraft in higher inclination orbits would experience somewhat smaller electric fields. For calibration, the voltage measured between the ends of the 19.5 km long TSS-1R tether was 3500 V, or 0.175 V/m.

Contacting the Space Plasma:

Although a voltage will build up between the ends of the conducting tether, no current will flow unless the circuit is completed. The circuit cannot be completed with another wire, for it too will have a similar voltage generated in it by the moving magnetic field. Fortunately, empty space is not empty, and in near-Earth regions not too distant from the Earth's atmosphere there exists highly electrically conductive space plasma, kept partially ionized by radiation from the Sun. The electron and ion density varies from the dark to light side, with altitude, with season, with sunspot cycle, with contamination level, etc. but it typically varies from 10^{11} to 10^{13} electrons/cc.

Fortunately, it has been found that if a bare conductive surface such as the spherical Italian spacecraft in the TSS-1R experiment, or the long bare wire to be used in the ProSEDS experiment, or a multiline conducting wire Hoytape mesh, is charged to a few hundred volts, the bare conductor will readily pull electrons out of the space plasma. So all that is needed to complete a connection to the space plasma at the positively charged (upper) end of the tether is a sufficient large area of uninsulated conductor.

It is more difficult to eject electrons from a wire or to collect positive ions from the space plasma. Although it is conceivable that a very large area at the other end of the tether could collect enough ions to complete the circuit as was demonstrated during the TSS-1R mission when the Shuttle orbiter was found to be an adequate plasma contactor for over an amp of current, the present method chosen is to use an electron emitter of some sort, either a hot cathode, a plasma cathode or contactor, a field-emission device, or something similar. Once provisions have been made at both ends of the tether to allow the flow of electrons out of one end of the tether and into the other end, and the altitude of the host spacecraft is not too high, then there will be sufficient conductivity in the space plasma surrounding the host spacecraft to allow current to flow through the tether.

Current Flow In The Tether:

The amount of current I flowing through the tether depends upon the total resistance R in the circuit. This resistance will consist of three components, the effective resistance of the plasma, the resistance of the tether, calculated earlier as $R_T=rL/A=rdL^2/m_T$, and a control resistor R_C, which will be varied as needed to optimize the Terminator Tether™ performance. There will also need to be a parasitic load on the current in the form of a charging device to charge some batteries. The batteries in turn will be used to power the control and communication circuits, and drive the electron emitting devices at the negative end of the tether. A well-designed Terminator Tether™ will thus be completely self-powered, except for an initial charge in the batteries to provide electrical power for the deployment and startup procedure. For simplicity of analysis it will be assumed that this battery charging load, which absorbs power like a resistor, but which stores it and uses it later instead of dissipating it immediately as heat, is included in the control resistor R_c. Normally, this load would act as a "base resistance" below which the control resistor could not be lowered, but since the charging circuit can be turned off when desired, and operations continued without interruption using the power stored in the batteries, it will be assumed that the control resistor can be taken to near zero value in those circumstances where the space plasma conductivity is low, or the magnetic field is in the wrong orientation and the voltage being generated in the tether is not large. Under these circumstances, lowering the control resistor to near zero allows a much higher current to flow for a given generated voltage, thus increasing the power being dissipated in the tether and maintaining a high level of electrodynamic drag on the host spacecraft.

A properly designed Terminator Tether™ will have plenty of bare metal area for electron collection at the positive end, while the electron emitters at the other end are efficient in terms of emitting large electron currents at low voltages and therefore low powers, while at the same time the mass, length, and area of the conducting tether have been made such that the resistance of the tether is moderately high. Under these conditions, the effective resistance of the space plasma will be much less than the design resistance of the tether. To make the mathematics more tractable it will be assumed that the plasma resistance is can be neglected and that the voltage available to drive the tether is the full voltage generated by the moving magnetic field. Although voltage will be needed to power the electron emitter, what-

ever its form, it will be assumed that the required voltage and power will be supplied by the batteries. The batteries in turn will be powered by the battery charging circuit, whose effective resistance is included in the control resistor (except for those short periods when the plasma or magnetic field interactions are weak).

Given all these assumptions concerning the total resistance in the circuit, the current I flowing through the tether is then given by:

$$I=V/R=vBL\cos\tau/(R_C+rdL^2/m_T)$$

A typical current level can be estimated by assuming that the control resistance R_C should be about the same size as the tether resistance R_T, which for an aluminum tether with resistivity r=27.4 nΩ-m, density d=2700 kg/m^3, length L=5 km, and mass m_T=10 kg, is R_T=185 Ω, giving a total resistance, including the control resistance R_C, of R=370 Ω. Thus the current flowing though a tether of length L=5 km, generating a voltage of V=932 V, would be I=V/R=2.52 A.

Power Dissipation Analysis:

The induced current I flowing through the tether resistance R_T will generate heat in the wire, which will be radiated into space and lost. That radiated energy must come from somewhere. There is also power taken out of the current flow by the battery charging circuit and ultimately dissipated. In order to conform to energy conservation laws, this power and energy must come from a decrease in the total kinetic and potential energy of the host spacecraft, causing it to deorbit. Set forth below is a detailed, optimized force analysis which will calculate the drag force on the host spacecraft. In this section, by using some simplifying assumptions, it is possible to produce a general argument based on energy conservation laws, which will illustrate the broad scope of the present invention.

For this energy conservation analysis it will be assumed that the plasma resistance is small compared with the tether resistance, and that the control resistance is equal to the tether resistance:

$$R_C=R_T=rL/A=rdL^2/m_T$$

Assume that the ballast mass at the end of the tether is a large piece of the defunct host spacecraft, such as a solar panel, antenna, or battery pack, so that the gradient force is large and the tether is always oriented along the vertical so that the angle τ=0°. Also assume the spacecraft is in an orbit above the magnetic equator and thus is moving at right angles to the Earth's magnetic field, so that the angle between the orbital velocity vector and the magnetic field vector is 90°, and the electric field vector is in the vertical direction, aligned perfectly with the tether length vector. Under these ideal conditions, the voltage between the ends of the tether is given by:

$$V=E\cdot L=(v\times B)\cdot L=vBL$$

The current in the tether is then just:

$$I=V/(R_C+R_T)=vBm_T/2rdL$$

The power dissipated as ohmic heating in the tether is then given by:

$$P=IV=(vB)^2m_T/2rd$$

This equation shows the interesting result that the power dissipated does not depend upon the length or the area of the tether (within reason), but only the mass of the tether m_T, the resistivity r and density d of the tether material, and the velocity v of the conducting tether through the Earth's magnetic field B.

For a typical aluminum tether of mass m_T=10 kg, the power dissipated is an impressive P=2350 W. Even if only a small fraction of this power is dissipated in a real system, the kinetic energy of the host spacecraft would suffer a significant energy loss with time.

Orbital Energy Extraction Analysis:

The total energy U of a spacecraft of mass M in orbit around the Earth consists of two components, its positive orbital kinetic energy and its negative gravitational potential energy. If a circular orbit of altitude h and radius $a=R_e+h$ is assumed, then the total energy of the spacecraft moving at a velocity $w=(GM_e/a)^{1/2}$ is:

$$U=+Mw^2/2-GMM_e/a=-GMM_e/2a$$

The system will be dissipating energy in the tether to decrease the energy U of the unwanted spacecraft from its relatively low negative value in a high Earth orbit to a greater negative value in a lower Earth orbit. To give a specific example, an unwanted spacecraft with a mass of M=1000 kg (a metric ton) in an orbit with an altitude of h=1000 km and a high orbital radius of $a(H)=R_e+h$=7371 km, then its (negative) total energy is:

$$U(H)=-GMM_e/2a(H)=-27.1\text{ GJ or }-27.1\text{ MJ/kg}$$

It is desired to lower the spacecraft to an orbit with an altitude just outside the atmosphere of h=200 km or a lower orbital radius of $a(L)=R_e+h$=6571 km, where atmospheric drag will finish the job. The total (negative) energy of a metric ton spacecraft at 200 km altitude is:

$$U(L)=-GMM_e/2a(L)=-30.4\text{ GJ}$$

Thus, the amount of energy needed to be dissipated in order to move the 1000 kg spacecraft from a 1000 km orbit with a total energy U(H)=−27.1 GJ down to a 200 km orbit with energy U(L)=−30.4 CJ is:

$$dU=U(H)-U(L)=3.3\text{ GJ.}$$

The decay time T of a metric ton spacecraft moving from a 1000 km altitude orbit to a 200 km altitude orbit with an energy difference of dU=3.3 GJ, when its energy is being dissipated at a power of P=2350 W by a typical aluminum tether massing just 10 kg or 1% the mass of the spacecraft, is found to be T=dU/P=16 days.

The actual decay time will be longer than this. If the electrodynamic drag force is very large, and becomes larger than the gravity gradient forces pulling on the ends of the tether, then the tether will tend to align itself along the magnetic field lines instead of across them, and the drag force will decrease because of the small angle between the conductor length and the magnetic field lines. The tether current will need to be controlled until the angle of the tether settles into an angle determined by the balance between these two forces. These electrodynamic torque vs. gradient torque dynamic interaction effects are discussed in the next section.

Force and Torque Balance Analysis:

It is now possible to calculate the forces and torques on the tether. It is also possible to use the fact that the electrodynamic and gravity forces and torques on the tether must balance each other out to calculate and teach some optimum values for some of the Terminator Tether™ parameters.

Electrodynamic Force and Torque:

As discussed above, both theory and experiment show that: provided the conducting tether is moved rapidly through the Earth's magnetic field in order to generate a voltage across it, and provided good contact is made with the space plasma, the conducting tether will have a current flowing through it. When a wire (moving or not) carrying a current I is embedded in a magnetic field B, there will be an electrodynatnic force F_E generated on each element of the wire. The electrodynamic force will be at right angles to the magnetic field vector and the length vector of the wire element, with a magnitude given by:

$$F_E=J\times B=ILB$$

where B is the horizontal component of the magnetic field, which is perpendicular to the assumed magnetic equator orbit plane, while the tether length vector L is assumed to lie in the orbit plane. If, as will be the case most of the time, the electron current is leaving the space plasma and entering the tether along the length of the tether, then IL needs to be replaced with an integral of the current along the length of the tether.

Note that the electrodynamic force amplitude or direction is not directly dependent on the motion of the tether through the Earth's magnetic field. The electrodynamic force would be the same if the tether were not moving and the current was being supplied by a battery. Since the current I is a function of the orbital velocity, however, there is a secondary dependence of the electrodynamic force magnitude on the orbital velocity, but not its direction. The electrodynamic force is always at right angles to the conductor, and stays at right angles to the conductor as the angle τ varies, as shown in FIG. **12**.

Assuming that the electrodynamic drag force is applied uniformly along the length of the tether, it is possible to make the simplifying assumption that the integrated force is effectively applied at right angles to the center of mass of the tether at the point L/2 as shown in FIG. **12**. The electrodynamic torque on the tether is then:

$$T_E=F_EL/2=IBL^2/2=vB^2L^3\cos\tau/2(R_C+rdL^2/m_T)=vB^2L^3\cos\tau/2R$$

Gravity Gradient Forces and Torques:

When a tether and its ballast end mass are deployed from a host spacecraft, the gravity gradient force field of the Earth, combined with the orbital centrifugal gradient force field, will cause the tether to deploy either up or down from the host spacecraft. The direction desired depends on which end of the tether is connected to the electron emitter. Normally, the electron emitter will be on the end attached to the host spacecraft, in which case the desired direction of deployment will be upward so that the induced voltage in the tether will produce an excess of electrons at the electron emitter end of the tether. The desired upward direction is chosen by having the deployer eject the ballast mass in the upward direction. Once the ballast mass has been started in that direction, the centrifugal force due to the orbital motion of the ballast mass will cause the ballast mass to continue to accelerate in the upward direction until it is brought to a halt by the full deployment of the tether.

If there were no electrodynamic or atmospheric drag, the equilibrium direction of the tether would be exactly along the vertical, since the combined gradient field is a maximum in that direction. Because a significant amount of electromagnetic drag is expected, the actual angle of the tether with respect to the local vertical will be at some angle τ, lagging behind the spacecraft motion in the plane of the orbit, as shown in FIG. **12**. In the following analysis shows that there is an optimum angle for τ that produces the largest electrodynamic drag force on the host spacecraft without producing tether instability.

The combined vertical gravity gradient and centrifugal gradient field 3Γ acting on the ballast mass m_B at the end of the tether of length L will produce a gradient force F_{GB} given by:

$$F_{GB}=-3\Gamma m_BL\cos\tau$$

The strength of the force depends not only on the ballast mass m_B and the strength of the gradient field 3Γ, but also the component along the radial direction of the distance of the ballast mass from the center of mass, which is L cos τ. This force acts in the vertical direction along the radius vector leading from the ballast mass away from the center of the Earth. The amount of gradient force is not large. For a ballast mass of m_B=10 kg and a tether length of L=5 km, the gradient force is about 0.175 N.

As can be seen in FIG. **12**, the component of this gradient force that is at right angles to the tether, given by $F_{GB}\sin\tau$, will produce a torque T_{GB} on the tether that tends to restore the tether toward the vertical, lessening the angle τ.

$$T_{GB}=LF_{GB}\sin\tau=-3\Gamma m_BL^2\sin\tau\cos\tau$$

The tether mass m_T also contributes to the gradient force and torque. If it is assumed that the tether has a uniform cross section, then it is possible to replace the distributed mass of the tether with an equivalent point mass m_T placed at the center of mass of the tether, which is the point L/2 along the tether, and a distance L/2 cos τ in the radial direction. The gradient force due to the tether mass is then:

$$F_{GT}=-3/2\Gamma m_TL\cos\tau$$

While the gradient torque is:

$$T_{GT}=-L/2F_{GT}\sin\tau=-3/4\Gamma m_BL^2\sin\tau\cos\tau$$

The total gradient torque attempting to restore the tether to its vertical orientation is then:

$$T_G=T_{GB}+T_{GT}=3\Gamma(m_B+m_T/4)L^2\sin\tau\cos\tau$$

It is important to notice the variation of the total gravity gradient torque as the tether angle τ is varied. Since the gradient force is always in the radial or vertical direction, there is no torque on the tether when the tether is vertical, as is the case when there are no aerodynamic or electromagnetic drag forces. Once the drag forces become important and start to apply torque to the tether, increasing the tether angle τ, those drag torques causing an increase in tether angle τ will be opposed by a rising gradient torque which will attempt to decrease the tether angle. For small tether angles, the gradient torque increases first linearly with τ, then as sin τ, since cos τ is near unity for small τ, then at τ=45° the gradient torque reaches its maximum, where sin τ=cos τ=0.707 and sin τ cos τ=0.50. When this angle is reached, the tether is a point of catastrophic instability, for if there is a further increase in the electrodynamic drag force, causing the angle τ to become greater than 45°, the gradient torque, instead of growing stronger to counteract the increased drag torque, will become weaker and the tether angle will go rapidly to 90°.

To restore control to the tether angle if the instability occurs, it will be necessary to turn off the electrodynamic drag forces by shutting off the current flow through the tether. The τ=90° position for the tether and ballast mass is

a gravitationally unstable orientation. After a time, slight fluctuations in the gravity field will allow the gradient force to slowly take over and restore the tether to the vertical orientation, which, unless it can be controlled in some way, is equally likely to be up or down. It would therefore be desirable to maintain control of the tether angle so as to avoid the tether angle getting into the region of instability.

Torque Balance on the Tether:

The angle τ of the tether is determined by a balance between the electrodynamic torque T_E attempting to increase the angle τ and the gradient torque T_G attempting to decrease the angle τ. Balance is achieved when the two torques are equal:

$$T_E=T_G=T_{GB}+T_{GT}$$

or:

$$vB^2L^3 \cos \tau/2R=3_r(m_B+m_T/4)L^2 \sin \tau \cos \tau$$

Simplifing and rearranging yields an equation giving us the angle τ at which torque balance occurs:

$$\tau=\arcsin[vB^2L/6_r(m_B+m_T/4)R]$$

The physical interpretation of this equation is that the maximum electrodynamic force that can be sustained on the tether is limited by the gradient force on the tether. It is possible to increase the electrodynamic force by decreasing the total resistance R of the tether (for example, by using a tether with a larger mass and a lower tether resistance), but if the tether resistance is too low, then the quantity in brackets becomes greater than unity and this equation has no solution, indicating that the tether has reached an angle where instability sets in.

To maintain control of the tether angle, it will be necessary to vary the control resistance of the tether to compensate for variations in magnetic field strength and direction, plasma density (which affects the plasma resistance), and other factors, and thereby maintain the tether at an intermediate angle where both the electrodynamic and gradient forces are at an appreciable level and balance each other.

Optimization of Tether Angle:

At first glance, it might seem that the optimum angle for the tether would be 45°, since at that angle the gradient torque is largest and therefore can counteract a larger electrodynamic drag force. However, since the 45° angle is the point where instability sets in, it is desirable to set the tether angle at some value below 45°. The optimum angle is that which maximizes the horizontal or drag component of the electrodynamic force. This optimum angle τ is derived from the equation for the horizontal component of the electrodynamic force, or the electrodynamic drag force, since it opposes the host spacecraft motion:

$$F_{ED}=F_E \cos \tau=6[m_B+m_T/4]\Gamma L \sin \tau \cos^2\tau$$

By setting the partial derivative $\partial F_{ED}/\partial \tau=0$ and solving, it is possible to calculate that the optimum angle for the tether that gives the maximum electrodynamic drag force F_{ED}, while still keeping the tether torques balanced and under control, is $\tau=\arctan(0.707)=35.26°$. With this angle selected and maintained by varying the control resistor R_C to compensate for variations in plasma contact resistance and variatins in the strength and direction of the Earth's magnetic field B seen at the spacecraft, the tether experience the maximum stable value for the electromagnetic drag force of:

$$F_{ED}(\max,\tau=35.26°)=2.31[m_B+m_T/4]\Gamma L$$

There are many ways to provide the sensing information needed to provide the feedback signals to the control resistor, but the simplest is to merely measure the drag acceleration on the host spacecraft with a set of accelerometers, and maximiize the force in the direction opposite to the host spacecraft motion. Another method would be to measure the current in the tether, and knowing the tether resistance and the amount of control resistance, calculate the power being extracted and maximize that value. Alternate methods would be to use an optical position sensor or GPS receivers at both ends of the tether to measure the angle of the tether or the position of the ballast mass with respect to the host spacecraft.

To make an estimate of the magnitude of drag force attainable, assume that a typical aluminum tether with a length of L=5 km, a tether mass of m_T=10 kg and a ballast mass of m_B=10 kg is being used. Then the maximum gradient force limited electrodynamic drag force is F_{ED}= 0.167 N. The power being dissipated in the canoical tether at the angle τ, with $R_C=R_T=rdL^2/m_T=185\ \Omega$ is given by:

$$P=IR=[vBL \cos \tau]^2(R_C+rdL^2m_T)$$

which for an angle $\tau=35.26°$ results in a power dissipation of 1570 W. Thus, the thrust level per unit power obtained by the typical Terminator Tether™ would be about 0.106 N/kW. This number is comparable to the value of 0.148 N/kW estimated for the much heavier and longer TSS-1R tether.

Reconciliation of Energy and Force Analysis:

By a force and torque balance analysis an optimum angle for the tether has been discovered at which it is possible to obtain a maximum in the drag component of the electrodynamic force. There is also an additional component of the electrodynamic force, the component in the vertical direction, $F_{EV=FE} \sin(\tau)$, which is downward for an upwardly deployed tether. This component of force combines with the gravity force of the Earth to effectively allow the host spacecraft to orbit a little faster than normal for that orbital altitude. It does not contribute to the deorbiting of the host spacecraft. But since this vertical component of force is created by current running through the tether, and that current is creating heat and dissipating energy as it passes through the tether, there might be some concern that the force and torque balance analysis above does not conform to the law of conservation of energy.

The inventors will now show, in a very general manner, that no matter what the tether angle, the electrical power being dissipated in the tether is exactly equal to the power being lost by the slowing of the host spacecraft.

The "deorbit power" P_D that must be removed from a spacecraft moving at a velocity v when that motion is opposed by a drag force F_{ED} is:

$$P_D=v*F_{ED}=vF_E \cos \tau=vILB \cos \tau=I[vBL \cos \tau]$$

But, since the voltage V induced across the tether of length L and tilt angle τ moving at a velocity v through a horizontal magnetic field B is

$$V=E*L=EL \cos \tau=vBL \cos \tau$$

Therefore:

$$P_D=IV=P_E$$

And the deorbit power P_D extracted from the slowing of the spacecraft by the drag component of the electrodynamic

force is always exactly equal to the electrical power P_E being dissipated as heat in the tether circuits, independent of the tether angle.

Optimization of Tether Mass Distribution:

If it is not possible to use a piece of the host spacecraft as ballast mass, then the mass of the ballast must be included in the Terminator Tether™ mass. It would be desirable to minimize the total Terminator Tether™ mass, since every kilogram saved means that another kilogram's worth of revenue-producing transponders can be added to the working payload of the host spacecraft. Given a total mass for the Terminator Tether™ and the mass of the deployer/controller unit, it is possible to optimize the mass distribution between the ballast mass and the tether mass to obtain a minimum total Terminator Tether™ mass. A well-designed Terminator Tether™ will also have most, if not all, of the deployer mass incorporated into the ballast mass.

Assume that the total Terminator Tether™ mass consists of the deployer/controller mass m_D, the tether mass m_T, and the ballast mass m_B, with $m_B>m_T>m_D$. Of the three mass components in the Terminator Tether™, two of them affect the electrodynamic drag performance. If it is assumed that the ballast mass is a factor X larger than the tether mass, or $m_B=Xm_T$, the maxinum drag force that can be obtained is now:

$$F_{ED}(max)=2.31m_T(X+0.25)\Gamma L$$

If it is assumed that the control resistor has been adjusted so that this maximum value for the electrodynamic drag force is maintained as the motion of the spacecraft along its orbit moves the spacecraft into regions with different magnetic field strengths and plasma densities, then for the angle $\tau=35.26°$, $\cos(35.26°)=0.817$, and the maximum electrodynamic drag force in terms of the electrodynamic parameters will be:

$$0.817vB^2L^2/(R_C+rdL^2/m_T)=F_{ED}(max)=2.31m_T(X+0.25)\Gamma L$$

or canceling out terms and rearranging:

$$(X+0.25)=0.353vB^2L/\Gamma m_T(R_C+rdL^2/m_T)$$

It is now possible to make the further simplifying assumption that to maintain control of the tether, the control resistor needs to be roughly the same size as the tether resistance or $R_C=rdL^2/m_T$. Using this assumption produces an equation for the optimum value for the ratio X of the ballast mass to the tether mass:

$$X = vB^2/\Gamma rdL - 0.25 = -0.25 + \frac{vB^2}{12\sin\gamma\cos\gamma\Gamma rdL}$$

$$= -0.25\frac{\Lambda}{L}$$

Where Λ is the "effective electrodynamic length".

If the tether is short, so that L is small, this equation indicates that the ballast mass must be increased to increase the gradient force, since it is the gradient force which determines the upper limit to the amount of electrodynamic drag force that can be generated without losing control of the tether.

Assuming the usual values for the Earth's magnetic and gradient fields, the velocity of the host spacecraft through the magnetic field, and the resistivity and density of aluminum, this equation becomes:

$$X=10.9/L-0.25$$

where L is in kilometers.

For a typical tether of length L=5 km, X=1.93. If the total mass for the Terminator Tether™ is 20 kg, or 2% of the host spacecraft mass, and the mass of the deployer is 10 kg, then the remaining 10 kg should be distributed so that 6.59 kg is in the ballast mass while 3.41 kg is in tether mass.

Optimization of Tether Length:

If the ballast mass consists of a piece of the host spacecraft, then the mass of the ballast does not have to be considered in the optimization of the Tether system. In this case, the optimum distribution of the Tether mass is to put as much mass as possible into the tether, with a minimum in the deployer/controller package. Under this assumption, the optimum length of the tether is determined by the desire to keep the Area-Time Product of the host spacecraft plus Tether to a minimum.

In a long tether of length L, the effective "collision" cross-sectional area is not the area of the tether, but the larger area produced by multiplying the length of the tether by sum of the width of the tether plus the width of the "target" spacecraft that would be damaged by the tether hitting it. Thus, to decrease the "area" portion of the Area-Time Product, it would be desirable to shorten the tether, making it thicker, and perhaps slightly wider, at the same time, thus keeping the same tether mass and electron collection area, and thereby maintaining the drag force and keeping the decay time at the same level. The result will be a shortening of the Area-Time Product.

If the tether is shortened too much, however, the smaller voltage generated across the shorter tether will leave less voltage margin for the operation of the plasma contactors and the battery recharge system. Since the maximum voltage that can be generated is about 200 V/km, and typical plasma contactors and battery, chargers take 25–100 V to operate, a minimum length for a Tether would be roughly 2 km. Host spacecraft operating in polar orbits, where the conditions for voltage generation are not as good, may require a tether length of 5 km or more.

Since many watts of heat power will be dissipated in the control resistor, means must usually be provided to radiate the heat away into space. One low-mass method of accomplishing this is to make the control resistor (or resistors) in the form of a long, electrically insulated, high resistivity wire similar to those used in electric blankets, but designed to operate at a higher temperature, and during the fabrication of the electrodynamic tether, incorporate the high resistivity wire (or wires) into the end of the tether closest to the control circuit by weaving or braiding the insulated high resistivity wire in with the uninsulated aluminum wire of the electrodynamic tether. The surface area of a long wire is very large, so in this extended wire configuration, exposed to the space all around it, the hot control resistor wire can self-radiate its power into cold space without incurring the mass penalty of a separate radiating surface.

Implementation:

The basic optimum structure for a Terminator Tether™ would be one of the many types of Hoytethers. A multiline (6–12 primary line) Hoytape™ will provide the largest contact area with the plasma, since both sides of the tape would be able to pass current to the plasma. If the spacing between the primary lines is chosen to be larger than twice the Debye length of the plasma, then the effective current collection area per unit length of the Hoytape is proportional to the width of the Hoytape mesh, not the diameter of the wires in the mesh. Thus, a Hoytape not only provides an assured longer life for the Terminator Tether™, but very short lengths will also provide a very large current collection areas.

The deployer for the tether can deploy the Terminator Tether™ either down or up or both. The deployer can stay

attached to the spacecraft as was done in the SEDS missions, or perhaps a better alternative would have the deployer ejected from the spacecraft, with one end of the tether still attached to the spacecraft, reeling out tether as it leaves. The empty deployer would then act as a ballast mass at the end of the Terminator Tether™, which would improve the performance.

The "Remora Remover"

In addition to attaching Terminator Tethers to spacecraft before launch, it is possible to consider a missile-like application. This "Remora Remover" missile would use a Terminator Tether™ carried by a seeker missile similar to the small "hit-to-kill" missiles developed by the Space Defense Initiative Office that deployed a net loaded with oriented metal rods. The Remora Remover missile would hunt down a spacecraft that needs to be removed from space, but instead of hitting the spacecraft, the missile would be programmed to rendezvous with the spacecraft and attach itself to the host spacecraft using a hooked net, harpoon, or adhesive "sucker". The Remora Remover missile would then deploy the Terminator Tether™, which would bring down both the spacecraft and the missile.

The inventors have presented two analyses, backed up with data obtained from space flight experiments. One analysis was based on generalized energy conservation laws while the other analysis use force and torque balance arguments. Both analyses show that optimized aluminum wire tethers 2 to 5 km in length and massing just 1% to 5% of the mass of the host spacecraft can deorbit the host spacecraft in the order of a few weeks, thus mitigating the long-lived orbital debris hazard created by a constellation spacecraft after their end-of-life.

Power Augmented Operation of the Tether:

It is well known in the aerospace literature that if a spacecraft has a power supply and a conducting tether hanging from it, and the spacecraft is in an orbit or trajectory that takes it near a body, such as the Earth or Jupiter, which has both a magnetic field and a region of moderate density electron-ion plasma, and electrical current is pumped from the power supply through the tether and back through the plasma, that the current flowing through the tether will interact with the magnetic field of the body, producing forces on the tether and thence on the spacecraft, changing its orbit or trajectory. These forces can be used to increase or decrease the spacecraft altitude and/or inclination. The amount of altitude or inclination change is proportional to the ratio of the power available from the power supply divided by the mass of the spacecraft and varies with altitude. The unpowered Terminator Tether™ is a simple example of such a system, in which only altitude decrease is possible, although small amounts of both inclination increase or decrease are possible at the same time. Some typical references to this prior art are: Les Johnson, "Propulsive Small Expendable Deployer System Mission (ProSEDS)", Proceedings of the OAST 8th Advanced Propulsion Workshop, JPL, Pasadena, Calif., 20–22 May 1997; and Les Johnson, Joe Carroll, Robert D. Estes, Enrico Lorenzini, Brian Gilchrist, Manuel Martinez-Sanchez, Juan Sanmartin, and Irwin Vas, "Electrodynamic Tethers for Reboost of the International Space Station and Spacecraft Propulsion, AIAA Paper 1996.

Since the Terminator Tether™ of the invention is normally associated with a satellite that has a power supply in the form of a solar panel combined with a storage battery, the Terminator Tether™ can be operated in the "powered propulsion" mode if desired. Such a mode would be useful when attempting to avoid a collision between the Terminator Tether™ and another spacecraft. In such cases, the power from the solar panel, augmented by the power stored in the battery, can be used to temporarily operate the Terminator Tether™ in the propulsion mode instead of the normal drag mode. This would enable to Terminator Tether™ to raise its altitude and/or increase or decrease its inclination to avoid a collision.

In addition, the Terminator Tether™ could be operated in the "power-augmented drag" mode. In this mode, there will be a current induced in the tether by the motion of the spacecraft through the magnetic field, which will cause a drag force on the spacecraft. This induced current would then be augmented by additional current in the same direction generated by the solar panel and the storage batteries in the power supply. The increased current will cause an increased drag force. If there is a significant vertical component of the magnetic field there will also be an increased force normal to the orbital plane, which will cause an increased rate of change of inclination.

When the Terminator Tether™ is operated in the "powered propulsion" or "power-augmented drag" mode, the conditions for stable optimum operation will be essentially the same as in the "unpowered drag" mode. The reason the conditions stay the same is that the maximum tether force than can be effectively utilized is limited by the strength of the gradient force, which has not changed, since the length and mass of the tether and the ballast mass has not changed for these different modes of operation. As a result the optimum operational angle for the tether is still 35.26 degrees, and the optimum ratio of ballast mass to tether mass for different tether lengths and tether material is still determined by the analysis of the invention as is set forth above.

In the analysis given above, where the optimum tether angle was found, the tether was assumed to be in the plane of the orbit and lagging behind the spacecraft motion, since in the "unpowered drag" mode, that would be its normal position, although if the component of the magnetic field along the orbit were high, there would be some tilt of the tether out of the plane of the orbit, producing a force tending to change the inclination of the orbit. In either of the "powered" modes of operation of the Terminator Tether™, however, the tilt of the tether could be forward toward the motion of the spacecraft or strongly tilted to one side or the other of the orbital plane. In all these cases, if the electrodynamic force is allowed to become too large, and the tether angle exceeds 45 degrees, the restoring force of the gradient field will drop off and the tether angle will go unstable. As a result, the optimum angle for the tether that will give the maximum stable force, whether it is a maximum drag force, and maximum propulsion force, or a maximum inclination change force, will be 35.26 degrees, and the optimum ratio for the mass of the tether versus the mass of the ballast will be the same as for the unpowered drag case.

The analysis that gave the optimum angle as 35.26 degrees assumed that the tether would be oriented like a rigid rotor. In reality, variations in forces along the tether will probably cause the tether to hang in a slightly curved shape, where the optimum angle may not be exactly 35.26 degrees from the local vertical. The optimum angle of the tether as it leaves the host spacecraft in such a case is where the drag force is largest.

The present invention is discussed in this disclosure in terms of its space applications as a Terminator Tether™ useful for the removal of unwanted satellites. It should be understood, however, that the present invention is useful in any application where a space object can use a conductive tether to produce electrodynamic force through interaction

with a magnetic field. The invention, therefore, should be limited not by this description, but only by the appended claims and their equivalents.

What is claimed is:

1. A method of operating a conductive tether attached to a space object, said conductive tether being oriented at an angle to magnetic field lines of an external magnetic field and said conductive tether moving across the magnetic field lines of said external magnetic field at said angle to producing an electric current in said conducting tether and a resulting electrodynamic force acting on said tether and said attached space object comprising,

Controlling the amount of electric current flowing in said conducting tether to vary the angle between the conductive tether the field lines of the external magnetic field and the electrodynamic force acting on said tether and attached space object.

2. A method as in claim **1** wherein said angle is less than 45 degrees.

3. A method as in claim **1** wherein said angle is 35.26 degrees.

4. A method as in claim **1** wherein said angle is controlled to average 35.26 degrees over time.

5. A method as in claim **1** wherein said angle is controlled to average 35.26 degrees over the length of the tether.

6. A method as in claim **1** wherein the space object and the tether connected to it are rotated about their center of mass while the conductive tether interacts with the external magnetic field.

7. A method as in claim **1** wherein the angle of the conductive tether to the external magnetic field is controlled by sensing a measurable parameter of the space object/conductive tether system.

8. A method as in claim **7** wherein the parameter is current flow in the conductive tether.

9. A method as in claim **7** wherein the parameter is the electrical power dissipated in the conductive tether and the current control system.

10. A method as in claim **7** wherein the parameter is the relative position of the space object and the position of the far end tip of the tether.

11. A method as in claim **7** wherein the parameter is the acceleration of the space object.

12. A method as in claim **6** wherein the parameter is the state vector of the space object as measured by the Global Positioning System.

13. A method as in claim **1** including the step of applying electric power to the conductive tether to change the state vector of the space object.

14. A method of operating a conductive tether attached to a space object, said conductive tether being oriented at an angle to the local vertical between said space object and a celestial body having a magnetic field having magnetic field lines external to said conductive tether; said conductive tether moving across said magnetic field lines of said external magnetic field at an angle to the local vertical to produce an electric current in said conducting tether and a resulting electrodynamic force acting on said tether and said attached space object comprising,

Controlling the amount of electric current flowing in said conducting tether to vary the angle between the conductive tether the local vertical between said space object and said celestial body to vary the electrodynamic force acting on said tether and attached space object.

15. A method as in claim **14** wherein said angle is less than 45 degrees.

16. A method as in claim **14** wherein said angle is controlled to average 35.26 degrees over time.

17. A method as in claim **14** wherein the space object and the tether connected to it are rotated about their center of mass while the conductive tether interacts with the external magnetic field.

18. A method as in claim **14** wherein the angle of the conductive tether to the external magnetic field is controlled by sensing a measurable parameter of the space object/conductive tether system.

19. A method as in claim **18** wherein the parameter is current flow in the conductive tether.

20. A method as in claim **18** wherein the parameter is the acceleration of the space object caused by the electrodynamic force acting on the space object.

21. A method as in claim **18** wherein the parameter is the change in the state vector of the space object as measured by the Global Positioning System.

22. A method as in claim **14** including the step of applying electric power to the conductive tether to change the state vector of the space object.

23. A method as in claim **14** wherein the celestial body is the Earth and the magnetic field is the Earth's magnetic field.

24. A method as in claim **14** wherein the celestial body is the sun and the magnetic field is the Sun's magnetic field.

25. A method as in claim **14** wherein the magnetic field is the vector sum of the magnetic fields from all celestial bodies in the solar system.

26. A method as in claim **14** wherein the conductive tether is a Hoytether.

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Cohen

(10) **Patent No.: US 8,253,639 B2**
(45) **Date of Patent: Aug. 28, 2012**

(54) **WIDEBAND ELECTROMAGNETIC CLOAKING SYSTEMS**

(76) Inventor: **Nathan Cohen**, Belmont, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 498 days.

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H01Q 15/02 (2006.01)
H01Q 19/06 (2006.01)

(52) **U.S. Cl.** **343/753**; 343/909

(58) **Field of Classification Search** 343/753, 343/909, 910; 333/135

See application file for complete search history.

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Primary Examiner — Michael C Wimer

(74) *Attorney, Agent, or Firm* — McDermott Will & Emery LLP

(57) **ABSTRACT**

Arrangement of resonators in an aperiodic configurations are described, which can be used for electromagnetic cloaking of objects. The overall assembly of resonators, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry corresponds to a moderate or high "Q" response that resonates within a specific frequency range, and that arrangement within that specific grouping of akin elements is periodic in the overall structure. The relative spacing and arrangement of groupings can be defined by self similarity and origin symmetry.

14 Claims, 4 Drawing Sheets

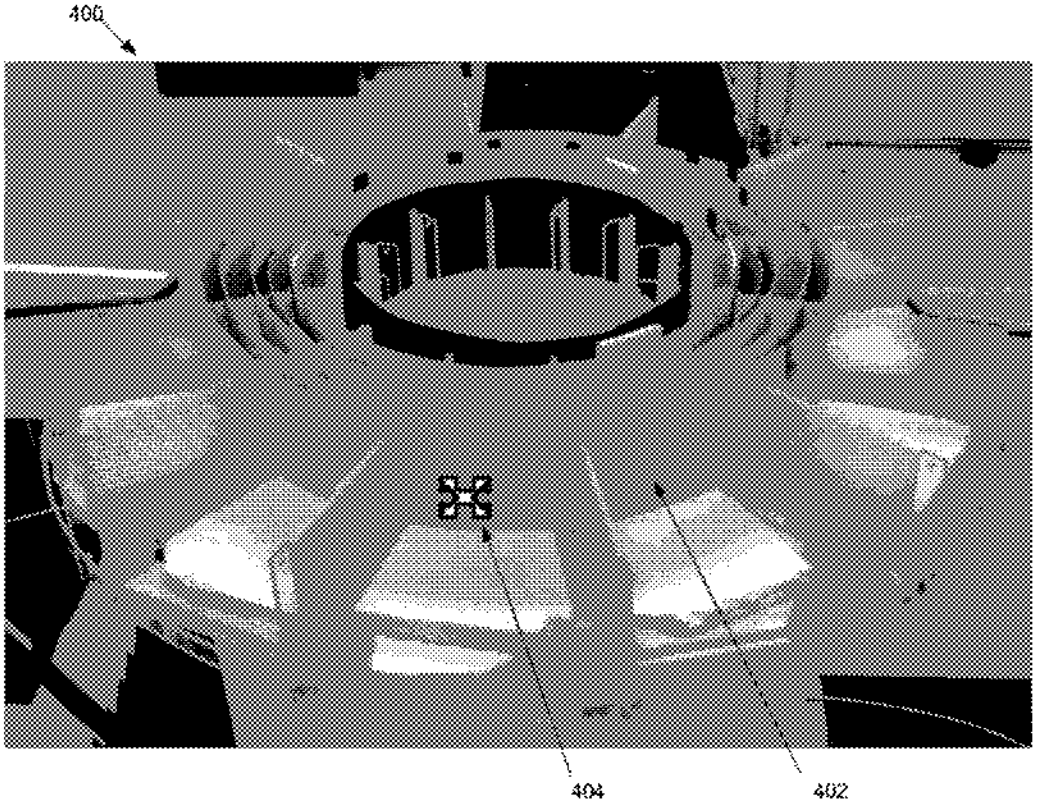

FIG. 1

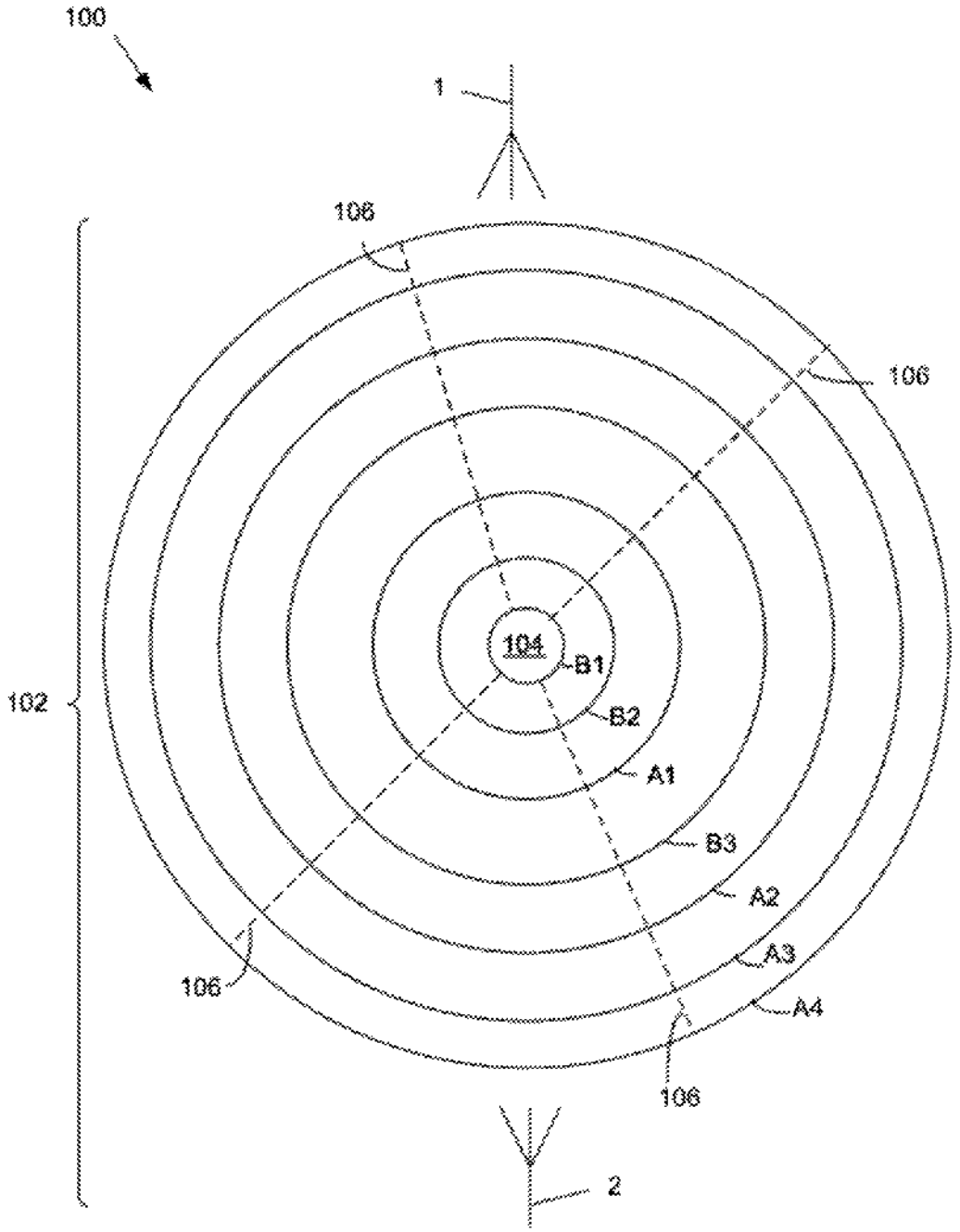

FIG. 2

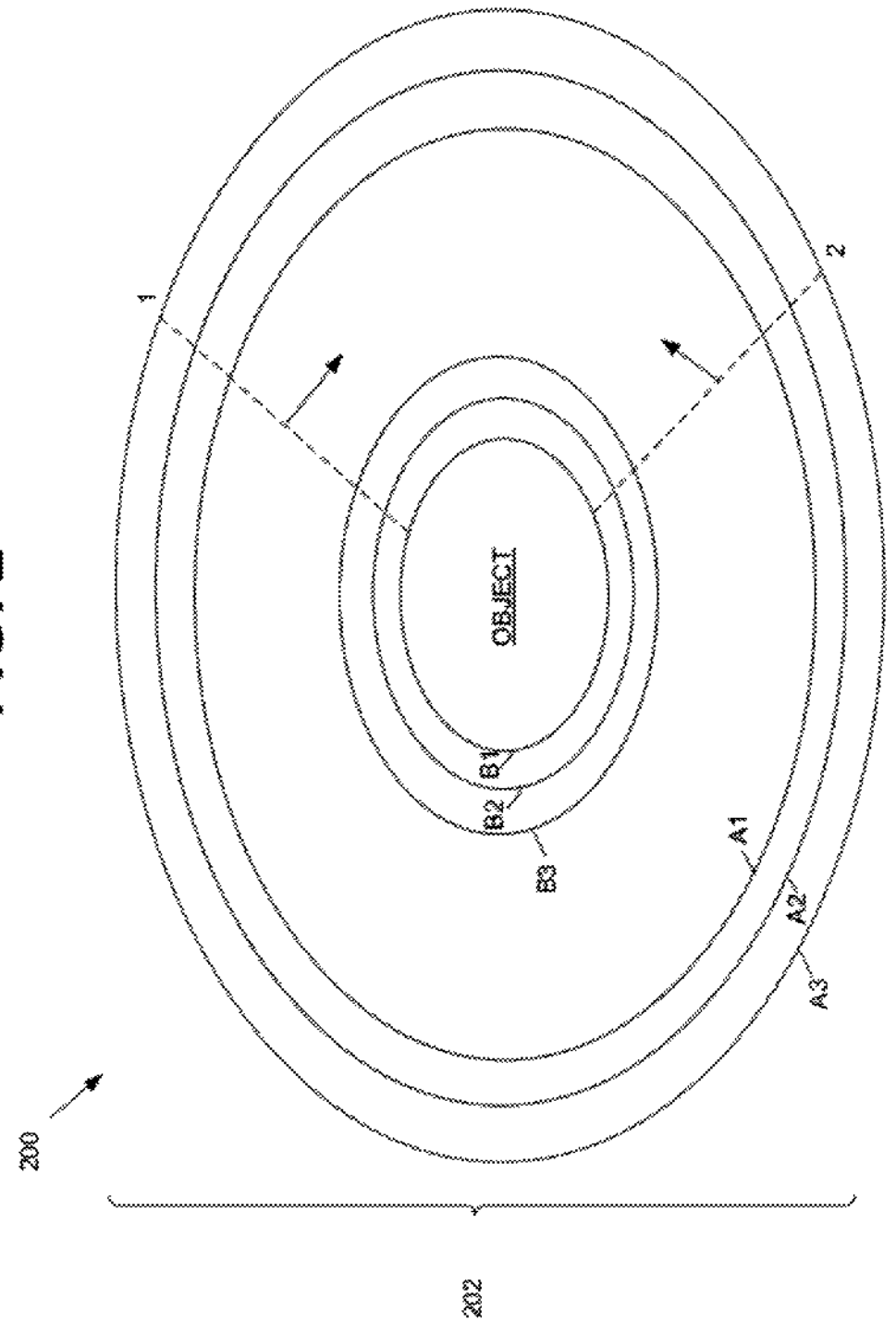

FIG. 3

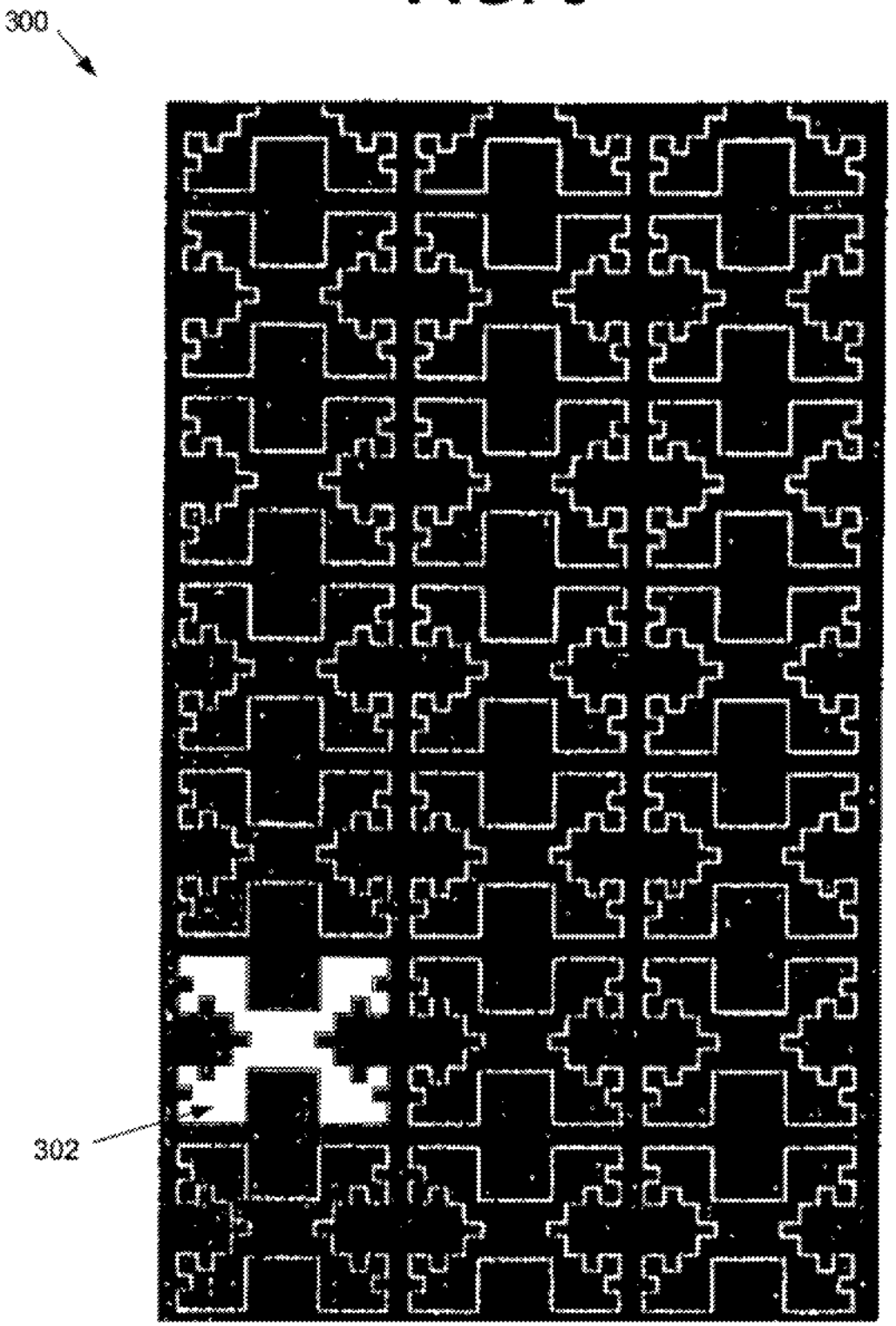

FIG. 4

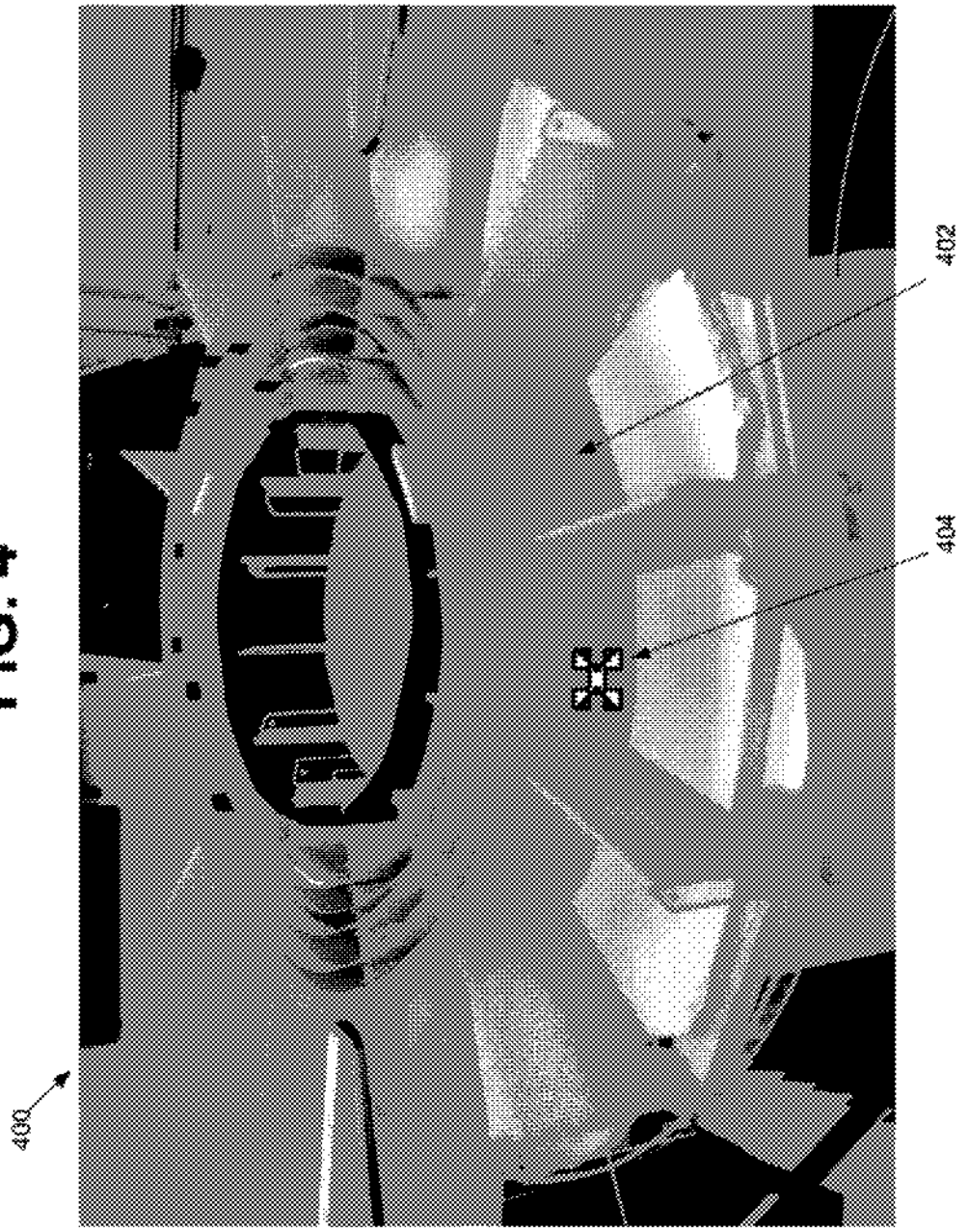

WIDEBAND ELECTROMAGNETIC CLOAKING SYSTEMS

RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No. 61/189,966, filed 25 Aug. 2008 and entitled "Method and Apparatus for Wideband Electromagnetic Cloaking, Negative Refractive Index Lensing and Metamaterial Applications," the entire contents of which are incorporated herein by reference.

BACKGROUND

Much time and effort has been devoted to the quest for so-called invisibility machines. Beyond science fiction, however, there has been little if any real progress toward this goal.

Materials with negative permittivity and permeability leading to negative index of refraction were theorized by Russian noted physicist Victor Veselago in his seminal paper in *Soviet Physics* USPEKHI, 10, 509 (1968). Since that time, metamaterials have been developed that produce negative index of refraction, subject to various constraints. Such materials are artificially engineered micro/nanostructures that, at given frequencies, show negative permeability and permittivity. Metamaterials have been shown to produce narrow band, e.g., typically less than 5%, response such as bent-back lensing. Such metamaterials produce such a negative-index effect by utilizing a closely-spaced periodic lattice of resonators, such as split-ring resonators, that all resonate. Previous metamaterials provide a negative index of refraction when a sub-wavelength spacing is used for the resonators.

In the microwave regime, certain techniques have been developed to utilize radiation-absorbing materials or coatings to reduce the radar cross section of airborne missiles and vehicles. While such absorbing materials can provide an effective reduction in radar cross section, these results are largely limited to small ranges of electromagnetic radiation.

SUMMARY

Embodiments of the present disclosure can provide techniques, including systems and/or methods, for cloaking objects at certain wavelengths/frequencies or over certain wavelength/frequency ranges (bands). Such techniques can provide an effective electromagnetic lens and/or lensing effect for certain wavelengths/frequencies or over certain wavelength/frequency ranges (bands).

The effects produced by such techniques can include cloaking or so-called invisibility of the object(s) at the noted wavelengths or bands. Representative frequencies of operation can include, but are not limited to, those over a range of 500 MHz to 1.3 GHz, though others may of course be realized. Operation at other frequencies, including for example those of visible light, infrared, ultraviolet, and as well as microwave EM radiation, e.g., K, Ka, X-bands, etc. may be realized, e.g., by appropriate scaling of dimensions and selection of shape of the resonator elements.

Exemplary embodiments of the present disclosure can include a novel arrangement of resonators in an aperiodic configuration or lattice. The overall assembly of resonators, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry ("grouping") corresponds to a moderate or high "Q" (that is moderate or low bandwidth) response that resonates within a specific frequency range, and that arrangement within that specific grouping of akin elements is periodic in the overall structure—even though the structure as a whole is not an entirely periodic arrangement of resonators. The relative spacing and arrangement of groupings (at least one for each specific frequency range) can be defined by self similarity and origin symmetry, where the "origin" arises at the center of a structure (or part of the structure) individually designed to have the wideband metamaterial property.

For exemplary embodiments, fractal resonators can be used for the resonators in such structures because of their control of passbands, and smaller sizes compared to non-fractal based resonators. Their benefit arises from a size standpoint because they can be used to shrink the resonator (s), while control of passbands can reduce or eliminates issues of harmonic passbands that would resonate at frequencies not desired.

It should be understood that other embodiments of wideband electromagnetic resonator or cloaking systems and methods according to the present disclosure will become readily apparent to those skilled in the art from the following detailed description, wherein exemplary embodiments are shown and described by way of illustration. The systems and methods of the present disclosure are capable of other and different embodiments, and details of such are capable of modification in various other respects. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the disclosure may be more fully understood from the following description when read together with the accompanying drawings, which are to be regarded as illustrative in nature, and not as limiting. The drawings are not necessarily to scale, emphasis instead being placed on the principles of the disclosure. In the drawings:

FIG. **1** depicts a diagrammatic plan view of a resonator cloaking system utilizing a number of cylindrical shells, in accordance with exemplary embodiments of the present disclosure;

FIG. **2** depicts a diagrammatic plan view of a resonator cloaking system utilizing a number of shells having an elliptical cross-section, in accordance with an alternate embodiment of the present disclosure;

FIG. **3** depicts an exemplary embodiment of a portion of shell that includes repeated conductive traces that are configured in a fractal-like shape; and

FIG. **4** depicts a perspective view (photograph) of an exemplary embodiment of the present disclosure.

While certain embodiments depicted in the drawings, one skilled in the art will appreciate that the embodiments depicted are illustrative and that variations of those shown, as well as other embodiments described herein, may be envisioned and practiced within the scope of the present disclosure.

DETAILED DESCRIPTION

The present disclosure is directed to novel arrangements of resonators useful for obscuring or hiding objects at given bands of electromagnetic radiation. Embodiments of the present disclosure can provide techniques, including systems and/or methods, for hiding or obscuring objects at certain wavelengths/frequencies or over certain wavelength/frequency ranges or bands. Such techniques can provide an

effective electromagnetic lens and/or lensing effect for certain wavelengths/frequencies or over certain wavelength/frequency ranges or bands. The effects produced by such techniques can include cloaking or so-called invisibility of the object(s) at the noted wavelengths or bands.

Representative frequencies of operation can include, but are not limited to, those over a range of about 500 MHz to about 1.3 GHz, though others may of course be realized. Operation at other frequencies, including for example those of visible light, infrared, ultraviolet, and as well as microwave EM radiation, e.g., K, Ka, X-bands, etc. may be realized, e.g., by appropriate scaling of dimensions and selection of shape of the resonator elements.

Embodiments of the present disclosure include arrangement of resonators or resonant structures in aperiodic configurations or lattices. The overall assembly of resonator structures can include nested or concentric shells, that each include repeated patterns of resonant structures. The resonant structures can be configured as a close-packed arrangement of electrically conductive material. The resonant structures can be located on the surface of a circuit board.

The overall assemblies, as structures, do not all repeat periodically and at least some of the resonators are spaced such that their phase centers are separated by more than a wavelength. The arrangements can include resonators of several different sizes and/or geometries arranged so that each size or geometry ("grouping") corresponds to a moderate or high quality-factor "Q" response (that is, one allowing for a moderate or low bandwidth) that resonates within a specific frequency range, and that arrangement within that specific grouping of like elements is periodic in the overall structure—even though the structure as a whole is not an entirely periodic arrangement of resonators. The relative spacing and arrangement of groupings (at least one for each specific frequency range) can be defined by self similarity and origin symmetry, where the "origin" arises at the center of a structure (or part of the structure) individually designed to have the wideband metamaterial property.

For exemplary embodiments, fractal resonators can be used for the resonators because of their control of passbands, and smaller sizes. A main benefit of such resonators arises from a size standpoint because they can be used to shrink the resonator(s), while control of passbands can reduce/mitigate or eliminate issues of harmonic passbands that would resonate at frequencies not desired.

Exemplary embodiments of a resonator system for use at microwave (or nearby) frequencies can be built from belts of circuit boards festooned with resonators. These belts can function to slip the microwaves around an object located within the belts, so the object is effectively invisible and "see thru" at the microwave frequencies. Belts, or shells, having similar closed-packed arrangements for operation at a first passband can be positioned within a wavelength of one another, e.g., $\frac{1}{10}\lambda$, $\frac{1}{8}\lambda$, $\frac{1}{4}\lambda$, $\frac{1}{2}\lambda$, etc.

An observer can observe an original image or signal, without it being blocked by the cloaked object. Using no power, the fractal cloak can replicates the original signal (that is, the signal before blocking) with great fidelity. Exemplary embodiments can function over a bandwidth from about 500 MHz to approximately 1500 MHz (1.5 GHz), providing 3:1 bandwidth; operation within or near such can frequencies can provide other bandwidths as well, such as 1:1 up to 2:1 and up to about 3:1.

FIG. **1** depicts a diagrammatic plan view of a cloaking system **100** and RF testing set up in accordance with exemplary embodiments of the present disclosure. As shown in FIG. **1**, a number of concentric shells (or bands) **102** are placed on a platform (parallel to the plane of the drawing). The shells include a flexible substrate (e.g., polyimide with or without composite reinforcement) with conductive traces (e.g., copper, silver, etc.) in fractal shapes or outlines. The shells **102** surround an object to be cloaked (shown as **104** in FIG. **1**). A transmitting antenna **1** and a receiving antenna **2** are configured at different sides of the system **100**, for verifying efficacy of the cloaking system **100** and recording results. The shells **102** can be held in place by radial supports **106** (while only four are shown, **12** were used in the exemplary embodiment indicated).

The shells indicated in FIG. **1** are of two types, one set (A**1**-A**4**) configured for optimal operation over a first wavelength/frequency range, and another set (B**1**-B**3**) configured for optimal operation over a second wavelength/frequency range. (The numbering of the shells is of course arbitrary and can be reordered, e.g., reversed.)

For an exemplary embodiment of system **100**, the outer set of shells (A**1**-A**4**, with A**1** being the innermost and A**4** the outmost) had a height of about 3 to 4 inches (e.g., 3.5 inches) and the inner set of shells had a height of about 1 inch less (e.g., about 2.5 to 3 inches). The spacing between the shells with a larger fractal shape (A**1**-A**4**) was about 2.4 cm while the spacing between shells of smaller fractal generator shapes (B**1**-B**3**) was about 2.15 cm (along a radial direction). In a preferred embodiment, shell A**4** was placed between shell B**2** and B**3** as shown. The resonators formed on each shell by the fractal shapes can be configured so as to be closely coupled (e.g., by capacitive coupling) and can serve to propagate a plasmonic wave.

It will be appreciated that while, two types of shells and a given number of shells per set are indicated in FIG. **1**, the number of shell types and number of shells for each set can be selected as desired, and may be optimized for different applications, e.g., wavelength/frequency bands.

FIG. **2** depicts a diagrammatic plan view of a cloaking system (or electrical resonator system) according to an alternate embodiment in which the individual shells have an elliptical cross section. As shown in FIG. **2**, a system **200** for cloaking can include a number of concentric shells (or bands) **202**. These shells can be held in place with respect to one another by suitable fixing means, e.g., they can be placed on a platform (parallel to the plane of the drawing) and/or held with a frame. The shells **202** can include a flexible substrate (e.g., polyimide with or without composite reinforcement) with a close-packed arrangement of electrically conductive material formed on the first surface. As stated previously for FIG. **1**, the closed-packed arrangement can include a number of self-similar electrical resonator shapes. The resonator shapes can be made from conductive traces (e.g., copper, silver, gold, silver-based ink, etc.) having a desired shape, e.g., fractal shape, split-ring shape, and the like. The shells **202** can surround an object to be cloaked, as indicated in FIG. **2**.

As indicated in FIG. **2** (by dashed lines **1** and **2** and arrows), the various shells themselves do not have to form closed surfaces. Rather, one or more shells can form open surfaces. This can allow for preferential cloaking of the object in one direction or over a given angle (solid angle). Moreover, while dashed lines **1** and **2** are shown intersecting shells B**1**-B**3** and A**1**-A**3** of system **200**, one or more shells of each group of shells (B**1**-B**3** and A**1**-A**3**) can be closed while others are open.

With further regard to FIGS. **1**-**2**, it should be appreciated that the cross-sections shown for each shell can represent closed geometric shapes, e.g., spherical and ellipsoidal shells.

As indicated previously, each shell of a cloaking system can include multiple resonators. The resonators can be repeated patterns of conductive traces. These conductive traces can be closed geometric shapes, e.g., rings, loops, closed fractals, etc. The resonator(s) can being self similar to at least second iteration. The resonators can include split-ring shapes, for some embodiments. The resonant structures are not required to be closed shapes, however, and open shapes can be used for such.

In exemplary embodiments, the closed loops can be configured as a fractals or fractal-based shapes, e.g., as depicted by **302** in FIG. **3** for an exemplary embodiment of a shell **300**, or **402** in FIG. **4**. The dimensions and type of fractal shape can be the same for each shell type but can vary between shell types. This variation (e.g., scaling of the same fractal shape) can afford increased bandwidth for the cloaking characteristics of the system (e.g., system **100** of FIG. **1**) This can lead to periodicity of the fractal shapes of common shell types but aperiodicity between the fractal shapes of different shell types.

Examples of suitable fractal shapes (for use for shells and/or a scatting object) can include, but are not limited to, fractal shapes described in one or more of the following patents, owned by the assignee of the present disclosure, the entire contents of all of which are incorporated herein by reference: U.S. Pat. Nos. 6,452,553; 6,104,349; 6,140,975; 7,145,513; 7,256,751; 6,127,977; 6,476,766; 7,019,695; 7,215,290; 6,445,352; 7,126,537; 7,190,318; 6,985,122; 7,345,642; and, U.S. Pat. No. 7,456,799.

Other suitable fractal shape for the resonant structures can include any of the following: a Koch fractal, a Minkowski fractal, a Cantor fractal, a torn square fractal, a Mandelbrot, a Caley tree fractal, a monkey's swing fractal, a Sierpinski gasket, and a Julia fractal, a contour set fractal, a Sierpinski triangle fractal, a Menger sponge fractal, a dragon curve fractal, a space-filling curve fractal, a Koch curve fractal, an Iypanov fractal, and a Kleinian group fractal.

FIG. **3** depicts an exemplary embodiment of a shell **300** (only a portion is shown) that includes repeated conductive traces that are configured in a fractal shape **302** (the individual closed traces). For the exemplary embodiment shown, each resonator shape **302** is about 1 cm on a side. Such resonator could, e.g., be used for the fractal shapes of shells B1-B3 of FIG. **1**, in which case similar fractal shapes of larger size (e.g., about 1.5 cm on a side) could be used for shells A1-A4. The conductive trace is preferably made of copper. While exemplary fractal shapes are shown in FIG. **3**, the present disclosure is not limited to such and any other suitable fractal shapes (including generator motifs) may be used in accordance with the present disclosure.

It will be appreciated that the resonant structures of the shells may be formed or made by any suitable techniques and with any suitable materials. For example, semiconductors with desired doping levels and dopants may be used as conductive materials. Suitable metals or metal containing compounds may be used. Suitable techniques may be used to place conductors on/in a shell, including, but no limited to, printing techniques, photolithography techniques, etching techniques, and the like.

It will also be appreciated that the shells may be made of any suitable material(s). Printed circuit board materials may be used. Flexible circuit board materials are preferred. Other material may, however, be used for the shells and the shells themselves can be made of non-continuous elements, e.g., a frame or framework. For example, various plastics may be used.

FIG. **4** depicts a perspective view (photograph) of an exemplary embodiment of a cloak system **400** according to the present disclosure. As shown, the system includes a number of resonator shells **402** each having a close-packed arrangement of electrically conductive material (self-similar resonators **404**) formed on one surface. Two different shell configurations are shown, four larger shells and two smaller shells. The smaller shells included close-packed arrangements of resonator structures in which each resonator shape (as shown by **302** in FIG. **3**) was about 1 cm on a side. Similar fractal shapes of larger size (e.g., about 1.5 cm on a side) were used for the larger shells.

In FIG. **4**, a transmitting (source) antenna and a receiving antenna are shown as triangular shapes on the left and right, respectively (though functionally of each could of course be interchanged for the other). Twelve radially arrayed spacers are shown in FIG. **4**. The system **400** is shown supported on a Nalgene tank and Delrin platform and Delrin supports (radial supports) RF absorbers were placed in the immediate vicinity of the set up; further RF tripods (e.g., available from ETS) were used; all such materials were substantially transparent at the RF frequencies investigated/used. The cloak system **400** consists of six belts of fractal metamaterial (i.e., fractal-resonant structures shown in FIG. **3**) on flexible Taconic EF35 (low loss) circuit board. The belts are shown surround a scattering ring (object). The arrangement is supported by RF transparent plastics in a comb support. The entire system **400** was shown to be easily built up and broken down within a minute or two. The scale in FIG. **4** is about 0.7 meters across. The height of each shell can of course be selected as desired depending on the situation/application.

While embodiments are shown and described herein as having shells in the shape of concentric rings (circular cylinders), shells can take other shapes in other embodiments. For example, one or more shells could have a generally spherical shape (with minor deviations for structural support). In an exemplary embodiment, the shells could form a nested arrangement of such spherical shapes, around an object to be shielded (at the targeted/selected frequencies/wavelengths). Shell cross-sections of angular shapes, e.g., triangular, hexagonal, while not preferred, may be used.

One skilled in the art will appreciate that embodiments and/or portions of embodiments of the present disclosure can be implemented in/with computer-readable storage media (e.g., hardware, software, firmware, or any combinations of such), and can be distributed and/or practiced over one or more networks. Steps or operations (or portions of such) as described herein, including processing functions to derive, learn, or calculate formula and/or mathematical models utilized and/or produced by the embodiments of the present disclosure, can be processed by one or more suitable processors, e.g., central processing units ("CPUs") implementing suitable code/instructions in any suitable language (machine dependent on machine independent).

While certain embodiments and/or aspects have been described herein, it will be understood by one skilled in the art that the methods, systems, and apparatus of the present disclosure may be embodied in other specific forms without departing from the spirit thereof.

For example, while certain wavelengths/frequencies of operation have been described, these are merely representative and other wavelength/frequencies may be utilized or achieved within the scope of the present disclosure.

Furthermore, while certain preferred fractal generator shapes have been described others may be used within the scope of the present disclosure. Accordingly, the embodi-

ments described herein are to be considered in all respects as illustrative of the present disclosure and not restrictive.

What is claimed is:

1. An electrical resonator system, comprising:

a plurality of concentric electrical resonator shells, each shell including a substrate having first and second surfaces and a close-packed arrangement of electrically conductive material formed on the first surface, wherein the closed-packed arrangement comprises a plurality of self-similar electrical resonator shapes and is configured to operate at a desired passband of electromagnetic radiation;

wherein the close-packed arrangements of at least two of the electrical resonator shells are different in size and/or shape; and

wherein a resonator in the close-packed arrangement comprises a second order or higher fractal.

2. The system of claim **1**, wherein said passband is about 2:1.

3. The system of claim **2**, wherein said passband is about 3:1.

4. The system of claim **1**, wherein the electrical system is configured and arranged so that radiation incident on the system from a given direction has an intensity on a point-by-point basis such at each respective antipodal point, relative to an object placed at the center of the system, the radiation has the same or similar intensity.

5. The system of claim **1**, wherein the system is configured and arranged so that radiation incident on the system from a direction in cylindrical coordinates has the same or similar intensity at the antipodal point after having traversed the system.

6. The system of claim **1**, wherein the plurality of shells comprises a first pair of shells having similar closed-packed arrangements for operation at a first passband, wherein the two shells are positioned within $\frac{1}{8}\lambda$ of one another.

7. The system of claim **6**, wherein the plurality of shells comprises a second pair of shells having similar closed-packed arrangements for operation at a second frequency band, wherein the two shells are positioned within $\frac{1}{8}\lambda$ of one another.

8. The system of claim **1**, wherein the plurality of shells are hemispherical.

9. The system of claim **1**, wherein the plurality of shells are cylindrical.

10. The system of claim **1**, wherein the plurality of shells are spherical.

11. The system of claim **1**, wherein said fractal is selected from the group consisting of a Koch fractal, a Minkowski fractal, a Cantor fractal, a torn square fractal, a Mandelbrot, a Caley tree fractal, a monkey's swing fractal, a Sierpinski gasket, and a Julia fractal.

12. The system of claim **1**, wherein the fractal is selected from the group consisting of a contour set fractal, a Sierpinski triangle fractal, a Menger sponge fractal, a dragon curve fractal, a space-filling curve fractal, a Koch curve fractal, a Lypanov fractal, and a Kleinian group fractal.

13. The system of claim **1**, wherein the plurality of concentric electrical resonator shells are configured and arranged for operation at K band, Ka band, or X-band.

14. The system of claim **1**, wherein the system is operational over a bandwidth from about 500 MHz to about 1500 MHz.

* * * * *

United States Patent [19]

Eastlund

[11] **Patent Number: 4,686,605**

[45] **Date of Patent: Aug. 11, 1987**

[54] **METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE**

[75] Inventor: **Bernard J. Eastlund**, Spring, Tex.

[73] Assignee: **APTI, Inc.**, Los Angeles, Calif.

[21] Appl. No.: **690,333**

[22] Filed: **Jan. 10, 1985**

[51] **Int. Cl.**[4] **H05B 6/64**; H05C 3/00; H05H 1/46

[52] **U.S. Cl.** ..... **361/231**; 89/1.11; 380/59; 244/158 R

[58] **Field of Search** ..... 361/230, 231; 244/158 R; 376/100; 89/1.11; 380/59

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Primary Examiner—Salvatore Cangialosi
Attorney, Agent, or Firm—Roderick W. MacDonald

[57] **ABSTRACT**

A method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating to thereby increase its charged particle density. In one embodiment, circularly polarized electromagnetic radiation is transmitted upward in a direction substantially parallel to and along a field line which extends through the region of plasma to be altered. The radiation is transmitted at a frequency which excites electron cyclotron resonance to heat and accelerate the charged particles. This increase in energy can cause ionization of neutral particles which are then absorbed as part of the region thereby increasing the charged particle density of the region.

15 Claims, 5 Drawing Figures

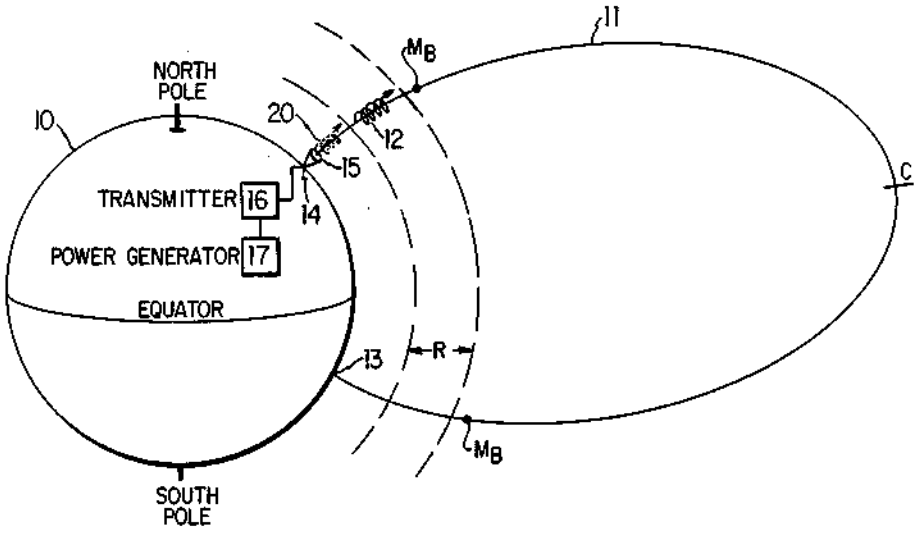

FIG. 1

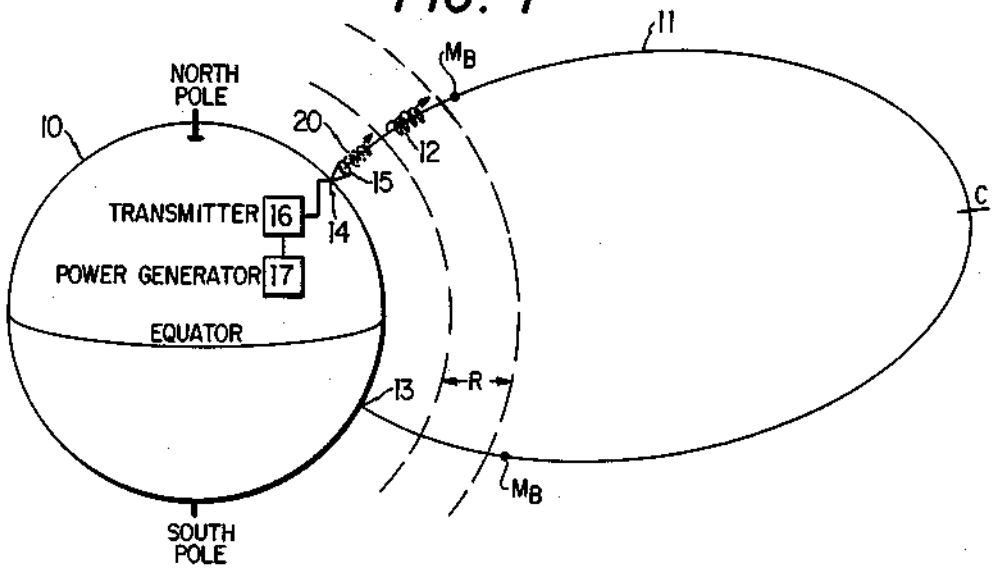
NORTH POLE
10
20
M_B
11
12
15
C
TRANSMITTER 16
14
POWER GENERATOR 17
EQUATOR
13
R
M_B
SOUTH POLE

FIG. 2

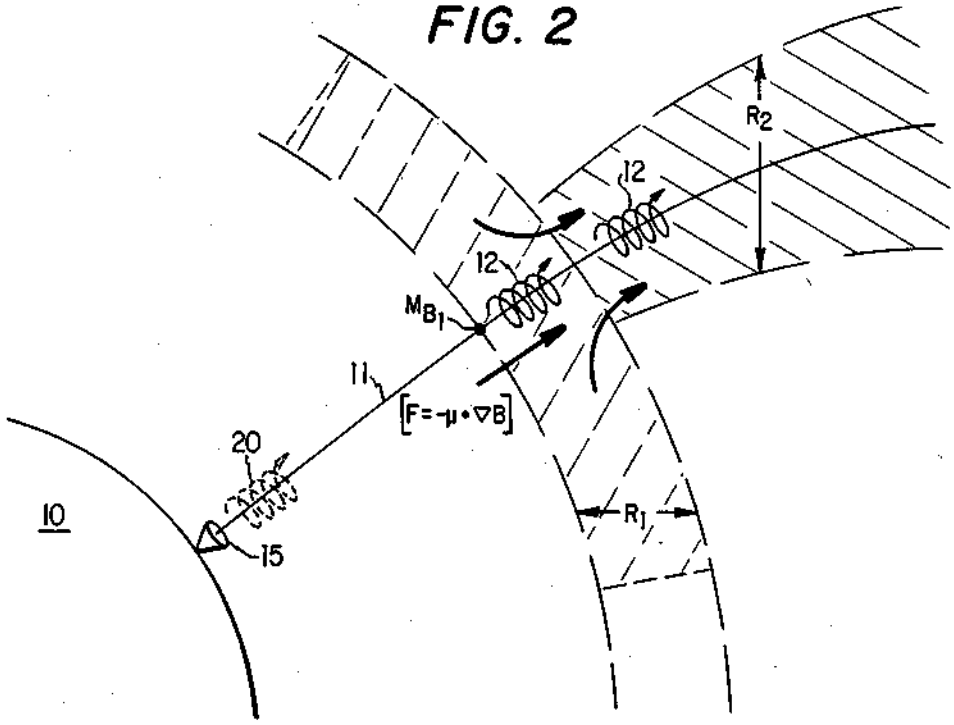
R_2
12
12
M_{B_1}
11
$[F=-\mu\cdot\nabla B]$
20
10
15
R_1

FIG. 3

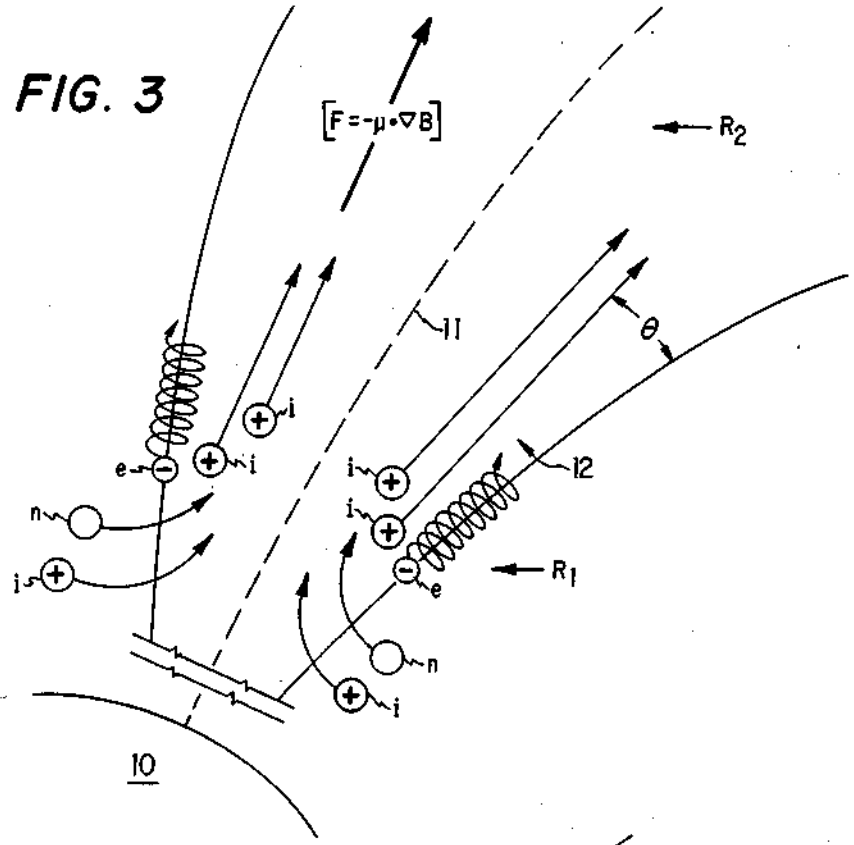

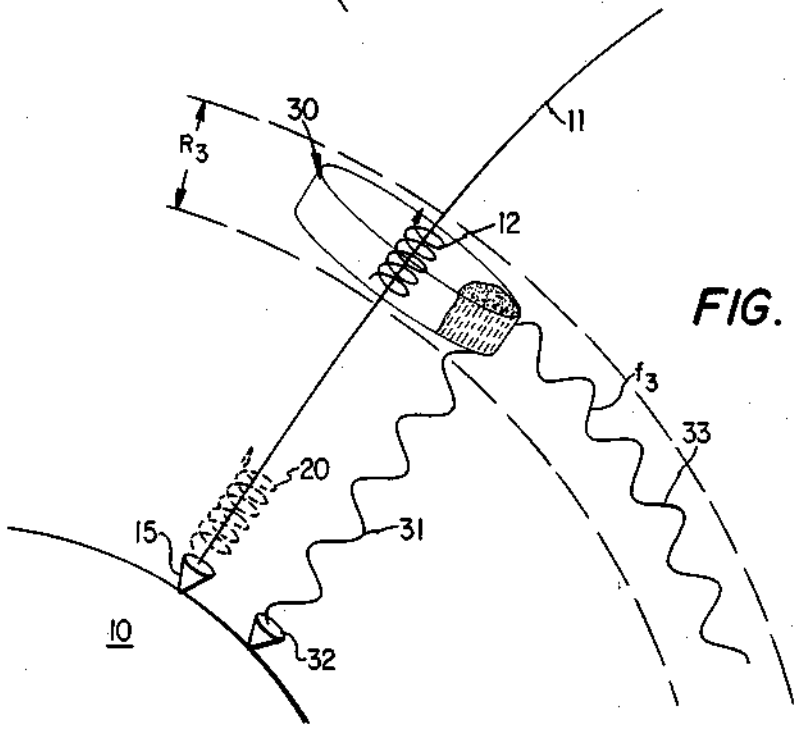

FIG. 4

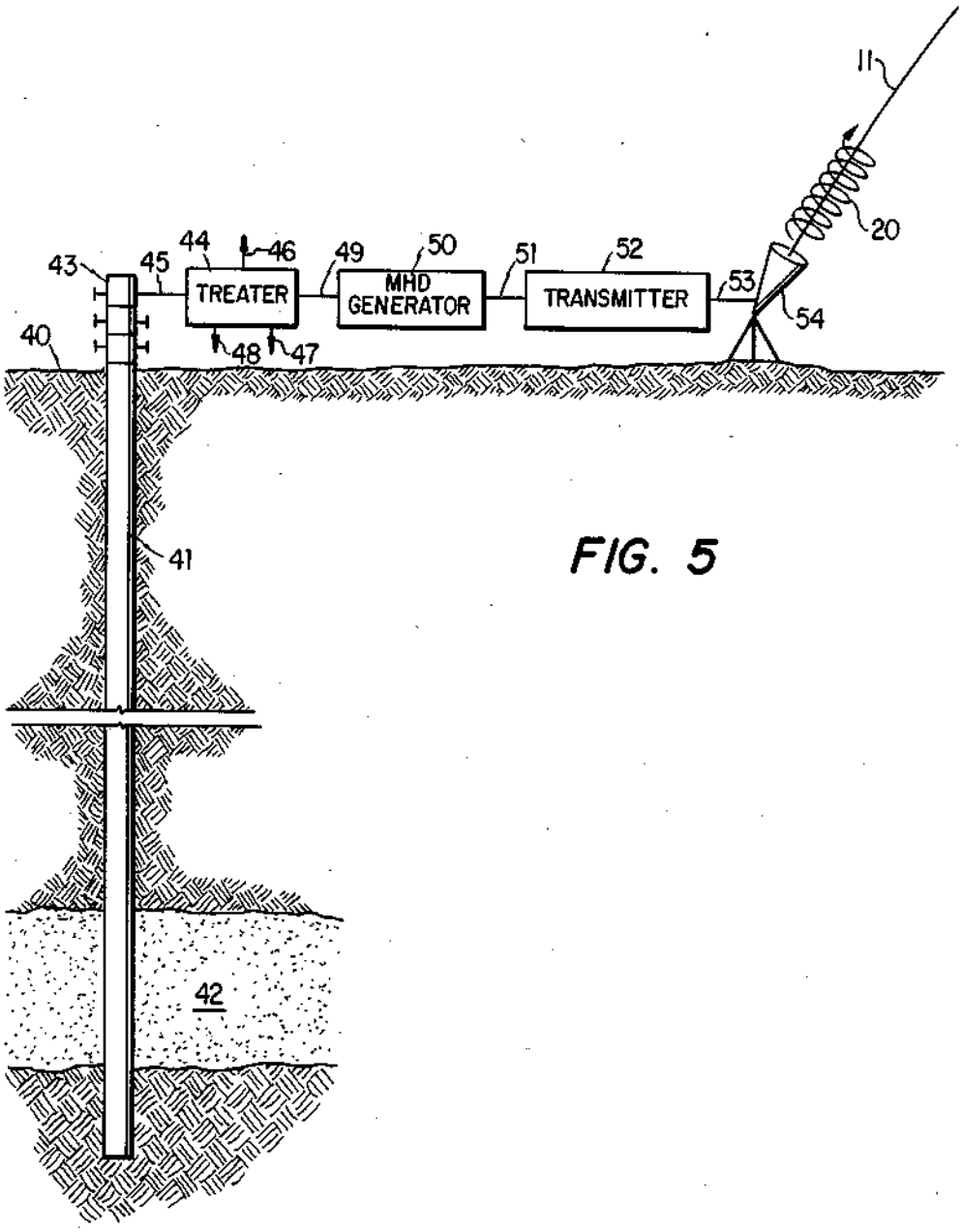
11
20
43
45
44
46
49
50
51
52
53
54
TREATER
MHD GENERATOR
TRANSMITTER
40
48
47
41
42

FIG. 5

METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

DESCRIPTION

1. Technical Field

This invention relates to a method and apparatus for altering at least one selected region normally existing above the earth's surface and more particularly relates to a method and apparatus for altering said at least one region by initially transmitting electromagnetic radiation from the earth's surface essentially parallel to and along naturally-occurring, divergent magnetic field lines which extend from the earth's surface through the region or regions to be altered.

2. Background Art

In the late 1950's, it was discovered that naturally-occuring belts exist at high altitudes above the earth's surface, and it is now established that these belts result from charged electrons and ions becoming trapped along the magnetic lines of force (field lines) of the earth's essentially dipole magnetic field. The trapped electrons and ions are confined along the field lines between two magnetic mirrors which exist at spaced apart points along those field lines. The trapped electrons and ions move in helical paths around their particular field lines and "bounce" back and forth between the magnetic mirrors. These trapped electrons and ions can oscillate along the field lines for long periods of time.

In the past several years, substantial effort has been made to understand and explain the phenomena involved in belts of trapped electrons and ions, and to explore possible ways to control and use these phenomena for beneficial purposes. For example, in the late 1950's and early 1960's both the United States and U.S.S.R. detonated a series of nuclear devices of various yields to generate large numbers of charged particles at various altitudes, e.g., 200 kilometers (km) or greater. This was done in order to establish and study artifical belts of trapped electrons and ions. These experiments established that at least some of the extraneous electrons and ions from the detonated devices did become trapped along field lines in the earth's magnetosphere to form artificial belts which were stable for prolonged periods of time. For a discussion of these experiments see "The Radiation Belt and Magnetosphere", W. N. Hess, Blaisdell Publishing Co., 1968, pps. 155 et sec.

Other proposals which have been advanced for altering existing belts of trapped electrons and ions and/or establishing similar artificial belts include injecting charged particles from a satellite carrying a payload of radioactive beta-decay material or alpha emitters; and injecting charged particles from a satellite-borne electron accelerator. Still another approach is described in U.S. Pat. No. 4,042,196 wherein a low energy ionized gas, e.g., hydrogen, is released from a synchronous orbiting satellite near the apex of a radiation belt which is naturally-occurring in the earth's magnetosphere to produce a substantial increase in energetic particle precipitation and, under certain conditions, produce a limit in the number of particles that can be stably trapped. This precipitation effect arises from an enhancement of the whistler-mode and ion-cyclotron mode interactions that result from the ionized gas or "cold plasma" injection.

It has also been proposed to release large clouds of barium in the magnetosphere so that photoionization will increase the cold plasma density, thereby producing electron precipitation through enhanced whistler-mode interactions.

However, in all of the above-mentioned approaches, the mechanisms involved in triggering the change in the trapped particle phenomena must be actually positioned within the affected zone, e.g., the magnetosphere, before they can be actuated to effect the desired change.

The earth's ionosphere is not considered to be a "trapped" belt since there are few trapped particles therein. The term "trapped" herein refers to situations where the force of gravity on the trapped particles is balanced by magnetic forces rather than hydrostatic or collisional forces. The charged electrons and ions in the ionosphere also follow helical paths around magnetic field lines within the ionosphere but are not trapped between mirrors, as in the case of the trapped belts in the magnetosphere, since the gravitational force on the particles is balanced by collisional or hydrostatic forces.

In recent years, a number of experiments have actually been carried out to modify the ionosphere in some controlled manner to investigate the possibility of a beneficial result. For detailed discussions of these operations see the following papers: (1) Ionospheric Modification Theory; G. Meltz and F. W. Perkins; (2) The Platteville High Power Facility; Carrol et al.; (3) Arecibo Heating Experiments; W. E. Gordon and H. C. Carlson, Jr.; and (4) Ionospheric Heating by Powerful Radio Waves; Meltz et al., all published in Radio Science, Vol. 9, No. 11, November, 1974, at pages 885–888; 889–894; 1041–1047; and 1049–1063, respectively, all of which are incorporated herein by reference. In such experiments, certain regions of the ionosphere are heated to change the electron density and temperature within these regions. This is accomplished by transmitting from earth-based antennae high frequency electromagnetic radiation at a substantial angle to, not parallel to, the ionosphere's magnetic field to heat the ionospheric particles primarily by ohmic heating. The electron temperature of the ionosphere has been raised by hundreds of degrees in these experiments, and electrons with several electron volts of energy have been produced in numbers sufficient to enhance airglow. Electron concentrations have been reduced by a few percent, due to expansion of the plasma as a result of increased temperature.

In the Elmo Bumpy Torus (EBT), a controlled fusion device at the Oak Ridge National Laboratory, all heating is provided by microwaves at the electron cyclotron resonance interaction. A ring of hot electrons is formed at the earth's surface in the magnetic mirror by a combination of electron cyclotron resonance and stochastic heating. In the EBT, the ring electrons are produced with an average "temperature" of 250 kilo electron volts or kev (2.5×10^9K) and a plasma beta between 0.1 and 0.4; see, "A Theoretical Study of Electron—Cyclotron Absorption in Elmo Bumpy Torus", Batchelor and Goldfinger, Nuclear Fusion, Vol. 20, No. 4 (1980) pps. 403–418.

Electron cyclotron resonance heating has been used in experiments on the earth's surface to produce and accelerate plasmas in a diverging magnetic field. Kosmahl et al. showed that power was transferred from the electromagnetic waves and that a fully ionized plasma

was accelerated with a divergence angle of roughly 13 degrees. Optimum neutral gas density was 1.7×10^{14}per cubic centimeter; see, "Plasma Acceleration with Microwaves Near Cyclotron Resonance", Kosmahl et al., Journal of Applied Physics, Vol. 38, No. 12, Nov., 1967, pps. 4576–4582.

DISCLOSURE OF THE INVENTION

The present invention provides a method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating of electrons which are already present and/or artifically created in the region to thereby increase the charged particle energy and ultimately the density of the region.

In one embodiment this is done by transmitting circularly polarized electromagnetic radiation from the earth's surface at or near the location where a naturally-occurring dipole magnetic field (force) line intersects the earth's surface. Right hand circular polarization is used in the northern hemisphere and left hand circular polarization is used in the southern hemisphere. The radiation is deliberately transmitted at the outset in a direction substantially parallel to and along a field line which extends upwardly through the region to be altered. The radiation is transmitted at a frequency which is based on the gyrofrequency of the charged particles and which, when applied to the at least one region, excites electron cyclotron resonance within the region or regions to heat and accelerate the charged particles in their respective helical paths around and along the field line. Sufficient energy is employed to cause ionization of neutral particles (molecules of oxygen, nitrogen and the like, particulates, etc.) which then become a part of the region thereby increasing the charged particle density of the region. This effect can further be enhanced by providing artificial particles, e.g., electrons, ions, etc., directly into the region to be affected from a rocket, satellite, or the like to supplement the particles in the naturally-occurring plasma. These artificial particles are also ionized by the transmitted electromagnetic radiation thereby increasing charged particle density of the resulting plasma in the region.

In another embodiment of the invention, electron cyclotron resonance heating is carried out in the selected region or regions at sufficient power levels to allow a plasma present in the region to generate a mirror force which forces the charged electrons of the altered plasma upward along the force line to an altitude which is higher than the original altitude. In this case the relevant mirror points are at the base of the altered region or regions. The charged electrons drag ions with them as well as other particles that may be present. Sufficient power, e.g., 10^{15}joules, can be applied so that the altered plasma can be trapped on the field line between mirror points and will oscillate in space for prolonged periods of time. By this embodiment, a plume of altered plasma can be established at selected locations for communication modification or other purposes.

In another embodiment, this invention is used to alter at least one selected region of plasma in the ionosphere to establish a defined layer of plasma having an increased charged particle density. Once this layer is established, and while maintaining the transmission of the main beam of circularly polarized electromagnetic radiation, the main beam is modulated and/or at least one second different, modulated electromagnetic radiation beam is transmitted from at least one separate source at a different frequency which will be absorbed in the plasma layer. The amplitude of the frequency of the main beam and/or the second beam or beams is modulated in resonance with at least one known oscillation mode in the selected region or regions to excite the known oscillation mode to propagate a known frequency wave or waves throughout the ionosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and apparent advantages of this invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. **1** is a simplified schematical view of the earth (not to scale) with a magnetic field (force) line along which the present invention is carried out;

FIG. **2** is one embodiment within the present invention in which a selected region of plasma is raised to a higher altitude;

FIG. **3** is a simplified, idealized representation of a physical phenomenon involved in the present invention; and

FIG. **4** is a schematic view of another embodiment within the present invention.

FIG. **5** is a schematic view of an apparatus embodiment within this invention.

BEST MODES FOR CARRYING OUT THE INVENTION

The earth's magnetic field is somewhat analogous to a dipole bar magnet. As such, the earth's magnetic field contains numerous divergent field or force lines, each line intersecting the earth's surface at points on opposite sides of the Equator. The field lines which intersect the earth's surface near the poles have apexes which lie at the furthest points in the earth's magnetosphere while those closest to the Equator have apexes which reach only the lower portion of the magnetosphere.

At various altitudes above the earth's surface, e.g., in both the ionosphere and the magnetosphere, plasma is naturally present along these field lines. This plasma consists of equal numbers of positively and negatively charged particles (i.e., electrons and ions) which are guided by the field line. It is well established that a charged particle in a magnetic field gyrates about field lines, the center of gyration at any instance being called the "guiding center" of the particle. As the gyrating particle moves along a field line in a uniform field, it will follow a helical path about its guiding center, hence linear motion, and will remain on the field line. Electrons and ions both follow helical paths around a field line but rotate in opposite directions. The frequencies at which the electrons and ions rotate about the field line are called gyromagnetic frequencies or cyclotron frequencies because they are identical with the expression for the angular frequencies of gyration of particles in a cyclotron. The cyclotron frequency of ions in a given magnetic field is less than that of electrons, in inverse proportion to their masses.

If the particles which form the plasma along the earth's field lines continued to move with a constant pitch angle, often designated "alpha", they would soon impact on the earth's surface. Pitch angle alpha is defined as the angle between the direction of the earth's magnetic field and the velocity (V) of the particle. However, in converging force fields, the pitch angle does change in such a way as to allow the particle to

turn around and avoid impact. Consider a particle moving along a field line down toward the earth. It moves into a region of increasing magnetic field strength and therefore sine alpha increases. But sine alpha can only increase to 1.0, at which point, the particle turns around and starts moving up along the field line, and alpha decreases. The point at which the particle turns around is called the mirror point, and there alpha equals ninety degrees. This process is repeated at the other end of the field line where the same magnetic field strength value B, namely Bm, exists. The particle again turns around and this is called the "conjugate point" of the original mirror point. The particle is therefore trapped and bounces between the two magnetic mirrors. The particle can continue oscillating in space in this manner for long periods of time. The actual place where a particle will mirror can be calculated from the following:

$$\sin^2 \text{alpha}_o = B_o/B_m \quad (1)$$

wherein:

alpha_o = equatorial pitch angle of particle

B_o = equatorial field strength on a particular field line

B_m = field strength at the mirror point

Recent discoveries have established that there are substantial regions of naturally trapped particles in space which are commonly called "trapped radiation belts". These belts occur at altitudes greater than about 500 km and accordingly lie in the magnetosphere and mostly above the ionosphere.

The ionosphere, while it may overlap some of the trapped-particle belts, is a region in which hydrostatic forces govern its particle distribution in the gravitational field. Particle motion within the ionosphere is governed by both hydrodynamic and electrodynamic forces. While there are few trapped particles in the ionosphere, nevertheless, plasma is present along field lines in the ionosphere. The charged particles which form this plasma move between collisions with other particles along similar helical paths around the field lines and although a particular particle may diffuse downward into the earth's lower atmosphere or lose energy and diverge from its original field line due to collisions with other particles, these charged particles are normally replaced by other available charged particles or by particles that are ionized by collision with said particle. The electron density (N_e) of the plasma will vary with the actual conditions and locations involved. Also, neutral particles, ions, and electrons are present in proximity to the field lines.

The production of enhanced ionization will also alter the distribution of atomic and molecular constituents of the atmosphere, most notably through increased atomic nitrogen concentration. The upper atmosphere is normally rich in atomic oxygen (the dominant atmospheric constituent above 200 km altitude), but atomic nitrogen is normally relatively rare. This can be expected to manifest itself in increased airglow, among other effects.

As known in plasma physics, the characteristics of a plasma can be altered by adding energy to the charged particles or by ionizing or exciting additional particles to increase the density of the plasma. One way to do this is by heating the plasma which can be accomplished in different ways, e.g., ohmic, magnetic compression, shock waves, magnetic pumping, electron cyclotron resonance, and the like.

Since electron cyclotron resonance heating is involved in the present invention, a brief discussion of same is in order. Increasing the energy of electrons in a plasma by invoking electron cyclotron resonance heating, is based on a principle similar to that utilized to accelerate charged particles in a cyclotron. If a plasma is confined by a static axial magnetic field of strength B, the charged particles will gyrate about the lines of force with a frequency given, in hertz, as $f_g = 1.54 \times 10^3 B/A$, where: B = magnetic field strength in gauss, and A = mass number of the ion.

Suppose a time-varying field of this frequency is superimposed on the static field B confining the plasma, by passage of a radiofrequency current through a coil which is concentric with that producing the axial field, then in each half-cycle of their rotation about the field lines, the charged particles acquire energy from the oscillating electric field associated with the radio frequency. For example, if B is 10,000 gauss, the frequency of the field which is in resonance with protons in a plasma is 15.4 megahertz.

As applied to electrons, electron cyclotron resonance heating requires an oscillating field having a definite frequency determined by the strength of the confining field. The radio-frequency radiation produces time-varying fields (electric and magnetic), and the electric field accelerates the charged particle. The energized electrons share their energy with ions and neutrals by undergoing collisions with these particles, thereby effectively raising the temperature of the electrons, ions, and neutrals. The apportionment of energy among these species is determined by collision frequencies. For a more detailed understanding of the physics involved, see "Controlled Thermonuclear Reactions", Glasstone and Lovberg, D. Van Nostrand Company, Inc., Princeton, N.J., 1960 and "The Radiation Belt and Magnetosphere", Hess, Blaisdell Publishing Company, 1968, both of which are incorporated herein by reference.

Referring now to the drawings, the present invention provides a method and apparatus for altering at least one region of plasma which lies along a field line, particularly when it passes through the ionosphere and/or magnetosphere. FIG. 1 is a simplified illustration of the earth 10 and one of its dipole magnetic force or field lines 11. As will be understood, line 11 may be any one of the numerous naturally existing field lines and the actual geographical locations 13 and 14 of line 11 will be chosen based on a particular operation to be carried out. The actual locations at which field lines intersect the earth's surface is documented and is readily ascertainable by those skilled in the art.

Line 11 passes through region R which lies at an altitude above the earth's surface. A wide range of altitudes are useful given the power that can be employed by the practice of this invention. The electron cyclotron resonance heating effect can be made to act on electrons anywhere above the surface of the earth. These electrons may be already present in the atmosphere, ionosphere, and/or magnetosphere of the earth, or can be artificially generated by a variety of means such as x-ray beams, charged particle beams, lasers, the plasma sheath surrounding an object such as a missile or meteor, and the like. Further, artificial particles, e.g., electrons, ions, etc., can be injected directly into region R from an earth-launched rocket or orbiting satellite carrying, for example, a payload of radioactive beta-decay material; alpha emitters; an electron accelerator; and/or ionized gases such as hydrogen; see U.S. Pat. No. 4,042,196. The altitude can be greater than about 50 km if desired,

e.g., can be from about 50 km to about 800 km, and, accordingly may lie in either the ionosphere or the magnetosphere or both. As explained above, plasma will be present along line **11** within region R and is represented by the helical line **12**. Plasma **12** is comprised of charged particles (i.e., electrons and ions) which rotate about opposing helical paths along line **11**.

Antenna **15** is positioned as close as is practical to the location **14** where line **11** intersects the earth's surface. Antenna **15** may be of any known construction for high directionality, for example, a phased array, beam spread angle (θ) type. See "The MST Radar at Poker Flat, Alaska", Radio Science, Vol. 15, No. 2, Mar.-Apr. 1980, pps. 213–223, which is incorporated herein by reference. Antenna **15** is coupled to transmitter **16** which generates a beam of high frequency electromagnetic radiation at a wide range of discrete frequencies, e.g., from about 20 to about 1800 kilohertz (kHz).

Transmitter **16** is powered by power generator means **17** which is preferably comprised of one or more large, commercial electrical generators. Some embodiments of the present invention require large amounts of power, e.g., up to $10^9$to 10^{11}watts, in continuous wave or pulsed power. Generation of the needed power is within the state of the art. Although the electrical generators necessary for the practice of the invention can be powered in any known manner, for example, by nuclear reactors, hydroelectric facilities, hydrocarbon fuels, and the like, this invention, because of its very large power requirement in certain applications, is particularly adapted for use with certain types of fuel sources which naturally occur at strategic geographical locations around the earth. For example, large reserves of hydrocarbons (oil and natural gas) exist in Alaska and Canada. In northern Alaska, particularly the North Slope region, large reserves are currently readily available. Alaska and northern Canada also are ideally located geographically as to magnetic latitudes. Alaska provides easy access to magnetic field lines that are especially suited to the practice of this invention, since many field lines which extend to desirable altitudes for this invention intersect the earth in Alaska. Thus, in Alaska, there is a unique combination of large, accessible fuel sources at desirable field line intersections. Further, a particularly desirable fuel source for the generation of very large amounts of electricity is present in Alaska in abundance, this source being natural gas. The presence of very large amounts of clean-burning natural gas in Alaskan latitudes, particularly on the North Slope, and the availability of magnetohydrodynamic (MHD), gas turbine, fuel cell, electrogasdynamic (EGD) electric generators which operate very efficiently with natural gas provide an ideal power source for the unprecedented power requirements of certain of the applications of this invention. For a more detailed discussion of the various means for generating electricity from hydrocarbon fuels, see "Electrical Aspects of Combustion", Lawton and Weinberg, Clarendon Press, 1969. For example, it is possible to generate the electricity directly at the high frequency needed to drive the antenna system. To do this, typically the velocity of flow of the combustion gases (v), past magnetic field perturbation of dimension d (in the case of MHD), follow the rule:

$$v=df$$

where f is the frequency at which electricity is generated. Thus, if $v=1.78\times10^6$ cm/sec and d=1 cm then electricity would be generated at a frequency of 1.78 mHz.

Put another way, in Alaska, the right type of fuel (natural gas) is naturally present in large amounts and at just the right magnetic latitudes for the most efficient practice of this invention, a truly unique combination of circumstances. Desirable magnetic latitudes for the practice of this invention interest the earth's surface both northerly and southerly of the equator, particularly desirable latitudes being those, both northerly and southerly, which correspond in magnitude with the magnetic latitudes that encompass Alaska.

Referring now to FIG. 2 a first ambodiment is illustrated where a selected region $R_1$of plasma **12** is altered by electron cyclotron resonance heating to accelerate the electrons of plasma **12**, which are following helical paths along field line **11**.

To accomplish this result, electromagnetic radiation is transmitted at the outset, essentially parallel to line **11** via antenna **15** as right hand circularly polarized radiation wave **20**. Wave **20** has a frequency which will excite electron cyclotron resonance with plasma **12** at its initial or original altitude. This frequency will vary depending on the electron cyclotron resonance of region R_1which, in turn, can be determined from available data based on the altitudes of region R_1, the particular field line **11** being used, the strength of the earth's magnetic field, etc. Frequencies of from about 20 to about 7200 kHz, preferably from about 20 to about 1800 kHz can be employed. Also, for any given application, there will be a threshhold (minimum power level) which is needed to produce the desired result. The minimum power level is a function of the level of plasma production and movement required, taking into consideration any loss processes that may be dominant in a particular plasma or propagation path.

As electron cyclotron resonance is established in plasma **12**, energy is transferred from the electromagnetic radiation **20** into plasma **12** to heat and accelerate the electrons therein and, subsequently, ions and neutral particles. As this process continues, neutral particles which are present within $R_1$are ionized and absorbed into plasma **12** and this increases the electron and ion densities of plasma **12**. As the electron energy is raised to values of about 1 kilo electron volt (kev), the generated mirror force (explained below) will direct the excited plasma **12** upward along line **11** to form a plume R_2at an altitude higher than that of R_1.

Plasma acceleration results from the force on an electron produced by a nonuniform static magnetic field ($\overline{B}$). The force, called the mirror force, is given by

$$F=-\mu\nabla B \tag{2}$$

where μ is the electron magnetic moment and $\nabla\overline{B}$ is the gradient of the magnetic field, μ being further defined as:

$$W_\perp/B=mV_\perp^2/2B$$

where $W_\perp$is the kinetic energy in the direction perpendicular to that of the magnetic field lines and B is the magnetic field strength at the line of force on which the guiding center of the particle is located. The force as represented by equation (2) is the force which is responsible for a particle obeying equation (1).

Since the magnetic field is divergent in region R_1, it can be shown that the plasma will move upwardly from the heating region as shown in FIG. 1 and further it can be shown that

$$\tfrac{1}{2}M_eV_{e\perp}^2(x)\approx\tfrac{1}{2}M_eV_{e\perp}^2(Y)+\tfrac{1}{2}M_iV_{i\parallel}^2(Y) \quad (3)$$

where the left hand side is the initial electron transverse kinetic energy; the first term on the right is the transverse electron kinetic energy at some point (Y) in the expanded field region, while the final term is the ion kinetic energy parallel to B at point (Y). This last term is what constitutes the desired ion flow. It is produced by an electrostatic field set up by electrons which are accelerated according to Equation (2) in the divergent field region and pulls ions along with them. Equation (3) ignores electron kinetic energy parallel to B because $V_{e\parallel}\approx V_{i\parallel}$, so the bulk of parallel kinetic energy resides in the ions because of their greater masses. For example, if an electromagnetic energy flux of from about 1 to about 10 watts per square centimeter is applied to region R, whose altitude is 115 km, a plasma having a density (N_e) of 10^{12} per cubic centimeter will be generated and moved upward to region R_2 which has an altitude of about 1000 km. The movement of electrons in the plasma is due to the mirror force while the ions are moved by ambipolar diffusion (which results from the electrostatic field). This effectively "lifts" a layer of plasma 12 from the ionosphere and/or magnetosphere to a higher elevation R_2. The total energy required to create a plasma with a base area of 3 square kilometers and a height of 1000 km is about 3×10^{13} joules.

FIG. 3 is an idealized representation of movement of plasma 12 upon excitation by electron cyclotron resonance within the earth's divergent force field. Electrons (e) are accelerated to velocities required to generate the necessary mirror force to cause their upward movement. At the same time neutral particles (n) which are present along line 11 in region $R_1$are ionized and become part of plasma 12. As electrons (e) move upward along line 11, they drag ions (i) and neutrals (n) with them but at an angle θ of about 13 degrees to field line 11. Also, any particulates that may be present in region R_1, will be swept upwardly with the plasma. As the charged particles of plasma 12 move upward, other particles such as neutrals within or below R_1, move in to replace the upwardly moving particles. These neutrals, under some conditions, can drag with them charged particles.

For example, as a plasma moves upward, other particles at the same altitude as the plasma move horizontally into the region to replace the rising plasma and to form new plasma. The kinetic energy developed by said other particles as they move horizontally is, for example, on the same order of magnitude as the total zonal kinetic energy of stratospheric winds known to exist.

Referring again to FIG. 2, plasma 12 in region R_1 is moved upward along field line 11. The plasma 12 will then form a plume (cross-hatched area in FIG. 2) which will be relatively stable for prolonged periods of time. The exact period of time will vary widely and be determined by gravitational forces and a combination of radiative and diffusive loss terms. In the previous detailed example, the calculations were based on forming a plume by producing 0^+energies of 2 ev/particle. About 10 ev per particle would be required to expand plasma 12 to apex point C (FIG. 1). There at least some of the particles of plasma 12 will be trapped and will oscillate between mirror points along field line 11. This oscillation will then allow additional heating of the trapped plasma 12 by stochastic heating which is associated with trapped and oscillating particles. See "A New Mechanism for Accelerating Electrons in the Outer Ionosphere" by R. A. Helliwell and T. F. Bell, Journal of Geophysical Research, Vol. 65, No. 6, June, 1960. This is preferably carried out at an altitude of at least 500 km.

The plasma of the typical example might be employed to modify or disrupt microwave transmissions of satellites. If less than total black-out of transmission is desired (e.g., scrambling by phase shifting digital signals), the density of the plasma (N_e) need only be at least about 10^6 per cubic centimeter for a plasma orginating at an altitude of from about 250 to about 400 km and accordingly less energy (i.e., electromagnetic radiation), e.g., 10^8 joules need be provided. Likewise, if the density $N_e$is on the order of 10^8, a properly positioned plume will provide a reflecting surface for VHF waves and can be used to enhance, interfere with, or otherwise modify communication transmissions. It can be seen from the foregoing that by appropriate application of various aspects of this invention at strategic locations and with adequate power sources, a means and method is provided to cause interference with or even total disruption of communications over a very large portion of the earth. This invention could be employed to disrupt not only land based communications, both civilian and military, but also airborne communications and sea communications (both surface and subsurface). This would have significant military implications, particularly as a barrier to or confusing factor for hostile missiles or airplanes. The belt or belts of enhanced ionization produced by the method and apparatus of this invention, particularly if set up over Northern Alaska and Canada, could be employed as an early warning device, as well as a communications disruption medium. Further, the simple ability to produce such a situation in a practical time period can by itself be a deterring force to hostile action. The ideal combination of suitable field lines intersecting the earth's surface at the point where substantial fuel sources are available for generation of very large quantitities of electromagnetic power, such as the North Slope of Alaska, provides the wherewithal to accomplish the foregoing in a practical time period, e.g., strategic requirements could necessitate achieving the desired altered regions in time periods of two minutes or less and this is achievable with this invention, especially when the combination of natural gas and magnetohydrodynamic, gas turbine, fuel cell and/or EGD electric generators are employed at the point where the useful field lines intersect the earth's surface. One feature of this invention which satisfies a basic requirement of a weapon system, i.e., continuous checking of operability, is that small amounts of power can be generated for operability checking purposes. Further, in the exploitation of this invention, since the main electromagnetic beam which generates the enhanced ionized belt of this invention can be modulated itself and/or one or more additional electromagnetic radiation waves can be impinged on the ionized region formed by this invention as will be described in greater detail herein after with respect to FIG. 4, a substantial amount of randomly modulated signals of very large power magnitude can be generated in a highly nonlinear mode. This can cause confusion of or interference with or even complete disruption of guidance systems employed by

even the most sophisticated of airplanes and missiles. The ability to employ and transmit over very wide areas of the earth a plurality of electromagnetic waves of varying frequencies and to change same at will in a random manner, provides a unique ability to interfere with all modes of communications, land, sea, and/or air, at the same time. Because of the unique juxtaposition of usable fuel source at the point where desirable field lines intersect the earth's surface, such wide ranging and complete communication interference can be achieved in a resonably short period of time. Because of the mirroring phenomenon discussed hereinabove, it can also be prolonged for substantial time periods so that it would not be a mere transient effect that could simply be waited out by an opposing force. Thus, this invention provides the ability to put unprecedented amounts of power in the earth's atmosphere at strategic locations and to maintain the power injection level, particularly if random pulsing is employed, in a manner far more precise and better controlled than heretofore accomplished by the prior art, particularly by the detonation of nuclear devices of various yeilds at various altitudes. Where the prior art approaches yielded merely transitory effects, the unique combination of fuel and desirable field lines at the point where the fuel occurs allows the establishment of, compared to prior art approaches, precisely controlled and long-lasting effects which cannot, practically speaking, simply be waited out. Further, by knowing the frequencies of the various electromagnetic beams employed in the practice of this invention, it is possible not only to interfere with third party communications but to take advantage of one or more such beams to carry out a communications network even though the rest of the world's communications are disrupted. Put another way, what is used to disrupt another's communications can be employed by one knowledgeable of this invention as a communications network at the same time. In addition, once one's own communication network is established, the far-reaching extent of the effects of this invention could be employed to pick up communication signals of other for intelligence purposes. Thus, it can be seen that the disrupting effects achievable by this invention can be employed to benefit by the party who is practicing this invention since knowledge of the various electromagnetic waves being employed and how they will vary in frequency and magnitude can be used to an advantage for positive communication and eavesdropping purposes at the same time. However, this invention is not limited to locations where the fuel source naturally exists or where desirable field lines naturally intersect the earth's surface. For example, fuel, particularly hydrocarbon fuel, can be transported by pipeline and the like to the location where the invention is to be practiced.

FIG. 4 illustrates another embodiment wherein a selected region of plasma R_3which lies within the earth's ionosphere is altered to increase the density thereof whereby a relatively stable layer 30 of relatively dense plasma is maintained within region R_3. Electromagnetic radiation is transmitted at the outset essentially parallel to field line 11 via antenna 15 as a right hand circularly polarized wave and at a frequency (e.g., 1.78 megahertz when the magnetic field at the desired altitude is 0.66 gauss) capable of exciting electron cyclotron resonance in plasma 12 at the particular altitude of plasma 12. This causes heating of the particles (electrons, ions, neutrals, and particulates) and ionization of the uncharged particles adjacent line 11, all of which are absorbed into plasma 12 to increase the density thereof. The power transmitted, e.g., 2×10^6 watts for up to 2 minutes heating time, is less than that required to generate the mirror force F required to move plasma 12 upward as in the previous embodiment.

While continuing to transmit electromagnetic radiation 20 from antenna 15, a second electromagnetic radiation beam 31, which is at a defined frequency different from the radiation from antenna 15, is transmitted from one or more second sources via antenna 32 into layer 30 and is absorbed into a portion of layer 30 (cross-hatched area in FIG. 4). The electromagnetic radiation wave from antenna 32 is amplitude modulated to match a known mode of oscillation f_3 in layer 30. This creates a resonance in layer 30 which excites a new plasma wave 33 which also has a frequency of f_3 and which then propogates through the ionosphere. Wave 33 can be used to improve or disrupt communications or both depending on what is desired in a particular application. Of course, more than one new wave 33 can be generated and the various new waves can be modulated at will and in a highly nonlinear fashion.

FIG. 5 shows apparatus useful in this invention, particularly when those applications of this invention are employed which require extremely large amounts of power. In FIG. 5 there is shown the earth's surface 40 with a well 41 extending downwardly thereinto until it penetrates hydrocarbon producing reservoir 42. Hydrocarbon reservoir 42 produces natural gas alone or in combination with crude oil. Hydrocarbons are produced from reservoir 42 through well 41 and wellhead 43 to a treating system 44 by way of pipe 45. In treater 44, desirable liquids such as crude oil and gas condensates are separated and recovered by way of pipe 46 while undesirable gases and liquids such as water, H_2S, and the like are separated by way of pipe 47. Desirable gases such as carbon dioxide are separated by way of pipe 48, and the remaining natural gas stream is removed from treater 44 by way of pipe 49 for storage in conventional tankage means (not shown) for future use and/or use in an electrical generator such as a magnetohydrodynamic, gas turbine, fuel cell or EGD generator 50. Any desired number and combination of different types of electric generators can be employed in the practice of this invention. The natural gas is burned in generator 50 to produce substantial quantities of electricity which is then stored and/or passed by way of wire 51 to a transmitter 52 which generates the electromagnetic radiation to be used in the method of this invention. The electromagnetic radiation is then passed by way of wire 53 to antenna 54 which is located at or near the end of field line 11. Antenna 54 sends circularly polarized radiation wave 20 upwards along field line 11 to carry out the various methods of this invention as described hereinabove.

Of course, the fuel source need not be used in its naturally-occurring state but could first be converted to another second energy source form such as hydrogen, hydrazine and the like, and electricity then generated from said second energy source form.

It can be seen from the foregoing that when desirable field line 11 intersects earth's surface 40 at or near a large naturally-occurring hydrocarbon source 42, exceedingly large amounts of power can be very efficiently produced and transmitted in the direction of field lines. This is particularly so when the fuel source is natural gas and magnetohydrodynamic generators are employed. Further, this can all be accomplished in a

relatively small physical area when there is the unique coincidence of fuel source 42 and desirable field line 11. Of course, only one set of equipment is shown in FIG. 5 for sake of simplicity. For a large hydrocarbon reservoir 42, a plurality of wells 41 can be employed to feed one or more storage means and/or treaters and as large a number of generators 55 as needed to power one or more transmitters 52 and one or more antennas 54. Since all of the apparatus 44 through 54 can be employed and used essentially at the sight where naturally-occurring fuel source 42 is located, all the necessary electromagnetic radiation 20 is generated essentially at the same location as fuel source 42. This provides for a maximum amount of usable electromagnetic radiation 20 since there are no significant storage or transportation losses to be incurred. In other words, the apparatus is brought to the sight of the fuel source where desirable field line 11 intersects the earth's surface 40 on or near the geographical location of fuel source 42, fuel source 42 being at a desirable magnetic latitude for the practice of this invention, for example, Alaska.

The generation of electricity by motion of a conducting fluid through a magnetic field, i.e., magnetohydrodynamics (MHD), provides a method of electric power generation without moving mechanical parts and when the conducting fluid is a plasma formed by combustion of a fuel such as natural gas, an idealized combination of apparatus is realized since the very clean-burning natural gas forms the conducting plasma in an efficient manner and the thus formed plasma, when passed through a magnetic field, generates electricity in a very efficient manner. Thus, the use of fuel source 42 to generate a plasma by combustion thereof for the generation of electricity essentially at the site of occurrence of the fuel source is unique and ideal when high power levels are required and desirable field lines 11 intersect the earth's surface 40 at or near the site of fuel source 42. A particular advantage for MHD generators is that they can be made to generate large amounts of power with a small volume, light weight device. For example, a 1000 megawatt MHD generator can be construed using superconducting magnets to weigh roughly 42,000 pounds and can be readily air lifted.

This invention has a phenomenal variety of possible ramifications and potential future developments. As alluded to earlier, missile or aircraft destruction, deflection, or confusion could result, particularly when relativistic particles are employed. Also, large regions of the atmosphere could be lifted to an unexpectedly high altitude so that missiles encounter unexpected and unplanned drag forces with resultant destruction or deflection of same. Weather modification is possible by, for example, altering upper atmosphere wind patterns or altering solar absorption patterns by constructing one or more plumes of atmospheric particles which will act as a lens or focusing device. Also as alluded to earlier, molecular modifications of the atmosphere can take place so that positive environmental effects can be achieved. Besides actually changing the molecular composition of an atmospheric region, a particular molecule or molecules can be chosen for increased presence. For example, ozone, nitrogen, etc. concentrations in the atmosphere could be artificially increased. Similarly, environmental enhancement could be achieved by causing the breakup of various chemical entities such as carbon dioxide, carbon monoxide, nitrous oxides, and the like. Transportation of entities can also be realized when advantage is taken of the drag effects caused by regions of the atmosphere moving up along diverging field lines. Small micron sized particles can be then transported, and, under certain circumstances and with the availability of sufficient energy, larger particles or objects could be similarly affected. Particles with desired characteristics such as tackiness, reflectivity, absorptivity, etc., can be transported for specific purposes or effects. For example, a plume of tacky particles could be established to increase the drag on a missile or satellite passing therethrough. Even plumes of plasma having substantially less charged particle density than described above will produce drag effects on missiles which will affect a lightweight (dummy) missile in a manner substantially different than a heavy (live) missile and this affect can be used to distinguish between the two types of missiles. A moving plume could also serve as a means for supplying a space station or for focusing vast amount of sunlight on selected portions of the earth. Surveys of global scope could also be realized because the earth's natural magnetic field could be significantly altered in a controlled manner by plasma beta effects resulting in, for example, improved magnetotelluric surveys. Electromagnetic pulse defenses are also possible. The earth's magnetic field could be decreased or disrupted at appropriate altitudes to modify or eliminate the magnetic field in high Compton electron generation (e.g., from high altitude nuclear bursts) regions. High intensity, well controlled electrical fields can be provided in selected locations for various purposes. For example, the plasma sheath surrounding a missile or satellite could be used as a trigger for activating such a high intensity field to destroy the missile or satellite. Further, irregularities can be created in the ionosphere which will interfere with the normal operation of various types of radar, e.g., synthetic aperture radar. The present invention can also be used to create artificial belts of trapped particles which in turn can be studied to determine the stability of such parties. Still further, plumes in accordance with the present invention can be formed to simulate and/or perform the same functions as performed by the detonation of a "heave" type nuclear device without actually having to detonate such a device. Thus it can be seen that the ramifications are numerous, far-reaching, and exceedingly varied in usefulness.

I claim:

1. A method for altering at least one region normally existing above the earth's surface with electromagnetic radiation using naturally-occurring and diverging magnetic field lines of the earth comprising transmitting first electromagnetic radiation at a frequency between 20 and 7200 kHz from the earth's surface, said transmitting being conducted essentially at the outset of transmission substantially parallel to and along at least one of said field lines, adjusting the frequency of said first radiation to a value which will excite electron cyclotron resonance at an initial elevation at least 50 km above the earth's surface, whereby in the region in which said electron cyclotron resonance takes place heating, further ionization, and movement of both charged and neutral particles is effected, said cyclotron resonance excitation of said region is continued until the electron concentration of said region reaches a value of at least 10^6 per cubic centimeter and has an ion energy of at least 2 ev.

2. The method of claim 1 including the step of providing artificial particles in said at least one region which are excited by said electron cyclotron resonance.

3. The method of claim 2 wherein said artificial particles are provided by injecting same into said at least one region from an orbiting satellite.

4. The method of claim 1 wherein said threshold excitation of electron cyclotron resonance is about 1 watt per cubic centimeter and is sufficient to cause movement of a plasma region along said diverging magnetic field lines to an altitude higher than the altitude at which said excitation was initiated.

5. The method of claim 4 wherein said rising plasma region pulls with it a substantial portion of neutral particles of the atmosphere which exist in or near said plasma region.

6. The method of claim 1 wherein there is provided at least one separate source of second electromagnetic radiation, said second radiation having at least one frequency different from said first radiation, impinging said at least one second radiation on said region while said region is undergoing electron cyclotron resonance excitation caused by said first radiation.

7. The method of claim 6 wherein said second radiation has a frequency which is absorbed by said region.

8. The method of claim 6 wherein said region is plasma in the ionosphere and said second radiation excites plasma waves within said ionosphere.

9. The method of claim 8 wherein said electron concentration reaches a value of at least 10^{12} per cubic centimeter.

10. The method of claim 8 wherein said excitation of electron cyclotron resonance is initially carried out within the ionosphere and is continued for a time sufficient to allow said region to rise above said ionosphere.

11. The method of claim 1 wherein said excitation of electron cyclotron resonance is carried out above about 500 kilometers and for a time of from 0.1 to 1200 seconds such that multiple heating of said plasma region is achieved by means of stochastic heating in the magnetosphere.

12. The method of claim 1 wherein said first electromagnetic radiation is right hand circularly polarized in the northern hemisphere and left hand circularly polarized in the southern hemisphere.

13. The method of claim 1 wherein said electromagnetic radiation is generated at the site of a naturally-occurring hydrocarbon fuel source, said fuel source being located in at least one of northerly or southerly magnetic latitudes.

14. The method of claim 13 wherein said fuel source is natural gas and electricity for generating said electromagnetic radiation is obtained by burning said natural gas in at least one of magnetohydrodynamic, gas turbine, fuel cell, and EGD electric generators located at the site where said natural gas naturally occurs in the earth.

15. The method of claim 14 wherein said site of natural gas is within the magnetic latitudes that encompass Alaska.

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Nov. 12, 1957 L. R. CRUMP 2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Filed March 12, 1954

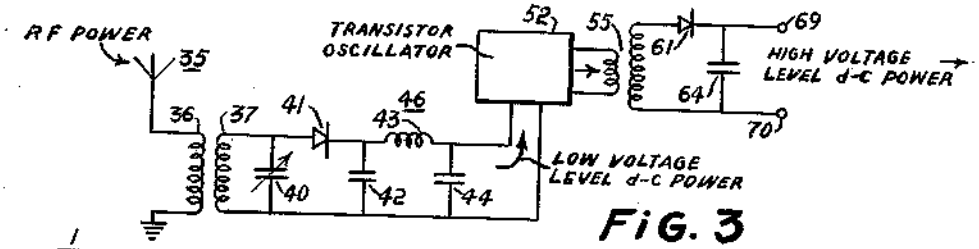

FIG. 3

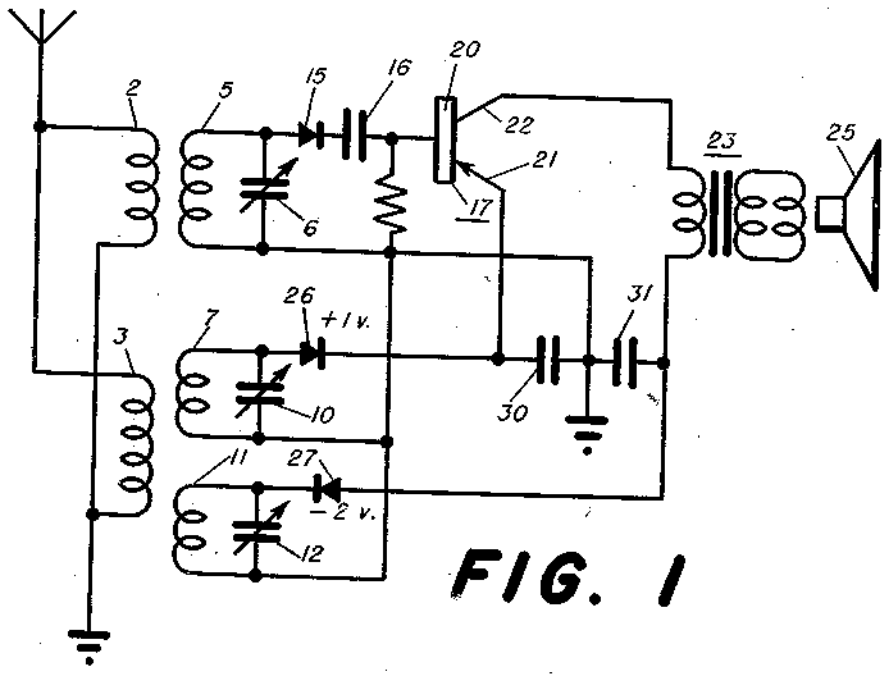

FIG. 1

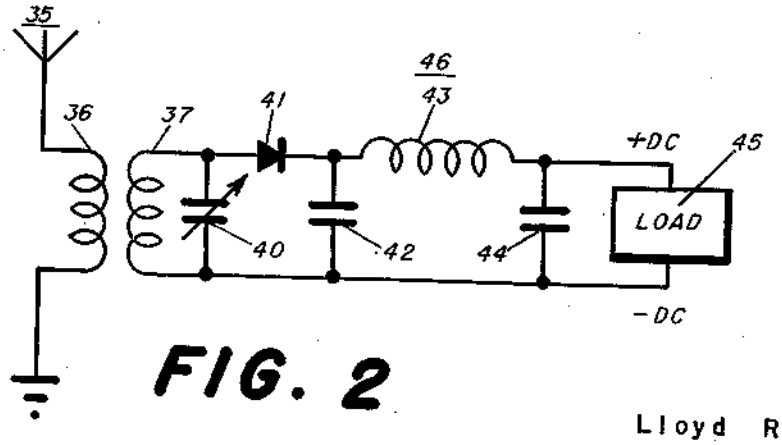

FIG. 2

INVENTOR

Lloyd R. Crump

BY W. E. Thibodeau & A. W. Dew

ATTORNEYS

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2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Lloyd R. Crump, Silver Spring, Md.

Application March 12, 1954, Serial No. 415,986

1 Claim. (Cl. 321—2)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to the convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices having modest power requirements.

A great advantage of transistors, and a major reason for their enthusiastic reception since their introduction a few years ago, is the fact that they will operate satisfactorily with very low supply voltages and currents. One milliwatt or even less is sufficient to power a transistor in many applications. Various batteries have been developed to provide, in a minimum of space, the relatively minute amounts of power needed by transistors.

My invention provides methods and means that permit transistor circuits, and also other low-powered electrical devices, to be economically and conveniently operated without any batteries whatever, and indeed without any power supply whatever as power supplies are ordinarily conceived.

The invention centers around my discovery that it is practicable to construct operative transistor circuits that are able to abstract from the atmosphere sufficient electromagnetic energy to provide all necessary supply voltages and currents for their own operation. Circuits and devices powered according to my invention will operate indefinitely without any local power source whatever.

I have successfully constructed and demonsirated such circuits. For example, I have constructed a batteryless transistor radio receiver on which I have listened to either nearby or distant broadcast stations as desired, using either headphones or a loudspeaker; this receiver has been powered entirely by electromagnetic energy abstracted from the atmosphere.

From the successful operation of this receiver, and from other experimental work, it becomes clear that, by the methods and means of the invention, a great variety of practical and useful transistor circuits can be powered entirely by energy abstracted from the atmosphere.

Furthermore, as will become apparent below, my invention is applicable to the powering of other electrical devices requiring relatively small amounts of power.

An object of the present invention is to provide methods and means for powering transistor circuits entirely from radiofrequency energy abstracted from the atmosphere.

Another object is to provide methods and means for powering remote radio receivers, low-powered radio transmitters, and other low-powered electrical devices, with energy received by radio from a master station, so that no local power supplies are needed by the devices and so that the powering or non-powering of the remote device is under the control of the master station.

A further object is to provide methods and means for powering transistor circuits and other low-powered electrical devices with radiofrequency energy received from one or more remote radio transmitters.

Other objects, aspects, uses, and advantages of the invention will become apparent from the following description and from the drawing.

Figure 1 is a schematic diagram of a transistor radio receiver in which all necessary power is supplied by energy abstracted from the atmosphere in accordance with the invention.

Figure 2 is a schematic diagram showing a general application of the invention to provide direct-current power to a load.

Figure 3 is a schematic diagram of a system for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere.

Referring to Figure 1, a receiving antenna **1** is connected to antenna coupling coils **2** and **3**, the other ends of which are connected to ground. A parallel resonant circuit consisting of coil **5** and capacitor **6** is coupled to coil **2**. A second parallel resonant circuit consisting of coil **7** and capacitor **10** is coupled to coil **3**. A third parallel resonant circuit consisting of coil **11** and capacitor **12** is also coupled to coil **3**.

Coil **5** and capacitor **6** are tuned to the frequency of a radio transmitter from which it is desired to receive information—for instance, an amplitude-modulated standard broadcast station. The signal received from this transmitter need not be strong. The signal is detected by diode **15** to obtain an audio-frequency information signal. This audio signal is coupled through a capacitor **16** and is amplified by a circuit that includes a transistor **17** having a base **20**, an emitter **21**, and a collector **22**. The amplified audio output of the transistor is coupled through an audio transformer **23** to an electroacoustical transducer, preferably a permanent-magnet dynamic loudspeaker **25** as shown.

The novelty of the invention lies largely in the method and means by which the necessary direct-current power is supplied to the emitter and collector circuits of transistor **17**. This method and means will now be described.

Coil **7** and capacitor **10**, and also coil **11** and capacitor **12**, are tuned to receive radio signals of relatively high strength. It does not matter whether these signals contain information. These power signals are rectified by diodes **26** and **27** to provide direct-current power that is filtered by capacitors **30** and **31**. The D.-C. power thus obtained is utilized to power the transistor **17**.

In the circuit shown, two tuned circuits (coil **7** and capacitor **10**, and coil **11** and capacitor **12**) are tuned to power signals and the D.-C. voltages obtained from each are connected in series. The tuned power circuits may be tuned to the same or different power signals. Under certain circumstances it may be desirable to use more than two tuned power circuits and to tune them to more than two power signals; in this way power can be obtained from several signals and combined. On the other hand, if a strong power signal is available, a single tuned power circuit may suffice to give the needed D.-C. power.

Even weak information signals can be received successfully. A plurality of transistor amplifier stages can be used if desired, or other circuits such as superheterodyne circuits can be used. It is merely necessary that a sufficiently strong power signal or signals be available to provide the small amount of D.-C. needed to power the transistors.

If the information signal happens to be strong, it can be used as the power signal; all of the tuned circuits (coil **5** and capacitor **6**, coil **7** and capacitor **10**, coil **11** and capacitor **12**) are tuned to the information signal.

Engineers who have observed my invention in operation have been surprised at the unexpectedly good results obtained, even with readily available power signals of quite moderate strength. For instance, sufficient power for satisfactory operation of a loudspeaker at low volumes is

readily obtained from a 5-kilowatt standard broadcast station 5 miles away, using only an indoor antenna to pick up the power signal as well as information signals. In typical operation under these conditions a D.-C. voltage of about 2.5 to 3 volts is obtained between the emitter and the collector, at a current of about 250 microamperes; D.-C. power input to the transistor is thus of the order of 0.5 to 1 milliwatt. So far as I am aware, no one has ever before discovered and demonstrated the practicability of this method of powering a radio receiver.

Because existing broadcast stations within a radius of a number of miles provide adequate power signals, the invention is readily practicable with existing power signals in almost any location in or near any city in the United States.

Although I have described a transistor radio receiver powered by my invention, it will be readily apparent that the invention is applicable to the powering of any transistor circuit using one or a number of transistors, and to the powering of other devices requiring relatively small amounts of power. For instance, sensitive electromechanical, electrochemical, or electrothermal devices can be operated by the method of the invention.

Referring to Figure 2, which shows a more general embodiment of my invention, an antenna 35 picks up radiofrequency energy from the atmosphere. This energy flows through coil 36, which is coupled to a tuned circuit consisting of coil 37 and capacitor 40. The radiofrequency voltage across capacitor 40 is rectified by diode 41 and filtered by a low-pass filter 46 consisting of capacitors 42 and 44 and choke coil 43. The resulting D.-C. voltage is applied to a load 45.

In the practice of my invention, larger amounts of power can be obtained for short periods of time by storing received energy in a suitable energy storage device. Stored energy may then be withdrawn at intervals at a more rapid rate than that at which it was received and put into the storage device. In this way the invention can be used to provide short pulses of relatively very high electrical energy. This result can be readily obtained by charging a relatively large capacitor with direct current and then discharging the capacitor rapidly into a load when desired. This rapid discharge can be initiated automatically when the voltage across the capacitor reaches a certain level, or it can be initiated when a transistor radio receiver receives a certain information signal.

Higher voltages can be obtained with the invention by means of well known devices for raising D.-C. voltages as shown in Figure 3. The D.-C. voltage output from the capacitor 44 can be used to power a low frequency transistor oscillator 52 whose A.-C. output is raised to a higher voltage level by the transformer 55. This relatively high A.-C. voltage can then be rectified by a diode 61 and fed to a capacitor 64 to provide a high energy D.-C. source at a relatively high voltage level at the terminals 69 and 70. If desired, energy can now be withdrawn from the capacitor 64 at intervals in short pulses of high energy at a high voltage level. Pulsed radio transmission is one of the possible uses for this form of the invention. Other uses would be to provide a single relatively powerful pulse needed to actuate an electrothermal or electromechanical device.

As has been indicated above, in many locations and particularly anywhere in or near most American cities, power signals normally present in the atmosphere are readily available for the easy and convenient practice of the invention. However, the invention also has important applications in systems in which the necessary power signal is generated and transmitted specifically for the operation of the particular system. Such systems can, for example, comprise a master station transmitting all the power that is needed for hundreds or thousands of fixed or mobile transistor receivers or other remote devices over a range of many miles. This eliminates the need for hundreds or thousands, as the case may be, of local power supplies. At the same time, such a system has the advantage that all of the remote devices can be simultaneously activated or deactivated at the will of the master station, simply by starting or stopping the transmission of the power signal. In such systems it will often be advantageous to use power signals of frequencies sufficiently high to permit the use of resonant receiving antennas of small physical dimensions for signal pickup at the remote devices. In addition to the power signal, the master station may transmit an information signal on the same or a different carrier.

Certain types of devices powered entirely by received radio waves are of course well known. The well-known "crystal set" of the early days of radio, which used a diode rectifier to demodulate an amplitude-modulated radiofrequency signal, is an outstanding example of such a device. My invention is readily distinguishable from such prior devices, however. In typical prior devices a modulated radiofrequency signal is applied to a diode to obtain unidirectional half-wave pulses whose amplitudes vary with modulation. These pulses are integrated by means of a capacitor to obtain a unidirectional signal the amplitude of which follows the audiofrequency modulation envelope. If the radiofrequency signal is received with sufficient strength the audio signal may have sufficient power to operate headphones or similar utilization device without power amplification; but the signal is utilized for its information content, rather than to supply non-information-containing power.

My invention, on the other hand, entails the utilization of received radiofrequency energy to supply power to at least one pair of circuit points (across capacitor 31 in Fig. 1, for example), such circuit points requiring power solely for its power content and not for any information or modulation it may contain. In other words, my invention entails the utilization of radiofrequency energy to supply power that would otherwise have to be supplied by batteries, generator, or other local power source.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

I claim:

An electrical device for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere, said device comprising in combination: resonant means for receiving radio waves, first rectifier means for converting said radio waves into first direct current energy, first capacitor means for storing said first direct current energy, an oscillator powered by said direct current energy, said oscillator producing an A.-C. output, transformer means for raising said A.-C. output to an increased voltage level, second rectifier means for converting the A.-C. output of increased voltage level from said transformer into second direct current energy, and second capacitor means for storing said second direct current energy.

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H. C. VION.

Electric Apparatus.

No. 28,793. Patented June 19, 1860.

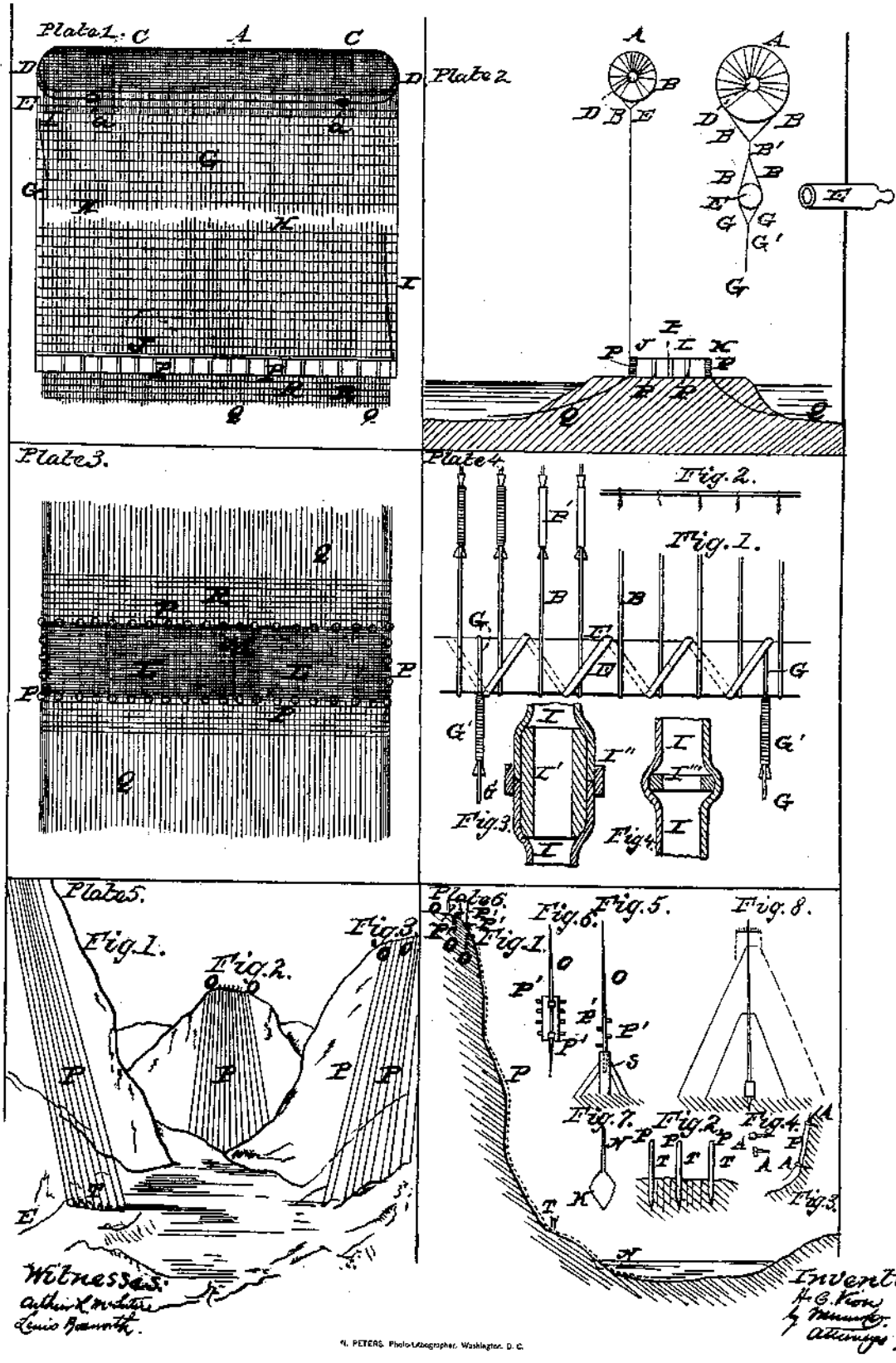

N. PETERS. Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

H. CHARLES VION, OF PARIS, FRANCE.

IMPROVED METHOD OF UTILIZING ATMOSPHERIC ELECTRICITY.

Specification forming part of Letters Patent No. **28,793**, dated June 19, 1860.

To all whom it may concern:

Be it known that I, HIPPOLYTE CHARLES VION, of Paris, in the Empire of France, engineer, have invented a new Mode of Obtaining Atmospheric Electricity and Terrestrial Electricity and its Industrial Applications; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the accompanying drawings, making part of this specification, in which—

Plate 1 represents a front elevation; Plate 2, a side elevation of an aerostat, in combination with certain other devices for obtaining atmospheric and terrestrial electricity; Plate 3, a plan of the device for obtaining terrestrial electricity; Plate 4, detached portions of the apparatus. Plate 5 shows a front view, and Plate 6 a vertical section and various details of the apparatus when applied in mountainous regions, the use of an aerostat being dispensed with.

The object of my invention is to form an electric pile of great power by using the positive electricity contained in the atmosphere, and the negative electricity contained in the earth, so as to make the electricity therein contained available for industrial purposes.

To enable others skilled in the art to make and use my invention, I will proceed to describe its construction and operation.

A is aerostat of a tubular form closed at both ends. It is made of suitable material, so as to be impervious to air. Its dimensions are such as to give it great ascensional power when filled with gas.

a a are valves in the surface of the aerostat, to be opened when the inflation of the aerostat should become too great.

A long india-rubber tube, I, communicates with the interior of the aerostat, being attached to the latter, near one end of its ends D, as seen in Plate 1, while the lower end of the tube I is attached to a gasometer, (not shown in the drawings.) The gasometer is to be fed with hydrogen gas, produced by the action of the pile itself, the negative wires of which (afterward to be described) enter a body of water at or near the base of the apparatus and decompose the water so as to produce the hydrogen gas. As the aerostat is supposed to be at a considerable height the tube I must be of corresponding length, and is constructed of a number of tubes, short wooden tubes I′ being inserted where the tubes I are joined, and a fastening-ring, I″, being slipped over each of the joints, as seen in Fig. 3 of Plate 4. At certain distances the tube I is fastened to the net-work of the positive wires (afterward to be described) in order to secure the tube against the action of the wind, and at each of these fastening-places a washer, I‴, is inserted in the tube in order that the tube shall not be compressed by the wire or other means employed to fasten it to the net-work of positive wires. (See Fig. 4, Plate 4.)

The aerostat is surrounded with a net-work of wires, one layer of the wires, C, being parallel with the axis of the aerostat and fastened to rings D at both ends of the aerostat, and the other layer of wires, B, extending partially around the aerostat at right angles to the wires C. One end of each of the wires B extends around an iron tube, E, some distance below the aerostat and meets the other end of it between the tube E and the aerostat. The two ends are fastened together by a ligature, B′. (See Fig. 1, Plate 4.) Each end of the tube E terminates into a ball, *e*. The wires B are fastened to the surface of the tube E by means of a helical wire, F, wound around the tube and across the wires B, as seen in Fig. 1, Plate 4. The upper ends of long vertical wires G are also wound around cylinder E, each wire G between two of the wires B, and the ends secured by a ligature, G′, as seen in Fig. 1, Plate 4. The helical wire F is also wound across the wires G, so as to keep them in their places on tube E.

The vertical wires G, which are to be the conductors of the positive electricity of the atmosphere, must be of a length proportionate to the desired efficacy of the electric pile, and the size and ascensional power of the aerostat must, of course, be adequate to sustain the weight of and keep suspended the wires G, (a weight still further increased by the horizontal cross-wires H, with which the vertical wires G are interlaced, in order to form a net-work not liable to be deranged by the action of the winds or similar influences.) The two outside wires, G, are stronger than the rest of them, and their lower ends are fastened to dyna-

mometers of any suitable construction. These dynamometers are attached to the ends or a massive iron cylinder, J, and they serve to indicate the tension in the outside wires, G, and the corresponding ascensional power of the aerostat. According to the reading of these dynamometers the aerostat has to be supplied (through tube I) with more or less gas. The lower end of each of the wires G is wound around the cylinder J, and secured by ligatures similar to those ab ve described. The wires G are all insulated (by a coating of gutta-percha or similar substance,) except where they are in contact with tube E and with cylinder J, and a similar insulating coating is laid on cylinder J, after the lower ends of the wires G have been fastened to it.

Another cylinder, K, similar to J, is placed at some distance from and parallel to cylinder J. It is connected with cylinder J by wires L, wound around both cylinders and interlaced with cross-wires M. The wire-work L M and cylinders are insulated (in a manner already described) against outside influences, so that the only electric communication between the two cylinders will be through the wires L. The two cylinders are placed upon insulated columns P. The cylinder K may be used as a substitute for cylinder J, and vice versa, whenever repairs become necessary. Insulated branch wire or wires are attached to the cylinders J K and wires L, so as to conduct the positive electricity obtained from the atmosphere by means of the above-described apparatus to wherever it is desired for industrial purposes. The insulated wires Q (interlaced with cross-wires R) are placed on the ground underneath and parallel to the positive wires L. Both ends of each of the wires Q are sunk into the earth or submerged in water, and fastened to a metallic plate coated with a metal not subject to oxidation. These wires Q are the conductors for the negative electricity of the earth, and a branch wire or wires attached to the wires Q serve to transmit the negative terrestrial electricity to wherever it is wanted for industrial or other purposes.

By uniting to the ends of the positive and the negative branch wire or wires a powerful electric current will be obtained, one pole of which is the atmosphere and the other the earth, and may be applied to any suitable useful purpose.

I will now proceed to describe the modification of the above-described apparatus when to be applied in mountainous countries.

P represents the positive electric copper or other metal wires coated over with an insulating substance. The upper ends of each of the positive wires is soldered to a prompter, O, at P′, Figs. 1, 5, and 6, Plate 6. The lower portion of each of the positive-wires is secured to an insulator, T, Fig. 2, Sheet 6. The positive wires are held above the ground by joints A, Figs. 3 and 4, Sheet 6, projecting from the soil at suitable distances from each other. The wires P are intended to follow the inequalities of the ground on which they are laid.

The prompters O, Figs. 5 and 6, Sheet 6, are iron rods sharpened to a point and silvered or coppered at their upper ends. The lower part of the prompter is fastened into a pole, S, covered with tar, which isolates the prompter and holds it in a firm position. A large metallic plate may be soldered to each prompter, as shown in Fig. 6. The positive wires may be soldered to the rod of each prompter or to the plate which is fastened thereto.

One or more branch lines, E, are soldered up to the positive wires to transmit the positive atmospheric electricity for which the wires P are the conductors to any desirable point.

N are negative iron or other metal conductors coated with an insulating substance. The upper ends of these wires rest on the ground near the positive insulators. The lower ends of these wires are soldered to a metallic plate or plates, V, Fig. 7, Plate 6, coated with a metal not subject to oxidation. The negative wires are sunk into the ground at very great depth or into wells, rivers, or into the sea. The negative electric branch wires are attached to the negative conductors N in the same manner as the positive branch wires are to the positive conductors. The branch wires and the soldering are coated over with an insulating substance. They are intended to carry the negative terrestial electricity to any desired point.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The peculiar arrangement of means herein specified, whereby I am enabled to use the positive electricity contained in the atmosphere and the negative electricity contained in the earth, and thus form an electric pile of considerable power and make the electricity therein contained available for industrial purposes, as set forth.

2. The combination of an aerostat and vertical wire-work with a tube, I, for admitting gas into the aerostat, in the manner and for the purposes above set forth.

CHARLES VION.

Witnesses:
HARRY W. SPENCER,
A. GUION, Jr.

W. I. PENNOCK.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

APPLICATION FILED JUNE 26, 1907.

911,260. Patented Feb. 2, 1909.

Fig. 1.

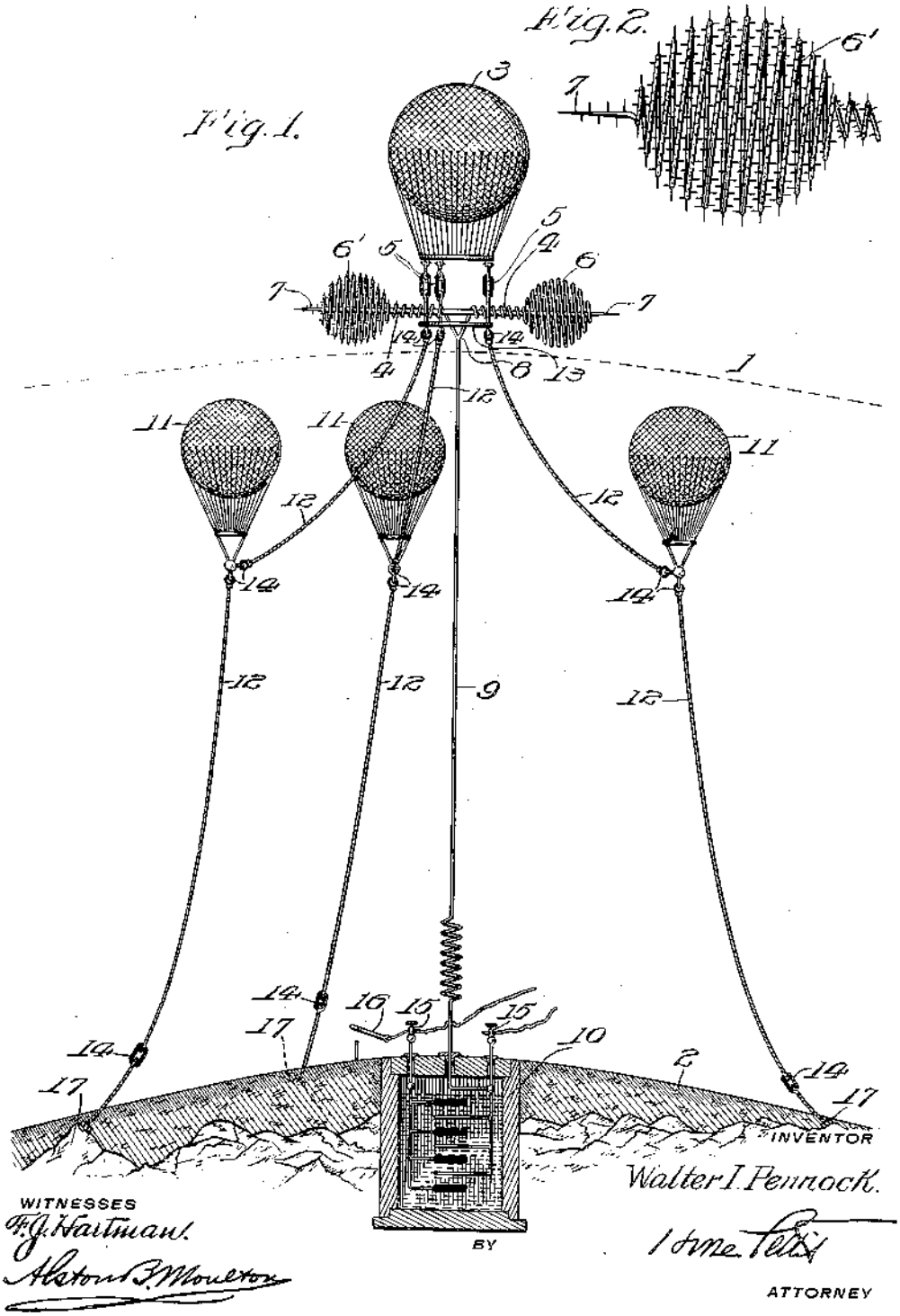

Fig. 2.

WITNESSES

F. J. Hartman.

Alston B. Mouton

INVENTOR

Walter I. Pennock.

BY

Howe & Fitzpatrick

ATTORNEY

UNITED STATES PATENT OFFICE.

WALTER I. PENNOCK, OF PHILADELPHIA, PENNSYLVANIA.

APPARATUS FOR COLLECTING ATMOSPHERIC ELECTRICITY.

No. 911,260. Specification of Letters Patent. Patented Feb. 2, 1909.

Application filed June 26, 1907. Serial No. 380,907.

To all whom it may concern:

Be it known that I, WALTER I. PENNOCK, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Atmospheric Electricity, of which the following is a specification.

My invention relates to a method of collecting electricity from a strata laden with electricity at high altitudes in the atmosphere, through the medium of a wire cable suspended from one or more balloons and in conveying this electricity to the earth's surface.

The object of my invention is to provide a conveyance of the electro motive force to be found in the upper strata of the atmosphere to the earth's surface; where it may be utilized for commercial and other purposes.

A further object of my invention is to provide a device or mechanism by which a suitable collector for the electrical energy in the upper strata of the earth's atmosphere may be elevated in the said strata and by which the said electric energy may be transmitted to and collected at the earth's surface, from which point it may be conducted to any place where it is desired to use the same.

A further object of my invention is to support and anchor said device in any desired position.

A further object of my invention is to provide an improved form of collector through which the energy of the said upper strata of the earth's atmosphere may be collected and transmitted for various purposes to the earth's surface.

Other objects of my invention will appear in the specification and claims below.

For a further full, clear and complete disclosure of my invention, reference may be had to the following description and accompanying drawings, in which like reference characters refer to corresponding parts.

Figure 1 is an elevational view of one form or embodiment of my invention and Fig. 2 is a detailed view of one form of my improved collector.

The passage of the electrical current to the earth under ordinary conditions is prevented by an obstruction afforded by the dense lower strata of the atmosphere, which is a bad conductor of electricity, as shown by the electrodes of an ordinary static machine. When the electrodes are placed close together, the atmosphere is seen to carry the current across from one electrode to another, but if placed far apart the current is obstructed by the intervening air. The dense lower strata of the atmosphere affords one of the best non-conductors of electricity, as shown in the conduction of the electric current by telegraph, or trolley wires on the earth's surface, where only a small quantity of the electric current escapes through the atmosphere; while rarefied atmosphere affords a good conducting media, as shown by the vacuum tube. The upper strata of the atmosphere being rare in proportion to the altitude, and being a good conductor of electricity while the lower strata of the atmosphere being dense and affording a non-conducting media for the electric current, thus causes an obstruction to the electric current, or power in its passage to the earth's surface from the electric strata of the atmosphere under ordinary conditions. When, however, the cumulus clouds of a thunder storm pass over the surface of the earth, these clouds being of very great height, the moisture in said clouds forms a better conductor of electricity than does the dry air, with the result that the electricity in the upper strata of the atmosphere breaks through the said cloud as a streak of lightning and in that form reaches even to the earth's surface, while the thin or shallow strata of clouds, observed in the so-called "settled rain" storm, do not extend upward to a sufficient height to form a conducting medium for the electricity from the electric strata to the earth's surface. For this reason there is usually no lightning during the said latter variety of rain storm.

By means of my invention, I have provided a mechanism for collecting the electrical energy or power created by nature and stored in the upper strata of rarefied air of the earth's atmosphere and have provided a conductor for said electric energy to the earth's surface.

Referring now to the drawings 1 indicates what may be called the lower limits or boundaries of the strata of electric energy above the surface 2 of the earth.

3 indicates a balloon which is elevated to a high altitude until it enters the said stra-

tum. The said balloon 3 carries a bar 4 of wood or any other suitable non-conducting material suspended by insulating links 5 or any other suitable form of insulation from the balloon 3. Upon either end of the said bar 4 I mount collectors, one form of which I have illustrated as spheres of coiled wire 6—6′ the outer ends 7 of which terminate in sharp points. The inner turns of the said spheres 6 and 6′ are wrapped around the wooden bar 4 and united as at 8 to a conductor of electric energy, preferably a large copper wire 9. This wire or conductor 9 extends to the earth's surface and may have its end suitably attached to an electric accumulator or other piece of electrical apparatus. I have illustrated one form of my invention in which the conductor 9 is connected to one pole of a storage battery 10 on the earth's surface.

The spiral spheres 6, 6′ are preferably provided with a polished metallic surface to form a good conductor of electricity and the material of said spheres should also be of such a character that it will not rust or corrode or tarnish. A polished copper wire or a copper wire plated with platinum or gold or a solid platinum or gold wire may be used for this purpose, inasmuch as these materials are least affected by moisture and the atmosphere. The said spheres or collectors may be made of smooth wire as shown in the sphere designated by the numeral 6 or of barbed wire, as is shown at 6′ and illustrated on a larger scale in Fig. 2 of the drawings. The latter form is preferable inasmuch as it provides a large number of points through which the electricity may flow to the wire from the surrounding air in the said upper strata of the earth's atmosphere.

In order that the supporting balloon 3 may be held in a relatively fixed position, it should be suitably anchored to the earth's surface. Inasmuch as the balloon 3 must be elevated to a very high position, the weight of the anchoring cables forms an important consideration, and if desired or necessary one or more supplemental balloons 11, 11, 11 may be attached to each of the anchoring cables 12, 12, 12 as illustrated in Fig. 1, to relieve the balloon 3 of such weight as would prevent it from ascending into the said electrical strata. In order that the electricity from the said upper strata of the earth's atmosphere may not be conducted down the anchoring cables 12, 12, 12, I attach them to the supporting balloon 3 and to the supplemental balloons 11 and to the earth's surface through suitable insulating devices 14.

In the form of my invention illustrated in Fig. 1, below the bar 4, I suspend a ring 13 of any suitable material from the balloon 3, and attach the anchoring cables 12 thereto by means of insulating rings 14, 14, 14. I may also provide additional insulating rings 14 between that portion of the anchoring cables 12 between the balloon 3 and the supplemental balloons 11, and also between that part of the cable 12 between the supplemental balloons 12 and the earth's surface. I may also provide, near the earth's surface and at the lower end of the anchoring cables 12, similar insulating links 14. While I have described links as forming a convenient form of insulating device for the purposes above set forth, I do not wish to be construed as being limited to the same, inasmuch as any suitable non-conducting connection may be used in place of the links 14.

The terminals 15, 15 of the storage battery 10 may be connected to any piece of electric apparatus which it is desired to run or operate and if desirable one of the poles of the battery is adapted to be connected by the switch 16 with the earth's surface. The lower ends of the anchoring cables 12 are securely anchored to the earth's surface as at 17.

With the apparatus arranged and connected in the manner illustrated in Fig. 1, the electric energy in the high strata of the earth's atmosphere passes to and through the conductive spiral spheres 6 or 6′ to the conductor 9 and is suitably stored or used at the earth's surface, while the balloons 11 support a part of the weight of the anchoring cables 12, and permit the balloon 3 to ascend as high as is possible, or necessary for it to enter the said electrical strata of the earth's atmosphere. By arranging the anchorage 17 of the cables 12 symmetrically or in any other position than in a straight line, the balloon 3 may be held in a substantially fixed position with relation to the earth.

While I have illustrated in the drawings and have described in the specification a form of apparatus in which my invention may be carried out, it is obvious that the drawings are more or less diagrammatic drawings, that is to say, that the proportions of the various parts are not necessarily those which would operate to the best advantage, inasmuch as certain portions have been shown as greatly enlarged in the drawings for the sake of clearness, and that it is likely that more than one supplemental balloon would be requird for each cable in order to support the weight of the same, and to relieve the supporting balloon 3 of such weight, as would prevent it from ascending into the high electrical strata of the earth's atmosphere, but such changes in form, proportion and arrangement I regard as being fully within the aim and scope of my invention, so long as such forms or modifications fall within the scope of the append-

ed claims. It is also to be understood that the storage battery or accumulator which I have shown as being connected to my collector, is only a type of apparatus which can be operated by the current collected by the spheres 6, 6′ and transmitted to the earth through the wire 9, and when I use the word "accumulator", I mean any piece of useful apparatus which is operated by the current transmitted thereto through the wire or conductor 9.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States is:

1. The combination with an electrical collector comprising a bar of non-conducting material, and an open spherical conductor carried by said bar, of means to support said collector in the high electrical strata of the earth's atmosphere.

2. The combination with a balloon, of an electrical collector supported thereby and insulated therefrom, comprising a bar of non-conducting material, and a conductor wound spirally around said bar.

3. The combination with an electrical collector comprising a non-conducting bar, and a conductive wire wound thereon to form an open substantially spherical body, and means to support said collector in the high electrical strata of the earth's atmosphere.

4. The combination with a balloon, of an electrical collector carried thereby and comprising a non-conducting bar, and a polished wire wound spirally thereon to form an open substantially spherical body.

5. The combination with an electrical collector comprising a non-conducting bar, and a wire wound spirally thereon to form an open substantially spherical body, said wire being provided with pointed conducting projections, and means to support said collector in the high electrical strata of the earth's atmosphere.

6. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, and a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof.

7. The combination with a balloon, of an electrical collector carried thereby comprising a non-conducting bar, a conducting wire wound spirally thereon to form open substantially spherical bodies upon the opposite ends thereof, an electrical accumulator, and an electrical connection between the said collector and said accumulator.

8. The combination with a balloon, and means to anchor said balloon, of an electrical collector supported by said balloon and insulated therefrom, an electrical accumulator, and a conductor connecting said collector and said accumulator.

9. The combination of an electrical collector, means to support said collector at a high elevation from the earth's surface and within the electrical strata of the earth's atmosphere, an electrical accumulator at the earth's surface, an electrical connection between said collector and said accumulator, and means to insulate said supporting means from said collector and from the earth.

In testimony whereof, I have hereunto set my hand this 25th day of June, 1907.

WALTER I. PENNOCK.

Witnesses:
HUGH F. QUINN,
WM. G. GLENN.

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719.

Patented Jan. 16, 1912.

2 SHEETS—SHEET 1.

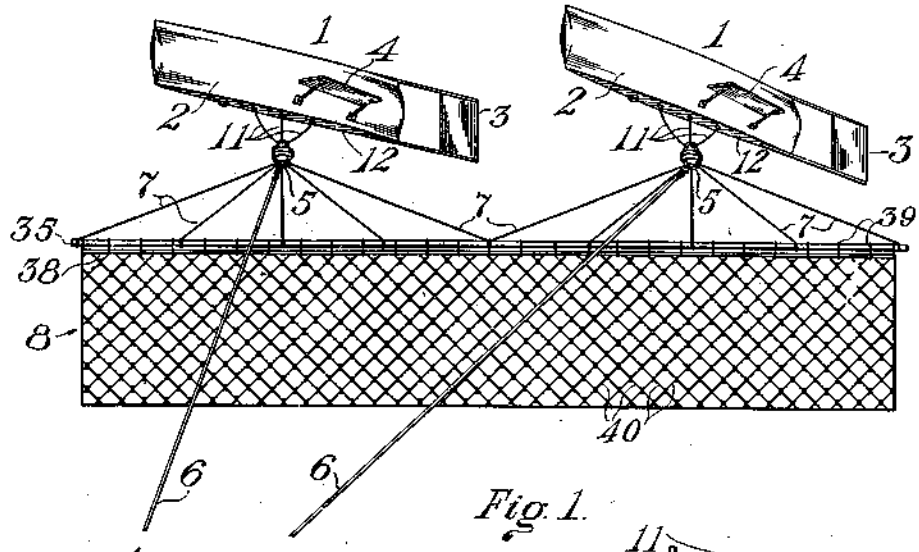

Fig. 1.

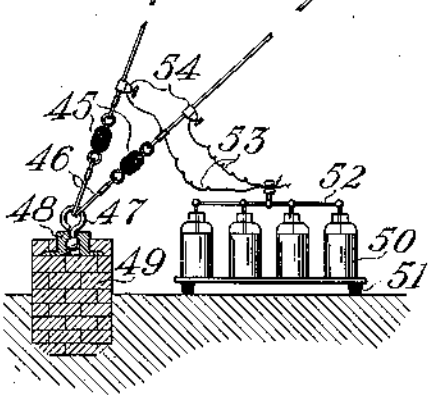

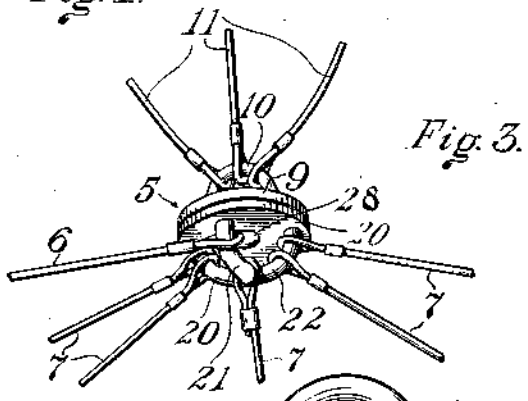

Fig. 3.

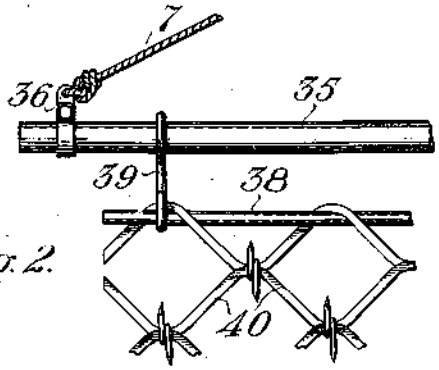

Fig. 2.

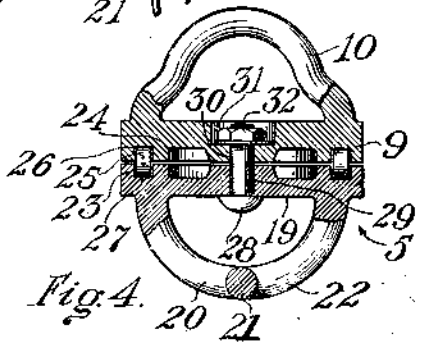

Fig. 4.

INVENTOR

Walter I. Pennock.

WITNESSES

Elizabeth L. Smith

J. Stuart Freeman.

BY

ATTORNEY

W. I. PENNOCK.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 4, 1911.

1,014,719.

Patented Jan. 16, 1912.

2 SHEETS—SHEET 2.

Fig. 5.

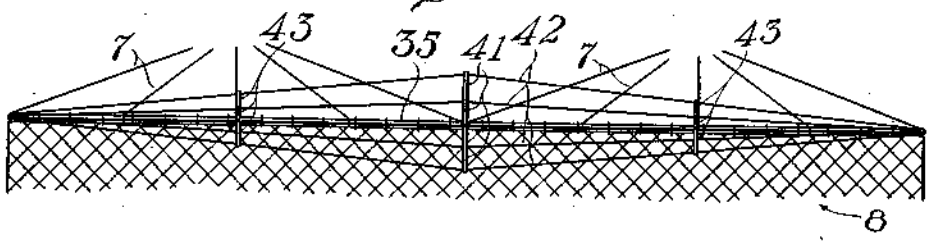

Fig. 6.
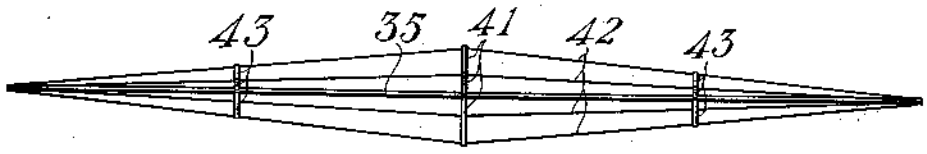
Fig. 7.

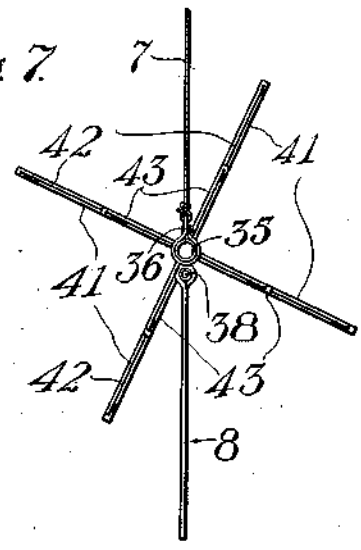

INVENTOR

Walter I. Pennock.

WITNESSES

Elizabeth L. Smith,

J. Stuart Freeman,

BY

Munn & Co.

ATTORNEY

UNITED STATES PATENT OFFICE.

WALTER I. PENNOCK, OF PHILADELPHIA, PENNSYLVANIA.

APPARATUS FOR COLLECTING ELECTRICAL ENERGY.

1,014,719. Specification of Letters Patent. Patented Jan. 16, 1912.

Application filed January 4, 1911. Serial No. 600,777.

To all whom it may concern:

Be it known that I, WALTER I. PENNOCK, a citizen of the United States, residing at Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Collecting Electrical Energy, of which the following is a full, clear, and exact disclosure.

The present invention relates to an improved means for collecting the charges of electricity from the upper atmosphere and more particularly to that form which consists in one or more captive balloons from which is suspended a suitable form of metallic conductor.

The principal objects of the device are: to provide a collector for atmospheric and static electricity, which when in operative position will present a large surface to currents of air, but which will offer comparatively little resistance thereto, to provide a collector of such material and construction as will be more efficient in its operation than any previously constructed for a similar purpose, to provide a means for maintaining such a collector suspended in the air and at right angles to opposing currents thereof, and to provide a suitable anchorage for holding said means captive.

With these principal objects in view, the present invention consists in further advantages which are brought out in the following specification and accompanying drawings, in both of which like numerals refer to like parts, and in which drawings—

Figure 1 is a perspective view of the complete device in operative position, Fig. 2 is an enlarged detail view of the wire mesh and the manner in which it is attached to the supporting balloons, Fig. 3 is a detail of the manner of securing the collector-supporting and anchor cables to the balloons, Fig. 4 is an enlarged cross section of the swivel connection shown in Fig. 3, Fig. 5 is top plan view of the reinforcing braces on the screen, Fig. 6 is an elevation of the same and Fig. 7 is an end view of the structure shown in Figs. 5 and 6.

Referring to the drawings, in Fig. 1 there-of, a plurality of balloons 1 of any suitable type is shown, each of which embodies hollow metallic elongated gas tanks 2, extending from the rear of which are single, rigidly affixed rudders 3, while on the sides of the tanks are secured stationary lifting planes 4.

To the bottom and slightly to the rear of the center of the tanks 2 is secured a suitable swivel 5, by which the anchor ropes 6 and the suspension ropes 7 for the metallic conductor 8 are secured to the balloons 1. A suitable form of swivel joint is illustrated in Figs. 3 and 4, but any type can be used that embodies the essential features shown therein.

The swivel joint illustrated consists in the base plate 9 having a looped portion 10 integral therewith and projecting from the upper face thereof. Secured to the loop 10 is a set of three light electrically conductive supporting ropes or cables 11 which extend upwardly and are secured at intervals to the bottom 12 of the balloon above.

The lower or revoluble member 19 of the swivel joint preferably comprises three upwardly directed curved arms, 20, 21, and 22, respectively, forming at their junction a T-shape as shown, said arms at their upper extremities being integral with the plate 23. The member 19 is revoluble below and concentric with the plate 9, and the two members are lightened in weight by opposed concentric grooves as shown at 24. Contact between said members is made through the roller bearings 25, which are carried in the opposed concentric grooves 26 and 27 of the respective upper and lower plates. Furthermore, said plates are maintained in coöperative relation with each other by means of a bolt 28 passing through centrally drilled holes 29 and 30 in the respective lower and upper plates, the drilled hole 30 opening upwardly into an enlarged recess 31, in which is sunken the nut 32 on the bolt 28. Two of the arms 20 and 22 of the lower revoluble member 19 extend in diametrical alinement, while from the central point thereof extends the third arm 21 at right angles thereto, and upward to the plate 23.

Suspended below the plurality of balloons is a hollow rod 35, of any suitable material, connected at regular intervals such as at points 36, by metallic ropes 7, to the alined arms 20 and 22 of the swivel joint 5. Below and parallel to the rod 35 is a similar but smaller rod 38 suspended therefrom by means of suitable couplings 39. From the rod 38 hangs a wire mesh 40 of any suitable form, such as can be extended over a considerable area and which will offer comparatively little resistance to the passage of air therethrough. The metal in such a screen is preferably rough, sharp or jagged and a convenient form embodying these characteristics is expanded sheet metal such as is used for lathing and for reinforcing concrete construction. Instead of the single hollow rod 35 alone, applicant contemplates the use of reinforcing means to prevent the buckling of the rod in a stiff wind, such, for instance, as the arrangement of wire bracing shown in Figs. 5, 6 and 7 in which cross rods 41, secured to the rod 35 at the center thereof are attached to the ends thereof by means of stretched wires 42. Between the rods 41 and the ends of the rod 35 are secured sets of cross rods 43 which support the wires 42 and strengthen the rod 35 at as many points as they may be placed.

For the purpose of maintaining the balloons and apparatus suspended therefrom captive, the light metallic cables 6 terminating downwardly in insulators 45 are employed. These insulators in turn are connected by means of short sections of rope 46 to the eye 47 of a suitable swivel 48, embedded in the anchorage 49.

When the balloons with the metallic screen suspended therefrom are allowed to rise into one of the higher altitudes, the entire apparatus being of metallic construction and uninsulated will become energized by contact with the surrounding natural charges of electricity. From the above description it is evident then that, while the screen 8, on account of its great extent, will be the greatest collecting agent, it will be seen that the balloons themselves and the suspending wires will also coöperate as one large collector, since no parts of which are insulated from any of the neighboring parts thereof. Consequently, when the apparatus described has reached an altitude or strata of the atmosphere abounding in static charges of electricity, an amount of the said charges proportionate to the surface area of the metal exposed will collect upon the apparatus as a whole and will be conducted downwardly toward the earth by means of the various anchor ropes 6, but will not pass into the ground on account of the interposition of the insulators 45.

To use the electrical charges thus acquired, a plurality of Leyden jars 50, or other suitable collectors are supported above the surface of the earth and insulated therefrom by any suitable means as represented by the blocks 51. Either the inner or outer conducting surfaces of the jars may be connected together and energized by the accumulated charge. In the present instance, the inner surfaces of the accumulators are shown to be connected, and the connecting means 52 is in turn connected to the ropes 6 by means of wires 53. These wires are secured to the ropes mentioned by means of suitable binding posts 54.

In the device described the anchor ropes 6 are of substantially the same length, and when the apparatus is raised to the desired altitude and is being blown by the currents of air, the balloons are turned by means of the vanes 3 to parallel relation with each other, and furthermore, from the manner in which the device is held captive and the collecting net 40 is suspended from the balloons, it is obvious that said net will at all times readily swing into a plane substantially perpendicular to any current of air acting upon the balloons above. The purpose of the swivel joint shown in Figs. 3 and 4 is principally for allowing the balloons to readily aline themselves with any new direction of the wind before the apparatus, including the suspended screen, can swing about the swivel 48, and said joint will also prevent the twisting of the ropes 7, when any rapid shifting of the air currents may occur.

While applicant has shown a set of Leyden jars as the accumulators in the accompanying drawings, it is obvious that any other suitable form may be used, and furthermore, that although not illustrated, any suitable apparatus may be run thereby, such as for instance, wireless telegraphic instruments.

Furthermore, although but one embodiment of the invention has been described, it is to be understood that various modifications may be made therein, and in fact several are contemplated by applicant that are of such structure as fall well within the scope of the appended claim.

Having thus described my invention, what I claim and desire to protect by Letters Patent of the United States, is:

A collector for charges of electricity, comprising a plurality of supporting means, a metallic gauze sustained thereby to lie in a plane and substantially equidistant from each of said supporting means, anchoring means emanating from a common point to each of said supporting means, means operative to maintain said supporting means

in their normal positions, and means between each of said supporting means and said gauze to permit each of said supporting means to readily and independently aline itself to accord with any alteration in the direction of opposing air currents.

In witness whereof I have hereunto set my hand this 28 day of December, A. D. 1910.

WALTER I. PENNOCK.

Witnesses:
MILDRED S. TEMPLE,
E. EUGENIA PENNOCK.

N. TESLA.

APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.

APPLICATION FILED JAN. 18, 1902. RENEWED MAY 4, 1907.

1,119,732. **Patented Dec. 1, 1914.**

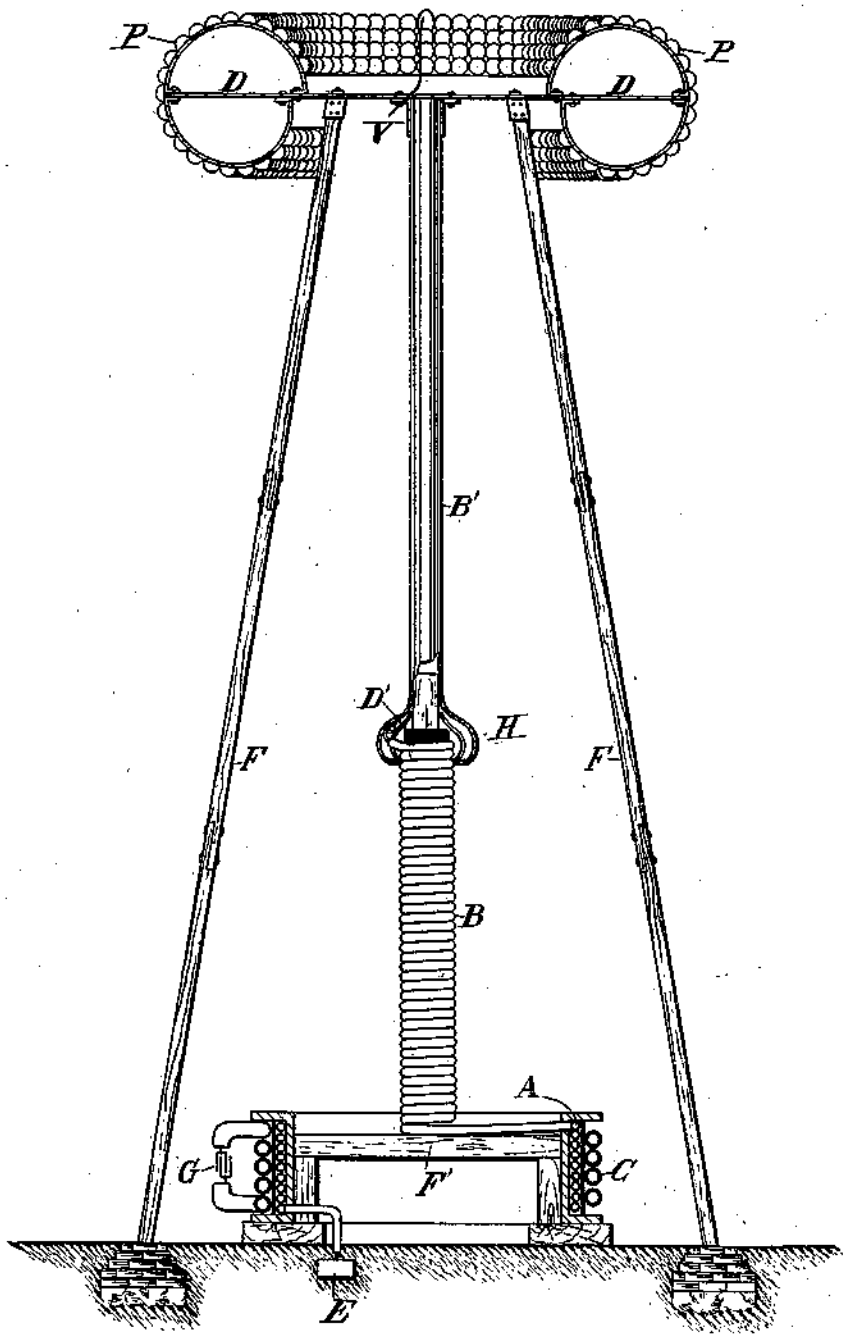

WITNESSES:

M. Lawson Dyer

Benjamin Miller.

INVENTOR,

Nikola Tesla,

BY Kerr, Page & Cooper,

his ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.

1,119,732. Specification of Letters Patent. Patented Dec. 1, 1914.

Application filed January 18, 1902, Serial No. 90,245. Renewed May 4, 1907. Serial No. 371,817.

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing in the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Apparatus for Transmitting Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

In endeavoring to adapt currents or discharges of very high tension to various valuable uses, as the distribution of energy through wires from central plants to distant places of consumption, or the transmission of powerful disturbances to great distances, through the natural or non-artificial media, I have encountered difficulties in confining considerable amounts of electricity to the conductors and preventing its leakage over their supports, or its escape into the ambient air, which always takes place when the electric surface density reaches a certain value.

The intensity of the effect of a transmitting circuit with a free or elevated terminal is proportionate to the quantity of electricity displaced, which is determined by the product of the capacity of the circuit, the pressure, and the frequency of the currents employed. To produce an electrical movement of the required magnitude it is desirable to charge the terminal as highly as possible, for while a great quantity of electricity may also be displaced by a large capacity charged to low pressure, there are disadvantages met with in many cases when the former is made too large. The chief of these are due to the fact that an increase of the capacity entails a lowering of the frequency of the impulses or discharges and a diminution of the energy of vibration. This will be understood when it is borne in mind, that a circuit with a large capacity behaves as a slackspring, whereas one with a small capacity acts like a stiff spring, vibrating more vigorously. Therefore, in order to attain the highest possible frequency, which for certain purposes is advantageous and, apart from that, to develop the greatest energy in such a transmitting circuit, I employ a terminal of relatively small capacity, which I charge to as high a pressure as practicable. To accomplish this result I have found it imperative to so construct the elevated conductor, that its outer surface, on which the electrical charge chiefly accumulates, has itself a large radius of curvature, or is composed of separate elements which, irrespective of their own radius of curvature, are arranged in close proximity to each other and so, that the outside ideal surface enveloping them is of a large radius. Evidently, the smaller the radius of curvature the greater, for a given electric displacement, will be the surface-density and, consequently, the lower the limiting pressure to which the terminal may be charged without electricity escaping into the air. Such a terminal I secure to an insulating support entering more or less into its interior, and I likewise connect the circuit to it inside or, generally, at points where the electric density is small. This plan of constructing and supporting a highly charged conductor I have found to be of great practical importance, and it may be usefully applied in many ways.

Referring to the accompanying drawing, the figure is a view in elevation and part section of an improved free terminal and circuit of large surface with supporting structure and generating apparatus.

The terminal D consists of a suitably shaped metallic frame, in this case a ring of nearly circular cross section, which is covered with half spherical metal plates P P, thus constituting a very large conducting surface, smooth on all places where the electric charge principally accumulates. The frame is carried by a strong platform expressly provided for safety appliances, instruments of observation, etc., which in turn rests on insulating supports F F. These should penetrate far into the hollow space formed by the terminal, and if the electric density at the points where they are bolted to the frame is still considerable, they may be specially protected by conducting hoods as H.

A part of the improvements which form the subject of this specification, the transmitting circuit, in its general features, is identical with that described and claimed in my original Patents Nos. 645,576 and 649,621. The circuit comprises a coil A which is in close inductive relation with a primary C, and one end of which is connected to a ground-plate E, while its other end is led through a separate self-induction coil B and a metallic cylinder B′ to the terminal D.

The connection to the latter should always be made at, or near the center, in order to secure a symmetrical distribution of the current, as otherwise, when the frequency is very high and the flow of large volume, the performance of the apparatus might be impaired. The primary C may be excited in any desired manner, from a suitable source of currents G, which may be an alternator or condenser, the important requirement being that the resonant condition is established, that is to say, that the terminal D is charged to the maximum pressure developed in the circuit, as I have specified in my original patents before referred to. The adjustments should be made with particular care when the transmitter is one of great power, not only on account of economy, but also in order to avoid danger. I have shown that it is practicable to produce in a resonating circuit as E A B B′ D immense electrical activities, measured by tens and even hundreds of thousands of horse-power, and in such a case, if the points of maximum pressure should be shifted below the terminal D, along coil B, a ball of fire might break out and destroy the support F or anything else in the way. For the better appreciation of the nature of this danger it should be stated, that the destructive action may take place with inconceivable violence. This will cease to be surprising when it is borne in mind, that the entire energy accumulated in the excited circuit, instead of requiring, as under normal working conditions, one quarter of the period or more for its transformation from static to kinetic form, may spend itself in an incomparably smaller interval of time, at a rate of many millions of horse power. The accident is apt to occur when, the transmitting circuit being strongly excited, the impressed oscillations upon it are caused, in any manner more or less sudden, to be more rapid than the free oscillations. It is therefore advisable to begin the adjustments with feeble and somewhat slower impressed oscillations, strengthening and quickening them gradually, until the apparatus has been brought under perfect control. To increase the safety, I provide on a convenient place, preferably on terminal D, one or more elements or plates either of somewhat smaller radius of curvature or protruding more or less beyond the others (in which case they may be of larger radius of curvature) so that, should the pressure rise to a value, beyond which it is not desired to go, the powerful discharge may dart out there and lose itself harmlessly in the air. Such a plate, performing a function similar to that of a safety valve on a high pressure reservoir, is indicated at V.

Still further extending the principles underlying my invention, special reference is made to coil B and conductor B′. The latter is in the form of a cylinder with smooth or polished surface of a radius much larger than that of the half spherical elements P P, and widens out at the bottom into a hood H, which should be slotted to avoid loss by eddy currents and the purpose of which will be clear from the foregoing. The coil B is wound on a frame or drum D^1 of insulating material, with its turns close together. I have discovered that when so wound the effect of the small radius of curvature of the wire itself is overcome and the coil behaves as a conductor of large radius of curvature, corresponding to that of the drum. This feature is of considerable practical importance and is applicable not only in this special instance, but generally. For example, such plates at P P of terminal D, though preferably of large radius of curvature, need not be necessarily so, for provided only that the individual plates or elements of a high potential conductor or terminal are arranged in proximity to each other and with their outer boundaries along an ideal symmetrical enveloping surface of a large radius of curvature, the advantages of the invention will be more or less fully realized. The lower end of the coil B—which, if desired, may be extended up to the terminal D—should be somewhat below the uppermost turn of coil A. This, I find, lessens the tendency of the charge to break out from the wire connecting both and to pass along the support F′.

Having described my invention, I claim:

1. As a means for producing great electrical activities a resonant circuit having its outer conducting boundaries, which are charged to a high potential, arranged in surfaces of large radii of curvature so as to prevent leakage of the oscillating charge, substantially as set forth.

2. In apparatus for the transmission of electrical energy a circuit connected to ground and to an elevated terminal and having its outer conducting boundaries, which are subject to high tension, arranged in surfaces of large radii of curvature substantially as, and for the purpose described.

3. In a plant for the transmission of electrical energy without wires, in combination with a primary or exciting circuit a secondary connected to ground and to an elevated terminal and having its outer conducting boundaries, which are charged to a high potential, arranged in surfaces of large radii of curvature for the purpose of preventing leakage and loss of energy, substantially as set forth.

4. As a means for transmitting electrical energy to a distance through the natural media a grounded resonant circuit, comprising a part upon which oscillations are impressed and another for raising the ten-

sion, having its outer conducting boundaries on which a high tension charge accumulates arranged in surfaces of large radii of curvature, substantially as described.

5. The means for producing excessive electric potentials consisting of a primary exciting circuit and a resonant secondary having its outer conducting elements which are subject to high tension arranged in proximity to each other and in surfaces of large radii of curvature so as to prevent leakage of the charge and attendant lowering of potential, substantially as described.

6. A circuit comprising a part upon which oscillations are impressed and another part for raising the tension by resonance, the latter part being supported on places of low electric density and having its outermost conducting boundaries arranged in surfaces of large radii of curvature, as set forth.

7. In apparatus for the transmission of electrical energy without wires a grounded circuit the outer conducting elements of which have a great aggregate area and are arranged in surfaces of large radii of curvature so as to permit the storing of a high charge at a small electric density and prevent loss through leakage, substantially as described.

8. A wireless transmitter comprising in combination a source of oscillations as a condenser, a primary exciting circuit and a secondary grounded and elevated conductor the outer conducting boundaries of which are in proximity to each other and arranged in surfaces of large radii of curvature, substantially as described.

9. In apparatus for the transmission of electrical energy without wires an elevated conductor or antenna having its outer high potential conducting or capacity elements arranged in proximity to each other and in surfaces of large radii of curvature so as to overcome the effect of the small radius of curvature of the individual elements and leakage of the charge, as set forth.

10. A grounded resonant transmitting circuit having its outer conducting boundaries arranged in surfaces of large radii of curvature in combination with an elevated terminal of great surface supported at points of low electric density, substantially as described.

NIKOLA TESLA.

Witnesses:
M. LAMSON DYER,
RICHARD DONOVAN.

Nov. 12, 1957 L. R. CRUMP 2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Filed March 12, 1954

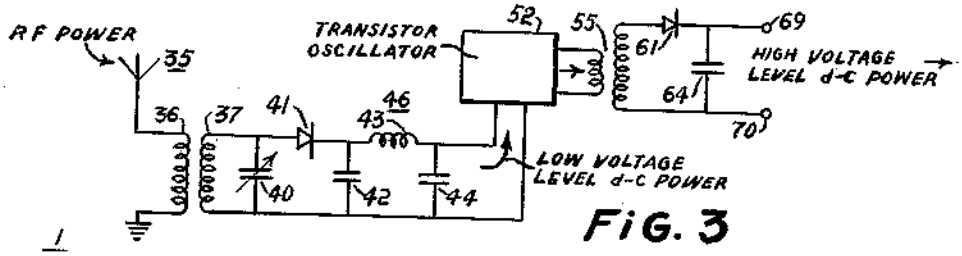

FIG. 3

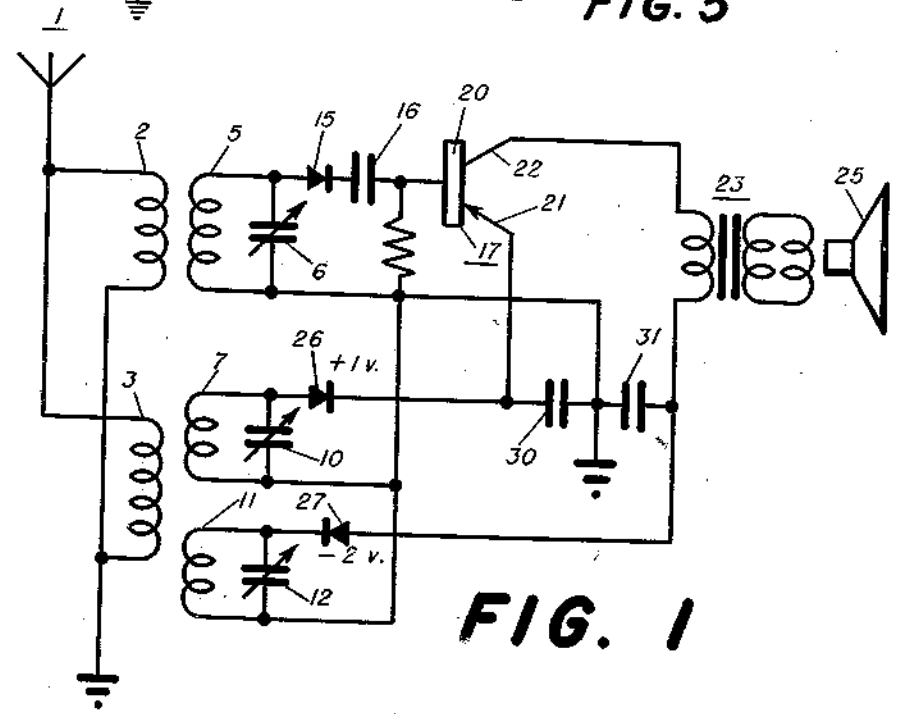

FIG. 1

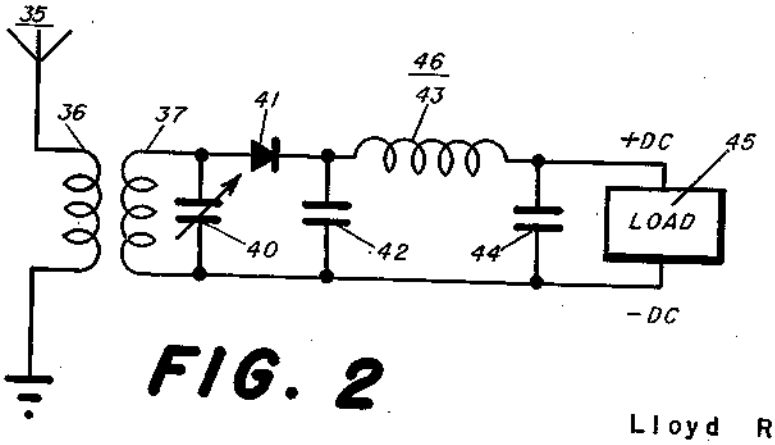

FIG. 2

INVENTOR

Lloyd R. Crump

BY W. E. Thibodeaux & A. W. Dew

ATTORNEYS

United States Patent Office 2,813,242 Patented Nov. 12, 1957

2,813,242

POWERING ELECTRICAL DEVICES WITH ENERGY ABSTRACTED FROM THE ATMOSPHERE

Lloyd R. Crump, Silver Spring, Md.

Application March 12, 1954, Serial No. 415,986

1 Claim. (Cl. 321—2)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to the convenient and economical provision of power for the operation of electronic circuits and devices using transistors, and of other electrical devices having modest power requirements.

A great advantage of transistors, and a major reason for their enthusiastic reception since their introduction a few years ago, is the fact that they will operate satisfactorily with very low supply voltages and currents. One milliwatt or even less is sufficient to power a transistor in many applications. Various batteries have been developed to provide, in a minimum of space, the relatively minute amounts of power needed by transistors.

My invention provides methods and means that permit transistor circuits, and also other low-powered electrical devices, to be economically and conveniently operated without any batteries whatever, and indeed without any power supply whatever as power supplies are ordinarily conceived.

The invention centers around my discovery that it is practicable to construct operative transistor circuits that are able to abstract from the atmosphere sufficient electromagnetic energy to provide all necessary supply voltages and currents for their own operation. Circuits and devices powered according to my invention will operate indefinitely without any local power source whatever.

I have successfully constructed and demonstrated such circuits. For example, I have constructed a batteryless transistor radio receiver on which I have listened to either nearby or distant broadcast stations as desired, using either headphones or a loudspeaker; this receiver has been powered entirely by electromagnetic energy abstracted from the atmosphere.

From the successful operation of this receiver, and from other experimental work, it becomes clear that, by the methods and means of the invention, a great variety of practical and useful transistor circuits can be powered entirely by energy abstracted from the atmosphere.

Furthermore, as will become apparent below, my invention is applicable to the powering of other electrical devices requiring relatively small amounts of power.

An object of the present invention is to provide methods and means for powering transistor circuits entirely from radiofrequency energy abstracted from the atmosphere.

Another object is to provide methods and means for powering remote radio receivers, low-powered radio transmitters, and other low-powered electrical devices, with energy received by radio from a master station, so that no local power supplies are needed by the devices and so that the powering or non-powering of the remote device is under the control of the master station.

A further object is to provide methods and means for powering transistor circuits and other low-powered electrical devices with radiofrequency energy received from one or more remote radio transmitters.

Other objects, aspects, uses, and advantages of the invention will become apparent from the following description and from the drawing.

Figure 1 is a schematic diagram of a transistor radio receiver in which all necessary power is supplied by energy abstracted from the atmosphere in accordance with the invention.

Figure 2 is a schematic diagram showing a general application of the invention to provide direct-current power to a load.

Figure 3 is a schematic diagram of a system for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere.

Referring to Figure 1, a receiving antenna **1** is connected to antenna coupling coils **2** and **3**, the other ends of which are connected to ground. A parallel resonant circuit consisting of coil **5** and capacitor **6** is coupled to coil **2**. A second parallel resonant circuit consisting of coil **7** and capacitor **10** is coupled to coil **3**. A third parallel resonant circuit consisting of coil **11** and capacitor **12** is also coupled to coil **3**.

Coil **5** and capacitor **6** are tuned to the frequency of a radio transmitter from which it is desired to receive information—for instance, an amplitude-modulated standard broadcast station. The signal received from this transmitter need not be strong. The signal is detected by diode **15** to obtain an audio-frequency information signal. This audio signal is coupled through a capacitor **16** and is amplified by a circuit that includes a transistor **17** having a base **20**, an emitter **21**, and a collector **22**. The amplified audio output of the transistor is coupled through an audio transformer **23** to an electroacoustical transducer, preferably a permanent-magnet dynamic loudspeaker **25** as shown.

The novelty of the invention lies largely in the method and means by which the necessary direct-current power is supplied to the emitter and collector circuits of transistor **17**. This method and means will now be described.

Coil **7** and capacitor **10**, and also coil **11** and capacitor **12**, are tuned to receive radio signals of relatively high strength. It does not matter whether these signals contain information. These power signals are rectified by diodes **26** and **27** to provide direct-current power that is filtered by capacitors **30** and **31**. The D.-C. power thus obtained is utilized to power the transistor **17**.

In the circuit shown, two tuned circuits (coil **7** and capacitor **10**, and coil **11** and capacitor **12**) are tuned to power signals and the D.-C. voltages obtained from each are connected in series. The tuned power circuits may be tuned to the same or different power signals. Under certain circumstances it may be desirable to use more than two tuned power circuits and to tune them to more than two power signals; in this way power can be obtained from several signals and combined. On the other hand, if a strong power signal is available, a single tuned power circuit may suffice to give the needed D.-C. power.

Even weak information signals can be received successfully. A plurality of transistor amplifier stages can be used if desired, or other circuits such as superheterodyne circuits can be used. It is merely necessary that a sufficiently strong power signal or signals be available to provide the small amount of D.-C. needed to power the transistors.

If the information signal happens to be strong, it can be used as the power signal; all of the tuned circuits (coil **5** and capacitor **6**, coil **7** and capacitor **10**, coil **11** and capacitor **12**) are tuned to the information signal.

Engineers who have observed my invention in operation have been surprised at the unexpectedly good results obtained, even with readily available power signals of quite moderate strength. For instance, sufficient power for satisfactory operation of a loudspeaker at low volumes is

readily obtained from a 5-kilowatt standard broadcast station 5 miles away, using only an indoor antenna to pick up the power signal as well as information signals. In typical operation under these conditions a D.-C. voltage of about 2.5 to 3 volts is obtained between the emitter and the collector, at a current of about 250 microamperes; D.-C. power input to the transistor is thus of the order of 0.5 to 1 milliwatt. So far as I am aware, no one has ever before discovered and demonstrated the practicability of this method of powering a radio receiver.

Because existing broadcast stations within a radius of a number of miles provide adequate power signals, the invention is readily practicable with existing power signals in almost any location in or near any city in the United States.

Although I have described a transistor radio receiver powered by my invention, it will be readily apparent that the invention is applicable to the powering of any transistor circuit using one or a number of transistors, and to the powering of other devices requiring relatively small amounts of power. For instance, sensitive electromechanical, electrochemical, or electrothermal devices can be operated by the method of the invention.

Referring to Figure 2, which shows a more general embodiment of my invention, an antenna 35 picks up radiofrequency energy from the atmosphere. This energy flows through coil 36, which is coupled to a tuned circuit consisting of coil 37 and capacitor 40. The radiofrequency voltage across capacitor 40 is rectified by diode 41 and filtered by a low-pass filter 46 consisting of capacitors 42 and 44 and choke coil 43. The resulting D.-C. voltage is applied to a load 45.

In the practice of my invention, larger amounts of power can be obtained for short periods of time by storing received energy in a suitable energy storage device. Stored energy may then be withdrawn at intervals at a more rapid rate than that at which it was received and put into the storage device. In this way the invention can be used to provide short pulses of relatively very high electrical energy. This result can be readily obtained by charging a relatively large capacitor with direct current and then discharging the capacitor rapidly into a load when desired. This rapid discharge can be initiated automatically when the voltage across the capacitor reaches a certain level, or it can be initiated when a transistor radio receiver receives a certain information signal.

Higher voltages can be obtained with the invention by means of well known devices for raising D.-C. voltages as shown in Figure 3. The D.-C. voltage output from the capacitor 44 can be used to power a low frequency transistor oscillator 52 whose A.-C. output is raised to a higher voltage level by the transformer 55. This relatively high A.-C. voltage can then be rectified by a diode 61 and fed to a capacitor 64 to provide a high energy D.-C. source at a relatively high voltage level at the terminals 69 and 70. If desired, energy can now be withdrawn from the capacitor 64 at intervals in short pulses of high energy at a high voltage level. Pulsed radio transmission is one of the possible uses for this form of the invention. Other uses would be to provide a single relatively powerful pulse needed to actuate an electrothermal or electromechanical device.

As has been indicated above, in many locations and particularly anywhere in or near most American cities, power signals normally present in the atmosphere are readily available for the easy and convenient practice of the invention. However, the invention also has important applications in systems in which the necessary power signal is generated and transmitted specifically for the operation of the particular system. Such systems can, for example, comprise a master station transmitting all the power that is needed for hundreds or thousands of fixed or mobile transistor receivers or other remote devices over

a range of many miles. This eliminates the need for hundreds or thousands, as the case may be, of local power supplies. At the same time, such a system has the advantage that all of the remote devices can be simultaneously activated or deactivated at the will of the master station, simply by starting or stopping the transmission of the power signal. In such systems it will often be advantageous to use power signals of frequencies sufficiently high to permit the use of resonant receiving antennas of small physical dimensions for signal pickup at the remote devices. In addition to the power signal, the master station may transmit an information signal on the same or a different carrier.

Certain types of devices powered entirely by received radio waves are of course well known. The well-known "crystal set" of the early days of radio, which used a diode rectifier to demodulate an amplitude-modulated radiofrequency signal, is an outstanding example of such a device. My invention is readily distinguishable from such prior devices, however. In typical prior devices a modulated radiofrequency signal is applied to a diode to obtain unidirectional half-wave pulses whose amplitudes vary with modulation. These pulses are integrated by means of a capacitor to obtain a unidirectional signal the amplitude of which follows the audiofrequency modulation envelope. If the radiofrequency signal is received with sufficient strength the audio signal may have sufficient power to operate headphones or similar utilization device without power amplification; but the signal is utilized for its information content, rather than to supply non-information-containing power.

My invention, on the other hand, entails the utilization of received radiofrequency energy to supply power to at least one pair of circuit points (across capacitor 31 in Fig. 1, for example), such circuit points requiring power solely for its power content and not for any information or modulation it may contain. In other words, my invention entails the utilization of radiofrequency energy to supply power that would otherwise have to be supplied by batteries, generator, or other local power source.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

I claim:

An electrical device for obtaining a high energy D.-C. source at a high voltage level using energy abstracted from the atmosphere, said device comprising in combination: resonant means for receiving radio waves, first rectifier means for converting said radio waves into first direct current energy, first capacitor means for storing said first direct current energy, an oscillator powered by said direct current energy, said oscillator producing an A.-C. output, transformer means for raising said A.-C. output to an increased voltage level, second rectifier means for converting the A.-C. output of increased voltage level from said transformer into second direct current energy, and second capacitor means for storing said second direct current energy.

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Sept. 13, 1966 L. H. RUHNKE SD 3,273,066

APPARATUS FOR DETECTING CHANGES IN THE ATMOSPHERIC ELECTRIC FIELD

Filed Dec. 20, 1963

2 Sheets-Sheet 1

Fig. 1

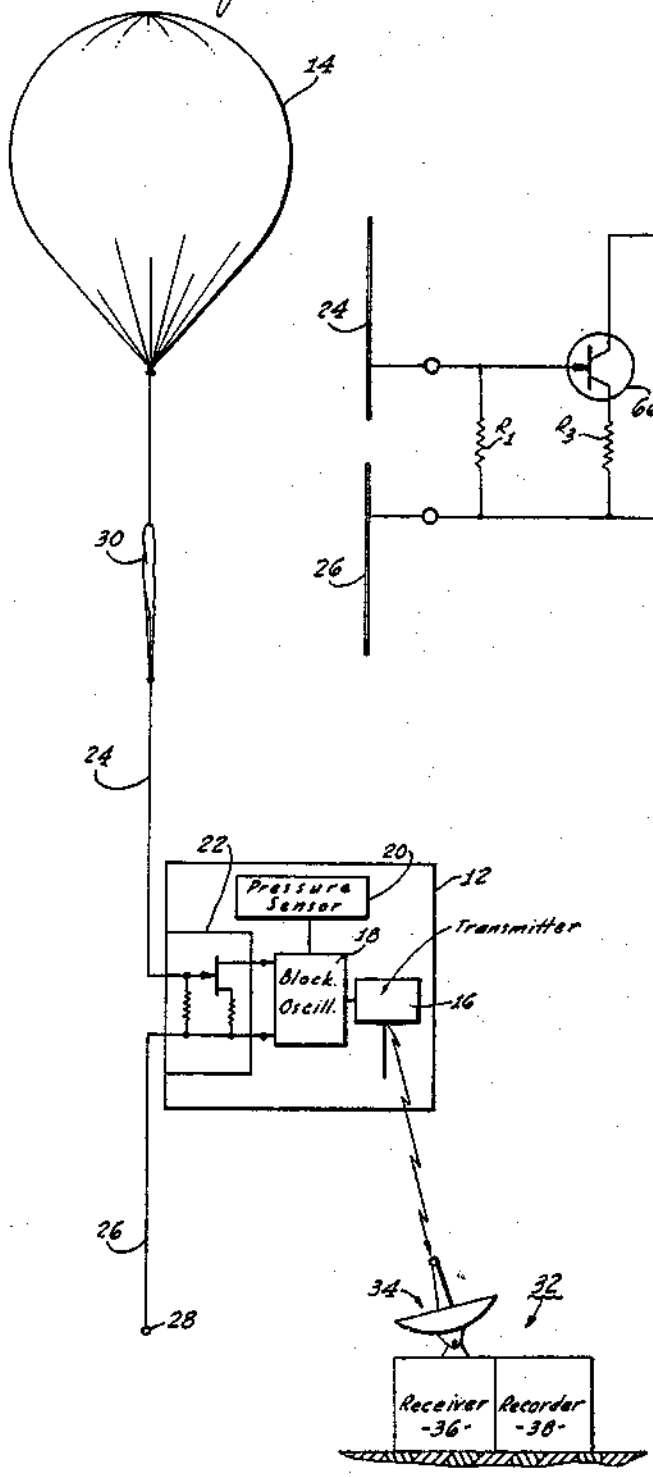

Fig. 3

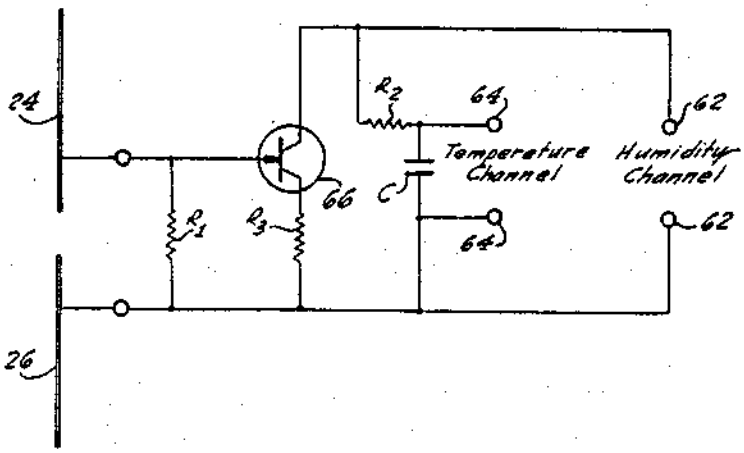

INVENTOR:
Lothar H. Ruhnke

By Alan C. Rose
Attorney

Sept. 13, 1966 L. H. RUHNKE 3,273,066

APPARATUS FOR DETECTING CHANGES IN THE ATMOSPHERIC ELECTRIC FIELD

Filed Dec. 20, 1963 2 Sheets-Sheet 2

Fig. 2

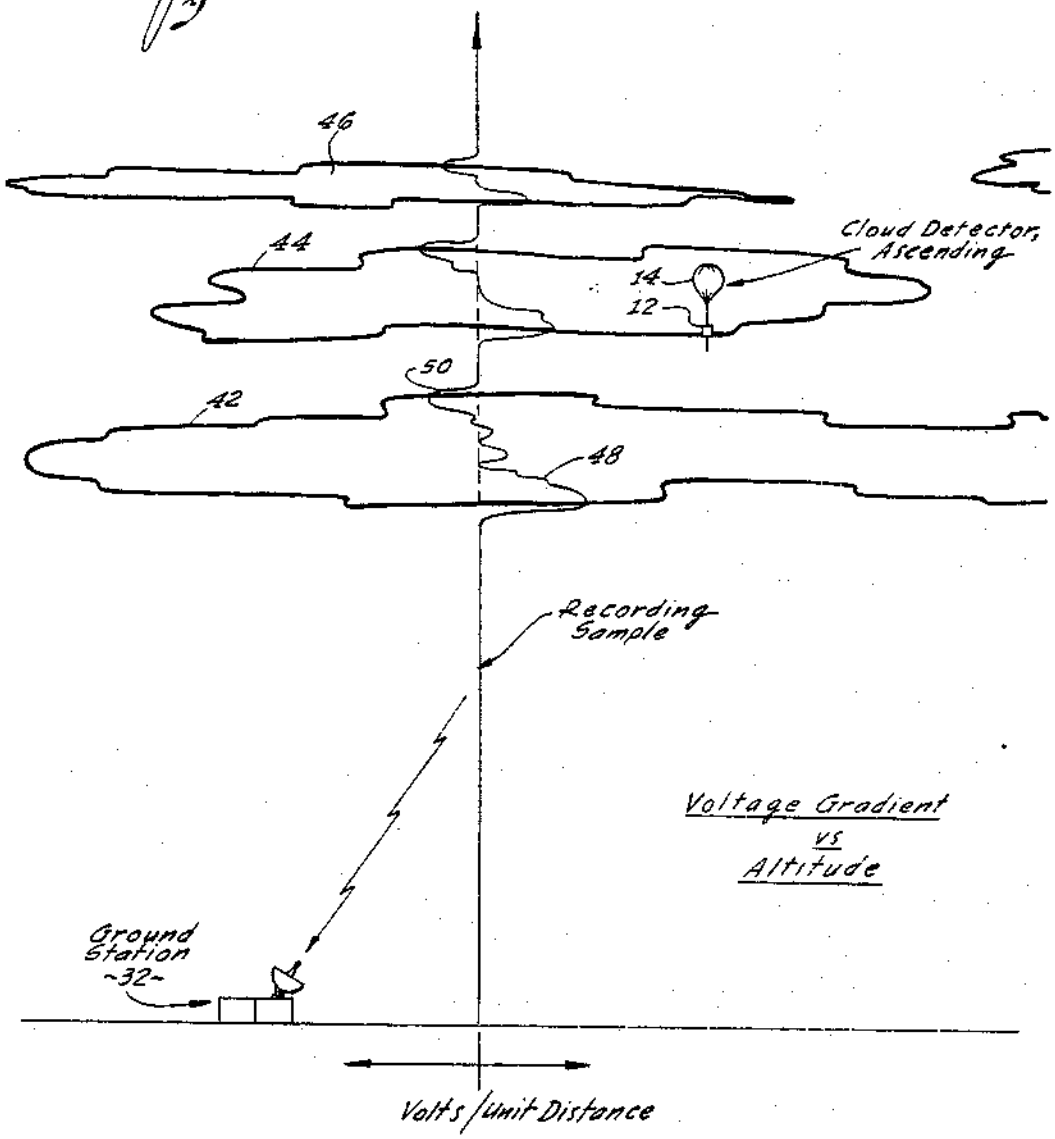

INVENTOR:
Lothar H. Ruhnke

By Alan C. Rose

Attorney

United States Patent Office

3,273,066

Patented Sept. 13, 1966

3,273,066

APPARATUS FOR DETECTING CHANGES IN THE ATMOSPHERIC ELECTRIC FIELD

Lothar H. Ruhnke, Minneapolis, Minn., assignor to Litton Systems, Inc., Beverly Hills, Calif.

Filed Dec. 20, 1963, Ser. No. 332,186
4 Claims. (Cl. 325—113)

This invention relates to a cloud detector or an apparatus for sensing electrostatic conditions in the earth's atmosphere.

Cloud detection apparatus which is presently employed is usually of the "ceilometer" type which merely measures the height of the lower surface of the clouds to indicate the ceiling conditions. One object of the present invention is to determine the location of both the top and the bottom of one or more cloud formations of the atmosphere.

While electrostatic sensors of one type or another have been proposed heretofore for use in the atmosphere, they have been so complex and expensive that they have not enjoyed widespread use. In addition, cloud radars have recently been developed, but their usefulness is limited by failures when different zones of the atmosphere contain droplets of different sizes, as discussed more fully below. Accordingly, it is another object of the present invention to simplify and reduce the cost of cloud detectors, while maintaining reliability, compatibility with existing equipment, and adequate sensitivity for all practical purposes.

In accordance with an illustrative embodiment of the present invention, a conventional U.S. Weather Bureau or U.S. Army meteoroligical radiosonde transmitter may be provided with a modulator which is controlled by a field effect transistor. The input to the field effect transistor is a dipole antenna. Each of the arms of the dipole antenna may be five to fifty feet in length, for example, and one of the dipole elements may trail the radiosonde package while the other element may extend forward in the direction of movement of the unit. When a balloon is employed to carry the cloud detector unit aloft, a weight may be attached to one of the antenna elements so it hangs below the instrument package, while the other antenna element can extend along, or even form the flexible connection between the radiosonde unit and the balloon. A receiving unit is provided to pick up the modulated signals from the radiosonde apparatus, demodulate these signals and record them. While it is contemplated that the receiver may normally be situated on the ground and receive signals from a rising radiosonde unit, the radiosonde unit could well be employed by an aircraft to determine conditions below a cloud layer. Under these conditions the receiver would be mounted on the plane and the radiosonde unit could be parachuted to the ground.

In accordance with a feature of the present invention, therefore, a system for detecting electrostatic field conditions in the atmosphere includes a transmitter, arrangements for moving the transmitter through the atmosphere, an antenna extending a substantial distance from the transmitter, and a field effect transistor connected to receive electrostatic input signals from said antenna and to modulate the output of the transmitter in accordance with voltages detected by the antenna.

In accordance with one aspect of the present invention, simplicity of circuitry and stability of operation are achieved by the use of dynamic circuitry which measures the instantaneous difference in potential between two antenna elements. Thus, a high input resistor may be connected between the input antenna elements. With this type of arrangement the instrument package must be continuously moved through the atmosphere in order to

give meaningful results. Under these conditions, the recorded output indicates changes in electric fields. A constant electric field, corresponding to a linear change in potential produces no substantial output signal. It has been determined that a balloon velocity of about five meters per second will produce good results with a dipole antenna shunted by a 1,000 megohm resistor and connected to a field effect transistor as discussed in detail in the present specification. With lower velocities, a higher input impedance or greater amplification would be required, with higher velocities, such as rocket propulsion or the like, permitting even lower input impedances and simpler input circuits.

Accordingly, it is a feature of the invention that apparatus is provided for moving a radiosonde unit through the atmosphere at a predetermined rate, that two element input antenna preferably of the dipole type is provided, and that the antenna is connected to the radiosonde by simple dynamic amplification circuitry, which requires continuous movement of the apparatus to give useful output information.

The novel features which are believed to be characteristic of the invention both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in conjunction with the accompanying drawings in which a typical embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

In the drawing:

FIG. 1 is a schematic block diagram of a radiosonde equipment for sensing changes in the electric field of the atmosphere, and thus detecting clouds, in accordance with the present invention;

FIG. 2 is a diagrammatic showing of the record obtained under typical cloud conditions; and

FIG. 3 is a circuit diagram indicating a typical arrangement of connections of a dipole antenna, a field effect transistor, and the input terminals of a standard meteorological radiosonde apparatus.

With reference to the drawings, FIG. 1 shows a radiosonde package 12 supported by a balloon 14. The radiosonde unit includes a transmitter 16, blocking oscillator 18, pressure sensor 20, and a field effect transistor unit 22. A dipole antenna having an upper element 24 and a lower element 26 is connected to the input of the field effect transistor unit 22. A small weight 28 is secured to the lower end of the antenna element 26 to hold it in the extended position. Similarly, the upper antenna element 24 extends in the other direction, and it may either form the support for the radiosonde unit 12 or may be closely associated with the supporting cable. A parachute 30 is provided for safe return of the instrument package to ground.

A ground or receiving station 32 may include an antenna 34, receiver and demodulator 36, and a recording apparatus 38.

FIG. 2 shows a typical recording of the electrostatic field obtained as the ballon 14 and instrument package 12 rise through the successive layers of clouds 42, 44, and 46, along the center line of the drawing. It is known that the electrostatic potential in the atmosphere increases from ground potential to plus 300,000 volts at elevations of about 30 miles. It is also known that the atmospheric electric field, which is the gradient of the potential, is substantially increased within clouds. As the package enters the lower edge of a cloud, the sudden increase in electric field causes a pulse of current to flow through resistor R_1 in one direction, and upon leaving the cloud, the sudden

reduction in electric field causes an oppositely directed current pulse. This produces the positive swing shown at 48 in FIG. 2 as the unit enters the cloud and the negative peak 50 as the apparatus is rising through the upper surface of the cloud stratus 42. A similar pattern is observed as the unit goes through the higher cloud formations 44 and 46. With a knowledge of the speed of ascent of the balloon and instrument package, the location of the upper and lower surfaces of successive cloud layers may be determined by the present apparatus. Accordingly, despite the presence of a relatively low cloud layer which completely obscures other cloud formations, ground personnel may readily determine the meterological conditions relating to clouds above this low ceiling.

Returning to FIG. 1, the radiosonde equipment represented by blocks 16, 18 and 20 is well known. The meterological radiosonde system which will be taken as typical is designated by the military by the numbers AN/AMT 4B. The Army technical manual which describes this radiosonde system is identified as TM 11–2432A–TO 31M4–2AMT–11, dated June 26, 1958. The radiosonde transmitter operates at a frequency of 1680 megacycles per second. This transmitter is modulated by a blocking oscillator 18, the frequency of the blocking oscillator being controlled by the meteorological conditions which are detected. Normally, a thermistor for measuring the temperature and a humidity sensor are alternately switched to the input terminals of the blocking oscillator 18. In the present case, the cloud detector circuitry is connected to both of these terminals. The barometric pressure sensor 20 may also be retained in the unit, and it may be connected to control the frequency of the blocking oscillator 18 by a switching action as described below.

With reference to FIG. 3, the humidity channel input terminals 62 and the temperature channel input terminals 64 of the standard radiosonde unit are shown at the right-hand side of the circuit. Atmospheric electric signals received by the dipole antenna elements 24 and 26 are applied to the field effect transistor 66 and are then coupled by a suitable circuit to the input terminals 62 and 64 of the radiosonde. While other field effect transistors may be employed, type C 610 of Crystallonics, Inc., was found to be suitable from a sensitivity and reliability standpoint for the present purposes. The input to the field effect transistor is shunted by a 1,000 megohm resistor R_1 to stabilize the input characteristic. Suitable biasing of the transistor 66 is provided by resistor R_3. Because the impedance of the transistor 66 is substantially lower than that of the temperature and humidity sensors which are normally employed, a 110,000 ohm resistor in the blocking oscillator was removed and a capacitor C was connected in parallel to the input terminals. The capacitor was selected to produce a modulation frequency of approximately 100 cycles per second in the absence of an input signal. Positive and negative voltages will then raise or lower this frequency.

In the radiosonde apparatus, signals from the pressure sensor 20 are normally employed to switch from the temperature channel terminals 64 to the humidity channel terminals 62. This switch is well known in the art as a baroswitch. The barometric pressure switching action provides an indication of altitude, so it is useful to preserve this information. Accordingly, the resistor R_2 is employed between the transistor 66 and one terminal 64 to reduce the output signal slightly, thus changing the modulation level and preserving the pressure and thus altitude information.

With regard to the length of the dipole elements 24 and 26, the size of resistor R_1 and the amplification of the field effect transistor, these are fixed by several factors. First, the antenna elements should be large enough to provide a substantial input signal, but should be relatively small as compared with normal cloud thicknesses. Lengths of 5 to 50 feet for each dipole would be of the proper order of magnitude. The resistor R_1 was chosen to reduce the input impedance between dipoles 24 and 26 below the point where fog and dampness and the resultant shunt impedance will introduce instability into the transmitted signals. With these parameters, and a speed of ascent of the order of 5 meters per second, it was determined that a single field effect transistor provided the necessary amplification for operation with the standard radiosonde unit.

As mentioned generally above, cloud radars are subject to failure under certain atmospheric conditions. Thus, the radar return is proportional to the sixth power of the droplet or particle size, while the human eye and optical systems respond to the second power of the droplet size. With the radar return proportional to such a high power of the droplet diameter, if a radar is adjusted to pick up a cloud having large particles, other clouds having small size particles are not detected. The present electrostatic system, however, responds in a manner which is nearly the same as the optical response, and therefore does not fail under atmospheric conditions where different size droplets or particles are present in successive clouds.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements within the scope of the invention may be devised by those skilled in the art. Thus, by way of example and not of limitation, a somewhat different shape of antenna could be employed to pick up electrostatic field variations and apply them to the field effect transistor, an inherently stabilized transistor may be used, and the instrument package may be carried by rocket or other suitable propulsion arrangements than the balloon shown in the drawings. Accordingly, it is evident that various changes may be made in the present invention without departing from the spirit of the invention as defined in the present claims.

What is claimed is:

1. An apparatus for sensing electrostatic conditions in the atmosphere comprising:
   - a radiosonde apparatus including means for modulating the output frequency thereof, said means including an R-C circuit;
   - a pair of probes positioned in respectively different locations in the atmosphere with respect to said radiosonde;
   - a field effect transistor having its drain and gate terminals connected across said pair of probes and having its source and drain terminals connected in series with the resistance of said R-C circuit to modulate said radiosonde; and
   - a stabilizing high resistance connected across the two probes and across said gate and drain terminals of said transistor.

2. In an apparatus for sensing atmospheric electrostatic field conditions;
   - a balloon;
   - an instrument package connected to and spaced from said balloon, said instrument package including a transmitter, means including an R-C circuit for modulating said transmitter, and a field effect transistor having source and drain terminals connected in series with the resistance in said R-C circuit to modulate said transmitter;
   - antenna means including an antenna and resistance means connected across said antenna, said resistance means also being connected across the gate and the drain of said field effect transistor, said antenna extending upward from said package toward said balloon and downwardly from said package for applying signals to said field effect transistor in response to said field conditions to render said modulating means responsive to said field conditions.

3. An apparatus for sensing changes of the atmospheric electric field at cloud boundaries, which comprises:
   - a blocking oscillator-type modulated radiosonde including fixed resistance means and capacitance means

connected in parallel with said fixed resistance means, said capacitance means being effective to discharge through said resistance means to control the modulation of said radiosonde;

dipole antenna means responsive to changes of the atmospheric electric field for producing a signal indicative of said changes;

resistance means connected across said dipole antenna means; and

a field effect transistor having source and drain terminals connected in series with said fixed resistance means and a gate terminal connected to said dipole antenna means for reception of said signal, said field effect transistor being responsive to said signal for varying the rate of discharge of said capacitance means to cause the blocking oscillator to modulate said radiosonde in accordance with the second changes in the atmospheric electric field.

4. An apparatus for sensing changes of the atmospheric electric field at cloud boundaries, which comprises:

radiosonde means including a blocking oscillator having fixed resistance means and capacitance means connected in parallel with said fixed resistance means, said capacitance means being effective to discharge through said resistance means to control the frequency of oscillation of said blocking oscillator;

dipole antenna means responsive to changes of the atmospheric electric field for producing a signal indicative of said changes;

resistance means connected across said dipole antenna; and

a field effect transistor having source and drain terminals connected in series with said fixed resistance means and a gate terminal connected to said dipole antenna means for reception of said signal, said field effect transistor being responsive to said signal for varying the rate of discharge of said capacitance means to control the frequency of oscillation of said blocking oscillator in accordance with the sensed changes in the atmospheric electric field.

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DAVID G. REDINBAUGH, *Primary Examiner.*

JOHN W. CALDWELL, *Examiner.*

United States Patent [19]

Phillips, Sr.

[11] **Patent Number: 4,685,047**

[45] **Date of Patent: Aug. 4, 1987**

[54] **APPARATUS FOR CONVERTING RADIO FREQUENCY ENERGY TO DIRECT CURRENT**

[76] Inventor: **Raymond P. Phillips, Sr.**, 1200 S. Frances, Terrell, Tex. 75160

[21] Appl. No.: **886,138**

[22] Filed: **Jul. 16, 1986**

[51] **Int. Cl.**[4] **H02M 7/06**

[52] **U.S. Cl.** **363/126**; 307/151

[58] **Field of Search** 363/125, 126; 307/151

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Primary Examiner—Patrick R. Salce
Assistant Examiner—Jeffrey Sterrett
Attorney, Agent, or Firm—Millen & White

[57] **ABSTRACT**

Apparatus for and methods of converting radio frequency energy into direct current for generating electric power includes a dipolar antenna for receiving radio frequency energy and a circuit connected thereto for converting the radio frequency energy to direct current. The circuit has a positive output line connected to one pole of the antenna and a negative output line connected to the other pole of the antenna. A positive transmitting diode is in the positive output line and a negative transmitting diode is in the negative output line. First and second bus lines and a pair of tuned circuits of opposite polarity couple the positive output line and negative line to the bus line with one of the bus lines being connected to ground. Each tuned circuit includes a first bridging line connecting the positive output line to the first and second ground lines and a second bridging line connecting the negative output line to the first and second ground lines. Each bridging line has a diode therein oriented at a polarity which is reverse with respect to the input diode. The bridging lines of each tuned circuit are connected to one another by an inductance and have capacitors disposed between the diode and the bus lines. A direct current device is connected to the positive line of the circuit.

11 Claims, 1 Drawing Figure

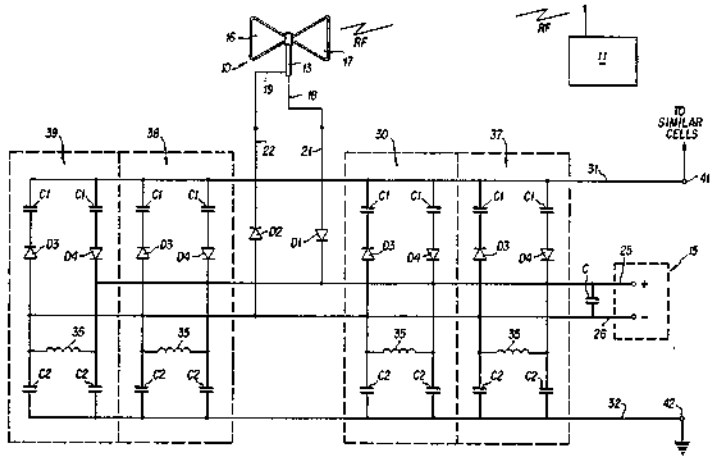

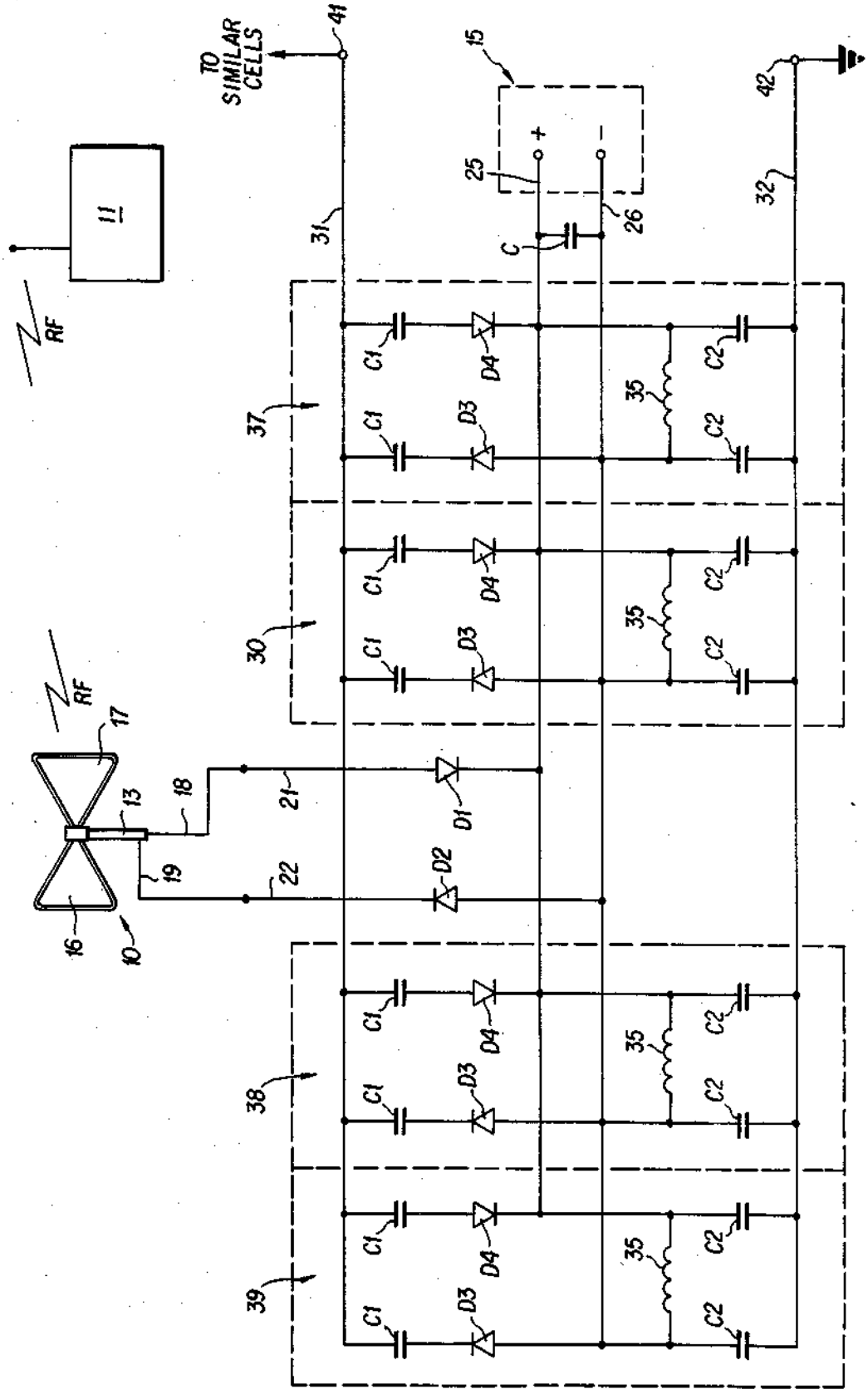
TO SIMILAR CELLS
41
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APPARATUS FOR CONVERTING RADIO FREQUENCY ENERGY TO DIRECT CURRENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The instant invention relates to methods of an apparatus for converting radio frequency energy to direct current; more particularly, the instant invention relates to methods and apparatus for converting radio frequency energy to direct current wherein the direct current is of sufficient magnitude to power devices such as battery charges and electric motors without the use of amplification.

2. Technical Considerations in Prior Art

There has long been interest in technology directed to transmitting electrical energy over a distance without utilizing conductors, such as wire conductors. Development of such a technology has enormous potential. This was first recognized by Nikola Tesla who in 1899 constructed a 200 foot Tesla coil rated at 300 kilowatts and 150 kilocycles. Tesla hoped to set up standing waves of electrical energy around the whole surface of the earth, so that receiving antennas set at optimum points could tap the power when needed. Tesla was able to light hundreds of lamps at a distance of about 40 kilometers with his device without utilizing electrical conductors. The scheme has generally remained a scientific curiosity but has provided the initial groundwork for current developments wherein attempts are being made to transmit power by microwaves. However, power transmitted by microwaves is envisioned in the form of a beam of very high intensity which is focused from a microwave generator to a receiving antenna. This technology is envisioned as being used for many types of purposes such as transmitting microwave energy collected from gigantic solar power satellites and "star wars"-type weapons systems. However, the focused microwave beam is not suitable for many applications in that the beam must be directed toward a receiving antenna and cannot be transmitted through most objects, including living objects, without destroying the objects.

The instant invention relies on converting energy from standing waves which are emitted from radio frequency antennas in the RF range rather than the microwave range. Of particular interest are very low frequencies which are not used in communications and are available for transmitting power. Also of interest with respect to the instant invention are the low frequency waves emitted by the earth due to pulsation thereof caused by its magnetic field. These low frequency standing "earth" waves can be picked up by receivers tuned thereto.

SUMMARY OF THE INVENTION

It is an object of the invention to provide new and improved methods of an apparatus for converting radio frequency currents to direct current for practical uses other than communications, wherein the direct current energy converted from the radio frequency input energy does not require amplification.

Upon further study of the specification and appended claims, further objects and advantages of this invention will become apparent to those skilled in the art.

The instant invention contemplates an RF antenna for receiving radio waves. The RF antenna connected to a circuit configured in accordance with the principles of the instant invention to convert the RF signals to direct current. The radio frequency signals received by the antenna are transmitted to first and second leads, with one lead being rectified to transmit positive voltage and the other lead being rectified to transmit negative voltage. The positive voltage lead being connected directly to a positive output line and the negative voltage lead being connected directly to a negative output line. The positive output line is connected to a pair of bus lines through a first pair of capacitors, while the negative output line is connected to the pair of bus lines by a second pair of capacitors. Disposed between the first bus line and the positive output line is a reverse diode of negative polarity, while disposed between the negative output line and first bus line is a reverse diode of positive polarity. The positive and negative output lines are connected to one another through an inductance which is in parallel with the capacitors of the first and second pair connected between the second bus line and the positive and negative output lines.

In accordance with one embodiment of the invention the afore-described circuit is duplicated for each positive and negative output line. In accordance with another embodiment of the invention, the afore-described circuitry is coupled to additional circuits identically configured in order to increase the direct current output of the arrangement.

In accordance with a further configuration of the invention, the antenna utilized is a dipolar antenna of aluminum wire arranged in a "butterfly" configuration.

The instant invention further contemplates the method of utilizing the afore-described elements so as to generate direct current having sufficient power to perform tasks such as charging batteries, lighting lamps and powering direct current electric motors without the use of amplifiers.

BRIEF DESCRIPTION OF THE DRAWING

Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood when considered in connection with the accompanying drawing, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

There is shown a diagram of a circuit in accordance with the instant invention in combination with a driven device and a dipolar antenna which receives radio frequency waves which are converted to DC current for powering the driven device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, there is shown a dipolar antenna, designated generally by the numeral **10**, which receives radio frequency waves from an RF transmitter **11**. The radio frequency waves are transmitted to a radio frequency to direct current converting circuit, designated generally by the numeral **12**, through a coaxial cable **13** and DC current from the circuit **12** is used to power an output device, designated generally by the numeral **15**, which may for example by a battery charger DC motor or lighting device. The circuit **12** has no other power inputs other than the radio frequency energy transmitted thereto by the antenna **10** and therefore includes no amplifiers for amplifying the RF energy.

The source of radio frequencies convertible to direct current by the circuit shown may include sources of high frequency, low frequency (LF), very low frequency (VLF) and extremely low frequency (ELF) radio waves as well as seismic vibration of the earth's magnetic fields.

Preferably, the dipolar antenna **10** is formed of two triangular loops of aluminum wire **16** and **17**, one of which is connected to the annular conductor **18** of the coaxial cable **13** and the other of which is connected to the center conductor **19** of the coaxial cable. The size of the bipolar antenna **10** is dependent on the particular application to which it is put. In accordance with one embodiment of the invention, the antenna **10** is approximately 12 inches in width and 18 inches in length. Such an antenna is used to receive five watt energy, such as that generated by a walkie-talkie or citizen-band radio.

The annular conductor **18** of the coaxial cable **13** is connected to a positive lead **21** of the circuit **12**, while the center conductor **19** of the coaxial cable is connected to a negative lead **22** of the circuit. A positive transmitting diode **D1** is disposed between the lead **21** and the remainder of the circuit **12** while a negative transmitting diode **D2** is disposed between the lead **21** to a positive output line **25** while the negative diode **D2** is connected to a negative output line **26**. Accordingly, the positive voltages with respect to ground are produced on output line **25** and negative voltages with respect to ground are produced on output line **26**.

In order to provide a DC output of sufficient power, a plurality of inductance-capacitance, RF, tuned circuits **30**, each forming a positive cell, or a negative cell, are utilized for connecting the positive output line **25** and negative output line **26** to first and second bus lines **31** and **32**, respectively. Bus line **32** is connected to ground while bus line **32** can be connected to circuits similar to circuit **12**. The positive output line **25** is connected by a first bridging line **33** to the first and second bus lines **31** and **32** while the negative output line **26** is connected by a second bridging line **34** to the first and second bus lines. The bridging line **33** has capacitors **C1** and **C2** disposed between the positive output line **25** and the first and second bus lines **31** and **32**, while the bridging line **34** also has capacitors **C1** and **C2** dispensed between the negative output line **26** and the first and second bus lines **31** and **32**. Connected between the bridging lines **33** and **34**, is an inductor **35** which serves as an RF choke, while disposed between the positive output line **25** and the capacitor **C1** there is a negative polarity diode **D4** referred to herein as a bridging diode and disposed between the negative output line **26** and capacitor **C1** in line **34** there is a positive polarity diode **D3** referred to herein as a bringing diode. As is seen of the drawing, the RF tuned circuit cell **30** is repeated a plurality of times. In the specific example shown, the circuit **12** has separate cells **30**, **37**, **38** and **39**. The cells **30** and **38** are of opposite polarity and balance one another while the cells **37** and **39** of opposite polarity and also balance one another. In order for the system to function, a pair of opposite polarized cells must be utilized. The particular number of cells **30** and the value of the components thereof are determined by the configuration of the dipolar antenna **10** and the power and frequency of the RF transmitter **11**.

The radio frequency to direct current conversion circuit **12** may itself be connected to a duplicate circuit via pins **41** so as to provide additional direct current output on lines similar to positive output line **25** and negative output line **26** the output lines may be connected together in order to boost the total output of the system.

An operative embodiment of the invention utilizes the following elements:

Diodes **D1**, **D2**, **D3** and **D4**—Germanium Diodes, Archer **1** N34A,Catalog #1123.

Inductor **35**–47 Milli henry R. F. Choke

Capacitors **C1** and **C2**–0.47 Pico Farads at 200 volts

Coaxial Cable **13**—50 ohms

Dipolar Antenna **10**—aluminum wire triangular loops approximately 12 inches by 18 inches.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

What is claimed is:

1. Apparatus for converting radio frequency energy into direct current for generating electric power, the apparatus comprising:

a dipolar input for receiving radio frequency energy;

a positive output line connected to one pole of the dipolar input and a negative output line connected to the other pole of the dipolar input;

a positive transmitting input diode means in the positive output line and a negative transmitting input diode means in the negative output line;

first and second bus lines and a pair of tuned circuits of opposite polarity coupling the positive output line and negative output line to the bus lines, one of the bus lines being connected to ground;

each tuned circuit including a first bridging line connecting the positive output line to the first and second bus lines and a second bridging line connecting the negative output line to the first and second bus lines, each bridging line having a bridging diode means therein oriented at a polarity which is reverse with respect to the transmitting input diode means of the respective output line; the bridging lines of each tuned circuit being connected to one another by an inductance and having capacitors disposed between the bridging diode means thereon and the bus lines, and

a direct current device connected to the bridging lines of the tuned circuit.

2. The apparatus of claim **1**, wherein there are a plurality of similarly configured tuned circuits connected between the output lines and the bus lines.

3. The apparatus of claim **2**, wherein there are a plurality of radio frequency-to-direct current conversion circuits connected to one another to provide a direct current power array tuned to a specific radio frequency such as a high frequency source, low frequency source, very low frequency source, extremely low frequency source, or source created by seismic vibrations of the earth's magnetic field.

4. The apparatus of claim **3** wherein the dipolar input is a dipolar antenna.

5. The apparatus of claim **1**, wherein the device connected to the output lines is a direct current motor.

6. The apparatus of claim **1**, wherein the device connected to the output line is an illuminating device.

7. The apparatus of claim **1**, wherein the device connected to the output lines is a battery charger.

8. The apparatus of claim **1**, wherein the device connected to the output lines is a DC-to-AC inverter.

9. The apparatus of claim 1, wherein there are a plurality of radio frequency to direct current converter circuits connected to one another to form an array of circuits tuned to a particular radio frequency.

10. The apparatus of claim 1 wherein the dipolar input is a dipolar antenna.

11. The apparatus of claim 10, wherein the dipolar antenna utilizes aluminum wire arranged in pair of triangular loops.

* * * * *

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(12) **United States Patent**
Ogram

(10) **Patent No.: US 7,855,476 B2**
(45) **Date of Patent: Dec. 21, 2010**

(54) **ATMOSPHERIC ELECTRICAL GENERATOR**

(76) Inventor: **Mark Ellery Ogram**, 780 S. Freeman Rd., Tucson, AZ (US) 85748

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 254 days.

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(22) Filed: **Jul. 14, 2008**

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H02G 11/00 (2006.01)

(52) **U.S. Cl.** **307/145**; 307/149; 361/218; 361/230

(58) **Field of Classification Search** 307/149, 307/145; 244/30, 31; 174/2; 361/212, 215–218, 361/230, 231

See application file for complete search history.

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Primary Examiner—Fritz M Fleming
(74) *Attorney, Agent, or Firm*—Mark Ogram

(57) **ABSTRACT**

A mechanism to tap an electrical source which uses an aircraft (preferably a lighter than air balloon) tethered by a conductive line. The conductive line is extended/withdrawn by a winch motor to adjust the altitude of the aircraft. The conductive line is isolated from the ground and an electrical conductor is connected to the conductive line and to an electrical load. In this manner, static electricity generated in the atmosphere is gathered for use.

15 Claims, 4 Drawing Sheets

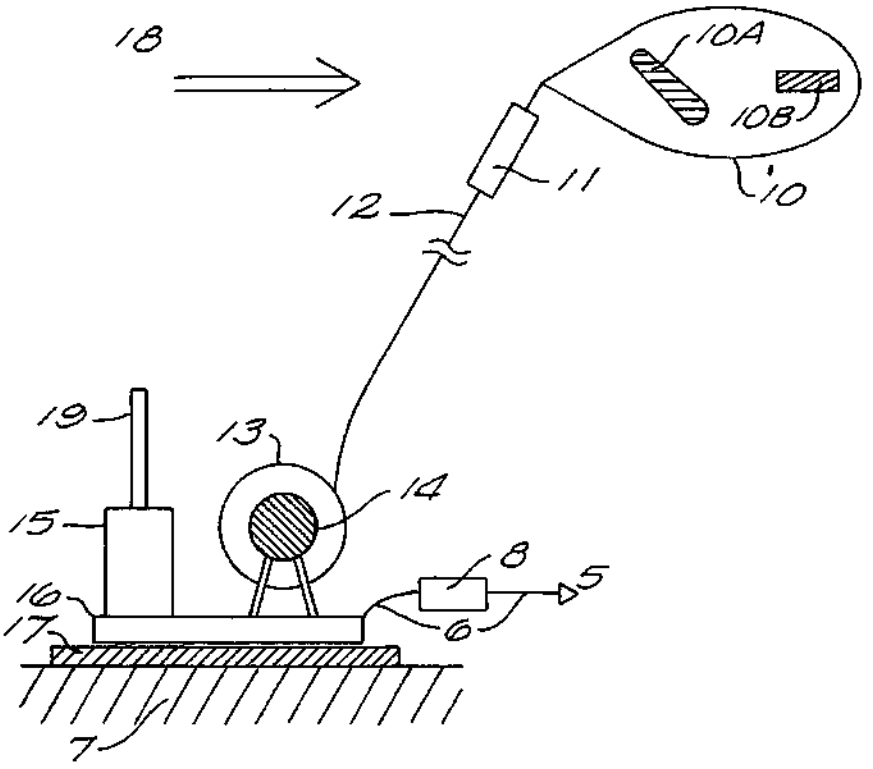

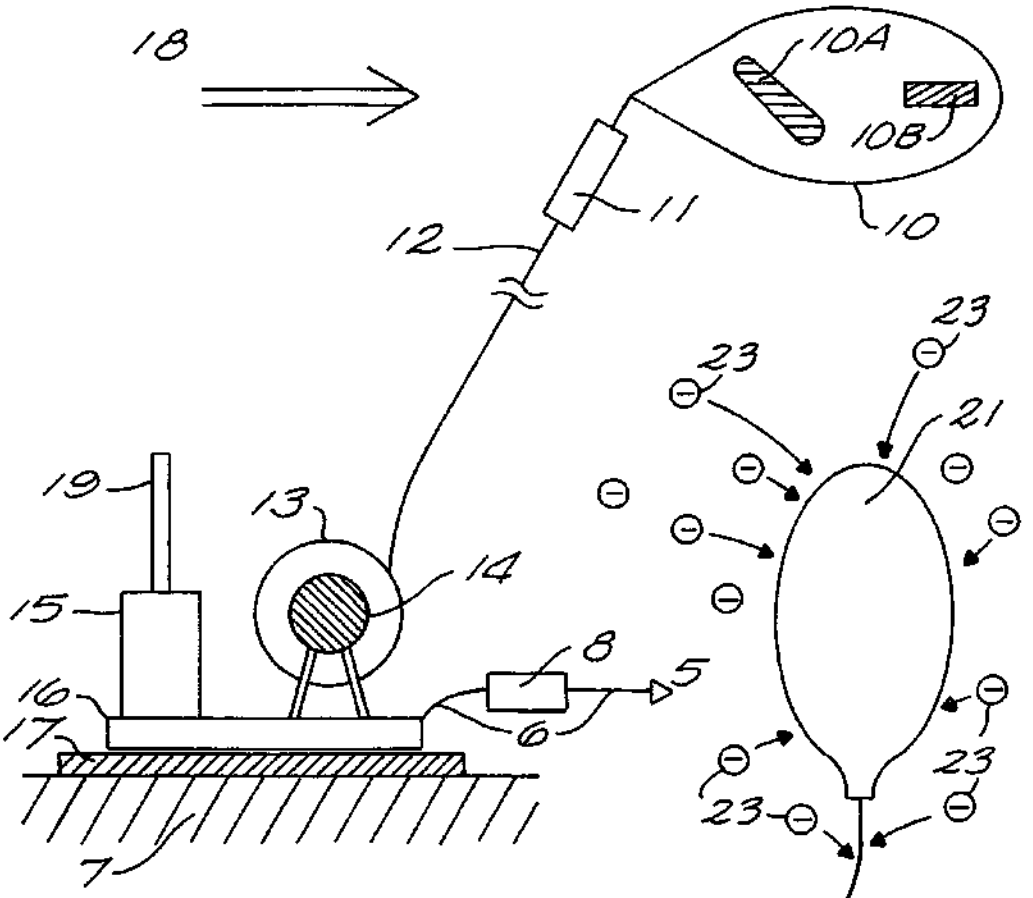

FIG. 1

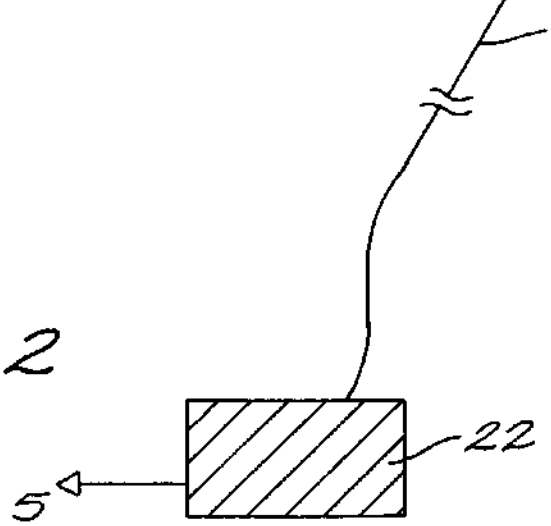

FIG. 2

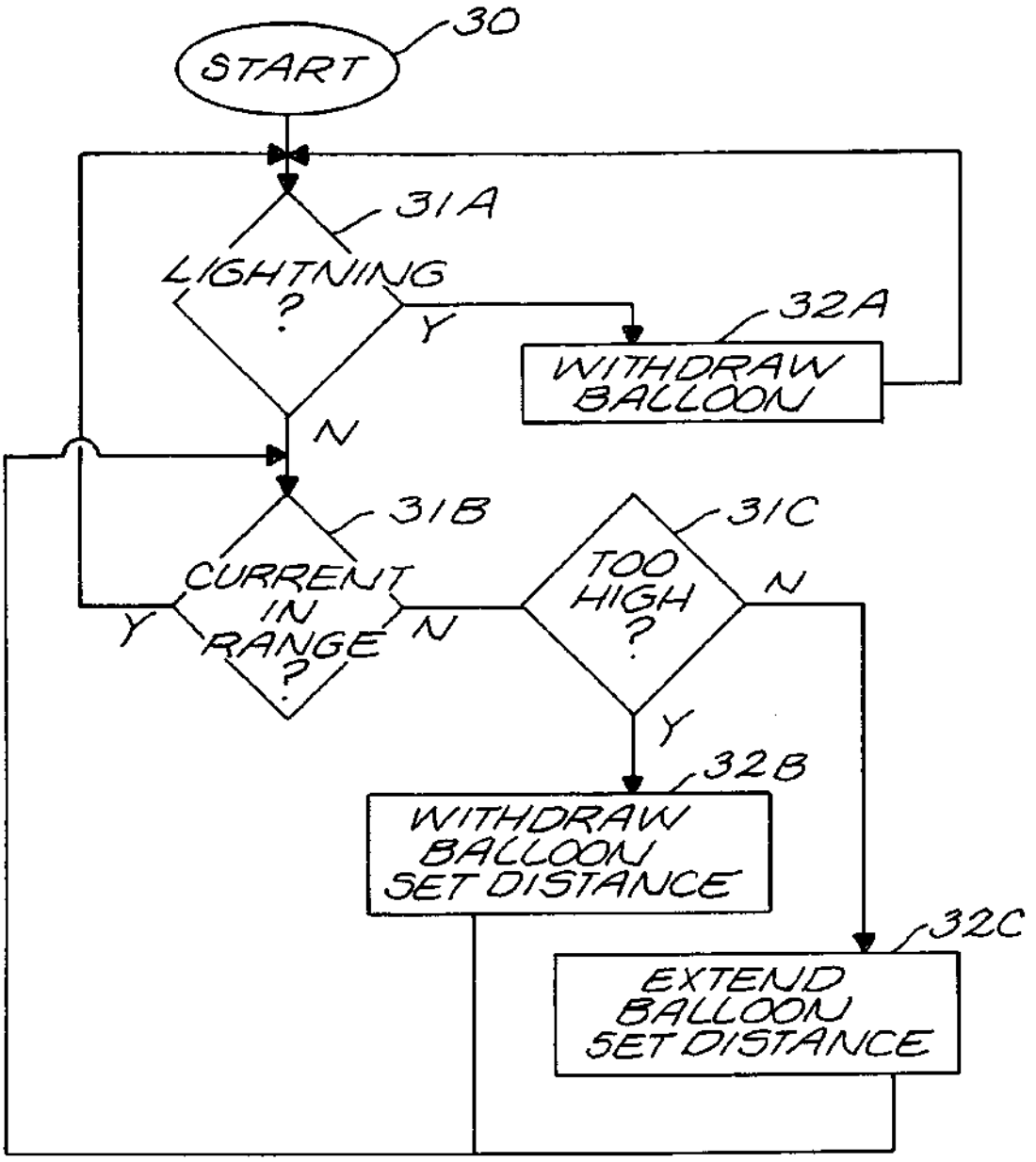
START
30
31A
LIGHTNING ?
Y
32A
WITHDRAW BALLOON
N
31B
CURRENT IN RANGE ?
Y
N
31C
TOO HIGH ?
N
Y
32B
WITHDRAW BALLOON SET DISTANCE
32C
EXTEND BALLOON SET DISTANCE

FIG. 3

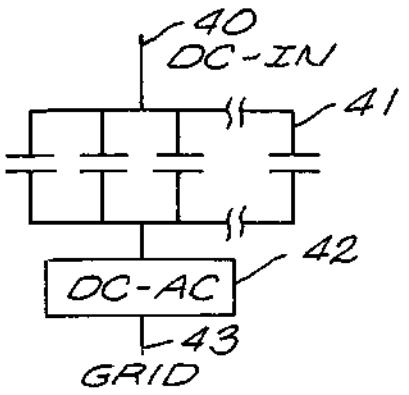

FIG. 4A

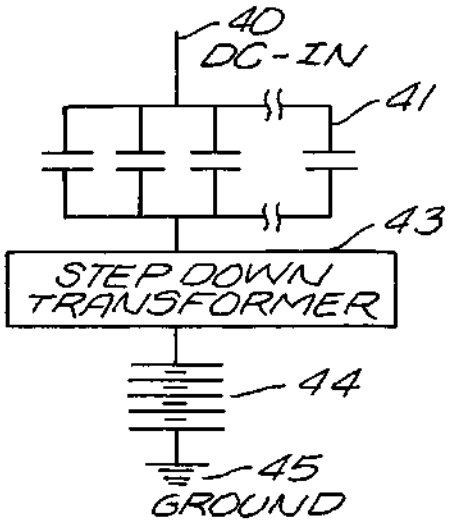

FIG. 4B

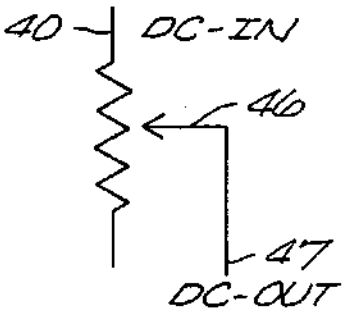

FIG. 4C

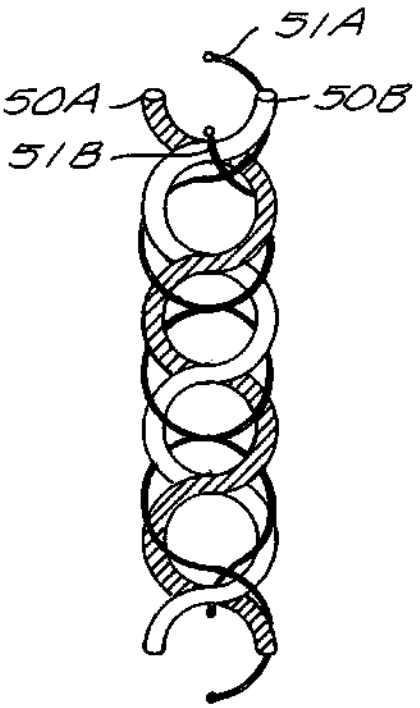

FIG. 5

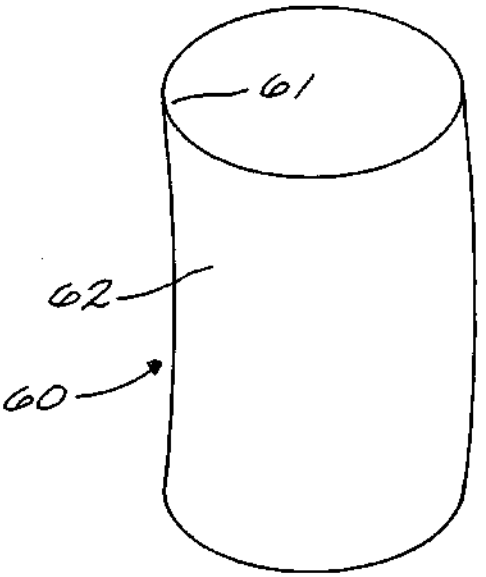

FIG. 6A

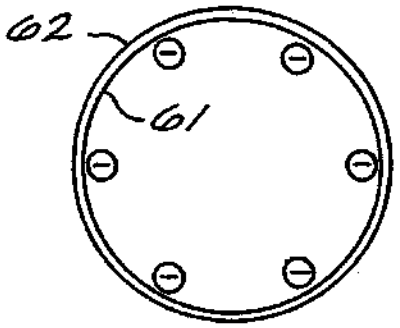

FIG. 6B
REPLACEMENT

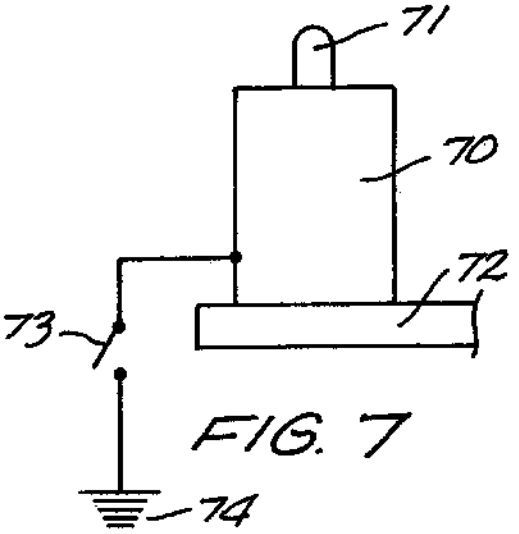

FIG. 7

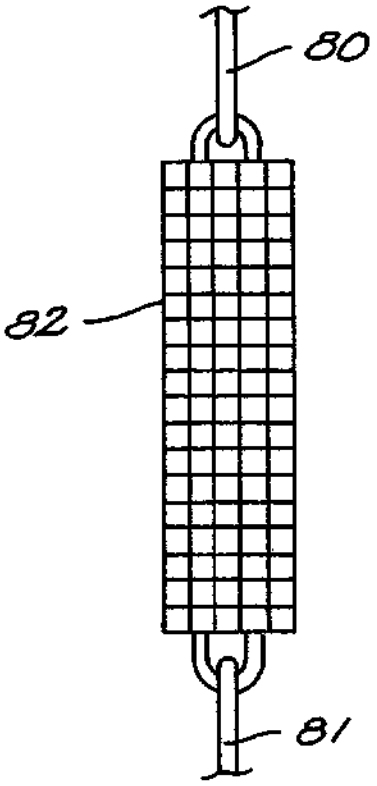

FIG. 8A

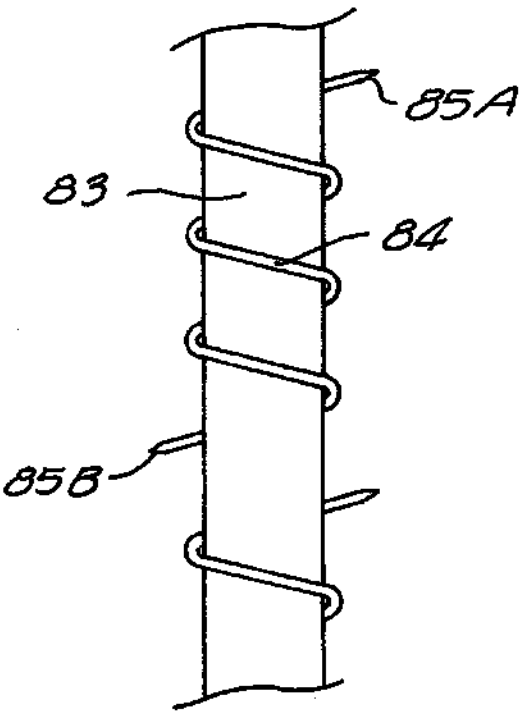

FIG. 8B

ATMOSPHERIC ELECTRICAL GENERATOR

BACKGROUND OF THE INVENTION

This invention relates to the production of electrical energy and more particularly to the production of electrical energy from the atmosphere.

Everyone is familiar with Benjamin Franklin's kite experiment of 1752. Using a kite whose string had become wet, negative charges from the passing clouds flowed into the string, down to the suspended key, and then into a Leyden jar via a thin metal wire. Franklin was protected by a dry silk string; but, when Franklin's knuckle came too close to the key, he received a strong shock. Fortunately, Benjamin Franklin was not killed, others who tried this same experiment were not so lucky.

Since then, the formation of lightning has remained something of a mystery. Lightning bolts are triggered when a negatively charged cloud base induces a positive charge from the ground, thereby forming a "pathway" for the discharge of the collected electrical energy.

Lightning travels up to 60,000 miles per hour with a flash that is brighter than ten million 100-watt lightbulbs. This wattage is as much power as is produced by all of the electricity plants in the United States and with a voltage of up to 300 million volts.

It is this very fact, the power within lightning is immense, that has prevented any successful collection of the electrical energy from lightning. The electricity in lightning is far too extreme for current technology to harness.

While lightning has attracted a energy starved industrial world, no one has developed any technique to harness this naturally occurring electrical source.

It is clear there is a continuing need for an electrical source other than carbon-based fuels and that the naturally occurring electricity in the atmosphere is being ignored.

SUMMARY OF THE INVENTION

The invention is a mechanism which taps into the naturally occurring static electricity in the atmosphere. Whereas heretofore, the attempt to garner electricity from the atmosphere has focused exclusively on capturing lightning, the present invention syphons off the static electricity which is generated from any agitated air and avoids lightning.

Lightning is only the final discharge of the static electricity, whether that lightning is intra-cloud lightning, cloud-to-ground lightning, or inter-cloud lightning. Other types of final discharges are known as heat lightning, summer lightning, sheet lightning, ribbon lightning, silent lightning, ball lightning, bead lightning, elves, jets, and sprites. Well before these discharges are observed, as the atmosphere becomes agitated by wind or thermal activity, static electricity is being generated.

The present invention recognizes that this static electricity is being formed and creates a mechanism to capture it.

The mechanism of this invention utilizes an aircraft such as a lighter than air balloon. While the preferred embodiment uses a foil balloon, a variety of other aircraft are obvious to those of ordinary skill in the art, including, but not limited to: gliders, rubber balloons (such as weather balloons), biaxially-oriented polyethylene terephthalate polyester film balloons, and latex balloons.

Within this discussion, the balloon is referenced, but, the invention is not intended to be limited solely to balloons.

The balloon is sent aloft and is tethered by a conductive line. In this context, the conductive line may be any obvious

to those of ordinary skill in the art. For the preferred embodiment, the conductive line is a generically referred to as a "poly-rope" and is commercially available through a variety of sources. A suitable conductive line is described in U.S. Pat. No. 5,203,542, entitled "Apparatus for Improved Electric Fence Wire Construction for use with Intensive Grazing" issued Apr. 20, 1993, to Coley, et al. and incorporated hereinto by reference.

The conductive line is played out of a winch to control the altitude of the balloon. The motor controlling the winch is able to reverse direction to both extend and withdraw the conductive line which is wrapped around a spool on the winch. The winch/spool combination are part of a base unit.

In some embodiments of the invention, the spool is constructed of rubber so as to insulate the conductive line from the winch assembly. In this embodiment, only the conductive line is charged by the atmospheric static electricity while the winch remains neutral.

In yet another embodiment, the winch/spool are part of a base unit which is itself isolated from the ground by an insulator. In this embodiment, the entire base unit is charged by the atmospheric static electricity.

A conductor, such as an insulated wire, is electrically connected to the conductive line. In one embodiment, where the conductive line is electrically isolated from the spool and winch motor, the conductor is connected to the conductive line. In the embodiment where the conductive line is electrically connected to the base unit, then the conductor is connected anywhere on a metallic base unit.

The other end of the conductor is connected to a load. The load in this case can be any of a variety of electrical loads well known to those of ordinary skill in art, including, but not limited to a motor, a battery system, or the electrical grid for the system.

In the preferred embodiment, a sensor array is used to monitor the activities both at the base unit (such as electrical flow within the conductor) and in the surrounding locale.

A sensor monitoring the electrical flow (i.e. voltage and/or current) within the conductor is used to monitor the electrical activity within the conductor.

In the preferred embodiment, a lightning sensor monitors for lightning activity within the locale. As noted earlier, the electrical characteristic of lightning is so extreme that ideally this discharge is avoided as it might damage the mechanism of this invention.

The sensor array is utilized by a controller, such as microprocessor, programmed to operate the mechanism as outlined herein.

The controller operates the winch motor to extend or withdraw the conductive line and by extension the altitude of the balloon. The controller is programmed to operate the winch by monitoring the electrical characteristics of the conductor and adjusting the balloon's altitude to maintain these characteristics within the conductor within a preset range.

This preset range is established either in the base programming of the controller or is established by an operator of the system.

As example, by controlling the amount of current being withdrawn from the atmosphere, the mechanism operates within a safe range and also provides a relatively stable current flow from which a variety of activities can take place (such as DC-AC conversion).

The controller also utilizes the lightning sensor to protect the mechanism from a lightning strike. Should lightning be detected within a pre-determined range (as established by the software or defined by an operator), then the balloon is pulled down to minimize the risk of damage from a lightning strike.

The invention, together with various embodiments thereof will be more fully explained by the following description of the accompanying drawings.

DRAWINGS IN BRIEF

FIG. **1** diagrams the preferred embodiment of the invention.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

DRAWINGS IN DETAIL

FIG. **1** diagrams the preferred embodiment of the invention.

Balloon **10** is an aircraft which, in this illustration, is a lighter than air balloon. Wings **10**A, extending from the body of balloon **10**, provide additional lift in air flow **18**. Tail **10**B helps to stabilize balloon **10**.

Balloon **10** is tethered to the ground via conductive line **12**. As noted earlier, a variety of configurations and materials are available to serve as conductive line **12**. In this illustration, a poly-wire is used Poly-wire is commercially available through a variety of vendors, including, but not limited to: Jeffers Livestock and Zareba Systems, Inc, of Ellendale, Minn.

In this embodiment, located proximate to balloon **10**, is an electrical collection enhancement lead **11** which assists in the collection of the static electrical charge in the atmosphere. Electrical collection enhancement lead **11** is configured to attract the static charge and conduct the charge into the conductive line **12**.

The electricity flows down the conductive line into spool **13**, where the conductive line **12** is collected and either withdrawn or dispensed through operation of winch motor **14**.

Winch motor **14** and spool **13** are mounted onto base unit **16** which is electrically isolated from ground **7** using insulator **17**. Note, in this embodiment of the invention, when electricity is being collected from the atmosphere, the entire base unit **16** becomes charged. In another embodiment of the invention, spool **13** is constructed of rubber, thereby preventing base unit **16** from becoming charged, thereby restricting the charging from the atmosphere to only conductive line **12**.

In this embodiment, conductor **6** is connected to base unit **16** (since the entire base unit **16** is charged and the base unit is metallic) to communicate the electrical current to load **5**. Conductor **6** is ideally an insulated wire.

The electrical current through conductor **6** is measured using sensor **8**.

In the alternative embodiment discussed above, where only the conductive line **12** is charged, then conductor **6** is connected to conductive line **12**.

Controller **15**, located in this embodiment on base unit **16**, operates winch motor **14** in response to signals from sensor **8** (measuring the current being discharged to load **5**) to maintain the current flow within a pre-defined range. As the current flow diminishes, then the conductive line **12** extended from spool **13** to increase the altitude of balloon **10** to that more static charge from the atmosphere is gathered; as the current flow falls exceeds a preset level, conductive line **12** is withdrawn onto spool **13** to decrease the static charge being collected from the atmosphere.

The range of current flow through conductor **6** is ideally set by the program, although some embodiments of the invention permit an operator to establish this range of operation.

In an alternative embodiment, the sensor monitoring conductor **6** monitors the voltage therein.

In the preferred embodiment of the invention, controller **15** is also equipped with a lightning sensor **19**. In this embodiment, when lightning is sensed within a preset range, then substantially all of conductive line **12** is wound onto spool **13** to pull balloon **10** near the ground and protect the entire mechanism from being damaged from a lightning discharge.

In the preferred embodiment, the "safe" distance form lightning is set in the programming of controller **15** and is ideally two miles; other embodiments permit the operator to "safe" distance.

There are a variety of lightning sensors well known to those of ordinary skill in the art, including, but not limited to those described in: U.S. Pat. No. 7,016,785, entitled "Lightning Detection" issued to Makela, et al. on Mar. 21, 2006; U.S. Pat. No. 6,829,911, entitled "Lightning Detection and Prediction Alarm Device" issued to Jones, et al. on Dec. 7, 2004; U.S. Pat. No. 7,200,418, entitled "Detection of Lightning" issued to Karikuranta, et al. on Apr. 3, 2007; and U.S. Pat. No. 6,961,662, entitled "Systems and Methods for Spectral Corrected Lightning Detection" issued to Murphy on Nov. 1, 2005; all of which are incorporated hereinto by reference.

In another embodiment of the invention, controller **15** is not located on base unit **16**, rather it is remote and communicates its control signals to winch motor **14** using radio waves.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

Static charges **23** are generated in the atmosphere by agitated air. These static charges are often collected at the bottom of clouds, but exist in other environments as well.

Balloon **21** is extended into this strata of static charges **23** which are then attracted to conductive line **12** to flow to base unit **22** and then onto load **5**.

By increasing or decreasing the altitude of balloon **21** (defined by the length of the extended conductive line **12**), conductive line **12** is selectively exposed to varying densities and levels of the static charge strata, and by extension, the current flow or voltage is increased or decreased.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

Once the program starts **30**, the lightning sensor is checked to determine if lightning has occurred within the unsafe range **31**A, if it has, then the balloon is lowered **32**A, and the program continues monitoring the status of lightning until no lightning is detected.

When the lightning status is acceptable, then the current within the conductor is checked to see if the current is within the prescribed range **31**B. If the current is acceptable (within range) the program returns to check the lightning status **31**A; otherwise a determination is made to see if the current is above the prescribed range **31**C.

If the current is above the prescribed range, then the altitude of the balloon is withdrawn a set amount **32**B (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

If the current is below the prescribed range, then the altitude of the balloon is extended a set amount **32**C (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

In this manner of feed-back and minor adjustments in the altitude of the balloon, the current is maintained within a prescribed range which can be handled by the downstream electrical system.

As noted earlier, some embodiments of the invention monitor the voltage instead of the current.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **4**A, **4**B, and **4**C illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations which will serve the same function.

Referencing FIG. **4**A, Direct Current In (DC IN) **40** is buffered by a gang of capacitors **41** before being communicated to a DC/AC converter **42**. The DC/AC converter converts the direct current into a an alternating current suitable for placement over an existing electrical grid **43** such as normally found from a power-plant.

Those of ordinary skill in the art readily recognize a variety of DC/AC converters, including, but not limited to: U.S. Pat. No. 7,394,671, entitled "Controller IC, DC-AC Conversion Apparatus, and parallel running system of DC-AC Conversion Apparatuses" issued to Fukumoto, et al. on Jul. 1, 2008; and, U.S. Pat. No. 7,330,366, entitled "DC-AC Converter" issued to Lee, et al. on Feb. 12, 2008; all of which are incorporated hereinto by reference.

FIG. **4**B illustrates an electrical arrangement suitable for use in charging a battery. DC IN **40** is buffered by capacitor bank **41** before entering into a step down transformer **43**. Step down transformer **43** reduces the voltage so that the voltage can safely be introduced into battery **44** which is connected to ground **45** at the battery's other pole.

Those of ordinary skill in the art readily recognize a variety of batteries which will work in this capacity, including, but not limited to those described in: U.S. Pat. No. 7,378,181, entitled "Electric Storage Battery Construction and Manufacture" issued to Skinlo on May 27, 2008; U.S. Pat. No. 7,388,350, entitled "Battery with Electronic Compartment" issued to Wright on Jun. 17, 2008; U.S. Pat. No. 7,397,220, entitled "Connection Member and Battery Pack" issued to Uchida, et al. on Jul. 8, 2008; and, U.S. Pat. No. 7,375,492, entitled "Inductively Charged Battery Pack" issued to Calhoon, et al. on May 20, 2008; all of which are incorporated hereinto by reference.

In FIG. **4**C, DC IN **40** is fed into an adjustable rheostat **46** which is controlled by the controller so that the DC OUT **47** falls within a specified range.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

This type of conductive line is commonly called poly-wire and consists of multiple interwoven strands of plastic **50**A and **50**B woven into a cord or rope arrangement having intertwined therein exposed metal wires **51**A and **51**B. While this illustration shows two plastic strands and two metal wires, any number of possible combinations is possible.

The exposed metal wires **51**A and **51**B attract the atmospheric static charge and transmit the charge down to the base unit (not shown).

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

This conductive line utilizes a tube **60** having an outer layer **62** of PET Film (Biaxially-oriented polyethylene terephtalate polyester film) which provides exceptionally high tensile strength and is chemically and dimensionally stable. The tube has an ideal diameter of between two and three inches.

An interior metal coating **61** provides an initial conduit for the flow of static charge. The static charge through the metal forces the tube to expand due to the repulsion experienced by like charges. Further, the flow of electricity causes the interior of the tube **60** to become ionized to provide an additional pathway for the atmospheric static charges to the base unit (not shown).

Because outer layer **62** provides a gas barrier, the resulting ionization is not dissipated by air currents, thereby providing a highly stable pathway.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

In this embodiment, controller box **70**, resting on insulating pad **72**, is in communication with the sensors as described above. Using the input from these sensors, when there is flow of electricity through the base unit, warning flashing light **71** is illuminated. To electrically neutralize the mechanism, switch **73** is activated to pass any existing current into the ground **74**.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

Referencing FIG. **8**A, enhanced electrical collection lead **82** is a wire mesh which is in electrical communication with conductive line **81** and balloon **80**. Because of the significant amount of metal exposed by enhanced electrical collection lead **82**, more static electricity from the atmosphere is drawn to the collection lead **82**, and then down conductive line **81** to the base unit (not shown).

Conductive lead **82** is positioned proximate to balloon **80**.

In FIG. **8**B, poly-wire **83** has enhanced electrical collection leads **84** wrapped therearound. Collection leads **84** have pointed ends **85**A and **85**B which have a propensity to attract more electricity than rounded ends do.

It is clear from the foregoing that the present invention captures an entirely new source of electrical energy.

What is claimed is:

1. A mechanism to tap an electrical source comprising:

a) a lighter than air balloon suspended in the atmosphere;

b) a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said lighter than air balloon, a portion of said conductive line collecting electricity in the atmosphere, said winch motor capable of selectively extending or withdrawing said conductive line from said spool;

c) an insulator electrically isolating said conductive line from ground;

d) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

e) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and,

f) a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

2. The mechanism to tap an electrical source according to claim **1**, wherein said selected operating range is established by an operator.

3. The mechanism to tap an electrical source according to claim **2**, further including a warning light activated when said electrical flow indicia is non-zero.

4. The mechanism to tap an electrical source according to claim **1**,

a) further including a lightning sensor generating a lightning presence indicia indicative of lightning within a prescribed range, said presence indicia being communicated to said controller; and,

b) wherein said control mechanism, in response to said lightning presence indicia, operates said winch motor to withdraw substantially all of said conductive line onto said spool.

5. The mechanism to tap an electrical source according to claim **4**, wherein said prescribed range is established by an operator.

6. The mechanism to tap an electrical source according to claim **1**, further including an electrical collection enhancement lead in electrical contact with a first end of said conductive material, said electrical collection enhancement lead configured to attract static electricity.

7. The mechanism to tap an electrical source according to claim **6**, wherein said electrical collection enhancement lead is positioned proximate to said lighter than air balloon.

8. The mechanism to tap an electrical source according to claim **7**, wherein said electrical collection enhancement lead includes at least two pointed electrical conductors.

9. The mechanism to tap an electrical source according to claim **1**, wherein said insulator electrically isolates said conductive line from said winch motor.

10. The mechanism to tap an electrical source according to claim **1**, wherein said insulator electrically isolates said base unit from ground.

11. A mechanism comprising:

a) an airborne aircraft having a conductive line secured to a winch capable of extending or withdrawing said conductive line from a spool, when said airborne aircraft is aloft, said conductive line collecting electricity from the atmosphere;

b) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load such that collected electricity from said conductive line powers said load;

c) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and,

d) a controller receiving said electrical flow indicia adjusting an altitude of said airborne aircraft via said winch such that said electrical flow indicia remains within a selected operating range.

12. The mechanism to tap an electrical source according to claim **11**,

a) further including a lightning sensor communicating with said controller; and,

b) wherein said controller, in response to selected signals from said lightning sensor withdraws substantially all of said conductive line.

13. A mechanism to tap an electrical source comprising:

a) a lighter than air balloon suspended in the atmosphere;

b) a base unit having a spool of conductive line on a winch motor, one end of said conductive line suspended by said balloon, a portion of said conductive line collecting electricity from the atmosphere, said winch motor capable of adjusting an altitude of said lighter than air balloon by selectively extending or withdrawing said conductive line from said spool;

c) a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by said collected electricity from said conductive line;

d) a sensor array having,

1) an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor, and,

2) a lightning sensor monitoring existence of proximate lightning; and,

e) a controller responsive to said electrical flow indicia from said sensor array to selectively operate said winch motor.

14. The mechanism to tap an electrical source according to claim **13**,

a) further including a warning light; and,

b) wherein said controller activates said warning light when said electrical flow in said conductor is non-zero.

15. The mechanism to tap an electrical source according to claim **14**, further including an electrical collection enhancement lead in electrical contact with said conductive material, said electrical collection enhancement lead configured to attract static electricity and positioned proximate to said lighter than air balloon.

* * * * *

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Allen et al.

(10) **Patent No.: US 9,160,156 B2**
(45) **Date of Patent: Oct. 13, 2015**

(54) **SYSTEM FOR HARVESTING ATMOSPHERIC ELECTRICITY**

(75) Inventors: **Edward H. Allen**, Lancaster, CA (US); **Sergey Macheret**, Palmdale, CA (US)

(73) Assignee: **Lockheed Martin Corporation**, Bethesda, MD (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 357 days.

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(22) Filed: **Oct. 18, 2011**

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(51) **Int. Cl.**

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H02G 13/00	(2006.01)
B64D 45/02	(2006.01)

(52) **U.S. Cl.**

CPC ***H02G 13/20*** (2013.01); ***B64D 45/02*** (2013.01); *H05F 7/00* (2013.01)

(58) **Field of Classification Search**

CPC H02G 13/20; B64D 45/02; H05F 7/00
USPC 361/231, 230
See application file for complete search history.

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Primary Examiner — Zeev V Kitov
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

Systems, methods and apparatus for harvesting atmospheric electricity are provided. The system includes a laser configured to form a plasma filament and a collector configured to collect electricity flowing along the plasma filament. The plasma filament comprises an electrically conducting plasma filament. Atmospheric electricity may be collected by having the plasma filament form at least a part of a conducting path: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. When the plasma filament is not long enough to form the entire conducting path, a lightning may be triggered to complete the conducting path needed to collect atmospheric electricity.

21 Claims, 6 Drawing Sheets

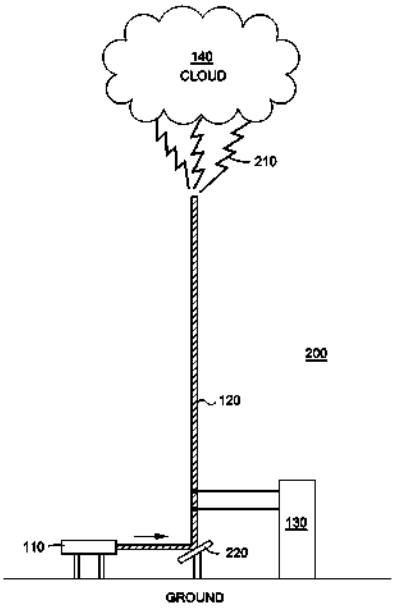

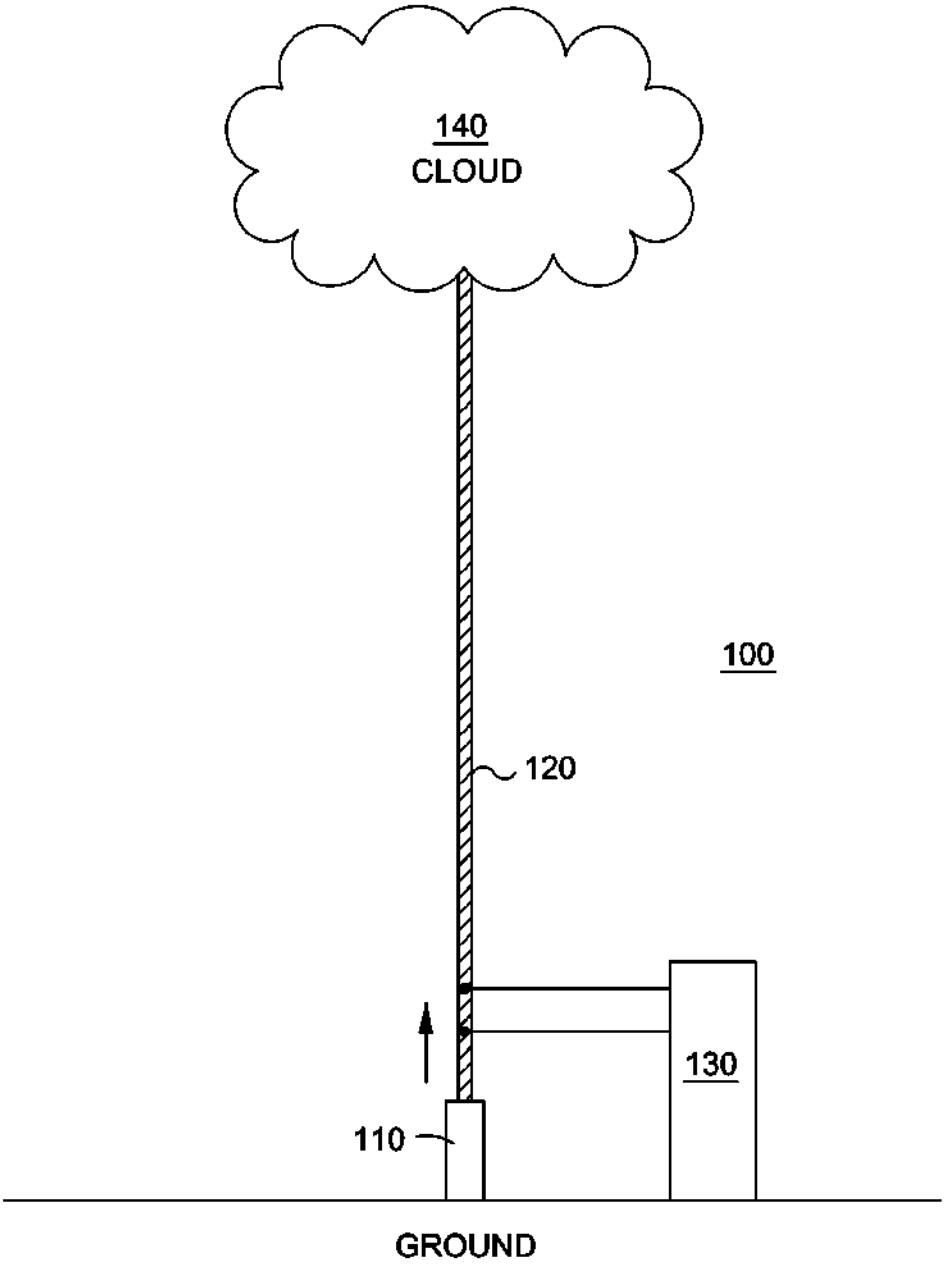

FIG. 1

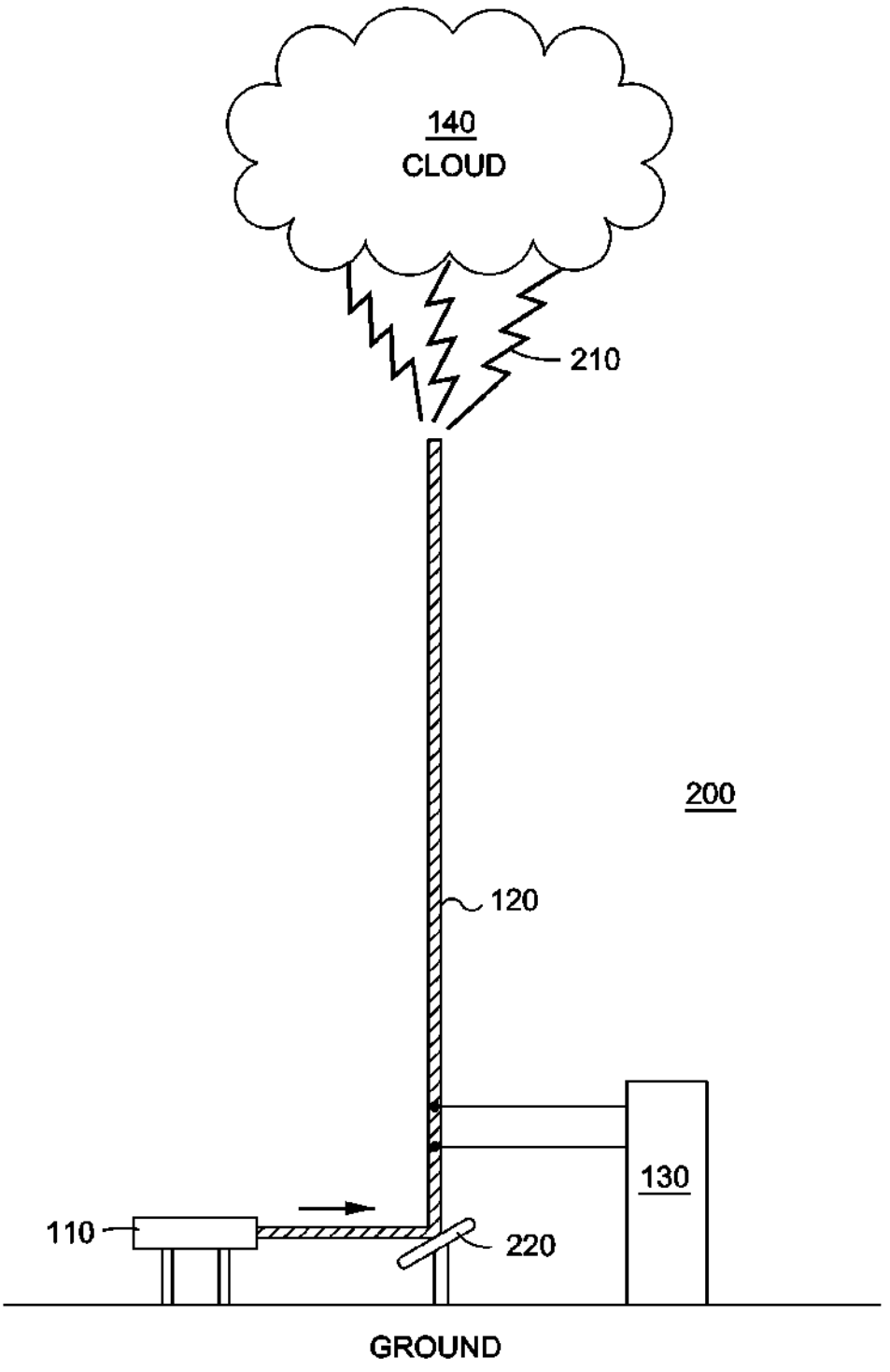

FIG. 2

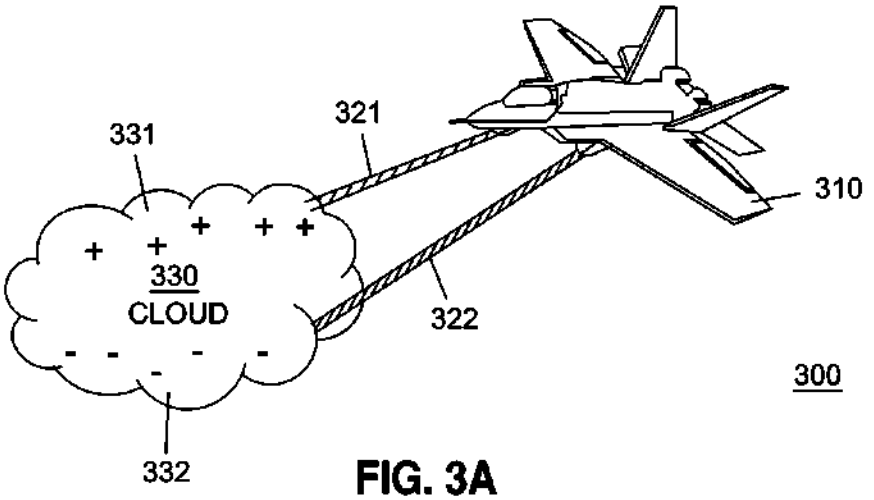
331
321
310
330
CLOUD
322
300
332

FIG. 3A

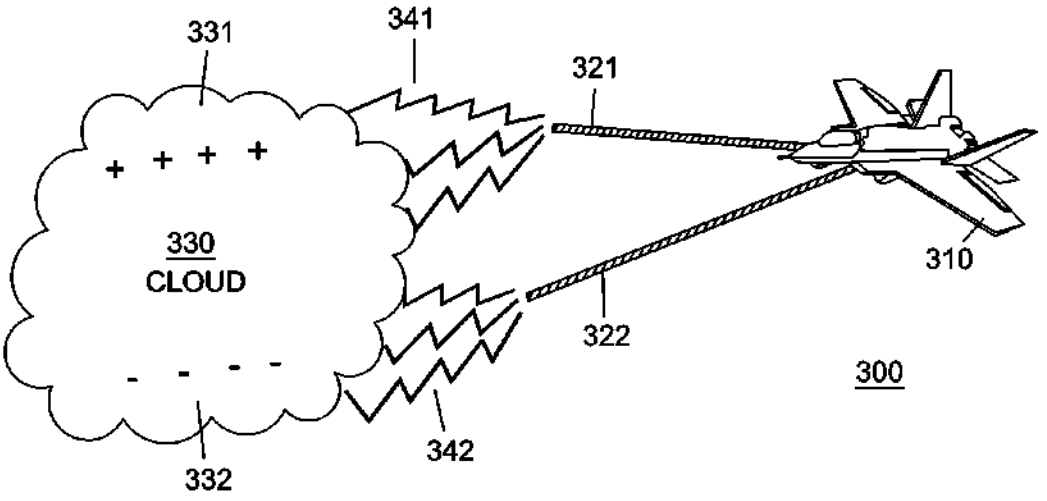
331
341
321
330
CLOUD
310
322
300
342
332

FIG. 3B

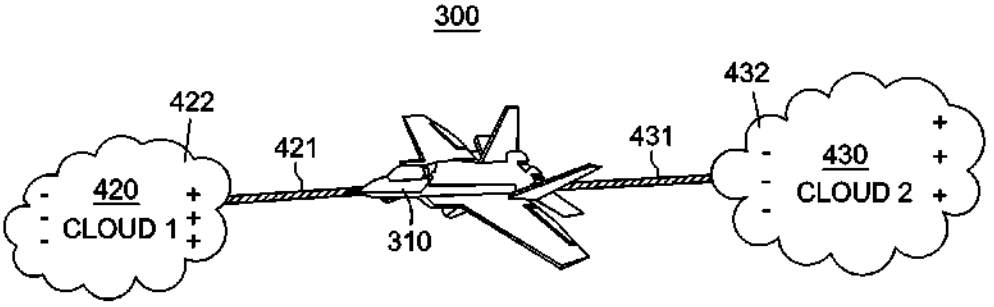

FIG. 4

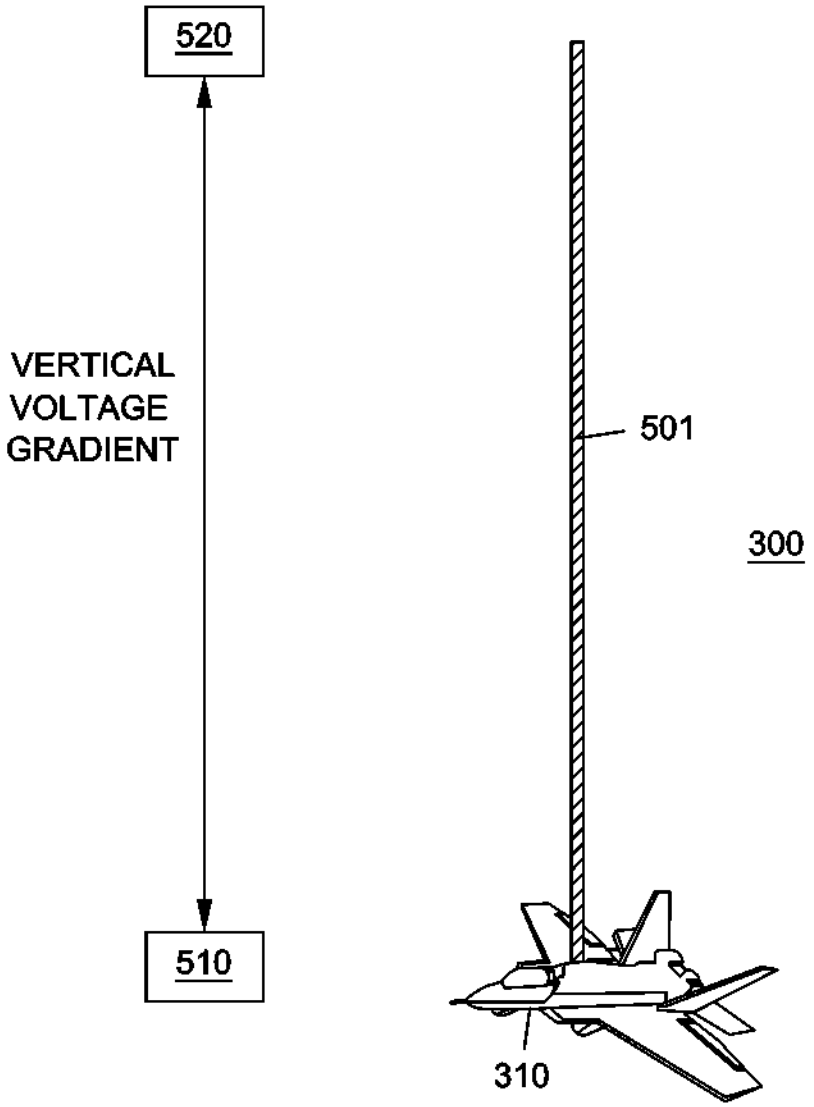

FIG. 5

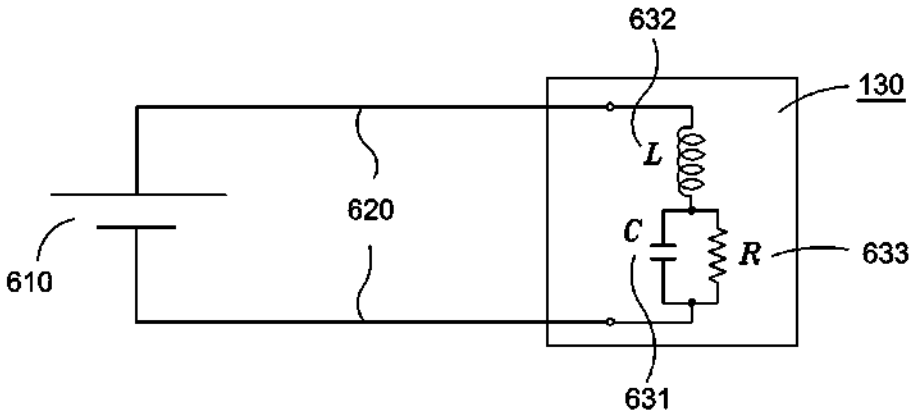

FIG. 6

SYSTEM FOR HARVESTING ATMOSPHERIC ELECTRICITY

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

FIELD OF THE INVENTION

The subject technology relates in general to a system for harvesting atmospheric electricity, and more particularly to a system that uses a laser to form an electrically conducting plasma filament for harvesting atmospheric electricity.

BACKGROUND

It is well known that large quantities of electrical energy are present in the atmosphere and in lightning. Lightning was one of the first forms of electricity harnessed in the modern age by Benjamin Franklin in his famous kite experiment.

A lightning discharge typically contains on the order of 10^{10} Joules of energy. It has been estimated that the total electrical power of lightning across the Earth is of the order of 10^{12} watts. Collection of electrical energy from clouds associated with lightning is a problem that needs to be resolved.

Lightning is but a small part of the total electrical activity of the atmosphere. When a local build up of charge above the Earth exceeds the local breakdown potential of the atmosphere a lightning discharge occurs. However, there is a continual invisible flow of charge from Ionosphere to Earth occurring day and night over the entire surface of the globe, which exceeds the global lightning power output by many times. The source of this flow of charge from the atmosphere to Earth is the Sun. Radiation from the Sun helps form most of the ions found in the Ionosphere, a highly charged region above the atmosphere, through ionization of atmospheric molecules. Solar radiation, particularly in the UV and soft x-ray bands, consist of photons whose energies are well suited to ionization. The Sun also emits continuously a solar wind of positively charged particles. These are captured by the Earth's magnetic field and further contribute to the Ionosphere. The positively charged region in the Ionosphere in turn induces (by electrostatic induction) a negative charge on the surface of the Earth. The Earth becomes in effect an enormous spherical capacitor. A potential gradient or electric field is thus established between the two "plates" of this capacitor, the Ionosphere (or Electrosphere) and the surface of the Earth. While the upper strata of the atmosphere conduct electricity reasonably well, the lower levels act as an insulator or dielectric. Near the surface of the Earth, this electrostatic potential gradient is on the order of about 100 Vm^{-1} in summer, rising to 300 Vm^{-1} in winter. This flow of charge can be tapped and directed to provide useable electrical power. This source of atmospheric electricity has the following advantages: (1) Simple and robust technology; (2) Low cost technology—much cheaper than photovoltaics or wind turbines; (3) Available day and night in all weather conditions—in fact, more power is produced at night than during the day; and (4) Available at any point on the Earth's surface. Collection of this source of atmospheric electricity is another problem that needs to be resolved.

SUMMARY

According to various aspects of the subject technology, a system for harvesting atmospheric electricity is provided that solves some or all of the foregoing problems. In some aspects, the system may be used to harvest atmospheric electricity arising from an electrostatic potential gradient: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. In other aspects, the system may be used to harvest atmospheric electricity arising from an electrostatic potential gradient between the Ionosphere (or Electrosphere) and the surface of the Earth.

According to various aspects of the subject technology, a system for harvesting atmospheric electricity is provided. The system comprises a laser configured to form a plasma filament. The system also comprises a collector configured to collect electricity flowing along the plasma filament.

According to various aspects of the subject technology, a method for harvesting atmospheric electricity is provided. The method comprises forming a plasma filament with a laser. The method also comprises collecting electricity flowing along the plasma filament.

According to various aspects of the subject technology, an apparatus for harvesting atmospheric electricity is provided. The apparatus comprises means for forming a plasma filament with a laser. The system also comprises means for collecting electricity flowing along the plasma filament.

It is understood that other configurations of the subject technology will become readily apparent to those skilled in the art from the following detailed description, wherein various configurations of the subject technology are shown and described by way of illustration. As will be realized, the subject technology is capable of other and different configurations and its several details are capable of modification in various other respects, all without departing from the scope of the subject technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide further understanding of the subject technology and are incorporated in and constitute a part of this specification, illustrate aspects of the subject technology and together with the description serve to explain the principles of the subject technology.

FIG. **1** illustrates a first example of a system for harvesting atmospheric electricity. The system comprises a laser configured to form a plasma filament and a collector configured to collect electricity flowing along the plasma filament. The plasma filament forms a conducting path between ground and a cloud.

FIG. **2** illustrates a second example of a system for harvesting atmospheric electricity. A plasma filament and a lightning together form a conducting path between ground and a cloud. A condensing mirror directs the beam of laser towards the cloud.

FIG. **3**A illustrates a third example of a system for harvesting atmospheric electricity. A laser system situated on an airplane forms two plasma filaments that together complete a conducting path between a first region of a cloud and a second region of the cloud. The first region of the cloud and the second region of the cloud carry opposite electric charges. A collector configured to collect electricity flowing along the two plasma filaments is also situated on the same airplane as the laser system.

FIG. 3B illustrates a fourth example of a system for harvesting atmospheric electricity. It is similar to FIG. 3A, except two lightnings complete the conducting path between a first region of a cloud and a second region of the cloud (i.e., a first lightning electrically connects the first region of the cloud to one of the plasma filaments and a second lightning electrically connects the second region of the cloud to the other plasma filament).

FIG. 4 illustrates a fifth example of a system for harvesting atmospheric electricity. A laser system situated on an airplane forms two plasma filaments that together complete a conducting path between a first cloud and a second cloud. The region of the first cloud that is connected to the first plasma filament and the region of the second cloud that is connected to the second plasma filament carry opposite electric charges.

FIG. 5 illustrates a sixth example of a system for harvesting atmospheric electricity. A laser situated on an airplane forms a plasma filament that completes a conducting path between a first region of atmosphere and a second region of atmosphere. A collector situated on the same airplane as the laser can collect electricity flowing along the plasma filament, because a vertical voltage gradient exists between the first region of atmosphere and the second region of atmosphere.

FIG. 6 illustrates an example of a collector configured to collect electricity flowing along the plasma filament. The collector may be a charge collection circuit characterized by capacitance, inductance, and resistance. The electricity may be collected by charging a capacitor.

DETAILED DESCRIPTION

The detailed description set forth below is intended as a description of various configurations of the subject technology and is not intended to represent the only configurations in which the subject technology may be practiced. The appended drawings are incorporated herein and constitute a part of the detailed description. The detailed description includes specific details for the purpose of providing a thorough understanding of the subject technology. However, it will be apparent to those skilled in the art that the subject technology may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring the concepts of the subject technology. Like components are labeled with identical element numbers for ease of understanding.

FIG. **1** illustrates a first example of a system **100** for harvesting atmospheric electricity. The system **100** comprises a laser **110** configured to form a plasma filament **120** and a collector **130** configured to collect electricity flowing along the plasma filament **120**. The plasma filament **120** forms a conducting path between ground and a cloud **140**.

The plasma filament **120** comprises an electrically conducting plasma filament. The plasma comprises of electrons and positive ions. The electrically conducting plasma filament may be formed in atmosphere using an ultra short pulse laser (USPL). The USPL forms a plasma filament by raising the conductivity of a very small diameter channel (~100 microns or less) for a very brief time. The propagation of high power (~10^{14} W/cm^2) pulses from the USPL is accompanied by filamentation—self-channeling of femtosecond laser pulses in stable high-intensity light filaments with ~100 microns diameters (so that the Kerr effect focusing balances defocusing due to plasma formation). This filamentation keeps the beam virtually free of diffraction divergence. The long plasma strings have high electron densities (10^{16}/cm^3) which support high conductivities. The ionization of air at these intensities results from multi-photon processes. Filamentation has been produced and detected at altitudes as high as 13-20 km. Almost no beam scattering occurs in filamentation phenomenon, and virtually all the pulse energy is invested in ionization of air molecules. With the typical electron density and channel diameter, a 160 mJ pulse is sufficient to generate a 1 km long channel.

Once initiated, plasma filaments cannot go on forever, and typically only propagate a kilometer or so before energy depletion and exhaustion. However, by using two coaxial USPL projection optics having different time-lensing parameters, a near and far filament could be initiated in a "daisy-chain" to extend the total length of the conductive channel. The onset of filamentation in the far filament is time-lensed to coincide with the exhaustion range of the near filament. Additionally, using negative chirp, femtosecond laser pulses can propagate almost without loss until different frequency components of the wave packet, propagating at different speeds due to dispersion in air, come together at a certain desired location so that the laser intensity there exceeds the filamentation threshold, resulting in long ionized filaments created at a distance of up to several miles from the laser source. In other words, negative chirp is used to essentially focus a beam of the laser at a desired distance to form the plasma filament there. Accordingly, this technique may be used to move the starting point and to extend the length of the plasma filament.

The size, electrical conductivity, and lifetime of the plasma filaments are enhanced by an auxiliary radio-frequency electromagnetic waves or microwaves. The plasma filament may act like an antenna to absorb the auxiliary radio-frequency (RF) electromagnetic waves or microwaves.

The pulsed collection of electric charge and energy is repeated with an optimal (possibly very high) repetition rate of the pulsed laser and of the auxiliary RF waves or microwaves. The energy collected per one pulse should exceed the energy spent on creating and enhancing the plasma filaments, so that the net energy collected is positive. The optimal pulse repetition rate (PRR) depends upon atmospheric conditions which can vary widely over even short time durations. As a general rule, one tries to tune the repetition rate to the plasma relaxation time (the ion-electron recombination time) so that the conductivity of the filament remain as high as is optimal given the atmospheric conditions at the time. A feedback control system that varies the PRR as well as the rest of the pulse-shaping parameters may be employed to optimize the net power production of the system. For more information regarding pulse shaping and tailoring, which is the central theme of the field called "quantum control", please see A. Assion, T. Baumert, M. Bergt, T. Brixner, B. Kiefer, V. Seyfried, M. Strehle, G. Gerber (30 October). "Control of Chemical Reactions by Feedback-Optimized Phase-Shaped Femtosecond Laser Pulses". Science 282 (5390): 919-922. doi: 10.1126/science.282.5390.919. PMID 9794756.

FIG. **2** illustrates a second example of a system **200** for harvesting atmospheric electricity. A plasma filament **120** and a lightning **210** together form a conducting path between ground and a cloud **140**. A condensing mirror **220** directs the beam of laser **110** towards the cloud **140**. A collector **130** is configured to collect electricity flowing along the plasma filament **120**.

In the case of electricity collection from the cloud **140**, the initial and RF-enhanced plasma filaments can be relatively short, not reaching all the way from ground to the cloud **140**. The relatively short plasma filament can be optimized so that it would trigger propagation of the so-called leader (as in natural lightning), which would effectively use the energy and potential of the cloud to eventually create an electrically

conducting path between ground and the cloud **140**. The final conducting path would comprise of a plasma filament **120** and a lightning **210**.

It is not shown in the figures, but alternatively both the laser **110** and the collector **130** may be placed on a mobile device, which moves together with the cloud. One such mobile device may be a vehicle moving on the ground, but another such mobile device may be an airplane flying in the air. In the case of an airplane flying in the air, plasma filaments may be formed by the laser to reach both ground and the cloud at the same time. In the event the plasma filament directed at ground is not long enough to reach ground, a lightning may also be formed to complete the conducting path to ground.

FIG. **3**A illustrates a third example of a system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms two plasma filaments (**321**, **322**) that together complete a conducting path between a first region **331** of a cloud **330** and a second region **332** of the cloud **330**. The first region **331** of the cloud **330** and the second region **332** of the cloud **330** carry opposite electric charges. In the example shown here, the first region **331** of the cloud **330** carries positive electric charges, while the second region **332** of the cloud **330** carries negative electric charges. A collector configured to collect electricity flowing along the two plasma filaments is also situated on the same airplane **310** as the laser. Positive and negative charges are naturally separated within the cloud, so this example makes use of the electrostatic potential gradient between different regions of the same cloud.

FIG. **3**B illustrates a fourth example of the system **300** for harvesting atmospheric electricity. It is similar to FIG. **3**A, except two lightnings (**341**, **342**) complete the conducting path between a first region **331** of a cloud **330** and a second region **332** of the cloud **330** (i.e., a first lightning **341** electrically connects the first region **331** of the cloud **330** to one of the plasma filaments **321** and a second lightning **342** electrically connects the second region **332** of the cloud **330** to the other plasma filaments **322**). The lightning formation is again because the initial and RF-enhanced plasma filaments can be relatively short, not reaching all the way from the collector situated on airplane **310** to the cloud **330**. These relatively short plasma filaments can be optimized so that they would trigger propagation of the so-called leader (as in natural lightning), which would eventually create an electrically conducting path between the two regions of cloud **330** via a connection through airplane **310**. The final conducting path would comprise of two plasma filaments (**321**, **322**) and two lightnings (**341**, **342**). Of course, one of the lightnings may not be formed, if one of the plasma filament can reach all the way from airplane **310** to cloud **330**.

FIG. **4** illustrates a fifth example of the system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms two plasma filaments (**421**, **431**) that together complete a conducting path between a first cloud **420** and a second cloud **430**. The region **422** of the first cloud **420** that is connected to the first plasma filament **421** and the region **432** of the second cloud **430** that is connected to the second plasma filament **431** carry opposite electric charges. In the example shown here, region **422** of cloud **420** carries positive electric charges, while region **432** of cloud **430** carry negative electric charges. Positive and negative charges are naturally separated within the cloud, so this example makes use of the electrostatic potential gradient between different regions of different clouds. Once again, in case one of the plasma filament cannot reach all the way from airplane **310** to any one of the clouds, then lightning may be formed to complete an electrically conducting path from airplane **310** to any one of the clouds. But these embodiments are not shown in the figures.

FIG. **5** illustrates a sixth example of the system **300** for harvesting atmospheric electricity. A laser system situated on an airplane **310** forms a plasma filament **501** that completes a conducting path between a first region **510** of atmosphere and a second region **520** of atmosphere. A collector situated on the same airplane **310** as the laser system can collect electricity flowing along the plasma filament **501**, because a vertical voltage gradient exists between the first region **510** of atmosphere and the second region **520** of atmosphere. Because no clouds are needed for this embodiment, atmospheric electricity collection is possible under fair weather conditions (relying on the naturally existing vertical voltage gradient in the atmosphere) as well as under foul weather conditions.

FIG. **6** illustrates an example of a collector **130** configured to collect electricity flowing along a plasma filament **620**. The collector may be a charge collection circuit characterized by capacitance **631**, inductance **632**, and resistance **633**. The electricity may be collected by charging a capacitor associated with capacitance **631**. Battery **610** represents these naturally existing voltage sources: (1) between ground and a cloud, (2) between differently charged regions of the same cloud, (3) between differently charged regions of different clouds, and (4) between different regions of atmosphere, where there is a vertical voltage gradient. The plasma filament **620** can, for the purpose of analysis and optimization of the charge collection process, be viewed as electromagnetic transmission lines characterized by their effective capacitance, inductance, and resistance per unit length. Accordingly, the parameters of the charge collection circuit and of the effective transmission line representing the plasma filaments are optimized, so as to maximize the net charge and energy collected (minus the energy spent on generating and enhancing the plasma filaments).

The foregoing description is provided to enable a person skilled in the art to practice the various configurations described herein. While the subject technology has been particularly described with reference to the various figures and configurations, it should be understood that these are for illustration purposes only and should not be taken as limiting the scope of the subject technology.

There may be many other ways to implement the subject technology. Various functions and elements described herein may be partitioned differently from those shown without departing from the scope of the subject technology. Various modifications to these configurations will be readily apparent to those skilled in the art, and generic principles defined herein may be applied to other configurations. Thus, many changes and modifications may be made to the subject technology, by one having ordinary skill in the art, without departing from the scope of the subject technology.

It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

A phrase such as "an aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all configurations, or one or more configurations. An aspect may provide

one or more examples of the disclosure. A phrase such as an "aspect" may refer to one or more aspects and vice versa. A phrase such as an "embodiment" does not imply that such embodiment is essential to the subject technology or that such embodiment applies to all configurations of the subject technology. A disclosure relating to an embodiment may apply to all embodiments, or one or more embodiments. An embodiment may provide one or more examples of the disclosure. A phrase such an "embodiment" may refer to one or more embodiments and vice versa. A phrase such as a "configuration" does not imply that such configuration is essential to the subject technology or that such configuration applies to all configurations of the subject technology. A disclosure relating to a configuration may apply to all configurations, or one or more configurations. A configuration may provide one or more examples of the disclosure. A phrase such as a "configuration" may refer to one or more configurations and vice versa.

Furthermore, to the extent that the term "include," "have," or the like is used in the description or the claims, such term is intended to be inclusive in a manner similar to the term "comprise" as "comprise" is interpreted when employed as a transitional word in a claim.

The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments.

A reference to an element in the singular is not intended to mean "one and only one" unless specifically stated, but rather "one or more." The term "some" refers to one or more. Underlined and/or italicized headings and subheadings are used for convenience only, do not limit the subject technology, and are not referred to in connection with the interpretation of the description of the subject technology. All structural and functional equivalents to the elements of the various configurations described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and intended to be encompassed by the subject technology. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the above description.

What is claimed is the following:

1. A system for harvesting atmospheric electricity, comprising:

- a laser configured to form a plasma filament comprising at least a first filament and a second filament, wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;
- an auxiliary source of electromagnetic energy operable to enhance the plasma filament by applying electromagnetic energy to the plasma filament; and
- a collector configured to collect electricity flowing along the plasma filament.

2. The system of claim **1**, wherein the plasma filament comprises an electrically conducting plasma filament.

3. The system of claim **1**, wherein the laser is a pulsed laser.

4. The system of claim **3**, wherein the pulsed laser is pulsed at an optimal repetition rate.

5. The system of claim **1**, wherein the electromagnetic energy comprises at least one of radio-frequency energy or microwave energy.

6. The system of claim **1**, wherein the plasma filament forms at least a part of a conducting path between ground and a cloud.

7. The system of claim **6**, wherein at least one lightning forms another part of the conducting path between ground and the cloud.

8. The system of claim **1**, wherein the plasma filament forms at least a part of a conducting path between a first region of a cloud and a second region of the cloud.

9. The system of claim **8**, wherein at least one lightning forms another part of the conducting path between the first region of the cloud and the second region of the cloud.

10. The system of claim **1**, wherein:

- the laser is further configured to form a second plasma filament,
- the plasma filament is connected to a region of a first cloud, and
- the second plasma filament is connected to a region of a second cloud.

11. The system of claim **1**, wherein the plasma filament completes a conducting path between a first region of atmosphere and a second region of atmosphere.

12. The system of claim **11**, wherein a vertical voltage gradient exists between the first region of atmosphere and the second region of atmosphere.

13. The system of claim **1**, wherein the collector comprises a charge collection circuit.

14. The system of claim **1**, wherein the laser is situated on ground.

15. The system of claim **1**, wherein the laser is situated on a mobile device.

16. The system of claim **15**, wherein the mobile device is an airplane.

17. The system of claim **1**, wherein negative chirp is used to move the starting point of formation of the plasma filament to a desired location.

18. A method for harvesting atmospheric electricity, the method comprising:

- forming a plasma filament with a laser, wherein the plasma filament comprises at least a first filament and a second filament, and wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;
- applying electromagnetic energy to the plasma filament to enhance the plasma filament; and
- collecting electricity flowing along the plasma filament.

19. An apparatus for harvesting atmospheric electricity, the apparatus comprising:

- means for forming a plasma filament with a laser, wherein the plasma filament comprises at least a first filament and a second filament, and wherein onset of formation of the second filament coincides with an exhaustion range of the first filament;
- means for applying electromagnetic energy to the plasma filament to enhance the plasma filament; and
- means for collecting electricity flowing along the plasma filament.

20. The system of claim **1**, wherein the laser is an ultra short pulse laser (USPL).

21. The system of claim **1**, wherein the laser comprises two coaxial USPL projection optics having different time-lensing parameters.

* * * * *

US005590031A

United States Patent [19]

Mead, Jr. et al.

[11] **Patent Number: 5,590,031**

[45] **Date of Patent: Dec. 31, 1996**

[54] **SYSTEM FOR CONVERTING ELECTROMAGNETIC RADIATION ENERGY TO ELECTRICAL ENERGY**

[76] Inventors: **Franklin B. Mead, Jr.**, 44536 Avenida Del Sol, Lancaster, Calif. 93535; **Jack Nachamkin**, 12314 Teri Dr., Poway, Calif. 92064

[21] Appl. No.: **281,271**

[22] Filed: **Jul. 27, 1994**

[51] **Int. Cl.**[6] **H02M 1/00**

[52] **U.S. Cl.** **363/8**; 363/178; 342/6

[58] **Field of Search** 363/8, 13, 178; 342/6, 61, 73, 173, 175

[56] **References Cited**

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Primary Examiner—Peter S. Wong
Assistant Examiner—Adolf Berhane
Attorney, Agent, or Firm—Chris Papageorge

[57] **ABSTRACT**

A system is disclosed for converting high frequency zero point electromagnetic radiation energy to electrical energy. The system includes a pair of dielectric structures which are positioned proximal to each other and which receive incident zero point electromagnetic radiation. The volumetric sizes of the structures are selected so that they resonate at a frequency of the incident radiation. The volumetric sizes of the structures are also slightly different so that the secondary radiation emitted therefrom at resonance interfere with each other producing a beat frequency radiation which is at a much lower frequency than that of the incident radiation and which is amenable to conversion to electrical energy. An antenna receives the beat frequency radiation. The beat frequency radiation from the antenna is transmitted to a converter via a conductor or waveguide and converted to electrical energy having a desired voltage and waveform.

14 Claims, 8 Drawing Sheets

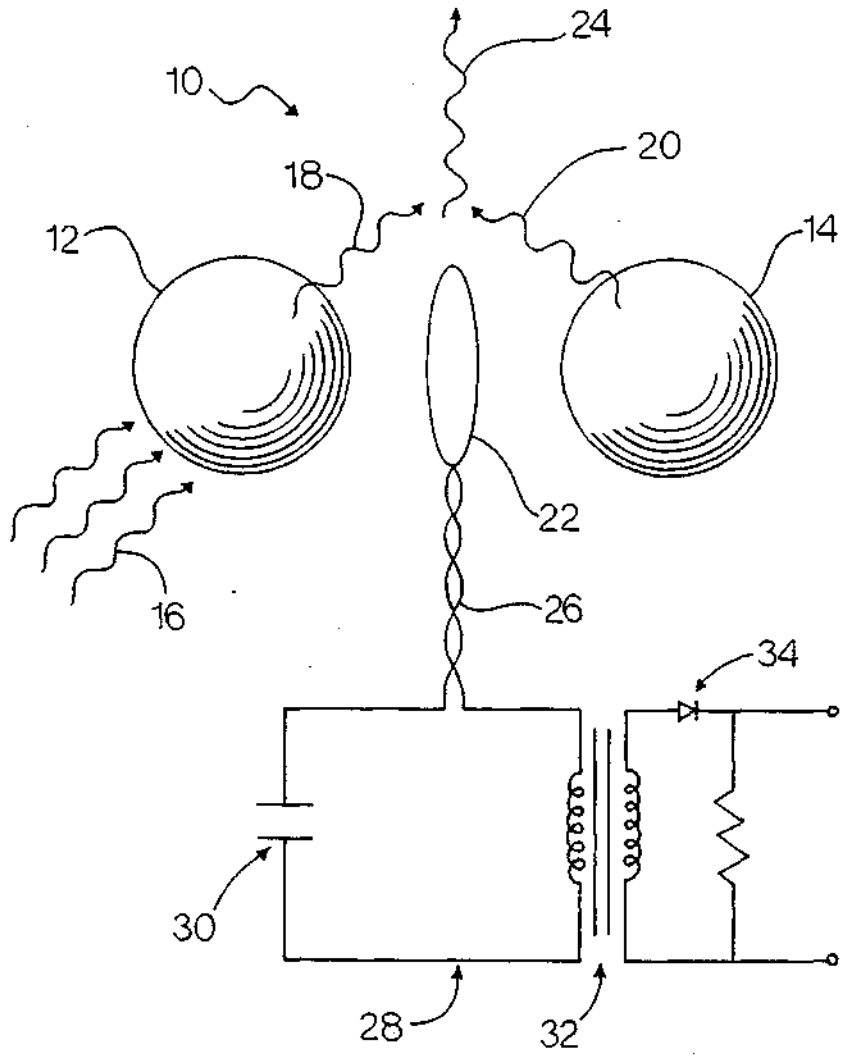

FIG. 1

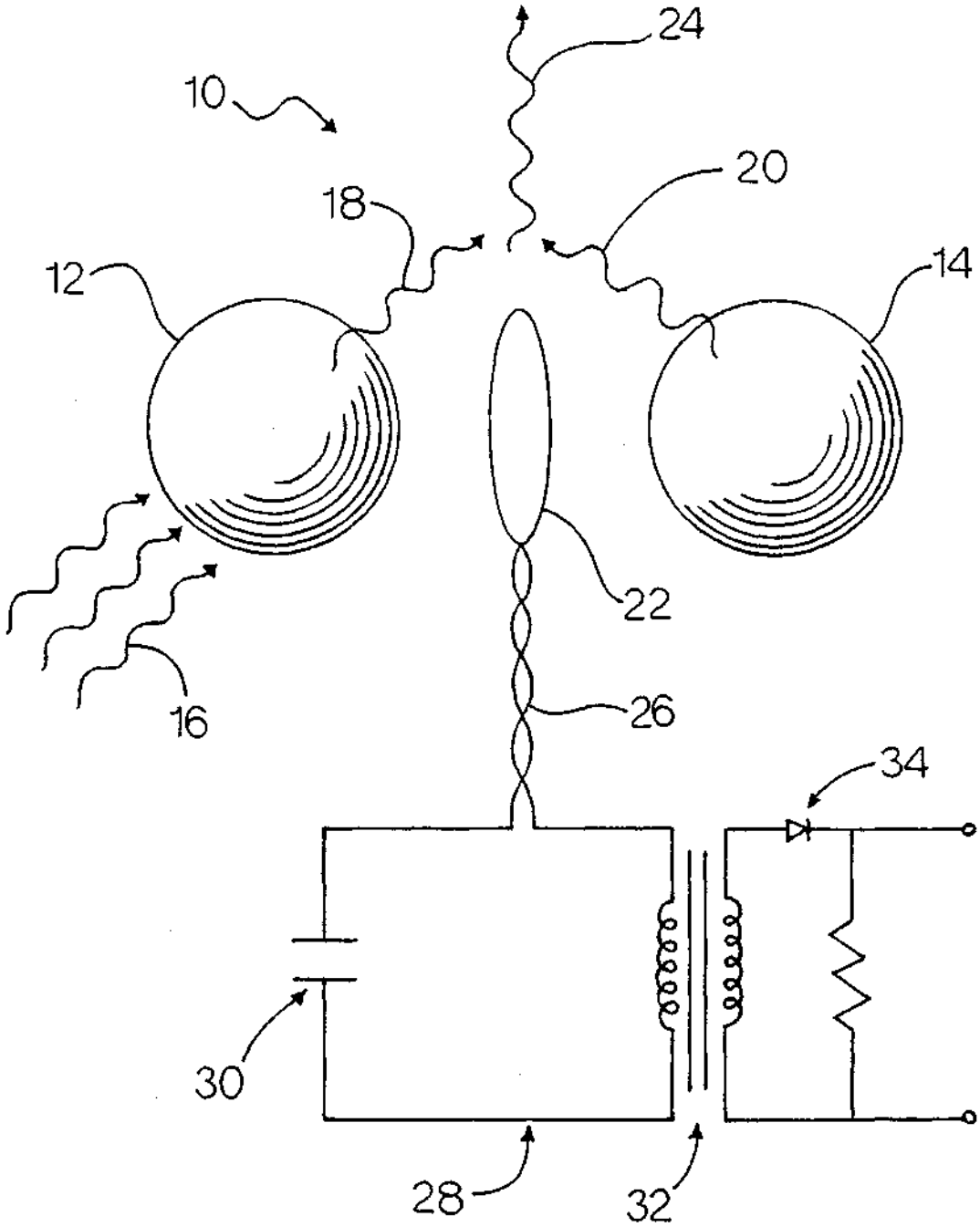

FIG. 2

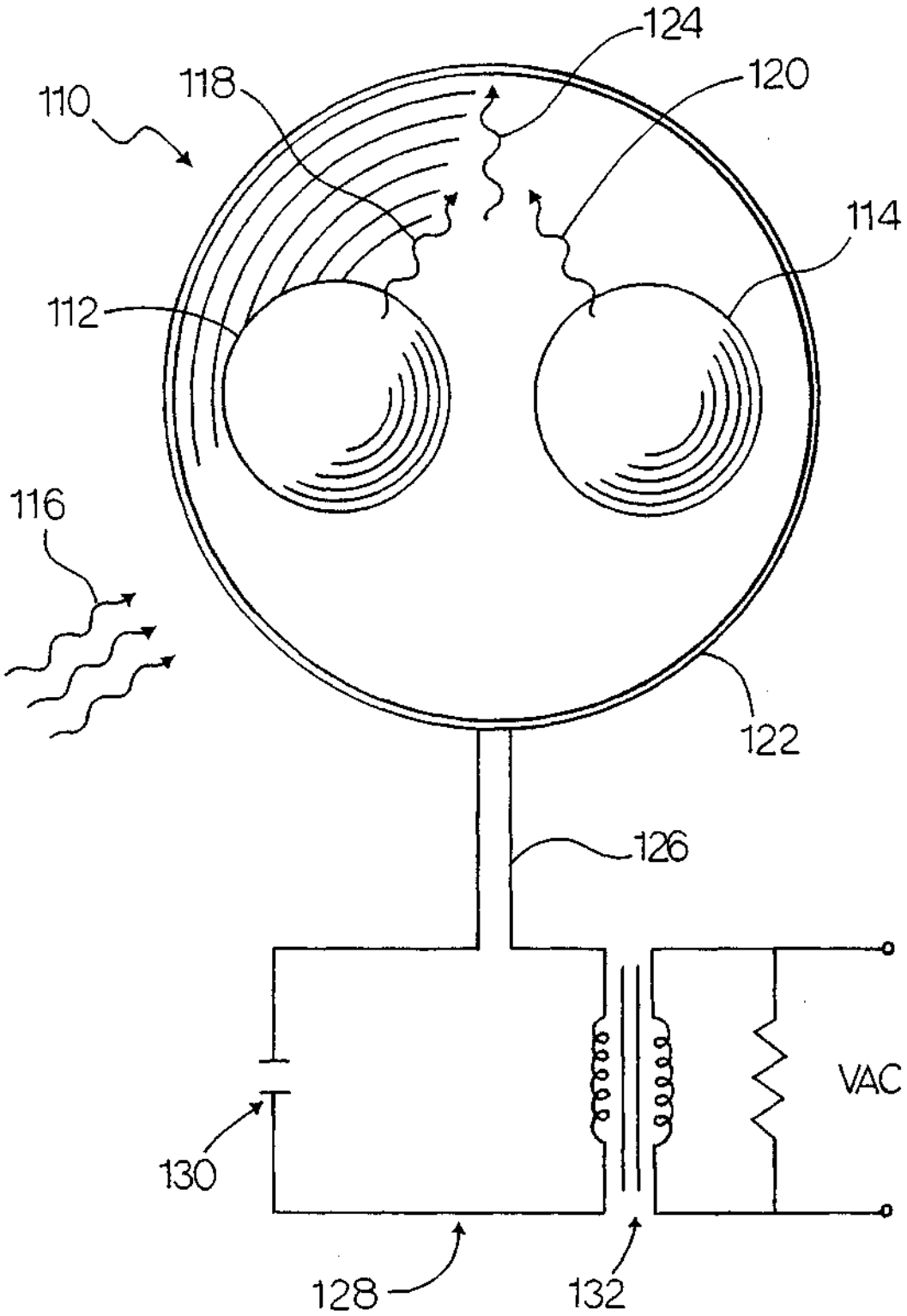

FIG. 3

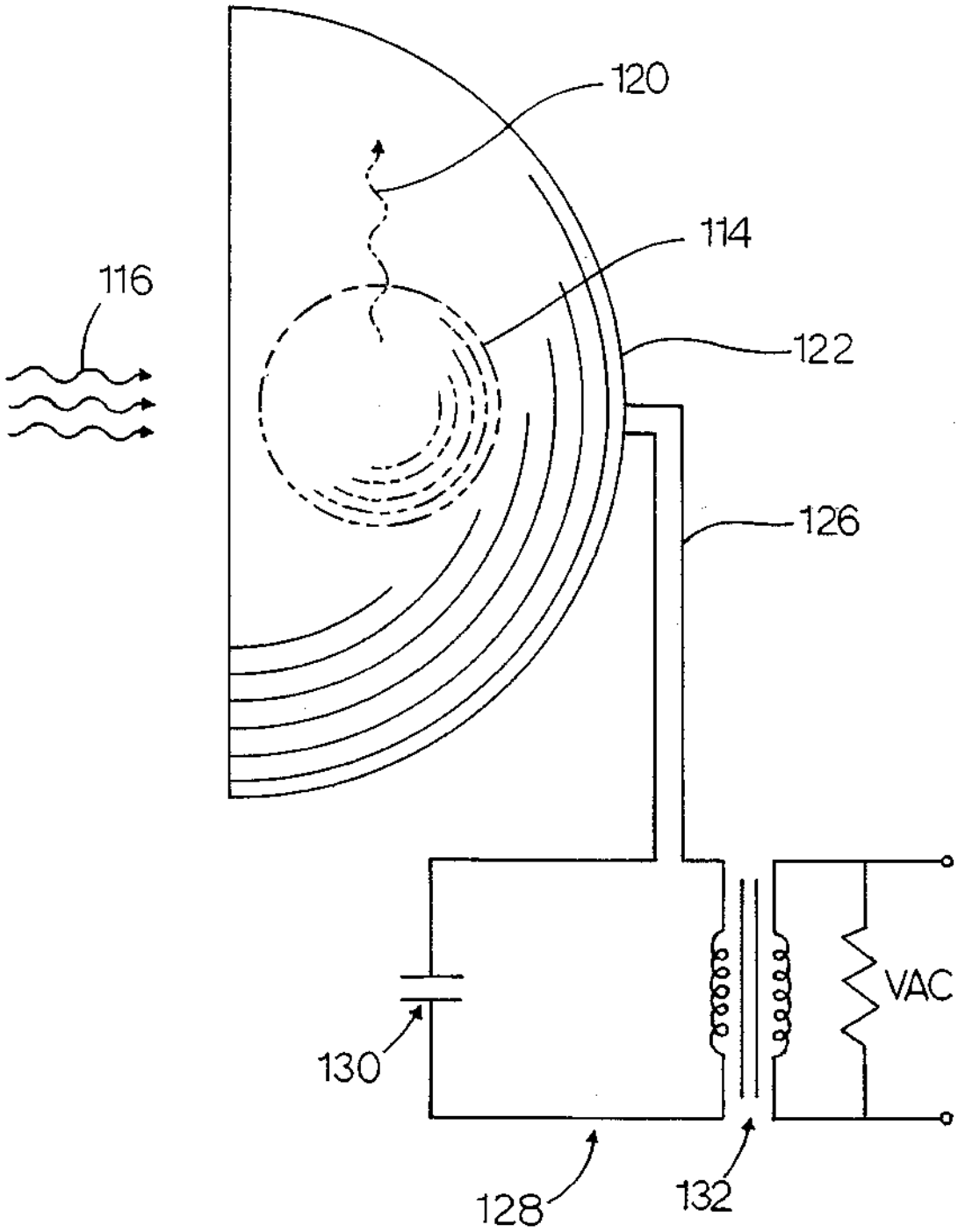

FIG. 4

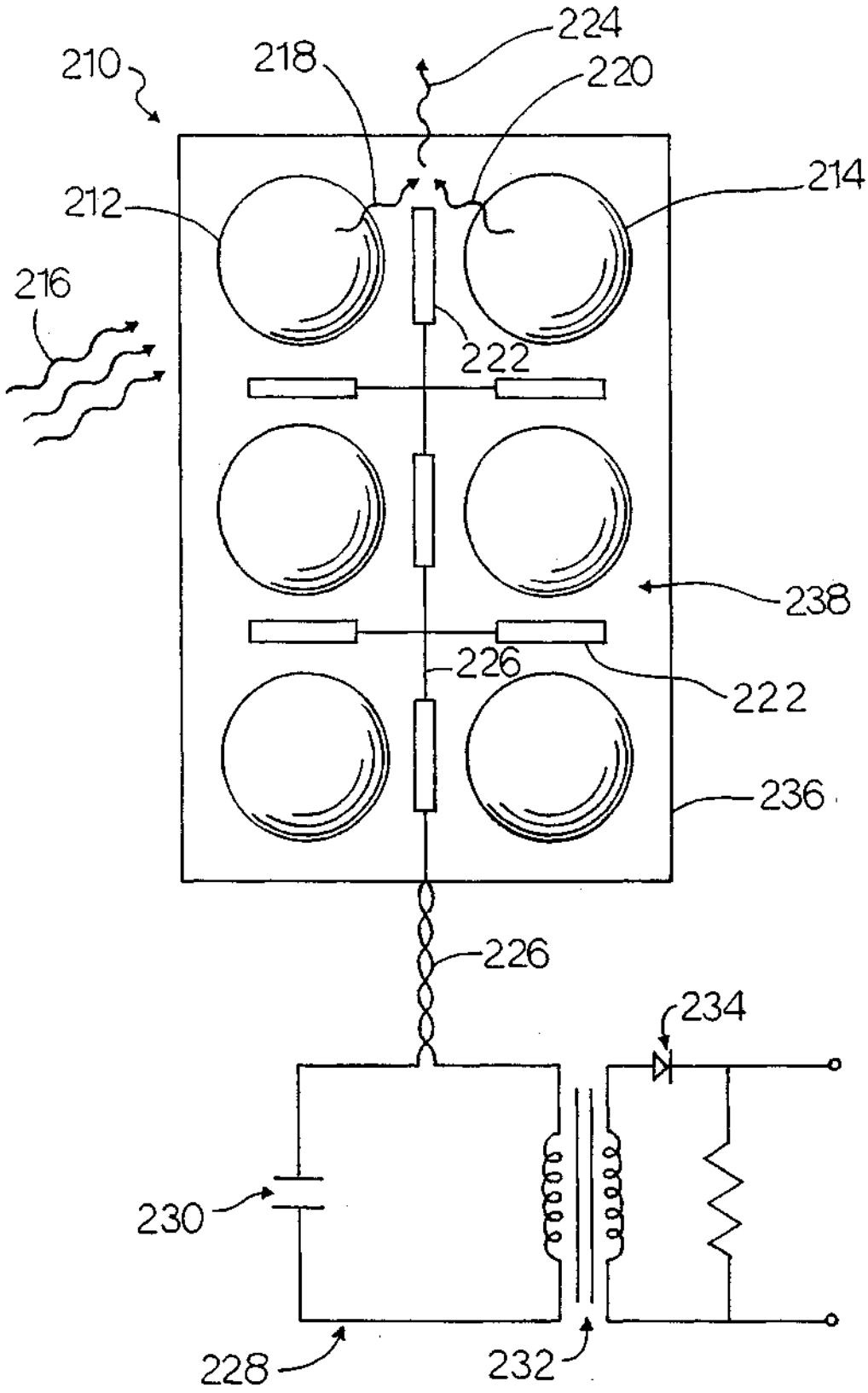
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FIG. 5

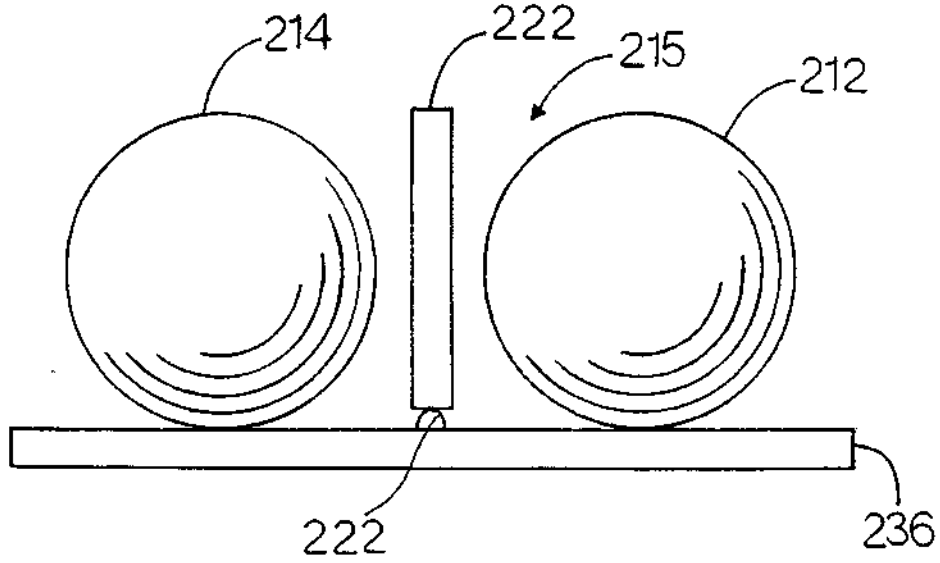

FIG. 6

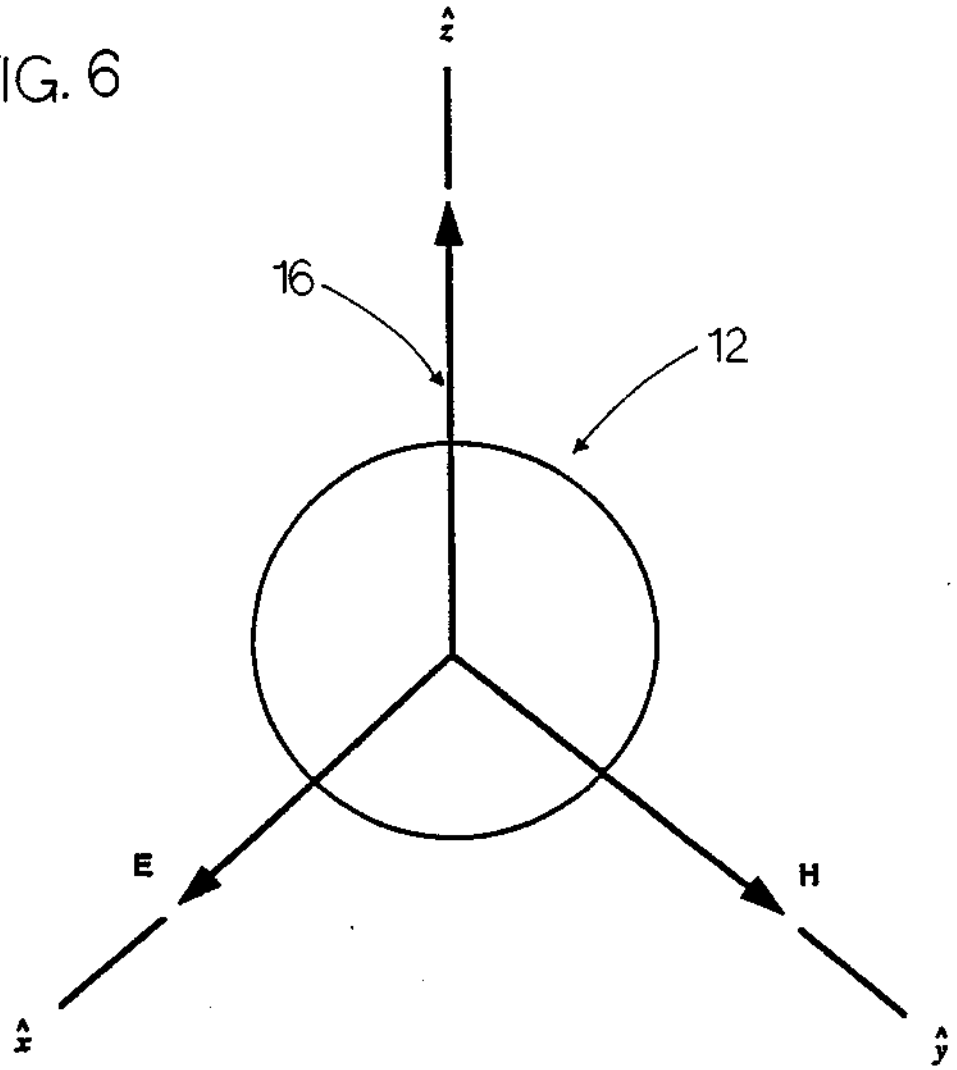

FIG. 7

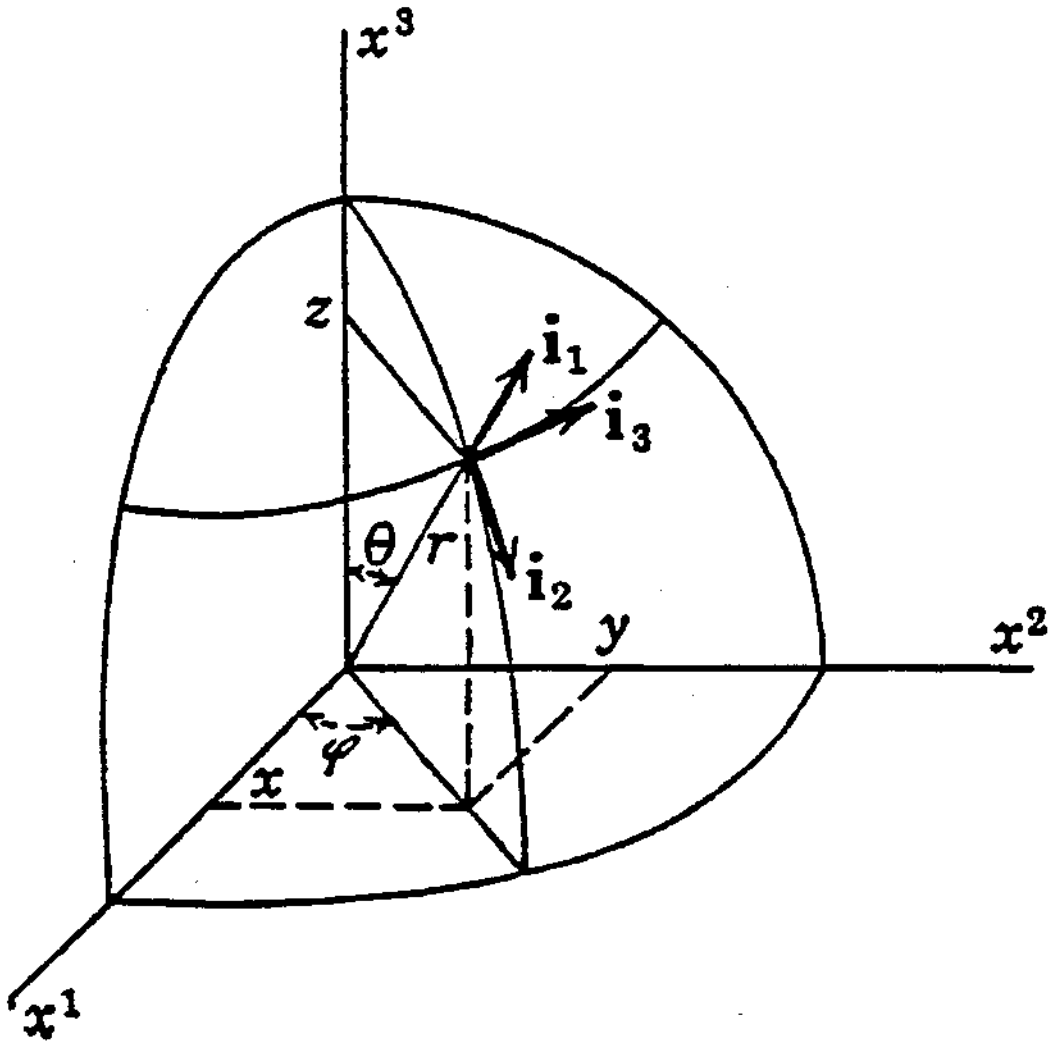

FIG. 8

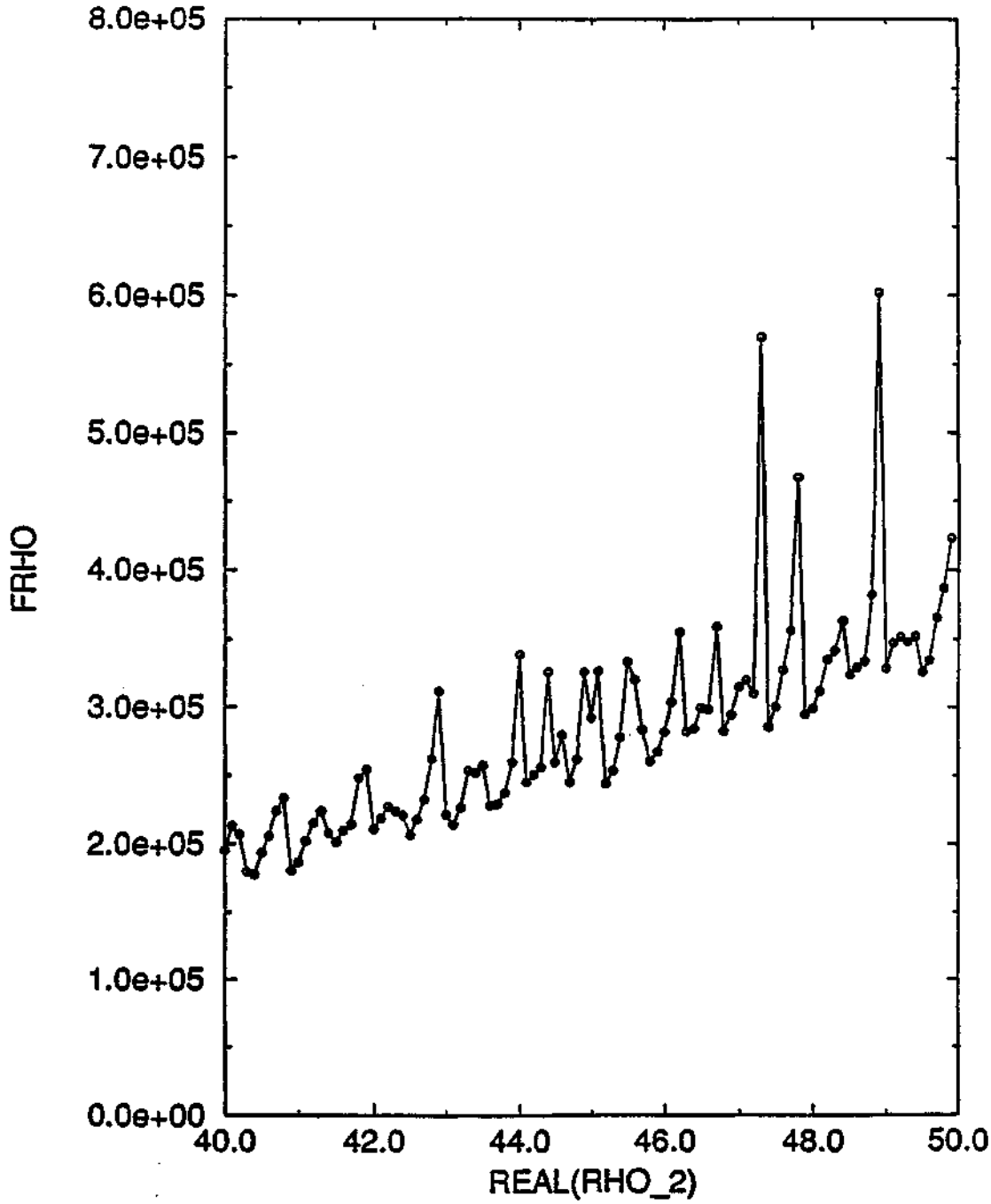
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FIG.9

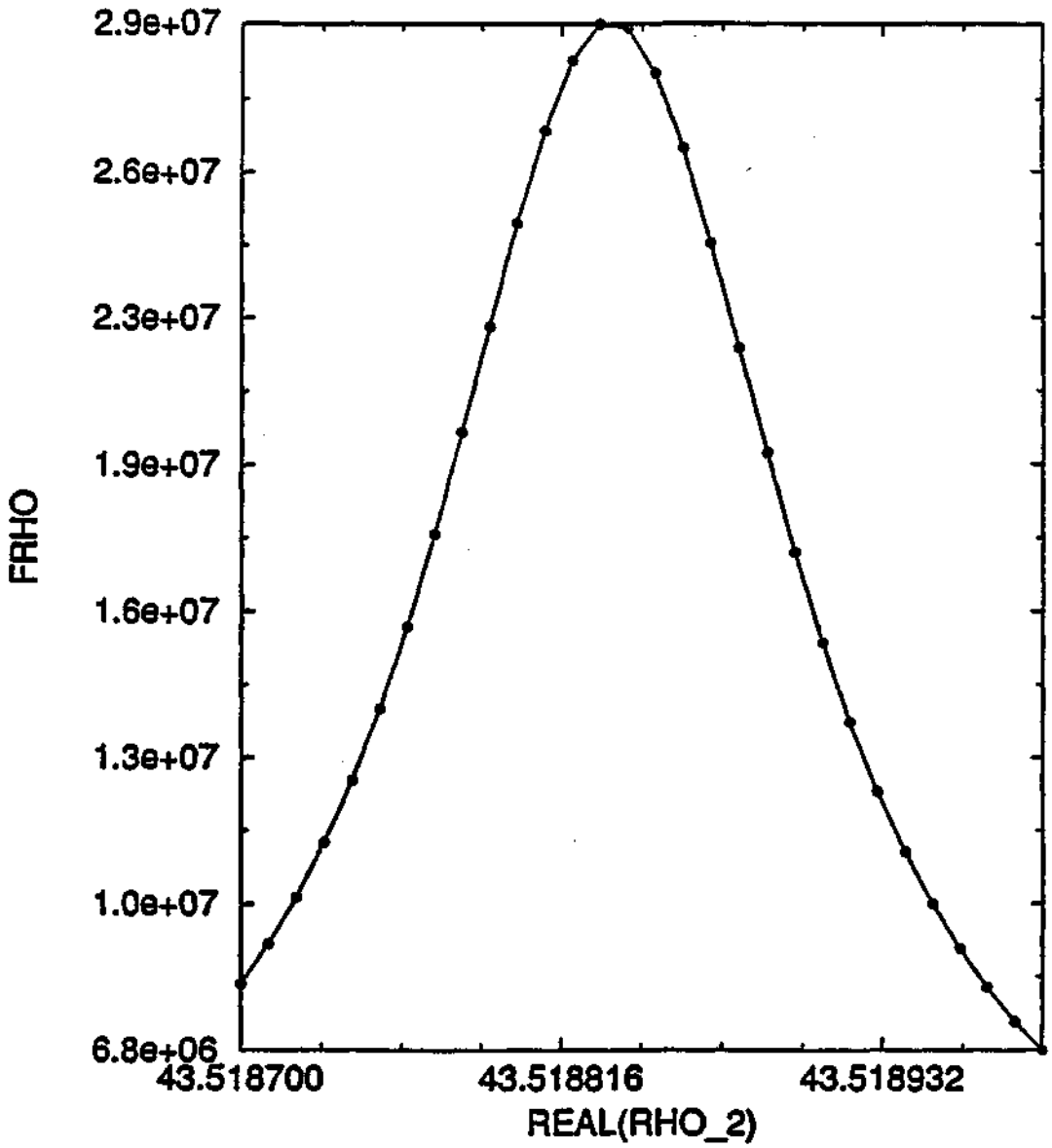
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43.518932
REAL(RHO_2)

SYSTEM FOR CONVERTING ELECTROMAGNETIC RADIATION ENERGY TO ELECTRICAL ENERGY

BACKGROUND OF THE INVENTION

The invention relates generally to conversion of electromagnetic radiation energy to electrical energy, and, more particularly, to conversion of high frequency bandwidths of the spectrum of a type of radiation known as zero point electromagnetic radiation to electrical energy.

The existence of zero point electromagnetic radiation was discovered in 1958 by the Dutch physicist M. J. Sparnaay. Mr. Sparnaay continued the experiments carried out by Hendrik B. G. Casimir in 1948 which showed the existence of a force between two uncharged parallel plates which arose from electromagnetic radiation surrounding the plates in a vacuum. Mr. Sparnaay discovered that the forces acting on the plates arose from not only thermal radiation but also from another type of radiation now known as classical electromagnetic zero point radiation. Mr. Sparnaay determined that not only did the zero point electromagnetic radiation exist in a vacuum but also that it persisted even at a temperature of absolute zero. Because it exists in a vacuum, zero point radiation is homogeneous and isotropic as well as ubiquitous. In addition, since zero point radiation is also invariant with respect to Lorentz transformation, the zero point radiation spectrum has the characteristic that the intensity of the radiation at any frequency is proportional to the cube of that frequency. Consequently, the intensity of the radiation increases without limit as the frequency increases resulting in an infinite energy density for the radiation spectrum. With the introduction of the zero point radiation into the classical electron theory, a vacuum at a temperature of absolute zero is no longer considered empty of all electromagnetic fields. Instead, the vacuum is now considered as filled with randomly fluctuating fields having the zero point radiation spectrum. The special characteristics of the zero point radiation which are that it has a virtually infinite energy density and that it is ubiquitous (even present in outer space) make it very desirable as an energy source. However, because high energy densities exist at very high radiation frequencies and because conventional methods are only able to convert or extract energy effectively or efficiently only at lower frequencies at which zero point radiation has relatively low energy densities, effectively tapping this energy source has been believed to be unavailable using conventional techniques for converting electromagnetic energy to electrical or other forms of easily useable energy. Consequently, zero point electromagnetic radiation energy which may potentially be used to power interplanetary craft as well as provide for society's other needs has remained unharnessed.

There are many types of prior art systems which use a plurality of antennas to receive electromagnetic radiation and provide an electrical output therefrom. An example of such a prior art system is disclosed in U.S. Pat. No. 3,882,503 to Gamara. The Gamara system has two antenna structures which work in tandem and which oscillate by means of a motor operatively attached thereto in order to modulate the radiation reflected from the antenna surfaces. The reflecting surfaces of the antennas are also separated by a distance equal to a quarter wavelength of the incident radiation. However, the Gamara system does not convert the incident radiation to electrical current for the purpose of converting the incident electromagnetic radiation to another form of readily useable energy. In addition, the relatively large size

of the Gamara system components make it unable to resonate at and modulate very high frequency radiation.

What is therefore needed is a system which is capable of converting high frequency electromagnetic radiation energy into another form of energy which can be more readily used to provide power for transportation, heating, cooling as well as various other needs of society. What is also needed is such a system which may be used to provide energy from any location on earth or in space.

SUMMARY OF THE INVENTION

It is a principle object of the present invention to provide a system for converting electromagnetic radiation energy to electrical energy.

It is another object of the present invention to provide a system for converting electromagnetic radiation energy having a high frequency to electrical energy.

It is another object of the present invention to provide a system for converting zero point electromagnetic radiation energy to electrical energy.

It is another object of the present invention to provide a system for converting electromagnetic radiation energy to electrical energy which may used to provide such energy from any desired location on earth or in space.

It is another object of the present invention to provide a system for converting electromagnetic radiation energy to electrical energy having a desired waveform and voltage.

It is an object of the present invention to provide a miniaturized system for converting electromagnetic radiation energy to electrical energy in order to enhance effective utilization of high energy densities of the electromagnetic radiation.

It is an object of the present invention to provide a system for converting electromagnetic radiation energy to electrical energy which is simple in construction for cost effectiveness and reliability of operation.

Essentially, the system of the present invention utilizes a pair of structures for receiving incident electromagnetic radiation which may be propagating through a vacuum or any other medium in which the receiving structures may be suitably located. The system of the present invention is specifically designed to convert the energy of zero point electromagnetic radiation; however, it may also be used to convert the energy of other types of electromagnetic radiation. The receiving structures are preferably composed of dielectric material in order to diffract and scatter the incident electromagnetic radiation. In addition, the receiving structures are of a volumetric size selected to enable the structures to resonate at a high frequency of the incident electromagnetic radiation based on the parameters of frequency of the incident radiation and propagation characteristics of the medium and of the receiving structures. Since zero point radiation has the characteristic that its energy density increases as its frequency increases, greater amounts of electromagnetic energy are available at higher frequencies. Consequently, the size of the structures are preferably miniaturized in order to produce greater amounts of energy from a system located within a space or area of a given size. In this regard, the smaller the size of the receiving structures, the greater the amount of energy that can be produced by the system of the present invention.

At resonance, electromagnetically induced material deformations of the receiving structures produce secondary fields of electromagnetic energy therefrom which may have eva-

nescent energy densities several times that of the incident radiation. The structures are of different sizes so that the secondary fields arising therefrom are of different frequencies. The difference in volumetric size is very small so that interference between the two emitted radiation fields, and the receiving structures at the two different frequencies produces a beat frequency radiation which has a much lower frequency than the incident radiation. The beat frequency radiation preferably is at a frequency which is sufficiently low that it may be relatively easily converted to useable electrical energy. In contrast, the incident zero point radiation has its desirable high energy densities at frequencies which are so high that conventional systems for converting the radiation to electrical energy either cannot effectively or efficiently so convert the radiation energy or simply cannot be used to convert the radiation energy for other reasons.

The system of the present invention also includes an antenna which receives the beat frequency radiation. The antenna may be a conventional metallic antenna such as a loop or dipole type of antenna or a rf cavity structure which partially encloses the receiving structures. The antenna feeds the radiation energy to an electrical conductor (in the case of a conventional dipole or comparable type of antenna) or to a waveguide (in the case of a rf cavity structure). The conductor or waveguide feeds the electrical current (in the case of the electrical conductor) or the electromagnetic radiation (in the case of the waveguide) to a converter which converts the received energy to useful electrical energy. The converter preferably includes a tuning circuit or comparable device so that it can effectively receive the beat frequency radiation. The converter may include a transformer to convert the energy to electrical current having a desired voltage. In addition, the converter may also include a rectifier to convert the energy to electrical current having a desired waveform.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of the receiving structures and antenna of a first embodiment of the system of the present invention with a schematic view of the conductor and converter thereof and also showing the incident primary and emitted secondary electromagnetic radiation.

FIG. **2** is a front view of the receiving structures, antenna and waveguide of a second embodiment of the system of the present invention with a schematic view of the converter thereof and also showing the incident primary and emitted secondary electromagnetic radiation.

FIG. **3** is a perspective view of the receiving structures, antenna and waveguide of the second embodiment shown in FIG. **2** with a schematic view of the converter thereof and also showing the incident primary and emitted secondary electromagnetic radiation.

FIG. **4** is a front view of the substrate and a plurality of pairs of the receiving structures and a plurality of antennas of a third embodiment of the system of the present invention with a schematic view of the conductor and converter thereof and also showing the incident primary and emitted secondary electromagnetic radiation.

FIG. **5** is a top view of some of the components of the third embodiment of the system of the present invention showing two of the plurality of pairs of receiving structures and two of the plurality of antennas mounted on the substrate.

FIG. **6** is a diagram of a receiving structure of the system of the present invention showing an incident electromagnetic plane wave impinging on the receiving structure and illustrating the directions of the electric and magnetic field vectors thereof.

FIG. **7** is a diagram of a spherical coordinate system as used in the formulas utilized in the system of the present invention.

FIG. **8** is a graph showing an imaginary ρ parameter plotted against a real ρ parameter illustrating the values thereof at resonance as well as values thereof at other than resonance.

FIG. **9** is a graph showing a portion of the graphical representation shown in FIG. **8** illustrating the real and imaginary ρ values at or near a single resonance.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, a first embodiment of the present invention is generally designated by the numeral **10**. The system **10** includes a first and second means for receiving **12** and **14** incident electromagnetic radiation **16**. The means for receiving **12** and **14** are preferably a pair of spherical structures **12** and **14** which are preferably composed of a dielectric material. Alternatively, the spheres **12** and **14** may be cubical structures or any other suitable shape. The spheres **12** and **14** may be mounted on a suitable foundation by any suitable mounting means (not shown), or spheres **12** and **14** may be suspended from a suitable foundation by any suitable suspension means (not shown). The spheres **12** and **14** are preferably composed of a dielectric material. The dielectric spheres **12** and **14** scatter and concentrate electromagnetic waves. At very sharpely defined frequencies, the spheres **12** and **14** will have resonances wherein the internal energy densities can be five orders of mangitude larger than the energy density of the incident electromagnetic field driving the spheres **12** and **14**. At resonance, the electromagnetic stresses, equivalent to pressures proportional to the energy density, can cause material deformation of the spheres **12** and **14** which produce a secondary electromagnetic field. The spheres **12** and **14** are preferably positioned proximal to each other, as shown in FIG. **1**. Although the proximity of the spheres to each other will adversely affect the resonances, the very high "Q"s of the isolated-sphere resonances results in such adverse affect being relatively small. However, the proximity of the spheres **12** and **14** allows the spheres to interact electromechanically which increases the magnitude of the secondary radiation emitted therefrom.

The electromagnetic radiation incident upon the spheres **12** and **14** which drives the spheres to resonance is preferably zero point radiation **16**. However, other types of electromagnetic radiation may also be used to drive the spheres **12** and **14**, if desired.

The effect of a dielectric sphere such as **12** or **14** on an incident electromagnetic radiation such as a plane wave thereof is shown in FIG. **6**. The plane wave propagates in the z axis direction and is diffracted by the sphere **12** resulting in scattering thereof. This scattering is commonly known as Mie scattering. The incident radiation wave has an electric vector component which is linearly polarized in the x axis direction and a magnetic vector component which is linearly polarized in the y axis direction.

An electromagnetic wave incident upon a structure produces a forced oscillation of free and bound charges in synch with the primary electromagnetic field of the incident electromagnetic wave. The movements of the charges produce a

secondary electromagnetic field both inside and outside the structure. The secondary electromagnetic radiation comprising this secondary electromagnetic field is shown in FIG. **1** and designated by the numerals **18** and **20**. An antenna which is shown simply as a loop antenna but may also be a dipole or any other suitable type of antenna is also shown in FIG. **1** and designated by the numeral **22**. The nonlinear mutual interactions of the spheres produces interference between the secondary electromagnetic radiation **18** and **20** produces a beat frequency radiation **24** which is preferably at a much lower frequency than the primary radiation **16**. It is this beat frequency radiation **24** which is desired for conversion into electrical energy because it preferably is within the frequency range of rf radiation which may be converted into electrical energy by generally conventional systems. Thus, the radiation **24** received by the antenna **22** is fed via an electrical conductor **26** to a means for converting the beat frequency radiation **24** to electrical energy. This means for converting is designated by the numeral **28** and preferably includes a tuning capacitor **30** and a transformer **32** and a rectifier (preferably a diode) **34**. Instead of including the capacitor **30**, transformer **32** and rectifier **34**, the converter **28** may alternatively include an rf receiver of any suitable type.

The resultant field at any point is the vector sum of the primary and secondary fields. For the equations that follow, the structure receiving the incident plane wave is a sphere of radius a having a propagation constant k_1 positioned in an infinite, homogeneous medium having a propagation constant k_2. The incident plane wave propagates in the z axis direction and is as shown in FIG. **6**. The spherical coordinate system used for the vector spherical wave functions is shown in FIG. **7**. Expansion of the incident field provides:

$$E_i = E_o e^{-i\omega t} \sum_{n=1}^{\infty} i^n \frac{2n+1}{n(n+1)} \left(m_{01n}^{(1)} - i n_{eln}^{(1)}\right)$$

$$H_i = -\frac{k_2}{\omega\mu_2} E_o e^{-i\omega t} \sum_{n=1}^{\infty} i^n \frac{2n+1}{n(n+1)} \left(m_{eln}^{(1)} + i n_{01n}^{(1)}\right)$$

where E is the electric field and H is the magnetic field; and

$$m_{\substack{01n \\ eln}}^{(1)} = \pm \frac{1}{\sin\theta} j_n(k_2R) P_n^1(\cos\theta) \begin{matrix}\cos \\ \sin\end{matrix} \phi i_2 - j_n(k_2R) \frac{\partial p_n^1}{\partial\theta} \begin{matrix}\sin \\ \cos\end{matrix} \phi i_3$$

$$n_{\substack{01n \\ eln}}^{(1)} = \frac{n(n+1)}{k_2R} j_n(k_2R) P_n^1(\cos\theta) \begin{matrix}\sin \\ \cos\end{matrix} \phi i_1 + \frac{1}{k_2R} [k_2Rj_n(k_2R)]' \times \frac{\partial P_n^1}{\partial\theta} \begin{matrix}\sin \\ \cos\end{matrix} \phi i_2 \pm \frac{1}{k_2R\sin\theta} [k_2Rj_n(k_2R)]' P_n^1(\cos\theta) \begin{matrix}\cos \\ \sin\end{matrix} \phi i_3.$$

The electric and magnetic fields of the incident wave transmitted into the sphere i.e., R<a, can be similarly expanded:

$$E_t = E_0 e^{-i\omega t} \sum_{n=1}^{\infty} i^n \frac{2n+1}{n(n+1)} \left(a_n^t {}^{(1)}_{01n} - i b_n^t {}^{(1)}_{eln}\right)$$

$$H_t = \frac{k_2}{\phi\mu_1} E_0 e^{-i\omega t} \sum_{n=1}^{\infty} i^m \frac{2n+1}{n(n+1)} \left(b_n^t {}^{(1)}_{eln} - i a_n^t {}^{(1)}_{01n}\right)$$

If $j_n(k_2R)$ is replaced by $h_n^{(1)}(k_2R)$ in the previous equations, the functions $m^{(1)}$ and $n^{(1)}$ become $m^{(3)}$ and $n^{(3)}$. The outgoing fields i.e., R>a, are represented by:

$$E_R = E_0 e^{-i\omega t} \sum_{n=1}^{\infty} i^n \frac{2n+1}{n(n+1)} \left(a_n^r {}^{(3)}_{01n} - i b_n^t {}^{(3)}_{eln}\right)$$

$$H_r = \frac{k_2}{\phi\mu_1} E_0 e^{-i\omega t} \sum_{n=1}^{\infty} i^m \frac{2n+1}{n(n+1)} \left(b_n^r {}^{(3)}_{eln} - i a_n^t {}^{(3)}_{01n}\right)$$

where H_r represents the resultant wave in the medium surrounding the sphere. At resonance, the values of ρ at resonance require that the a_n^t and b_n^t coefficients be infinite. In order to determine these values of a_n^t and b_n^t, the boundary conditions at the sphere radius are needed. Since there must be continuity of the E and H values at the surface, the following equations are used:

$i_1\times(E_i+E_r)=i_1\times E_t$ and

$i_1\times(H_i+H_r)=i_1\times H_t$

which lead to two pairs of inhomogeneous equations:

$a_n^t j_n(N\rho)-a_n^r h_n^{(1)}(\rho)=j_n(\rho)$

$\mu_2 a_n^t[N\rho j_n(N\rho)]'-\mu_1 a_n^r[\rho h_n^{(1)}(\rho)]'=\mu_1[\rho j_n(\rho)]'$ and

$\mu_2 N b_n^t j_n(N\rho)-\mu_1 b_n^r h_n^{(1)}(\rho)=\mu_1 j_n(\rho)$

$b_n^t[N\rho j_n(N\rho)]'-N b_n^r[\rho h_n^{(1)}(\rho)]'=N[\rho j_n(\rho)]'$

where $k_1=Nk_2$, $\rho=k_2a$, $k_1a=N\rho$. Spherical Bessel functions of the first kind are denoted by j_n, while those of the third kind are denoted by $h_n^{(1)}$. The resulting equations are:

$$a_n^t = \frac{\mu_1 j_n(\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 h_n^{(1)}\rho)[\rho j_n(\rho)]'}{\mu_1 j_n(N\rho)[\rho h_n^{(1)}(\rho)]' - \mu_2 h_n^{(1)}(\rho)[N\rho j_n(N\rho)]'}$$

and

$$b_n^t = \frac{\mu_1 N j_n(\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 N h_n^{(1)}\rho)[\rho j_n(\rho)]'}{\mu_2 N^2 j_n(N\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 h_n^{(1)}(\rho)[N\rho j_n(N\rho)]'}$$

At a resonance, the denominator of either a_n^t or b_n^t will be zero. Thus, ρ values are found using the above equations that correspond to a resonant combination of angular frequency (ω) and radius (a) for a given sphere material and given surrounding medium. In determining such values of ρ, the following equations are also specifically used:

$$\rho = ak_2 = a\omega\sqrt{\epsilon_2\mu_2} \text{ and}$$

$$\rho_1 = (k_1/k_2)\rho$$

where ρ_1 corresponds to the sphere material. An iterative method is preferably used to find the desired values of ρ at resonance. In calculating ρ utilizing the above equations for purposes of example, it was assumed that $\mu_1=\mu_2=\mu_0=4\pi\times10^{-7}$ and $\epsilon_2=\epsilon_0=8.85419\times10^{-12}$.

One major root of ρ which was found has a value of:

Real (ρ)=+66.39752607619131

Imaginary (ρ)=−0.6347867071968998.

These particular values are not shown in FIG. **8**. However, other values of ρ found using the equations set forth herein are shown in FIG. **8**. The peaks in FIG. **8** are the resonances. One of these resonances shown in FIG. **8** is shown in detail in FIG. **9**. These resonance values are shown for purposes of example. Other resonances also exist which have not been determined; thus, not all possible resonance values are shown in FIGS. **8** and **9**.

Calculation of these values also allows the determination of a possible am combination which would have these root values. For ρ, ϵ (epsilon)=ϵ_0 and μ=μ_0, and

$$\rho = a\omega\sqrt{\epsilon_0\mu_0} = a\omega/c.$$

Expressed in SI units, the speed of light c=2.99792458×10^{14} m/s. If an a value of 10^{-6} m is assumed for the examples shown herein, then:

$$\omega=\rho c/a\approx 1.9919\times10^{16}-i1.9044\times10^{14} \text{ radians/s.}$$

This is an example of the angular frequency required within the impingent EM radiation in order to create a resonant situation. Examples of other resonances were indicated, and these are shown in FIG. **8**. No complex-frequency plane waves exist. Therefore, the calculations were made by considering only the real portion of the above root and setting the imaginary portion equal to zero. However, upon doing this, the iterative calculation procedure becomes insensitive to any root in the vicinity of the root's real portion. In the iterative calculation procedure, initially a range of ρ values is input into the equations. These ρ values are in the neighborhood of the prospective root. A range of ρ values is subsequently studied to find any imaginary ρ i.e., fρ (a function of ρ), peaks in that range. Next, once a peak has been chosen, the function order n giving the dominant fρ is determined. This also gives a clue as to whether the peak is due to a magnetic resonance (a_n approaches infinity) or an electrical resonance (b_n approaches infinity). A large number of Newton-Raphson iterations is preferably performed in order to converge upon a root ρ value.

FIGS. **2** and **3** show a second embodiment of the present invention generally designated by the numeral **110**. Embodiment **110** is essentially the same as embodiment **10** except that the antenna is a rf cavity structure **122** which feeds the received beat frequency radiation **124** to a waveguide **126**. Embodiment **110** also preferably includes two spheres **112** and **114** which receive the primary incident electromagnetic radiation **116** and emit the secondary electromagnetic radiation **118** and **120**. As with the spheres **18** and **20** of embodiment **10**, spheres **118** and **120** are preferably composed of a dielectric material. Embodiment **110** also includes converter **128**, capacitor **130**, transformer **132** and rectifier **134** which are essentially identical to the correspondingly numbered elements of embodiment **10**. Therefore, a description of these components of embodiment **110** will not be repeated in order to promote brevity. In addition, the same equations and method of calculation set forth above with regard to embodiment **10** also apply to embodiment. Therefore, their description will not be repeated in order to promote brevity.

FIGS. **4** and **5** show a third embodiment of the present invention generally designated by numeral **210**. Embodiment **210** is essentially identical to the first embodiment **10** except that the embodiment **210** includes a plurality of pairs **215** of receiving means (spheres) **212** and **214** mounted on a substrate **236**. The spheres **212** and **214** are thus in the form of an array **238**. The pairs **215** of the array **238** are preferably positioned proximal to each other in order to maximize the amount of energy extracted from a particular area or space of a given size. Since, as set forth hereinabove, the energy density of the zero point radiation increases as the frequency of the radiation increases, it is desirable that the spheres resonate at as high a bandwidth of frequencies as possible. Because the spheres **212** and **214** must be small in direct proportion to the wavelength of the high frequencies of the incident electromagnetic radiation **216** at which resonance is desirably obtained, the spheres **212** and **214** are preferably microscopic in size. Current lithographic techniques are capable of manufacturing such microscopically small spheres mounted on a suitable substrate thereby providing a suitably miniaturized system **210**. A miniaturized system enhances the energy output capability of the system by enabling it to resonate at higher frequencies at which there are correspondingly higher energy densities. Consequently, utilization of array **238** in the system **210** enhances the maximum amount of electrical energy provided by the system **210**.

Lithographic techniques may be more amenable to manufacturing microscopically small receiving structures **212** and **214** which may be disc shaped, semispherical or have another shape other than as shown in FIGS. **4** and **5**. Consequently, the receiving means **212** and **214** may accordingly have such alternative shapes rather than the spherical shape shown in FIGS. **4** and **5**. In addition, a large number of small spheres may be manufactured by bulk chemical reactions. Packing a volume with such spheres in close proximity could enhance the output of energy.

Embodiment **210** also includes a plurality of antennas **222** positioned preferably between the spheres **212** and **214** which receive the beat frequency radiation **224** produced by the interference between the secondary radiation **218** and **220**. The antennas **222** are shown as loop antennas **222** but may be any other suitable type of antennas as well.

Embodiment **210** has a plurality of electrical conductors **226** which preferably include traces mounted on the substrate **236** which occupies a finite volume. The electrical conductors **226** feed the electrical output from the antennas **222** to a suitable converter **228** which preferably includes tuning capacitor **230**, transformer **232** and rectifier **234**, as with embodiments **10** and **110**. Except as set forth above, the components of embodiment **210** are identical to embodiment **10** so the detailed description of these components will not be repeated in order to promote brevity. In addition, the same equations and method of calculation set forth above for embodiment **10** also apply to embodiment **210**. Therefore, the description of these equations and method of calculation will not be repeated in order to promote brevity.

Accordingly, there has been provided, in accordance with the invention, a system which converts high frequency zero point electromagnetic radiation into electrical energy effectively and efficiently and thus fully satisfies the objectives set forth above. It is to be understood that all terms used herein are descriptive rather than limiting. Although the invention has been specifically described with regard to the specific embodiments set forth herein, many alternative embodiments, modifications and variations will be apparent to those skilled in the art in light of the disclosure set forth herein. Accordingly, it is intended to include all such alternatives, embodiments, modifications and variations that fall within the spirit and scope of the invention as set forth in the claims hereinbelow.

What is claimed is:

1. A system for converting incident electromagnetic radiation energy to electrical energy, comprising:

a first means for receiving incident primary electromagnetic radiation, said means for receiving producing emitted secondary electromagnetic radiation at a first frequency, said first means for receiving having a first volumetric size selected to resonate at a frequency within the frequency spectrum of the incident primary electromagnetic radiation in order to produce the secondary electromagnetic radiation at the first frequency at an enhanced energy density;

a second means for receiving the incident primary electromagnetic radiation, said means for receiving producing emitted secondary electromagnetic radiation at a second frequency, the secondary radiation at the first frequency and the secondary radiation at the second frequency interfering to produce secondary radiation at a lower frequency than that of the incident primary radiation, said second means for receiving having a second volumetric size selected to resonate at a frequency within the frequency spectrum of the incident primary electromagnetic radiation in order to produce the emitted secondary electromagnetic radiation at the second frequency at an enhanced energy density;

an antenna for receiving the emitted secondary electromagnetic radiation at the lower frequency, said antenna providing an electrical output responsive to the secondary electromagnetic radiation received;

a converter electrically connected to said antenna for receiving electrical current output from said antenna and converting the electrical current output to electrical current having a desired voltage and waveform.

2. The system of claim **1** wherein:

said first means for receiving is composed of a dielectric material; and

said second means for receiving is composed of a dielectric material.

3. The system of claim **1** wherein:

said first means for receiving is spherical; and

said second means for receiving is spherical.

4. A system for for converting incident zero point electromagnetic radiation energy to electrical energy, comprising:

a first means for receiving incident primary zero point electromagnetic radiation, said means for receiving producing emitted secondary electromagnetic radiation at a first frequency;

a second means for receiving the incident primary zero point electromagnetic radiation, said means for receiving producing emitted secondary electromagnetic radiation at a second frequency, the secondary radiation at the first frequency and the secondary radiation at the second frequency interfering to produce secondary radiation at a beat frequency which is lower than that of the incident primary radiation;

an antenna for receiving the emitted secondary electromagnetic radiation at the lower frequency, said antenna providing an electrical output responsive to the secondary electromagnetic radiation received;

means for transmitting the emitted secondary electromagnetic radiation at the beat frequency from said antenna, said means for transmitting connected to said antenna;

a converter connected to said means for transmitting for receiving the emitted secondary electromagnetic radiation at the beat frequency from said antenna and converting the same to electrical current having a desired voltage and waveform.

5. The system of claim **4** wherein:

said first means for receiving has a first volumetric spherical size selected to resonate in response to the incident primary electromagnetic radiation in order to produce the secondary electromagnetic radiation at the first frequency at an enhanced energy density; and

said second means for receiving has a second volumetric spherical size selected to resonate in response to the incident primary electromagnetic radiation in order to produce the emitted secondary electromagnetic radiation at the second frequency at an enhanced energy density, said first and second volumetric sizes selected based on parameters of propagation constant of said first and second means for receiving, propagation constant of medium in which said first and second means for receiving are located and frequency of the incident primary electromagnetic radiation.

6. The system of claim **5** wherein the first and second volumetric sizes are selected by utilizing the formulas:

$$a_n^t = \frac{\mu_1 j_n(\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 h_n^{(1)}\rho)[\rho j_n(\rho)]'}{\mu_1 j_n(N\rho)[\rho h_n^{(1)}(\rho)]' - \mu_2 h_n^{(1)}(\rho)[N\rho j_n(N\rho)]'}$$

$$b_n^t = \frac{\mu_1 N j_n(\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 N h_n^{(1)}\rho)[\rho j_n(\rho)]'}{\mu_2 N^2 j_n(N\rho)[\rho h_n^{(1)}(\rho)]' - \mu_1 h_n^{(1)}(\rho)[N\rho j_n(N\rho)]'}$$

$$\rho = a\omega\sqrt{\epsilon_2\mu_2}$$

wherein at a resonance, the denominator of either equation for a_n^t or b_n^t will be approximately zero and wherein k_1=propagation constant of the means for receiving, k_2=propagation constant of medium through which the incident electromagnetic radiation propagates, a is the radius of either means for receiving, $N=k_1/k_2$, $\rho=k_2a$, $k_1a=N\rho$, a_n^t=magnitude of oscillations of the electric field of the nth order, b_n^t=magnitude of oscillations of the magnetic field of the nth order, ω=angular frequency of the incident electromagnetic radiation, ϵ is the permittivity of the material or medium and μ is the permeability of the material or medium.

7. The system of claim **6** wherein the radius of the first means for receiving is different from the radius of the second means for receiving, difference between the radius of said first means for receiving and the radius of said second means for receiving selected so that the beat frequency resulting from the difference is a frequency which facilitates conversion of the beat frequency electromagnetic radiation to electrical energy.

8. The system of claim **4** wherein:

said first means for receiving is composed of a dielectric material; and

said second means for receiving is composed of a dielectric material.

9. The system of claim **4** wherein:

said first means for receiving is spherical; and

said second means for receiving is spherical.

10. The system of claim **4** wherein said antenna is positioned generally between said first and second means for receiving.

11. The system of claim **4** wherein said antenna is a loop antenna.

12. The system of claim **4** wherein said antenna is a generally concave shell partially enclosing said first and second means for receiving.

13. The system of claim **4** wherein said means for transmitting is a waveguide.

14. A system for for converting incident zero point electromagnetic radiation energy to electrical energy, comprising:

a substrate;

a plurality of pairs of first means for receiving incident primary zero point electromagnetic radiation and second means for receiving incident primary zero point electromagnetic radiation, said plurality of pairs of means for receiving mounted on said substrate, said first means for receiving producing emitted secondary

electromagnetic radiation at a first frequency, said second means for receiving the incident primary zero point electromagnetic radiation producing emitted secondary electromagnetic radiation at a second frequency, the secondary radiation at the first frequency and the secondary radiation at the second frequency interfering to produce secondary radiation at a beat frequency which is lower than that of the incident primary radiation, said first means for receiving having a first volumetric size selected to resonate in response to the incident primary electromagnetic radiation in order to produce the secondary electromagnetic radiation at the first frequency at an enhanced energy density, and said second means for receiving having a second volumetric size selected to resonate in response to the incident primary electromagnetic radiation in order to produce the emitted secondary electromagnetic radiation at the second frequency at an enhanced energy density, said first and second volumetric sizes selected based on parameters of propagation constant of said first and second means for receiving, propagation constant of medium in which said first and second means for receiving are located and frequency of the incident primary electromagnetic radiation, said first and second volumetric sizes being different from each other;

a plurality of antennas for receiving the emitted secondary electromagnetic radiation at the lower frequency, said antenna providing an output responsive to the secondary electromagnetic radiation received, said plurality of antennas mounted on said substrate, each of said plurality of antennas receiving the emitted secondary electromagnetic radiation of one of said pairs of first and second means for receiving;

means for transmitting the emitted secondary electromagnetic radiation at the beat frequency from said antenna, said means for transmitting connected to said plurality of antennas;

a converter connected to said means for transmitting for receiving the emitted secondary electromagnetic radiation at the beat frequency from said antenna and converting the same to electrical current having a desired voltage and waveform.

* * * * *

"The machines I made out there did the work", Mr Perrigo said, "but they were bulky and bunglesome and got out of order easily.

"Other things than getting rid of bulk bothered me, too. My early machines were affected by passing air currents. Power would increase when I fanned the machine or when a person walked past it, and decrease when the atmosphere was calm.

"The machine I have now gives a steady flow of current, whether in the basement, 14,000 feet in the air, in a motor car or on a fast moving train. The copper pegs in the wooden block do that."

The Completed Machine ~

The Perrigo consists of only four parts: two lead plates, a wooden block and a coil of copper wire. The coil that Mr Perrigo says will deliver 500 horsepower is 10 inches across, 4 inches high, of solid copper. Fine copper wire is wound smoothly about neat rows of copper stays, hardly larger than a toothpick, but longer, as long as the coil is high. The wire is connected in many devious ways. In those connections is the secret of the mysterious power.

The lead plates for this size Perrigo are a foot square. On each plate are 100 spring coils of copper wire, spaced in rows, an inch apart. The plates appear identical, but are different in the way the connections of hair-like copper wire run from one coil to another.

The wooden block is a foot square, also, and an inch thick. One hundred copper plugs run through the block, spaced just as the coils on the lead plates are spaced. Each plug is a bundle of copper stays, making a contact.

That is all there is to the Perrigo, so far as anyone can see. Complete, the 500 horsepower size weighs 87 and one-half pounds. There are no moving parts.

A Perrigo to operate an ordinary size motor car need be no larger than a 1-pound coffee can", Mr Perrigo said. "A size to provide all the current needed to heat and light a 5-room house will go into the can. The different sizes can be made to furnish any desired voltage, and either direct or alternating current, by a slight change in the wiring."

The Inventor Explains It ~

Trying to avoid technical terms, difficult business for an engineer, Mr Perrigo explained his invention this way:

"The device is a generator as truly as the power-driven rotary generator in any power plant. Those generators don't actually 'make' electricity. They condense it from the air. So does the Perrigo. But it does it through the system of wiring, rather than revolutions through a magnetic field. I get my starting point from the air by breaking up the ether waves. The coils on the lead plates do that. I know why they do. It's the way they are connected, one from the other. That's my secret.

"They do break up the ether waves, gathering electricity and conducting it into the big coil underneath. That's the generator. Its size and the way it is wired determines the voltage, the horsepower. Outgoing wires from this coil take the 'juice' where you want it and it is there when you want it."

Mr Perrigo has great plans for his electric 'chore boy' and great faith in it.

"It will replace every other source of power, light and heat", he predicts. "It means the doom of the steam engine, the end to coal mining, to the cutting of timber for fuel. It means petroleum will be used only for lubrication. It means smokeless, sootless cities. It means chimneys will disappear from housetops. It means cheap power for the farmer, the reclamation of much country that cannot be irrigated now because power is not available."

What Other Persons Think ~

Mr Perrigo is able to impart his faith to others, too. The enthusiasm of persons who have seen the device work is second only to that of Mr Perrigo himself.

S.W. Fries, an electrical engineer, and district sales manager here for the Economy Fuse and Manufacturing Company, saw the Perrigo first about three months ago.

"When I heard about the machine through Dr McDowell, I told him it couldn't be done", Mr Fries said the other day. "I've been converted. I don't know how it works, but it does. Its possibilities are too big to grasp. Its use will mean a new age in industry. I believe Mr Perrigo will be the most widely known inventor in the world as soon as his device comes into general use, and he will become one of the world's most wealthy men, just from returns which already seem assured."

"Mr Perrigo gets enough electricity from somewhere to knock him unconscious", Dr O.W. Butler (3700 Benton Blvd) pointed out. "I've been called to his house many times in the last four years to revive him, and once I carried him out of his basement. He has worked at his experiments as long as four days and nights without sleep --- worked until his health is broken and his constitution is a bundle of jagged nerves."

"How are you going to manufacture your machine and get it on the market?" Mr Perrigo was asked when he asserted there was no stock for sale and he was seeking no financial aid.

"Responsible backers are furnishing all the money I need for experiments, models for the patent office and other work I'm doing now", he answered.

"As soon as one final amendment to my patent application is approved I'll be ready to permit motor car manufacturers to make the Perrigo in their own plants, charging them a small royalty on each machine. They will be eager for it when they see what it is. This will provide funds enough in a short time for my associates and myself to being to manufacture the machines for home use.

"We don't expect to sell the Perrigo. We will lease them on the same plan the telephone companies use for their machines, charging a monthly rent, probably about $3 for a 5-room cottage size. That's cheap enough, isn't it, for all heat and light and power?

"I've always said I never would sell out to any big corporation. My invention is for the benefit of the poor amn. Even on that basis I'll get more money out of it than I can ever use."

The Householder's Point of View ~

Mr Perrigo explained that it will not be necessary for the householder who desires the Perrigo installed to buy an expensive electric furnace, electric range or any special equipment.

"A gas range can be wired through the pipes which now carry gas", he said. "It will be necessary only to replace the gas burners with electric heating plates and install snap switches where the gas valves are now. A furnace can be fitted in the same way, by removing the grate. No change will be necessary with the lights. The new machine will be installed where the meter is now. That's all."

"When one man has a machine, won't it be possible for his neighbors to come in, see how it works, and manufacture their own?" Mr Perrigo was asked.

"No", he answered, "Each one will be sealed, just as the electric meter is sealed. To break the seal will put it out of order and the subscriber will have to call for a 'trouble' man. Anyway, if a man would take one apart he couldn't put it back together again without my drawings and blueprints. That's my secret and I'll keep it."

A Demonstration ~

When a visitor expressed a desire to see a machine actually produce light or power or heat, Mr Perrigo acquiesced. He went to the basement and returned almost immediately, bearing a boxlike affair, mounted on a little platform. A small electric motor, light sockets and switches were on the platform. The top of the box was glass. Through it Mr Perrigo pointed out parts of the machine inside.

Mr Perrigo fastened the loose ends of two wires that extended from the box to the connection posts of the motor and pushed a switch button. The motor started at once. The inventor said he had not changed the machine or even opened the box, which was closed with screws since he made it five years ago.

Kansas City Star (March 27, 1922) ~

"Can't Use His Invention"

Patent Laws Prevent Demonstration, H.E. Perrigo Tells Inquirer ~

Miami, OK --- To *The Star*: "In your paper of January 15 there appeared a wonderful story relating to the invention of Harry E. Perrigo, an electrical engineer of Kansas City, of a device to generate electrical energy.

"One got the impression from reading the story that Mr Perrigo's device was a demonstrated success, that it had been patented, and that he was practically ready to permit its manufacture as a source of power.

"It was a whale of a story and interested me, for it seemed if it were true that his device was destined to have as far-reaching influence on the human race in the future as the grain binder and the gas engine had had in the past.

"I wrote to various publications devoted to mechanics and electricity, seeking further information. None knew anything about it. One said no such device had been patented, another that a vast amount of research and experimentation had been done in an effort to develop such

a device and that the only result had been failure.

"I would like to know if Mr Perrigo's device has been patented and if he is prepared at the present time to demonstrate it in a convincing way."

The story of Mr Perrigo's invention was printed in the Star as the record of an ambitious and interesting enterprise. The apparent success of the device was vouched for by persons who had seen the machine in operation and were convinced it produced the results Mr Perrigo claimed for it.

Questioned recently as to new developments, Mr Perrigo said there could be no new mechanical developments.

"The machine has been developed to a state as near perfect as I can make it, for two years", he said. "I am waiting for the patent office to take final action. My applications have been approved and investigation has shown no conflicting patents on record. The rest is simply a matter of routine work in the patent office. As soon as the final patents are granted I'll be ready to manufacture the Perrigo.

"I can't give a demonstration without going to considerable trouble to set the machine up. Of can't keep it set up, nor even use it in my home, because technically that would amount to 'commercial use' and would interfere with the granting of patent rights."

---

(1) Harry E. Perrigo, the inventor of a "free energy" device which he believes will revolutionize all industry ~

HARRY E PERRIGO, THE INVENTOR OF A "FREE ENERGY" DEVICE WHICH HE BELIEVES WILL REVOLUTIONIZE ALL INDUSTRY

(2) Here, Perrigo says, is his secret: the 100 little spring coils of copper wire break up the aether waves and conduct the electricity they gather into the big generating coil. There are two of these plates, identical in appearance but different in wiring.

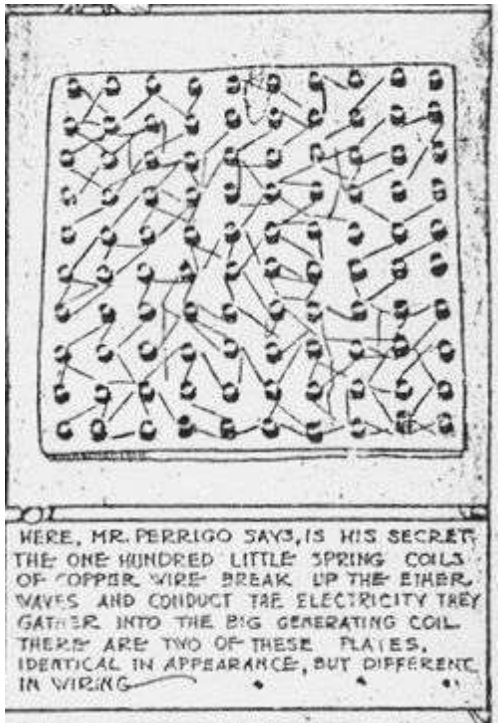

(3) The 100 little bundles of copper stays form the plugs driven through the wooden block are soldered over the ends, making them appear smooth.

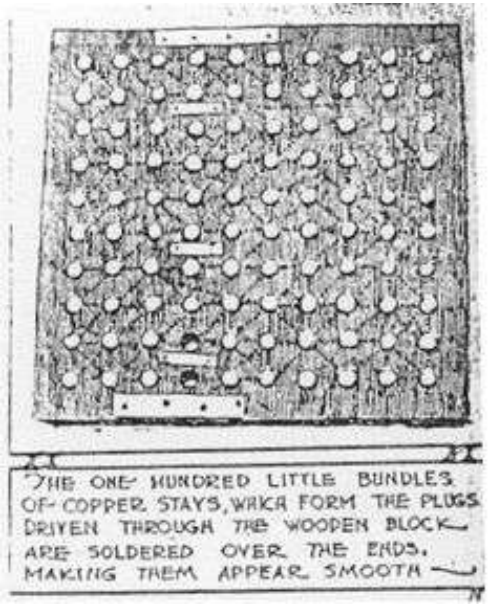

(4) Mr. Perrigo's first machine, as he remembers it, was a crude device made from two embroidery hoops, a table leaf, bread box and other materials picked up around the house.

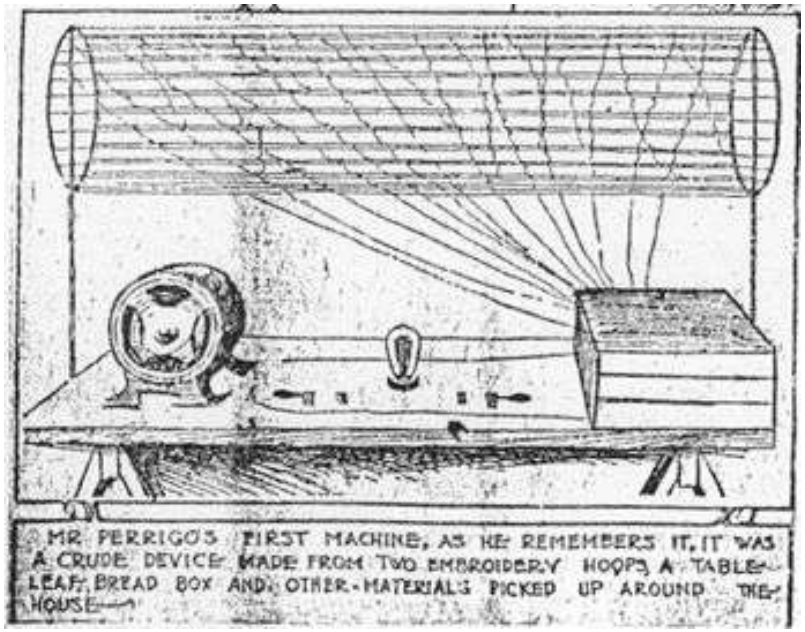

(5) The top of the big coil, showing the ends of the copper stays and the windings of wire. The space separating the two parts of the coil are the "field gap", Mr. Perrigo says.

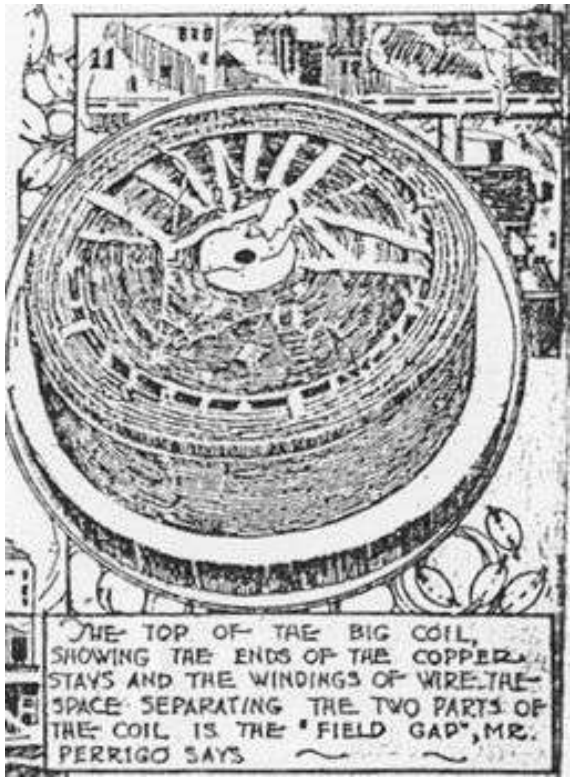

(6) At left, a closeup of one of the 100 plugs in the wooden block.

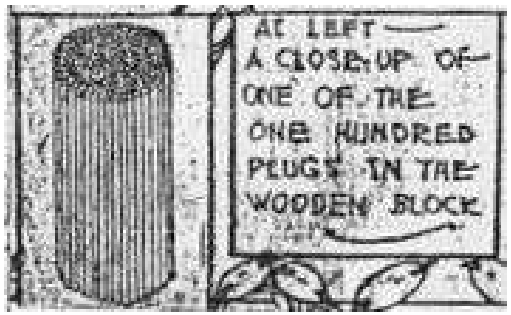

(7) The complete Perrigo, without its wooden case. The drawing was made from a machine Mr. Perrigo made by hand which, he says, has developed more than 500 horsepower. The commercial machine will be an exact copy of this.

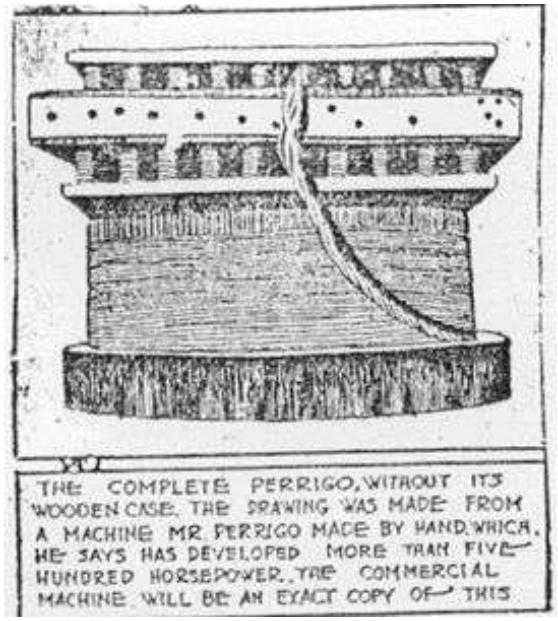

(8) This is the machine the writer saw in operation. It was built by Mr. Perrigo 5 years ago for demonstration in Washington, when the inventor successfully opposed a war measure which would have prevented for a period of 17 years the granting of his patents on any "free energy" device. The operation of this machine, on the speaker's table in the lower House, is recorded in the ***Congressional Record*, December 15, 1917, pages 369-383.** [Actually, pp. 357-372]

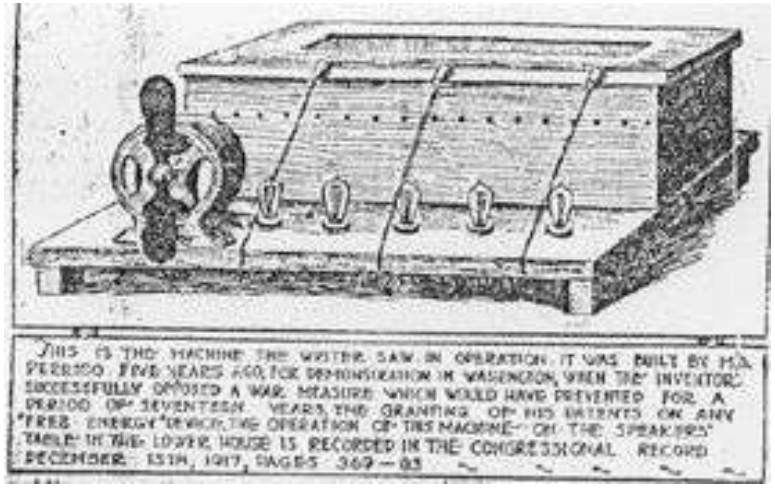

Kansas City Journal (August 7, 1927), page 1 ~

"Power Drawn From Air Propels Auto Over K.C. Streets"

Inventor Claims Tiny Motor Will Drive Plane Around World, Doing Away With Transportation of Fuel

A motor car was driven 40 miles an hour in Kansas City yesterday on power drawn from the air.

A device making this feat possible was demontrated after years of rebuffs and failures by its inventors, Harry Perrigo, 1116 Bennington Avenue, in the presence of Col, Paul Henderson, Chicago, vice president of the National Air Transport Inc., air mail contractors.

"It is the greatest invention since the stone age", was Col. Henderson's comment.

Lou E. Holland, president of the Chamber of Commerce, who saw the demonstration with Col. Henderson, was enthusiastic over the invention and said he believed it would have a great effect on public utilities if it can ever be brought into general use.

Coils Gather Power ~

The device consists of a plate 14 inches square which, by a multiple arrangement of connected copper coils, it was explained, attracts electric current from the air.

The electricity thus trapped passes through a generator and to a regular direct current motor, which was connected to the transmission shaft of the car.

Mr Perrigo has been working on the device more than 10 years. Three years ago he suffered a nervous breakdown and has been back at his workshop only two months.

While photographers focused their cameras, Mr Perrigo and his wife entered his roadster in which the device was installed. He turned a switch and the motor hummed.

The inventor sat silent, listening. Then he threw in the clutch gently. The car moved away with only the sound of the cogs, whining softly as they meshed. He threw it into high and sped away.

At the corner of 10th Street and Bennington Avenue, near his home, he stopped the machine while movie cameramen ground their machines. Then he backed it and turned around, stopping in the middle of the street.

Later Mr Perrigo took the car out for a spin. It breezed along at 40 miles an hour.

"100 Just As Easy" ~

"I could make it go 100 miles an hour just as easily", the inventor remarked, "if it were not for the danger of hurting someone."

The total weight of the motor, generator and controls is about 86 pounds, according to the inventor. In the rear of the car are reduction coils, because the device is five times too powerful for the work of pulling the car, Mr Perrigo said.

The proper motor for a Reo car will not weigh more than 30 pounds", he said. "The motor to run a Chevrolet will weigh not more than 10 pounds. An airplane motor would weigh around 50 pounds, and with that motor the air traveler could go around the world without waiting."

Col. Henderson walked around the machine, inspecting it.

"What it would mean to my airplanes", he said, "--- no weight for motors, no space for gas, no motor trouble."

Like other spectators, he had difficulty in believing what he saw.

The work of bringing the invention to its present state of development has been the story of a lone man working with the unknown, usually meeting with discouragement.

Congress Wouldn't Believe ~

Five years ago, the inventor took one of his electric motors to Washington, set the boxlike contrivance on the speaker's stand in Congress and ran a motor and five lights with it. They called it an infernal machine.

Even now, when he is seeking patents for his invention, the patent office refuses to believe the principles he advances are possible.

"The machine has been taken up in an airplane 10,000 feet and it operated the same as if it were on the ground", Mr Perrigo said. "It has been tried out in hot places and cold places."

He pictures it as power for every purpose --- the farm, the factory, the office, doing away with coal, gas, cost of water power and the cumbersome weight of engines.

The models of the machine now are being kept in bank vaults.

Mr Holland is convinced, after two weeks investigation, that the invention is genuine.

Kansas City Journal (August 8, 1927), p. 3 ~

"Perrigo Dreams Of Aiding Humanity With Ether Wave Machine"

Inventor Declares Generator, When Patented, Shall Not Be "Hogged" or "Shelved", But World Will Reap Benefits Of Cheap Power.

Homes lighted and meals cooked for a cost of $5 per month; motor cars operating with a quart of lubricating oil about once every six months and a little grease in the rear axles and yet damaging no existing corporations by the working of these revolutions.

These are the dreams of H.E. Perrigo, 1116 Bennington Avenue, inventor of the Perrigo ether wave generator.

Lou E. Holland, president of the Chamber of Commerce and Col. Paul Henderson, general manager of the National Air Transport, Inc., are convinced his invention is practical.

Mr Holland, Mr Henderson and newspaper men Saturday witnessed a demonstration in which Mr Perrigo drove a motor car on electric power generated from the air.

"It is too early yet to talk to manufacturing the invention", Mr Holland said yesterday. "The patent rights must be perfected in both the United States and foreign countries. Also, it must be made clear that nothing will be done to demoralize present power manufacturing."

Mr Perrigo's invention is the result of more than 12 years labor on the part of the inventor.

"Twelve years ago I conceived the idea that the generation of power from ether waves was possible, while I was employed ion the power plant at Pee Dee, NC, where some wires not connected with anything that was 'live' seemed to be generating power", Mr Perrigo said yesterday.

"After more than a year of experimenting I finally produced light in a bulb about the size of those used in flash lights. Now in my laboratory I light three 300 watt globes from a wire no larger than the thread which holds the button on a man's overcoat.

"Three times in my experiments I was knocked unconscious because I did not know how much power it would generate.

"The invention has been tested under all conditions. It has been strapped to the running board of a locomotive running between Kansas City and Chicago, it has been tested in an airplane at a height of 12,000 feet. It will generate power anywhere that air circulates.

"With the invention every home will have its own power plant and all the electricity needed for any purpose can be provided at a roughly estimated cost of $5 per month.

"The Kansas City Public Service company, for instance, could afford to install these plants because they would eliminate the enormous overhead which is the principal expense of such companies."

Both Mr Perrigo and Mr Holland made it plain that the invention will not be permitted to upset the electrical world. No one will be given exclusive rights of its use, they said.

"Any person or any manufacturer can use the invention who will pay the royalty fees", Mr Perrigo explained. "No one will be permitted to 'hog' the invention and no one can purchase it and shelve it.

"I have no doubt that it will bring me more money than Mrs Perrigo and I will need to supply our simple wants and I want humanity to benefit.

"I want to see rural sections which have remained barren because it cost too much to pump the water to irrigate them, spring into bloom. I want to see the smallest farm house in the most isolated places with its electric lights and stoves; in other words, I want humanity to benefit."

"How about the gasoline industry if motor cars are to be run without fuel?" he was asked.

"The supply of petroleum is limited", he answered. "There are 30 other purposes to which petroleum products can be turned, so the oil producers will not suffer."

"Can you explain your invention so that the non-technically trained can understand it?"

"That would be difficult, especially without divulging information that is now in the patent office; besides, the generation of power always is difficult to explain.

"Electric generators have been used in power plants for a great many years. We all know what you have to do to make a generator and we all know that electricity is its product but we don't know very much about what really is going on inside that generator."

While the patents for his device still are pending, Mr Perrigo is keeping his working models in the vault of a downtown bank to prevent the possibility of their being copied.

Kansas City Star (August 7, 1927) ~

"Electricity Power from Air?"

An invention that will revolutionize radically all power producing and power using machinery of the entire world, if in practical use it equals the miracle of its demonstration, was given a showing here yesterday to newspaper men and Lou E. Holland, president of the Chamber of Commerce.

It is a device to collect electrical energy from the ether and convert it into a powerful current of electricity of a type dissimilar in many ways from the direct or alternating current now known to electricians.

So far as could be determined even by the most skeptical of those witnessing the demonstration yesterday, the device is exactly what Harry E. Perrigo, the inventor, asserts it to be -- a method for collecting natural electricity from the ether, in unlimited quantity and without cost.

More Power Than Needed ~

One feature of the demonstration was the operation of a motorcar by power from a small model of the invention. The engine had been removed from the car and an electric motor substituted. The device supplied power in such quantity that it had to be reduced and yet propelled the car with speed and ease.

A detailed examination of the car showed the absence of any possible form of power except the inventor’s small device and it is of such an open type that one may see clear through the mass of wires and coils.

Other demonstrations were given with other models of the device, with the machine and electric lights and motors held in the hands of spectators, yet the device produced current to do any electrical task assigned to it.

Col. Paul E. Henderson, general manager of the National Air Transport, Inc., was there with Mr Holland, being his guest for the day. He took an active part in the testing and enthusiastically was declaiming the invention as revolutionary.

Cheap As Similar Motor ~

To operate a motor car would require a model weighing about 20 pounds, Mr Perrigo computes, but he has given no thought the probable cost of building it. However, he estimates the cost at no more than an electric motor of the same size.

A device of the size of a coffee can would light and heat an average home, he declares, cutting off forever all fuel and lighting bills.

And one can go on and dream of an electrified world with free power for all industries and operations, increased yields of foods from dry areas that cold be irrigated with this free energy, the passing of wood and coal and oil as fuels.

At first thought, not one of the persons seeing yesterday's demonstration could give much credence to the inventor's declaration that his invention was a way to obtain unlimited electrical power from the ether without any cost.

There was not a doubter left as to the success of the demonstration, but the witnesses could not in any sense qualify as electrical engineers.

Electricity Always In Ether ~

As near as a layman can understand, Mr Perrigo's theory is the revolution of the earth sets up a form of electric currents that are forever present in the ether. His theory is to capture those electrical impulses in very much to same way that a radio antenna picks up the programs broadcast from WDAF. Instead of a machine to turn the radio impulses into music, Mr Perrigo has a machine to turn the ether's electrical store into controlled power. He declares it is really no more mysterious than the fact that an electric dynamo picks electricity out of the air, although the dynamo must have a power to revolve it while his device sits perfectly still and seemingly produces many fold more electricity than a dynamo of the same bulk.

Demonstrating the different nature of this electricity, Mr Perrigo showed how high voltage could be transmitted over hair-size wires and light a series of electric lamps although a sufficient power of the well known electricity to light those lamps would have melted the small wires immediately.

Clearer Light Than Usual ~

And it imparted an unusual glow to the electric lamps, giving them a clear brilliancy with none of the effervescent haze that surrounds the wires in a lamp when lighted with ordinary electricity.

Mr Perrigo has spent years on his invention. Years ago he conceived the idea that there was an unlimited source of electricity in the air that could be harnessed with a collector. He has not reached the present measure of success without a row of hard knocks along the way.

In whatever neighborhood he has lived since moving here 15 years ago, it has been common knowledge that Mr Perrigo was the frequent victim of electric shocks that often came near proving fatal. He has been revived by pulmotors time and again.

The first model of his device was constructed with makeshift material. A leaf from Mrs Perrigo's dining room table was the basis, with the bread box used, sheets torn up and the strips shellacked to be used for insulation. But as junky as it was, it operated a small motor, and that original model is still preserved and used a s part of his demonstration.

Sickness Delayed His Work ~

In 1922 he got the device to such a point of perfection that he went before Congress and defeated a war-time measure that proposed to give 17-year rights to another person for a blanket patent on all free energy devices.

Then three years of sickness came, and the invention progressed slowly. Mrs Perrigo is not electrically inclined, but she has carried forward the experiments under his direction and has always been his assistant.

Mr Perrigo is not offering stock for sale and says he has made all necessary arrangements for financing the device when it is ready for manufacture.

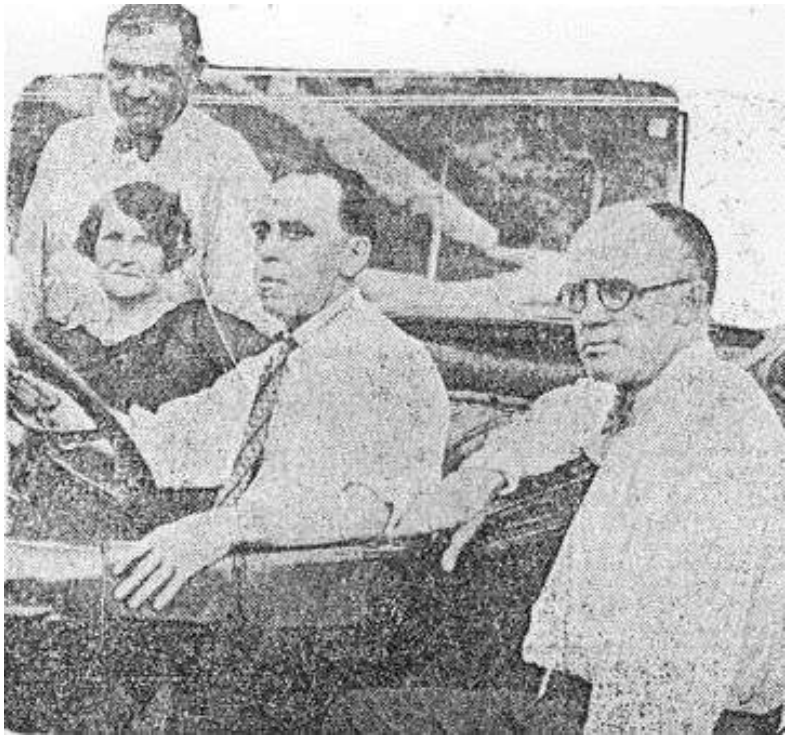

Photo Caption: In a semi-public demonstration here yesterday of an invention said by its inventor to be able to collect electricity from the ether, in unlimited quantity and without cost, a motor car was propelled with perfect success, then an examination of the car allowed to show the absence of engine, storage battery or other usual form of power. The upper photograph shows under the motorcar hood, engine missing and an electric motor in its place. The equipment above the motor is a series of resistance coils, the collection device used being too powerful for the motor. The middle photograph shows the collector placed on the floor by the driver, a makeshift arrangement for the test. Below is Mr Perrigo, with his wife, seated in the test car. Lou E. Holland, president of the Chamber of Commerce, is standing on the near side of the car. Col. Paul E. Henderson, general manager of the National Air Transport, Inc., stands on the other side. They were among those attending the demonstration.

Kansas City Times (August 8, 1927) ~

"Electricity from the Air"

H.E. Perrigo, a nervous, red-haired little electrician, stood last nigh among a confused display of strange devices in is basement workshop at 1116 Bennington Avenue. He was still a bit haggard from an illness of three years, but is energy, dynamic as that which his devices "pick out of the air", was unabated. Mr. Perrigo had just returned from a conference with Lou E. Holland, president of the Chamber of Commerce.

"There are no batteries in this room", he said. "There are no light and power wires. There is nothing but these unconnected accumulators you see before you."

On an old kitchen chair stood an object about one and one-half feet square, several inches thick. It appeared to consist of two parallel metal squares, separated and held together by numerous pegs woven around which was a maze of thin copper wires. It stood on edge, resting against the back of a chair. On the seat of the chair was a round metallic object, resembling, at a glance, a huge spring, a foot and a half in diameter, from an alarm clock. In a mechanical sense it was in no way similar. But it might as well have been an alarm clock spring, for all Mr. Perrigo would tell of its construction. The first object was the collector, the second the generator.

No Moving Parts, No Wheels ~

Neither had any moving parts. They have no wheels. They are immobile, simply an arrangement of wires. On the to edge of the flat box was a switch. Thence ran two wires, connected with forty-five 100-watt standard electric light bulbs.

Mr. Perrigo pulled the switch. There was no arc as the contact was made. The 45 bulbs flashed brightly and burned with a steady white glow. There was never a flicker. He turned 44 lights off, leaving one. It did not flicker as the 44 lights went off and on.

"This little device, the Perrigo Electric Accumulator", said Mr. Perrigo, will light 8,000 bulbs as easily as it lights one. I can build one of any size, to produce the results that any amount of dynamo electricity will produce."

He picked up a little narrow box, in the top of which was a pane of glass, through which one might see more pegs, more intricate wiring. He connected a small electric fan to the poles, and the fan whizzed.

Tests Everywhere But Under The Sea ~

"There are skeptics yet", he said. "Some think I am picking up leaking electricity. This free energy device has been tested at an altitude of 12,000 feet, on the sea, on deserts, everywhere except in a submarine. Everywhere it runs smoothly, without fluctuation".

In his Reo roadster he had a large motor mounted, the one he demonstrated Saturday to Lou E. Holland, president of the Chamber of Commerce, and Col. Paul E. Henderson, general manager of the National Air Transport, Inc. Mr. Perrigo crawled into the seat, threw a switch, and a big all-speed motor, standing in the place of the gasoline engine, roared.

"Rheostat control", said Mr. Perrigo. "It will run at all speeds. I do not need clutches".

There were two "mystery boxes" in the car, one of which picked the electricity out of the ether, the inventor explained, another which regulated its intensity.

"It will be on the market in the near future", Mr. Perrigo said. "I cannot say more at this time. It will be manufactured by a Kansas City company.

"We do not intend to harm the men who produce electrical current by other means. Perhaps they will manufacture and distribute the little units. The can do it gradually, so there will not be a sudden, destructive revolution. That is bad economy. There is to be no monopoly. But

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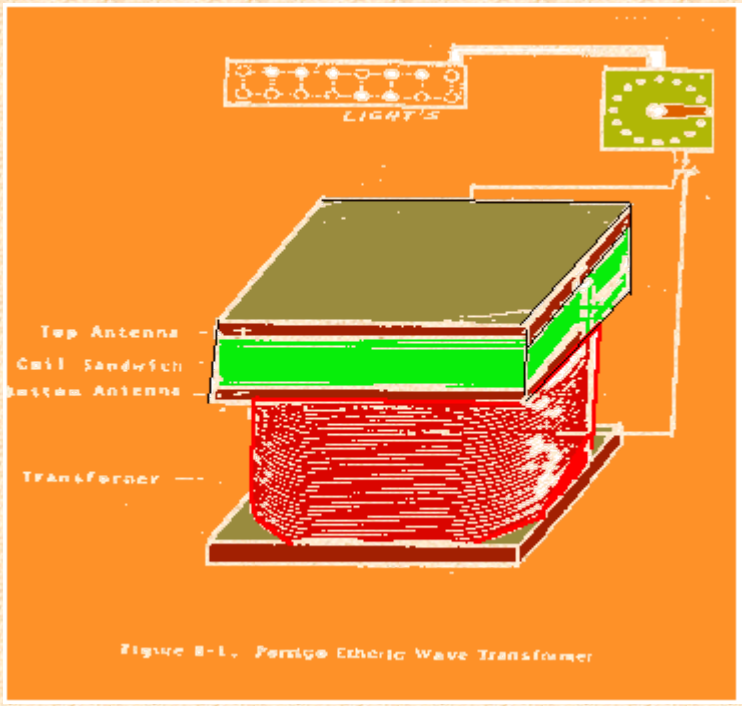

METHOD AND APPARRATUS FOR ACCUMULATING ELECTRIC ENERGY AND TRANSFORMING ETHER ELECTRIC ENERGY

Drawings by Geoff Egel ,Content Author unknown

In 1926. Harry E. Perrico claimed to have discovered a method to tap the energy from atmospherics. He even had a car which he converted to run on electricity. that was generated in his ether wave accumulator".

He applied for a patent December 31 1925 with serial number 78,715 being assigned. Perrigo's patent application Is considered a "classic" In patent law and Is listed under the classification of Perpetual Motion Machines and other Impossible Inventions.

Despite the Patent Office's attitude towards Perrico's invention, there were a number of reputable people who claimed to have witnessed his device In action producing useable electric power.

The existence of electromagnetic radiation, the modem term, or electric waves In the ether as it used to be called was known by Hertz, a research scientist who discovered the photoelectric effect

In 1887. Atmosphierics, an electrical disturbance in the atmosphere, were known to produce noises In the early radio telegraph stations, some being strong enough to drown out the received signal.

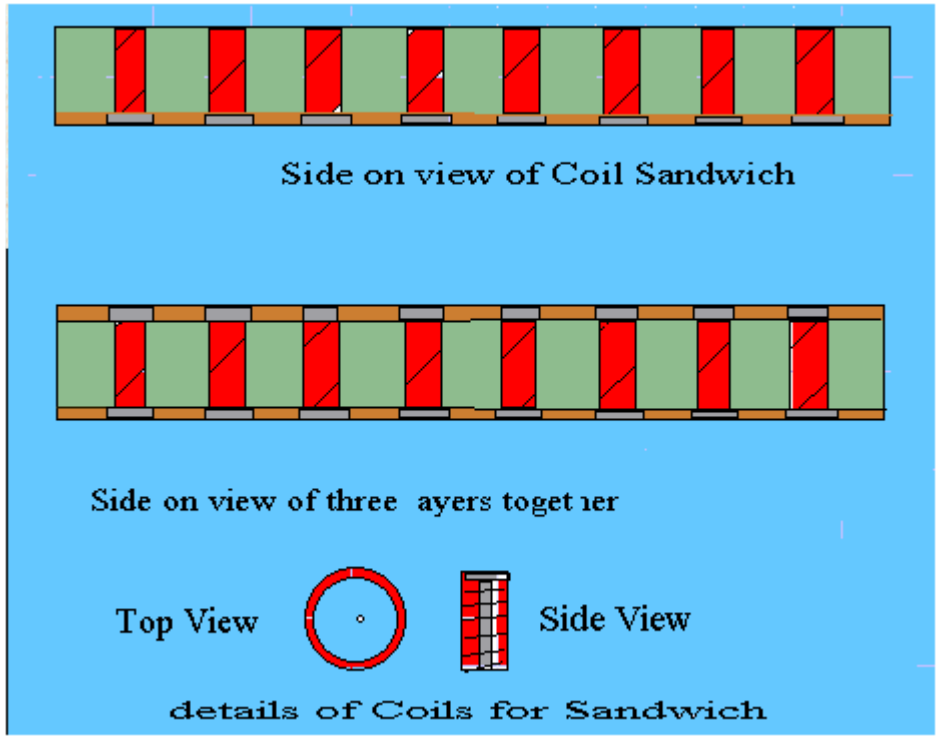

> Perrigo deduced that here was a possible source of electrical power.

All that was needed was a method of transforming the existing radiation Into useable energy. Hie claimed to have developed a mechanism to intercept and collect from the general ether field electric wave energy and to transform it into useable electromotive force.

The basic method he used was an antenna arrangement which collected and resisted the Incoming energy raising It to a high enough current level where it could be run through a special electrical transformer to further intensify the available power.

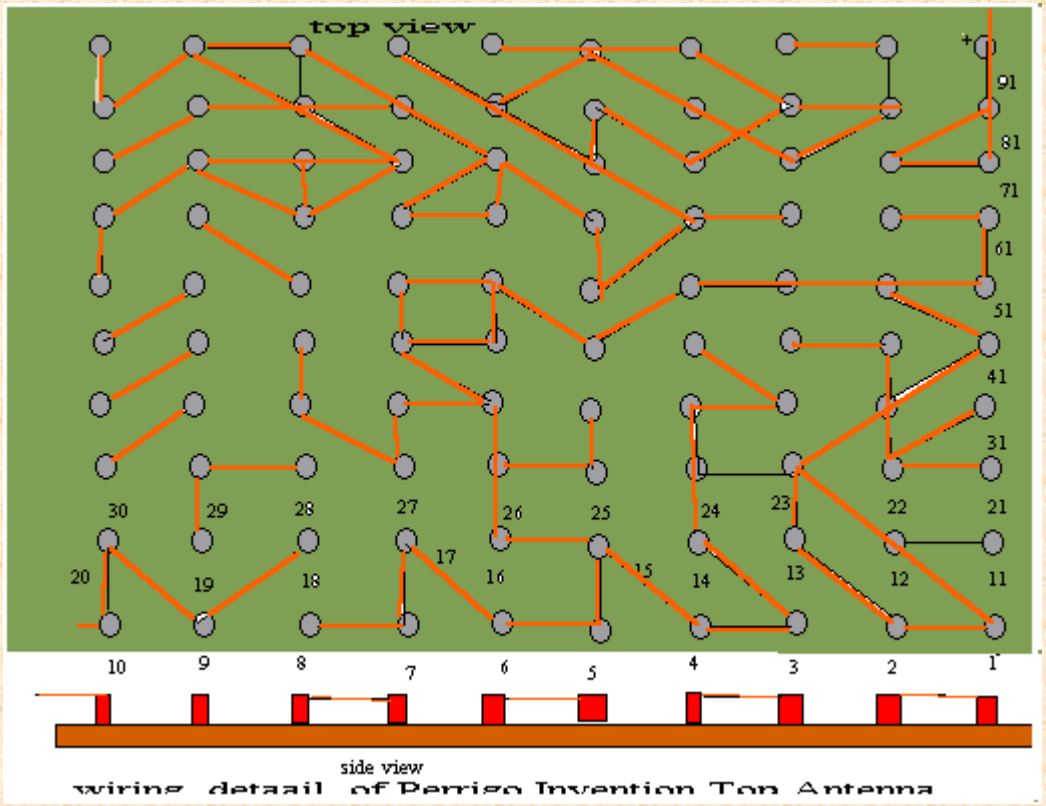

Perrigo's antenna was derived from his experiments with various wire shapes, sizes and arrangements. One of his more successful attempts was to partially pound 100 roofing nails into a board a 10 x 10 array and wrap very fine wire around each nail,making it a small electromagnet.

Then by trial and error approach he connected the ends of the electromagnets to other nails in such a way that there was a maximum voltage between the wire and the nail.. His patent application mirrored this electrical connection scheme in a more refined electromechanical approach.

Two accumulator plates were made with 100 round protruding knobs in a square 10 X 10 array

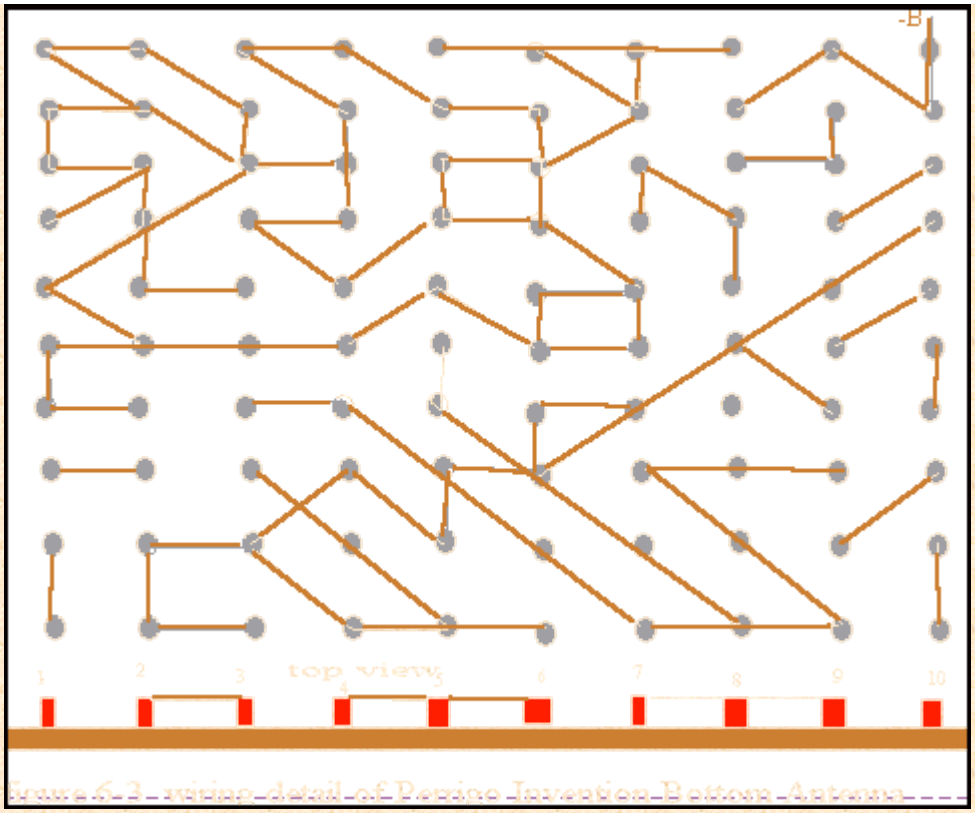

The accumulator plates were then sandwiched together with an insulator material between them. The insulator had 100 holes matching the protrusions on the plates. Placed in each hole was a special coil wrapped around a bundle of wire . Once the accumulator plates were sandwiched ,a measureable electrical voltage existed between points A and B on plates one and two respectively.

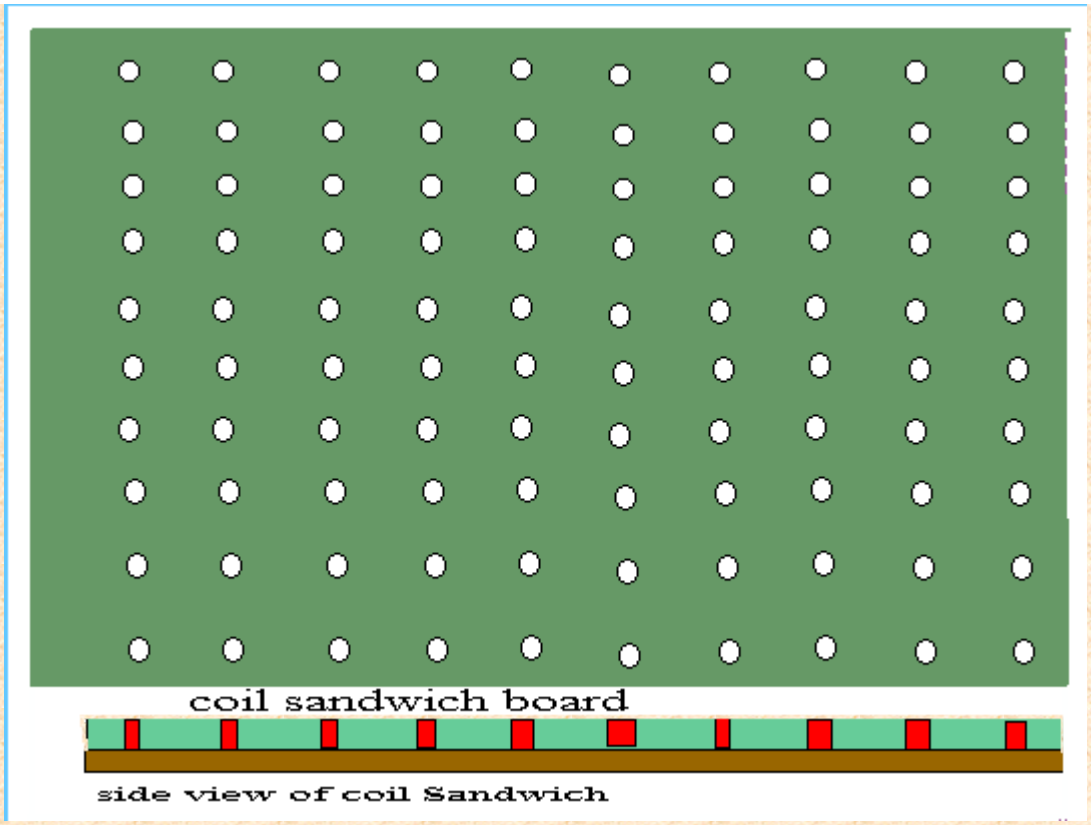

A very complicated transformer was attached to these two points.

The plates were set on top of the transformer and Perrigo claimed this arrangement enhanced the energy accumulation process.

I have no idea of what materials the plate or protrusions were made The patent drawing would lead one to believe they are the same material.

It could be a metal or a nonconductor. such as wood or a combimation. The protrusions were connected by the same wiring scheme

Previously mentioned for the roofing nail model. The connections were different for the two plates.

(See diagrams for the plates connections

egel@main.murray.net.au

Geoff Egel 18 Sturt Street, Loxton ,5333, South Australia ,Australia

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(12) **United States Patent**
Ogram

(10) **Patent No.: US 8,102,082 B2**
(45) **Date of Patent: *Jan. 24, 2012**

(54) **ATMOSPHERIC STATIC ELECTRICITY COLLECTOR**

(75) Inventor: **Mark Ellery Ogram**, Tucson, AZ (US)

(73) Assignee: **Sefe, Inc.**, Scottsdale, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 295 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/321,306**

(22) Filed: **Jan. 16, 2009**

(65) **Prior Publication Data**

US 2010/0008011 A1 Jan. 14, 2010

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/218,297, filed on Jul. 14, 2008, now Pat. No. 7,855,476.

(51) **Int. Cl.**
H02G 11/00 (2006.01)

(52) **U.S. Cl.** **307/145**; 307/149; 307/151; 361/218; 361/230

(58) **Field of Classification Search** 361/212, 361/215, 216–218, 230, 231; 307/145, 149, 307/151; 174/2; 244/30, 31
See application file for complete search history.

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Primary Examiner — Fritz M Fleming
(74) *Attorney, Agent, or Firm* — Mintz Levin Cohn Ferris Glovsky and Popeo, P.C.

(57) **ABSTRACT**

An antenna for the collection of atmospheric static electricity in which an electrically conductive hub is suspended from a balloon or blimp via a tether. The hub is either solid or uses a spoke/arm arrangement. A number of rods extend from the hub enhance the collection of atmospheric static electricity. The collected atmospheric electricity is conducted from the rods to an electrical connection where the electricity is conducted to earth via a conductive line.

16 Claims, 7 Drawing Sheets

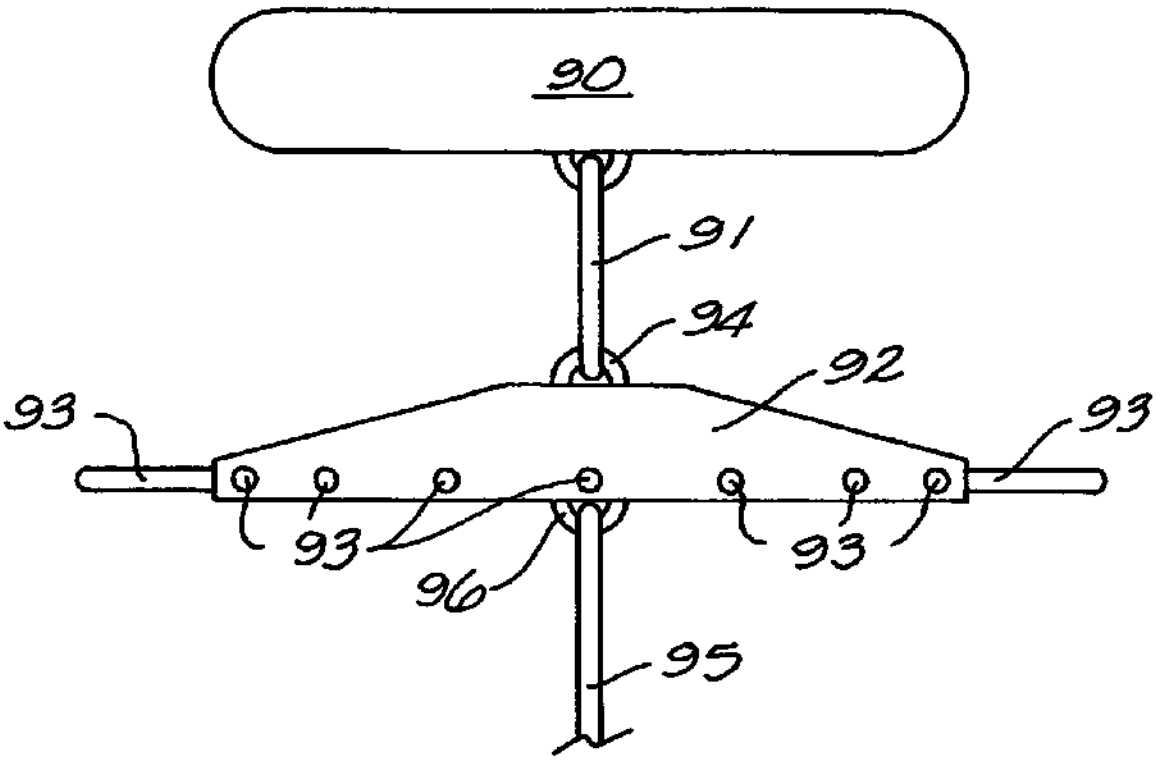

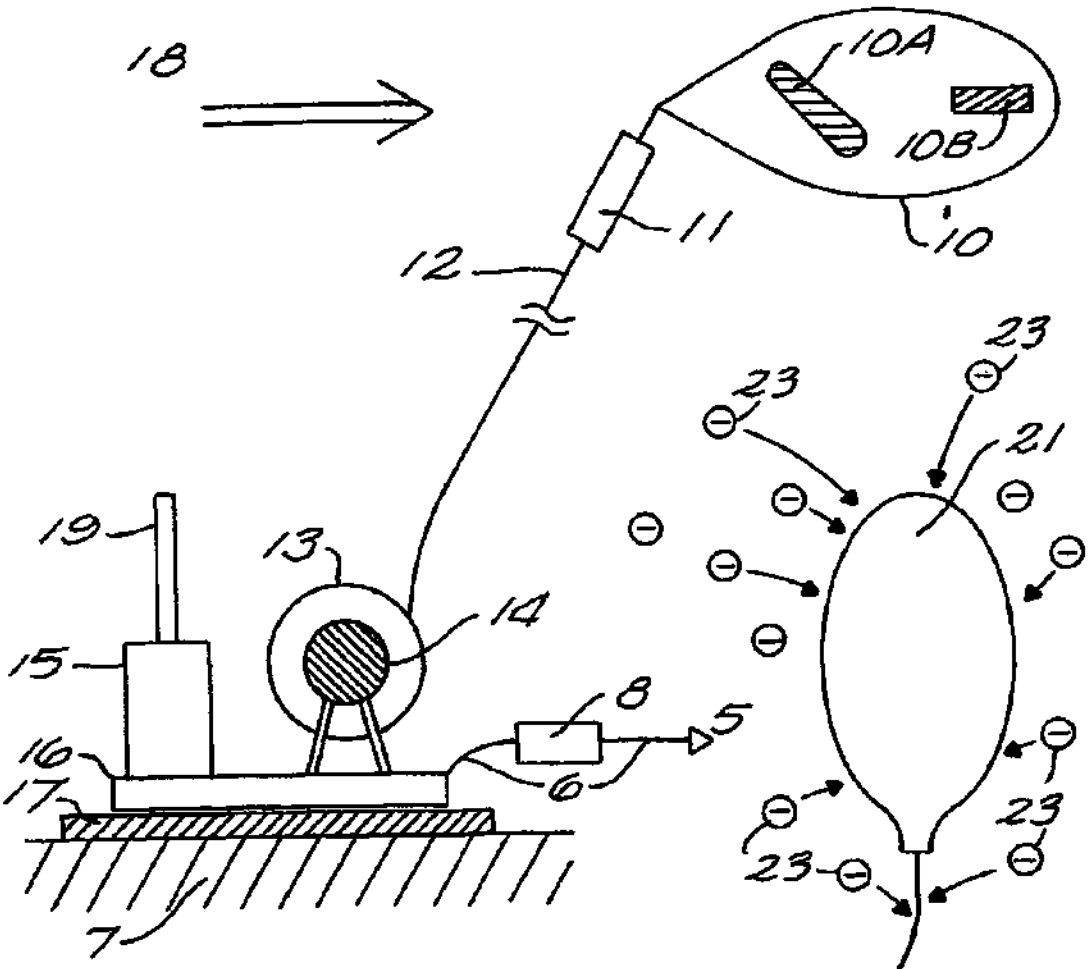

FIG. 1

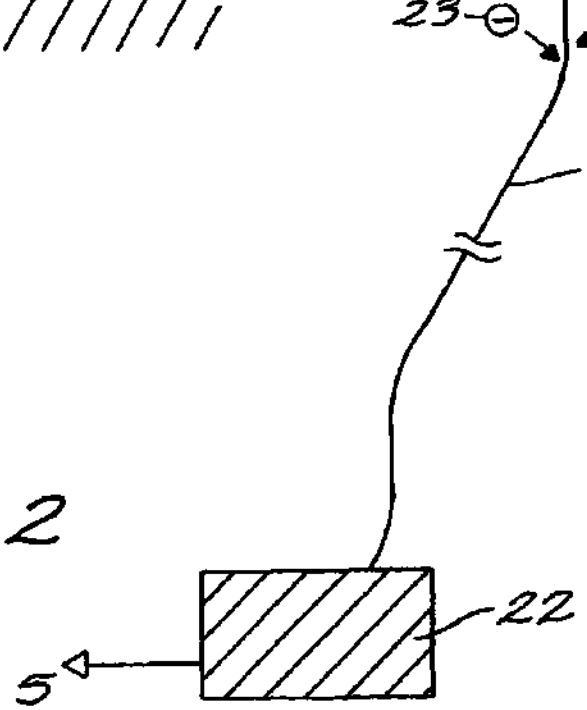

FIG. 2

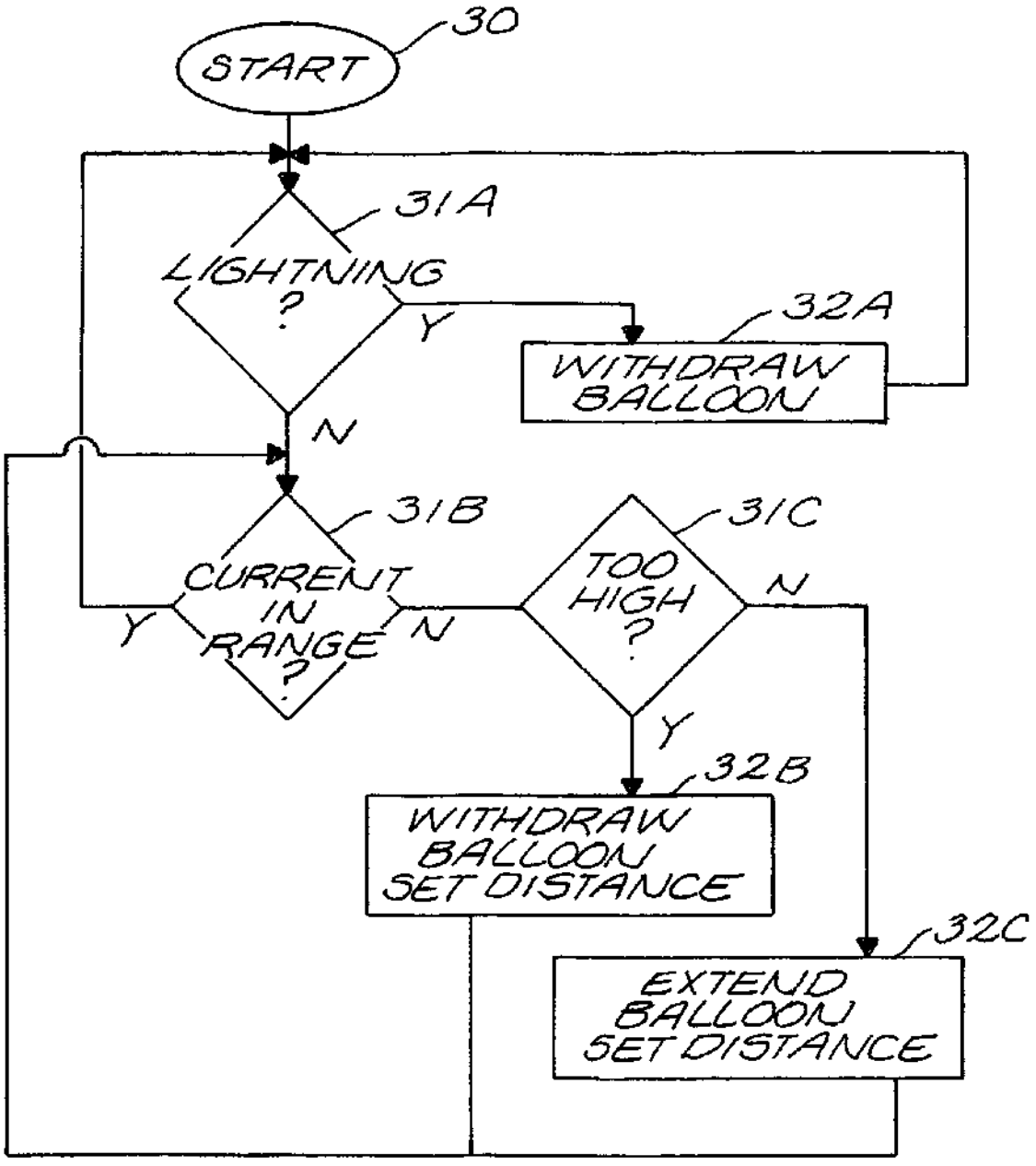
START
30
31A
LIGHTNING ?
Y
32A
WITHDRAW BALLOON
N
31B
CURRENT IN RANGE ?
Y
N
31C
TOO HIGH ?
N
Y
32B
WITHDRAW BALLOON SET DISTANCE
32C
EXTEND BALLOON SET DISTANCE

FIG. 3

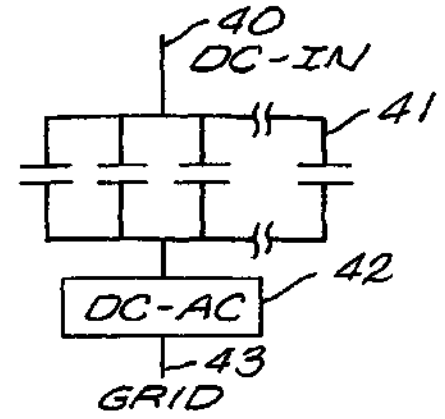

FIG. 4A

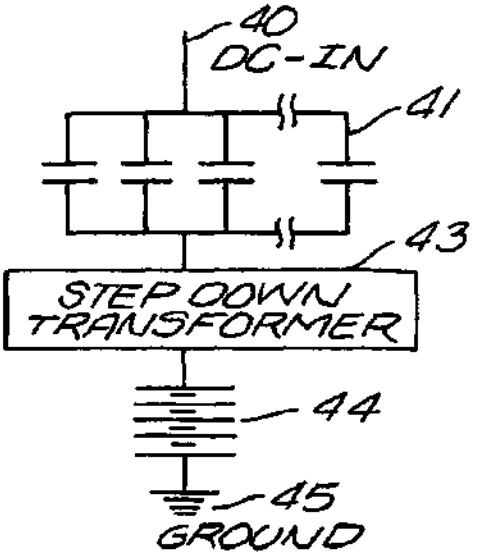

FIG. 4B

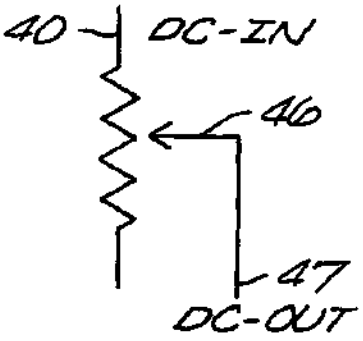

FIG. 4C

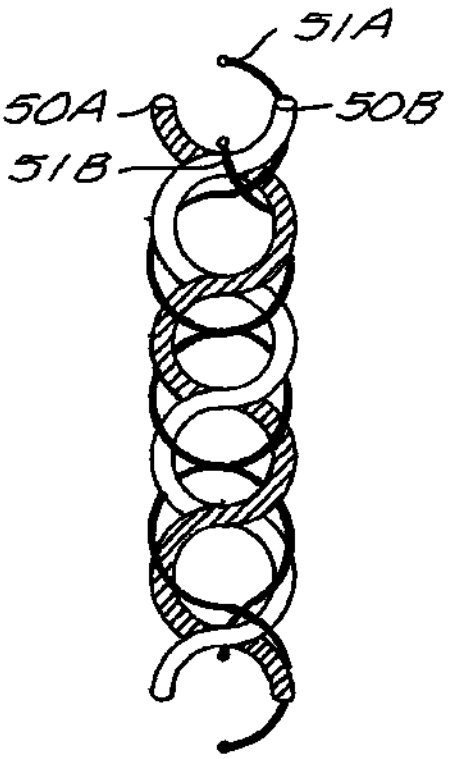

FIG. 5

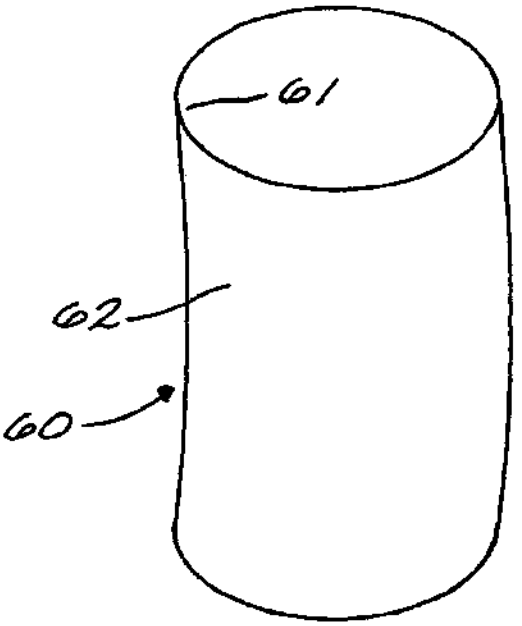

FIG. 6A

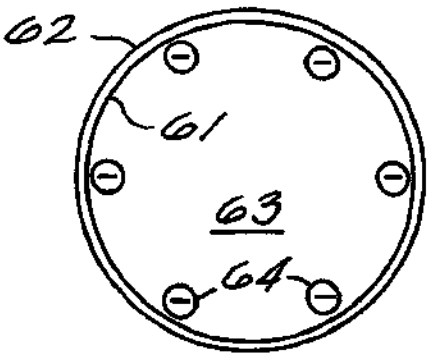

FIG. 6B

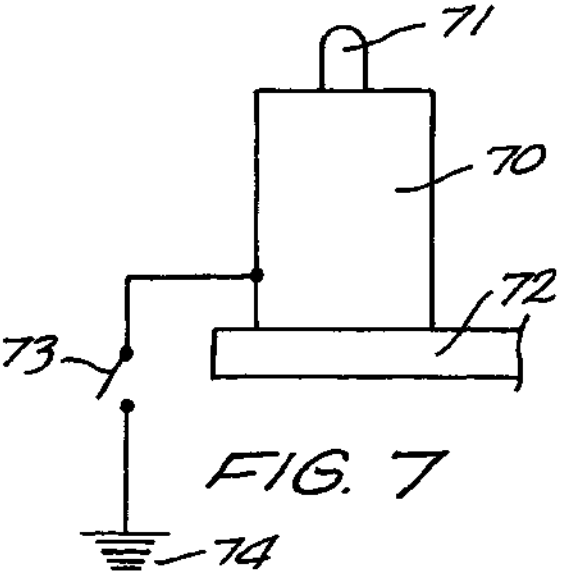

FIG. 7

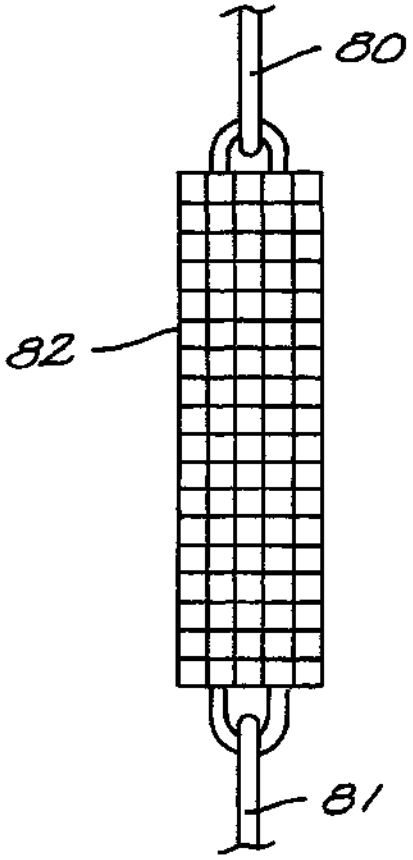

FIG. 8A

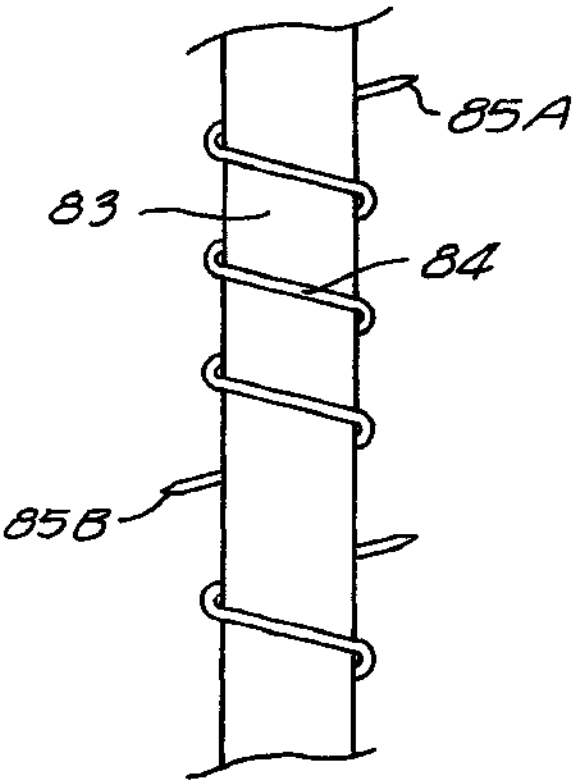

FIG. 8B

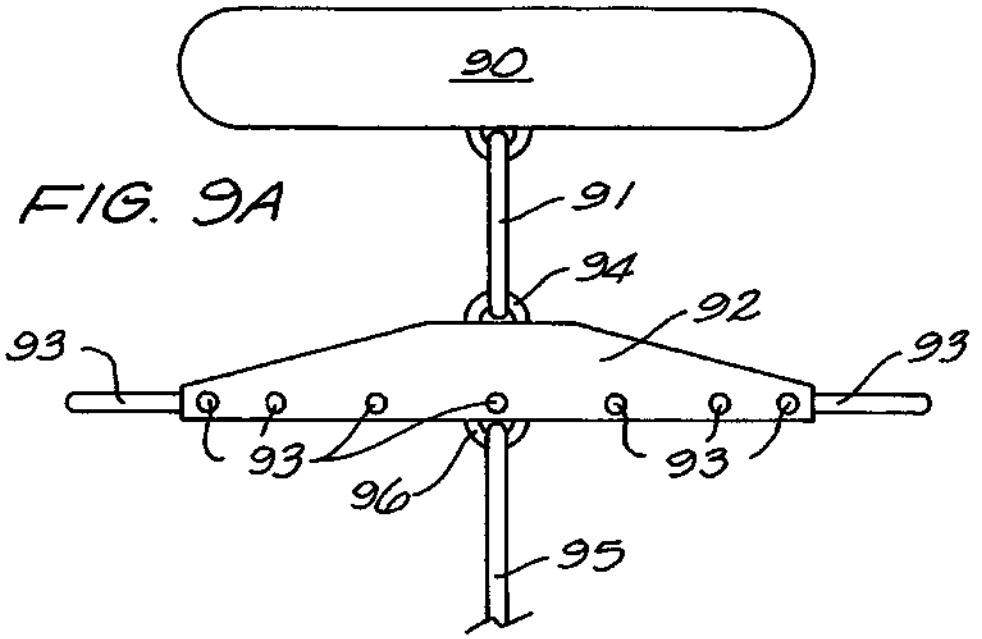

FIG. 9A

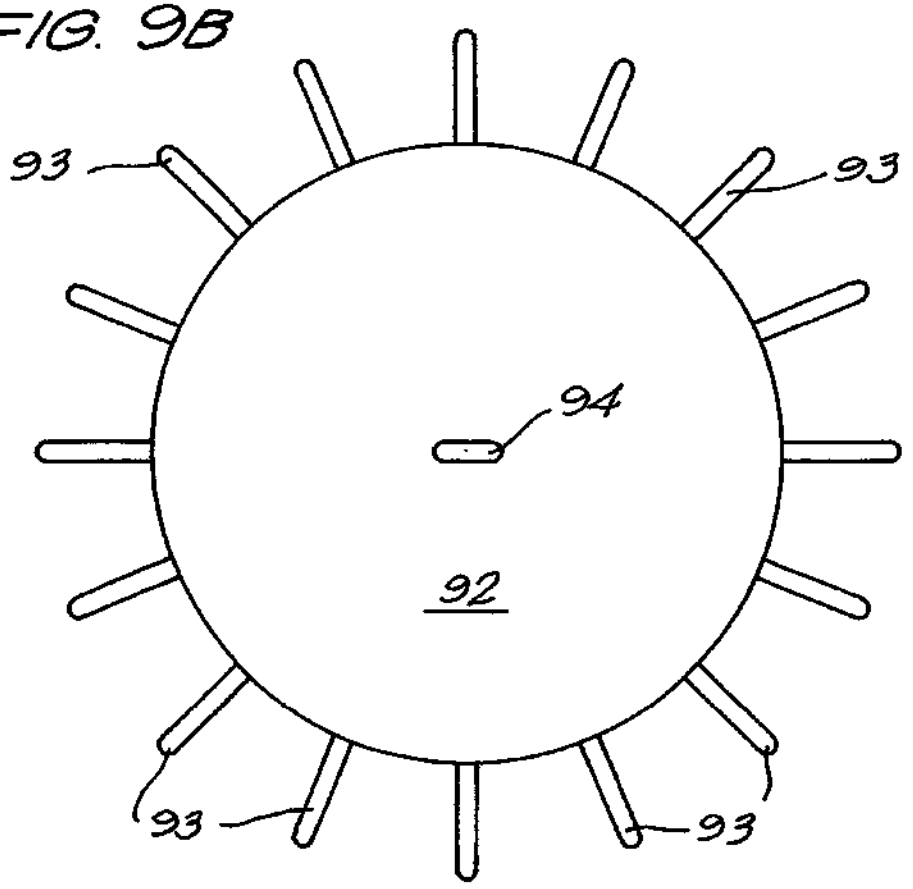

FIG. 9B

FIG. 10

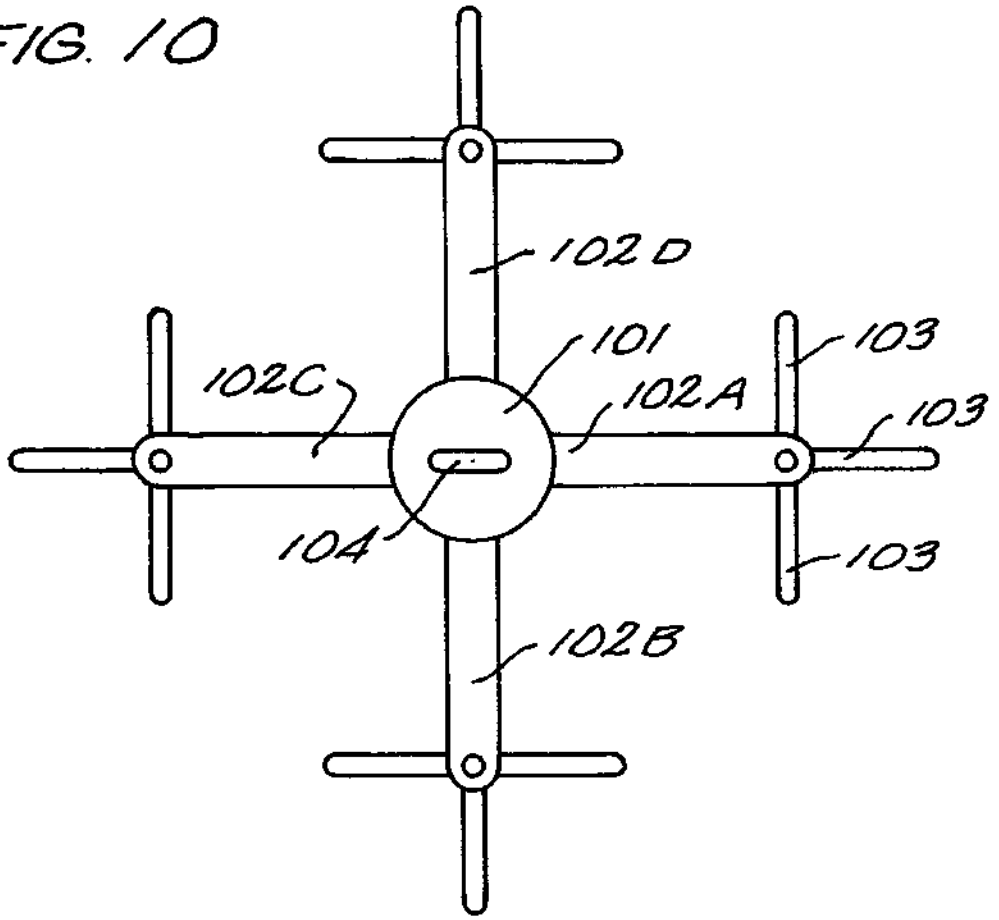

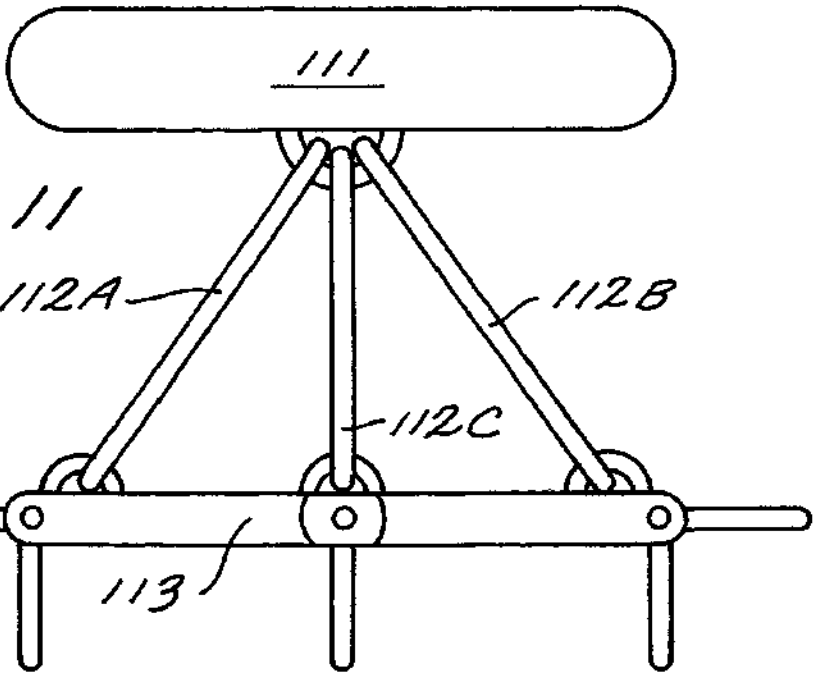

FIG. 11

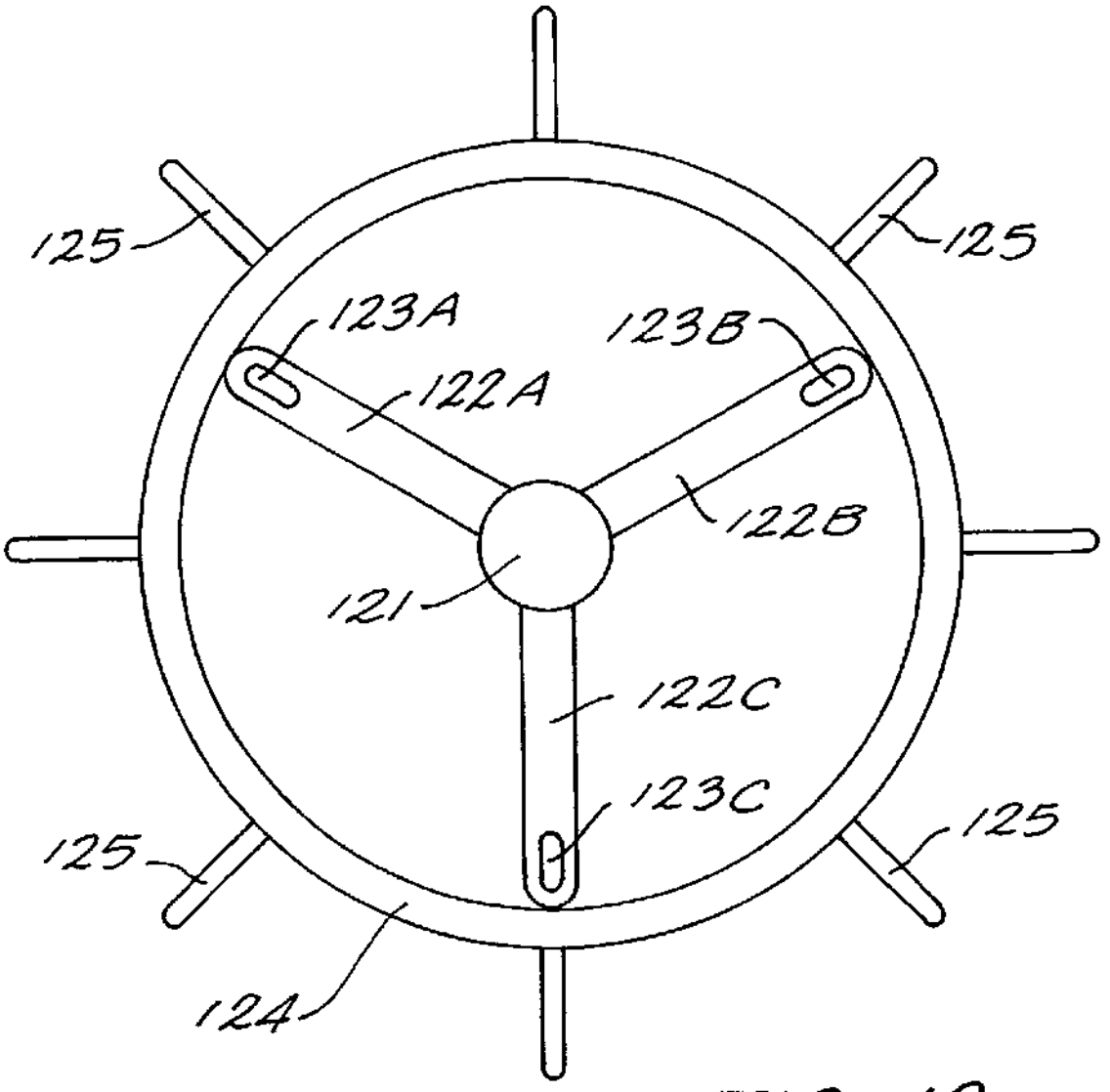

FIG. 12

ATMOSPHERIC STATIC ELECTRICITY COLLECTOR

This is a continuation in part of U.S. patent application Ser. No. 12/218,297, filed on Jul. 14, 2008, now U.S. Pat. No. 7,855,476 and entitled, "Atmospheric Electrical Generator".

BACKGROUND OF THE INVENTION

This invention relates to the production of electrical energy and more particularly to the collection of static electricity from the atmosphere.

Everyone is familiar with Benjamin Franklin's kite experiment of 1752. Using a kite whose string had become wet, negative charges from the passing clouds flowed into the string, down to the suspended key, and then into a Leyden jar via a thin metal wire. Franklin was protected by a dry silk string; but, when Franklin's knuckle came too close to the key, he received a strong shock. Fortunately, Benjamin Franklin was not killed, others who tried this same experiment were not so lucky.

Since then, the formation of lightning has remained something of a mystery. Lightning bolts are triggered when a negatively charged cloud base induces a positive charge from the ground, thereby forming a "pathway" for the discharge of the collected electrical energy.

Lightning travels up to 60,000 miles per hour with a flash that is brighter than ten million 100-watt lightbulbs. This wattage is as much power as is produced by all of the electricity plants in the United States and with a voltage of up to 300 million volts.

It is this very fact, the power within lightning is immense, that has prevented any successful collection of the electrical energy from lightning. The electricity in lightning is far too extreme for current technology to harness.

While lightning has attracted a energy starved industrial world, no one has developed any technique to harness this naturally occurring electrical source.

It is clear there is a continuing need for an electrical source other than carbon-based fuels and that the naturally occurring electricity in the atmosphere is being ignored.

SUMMARY OF THE INVENTION

The invention is a mechanism which taps into the naturally occurring static electricity in the atmosphere. Whereas heretofore, the attempt to garner electricity from the atmosphere has focused exclusively on capturing lightning, the present invention syphons off the static electricity which is generated from any agitated air and voids lightning.

Lightning is only the final discharge of the static electricity, whether that lightning is intra-cloud lightning, cloud-to-ground lightning, or inter-cloud lightning. Other types of final discharges are known as heat lightning, summer lightning, sheet lightning, ribbon lightning, silent lightning, ball lightning, bead lightning, elves, jets, and sprites. Well before these discharges are observed, as the atmosphere becomes agitated by wind or thermal, static electricity is being generated.

The present invention recognizes that this static electricity is being formed and creates a mechanism to capture it.

The mechanism of this invention utilizes an aircraft such as a lighter than air balloon. While the preferred embodiment uses a foil balloon, a variety of other aircraft are obvious to those of ordinary skill in the art, including, but not limited to: gliders, rubber balloons (such as weather balloons), biaxially-oriented polyethylene terephthalate polyester film balloons, and latex balloons.

Within this discussion, the balloon is referenced, but, the invention is not intended to be limited solely to balloons.

The balloon is sent aloft and is tethered by a conductive line. In this context, the conductive line may be any obvious to those of ordinary skill in the art. For the preferred embodiment, the conductive line is a generically referred to as a "poly-rope" and is commercially available through a variety of sources. A suitable conductive line is described in U.S. Pat. No. 5,203,542, entitled "Apparatus for Improved Electric Fence Wire Construction for use with Intensive Grazing" issued Apr. 20, 1993, to Coley, et al. and incorporated hereinto by reference.

The conductive line is played out of a winch to control the altitude of the balloon. The motor controlling the winch is able to reverse direction to both extend and withdraw the conductive line which is wrapped around a spool on the winch. The winch/spool combination are part of a base unit.

In some embodiments of the invention, the spool is constructed of rubber so as to insulate the conductive line from the winch assembly. In this embodiment, only the conductive line is charged by the atmospheric static electricity while the winch remains neutral.

In yet another embodiment, the winch/spool are part of a base unit which is itself isolated from the ground by an insulator. In this embodiment, the entire base unit is charged by the atmospheric static electricity.

A conductor, such as an insulated wire, is electrically connected to the conductive line. In one embodiment, where the conductive line is electrically isolated from the spool and winch motor, the conductor is connected to the conductive line. In the embodiment where the conductive line is electrically connected to the base unit, then the conductor is connected anywhere on a metalic base unit.

The other end of the conductor is connected to a load. The load in this case can be any of a variety of electrical loads well known to those of ordinary skill in art, including, but not limited to a motor, a battery system, or the electrical grid for the system.

In the preferred embodiment, a sensor array is used to monitor the activities both at the base unit (such as electrical flow within the conductor) and in the surrounding locale.

A sensor monitoring the electrical flow (i.e. voltage and/or current) within the conductor is used to monitor the electrical activity within the conductor.

In the preferred embodiment, a lightning sensor monitors for lightning activity within the locale. As noted earlier, the electrical characteristic of lightning is so extreme that ideally this discharge is avoided as it might damage the mechanism of this invention.

The sensor array is utilized by a controller, such as microprocessor, programmed to operate the mechanism as outlined herein.

The controller operates the winch motor to extend or withdraw the conductive line and by extension the altitude of the balloon. The controller is programmed to operate the winch by monitoring the electrical characteristics of the conductor and adjusting the balloon's altitude to maintain these characteristics within the conductor within a preset range.

This preset range is established either in the base programming of the controller or is established by an operator of the system.

As example, by controlling the amount of current being withdrawn from the atmosphere, the mechanism operates within a safe range and also provides a relatively stable current flow from which a variety of activities can take place (such as DC-AC conversion).

The controller also utilizes the lightning sensor to protect the mechanism from a lightning strike. Should lightning be detected within a pre-determined range (as established by the software or defined by an operator), then the balloon is pulled down to minimize the risk of damage from a lightning strike.

An aspect of the present invention is the use of an antenna which are used to collect the atmospheric static electricity. The antenna is shaped as a hub which is suspended from the blimp/balloon. The hub is ideally spoked shaped although an alternative embodiment uses a solid hub.

A number of rods extend from the hub so as collect atmospheric static electricity These rods are ideally rounded at the ends to enhance the attraction of the atmospheric static electricity.

The collected atmospheric electricity is conducted from the rods to an electrical connection on the hub where the electricity is conducted to a power plant on earth such as described above.

The invention, together with various embodiments thereof will be more fully explained by the following description of the accompanying drawings.

DRAWINGS IN BRIEF

FIG. **1** diagrams the preferred embodiment of the invention.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

FIG. **3** is a flow-chart of the operation of the controller for the preferred embodiment of the invention.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

FIGS. **9**A and **9**B are side views and top views of an embodiment of the antenna used to collected atmospheric electricity.

FIG. **10** is a top view of an alternative embodiment of the antenna of this invention.

FIG. **11** is a side view of yet another alternative embodiment of the antenna used to collect atmospheric electricity.

FIG. **12** is the preferred embodiment of the antenna of this invention.

DRAWINGS IN DETAIL

FIG. **1** diagrams the preferred embodiment of the invention.

Balloon **10** is an aircraft which, in this illustration, is a lighter than air balloon. Wings **10**A, extending from the body of balloon **10**, provide additional lift in air flow **18**. Tail **10**B helps to stabilize balloon **10**.

Balloon **10** is tethered to the ground via conductive line **12**. As noted earlier, a variety of configurations and materials are available to serve as conductive line **12**. In this illustration, a poly-wire is used. Poly-wire is commercially available through a variety of vendors, including, but not limited to: Jeffers Livestock and Sareba Systems, Inc. of Ellendale, Minn.

In this embodiment, located proximate to balloon **10**, is an electrical collection enhancement lead **11** which assists in the collection of the static electrical charge in the atmosphere. Electrical collection enhancement lead **11** is configured to attract the static charge and conduct the charge into the conductive line **12**.

The electricity flows down the conductive line into spool **13**, where the conductive line **12** is collected and either withdrawn or dispensed through operation of winch motor **14**.

Winch motor **14** and spool **13** are mounted onto base unit **16** which is electrically isolated from ground **7** using insulator **17**. Note, in this embodiment of the invention, when electricity is being collected from the atmosphere, the entire base unit **16** becomes charged. In another embodiment of the invention, spool **13** is constructed of rubber, thereby preventing base unit **16** from becoming charged, thereby restricting the charging from the atmosphere to only conductive line **12**.

In this embodiment, conductor **6** is connected to base unit **16** (since the entire base unit **16** is charged and the base unit is metalic) to communicate the electrical current to load **5**. Conductor **6** is ideally an insulated wire.

The electrical current through conductor **6** is measured using sensor **8**.

In the alternative embodiment discussed above, where only the conductive line **12** is charged, then conductor **6** is connected to conductive line **12**.

Controller **15**, located in this embodiment on base unit **16**, operates winch motor **14** in response to signals from sensor **8** (measuring the current being discharged to load **5**) to maintain the current flow within a pre-defined range. As the current flow diminishes, then the conductive line **12** extended from spool **13** to increase the altitude of balloon **10** to that more static charge from the atmosphere is gathered; as the current flow falls exceeds a preset level, conductive line **12** is withdrawn onto spool **13** to decrease the static charge being collected from the atmosphere.

The range of current flow through conductor **6** is ideally set by the program, although some embodiments of the invention permit an operator to establish this range of operation.

In an alternative embodiment, the sensor monitoring conductor **6** monitors the voltage therein.

In the preferred embodiment of the invention, controller **15** is also equipped with a lightning sensor **19**. In this embodiment, when lightning is sensed within a preset range, then substantially all of conductive line **12** is wound onto spool **13** to pull balloon **10** near the ground and protect the entire mechanism from being damaged from a lightning discharge.

In the preferred embodiment, the "safe" distance form lightning is set in the programming of controller **15** and is ideally two miles; other embodiments permit the operator to "safe" distance.

There are a variety of lightning sensors well known to those of ordinary skill in the art, including, but not limited to those described in: U.S. Pat. No. 7,016,785, entitled "Lightning Detection" issued to Makela, et al. on Mac. 21, 2006; U.S. Pat. No. 6,829,911, entitled "Lightning Detection and Prediction Alarm Device" issued to Jones, et al. on Dec. 7, 2004; U.S. Pat. No. 7,200,418, entitled "Detection of Lightning" issued to Karikuranta, et al. on Apr. 3, 2007; and U.S. Pat. No. 6,961,662, entitled "Systems and Methods for Spectral Corrected Lightning Detection" issued to Murphy on Nov. 1, 2005; all of which are incorporated hereinto by reference.

In another embodiment of the invention, controller **15** is not located on base unit **16**, rather it is remote and communicates its control signals to winch motor **14** using radio waves.

FIG. **2** illustrates the collection of the negative charged particles in the atmosphere.

Static charges **23** are generated in the atmosphere by agitated air. These static charges are often collected at the bottom of clouds, but exist in other environments as well.

Balloon **21** is extended into this strata of static charges **23** which are then attracted to conductive line **12** to flow to base unit **22** and then onto load **5**.

By increasing or decreasing the altitude of balloon **21** (defined by the length of the extended conductive line **12**), conductive line **12** is selectively exposed to varying densities and levels of the static charge strata, and by extension, the current flow or voltage is increased or decreased.

FIG. **3** is a flowchart of the operation of the controller for the preferred embodiment of the invention.

Once the program starts **30**, the lightning sensor is checked to determine if lightning has occurred within the unsafe range **31**A, if it has, then the balloon is lowered **32**A, and the program continues monitoring the status of lightning until no lightning is detected.

When the lightning status is acceptable, then the current within the conductor is checked to see if the current is within the prescribed range **31**B. If the current is acceptable (within range) the program returns to check the lightning status **31**A; otherwise a determination is made to see if the current is above the prescribed range **31**C.

If the current is above the prescribed range, then the altitude of the balloon is withdrawn a set amount **32**B (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

If the current is below the prescribed range, then the altitude of the balloon is extended a set amount **32**C (ideally twenty-five feet) and the program loops back to see if the current is within range **31**B.

In this manner of feed-back and minor adjustments in the altitude of the balloon, the current is maintained within a prescribed range which can be handled by the downstream electrical system.

As noted earlier, some embodiments of the invention monitor the voltage instead of the current.

FIGS. **4**A, **4**B, and **4**C are electrical schematics for handling the static charge from the atmosphere.

By maintaining the voltage being collected in a prescribed range, an electrical conversion system is easily designed. While FIGS. **4**A, **4**B, and **4**C illustrate some electrical configurations, those of ordinary skill in the art readily recognize a variety of other configurations which will serve the same function.

Referencing FIG. **4**A, Direct Current In (DC IN) **40** is buffered by a gang of capacitors **41** before being communicated to a DC/AC converter **42**. The DC/AC converter converts the direct current into a an alternating current suitable for placement over an existing electrical grid **43** such as normally found from a power-plant.

Those of ordinary skill in the art readily recognize a variety of DC/AC converters, including, but not limited to: U.S. Pat. No. 7,394,671, entitled "Controller IC, DC-AC Conversion Apparatus, and parallel running system of DC-AC Conversion Apparatuses" issued to Fukumoto, et al. on Jul. 1, 2008; and, U.S. Pat. No. 7,330,366, entitled "DC-AC Converter" issued to Lee, et al. on Feb. 12, 2008; all of which are incorporated hereinto by reference.

FIG. **4**B illustrates an electrical arrangement suitable for use in charging a battery. DC IN **40** is buffered by capacitor bank **41** before entering into a step down transformer **43**. Step down transformer **43** reduces the voltage so that the voltage can safely be introduced into battery **44** which is connected to ground **45** at the battery's other pole.

Those of ordinary skill in the art readily recognize a variety of batteries which will work in this capacity, including, but not limited to those described in: U.S. Pat. No. 7,378,181, entitled "Electric Storage Battery Construction and Manufacture" issued to Skinlo on May 27, 2008; U.S. Pat. No. 7,388,350, entitled "Battery with Electronic Compartment" issued to Wright on Jun. 17, 2008; U.S. Pat. No. 7,397,220, entitled "Connection Member and Battery Pack" issued to Uchida, et al. on Jul. 8, 2008; and, U.S. Pat. No. 7,375,492, entitled "Inductively Charged Battery Pack" issued to Calhoon, et al. on May 20, 2008; all of which are incorporated hereinto by reference.

In FIG. **4**C, DC IN **40** is fed into an adjustable rheostat **46** which is controlled by the controller so that the DC OUT **47** falls within a specified range.

FIG. **5** illustrates a conductive line used in the preferred embodiment of the invention.

This type of conductive line is commonly called poly-wire and consists of multiple interwoven strands of plastic **50**A and **50**B woven into a cord or rope arrangement having intertwined therein exposed metal wires **51**A and **51**B. While this illustration shows two plastic strands and two metal wires, any number of possible combinations is possible.

The exposed metal wires **51**A and **51**B attract the atmospheric static charge and transmit the charge down to the base unit (not shown).

FIGS. **6**A and **6**B illustrate an alternative conductive line creating an ionized pathway for the flow of the static charges from the atmosphere.

This conductive line utilizes a tube **60** having an outer layer **62** of PET Film (Biaxially-oriented polyethylene terephtalate polyester film) which provides exceptionally high tensile strength and is chemically and dimensionally stable. The tube has an ideal diameter of between two and three inches.

An interior metal coating **61** provides an initial conduit for the flow of static charge. The static charge through the metal forces the tube to expand due to the repulsion experienced by like charges. Further, the flow of electricity causes the interior of the tube **60** to become ionized to provide an additional pathway for the atmospheric static charges to the base unit (not shown).

Because outer layer **62** provides a gas barrier, the resulting ionization is not dissipated by air currents, thereby providing a highly stable pathway.

FIG. **7** illustrates the controller of an alternative embodiment and the associated safety devices.

In this embodiment, controller box **70**, resting on insulating pad **72**, is in communication with the sensors as described above. Using the input from these sensors, when there is flow of electricity through the base unit, warning flashing light **71** is illuminated. To electrically neutralize the mechanism, switch **73** is activated to pass any existing current into the ground **74**.

FIGS. **8**A and **8**B illustrate two embodiments of enhanced electrical collection leads.

Referencing FIG. **8**A, enhanced electrical collection lead **82** is a wire mesh which is in electrical communication with conductive line **81** and balloon **80**. Because of the significant amount of metal exposed by enhanced electrical collection lead **82**, more static electricity from the atmosphere is drawn to the collection lead **82**, and then down conductive line **81** to the base unit (not shown).

Conductive lead **82** is positioned proximate to balloon **80**.

In FIG. **8**B, poly-wire **83** has enhanced electrical collection leads **84** wrapped therearound. Collection leads **84** have

pointed ends **85**A and **85**B which have a propensity to attract more electricity than rounded ends do.

FIGS. **9**A and **9**B are side views and top views of an embodiment of the antenna used to collected atmospheric electricity.

Blimp **90** supports antenna **92** via tether **91** which is attached to antenna **92** by connection **94**. In this embodiment, antenna **92** is made of electrically conductive material and is ideally light in weight to lessen the payload requirements on blimp **90**.

Encircling antenna **92** and extending therefrom are rods **93** which are rounded at their distal ends so as to enhance attraction of the atmospheric static electricity. The static electricity is communicated to connection **96** and then to electrical line **95** which communicates the electricity to the ground based station (not shown) as described above.

FIG. **10** is a top view of an alternative embodiment of the antenna of this invention.

In this embodiment of the antenna a central hub **101** has the blimp connection **104** (capable of receiving the tether to the blimp) secured thereto. In this illustration, four arms **102**A, **102**B, **102**C, and **102**D extend from hub **101**. Hub **101**, and arms **102**A, **102**B, **102**C, and **102**D are all electrically conductive in this embodiment.

At the end of each arm are rods **103** which are used to enhance the collection of the atmospheric static electricity.

Although this embodiment illustrates four arms, the invention is not intended to be limited to four arms, rather, any number of arms may be used and the number of rods extending from the distal ends of the arms also varies.

FIG. **11** is a side view of yet another alternative embodiment of the antenna used to collect atmospheric electricity.

In this embodiment, several tethers **112**A, **112**B, and **112**C, are used to secure the antenna **113** to the blimp **111**. This arrangement of several tethers provides heightened stability of the antenna by reducing the affects wind will have on the antenna.

FIG. **12** is the preferred embodiment of the antenna of this invention.

In this embodiment of the antenna, arms **122**A, **122**B, and **122**C extend from a central hum and are electrically connected to rim **124**. Tether connectors **123**A, **123**B, and **123**C, are used to secure the antenna to the blimp or balloon.

Rods **125** extend from rim **124** to increase the collection of the static charges in the atmosphere.

It is clear from the foregoing that the present invention captures an entirely new source of electrical energy.

What is claimed is:

1. A system for collection of atmospheric static electricity comprising:

a balloon;

a hub that is electrically conductive and connected to the balloon by a tether, the hub having:

at least three electrically conductive arms, a first end of each of said conductive arms electrically connected to said hub; and

a plurality of rods, a first end of each of said rods being electrically connected to a second end of at least one of said at least three arms;

a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said hub, a portion of said conductive line and said hub collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;

a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and

a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

2. The system according to claim **1**, wherein each of said plurality of rods has a rounded second end.

3. The system according to claim **2**, wherein at least two rods are attached to the second end of each of said at least three arms.

4. The system according to claim **1**, further comprising an electrically conductive rim connected to a second end of said electrically conductive arms.

5. The system according to claim **4**, wherein at least a portion of said plurality of electrically conductive arms are connected substantially at right angles to an exterior of said electrically conductive rim.

6. A system for collection of atmospheric static electricity comprising:

a radial arrangement of at least three electrically conductive arms;

a plurality of rods, each of said rods being electrically connected to at least one of said at least three arms; and

a balloon tether connected between a balloon and said radial arrangement of at least three electrically conductive arms;

a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said radial arrangement of at least three electrically conductive arms, a portion of said conductive line and said radial arrangement of at least three electrically conductive arms collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;

a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and

a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

7. The system according to claim **6**, wherein each of said plurality of rods has a rounded end distal from said electrically conductive arm.

8. The system according to claim **7**, further including a balloon tether connection secured to the first end of said at least three arms.

9. The system according to claim **8**, further including an electrical connection secured to the first end of said at least three arms.

10. The system according to claim **9**, wherein said at least two rods attached to said at least three arms is five rods.

11. The system according to claim **9**, further including an electrically conductive rim connected to a second end of said electrically conductive arms.

12. The system according to claim 11, wherein said plurality of arms are electrically connected to said electrically conductive rim.

13. The system according to claim 12, wherein at least a portion of said plurality of rods are connected to an exterior of said electrically conductive rim substantially at right angles thereto.

14. A system for the collection of atmospheric static electricity comprising:

a generally circular electrically conductive body;

a balloon tether connected to a first side of said generally circular electrically conductive body and to a balloon; and

an electrical connection connected to a second side of said generally circular electrically conductive body;

a base unit having a spool of conductive line on a winch motor, one end of said conductive line secured to said electrical connection, a portion of said conductive line and said generally circular electrically conductive body collecting electricity in the atmosphere, said winch motor selectively extending or withdrawing said conductive line from said spool;

a conductor having a first end electrically connected to said conductive line and a second end electrically connected to a load being powered by collected electricity from said conductive line;

an electrical flow sensor monitoring electrical flow through said conductor and generating an electrical flow indicia indicative of said electrical flow in said conductor; and

a controller receiving said electrical flow indicia and selectively operating said winch motor such that said electrical flow indicia remains within a selected operating range.

15. The system according to claim 14, wherein said generally circular electrically conductive body comprises:

an electrically conductive hub;

at least three electrically conductive arms, each of said arms connected at a first end to said hub; and

an electrically conductive rim connected to the second end of each of said at least three arms.

16. The system according to claim 15, further comprising a plurality of electrically conductive rods, a first end of each of said rods connected to said rim and extending therefrom substantially at rights angles thereto.

* * * * *

The Lakhovsky Multiple Wave Oscillator Handbook

Compiled and Edited by
Thomas J. Brown

The Lakhovsky Multiple Wave Oscillator Handbook

Comprising the
Borderland Sciences Research Foundation
Lakhovsky Multiple Wave Oscillator
&
Radio-Cellular Oscillator
Research Files

Compiled and Edited by
Thomas J. Brown
Executive Director of
Borderland Sciences Research Foundation

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in the interests of BSRF Associates by:

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DISCLAIMER

This book is a research publication of Borderland Sciences Research Foundation. It consists of our MWO and RCO files which have been put into some semblance of order to preserve the records of many people with new and different ideas on how to study the energetic states of living systems and how these systems may be influenced by externally applied energies, and also to allow for further experimentation in this field by competent researchers. Read this book thouroughly before undertaking any experiments becasue you will find many different opinions, some conflicting, as to how to proceed. High frequency electrical apparatus can cause serious shock injury and should only be handled by knowledgable, competent people. All experiments are conducted solely at your own risk. We disclaim any responsibility for the use or misuse of any information in this book. While this book touches on the subject of human health, all information should be considered as anecdotal and should not in any way be construed as medical advice. We are not qualified to give medical advice and the use of the experimental equipment and research techniques described in this book may provide a false sense of security wherein one may neglect professional medical care. Use your brains. Thanks.

Tom Brown
Editor/Publisher

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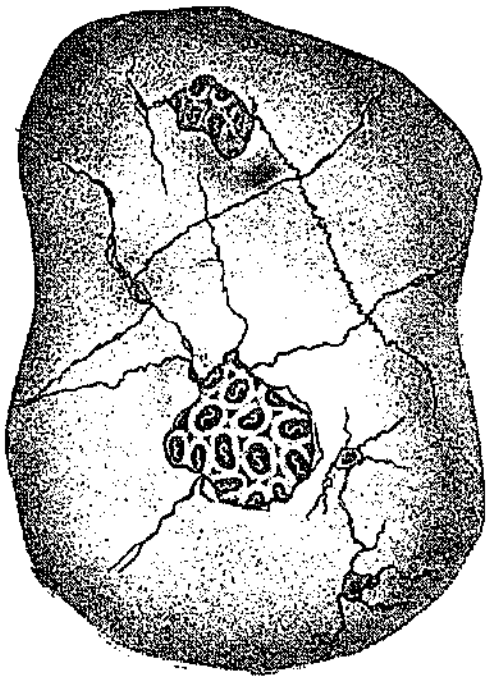

A dead cell. This diagram shows a cell where the chromosomes have stopped oscillating, and for this reason have ceased to live. But the chondromes, visible through the opening, continue to live an independent life. They are surrounded by a tough membrane and are multiplying so as to burst open the outside of the cell, as a baby chick, when it comes to maturity, breaks through the egg shell to come out.

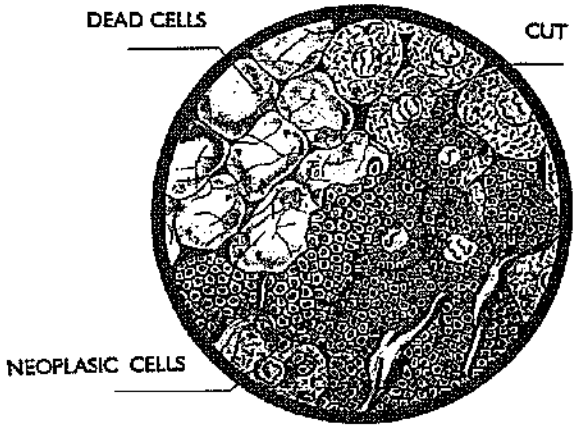

A group of dead cells, but not yet destroyed, in which the neoplasic cells are forming. One can see the transformation in the neoplasic tissue.

Photograph taken during the treatment of Mrs S..., who sits between the MWO antennas at Calvary. Behind the patient is Dr. Marquer, head physician of the hospital, to the left is Dr Z..., assistant, three voluntary Nurses, & to the right is Georges Lakhovsky.

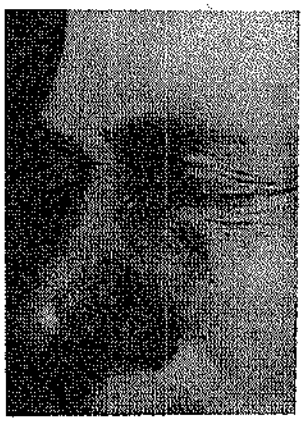

At left, Madame C... *Before Treatment.* Rodent Ulcer in inner angle of left eye.

At right, Madame C... *After Treatment.*

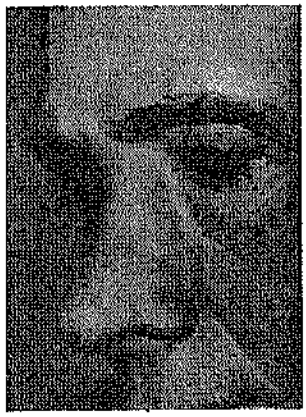

Excerpts from:

RADIATIONS AND WAVES
Source of Our Life

by Georges Lakhovsky, 1941

THEORY OF CELLULAR OSCILLATION

Before presenting the therapeutic results obtained with my multiple short wave oscillator and presented at the International Congress of Short Waves in Vienna (July, 1937) it may be useful to give a rapid survey of my theory of cellular oscillation which I have developed fully in a number of books.*

All living cells are composed of two essential elements; the nucleus and the protoplasm in which it is bathed. This nucleus is itself composed of many tubular filaments: the chromosomes. In addition, hundreds of much smaller filaments or chondromes are present in the cytoplasm.

Chromosomes and chondromes are sheathed in an insulating substance (cholesterine, resin, fat, plastrin, etc.) and contain a liquid-like serum with the same mineral content as sea water, and consequently a conductor of electricity. Thus, these filaments constitute ultramicroscopic oscillating circuits capable of oscillating electrically over a wide scale of very short wavelengths.

I have demonstrated in my works that these cellular oscillating circuits, chromosomes and chondromes, vibrate electrically under the stimulus of electro-magnetic waves: cosmic, atmospheric and telluric.

Now, many internal and external influences may upset the oscillating equilibrium of these cells. For instance, a variation or change in the field of cosmic, telluric or atmospheric waves, a demineralization of the organic matter constituting the cellular substance, traumas causing the destruction by shock of the protoplasm or the nucleus.

I have shown in my books, **The Secret of Life** and especially in **The Earth and Ourselves**, that every living cell draws its oscillatory energy from the field of secondary radiations resulting from the ionization of the geological substances of the earth by cosmic radiations.

But certain natural radiations are particularly toxic, especially those originating in geologically-induced geopathic zones. Many cancer cases have been attributed to these toxic radiations which has been proven experimentally, notably in Germany by Dr. Rambeau of Marburg. Therefore, earth radiations sometimes cause disturbance of the cellular oscillatory equilibrium of the organism.

Under these varied circumstances cellular oscillation may cease; the cell is then dead. But within the dead cell, the chondromes sometimes continue to oscillate electrically on their own natural frequencies. Fortunately, this phenomenon occurs rarely, or all humanity would already have perished from cancer.

The chondromes then envelope themselves in a membrane and continue to oscillate and multiply independently of the cell. They may then become neoplasic cells.

THE RADIO CELLULAR OSCILLATOR

To re-establish this equilibrium, I thought of creating, in 1923, a constant compensating field of very short radiations (2 to 10 metre wavelengths) to neutralize the action of the disturbing rays, and give the living cell the necessary stimulation for a return to its normal oscillation.

To this end, in 1923, I constructed my short-wave oscillator, using two triode tubes for very short waves made especially for this apparatus. I tried several cross leakages for this machine using one or more tubes and then multiple triodes with a tube containing oscillatory circuits within the bulb. Finally I adopted the oscillator with symmetrical cross leakage comprising two triodes. The oscillating circuits formed a single spiral, branched between the two grilles and the two anodes. It was fed directly by alternating current from the local supply circuit.

With this short-wave apparatus I was able to cure plants inoculated with cancer. For six years at the Saltpetriere I observed and checked the effects of these short waves.

Using very low power, from 10 to 12 watts, and a limited duration of treatment, I succeeded in curing cancer in human beings, but also had to record some failures.

The news of the success of my experiments became widespread. In many countries, as early as 1928, they began to build short-wave oscillators of considerable power producing thermal effects.

But here was great danger that the chromosomes and

---

* **The Secret of Life; Contribution to the Etiology of Cancer; The Earth and Ourselves; Cellular Oscillation; Nature and Her Wonders.**

chondromes, which are barely a ten-thousandth or twenty-thousandth of a millimeter in thickness, might not survive under a high frequency current. They offer much resistance, even to a low current which is sufficient to dissolve and destroy them.

It is simple to prove this by bringing a small bulb of from 2 to 5 volts with a filament of several hundredths of a millimeter, inserted between metal rods forming antennas, within the radius of a short wave transmitter. The bulb will light up and sometimes burn out, if it is brought too near the apparatus.

Moreover, the chondromes and chromosomes of all living cells, which are infinitely finer than the filaments of the bulbs, are sensitive centers of thermal phenomena, which may provoke their fusion. Undoubtedly this method is effective in killing microbes in the organism and in neoplasic cells. But it can also destroy millions of cells of healthy tissue in every irradiation.

THE MULTIPLE WAVE OSCILLATOR

On the other hand, I thought it possible to obtain better results by administering an oscillatory shock to all the cells in the organism simultaneously. Such a shock, very brief, produced by dampened or weakened electrostatic waves, does not provoke thermal and prolonged effects and involves no risk of burning living cells.

I therefore sought to produce an artificial oscillatory shock causing a periodic oscillation of the weak or dead cells.

At first glance this problem seems physically insoluble as there are approximately 200 quintillion cells in our bodies, each oscillating on its own natural wavelength. Theoretically, therefore, we would have to have a different wave length for each cell, so that every cell in the organism would oscillate in resonance on its own wavelength.

After much research I was able to construct an apparatus creating an electrostatic field covering all frequencies from 3 metres to the infra-red, so that every cell can find its natural frequency and vibrate in resonance.

We know that in physics, a circuit fed by damped or weakened high frequency currents creates many harmonics. Consequently, I conceived an oscillator of multiple wavelengths with a broad scale in which every organ, every gland, every tissue, every nerve, could find its natural frequency.

To obtain this result I set up a transmitter composed of a series of circular concentric oscillating circuits linked by a silk cord but not contiguous. These circuits are stimulated by damped high frequency currents from a spark gap. Thus each circuit of the transmitter vibrates not only on its natural frequency, but also on numerous harmonics.

Thus, I built an oscillator with all the basic wavelengths from 10 centimetres to 400 metres, that is, all frequencies from 750,000 to 3,000,000,000 cycles per second. But each circuit also emits many harmonics, which, with their basic waves, their interferences and their effluvia can reach the scale of infra-red and even that of visible light (1 to 3000 trillion vibrations per second.)

Since all the cells as well as the chondromes oscillate precisely at frequencies in that range, they can therefore find, in the output of such an oscillator, the frequencies which cause them to vibrate in resonance.

You know the results I obtained with continuous very short waves using triode tubes at a distance, with no contact electrode....

As early as 1931, I began using this multiple wave oscillator in various Paris hospitals: the Saint Louis, Val-de-Grace, Calvary, Necker, etc... Among the many cures with this treatment, I will mention especially those of various cases of cancer which X-ray and radium treatments failed to improve. These patients, cured six years ago, have had no recurrence and are in perfect health at this date. In all pathogenic cases this treatment gives very good results. As it does not attack the microbes directly, it does not destroy live tissue, but reinforces the vitality of the organism by accelerating cellular oscillation. It is therefore the reinforced organism that successfully resists the microbes and all pathogenic causes.

So, while X-rays and radium destroy microbes, neoplasic cells and healthy tissue at the same time -- which accounts for the serious accidents which occur during and after such treatments -- high frequency radiations (short waves) applied at a distance and without thermal effect cure diseases of all kinds, even those of the prostate to a considerable degree.

Whatever the pathogenic cause, the multiple wave oscillator reproduced the frequencies necessary to re-establish the cellular oscillatory equilibrium.

In general, it is sufficient to seat the patient, or to have him stand in the radius of the apparatus, before the transmitter. The duration of the treatment is usually from five to ten minutes, every other day. These figures are purely arbitrary, since these radiations reinforcing cellular oscillation do not produce organic disturbances, whatever the duration of the treatment may be.

Despite the many cases successfully treated, almost without exception, it must be understood that my oscillator cannot cure all types of cancer in all its stages of development. In many cases, when the cancerous tumor has already destroyed important blood vessels, my apparatus is powerless to rebuild that tissue before the fatal haemorrhage.

INFLUENCE OF COSMIC WAVES ON THE OSCILLATION OF LIVING CELLS

Part 3, Chapter 1, From La Science et le Bonheur, by Georges Lakhovsky, Paris 1930

Translated by Brigitte Donvez, Edited by Tom Brown

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This part of my study is devoted to the trials, experimentation and applications of the theory of the oscillation of living beings.

I have assembled here short technical reports about the processes and methods employed, as well as a collection of all the papers read at the French Sciences Academy and at various French and foreign Scientific Societies about oscillatory therapeutics and all its domains of application.

We intend first to examine successively the influence of cosmic waves on the oscillation of living cells, taking as a concrete example the influence of solar activity upon the quality of wine and vintage. Then we will examine the construction of an electromagnetic short-wave generator, such as the radio-cellular-oscillator for the treatment of animal and plant organisms.

We will later consider the applications of the radio-cellular-oscillator, particularly in the experimental treatment of plant cancer, diathermy and the artificial production of fever.

Concurrently, we will introduce the application of open oscillating circuits to the treatment of diseases in various living beings, in the absence of any other oscillations but those produced by the natural cosmic and atmospheric waves. We will also review in this chapter the observations of scientists and practitioners who clinically applied my oscillating circuits.

Finally we will take up the very latest applications of oscillating circuits to water and liquid sterilization, and to the activation of the germinative power of plants.

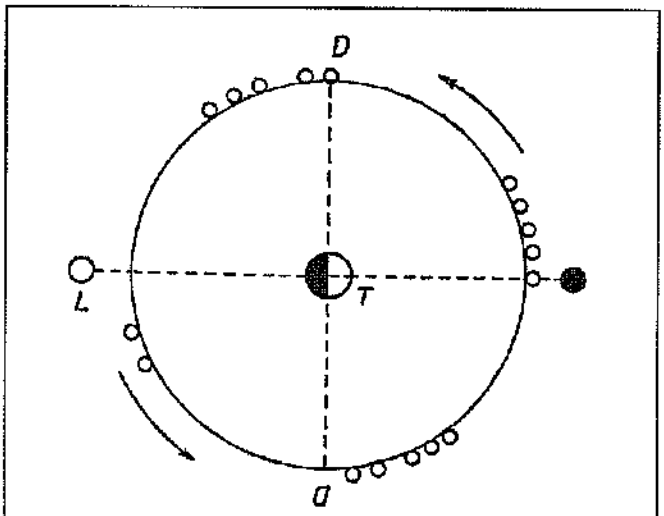

Fig. 1 – Distribution of the highest intensity of electromagnetic waves observed by Mr. Vincent, as a function of the moon phases.

Obviously, the number of these applications, presently limited to certain domains, tends to rapidly expand and touch upon the various problems presented by therapeutics, biology, agriculture and zoology.

I have discussed elsewhere the role played by cosmic radiations in the development of living beings, due to the very oscillatory nature of the cell. Now, as a consequence of the earth's rotation and the stars' reciprocal motion, the cosmic and atmospheric radiation field is not constant, but rather variable. Living beings are subsequently under the influence of these variable cosmic radiations, whose nature either weakens or strengthens the cell's oscillatory balance.

I have mentioned elsewhere[1] that the lunar radiation interferes with the waves of radioelectric stations. Every week, the recurrence of moon phases enables us to obtain highest and lowest intensities in the reception of electromagnetic waves (see Fig. 1).

On the other hand, the sun does not only send light, heat and actinic (ultra-violet) radiations, but also electromagnetic waves, especially during the eruptive periods of its prominences (sun-spots). The influence of the sun's electromagnetic radiation becomes obvious if we consider the variations in the earth's magnetic field and the spinning of a compass' magnetic needle during magnetic storms, under the influence of the telluric currents induced in the ground. The ionization produced by the sun's radiation also generates atmospherics and statics which disturb radioelectric receptions.

Astrophysicists, notably those of the Meudon Observatoire under the direction of Mr. Deslandres, have been able to establish a correlation between the periodicity of cataclysms on earth (tidal waves, tides, earthquakes) and that of the recurrence of sun-spots in the earth plane (about 27 days).

We can observe that the graphs which render geophysical, electric (ionization, gas conductivity, aurora borealis—northern lights), magnetic (variations of the earth field, compass spinning) and electromagnetic (disturbance in wave propagation, atmospherics and telluric parasites) phenomena, as a function of time, are very appreciably parallel to each other and to the curve of solar activity. An 11½ year periodicity appears on these graphs, confirmed by numerous, previous observations in the domain of meteorology. In particular certain tropical rainfall patterns show a 33 to 35 year periodicity, three times longer than the previous one.

I researched the extent to which cosmic radiations which condition physical and meteorological phenomena, also influence biological phenomena and the development of living beings.

As early as 1801, while cosmic radiations were not even suspected, Hershel pointed out: "the scarcity of vegetation when the sun has no spots". Starvations recur every eleven years in India with alternances of heat and rain. From 1901 to 1909, the canon Th. Moreux noticed that the wheat crop in France and in the world more or less followed the solar activity, so did arthritic conditions, and the nervousness of students and teachers.

I compared the graphs of the solar activity, as recorded at the Meudon Observatory, with the statistics of wine production in the Bourgogne and Beaujolais regions, and I noticed that the outstanding vintages coincided precisely with the year of recrudescent solar activity.

On this topic, Professor d'Arsonval agreed to present in my

1. L'universion, p.127, Gauthiers Villars publishers

name at the Academie des Sciences (Academy of Sciences) on March 28, 1927, an original report entitled Influence of Cosmic Waves On The Oscillations Of Living Cells which is entirely reproduced here.

INFLUENCE OF COSMIC WAVES ON THE OSCILLATION OF LIVING CELLS

(Paper by Mr. Georges Lakhovsky, presented on March 28, 1927 to the Academie des Sciences (Academy of Science) by Professor d'Arsonval.)

In my book The Origin of Life, Radiation and Living Beings, that Professor D'Arsonval did me the honor to present to the Academie des Sciences (Academy of Science), at the sitting of the 15th of February 1926, I exposed my theory about the influence of (cosmic) penetrating radiations on living beings. As a matter of fact, I demonstrated that the nucleus of each living cell, having the form of a tubular filament made of a dielectric matter filled with a conductive substance, could be compared to an oscillating circuit, equipped with self-inductances, electric resistance and capacity. The living cells can thus oscillate at very high frequencies under the influence of cosmic radiation emitted by stars.

I made certain to verify the exactness of this theory by studying the influence of cosmic radiations (sun-spots, comets, interferences of stars' radiations, etc...) on biological matter.

My observations were based on the curves recorded by the astrophysicists of the Meudon Observatoire, curves which revealed since 1845 the activities of the sun-spots, the frequency of magnetic disturbances, and the frequency of aurora borealis — northern lights.

These three curves are appreciably parallel. I endeavored to study the existing correlation between these cosmic radiations, on the one hand, and the development of vital activity in the plant and animal domains, on the other. As for any given individual, periods of fatigue and illness alternate with periods of health, in the same way there is, for fruit and crops in general, for each species, years of good quality and years of rather mediocre quality.

As to what concerns wine, according to the documentation established by the Chambers of Commerce of the Bordeaux and Bourgogne regions, I observed that, from 1845 until 1915, the outstanding vintages corresponded exactly to the highest activity of the sun-spots, as shown by the curves on Figure 2.

The results for red Bordeaux wines are:

Maximum of 1848: outstanding vintages of 1847 and 1848;

Maximum of 1858: outstanding vintages of 1857 and 1858;

Maximum of 1869: outstanding vintages of 1869 and 1870;

From 1880 to 1889: period of phylloxera.

Maximum of 1893: rather good vintages of 1890 and 1893;

Maximum of 1906: good vintages of 1906 and 1907.

In addition, let's point out that the wine of 1811 was called the wine of the comet, and we could ascribe its excellent quality to this comet's radiation. It is the same with white Bordeaux and Bourgogne wines.

I am sure that there are many other biological phenomena which recur periodically after a few years or a few centuries as a function of the relative revolution of the earth around the stars. I am convinced that all the scourges which ravaged humanity during the Middle-Ages: plague, leprosy, cholera, etc... and disappeared thereafter without traces in other regions will reappear some day, when the earth shall once more occupy the same position as then in relation to the stars, producing thus by interference with the cosmic waves the same oscillatory imbalances of the cells, which at that time, had produced these same diseases.

Fortunately till then, thanks to the oscillating circuits and the new methods that scientific discoveries will put to our disposal without delay, we'll be in a position to fight victoriously against these illnesses provoked by the interference of the stars' radiations.

Figure 2
RED BORDEAUX WINES

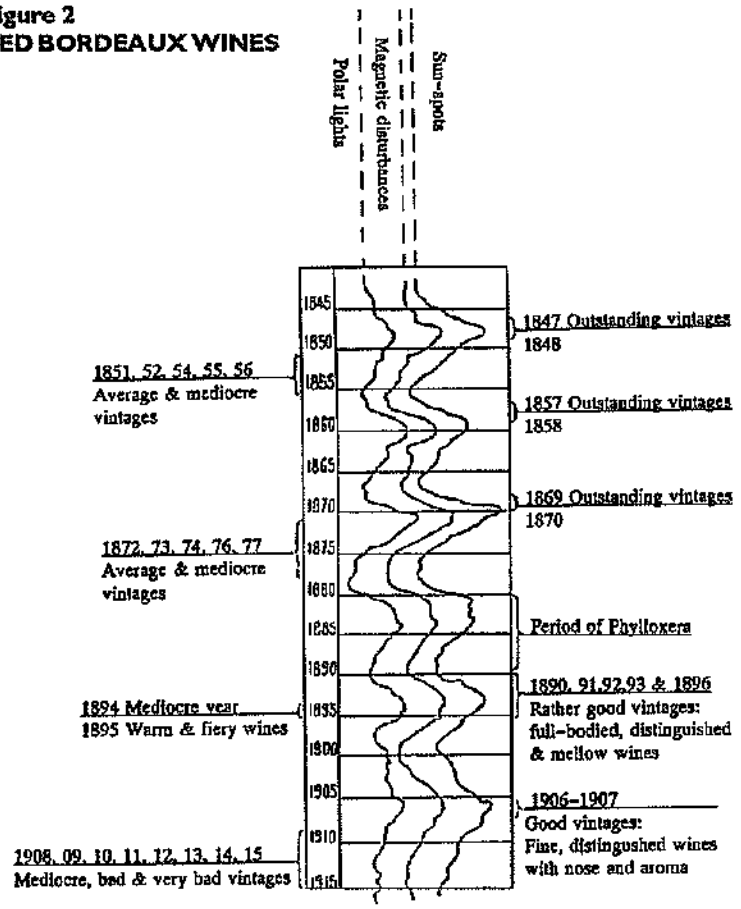

Figure 2 -- Graph showing the coincidence of outstanding vintages with the intensity of the waves emitted by the sun and corresponding to the variation in intensity: 1) of sun-spots, 2) of earth magnetic disturbances, 3) of polar lights. The graph has been established for red Bordeaux wines; the greatest intensities correspond to the outstanding vintages, the lesser intensities correspond to the years of mediocre wines. We can establish a similar graph for the other vintages, notably Bourgogne and Beaujolais wines.

THE RADIO-CELLULAR-OSCILLATOR AND ITS APPLICATIONS

by Georges Lakhovsky

Part 3, Chapter 2, from La Science et le Bonheur, Paris 1930

I demonstrated in the last chapter, how, according to my cellular oscillation theory, alteration in organic tissues came from a variation in the intensity of the cosmic waves' radiations and from these waves' frequency, thus causing the oscillation of the cells.

To reestablish the balance of these natural astral fields, the radiation of which we can no more directly influence, than a meteorologist can influence the weather, I thought of using a local oscillator, generating waves and creating an artificial and auxiliary magnetic field.

Incidentally, I should add that this method is analogous to the methods used in radiotelegraphy, known as heterodyne and super-heterodyne methods. These methods use the interferences produced between the waves received and the waves generated by the local generator at the required frequency and intensity.

About 40 years ago (1890) Professor D'Arsonval advocated the treatment of certain illnesses by high frequency electrical currents, that were at the time produced in waves strongly damped by means of a Ruhmkorff coil and a spark gap (arrester).

My radio-cellular-oscillator is a generator of continuous waves of very high frequencies, the first application of triode lamps to biological research and pathological treatments.

We know the difficulty of obtaining very short waves, because of the parasitic capacitance present in electronic lamps due to the electrodes themselves and, within the bulbs, to tube sockets and connective wires.

In 1924, when I studied the possible construction of a triode lamp oscillator for very short waves, shorter than 2 meters, the radioelectrical technique, in France and abroad, was still at the stage of long-waves and the length of the so-called short-waves was in fact from 200 to 500 meters.

Therefore, I had to do my own research in view of studying a type of lamp appropriate to the generation of very short waves. Thus, I have been led to design lamps with multiple electrodes enclosed in the same bulb. These multiple lamps have been patented in France[1] and in Germany[2].

Later, I intentionally abandoned the idea of working this patent and preferred to give it up to the public domain, in a scientific aim, so that no patent claim could oppose disinterested researches undertaken for the radioelectric prophylaxis of diseases, especially cancer.

However, if the French industry did not engage in the construction of these multiple lamps, the problem was reconsidered in Germany three years later and partly resolved as the double or triple "multi-valve" by Dr. Siegmund Loewe[3].

To reduce connections to a minimum, as well as the parasitic capacity between electrodes, to achieve the generation of waves of less than 1.5 meters while avoiding low efficiency, deformation, or distortion of the wave which would jeopardize the purity of the transmission and particularly alter the modulation, I proposed in my patent to enclose the oscillating circuit and its connections within the bulb. This invention, which cannot conveniently be applied to long waves is, on the contrary, easy to carry out for very short wave circuits, of which the bobbins are reduced to several turns of coil, even to a fraction of a turn, and of which the condensers have a very small capacity (Fig. 3).

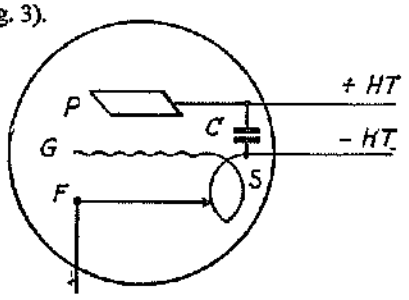

Fig. 3 -- Triode generator of very short waves, after the original drawing of Lakhovsky's patent.

Practically, the oscillating circuit only includes a turn of several centimeters in diameter. The only connections getting out of the tube are the feeders, bringing in the plate voltage (anode voltage) and the heating current (thermo-current).

These tubes can generate oscillations and transmit them by induction to outer circuits (aerials, loops, antennas).

Beside the practical simplification, the improvement of the efficiency comes from the fact that all electronic elements work with the same degree of vacuum. This is what I observed when I grouped within one same glass tubing the bulbs of a 4 triode lamp device (Fig. 4). The equal distribution of the vacuum among the various electrodes increases the purity and stabilizes the functioning.

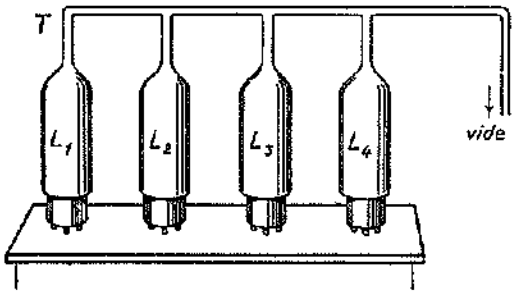

Fig. 4-- Glass tube T helps maintain the same vacuum pressure inside the four triodes of a classic resonance receiver. Author's realization.

According to this principle, I indicated the possibility of constructing not only a certain number of simple or multiple electrical cell oscillators but also all kinds of triodes or electronic lamps contained in a same bulb. Figure 5, quoted from my patent, shows the diagram of a symmetrical oscillator, with double electrodes and filaments connected in parallel. This oscillator is completely enclosed in a same casing.

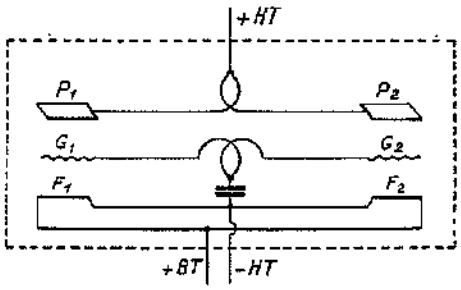

Fig. 5 -- According to the original drawing of the author's patent. Multiple triode including inside the bulb the connections of a symmetrical short-wave transmitter, with filaments set up in parallel.

1. G. Lakhvosky. French patent #601,155 of October 18, 1924
2. G. Lakvhosky. German patent #427,596 of May 26, 1925
3. Patent application in France on May 7, 1927

Figure 6, also taken from my patent, presents a double, symmetrical oscillator of which the filaments are connected in series. A possible tuning condenser is anticipated, which would be placed in the same vacuumed bulb as the electrodes and turns of the circuit.

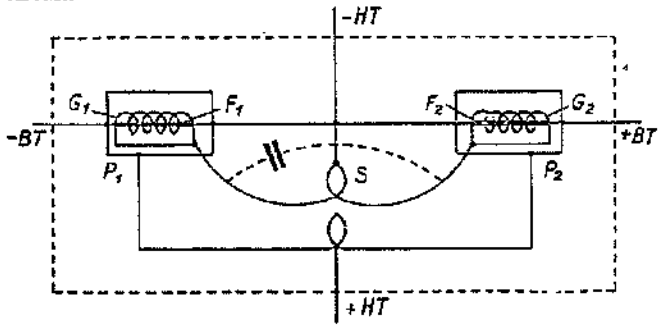

Fig. 6 – Multiple triode symmetrically connected with filaments in series, according to the original drawing of the author's patent.

Figure 7 shows the case of a double oscillator with a unique filament.

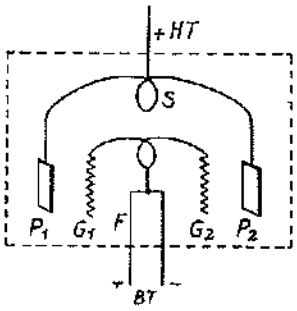

Fig. 7 – Double triode multiple lamp with symmetrical connections and a single filament, according to the original drawing of the author's patent.

For long-waves, moreover, I indicated the possibility of putting together the circuits outside the bulb.

These various constructions are extremely general. We know that for all practical purposes Dr. Loewe has only introduced resistances and capacitances inside his multiple lamps, reducing therefore its use to low and high frequencies amplifications of long waves. These lamps' efficiency is bound to be rather mediocre for the following reasons: great connection resistances, strong plate voltage (about 160 to 200 volts), and impossibility to stabilize the circuits and cause a resonance.

On the contrary, I always anticipated inner couplings through bobbins and capacitances ensuring the greatest efficiency. The resonance is obtained through a variable condenser inside the lamp and commanded from outside without any mechanical element. For example, if you use the gravity field, it suffices to place a counterweight on the sliding condenser and to direct the lamp in space. Or you can use a magnetic field produced by a magnet or an electromagnet. (Fig. 8).

I indicated the means of building an oscillator of good efficiency for ultra-short waves, with the possibility to tune it into a whole range of frequencies.

To resolve this problem on a practical level, before people started to produce multiple lamps, I used a symmetrical oscillator including two triode lamps. It is the radio-cellular-oscillator which I used in 1924, at the wards of the Saltpetriere Hospital in Paris, to treat and heal geraniums inoculated with experimental plant cancer.

Fig. 8 – Variable sliding condenser M, balanced with a counterweight W within a triode lamp, according to the original drawing in author's patent.

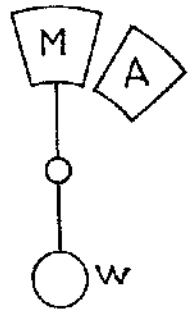

The simplified diagram of the radio-cellular-oscillator is indicated in Figure 9 (Mesny set-up).

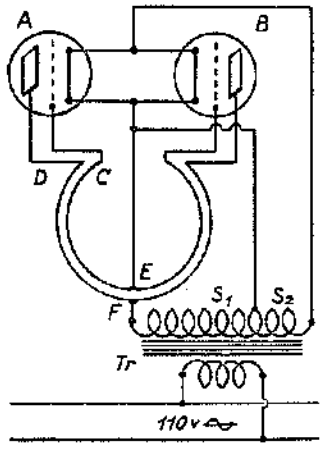

Fig. 9 – Simplified diagram of the Lakhovsky radio-cellular-oscillator.

Plates, grids and filaments paralliel connected. The grids and plates circuits all comprise one turn. These two turns are variably coupled between them. Plates and filaments are directly supplied with alternating current of the mains by means of the appropriate transformer. In these conditions, the transmission of waves starts as soon as the plug is connected onto the mains. By using a tuning condenser, one can produce the entire range of waves of a length comprised between 2 and 10 meters. The supply of alternating current creates a great number of harmonics with which the oscillations of the various cells can enter into resonance. The fundamental wave length can moreover be regulated according to the nature of the cells to be treated.

The biological role of the radio-cellular-oscillator is to reestablish the oscillatory equilibrium of the living cell, threatened by any alteration, and in particular by neighboring microbes. When it resumes its normal vigor, thanks to the auxiliary radiation of the radio-cellular-oscillator, the cell can destroy the microbe itself by damping down its pernicious radiations.

The fundamental experiment I presented at the Saltpetriere Hospital demonstrates the functioning of the radio-cellular-oscillator. It dealt with cancerous plants inoculated according to Erwin Smith's method.

This fundamental experiment was the subject, on the 26th of July 1924, of a report to the Societe de Biologie (Society of Biology) and it is reproduced here in extenso, from the society's newsletter.

ATTEMPT AT TREATMENT OF EXPERIMENTAL PLANT CANCER

Report to the Society of Biology

by A. Gosset, A. Gutmann, G. Lakhovsky, J. Magrou

We know that we can produce tumors comparable to animal cancer (Erwin F. Smith)[1] on various plants, by inoculating them with the Bacterium tumefaciens. Using this method[2], one of us obtained experimentally a great number of tumors. These tumors have an indefinite growth; they might partially necrotize but they only die completely when the entire plant or at least the branch infected by the tumor has succumbed to the cachexia. Even when surgically removed, these tumors continued to proliferate.

We intend to study, in this present report, the influence of magnetic waves of great frequencies, obtained by means of a device built by one of us, for therapeutic applications and following his theoretical views[3]: the Georges Lakhovsky Radio-Cellular-Oscillator. This device generates oscillations of a λ wave length = about 2 meters, and corresponds to 150 millions (150,000,000) vibrations per second.

A first plant (Pelargonium zonatum) has been experimented with a month after its inoculation with Bacterium tumefaciens; it showed at that point several, small, white tumors, of the approximate volume of a cherry kernel. The plant has been exposed twice to the radiation, with a 24-hour break and during three hours each time.

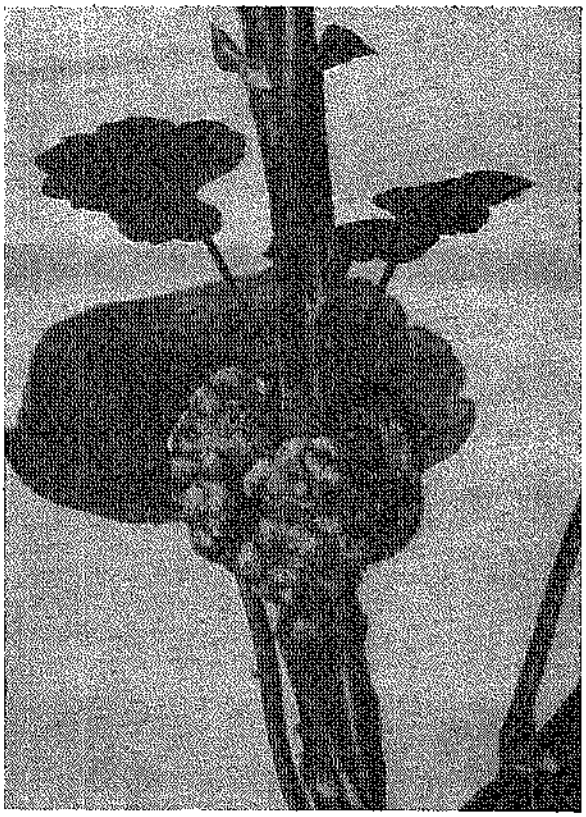

Fig. 10 – Sight of the tumor of an untreated witness check sample. – Subject: Pelargonium zonatum inoculated April 10, 1924. We see the growth of the cancerous tumor on the stalk. (*Clinique Chirurgicale de la Saltpetriere*).

In the days following the treatment, the tumor continued to grow rapidly, like the check sample tumors, forming a great plurilobate mass. About sixteen days later, after the first treatment day, the tumor suddenly started to necrotize. A few days later (about 15 days) the necrosis was complete; the lobes of the tumor, retracted and completely dried out, separated from the stalk bearing them, through furrows of elmination, and the tumor could be taken off by the slightest traction. The necrosis effect of the radiation was extremely elective, limited only to the cancerous tissues which it followed into the very depth and root of the tumor; the healthy parts, stalk and leaves remained unhurt and retained all their vigor.

A second Pelargonium was treated in the like manner, but the time of exposure to the radiations was lengthened (eleven 3-hour sessions); 16 days after the first session, the tumor it carried started to necrotize and several days later it dried out completely. As in the first case, the healthy part remained unhurt.

With a third Pelargonium which underwent nine hours of radiation (three 3-hour sessions) the necrosis of the tumor's lobes followed the same path.

Sixteen control Pelargoniums remained untreated. All bore tumors in full activity which often became enormous.

As a summary, we may say that the Pelargonium which became cancerous after inoculation of the bacterium tumefaciens and for which a surgical intervention could not prevent recurrence seemed to heal under the influence of the magnetic waves indicated above. *(Clinique Chirurgicale de la Saltpetriere.)*

A very clear conclusion can be drawn from this experiment and its counterpart.

On the one side, we observe that, on the control subjects, inoculated with the *Bacterium tumefaciens* and left untreated, enormous tumors grew which by absorbing the plants' vital energy lead them to a quick and certain death.

On the other hand, the plants treated by the radio-cellular-oscillator, and moreover taken at random from among the inoculated subjects, have been healed quickly and acquired a considerable vitality, as is proven by their growth, their continual development and abundant flowering.

We can see it in the photograph (Figure 12), taken one year after the healing of the geranium.

My theory of cellular oscillation, that I had moreover proposed before I realized this experiment, enables us to understand cancer pathology and to direct its therapy onto a new path.

Cancer, mostly reaching older people, comes from the ageing of tissues as a result of the cells and blood decay. This impairing of the cells results from a modification of the

1. Erwin F. Smith, *An Introduction to Bacterial Diseases of Plants*, 1st vol., Philadelphia and London 1920.
2. J. Magrou, *Revue de pathologie comparee*, March 1924. Two other reports will be soon published in the *Revue de pathologie vegetale et d'entolmologie agricole* and in the *Annales de l'Institut Pasteur*.
3. Georges Lakhovsky, *Radio-revue*, November 1923 and Conference to *L'Ecole Superieure des P.T.T.*, June 2nd, 1924.

Fig. 11 Sight of the scar of the treated subject. Subject: Pelargonium zonatum, inoculated April 10, 1924 with the Bacterium tumefaciens, treated from May 24, to June 14, 1924, during eleven three-hour sessions with the Lakhovsky oscillator with antennas, photographed after it healed on July 24, 1924. *(Clinique Chirurgicale de la Saltpetriere).*

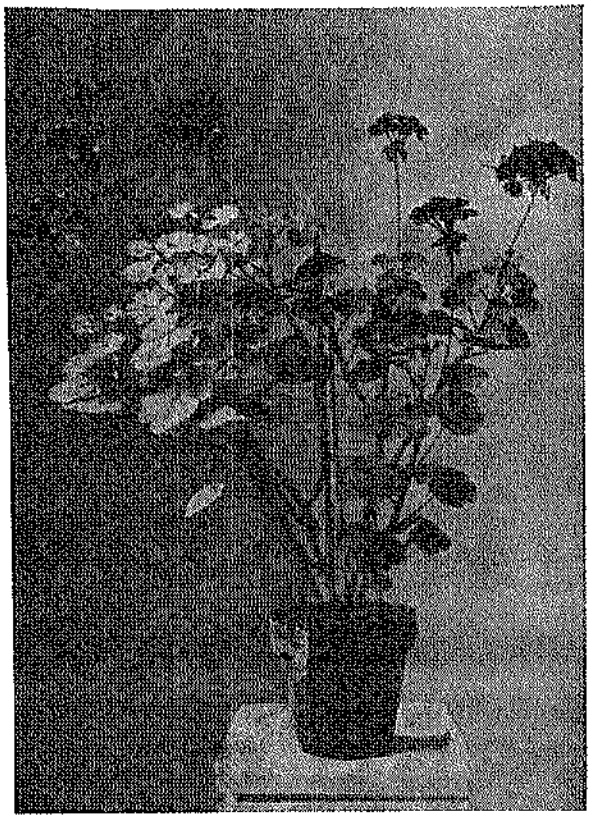

Figure 12 Sight of the treated subject after healing. -- This pelargonium is no other than the one of Figure 10, treated by the Lakhovsky oscillator, on May 24, 1924, healed on the 4th of June, 1924, and photographed in July 1925. As you can see, this plant is in perfect health and abundantly flowered. On the other hand, the sixteen inoculated but untreated check samples died long ago.

chemical composition due to the contribution of foreign bodies which appear as residues of the organism. Such are, for instance, blood haematoblasts, rich in iron and phosphorus, produced by residues of fibrin, leucocytes, and hematites. Each cell destruction brings with it a small mass of cholesterol, an insulating substance forming the armature of the nuclear filament, which later clogs the nucleus. Therefore older people first experience a decrease in the number of active cells and of the white and red corpuscles, which is reflected in the regression of the blood count, and on the other hand, an increase of the quantity of mineral (iron, phosphorus, haematoblasts) and organic (cholesterol) residues. These chemical modifications of the cell result in the variation of the cellular oscillation both in intensity, as a consequence of the changes of electric conductivity and resistance, and in the radiation frequency, because of the changes of capacitance and inductance.

The decayed cell appears like a pendulum with a pendulum-bob one could have lengthened, shortened or damaged. This oscillatory disorder provokes, because of the excess of cosmic waves, a too rapid cellular division, which results in the formation of neoplasms, or cells vibrating at a different frequency from the regular frequency of the tissue.

For long years, it has been wondered whether cancer is contagious and hereditary, or whether it is caused by a microbe. Histological analyses seem to invalidate the existence of a microbe. On the other hand, inoculations of cancer only succeed, and moreover very rarely, with impaired tissues composed of abnormal cells, such as certain moles and this would seen to ruin the hypothesis of contagion and heredity.

In fact, I believe that the true cancer microbe is the neoplastic cell which forces the neighboring cells into oscillating at its own frequency, thus transforming by electromagnetic induction, the healthy cells into neoplasms. To prevent cancer, is to prevent this neoplastic induction and to give back the healthy cell enough vigor to reestablish its oscillatory equilibrium.

I was pleased to observe that, apart from the skepticism of a few, my experiments have been taken up again with great success in France and abroad by various scientists and practitioners who understood the future of oscillation therapeutics.

It seems appropriate to quote the works pursued in Germany by Professor Esau at the Technisch-Psychaliches Institut of Iena.

Although directed toward paths sometimes very different from mine, these works present a very clear analogy with

those I have conducted from the use of a very short wave oscillator similar to my radio-cellular-oscillator.

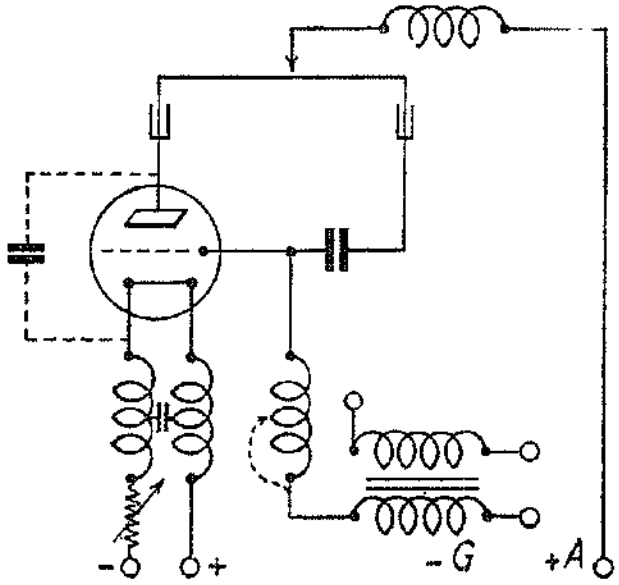

Fig. 13 -- Simplified diagram of Dr. Esau's very short wave oscillator.

The transmitter-receivers used by Professor Esau do not essentially differ from the devices I advocated. I indicated moreover that connections were irrelevant as long as they produced the desired very short waves. Professor Esau's connections, which were described in the technical magazines of Dr. Ernest Busse, assistant at the Ieana Institute[4], are characterized by the use of a single triode lamp, functioning in direct current. The transmitter's filament (Fig. 13) is supplied through a filter preventing high frequency back currents. The coilings are simple fractions of turns, as in the radio-cellular-oscillator, which only includes about half a turn for each oscillating circuit.

A test receiver (Fig. 14) is provided with square loop circuits on which variable plugs can be installed. Another device is provided with a circular turn, of which a radial cursor allows connection to the necessary position.

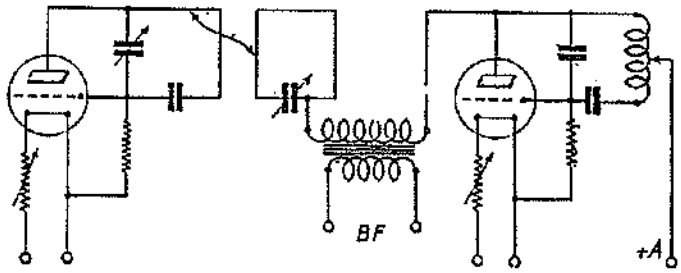

Fig. 14 -- Simplified diagram of Dr. Esau's very short wave receiver.

The works of Professor Esau in the biological domain are rather recent, for during the Radio-electric Symposium in Bremen (August 1928)[5], he stated that he had been doing research, for only a year, on the physiological effects of *ultra-short* waves, or, according to his definition, very high frequency waves comprised between a length of 1.50 and 3 meters, of which I indicated the use in 1924 in my report addressed to the Societe de Biologie, reproduced here. He indicated then that since July 1928, he successfully constructed a very short wave receiver.

About this subject Professor Esau pointed to the fact that the main difficulties came from the electronic lamps, and that he had to use foreign lamps, particularly French lamps, which are more appropriate for very short waves techniques. I indicated earlier that, 4 years before, I had studied and had these special short-wave lamps built, which were designed for my radio-cellular-oscillator.

I shall also point out that a very short transmitter has recently been used by Dr. Frantz Seidel from Vienna, for the destruction of bacteria, particularly in the sterilization of milk.[6] This subject will be investigated at a later time.

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4. Dr. Ernest Busse, *Die Erzeugung ultrakurzer Wellen.* (*Radio-Welt*, No. 49, 1928, p. 77. Vienna.)

5. Oscar Gadamer. *The ultra-short waves and their field of application.* (*Der Deutsche Rundfunk*, August 31, 1928, t. VI, p. 240, Berlin.)

6. *Les ondes ultra-courte contre les bacteries.* (*Radio-Welt*, January 27, 1929, No. 4, p. 108, Vienna.)

THE LAKHOVSKY RADIO-CELLULAR OSCILLATOR

a synopsis by Jorge Resines

What you are about to read is my resume of the book La Science et le Bonheur, Longevite et Immortalite par les vibrations -- *Science and Good Health, Longevity and Immortality Through Vibrations* -- by Georges Lakhovsky. More specifically, this synopsis encompasses Part III, chapters 1 and 2, being pages from 137-171 of said work, and whatever I translate from it will be forwarded by the words "Lakhovsky said:".

Mr. Lakhovsky begins by indicating the influence of heavenly bodies upon all facets of everyday life, from their influence upon the cells up to how magnetic compasses are affected by magnetic storms originating in the Sun (he refers the readership to his book L'Universion, published by Gauthier-Villars of Paris, France). He says that the French Astronomer Mr. Deslandres with his collaborators at the Observatory of Meudon have established a cycle of about 27 days for sunspots affecting both tides and earthquakes. This lapse is part of another larger cycle of 11½ years (or about) that most usually forms in turn part of another, larger, cycle of 33 to 35 years.

Mr. Lakhovsky also discovered, as indicated by the small circles at the lunar orbit of Figure 1, that lunar radiations provoke interferences with the waves broadcasted from radioelectric stations at said marked positions.

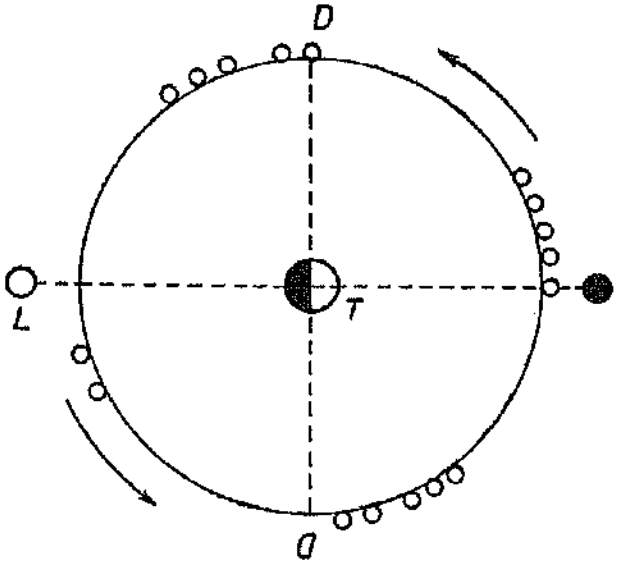

Figure 1

L1 = Full Moon
L2 = Waning Moon
L3 = New (Dark) Moon
L4 = Waxing Moon
T = Earth

Carrying his researches a step further, helped also by the people at the Observatory of Meudon, he correlated the highs-and-lows of three different factors (to wit: a. Sunspot activity, b. Perturbations of Terrestrial Magnetism, and c. Polar Aurora) with the type of wines collected at different French regions. For a single zone and type of wine, his findings are shown in Figure 2 (next page). You will easily notice how the highs of the three factors are in coincidence with the best collections of wines, with a single exception: the 1880-1889 period when the grape-wines were massively attacked at France by the "Phylloxera" plague. Though Mr. Lakhovsky does not explain the reason for this adverse period (when the opposite was expected), he does voice his opinion that cellular and biological phenomena is periodically affected by the same type of radiations (and the generated-sicknesses they produce), proposing at the same time to destroy the scourges by overriding the "astrally-produced radiations" (his words) with this "Radio-Cellular Oscillator."

About the basic concept behind his devices, Lakhovsky said: "To re-establish the balance of these heavenly fields from nature, upon which variations we are able to act directly, unlike Meteorology which cannot make weather change, I will resort to a local oscillating-generator of waves creating an auxiliary artificial electromagnetic field.

"By the way, I must add this method is analogous to that employed in radiotelegraphy and known under the names of heterodyning and superheterodyning. These procedures employ the interferences generated between the received and generated waves by a local generator, at the necessary frequency and intensity."

Mr. Lakhovsky states that his inspiration came from Professor Arsene D'Arsonval, who in 1890 had put forth the opinion that different sicknesses could be eliminated by means of high-frequency currents. He continues on, explaining that by about 1924 he studied the possibility of generating waves under 2 meters in length, but that the electronics of said period considered "short" only those waves from 200 to 500 meters.

To overcome such a hindrance, Lakhovsky developed a vacuum tube with multiple-electrodes and received two patents for it -- French Patent No. 601,155 granted in October 18, 1924 and German Patent No. 427,596 granted in May 26th, 1925 -- afterwards another scientist of that time, Dr. Siegmund Loewe, improved on his ideas and demanded a French Patent on May 07, 1927 (this Patent is not indicated as either granted or not; further investigation is needed here).

Figure 3

+HT = Positive High Voltage
-HT = Negative High Voltage
G = Grid
P = Plate
C = Condenser
S = Loop of Coil
F = Filament

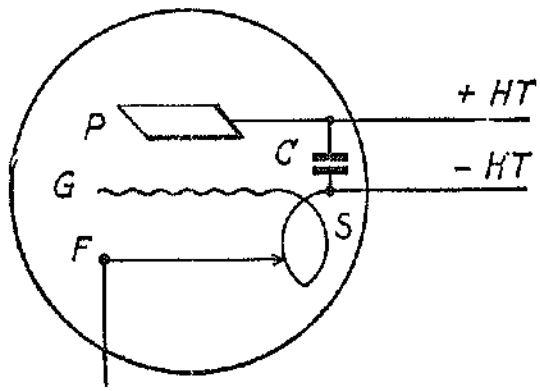

Figure 2 -- RED BORDEAUX WINES

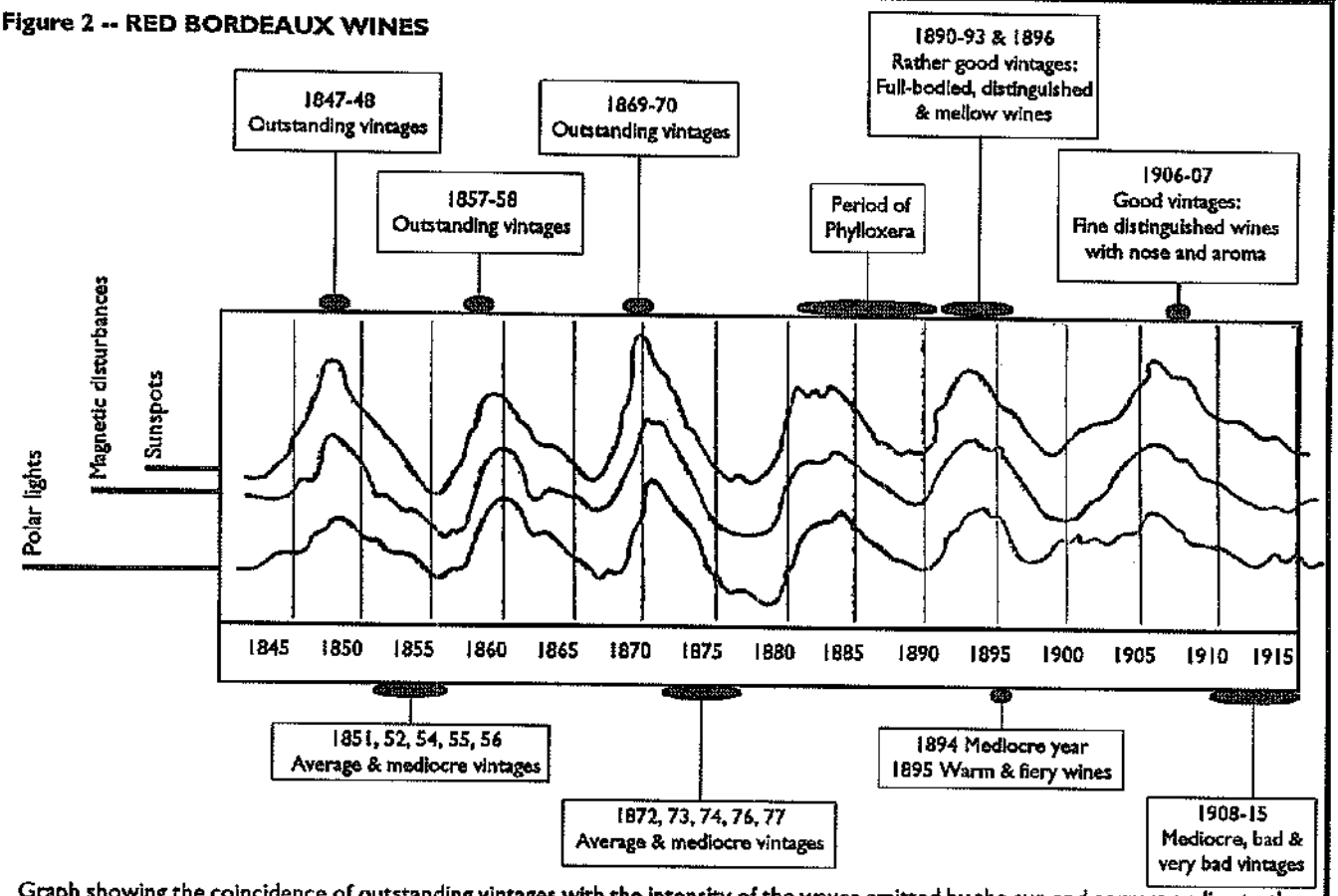

Graph showing the coincidence of outstanding vintages with the intensity of the waves emitted by the sun and corresponding to the variation in the intensity: 1) of sun-spots, 2) of earth magnetic disturbances, 3) of polar lights. The graph has been established for red Bordeaux wines; the greatest intensities correspond to the outstanding vintages, the lesser intensities correspond to the years of mediocre wines. We can establish a similar graph for the other vintages, notably Bourgogne and Beaujolais wines.

To produce waves "under 1½ meters" (his words), Mr. Lakhovsky enclosed within a vacuum tube's glass vessel different elements, as is seen in Figure 3. About this new type of tube, Lakhovsky said: "The oscillating circuit does not involve but a loop with a diameter of several centimeters. The only connections going out of the tube are the supply-wires, leading the plate-voltage and the heating current. These tubes can generate oscillations and transmit them to external circuits (square-loop antennas) by induction."

I will stop now the synopsis to introduce a personal comment: It is not clear on the illustration of Figure 3, WHY the filament is connected -- in a controllable fashion as the schematic indicates -- to the loop "S"; neither do I see clearly indicated whether the tube is one of direct or indirect heating and which type of vacuum tube -- existing at the time, with its specifications of that era -- served as the foundation to develop the tube of Figure 3, and how this was made in both constituents, procedure of manufacture, etc.

Neither is it indicated if there was a constitutional modification involving a change of material(s) for the new type of tube Mr. Lakhovsky first employed. I do not want to spoil anybody's fun in experimentation, I am just suggesting caution... Let's go on with Mr. Lakhovsky.

Another feature employed to ensure a high-quality when in use by Mr. Lakhovsky was to put a group of electronic tubes, as illustrated in Figure 4, directly over these lines, in the same vacuum pump. As all the tubes were connected in series, when the apparatus was made to work it produced the same degree of vacuum within them all.

Figure 4

L_1, L_2, L_3, L_4 = Identical Vacuum Tubes
T = joining tube

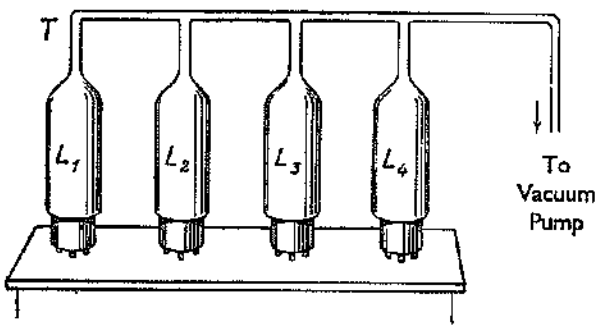

A further development of his idea, "extracted from his patent" he claims without indicating which one (French or German) this is, is the multiple triode illustrated in Figure 5. From its analysis we notice that Mr. Lakhovsky adhered to electronic theory, which says that electricity is a flow of electrons, and in a semiconducting device as the usual vacuum tube there is only a single direction of flow, from the "Cathode" (or negative pole) to the "Anode" (or positive pole). In the multiple triode of Figure 5, the filaments are connected in parallel.

Figure 5

+BT = Positive Filament Voltage
+HT = Positive High Voltage
-HT = Negative High Voltage
P_1 = Plate Tube No. 1
G_1 = Grid Tube No. 1
F_1 = Filament Tube No. 1
P_2, G_2, F_2 = Same for Tube #2
C = Condenser

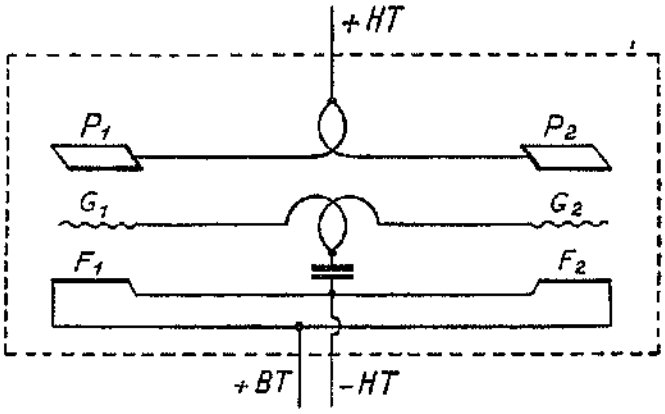

A further improvement of the device is seen in Figure 6, of which Lakhovsky says: "This illustration, also taken from my patent, shows a double and symmetrical oscillator where the filaments are mounted in series. It is also provided for, eventually, to place within a condenser so located as the electrodes and the loops of the oscillating circuit, within the same evacuated glass-vessel".

Figure 6

G_1 = Grid Tube No. 1
P_1 = Plate Tube No. 1
P_2, G_2, F_2 = Same for Tube #2
F_1 = Filament Tube No. 1
-HT = Negative High Voltage
C = Condenser
-BT = Negative Filament Voltage
+HT = Positive High Voltage
+BT = Positive Filament Voltage

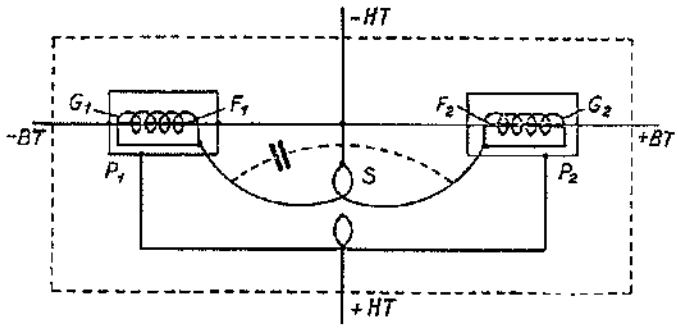

Figure 7 shows us a double-oscillator with a single filament, that is the two lamps of Figure 6 within a single vessel and with just one heat-source.

Figure 7

+HT = Positive High Voltage
+/- BT = Positive and Negative Filament Voltage
F = Filament
S = Loop of Coil
G_1 = Grid No. 1
P_1 = Plate No. 1
G_2 = Grid No. 2
P_2 = Plate No. 2

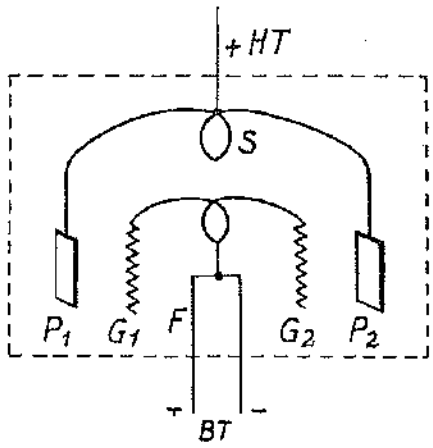

I remind the readership that all the models of vacuum tubes shown so far are for short waves under 2 meters. Lakhovsky indicated that to obtain long waves it sufficed to place the same elements outside a vacuum tube.

After saying that everything so far shown were just "extremely general things" Lakhovsky said: "One can, almost, say that Dr. Loewe just introduced resistances and capacities within his multiple-tubes, where performance is just reduced to amplifying low and high frequencies upon long waves. The performance of these tubes is very mediocre because of the following reasons: a) Heavy linking resistances, b) Strong plate-voltages (about 160 to 200 volts), c) impossibility of coupling circuits and thus producing a resonance."

Figure 8

M = Mobile blade of condenser
A = Fixed blade of condenser
W = Weight to move blade "M"
H = Turning point for the combination of "M" with "W"

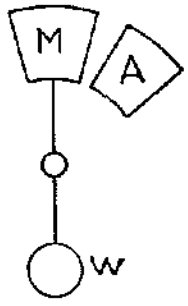

Here, in the former comment, is an apparent contradiction: Lakhovsky criticized Dr. Loewe for including resistances and capacities within his multiple-tubes, while at the

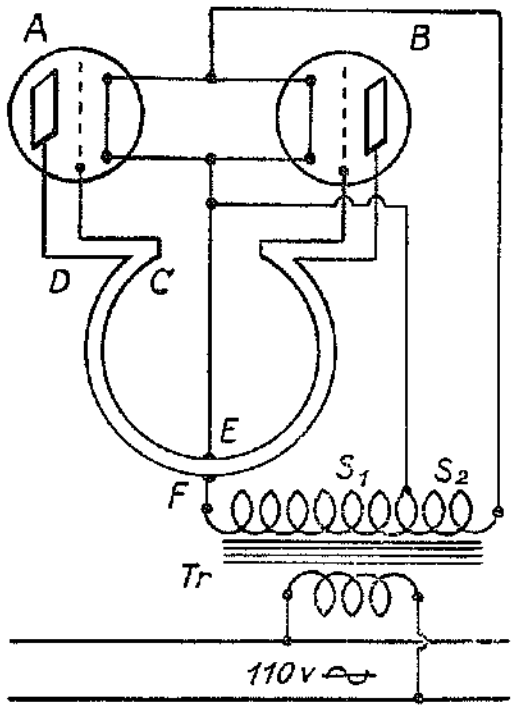

Figure 9
A = a Lakhovsky Triode
B = another Lakhovsky Triode
C = Loop associated to Grids
D = Loop associated to Plates
E = Connection to Filament
F = Connection to High Voltage of Transformer secondary tap S_1
S_1 = High Voltage tap of AC Transformer secondary
S_2 = Filament Voltage tap of AC Transformer secondary
Tr= AC step-up Tranformer with a tapped secondary winding

same time he did the same! But Lakhovsky's capacitors are different to the common types.

What he did was to "separate" a variable condenser's blades and to "counterweight" the moving blades, as indicated in Figure 8, so that the blades would move within the fixed armature of the condenser as the whole tube was rotated and weight "W" responded to gravity! He does not indicate, thus making it an object of personal experimentation on the part of the readership, if there was just one or more of these special variable condensers.

Now, in order to produce a wide range of frequencies with only two of his special triodes, Lakhovsky built the "Radio-Cellular Oscillator" that is shown in schematic form in Figure 9, which he used at the Clinic of Salpetriere in 1924 to treat and heal Geranium plants which he experimentally inoculated with the disease of cancer; it was mounted, he says, according to the "Montage Mesny," thus indicating that one man called Mesny originated the setup at that time (this is another source for research, try finding in old books from either the '20s or '30s anything made by a Mr. Mesny).

This is what, on the device, Lakhovsky says: "Plates, grids and filaments are connected in parallel. The circuits of grid and plate have each a single loop. These two loops are coupled variably between themselves. Plates and filaments are fed directly from the Alternating Current of the place by means of the appropriated transformer. Within these conditions, it is produced the emission of waves because it is branched the intake of current upon the electrified section.

"Using, accordingly, a condenser it is possible to produce the whole spectrum of waves between 2 and 10 meters of wavelength. The supply from AC produces a large number of harmonics upon which can enter into resonance the oscillations of different cells. Therefore, the fundamental wavelength can be regulated according to the nature of those cells to treat.

"The biological role of the Radio-Cellular Oscillator is to re-establish the oscillatory equilibrium in the living cell, under threat by any alteration, particularly by a close microbe. When recovering its normal strength thanks to the auxiliary irradiation from the Radio-Cellular Oscillator, the cell can all-by-itself destroy the microbe by counter-acting its deleterious radiation."

Mr. Lakhovsky goes on indicating that he established the aforementioned concept as the foundation of his device by first inoculating several plants of *Pelargonium zonatum* with the *Bacterium tumefaciens* in order to generate tumors similar to those of animals in plants (his source was: An Introduction to Bacterial Diseases of Plants by Erwin F. Smith, London and Philadelphia, 1920). He was helped with inoculating the plants by Mr. A. Gosset, Mr. A. Gutmann and Mr. J. Magrou, the latter being the one who had more articles published on the subject of plant-inoculation (see the Revue de Pathol. Vegetale et d'entomologie agricole and within that the Annales de L'Institut Pasteur, by this author).

He then applied his Radio-Cellular Oscillator, using waves of about 2 meters, which he equated with a vibration of 150,000,000 cycles per common-second. He broadcasted the oscillator's output upon the infected plants and got them all back to health after a given time. He had already explained how his oscillator worked to his fellow Frenchmen in an article (Radio-Revue, November 1923) and a conference (given at the Ecole Superieur des Postes, Telegraphes and Telephones

Figure 10

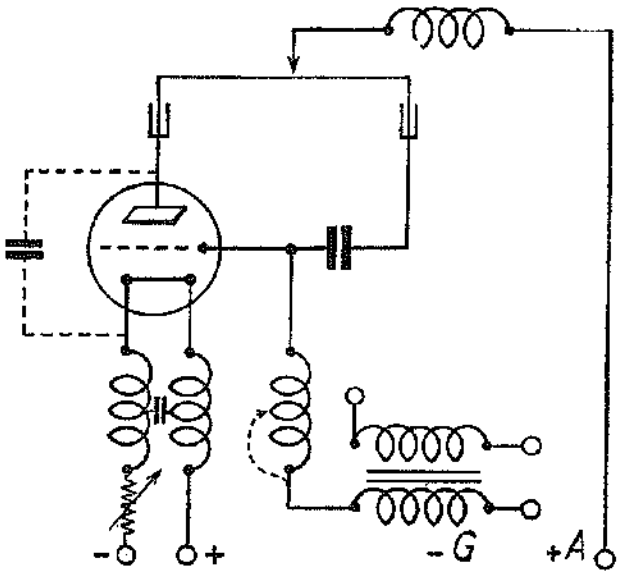

on June 2nd, 1924).

After detailing how the experiment in plant-healing progressed and how the plants were healed, he goes on to explain that -- in his conception -- cancer is provoked by an "aging" of the cells that makes them both reproduce at a slower rate and to evacuate a higher amount of wastes. This, in combination with radiations coming from space at different times, produces an oscillatory disequilibrium in the cells resulting in cancer of different types. Mr. Lakhovsky rejects, on the ground of histological examinations he performed, both the "microbial" theory of cancer and its hereditary transmission.

If you have followed all of the writing up to this point, carefully noting the concepts involved in Lakhovsky's procedures, you will remember that:

(1) His Radio-Cellular Oscillator created an auxiliary electromagnetic field capable of restoring balance to the diseased cell(s) and body.

(2) This was done by means of very short waves (during the period he experimented) of about 2 meters and 150,000,000 cycles per second.

(3) To achieve the necessary shortness of wave he introduced different elements within an evacuated glass-vessel, thus creating a different type of vacuum tube.

(4) He purposely indicated that external elements created long waves that did NOT comply with what he needed for therapy.

(5) He included, within his special tubes, a variable condenser that could be tuned to the desired capacity by moving the tube in space so that the internal variable capacity could generate the coupling needed in therapy.

If all of this has been, so far, an essential group of conditions necessary to produce the short waves of about 2 meters, then why -- as seen in Figure 9 -- does he place two electrified loops OUTSIDE the vacuum tubes of his special design????

In compliance with this "loops outside" line, he goes on quoting the works by one of many foreign scientists who, he claims, have followed his line of research:

Lakhovsky says: "It is convenient to quote the works made by Professor Esau at Jena's Technisch-Physicalishes Institut (Germany). If they are directed by ways somewhat different to mine, his works show the similitude of using an oscillator of very short waves similar to my Radio-Cellular Oscillator. Professor Esau's emitters and receivers do not differ essentially from the apparatus I champion. I have already indicated that the arrangements of constituents are indifferent, because they produce the very short waves needed.

"The setups by Professor Esau -- described in the Institute's technical magazines by Dr. Ernest Busse (see Die Erzeugung Ultakurzer Wellen -- *Research on Ultrashort Waves* -- in Radio Welt, No. 49, page 77, Vienna, 1928), secretary to the Institute of Jena, are characteristic because they employ a single triode working with DC.

"The emitter's filament -- as seen in Figure 10 -- is fed by a filter preventing the return of high-frequency currents. Windings are made with simple fractions of turns, as in the Radio-Cellular Oscillator, which does not involve but a half-turn per oscillating circuit.

"An experimental receiver (see Figure 11) is supplied with a circuit possessing a single square-loop, upon which can be made variable taps. Another apparatus is possessed of a single circular-loop upon which a radial cursor allows to take just the necessary fraction of circuit.

"Works by Professor Esau in the realm of Biology are very recent, because at the August 1928 Radioelectric Con-

Figure 11

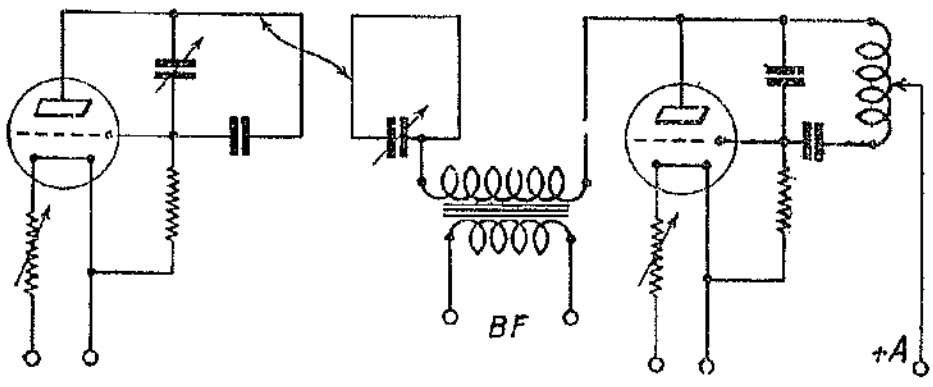

gress of Bremen (see Les ondes ultra-courtes et leur champ d'application -- *Ultrashort-waves and Their Field of Application* -- by Oscar Gadamer in Der Deutsche Rundfunk -- *German Radio* -- of August 31st, 1928, volume VI, page 240, Berlin) this author states that after about a year he investigated the physiological effects of ultrashort-waves that is, according to his definition, waves of very high frequencies between 1½ and 3 meters in length, of which I have indicated how I employ them in a 1924 communication to the Society of Biology (Note: It is on the inoculation and healing of the *Pelargonium zonatum*, as explained on page four of this writing). Prof. Esau then indicated that, since July 1928, he built a receiver of very short waves.

"About this subject, Professor Esau remarked that the main difficulties come from electronic tubes, for he was forced to use foreign tubes, particularly French ones, that are better fitted to the technology of very short waves. I must remind (the readership) that four years before him I studied and had built these special lamps for short waves, to be used in my Radio-Cellular Oscillator.

"I will also point out that an emitter of very short waves has recently been employed by Dr. Franz Seidel of Vienna for destroying bacteria, particularly to sterilize milk (see Les ondes ultra-courtes contre les bacteries -- *Ultra-short Waves Against Bacteria* -- in Radio Welt -- *Radio World*, January 27th, 1929, No. 4, page 108, Vienna)."

We have two definitely contradictory positions in the same chapter dealing with the same type of device:

(1st) In the paragraph translated under Figure 3 of this paper, Lakhovksy emphasized that the elements to produce ultrashort waves (under 2 meters) must be inside the tube. Figures 3 to 8 are dedicated to showing specific constituents for this special type of tube. Though he only speaks on Triodes, there is no reason to suppose he did not experiment with Tetrode and Pentode tubes (plus others of his own design not usually covered in publicly available technical literature).

(2nd) The formerly-indicated conditions change radically when he speaks of his experimental device employed to eliminate tumors affecting inoculated plants, this being the device of Figure 9 of this paper. Notice how the emitting elements in this apparatus are outside the vacuum tube; furthermore Mr. Lakhovsky claims that other, similar, devices developed by Professor Esau at Jena's Technisch-Physicalysches Institut are based in his "internal" design when the opposite is quite true!

(3rd) In order to make a better synopsis, I went back to read my copy of The Secret of Life, a translation into Spanish by M. Aquilar (Madrid, 1929). Therein are explained the basics of the Multi-Wave Oscillator but the Radio-Cellular Oscillator is NOT shown. It is reproduced in the 1924 communication to the Society of Biology. Neither source mentioned here reproduced the special vacuum tubes, with internal constituents, as explained in La Science et le Bonheur, the subject of this synopsis.

(4th) In Mark Clement's The Waves that Heal, the Multi-Wave Oscillator is explained as: "The apparatus consists of a transmitter and a receiving resonator, both arranged so as to set up an electromagnetic field in their immediate vicinity." The Multi-Wave Oscillator seems, in my opinion, derived from the "experimental receiver" of Figure 11 plus those of Heinrich Hertz (as I have indicated in my Some Free Energy Devices, a BSRF publication, quoting directly from The Secret of Life and introducing complementary information from other sources), rather than from the multiple-tubes shown in Figures 3 through 8 of this paper.

(5th) Considering everything explained from (1st) to (4th), it is my opinion Mr. Lakhovsky produced several types of apparati, along different lines of research, while pretending in his books that only a single-line of investigation was being pursued.

What are the reasons for doing this? There are many:

(*) Trying to disorient his fellow scientists by covering up his actual intentions and actions, so that the actual secret of the apparati rested with him.

(*) Trying to foil any attempt by the "organised medical profession" to steal his "secret" -- whatever this could actually be.

(*) Having discovered something that he wanted to keep for himself in the course of his researches. This is, in my opinion, the most likely possibility, for Mr. Lakhovsky's researches were well-received in Europe, South America and Asia before WWII began. Even more, he was outspokenly backed by men of science and Academies of great reputation and his enemies were very few (outside of the USA, of course....).

I do not mean to slander him and his researches, I just want to indicate the necessity for greater and deeper research into what he did from all possible sources of information.

VERY IMPORTANT NOTE

In order to facilitate the understanding of the illustrations, I have taken a few liberties to aid the non-French speaking associates:

(1) All the "lateral letterings" from Figure 3 to Figure 9 are of my doing, they did not exist in the original text.
(2) I changed into English, keeping the true meaning in translation, the writing in Figure 2.
(3) I made some additional lettering in some illustrations for greater understanding: L1 to L4 in Figure 1; I added the "C" in Figure 5, the same "C" was added in Figure 6; Finally, I added the "H" in Figure 8 for greater clarity.
(4) In French the letters "HT" are the abbreviation of "Haute Tension" that means in English "High Voltage"; in Spanish we also use the word "Tension" in electricity meaning "Voltage," as the French do. The letters "BT" stand for "Basse Tension" which I translate not as "Low Tension" but as "Filament Voltage" for this is the actual meaning.

UNITED STATES PATENT OFFICE

1,962,565

APPARATUS WITH CIRCUITS OSCILLATING UNDER MULTIPLE WAVE LENGTHS

Application November. 13, 1931, Serial No. 574,907

In France, May 2, 1931

7 Claims. (Cl. 250-23)

Fig. 1.

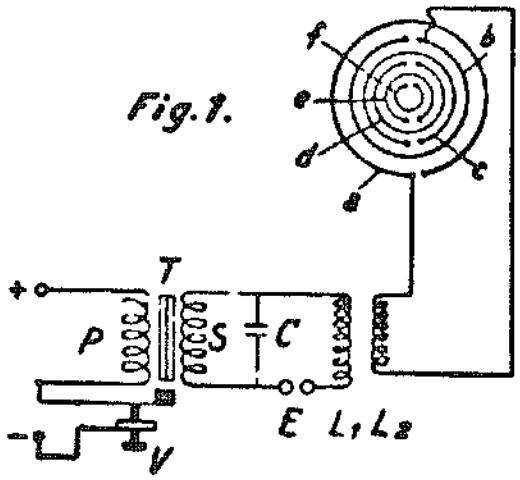

Fig. 2.

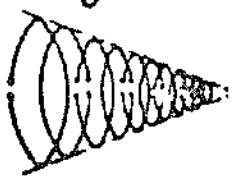

Fig. 3.

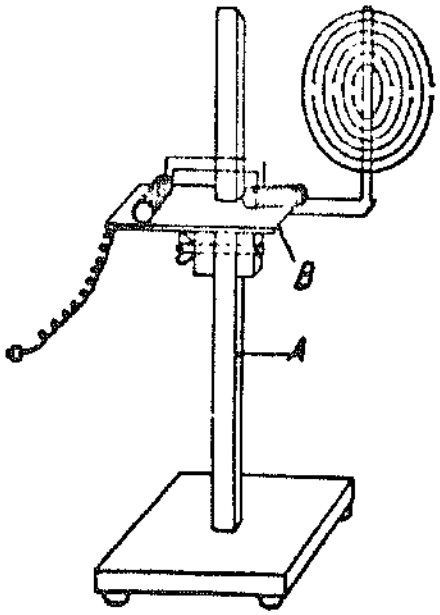

The present invention has for its object an apparatus capable of sending out simultaneously different wave lengths so that among these waves or their harmonics there is found almost always one or several capable of producing the best effect sought for any application whatever.

There is used for that purpose the property of open circuits having well determined wave length if they are excited by electric impulses emanating from discharges of any source.

The radiating part of the system, producing waves of various lengths, is therefore constituted by a certain number of concentric open rings of different diameters, which are maintained insulated by any appropriate means. These rings may or may not be terminated by small spheres forming capacities.

These rings may be arranged either in the same plane or in different planes so as to form any surfaces, such as portions of cones, spheres, paraboloids, ellipsoids, etc..., these surfaces being of a nature to concentrate the waves in a determined direction in the manner of a reflector, for example.

These rings may be fed by any producing device whatever of high frequency, for example, a combination comprising a trembler coil (or any other transformer) and a high frequency circuit provided with a self-induction coil and a capacity.

One of several points of this high frequency circuit is or are connected to the end of one or several of the rings forming the radiating apparatus. The other rings not connected are excited by induction.

The complete apparatus (coil, high frequency circuits, rings, etc....), may be mounted in a box or upon a small board capable of sliding along a guide or rocking so as to be able to be placed in the most convenient position.

In the accompanying drawing, by way of ex-

ample, not limitative, there is shown:

Fig. 1 a diagram of the system.

Fig. 2 the position of the rings in the form of a cone.

Fig. 3 the apparatus mounted upon a foot or base.

In Fig. 1 there is seen at T the transformer or coil (P the primary, S the secondary of this coil), V the screw of the trembler, C the condenser the discharge of which across the spark gap E produces oscillations in the self-induction coil L1, which in its turn acts by induction upon the self-induction coil L1; this self-induction coil L2 is connected on one side to the first exterior ring a, on the other side to the following ring b. It thus forms an electrostatic field of high frequency which induces oscillations in the other rings c, d, e, f.

As a modification, L2 may be suppressed and the rings a and b may be connected each to one of the ends of L1.

One of the ends, or even any point of the self-induction coils L1 or L2 may likewise be connected to any one of the rings.

Fig. 2 shows the arrangement of the rings in the form of a cone. The open circuits a, b, c....f can be constituted by solid conductors. They can also be tubular circuits, this being advantageous, since, for the same bulk, the radiating surface is larger. Finally, the area of the cross section of each of these various circuits can vary from one circuit to the other for instance, this area can decrease from the periphery (ring a) to the center (ring f) of the radiating system.

Fig. 3 shows the apparatus mounted upon a foot A along which it can slide, in order to be placed at any desired height and upon a hinge B which allows it to be oriented upon the horizon.

I claim:—

1. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters, the split ends being spaced from each other and terminating with small spheres.

2. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and terminated by small spheres forming capacities.

3. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits constituted by concentric insulated split rings of different diameters and arranged in one and the same plane the split ends being spaced from each other and terminating with small spheres, in staggered position as regards adjacent rings.

4. An apparatus of the type described comprising a base, a plate slidably mounted on said base, a support pivoted to the said plate, a series of open and insulated, high frequency radiating circuits mounted on the pivoted support, and a high frequency producing device for the excitation of the said circuits.

5. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits, said circuits being open, insulated, and having dimensions different from each other.

6. An apparatus adapted to produce electric fields of high frequency having multiple wave lengths, comprising a high frequency producing device, a series of high frequency radiating circuits arranged in the same plane, said circuits being open, insulated, and having dimensions different from each other.

7. An apparatus of the type described comprising a transformer, a high frequency energizing circuit fed by the said transformer and provided with a self-induction coil and a capacity, a series of open and insulated high-frequency radiating circuits having dimensions different from each other, and inductive connection between two of these radiating circuits and respectively each of the poles of the outgoing element of the high frequency energizing circuit.

G. Lakhovsky
INVENTOR

By: Marks & Clark
Attys.

June 13, 1944. G. LAKHOVSKY 2,351,055

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

Filed Nov. 21, 1941

Fig. 1.

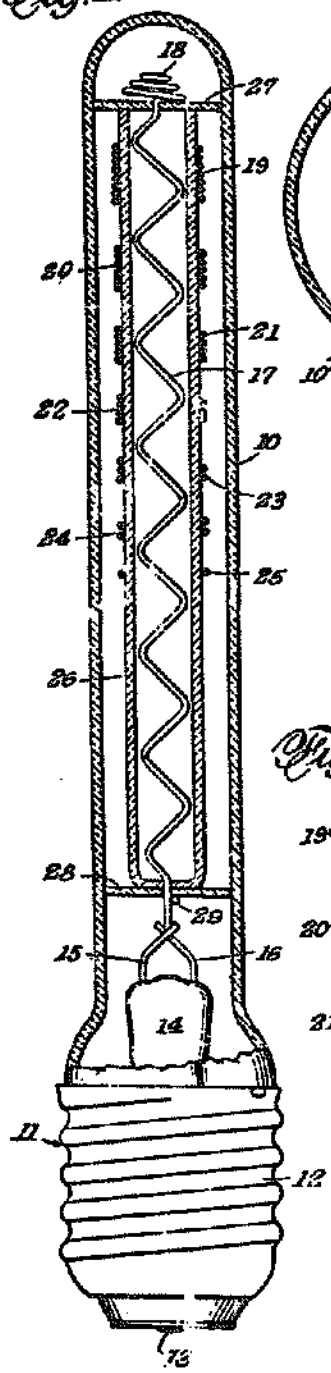

Fig. 2.

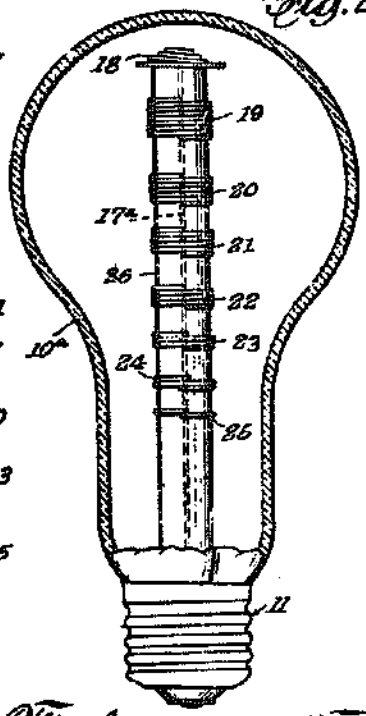

Fig. 3.

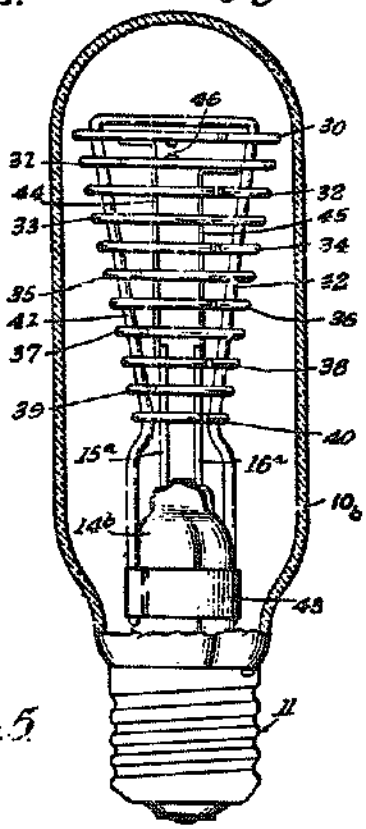

Fig. 4.

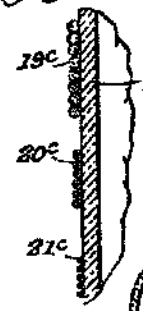

Fig. 5.

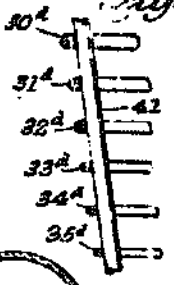

Fig. 6.

Fig. 7.

Fig. 8.

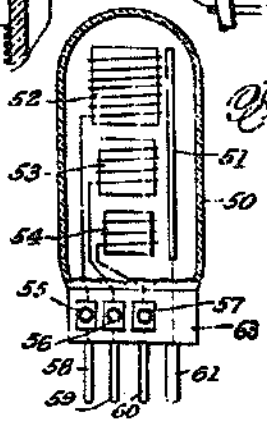

Fig. 9.

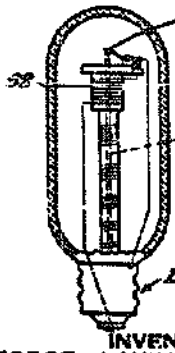

INVENTOR
GEORGE LAKHOVSKY

BY Chas M. Strauss
ATTY.

Patented June 13, 1944

2,351,055

UNITED STATES PATENT OFFICE

2,351,055

TUBE FOR PRODUCING MULTIPLE WAVE LENGTHS

George Lakhovsky, New York, N. Y.; Anne-Marie Louise Lakhovsky, administratrix of said George Lakhovsky, deceased, assignor to Henry S. Blum, Chicago, Ill.

Application November 21, 1941, Serial No. 420,606

11 Claims. (Cl. 250—33)

This invention relates generally to electric devices excited by electric impulses and more particularly to multiple wave length conducting and/or producing means. This invention has for its primary object the provision of such means disposed within a vacuum tube or a tube containing rare gas or gases.

My work over a period of more than 20 years has led me to the belief that there is great need for means conducting and/or producing multiple wave lengths which may be employed in many industrial and medical fields. Suitable apparatus for producing waves of various lengths is disclosed in my U. S. Letters Patent No. 1,962,565, dated June 12, 1934. Embodiments of this apparatus have been in use the world over. Because of the need for simplification in such apparatus so that it may be handy and easily used by persons lacking skill in electrical matters, I have concluded that by providing one unit which incorporates oscillation generating means and another in which the wave lengths are produced, the apparatus may be more universally used in the treatment of cellular life in therapy, in the aging or treating of liquids and in other industrial fields.

The present invention deals with those units, preferably combined with one another and constructed as a portable device and as stated above, has for its major object the provision of a unitary multiple wave length producing and/or conducting device in the form of a vacuum tube.

The present invention further contemplates the incorporation in such a tube, of means for varying the effect of wave lengths, or selectively employing the means therefor enclosed in or forming part of said tube.

This invention further seeks to provide a tube of the indicated type incorporating means for generating oscillations.

Another object of the invention is to provide a single unit which contains an oscillation generator, which produces waves of definite frequency, and further inductance means each permitting emanation of wave lengths of various values.

The structural features of my invention also form a material part of this disclosure, the objects and advantages being attained in structures such as shown in the accompanying drawing, which exemplifies the invention. The following specification, based on said drawing, more clearly points out the purposes and advantages of my invention.

In the drawing:

Fig. 1 is a vertical, partial sectional, partial elevational view of a tube incorporating features of my invention.

Fig. 2 is a similar view of an alternate form thereof.

Fig. 3 illustrates in a similar manner a modified form of my invention.

Fig. 4 is a fragmentary sectional view of a modification made in accordance with the invention.

Fig. 5 is a similar view of another modification.

Figs. 6 and 7 are sectional views illustrating types of wires used in either of the forms of my invention as shown in Figs. 1, 2 and 3.

Fig. 8 is a partial sectional, partial elevational view illustrating a tube incorporating a plurality of grids and selective capacity means for varying the effects of said grids.

Fig. 9 is a similar view of a tube, such as shown in Figs. 1 or 2 and incorporating oscillating or vibrating means.

In that form of my invention shown in Fig. 1, there is provided a sealed preferably transparent envelope 10 made of glass or like material affixed in the usual manner to a screw or Edison plug 11. The latter is conventionally provided with a shell terminal 12 and a central terminal 13. The support or seal 14 of the tube serves to hold wires such as 15 and 16 which connect to the terminals 12 and 13.

Connected to the wires 15 and 16 is a primary inductance member in the form of a loose coil 17 which may be disposed axially of the envelope 10, as shown. The upper end of said member 17 forms a tight wound coil 18 which serves to radiate the strongest induced wave lengths.

Surrounding the primary inductance member 17, there are arranged a plurality of separate coils of wire each being of different length and capacity. Thus, I provide a coil 19 having greatest capacity and successive coils 20, 21, 22, 23, 24, and 25, each having less capacity than the preceding coil. These coils 19 to 25 form secondary inductance means each permitting emanation of a wave length of different magnitude and value than the other.

I may support the secondary coils in several ways. As shown, I prefer to provide a dielectric member such as a glass sleeve 26 surrounding the primary inductance wire member 17 and to mount the secondary coils 19 to 25 on the outer surface of said sleeve, leaving the coil 18 exposed at the top thereof. In order to effectively support and centralize the glass sleeve 26, I provide spacing washers 27 and 28 of mica or the like, top and bottom, and provide a supporting cross-piece 29 on the lower portion of the wire 17.

The tube above described may be employed as indicated for the treatment of cellular structures by connecting it to any one of the rings in the electrostatic field of high frequency, such as shown in said U. S. Letters Patent No. 1,962,565, each of the coils 18 to 25 producing by induction a different wave length, as can be understood.

In the form of my invention shown in Fig. 2, the envelope 10*a* is somewhat differently shaped, and the wire 17*a* straight instead of arranged as an open coil. In other respects, the structure follows that described with reference to Fig. 1.

As shown in Fig. 3, there may be arranged a plurality of open rings 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, and 40 in frustro-conical form, for instance, with the largest of said rings at the top and the smallest one adjacent the bottom. I have shown said rings as supported, for instance, by glass posts 41 and 42, said posts being supported on the seal 14*b*, as by a band 43. I provide extensions for the terminal wires 15*a* and 16*a* and connect said extensions 44 and 45 to the upper ring 30 and the next lower ring 31, respectively.

The rings 30 and 31 may become the primary inductance members, whereas the remaining rings constitute the secondary inductance members as before set forth. Electric current conducted to the suitably spaced rings 30, 31 will cause a spark 46 to be drawn between the rings 30 and 31 providing oscillations emanating from electrical discharges therebetween and causing the radiation of waves of various lengths within the envelope 10*b* and affecting the remaining rings.

In Figs. 1 and 2, I have shown the secondary coils as formed of wires having uniform cross-section. Fig. 4 illustrates how such wires may be made progressively smaller in the succeeding coils 19*c*, 20*c*, and 21*c*, etc. Similarly, I have shown the rings of Fig. 3 made progressively smaller in Fig. 5, said rings being designated by numerals 30*d*, 31*d*, 32*d*, 33*d*, 34*d* and 35*d*, etc. In such various manners, the wave length producing effect of the secondary coils or rings may be arrived at.

The secondary coils or rings may be round or somewhat flattened wire as shown in Fig. 6 or tubular as in Fig. 7, offering a yet greater flexibility of design.

The devices of Figs. 1 and 2 above described may be incorporated in the system shown in said U. S. Letters Patent by connecting one of the rings *a*, *b*, *c*, *d*, *e*, or *f* with plug 11 of Fig. 1, since either terminal 15, 16 is in contact with primary inductance member 17. To this end a conductor (not shown) connects such a ring with said plug or socket.

In Fig. 8, I have shown a modification of the invention which comprises a vacuum tube 50 containing a plate 51 and a plurality of different wave lengths producing grids 52, 53, and 54. I connect each grid with a variable capacity device, such as 55, 56, and 57 carried by said tube 50 and preferably by its base support 62, whereby the grids may be selectively connected into an operating circuit (not shown) by means of the respective prongs 58, 59, and 60, and the plate prong 61. Heating or other exciting means may be incorporated in the tube in a well-known manner. This combination tube 50 is designed to replace a plurality of known tubes each operating with different and variable wave length effect, more exterior manipulation at said base support brings about change of the capacities 55, 56, and 57 and cutting in one or more of the grids 52, 53, and 54.

The effect of the spark as produced in the form of the invention depicted in Fig. 3 may be further utilized in Fig. 9 in which I also incorporate a vibrator 62 which produces electrical oscillations by a spark intermittently generated between the end of the primary inductance member 17*d* and vibrator armature 64. In other respects the structure follows that of Fig. 1.

It may be noted that any type of spark producing or oscillation generating means may be substituted for the vibrator shown. The tubes shown in Figs. 3 and 9 may be used in the manner described for Fig. 1 by connecting one terminal of the base as set forth to produce an induction effect. These tubes may be also connected across both terminals with a suitable potential to obtain the spark effect.

From the foregoing it may be seen that I have provided tubes in various forms for the purpose of generating and conducting multiple wave lengths. Other forms of the invention may be produced within the spirit and scope of the invention as claimed.

Having thus described my invention, what I claim as new and desire to be secured by Letters Patent, is:

1. A device of the character described comprising a vacuum tube having an envelope and base, primary inductance means, and a plurality of separate secondary inductance means of different length for radiating waves of various lengths extending above said primary inductance means, all said inductance means being arranged within said envelope.

2. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said envelope, and a plurality of secondary inductance members spaced apart and independent from each other each member surrounding a respective portion of said primary inductance member and within the field of influence thereof.

3. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member axially arranged in said envelope, and a plurality of secondary inductance members each surrounding the primary inductance member and within the field of influence thereof, each of said secondary inductance members having a different wave length effect than the others.

4. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings.

5. A device of the character described comprising a vacuum tube having an envelope and base, a primary inductance member comprising a pair of split rings in inductive relation, and a plurality of secondary inductance members each comprising split rings, said latter rings being arranged in different planes and being of different length to produce a different wave length effect.

6. In a device of the character described, means for producing multiple wave lengths comprising a wire member, enclosing dielectric means for said member, and a plurality of separate wire coils of different lengths on said dielectric means and in the field of inductance of said wire member.

7. In a device of the character described,

means for producing multiple wave lengths comprising a wire member, enclosing dielectric means for said member, and a plurality of wire coils on said dielectric means and in the field of inductance of said wire member, each coil extending over said wire member and having a different number of convolutions than the others.

8. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings.

9. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others.

10. In a device of the character described, means for producing multiple wave lengths comprising two split rings in inductive relation, and a plurality of split rings in inductive relation to the two split rings, the plurality of rings being of smaller diameter than the mentioned two rings and each progressively smaller than the others, all of the rings being arranged in frusto-conical disposition.

11. In a vacuum tube having a primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member and secondary inductance members, a vibrator arranged in the field of influence of said primary inductance member for affecting the induction of said secondary members.

GEORGE LAKHOVSKY.

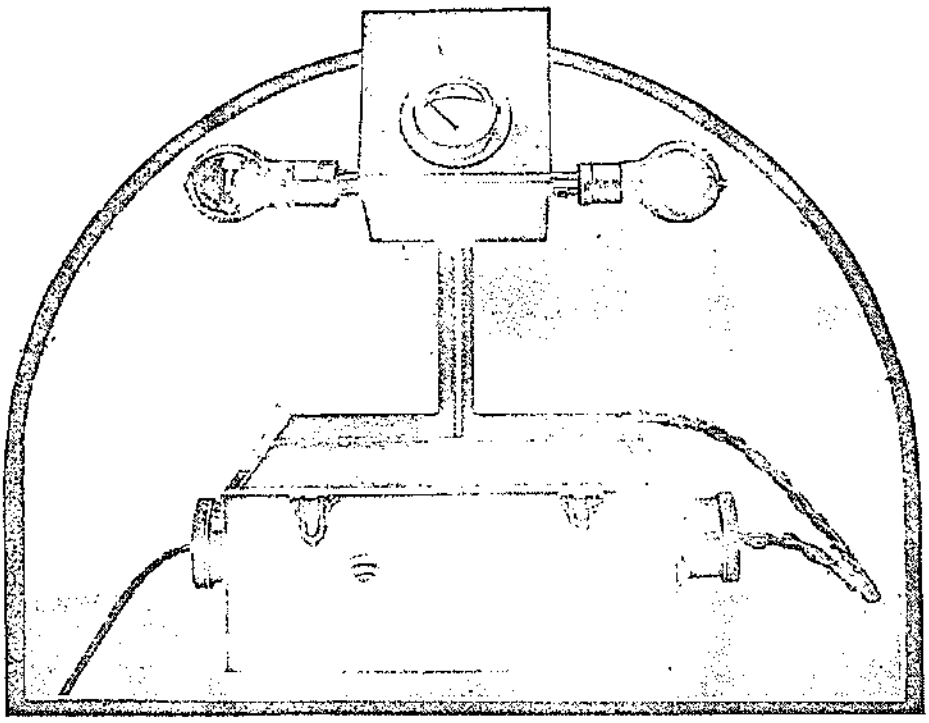

The two-meter oscillator used by the author in his experiments with the supply box containing the necessary controls and transformers.

Picture from *Radio News* for February 1925
Curing Cancer with Ultra Radio Frequencies
by George Lakhovsky

LAKHOVSKY'S VIBRATORY CIRCLE

Author Unknown, Source: BSRF files
Translated from the German by Bodo Capeller, 1988

"We owe to magic all progress in physics and chemistry."
(Jules Lermina, 1915)

The Paris professor with the Russian name Georges Lakhovsky claims to capture, with so called open vibratory circuits (circuits oscillants), cosmic waves and pass them on to humans (neck antenna) and plants. Healing of people has been verified by French and Italian medical practitioners, healing of Cancer injected plants has been proven through photographic records.

The vibratory circles are manufactured from heavy copper wire with a diameter of 5-10 millimeters. Those wires 5-8 millimeters in diameter had a more pronounced effect than the much thinner variety. The spiral (of the open ended circle), which can be single or double, is guided around the plant and is supposed to be insulated against its support by "Ebonit" (1).

Instead of copper wire medical practitioner Dr. Ernst Busse (Garmisch, Germany) recommends the use of thin copper tubing: "because of the short wave length of cosmic vibration only the surface effect (skin effect) is effective (that means electricity is only present on the surface of a conductor, not in the middle) which requires the use of maximum surface area. Besides this the tubing is easier to work with and has less weight. (Private Correspondence 1/10/1953)

Helmut Friedensdorff (Berlin, Germany) did report already in 1932, from himself as well as others, on the effectiveness of an open vibratory circuit against lumbago among other ailments. He inserted a simple isolated copper wire into surgical tubing and positioned it at the problem spot in a manner that both wire ends did not touch (2).

Canon Smythe of Great Britain did proceed in a similar manner: "The only tools required are a one meter length of flexible electrical wire and a sidereal pendulum. The insulation is removed at both ends for a length of 2 centimeters, the wire is stripped and the wire strands are removed except a single strand. Then the wire is laid out on a table and the pendulum is positioned over the wire ends. It will rotate over the positive end in a clockwise motion, over the negative end in reverse. Then one proceeds to make a knot at the negative end for identification purposes. It should be positioned on the left side of the body or in the vicinity of the leg, the bare wire pointing to the left. The wire may be installed over the clothing and can be braided or fastened with safety pins, the ends should point into the proper direction.

"Arthritis in one toe should be treated by using the wire like a stocking holder wound around the leg where the knotted end will point to the left. The author makes no claims for the healing arthritis but reports a lessening of pain.

"With severe headaches the wire is wound just above the eye level around the head so that the negative end rests over the left temple.

"Severe coughing is treated with one wire around the throat, another one around the abdomen."

A just started cold is removed by our associate in a few hours with two wires, one with the positive connected to the negative end of the next wire joined as a 2 meter long wire. "I wound the wire over the shirt under a sweater around the chest until I reached under the arm pits and made sure that the negative end is on left side of the chest pointing to the left, the positive end pointing the opposite way."

Smythe published this in a paper many years ago called "The Other Half of Medicine". He is supported by the research of a recently deceased friend, Dr. Martin of Airaines, France who had been promoted to the medical faculty in Paris in 1932 with a dissertation "Diagnostic Radiesthesique en medecine veterinaire" under the tutelage of professor Nathering--without an examination! In 1935 a Dr. Girard presented a similar thesis before the University at Lyon.

Medical practitioner Arnold Mannlicher (1880-1958) from Salzburg carried in his rear pocket an open vibratory circuit which also acted as a cell detector.

Vibratory circuits proliferated after the announcements by Lakhovsky's discovery as "throat antennas, broadcast jewelry and healing chains" in the market place. I cannot say at the moment if they were of the open or closed kind. Apparently between the two kinds exists a fundamental difference in their effectiveness, open circuits reduce the tension within the body, closed circuits raise it. A closed broadcast chain can easily be transformed into an open one when it is opened and is closed with an insulator inbetween (rubber band, silk thread).

The open circuit is nothing new at all. Dr. Beck, former head of the municipal children's clinic in Bayreuth says: "the open bronze rings of the Hallstadt area from grave sites can be understood as protection against radiation effects very similar to the rings worn by the Negro tribes around the arms, legs and throat." The ancient Germans wore "broadcast jewelry"--in order to coin a modern word--an open solar spiral. Dr. Heermann has revived this. He writes: "invigorating liver and intestines the solar wheel acts like a plated iron spiral with the windings running from the center clockwise."

Smaller--sown into green material--is my usual aid in stomach ulcers and swollen glands. Underneath his illustration (not shown) the researcher explains: "a spiral ending growth rays to the abdomen" (3).

The never tired Dr. Busse since 1954 has also tried out open rings beside vibratory chains and belts. Earlier he replaced acupuncture needles with metal foil band aids and states now in a letter dated 4/19/1954: "instead of metal foil one may arrive at the same effect by wearing open copper rings on certain fingers and joints. When you put a ring that is cut open or manufactured from heavy copper wire on the corresponding finger an immediate change of pulse at the radial pulsation can be observed".

One of his associates who experimented with these open finger rings was surprised by the achieved results.

I am very much indebted to this versatile medical practitioner.

Because copper rings are a tuner (strengthening, invigorating) it was required to find a second metal which reduces organic functions. It turned out to be aluminum. On closed rings it was already reported in the chapter "Amulets". As far as the application of aluminum is concerned the welder Herbert Bauer (born 1921) from Freiburg, Germany has manufactured many years ago the so called "Zelemente".

According to the description it was recently manufactured from a three metal alloy which reminds of the "seven metal (electrum magicum)" of Hermetic fame. We are dealing here with closed chains that are supposed to protect from dangerous radiations of technical and cosmic nature and are therefore named radiation protective antennas. They look flat and are meant to be moistened in the morning and evening.

Whatever the effect is of the vibratory circuit on the world of plants has been shown in 1905 when sick elm trees were healed on a Hamburg street.

The Vienna engineer Lambert Binder (born 1905) caused, during a growth experiment in 1944 on orange trees, accelerated growth by surrounding the tree with an isolated wire spool.

R.E. Esspiau tried out in 1954 the following experiment with the Lakhovsky antenna arrangement. He connected the first on a three stalk head of cabbage to free standing antenna, the second to ground the third one to water which was replaced every 24 hours. In less than a week the first buds began to form, within four weeks other stalks were formed and developed leaves while a control plant withered away (4).

PHOTO TEXT:

Illustration A: This illustration shows a Lakhovsky experiment on a Cancer infected geranium plant. The cancerous growth is clearly visible. Pelargonium zonatum (Geranium) inoculated with Bacterium tumefaciens on April 10th, 1924 and photographed June 6th, 1924. It will be observed that the stem of the plant bears a massive tumour.

Illustration B: An astounding discovery by Prof. Lakhovsky: a free standing antenna ring manufactured from copper that surrounds the geranium caused the plant to drop the cancerous growth (resting on the rim of the container) and made the plant whole again. Photographed June 1925.

Illustration C: The test plant three years later. The antenna ring has completely healed the plant and protected it from other damage. To the side are two unprotected similar control plants of same age that became victims of the same disease. Photographed on March 13, 1928.

Picture credits: These three illustrations are designated tables II, V, and VII in Lakhovsky's Secret of Life.

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(4) "La Radiesthesie pour Tous", December 1954, Paris. Schroedter, Willy: Kosmische Strahlen und vitale Schwingungen, "Mensch & Schicksal", #5, 5/15/1953, Villach, page 7

Illustration A

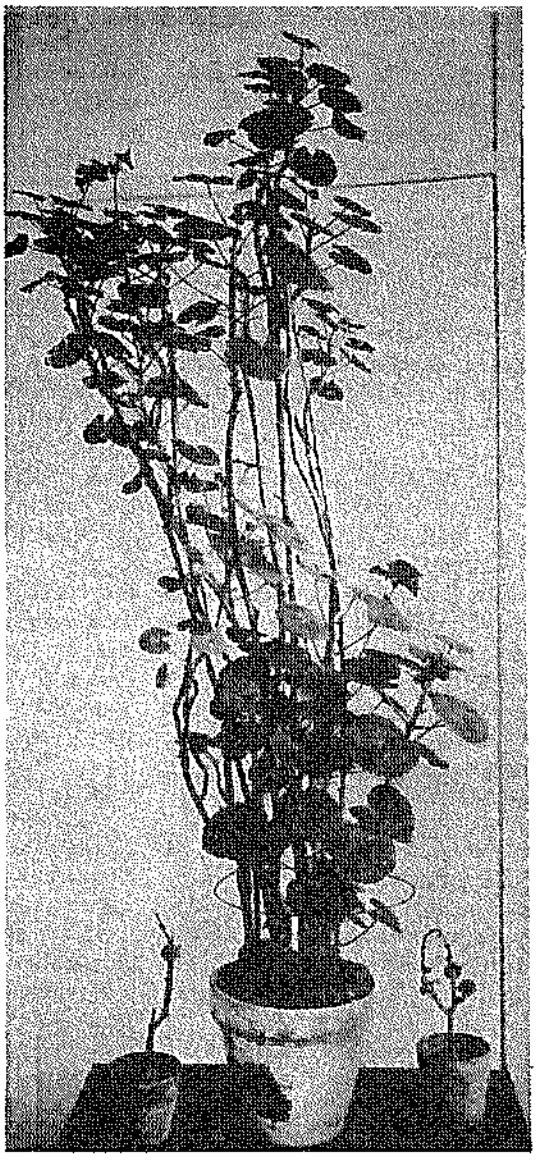

Illustration C

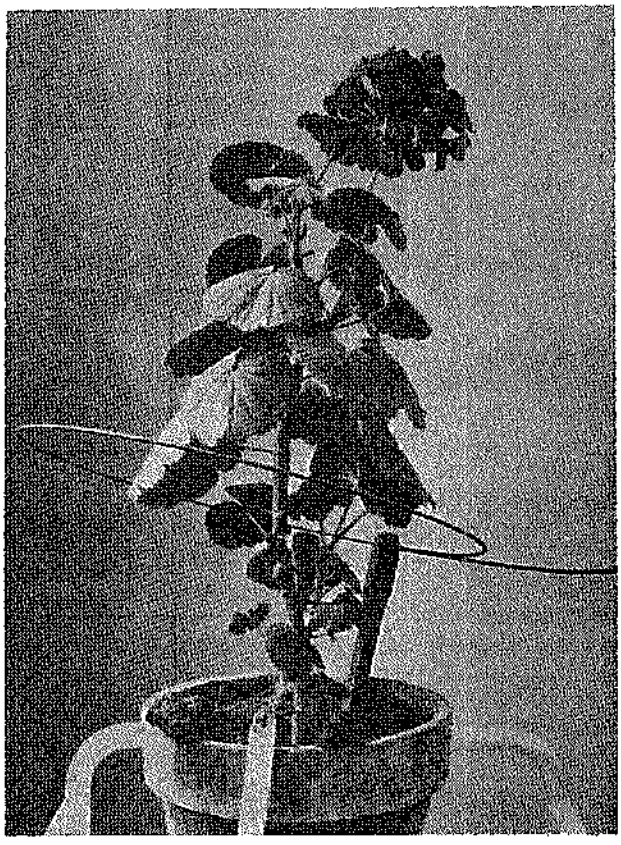

Illustration B

THE RUSSIAN LAKHOVSKY REJUVENATION MACHINE

by Bob Beck

from the November 1963 Journal of Borderland Research

In September 1963, Dr. L.O. Anderson, Anderson Research Center Director and BSR Associate, phoned me about a "marvelous electronic machine" purported to "cure" almost any human ailment. I've looked into dozens of these "modalities" every year; so with extreme skepticism I gathered instruments and took off to check another possible hoax.

I found a heavy spark-gap Tesla Coil inside a four-foot cabinet. This console was rigged to circular "antennas" and was partially shielded inside a home-built Faraday cage in the living room of Dr. Anderson's friend. It hadn't functioned in over a decade, and had been given up by some twenty-odd medical instrument repairmen and engineers as unfathomable.

The machine, which had no nameplate or other identification, turned out to be a Lakhovsky "Multiple Wave Oscillator", or MWO. Fortunately the present owner had found patents and two books describing its operation. We were able to reconstruct the circuits and after several hours had it operating perfectly. The machine was not a hoax.

Lakhovsky did his research prior to world War II and died in 1942. No infringement can be involved in duplicating Lakhovsky's work, since his U.S. Patent #1,962,565 expired in 1951 and is in public domain. I have found from the book **The Waves that Heal** by Mark Clements that MWOs are extensively used in hospitals in France, Germany and Italy, and although tested in a New York Hospital with fantastic success, MWOs remain practically unknown in the United States.

MDs testing Multiple Wave Oscillators reported up to 98% cures of terminal cancer, arthritis and other "hopeless" conditions. Case histories were complete with before-and-after photos. Often rejuvenation was demonstrated, not only in human beings but in plants and animals as well!

So, on Sept. 18, 1963, I designed and built a modern MWO based on Nikola Tesla and Lakhovsky's original work and patents. The transistorized instrument fits into a brief case and weighs under 14 lbs. Experiments with the MWO on some eighteen volunteers have demonstrated almost unbelievable results. At this writing, Oct 20th, every single subject, including myself, reports fantastic gains.

My mother, age 72, who has suffered from hypertension and glaucoma for many years, measured absolutely normal blood pressure the morning after her first treatment. And the eye tension, tested by her MD the week following, had dropped to a lower point than in the previous two years. Another woman with a long-standing back condition says she was permanently relieved in one 15 minute exposure. An asthmatic with chronic bronchial complications claims he is now symptom-free after two exposures and her husband with a bad dermatological condition of seven years history appears to be very definitely improved. Perhaps the most dramatic is Mr. N.V.C. who had broken his leg skiing last December. Because of an old polio complication the broken leg had never healed and flesh surrounding the fracture was in a very poor, waxy condition. After one exposure he phoned to say he had regained feeling in the area. The next day we made an "after" photo slide of nearly normal tissue.

A friend suffering allergies of long standing says she can now eat anything and her MD admits he as startled by her youthful appearance and new vitality. The Lakhovsky literature illustrated many such rejuvenations as an unexpected side effect of cancer cases. Subject's wrinkles disappeared along with the tumors!

THEORY OF OPERATION

Lakhovsky pointed out that all cells capable of reproduction contain in their nuclei "filaments" of highly conductive material surrounded by insulating media. This filament, which may be the RNA-DNA complex, is always in the form of a spiral or helix -- in other words, a coil. Therefore, each will react as a tuned circuit if its resonant frequency can be approximated by an external oscillating coil.

Lakhovsky didn't carry this to it's conclusion; however, I postulate that by exciting the nuclei with electromagnetic energy a "charge" can be induced by the long established principle of electromagnetic induction. This demonstratively raises the energy level and perhaps the vitality of every cell in the field simultaneously. Since each cell is an individual, and of slightly different physical dimensions, the exciting wavelengths must be multiple, and must span a broad frequency spectrum. Diathermy machines, limited to crystal-controlled single frequencies in the 27.255 MC region, can do nothing but heat the tissue; and yet this approach, abandoned by Lakhovsky in the 1930s, can still be found in "modern" doctor's offices!

The Electromotive Force (EMF) produced by the MWO and induced in the cell nucleus, can raise the cell's metabolic rate by Electrolysis, and perhaps jog the RNA-DNA "memory" and reproductive capabilities to their level at an earlier, younger age, thus the rejuvenation. Even more subtle changes might be postulated, such as magnetic "progression" effects as evidenced by heavy water in magnetic fields.

By contrast, any chemical taken into one's system by mouth or by injection -- such as vitamins, food or medicine -- must first be absorbed in proper solution and ratio with unknown tract elements, then be transported by the blood to affected tissue only to be possibly rejected by the target areas.

Perhaps in cancer the EMF induced by the MWO raises the vitality and memory of marginal cells to normal reproduction levels. In the case of other disease, perhaps a cell's given higher energy levels can more readily throw off affliction.

A WAVE FOR EVERY BODY CELL

The Multiple Wave Oscillator described here radiates a bandwidth of radio frequency (RF) energy from the audio frequencies up beyond microwave frequencies. By actual measurement with standard field strength meters, this vast bandwidth of frequencies and harmonics can be shown. In fact, a bluish glow of "brush discharge" surrounds the antenna when operating. A fluorescent lamp held anywhere within several feet of the subject glows brilliantly. Within this multiple-wave range of frequencies, every cell in the body can find its ONE resonant frequency and absorb energy at its own natural wavelength.

Obviously the Electrostatic energy cannot penetrate the body. This is known as the "skin effect". However, the Electromagnetic component of the energy can and does permeate and will induce an EMF in each cell. It is precisely this energy to which Lakhovsky attributes his almost miraculous "cures".

A word of warning, although no deleterious side effects have ever been reported for human reactions, the MWO has input power exceeding 35 watts. It radiates RF interference over a bandpass of 15 Kilocycles to well beyond 250 Megacycles. The Federal Communications Commission has stiff penalties for unlicensed transmitters and radio and TV interference -- not to mention making all your neighbors very unhappy. We operate our machine in a shielded room, and the battery input prevents RF interference from feeding back into the power line.

The deluxe MWO diagrammed here can be built by any intelligent 16-year old with readily available electronic parts. I do not plan to build, manufacture, sell or otherwise exploit this device, as my interest is purely in

research. Several Associates given this circuit have successfully constructed MWOs. We would certainly like to hear from any BSR Associates who undertake this project, but please do not communicate until after building the unit. I cannot correspond over details which any intelligent person would be able to thresh out with his or her own technical friends.

At one stage we had planned constructing a much higher-powered unit but the results with the "portable" are so gratifying that Model Two was shelved. Extensive tests are scheduled with plants and animals, and every effort is being made to remove any element of "suggestion" from results. A physician friend is cooperating with the project by sending a few "problem" patients for test. It is much too soon, however, to make a finished statement concerning the MWO's potential. No cures can be claimed even if obviously demonstrated, since our laws are controlled by medical unions forbidding the use of the word except by MDs. But I have satisfied myself with nearly twenty miracles in these few weeks of tests that the MWO might well be the most promising device to come to light in many years.

I have one request, that no one building this device ever be tempted to charge a fee, donation, or reimbursement of any kind whatsoever for its use. I feel most strongly that any device potentially helpful to suffering humanity should be available completely free of charge to anyone needing it.

CONSTRUCTION TIPS

My MWO is built on an 11 x 11½ inch plastic panel. Components extend 3½ in. below this, so the unit fits nicely into a small attache case. The 6 volt battery was a Sonotone lifetime Nickel Cadmium unit; however, five war-surplus NiCads (1.2 v each) wired in series would be less expensive.

My first unit used a transistorized driver for the Tesla Coil but the Ford coil works equally well, is far cheaper, but has the disadvantage of making a buzzing noise. The Ford Model T coils may still be available at Pep Boys stores in California, or can possibly still be purchased from J.C. Whitney & Co., 1917 Archer Ave., Chicago, IL 60616. The spark gap was made from salvaged tungsten relay contact points about 1/4 in. in diameter. (Chevrolet Six timer points, 1950, do very well). The relay spring arm can be tuned by a Nylon 6-32 screw adjusting its natural spring tension. The gap must be carefully tuned for maximum output for every individual, since the subject's absorption seems dependent on his body fluids and weight. *Adjust for maximum sparking at random times and intervals between several of the inner antenna rings.*

The automatic timer, zero to 15 minutes, the meter, the internal battery charger, the RFC circuits, etc. are all simply conveniences and may be left out of the circuit without in any way subtracting from results. By not building in these deluxe features, the entire MWO will cost much less to build. Use plastic instead of metal screws around the high voltage coils. High voltage capacitors can be tracked down at surplus stores or well stocked electronics parts sources. The Tesla Coil must be hand wound as it is not available commercially.

We have determined experimentally that a workable pair of antennas, radiator and resonator, can consist of 16 concentric rings, ranging from an outside diameter of 10-3/4 inches down to 1/2 inch. These were constructed by cementing a one-foot square of

BECK ADAPTATION OF LAKHOVSKY MULTIPLE-WAVE OSCILLATOR, U.S. Patent #1,962,565

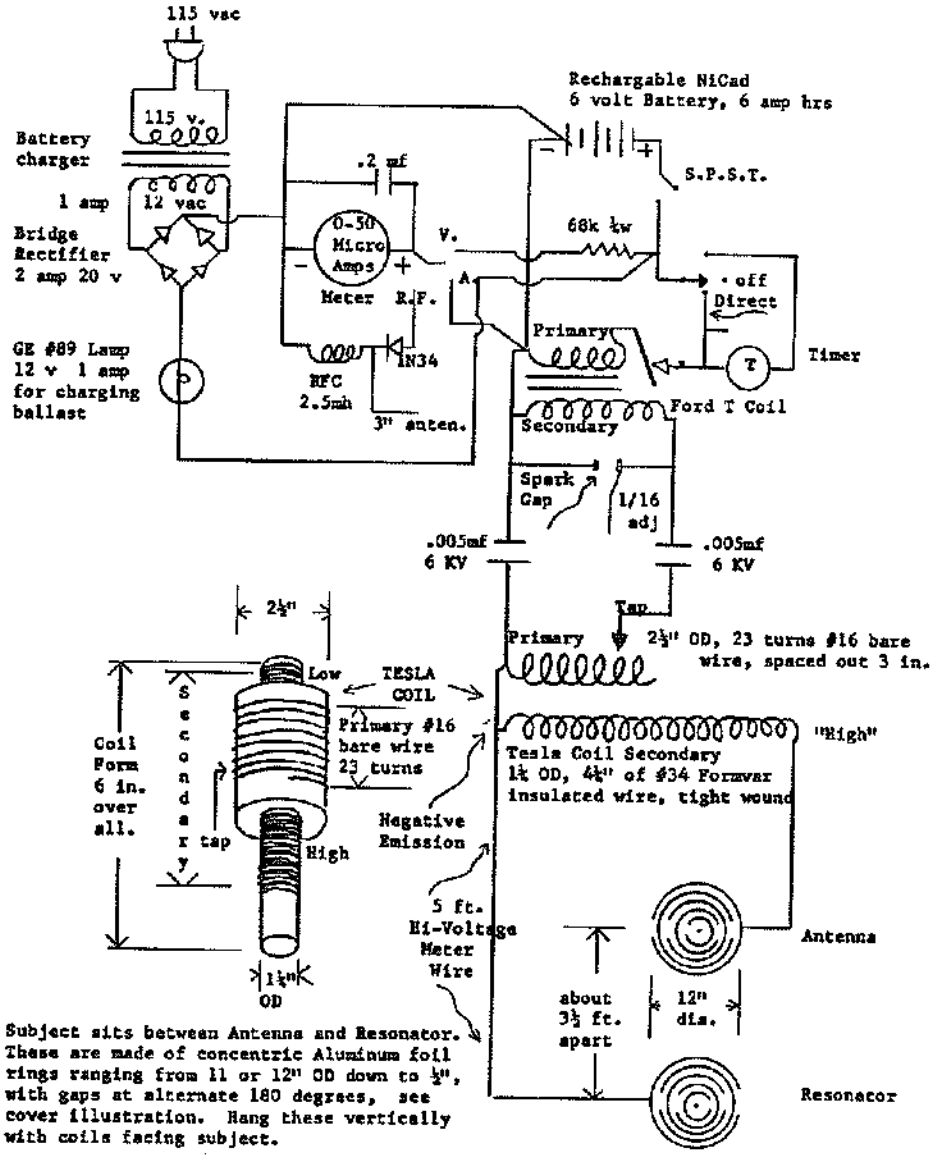

Subject sits between Antenna and Resonator. These are made of concentric Aluminum foil rings ranging from 11 or 12" OD down to ½", with gaps at alternate 180 degrees, see cover illustration. Hang these vertically with coils facing subject.

Original cover providing template for aluminum MWO antenna.

Reynolds kitchen aluminum foil to an 11-inch square of thin fiberglass. The outline of each set of circles was carefully scribed with a sharpened compass, razor or Scripto blade. By scoring or cutting the aluminum foil was cut through to the plastic backing and the waste area strips pulled away before the cement hardened. Excess cement was removed with a solvent. The gaps were then cut with the razor. Note that gaps are alternated in position each 180^{0}, as per drawing on original cover page. This was drawn from an actual antenna and you can set your compass distances for each ring from it. Keep gaps between inner rings narrow to encourage random arcing between rings. Trim the corners from the gaps of the three or four outside rings to discourage fixed arcing at these places. Also be sure to clean away any bits of foil between rings. These also will cause fixed arcing.

In use, the ring second from the outside is connected to the high side of the Tesla secondary. (Refer to "antenna terminal" on original cover page illustration) This is the radiator coil. The arcing from this ring to the outside ring causes the "shock excitation" of the fourteen other antenna elements. Since each radiator is of different diameter, the array spans a broad, multiple-wave segment of the Radio Frequency (RF) spectrum. The other antenna element, called the Resonator, is connected with a five-foot, high-voltage meter wire to the ground side of the Tesla coil secondary.

PUTTING THE MWO TO USE

The antenna and resonator are suspended from non-conductive supports about three feet apart, such as wooden chairs with no nails or screws. The subject of the experiment, preferably with all metal removed from their person, including belt buckles, zippers, hooks, fasteners, coins, hairpins, earrings, rings, etc, is seated on a wooden or plastic rest between the antenna and resonator (hung vertically, the foil rings toward the subject. Unless the Resonator is powered by a separate Tesla Coil it will not arc. Metal on the subject will produce eddy currents in the field of radio frequencies, reducing their effectiveness.) Experiments should last from nine to over 15 minutes. A four-day interval between experiments is recommended. Four such experiments over 16 days should suffice to demonstrate anything.

Warning, two-inch sparks can be drawn from antenna; so keep subject at least three inches away. If touched a mild and harmless sting can be felt. HF effects can be demonstrated in a darkened room by holding a fluorescent lamp anywhere near the subject. The RF energy will cause the lamp to light although no wires are touching it. Field strength measurements read several watts of power from the audio frequency spectrum to beyond 250 megacycles.

The illustration to the right is from Clement's **Waves That Heal**, Lakhovsky's illustration of a living cell. "In the centre is a twisted filament which, possessing self-inductance and capacity, constitutes an oscillating circuit. The similarity to a short-wave circuit is manifest; the filament shown here oscillates like a coil having a very small number of spirals." He quotes Lakhovsky: "Every living being emits radiations", and adds: "the living cell can thus play the part of a transmitter or receiver of exceedingly short radio-electric waves which give rise to high frequency currents in the circuits of the cellular nucleus."

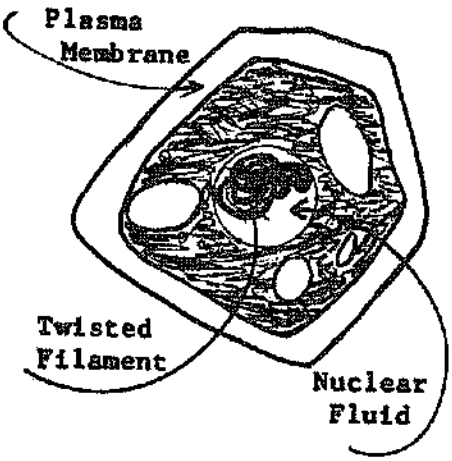

THE FOLLOWING PHOTOS were kindly furnished by Borderland Sciences Research Associates from their own experimental work with the MWO during the years of 1964 and 1965.

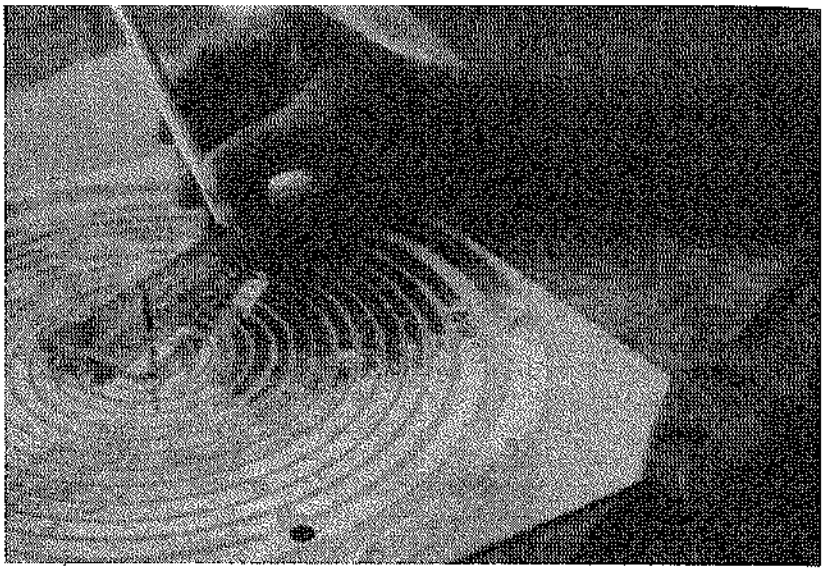

THE PRINTED-CIRCUIT ANTENNA foil is glued to an 11-inch square of 1/16th inch thick fiberglass. Spray one surface of the fiberglass with Hobby Shop spray glue and stretch smooth-surfaced kitchen aluminum foil across it. Press the foil on firmly from the center out, smoothing out repeatedly with a soft cloth. Any remaining air bubbles can be released through a small pin hole. The circles are more easily cut if you make a jig with a 16-inch square of plywood with a headless nail for a center post. Using the antenna pictured on the front cover as a pattern, mark and notch an old ruler or stick where each circular cut is to be made. This marked guide ruler is mounted over the antenna on the plywood jig as shown at right. The foil-covered surface is then turned clockwise with the left hand against the Scripto blade held firmly in the successive notches by the right hand. Be careful to cut through the foil. If you don't, in lifting the cutouts afterward, you may also lift or tear the rings. If a metal grommet is placed in the terminal hole in the second ring this will prevent the high-frequency arc from burning the foil and fiberglass during operation. Copper foil can be used for the printed-circuit antenna rings but deposits build up on it from arcing, wherever it occurs. There is no deposit buildup on aluminum foil.

THE RADIANT ENERGY of the MWO is obvious in this three-minute time exposure during operation in a darkened room. Note the brush discharge of etheric energy all along the edge of the outside ring, going three or four inches. Look at the random arcing between the antenna rings, down to the eighth ring! This antenna received full power by being mounted on the MWO case, directly at the positive end of the Tesla Coil.

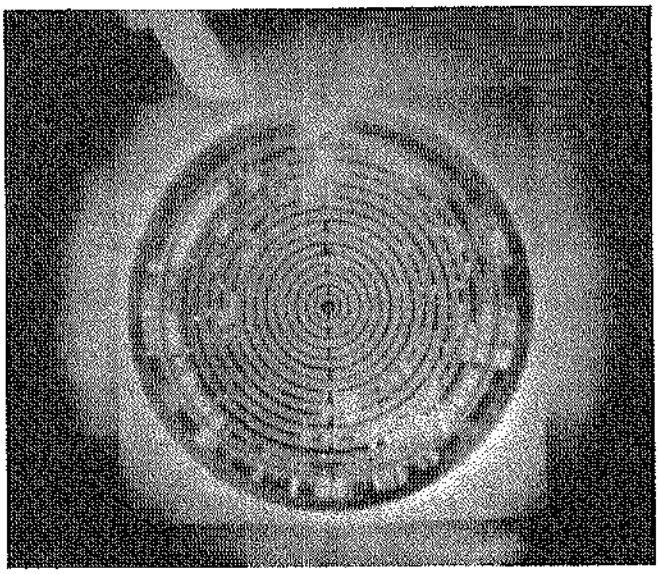

AT LEFT IS A TYPICAL EXPERIMENTAL SETUP, with a chair for "guinea pig" between antenna and resonator. Beck's original equipment called for an 18-inch lead wire from the positive end of the Tesla coil to the antenna. It was found that there was too much loss of power along this wire. The later development shown above has the MWO set upright, with the antenna mounted directly against the positive end of the Tesla Coil in the case.

THE INTERIOR HARDWARE LAYOUT is shown at right in this photo of another MWO, neatly packaged for an attache case. A. The five Ni-Cad batteries, 1-1/4 volts each at full power. B. Timer. C. Tesla Coil. D. 115VAC transformer (for house current operation if desired). E. Spark-gap using modified Chevy Six points. F. Model T Ford Coil. G. Battery Charger.

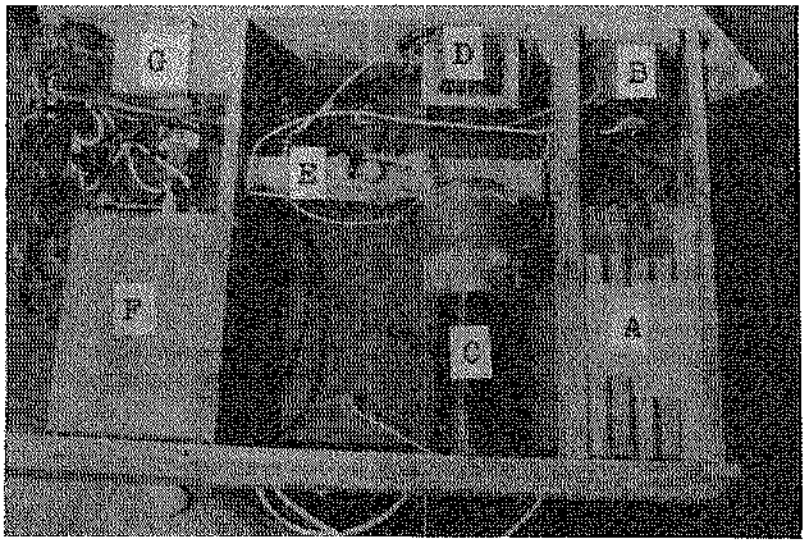

RECTIFYING THE FORD COIL OUTPUT using a 1B3GT or 1G3GT high-voltage tube.

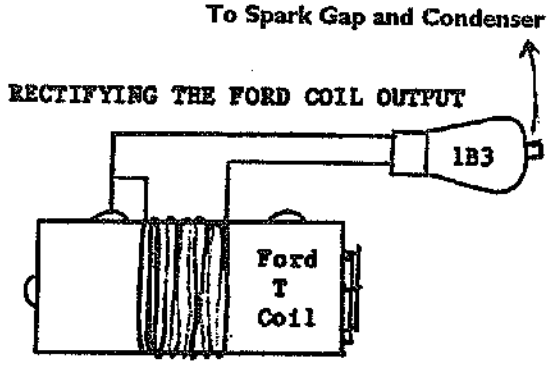

Wind 15 or more turns of fairly heavy insulated copper wire around the middle of the Model T Ford Coil. One lead from the winding goes to the Hi-voltage output of the Coil, and to pin 2 or 7 of the 1B3 tube. The other lead goes to the other pin, as only two pins of the tube, 2 and 7, are used in this hookup. The souped-up or rectified voltage is drawn off the top of the tube to the spark gap and condenser.

MODIFIED VERSION OF THE BECK TESLA COIL

115 volt house current into the black leads of the 6 volt transformer, one green lead to the T Coil negative terminal, the other to an SCR 45 amp Diode to make direct current to the Plus terminal of the T Coil. A 12-volt current to the T Coil heats it up and will not increase the spark. Radio Shack's 6.3 volt, 3 amp transformer does very well for a power supply.

Wrap 16 turns of insulated hookup wire around the middle of the T Coil and feed to pins 2 and 7 of the 1B3 rectifier tube. Feed the plus output of the T Coil into pin 2 or 7 of the 1B3 also.

Hi-voltage from the top of 1B3 goes to Spark plug. Widen gap of plug to 1/8 inch or more for maximum output of Secondary coil to Antenna.

One 10,000 WVDC (Working Volts Direct Current) commercial-type Capacitor, on the plus side, will do very well in this circuit. Capacity can be from .0015 to .005 microfarads.

Beck's tunable Tesla Primary called for 20 or more turns of bare wire for his movable contact but experience shows that 16 turns of insulated #19 wire for a Primary and adjust one turn more or less for maximum spark at Plus end Secondary coil. This is 4-1/4 inches of #34 insulated wire, or 4-3/4 inches of #32 insulated wire, for 420 turns more or less on 1-1/4 inch coil form 6 in. long. The Primary is wound on a 2 or 2½ in. coil form. There should be heavy insulation between Primary and Secondary to prevent power-loss arcing between Coils.

REMEMBER, the goal is a thin blue, or blue-white spark at least 3/4 inch long at the plus end of the Secondary. When fed into the center hole of the Antenna it should light up like a Christmas tree, with arcing between every ring. Feeding the coil output into the center hole gives more power to the shorter wave lengths. We get plenty of the longer wave-lengths from other electrical apparatus and from power lines.

This coil would be a good high-frequency power supply for Kirlian Photography.

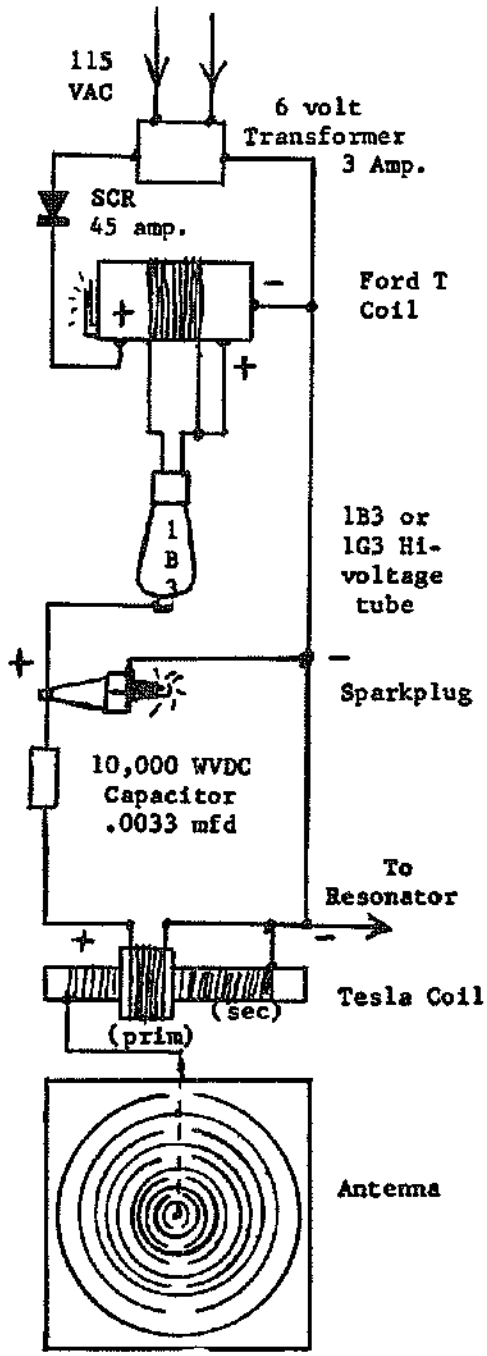

THE TRANSISTORIZED MWO

By Gerald W. Steele

Here is tentative information on the solid-state MWO. I say tentative since this is the 3rd version I've built. The first used an automobile spark coil for T2 but I found this undesirable since it lacked higher frequency harmonics. Even worse, the lower frequency ones could be harmful to living systems.

Version 2 was with a small black and white TV flyback transformer running at a slow (100 pulses per sec.) pulse rate. I eventually sped it up but could never get the required 1" spark from the Tesla coil.

This version uses a color TV flyback and a higher power discharge circuit. Nominal lowest frequency is 1.5 Khz though it could go as low as 270 Hz.

All diodes, SCR, and transistor can be substituted with universal replacement types available at electric part outlets.

As you can see, electronically it is simple. The power metering circuitry in the original MWO can also be used here if desired. I've had enough trouble maximizing the output of this device to worry about monitoring the power.

This device is excellent for use in Kirlian photography several ways: A modified circuit could be used for A, for a wide range of pulse rate settings.

There are two possible voltage sources for Kirlian use, each with unique characteristics. First is the output directly from T2 with or without the Tesla coil circuitry connected. Second is the Tesla coil output itself.

Other modifications include rectifying T2's output. The old MWO manual recommended the use of a tube rectifier out there are solid state types available.

Be sure it is a color TV high voltage rectifier. Connect as shown:

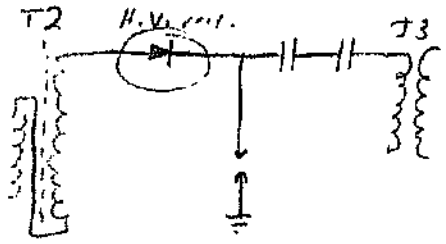

One question may arise in the builders mind: the need to heatsink SCR. No need. Not much heat generated.

Be sure R3 (or combination of resistors forming it) get ventilation. They get hot.

Always short C1 just after turning off power to work on the device. Remove short before reapplying power. The device is perfectly safe if you exercise care. R6 is a safety feature, it discharges C1 when turned off - but still short C1 when servicing, a standard safety procedure.

I am making constant improvements. The alternate values given for R3, C5 may give greater power at a higher pulse rate. I have yet to try them since 225 watt resistors are hard to find and apply. Besides it seems to work quite well as it stands. The only complaint one might have is the cost of construction principally due to the flyback transformer T2. But scavenging could help here.

Enclosing the spark gap in a plastic box could reduce its audible noise level. Ventilation of the spark gap gives more consistent operation. If the spark gap can be physically constructed above R3 the heat will produce air currents giving natural ventilation.

As I said, I am making constant improvements. Its too early to finalize it, but perhaps other associates may be interested in constructing and improving it. The lack of interrupter contacts gives a high level of reliability and consistent output.

Its too early in use for me to comment on its effects except that I think it is quite positive.

CIRCUIT DESCRIPTION:

The circuit consists of: low voltage oscillator, high voltage capacitive discharge generator, and Tesla coil.

The low voltage oscillator consists of Q1 a unijunction transistor operating as a relaxation oscillator. Frequency is variable from 270 Hz to 26 Khz with most power generated at 1500 Hz. VR1 controls this frequency. The DC Power for this circuit comes from a voltage doubler on the power transformer low voltage windings. The low voltage DC value was chosen to be as low as possible with consistent firing of the SCR.

The high DC voltage is rectified and filtered in C1. R1 is surge protection. The high DC voltage charges C5 through R3 until Q1 fires SCR1 whereby C5 is discharged through the primary of flyback transformer T2. D5 protects the SCR from high reverse voltage transients.

The secondary of T2 feeds the adjustable shunt spark gap and then through the Tesla coil resonating capacitors. Two capacitors are used here due to voltage requirements though one 15Kv capacitor could be used. From this point on it is all standard MWO fare.

Transformer T2 is expensive although any used color TV flyback could be tried. In all experimentation or adjustment the goal is maximum spark output at the Tesla coil secondary.

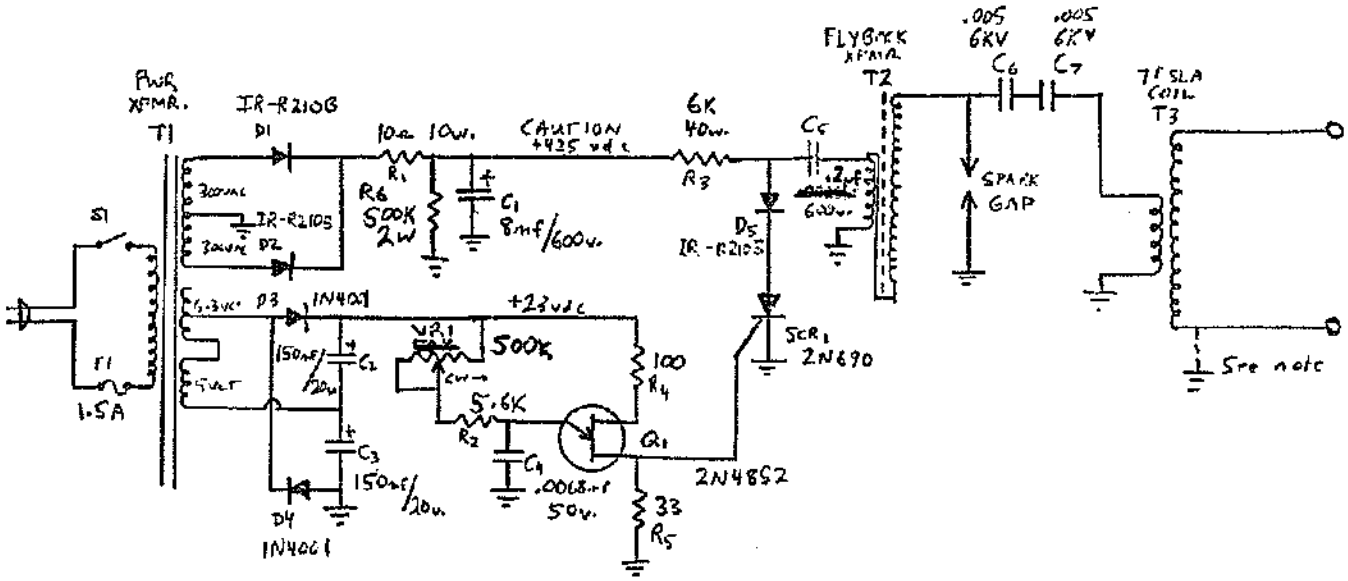

Note: Optional ground for Tesla coil secondary, if it reduces output do not use.
R3 made from four 25K 10w resistors in parallel. VR1 linear taper. C1 may or may not be polarized. C6, C7 could be single .0025/15KV capacitor. SCR1, Q1 and all diodes can be standard replacement equivelants.
MFR Type: T1 - TRIAD. T2 - Stancor HO 6246, Thordarson fly.
Alternate values: R3 - 1K ohm, 225 watts; C5 - 1 microfarad, 600v.

THE LAKHOVSKY MULTI-WAVE POWER SUPPLY
by KLARK KENT

Many of us have read the Borderland Sciences Research Foundation (BSRF) publication "The Lakhovsky MWO" in which electrical wizard Bob Beck astounds us with tales of wonder. He tells how he was informed of the location of an old Lakhovsky Multi-Wave Oscillator that had been declared "unfathomable". He was able to reconstruct the circuits and after several hours the machine worked perfectly!

Mr. Beck and fellow experimenter Ed Skilling designed and built a modern version of the MWO based upon Nikola Tesla's and Lakhovsky's original works and patents. Georges Lakhovsky, a herald of the New Age, was no doubt a skilled experimenter and investigator of the Life Energy. This is evident by his practical application of Nikola Tesla's famous coil.

Super Science has updated both Lakhovksy's original and Bob Beck's adaptation of the Multi-Wave Oscillator. Looking at the schematic diagram in Bob Beck's article, we will eliminate everything but the 12 volt battery (or 12 volt power supply), switch, Model T Ford Coil, high voltage capacitors, and the Tesla Coil. A large high voltage diode is added to rectify the output of the Model T Ford coil which leaves us with a stripped down but thoroughly functional MWO power supply.

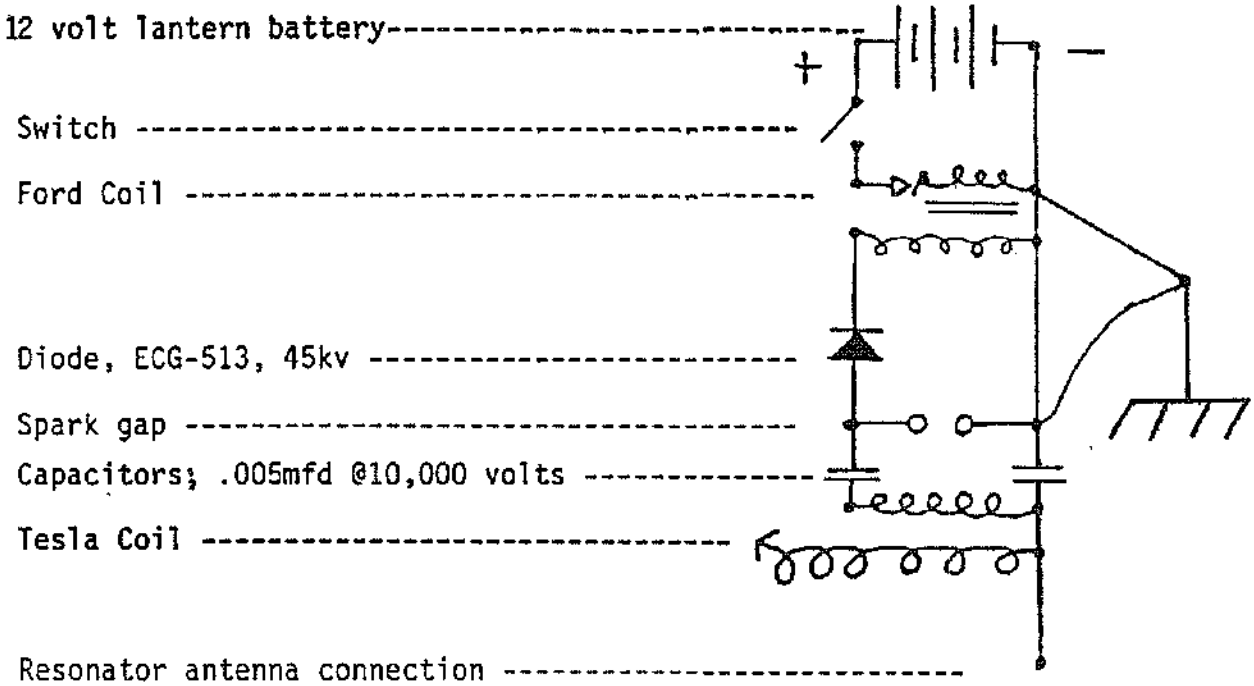

Before proceeding further, let's remember that the MWO is an experimental device and not for any healing or medical purposes! All experimenters should be in at least reasonably good health when building or experimenting with this high voltage, high frequency Tesla Coil Multi-Wave Oscillator power supply.

LET'S BUILD!

To begin our MWO Tesla Coil power supply project, we can round up the needed parts and components. Basic parts list:

-12 volt power supply; this can be a 12 volt lantern battery available from Radio Shack or any plug in power supply rated from approx 2 to 7 amperes.

-Model T Ford Coil; these old time induction coils are still available from J.C. Whitney Co, 1917 Archer Ave, PO Box 8410, Chicago, IL 60680. The MWO power supply will work adequately with the Model T Ford coil but a transistorized driver for a modern "hot rod" auto ignition coil will produce a Tesla Coil power supply with far more power!

-Switch; the on/off switch can be of any type. There is a switch already present on the plug in 12 volt power supply. I prefer to add a second switch of the key type, which prevents unauthorized use of the unit and a piece of vinyl tubing can be fitted over the metal key to create an insulated switch (this is important when turning the unit off).

-Diode, ECG-513 at 45 KV. The diode rectifies the output from the Model T Ford coil or the auto ignition coil by taking out the stray ac signals. This diode is a high voltage device rated at 45 Kilovolts (45 KV) peak inverse voltage.

-Spark Gap; an ordinary spark plug works adequately in this application. Try wrapping the spark plug in a large piece of vinyl tubing to insulate the spark gap. For a better spark gap, use a set of tungsten points. Chevy 6 cylinder 1965 model year works well to fabricate an adjustable gap.

-Capacitors; .005 mfd and rated at least at 10 KV (20 KV is better). We buy our capacitors or make them ourselves. I prefer to buy them. Check with your local electronic supply house to special order these high voltage capacitors; they will not be cheap... An alternative is to scrounge the local surplus stores to fabricate high voltage capacitors from several capacitors of a lower rating. It is easy to round up some 2500 wvdc capacitors with a 5000 volt test rating and .005 mfd capacitance. Wire the capacitors together in a series/parallel arrangement to arrive at the desired value. Series connections add the voltage rating and lessen the capacitance by division of the total number of capacitors in the series. Thus four capacitors rated at 5000 volts wired together in series yield one 20,000 volt capacitor. If the capacitance was originally .005 mfd each, now it will be .00125 mfd for the series. Thus we need to connect four of the series capacitors together in a parallel arrangement to create one 20 KV capacitor at .005 mfd. Parallel connections have no effect on the voltage rating but parallel connections add the capacitance of each individual capacitor.

CAUTION! Capacitors store electrical energy and can shock even when unit is turned off. Be sure to discharge the capacitors before touching them...

TESLA COIL

We make the Tesla Coil ourselves using the basic parameters worked out by Bob Beck in his original MWO adaptation from Georges Lakhovsky. The Super Science Tesla Coil is a close coupled, liquid filled coil that produces a 3" spark discharge when driven by a Darlington transistor and "hot rod" auto ignition coil setup.
For making the Tesla Coil, I like to use pvc pipe for the secondary coil form and acrylic tube for the primary coil form. The acrylic is transparent which permits visual inspection of the interior of the coil to observe any corona leakage or malfunction.

For the secondary winding: cut a 1 1/4" outside diameter piece of pvc pipe seven inches long. For the primary winding: cut a 2 1/2" outside diameter piece of clear acrylic tubing (1/4" wall thickness) seven inches long. Wind the secondary coil form with #32 gauge bare enameled copper wire so that the turns are tightly packed to create a winding approx six inches long with a 1/2" gap at either end. Wind the primary coil form with #14 gauge stranded and insulated copper wire. Wind exactly 18 turns and tightly pack them together. The vinyl insulation on the #14 gauge stranded wire will provide the correct spacing between turns.

Place the secondary winding inside the primary winding and use Super glue to hold the windings in place. For the terminals of the windings, use ordinary banana jacks to create a modular coil with a standard banana plug connector system. There will be tremendous electrical stress between the primary and secondary windings. We could reduce this dialetric stress by using a pancake style primary winding, but the pancake style primary takes up a lot of room. To solve the dialetric breakdown between the two windings, we insulate the space with liquid mineral oil. The liquid mineral oil is self healing should a dialetric breakdown occur. Solid forms of insulation such as paraffin wax are useless once a short circuit path has been created between the two windings.

To use the mineral oil insulation system, finish the coil first. Then drill a small hole in one end and squirt the oil in using a squeeze bottle. Then seal the hole using a piece of acrylic and Super glue. A word about Super Glue! This stuff is quite remarkable and is sold in hobby shops that specialize in flying, gas powered, model airplanes. Use accelerator to fast dry the glue. The brand name of the Super glue is "Gap Filler" and the accelerator is "Insta Set" both made by Bob Smith Industries.

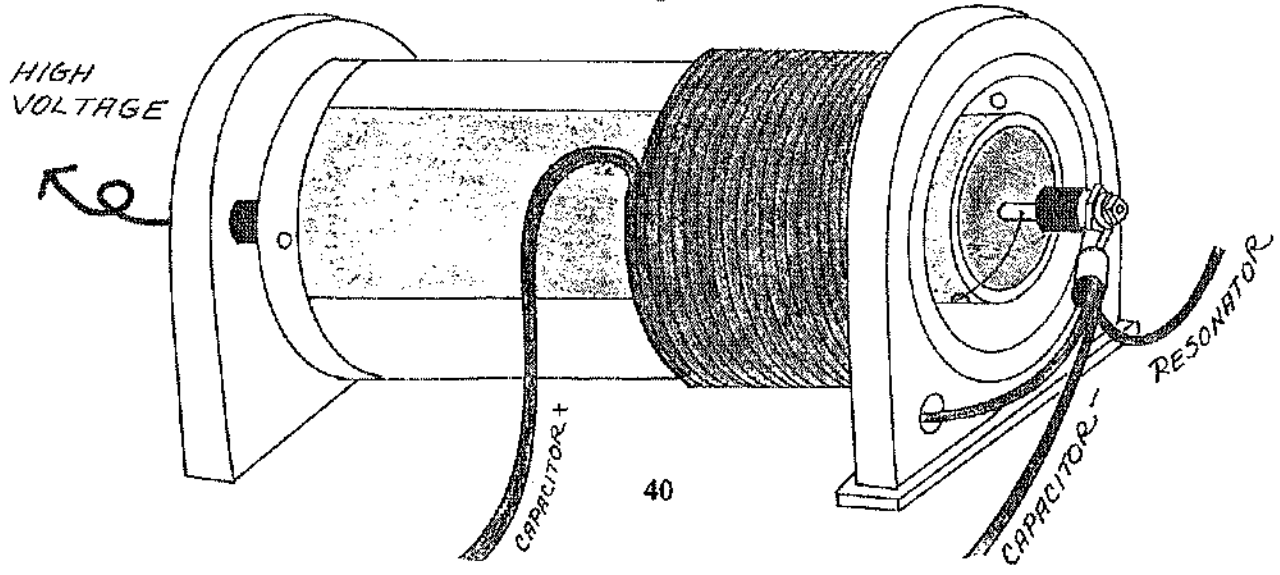

SPARK GAP

Even though an ordinary spark plug will work for a spark gap, we can do much better with an adjustable spark gap made from a set of tungsten auto ignition points. Chevy six cylinder, vintage 1960's are fine. To fabricate the adjustable spark gap, cut the base plate of the point assembly into two parts; make the cut near the spot where the two tungsten contacts normally meet. You should now have two base sections, with a contact point on each section. The reason we cut the base plate is to prevent the high voltage from jumping from the connections to the base and bypassing the breaker points. File down any sharp points where the base was cut. Mount the two tungsten points in such a way that the contact points barely touch each other and the base sections are as far apart as possible. Mount the spark gap assembly on a small piece of acrylic sheet. Wood is not suitable to mount the spark gap because the high voltage current will pass right through the wood base, possibly setting it on fire! Use a large nylon bolt to mechanically adjust the points. Mount the nylon bolt (Toilet seat bolts work well) in the side of the briefcase so that it butts against the spring loaded contact arm; this acts as a spark gap adjuster.

The advantage with an adjustable spark gap is that we can tune the gap while the MWO is in operation. The closer the two tungsten points are to each other, the faster the frequency of the spark jumping the gap. The further apart, the slower the frequency of the spark jumping the gap. Typically the Violet Ray Bulb Assembly calls for a fast frequency spark gap setting; while the High Power Radiator Antenna or Golden Ratio Antenna call for a wider gap spark setting to produce more power.

One side of the spark gap points will be at "ground" potential; while the other side will be at "high voltage" potential. Leave a metal discharge point exposed on the high voltage side of the spark gap assembly. We do this so that the entire MWO power supply may be discharged with a test wire running from the Ground Bus to the high voltage point. This provides a quick way to discharge the capacitors before troubleshooting the unit. Also, cover the spark gap assembly with a visual block made from translucent acrylic. This visual screen will block the ultraviolet light emitted by the spark jumping the gap. Leave the sides of the spark gap assembly open to allow circulation of air around the points; this will "quench" the spark gap and prevent the jumping spark from turning into a constant arc. Also, mount the cooling fan air intake near or directly above the spark gap assembly; this will serve to further quench the gap for better, more bouncy performance...

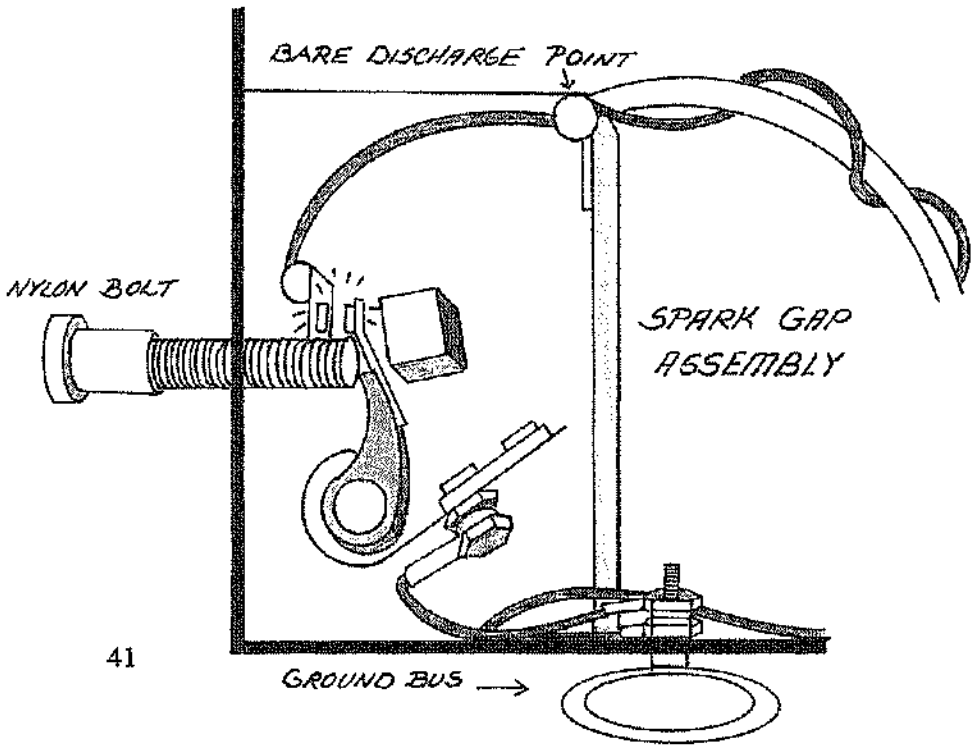

555 TIMER AND TRANSISTORIZED DRIVER

Even though the Model T Ford coil works adequately to power the MWO Tesla Coil power supply, we can really do better with a modern "hot rod" auto ignition coil. Mallory makes an aftermarket coil for drag racing that puts out approx 45 KV. The "MSD Blaster" is another aftermarket auto ignition coil that really gets the job done. Even an ordinary UC-15 replacement coil with its 30 KV rating will outperform the Model T Ford coil.

However there is one consideration to using an auto ignition coil as the primary high voltage source. Since we are working with 12 volts direct current, we need to interrupt or chop the 12 volts going into the auto coil to enable it to function as a transformer. The Model T Ford coil had a built in interrupter for this purpose. We will make a much better interrupter from a 555 timer chip and a high power Darlington transistor. The 555 timer chip will chop or interrupt the 12 volts going into the auto ignition coil from 130 times per second to 1300 times per second while the Darlington transistor handles the power. With the Model T Ford coil we were stuck with the fixed frequency of the interrupter (approx 200 Hz). With the 555 timer system, we can tune the frequency of the primary high voltage from 130 Hz to 1300 Hz. This really makes a difference when we try to get maximum performance from our Tesla Coil when it is driving the MWO Golden Ratio Radiator Antenna or driving the Violet Ray Bulb Assembly for direct stimulation.

Below is the schematic for the 555 Timer/Transistor Assembly. It is shown hooked up to the auto ignition coil. You can hardwire this circuit using a Radio Shack #276-162 project board. I use a large heatsink to mount the Darlington transistor (RCA 8766) and to mount the 50K ohm tuning potentiometer. When the MWO power supply is housed in a briefcase, the shaft of the 50K ohm potentiometer can extend through a hole in the side of the case. Go ahead & slip a short piece of vinyl tubing over the potentiometer shaft both to extend the shaft and to insulate it from high voltage.

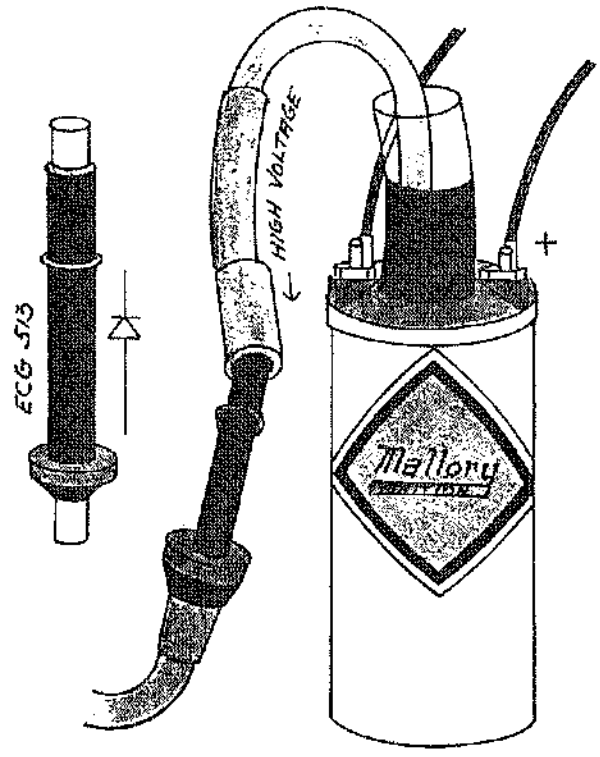

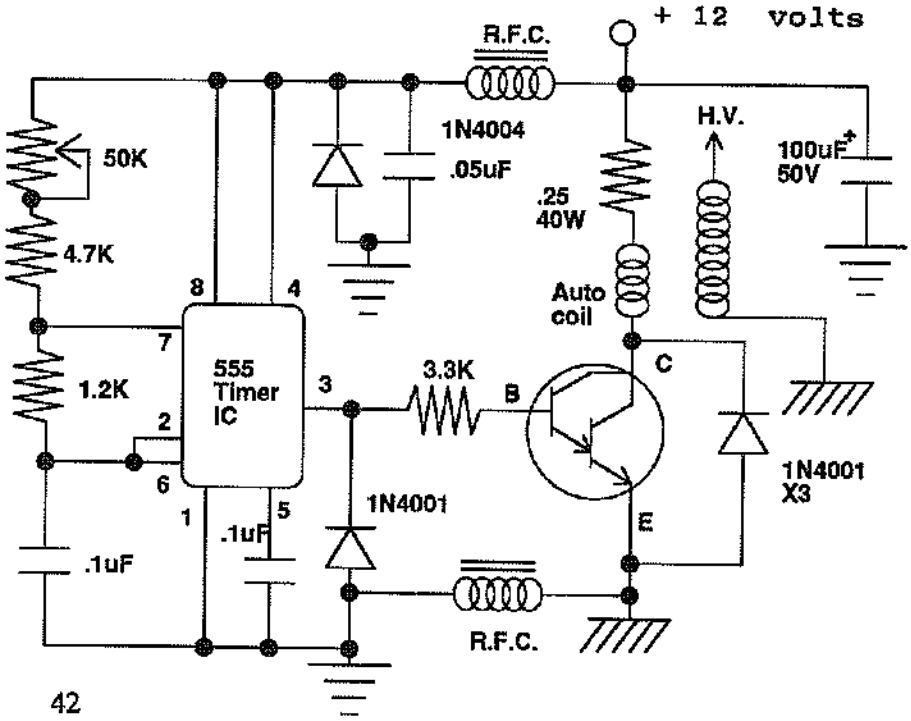

GROUND BUS

An external Ground Bus is important because it lets us reference the high voltage to the zero potential of the Earth itself. Without a true Earth ground, the negative side of the circuit can pick up a substantial voltage by induction from the high voltage potentials in the circuit. This condition is known as a "floating ground" and could result in the experimenter getting shocked. The shock itself is harmless, but the surprise that an accidental shock causes may lead the experimenter to jump back and bump his head! The Ground Bus may be connected by a long wire to a cold water pipe or to a steel fence post or to a piece of rebar driven into the ground. The Ground Bus is a handy reference point when discharging the circuit before troubleshooting.

SAFETY

Try to follow the "one hand rule" when actively adjusting the live high voltage circuit. This means keep one hand in your pocket or one hand behind your back. If an accidental shock should occur, then the electrical current does not travel across the heart when the experimenter follows the "one hand rule". Another safety procedure is to use a 12 volt lantern battery to power the circuit while it is still under construction. Once all the problems have been solved, then a more powerful 12 volt supply can be used.

TESTING THE CIRCUIT

Let the circuit run in darkness and try to observe any corona leaking from exposed high voltage points. There are two good and easy ways to stop high voltage leaks. One method is ordinary vinyl tubing: wrap wires carrying high voltage in vinyl tubing to absolutely stop them from leaking power robbing corona. Auto parts store sell expensive spark plug wire which will withstand the high voltages we are dealing with. If you use spark plug wire, be sure that it is metal wire, not "radio suppressor" wire (it's carbon fiber and impossible to solder or connect to).

Another good method of insulating high voltage is 100% silicone clear caulk! With your caulking gun, apply some 100% silicone clear caulking to exposed wires, exposed high voltage points and other places where you can observe leaking high voltage corona.

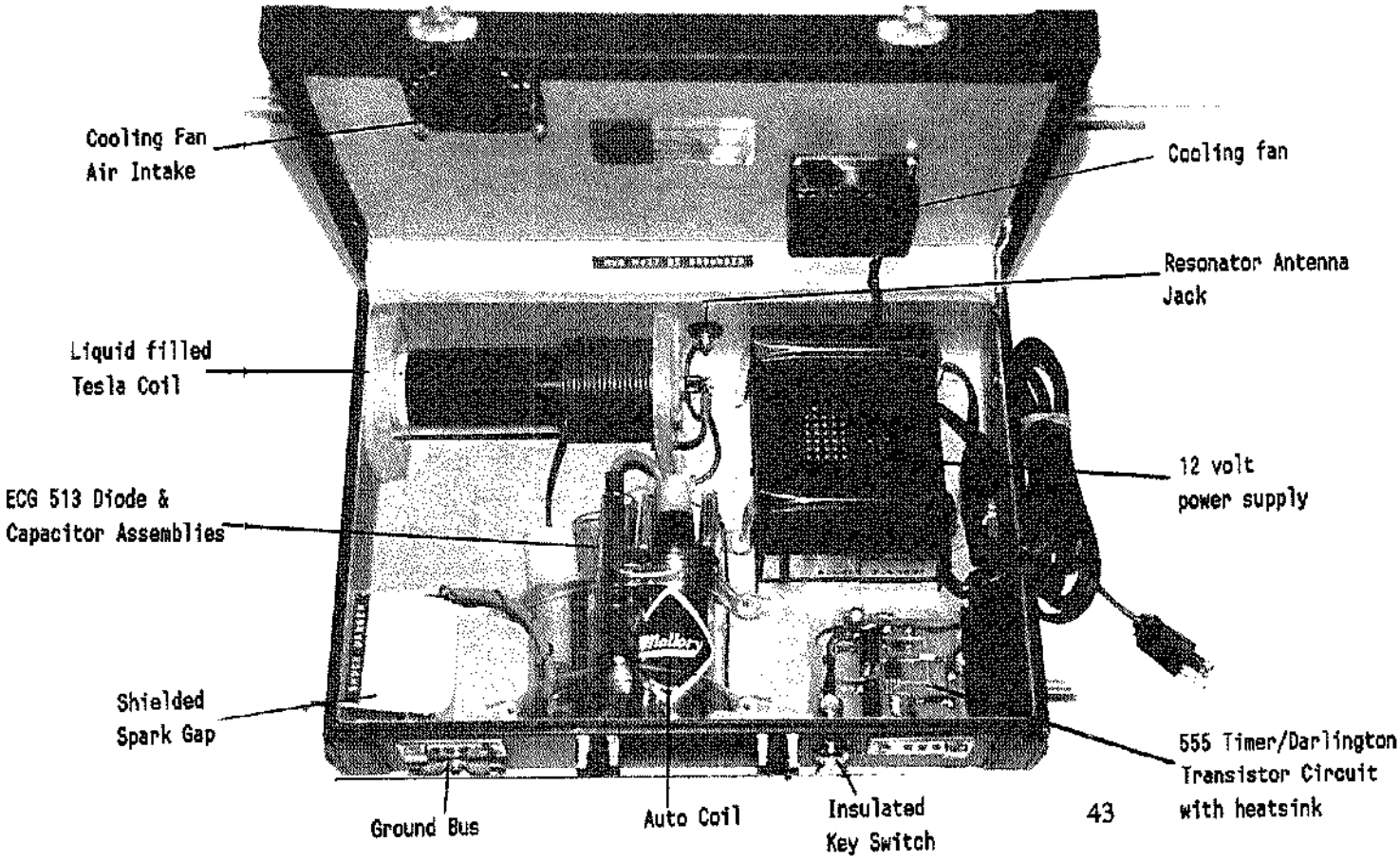

LAKHOVSKY MULTI-WAVE OSCILLATOR.

HOW IT WORKS:
The MWO sets up a high voltage oscillating electromagnetic field between the two antennas. Experimental subject sits or stands in this field and every cell in the body is exposed to the resonant effect of the multiple waves. Just as one guitar string will sound when exposed to its resonant tone; so will each cell vibrate to its own natural frequency!

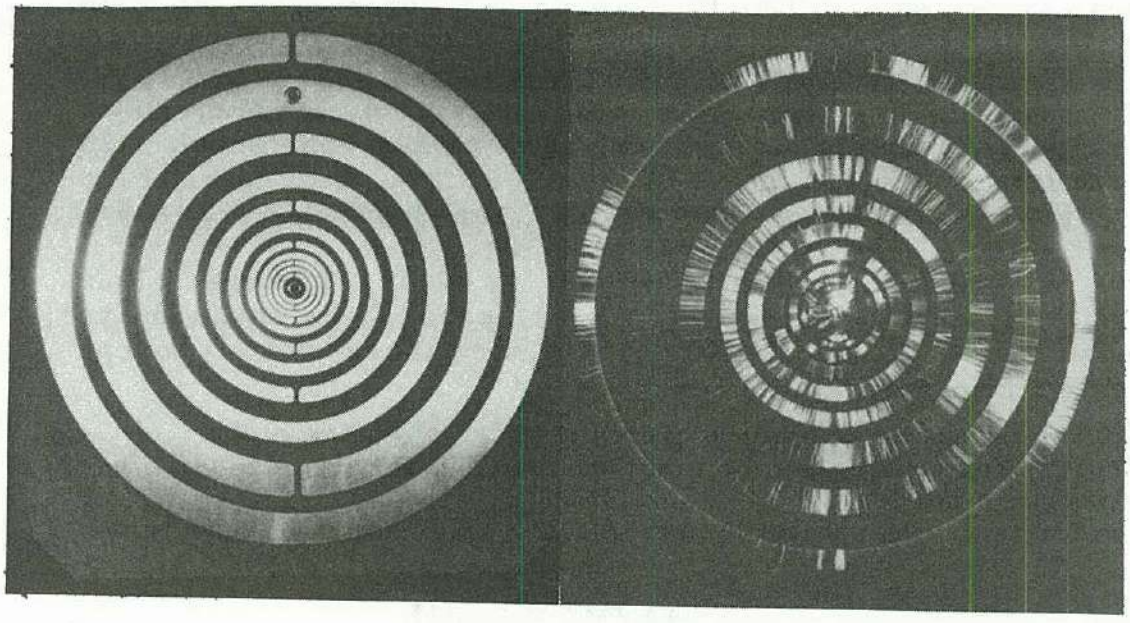

In this time lapse photo, we can see the dramatic effect of the high voltage excitation of each ring of the MWO antenna! Each ring radiates at its characteristic wavelength and frequency to cover a range from approx 200 Hz to 14 Giga Hz!

Modular construction works well for the Tesla Coil in the Super Science MWO power supply. This high voltage Tesla Coil can produce a 3" spark discharge from the smooth HV Discharge Terminal! The unit is a versatile experimenter's kit that can be used for Kirlian photography, or to create a plasma of Argon gas in the Violet Ray Bulb Assembly.

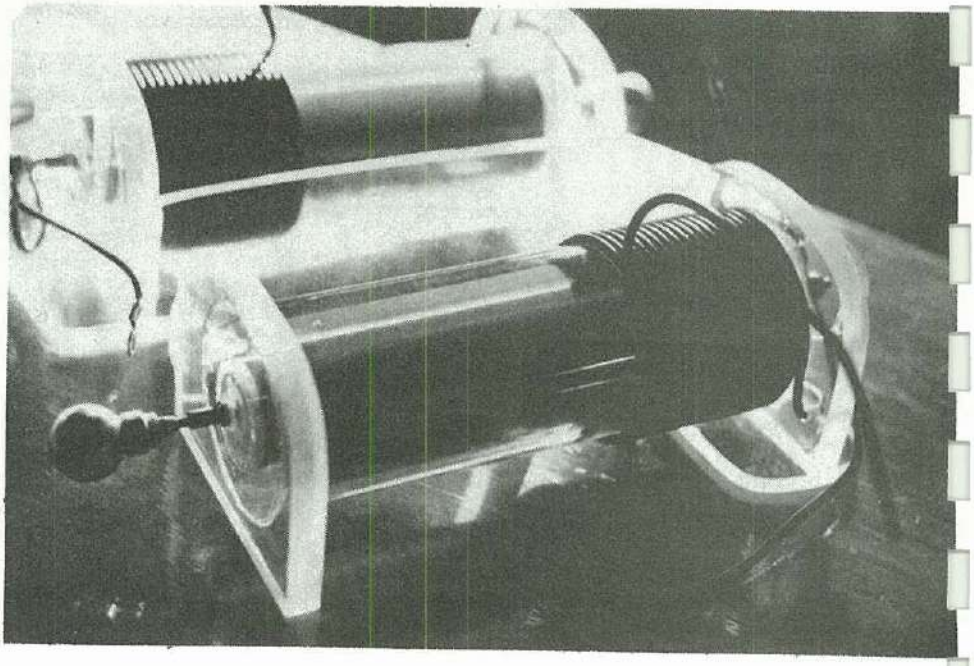

SUPER SCIENCE
P.O. Box 392
Dayton, Ohio 45409
(513) 298-7116

ANTENNA HOOKUP

Experimental subject is placed within the oscillating electrostatic field between the two antennas which are approx 4 to 6 feet apart. All metal such as heavy belt buckles is removed from the body. Clothes are optional. Sessions should last approx 20 minutes; skip at least one day between sessions to allow the body a chance to detoxify.

With the Golden Ratio Radiator Antenna, the use of the second Resonator is not required due to the unique "Scalar" properties of this design.

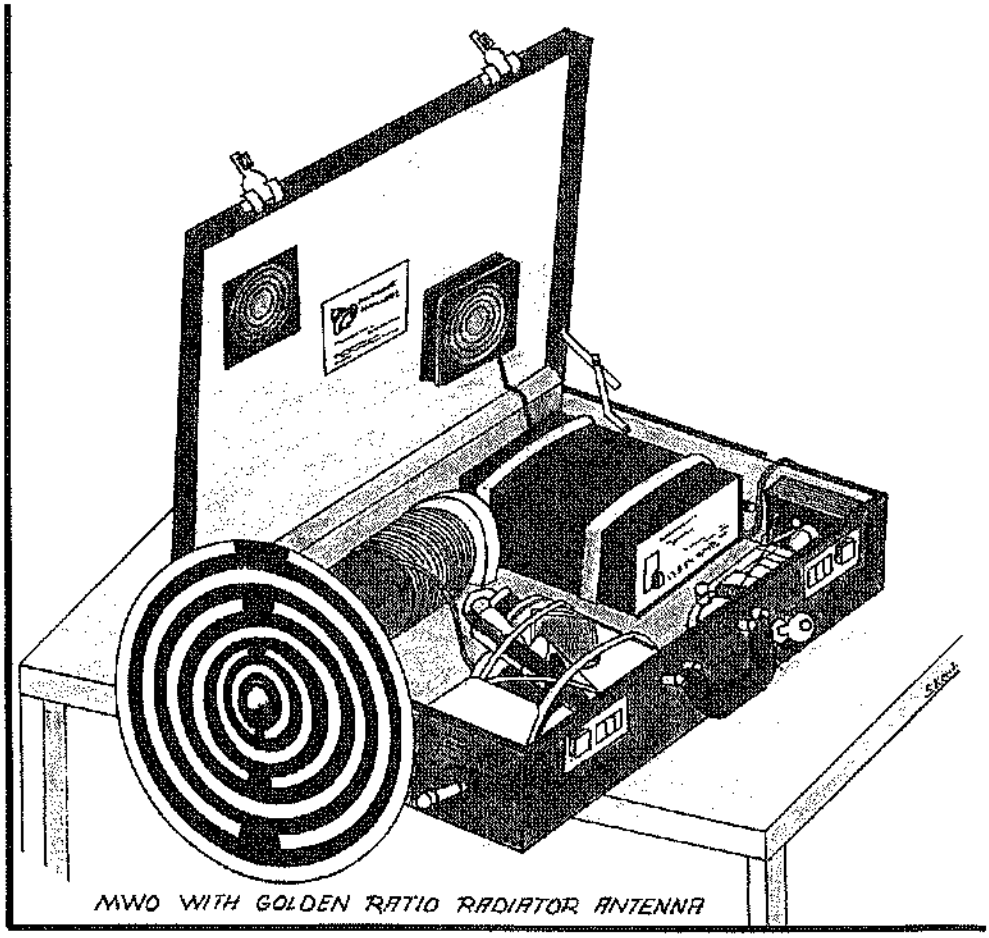

MWO WITH GOLDEN RATIO RADIATOR ANTENNA

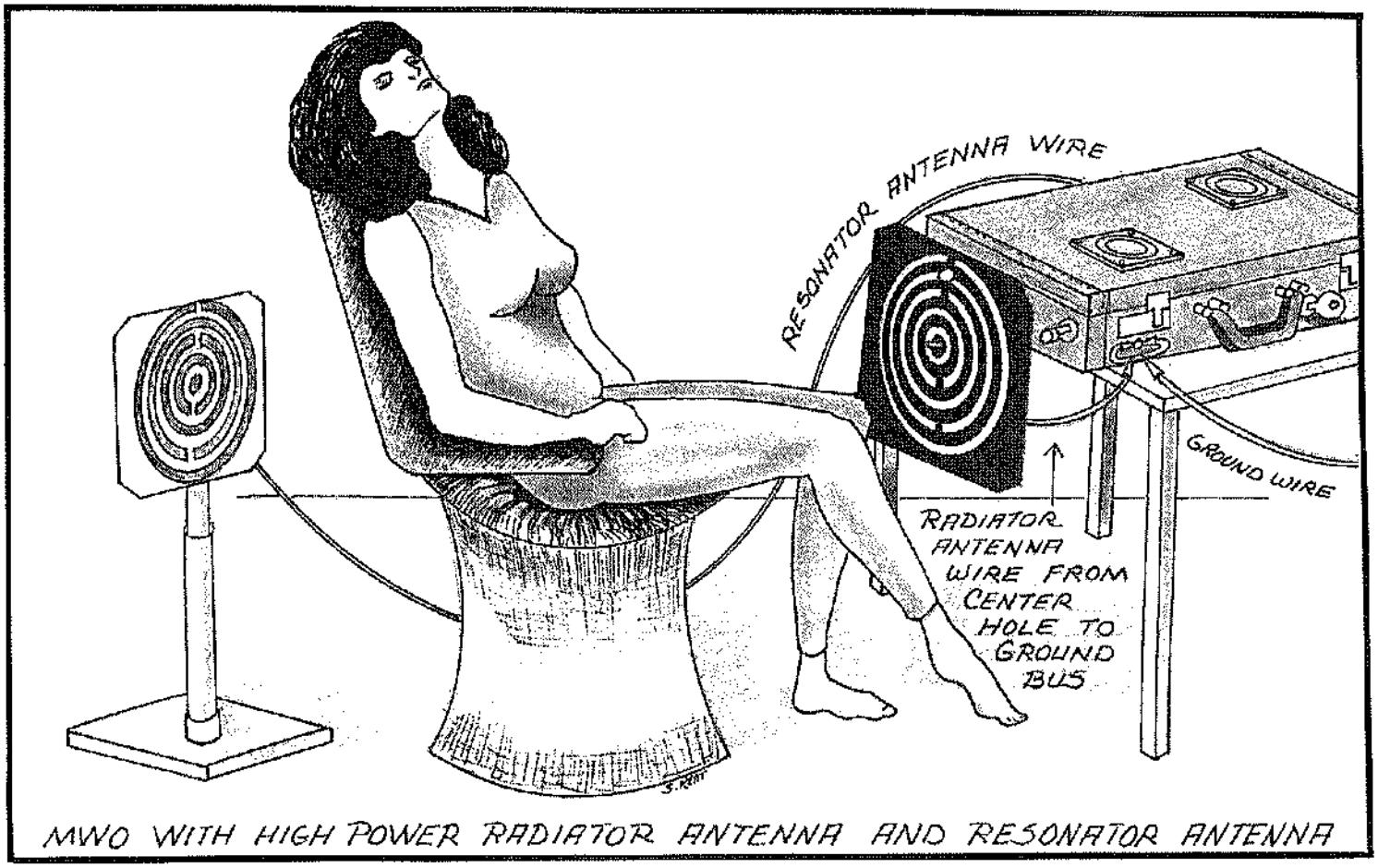

MWO WITH HIGH POWER RADIATOR ANTENNA AND RESONATOR ANTENNA

From the December 1963 Journal of Borderland Research
Excerpts from:

THE WAVES THAT HEAL

The New Science of Radiobiology

by Mark Clement
edited with commentary by Riley Hansard Crabb

Bob Beck has loaned us a copy of the late Mark Clement's brief, illustrated review of Georges Lakhovsky's Multiple Wave Oscillator showing pictures of antennas, before-and-after skin cancers apparently cured by the Oscillator, and of cancerous plants returned to normal health by two means: 1. Radio-Cellular Oscillator, and 2. Single Wire Oscillating Circuits.

"On the day Hitler's mechanized hordes drove into Prague a book was published in London entitled **The Secret of Life** by Georges Lakhovsky, a Russian-born engineer resident of Paris. The book had previously appeared in French, German, Italian and Spanish translations and Lakhovsky's theories were well known on the Continent long before the English Translation was published.

"The evil designs of the Nazis soon gave rise to depressing repercussions in all spheres of human activity and Lakhovsky's remarkable work was left virtually unnoticed in this country (England) by the medical profession and the public alike. A few discerning critics, however, expressed their views with appreciative understanding. The Hospital said 'Lakhovsky's theories are so interesting from the point of view of future developments that it will repay any keen hospital officer to give them his close attention.' Science Forum said 'The admirable translation of Lakhovsky's **The Secret of Life** will be heartily welcomed in progressive circles. The general theory is one which physicists, biologists and medical men cannot afford to ignore.' But these were voices in the wilderness and the field for experimental investigation was left open to a few amateurs devoid of scientific training and lacking the necessary resources.

"The impartial investigation of claims of cure of various diseases by un-orthodox methods demands high qualities of mind and character possessed by very few men indeed. Scientific truth is no respecter of persons or of vested interests, and Lakhovsky's spectacular results in the treatment of plants and animals and human beings were inevitably bound to antagonize orthodox practitioners and exponents of popular medical cults.

"On the Continent Lakhovsky's work attracted a great deal of attention in scientific circles, particularly in Germany and Italy. Italian investigators were among the first to study Lakhovsky's theories and put them to the test in laboratories and clinics. It was, of course, to be expected that the new science of Radiobiology should make a special appeal to the intellectual heirs of Galvani, Volta and Marconi. It is somewhat depressing to observe that in England, the country of Faraday and Clerk Maxwell, Lakhovsky's theories have not yet received the attention they deserve.

REGENERATING OSCILLATING CIRCUITS

"Lakhovsky has been criticized by physicists ignorant of biology and by biologists ignorant of physics! These self-appointed censors of knowledge soon found they were confronted with a redoubtable opponent who fully realized the value of experimental evidence. Its publication resulted in causing annoyance to the custodians of infallible doctrines who made up with carping verbiage what they lacked in clarity of vision. But Lakhovsky's achievements with his oscillating circuits supported by astonishing photographs of regenerated tissues in plants and human beings could not be exploded by mere verbal fireworks, and as evidence accumulated the skepticism of hostile critics relapsed into morose silence.

"The indisputable fact remains that Lakhovsky was the first experimenter to make use of high frequency electro-magnetic waves in the domain of biology. Thus out of the application of radio-electricity to biology his work developed and gradually established the foundations of the new science of Radiobiology. The first international Congress of Radiobiology was held in Venice in 1934. A leading authority on electro-therapy, the late Dr. E.P. Cumberbatch, wrote: 'Although it had been frequently observed that the short Hertzian waves could produce heat at a distance from the transmitter the first scientific investigation from a biological point of view was made by Lakhovsky and his colleagues who published a paper in 1924 on the effects of very short waves on cancer in plants...'

"When France was occupied by German troops, Lakhovsky, being a prominent anti-Nazi, decided to leave Paris and made his way to New York where he died in 1942 at the age of 73.

"In the United States Lakhovsky's theories were put to the practical test with typical American speed. Noticing that patients treated with Lakhovsky's Multiple Wave Oscillator showed signs of rejuvenating appearance, the possibility of exploiting this side-effect proved irresistible to an enterprising 'beautician'. A film was made featuring cases after treatment with Lakhovsky's MWO, which proved to be both interesting and convincing.

"In New York Lakhovsky was approached by several hospitals with a view to testing his apparatus experimentally. The remarkable results obtained . . . in a large New York City hospital, and also by a prominent Brooklyn urologist are fully set out in the text.

"In this country (England), owing mainly to the inauspicious time at which Lakhovsky's major work was published, very little interest has been shown on the part of those best qualified to judge its merits. The medical profession, whose conservatism is the most formidable barrier to progress, has been notoriously slack in investigating the new radio-electrical methods of treating disease as originated by Lakhovsky...."

Mark Clement's observation on the formidable conservatism of the medical profession in 1949 is still true today. Effective electronic diagnosis and treatment of disease is still a closed door here in America as far as the AMA is concerned. Those brave MDs who have tried to keep medical practice abreast of developments in electronic science have been discouraged, if not actually driven out of practice. Dr Abrams is a good example, with his Oscilloclast, developed and proven effective in San Francisco about the time Lakhovsky was developing the MWO in Paris in the 1920s. Radical innovations in any line of endeavor are usually thought up and proven by rank outsiders. Georges Lakhovsky was no doctor, but an electrical engineer!

Doctors, with their own pharmacies and with massive investments in the drug industry, are not likely to show much interest in radical new ways for treating human ailments, especially if the new way is a threat to profitable practice; and, as long as Americans think they can buy health in a pill or a shot in the fanny, doctors will continue to treat them with poisonous drugs at top prices. This is good business.

BORDERLAND RESEARCH

But for those of us who would like to keep our bodies as uncontaminated -- and as healthy -- as possible, Lakhovsky's theories

It is highly significant that about the only rays and ray machines approved for general use by the American Medical Association are the destructive ones of X-rays and atomic radiation for the mis-treatment of cancer.

"Since Lakhovsky's oscillating circuits were first used for the treatment of cancerous geraniums, an experiment fully described in communications to the French Academy of Science, the same method has been successfully applied in Continental hospitals and nursing homes."

Photos of the successful treatment of cancerous geranium plants are included in Clement's book, along with the pictures of the disappearing skin cancers in human beings. So Clement describes the major features of Lakhovsky's work in this first chapter, the simple, one-coil Oscillating Circuit powered by cosmic rays, and the electric-powered Multiple Wave Oscillator. There are photos of the Multiple Wave Oscillator, showing clearly the unique circular antennas. These were made of metal tubing, separated and suspended with silk thread. The simpler, aluminum-foil printed circuit in Bob Beck's adaptation is an easy way to experiment with the idea.

THE OSCILLATING CIRCUIT

"The diagram on this page shows where the oscillating circuits should be worn, i.e. round the neck, waist, and above the elbows and knees. The effect is intensified if more than one circuit is worn. Generally speaking, the neck and waist are the favoured sites and likely to bring about the best results.

"In the light of Lakhovsky's theories the fight between the living organism and microbes is fundamentally a 'war of radiations'. If the radiations of the microbe win the cell ceases to oscillate and death is the ultimate result. If, on the other hand, radiations of the cell gain the ascendant the microbe is killed and health is preserved.

THE SECRET OF LIFE (AT THE FORM LEVEL)

"Broadly speaking, health is equivalent to oscillatory equilibrium of living cells whereas disease is characterized by oscillatory dis-equilibrium. This general principle has given rise to a vast number of experiments covering the whole field of biology. Plants, animals and human beings have been successfully treated by the application of Lakhovsky's oscillating circuits and the reader is referred to his major work The Secret of Life for a full discussion of this important subject.

Those of you who have been studying the Kabala with Mrs. Crabb and me must have been struck immediately by the metaphysical soundness of Lakhovsky's basic theory expressed above. One wonders if this Russian escapee from Communism, and from Naziism, wasn't indeed a student of the Western Mystery Tradition, perhaps even an Initiate! The Tree of Life is the groundplan of our Tradition. On the Tree we show the descent and the ascent of power, oscillating back and forth from left to right and right to left across the Middle Pillar, or balance point.

Now for the final paragraph of Chapter One. "During recent years observations on the part of several investigators have established the fact that most animals, including insects and birds, emit radiations while they are also sensitive to the influence of external electromagnetic waves. These radiations

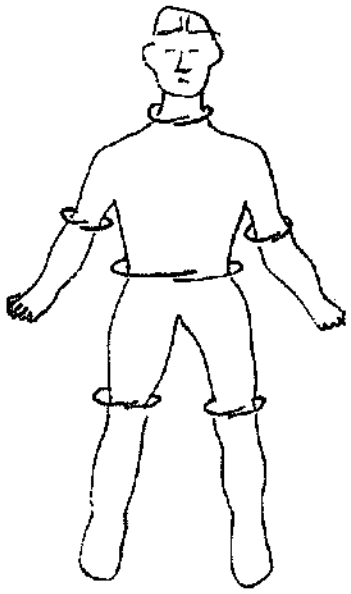

Single wire oscillating circuits around subject's neck, arms, waist and knees.

emitted by all living beings cover an indefinite range (infinite range?) and are characterized by a multitude of different wave lengths. In the immense range of existing radiations we can only perceive the luminous octave (visible light) but we know that whole gamuts of radiations exist beyond the narrow limits of the visible spectrum. The limitations of our senses prevent us from perceiving radiations of living beings and this sensory incapacity also excludes from the field of direct awareness the vast gamut of electromagnetic waves traversing our atmosphere. Yet all these radiations and waves exist and affect all forms of organic life in various ways."

DR. RAUL ARAUJO'S REPORT

In Chapter Two Mark Clement gives "Medical Reports on Lakhovsky's Oscillating Circuits." We'll give only one, by Dr. Araujo, Physician at the Prophylactic Institute, Montevideo Uruguay. "In 1929, Dr. Araujo was suffering from a long-standing infection of the larynx which his eminent colleagues had failed to cure. While in Paris he met Lakhovsky who advised him to wear one of his oscillating circuits in the form of a collar. Although feeling rather skeptical about this unorthodox method of treatment Dr. Araujo wore the oscillating circuit for several months with the result that he fully recovered and has had no relapse since. This personal experience led him to treat his own patients with Lakhovsky's oscillating circuits. Having treated over 300 patients suffering from a wide variety of diseases Dr. Araujo succeeded in curing or greatly improving cases of rheumatism, asthma, anemia, neuralgia, gastric ulcer, colitis, glandular disturbances, sterility, genito-urinary affections, general weakness and even cancer. Dr. Araujo observed that in cases in which Lakhovsky's oscillating circuits appeared to give no definite results there was invariably a latent infection which required special treatment such as syphilis, cholecystitus, sinusitis, pyelitis, dental sepsis, etc. . . A full account of Dr. Araujo's Report appeared in a monograph entitled 'Cosmic Rays and Oscillating Circuits' by Dr. P. Rigaux, Paris, 1932."

CHAPTER THREE, THE MULTIPLE WAVE OSCILLATOR

Most of this has been well explained by Bob Beck in his article in the November Journal, though we might quote again in Clement's own words: "After many experiments Lakhovsky succeeded in constructing an apparatus generating an electrostatic field in which all frequencies from 3 metres to the infra-red region could be produced. Hence in this field every cell could find its own frequency in resonance... Thus a type of oscillator was obtained giving all fundamental wave lengths from 10 cms. to 400 metres, corresponding to frequencies of 750,000 to 3 milliards per second. . .

"Since 1931 the Multiple Wave Oscillator has been used in most European countries and in America for the treatment of many diseases including cancer. No contra-indications for the use of the apparatus nor any harmful effects on patients have ever been reported. This is in striking contrast with short-wave therapy in general, X-rays and radium whose application in the hands of experts has not infrequently been followed by the most serious consequences. . ."

Then follow several pages of photos of before-and-after cancer cures and medical reports from doctors. This one is typical, from Dr. Nicholas Gentile, Chief Radiologist of the Clinic for Incurables of the Apostolic Ladies of the Sacred Heart of Jesus,

offer a way out of the clutches of the medical trust. There is little likelihood that the AMA will support research in this area of electronic science for years to come. There is every probability that there will be murderous opposition to any attempt to exploit the MWO on a national scale. This means that you will have to build and test your own equipment, or make friends with some electronic technician – engineer, TV or radio repairman – and prevail upon him or her to build it for you. This is the active kind of borderland research which requires that you get up out of your easy chair and get to work! If you live in an isolated spot, take a mail order course in basic radio construction. If you live near a high school that has an adult education program, sign up for the evening class in radio theory and bench work. I did at Barstow in 1958, so can you. If you want to be a citizen of the New Age you should make some effort to keep up to date, even if the sick industry doesn't!

What are Lakhovsky's general theories? Mark Clement sums them up neatly in Chapter One of **The Waves That Heal:**

"The fundamental principle of Lakhovsky's scientific system may be summed up in the axiom 'Every living being emits radiation'. Guided by this principle Lakhovsky was able to explain such diverse phenomena as instinct in animals, migration in birds, health, disease, and, in general, all the manifestations of organic life.

"According to Lakhovsky the nucleus of a living cell may be compared to an electrical oscillating circuit. This nucleus consists of tubular filaments and chromosomes made up of insulating material and filled with a conducting fluid containing all the mineral salts found in sea water. These filaments constitute minute oscillating circuits endowed with capacity and inductance and capable of oscillating according to a specific frequency. They are comparable to the circuits, coils and windings of radio receivers."

I believe Clement's comparison of a body cell with a radio receiver is only half-true. The cell can also be compared with a radio transmitter when it is releasing energy. We are both radio-receptive and radio-active! Lakhovsky's theory should be acceptable to any occult scientist. The push-pull idea, the positive and the negative, the Law of Opposites, is basic to all forms and to all life at this level of existence. By inductance Clement means that radio-electricity can be induced or put into every cell of your body. By capacity he means that each body cell can hold a charge of radio-electricity, just as the battery of your car can carry a charge of electricity. In the case of your body, the charge is put in through invisible but very real radio waves. These can travel unimpeded through any solid object!

"The living cell can thus play the part of a transmitter or receiver of exceedingly short radio-electric waves which give rise to high frequency currents in the circuits of the cellular nucleus. Now the vibration of an oscillating circuit is maintained by radiated energy. But where does it come from.

COSMIC RAYS

"Scientists have established the existence of highly penetrating waves to which, by reason of their universality, they have given the name of cosmic rays. These rays, generated by the interference of astral radiations, are capable of traversing dense metals and soils to a great depth. Lakhovsky has demonstrated the cellular oscillation of living organisms is maintained by cosmic radiation. According to him disease may be said to result from oscillatory dis-equilibrium due to either a deficiency or an excess of cellular radiation. An important factor in this connection is the nature of the soil. A reinforcement of cosmic rays takes place on soils which are good conductors of electricity such as clay, ferruginous and carboniferous soils.

RESONATE IN HARMONY WITH THE UNIVERSE

"To avoid the harmful effects of loss of oscillatory equilibrium it is necessary to ensure the regularization of the cosmic field round the living organism by filtration. Lakhovsky's own explanation of the problem of filtration is as follows: 'The terrestrial atmosphere is known to be impregnated by a vast range of electro-magnetic oscillations of all wave lengths and intensities as a result of unceasing electrical discharges (thunder, etc.). Besides that we know that electric motors and other electrical machines create in the atmosphere a field of auxiliary waves. Moreover, during the past 25 years the earth has been flooded with radio-telegraphic, radio-telephonic and other waves. Under such conditions it is easy to understand why any oscillating circuit of any form or dimensions is likely to find in this vast field of waves its own resonance with which it can vibrate harmoniously. It is therefore obvious that to make any oscillating circuit oscillate there is no need to have recourse to a local generator such as the Radio Cellular Oscillator used by Lakhovsky in 1924 when he first treated and cured geraniums inoculated with cancer. The oscillating circuit utilized by Lakhovsky in his second series of experiments – a circuit having no artificial source of excitation – proved equally effective in curing geraniums rendered cancerous by inoculation."

Yes, in 1924 Lakhovsky 'graduated' from electronics to radionics! He discovered and proved to his own satisfaction that in some ways a simple, one-turn coil of wire or fibre was as effective as the electric powered Multiple Wave Oscillator. The simple Oscillating Circuit, as Lakhovsky called it, has two advantages over the MWO. It doesn't have to be plugged in to a battery or 110 volt home power supply, and it broadcasts no interference with radio and TV sets. It acts as a step down transformer for life-positive cosmic radiation.

Clement says that "it must be particularly stressed that only Circuits made in strict accordance with Lakhovsky's directions should be used, otherwise the results will prove to be entirely negative." Unfortunately we do not have Lakhovsky's directions, and Clement certainly doesn't give them. You are still free to investigate this type of research and many have. If you want to experiment in this area then get yourself some copper wire (solid or stranded, research should be done on both) in various lengths, (8 inches is one wave length which has worked well on tomato plants) and make them into a circle with the ends overlapping, but with the metal ends insulated or separated from each other. Lengths can be determined through radiesthetic means (that is, by dowsing) or perhaps in geometric relationship with the structure of the plant. Considering the radionic and radiesthetic viewpoint geometric shapes would also have an influence and can be experimented with. Always use control samples in your experiments to see what works and what doesn't.

To get back to Clement's text: "Through the action of this constant field of radio-electric waves which emanates from the surrounding atmosphere the oscillating circuit is made to resonate like an instrument in tune with certain sounds. Thus the oscillating circuit creates a field which canalizes and filters, so to speak, the cosmic waves necessary for cellular oscillation.

THE DANGER OF BURNING X-RAYS

"Furthermore, this filtration is a general phenomenon. It has been discovered, through the investigations of Lakhovsky, that radiations such as those associated with light, ultra-violet rays, X-rays, etc., have the property of making cosmic rays act, as it were, to the advantage or disadvantage of the cells. Now the field created by an oscillating circuit is constant and emits a steady and sustained force. It invariably acts in a favorable manner on the oscillation of the body cells, facilitating by the filtration of cosmic rays, regular cellular division, a fact which explains the immunity imparted to the cells and their consequent capacity of resistance to diseases and microbes.

Rome, published in the medical review Medicina Nuova XXVI, N.5., 1935, Rome: **"Effects On The Nervous System.** Generally speaking I have observed a marked analgesic action following the application of the Multiple Wave Oscillator in all affections associated with pain, particularly in the classical cases typical of such affections. For example, a patient suffering from cephalagia, resulting from violent cranial trauma, for a duration of 10 years, was subjected to a great variety of treatments, but all in vain. The patient was definitely cured after 2 months' treatment with the MWO. Improvement was manifest after only 3 applications."

Dr. Gentile also reported the effects of the MWO on the Central Nervous System, on Chronic Inflammations, on Metabolism, on Disorders of the Cardio-Vascular System, and on miscellaneous cases. He says he adopted the "technique of localized irradiation. Generally speaking, treatment is given every 4 days for a duration of 5-15 minutes per session. This is the technique which has given me the best results after having experimented with many forms of application. For children, old people and debilitated women, a relatively weaker application is indicated. If results are not apparent after 7 or 8 applications, I continue until 15-30 applications are given at the rate of a single treatment once a week. I have never observed any ill-effects from the MWO treatment, whatever the number of applications was in any given case. Moreover, the general condition of patients is always improved, even if only temporarily, so much so that the patients themselves sometimes insist on having further treatments. . ."

This chapter on the MWO concludes with four pages of reports of notable improvement or cure by American doctors. Chapter Five is concerned with the remarkable results obtained by using the Multiple Wave Oscillator on animals. Chapter Six contains Lakhovsky's prophecy that some time in the future diagnosis of disease would be obtained by television! This is something which Dr. Ruth Drown's Radio-Vision and Homo-Vibra Ray instruments have already accomplished.

THE NOVEMBER CONVENTION TESTING PROGRAM

There were two Multiple Wave Oscillators available. These were generously furnished by Bob Beck and Ed Skilling, and were set up in the shielded seance room. Only short exposures of from 2 to 5 minutes were given, during the lunch and dinner hours on Saturday and Sunday. In that time perhaps 100 people volunteered for tests. Until a follow up inquiry is made, no statistical conclusion can be made, or even begun!

A few individual cases reported to your Director are worthy of note, including my own. By mid-morning on Saturday a spinal injury from my old, hockey-playing days was acting up. Doctors have called it a spasm in the sacro-iliac area. Ed Skilling invited me to sit in the rays from the MWO for a couple of minutes while the seance room was being readied for testing. Within a minute the spasm relaxed completely and the pain was gone. This was not a permanent change, of course, but the analgesic effect was certainly noticeable.

Mrs. Fred Rannenberg, financial secretary of Harmony Grove and a BSR Associate, told me she had had a sharp pain in the area of her left hip for over two weeks at the time of the Convention. One 3-minute exposure to the rays of the MWO removed this completely. When I attended the Grove Board meeting a week later she said the pain had still not returned.

One Associate did report a negative reaction to the MWO. She attributed it to arsenic poisoning. She had a severe case of this earlier in the year. When the machine was turned on she felt a severe pain through her right side, as though someone had jabbed a knife into her. It could be that some of the lead poison was still in her system and the stirring of the cells in the mid-section produced this reaction. It was endurable, however, and she sat out the exposure without a murmur. The pain persisted that night and she had to put cold compresses on her side to get to sleep. The next morning she felt fine and was eager to take another exposure to the multiple waves. This time there was no negative reaction.

The most startling subject of all was the woman who had been awake all Saturday night with a migraine headache, an old and recurring ailment. By Sunday morning, Nov. 10th, she was sick and nauseated. It was suggested that before taking her to a doctor or hospital she be given a short exposure to MWO rays. Within minutes all pain was gone and she returned to her cottage to lay down and sleep like a baby.

THE PSYCHEDELIC EFFECT

Ed Skilling is the only I know who has stayed in the MWO field or rays for longer than 15 minutes. While testing and adjusting his equipment at his microphone factory several weeks ago he deliberately stayed between the antennas for an hour. At the end of that time he was beginning to feel lightheaded and dreamy he thought it a good idea to get out before losing consciousness altogether.

An even more spectacular possibility is the Time-Machine effect in connection with rejuvenation. If, as Bob Beck suggested in his article, the MWO tends to take the body cell back down the time-track to a more youthful, more vital period, what would happen to a person who stayed in the field of the machine for four hours? Would his vibratory rate be speeded up to where he would disappear completely? Like the hero of H.G. Wells' "Time Machine"? Anybody want to try it? It seems, from hints George Van Tassel has been dropping over the years, that his Integratron at Giant Rock, California might do something like this -- if and when he gets it working! As I recall, both George and the Canadian Saucerian, the late W.B. Smith, spoke of the four dimensions of electricity: 1. is the electricity moving in one direction along a copper wire, 2. is the magnetic field around the wire, 3. is the static charge created by the first two effects, and 4. is Time -- or the "tempic field" as Smith called it. The Time Field equates with Space, where consciousness is everywhere present. Seems to me Lakhovsky's Multiple Wave Oscillator is a gadget which gives us the opportunity -- for the first time -- of approaching the Time Field with scientifically acceptable equipment, operating in known frequencies. Remember, that with its circular antennas it operates on the vortex principle. Each individual antenna in the group is a segment of a 60 degree cone. The 1/2 inch gaps, at alternate 180 degrees from each other, conform to the alternating principle and give a damped or pulsed wave.

THE SPACE AGE EFFECT

Copies of our November 1963 **Journal** have gone all over the world. Each day's mail brings new orders. We are confident that Lakhovsky's invention, far ahead of its time in the 1920s and 30s, has been given a new lease on life and will be pushed to its ultimate development on every continent. There will be vigorous opposition from the right-wing conservatives and reactionaries. Their resistance will furnish the platform from which electronic "medicine" will eventually sweep the world.

I see the day when a device, similar to the MWO, will be a standard part of every home bathroom or cleansing center. You will consider it as necessary and as routine to take an electronic showerbath, as to take a water bath. Home from work, tired, dirty and discouraged, you strip, flip on the MWO switch, and while shaving, doing your hair or whatever, re-balance your whole system with a two or three minutes exposure to the pulsing waves from the oscillator as they flood the whole room. For the sale of the house of the future it will be as important for the ad to say "shielded bath with MWO" as it will to say "tile bath with radiant heat."

Mr. Skilling told me he was tired and

"dragged out" after processing dozens of volunteer "guinea pigs" late Saturday afternoon. Before shutting down the equipment he sat in the nail-less wooden chair between the antennas and gave himself a three minute shot of pulsed waves. Refreshed and revived he looked forward to a good dinner and the full evening program.

I don't know of a better Christmas gift we could have given the Associates than the idea and the plans for the Lakhovsky MWO, researched and so generously offered us by Bob Beck in the true borderland science tradition. Now it is up to you to carry it forward in your own individual way. We welcome your comments, observations and research data as you develop equipment and a testing program.

AND NOTHING HAPPENED!

"No doubt you are deluged with correspondence about your articles on the Lakhovsky Rejuvenation Machine. Since you said it is possible for any intelligent 16-year-old to build one that is exactly that which I have had to rely on. Fortunately, my son is fairly well informed on electronics but obviously no expert at his age, 16. He followed your diagram but instead of battery power he used an electric train transformer, which he assures me, is equally efficient. He also found he had to make one change in the hookup of the Tesla Coil. I have taken four exposures and the results! Nil!"

Maybe this lady expected to be rejuvenated back to her early twenties. As far as we know, no such claims have ever been made for the Lakhovsky gadgets -- though it would be interesting if it happened! As for power supply to the Model T Ford coil, any 6, 8, 10 or 12 volt battery or transformer should do, depending on what you have available and where you intend to do your experimenting. We understand the old Model T magneto delivered as high as 18 volts to the four coils. One handy source of 6 or 12 volt electricity is the cigarette lighter on the dash of the car. Plug in there for power when you want to expose yourself while driving or out in the country.

"I had been fighting a virus for several days and the day after the first exposure I felt a great deal better, but the second day I was right back where I had been. But that was the pattern the virus had been taking. One day I'd feel fairly normal, the next miserable again. So it is difficult to know if the Lakhovsky machine could be credited with the temporary improvement."

That's right, ma'am, some people show little or no reaction to the mytogenic waves put out by the Lakhovsky instrument. The results are unpredictable. Perhaps that's why the research was pushed no further in the 1930s by authorities here in the United States. You, like most people, think that health can be bought in a package. Lakhovsky didn't agree with this erroneous conclusion. His theory was that health is a condition of balance of all the forces of the body. Ill health is a condition of imbalance caused by your misbehavior. If you continue to misbehave, any force applied from the outside, whether it be mytogenic waves, manipulation, drugs, medicine or surgery, will only bring temporary relief. Pain is an insistent teacher, urging you to change your mind; but if you can't change your mind, how can you change your body?

"One possible reaction to the exposure I can report is that I took the first one just before going to bed at night. It took me three hours to get to sleep. Several things puzzle me about the machine we have constructed. First of all, although we have experimented with a Tesla coil of the size your diagram calls for, as well as one almost twice the size and strength, we cannot get a two-inch spark from the antenna or resonator, 1/2 to 3/4 of an inch is the absolute maximum."

The mention of the two-inch spark was Mr. Beck's error. 1/2 to 3/4 inch arcing is all this circuitry will produce and that is adequate to affect notable changes in many forms of cell life. More power might produce faster changes, and much harm! Be reasonable, a living cell is so small as to be invisible without a microscope. Only minute amounts of energy are necessary to affect a cell, to stimulate it or to kill it.

"Second, under no conditions do we get the 'bluish glow of brush discharge' from the antenna that you mention; although we have no trouble lighting up a two-foot fluorescent lamp."

Operate your Oscillator in total darkness and you should see some brush discharge at some points on the antenna. True this redesigned equipment puts out nothing like the five-inch brush discharge visible in the photo of some of the original Lakhovsky equipment in Mark Clement's book, "Waves That Heal", and Lakhovsky's antenna appears to be at least two feet across.

But power is not the answer to balanced cell life! Dr. Abrams discovered this with his early electronic experiments in San Francisco in the 1920s. It is the quality and the variety of the pulsed waves that counts! In any event weaker equipment can be compensated by longer exposure, and this may be more beneficial to living matter.

"And thirdly, since we have not constructed any outer shield for the machine, such as a Faraday cage of copper screen, I have been monitoring the operation on our radios and television. On the radio, one notes an annoying and loud buzz, but on T.V. except for a couple of light horizontal lines and a very slight hum, there is no serious effect. So I doubt that we're bothering our neighbors very much. In any case, we try to use the oscillator very early or very late in the day, when few people are using their radios or TV. I have sent for Clement's book, 'Waves That Heal,' and Lakhovsky's 'The Secret of Life', not only to better understand what we are trying to work with but also in the anxious hope that I will find out why our machine does not have the affect it apparently should have."

Let me assure you, good lady, there is no single cure-all for man's ills. The clue to better health is in the profound statement of the Savior of our race: "As a man thinketh in his heart, so is he." Pain is still the great teacher in the world and will be for a long, long time to come. I don't know what your physical condition is and it's none of my business; that's between you and your doctor. If you have a long history of frustration and thwarted ambition, going back to childhood and even into past lives, this mass of energy of crystallized thought-forms, is not going to be broken up and dissipated overnight. If you have consciously and willfully flouted Cosmic laws, or have turned them to your own selfish ends, the consequences of this misbehavior will have to be worked out at this level. The occult scientist calls this Fixed Karma. In this connection, one of my favorite teachers, Dion Fortune, reminds us: "What cannot be cured must be endured."

If the Lakhovsky oscillator does have an analgesic affect -- as it appears to have had in some cases -- it has this advantage over pain-relieving drugs; it does not leave a residue of poison in our already over-loaded liver and kidneys!

WORD OF A SIMILAR INSTRUMENT UNDER DEVELOPMENT

We have a second letter from this same lady Associate, also worthy of note in connection with the Lakhovsky Multi-Wave Oscillator.

"First off, when my brother received the machine we had built for him, using the battery indicated in the schematic, he felt the power source might be too weak. It so happens he has a business contact with one of the largest electronic instrument companies in the area where he lives. He decided to go straight to the president and seek his advice. With the whole idea placed before him this gentleman said, 'This is very interesting. I want you to meet one of our physicists who is working on a very similar instrument.' A meeting with the physicist revealed two interesting pieces of information: first, the physicist had never heard of Lakhovsky or his machine; second as soon as this new

instrument was completed, arrangements had been made to test it in a large nearby hospital! Is this latter not a cheering bit of news?"

Both cheering and discouraging. The basic principle discovered by Lakhovsky is certainly available to the mental probing of other sincere researchers, so let us keep it alive by all means. But barring a revolution in the ultra-conservative leadership of the American Medical Association, no electronic developments will be allowed to threaten the high-profit position of the drug industry.

"In their discussion of the power source, the physicist suggested my brother use a wet-cell car battery, #50, 39 plates, 70 A.H. We are using one too and it makes a much better spark from the antenna, although it still is no greater than 1/2 to 3/4 inch. It does seem stronger. Of course the machine is not so readily portable with such a heavy battery. My brother had only one exposure at this writing but he reports a noticeable improvement in the arthritic pain bothering him in his right arm for months. On the other hand, the report on the use of my own machine is somewhat less encouraging. The only positive results concern my husband. After his first ten-minute exposure, within a few hours, a painful bursur in his shoulder cleared up. He has been subject to off-again, on-again attacks of bursitis there for some 15 years; for which he had taken medication, short wave, and even X-ray treatments, when the attacks were severe. He has since taken another exposure, but neither this nor the first one seemed to help an itching-skin allergy which has bothered him for some years.

NOT THE FOUNTAIN OF YOUTH SHE EXPECTED!

"As for myself, I have taken at least a half-dozen exposures and cannot in all honesty detect the slightest difference from them. I'm not sure if it is a matter of 'suggestion' or a desire to prove the capabilities of the machine. On the contrary, I notice such strange contradictions as the fact that although I took an exposure yesterday morning, in the evening the fourth and fifth fingers on my right hand were painful, from some kind of arthritis or rheumatism. I had never had anything like this before. Does it not seem odd that it should develop on the day of the exposure?"

Not at all! Any positive reaction to exposure to the mytogenic rays of the Lakhovsky oscillator indicates that it is working! Mr. Lakhovsky's theory is that the waves or oscillations excite the cell, causing it to release mor energy, also to shake off accumulated poisons and/or tensions. If your system is loaded down with tensions from daily living in America, if your system is loaded down with poisons from processed foods and contaminated air and water, you can expect painful reactions when the junk breaks free. I believe that is what sickness is the body struggling to get rid of poison. For you, things may get worse before they get better!

HOW OFTEN AND HOW LONG?

"With the mention of two successive exposures in two days I get to what is the most important question in the use of the MWO. No one has explained why exposures are suggested at four-day intervals. Is it harmful or useless to take them more frequently? When one is uncomfortable or in pain, one is anxious to rid oneself of the discomfort as quickly as possible. And to have to wait four more days for additional improvement seems unnecessary if there is no harm in the exposures. I have exposed myself at more frequent intervals and still have observed no reactions?"

The suggested exposure rate of fifteen minutes every four days came from Dr. Gentile's extensive researches with Lakhovsky equipment in Rome in the 1930s. This is a typical professional approach to treatment of disease by doctors. From long experience with drugs and other proven forms of therapy, they know that it takes time for the human organism to adjust itself to radical changes -- without harming the organism.

Whether or not this holds true for the operation and effect of the Lakhovsky machine remains to be proven and you'll have to be your own guinea pig. It's your machine; it's your body; it's your life. You can take an exposure every hour on the hour if you like; stay in all day. Who's going to stop you? This is borderland research and you are a borderland scientist, looking for new knowledge which may be of benefit to yourself and the human race, judging from the last lines of your letter.

"I am so excited and hopeful of the efficacy of this MWO machine that I do not want to leave any avenue unexplored that may possibly help in understanding its use and making it freely available to anybody I can possibly help. May I take this opportunity to tell you how tremendously enthusiastic and interested I am in BSRA, not only what you are <u>trying</u> to do but what you are <u>accomplishing</u>, too. From what you imply of the financial situation, it seems to be largely a labor of love and service on your part, for which you deserve great praise and the heartfelt thanks of every BSRA member and others whose lives they touch. Please accept this very, very small donation of the enclosed check, as a symbol of <u>my</u> appreciation."

The donation is most welcome and will be put toward the expenses of carrying on this work, also the words of appreciation. The lady was also most curious about the Lakhovsky circuits, those single bands of wire which are placed around the waist, or knees, or ankles, wrist or neck, and seem to have a subtle but very real affect on the wearers. We have some information on the Lakhovsky Circuits or Belts from Associate A.E. Powell, a retired lieutenant colonel of the British Indian Army:

THE OSCILLATING CIRCUIT

"The Belts can be made by almost anyone, for a few cents. At most hardware stores, for a few cents per foot, one can buy twin electric cable insulated with white rubber, used for lamps, etc. Get the smaller size 1/4 inch wide, having 42 strands of copper wire. Slit an end with a knife and the two wires easily tear apart.

"For the button, get white sheet plastic about 1/8th inch thick, saw it into pieces about 1½ by 5/8th inches, and drill near each end a hole large enough to take two wires. Round the corners of the plastic and bevel edges. Thread the wires, from opposite directions, up through one hold and down through the other, leaving about half an inch projecting beyond each end of the button. Where a circuit can be slipped off the body without unbuttoning, you may overlap the ends of the wire belt an inch or two, bind with fine string and smear with Duco cement for strength.

"Parallelism and overlap of the ends are important. This builds up capacitance, produces inductance and generates an alternating current. Circuits may be worn, as many as you please, round chest, waist, neck, arms, wrists, legs, ankles, neck or head continuously. Water will do them no harm.

"Gladly will I supply Circuits, in any quantity, with buttons or bound ends. To avoid trouble with the Food and Drug people, I make no charge. Donations, however, are acceptable, and go intact into my Fund for the Sick. For long this has been doing fine work and I'm sure you will approve. For reasons stated I make no claims whatsoever for the Circuits, and no guarantee or promise of any kind. If you want to give them a trial, that is wholly your affair." Col. A.E. Powell (Col. Powell died in March 1969).

MWO USED TWENTY YEARS AGO

"The recent article in the BSRA Journal pertaining to the Lakhovsky Oscillator is of special interest to me. First, I am an engineer, Physician and Surgeon, and a Scientific Consultant for the U.S. Government. (Technical Intelligence). I am not in any manner snooping for the government. This is completely personal. We built several oscillators in 1944. These were used in my sanatorium in Dallas where we had some startling results. As we did not have the proper facilities

to research the instruments adequately, we became more and more conservative. Many patients would show reactions, resembling the old fashioned Flu, after a few days following exposure to the oscillator. I realized we were using too much power, so cut the level several times with good results; but we did not completely eliminate the side effects. In 1946 I was sent to Germany for the Government to explore Electro-biology and Biophysics in its application to electro-medical equipment. I felt it wise to destroy the machines so injudicious use would not be indulged. The possibilities have intrigued me ever since. It looks as though you have solved most if not all of the problems involved. Hence my renewed interest. The excess power upset the enzyme complex of the body, or as some felt, distorted the double electric layers of charge carried on the cells, hence allowing for the penetration of virii directly into the cells (virii operate within the cells -- bacteria operate between the cells). Cells as well as organs function in a force field so mild oscillating currents not only work through resonance but seem to regenerate these force fields. Here is where application to cancer can be optimistically explored."

Speak for your own state, Doc! Here in California the medical association has decreed that only four forms of treatment for cancer are legal; drugs, surgery, burning rays and death.

"Proof of energy flow from the fingers and thumb is here and must be recognized. We have demonstrated it by its effect on Yeast cells, viewed under the microscope (Girwich research). Whether it comes from the conscious rather than the subconscious mind is harder to prove, but I am impelled to believe it does. This may interest you. Years ago we experimented with crystallization. Precipitated water vapor to snowflakes in a chamber with electrodes planted in two sides. When we threw a current into the chamber at a given frequency the flakes were all the same. Changing the wave length changed the crystallization pattern. Each frequency had its own pattern. Here is the explanation of energy absorption by the chemical used, and the control of the crystalline patterns by the nature of the energy flowing."

Naturopaths are in 100% disagreement with the doctor's above explanation of the side affects of his use of the MWO on his patients. If I understand the theory correctly, according the natural view of colds, flu, virus infections, etc., these are attempts by the human organism to throw off mucous, to eliminate intolerable accumulations of poison from the system. Exposure to the field created by the MWO tends to raise the general tone of the whole system by stimulation. The raised vibrations release an unusual amount of mucous and other junk into the elimination channels, and until this is eliminated one would have a cold or flu and the usual aches and pains which generally go with such a condition.

Another doctor stopped by here not long ago to tell of his sad experience in trying to use spark-gap electronic equipment in his medical practice "for those suffering patients not helped by drugs." This powerful, high-frequency machine produced a two-inch spark! Every time he turned it on, everyone in town seemed to know it and the phone would ring. Even a Faraday cage didn't shield the output of this monster. Finally he was called before the county medical board to explain what he was doing. The board presented a staggering combination of fatuous conceit and stubborn ignorance. "They didn't want to know anything about the affects of radio waves on the body and didn't care!"

CURING CANCEROUS PLANTS WITH ULTRA RADIO FREQUENCIES

by Georges Lakhovsky

From Radio News February 1925

"The new application of short wavelength oscillations described in the following article" wrote the Editor of Radio News, "is one of the most important ever found, and we are pleased to present to our readers this article by Mr. Georges Lakhovsky, the well known French scientist. The experiments described were carried out in collaboration with several doctors and scientists of high standing and it seems from results obtained, that the very high frequency treatments will play an important role in the future. We shall publish in a later issue another article on this new system together with the effects of ultra radio frequencies in the treatment of diseases in human beings."

Since November 1923 I have published in various technical and radio publications, several papers in which I explained my theory that the instinct or special feeling, which permits birds to direct themselves in space, is only the results of the emission and reception of rays by living beings. While developing this theory, I explained how thoroughly I was convinced that science will discover, some day, not only the nature of microbes by the radiation which they produce, but also a method of killing disease bacilli within the human body by means of the proper radiations.

The researches I have made by means of special apparatus have shown such results, that I believe my theory is correct. This theory is that life is born from radiations, kept going by radiation and suppressed by any accident producing the destruction of the oscillatory equilibrium, especially by the radiations of certain microbes, which suppress those of the weaker cells.

Before going any further in our reasoning, it is necessary, in order to present the facts to the uninitiated reader, to imagine what oscillations really are. The motion of a pendulum will be used for this explanation. When a pendulum is displaced from the position of equilibrium, it moves back and forth producing what are known as ochrone oscillations, until the energy stored is entirely exhausted. By means of a motor, a spring, or an electro-magnet, it is possible to keep the motion of the pendulum of constant amplitude, producing undamped oscillations. If, on the contrary, the source of power is removed, the oscillations die down and it is necessary not only to re-apply the power sustaining the oscillations, but also to furnish additional energy to start the pendulum in motion. This oscillation of a pendulum reproduces exactly what happens in the cells of a living being.

Our organs are composed of cells formed of protoplasm containing various mineral matters and acids, such as iron, chloride, phosphorous, etc. It is by the combination of these elements that the cells detect outside waves and vibrate continuously at a very high frequency, probably higher than the period of X-rays or over all other vibrations known and measured today (1925). The amplitude of cell oscillations must reach a certain value, in order that the organism be strong enough to repulse the destructive vibrations from certain microbes.

COSMIC RAYS AND CELL LIFE

The astrophysicians are actually carrying out experiments of great interest on the existence of vibrations, which have been called penetration rays and of which the frequency is higher than that of X-rays and of the alpha, beta and gamma rays of radium. Such rays, according to the theory, are produced by the earth itself and some others come from outer space. Some accurate measurements have proved the correctness of this theory. Therefore, it is quite permissible to believe that these penetration rays, or at least some of them, produce the vibratory motion of living cells and consequently their life.

For instance, let us suppose a cell vibrates at a certain frequency and a microbe vibrates at a different frequency; the microbe begins to fight the cell, and sickness is started. If the cell cannot repel the stronger vibrations and if the amplitude of its own vibration decreases, the microbe gains and its vibrations in decreasing and stopping those of the cells, bring dangerous sickness or death. If, on the contrary, the living cell is started vibrating with the proper amplitude by inside or outside causes, the oscillatory attack is repulsed. Such is my theory.

The problem is somewhat similar to the situation in which a rescuer finds himself when, coming to help a friend in a dangerous situation, finds himself fighting hand to hand against strong aggressors. The rescuer does not dare to fire his gun; fearing to harm his friend mixed up with the aggressors in the melee. Similarly, microbes and healthy cells are exposed to electric or radio-active action, which could be used to destroy the unwanted rays and it is difficult to suppress them without harming or killing at the same time, the cells which are to be treated. In fact, since Pasteur, scientists have been constantly searching for means of destroying microbes. The great difficulty with all methods found was that in destroying the bacillae, the cell was attacked too. The experience gained in cancer and tuberculosis treated with radium, X-ray, or ultra-violet rays, shows how difficult is the work of the investigators.

A RADICALLY NEW METHOD

The remedy in my opinion is not to kill the microbes in contact with the healthy cells, but to reinforce the oscillations of the cell either directly by reinforcing the radio activity of the blood or in producing on the cells a direct action by means of the proper rays. During January 1924 I began to build, according to this theory, and with the purpose of therapeutic applications, an apparatus which I have called Radio-Cellular-Oscillator, with the firm belief that the cells vibrating at extremely short wave-lengths would find their own in the Hertzian waves, which have the properties of producing extremely short harmonics. The cell with very weak vibrations, when placed in the field of multiple radiations, finds its own frequency and starts again to oscillate normally through the phenomenon of resonance. This type of vibration which I propose to use, is harmless, unlike those of X-rays and radium. Their application, therefore, does not present any danger to the operator.

I exposed in front of my apparatus, during long periods, a certain number of microbes in culture, which developed themselves normally. I, myself, have never felt the effect of these ultra radio frequencies, although I remained for a great many days near the apparatus, during the treatment applied to the living cells. It is only when two living beings such as a cell and a microbe, are in contact, that the rays produced by the Radio-Cellular-Oscillator have any direct effect upon cellular structure.

WORK IN A FRENCH HOSPITAL

The experiments which I carried out at the Salpetriere Hospital in Paris, in the service and with the collaboration of Prof. Gosset, were made with plants inoculated with cancer, and the results were described in a paper presented on July 26, last year, before the Biological Society. The text of this paper follows.

"One knows that it is possible to produce by inoculation of Bacterium tumefaciens in plants tumors similar to those of cancer in animals. One of us obtained experimentally by this method, a great number of tumors. These had various degrees of development. Some of them dry up partially, but do not die entirely until the entire plant or at least the limb bearing the tumor dies. Even removed by surgical methods, these grew again on a sick limb.

"We propose to describe in this paper, the action of electromagnetic waves of very high frequency obtained by means of the Radio-Cellular-Oscillator of Georges Lakhovsky. This apparatus produces wave-lengths of the order of two meters and less, corresponding to 150 million cycles per second. A first plant was submitted to the effect of radiation one month after being inoculated with cancer; at this time small tumors of the size of a cherry stone were visible upon it. This plant was submitted to the rays twice, for three hours each time. During the following days, the tumors continued to grow rapidly in the same way as those on plants, which had not been submitted to the effect of radiations. However, 16 days after the first treatment, the tumors began to shrink and dry up. A few days later the tumors were entirely dried up and could be very easily detached from the limb of the plant by merely touching them. The drying action of the radio frequency radiations is selective and affects only the sick part of the plant. Even the inside sick tissues were destroyed, although they were next to healthy cells in the center of the limb, showing that the radiations had not affected the healthy parts.

"Another plant was treated in the same way, except that it was exposed 11 times for three hours each time, to the radiations of the oscillator. Sixteen days after the first exposure the tumors, which were rather large as shown in one of the photographs, began to shrink and dry up and were easily detached from the limb exactly as in the first case. Again in this case, the healthy parts of the plant were not affected in the least. A third plant exposed to the radiations for nine hours, that is, three treatments of three hours each, was cured in the same manner as the two others. Sixteen plants also inoculated with cancer, were left without treatment. They have tumors in full activity, several of which are very large. These experiments show conclusively that plants inoculated with cancer can be treated and cured by means of the ultra radio frequency vibrations, whereas surgical treatment fails.

"Such are the results of my researches with plants. At the present time, similar experiments are being carried out with animals and it seems that the effect on cancerous animals is the same as on cancerous plants.

"I am highly pleased to present my theory and the results of my work in a scientific review of the United States, this great country, which has always been in the lead in the fight against this horrible sickness, cancer, and whose sympathy and help I would greatly appreciate.

"In conclusion I wish to call the attention of the reader to the fact that I have obtained very conclusive results not only with a wave length of two meters, but with longer and shorter wave-lengths. The main thing is to produce the greatest number of harmonics possible."

* * *

This February 1925 article from Radio News magazine shows how long some of Lakhovsky's theories have been known in America. This article was furnished to BSRA by an Associate who had met the Russian-French scientist in New York. He claims also to have visited several times the New York hospital which set up a research program on the Multi-Wave Oscillator and saw the Lakhovsky-type equipment. No information on the machine or its effects could be elicited from the hospital authorities and in the early 1950s the shielded room was dismantled and equipment destroyed.

We feel that Lakhovsky's theories and early researches should be followed up. It should be publicly proven that high-frequency waves, in the proper concentrations, do affect living organisms in a beneficial way, or that Lakhovsky be declared an idle dreamer. Since research of this kind falls within the purposes of Borderland Sciences Research Foundation, Inc., members are encouraged to build their own equipment and, in a suitably shielded or isolated environment, carry on their own research program. If you cannot

obtain the necessary materials, BSRF may be able to put you in touch with another borderlander who can be of help. Until the medical authorities come forth with official approval of this radical approach to the state of imbalance or un-health attributed to disease, no one but a fool would go into commercial production of this kind of equipment in America today. It is now said to take a minimum of $300,000 in research money and three years of testing to develop medically acceptable data.

HOW DR. JAMISON WAS TRAPPED

In a letter dated Aug. 29, 1967, Dr. Jamison enclosed this news clip from the **Modesto Bee**: "Turlock — Veterinarian Stanton L. Jamison yesterday was fined $249 in Turlock Judicial District Court after being convicted of three charges stemming from his use of an electronic machine to treat human patients for cancer. A jury of nine women and three men returned a verdict of guilty on one count of practicing medicine without a license and two counts of advertising a device represented to have effect on cancer, stomach ulcers or bone diseases. The decision followed a two day trial in which Jamison defended himself. . .

"They (Jamison and his assistant, Martha Ann Davis) were arrested last December following a lengthy investigation by Turlock police officers and agents of the State Bureau of Food and Drug Inspection. The investigation began when Police Chief John Viarengo requested assistance from the bureau after learning 'the cancer-curing machine' was being operated here.

"During the investigation, Food and Drug agents Willis Worley and Harvey Lee arranged several meetings with Jamison on the pretense they were interested in purchasing machines similar to his. Jamison reportedly organized a church as a front for his operation. The facility, located at 200 West Main St., was known as the Life Aquarium Center. Worley and Lee became bishops of the church as did deputy District Attorney Frank Damrell, Jr., who prosecuted the case. At the time of the investigation, Damrell was employed in the State Attorney General's office.

"Worley said Jamison's intention was to open other treatment centers throughout the state, using his bishops to set up facilities under protection of the church. 'This was the most fantastic investigation I've ever been involved in,' said the agent this morning.

(Yes, it is fantastic to think anyone would want to give or donate healing services free when there are billions to be made on the four kinds of cancer treatment authorized by the California Medical Association: Drugs, Surgery, Radiation and Death. RHC.)

"Worley points out the manufacturer of Jamison's machine was convicted of grand theft two weeks ago in Los Angeles after selling a similar machine to a Food and Drug agent under false pretenses. (This was probably Ralph Bergstresser, Burbank, Calif., who was manufacturing and selling the Bob Beck MWO for $250.)

"After Jamison's conviction yesterday, Damrell called for imposition of a prison term for the veterinarian. If he had received the maximum penalty, he could have been sentenced to 18 months in jail and fined $1,500.

"We felt very strongly on this," said Worley, "because Jamison could easily become a menace to many innocent victims throughout the state."

MWO IN USE AT INDIAN CLINIC

"I am continuing my experiments with the MWO and my experience is that in practically all cases there is an aggravation of the existing symptoms, and previous symptoms are brought to the surface. Hemorrhage was seen in another case and treatment was stopped forthwith. This is one problem which has to be tackled before MWO can be used with confidence. I think MWO treatment should not be given to tubercular cases. Also in cases where there is a hemorrhagic tendency this would do more harm than good.

"Neuritis seems to respond nicely to this treatment. Sciatica is definitely cured by this. Some cases of Rheumatism and Arthritis are benefited, responding at first but the improvement does not last much longer. I cannot understand the reason for this eccentric behavior. I think there must be something with the frequencies."

Don't blame it on the frequencies, Doc, blame it on the patients who stubbornly clings to their fixed ideas and rigid unyielding mental patterns. We have no evidence that the radio frequencies of the MWO reach into the mental world. Each person's aura is loaded with "signatures", national, family and religious concepts hammered into him over the years. His creative energies, flowing freely down from the higher worlds, channel through these deeply cut "grooves" in mind and emotions. The health or illth of the physical body indicate whether the person's ideas are in tune or out of tune with Creation. As a man thinketh in his heart, so is he.

"Can you please let me know what are the ranges of frequencies these machines have? Have they been measured and are they the same in all instruments? Is there any difference in the models prepared in the USA and France? Which model was tried by Lakhovsky in the New York hospital? What are the actual frequencies used by him?"

The only frequency readings we have on an MWO were those submitted by Bob Beck originally, from the output of his own machine. "It radiates RF interference over a bandpass of 15 Kilocycles to well beyond 250 Megacycles. This blocks AM, FM and Television reception for hundreds of yards" But so does my electric razor, and I've been using one for years. I was told by a sailor that electric razors are very effective as "scramblers" for knocking out the electronic brains of guided missiles, and have been so used as defensive equipment during missile exercises on aircraft carriers at sea. No one has furnished us with RF output figures from original Lakhovsky equipment, either at the New York hospital or from Europe. If anyone has these figures I hope they will be kind enough to forward them to you. Lakhovsky's available technical record is very slim.

"An Associate writes 'A very good psychic in Florida gave the following, in a sitting devoted to the MWO. It is not anywhere near developed to its potential. It has unlimited amplifications to be made. The use of the MWO can change the auric field, thus spiritually it can change the individual. This is done with the work of the seven rays of life. The MWO should be used in conjunction with the radionics instrument.' What about this radionics instrument? I would appreciate it if you can throw some light on this."

Sorry Doc, the punitive hand of the American Medical Association has driven radionics builders and users underground here in the United States. No one but a fool like me would stand up on the firing line. England isn't quite the police state America is and you can get information on radionics and radionics equipment from the Delawarre Laboratories, in England, and from Bruce Copen, in Sussex, England. Radionics experts have developed rates for every organ in the body. Equilibrating those rates with specific radio frequencies offers an interesting field for borderland research.

"I have tried both the Vitic and the Eeman Screens. I am still continuing my experiments with the Eeman Screens. Only a couple of days back I gave a set of screens to a patient who is having an encyclopedia of complaints. The MWO did not give her much improvement hence the change. I have one set of Vitic with me and whenever I feel a bit out of sorts I sit for ten minutes and get back my vigor. I am using a very strong pair of magnets and a carbon rod 1½ inch in diameter. After I received the MWO my interest in the other two flagged. I think I will have to cultivate them again."

Dr. A.K. Bhattacharya

From the March 1964 Journal of Borderland Research

ARMY MEDICAL RESEARCH SUPPORTS LAKHOVSKY THEORY!

That's our headline, and it's derived from news clips loaned to us by an Associate. One especially is from the New York "Times" for Friday, Aug. 19, 1960 by John Osmundsen.

The heading says that Radio Microwaves Produce Molecular Changes in Human Beings. This is merely a repetition of what Georges Lakhovsky proved with his pioneering work in Paris hospitals in the 1920s!

"New and possibly important biological effects of radio and radar waves were reported at a three-day scientific meeting that concluded here yesterday. One scientist told of producing 'a profound molecular change' in human gamma globulin with specific wave lengths of radio waves in the high frequency to very high frequency, or VHF range.

"Alterations so created in the molecules that constitute an important part of the body's defense apparatus were accompanied by at least a fourfold increase in their biological activity, the scientist said. 'The changes can be produced under widely varying conditions of voltage, power, pulse width, and pulse repetition rate, provided the frequency is suitable,' according to Lieut. Col. Sven A. Bach of the Army Medical Research Laboratory in Fort Knox, Ky."

If Col. Bach had been working from Lakhovsky's original theories and equipment, he wasn't saying. This is obvious in reporter Osmundsen's next paragraph.

"This is believed to be the first report of a proven frequency-specific effect of radio waves on human chemistry. Dr. Bach's report appeared to cause more comment at the conference than almost any other, for the effect of radio frequencies on human gamma globulin in the test tube were clearly not a result of heating.

It was suggested by Dr. Bach that the increased biological activity of the molecules as measured against a rabbit serum sensitized to them might have resulted from an unfolding of their structure, thus exposing more active spots."

YUP, THEY MIGHT EVEN CURE CANCER

Later in 1960 an electronics magazine revealed even more about the proceedings of this Fourth Annual Tri-Service Microwave Conference held in New York. Our news clip is only half a page which reveals neither the magazine nor the writer, but about Dr. Bach's claim of a four-fold increase in the production of gamma globulin, he says:

"What does this mean to you? Gamma globulin plays an important part in the body's defenses against disease. Speed up its activity fourfold and it may be four times as effective a disease fighter. Some day your doctor may give you 'a shot of microwave' to keep you well.

Dr. Joe Howland of the University of Rochester found that dogs which had been exposed to microwaves were able to withstand heavy doses of X-rays far better than dogs not so treated. No specific application for this technique is now known, but such discoveries frequently lead to undreamed-of advances.

"And finally, some evidence has been gathered to indicate that certain kinds of cells, under the right conditions, will simply disintegrate -- fly to pieces -- in the presence of the right radiation. But surrounding cells are unaffected. Could such a selective beam ever be used to destroy cancer cells while leaving healthy tissue unaffected? Scientists don't yet know."

The writer didn't say which scientists he is speaking for, certainly not for Georges Lakhovsky, who died in that very same New York City 17 years before the Microwave Conference. Before-and-after photos of skin cancer cures effected by the Lakhovsky Multi-Wave Oscillator in Paris hospitals in the 1930s show that the Russian inventor did know just how selective radio microwaves can be. These pictures are reproduced in Lakhovsky's book, "The Secret of Life".

To continue with the magazine article: "said Col. George M. Knauf, one of the foremost experts on the biological effects of microwaves, speaking of these recent advances, 'Our work has progressed sufficiently for us to be fairly certain that the beneficial uses to which this energy may be put will greatly outweigh any harmful results it may produce in men.' All this of course does not mean we should forget that uncontrolled microwave energy can be dangerous. But like fire or W-rays, microwaves can, when used intelligently and with understanding and respect for the hazards involved, be among man's most valuable tools."

MULTI-WAVE OSCILLATOR USE IN A NEW YORK HOSPITAL

Georges Lakhovsky crossed the Atlantic to New York City in 1941, there to observe the effects of his MWO under controlled, technical conditions in a New York Hospital. A brief report of the positive and beneficial results of MWO treatments is appended to the English translation of his book, "The Secret of Life", by Mark Clement, on page 201. These treatments were given from July 1st to Aug. 21st and the name of the hospital and of each patient are withheld for ethical reasons.

Patient	Illness	Treatments	Results
X.	Arthritis, both knees	14	Good improvement
O.P.	Endocervicitis. Abdominal pain	6	Condition good
F.T.	Periarthritis of shoulder	12	Marked improvement after first treatment, condition good
M.M.	Osteoarthritis	7	Marked improvement after two treatments, stiffness diminished
M.K.	General Chronic Arthritis	11	Slight improvement
M.O.	Arthritis of ankle	3	Results good
A.E.	Post-operative fracture	6	Results good
C.V.	Arthritis, both knees	14	Marked improvement
M.D.	General arthritis	8	Marked improvement
J.H.	Epicondylitis of elbow	7	Results good
D.G.	Chronic arthritis	10	No cough, no soreness, marked improvement
S.L.	General arthritis	10	Marked improvement
B.M.	Arthritis and circulatory disturbances	6	Improving
M.L.	Arthritis of ankle and knee	7	Improvement, no recurrence
M.B.	Arthritis of shoulder	7	Marked improvement
M.O.	Tenosynovitis, hand	6	Improvement
S.S.	Arthritis, both knees	7	Improvement

S.C.N.	Congenital hip dislocation	3	Marked improvement
R.L.	Fracture, both ulnae.		
	Synovitis, both knees	5	No pain

Additional Cases

Case 1. G.D., female, aged 25: Patient complained of pain in the chest and muscles of the right arm and back, and constant cough. She did not respond to medical treatment and massage. Treatment with Lakhovsky Multiple Wave Oscillator was instituted. After the fourth treatment coughing stopped, pain in the chest became infrequent, and the tired feeling in the back disappeared. At the end of 12 treatments the patient no longer complained of previous symptoms.

Case 2. M.M., female, aged 51: Patient complained of pain and stiffness in the right hip. X-ray examination disclosed a marked narrowing of this articulation associated with large spurs at the margin of the acetablum which appeared to ankylose the joint. There were proliferative changes in the upper margin of the femoral head. Diathermy and massage failed to relieve the pain and stiffness. After 10 treatments with Lakhovsky's M.W.O. the stiffness markedly reduced.

Case 3. F.T., female, aged 38: For two months the patient complained of pain in both shoulders. Abduction of the right humerus was limited to 45 degrees. A diagnosis of periarthritis was made and treatment with Lakhovsky's M.W.O. was started. After three treatments the patient said she felt much better. The improvement continued. After a series of 11 treatments the patient did not return. Apparently permanent relief had been obtained.

Case 4. A.B., male, aged 60: Patient gave history of pain in both knees beginning in 1940. Diathermy and massage for one year gave only slight relief. Treatment with Lakhovsky's M.W.O. was instituted. After one treatment patient stated that he felt better. After four treatments patient felt so much better that he took only one treatment in two weeks.

Case 5. M.M., female, aged 42: Patient complained of pain in lower left back and hip. X-ray examination of the lumbar spine and pelvis showed calcification at the anterior margins of the inter-vertebral discs between the ninth and tenth and the tenth and eleventh vertebrae. There was also a slight scoliosis of the lumbar spine. Treatment with Lakhovsky's M.W.O. was instituted. After the first treatment patient felt better. After the fifth treatment improvement was very marked. Patient did not return after nine treatments.

Case 6. S.N., female, aged 59: Patient complained of pain in the right shoulder and inability to extend the arm more than 5-10 degrees, accompanied by severe pain. X-ray examination disclosed irregular calcification in the region of the greater tuberosity of the right humerus. Treatment with Lakhovsky's M.W.O. was instituted. After one treatment patient said she felt much better. The improvement continued steadily until 10 treatments were completed.

Case 7. C.P., female, aged 38: Gynecological examination showed uterus slightly enlarged and hard. Right para-metrium tender. Diagnosis --Parametritis. Treatment with Lakhovsky's M.W.O. was instituted on July 17, 1941. After four treatments patient felt better, and after 12 treatments patient was found to be much improved. Examination on Oct. 7th showed the adnexa and parametrium to be painless. Patient was considered cured.

REPORT OF CASES TREATED WITH LAKHOVSKY'S MULTIPLE WAVE OSCILLATOR BY A PROMINENT BROOKLYN UROLOGIST

The following results were obtained by a prominent Brooklyn urologist whose name must be omitted for ethical reasons. He is a Fellow of the American College of Surgeons and enjoys a great reputation as a skilled specialist. He treated hundreds of patients with Lakhovsky's MWO but only a few typical cases can be given here.

H.G.	Acute urinary retention due to enlarged prostate	2	Retention ceased
R.B.	Bleeding from uterine fibroids of two years standing	3	Bleeding ceased
S.M.	Mild multiple sclerosis with halting gate	6	Marked improvement, was able to run on several occasions
R.R.	Cellulitis of nose with pain	2	Cleared completely after two treatments of ten minutes each in one day.
B.T.	Acute urinary retention due to enlarged prostate	2	Retention ceased.
S.B.	Bleeding from cancer of the bladder	3	Bleeding checked. The tumor cleared up nicely and was reduced in size when seen again on cystoscopy three weeks later.
J.G.	Chronic aczema of Axilla	2	Cleared entirely.
L.G.	Severe pains form duodenal ulcer	2	Greatly improved.

In addition to the above cases this Brooklyn specialist treated six cases of enlarged prostate with nocturnal frequency (three to five times per night). After two treatments with Lakhovsky's M.W.O. frequency was reduced "to only once a night or did not occur at all..."

The above American reports were not included in the first edition of Georges Lakhovsky's "The Secret of Life", published in 1935, but were added by the English translator, Mark Clement, to later editions. We are quoting from the 1963 edition published by Health Science Press, Sussex, England. Health Research, (P.O.Box 70 Mokelumne Hill, California 95245) offers this same book.

This early (1941) research with the Lakhovsky equipment seems to nave been ignored by the American medical authorities, who are still concentrating on cure by surgery or medicine. If you want to discover the effects of weak radio waves on living organisms you'll have to dig for yourself. Our BSRA brochure, "The Lakhovsky Multi-Wave Oscillator", will give you some hints about setting up your own research program, and is available from headquarters.

'DOCTORS SAY RADIO TREATMENT IS EFFECTIVE AGAINST ARTHRITIS'

Apparently some doctors didn't ignore the research work done by Georges Lakhovsky. Take this news item from the New York "Post" for Feb. 8, 1962, with an Associated Press dateline from Washington, D.C. "A device theoretically capable of bouncing radio signals off the moon has yielded highly effective results in the treatment of stubborn cases of arthritis and certain other ills, a group of doctors

reported today. The machine generates high-frequency, short-wave-length radio waves and emits them as pulses lasting only 1/17,000th of a second each. The pulsed currents are directed into a patient's body, with a maximum achievable penetration of eight inches.

"Use of the technique in treating arthritis, bone infection after hip operations, inflammation of the female pelvis due to gonorrhea and other conditions, and in speeding the healing of surgical wounds was described in reports by Dr. Euclid M. Smith of Hot Springs, Ark.; Dr. Dana Street of the University of Arkansas; Dr. Bruce Camern of Baylor University; Dr. Marshall Lobell of Harlem Hospital, N.Y.; and Dr. Solon N. Blackberg of Chicago. The reports were made last night at a private conference to which several Congressmen and Public Health Service doctors were invited. Blackberg later told reporters the researchers would like to enlist government support for expanded research by themselves and their investigators.

"Smith, in his report on arthritis, said the technique had been employed with "highly "effective results in 99 out of a series of 100 cases treated by him. Declaring that some of the patients treated had arthritis for up to 25 years before receiving radioactive treatment. Smith told reporters that "marked improvement" was achieved in all cases in from three to six months.

PUBLIC RECOGNITION OF RADIOWAVE TREATMENT

This sensational advance in the treatment of human ailments should have been welcomed from coast to coast in every newspaper. Dr. Blackberg and his distinguished fellow scientists from Baylor, Arkansas and Harlem should have received public acclaim from President Kennedy's Dept. of Health and Welfare and from the American Medical Association. But only a thunderous silence followed that early 1962 news item ion the private meeting in Washington -- until the Aug. 24, 1963 edition of the Saturday evening Post! In this national magazine, radiowave treatment of arthritis was branded medical quackery in the article "Hucksters of Pain". There Drs. Smith, Street, Camern, Lobell and Blackberg had their answer to "government support for expanded research". Fortunately, not every American is going to take this kind of libel without striking back at the mouthpieces of the vested interests who lend themselves so readily to control of the mass mind. Read this news clip from the Los Angeles "Times" for Nov. 1, 1963.

"SATURDAY EVENING POST SUED FOR $7.5 MILLION"

"New York -- The Saturday Evening Post, still smarting from one of the largest libel awards in history, was hit Thursday with another libel suit demanding $7.5 million.

"The suit was filed in Federal District Court here by the Diapulse Corp. of America, manufacturer of a machine that employs high-frequency waves in the treatment of infections and inflammations, including arthritis. The company said it was defamed in an article, "The Hucksters of Pain", which appeared in the Aug. 24 edition of the magazine. The article dealt with quack remedies for arthritis. The suit seeks $2.5 million in compensatory damages and $5 million in exemplary damages."

From the June 1964 Journal of Borderland Research

LAKHOVSKY OSCILLATING CIRCUITS

"About eight years ago I sent to the Health Science Press, Sussex, England for a little book, "Quick and Free Healing", and also "The Waves That Heal" and found that there are healing waves in the air we breathe. I am a sensitive with the pendulum. The book told to take an insulated copper wire and find the positive and negative ends with the pendulum, so I would know which end to put to the left side of my body --positive to the right and the ends overlapping. If you can't keep them in place, wrap an elastic band around them. For me, the pendulum swings clockwise for negative and back and forth for positive. First use of the wire came when I skinned my shin with a five-inch gash. The bleeding made me sick and I had to lie down. I thought of my wire circuit, got up and put it on just above the knee. It always had taken a long time for sores to heal on my body but this healed in three days time and showed only a narrow line about the width of small yarn. This convinced me that the oscillating circuit wasn't foolish.

"I loaned my little books to a high school student that was taking science. I thought they would interest him but he made all manner of fun of me, for believing such a thing. None of my family are interested in the good things that I have learned. I have been a member of BSRA since 1951 and think your journal is the best magazine I have ever read. Anyone wanting to learn more about the Lakhovsky circuits can write to Col. A.E. Powell. (Now deceased)

"Forty years ago I was taking treatments from an osteopathic doctor who sometimes diagnosed with the pendulum. When I became pregnant he told me he was going to discover the sex of my unborn child. He took his gold band ring off, tied a string to it and held it over me. It didn't seem to have any definite swing, maybe around once and back and forth. 'That's strange,' he said, 'I've never missed yet!' When the baby came there were two, a boy and a girl! I didn't ask him then where he learned about the pendulum or what it meant. Years afterward I sent to New York for one and found that I could ask questions and get yes or no answers that satisfied me. A medium told me that the pendulum is spirit controlled and mine was controlled by a young girl who was rather mischievous. If you want to put my experiences in the BSRF Journal it is all right with me. I got my education in the little red schoolhouse. I am 73 years old and still learning. They say you never get too old to learn and I find it is very true." Mrs. Earl Holfinger, Piqua, Ohio

A "HOPPED UP MWO" IS DANGEROUS!

"It is far too early to draw final conclusions regarding my experiences with the higher powered Multi-Wave Oscillator, a word of warning is in order. I powered mine with a 250 VA, 10 KV oil burner transformer. This is DYNAMITE and could, in my opinion, be fatal if too much power is used and I didn't miss it by much. My equipment sparks the antenna down to the 4th ring and the resonator to the second, with occasionally a week spark to the third. 10 hours after the first high-power exposure I felt like running instead of walking (age 72) and walked all around town and back, about six miles and no tiredness, whereas two miles would tire me before. That first exposure was about ten minutes for me and four for the wife (age 75). Immediate reaction for me was a moderately strong sensation of tingling from head to foot for about three hours before I could get back to sleep. None of this for the wife. Then, as aforementioned, I felt on top of the world. 24 hours after that, however, the wife and I developed the grandaddy of all colds and flu symptoms that we'd ever had. I hadn't had any real cold or flu in 15 years. This one dredged such an amount of mucus and toxic waste as I'd never seen before in my life. It was

rough. It lasted two days before it wore off.

"This all had me guessing until your brochure arrived, with the experience of your Engineer-Physician Associate. He told that many of his patients developed flu symptoms after MWO exposure. His increasing conservatism was well founded. I decided to find out if the doctor's hypothesis of viral penetration would hold up. If so, a second high-powered treatment of equal strength and duration should produce much the same flu symptoms. But, having wound another coil, I used more power than the first time, sparking antenna and resonator down to the fourth and fifth rings. Results: no more flu, only a very slight tingling sensation, no feeling of exhilaration as before. Five days later I took another exposure, of seven minutes, with a little less power. This one did it. No tingle, no exhilaration, only a feeling of rapidly increasing depression, no sleep that night, a rather severe pain in the chest and heart region, extremely weak pulse, hardly pep enough to life an arm, and a nervous shaking all over. For a while I thought, this is it. It took five days for this to wear off and it isn't all gone yet. One night I lay awake until three a.m. figuring out how to pep up the MWO still more. Out of the blue, a voice clear and distinct and very emphatic: 'This is dangerous!' Again very emphatically, "Yes!" Normally I am not the least psychic, clairvoyant or clairaudient; so I choose to heed this as a warning from a discarnate guide or guardian."

Let this Associate's experience be a warning to you, if you feel the urge to build a hopped-up Oscillator, to transform yourself overnight! Bob Beck's original article cautions against this and his original equipment falls well within the safety tolerances set by the Air Force and the telephone companies for personnel working around radar and micro-wave broadcasting and relay equipment. Most of you taking part in this research program have built your equipment only in the last two or three months. It would be wise to stick closely to the original design for a year before altering it for further research.

LAKHOVSKY'S ORIGINAL THEORIES ARE SOUND!

With one or two exceptions all reports in to date show beyond question that Georges Lakhovsky's theories are sound: Radio waves do effect living organisms. In certain concentrations these waves appear to benefit cell growth, even to stimulate it. This BSR Associates have proven to their own satisfaction in only six months from the publication of our first article. Now it is up to others to exploit this knowledge while we turn our attention to other projects.

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From the July-August 1964 Journal of Borderland Research

LAKHOVKSY OSCILLATING CIRCUITS

"The danger of strong reaction to a hopped up MWO, as told in the June Journal, reminds me of my experience with the single circuits. Months ago I wrote to Col. A.E. Powell and he sent me single circuits to wear around waist, neck etc. This I did for two months or so, daily. I'd been under the weather enough to hope for benefit. Instead, I had three successive colds -- something I never, never had in my life before, even during the worst of my catarrh years. It never once dawned on me it could have been the Lakhovsky oscillating circuits; now I wonder?"

A California Associate

Yes, it had been the experience of others that the apparently powerless Oscillating circuit, of only one wire looped around the body, can produce a strong reaction on living tissue. A San Fransisco Associate told us during our May trip north that she received a wire loop from Co. Powell and wore it to bed that night, and forgot about it. Early in the morning she awoke with such a violent pain through her middle she thought she'd die! She lay there and stuck it out until the pain left and went back to sleep. In the morning she awoke refreshed and ready to go, with the oscillating circuit still around her middle. It began to dawn on her that this was the cause of the pain, but it also had affected the healing of a long-suffered condition. At the time we were there, weeks later, the condition had not returned. Certainly no permanent cure of any condition can be expected unless the original cause in mind, emotions or spirit is changed, and if a person insists on indulging his vices, use of oscillating circuits may only cause needless pain!

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From the OCTOBER 1964 Journal of Borderland Research

HE PREFERS VITIC TO MWO

"Personally, while feeling the passage of the high tension flow from the antenna of the Multi-Wave Oscillator, I found no beneficial effect. On the other hand, the Associate with whom I obtained the MWO realized definite improvement. He has kept up the use and told me lately that he is feeling steadily better and lays the improvement to the use of the outfit. Some years ago I had frequent conferences (thru a medium) with one who was said to be Madame Blavatsky. During the course of these talks she dismissed the subject of electricity as of little value in comparison with a study of magnetism. That in the study of magnetism lay the secrets of many valuable matters. I am led to refer to this because I recently obtained relief, and apparent cure, from a troublesome irritability of the bladder by the use of a magnet. Other treatments had been of no value. I made no report of this until the fact was definite. The use of the magnet was experimental and came from the suggestions of a Chicago University specialist in the subject, relayed to me via various Biomagnetic reports and some correspondence."

Associate A.N. Onymous, Dixie, U.S.A.

This letter from an elderly Associate was dated Sept. 3, 1964. It certainly provides an interesting and stimulating commentary on the material in the preceding pages of the Journal. Interestingly enough, we've had many reports of successful and continued relief of irritating bladder and prostate conditions from exposure to the MWO. In the Vitic device we now have a borderland gadget that is far less troublesome to build and to operate. How effective it is remains to be proven.

THOSE LAKHOVSKY CIRCUITS AT WORK

"About the Lakhovsky wire circuits, there is no other way to account for the consistently maintained energy I receive. I wear one all the time as do several others I know, all of whom report amazing results. One man past 80 finds it peps him up too much, so he wears it intermittently."

Howard D. Clark, Yucca Valley, Calif.

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From Jan-Feb 1965 Journal of Borderland Research

HE WORKED WITH GEORGES LAKHOVSKY

"A friend of mine sent me your pamphlet describing the Lakhovsky Multiple Wave Oscillator. I was the first man that bought this instrument in New York in 1940, on the advice of a physician who saw it at a medical congress in Vienna. My young son had developed a face lesion. It was diagnosed as tubercular. I was having a joint office at that time with a progressive MD. I was practicing dentistry. Her success with the MWO was phenomenal, but when she began to treat cancer cases the American Medical Association got after her and me and revoked our licenses. I had translated some of Lakhovsky's works into English from the French. Professor Lakhovsky came often to my New York office. He told me the Pope was using one of his instruments. The success obtained in the hospitals was excellent but the reports were suppressed. The good professor died of a broken heart. Our case was a regular frameup by the AMA, the lawyers and the courts. I was foolish enough to fight the case and spend lots of money, not knowing that the AMA controls even the courts and judges. I still have some copies of the booklet and a photo of my Lakhovsky instrument. If I can locate them I'll send them to you. I sold my instrument to a doctor in Texas and left New York state in 1945. I am a licensed Naturopath in Florida and Chiropractor in California. Am enclosing $ for membership. I belonged to BSRA several years ago."

Dr. N.S. Hanoka, Miami Beach, Florida

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From March 1965 Journal Borderland Research

"THE SECRET OF LIFE"

"I loaned my copy of Lakhovsky's 'The Secret of Life' to my chiropractor, also your Journal. He had one build and I've been taking treatments from him on the Multi-Wave Oscillator. After two treatments I got an awful cold and I have never blown so much bloody mucous out of my nose. Also, after each treatment, it would leave me weak. I would have to lie down several times a day. There always was a reaction but my bad sinus condition has cleared up considerable. I also had trouble with my liver and there were so many things that I hadn't been able to eat, for 15 years or more. Now I can eat them and enjoy them. The MWO is certainly worth having and I am improving."

Mrs. A.N. Onymous, Somewhere, Indiana.

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From the October 1966 Journal of Borderland Research

HITTING THE HEALING TRAIL WITH THE MWO

"It would be appreciated if you would put an announcement in the Journal that Dr. S.L. Jamison, D.V.M., N.D. (Gr.Br.) announces the opening of a practice of naturopathy in Santa Cruz, California.

"The climate has changed greatly from the old burning-of-books days by the FDA. We cannot all stand back and wait for "George" to do something. I have the advantage of a lot of training in a legitimate field of allopathic medicine. Only a veterinarian would be able to make such a move and escape retribution for it. A regular M.D. would be branded a traitor to his fellows.

"I have moved to Santa Cruz to set up practice as a naturopath, using the M.W.O. unit, spiritual healing and diet -- along with naturopathy measures for the

healing of old injuries and chronic degenerative diseases. There will be no charge if there are no results. Since my fees will have no legal status, this will be made clear to the people using the service so they will be under no compulsion to pay, even if results are satisfactory!

"There are no incurable diseases but there are incurable patients!

"With the MWO we have not gotten uniform results classified by the disease the patient had. About two out of ten people do not respond to the MWO unit at all. You had just as well breathe on them. I strongly suspect that these people should consult an allopathic physician, M.D., as they would be helped better by conventional medicine. You might say our cases were selected, as people came to us in the last stages of sheer desperation -- conventional methods (including chiropractic) having failed.

"Some of these (not many) also do not respond to the MWO. They usually respond to spiritual healing methods when this happens. This I have not figured out good as yet. Once in awhile an arthritic will claim to have been worsened by the unit. This occurs usually in an arthritic with arthritis in a number of joints. One treatment seems to break the poison loose in their body, and they fall like the wrath of hell about two days after. Get them in immediately and run them again, and everything is alright.

"To sum it all up, I have got so I do not care what disease a person has got as long as it is not an acute infectious disease, or a recent stroke case. I have been afraid to try it on either of these as all we would need is for somebody to fall over dead while on the unit and we would be wearing striped suits or breathing HCN in a gasper chamber. . . The unit regenerates the whole body." S.L. Jamison, D.V.M.

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From the July-Aug 1967 Journal of Borderland Research

A TRANSISTORIZED MWO

"I would like to compare operational notes with some one who has built one of these MWOs because I question some of the statements made in the original article. I'll just give a brief description of mine and some of the things I ended up doing. I started with aluminum elements but had trouble with the gluing process so ended up with using printed circuit boards so my elements (antennas) are copper. I have good arcing between first four rings. Can make 'em all arc if I bring point of wooden pencil near the smallest, but pencil must be held certain way or I'll get knocked on my haunches.

"I ended up with a 9 in. Tesla coil. Tried 7, 6 and 5 but ended up with nine. The trouble here was with leakage between primary and secondary. It was terrific until I took means to reduce to a minimum. The transistorized drive I use is partially a hangover from the days of when I used transistorized ignition in my one vehicle. The ignition coil was modified to increase the step-up ratio and since the coil was mounted originally in oil, it was a 'slippery as an eel' project. The driver uses 5 transistors plus diode and operates on a source power supply which can supply up to 20 volts d.c. The drive seems to function best at about 15 - 16 volts.

"Now for a question. If Mr. Beck, as he indicated in his original article, 'reconstructed the circuits' of an original MWO in a certain man's house, why didn't you people publish a diagram and dimensional data on that original piece of equipment? That would be a project a man could sink his teeth in. Instead this pee-wee MWO which you now say is not much good unless everything arcs. You mean arcing all the way down to the smallest ring?????? When you get your up-dated MWO data published, let me know as I would like a copy. R.A. Rieck, Rochester, Minn.

Arcing between the first four rings, from the outside in on the MWO antenna, is about as good as any we saw when we were researching the instrument in 1964; so it sounds as though your transistorized MWO -- the first we've heard of --is doing very well and should be putting out enough energy to affect living cells. You any wish you had cut aluminum antenna rings after all. For some reason, the arcing between copper rings builds up deposits which must be cleaned off periodically. Bob Beck didn't offer us a schematic of the original Lakhovsky equipment he saw. He said it was housed in a 300 lb. cabinet. The antennas were of circular-formed pipe rings. The outside ring was two feet in diameter. There was a large, separate Tesla Coil driving each antenna. This is a professional model designed to impress the patient. It also probably puts out enough static to antagonize the neighbors for blocks around. We believe Bob Beck deserves all credit for grasping the principle of multiple wave propagation developed by Lakhovsky during radio's infancy in the 1920s and redesigning it into a simpler, smaller device for present-day borderland research.

LATER COMMENT ON THE MWO BY MR. BECK

"The key factor is that the rings MUST arc profusely all around the circumference of the outside and THIRD ring simultaneously. There is no effect, either on a calibrated Hewlett-Packard field strength meter, or physiologically, at the target frequencies if this arcing does not shock-excite the rings. And yet I have seen at least three machines that did not have sufficient voltage from the Tesla Coil to even drive the outside ring, let alone the third element! It would be a shame to invalidate the device because of this. Some of the machines I've seen drive the Model T Coil from an A.C. transformer! The obvious fallacy here is that the coil's vibrator is a resonant device supplying the make-and-break voltages (and magnetic field) to the T coil primary at the designed frequency. Since the transformer is on and off 120 times a second, the chances of the T coil points 'breaking' at the precise instant that the 60-cycle house current is at a POSITIVE peak is about one in fifty. And even if it fires 'sometimes', the T coil is modulated with the 120 cycle line (twice the 60 cycle frequency, since each cycle has two peaks, both a positive and a negative).

"Try it at 300 mc. and 10 kmc. on a field-strength meter some time. You'll see what I mean. The Tesla Coil, incidentally, is just a convenient supply of free electrons. The cascade of electrons or 'high voltage' breaks down the air's resistance (by arcing) and then drives the antenna rings. But if the drive is interrupted, the rings may not absorb and resonate properly. At any rate, it is difficult to kid the Hewlett-Packard meter, and I'd like to see the original design followed, at least for the first year."

AN IMPORTANT MODIFICATION

"The greatest modification to date was the discovery of a box of war surplus very high voltage rectifiers in a bin at a Burbank electronics store. The 30,000 to 60,000 volt selenium stack rectifiers.....eliminates the necessity for a tuneable gap, and roughly quadruples the output of the Tesla Coil, also lowers battery drain to half."

BEWARE THE PUNITIVE HAND OF THE AMA

Turlock, Calif. "Daily Journal", Dec. 2, 1966: "Dr. Stanton L. Jamison, formerly in charge of the state Poultry Pathological Lab here, was arrested yesterday for practicing medicine without a license. The veterinarian is charged with using an electronic device -- with high voltage sparks crackling and jumping about on either side of a patient --with the claim it was beneficial in cancer and bone diseases.

"After posting $1100 bail, Dr. Jamison defended his machine. He said parts for the machine cost less than $50. If someone followed up on the apparatus, he claimed, it would be a 'blessing to humanity'. Police Chief John Viarengo, Lt. Bill Ladd and investigators for the California Bureau of Food and Drug Inspection took Dr. Jamison into custody in the offices of his Life Aquarian Center in the Mercantile Building. Lt. Ladd said a sign reading 'Universal Life Church, Inc.' was prominently displayed in the front office. He said four or five agents had been 'ordained' as ministers in the church by telling Dr. Jamison they wanted to become preachers. Soon their official ordination certificates arrived in the mail, said Lt. Ladd.

"Police described the apparatus as similar to an electric chair, with four-inch metal rings looking like handcuffs hanging over doors to the room. The theory was to determine polarity of a patient with a pendulum and then proceed to change negative polarity to positive with the 70,000 volt device. Chief Viarengo said patients were being treated for a variety of diseases, including stomach ulcers and cancer. Investigation into Dr. Jamison's operations started in May, when police began receiving complaints from relatives of patients. No money was charged for treatment, according to Lt. Ladd, but patients were expected to make donations to the church. Dr. Jamison headed the state poultry lab here for a decade. He will be arraigned on the charges in Turlock Judicial Court next Friday morning.

"In a statement released following his arrest, Dr. Jamison said the 'multiple wave oscillator' picked up by police resembles many electronic gadgets used, usually ineffectively, in the past for treatment of many complaints. However, he insisted, his oscillator appears to be the exception that proves the rule.

"'The unit suffers from a sort of 'guilt by association' with other electronic gadgets to the point where serious doubt would be the reaction of any trained scientist on first observing it,' he admitted. 'I know that this was my reaction.' However, he said he suffered continuous pain following a 1962 automobile accident and, willing to try anything, tried the unit. It helped him, he insisted, and has helped many others. He said the unit had been tested and checked by qualified medical men in Europe in the late 1930s. 'Some progressive healer will follow up my lead in continuing to develop the electronic unit,' he said."

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From the November 1968 Journal of Borderland Research

AN MWO PHENOMENON

"Please find enclosed $ for another year's subscription to your wonderful Journal. It has been very enlightening, and I always look forward to receiving it. I have taken treatments on the MWO for a long time and have been puzzled. Soon after I started to take treatments, the hair stopped growing under my arms. I have wondered about this and if anyone else has had the same reactions?"

Mrs. E.H. Piqua, Ohio

This is new to us! If any of you researchers have experienced or observed a similar phenomenon, we'd be glad to hear about it and share it with the rest through

the pages of the Journal. The Tesla Coil problem has been solved with the discovery of a good commercial coil made by Master Appliances, Marion Indiana. This coil will drive one antenna very well.

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From the Jan-Feb 1971 Journal of Borderland Research

THE PASSING OF CYRIL SCOTT

"Cyril Scott, born Sept. 27. 1879 in England, died first week of 1971, so two friends here inform me. I'm always happy to see one who writes so intelligently regarding diet and health, vindicates his ideas by living that long. Not many do! BUT, I read in our local paper yesterday of the death of a former neighbor who died on 11th January at 93, and she knew nothing regarding diet, positive thinking, etc. So, where are we? I can't ever make 2 & 2 come to four, woe is me.

"Two small books come from Muriel Archdale, England, by Cyril Scott, 'Safe and Saner Remedies', and 'Health, Diet and Common Sense'. On page 162 of the latter he mentions the George Lakhovsky book, 'The Secret of Life', memory of which caused Mr. Scott to suggest using a copper wire around his middle to a man who was too breathless to walk far or uphill. The man wore the Lakhovsky loop for twelve hours, had a copious and offensive bowel movement, then on following day and another uphill walk, the man was able to keep up with Scott! I found my copper flex soon after but it is awkward to keep in place to make sure the negative end is to the left. Cyril Scott gives the homeopathic remedies needed, particularly emphasizes potassium for cancer."

A.F., Santa Cruz, California

COPPER BRACELET CURES "TENNIS ELBOW"

News Item from Crosby Golf Tournament at Pebble Beach, California a year ago. 1/24/70: "Bert Yancey one had to give up golf because of a nervous breakdown. He also came close to quitting the professional tour last year because of a 'tennis elbow'. But he didn't mainly because he found a remedy endorsed by Australian tennis pros John Newcombe and Tony Roche. The so-called remedy is a $7.50 copper bracelet, otherwise known as 'The Absorber' or a 'Voodoo Bracelet".

"Yancey wears one on his right wrist to correct an arthritic condition in his elbow and he has worn it for the past five tournaments, including the $150,000 Bing Crosby National Pro-Am, which he leads by two strokes at 137 going into today's third round.

"'I don't know why it works, but it does,' said Yancey, a 31-year old former West Point cadet who finished third in the 1967 and 1968 Masters and won the Atlanta Classic last year. He said a tennis pro in Napa Valley suggested last summer that he wear the bracelet and got confirmation from Newcombe and Roche, who have suffered from similar ailments, that it would work.

"Yancey strained his right elbow two summers ago lifting a concrete birdbath in the backyard of his home in Tallahassee, Fla. He took a pain-killing drug that enabled him to compete in the U.S. Open at Rochester (where he finished third), but he was warned that the drug w 'dangerous...that it gives you ulcers'. 'I never got ulcers, but I felt a pull in my stomach. That's when I quit using the drug.'

"He said he hasn't needed the pills anyway, since wearing the bracelet. The therapeutic effect of the copper, he said, has to do with chemical displacement within the body. 'I majored in chemistry while taking pre-med courses in college and I think I know enough about copper deficiency in the body to believe that, somehow, the bracelet can help me.'

"Somebody then pressed Yancey for an answer about what makes the bracelet such an effective remedy. 'I don't know for sure,' he drawled, 'maybe it's all psychological.'"

YANCEY WINS THE CROSBY OPEN

Sports writers are always looking for a new angle for stories and Bert Yancey withstood a spectacular charge by Jack Nicklaus on the final round, with a 65, and came in with a hot round of his own a 69, to win the tournament and a cash prize of $25,000. Yancey and his Voodoo Bracelet were headlined all over the country. The LA "Times" called it a "Copper Caper" in its Jan. 26, 1970 story.

As was to be expected, the medical authorities in desperation had to prepare an immediate counter blast of propaganda to keep the public hypnotized. The sales of medical snakeoil went down as arthritis sufferers flocked to buy non-medical copper bracelets! The "Times" and other metropolitan newspapers willingly cooperated. After all, patent medicine advertising is a big source of revenue, and who knows how much profitable pharmaceutical stock is owned by the publishers of the papers?

The "Times medical writer, Harry Nelson, dutifully wrote: "The Arthritis Foundation, a legitimate group interested in getting better treatment for arthritis sufferers (There is a contradiction here, Harry, for medical authorities claim there is no cure for arthritis!) refers to copper bracelets as 'an age-old fraud which has no scientific basis whatsoever'. Yancey is the latest sports figure to get taken by the 'copper caper', which the attorney general of New York last summer called 'one of the oldest and most vicious swindles'."

These opinions by the Arthritic Foundation and the attorney general are of course; utterly worthless. They are not based on the results of intelligent scientific research, but are based on the profit motive of the medical trust. The electrical nature of living cells was established beyond any shadow oaf doubt two generations ago, by the sound theories and research of Dr. Abrams in San Fransisco and Georges Lakhovsky in Paris. Thousands of supporting tests since then have proven conclusively that body cells have polarity, and that in an unbalanced or unpolarized condition, disease or injury, the subtle oscillations of a wire coil or loop will restore polarity. Sad to say, there is nothing of this in the training of medical students today and it is left to Borderland science to carry the torch. The honest, straightforward testimony of public figures like Bert Yancey, Tony Roche and John Newcombe is ridiculed by the witch doctors of authority for medicine.

JUST KEEP TAKING YOUR EXPENSIVE PILLS!

Under orders from above Harry Nelson interviewed Dr. John Calabro, the arthritis authority at University of California in Los Angeles, "He points out that the bracelets may seem to work because arthritis can improve spontaneously and it is easy for the person to associate his improvement with the bracelet.

"'I tell patients it's OK to wear the bracelet providing they do all the other things I ask them to do,' said Dr. Calabro." Including, of course, the purchase of poisonous pain killers at fancy prices. How much scientific integrity does Dr. Calabro have when he and his university accepts fat research contracts from the medical trust? Is it any wonder that today's Aquarian Age students are publicly questioning the morals and ethics of their professors? They are told that the goal of a university is the search for truth -- at least that is what the Chancellors say in their public speeches. But when the student gets to the laboratory he finds that the search is for profitable products for industry -- or help maintain a well-established profit position.

LAKHOVSKY BELTS, LOOPS or OPEN CIRCUITS

"Thank you for the clarification of the Lakhovsky belts described by the late Col. Powell in his publication. I tried what you suggested and after some thought I finally understood what he meant and I believe the belts should look like this:

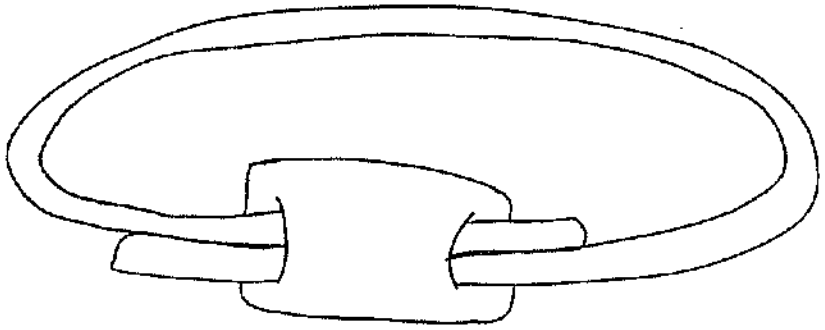

You might want to try experimenting with flat ribbon cable for these belts or coils. It can be bought at most electronic stores and it comes in different widths or colors. I am wondering also, is it really necessary to separate the lamp cord and use only half of it? Could it not be used as it is, with two strands of copper wire, insulated, side by side?" G.B.F., San Fernando, California

Yes, in our one-loop coils of white insulated lamp cord, we now use it just as it comes from the store, without separating the two strands. But you plastic 'buckle' or 'button' shown above may allow too much slippage; so the ones we make for ourselves and for research-minded Associates have separate entrance and exit holes for each end of the insulated wire. The white insulated wire seems preferable from the hygiene angle, seeing that it is usually worn next to the skin.

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From the March-April 1971 Journal of Borderland Research

OUR LOOP-THE LOOP PROJECT

"It looks to me like the Lakhovsky loops work homeopathically. It's not the copper element, per se, but the loop the loops it makes, throwing back into the body forces which the body is throwing off. It's an automatic homeopathic prescription, each body being its own pharmacist!

"The Yogi does it when he goes into suspended animation, re-breathing his own air. Urine therapy, drinking one's own urine, as described by Armstrong, is homeopathic. An ostrich putting his head in the sand breathes his own air. Breathing into a paper bag and re-breathing the contents is a specific cure for old age pains and hiccoughs. Dianetics was mental homeopathy, i.e., the original book but not no more. Dianetics is re-thinking one's own thoughts. You imbibe your own aberrations, attaching like with like. Homeopathy is like a feedback system. Gods ate their own offspring. It's Isis picking up the pieces. The smaller the dose the more potent the cure. Etc. Etc.

"Send me two kits of three experimental loops. Maybe I can fatten up on them." P.F., Florence, Arizona

HE FEELS LIKE A NEW PERSON

"I read that part in the Journal about the copper wire loop; so today I did loop one around me and sure enough the oscillating motion calmed me down. It sure was a sensational feeling because lately at times it got so bad I though I would spin off, even though I do the five Rites nightly. On occasion I also experience a terrific pain in my left side which forces me to sit down, just a great pressure especially after standing over the stove preparing meals for maybe three to four hours at a time. The customers just couldn't understand how I stood up under pressure of serving so many people. Seems like mass production.

"So with this new item I feel like a new person! And I'm going to have you send me one of your experimental kits, to see how it compares to what I hooked up on myself. Of course I just taped the wire on and this is only about six hours since I put it on."

J.M.S., Charleston, South Carolina

A DEDICATED BORDERLANDER

"Enclosed is a check for membership renewal and for five sets of experimental loops. I want to compare the effects of the Lakhovsky coil with the Japanese-made magnetic health bands which I sell to my tennis customers. I am very active in tennis playing and teaching. The results with this band are very good."

A.M., Miami, Florida

BEYOND THE PHYSICAL

An Associate writes that she had success in "curing" and arthritic elbow by wearing a copper bracelet on her wrist. Then the pesky condition showed up in her knee! From there is moved to another part of her body. Then it began to dawn on her that their Higher Self was trying to tell her something, that the swollen and painful joints were an outward manifestation of an inner mento-emotional condition of resentment and bitterness over an unhappy marriage. With the cooperation of an understanding doctor and more orthodox heat treatments, etc., and a more positive and cheerful attitude on her part, the condition was finally eliminated. It took months to cleanse the system of the accumulated poisons, physical, emotional and mental.

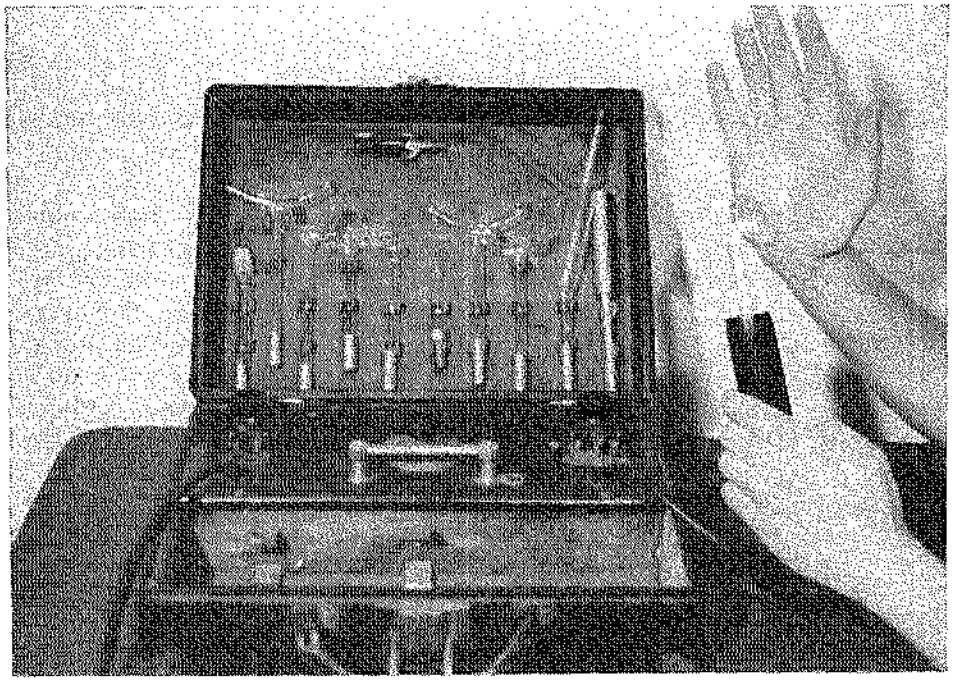

1920's era Violet Ray Massager. From the BSRF Collection.

From the Jan-Feb 1966 Journal of Borderland Research

THE LAKHOVSKY MWO IN INDIA

"The MWO is giving wonderful service and days are passing and I am gaining some new experiences which have not been recorded in the book. I will appreciate if you kindly clear some of my doubts. In practically all the cases I am finding aggravation after three or four sittings. Do you think that it is due to a sudden oscillatory shock that is given to the patient as it so happens when Homeopathic medicine is given? I feel that it should have at least been recorded by some one. One more question. What is the reason for metals being removed from the person of the patient? In case they are not removed will there be any adverse effect? This is very vital because here in Bengal there is a custom that the married ladies must wear one Iron bangle. They will not remove it under any circumstances. What is the remedy for this?

"I find that the appetite improves in practically all cases. Rheumatism and Arthritis cases are definitely benefitted. In one case a Tumour which is there since about 20 years has definitely gone down with only 4 sittings. I am watching the case carefully and if the Tumour disappears it will be a great achievement for the MWO. Debility is markedly reduced in nearly all cases. In a recent case of Spondylitis the MWO has done wonderful work. The flexibility was 8-1/2" from the floor which has come to 6" after 7 treatments and all the pains have practically disappeared. Due to the New Moon and Eclipse there is an aggravation but I hope it will gradually go. Asthma cases have not responded so well but I am not yet disappointed with the results. It is as yet too early for me to assess the capabilities of the MWO on various diseases. As you say I also believe that this instrument will work on all persons irrespective of their complaints but still there must be some specific organs on which there is more influence of this.

"Something which I forgot to mention previously, can you tell me whether you have seen Hemorrhage as a result of MWO treatment? In at least 3 cases I have seen bleeding start where there was no previous history of bleeding. What is it due to? In one case there was profuse bleeding after 2 sittings and that has made me a bit nervous. Just now a patient reported that he was getting blood in the sputum even though there is nothing in the lungs. In the third case blood appeared in the urine. Please give a thought to this as this is a very serious complication if it is caused by the MWO." Dr. A.K. Bhattacharya, West Bengal, India.

The above is a portion of a letter to Associate Al Goeke, Redmond, Washington, which Al passed on to me for comment. I thought the rest of you would be pleased to know that this East Indian doctor has gotten very encouraging results from the very beginning in the use of the Multi-Wave Oscillator. If by aggravation the doctor means a sudden release of mucous, heavy cold or flu, this is a sure indication that the MWO is working and affecting a release of accumulated poisons in the body. This is touched on in our brochure, in the comment from a midwestern doctor which built and used such equipment in the 1940's. When he began producing mild flue -- as he called it -- in his patients, he got scared off! The hemorrhaging by the doctor's East Indian patients is more serious but we believe it is still a result of the same thing, a sudden releasing of accumulated poisons through the shedding of bad blood. We know one oriental who had a heavy nose bleed after the first exposure to the MWO field. Apparently orientals, some of them at least, are more sensitive to the soft radio wavers than Caucasians living in America; so the doctor's prescribed treatments should probably be somewhat shorter in duration and spaced further apart.

Yet I well remember the radio technicians in Honolulu, Hawaii. I was an announcer and producer there for several years. Some of them were of Chinese and Japanese ancestry. When repairs were needed on the radio towers, these men wouldn't

hesitate to jump on, climb up and work for hours while the station was putting out a steady five to ten thousand watts of power. I don't recall any of them suffering any ill effects such as internal bleeding. Yet their tools would get so hot because of the strong field that they would have to wear gloves in handling them! It was these eddy currents caused by an inert piece of metal in the pulsing field that Bob Beck was concerned about. There isn't enough power in the MWO to cause heating in bits of metal about the body, if one can't strip down for an exposure. The piece of metal, say a zipper or a ring, might reduce the efficiency of the field in that area but we didn't worry about this when testing the equipment we had for a short while in 1964. I don't think Dr. Bhattacharya should either. The machine seems to produce results anyhow.

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From the March 1966 Journal of Borderland Research

BASIC NEW AGE PHYSICS
by Trevor Constable

(Publication of Dr. Bhattacharya's letter in the Journal, page 20, Jan-Feb 1966 issue, elicited the following significant comments by Mr. Constable.)

A word on Dr A.K. Bhattacharya's reports concerning the Lakhovsky Multi-Wave Oscillator he is using successfully at his West Bengal, India clinic. The results are indistinguishable from those systematically recorded and published over a long period by the late Dr. Wilhelm Reich, M.D., concerning his "orgone therapy". Reich was the discoverer of Primary Energy -- pre-material and mass-free -- which he named Orgone.

The improvement of the appetite, the reversal of rheumatism and arthritis even to structural changes, the rapid reduction of tumors and the hemorrhage effects are all to be found in Reich's massive clinical literature on orgone therapy. Dr Bhattacharya's reports, plus others any my own experiences with the MWO serve to confirm my previous evaluation of this unit as published in the Journal over two years ago. In essence, the MWO is a device for orgone therapy. It achieves its startling results because it is a generator of primary energy, or at least a focus for primary energy.

Any person with a modest extension of physical vision who will observe an operating MWO under conditions of indirect, rather dim fluorescent lighting, will see for himself that primary energy from the earth's atmosphere (the Orgone of Reich) condenses prolifically between the coils of the unit. The concentration is many times that which normally surrounds a living organism.

The basic New Age physics involved, for which we are indebted to Reich, are as follows: Wherever secondary energy, i.e. energy obtained from matter in some way, is released, primary energy tends to concentrate to extinguish this energy. Secondary energy is life-negative, i.e. inimical to the living, a fact which is illustrated, in its ultimate extension, in the lethality of atomic energy. Where so-called "soft" radio waves are involved, the antagonism of primary energy to their emission is evidently considerably diminished over the violent effects that accompany radioactive substances in the presence of primary energy accumulators.

In the case of the MWO, the tremendous band of frequencies covered results in an extreme concentration of primary energy, which also has its frequencies and correspondences (the Rates of radionics) with the secondary, electromagnetic spectrum. That this effect is achieved with minimal secondary emission is the beauty of the Lakhovsky unit.

TWO-FOLD FUNCTION OF THE MWO

In my view, the dramatic results obtained are due to a two-fold function of the unit. First, there is the undeniable concentration of primary energy around the body of the patient, particularly potent where a limb or other readily accessible member may be exposed. Secondly, there is the reaction of the specific biological energy of the individual organism, from within, to the stimulus of the secondary waves, which it rushes to combat.

Under the laws of primary energy first discovered by Reich, the patient, as a living organism, is a stronger vital system than the MWO. Accordingly the patient attracts and withdraws the charge of primary energy produced by the device. This is in direct contradiction to formal electrical laws, and as such is typical of the criteria that rule primary energy. The continued emissions of the Lakhovsky unit provide a continuous concentration of primary energy on which the patient draws. Just how long this process should be allowed to continue, per treatment, is where we run afoul of allopathic (MD) thinking.

The acquisition of a strong primary energy charge by the ailing organism results in a reversal, or at least in the reduction of life-negative, i.e. diseased, processes. Reich found with his orgone accumulators that the reduction of tumors was not as great a problem as the auto-infection resulting from the overloading of the excretory apparatus. The debris and bacilli from the diminishing tumors must be eliminated, and unfortunately, because the excretory apparatus is frequently involved in the general putrefaction of which the tumor is the end result, this was the major problem in managing such cases, in Reich's experience.

The medical lectures of Rudolf Steiner, Ph.D., contain one of the master keys to successful therapy, particularly appropriate to the use of the MWO. Steiner points out that what the ailing organism needs is the significant, vital impulse in the right direction, then careful nursing and management as it recovers out of its own forces. This was also the view of another genius, the late Dr Ruth Drown, who knew from experience how important the first impulse back to health is for the sick individual.

Hence, it seems that the old allopathic urge to convulse the patient with therapy, to repeat the massive dose again and again, is something that should be resisted in using the MWO, at least where tumors are being dealt with. The idea of applying the MWO in daily doses may stand in need of modification. We are all to some degree creatures of gross, non-vital thinking that stands behind our allopathic medical civilization, and we will need to carefully train and think ourselves out of the absurdity that the massive dose is the sine qua non of therapeutic success.

THE TRUE-BLUE ROOT CAUSE OF DIS-EASE

As far as unexpected hemorrhaging from the lungs and similar manifestations are concerned, I think the problem is essentially that diagnosis is so inept and inaccurate that the physician does not have a true blueprint of his patient. After my years of association with Dr Drown I am sharply aware of the fact that nobody just has one ailment or problem, but that we are all bearers of a veritable plexus of malfunctions which usually proceed from one primary and obscure root cause. What happens with the MWO is that the injection of primary energy into an ailing organism results in multiple manifestations of the healing impulse, and not just a direct effect upon the object of our attention --which may be a tumor, ulcer or other extreme symptom.

All the effects produced by exposure to MWO units are identical to those experienced in orgone accumulator. The healing agency in both cases is primary energy, and I hold that this is so no matter what plausible arguments might be

advanced to reconcile the MWO with formal theories and thus win the neurotically-desired approval of physicists and doctors. It perhaps seems incredible that one can obtain the same effects produced by the MWO by sitting in an orgone accumulator, with absolutely no electronic apparatus connected to is, but it happens to be so. Try it and see!

MWO experimenters owe it to themselves to study Reich's work in full. As long as they wander in these fields, they may as well build into themselves the realization that electromagnetic energy has an inevitable and unavoidable and inescapable concomitant -- primary energy, life-positive, mass-free energy whose criteria and laws are the exact opposite of the energy accepted by formal physics. The best testimony to Reich's tremendous contribution to human advancement is that he died in a U.S. Federal Prison. As all Borderlanders know, innocent bumblers die in bed in their own homes, untroubled by the status quo.

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From the April 1966 Journal of Borderland Research

MWO SURGERY AT SHASTRI VILLAGE AND RELATED MATTERS

by Al Goeke

I believe you and the Associates would like to hear the latest comments from Dr. A.K. Bhattacharya, Naihati, West Bengal, India on the Beck adaptation of the Lakhovsky Multi-Wave Oscillator he is using in his clinic there.

"The other day I had an unique experience with the MWO. I think this should be published. I was treating a lady for rheumatism. After four sittings, once a week, she had a pain under the tongue and there was some inflammation with pus coming out. I asked her to take a further sitting. After about five minutes all of a sudden the thing burst inside the mouth and five pieces of stone came out. When I took her medical history I found that she had an operation two years before and a bit of Salivary Calculi was extracted, but the surgeon had told her that some still remained behind. The MWO treatment eliminated the foreign matter which would not have come out without an operation. This then paves the way for research with Gall Stones and Kidney Stones. I would like to know if anyone else had an experience like mine.

"This time I can give you some reports about the special attachment you sent. A patient was having much pain in the knee and there was swelling. I held the Bulb against the knee for five minutes, and after that it was found that the swelling had reduced and the pain also was much less. In an asthma case I applied the Bulb on the chest for ten minutes. The report is the patient had no recurring attack for two days. Yesterday I was having pain in my thigh so I applied the Bulb. In five minutes I got wonderful relief. Gradually I am getting the hang of it and I think I will be using it more and more."

I, too, am using the Argon more and more, and the more I experiment with it, the greater I think it is, also the MWO. I have had two test cases of young men who, after five minutes in the MWO, said they could feel something happening inside their heads. Both cases had a history of head injuries. I take it that the MWO reactivates a dormant, abnormal condition that perhaps one day would cause trouble. Another test case was a mental patient in Texas. The use of the MWO was part of the test program which brought about a marked improvement in only nine days.

Some time ago a BSRA associate spent an evening with me and told of an

interesting borderland gadget. People came from miles around to sit in its healing radiations. I built one for experimentation and found the results good. A Texas Associate says that it works! The original was set in the ground, but I wanted it in the house where it would be more convenient, and figured on running a ground wire outside; but this is not necessary. I have found that it corrects polarity of anyone sitting in the same room. The one I built radiates out 25 ft. One length of 6" stovepipe is used, filled with alternate 2" layers of crushed granite, and of charcoal. For a quick charge of energy, touch your foot on wire at lower end and hand on wire or rod sticking out of the upper end. I have checked the walls and ceilings or rooms (with pendulum) and found them negative. After a few minutes with this borderland gadget in a room, the walls and ceilings check positive! Here is something that should be shared with Associates.

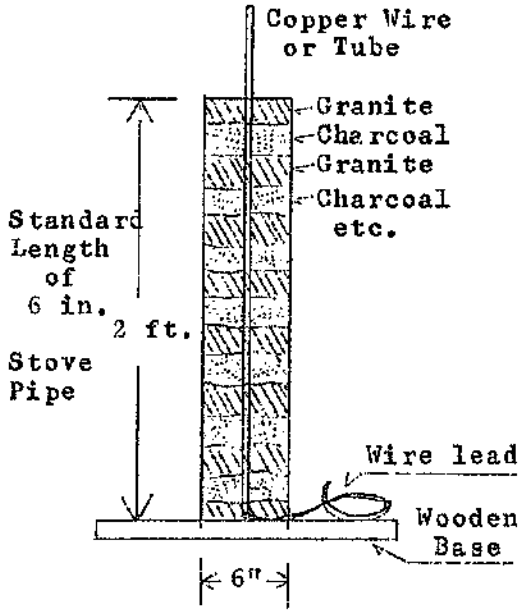

ETHERIC CONDENSER

(Here is our drawing from the rough sketch in Goeke's letter, of the borderland gadget explained above. This is just another of many simple devices which concentrate or condense etheric energies of the higher physical sublevels into a field or vortex of force available or useful in beneficial amounts to a living organism within that field. The drawing is not to scale. The dimensions are not critical. It is the relation of the parts that is important. You can consider the upper end of the copper wire as positive and the lower end coming out of the base as negative, but with the alternating layers of crushed granite and charcoal there must be an alternating or pulsating effect. Remember, charcoal is carbon, so this Etheric Condenser is a Vitic device, but not nearly so concentrated as the field between the Alnico magnets of Vitic. Iron filings sifted in the crushed granite would probably increase the power of this thing. This gadget would augment the power of your Eeman Screens, if you are using them, by adding extra etheric vitality to the circuit. Add long wire leads to the upper and lower ends of the Condenser, so you can hold one in each hand while holding the handles of the Eeman Screen leads. Which Condenser lead should go to each hand? I dunno! This is borderland research and you'll have to experiment on yourself, and be you own authority! This is one of the first principles of the Aquarian Age into which we are moving at breakneck speed. Now to continue Al Goeke's article. RHC)

GERMICIDAL EFFECT OF ULTRA-VIOLET LIGHT

The use of the Argon bulb (General Electric AR-1) as a pain-killer and infection reducer is not a new idea. Nikola Tesla used a gas-filled tube or bulb, excited by high-frequency current to rejuvenate himself every day in his laboratory. 40 years ago the RenuLife Electric Co. of Detroit was making and selling such a treating device to doctors all over the country. The offered a choice selection of vacuum tubes for getting into the body to release rejuvenating, purifying ultra-violet rays. I don't know that their tubes were filled with Argon gas, as is the current General Electric bulb. Maybe this is why the GE bulb is so effective. There is a greater concentration of ultra-violet light in the most beneficial wave-lengths, from pure, excited Argon gas.

We visited one chiropractor on a trip last year who used an MWO machine on his patients, and also uses the Tesla Coil of the MWO to drive the Argon bulb. General Electric designed this little gas-filled bulb for use on the regular 115 volt house current. As a very dimly burning, ultra-violet night light it is a good spook-chaser and can be left on all the time because it uses only pennies worth of electricity in a month! The little bulb has a curved metal plate inside it, as shown here, on which you can see a faint, ultra-violet luminescence when it is turned on, in a standard light socket.

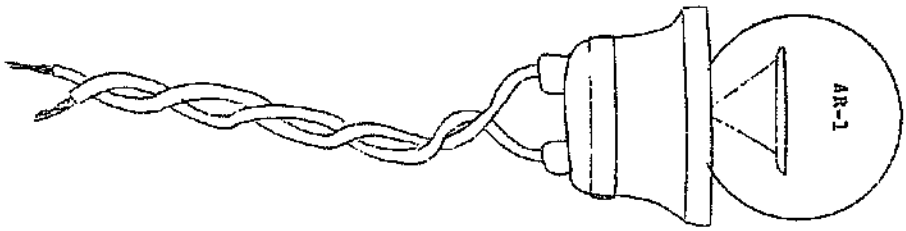

BUT, when you put a hundred thousand volts through it from the MWO Tesla Coil, that Argon gas gets real excited and throws off powerful ultra-violet energy which can penetrate into the body and destroy infection and break up tension, inflammation. Showers of sparks jump from the surface of the clear glass to the skin unless the bulb is held so it touches. Sparks will also jump into your hand unless the socket mounting is well insulated. The mounting or socket shown here is the standard rubber base with heavy, six-inch leads for outdoor lighting. Our local hardware store sells the socket for 39 cents. The Argon bulb needs only one connection -- to the antenna lead of your MWO. The black and white leads from the socket can be twisted together and soldered to a female Banana Plug. This will take the male connection from the Antenna lead. The twisted socket leads can be wrapped with heavy, insulating tape if any of the ultra-high voltage gets through to tickle your hand.

The chiropractor who makes use of this in his work asks his patients if they have any infected teeth, or a toothache. One five-minute treatment over an aching tooth, rubbing the Argon bulb on the cheek over the infected area, stopped a toothache for us. It also relieved a throat, sore from too much lecturing.

General Electric also makes an identical Neon bulb. This gas throws off an orange radiation, which would probably give off more of a surface, heating effect because of the longer wave-length. You won't find these special bulbs in your local stores, probably, but will have to order them through some wholesale dealer, say an electric contractor and builder who has the GE catalog of special bulbs. A compact, professionally built Tesla Coil can be bought from Edmond Scientific Co, Barrington, New Jersey. It doesn't put out as much energy as the MWO coil designed by Bob Beck, but it will cause the GE Argon bulb to emit considerably more ultra-violet radiation than the 115 volt house current.

From the MAY-JUNE 1971 Journal of Borderland Research

A HIGH-POWERED MULTI-WAVE OSCILLATOR

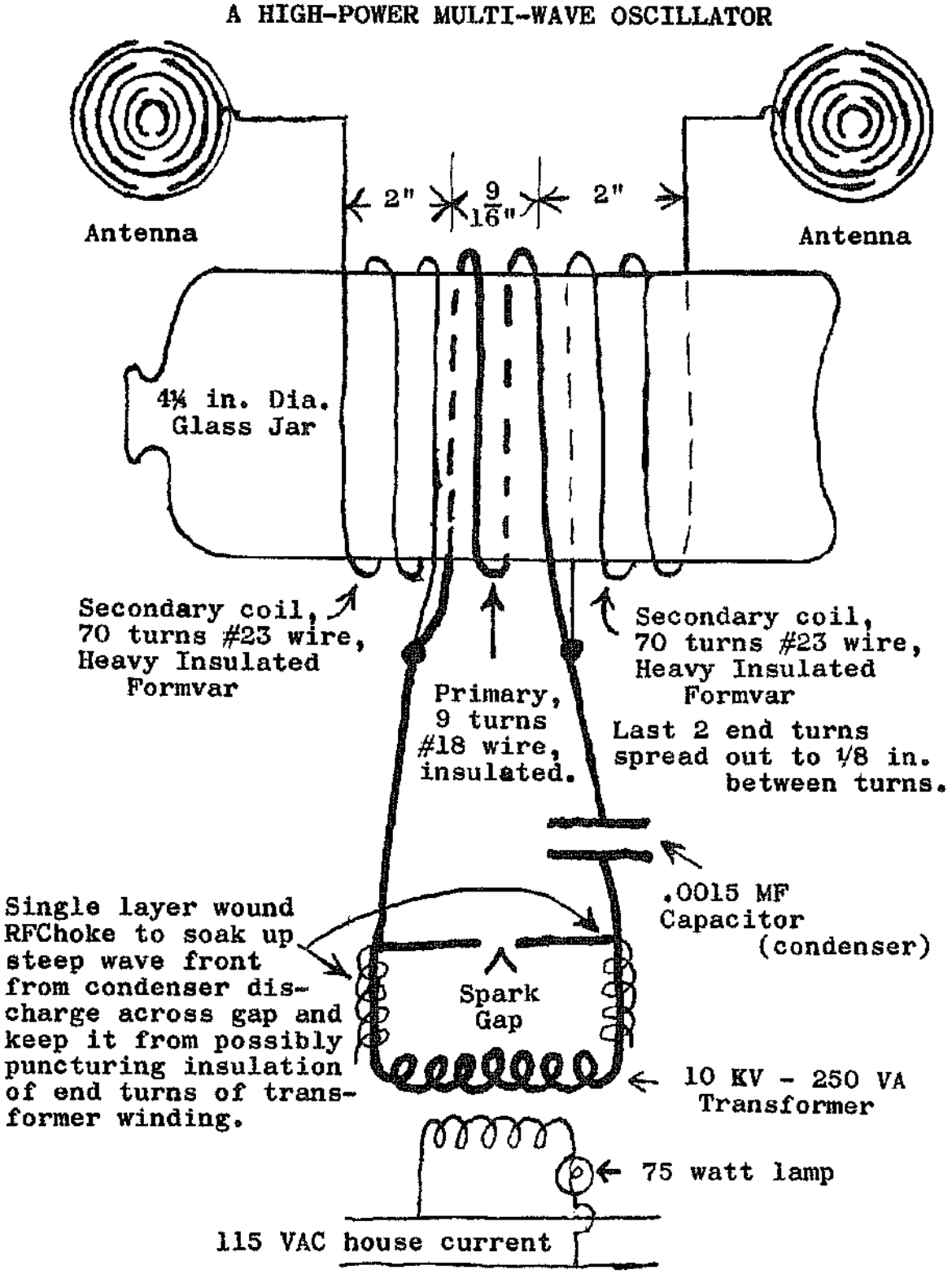

"Your brochure article stating that Georges Lakhovsky's original MWO had a separate Tesla coil driving each antenna is most interesting. This is in line with my experience here in Manila. I find that when livening up both antennas to full voltage, to spark each antenna down to the 3rd ring with an occasional slop-over to the 4th ring, it is much more effective than when keeping one antenna (or resonator) down to near ground potential; and it is least effective when actually grounding this antenna -- as Mr. Beck does --through a 1/10 MF capacitor!

"One five minute treatment a week is enough for me and the equivalent of two 15 minute treatments with only one antenna up to full voltage. However, I drive both antennas up to full voltage with only one Tesla coil. It has rather tightly coupled primary and secondary windings, wound as an auto-transformer, on a 4-1/4 in. diameter glass jar, as per enclosed sketch.

"The present spark gap is 1/8 inch, a fixed, constant gap, needs no turning with variable distances between antennas, subject or no subject. The sparking is much the same and the gap is not at all critical, 1/32nd, plus or minus, works just as well. Gap electrodes are 1/4 inch tungsten. The present primary circuit capacitor is .0015 Micro Farads, but this also is not at all critical, can be varied up to .0025 and still give much the same sparking and effect on subject.

"I tried using #28 Formvar wire, heavy insulated, 70 turns each on the secondaries, to shorten coil and get tighter coupling, primary to secondary, but coil was too short and flashed over from end to end.

"Just plug it in and use it, no tuning manipulation of any kind required. The input of 115 VAC to the 10,000 volt oil burner ignition transformer is only 17 VA through the 75 watt lamp as a limiting resistor. Never use more than a 100 watt lamp. This is all I can take. More power becomes rapidly depressing. And the full 250 VA out put of the transformer I once used, with a 5/8 inch spark gap, was nearly fatal. It took me four months to get over the effects of it. Pass this info on to your Associates."

J. Gilbert E. Wright

Associates can benefit from this dedicated borderlander's experience, which confirms Lakhovsky's warning that healthy cells can be over-stimulated and killed by powerful high-frequency waves -- as well by X-ray and radium waves. It may be easier to locate Neon Sign transformers of 5,000 to 7,500 volts output as power supplies for this MWO, at a cost of $15 to $20. In this case the wattage of the "limiting resistor" electric light could be increased to 150 or 200 watts, or eliminated altogether, if it is necessary to get enough power to cause random arcing down to the third and fourth rings on both antennae. The good doctor says nothing about shielding but care should be taken to prevent radio interference from this powerful spark.

"No data is given in the drawing (May-June 71 Journal) on the size of the antennas. I would suggest that the outer ring be about 18 inches in diameter with a 3 inch gap. Alternate down through the rings separating them about 2 inches apart and held together with plastic electrical tape. Wire should be #10 bare. The secondary leads connects to the second ring from the largest diameter outside ring."

George Van Tassel, Giant Rock, California

An even more spectacular possibility is the Time-Machine effect in connection with rejuvenation. If, as Bob Beck suggested in his article, the MWO tends to take the body cell back down the time-track to a more youthful, more vital period, what would happen to a person who stayed in the field of the machine for four hours? Would his vibratory rate be speeded up to where he would disappear completely? Like the hero of H.G. Wells' 'Time Machine'? Anybody want to try it? It seems, from hints George Van Tassel has been dropping over the years, that his Integratron at Giant Rock, California might do something like this -- if and when he gets it

working! As I recall, both George and the Canadian Saucerian, the late W.B. Smith, spoke of the four dimensions of electricity: 1. is the electricity moving in one direction along a copper wire, 2. is the magnetic field around the wire, 3. is the static charge created by the first two effects, and 4. is Time -- or the 'tempic field' as Smith called it. The Time Field equates with Space, where consciousness is everywhere present. Seems to me Lakhovksy's Multiple Wave Oscillator is a gadget which gives us the opportunity -- for the first time -- of approaching the Time Field with scientifically acceptable equipment, operating in known frequencies.

BIOPHYSICIST CONFIRMS LAKHOVSKY'S THEORIES!

LA "Times", March 28, 1971: "The 'magnetic resonance' of the nuclei of atoms (in living cells) has been used to tell the difference between cancer and normal tissues. This resonance is the reaction of the nuclei to electromagnetic energy --first its absorption and then its emission. The process can be timed.

"Raymond Damadian, a biophysicist at the State University of New York's Manhattan Medical Center, said his achievement may open the way to major advances in the diagnosis of cancer in humans... Like other attempts to find a way of making early diagnosis of cancer, Damadian's research began with a hunt for significant differences between cancer and normal cells.

"He relied on a law of physics on which nuclear magnetic resonance is based -- that the atoms in each element in the periodic table absorb and then emit electromagnetic energy on an individual wavelength that is different from that absorbed and emitted by the atoms of any other element. In his system, radio waves are aimed at atoms in strong magnetic fields. If the wavelength is the right one for that atom, the atom will absorb the energy and then emit it, returning to a 'resting' state afterwards.

"The reactions differ according to the kind of molecule the various atoms are incorporated in. They also differ when very subtle changes have taken place in the molecules. The measure Damadian uses is what is called the 'relaxation time' of hydrogen atoms in water molecules within the (body) cells... He found that it takes longer for protons (nuclei) in cancerous tissue to 'relax' than it does for protons in normal tissue... The relaxation time of protons in normal liver tissue, as one example, was .25 of a second, compared with .86 of a second for cancerous tissue.

"Damadian's findings confirm the theory proposed by several scientists that water molecules in a normal cell are held in a fairly well organized structure by electromagnetic attraction exerted by the molecules in the cell. But, it was theorized, when a cell begins the uncontrolled growth of cancer, the structure begins to collapse because of the cell's increasing disorganization.

"Damadian thinks the device for detecting cancer in humans (his experiments were conducted on mice and mouse tissue) that may come out of his work would be a radio frequency coil to emit the electromagnetic waves to be aimed at the atoms in the water molecules under study. The device also would include a magnet to create the field required for measurement.

"The coil would be wrapped around the patient while the magnet would be moved back and forth over his body. The reading of how long it takes the atomic nuclei to relax would be made and then computers would do the matching up and make the diagnosis."

Interesting, isn't it, how the 1970s researches of biophysicist Damadian parallel the pioneering work of electrical engineer Georges Lakhovsky in the 1920s? The goals are quite different, of course, in that Damadian only wants to prove the existence of cancer so the victim can go on to be drugged, operated or radiated with destructive X-rays or Cobalt rays, at fancy prices, a procedure inspired by the

soulless monsters who guide the American Medical Association from the Lower Astral plane.

The irony of Damadian's proposed diagnostic technique is that it combines two electro-magnetic healing procedures. If it is used on sick people, sooner or later someone is going to be healed of cancer while being diagnosed! Can you imagine the disagreeable shock this would cause in orthodox medical circles? Extensive surgery would have to be cancelled. The sale of drugs would be lost. Under these circumstances it isn't likely that his diagnostic technique will ever receive the approval of the AMA.

So, borderland science will have to continue to carry the torch of research on electro-magnetics in this area, as George Van Tassel is doing with his Integratron up at Giant Rock, California. In his newsletter "Proceedings" he gives more details of his research program there. We learn that in addition to creating a field of soft, high frequency radio waves, and a magnetic field, the Integratron will also bathe the subject in an atmosphere charged with negative ions.

HOPPING UP THE HIGHER FREQUENCIES

"There is one thing you may wish to try on the MWO. Close the center hole in the driven antenna with a washer and screw. Connect this to the driven ring (second ring from the outside) with a 500 mmf condenser, 10,000 volt rating. This increases the power of the higher frequencies. I think you will be pleased with the results. Mount the condenser at the back of the antenna. Mankind has been saturated with the lower frequencies for years; 60 cycles and their first few harmonics are almost everywhere in more than adequate power. Radio, TV, radar, etc. also saturate our world but the amount of power available to the average person is very small. In 1942 I used to cure my sinus trouble in minutes by getting close to the transmitter section of a radar transmitter. Few get that close, though, and it is a good thing as this power can kill. I have seen birds and larger animals killed instantly. It can happen to humans, too." H.B., Melbourne, Florida

SEND A FEW BUTTONS

"Received the Lakhovsky loops and am pleased to feel the response to the body. I wear my belt only at night. I gave one to a friend who was having a problem with her leg and anticipating hospital treatment for same and the response was also to the good... So all I want now is for you to send me a few buttons so I can make some more loops myself and help to lessen some misery around here, for someone. I tried to have some buttons made here, but no success." J.M.S., Charleston, S.C.

The non-slip loop buttons we make are of 1/16 inch thick, white fiber glass plastic.

MORE POWER NEEDED

"Enclosed is $. Please send me the magnet assembly with carbon rod (March-April 71 Journal). Have not had the hoped for results with the loops. Possibly the assembly, which can be used more directly over the research area, will be more effective." M.S., Ellensburg, Washington

If we've proven one thing in our borderland research, there is no single cure for any or all of mankind's ailments. Injury and disease are outward manifestations

of an invisible cause, which may involve three or four levels of consciousness and extend back two or three lives. You Director has found in over thirty years of counselling people on their borderland problems, half of them don't really want to get well, they just want to be free of pain so they can go on indulging their vices. And by the time the hidden vice surfaces as a disease in some target organ of the body, an unhealthy trend has been established in the cell life there. It usually requires a strong jolt or shock to reverse this trend, such as a powerful magnetic field, a drug, chiropractic, even surgery -- anything to break the negative pattern which created the condition. One of the simplest and most effective methods, and cheapest, is fasting for a week or two. This gives the system a chance to purge itself of all filth.

OPEN ENDED COPPER BRACELETS

"Your article on copper bracelets sent me to the typewriter! It is quite well known in England and has figured on TV as anklets for racehorses! Open-ended copper bracelets sold freely in shops for some years here, but not recently. However, I have a copper bracelet from Rhodesia which I wear always, never take it off, and of course no arthritis or rheumatism. But I'd like your experimental loops for throat, waist and wrist.

J.G., London, England

THE PRO AND THE CON

"Thanks for the wire rings. Sorry to report no favorable results. My husband refused to try. I wore them several nights but seemed to feel even worse afterward. It was a good experiment. I guess my trouble is psychosomatic."

Mrs. A.H., Enid, Oklahoma

"I want to thank you for sending me the kit of Lakhovsky coils. I especially appreciate your taking the time to prepare a larger-than-usual coil for my chest. I guess I'm, too young to have any really serious physical ailments -- except for insomnia! And the coils eliminated that the first night I wore them to bed!"

J.T.D, Venice, California

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From the September-October 1971 Journal of Borderland Research

UPGRADING CELLULAR ACTIVITY WITH ELECTRO-MAGNETISM

By Aaron H. Steinberg, Ph.D.

For too many years now the scientific knowledge of electro-magnetics and its positive effects on cell life has been collecting dust and cobwebs on the shelves of ignorance, brought on by those special interests who fear the Truth. We are now seeing a rebirth, if you will, with scientists both professional and amateur, who are reviewing the work of their predecessors and making improvements in the mechanical application of magnetic fields.

In 1969 I visited the USSR to see for myself what and how they were utilizing Electro-magnetism. In several country homes for retirees I was most pleasantly surprised to see electro-magnetism used daily on most of the old folks. I should say young folks since may who claimed to be over 100 years young, looked and acted like most people at 50! The main object of the E-M was to reverse the ageing process by

altering the cellular structure. I was most anxious to purchase a piece of the equipment, but alas no sale.

Seek and you shall find has always been one of my dominant characteristics. So when I learned that Japan was truly advanced in this field, having been using such equipment since 1936, I decided to go there in 1970. I sought out the one company that had been most productive in this field. They were most kind and cooperative. I was introduced to several scientists who had done much useful research. Their claims were backed up by scientific facts and I was convinced that they had a well constructed instrument, simple to use by anyone so desirous. They named their equipment The Magnetizer.

I returned to the U.S. with a Magnetizer and immediately began a research program. I can report that the results obtained to date have been most favorable, after nine months of experimentation. The magnetic flux generated by the coils can be measured accurately over any part of the body, thus determining those areas where the flux is penetrating as well as those where it is weak.

Chemicals and pollution are surely contributing to an unhealthy alteration in our cellular activity and human magnetic filed. It will be many years, if at all, before this mess can be rectified and controlled. But in the meantime, those who are aware and see the danger signals, will not sit by and wait for the clean up, which may never happen. Instead they will seek to upgrade their cellular activity so that the body's natural resistance may be at peak ohms. There is some indication that the aura force centers known as chakras or vortexes are stimulated by electro-magnetism.

From the Japanese scientists I learned the following about the effects of magnetic flux. It is different from ordinary electric current, which only flows along the surface of matter. It is different from X-rays, which do not penetrate the bones. The magnetic flux of ultra-long wave generated by the Magnetizer penetrates deeply in muscles, fat and bones and has an intensive effect on the nerves.

Magnetic flux never causes unpleasant sensations in the body, such as pain or shock, but instead produces comfortable, warm sensations. These sensations are also known as Joule's heat, which strengthens the function of the cell, corrects spasms and inflammations. When magnetic flux passes through tissues, a secondary electric current called the eddy current is created around the magnetic lines of force in the tissue cells, which ionized the protoplasm and rejuvenates the tissues as a result of activating metabolism. Furthermore, magnetic flux, in the process of penetrating the tissues, works to increase hormone secretions. These maintain youth by providing energy as a result of normalizing function of the internal organs.

Flux strongly stimulates magnetic substances in the blood, like iron. Accordingly, the hemoglobin in the blood vessels moves actively, accompanying the lymph circulation, when the Magnetizer is turned on. The therapeutic effect is not singular but collective, thus eliminating constitutional weakness.

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From the May-June 1971 Journal of Borderland Research Clips, Quotes & Comments

OSCILLATING LOOPS AND COILS

"I have a necklace which is definitely an oscillating circuit. I'm sure you have seen them. They are a wire around the neck instead of a chain. The only thing is that they come with a hook arrangement to clasp them. I cut the ends off, and rounded them to make a real oscillating circuit. Then, too, I got a pair of earrings which are simply coiled wires, like this:

One of these days maybe I'll have a headache (this is rare), and I will try either or both of these. Mrs. C.M., Watertown, Wisconsin

REMEDIES, HOMEOPATHIC AND ELECTRO-MAGNETIC

"You might spread the word around that the Copen Vibro-Potentizer actually can make any Homeopathic remedy in any potency from 1X to 10M.

"Since the medical-industrial complex is trying to destroy Homeopathy and its pharmacists, those who know of it and are doing research on its remedies would do well to get such a machine. It can also make a remedy from a radionic rate. I made Skull-Staphylococcus 10M and reduced an intractable sinus infection. The possibilities are fantastic and open up a new field in healing. One can make color remedies and aura remedies with greater power than radionic treatment of the same."

From his own research this Associate is suggesting that homeopathic remedies, being closer to physical matter than radionic treatment rates, may bring physical body changes more effectively. A hundred years ago in Philadelphia, Dr. Pancoast was curing practically every known human disease with colored light, either blue or red. But he (she?) also prepared color-treated dosages of oil or water for internal use, to back up or augment the shining of colored light on the outside of the body.

"May I remind you that the Multi-Wave Oscillator requires an antenna without any edges, to give efficient radiation. Lakhovsky's original had round bars or tubing with spherical ends. Edges lose most of the radiation. In addition the largest ring should be based on that fundamental resonance of the human organism, 3.66 meters as discovered by Bell Laboratories. This could be a quarter-wave antenna length of .91 meters or a circle of pi diameter.

"However, this should be doubled so that the human organism resonance is the first octave. Individual resonances vary slightly above and below 3.66 meters. By giving lower octave and with the variations supplied by the spark gap all wavelengths would be reached. Therefore, the outer ring should be 1.82/pi meters.

"The relative size of the outer rings could be determined by examining one of Lakhovsky's original antennas. The outer ring should be fed current at both ends, quarter wave style, I believe (to a H.V. Coil) not at the middle of the second ring as the Beck antenna does. The frequency of human resonance, 3.66 meters or approximately 84.6 megacycles is the key to radionics. [By my calculations, using the formula wavelength in meters (3.66 meters) equals (=) the speed of light in meters per second (300,000,000 m/s) divided by the frequency in cycles per second, I figure the frequency to be 81.97 megacycles. T.B.] The human sample or witness -- blood spot, etc. radiates around that frequency, varying according to the disease and the person, I believe. The homeopathic remedy also has a resonant frequency and alters the human frequency for better (or worse). In addition there are harmonics and possibly sub-harmonics.

"The resistance rates discovered by Dr. Abrams, followed by Guyon Richards, are still valid even though this work was done 50 years ago. The rate for Aqua Marina (sea water) put on a Copen V.P. produces a very effective remedy good for almost everyone. This rate comes from Richards' book 'Chain of Life', 1934."

S.M.S., Chicago, Illinois

We welcome this Associate's observations on the MWO antenna, radionics rates and homeopathic remedies.

Riley Hansard Crabb, editor JBR 1959-1985

BSRF MWO Update - Issued May 31, 1988

Compiled by Tom Brown from the BSRF Files
In consultation with Eric Dollard & other BSRF Associates
(Contains the complete 1986-87 MWO Update materials)

As there has been a continuing strong interest in the Lakhovsky Multi-Wave Oscillator we felt the need to compile this information into the present book. This documentation is the result of a wide variety of analysis and experimentation with the MWO and covers many years of active research.

There have been many comments made concerning the inherent healing effects of the MWO, but as it cannot be stated enough, the device is merely a tool of research, of which one may draw their own conclusions as to whether or not the device actually has any healing properties. It may be interesting to note that in a personal conversation with Dr. Ita Wegman, Rudolf Steiner stated that electricity, magnetism, and the force upon which nuclear phenomena is based, are all corrupted ethers.

We have found through studying Goethe's indications on the phenomenon of Light and Color in conjunction with Eric Dollard's high frequency researches that electricity is a reflection of the Light Ether. This matter is being discussed further in The Journal of Borderland Research, so it is sufficient for present reference to say that Light has its two poles, red-yellow and blue-violet. The red-yellow pole in nature is longitudinal (direct rays from sun) and the blue-violet pole is a progressive type of transverse wave (rounded sky, Reich's KRW wave/blue orgone). Electricity has its two poles, electro-magnetism: red-yellow-hot, (retarded transverse); and dielectricity: blue-violet-cold (longitudinal). Hence, there are experimental indications that electricity really is a reflection of the Light Ether.

In light of this trail of thought we quote with permission from a 1986 private communication with Trevor James Constable: "The MWO I regard as a false path. The cellular stimulation theories sound and seem good because they are mechanistic, and therefore sympathetic with the mechanistic weltanschaung. With the MWO you can avoid the etheric--or so it seems--and therefore those who feel adrift in the etheric ocean cling to things like this. Healing is one hundred percent an etheric problem. Any dysfunction or hyperfunction not caused by direct trauma has to be tackled via the ether body, and even the direct traumas respond best to etheric correction, such as getting the displaced double back into occlusion through the use of arnica compresses, etc., etc. In between the MWO antennas, there is a general marshaling or focus of light and chemical ethers. Its quite evident even with a minor extension of vision. This is the healing agency, not the sparks. The ether rushes to suppress the EM activity, and because it is low power, the ether accumulates around the spirals and in between them. Any stricken area placed in such a high concentration of formative energy, is going to respond with a return towards normal. BUT, why go to all that trouble when a simple orgone blanket--a layered structure that can be directly applied to a traumatized or dysfunctional area--does a much more efficient, controllable job without that infernal juice. In my time with Ruth Drown, I heard it over and over again, and I pass it on to you: keep that 115V juice away from the organism. The post material EM energy is life negative, but no one seems to feel that they can get results unless they INJECT the alien EM activity into the stricken carcass. It's pure ignorance really. My own experience with orgone accumulators and blankets leaves me with no other choice but to regard the MWO as superfluous. A good rule for any experimenter: If it gets simpler, you are on the right track. Remember always Steiner's dictum: "the spirit of man is always healthy!.....it is the obstruction or dysfunction in the lower sheaths that distorts the manifestation of the spirit and personality via the body."

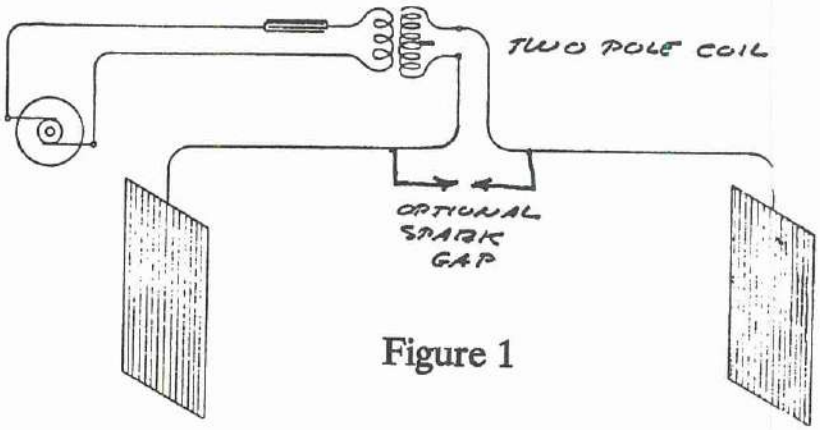

Figure 1

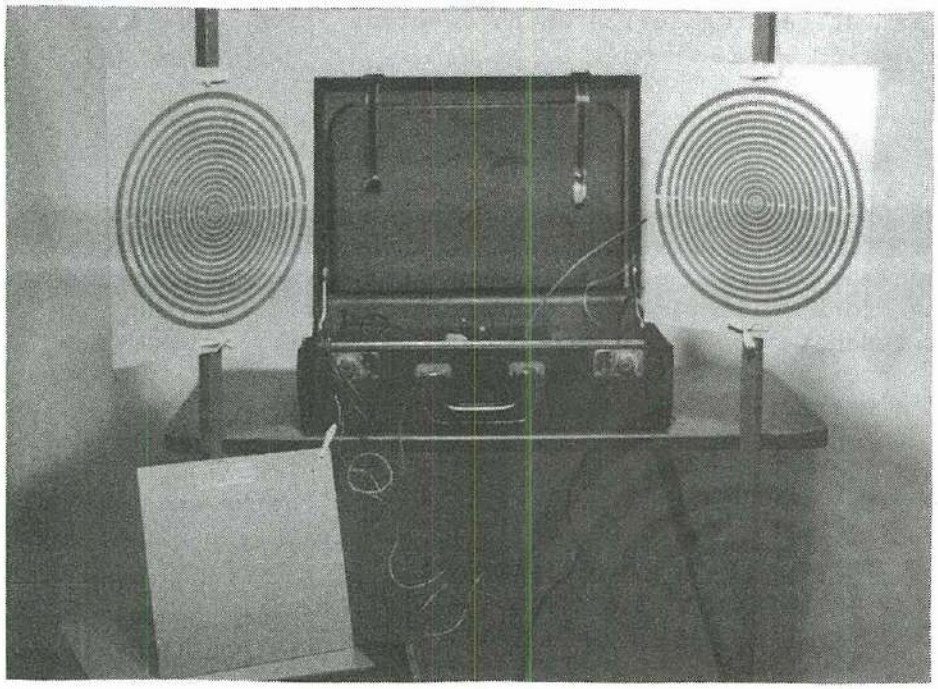

Photo 1
"Beck" style MWO from the BSRF collection (note: foot plate at lower left goes to ground)

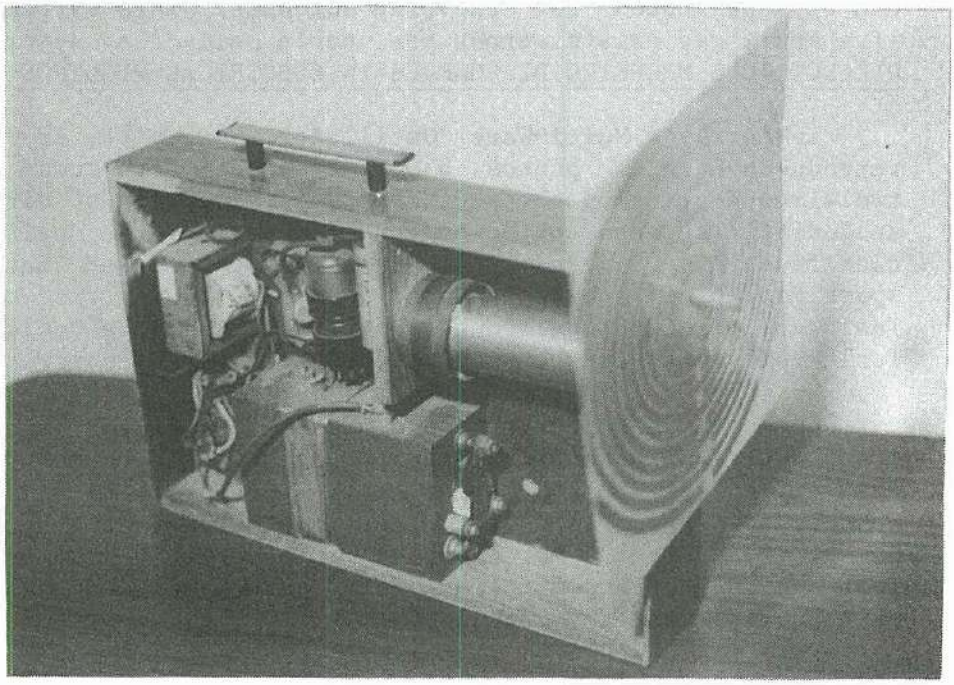

Photo 2
Single antenna version from the BSRF collection (Resonator antenna can be attached at ground)

Not much more need be said in that vein except that of a reinforcement of Trevor's comment. Our present society is not on the path of Nature so therefore some people feel the need for a device such as this. Wilhelm Reich discovered how to concentrate the living energy of the universe, which he termed the Orgone. The Yogic sciences teach us how to accumulate this energy without any outside apparatus, so therefore the simpler and more passive a device is, the closer it resembles Nature.

In the following pages you will find some of the results of MWO experimentation and consideration by BSRF and Associates. We hope the information proves useful, but again it is for research purposes only. We do not recommend the MWO for medical use because we are not qualified to give medical advice, nor do we want to create any false hope where one may neglect professional health care. We do fully support a persons right to investigate and research with devices such as the MWO. No one has all the answers and the MWO is an interesting device which deserves true scientific verification or rejection.

THE BASICS

The general theory behind the MWO is to excite a concentric ring antenna which produces a wide spectrum of radio frequency waves. In this theory it is understood that the RNA-DNA coil in the nucleus of every cell has a resonant frequency within this range. Just as a tuning fork will ring when an identical fork is struck in close proximity, the cells will resonate to their individual frequency pulled from the frequency ocean of the MWO. Most people don't consider that there are different types of waves and two poles of electricity, and these distinction have not generally been noted.

The antennas on the currently popular "Beck" MWO system, serve as simple capacitor plates which transmit dielectric waves out of the Tesla Coil (see figure 1 and photos 1 and 2). The second MWO plate in such a system must be connected to a second Tesla coil or to a double pole (half wave) Tesla coil (May-June 1971 JBR), not a single pole (quarter wave) Tesla coil as per the Bob Beck/Klark Kent style MWO. Action in the MWO antenna is neutralized by the fact that capacitor currents flow radially inward and little electron current flows around the loops. Copper plates can be substituted for the ring antennas. This system operates 1000 times stronger if a spark gap exists across the double coil. A description of the action is in DIELECTRIC & MAGNETIC DISCHARGES IN ELECTRICAL WINDINGS by Eric Dollard from BSRF.

Lakhovsky's Multi-Wave Oscillator, as pictured in THE SECRET OF LIFE and reproduced here as photos 3 & 4, created a structured electro-magnetic field fed by two wires contacting the ends of the outside ring of his antennas. This is obviously an end-fire antenna so the component reaching the person is a novel energy needing clarification. Several researchers have expressed that Lakhovsky used a quenched spark gap which creates damped waves allowing free oscillation in the antenna. A Tesla coil is not required since the Multiple Wave Oscillator IS THE COIL. However a Tesla coil still can be used as the high voltage power supply.

Lakhovsky's patents will cover both types of units so it seems as though he experimented with both, but the pictures in THE SECRET OF LIFE are an indicator as to what he actually used. After having gone over the patents I'm beginning to think that Lakhovsky buried his secret to mislead copycats. That is the purpose for a patent, to protect the inventor. The Tube MWO Patent 2,351,055 gives some interesting insights into the overall picture of Lakhovsky's work and study of it will provide many research leads.

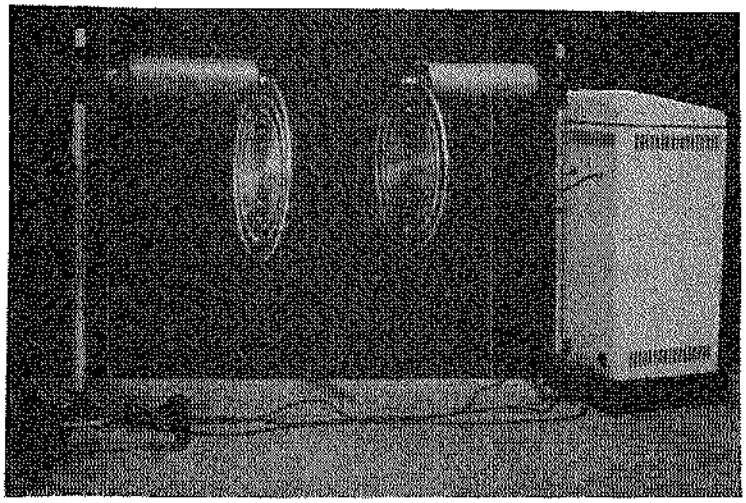

Photo 3
Lakhovsky's Multiple Wave Oscillator

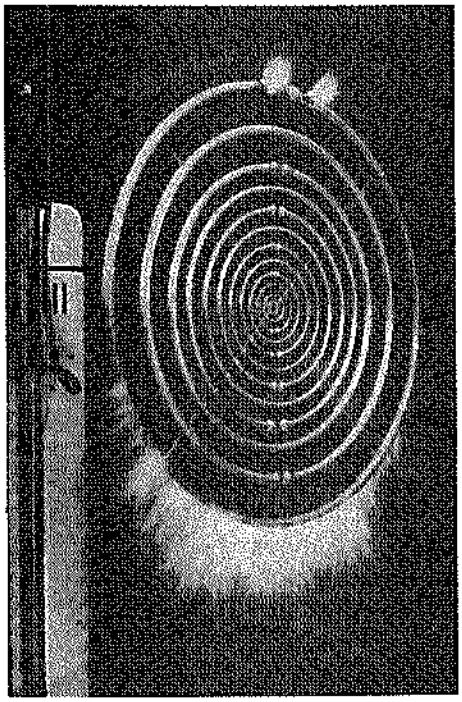

Photo 4
Lakhovsky's MWO. Close-up of transmitter in action, showing *effluve* (electric brush). Note this is end-fire antenna. Regeneration may have come from novel component at 90° to antenna plane.

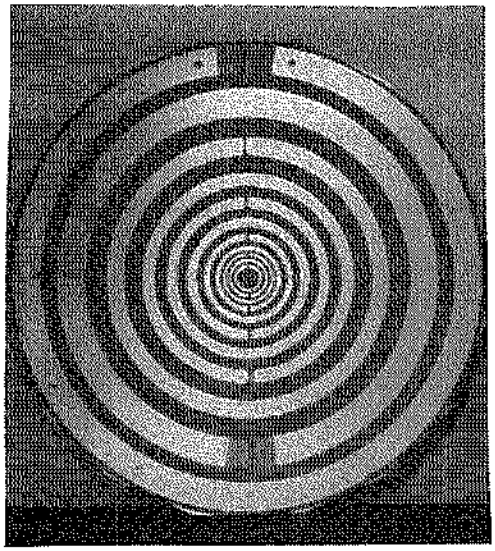

Photo 5
Yagi MWO antenna

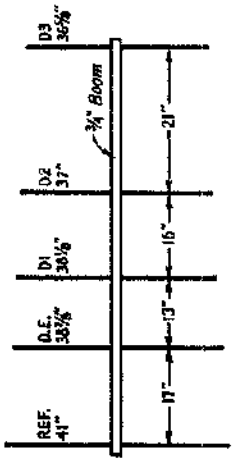

Yagi antenna

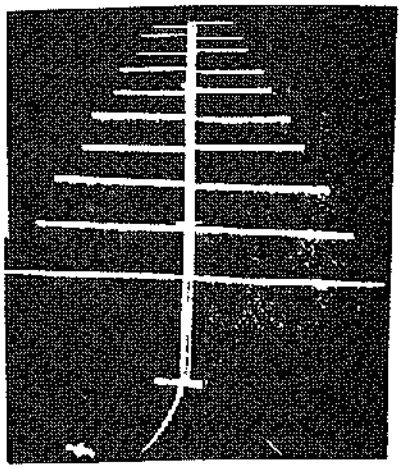

Log periodic antenna

Figure 2

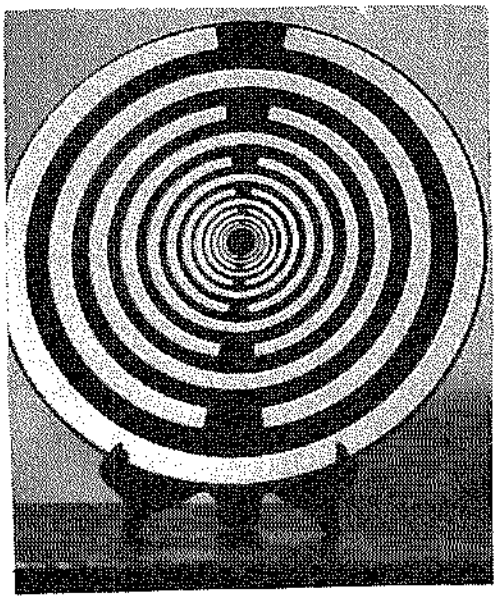

Photo 6
Golden Ratio – Log Periodic
MWO antenna

LOG PERIODIC ANTENNAS

Our research indicates that Lakhovsky worked with log periodic antennas and may have been the first to use them. The antenna will create a harmonious structure in the ether. The Beck style MWO produces a dielectric field 90 degrees out of phase with this, and utilizes the dielectric breakdown (arcing) of the field. This is basically a radio frequency noise generator and the most popular derivation of Lakhovsky's first MWO patent.

Scaling the rings non-uniformly using correction factors is not needed according to log periodic antenna theory (see figure 2 and photos 5 & 6). Lakhovsky states that any high frequency radiating circuit will drive the antennas. We are striving for waveforms mirroring the harmonic laws of nature. As an example the old Yagi antenna has non-uniform distribution of the elements. Log periodic design uses the uniform distribution of the elements such as is found everywhere in nature. This presents superior MWO performance. Lakhovsky's Speaker and Microphone Patent indicates that the log periodic design can be applied to sound as well as radio frequency energy.

LAKHOVSKY'S MWO

Figures 3 & 4 are a preliminary attempt by Eric Dollard to accurately reproduce the MWO system as pictured in SECRET OF LIFE. Figure 3 is a simplified version for a single antenna, figure 4 is a double antenna system. Photo 7 is an experimental setup utilizing this design. We feel that Lakhovsky was working with quenched spark gaps which produce damped waves in the form of the antenna. This type of circuit is needed to power log periodic antennas to create their structure in the ether harmonious with the Golden Ratio structure of the human body and life in general.

This information is not definitive, but is the result of experimental and theoretical considerations. We present this so that Borderland researchers can carry on with new input. We are not saying that the "Beck/Kent" models do not work. There are many claims that they do, but based on Tesla's theories, rather than Lakhovsky's. Figure 1 unit works off of longitudinal dielectric waves (displacement current). Figs 3 & 4 work off of Transverse electromagnetic waves (Hertzian) and residual scalar waves.

Figure 5 is a low power driver based on the Steinmetz lightning wave, a reproduction of the wave naturally occurring in the atmosphere. Values given need to be experimented on for optimum pulse formation. A mathematical analysis of this wave by Steinmetz is included as an addendum to this book. See DISTRIBUTED SERIES CAPACITY.

GOLDEN RATIO ANTENNA

Eric Dollard has designed a log periodic antenna based on the Golden Proportion, as found in living systems such as plants and animals. These antennas are two sided, the first side looking somewhat similar to currently used MWO antennas, the second side being capacitive loading (as Lakhovsky mentions, he used spheres on the ends of his antenna rings) based on the Golden Ratio. This design can be seen in photo 8. These antennas are gold plated to provide direct contact with the ether. Their actual size is 12" in diameter.

Figure 3

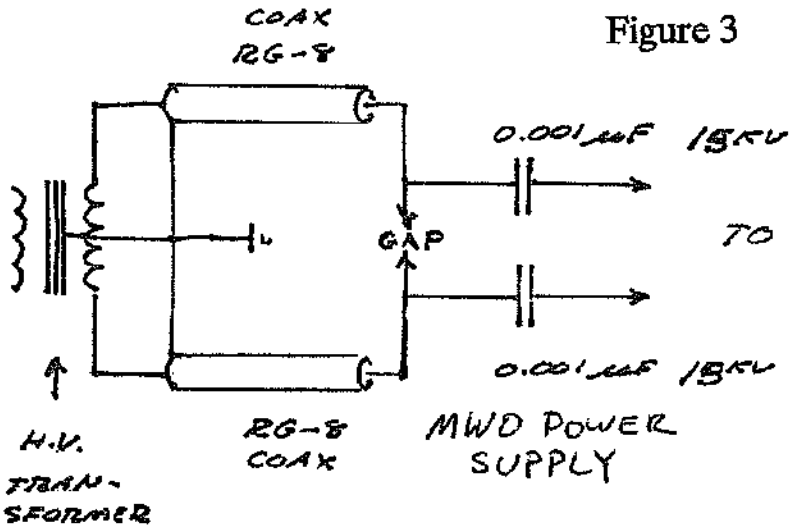

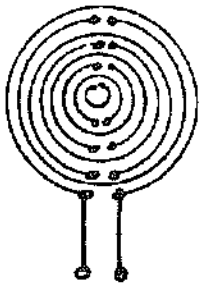

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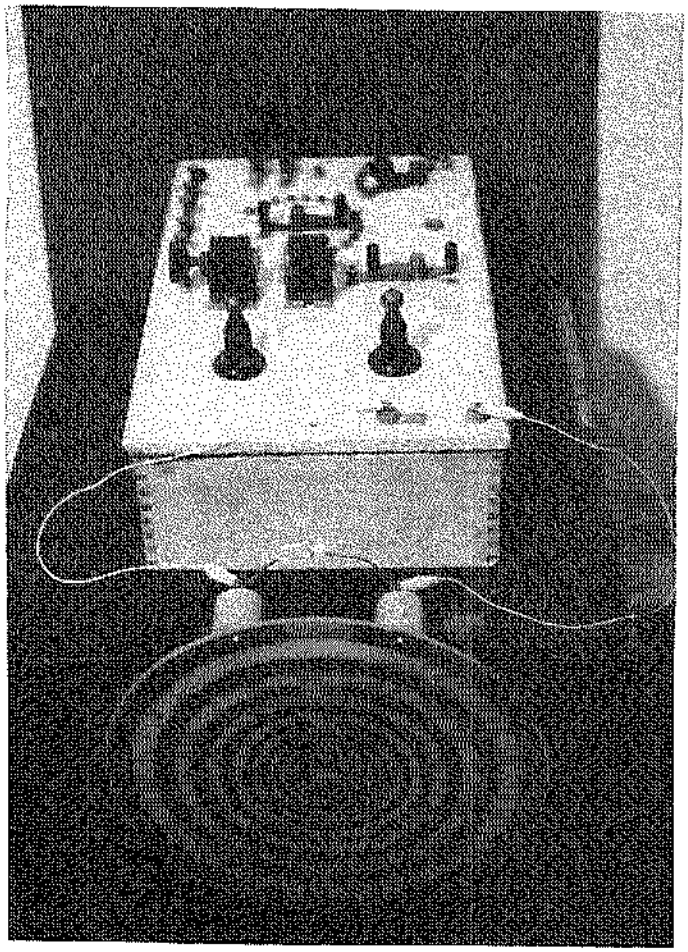

Photo 7
Golden Ratio antenna driven by 1919 era double-phase marble-top medical Tesla Coil. Mid-frequency D'Arsonval currents are utilized in this arrangement. Setup is as per Figure 3 (above), and is our understanding of the arrangement as utilized in THE SECRET OF LIFE. Coil donated to BSRF by John Crane from laboratory of Royal R. Rife.

Action of Lakhovsky setup

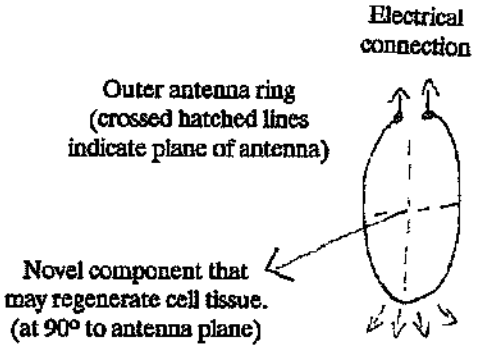

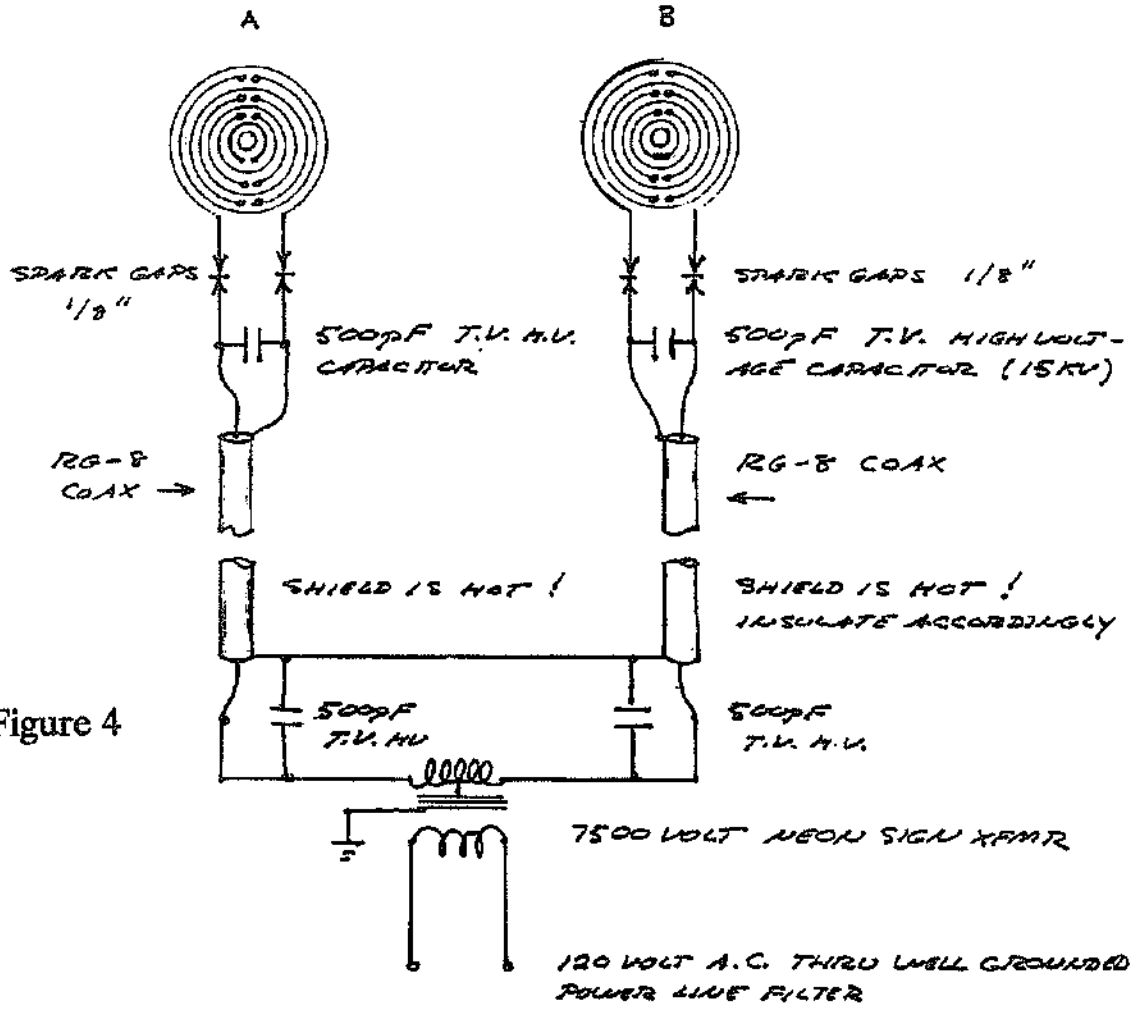

Figure 4

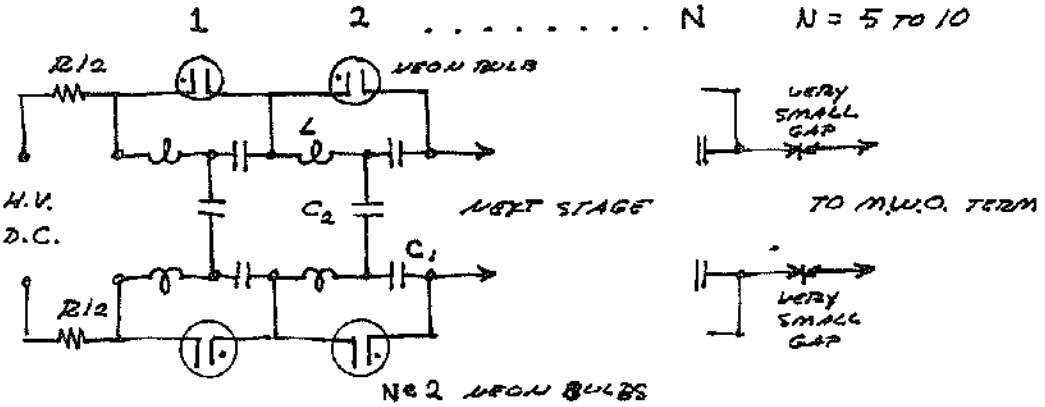

Figure 5

D.C. INPUT = 240V / STAGE ALL C_1 RATED 600V

R = 100KΩ / STAGE 1 WATT / STAGE

L = 2 μH / STAGE C_1 = 100pF X № OF STAGES

C_2 = 0.02 μF / STAGE 600V X № OF STAGES

The term Golden Mean, Ratio or Section refers to the mathematics of life, which is a logarithmic function. This ratio can be found everywhere in nature. It is the Sacred Geometry used in the architecture of ancient Greek and Roman temples, the Great Pyramid, etc. It has also been concluded by certain Orgonomists that "the Golden Ratio is a basic mathematical property of the orgone energy" discovered by Dr. Wilhelm Reich. (Journal of Orgonomy, V.8, N.2, Rosenblum, THE GOLDEN SECTION). It is evident from Lakhovsky's MWO Tube patent that he was aware of the Log Periodic design.

The MWO has usually been understood as having to be driven by a high-frequency source such as Tesla Coils and neon transformers generate. However, those who have looked into Lakhovsky's work know that he used simple wire circles to cure plants of cancers, and to make plants grow better in general. The Golden Ratio Antenna is a series of Lakhovsky rings because the rear conjugate strips on the antenna close the loops and in effect make Lakhovsky oscillating rings which are a complete circuit for focusing the ethers. The log periodic (following a logarithmic pattern) antenna design carries this effect further and preliminary indications are that the log periodic design creates a structure in the ether even without power, in may be an orgone accumulator of sorts. Further experimentation in this vein is being undertaken.

Log periodic antennae have the interesting property of creating a virtual (non existent but functioning) antenna extending about 1-1/2 times beyond the actual. It is also frequency independent and is an excellent antenna for Amateur Radio communications.

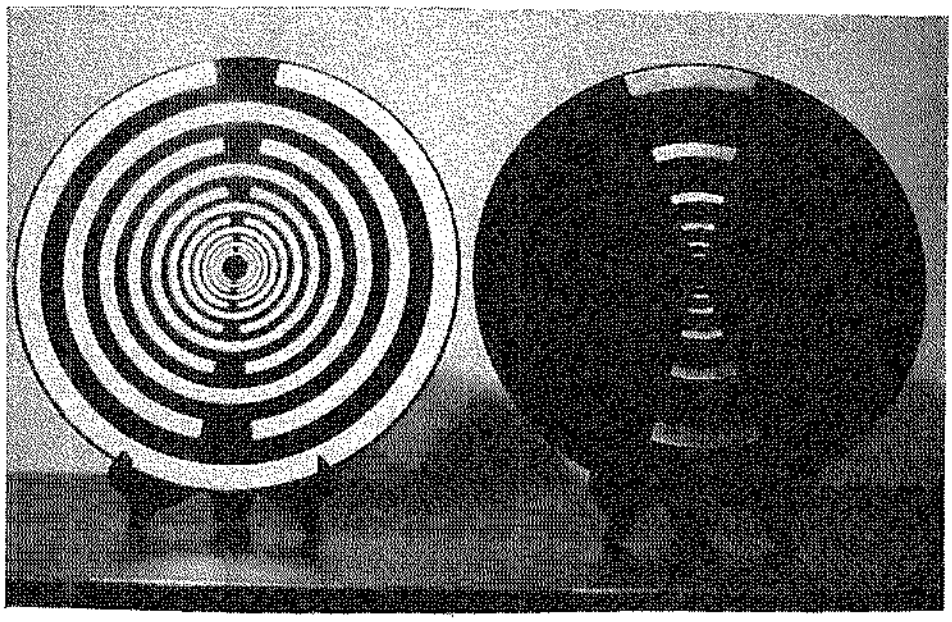

Photo 8
Golden Ratio antennas designed for MWO use by Eric Dollard. Forward side similar to Lakhovsky antenna. Reverse side provides capacitance as did metal spheres at ends of original Lakhovsky antennas. (see Photo 4)

The ethers harmonize to Golden Section Mathematics, (as demonstrated by Trevor Constable in his PRIMARY ENERGY WEATHER ENGINEERING ON THE HIGH SEAS video), so it can be understood that a living organism is a discharge of energy into the Golden Section space. We have observed the discharge of sprout energy into living sprouts when one of these antennas is directed at them. We found that it makes the sprouts grow better. Then we found that simply the pattern makes the sprouts grow better. So here we present you with the Golden Ratio Pattern that you can photocopy and use for experiments. This pattern may be copied as many times as you like for experimentation. We have reports that this pattern keeps the scale out of water heaters and fish tanks.

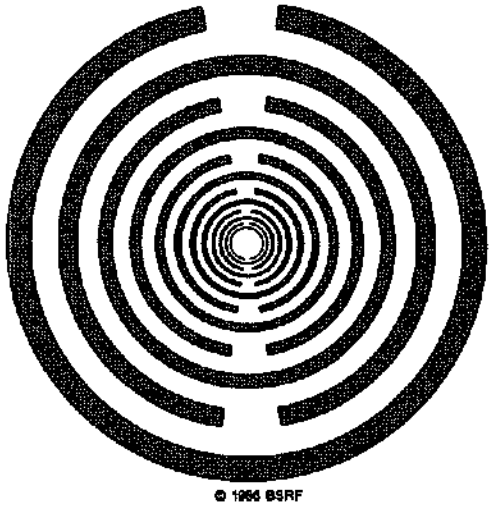

Log Periodic -- Golden Ratio design for research into the subtle vibrations from patterns.

In 1986 Borderland produced a limited amount of Golden Ratio Antennas in copper and gold. These were precision engineered Log Periodic antennas, and were quickly absorbed into the research network. They can be reproduced if sufficient interest is generated through this book. There is an appendix on log periodic antennas in this book for those who wish to pursue this interesting subject directly related to MWO research.

BUT - DO THEY WORK?

For all the material in this book we still haven't personally seen any solid documentation on the results of either type of MWO that could be re-verified as true to any investigator. I've seen listings and testimonials, but even the photos in THE SECRET OF LIFE look doctored to enhance the cancers (tar can be seen on the wound and the hair!). What was Lakhovsky really up to and which type of device works better? If anyone reading this knows any more than we do then please drop a line. In Lakhovsky's Tube patent he states that his instruments are in use the world over. It is important to check out one of his originals first hand, if any readers have access to such please drop Borderland Sciences a line. We'll make the information available for research. Thanks.

CONCLUSIONS

There are no conclusions at this point in time. Borderland has been publishing MWO information for 25 years now. This book marks the beginning of a new phase of research and development. Perhaps in 1995 after people do some serious research into the subject of the Multi-Wave Oscillator can some conclusions be drawn.

It is important to keep in mind during these researches that just because a frog leg will jump when electricity is applied it doesn't necessarily mean that electricity and life are the same thing. If we labor under this (quite common) delusion we may as well hope for our television sets to "heal" us of our ills. Rather, as astute phenomenological observers, we see that there is a relationship between electricity and life and in the understanding of that relationship we can come to a clearer comprehension of our place in this manifest universe.

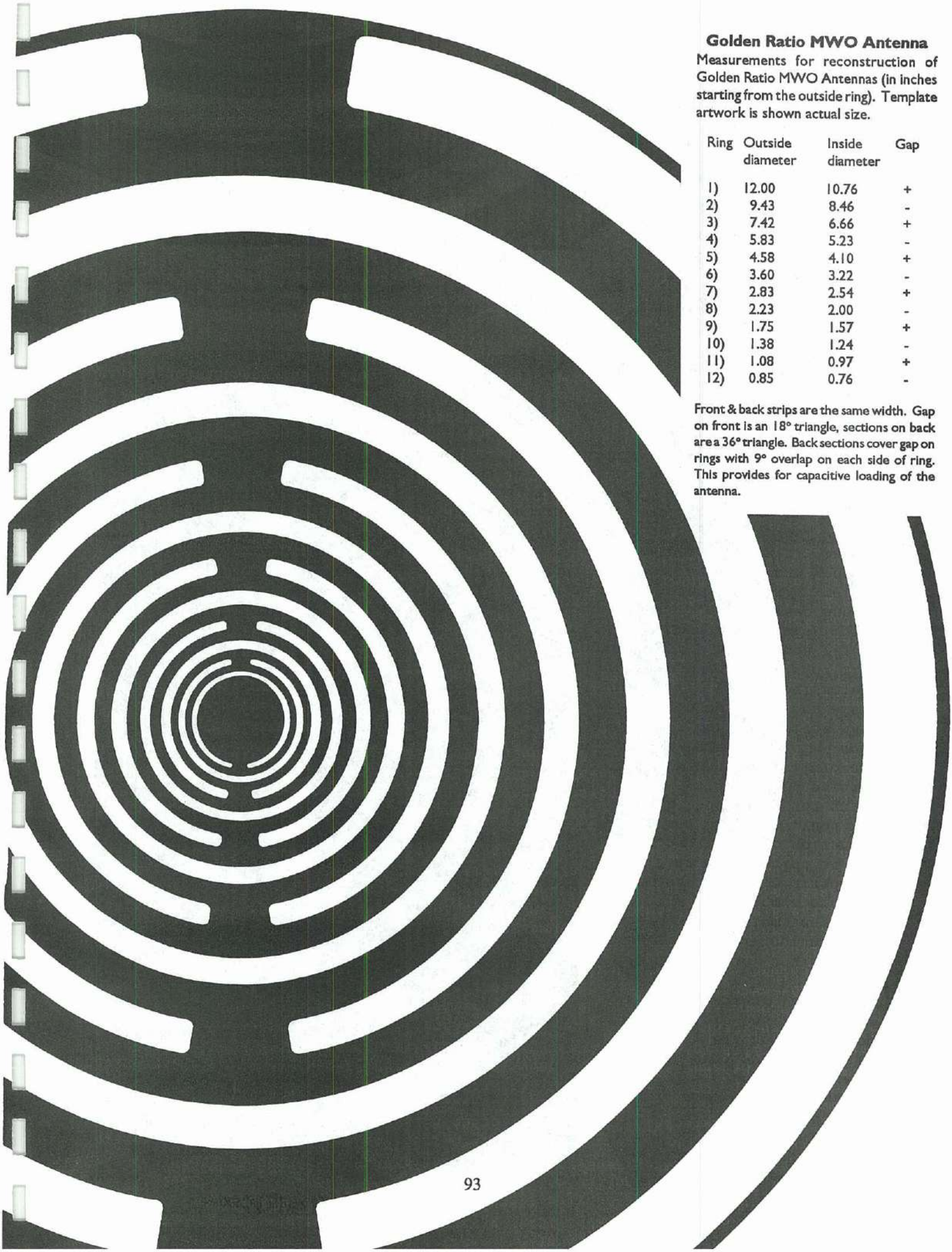

Golden Ratio MWO Antenna

Measurements for reconstruction of Golden Ratio MWO Antennas (in inches starting from the outside ring). Template artwork is shown actual size.

Ring	Outside diameter	Inside diameter	Gap
1)	12.00	10.76	+
2)	9.43	8.46	-
3)	7.42	6.66	+
4)	5.83	5.23	-
5)	4.58	4.10	+
6)	3.60	3.22	-
7)	2.83	2.54	+
8)	2.23	2.00	-
9)	1.75	1.57	+
10)	1.38	1.24	-
11)	1.08	0.97	+
12)	0.85	0.76	-

Front & back strips are the same width. Gap on front is an 18° triangle, sections on back are a 36° triangle. Back sections cover gap on rings with 9° overlap on each side of ring. This provides for capacitive loading of the antenna.

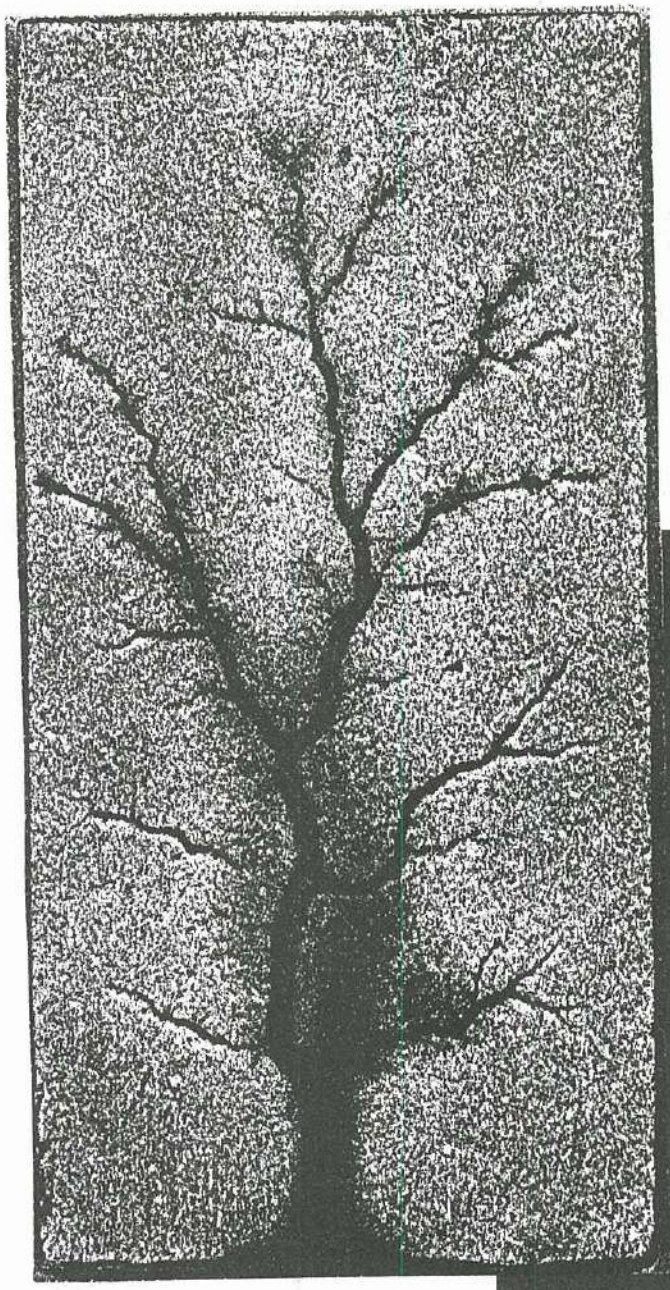

At left is a Golden Ratio pattern burned into particle board using Tesla Coil pictured below, seen here discharging into free space. Scientist Eric Dollard, builder of this coil, has deduced that the Golden Ratio is a property of space itself. The proportions are decided by the amount and type of discharge.

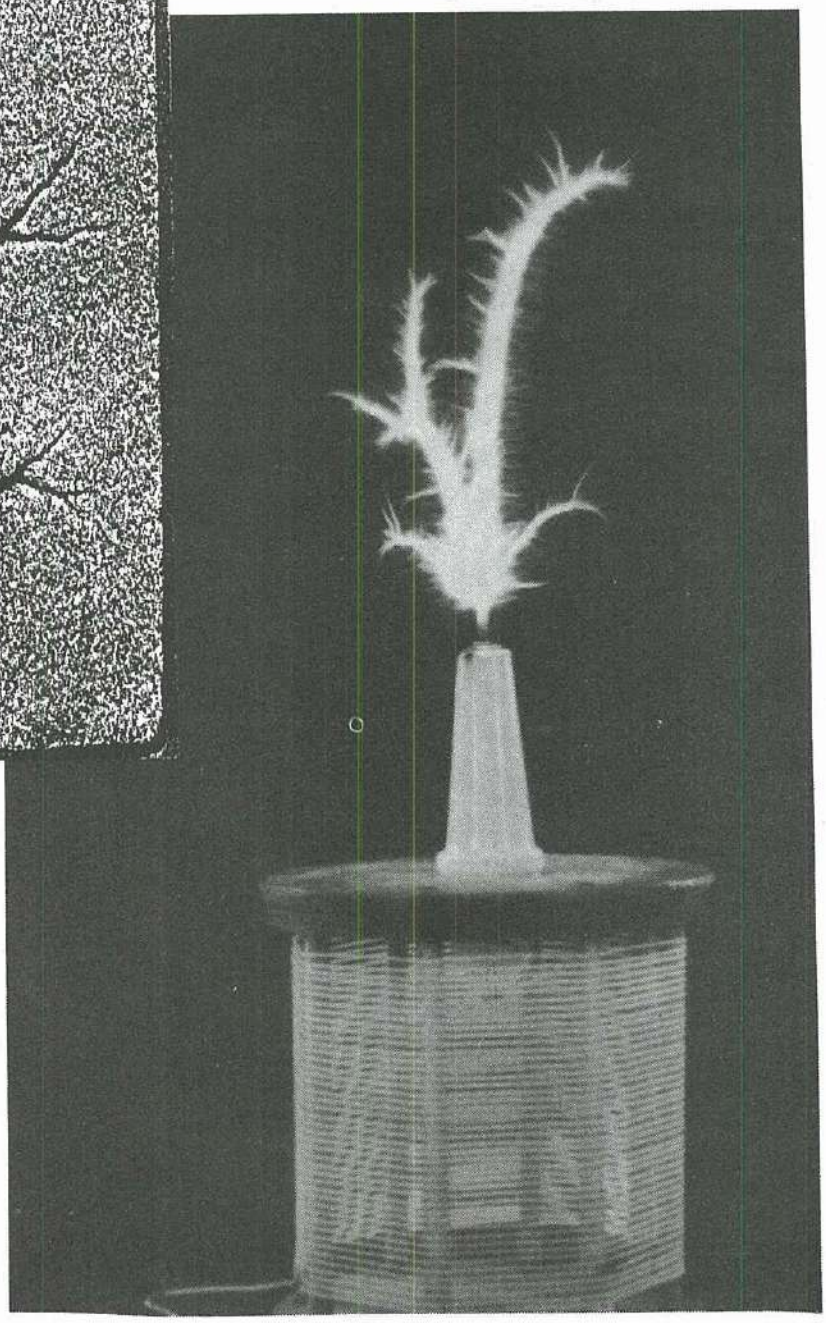

THE SPIRAL COIL MULTI-WAVE OSCILLATOR

Louis A. Schad

DISCLAIMER

Let me make it perfectly clear, I present this information for information and research purposes only and I make no suggestions or recommendations as to its use for healing or medical purposes whatsoever. If you are sick see your doctor. I present to you only what I have learned in my research and observations. I am not a medical doctor and the information I give should be used for education and research only.

To preface this, I have been interested in and studied and collected articles on the unusual sciences for over 30 years and have built many unusual devices. My attention was directed to the Lakhovsky M.W.O. by an article given to me by a friend. I read it several times and studied it and then put it away, (punched holes in it and put it in a notebook). I don't know why -- I can't tell you -- but I couldn't get it out of my mind, so I got it out again and read it some more -- this time going through it sentence by sentence digesting it -- now I was hooked!

I tried to gather all the information I could on the M.W.O., and as usual it wasn't easy -- I had to dig. Bottom line, I started to build Bob Beck's high power multi-wave oscillator -- I still haven't finished it, but I will. The more I studied the M.W.O. (being an average person -- not an electrical engineer, but a mechanical engineer) it seemed to me, complicated, difficult, and had to be adjusted for each person and circumstance. Looking at it now I see that isn't all true -- it was me. Back to square one -- I search for some way simpler, and out of it came the spiral coil M.W.O.

I am a recent member of Borderland Sciences and I have read many fine articles published in this Journal. Many of the articles are very high-tech and delve into the how, where, when and why, and that is how it should be if one is to research. Questions have to be asked and answers have to be found. I am not a professional writer and it isn't one of my greatest talents, so I ask that you have patience with me and I will do my best to tell you about my spiral coil M.W.O.

When I was trying to develop this spiral coil M.W.O. all I wanted was results and I didn't really care how or why it worked, my goal was results, and in doing so I tried many things that I wouldn't have normally tried had I planned each step and tried to fight my way through with pure brain power. In retrospect, I can see that I approached this project with a more light hearted attitude and I have enjoyed developing and building this M.W.O. But at times I did have problems to work out.

I experimented by winding coils, and coils, and coils. I got to be the electric supply house's best copper wire customer, or at least it seemed that way. After boxes and boxes of copper coils, I was ready to throw in the towel and give up -- but having the handicap of being stubborn like I am, I decided to wind one more coil, so I went out to the garage and wouldn't you know it, no more wire. I looked around and all I could find was some old solid strand 16 gauge house wire. It was too light and flimsy for what I wanted, so in desperation I decided to take 2 pieces and twist them together to make 1 heavy piece of wire. Well -- bingo -- I made a coil and got a tingle, that did it. After winding more coils and more coils and experimenting I got to where I am now, so I present to you the Spiral Coil Multi-Wave-Oscillator.

Warning -- this unit is deceiving (it just sits there and looks innocent like it couldn't do much), in fact some of my friends upon first seeing it have laughed at it, and commented you have to be kidding. Another friend of mine asked me to help him build one -- which I did -- and he was lying on his bed in his shorts with a sheet over him and had the unit about 2 foot above the bed and he fell asleep for about 3 hours (he had an infection from a wound in his leg). When he woke up he had a white blister on him about the size of a nickel -- he has done this twice. I warn you, use it with care, it is more powerful than it seems. I think he percolated the infection up out of his leg, as he is fine now.

Now, I know someone is going to say -- I made mine from an old coat hanger and hung it off the coiling with a piece of string, and I'll say -- gee that's nice, do what you wish -- but if you want it to work and work properly build it as it is, use it, experiment with it, and then change it as you wish.

Warning -- persons who have or are diabetic should not use this unit, as it may change the blood sugar level in some people. Diabetes is one of the few things that a M.W.O. will not correct or help. Lakhovsky states this in his book **THE SECRET OF LIFE**. I think I know why but I won't get into it now.

NOTE -- The spiral coils of this unit work <u>all</u> the time -- that is -- they never stop -- they work with or without the vibrator. Who said there is no free energy? If you put it over a bed with an electric blanket, it will charge the blanket and you will probably have difficulty sleeping. If you do not swing it far enough away from the bed at night it will cause unusual dreaming.

As near as I can tell this coil broadcasts at about 120° angle, although its peak energy is centered straight down from the small coil.

Question: is it patented or am I going to patent it? Answer: NO -- as far as I'm concerned it's free to everybody and that's as it should be.

The advantage of using a spiral is that one should get all the frequencies up to the maximum diameter of the outer diameter (O.D.) of the spiral. If you draw a spiral on a paper and place one point of a compass at the center, you can choose any diameter you wish up to the coil O.D. diameter and the scribing diameter will

fall some place on the spiral.

This unit can be operated in 6 modes:

1. The coil only.
2. The coil plus the vibrator.
3. The coil plus the vibrator plus the coil shocker.
4. The coil plus the vibrator plus constant coil charge.
5. The coil (no vibrator) plus the coil shocker.
6. The coil (no vibrator) plus the constant coil charge.

So as one can see there is plenty to experiment with here.

NOTE -- I also tried connecting a ion generator to mine -- that really blows me away -- try it if you have one.

If you are experimenting with magnets -- be careful if you use them with this unit as some people get bad reactions. I personally have used magnetic water and this M.W.O. and have had no bad reactions.

Warning -- although I have -- I suggest you do not use this on the head or above the neck.

Warning -- if you have a heart problem do not use this unit as in some people it tends to reduce blood pressure and lower the pulse or heart rate.

Well -- now that I've scared the hell out of you, if you still want to build it I'll tell you the good side. In most all people who have used it or tried it they get a tingle or a feeling of heat (light). Most people get a boost of energy when they use it and it seems to help circulation. I am not sure why. I don't know if it tends to dilate the blood vessels of not. One man that used it can now wiggle his toes and he hadn't been able to do that for about 3 to 4 years.

I know someone will ask what type or kind and amount of energy is emitted by these coils and the answer is I do not know, but I do know that it works. I will leave that to someone who has the proper instruments and the know how to check it, so there is still a lot of work to be done here if someone wishes to do it. Now, before someone starts climbing my ladder, let me say that I give the credit to Lakhovsky -- what I did was to modify, update and expand upon the base of some of his work. You do not have to be gifted in the knowledge of the sciences to build this M.W.O. and do not need special equipment or tools. However, there are little tricks that I have learned that make it easier to build that I will give in another article. The body or base of this unit is made of P.V.C. pipe, also the vertical and swing arm, the vibrator base and also the drop tube that hangs the coils. We want a unit that is low in cost, tough and durable, light in weight, corrosion resistant, portable, easy to fabricate (and repair if necessary) and looks nice, so we will build our unit out of P.V.C. pipe.

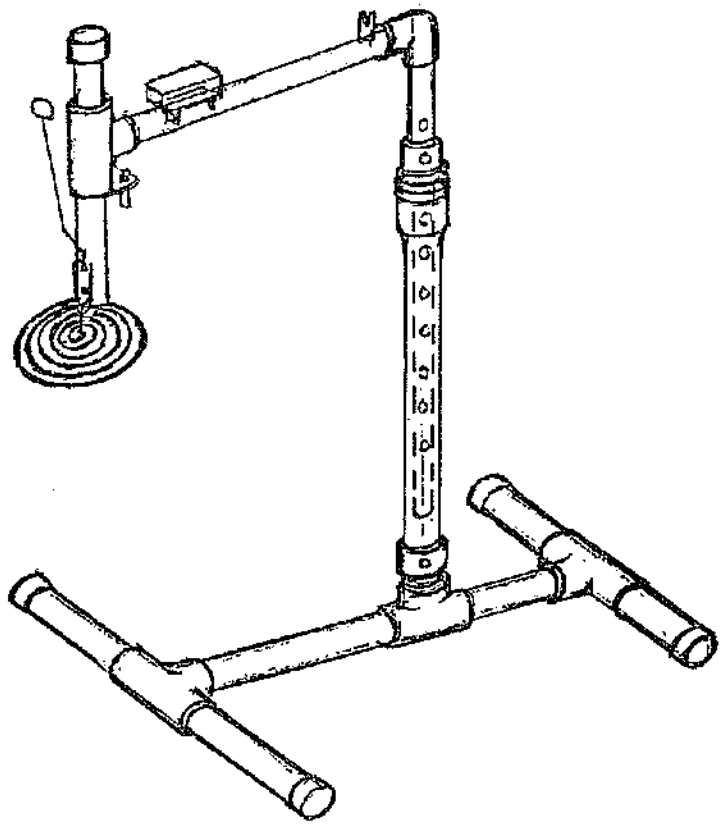

Spiral Coil Multiple Wave Oscillator

ALL COILS ON THIS M.W.O. MUST BE RIGHT HAND COILS, IN RELATION TO THE UNIT AND EACH OTHER. If they are not you will get negative energy. (I'm not speaking of polarity here.)

I use a fish tank air pump (modified) -- (Challenger 1) about $8.50. This provides the oscillatory motion to the coils. I'm not in love with it and would like to find something better -- something of higher frequency, but it works. If anyone has any suggestions on this I would like to hear from them.

I chose to design the unit so it can access any part of the body freely without a lot of excess adjustments. The body when lying down is in one plane or height (approximately), so I built the unit so it would extend over a bed or table, added a swing arm, and a vertical adjustment (holes in the vertical tube arm and a wood dowel or pin stop) -- that seemed simple enough, remember we're trying <u>not</u> to get complicated here.

If you are going to build this M.W.O. I strongly suggest that you read Lakhovsky's book, THE SECRET OF LIFE. When I finally decided to try to build an alternative type of M.W.O., I read everything I could get my hands on about the subject. I read carefully and took notes of key points, functions etc., then I put my books away and studied my notes -- the basics.

M.W.O. -- MULTI-WAVE OSCILLATOR

MULTI -- meaning more than one or many.

WAVE -- energy (given off)

OSCILLATOR -- I looked this up in Webster's -- and simply stated it says -- motion deflected from center to one side -- back to center -- deflected to the opposite side -- back to center, OR -- Vibration.

Now, Lakhovsky in his book stated he made an oscillator of 1 loop or coil of wire

errata: This page was inadvertantly left out of the book.

electrical supply house. If you cannot get bare wire, you will have to get plastic coated and strip the coating with a sharp jack knife, taking care not to nick the wire, or yourself.

2. You need a piece of aluminum bar 3/16 x 1-1/2 inces, 20 to 24 inches long.
3. You need a medium size pair of pliers.
4. Soldering iron and acid core solder.
5. Small coil of 19 gauge coated (shellacked) copper wire.

Now – we have 17-1/2 ft. of 10 gauge copper wire, lay it out on a flat clean surface and straighten it out taking the curve out of it and the kinks and bends. Next we need a secure and strong place to fasten the ends of the wire to – like a trailer hitch or bumper of a car or truck etc. After you have found a place to secure your wire, fasten both ends of the wire to it as shown in Fig. 1.

Slowly pull the center of the wire so that you have 2 pieces of wire, put your aluminum bar in the loop and pull tight. With a pair of pliers close the wire down on the bar tight so that it passes between the screws. Pull hard on the wire with the bar – it won't break. Start twisting as shown in Fig. 1 – always keep tension on the wire – do not let go of the bar. (COUNTER CLOCKWISE). Twist the wire, stopping at time, give the wire a couple of good yanks. NO, it won't break. Twist the wire until you have a good tight twist on it. When you think you have twisted it enough – twist it a little more. When you get it where you like it – SLOWLY back the pressure off of the bar.

Remove 1 screw on the bar and slide the loop out or off of the bar. Unfasten the wire where you secured it and cut the spiral wire as close as possible at secured end. Lay the twisted wire down flat. Measure 3" down from the top of the loop as shown in Fig. 2 and mark it with a pencil or pen. Hard or tight bend the wires as shown in Fig 2, 90 degrees. Grip the twisted wire at the bend point with a pair of pliers, and start forming the spiral. Continue forming 1 or 2 loops. Remove the pliers, grip the wire and hand form the spiral as shown in the drawing #2. When you have formed about 4 loops of the spiral, stop and apply light heat to the coil with a hair dryer or similar device to relieve some of the stress in the wire, so that the loops that you have formed will stay where you have bent them. Repeat the operations and continue forming until you have your spiral.

DO NOT BEND END OR TIP IN YET.

Put your spiral in the freezer of your refrigerator for 30 to 45 minutes, and freeze it. This will tend to stabilize the copper some and relieve some more of the stress.

In Fig. 4 we can see that if we bend a piece of metal the inside of the curve is compressed and the outside is stretched, this stress is what we are trying to get rid of. About now some of you will be thinking – GAD – he even tells us how to hold the hammer. I am sure that some of your who are pro's at metal forming and fabrication can build this thing – WHAM-BANG, but please have patience, not all are gifted in some of these skills.

When you have formed your spiral and it is shaped as you want it, hold the loop of the spiral with your thumb and point fingers at eye level height and sight across the spiral, it should hang so that all coils are level and even with each other, so that it is flat – if not form it so it is. Put the coil in the freezer again, repeat freezing operation several times, this tends to age harden the coil some.

With a very hot soldering iron solder the end of the coil, wash it in warm water, dry it, and bend end in as on drawing #2. After you bend the tip in, bend it down a little bit so the bent in tip clears the crossed coil by about 1/4 inch.

Drill 2 small holes in the spiral at points marked on Fig. 6, taking care not to break the drill, use light pressure. Cut 1 piece of coated coil wire (19 ga.) about 4 1/2 feet long. Push one end of wire (about 1-1/2 inches) up through bottom of hole in spiral, and wrap wind (twisted) loops of wire to second hole. Straight wrap 1 loop at hole area, this locks the standing wire. Pull standing wires tight with pliers and cut standing wires to about 1-1/4 inches.

Refreeze spiral and warm to room temperature. Sand or remove shellac from standing wires down about 3/4 of an inch, this makes electrical contact for the coil shocker. You have finished the main spiral coil. You have just done the hardest part, the rest of it is easy. Save your aluminum bar; you may want to build other types and shapes of coils and spirals to experiment with. I have wound and tried 2 wire coils, 3 wire coils, cone shaped spirals, step spirals, spirals with wires attached and hanging down with soldered tips etc. There is no end – you can experiment to your heart's delight, it's only limited by your imagination.

In closing, I would like to tell you a story – a true story about a close relative who gave me permission to tell of his experience with my M.W.O., but prefers to remain anonymous. I will not elaborate, but just state the facts as told to me by him and his nurse.

This relative took a trip by car to the southwest part of the U.S. with some friends. Before he left he called me and said that he would come to California and would stop to visit with me. This was in the late summer of 1990. After arriving at his destination in the southwest, the weather turned very hot for the whole western U.S. Due to this extreme hot spell, he phoned me and said he was returning home and would not come to California.

When I talked to him on the phone before he left, I told him I had built a Multi Wave Oscillator for him and I would give it to him when he came to see me, and he could take it back with him. He did not make it to Calif. but returned to his home in the midwest. After returning home he became ill and went to see his doctor. After being checked by his doctor, he had tests, and the doctors discovered that he had cancer of the large intestine. When I phoned him and found that he had cancer, I asked him if he wanted to try my M.W.O. I told him that I could not guarantee that it would help him – but I said – what do you have to lose. He said yes, he wanted to try it, so I sent it to him.

When he received the M.W.O., it was assembled from instructions I sent him. He used it twice a day for approximately 6 weeks. He had additional medical problems, he had diabetes and congestive heart failure plus the cancer plus a back problem. I had made the M.W.O. for him in hopes that it might help his back. When he went back in 6 weeks to see a cancer specialist doctor they gave him extensive tests and could <u>not</u> find any traces of

of a given diameter that overlapped. Also, I have read that it isn't the intensity or power of the unit that is desired, but the quality of the signal and also the number of frequencies, signals or waves, as the power can be offset by a longer exposure time. It seemed obvious that a spiral should produce all or most of the waves or signals desired and that it would be better than one loop with a limited signal effect. If Lakhovsky could cure cancer in plants and people with one loop it is logical that a spiral should be even better. OSCILLATION -- how about inducing it artificially -- vibrate or agitate the coil or coils.

This unit produces it's peak energy at 12 o'clock at night, but it can be used during the daylight hours too; it's energy diminishes some toward mid-day. Lakhovsky stated this and he is right. I've got to give it to him, he did his homework. Exposure rates or time of treatment with an electronic double screen M.W.O. is said to be 10 to 15 minutes every 3 to 4 days. Exposure time for a spiral coil M.W.O. (rule of thumb) is about 20 to 25 minutes or 45 minutes maximum per day, or less, depending on what is treated.

Lakhovsky also stated that he treated plants, animals and people with belts, collars, bracelets etc., consisting of a single loop of copper wire. From what I can gather, if a subject was wearing a Lakhovsky coil they never took it off.

My spiral coil M.W.O. is half and half -- part 1 loop + of wire, and part electronic. If a subject got 1 exposure every 3 to 4 days with a conventional M.W.O., it means that the subject's system was hit hard or shocked, and it needs time to adjust. A spiral coil M.W.O. requires a longer or more often exposure and this can be an advantage as it gives us more control of the research subject's requirements. The negative side is that the subject has to spend more time more often.

There is one unusual thing that I and others have experienced with this unit. When you first use it the sensation of heat or tingling is light and you require longer exposure time, like about 25 minutes before you feel that you have had enough. After you use it for about 1 to 2 weeks you will find that after 10 to 15 minutes you feel that you have had enough. Simply stated Lakhovsky said that a M.W.O. activates or excites the cells. It's kind of like pushing a car, it takes a lot of energy to get it started, but once it's rolling it's easier to push. Maybe the body just becomes more sensitized to the energy after the M.W.O. is used for a while. In Lakhovsky's THE SECRET OF LIFE on page 75, "The circuit is subjected to any kind of electric or magnetic shock it is then said that it vibrates according to its natural period." So, now what do we have?

1. A spiral coil (Providing Multiple Frequencies)
2. Vibrator (artificial oscillation).
3. Electric current (D.C.) (shock to the coil) provided by a small transformer limited by bulbs turned on and off by a Christmas light blinker or winker.

Now I said previously that most of the unit is made of P.V.C. schedule 40 pipe (white). P.V.C. pipe being what it is has the tendency to sag if placed in a horizontal position, fastened at one end with weight suspended at the other end. We can correct this by inserting a piece of 1 inch diameter .050 aluminum tubing inside the P.V.C. and gluing it with an adhesive or simply by drilling a 1/8 inch hole through both pieces and inserting a #8 sheet metal screw. Remember also I said there were little tricks you can use to build it as given above, so before you get too anxious to build, wait till I can write the HOW TO BUILD article, it may make your job easier and you will not have to change or rebuild the second time. I am trying to save some of you all the mistakes I made.

The heart of this M.W.O. is the large main spiral coil. This coil is in simple terms an antenna. It is a dual antenna, that is, 2 in 1 as it is a receiving antenna and also a broadcasting antenna. The antenna can be shaped in many forms and still retain the right hand spiral. Do we wind it tight toward the center and increase the spacing as we go out? This configuration I have found best, but other configurations can be formed to achieve different effects. I have experimented with different shapes and some have given unusual results. There is still a lot of work that could be done here also. I wound a 3 wire coil that was very effective but I had problems twisting the copper wire and lost several of them. I would suggest that the first coil you make be a 2 wire twist coil. If you want to build the M.W.O. complete you will have a total of 4 coils.

1 large main spiral coil.
1 small spiral coil (that is mounted under the large coil).
2 straight tube coils.

We use these coils because they all have independent functions. We are going to squeeze it and milk it for all we can, to get everything we can out of it. The main spiral coil produces most of the waves or energy, however, due to its design and nature the inside of the spiral cannot be wound tight to create small loops in the coil, so we will add another smaller spiral coil under the large main-spiral, this will give us the higher waves or frequencies we desire. We drill 2 small holes in the main spiral and tight wind a piece of 19 gauge coated coil wire around the twisted copper wire, and pull the wire up through the holes, leaving 2 standing 19 gauge wires. We sand the ends of these and fasten spring clips that hold the tube coils. The other end of the tube coil wire is connected to a banana plug -- into a receptacle, we connect our coil shock to these.

I know there are some of you out there who are like I am, (impatient) and are curious and would like to try this to see if this guy is telling the truth or if he is just full of it. I am aware that the Journal is published every 2 months and maybe some of you don't want to wait 2 months, so for those of you who are like I am -- let me tell you how to build the main spiral coil. This one coil in and of itself won't knock you over -- but you can get started, and you can play with it until I can write the HOW TO BUILD article. This coil will emit energy by itself if suspended horizontally. Fasten it to something, a piece of plastic tube or wood dowel etc. Try it on your feet as the feet seem to be sensitive to these energies. Well -- here we go.

HOW TO BUILD THE MAIN SPIRAL COIL

You will need to purchase a few things.

1. You need 17-1/2 feet of 10 gauge (solid) bare copper wire (cost about 14 cents per foot). You can get this at any

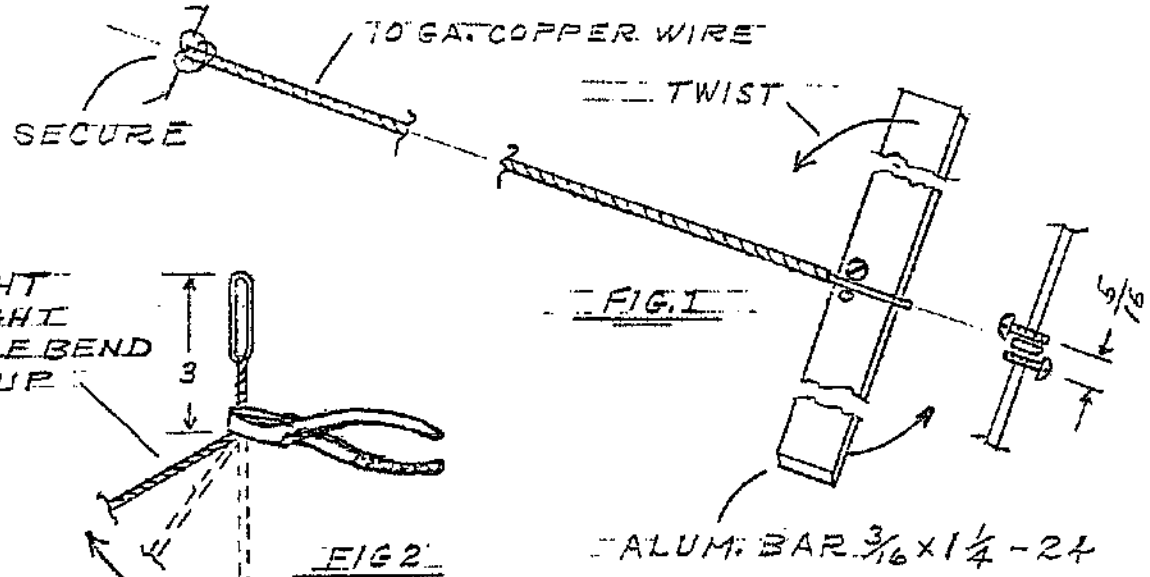

FIG. 1

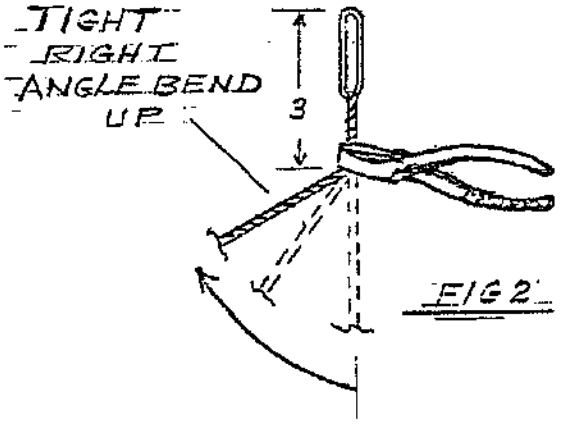

FIG 2

ALUM. BAR 3/16 x 1 1/4 - 24

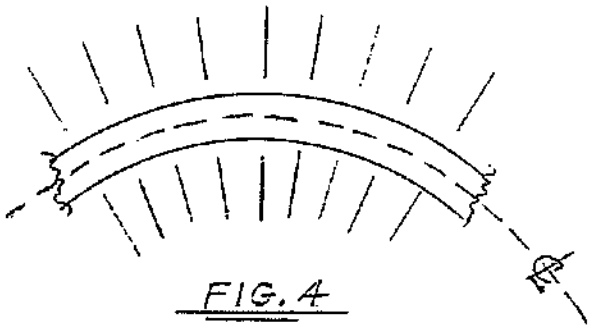

FIG. 4

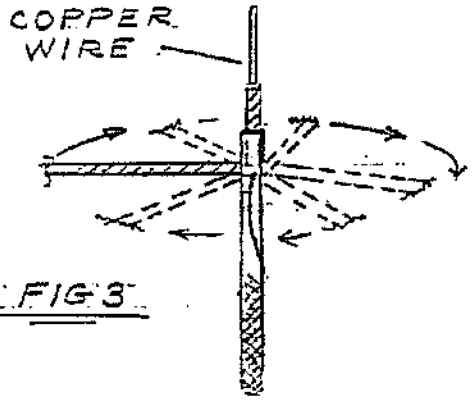

FIG 3

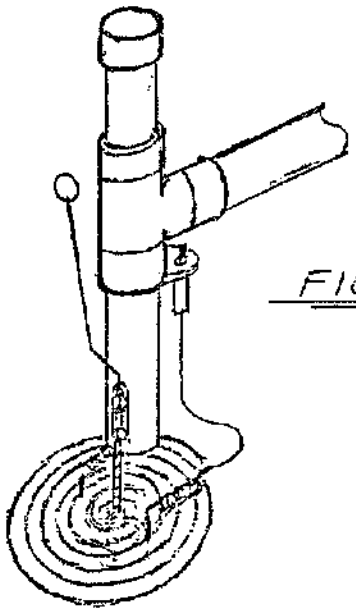

FIG. 5

SPIRAL COIL MULTIPLE WAVE
OSCILLATOR ANTENNA
CONSTRUCTION DRAWINGS
FIGURES 1-5

cancer. After his tests he phoned me and said the doctors could find NO traces of cancer whatsoever. I asked him -- did you take any medications whatsoever for your cancer? -- he said NO. I asked him -- did you take any radiation treatments for you cancer? -- he said NO. I asked him -- did you take anything at all for your cancer? -- he said NO. To this date he has not had any return of his cancer.

Now, where does this leave us? He either had spontaneous remission or he was helped by the M.W.O. As I understand and have been told, some forms of cancer in the upper stomach are inoperable. My relative is the 3rd person who seemingly has had remission from cancer from using my M.W.O. I do not like to use the word cured when speaking of cancer, and I say seemingly as this is all in the experimental stages of research.

Then there is Al Mills who built and used a copy of my M.W.O. He had prostate cancer; he's fine now, but we can't count him as he has taken medications for it. I have heard that doctors have said that prostate cancer is very difficult to treat. Then there also is Simon Lucas who built my M.W.O. and loaned it to a lady who has LUPUS (a cutaneous disease due to the tubercle bacillus). He said she is feeling and doing much better now. I also built a M.W.O. for my mother who lives in So. Sioux City, Nebraska, across the river from Sioux City, Iowa. I sent it to her -- she could not assemble it so I flew back to do it for her. Several years back she was leaving a market and caught her foot in a disposed plastic bag on the sidewalk, fell and broke her hip and leg. The doctors repaired it by wrapping screen around the bone and added a few screws and pins here and there. She was OK for several years and then she got to the point where the pain was so bad she could walk only a short distance.

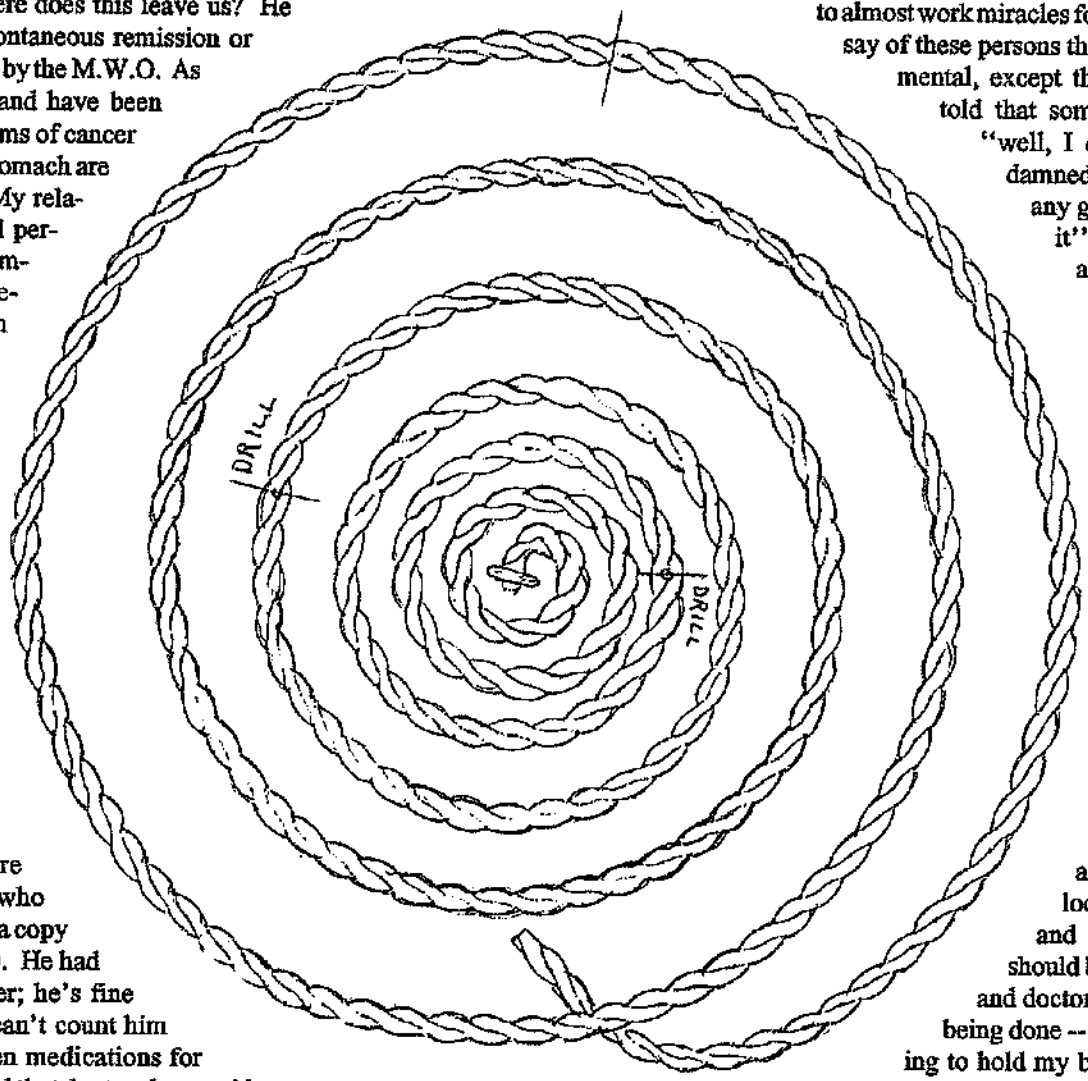

FIGURE 6

She has used the M.W.O. for about 2 months. She called me the other day and said she took the bus all over town, did shopping, came back, took her pull cart and did her food shopping -- 6 blocks up and 6 blocks back -- and then walked up to the restaurant and got her dinner, all in 1 day and she said she feels fine. The doctors gave her the choice of pain shots or cutting off her leg -- (some choice). NOTE -- She does not have a coil shocker on her unit.

In all honesty I have to say that my spiral coil M.W.O. does not affect all people the same. I have had no negative or bad reports to date from anyone using it with good common sense and discretion. There are a few people that it does not seem to help to any great degree. There are also some people that it seems to almost work miracles for them. I would say of these persons that maybe it was mental, except that I have been told that some have said -- "well, I don't think the damned thing will do any good, but I'll try it". I could go on and on but we'll leave it at that.

If you decide to build my M.W.O. I would welcome any serious and honest experimental input as this unit still has many areas that need to be explored. Sometimes I back way off and just stop and look at all this -- and realize that it should be the scientists and doctors doing what is being done -- but I'm not going to hold my breath until that happens. I guess the only way it's going to get done is for people like you and me getting off our backsides and getting it done. If enough will work at it and add a little bit, it'll get done. I sometimes wonder what the end-run potential of my M.W.O. is. I love the doctors (God Bless them!), we need them, but I wish they were more open minded and that they were not so profit orientated and stigmatized by their organizations. I think these ideas I present here will help.

THE SPIRAL COIL M.W.O.
PART II - HOW TO BUILD
by Lou Schad

In Part One I explained how the spiral coil M.W.O. evolved and how I came to build it and notes on things I have learned about it and its use. I also explained with drawings how to build the main spiral coil. For those of you who wish to build this unit, I have added additional drawings and notes so you can build the rest of the coils, base, etc.

Before I begin I would like to address an issue that has bothered me for some time, it pertains to my M.W.O. and maybe other M.W.O's in general. It is a situation or function that has been ignored by many or all but a few. In my article in Part I, I said all coils on this unit must be right hand coils. What I am referring to is what I call RIGHT HAND SPIN. In my study of Lakhovsky's and others work, I have not been able to find any information pertaining to direction of spin, although he gave very precise directions -- how collars, belts, bracelets etc. were to be made. Did he know and was it his secret? Was he not telling? Lakhovsky stated that his M.W.O. stimulated the twisted filament or nucleus of the cell, and the cell oscillated according to its natural frequency. A weak oscillating cell would increase its oscillations back to normal. The question is, do certain oscillations cause the cell to spin right hand or left hand, or clockwise or counter-clockwise, if the frequencies spin right hand or left hand? Some might say -- what difference does it make. The people who use or practice the Five Tibetan Rites always spin right -- never left. Sir Lawrence Bragg (Nobel Prize winner) discovered that healthy people have "RIGHT HAND" spinning blood. And physicist Dr. E. Mersmann discovered that people exposed to electronic smog have "LEFT HAND" spinning blood, the same as people who have cancer -- they also have "LEFT HAND" spin blood. Maybe if the earth spun in the opposite direction, left hand spin blood would be normal. So, is left hand spin or right hand spin important? Yes, I think so. I have purposely made and used left hand coils and they made me feel sick and ill. There is an instrument that has been built that emits weak pulsed electromagnetic waves that causes the blood to spin right hand in people who have left hand spin blood, however if the unit is removed the blood will go back to abnormal left hand spin.

If you put your hand in a bucket of water you can spin it to the right or to the left -- is this polarity? Does magnetic polarity have an effect on matter causing right or left spin? Yes, it seems to. But how about induced spin direction on a non-magnetic or non-electrical energy or wave? If I hold a magnetic compass near the spiral coil of my M.W.O., I get nothing -- no needle movement. If I hold a pocket radio under the coil with vibrator and tune it off station, I get static on A.M. from about 80 on down, none above 90 and up, but I don't think that static is coming from the vibrator. Warning: I damaged my radio by using if for testing. At first I thought it was the battery, but a new battery did not correct it. Sometimes when I turn it on now it doesn't want to come on, by flipping the switch on and off several times it then works. I had no problem with this radio before I used it for testing.

Whatever the answers are, I would suggest you use right hand coils. Look very carefully on pages 113 and 114, these are right hand coils in relation to the subject, (ref. The Secret of Life). If you build the spiral coil M.W.O. you will have the basic unit. You can experiment and try all types of coils and spirals, as I said in Part I, it is only limited by your imagination. I find it fun and interesting to try unusual and weird coils, it's not expensive and you only have to remove a couple of screws, no big deal.

I have been thinking of building a cheap copy of Lakhovsky's coil of tube and wire, also a foil coil of equal size, to test if the coils when vibrated emit equal energies etc., and what the differences would be. It may answer the question why some of the foil coils don't seem to produce the results as good as some would like. In Lakhovsky's book there are pictures of, and he speaks of, the oscillator coils of Hertz. There is a striking resemblance of Lakhovsky's coils on his oscillator antenna to Hertz's coil. Could he have been influenced by or borrowed the Hertz oscillator coil for his unit -- did he expand upon the base of Hertz's work for his antenna coil? (interesting thought)

Enough digression -- back to our spiral coil building project. If you look at drawing #3 you will see that it is self descriptive, giving diameters, lengths etc. We make most all of our unit out of schedule 40 PVC plastic pipe. Take enough care to make your cuts square and clean, debur the ends of the tubes so they will slide into the glued slip fittings correctly. Now, here comes the stinky part. If you want your unit to look nice, you will have to clean the tube, (after cutting), taking off all the dirt, the ink lettering etc. I use a laundry tub, a small amount of water, laundry detergent, Comet, and some wet or dry #200 sandpaper and a lot of elbow grease.

Warning: PVC glue sets fast, in a matter of seconds. I put glue on the female fittings only -- none on the male side, slide it together firmly and whack it with a short piece of 2 x 4. Glue part #7 to part #8 and drill a 5/16 hole through fitting -- this is so you can tighten or remove the threaded fitting by inserting a phillips screw driver or rod in the hole. This makes your unit portable.

Glue pieces 1-1-5-4-4, also 3-3-5-4-4.

Now glue part 2 to part 6, also part 3 to part 6.

Thread assembly 7-8 (large vertical tube) into assemble 2-6-3.

We will slide assembly 11-5-44 onto tube #2, but we will not glue it. Place this on a flat table, and adjust tube 8 so it is vertical.

When you get it where you like it, glue assembly 33-5-44 to loose tube 3, let this dry for 20 minutes.

Now remove assembly 11-5-44, apply glue to fitting #5 and glue it to tube #2 on your flat table. You now have the base finished.

Glue the rest of the tubes and fittings together on your table. NOTE: Do not glue parts #19 and #20, we leave these loose and just set them in place, as we may add something additional here later.

NOTE: Before you glue tubes #11 and #15, cut some one inch diameter .050 aluminum tube full length of tubes and slide them inside of plastic tubes, this eliminates sag. Drill a 1/8 inch hole through plastic tube and aluminum tube, screw a #8 sheet metal screw through both tubes. Tube #11 has holes in it so we can adjust the height, drill these 2 inches apart, 5/16 inch holes. We insert a 1/4 inch wood dowel through fitting #10 and through tube #11.

We drill 2 holes in tube #21 and thread them 10-24, we fasten our spiral coils and antenna to these. The first hole is drilled 5/16 of an inch up from the bottom edge of the tube and the second hole is drilled 3/4 of an inch from the first hole.

When you buy your 1-1/2 PVC tube, get a piece with a flared end, as we set a reducer fitting in it to make a sleeve for the #11 one inch tube. To keep tube #11 guided at the bottom of tube #8, drill 3 holes at the bottom of tube #11 equally spaced around the diameter and insert 3 #8 sheet metal screws.

Parts #9 and #10 will have to be filed out or machined out so the one inch tube will slide through them.

Part #16, the vibrator base, is made of flat stock PVC. If you cannot buy it from a plastic supply house, cut a couple pieces of 1-1/2 PVC tube about 3-1/2 inches long, cut them again length wise, so you have half tube pieces. Place the half tube pieces between two - 1/8 inch aluminum plates and heat in a stove oven with a brick or weight on top. Let them cool and the plastic will come out flat. Layout and mark parts on flat sheet and cut out.

Glue all the pieces of vibrator base together and fit to tube #15 and glue it tight. A wood match works wood to lay glue in joints.

Make and fit your metal brace from aluminum or non-corrosive metal and fasted with two - #8 sheet metal screws. Cut out part #23, fit it to T - #22, drill two holes for banana receptacles and glue securely, also cord holder #14.

Make your small spiral coil from .0625 low carbon stainless steel heli-arc welding rod -- 36 inches long, do not twist wire, use as is. You can get this from any welding supply; get 4 or 5 pieces. Also make antenna from same wire. To make small spiral use the full length or rod. Start by forming an eye on one end for the 10-24 screw. Move down 3 1/4 inches and form spiral same as large spiral coil, also bending end tip in. Put an offset kink in the stem so it will pass through the main coil.

The tube coils are made from #19 shellac insulated coil wire, 12 to 14 turns. I tight bend a 90 degree bend, so I have a 1 inch long tail. I place this parallel on a pencil or wood dowel and tight wind the coil. Grip the wire tail and dowel with a pair of pliers. Remove the dowel and freeze for 30 minutes, warm to room temperature. Grip the ends of the coil with your thumb and middle finger nails and stretch the coil to the desired length, refreeze for 30 minutes. Bend long tail of coil 90 degrees and fit to banana plug. Trim short end to 3/4 inch, clean and solder pinch clip to coil. The pinch clip is made from light gauge hard stainless or brass. Blank size is 7/32 x 1-1/4.

After you have everything glued and finished put a coat of auto polish on PVC tubes, as this keeps them clean and they will not finger mark or get dirty. Also put a coat of vaseline on the threaded fittings so they can be removed easily as they tend to stick.

If you are, or want to be, the serious experimenter type, buy a note book and keep records and notes. Keeping a log with dates, exposure times, etc. can be a very useful tool to compare results of different coils etc. I would welcome hearing from you on the use of the spiral coil M.W.O., i.e. your success and problems. NOTE: Don't expect results in 2 or 3 exposures, as this unit is more gentle and may require a longer time of weeks or several months to get permanent results. To this date I have not had a single report from anyone for over-exposure if used with common discretion. I have used belts, collars, wire loops etc. with the M.W.O., this seems to multiply the energy. I also have used a spin magnetic unit with a reticular energy filter before and after M.W.O. exposure. This seems to work well for joint problems.

Please Note: Lou Schad does not manufacture or sell this MWO. He is giving his knowledge and experience as a gift to the world. He may be written c/- BSRF.

LEGEND

USE P.V.C. (WHITE) SCHEDULE 40

KEY

L=LENGTH D=DIAMETER C=CUT
T=TUBE T.F.=THREADED FITTING

PART #	DESCRIPTION (in inches)
1.	T-D=1-1/2, CL=10
2.	T-D=1-1/2, CL=15-1/2
3.	T-D=1-1/2, CL=8-1/4
4.	CAP-D=1-1/2 (4)
5.	TEE-D=1-1/2 (2)
6.	TEE-D=1-1/2 THD'D
7.	NIPPLE-D=1-1/2 THD'D
8.	T-D=1-1/2, CL=28-1/2
9.	REDUCER - D=1-1/2 TO 1
10.	REDUCER - D=1-1/2 TO 1 INV.
11.	T-D=1, CL=28-1/2
12.	T.F.-D=1 NIPPLE
13.	ELBOW - D=1 - T.F.
14.	CORD HOLDER (ELEC.)
15.	T-D=1, CL=20-1/2
16.	VIBRATOR BASE
17.	METAL BRACE
18.	TEE-D=1
19.	T-D=1, CL=3-1/4
20.	CAP - D=1
21.	T-D=1, CL=5-1/2
22.	ANTENNA
23.	F.T.G. BANANA RECP.

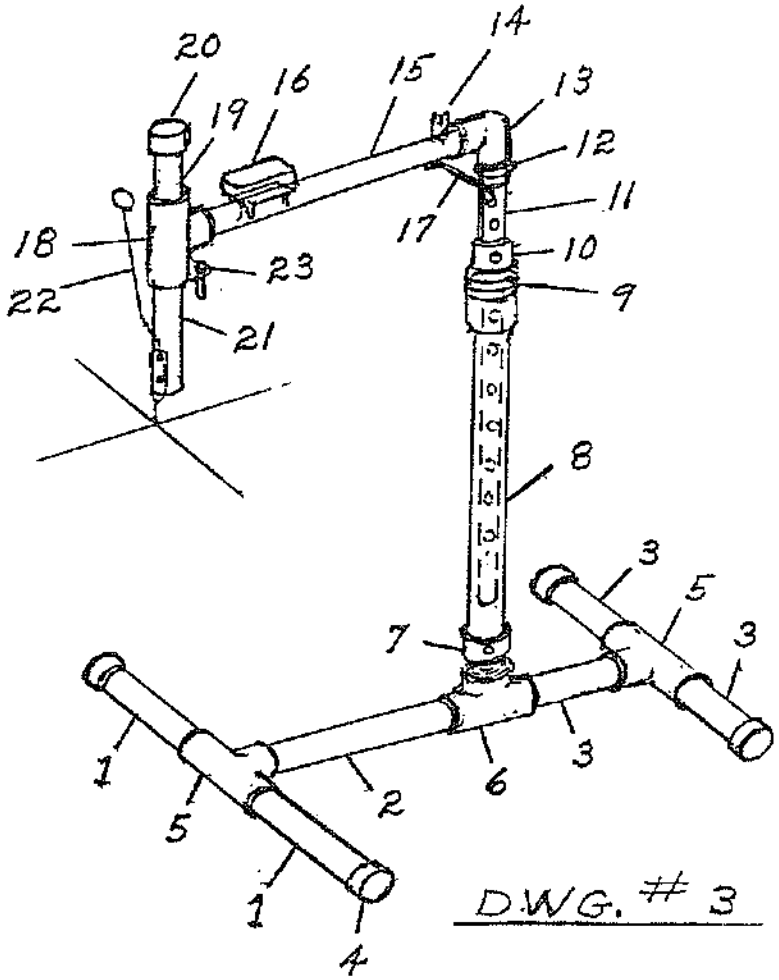

DWG. # 3

COIL SHOCKER FOR SCHAD SPIRAL COIL M.W.O.

This unit provides a D.C. shock to the spiral coil. It should be built in a wood box, or grounded metal box for safety sake as we use 115V A.C. power source. All the parts can be purchased from an electrical supply, except auto bulb and socket. Get these from an auto parts supply house.

The Leviton dimmer is not necessary, but it gives more control. I use a ceramic base for 40 watt bulb. A smaller transformer can be used, but I find the 3A-12V best. It is nice to add a handle to the box. I dropped mine once. Put ventilation holes in the box, and rubber bumper feet on the bottom.

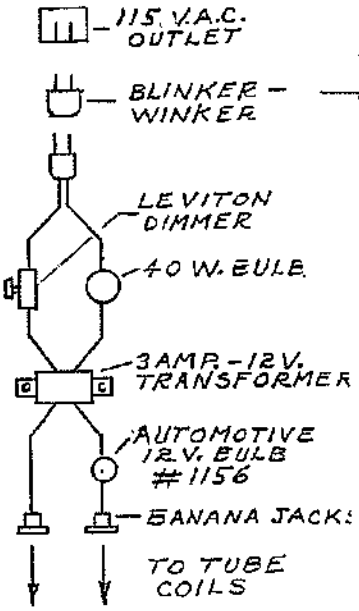

POOR MANS COIL SHOCKER

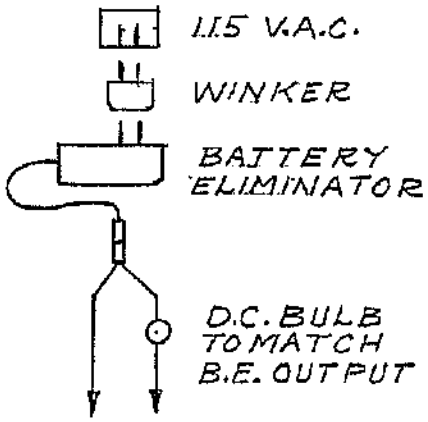

DWG. # 4

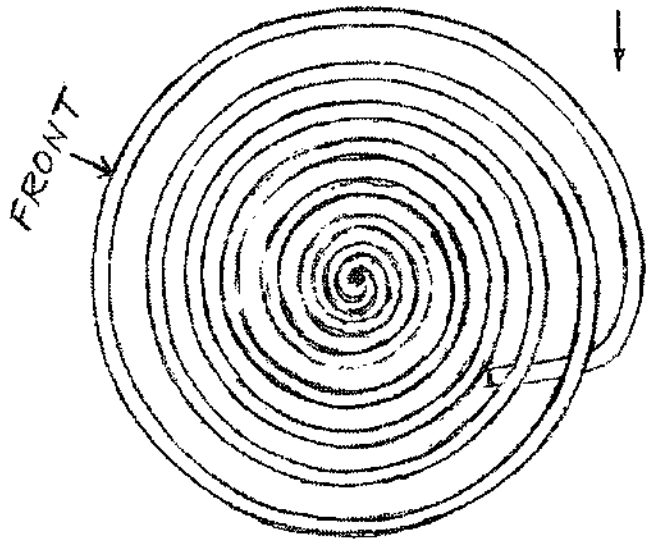

TRACING OF SMALL SPIRAL

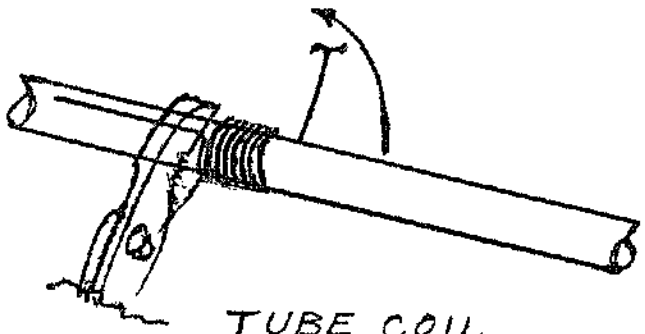

TUBE COIL
#19 COIL WIRE 2 REQ.

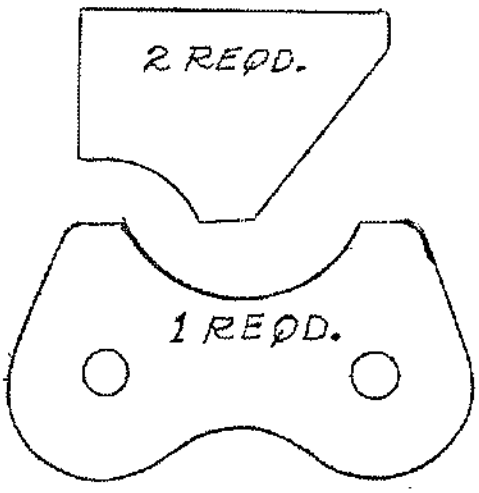

DWG. # 5

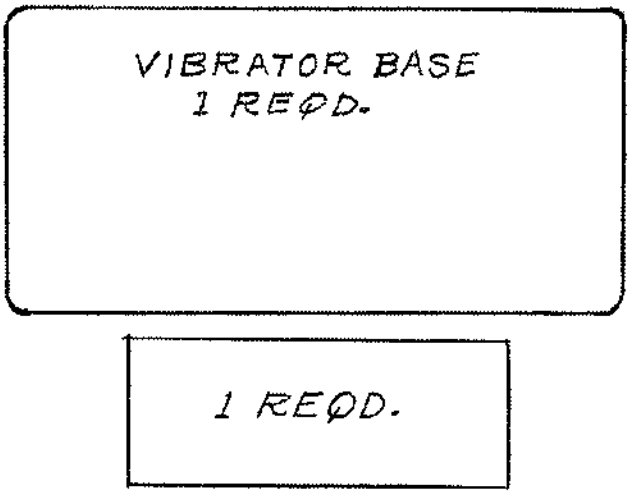

SPIRAL COIL M.W.O. UPDATE

Lou Schad

This is an update on the work I have done on the spiral coil MWO. I have built and tested several new coils and made changes in design of shapes and twist of the wire and different size of wires etc. I have experimented on plants and myself for the past several months.

In my article in the Journal of Borderland Research of March-April 1991, page 15, figure 1, I stated, to twist the wire counter clockwise, as I was told by someone of authority that this was best. I now find after experimenting and testing that this is not so. I now twist the wire clockwise, causing a left hand spin of the wire when viewed -- or counter clockwise. If the wire is twisted in this manner it more than doubles the energy and the plants and I both seem to like it better. If the wire is twisted as stated itwill produce energy not only in a spiral shape but also in single loop rings (overlapped) and also in just a straight length of twisted wire.

I made a coil like a target or a series of one loop rings of twisted wire of different diameters and wire sizes, from about 1 inch to 8 inch and overlapped them about ¾ inch and wired them to a X shaped piece of thin plywood, and it produces more energy than I need. I can stay under it only about 7 to 10 minutes. If I stay under it longer than this, I get over exposure or too much energy in my body, and it makes my feet and hands tingle.

I made a spiral coil from 1/8 inch copper tubing, twisting it like a solid wire, and it produces more energy than a like spiral made from solid wire. I do not know if the energy travels on the inside of the tube and the outside also, but the energy produced is much more than is required for normal use.

I also have been experimenting with new and different ways to pump or project the energy. In my original design I used a vibrator to increase the output. I now find that with the new coils (twisted as stated) that they develop as much or more energy without the vibrator as the old coils did with the vibrator. It seems that the field or energy pattern given off by a straight (twisted) wire is different than those of a single loop (twisted wire) shape or spiral shape.

I am building a new coil that uses both and looks like a spider with 8 legs of different length. It has 2 single loops (overlapped). One loop is 2-3/8 in diameter and the other is 4-1/8 in diameter. The small loop is centered in the large loop and in the same plane. I made a wood jig with nails for pins to hold them in place and soldered twisted straight lengths of wire pointing from the center outward. I will bend the tips of the straight twisted wires down 90° producing a shape like a spider. I'll let you know if it is different from the spiral coil shape in energy output.

It now becomes obvious that a spiral is not the only configuration that will generate or collect and broadcast energy of unknown origin. If other shapes or designs will also produce energy, is their output different? If so, what are the differences? Are the wave lengths different, are there different patterns to the waves or energy? How does it affect the living organism?

When a spiral or coil is placed in front of a reticular energy field it produces unusual results. Coils can be combined with many other forms of energy, magnetics, light, audio, vibration etc.

In my article I said you can design and build coils of all shapes and types, as it is only limited by your imagination. It is my personal belief that someday someone will design and develop a coil of a nature that will be highly beneficial to humanity, we need your input, ideas and help.

If a coil of twisted wire was built in a target configuration of a series of overlapping loops so as to be similar in design to a Lakhovsky coil, and was powered by a Beck MWO output, what would be the results? If a twisted wire coil will produce and project energy, connecting it to the field of a Beck type unit should be interesting. Are there any takers?

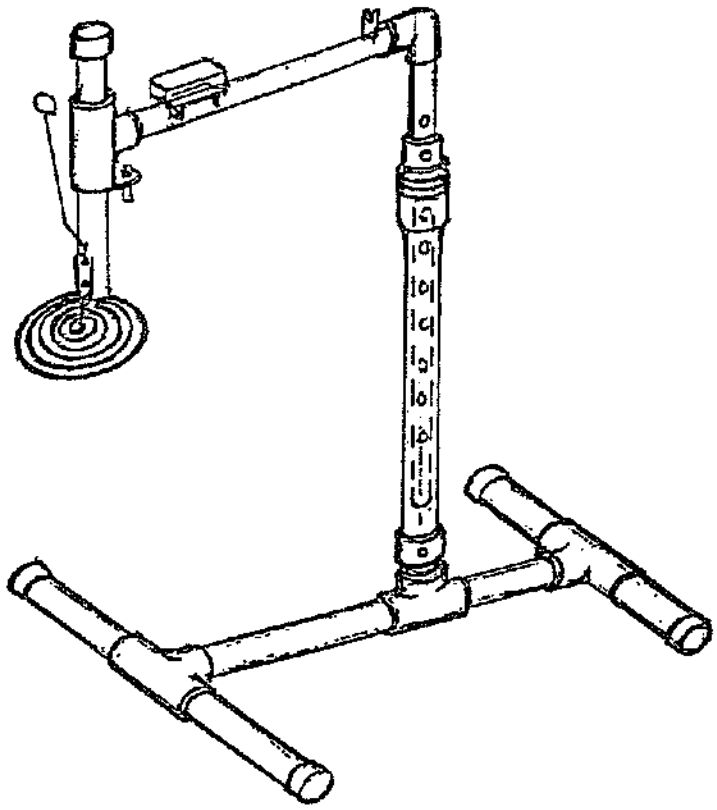

SPIRAL COIL MULTIPLE WAVE OSCILLATOR

ELECTROSTATIC M.W.O.

Introduction to a New Phase of Research

by Peter A. Lindemann

Lakhovsky's multiple wave oscillator has always intrigued me. I tried to build my first one in 1976 based on Bob Beck's schematics. These early experiments failed miserably, but I remained interested. In 1987, I had the opportunity to see one of Bob Beck's MWOs at a meeting of the Los Angeles Psychotronics Association. I am a healer and a sensitive by nature, and I was looking forward to finally seeing the mythical machine in action. Bob had said that is was a very high power model and he was right about that.

The unit was of the design that has been popular since the 60s; a high voltage spark-gap transmitter driving an antenna of concentric rings. Bob turned it on and ran it for about three minutes. It made a loud zapping noise as hundred of sparks jumped from ring to ring on the antenna.

I was standing in the back of the room, about 30 feet from Bob's MWO. As soon as he turned it on I felt a blast of irritation hit my aura. I could handle the etheric frying of my energy field for only about thirty seconds before I had to leave the room. When I came back in, everyone's energy had been fried. The meeting quickly digressed into a break, with everyone talking to their neighbor. It was quite a sensation!

In thirty seconds I had become convinced of two things. First, this MWO was extremely damaging to the subtle energy field and therefore must be incapable of promoting systemic healing. And second, this MWO must be unrelated to what Georges Lakhovsky was reporting in his book Secret of Life.

Since I drew those conclusions back in 1987, I have been confronted with numerous testimonials of people gaining benefit from this style of MWO. While I do not doubt the accuracy of these stories, I must admit, I do not understand by what process the benefit is derived.

Here is where the MWO languished in my mind until Lou Schad's articles appeared in the March/April and May/June 1991 issues of this journal. Intuitively I felt Lou was on to something very important. On a visit to Borderland Headquarters, I had a chance to evaluate a unit Lou had given to Tom. The energy coming from the antenna was gentle but very penetrating. I was excited. I went home with the intention of building one of Lou's units to experiment with.

After considering Lou's design carefully, I decided to make a few changes and by late May 1991 I had my first unit. As it turned out, my unit did not look at all like Lou's, but it did embody the fundamental principles that he innovated. These included a spiral main antenna that was charged with static electricity and physically vibrated. Lou's antenna was complicated to build. I decided to use an antenna design that I had been developing uses for for three years, a spiral based on the phi ratio that I could have printed right onto a circuit board. That solved the problem of antenna fabrication. Another thing I changed was the method to induce the physical vibrations. Lou had used an aquarium pump. It worked well but was limited to only one rate of vibration. I decided that the rate of vibration might be important to look at so my unit was made with a variable rate of vibration from 2½ vibrations per second up to about 14 vibrations per second. The last change I made was the vertical antenna. Not knowing the height I needed for the optimum effect, I simply used a retractable replacement antenna from Radio Shack, the kind you usually see on portable radios. This gave me a way to vary the electrostatic charge on the spiral, by raising or lowering the antenna.

By early June 1991 I had made an arrangement with a local acupuncturist in town to run some clinical trials with the unit. This medical professional has asked to remain anonymous and so for the purposes of this article, I will refer to this person as "John". John is a gifted sensitive and an advanced bio-energetic diagnostician using equipment from Germany called the VegaTest. John also has had assistance in this evaluation by another gifted sensitive who can see auras in vivid color and detail. I will refer to this second person as "Pam". As of this writing in early November, their evaluation has been on-going for 4½ months or since mid-June. The results are preliminary. No cures are claimed. However, all indications point to systemic detoxification, energizing and rejuvenation, just what you would expect to see from a broadly stimulated natural healing process.

The VegaTest procedure is very sophisticated. It uses a bio-feedback mechanism to establish baselines for toxicity level, systemic stress and specific organ stress as well as the presence and location of specific pathogens and types of toxic substances. Toxicity level is measured on a scale of 0 to 21, where 21 is the most toxic. A "Biological Score" is developed from the toxicity values that come up and can have from 1 to 6 numbers ranging from 1 to 21, 6 numbers being the most toxic. An "Ideal Score" is determined on a scale from 1 to 15 where normal for adults on first testing range from 7 to 11. Stress on the immune system and endocrine system is measured on a scale from 0 to 5.

CASE A is a 21-year old female who has never been treated with other remedies. The patient was VegaTested, then received one 20 minute session with the MWO and then was retested. (See box insert) These scores suggest that even one session can temporarily reduce stress levels significantly and promote detoxification.

SCORES BEFORE SESSION	SCORES AFTER SESSION
Ideal Score: 8	Ideal Score: 6
Biological Score: 19-16-14-12-9	Biological Score: 12-10-8
5 scores with high numbers is considered very toxic.	Immune System Stress: 1
Immune System Stress: 3	Endocrine System Stress: 0
Endocrine System Stress: 5	

CASE B is a 72-year old male with extreme intraocular pressure. The patient received only three sessions with the MWO. The pressure within the eyes lessened with each session. Pam reported that before the MWO sessions, the region of the eyes and head was completely dark and devoid of life force. After the first session, the darkness cleared about 40%. With the second session, the darkness cleared about 80% and with the third session, the energy around the eyes was completely vibrant.

Without going into a lot of specific case histories, or naming disease conditions treated, John and Pam are consistently seeing the following:

1. The MWO expands the energy field around the body 3 to 6 feet.
2. It functions to reduce accumulated stress on many levels.
3. It clears the energetic imprints of illnesses.
4. It fills in breaks and cracks in the aura.
5. It builds vitality at a very deep level and combats fatigue.
6. It promotes the drainage of stale and stagnant life energy down the arms and legs and out the hands and feet. Several times

Pam has seen dark yellow or dark green energy drain out of acupuncture points or organs, to be replaced by cleaner and clearer colors.

7. Everyone experienced improvement, regardless of their condition.

METHOD OF USE FOR THE MWO, (developed by John and Pam during this testing period) is as follows:

1. A person using the MWO should sit in a comfortable chair with their feet flat on the floor and their hands apart, laying on their thighs, palms up is best. The chair should be about 6 feet from the MWO. During the session they should periodically rotate their wrists and ankles to help promote the draining.
2. The MWO should be started at slow vibration rates (2-3) and slowly moved to higher vibration rates (5-9) and then at the end, moved to slower ones again. Sessions can be from 10 to 25 minutes.
3. After the MWO is turned off, the person should remain seated for 10-15 minutes to continue to drain while the energy field slowly shrinks back from its highly expanded state.
4. Rooms where the MWO is used may need to be cleared after its use due to the stale energies that drain out. Sun light, fresh air, toning, sage or other means may need to be employed to keep the MWO session room clear.

THE BSRF MWO PROJECT continues to develop, as this and other articles in this issue clearly show. A special thanks to Lou Schad for his brilliant and original departure from the errors of the past and showing us the true Borderland spirit in action.

One final note. We at Borderland are constantly railing against people who invoke the name of some famous researcher, like Rife, Tesla or Lakhovsky, and then sell the public a piece of equipment unrelated to the original work. This is no better than bait-and-switch hucksterism and we deplore it. Therefore, let us state for the record from the outset, that this new Electrostatic MWO is not what Georges Lakhovsky was doing. Neither is it a direct attempt to duplicate his work. Lakhovsky claimed to have had his units in use around the world, but after years of research we have found no physical evidence of this. He never published detailed schematics of any complete devices. This new MWO is a modern attempt to address the same problems that Lakhovsky was grappling with. We call it a multiple wave oscillator because it is, clearly, a device that produces a wide spectrum of oscillatory emissions simultaneously. Lakhovsky pioneered this line of research. This unit is not a "Lakhovsky MWO" but, strictly speaking, no other unit sold in the last 30 years has been either.

As this MWO is part of an ongoing research project, a limited number of these units will be produced and made available to the public.

The new BSRF Electrostatic MWO is for investigational purposes only. It is <u>not</u> a substitute for professional medical care and is <u>not</u> indicated as a specific cure for any disease condition. Any such use goes directly against the intent of the manufacturer. The performance characteristics of this device have not been established.

MULTIPLE WAVE OSCILLATOR

Borderland Sciences Research Foundation is proud to announce that their new Electrostatic Multiple Wave Oscillator is now available for investigational purposes.

TOTALLY NEW APPROACH

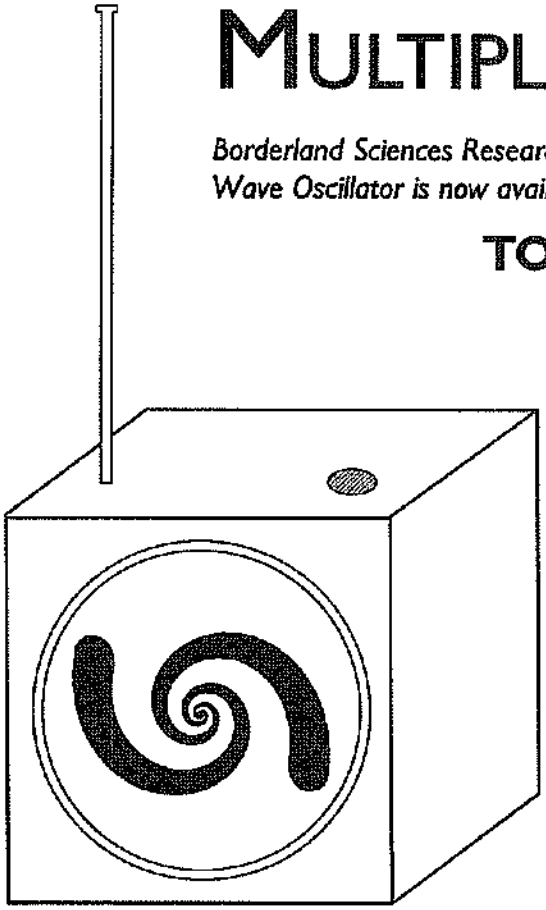

This unique Multiple Wave Oscillator uses a specially designed spiral coil that is both physically vibrated and simultaneously charged with a safe quantity of static potential, unlike designs using high voltage discharges between concentric rings. The result is a wide-spectrum wavefront of electromagnetic and etheric vibrations. It also provides a means to introduce a wide variety of other subtle influences into the broadcast much like a substance biocircuit. The Electrostatic MWO from Borderland Sciences is a versatile investigational tool.

The MWO has a wide range of vibratory rates and charge intensities. It is a one square foot cube with a Golden Mean Spiral MWO antenna on the front and a retractable antenna on the top for tuning. Powered with standard AC. Constructed using no toxic materials.

ELECTROSTATIC MWO

The Electrostatic MWO is a high quality device produced in limited quantity for our research network. Interested researchers may inquire with BSRF as to current availability of units.

SUN-ETHER DISC

By Albert Zock

The German inventor Oscar Korschelt based his cosmic ether accumulator, German Patent #69340, dated July 14, 1891, on the teaching of Wilhelm Weber not realizing that it incorporated the implosion principle as well. Weber professed that all particles of the ether, having an electrical charge, are circling around solid objects without touching them, the molecular particles being negative and the ether particles being positive, according to the law of attraction and repulsion. Since a solid body attracts ether particles, Korschelt searched for a way to collect, condense and to rectify them.

On a wooden disc with a hole in its center, Korschelt fastened spirals of copper wire, on both sides, one wound clockwise and the other, as a mirror image, counter clockwise, and connected the ends together through the hole in the center. His assumption was that the collected energy would be condensed in the center and then be beamed off at a right angle to the disc. He termed the side facing the light positive and the other negative. To increase the condensation and lengthen the antenna, Korschelt wound small coils like key rings and assembled them like links in a chain. He was convinced this device would give additional life energy if the beam was directed at the neck of a person in the height where the 18 cranial nerves are leaving the skull, (medulla oblongata). Such a spiral resembles a Nornen coil, which is stretched out and is used to eliminate undesirable emanations.

An application of a Korschelt coil seems to have its merits. In one case a relative of an elderly man suffering an acute pneumonia, being already unconscious and according to his physician, beyond hope, hung a Sun-Ether Disc over his bed. From this moment, his condition improved rapidly. Fourteen days later, he was almost normal again. In another case, a Sun-Ether Disc hangs over the door in the waiting room of a Naturopath. Every one walking in is amazed over its warmth, and the flowers are flourishing like in a green house, even though it is not heated and faces north. When asked for the reason, the owner points smilingly to the disc and gladly explains how it works and how to build one.

On a plywood disc with a diameter of 50 cm (20-3/4 in.) are two coils, one on each side, wound in a mirror image, the front one counter-clockwise and the other clockwise, almost on top of each other. Both are connected through the hole in the center which has a diameter of 10 mm (6/8 in.). The space between each winding is 15 mm (5/8 in.). Aluminum wire is best. To make the key rings, take a 4 mm (3/16 in.) thick wire, fasten it into an electric drill and wind the armature wire around it tightly, by allowing the rotating wire in the drill to do the spinning. Make sure to wind the links for the front counter-clockwise and for the back clockwise. Then separate every fourth winding and cut it to get the links shaped like key rings. Now attach the rings onto one another like a chain. Each link will lengthen the antenna and work like an oscillator. Fasten the chain onto the board, using nails or screws, but to be accurate, give the chain a light tension so it will not slip off. Twist the ends in the hole together, or better, solder them. The counter-clockwise winding for the front applies to people living in the northern hemisphere; in the southern hemisphere it might need to be reversed.

In Korschelt's time, some made "beam-handbags" carried on a shoulder strap. The material had to be framed to it could not move, then the spiral was embroidered and fasted to the inside of the bag, the whole bag measuring about 20 x 20 cm (8 x 8 in.) and the windings being 1 cm (3/8 in.) apart. Such bags were more powerful than the disc.

From Mar-Apr 1988 Journal of Borderland Research

ETHER RADIATING APPARATUS

An Apparatus For Therapeutic Use Without Direct Or Indirect Suggestion

Oscar Korschelt of Leipzig. German Patent #69340, July 14, 1891
Translated from the German by Bodo Capeller, 1986

This apparatus utilizes the living forces of the ethers for healing purposes. The electro dynamic theory of Wilhelm Weber concerning the structure of smallest parts results in the insight that all ether is identical with Webers electric particles, that all solids rotate around it at a certain distance because of attraction of positive to negative ether particles in relation to solids. Through a corresponding arrangement of solids it ought to be possible to condense the diffuse ether and redirect it. A similar arrangement has been utilized in the following described apparatus which has been named by the inventor "Ether Radiating Apparatus".

This apparatus can be used for the purpose of increasing the intensity of the power of living ether. The difference between several versions of this apparatus is that of shape of materials used. In order to get increased power electric current may be used. Since the same appears to consist of positive and negative particles that try to find equilibrium, the amount of liberated ether particles within the wiring of the apparatus and the diameter of the wire formed ether vortex will increase with the spun off ether particles.

In drawings 1 through 5 an ether radiating device is shown. Within the apparatus the arrangement of the metal wiring is formed in a spiral that will cause ether particles to spin in a predetermined direction so that the living force can be utilized in many ways.

The version in drawing #3 shows the wire is formed in spiral configuration on both sides of plate E and is connected in the center. Through this arrangement the ether particles will accumulate in the center of the disk and be thrown forward. In order to achieve a longer path for the ether vortex one may utilize a chain instead of a simple wire which consists of horizontal displaced links (drawing #5). The disk is intended to cause physiological changes in humans (see drawing #1).

Patent request: An apparatus for therapeutic purposes with direct or indirect suggestion consisting of a non conductive disk (E), free standing or installed in a tube, where both sides of the disk contain spiral wound wire with the side toward the light exposed as the collector and the opposite the radiating portion.

Fig. 1

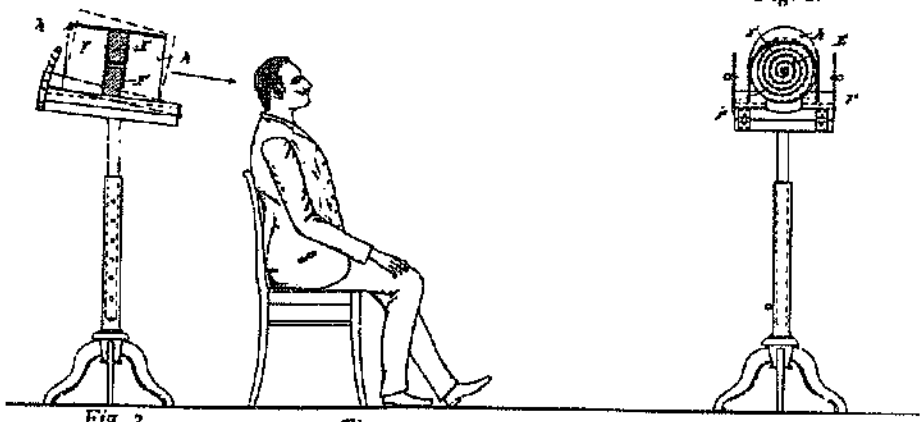

Fig. 2.

Fig. 3.

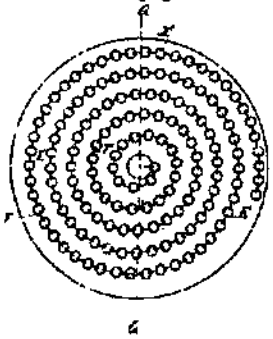

Fig. 4.

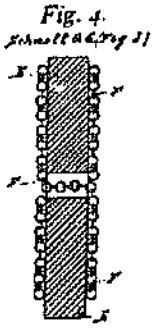

Fig. 5.

Fig. 6.

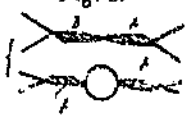

March-April 1988 JBR.
VIEW FROM THE BORDERLANDS
by Tom Brown

NATURAL ELECTRICITY

Ernst Lehrs, writing in **MAN OR MATTER** about early views by Volta and Galvani on electric fish, provides insight into the nature of animal electricity. "The electric organ of such a fish consists of many thousands of little piles, each made up of a very great number of plates of two different kinds, arranged in alternating layers. The two kinds differ in substance: in one case the plate is made from a material similar to that present in the nervous system of animals: in the other the resemblance is to a substance present in the muscular system, though only when the muscles are in a state of decay. In this way the two opposing systems of the animal body seem to be brought here into direct contact, repeated many thousands of times.

"In the electric fishes, accordingly, sensation and will are brought into a peculiar interrelation. For as a result of the spatial fixation and the state of deterioration of its bodily foundation the animal's will-pole is related to its bodily foundation in a manner which otherwise obtains only between the nervous system and the psychological processes co-ordinated with it. These fishes have the capacity to send out force-currents which produce in other animals and in man 'concussion of the limbs', or in extreme cases paralysis and even death. When contemplated with pure observation this phenomenon tells us that in cases of minor strength, this force causes processes of a volitional character in bodies affected by it. Through stronger effects the organic system which serves the will of the creature involved passes into disuse, either for a time or for good. By describing the process in this way we realize that electricity appears here as metamorphosed animal will, which takes this peculiar form because part of the animals' volitional system is assimilated to its sensory system in an exceptional manner.

"It is known today that what nature reveals so strikingly in the case of the electric fish is nothing but the manifestation of a principle at work in the bodies of all beings endowed with sensation and volition -- in corporeal terms, with the duality of a nervous and a muscular system -- and therefore at work also in the human body. Observation has shown that the activities of these two systems in man and animal are accompanied by the occurrence of different electric potential in different parts of the body. Manifold in detail though the relevant observations are, they all confirm a definite correlation of negative electricity with the nerve-and-sense pole (sensation) and of positive electricity with the blood-and-muscle pole (volition)." From **MAN OR MATTER**, © 1958 Ernst Lehrs, Rudolf Steiner Press, London.

Thus we see that natural electricity is formed by processes which can be mirrored in non-living matter. But if we can have access to the primary form of the energy why pursue the secondary, and seek out that "magic frequency" that will cure AIDS, cancer, and assorted body clogs that go under fancy medical names? The answer is that everyone has their individual path to travel. Spiritual healing sometimes takes a long time, while an electronic device may get the person back on the track of their day-to-day life. The spiritual lesson of the sickness is buried for the future. Electricity is the subsensible force, but it is a real force with the ability to alter the functioning of the human body.

November-December 1989 JBR.
VIEW FROM THE BORDERLANDS
by Tom Brown

MWO NOTES

The work of Georges Lakhovsky continues to be of strong interest. I have been investigating the Lakhovsky MWO for about four years now and my views have consistently changed with new information. BSRF's MWO Handbook is getting quite popular! However, my views have changed somewhat since doing that book, and eventually a new edition will have to be put out to keep up with the new data.

What was Lakhovsky really up to? Well, his basic experiments were with copper wires which were circled around plants. Lakhovsky felt that these rings were activated by cosmic radiation. Lakhovsky was extremely interested in subtle energies, such as those that guided birds on their migrations. The copper rings, when placed around plants, would heal cancers in the plants. THE SECRET OF LIFE, Lakhovsky's best known book in English shows pictures of these experiments. Lakhovsky then moved to bring these healing energies to humans.

Lakhovsky also intuited the DNA spiral coil in the center of every cell long before anyone "discovered" it. He felt that a properly generated multiple wave electrical field would make the coil in each cell resonate at its proper frequency, just as a tuning fork resonates when its frequency is struck on a nearby similar fork.

Today's conceptions of a Multiple Wave Oscillator (MWO) are quite different from what Lakhovsky was really doing. Lakhovsky tried to reproduce the healing energies of the cosmos by electrically energizing coils to produce energy fields which apparently regenerated aberrant cells along the lines of his theories. Lakhovsky first did this by producing an antenna, comprised of concentric copper tubes, the outer one being energized with two wires from his power source. Our impression of his antennas is that they were log periodic, that is logarithmic in nature (Lakhovsky doesn't come right out and say this, but his patents are definitely worded to cover such an arrangement). New data coming in (but not yet verified) tells us that these copper tubes were filled with one or more of the noble gasses (also called rare, or inert gasses).

As anyone could guess, these antennas would be somewhat hard to manufacture. Lakhovsky then miniaturized the antenna and inserted it in a gas bulb. His US patent #2,351,055 says vacuum bulb, but also covers low pressure gasses. There are two main keys here. One is the log periodic antenna. All higher forms of life are based on logarithmic patterns, from ferns to humans. Lakhovsky was creating a structure in the ether which would bring cells into proper functioning. The other is the vacuum / low pressure gas effect. For those who wish to understand the potent effect of the vacuum on life then the reading of The Nature Of Substance by Rudolf Hauschka is required. According to Walter Russell the noble gasses are the octave markers in the harmonic spiral of the elements, which also exists in a logarithmic pattern.

I recently visited with Dr. Norman McVea of Stinson Beach, California. Norman has several high frequency gas tubes built trying to understand what Lakhovsky and Royal R. Rife were up to. Norman has a MWO built of 12 glass concentric rings with various noble gasses inserted in them. When we checked it out it was running at 60 cycles, pulsed at 7.8 cycles. My recommendation to Norman was to run the unit with a radio-frequency oscillator which can be tuned from 1 to 30 megacycles, and modulated with a variety of sources for research. Norman has produced the most unique MWO I've seen in our modern times, and he is certainly on the right track. He is also working to reproduce Rife's high-frequency gas bulbs.

The key to Royal R. Rife's frequency instrument is also the use of the noble gasses energized at high frequency (possibly 4.5 megacycles), which were then modulated with specific musical tones. Lakhovsky's units were energized similarly, but used the

frequency-independent log periodic antennas, giving a broad band of treatment, rather than the specifics of Rife's units. In many ways these two pioneers were working with the same keys.

WHO DUNNIT?

Rife and Lakhovsky have another similarity, that is, that people today are building equipment obliquely related to their work and offering them as original, or "improvements." This needs serious examination. The last two years has brought on an underground cult of so called "Rife Frequency Generators." There are hordes of these so-called "Rife" units being sold which are merely fancy variations of TENS (Transcutaneous Electrical Nerve Stimulation) devices. The conception for these units, usually producing square audio waves, comes from John Crane who knew and worked with Rife in his later years. John has affidavits from people who swear that they were healed from cancers and such by his square wave units in the early 1960's. It is extremely important to note that Rife's work in the 1930's through the 1950's was with high frequency gas tubes and all his documentation covers those units. History is rapidly becoming blurred in the race to cash in on people's poor health.

Modern purveyors of the so-called "Rife" equipment are making several errors: The first is that they claim that Rife developed the use of the square wave generators with electrodes. That is incorrect, it was John Crane (which makes Crane a pioneer of TENS research!). The second is that they claim that Crane's equipment was junk and would never work. Maybe the equipment wasn't of the highest quality (we have an original unit in our collection!) but Crane does have a lot of signed affidavits, several of them in our files, claiming that the units worked on specific diseases. In general, people are being misled in order to sell them equipment they probably don't need. That is a bad reflection on the field of electrotherapeutic research.

Perhaps these modern "Rife" (TENS) units have some merit in killing certain types of pathogens. I've spoken with many people who were completely dissatisfied with their so-called "Rife" units, and I've spoken with two people who have claimed that they have killed infections such as foot rot and herpes. Maybe they do, but for all of the thousands of devices being put out where is the documentation? Where is the proof? I have seen Crane's affidavits of the early 1960's, but have seen no medical studies from anyone, not even basic notes!!! There is obviously a very important bit of work to do in researching the effects of pulsed DC on the human body. TENS units kill pain, that has been clinically documented. The claims of the so-called "Rife" units are just that -- claims, *and unsubstantiated to boot.* Until any substantial research work is done in this area I would recommend that people do not follow the mob hysteria which shrewd hucksters have instigated over Royal R. Rife's work.

Lakhovsky's story is similar. All the units being built today are based on Bob Beck's early 1960's interpretation of Lakhovsky's first patent (#1,962,565). After four years of looking at these devices and reading Lakhovsky's patents and books I've come to the conclusion that Bob was misled by the patent. From an electrical engineer's viewpoint Bob's units make sense. From the standpoint of understanding subtle energies within and surrounding the body the units are merely RF noise generators which have questionable effects on the body, and most likely interfere with natural energetic processes (chi flow, etc.). The Beck MWO is a variation of one of Tesla's electrotherapeutic devices, the variation being that Tesla went to great pains to make the antennas spark-proof, and Beck's antennas spark away. Lakhovsky's units didn't spark either!

What makes this more interesting is an article which appeared some months ago in the **Health Freedom News**, titled Who Dunnit? by Mike Brown. Mike gives a weak case for his view that Lakhovsky was inept, that his earlier units didn't work, and who needed Tesla to fix them up and make them work. Perhaps Mike didn't notice that Lakhovsky's SECRET OF LIFE, which he sells to promote his units (in the ad following the article), is based on the units he claims in the article didn't work! Mike refers readers to Tesla's article High Frequency Oscillators For Electro-Therapeutic And Other Purposes (**Lectures, Patents, Articles** by Nikola Tesla, Beograd, 1956), but fails to notice that Tesla's article contradicts what he is doing with his units. I wonder how that article got past the editors?

CORRECT DIRECTIONS

Lakhovsky was a brilliant scientist, highly regarded on the European continent. His name comes up in many books, most recently I found him referenced in Lilly Kolisko's **AGRICULTURE OF TOMORROW**. If he and Tesla met, I'm sure it was for more than to fix poorly engineered units. There are three types of units that I feel should be built for research into this area: One is Tesla's oscillator circuit. The higher quality Beck MWO units, such as those built by Klark Kent, can be converted fairly easily. Use the unit's power supply as is, but for antennas use insulated copper plates (or spheres, as Tesla preferred for maximum effect) coated with heavy dielectric material such as beeswax. Eliminate the sparking! A necessary design change for future units will be to change the ¼ wave coil to ½ wave.

The second is a reproduction of Lakhovsky's Tube MWO. It will take miniaturizing the Golden Ratio antennas that Eric Dollard designed for the MWO and inserting them into low-pressure rare gas bulbs, which will then be driven at high frequencies. It is my estimation that this is the best way to pursue Lakhovsky's high frequency researches. The mathematics for the antenna, along with further reference materials on log periodic antennas, are in The Lakhovsky MWO Handbook.

The third is a reproduction of Rife's original type of equipment being a rare gas bulb driven at high frequencies, modulated with musical tones. This will take RF broadcast equipment and a rare gas tube. No electrodes!

It is time that researchers in this area begin to go in the correct direction. Bob Beck made a noble effort in the early 1960's with his conception of the MWO, and gave people something to work with for 25 years. That phase is definitely over and a new one beginning.

The "Rife generator" craze should be stopped now before it takes people another 25 years to find they've been misled. Serious research into the effects of pulsed DC should be undertaken by those with the wherewithal.

And keep it uppermost in your mind that electricity is a sub-sensible force. In the borderland sciences one should look to the supersensible, such as Dr. Wilhelm Reich's orgone energy (which, by the way, reacts to electricity in such a way that makes it detrimental to the human body), and the human vital energy such as is utilized in Biocircuit research (as begun by L.E. Eeman).

January-February 1990 JBR,
VIEW FROM THE BORDERLANDS
by Tom Brown

THE WONDROUS ELECTRICAL FORCES

Electrical research is a primary area of borderland research. While the term "occult" puts many people off, it should be realized that electricity is an occult force whose effects we only see when equipment is properly engineered. Four to five hun-

dred years ago one would probably be burned at the stake if it would have been possible for them to demonstrate electrical devices.

Electricity is considered by some to be a degraded form of the Light Ether, that the etheric force gets bound up in matter in a way that it can be used. But being bound up in matter it provides mankind with the option of using it properly or improperly. Many articles on the detrimental effects of electric fields have been published, and more studies are no doubt underway on this important topic. There are also some records of electro-therapeutic devices that used this force for healing. Tesla envisioned a world-wide electrical power system and did the basic testing to show himself that it was viable, and needed but to be built. Tesla was a man of great intellect and was a reader of Goethe and other great minds. One would feel that he was in some way familiar with Goethe's *Farbenlehre* (color theory). The type of electricity being sent around our globe on wires is of a different, lower form that that of Tesla's transmission of electricity without wires. It is quite possible that Tesla's electricity was of a beneficial nature. Tesla did research into electro-therapeutics and was no doubt aware of both beneficial and detrimental effects. With the power system he envisioned on line we may not have ended up with the electrical problem we are just beginning to see the "tip of the iceberg" of.

This point needs clarification and elaboration beyond what most people now imagine. We periodically mention certain aspects of Dr. Lilly Kolisko's experiments with the crystallization of metallic salts rising *contra* gravity. These experiments were done to establish whether or not the planets had any direct connection to the metals as alchemical lore supposed.

The connections she investigated are Gold-Sun, Silver-Moon, Mercury-Mercury, Copper-Venus, Iron-Mars, Tin-Jupiter, Lead-Saturn. For example Dr. Kolisko would take a gold chloride solution (1%) and allow a portion of it in a laboratory dish to *climb* a segment of blotter paper. As it dried the fine details of crystalline form could be seen. After many experiments the characteristic form of each metal's salt could be comprehended. It was scientifically established that the actions of cosmic bodies would have direct effects upon the crystallizing actions in the lab. Gold chloride would not crystallize properly during several solar eclipses that Dr. Kolisko reported on (1927, 1947). A darkening effect was noticed on these slides.

Just recently I came across this in the recollections of Dr. Rudolf Hauschka, founder of Wala Pharmaceuticals: "In the course of researches into the delicate changes in matter which are revealed in the capillary-dynamic method, an alarming symptom came to the fore. At one of the Easter conferences of the Anthroposophical Doctors' Working Group in Comburg in 1964, Frau Kolisko, the past-master of the capillary-dynamic method, spoke on 'Gold and the Signs of the Times.' In earlier years she had demonstrated by means of the *Steigbild* (literally rising pictures, also known as chromatograms) the connections between the metals and the planets, and in particular the effect on gold of an eclipse of the sun. During an eclipse of the sun the gold *Steigbild* which normally glows with beautiful colors, shows a darkening and the emergence of grey formations. Frau Kolisko now showed a series of gold *Steigbild* produced in the last years almost hourly and at all times of the day and of the year. Without exception all of them showed the same sinister dark formations which had appeared earlier, in the first half of the century, only at the time of a sun eclipse. She closed her lecture with a question to the doctors, namely whether, considering the change now in gold, they could still be answerable for its use as a medicine. There was no doubt about it: since the middle of the century gold had become different – it was sick. Or, to express it differently, the connection between the spheres of the sun which stream down and the metal which they permeate is disturbed."

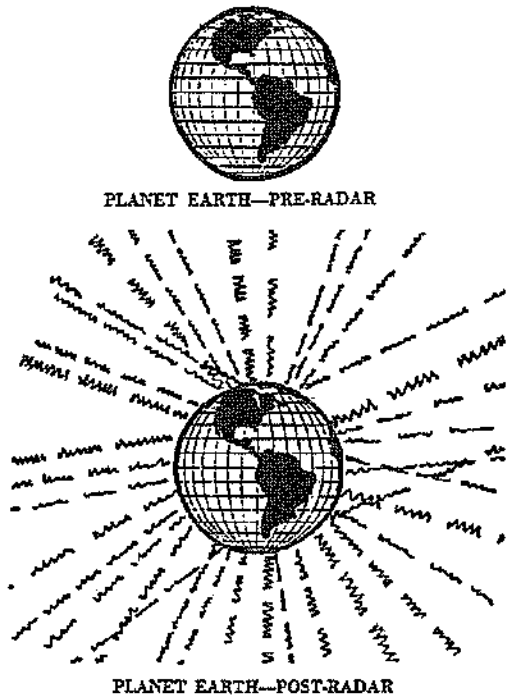

PLANET EARTH—PRE-RADAR

PLANET EARTH—POST-RADAR

Entire planetary environment permeated with pulsed electromagnetic radiation—an unprecedented condition.

ELECTRICITY: THE MAIN CULPRIT

The main culprit in this sickness of earthly matter is none other than the electrical environment that has manifested on this planet. Certainly there were radio communications going during Dr. Kolisko's early experiments, but as this chart from Trevor Constable's *COSMIC PULSE OF LIFE* shows, the post WWII environment was heavy with these signals, culminating in today's total saturation point. Imagine what the *Steigbild* would have shown in previous centuries before the electrical force began its manifestation.

Nuclear proliferation must also be considered as adding to this phenomenon, but electricity is the degraded form of the light ether, whose source the sun is related to gold. Walter Russell, in ATOMIC SUICIDE, indicates that the spread of nuclear energy will destroy the atmosphere surrounding this planet and now scientists are scratching their heads as the hole in the planetary ozone layer gets larger. (Of course chlorofluorocarbons and New Zealand sheep farts have all been blamed for the ozone depletion, but nuclear energy is a primary cause.) This atmospheric destruction could well aid in cutting off gold from its cosmic wellspring of life.

Rudolf Steiner had many insights into the true nature of electricity, its relationship to humanity and its role in our future. Pertinent to the matter at hand let us consider the following remarks, a portion of his answer to a question about electrical treatment of animal fodder:

"You must consider the whole part played by electricity in Nature ... to the effect that human beings cannot go on developing in the same way in an atmosphere permeated on all sides by electric currents

and radiations. It has an influence on the whole development of man. This is quite true; man's inner life will become different if these things are carried as far as is now intended. It makes a difference whether you simply supply a certain district with steam-engines or electrify the railway lines. Steam works more consciously, whereas electricity has an appallingly unconscious influence; people simply do not know where certain things are coming from. Without a doubt there is a trend of evolution in the following direction. Consider how electricity is now being used above the earth as radiant and as conducted electricity, to carry the news as quickly as possible from one place to another. This life of men in the midst of electricity, notably radiant electricity, will presently affect them in such a way that they will no longer be able to understand the news which they receive so rapidly. The effect is to damp down their intelligence. Such effects are already to be seen today. Even today you can notice how people understand the things that come to them with far greater difficulty than they did a few decades ago.

"It is a remarkable fact that whenever something new appears, as a rule in the early stages it is heralded as a remedy--a means of healing. Then the prophets get hold of it. It is strange, where a new thing appears, clairvoyant perception is often reduced to a very human level! Here is a man who makes all sorts of prophecies about the healing powers of electricity, where no such thing would previously have occurred to him. Things become fashionable! No one was able to imagine healing people by electricity so long as electricity was not there. Now--not because it is there, but because it has become the fashion--now it is suddenly proclaimed as a means of healing. Electricity--applied as radiant electricity--is often no more a means of healing than it would be to take tiny little needles and prick the patient all over with them. It is not the electricity--it is the shock that has the healing effect.

"Now you must not forget that electricity always works on the higher organization, the head-organization both of man and animal; and correspondingly, on the root-organization in the plant. It works very strongly there. If... you pour electricity through the foodstuffs--you create foodstuffs which will gradually cause the animal that feeds on them to grow sclerotic. It is a slow process; it will not be observed at once. Electricity will not at first be recognized as the cause; it will be ascribed to all manner of other things.

"Electricity, once and for all, is not intended to work into the realm of the living--it is not meant to help living things especially; it cannot do so. You must know that electricity is at a lower level than that of living things." (from **Agriculture** by Rudolf Steiner)

How pertinent and timely these words are today on many levels of borderland research. Electrical/electronic medicine has the glamorous position on stage at most of the conferences, and in many people's minds, in today's 'borderland' field. People are racing to buy instruments which are designed by electronic engineers with little or no training in the comprehensive constitution of humans. *It is the fashion!* There is no consideration that true healing comes from the spiritual realms, that the spirit is always healthy, and that dis-ease comes from a condition where the various subtle levels of the body are not aligned properly with the physical.

These electrical instruments have the potential to produce apparent results in treating disease symptoms. But what of the long term effects of the subsensible electric current? Considering the alarming state of affairs viewed through the information just presented I pose the question to the reader, "Do you prefer the natural or the unnatural forms of treatment?" Many people flock to electronic medicine because they feel that the petro-chemical drugs that are prescribed by the medical establishment are detrimental to their long term health. Very possibly so, but will electricity be any better? What about your own vital energy and its relation to cosmic life forces?

Electrical stimulation of the body treats a symptom and fails to allow for the body's natural healing process. As electricity is an externalized part of humanity's inner volitional force we can see that there will be definite effects from the subsensible current. But the effects will be relative and the inner healing process put on secondary mode. Electro-therapy, while emerging as a viable medicine of the future, still ignores the natural healing process.

This does not mean that we should not research electro-therapy. In what may seem a contradiction to many readers, I am 100% for further research into this area. It will no doubt be of benefit to many. Our relationship with electricity is one of the greatest questions of our time. People unconsciously use this force, and the results are such as those noted by Lilly Kolisko. Electricity is intimately connected to the Life Force, but great care must be taken not to confuse the two. Electro-therapeutic research helps define the boundaries, and thus is of interest to Borderland Researchers, but it certainly does not mean I recommend it!

<u>Mar-Apr 1990 JBR</u>
BSRF Bulletin Board

MWO QUESTIONS

Your comments re the MWO in the Nov-Dec 89 JBR are of much interest and raise the following questions in my mind:

1. Will you be publishing any information by Dr. Norman McVea?

2. How can the Kent units now in circulation be converted to produce a 1/2 wave? Perhaps Klark would be willing to publish an article on this or be willing to do the converting for a price.

3. Has any member ever tried to obtain any information on the circumstances of Lakhovsky's death? About three years ago a reference librarian made a serious effort for me to obtain any information re Lakhovsky, with absolutely no success. Perhaps there was an obit in the NY Times at the time he died, assuming that is where he was at the time.

4. Where in the world would we obtain copper spheres like Tesla used? Perhaps a member can suggest a source.

P.V.P.
California

In answer to your questions:

1. Norman McVea has sent us in a bit of material on his latest oxygen researches. He has opted for the oxygenation approach instead of the electrical.

2. I don't know about conversion of Kent's units to 1/2 wave, you should check with him on that. It will probably be easier to use it as it is -- they are good power supplies for experimentation -- and in the future engineer units with more refined outputs. After reading my column Klark added a rare gas tube assembly to his "Rife" units. He has always listened to other people and has constantly worked to improve his units.

3. If any readers have info on Lakhovsky's death, or his life for that matter, these pages are open to pursue the matter.

4. Anybody know where to get copper spheres? Tesla also used copper plates coated with a heavy dielectric.

<u>September-October 1990 JBR</u>
BSRF Bulletin Board

MWO EXPERIMENTS

I have been very fascinated with your Journal. Thank you for the new world you have opened up to me. For the last few months I have begun to work on an MWO.

I have completed the antennas but did not do as well with the Tesla-coil. I decided to buy the ready made coil from

"Edmonds". I connected the secondary to the center of my antennas and did get some action in the form of a purple glow around the third and fourth smaller rings. I can only assume that I need more power to this unit although I was "Quite" pleased at the limited reaction on my first attempt. I would like to reach out to a fellow member who might be able to help me with some advice at this point.

Any advice you would send my way would be greatly appreciated.
P.D.
New York

Naturally, the quality of output of any electrical device is dependent on not only the quality of materials, but also the geometry of structure and arrangement. The better the coil, the better the antenna, the more refined the fields will be that are put out around the device. As I have pointed out in the article mentioned above in my remarks about the "Rife" devices, the types of "Lakhovsky" MWO's being built today vary quite a bit from what Lakhovsky was actually building and using himself.

Lakhovsky used very refined electrical designs and probably log-periodic antennas with both poles of a Tesla coil feeding the outside ring in such a manner that there was a logarithmic, electro-magnetic structure oscillating in space which apparently had quite beneficial effects on living organisms.

The modern variations, based on Bob Beck's schematic of 1963, feed one pole into an antenna (and the other into a second antenna), creating a dielectric field, which when it collapses, due to the rings on the antennas, creates unnecessary sparking and random radio-frequency noise with questionable effects. It is an organic system alterant, but is quite different electrically from Lakhovsksy's original equipment.

Nov-Dec 1990 JBR,
BSRF Bulletin Board

THAT MWO AGAIN

I recently purchased your MWO HANDBOOK. In the book are many references to the "Golden Ratio". I was unable to determine what the mathematical basis for the Golden Ratio is. I have other material which describe the Golden Section, and it is a ratio of .618 to 1. The closest I came to a value for the Golden Ratio is from the MWO antenna data on page 188 of your book the ratio appears to be 1.27:1. Could you please clarify the mathematics of the Golden Ratio antenna?
B.C.S., California

*** I recently purchased THE LAKHOVSKY MWO HANDBOOK. I am in the process of building an oscillator. I have all the parts except 6Kv .005mf capacitors. No electronic store in Alaska has them, or knows how to get them. I would appreciate it if you would send the address of either the manufacturer or an electronic store that carries 6Kv .005μf capacitors. I have one more question. Do you know of a meter or electronic apparatus that measures the amount of energy level the human body produces? It seems that like fingerprints, all human bodies are different in the amount of energy they use or produce. If one can coordinate the energy level of the oscillator to that of the body far less damage would be done and far greater healing potential be made.**
S.N.
Alaska

For the first question, the Golden Ratio antenna uses the golden ratio as a base, but it was engineered to conform to other considerations of antenna propagation. It is what is called a log periodic antenna. These antennas are based on the square root of phi, that is the inner ring is multiplied by the square root of phi to get the next ring, or inversely the outer ring is multiplied by one over the square root of phi to get the next inner, etc. This provides the Golden Ratio mathematics (every other ring is phi related).

MWO NEWS FROM FRANCE

I'd like to mention with regard to "Electricity the Main Culprit" that just after the war, Gurdjieff wrote a chapter in his book ALL AND EVERYTHING entitled "Beelzebub says that man's capture and subsequent destruction of electricity from nature is one of the main causes of the reduction in the human lifespan." And you are lucky in the US. In Europe we have a 230V system that is far more harmful than yours.

A final comment on the MWO which seems as popular as ever. When I lived in Paris I made the acquaintance of Lakhovsky's son and saw two of the MWO's built by his father in operation. The demonstration was very impressive but it didn't last too long because the old units interfered seriously with radio and television reception in the area. They were very big units, about as large as an early TV set. I don't know where they are now since he later loaned them to friends living in the country.
R.C.
France

Very curious quote from Gurdjieff as it concurs with what Steiner indicated, that electricity makes living things sclerotic. If perhaps you wouldn't mind searching your memory a bit more I have a question about Lakhovsky's device: You say it interfered with radio and television reception. Was this from internal spark gaps, or did any unit you see arc between antenna coils. The pictures in THE SECRET OF LIFE indicate that the then necessary spark gaps were interior to the unit, and the pictures of the effluvia coming off the antenna are obviously pictures of corona discharge and not arcing as in the units built in the US today. Bob Beck, in his 1963 article on MWO's claims he built a unit from an original, but his antenna hook-up is quite different from Lakhovsky's pictures. Many years of searching have failed to produce an original unit. The modern units are derived from the most obvious derivation of Lakhovsky's first MWO patent, which is written to both protect his design and cover infinite variations thereof. A detailed account of an original MWO in action would be of great value in this research.

SOUTH OF THE BORDERLAND

I have read Mark Clement's THE WAVES THAT HEAL and discovered a little piece of information not included in the current edition to THE LAKHOVSKY M.W.O. HANDBOOK. In WAVES I noted a short sentence indicating that one set of rings transmits energy through space which falls upon the patient's body and (it must be ascertained through experiment whether this is as I tell here or otherwise) later absorbed by the receiving resonator which resonates it for rebroadcasting into the patient's body. Thus the true Lakhovsky MWO, and UNLIKE the Beck-reconstructed model, would be a more-complex device involving features so-far unthought of. It must be ascertained what KIND of "receiving resonator" Lakhovsky employed, if it had or not special constituents not described at any of his patents included in the MWO HANDBOOK and what other features could be complementary to both.

Another feature to be considered, and which I discovered in the photo on page 30 of Clement's book is that there are two protruding spheres connected to the outermost ring of the Lakhovsky set-up. In the copy of the BSRF publication I have, these two photographs are reduced and with not the same kind of resolution of the work by Clement. Each protruding sphere is connected to a cable and following the path of least resistance

the electrostatic current flows both along the metallic path of the outermost ring and the excesses accumulated from attracting ether from the environment are projected towards the patient (in the case of the transmitter) and collected for resonating (in the instance of the receiving resonator). Also notice that there are two "bracing wires" to both keep the rings in place and at the same time to fulfill the 90° division determined for Earth by the metric theorems which are the foundation of the Energy Grid! This adds another feature of complexity to the duplication of the MWO, which carries the Lakhovsky invention, again, farther from the Beck-built model.

Please mention my paper SOME FREE-ENERGY DEVICES for the MWO analysis I made is at best very incomplete, not including the feature of non-uniformity the true MWO does possess.
Jorge Resines
Buenos Aires, Argentina

Thanks for your further insights into the MWO. I feel that a continuing dialogue will eventually produce more evidence as to what type of equipment Lakhovsky used in his successful researches into cell regeneration and how to best reproduce it. The resonator antenna setup on Lakhovsky's original is more complex than the Beck MWO, as, like the primary antenna, it also has two feeder wires. The two spheres you mention, from which brush discharges can be seen, have always struck me as the nuts that held the heavy antenna onto its stand. Some mechanical contrivance was necessary and the mini-spheres fit the bill with the possibility that they may have been further configured to produce a specific capacitance, as our evidence indicates that Lakhovsky's antennas were very precisely built, probably log periodic. We have heard that Lakhovsky was a radiethesiest and would dowse the sites where he set his equipment up. He was certainly into the subtle energies, and the French school was very precise in its radiesthetic work, being the source material for much of Christopher Hills Supersensonics work. We have an unconfirmed report that the original tube antennas were filled with a rare gas such as argon. This would seem to be the case as in Lakhovsky's second MWO patent he reduced the antennas and puts them into vacuum or low pressure gas bulbs (as the first, this patent is written to be very specifically vague). This was meant to be an improvement over the original units, and probably was. What it tells us is that the "Beck" units appear to be far from what Lakhovsky was doing and where he was going, though because of more than 25 years of people building and using Beck models it is hard find information on the original. The "bracing wires" are supposedly silk. Their angle was probably determined solely by mechanical function.

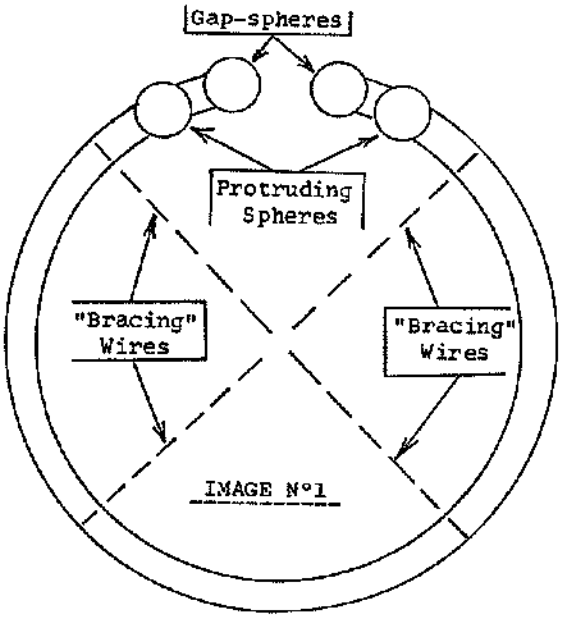

Detail of outer ring on Lakhovsky's original MWO antenna. Front view above, side view below

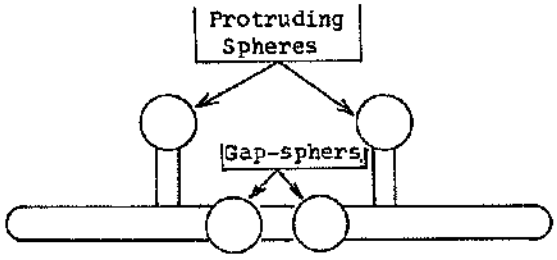

We have actually come under attack for our attempts to clarify the MWO story! In a brochure put out by MWO salesman Mike Brown, Box 25, Pleasant Hope, MO 65725, we come in for the following treatment: "Then there are the characters who, with no formal training whatsoever, denigrate tings [sic] they know less than nothing about. One outfit calling itself Borderland Research sent out a bulletin claiming that no-one today is manufacturing a Lakhovsky Multiple Wave Oscillator. These characters arrived at their conclusion by comparing photos of a 1935 unit to ones being made today. The units don't have the same external appearance. Quite often people with no formal training in electronics or electricity don't understand that an electronic device and how it operates are determined by the circuitry contained within the unit, not by the box it comes in." My comments are that there are perhaps *tings* we don't know but we do know that what is inside counts as much as the outside on the MWO. I have put five years of serious investigation into the MWO and would have to say that what we published is the result of serious consideration by a number of intelligent people--some highly trained electrical and mechanical engineers--interacting and exchanging ideas. We have published the evidence to support our contention, and have in fact stated that if we can be shown to be wrong then we would like to know, that we have no final conclusions, just some of the facts. A crude attempt to belittle BSRF's research by ignoring the main facts does not change the facts and the facts are that the units pictured in Lakhovsky's book **THE SECRET OF LIFE** are quite a bit different than the units being built today, indicated specifically by the antenna hookups, from which basic logic would indicate the need for a different interior setup. A thorough analysis of the basic differences between the two types of units can be found in The Lakhovsky Multiple Wave Oscillator Handbook, edited by myself, Tom Brown (no relation to Mike). Mike's brochure then goes on to claim that "the equipment necessary to regrow arms and legs can be purchased at Radio Shack for about $10", that is a "metal plate, copper wire, battery, and 100 K-ohm to 1.5 Megohm resistor." Heck, if you can regenerate an amputated limb with a only battery and a resistor then why do we need all the electronics in a MWO just to drive out mere cancerous tissue?!

As a final note on this, I would like to point out that electricity is a system alterant. Whether it alters the system for better or worse depends on many other factors, in-

cluding mental status and diet. As Trevor Constable pointed out back in the 1960s in this Journal, the healing powers attributed to the MWO could be caused by the etheric force rushing to suppress the life-negative electro-magnetic activity. It is also possible that any benefits coming from modern day MWOs are psycho-tronic in nature -- that is the mind is doing the cure and the instrument provides a physical anchor for the psychic energies. The actual operation of the equipment, the sparking and gross electrical output, is superfluous to the matter, other than in convincing the mind that *someting* is happening.

Jan-Feb 1991 JBR.
BSRF Bulletin Board

LAKHOVSKY'S ORIGINAL

You ask whether the original Lakhovsky MWO had any arc between antenna coils. I don't remember any but to make sure I checked up with a friend who has worked on the MWO and knows it inside out. He was also present when I saw the device working. He tells me that there is definitely no arc between coils. The arc occurs inside the machine after the "Ruhmkorff coil". He also says that there are two tungsten plates which are drawn apart and brought together manually.

The other thing I remember is a sort of metal wand with a knob at one end which is used between the two units to treat people. At the time I saw it, one of the persons present had a bad back. The two MWO antennas were turned on and were facing each other about 6 ft apart. The "wand" was applied to the sore back. I seem to remember that it kind of gave off sparks, but I'm not sure of this. I touched the wand and I could clearly feel something coming through. My knowledge of electricity is nil, however, if you have further questions, I could always try my friend who should be able to answer them for you.
R.C., France

Many thanks, as this confirms the evidence of Lakhovsky's own pictures used in his books. Would you be so kind as to ask your friend if it is possible to get a schematic (even a rough drawing from memory) of the basic layout of the MWO, which we could reproduce on these pages, also any antenna construction details. Many questions remain such as what components are in the metallic tubes holding the antennas up, and such (Eric Dollard finger-dowsed the pictures of the tubes and felt it was an arrangement of capacitors and spark gaps -- his basic MWO diagram, an intelligent guess of what Lakhovsky was doing, is in this Handbook). A basic schematic would probably be the most important piece of information to date. Please read on, pot has been stirred.....

LAKHOVSKY ANTENNAS

I got my Nov-Dec 89 Journal where it shows an update on Lakhovsky's antennas. On page 181 of SECRET OF LIFE it also shows the same thing. Take a magnifying glass and you can see it. I disagree with all the experts, it seems that they are chasing a phantom ghost. Lakhovsky gave us all his secrets in his book, all we have to do is read carefully.

He could cure cancer and other ailments with a simple piece of copper wire. Lakhovsky wasn't dumb, can you see him telling doctors to cure with a piece of wire they would tell him to get lost, so he built a very complex machine to impress them, also he would have something to sell. I think Beck's machine is close except the antenna. Who came up with this aluminum foil glued to plastic? That's where they fell on their face. If you read page 75 of the same book he repeats VIBRATES 3 times. That's why he hung his rings with silk thread, so it wouldn't damp the VIBRATIONS.

Can you imagine a pipe organ with copper strips glued to a board? I have designed an antenna using copper tube of varying sizes held by fish leader that I think would work fine. I'd bet a penny to 10 bucks that George used thin wall bronze tube as it will resonate better -- but it's expensive to fabricate.
Louis A. Schad
California

Yup, I agree that Georges was no dummy. His book shows plant cancers that have been cured via use of a single copper wire single-coiled around the plant. He felt that the pre-matter cosmic rays (or what I would call the material pole of the etheric instreams) were "ringing" the copper coil, in effect creating a tone that would heal the plant. I got the impression, from studying Lakhovsky's progress towards the vacuum (or low pressure rare gas) patent, that in his equipment Georges tried to invert the process -- exciting the ring with a post-material high frequency current that would create a healing tone. By using log periodic antennas (as would be allowed under the MWO patents) a vibrant chorus would ring in the ether, the tones, via the structure of the antenna, would be such that they could harmonize the functioning of the human body.

The aluminum foil antennas were developed by Riley Crabb, as a low cost way for experimenters to make their own antennas without having to have printed circuit boards made, and many folks were quite happy with the results. The physical evidence now clearly indicates that the Beck unit is quite different from the original Lakhovsky unit for which the cell regeneration results were recorded. What I have termed the "BECK MWO" must stand on its own merits and it can lay no claim to Lakhovsky's recorded results. As stated several times in the past Beck's device is more like one of Tesla's electro-therapeutic oscillators, except Tesla used copper sphere antennas, coated with a heavy dielectric to suppress sparking. Beck's unit would be covered under Lakhovsky's original (and very generalized) patent, but research of Lakhovsky's own material shows it is not what he used for electro-therapeutic researches. To excite the antennas in the Beck manner will not create the same vibrating field that Lakhovsky's antennas excitation circuit will. But it does create an electrical field that some claim is beneficial to a live body placed in its proximity.

It makes much sense that the antenna should also vibrate physically as well as electrically. Ah... if we simply had an original unit to weigh and measure...

Lou has sent us in a MWO of his own design with a single spiral antenna made of two twisted bare copper wires. We will be running a several part article on construction and use starting next issue. This unit is reminiscent of the Sun-Ether disc of Oscar Korschelt, circa 1891. Having sat in front of a number of different operating MWO's over the last six years I have to say that Lou's unit is the most exciting thing I've ever seen like this. I could strongly feel the effect 10-12 inches away, and there was no electrical excitation of the antenna, rather it is physically vibrated. There is a low voltage shocker that can drive the antenna through two smaller copper coils. It's easy to build and use, simpler than the Beck units, and should provide borderlanders with years of workable ideas. Lou will not be selling these devices but will provide complete building plans in the JBR.

We received a call from Patrick Flanagan. He reports that he has a MWO unit built by Lakhovsky's son in Paris. It is a little box with a one tube white noise generator and it has a multi-stranded cable which wraps around the body. It shows that the evolution of Lakhovsky's device has taken a different turn among those who actually knew what he was doing. This unit is based on the Radio-Cellular Oscillator.

Also, Klark Kent (of Super Science, Box 392, Dayton OH 45409) just called to say that he has completed a run of Golden Ratio antennas from the original B.S.R.F. artwork. These are double sided (with inverse gap strips, to simulate the ball capacitance on the original tube antennas, on back) gold plated and are available from Klark for $100 each. (These antennas have produced beneficial effects on plants without any electrical excitation. Many experiments can be done and the results quantified with various protocols such as those used by Rudolf Hauschka and Lilly Kolisko.)

There is no doubt that there is a new phase of MWO research being undertaken. For 25 years people built Beck's model, with many people claiming beneficial results, and others experiencing nothing but no one keeping track of results for evaluation. Thanks to Bob Beck's schematic (published by B.S.R.F. in 1963) the idea was kept alive and now people will have many ideas to choose from in their search for measurable effects from energies ranging from the gross electrical to the fine etheric. Thanks to everyone who has interacted on this ongoing aspect of our researches!

EVEN MORE LAKHOVSKY STUFF

Some time ago I bought your excellent handbook of the Lakhovsky Multi Wave Oscillator and due to pressure of other things have only just found time to read it. Interesting because it parallels some research done by myself and friends, or should I say we duplicated some of the original. This was only to be expected as the entire principle is so outrageously simple, too simple for establishment minds to comprehend.

I should like to offer a few ideas which might be of interest and in return I would be grateful for some additional information.

I helped develop the Betatron now sold by All-Source Systems, PO Box 596, Morton, WA 98356. The Betatron uses a TV Flyback transformer and is very similar to the Master Violet Ray devices. The nicest feature is that the applicator is an ordinary clear light bulb. Even a burnt out one will do. There are differences; some makes of bulb will not work at all, perhaps due to different gas fillings. The Betatron can also be used with the Lakhovsky concentric antenna with spectacular results. This of course has been done in the book's articles although as far as I know it was not actually copied, but was an obvious choice of experiment.

I have tried out an improvement which I did not see in the Handbook or anywhere else, perhaps you will be interested. The Standard circuit whilst apparently covering a very wide range of frequencies, must, because of its inherent fixed inductance and capacitance have its own natural fundamental frequency. Our Betatron is around 21 Kilocycles (I refuse to use the meaningless term Kilo Hertz), and other units seem to be basically tuned to one fundamental even though they do stray and produce an almost infinite range of harmonics.

My first improvement is to substitute a "Jacob's Ladder" for the spark gap. This consists of two 1/4" copper tubes spaced 5/32" apart at the bottom and tapering outwards to 1" at the top then abruptly turning out at 1" radius. The spark travels up the ladder from bottom to top and is extinguished by the sudden increase of gap, then begins again at the bottom. This sequence takes place at about 2 second intervals. The whole point of this is, as the spark progresses up the ladder, the length of the tuned circuit is progressively increased, then suddenly decreased again ditto repeato. As the ladder is about 9" long the length of the tuned primary of the Tesla coil is progressively made 18" longer, then back to its original length. Thereby resonating at infinite numbers of frequencies within its range and delivering virtually the same power at all those frequencies.

A further improvement on this feature is to make the ladder a Spiral Staircase by using a solid rigid central electrode, say a ½" copper tube and the spiral be wound in an ever increasing diameter on the outside, the start being about 5/32" gap and vertical to begin with.

Alternatively the spiral can be the inside element wound on a porcelain former such as is used in radiant "bowl" heaters with a plain copper tube surrounding it or perhaps a perforated tube as used in decorative lighting fixtures. The spark winds its way around the spiral staircase and alters the frequency accordingly. The Spiral Staircase provides a much longer path and more variation in frequency range. I have not yet perfected this and ruined a few porcelain formers in the process. It requires some exact progressive increases in the travelling spark gap but there are no serious obstacles.

Both the Jacobs Ladder and the Spiral Staircase have the advantage of easily cooling the spark gap. We had experienced problems due to overheating of the electrodes in a fixed gap, even spark plugs transmitted the heat to other parts and carbonized insulation. The addition of a cooling fan (the low power kind used in computers) provides a current of air which accelerated the progress of the spark up the Jacobs Ladder and more importantly up the Spiral Staircase. The spark is sometimes reluctant to leave its easy path at the base of the ladder and even more reluctant to wend its winding way up the coil, but the air flow does the trick and keeps everything cool.

The fan also helps remove Ozone from the enclosure. Ozone has the delightful habit of attacking insulation. It has also been blamed for respiratory illnesses. I am skeptical of the latter as I have breathed plenty of Ozone and found it exhilarating.

Master Violet Ray even included an Ozone Inhaler with its de-luxe model!!!, recommended for asthma, bronchitis etc. What's more M.D.s used it on their patients. Certainly Ozone is about the only thing which will quickly digest Carbon Monoxide in a hurry and it deodorizes a room when the cat has misbehaved.

The Betatron and Lakhovsky machine both can be used to destroy troublesome warts and moles, by simply wrapping a wire around the electrode and applying the point of the wire to the offending growth. I had some troublesome warts removed in this way by a Dermatologist. It was not until I got involved with this project that I realized the Dermatologist was using a Lakhovsky device.

He anesthetized the area first but I have since got rid of warts and moles without this. It caused some "Discomfort" which as any mother knows is worse than mere pain, but it was tolerable.

I hope the foregoing will be useful and will not be in the least surprised it has not already been done, but I would like to know what you think of it.

Regarding Spark Coils. I recently found at the local Flea Market, a small spark coil about 3½" overall length 2" dia. with a sturdy vibrator assembly and a turret mounted sideways. It looked like a small steam boiler in fact. It is labelled "Coil, Booster, Battery Operated. Type C1, (24 Volts DC) Spec. #94-32182, Serial #96082, order #A,C 27073, Eclipse Aviation Bendix, N.J. Division of Bendix Corp. I don't know what it is for but on 12 volts it delivers a lively 3/8" spark. The absence of a Zip Code suggests it is fairly old, but this is the ideal driver for a compact tesla coil. I do not know if it contains condensers but I added some anyway. The adjusting screw has a click stop adjustment. Have you come across

one of these? It works well on 6 volts which is just as well as it draws a lot of juice and 8 D cells won't fire it.

Now a request for information about Lakhovsky Treatment and parts. Please Please. On my knees!! Where can I obtain High Voltage Capacitors as used in the Lakhovsky Machine?????? I have tried all the surplus stores I know of in this area but the highest voltage they have is 450. I recently paid over $50 for a 660 volt one for a 12 v trailer power supply and that was ordered specially from New York. HELP!!! I even tried making one from instructions in the Boy Electrician, a Sunday School prize from the 1930s. I used Acrylic 1/8" dielectrics instead of glass. They worked well for a time but soon tracked and failed. I don't fancy using glass plates any way but I desperately need some H V Capacitors at less than Pentagon prices.

Re Treatments. One of the contributors to the Handbook reports that treatment with the Lakhovsky Machine resulted in the dis-appearance of underarm hair. (The report of decreasing underarm hair is from the Nov. 1968 Journal of Borderland Research by Mrs. E.H., Piqua, Ohio.) This is very interesting as I am a heavy construction worker, and after a hard day at the office I like to drop in for a cool beer and fraternize with nice hot ladies. However, underarm odor which results from my daily exertion and defies Right Guard AFTER for 2 hours, is a Repellant. I did find that shaving the offending fuzz helped a lot. Tearing it out by the roots was even better; it seemed to de-activate the sweat glands.

After I sprained my shoulder I used the Betatron all around the joint and have noticed that underarm hair now grows much more slowly, and I have much less trouble with B.O. I used the Betatron frequently and the Ozone removes any residual stink...

NOW the Big question. Has anyone succeeded in using the Lakhovsky machine to stimulate hair growth??? I have hair like Yul Brynner. Maybe some folks think its sexy but I find it repulsive and worst of all it makes me look and feel 20 years older at least without a hat. It seems to me that the machine could well be used to rejuvenate hair cells since it can reverse most other degenerative processes. Its a strange thing that men who are short on top have an overabundance of superfluous body hair in places where it is utterly wasted.

Has anyone done any research on this subject with the Lakhovsky Machine??? If so please let me know. I will be most grateful for any information and will of course inform you of the results of my own experiments.

It occurs to me that such a phenomenon could well dispense with the daily chore of shaving and make Gillette obsolete. I am forever disgusted that such a lot of life force is wasted growing hair on my face instead of where it belongs, On Top! Would be most grateful for your ideas.

I remember the Master Violet ray being demonstrated in a department store in the 1930s, I must have been about 7 years old. My mother who was with me watched the demonstration and I, of course, was fascinated. I said, "Oh Mom do buy one, it's just what you need for your rheumatism". Mother replied, "Oh no, You just want it to play with". How right she was. Well, in spite of all the quack devices which come and go, Lakhovsky in all his forms is still with us. That's recommendation enough. The AMA persecution of course confirms its effectiveness.

A Naturopathic Doctor saw me wearing a copper bracelet. He was treating me for arthritis, effectively with electro therapy etc. and asked if I really believed in the copper. I said "No", then he said "Why wear it?" "Because it works." He laughed and said,

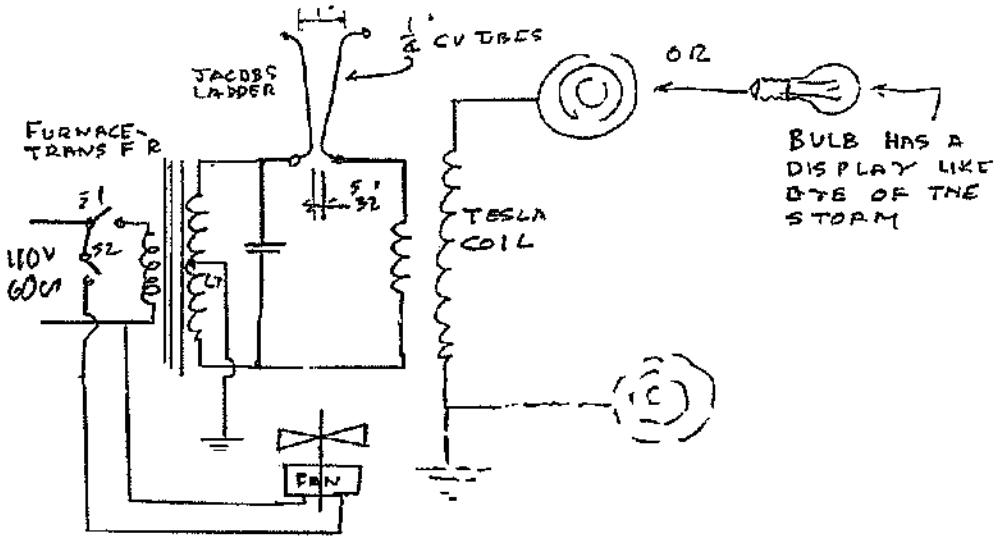

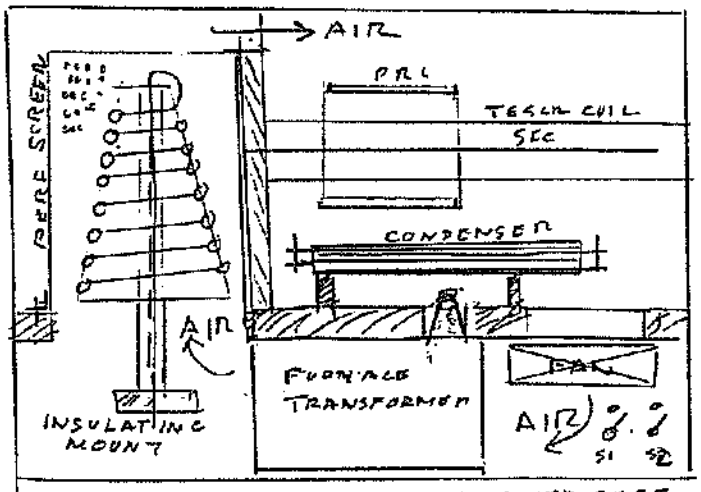

UNIT MOUTED IN TYPEWRITER CASE WITH ACRYLIC FRONT COVER TO DIRECT AIR FLOW

"Look at that green stain on your wrist. That's copper salts and they are being ingested; maybe that's how it works, you might have a copper deficiency, well it's cheaper than pills."
Very Sincerely,
K.V.A.R., Washington

First off, without further ado, let me congratulate you on taking a stand on refusing to use the word Hertz to designate cycles per second. Why use mumbo-jumbo designators when simple English will do. Tesla said that the acceptance of the Hertzian theory would come to be seen by future generations as the greatest aberration of the scientific mind. Of course Tesla is probably rolling in his grave (at 3600 rpm?) at the modern etherless explanations of electricity. He, and others of his day, regarded the (transverse) Hertzian waves as the "waste" put off by coils. The Tesla (longitudinal) wireless system would have been worldwide (including radio and power), with the transverse waves engineered to a minimum, whereas the radio we have today, with the transverse waves engineered to a peak, fades out as one goes around a hill or a decent distance from the emitting source. This is dealt with much more specifically in THE THEORY OF WIRELESS POWER by Eric Dollard. Regarding use of the Jacobs Ladder as a spark gap, that is an interesting idea and thanks for sending it in. As far as your hair growth problems go, perhaps our other readers have further comments. You have provided a lot of food for thought, thanks!

HIGH VOLTAGE SOURCES:
Re: Nov/Dec Journal and inquiry of S.N. Capacitor 6KV (6000V) .0047 uF (which is the standard value, not .005!) available ($4.90) from: Antique Electronic Supply, 6221 S. Maple Ave., Tempe, Arizona 85283. (602) 820-5411.
A.A.
Massachusetts

Source for high voltage equipment: Plastic Capacitors, Inc., 2623 N. Pulaski Rd., Chicago IL 60639-2190. Write for catalog (Dealer for above is Newark Electronics). Also recommended is Homemade Lightning: Creative Experiments in Electricity by R.A. Ford, ISBN 0-8306-3576-9, TAB Books, Blue Ridge Summit, PA 17294-0850. Can be ordered through your bookstore.
Simplified Tech Service
PO Box 2140A, Champaign IL 61825

In the Nov-Dec 90 issue S.N. of Alaska asks about a 6Kv .005 uf capacitor. Radio Shack sells a 2Kv .01 capacitor #272-160. Three connected in series will be 6Kv .003 uf, another 3 connected in parallel across the first three will be 6Kv .006 uf. Six of these costs about $3.

Regarding the MWO, when Hieronymus lived near me in Ft. Lauderdale I asked him about the MWO. He didn't recommend it because the broad spectrum of frequencies had both beneficial and harmful frequencies which could not be separated.
R.B.
Florida

Thanks for all the input on where to get HV capacitors. Also, thanks Ron, for Hieronymus' viewpoint. With the Beck style MWOs I would agree. A mass of radio frequency noise is generated. With Lakhovsky's original units driving structured antennas one could produce multiple wavelengths of a more refined nature. We don't recommend the MWO to anyone, that is not our purpose. This Journal acts as a forum to ideas such as these to be explored, and the MWO refuses to go away, rather interest is growing and it is time we closely examine the field. Read on...

THE BECK MWO
My MWO is a Beck model. It has successfully killed a skin cancer on the back of my hand. Yet I am wondering about its resonator. There seems to be no action, it's of no use and is as if dead. I did not realize that we are having trouble establishing a real Georges Lakhovsky MWO. This [enclosed] information from Europe may help clear up our need.
D.M.
Bryte,

A good puzzle truly has many pieces, so thanks for your experiences. I never said that the Beck MWOs didn't work, but that they are not the same as Lakhovsky built. The enclosed ad was for radionic and related equipment including MWOs from Radionic Instrumentation & Research, Dorset, England. It may be that this is the radionic type of MWO originally sold by Copen Labs. I honestly don't know a thing about these MWOs, so any info would be greatly appreciated especially a schematic. Years ago I had heard them spoken of disparagingly by people who claimed that they wouldn't work because there wasn't enough power, an argument I never bought. It would seem that the more subtle and refined the energy the more beneficial it is to the human organism. The field is still open for new ideas and fresh impulses...

KLARK KENT CHECKS IN!
Just a note to say thanks for the mention in the Journal about the availability of the Golden Ratio Antennas from Super Science. And also to say that the articles on the continuing developments of the MWO are most welcome. Especially interesting is the comparison of the Beck MWO to the Lakhovsky original!

I have never seen an original Lakhovsky MWO. Only from the patent information can we really get schematic information, circuit diagrams, antenna structures, etc. As you know from all of the free energy patents circulating around, a patent wrapper and drawing is not really enough to produce the claimed device. If it were, then we should have many free energy devices in production today!

Several months ago a contact in New York made a generous offer to procure an original Lakhovsky MWO. I passed this information along to you and to others. So far no one has come forth to my knowledge with information leading to the whereabouts of an original Lakhovsky MWO. What this means is that we must grope our own way in replicating the technology first developed by Lakhovsky.

So I guess I owe Bob Beck a word of thanks because he was the one who made it possible for researchers to actually build a MWO. The information left to the world by Lakhovsky is (in my opinion) wholly inadequate to build and construct the device. The patent information is, like most patents, just not adequate to enable someone to replicate the device. And this brings up the question: Just what constitutes the original Lakhovsky MWO? We don't have an original device (and a bounty of $100,000 has so far failed to produce one). The information given in the patents doesn't really tell us enough.

Borderland Sciences can help out by continuing to publish articles about the MWO which emphasize circuit diagrams and construction details. In this way, Borderland researchers can redevelop this important technology.

I enclose a letter we received from a customer. Since the letter is of the testimonial variety, it is best not to reference it in the Journal. But the point is that even a Beck adaptation MWO can seem to produce positive experimental results!
Klark Kent, Super Science,
P.O. Box 392, Dayton, OH 45409

Glad to hear you are open to new research. Lakhovsky left much information -- it just never got translated into English. BSRF will continually publish the results of ongoing MWO research, and will always be on the lookout for the best information available. Here is the letter submitted to Klark, from a person known to us here also:

Dear Mr. Kent,
At long last I get around writing to you and share some of my experiences with the MWO I bought from you.

The unit arrived on May 17, 1990 in excellent condition. Your packaging is superb. I inspected the unit superficially but, because of some professional problems, was not able to make use of it until October.

Let me comment first on general appearance and workmanship. While obviously not industrially produced, this is a well-built high quality machine, using fine components. Having been an electronics engineer part of my life (before I became a philosopher), I feel well qualified to make that judgement.

The instructions are generally adequate but I was glad that I did order your audio cassette, done by you with a fine dramatic flair, worthy of Christopher Reeve, who does resemble you. My suggestion: include the cassette with the MWO as a matter of course.

I used the machine about thirty times, sometimes daily, sometimes skipping a day or two for 35 min. per session, mostly in the High Power Radiator mode.

I suffered over a period of about fifteen years from a mild chronic bronchitis, some coughing in the morning with some phlegm, rest of the day just fine. The medicine men told me that I "just have to live with it". Though I am 70, I judge myself being in great health.

Now, your machine has definitely improved my condition. I know, of course, that my testimonial is worthless to you, since you cannot make, and do not make, any health claims. But still I thought you might want to know.

I do have several radionics machines (De la Warr and Copen) but we all realize that this is sympathetic magic; great stuff, though!
With best wishes, faithfully yours,
NAME WITHHELD

ELECTRONIC ENTITY REMOVAL

Judging by the letters you receive and print in the BULLETIN BOARD people **are still experimenting and building MWOs. It should be accepted that no two MWOs will be identical due to different components, circuits, etc. Also, Lakhovsky did not have some mystical secret that is exclusive to his particular instruments; he built one that generated his required multi-frequencies and there are no doubt many ways to effect this.**

The large MWO I built in 1966 worked as well as I could expect and, although I never use it now, its circuit can be regarded as a basic Tesla coil, starting out with a 12KV neon transformer. Other circuits I have experimented with unfortunately appeared not to give the same results. Your MWO Handbook should be the starting point for would-be experimenters keeping in mind that most of the 'transistorized' models do not have enough energy to effect the desired results.

A major point that never seems to be mentioned is that the subject should be seated ON AN INSULATED PLATFORM with the antenna about six inches from the back. In this way all the cells of the body are raised to their full potential for, say, ten minutes during which each cell can absorb energy at its one resonant frequency. The subject should ground himself for an instant before stepping off the platform. Then switch off the instrument. I found this procedure mandatory to obtaining positive results and have found it odd that this point has never been mentioned in the literature.

I might also bring up the very real possibility (discussed with Riley Crabb in the past) that at least part of the positive results obtained with the MWO could be attributed to the removal of spirit entities by the high voltage involved. Regrettably, Borderland appears to skirt this issue.

As I have stated before, the Journal is an important platform for the meeting of the minds and I wish you well in your efforts.
R.M.
Nevada

Appreciate your input and valuable ideas. I'm certainly open to the possibility that the results obtained from the MWO could be attributed to the removal of spirit entities. This should also bring up the question of whether or not what is perceived as spirit entities (negative in this sense) could be also related to their potential physical anchors, i.e. virus and bacteria. Maybe we see the same thing but interpret differently.

As far as using different configurations to achieve multiple wavelengths, different arrangements will produce qualitatively different results. A French horn and a clarinet will show the same frequency for the same note played, but the difference in quality of sound should be obvious to all. The major difference between the hookup of Lakhovsky's and Beck's units makes them fall into quite separate categories. A silver bell rings finer than tin.

MWO REPORT FROM FRANCE

I finally managed to get hold of my friend (see BSRF Bulletin Board, Jan-Feb 1991) but he is very, very busy and only gave me some of the information I wanted.

Firstly, he declined to provide any basic layout of the MWO because he say no two units were the same. Apparently Lakhovsky experimented all the time and each machine was a "one-off" model, different from the others.

The origins of the MWO are in Tesla's work. A French professor, Mr. D'Arsonval took some of Tesla's equipment and modified it. Lakhovsky used D'Arsonval's work to build his machine. Tesla heard about D'Arsonval's experiments and, convinced that D'Arsonval was stealing his patents, came to France with the idea of starting legal proceedings against the professor. However, he found D'Arsonval so courteous and charming that he returned to America having dropped the idea of court action.

My friend tells me that the whole secret of the MWO is in the "diffuseur". He further indicated two sources of information, both in French. A series of books have been written and published by the Study Group "Arkall" called "L'Emergence de l'Enel" dealing with all aspects of the MWO. The second source is George Lakhovsky's book "L'oscillation cellulaire" which has been re-edited in Belgium. Unfortunately, my friend did not know the editor, so I suggest you will have to contact the American Embassy in Belgium and they should be able to give you addresses of bookshops where it can be obtained. Apparently, this book gives all the references concerning the people I have mentioned.

I'm sorry I can't be more helpful but the whole question seems to be much more complicated that I at first thought. In short, I'm afraid you will have to wade through "L'oscillation cellulaire" and the "L'Emergence de Enel" to see how Lakhovsky himself worked out the idea of the first MWO's.
R.C.
France

Thank you, your input has been most valuable and stimulating. The "diffuseur" (literally: loudspeaker or nozzle) would probably be the antenna, so the "secret" could very well be (as we have intimated over the years) in his mathematical arrangement – a much more important consideration under Lakhovsky's antenna feed arrangement than with Beck's.

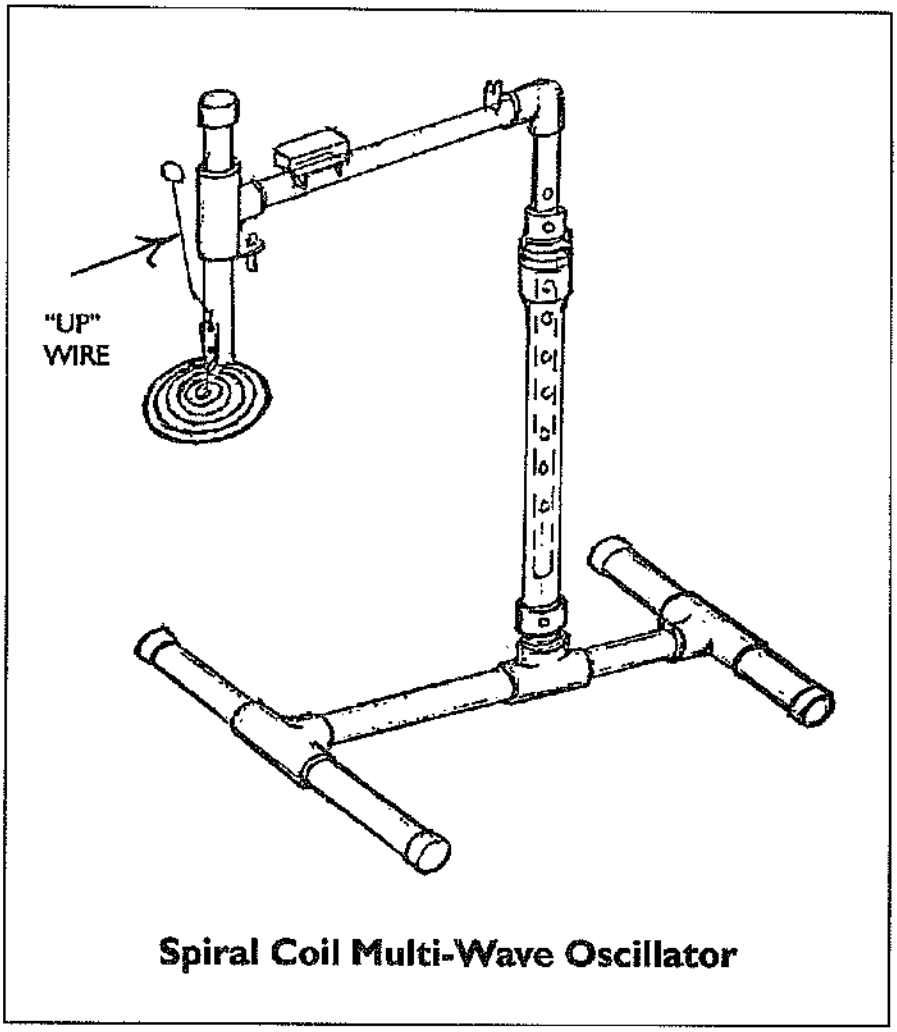

Spiral Coil Multi-Wave Oscillator

<u>Jul-Aug 1991 JBR.</u>
BSRF Bulletin Board

MWO CORNER

Received the Journal yesterday and was very excited about the Spiral Coil MWO. I congratulate Mr. Schad on doing a very good job and would submit the following input for future models.

1) No aluminium tubing should be used. Copper or steel tubing should be used instead. Aluminium is wholly negative. It attracts negative radiation like honey attracts files. In this connection, I heard this morning on the British radio that a "mobile home" site had just been devastated in the USA. If I'm right, "mobile home" site means trailer park, in which there is a huge quantity of Al. These are prime targets for tornadoes and all kinds of negative influence. My chief reference for this is Dr. Starbard Webb, Box 200, Orangevale, CA 95662. She has been studying the subject since 1956 and has accumulated a mass of data. Be patient for she travels a lot in the States doing seminars etc.

2) The rest is from a Tibetan lama to whom I showed the drawing. If you're wondering what a lama would know about the MWO I would say that they seem to know about everything that matters. For instance, in my own field (medicinal plants), their knowledge is not great, it is simply colossal, far beyond anything known in the West. The Lama tells me that there should be 12 coils, no more no less (Fig. 6). The "up" wire (see illustration) should be five times longer than the diameter of the coil. No doubt further information will be forthcoming when the whole of the MWO is described.
Yours sincerely,
R.C.
France.

Glad to hear of your suggestions for further research on Lou's spiral coil MWO. His articles have stimulated a lot of work that should provide a lot of new ideas over time. Peter Lindemann has taken Lou's concept of physical vibration and is experimenting with phi ratioed antennas that are stimulated with sub-audible sound. Also, Lou called to make sure that it was clear that the antenna side facing the subject is a counterclockwise spiral. It is clockwise from the top.

Interesting thoughts on the mobile homes, which are reverse orgone accumulators. A few items congruent with your comments have showed up over the years and perhaps we can get more on that in an upcoming issue.

LAKHOVSKY COIL INFORMATION

The following was forwarded to us from Health Research, Box 70, Mokelumne Hill CA 95245:

On Health Research's flyer for THE HANDBOOK OF UNUSUAL ENERGIES, the artist shows the copper wire positioned incorrectly through the wood support.

I have made a number of discoveries which I even find hard to believe by using this COILED COPPER WIRE. I expect to write a booklet on my findings and you may want to represent it in your sales catalog. I have proven over and over again what I have done but, to date, have not shared anything with anyone else. I had to be ABSOLUTELY CERTAIN before I 'went public'.

When I first received the books THE SECRET OF LIFE and THE WAVES THAT HEAL from you about 4 years ago, I noted carefully just how the copper wire was COILED around the plant. Please note that the copper wire STARTS from INSIDE THE EBONITE and MOVES COUNTER CLOCKWISE and then ends ABOVE the ebonite... This is shown on page 14 of THE WAVES THAT HEAL and page 110 of THE SECRET OF LIFE.

In the past four years I have made dozens of experiments and I've gone far beyond what even Lakhovsky did or thought of. NOW, to prove my point about the proper way the copper MUST be coiled, I deliberately experimented by coiling the wire the way you have shown it and NOTHING HAPPENED in all my experiments. That's why I KNOW THAT

I AM RIGHT and it is imperative that you change your picture to show the correct way. I am not a scientist of a professional person, but I KNOW what I have done and you will have to take my word for it unless you want to YOURSELF, conduct the same experiments I have and PROVE it to yourself... I have not the slightest idea WHY the copper wire MUST be coiled this way but I DO KNOW THAT IT MUST.

You know as well as I that EVERYTHING in the COSMOS is perfect, exact, precise and absolute that the LAWS, FORCES, ENERGIES, POWERS, FREQUENCIES, RAYS... and all the rest function flawlessly and cannot allow any variations even for an instant. Life as we know it will cease forever if even an INSTANT change is made by whatever cause.

I would dearly love to see one of Lakhovsky's BELTS, COLLARS, BRACELETS he calls them OSCILLATING CIRCUITS, of course, and although the picture on page 63 of WAVES THAT HEAL is interesting, I am wondering if there is more to it that what this artist

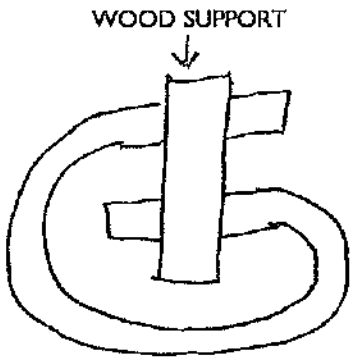

WRONG

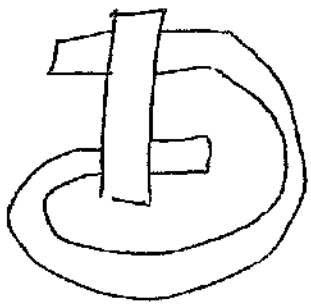

RIGHT

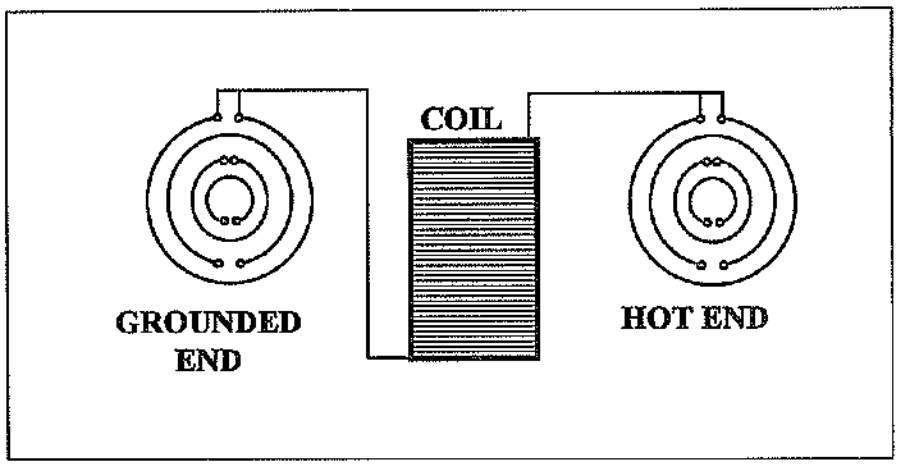

concept shows. I have yet to experiment with a HUMAN BODY as I will need to be very careful to use the RIGHT PERSON who will not think that I have gone off the deep end and headed for the 'funny farm'. But Lakhovsky certainly has plenty of evidence to show. If you know of anyone who has one of the ORIGINAL Lakhovsky oscillating circuits, let me know. It is imperative that the 'human' circuits MUST be done, and applied, correctly.
A.P.
Nebraska

Nov-Dec 1991 JBR, BSRF Bulletin Board

MWO RESEARCH

Five years ago I duplicated the MWO as best I could with my limited knowledge. I scaled up the antennas from the book WAVES THAT HEAL using copper tubing of all different sizes and soldering brass hex caps of various sizes on the ends after I rounded them off with a grinder. The outside ring was about 2 ft. across.

I was able to duplicate the exact brush discharge pattern in the picture with Tesla coil 4" diameter with about 1,000 turns of regular hook up wire. 500 turns gave a discharge of 2"-3" evenly all around the outer ring. 1,000 turns gave a discharge of 5"-6" at the bottom with less and less towards the top except for some off the two balls at the top, like in the picture.

I found it necessary to run two connections from the feed wire otherwise with one connection the spark would travel around the ring and out the other end burning anything used to suspend the ring. Two connections eliminated this problem forcing all energy towards the bottom of the ring like in the picture.

The resonator was grounded just like the Beck model to the ground end although I used two wires one going to each end of the outer ring. Even so, at this power you could draw a small spark off the outer ring and if you turned the unit off and on you could hear the resonator ring just like it was struck by a small hammer.

I used a 30mA 15,000 volt sign transformer or stronger. These tend to burn out unless you put the primaries of two in series to share the load and restrict current. Actually, I started using half burned out transformers using mid point ground and the good half for 7,500 volts which is much safer for the capacitors. I used two .005 uf 20,000 volt capacitors in parallel for .010. The stationary spark gap was air cooled with a small blower fan.

There was no spark between rings. The side effects from this unit were too strong to continue treatments so I am now working on smaller units. After 15 minutes your head would be full of mucus. The closer the antennas were to each other the stronger the effect to the point of making one very nauseous.

Also, did anyone else purchase and test Dr. Charles T. Turley's square wave sound MWO two printed antennas powered by a sound generator?
J.A.
Ohio

Thanks for your most helpful input. Would be most interested in Dr. Turley's MWO as it may very well relate to Lou Schad's spiral coil MWO, presented several issues back, which worked on physically vibrating the coil. Peter Lindemann has picked up on this and is experimenting with vibrating the antennas with sound waves and through other mechanical means. A whole new field of MWO research is opening up and it sounds like Dr. Turley is working in the same direction. Please send us any information you may have on this. Thanks.

From the March-April 1992 JBR
BSRF Bulletin Board

MWO CORNER!

Here is a nice present for you and your readers. Some tidbits about George Lakhovsky. I phoned my knowledgeable friend on Sat, 14th Dec. To my surprise not only was he at home but he invited me to spend the afternoon with him the following day.

Firstly, it is comforting to know that there are still about four original MWO's within a radius of 200 miles from Paris, and the people who have them are likely to take good care of them.

Secondly, from what I can gather, L. took very great pains with each MWO. I understand now what my friend meant when he said that each one was different. L. would calculate all sorts of parameters relating to the place where the MWO was to be used. He would then do the "fine tuning" with the help, sometimes, of an unusual cleric Abbe Breuil.

L. arrived in France around 1896. He was a friend of Tesla and when the latter came to France the first person he wanted to see was L. I don't know anything about this early period but two episodes occurred later which gave L. quite a bit of money and enabled him to finance his future research himself. 1) During the 1914 war, there was a dearth of methylated spirits in France and L. negotiated supplies, on behalf of the French government, with the Russians. 2) He invented a gadget which was used everywhere on the French railways and which brought in tidy sums in royalties. He was thus able to invite titled people to his table, the Count of this and the Duke of that and, of course, Abbe Breuil. This curious cleric was very well known in France, not for saintly endeavors on behalf of the Church but for his exploration of caves in search of traces of early man. He became the High Priest of Pre-history. However, what interests us here is that he was an extraordinary medium. For instance, L. at table, would say something like this: "Abbe, I've just thought up a new design for the MWO (passing him the drawings) what do you think of it?" And the Abbe might reply: "The antenna's too thick here, you should take 1 millimetre off and here, you are using the wrong kind of metal." In this way, L. gradually refined each model, using the Abbe's intuition to verify his own findings, until he got it as near perfect as possible.

What follows is a translation of the notes scribbled down by my friend yesterday. I offer no comments because I wouldn't know a Hertz dipole if I fell over one in the dark.

These are some of the parameters taken into consideration by L.

1) Diameter: D.
2) Thickness of the wire of the tube (not to be confused with the section).
3) Distance "e" between the two ends.
4) Orientation of the circuit with respect to the horizontal plane (29^0 70 N).
5) Kind of circuit. Should it be made of metal or hollow glass containing chemical salts.
6) Orientation of the distance "e" with respect to the magnetic North.
7) Study of the terrain: the mineralogical, geological, geodesic and tectonic factors.
8) Study of the nature of the surface of the circuit and whether and how it should be covered.

I see now that what I had taken for solid rods making up the antenna were in reality hollow tubes.

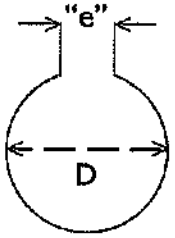

Hertz dipole

MWO antenna

I hope that you and your readers will find this information interesting. It sheds a new light on how L. operated. He used the pendulum a lot and, as we have seen, the mediumistic talents of his friend Abbe Breuil. My best wishes to yourself and to BSRF in 1992.

R.C.
France

Your input on the MWO project has been most helpful to everyone trying to find the truth of the story, and I offer my thanks and I'm sure the thanks of BSRF members the world around. Georges Lakhovsky was a complex individual whose ideas on cell regeneration have ignited many a seeking mind. It seems as though he had some rather interesting friends also, Nikola Tesla, Professor D'Arsonval, and the curious Abbe Breuil! Your friend's comments indicate some important factors in Lakhovsky's considerations: He was very concerned about the orientation towards the natural energetic lines of the earth, even considering latitude (what you have termed the horizontal plane) as a determining factor in the energetic output of his devices. He must have been aware of the interaction of the electric output with the planetary magnetic, electrostatic and etheric fields. He was also concerned about the underlying earth itself. In his Secret of Life he proposes his theory that cancers are more predominant in areas where the soils (such as clays) reflect the cosmic radiation back to the surface, causing interference patterns that disrupt the body's energetic flows. It is interesting to note that his antennas were constructed with all these factors involved. It is also very interesting that he relied on the pendulum and the mediumship of Abbe Breuil for his refinements. Lakhovsky was a true borderland scientist! Also of note is your point #5 mentioning the hollow glass circuit containing chemical salts. Something new to figure in our researches. We also have the open question of whether or not some of his tube antennas contained rare gases, which his MWO Tube Patent implies by its refinements in miniaturization. This has been an exciting period of discovering what Lakhovsky was really up to in his vast researches. Please read on....

A REAL LAKHOVSKY SCHEMATIC!

This schematic is from a Lakhovsky Radio Cellular Oscillator manufactured by Lakhovsky's son in Paris long after the untimely death his father in the early 1940s. It shows that the Lakhovsky's own family followed the path of the radio-cellular oscillator and not that suggested by Lakhovsky's turn to damped electrostatic power supplies in his MWO. Our many thanks go to Patrick Flanagan for providing this information to BSRF. Patrick obtained the unit, removed the seal at risk of voiding the warranty, and provided us with the circuit description you see here. Also, a special thanks to Roger Modjeski of RAM Tube Works of Santa Barbara, California for providing the pinouts and tube conversion info. As far as our extensive research notes show, this is the first real, complete schematic of an working Lakhovsky device that has been published in the US!

This unit, which fits in a small box that can be held in the hand, is a very powerful white noise generator with a treatment coil comprising of coax cable which is looped around the subject when in use. The treatment coil loop is 1 meter in length, the center wire and shield are connected. This unit will interfere with electronic communication devices up to the satellite TV range, and may be illegal to operate under FCC rules. The tube is an EL83, a French tube (Telefunken manual gives the German number as PL83) whose US equivalent is given as a 6CK6 video output pentode, but GE never made them. It is very similar in function to a 6CL6 which has a different

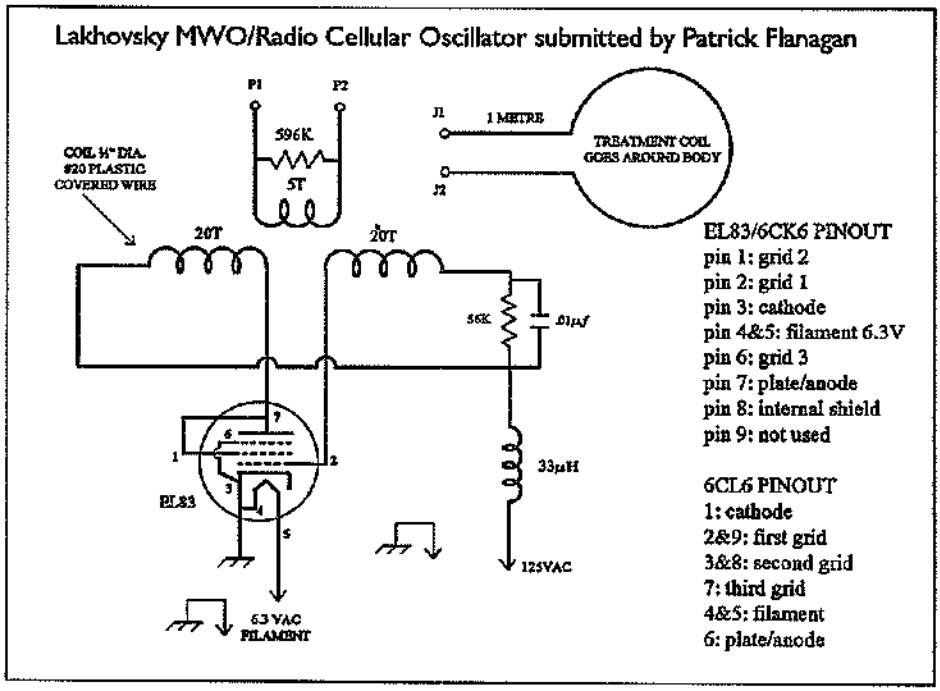

pinout. We provide the pinouts for both.

The 5 and 20 turn coils are ½ inch diameter tightly wound with #20 plastic coated wire. They are air core and all three are wound in the same right hand direction. They are spaced tightly and arranged exactly as shown. Varying the physical distance between the primary and secondary coils would vary the output strength. The resistors are ½ watt. The .01 capacitor is ceramic at 500 volts. The choke is 33 μH. The power supply is not shown, but is implied by the circuit.

We have no exact details of the interaction of this generation of Lakhovsky device with the human system, only that suggested by Lakhovsky's original RCO research and its extension through time. This data is provided for research purposes and to record yet another development in radio-biological research.

We would still be most interested in finding the schematic of one of the original MWOs pictured in Lakhovsky's various publications such as that pictured below from his book **La Terre Et Nous (The Earth and Ourselves)**, Fasquelle Editeurs, Paris, 1933, as it would provide the exact antenna feed for the concentric ring antennas and other pertinent details. Note that the antennas on this unit stand above the arm, unlike the well publicized pictures from **The Waves that Heal** and **Secret of Life**. This indicates that the protruding spheres seen in the detail on those pictures have a mechanical function, perhaps more important than their electrical function, though with Lakhovsky's methodology, he would certainly incorporate the optimum characteristics for the main antenna feeds.

We have discovered the basic construction of the Radio-Cellular Oscillator and know that Lakhovsky moved from them to the MWOs with damped electrostatic power supplies and concentric ring antennas because of the potential for thermal shortwave damage from continuous-wave radio frequencies. But then we see that Lakhovsky's son was still manufacturing RCOs after the death of his father! So we can see that the final conclusion has yet to be drawn as to exactly how the original MWOs were built, and of course we would also like to see some actual MWO Tube units that Lakhovsky patented. We also see the RCO as a potential low-cost method of researching Lakhovsky's basic theory of radio-frequency cell regeneration. This MWO Handbook contains the essential keys to all our questions and more. Much research has to be done and Borderland Sciences is willing to help any serious researcher who wishes to pursue these streams of activity.

The Journal of Borderland Research is the publication of record in the English language for these and many other research subjects. Please join in and exchange information with us. Without the help of the many borderland researchers sending us their ideas for over a quarter of a century this book would not exist. Thanks to all and best wishes on your researches -- may they be serious, straightforward, and well documented for others to learn from.

Tom Brown

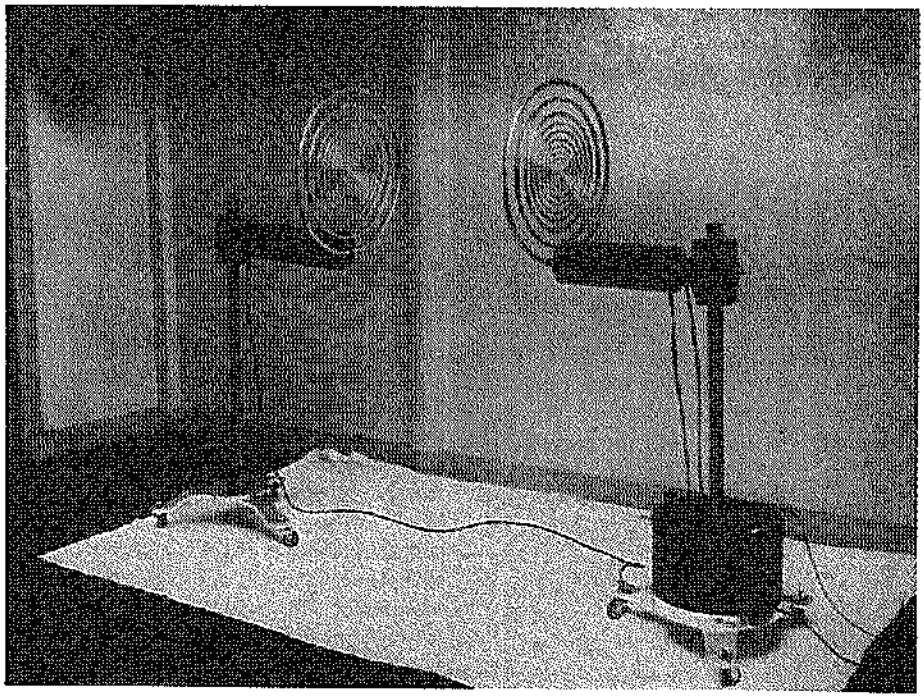

The complete Lakhovsky Multiple Wave Oscillator apparatus which creates an ambient electromagnetic field between its two *resonateurs*.

5

HIGH FREQUENCY OSCILLATORS FOR ELECTRO-THERAPEUTIC AND OTHER PURPOSES*

by Nikola Tesla

Some theoretical possibilities offered by currents of very high frequency and observations which I casually made while pursuing experiments with alternating currents, as well as the stimulating influence of the work of Hertz and of views boldly put forth by Oliver Lodge, determined me some time during 1889 to enter a systematic investigation of high frequency phenomena, and the results soon reached were such as to justify further efforts towards providing the laboratory with efficient means for carrying on the research in this particular field, which has proved itself so fruitful since. As a consequence alternators of special design were constructed and various arrangements for converting ordinary into high frequency currents perfected, both of which were duly described and are now — I assume — familiar.

One of the early observed and remarkable features of the high frequency currents, and one which was chiefly of interest to the physician, was their apparent harmlessness which made it possible to pass relatively great amounts of electrical energy through the body of a person without causing pain or serious discomfort. This peculiarity which, together with other mostly unlooked-for properties of these currents I had the honor to bring to the attention of scientific men first in an article in a technical journal in February, 1891, and in subsequent contributions to scientific societies, made it at once evident, that these currents would lend themselves particularly to electro-therapeutic uses.

With regard to the electrical actions in general, and by analogy it was reasonable to infer that the physiological effects, however complex, might be resolved in three classes. First the statical, that is, such as are chiefly dependent on the magnitude of electrical potential; second, the dynamical, that is, those principally dependent on the quality of electrical movement or current's strength through the body, and third, effects of a distinct nature due to electrical waves or oscillations, that is, impulses in which the electrical energy is alternately passing in more or less rapid succession through the static and dynamic forms.

Most generally in practice these different actions are coexistent, but by a suitable selection of apparatus and observance of conditions the experimenter may make one or other of these effects predominate. Thus he may pass through the body, or any part of the same, currents of comparatively large volume under a small electrical pressure, or he may subject the body to a high electrical pressure while the current is negligibly small, or he may put the patient under the influence of electrical waves transmitted, if desired, at considerable distance through space.

While it remained for the physician to investigate the specific actions on the organism and indicate proper methods of treatment, the various ways of applying these currents to the body of a patient suggested themselves readily to the electrician.

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* Read at the eighth annual meeting of The American Electro-Therapeutic Association, Buffalo, N. Y., Sept. 13 to 15, 1898

As one cannot be too clear in describing a subject, a diagrammatic illustration of the several modes of connecting the circuits which I will enumerate, though obvious for the majority, is deemed of advantage.

The first and simplest method of applying the currents was to connect the body of the patient to two points of the generator, be it a dynamo or induction coil. Fig. 1 is intended to illustrate this case. The alternator G may be one giving from five to ten thousand complete vibrations per second, this number being still within the limit of practicability. The electromotive force — as measured by a hot wire instrument — may be from fifty to one hundred volts. To enable strong currents to be passed through the tissues, the terminals T T, which serve to establish contact with the patient's body should, of course, be of large area, and covered with cloth saturated with a solution of electrolyte harmless to the skin, or else the contacts are made by immersion. The regulation of the currents is best effected by means of an insulating trough A provided with two metal

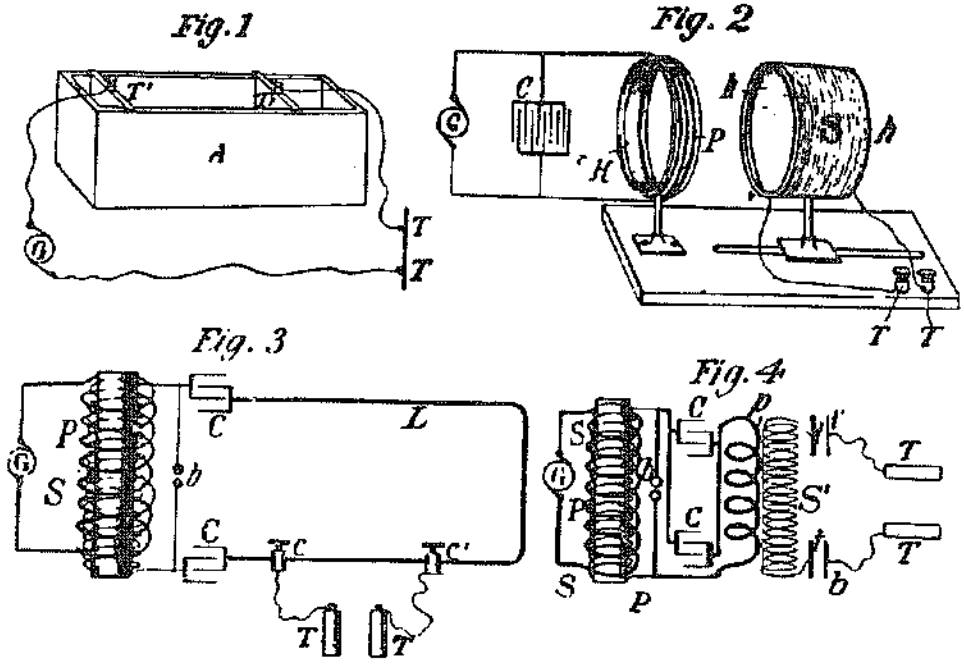

Figs. 1, 2, 3, 4.

terminals T' T' of considerable surface, one of which, at least, should be movable. The trough is filled with water, and an electrolytic solution is added to the same, until a degree of conductivity is obtained suitable for the experiments.

When it is desired to use small currents of high tension, a secondary coil is resorted to, as illustrated in Fig. 2. I have found it from the outset convenient to make a departure from the ordinary ways of winding the coils with a considerable number of small turns. For many reasons the physician will find it better to provide a large hoop H of not less than, say, three feet in diameter and preferably more, and to wind upon it a few turns of stout cable P. The secondary coil S is easily prepared by taking two wooden hoops h h and joining them with stiff cardboard. One single layer of ordinary magnet wire, and not too thin at that, will be generally sufficient, the number of turns necessary for the particular use for which the coil is intended being easily ascertained by a few trials. Two plates of large surface, forming an adjustable condenser, may be used for the

purpose of synchronizing the secondary with the primary circuit, but this is generally not necessary. In this manner a cheap coil is obtained, and one which cannot be easily injured. Additional advantages, however, will be found in the perfect regulation which is effected merely by altering the distance between the primary and secondary, for which adjustment provision should be made, and, furthermore, in the occurrence of harmonics which are more pronounced in such large coils of thick wire, situated at some distance from the primary.

The preceding arrangements may also be used with alternating or interrupted currents of low frequency, but certain peculiar properties of high frequency currents make it possible to apply the latter in ways entirely impracticable with the former.

One of the prominent characteristics of high frequency or, to be more general, of rapidly varying currents, is that they pass with difficulty through stout conductors of high self-induction. So great is the obstruction which self-induction offers to their passage that it was found practicable, as shown in the early experiments to which reference has been made, to maintain differences of potential of many thousands of volts between two points — not more than a few inches apart — of a thick copper bar of inappreciable resistance. This observation naturally suggested the disposition illustrated in Fig. 3. The source of high frequency impulses is in this instance a familiar type of transformer which may be supplied from a generator G of ordinary direct or alternating currents. The transformer comprises a primary P, a secondary S, two condensers C C which are joined in series, a loop or coil of very thick wire L and a circuit interrupting device or break b. The currents are derived from the loop L by two contacts c c', one or both of which are capable of displacement along the wire L. By varying the distance between these contacts, any difference of potential, from a few volts to many thousands, is readily obtained on the terminals or handles T T. This mode of using the currents is entirely safe and particularly convenient, but it requires a very uniform working of the break b employed for charging and discharging the condenser.

Another equally remarkable feature of high frequency impulses was found in the facility with which they are transmitted through condensers, moderate electromotive forces and very small capacities being required to enable currents of considerable volume to pass. This observation made it practicable to resort to a plan such as indicated in Fig. 4. Here the connections are similar to those shown in the preceding case, except that the condensers C C are joined in parallel. This lowers the frequency of the currents, but has the advantage of allowing the working with a much smaller difference of potential on the terminals of the secondary S. Since the latter is the chief item of expense of such apparatus and since its price rapidly increases with the number of turns required, the experimenter will find it generally cheaper to make a sacrifice in the frequency, which, however, will be high enough for most purposes. However, he only needs to reduce proportionately the number of turns or the length of primary p to obtain the same frequency as before, but the economy of transformation will be somewhat reduced in so doing and the break b will require more attention. The secondary S' of the high frequency coil has two metal plates t t of considerable surface connected to its terminals, and the current for use is derived from two similar plates t' t' in proximity to the former. Both the tension and volume of the currents taken from terminals T T may be easily regulated and in a continuous manner by simply varying the distance between the two pairs of plates t t and t' t' respectively.

A facility is also afforded in this disposition for raising or lowering the potential of one of the terminals T, irrespective of the changes produced on the other terminal, this making it possible to cause a stronger action on one or other part of the patient's body.

The physician may find it for some or other reason convenient to modify the arrangements in Figs. 2, 3 and 4 by connecting one terminal of the high frequency source to the ground. The effects will be in most respects the same, but certain peculiarities

will be noted in each case. When a ground connection is made it may be of some consequence which of the terminals of the secondary is connected to the ground, as in high frequency discharges the impulses of one direction are generally preponderating.

Among the various noteworthy features of these currents there is one which lends itself especially to many valuable uses. It is the facility which they afford for conveying large amounts of electrical energy to a body entirely insulated in space. The practicability of this method od energy transmission, which is already receiving useful applications and promises to become of great importance in the near future, has helped to dispel the old notion assuming the necessity of a return circuit for the conveyance of electrical

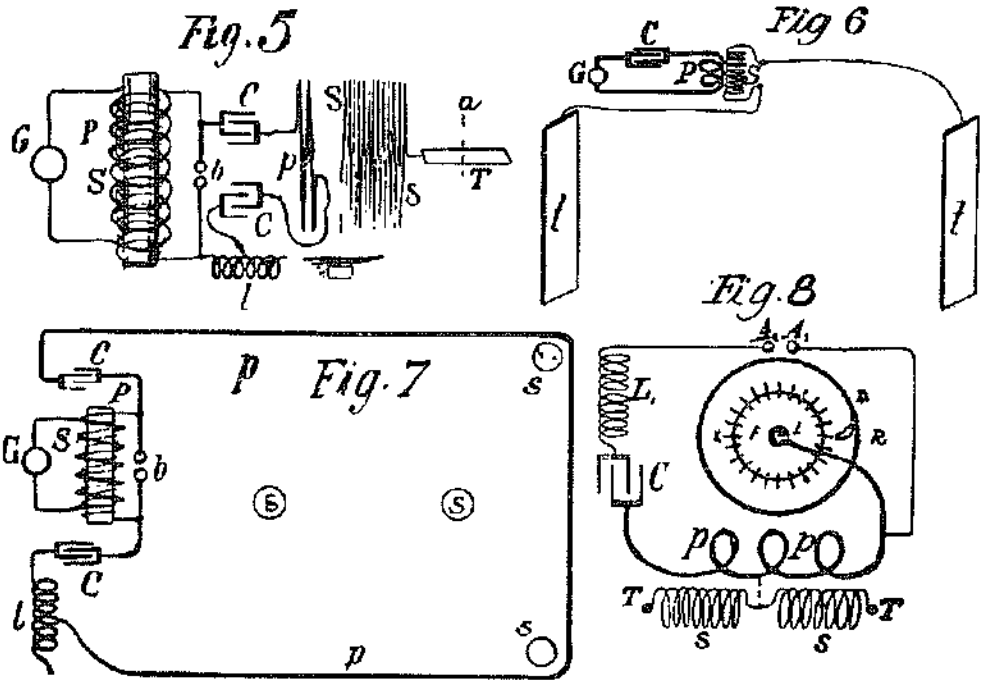

Figs. 5, 6, 7, 8.

energy in any considerable amount. With novel appliances we are enabled to pass through a wire, entirely insulated on one end, currents strong enough to fuse it, or to convey through the wire any amount of energy to an insulated body. This mode of applying high frequency currents in medical treatment appears to me to offer the greatest possibilities at the hands of the physician. The effects produced in this manner possess features entirely distinct from those observed when the currents are applied in any of the before mentioned or similar ways.

The circuit connections as usually made are illustrated schematically in Fig. 5, which, with reference to the diagrams before shown, is self-explanatory. The condensers C C, connected in series, are preferably charged by a step-up transformer, but a high frequency alternator, static machine, or a direct current generator, if it be of sufficiently high tension to enable the use of small condensers, may be used with more or less success. The primary p, through which the high frequency discharges of the condensers are passed, consists of very few turns of cable of as low resistance as possible, and the secondary s, preferably at some distance from the primary to facilitate free oscillation, has one of its ends — that is the one which is nearer to the primary — connected to the ground, while the other end leads to on insulated terminal T, with which the body of the patient is

connected. It is of importance in this case to establish synchronism between the oscillations in the primary and secondary circuits p and s respectively. This will be as a rule best effected by varying the self-induction of the circuit including the primary loop or coil p, for which purpose an adjustable self-induction e is provided; but in cases when the electromotive force of the generator is exceptionally high, as when a static machine is used and a condenser consisting of merely two plates offers sufficient capacity, it will be simpler to attain the same object by varying the distance of the plates.

The primary and secondary oscillations being in close synchronism, the points of highest potential will be on a part of terminal T, and the consumption of energy will occur chiefly there. The attachment of the patient's body to the terminal will in most cases very materially affect the period of oscillation in the secondary, making it longer, and a readjustment of the primary circuit will have to be made in each case to suit the capacity of the body connected with terminal T. Synchronism should always be preserved, and the intensity of the action varied by moving the secondary coil to or from the primary, as may be desired. I know of no method which would make it possible to subject the human body to such excessive electrical pressures as are practicable with this, or of one which would enable the conveying to and giving off from the body without serious injury amounts of electrical energy approximating even in a remote degree those which are entirely practicable when this manner of applying the energy is resorted to. This is evidently due to the fact that action is chiefly superficial, the largest possible section being offered to the transfer of the current, or, to say more correctly, of the energy. With a very rapidly and smoothly working break I would not think it impossible to convey to the body of a person and to give off into the space energy at the rate of several horse power with impunity, while a small part of this amount applied in other ways could not fail to produce injury.

When a person is subjected to the action of such a coil, the proper adjustments being carefully observed, luminous streams are seen in the dark issuing from all parts of the body. These streams are short and of delicate texture when the number of breaks is very great and the action of the device b (Fig. 5) free of any irregularities, but when the number of breaks is small or the action of the device imperfect, long and noisy streams appear which cause some discomfort. The physiological effects produced with apparatus of this kind may be graduated from a hardly perceptible action when the secondary is at a great distance from the primary, to a most violent one when both coils are placed at a small distance. In the latter case only a few seconds are sufficient to cause a feeling of warmth all over the body, and soon after the person perspires freely. I have repeatedly, in demonstrations to friends, exposed myself longer to the action of the oscillations, and each time, after the lapse of an hour or so, an immense fatigue, of which it is difficult to give an idea, would take hold of me. It was greater than I experienced on some occasions after the most straining and prolonged bodily exertion. I could scarcely make a step and could keep the eyes open only with the greatest difficulty. I slept soundly afterward, and the after-effect was certainly beneficial, but the medicine was manifestly too strong to be used frequently.

One should be cautious in performing such experiments for more than one reason. At or near the surface of the skin, where the most intense action takes place, various chemical products are formed, the chief being ozone and nitrogen compounds. The former is itself very destructive, this feature being illustrated by the fact that the rubber insulation of a wire is destroyed so quickly as to make the use of such insulation entirely impracticable. The compounds of nitrogen, when moisture is present, consist largely of nitric acid which might, by excessive application, prove hurtul to the skin. So far, I have not noted injuries which could be traced directly to this cause, though on several occasions burns were produced in all respects similar to those which were later observed and attributed to the Röntgen rays. This view is seemingly being abandoned, having not been substantiated by experimental facts, and so also is the notion that these rays are

transverse vibrations. But while investigation is being turned in what appears to be the right direction, scientific men are still at sea. This state of things impedes the progress of the physicist in these new regions and makes the already hard task of the physician still more difficult and uncertain.

One or two observations made while pursuing experiments with the apparatus described might be found as deserving mention here. As before stated, when the oscillations in the primary and secondary circuits are in synchronism, the points of highest potential are on some portion of the terminal T. The synchronism being perfect and the length of the secondary coil just equal to one-quarter of the wave length, these points will be exactly on the free end of terminal T, that is, the one situated farthest from the end of the wire attached to the terminal. If this be so and if now the period of the oscillations in the primary be shortened, the points of highest potential will recede towards the secondary coil, since the wave-length is reduced and since the attachment of one end of the secondary coil to the ground determines the position of the nodal points, that is, the points of least potential. Thus, by varying the period of vibration of the primary circuit in any manner, the points of highest potential may be shifted accordingly along the terminal T, which has been shown, designedly, long to illustrate this feature. The same phenomenon is, of course, produced if the body of a patient constitutes the terminal, and an assistant may by the motion of a handle cause the points of highest potential to shift along the body with any speed he may desire. When the action of the coil is vigorous, the region of highest potential is easily and unpleasantly located by the discomfort or pain experienced, and it is most curious to feel how the pain wanders up and down, or eventually across the body, from hand to hand, if the connection to the coil is accordingly made — in obedience to the movement of the handle controlling the oscillations. Though I have not observed any specific action in experiments of this kind, I have always felt that this effect might be capable of valuable use in electro-therapy.

Another observation which promises to lead to much more useful results is the following: As before remarked, by adopting the method described, the body of a person may be subjected without danger to electrical pressures vastly in excess of any producible by ordinary apparatus, for they may amount to several million volts, as has been shown in actual practice. Now, when a conducting body is electrified to so high a degree, small particles, which may be adhering firmly to its surface, are torn off with violence and thrown to distances which can be only conjectured. I find that not only firmly adhering matter, as paint, for instance, is thrown off, but even the particles of the toughest metals are torn off. Such actions have been thought to be restricted to a vacuous inclosure, but with a powerful coil they occur also in the ordinary atmosphere. The facts mentioned would make it reasonable to expect that this extraordinary effect which, in other ways, I have already usefully applied, will likewise prove to be of value in electro-therapy. The continuous improvement of the instruments and the study of the phenomenon may shortly lead to the establishment of a novel mode of hygienic treatment which would permit an instantaneous cleaning of the skin of a person, simply by connecting the same to, or possibly, by merely placing the person in the vicinity of a source of intense electrical oscillations, this having the effect of throwing off, in a twinkle of the eye, dust or particles of any extraneous matter adhering to the body. Such a result brought about in a practicable manner would, without doubt, be of incalculable value in hygiene and would be an efficient and time-saving substitute for a water bath, and particularly appreciated by those whose contentment consists in undertaking more than they can accomplish.

High frequency impulses produce powerful inductive actions and in virtue of this feature they lend themselves in other ways to the uses of the electro-therapeutist. These inductive effects are either electrostatic or electrodynamic. The former diminish much

more rapidly with the distance — with the square of the same — the latter are reduced simply in proportion to the distance. On the other hand, the former grow with the square of intensity of the source, while the latter increase in a simple proportion with the intensity. Both of these effects may be utilized for establishing a field of strong action extending through considerable space, as through a large hall, and such an arrangement might be suitable for use in hospitals or institutions of this kind, where it is desirable to treat a number of patients at the same time.

Fig. 6 illustrates the manner, as I have shown it originally, in which such a field of electrostatic action is established. In this diagram G is a generator of currents of very high frequency, C a condenser for counteracting the self-induction of the circuit which includes the primary P of an induction coil, the secondary S of which has two plates t t of large surface connected to its terminals. Well known adjustments being observed, a very strong action occurs chiefly in the space between the plates, and the body of a person

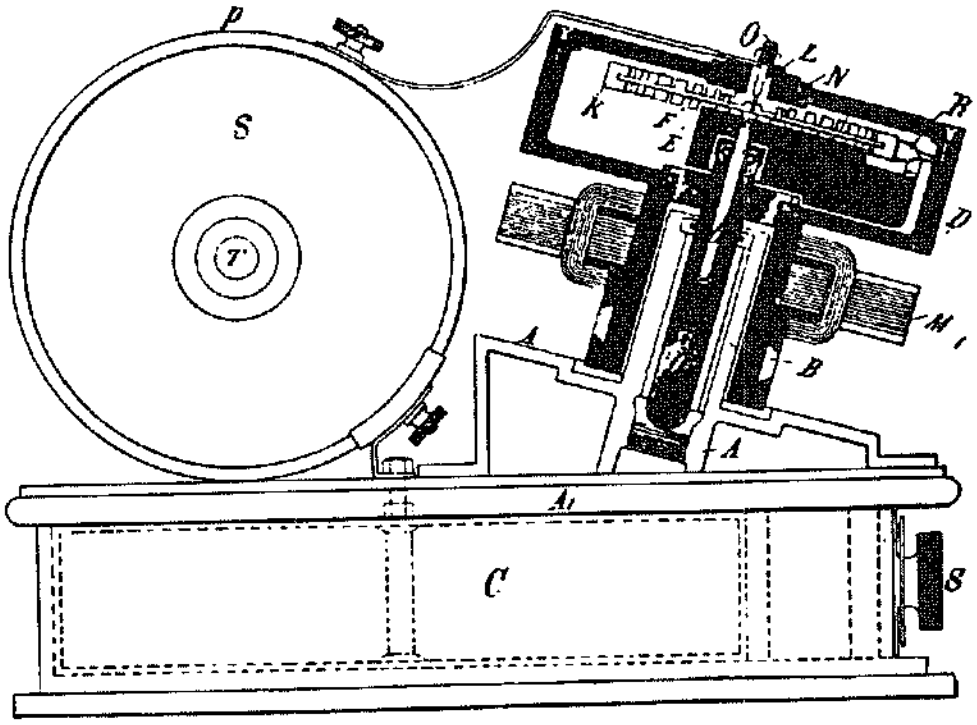

Fig. 9.

is subjected to rapid variations of potential and surgings of current, which produce, even at a great distance, marked physiological effects. In my first experiments I used two metal plates as shown, but later I found it preferable to replace them by two large hollow spheres of brass covered with wax of a thickness of about two inches. The cables leading to the terminals of the secondary coil were similarly covered, so that any of them could be approached without danger of the insulation breaking down. In this manner the unpleasant shocks, to which the experimenter was exposed when using the plates, were prevented.

In Fig. 7 a plan for similarly utilizing the dynamic inductive effects of high frequency currents is illustrated. As the frequencies obtainable from an alternator are

not as high as is desired, conversion by means of condensers is resorted to. The diagram will be understood at a glance from the foregoing description. It only need be stated that the primary p, through which the condensers are made to discharge, is formed by a thick stranded cable of low self-induction and resistance, and passes all around the hall. Any number of secondary coils s s s, each consisting generally of a single layer of rather thick wire, may be provided. I have found it practicable to use as many as one hundred, each being adjusted for a definite period and responding to a particular vibration passed through the primary. Such a plant I have had in use in my laboratory since 1892, and many times it has contributed to the pleasure of my visitors and also proved itself of practical utility. On a latter occasion I had the pleasure of entertaining some of the members with experiments of this kind, and this opportunity I cannot let pass without expressing my thanks for the interest which was awakened in me by their visit, as well as for the generous acknowledgment of the courtesy by the Association. Since that time my apparatus has been very materially improved, and now I am able to create a field of such intense induction in the laboratory that a coil three feet in diameter, by careful adjustment, will deliver energy at the rate of one-quarter of a horse power, no matter where it is placed within the area inclosed by the primary loops. Long sparks, streamers and all other phenomena obtainable with induction coils are easily producible anywhere within the space, and such coils, though not connected to anything, may be utilized exactly as ordinary coils. and what is still more remarkable, they are more effective. For the past few years I have often been urged to show experiments in public, but, though I was desirous to comply with such requests, pressing work has so far made it impossible. These advances have been the result of slow but steady improvement in the details of the apparatus which I hope to be able to describe connectedly in the near future.

However remarkable the electrodynamic inductive effects, which I have mentioned, may appear, they may be still considerably intensified by concentrating the action upon a very small space. It is evident that since, as before stated, electromotive forces of many thousand volts are maintained between two points of a conducting bar or loop only a few inches long, electromotive forces of approximately the same magnitude will be set up in conductors situated near by. Indeed, I found that it was practicable in this manner to pass a discharge through a highly exhausted bulb, although the electromotive force required amounted to as much as ten or twenty thousand volts, and for a long time I followed up experiments in this direction with the object of producing light in a novel and more economical way. But the tests left no doubt that there was great energy consumption attendant to this mode of illumination, at least with the apparatus I had then at command, and, finding another method which promised a higher economy of transformation, my efforts turned in this new direction. Shortly afterward (some time in June, 1891), Prof. J. J. Thomson described experiments which were evidently the outcome of long investigation, and in which he supplied much novel and interesting information, and this made me return with renewed zeal to my own experiments. Soon my efforts were centered upon producing in a small space the most intense inductive action, and by gradual improvement in the apparatus I obtained results of a surprising character. For instance, when the end of a heavy bar of iron was thrust within a loop powerfully energized, a few moments were sufficient to raise the bar to a high temperature. Even heavy lumps of other metals were heated as rapidly as though they were placed in a furnace. When a continuous band formed of a sheet of tin was thrust into the loop, the metal was fused instantly, the action being comparable to an explosion, and no wonder, for the frictional losses accumulated in it at the rate of possibly ten horse power. Masses of poorly conducting material behaved similarly, and when a highly exhausted bulb was pushed into the loop, the glass was heated in a few seconds nearly to the point of melting.

When I first observed these astonishing actions, I was interested to study their effects upon living tissues. As may be assumed, I proceeded with all the necessary caution, and well I might, for I had the evidence that in a turn of only a few inches in diameter an electromotive force of more than ten thousand volts was produced, and such high pressure would be more than sufficient to generate destructive currents in the tissue. This appeared all the more certain as bodies of comparatively poor conductivity were rapidly heated and even partially destroyed. One may imagine my astonishment when I found that I could thrust my hand or any other part of the body within the loop and hold it there with impunity. More than on one occasion, impelled by a desire to make some novel and useful observation, I have willingly or unconsciously performed an experiment connected with some risk, this being scarcely avoidable in laboratory experience, but have always believed, and do so now, that I have never undertaken anything in which, according to my own estimation, the chances of being injured were so great as when I placed my head within the space in which such terribly destructive forces were at work. Yet I have done so, and repeatedly, and have felt nothing. But I am firmly convinced that there is great danger attending such experiment, and some one going just a step farther than I have gone may be instantly destroyed. For, conditions may exist similar to those observable with a vacuum bulb. It may be placed in the field of the loop, however intensely energized, and so long as no path for the current is formed, it will remain cool and consume practically no energy. But the moment the first feeble current passes, most of the energy of the oscillations rushes to the place of consumption. If by any action whatever, a conducting path were formed within the living tissue or bones of the head, it would result in the instant destruction of these and death of the foolhardy experimenter. Such a method of killing, if it were rendered practicable, would be absolutely painless. Now, why is it that in a space in which such violent turmoil is going on living tissue remains uninjured? One might say the currents cannot pass because of the great self-induction offered by the large conducting mass. But this it cannot be, because a mass of metal offers a still higher self-induction and is heated just the same. One might argue the tissues offer too great a resistance. But this again cannot be the reason, for all evidence shows that the tissues conduct well enough, and besides, bodies of approximately the same resistance are raised to a high temperature. One might attribute the apparent harmlessness of the oscillations to the high specific heat of the tissue, but even a rough quantitative estimate from experiments with other bodies shows that this view is untenable. The only plausible explanation I have so far found is that the tissues are condensers. This only can account for the absence of injurious action. But it is remarkable that, as soon as a heterogeneous circuit is constituted, as by taking in the hands a bar of metal and forming a closed loop in this manner, the passage of the currents through the arms is felt, and other physiological effects are distinctly noted. The strongest action is, of course, secured when the exciting loop makes only one turn, unless the connections take up a considerable portion of the total length of the circuit, in which case the experimenter should settle upon the least number of turns by carefully estimating what he loses by increasing the number of turns, and what he gains by utilizing thus a greater proportion of the total length of the circuit. It should be borne in mind that, when the exciting coil has a considerable number of turns and is of some length, the effects of electrostatic induction may preponderate, as there may exist a very great difference of potential — a hundred thousand volts or more — between the first and last turn. However, these latter effects are always present even when a single turn is employed.

When a person is placed within such a loop, any pieces of metal, though of small bulk, are perceptibly warmed. Without doubt they would be also heated — particularly if they were of iron — when embedded in living tissue, and this suggests the possibility of

surgical treatment by this method. It might be possible to sterilize wounds, or to locate, or even to extract metallic objects, or to perform other operations of this kind within the sphere of the surgeon's duties in this novel manner.

Most of the results enumerated, and many others still more remarkable, are made possible only by utilizing the discharges of a condenser. It is probable that but a very few — even among those who are working in these identical fields — fully appreciate what a wonderful instrument such a condenser is in reality. Let me convey an idea to this effect. One may take a condenser, small enough to go in one's vest pocket, and by skilfully using it he may create an electrical pressure vastly in excess — a hundred times greater if necessary — than any producible by the largest static machine ever constructed. Or, he may take the same condenser and, using it in a different way, he may obtain from it currents against which those of the most powerful welding machine are utterly insignificant. Those who are imbued with popular notions as to the pressure of static machines and currents obtainable with a commercial transformer, will be astonished at this statement — yet the truth of it is easy to see. Such results are obtainable, and easily, because the condenser can discharge the stored energy in an inconceivably short time. Nothing like this property is known in physical science. A compressed spring, or a storage battery, or any other form of device capable of storing energy, cannot do this; if they could, things udreamt of at present might be accomplished by their means. The nearest approach to a charged condenser is a high explosive, as dynamite. But even the most violent explosion of such a compound bears no comparison with the discharge or explosion of a condenser. For, while the pressures which are produced in the detonation of a chemical compound are measured in tens of tons per square inch, those which may be caused by condenser discharges may amount to thousands of tons per square inch, and if a chemical could be made which would explode as quickly as a condenser can be discharged under conditions which are realizable — an ounce of it would quite certainly be sufficient to render useless the largest battleship.

That important realizations would follow from the use of an instrument possessing such ideal properties I have been convinced since long ago, but I also recognized early that great difficulties would have to be overcome before it could replace less perfect implements now used in the arts for the manifold transformations of electrical energy. These difficulties were many. The condensers themselves, as usually manufactured, were inefficient, the conductors wasteful, the best insulation inadequate, and the conditions for the most efficient conversion were hard to adjust and to maintain. One difficulty, however, which was more serious than the others, and to which I called attention when I first described this system of energy transformation, was found in the devices necessarily used for controlling the charges and discharges of the condenser. They were wanting in efficiency and reliability and threatened to prove a decided drawback, greatly restricting the use of the system and depriving it of many valuable features. For a number of years I have tried to master this difficulty. During this time a great number of such devices were experimented upon. Many of them promised well at first, only to prove inadequate in the end. Reluctantly, I came back upon an idea on which I had worked long before. It was to replace the ordinary brushes and commutator segments by fluid contacts. I had encountered difficulties then, but the intervening years in the laboratory were not spent in vain, and I made headway. First it was necessary to provide for a circulation of the fluid, but forcing it through by a pump proved itself impractical. Then the happy idea presented itself to make the pumping device an integral part of the circuit interrupter, inclosing both in a receptacle to prevent oxydation. Next some simple ways of maintaining the circulation, as by rotating a body of mercury, presented themselves. Then I learned how to reduce the wear and losses which still existed. I fear that these statements, indicating how much effort was spent in these seemingly insignificant details will not

convey a high idea of my ability, but I confess that my patience was taxed to the utmost. Finally, though, I had the satisfaction of producing devices which are simple and reliable in their operation, which require practically no attention and which are capable of effecting a transformation of considerable amounts of energy with fair economy. It is not the best that can be done, by any means, but it is satisfactory, and I feel that the hardest task is done.

The physician will now be able to obtain an instrument suitable to fulfil many requirements. He will be able to use it in electro-therapeutic treatment in most of the ways enumerated. He will have the facility of providing himself with coils such as he may desire to have for any particular purpose, which will give him any current or any pressure he may wish to obtain. Such coils will consist of but a few turns of wire, and the expense of preparing them will be quite insignificant. The instrument will also enable him to generate Röntgen rays of much greater power than obtainable with ordinary apparatus. A tube must still be furnished by the manufacturers which will not deteriorate and which will allow to concentrate larger amounts of energy upon the electrodes. When this is done, nothing will stand in the way of an extensive and efficient application of this beautiful discovery which must ultimately prove itself of the highest value, not only at the hands of the surgeon, but also of the electro-therapist and, what is most important, of the bacteriologist.

To give a general idea of an instrument in which many of the latter improvements are embodied, I would refer to Fig. 9, which illustrates the chief parts of the same in side elevation and partially in vertical cross-section. The arrangement of the parts is the same as in the form of instrument exhibited on former occasions, only the exciting coil with the vibrating interrupter is replaced by one of the improved circuit breakers to which reference has been made.

This device comprises a casting A with a protruding sleeve B, which in a bushing supports a freely rotatable shaft a. The latter carries an armature within a stationary field magnet M and on the top, a hollow iron pulley D, which contains the break proper. Within the shaft a, and concentrically with the same, is placed a smaller shaft b, likewise freely movable on ball-bearings and supporting a weight E. This weight being on one side and the shafts a and b inclined to the vertical, the weight remains stationary as the pulley is rotated. Fastened to the weight E is a device R in the form of a scoop with very thin walls, narrow on the end nearer to the pulley and wider on the other end. A small quantity of mercury being placed in the pulley and the latter rotated against the narrow end of the scoop, a portion of the fluid is taken up and thrown in a thin and wide stream towards the centre of the pulley. The top of the latter is hermetically closed by an iron washer, as shown, this washer supporting on a steel rod L a disk F of the same metal provided with a number of thin contact blades K. The rod L is insulated by washers N from the pulley, and for the convenience of filling in the mercury a small screw o is provided. The bolt L forming one terminal of the circuit breaker is connected by a copper strip to the primary p. The other end of the primary coil leads to one of the terminals of the condenser C, contained in a compartment of a box A, another compartment of the same being reserved for switch S and terminals of the instrument. The other terminal of the condenser is connected to the casting A and through it to pulley D. When the pulley is rotated, the contact blades K are brought rapidly in and out of contact with the stream of mercury, thus closing and opening the circuit in quick succession. With such a device it is easy to obtain ten thousand makes and breaks per second and even more. The secondary a is made of two separate coils and so arranged that it can be slipped out, and a metal strip in its middle connects it to the primary coil. This is done to prevent the secondary from breaking down when one of the terminals is overloaded, as it often happens in working Röntgen bulbs. This form of coil will withstand a very much greater difference of potential than coils as ordinarily constructed.

The motor has both field and armature built of plates, so that it can be used on alternating as well as direct current supply circuits, and the shafts are as nearly as possible vertical, so as to require the least care in oiling. Thus, the only thing which really requires some attention is the commutator of the motor, but where alternating currents are always available, this source of possible trouble is easily done away with.

The circuit connections of the instrument have been already shown and the mode of operation explained in periodicals. The usual manner of connecting is illustrated in Fig. 8, in which A_2 A_2 are the terminals of the supply circuit, L, a self-induction coil for raising the pressure, which is connected in series with condenser C and primary P P. The remaining letters designate the parts correspondingly marked in Fig. 9 and will be understood with reference to the latter.

THE MAGNETIC-ARC INSTRUMENT OF S.S. KNIGHT

by Mark L. Gallert

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Mr. Knight, a chemical and electrical engineer of Walnut Creek, California, was impressed with the severity and persistence of pain suffered in certain types of cancer. Realizing that pain is a sensation representative of an electrical phenomenon of excessive nerve-current flow, he decided to experiment to see if there was some way of interfering with that nerve flow through artificial impulses, in the effort to stop or alleviate the pain.

Towards this end, he developed an instrument combining several features of electro-therapy:

1. A wave pulsed at 90 times per minute, taking advantage of data obtained from experience with the older types Faradic machines.
2. A rest interval exceeding 75% of the duration of each pulsing cycle - enhances the beneficial effect.
3. Breaking the treatment by mechanical opening of contacts in such a way as to create an arc at each of the pulsing intervals. An arc produces a very wide band of frequencies, from those of very low frequency, to the highest that can be measured. The multiplicity of frequencies seems to play a part in masking or interrupting the sensation of pain.
4. A unique feature of the Knight instrument is that the arc is broken in a strong magnetic field produced by a large, powerful, permanent magnet. This introduces what is called the "Zeeman effect", that is, a magnification of the arc impulses, and a spreading of frequencies.
5. Use of very low power output - below 1/100 of a watt, so that there will be no perceptible heating of tissue when the complex of impulses from the instrument are fed to the patient through electrodes applied to the skin.

Experiments on cases which had been declared terminal cancer by medical doctors, showed that this device not only brought outstanding relief of pain in the majority of instances, but also produced some surprising "remissions" characterized by shrinking of tumour masses, and restoration of general health to the patient.

Dr. C.P. Bryant of Seattle, Washington, who used these instruments extensively in his practice over a period of years, declared that with their use he was able to restore to health 75% of all cancer cases which had not undergone surgery, X-ray or radium, and 25% of those cancer cases which had been subjected to surgery, X-ray or radium.

The Knight family has never represented these instruments as a "cancer cure". The original aim was to find some way to relieve the pain of cancer. Reports from doctors of apparent cures through use of the instruments were received with interest, as well as reports of benefits from the application of the instrument to conditions other than cancer.

Mr. S.S. Knight, a man with pronounced humanitarian ideals, made the circuit of the instrument available to all inquirers and encouraged the building of instruments by anyone who wished to copy his circuit and specifications. He was keenly disappointed when reports reached him of failure, or lack of therapeutic effect from instruments constructed by others. It developed that adjustments were quite critical, particularly concerning the making and breaking of the arc. Mr. Knight could tell by looking at the arc and listening to it, when it was "right". It was difficult to develop objective criteria for adjustment of the equipment.

A puzzling circumstance, was that the maximum effect from Mr. Knight's instruments was obtained when they were new; after a few weeks of use the effect began to diminish; after some months it was perceptibly weaker, and after a year or more, of very little use. Several years ago, the reason for the lessening of effect was determined. The isolation transformer used to block the direct flow of the arc frequencies from the electric line supply (an isolation required to eliminate radio interference) was being saturated by the magnetism from the large magnet surrounding the arc. The more saturated the transformer became, the less electricity it passed. The equipment was re-designed to place the transformer out of range of the field of the magnet.

The instrument can be classed with experimental devices, as there have not been sufficient tests made under controlled conditions to establish with certainty the percentage of cases of various types of cancer that can be alleviated, arrested, and perhaps cured, but the tests to date indicate at least that this is a promising approach, which should be explored further.

An imitation instrument has been marketed by others, using an electro-magnet instead of a permanent magnet. Mr. Knight was opposed to this substitution, having a number of reasons for believing that the permanent magnet was preferable. Other changes have also been made in constructing these imitation instruments, including the type of electrodes. So far as your compiler has been able to determine, the instruments using electro-magnets have some value in relieving pain in a variety of conditions, but the effect on cancer seems to be slower and less pronounced than that obtained from the genuine Knight instruments when the latter are functioning properly and are in adjustment.

FIG. 1—Balanced planar equiangular or logarithmic spiral-slot antenna (left) radiates a broad circularly polarized beam on each side of, and perpendicular to, the plane of the antenna

electronics

April 20, 1962

Frequency-Independent Antennas

SURVEY OF DEVELOPMENT

Antennas now provide continuous coverage of large portions of the frequency spectrum. These very-wide-band antennas offer a challenge to the systems engineer to design equipment that will match bandwidths now available

By JOHN D. DYSON
University of Illinois,
Urbana, Illinois

THE NECESSITY of providing continuous coverage of large portions of the electromagnetic frequency spectrum for defense purposes has exerted great pressure on the antenna engineer to produce antennas that could be used over wider and wider bands of frequencies. Such requirements have led to an important breakthrough in the antenna field. The conception of the frequency-independent antennas at the University of Illinois and their development at this and at other laboratories has produced advances in the state of the art that now puts pressure on the electronics and system engineer to design equipment that will match the available antenna bandwidths. The purpose of this survey is to outline the development of these antennas.

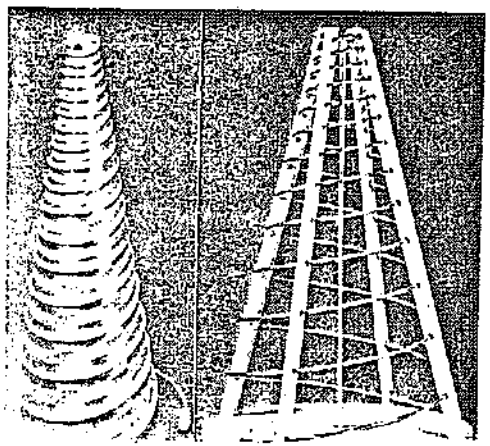

FIG. 2—Balanced conical logarithmic spiral antenna (left) with feed cable carried along one arm; wire version of balanced conical logarithmic spiral antenna (right), fed with coaxial line and balun along axis of cone

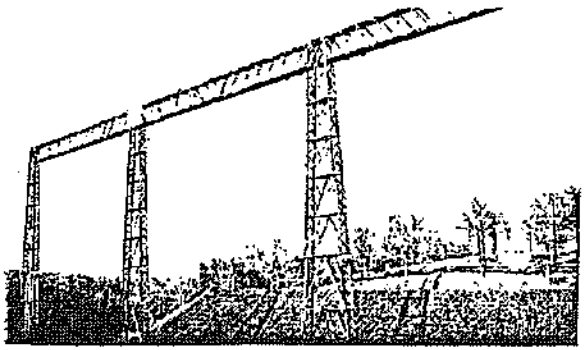

FIG. 3—The University of Illinois radio telescope. The focal line array, 155 feet above the 400-by-600-foot parabolic reflector, is visible below the wooden truss

As of 1945, antenna research and development had led to a few structures that operated over a 2 to 1 or slightly greater range of frequencies, with acceptable radiation and impedance characteristics. In a majority of cases, it was the radical changes in the radiation pattern with changes in operating frequency which limited the usefulness of antennas to somewhat less than this 2 to 1 range, since antennas had been developed with an input impedance that remained relatively constant with a change in frequency.

The discone antenna[1] introduced in 1946 was one of the first antennas that could be used over approximately a 4-to-1 range of frequencies. Advances during the next 7 or 8 years were limited, mainly, to increasing the bandwidth of existing antennas by a few percent. The one exception during this period was a modified helical antenna[2, 3, 4]. These unbalanced conical helical structures, fed against a ground plane, had acceptable pattern bandwidths of 4 or 5 to 1.

The spiral antenna introduced in 1953 was a major step forward in wide band antenna design. This construction consists of two flat, narrow, constant-width metallic arms, wound in an Archimedean spiral.[4] Fed at the center in a balanced manner, it radiates a broad circularly polarized lobe on each side of the plane of the antenna. Subsequent development of this configuration produced forms that had stable pattern and impedance characteristics over bandwidths up to 10 to 1.[5,6]

Arrays of the Archimedes spiral antenna provide variable polarization of the radiated field[7] and beam scanning by simple rotation of the antennas.[5,7]

In 1954 a major breakthrough occurred when V.-H. Rumsey suggested that an infinite length structure based upon the equiangular or logarithmic spiral could be specified completely in terms of angles, and hence it should have characteristics independent of frequency. A study of balanced planar antennas based on these curves disclosed the equiangular spiral antenna to be the first antenna of practical size that had characteristics associated with an infinite structure.[8,9] This structure became the first of a class now called frequency-independent antennas.[9]

This descriptive term is applied to antennas set apart from the usual concepts of operating bandwidth. The upper and lower frequencies at which these antennas may be operated are determined by independent paramters, and hence the bandwidth over which the radiation pattern and input characteristics are essentially constant is theoretically unlimited. Actually, the bandwidth is limited only by practical considerations of construction, and such antennas have been built to operate over a bandwidth of more than 42 to 1. There is no fundamental reason why this bandwidth cannot be extended.

The general philosophy behind the frequency-independent antennas is to design a radiating structure such that successive applications of a scaling factor result in structures identical with the original, or which at most, differ by some rotation about an axis through the origin of the original structure. Although the structure must be infinite in size to fulfill the scaling condition of exact equivalence, forms based upon the equiangular, or logarithmic, spiral curve may be truncated to a finite size and still retain, over an extremely wide range of frequencies, characteristics associated with the infinite structure.

A second breakthrough occurred in 1955 when R. H. Du Hamel proposed to force radiation from otherwise angular structures by periodic discontinuities. This led to a linearly polarized antenna with pattern and impedance characteristics that repeat periodically with the logarithm of frequency.[10,11] Although these logarithmic-periodic antennas scale exactly at only certain discrete frequencies, they can be designed so that the radiation characteristics do not change appreciably over the period between these frequencies. Hence they also exhibit nearly frequency-independent characteristics.

Many versions of the log-spiral and log-periodic antennas have been developed. The planar log-spiral antenna shown in Fig. 1 is bidirectional, radiating a broad circularly polarized beam on each side of, and perpendicular to, the antenna plane.[9] This spiral antenna may be made unidirectional, and hence more useful, by an orthogonal projection of the balanced spiral arms upon the surface of a cone (see Fig. 2 left).[9,12] For included cone angles less than about 45 degrees, radiation is confined to one broad circularly polarized lobe with maximum radiation off the apex of the cone. The antenna is balanced, with the feed voltage applied between the two arms at the apex of the cone. This feed voltage may be supplied by a conventional balanced line carried along the axis of the cone, or by a coaxial line and balun.

The characteristics of equiangu-

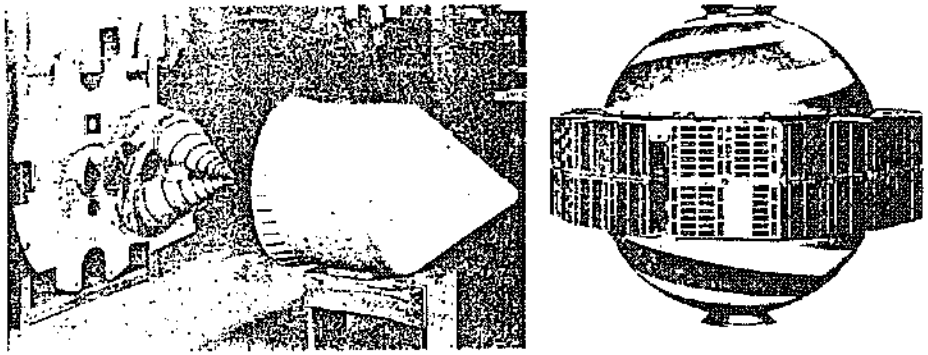

FIG. 4—First production of Dynatronics 500-to-4,000-Mc dual conical spiral Autotrack feed for 40-foot diameter parabolic reflector (left); Transit 5B satellite (right) by Applied Physics Lab. of the Johns Hopkins University. The logarithmic spiral antenna projected onto the spherical surface provides for transmission at 54, 108, 162 and 216 Mc

lar spiral antennas permit a third method. The feed line, a coaxial cable, may be carried along and soldered in contact with one of the arms. The amplitude of the antenna currents on the arms, and also on the outside of the cable, fall off rapidly with distance from the apex, so the ends of the arms where the cable enters carry negligible antenna current. This optional feed, conveniently and automatically, provides a frequency-independent balun, permitting feeding the balanced antenna by means of an unbalanced line.

Conical log-spiral antennas have been constructed to operate over more than 40-to-1 bandwidths. The upper usable frequency is determined by the truncated region at the apex which must remain less than 1/4 wavelength at the highest frequency of operation. The lowest usable frequency is determined by the base diameter of the cone which, for tightly wrapped antennas, must be approximately 3/8 wavelength at lowest operating frequency.

A highly practical conical log-spiral antenna can be constructed by allowing the exponentially expanding arms to degenerate into narrow constant width structures following the logarithmic spiral curve (see Fig. 2 right).[5,6] For tightly wrapped spirals this version has characteristics similar to the original antenna. This wire version, simple to construct, may be excited by bringing the feed cable up the axis of the cone. If the infinite balun feed is desired, the feed cable itself can become one of the arms, with a dummy cable becoming the second arm of a balanced structure.

The balanced conical log-spiral antenna has characteristics other than bandwith that are attractive. The electromagnetic fields radiated by these antennas are essentially circularly polarized over very wide angles off the axis of the antenna. In addition, the phase of the far field of the two-arm antenna has essentially a one-to-one relationship with the azimuthal angle around the antenna. These two properties were utilized in the line feed for the University of Illinois radio telescope shown in Fig. 3. The focal-line array for this 400-by-600-foot parabolic reflector consists of a linear array of 286 conical logspiral antennas.[7] The beam is steerable in declination ±30 degrees and the phase adjustment to provide this scan is secured by a physical rotation of each element of the array to a prescribed orientation. Thus it is of importance that the beam of each element be circularly polarized over at least a sector ±30 degrees from the axis and that the phase of the radiated field be linearly related to the angle of orientation around the antenna.

Multiarm versions of the balanced conical log-spiral antenna operate in several distinct modes.[5,6] Thus a four-arm symmetrical structure may be excited to radiate an axial beam with an $e^{j\phi}$ variation, that is, the phase of the far field varies linearly with the azimuthal angle ϕ, around the antenna. It can be excited to produce a conical beam with an $e^{\pm j\phi}$ and a conical beam with an $e^{\pm j2\phi}$ variation. Since orientation of the maximum of the conical beam may be controlled by varying the rate of spiral of the antenna arms, it can be positioned perpendicular to the axis of the antenna to provide a simple very-wide-band circularly polarized omnidirectional source. The well-behaved phase characteristics of these antennas suggest the basis for many variations of phase-comparison direction-finding systems.[8]

The conical log-spiral antennas have been developed as feeds for dishes used in tracking applications.[9,10,11] A modernization program is now under way to equip many of the large parabolic reflector antennas on the Atlantic Missile Range with dual conical spiral feeds designed to cover a 10-to-1 range of frequencies.[12] The first production model of one of these feeds is shown in Fig. 4 (left).

In an interesting modification of the log-spiral geometry, the planar antenna, was projected upon a spherical surface and used on the Transit satellites[5] shown in Fig. 4 (right). Although this geometry is no longer frequency independent, the antenna operates well over four frequencies, spaced from 54 to 216 Mc. Similarly, the planar antenna can be projected upon a myriad of surfaces. However, it can be shown that the conical surface, which includes the plane, is the only surface satisfying the required scaling principles for unlimited bandwidth.

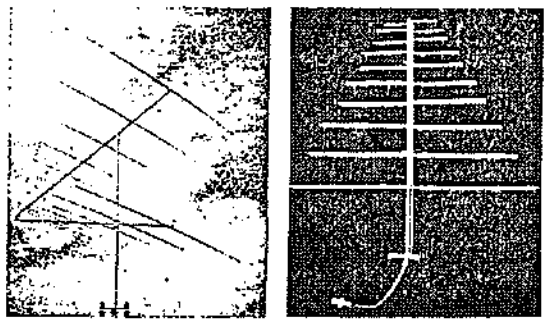

FIG. 5—Trapezoidal tooth nonplanar log-periodic antenna (left) designed by Collins Radio Company to cover 6.5 to 60 Mc; and logarithmic periodic dipole array (right)

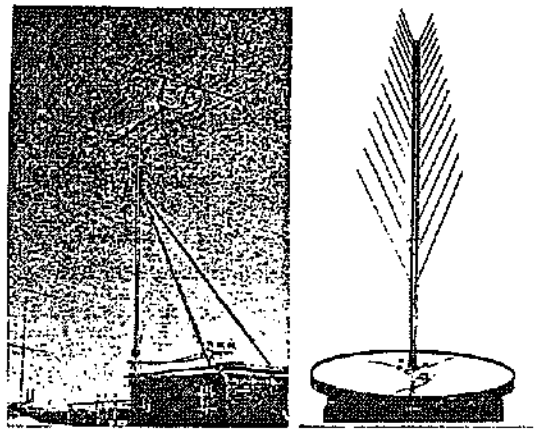

FIG. 6—Militarized version of the log-periodic dipole array (left) by Collins Radio Company; and log-periodic resonant-V array (right), an adaption of the log-periodic dipole array, designed to operate in several different modes

The log-periodic antennas have been extensively investigated. The planar antenna can be modified to provide unidirectional patterns by forming the two elements of the antenna into a V, that is, a nonplanar arrangement.[5] A wire version of the log-periodic elements (see Fig. 5 left), and omnidirectional horizontally polarized, and unidirectional circularly polarized log-periodic antennas have been described.[6] Multielement arrays have been described,[4] and design information for log-periodic antennas as feeds for dishes, and as point-to-point h-f communications antennas has been given.[5,6]

The dipole array of Fig. 5 (right) is a simple log-periodic structure.[4] The length of each element in this array bears a fixed ratio to the length of the preceding element, and the adjacent element spacings bear the same ratio one to another. The pattern and impedance characteristics of the array at frequency f_n, such that the nth element is resonant, will be repeated at a higher frequency f_{n+1} which makes the $(n+1)$th element resonant. The characteristics repeat periodically at all frequencies given by $\tau^n f$, where n is an integer and τ the ratio of the lengths of adjacent elements. The geometry shown in this figure provides an excitation with a 180-deg phase shift between elements. Thus it radiates a single-lobe, linearly polarized beam, directed toward the apex of the array. Analysis and design information for this array has been presented.[4,5] A militarized version of the antenna is shown in Fig. 6 (left).

In an extension of this work, a log-periodic monopole array has been described in which simple reactive networks produce the proper monopole current amplitude and phase distribution for unidirectional frequency-independent operation.[5] A slot complement of the log-periodic dipole array has also been investigated.[5]

The log-periodic resonant-V array[4] (Fig. 6 right) is an adaptation of the log-periodic dipole array, designed to operate in several modes. In the lowest order mode, the performance approximates the log-periodic array. The active portion of the antenna centers around elements whose lengths are near a half-wavelength at the frequency of operation. As the operating frequency is increased, this active region moves toward the apex. The antenna may be designed so that as the $\lambda/2$ region moves off the apex of the antenna the large elements on the other end approach a $3\lambda/2$ resonance. Thus, as the operating frequency is increased, the active region moves through the array in the $3\lambda/2$ wave mode, then in the $5\lambda/2$ mode, etc. Forward tilt of the individual elements insures a unidirectional beam and provides increased directivity. This antenna has transition regions between modes where the characteristics deteriorate, but it can provide a gain of approximately 15 db over an isotropic radiator in the higher modes.

Triangular or zig-zag log-periodic structures have received considerable attention. A flush-

mounted sinuous structure, fed by a waveguide, has been studied,[46] and a balanced zig-zag antenna has been proposed.[47] A vertically polarized log-periodic zig-zag antenna[48] is shown in Fig. 7. The teeth bent parallel to the ground plane serve as a delay line to phase the vertical radiating portions.

Tapering structures, not constructed in a logarithmic periodic manner, have led to antennas of appreciable bandwidth. One tapered ladder antenna[49-50] consists of symmetrical elements excited by a balanced line. In addition long slot, tapered feed, structures that can be used over a 10-to-1 bandwidth have been proposed.[51] A radiating horn with side walls of periodically spaced wires,[52] when fed from a ridged waveguide, can be operated over a 4-to-1 range of frequencies.

The frequency-independent antennas have opened up a new era in wide-band antennas. However, in view of their complex geometry, the experimental and empirical development of these antennas have outstripped their theoretical analysis.

The theoretical problem of the log-spiral antenna has received considerable attention. This problem has been attacked by calculating the fields due to a logarithmic spiral filament,[53] and the fields produced by an infinite number of planar logarithmic spiral filaments.[54-56] An approximate analysis for the radiation patterns of a filamentary log-spiral antenna with an assumed current distribution has been published.[55-57-58]

A recent comprehensive analysis of the log-periodic dipole array has been reported.[59]

A new and promising approach considers the log-periodic antenna as a locally periodic structure whose period varies slowly, increasing linearly with distance to the origin or apex.[60] This approach indicates that the basic ingredients for a frequency-independent antenna are a slow-wave transmission medium and a series of radiating elements, satisfying the similarity condition, coupled to the transmission medium at points spaced in geometric progression. Such a structure produces a wave substantially radiated toward the feed point with characteristics that vary little as the operating frequency is varied over extremely wide bandwidths.

A general consideration of the log periodic zig-zag antennas and the conical log-spiral antennas as locally periodic, slow wave structures has led to a better understanding of their operation and to some useful design criteria.[61-72]

This survey has covered the work of many people. It has been impossible to acknowledge the work of many others, however an extensive list of references has been included.

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Medical Aspects of Ultra Short Waves

By C. H. West
U. S. Public Health Service

Mr. West here describes some of the effects and also some of the dangers of subjecting the human body to powerful ultra short wave fields

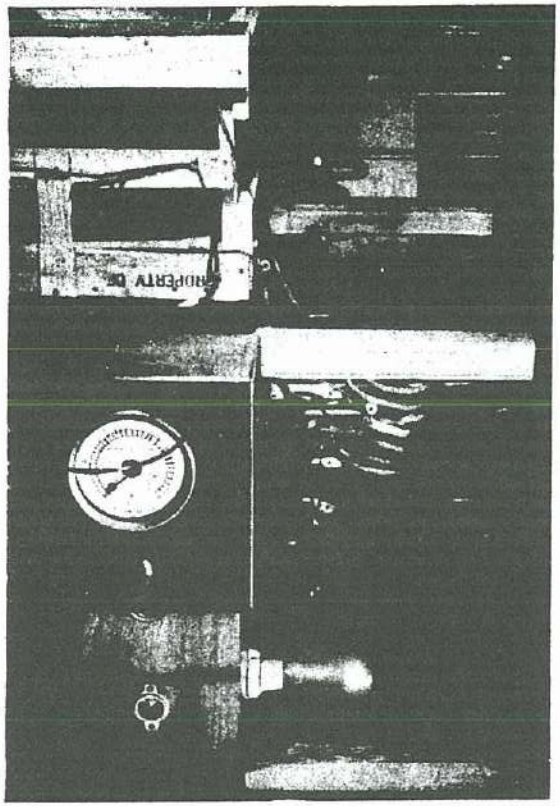

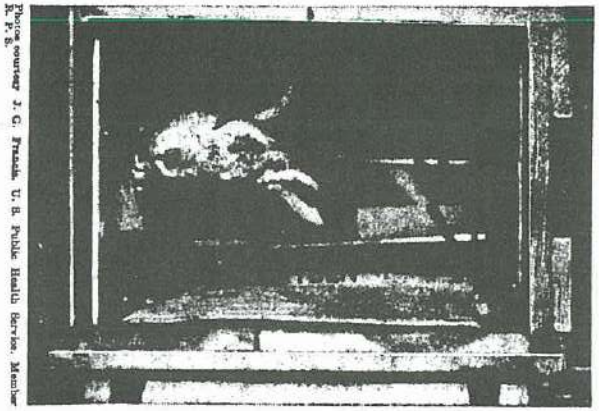

Photos courtesy J. G. Francis, U. S. Public Health Service, Member I.R.E.

Above—A rabbit about to be exposed to a powerful ultra short wave field; the sides as well as the top and bottom linings of the cabinet are of metal.

At left—The appearance of the ultra short-wave apparatus built and tested by Mr. West in his experiments.

● IT SEEMS that the general public is once again taking to radio and the art of building as a pastime. The amateurs are busy developing the five meter band, while the engineers are devoting a goodly portion of their time

to dabbling in the mysteries that the ultra short waves have created.

On the other hand, medical-scientific personages are making use of their medical knowledge, plus a large portion of electronics, in efforts to make the world a better place to live in with less aches and pains to bother us.

Many engineers employed in large electrical laboratories have made valuable use of their knowledge pertaining to the ultra short waves, and have constructed oscillators of high power for the purpose of producing fever in the human body at will. It is a known fact that fever is nature's doctor to a certain degree. If it can be produced in cases where there is no cause for a high fever, the patient's chance for recovery and cure is far better than combatting disease by injection of malaria germs, etc., which may produce reactions worse than the disease itself

Unknown Qualities

However, the production of fever by an oscillator is a simple procedure, but the application of these high wave speeds to the human body is an entirely different matter. Secondly, the output or radiation of an ultra high frequency oscillator has never been completely identified.

It seems that for every known element discovered there are many others within—undiscovered. An illustration of this fact was brought to light very recently, in which the writer witnessed a demonstration of photo-electric cell work.

A double-cell apparatus manufactured by the Weston Electrical Instrument Corporation produced readings in foot-candles from the output of a 10 k. w. X-ray tube in which the cells were completely covered by ⅛ inch lead sheet.

The roentgen rays do not penetrate lead, and as the tube was quite a distance from the cells, the reaction in the sensitive meter was not due to heat waves, but simply a current output which registered through the lead upon the faces of the cells. The X-ray is noted for producing very bad burns if not handled properly, and the deflection from the *target* is called and identified as the *roentgen ray* after the name of the discoverer. How does science know whether the burns are caused from this additional element as registered in *foot candles*, for want of a better name?

U. S. W. "Fever" Apparatus

Recently, the writer constructed and put into practice an *ultra short wave oscillator* for the production of fever or temperature. This apparatus consisted of two UX-852 tubes arranged in push-pull, but with the "back-to-back" arrangement of *Mesny-Valuri*. It is a persistent oscillator and is capable of running long hours on wavelengths from 2 to 10 meters.

An auxiliary cabinet was constructed with two leads to couple across the plate inductance. This cabinet has one adjustable side; the top and bottom being one lead, and the two sides the other and forming a large condenser.

Rabbits were used in experiments and their temperature reached 41 degrees (Centigrade) from the usual 38 degrees (normal). However, after a few weeks severe burns were noticed. Since that time research has been carried on by other factions in an effort to ascertain the direct cause of the burns, which do not seem to be due to collections of moisture, or from coming in contact with the condenser plates.

This brings to mind that experiments by the writer with the very short waves disclose the fact that some sort of a photo-electric ray could be produced and would highly expose small dental films. It is believed this elementary action was first discovered by Mr. John Reinartz, the noted radio amateur, who perceived a bluish glow within an auxiliary indicator at a certain frequency.

Before any actual application to humans may be applied, it is our duty to ascertain accurately whether other elements are prevailing. To all indications there are many, and one of them is severe burns, which may be caused by an unidentified element.

Constructional Data and Summary

As will be noted in the photographs, the apparatus is entirely enclosed and surrounded by glass sides to better view the "works" in case things tend to go the "hay-wire" route. The lower portion of the cabinet contains the necessary plate and filament transformers, which operate direct from the 110 volt, 60 cycle line. The plate power is raw A. C. at a potential of 2600 volts, the filament transformer being the customary 10 volt affair. Inductances are removable; the ones shown are at present used for 30,000 kc. work. The circuit is shown in Fig. 1, which is the conventional push-pull method.

However, the auxiliary cabinet is for purpose of holding an animal within the field and without strapping him and causing discomfort. The condenser plates are of sheet metal and insulated, the schematic diagram appearing in Fig. 2.

When a rabbit is placed in this pen and the power applied, he fails to react immediately; but as he "warms" up to the situation the veins in the ears show dilation, and in 20 minutes his temperature starts to rise and keeps going. It is only at a much later date that burns are noticed.

From the foregoing it would hardly seem advisable to subject a human to any lengthy treatment, at least, for the present; but the value of high frequency in various forms have proved essential in many cases. Secondly, the natural heavy perspiration that is produced is essential in one degree in opening the pores (some of which have probably never been opened before) and allowing the natural poisons of the body to escape more quickly than could have been accomplished with potent medicines.

The majority of high frequency apparatus produces this result. In the case of pulsating currents, which produce a series of reactions or "jumps" within the muscular system, this often is very beneficial in activating those muscles which could not have been manipulated manually without a great degree of pain.

Probably the first reaction noticed with reference to the ultra high frequencies were from early experimenters while conducting transmission tests with high power. It was noticed that the body temperature tended to rise at various times, due entirely to their proximity to a powerful oscillator. Science has been looking for a long time for some method to raise the temperature in the human body *quickly*. Ultra high frequency oscillators have solved that problem but have brought many other matters to light. Secondly, to produce the desired results the patient must be enclosed between two or more condenser plates of large proportions. The oscillator must be of high power, capable of delivering 500 watts output and the patient must be wrapped in a suitable covering to prevent his contact with any portion of the charged plates.

Various research workers who have volunteered their services as "trial patients" have received a goodly portion of burns as compensation, and are quite satisfied that ultra high frequency currents are "hot stuff!" Where heat is concerned, one could get equivalent results by setting on a hot steam radiator. The writer knows this to be true, and has experienced many a painful burn which he would have been willing to trade for a shock from a quarter kw. closed-core transformer.*

It could hardly seem probable that burns would prevail where the body is not in contact with any metallic object; but an examination under darkness of a large condenser tapped from the oscillator, will disclose a bluish aurora between the two elements, which is similar to that noted in Tesla coil experiments. Within this bluish discharge there can be many components not yet identified, which have a tendency to attack tender portions of the body and produce an internal burn, which does not come to the surface for identification until some days have passed.

It is open to discussion whether one-half of the electrical apparatus in present use actually cures the patient of pains, or whether it is the psychology of the matter in which the patient is surrounded by, many cabinets of mysteries, of which he knows absolutely nothing. What cures one man does not seem to cure another with the identical complaint.

*Yes—but it is generally understood we believe, that the high frequency currents or field causes heat to be developed inside the body; even in organs such as the liver, etc., without heating up the whole body, which is not the case with direct application of heat as when seated on a hot radiator, etc.—Editor.

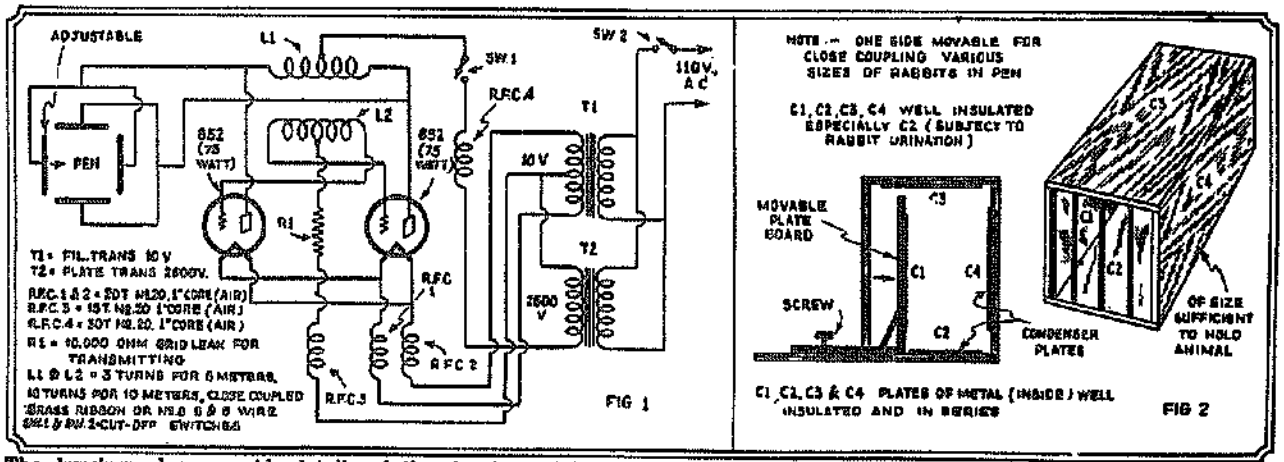

FIG 1
FIG 2

The drawings above provide details of the circuit used by Mr. West in building his ultra short-wave physiological apparatus, together with details of the apparatus itself.

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Short Waves in Medicine

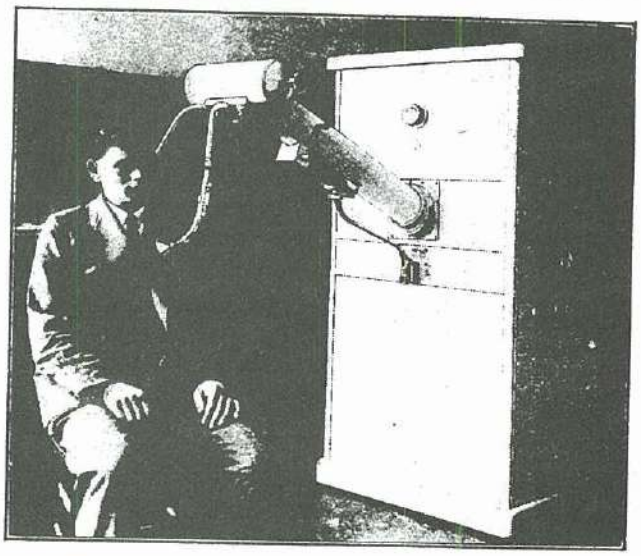

ULTRA SHORT WAVES IN *MEDICINE*

By DR. FRITZ NOACK
(*Berlin*)

PROFESSOR ESAU, of the University of Jena, the well-known pioneer in the field of ultra short waves, was the one who nearly two years ago pointed out that very evidently the ultra short wave exercised beneficial medicinal effects.

For further investigation of this effect, small mice were put between the condenser plates of the sender; and Lo! after some time the mice fell victims to a sort of tetanus, which eventually led to death. The result of this fact was that Prof. Esau resolved to commission a physician to make a further study of the physiological effect of these ultra short waves. Naturally the serious investigation of medicinal effects requires experience in physical measurements, likewise an apparatus operating in a constant and easily controlled manner.

Siemens and Halske Interested

It is gratifying that a manufacturer which already possesses very great experience in constructing electro-medical apparatus and which also has the requisite experience in physical measurements, the prominent firms of Siemens and Halske took up the matter. Now this company has manufactured a first ultra-short wave *radiation apparatus* and recently exhibited it to a picked group of scientists and to the press.

The pictures show the new set which, of course, has to be considered as the first of an evolutionary series. There will still be necessary all sorts of experiments to produce the set in such form that it will correspond to all the needs of the medical profession. The present set will, for the time being, be used for the further study of the physiological effect of ultra short waves. It will be the problem of the doctors to investigate the fields of use and the conditions under which the set may be used.

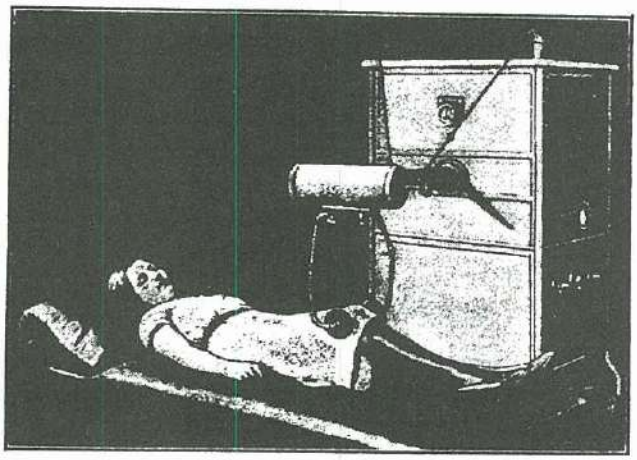

One of the "fair sex" receiving a treatment through the knee by ultra-short waves. Several treatments are given for the average ailment.

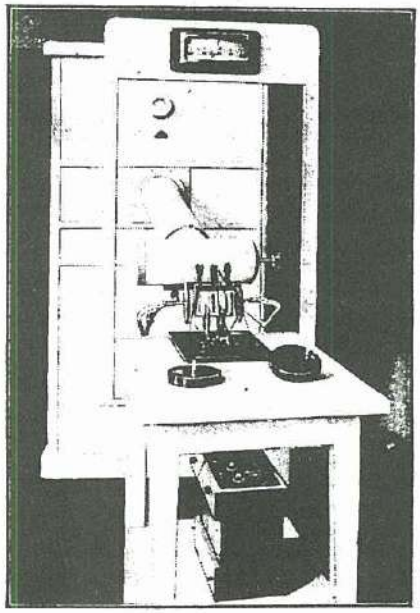

The ultra-short wave medical apparatus with its electrode arm adjusted to permit the waves passing through a solution for experiment.

Arrangement of U. S. W. Generator

In the large shielded box are the real ultra short wave generator—(actually resembling a radio transmitter) and the parts needed for its operation. The generator can work on two waves, four and eight meters. The wavelength is adjusted by inserting the proper tuning coils. The arm which projects out of the apparatus has inside it two lead wires which convey the oscillations outward; they are led to the two electrodes, which are placed at the ends of the two visible supports.

In the cross-beam at the end of the arm is a "tuning" device, which tunes the electrode oscillatory circuit exactly to the wavelength of the generator. The exact tuning can be read on a meter, which is above the arm on the box; this shows the direct plate current of the transmitter, which, with correct tuning of the electrode circuit, adjusts to a minimum; the value then indicated by the meter gives, after calibration of the a value for the electrode energy.

To be able to adjust the electrodes, as is necessary from one case to an-

other, the electrode arms are set in ball-joints. To ascertain whether oscillations are actually present in the electrode oscillatory circuit, there is on one electrode arm a little *glow lamp* (Neon tube), which lights up in the presence of oscillations.

Electrodes Swing on Giant Arm

The arm projecting out of the apparatus can be swung in all directions, for the better use of the whole unit. To accomplish this, it is fixed to the box in a universal joint. The end cross-piece of the arm can furthermore be turned, so that the electrodes can assume any desired direction. The right side wall of the box contains the main current switch, as well as a resistor with which the filaments of the tubes are regulated. The apparatus is in fact constructed just like a vacuum tube radio transmitter. The electrodes may take various forms; in accordance with the most recent experiences, they are so shaped that they do not have to be put firmly against the body, but exercise their effect even in the presence of a layer of air between body and electrode. At the same time, the remarkable fact may be determined, that the thickness of the layer of air and the "depth effect" are dependent on each other.

Advantages of Ultra Short Waves

According to all experiences thus far, the medicinal ultra-short wave radiator is a sort of *diathermal* apparatus; therefore it serves to conduct to the part of the body, or the organ to be treated, electric wave energy, which is converted into heat and thereby exercises a healing effect. As compared with the usual diathermal sets (which operate on a wavelength of about 600 meters, using leaden electrodes, which have to be put right on the body), the *ultra-short wave set* offers a considerably better control of the direction in which the heat is to be applied, so that one can better reach any desired organ than was possible before. Furthermore, by changing the wavelength, one can also adjust for a definite deep-lying stratum. Unpleasant accompanying phenomena, which result with the usual diathermal sets, where the electrodes do not rest firmly on the body, do not occur in the case of the ultra short wave radiator. It is especially important to note that one can now, for the first time, perform a "therapy" or treatment directly on the head. The operation of the set is very simple.

Whether, besides the warming of the different strata in the body, still other biological effects occur or can be accomplished, with the new ultra short wave radiator, is, at the present time, still a matter of question.

HUMAN BEINGS *as* ANTENNAS

By DR. ERWIN SCHLIEPHAKE, M.D.
Of the Jena University Medical Clinic

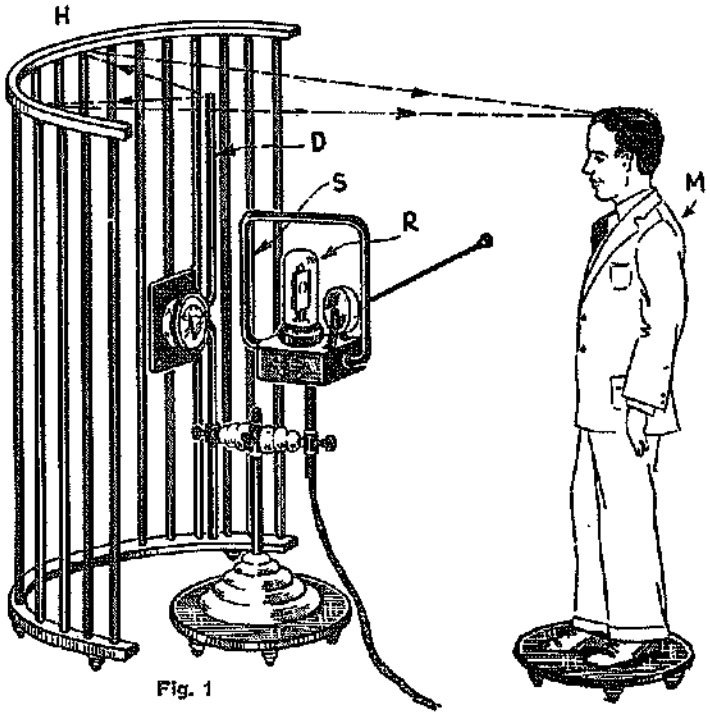

Fig. 1

Arrangement of the apparatus used by Dr. Schliephake in measuring and observing the effects of short waves on the human body, absorption, et cetera. H, parabolic reflector formed of wires; D, antenna, charged inductively by the coil S; vacuum tube at R, and beside it wave changing condenser; subject at M.

IF human beings remain in the vicinity of powerful radio transmitters, they are exposed to a very strong electromagnetic field. One must therefore ask what significance these radiations have for the internal organs, and how the body reacts to them. This question is justified by the fact that all other kinds of electromagnetic rays influence the human body more or less strongly.

The character, however, of the reaction is different, according to the wavelengths. Radium rays and X-rays, for example, because of the extraordinary shortness of the waves and the high effectiveness of energy under these conditions, exercise a very strong effect on the structure of atoms; so that serious injuries to the organism can arise (for instance, under certain conditions, cancer). Less serious are the effects of light rays which, however, in the ultra-violet part of the spectrum, can still occasion serious injuries; while the visible light which we perceive is of too low a frequency to injure healthy persons. There are, however, subjects, made sensitive by illness, who suffer serious affections of the skin from strong illumination. Above the optical spectrum, there follow the infra-red and heat waves, whose effect on atoms is relatively slight; in the case of still longer waves only molecular effects are to be expected. Here we are entering

the range of the Hertzian waves, electric waves in the stricter sense. Of these, the shortest are about half a millimeter (.02-inch) long, and therefore just above the heat radiations.

From direct analogy, it is to be assumed that the shortest of these waves must be absorbed by human bodies, as in the case of heat rays, and this absorption can be actually demonstrated.

DO YOU KNOW —

¶ What effect short waves have on the hair and scalp in general?

¶ Whether the current in the exciting antenna increases or decreases when a person stands in its field? Why?

¶ If the person stoops will this affect the reading of the antenna current meter?

¶ Whether "cold" or "heat" is produced inside the body by an overdose of the high frequency waves?

¶ The effect of short waves on the nervous system?

Absorption of Radio by the Body

With specially-built transmitters, especially such as those which have been described by Kohl, electric waves only a few centimeters in length can be produced; these waves can be reflected by mirrors, exactly like light rays. If one puts the antenna in the focus of a concave mirror, then there is formed a parallel beam of radiation which can be concentrated again in another concave mirror. By means of a lens placed in the course of the radiation, the ray is made very sharp. If a person steps into this path, reception ceases. Since no reflection by the human body or only a very slight one is demonstrable, absorption of the radiation must have occurred; this effect is, moreover, demonstrable in the case of other organic substances or water. Unfortunately, not much can yet be said about the physiological effects of these radiations; the power of the transmitters of extremely short waves is still too low to produce perceptible changes.

It is otherwise with the wavelengths from three meters up, to the production of which powers of several kilowatts can be applied. Here the above described optical phenomena cannot be so well demonstrated, because the diffraction is much greater; but absorption by the human body can be very well shown.

When an antenna is inductively coupled to a 3-meter transmitter, the oscillations can be indicated by a detector even at a considerable distance away. If however, a person puts himself in the place of the antenna, the detector responds much more weakly, although the power consumed by the transmitter remains the same. Accordingly, a part of the power must have been used up in the body. The same phenomenon can be demonstrated as follows: a closed or open oscillation circuit is inductively coupled with the transmitter (see Fig. 1). The ammeter in the circuit shows a definite current strength. If a person places himself on an insulating stool beside it, the current in the oscillation circuit is reduced. This withdrawal of energy, however, depends on the length of the body; for if the subject stoops, or changes to a sitting position, the current in the other circuit increases (Fig. 2). Therefore, it appears as though, by the tuning of the subject, *to about half the wavelength, the power transmitted to him becomes much greater.*

Concentrating Power by Means of a Reflector

By means of a large concave mirror one can also collect the transmitted power to a focus. Such a mirror need consist only of parallel wires stretched between two wooden frames. Its height must be equal to the wavelength, the opening one and one-half times the wavelength. It is best to use elliptical reflectors, with the transmitting antenna at one focus; then the reflected radiation is at the other focus of the ellipse. With a "dipole" ("Hertzian" antenna) containing an ammeter, especially strong concentration of energy at this point can be demonstrated. Here a lessening of the current in the dipole is instantly shown if a person steps into the vicinity. Since the human body is to be regarded essentially as an electrolytic system, with regard to the electric wave, and I have tried to demonstrate the effect in the following manner in a model experiment.

A glass tube, of half the wave's length, was filled with an 0.5% sodium chloride (salt) solution, to which gelatine was added to prevent convection. In this jelly the temperature was measured, at different places, by thermo-elements. It was shown that the heating was greatest in the middle and least at the ends; being half as strong at the quarter points of entire length as it was in the middle. Since the maximum strength of the current is at the middle, the greatest heating is therefore connected with this.

Physiological Effect of Short Waves

Especially noteworthy, also, was a feeling of vibration, which was particularly evident if the hand was raised in front. We could establish this sensation only at our transmitter, which is operated with 50-cycle alternating current. There must be, therefore, a direct influence on the nervous system. Here too we have, therefore, another proof that the ultra-short radio waves exercised an effect on the nerves.

These vibrations are also felt if the hand is placed in a condenser's field. Many persons who remain close to the transmitter also experience remarkable sensations on the head, near the roots of the hair; these are like a peculiar prickling, the hair likewise standing up a little. In many subjects we could also observe slight increases in bodily temperature, which however did not exceed 0.5 of a degree, Centigrade (0.9 degree Fahrenheit). Since the body contains extremely fine regulators, by which the temperature is always kept constant, and since also the amounts of energy which can be conveyed into the body, even by powerful radio transmitters, give (when translated into heat units) only a relatively low number of calories, this increase in heat is probably not attributable to the received energy alone. As is to be shown later, nervous effects may play an important part in this.

The effect on the nervous system is

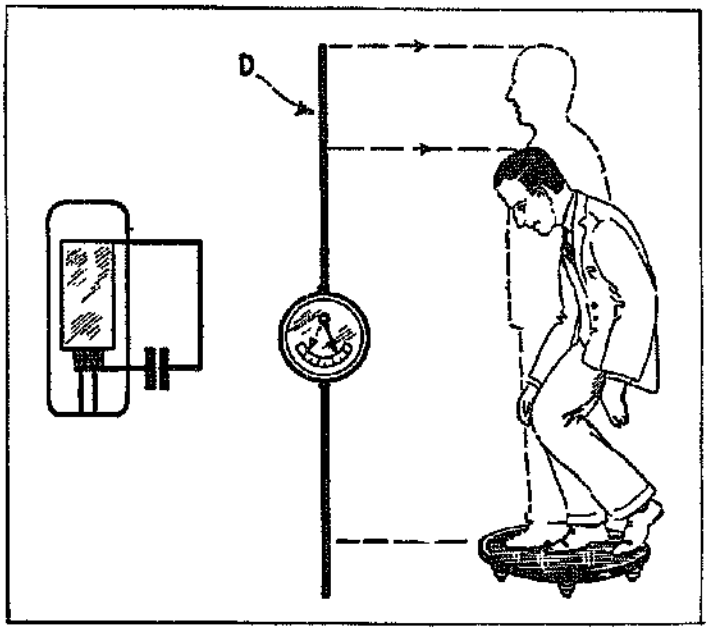

Fig. 2. One of the most interesting effects of placing a human being in the field of a short wave (high frequency) oscillator is that of absorption. The antenna "D" is excited by the power tube and loop circuit at the left. Do you think the antenna current is increased or decreased by bending the body?

plainly felt by all persons who work a fairly long time with short waves. The sensations are different with the individuals; there are persons who are relatively insensitive, and others who very soon complain about the disturbances of their health. Usually there is first an increasing sleepiness; they are very tired by day, but at night they sleep badly. Several times a night they start out of their sleep, and they are tired and sleepy in the morning.

These phenomena increase more and more. Often there are also intensive headaches, particularly covering the back of the head. Many persons complain of digestive disturbances and pressure on the stomach. Most of them are furthermore easily excited and irritated, being inclined to complaining and to violence. This increased excitability of the nervous system can also be shown by electrical tests of the nerves.

Effects of the Electrostatic Field

It is much easier to study these changes by using the condenser field. Here it is not the electromagnetic wave which is used, but the electrostatic field, which always accompanies it. Here, however, the effect may be much more strongly concentrated. I have generally used plates four inches in diameter, between which the parts of the body in question were treated. The field between these plates suffices to heat 100 cc. of a 0.5% sodium chloride (salt) solution 5 degrees C. (9° F.) in one minute. If parts of the human body are introduced into this field, and the blood is then taken from some part of the body (for instance, from the earlobe) on investigation obvious changes are found.

The number of red corpuscles per cubic millimeter is very greatly increased; i. e., if they formerly amounted to 5 million, the number has risen to 8 million. The same is true of the haemoglobin (a constituent of the blood) and the white corpuscles, the number of which likewise increases. But this is not always true to the same extent, depending upon the strength of the radiation and the place treated. One frequently sees instead a lessening of these amounts, which would therefore correspond to a thinning of the blood. Likewise, the albumens of the blood undergo certain changes which I cannot discuss here.

In the case of these strong effects it is to be assumed that the tissues of the body also undergo changes; which, however, cannot be directly proved in a subject.

Human Beings As Antennas

By Dr. Erwin Schliephake, M.D.

Results of Experiments on Animals

In experiments with animals, on the contrary, such changes are plainly recognizable. They occur particularly strong in projecting parts of the animals, such as in the ears and tips of the tails; since there the electric field is distorted. Very often, one sees, some time after the treatment, that the parts in question are dying and falling off. In the case of a rabbit whose leg had been too strongly exposed to the electrostatic field, I noticed a complete disintegration of the flesh in a ring-shaped region, so that only the bone remained; but then, after a while, that also fell off.

That the nervous sytem of the animals is also influenced is shown by the fact that many of them shudder on the switching on or off of the field, at a time when there can be no question of a strong heating effect.

Also very interesting are the disturbances of the internal heat regulation, which one can produce in animals. If the region of the neck and the back of the head of a rabbit are exposed to a limited capacitative field and the temperature is afterward measured, one can soon note a permanently increased temperature, which often lasts for some weeks. If a very powerful dose of "irradiation" is administered the opposite can occur: the bodily heat falls more and more, often below 35 degrees C. (95° F.), until these low temperatures are no longer compatible with life. At the same time, it is interesting to observe that almost all animals which have had such disturbances of their heat regulation after a few weeks developed inflammation of the lungs and pleurisy, afterward dying. It seems as though, by the disturbance of the heat regulation, the resistance of the animals to disease had suffered greatly; so that in this path throughout the central nervous system there was created a special susceptibility to colds. On investigating the spinal marrow of such animals microscopically, serious injuries to the nerve cells have been observed.

Dangers and Beneficial Possibilities

After these experiences, I have not dared to expose entire human beings to a condenser field and in this way produce artificial rises in temperature. The responsibility seemed too great. At the same time, effective heating of the body can be accomplished equally well in other ways; such as with the well-known Apostoli "condenser bed," which can be connected to any diathermal apparatus. With the method previously described, only serious dangers for the patients treated would have been conjured up, without the possibility of producing a fundamentally new effect.

On the other hand, the disturbances of the physical health, which we could observe in the field of free radiation of powerful transmitters, have never been serious. After a period of recovery of a few weeks, with no irradiation, all effects have been observed to vanish. For four years now, I have almost daily worked for several hours at a transmitter with 1½ kw. plate dissipation; and the effects, often very unpleasant, have always gone back to normal on stopping the work.

In these things the wavelength is also certainly of importance, and in fact we have the impression that the disturbances to health became stronger as the wave was shortened. Anyway, the unpleasant sensations appear much quicker with a three-meter wave than with longer ones.

From all these experiences, it is at any rate clear that treatment with electric waves can in no way be regarded as always harmless for the human body. It is plain that their incorrect use can cause serious injuries to health. Certainly such injuries are to be expected only when the frequencies are very high; that is, with ultra-short waves; even then there is nothing to fear except with fairly high transmitter power.

On the other hand, with proper use, the short electric waves seem to be a valuable means of treatment. According to our experiments to date, with bacteria cultures and infected animals, the germs of disease can be killed. There is the added point that certain defensive processes are stimulated in the body. I have also already repeatedly treated human beings; and, in about a hundred cases, I have been able to attain an extraordinarily quick cure of suppuration (pus formation).

Ills Treated by Short Waves

● IN a dispatch to the N. Y. Times, a report from London states that cures for various ailments by the use of short radio waves were claimed by Dr. Erwin Schliephake, a German physician and scientist.

Writing in the *British Medical Journal* he described how he succeeded in treating deep-seated abscess in the human body by passing ultra-short wireless waves through the patient, who was not in immediate contact with any instrument. He found, he said, that various tissues exhibit different degrees of conductivity in the presence of these waves.

Dr. Schliephake declared he has used waves to treat pulmonary abscesses after pneumonia, in pleural empyema, pneumonic tuberculosis, in certain forms of peritonitis, in migraine and acute tonsilitis.

Dr. Willis R. Whitney, research director of the General Electric Company, revealed in April, 1930, that he had developed a radio type of apparatus for killing bacteria in the body.

From THEORY AND CALCULATION OF TRANSIENT PHENOMENON & ELECTRIC OSCILLATIONS by Charles Proteus Steinmetz, 1920

CHAPTER V.

DISTRIBUTED SERIES CAPACITY.

43. The capacity of a transmission line, cable, or high-potential transformer coil is shunted capacity, that is, capacity from conductor to ground, or from conductor to return conductor, or shunting across a section of the conductor, as from turn to turn or layer to layer of a transformer coil.

In some circuits, in addition to this shunted capacity, distributed series capacity also exists, that is, the circuit is broken at frequent and regular intervals by gaps filled with a dielectric or insulator, as air, and the two faces of the conductor ends thus constitute a condenser in series with the circuit. Where the elements of the circuit are short enough so as to be represented, approximately, as conductor differentials, the circuit constitutes a circuit with distributed series capacity.

An illustration of such a circuit is afforded by the so-called "multi-gap lightning arrester," as shown diagrammatically in Fig. 90, which consists of a large number of metal cylinders p, q . . . , with small spark gaps between the cylinders, connected between line L and ground G. This arrangement, Fig. 90, can be represented diagrammatically by Fig. 91. Each cylinder has a capacity C_0 against ground, a capacity C against the adjacent cylinder, a resistance r,— usually very small,— and an inductance L.

The series of insulator discs of a high voltage suspension —or strain—insulator also forms such a circuit.

If such a series of n equal capacities or spark gaps is connected across a constant supply voltage e_0, each gap has a voltage $e = \frac{e_0}{n}$. If, however, the supply voltage is alternating, the voltage does not divide uniformly between the gaps, but the potential difference is the greater, that is, the potential gradient steeper the nearer the gap is to the line L, and this distribution of potential becomes the more non-uniform the higher the frequency; that is, the greater the charging current of the capacity of the cylinder against the ground. The charging currents against ground, of all

ing frequency, does not remain constant, but decreases with increase of frequency, when the frequency becomes sufficiently high to give appreciable charging currents. Hence high frequency oscillations discharge over such a structure at lower voltage than machine frequencies.

For a further discussion of the feature which makes such a multigap structure useful for lightning protection, see A. I. E. E. Transactions, 1906, pp. 431, 448, 1907, p. 425, etc.

44. Such circuits with distributed series capacity are of great interest in that it is probable that lightning flashes in the clouds are discharges in such circuits. From the distance traversed by lightning flashes in the clouds, their character, and the disruptive strength of air, it appears certain that no potential difference can exist in the clouds of such magnitude as to cause a disruptive discharge across a mile or more of space. It is probable that as the result of condensation of moisture, and the lack of uniformity of such condensation, due to the gusty nature of air currents, a non-uniform distribution of potential is produced between the rain drops in the cloud; and when the potential gradient somewhere in space exceeds the disruptive value, an oscillatory discharge starts between the rain drops, and gradually, in a number of successive discharges, traverses the cloud and equalizes the potential gradient. A study of circuits containing distributed series capacity thus leads to an understanding of the phenomena occurring in the thunder cloud during the lightning discharge.*

Only a general outline can be given in the following.

45. In a circuit containing distributed resistance, conductance, inductance, shunt, and series capacity, as the multigap lightning arrester, Fig. 90, represented electrically as a circuit in Fig. 91, let r = the effective resistance per unit length of circuit, or per circuit element, that is, per arrester cylinder; g = the shunt conductance per unit length, representing leakage, brush discharge, electrical radiation, etc.; L = the inductance per unit length of circuit; C = the series capacity per unit length of circuit, or circuit element, that is, capacity between adjacent arrester cylinders, and C_0 = the shunt capacity per unit length of circuit, or circuit element, that is, capacity between arrester cylinder and

* See paper, "Lightning and Lightning Protection," N.E.L.A., 1907. Reprinted and enlarged in "General Lectures on Electrical Engineering," by Author.

the cylinders from q to the ground G, Figs. 90 and 91, must pass the gap between the adjacent cylinders p and q; that is, the charging current of the condenser represented by two adjacent

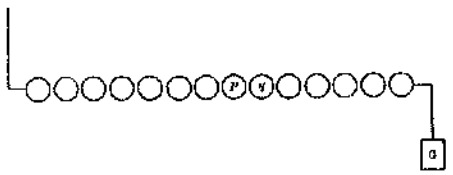

Fig. 90. Multi-gap lightning arrester.

cylinders p and q is the sum of all the charging currents from q to G; and as the potential difference between the two cylinders p and q is proportional to the charging current of the condenser

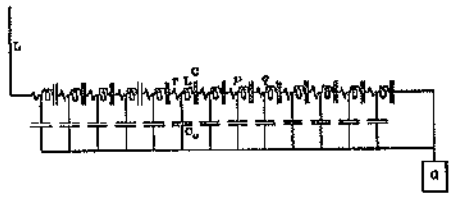

Fig. 91. Equivalent circuit of a multi-gap lightning arrester.

formed by these two cylinders, C, this potential difference increases towards L, being, at each point proportional to the vector sum of all the charging currents, against ground, of all the cylinders between this point and ground.

The higher the frequency, the more non-uniform is the potential gradient along the circuit and the lower is the total supply voltage required to bring the maximum potential gradient, near the line L, above the disruptive voltage, that is, to initiate the discharge. Thus such a multigap structure is discriminating regarding frequency; that is, the discharge voltage with increas-

ground. If then f = the frequency of impressed e.m.f., the series impedance per unit length of circuit is

$$Z = r + j(x - x_c); \tag{1}$$

the shunt admittance per unit length of circuit is

$$Y = g + jb, \tag{2}$$

where

$$\left.\begin{aligned} x &= 2\pi f L, \\ x_c &= \frac{1}{2\pi f C}, \\ b &= 2\pi f C_0; \end{aligned}\right\} \tag{3}$$

or the absolute values are

$$\left.\begin{aligned} z &= \sqrt{r^2 + (x - x_c)^2} \\ \text{and} \qquad y &= \sqrt{g^2 + b^2}. \end{aligned}\right\} \tag{4}$$

If the distance along the circuit from line L towards ground G is denoted by l, the potential difference between point l and ground by $\dot{E}$, and the current at point l by $\dot{I}$, the differential equations of the circuit are *

$$\frac{d\dot{E}}{dl} = Z\dot{I} \tag{5}$$

and

$$\frac{d\dot{I}}{dl} = Y\dot{E}. \tag{6}$$

Differentiating (5) and substituting (6) therein gives

$$\frac{d^2\dot{E}}{dl^2} = YZ\dot{E}. \tag{7}$$

Equation (7) is integrated by

$$\dot{E} = A_1\varepsilon^{-al} + A_2\varepsilon^{+al}, \tag{8}$$

where

$$a = \sqrt{YZ} = \alpha + j\beta, \tag{9}$$

and

$$\left.\begin{aligned} \alpha &= \sqrt{\tfrac{1}{2}\{yz + gr - b(x - x_c)\}} \\ \beta &= \sqrt{\tfrac{1}{2}\{yz - gr + b(x - x_c)\}}. \end{aligned}\right\} \tag{10}$$

* Section III, Chapter II, paragraph 7.

Substituting (10) in (8) and eliminating the imaginary exponents by the substitution of trigonometric functions,

$$E = A_1\varepsilon^{-\alpha l}(\cos\beta l - j\sin\beta l) + A_2\varepsilon^{+\alpha l}(\cos\beta l + j\sin\beta l). \quad (11)$$

46. However, if n = the total length of circuit from line L to ground G, or total number of arrester cylinders between line and ground, for $l = n$,

$$E = 0, \quad (12)$$

and for $l = 0$,

$$E = e_0 = \text{the impressed e.m.f.} \quad (13)$$

Substituting (12) and (13) into (11) gives

$$0 = A_1\varepsilon^{-\alpha n}(\cos\beta n - j\sin\beta n) + A_2\varepsilon^{+\alpha n}(\cos\beta n + j\sin\beta n)$$

and

$$e_0 = A_1 + A_2;$$

hence,

$$\left.\begin{aligned} A_1 &= \frac{e_0}{1-\varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)},\\ A_2 &= -A_1\varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n), \end{aligned}\right\} \quad (14)$$

and the potential difference against ground is

$$E = e_0\frac{\varepsilon^{-\alpha l}(\cos\beta l + j\sin\beta l) - \varepsilon^{-\alpha(2n-l)}[\cos\beta(2n-l) - j\sin\beta(2n-l)]}{1-\varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)} \quad (15)$$

From equation (5), substituting (15) and (9), we have

$$I = -\sqrt{\frac{Y}{Z}}\,e_0\frac{\varepsilon^{-\alpha l}(\cos\beta l - j\sin\beta l) + \varepsilon^{-\alpha(2n-l)}[\cos\beta(2n-l) - j\sin\beta(2n-l)]}{1-\varepsilon^{-2\alpha n}(\cos 2\beta n - j\sin 2\beta n)} \quad (16)$$

Reduced to absolute terms this gives the potential difference against ground as

$$e = e_0\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} - 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1+\varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}, \quad (17)$$

the current as

$$i = e_0\sqrt{\frac{y}{z}}\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} + 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1+\varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}, \quad (18)$$

and the potential gradient, or potential difference between adjacent cylinders, is

$$e' = x_c i = e_0 x_c\sqrt{\frac{y}{z}}\sqrt{\frac{\varepsilon^{-2\alpha l} + \varepsilon^{-2\alpha(2n-l)} + 2\varepsilon^{-2\alpha n}\cos 2\beta(n-l)}{1+\varepsilon^{-4\alpha n} - 2\varepsilon^{-2\alpha n}\cos 2\beta n}}. \quad (19)$$

For an infinite length of line, $n = \infty$, that is, for a very large number of lightning arrester cylinders, where $\varepsilon^{-2\alpha n}$ is negligible, as in the case where the discharge passes from the line into the arrester without reaching the ground, equations (17), (18), (19) simplify to

$$e = e_0\varepsilon^{-\alpha l}, \quad (20)$$

$$i = e_0\sqrt{\frac{y}{z}}\,\varepsilon^{-\alpha l}, \quad (21)$$

and

$$e' = e_0 x_c\sqrt{\frac{y}{z}}\,\varepsilon^{-\alpha l}; \quad (22)$$

that is, are simple exponential curves.

Substituting (4) and (3) in (21) and (22) gives

$$e' = e_0\varepsilon^{-\alpha l}\sqrt[4]{\frac{C_0^2 + \left(\frac{g}{2\pi f}\right)^2}{C^2\{[1-(2\pi f)^2 CL]^2 + (2\pi f C r)^2\}}} \quad (23)$$

and

$$i = 2\pi f C e'; \quad (24)$$

or, approximately, if r and g are negligible, we have

$$e' = e_0\varepsilon^{-\alpha l}\sqrt{\frac{C_0}{C\{1-(2\pi f)^2 CL\}}} \quad (25)$$

and

$$i = 2\pi f e_0\varepsilon^{-\alpha l}\sqrt{\frac{CC_0}{1-(2\pi f)^2 CL}}. \quad (26)$$

47. Assume, as example, a lightning arrester having the following constants: $L = 2\times10^{-8}$ henry; $C_0 = 10^{-13}$ farads; $C = 4\times10^{-11}$ farads; $r = 1$ ohm; $g = 4\times10^{-6}$ mho; $f = 10^8$ = 100 million cycles per second; $n = 300$ cylinders, and $e_0 = 30{,}000$ volts; then from equation (3), $x = 12.6$ ohms, $x_c = 39.7$ ohms, and $b = 62.8\times10^{-6}$ mhos;

from equation (1),

$$Z = 1 - 27.1\,j \text{ ohms};$$

from equation (2),

$$Y = (4 + 62.8\,j)\,10^{-6} \text{ mho};$$

from equation (4),

$$z = 27.1 \text{ ohms and } y = 62.9\times10^{-6} \text{ mho};$$

from equation (10),

$$\alpha = 0.0021 \text{ and } \beta = 0.0412;$$

from equation (17),

$$e = 35{,}500\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} - 0.568\cos(24.72 - 0.0824\,l)};$$

from equation (18),

$$i = 54\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} + 0.568\cos(24.72 - 0.0824\,l)},$$

and from equation (19),

$$e' = 2140\sqrt{\varepsilon^{-0.0042\,l} + 0.08\,\varepsilon^{+0.0042\,l} + 0.568\cos(24.72 - 0.0824\,l)}.$$

Hence, at $l = 0$, $e = 30{,}000$ volts, $i = 64.6$ amperes, and $e' = 2560$ volts; and at $l = 300$, $e = 0$, $i = 57.5$ amperes, and $e' = 2280$ volts.

With voltages per gap varying from 2280 to 2560, 300 gaps would, by addition, give a total voltage of about 730,000, while the actual voltage is only about one-twenty-fourth thereof; that is, the sum of the voltages of many spark-gaps in series may be many times the resultant voltage, and a lightning flash may pass possibly for miles through clouds with a total potential of only a few hundred million volts. In the above example the 300 cylinders include 7.86 complete wave-lengths of the discharge.

Jan 3, 1988

Los Angeles Times

Ham Radio Operators' High Cancer Rate Poses a Puzzle

TACOMA, Wash. (AP)—Amateur radio operators in Washington and California appear to die at abnormally high rates from several forms of cancer, suggesting a possible link between cancer and electromagnetic fields, according to data collected by a state epidemiologist.

Others cautioned that evidence of such a link has been inconsistent and that other factors may be involved.

Dr. Samuel Milham Jr. of the Washington Department of Social and Health Services studied the deaths of 2,485 Washington and California ham operators between 1979 and 1984.

He reported in the American Journal of Epidemiology that 29 leukemia deaths would be expected in a group of people that size, but he found 36 deaths. Statistically, he expected to find 72 lymphatic and blood-forming organ cancers, but found 89. And he expected to find 67.6 deaths from prostate cancer, but found 78.

'Excess Mortality'

The study "indicates that amateur radio operator licensees in Washington state and California have significant excess mortality due to acute myloid leukemia, multiple myeloma and perhaps certain types of malignant lymphoma," Milham reported.

Leonard Sagan, program manager for radiation studies at the Electric Power Research Institute in Palo Alto, Calif., warned that studies like Milham's can be misinterpreted. Milham's findings could be simple associations that have nothing to do with cancer causes among people who work with electricity, he said.

Sagan said his own research hasn't shown whether electricity causes cancer. But he predicted that if it does, it's rare.

"I think it would be unfortunate for people with children to become overly concerned about this," he said. "Evidence is weak and inconsistent and in a few years we will have better evidence."

Here's something to consider while using a Multi Wave Oscillator. Just "any old" radio frequency broadcast energy may not be desireable. Use this handbook in your detective work to discover Lakhovsky's secret.

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Is it possible to restore aging or diseased tissue? Earlier this century scientist Georges Lakhovsky conducted researches indicating that living cells can be regenerated by applying special fields of electrical energy.

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Earlier this century this Multiple Wave Oscillator was shown to neutralize certain types of cancer--but no exact plans are available. This book contains the records of many people who have attempted to reconstruct the original equipment and continue with this fascinating research.

This book describes researches such as the enhancement of plant grown through the amplification of cosmic waves with simple wire coils, and the neutralization of cancerous tissue with radio waves. This was done with cosmic radiations ringing wires coiled around plants, and with refined electrical fields ringing specially designed antennas. Lakhovsky's original work into the dramatic impact of the subtle forces of nature included the effects of sunspot cycles on plant and animal health, the nature of cancer and how it appears in clusters over areas which have soils that reflect cosmic radiations, thereby causing interference patters, and how diseased cells would turn to a state of health when specific natural or electrical fields were applied in a proper manner.

Nikola Tesla provided some of the early electro-therapeutic research and Lakhovsky was introduced to this through Professor D'arsonval. Lakhovsky, a brilliant scientist, combined this knowledge with his original work and produced a device known as the Multiple Wave Oscillator.

The Multiple Wave Oscillator is an ongoing research project of Borderland Sciences Research Foundation, begun in 1963. This book is the published record of our search for Lakhovsky's secrets and the potential for reversing the aging process.

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THE LAKHOVSKY MUPTIPLE WAVE OSCILLATOR HANDBOOK

The Rife Machine Report

A History of Rife's Instruments and Frequencies

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The Rife Machine Report

A History of Rife's Instruments and Frequencies

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This report from its first writing back in 2003 has been an evolving document. The current report supersedes all previous reports that have been released.

Whenever original Rife instruments, schematics or documents have been found this report has been updated according to the information that was obtained. This report was updated in 2010 because at that time an original 1938-1939 Rife Ray #5 or Beam Ray Clinical Instrument had been found and analyzed. That instrument was built by the original 1938-1939 Beam Ray Corporation. At that time the analyzing of that instrument finally showed where the audio frequency instruments came from which Dr. Rife used in the 1950's. It was updated in 2011 and 2012 when some new information came to light about Dr. Gruner's Rife machine and John Marsh's documents. The last revision of this report was dated 12/01/2012.

This report is being updated now because more of John Marsh's documented information has come to light. Two of his ray tube instruments have been obtained that were built in the 1970's and 1980's. More extensive photos have been taken of those instruments and have been added to this report at this time. Also this report has had a great deal of updating and clarifying in almost all of its chapters. With these updates the report has increased from 153 pages to 224 pages.

In this report we will examine the way Dr. Rife's instruments were built. We will look at the evidence by quoting the sources such as Dr. Rife, John Crane, John Marsh, Dr. Couche, Dr. Lara, Dr. Stafford and Bertrand L. Comparet (Dr. Rife's attorney in the 1939 Beam Ray Corporation Trial, and later John Crane's attorney for Life Labs' trial in 1961). Hopefully anyone who reads this report will have a better understanding about Dr. Rife and the methods he used. Our goal is to try to give people information so that they will know how Dr. Rife's equipment worked so that they will not be misguided by all the misinformation and disinformation that has been published on this subject. The writer of this report has tried to explain the information in layman's terms.

This report, called by the same name, is also online at www.rifevideos.com. All of the quoted documentation is linked in the online report for those who want to study the documents used to back up the quotes used in this report. Also online are more photos of the equipment shown in this report.

We will continue to update this paper when new information is obtained.

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Chapter #1

What is a Rife ray tube and how does it work?

Dr. Rife used a ray tube with his Rife Machines. The photo, shown above, is a picture of the style of double-bubble ray tube which Dr. Rife used for many years in his laboratory. A ray tube was made out of glass, quartz or Pyrex and was filled with a noble gas or a mixture of noble gases.

The next photo, shown below, shows Dr. Rife's double-bubble ray tube in his laboratory right next to his microscope.

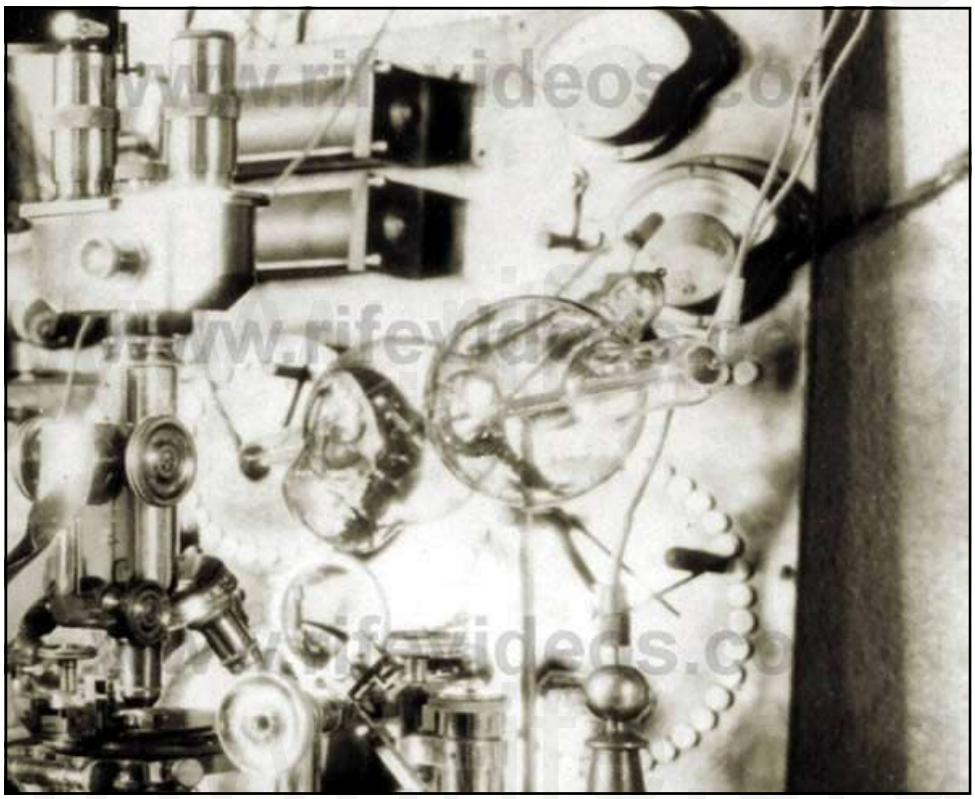

Some people believe that there was something magical to the gas mixture that Dr. Rife used in his ray tube. There are also people who claim that they use some proprietary blend of gases that makes their ray tubes work exactly like Dr. Rife's. Others even claim that their gas formula works better than Dr. Rife's did. The truth is that none of this rings true because of what Dr. Rife has said on this subject. Dr. Rife knew more about these gases than most anyone else since he used different gas mixtures over a thirty year time span. The fact is Dr. Rife used many different mixtures of gases but eventually ended up using only helium. To verify this we will read his statement:

RIFE: *"We have experimented with various inert gases and we found that helium stood up by the bombardment better than any of the other gases. That's why we use it. We don't care about the color or anything of that sort. It stood up better over many more hours of bombardment than the argon and the crypton* [krypton] *and those different gases that we tried."* (John Marsh Collection, Gonin and Siner Papers, Page 25)

From what Dr. Rife said in the above quote it is apparent that he tested many different gases over the years in his laboratory and they all worked. But we find that he decided to use only helium because it lasted longer in the ray tube.

The ray tube was connected to Dr. Rife's Machine by two wires. These wires were connected to two round metal bars that went into the glass tube and they had round disks connected to their ends. One disk was straight and the other one was on a 45 degree angle. This gave it a directional effect towards the patient.

Below is a photo showing the internal electrodes that were built into the ray tube. You can see that one is straight and the other is on a 45 degree angle.

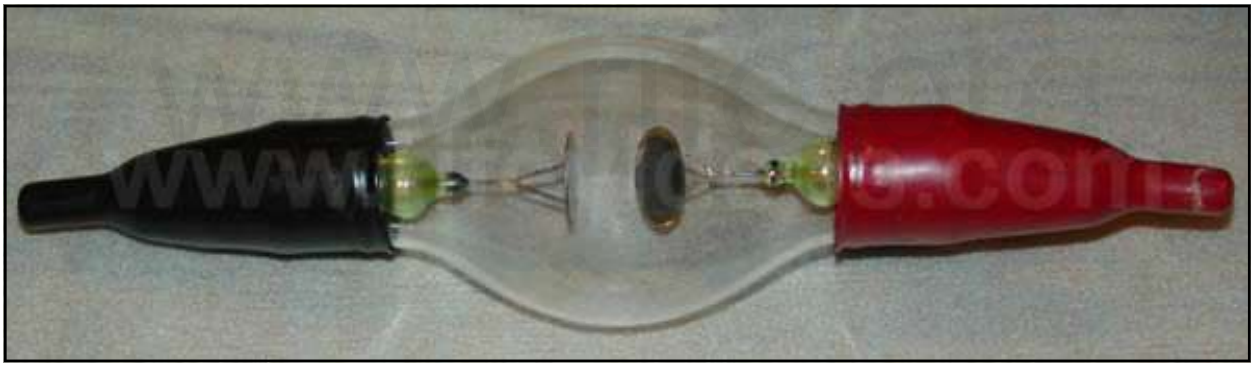

Dr. Rife stated that the ray tube was "a partial directional antenna". Because the scientific technology behind ray tubes had already been perfected, Dr. Rife worked with that technology and only had to make some adjustments for it to work the way he wanted it to in his applications. Bertrand L. Comparet, Dr. Rife's attorney, stated in an interview:

COMPARET: *"Now, the original instrument had a tube, like an X-ray tube. That was the way in which Rife developed it. You see, all the X-ray work necessarily was done with a beam projected from a tube. So, Rife worked on the same basis."* (1970's Bertrand Comparet Interview #32)

Although Dr. Rife used X-ray tubes in his work they did not put out any X-rays. Because the ray tubes used inert gases they did not produce X-rays. They work on the same principle as a neon sign. The gas that is used in a neon sign does not produce any harmful rays of any kind. Inert gases such as helium, argon, krypton, neon and others can safely be use in these ray tubes without producing X-rays. These gases are considered noble gases and there are 18 different types. The ray tube is just an antenna and the noble gas will emit the frequency when the plasma is lit. This makes a ray tube a safe

method of delivering the frequencies. If you use a metal antenna and someone just happened to touch it they could receive severe third degree RF (Radio Frequency) burns.

Many people believe that ray tubes are just as efficient as metal antennas, and this may be true. They also believe that the energy emitted from a ray tube will actually travel farther with less loss than a metal antenna. Since there are no actual scientific tests comparing the output of ray tubes to metal antennas it is hard to know for sure if these assumptions are correct. For this report we will accept what is known, not what is un-known. Therefore we will compare ray tubes to metal antennas since they both are designed to emit frequencies.

There are limitations to metal antennas that need to be understood and this has to do with the laws of physics. It is referred to as the "Inverse-Square Law". This law deals with power loss and distance. We will give a simple explanation which should suffice since we are trying to stay in layman's terms and make it easy for the average person to understand this information. When a circuit is properly tuned metal antennas are very efficient. About 100% of the energy that you put into a metal antenna comes out, but only if the impedance is matched correctly.

Dr. Rife's Rife Ray #3 instrument information which has been obtained from the Rife documents list that about 50 RF watts was input into the ray tube. If we compare this to a metal antenna this means about 50 watts would have passed through and come out of the ray tube. When it comes to metal antennas and the inverse-square law on signal loss this would mean that you would have to divide the 50 watts which come out of the metal antenna by four for every foot that you move away from the antenna. The exact power loss of a ray tube, as stated before, is not known but if a ray tube is equally as efficient as a metal antenna, and we believe it is, then the same laws of physics would also apply to it.

Because no actual scientific tests have been done with ray tubes demonstrating that they are exempt from the inverse-square law then we are left with only one conclusion, this law does apply to ray tubes. Because of this we will use this inverse-square law of power loss for a ray tube. Therefore, with a 50 watt power output at one foot away from the ray tube you would only have 12.5 watts. At two feet you only have 3.125 watts and at 3 feet you only have about .78 of a watt. The laws of physics are important to understand because Dr. Rife and the doctors that used his equipment put the ray tube within a few inches to a few feet of the patient's body. One of Dr. Rife's 1950's business partners, John Marsh, wrote a paper in which he stated that the Ray tube should be used from 12 to 24 inches from the body:

MARSH: *"A frequency instrument with therapeutic applications which has been developed and successfully tested over a period of year's works on the principle of stimulating tissue with low energy, low frequency pulsating current. It applies electron transmission at variable frequencies from an applicator source, which consists of either (1) a bare anode and cathode (in direct contact with the body) and constructed from metal for easy transmission flow of electrons, or (2) from an antenna broadcast source at a distance of 12 to 24 inches."* (An Explanation of the JLMSQ-1A frequency instrument and its use. Page 1-2).

Dr. Couche said that he would sometimes touch the body of the patient in the area that needed to be treated. When we discussed this with Dr. Robert P. Stafford M.D., he said that when he treated cancer patients he would put the ray tube within a few inches of the body and treat a 6 inch square area. He would move the ray tube up and down and back and forth so that the whole 6 inch area was treated. He said that he did this because of the way the phanotron (ray tube nickname) ray tube worked. The design of a phanotron ray tube makes it partially directional and concentrates its energy or power into a smaller area. Due to the "Inverse-square law" power loss it is easy to understand why Dr. Stafford, Dr. Couche, Dr. Rife and the other doctors used the ray tube right next to the body. Many

people have used these RF (Radio Frequency) ray tube instruments and have notice that within several feet they will get a strong reaction but beyond this it drops of very quickly. It is apparent that there was a good reason why the ray tube was used close to the patients body.

We built both the Aubrey Scoon Beam Ray replica ray tube instrument and the 1953 AZ-58 Beam Ray replica ray tube Rife Machine. The 1953 AZ-58 (Rife instrument made by Life Labs) was built from schematics that are on Stan Truman's site, http://www.rife.org, under AZ-58 research information. This AZ-58 instrument is nearly the same as the original Rife Ray #5 or Beam Ray Clinical instrument and schematics can be found on this page.

Both Aubrey Scoon's instrument and the original Beam Ray instrument use sine wave audio frequencies and the 1953 AZ-58 uses square wave audio frequencies. We tested the AZ-58 and Aubrey Scoon's replica for penetration and found that at about 32 inches from the body full penetration of the carrier frequency emitted from the ray tube was lost with our frequency detection device. This test was done in this manner. A B&K frequency counter was used and the antenna was put in a fold of body tissue on the front of the body. The ray tube was put behind the person and move backwards until the carrier frequency could no longer be read through the person's body. John Crane listed the AZ-58 as outputting 14 watts out of the ray tube but we tested it and found it outputs at least 30 to 40 watts. The 1950's Aubrey Scoon instrument puts out about 30 to 40 watts also.

Another test was made using a crystal for testing resonance. The audio frequencies broadcast out of the ray tube from both of these machines could only resonate a crystal designed to test resonance through about two inches of tissue. From the tests made, it takes a carrier frequency of at least 0.125 watts to penetrate all the way through the body. It could take an output of 50 watts from a ray tube to resonate a crystal through 14 inches of tissue. These tests showed that it takes more power to penetrate all the way through the body when modulating an audio frequency on a carrier frequency than when a single un-modulated frequency is used. The tests were done using the AZ-58 replica and the Aubrey Scoon replica Rife machine using a phanotron ray tube outputting about 30 to 40 watts. Another interesting thing worth noting is when we turned the ray tube more than 45 degrees either to the right or the left of center we could not resonate the crystal. Another test showed we could not resonate the crystal at all on the backside of the phanotron ray tube proving what Dr. Rife said:

RIFE: *"The ray tube is a partially directional antenna."*

One interesting fact worth noting is the ray tubes that do not use the internal electrodes, like the Phanotron ray tube, have a higher field strength reading which indicates a greater output. These ray tubes use copper collars or wire wrapping around the ray tube. These ray tubes also last longer because the gas inside the ray tube does not get contaminated. The contamination comes from the internal metal electrodes. Over time the metal from the internal electrodes comes off and slowly contaminates the gas. It will also deposit on the inside of the glass making the ray tube go darker. In the photo below you can see how the ray tube has darkened.

The next photo, show below, is a picture of Dr. James B. Couche's Rife Ray #5 or Beam Ray Clinical instrument which he purchase from the original 1938-1939 Beam Ray Corporation. The ray tube is Dr. Rife's original double-bubble ray tube which he used for over 30 years in his laboratory. You can see how the ray tube has darkened. This was a common problem which required the ray tubes to be cleaned and re-gassed on a regular basis. A better view of this double-bubble ray tube is shown in the two photos on page 4.

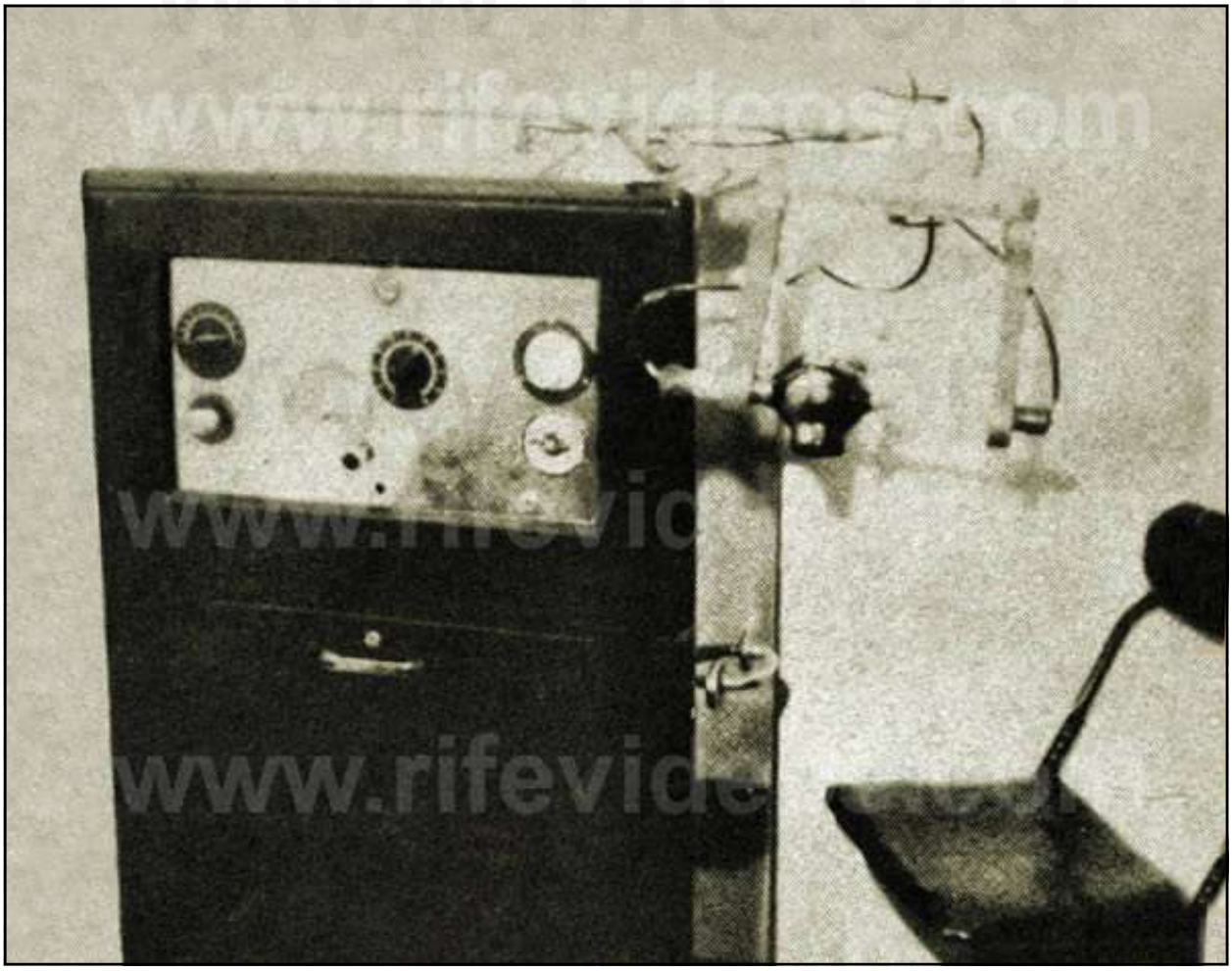

Chapter Summary: A ray tube is a plasma antenna built for the purpose of outputting frequencies. Dr. Rife built many different styles of ray tubes. The gas used inside the ray tube does not really matter as long as it is a noble gas (Helium, Argon, Krypton, Neon, etc.). Dr. Rife settled on using helium because it lasted longer in a ray tube that uses internal electrodes. The ray tube made it possible for Dr. Rife to safely use a powerful RF (Radio Frequency) frequency instrument next to a person or microscope. Dr. Rife preferred using a ray tube over pad type instruments because a great deal more power meant a better outcome for the patient.

Many people have wondered what power levels did Dr. Rife use in his instruments. In the next chapter of this report we will discuss the power levels of Dr. Rife's instruments.

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Chapter #2

What power levels did Dr. Rife use in his Rife Machines?

Many people have wondered what power levels are safe to use when using an instrument like Dr. Rife's machine. According to the documents we have Dr. Rife's ray tube instruments, such as the Rife Ray #4 Rife Machine, was listed to be able to output as much as 400 watts. When the test for B. Typhosis was made it was listed that they used 400 watts. The milliamp meter was listed at 450 milliamps for those 400 watts. Since the equipment of that era would have only been about fifty percent efficient then the true power output from the ray tube would not have been more that about 200 watts, not 400 watts. The Rife Ray #4 was the most powerful of the five machines that Dr. Rife built. Dr. Rife did not notice any problems using instruments with power levels between 40 to 250 watts of power output. Next are two statements made by Dr. Rife about the safety of his instruments:

RIFE: *"I have operated the frequency instrument since 1921. I have watched it advance in style and performance with the advancement of electronics. In the many years I have used this equipment in my research, I have never suffered an injury or any ill effects whatsoever. I found it reliable in performance and efficient in results."* (Letter from Dr. Rife to Dr. Justin Stein, July 2, 1956)

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Also on the John Marsh, Rife audio CD's Dr. Rife made this statement about his RF frequency instrument:

RIFE: *"I stood in front of that thing for thirty years finding these different frequencies that devitalize these different bacteria. And that thing* [RF ray tube] *was shooting on me right here [his chest], but it is absolutely harmless to normal tissue and each individual bacteria requiring a different frequency to devitalize."* (John Marsh Rife CD's)

The Rife Ray #5 or Beam Ray Clinical instrument built by the Beam Ray Corporation in the 1930's output, at the most, about 40 watts out of the ray tube. The 1950's AZ-58 Life Labs instrument and the Aubrey Scoon 1950's instrument also only output about 40 watts. Because some of Dr. Rife's information about instrument power levels is confusing, most have believed Dr. Rife's Machines put out 400 to 600 watts to the ray tube: however, the new information from the building of some of these instruments shows these assumptions are not correct. The problem has been that the people who wrote down this information were incorrectly giving the power usage of Dr. Rife's Machines as the output power. Dr. Rife's Machines used generally about 400 to 600 watts but they only output about 40 to 250 watts out of the ray tube. The Rife Ray #4 did output more power but this was the exception not the rule. In the paper entitled "Development of the Rife Ray" it states:

"The frequencies were generated by a tube oscillator with many stages [5 stages] *of amplification, the final stage being a 50 watt output tube."* (Development of the Rife Ray and use in devitalizing of pathogenic micro-organisms)

This part of the description is of his pre-1935 instrument. The output tube was not the ray tube. It appears from the documents that Dr. Rife's pre-1935 instruments did not output any more power than about 50 watts out of the ray tube. He said he lit the ray tube from another power source then input the frequencies into the ray tube. When Dr. Rife, John Crane and John Marsh were working on sea water conversion - a process that used frequencies - they boosted the output power in the instrument. Concerning that instrument and some 1930's Beam Ray instruments that Dr. Yale had increased the power level on, Dr. Rife said the following:

RIFE: *"Now this outfit here - the way we have it boosted up here now with an extreme lot of power behind the actual output that is coming out of the thing...I wouldn't want to use this - or I wouldn't want to use this instrument here the way it is souped up there for this salt water proposition to treat a patient with."*

GONIN: *"No."*

RIFE: *"You can get beyond the limit* [power levels in excess of 250 watts]*."*

GONIN: *"Yes, quite."*

CRANE: *"That's what Dr. Yale did. You see, he stepped it up and up and up…"*

RIFE: *"When Verne Thompson used to go down there and take care of Yale's machines - when he began stepping them up and so...where you get up into that extreme power…oh yes, that is not good. With the power that is in these* [50 to 100 watts of power coming out of the ray tube], *there is absolutely no harm because I had my microscope here - I had my tube [ray tube] right here in front of it - oh, about 11 or 12 inches away from the slide in the microscope and here I was with this thing all around like that and that tube going here and my specimens and the microscope year after year tuning that thing and it never harmed me any."* (See the photo at the beginning of this chapter for a better understanding of this statement about where the ray tube was located.) (1950's Gonin, Rife, Crane and Marsh Paper #27-32)

Because Dr. Yale's 1938-1939 Beam Ray Corporation Rife Machines were modified they were putting out a lot more power than Dr. Rife felt was safe. We do not know how Dr. Yale had his machines modified so it is not possible to know the exact power output they had. But he must have been exceeding the power output of the Rife Ray #4 which could output about 250 watts (true power). It may be that Dr. Rife was just overly cautious but his statement should be considered when anyone starts using power levels in excess of 250 watts true power output.

Chapter Summary: Dr. Rife's ray tube instruments output anywhere between 40 to 250 watts of RF (Radio Frequency) power levels. Dr. Rife found that his instruments were safe to use with power levels between 20 to 250 watts. Power levels in excess of about 250 watts (true power output) were not recommended by Dr. Rife.

In the next chapter we will discuss whether it is absolutely necessary that a ray tube should be used or if it is possible to use the contact method of delivering Dr. Rife's frequencies which he used on microorganisms.

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Chapter #3

Is it necessary to use a Ray tube to output the frequencies?

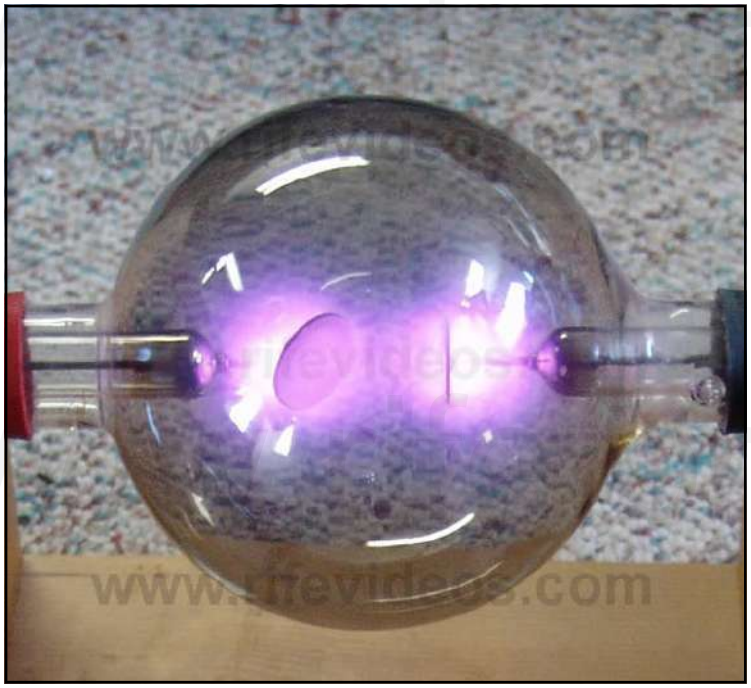

We really shouldn't care if an instrument uses a ray tube or hand cylinders and footplates (commonly called pad instruments) as long as it will devitalize the microorganism we desire. In the next photo, shown below, we see one of the first pad instruments built by John Crane and John Marsh back in the late 1950's early 1960's. You can see the aluminum disks which were used to come in contact with the body and deliver the frequencies. In the strictest sense of the word just because a ray tube is used doesn't mean its "Rife." By the time you read this whole report you will find out that very few are doing exactly what Dr. Rife did. But does this mean that these instruments don't work? Most of those who are building pad instruments are not using ray tubes, and most are not using Dr. Rife's original frequencies. Those who are building ray tube instruments are also not using Dr. Rife's original frequencies or methods. So where does this really leave us since very few are really doing what Dr. Rife did?

We have quite a paradox. This is the problem we face. If we were to build a ray tube Rife Machine that worked exactly the way Dr. Rife's did and use frequencies from 139,200 to 1,607,450 Hertz then we would have an instrument that could cause interference with AM radio stations if we were too close to them. These ray tube instruments may have to be used with a Faraday cage which is a conducting cage used to stop electromagnetic fields. We may be able to use them as long as we do not operate them within one half of a mile of a radio station on that stations particular wavelength or call number. We can build a pad instrument that will use all of the frequencies Dr. Rife's Machines used but then we are not using a ray tube. When we consider the problems we face today with building instruments, the least expensive instrument we can build is a pad instrument. This type of instrument can produce all of Dr. Rife's frequencies output by his Rife Machine. Therefore we should look at this method carefully and not reject it out of personal bias.

As we already said, it really shouldn't matter if an instrument uses pads or a ray tube as long as it works. With this in mind let's look at the reasons why pad instruments were built in the first place. John Crane and John Marsh had really good reasons why they built pad instruments. After nearly 50 years of research and use, there is enough evidence that a pad instrument may work just as well as a ray tube instrument, as long as there is sufficient power used. In some cases, because of the electrical stimulation like a T.E.N.S. instrument, they may work even better than a ray tube on some problems. We will now take a look at some of the reasons that prompted John Crane and John Marsh to use pads:

RIFE: *"But the principle of this thing is basically built on a coordinative vibration. Just like one tuning fork pitched to the C. Another one here—you strike this one and this one vibrates."*

DR. LARA: *"What kind of vibration is it? Electromagnetic vibration?"*

RIFE: *"We won't say magnetic, we will say electronic frequency vibration. The same as put out on a broadcasting station for the radio. The same thing you know, only it's transmitted into a tube. And the tube acts as a partial directional antenna you see."* (John Marsh Rife CDs - CD 6 track 2)

In the John Marsh papers describing his trip to Ohio we read a statement made by Dr. Rife:

RIFE: *"You know we had an idea when we had our Clinic in La Jolla, of course that was battery and motor generator operated that set, you know, and boy it would sure raise the devil with all the radios so we had a couple of cars that was equipped with car radios and we sent them out and we would take the switch of that thing, and had a code you know like an S.O.S., and one of them went up north, and one of them went south from La Jolla. Before we started in we wanted to see how far we were going to disturb things with it you know, and incidentally we had it in a steel room, a steel lined vault about this size at the old Ellen Scripp's home. It was the vault in the library of the Scripp's home where they kept their valuable manuscripts and books in all steel lined and a door on it like a safe. We had the thing inside of that too, but it didn't make much difference, but we started in, and one car lost the pick up on top of Torry Pines, and the other one half ways through Mission Beach picked it up, and then they could go a hundred feet and lose and then they would have to pick it up again. Old Henry [Henry Siner] the boy that was with us out there, one of the lab boys, boy he went up in the air. He says, "By God" he says "look, we're going to fix them up right. At two o'clock we'll hook this up to a big radio station, a big transmitting station, and at two o'clock next week we'll broadcast for tuberculosis, and at half past three the week after we will broadcast for cancer, and everybody at the radio will pick it up". See, boy I said Henry that really is an idea."* (1957 John Marsh Trip to Ohio Paper #24)

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In 1960 one of Dr. Rife's close friends, Ben Cullen, stated in a talk given at a Rife Virus Microscope Conference the following:

CULLEN: *"The fact is, had it not been for certain very, very unpleasant circumstances, Dr. Rife would've had an arrangement with KFI or KFSD* [Radio stations] *where he would have been broadcasting out over quite a large radius from each broadcasting station the rays which are responsible for eradicating these various viruses, which we now know as being "killing" viruses. Just imagine as you walked around shopping downtown, or out in the street, you would receive the rays of this wonderful current."* (Ben Cullen's 1960 talk given at the First International Convention of the Rife Virus Microscope #G)

These two statements made by Dr. Rife and Ben Cullen were made over 20 years after the 1934 clinic. Dr. Rife knew that the frequencies would broadcast from a metal antenna just as well as from a ray tube. The fact that he felt that Henry Siner's idea was a good idea and the fact that he wanted to use a radio station indicates that Dr. Rife knew a metal antenna would give the same results as a ray tube. It is apparent from what we have read that Dr. Rife believed it was the frequency that was devitalizing the organism and the method of application really didn't matter. Clearly, Dr. Rife understood that the frequencies could be broadcast by a radio station, using a metal antenna, if they had enough power.

When John Crane and John Marsh, Dr. Rife's two business partners in the 1950's, came to understand this, they eliminated the ray tube and used pads or hand cylinders to apply the frequencies. The pads and hand cylinders work just like an antenna except you do not want too much power so that they are safe to use. The body also becomes an antenna when you hold the hand cylinders or use the pads and this is why pad instruments work. Bertrand Comparet stated this in his interview:

COMPARET: *"Now, Crane said "Well now look, Rife himself admits that no matter how much tube and ray, and so on, you have, you can't get any results unless you've got the right frequency. Therefore the real clue to the thing is the frequency and not the means by which you deliver it." Comparet also said: "Well, Crane originally was, with more modern techniques, duplicating the Rife machine, tube and all for early experiments. And, as I say, he came to the conclusion that you just weren't getting anything additional by the use of the tube. If you didn't get the frequency, you could run the rest of it indefinitely and nothing happened. So, what Crane did, he got an audio frequency generator. Now, you could make them up yourself by an awful lot of work, or you could buy a Heathkit audio frequency generator and get all the same results with a lot less time and effort. So he was using these Heathkit generators. Now, instead of a beam projected from a tube, a ray, he simply had two wires. I think they were aluminium knobs on the end of them, which would be used. They would be put on the body in such a position that the natural flow of the current from one to the other would go through the diseased area, and he got astonishing results."* (1970's Bertrand Comparet Interview #33 & 47)

These pads or hand cylinders act just like an antenna when in contact with the body, but only if you have an RF carrier frequency. This is where John Crane and John Marsh made a critical error, we believe, and the reason Dr. Rife probably did not like their pad instrument. Without an RF carrier frequency the audio frequencies will only go through the connective tissue and not the cell. There are exceptions to this and they have to do with the wave form of the frequency. If a square wave audio frequency is used then the higher harmonics produced from this waveform may penetrate the cell to some degree. How much power from these harmonics penetrates the cell is not known. But this may explain why instruments that do not use an RF carrier frequency also seem to work well. Dr. Rife expressed his dislike for John Crane and John Marsh's instrument that did not use a carrier frequency when Bertrand Comparet asked him about it:

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COMPARET: *"And I asked Rife, because I thought Rife would certainly say that the way Crane was working on it then was still using the Rife principle, but he indignantly denied it.*" (1970's Comparet interview papers #32)

We know that Dr. Rife knew that a metal antenna would work and we also know that the pad instrument worked on this principle. Logically it must have been the fact that it did not use an RF carrier frequency is what upset Dr. Rife. Pad instruments that do not use a carrier frequency are limited in power. The highest power output that can be safely used from a non RF carrier pad instrument is about 1/5 of one watt (0.20 to 0.40). Any more power than this and the muscles of the body will begin to lock up. If you use an RF carrier frequency then you can output a hundred times more power safely. It is apparent that it was the lack of power that concerned Dr. Rife. All of Dr. Rife's original frequencies were in the RF (Radio frequency) broadcast band of frequencies and used with at least 40 to 50 watts of power. We will cover these frequencies and the audio frequencies along with the importance of a carrier frequency later in this article.

In the next photo, shown below, we see another pad type instrument built by John Crane back in the 1960's. You can see the same kind of disks that he used to come in contact with the body.

Some people have thought that it was the color of the light from the ray tube that made the Rife Machine work. But the evidence doesn't seem to support that concept either because in the Gonin Papers of John Marsh, Dr. Rife said this with regard to the light that came from the ray tube:

RIFE: *"We don't care about the color or anything of that sort."* (John Marsh Collection, Gonin Papers, Page 25)

Dr. Couche, while visiting Dr. Rife's lab with some other men, said:

DR. COUCHE: *"There was fifteen inches of concrete on the floor so as to stop any earthquake shocks from interfering with his work. And in his laboratory upon the ground floor he had a microscope with a slide on it that this group of people and myself looked at. And this was not stained, there was no killing*

of the bacteria on it. It was just a fresh culture of the colon bacillus…..Well we all went down under the stairs into the cellar right immediately under the microscope upon the floor above us and the Rife machine was down in underneath there under the culture in the cellar probably I suppose about ten feet away, eight or ten feet away. And he turned the machine on and gave it less than a half minute's frequency for the colon bacillus...Then he turned the machine off and we all came upstairs and waited for ten or fifteen minutes. And presently he came back to his microscope and he said, "Well gentlemen come and look at the slide now." Well to my astonishment the bacilli all had been killed and they were all stacked up on the slide." (John Marsh Rife CDs - CD 3 track 1)

There is no possible way the light from the ray tube of the Rife Machine could have penetrated that fifteen inch concrete floor. It is obvious that the light didn't make any difference but that it was the frequencies that were broadcast through the ray tube. It is easy to see that there is more than one way to deliver the frequencies. The ray tube could be easily replaced with metal hand cylinders and foot pads. It is interesting to note here that Dr. Rife said Abrams' Oscilloclast would devitalize the BX cancer virus and it was a contact type device. The waveform the Oscilloclast produced is shown in Dr. Rife's 1936 film. John Crane and John Marsh probably used this contact method because of the success of Abrams' instrument. The Abrams' instrument proved that a contact type device would work and it was used before Dr. Rife even started using a ray tube. In fact Abrams' contact instrument predates all of Dr. Rife's work. Pad instruments like Abrams' instrument come in contact with the body. Abrams instrument worked on the same RF principles as Dr. Rife's instruments. Pad instruments with an RF carrier turn the body into an antenna and work on the same principle as a metal antenna or ray tube. People have been using pad instruments without an RF carrier for almost 50 years now and have had very good results. But, in order to work the way the ray tube instruments do, an RF carrier frequency is necessary.

Chapter Summary: Dr. Rife knew that a metal antenna could be used in place of a ray tube. Frequency generators that use hand cylinders or footpads or footplates may work as well as a ray tube instrument as long as sufficient power is used. The only way to increase the power level in a pad instrument is with the use of an RF (Radio Frequency) carrier. Dr. Rife did not approve of John Crane and John Marsh's pad instrument due to its lack of power and its lack of an RF carrier frequency. Unless you can have a frequency generator with sufficient power you are better off using a ray tube instrument with 40 to 250 watts of power output. If a person is dealing with a very serious condition they may want to use a ray tube instrument instead of a pad type instrument if they have access to one.

Many people have wondered if the frequencies that Dr. Rife used are safe. In the next chapter we will discuss the safety of these frequencies.

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Chapter #4

Are Dr. Rife's RF frequencies safe to use?

Rife Ray #3 And Rife Ray #4 High Sine Wave RF Frequencies	
Actinomycosis (Streptothrix)	192,000 Hz
Anthrax	139,200 Hz
B. Coli (Rod form)	417,000 Hz
B. Coli (Filterable virus)	770,000 Hz
Bacillus X or BX (Cancer Carcinoma)	1,604,000 Hz
Bacillus Y or BY (Cancer Sarcoma)	1,530,000 Hz
Gonorrhea	233,000 Hz
Spinal Meningitis	427,000 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz
Staphylococcus Pyogenes Albus	549,070 Hz
Streptococcus Pyogenes	720,000 Hz
Syphilis	789,000 Hz
Tetanus	234,000 Hz
Tuberculosis (Rod)	369,000 Hz
Tuberculosis (Virus)	769,000 Hz
Typhoid Fever (Rod)	760,000 Hz
Typhoid Fever (Virus)	1,445,000 Hz

Today there are many who profess to believe in Dr. Rife and his method of coordinative resonance using frequencies. But they also claim that RF or Radio frequencies are bad or harmful. Some of these people build and sell instruments that do not use any RF carrier frequency and put in their sales information that RF frequencies are harmful. This is a great disservice to Dr. Rife. The instruments they build use low audio frequencies like those used in the Rife Ray #5 or Beam Ray clinical Rife Machine and the 1953 AZ-58 instrument. But they ignoring the importance of the RF carrier frequency these machines used. (These low audio frequencies will be discussed later).

When it comes to Dr. Rife and the method he used in his Rife Machine you cannot "have your cake and eat it too." Dr. Rife's principles were all based on coordinative resonance from RF frequencies. Any method used that does not use RF frequencies cannot be called Dr. Rife's method nor can it truly be called a "Rife Machine." Today, regardless of the method used, people call their instruments "Rife Machines" no matter how they are built. Dr. Rife specifically asked that his name not be put on any instrument, yet this is exactly what people do. There is nothing wrong with people building non RF instruments, but claiming that RF is bad or unsafe just to sell their instruments is where the problem lies. Dr. Rife's Colin B. Kennedy equipment (which will be discussed later in detail) had a frequency range of about 12,000 Hertz to about 2,000,000 Hertz. With this equipment Dr. Rife found the many frequencies (shown above in the chart) that would eliminate or devitalize the various organisms he tested.

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Anyone who understands anything about frequencies knows that the frequencies in that chart are all RF or radio frequencies. It is impossible to build an instrument that could output these frequencies of Dr. Rife's without it using RF frequencies. Every one of Dr. Rife's instruments from the Rife Ray #1 to the Rife Ray #5 used RF frequencies. This is a fact of history and it cannot be changed. Yet there are some who are so foolish as to state that RF instruments such as Dr. Rife's instruments are "Dangerous Rife Machines." It is hard to believe that this is being said by some who claim to be selling "Rife Machines." It is obvious that they know very little about Dr. Rife and his methods. All of the frequencies that Dr. Rife used were in the AM radio band of frequencies. If they were dangerous then we would not have any AM radio stations on the air today. AM radio stations have been around for almost 100 years. If these frequencies were dangerous then people would have been falling dead all over the place for the last 100 years. This is how foolish the idea is that Dr. Rife's RF frequencies and instruments were dangerous.

Another foolish statement that some have made is that these instruments include frequencies in the "Microwave band." The AM radio band is not in the Microwave band. Dr. Rife's Rife Ray #4 had a frequency range that went as high as 22.5 Megahertz (22,500,000 Hertz or 22.5 million Hertz). The microwave band begins at about 300 Megahertz (300,000,000 Hertz) and goes to about 3 Gigahertz. None of Dr. Rife's machines were ever in the microwave band of frequencies. It is clear that people who have written this false information clearly know nothing about Dr. Rife or his equipment. In this report we have no ax to grind other than to point out how foolish some of the false information that is being written by those who claim to know a great deal about Dr. Rife. There is a lot of nonsense being written by some people in order to try and sell some kind of so called "Rife Machine".

In Dr. Rife's tests he would have naturally started in the low frequency range and slowly worked his way higher until he found a frequency that would eliminate the organism. All of the frequencies that he found were in the RF range. They went from 139,200 Hertz for Anthrax to 1,604,000 Hertz for the BX cancer virus (Frequency range taken from the Rife Ray #4 documents). It was only these frequencies that Dr. Rife found that would resonate the organisms and devitalize them. Since Dr. Rife found that only these RF frequencies would resonate and kill the organism then it is impossible to separate RF from coordinative resonance. It would also be impossible to build an instrument that truly worked on Dr. Rife's principles without the use of RF or radio frequencies. In order to prove the safety of Dr. Rife's work we must quote him since he is the person who used these frequencies for over 30 years in his laboratory. Below are two of his quotes on the safety of using RF frequencies in the range and power level that he used in his Rife Machines. The first quote comes from a letter sent to Dr. Stein in 1956:

RIFE: *"I have operated the frequency instrument since 1921. I have watched it advance in style and performance with the advancement of electronics. In the many years I have used this equipment in my research, I have never suffered an injury or any ill effects whatsoever. I found it reliable in performance and efficient in results."* (Letter from Dr. Rife to Dr. Justin Stein, July 2, 1956)

On the John Marsh, Rife audio CDs Dr. Rife also made this statement about his RF frequency instrument:

RIFE: *"I stood in front of that thing for thirty years finding these different frequencies that devitalize these different bacteria. And that thing [RF ray tube] was shooting on me right here [his chest], but it is absolutely harmless to normal tissue and each individual bacteria requiring a different frequency to devitalize."* (John Marsh Rife CDs)

Dr. Milbank Johnson, M.D. also used the RF Rife Machine for many years and conducted clinics and found the instrument safe to use. Dr. James B. Couche, M.D. used the instrument in his private practice for over 22 years and also said he found the instrument safe to use. Dr. Tully, D.D.S. pur-

chased one of Dr. Couche's instruments and used it for several years and found it completely safe to use. Dr. Robert P. Stafford, M.D. used the frequency instrument for over 5 years and also expressed that he found the instrument completely safe to use. These statements along with Dr. Rife's that we quoted above show that Dr. Rife found that his RF frequencies, in the ranges he used, were as safe to use as the frequencies output by any radio station. These frequencies are broadcast through the air day and night passing through our homes without any harm to the human body. There may be some people with RF sensitivity but this does not mean that RF is unsafe to use. This only means that these people are sensitive to RF and should avoid it if they find a problem using it.

Chapter Summary: An instrument that does not output Dr. Rife's RF frequencies is not a "Rife Machine" in the strictest sense of the word. Neither can they resonate the microorganisms that Dr. Rife proved could be devitalized with his RF frequencies. None of Dr. Rife's RF instruments ever put out frequencies in the "Microwave band" of frequencies. Dr. Rife found that his frequencies and the power levels he used in his instruments were safe to use. Non RF frequency generators appear to be very good instruments and help may people but they do not work on the same methods and principles that Dr. Rife used.

Many people have wondered if Dr. Rife ever used audio frequencies. In the next chapter we will discuss whether Dr. Rife ever used audio frequencies with his equipment.

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Chapter #5

Did Dr. Rife use audio frequencies?

In Dr. Rife's 1961 deposition he revealed the fact that he was using some form of audio modulation from the beginning of his work with frequency instruments:

RIFE: *"Initially I worked with loose couplers to get an audio oscillation and then with the use of transmitters, I tried to balance the audio and modulate the audio on a carrier wave to transmit the audio energy."* (Dr. Rife's 1961 Deposition, answers page 5)

Dr. Rife stated that at the beginning of his work, back in the 1920's when loose couplers were used in generating frequencies, he was using audio modulation with an RF or radio frequency carrier. Above is a photo of a loose coupler courtesy of "Henry Rogers, Western Historic Radio Museum" (www.radioblvd.com). These loose couplers worked by moving one coil inside the other in order to change the frequencies.

In Dr. Rife's Rife Ray #3 and Rife Ray #4 Rife Machines he used a specific audio circuit which gated or pulsed his frequencies. This circuit modulated a fixed audio frequency with all of his high frequencies which he used on the various organisms. This circuit will be discussed later when we discuss these Rife Machines.

It is apparent that Dr. Rife first tested audio frequencies on organisms in his search for the frequency which would devitalize them. The audio range would be the logical place to start. If he couldn't find a frequency in the audio range, he then moved up into higher frequency ranges until he found a frequency that would devitalize an organism. In Dr. Rife's early lab notes, he listed only two organisms that had an audio frequency M.O.R. Later when Dr. Rife found out that he was reading his frequencies incorrectly, one of those audio frequencies was changed to a much higher RF frequency. There are other statements made by Dr. Rife which show that he tested the audio range. In fact Dr. Rife gave the full range of his frequencies:

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RIFE: *"Some of them are in the visible band, or I mean not only the visible band but, uh, band of frequencies audible to the human ear [audio frequencies are frequencies that you can hear as tones]. Some of them are way beyond either way. They run through a very, very large gamut. Some of them are very, very broad, long. Some of them are...not extremely short. There are none of them what we call our ultra short wave that I have found yet. Well there's many of them...we would, uh, classify in the ultrasonic band because they're not visible* [sic] *with the human ear. They're way beyond you know. And some of them are even in the broadcast band. Your cancer is very high* [1,604,000 Hertz]. *You can't hear it, the oscillation. But now you take your T.B.* [Tuberculosis Rod 369,000 Hertz & Virus 769,000 Hertz]. *Now that's down. A little more you see...if you don't have an absolute coordinative resonance, you have nothing. One tenth of one meter off and you have nothing. Its got to be absolutely correct for that individual organism. It's got to be precise...the virus of cancer has a certain frequency. And it has to be there, otherwise if it's a little one way or the other, no good, no good for nothing. Infrared will penetrate, yes, but the heat is not the thing because the heat is not the frequency, it's [Infrared] way down in the very low band of frequencies and the laboratory rate of the BX is up into the high band."* (John Marsh Rife CDs - CD 5 track 2, CD 6 track 2, CD 7 track 1 and CD 9 track 1)

In these statements Dr. Rife clearly explains the broad range of his frequencies. Some were audio and could be heard by the human ear; others were in the ultrasonic range, and some were even in the broadcast band. Cancer he said was very high. He states the frequencies have to be very accurate to work. One tenth of one meter off and they would not work at all. We will talk about this later. Here are two additional statements that also verify that Dr. Rife's Machine's could output a modulated audio frequency:

RIFE: *"You know we had an idea when we had our* [1934] *Clinic in La Jolla, of course that was battery and motor generator operated that set, you know, and boy it would sure raise the devil with all the radios so we had a couple of cars that was equipped with car radios and we sent them out and we would take the switch of that thing, and had a code you know like an S.O.S., and one of them went up north, and one of them went south from La Jolla. Before we started in we wanted to see how far we were going to disturb things"* (John Marsh Collection, Trip to Ohio Papers, #24)

In the next photo, shown below, is the Rife Ray #3 which was used at the 1934 Clinic in La Jolla.

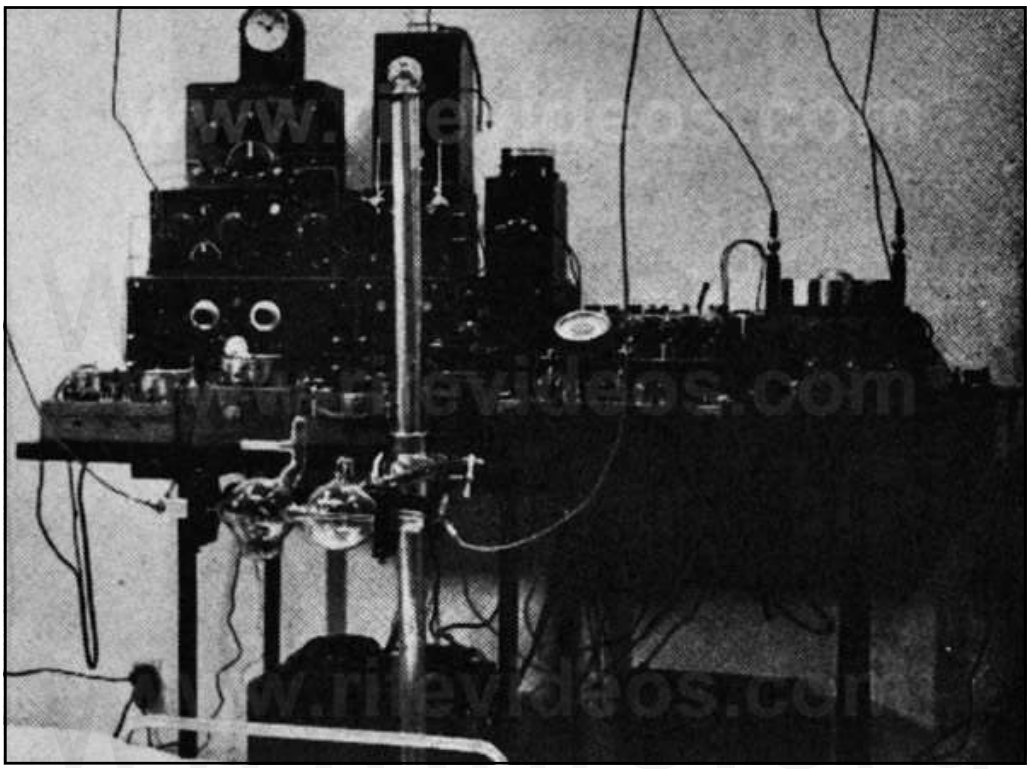

In order to be able to put out an S.O.S. type signal he would have had to modulate the audio frequency onto a carrier in order for the car radios to pick up the signal. On the John Marsh Collection of Dr. Rife's audio CD's, Dr. Couche makes an interesting comment about the Rife Ray #3 instrument. He was present at the 1934 clinic sponsored by Dr. Johnson and the University of Southern California. He stated:

DR. COUCHE: *"They gave him a treatment of the Rife frequencies which are in the auditory band."* (John Marsh Rife CD's - CD 3 track 1)

The cancer frequency (Rife Ray #4 1,604,000 Hertz and 1,607,450 for the Rife Ray #5) and tuberculosis (Rife Ray #4 Rod form 369,000 Hertz and 369,433 for the Rife Ray #5)(Rife Ray #4 and Rife Ray #5 Virus form 769,000 Hertz) frequencies used in the 1934 clinic were not audio frequencies. Why would Dr. Couche make this statement? The evidence shows that Dr. Couche was getting the Rife Ray #4 and the Rife Ray #5 methods of generating the frequencies mixed up. The Rife Ray #5 or Beam Ray Clinical Rife Machine which Dr. Couche used for over 22 years used audio frequencies to create the proper sideband spacing to hit the high harmonic RF M.O.R. frequency (Mortal Oscillatory Rate or the frequency that will kill or devitalize an organism). Dr. Couche purchased two of these clinical Rife Machines and used them until 1952 when he retired. We will cover this instrument later in this paper. All the evidence that we have acquired from the quotes show that the Rife Machines from 1934 and earlier could output audio frequencies above 12,000 Hertz and that Dr. Rife tested audio frequencies right from the beginning of his work in 1920.

Although we have been able to prove that Dr. Rife tested the audio range of frequencies, as any good scientist would have done, it should be pointed out that by 1935 when the Rife Ray #4 Rife Machine was built, he no longer felt that he needed to test audio frequencies any longer. This is indicated by the fact that no variable audio oscillator was included in this new Rife Ray #4 frequency instrument. The Rife Ray #4 Rife Machine will be discussed later in this article.

In 1936 Dr. Rife's engineer, Philip Hoyland, developed a new machine which used audio frequencies to create Dr. Rife's high RF frequencies through harmonic sidebands. The audio frequencies were not the frequencies that would devitalize or kill the various microorganisms. These audio frequencies were used to produce the frequencies that would devitalize or eliminate the disease organisms. This method of using harmonic sidebands will be discussed later in this report when we examine the Rife Ray #5 or Beam Ray Clinical instrument.

Chapter Summary: Dr. Rife tested and use audio frequencies in his instruments. Primarily the audio frequency was modulated onto the high RF frequency to create a pulse in the higher RF or radio frequencies he was using to devitalize the various microorganisms. When his engineer, Philip Hoyland, developed the new Rife Ray #5 or Beam Ray Clinical instrument the audio frequencies were used to produce Dr. Rife's High RF frequencies through harmonic sidebands.

In the next chapter we will look at Dr. Rife's first frequency instrument called the Rife Ray #1 and how he was able to devitalize his first microorganism using it.

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Chapter #6

Dr. Rife's 1920 to 1922 Rife Ray #1 Rife Machine

1. Used a Ray tube.
2. Frequency range was probably about 1 MHz or less using loose couplers: Could modulate audio frequencies.
3. Output to the Ray tube was 8 to 10 watts.

From information taken from many different documented sources there is finally enough information to know what Dr. Rife did in the early years, from 1920 to about 1934. Dr. Rife designated his machines in numerical order beginning with the Rife Ray #1. Even though we do not have any photos of his Rife Ray #1, we know that Dr. Rife was using loose couplers (photo shown above is a loose coupler) because of this statement:

RIFE: *"Initially I worked with loose couplers to get an audio oscillation and then with the use of transmitters, I tried to balance the audio and modulate the audio on a carrier wave to transmit the audio energy."* (Dr. Rife's 1961 Deposition, question and answer #35)

In a paper that was written in the 1930's, probably by Jack Free, one of Dr. Rife's lab assistants, we get a history of Dr. Rife's machines. This paper starts with the Rife Ray #1.

"In January 1920 experiments were started at the Rife Research Laboratory by Commander Royal R. Rife U.S.N. Ret. to determine the effect of electrical influences upon pathogenic microorganisms. Tests were made for anode and cathode polarity influences and the effect of infrared, ultraviolet and X-ray. During these experiments the idea was conceived of the possibility of devitalizing the pathogenic micro-organisms by electrical frequencies of varying wavelengths. The initial apparatus [Rife Ray #1] *for the tests along this line of experiments was constructed and used in prolonged experiments during 1921 and 1922, with results that warranted the belief that the principles involved contained possibilities."* (Development of The Rife Ray and use in devitalizing of pathogenic microorganisms).

The tests that were done with the Rife Ray #1 which showed that it was possible to devitalize micro-organisms with frequencies was talked about in a 1938 Evening Tribune newspaper article. Also in this newspaper article we learn the power output of the Rife Ray #1 and the first organism that he was able to devitalize.

"Rife built a simple frequency generating apparatus of about 8 or 10 watts output. He grew some cultures of bacteria. Then he began the studies whose reported results now promise to revolutionize the entire theory and the whole treatment of the human diseases, other than those of a functional or accidental nature. Machine and cultures ready, the San Diegan anxiously, feverishly began testing his idea. Would those minute killers of men die under the frequency bombardment? It would be a patience-wracking task, for there was no way to measure what wave length or frequencies the organism might have. In the quiet loneliness of the laboratory, Rife simply had to turn and turn and turn the tuning dials of his machine and check after each bombardment the conditions of the disease organisms in his cultures to see if anything had happened to them. He just had to hunt by trial and error a frequency, which might do something to a certain organism. Then, if he found one for that disease, he would have to start all over again on the next kind.

The scientist took first a culture of b. coli, the organisms, which always seem to accompany the agency of typhoid fever yet apparently, are harmless themselves. He prepared microscope slides from the culture and saw that his little subjects were alive. Then he turned the ray on them, tuned it to a certain frequency, then took the slide back to the microscope to see if anything had happened. He did this time after time and the b. coli still remained discouragingly healthy. Then one day, Rife recounted, a culture of the organisms which had been bombarded with a certain frequency [417,000 Hertz] *appeared different under the microscope. They seemed lifeless! He tried to get them to grow, to reproduce in their laboratory media. He tried that same frequency on culture after culture of b. coli and always the results were the same. The organisms were dead. "It did kill them!" Rife told himself. And probably, cool, conservative scientists though he is, he allowed himself to hope that he, Royal Raymond Rife, had found that 'bullet" which scientist have sought for years, that "magic bullet' which would surely, certainly slay mankind's diseases."* (Dread Disease Germs Destroyed By Rays, Claim Of S.D. Scientist-Cancer Blow Seen After 18-year Toil by Rife, The Evening Tribune, May 6, 1938)

These few statements that we have just read give us all that is really known about the Rife Ray #1. The most important development that was accomplished with the Rife Ray #1 was Dr. Rife was able to test and prove that microorganisms could be killed or devitalized using RF frequencies pulsed with an audio frequency.

The photo, shown below, is a picture of a more complex loose coupler setup.

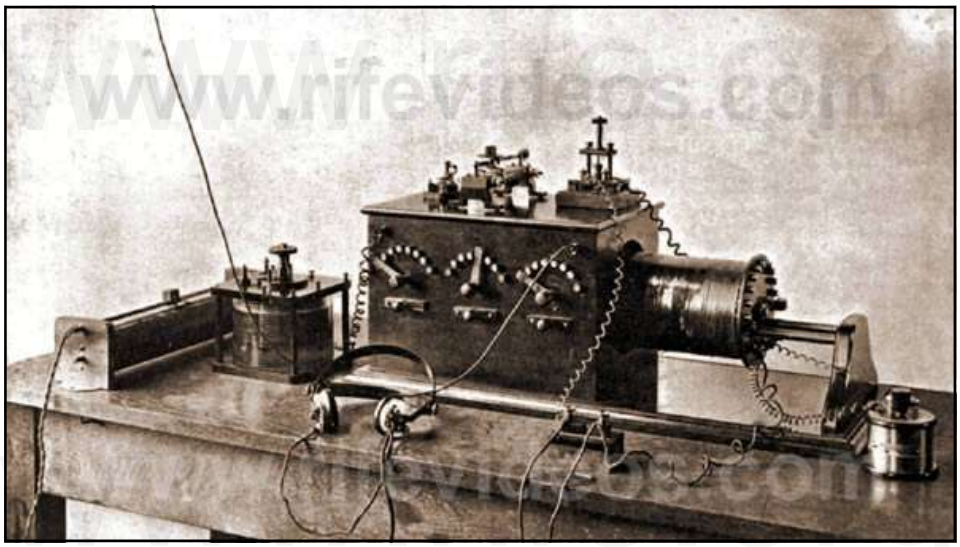

By 1923 Dr. Rife assembled his next Rife Machine called the Rife Ray #2 using off-the-shelf frequency generators. The same equipment that was used with the Rife Ray #2 was also used with the Rife Ray #3. The changes made to the Rife Ray #2 to create the Rife Ray #3 appear to be mostly an increase in the power output of the instrument through the ray tube. Since the full details of the changes are not known and the same equipment that was used with the Rife Ray #2 was used with the Rife Ray #3 we will look at the Rife Ray #3 in the next chapter.

Chapter Summary: The Rife Ray #1 was a simple frequency generating device built to determine if microorganisms could be devitalize by frequencies. The instrument was built using loose couplers which when moved in and out of the coil would produce different electrical RF frequencies. Dr. Rife modulated an audio frequency on the RF frequency he was using in order to produce a pulsed waveform. With this simple frequency generator he was able to devitalize his first organism which was B. coli. Dr. Rife after proving his theory went on to build more powerful equipment which we will look at in succeeding chapters in this report.

In the next chapter we will look discuss Dr. Rife's Rife Ray #3 instrument which was used in the 1934 cancer and tuberculosis clinic which Dr. Milbank Johnson conducted.

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Chapter #7

1934 Rife Ray #3 Rife Machine used in the 1934 clinic

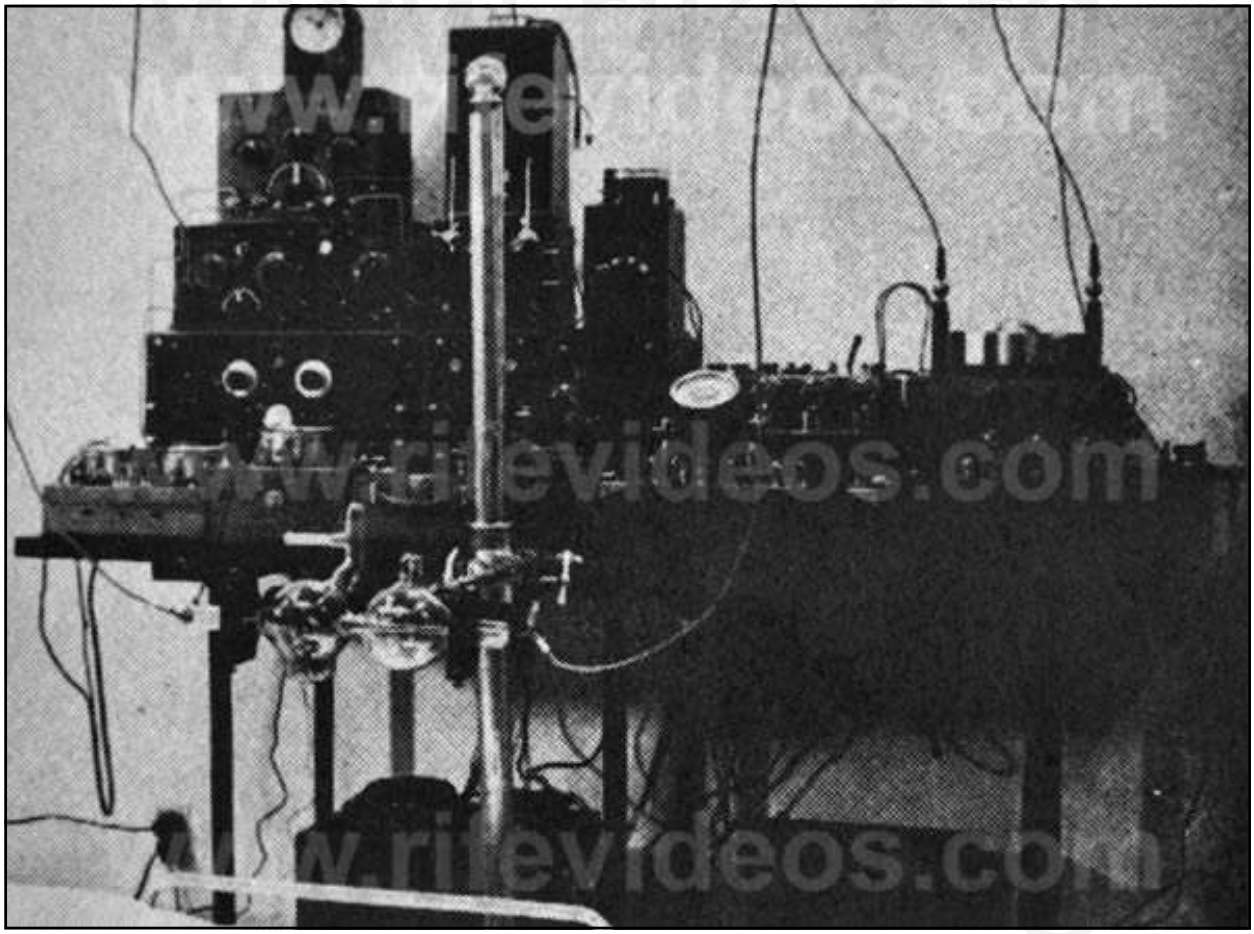

1. This was a regenerative instrument that used a ray tube.
2. It consisted of two Kennedy Regenerative Receivers (the model numbers were the 110 and 281). These two receivers made it possible to have a combination of one low frequency oscillator and one high frequency oscillator or two high frequency oscillators.
3. The output was sine wave.
4. Power usage was from batteries. Output to the ray tube was about 50 RF watts?

This instrument was described in a document believed to have been written by Jack Free one of Dr. Rife's lab assistance. We will quote the portion of that document that pertains to this instrument:

"In 1923 more appropriate apparatus [Rife Ray #2 when improved became the Rife Ray #3] *was assembled and used. The different frequencies were generated by a tube oscillator with many stages of amplification, the final stage being a 50 watt Telefunken tube.*

This amplified frequency was in turn fed into an output tube, and as the voltage at this point was quite small, it was found necessary to apply external voltage across the anode and the cathode of the output tube [ray tube] *to act as a carrier wave for the frequencies that were generated in the apparatus.*

The output tube was constructed with a double expansion bulb, blown from quartz, using platinum anode and cathode it having a 45° target for directional effect. No heat is generated in output tube-

temperature constant. The frequency control of the instrument was exact to a fraction of a wavelength making it possible to coordinate the frequency in each pathogenic micro-organism with its own wavelength of frequency delivered from the instrument. The current supply for the whole apparatus was supplied by batteries and generators.

During the next eight years these experiments continued and with the aid of the Rife super microscope and the frequency instruments the coordinating frequencies (termed mortal oscillatory rate MOR) of most of the pathogenic micro-organisms were found and recorded including the frequencies of many of the virus or filter passing forms of these organisms." (Development of the Rife Ray and use in devitalizing of pathogenic micro-organisms).

Dr. Rife was asked by Dr. Milbank Johnson M.D. to write a description of his Rife Ray #3 instrument in 1935. Dr. Rife had Jack Free, his lab assistant; include this description in a letter that Jack Free wrote to Dr. Milbank Johnson. Below is Dr. Rife's description.

RIFE: *"The basic principle of this devise is the control of a desired frequency. These frequencies varying upon the organisms being treated.*

The frequency is set which controls the initial oscillator, which in turn is run thru six stages of amplification, the last stage driving a 50 watt output tube.

The frequency with its carrier wave is transmitted into an output tube [double-bubble ray tube] *similar to the standard X-ray tube, but filled with a different inert gas. This tube acts as a directional antenna.*

The importance in the variable control of these frequencies is that each pathogenic organism being treated is of a different chemical consistency, the consequence being they carry a different molecular vibratory rate. Each one in turn under these conditions requires a different frequency or vibratory rate to destroy." (Letter from Jack Free to Dr. Milbank Johnson M.D., December 17, 1935).

This Rife Machine was used in the 1934 clinic by Dr. Milbank Johnson. See photo of Rife Ray #3 on page 26. If you look at the bottom of that photo of the Rife ray #3 you can see part of the bed railing and mattress where they treated the patients. If you look at the table you can see that the instrument was not a one piece instrument but had many components. This Rife Machine has always been considered the best instrument used by Dr. Rife because it produced the results of the 1934 cancer and tuberculosis clinic. Those interested in the work of Dr. Rife have always wanted to know how this instrument worked. They have also wondered what equipment he used. This has been one of the biggest Rife mysteries. There have been all kinds of speculation on how his first instrument worked. What was its waveform? What was the frequency range? Could it generate audio frequencies? Was it super-regenerative (as he wrote on his lab notes), or was it just regenerative? All of these things have remained mysteries for over fifty years. It was generally believed that the 1934 instrument was custom made for Dr. Rife. However, if the equipment had not been custom made, the mystery could be solved. And today, thanks to some great detective work done by Mr. Peters, the mystery, in fact, is now solved. The instruments were not custom made. They were standard off-the-shelf frequency generating equipment that Dr. Rife purchased. The equipment and frequency ranges are now known.

A better photo of the equipment Dr. Rife used is the first photo on the next page. It was when Mr. Peters was looking at this photo that he recognized the Kennedy frequency generating equipment. Dr. Rife most likely stacked it all up on a table and took a picture of it after he started to use the newer equipment built for him in 1935. This photo, amongst others, made it possible to figure out the equipment Dr. Rife used. This photo has been provided courtesy of Jason Ringas of Rife Research Group of Canada. Here in this paper you will be able to see the actual equipment along with the selling advertisements of the 1920's that give the specifications of the equipment.

We will now look at each piece of equipment and take an in-depth look at the specifications of each. All pieces of equipment except the ray tubes and possibly the five stage amplifier were considered off-the-shelf equipment. This means that this was standard frequency generation equipment which could be purchased from companies in the 1920's. Although they are regenerative receivers, they could output whatever frequency Dr. Rife wanted to use when the regenerative circuit was turned up. Dr. Rife used top-of-the-line Kennedy equipment from the Colin B. Kennedy Company, which built some of the most accurate, high quality equipment that could be purchased in 1923. It was also some of the most expensive equipment to purchase.

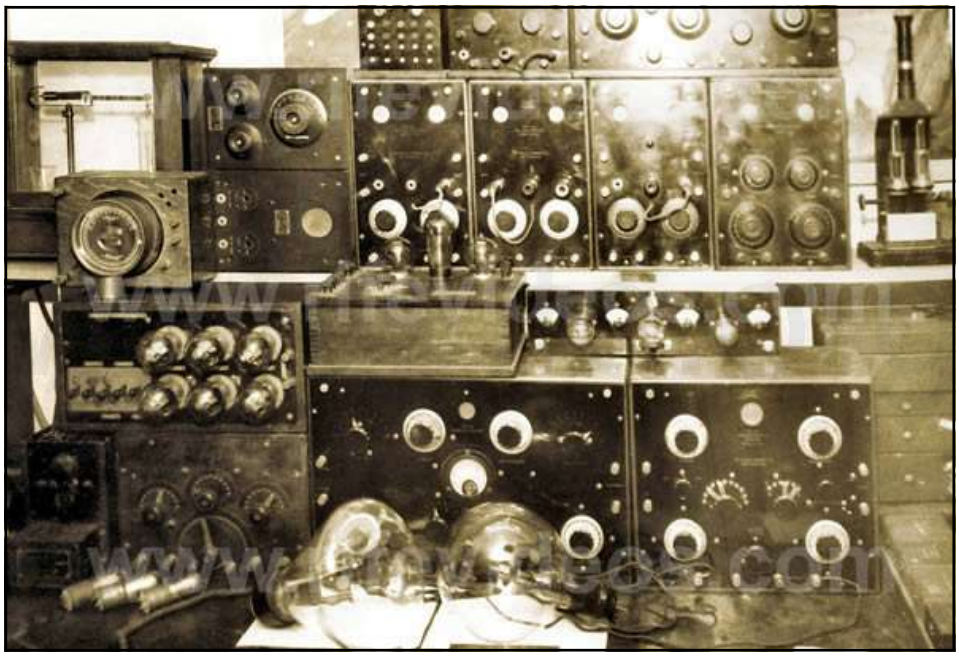

We will now take a look at the next photo, shown below. This photo is one of several pictures of Dr. Rife's laboratory instruments. The bottom two pieces of radio equipment were the Kennedy Receiver Model 110 connected to the Kennedy Two-Stage Audio Amplifier Model 525. The other piece of equipment sitting on top of the Kennedy Receiver Model 110 we will look at later. On the next page are two more photos. The first photo is a better photo of this old antique equipment. The second photo is the 1923 advertisement from the Colin B. Kennedy Company which provides the frequency range and features of this regenerative receiver. It also gives the effective frequency range from 175 to 25,000 meters or from 12,000 Hertz to 1,700,000 Hertz.

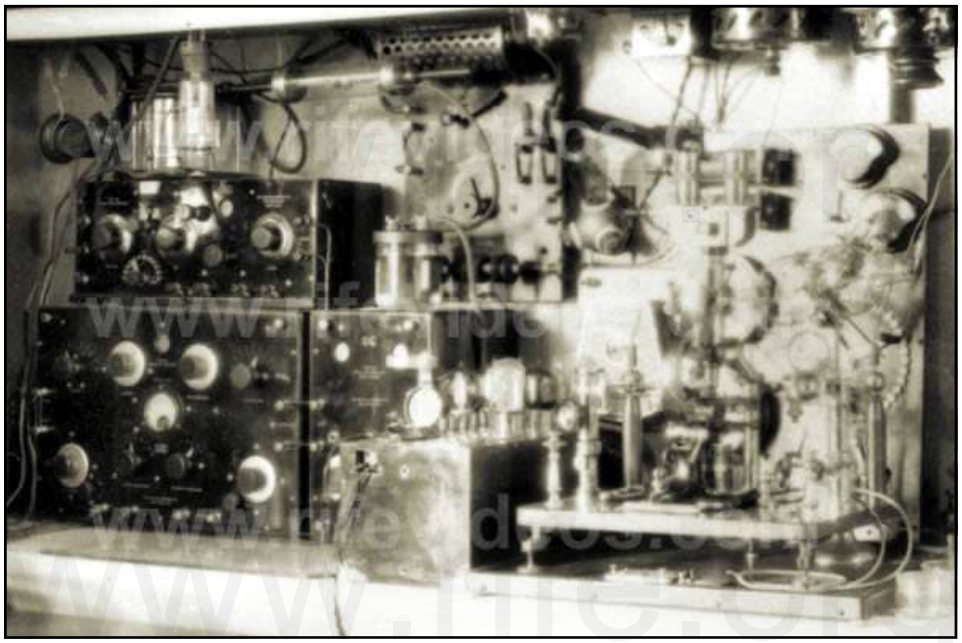

KENNEDY
EQUIPMENT

ANNOUNCING

THE NEW KENNEDY UNIVERSAL REGENERATIVE RECEIVER

TYPE 110

EFFECTIVE RANGE: 175 TO 25,000 METERS

DETECTS
REGENERATES
OSCILLATES
On all wave lengths in common use.

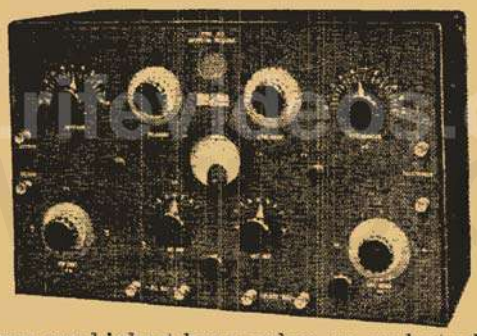

Licensed under Armstrong U. S. Patent No. 1,113,149

Surpassing even our highest hopes when we undertook its development, this latest addition to the Kennedy line is of interest **to everyone who uses a radio receiving set.**

Our engineering staff spent many months in developing this unit and released it for production only when its performance surpassed every requirement we had set for it. By our long specialization in receiving equipment we have built up a reputation which is so precious that we can afford to put the Kennedy trade-mark on only the highest quality product.

We have spared no effort to make this the best receiver on the market. We honestly believe that it is.

These are some of its features:

Variable inductive coupling between primary and secondary.
Extremely sharp tuning because of very efficient inductance units.
Special Kennedy bank-wound moisture-proof inductors.
Generous overlap between inductance steps.
Large balanced primary and secondary variable condensers.
Micrometer adjustment of secondary condenser
Variable grid condenser with air dielectric, permitting most effective use of all types of available receiving tubes.
Adjustable feed-back circuit.
Fine adjustment of plate voltage by means of potentiometer connected between terminals of filament battery.
Weston ammeter for measuring filament current.
Bus-bar type insulated wiring.

Further details in Bulletin 101, mailed on request.

Ask your dealer for a demonstration. Compare the performance of this receiver with any other you have ever seen. The users of Kennedy Equipment are our best advertisers.

THE COLIN B. KENNEDY COMPANY

INCORPORATED

RIALTO BUILDING SAN FRANCISCO

The Kennedy Model 110 could actually go from 12,000 Hertz to about 1,800,000 Hertz. The Kennedy Company was just being conservative in its advertisement. The next instrument that was on top of the Receiver Model 110 in Dr. Rife's laboratory photo is the Kennedy Short-Wave Regenerative Receiver Model 281. Below is a photo of the Kennedy Receiver Model 281. Below the 281 is a picture of the 1923 Kennedy 281 advertisement.

This Kennedy 281 instrument had an effective range from 185 meters to 620 meters or from 483,000 Hertz to 1,620,000 Hertz. This instrument could actually go to about 1,800,000 Hertz. The Kennedy Company again being conservative on its frequency range.

Above in the original lab photo which showed all of Dr. Rife's equipment stacked up on a table we see another Kennedy Regenerative Receiver, this being the Kennedy Model 220. The first photo, shown below, is a photo of this instrument. Its effective frequency range was from 175 meters to 3250 meters or from 92,000 Hertz to 1,700,000 Hertz. It could also go to about 1,800,000 Hertz. All three models of this Kennedy equipment could go higher in frequency than the advertisements state. Below the Kennedy Model 220 photo we see the 1923 advertisement for the Kennedy 220 instrument.

Now that we have all the frequency generating equipment identified we can now come to some conclusions. All of this Kennedy equipment was sine wave. Square wave was not used or even generated in this old equipment. The Kennedy Receiver Model 110 had a frequency range from 12,000 to about 1,800,000 Hertz. This shows that Dr. Rife's instruments had the ability to output audio frequencies, a fact that he mentioned in his 1961 deposition. The only audio frequencies he could have used would have been modulated from this equipment. Dr. Rife also mentioned in his 1961 deposition that he balanced the audio on a carrier which would have been a modulated waveform.

What is really surprising is the fact that none of the Kennedy equipment that Dr. Rife used could output a frequency higher than about 2 Megahertz (MHz). This fact changes a lot of things with regard to his lab notes dated before 1934. It was impossible for him to produce 11,780,000 Hertz or 17,033,000 Hertz using this equipment. These are the two frequencies that Dr. Rife listed on his lab notes for the BX cancer virus. The frequency range of the Kennedy equipment now explains why Dr. Rife's Engineer, Philip Hoyland, told Mr. Edwards, a business partner in Beam Ray Corporation, that Dr. Rife and not taken some factors into consideration when he read his frequencies prior to 1935. What this implies is that Dr. Rife may have misread his frequencies prior to 1935.

With Dr. Rife's approval, Philip Hoyland was hired by Dr. Milbank Johnson, M.D. and the University of Southern California Special Medical Research Committee in 1935 to build a more up-to-date portable frequency instrument to be used for their research. Dr. Rife's 1934 instrument was cumbersome because it was not just one, but several, pieces of equipment which were difficult to move and use. In order to build the new instrument, Philip Hoyland needed to know what frequencies Dr. Rife was using.

This is where the story gets interesting. Dr. Rife had many lab notes which had the frequencies written down on them for the various microorganisms. Dr. Rife could have just given Philip Hoyland a copy of the frequency ranges that the lab notes covered and he could have built the instrument from that information. But this is not what happened. Philip Hoyland brought his standard master oscillator into the laboratory and then Dr. Rife and Philip Hoyland went through the long process of putting many organisms under the microscope and checking to see what the frequency was when it was devitalized. If Dr. Rife had been confident that his original frequencies were correct on his lab notes this testing would not have been necessary. It is apparent that there were probably some questions in Dr. Rife's mind about the accuracy of his initial readings and frequencies which made this retesting of the organisms M.O.R. frequencies necessary.

Keeping this in mind, it was difficult to read the correct frequencies prior to this time unless you were very proficient at doing it. Philip Hoyland apparently wanted to know exactly what frequencies Dr. Rife was using in order to build the new instrument. While testifying on the stand in the 1939 Beam Ray trial, Philip Hoyland stated this about how he obtained the frequencies: (1939 Beam Ray Trial Transcript #778)

HOYLAND: *"They were taken off the last machine* [the Kennedy equipment] *that was built by Dr. Rife. I transferred them from one machine to another."*

At another point during the trial the transcript reads as follows. (#905-916):

COMPARET: *"In June of 1935 was when you made an agreement with the* [transcript missing words] *medical research to build a Rife Ray machine,* [the Rife Ray #4] *you did build it soon after that?"*

HOYLAND: *"Yes."*

COMPARET: *"You had an agreement with them that all work was to be done under Dr. Rife's direction?"*

HOYLAND: *"That's what the contract called for."*

COMPARET: *"Did you do this work without getting the frequencies from Dr. Rife?"*

HOYLAND: *"I recalibrated the machine according to the bacteria."*

COMPARET: *"What specifically did you do that constituted this recalibration?"*

HOYLAND: *"I used a standard oscillator against his machine to see what frequencies he was using."*

COMPARET: *"He set his machine and you measured his frequencies?"*

HOYLAND: *"Yes."*

COMPARET: *"Did you make any memorandum of these particular frequencies?"*

HOYLAND: *"Yes, I gave Dr. Johnson and Dr. Rife a list of them."*

Later during the trial Dr. Rife was asked where the frequencies came from. (#1290-1293):

JUDGE KELLY: *"When you constructed this Beam Ray machine* [from Kennedy equipment] *you had a dial representing the frequencies or harmonics?"*

RIFE: *"We had many dials on the original machine* [Kennedy Model 110]."

JUDGE KELLY: *"Is that the machine Mr. Hoyland got the frequencies from?"*

RIFE: *"Yes, he took them off that old machine* [Kennedy Model 110]."

From the court testimony given by Dr. Rife and Philip Hoyland we see the frequencies were read by Philip Hoyland off of the Rife Ray #3 or Kennedy Model 110 and 281 and used in the next instrument which was the Rife Ray #4 (We will be discussing this instrument next). Now let's continue on reading the court testimony: (Beam Ray Trial Transcript #1553-1555)

COMPARET: *"Now going back to your assumption that Dr. Rife knew the frequencies, had Mr. Hoyland ever told you that Dr. Rife knew them?"*

EDWARDS: *"No, he told me that Dr. Rife only thought he had them."*

COMPARET: *"What did you think that meant?"*

EDWARDS: *"Well, Mr. Hoyland told me about that time* [1934 and before], *that Dr. Rife measured the frequencies only by the length of the wire and that he did not take other factors into consideration."*

Here in the court testimony we just read that Dr. Rife had not read his frequencies correctly when he measured them. This would have been a mistake easy to make in the 1920's and 1930's. The frequencies which Philip Hoyland read off of Dr. Rife's #3 instrument, which consisted of the Kennedy equipment, were different from the earlier lab note frequencies recorded by Dr. Rife. This has caused a lot of confusion because the frequencies that Philip Hoyland read were all lower than 2,000,000 Hertz.

Dr. Rife had written down on his lab notes frequencies as high as 11,780,000 and 17,033,000 Hertz for the BX cancer virus. However, the Kennedy Models 110, 220 and 281 could not output these high frequencies. It is apparent that Philip Hoyland was absolutely correct when he told Mr. Edwards that Dr. Rife had misread his frequencies. Also, Philip Hoyland testified in court that he gave both Dr. Rife and Dr. Johnson a list of the correct frequencies he read off of the Kennedy Model 110. This verifies the truth of what Philip Hoyland said in court.

There is another verification that Dr. Rife had misread his frequencies. On the Rife audio CD's, Henry Siner, Dr. Rife's lab assistant, read from a lab note of the BX cancer virus. All the information was the same as Dr. Rife's earlier pre-1935 lab notes except the frequencies. On that corrected lab note Henry Siner read 187 meters for the wave length and 1,604,000 Hertz for the cycles per second frequency for the BX cancer virus. Both the meter frequency and the cycles per second measurement being the same frequency. However, on the pre-1935 lab note, both were different. One frequency was 11,780,000 and the other was 17.6 meters or 17,033,000 Hertz. Henry Siners reading of this corrected lab note also verifies that Dr. Rife had not read his frequencies correctly. At the end of that discussion about the BX cancer virus and the Lab note Henry Siner made this statement, quote:

SINER: *"That was a long time ago, but, and remember, I was just copying what he* [Dr. Rife] *dictated."* (John Marsh Rife CD's - MP3 track 11).

This quote from Henry Siner shows that it was Dr. Rife who made the corrections to the lab note. The frequency of 1,604,000 Hertz was the frequency Philip Hoyland read and gave to Dr. Rife and Dr. Johnson and it was used in the new instrument built in 1935 called the Rife Ray #4.

There is one thing we need to consider. Dr. Rife could have read a harmonic of the frequency instead of the correct frequency. It appears this is in fact what Dr. Rife did. Dr. Rife understood how easy it was to read a harmonic frequency instead of the correct frequency and recognized that he may not have had true fundamental frequencies. He stated:

RIFE: *"I've talked to you* [John Crane] *and Verne* [Verne Thompson] *and other people too that there may be some of the frequencies that we are using that may be harmonics, you know...It's not an impossibility that some of those frequencies may be a harmonic. We may not know the true frequencies of some of them. But it does the business. Maybe if we had the true frequency it would do it better because it has more power than a harmonic."* (John Marsh Rife CD's - CD 7 track 2).

The frequency that Philip Hoyland read off of Dr. Rife's 1934 Rife Ray #3 Machine was 1,604,000 Hertz. Dr. Rife had written two frequencies down on his pre-1934 lab notes. One was 11,780,000 Hertz and the other was 17,033,000 Hertz. The seventh harmonic of 1,604,000 is 11,228,000 which is close to the 11,780,000 especially if you consider that Dr. Rife was not reading his frequencies correctly. We now know Dr. Rife was not even reading the harmonic correctly. Now the eleventh harmonic of 1,604,000 is 17,644,000 which is close also to 17,033,000 Hertz. Had Dr. Rife read the frequencies correctly then both the meter frequency and the cycles per second frequency should have been the same frequency. This was the case with the new lab note when it was corrected by Dr. Rife and read by Henry Siner in the 1950's. The evidence is absolutely overwhelming that Dr. Rife was not reading his frequencies correctly because the frequencies Philip Hoyland read were used in the next Rife Machine which was called the Rife Ray #4. In the space of about 60 days all Dr. Rife's frequencies changed from from the pre-1935 lab note frequencies to the new frequencies that were used with the Rife Ray #4.

We wondered where these harmonics that Dr. Rife read might of come from. Did the Kennedy Model 110 have harmonics in its waveform? Did it output a sine wave waveform? Was the waveform distorted? The only way to answer these questions was to find a working Kennedy 110 and put it on a

spectrum analyzer. Jason Ringas of the Rife Research Group of Canada and I contacted Henry Rogers the owner of the Western Historic Radio Museum (www.radioblvd.com) who owns two Kennedy 110s that are still operational. Henry Rogers knew nothing about Dr. Rife but agreed to let me come visit his location to check the readings of the Kennedy Model 110. He also owns a Kennedy 220 and a Kennedy Model 281, both of which are also in working condition. The Kennedy Company built top-of-the-line equipment and we were surprised to find out even after over 80 years, they still worked as well as they did when they were new. Very little attention is ever needed to get these instruments back in working condition because of the quality of their construction. So with spectrum analyzer in hand, I went to see Henry Rogers and we put the Kennedy 110 on the spectrum analyzer to get the answers to our questions. Below is the reading of the waveform of the Kennedy Model 110 at 417,000 Hertz using a PicoScope 3205 spectrum analyzer. On the left is the waveform which proves that Dr. Rife was using sine wave.

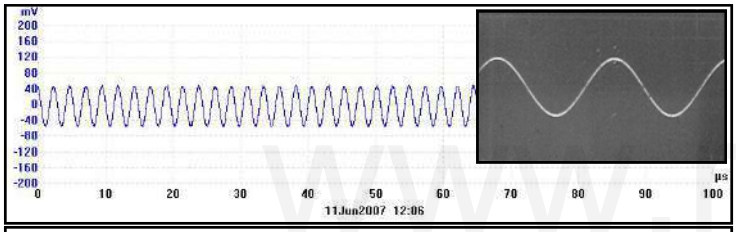

Kennedy Model 110 at 417,000 Hertz

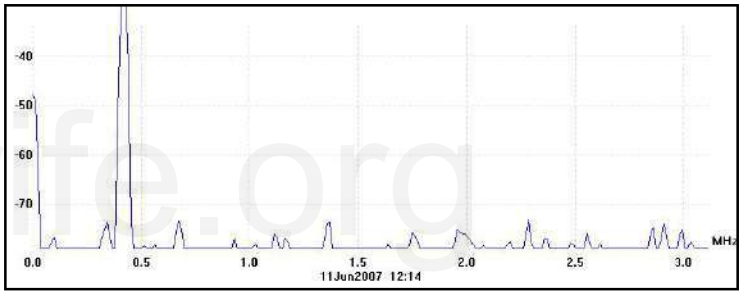

That question was finally answered. The spectrum analyzing of the frequency revealed that there were no harmonics in the waveform. The noise which shows up as little spikes are from the power supply. These old receivers ran on batteries and when they are hooked up to batteries the noise in the circuit is greatly reduced. The amazing thing about the Kennedy Model 110 sine wave waveform was that it was picture perfect. This amazed us because everyone believed that the equipment that Dr. Rife used would have had a distorted waveform. No one that I have ever talked with believed that this old equipment was capable of producing a nearly-perfect waveform. It was as good as we can do today with our sophisticated modern frequency generating equipment. The fact that it produced no harmonics also amazed us. Below are the readings of the Kennedy Model 110 at 770,000 and 1,604,000 Hertz. At 1,604,000 Hertz the sine wave was still nearly perfect and it did not produce any harmonics. We checked all frequencies out to 50 Megahertz for harmonics and found none.

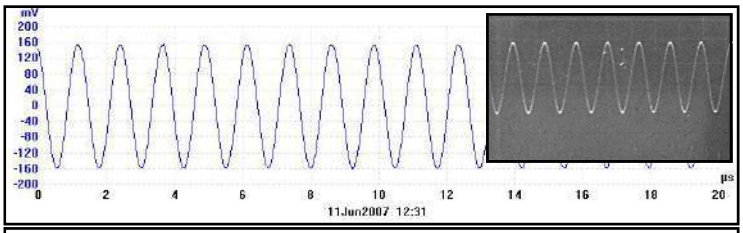

Kennedy Model 110 at 770,000 Hertz

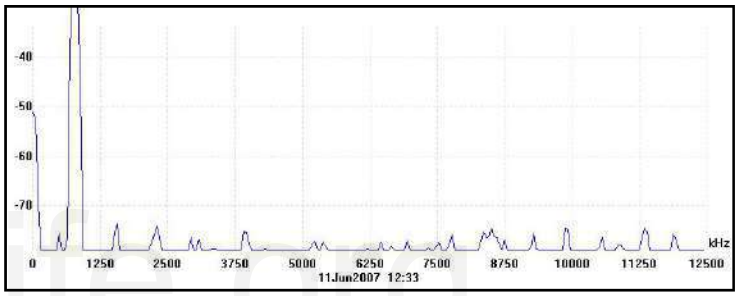

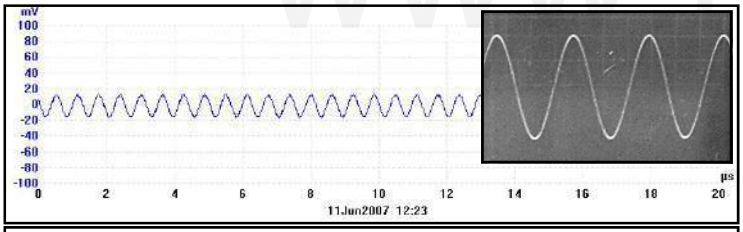

Kennedy Model 110 at 1,604,000 Hertz

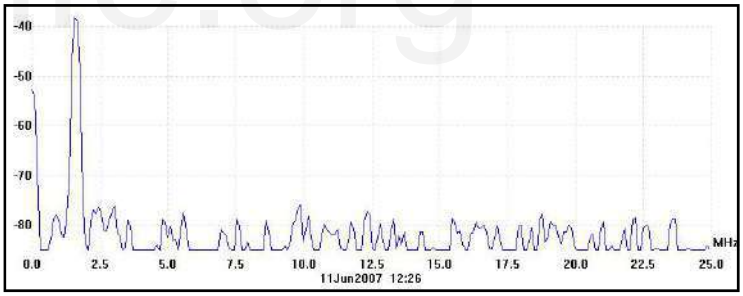

This testing showed that Dr. Rife's equipment, call a Rife Machine, output a sine wave waveform with no harmonics. So where did the frequencies come from that Dr. Rife read and recorded on his old lab notes? Why did he record two frequencies in his lab notes? We now knew what equipment he

used. His pre-1935 lab notes just didn't make any sense. We know from Henry Siner's reading of the corrected BX lab note that the meter frequency and the cycles per second frequency should be the same. It is apparent that Dr. Rife used two different pieces of equipment to read his frequencies. One piece of equipment gave a reading in meters and the other piece of equipment gave a reading in cycles per second. However even knowing this did not explain where the harmonics came from.

We knew that the noble gas he used in his ray tube could double the frequency that went through it. These types of tests have been done with plasma in laboratories in the past. So we decided to make some tests. We tested the Icom 718 which we hooked up to a phanotron ray tube. This is the type of ray tube Dr. Rife used and is the only one we tested. We first tested to see what the sine wave looked like coming out of the Icom 718. We wanted to make sure that it did not produce any harmonics, and in fact, our testing showed it did not produce any harmonics. Then we hooked it up to the antenna tuner to see if the tuner distorted the waveform and produced any harmonics. We found it did not distort the waveform or produce harmonics through the antenna tuner except at 1,604,000 Hertz. This is only because the Icom is not supposed to output a frequency below 2,000,000 Hertz. Below this frequency it will produce two harmonics (see graph on page 37). The other two frequencies we tested were 11,780,000 and 17,033,000 Hertz. These were the frequencies Dr. Rife recorded on his pre-1935 lab notes and neither of these produced harmonics through the antenna tuner. Then we put it through the ray tube. The ray tube didn't just double the frequency - it also produced all the harmonics that Dr. Rife would have read. We now had the answers as to where the harmonics came from. The ray tube produces the harmonics. You can put a harmonic-free sine wave through a ray tube and get all the harmonics that Dr. Rife recorded on his lab notes. The photo below is the Icom 718 and on the next three pages are three graphs that show the readings taken in this testing.

Testing done with PicoScope 3205 spectrum analyzer at 1,604,000 Hertz using Icom 718

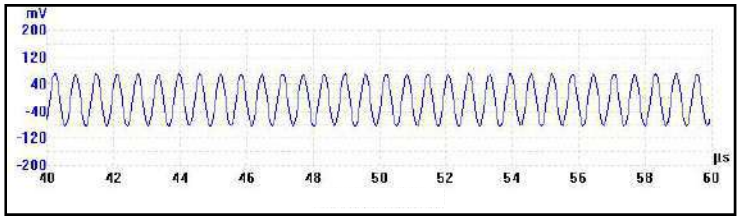

Sine wave out of Icom 718 at 1,604,000 Hertz.

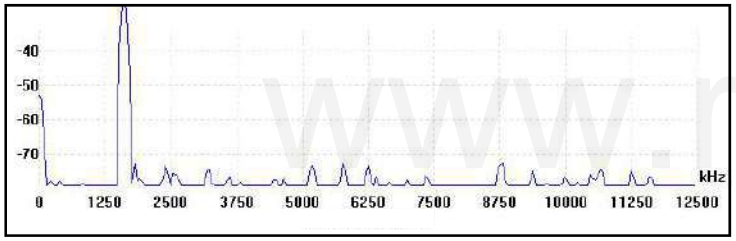

Icom 718 at 1,604,000 Hertz measured with spectrum analyzer showing no harmonics.

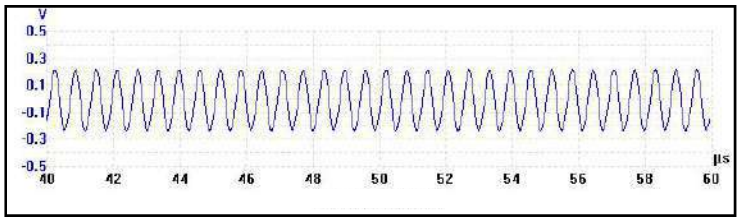

Sine wave out of Icom 718 at 1,604,000 Hertz using the antenna tuner.

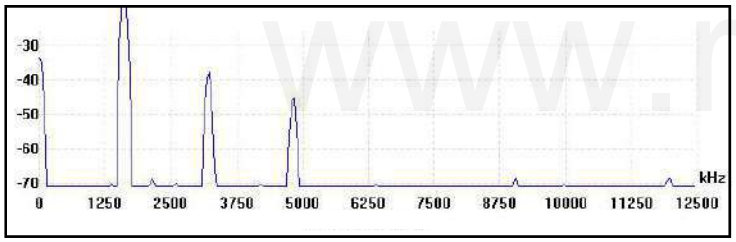

Icom 718 and antenna tuner at 1,604,000 Hertz measured with spectrum analyzer showing two harmonics. These two harmonics are only produced because the Icom is not designed to go below 2,000,000 Hertz. If you output 2,000,000 Hertz it produces no harmonics.

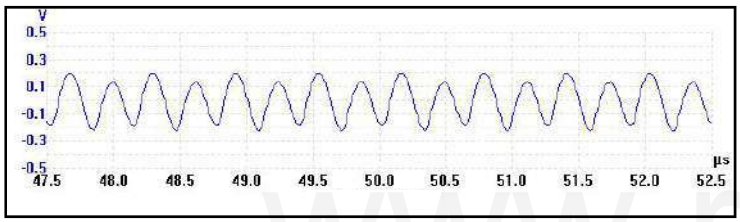

Sine wave out of Icom 718 at 1,604,000 Hertz using antenna tuner and ray tube. Sine wave is distorted. In all tests done the sine wave was always distorted when put through a ray tube.

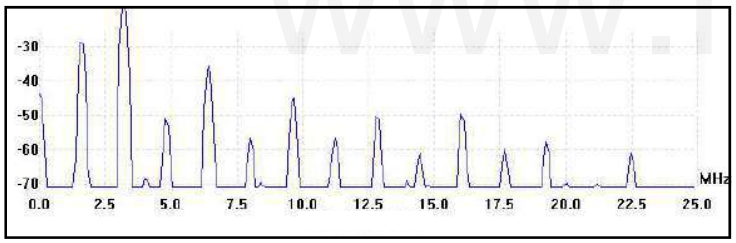

Icom 718 at 1,604,000 Hertz using antenna tuner and ray tube. Measured with spectrum analyzer showing harmonics all the way up to 22,000,000 Hertz. This shows that Dr. Rife's Kennedy Model 110 which only had a top range of 2,000,000 Hertz did produce harmonic frequencies in the 11,000,000 and 17,000,000 Hertz range.

www.rife.org

Below are the measurements taken with the PicoScope 3205 spectrum analyzer from the Icom 718 using the antenna tuner and ray tube at 11,780,000 Hertz. This was the first frequency Dr. Rife listed on his pre-1934 lab notes which was later changed to 1,604,000 Hertz.

Testing done with PicoScope 3205 spectrum analyzer at 11,780,000 Hertz using Icom 718

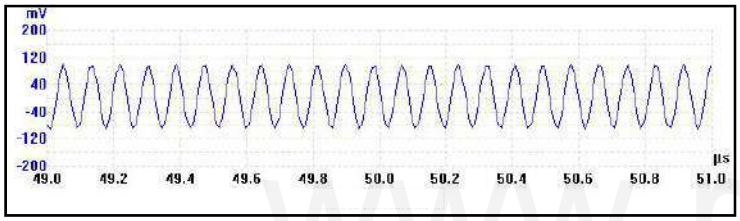

Sine wave out of Icom 718 at 11,780,000 Hertz.

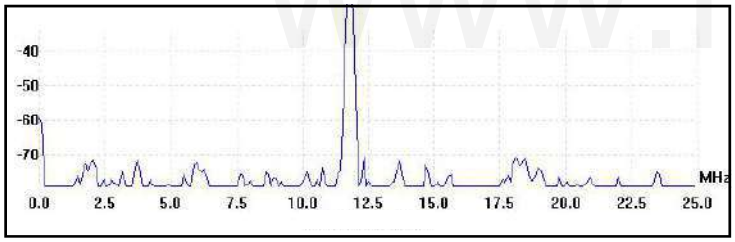

Icom 718 at 11,780,000 Hertz measured with spectrum analyzer showing no harmonics.

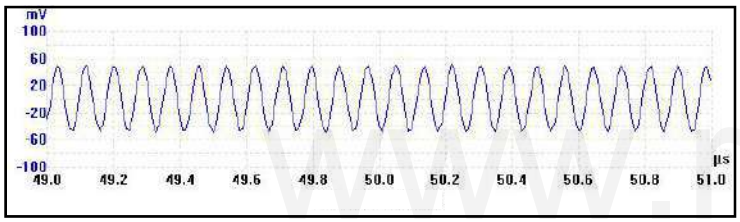

Sine wave out of Icom 718 at 11,780,000 Hertz using the antenna tuner.

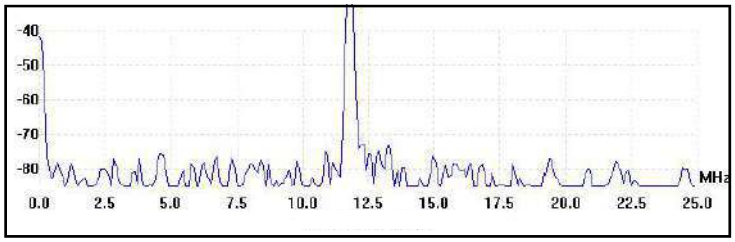

Icom 718 and antenna tuner at 11,780,000 Hertz measured with spectrum analyzer showing no harmonics.

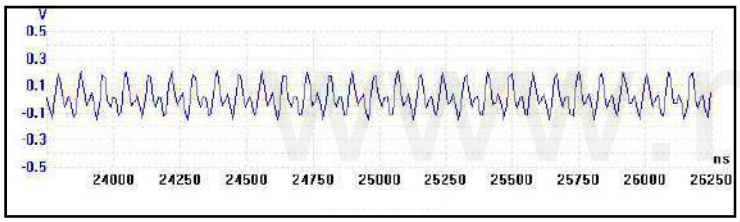

Sine wave out of Icom 718 at 11,780,000 Hertz using antenna tuner and ray tube. The sine wave does not look like a sine wave. In all cases the sine wave is distorted to some degree when put through a ray tube.

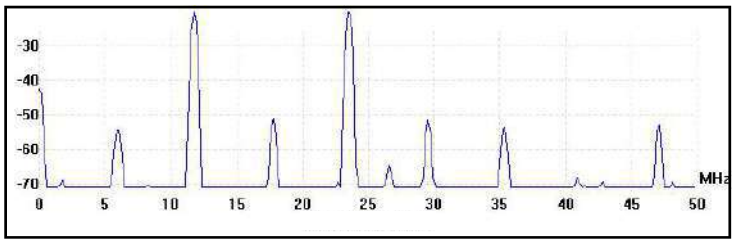

Icom 718 at 11,780,000 Hertz using antenna tuner and ray tube. Measured with spectrum analyzer showing harmonics all the way up to 50 MHz.

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Below are the measurements taken with the PicoScope 3205 spectrum analyzer from the Icom 718 using the antenna tuner and ray tube at 17,033,000 Hertz. This was the second frequency on his pre-1934 lab notes which was recorded in meters. This was later changed to 187 meters which would give us a frequency of about 1,604,000 Hertz. This confirms that Dr. Rife was just reading a harmonic at 17,033,000.

Testing done with PicoScope 3205 spectrum analyzer at 17,033,000 Hertz using Icom 718

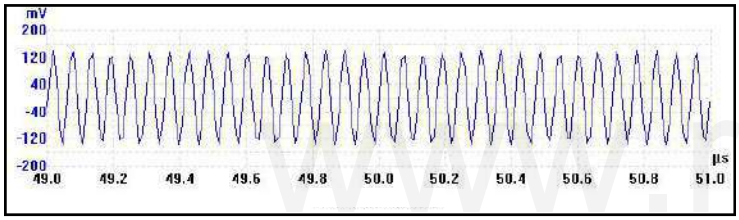

Sine wave out of Icom 718 at 17,033,000 Hertz. Some distortion was in the sine wave.

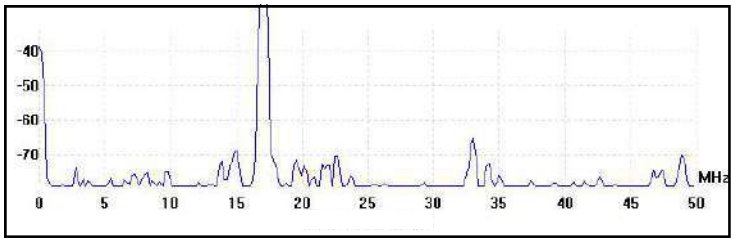

Icom 718 at 17,033,000 Hertz measured to 50 MHz with spectrum analyzer showing no harmonics.

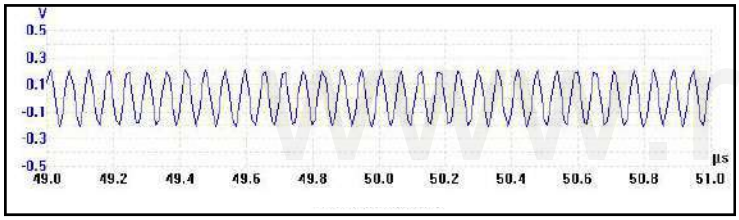

Sine wave out of Icom 718 at 17,033,000 Hertz using the antenna tuner. Same slight distortion noticed.

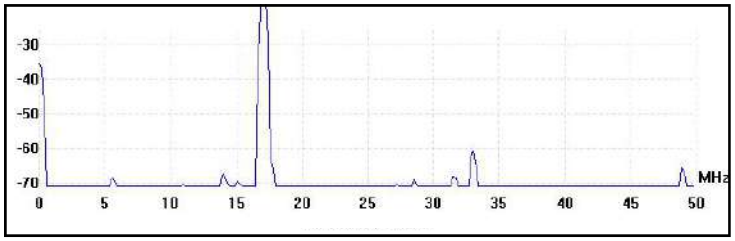

Icom 718 and antenna tuner at 17,033,000 Hertz measured to 50 MHz with spectrum analyzer showing no harmonics.

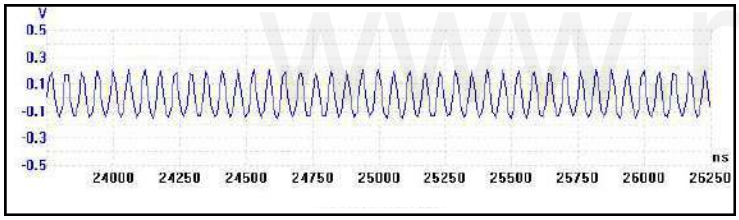

Sine wave out of Icom 718 at 17,033,000 Hertz using antenna tuner and ray tube. Sine wave was distorted even more when put through a ray tube.

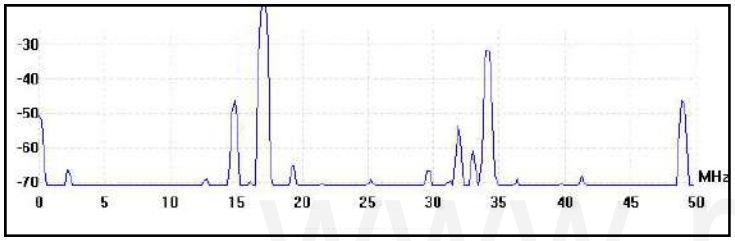

Icom 718 at 17,033,000 Hertz using antenna tuner and ray tube. Measured with spectrum analyzer showing harmonics all the way up to 50 MHz.

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Westinghouse RC Receiver & Amplifier

Western Electric Audio Amplifier 7A

Kennedy Model 281 Receiver

Photo of Rife's equipment that he used in his lab for doing M.O.R. work.

Five stage 50 watt class A cascade RF amplifier

The three photos of Rife's lab on this page are courtesy of the Rife Research Group of Canada.

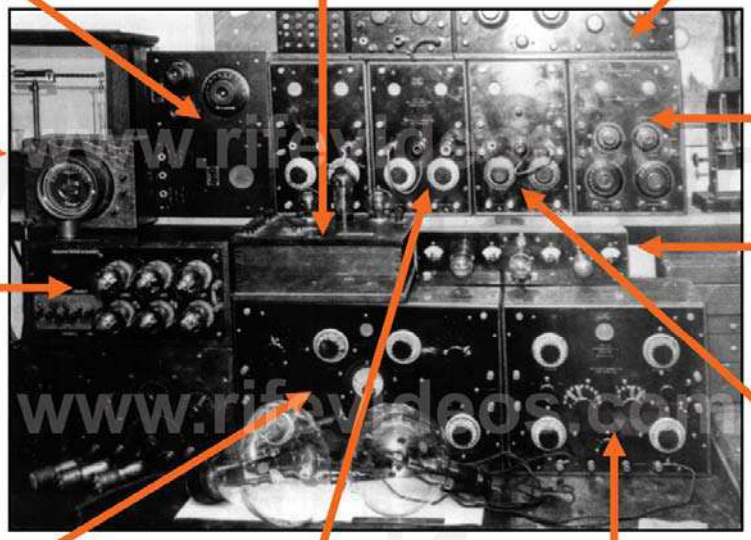

Kennedy RF Amplifier

Remler 700 I.F. Amplifier 3.5 MHz

Kennedy Model 110 and 525 Audio Amplifier

Kennedy Model 220 and 525 Audio Amplifier

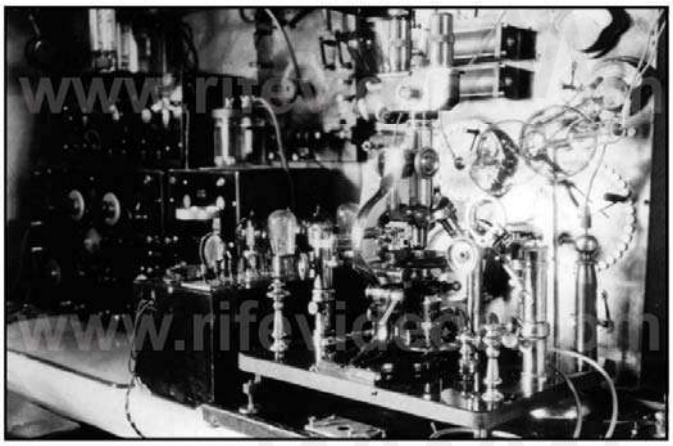

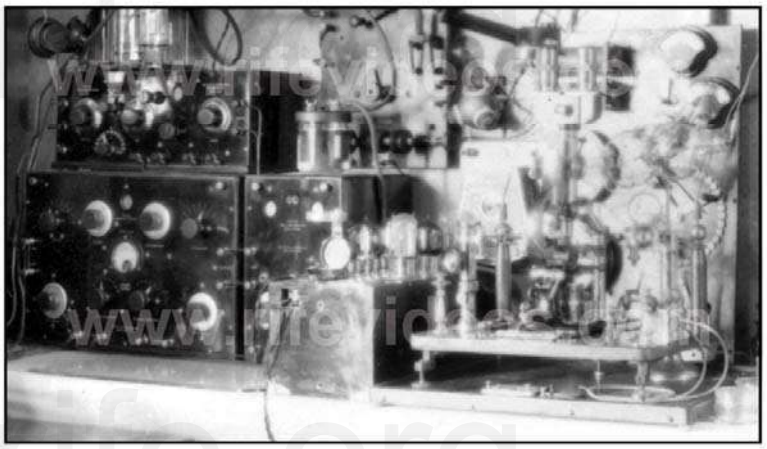

Kennedy Model 110, 281 and 525 Audio Amplifier Set Up In Rife's Lab For Doing M.O.R Work

After having done all this spectrum analysis testing we now know how Dr. Rife misread his frequencies. The ray tube gave him the harmonics that he read. Also, he evidently did not read the harmonics correctly. Philip Hoyland read the frequencies correctly because he was an electronics engineer and had the ability to read the frequencies properly. We wish to mention that we do not feel this in any way diminishes or questions the brilliance of Dr. Rife. Even Dr. Rife himself said he was not an electronics man and never claimed to be one. He made a mistake that any untrained person could have easily made.

Having said this, let's move on to the facts. Philip Hoyland read 1,604,000 Hertz for the frequency of the BX cancer virus. Dr. Rife corrected his lab notes to this frequency. This frequency was used in the later Rife Ray #4 instrument. With these documented facts, we now know what must have happened. Dr. Rife read the seventh harmonic of 1,604,000 Hertz and recorded it on his pre-1934 lab notes. The only problem was he was unable to read the seventh harmonic correctly and misread it as 11,780,000 Hertz. It should have been 11,228,000 Hertz because this is the actual harmonic frequency that came out of the ray tube. Dr. Rife had two different pieces of equipment for reading frequencies - one which read in cycles per second and the other which read in meters. These types of meters used to measure wavelengths were common electronic test equipment, just as digital frequency counters are in common use today. Wavelength meters were much harder to use and measure frequencies with if you didn't really understand how to use them. We know that this was the case. Dr. Rife then misread the eleventh harmonic of 1,604,000 Hertz. This harmonic should have been 17,644,000 Hertz instead of the 17,033,000 Hertz. Again, we know from the corrected lab note read by Henry Siner that the cycles per second and meters frequencies should match or be the same. In these early pre-1934 lab notes none of the cycles per second and meter frequencies matched. This shows Dr. Rife used two different pieces of equipment to read the frequencies. The final fact is the Kennedy Company equipment could only output frequencies up to about 1,800,000 Hertz (far below the 11 and 17 MHz range).

When we read the Kennedy Model 110 the instrument was surprisingly accurate. Dr. Rife could have very easily hit the frequency he wanted within the tolerances he gave. He gave "one tenth of one meter" as a gage to show how close you had to be to an organism's M.O.R. At 1,604,000 Hertz this would be 858 Hertz. He said if you were off by this amount the frequency wouldn't work. With that in mind it would be necessary to be within a few hundred Hertz of the BX M.O.R. in order to make sure the frequency was effective. The Kennedy instrument could hit within 200 to 300 Hertz very easily at 1,604,000 Hertz. After changing the dials and then coming back to the same dial settings you could get within 2000 to 6000 Hertz at 417,000 Hertz. This is less than 1% inaccuracy which is quite amazing. Even Philip Hoyland, when he measured the frequencies rounded off all but one frequency to the nearest thousandth. The testing of the Kennedy Model 110 shows that the frequency for the BX is most likely somewhere between 1,600,000 and 1,608,000 Hertz, however it could be as much as 10,000 Hertz plus or minus of 1,604,000 Hertz. All of the frequencies are only close and this should be considered when using them. One fact that helps to point this out is Philip Hoyland read 1,604,000 Hertz for the frequency of the BX. He also gave 187 meters as the frequency. One hundred and eighty seven meters is 1,603,168 Hertz. This is a difference of 832 Hertz and shows why the frequencies are only close. Today's frequency generating equipment is very accurate at hitting a specific frequency but in Dr. Rife's era this was not the case. Dr. Rife's microscope gave him an advantage that we do not have. He could see the organism die.

So now that we know that Dr. Rife's Kennedy Model 110, 220 and 281 only went to 1,800,000 Hertz with harmonics going to about 20,000,000 Hertz (see graph on the top of the next page). We have to ask this question: What frequency is really the true M.O.R? Is it the 1,604,000 Hertz or a harmonic of it? The actual M.O.R. frequency could have been very easily a harmonic, and Dr. Rife would have never known it. The spectrum analyzer graph, second down on the next page, of 1,604,000 Hertz shows it could be any one of these harmonics. Since the ray tube is what produces these harmonics it may be very important to have all these harmonics. Myth Busters, a cable television program did a test

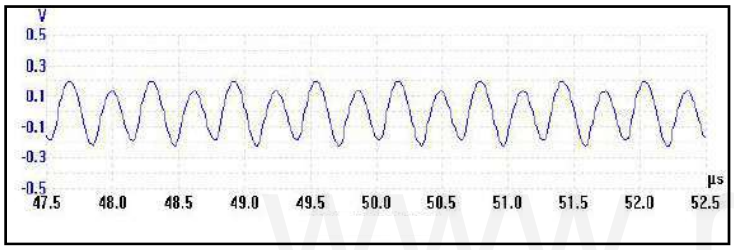

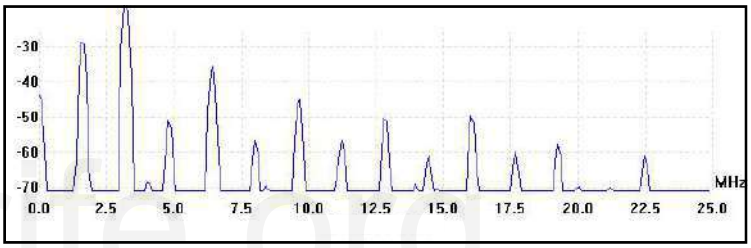

to see if they could break a crystal glass with sound waves. They found when they used only the fundamental frequency without the harmonics they could not break the glass. But when they used the harmonics along with the fundamental frequency then they were able to break the glass. This may or may not be pertinent but it is something that should be considered.

With this in mind we decided to see if there was a way that we could duplicate the harmonics without having to use a ray tube. The below reading with the spectrum analyzer shows that if we distorted the sine wave no more than what the ray tube did we could produce the same harmonics as a ray tube.

GB-4000 at 1,604,000 Hertz using PicoScope 3205 Spectrum Analyzer

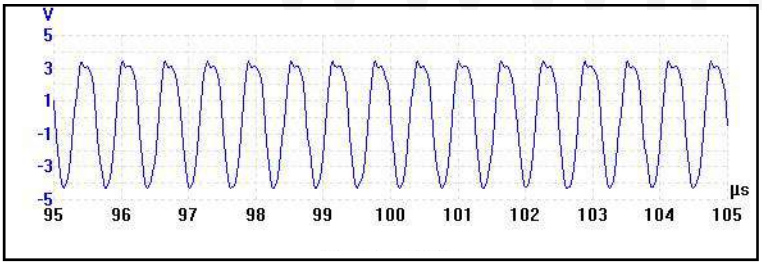

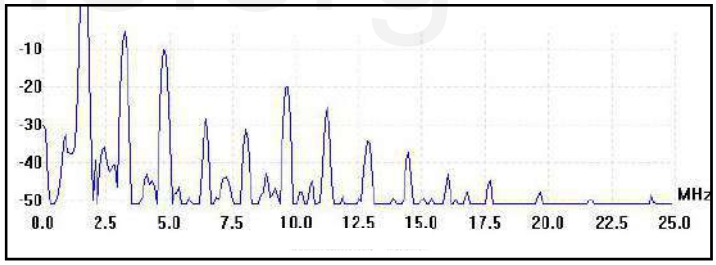

The reading was done at 1,604,000 Hertz taken from an off-the-shelf GB-4000 Function Generator. This test showed it was very easy to duplicate the harmonics produced by a ray tube. We decided to test a triangle wave since the distorted sine wave out of the ray tube resembled it. It also produced the same harmonics as a ray tube. Then we gated an undistorted sine wave and it produced the harmonics. It is apparent that any sine wave frequency from any frequency generator, when gated will produce harmonics.

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We will now discuss Dr. Rife's tuning of the Kennedy Receiver Model 110 using headphones. In the photo above, on the left, you can see a set of headphones on the Model 525 audio amplifier. Headphones were used to tune the Kennedy Receiver Model 110 and Dr. Rife's earlier instrument that he used before purchasing the Kennedy equipment. When Dr. Rife first tested the audio range of frequencies he would tune his instrument using headphones. Bertrand Comparet, Rife's attorney for the Beam Ray trial of 1939 made this statement when he was interviewed by Dr. John Hubbard:

COMPARET: *"Way back in the old days, way, way back, Rife told me that the way he used to tune his instrument, which in those primitive days was, I guess, garbled. He would hook up headphones and turn the thing. He had a very keen musical sense of pitch and so on, and he would tune it in his headphones until he got the right pitch, and that was the frequency."* (1970's Bertrand Comparet interview #89).

The headphones were used for tuning the audio frequencies in Dr. Rife's early tests when he used loose couplers. The headphones also played an important role in the tuning of the Kennedy Receivers. In the second photo, above on the right, you can see the regeneration dial of the Kennedy Receiver Model 110. When you turned up the regeneration you would listen for clicks or some static in the headphones, this would tell you that the instrument was oscillating. If you turned the regeneration up too high you would hear feedback in the headphones. This feedback meant you did not have a pure sine wave waveform. The photo below, on the left, is the waveform with the feedback from the Kennedy Receiver Model 110. It is a form of audio modulation. The other photo, below on the right, is what is produced when there is no feedback. Dr. Rife always wanted to use a pure waveform. The fact that we could actually listen to the original type of equipment that he used made it so we could understand what Dr. Rife was doing.

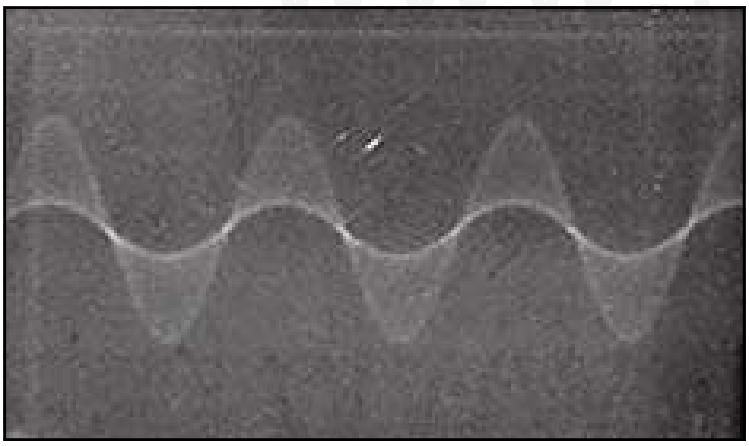

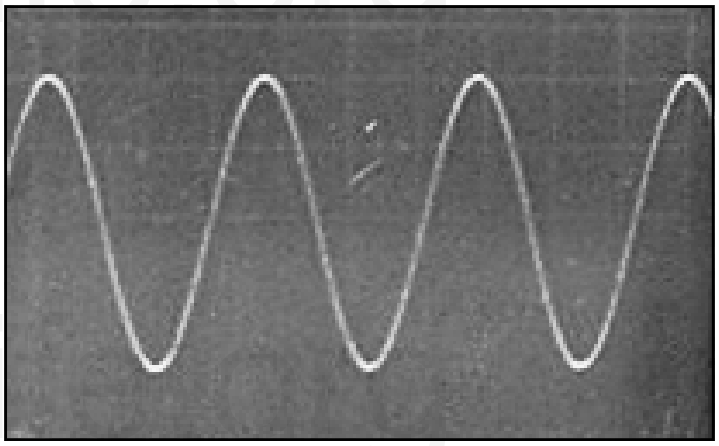

We will now discuss Dr. Rife's multi-stage-amplifier that he used with the Kennedy equipment. This was most likely a class A RC coupling cascade style amplifier. Daven Company started building this type of amplifier back in about 1925. Dr. Rife may have had Daven custom build his multi-stage-amplifier but we cannot be sure. The two photos, at the bottom of this page, are Daven amplifiers. Both of them are three stage amplifiers. The Kennedy Receiver Model 110 only output about 1.5 to 3 volts. Dr. Rife needed to be able to amplify the signal to a high enough power level to make it effective. In the three old lab photos above we see Dr. Rife's multi-stage-amplifier. In the above photo, bottom right, you can see the type of tubes he would have used in the early to mid 1920's. These tubes would have made it so Dr. Rife could amplify the signal from the Kennedy Receiver Model 110 to about 50 watts in multi-stages. If you look at the above three photos of Dr. Rife's multi-stage-amplifier you will see five switches. These five switches (representing five-stages) made it so he could choose different power levels determined by how many stages of amplification he wanted to use.

With this five stage configuration he could have easily produced the 50 watts he said he used. This 50 watts, was the power level that was mentioned in the Rife CD's for this instrument.

Ben Cullen, a close friend of Dr. Rife's, mentions on the Rife CD's that Dr. Rife would light the ray tube with a separate power source. His lab photos shows a spark gap transmitter which he probably used, in the 1920's, to light the ray tube. If you look at Dr. Rife's lab photo, shown below, you can see the spark gaps. The spark gaps are right below the "Spark gap" writing.

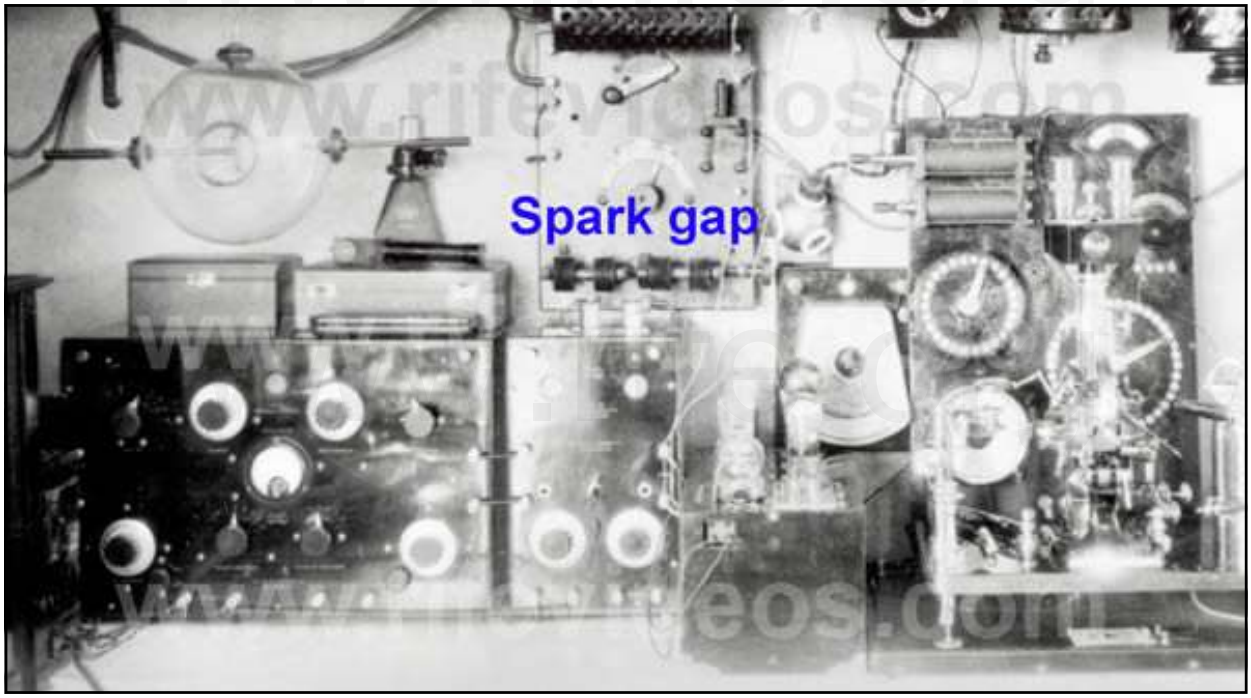

The next photo, shown below, is an up close photo of the spark gap transmitter diathermy from the 1920's. We purchased it so we could test the lighting of a ray tube with it.

The next photo, shown below, shows the lighting of the ray tube using this spark gap transmitter. It lit the ray tube with ease and could output more power than the ray tube could handle.

This spark gap transmitter would make it so Dr. Rife didn't have any difficulties tuning the ray tube when he changed frequencies from a low frequency of 139,000 Hertz to a higher frequency of 1,604,000 Hertz. The spark gap transmitter had a damped waveform and would have given him a damped wave carrier frequency (see the photo, below left) most likely somewhere around one Megahertz. This transmitter we purchased has a frequency of 920 KHz. Dr. Rife would not have modulated frequencies onto this carrier frequency but he would have just mixed the frequencies in the ray tube (see the photo, below right, is of sine & spark mix).

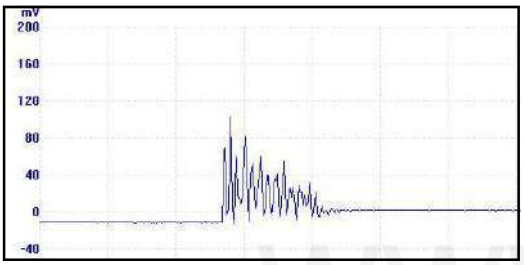

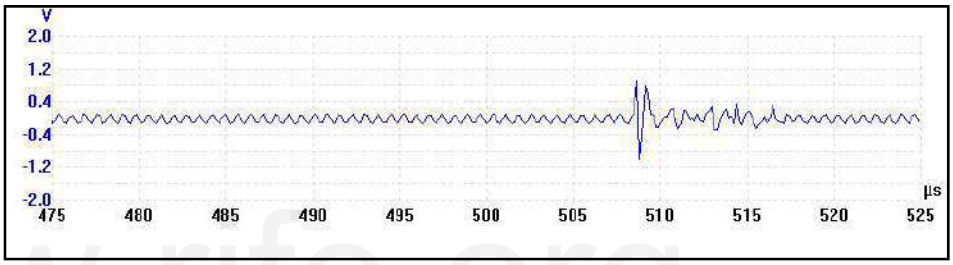

Mixing would have given him the combination of a damped wave and one or two sine wave frequencies, depending if he used two sine wave frequencies simultaneously. We do not believe that Dr. Rife continued to use a spark gap transmitter because it would have made it impossible for him to read the ray tube harmonic frequencies that his ray tube output. This is because a spark gap outputs broadband noise that makes it impossible to read any harmonic frequencies. Dr. Rife must have only used the spark gap transmitter in his early 1920's work. From the document "Development of the Rife Ray" we learn what he replaced the spark gap transmitter with.

"And as the voltage at this point was quite small, it was found necessary to apply external voltage across the anode and the cathode of the output tube [ray tube] *to act as a carrier wave for the frequencies that were generated in the apparatus."* (Development of the Rife Ray and use in devitalizing of pathogenic micro-organisms).

It appears that the spark gap transmitter accomplished to important things. One: It lit the ray tub with an external voltage. Two: It produced a high potential voltage spike in the frequencies. Later he used a DC voltage transformer much like a neon light transformer to light his ray tube. Then he added an audio pulsing circuit to create the high potential voltage spike.

To better understand the reason why a high potential voltage spike is important we need to jump forward in the history of Dr. Rife's instruments to 1936-1937. The Beam Ray Laboratory instrument built by Philip Hoyland was built at this time and it had a fixed audio frequency pulsing circuit. The audio frequency that it produced was modulated with the RF frequencies it output. This audio pulsing circuit would have given Dr. Rife's frequencies a very high potential voltage spike almost identical to the damped wave of the spark gap. John Crane made this statement when he was narrating Dr. Rife's lab film.

CRANE: *"Now the spikes that you see on the frequencies are the lethal part that kill and devitalize the virus. They are the resonant peaks of the frequencies which increase the voltage to a very high potential which the cells of the virus wall can not tolerate and they break up into many pieces and are destroyed."* (Dr. Rife's Lab Film Narrated by John Crane in the 1970's).

The modulated audio frequency in the 1936-1937 Beam Ray Laboratory instrument was in the shape of a damped wave. With both the Rife Ray #4 and the Beam Ray Laboratory instruments having waveforms in the shape of a damped wave doesn't seem like a coincidence. When Dr. Rife discontinued using the spark gap and replaced it with an external high voltage current to act as a carrier frequency he would have had to develop a new method of creating this high potential voltage rise in his frequencies. It appears, with the help of Lee Deforest, that Dr. Rife must have developed this audio frequency pulsing circuit for his instruments. It is apparent that this pulsing of the M.O.R frequencies is the reason why Dr. Rife was able to devitalize the many microorganisms he tested.

Dr. Rife described the method he used to find these frequencies on the Rife audio CD's.

RIFE: "*Because when I check on that thing and look through that microscope hour after hour day after day, tuning that damn thing* [Kennedy 110] *to find something that will kill that bug. And every hour or half an hour, whatever is required, I put a new fresh culture under the microscope and keep that on and I find something that folds it up, alright!"* (John Marsh Rife CD's - CD 7 track 2).

It was a very tedious task to find a frequency that would devitalize and organism. Dr. Rife recorded all his frequencies on lab notes. Even though he misread his frequencies many people want to know those frequencies anyway. On the next page in a chart are the misread lab note frequencies which he recorded prior to 1935. Each lab note had two frequencies. One was listed in cycles per second and the second was listed in meters. For the purpose of making this report easier to understand the meter wave lengths on Dr. Rife's lab notes have been converted to cycles per second or Hertz. You will notice that there are two audio frequencies listed for organisms that are above 12,000 Hertz. They are the only audio frequencies ever listed by Dr. Rife for any organisms. One of them was changed to a higher RF frequency when Philip Hoyland read the correct frequencies in 1935 when he built the Rife Ray #4. Most likely the other audio frequency was really a higher RF frequency.

Chapter Summary: The Rife Ray #3 frequency generating equipment which Dr. Rife purchased back in 1923 was made by the Collin B. Kennedy Company. It mainly consisted of the Kennedy model 110 and model 281 to produce its frequencies. This equipment was regenerative not super-regenerative. Its frequency range, when the model 110 and model 281 were connected together, was from about 12,000 Hertz to about 2,000,000 Hertz (2 Million Hertz). Its power output through the ray tube was about 50 watts. The frequencies it output were mostly in the AM radio band of frequencies. This equipments frequency range now explains why all of Dr. Rife's frequencies were less than 2 million Hertz as

listed on the Rife Ray #4 documents. The Rife Ray #3 was the instrument that was used by Dr. Rife and Dr. Milbank Johnson M.D back in the 1934 clinic on cancer and tuberculosis patients.

In the next chapter we will look at Dr. Rife's Rife Ray #4 Rife Machine and the correct frequencies which Philip Hoyland read with his master oscillator in order to build this instrument.

Dr. Rife's Misread Lab Note Frequencies From Before 1935

Microorganism	First Frequency In Hertz	Second Frequency Meters To Hertz
Actinomycosis (Streptothrix)	678,000 Hz	186,554 Hz
Anthrax	900,000 Hz	272,539 Hz
Anthrax Symptomatic	400,000 Hz	16,655 Hz
B. Coli (Rod form)	683,000 Hz	317, 914 Hz
B. Coli (Filterable virus)	8,581,000 Hz	11,103,424 Hz
Bacillus X Cancer	11,780,000 Hz	17,033,662 Hz
Bubonic Plague	160,000 Hz	512,466 Hz
Catarrh	1,800,000 Hz	1,713,100 Hz
Cholera Spirillum	851,000 Hz	960,873 Hz
Contagious Conjunctivitis	1,206,000 Hz	2,025,625 Hz
Diphtheria	800,000 Hz	1,090,154 Hz
Glanders	986,000 Hz	736,591 Hz
Gonorrhea	600,000 Hz	150,649 Hz
Influenza	1,674,000 Hz	1,946,704 Hz
Leprosy	743,000 Hz	251,926 Hz
Pneumonia	1,200,000 Hz	381,901 Hz
Spinal Meningitis	927,800 Hz	1,795,164 Hz
Staphylococcus Pyogenes Aureus	998,740 Hz	555,171 Hz
Staphylococcus Pyogenes Albus	Found in Dr. Rife's papers	549,070 Hz
Streptococcus Pyogenes	1,214,000 Hz	2,111,214 Hz
Syphilis (Treponema Pallidum)	900,000 Hz	2,775,856 Hz
Tetanus	700,000 Hz	15,779 Hz
Tuberculosis (Rod form)	583,000 Hz	541,142 Hz
Typhoid Fever (Rod form)	900,000 Hz	868,964 Hz
Typhoid Fever (Filter passing)	9,680,000 Hz	13,943,835 Hz

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Chapter #8

1935 Rife Ray #4 Rife Machine

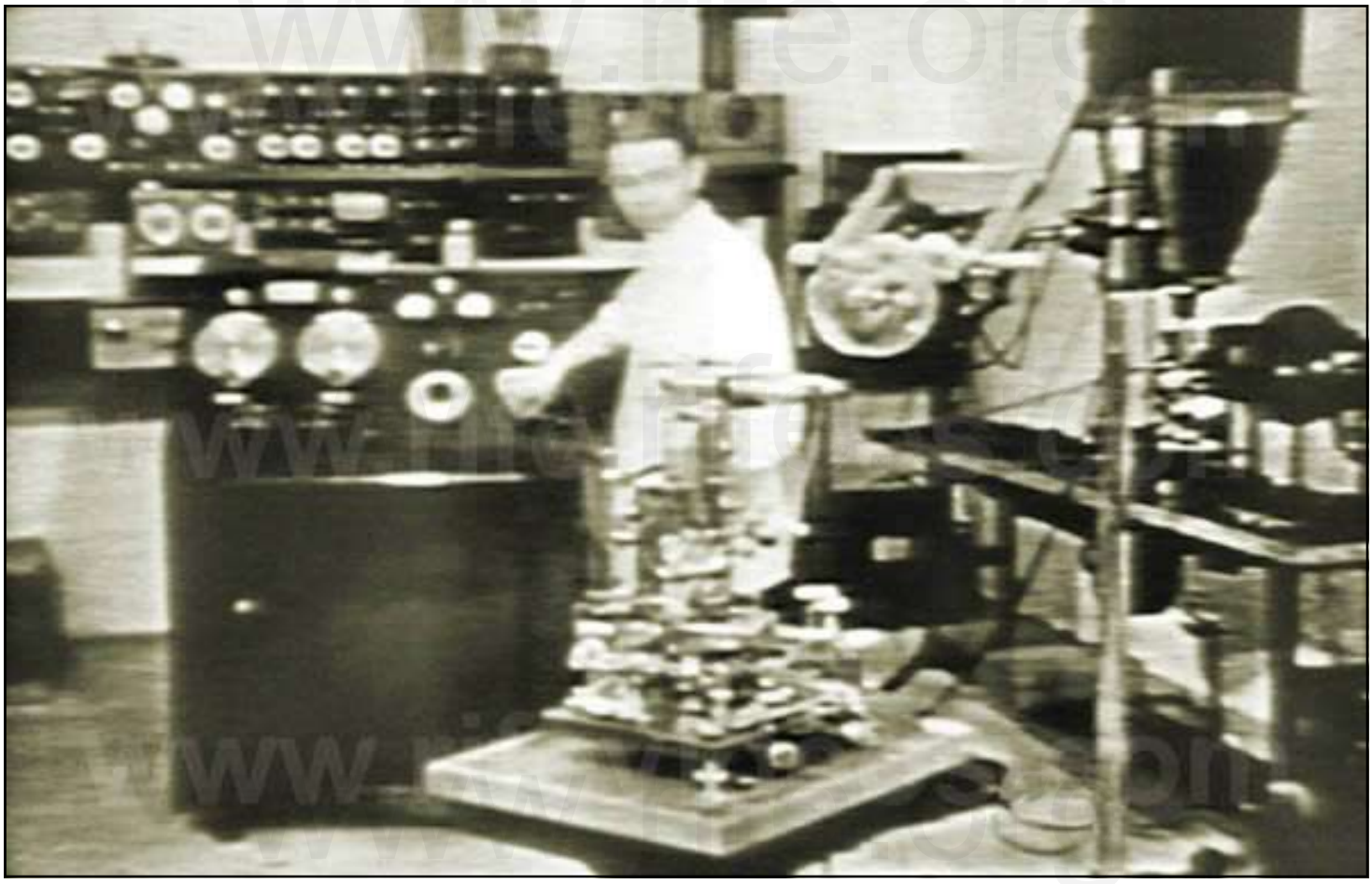

1. Used a ray tube.
2. Had two separate oscillators so it could output two frequencies at a time. Frequency range was from 87,000 Hertz to 22.5 MHz.
3. Power usage was about 450 to 600 watts. Output to the ray tube was variable (50 to about 250 RF watts).

Some have asked how we can be sure these photos we have are of the Rife Ray #4 Rife Machine. It is a simple process of deductive reasoning. John Crane, one of Dr. Rife's 1950's business partners, incorrectly dated the Rife Ray #4 as a 1942 Rife Machine. This misdating has led to some confusion which we will now attempt to clear up. In the photo, shown above, we see Dr. Rife using the instrument which John Crane dated as built in 1942. However, the lab film this picture was taken from was made in the summer of 1936 for use at a conference which Dr. Rife planned to attend in the autumn of that same year. He was presenting this film at this conference to demonstrate the isolation of the BX cancer virus. This properly dates the instrument as having been built before the summer of 1936 and shows that John Crane was incorrect. In the background of this photo, behind the instrument Dr. Rife is using, we see his Kennedy Company equipment back against the wall. Therefore this instrument could have only been built in late 1935 or early 1936. The Rife Ray #4 documents show it was completed in the fall of 1935. This logically dates the Rife Machine Dr. Rife is using in the 1936 film as the Rife Ray #4. The next picture, shown on the next page, is a better photo of the Rife Ray #4 instrument.

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Bertrand Comparet, Dr. Rife's attorney, said three experimental machines were built. With the proper dating of this Rife Machine, which shows it is the Rife Ray #4, we will now discuss it in detail.

Of the three experimental machines it appears that two were Rife Ray #4's and the third was the Rife Ray #5 or Beam Ray Clinical experimental instrument which was used in a clinic in 1937. We will cover the Beam Ray Clinical instrument later.

Dr. Johnson's machine was the first Rife Ray #4 that was built in 1935. After Dr. Johnson's instrument was built he states in a letter that the second #4 instrument was soon to be built for Dr. Rife:

DR. JOHNSON: *"While you have the machine* [Dr. Johnson's Rife Ray #4] *down there, I hope you and Jack are working on those bananas so we can get an M.O.R. for them, if possible. As soon as you send Phil and the machine back, I am going to start Phil on making your Machine."* (Letter from Dr. Johnson to Dr. Rife, November 15, 1936).

Now that we have established the fact that both Dr. Milbank Johnson and Dr. Rife had their own Rife Ray #4 instrument we can continue with the history of this instrument. As pointed out earlier in this report Philip Hoyland eventually became Dr. Rife's engineer and business partner. Philip Hoyland was the one who measured Dr. Rife's frequencies when he came to Dr. Rife's lab in 1935.

We will also point out that the frequencies used in this instrument were transferred from the Rife Ray #3 to the Rife Ray #4 after Philip Hoyland read the correct frequencies. We have in the document "Development of the Rife Ray" a description of this instrument:

"In 1935 in entirely new application of the old principle was incorporated in an instrument built under the direction of Commander Rife by Philip Hoyland of Pasadena California. The new instrument was light socket powered and had an output of 500 Watts. Designated #4 [Rife Ray #4] [Many of the power output measurements of Dr. Rife's equipment were misread]. *Furthermore it was equipped to deliver two distinct frequencies simultaneously and both variable. This apparatus proved to be more efficient with decidedly fewer factors of error in the laboratory tests using 75 pounds of horse meat."* (Development of the Rife Ray and use in devitalizing pathogenic micro-organisms).

In the laboratory tests that were performed with the Rife Ray #4 they made many tests to determine its capability. Dr. Johnson talked about the many different aspects of the machine they had to test in a letter:

DR. JOHNSON: *"Also, about this time, the new Rife Ray Machine* [#4] *had arrived at its point of construction when elaborate tests had to be made in order to synchronize the M.O.R. produced by it with the M.O.R. produced by the old machine* [#3]. *Now, we are in the throes of accurately charting the 14,000 possible settings on the new machine. Our next process, beginning next week, is to test its penetration, the time required in the different exposures, the different depths of lesions. So, take it altogether we are just about as busy as a bear in berrytime."* (Letter from Dr. Johnson to Dr. Schram, dated September 25, 1935).

Dr. Rife's Single M.O.R. Frequency

The Rife Ray #4 instrument documents show it could put out two RF or radio frequencies simultaneously. Dr. Rife's previous Kennedy Model 110 when connected to the Model 281 could output two frequencies simultaneously like the Rife Ray #4. It is apparent that Dr. Rife still wanted this capability in this new instrument. Dr. Rife from time to time would run two frequencies or M.O.R.s. simultaneously on two different organisms. This is pointed out by Dr. Rife on the John Marsh Rife audio CD's:

RIFE: *"We found the frequency of the virus, we found the frequency of the rod, which we had for years of course. But if we use the two of them simultaneously over the same carrier wave, the patient gets well and the Guinea pig gets well, but if you use one or either individually you either kill the patient or you don't do nothing.*"

This statement from Dr. Rife also shows that each organism only requires a single frequency to devitalize it. The rod form of tuberculosis requires a different frequency than the virus form. In the above quote from Dr. Rife he clearly states "frequency" for each organism, not frequencies. Since his instrument could only output two frequencies at the same time this clearly shows that each organism has a single frequency as its M.O.R. In another statement when Dr. Rife was talking to John Crane about tuberculosis he said:

CRANE: *"We have the frequency that will devitalize E. coli, don't we?*"

RIFE: *"We have yes. And we have the frequency also that will devitalize the filterable form of B. coli which is not necessary. There is only one organism that we have to use two frequencies simultaneously, and that as we've spoken of before John, and that is the Bacillus of tuberculosis, where it has that so-called poison molecule of Von that is released by any known methods of devitalizing the organism and that's it."* (Marsh collection, Rife audio CD's).

Dr. Rife states in this quote that there is only one organism that needs two different frequencies to devitalize it. All the other organisms only need a single frequency to devitalize them. The reason that Tuberculosis needs two frequencies is due to the fact that Dr. Rife said both the rod form and the virus form must be devitalized at the same time or the virus form will feed on the dead body of the rod form causing the patient to die from toxemia.

Even with what Dr. Rife has said many have still believed that it took two frequencies to devitalize a single organism. This misunderstanding came about because Dr. Rife had two frequencies listed for each organism on his pre-1935 lab notes. From the reading of these documents we can see this is not the case. It was Dr. Rife's misreading of his frequencies, prior to 1935, which lead to this misunderstanding. To further make the point that it only takes a single frequency to devitalize an organism we will read more statements made by Dr. Rife on the Rife Audio CD's:

RIFE: *"The frequency of each bacteria is absolutely individual. They run through a very, very large gamut. Some of them are very, very broad, long. Some of them are not extremely short. There's none of them what we call our ultra short wave that I have found yet."* (Marsh collection, Rife audio CD's).

DR. DICKLAND: *"Is there a different frequency between cancer and tuberculosis?"*

RIFE: *"Oh much. Every organism requires a different frequency owing to its own chemical constituents or its premodel cell or predominate chemical factor. "* (Marsh collection, Rife audio CD's).

RIFE: *"We found the frequency of the virus, we found the frequency of the rod, which we had for years of course."* (Marsh collection, Rife audio CDs).

RIFE: "*So we're throwing an electronic frequency through the tissues of the body that simply devitalizes the bacteria with no harm to normal tissue."* (Marsh collection, Rife audio CD's).

These statements clearly show again that each organism has its own frequency and that it only takes a single frequency to kill, devitalize or render it harmless. As we read other statements or documents you will easily be able to see that this understanding was plainly understood by Dr. Rife and all the other doctors that used his equipment.

Because this is a very important point that needs to be understood we will read a few more documents which contain added information on this subject. When the Rife Ray #4 was finally completed Dr. Johnson wrote a letter to Dr. Rife in which he made this observation:

DR. JOHNSON: *"Maybe these Much glands are another form of the T.B.* [tuberculosis] *corresponding to our filter passing form and we will have to get an M.O.R. for them so as to destroy them at the same time that we do the rod form of tuberculosis....Now that we have a machine in which we can give two M.O.Rs at one time, it would be easy to treat all forms of tuberculosis, both for the tubercle bacilli and the Much granules."* (Letter from Dr. Johnson to Dr. Rife dated, September, 12 1935. Page 3).

Since the Rife Ray #4 only had two variable oscillators and each one was set on a different M.O.R. frequency then it would only take one frequency to devitalize each organism. In another letter this same understanding is given:

DR. JOHNSON: *"I would suggest that you set up a slide with a hanging drop planted with the cryptomyces pleomorphia. Set your machine and the microscope together. After it gets growing, start out and set on of the groups to the MOR of BX. Then with the other group, start with a certain switch on Group 2 beginning at zero. Give one minute exposure, wait about fifty minutes, and then see if there is any change. Then move the dial of Group 2 up to ten and give another exposure, waiting about fifty min-*

utes and the examining it carefully. Go on that way throughout the dial and you will get through about one switch a day. Pretty soon you will find some setting that will kill the organism. Mind you, you are running at every exposure Group 1 on the BX MOR. If you got this setting started, Jack could do the microscope work and if he got any change, he could call your attention to it. That would save your eyes and your time. It is very important that we find the MOR of this fungus before I start in with the clinical work in the hospital with this new machine." (Letter from Dr. Johnson to Dr. Rife dated, October 10, 1935).

When this letter was written they already had the frequency for the BX cancer virus and they were trying to find the frequency for the cryptomyces pleomorphia fungi. It is clearly pointed out that one oscillator was set on the BX organism and the second oscillator was being used to try and find the frequency for the cryptomyces pleomorphia fungi. Dr. Rife when speaking about the BX virus clearly states that it had a certain frequency not frequencies:

RIFE: *"If you don't have an absolute coordinative resonance, you have nothing. One tenth of one meter off and you have nothing. It's got to be absolutely correct for that individual organism. It's got to be precise...the virus of cancer has a certain frequency. And it has to be there, otherwise if it's a little one way or the other, no good, no good for nothing."* (John Marsh Rife CD's - CD 5 track 2, CD 6 track 2, CD 7 track 1 and CD 9 track 1).

There are even more documented examples which show that only one frequency is needed for each organism. From the horse meat tests done with the Rife Ray #4 we read:

"The test being ready, the No. 4 Rife Ray Machine was set for the MOR of B. Typhosis (rod) and also for the filter-passing form. It was turned on for an exposure of three minutes at 400 watts..." (Test of the No. 4 Rife Ray Machine, Page 2).

The frequency listed on the Rife Ray #4 documents for B. Typhosis rod form is 760,000 Hertz and the frequency for the B. Typhosis filter-passing virus form is 1,445,000 Hertz. This document also confirms that only one frequency is needed for each organism to devitalize it.

There is one more document that we will look at. This document has the misread frequency of 11,780,000 Hertz for the BX frequency. The correct frequency that was read by Philip Hoyland was 1,604,000 Hertz. It is apparent that Dr. Rife was reading the 7th harmonic of 1,604,000 Hertz incorrectly. The correct 7th harmonic frequency of 1,604,000 Hertz is 11,228,000 Hertz. Had Dr. Rife read the 7th harmonic correctly this frequency would have been on his lab note. Regardless of this mistake Dr. Rife listed only one frequency for devitalizing the BX virus. Below is his statement:

RIFE: *"Since experiments show that the Bacillus X* [BX cancer virus] *in form A exists in malignant tissue, it is theoretically possible to change the cycle to form B by application of the Argon Ray and vacuum conditions. After the cycle change has been accomplished (in theory), the application of the oscillative ray at a cycles per second vibration of 11,780,000* [correct frequency measured in 1935 was 1,604,000] *should completely destroy the B.X. in the malignant tissue."* (Rife Research Laboratory lab note on the BX).

So that no one misunderstands this quote. It was the change of the Bacillus form from A to B using the Argon Ray and vacuum conditions that was the "theory" not the destroying of the B.X. using the 11,780,000 (corrected frequency of 1,604,000) Hertz. All these document show that Dr. Rife found that only one frequency is required for each organism.

There is one other thing that apparently needs to be combined with the M.O.R. frequency and that is the pulsing of the waveform. When we discussed the Rife Ray #3 we talked about a fixed audio

frequency pulsing circuit. The Rife Ray #4 also had a fixed audio frequency pulse circuit. The waveform that it output was shown in Dr. Rife's lab film and is the next photo, shown below.

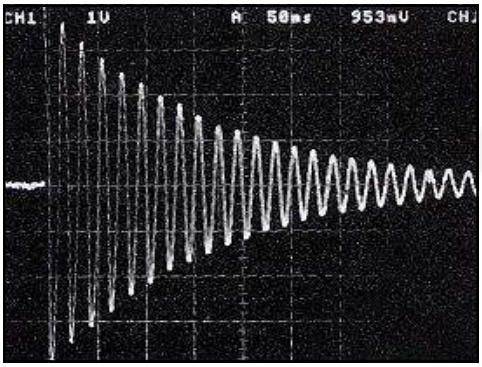

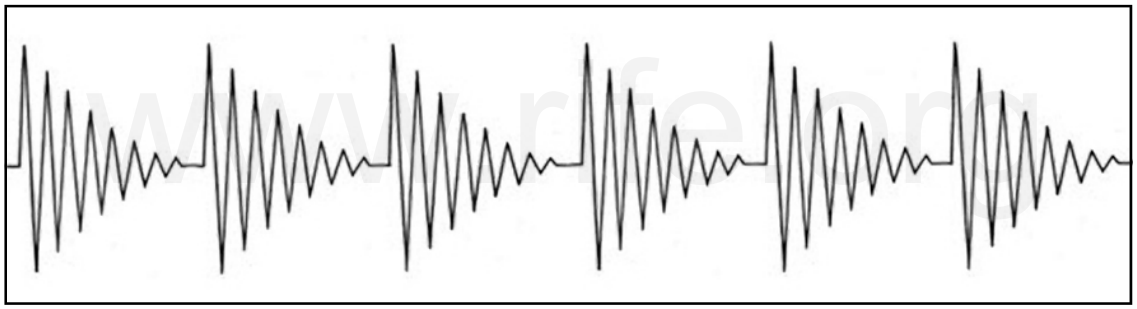

The other photo shown above, top left, is a clearer photo of what a damped wave looks like. Below those two photos is drawing of what a damped waveform looks like. How Dr. Rife created this waveform was not known until a circuit from an original Beam Ray Laboratory Rife Machine was rebuilt. This circuit will be discussed in detail later in this paper when we cover that instrument.

Dr. Rife's Audio Pulsing Circuit

Though we will discuss the building of this circuit later the importance of that fixed audio frequency pulsing circuit will be discussed now. The reason for this is without this pulsing circuit no organism could have been devitalized. This pulsing circuit was the secret to making Dr. Rife's high RF frequency instruments work. Bertrand Comparet, Dr. Rife's attorney said this in his 1970's interview:

COMPARET: *"The whole secret of the Rife thing was the audio frequency because Rife, way back in the old days, way, way back, Rife told me that the way he used to tune his instrument…he would hook up headphones and turn the thing. He had a very keen musical sense of pitch and so on, and he would tune it in his headphones until he got the right pitch, and that was the frequency."* (1970's Bertrand Comparet interview paper #89).

This audio frequency pulsing circuit was put into the Rife Ray #4 Rife Machine as a fixed audio frequency. It was not a variable audio frequency circuit. The Rife Ray #4 instrument documents show the #4 instrument had no variable audio oscillator which indicates that Dr. Rife believed that it was no longer necessary for M.O.R. work. But the fix audio pulsing circuit was absolutely necessary to be put into the instrument so that the high RF frequency M.O.R. frequencies were pulsed in order to devitalize the various organisms. All of the frequencies that Philip Hoyland read from the Kennedy Model 110 and transferred to the Rife Ray #4 were RF frequencies and needed to be pulsed. The lowest frequency was for Anthrax at 139,200 Hertz; the highest was 1,604,000 Hertz for the BX organism that caused cancer.

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The Rife Ray #4 would have also been a sine wave instrument just as the Kennedy Company equipment was. Since the Rife Ray #4 had two high RF frequency oscillators it would allow for the oscillators to be set at two different M.O.R.s. This instrument was probably built much like the Beam Ray Laboratory instrument which connected the ray tube between the two RF oscillator tank coils. The reason for this is the fact that the bandwidth of the RF tank coils could only pass a frequency of about 250,000 Hertz and Dr. Rife was using frequencies much higher than this.

Dr. Rife's Carrier Wave

We will now discuss Dr. Rife's use of a carrier wave in his instruments. This next statement by Dr. Rife's verifies the fact that with the Kennedy equipment or Rife ray #3 he used a carrier wave:

RIFE: *"We found the frequency of the virus, we found the frequency of the rod, which we had for years of course. But if we use the two of them simultaneously over the same carrier wave, the patient gets well and the Guinea pig gets well, but if you use one or either individually you either kill the patient or you don't do nothing".* (Marsh collection, Rife audio CD's).

Dr. Rife's mention of a carrier wave has lead to some confusion in the past because when we think of a carrier wave we think of a higher RF frequency that the lower RF or audio frequencies would ride on. But the documents show this was not the case. The "Development of the Rife Ray" document tells us what that carrier wave was:

"And as the voltage at this point was quite small, it was found necessary to apply external voltage across the annode and cathod of the output tube to act as a carrier wave for the frequencies that were generated in the apparatus." (Development of the Rife Ray and use in devitalizing of pathogenic micro-organisms).

Dr. Rife's carrier wave was just an external high voltage current that was used as a means to light the ray tube. The use of this high voltage current as a carrier wave was also used with the Rife Ray #4 and was not remove from the instruments until the summer of 1936 when the new Beam Ray Clinical instrument was built. This will be covered later.

Dr. Rife used the Rife Ray #4 Rife Machine in his laboratory until he closed it down in about 1947. The Rife ray #5 or Beam Ray Clinical instrument was completed in the summer of 1936 and was the new design that was used by all the doctors. Dr. Johnson used his Rife Ray #4 instrument in at least two medical trials. Dr. Johnson always had his patients sign a release card, shown on the bottom of page 56, in order to be treated with the frequencies output by the Rife instrument.

On page 57 is a chart showing the sine wave frequencies read off of the Kennedy Company equipment and used in the Rife Ray #4 instrument. We now know these frequencies were the frequencies used in the 1934 clinic since they were taken off of the Rife Ray #3 which was used in that clinic. The chart was made from The Rife Ray #4 document. This same document along with its additional page was mentioned in a letter written by Dr. Milbank Johnson to Dr. Rife dated Oct. 15, 1935:

DR. JOHNSON: *I am also inclosing a copy of a chart prepared for me by Phil* [Philip Hoyland] *which show the frequencies in kilocycles of the different M.O.R.'s we have worked with. Opposite these frequencies you will find the proper switch and settings on both groups. Now, in looking over the frequencies representing the M.O.R. of certain organisms, I find that the typhoid rod has 760 kc. And just above that you will find that the typhoid filter passing has 1445 kc. - that is almost an exact harmonic of the rod. Assuming that the banana might represent the rod form of the cryptomyces pleomorphia - on the same plan let us assume that the B.X. is the filter passing form of this organism. If that is so, we should kill the rod, it being the harmonic of the rod form, at 800 kc.* [this statement verifies that the BX

M.O.R. frequency was 1.604 kc. - or 1,604,000 Hertz]. *This 800 kc. Will come in group No. 2 on switch 6. A reference to the proper chart under Group No. 2 would give the exact setting to get 800 kc. This is just a chance and I have no assurance that it will work out, but I think it is worth trying so I think I would try on switch 6 in Group N. 2 for your first effort to kill the fungus, or rather to kill the bananas.* (Letter from Dr. Milbank Johnson to Dr. Rife, October 15, 1935).

This letter and the Rife Ray #4 document confirm that Dr. Rife had misread his frequencies prior to 1935 and that each organism only has a single frequency as its M.O.R. The letter also shows that they were using the corrected frequencies read by Philip Hoyland when he came to Dr. Rife's lab to read the Rife Ray #3 in 1935. The frequencies used in Rife Ray #4 were used to create the next version of Dr. Rife's machine.

Chapter Summary: The Rife Ray #4 was built in 1935 at the request of Dr. Milbank Johnson because he wanted an instrument that was in the comforts of a single cabinet. It had the highest frequency range and power output of any of Dr. Rife's machines. There were only two of these machines built. The first one was built for Dr. Milbank Johnson and the second one was built for Dr. Rife. The frequencies used in this machine were the same frequencies that were used with the Rife Ray #3. Each organism only required one frequency to devitalize it. Like the Rife Ray #3 the Rife Ray #4 used a fixed audio frequency pulsing circuit to create a high potential voltage rise in the RF M.O.R frequency to devitalize the organism treated with the instrument. The Rife Ray #4 was used by Dr. Milbank Johnson in two clinical trials.

In the next chapter we will take an in-depth look the next instrument that was built by Dr. Rife's engineer, Philip Hoyland. Philip Hoyland developed a new method of delivering Dr. Rife's M.O.R. frequencies.

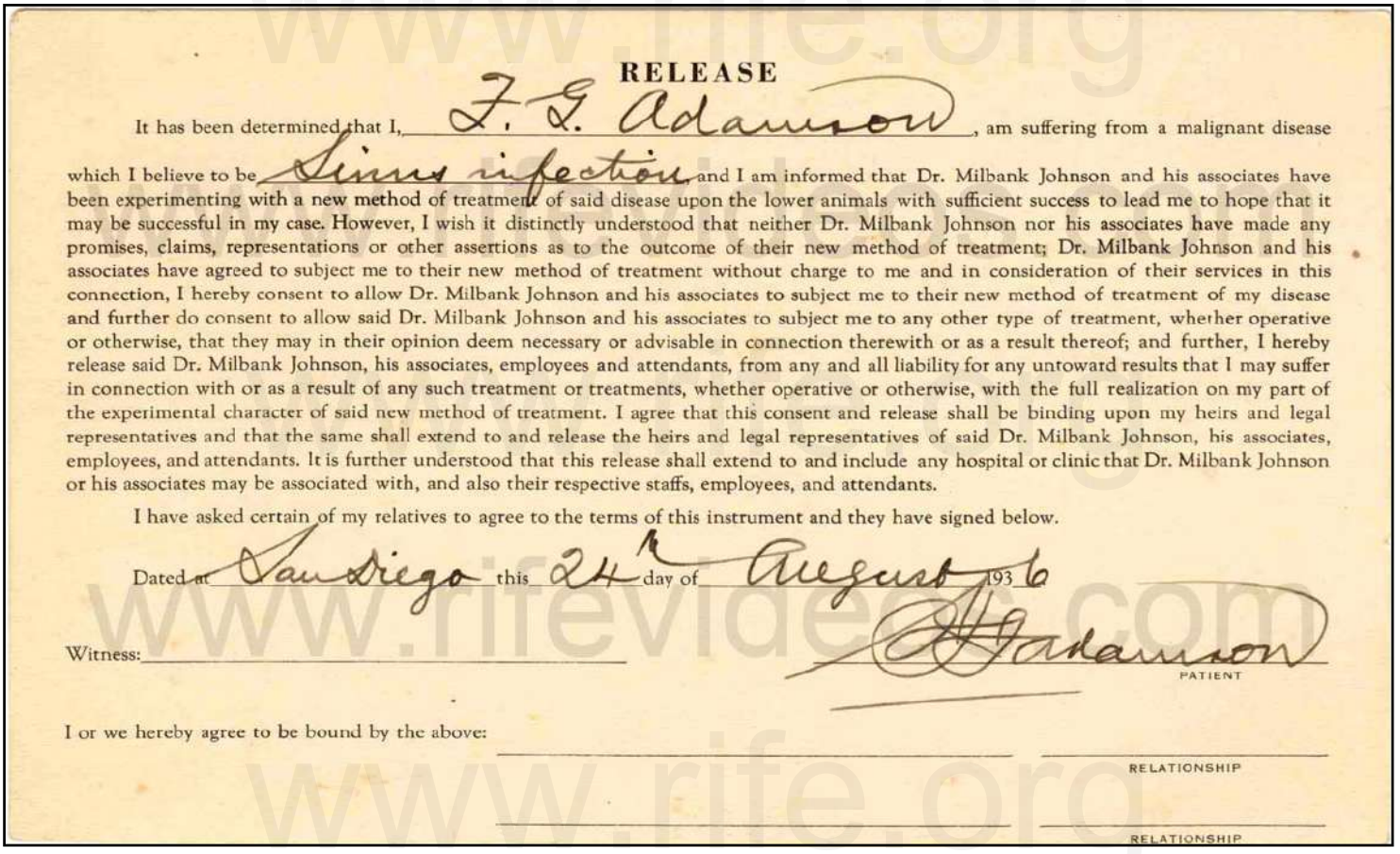

RELEASE

It has been determined that I, F. G. Adamson, am suffering from a malignant disease which I believe to be Sinus infection, and I am informed that Dr. Milbank Johnson and his associates have been experimenting with a new method of treatment of said disease upon the lower animals with sufficient success to lead me to hope that it may be successful in my case. However, I wish it distinctly understood that neither Dr. Milbank Johnson nor his associates have made any promises, claims, representations or other assertions as to the outcome of their new method of treatment; Dr. Milbank Johnson and his associates have agreed to subject me to their new method of treatment without charge to me and in consideration of their services in this connection, I hereby consent to allow Dr. Milbank Johnson and his associates to subject me to their new method of treatment of my disease and further do consent to allow said Dr. Milbank Johnson and his associates to subject me to any other type of treatment, whether operative or otherwise, that they may in their opinion deem necessary or advisable in connection therewith or as a result thereof; and further, I hereby release said Dr. Milbank Johnson, his associates, employees and attendants, from any and all liability for any untoward results that I may suffer in connection with or as a result of any such treatment or treatments, whether operative or otherwise, with the full realization on my part of the experimental character of said new method of treatment. I agree that this consent and release shall be binding upon my heirs and legal representatives and that the same shall extend to and release the heirs and legal representatives of said Dr. Milbank Johnson, his associates, employees, and attendants. It is further understood that this release shall extend to and include any hospital or clinic that Dr. Milbank Johnson or his associates may be associated with, and also their respective staffs, employees, and attendants.

I have asked certain of my relatives to agree to the terms of this instrument and they have signed below.

Dated at San Diego this 24th day of August 1936

Witness: _____ F. G. Adamson PATIENT

I or we hereby agree to be bound by the above:

_____ _____ RELATIONSHIP

_____ _____ RELATIONSHIP

Rife Ray #4 Sine Wave High RF Frequencies	
Actinomycosis (Streptothrix)	192,000 Hz
Anthrax	139,200 Hz
B. Coli (Rod form)	417,000 Hz
B. Coli (Filterable virus)	770,000 Hz
Bacillus X or BX Virus (Cancer Carcinoma)	1,604,000 Hz
Bacillus Y or BY Virus (Cancer Sarcoma) This frequency was not on the Rife Ray #4 document because it was not found at that time. It was in 1936 when this viruses frequency was obtained and it was used in the Beam Ray Clinical machine. We included it here with this explanation.	1,530,000 Hz
Gonorrhea	233,000 Hz
Spinal Meningitis	427,000 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz
Streptococcus Pyogenes	720,000 Hz
Syphilis	789,000 Hz
Tetanus	234,000 Hz
Tuberculosis (Rod)	369,000 Hz
Tuberculosis (Virus)	?769,000 Hz
Typhoid Fever (Rod)	760,000 Hz
Typhoid Fever (Virus)	1,445,000 Hz

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Chapter #9

1938 to 1939 Beam Ray Corporation Clinical Rife Machine

1. The instrument used a ray tube.
2. Had one variable Audio oscillator and one Fixed RF oscillator set at 3.30 or 3.80 MHz.
3. Power usage was about 450 to 600 watts. Output to the ray tube about 40 to 50 RF watts.

Just as with the Rife Ray #4 Rife Machine we must determine what the Rife Ray #5 or Beam Ray Corporation Rife Machine looked like. The reason we need to determine this is because unless we know what those instruments really looked like we may think we have a true Rife Ray #5 or Beam Ray Clinical instrument and find out later that it is not one. Beam Ray Corporation built two different instruments, one was called the Clinical instrument and the other was called the Laboratory instrument. The fact that Beam Ray built two different instruments was pointed out in the Trial: (Beam Ray Trial Transcript #209-210)

COMPARET: *"The four machines bought by the British were two so called laboratory types and two so called clinical types, what was the difference between the two?"*

HOYLAND: *"The clinical type was similar in all respects to the Rife machine except that it did not have* [word missing] *of the* [word missing] *used on Mrs. Henderson."*

We now know that Beam Ray Corporation built two different Rife Machines of which one was built using the original Rife principles and it was considered the Laboratory instrument. The other was built using a different method of generating the frequencies and we will show that it was called the Clinical instrument. First we will prove that the photo, shown above, and the next photo, shown on the top of the next page, are photos of the Rife Ray #5 or Beam Ray Clinical instrument.

The instrument, shown below, is a photo of one of two Rife Machines owned by Dr. James B. Couche which he purchased from Beam Rays Corporation. Dr. Hamer also purchased one of these Clinical Rife Machines. This information was pointed out during the Trial and gives us the proof we are looking for: (Beam Ray Trial Transcript #98-99, 217-218, 1128-1131 and 2700)

COMPARET: *"Before this agreement was signed did the company manufacture any Rife ray machines?"*

HOYLAND: "*They started to about the first of May* [May 1, 1938]. *Dr. Hamer was sold one."*

COMPARET: *"How was the price of these machines fixed?"*

HOYLAND: *"The price was decided from the costs of what it cost to manufacture the first machine that was sold to Dr. Hamer."*

COMPARET: *"Were the clinical machines the same as were made for Dr. Hamer?"*

HOYLAND: *"Yes."*

COMPARET: *"Was that the same as the machine used on Mrs. Henderson?"*

HOYLAND: *"No, but the same type."*

SAPIRO: *"These machines are perfectly good, they are just the same as the* [Dr.] *Couche machine and the one that gave Mrs. Henderson such relief."*

These quotes show that Beam Ray Corporation sold the Clinical style Rife Machines to Dr. Hamer and Dr. Couche. In 1951 Dr. Couche sold one of his Beam Ray Clinical instruments to Dr. Tully.

The photo on the previous page of Dr. Couche's machine and the documents we have read show us that his machine is an original Rife Ray #5 or Beam Ray Rife Machine. With this machine we can make comparisons against it when looking at other instruments.

The next photo, shown below, is a picture of Dr. Rife and Philip Hoyland. Philip Hoyland was Dr. Rife's engineer and business partner in the Beam Ray Corporation. In this photo is an instrument. We will prove that this instrument is also a Beam Ray instrument by making some comparisons with other Beam Ray machines.

This photo of Dr. Rife and Philip Hoyland was taken for a May 6, 1938 newspaper article published by the San Diego Tribune. In the newspaper the caption below the photo said: "Royal Raymond Rife, left and Philip Hoyland with Rife ray apparatus". On May 1, 1938 the Beam Ray Corporation started selling its Rife Ray #5 or Beam Ray Clinical Machine to doctors. This front page newspaper article had the capability of selling many instruments. It is only logical they would have photographed the instrument they were selling.

The next two photos, shown at the top of the next page, are close-up photos of these instruments. You will notice the similarities of these two instruments. They are almost exactly alike except for the case. Beam Ray used both types of cases with the Rife Ray #5 or Beam Ray Clinical instruments they sold.

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Dr. Couche's Rife Machine, above on the right, was in a case that extended all the way down to the floor. It had handles on the side and wheels on the bottom which would make it very easy to move around. Both instruments have one oscillator dial which is located on the left side of the front panel. Below that dial on Dr. Couche's instrument was a four position band switch and on the other instrument, above on the left, is a fine tuning dial. The fine tuning dial was replaced by a four position band switch in order to give the instrument better accuracy. The second dial, in the center of both instruments, goes to 100 and was the amplitude dial. Above that dial on both instruments is a tuning eye for calibrating the instrument's RF carrier frequency. Below is a photo of one of these tuning eyes.

Both instruments have a milliamp power meter located all the way over to the right next to where the ray tube is connected. Dr. Couche's instrument had a timer below the power meter to help him make sure he treated the patient for the correct amount of time. Along the bottom are the filament, sweep and output switches which are not clearly marked on Couche's instrument but we can see what appears to be three different switches, two below the center amplitude dial and one below the timer. The comparison we have just made with Dr. Couche's Beam Rays instrument shows they are both Beam Ray instruments. Beam Ray Corporation just put this Clinical machine into two different cases.

In the document "Development of the Rife Ray" we have a description of this Beam Ray Clinical instrument:

"In the early part of 1936 Commander Rife and Mr. Hoyland spent much time collaborating on revising some of the applications of the fundamentals of the instruments due to the advancement that had

taken place in the application of electronics and it was found that the carrier wave used in the previous instruments could be eliminated. During the summer of 1936 further experiments were carried on, which resulted in an entirely new method of generating the desired frequencies and produced a constant input and output in the instruments.

During this work several new test appliances were built for further studying the different frequencies and waveforms noteworthy among these was a 9 inch Cathode-Ray oscillograph of high sensitivity, built for the purpose of photographing the different frequencies on motion picture film and thereby allowing the numerous waves to be studied at will. During the fall of 1936 Dr. Couche of San Diego and Jack Free assistant to Commander Rife conducted a clinic with one of the frequency machines treating experimentally cases of carcinoma and senile cataract..." (Development of the Rife Ray and use in devitalizing pathogenic micro-organisms).

The first thing that we learn from this document is the high voltage current carrier wave that was used to light the ray tube in the Rife Ray #3 and Rife Ray #4 was no longer used or needed with the new Rife Ray #5 or Beam Ray Clinical instrument. The document is correct because this style of instrument only uses an RF carrier frequency to light the ray tube. The second thing we learn is that this instrument was working on an entirely new method of generating the M.O.R. frequencies. This method has been referred to over the years as harmonics. But it is more complex that what was originally believed.

This new method that was used to generate the frequencies has been a mystery for the past 75 years. Finally with the location and purchase of an original Beam Ray Clinical instrument and the use of spectrum analysis the method that Philip Hoyland used has been discovered.

In the first photo, below on the left, is the Rife Ray #5 or Beam Ray Clinical Machine that Dr. Rife and Philip Hoyland were photographed with for the may 1938 newspaper article. In the second photo, below on the right, is a picture of an original Beam Ray Rife Ray #5 instrument. This instrument was obtained from Dr. Larry Low. He has owned it for over 25 years. This is the only known original Beam Ray Corporation Clinical instrument to have survived. It was used by a Medical Doctor who died in the mid 1960's.

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We would like to thank Dr. Low for allowing us to get this instrument so we could analyze it. It is a low audio frequency instrument which uses an RF carrier frequency. This Rife Ray #5 or Beam Ray Clinical instrument is very important. The significance of this instrument is due to the fact that it is the only known original Rife Ray #5 or Beam Ray Clinical instrument to exist. There were about 14 instruments built by the original Beam Ray Company and until now no one has ever been able to find one. The fact that even one has survived is a miracle. This instrument proves beyond any doubt that Philip Hoyland was the one who first built the low audio frequency instruments such as the Rife Ray #5 Beam Ray Clinical instrument.

The next photo, below on the left, is also a Beam Ray Clinical instrument. This photo, was found inside the case of the original Rife Ray #5 or Beam Ray Clinical instrument obtained from Dr. Larry Low. The second photo, below on the right, is Dr. Couche's Beam Ray machine. Both of these Rife Machines are in the same case. If you look closely you will notice that both instruments have the same metal arm attached to the top of the instrument which holds the ray tube. This same arm is also on the top of the original machine obtained from Dr. Low.

In every detail the cases are the same. The only difference between these two machines is the layout of the front panel. Though the panels are laid out differently both machines have the frequency dial, amplitude dial, band switch, milliamp meter, timer, power light and two switches. It appears when Beam Ray Corporation built their first instrument, which was shown in the May 1938 newspaper photo, they had no band switches dividing out the audio frequency range. The doctors that used these instruments complained about the accuracy problems. It is apparent from the Beam Ray Trial testimony that a four position band switch was added to help stabilize the audio oscillator and hopefully solve this problem. The original Beam Ray instrument that we obtained has a band switch with four settings. Aubrey Scoon's Beam Ray Clinical replica instrument also has a four position band switch. We will fully evaluate the Aubrey Scoon instrument later in this report. But we will refer to it from time to time as needed as we look at this original Beam Ray Clinical instrument. The 1953 AZ-58 Beam Ray Clinical replica, which we will also evaluate later in this report, had a three position band switch. They only used a three position switch because they used audio frequencies which were ten times lower than the original Beam Ray Clinical instrument. Because of this they did not need or use a fourth band.

To further analyze the two original Rife machines we will now do a comparison of the faceplates. We will look at the instrument obtained from Dr. Low and the instrument Dr. Rife and Philip Hoyland were standing next to in the 1938 news paper photo.

The first close up photos are of the variable audio oscillator control. The photo, below on the left, is the May 1938 photo. The photo, below on the right, is the original instrument we obtained. Normally the dial should only go 180 degrees from 0 to 100 as shown on the May 1938 dial. Our instrument does not have the original dial because it goes from 0 to 100 in 270 degrees.

Though the dial shows 270 degrees it will only go 180 degrees. You will also notice that our dial is bigger than the original dial and partially covers where the old fine adjustment dial was located. The fact that the hole is still there, but was covered, indicates that this instrument at one time worked the same as the instrument in the 1938 photo. When they added the four position band switch the fine adjustment knob was no longer needed.

Our Rife Ray #5 or Beam Ray Clinical Rife Machine, like Aubrey Scoon's instrument, had four bands that cover these frequency ranges.

Band 1: 160 Hertz to 820 Hertz.

Band 2: 594 Hertz to 3,190 Hertz.

Band 3: 2,440 Hertz to 12,930 Hertz.

Band 4: 9,430 Hertz to 42,600 Hertz.

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Aubrey Scoon's Beam Ray Clinical Replica instrument band ranges, listed below, were different.

Band 1: 20 Hertz to 200 Hertz.

Band 2: 200 Hertz to 2,000 Hertz.

Band 3: 2,000 Hertz to 20,000 Hertz.

Band 4: 20,000 Hertz to 200,000 Hertz.

These four bands were discussed by Philip Hoyland and Bertrand Comparet during the trial. (#257-260):

COMPARET: *"If you wanted to treat one with typhoid for instance wouldn't you have to set the machine so that it would be on a particular frequency."*

HOYLAND: *"No, the machines were made so that they varied over a band of frequencies."*

COMPARET: *"That band used for the treatment of each disease was different from other bands for other diseases, wasn't it?".*

HOYLAND: *"The whole list of bacteria that the machine was treating was divided into four bands."*

The next two photos, shown below, are of the tuning eye and the amplitude control. The photo, on the left, is from the May 1938 instrument. The photo, on the right, is our original Beam Ray Clinical instrument. Above the amplitude dial on the photo of the May 1938 instrument is the tuning eye.

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On our instrument you can see that the tuning eye was removed. Notice that you can still see the outline of the tuning eye mounting ring. On the May 1938 instrument the amplitude dial went from 0 to 100 and adjusted the audio frequency modulation. On our instrument the amplitude dial also goes from 0 to 100 and adjusts the modulation of all the audio frequencies. This modulation is not a true (AM) amplitude modulation. It is more of a pulse width modulation.

The next two photos, shown below, are of the milliamp meter that goes to 300 and the ray tube hookup. The photo below, on the left, is the May 1938 instrument. The photo, on the right, is our instrument.

Until the discovery of our Rife Ray #5 or Beam Ray Clinical instrument we did not know exactly where the fixed RF tank coil was located. We thought it was probably behind the milliamp meter but now we know this is exactly where it was located.

The next two photos, shown below, are of the plaque. The first photo is of the May 1938 instrument. The second photo is our instrument. These photos show where the original plaque was on the instrument.

The plaque read; “Property of the Rife Research Laboratory, Designers and Builders.” On our instrument the plaque is missing but you can still see the four mounting screws that held the original plaque. Since this plaque had Dr. Rife's name on it this could have caused the doctor problems. So he may have removed it in order to avoid the machine being called a “Rife Machine.”

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In the next two photos, shown below, you can see the “Filament”, “Sweep” and “Output” switches. The first photo is of the May 1938 instrument. The second photo is our instrument. On our instrument the sweep plaque was removed and the switch was replaced with a red light that indicated that the instrument had power.

This is where the power indicator light was put on almost all of the instruments built during the 1940's and 1950's. The filament switch turned on the power to the 866 rectifier vacuum tubes and the output switch turned on the power to the 809 main amplifier vacuum tube section. Turning on the power to the 809 tube would light the ray tube. Because of the accuracy problems (due to the old (RC) resistor capacitor audio oscillator) of the Beam Ray audio instruments the sweep switch was probably used to try and help solve this problem. The sweep switch appears to have been removed when the band switch was added. Above the output label on our instrument we see a 15 minute timer for setting the desired runtime for each frequency that was used. The Original 1938 Beam Ray Clinical instrument photo does not have a timer but Dr. Couche’s Beam Ray instrument shows his instrument had a timer on the front panel. Even the photo of the other Beam Ray Clinical instrument which was found inside our instrument has a timer built into it. These photos show that a timer was put in most all of the original Beam Ray instruments. The next photo, shown below, is a larger photo of the Rife Ray #5 or Beam Ray Clinical Rife Machine with the ray tube lit.

The next photo, shown below, is of the inside of the Rife Ray #5 or Beam Ray Clinical instrument. The RF tank coil of our instrument was set at 3.80 MHz. The 809 was the main output power tube. There were two 866 rectifier tubes.

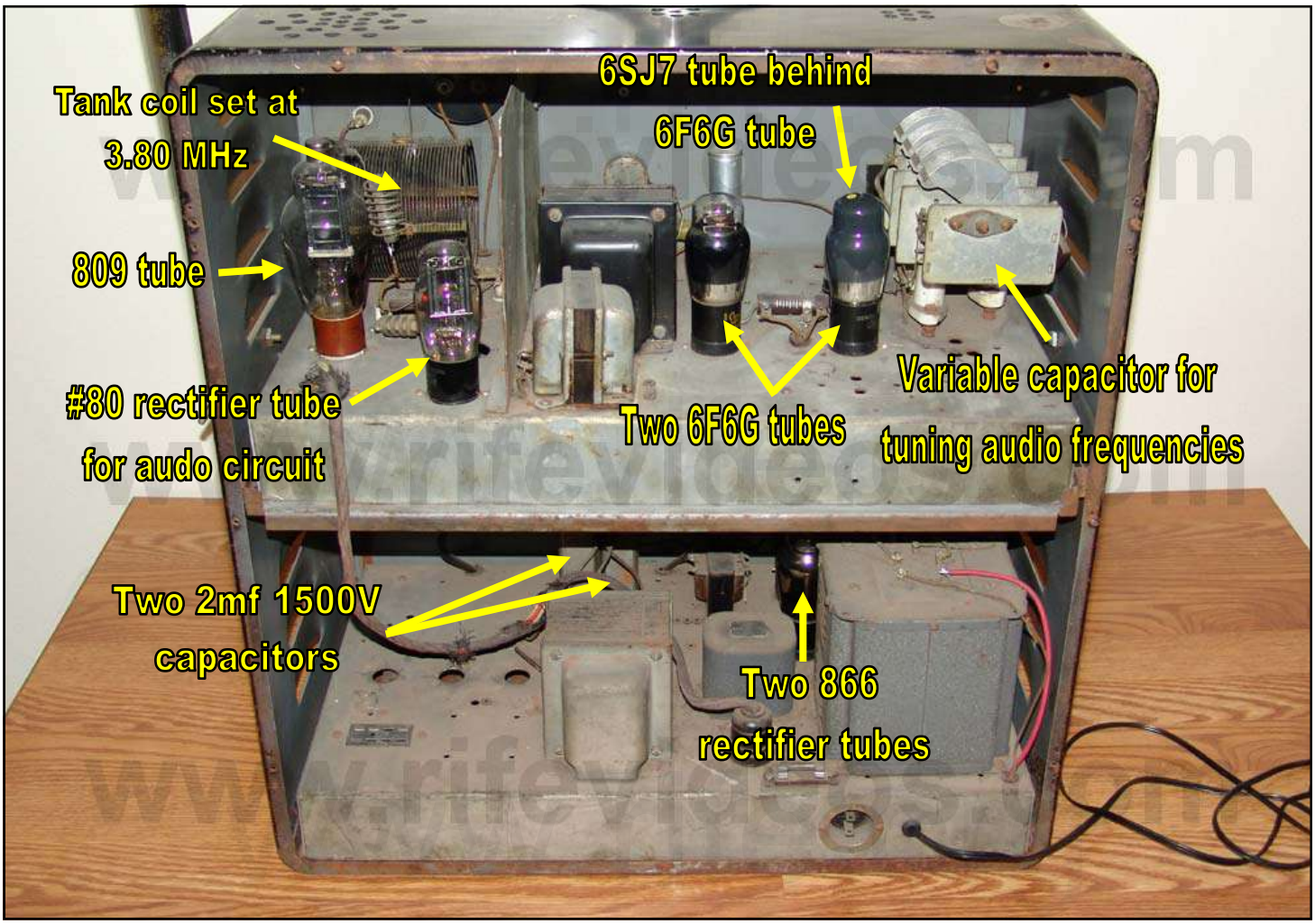

The audio section consists of 2 6F6G tubes and one 6SJ7 tube. All of the Philip Hoyland audio instrument designs built from 1936 through the 1953's AZ-58 resemble each other. Anyone looking at the different instruments can see that they are all built almost in the same way. Tubes may vary, such as the 812a eventually replaced the 809, but the workings of all the instruments are similar. Both this original Beam Ray Clinical instrument and Aubrey Scoon's Beam Ray Replica instrument have Hewlett Packard sine wave audio oscillators. Mr. Peter's and I was able to repair the audio oscillator and read the different frequency band settings. It was only a 25 watt 10,000 ohm resistor which had burned up that made it so this instrument would not work.

The readings for this report was done with this original Rife Ray #5 or Beam Ray Clinical instrument . Also with Aubrey Scoon's Rife Ray #5 instrument and the AZ-58 replica instrument that we built. They all work identically the same as the original instrument. This original Beam Ray Clinical instrument did not come with any paperwork which gave the dial settings for the various audio frequencies it used. This actually turned out to be for the best because we had no audio frequency data that could have stopped us from discovering how this instrument really worked on Dr. Rife's original high RF frequencies.

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The Next photo, shown below, is the underside of our original Rife Ray #5 or Beam Ray Clinical instrument. The underside of the chassis shows both the audio section and part of the RF section.

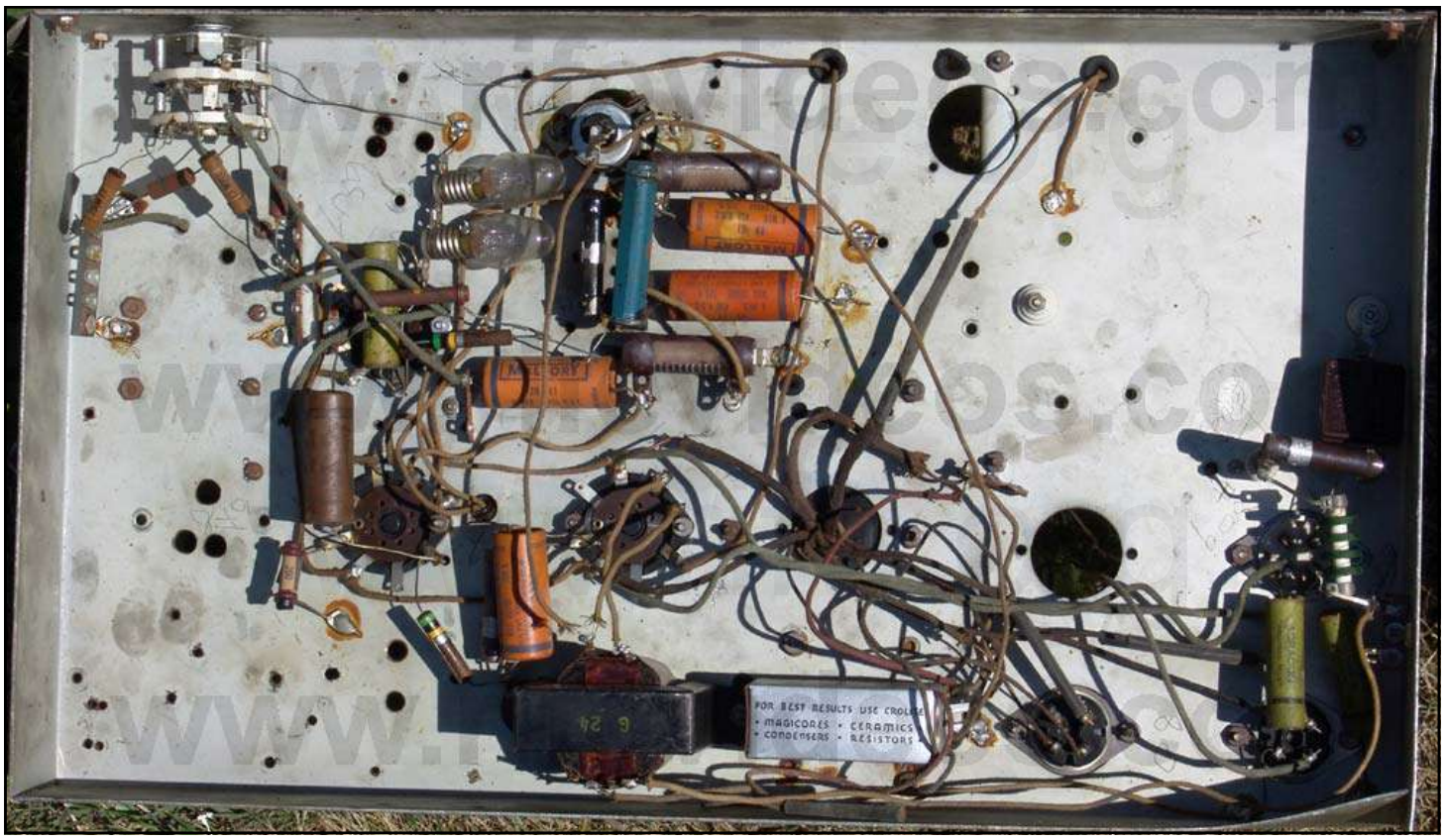

Now that we have an original Beam Ray Clinical instrument we know without any doubt that Philip Hoyland's Clinical instrument design used audio frequencies and it modulated those audio frequencies onto a fixed RF carrier frequency. Dr. Rife and Philip Hoyland had an agreement that they would share evenly on the financial profits of the instruments. Philip Hoyland stated this when he was on the stand during the Beam Ray Trial: (Beam Ray Trial Transcript #505-507)

HOYLAND: *"Dr. Rife and I had always had the understanding that we shared evenly, as I had done all the development work."*

COMPARET: *"What do you mean by that."*

HOYLAND: *"I had done all of the building and designing of the machines other than the one original machine* [Rife Ray #3 which consisted of the Kennedy equipment] *that he had in his laboratory. I had brought that to a state where it could be carried around"* [Rife Ray #4].

From these trial statements we know that all the designs were Philip Hoyland's designs. When Hoyland built the audio instrument he built it on a completely different principle or method. Philip Hoyland had changed the instrument to work on a different method which used harmonics. Dr. Rife believed they were using the Rife Ray #4 RF frequencies along with harmonics. This was pointed out in the 1939 Beam Ray Trial (#1247-1250, 1278-1281):

COMPARET: *"Has the Plaintiff* [Philip Hoyland] *ever informed you that the machines that he designed and built for the Beam Ray were not operating on the same frequencies as your own?"*

RIFE: *"They were supposed to be operating on the same with harmonics."*

COMPARET: *"Did he ever tell you that there was a fundamental difference?"*

RIFE: *"He said on one or two occasions that there was a difference in harmonics."*

SAPIRO: *"You say that the devices that were being built in the early part of 1938, the one that went to Dr. Couche and two that were in the lab were built on new harmonics?"*

RIFE: *"They were built on a different principal, we have a given wave length and it can be produced in different ways, but it should be the same no matter how it is produced."*

SAPIRO: *"You knew that these machines were being built with that machine."*

RIFE: *"Yes"*

Philip Hoyland when he was on the stand was asked (#935-938, 953-958):

COMPARET: *"I understand you say that the frequencies used in the machines put out by the corporation were not set to the same frequencies as Dr. Rife's machines* [Rife Ray #4]*."*

HOYLAND: *"That is correct."*

COMPARET: *"Did you inform the board of directors of Beam Ray that the machine you built was not the same as Dr. Rife's?"*

HOYLAND: *"I had spoken to them about it."*

COMPARET: *"Then it was during the period between September and November that you told Edwards at his home that the machines you were building were not putting out the same frequencies as Dr. Rife's machines?"*

HOYLAND: *"Yes."*

COMPARET: *"How did you explain that?"*

HOYLAND: *"In the summer of 1936 I designed a new machine, or rather I checked it there at the lab* [The Beam Ray Clinical instrument]. *I had designed it in Pasadena, and we tested it out then and the frequencies were not the same as on Dr. Rife's machine."*

COMPARET: *"Did you tell him how great the difference it was?"*

HOYLAND: *"I explained that there was quite a fundamental difference."* [Harmonic frequencies]

Comparet when asked a question by Judge Kelly made this statement. (#2673 & 2685):

COMPARET: *"Hoyland has said that the design and the frequencies of the machine itself is not that of a Rife Ray machine, and that the machine is in fact different. The company will have to have these machines junked, must draw up new designs according to Dr. Rife's ideas, must have Dr. Rife ok these designs, etc…Dr. Rife is not going to be a party to a fraud, and if the machines we sell are not the true Rife machines they are a fraud."* (Beam Ray Trial Papers).

When Edwards was on the stand he stated. (#1384-1385):

COMPARET: *"Did Mr. Hoyland tell you at any time in the fall of last year that the machines he was manufacturing for Beam Ray corporation operated on a principle fundamentally different from Dr. Rife's machine?"*

EDWARDS: *"No, Mr. Hoyland told me at one time that Dr. Rife thought that he had the frequencies but he didn't have them* [Here Edwards is talking about the Beam Ray Corporation instruments not the Rife Ray #4 instrument because Philip Hoyland said, on the stand, that he gave the Rife Ray #4 frequencies to Dr. Johnson and Dr. Rife in 1935]*."* (Beam Ray Trial Papers).

Philip Hoyland also stated this when he was on the stand. (#800):

HOYLAND: *"Regarding the frequencies of the machine* [Beam Ray Corporation Clinical instrument], *you will remember me telling you that the frequencies used are not the same ones on the Rife machine* [The Rife Ray #4]. *They* [Meaning the Rife Ray #4 frequencies] *were in the upper bands* [139,000 to 1,604,000 Hertz]*."* (Beam Ray Trial Papers)

In a letter which he sent to Dr. Gonin in 1939, there are indications that Dr. Rife wanted the so-called harmonics removed:

RIFE: *"I spoke only Friday evening to a Mr. John Chamblin, a radio man now connected with Beam Ray Inc., about the redesign and building of a device according to the old Rife Ray principles; as the present instrument has been so deviated away from that old principle that it is nowhere near the same...those devices which you have are merely working on a harmonic and not a true frequency; and in our research on electronics, we definitely know that there is no possible way of controlling electrical harmonics of a frequency."* (Letter from Dr. Rife to Dr. Gonin, May 14, 1939. Page 1 of 3).

We have just read a lot of trial testimony about how this Rife Ray #5 or Beam Ray Rife Machine worked on harmonic frequencies. Also, in the trial testimony it is mentioned that these Beam Ray audio machines were tested in Dr. Rife's lab to see if they would devitalize microorganisms. It was Philip Hoyland who made the tests using Dr. Rife's organisms. These tests were also repeated again in Dr. Johnson's laboratory in the summer of 1936. From the documents we know that Philip Hoyland put a lot of work into this instrument and didn't finish it until late 1936. Benjamin Cullen said Philip Hoyland spent a lot of time at the lab and stated the following in a taped interview in the 1950's:

CULLEN: *"Philip Hoyland was in there quite a lot...Hoyland developed some few items in the lab...Hoyland seemed to help quite a lot and he got into the bacteriology side with Rife a good deal because Rife had so much to work out...he finally got to the point where he* [Dr. Rife] *had to delegate some of the work."* (John Marsh Rife CDs, CD 6 track 1).

In the Beam Ray Trial manuscript we also read the following. (#91 & 93):

COMPARET: *"Were any experimental activities carried on in the lab?"*

HOYLAND: *"Yes."*

From the trial we learn that Philip Hoyland developed and tested his harmonic instrument in the lab. How could Philip Hoyland have tested it unless he put micro-organisms under the microscope? From the "Development of the Rife Ray" document we learned that:

"During the fall of 1936 Dr. Couche of San Diego and Jack Free assistant to Commander Rife conducted a clinic with one of the frequency machines treating experimentally cases of carcinoma and senile cataract..." (Development of the Rife Ray and use in devitalizing pathogenic micro-organisms).

From the trial papers we learn that Philip Hoyland didn't tell Dr. Rife what frequencies he was using in the instruments. Dr. Rife thought the instruments were using his frequencies (the upper band frequencies) but with harmonics because this is what Philip Hoyland told him. The information that we now have obtained from this original Rife Ray #5 or Beam Ray Clinical instrument shows that Philip Hoyland's instrument was working on Dr. Rife's principles and on his frequencies but in a different manner than Dr. Rife was lead to believe. This is the reason that the instrument worked so well. Philip Hoyland was still using Dr. Rife's principle of coordinative resonance but hid the truth from Dr. Rife to protect his ownership interest. Philip Hoyland was a business man and Dr. Rife was not.

The fact that these tests were done along with the fact that these instruments were used by many doctors with incredible results show that this instrument which used audio frequencies modulated onto an RF carrier frequency did devitalize microorganisms. Though Dr. Rife did not like the method of harmonic frequencies that Philip Hoyland used it was pointed out in the trial that Dr. Rife knew there were changes. Dr. Rife also didn't think that these changes would make much of a difference as long as the instrument worked: (Beam Ray Trial Transcript #2700)

SAPIRO: *"Dr. Rife said that he knew there were changes made in his machine and that they were not changes that would make any difference. Dr. Rife is a genius but he didn't know how to put the machines in a form that could be used in offices of doctors. These machine are perfectly good, they are just the same as the* [Dr.] *Couche machine and the one that gave Mrs. Henderson such relief."*

It was only with the release of the complete Beam Ray Trial manuscript and other Rife documents; found in California a few years ago that we now know why Dr. Rife continued to have this style of instrument built even in the 1950's. Though Dr. Rife originally did not like Philip Hoyland's Rife Ray #5 or Beam Ray Clinical design instrument, because of the use of harmonics, he later tested it in his laboratory and found it would work as well as his original instruments that did not use harmonics. We will quote the complete letter since all of this information is important:

RIFE: *"My first association with Dr. Yale came through an organization known as the Beam Ray Corporation. In order to acquaint you with the details of the formation of this corporation I shall bring in a little background. My assistant at that time* [1934] *in the laboratory was Philip Hoyland whom I met through Dr, Milbank Johnson M.D., Medical Director for the Pacific Mutual Life Insurance Company. I considered Hoyland as a capable electronic engineer and brought him to my laboratory in Point Loma on Alcott Street, San Diego, Calif. Hoyland became associated with a promoter named Hutcheson and Dr. James B. Couche M.D. They came to me with the idea or forming the Beam Ray Corporation to manufacture and distribute the Frequency Instrument to the medical profession. I gave this considerable thought and came to the conclusion that if these instruments were manufactured and placed into the hands of legitimate and bonafide medical practitioners, my efforts, over a period of years would derive exceedingly more benefits, so I gave this corporation permission to manufacture these devices on two stipulated conditions (1) that they would adhere decidedly to the original basic principles of the Frequency Instrument and (2) that each Frequency Instrument would be thoroughly tested before delivery to determine its true devitalizing power and effect on pathogenic bacteria. And so they went ahead. Three instruments were built. The first two were shipped to England (unwired as Hoyland wanted a trip to England) and the third went to Dr. Hamer M.D. at the Paradise Valley Sanitarium and Hospital. Dr. Hamer was the superintendent there I believe. Hoyland was like many men with whom I have associated over a period of years. In a short time he began changing the basic principles of these instruments according to his own ideas. About this time he became associated with Dr. Yale and Yale ordered and received another or the Fourth Frequency Instrument. Since I was out of the city or San Diego at the time, all of these devices were delivered without being tested by myself.*

At a much later period, I called on Dr. Yale at 333 Plaza in San Diego which was the address of his clinic at that time and told him that I did not feel that the Frequency Instrument had been calibrated

properly so that it would not work. In the interim, I became associated with another electronist by the name of Verne Thompson, of San Diego. Under my supervision, Thompson rebuilt Dr Yale's Frequency Instrument which I tested in my research laboratory on pathogenic bacteria and the Frequency Instrument proved effective. Then later at different times I had this instrument checked and found it lacking in its ability to devitalize anything. I later learned that Dr. Yale had ideas of his own and would have somebody change the Frequency Instrument to suit his individual whims. I will state here definitely that I have never been associated in any way with Dr. Yale outside of the interest that I have taken in some of the patients of Dr. Yale." (Letter written by Dr. Rife, March 22, 1958).

This document shows that Dr. Rife, after the shutdown of Beam Ray Corporation, eventually tested Philip Hoyland's Beam Ray Clinical design and found that it would devitalize all the microorganisms it was tested on. This also confirms that Philip Hoyland's statement that he tested it out in the laboratory was a truthful statement.

With this information taken from the Rife documents we now know why Dr. Rife considered the Beam Ray Clinical machine his instrument and knew it worked. Add to this the fact that all of the doctors who used it had a great deal of success with this Rife Ray #5 or Beam Ray Clinical instrument design. This is why Dr. Rife, John Crane and John Marsh built this Rife Machine in the 1950's and called it the AZ-58. The only difference in the 1953 AZ-58 design was it only had a three band switch which covered a lower audio frequency range. Other than this change the 1953 AZ-58 was a replica of Dr. Couche's and Dr. Tully's original Beam Ray machine. In a letter dated July 6, 1956 this fact was pointed out:

"The Frequency Instruments used by Dr. Tully and Dr. Couche were built in 1938 and do not apply to this code. However the Frequency Instrument currently built are a copy of these earlier Frequency Instruments and are labeled "For Investigational Use Only" at the present time." (Application letter for approval of device in compliance with California Pure Drugs Act. Page 2).

This information that we have just read which shows that the 1953 AZ-58 was a copy of Dr. Couche's machine has more importance than it appears. We will explain why. The 1953 AZ-58's audio frequencies, which it used, were 10 times lower than the audio frequencies used in Aubrey Scoon's instrument. This correlation is important because it shows a direct link to the original Beam Ray Clinical instrument built by Philip Hoyland. This correlation shows that Dr. Couche's instrument used audio frequencies 10 times higher than the 1953 AZ-58. It also shows that Aubrey Scoon's Beam Ray Clinical replica instrument is also a replica or copy of Dr. Couche's Machine. This information now ties all these instruments together and shows that the original audio frequencies which came from Philip Hoyland and used in the Beam Ray Clinical instrument were the same audio frequencies used in Dr. Couche's machine and Aubrey Scoon's machine. This information also shows that these original audio frequencies were later lowered and used in the 1953 AZ-58 built by Dr. Rife, John Crane and John Marsh. Now we can understand why this letter showing that the 1953 AZ-58 is a copy of Dr. Couche's machine is so important. It ties all these machines together.

Since we now know the history of this instrument and that this instrument worked on Dr. Rife's frequencies we will go back to the harmonic method used by Philip Hoyland. From the documents that we have read we know that Hoyland's machine worked on harmonics. The problem with the Beam Ray instrument is it has to be built a certain way in order for it to work on the correct harmonics. It was from the analyzing of this original Beam Ray Clinical instrument that the mystery of how it worked was discovered. We will show how it worked after we read another important quote. Bertrand Comparet, Rife's attorney who eventually defended Dr. Rife against Philip Hoyland in the 1939 Beam Ray trial said this about Philip Hoyland's Beam Ray Clinical instrument:

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COMPARET: *"Well, none of us know enough about it. Now, I remember at that time Rife saying that Hoyland had not used a simple straight forward circuit, as Rife had used, but he thought he had a short cut, through use of harmonics and so on, and Rife had no faith in Hoyland's circuit".* (1970's Bertrand Comparet interview #28).

This statement by Bertrand Comparet and all the quotes we have read sums up Dr. Rife and his Beam Ray business partners understanding of how this instrument worked on harmonic frequencies. Anyone can see that only Philip Hoyland knew how this machine really worked and he would not reveal the secret to anyone.

This confusion of how the instrument worked still remained throughout the building of the 1940's and 1950's Beam Ray replica instruments and even up until the present day (2010). It appears from the Beam Ray Trial testimony that Dr. Rife and the other owners of Beam Ray Corporation really didn't know how this instrument worked. The trial testimony shows that Philip Hoyland would not tell anyone in the Beam Ray Corporation the frequencies used with the Clinical instrument or explain how it worked on harmonics. John Crane and John Marsh who worked with Dr. Rife didn't understand how it really worked either. If Dr. Rife had really known how it worked then he would not have allowed John Crane and John Marsh to have a variable RF carrier frequency in the instrument. Having a variable RF carrier, in and of its self, is not the problem. Having a variable RF carrier frequency would be a good thing as long as you also understand that the audio frequencies have to be correctly matched to the RF carrier frequency in order to produce Dr. Rife's higher harmonic M.O.R. frequencies. The problems came about because John Crane and John Marsh did not have this understanding. The reason why John Crane and John Marsh put a variable capacitor in the instrument was so that they could tune the RF carrier frequency in order to make the ray tube brighter. By doing this it also made it so they could change the RF carrier frequency from about 4.9 MHz to about 2.2 MHz. This change showed that they did not understand how the instrument worked. They mistakenly believed that the audio frequencies were the M.O.R.s. or the frequencies that would devitalize the microorganisms. They also mistakenly believed that the RF carrier frequency was not important. This belief shows without any doubt that they did not understand how the Beam Ray Clinical instrument worked. If they had really understood how it worked they would have never called any of the audio frequencies M.O.R.s.

At this point we need to explain a few things. Philip Hoyland had very good reasons why he wanted to hide how this new Rife Ray #5 machine worked. He became Dr. Rife's Engineer in 1935 when he built the Rife Ray #4. In 1936 Philip Hoyland also began building the Beam Ray Clinical instrument that would be sold in 1938 by Beam Ray Corporation. Philip Hoyland was worried about keeping the original frequencies a secret because he felt people would try to steal their technology. This concern of Philip Hoyland's was not unfounded because Mr. Parsons of the British Group did try to steal their instrument. From the trial transcript we learn they had no way to patent the instrument because everything they were doing was in public domain in regards to the frequency generating equipment. Even the frequencies themselves cannot be patented. Philip Hoyland felt that he had to come up with a way to keep anyone from finding out what the true frequencies were. So he built the instrument a different way using harmonics to hit the harmonic frequencies of the Rife Ray #4 and Rife Ray #3 Kennedy equipment. Until a genuine Beam Ray Clinical Rife Machine could be found and tested, we would never know for sure how Philip Hoyland generated and used the harmonics in his instrument. Even though we now know that Aubrey Scoon's instrument is a Beam Ray Clinical replica no one knew for sure that it really was a genuine replica when he obtained it. This confusion and the lack of having the chronological history of when and what type of instrument was built made it very hard to find the truth.

Not only would Philip Hoyland not tell anyone how his instrument worked he also would not let anyone know the new frequencies he was using. Everything he did hid the frequencies. In the Beam Ray Trial manuscript we read that he always used a code to give the frequencies. This code would work with the dials. No digital readout was available in those days like we have today.

Since no one was ever given the frequencies from Philip Hoyland this has led to many problems. Some of the later Beam Ray Clinical instrument replicas have different audio frequencies and this also has led to a lot of confusion. Even John Crane was sending people different audio frequencies other than the standard set he used with the 1953 AZ-58. Because of the different audio frequencies used in these Beam Ray replicas we really didn't know which set of audio frequencies Philip Hoyland really used. So it was not possible to use any of these frequency sets and come to any reasonable conclusions.

When we obtained this original Rife Ray #5 or Beam Ray Clinical Rife Machine, from Dr. Low, we had to put aside all the frequency lists and thinking of the past in order to figure out how the instrument worked. From everything we had read about Philip Hoyland's instrument we had come to the conclusion that the answer would be found in the math. However Hoyland came up with his idea it had to be a mathematical method. Like many others we tried to reconcile the audio frequencies as lower harmonics of Dr. Rife's original high RF frequencies. But this proved not to be the case. We tested the frequencies that were used in Aubrey Scoon's Beam Ray Clinical instrument and they didn't match either as harmonics of Dr. Rife's original frequencies. We did the same with the AZ-58 audio frequencies and they didn't match. We took the other audio frequencies that Crane had a list of and they also didn't match. There is an instrument known as the 1947 instrument which we tried to reconcile with no success either. With all these audio frequencies only a few were close harmonic matches. If all these audio frequencies were true harmonics of Dr. Rife's original high RF frequencies then they should have harmonically match up, but they did not.

Once we put all this aside and began to analyze this instrument we found out how it worked. This Beam Ray Clinical instrument is truly a harmonic instrument and works on harmonic frequencies of Dr. Rife's original frequencies which he found. Philip Hoyland was telling the truth when he told Dr. Rife that the instrument was working on harmonics. The only thing was Philip Hoyland would not tell exactly how this was being done. The fact that both the audio frequency and the RF carrier frequency were sine wave did not make it easy to understand how it worked. How could it be a harmonic instrument when it used a sine wave waveform for both the audio and the RF frequencies? The 1953 AZ-58 Beam Ray Clinical replica worked on square wave audio frequencies and the harmonics came from the square wave waveform. But this is not how the Beam Ray Clinical instrument was suppose to work.

The 1950's square wave method has been used ever since the 1950's. But how can an instrument that uses sine wave audio frequencies be a harmonic instrument? With this understanding we knew that the audio frequencies could never be the true M.O.R.s. But how did they work in the instrument to produce Dr. Rife's M.O.R.s? The harmonic square wave method has been an accepted method for many years. For many years almost everyone has understood and has generally accepted that you can take a square wave audio frequency and the harmonics it creates and hit a higher frequency M.O.R. through those harmonics. These audio frequencies are usually many hundreds of harmonic steps lower that the higher M.O.R. frequency. This harmonic method must be kept in mind as well as the fact that not once, but several times, in the Beam Ray Trial manuscript and other documents everything said about this machine showed that it was using the harmonic method. We must remember that Dr. Rife said that he believed that many of his frequencies were sub-harmonics of a higher frequency. He said if we knew the true higher frequency it may even work better. Because of how this instrument works it is logical to conclude that Philip Hoyland understood this concept and apparently found through testing that all of Dr. Rife's frequencies were sub-harmonics of higher frequencies. With this understanding he built the Rife Ray #5 or Beam Ray Clinical instrument. Philip Hoyland was being truthful when he said that this machine was using harmonics. With all this knowledge from the Trial testimony and the Rife documents we how have a good understanding of the facts behind this new instrument design. Here is what we found when we analyzed the Beam Ray Clinical instrument.

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The graph, below on the left, is of the harmonics from the 3.80 MHz RF carrier frequency coming out from the ray tube of our original Beam Ray Clinical instrument. It was taken using a PicoScope 3205 spectrum analyzer. The first photo, below on the right, with the black waveform comes from Dr. Rife's 1936 lab film. The photo to the right of that photo is an oscilloscope reading that we took of the waveform of the Beam Ray Clinical Rife Machine. You will notice the similarity of the waveforms. All the M.O.P.A. (Master Oscillator Power Amplifier designs used by Philip Hoyland) RF carrier waveforms we have tested look like this. When you put a non harmonic sine wave into a ray tube you will always see a distortion of the sine wave which will produce both odd and even harmonics through the ray tube. This is the reason the sine wave looks distorted.

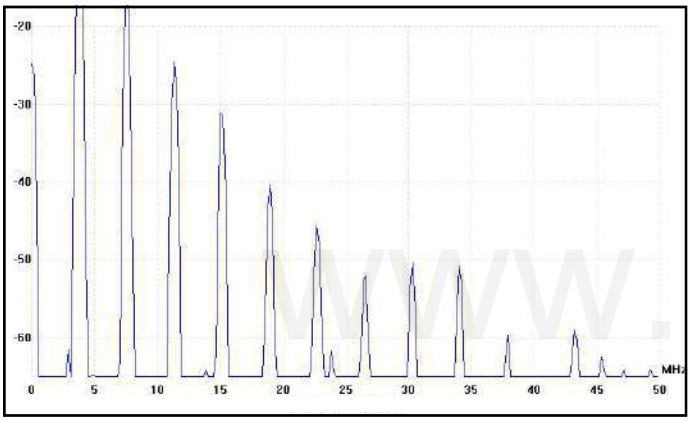

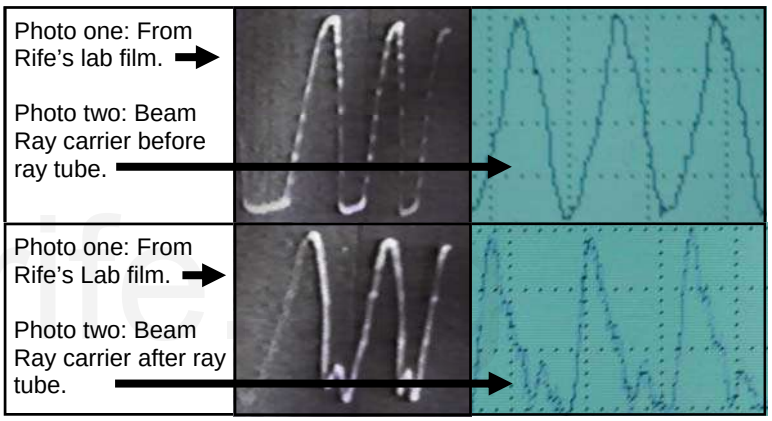

The graph, below on the left, is of a pure 2000 Hertz sine wave frequency. The oscilloscope photo, below on the right, shows a 2377 Hertz sine wave waveform coming from the audio oscillator of the original Beam Ray Clinical Rife Machine. The small photo shows it after it goes through the ray tube. You will notice that it almost looks like a square wave, but it is not. The circuit creates this waveform.

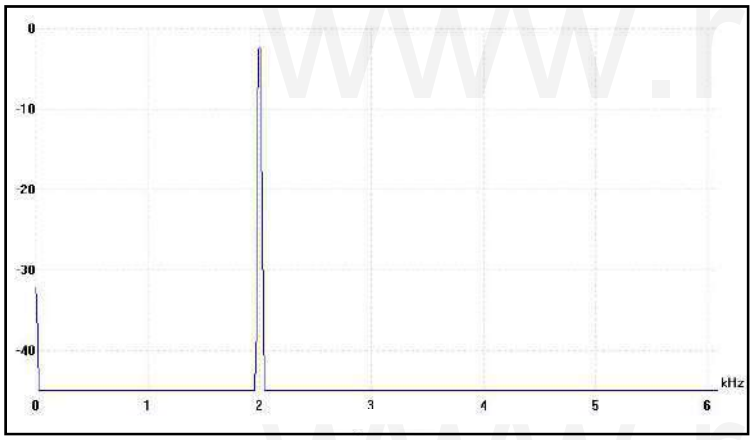

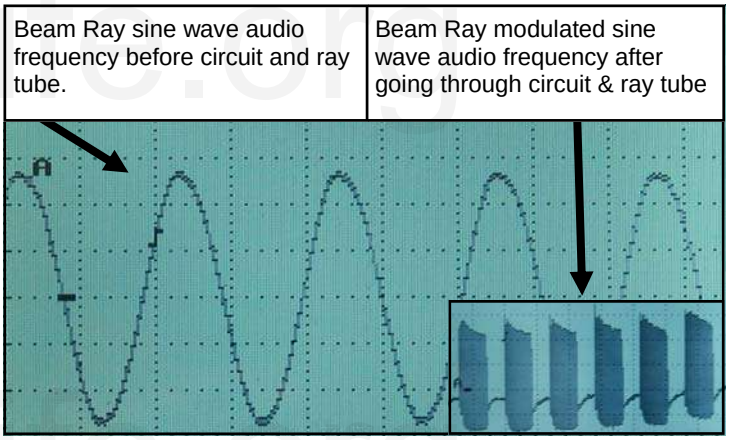

The next two graphs we will look at are on the top of the next page. The graph, on the left, was before modulation. The graph, on the right, during modulation. When we modulated 40,000 Hertz on a harmonic sine wave 3.80 MHz RF carrier frequency this is what the PicoScope spectrum analysis showed coming out of the ray tube. This was interesting to see. Not only did it create sideband frequencies 40 thousand Hertz above and below the harmonic RF 3.80 MHz carrier frequency but it created many harmonic sidebands every 40,000 Hertz. These harmonic sidebands covered a large frequency range of hundreds of thousands of Hertz.

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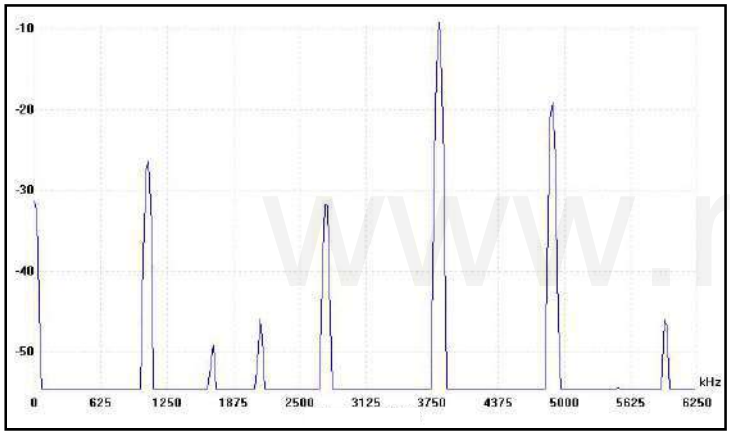

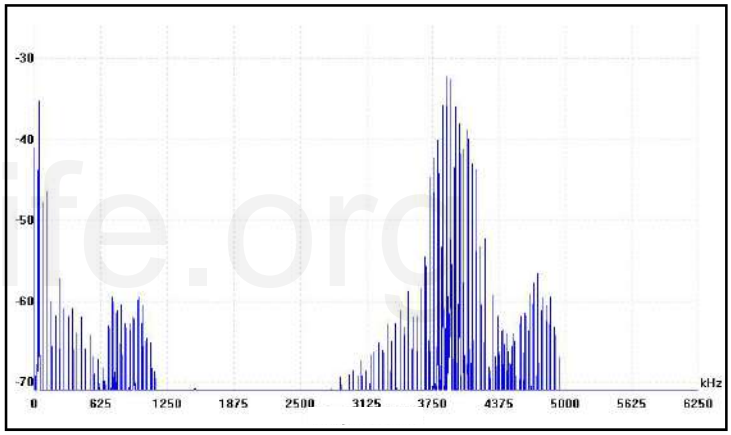

Below are two more graphs showing a closer view of these sidebands that were created from one audio frequency. The graph, below on the left, is with a 50,000 Hertz sine wave frequency. The graph, below on the right, is with a 100,000 Hertz sine wave frequency. This was done with a harmonic sine wave 2.4 MHz RF carrier frequency so you can see a closer view of these sidebands. When we saw this we knew there was only one way this Beam Ray Clinical Rife Machine could work on Dr. Rife's frequencies and principles. We will now explain how Philip Hoyland's Rife Ray #5 or Beam Ray Clinical instrument worked using a fixed RF carrier frequency of 3.80 MHz and a variable audio frequency. Philip Hoyland knew from working with Dr. Rife that his frequencies or M.O.R.s. were sub-harmonics of true higher frequencies. Understanding this must have given him the idea of how to build the new Rife Ray #5 or Beam Ray Clinical instrument. If we also understand this concept, that all frequencies have lower and higher harmonic frequencies, is half the key to understanding how Philip Hoyland made this machine work. What Philip Hoyland did was multiply Dr. Rife's original M.O.R. frequencies up in harmonic steps until he had the highest harmonic frequencies closest to 3.80 MHz. From the Beam Ray Trial quotes we know that Dr. Rife was told by Philip Hoyland that this Beam Ray Clinical machine was working on his frequencies with harmonics. What Philip Hoyland would not do is clarify exactly how it was working on harmonics of Dr. Rife's frequencies. Philip Hoyland also stated that his frequencies were not the same frequencies as Dr. Rife's frequencies. He was being truthful when he said this but what he would not reveal is the fact that his frequencies were exact harmonics of Dr. Rife's frequencies.

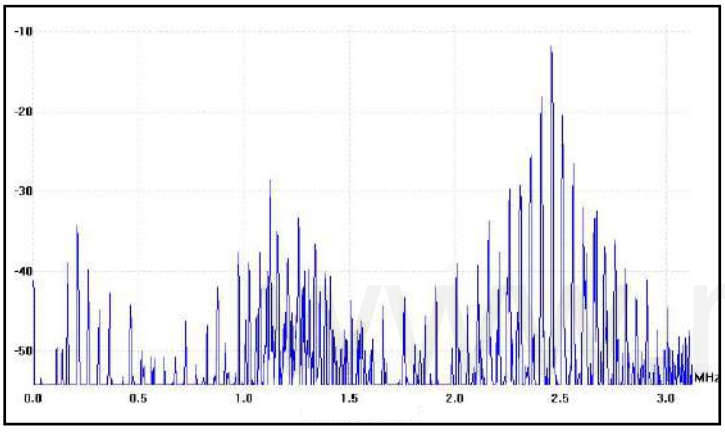

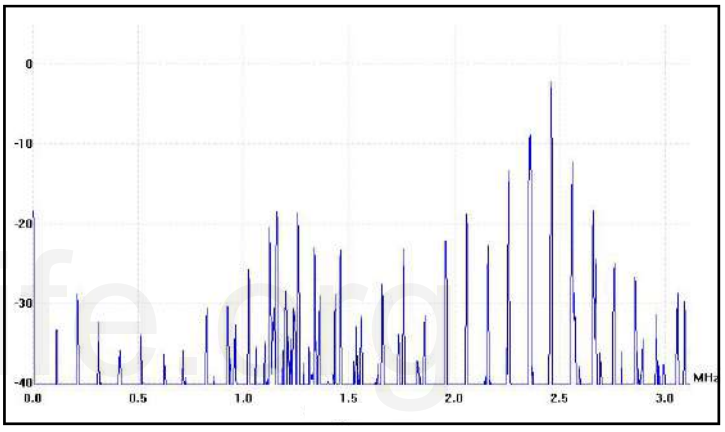

To clearly explain how Philip Hoyland used Dr. Rife's frequencies to come up with his new frequencies which were to be used in the Rife Ray #5 or Beam Ray Clinical instrument we will use the Rife Ray #4 frequency for Streptothrix as an example. That frequency was 192,000 Hertz. Philip Hoyland multiplied 192,000 Hertz by 20 times which will give you the 20th harmonic frequency at 3,840,000 Hertz. Since the RF carrier frequency of the Beam Ray Clinical instrument was fixed at 3,800,000 Hertz the difference would only be 40,000 Hertz between the two frequencies. This method of multiplying Dr. Rife's frequencies up in harmonic steps and using those frequencies was an ingenious method used by Philip Hoyland. Even though this was an igneous method it is only half the mathematical equation. The second half of the mathematical equation is probably even more ingenious than the first part.

Philip Hoyland then put into this Beam Ray Clinical instrument an audio oscillator. We must keep in mind that none of Dr. Rife's frequencies that were transferred from the Rife Ray #3 to the Rife Ray #4 and then to the Rife Ray #5 or Beam Ray Clinical instrument were audio frequencies. The audio oscillator was put into this instrument to accomplish the second half the mathematical equation. Using the audio oscillator all Philip Hoyland had to do was use an audio frequency of 40,000 Hertz. The 40,000 Hertz frequency would then create what are called sideband frequencies. These sideband frequencies would be created by the 40,000 Hertz both above and below the RF carrier frequency being used. The first upper sideband frequency would then be 40,000 Hertz above the RF carrier frequency and hit the harmonic M.O.R. frequency of Streptothrix at 3,840,000 Hertz. This method of using sidebands was the second half of the mathematical method used by Philip Hoyland in this Beam Ray Clinical instrument. Now for further clarification of these sidebands, as shown in the photo on the previous page, which extend out many times above and below the RF carrier frequency depending on the audio frequency which is used. They are like pickets on a fence and every picket represents a harmonic sideband created from the audio frequency. These harmonic sidebands are part of the harmonics that the Rife Ray #5 or Beam Ray Clinical instrument used. So Philip Hoyland took Dr. Rife's frequencies and multiplied them up in harmonic steps as close as he could get them to the fix 3.80 Megahertz RF carrier frequency. Then these new higher harmonic frequencies of Dr. Rife's original frequencies then became Philip Hoyland's new M.O.R. frequencies which he would not reveal to Dr. Rife or any of his Beam Ray Corporation partners. Next he then used harmonic sidebands to hit those new higher frequencies.

Though Philip Hoyland's new frequencies were harmonic frequencies obtained from Dr. Rife's original frequencies they did not create harmonics in the Beam Ray Clinical instrument. The harmonics came from the RF carrier frequency and the harmonic sidebands created from the audio frequencies, which Philip Hoyland used. By using both of these methods combined into and instrument Philip Hoyland could then say that the Rife Ray #5 or Beam Ray Clinical instrument was a harmonic instrument capable of outputting Dr. Rife's frequencies. His method was truly a harmonic method but he kept it as a secret form Dr. Rife and the other owners of the Beam Ray Corporation. The sideband method that Philip Hoyland used was the new cutting edge of electronic technology back in 1936. There would be very few people who could understand what Philip Hoyland was doing unless it was fully explain to them as we have explain here.

We will now explain Philip Hoyland's method further so that there can be no misunderstanding. But first what needs to be pointed out here is this IMPORTANT fact which came from the analyzing of this Beam Ray instrument. Neither the harmonic 3.80 MHz RF carrier frequency nor the audio frequencies will do anything by themselves. But when the harmonic 3.80 MHz RF carrier frequency and the audio frequencies are combined together they will produce many sideband frequencies. And one of these sideband frequencies will line up with the true higher harmonic Rife M.O.R frequency and devitalize or render harmless the harmful microorganism. To re-emphasize this so that no one misunderstands. If you just use the audio frequencies by themselves you will get nothing. If you just use the 3.80 MHz RF carrier frequency without the audio frequencies you will get nothing. The audio frequencies used in this instrument must have the RF carrier frequency of 3.80 MHz or they will not produce Dr. Rife's frequencies. This is the reason the 1953 Beam Ray Clinical instrument called the AZ-58 did not work properly. In that instrument they were only using the audio frequencies without correctly matching them to the RF carrier frequency. In other words they were not using the sideband method that Philip Hoyland originally developed to be used in this style of instrument.

We know that Philip Hoyland was trying to hide the true M.O.R. frequencies of the organisms from anyone who used the equipment. Twice in the Beam Ray Trial it was mentioned that Dr. Rife had no ability to patent the Rife Ray tube instrument. The only secret was the frequencies and Philip Hoyland was trying to protect his and Beam Rays interests. The third and final secret that Hoyland used to hide the M.O.R. frequencies will now be explained. Keeping the harmonic sideband method in mind

Philip Hoyland could have just divided the 40,000 Hertz by two and used a 20,000 Hertz audio frequency. Then you would have one upper sideband at 3,820,000 Hertz and the second upper harmonic sideband at 3,840,000 Hertz. The 3,840,000 Hertz sideband would hit the 20th harmonic of 192,000 Hertz. Philip Hoyland could have divided it by three and used a 13,333 Hertz frequency. He also could have divided it by 4 and used a 10,000 Hertz frequency. If he would have divided it by five he could have used an 8,000 Hertz frequency. Divided by six he could have used a 6666 Hertz frequency.

We could go on but anyone can see the many variable frequencies that could have been used to create the correct sideband frequency. Also, because of the "one tenth of one meter" factor that Dr. Rife mentioned you could add a few Hertz to each frequency without changing the frequency enough to make it so it would not work. This means you could change the 6,666 Hertz to 6,669 Hertz just to make things a little more confusing. By using this method Philip Hoyland could use many different audio frequencies to produce which ever number of sidebands he wanted to use. This would make it impossible to figure out which sideband was hitting the M.O.R. frequency that would devitalize the organism. By using this new method of using higher harmonic frequencies of Dr. Rife's original frequencies and then using harmonic sideband frequencies Philip Hoyland was able to build a machine that would hide the frequencies from anyone. Philip Hoyland's method as anyone can see was ingenious.

We know that Philip Hoyland's method worked very well except that the technology of the mid 1930's did have a few drawbacks. Dr. Couche said that he had to sweep the frequency dial in order to get his instrument to work consistently. This is understandable since the 3.80 MHz RF carrier frequency will wander in a sweeping motion five hundred to one thousand Hertz up or down from the fixed RF carrier frequency. The audio frequency oscillator also varied. Bertrand Comparet in his 1970's interview said this about the Beam Ray Clinical instruments inherent frequency drift:

COMPARET: *"Well, as they warmed up they'd shift frequency...Now, whether this was Hoyland's inability to do better, or whether it was just inevitable in those days, I don't know, but Hoyland's devices did have that frequency shift as they warmed up. So, they had their problems. Now what Couche did, see, he would have cases where he would get an instantaneous cure, like that, and other times when the treatment just didn't produce any results, because of the frequency shift. So, he would start in, he had from Rife (Hoyland dial settings) a set of the frequencies for several different diseases and he would tune it deliberately to one side of that frequency and then gradually tune it across to the other side making sure that somewhere in the process he crossed the correct frequency, even if the instrument wasn't exactly in tune anyway. Well, when they hit the exact frequency they got amazing results."* (1970's Bertrand Comparet interview #10).

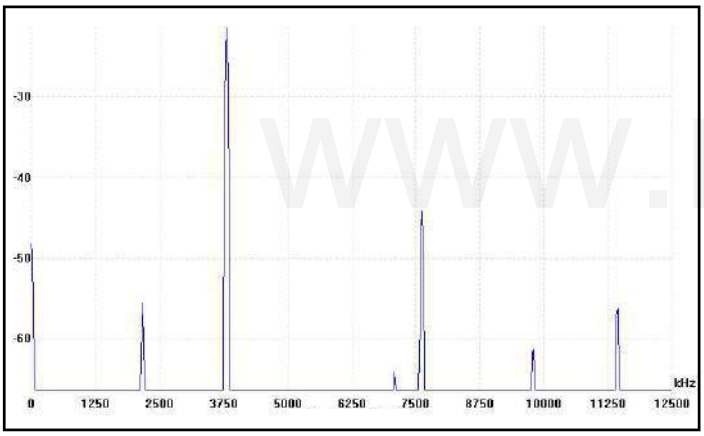

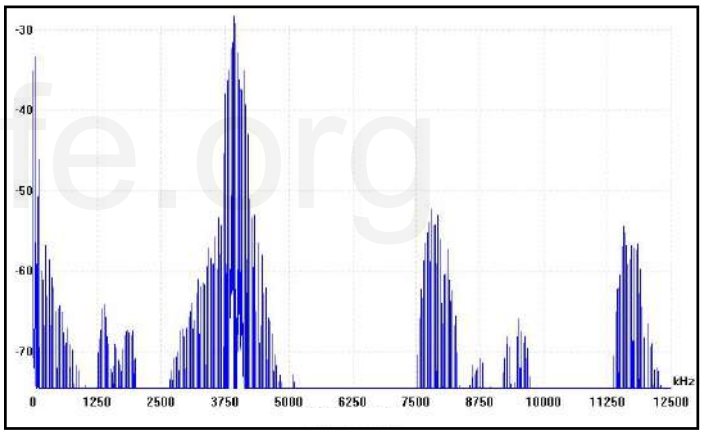

Again if you look at the first graph, above on the left, you will also notice that there are harmonic frequencies created from the 3.80 MHz RF carrier frequencies at 7.60 MHz and 11.40 Megahertz. These sideband frequencies as shown in the above graph, on the right, are created not only for the 3.80 MHz RF carrier frequency but its entire harmonics. These harmonics continue all the way up to

about 12 MHz with reasonable power. This creates an interesting effect and shows that all the harmonics of 192,000 Hertz are being hit over the whole spectrum of about 12 Megahertz. This is probably why this Beam Ray harmonic instrument worked as well as it did, when they hit the correct frequency. This Rife Ray #5 or Beam Ray Clinical machine was definitely a harmonic instrument as Philip Hoyland had stated. It may have even exceeded Philip Hoyland's original concept.

Now going back to the audio frequency method of creating the sidebands that Philip Hoyland used. No one could ever determine the 20th harmonic frequency of 3,840,000 Hertz or the original Rife Ray #4 frequency of 192,000 Hertz using this method. The secret of the Beam Ray Clinical instrument and the frequencies that would devitalize the microorganisms could never be figured out unless you had the original Rife Ray #4 frequency of 192,000 Hertz. Only a spectrum analysis of this instrument made it possible to figure out what Philip Hoyland was doing. Without this modern technology a person would have to be very knowledgeable about how frequencies and their harmonics worked.

The fact that it has taken this long, almost 75 years, to figure out how this Rife Ray #5 or Beam Ray Clinical Rife Machine worked is proof enough that the secret was well hidden. As pointed out earlier, Philip Hoyland would never tell anyone how this instrument really worked. If anyone changed the 3.80 MHz RF carrier frequency then the audio frequencies would not work. New audio frequencies would have to be calculated to match the new RF carrier frequency. Also, Philip Hoyland could have changed the audio frequencies any time he wanted for any machine in order to confuse anyone who had the equipment. Since the instrument that we obtained from Dr. Low is an original Beam Ray Clinical instrument then one would assume that its 3.80 MHz RF carrier frequency is the carrier frequency that was used with all the Beam Ray Clinical instruments. But we know that this is not the case because they used a different carrier for other machines. None of the audio frequencies used in all the replica instruments from the 1940's to the 1953 AZ-58 match up to the 3.80 MHz RF carrier frequency. With this understanding we also have to assume that the audio frequencies used in this original Beam Ray Clinical instrument were different than the 1940's and 1950's instruments. Aubrey Scoon's instrument had a 3.30 MHz carrier frequency so if his machine is a replica of one of the original machines, which it is, then the audio frequencies would logically have to be matched to its 3.30 MHz carrier frequency, which they are.

The 1953 AZ-58 technical data shows that it used a 4.68 MHz RF carrier frequency. But when the variable capacitor was put into the AZ-58, in about 1956, the carrier frequency then became variable. This made is so Dr. Robert P. Stafford could change the RF carrier frequency to different carrier frequencies. In Dr. Robert P. Stafford's "Electromagnetic Field Therapy" report he said the following about the carrier frequency they used on his patients with the 1953 AZ-58:

DR. STAFFORD: *"Radio Wave transmission is used as a carrier wave. We use between 3100 KC [3.10 MHz] and 3300 KC* [3.30 MHz] *(This does not appear to be a critical value). The carrier wave is modified with specific cycles per second modulations. We believe that the CPS [audio frequencies] is a critical value and it actually may prove to be the most important factor which this research may offer."*

You will notice that Dr. Stafford did not think that the RF carrier frequency was critical. He clearly states that they believed it was the "CPS" or cycles per second of the audio frequencies which were the most important part of making the AZ-58 work. If the AZ-58 was going to work on the sideband method that Philip Hoyland developed then the RF carrier frequency and the audio frequencies had to be correctly matched. John Crane and John Marsh at this time also did not think that the setting of the carrier frequency was important to make the instrument work properly. Dr. Stafford would have gotten his understanding from them. We now know that the proper setting of the carrier frequency was important. The audio frequencies used with the AZ-58 should have been recalculated to match its 4.68 RF carrier frequency because its carrier frequency was different than Aubrey Scoon Beam Ray replica instrument carrier or our original Beam Ray Clinical instrument carrier frequency. When the math is done to check

the sidebands with the audio frequencies that were used with the AZ-58 it shows that those audio frequencies will not create the correct sideband spacing which will match up to the harmonic Rife Ray #4 frequencies. This is probably why Dr. Robert P. Stafford could not get the AZ-58 to devitalize any of the microorganisms he was testing in the laboratory. Here are two of his statements:

DR. STAFFORD: *"Please excuse my format in the following letter for I intend to ramble a bit and forget strict grammatical dictum. I am writing you at this time partially because John Marsh informs me in a recent letter that you may be somewhat disheartened or at least worried about your role in the experimentations with the Rife Machine. Believe me, Dr. Edward I know how you feel for I too have been through this same feeling with this matter. I have observed clinical results after treatments with this gadget which I can scarcely believe myself. Yet, despite these good results, I have been confused by some rather simple failures such as a recent experiment which I conducted at Good Samaritan Hospital where we used the machine to treat some cultures of Staph Aureus and Strept. Fecalis. In this work we failed to inhibit growth at all or influence the cultures with the Rife Rx. I sent the results to John Marsh and asked for clarification and to be very frank I am not satisfied with John's excuse of the failure as described by Dr. Rife. I am afraid I'm not a very good apostle for I'm getting some ideas myself on how this thing may work. I really wonder if this ultrasonic kills bacteria and virus at all or does it work like other forms of ultrasonic and merely stimulate the tissue in some unusual manner thereby improving the circulation and secondarily enhancing the body's defenses against infection…To summarize some of this rambling: I feel that the Rife Ultrasonic Therapy has a very definitely beneficial effect on the human (and canine) body...I furthermore feel that we, as doctors of medicine, using this machine must remain constantly alert to the condition of our patient and vary the Rx as indicated." (*Dr. Stafford letter to Dr. Jeppson April, 1 1958).

DR. STAFFORD: *"As yet, we have failed to "cure" any case of advanced, terminal malignancy. It appears in several instances that we may have impressed the disease favorably, temporarily. It is difficult to rule out the psychological, morale booster effect to the terminal patient when some definitive effort is made again in his behalf. However, several improvements have appeared to be more physical than emotional...All the patients in the series were treated with the same frequencies (e.g., 728 - 784 - 880 - 2008 - 2128). Perhaps these frequencies may be wrong, or only nearly correct."* (John Marsh Collection, Dr. Stafford's Report on using the AZ-58, page 4, www.rife.org)

If the incorrect audio frequencies were used with the 3.10 MHz to 3.30 MHz RF carrier frequency what Dr. Stafford M.D. reported is exactly what would have happened. From Dr. Stafford's statement we know that he did not think the RF carrier frequency was critical. If Dr. Rife had fully understood how Philip Hoyland had designed the instrument he would have never allowed John Crane or John Marsh to put a variable capacitor in its circuit without recalculating the audio frequencies for the new RF carrier frequency they wanted to use. Also they would not have lowered the original audio frequencies by a factor of 10 times and used them. The AZ-58 would have had a new set of audio frequencies correctly match to the new 4.68 MHz RF carrier frequency it was originally given in 1953. The new set of audio frequencies would then have been the correct audio frequencies that would create the proper sideband spacing. Dr. Rife would have also made sure that Dr. Stafford knew that the carrier frequency was critical. If John Crane and John Marsh really understood how this instrument worked they never would have wanted to change the 4.68 MHz carrier frequency. The 4.68 MHz RF carrier would have been a good carrier frequency if they would have used the correctly matched audio frequencies.

It is obvious they never really understood how the instrument worked or how the audio frequencies interacted with the carrier frequency to produce the M.O.R.s. which would devitalize the organisms. They, like us, were under the false belief that the audio frequencies they were using were the M.O.R.s. They unknowingly promoted this idea because Philip Hoyland would never tell anyone how the instrument worked. We know that Dr. Rife knew that this Beam Ray Clinical machine somehow

worked on his frequencies with harmonics but it is apparent that no one but Philip Hoyland really understood how the instrument worked on the harmonic sideband method.

With the new variable capacitor that John Crane and John Marsh put into the AZ-58 they could change the RF carrier frequency from about 2.40 MHz to about 4.90 MHz. Dr. Stafford told me personally, when I talked to him, that it did not make any difference which carrier frequency he used, they all worked the same. We will probably never know the full story of how these mistakes were made but it is obvious that no one but Philip Hoyland had the proper understanding of how the instrument worked. Since the AZ-58 used the square wave harmonics method rather than the harmonic sideband method it would have been better if Dr. Rife, John Crane and John Marsh had used a true lower harmonic frequency of the Rife Ray #4 frequencies, but they didn't. Using the correct sub-harmonic audio frequencies derived from the higher Rife Ray #4 RF frequencies would have been a better approach. Those Rife Ray #4 sub-harmonic audio frequencies used with the square wave harmonics method, probably would have worked better than the incorrectly match 1950's audio frequencies they were using in the AZ-58. We should do the same today with our frequencies.

All that we have discovered with the analyzing of this original Rife Ray #5 or Beam Ray Clinical instrument reveals that the audio frequencies used with this equipment are not Dr. Rife's true M.O.R.s. They are just the frequencies needed to produce the proper sideband spacing in order to hit the correct higher RF harmonics of Dr. Rife's original M.O.R. frequencies. If the audio frequencies were the frequencies that would devitalize the microorganisms then logically all Dr. Rife's frequencies would have been audio frequencies, but they are not. If these audio frequencies were Dr. Rife's true M.O.R. frequencies then an RF carrier frequency would not have be needed and he would have never even needed to build a Ray Tube instrument. Dr. Rife would have been able to do all of his work with a simple frequency generator that would have had a frequency range of only about 25,000 Hertz. But this is not the case. Dr. Rife always said that almost all his frequencies were in the upper bands which match the Rife Ray #4 frequencies which covered a frequency range from 139,200 Hertz to 1,604,000 Hertz. None of those Rife Ray #4 frequencies where audio frequencies.

It is interesting to note that this Rife Ray #5 or Beam Ray Clinical instrument did not have a dedicated fixed audio pulsing circuit. This is also the case with the 1953 AZ-58. Aubrey Scoon mentions a sixty Hertz feedback pulse into the circuit of his instrument but he could not determine if the instrument was intended to work this way or if it was just a malfunction. When we built his instrument we could not get our instrument to work in the same manner as his did in producing this feedback, therefore we believe that it most likely was malfunctioning and was not intended to work in that manner. Since this original Rife Ray #5 or Beam Ray Clinical Rife Machine that we obtained didn't work in this manner either and none of the other replica instruments work this way we believe that our conclusion is correct.

We know that Dr. Rife's high RF frequency instruments such as the Rife Ray #3 and Rife Ray #4 used a fixed audio frequency pulsing circuit. This fixed audio frequency modulated the high RF frequency and was used to devitalize the organism. We have shown already in this report that this pulsed waveform was needed to devitalize the various microorganisms that Dr. Rife tested. The Beam Ray Clinical instrument did not use this circuit. The logical reason why it did not us this circuit is the modulated waveform created from the variable audio oscillator must have been sufficient to create the effect. The variable audio frequencies, which created the sidebands, would also pulse the waveform and this must have been sufficient to accomplish the same result. From this we can conclude that all that is needed is a modulated or pulsed waveform with the proper M.O.R. high RF frequency to devitalize microorganisms.

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In the photo, shown below, is the Rife Ray #5 or Beam Ray Clinical instrument waveform. It looks almost like a modulated square wave waveform but it is not produced with a square wave. This waveform is produced using a sine wave audio frequency.

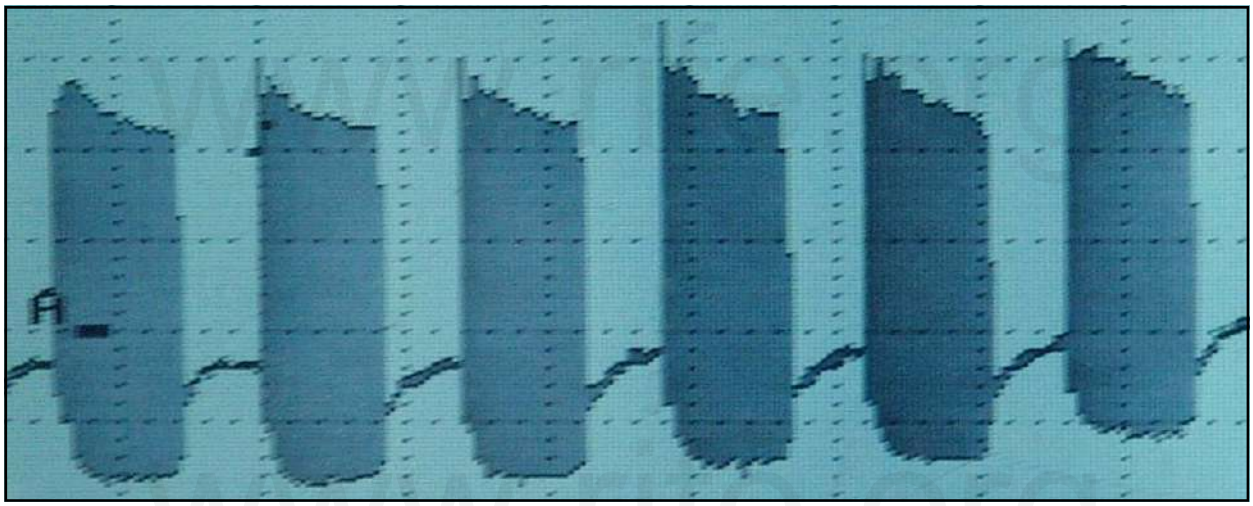

The Beam Ray instrument uses sine wave audio frequencies modulated onto a sine wave RF carrier frequency. It is the unique design of the Beam Ray Clinical circuit that produces this waveform. The M.O.P.A (Master Oscillator Power Amplifier) circuit that Philip Hoyland used was built in a different manner than would normally be used. Instead of using one vacuum tube for the RF oscillator section and a second vacuum tube for the amplifier section he only used one vacuum tube for both sections.

Because he used only one vacuum tube the circuit over oscillates and shuts off for half of the cycle. This shutting off for half of the cycle makes the waveform look almost like a square wave. This new waveform replaced the damped wave waveform that was used in the Rife Ray #4 instrument. In the 1953 AZ-58 Beam Ray Clinical instrument the variable sine wave audio oscillator was replaced with a variable square wave audio oscillator. Had they really understood how the AZ-58 instrument was really supposed to work on the harmonic sideband method they probably would not have made this change. Changing the waveform from sine wave to square wave did not change how the harmonic sidebands worked in the AZ-58. It only shaped the waveform in a true square wave waveform. The only real change that could affect the output of the instrument is not matching the audio frequencies with the new 4.68 MHz RF carrier frequency. It was this change that proved to be the biggest mistake they made.

What must be kept in mind is the treatment frequencies were not the audio frequencies in the original Beam Ray Clinical instrument. It was the sideband frequencies created by the audio frequencies when match and combined with the 3.80 MHz RF carrier frequency that would create the M.O.R. treatment frequencies. We tested both sine wave and square wave with the spectrum analyzer and there was no change in the sidebands. But in the 1950's they were under the false assumption that the audio frequencies were the treatment frequencies.

Variable Audio Frequencies

Now we will discuss the variable audio frequencies used in the Rife Ray #5 or Beam Ray Clinical instrument. When we figured out how this instrument worked on harmonic sidebands we did not choose the optimum audio frequencies. We just used audio frequencies that would show how the instrument worked. There are better audio frequencies that could be used for optimum performance to hit the Rife Ray #4 higher harmonic frequencies. In order to determine the audio frequencies that were used to create the sideband spacing frequencies we first had to determine the difference between the 3.80 MHz RF carrier frequency and Hoyland's new higher harmonic M.O.R.s. which were derived from

Dr. Rife's original frequencies. In order to make it easier for the reader to understand the difference between the RF carrier frequency and Dr. Rife's higher harmonic frequency will be call that the "difference number" in this report. In most cases we divided, the difference number, by 5 but the BX was divided by 15. The BX M.O.R. higher harmonic frequency, based on the Rife Ray #4 frequency, is 3,208,000 Hertz. This frequency is only the second higher harmonic of the Rife Ray #4 frequency of 1,604,000 Hertz, so it will still work just as well as all the other frequencies.

One must keep in mind that the modern square wave audio frequency harmonics are projected to hit frequencies hundreds of harmonics up. This Beam Ray instrument has far more power in its harmonic sidebands than any square wave harmonic has in it. And the Beam Ray instrument only has to go to the 15th lower sideband to hit the BX M.O.R. frequency, not hundreds of harmonics like a square wave harmonic would. This Philip Hoyland method would be far superior to using low square wave audio frequencies since the harmonics would all be 40 harmonic steps or less.

So that you can better understand how this instrument worked we need to determine what RF carrier frequencies would be best to use with this Beam Ray Clinical instrument. Philip Hoyland would have also done these calculations back in the 1930's. The best RF carrier frequencies to use would always be calculated based on Dr. Rife highest original M.O.R. frequency. As an example the highest frequency that Dr. Rife used in the Rife Ray #4 was the BX cancer virus frequency of 1,604,000 Hertz. The best RF carrier frequency would be this 1,604,000 Hertz frequency multiplied by two which would be 3,208,000. So an RF carrier frequency in the 3.10 to 3.30 Megahertz range would be a good RF carrier frequency range. Dr. Couches' Rife Ray #5 or Beam Ray Clinical instrument, built by Philip Hoyland, used an RF carrier frequency of 3.30 MHz and Aubrey Scoon's instrument which is a copy of it also used a 3.30 MHz carrier frequency. The importance of this 3.30 MHz RF carrier frequency will be discussed later. The next best carrier frequency would then be three times this frequency which would be 4,812,000 Hertz. So a carrier frequency in the AZ-58 4.68 MHz range would also work very well. By using Dr. Rife's highest M.O.R. frequency it is easy to see that the best RF carrier frequencies can be determined. We are sure that Philip Hoyland had this same understanding.

Some of the following information was originally part of Chapter 8 but after restudying the Rife documents we found that this information, including the additional documents we found, actually belonged in this chapter. This information confirms Philip Hoyland's use of higher harmonic frequencies obtained from Dr. Rife's original M.O.R. frequencies.

When Dr. Johnson and Philip Hoyland were testing the first proto-type of the Rife Ray #5 or Beam Ray Clinical instrument in the summer of 1936 they had an interesting effect take place. At that time they were at Dr. Johnson's laboratory testing different bands of frequencies on the various microorganisms. Dr. Johnson wrote about what happened at his laboratory in a letter he sent to Dr. Gruner and Dr. Rife on November 4, 1936:

DR. JOHNSON: *"Last summer, in hunting for the M.O.R. for the other two reproductive forms of the cryptomyces pleomorphia, we ran into a new band of oscillations which introduced itself to us by killing all three forms - those that we called BX, our filter-passing form; then a transitional form such as you found in the monocytes in the blood; and then the third or highly developed form coming from the sporangius forming from the hyphas of the mycelium. At the same time that this new wave band arrived, we broke all the glass in the laboratory of a certain shape, not only in the room where we were working but in all the other rooms...we had been troubled a great deal with a mold because in the microscope room there were no windows, but this band not only destroyed that mold, which was growing on the leather objects in the room, but every bacteriological culture that we had in the laboratory! It cleaned us out completely so we had to start from scratch and replace our losses. In fact, we were all so surprised that we began to feel each other's pulses to see if we were still alive. As no harm had been done to us, we proceeded to test the new band out on mice, rats, rabbits, guinea pigs and dogs. So far as we were*

able to discover, it is not at all destructive or injurious to normal cell tissue. While we have been forced to modify our machine so as to produce this new band, still it is so much more effective clinically that we look upon it as a very advantageous discovery. However, our experience has forced us to do all of our experimenting with the new ray [Rife Ray #5 or Beam Ray Clinical instrument] *completely outside of our laboratory building or abandon all form of bacteriological experiments, because it instantly kills them all."* (Letter from Dr. Johnson to Dr. Gruner (copy sent to Dr. Rife) dated, November 4, 1936).

Dr. Johnson clearly points out in this letter that this was done with a new Rife Ray. Dr. Johnson had been using the Rife Ray #4 since the fall of 1935 on his patients but here he points out that they were using a new Rife Ray machine and that it was clinically more effective than the machine he had been using up until this time. In the Beam Ray Trial documents Philip Hoyland stated that he had built a new Rife Ray instrument in the summer of 1936: (Beam Ray Trial Transcript #956)

HOYLAND: *"In the summer of 1936 I designed a new machine, or rather I checked it there at the lab. I had designed it in Pasadena, and we tested it out then."* (Beam Ray Trial Papers #956).

Also in another document called "Development of the Rife Ray" we have supporting evidence that a new Rife Ray was built in 1936:

"In the early part of 1936 Commander Rife and Mr. Hoyland spent much time collaborating on revising some of the applications of the fundamentals of the instruments due to the advancement that had taken place in the application of electronics and it was found that the carrier wave used in the previous instruments could be eliminated. During the summer of 1936 further experiments were carried on, which resulted in an entirely new method of generating the desired frequencies and produced a constant input and output in the instruments."

With the Rife documents showing that Philip Hoyland built the new Rife Ray or Beam Ray Clinical instrument in the summer of 1936 we know that this was the machine that Dr. Johnson was referring to in his letter. In that letter Dr. Johnson clearly states that during the summer of 1936 they had tested this new machine in his laboratory. Dr. Johnson's statement also confirms Philip Hoyland's statement given in the Beam Ray Trial documents that the machine was tested in the laboratory. The documents all support each other and show that it was the Rife Ray #5 or Beam Ray Clinical instrument that they were using which produced this amazing effect. In this same letter Dr. Johnson stated, not once, but twice that this work was done with the new Rife Ray machine. Here is his other statement:

DR. JOHNSON: *"I can assure you that no one, not even myself, could help but be astounded at the results we are now obtaining with the assistance of our new machines and our new band of MOR's."*

This letter was written in November of 1936 a few months after the laboratory testing was completed on this new Rife Ray machine. They now had built more than one of these new machines as pointed out by Dr. Johnson when he said "our new machines." Again Dr. Johnson points out that this is a new style of machine and it has a "new band of MOR's." In the Beam Ray Trial documents Philip Hoyland's complete statement reveals that he was using different frequencies than Dr. Rife:

HOYLAND: *"In the summer of 1936 I designed a new machine, or rather I checked it there at the lab. I had designed it in Pasadena, and we tested it out then and the frequencies were not the same as on Dr. Rife's machine."* (Beam Ray Trial Papers #956).

This statement made by Philip Hoyland about the frequencies not being the same as Dr. Rife's original frequencies is confirmed by Dr. Johnson. So Dr. Johnson's statement in his letter clearly shows that he understands that this new machine is using different M.O.R.s. than what Dr. Rife was originally

using in the Rife Ray #4. Dr. Johnson also points out that these new M.O.R.s are more effective than the original M.O.R.s found by Dr. Rife. Today we now know that these new M.O.R.s. that Philip Hoyland was using were based on Dr. Rife's original M.O.R.s. They were just higher, more powerful, harmonics of Dr. Rife's original frequencies. From the Beam Ray Trial we know that Philip Hoyland stated that the frequencies he was using in this machine were not the same as the frequencies that Dr. Rife originally found. This however does not change the fact that all Philip Hoyland did was multiply Dr. Rife's original frequencies up in harmonic steps to use them with this new Rife Ray #5 or Beam Ray Clinical instrument. Without Dr. Rife's original frequencies Philip Hoyland would have had nothing. Probably the most important fact is the higher harmonics seemed to work better at devitalizing the organisms. As mentioned before, Dr. Johnson indicates in his letter that this new machine works better than any of the previous machines they had used up until that time (Rife Ray #3 and Rife Ray #4). His letter also shows that he is very impressed with the results they were obtaining with it. Another important fact we learn from this letter is Dr. Johnson now had the M.O.R. for the cryptomyces pleomorphia fungi. He had been trying to get Dr. Rife to find this M.O.R. for many months, without success, because Dr. Rife had developed eye problems and could not use his microscope. But now he had the ability to produce its frequency with the new machine. Another thing that Dr. Johnson pointed out was the fact that they had killed all the bacteriological specimens in his laboratory with the new Rife Ray machine and that they had to use it outside of the laboratory or it would kill all the new replacement specimens they had to obtain.

Dr. Johnson in this same letter to Dr. Gruner said the following about this new Rife Ray machine which Philip Hoyland built:

DR. JOHNSON: *"We are having a great time out here. I have opened a clinic in the Pasadena Home for the Aged and am having excellent luck. Of course, what I am trying to do is to experiment with the effect of the Rife Ray on bacteria in vivo. Our laboratory work has demonstrated pretty conclusively what it will do in vitro. The clinic is held three mornings a week, Tuesday, Thursday and Saturday. Yesterday I had eighteen patients. Among them were two cases of pulmonary tuberculosis, three cases of carcinoma, two cases of old chronic varicose ulcers of the leg, and sundry other cases of more or less definite infectious origins…I certainly wish that you were here to work with me because I am afraid that even you, who know what we are trying to do, will not believe some of the yarns that I would have to tell you as to what is occurring in the clinic without actually seeing them for yourself."* (Letter from Dr. Johnson to Dr. Gruner (copy sent to Dr. Rife) dated, November 4, 1936).

Many people believe that Philip Hoyland's Rife Ray #5 or Beam Ray Clinical machine was somehow inferior to Dr. Rife's previous instruments in effectiveness in devitalizing microorganisms. But Dr. Johnson points out that this instrument was working better than any previous instrument they had used in the past. In another letter to Dr. Meyer, M.D. Dr. Johnson again talks about the effectiveness of this new Beam Ray Clinical machine:

DR. JOHNSON: *"I am conducting a very interesting clinic three times a week with the Rife Ray, treating about twenty two patients a session, and we are obtaining much valuable information from our work. We are encountering many physical problems in the production of the Ray, the greatest difficulty being to obtain uniform results from the apparatus which we have. At times the results of the Ray are absolutely astounding, causing an instantaneous sterilization of the wounds whether interior or exterior. But owing to the slight changes in the temperature of the room and apparatus, the same setting of the dials does not give us the same output, and hence our results are unsatisfactory. However, we believe now that we have developed it to a point where we can very greatly diminish the errors in output and substantially increase the beneficial results or the effect of the apparatus."* (Letter from Dr. Johnson to Dr. Karl F. Meyer dated, December 7, 1936).

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Even with the calibration problems with the instrument Dr. Johnson was still impressed with how well the instrument was working. If Dr. Johnson only would have had the ability that we have today to measure the frequency correctly, rather that relying on dial settings, he would have always had consistent results. With modern technology we can accurately measure a frequency regardless of any changes that the climate may make. Dr. Johnson only had the dial settings to work with back in the 1930's. The limits of the 1930's technology would have given him the problems he talked about in his letter. Even with the limits of the 1930's technology Dr. Johnson stated they had solved many of their problems with the instrument and this helped them to obtain even better results.

During this same clinic which Dr. Johnson was conducting he was also using this new Rife Ray on 30 cataract patients. In a letter that Dr. Johnson wrote to Dr. Joseph Heitger he stated the following:

DR. JOHNSON: *"I closed my clinic on May 28, having been running it for eight months. Our special effort this past winter has been working on cataracts, and while we have treated a number of other infectious conditions (if cataract is an infection), still our principal work has been on the eye. We have had about thirty cases of cataract...Every case that we have treated, with the exception of one which was a traumatic cataract where the lens was absolutely opaque and of recent origin, has been benefited...The application of the Rife Ray as we have used it , does, in the great majority of cases restore the full visual function of the eye; that is, that portion of the visual disturbance due to opacities in the lens. How it does it and why it does it, I do not know, but the above statement is an actual fact, supported by many cases…Oh Lord; How I wish we could get together and go over this work! I believe it will result in epochal changes in the profession's handling of cataract cases."* (Letter from Dr. Johnson to Dr. Joseph D. Heitger dated, June 1, 1937).

In this letter to Dr. Heitger, Dr. Johnson again points out how well this instrument worked. In this letter he also talked about the calibration problems they were having with this new Rife Ray machine. The Beam Ray Clinical machine was known for its calibration problems. Even the Beam Ray Trial testimony and other documents show that this instrument had calibration problems. Eventually Philip Hoyland divided the audio frequency range of the Beam Ray Clinical instrument into four bands. This helped but did not solve the problems completely. By the early 1940's the audio oscillator was replaced by the new stable Hewlett Packard audio oscillator. This Hewlett Packard audio oscillator was far superior to the original RC (Resistor Capacitor) style audio oscillator used by Philip Hoyland. Had they had a modern frequency counter they could have easily solved any of the calibration problems they had. Today if anyone builds this instrument they would want to have the ability to check the RF carrier frequency so that they will have consistent results.

Next we will explain how this instrument had the ability to devitalize so many organisms as described by Dr. Johnson in his letter. He stated in his letter of November 4, 1936 that it was done using a "new band of oscillations." This happened at the time they were testing this new Rife Ray #5 or Beam Ray Clinical instrument at Dr. Johnson's laboratory. Since it was a proto-type machine we do not know what the original frequency range of the audio oscillator was when this happened. What we do know is the original Beam Ray Clinical instrument which we obtained from Dr. Low had four frequency bands which covered a frequency range from 160 Hertz to about 42,000 Hertz. Whether it was one of the lower bands or one of the higher bands we do not know. But this we do know, Dr. Johnson would have had this band put into the new instrument because he stated this:

DR. JOHNSON: "*While we have been forced to modify our machine so as to produce this new band, still it is so much more effective clinically that we look upon it as a very advantageous discovery."* (Letter from Dr. Johnson to Dr. Gruner (copy sent to Dr. Rife) dated, November 4, 1936).

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This statement from Dr. Johnson leaves no question that this band of oscillations was included in the new Rife Ray machine which eventually became the finished product that was sold by Beam Ray Corporation. Why this new machine was able to kill all the organisms that Dr. Johnson talked about is easy to explain since we now know how this instrument worked. If you look at the spectrum analysis graph, shown below, you can see the many sideband frequencies created by a single audio frequency.

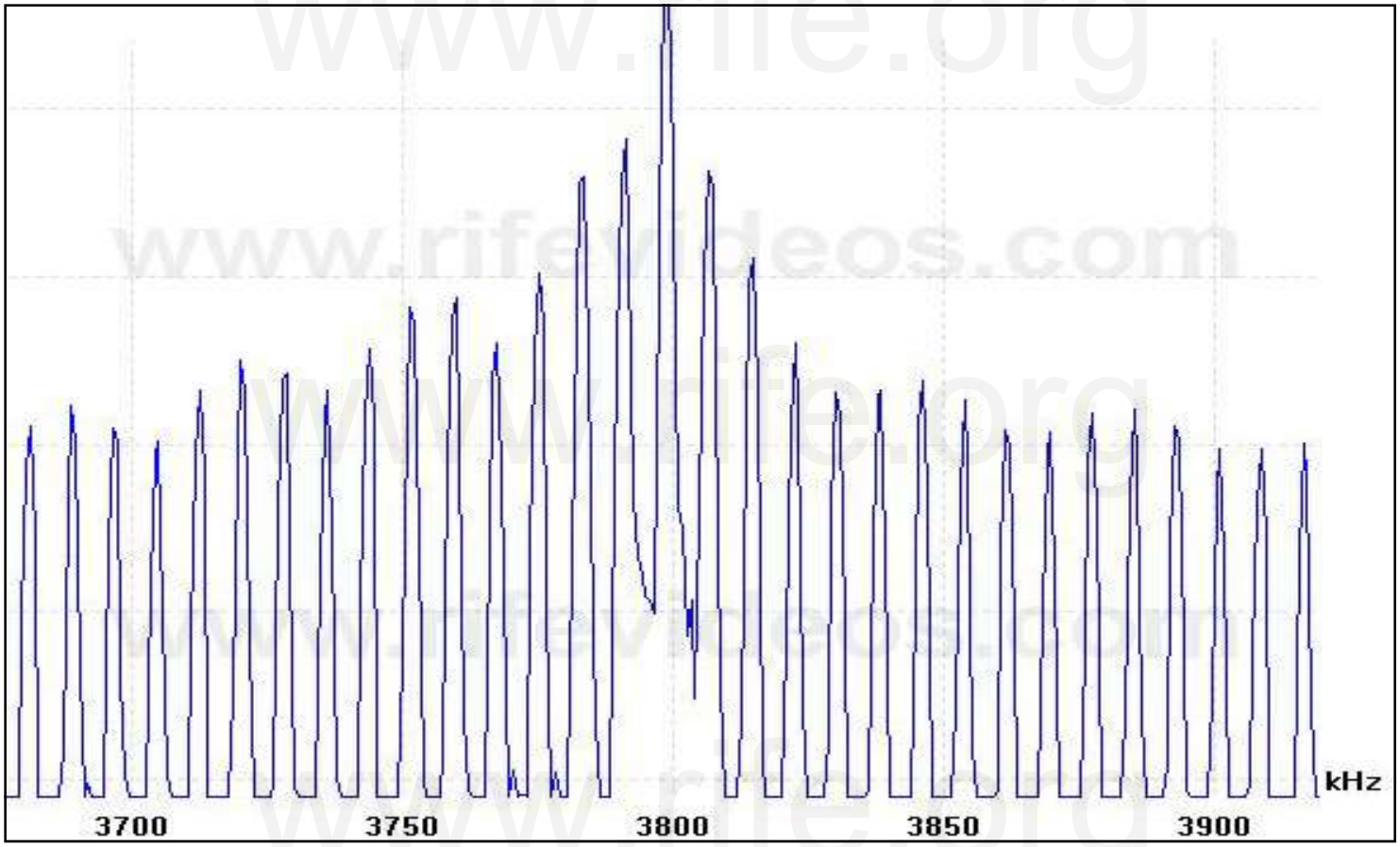

It has been said that a "picture is worth a thousand words." From this spectrum analysis graph of the Beam Ray Clinical machine we know it produced many sideband frequencies simultaneously, sometimes over 100. This explains how this effect happened. Dr. Johnson did not say that it was a single frequency that killed the organisms. He stated that it was a band of frequencies. By the word “band” we know that they must have been turning the frequency dial of the audio oscillator looking for a frequency that would kill the “two reproductive forms of the cryptomyces pleomorphia” organism. These two forms of this disease were found to be a factor in cancers and Dr. Johnson wanted the M.O.R. for these organisms. If the dial of this instrument was turned slowly, as they would have done, then they would have be sweeping the frequency. Even though you are only sweeping a single audio frequency you are also sweeping as many as 100 harmonic sideband frequencies simultaneously which were created by a single audio frequency. For an example we will explain how this works. It must be kept in mind that if you sweep an audio frequency in the Beam Ray Clinical instrument from 6000 Hertz down to 500 Hertz all of the RF sidebands produced from the RF carrier frequency will start with a distance of 6000 Hertz apart and as you sweep down to 500 Hertz these sidebands will slowly close until they are only 500 Hertz apart. During this sweep every frequency between these sidebands will be hit because these sidebands are also all going in towards the RF carrier frequency.

Not only are the sidebands closing and getting closer together but they are also moving in towards the RF carrier frequency completely overlapping each other. Both the upper sidebands and the lower sidebands produced by the audio frequency close in towards the RF carrier frequency. This produces a large broadband sweep, with these many sideband frequencies, that can cover up to a one Megahertz or one million Hertz frequency range. This instrument would be very advantageous to use

on patients but in a laboratory setting it would be your worst nightmare because it could very easily kill all your specimens as described by Dr. Johnson:

DR. JOHNSON: "*experience has forced us to do all of our experimenting with the new ray completely outside of our laboratory building or abandon all form of bacteriological experiments, because it instantly kills them all."*

We know that Philip Hoyland used at least two different RF carrier frequencies, 3.80 MHz and 3.30 MHz, with his Beam Ray Clinical instruments. We also know from the Rife documents that Dr. Couche's Beam Ray Clinical instrument RF carrier frequency was set to 3.30 MHz. The audio frequencies went from 1200 Hertz for Tetanus to 21,275 Hertz for the BX Cancer virus. These audio frequencies produced the correct sidebands which hit the correct frequency for each organism. It is easy to understand that if all of Dr. Rife's frequencies for the various organisms are covered over this range from 1200 Hertz to 21,275 Hertz then a slow sweep over this range would cover all the organisms' M.O.R.s. or frequencies. It is also logical to conclude that if any organism's frequency is located between about 40,000 Hertz up to about 1.80 MHz it would also be hit at some point during this sweep. This is because any organism's frequency could be multiplied up in harmonics so that it would be as close to 3.30 MHz as you can get. With this understanding it would also be logical to assume that a sweep through that complete frequency range down to about 500 Hertz would cover all Dr. Rife's M.O.R. frequencies both known and unknown. During the Beam Ray Trial it was pointed out that Dr. Rife had found the M.O.R.s. for about 40 more organisms that were not included in the Beam Ray Clinical Machine. Here is that statement:

HUTCHINSON: *"There are about 40 frequencies discovered by Dr. Rife that have not yet been released to the public, and have not been included in the machine."* (Beam Ray Trial Papers #1689)

Those 40 frequencies could have been put into the Beam Ray Clinical machine had Dr. Rife understood how Philip Hoyland built the machine using the sideband method. Though they were never put into the instrument using a dial setting this does not change the fact that the instrument could output those frequencies. Since they probably all would have been within this same sweep range then it is reasonable to assume that this same sweep range would also hit all of these organisms' frequencies. This is why we said *"All Rife's M.O.R.s. both known and unknown."*

If you wanted to cover an even larger frequency range you could sweep from 40,000 Hertz down to about 100 Hertz. The mathematical calculations show that to hit each organism's M.O.R. with sufficient time a sweep should not cover more than 25,000 Hertz in 4 hours. One important fact that should be realized is when this sweep is done from 25,000 Hertz down to about 500 Hertz, or lower, each organism's frequency is hit more than 20 times. To understand how this is possible requires the understanding that when these sidebands close and move in toward the carrier frequency each organism's frequency is hit with multiple sidebands. To explain how this happens we will take the BX Cancer virus frequency of 21,275 Hertz as an example. It is the fourth lower sideband that first hits the BX Cancer virus frequency of 3,214,900 Hertz (1,607,450 X 2 = 3,214,900) when it hits 21,275 Hertz. The fifth lower sideband again hits 3,214,900 Hertz at 17,020 Hertz. The sixth hits it at 14,183 Hertz and the seventh at 12,157 Hertz. This continues on until each organism is hit by more than 20 sidebands.

What has just been explained is why Dr. Johnson had the experience of this instrument killing all the organisms in his laboratory. Just a sweep through one of these four frequency bands with the Beam Ray Clinical instrument could wipe out a great many organisms because the sidebands would hit many organisms' M.O.R.s one right after another. This is because there can be nearly 100 sidebands generated at the same time.

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The reason we did not make a schematic for this original Beam Ray Clinical instrument is due to the fact that Aubrey Scoon's Rife Ray #5 or Beam Ray Clinical replica schematic is available and will build the same type of instrument. Aubrey Scoon's instrument carrier frequency has been discovered even though his instrument was malfunctioning or had parasidic oscillations. He originally gave a 3.33 MHz carrier frequency using an 812a tube. Then he made the wrong assumption and used an 809 tube and replaced the 812a with the 809, but this did not eliminate the parasitic oscillations. The problem with the instrument malfunctioning is what made it hard to determine the true carrier frequency. Without having the correct RF carrier frequency it makes it very hard to verify the audio frequencies it used. Having done a lot of work with this style of instrument and knowing how harmonics can shift the carrier frequency we decided to test a 3.30 MHz carrier to see if it was the correct frequency it used. This 3.30 MHz carrier frequency would have been a more logical choice to use especially when it comes to making the correct sideband frequencies. The results of that decision will be shown later when we take a look at Aubrey Scoon's 1940's (actually 1950's) Beam Ray Clinical replica instrument built by Verne Thompson.

On the next page is a chart showing the "Rife Ray #4 Frequencies" with their "Higher Harmonic Frequencies" along with the "Carrier Difference Frequencies" and the "1/10 tenth Of One Meter" mentioned by Dr. Rife, converted to Hertz. Also included in this chart are "Beam Ray Clinical Frequencies" which are audio frequencies that would work with the Beam Ray Clinical instrument. It also includes "Aubrey Scoon's Frequencies" for a comparison even though we have not yet examined Aubrey's Beam Ray replica machine. After you have read about Aubrey Scoon's instrument this information will be even more understandable.

You will notice in the chart on the next page that many of the Beam Ray Clinical instrument audio frequencies, when divided with some numbers are very close to the audio frequencies used by Aubrey Scoon's Beam Ray instrument. It is easy to see the correlation between these two machines and the sideband method used by Philip Hoyland to hit the proper high frequency M.O.R. harmonics of the Rife Ray #4 frequencies. There could be many more audio frequency sets depending how you divide the "*Carrier Difference Frequencies." The best audio frequency set would be a list with the highest frequencies so that you have the lowest number of sideband harmonics. The reason for this is power loss: the more sidebands the less power in each sideband. The power loss after about 40 sidebands is so great, when looking on a spectrum analyzer, it is doubtful the sideband frequencies would work.

As mentioned before the higher the audio frequency used the more power there is in the sidebands. For this reason we have put in the chart, shown below, a list of the optimum Beam Ray Clinical instrument audio frequencies to be used with a 3.80 MHz RF carrier frequency and a 40,000 Hertz audio oscillator. We did this since this original Beam Ray Clinical instruments oscillator went to just over 40,000 Hertz. This would give the lowest number of sideband harmonics and the greatest power in each sideband.

Beam Ray Clinical Instrument Sideband Sine Wave Audio Frequencies			
Anthrax	20, 800 Hz	Streptococcus	33,333 Hz
B or E Coli Rod	23,500 Hz	Steptothrix	40,000 Hz
B or E Coli Virus	25,000 Hz	Syphilis or Treponema	36,250 Hz
BX Virus Carcinoma	39,467 Hz	Tetanus	28,000 Hz
BY Sarcoma	?37,000 Hz	Tuberculosis Rod	36,667 Hz
Gonorrhea	36,000 Hz	Tuberculosis Virus	?22,500 Hz
Spinal Meningitis	21,500 Hz	Typhoid Rod	100 Hz
Staphylococcus	24,000 Hz	Typhoid Virus	38,214 Hz

The Beam Ray Clinical Instrument Sideband Sine Wave Audio Frequencies Based On A 3.80 MHz Carrier							
Microorganism	**Rife Ray #4 Frequencies**	**Higher Harmonic Frequencies**	***Carrier Difference Frequencies**	**1/10 Of One Meter Freq.**	**Number of Sideband Harmonics**	**Aubrey Scoon's Frequencies**	**Beam Ray Clinical Frequencies**
Actinomycosis or Strepto-thrix	192,000 Hz	3,840,000 or 20th	40,000 Hz	12 Hz	4	7,870 Hz	10,000 Hz
Anthrax	139,200 Hz	3,758,400 or 27th	41,600 Hz	6 Hz	5		8,320 Hz
B or E Coli Rod	417,000 Hz	3,753,000 or 9th	47,000 Hz	58 Hz	6	8,020 Hz	7,833 Hz
B or E Coli Virus	770,000 Hz	3,850,000 or 5th	50,000 Hz	198 Hz	3	17,220 Hz	16,667 Hz
BX Virus Carcinoma	1,604,000 Hz	3,208,000 or 2nd	592,000 Hz	858 Hz	15	21,275 Hz	39,467 Hz
BY Sarcoma	?1,530,000 Hz	3,060,000 or 2nd	740,000 Hz	780 Hz	20	20,080 Hz	37,000 Hz
Gonorrhea	233,000 Hz	3,728,000 or 16th	72,000 Hz	18 Hz	5		14,400 Hz
Pneumonia or Spinal Meningitis	427,000 Hz	3,843,000 or 9th	43,000 Hz	61 Hz	5	7,660 Hz	8,600 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz	3,824,000 or 8th	24,000 Hz	76 Hz	3	7,270 Hz	8,000 Hz
Streptococcus Pyogenes	720,000 Hz	3,600,000 or 5th	200,000 Hz	173 Hz	24	8,450 Hz	8,333 Hz
Syphilis	789,000 Hz	3,945,000 or 5th	145,000 Hz	207 Hz	22	6,600 Hz	6,591 Hz
Tetanus	234,000 Hz	3,744,000 or 16th	56,000 Hz	18 Hz	5	1,200 Hz	11,200 Hz
Tuberculosis Rod	369,000 Hz	3,690,000 or 10th	110,000 Hz	45 Hz	13	8,300 Hz	8,462 Hz
Tuberculosis Virus	?769,000 Hz	3,845,000 or 5th	45,000 Hz	197 Hz	3	16,000 Hz	15,000 Hz
Typhoid Rod	760,000 Hz	3,800,000 or 5th	0 Hz	192 Hz	1	6,900 Hz	100 Hz
Typhoid Virus	1,445,000 Hz	4,335,000 or 3rd	535,000 Hz	694 Hz	14	18,620 Hz	38,214 Hz
Worms						2,400 Hz	

On page 93 you will find oscilloscope images of the original Beam Ray Clinical instrument. On pages 94 through 100 you will find the spectrum analyzer graphs showing the sideband frequencies for each organism using the Beam Ray Clinical instrument 3.80 MHz RF carrier frequency. These graphs show which sideband frequency is hitting the Harmonic Rife Ray #4 frequency that is closest to the 3.80 MHz carrier frequency. These graphs show clearly how this instrument worked.

On pages 101 and 102 are two charts that show the Rife Ray #4 frequencies and their M.O.R. harmonics so you can see the progression of harmonic frequencies as they go up in harmonics to the frequencies that were used by Philip Hoyland in this Beam Ray Clinical instrument. With these two charts you can do the same math that we did to determine the audio frequencies that will produce the proper sideband spacing. You will notice in the chart above called "The Beam Rays Clinical Instrument Sideband Sine Wave Audio Frequencies Based On A 3.80 MHz Carrier" that our list of audio frequencies for the Beam Ray Clinical instrument are in all four bands of frequencies. Philip Hoyland said:

HOYLAND: *"The whole list of bacteria that the machine was treating was divided into four bands."* (Beam Ray Trial Transcript #260)

You will notice that Aubrey Scoon's Beam Ray replica frequencies are only in three bands (bands 2, 3 and 4). This is because Dr. Rife's engineer, Verne Thompson, used a different audio oscillator with this instrument than the audio oscillator used in our original instrument. The first band which covered from 20 Hertz to 200 Hertz is not used since the lowest audio frequency was 1200 Hertz when

using a 3.30 Megahertz carrier frequency. In the original Beam Ray Clinical instrument we obtained the audio oscillator was also changed but the RF carrier frequency was 3.80 Megahertz. With this carrier frequency you will get one audio frequency that has to be in band one because it is so close to the carrier frequency that only a frequency of less than two hundred Hertz will work.

IMPORTANT INFORMATION: Many people have asked why the frequencies that were used to determine how this Beam Ray Clinical instrument worked are different than those used with Aubrey Scoon's Beam Ray replica instrument. The reason they are slightly different is this instrument was evaluated and analyzed first. It also used an RF carrier frequency which is different than Aubrey Scoon's instrument. It was the evaluating and analyzing of this instrument using the Rife Ray #4 frequencies that made it possible figure out Aubrey Scoon's Beam Ray Clinical replica instrument. It was the information that was obtained from this Original Beam Ray Clinical instrument that made it possible to obtain the most accurate frequencies from Aubrey Scoon's Beam Ray Clinical instrument. In the Beam Ray Clinical instrument the frequencies had to be calculated precisely or it would not work. The reason for this precision is, if you happen to be off 20 Hertz on the first sideband then the second sideband will be off 40 Hertz. The error will continue to compounded with every sideband. It is easy to see that this simple small error would compound and make it so the instrument would not work. It is easy to see that though the instruments frequencies would wander a little the math to determine where the sidebands needed to be had to be exact. It was Philip Hoyland's precise math that made it so we would have the most accurate frequencies for the various microorganisms. Philip Hoyland said, on the stand, in the 1939 Beam Ray Trial that he tested the instrument in Rife's lab. His testimony revealed that he had tested the Beam Ray Clinical design using microorganisms to determine its effectiveness. Dr. Rife also tested this same instrument in his lab on micro-organisms in the early 1940's. So we know that this design worked.

Please read Chapter 11 of this report to understand how we obtained the most accurate frequencies from Aubrey Scoon's Beam Ray Clinical replica instrument.

Chapter Summary: Dr. Rife's engineer, Philip Hoyland, not John Crane, was the first person to built the instruments that used audio frequencies and an RF carrier frequency. This instrument which was called the Rife Ray #5 or Beam Ray Clinical instrument was fundamentally different than the Rife Ray #3 and Rife Ray #4 instruments because it was built with a variable audio oscillator and a fixed RF Carrier frequency. It was the modulation of the audio frequency with the RF carrier frequency which produced Dr. Rife's higher harmonic M.O.R. frequencies which devitalized the microorganisms. This new method which Philip Hoyland developed used harmonic sideband frequencies produced by the audio frequencies to produce Dr. Rife's higher harmonic frequencies. Dr. Rife's higher harmonic frequencies were the frequencies used in both the Rife Ray #3 and Rife Ray #4 instruments.

Philip Hoyland built this Beam Ray Clinical instrument using this new method because Dr. Rife was not able to patent his equipment or his frequencies. The audio frequencies were not the frequencies that devitalized any microorganisms as many believe today. The audio frequencies had to be combined with the correct RF carrier frequency to produce the correct sideband frequencies or they would not produce Dr. Rife's frequencies which would devitalize the various microorganisms. Because Philip Hoyland hid how the Beam Ray Clinical instrument worked it resulted in John Crane and John Marsh believing that the audio frequencies were the treatment frequencies for the microorganisms. They in turn passed on this incorrect understanding of the audio frequencies which has lead to the current belief that the audio frequencies are the treatment frequencies. It was the analyzing of the original Beam Ray Clinical instrument obtained from Dr. Low which revealed how the audio frequencies produce Dr. Rife's original higher harmonic frequencies through harmonic sidebands.

In Chapter 10 we will look at the next Rife Machine built by Philip Hoyland which was call the Beam Ray Laboratory instrument.

Oscilloscope Readings Of The Original Beam Ray Clinical Instrument

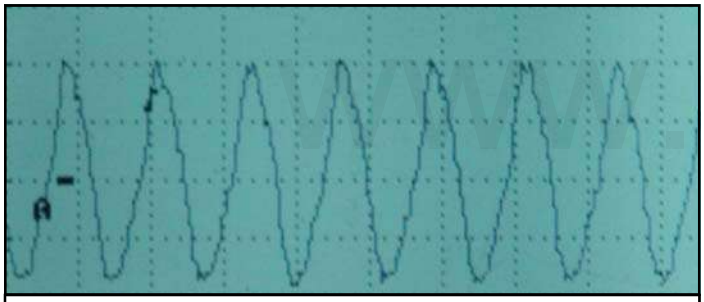

3.80 MHz carrier frequency before ray tube.

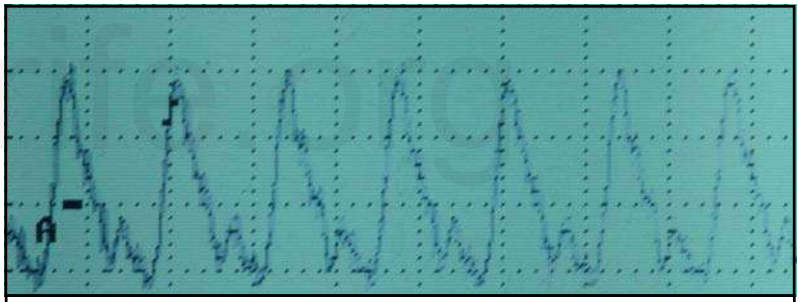

3.80 MHz carrier frequency after ray tube.

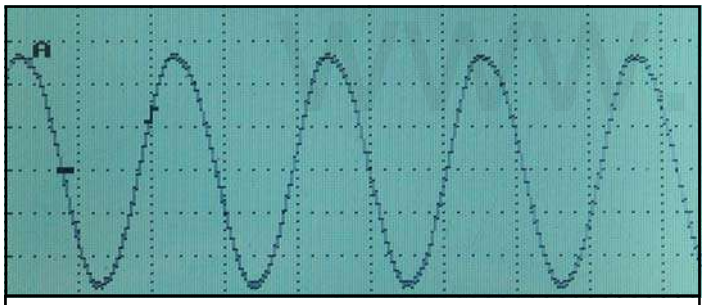

2,377 Hertz frequency from audio oscillator.

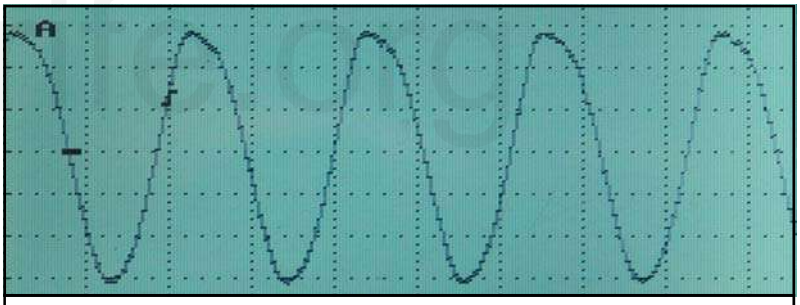

9,360 Hertz frequency from audio oscillator.

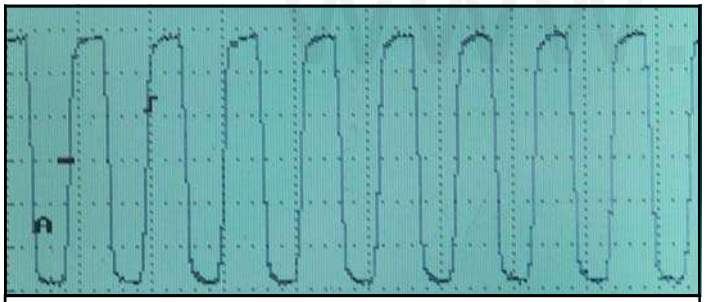

18,630 Hertz frequency from audio oscillator.

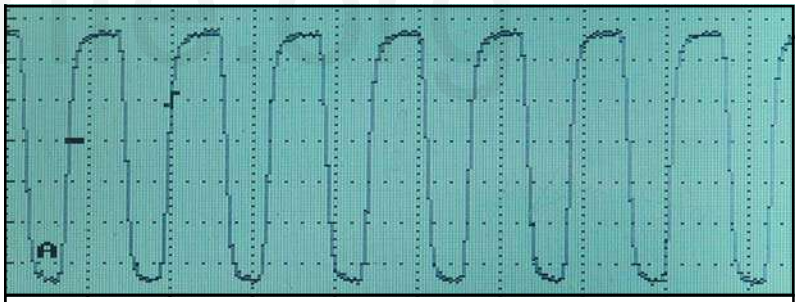

40,980 Hertz frequency from audio oscillator.

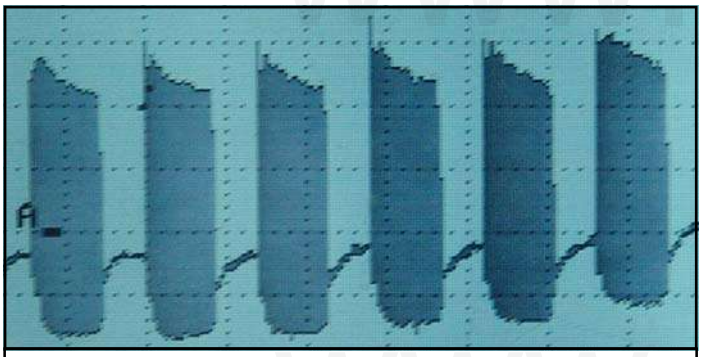

Original Beam Ray modulated waveform.

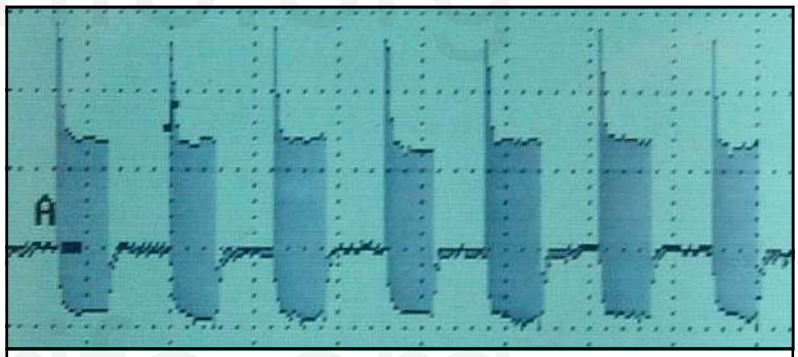

Aubrey Scoon's Beam Ray replica modulated waveform.

www.rife.org

Rife Ray #4 192,000 Hertz for Actinomycosis or Streptothrix. The 20th Higher harmonic frequency is 3,840,000 Hertz. The audio frequency used for the proper sideband spacing is 10,000 Hertz. The 4th upper sideband hit the M.O.R.

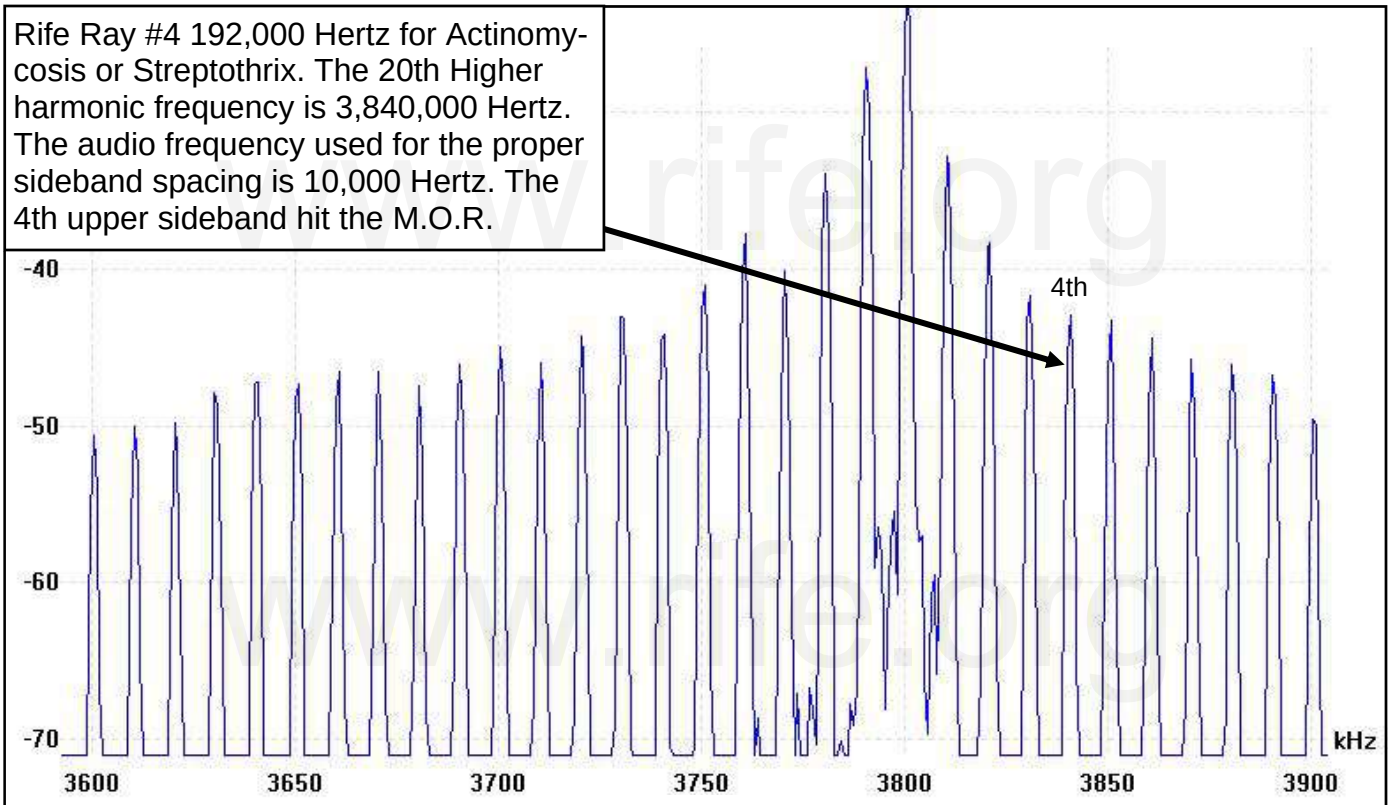

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 139,200 Hertz for Anthrax. The 27th Higher harmonic frequency is 3,758,400 Hertz. The audio frequency used for the proper sideband spacing is 8,320 Hertz. The 5th lower sideband hit the M.O.R.

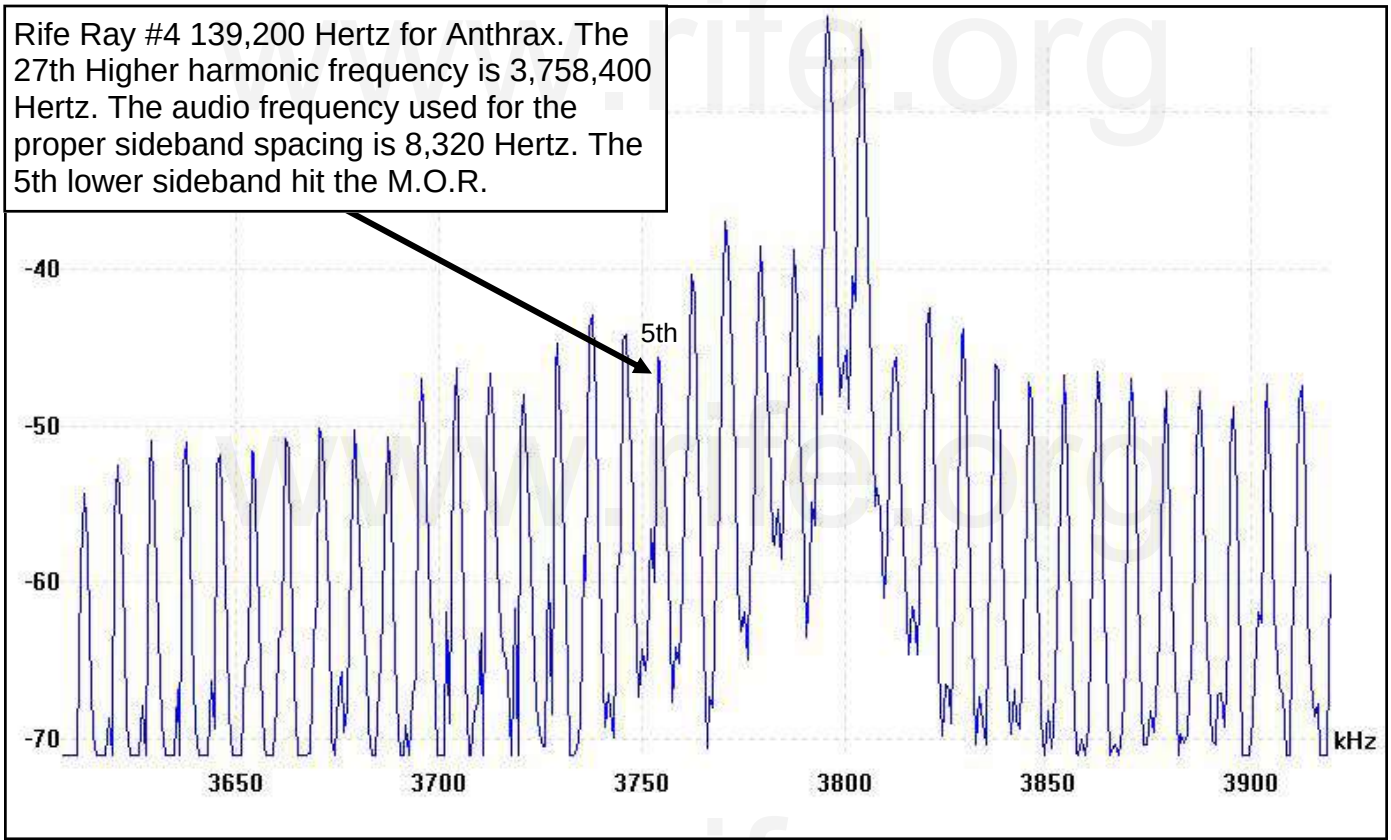

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

Rife Ray #4 417,000 Hertz for B or E Coli Rod. The 9th Higher harmonic frequency is 3,753,000 Hertz. The audio frequency used for the proper sideband spacing is 7,833 Hertz. The 6th lower sideband hit the M.O.R.

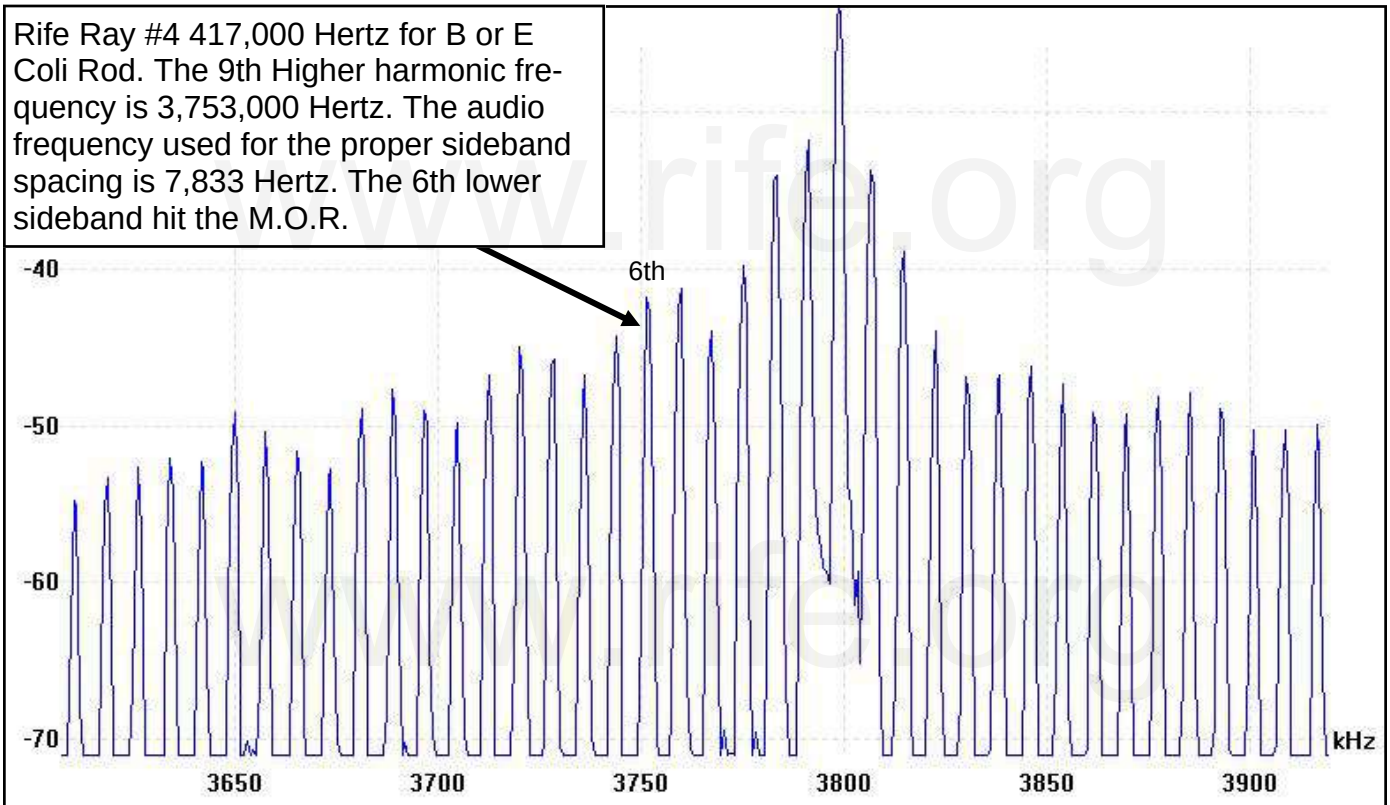

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 770,000 for B or E Coli Virus. The 5th Higher harmonic frequency is 3,850,000 Hertz. The audio frequency used for the proper sideband spacing is 16,667 Hertz. The 3rd upper sideband hit the M.O.R.

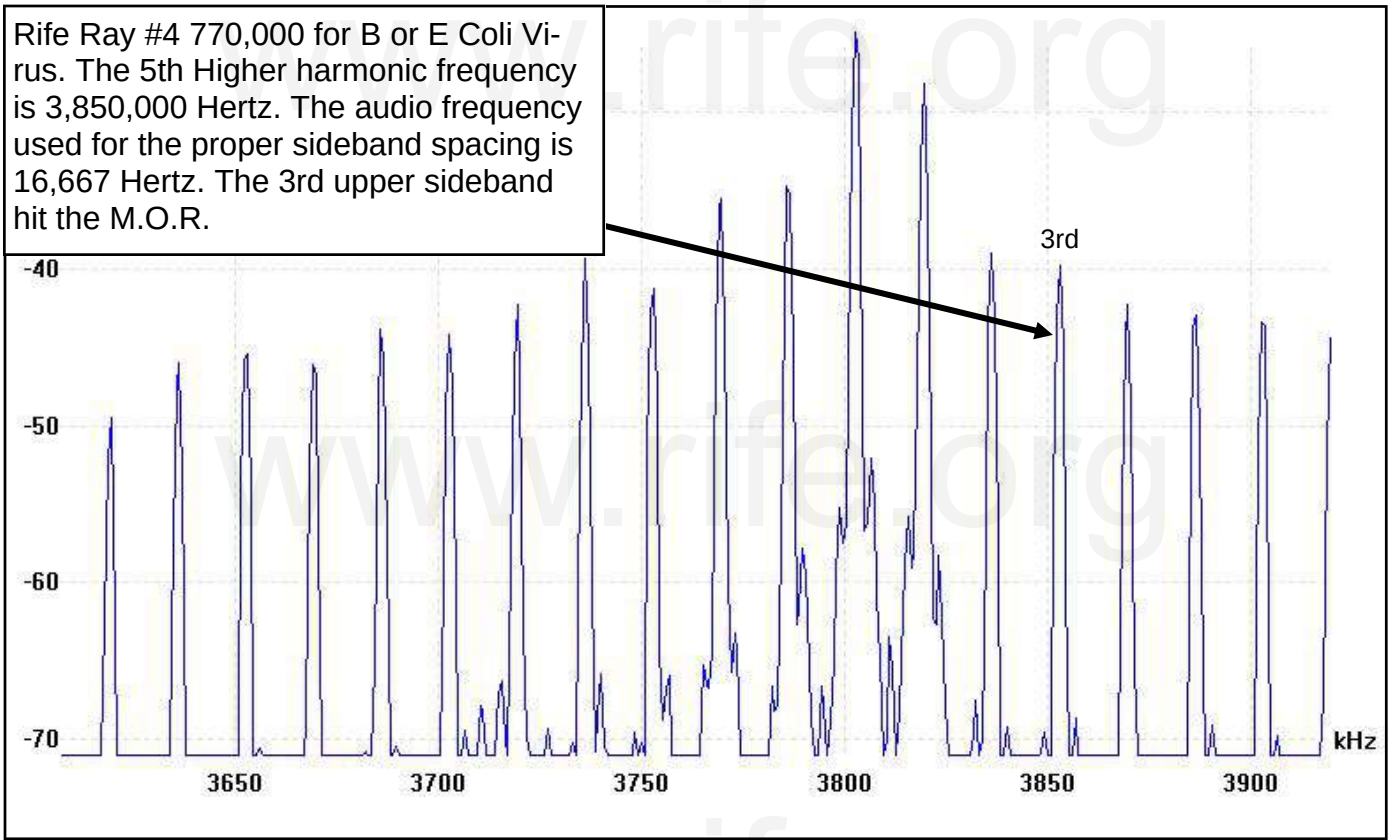

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

Rife Ray #4 1,604,000 Hertz for the BX Cancer Virus. The 2nd Higher harmonic frequency is 3,208,000 Hertz. The audio frequency used for the proper sideband spacing is 39,467 Hertz. The 15th sideband hit the M.O.R. The greater the frequency difference from the carrier frequency to the M.O.R the weaker the sidebands become. The 15th lower sideband is about all you would want to have over a 592,000 Hertz spread.

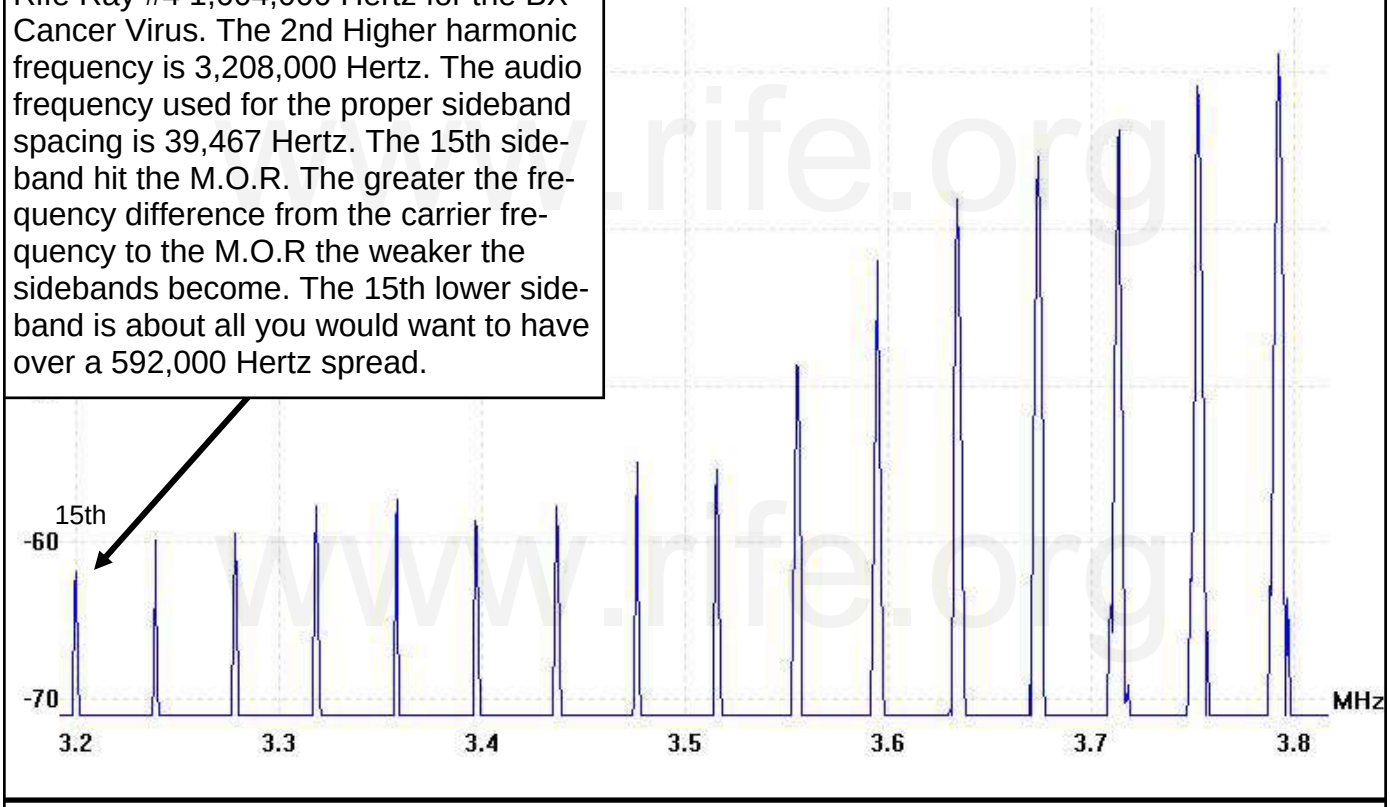

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 233,000 Hertz for Gonorrhea. The 16th Higher harmonic frequency is 3,728,000 Hertz. The audio frequency used for the proper sideband spacing is 14,400 Hertz. The 5th lower sideband hit the M.O.R.

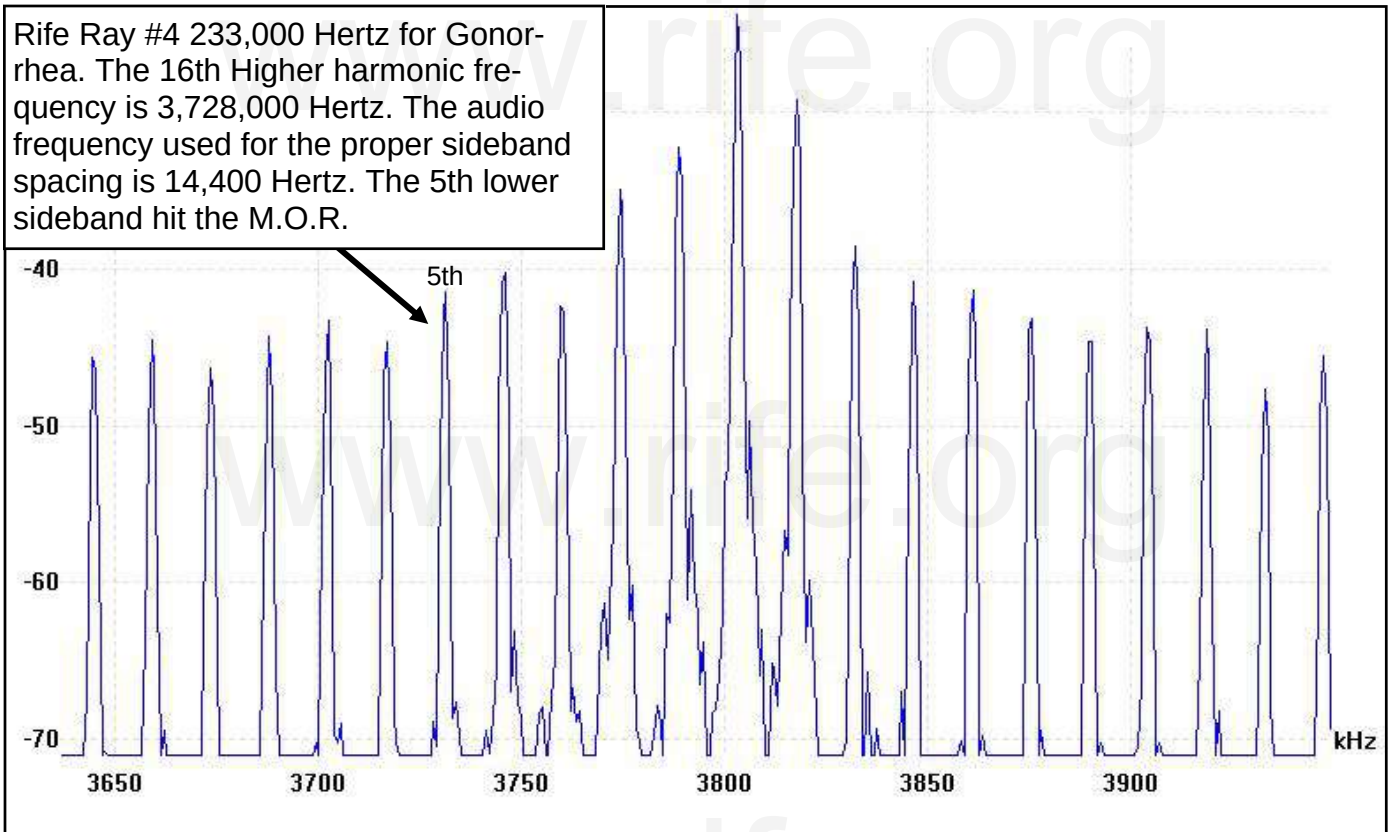

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

Rife Ray #4 427,000 Hertz for Spinal Meningitis. The 9th Higher harmonic frequency is 3,843,000 Hertz. The audio frequency used for the proper sideband spacing is 8,600 Hertz. The 5th upper sideband hit the M.O.R.

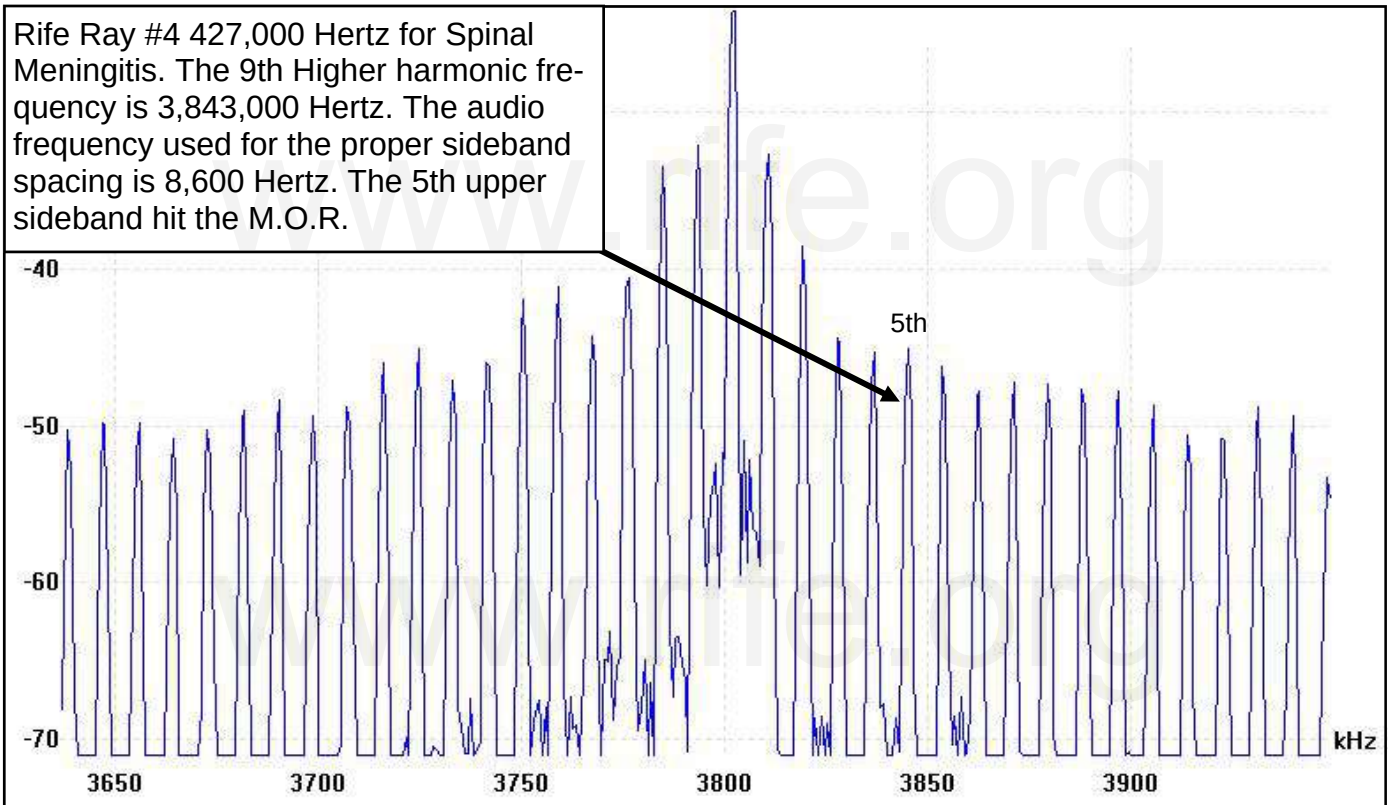

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 478,000 Hertz for Staphylococcus Pyogenes Aureus. The 8th Higher harmonic frequency is 3,824,000 Hertz. The audio frequency used for the proper sideband spacing is 8,000 Hertz. The 3rd upper sideband hit the M.O.R.

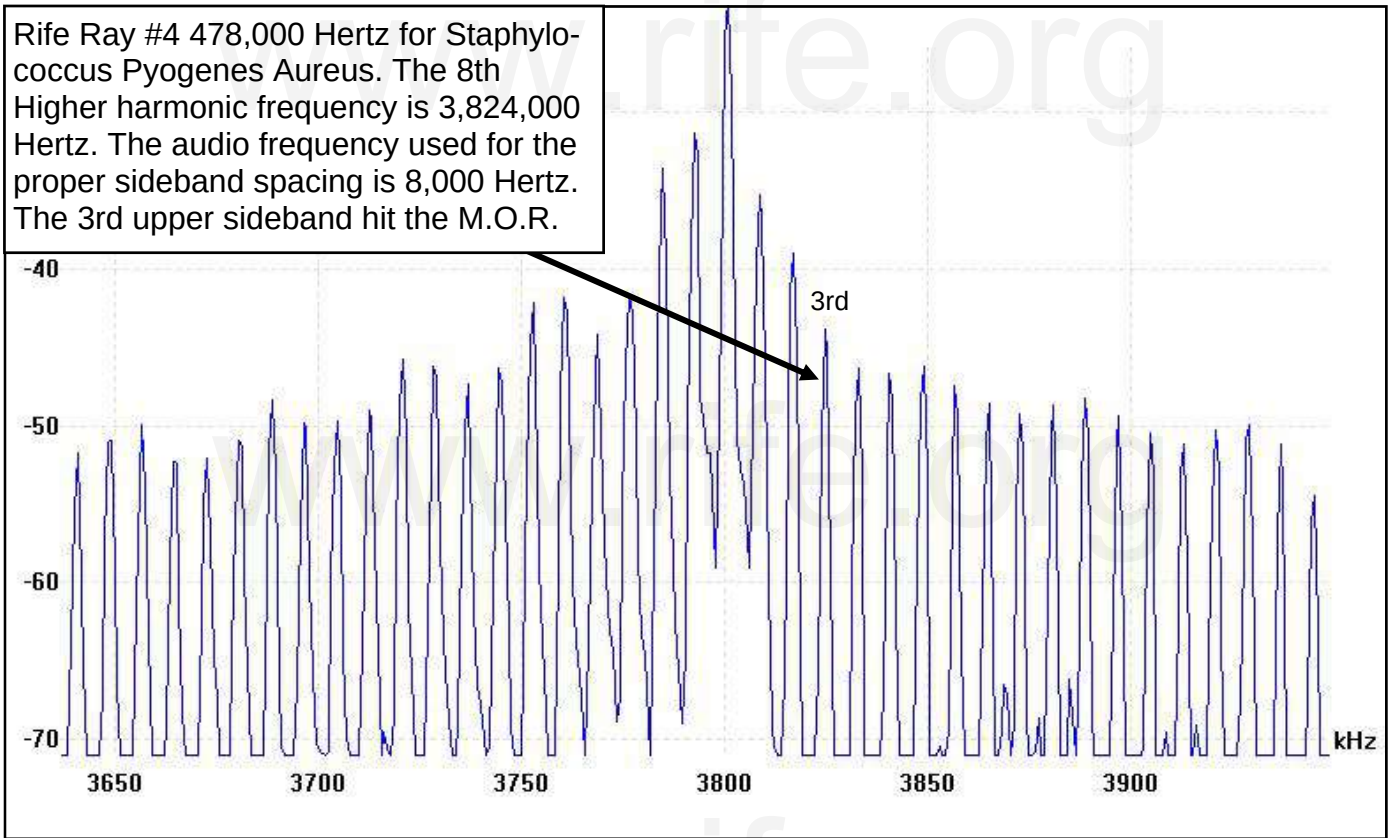

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

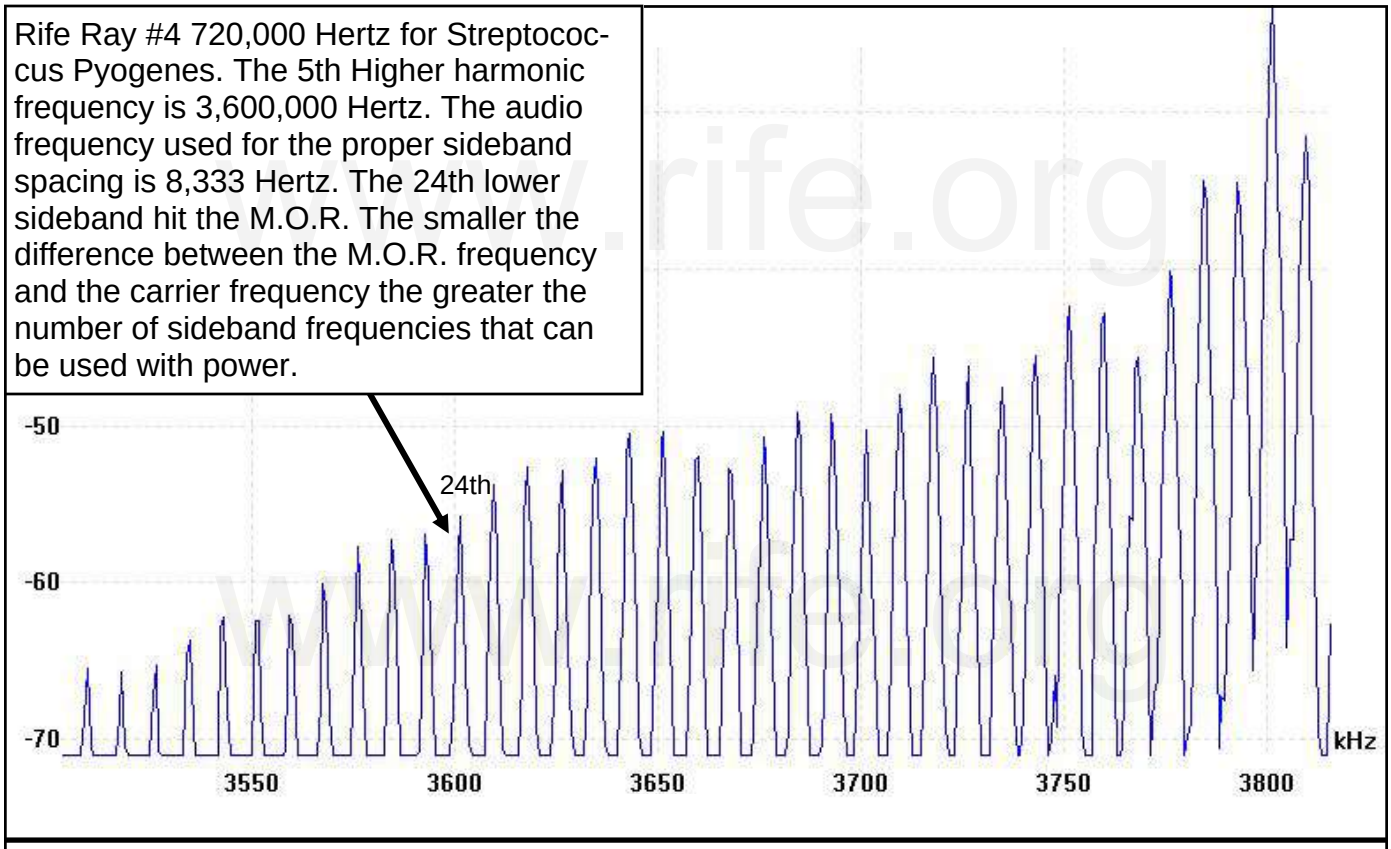

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

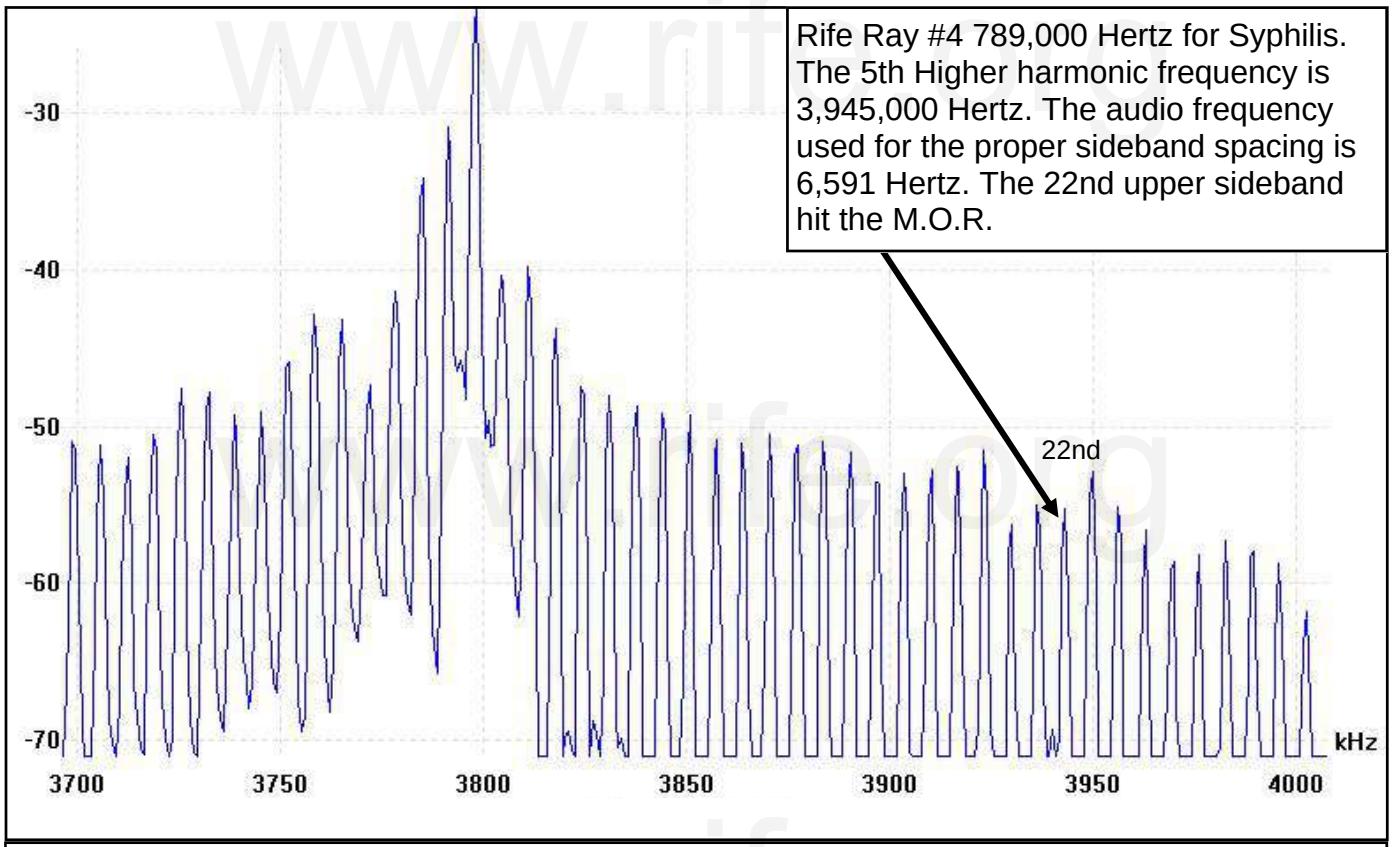

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

Rife Ray #4 234,000 Hertz for Tetanus. The 16th Higher harmonic frequency is 3,744,000 Hertz. The audio frequency used for the proper sideband spacing is 11,200 Hertz. The 5th lower sideband hit the M.O.R.

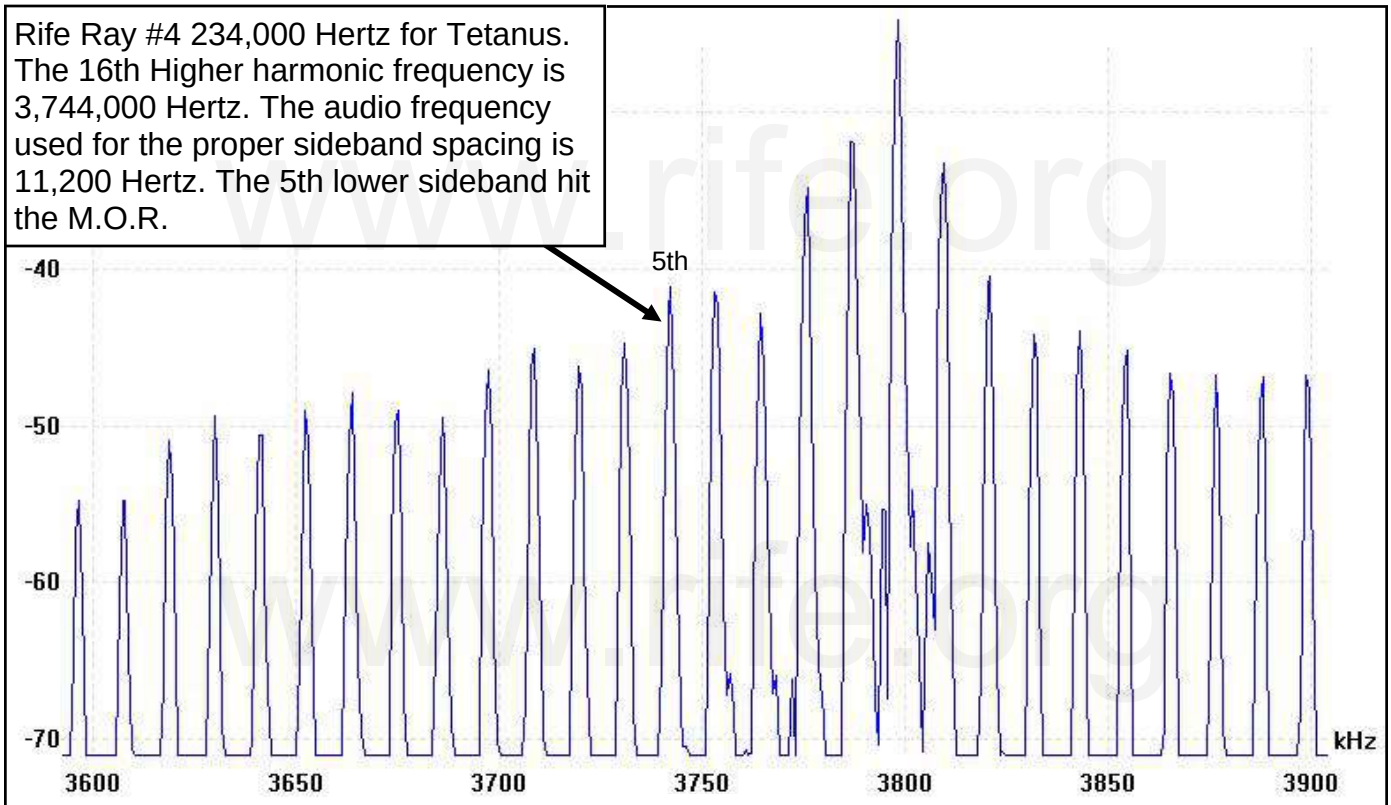

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 369,000 Hertz for Tuberculosis Rod. The 10th Higher harmonic frequency is 3,690,000 Hertz. The audio frequency used for the proper sideband spacing is 8,462 Hertz. The 13th lower sideband hit the M.O.R.

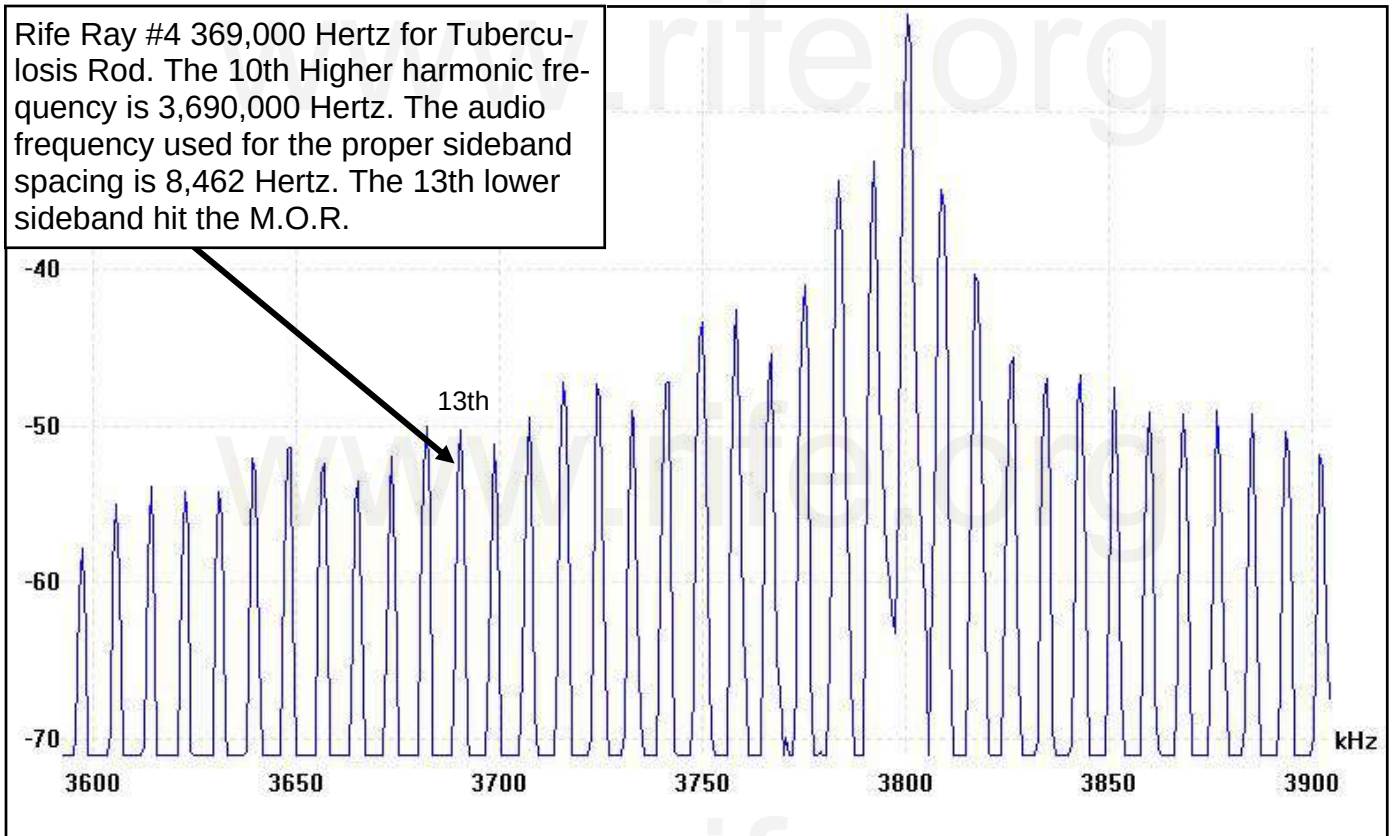

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

www.rife.org

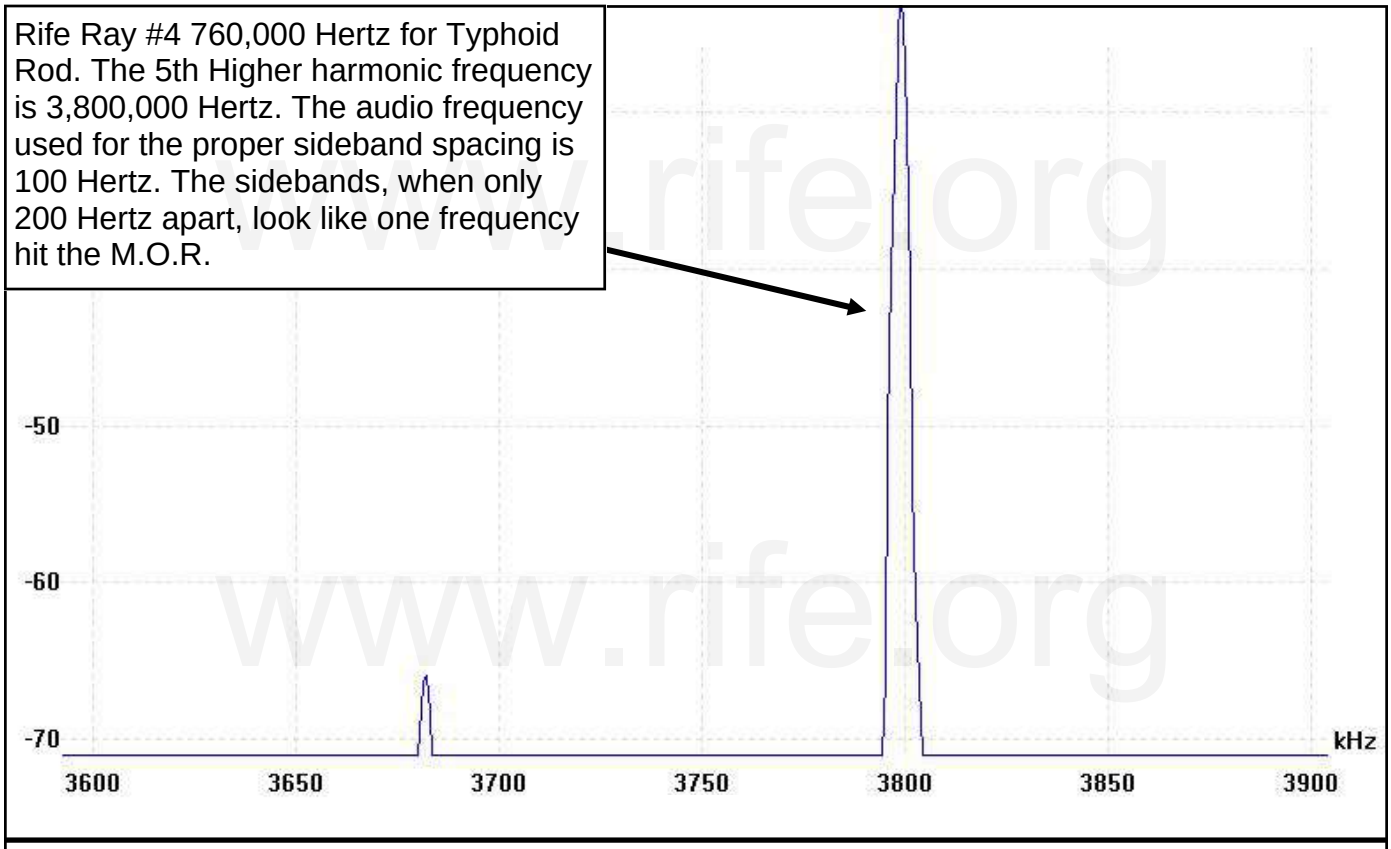

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

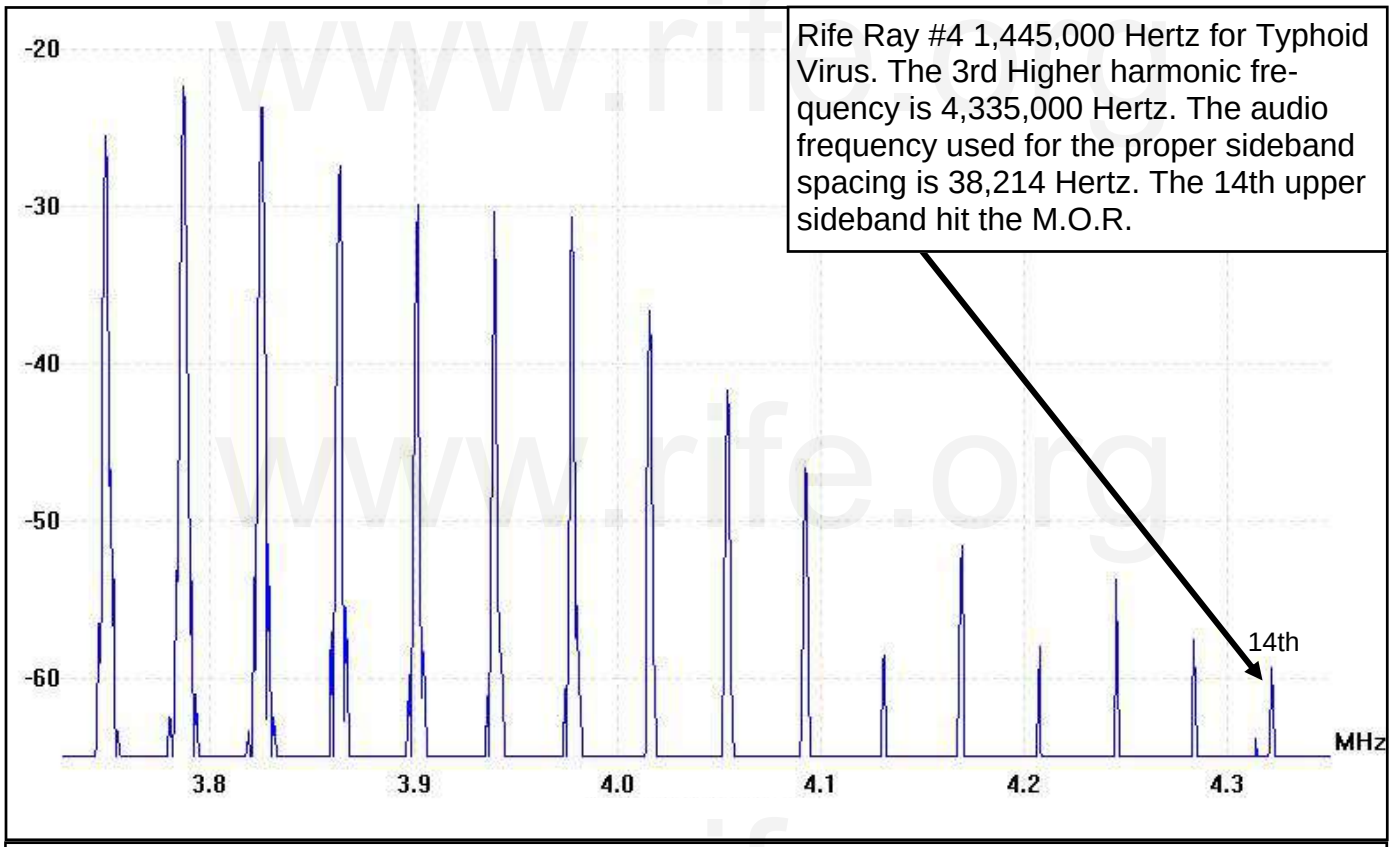

Philip Hoyland's Beam Ray Clinical instrument 3.80 Megahertz spectrum analysis of sideband harmonic frequencies.

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Streptothrix	
1	192000
2	384000
3	576000
4	768000
5	960000
6	1152000
7	1344000
8	1536000
9	1728000
10	1920000
11	2112000
12	2304000
13	2496000
14	2688000
15	2880000
16	3072000
17	3264000
18	3456000
19	3648000
20	3840000
21	4032000
22	4224000
23	4416000
24	4608000
25	4800000
26	4992000
27	5184000
28	5376000
29	5568000
30	5760000
31	5952000
32	6144000
33	6336000
34	6528000

Anthrax	
1	139200
2	278400
3	417600
4	556800
5	696000
6	835200
7	974400
8	1113600
9	1252800
10	1392000
11	1531200
12	1670400
13	1809600
14	1948800
15	2088000
16	2227200
17	2366400
18	2505600
19	2644800
20	2784000
21	2923200
22	3062400
23	3201600
24	3340800
25	3480000
26	3619200
27	3758400
28	3897600
29	4036800
30	4176000
31	4315200
32	4454400
33	4593600
34	4732800

B or E Coli Rod	
1	417000
2	834000
3	1251000
4	1668000
5	2085000
6	2502000
7	2919000
8	3336000
9	3753000
10	4170000
11	4587000
12	5004000
13	5421000
14	5838000
15	6255000
16	6672000
17	7089000
18	7506000
19	7923000
20	8340000
21	8757000
22	9174000
23	9591000
24	10008000
25	10425000
26	10842000
27	11259000
28	11676000
29	12093000
30	12510000
31	12927000
32	13344000
33	13761000
34	14178000

B or E Coli Viurs	
1	770000
2	1540000
3	2310000
4	3080000
5	3850000
6	4620000
7	5390000
8	6160000
9	6930000
10	7700000
11	8470000
12	9240000
13	10010000
14	10780000
15	11550000
16	12320000
17	13090000
18	13860000
19	14630000
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26	20020000
27	20790000
28	21560000
29	22330000
30	23100000
31	23870000
32	24640000
33	25410000
34	26180000

BX Cancer Virus	
1	1604000
2	3208000
3	4812000
4	6416000
5	8020000
6	9624000
7	11228000
8	12832000
9	14436000
10	16040000
11	17644000
12	19248000
13	20852000
14	22456000
15	24060000
16	25664000
17	27268000
18	28872000
19	30476000
20	32080000
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22	35288000
23	36892000
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25	40100000
26	41704000
27	43308000
28	44912000
29	46516000
30	48120000
31	49724000
32	51328000
33	52932000
34	54536000

Gonorrhea	
1	233000
2	466000
3	699000
4	932000
5	1165000
6	1398000
7	1631000
8	1864000
9	2097000
10	2330000
11	2563000
12	2796000
13	3029000
14	3262000
15	3495000
16	3728000
17	3961000
18	4194000
19	4427000
20	4660000
21	4893000
22	5126000
23	5359000
24	5592000
25	5825000
26	6058000
27	6291000
28	6524000
29	6757000
30	6990000
31	7223000
32	7456000
33	7689000
34	7922000

Spinal Meningitis	
1	427000
2	854000
3	1281000
4	1708000
5	2135000
6	2562000
7	2989000
8	3416000
9	3843000
10	4270000
11	4697000
12	5124000
13	5551000
14	5978000
15	6405000
16	6832000
17	7259000
18	7686000
19	8113000
20	8540000
21	8967000
22	9394000
23	9821000
24	10248000
25	10675000
26	11102000
27	11529000
28	11956000
29	12383000
30	12810000
31	13237000
32	13664000
33	14091000
34	14518000

Staph Pyo Aureus	
1	478000
2	956000
3	1434000
4	1912000
5	2390000
6	2868000
7	3346000
8	3824000
9	4302000
10	4780000
11	5258000
12	5736000
13	6214000
14	6692000
15	7170000
16	7648000
17	8126000
18	8604000
19	9082000
20	9560000
21	10038000
22	10516000
23	10994000
24	11472000
25	11950000
26	12428000
27	12906000
28	13384000
29	13862000
30	14340000
31	14818000
32	15296000
33	15774000
34	16252000

Strept Pyogenes	
1	720000
2	1440000
3	2160000
4	2880000
5	3600000
6	4320000
7	5040000
8	5760000
9	6480000
10	7200000
11	7920000
12	8640000
13	9360000
14	10080000
15	10800000
16	11520000
17	12240000
18	12960000
19	13680000
20	14400000
21	15120000
22	15840000
23	16560000
24	17280000
25	18000000
26	18720000
27	19440000
28	20160000
29	20880000
30	21600000
31	22320000
32	23040000
33	23760000
34	24480000

Syphilis	
1	789000
2	1578000
3	2367000
4	3156000
5	3945000
6	4734000
7	5523000
8	6312000
9	7101000
10	7890000
11	8679000
12	9468000
13	10257000
14	11046000
15	11835000
16	12624000
17	13413000
18	14202000
19	14991000
20	15780000
21	16569000
22	17358000
23	18147000
24	18936000
25	19725000
26	20514000
27	21303000
28	22092000
29	22881000
30	23670000
31	24459000
32	25248000
33	26037000
34	26826000

Tetanus	
1	234000
2	468000
3	702000
4	936000
5	1170000
6	1404000
7	1638000
8	1872000
9	2106000
10	2340000
11	2574000
12	2808000
13	3042000
14	3276000
15	3510000
16	3744000
17	3978000
18	4212000
19	4446000
20	4680000
21	4914000
22	5148000
23	5382000
24	5616000
25	5850000
26	6084000
27	6318000
28	6552000
29	6786000
30	7020000
31	7254000
32	7488000
33	7722000
34	7956000

Tuberculosis Rod	
1	369000
2	738000
3	1107000
4	1476000
5	1845000
6	2214000
7	2583000
8	2952000
9	3321000
10	3690000
11	4059000
12	4428000
13	4797000
14	5166000
15	5535000
16	5904000
17	6273000
18	6642000
19	7011000
20	7380000
21	7749000
22	8118000
23	8487000
24	8856000
25	9225000
26	9594000
27	9963000
28	10332000
29	10701000
30	11070000
31	11439000
32	11808000
33	12177000
34	12546000

Typhoid Rod	
1	760000
2	1520000
3	2280000
4	3040000
5	3800000
6	4560000
7	5320000
8	6080000
9	6840000
10	7600000
11	8360000
12	9120000
13	9880000
14	10640000
15	11400000
16	12160000
17	12920000
18	13680000
19	14440000
20	15200000
21	15960000
22	16720000
23	17480000
24	18240000
25	19000000
26	19760000
27	20520000
28	21280000
29	22040000
30	22800000
31	23560000
32	24320000
33	25080000
34	25840000

Typhoid Virus	
1	1445000
2	2890000
3	4335000
4	5780000
5	7225000
6	8670000
7	10115000
8	11560000
9	13005000
10	14450000
11	15895000
12	17340000
13	18785000
14	20230000
15	21675000
16	23120000
17	24565000
18	26010000
19	27455000
20	28900000
21	30345000
22	31790000
23	33235000
24	34680000
25	36125000
26	37570000
27	39015000
28	40460000
29	41905000
30	43350000
31	44795000
32	46240000
33	47685000
34	49130000

Photos of the original 1938-1939 Beam Ray Clinical instrument when it was found

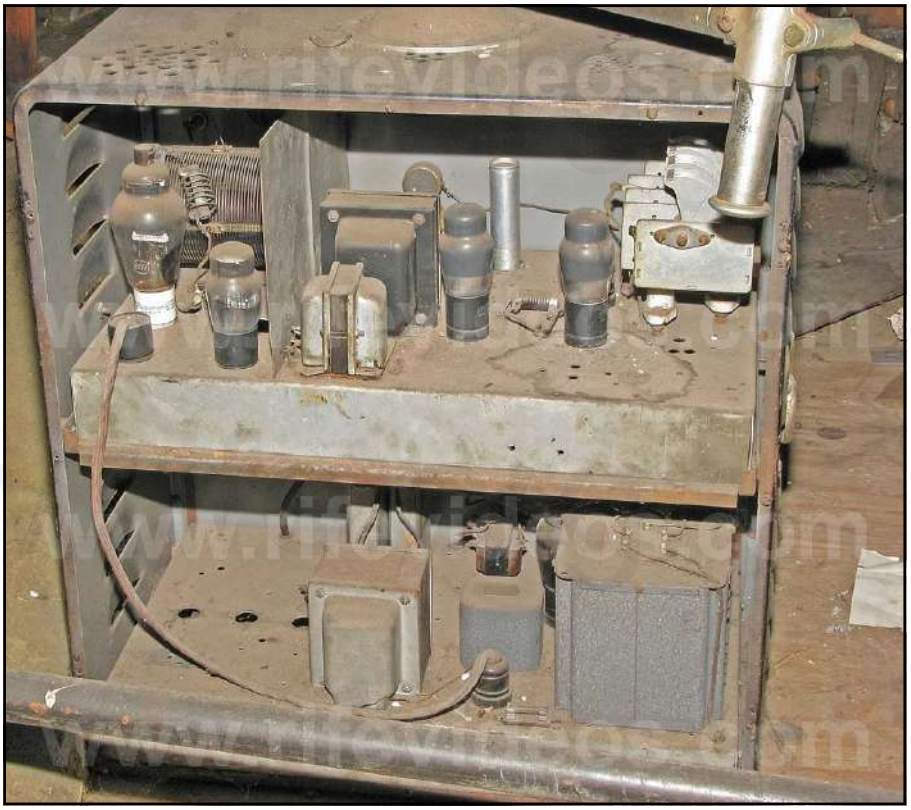

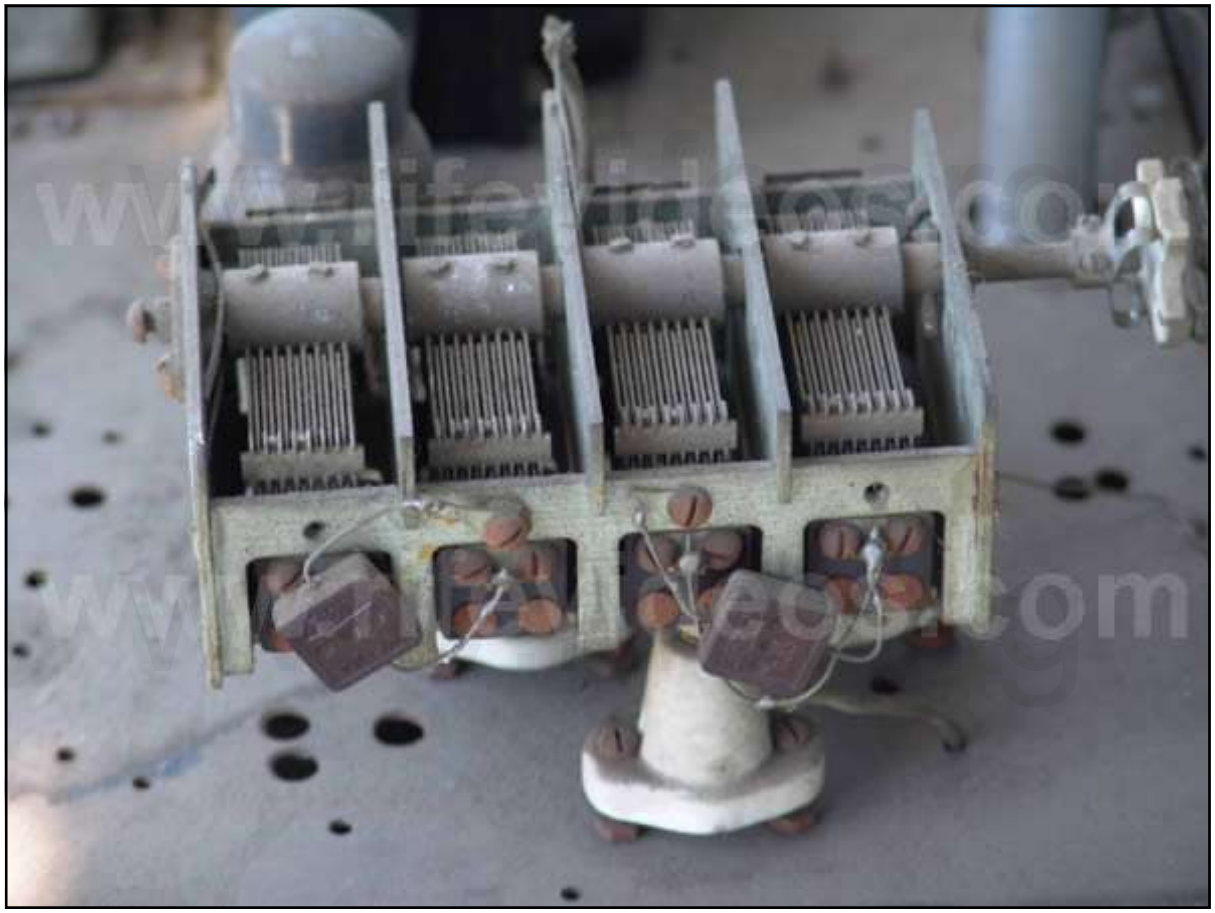

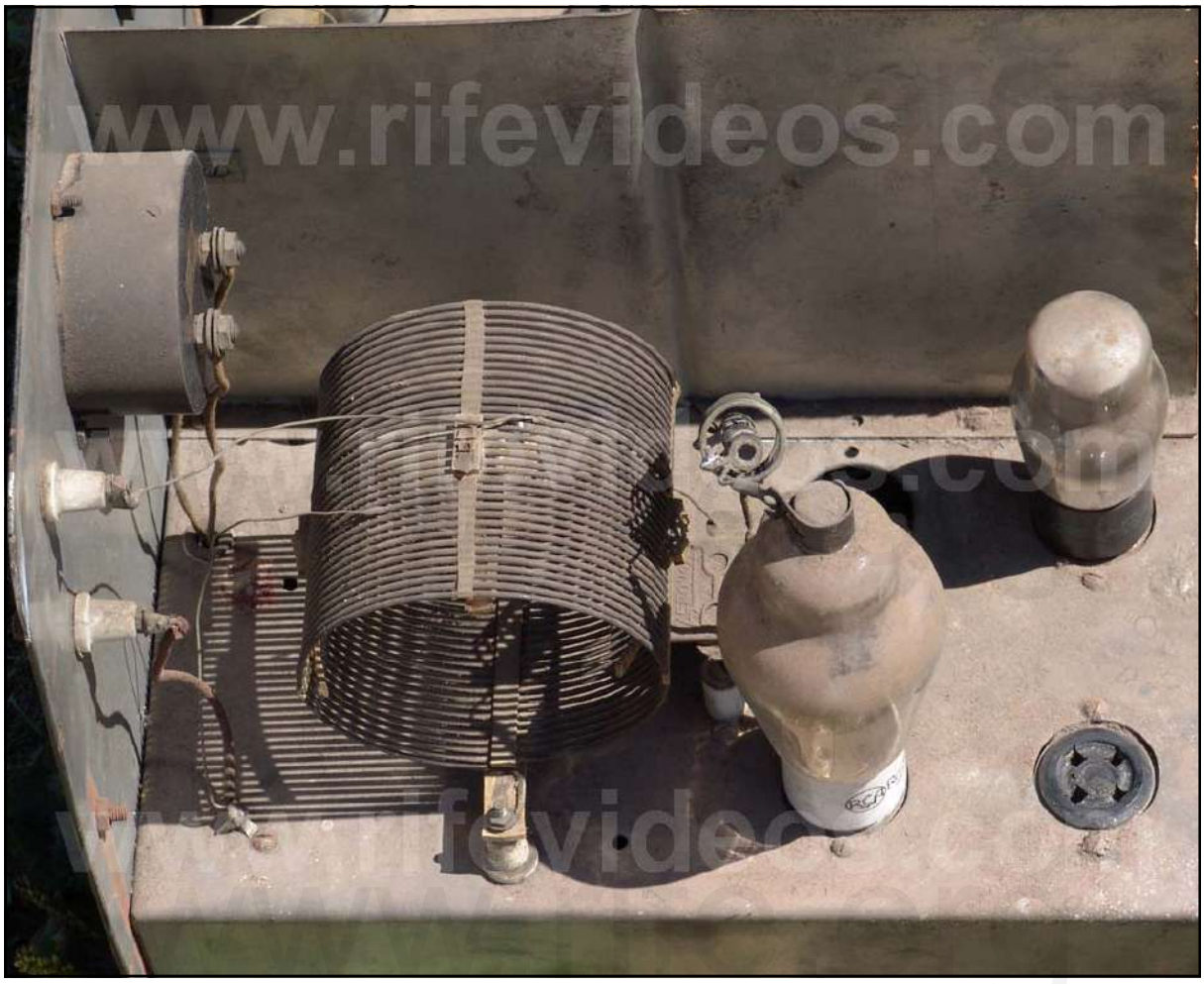

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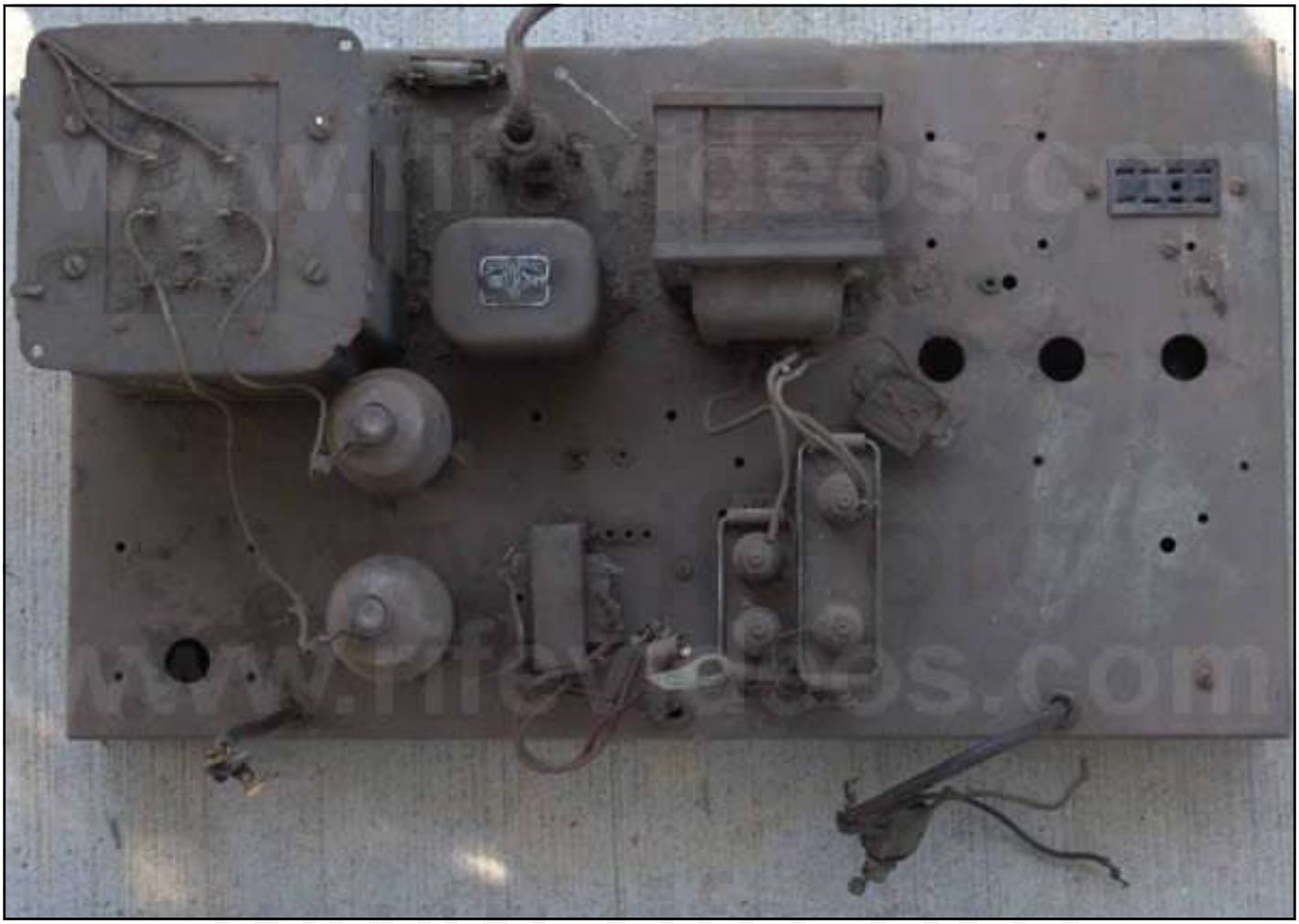

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Chapter #10

The Gruner Schematic and Philip Hoyland's Beam Ray Laboratory Rife Machine

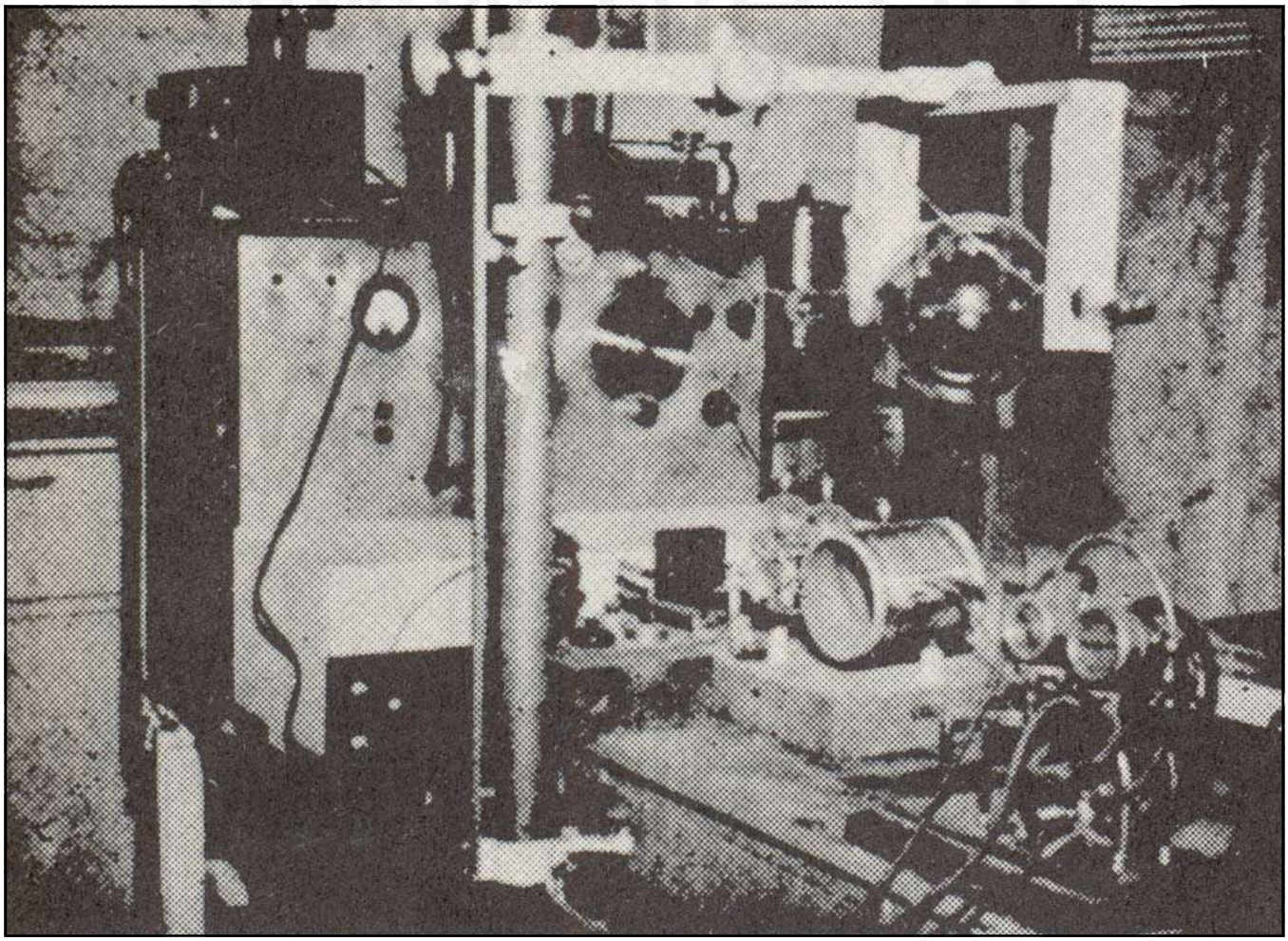

1. Used a ray tube.
2. Had one RF oscillators which was set on a fix frequency.
3. Had a fix audio pulsing circuit.
4. Power usage was about 450 to 600 watts. Output to the ray tube was probably about 40 watts.

In this chapter we will cover two instruments. First, Dr. Gruner's Rife machine and second, the Beam Ray Laboratory Rife machine. The reason for this is the work done on the Gruner instrument lead too many discoveries of how Dr. Rife's machines worked. The first instrument we will discuss is the Gruner Rife Machine. From some recent documents that were found by Mr. Ringas we have found it necessary to change some of the information in this chapter which deals with Dr. Gruner's Rife instrument.

The new documents that were found by Mr. Ringas reveal the fact that the Gruner Rife machine had one fixed RF oscillator. It was previously believed that this instrument was a Beam Ray laboratory instrument which had two high RF frequency oscillators. We now know from these documents that this was an incorrect assumption. The new information comes from two letters written to John Crane back in 1953 from Dr. O. C. Gruner. John Crane at that time was inquiring about the status of Dr. Gruner's Rife machine that was sent to him in 1942 by Dr. Milbank Johnson M.D.:

DR. GRUNER: *"You refer, I suppose, to the ray machine which Milbank Johnson sent "in bits" to me in Montreal* [Canada]*. Vergil Neher assembled it, but actually I had to purchase a large amount of the radio material to be able to get it completed. I used this machine quite a bit, and it was very successful at first; but after about six months it "faded", first the tubes seemed all right. The only reason would have been changes in the glass of the globe* [ray tube] *as a result of the discharges… I could send the plan* [schematic] *of the apparatus."* (Letter from Dr. Gruner to John Crane, March 31, 1953).

DR. GRUNER: *"I enclosed the diagram* [schematic] *of the Ray Machine as made here in 1942. So I hope it will be of interest to you. It will not be necessary to return it. It is to be noted that it was made only for one frequency; obviously it would be necessary to alter the design to enable many frequencies to be used."* (Letter from Dr. Gruner to John Crane, April 29, 1953).

These two letters changed all our understanding of this instrument. John Crane had altered the schematic and put a second Hartley oscillator on the schematic which confused us when we originally built the instrument. This second Hartley oscillator, added by John Crane, which will be shown in a photo below, made it so the instrument would have had one fixed RF oscillator and a second variable RF oscillator. This second variable RF oscillator, that John Crane added to the schematic, would make it so that instrument could output many different frequencies. Logically this is what Dr. Rife, John Crane and John Marsh wanted in an instrument. But this is not how Dr. Gruner's original instrument worked.

From the analyzing of the original Beam Ray Clinical instrument, which was built by Philip Hoyland, we know that it had the capability of variable audio frequencies. We need to point out here that Dr. Gruner's ray tube instrument did not work on the Beam Ray Clinical instrument harmonic sideband method. From these two letters we now know that Dr. Gruner's instrument work on the same principles as the Rife Ray #4 instrument. That instrument output the specific frequencies directly from its two variable RF oscillators. Because the Rife Ray #4 put out specific frequencies it also used a modulated fixed audio pulsing circuit to pulse the high RF frequencies that were used to devitalize the various microorganisms. This modulated fixed audio frequency pulsing method was used with all of Dr. Rife's instruments. The Gruner schematic which has this modulated fixed audio frequency pulsing circuit reveals how Dr. Rife used this pulsing method in his instruments. With this understanding we now have a clearer understanding of how these four instruments, Rife Ray #3, Rife Ray #4, Beam Ray Laboratory and Gruner Rife machine really worked.

As we pointed out when we initially looked at Dr. Gruner's schematic, several years ago, we were under the wrong assumption, because John Crane altered the schematic by adding the second Hartley oscillator to Dr. Gruner's schematic. But that wrong assumption actually caused us to build an instrument that worked almost exactly as the Rife Ray #4 did. Except the instrument that we built from Dr. Gruner's schematic did not have as high a frequency range as the Rife Ray #4. Because of what we have just explained we feel that the information that we obtained from the initial building of the Gruner schematic, several years ago, should be kept in this report. What was learned, even under the wrong assumption, revealed how the Rife Ray #4 was built and will still be of interest to those who may want to build this instrument.

The Beam Ray Laboratory instrument would have worked like the Gruner instrument and the Rife Ray #4 instrument since both of these were to be used in laboratory work. An instrument that worked like the Beam Ray Clinical instrument, which worked on the harmonic sideband method, would have been useless in any laboratory work since you could never know the exact frequency that killed, devitalize or rendered harmless an organism. For this reason the Beam Ray Laboratory instrument is still included in this information about Dr. Gruner's Rife instrument.

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The initial Gruner schematic work done in 2007-2008

In one of the previous version of this report we dealt with the concept that the Gruner instrument was a heterodyning instrument. We now know that this method was not used in the Gruner Rife Machine therefore the heterodyning concept was removed from a previous rewriting of this document. Though the Rife Ray #4 Rife Machine could output two frequencies at the same time and those two frequencies did heterodyn in the ray tube, this was a byproduct of the instrument not the method used to produce the M.O.R. frequencies needed to devitalize or render harmless the microorganisms. The knowledge that we gained through our testing of this concept is the reason much of the history and work that we did at that time is still included in this report. It was that testing which gave us the understanding of how the Rife Ray #4 worked and how the Beam Ray Laboratory Rife Machine would have worked.

We do not have a picture of Dr. Gruner's Rife instrument so we have no idea what it looked like. This however did not affect building the instrument from the schematic. The Rife Machine in the photo shown at the beginning of this chapter is probably a photo of the Beam Ray Laboratory instrument built by Philip Hoyland. John Crane dated that instrument as being built in 1935 but we know that the Rife Ray #4 was built in 1935. The knowledge of the Laboratory instrument came from the Beam Ray Trial manuscript. A complete copy of this transcript was provided when Steven Ross allowed us to scan it. I would like to acknowledge his generous contribution of this information which has given us a great deal of understanding so that we could figure out the history of how and when the instruments were built.

After reading for the first time the complete Beam Ray Trial manuscript I found there was mention of a Laboratory instrument. It appeared that this Laboratory instrument was probably to be used by those who would be working in laboratories with microorganisms for testing. Dr. O. C. Gruner worked in a laboratory with organisms and worked with Dr. Rife on the organism called Cryptomyces Pleomorpha fungi. The Laboratory instrument was mentioned two or three times but no real information was given about it. Below are statements made by Bertrand Comparet and Philip Hoyland in the Beam Ray Trial that gives us some important information about this instrument. (#209-210, 217-222):

COMPARET: *"The four machines bought by the British were two so-called laboratory types and two so-called clinical types, what was the difference between the two."*

HOYLAND: *"The clinical type was similar in all respects to the Rife machine except that it did not have* [word missing] *of the* [word missing] *used on Mrs. Henderson."*

COMPARET: *"How was the price of these machines fixed."*

HOYLAND: *"The price was decided from the costs of what it cost to manufacture the first machine that was sold to Dr. Hamer."*

COMPARET: *"How much was that?"*

HOYLAND: *"I think it was four hundred dollars plus the royalty."*

COMPARET: *"Wasn't it five hundred dollars plus royalty on the clinical type and six plus royalty on the lab type."*

HOYLAND: *"I don't remember."*

Since this Beam Ray Laboratory Rife Machine was for Laboratory work it would have worked like the Rife Ray #4 but because the case was smaller it probably had a smaller frequency range. The

Rife Ray #4 had nine frequency bands that covered from 87,000 Hertz to 22.5MHz (22,500,000 Hertz). The first four bands of the #4 covered from 87,000 Hertz to 2,140,000 Hertz. These four frequency bands would cover the whole list of Dr. Rife's disease organisms listed on the Rife Ray #4 documents. With this understanding we know that the Laboratory instrument at least covered this frequency range. We will not speculate if it had a higher frequency range because we really do not know if it did.

Deciphering Dr. Gruner's Beam Ray instrument schematic

Several years ago a group of us had been looking on the Gruner schematic in hopes of trying to figure out how it worked. I had built and tested both the 1953 AZ-58 Beam Ray Clinical instrument and 1950's Aubrey Scoon, Beam Ray Clinical replica instruments. To our knowledge none of these instruments ever obtained the same results as the original Beam Ray Clinical Rife Machine built by the original 1938 Beam Ray Corporation. All the documentation we had showed that there were changes made to the original Beam Ray design which compromised the1953 AZ-58, and possibly 1950's Aubrey Scoon, Verne Thompson instruments. John Crane, over the years told many people that the AZ-58 and the audio frequencies it used were Dr. Rife's original frequencies. The Rife documents we have show that what John Crane claimed was not correct. Dr. Rife was not using audio frequencies in 1934 as John Crane and John Marsh claimed. Rebuild of the 1953 AZ-58 and Aubrey Scoon's instrument partially made the rediscovery of the Beam Ray Laboratory instrument possible.

At the 2003 Rife Conference, a gentleman put up the Gruner schematic of an original Beam Ray instrument. From reading the Rife documents I knew that this schematic existed because John Crane had mentioned it in his papers. John Crane said that the AZ-58 was built from that schematic. When I saw it I knew it was important, so I took still photos of it with my video camera. Because the video camera only had a one mega-pixel capability I took many up close photos knowing I could put it back together at a later date. Back in 2004 I gave this schematic to Aubrey Scoon and his British Rife group in hopes that they could look it over and correct any mistakes that may have been made. They redrew the schematics, unfortunately without fully correcting them, and put them up on their web site. This information was released because we wanted everyone to have access to it.

Back on July 27, 2007 a Mr. Andrews, who was one of the British Rife group and I got into another conversation about the Gruner schematic. He asked me to send him another copy of the original Gruner schematic so he could look it over again. An email conversation began at that time which included Mr. Peters, Mr. Ringas, Mr. Andrews, Mr. Berger and myself. Mr. Peters immediately noticed that the schematic that had been redrawn by the British group had some errors in it. Discussions continued on and off for a few months until one day Mr. Peters noticed an over sight when looking over the schematic again. At the time we thought it had to do with the heterodyning method. But now we understand that this oversight was one of the keys to understanding how the Rife Ray #4 and Beam Ray Laboratory Rife Machines would have worked.

Mr. Peters sent Mr. Ringas and I an email. He mentioned that a possible test could be made that would determine if this observation of his was the key to understanding how the Beam Ray Laboratory instrument really worked. I called Mr. Peters and had a discussion with him and he told me how we could make these tests. I told him that we did not need to do the test with solid state frequency generators because I had conducted a similar test back when John Bedini and I were working on the AZ-58 tests. John Bedini and I knew that the original Rife Ray #4 instrument was a lot more powerful than the AZ-58 because of the Rife documents. After more accurate testing we found the AZ-58 only output about 40 watts from the ray tube. I told him that I still had my 1950's Aubrey Scoon replica and several AZ-58's on the shelf. I told John Bedini that the original Beam Ray Clinical instrument, from the documentation that we had, may have output about 50 to 60 watts from the ray tube. He told me how I could make a test, by putting two AZ-58s together, which would give me at least 60 watts out of the ray tube. I didn't know it at that time but that test was probably the way the Rife Ray #4 and Beam Ray Labora-

tory instrument worked. I told Mr. Peters I would connect the AZ-58 and Aubrey Scoon instruments together again and make the tests that he suggested, but this time I would use my spectrum analyzer and we would fully make tests and find out if this was the method Philip Hoyland used. This test made the two instruments work exactly the same as the Gruner Beam Ray schematic would have worked with John Crane's addition of the second variable RF oscillator. This test was the key to understanding how Philip Hoyland's Laboratory instrument and Rife Ray #4 instrument worked. I had always stated that Philip Hoyland had to have come up with his method using math because they didn't have any spectrum analyzers back in 1936. In looking back that test showed that the Rife Ray #4 was heterodyning in the ray tube. Though we now know the heterodyning method was not used by Dr. Rife the method of connecting the ray tube up to two RF oscillators showed that this was the method used with the Rife Ray #4 which had two RF oscillators.

We will now show how Philip Hoyland's Rife Ray #4 and Beam Ray Laboratory instrument worked. We can do this because we have been able to rebuild these instruments from the Gruner schematic. This information should be of great interest to all who have been interested in Dr. Rife's work.

Rebuilding the Philip Hoyland Beam Ray Laboratory instrument

When this schematic was analyzed Mr. Peters noticed that the British group had overlooked a second Hartley RF oscillator that was in the lower left corner of the Gruner schematic. This was the variable oscillator that John Crane added to the schematic after he received it from Dr. Gruner. At this time we did not know that this second oscillator was not a part of the original schematic. The British group believed this oscillator was the same RF fixed Hartley Oscillator that used the 809 tube. Below is a photo of the complete Gruner Beam Ray schematic.

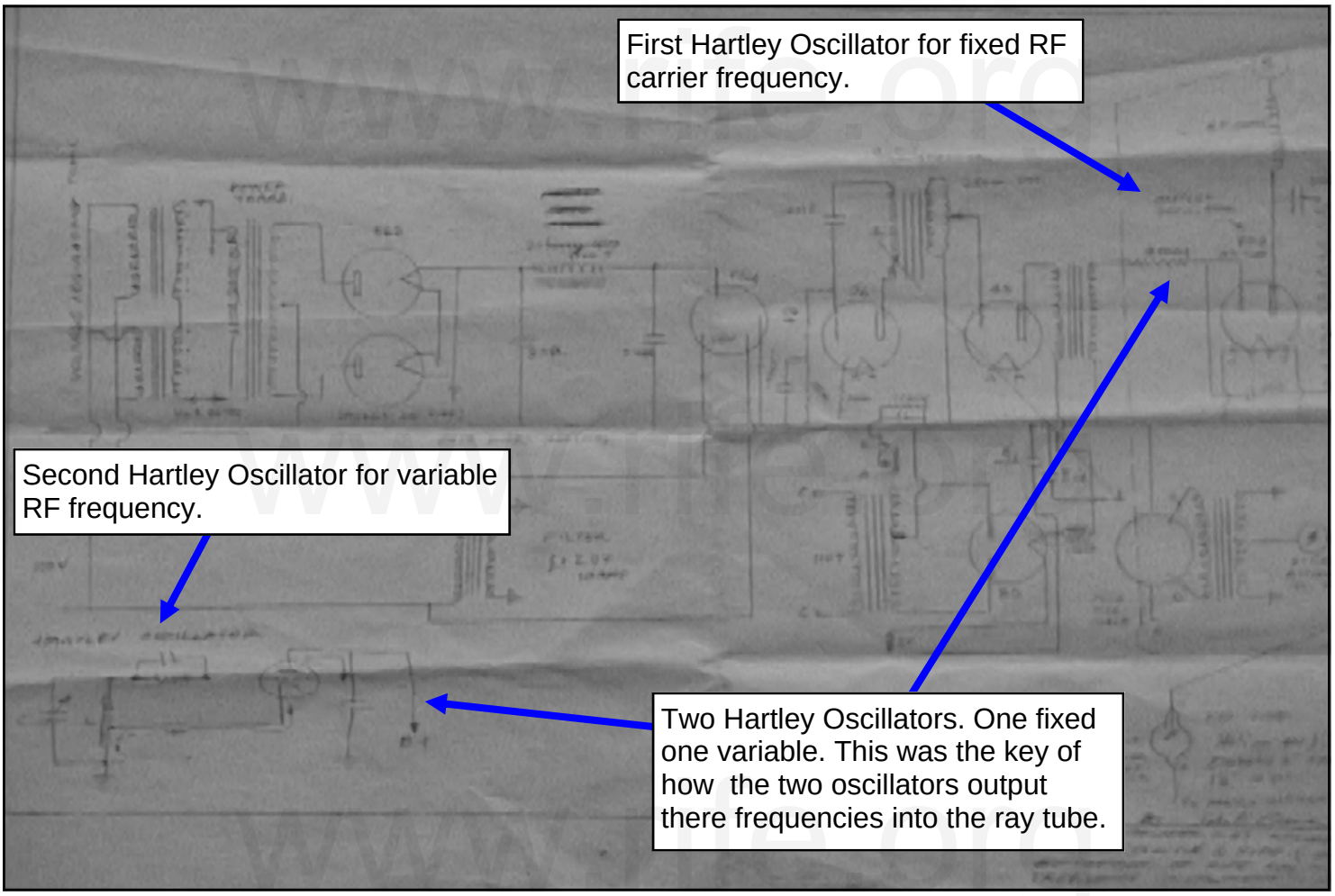

In next schematic photo, shown below, is the fixed RF carrier frequency section that used the 809 tube.

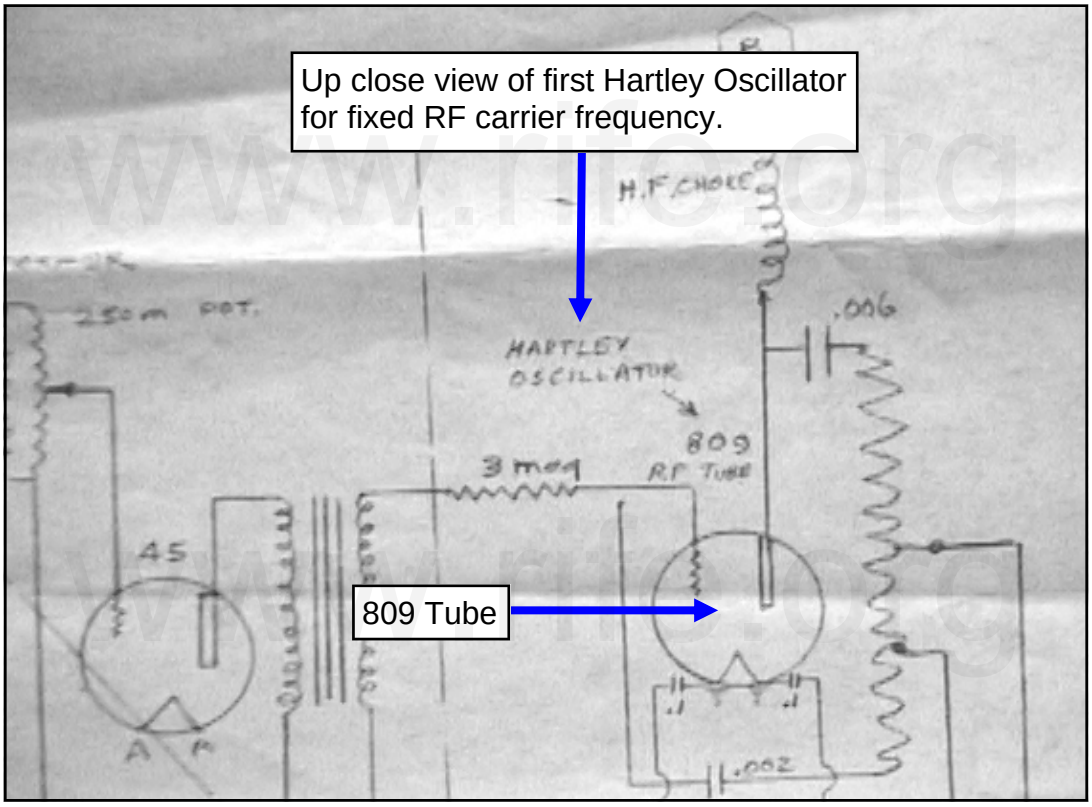

In the next schematic photo, shown below, is the second oscillator that was overlooked by the British group. This was the oscillator that John Crane added to the schematic which caused us to mis-interpret how the instrument worked. You will notice that the second oscillator that John Crane added says “Hartley Oscillator.” Because the first fixed oscillator that used the 809 tube is a Hartley Oscillator the British group assumed that both of these oscillators were the same. This overlooking of the second oscillator that John Crane added would have made the instrument work exactly as Dr. Gruner had stated his instrument worked. Dr. Gruner stated that the instrument was fixed on one frequency. It was the overlooking of this second Hartley oscillator, added by John Crane, that Mr. Peters noticed. If you look at the second Harley Oscillator, in the photo below, that does not use the 809 tube, you will notice that it has a variable capacitor. This variable capacitor shows that there were two Hartley Oscillators shown on the schematic. One fixed and one variable.

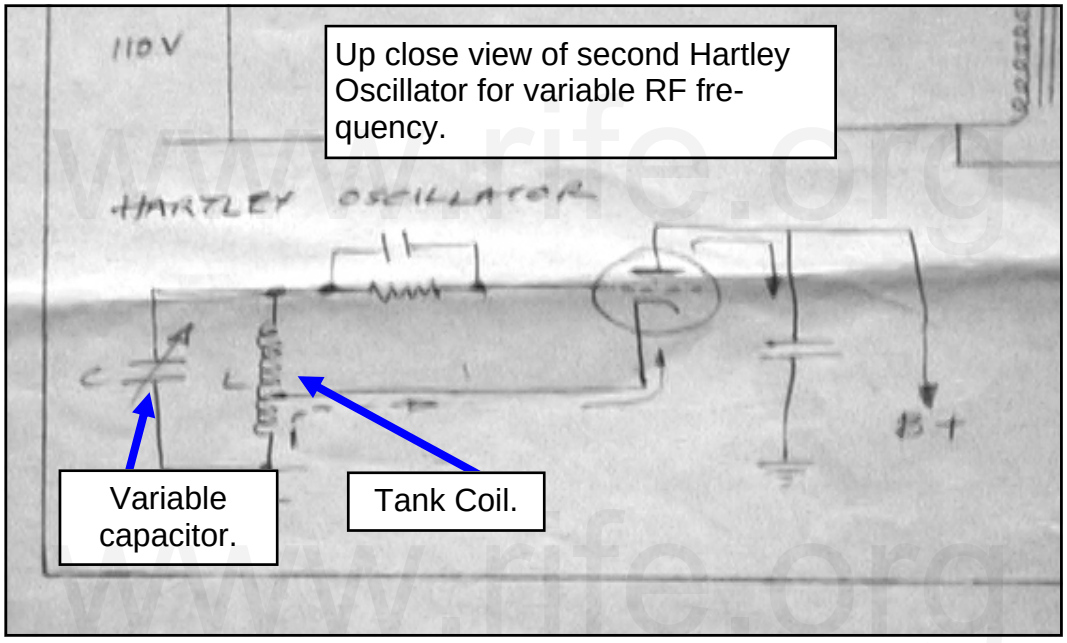

The next schematic photo, shown below, shows that the first fixed Hartley Oscillator was connected from the tank coil to the negative side of the ray tube. If you look closely at the photo you will notice that the positive side of the ray tube was also to be connected to a Hartley Oscillator.

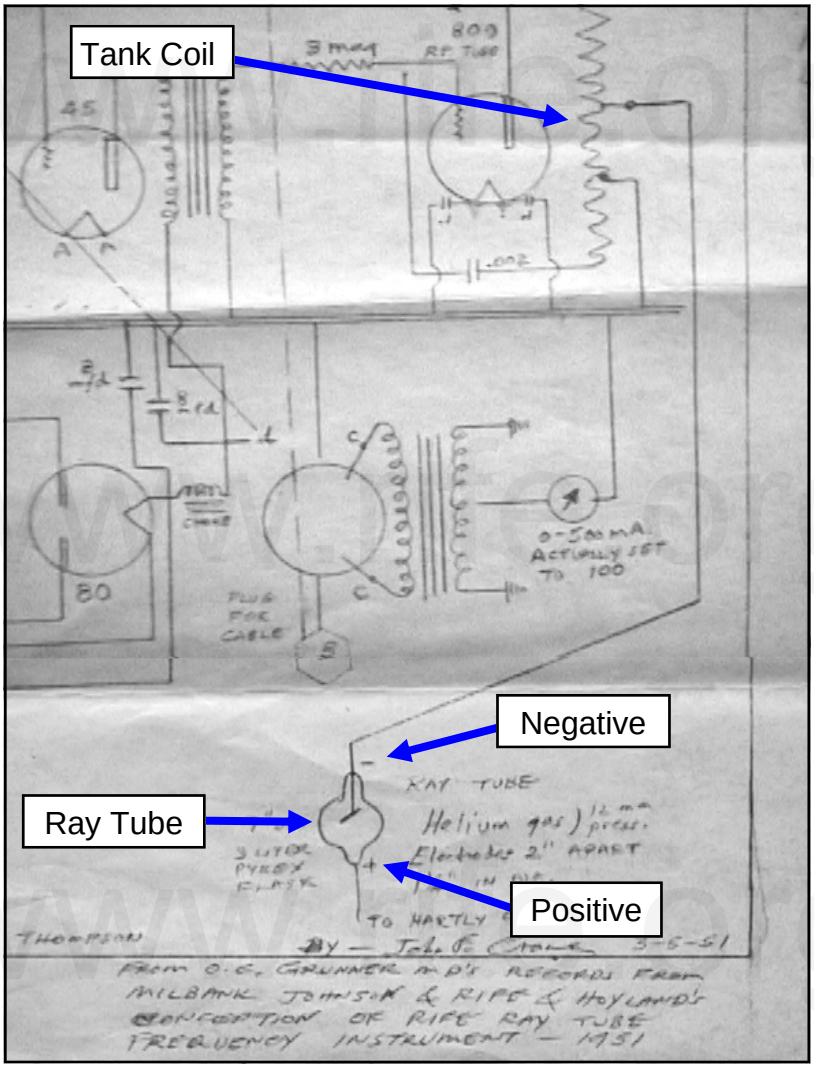

If you hooked the positive side of the ray tube back up to the same fixed Hartley Oscillator it would have only output one frequency as described by Dr. Gruner. This adding of the second oscillator, by John Crane, is why there was confusion on how this instrument worked. The positive side of the ray tube was supposed to be hooked back up to the same fixed oscillator. But with the adding of the second variable Hartley Oscillator, by John Crane, would mean that the positive side of the ray tube would have been hooked up to the second Hartley oscillator. This would have made it so the ray tube would be connected between the two Hartley Oscillators. The negative side of the ray tube connected to one oscillator and the positive side of the ray tube connected to the other oscillator.

The second Hartley Oscillator was also an RF Oscillator. It had a tank coil and a variable capacitor for changing the RF frequencies. Anyone looking at this schematic will notice that it does not have any variable audio oscillator. Philip Hoyland's Beam Ray Gruner instrument was using an RF frequency not an audio frequency. This would logically mean that Dr. Gruner was using one of the Rife Ray #4 frequencies. Because Dr. Gruner was working on the cancer organism of Cryptomyces Pleomorpha fungi his instrument was most likely set on that organisms frequency.

Because we did not know that John Crane had added this second oscillator we came to the conclusion that the logical way to build the instrument would have been to have had two Hartley Oscillators using the 809 tubes. So this is the way that we rebuilt the instrument. By using the method of connect-

ing the ray tube between the two Hartley Oscillators, both variable, the instrument could output two high RF frequencies at the same time without the bandwidth problems that would have come with trying to modulate frequencies through a tank coil. The tank coil in the Beam Ray Clinical instrument can only pass modulated frequencies up to about 250,000 Hertz. Because we put the ray tube between the two Hartley Oscillators and found that the instrument could work this way we determined that Philip Hoyland most likley built the Rife Ray #4 and Beam Ray Laboratory instrument in this same way. Our instrument could output two frequencies at the same time.

The Beam Ray Laboratory instrument probably had some band switches like the Rife Ray #4. What the frequency range of this Beam Ray Laboratory instrument was is not known but it would have gone up to at least 1.80 MHz like the Rife Ray #3 Kennedy equipment did. Dr. Rife's Rife Ray #3 and Rife Ray #4 machines put out specific frequencies and this instrument, it appears, was built to do the same thing. If Dr. Rife wanted 1,604,000 Hertz he would set the oscillator to 1,604,000 Hertz. This was the type of instrument Dr. Rife used. When you look at the case of the Laboratory instrument it is a large case that could have easily held the necessary components for this instrument. The instrument would have had two large dials on the front of it. In the photo, shown at the beginning of this chapter, the pole that holds the ray tube is blocking part of the panel where we would expect to see the second dial for the second oscillator.

The modulated Audio Frequency pulsing circuit

In this report, in the previous chapters, we have mentioned a fixed audio frequency pulsing circuit. We will now cover it in more detail because the Beam Ray Gruner instrument had this circuit in its schematic. This circuit pulsed the high RF frequencies. We know it was important because it was considered the secret that made the instrument work. If you look at the next schematic photo, shown below, you will see two audio transformers. This is the only indication of any audio frequency used in Dr. Gruner's instrument.

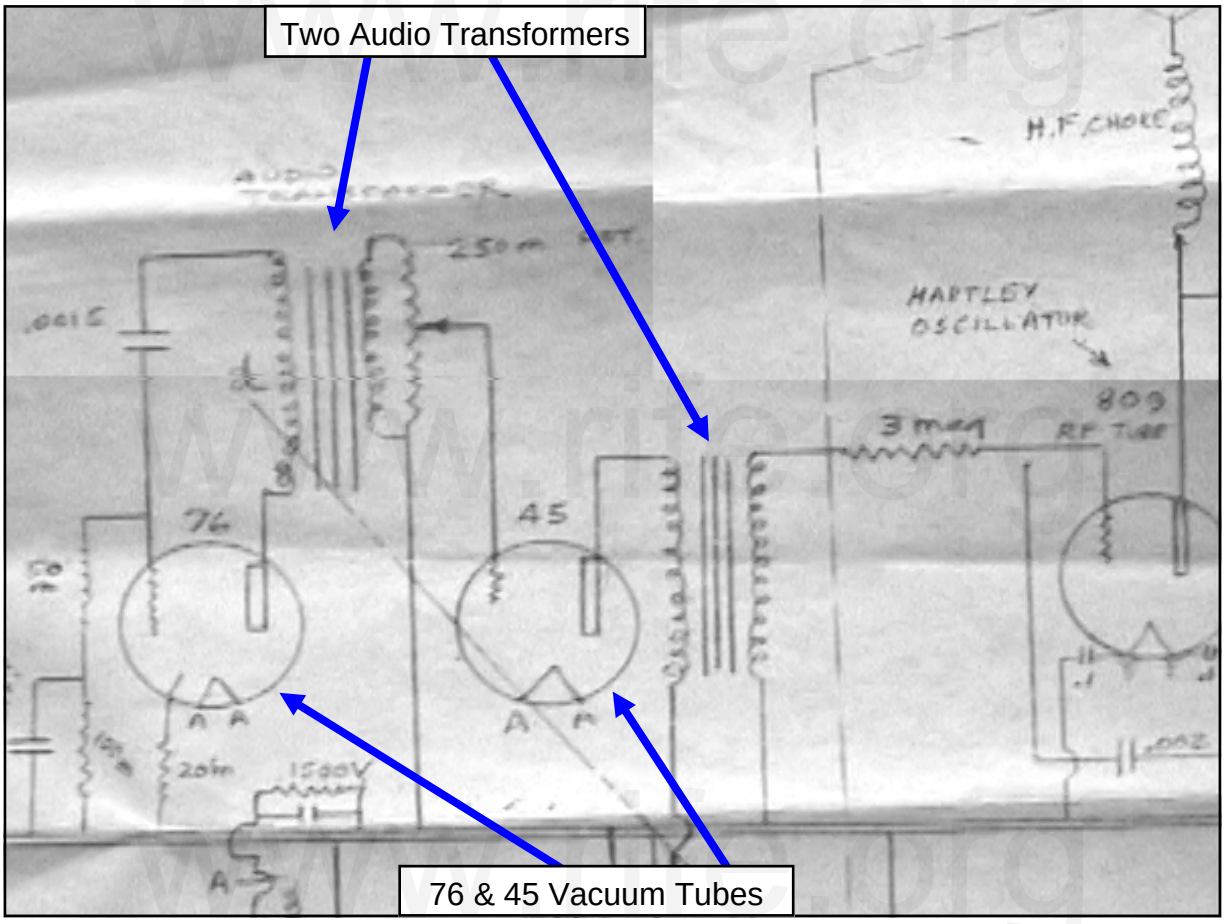

It was not a variable audio oscillator but it was for a single fixed audio frequency. The 76 and 45 vacuum tubes along with the two audio transformers make up this circuit. Mr. Peters built this section and found that the frequency was at about 1330 Hertz and it pulses, through modulation, the fixed Hartley Oscillator RF carrier frequency that used the 809 tube. The next two photos, shown below, is this rebuilt circuit.

This 1330 Hertz frequency could have been a little higher or a little lower frequency because he used modern transformers instead of the original 1940's transformers. This pulsing frequency is a lot faster than the eye can see so no one would know it was in the instrument. If you look at the next photo, shown below, you will see the waveform of the pulsing frequency. It resembles a damped wave minus the ring oscillations of a true damped wave.

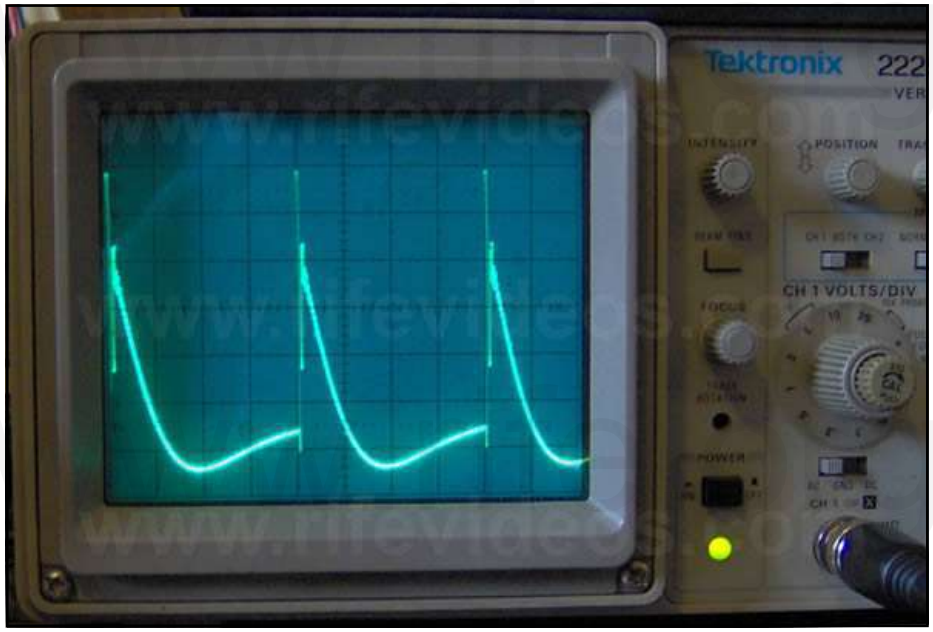

This waveform also looks like the waveform of the Rife Ray #4. This waveform would produce the effect that John Crane mentioned as he narrated Dr. Rife's 1936 Lab video:

CRANE: *"Now the spikes that you see on the frequencies are the lethal part that kill and devitalize the virus. They are the resonant peaks of the frequencies which increase the voltage to a very high potential which the cells of the virus wall can not tolerate and they break up into many pieces and are destroyed."* (Dr. Rife's Lab Film Narrated by John Crane in the 1970's).

It's doubtful that this understanding of the spikes would have been something that John Crane would have known anything about had Dr. Rife not told him about it. From the statements we have read the resonant frequency of an organism is not enough to devitalize it. It's apparent that an organism's resonant frequency will not harm it unless the resonant frequency is pulsed through modulation with a waveform that produces a high potential voltage rise. It also appears that this modulated audio pulsing circuit would have been necessary for all of Dr. Rife's high RF frequencies. Logically this same type of circuit would have been in Dr. Rife's Rife Ray #3 and Rife Ray #4 and this is why the Gruner instrument also had this kind of circuit built into it. Also, logically his Beam Ray Laboratory instrument had this circuit.

In the previous chapter of this report when we covered the original Beam Ray clinical instrument. We showed that a sine wave audio frequency modulated onto a carrier frequency, in this M.O.P.A. style instrument, was sufficient enough to create the necessary pulse to devitalize the various microorganisms. The analyzing of that Beam Ray Clinical circuit showed that it almost creates a square wave frequency. The Beam Ray Clinical instrument output variable audio frequencies well above 10,000 Hertz. This indicates that the pulse rate of the modulated audio frequency is not important, only that the high RF frequency is pulsed.

There is another important effect that happens to the plasma of a ray tube when you pulse it with a low audio frequency of a damped shaped waveform or square wave waveform. Because the duty cycle is very low it allows deionization of the plasma which makes it possible for the very high potential voltage rise to be emitted from the ray tube. A square wave audio frequency of a 50% duty cycle should be just as effective as a damped waveform. A square wave has the same high potential voltage rise on the leading edge as this damped wave. Philip Hoyland found that even a sine wave frequency was sufficient to achieve the same result when used in the M.O.P.A circuit. His Beam Ray Clinical instrument circuit was modulated with a sine wave audio frequency that produced a waveform that almost looks like a square wave waveform and that waveform would devitalize the organisms. The next photo, shown below, is that waveform. We are showing this waveform so that the reader will understand what we are talking about.

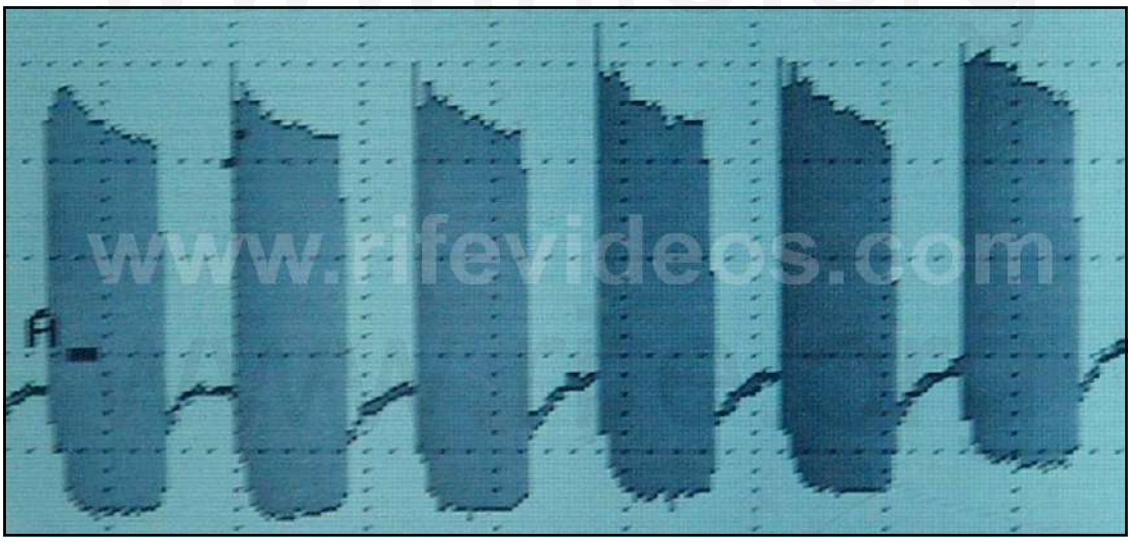

This all indicates that an audio frequency modulation with a high RF frequency is what makes the frequencies work on microorganisms. The waveform of the audio frequency whether it is a damped wave or square wave makes no difference in its effectiveness because both of these waveforms have been used in Dr. Rife machines.

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The next photo, shown below, is a picture of Dr. Rife's waveform from his Rife Ray #4 Rife Machine. We showed this waveform in a previous chapter but we need to show it again. This waveform came from Dr. Rife's 1936 lab film. The lab film shows that he put a metal plate about 3" X 8" under the ray tube and ran his oscilloscope lead to it so he could read the frequencies. This photo shows the type of waveform he was using to devitalize organisms. It also matches the waveform produced by the 76 and 45 vacuum tubes in the Gruner instrument we are looking at in this chapter. We now know from the rebuilding of Dr. Gruners instrument and from the analyzing of the Beam Ray Clinical instrument, the two waveforms that were used, how they were created, and the method that should be used for doing M.O.R. research.

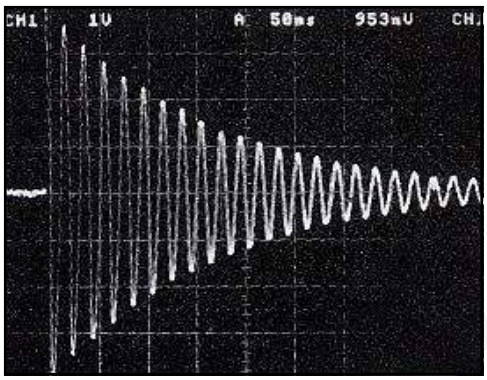

Both Mr. Peters and I rebuilt the Gruner instrument using two variable RF oscillators. We did not put the various bands in it like the Rife Ray #4 or the Beam Ray Laboratory instrument because we first believed it was a heterodyning instrument. Now that we know that Philip Hoyland's Beam Ray Clinical instrument used upper harmonics of the Rife Ray #4 frequencies it doesn't seem necessary that we put the different bands into the instrument. Our instruments will probably be adjusted so we can cover a range from about 1 MHz to about 4 or 5 MHz. Then we will multiply up the Rife Ray #4 frequencies into these ranges, like Philip Hoyland did with the Beam Ray Clinical instrument, and use them with this instrument. Other than John Crane adding the second Hartley oscillator the Gruner schematic was a complete schematic. The pulsing circuit was drawn correctly and worked. It also showed how Dr. Rife produced the damped waveform which pulsed his high RF frequencies in his instruments.

Mr. Peters built his instrument using 805 tubes and I built my instrument using 812A tubes. The AZ-58 Beam Ray Clinical replica RF section was almost exactly the same (809 vacuum tube replaced with the more powerful 812A tube) as the Gruner circuit. The reason I built the Gruner instrument using the 812A tubes is because the 809 is no longer being manufactured. We were also able to replace the modulated pulsing circuit consisting of the 45 & 76 tubes with a single high voltage switching transistor driven with a function generator which outputs the 1330 Hertz pulse frequency. With the use of this transistor we can use any audio frequency we want to use. Using this transistor we believe makes the design better because we can output all the lower audio frequencies including the original audio frequencies used in the AZ-58. My instrument has two Vernier dials which allows me to output two high RF frequencies at the same time like the Rife Ray #4 did. The ray tube is connected to both tank coils instead of having one side of the ray tube go to ground. It is the connecting of the ray tube between the two RF oscillators that makes this design work like the Rife Ray #4 would have done.

Please note: There is a modern instrument built today that is called the "Beam Ray." It works nothing like this original 1930's Beam Ray Laboratory instrument built by Philip Hoyland. We are not saying anything negative about the modern Beam Ray instrument but some people have asked us if these instruments work on the same principles and frequencies and they do not. We have only given this information so people are not confused about these two instruments.

www.rife.org

On page 118 are photos of Mr. Peters instrument which he built. On pages 119 through 121 are the photos of the Gruner instrument that we built. Because John Crane altered the schematic by adding the second oscillator we built this instrument with two oscillators. I built mine with two variable RF oscillators which made it work like the Rife Ray #4 and the Beam Ray Laboratory instrument. For this reason we refer to this instrument, in the photos below, as the Laboratory instrument.

On page 122 is a redrawn schematic of this design. We replaced the smaller vacuum tube of the second Hartley Oscillator with the 809 tube. The layout of the electronic parts of this instrument is very important because of the inherent interference problems that come with RF oscillators. Anyone wanting to build this instrument should have a good understanding of old tube technology. Some parts of this circuit use up to 2000 volts DC with substantial current and can easily kill anyone not experienced in working with this kind of current or voltage. We take no responsibility for anyone who builds this instrument. We recommend that you have professional help.

Chapter Summary: Dr. Gruner's machine was built to be set on one high RF frequency. It had no variable audio oscillator and did not work on the sideband method developed by Philip Hoyland. It had a fixed audio pulsing circuit that modulated the high RF frequency causing a high potential voltage rise in the waveform of the RF frequency being outputted to the ray tube. Because it used only one high RF oscillator it would have been set on Dr. Rife's high RF frequency for the organism Dr. Gruner was working on.

The Beam Ray Laboratory machine was built to work like the Rife Ray #4. It was built to be used in a laboratory for doing M.O.R. work on microorganisms. It would not have been built like the Rife Ray #5 or Beam Ray Clinical instrument which worked on harmonic sidebands. The Beam Ray Clincal instrument would not have worked in a laboratory setting since it devitalized all of the organisms in Dr. Johnson's laboratory due to the many sideband frequencies it would output.

In the next chapter we will now look at the next original Rife Machine replica that was purchased by Aubrey Scoon and his British Rife group.

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Mr. Peters' photos of the rebuilt Beam Ray Laboratory instrument

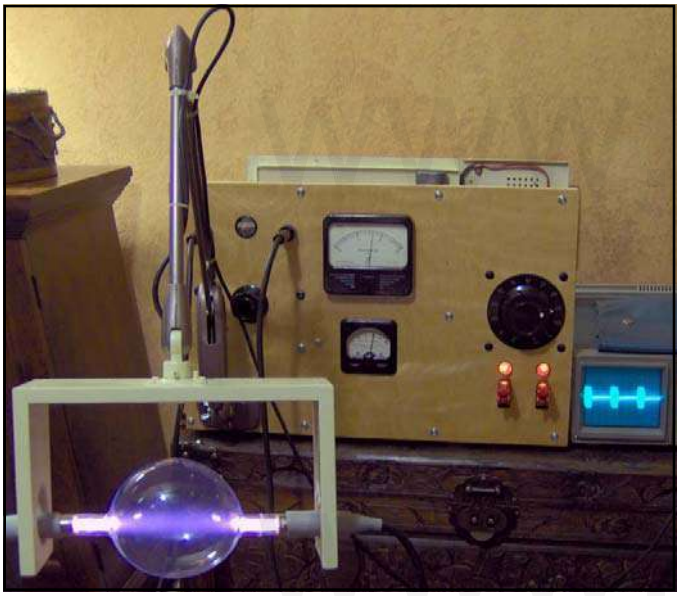

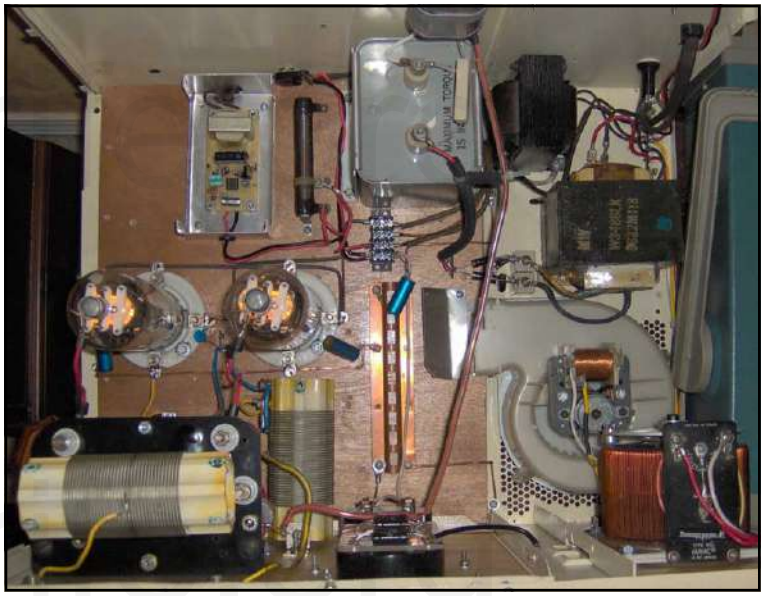

www.rife.org

Photos of the rebuilt Beam Ray Laboratory instrument

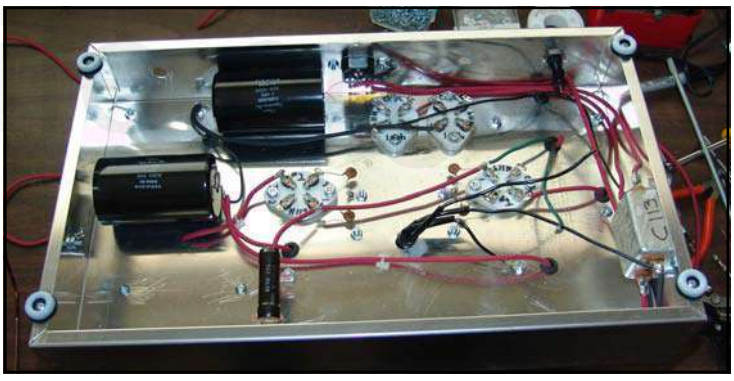

www.rife.org

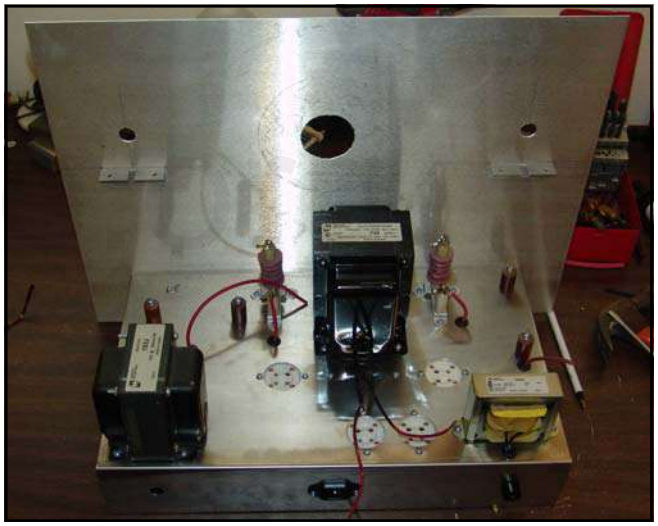

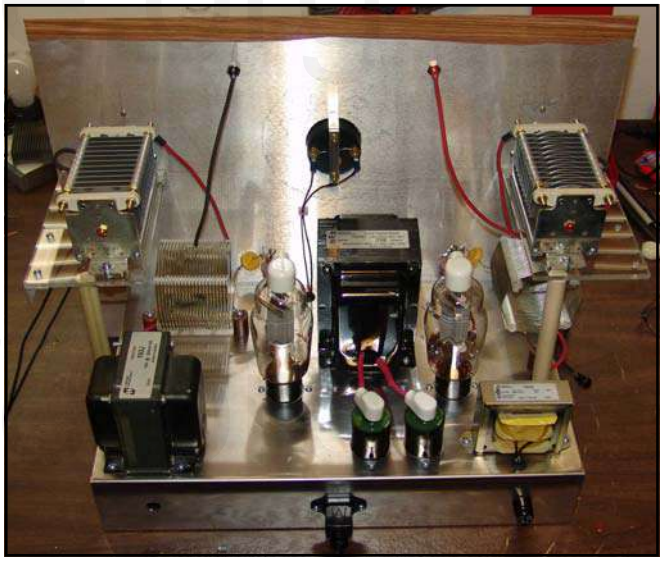

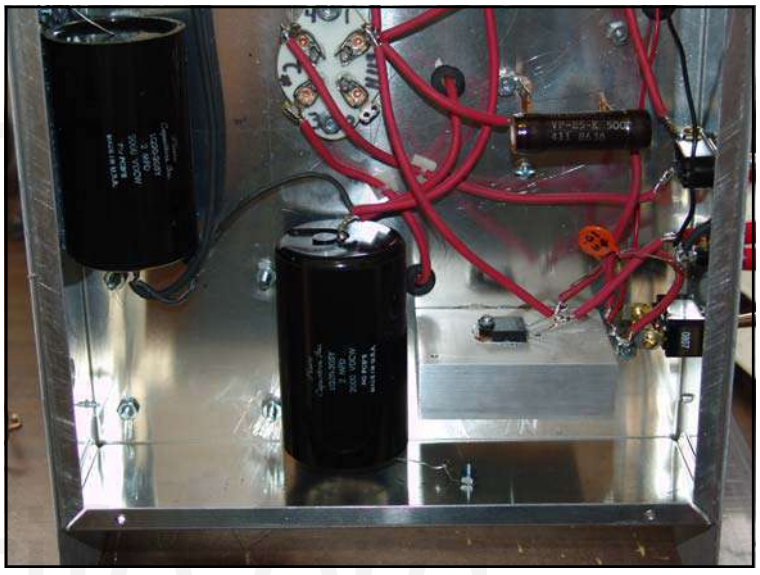

www.rife.org

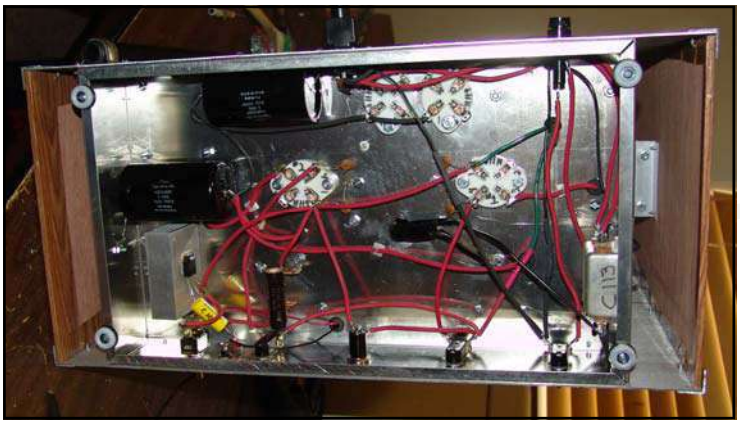

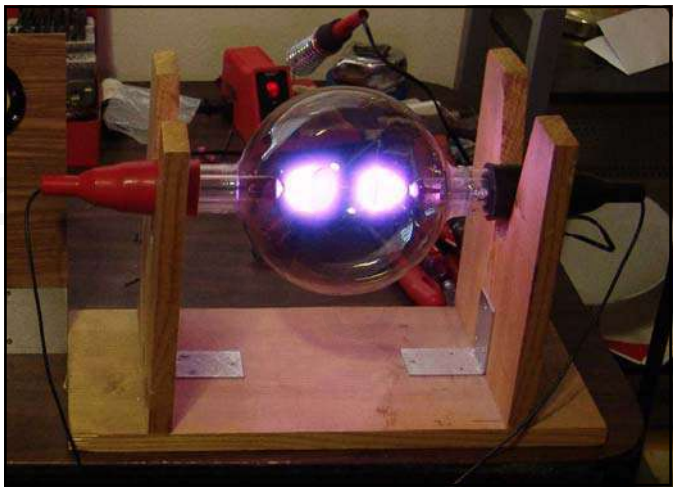

3073kHz
269.6mV

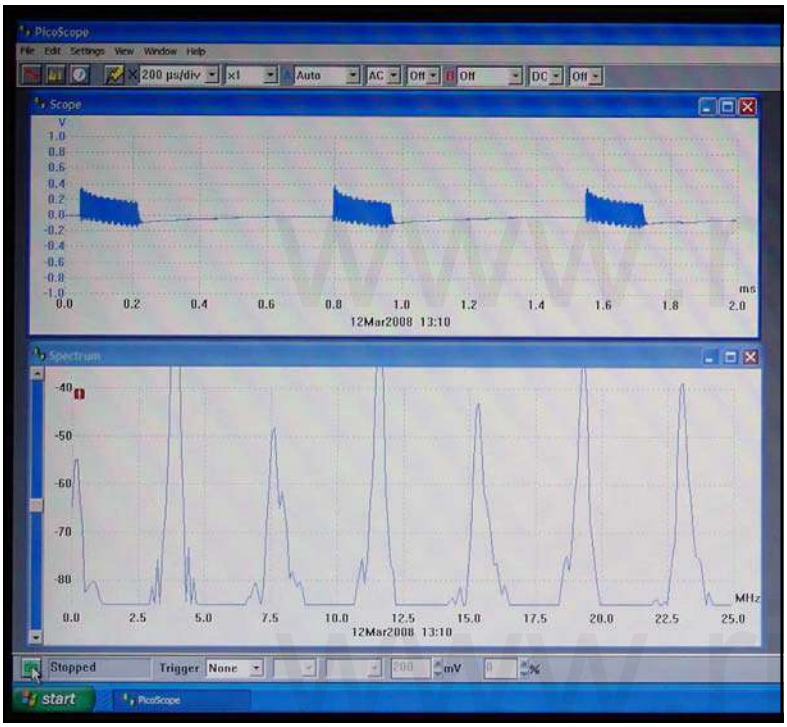
PicoScope
File Edit Settings View Window Help
200 µs/div
Scope
12Mar2008 13:10
Spectrum
MHz
12Mar2008 13:10
Stopped
Trigger None
start

www.rife.org

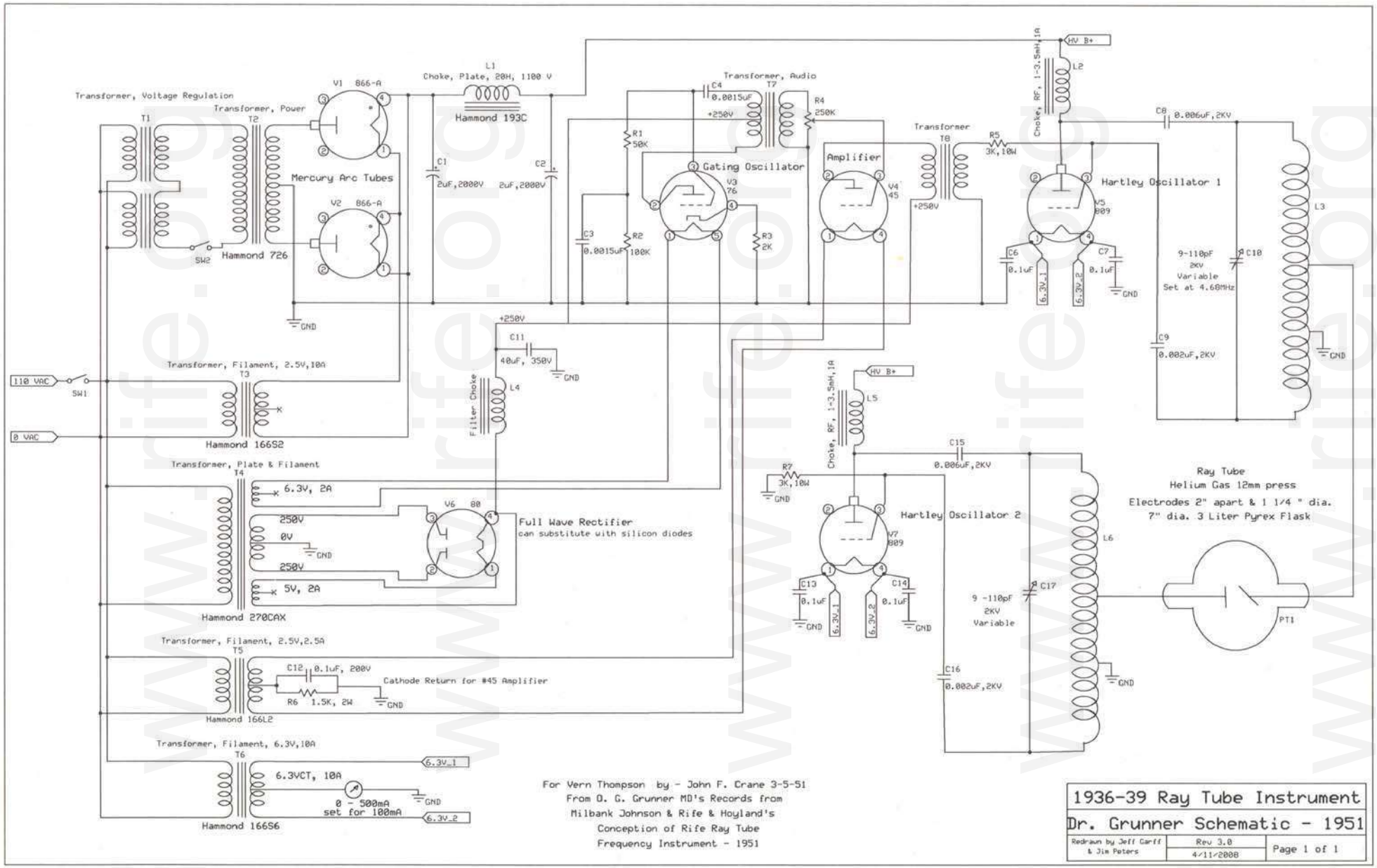
Transformer, Voltage Regulation
T1
Transformer, Power
T2
V1 866-A
V2 866-A
Mercury Arc Tubes
Hammond 726
SW2
L1
Choke, Plate, 20H, 1100 V
Hammond 193C
C1
2uF,2000V
C2
2uF,2000V
GND
Transformer, Audio
T7
C4
0.0015uF
+250V
R4
250K
R1
50K
Gating Oscillator
V3
76
C3
0.0015uF
R2
100K
R3
2K
Amplifier
V4
45
Transformer
T8
+250V
R5
3K,10W
Choke, RF, 1-3.5mH,1A
L2
HV B+
C8
0.006uF,2KV
Hartley Oscillator 1
V5
809
C6
0.1uF
C7
0.1uF
6.3V_1
6.3V_2
GND
9-110pF
2KV
Variable
Set at 4.60MHz
C10
L3
C9
0.002uF,2KV
GND
+250V
C11
40uF, 350V
GND
Transformer, Filament, 2.5V,10A
T3
110 VAC
SW1
0 VAC
Hammond 166S2
Filter Choke
L4
Transformer, Plate & Filament
T4
6.3V, 2A
250V
0V
GND
250V
5V, 2A
Hammond 270CAX
V6 80
Full Wave Rectifier
can substitute with silicon diodes
Choke, RF, 1-3.5mH,1A
L5
HV B+
C15
0.006uF,2KV
R7
3K,10W
GND
Hartley Oscillator 2
V7
809
C13
0.1uF
C14
0.1uF
6.3V_1
6.3V_2
GND
C17
9 -110pF
2KV
Variable
L6
C16
0.002uF,2KV
GND
Ray Tube
Helium Gas 12mm press
Electrodes 2" apart & 1 1/4 " dia.
7" dia. 3 Liter Pyrex Flask
PT1
Transformer, Filament, 2.5V,2.5A
T5
C12
0.1uF, 200V
R6
1.5K, 2W
Cathode Return for #45 Amplifier
GND
Hammond 166L2
Transformer, Filament, 6.3V,10A
T6
6.3VCT, 10A
0 - 500mA
set for 100mA
6.3V_1
6.3V_2
GND
Hammond 166S6
For Vern Thompson by - John F. Crane 3-5-51
From O. G. Grunner MD's Records from
Milbank Johnson & Rife & Hoyland's
Conception of Rife Ray Tube
Frequency Instrument - 1951
1936-39 Ray Tube Instrument
Dr. Grunner Schematic - 1951
Redrawn by Jeff Garff & Jim Peters
Rev 3.0
4/11/2008
Page 1 of 1

Chapter #11

Aubrey Scoon's Beam Ray replica Rife Machine Re-evaluation

1. Used a ray tube.
2. Used a fixed 3.30 MHz RF carrier frequency.
3. Modulated sine wave audio frequencies onto a sine wave RF carrier frequency.
4. Power usage was about 460 watts. Output to the ray tube about 40 watts.

In 2009 Aubrey Scoon passed away. His web site remained up on the web until the domain name expired last year. Since his web site is no long available and is an important part of this chapter, including this report, we have included all of his information pertaining to his machine on the www.rifevideos.com web site. To fully understand this chapter we suggest that you read Aubrey's information about his Beam Ray replica instrument at this web address:

http://www.rifevideos.com/aubrey_scoons_1939_rife_beam_ray.html

Aubrey Scoon's 1950's Beam Ray Clinical replica Rife Machine was originally mistaken for an g original 1938-1939 Rife Ray #5 or Beam Ray Clinical instrument built by Philip Hoyland and the Beam Ray Corporation. We now know that it was not an original Beam Ray instrument built by Beam Ray Corporation but it is an exact replica of that instrument. It was originally for sale on www.rife.org. John Bedini and a group of men who had worked with John Crane for a year and a half considered purchasing it. After careful examination of the information available, at that time, they concluded that this instrument was not an original Beam Ray instrument built by the original 1938-1939 Beam Ray Corporation. They concluded that it was built later, perhaps, in the 1940's by Dr. Rife's engineer, Verne Thompson. Verne Thompson eventually replaced Philip Hoyland as Dr. Rife's new engineer and he was building instruments during the 1940's and 1950's for doctors that wanted Dr. Rife's machines.

The reason we are re-evaluating Aubrey Scoon's Rife Ray #5 or Beam Ray Clinical replica instrument is this instrument is the second most important instrument that we have analyzed. When it was first analyzed by Aubrey Scoon's team they did not take their original evaluation of this instrument far enough. Had they used a spectrum analyzer there is a possibility that they may have figured out

how this instrument really worked, but they did not. Once we determined how the "Original Rife Ray #5 or Beam Ray Clinical" instrument worked we were able to re-evaluate Aubrey Scoon's Beam Ray replica and show that it worked on the same principles and frequencies as the original Beam Ray Rife Machine obtained from Dr. Low. All of Dr. Rife's instruments, from the first to the last, worked on the same principles and the same high RF frequencies, or higher harmonics of Dr. Rife's original frequencies. The method of generating the frequencies may have changed but all the frequencies used in Dr. Rife's machines were based on the original frequencies he found that would eliminate, deactivate or devitalize those organisms he worked on in his laboratory.

For a better understanding of Aubrey Scoon's Beam Ray Clinical Rife Machine we need to give the history of it. Aubrey Scoon and a group of men from England purchased the above instrument believing it was an original Beam Ray Clinical instrument built by the 1938-1939 Beam Ray Corporation. The original Beam Ray Clinical instrument was known to be working on harmonics. Without really knowing it, they purchased a replica of the Beam Ray Clinical instrument. At that time no original instrument had been located. Because of this and the fact that we had no absolute concrete evidence that Dr. Rife's engineer, Philip Hoyland, built this style of audio frequency instrument it was not fully accepted as a genuine Rife instrument. Not even the later 1953 AZ-58 Beam Ray Clinical replica was accepted as a genuine instrument either.

A few years ago, before Aubrey passed away, I was communicating with him about this instrument. In the course of our communications he told me that he believed he had used the wrong main output vacuum tube in the instrument when they worked on it. Because they believed they had used the wrong vacuum tube (812a vacuum tube) the carrier frequency had parasitic oscillations which created harmonics. He said that when they discovered this mistake they put what they believed was the proper tube (809 vacuum tube) in and most of harmonics from the parasitic oscillations were gone. Aubrey Scoon mentions the change of this tube (809) on his web site. But they did not change the photos of the waveforms so we do not know how much the waveform really changed. This much we do know all of the photos of the waveforms on his web site are of an instrument that has parasitic oscillations. Using the wrong tube was a simple mistake that anyone could make but it led to a great deal of confusion causing many to believe, including myself, that this instrument was, an original Beam Ray Clinical instrument because of those parasitic oscillations. We believed these parasitic oscillations created the harmonics which the original Beam Ray Clinical instrument was supposed to be working on.

Both Jim Berger and I separately built Aubrey Scoon’s instrument with the correct vacuum tubes (812a) and found using an oscilloscope that the RF output was clean of any parasitic oscillations. In our tests the 812a vacuum tube produced no harmonics like those seen in Aubrey Scoon’s photos. At this time it confirmed to us that if the circuit was working correctly there would be no parasitic oscillations or harmonics from parasitic oscillations. The building of this instrument also showed that it didn't have the reported harmonics which the genuine Beam Ray Clinical instrument was supposed to have. Little did we know, at that time, that the harmonic concept we were looking for was there but we didn’t really understand how the instrument was supposed to work. This wrongly convinced both Jim Berger and I that Aubrey Scoon's instrument was not a genuine Beam Ray instrument. Nevertheless, this mistake does not change the fact that we now know that this instrument is a genuine Beam Ray machine replica.

At a later date when both the 809 and 812a vacuum tubes were tested in the circuit neither tube created the same kind of waveforms as Aubrey Scoon's machine was producing. This proved to us that the parasitic oscillations are due to some other problem in the RF circuit of his machine. It was also determined that the 812a vacuum tube was the correct tube that should be used, not the 809 vacuum tube. The 812a vacuum produces the correct carrier frequency which should be used with the audio frequencies Aubrey Scoon's instrument used.

The original Beam Ray Clinical instrument built by Beam Ray Corporation that we obtained from Dr. Low did not have any frequency list that came with it showing us what frequency band or dial settings should be used for the various microorganisms. However, Aubrey Scoon's Beam Ray replica instrument built by Verne Thompson came with a list of frequencies which the doctor used on the various organisms. It is this list of frequencies that makes this instrument so important.

We know from the previous documents that we have read in this report that Dr. Rife had Verne Thompson rebuilding and repairing these instruments. We also read that Dr. Rife had Verne Thompson rebuilt Dr. Yale's machine in 1940. Because Verne Thompson became Dr. Rife's engineer he would periodically repaired Dr. Couche's and Dr. Tulley's machines. We also know that Verne Thompson was making copies of Dr. Couche's Beam Ray Clinical instrument for other doctors. With this understanding we know that Verne Thompson was the one who would have written down these audio frequencies that were used in Aubrey Scoon's Beam Ray Clinical instrument. Also with this understanding we know that the same audio frequencies used in Aubrey Scoon's Beam Ray Clinical instrument were used in Dr. Couche's Beam Ray Clinical instrument. This information is very important. The importance of this information will become very clear as we continue to look at this instrument and the 1953 AZ-58 Beam Ray Clinical Replica instrument.

Since this paper was updated on 9/20/2010 we decided to test a 3.30 MHz RF carrier frequency believing that it could have been the correct RF carrier frequency. When Aubrey Scoon first tested the instrument with the 812a vacuum tube (not the 809 vacuum tube) he listed 3.33 MHz as the RF carrier frequency on his website. Knowing how parasitic oscillations in an RF carrier frequency could easily have shifted the carrier frequency 30,000 Hertz, it was thought that a 3.30 MHz RF carrier frequency would have been a more logical frequency to use. This assumption proved to be correct. In the summer of 2011 we obtained more of John Marsh's documents from his nurse. In one of these documents dated November 20, 1967 John Marsh stated the following:

MARSH: *John Crane's, a simple oscillator, which can be obtained easily for about $33.00. It produces a fuzzy band. He experimented with hooking up wires with an ordinary radio speaker and produced a different musical note for each frequency. The large instrument* [Beam Ray Clinical replica instrument] *is a RF frequency generator which carriers wave oscillations at 3300 kilocycles (3.3 Megahertz) on the marine band. Pre-auditory sound waves.* (John Marsh 1967 document about Dr. Robert P. Stafford).

This letter of John Marsh's confirms that the RF carrier frequency in the original Rife Ray #5 or Beam Ray Clinical instrument, which Dr. Rife, John Crane and John Marsh made a replica of in 1953, was set at 3.30 MHz. This also confirms that the 812a vacuum tube is the correct tube. It also confirms that that the original reading done by Aubrey Scoon of the RF carrier frequency being about 3.30 (3.33) was a correct reading. It was only slightly off due to the parasitic oscillations.

As mentioned before, Aubrey Scoon's instrument had four bands. These four bands were mentioned by Philip Hoyland in the Beam Ray Trial. He stated that they covered all the frequencies for the various organisms this instrument treated. The frequency range of each of the four bands is as follows:

Band 1: 20 Hertz to 200 Hertz.

Band 2: 200 Hertz to 2000 Hertz.

Band 3: 2000 Hertz to 20,000 Hertz.

Band 4: 20,000 Hertz to 200,000 Hertz.

Our original Beam Ray Clinical instrument, along with Aubrey Scoon's Beam Ray replica instrument design, predates John Crane and John Marsh and this reveals that the audio frequencies came from Philip Hoyland not John Crane or John Marsh. This Aubrey Scoon Beam Ray replica instrument also shows a connection to the original 1938-1939 Beam Ray Clinical Rife Machine and the audio frequencies that were used in the 1953 AZ-58. This AZ-58 instrument will be discussed in greater detail later in this report. The 1953 AZ-58 Beam Ray replica instrument used almost the same frequencies as Aubrey Scoon's instrument except Crane and Marsh divided them down by a factor of 10 times and used these lower audio frequencies in the AZ-58.

Below is a chart that has the audio sideband frequencies that were used in Aubrey Scoon's Beam Ray Clinical replica instrument. It was these frequencies that John Crane and John Marsh lowered to get the audio frequencies they used in the 1953 AZ-58. We will reconcile these frequencies in this chart to Dr. Rife's original high RF frequencies that were used in the Rife Ray #3 and Rife Ray #4 Rife Machines in this section of this report. Before we do this we need to compare Aubrey Scoon's Beam Ray Clinical replica to the original Beam Ray Clinical Rife Machine which we obtained from Dr. Low.

The list of audio frequencies, shown below, of Aubrey Scoon's Beam Ray replica sine wave audio frequencies must be used with a 3.30 MHz RF carrier frequency. Testing of this 3.30 MHz RF carrier frequency showed that this was the correct carrier frequency for this instrument. It was this testing with the 3.30 MHz RF carrier frequency in combination with the audio frequencies which produced the correct sideband frequencies that hit the Rife Ray #3 and Rife Ray #4 higher harmonic frequencies.

What we need to point out here is this **IMPORTANT** fact which came from the analyzing of the original Beam Ray Clinical instrument. This fact also applies to Aubrey Scoon's Beam Ray replica instrument. Neither the 3.30 MHz RF carrier frequency nor the audio frequencies will do anything by themselves. But when the 3.30 MHz RF harmonic carrier frequency and the audio frequencies are combined together they will produce many sideband frequencies. And one of these sideband frequencies will line up with the true Rife M.O.R. frequency and devitalize or render harmless the harmful microorganism. To re-emphasize this so that no one misunderstands. If you just use the audio frequencies by themselves you will get nothing. If you use the 3.30 MHz RF carrier frequency without the audio frequencies you will get nothing. The audio frequencies used in Aubrey Scoon's instrument must have the RF carrier frequency of 3.30 MHz or they are useless. This is the reason the 1953 Beam Ray Clinical instrument called the AZ-58 did not work properly. In the chart, shown below, are the audio frequencies used in Aubrey Scoon's instrument. It is these audio frequencies when combined with the 3.30 MHz RF carrier frequency that will produce Dr. Rife's higher harmonic M.O.R. frequencies. It must be understood that these audio frequencies were not meant to treat these organisms.

Aubrey Scoon's Beam Ray Clinical Replica Audio Sideband Frequencies			
B or E Coli Rod	8,020 Hz	Syphilis or Treponema	6,600 Hz
B or E Coli Virus	17,220 Hz	Tetanus	1,200 Hz
BX Virus Carcinoma	21,275 Hz	Tuberculosis Rod	8,300 Hz
BY Sarcoma	20,080 Hz	Tuberculosis Virus	16,000 Hz
Pneumonia or Spinal Meningitis	7,660 Hz	Typhoid Rod	6,900 Hz
Staphylococcus	7,270 Hz	Typhoid Virus	18,620 Hz
Streptococcus	8,450 Hz	Worms	2,400 Hz
Streptothrix	7,870 Hz		

The two photos below show Aubrey Scoon's RF section. The electronic components are almost identical to our original Beam Ray Clinical instrument. It used the same 866 rectifier tubes (two used) along with the 812a vacuum tube (one used).

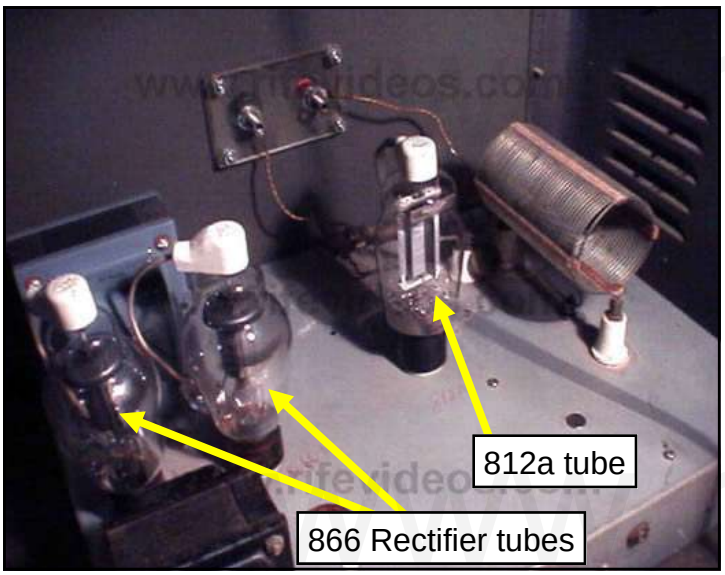

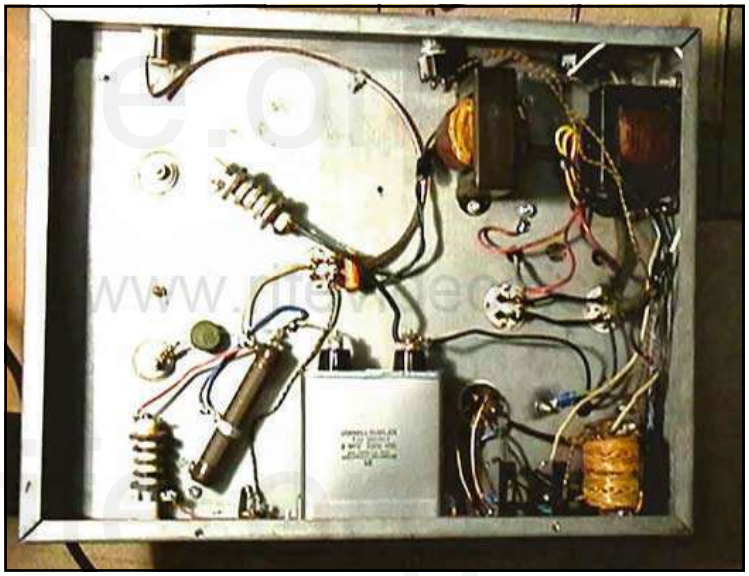

Like the original Beam Ray Clinical instrument which used a Hewlett-Packard audio oscillator, Aubrey Scoon's Beam Ray replica instrument also used a Hewlett-Packard audio oscillator design. By design we mean that this oscillator used an incandescent light bulb in the circuit (patented by Hewlett-Packard) which stabilized the audio oscillator frequencies and waveform which it output. In the next two photos, shown below, is Aubrey Scoon's Beam Ray Rife Machine audio oscillator. In the photo, below on the right, you can see the small incandescent light bulb.

In 1938 when Beam Ray Corporation built this style of instrument the Hewlett-Packard Wein Bridge audio oscillator was not invented yet. Since this newer Hewlett-Packard audio oscillator patent was not filed until July of 1939 and the Beam Ray Corporation was at this time in a court battle it is only logical that the original Beam Ray instrument did not use Hewlett-Packard's new design. It was invented in early 1939 and a patent was filed July 11, 1939. The patent was granted on Jan 6, 1942.

In 1938 and 1939 the original Beam Ray Clinical instrument would have had an RC (resistor capacitor) type of audio oscillator. These RC audio oscillators were known to be very unstable and it was replaced in the original Beam Ray instrument that we have with the newer Hewlett-Packard design. The audio oscillator section of the original Beam Ray Clinical instrument that we have has many extra

holes in the chassis and shows that modifications were made to update this instrument to the newer Hewlett-Packard design.

Aubrey Scoon in his evaluation of his Beam Ray replica instrument believed that his instrument was an original machine built by the 1938-1939 Beam Ray Corporation. He was correct that it was an original design but he was wrong about the year it was built. John Bedini was correct in his belief that it was not an original machine built by the 1938-1939 Beam Ray Corporation. The fact that the Hewlett-Packard design patent was not issued until 1942 should have indicated to Aubrey Scoon that his instrument was built later than 1939. Rather than accept that the patent had not been filed until July of 1939 and issue until 1942 he believe that Hewlett-Packard had somehow allowed Beam Ray Corporation the right to use their design before they even filed a patent on it. Of course this does not make any sense since they could have lost any patent rights if they did this. Just this information alone should have indicated that this machine was not an original machine built in 1938-1939.

Aubrey Scoon's audio oscillator update

Roger Blain, who has had a great deal of interest in this technology, uncovered some very important information about the manufacture date of the audio oscillator design that was used in Aubrey Scoon's instrument. If you look at the above two photos which show both the underside and top view of the audio section of Aubrey's instrument you will notice that there are no signs of any retro-fitting of the audio oscillator to a newer design. If it had been built in 1938 or 1939 then it would have had the original (RC) resistor capacitor design which would have been replace. It also would have showed obvious signs of the necessary changes needed to update the old style (RC) audio oscillator to the newer Hewlett-Packard design which it now has. The next photo, shown below, shows the underside of the audio oscillator of the original 1938-1939 Beam Ray machine obtained from Dr. Low.

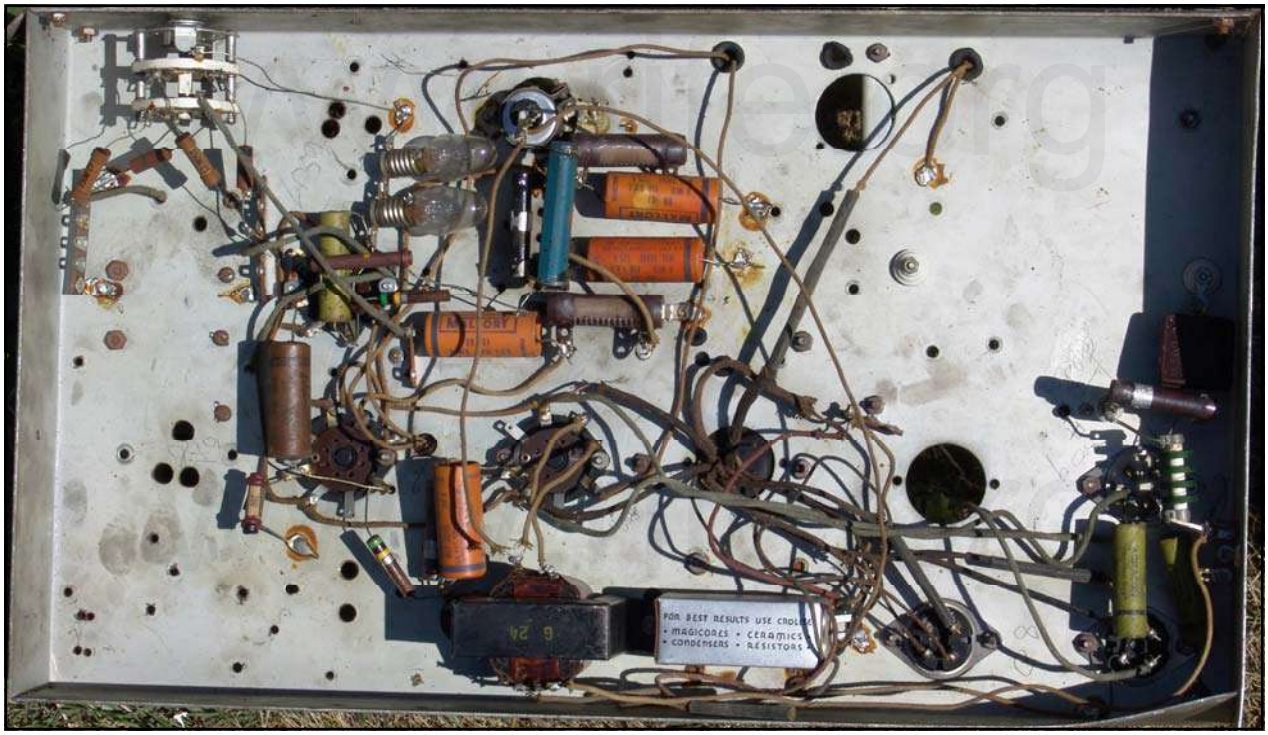

You will notice many small holes including two larger old vacuum tube holes (empty and without any vacuum tube sockets) in its chassis. This is what we would expect to see if an instrument's audio section had been replaced with the newer more accurate Hewlett-Packard design. The lack of any modifications to the audio section of Aubrey Scoon's instrument indicates that the instrument still has the original audio oscillator it was built with. Just this fact alone puts the building of his instrument after the original Beam Ray Corporation shut down in 1939.

Roger Blain decided that if he could determine which design of audio oscillator was used in Aubrey Scoon's instrument then the correct dating of that instrument could be determined. In his discovery work he found that the audio oscillator that was used in the construction of this instrument was the EICO 377. Aubrey Scoon's instrument audio oscillator frequency range and the circuit design are identical to the EICO 377 including the component values, wiring and layout. The only thing that was left out was the double pole double throw switch that allowed for switching between square and sine wave. This new information leaves no doubts as to the approximate date Aubrey Scoon's instrument was built. This information also firmly put its construction date at 1952 or later instead of the 1939 date Aubrey Scoon gives in his report. The next three photos are of the EICO 377.

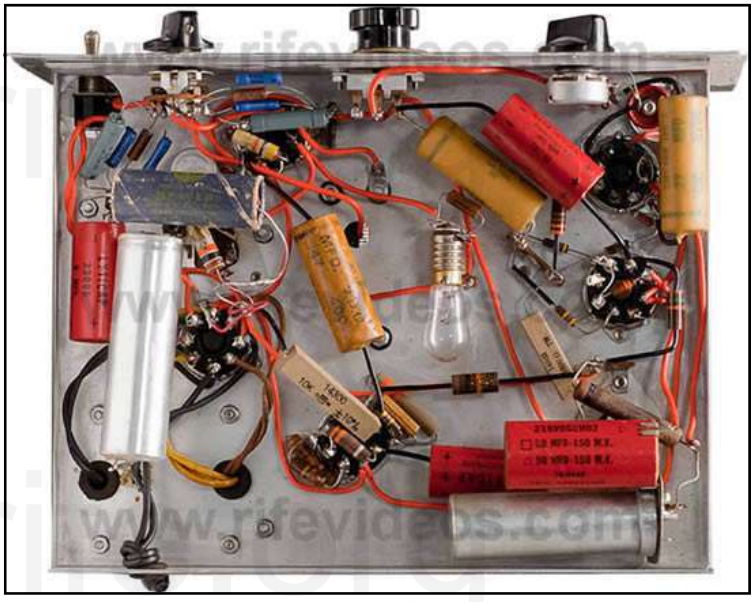

Below are three more photos. The first photo, below on the left, again shows the top view of the EICO 377 component layout. The second photo, below on the right, shows the layout of Aubrey Scoon's audio oscillator. Looking at both of these two photos you can see that the layout is identical. The third photo is a slightly different view of the second photo.

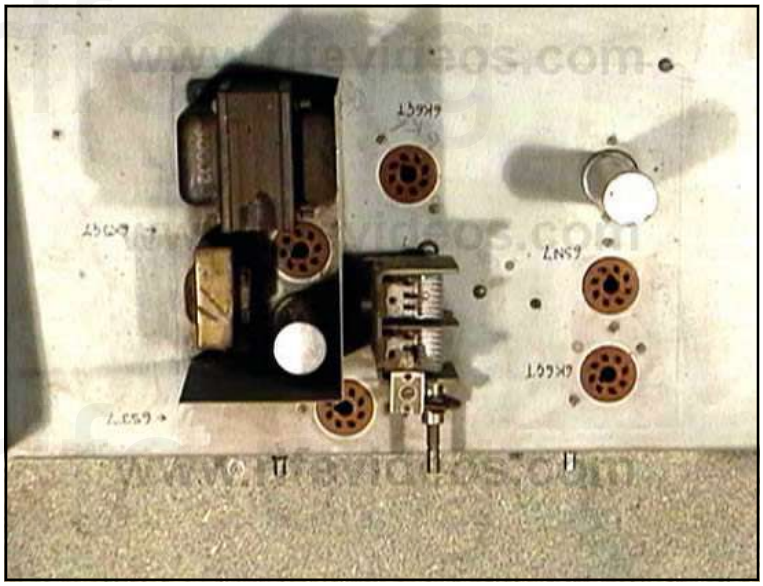

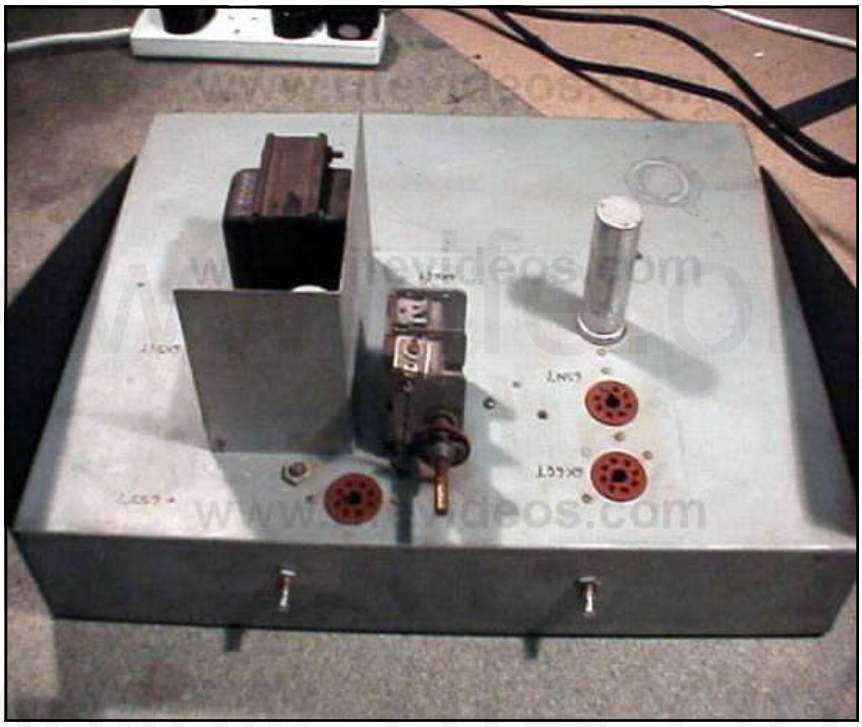

Once we knew that the EICO 377 was the audio oscillator that was used by Verne Thompson in the building of Aubrey Scoon's instrument we went through John Marsh's papers to see if they happened to mention the EICO 377 instrument. We found in his papers a document which shows that John Crane and John Marsh were using the EICO 377 as a pad instrument. This new style of pad instrument used aluminum discs to come in contact with the body of the user instead of using a plasma tube. Below is a quote found in that document:

"The device consists of: 1. An audio oscillator. These are produced by various firms such as Heath Company of Benton Harbor, Mich.; Electronic Instrument Co. of Long Island City, New York; R.C.A. ; General Radio; Knight Co.; and others as well as our own which was a Hartley oscillator initially.

The model submitted herein is Model 377 EICO which is manufactured and sold by them as a commercial item." (Rife Virus Microscope Institute - EICO 377 document).

It really shouldn't be a surprise that Verne Thompson used the EICO 377 in his building of Aubrey Scoon's original Beam Ray Clinical replica design since he was using it for their pad instrument. Since the EICO 377 was first built in 1952 this dates the building of Aubrey Scoon's instrument to 1952 or later. This is also when the 812a vacuum tube was used by Verne Thompson in the newer design called the AZ-58. The AZ-58, built in 1953, was also a Beam Ray Clinical replica design. This explains why the correct vacuum tube for Aubrey Scoon's machine was not the 1930's 809 vacuum tube but the 1950's 812a tube.

In the 1940's and 1950's Verne Thompson was still building Beam Ray replica designs for those doctors who wanted to own an instrument. It is apparent that he was building instruments for anyone that wanted one and was not exclusive to John Crane or John Marsh since Dr. Rife and Verne Thompson did not meet John Crane until 1950. The Rife documents show that Rife, Crane and Marsh had Verne Thompson build their new machine which they called the AZ-58 in 1953. It used lower audio frequencies (original 1930's audio frequencies divided by a factor of 10 times) than what the original Beam Ray Clinical design used. Even though Verne Thompson was building the AZ-58 he was still building the original 1930's design which used the higher audio frequencies. The fact that Aubrey Scoon's instrument was built in 1952, or later, proves that both designs were being built at the same time in the 1950's. The 1953 AZ-58 was using the lower audio frequencies (from 120 Hertz to 2128 Hertz) and Aubrey Scoon's original Beam Ray replica was using the higher audio frequencies (1200 Hertz to 21275 Hertz).

Another discovery made by Roger Blain is also important. It is in regards to the Logo emblem that was on the case of Aubrey Scoon's instrument. Aubrey believed that the "B" Logo found on his instrument must have been the original 1939-1939 Beam Ray Corporation emblem. Below is a photo of this emblem. This was actually the Logo of the company that built the instrument case. The company was Bud Industries. This company is still in business today and are building encloses for electronic devices. Their web site is http://www.budind.com. This discovery, by Roger Blain, also indicates that Aubrey Scoon just didn't do enough investigative work or he would have also discovered that this logo was not Beam Ray Corporations logo.

The information in the next two paragraphs should actually be in Chapter 12. But we are also including it here for those who already have a good understanding of the audio frequencies used in this type of instrument. The reason we are including this information here is some people have asked whether the low audio frequencies (120 Hertz to 2128 Hertz) used in the 1953 AZ-58 are actually the original audio frequencies used in the 1938-1939 Beam Ray machine rather than the high audio frequencies (1200 Hertz to 21275 Hertz) used in Aubrey Scoon's Beam Ray replica instrument. This is a good question and it can easily be answered with certainty. The answer is in the math which produces the correct sidebands for each organism. Only the high audio frequencies (1200, 2400, 6600, 6900, 7660, 7270, 7870, 8300, 8450, 8020, 16000, 17220, 18620, 20080, 21275) will produce the correct sideband frequencies which will produce the higher harmonic frequencies from Dr. Rife's original frequencies. Only six of the low audio frequencies (120, 660, 727, 1862, 2008, 2127-2128 or 2127.5 Hertz as given by John Crane) used in the 1953 AZ-58 when multiplied by a factor 10 times give the exact same high frequency used in Aubrey Scoon's instrument. But the other seven (712, 784, 776, 800, 803, 880 and 1552 Hertz) when multiplied by a factor of ten times will not give the correct high audio frequency. These facts reveal which frequency list came first. Since we know that Philip Hoyland designed this Beam Ray Clinical machine and hid the method of using sideband frequencies to produce higher harmonics of Dr. Rife's M.O.R. frequencies then only the list (Aubrey Scoon's list) that will produce Dr. Rife's higher harmonic frequencies could be the original list.

We will point out a few more facts. From the Beam Ray Trial we learned that no one but Philip Hoyland understood how the instrument worked. Not even Dr. Rife, Verne Thompson, John Crane or John Marsh or anyone else understood that the RF carrier frequency had to be matched to the audio frequencies in order to produce the sideband frequencies that would hit the higher harmonic frequencies of Dr. Rife's original frequencies. John Crane and John Marsh said many times the RF carrier frequency did not matter. In fact, they eventually quit using the RF carrier frequency when they built their 1950's contact pad style instrument. This clearly shows that they did not understand that the original Rife Ray #5 or Beam Ray Clinical instrument worked on harmonic sidebands. Had they understood this simple fact they never would have changed the RF carrier frequency or built their contact pad style instrument without using an RF carrier frequency. They also would not have lowered or changed any of the audio frequencies if they understood the sideband method used by Philip Hoyland. Both frequency lists would be identical except that one list would be 10 times higher than the other list. Only someone who did not understand how the audio frequencies really worked would have lowered them and then changed them. Only the list which came first would have all the correct frequencies. Again this information proves that the high audio frequency list came first. The low audio frequency list used in the 1953 AZ-58 would have come later in the 1950's because it is the list, when multiplied by 10 times, will only produce some of the correct sideband frequencies. Only someone such as Philip Hoyland could have made the high audio frequency list since the high audio frequencies are the only frequencies that will produce Dr. Rife's higher M.O.R. harmonic frequencies. As we said, the answer to this question is found in the math.

Now we will go back to the EICO 377 and Aubrey Scoon's audio oscillator. Other than the audio oscillator going to 200,000 Hertz (original Beam Ray instrument going to about 42,000 Hertz) Aubrey Scoon's instrument is a replica of the original Beam Ray Clinical instrument. With this knowledge we know that Aubrey Scoon's instrument was a faithful reproduction of Philip Hoyland's Beam Ray Clinical instrument. Just like the original Beam Ray Clinical instrument Aubrey Scoon's Beam Ray Clinical replica instrument used the sine wave waveform for both the RF carrier frequency and the low audio frequencies. The original machines waveform is shown in the first photo, on the left, at the top of the next page. The second photo, on the right, at the top of the next page shows Aubrey Scoon's instrument's modulated waveform. These two waveforms are similar. The replica that we built of Aubrey Scoon's instrument does not have any parasidic oscillations and its waveform looks like the original Beam Ray Clinical instrument waveform shown in the first photo, on the left, on the next page.

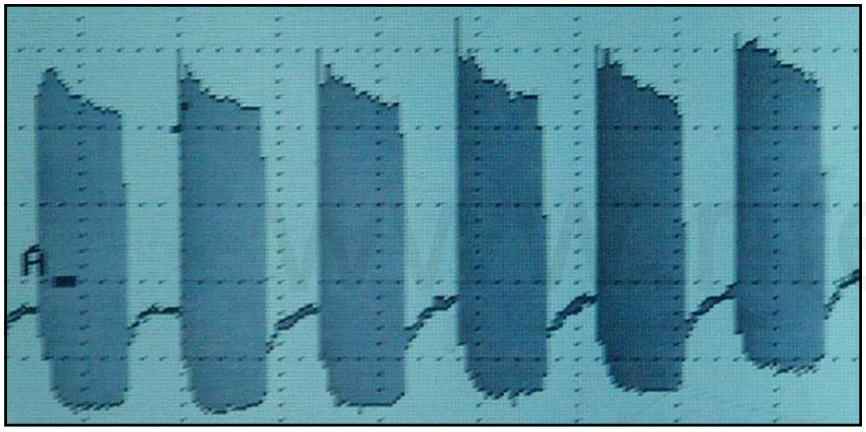

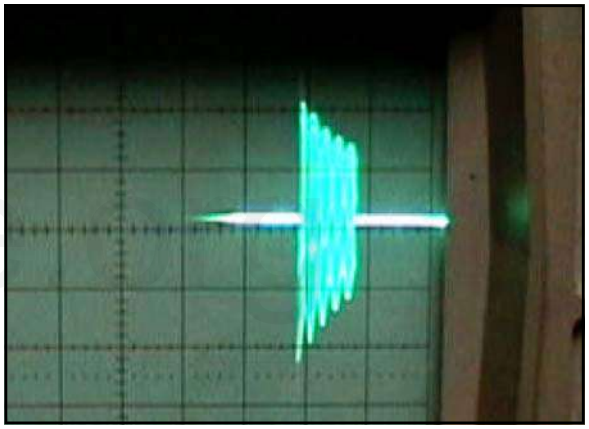

The most important information that came with Aubrey Scoon's instrument was the higher audio frequency list which the doctor who owned it used on his patients. Dr. Low's original Beam Ray Clinical instrument frequency list was lost to time. However, Aubrey Scoon's frequency list was not lost so we can use it and reconcile its audio frequencies to Dr. Rife's original high RF frequencies using the side-band method that was used in this style of instrument.

Since we know that Philip Hoyland tested this Clinical instrument in the laboratory he would have calculated the exact audio frequencies to hit the M.O.R.s. The Rife ray #4 frequencies could be one quarter of one percent off, because of the limits of the 1930's technology, if Philip Hoyland only read the frequency one time. This appears to be what happened because the frequencies read in 1935 are rounded to the nearest one thousandth. In 1935 Philip Hoyland needed the information about the range of Dr. Rife's frequencies to build the Rife Ray #4. But in 1936 when he was building the Rife Ray #5 or Beam Ray Clinical instrument he needed more accurate frequencies for this new instrument since it was using the new sideband method. When the math was done using the high audio frequencies it showed that the frequencies were not rounded to the nearest one thousandth, but they were more precise. It is apparent that the testing Philip Hoyland did in the laboratory in the summer of 1936 on microorganisms allowed him to get the most accurate frequency for each organism. In 1935 the Rife Ray #4 frequency given for Streptothrix was 192,000 Hertz but the frequency for the 1936 Rife Ray #5 or Beam Ray Clinical instrument was 191,803. Not only was this frequency just a little different, but all the frequencies were a little different. This indicates that Philip Hoyland took a more accurate reading of the frequencies of each organism in 1936 for use in his new instrument.

When we did the mathematical equations in order to determine if the audio frequencies from Aubrey Scoon's instrument could produce the correct M.O.R. frequencies when used with the 3.30 MHz RF carrier frequency the math had to be done in reverse order. Using the audio frequencies to determine the most accurate M.O.R.s through the sideband frequencies was the only way to figure out what the frequencies were for each organism listed. If these harmonic frequencies, when divided down, were within one quarter of one percent of the Rife Rays #4 original M.O.R.s. then we knew that the 3.30 MHz RF carrier frequency was the correct carrier frequency. This would also prove that the sideband method was the method of producing the M.O.R.s. in the Beam Ray Clinical instrument. Doing this would also show that the two instruments worked identically the same way. Aubrey Scoon's Beam Ray Clinical instrument with its audio frequencies would firmly prove the sideband method was the method that Philip Hoyland developed. Aubrey Scoon's instrument would also prove that Philip Hoyland used at least two different fixed RF carrier frequencies in the instruments in order to help keep anyone from figuring out the secrets of the instruments. If the carrier frequency is different then the audio frequencies will also be different because they have to be properly matched in order to create the sidebands on the correct high RF harmonic M.O.R. frequencies.

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Below is a frequency comparison chart of Aubrey Scoon's Beam Ray Clinical replica instrument. In the "Rife Ray #4 Frequencies In Hertz" column are Dr. Rife's M.O.R. frequencies read by Philp Hoyland in 1935. In the "Aubrey Scoon's Sideband Audio Frequencies In Hertz" column are the audio frequencies used to create the correct sideband frequencies to hit the harmonic Rife Ray #4 frequencies. In the "Rife Ray #4 Frequencies Based on Scoon's Audio Frequencies" column we see the more accurate M.O.R. frequencies that these audio frequencies produce. You will notice in the "Rife Ray #4 Frequencies In Hertz" column that the frequency for Actinomycosis or Streptothrix is 192,000 Hertz and in the "Rife Ray #4 Frequencies Based on Scoon's Audio Frequencies" column is the frequency of 191,803 Hertz. There is only a 197 Hertz difference between these frequencies. If you compare both of these columns you will notice how closely these frequencies match up. All the frequencies which are in the column "Rife Ray #4 Frequencies Based On Scoon's Audio Frequencies" are less than one quarter of one percent off of the "Rife Ray #4 Frequencies In Hertz." Anyone looking at this chart can see that this could not be just a coincidence.

Aubrey Scoon's Sideband Audio Frequencies Reconciled To Rife's Original High Frequency M.O.R.s.

Microorganism *These frequencies were not included in Aubrey Scoon's instrument.	**Rife Ray #4 Frequencies In Hertz**	**Higher Rife Ray #4 Harmonic Frequencies In Hertz**	**Aubrey Scoon's Sideband Audio Frequencies In Hertz**	**Higher Rife Ray #4 Harmonic Frequencies in Hertz Based On Scoon's Audio Frequency and 3.30 MHz Carrier**	***Carrier Difference Frequency**	**Number of Sideband Harmonics**	**Rife Ray #4 Frequencies Based On Scoon's Audio Frequencies**
Actinomycosis or Streptothrix	192,000 Hz	3,264,000 or 17th	7,870 Hz	3,260,650 or 17th	39,350 Hz	5	191,803 Hz
Anthrax	139,200 Hz	3,340,800 or 24th	*10,200 Hz	3,340,800 or 24th	40,800 Hz	4	139,200 Hz
B or E Coli Rod	417,000 Hz	3,336,000 or 8th	8,020 Hz	3,332,080 or 8th	32,080 Hz	4	416,510 Hz
B or E Coli Virus	770,000 Hz	3,080,000 or 4th	17,220 Hz	3,076,140 or 4th	223,860 Hz	13	769,035 Hz
BX Virus Carcinoma	1,604,000 Hz	3,208,000 or 2nd	21,275 Hz	3,214,900 or 2nd	85,100 Hz	4	1,607,450 Hz
BY Sarcoma	1,530,000 Hz	3,059,040 or 2nd	20,080 Hz	3,059,040 or 2nd	240,960 Hz	12	1,529,520 Hz
Gonorrhea	233,000 Hz	3,262,000 or 14th	*9,500 Hz	3,262,000 or 14th	38,000 Hz	4	233,000 Hz
Pneumonia or Spinal Meningitis	427,000 Hz	3,416,000 or 8th	7,660 Hz	3,414,900 or 8th	114,900 Hz	15	426,862 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz	3,346,000 or 7th	7,270 Hz	3,343,620 or 7th	43,620 Hz	6	477,660 Hz
Streptococcus Pyogenes	720,000 Hz	3,600,000 or 5th	8,450 Hz	3,595,750 or 5th	295,750 Hz	35	719,150 Hz
Syphilis	789,000 Hz	3,156,000 or 4th	6,600 Hz	3,154,800 or 4th	145,200 Hz	22	788,700 Hz
Tetanus	234,000 Hz	3,276,000 or 14th	1,200 Hz	3,276,000 or 14th	24,000 Hz	20	234,000 Hz
Tuberculosis Rod	369,000 Hz	3,321,000 or 9th	8,300 Hz	3,324,897 or 9th	24,897 Hz	3	369,433 Hz
Tuberculosis Virus	769,000 Hz	3,076,000 or 4th	16,000 Hz	3,076,000 or 4th	224,000 Hz	14	769,000 Hz
Typhoid Rod	760,000 Hz	3,040,000 or 4th	6,900 Hz	3,037,800 or 4th	262,200 Hz	38	759,450 Hz
Typhoid Virus	1,445,000 Hz	2,890,000 or 2nd	18,620 Hz	2,890,360 or 2nd	409,640 Hz	22	1,445,180 Hz
Worms	?		2,400 Hz				

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We will now give a simple description of how we reconciled these audio frequencies to Dr. Rife's original high RF frequencies which were used in the Rife Ray #3 and Rife Ray #4 Rife Machines. The Rife Ray #4 paperwork gives us the Streptothrix frequency of 192,000 Hertz. Since we know that Philip Hoyland used the higher harmonic frequency closest to the RF carrier frequency in these instruments what we have to do is multiply 192,000 Hertz by 17 to get the closest frequency to the 3,300,000 Hertz. The 192,000 Hertz multiplied by 17 give us a frequency of 3,264,000 Hertz. The difference between these two frequencies is only 36,000 Hertz. This math gives us the method that Philip Hoyland used.

Now Hoyland used an audio frequency of 7,870 Hertz as the frequency to produce the proper sideband spacing in Aubrey Scoon's instrument. If we multiply 7,870 Hertz times 5 we get the frequency of 39,350 Hertz which is the closest frequency to 36,000 Hertz. If we take 3,300,000 Hertz and minus 39,350 Hertz we get 3,260,650 Hertz which would be the higher harmonic frequency which was used by Philip Hoyland on Streptothrix. Now if we divide 3,360,650 Hertz by 17 we get the true frequency of 191,803 Hertz used by Dr. Rife on Streptothrix. Aubrey Scoon's sideband audio frequencies now give us the most accurate frequencies for the organisms since they are not rounded to the nearest thousandth. Those frequencies are found in the chart, on the previous page, with the column labeled "Rife Ray #4 Frequencies Based on Scoon's Audio Frequencies". The math we did for this chart shows that Aubrey Scoon's Beam Ray Clinical Replica instrument works on the harmonic sideband method to produce the M.O.R.s.

It wasn't until we were able to get the original Beam Ray Clinical instrument and figure out how it worked did we have the ability to determine how Aubrey Scoon's replica instrument really worked. Once we understood how these instruments really worked we could finally figure out the M.O.R. frequencies for Sarcoma, Pneumonia and Tuberculosis. This was made possible because some other documents that we have gave a second reference point to work with to help us determine the correct frequency. Worms (hookworms) however, did not have a second reference point so the only way to produce the M.O.R. frequency for worms is through the sideband method using the audio frequency of 2,400 Hertz in combined with the 3.30 MHz RF carrier frequency.

Also included on pages 137 through 144 are the spectrum analyzer graphs showing the sideband frequencies for each organism using Aubrey Scoon's Beam Ray replica instrument audio frequencies with his 3.30 MHz RF carrier frequency. These spectrum analyzer graphs also include Anthrax and Gonorrhea which was not included with Aubrey Scoon's audio frequency list.

On page 145 are photos of Aubrey Scoon's instrument that we built. On page 146 is the schematic of this 1950's instrument. The 866 vacuum tubes have been replaced with solid state rectifiers. Also the old vacuum tube audio oscillator was not included in the case of the instrument. It is easier and more accurate to use Aubrey Scoon's booster amplifier and a modern function generator to produce the audio frequencies that were used in this instrument. The layout of the electronic parts of this instrument is also very important because of the inherent interference problems that come with RF oscillators. Again anyone who would like to build this instrument should have a good understanding of old tube technology. Some parts of this circuit use up to 2000 volts DC with substantial current and can easily kill anyone who is not familiar with this kind of current or voltage. We take no responsibility for anyone who builds this instrument. We recommend that you have professional help.

On pages 147-159 we have included in this report Aubrey Scoon's original report that was on his website. The reason we have included his report in this report is due to the fact that Aubrey Scoon passed away a few years ago and his website is no longer available on the internet. The information that his report gives is very important to those who are interested in how Dr. Rife's machines worked.

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Chapter Summary: We now know that Aubrey Scoon's instrument is a copy Dr. Couches' original Rife Ray #5 or Beam Ray Clinical instrument which Dr. Couche purchased from the original 1938-1939 Beam Ray Corporation. Aubrey Scoon's instrument was built by Dr. Rife's engineer, Verne Thompson, sometime in 1952 or later. Dr. Low's original Beam Ray Clinical instrument, which was built by the original Beam Ray Corporation, was the most important machine found because it made it so we now know that it was Philip Hoyland who built the audio frequency instrument that used a fixed RF carrier frequency. With this information we were able to prove that Aubrey Scoon's instrument was a faithful replica of the original Beam Ray Clinical instrument. It came with a frequency list that the doctor who owned it used on his patients.

When it comes to the audio frequency list Aubrey Scoon's instrument is the most important Rife machine found because it gives us the original audio frequencies used in the original Beam Ray Clinical instrument. With this frequency list we have been able to prove that Philip Hoyland used higher harmonic frequencies of Dr. Rife's original Rife Ray #3 and Rife Ray #4 frequencies in his Beam Ray Clinical instrument. This list also gives us some of Dr. Rife's frequencies which had been lost, such as the BY Cancer virus frequency. This same audio frequency list was lowered by a factor of 10 times and used in the 1953 AZ-58 which was built by Verne Thompson. With this information we have been able to prove that these audio frequencies are not Dr. Rife's original M.O.R. frequencies and that they do not devitalize any microorganisms. These audio frequencies, when used with a 3.30 Megahertz carrier frequency, will produce harmonic sideband frequencies which will hit the higher harmonic RF M.O.R. frequencies found by Dr. Rife. Though Aubrey Scoon did not live to realize how important his instrument was we now know how important this Rife instrument really is. Dr. Low's instrument and Aubrey Scoon's instrument have revealed how Philip Hoyland's Beam Ray Clinical instrument was a harmonic instrument.

In the next chapter we will discuss the 1953 AZ-58 built by Verne Thompson and the history of that instrument in detail.

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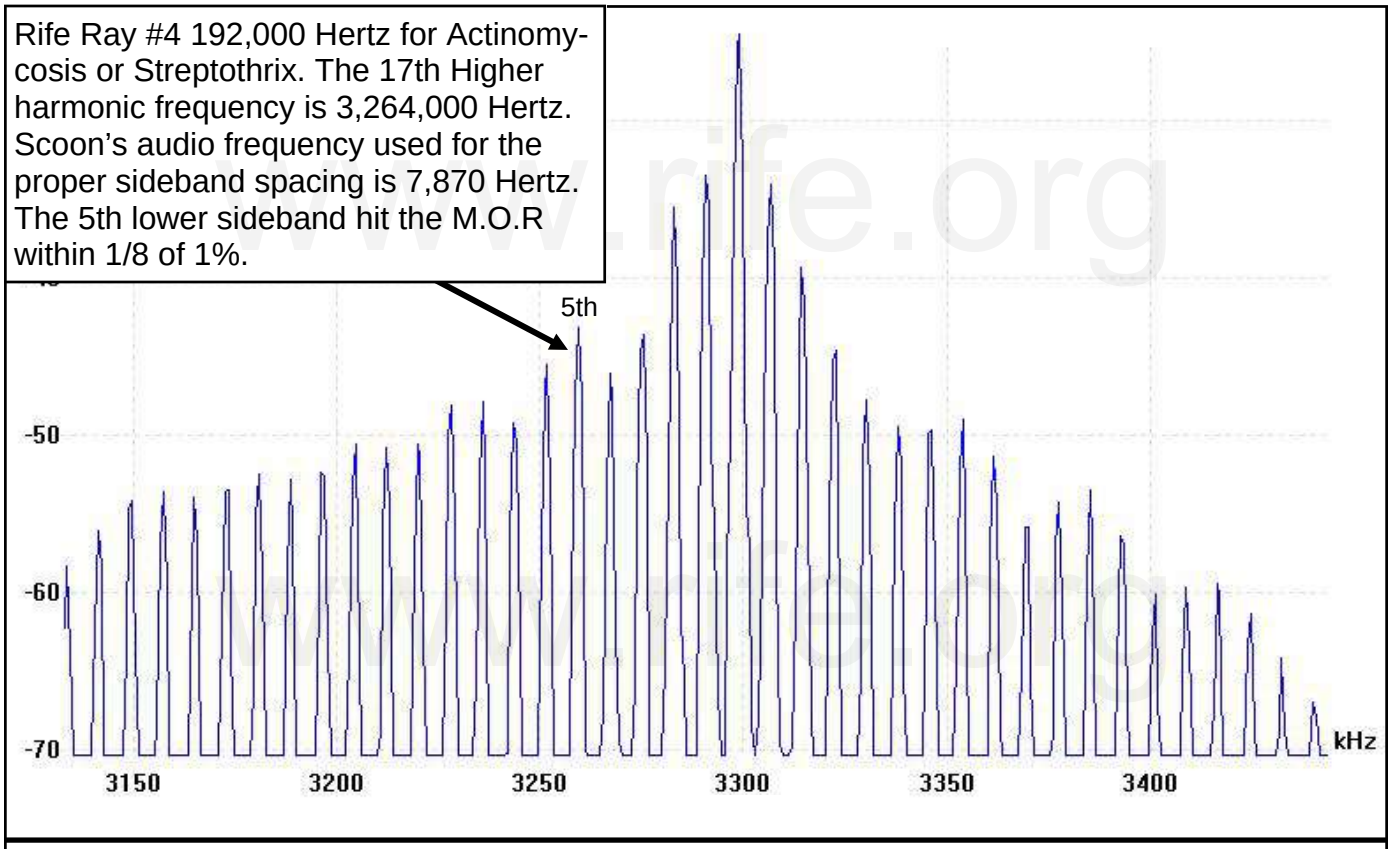

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

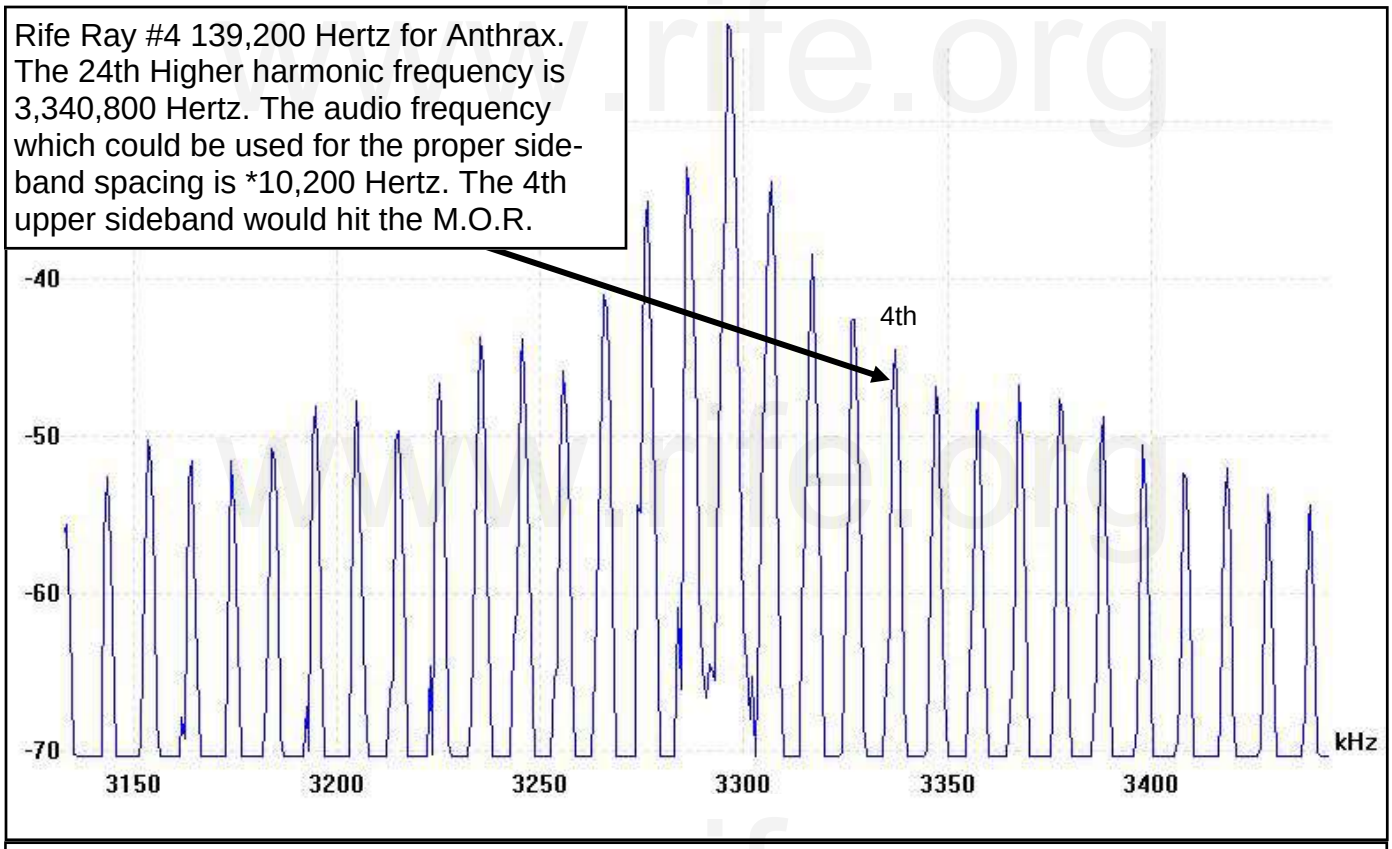

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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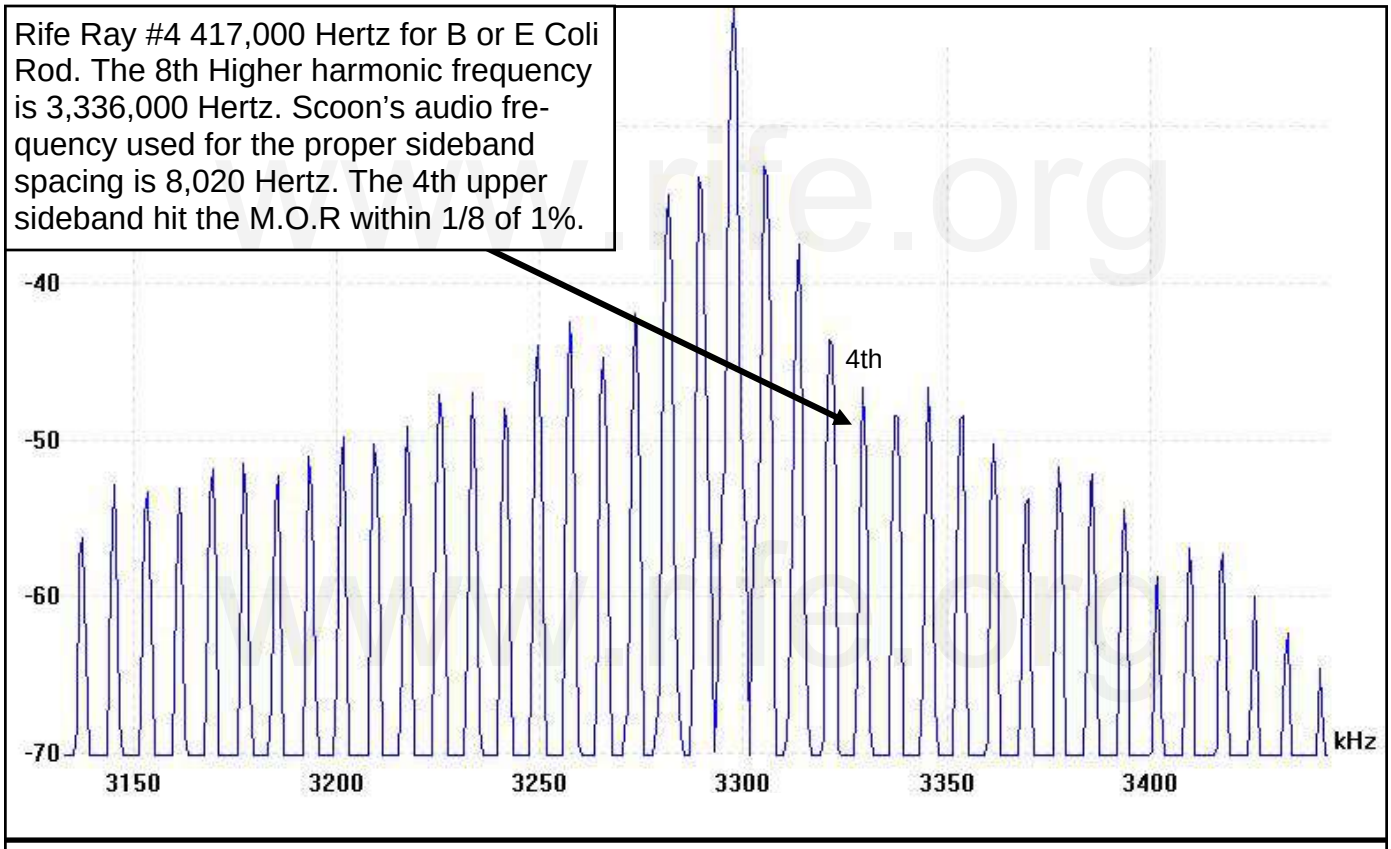

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

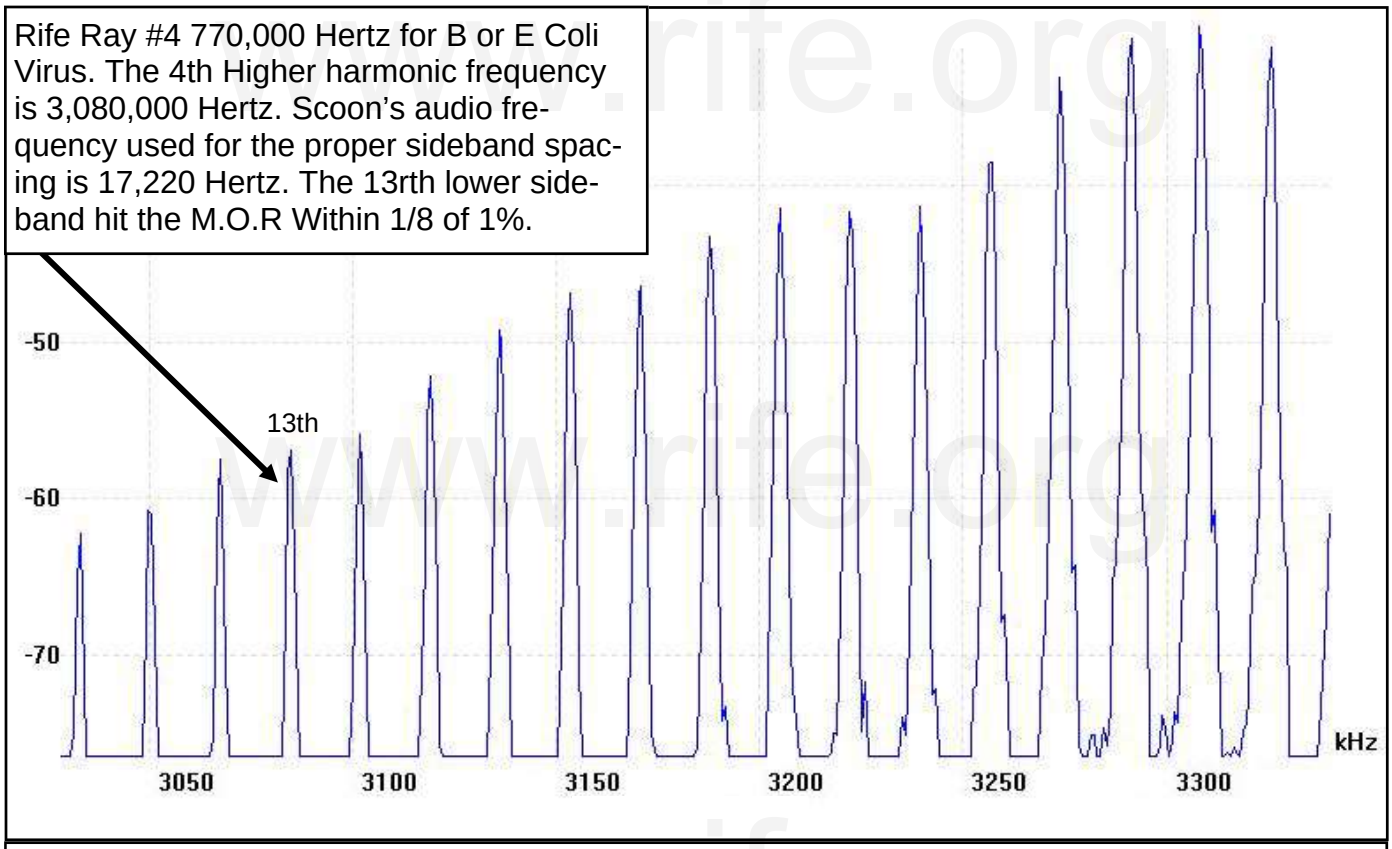

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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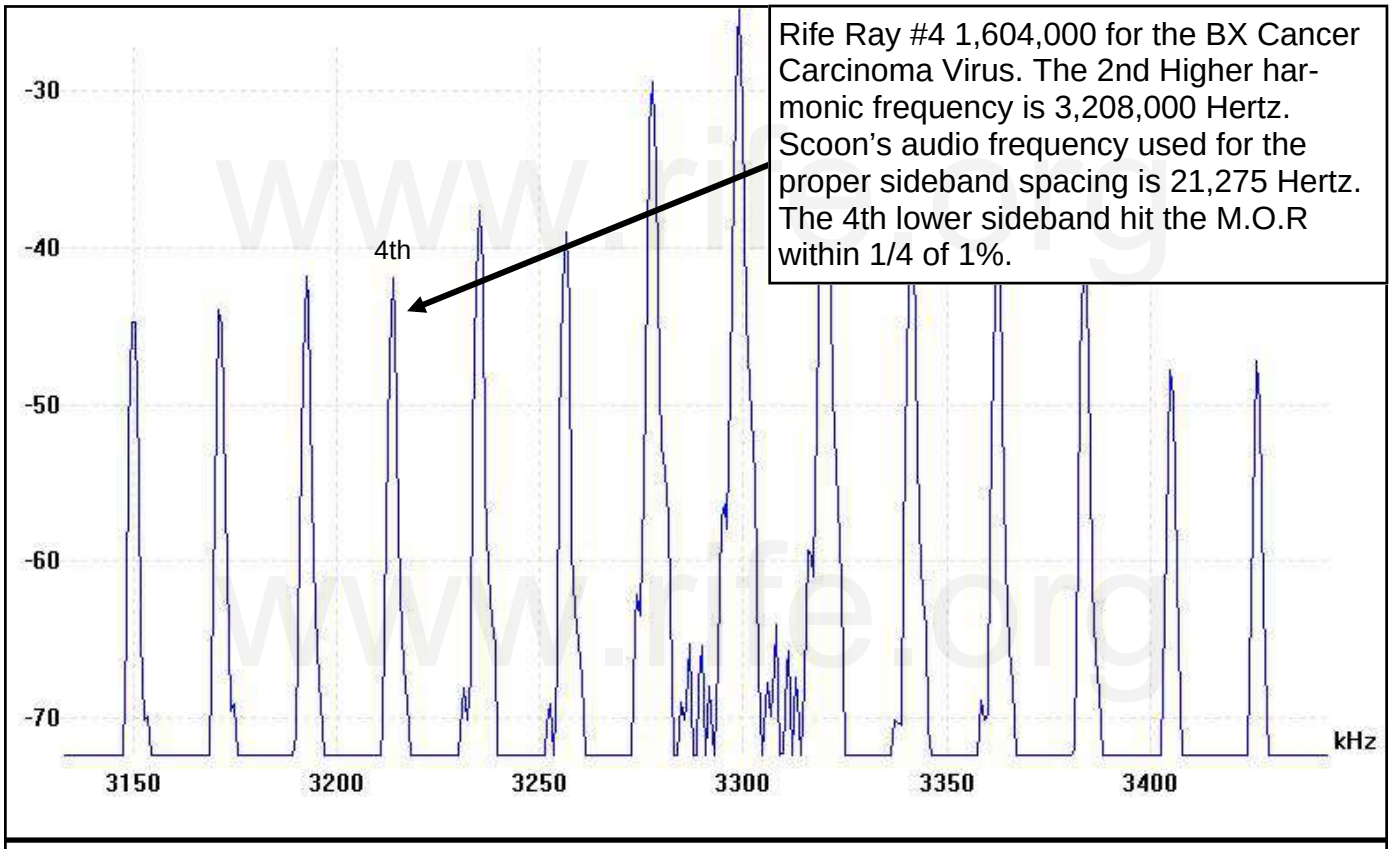

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

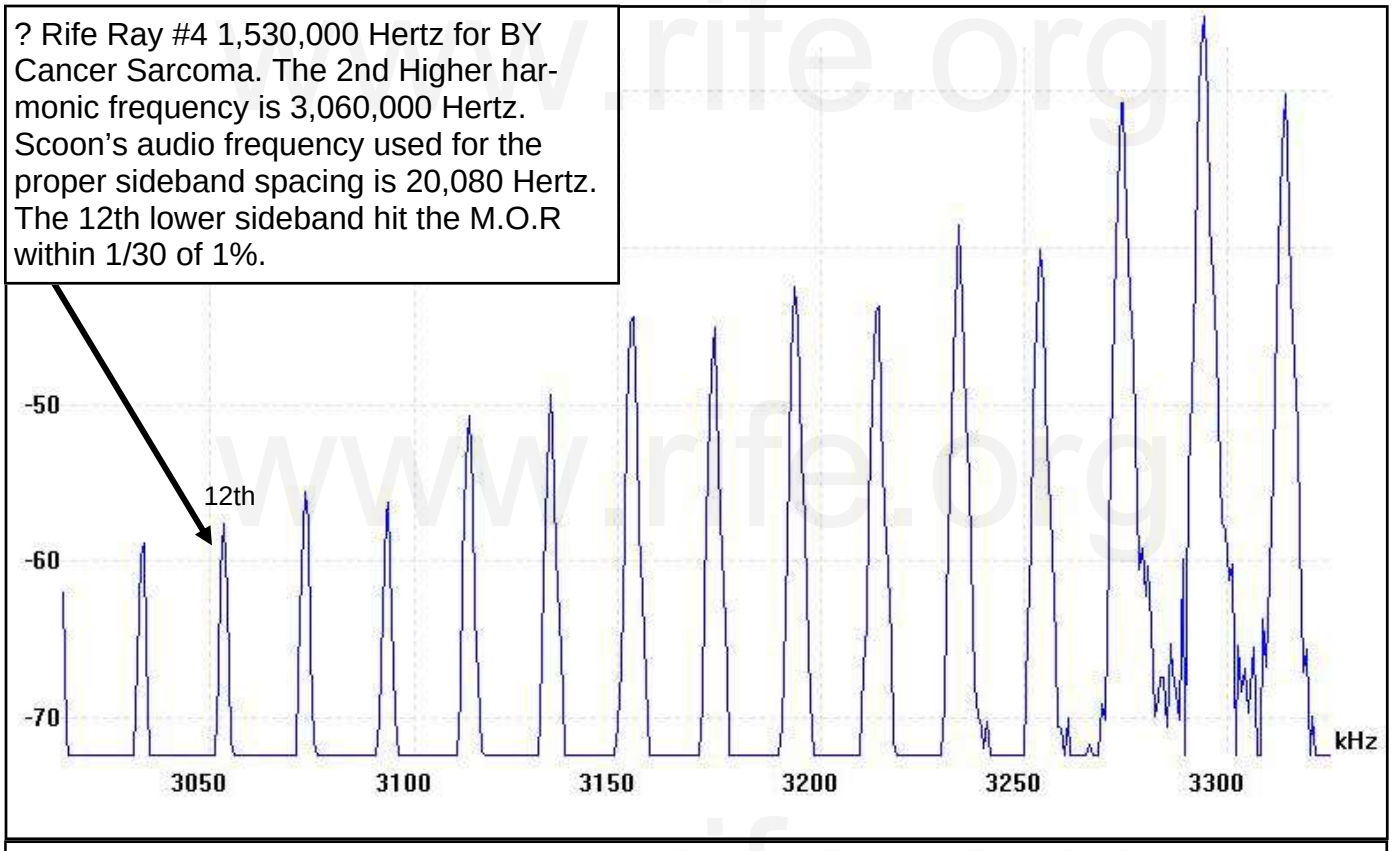

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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Rife Ray #4 233,000 Hertz for Gonorrhea. The 14th Higher harmonic frequency is 3,262,000 Hertz. Audio frequency which could be used for the proper sideband spacing is *9,500 Hertz. The 4th lower sideband would hit the M.O.R.

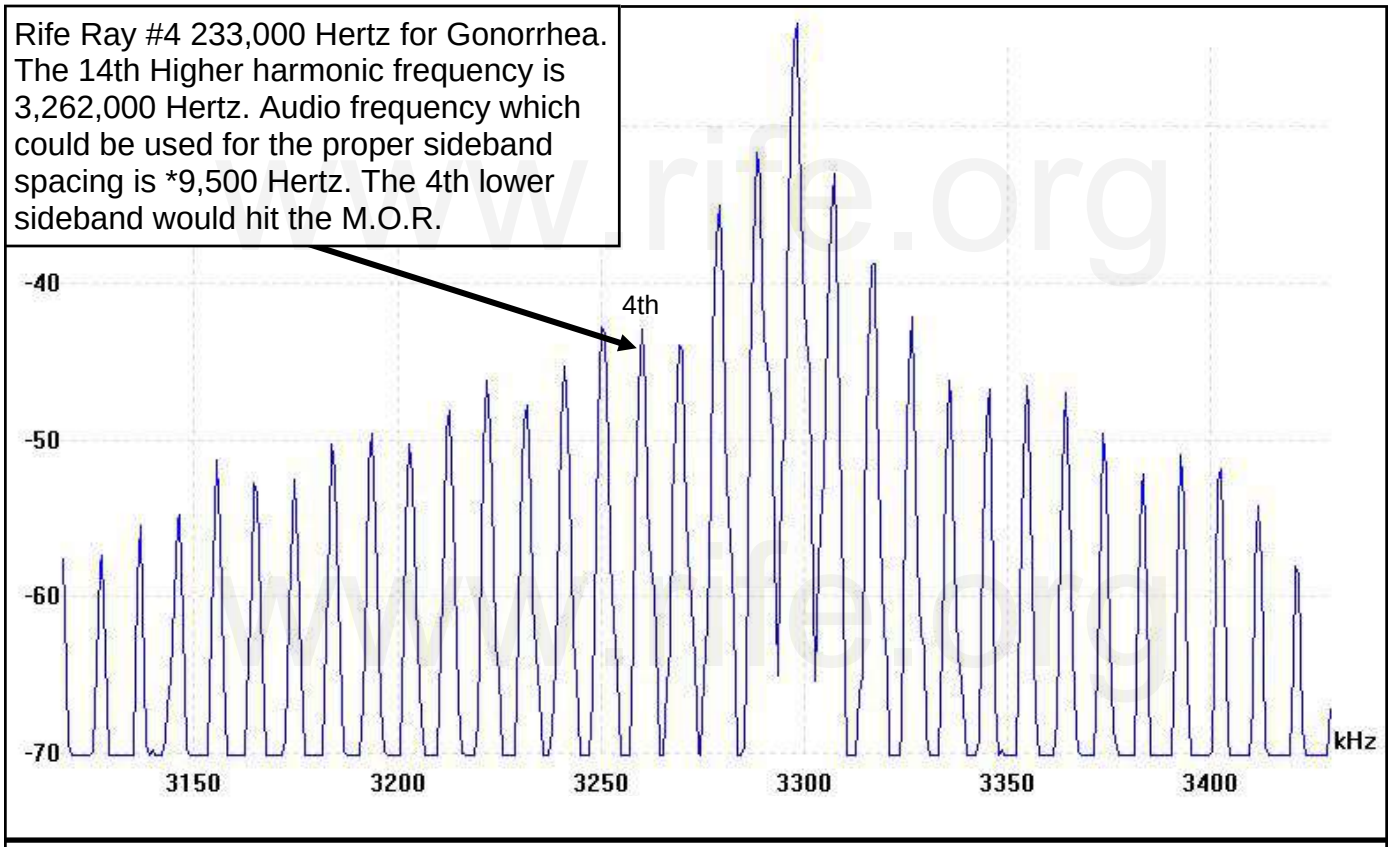

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

Rife Ray #4 427,000 Hertz for Spinal Meningitis. The 8th Higher harmonic frequency is 3,416,000 Hertz. Scoon's audio frequency used for the proper sideband spacing is 7,660 Hertz. The 15th upper sideband hit the M.O.R within 1/30 of 1%.

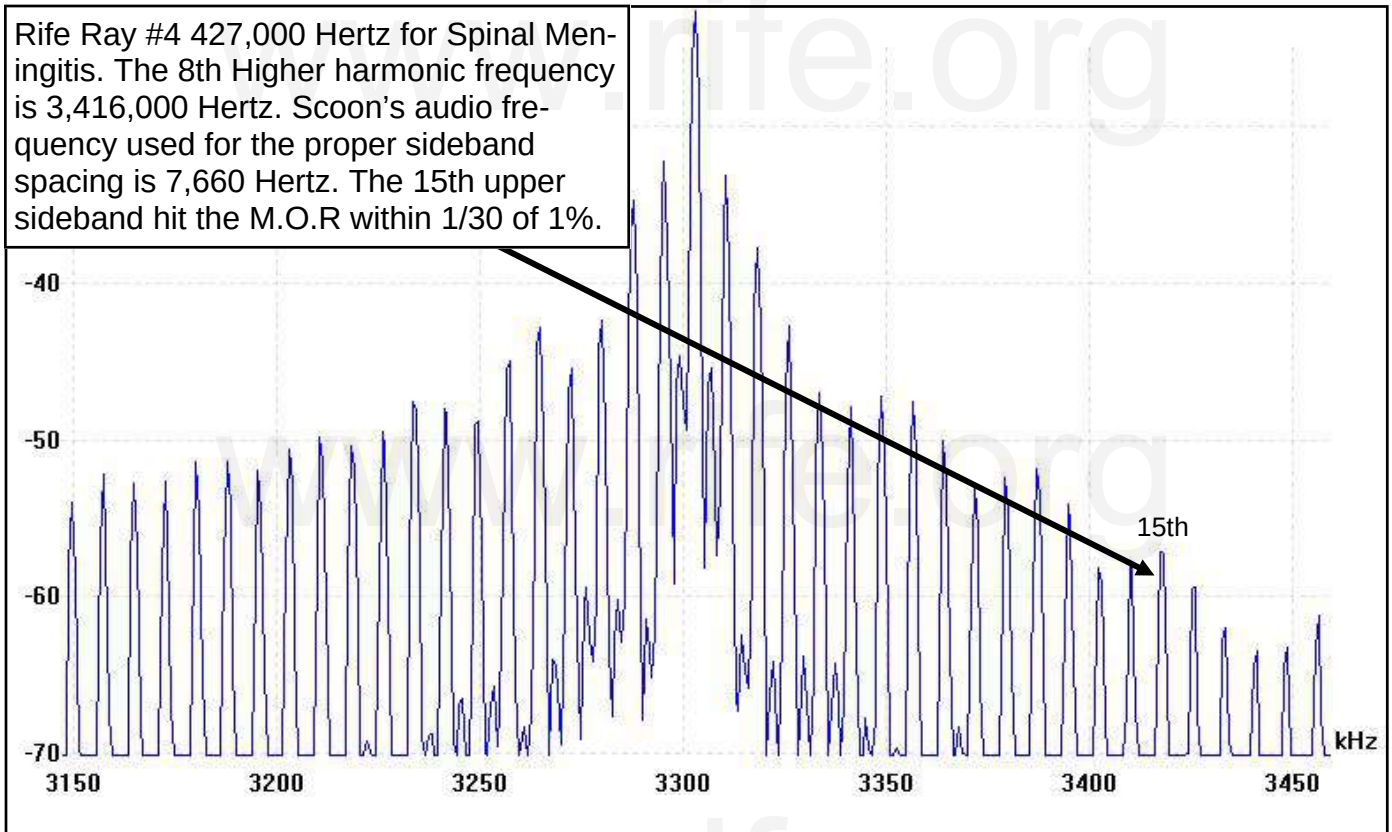

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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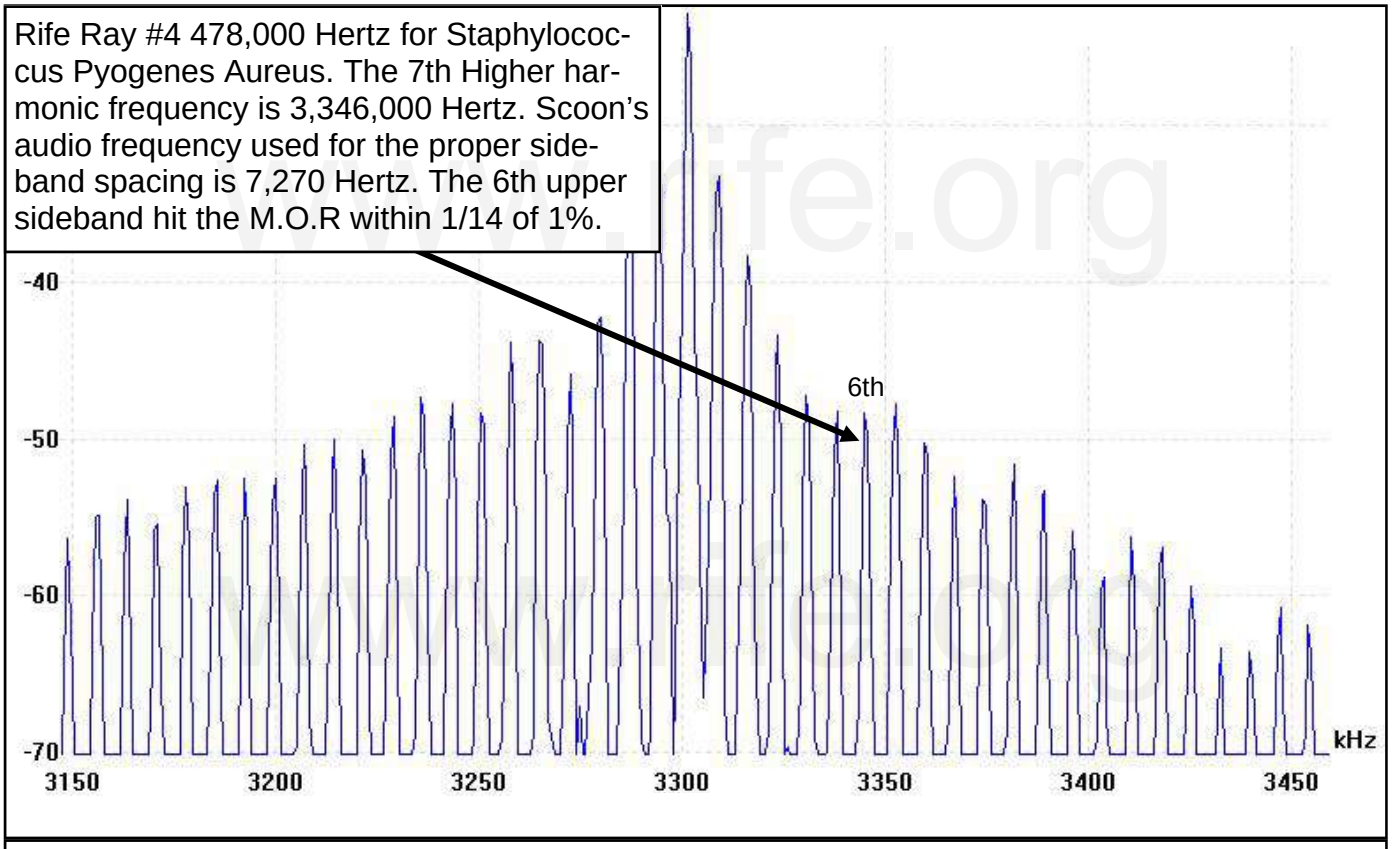

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

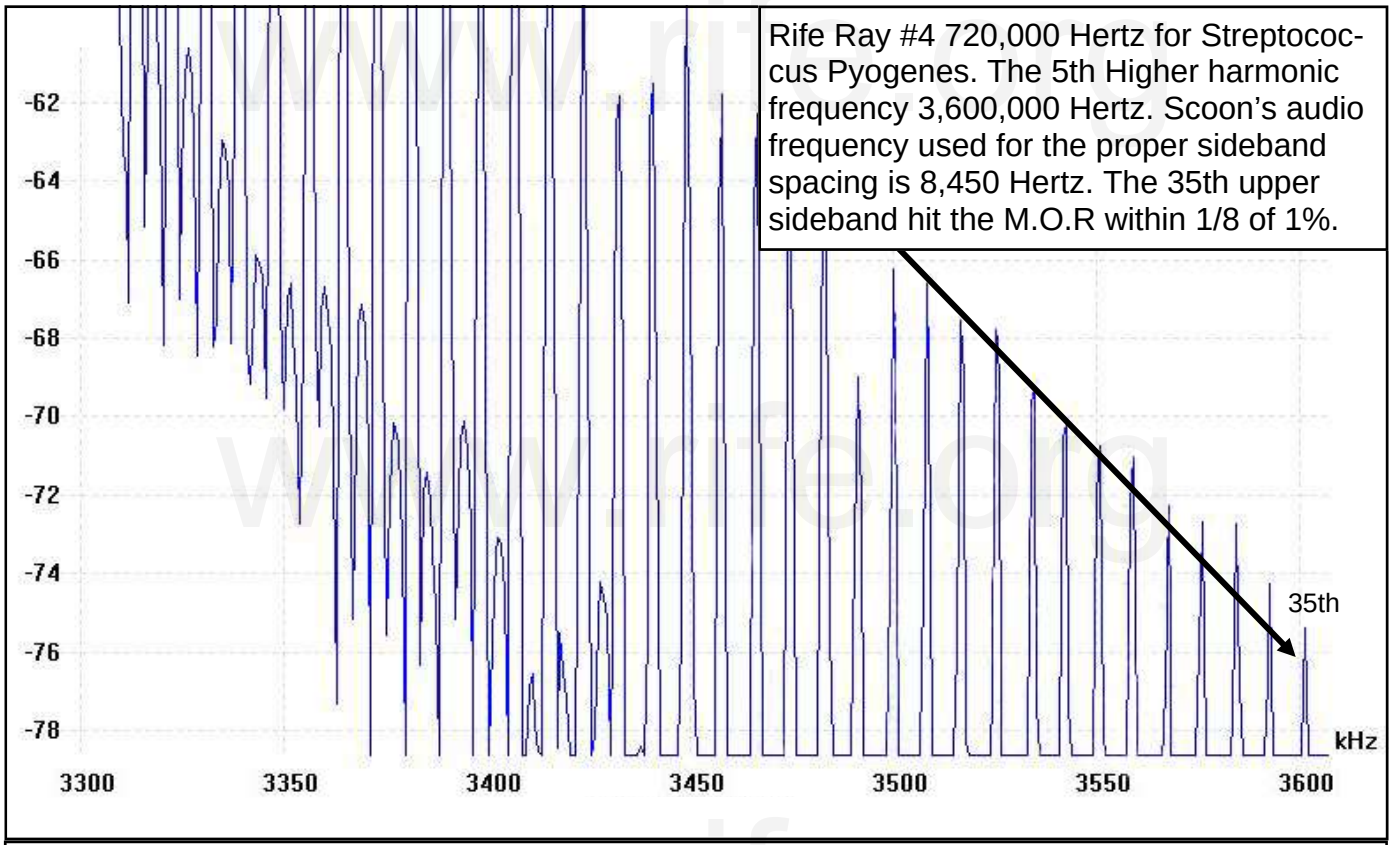

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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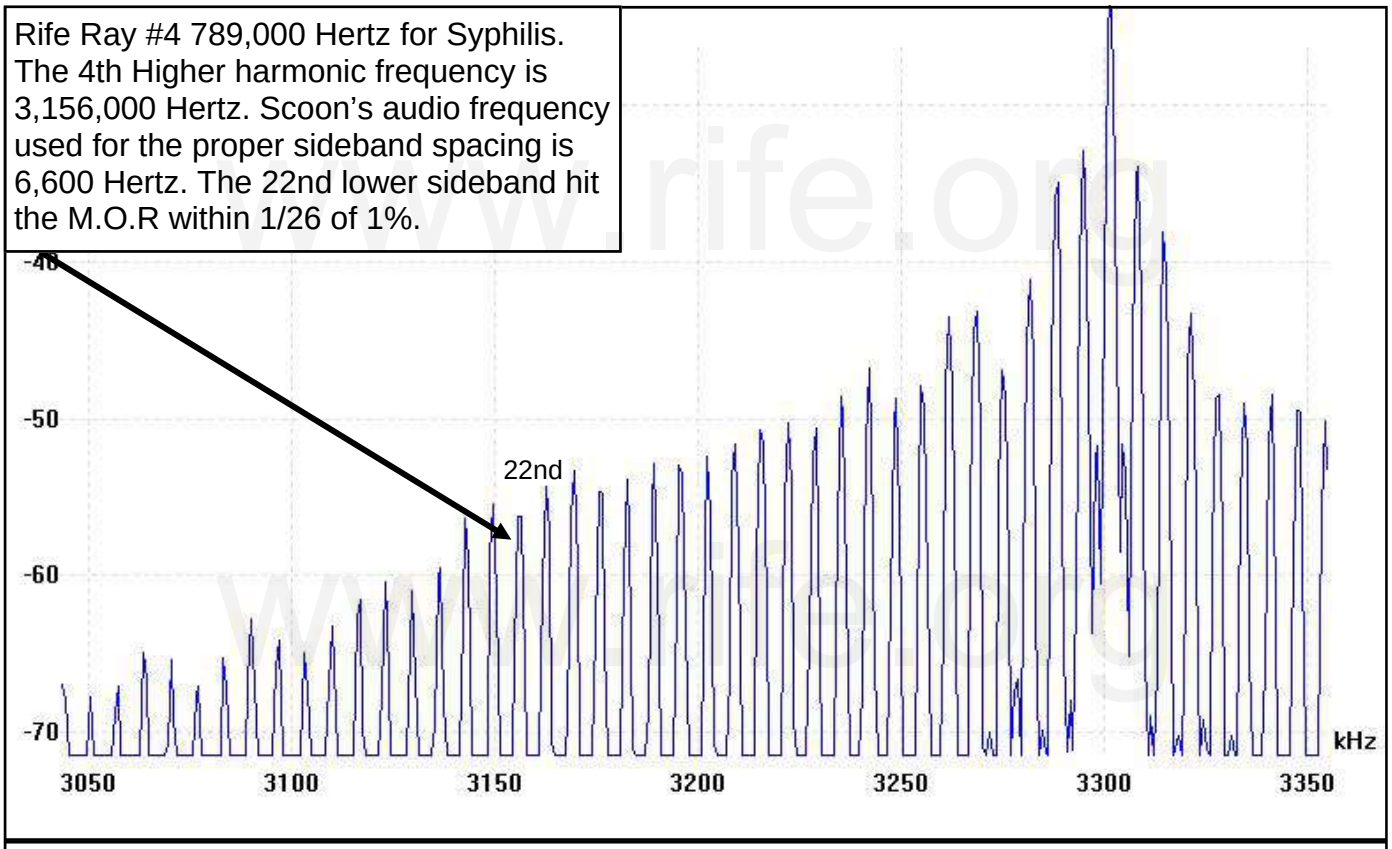

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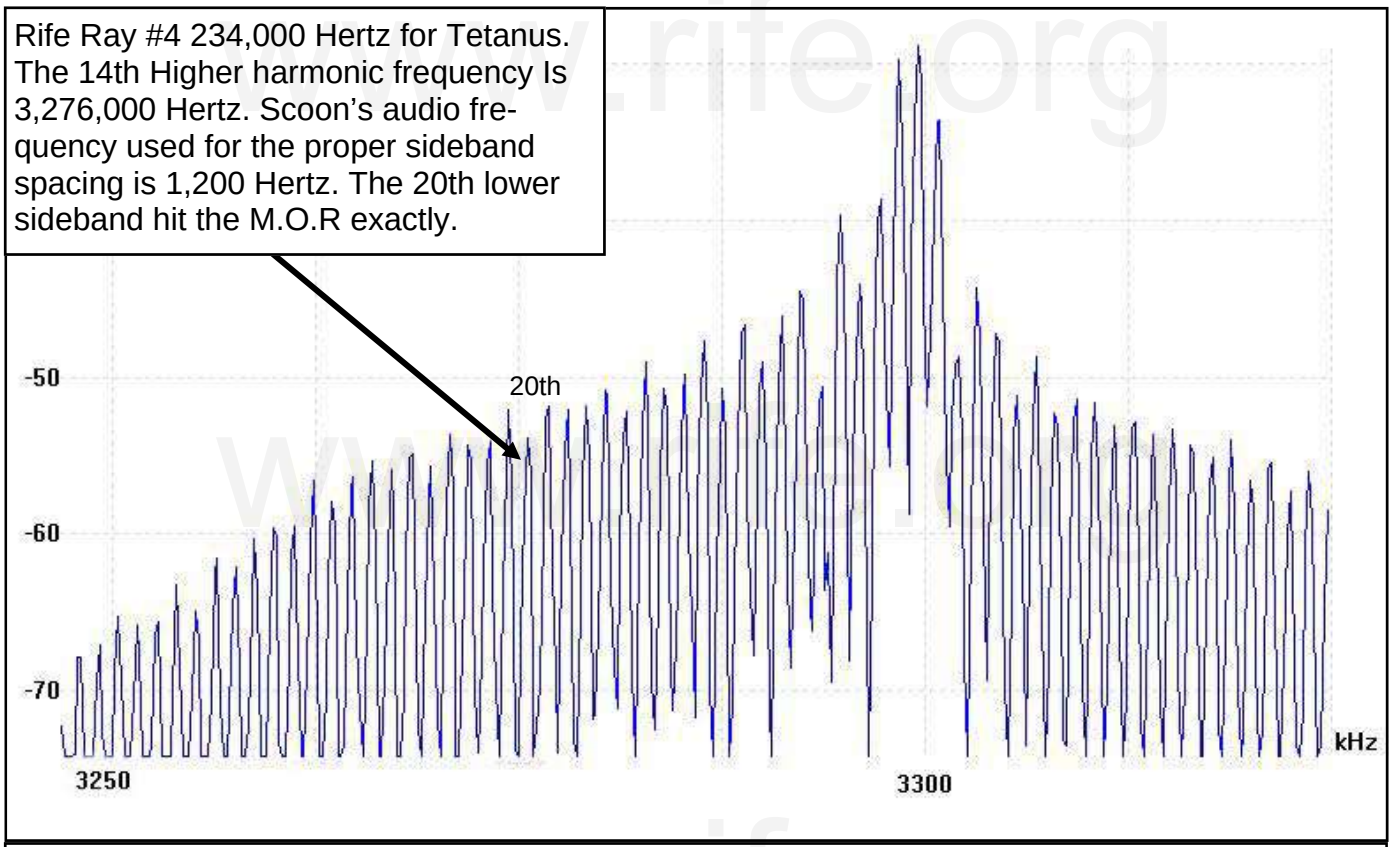

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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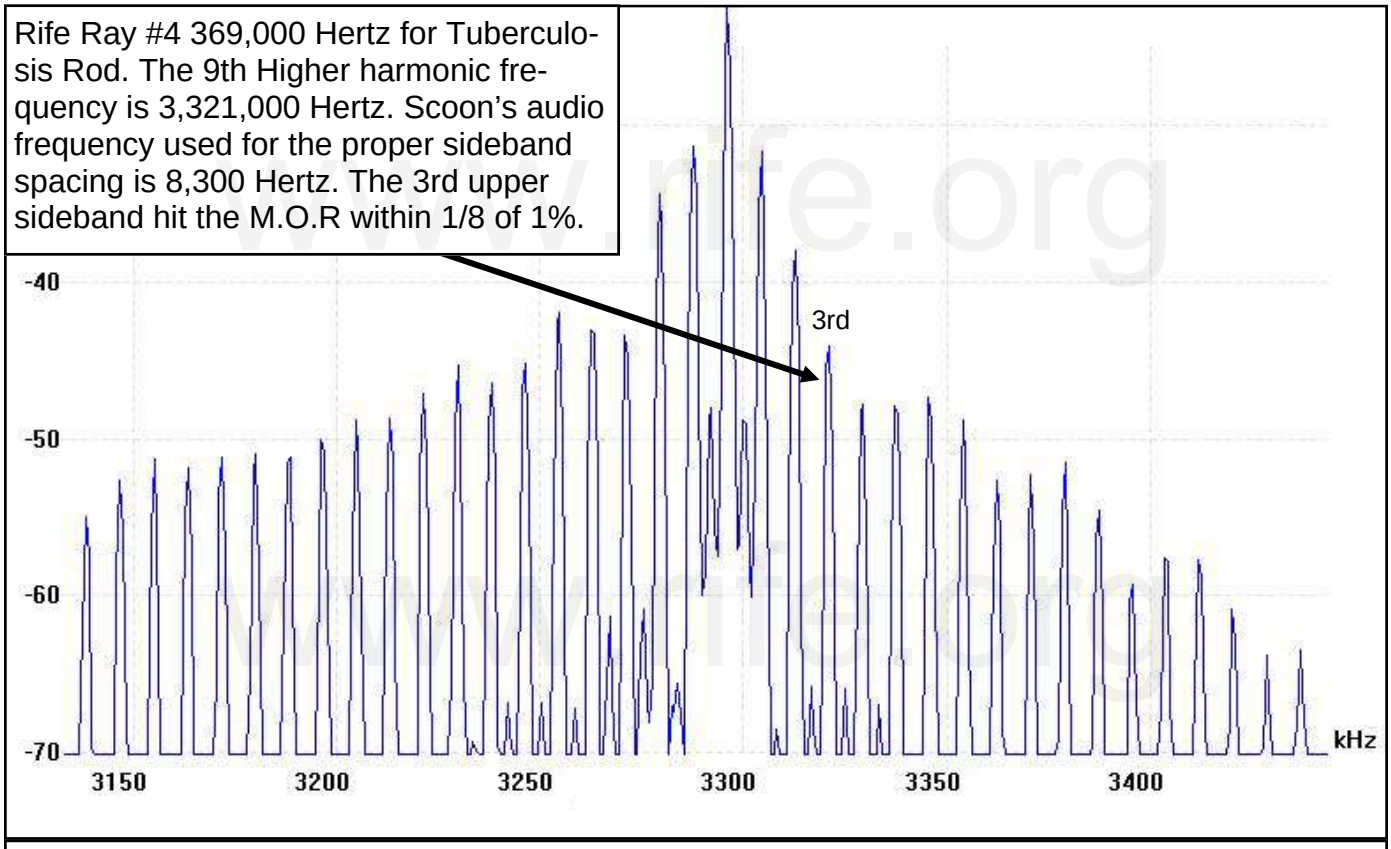

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

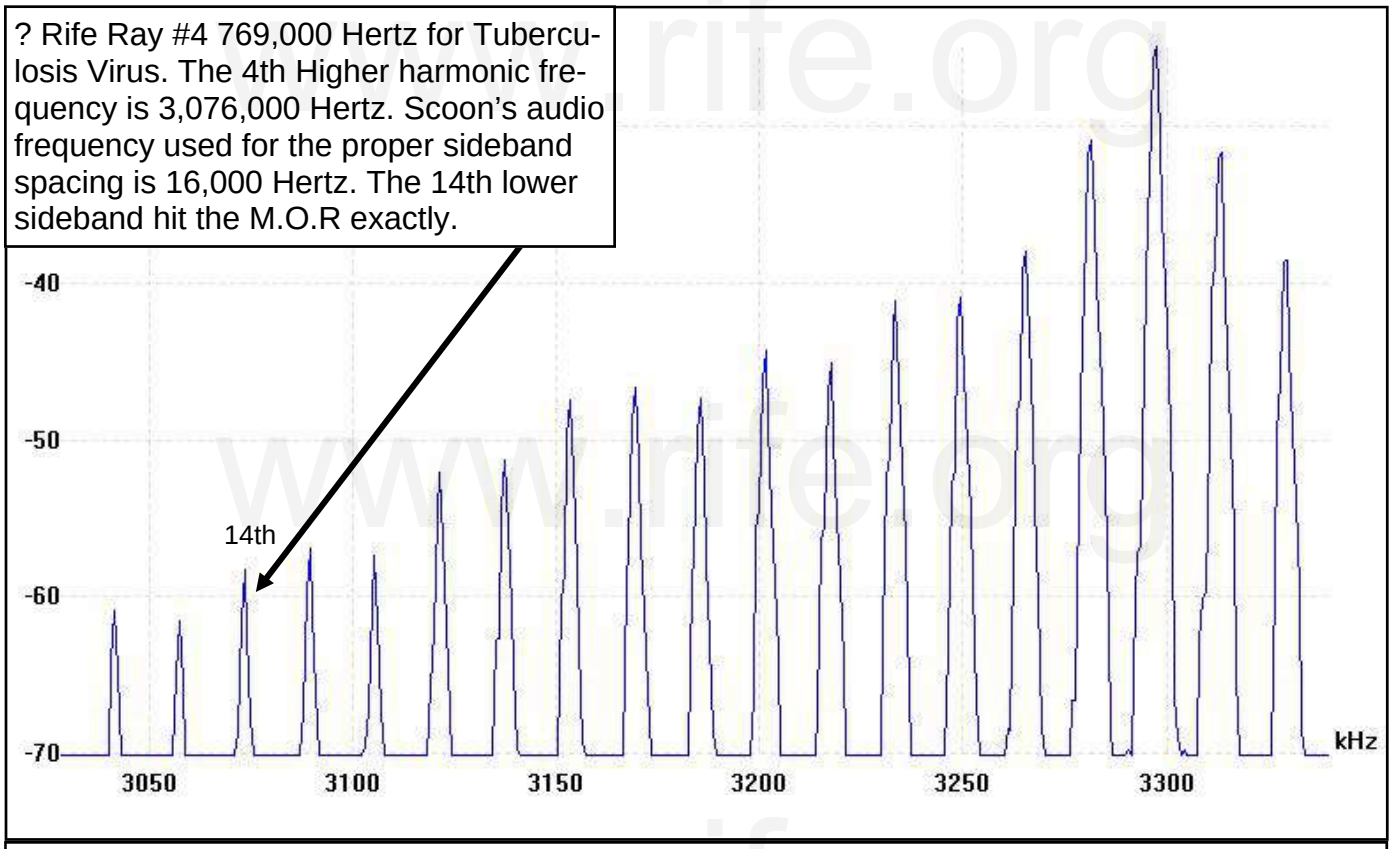

Scoon's Beam Ray Clinical instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

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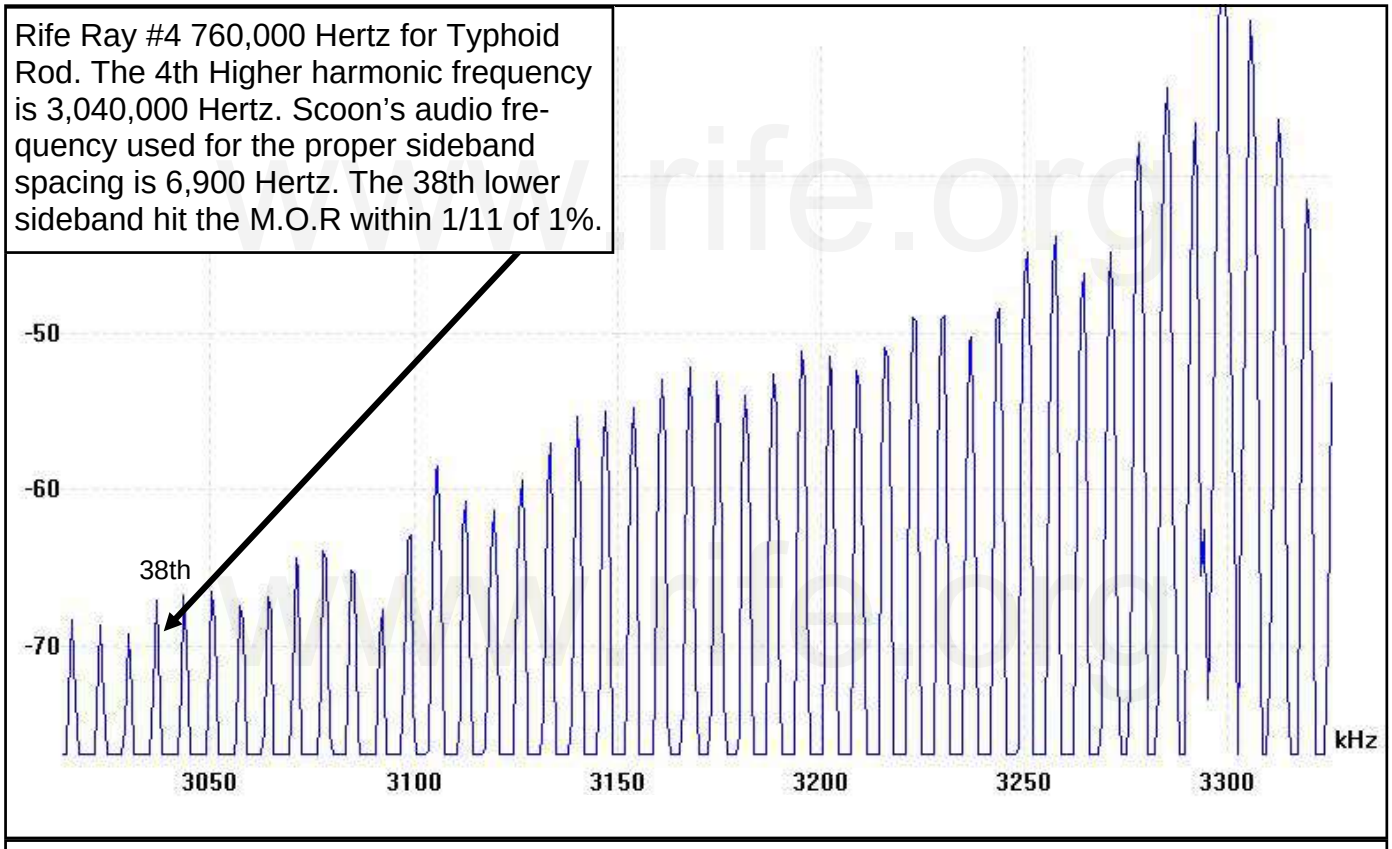

Scoon's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic frequencies.

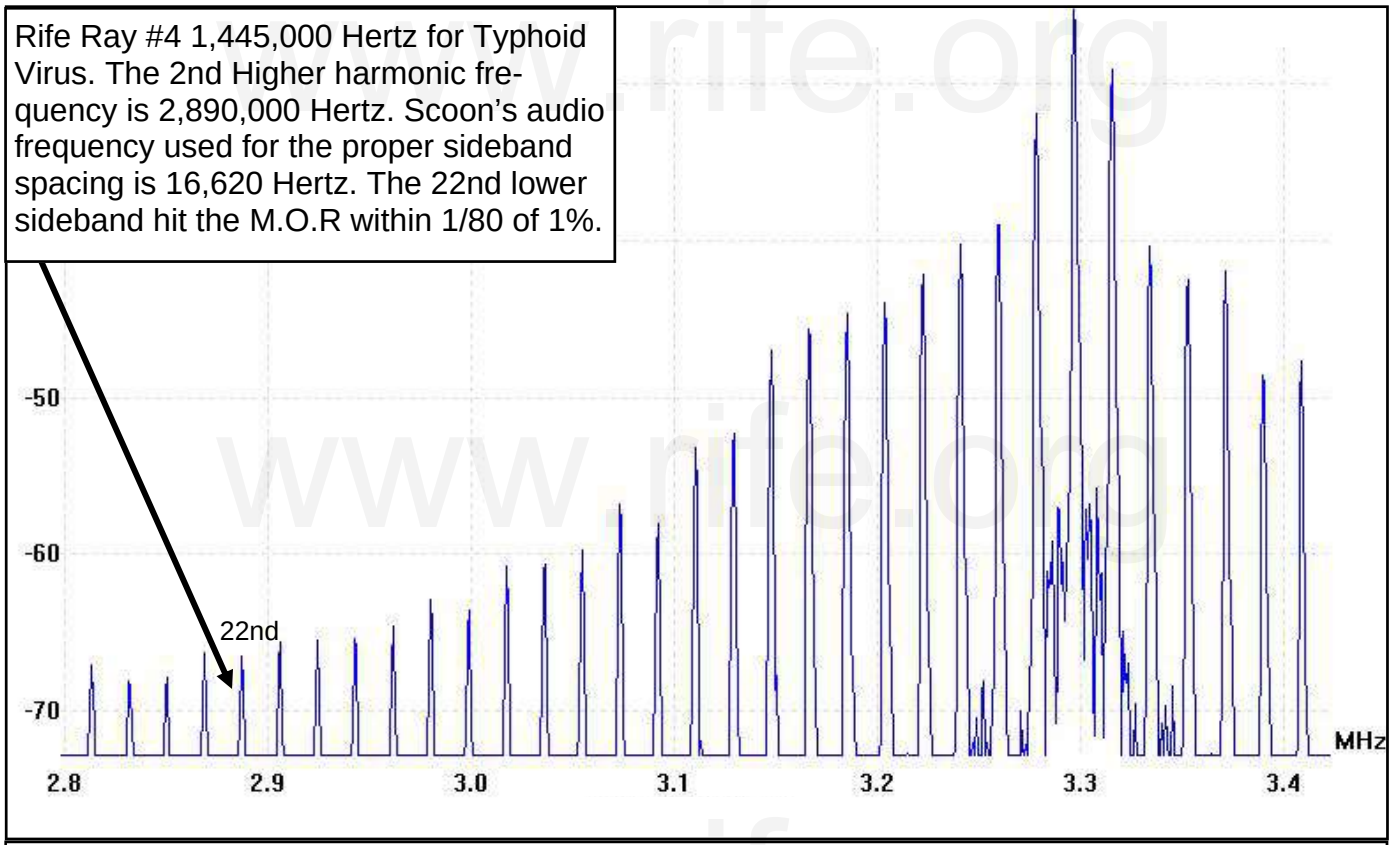

Scoon's Hoyland's Beam Ray Clinical replica instrument 3.30 Megahertz spectrum analysis of sideband harmonic

Photos of the rebuilt Aubrey Scoon Beam Ray Clinical instrument

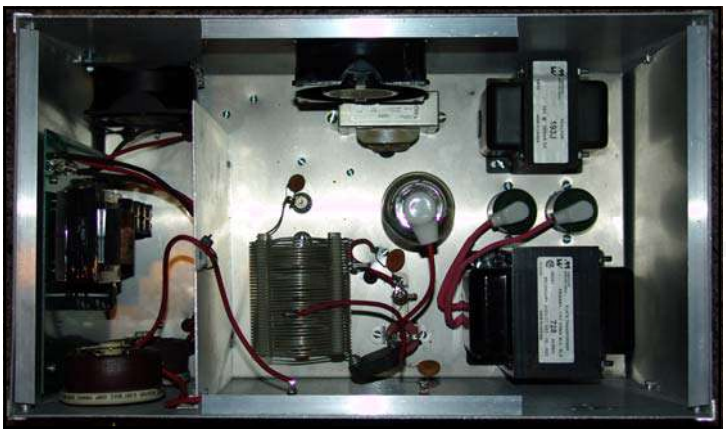

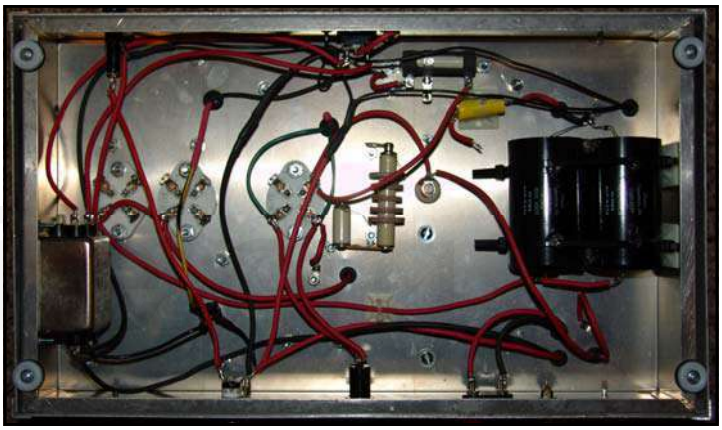

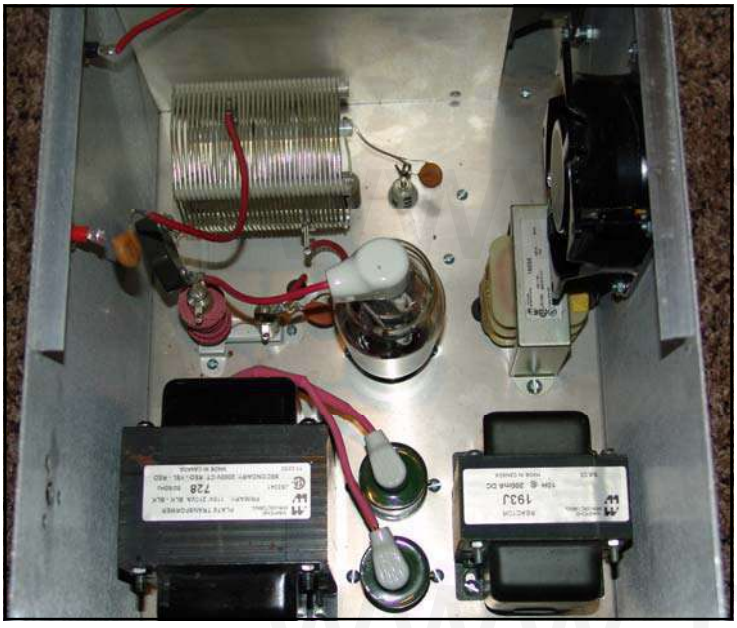

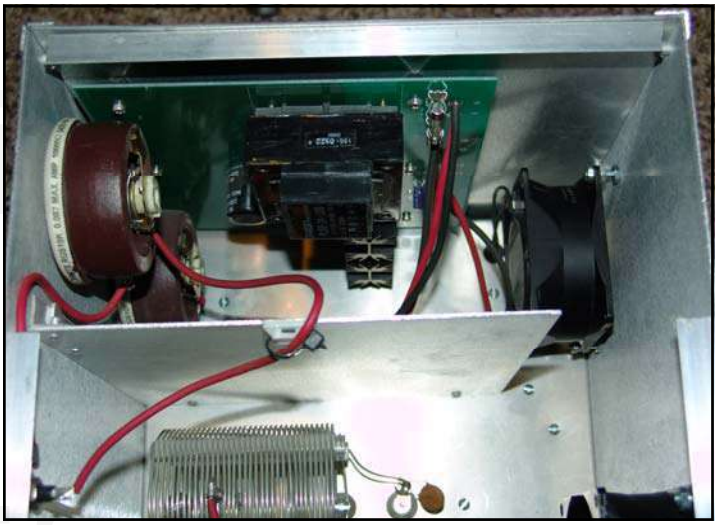

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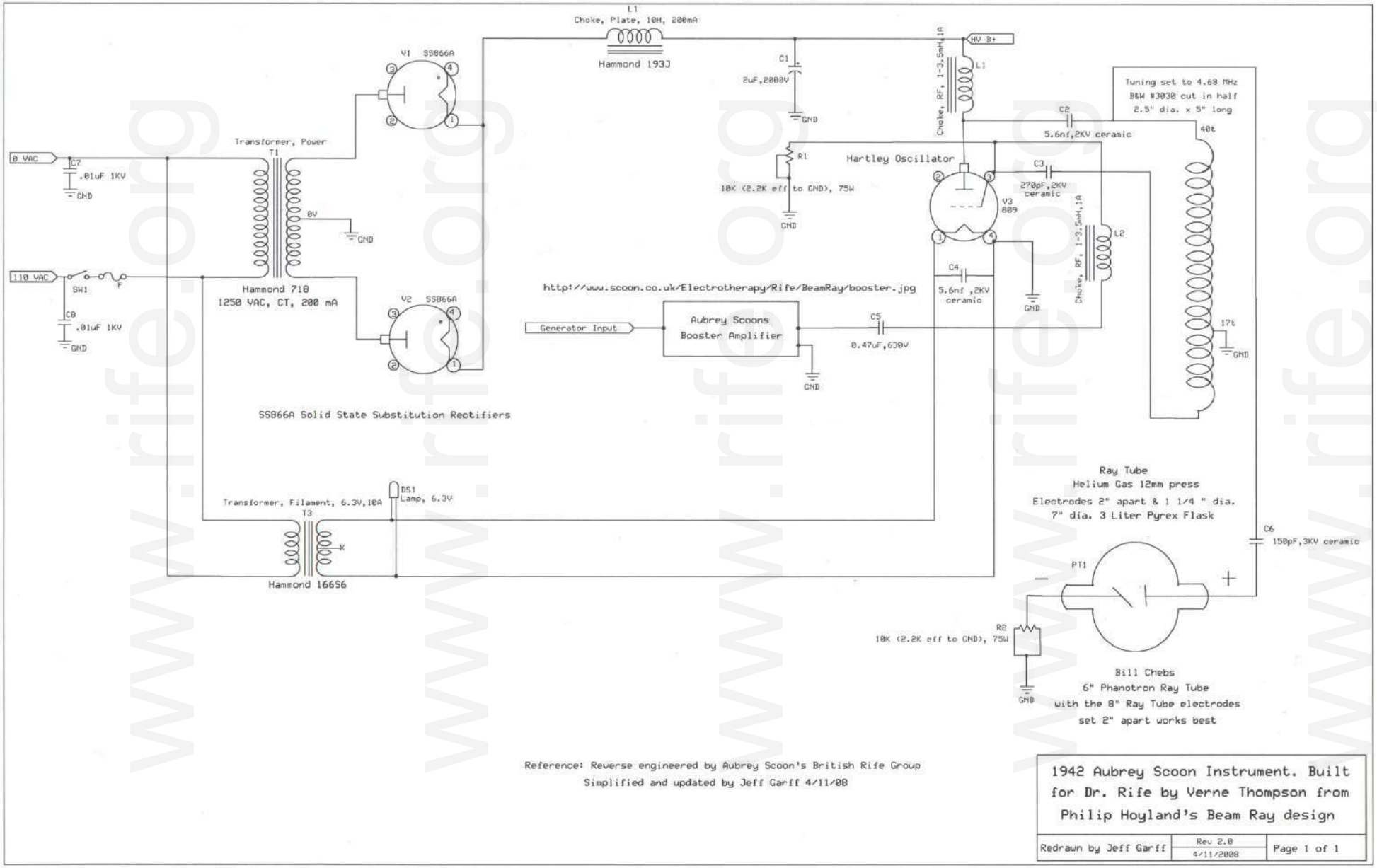
L1
Choke, Plate, 10H, 200mA
Hammond 193J
V1 SS866A
C1
2uF,2000V
GND
HV B+
Choke, RF, 1-3.5mH,1A
L1
Tuning set to 4.68 MHz
B&W #3030 cut in half
2.5" dia. x 5" long
C2
5.6nf,2KV ceramic
40t
Transformer, Power
T1
0 VAC
C7
.01uF 1KV
GND
0V
R1
10K (2.2K eff to GND), 75W
Hartley Oscillator
C3
270pF,2KV
ceramic
V3
809
L2
Choke, RF, 1-3.5mH,1A
110 VAC
SW1
F
Hammond 718
1250 VAC, CT, 200 mA
C8
.01uF 1KV
V2 SS866A
http://www.scoon.co.uk/Electrotherapy/Rife/BeamRay/booster.jpg
C4
5.6nf ,2KV
ceramic
Generator Input
Aubrey Scoons
Booster Amplifier
C5
0.47uF,630V
17t
SS866A Solid State Substitution Rectifiers
Ray Tube
Helium Gas 12mm press
Electrodes 2" apart & 1 1/4 " dia.
7" dia. 3 Liter Pyrex Flask
DS1
Lamp, 6.3V
Transformer, Filament, 6.3V,10A
T3
Hammond 166S6
C6
150pF,3KV ceramic
PT1
R2
10K (2.2K eff to GND), 75W
Bill Chebs
6" Phanotron Ray Tube
with the 8" Ray Tube electrodes
set 2" apart works best
Reference: Reverse engineered by Aubrey Scoon's British Rife Group
Simplified and updated by Jeff Garff 4/11/08
1942 Aubrey Scoon Instrument. Built for Dr. Rife by Verne Thompson from Philip Hoyland's Beam Ray design
Redrawn by Jeff Garff
Rev 2.0
4/11/2008
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Aubrey Scoon's 1939 Rife Beam Ray Website Report

1) Used a Ray Tube.
2) Used a fixed 3.30 MHz carrier frequency.
3) Modulated sine wave audio frequencies onto a sine wave carrier frequency.
4) Power usage was about 460 watts. Output to the ray tube about 40 watts.

The 1939 Beam Ray Machine?

Aubrey Scoon's instrument is an important part of this report. We felt that his information about this machine should be added and included in Chapter 11. All of this information was originally on Aubrey Scoon's web site but since he has passed away his website is no longer available. This information is to important to be lost. Even though we now know that his machine was not built by the original Beam Ray Corporation it is still a copy of the original Rife Ray #5 or Beam Ray Clinical instrument. This machine was built by Verne Thompson in 1952 or later and used the original 3.30 MHz RF carrier frequency. It also used Philip Hoyland's original audio frequencies that will produce the original sideband frequencies that will would hit the higher harmonic frequencies of Dr. Rife's original M.O.R.s.

Below is Aubrey Scoon's written Report:

In 1938, a group of British researchers headed by Dr Bertram Winter Gonin, sought to buy some experimental machines from Rife to confirm his work. At that time, Rife had no commercial operation capable of handling the orders and at the instigation of his old friend Ben Cullen, Rife consented to the formation of a commercial company called Beam Rays Inc. At that time, the majority owner of the

rights to the machine was an electronics engineer called Philip Hoyland. Hoyland had designed and developed all of the original Rife machines since late 1934. Hoyland and Rife became partners in Beam Rays Inc. The company produced a small number of machines but suffered internal conflicts because of the actions of some of the other partners and because of frictions between Hoyland and Gonin's group. Hoyland believed that Gonin and his partners were trying to steal the technology for themselves. Subsequently, the company was destroyed in 1939/1940 when Hoyland brought a lawsuit against Beam Rays in an attempt to stop one of the partners from illegal stock trading and also to dissolve the contract with the British. Fuller details of this are being written up and will be posted here in the near future.

The Beam Ray Corporation produced a number of machines. I'm not sure of the exact number as I have seen varying accounts, but I believe that about 17 machines were produced and shipped to MD's in California. Another four machines were shipped to England to Dr. B. Winter Gonin of the London School of Tropical Medicine. There was some argument between Rife and Hoyland over these machines and their operating principle, however various MD's including James Couche used one of these machines for many allegedly successful treatments of patients for many years.

The U.K. Rife Research Group managed to get access to one of the machines believed to be one of the originals that were shipped to California in the late 1930's. I reverse engineered that machine and present the results below. I have a lot of data on this machine of which this is only part, I will add things as I get time as much of the data needs to be organized properly. The exact date of the machine is unknown - we know that it was built sometime between the autumn of 1938 and the early part of 1939 - so it may actually be a 1938 machine.

I would like to express my thanks to Robert Harrison, an expert valve/tube engineer (I'm not a valve/tube expert) who gave me massive help and support during the reverse engineering process and who corrected numerous silly mistakes that I made! My thanks also to Stuart Andrews and Bob Haining for their help and support in this effort.

Machine Schematic

Below are the machine schematics and links to some photographs. The schematics have been rendered into PDF format which allows them to be zoomed to resolve fine detail.

These machine schematics are only included in the online report due to the fact that some of them would not be readable. Please go to the following web address to obtain these schematics:

www.rifevideos.com/aubrey_scoons_1939_rife_beam_ray_.htm.

WARNING: These schematics are presented for information only. Do not try to construct a copy of this machine unless you are knowledgeable and experienced in high voltage valve/tube work. The tube filaments need to be heated for a couple of minutes before switching on the HT - failure to do this will blow them. In addition, some parts of this circuit use up to 1750 volts DC at substantial current and can easily kill in inexperienced hands.

Booster Amplifier Schematic

At the same www.rifevideos.com link, given above, is the booster amplifier schematic. This is for a transistor booster amplifier I designed. It is possible to separate the Beam Ray machine output stage from the oscillator stage and to drive the output stage directly from a modern digital frequency generator. This allows much more precise and accurate frequency control than the original. But the output

stage requires over 40 V p-p to drive it properly at 100% modulation and most modern generators are not capable of outputting this kind of voltage. So the booster stage allows a low level signal between 20Hz and 200Khz (the original range of the machine) to drive the output at up to approx 66 V p-p without significant signal distortion (it can be driven at higher inputs of up to 2 V p-p with clipping). An input of 951 mV will cause 100% modulation of the Beam Rays machine and an input of 1.5 V p-p will result in significant over modulation without distortion of the modulating signal itself. The booster amplifier has a bandwidth of approximately 800 KHz and so can also be used as a general purpose wideband, high voltage buffer amplifier as well.

Plasma Tube Photos

The first two photographs below show the Nazarov phanotron running on the Beam Ray Machine. And below in the third photo is a close-up of the electrodes of the original plasma tube.

Inside the Beam Rays Machine

The picture below is of the output stage of the machine. The tank coil can be clearly seen on the right with the 812 (should be 809) output triode next to it. The output jacks are in the center top. The HT transformer is at the back left with the two 866 mercury vapour rectifiers in front of it. Picture courtesy of Stuart Andrews.

The next photo below is the underside of the output stage (note that some components on both stages had to be replaced with modern ones to get the machine working because the originals had deteriorated too much).

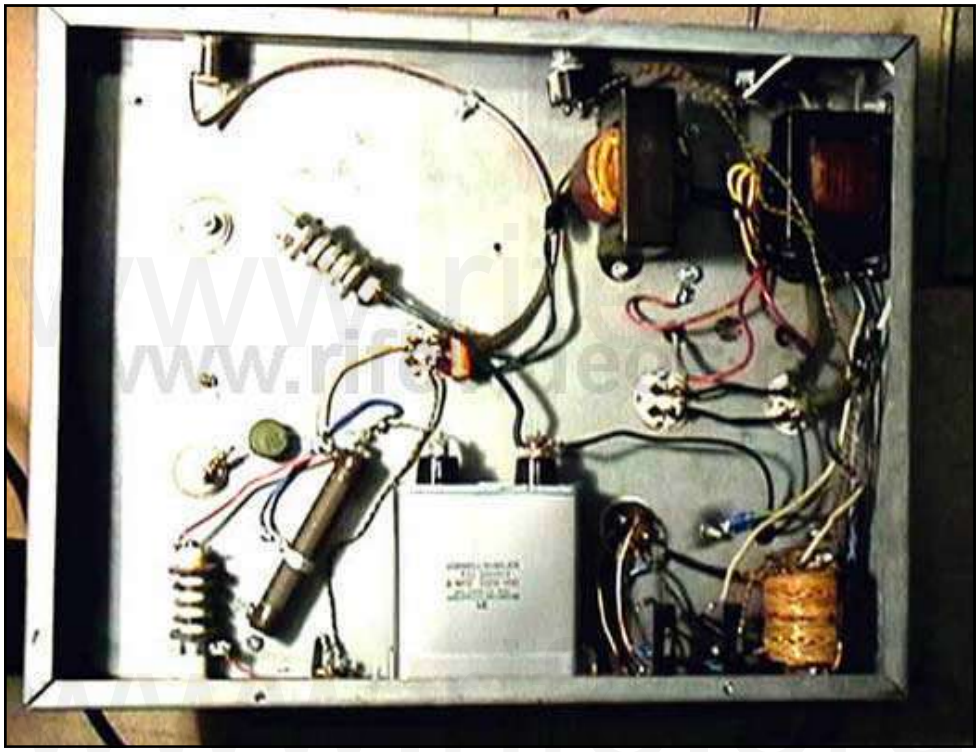

And this photo below is of the underside of the oscillator stage.

Beam Ray Carrier Waveform Photographs

Here are various photographs I took of the machine's waveforms on an oscilloscope. Note: these were taken with the 812A tube in place. The waveforms produced when an 809 is used are smoother and more sinusoidal.

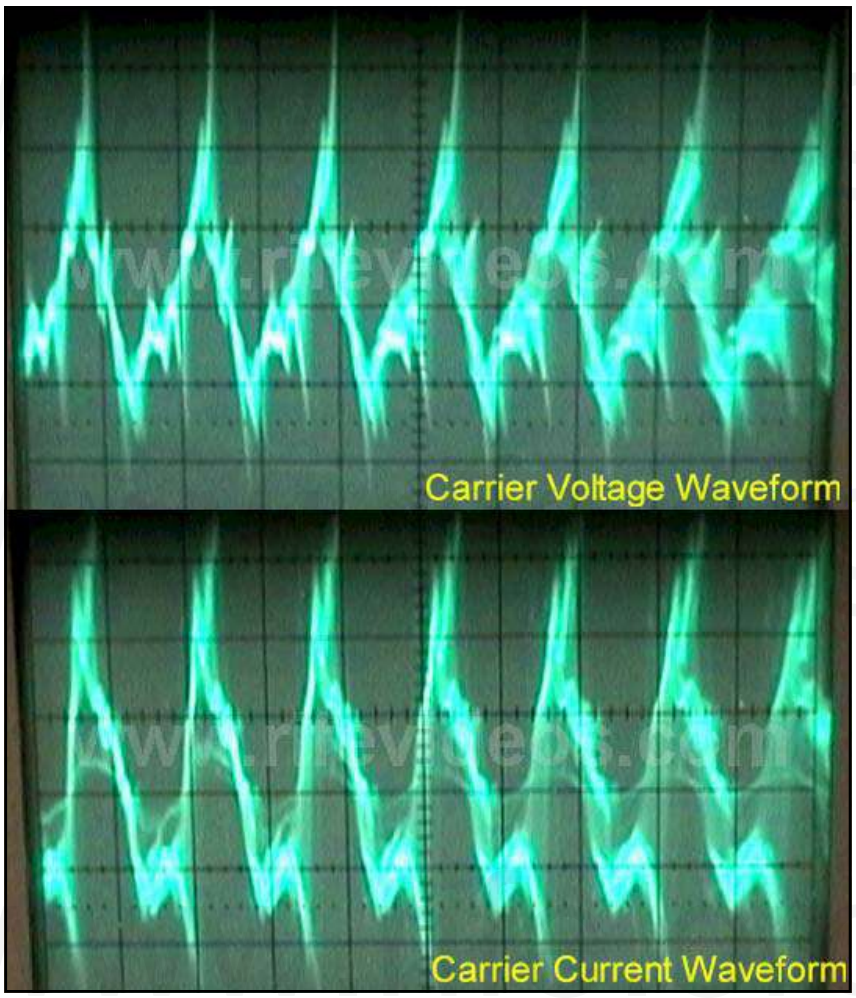

These photos on the previous page are the carrier waveforms for both voltage and current. The actual carrier frequency of the machine depends very much on the plasma tube and also on coupling effects between the tube and any person in the vicinity.

This has made it very difficult to get accurate measurements of the machine because even being in the same room as the machine causes the frequency to alter!

However, after many experiments I am reasonably certain that the resting carrier wave frequency, undisturbed by any local effects is approximately 3.33 MHz.

Because the wave is not a pure sine there are strong harmonics at many other frequencies as well. Some of the dominant harmonics have been observed at approximately 2.3 MHz, 4.6 MHz and 9.09 MHz.

Photo Comparison To Earlier Rife Machine

Comparison of wave from original Rife machine (top) with the waveform from the Beam Rays machine (bottom). Note the similarities in the wave envelopes.

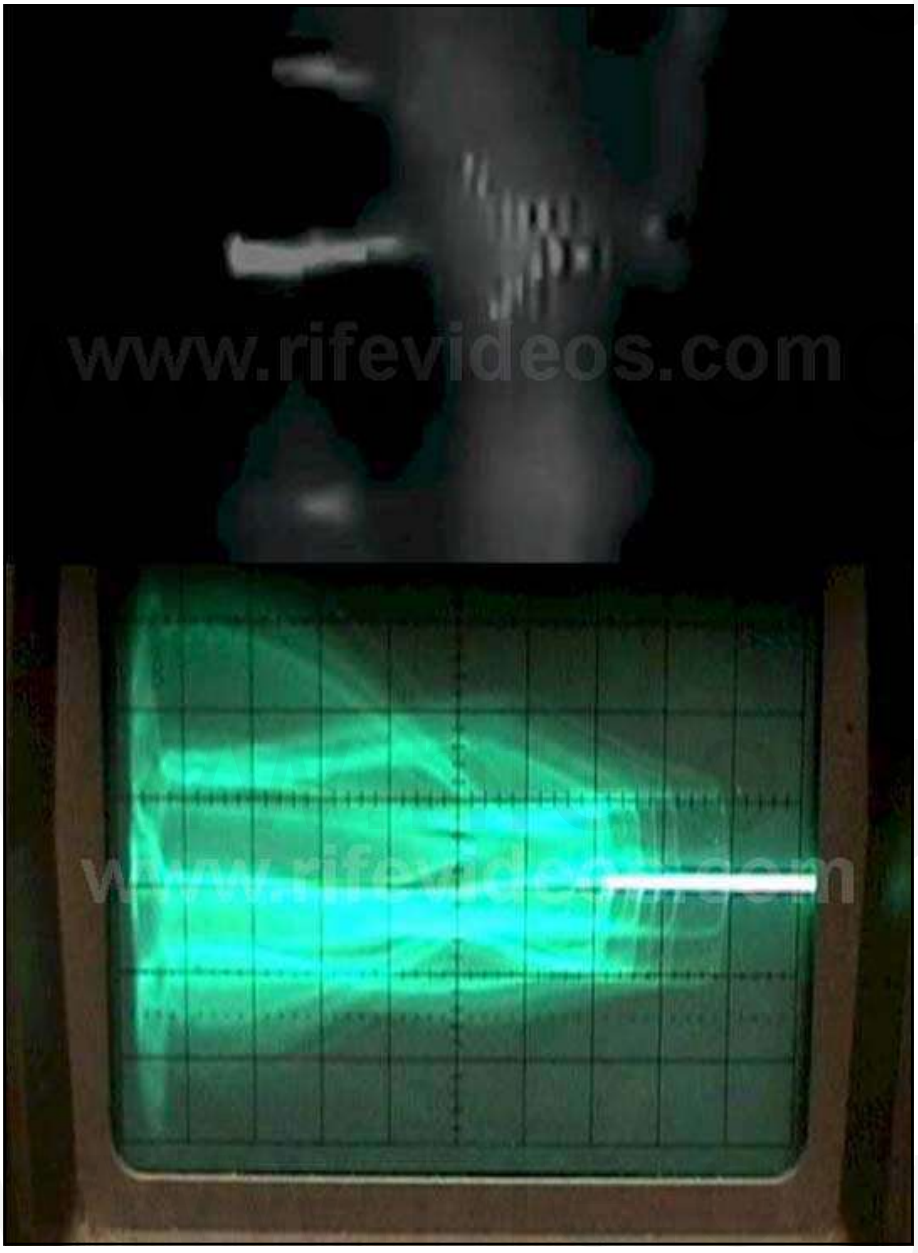

Effect of Modulation Depth

Wave 1 - this is one burst of the tank waveform at 1430 Hz (scope settings on uncalibrated and adjusted for better resolution) and in excess of 90% modulation depth (sine wave).

Wave 2 through Wave 4, this is what happens as the modulation depth is successively increased - Wave 4 is pretty much 100%. The number of cycles per burst (a burst is approx 20ms apart and is set by the mains cycle) decreases with increasing modulation.

Wave 5 - as you enter over modulation, the burst breaks up into smaller chunks.

Wave 6 - at approx 50V p-p modulation the wave is over modulated and consists of single cycle pulses grouped into bursts.

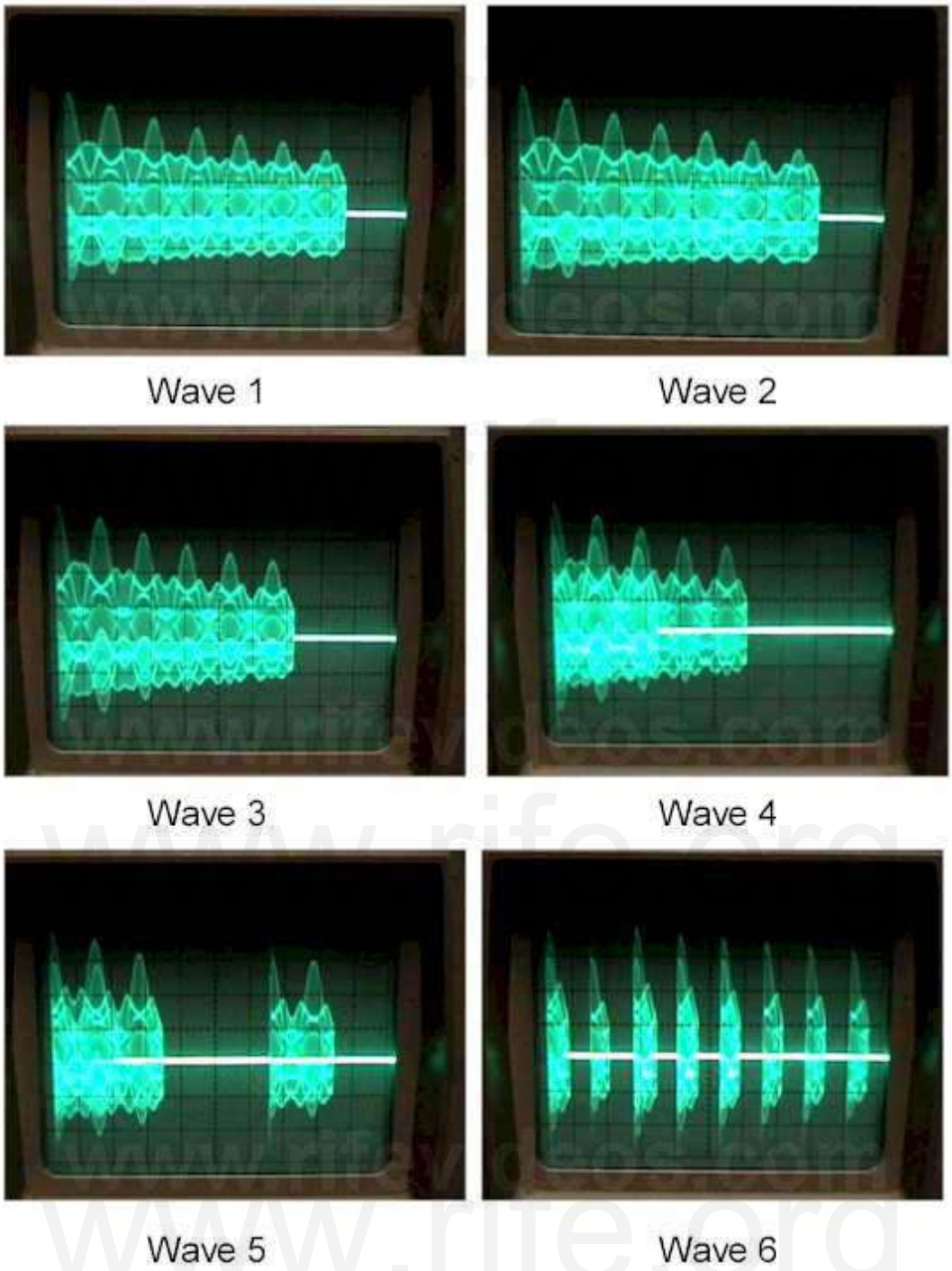

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Analysis Of Beam Ray Machine Operation

Below is a more detailed description and brief analysis of the operation of the Beam Ray machine.

The machine has 3 external controls. The leftmost one is a 4 way rotary switch with positions labeled 1 through 4. These are the (modulation) frequency bands of the machine. The total range of the modulation settings is from approximately 20 Hz to 200 KHz in 4 decades as follows:

Band Frequency Ranges

Band 1: 20 Hertz to 200 Hertz.

Band 2: 200 Hertz to 2000 Hertz.

Band 3: 2000 Hertz to 20,000 Hertz.

Band 4: 20,000 Hertz to 200,000 Hertz.

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Main frequency Dial Adjustment

The center control is the main modulation frequency dial. This is calibrated in one step units from 0-100. The dial superficially appears to be a vernier dial but isn't, although it is finely marked, of good quality and is geared down, so a single turn does not move it completely from end to end. A resolution of 1/2 a division is easily possible.

Modulation Amplitude Control Dial

The right hand control is the modulation depth control. It varies the modulation applied to the grid of the output triode from 0 to 50 V p-p. The highest setting of 50V p-p is not 100% modulation, but rather over modulation of about 115%.

Treatment Settings

The machine came with some old diary pages with a series of treatment settings scribbled on them. The year of the diary was not shown, just the months but February was shown. It was not a leap year and by matching the days of the week to the dates it had to be 1939. There were the "usual" Rife pathogens plus a few more ailments that I had never seen quoted on any other early Rife machine list. Unfortunately they were not all complete so it wasn't possible to derive the true frequencies for all of them. The anomalies included:

"V" with a setting of band 3, dial 39 - but I have no idea what this is.

"Radiation" with a strange setting of "2-17-3" which could mean band 2 or 3 dial setting 17.

Pain - "20", Iodine Poisoning - "92", Mercury Poisoning - "55", Tissue repair - "58", Scar Tissue - "13", Mucous Colitis - "38", Hemorrhoid - "88", Catarrh - "17", Inflammation - "40" and Irritation - "30".

The ones that could be clearly resolved are shown in the table Below. The treatment frequencies are all approximately 10 times the ones listed in the modern Crane derived frequency lists for the various conditions.

Pathogen	Band	Dial	Frequency
BX Carcinoma	4	10	21275
BY Sarcoma	4	6.5	20080
Typhoid Virus	3	94	18620
Typhoid Rod	3	58.5	6900
Tetanus	2	78.5	1200
Treponema or Syphilis	3	56	6600
Staphylococcus	3	59	7270
Streptococcus	3	63.5	8450
Streptothrix	3	61.5	7870
E Coli Rod	3	62	8020
E Coli Virus	3	89.5	17220
Tuberculosis Rod	3	63	8300
Tuberculosis Virus	3	88	16000
Pneumonia	3	61	7660
Worms	3	24	2400

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Audio Frequency Circuit Analysis

The most striking thing about the Beam Rays audio frequency circuit at first glance is the oscillator section. The machine oscillator is clearly a first generation Hewlett Wein Bridge circuit. What makes this particularly notable is that Hewlett (Hewlett-Packard) only invented the circuit around the time the Beam Rays machine was built. Because it was so new and had not found its way into commercial designs it tends to imply that there might have been some connection between Hewlett and Beam Rays.

I have written a detailed account of the history entitled: "The Hewlett Connection." To read this report go online to: www.rifevideos.com/aubrey_scoons_1939_rife_beam_ray_.htm.

The earlier Rife machines had used the Hartley oscillator circuit which was no where near as stable as the Hewlett Wein Bridge. So the use of this circuit was a big step forward for Beam Rays. The earlier machines had been plagued with apparent frequency instability which made consistent use very difficult. The Wein bridge circuit was an apparent solution, but in practice there was another factor that they apparently did not take into account.

The Beam Rays oscillator is remarkably stable - it drifts by only a few Hertz during normal operation and is superior to many modern analog generators. But it has one major drawback. Tuning is achieved by way of a variable capacitor. This capacitor is connected directly to the tuning dial. The tuning dial is a geared down dial that allows very precise turning of the capacitor shaft. However in practice it suffers from a slight degree of "backlash" - in other words, no matter how carefully you turn the dial, there is always some residual pressure on the rotary shaft - and left to itself for a while this residual pressure or tension causes the capacitor shaft to turn back by a small amount. This is enough to throw the tuning out by a couple of Hertz in the lowest range - and the problem multiplies by a factor of 10 for each higher range. So in the top range the backlash can throw the frequency setting off by approximately 2 KHz. In addition, because the relationship between the dial setting and the actual frequency is non-linear, the problem is always worse toward the top of the scale (i.e. the dial is calibrated

from 0 to 100 - the problem is much more pronounced near 100 than it is near 0). One of the ways in which this manifests most noticeably is that turning the dial down from a higher number results in a lower overall frequency than turning the dial up from a lower number to the same final setting.

The frequency setting is obviously critical and this may explain why some frequency stability related problems were encountered even with this extremely good oscillator.

The presence of the Hewlett oscillator explains also the general build of the machine. When I examined the machine there were various minor anomalies. One of which was the size of the two chassis. They are both much bigger than they need to be. Also there are two separate chassis and the earlier Beam Rays machines had only one. Another thing is that there is a circuit on the oscillator stage which is not connected and not used. This was probably meant to be able to create square waves by sine overdrive and clipping. Finally the mounting holes on the chassis do not correspond with the mounting holes on the case - someone has drilled new holes in both chassis to remount them in the case. This could mean that the case the machine is in is not the original case it was shipped in. Alternatively it could mean that the chassis were previously mounted in a different way (maybe in a different case) prior to shipping.

Taking all these things together leads me to the conclusion that the machine I examined is probably an original prototype. This makes sense considering that the Hewlett oscillator was so new. Obviously, Phillip Hoyland or whoever built the machine decided to try making the oscillator stage separately from the output stage. The output stage is presumably the same as in earlier Beam Rays machines (it looks the same as a 1937 Beam Rays machine), but clearly they decided to build the oscillator on a separate chassis. The chassis were overlarge to allow for circuit expansion and modification. The unused circuit was probably tested at some point and found to be unnecessary. And it is likely that during development the different mountings were used on some sort of open frame to allow testing and measurement.

But this prototype machine was shipped and sold as a finished unit, why? The answer is probably quite obvious. The machine was produced during the great depression. Everything was expensive; Beam Rays was a small company and needed to keep down costs. The prototype was probably only needed during development. Once everything had been worked out satisfactorily, the prototype was no longer needed - and could be sold for a substantial profit, as it was effectively a working machine of a new design.

The 6SJ7 and 6K6(B) tubes on the combined schematic are the basic Hewlett Wein Bridge oscillator circuit. See "The Hewlett Connection" for a schematic of Hewlett's patented design. The third tube marked 6K6(A) is a simple cathode follower buffer stage, analogous to a modern transistor emitter follower circuit. This circuit has high input impedance, low output impedance and unity gain. It is designed to insulate the sensitive oscillator section from the following output stages. The 6SN7 tube is the unused circuit and as mentioned above was probably meant to be part of a fast clipper amplifier to produce square wave modulation.

The oscillator stage creates a pure sine wave from approx 20 Hz to 200KHz depending on range and dial setting. It also produces a variable amplitude output which can be adjusted from 0v right up to approx 50V peak to peak.

The output stage consists mainly of a single power triode. Although the machine had an 812A triode in it when I got it, I believe the correct original tube was an 809. The machine runs a lot more cleanly and stably with an 809 than an 812A. The stage is self-oscillating; it has a simple regenerative feedback arrangement from plate to grid via two capacitors and the tank coil. The degree of feedback can be adjusted by means of a large power resistor from the grid to ground.

Note: the machine was not actually grounded, the negative end of the supplies connected to the chassis and all "grounds" were actually referenced to the chassis. I found in practice that the chassis did tend to accumulate quite a nasty residual charge after the machine had been operating and so I grounded it which did not seem to affect the operation of the machine. The output stage is actually a Hartley oscillator, although not obviously so, because the output capacitor in series with the plasma tube capacitance represents the "tuning" capacitance of the circuit. The large power resistor in series with the tube affects the oscillator loading, the output field impedance and also the Q of the resonant circuit. Because the plasma tube is an active circuit element, capacitive coupling from anybody in the vicinity of the plasma tube actually causes changes in the oscillator frequency. The "resting" frequency of the output oscillator is around 3.30 MHz using the 812A and an Argon (Nazarov) phanotron tube. When the tube was was changed to an 809 and a 15mm Helium Cheb phanotron was used, the "resting" frequency changed to 4.68 Mhz and the wave became much more sinusoidal .

The output from the modulation oscillator stage is capacitively coupled to the output triode grid via an inductor. The latter is designed to prevent the carrier oscillations from feeding back into the modulation oscillator stage.

The DC HT power for the output triode is derived from a 1235 VAC plate transformer by two 866 mercury vapour rectifiers. The DC output is smoothed via a large choke and a filter capacitor to ground. There is also an RFC choke in the line to the plate. The net voltage at the plate of the triode is only around 550V DC which is consistent with a choke smoothed circuit. However much more interesting is the other end of the tube - the filaments (which double as cathodes) are connected to a direct AC filament heater transformer which means that there is an additional modulation at the 60Hz mains frequency (cathode modulation).

In practice during operation, the machine creates the carrier waveform (which is not very clean and contains a lot of harmonics - it has a superficial similarity to a sawtooth wave).

UPDATE: the carrier waveform is smoother with the 809, but still contains some strong harmonics. The carrier is then amplitude modulated by the sine wave produced by the modulation oscillator. However, in addition, the AC cathode connection causes a further modulation at 60Hz. In effect the modulated wave is chopped into chunks or bursts that are one period of a 60 Hz cycle apart. And the envelope of the wave is effectively the first quarter cycle of a 60Hz cosine wave. In some respects this is like a very crude approximation to a damped wave. I believe that the latter is not a design flaw but rather a feature.

In the next chapter we will discuss the 1953 AZ-58 built by Verne Thompson and the history of that instrument in detail.

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Chapter #12

Dr. Rife and Verne Thompson's 1950's AZ-58 Beam Ray Replica Rife Machine

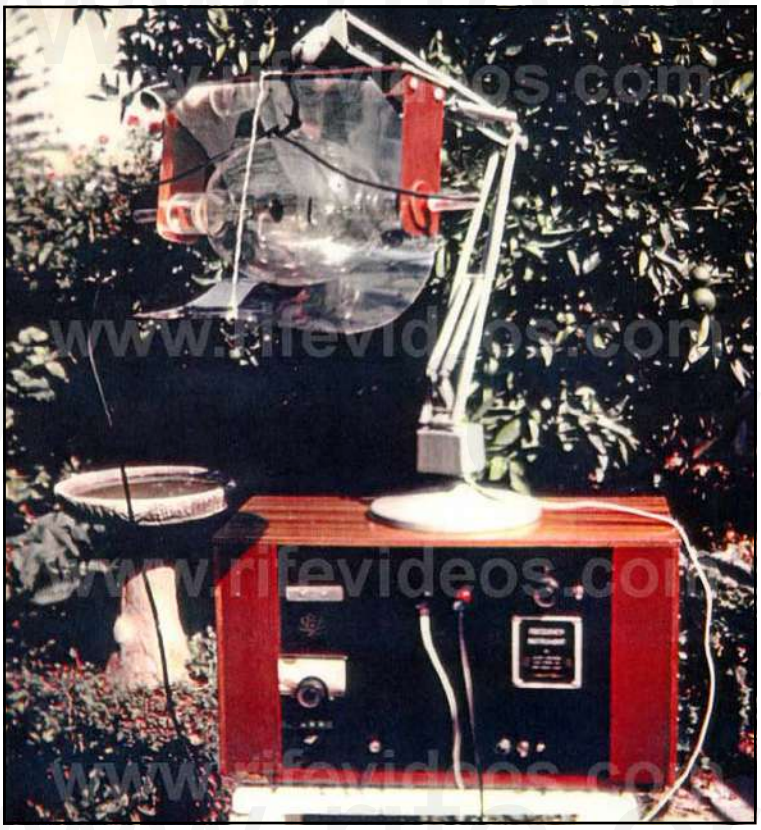

1. Used a ray tube.
2. Variable RF carrier frequency between 2.20 and 5 MHz. (First used 4.68 carrier).
3. Modulated square wave audio frequencies onto the sine wave carrier frequency.
4. Power usage was about 460 watts. Output to the ray tube about 40 watts.

With the knowledge gained from obtaining the original Rife Ray #5 or Beam Ray Clinical instrument we know that the 1953 AZ-58 design is an updated replica of Philip Hoyland's Beam Ray Clinical Rife Machine. The 1953 version was updated with newer component parts. Dr. Rife's engineer, Verne Thompson had been building this type of Rife Machine during the 1940's and 1950's. We will now cover this information in more depth. This style of instrument worked well as long as it was using the sideband method. From the stress of the Beam Ray Trial, Dr. Rife became an alcoholic and all that he had worked so hard to accomplish was almost destroyed. Many of the doctors had returned their instruments because of AMA threats. Some of these returned Beam Ray Clinical instruments Dr. Rife parted out and sold to anyone who wanted radio parts. Under these circumstances Beam Ray Corporation eventually closed its doors. Verne Thompson became Dr. Rife's engineer around 1940 and built the Beam Ray style Rife Machines during the 1940's and 1950's for anyone who wanted an instrument. The documents show that back in 1939 Dr. Rife wanted to go back to the original principles of his instrument rather than use Philip Hoyland's harmonic Beam Ray Clinical design. This is what Dr. Rife said in a 1939 letter sent to Dr. Gonin:

RIFE: *"I spoke only Friday evening to a Mr. John Chamblin, a radio man now connected with Beam Ray Inc., about the redesign and building of a device according to the old Rife Ray principles; as the present instrument has been so deviated away from that old principle that it is nowhere near the*

same...those devices which you have are merely working on a harmonic and not a true frequency; and in our research on electronics, we definitely know that there is no possible way of controlling electrical harmonics of a frequency." (Letter from Dr. Rife to Dr. Gonin, May 14, 1939. Page 1 of 3).

Because Dr. Rife didn't understand Philip Hoyland's harmonic sideband method he believed that the harmonics could not be controlled. Sidebands can be controlled by the audio frequency which is used to create them. Had Dr. Rife been given the understanding of how the instrument worked he would have known that they were controllable. Because of this misunderstanding Dr. Rife wanted to go back to the original designs of his earlier Rife Machines. It is also a historical fact that he never did go back to using his original designs like the Rife Ray #4. There is a reasonable explanation for this. Back in the late 1930's and early 1940's the FCC began controlling the airwaves and hundreds of new radio stations were being granted licenses. The RF M.O.R. frequencies which were output by the Rife Ray #3 and Rife Ray #4 were almost all in the A.M. radio band of frequencies and would interfere with these new broadcasting stations. These events probably brought about the continued use of Philip Hoyland's Beam Ray Clinical Rife Machine since it operates out of the A.M. band and in the low ham radio range. In Chapter 9 of this report we also read that Dr. Rife tested Philip Hoyland's instrument, in about 1940, when he had Verne Thompson rebuild Dr. Yale's Beam Ray Clinical instrument. In those tests Dr. Rife found that Philip Hoyland's design would devitalize all the microorganisms. The tests that were done by Dr. Rife showed that this style of instrument worked. This meant that he really didn't need to go back to his earlier designs even though he may have wanted too.

There are a few important facts that should be pointed out. Dr. Rife at any time could have had an original Ray tube instrument built. He had a Rife Ray #4 in his lab that could have been copied. I am sure that he also had access to the Beam Ray Laboratory instrument. These facts, I believe show that it was probably because he knew that Philip Hoyland's design was a good design that he continued to use it. It could also be because of the FCC regulations Dr. Rife either had to use the Beam Ray Clinical instrument design or no longer build one. We know, from the documents, that Verne Thompson was copying Dr. Couches' instrument with its fixed RF carrier frequency of 3.30 MHz. This carrier frequency was well above the A.M. band of radio stations. Since the Beam Ray Clinical instrument used the higher harmonics of the original Rife Ray #4 frequencies this would not cause any problems with the A.M. radio stations. The FCC was, at the least, a contributing factor in why Dr. Rife continued to use Rife Ray #5 or the Beam Ray Clinical design.

With the understanding of this information let us continue on with the history of Dr. Rife's instruments. John Crane met Dr. Rife in 1950 when he inquired about purchasing a drafting set that Dr. Rife was selling. John Marsh met John Crane in 1952 when they were both working at Convair. See photos below. John Crane is the photo on the left and John Marsh is the photo on the right.

They both went to talk to Dr. Rife in 1953 to see if he would be willing to help with John Marsh's wife who had cancer. In Dr. Rife's 1961 deposition #123-125 we have the verification that Dr. Rife gave John Crane his frequencies in 1950:

COMPARET: **"***Did you ever explain to John F. Crane, one of the defendants in this case, the principles upon which your electronic frequency-generator is used in the treatment of diseases?"*

RIFE: "*Yes in 1950."*

COMPARET: "*Did you also inform him of the particular frequencies which you had found to be effective in the treatment of various diseases?"*

RIFE: "*Yes. Verne Thompson and I gave the frequencies to John Crane."*

COMPARET: "*When did you furnish him with this information?"*

RIFE: "*In 1950."*

Dr. Rife always said that almost all his frequencies were in the upper bands (139,200 Hertz to 1,607,450 Hertz) so we know that he gave these high RF frequencies to John Crane in 1950. These frequencies would have been the frequencies used in the Rife Ray #4. The audio frequencies that were used in Dr. Couche's Beam Ray Clinical instrument also may have been given to John Crane at this time. There is an interesting correlation of these audio frequencies that needs to again be mentioned at this time which ties these machines together. The higher audio frequencies, which produce the side-band spacing, used in the 1950's Aubrey Scoon, Verne Thompson Beam Ray Clinical instrument were 10 times higher than those used in the Verne Thompson 1953 AZ-58 Beam Ray Clinical replica. It is apparent that these higher audio frequencies were lowered in the 1950's by Dr. Rife, John Crane and John Marsh and were used in the AZ-58 replica instrument. This gives us the knowledge that these audio frequencies came from Verne Thompson's reading of one of these Beam Ray Clinical instruments. The chart, shown below, is a list of the lowered audio frequencies which were used in the 1953 AZ-58.

AZ-58 Lower Audio Frequencies Derived From Aubrey Scoon's Beam Ray Replica Instrument.

B or E Coli Rod	800Hz	Streptothrix	784 Hz
B or E Coli Virus	1552 Hz	Syphilis or Treponema	660 Hz
BX Virus Carcinoma	2128 Hz	Tetanus	120 Hz
BY Sarcoma	2008 Hz	Tuberculosis Rod	803 Hz
Gonorrhea	712 Hz	Tuberculosis Virus	1552 Hz
Pneumonia or Spinal Meningitis	776 Hz	Typhoid Rod	712 Hz
Staphylococcus	727 Hz	Typhoid Virus	1862 Hz
Streptococcus	880 Hz		

The original Beam Ray Clinical instrument we have has an RF carrier frequency of 3.80 MHz. Aubrey Scoon's Beam Ray Clinical replica instrument's RF carrier frequency is 3.30 MHz. The audio frequencies Aubrey Scoon's instrument used, we showed earlier in this report, will not work with the original Beam Ray Clinical instrument that we have because the audio frequencies have to be matched

to the RF carrier frequency. The AZ-58's RF carrier frequency was set at 4.68 MHz as written down on the schematic and as per the FCC. Aubrey Scoon's Beam Ray Clinical instrument audio frequencies would not produce the correct sideband spacing with the AZ-58 RF carrier frequency because the audio frequencies are calculate to work with a 3.30 MHz RF carrier frequency not a 4.68 MHz RF carrier frequency. This also verifies to us that Philip Hoyland was using different RF carrier frequencies in the Beam Ray Clinical instrument. It also indicates that both Rife and Verne Thompson did not understand the importance of using the correct RF carrier frequency with the correct audio frequencies.

John Crane said this in his "Crane Report":

CRANE: *"The instruments were completed by Crane and Thompson in 1953, but the test results were negative."* (The Crane Report" page 6).

With the carrier frequency set at 4.68 MHz as per their FCC license, instead of 3.30 MHz, the audio frequencies they used would not make the correct sideband spacing and the instrument wouldn't have worked like they expected. Logically, if they understood the relationship of the RF carrier frequency and the audio frequencies they would have change the RF carrier frequency back it to 3.30 MHz or recalculated new audio frequencies to work with the 4.86 MHz RF carrier frequency, but they didn't do either.

Even with the wrong RF carrier frequency Dr. Rife, John Crane and John Marsh would have first tried the higher audio frequencies in the sine wave waveform like the original Beam Ray Clinical instrument used. Apparently when this didn't work, because the carrier frequency was wrong, they lowered the audio frequencies by a factor of 10 times and then changed the sine wave waveform to a square wave waveform. This appears to be the first time square wave was used. This change from sine wave to square wave wasn't really necessary since the circuit design will create a square wave looking waveform out of a sine wave anyway. The photo, shown below, is of AZ-58 waveform.

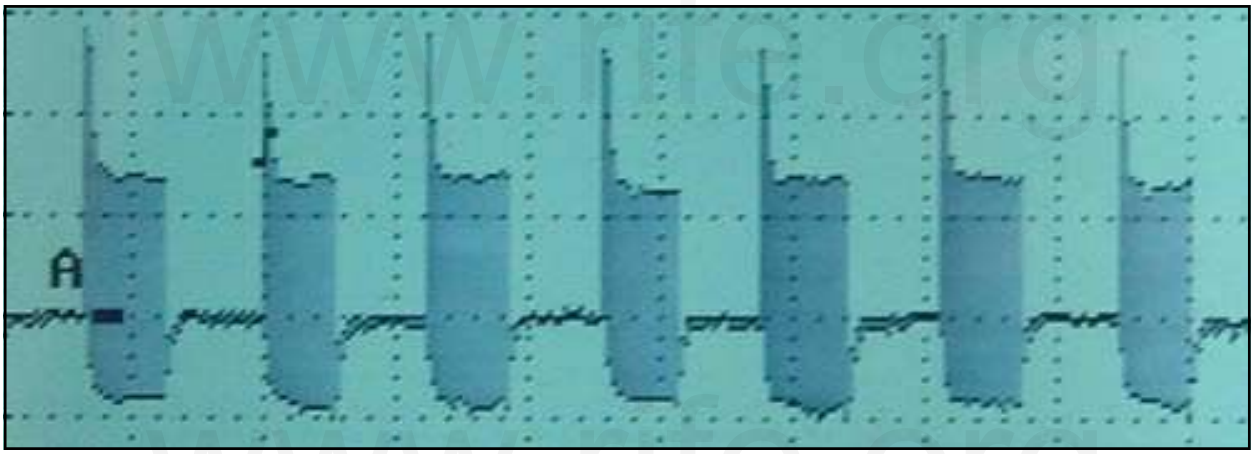

Using the square wave waveform would not have changed how the sidebands would have worked. But it would have created true square wave harmonics which the instrument did not have when it was using the sine wave waveform. John Crane mentions that this is when the instrument started to work better. So we are left to assume that he was referring to the use of the square wave waveform. It is ironic that they used a square wave waveform that produces harmonics in order to get the instrument to even begin to give them any results. Had they really understood how the audio frequencies interacted with the RF carrier frequency they would have recalculated the audio frequencies to work with the new 4.68 MHz carrier frequency instead of lowering the audio frequencies by a factor of 10 times. Then the square wave waveform change would not have been necessary. These important facts that have been pointed out again show they did not understand the relationship between the RF carrier frequency and the audio frequencies. All they managed to prove is neither the carrier frequency nor the audio frequencies will do anything by themselves.

This change from sine wave to square wave also created a whole new methodology of using frequencies. Instead of relying on the interaction of the sine wave audio frequency with the sine wave RF carrier frequency to produce the correct sideband harmonic M.O.R. to devitalize the organisms they were now depending only on the harmonics from the square wave waveform to hit the correct M.O.R. frequency. This change was also another indication that they didn't understand how the Beam Ray Clinical instrument worked.

Another thing that shows that they did not understand how the Beam Ray instrument worked is the fact that they didn't recalculate the audio frequencies to properly use the square wave harmonics to hit the high frequency M.O.R.s. This shows that they believed that the lower audio frequencies, which they were using, were the M.O.R.s. of the organisms even though they had no harmonic relationship with the original M.O.R.s. used in the Rife Ray #4. We must point out that the square wave mathematical method we are talking about here is completely different than the harmonic sideband method which Philip Hoyland used.

In many of the documents we find that both John Crane and John Marsh firmly believed that these lowered audio frequencies were the M.O.R. frequencies that would devitalize the organisms. Even Dr. Rife appears to have believed that the audio frequencies were the M.O.R.s. as long as they were used with Philip Hoyland's Beam Ray Clinical design. In Dr. Rife's original equipment like the Rife Ray #3 and the Rife Ray #4 he knew that the M.O.R. frequencies were the high RF frequencies. But since Dr. Rife didn't really understand exactly how Philip Hoyland's instrument worked it appears that he accepted the concept that the audio frequencies were the M.O.R.s, or created the M.O.R.s, as long as they were used with that style of instrument. Without understanding these facts it is hard to understand the rest of the history of Dr. Rife's instruments. The fact that they believed that the audio frequencies were the M.O.R.s. compromised the effectiveness of the 1953 AZ-58 Beam Ray Clinical replica.

Below and on the next page are four photos of ray tube instruments which Verne Thompson built. The first instrument was Aubrey Scoon's 1950's Beam Ray replica. The second instrument is believed to have been built in 1947 but some of the transformers are 1960's vintage which indicate it was built in the 1950's or 1960's. The audio frequencies used in it were even lower than the 1953 AZ-58. Since all the evidence we have shows that the lower audio frequencies began with the 1953 AZ-58 this indicates that the instrument was not built in 1947 but was built sometime after 1953. The third and fourth photos, on the next page, are of two of the AZ-58 instruments built by Verne Thompson in 1953 for Dr. Rife, John Crane and John Marsh of Life Labs Co.

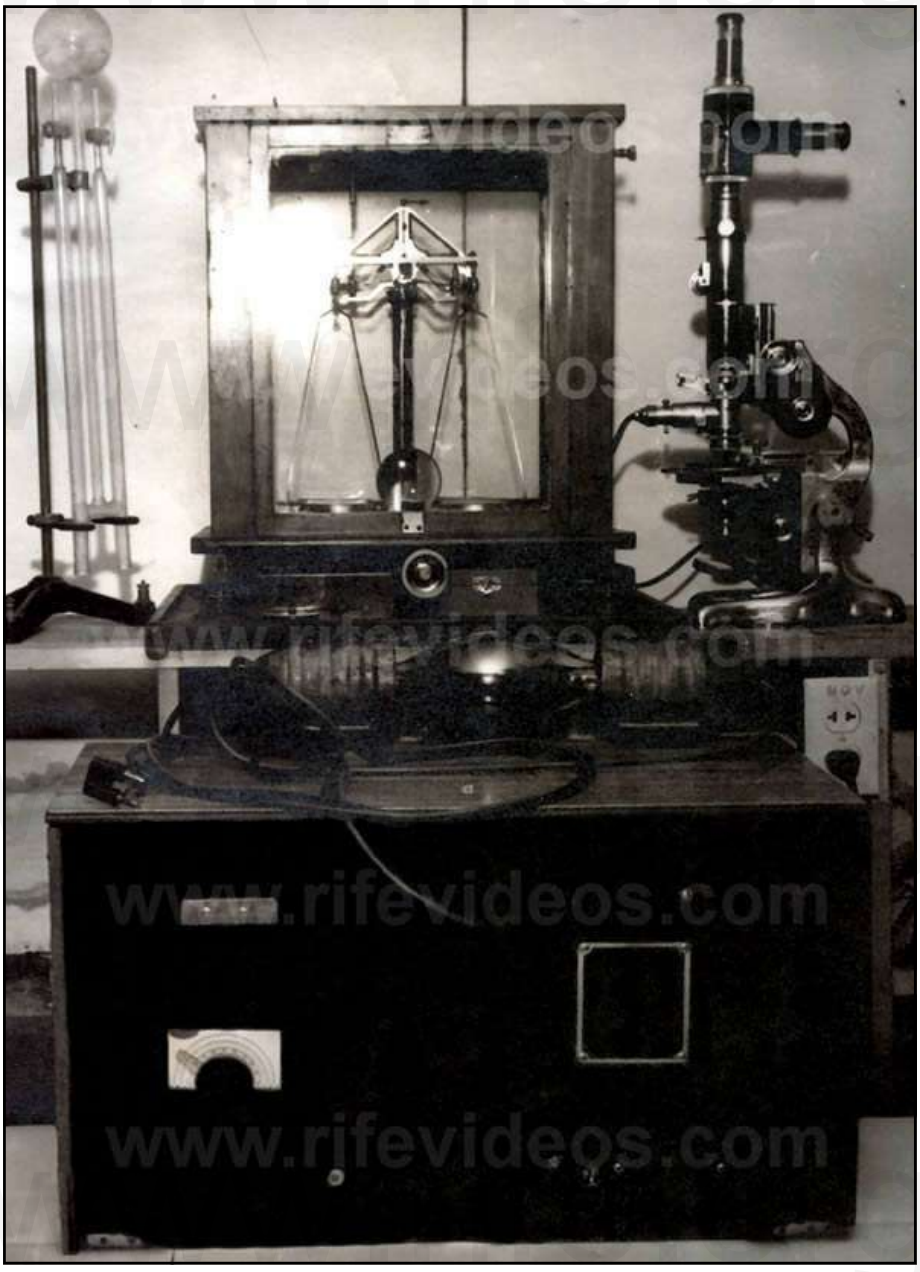

All four of these instruments, like the Beam Ray Clinical instrument, had the fixed Hartley Oscillator section which created the RF carrier frequency. Verne Thompson changed the 809 tube to the 812 tube as he updated the instruments from the 1940's to the 1950's. All three instruments also had one main frequency dial for adjusting the audio frequencies. The other two smaller dials were for adjusting the modulation amplitude of the audio frequencies and changing the audio frequency bands. These bands would take you through the various audio frequency ranges. The AZ-58 was limited to about 6000 Hertz, using 3 bands, because they lowered the audio frequencies. The original Beam Ray Clinical instrument we have went to just over 40,000 Hertz using 4 bands. The 1950's Aubrey Scoon Beam Ray Clinical replica instrument could go to about 200,000 Hertz using 4 bands. Other than the bands there is very little difference in the way these instruments worked. We built two of the three, tested them, and found no significant difference other than the use of sine or square wave audio frequencies. At any time the AZ-58 could have been changed to work on the original Beam Ray Clinical sideband method just by adding a fourth band and then recalculating the audio frequencies to work with the 4.68 MHz RF carrier frequency. As pointed out before we made some tests with the spectrum analyzer to see if square wave could be used instead of sine wave in creating the proper sideband spacing and found that the square wave waveform produces the same sidebands as the sine wave waveform.

The basic design of Philip Hoyland's Beam Ray Clinical instrument is very apparent when you compare the schematics. Six of the 1953 AZ-58's were originally built by Dr. Rife, John Crane and John Marsh. We decided to test the AZ-58 with the spectrum analyzer. Below in the graph you can see the results of these tests.

Testing done with PicoScope 3205 spectrum analyzer at 2,400,000 Hertz using AZ-58

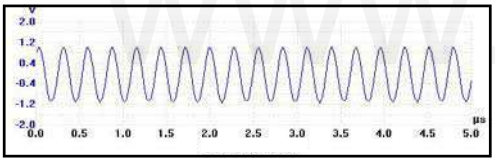

Sine wave out of AZ-58 at 2,400,000 Hertz.

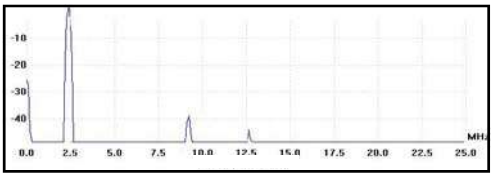

AZ-58 without ray tube at 2,400,000 Hertz measured with spectrum analyzer showing no real harmonics.

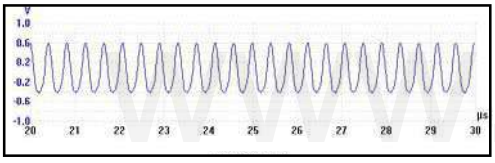

Sine wave carrier out of AZ-58 at 2,400,000 Hertz using ray tube. Sine wave carrier was always distorted when put through a ray tube.

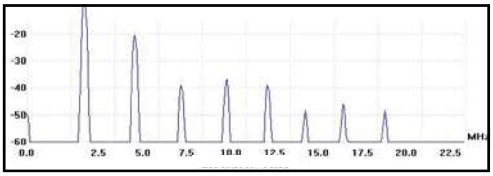

AZ-58 at 2,400,000 Hertz using ray tube. Measured with spectrum analyzer showing harmonics all the way up to 20,000,000 Hertz.

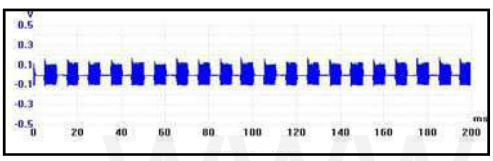

AZ-58 at 2,400,000 Hertz using ray tube. Showing 50% square wave audio frequency modulation. The square wave shows some distortion.

www.rife.org

The instrument called the AZ-58 is significant because we have more information about what took place in the 1950's than any period before this. At this time in the 1950's John Crane and John Marsh recorded interviews with Dr. Rife, Dr. Couche, Ben Cullen, Henry Siner and many other individuals who were key players in the early years of Dr. Rife's work.

We will now cover in more detail the history of the 1953 AZ-58 instrument so we have more information about this instrument. Some of the information comes from the John Marsh Collection of Rife audio CD's. As we said, in 1950 John Crane met Dr. Rife and in 1952-53 he met John Marsh. John Marsh became John Crane's supervisor at Convair Aeronautics when John Marsh moved from Tucson, Arizona to California. John Marsh's wife had cancer and they were not able to help her in Tucson. The doctors recommended that he take her to San Diego for specialized care. John Marsh and John Crane became friends. John Crane told John Marsh about Dr. Rife and they went to see him. Dr. Rife gave them an old Beam Ray Clinical instrument which they had Verne Thompson repair. John Crane and John Marsh then used this instrument on John Marsh's wife and after several treatments John Marsh said she fully recovered. Here are John Marsh's statements which he made in 1976 and 1986:

MARSH: (1976) *"I met this Rife. I said Dr. Rife, I said, my name is John Marsh, I've got a wife that's dying. She's got cancer of the uterus." Dr. Rife said: "I won't touch that thing with a 20 yard pole."*

After some discussion Dr. Rife said:

RIFE: *"I have an old instrument down here in the basement."*

MARSH: *"I dug up that old instrument and of course it had tubes in it, antique stuff, and so I rebuilt the darn thing."* (John Marsh Rife CDs, CD 10 track 1)

MARSH: (1986) *"I went to see him* [Dr. Rife], *and I talked with him and he said he didn't want to have any part of it...I said look, I got a wife that's dying and I need your help! And so I got him out of his cocoon, so to speak, and we took an old instrument and rebuilt it. And I treated my wife and by darn all the pain left her and she got well." In another part of the tape he said: "I discovered that this Dr. Rife was a very great individual...I told John* [Crane], *I said look if we have any of those old instruments laying around loose, let's rejuvenate one of them and see if we can get my wife well. Well Verne Thompson who was with the San Diego police department radios, uh, radio expert, uh, had built some instruments and they were antiques when I saw them."* (John Marsh Rife CDs, CD 2 track 3).

John Marsh and John Crane then decided they would like to work with Dr. Rife and try to get the frequency instruments rebuilt and back into doctor's hands. They wanted to help people who were suffering from many incurable diseases. From earlier quotes we learned that Verne Thompson had worked on Dr. Yale's Beam Ray Clinical machine. He knew how to build these instruments and this is why John Marsh and John Crane had him repair the instrument that Dr. Rife gave them. It is apparent that Verne Thompson knew this instrument's circuit designs very well but he didn't understand how the Beam Ray Clinical instrument was using harmonic sidebands to hit Dr. Rife's higher harmonic M.O.R.s. From a patent application that Dr. Rife and Verne Thompson filed we know that Verne Thompson also believed the audio frequencies were the M.O.R.s. This document leads us to only one conclusion; no one in the 1950's understood how Philip Hoyland's sideband spacing method worked.

John Crane in his later years (1970's & 1980's) was not being very truthful in some of his statements. He said this in his paper titled "The Crane Report":

CRANE: *"Unfortunately, Rife had enlisted the help of electronic experts in the '30's who never wrote down the details of the instruments. Rife was unable to duplicate the marvels of his earlier Frequency instruments."* (The Crane Report, page 6).

The documents we have read in this report show that Dr. Rife was having Verne Thompson build and repair the Beam Ray instruments originally built in the 1930's. For this reason we know that John Crane's statement, in his report, was not truthful. The facts have shown that this instrument design came from Philip Hoyland. It was Verne Thompson who updated the Beam Ray Clinical instrument for Dr. Rife, John Crane and John Marsh in 1953. If Verne Thompson was building these Beam Ray Clinical instrument then he surely would have had a schematic for them.

Others have felt that John Crane took advantage of Dr. Rife. This may be true in some things that took place later on in the late 1960's, 1970's and 1980's but the evidence does not support this in the 1950's and early 1960's. Here is a quote from the John Marsh Collection "Trip to Dayton Ohio Papers" and Gonin Papers. Dr. Rife, John Marsh and John Crane were talking at great length about John Marsh's trip to Ohio to see Dr. Robert P. Stafford M.D. In the Gonin papers they talked about the frequencies. I would recommend that everyone read these papers because they show that Dr. Rife, John Crane and John Marsh worked as a team. They also show that John Marsh and John Crane considered the frequencies to be Dr. Rife's and the AZ-58 Beam Ray replica instrument to be Dr. Rife's instrument. The following statements confirm this:

RIFE: *"Well I have lived my life for the benefit of humanity, and it is the end result of the accomplishment."*

MARSH: *"Yes, now here is what I did tell them. They wondered where I fit into the picture. I told them I had lay outs at the base, I designed part of it. You would say that I was possibly not an exactly an inventor, but I think we are all co-inventors of a sort by adding what we think would make the instrument better and if they try to validified* [verify] *any of the statements that I have said to them please don't let me down, and say no this isn't so, which might upset what might be the truth to them. I mean just by accident. Now what I mean by that is this. I don't think that I have in my own right lied to them. I did [didn't] try to impress them with the idea that I was the one that did it. I did impress that you* [Dr. Rife], *John Crane and myself had worked together on this thing, but that you* [Dr. Rife] *were inventor and John* [John Crane] *was the designer and inventor, co-inventor and myself for putting this thing together and making it. They asked if I helped putting this thing together and making it from time to time. I couldn't tell them that I didn't, because if I had built up a feeling in them that I knew nothing about what I was doing; psychologically that could have torn down, or have caused delay the foundation that now is laid. Now I think we have a solid footing there. I under no circumstances would want that torn down, and I will not under any circumstances accept the credit for this instrument as being invented, because it is Rife's instrument as printed on the plate in front and that is one of the reasons in building you up to them, which I don't think is unwarranted; not by a darn sight, and that is why they want you there. They want to hear you talk, and they also want to know your past experiences with the people of La Jolla and also I was very happy to have received the paper concerning the Dr. etc., because I'm sure Stafford will contact every blooming Dr. that you had given him to me and I turned over all the letters to him, because I didn't want anything to stand in the way if he could contact him, now whether he would do that, before he would talk to the group, and I do not know. I suppose he will, but he wants the truth as badly as you do. Now I don't know an easier way it can be done. I don't think there is going to be an easy way to get it on, but I think I've outlined this thing. I studied the moves I was going to make before I ever went there. I studied what I was going to do if I had the opportunity to do so, which I did."*

RIFE: *"Well I think that you did a very excellent job."* (1957 John Marsh trip to Dayton, Ohio #8, 9 and 16)

And in the John Marsh Collection, Gonin Papers we read:

CRANE: *"So the frequencies* [audio] *we have written down. I will give you those or Rife will give them to you. I think you ought to have them. Each one [organism] has a different frequency, you see. I don't*

remember any of them off-hand. I should memorize them all, but I haven't yet. I've just written them down and they are in the lab."

GONIN: *"Those frequencies that you have written down, would only apply to your own machine* [AZ-58], *wouldn't it?"*

CRANE: *"That is because they have been calibrated for each machine. Each machine has its own calibration."*

GONIN: *"And that's constant?"*

CRANE: *"Yes."* (John Marsh Collection, Gonin and Siner Papers, Page 15)

After reading these documents the facts stand out that all three of these men knew the audio frequencies and they were not John Crane's invention. Both John Marsh and John Crane considered the instrument to be Dr. Rife's. Dr. Rife also had a plaque on the front of the instrument with his name on it. It is also clear from John Marsh's papers that Dr. Rife was not on the sidelines but he a working partner in Life Labs. Dr. Rife by this time had become what some people call a "working alcoholic." This type of drinker would have a little to drink during the day to take the edge off but would not be a total drunk. The documents show that Dr. Rife knew the audio frequencies that were used in the AZ-58. But it is clear that he didn't understand how those audio frequencies worked with the RF carrier frequency with Philip Hoyland's design. On the Rife CD's all of Dr. Rife's recorded conversations were very positive about the 1953 AZ-58 instrument. This does not sound like a man who was ignorant of what was going on, as some have claimed.

Anyone who reads the documents from this period of time can tell that there were a lot of high hopes for this instrument and the lower square wave audio frequencies it was using. Now the real question is how well did this instrument work when it was only working on square wave harmonics? There were a lot of good reports on how well the instrument worked but what really counts is how well it worked in the hands of the doctors who used it on their patients. Dr. Robert P. Stafford M.D., used the AZ-58 for 5 years on his patients and wrote a report and sent it to Dr. Rife, John Crane and John Marsh. The photo below is a picture of Dr. Robert P. Stafford M.D.

Dr. Stafford's report is very favorable on many conditions that he used the AZ-58 on but when it came to cancer this instrument did not work as well as the Beam Ray high frequency harmonic sideband method. Dr. Stafford's report showed he treated 16 cancer patients and had a varied response rate using the AZ-58 on cancer. We must point out that the instrument did temporarily help some of his cancer patients while others did not see any benefits. Two of the women that he treated received a great deal of benefit but died from other complications. This made it so that he could not say they were cured by the instrument. When the first woman was autopsied she only had a small amount of cancer left in her breast. When Dr. Stafford started treating her she had cancer in several other places including her neck. Had she not died from a fall she probably would have fully recovered.

The second woman had cervical cancer for which other doctors used a great deal of radiation therapy. Dr. Stafford treated her at the hospital and after about four weeks she went home. She died of radiation damage that was done to the tubes that go from the kidneys to the bladder. When she was autopsied they found no cancer cells in her abdomen. In this case the cancer was completely gone. Since neither of these women lived for at least five years they could not be considered cured. So Dr. Stafford could never say that he had cured anyone of a terminal malignancy. He said this about the AZ-58 square wave audio frequency instrument:

DR. STAFFORD: *"As yet, we have failed to "cure" any case of advanced, terminal malignancy. It appears in several instances that we may have impressed the disease favorably, temporarily. It is difficult to rule out the psychological, morale booster effect to the terminal patient when some definitive effort is made again in his behalf. However, several improvements have appeared to be more physical than emotional...All the patients in the series were treated with the same frequencies (e.g., 728 - 784 - 880 - 2008 - 2128). Perhaps these frequencies may be wrong, or only nearly correct."* (John Marsh Collection, Dr. Stafford's Report on using the AZ-58, page 4).

It is clear that Dr. Stafford was questioning the accuracy of the square wave audio frequencies and felt that something was wrong. Everyone who has been around Rife technology for a long time has seen the very same results as Dr. Stafford. From time to time we see that someone has an amazing experience of recovery from cancer but for the majority this does not happen. Today these frequencies **728, 784, 880, 2008 and 2128** Hertz which Dr. Stafford used are the same frequencies used by just about everyone for cancer.

Many have wondered why the AZ-58 worked well for a few patients and not for others. We believe we know the reason why. The RF carrier frequency is the reason it worked. The AZ-58 RF carrier frequency was set at the new 4.68 MHz to comply with the new 1950's FCC license. Dr. Stafford changed the RF carrier frequency using the variable capacitor to operate between 3.10 MHz to 3.30 MHz with the two women who were treated for cancer. He also used this same RF carrier frequency with some of his other patients. If per chance the RF carrier frequency was set at about 3.20 MHz it would have been only about 15,000 Hertz off of the second higher harmonic of Dr. Rife's original BX cancer virus frequency, which was 3,214,900 Hertz. This second harmonic of the BX (1,607,450 X 2 = 3,214,900 Hertz) was the primary frequency used by Philip Hoyland in the Beam Ray Clinical instrument for the BX cancer virus. If an audio frequency of 2128 Hertz (AZ-58 BX audio frequency) was used, and it was, it would have created many harmonic sideband frequencies and the 7th harmonic sideband frequency would have hit Dr. Rife's higher harmonic BX frequency of 3,214,900 Hertz. We need to keep in mind that Dr. Stafford also used 728, 784, 880 and 2008 Hertz. It would have been almost impossible for him not to hit the BX frequency of 3,214,900 Hertz with one of the sidebands from all these frequencies. If we also take into account the "one tenth of one meter" tolerance frequency of 858 Hertz it gives room for the frequency to be off a few hundred Hertz and still work. What we have just explained is the reason why we think the AZ-58 worked so well on these two women.

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It is also known that Dr. Stafford tried other RF carrier frequencies. Once he changed the RF carrier frequency the instrument would have been relying completely on the harmonics from the square wave waveform of the audio frequency. This would have greatly affected the outcome of his testing. The fact is the square wave harmonics method did not work as well as the Beam Ray Clinical sideband spacing method. **The real problem is almost everyone believes the square wave audio frequencies are Dr. Rife's true M.O.R. frequencies.** The evidence shows that John Crane and John Marsh believed the audio frequencies were the true M.O.R. frequencies and they had given this understanding to Dr. Stafford. Without the correct understanding of how the instrument worked Dr. Stafford would not have understood how important the fixed RF carrier frequency was. If he changed it off of the 3.20 MHz RF carrier frequency many of the 16 cancer patients could have been affected negatively. Dr. Stafford followed these 16 people over many years and in some cases things looked good at first, but the people eventually died from their cancer anyway. One thing that needs to be pointed out is we do not know if Dr. Stafford treated many of his patients over a long enough time period as Dr. Couche and the other doctors did their patients.

In the 1934 clinic 16 patients who had cancer and tuberculosis were treated and considered clinically cured. This is quite a contrast; 100% success in 1934 using Dr. Rife's high RF frequency method. And a very limited success rate on cancer for the low square wave audio frequency harmonics method. Only when Dr. Stafford accidently used an RF carrier frequency close to the BX cancer virus frequency did the AZ-58 seem to get good results. Dr. Stafford used the AZ-58 instrument for a little over five years and sent his report to John Marsh. I am sure John Crane received it also. The big question that needs to be asked is why did John Crane and John Marsh continue to tell people these low audio frequencies were the frequencies which Dr. Rife used in the 1934 clinic when the medical proof showed they didn't work as well as the high RF frequencies? This again clearly shows they did not understand the sideband method. We have to ask the question, why do people today continue to say these frequencies cure cancer even after they have seen the same results? Could it be because having had a few good results they ignored the evidence and fool themselves? By the time all the evidence was available, John Marsh and John Crane were in jail on three or four different legal counts, one of which was for treating a woman without a medical license.

Dr. Rife did not want to have anything to do with all the legal trouble they were in. He was able to avoid it because he never made any claims and he would never treat anyone. The legal problems shut down Life Labs. Had this not happened I wonder if Dr. Rife would have ignored this evidence? I do not believe he would have. He would have realized that the changes they made to the instrument which depended solely on square wave audio frequency harmonics compromised its effectiveness. I think Dr. Rife would have eventually realized that they didn't fully understand how the Beam Ray Rife Machine worked and he would have gone back to the higher audio frequencies and put the RF carrier frequency back on 3.30 MHz. We will never know what he would have done because I do not think Dr. Rife ever read Dr. Stafford's report. This is because John Marsh received the report after he and John Crane were released from jail.

The troubling thing is this, because so few really understand Dr. Rife's early instruments and how Philip Hoyland's Beam Ray Clinical Rife Machine worked almost all frequency generators have been built using this limited square wave audio frequency harmonic method. The people who purchase these low square wave audio frequency instruments have been led to believe it is the same type of instrument used in the 1934 clinic. All because we didn't know the truth. Are people today just fooling themselves also? Are we trying to get these same square wave audio frequency harmonic type instruments and the frequencies they use to do what Dr. Stafford could not get them to do? Cure cancer? We know there have been incredibly good results on many other conditions using audio frequencies which show this type of instrument and method is of great worth but the truth is sometimes hard to accept.

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As we have already read, Dr. Stafford came to suspect that the audio frequencies were not true M.O.R.s. Another letter written by Dr. Stafford to Dr. Edward Jeppson in Salt Lake City also confirms his concerns. He wrote this letter to Dr. Jeppson because he was having the same type of results that he was having. Here is his statement from his letter:

DR. STAFFORD: *"Please excuse my format in the following letter for I intend to ramble a bit and forget strict grammatical dictum. I am writing you at this time partially because John Marsh informs me in a recent letter that you may be somewhat disheartened or at least worried about your role in the experimentations with the Rife Machine. Believe me, Dr. Edward I know how you feel for I too have been through this same feeling with this matter. I have observed clinical results after treatments with this gadget which I can scarcely believe myself. Yet, despite these good results, I have been confused by some rather simple failures such as a recent experiment which I conducted at Good Samaritan Hospital where we used the machine to treat some cultures of Staph Aureus and Strept. Fecalis. In this work we failed to inhibit growth at all or influence the cultures with the Rife Rx. I sent the results to John Marsh and asked for clarification and to be very frank I am not satisfied with John's excuse of the failure as described by Dr. Rife. I am afraid I'm not a very good apostle for I'm getting some ideas myself on how this thing may work. I really wonder if this ultrasonic kills bacteria and virus at all or does it work like other forms of ultrasonic and merely stimulate the tissue in some unusual manner thereby improving the circulation and secondarily enhancing the body's defenses against infection…To summarize some of this rambling: I feel that the Rife Ultrasonic Therapy has a very definitely beneficial effect on the human (and canine) body...I furthermore feel that we, as doctors of medicine, using this machine must remain constantly alert to the condition of our patient and vary the Rx as indicated."* (Letter from Dr. Stafford to Dr. Edward Jeppson dated, April 1, 1958).

Clearly Dr. Stafford was questioning whether the audio frequencies were correct. Little did he know they were not the same frequencies used with the Rife Ray #3 or the Ray #4 instrument? The AZ -58 could have output the higher harmonic sideband frequencies that Philip Hoyland used in his Beam Ray Clinical instrument if they had only understood how it really worked. Whatever was told to Dr. Stafford by Dr. Rife through John Marsh it did not satisfy Dr. Stafford's concerns. Dr. Rife, John Crane and John Marsh probably felt that Dr. Stafford had just made some errors in his work. The one thing that Dr. Stafford did inadvertently find out was the AZ-58 using the square wave audio frequency harmonic method did not kill organisms in the laboratory at the hospital. In the 1950's Dr. Rife no longer had a laboratory for testing any microorganisms. There is no evidence they ever tested just the square wave audio frequencies with Dr. Rife's microscopes. So they did the only thing they could. They let the doctors use the AZ-58 and tell them how well it worked. We must keep in mind that the instrument Dr. Rife gave to John Marsh and John Crane was an original Beam Ray Clinical instrument which used the harmonic sideband method developed by Philip Hoyland. It used the correct higher audio frequencies and the correct 3.30 MHz RF carrier frequency. This instrument apparently worked because John Marsh said it cured his wife of cancer. Again the fact is the AZ-58 Beam Ray Clinical instrument using square wave audio frequency harmonics never worked as well as Philip Hoyland's sideband method. It also didn't work as well as the Rife Ray #3 or Rife Ray #4.

The square wave harmonic method used in the AZ-58 produced very good results on many conditions but not the results hoped for on cancer. But still even with the changes the AZ-58 worked very well on many different conditions. These square wave audio frequencies are what people have been using for the past 50 years believing they were Dr. Rife's true M.O.R.s. All this time not knowing they were not Dr. Rife's original frequencies which he used in his earlier instruments built in the 1920's and 1930's. It wasn't until the papers from the 1939 Beam Rays Trial, John Marsh Papers, Kennedy Company equipment spectrum analysis and Philip Hoyland Beam Ray Clinical Rife Machine spectrum analysis came to light did we have the ability to finally figure out where all these frequencies came from. This information finally reveals which frequencies were the correct M.O.R.s. Notwithstanding the various setbacks Dr. Stafford was still amazed at the results he achieved with the AZ-58.

Since we were able to obtain access to John Marsh's papers we were also able to discover that in 1976 John Marsh had some of these low square wave audio frequencies tested on microorganisms by a laboratory using his 1970's model of the AZ-58 Beam Ray Clinical ray tube instrument. Keep in mind that this instrument was miscalibrated like all the 1950' AZ-58 Beam Ray Clinical instruments. It was also only working on square wave harmonics. He paid for these tests and they were carried out between May 1976 and March 1977. The University that did the tests specifically stated that, whatever the outcome of the tests, John Marsh could not use their name in any way to endorse his equipment. These tests were similar to the tests Dr. Stafford conducted at Good Samaritan Hospital. Dr. Stafford's tests showed that these low square wave audio frequencies, which did not produce the correct sideband M.O.R. frequencies, would not devitalize any organisms. John Marsh's tests which he had done at this laboratory also showed that the low audio frequencies working on square wave harmonics will not devitalize any organisms. Both Dr. Stafford's and John Marsh's tests convincingly show the low square wave audio frequencies are not true M.O.R.s. Unless these instruments use the higher audio frequencies with a 3.30 MHz RF carrier frequency they will not devitalize anything.

No one that reads this information should in any way believe that this means that Dr. Rife's method of coordinative resonance is without merit. What these laboratory tests showed is that it is absolutely necessary that the instrument work on the same principles and frequencies as the original instruments that produce the true M.O.R. frequencies use in the Rife Ray #3, Rife Ray #4 and the Beam Ray Clinical instrument. These 1950's AZ-58 Beam Ray Clinical instruments were not calibrated correctly and they used the wrong audio frequencies. This miscalibration made it so the instruments did not work on the original sideband principles which produced Dr. Rife's frequencies. Because they were not calibrated correctly it rendered the instruments incapable of devitalizing any microorganism using just low square wave harmonics audio frequencies.

Even after these tests proved that the low square wave audio frequencies would not devitalize any microorganisms John Marsh continued to hold on to the false notion that these low square wave audio frequencies would devitalize microorganisms. He never would consider that something was wrong with the instruments. Today we understand that a simple correction would have solved all the problems. To read the document about this laboratory test that conclusively proves that the audio frequencies are not M.O.R.s. go to www.rifevideos.com and read this chapter and you will find the following link. (John Marsh's tests performed by: Brigham Young University Microbiology Department)

We covered this information in a previous chapter but it should be reviewed again here. Some people have wondered if the low audio frequencies (120 Hertz to 2128 Hertz) used in the 1953 AZ-58 are actually the original audio frequencies used in the 1938-1939 Beam Ray machine rather than the high audio frequencies (1200 Hertz to 21275 Hertz) used in Aubrey Scoon's Beam Ray replica instrument. This is a good question and it can easily be answered with certainty. The answer is in the math which produces the correct sidebands for each organism. Only the high audio frequencies (1200, 2400, 6600, 6900, 7660, 7270, 7870, 8300, 8450, 8020, 16000, 17220, 18620, 20080, 21275) will produce the correct sideband frequencies that will produce the higher harmonic frequencies from Dr. Rife's original frequencies. Only six of the low audio frequencies (120, 660, 727, 1862, 2008, 2127-2128 or 2127.5 Hertz as given by John Crane) used in the 1953 AZ-58 when multiplied by a factor of 10 times give the exact same high frequency used in Aubrey Scoon's instrument. But the other seven (712, 784, 776, 800, 803, 880 and 1552 Hertz) when multiplied by a factor of 10 times will not give the correct high audio frequency. These facts reveal which frequency list came first. Since we know that Philip Hoyland designed this Beam Ray Clinical machine and hid the method of using sideband frequencies to produce higher harmonics of Dr. Rife's M.O.R. frequencies then only the list (Aubrey Scoon's higher audio frequency list) that will produce Dr. Rife's higher harmonic frequencies could be the original list.

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From the Beam Ray Trial we learned that no one but Philip Hoyland understood how the instrument worked. Not even Dr. Rife, Verne Thompson, John Crane or John Marsh understood that the RF carrier frequency had to be matched to the audio frequencies in order to produce the sideband frequencies that would hit the higher harmonic frequencies of Dr. Rife's original M.O.R. frequencies. John Crane and John Marsh said many times the RF carrier frequency did not matter. In fact, they eventually quit using the RF carrier frequency when they built their 1950's contact pad style instrument. This clearly proves that they did not understand that the original Rife Ray #5 or Beam Ray Clinical instrument worked on harmonic sidebands. Had they understood this simple fact they never would have changed the RF carrier frequency or built their contact pad style instrument without using an RF carrier frequency. They also would not have lowered or changed any of the audio frequencies if they understood the sideband method used by Philip Hoyland. Both audio frequency lists would be identical except that one list would be 10 times higher than the other list. Only someone who did not understand how the audio frequencies really worked would have lowered them and then changed them. Only the list which came first would have all the correct frequencies. This information proves that the high audio frequency list came first. The low audio frequency list used in the 1953 AZ-58 would have come later in the 1950's because it is the list, when multiplied by 10 times, will only produce some of the correct sideband frequencies. Only someone such as Philip Hoyland could have made the high audio frequency list since the high audio frequencies are the only frequencies that will produce Dr. Rife's higher harmonic M.O.R. frequencies. As we said, the answer to this question is in the math.

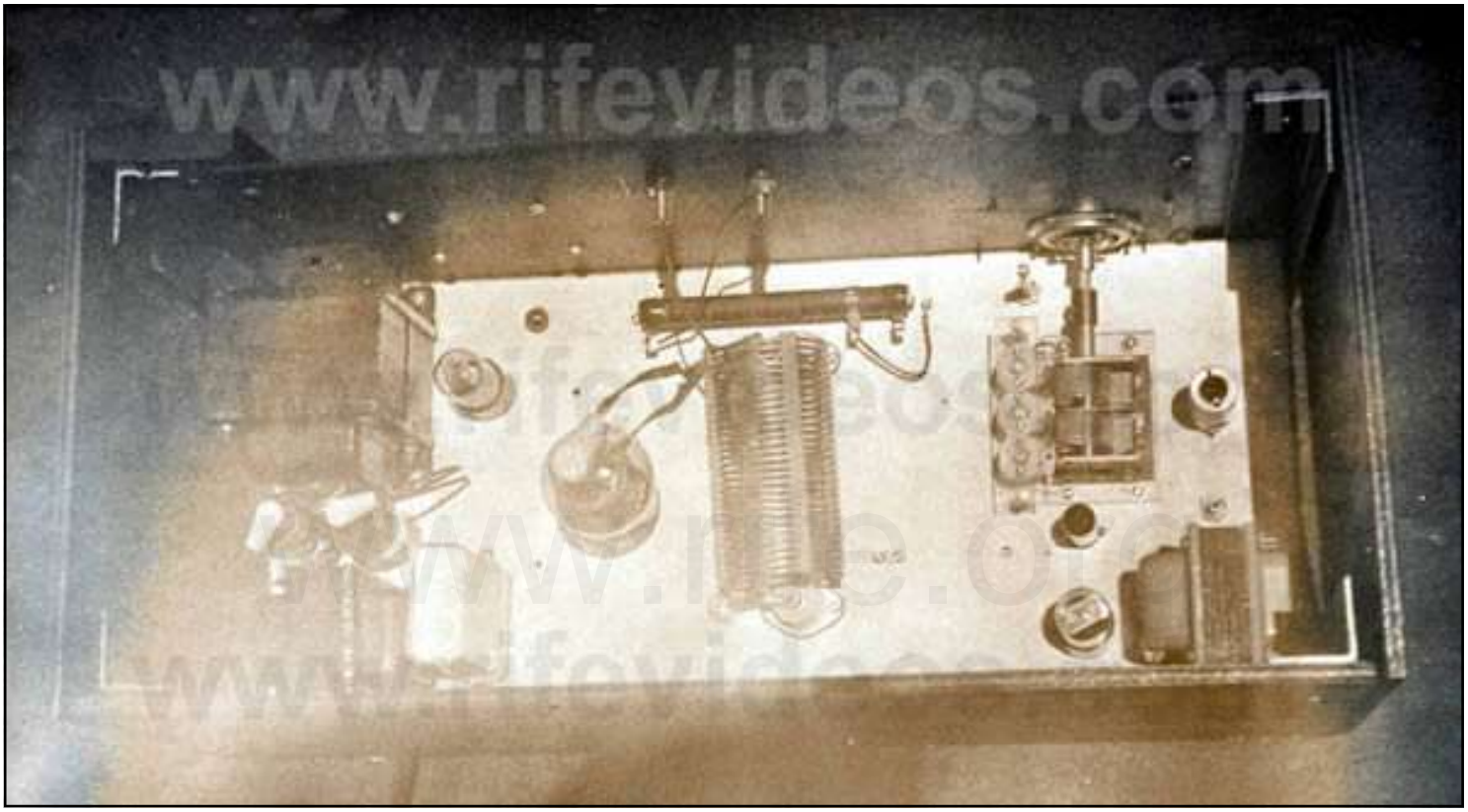

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Below in the chart is a list of the “Original 1950s AZ-58 Frequencies” used by Dr. Stafford. The column to the right of the "Original 1950's AZ-58 Frequencies" is based on a 4.68 MHz RF carrier and is labeled “4.68 Correct Sideband Frequencies”. They would be the correct sideband frequencies to make the AZ-58 instrument work like the original Beam Ray Clinical instrument, but, the problem is the large “Number of Sideband Harmonics”. You will notice that almost all of the low audio frequencies exceed more than 40 sideband spacing steps to hit the high frequency M.O.R.

Original 1950’s AZ-58 Frequencies Used By Dr. Robert P. Stafford M.D.

Microorganism	Rife Ray #4 Frequencies	Higher Harmonic Frequencies	*Carrier Difference Frequency	1/10 Of A Meter Freq.	Number of Sideband Harmonics	Original 1950s AZ-58 Frequencies	4.68 Correct Sideband Frequencies
Actinomycosis or Strepto-thrix	192,000 Hz	4,608,000 or 24th	72,000 Hz	12 Hz	92	784 Hz	782 Hz
Anthrax	139,200 Hz	4,732,800 or 34th	52,800 Hz	6 Hz	85		621 Hz
B or E Coli Rod	417,000 Hz	4,587,000 or 11th	93,000 Hz	58 Hz	116	800 Hz	802 Hz
B or E Coli Virus	770,000 Hz	4,620,000 or 6th	60,000 Hz	198 Hz	38	1552 Hz	1538 Hz
BX Virus Carcinoma	1,604,000 Hz	4,812,000 or 3rd	132,000 Hz	858 Hz	32	2128 Hz	2129 Hz
BY Sarcoma	1,530,000 Hz	4,590,000 or 3rd	90,000 Hz	780 Hz	45	2008 Hz	2000 Hz
Gonorrhea	233,000 Hz	4,660,000 or 20th	20,000 Hz	18 Hz	28	712 Hz	714 Hz
Pneumonia or Spinal Meningitis	427,000 Hz	4,697,000 or 11th	17,000 Hz	61 Hz	17	776 Hz	1000 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz	4,780,000 or 10th	100,000 Hz	76 Hz	137	727 Hz	730 Hz
Streptococcus Pyogenes	720,000 Hz	4,320,000 or 6th	360,000 Hz	173 Hz	409	880 Hz	880 Hz
Syphilis	789,000 Hz	4,734,000 or 6th	54,000 Hz	207 Hz	82	660Hz	658 Hz
Tetanus	234,000 Hz	4,680,000 or 20th	0 Hz	18 Hz		120 Hz	20 Hz
Tuberculosis Rod	369,000 Hz	4,797,000 or 13th	117,000 Hz	45 Hz	146	803 Hz	801 Hz
Tuberculosis Virus	769,000 Hz	4,614,000 or 6th	66,000 Hz	197 Hz	44	1552 Hz	1500 Hz
Typhoid Rod	760,000 Hz	4,560,000 or 6th	120,000 Hz	192 Hz	168	712 Hz	714 Hz
Typhoid Virus	1,445,000 Hz	4,335,000 or 3rd	345,000 Hz	694 Hz	185	1862 Hz	1865 Hz

The large “Number of Sideband Harmonics” means that the power level of the correct sideband that hit the higher harmonic M.O.R. would be so weak that it would never work. If the “Number of Sideband Harmonics” go over about 40 sideband steps the power level on a spectrum analyzer shows that they become too weak to work.

You will notice how closely these two sets of low audio frequencies correspond to each other. The problem is when Dr. Rife, John Crane and John Marsh lowered the audio frequencies they compromised the AZ-58. The BX audio frequency that Dr. Stafford used was 2128 Hertz and the RF carrier frequency was about 3.20 MHz. The sideband spacing to the “Higher Harmonic Frequency” M.O.R. took only a few sidebands which had enough power to work. This appears to be the reason why the two women and a few others that he treated had such amazing results. The problem is most of the organisms far exceed the 40 sideband harmonics when using these low audio frequencies. This will happen even if you use a 3.20 MHz or 4.68 RF carrier frequency. As mentioned before the higher the audio frequency used the more power there is in the sidebands. For this reason in the next chart, at the top of the next page, we have put a list of the optimum AZ-58 audio frequencies to be used with a 4.68 MHz RF carrier frequency and a 40,000 Hertz audio frequency oscillator. This would make the instrument work like the original Beam Ray Clinical instrument.

1950's Beam Ray Clinical Instrument Optimum Sideband Square Wave Audio Frequencies Based On A 4.68 MHz Carrier			
Anthrax	26,400 Hz	Streptococcus	32,727 Hz
B or E Coli Rod	31,000 Hz	Streptothrix	36,000 Hz
B or E Coli Virus	30,000 Hz	Syphilis or Treponema	18,000 Hz
BX Virus Carcinoma	33,000 Hz	Tetanus	20 Hz
BY Sarcoma	30,000 Hz	Tuberculosis Rod	39,000 Hz
Gonorrhea	20,000 Hz	Tuberculosis Virus	33,000 Hz
Pneumonia or Spinal Meningitis	17,000 Hz	Typhoid Rod	40,000 Hz
Staphylococcus	25,000 Hz	Typhoid Virus	38,333 Hz

Below and on the next page are three photos of the original AZ-58. The first photo is of the inside of the case showing the variable capacitor (bottom left corner with the black knob and the black wire leading to it) which could change the RF carrier frequency. The second photo is a view of the underside of the chassis. From the 1930's to the 1950's the instrument had only a few changes made in the electronic parts. The third photo is a side view of the first AZ-58 built in 1953. If you take a close look at this photo you will see that it did not have the variable capacitor when it was first built. The variable capacitor was added in 1956 and was used for tuning the brightness or resonance of the ray tube. This was done because they didn't believe the carrier frequency made any difference. It was not added for the purpose of changing the RF carrier frequency, this was just a side benefit. Doctor Stafford used this variable capacitor to set the carrier frequency to about 3,200,000 Hertz for some of his tests. This is the reason we believe he had such good success with the two women patients who had cancer. The BX cancer frequency was 3,214,900 Hertz (1,607,450 X 2 = 3,214,900 Hertz) and even using the low audio frequencies this would have worked very well because he would have been hitting the BX frequency with powerful harmonic sideband frequencies.

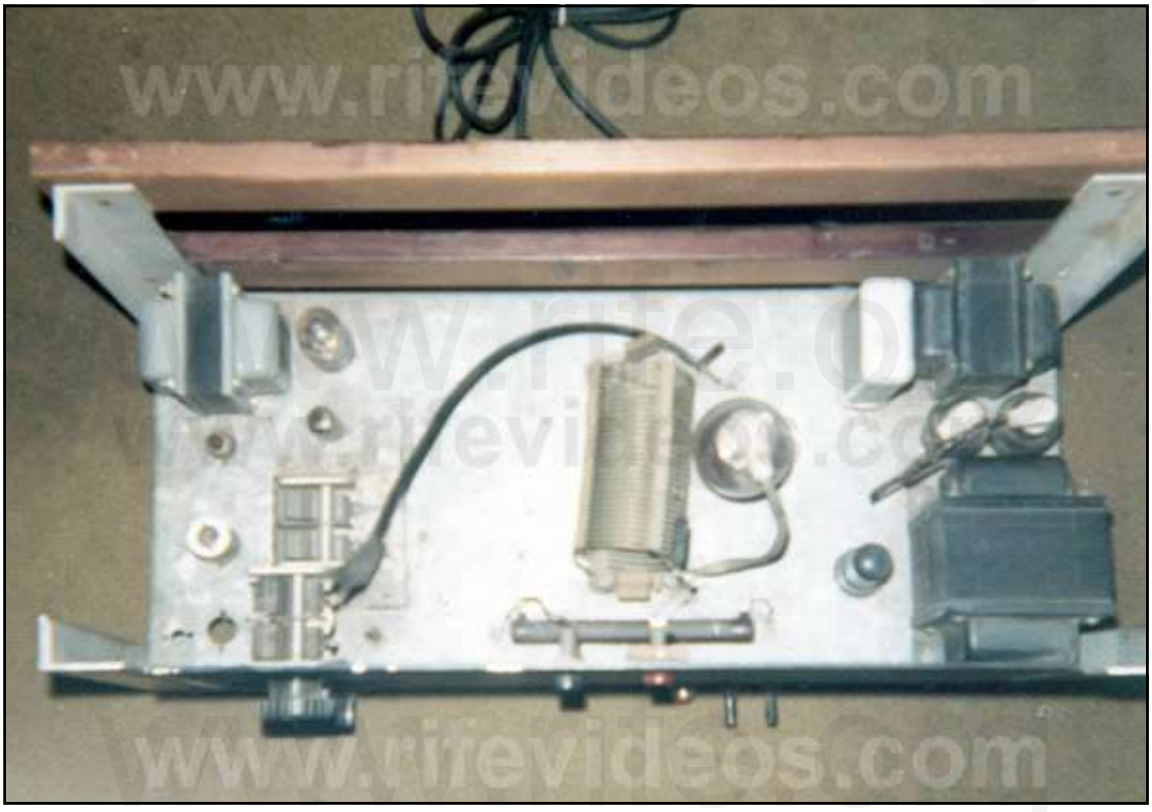

The photos, shown on page 179, are of the AZ-58 we built back in 2000. It used to have the vacuum tube audio oscillator built into it but it never worked properly. So it was removed and replaced with Aubrey Scoon's audio amplifier.

On page 180 is a schematic of the 1950's AZ-58 instrument. The 866 vacuum tubes have been replaced with solid state rectifiers. Also the old vacuum tube audio oscillator has been removed. It is easier and more accurate to use Aubrey Scoon's booster amplifier and a modern function generator to produce the audio frequencies that were used in this instrument. The layout of the electronic parts of this instrument is very important because of the inherent interference problems that come with RF oscillators. Again anyone who would like to build this instrument should have a good understanding of old tube technology. Some parts of this circuit use up to 2000 volts DC with substantial current and can easily kill anyone who is not familiar with this kind of current or voltage. We take no responsibility for anyone who builds this instrument. We recommend that you have professional help.

Chapter Summary: To sum things up only a few changes were made to the original Beam Ray Clinical instrument design which produced the 1953 AZ-58 Beam Ray Clinical replica. Dr. Rife and Verne Thompson kept the original Hartley oscillator but changed the fixed RF carrier frequency from 3.80 MHz to 4.68 MHz as per the new FCC license. The RF carrier frequency section did not significantly changed with the use of the 812a vacuum tube instead of the 809 vacuum tube. They kept the variable audio oscillator which produced the low audio frequencies but lowered its range of frequencies using only three bands with a top audio frequency range of about 6000 Hertz. They then lowered Philip Hoyland's original sideband audio frequencies by a factor of about 10 times and used these lower audio frequencies in the AZ-58. Then they changed the audio frequency waveform from sine wave to square wave and depended on the harmonics produced by the square wave waveform instead of the sidebands. It is interesting that Philip Hoyland found that a modulated sine wave waveform when put thought his M.O.P.A. circuit was sufficient to devitalize organisms because it creates a wave form that looks almost like a square wave waveform. It appears that a damped wave is not really necessary. When you compare the original Beam Rays Clinical instrument and Aubrey Scoon's 1950's Beam Ray Clinical instrument to the 1950's AZ-58 Beam Ray Clinical replica they are almost identical except for the audio frequency bands. When we built both of these instruments, Aubrey Scoon's and the AZ-58, and compared them we found the AZ-58 replica appears to be the better design and easier to build.

Even with the changes Dr. Stafford had very good results which greatly impressed him. Today because of the changes that were made during the 1950's most people believe that the lowered audio frequencies that were used in the AZ-58 are Dr. Rife's original M.O.R. frequencies, but they not. Dr. Rife's original M.O.R. frequencies were the frequencies used in the Rife Ray #3 and Rife Ray #4. The Rife Ray #5 or Beam Ray Clinical instrument also worked on higher harmonics of Dr. Rife's frequencies. An instrument that could output both square wave harmonics and Philip Hoyland's harmonic sidebands would take advantage of both of these methods.

In the next chapter we will discuss the difference between using square wave harmonics and sideband harmonics.

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Photos of the rebuilt AZ-58 Beam Ray Clinical instrument

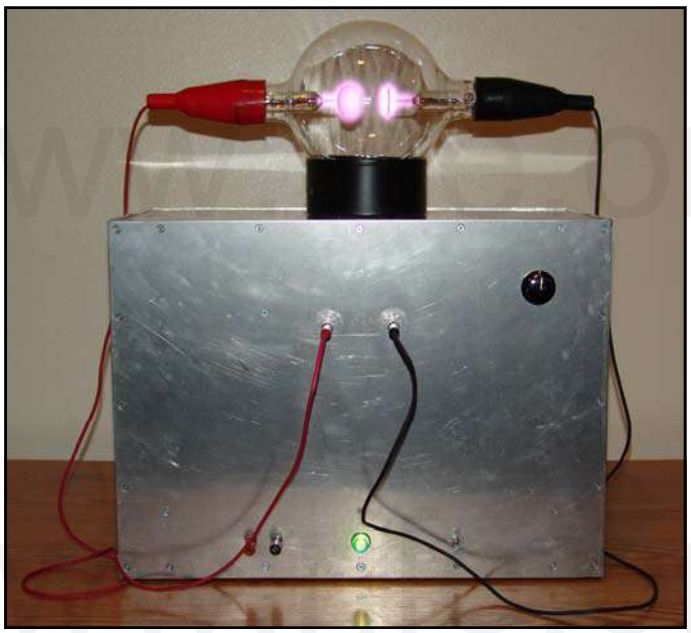

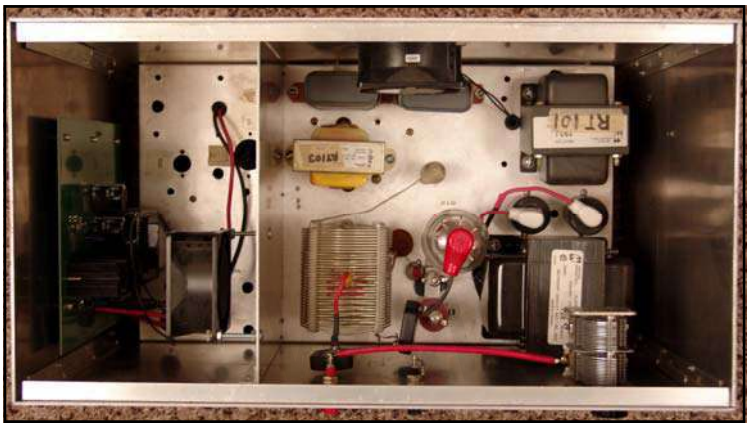

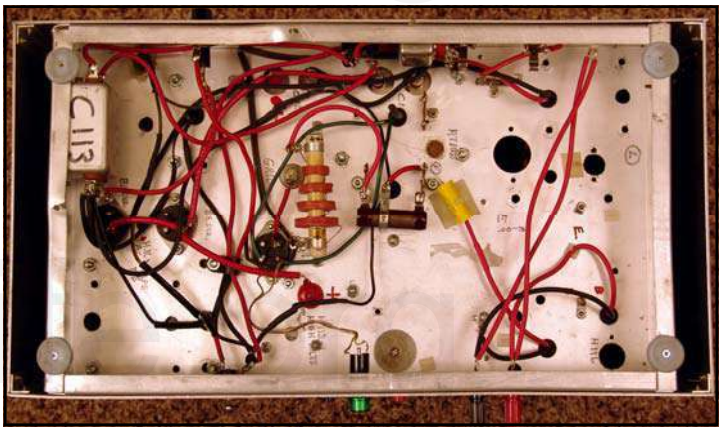

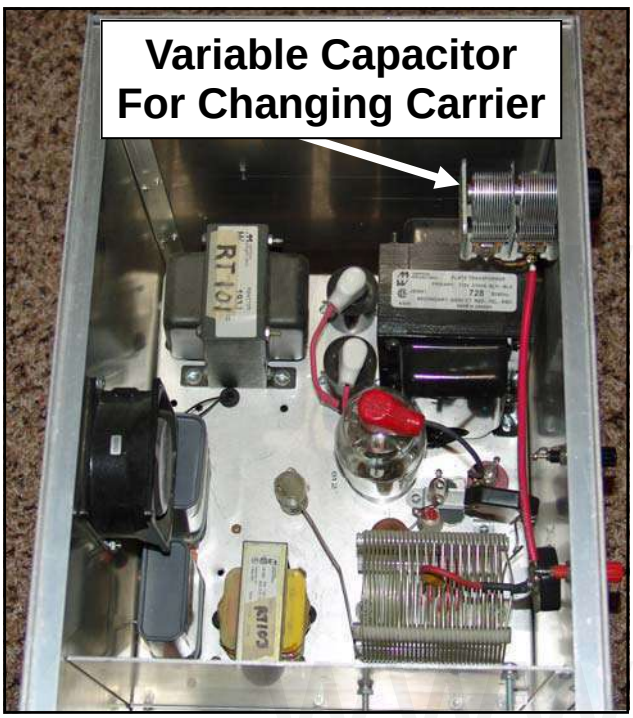

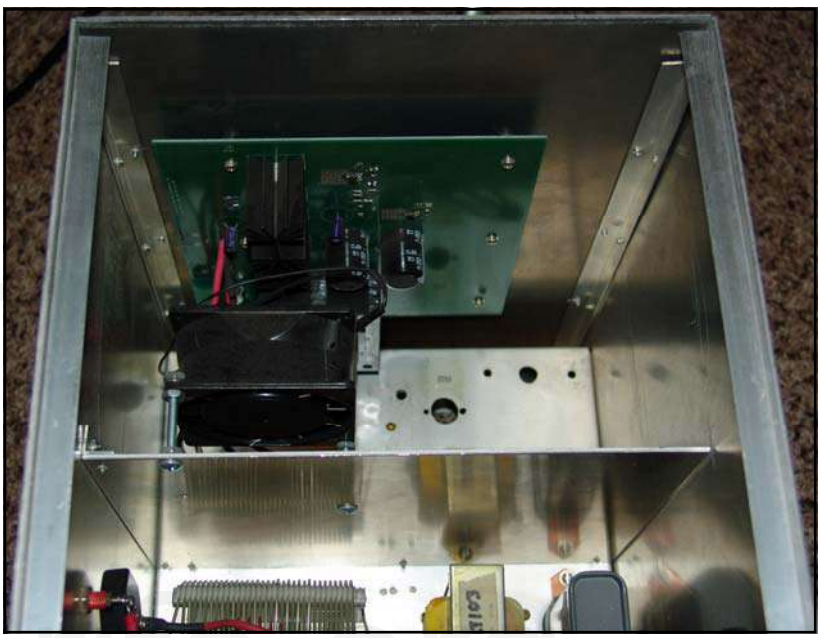

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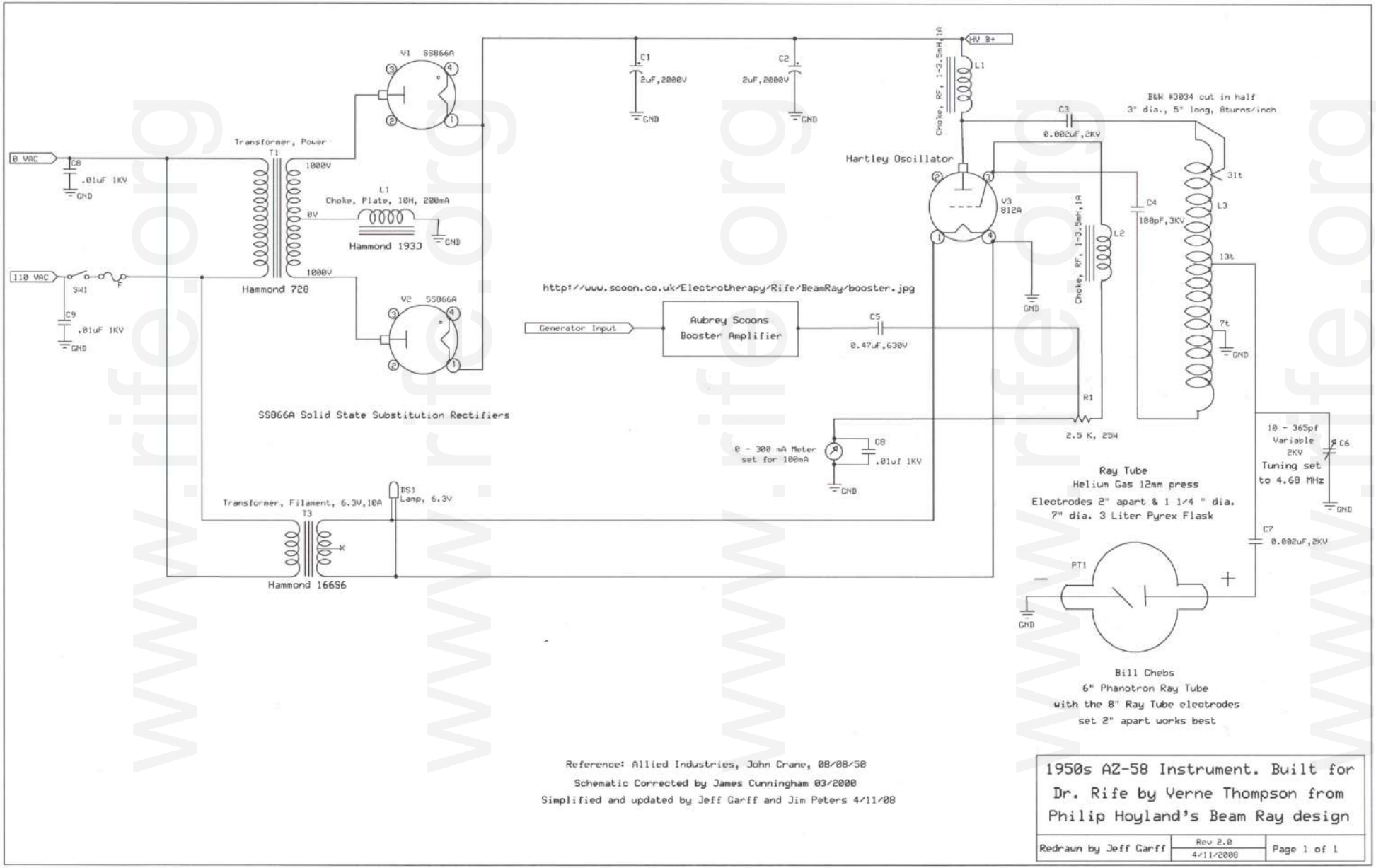
V1 SS866A
C1
2uF,2000V
C2
2uF,2000V
HV B+
Choke, RF, 1-3.5mH,1A
L1
B&W #3034 cut in half
3" dia., 5" long, 8turns/inch
C3
0.002uF,2KV
Transformer, Power
T1
0 VAC
C8
.01uF 1KV
GND
1000V
0V
L1
Choke, Plate, 10H, 200mA
Hammond 193J
Hartley Oscillator
V3
812A
C4
100pF,3KV
31t
L3
13t
7t
L2
Choke, RF, 1-3.5mH,1A
110 VAC
SW1
F
C9
.01uF 1KV
Hammond 728
V2 SS866A
http://www.scoon.co.uk/Electrotherapy/Rife/BeamRay/booster.jpg
Generator Input
Aubrey Scoons
Booster Amplifier
C5
0.47uF,630V
R1
2.5 K, 25W
SS866A Solid State Substitution Rectifiers
0 - 300 mA Meter
set for 100mA
C8
.01uf 1KV
10 - 365pf
Variable
2KV
C6
Tuning set
to 4.68 MHz
Ray Tube
Helium Gas 12mm press
Electrodes 2" apart & 1 1/4 " dia.
7" dia. 3 Liter Pyrex Flask
C7
0.002uF,2KV
PT1
Transformer, Filament, 6.3V,10A
T3
DS1
Lamp, 6.3V
Hammond 166S6
Bill Chebs
6" Phanotron Ray Tube
with the 8" Ray Tube electrodes
set 2" apart works best
Reference: Allied Industries, John Crane, 08/08/50
Schematic Corrected by James Cunningham 03/2000
Simplified and updated by Jeff Garff and Jim Peters 4/11/08
1950s AZ-58 Instrument. Built for
Dr. Rife by Verne Thompson from
Philip Hoyland's Beam Ray design
Redrawn by Jeff Garff
Rev 2.0
4/11/2008
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Chapter #13

Rife Machine Harmonic Audio Frequency Misunderstanding

There is a belief that the audio frequencies that were used in the original Rife Ray #5 or Beam Ray Clinical Rife Machine and its 1940's and 1953 AZ-58 replica Rife Machines are harmonic M.O.R. frequencies derived by dividing Dr. Rife's original high RF frequencies down in octave steps until you reach the audio range of frequencies. For this to be true then all of the audio frequencies would have to be true harmonics of the higher RF frequencies. But this is not the case.

All the documents we have quoted and the understanding we now have, prove as a myth, the long believed concept that the low audio frequencies used in the 1950's were created by John Crane and John Marsh by dividing Dr. Rife's high frequency M.O.R.s down by harmonic steps until they reached the audio range of frequencies. If we take the correct frequency for the BX of 1,607,450 Hertz read by Philip Hoyland and divide it down by harmonics we do not get 2008 Hertz or 2128 Hertz. In fact, we do not get Philip Hoyland's higher audio frequencies of 20080 Hertz or 21275 Hertz either. This clearly proves John Crane and John Marsh did not create the audio frequencies by just dividing down Dr. Rife's higher RF M.O.R. frequencies. The fact is we know that the origin of these audio frequencies came from the sideband harmonic method used by Philip Hoyland in the original Beam Ray Clinical instrument.

The documented information we have shows that Dr. Rife's true M.O.R.s that would resonate organisms were the higher RF frequencies (139,200 Hertz to 1,607,450 Hertz) used in the Rife Ray #3 which consisted of the Kennedy Models 110, 281. These same frequencies were used in the Rife Ray #4 Rife Machine and the higher harmonic frequencies of these frequencies were used in the Rife Ray #5 or Beam Ray Clinical Rife Machine. All of Dr. Rife's Machines worked on RF frequencies not audio

frequencies. From the spectrum analysis of Philip Hoyland's Beam Ray Rife Machine we know that it used audio frequencies for one purpose only, to create the method of sideband harmonic spacing to hit the higher harmonic frequencies which were harmonics Dr. Rife's true RF M.O.R.s. Henry Siner reported Philip Hoyland's design killed the organisms under microscope observation. This same instrument was tested by Dr. Rife in 1940 when Verne Thompson repaired it. Add to this the list of doctors who used the instruments and said they had many diseases cured. This shows that Philip Hoyland's harmonic method works beyond question.

Dr. Robert P. Stafford was not able to kill any organisms in laboratory tests using just the square wave audio frequency harmonics. He did his tests under microscope observation. Today, like Dr. Stafford many have tried to kill the organisms which these audio frequencies correspond to, with no success. John Marsh had laboratory tests done in 1976-1977 which also confirmed Dr. Stafford's tests.

If these audio frequencies, as some have claimed, were really harmonic frequencies derived from the higher RF M.O.R. frequencies then one would think that they should be able to kill the microorganism they correspond to. If a true audio frequency harmonic of Dr. Rife's RF M.O.R. will not devitalize an organism under microscope observation, can the harmonic association be valid? No rational person would believe this. Yet today this is exactly what most people believe because they do not have all of the facts.

When Dr. Rife started looking for frequencies to devitalize microorganisms he worked his way up from the lower frequency ranges to the higher frequency ranges until he found a frequency which would devitalize an organism he was working on. His Rife Ray #3 had the ability to start at about 12,000 Hertz which is in the upper audio frequency range. So Dr. Rife would have naturally started at 12,000 Hertz and moved up in the frequency range in his testing until he found the frequency that would devitalize the organism. Since the Rife Ray #4 documents show that the lowest frequency for any of the organisms was 139,200 Hertz we can conclude that he did not find any frequencies in the audio range or less than 139,000 Hertz that would devitalize any of these organisms listed on the Rife Ray #4 documents. Now this method of starting at the lowest frequency and moving up into the higher frequency ranges would be a logical method of finding the M.O.R. of an organism. What this also logically tells us is that no frequency lower than 139,000 Hertz could ever be a frequency that would devitalize any of these organisms. What this also reveals to us is that Dr. Rife had to get to a high enough frequency range before a resonant effect would devitalize an organism. What is the point that we are trying to make with this simple logic. Philip Hoyland found that higher harmonics of Dr. Rife's original M.O.R. frequencies would devitalize those organisms. But what Dr. Rife found was that there were no frequencies lower than the frequencies he found that would devitalize the organisms found in the Rife Ray #4 documents. We must keep in mind that the Rife Ray #4 did not have any variable audio oscillator. Its frequency range started at 87,000 Hertz. From this we can conclude that Dr. Rife found that the audio range up to about 87,000 Hertz was not needed because you cannot truly resonate any organism with frequencies below 87,000 Hertz using his method.

With this logical understanding you would not divided down in octave or harmonic steps any of the Rife Ray #4 resonant frequencies and expect these lower frequencies to devitalize those organisms using the same method Dr. Rife used. But this is what people claim can be done. If Dr. Rife could not find any frequency lower than 139,000 Hertz to devitalize the Rife Ray #4 organisms then this concept that people are claiming is a questionable concept depending on the number of harmonic or octave steps used. It is a known fact that square waves will create higher harmonic frequencies. Some claim infinite harmonics but this could only be true if there was infinite power behind those harmonics. So power determines the number of harmonics. In most situations the harmonics from a square wave are only readable, with sufficient power, to about 9 harmonics up from the original frequency used. Understanding this you would not take any of Dr. Rife's frequencies and divide them down in either harmonic steps or octave steps more than about 9 times and expect an audio frequency with a square wave

waveform to resonate those organisms. Yet this is what people are claiming can be done using audio frequencies and square wave harmonics. They actually promote the idea that you can go down hundreds of harmonic steps with Dr. Rife's frequencies and get them to resonate organisms with low audio frequencies. It is this false concept that John Crane and John Marsh promoted. This false concept has caused all of the confusion we have today. This is why so many people claim that Dr. Rife's original M.O.R. frequencies where the low audio frequencies that were used in the AZ-58.

We are not saying that low audio frequencies do not have positive effects, because they do. But they are working on a different concept than coordinative resonance. No one knows exactly how these low audio frequencies work, they just know they are beneficial. Dr. Stafford believed that they somehow stimulated the adrenals which in turn stimulated the immune system. He also believed when the immune system is stimulated the body will be able to overcome many ailments that it otherwise could not overcome. Again we will point out that it is not known how these low square wave audio frequencies work. But what is known is that they do not create a true resonate frequency effect like Dr. Rife's high RF frequencies or the higher harmonic RF frequencies Philip Hoyland used.

The evidence we have given in this report shows that if the RF M.O.R. frequency is lowered by too much it will lose its ability to devitalize an organism even though it is a lower harmonic frequency. Dr. Stafford's and John Marsh's laboratory tests showed this when they treated the organism with the low audio frequency that was supposed to devitalize it. The tests showed that the organism continued to grow even when they transferred it from one culture to another. Can there be any greater scientific proof than this? Even Dr. Rife would not have argued with this method of determining true M.O.R.s, because this is the method he used. This is the greatest proof, along with the fact that almost all the audio frequencies are not true harmonics of the original high RF frequencies. We know many other people who have made the same tests on microorganisms as Dr. Stafford and John Marsh and they told us they obtained the same results he did. John Marsh said on the Rife CD's that they came up with the frequencies using math. The documented information we now have show that the math they used was to lower Philip Hoyland's original audio frequencies by a factor of 10 times. If every audio frequency was a perfect harmonic match to its higher RF M.O.R. then we could say they were all derived from Dr. Rife's original M.O.R.s, but they are not. So this leaves us with only one conclusion. They lowered Philip Hoyland's higher audio frequencies and wrongly considered those lowered frequencies to be the true M.O.R. frequencies. Another thing we must understand is that even if the audio frequencies were derived from Dr. Rife's original RF M.O.R.s in lower harmonic steps or octave steps and they do not devitalize the organism they are not real M.O.R.s. either.

What the evidence in this report certainly proves is, without really knowing it, Dr. Rife, John Crane and John Marsh discovered that these lower square wave audio frequencies are beneficial. Even though they will not devitalize the organism they correspond to under microscope observation they still seem to help people? The fact is we really don't know why the audio frequencies are beneficial, but for some unknown reason they are. Though the method of modulating a square wave audio frequency onto a fixed RF carrier did not work as well as Philip Hoyland's sideband method, nevertheless it works very well on many conditions. Even though the audio frequencies are beneficial in many ways, this still does not prove the claim that the 1950's audio frequencies are harmonic M.O.R.s.

What needs to be kept in mind is how the original Beam Ray Clinical instruments worked. We will again point out here that neither the 3.30 or the 3.80 MHz RF carrier frequency nor the audio frequencies will do anything by themselves. But when the 3.30 or the 3.80 MHz RF carrier frequency and the audio frequencies are combined together they will produce many sideband frequencies. And one of these sideband frequencies will line up with the true Rife M.O.R. frequency and devitalize or render harmless the harmful microorganism. If you just use the audio frequencies by themselves you will get nothing. If you use the 3.30 or the 3.80 MHz RF carrier without the audio frequencies you will get nothing. The audio frequencies used in this style of instrument must be match to the RF carrier frequency of

3.30 or 3.80 MHz or they are useless. This is the reason the 1953 AZ-58 Beam Ray Clinical instrument did not work properly.

Below is a chart showing the “High Frequency M.O.R.s” which were taken from the Rife Ray #3 and used with the Rife Ray #4. These frequencies were recorded in 1935 when Philip Hoyland went to Dr. Rife's laboratory to read them with his master oscillator. They were fine tuned with more precision in 1936 when Philip Hoyland built the Beam Ray Clinical instrument. This is the reason for the slight discrepancy in Dr. Rife's high frequencies. In 1935 the frequencies were rounded off to the nearest thousandth. In 1936 a more accurate reading was done of these frequencies so that the higher harmonics could be used in the Beam Ray Clinical instrument. These frequencies are the true M.O.R.s. The “Harmonic Higher Audio Frequency” column is the true harmonic of the “High Frequency M.O.R.s” column. How well these higher frequencies under 60,000 Hertz would work is anyone's guess using the square wave harmonic waveform that was used in the AZ-58 replica instrument. The “Harmonic Higher Audio Steps” column shows how many harmonic steps it takes to hit the fundamental “High Frequency M.O.R.s” using the “Harmonic Higher Audio Frequency” using a square wave waveform. As can be seen the higher the frequency the less harmonic steps it takes to hit the fundamental M.O.R. frequency. We did this chart just to show how the concept of square wave harmonics would work. Just keep in mind that any square wave audio frequency only goes up for about 9 harmonics with sufficient power. Many of the “Harmonic Higher Audio Steps” exceed 9 harmonics. With this understanding a higher frequency should be chosen that would be within 9 harmonics of Dr. Rife’s original high RF M.O.R. frequency.

AZ-58 M.O.R. Audio Frequencies Square Wave Harmonics

Microorganisms	1950’s Low Audio Frequency For AZ-58	True Harmonic Low Audio Frequency For AZ-58	Harmonic Low Audio Steps for AZ-58	Harmonic Higher Audio Frequency	Harmonic Higher Audio Steps	High Frequency M.O.R.s
Actinomycosis (Streptothrix)	784 Hz	750 Hz	256	48,000 Hz	4	192,000 Hz
Anthrax	None	1087.5 Hz	128	34,800 Hz	4	139,200 Hz
B. Coli (Rod form)	800 Hz	814.4531 Hz	512	52,125 Hz	8	417,000 Hz
B. Coli (Filterable virus)	1552 Hz	1503.9063 Hz	512	48,125 Hz	16	770,000 Hz
Bacillus X or BX (Cancer Carcinoma)	2128 Hz	3132.8125 Hz	512	50,125 Hz	32	1,604,000 Hz
Bacillus Y or BY (Cancer Sarcoma)	2008 Hz	2988.28125 Hz	512	47,812.5 Hz	32	1,530,000 Hz
Gonorrhea	712 Hz	910.15625 Hz	256	29,125 Hz	8	233,000 Hz
Pneumonia or Spinal Meningitis	776 Hz	1667.96875 Hz	256	53,375 Hz	8	427,000 Hz
Staphylococcus Pyogenes Aureus	727 Hz	933.59375 Hz	512	59,750 Hz	8	478,000 Hz
Streptococcus Pyogenes	880 Hz	703.125 Hz	1024	45,000 Hz	16	720,000 Hz
Syphilis	660 Hz	770.5078 Hz	1024	49,312.5 Hz	16	789,000 Hz
Tetanus	120 Hz	914.0625 Hz	256	29,250 Hz	8	234,000 Hz
Tuberculosis (Rod)	803 Hz	720.7031 Hz	512	46,125 Hz	8	369,000 Hz
Tuberculosis (Virus)	1552 Hz	1501.953125 Hz	512	48,062.5 Hz	16	769,000 Hz
Typhoid Fever (Rod)	712 Hz	742.1875 Hz	1024	47,500 Hz	16	760,000 Hz
Typhoid Fever (Virus)	1862 Hz	1411.1326 Hz	1024	45,156.25 Hz	32	1,445,000 Hz

Now if we take a look at the "1950's Low Audio Frequency For AZ-58” column we see the frequencies that were used by the AZ-58 back in the 1950's. These frequencies are still used today. In the “True Harmonic Low Audio Frequency For AZ-58” column we find the true low audio frequency harmonics of the “High Frequency M.O.R.s.” As you compare these columns you can see that the 1950's frequency for Actinomycosis or Streptothrix was 784 Hertz but the true harmonic frequency is 750

Hertz. It is easy to see that the AZ-58 was not working on square wave harmonics of the true M.O.R.s. If you look at the “Harmonic Low Audio Steps For AZ-58” column you can see how many harmonic steps it takes to reach the true “High Frequency M.O.R.” These range from 128 harmonic steps to 1024 harmonic steps. Anyone looking at these numbers would wonder if these frequencies could ever work. Logically the higher the frequency the better the chance they will work. Also logically the less you go up in square wave harmonics the greater the chance they will work. When using the square wave method the highest frequency possible should be used.

Chapter Summary: None of the low audio frequencies used in the AZ-58 were Dr. Rife's original M.O.R. frequencies. Not even the higher audio frequencies used in the Beam Ray Clinical instrument were his original M.O.R. frequencies either. Both the lower and the higher audio frequencies are not true harmonics of Dr. Rife's original M.O.R. frequencies, as some have thought. The frequencies that Dr. Rife discovered were the lowest frequencies which he found that would resonate an organism and devitalize it. Dr. Rife knew that his frequencies were lower harmonics of a true higher frequency. Philip Hoyland used this understanding in the Rife Ray #5 or Beam Ray Clinical instrument. One thing we do know is dividing Dr. Rife's original frequencies down in octave or harmonic steps until you get into the low audio frequency range has not been proven through laboratory testing to resonate those organisms or any other organisms. Dr. Stafford and John Marsh had laboratory tests done and found that the 1950's AZ-58 square wave low audio frequencies would not devitalize any organisms they were tested on. The audio frequency range does have many beneficial frequencies but it is not understood how they really work. Dr. Stafford believed they stimulate the adrenal glands thus stimulating the immune system.

The real problem with not understanding which frequencies are Dr. Rife's original M.O.R. frequencies means that people will purchase frequency generating equipment that does not output Dr. Rife's original frequencies. It really is "buyer bewares". If a frequency generating piece of equipment cannot output both the low audio frequency range and the high RF range then you may want to reconsider purchasing it. Look for a frequency generator that can output all of Dr. Rife's frequencies. If a company will not tell you what the frequency range of their so called "Rife Machine" is then keep looking until you find a good frequency generator with the correct frequency range. Any frequency generator worth purchasing should have a range from at least 1 Hertz to 5,000,000 Hertz so you can use the full frequency range that Philip Hoyland used with the higher harmonics of Dr. Rife's original M.O.R. frequencies. If a frequency generator can go to 20,000,000 million Hertz, even better, because you can also work with many of the higher harmonics of Dr. Rife’s frequencies.

In the next chapter we will look at the pad type instrument developed by John Crane and John Marsh in the late 1950's.

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Chapter #14

Life Labs 1950's Pad Instrument without Ray Tube

1. Used round disks that came in contact with the body. Later changed in the 1960's to hand cylinders or foot pads.
2. Had no RF carrier frequency.
3. Used the square wave audio frequencies used in the AZ-58.

It was about 1957 when John Crane and John Marsh began building instruments without a ray tube. Earlier in this article Bertrand Comparet was quoted as saying:

COMPARET: *"Now, Crane said "Well now look, Rife himself admits that no matter how much tube and ray, and so on, you have, you can't get any results unless you've got the right frequency. Therefore the real clue to the thing is the frequency and not the means by which you deliver it."* (1970's Bertrand Comparet Interview #33).

John Crane and John Marsh replaced the ray tube with two aluminum disks (shown in the above photo) which they developed that came in contact with the body. As we pointed out earlier in this report it is interesting to note that Dr. Rife said Abrams' Oscilloclast would devitalize the BX cancer virus and it was a contact type device. John Crane and John Marsh probably used this contact method because of the success of Abrams' instrument. From the documented information we have it was also the high cost of building ray tube instruments that caused them to look at doing things in a different way. In addition to being expensive to build, the ray tube could break very easily. They had many problems with them. It does not appear that Dr. Rife, at least in his early years, ever had a reason to look at doing

things differently. John Crane and John Marsh did. They didn't have the kind of money to spend that Dr. Rife did. They say that "Necessity is the mother of invention!"

In the photo, shown below, we see that they eventually added handles onto the disks so that they were easier to use.

John Crane and John Marsh used a Heathkit function generator to produce the frequencies. These Heathkit function generators had no built-in carrier frequency on which to modulate the audio frequencies. Therefore, the RF carrier frequency was no longer used. The fact that they didn't feel the RF carrier frequency was necessary shows that they totally believed that the audio frequencies were the M.O.R. frequencies. This also shows beyond doubt that they never knew the importance of the RF carrier frequency or had any understanding of the harmonic sideband method used in the original Rife Ray #5 or Beam Ray Clinical Rife Machine. They could have made a pad instrument work like the Beam Ray Clinical Rife Machine if they would have used a harmonic sine wave RF carrier frequency at 3,300,000 Hertz. After the many years that these pad instrument have been used it appears that the removal of the ray tube was not as important as the removal of the RF carrier frequency.

Dr. Rife would have never approved of using an instrument without an RF carrier frequency. He knew that Philip Hoyland's Beam Ray Clinical instrument which used the sideband method somehow needed an RF carrier frequency to make it work properly. Though Dr. Rife didn't fully understand Philip Hoyland's instrument he clearly understood the importance of the RF carrier frequency. The positive thing about using a Heathkit function generator in this way is they were inexpensive (about $200) and a lot more people could afford one. Many people can thank John Crane and John Marsh for this innovative method. John Crane and John Marsh proved that the square wave audio frequencies worked the same whether applied through a ray tube or pads if sufficient power is used. Many people think that John Crane and John Marsh built the pad instrument without Dr. Rife being fully informed about it. But this was not the case. John Crane and John Marsh had talked for some time about building a smaller ray tube instrument but instead of building it they built the pad instrument. In John Marsh's Trip to Ohio Papers we read this:

RIFE: *"That is the only way that it can be handled properly."*

MARSH: *"Maybe we can sell small instruments for the purpose of small diseases like colds, flu and stuff like that, which are minor, which the Dr.s prefer not treating those kind anyway, because they are chronic, and there isn't anything they can do with them. People keep coming in and coming in and they take up his time where he could spend it taking care of a bad case, or something or other. Dr. Stafford said that he would prefer that a small instrument would be made...What do you think John? I've been doing a lot of talking not even giving you a chance to get a word in edgewise."*

CRANE: *"There is no doubt there is going to be an awful lot of development on this design…"* (1957 John Marsh trip to Dayton, Ohio #36-38).

From these statements we learn that Dr. Rife knew that they wanted to build small instruments. Also we learn that it was John Marsh and John Crane's idea to build the pad instruments, not Dr. Rife's. We know that Dr. Rife was upset with John Crane and John Marsh over the building of these pad instruments because he expressed it to Bertrand Comparet during his 1961 deposition. Comparet said:

COMPARET: *"And I asked Rife, because I thought Rife would certainly say that the way Crane was working on it then was still using the Rife principle, but he indignantly denied it."*

HUBBARD: "*All right, I see. But, getting back, you say that Rife was very indignant, that the machine that Crane was building was really his* [Cranes] *idea. I suppose he did not compromise on that, did he?*

COMPARET: *"Oh no, he just blew up."* (1970's Bertrand Comparet interview #32 & 40).

At this time John Crane and John Marsh were working on both the ray tube instrument and the pad instrument. We know that Dr. Rife considered the ray tube instrument to be his instrument. The ray tube instrument used an RF carrier frequency on which the square wave audio frequencies were modulated. So it is clear that the pad instrument without an RF carrier frequency is what Dr. Rife was upset about. It is also clear that Dr. Rife fully knew what they were doing but he did not approve of what they were doing. Because they didn't use an RF carrier frequency the pad instrument would not be working on Dr. Rife's principle of coordinative resonance through high RF sideband frequencies. We know that this was the method Philip Hoyland used in his design. If there is no RF carrier then there would be no sideband frequencies and this would mean that none of Dr. Rife's higher harmonic RF frequencies would have been produced. This also means the pad instrument only worked on low square wave audio frequency harmonics not high RF frequencies. However, John Marsh and John Crane's innovation with a pad instrument proved that the ray tube could be removed and frequencies could be applied electrically through the contact method which they used.

This new method made it possible for more people to have access to a less effective form of Dr. Rife's technology. Though it was a less effective method many people over the years have been helped by this method of only using low square wave audio frequencies. Back when John Crane and John Marsh were building these pad instruments they could have built a pad instrument capable of producing all of Dr. Rife's frequencies. The reason they did not do this is due to the fact that they believed that the low square wave audio frequencies would work as well as Dr. Rife's original high RF frequencies. Time has proven that they were not correct in this belief. Today all of Dr. Rife's original high RF frequencies and the higher harmonics of those frequencies which Philip Hoyland used can be produced by any function generator with the proper frequency range of at least 1 Hertz to about 4,000,000 Hertz.

It appears that one of the reasons why John Crane and John Marsh didn't use an RF carrier frequency is the Heathkit function generator that they used didn't have the capability of using an RF carrier frequency. Audio frequencies will not broadcast; therefore, they are modulated upon the RF carrier frequency so that they will penetrate the body. In laymen's terms, modulation is piggy-backing one or

more low frequencies onto another higher frequency. The frequencies travel together but still keep the components of both waveforms. Almost all of the so called "Rife Machines" built today do not use an RF carrier frequency even though Dr. Rife's Beam Ray Clinical instrument and the 1953 AZ-58 Machine did. If Dr. Rife could have removed the RF carrier frequency from his instrument and gotten the same results, I believe he would have removed it because it would have made building an instrument a lot easier. He became upset with John Crane and John Marsh for doing this. As it is, Dr. Rife never removed the RF carrier frequency from any of his instruments. It was John Crane and John Marsh who remove it. If a person wants to try and obtain the same type of results which Dr. Rife did, then an RF carrier frequency should be considered and used with any audio frequency instrument.

We realize that there are ray tube instruments today that do not use an RF carrier frequency. These use a high electromagnetic field (EM) which will transfer the energy into the body. We do not doubt that these instruments work very well with low square wave audio frequencies. We have talked with people that are using these instruments and they say that they are getting very good results. But these instruments are still using just the low square wave audio frequencies without an RF carrier frequency. What we are talking about in this report is the way that Dr. Rife used RF frequencies and an RF carrier frequency modulated with an audio frequency to produce the proper sideband method. Some of these EM ray tube instrument builders like to compare EM devices to RF devices. This is like comparing apples and oranges. There is no comparison because if you do not have an RF carrier frequency then you cannot create any sideband frequencies. The EM devices work on a high electromagnetic field, the stronger the better. RF devices work on radio frequencies and the power output is measured in watts. Dr. Rife's instruments were all RF instruments and could resonate an organism when the proper RF frequency was used. EM devices use low audio frequencies because they cannot output RF frequencies. RF versus EM or apples and oranges cannot be compared because they are two totally different principles. EM devices are also limited in their frequency range. Usually they can only output frequencies to about 20,000 Hertz where Dr. Rife's RF devices were putting out frequencies in the millions of Hertz or cycles per second.

There is some misinformation being put out about pad instruments. Mostly it is done by people who believe that only a ray tube will work in delivering frequencies to the body, whether it is through the RF or the EM method of delivering frequencies. These people promote the false belief that audio frequencies when used in a pad instrument without an RF carrier or without an EM field will only travel along the surface of the skin of the body. They say that the frequencies cannot penetrate the body because of the "Skin Effect." We need to point out that the "Skin Effect" has nothing to do with human tissue or human skin. The "Skin Effect" has to do with the skin or surface of a metal conductor such as a copper wire. If the human body was made of metal then the "Skin Effect" would apply. These people are either totally ignorant or willfully trying to mislead people so that they will only purchase an instrument that uses a ray tube. What we should really believe is what the scientific tests have proven in regards to the "Skin Effect" as it pertains to human or animal tissue.

In scientific studies called "Bioelectric Impedance Analysis" it has been shown that sine wave audio frequencies, without an RF carrier frequency, will enter the body but will only travel in the connective tissues around the cells. These tests have prove beyond doubt that the frequency does go right through the skin contrary to what people have claimed. Also in these scientific studies it has been shown that the closer you get to 1 Megahertz the greater the penetration of the current through the cell. At 1 Megahertz or one million Hertz the current of the frequency will go through the cell and fully penetrate the body. These type of tests show why it is very important that an RF carrier frequency be used. A virus can enter a cell and live there. An RF frequency can enter the cell where it can do the most good. These kinds of scientific studies and their importance were not understood by John Crane and John Marsh in the 1950's and 1960's. These "Bioelectric Impedance scientific tests also prove that what many people have been saying about the "Skin Effect" is absolutely false. In this Rife machine report we do not ask people to believe what has been said without proof. For this reason we have in-

cluded one of these scientific reports for you to read. There are other reports on the web that you can read but we found that this one is the easiest to understand. But even with that said, unless you have some understand of how electricity works then it may be difficult for some to understand. Because of this we added, in blue print, a layman's understanding at the end of each section. To read this file go to the following website address.

www.rifevideos.com/pdf/skin_effect_and_bio_electrical_impedance_analysis.pdf

Below is a schematic of John Crane & John Marsh's pad instrument. It was nothing more than an off-the-shelf audio frequency generator with the faceplate changed. There was nothing special about this frequency generator because any common function generator can do the same thing that this one could do. There have been people who have copied this instrument and who charge enormous sums of money for a replica. As much as four or five thousand dollars. They claim that this is a real genuine Rife Machine. Do not be fooled. The same audio frequencies that were used in the 1953 AZ-58 were also used with this instrument. Those frequencies were 120, 660, 712, 727, 776, 784, 800, 803, 880, 1552, 1862, 2008, 2128.

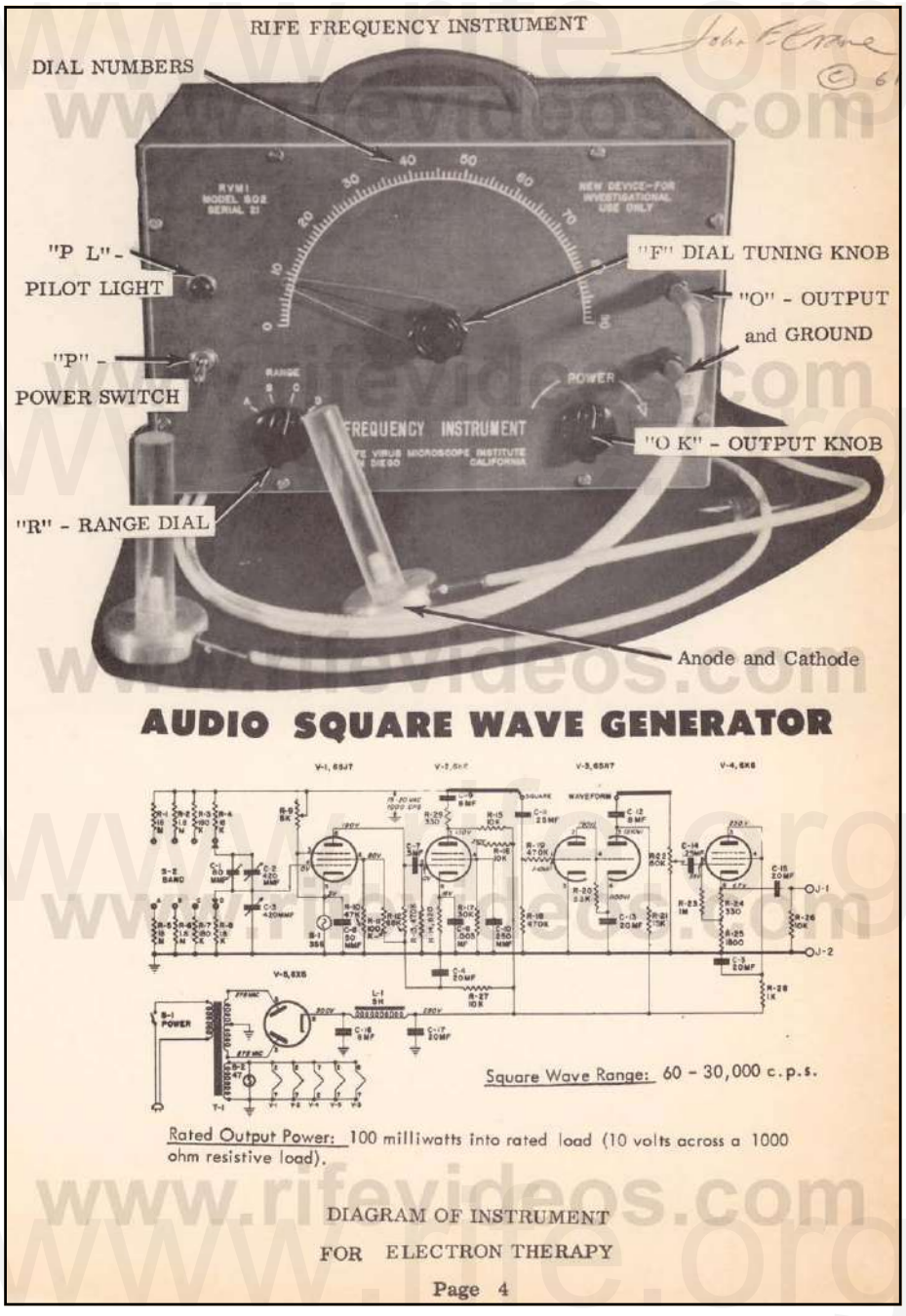

Below are several photographs of the many pad type frequency generators that John Cane and John Marsh built. The first one was built by John Crane.

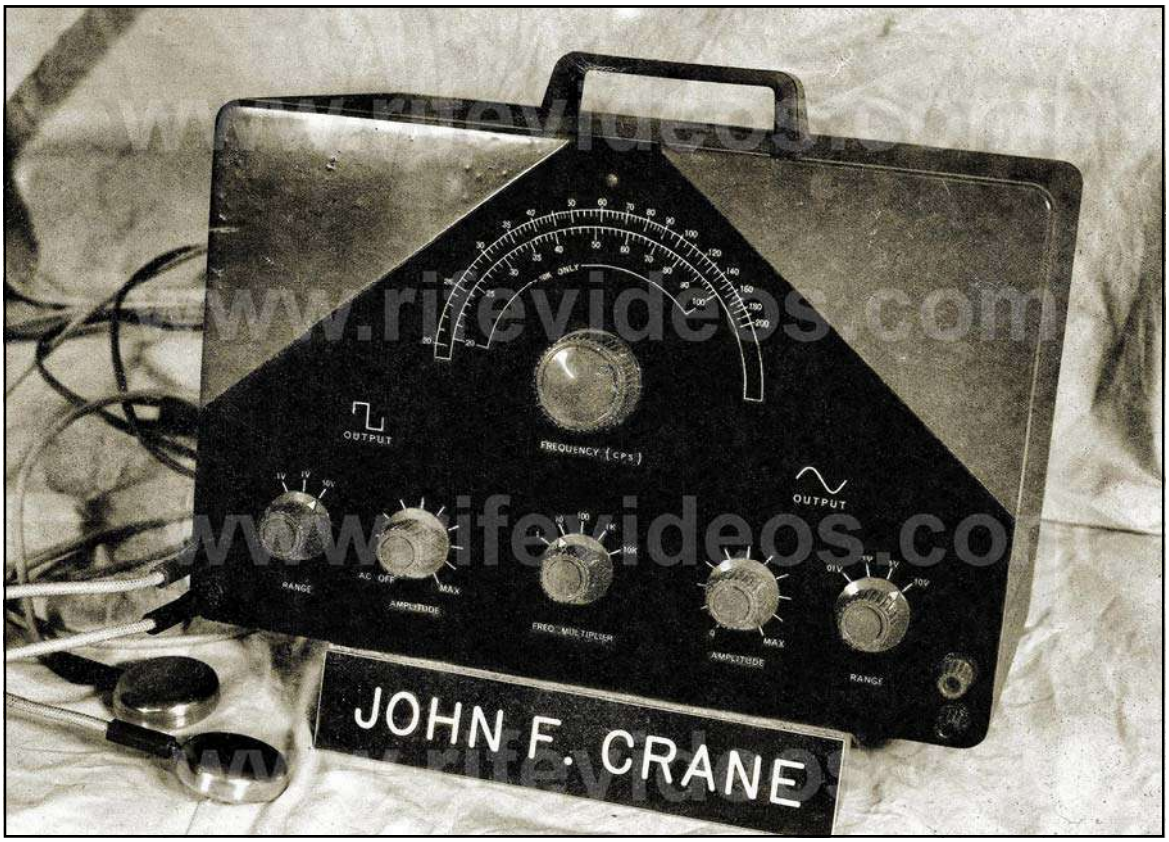

This next three photos, shown below and on the next page, are of another one of John Crane's pad instruments built in the 1960's.

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The next two photos, shown below, are of the pad instrument built back in 1961 by John Crane and John Marsh. They at that time were calling their organization the "Rife Virus Microscope Institute". This name is on the front of their instrument. The first photo is from back in 1961 and the second photo is a new photo of one of these instruments which has survived.

The next two photos, shown below, are pictures of one of John Marsh's pad instruments which he built in the 1980's. The first photo is from the 1980's and shows the aluminum disks which he was using at that time. The second photo shows this same instrument with another pad instrument which he built.

The next photo, shown below, is a new photo take of an instrument which John Marsh owned and gave to his nurse. It is similar to the instrument show in the first photo above.

The next two photos, shown below, are of a pad machine that John Marsh made out of a 1950's Heathkit frequency generator. Almost all of the pad type machines that both John Crane and John Marsh built were really made from off-the-shelf frequency generators without any changes being made to them. Many times they would either replace the faceplate with their own or they would cover it so that no one would know that they were just using an off-the-shelf frequency generator. Above in one of the photos of John Crane's machine you can see that he covered the original faceplate so no one would know what he was doing. In the next two photos you can see that John Marsh did the same thing with this one. The first photo was taken by John in the 1980's and the second photo is a new photo of this instrument.

Chapter Summary: Pad type audio frequency instruments have done a lot of good over the years. But without an RF carrier frequency properly match with the correct audio frequencies Philip Hoyland's sideband method cannot be used with them. These instruments need to have an RF carrier frequency or the ability to output the exact frequency that Dr. Rife used. We know from the documents that Dr. Rife preferred using the exact frequency rather than Philip Hoyland's sideband method, but either method will work and Dr. Rife used both. Dr. Rife's frequency range included both the audio range and the RF range of frequencies from 1 Hertz to about 1,800,000 Hertz. Philip Hoyland's design produced higher harmonic frequencies of Dr. Rife's original frequencies in the 2,000,000 and 3,000,000 Hertz range.

The so called pad "Rife Machines" that are sold today which cannot produce these frequency ranges cannot produce Dr. Rife's results. Make sure that the frequency generator you purchase can produce both the audio and RF frequencies that Dr. Rife used. Also it should be understood that the pad type instruments are not able to output the power that the ray tube instruments can. Pad style instruments that do not use an RF carrier frequency or the higher RF frequency range generally do not exceed one half of one watt of power. This is because the body cannot take more that about one fifth of one watt before the electrical current begins to lock up the muscles of the user. When an RF carrier frequency is used then the body does not react to the electricity and this makes it so that higher power levels can be used up to the 10 to 12 watt range. Dr. Rife's ray tube instruments had power ranges from 50 to 200 watts output. The Rife Ray #5 or Beam Ray Clinical instrument power output was between 40 to 50 watts.

In the next chapter we will look at an AZ-58 type of ray tube instrument built by John Marsh in the 1970's.

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Chapter #15

John Marsh's 1970's Beam Ray replica Rife Machine

1. Used a ray tube.
2. Carrier frequency was 4.150 MHz.
3. Modulated sine and square wave audio frequencies onto the sine wave carrier frequency.
4. Power usage was about 460 watts. Output to the ray tube about 40 watts.

John Marsh had this replica of the Beam Ray Clinical Rife Machine Model #JLMSQ-1A built back in November 1971 for $3,800. It was completed by January 1, 1972. He and John Crane were under court order not to associate with each other. Because of this court order they went their separate ways but communicated often through phone calls and letters. John Crane stayed in California and John Marsh went to Colorado but eventually settled back in SLC, Utah until his death in 1987. All of his Rife Machines and Rife information were given to his nurse before his death. His equipment and documents were obtained from her in 2012. Since we were able to obtain this instrument we have been able to properly date it and take better photos of the complete instrument. Some of this information and new photos are shown below and are now apart of this report.

The photo at the top of the next page shows the two chassis that were connected by wires with their covers taken off. This instrument was a mix of both tube technology and modern solid state components.

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In the next photo, shown below, you can see that the instrument could output both sine and square wave audio frequencies. The frequency range of the audio oscillator went from 20 Hertz to 20,000 Hertz over three bands. John Marsh initially want it to have a frequency range from 0 to 100,000 Hertz. It had coarse and fine adjustments for the audio frequencies. Above those knobs we see the digital readout window of the frequencies. John Marsh put in a modern solid state audio oscillator with a digital readout. To the right of the digital readout we see a timer with a range of up to 5 minutes.

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To the right of that timer, shown below, in the first photo on the left, we see the power meter which is written on it “Standing wave ratio” and “Percent reflected power”. The knob below the meter was for adjusting the standing wave ratio. Below the knob is where the ray tube was connected. John Marsh used the CB antenna style connection instead of the banana jack method use in the original 1953 AZ-58. In the second photo, shown below on the right, you can still see an up close view of the John Marsh's masking tape with the 1950’s frequencies written on it.

The next photo, shown below, is a top view of the chassis with the case removed. You can clearly see that John Marsh used a mix of old tube technology and solid state electronics.

The next four photos, shown below and on the next page, are close up photos of the top of the chassis. The first photo is the built in timer. The second photo is the solid state audio oscillator.

The third photo shows the 811a main power output vacuum tube. The fourth shows the transformer that powers the audio oscillator board.

The next photo, shown below, is a back view of the instrument. The meter is a D.C. milliamp meter. The socket to the right of the meter is for connecting the smaller box that has the power transformers.

In the next four photos, shown below, give you an understand of the various components. The first photo labeled #1 is looking at the inside front of the instrument and shows the audio oscillator. To the left of the audio oscillator is the five minute timer. Photo #2, is looking at the back of the instrument and shows the three vacuum tubes. The three photos of vacuum tubes labeled #4, #5 and #6 show a clear view of the 811a, 6L6GC and 6GK6 vacuum tubes and their placement into the chassis. Photo #3 is one of John Marsh's original 1970 photo which shows the underside of the chassis where you can see the RF tank coil that was fixed at 4.150 MHz (4,150,000 Hertz).

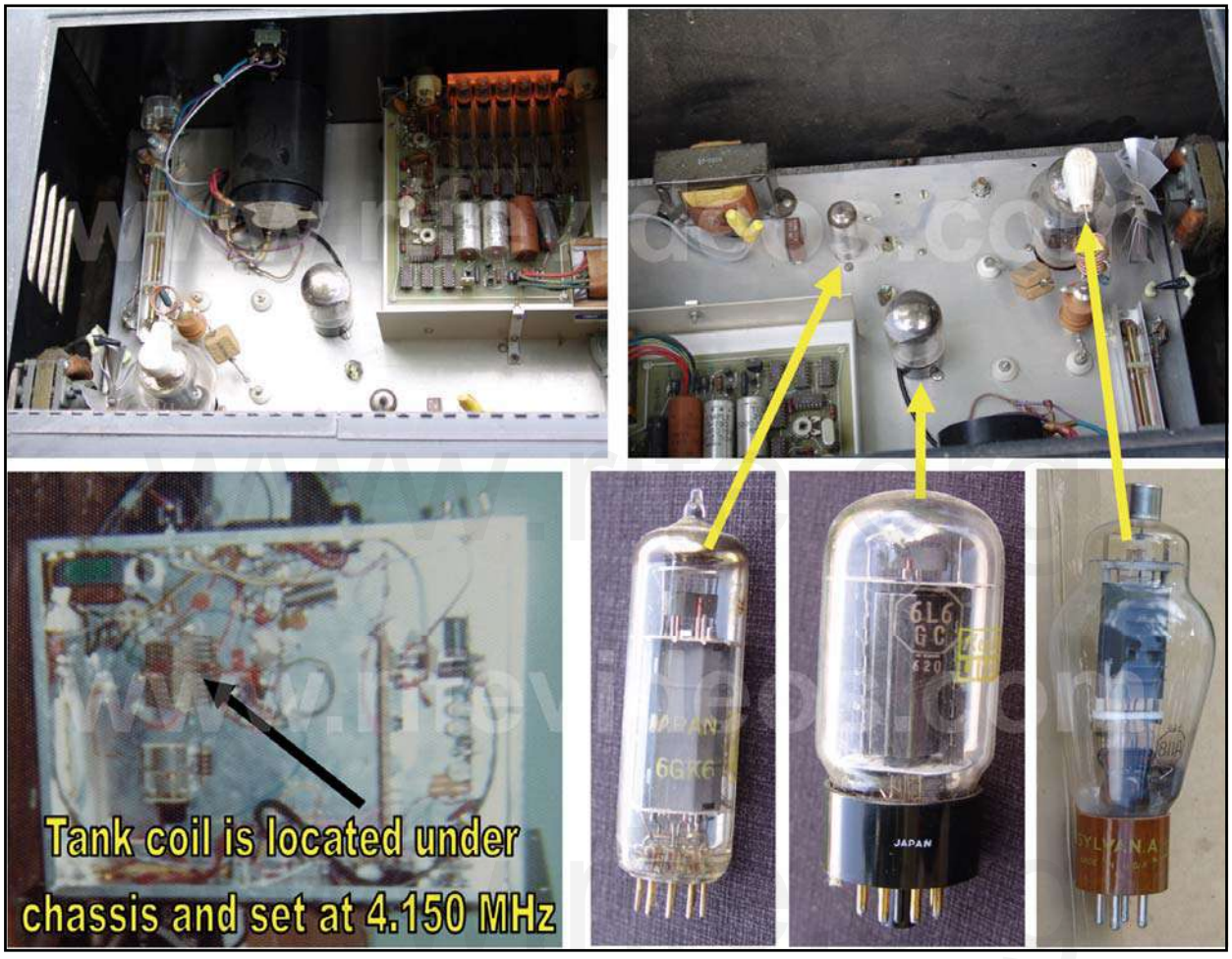

The next photo, show below, is a side view of the 811a tube. You can also see the RF choke right in front of the 811a tube with a small coil on top of it. This coil helped eliminate any parasitic oscillations.

The first of the next two photos, shown below and on the next page, is a photo which was taken of the underside of the chassis. The first photo, was one of the three pictures we have of the underside of the chassis. This photo was not very detailed and was taken back in 1971 when the instrument was built.

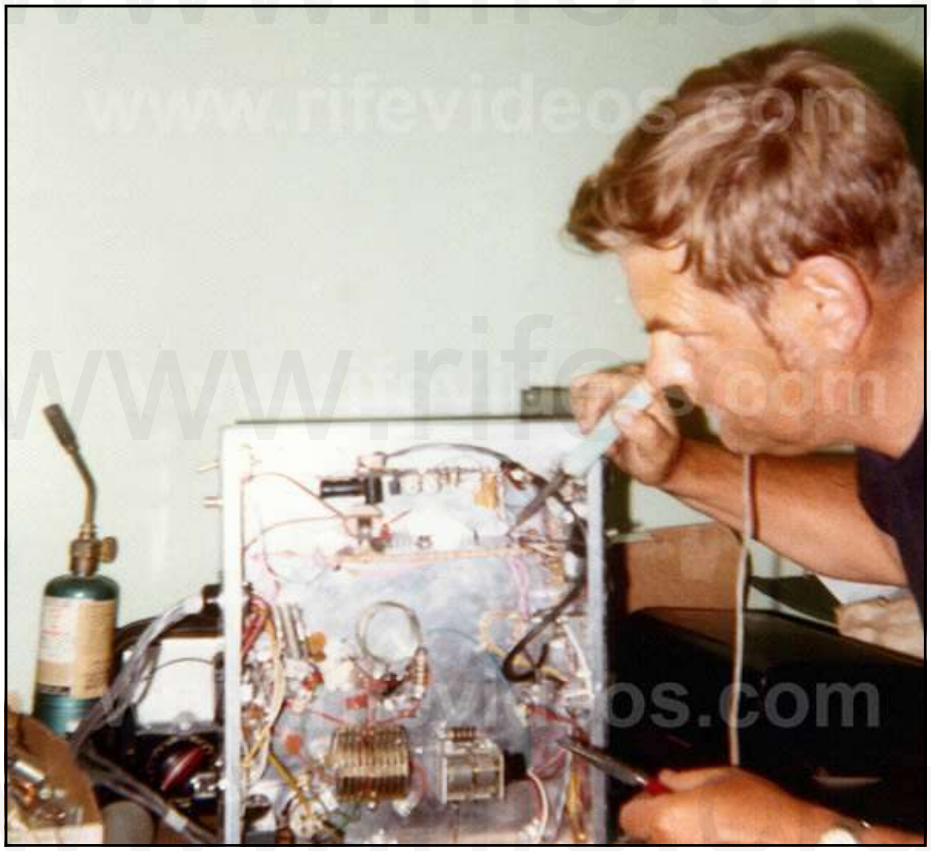

In the second photo, shown below, (new clearer photo) the larger coil is the RF tank coil which was set to 4.150 MHz. The variable capacitor which has the black knob was used to tune the carrier frequency to 4.150 MHz.

The next four photos, shown below and on the next page, are up close photos of the underside of the chassis showing the various components used to build this instrument.

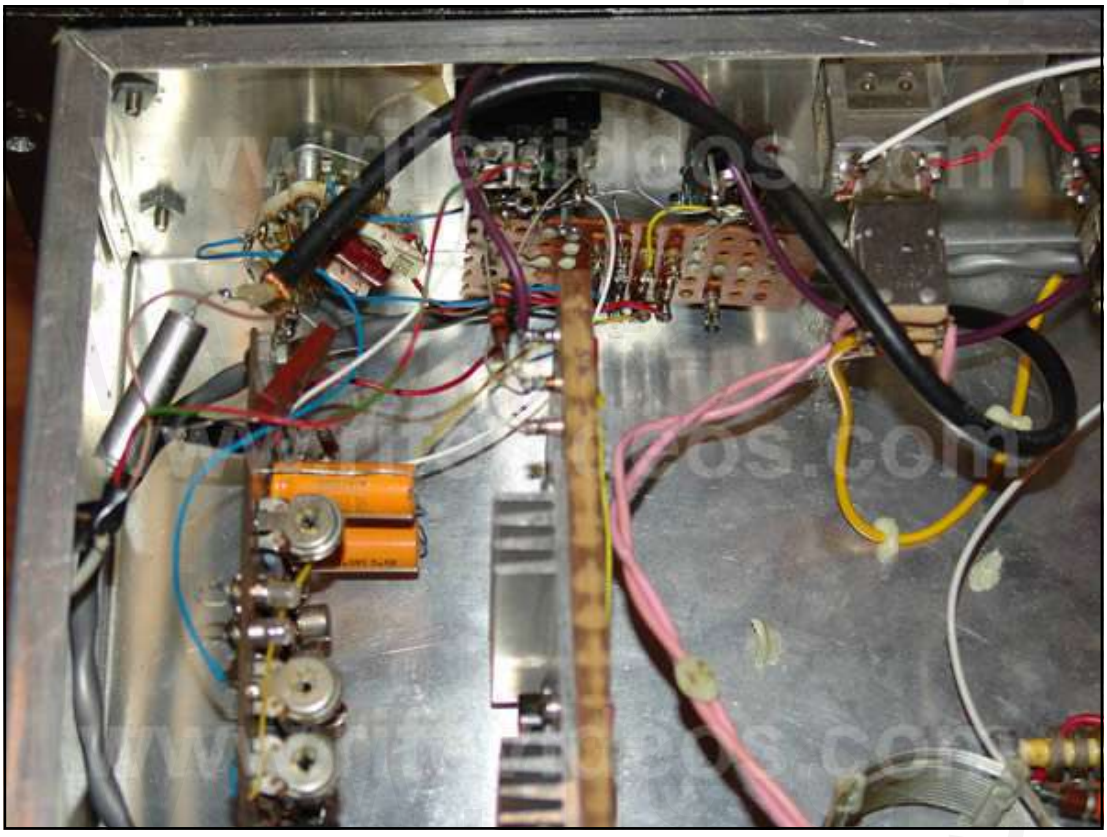

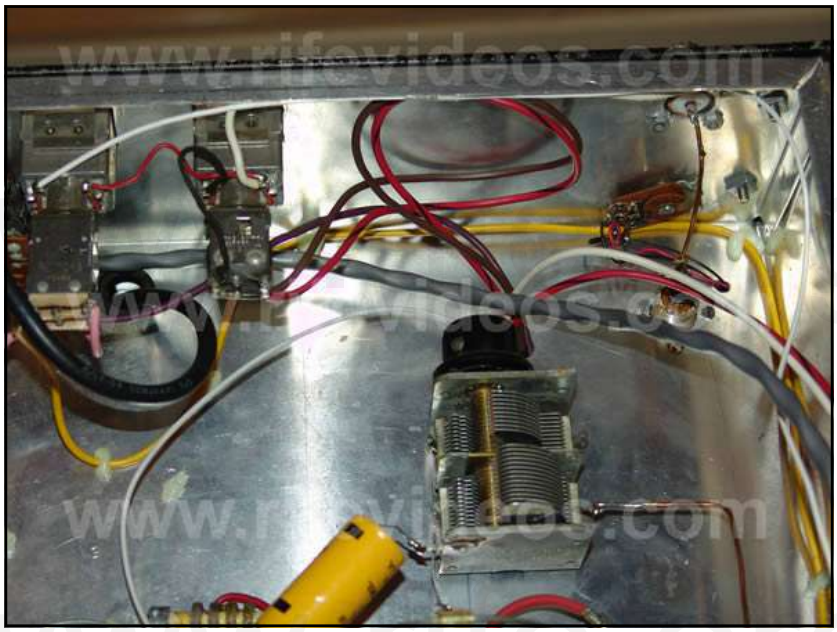

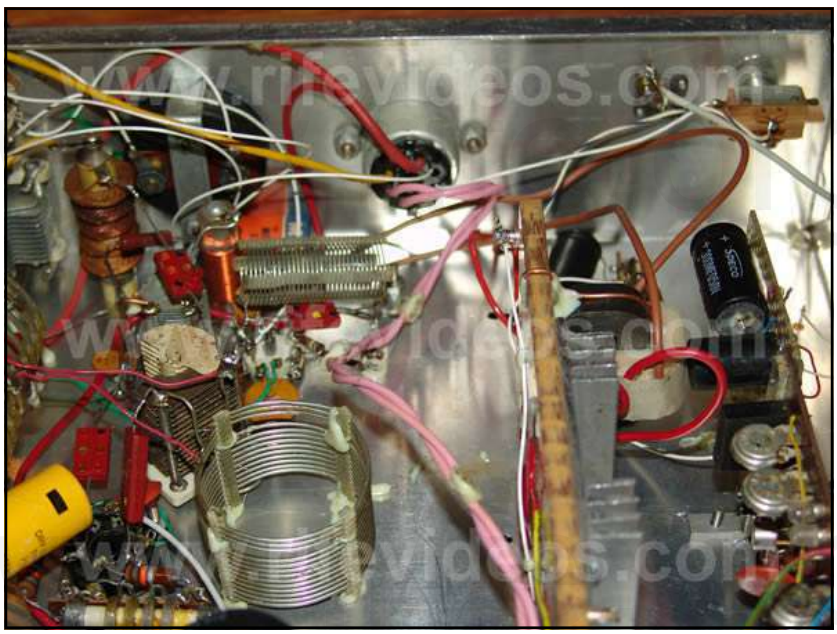

The next two photos, shown below are of the inside of the small case. It contained almost all the transformers. The standard Beam Ray Rife Machine had two shelves in one case for components. The AZ-58 combined everything into one case but for some reason John Marsh used two cases to hold the components.

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The next two photos, shown below, are of this instrument being used in a doctors office back in 1972 when John Marsh live in Colorado.

The photo below is the ray tube which was used with this instrument. The ray tube still worked when we tested it.

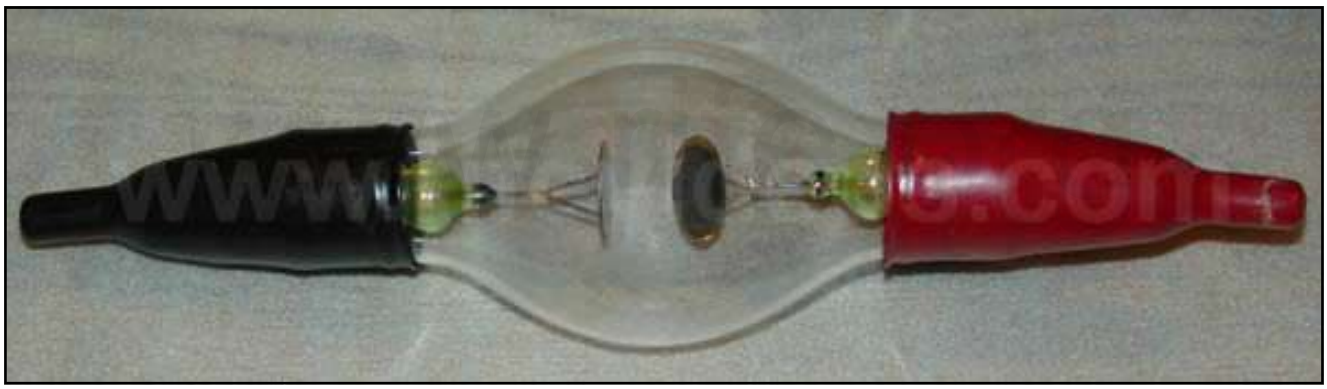

John Marsh's instrument, like the AZ-58, was a more modern replica version of the original Beam Ray Clinical Rife Machine. The carrier frequency that John Marsh chose to use with this instrument again clearly shows he did not understand the importance of the RF carrier frequency. He changed it from the 1953 AZ-58's 4.68 MHz to 4.150 MHz. The 4.150 MHz RF carrier frequency is probably one of the worst carrier frequencies he could have chosen using the AZ-58 low audio frequencies for the sideband method. In fact it would not be a good carrier for the higher audio frequencies either. We will explain again how to determine the best RF carrier frequencies to use in an instrument.

The method Philip Hoyland used to determine the best RF carrier frequency to use was by doing multiples of the BY (Sarcoma 1,529,520 Hertz) and the BX (Carcinoma 1,607,450 Hertz) frequencies. Logically, multiples of these frequencies are the best RF carrier frequencies to use because they were Dr. Rife's highest M.O.R. frequencies that he found. If you multiply the BY frequency by two you get 3,059,040 Hertz and if you multiply the BX frequency by two you get 3,214,900. So an RF carrier frequency in the 3,100,000 to 3,300,000 Hertz range would work well. Philip Hoyland used 3,300,000 Hertz. The next best range would be to multiply these two frequencies by a factor of three. The BY multiplied by three gives you 4,588,560 Hertz and the BX multiplied by three gives you 4,822,350 Hertz. So a carrier frequency in the 4,600,000 to 4,700,000 Hertz range would be the next best RF carrier frequency to use in an instrument. So you can see by the math that 4,150,000 Hertz would not be a good carrier frequency to use if you were going to used the sideband method that Philip Hoyland used when building the Rife Ray #5 or Beam Ray Clinical instrument. The RF carrier frequency should always be determined by multiples of the highest frequencies that Dr. Rife found for the various organisms. The 1953 AZ-58 had an RF carrier frequency of 4,680,000 Hertz. This carrier frequency would have worked very well had they understood the sideband method Philip Hoyland used. Since they lowered the audio frequencies instead of recalculating them to work on the sideband method then this also again reveals that they did not understand how Philip Hoyland's instrument really worked.

With the above understanding it is easy to see that the only reason you would use a 4.150 MHz RF carrier frequency is if you did not care what RF carrier frequency you used. The fact that they didn't really care what RF carrier frequency they used is without question since both John Marsh and John Crane have said in several documents and on audio tapes that the audio frequencies were the M.O.R. frequencies. The whole concept of using the sideband spacing method is to choose a carrier frequency that would work the best with all of the Rife Ray #4 higher frequency harmonics. Had John Marsh really understood the significance of the RF carrier frequency he would have chosen a different one. But just like the 1953 AZ-58 they changed it and relied on the square wave audio frequency harmonics rather than the sideband spacing method used in the original Beam Ray Clinical instrument. The Aubrey Scoon Beam Ray Clinical instrument replica was working on the sideband spacing method because the audio frequencies used with it were high enough to make the number of sideband harmonics reasonably low. So far Aubrey Scoon's instrument is the only instrument that we have seen, except for the original Beam Ray Clinical Rife Machine, which worked properly on the sideband spacing method.

It is clear that the 1953 AZ-58 was not working fully on the sideband principle even though it could have. It appears that just by chance or accident some of the frequencies, like the BX frequency, worked because the RF carrier frequency was set at about 3.2 MHz by Dr. Stafford. Just the fact that they lowered the audio frequencies by a factor of 10 and then depended solely on square wave audio frequencies showed they didn't understand Philip Hoyland's sideband method. Had Philip Hoyland revealed how his Beam Ray Clinical Rife Machine worked a lot of confusion could have been avoided. This machine of John Marsh's could have easily been changed to work properly on the sideband method. The audio frequency range was designed to go to 20,000 Hertz. If the RF carrier frequency was changed to 3,300,000 Hertz, which would have been easy to do, then most of the original audio frequencies could have been used. The only two that would need to have been re-calculated would have been the BX and the BY frequencies. This also would have been easy to do.

In the chart, shown below, the frequencies have been calculated for John Marsh's instrument. You will notice that the "Original 1950's AZ-58 Frequencies" (low audio frequencies) are almost a perfect match to the "Correct Sideband Frequencies." But before we place too much significance in this coincidence we need to keep in mind the "Number of Sideband Harmonics." These numbers are so high that almost any low frequency can be divided into the "Carrier Difference Frequency" and come out within a few Hertz of the "Correct Sideband Frequency." The audio frequency needs to be a great deal higher in order to make it so the sideband frequencies will work. This is due to the fact that power is lost in sidebands. We must keep in mind that the higher the audio frequency is, the lower the number of sidebands that will be created and the better they will work. So these low audio frequencies in the chart below are two low to work with an RF carrier frequency of 4.150 MHz. In fact they would be too low to work even if they were used with a 3.30 MHz RF carrier frequency as was used in the original Beam Ray Clinical instrument. Using the higher audio frequencies like Philip Hoyland used is the

John Marsh's Beam Ray Clinical Instrument Sideband Square Wave Audio Frequencies Based On A 4.150 MHz Carrier

Organism	Rife Ray #4 Frequencies	Higher Harmonic Frequencies	*Carrier Difference Frequency	1/10 Of A Meter Freq.	Number of Sideband Harmonics	Original 1950's AZ-58 Frequencies	Correct Sideband Frequencies
Actinomycosis or Streptothrix	192,000 Hz	4,032,000 or 21st	118,000 Hz	12 Hz	151	784 Hz	781 Hz
Anthrax	139,200 Hz	4,176,000 or 30th	26,000 Hz	6 Hz	41		634 Hz
B or E Coli Rod	417,000 Hz	4,170,000 or 10th	20,000 Hz	58 Hz	25	800 Hz	800 Hz
B or E Coli Virus	770,000 Hz	3,850,000 or 5th	300,000 Hz	198 Hz	193	1552 Hz	1554 Hz
BX Virus Carcinoma	1,604,000 Hz	4,812,000 or 3rd	662,000 Hz	858 Hz	311	2128 Hz	2129 Hz
BY Sarcoma	?1,530,000 Hz	4,590,000 or 3rd	440,000 Hz	780 Hz	219	2008 Hz	2009 Hz
Gonorrhea	233,000 Hz	4,194,000 or 18th	44,000 Hz	18 Hz	62	712 Hz	710 Hz
Pneumonia or Spinal Meningitis	427,000 Hz	4,270,000 or 10th	120,000 Hz	61 Hz	155	776 Hz	774 Hz
Staphylococcus Pyogenes Aureus	478,000 Hz	4,302,000 or 10th	152,000 Hz	76 Hz	209	727 Hz	727 Hz
Streptococcus Pyogenes	720,000 Hz	4,320,000 or 6th	170,000 Hz	173 Hz	193	880 Hz	880 Hz
Syphilis	789,000 Hz	3,945,000 or 5th	205,000 Hz	207 Hz	311	660Hz	659 Hz
Tetanus	234,000 Hz	4,212,000 18th	62,000 Hz	18 Hz	517	120 Hz	120 Hz
Tuberculosis Rod	369,000 Hz	4,059,000 or 11th	91,000 Hz	45 Hz	113	803 Hz	805 Hz
Tuberculosis Virus	769,000 Hz	3,845,000 or 5th	305,000 Hz	197 Hz	197	1552 Hz	1548 Hz
Typhoid Rod	760,000 Hz	3,800,000 or 5th	350,000 Hz	192 Hz	492	712 Hz	711 Hz
Typhoid Virus	1,445,000 Hz	4,335,000 or 3rd	185,000 Hz	694 Hz	99	1862 Hz	1869 Hz

method that worked in the original equipment. If the frequency you want to hit is close to the RF carrier frequency then the lower the audio frequency you can use. But if the frequency is farther away from the carrier frequency then the higher the audio frequency you will need to use in order to make it work properly. Philip Hoyland could have used even higher audio frequencies since his audio oscillator in the original Rife Ray #5 or Beam Ray Clinical instrument would go to a little over 40,000 Hertz. He could have used frequencies up in the 30,000 to 40,000 Hertz range which would have worked with even less sidebands. But Philip Hoyland was also trying to hide the method he was using. So Philip Hoyland balanced his frequencies in order to make sure they would work and also not reveal the method he was using. He did accomplish his goal.

If you look at the “Number of Sideband Harmonics” it takes to hit the correct Rife Ray #4 “Higher Harmonic Frequencies” you will understand that this instrument could never work on the sideband spacing method using these low audio frequencies. None of the “Number of Sideband Harmonics” are less than 59 sideband steps and the highest is 750. The chance of this working would be almost zero. The best method to use with John Marsh’s instrument is the audio frequency square wave harmonic method. This is the method he used with his instrument.

Below in the chart is a list of the higher audio frequencies, 20,000 Hertz or lower, that could be used with John Marsh’s instrument and make it work using the harmonic sideband method. Many different audio frequencies could be calculated to work. We did the highest audio frequency for each organism. The BX and the BY frequencies probably would not work since the sidebands would have to go nearly 600,000 Hertz to hit the correct frequency. For this reason the RF carrier frequency should be changed. The best frequencies would always be the highest audio frequency you could use within in the 20,000 Hertz frequency range of the instrument.

John Marsh’s Beam Ray Clinical Instrument Higher Sideband Square Wave Audio Frequencies Based On A 4.150 MHz Carrier			
Anthrax	13,000 Hz	Streptococcus	18,889 Hz
B or E Coli Rod	10,000 Hz	Steptothrix	19,667 Hz
B or E Coli Virus	20,000 Hz	Syphilis or Treponema	18,636 Hz
BX Virus Carcinoma	19,471 Hz	Tetanus	15,500 Hz
BY Sarcoma	19,130 Hz	Tuberculosis Rod	18,200 Hz
Gonorrhea	14,667 Hz	Tuberculosis Virus	19,062 Hz
Pneumonia or Spinal Meningitis	17,143 Hz	Typhoid Rod	19,444 Hz
Staphylococcus	19,000 Hz	Typhoid Virus	18,500 Hz

Chapter Summary: The fact that John Marsh built these Beam Ray replica Rife Machines and used different RF carrier frequencies with the same audio frequencies conclusively proves that he never understood how the instrument was really intended to work. This also shows that John Crane didn't really know how the instrument was intended to work either. John Crane was doing the same thing that John Marsh was doing. The fact that Philip Hoyland did not reveal how the Beam Ray Clinical instrument really worked has affected Rife's work in a negative way to this very day.

In the next chapter we will look at the ray tube instrument that John Marsh built back in the 1980's when he lived in Salt Lake City, Utah.

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Chapter #16

John Marsh's 1980's Ray Tube Rife Machine

1. Used a ray tube.
2. Carrier frequency was ?
3. Square wave audio frequencies modulated onto a sine wave carrier frequency.
4. Power usage was about 125 watts. Output to the ray tube about 25 to 30 watts.

This style of ray tube instrument Model JLMSQ-101, which was built in the 1980's, was the last design that John Marsh built before his death. All of his Rife Machines and Rife information were given to his nurse before his death. His equipment and documents were obtained from her in 2012. Since we were able to obtain this instrument we have been able date it and take better photos of the complete instrument. Some of this information and new photos are shown below and are now included in this report.

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John Marsh built two different models of this style of Rife Machine. In the next two photos, shown below, we see the first model of this style of instrument. The instrument was a mix of both old vacuum tube technology and modern solid state technology. The audio oscillator was a solid state variable audio oscillator with a digital readout for displaying the frequencies. The frequency range went from about 20 Hertz to 20,000 Hertz. The instrument used the same low square wave audio frequencies that were used in the 1950's AZ-58 Rife Machine built in 1953. Those thirteen frequencies were 120, 660, 712, 727, 776, 784, 800, 803, 880, 1552, 1862, 2008, 2128. The RF carrier frequency section was built using old vacuum tube technology. The RF carrier frequency was set at 2,200,000 Hertz. This RF carrier frequency again shows that John Marsh did not understand the harmonic sideband method that Philip Hoyland used in the original Rife Ray #5 or Beam Ray Clinical Rife Machine sold by the 1938-1939 Beam Ray Corporation. His earlier 1971 instrument which was discussed in Chapter 15 of this report used a 4.150 MHz (4,150,000 Hertz) RF carrier frequency. Both of these RF carrier frequencies (2.2 MHz and 4.150 MHz) clearly show that Philip Hoyland's sideband method was not used. What became of this instrument is not known. John Marsh most likely sold it to someone because he was building these for a few people who wanted them.

In the first photo, shown below, we see John Marsh's second style of Rife Machine. This is the same machine shown in the first photo of this chapter. This machine John Marsh used until his death in 1987. This machine was given to his nurse. We now have this machine and know how it worked. The instrument uses the same low square wave audio frequencies that were used in the 1953 AZ-58 Rife Machine. This instrument was unique because he did not have it built with a variable audio oscillator. Instead it had a dial which had 13 different positions for the 13 different audio frequencies which he used. John also had this instruments RF section built using old vacuum tube technology. The RF carrier frequency was also set to 2,200,000 Hertz (2.20 MHz). The fact that this instrument is still being used even after about thirty years speaks of its quality of construction. In the second photo, shown below, we see John Marsh with this instrument in the 1980's shortly before his death.

The ray tube used with this instrument has an interesting design because it was designed to stand up. In the new photo, show below, you can see an up close view of this ray tube.

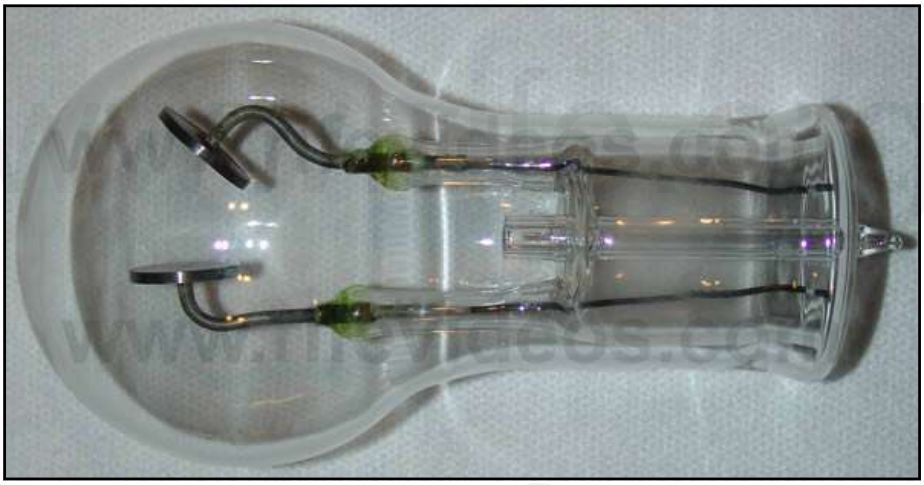

Below is a photo of the inside of the case that held the ray tube. You will notice that the ray tube is darkened. This happens to this type of ray tube because the metal electrodes are on the inside of the ray tube. When the ray tube is lit the metal comes of the electrodes and over time slowly contaminates the gas and the interior of the tube. The metal deposits or coats the inside of the ray tube and then the ray tube becomes less effective. In many cases the ray tube begins to sputter requiring it to be replaced or cleaned out and re-gassed. The photo of the new ray tube, shown above, is one of the extra ray tubes that John had built for this instrument. Many people no longer use ray tubes with internal electrodes because of this problem. The tubes without internal electrodes last for many years without any need of replacement. Some people have used them for more than 15 years and the ray tubes are still working without any problems.

The photo, shown below, is the underside of the instrument with the bottom removed.

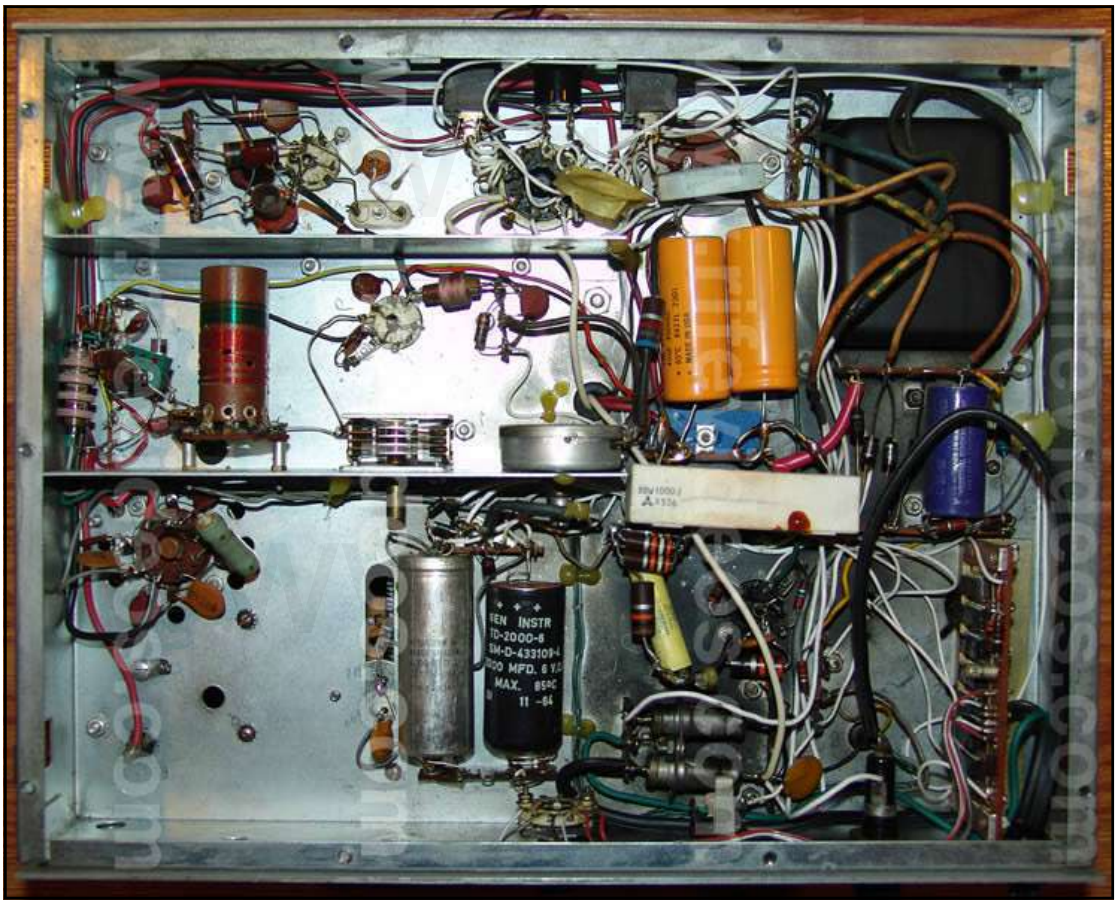

The next picture, shown below, is a photo of the instrument with the top cover removed.

The next photo, shown below, is a close up of the RF carrier frequency section showing the RF tank coil and the two variable tuning capacitors for tuning the RF carrier frequency to 2.20 MHz and for tuning the ray tube resonance.

In the next photo, shown below, you can see the two brass colored nuts with regular screw driver slots. The one on the left labeled “Load” was for tuning the ray tube and the other on the right which is labeled “Tune” was for tuning the carrier frequency.

The next photo, shown below, is a side view of the instrument showing the electronics for the thirteen square wave audio frequencies.

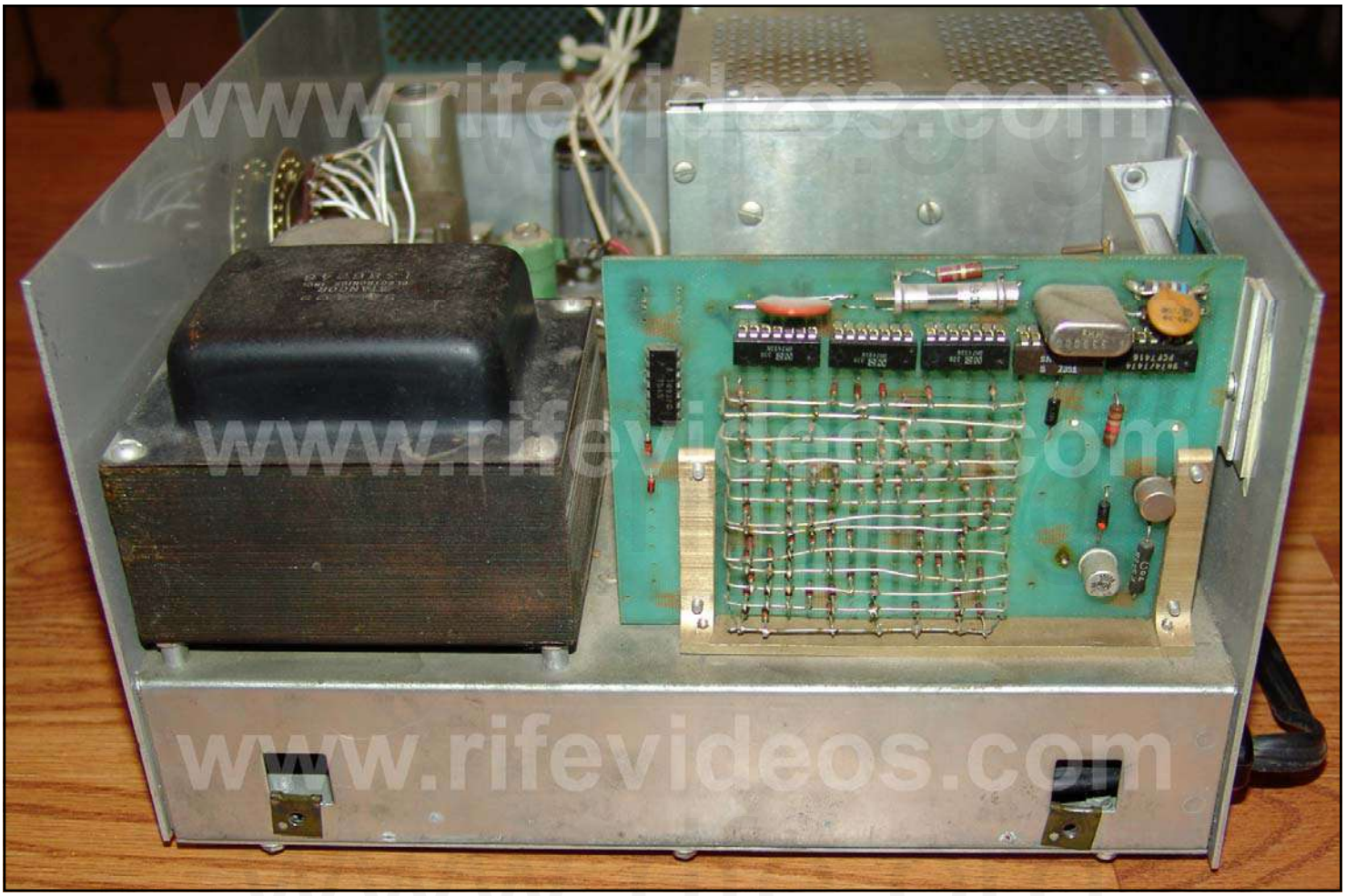

In the next photo, show below you can see the tuning dial for each of the thirteen square wave audio frequencies. The dial started with the lowest audio frequency and went to the highest. The audio frequencies went in clockwise order from the first setting to the last setting 120, 660, 712, 727, 776, 784, 800, 803, 880, 1552, 1862, 2008, 2128.

The final photo, shown below, is of the machine with the ray tube lit. The ray tube would be a lot brighter if the tube was in new condition.

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Chapter Summary: This instrument built by John Marsh used the same frequencies as the 1953 AZ-58. It also worked on the same low audio frequency square wave harmonics method as the AZ-58. The power level was lower than the AZ-58 and his 1970's AZ 58 replica discussed in chapter 15 of this report. This instrument was the last ray tube instrument John Marsh built before his death in 1987.

The next chapter will be a summary of the complete "Rife Machine Report."

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Chapter #17

Summery of the Rife Machine Report

In summary, with all the historical information that has come to light in the past few years we finally know the truth about which frequencies were Dr. Rife's M.O.R.s. We also understand the audio frequency sideband spacing method used in the Rife Ray #5 or Beam Ray Clinical instrument which hit the high harmonics of Dr. Rife original RF M.O.R. frequencies. Because Philip Hoyland hid how his instrument worked these audio frequencies, due to lack of knowledge, were lowered and used with a square wave waveform in the 1953 AZ-58. These lower square wave audio frequencies may not work as well as Dr. Rife's original frequencies but they have accomplished a lot of good helping many people. With the use of even more square wave audio frequencies a whole new field of frequencies are now available for our use. Having said this, we still need to remember Dr. Rife still maintained his true M.O.R. frequencies were in the RF band of frequencies. Even though Dr. Rife, John Crane and John Marsh tested these square wave audio instruments in the 1950's and early 1960's to see how well they would work. It wasn't until after John Crane and John Marsh were released from prison that they received Dr. Stafford's report showing the limited capability of the low square wave audio frequencies on cancer.

From about 1964 on, John Crane and John Marsh continued to build the audio frequency instruments even though they had the evidence from Dr. Stafford which showed the audio frequencies alone didn't work on cancer like the original high RF frequencies. Even though John Crane and John Marsh said the square wave audio frequencies were Dr. Rife's true M.O.R.s this does not change the fact that

we now know the true purpose of the audio frequencies. The evidence in this report proves that Dr. Rife, John Crane and John Marsh really didn't understand how Philip Hoyland's Beam Ray Clinical instrument worked. This lack of understanding caused them to miss the truth when it was right before their eyes. We would still be in the dark had it not been for the original instruments found and the written documents that revealed Dr. Rife's high frequencies. Add to this the audio tapes which have Dr. Rife's own voice on them telling us his frequencies ranged from the audio to the broadcast bands. Dr. Rife was a pure scientist and only believed what he could prove. Had he seen Dr. Stafford's final report we feel certain he would have considered the cancer tests a failure. Dr. Rife said "he never fooled himself". It is entirely possible that Dr. Rife would have insisted they go back to his original high frequency design used in the Rife Ray #4 or put the 1953 AZ-58 RF carrier frequency back on 3.30 MHz and use Philip Hoyland's audio frequencies.

The most important information that has been obtained from the original Rife Ray #5 or Beam Ray Clinical instrument and Aubrey Scoon's Beam Ray replica instrument is the fact that the audio frequencies used in these instruments had nothing to do with the treatment of disease. To put it bluntly, all of us have been led down the primrose path because we did not understand how the Beam Rays Clinical instrument really worked. The mistakes made have major implications since the audio frequencies used with the AZ-58 (120, 660, 712, 727, 776, 784, 800, 803, 880, 1552, 1862, 2008 and 2128 Hertz) have no ability to eliminate the diseases we thought they would eliminate. In all reality these audio frequencies should be replaced with higher frequencies that are true harmonics of Dr. Rife's original high frequency M.O.R.s instead of clinging to the old dogma. Those who are really trying to do what Dr. Rife did should no longer promote the concept that these AZ-58 audio frequencies are M.O.R.s and by so doing put many people at risk. The best frequencies to use would always be the original high frequency M.O.R.s followed by lower audio frequencies that are exact lower harmonics of the high RF M.O.R. frequencies. For the most accurate list of Dr. Rife's original high RF frequencies go to the first chart on page 223. These frequencies were set by Philip Hoyland in Dr. Rife's laboratory using his microscope.

Hopefully this information will help make a change and in the future we will begin to see what Dr. Rife's original high frequency M.O.R.s will do. Many helpful people have provided the records and resources so this new information could be brought to light: the release of the John Marsh information from John Marsh's nurse; the Beam Ray Trial Papers from Steven Ross; the many photos from Jason Ringas of the Rife Research Group of Canada; the great benefit from Dr. Larry Low who allowed us to purchase the original Beam Ray Clinical instrument; the British Rife group and their work on the Aubrey Scoon replica instrument; the help of James Cunningham along with the great detective work done by James Peters in figuring out that Dr. Rife was using the Kennedy company Model 110, 220 and 281 receivers. We also want to recognize the great work Jim Peters did on the schematic of Dr. Gruners original Beam Rays Laboratory instrument. His recognition of the second variable Hartley Oscillator made it possible to rebuild an instrument that works like the original Beam Ray Laboratory instrument.

The spectrum analyzing of these machines has finally given us the answers to how all these different instruments really worked. I believe the recognition of the Kennedy equipment and the locating of the original 1938-1939 Beam Ray Clinical instrument along with the Beam Ray Laboratory instrument schematic correction and rebuilding are three of the greatest pieces of information we have yet discovered about Dr. Rife. No longer are we guessing in the dark. We have purchased the Kennedy Company equipment Models 110, 220 and 281 along with the original Beam Ray Clinical instrument for all of this testing. We plan on doing more extensive spectrum analysis work on this equipment. We have built, into one case, the Beam Ray Clinical and Laboratory instrument designs. We wish also to give special thanks to Henry Rogers the owner of the Western Historic Radio Museum (www.radioblvd.com). He allowed us the opportunity to come and test the Kennedy receivers that he owns. As more information comes out we will update this article as necessary.

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For those who would like a complete list of Dr. Rife's frequencies output by the Rife Ray #3, Rife Ray #4, Philip Hoyland's Rife Ray #5 or Beam Ray Clinical instrument, Aubrey Scoon's 1950's Rife Ray #5 and the AZ-58 Beam Ray replica instrument we have listed them in a chart on page 222. Other charts that may be of interest are included on pages 223 and 224.

None of the sets of the low audio frequencies are true M.O.R.s and were originally used to create the proper sideband spacing frequencies. The square wave audio frequencies used by the AZ-58 were used in a different manner or method relying only upon the harmonics from the square wave waveform. This method has been used with very good results over the past 50 years by many people, but, these audio frequencies have never produced the true M.O.R. effect of devitalizing organisms. The correct high RF M.O.R.s are the frequencies that should be used since we know what these frequencies are. If people are determined to use the lower audio and ultrasonic range of frequencies below 50,000 Hertz then they should at least use the highest harmonic frequency of the true M.O.R.s. At the very least we should make sure that all frequencies used are true harmonics of the fundamental M.O.R.s that Dr. Rife found.

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Rife's M.O.R Frequencies And Audio Sideband Frequencies

Microorganisms From Rife's Lab Notes And Other Documents.	Square Wave Frequencies for Rife, Crane, Marsh 1950s AZ-58 Beam Ray Replica. Built by Verne Thompson.	Sideband Frequencies For Aubrey Scoon's 1940s Beam Ray Replica. Built by Verne Thompson. Used with 3.30 MHz	Sideband Frequencies For Original Beam Ray Clinical Instrument. Built By Philip Hoyland 1938-1939. Recovered in 2008. Used with 3.80 MHz	High RF Frequencies For Dr. Rife's Rife Ray #3 and #4 Instruments. Correctly read in 1935 By Philip Hoyland*. Rife Ray # 4 built by*.	1/10th Of One Meter Frequency Tolerance.	Rife's Misread Lab Note Frequencies Before 1935. Frequency #1	Rife's Misread Lab Note Meter Frequencies Before 1935. Meters	Rife's Misread Lab Note Meters Converted To Hertz. Frequency #2
	Square Wave	Sine Wave	Sine Wave	Sine Wave		Sine Wave	Sine Wave	Sine Wave
Actinomycosis or Streptothrix	784 Hz	7,870 Hz	10,000 Hz	192,000 Hz	12 Hz	678,000 Hz	1,607 M	186,554 Hz
Anthrax			8,320 Hz	139,200 Hz	6 Hz	900,000 Hz	1,100 M	272,539 Hz
Anthrax Symptomatic						400,000 Hz	18,000 M	16,655 Hz
B or E Coli Rod	800 Hz	8,020 Hz	7,833 Hz	417,000 Hz	58 Hz	683,000 Hz	943 M	317,914 Hz
B or E Coli Virus	1,552 Hz	17,220 Hz	16,667 Hz	770,000 Hz	198 Hz	8,581,000 Hz	27 M	11,103,424 Hz
BX Virus Carcinoma	2,128 Hz	21,275 Hz	39,467 Hz	1,604,000 Hz	858 Hz	11,780,000 Hz	17.6 M	17,033,662 Hz
BY Sarcoma	2,008 Hz	20,080 Hz	37,000 Hz	? 1,530,000 Hz	780 Hz			
Bubonic Plague						160,000 Hz	585 M	512,466 Hz
Catarrh						1,800,000 Hz	175 M	1,713,100 Hz
Cholera Spirillum						851,000 Hz	312 M	960,873 Hz
Contagious Conjunctivitis						1,206,000 Hz	148 M	2,025,625 Hz
Diptheria						800,000 Hz	275 M	1,090,154 Hz
Glanders						986,000 Hz	407 M	736,591 Hz
Gonorrhea	712 Hz		14,400 Hz	233,000 Hz	18 Hz	600,000 Hz	1,990 M	150,649 Hz
Influenza						1,674,000 Hz	154 M	1,946,704 Hz
Leprosy						743,000 Hz	1,190 M	251,926 Hz
Pneumonia						1,200,000 Hz	785 M	381,901 Hz
Pneumonia or Spinal Meningitis	776 Hz	7,660 Hz	8,600 Hz	427,000 Hz	61 Hz	927,740 Hz	167 M	1,795,164 Hz
Staphylococcus Pyogenes Aureus	727 Hz	7,270 Hz	8,000 Hz	478,000 Hz	76 Hz	988,740 Hz	540 M	555,171 Hz
Staphylococcus Pyogenes Albus							546 M	549,070 Hz
Streptococcus Pyogenes	880 Hz	8,450 Hz	8,333 Hz	720,000 Hz	173 Hz	1,214,000 Hz	142 M	2.111.214 Hz
Syphilis (Treponema Pallidum)	660 Hz	6,600 Hz	6,591 Hz	789,000 Hz	207 Hz	900,000 Hz	108 M	2,775,856 Hz
Tetanus	120 Hz	1,200 Hz	11,200 Hz	234,000 Hz	18 Hz	700,000 Hz	19,000 M	15,779 Hz
Tuberculosis Rod	803 Hz	8,300 Hz	8,462 Hz	369,000 Hz	45 Hz	583,000 Hz	554 M	541,142 Hz
Tuberculosis Virus	1,552 Hz	16,000 Hz	16,910 Hz	? 769,000 Hz	197 Hz			
Typhoid Rod	712 Hz	6,900 Hz	100 Hz	760,000 Hz	192 Hz	900,000 Hz	345 M	868,964 Hz
Typhoid Virus	1,862 Hz	18,620 Hz	38,214 Hz	1,445,000 Hz	694 Hz	9,680,000 Hz	21.5 M	13,943,835 Hz
Worms		2,400 Hz						

Dr. Rife's Original High RF Frequencies Fine Tuned To The Precise Frequencies By Philip Hoyland.	
Actinomycosis (Streptothrix)	191,803 Hz
Anthrax	139,200 Hz
B. Coli (Rod form)	416,510 Hz
B. Coli (Filterable virus)	769,035 Hz
Bacillus X or BX (Cancer Carcinoma)	1,607,450 Hz
Bacillus Y or BY (Cancer Sarcoma)	1,529,520 Hz
Gonorrhea	233,000 Hz
Spinal Meningitis	426,862 Hz
Staphylococcus Pyogenes Aureus	477,660 Hz
Staphylococcus Pyogenes Albus	549,070 Hz
Streptococcus Pyogenes	719,150 Hz
Syphilis	788,700 Hz
Tetanus	234,000 Hz
Tuberculosis (Rod)	369,433 Hz
Tuberculosis (Virus)	769,000 Hz
Typhoid Fever (Rod)	759,450 Hz
Typhoid Fever (Virus)	1,445,180 Hz

Philip Hoyland's Audio Frequencies Used With 3.30 MHz To Produce Through Sidebands Dr. Rife's Frequencies			
B or E Coli Rod	8,020 Hz	Syphilis or Treponema	6,600 Hz
B or E Coli Virus	17,220 Hz	Tetanus	1,200 Hz
BX Virus Carcinoma	21,275 Hz	Tuberculosis Rod	8,300 Hz
BY Sarcoma	20,080 Hz	Tuberculosis Virus	16,000 Hz
Pneumonia or Spinal Meningitis	7,660 Hz	Typhoid Rod	6,900 Hz
Staphylococcus	7,270 Hz	Typhoid Virus	18,620 Hz
Streptococcus	8,450 Hz	Worms	2,400 Hz
Streptothrix	7,870 Hz		

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Philip Hoyland's New M.O.R.s. Used In The Beam Ray Clinical Instrument.			
B or E Coli Rod	3,332,080 Hz	Streptothrix	3,260,650 Hz
B or E Coli Virus	3,076,140 Hz	Syphilis or Treponema	3,154,800 Hz
BX Virus Carcinoma	3,214,900 Hz	Tetanus	3,276,000 Hz
BY Sarcoma	3,059,040 Hz	Tuberculosis Rod	3,324,897 Hz
Gonorrhea	3,262,000 Hz	Tuberculosis Virus	3,076,000 Hz
Pneumonia or Spinal Meningitis	3,414,900 Hz	Typhoid Rod	3,037,800 Hz
Staphylococcus	3,343,620 Hz	Typhoid Virus	2,890,360 Hz
Streptococcus	3,595,750 Hz		

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30 29 28 27 26 25 24 23 22 21

Notice to the Reader:

The opinions and conclusions expressed in this book are mine, and unless expressed otherwise, mine alone. The opinions expressed herein are based on my scientific research and on specific case studies involving my patients. Be advised that every person is unique and may respond differently to the treatments described in this book. On occasion we have provided dosage recommendations where appropriate. Again, remember that we are all different and any new treatment should be applied in a cautious, common sense fashion.

The treatments outlined herein are not intended to be a replacement or substitute for other forms of conventional medical treatment. Please feel free to consult with your physician or other health care provider.

I have indicated throughout this book the existence of pollutants in food and other products. These pollutants were identified using a testing device of my invention known as the Syncrometer.™ Complete instructions for building and using this device are contained in this book. Therefore anyone can repeat the tests described and verify the data.

The Syncrometer is more accurate and versatile than the best existing testing methods. A method for determining the degree of precision is also presented. However at this point it only yields positive or negative results, it does not quantify. The chance of a false positive or a false negative is about 5%, which can be lessened by test repetition.

It is in the public interest to know when a single bottle of a single product tests positive to a serious pollutant. If one does, the safest course is to avoid all bottles of that product entirely, which is what I repeatedly advise. These recommendations should be interpreted as an intent to warn and protect the public, not to provide a statistically significant analysis. It is my fervent

hope that manufacturers use the new electronic techniques in this book to make purer products than they ever have before.

Dedication

I would like to dedicate this book to all the persons who visited me professionally, from the very first person in 1963, **Mrs. R. Biehl**, to the present. I learned so much from each of you and I appreciate your confidence, your intelligence and your reluctance to be defeated.

Acknowledgments

I would like to express my gratitude to my son, **Geoffrey**, who always listened to my "crazy ideas" on Sundays, right at supper time. He was patient, kind, helpful and willing to share his expertise in electronics and computers. Without him, this book could not have been written.

A big thank you goes to **Frank Jerome, DDS**. Without the loan of his parasite slide collection many of my discoveries could not have been make, and without his development of metal-free dentistry, many of these patient histories could not have ended happily. Thank you to **Linda Jerome** for nurturing us both with personal interest and patience. And thank you to **Edna Bernstein** for her resourceful assistance.

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Preface

The sick have been held hostage for their money or intangible assets since time immemorial. Doctors, even primitive and natural healers, surround themselves with mystery as they use herbs or chemicals and incantations or "prognoses" to help the sick recover. Today, the medical industry (doctors and their suppliers and insurers) take a significant amount of the worker's earnings. Wouldn't it be nice if they could all go back to gardening or some other primitive and useful endeavor? Wouldn't it be wonderful if the sick could join them?

The most promising discovery in this book is the effectiveness of electricity to kill viruses, bacteria and parasites. Does this mean you can cancel your appointment with your clinical doctor? No it does not. Killing your invaders does not make you well instantly. But happily, at your next doctor visits she or he will be removing drugs, not adding them.

You might think that such an invention should be quickly patented. That was my universal advice. But I chose not to. It helps me, my children, and my grandchildren, if you are well. The whole world needs to come out of the dark ages of medicine and illness. And to learn the true causes of infection and disease. We must and can usher in the **new age of disease-free living.**

No diabetes, no high blood pressure, no cancer, no HIV/AIDS, no migraines, no lupus and so on!

Not a single disease is left unconquerable with this new understanding!

The Promise

Step into a new world.

A world without chronic diseases.

Step out of your old world.

It has kept you a prisoner.

Try something new.

The prison has no walls. It has only lines. Lines that mark the ground around you. Inside the lines are your old ideas. Outside are new ideas that invite you to step over and escape your prison. Dare to try these new ideas and your illness promises to recede. In a few weeks it can be gone.

If you are very ill or chronically ill you must have asked yourself many times: why have these problems chosen me? Will there never be a way to conquer them?

You may be quite familiar with your doctor's explanation of your illness or your child's illness. A *Coxsackie* virus has entered your child's brain causing inflammation (encephalitis) there. You pray that your child's immunity will overcome it. You may be familiar, but so very helpless against this microscopic invader.

If you had the proverbial 3 wishes they would be: 1) please spare my child's life; 2) please make it so my child doesn't have permanent damage; 3) please bless and guide the wonderful doctors and nurses who are keeping the oxygen tent going, and are watching my child's temperature and vital signs.

What if you could turn a dial and in 3 minutes kill every Coxsackie virus in your child's body?

What if this had no side effects?

What if the virus never came back?

In this book you will learn how to do that. You will also learn why your child got encephalitis or other disease and how to prevent it forever.

If this is too mind boggling, just take it a step at a time: First, learn about the radio-type broadcasting that all living animals do. Second, find the "station frequencies" that your particular invader(s) broadcast at. Third, learn how to "jam" their frequency until they **expire**: it takes only minutes!

Finally, learn how to make your own diagnostic and treatment devices. The instructions are simple enough for anyone. Only by putting this power in your hands will it be safe from government regulation, however well intended.

Only Two Health Problems

No matter how long and confusing is the list of symptoms a person has, from chronic fatigue to infertility to mental problems, I am sure to find only two things wrong: they have in them **pollutants** and/or **parasites**. I never find lack of exercise, vitamin deficiencies, hormone levels or anything else to be a primary causative factor. So the solution to good health is obvious:

Problem	**Simplest Cure**
Parasites	Electronic and herbal treatment
Pollution	Avoidance

It's a valiant quest: The quest for health. With optimism in one hand and determination in the other, you too can work the

miracles for yourself that my clients accomplished in the case histories.

More good news is that it is not expensive. The cost will range from a few hundred dollars to only a few thousand in order to eliminate both problems and cure your chronic diseases.

Be A Health Detective

After curing your own diseases, teach your friends and family how it's done. Families are related and their problems are related. This should make the task easier. Keep a small notebook to become part of the treasured family legacy as much as photographs do. If your aunt, father and brother had diabetes as well as yourself and all were cured after introducing them to this concept and technology, isn't this worthy of notes in your family's history?

Notice what a strong line of inheritance there can be, **not due to sharing genes** but due to sharing a roof, a table, a supermarket, and a dentist!

Many problems can be disinherited. Cure yourself of retinitis pigmentosa, Muscular dystrophy (the "inherited" kind), and break down your family's faith in the gene-concept for these diseases. Bring hope to your family by proving diseases' true etiology. Bring respect back for your loyal genes that bring you hair color, and texture, not hair loss. That bring you eye color, not eye disease. Your genes brought you the good things about your ancestors, not the bad things. Parasites and pollution brought you the bad things.

Killing all your invaders is just the first step, though. It is indeed the life-saving step. But getting well is more than saving your life. Next comes the more tedious task of finding their sources. Where did they come from? Why did they invade you so massively. Why you?

The story of your personal pollution unfolds as in a book. Look closely and you see the whole panorama of your numerous tiny invaders being held at bay by your valiant immune system, your white blood cells. You can see what they are fighting besides the invaders. Your ill-chosen diet and lifestyle products!

Your heart may go out to those tiny white blood cells. Never again, you may say, will you give them arsenic and mercury and lead. Never again, cobalt and asbestos and freon.

That great body of wisdom, your body, the same as listened to your three wishes, will reward you over and over as you co-operate with it, until you have had not 3 but 30 wishes granted, each one seemingly as impossible as climbing Mt. Everest.

- Your chronic yeast infection can go away.
- Your hair can stop falling out–might even grow back.
- Your body can become pregnant–when you had already given up.
- Your fatigue can vanish.
- Your insomnia can be gone.
- Your warts can fall off.
- Your sight and hearing can sharpen.
- Your constant hunger can disappear.

Health isn't just being free of sickness. Health is feeling great, feeling like laughing at funny things. Health is feeling grateful to be alive. It is feeling happy to see the sky and to see growing things and to feel confident in human society's progress. Health is remembering the good parts of childhood and believing you still have a lot of them.

The Discovery

What makes me think I can find things in the human body that a blood test can not? What new technology makes this possible? Why is electronic testing superior in many ways to chemical methods? What are my claims of electrically killing parasites based on?

In 1988 I discovered a new way to scan a body organ. It was electronic. We already can "see" an organ with a sonogram, X-rays, computerized tomography (CAT) scan, or with magnetic resonance imagery (MRI). These techniques can identify abnormal shapes in an organ without having to explore or guess. But my new electronic technique can check for viruses, bacteria, fungi, parasites, solvents and toxins, and in addition is simple, cheap, fast and infallible. Electricity can do many magical things; now we can add detecting substances in our body to that list.

The method rests on radio electronic principles.

If you match, very precisely, the capacitance and inductance properties of an external circuit so that its resonant frequency is the same as the emitted frequency coming from somewhere else, the circuit will oscillate. This means there will be positive feedback in an amplifier circuit. You can hear it. Like when a public address system squeals.

The external circuit I use is called an *audio oscillator*, quite easy to build or buy. Your body provides the emitted frequencies. When you combine the audio oscillator circuit with your body, and you hear *resonance*, then you have detected a match! Something in your body matches something in the circuit on the test plate. By putting a laboratory sample of, say, a virus on the test plate, you can determine if your body has that virus by listening for resonance. Hearing resonance is easy if you're a radio

technician or musician. Others must patiently practice. The details are given in the Bioelectronics chapter (page 457).

You do not have to be an expert in anything to learn the electronic detection method. But a keen sense of hearing helps.

In 1988 I learned a way to put anything on my skin, blindfolded, and identify it electronically in a few minutes. I could taste something without flavor and identify it electronically. The system worked fine for detecting things in the skin and tongue. Would it be reliable for internal organs, too?

A whole world of discovery lay ahead of me. I wanted to know what was in my inner ear causing tinnitus, in my eyes causing pain, in my stomach causing indigestion and a thousand other things.

But behind the daily excitement of new discoveries, a gnawing question lingered in my mind. How is this possible without some pretty high frequency energy source, radio frequency in fact, running through my circuit? My audio oscillator was only 1000 Hz (*hertz*, or cycles per second); radio frequency is hundreds of thousands of Hz. And the phenomenon could be produced with an old-fashioned *dermatron*[1], too, that only puts out DC (direct current)–no frequencies at all!

A high frequency energy had to be coming from somewhere. Was it me? *Ridiculous*!

But there was a way to test. If my own body was putting forth the high frequency energy, it could be bled off and diverted into the ground with a correct size capacitor. This should stop the feedback oscillations. This turned out to be true; it was stopped. But *ridiculous* kept ringing in my ears and I tried an-

[1]The dermatron was invented decades ago and made famous by Dr. Voll. Establishment science disdained it!

other test. If there was indeed radio frequency (RF) running through my circuit I should be able to block it with the right snap-on choke. It did block. I thought of a third test. If this was truly a resonance phenomenon I should be able to add a capacitance to this circuit and see the resonance destroyed. Then add an inductance and see the resonance return. It did just that. I made graphs of the relationship between capacitance and inductance. They were entirely reproducible.

Then why couldn't I see the RF on my RF oscilloscope? Probably because it was high frequency energy, not high energy frequency, and I didn't know how to amplify it above the background noise level. It was nevertheless not convincing. Yet much too tantalizing to ignore.

I thought of yet a fourth test. If I was really producing RF radiation that could be channeled through a circuit, I should be able to interfere with it by adding another RF radiation from an outside source. I added a frequency from my frequency generator, first at 1,000 Hz. Now there was no resonance. It interfered. Did this mean that my body was not producing radiation at 1,000 Hz? Or was my 1,000 Hz radiation being matched and canceled? I raised the frequency gradually, from 1,000 to 10,000 to 100,000 to 1,000,000 Hz. There was no resonance anywhere, and I couldn't draw any conclusions. It was 5 o'clock on Sunday afternoon. Quitting time. But one last look at my generator reminded me that it could reach 2,000,000 Hz and I was just at 1,000,000. One more quick experiment wouldn't take much time. I cranked it to 1,800,000 Hz. And now a resonance screamed out! Was I “hearing things?” No more interference. I did it over and over. Why was it resonating now and not before? Had I arrived at my body's own *bandwidth* (transmission range), and this was the reason it no longer interfered?

I found the lowest frequency that resonated to be 1,562,000 Hz. All frequencies that I checked (about 2,000) from there up

to 2,000,000 (my frequency generator would go no higher) also resonated.

A year later I purchased a better frequency generator to search for the upper end of my bandwidth. Any frequency between 1,562,000 and 9,457,000 Hz could be added to the circuit and produce resonance.

It seemed obvious, then, that the human body broadcasts electrically, just like a radio station, but over a wide band of frequencies and very low voltages, which is why it has not been detected and measured until now.

Everything Has A Unique Frequency

It was a busy year, now 1989. I was determined to find a bandwidth for other living things: I found them for flies, beetles, spiders, fleas, ants. They were between 1,000,000 Hz and 1,500,000 Hz; cockroaches were highest amongst insects I tested.

Then came a dismaying finding. A dead insect had a bandwidth too! Much narrower, and near the top end of the same range it had when living, but distinctly present. So it wasn't altogether a living phenomenon.

But if dead things had a resonant bandwidth, then maybe a prepared microscope slide of a dead creature could be used, and my trips to the garden and telephone calls to abattoirs (for meat parasites) could cease. That was a lucky thought. My first slide was of the *human intestinal fluke*, a huge parasite, scourge of humanity. I had just found it to be present in the liver (not intestine) of every cancer sufferer I saw. The (dead) adult parasite

had a resonant frequency around 434,000 Hz. Slides of that parasite's redia resonated nearby (432,000 Hz), as did its other stages.

Dead things still resonated! The entire catalog of biological supply companies, hundreds of specimens of viruses, bacteria, parasites, molds, and even toxins, were now available to research with this new technique!

Suddenly an idea bolted out of the blue. If a person were to hold on to the frequency generator while it was generating 434,000 Hz, what would happen to the adult fluke, if you were infected with it?

I tested this plan that same week on myself, not with the fluke but with *Salmonella* bacteria and *Giardia* and *Herpes* that I carried chronically. After a 3 minute treatment, I retested myself. I could no longer find them in my organs! There were no emissions at their characteristic frequencies. I repeated and repeated. Were they really dead? Maybe they were just numbed or were suddenly hiding. But symptoms were gone quickly too. My *Herpes* lesion stopped tingling. It was all too simple and unbelievable.

But was it safe? Within three weeks I had reliable data regarding the necessary level of electrical treatment. It only took 5 volts for three minutes at the specific frequency. It is not as if you had to use house current which would kill you, along with the parasite.

Selective Electrocution

In twenty minutes (three minutes at six different frequencies) a whole family could get rid of this parasite. Cancer cases showed that in a few hours the universal cancer marker, *ortho-phospho-tyrosine* could be banished from their bodies by killing this same parasite.

"Incurable" HIV cases lost their virus in a few hours, too. Laboratory retesting for HIV came back negative! Most cases of pain got immediate relief if I could identify the correct "bug" and have its frequency found by the next office visit. This seemed to be absolute proof that living things had an essential high frequency output of some kind of energy.

What was actually happening to the bacteria or parasites? If I could kill something as large as an *Ascaris* worm or intestinal fluke, then perhaps I could kill something even larger, like an earthworm or flea, something I could see with my own eyes instead of having to imagine its demise inside my body.

Ten minutes at a frequency chosen near the top of their broadcast range seemed to anesthetize them. But they didn't die. Later I checked the body bandwidth (the range of frequencies they emit) of each. The earthworms had lost a lot of their bandwidth, both at the top and bottom. The fleas seemed hardier; they had only lost a little. However they did not recover, even weeks later, from this loss.

Could it harm humans to douse them with RF frequencies **in their own bandwidth?** Quite probably, if the voltage were high enough. There was no need to experiment, though, because the parasites we want to kill have characteristic frequencies that **do not overlap** the characteristic frequencies of a human. In fact, they are far away (see the chart on page 17).

So my electronic method attacking illness was born. Find the resonant frequency of a bacterium, virus or parasite using a slide or dead bit. Treat the living invaders inside the human body with this frequency and in a matter of minutes they are no longer transmitting their own bandwidths—they are dead or sick and will be removed by our white blood cells.

It was a worrisome truth. Perhaps the department of defense would use this knowledge and develop super high voltage devices to kill people ("enemies") somewhere in the world. But I couldn't let sick people suffer. Besides, it would probably re-

quire a voltage much like lightning to kill people from a distance. Possibly a way could be found to shield yourself from frequencies harmful to humans by wearing a choke (inductor) coil which suppresses these frequencies. Remember, there was no recovery, just a slow death for my experimental animals. It must not happen to humans!

Meanwhile, people must be alerted that they can safely kill their invaders and heal their chronic illnesses. Invaders that have been increasing exponentially due to lowered immunity in recent decades. Possibly this is true for all species on our planet. The pollution of the entire biosphere has been increasing and with it the prospect of acquired immune deficiency syndrome (AIDS) for all of us.

Remember, though, that the true challenge is not to kill our invaders but to regain our health and immunity.

More than just parasites are making us sick! Pollution is too. Selective electrocution rarely makes people completely well. Sick people always have an environmental factor that must be corrected also.

How do we do that? The ship of "progress", of increasingly complex, processed foods and products, must be turned around and simplicity become our goal. Survival is in simplicity of food intake, simplicity of life habits. Did Ralph Waldo Emerson foresee this when he said "To be simple is to be great"? Or will daily parasite and pathogen electrocution become another crutch that makes us just enough better that we can continue a detrimental lifestyle? Yet another "Band-Aid" treatment for our poisoned planet?

Bioradiation

Strange as it appears, it now seems obvious that every living creature broadcasts its presence like a radio station, the sun, or the stars. I have named it *bioradiation*.

Perhaps it is the same energy as the Asian *chi*; perhaps it is merely related to it. Perhaps it is the energy that runs along the meridians discovered eons ago by Asian practitioners.

Perhaps it is the energy that faith healers and religious teachers know how to harness, perhaps not.

Perhaps it is the energy that psychics perceive and that drives occult phenomena, perhaps not.

What is truly amazing is that ordinary persons have discovered such energy well ahead of scientists. Persons using the "art" of kinesiology, pendulums, radionics, dousing rods and many other forms of "strange energy" have no doubt harnessed a part of this bioradiation. It is a tribute to the generally high intelligence of common people and to their open-mindedness that they discovered this energy, **in spite of** opposition from scientists of today.

Over a century ago the scientists of Europe proposed the existence of a "life force" called "élan vitale." They were scorned out of existence (and out of jobs). Young scientists, (including myself) were systematically taught to scorn this idea. Of course we were also taught that a good scientist was unemotional, does not scorn ideas, has a completely open mind, and does not rule something out until it is disproved to their satisfaction. The youthfulness of college years is so susceptible to prejudices of all kinds, and the desire for acceptance is so great, that special effort needs to be made to teach neutrality. Or at least to distinguish between emotion and fact. Where have these basic pedagogic principles gone? I was indeed inspired with the phrase "search for truth" but then promptly led down the path of "search for acceptance."

I do not know what bioradiation, this electrical broadcast from our cells, is made of. Only its frequency was noticed and caught (modulated) in such a way as to be measurable. And this frequency, 1,520,000 to 9,460,000 Hz (for a human infant) is in the radio frequency (RF) range[2].

Anyone who is experienced with RF knows its strange behavior. Not strange in the "unknown" sense but in the amazing sense. Circuits don't need to be complete or closed for it to travel. Bodies and objects can "pick it up" without being in the circuit. These amazing properties are due to the capacitive and inductive properties of objects all around us, including ourselves.

Zapping Bugs

By *zapping* I mean selectively electrocuting pathogens. For years I used a commercial frequency generator to "zap" one pathogen after another.

First I made a chart of the frequencies for most of the bacteria and viruses in my collection (over 80, see page 561). Then I would test the sick client for each one of these, and hope they did not have one for which I didn't have a sample. Even persons with a simple cold typically had a dozen they tested positive to (not just *Adenovirus*).

Next it was time to tune in the frequency generator to a dozen frequencies for three minutes each. The total process, testing and treatment, would take about two hours. They frequently got immediate relief. But often the relief would be temporary. What I didn't know at that time was that viruses could

[2]AM radio broadcasts are from 540,000 Hz to 1,600,000 Hz (slight overlap with lower end of human band), FM is 88,000,000 to 108,000,000 Hz (out of the human range).

infect a larger parasite such as a roundworm. Until you killed your roundworm and your virus, you would keep getting the virus back promptly.

In 1993 my son, Geoffrey, joined me and we tried a new approach. He programmed a computer controlled frequency generator to automatically cover all the frequencies populated by all the parasites, viruses, and bacteria, from 290,000 Hz to 470,000 Hz. It spent about three minutes for every 1000 Hz it covered. This was more efficient, but it meant spending ten hours being zapped.

Again, the results were disappointing. Arthritis pain, eye pain, colds were improved, but not completely cured overnight. Months later I would find that organisms were transmitting as low as 170,000, and as high as 690,000 Hz. My specimen collection was obviously incomplete. To cover this larger range, spending three minutes for every 1000 Hz, would take 26 hours. Still worth doing if it would indeed help all our illnesses. But even this method of zapping was not 100% effective for reasons yet to become clear.

In 1994 my son built a hand held, battery operated, accurate frequency generator. The purpose was to enable everyone to kill the intestinal fluke at 434,000 Hz with a low cost device. Enough benefit would be derived from zapping at various frequencies that I thought everyone should know how to make one. When I tested it on one of my own bacteria, however, **three others at much different frequencies died also!** This had never happened before. When I tested it on others, even though they had dozens of pathogens, all were killed!

Subsequent testing showed it was not due to some unique design, or special wave form produced by the device. It was due to battery operation!

Any positively offset frequency kills all bacteria, viruses and parasites simultaneously

given sufficient voltage (5 to 10 volts), duration (seven minutes), and frequency (anything from 10 Hz to 500,000 Hz).

Before this I had always set my commercial frequency generator to alternate between positive and negative voltage. Now I tried setting it to alternate between positive and zero voltage (*positive offset*). It was just as effective as the battery operated frequency generator my son designed.

Generating positive offset frequencies is the best way to kill all pathogens quickly.

But it takes more than one treatment.

It takes three treatments to kill everything. Why? The first zapping kills viruses, bacteria and parasites. But a few minutes later, bacteria and viruses (different ones) often recur. I conclude they had been infecting the parasites, and killing the parasites released them. The second zapping kills the released viruses and bacteria, but soon a few viruses appear again. They must have been infecting some of the last bacteria. After a third zapping I never find any viruses, bacteria or parasites, even hours later.

Why didn't the virus inside the parasite die with the first zapping? It may be because electricity travels on the exterior of things. The body of the parasite shielded the interior. This is why my earlier, promising work spending hours on a frequency generator gave only partial or temporary improvement—it was

only done once, not three times. And it explains why a single treatment with a frequency generator or zapper frequently gives you a cold!

Zapping does not kill shielded organisms

such as those that may be in the middle of your stomach or intestines. The electricity travels along the stomach or intestine wall, not through their contents.

So zapping is still not perfect, but can bring such manifest relief that everyone should buy or make one. Parts cost less than $25.00; the plans are in the next chapter.

The Bioradiation Spectrum

Everything emits a characteristic range of frequencies (bandwidth). In general, the more primitive the organism, the lower its bandwidth. Advanced animals have higher frequencies and the range is wider.

BANDWIDTH OF BIORADIATION OF ANIMALS

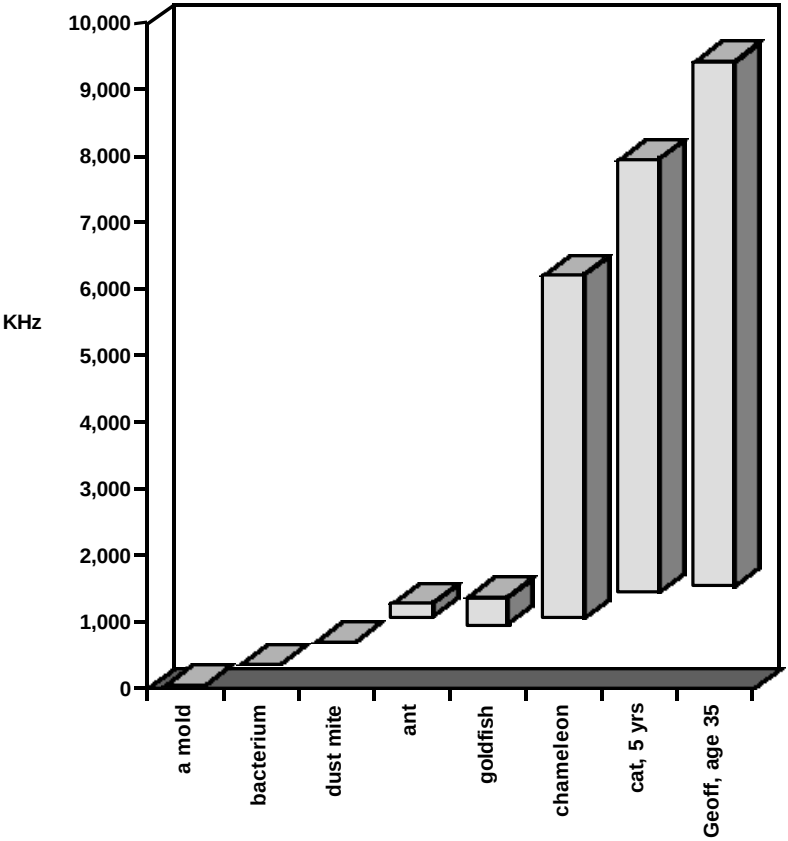

Fig. 1 Selected animal bandwidths.

The human range is from 1520 KHz to 9460 KHz. Pathogens (molds, viruses, bacteria, worms, mites) range from 77 KHz to 900 KHz. Fortunately for us we can work on zapping pathogens in the lower ranges without affecting humans in the upper range.

BIORADIATION OF TYPICAL PATHOGENS

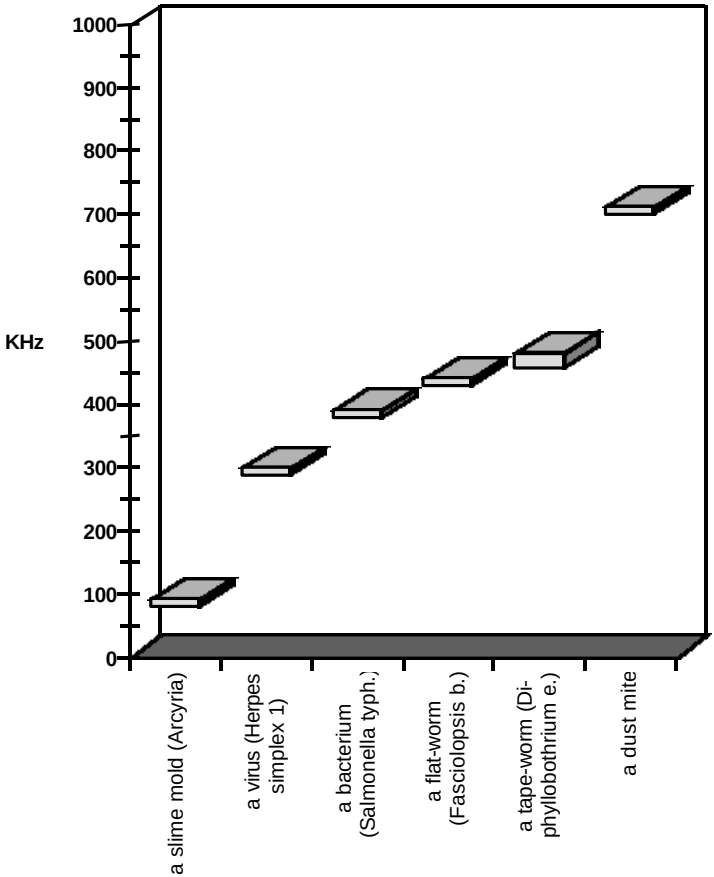

Fig. 2 Selected pathogen bandwidths.

Applying an alternating electrical voltage within an organism's bandwidth injures it. Small organisms with narrow bandwidths are extinguished quite readily (three minutes at five volts).

Positively offset frequencies can kill the entire range of small organisms (viruses, bacteria, parasites) in just seven minutes.

Building A Zapper

Being able to kill your bacteria and other invaders with electricity becomes much more of a panacea when you can do it all in three 7 minute sessions. No need to single out specific frequencies or to sweep through a range of frequencies one KHz at a time. No matter what frequency it is set at (within reason), it kills large and small invaders: flukes, roundworms, mites, bacteria, viruses and fungi. It kills them all at once, in 7 minutes, even at 5 volts.

How does it work? I suppose that a positive voltage applied anywhere on the body attracts negatively charged things such as bacteria. Perhaps the battery voltage tugs at them, pulling them out of their locations in the cell doorways (called *conductance channels*). But doorways can be negatively charged too. Does the voltage tug at them so they disgorge any bacteria stuck in them? How would the positive voltage act to kill a large parasite like a fluke? None of these questions can be answered yet.

Other fascinating possibilities are that the intermittent positive voltage interferes with electron flow in some key metabolic route, or straightens out the ATP molecule disallowing its breakdown. Such biological questions could be answered by studying the effects of positive frequencies on bacteria in a lab.

The most important question, of course, is whether there is a harmful effect on you. I have seen no effects on blood pressure, mental alertness, or body temperatures. It has never produced pain, although it has often stopped pain instantly. This does not prove its safety. Even knowing that the voltage comes from a small 9 volt battery does not prove safety, although it is reassuring. The clotting of red blood cells, platelet aggregation and functions that depend on surface charges on cells need to be investigated. But not before you can use it. Your safety lies in the short period of exposure that is necessary. Viruses and bacteria

disappear in 3 minutes; tapeworm stages, flukes, roundworms in 5; and mites in 7. One need not go beyond this time, although no bad effects have been seen at any length of treatment.

The first seven minute zapping is followed by an intermission, lasting 20 to 30 minutes. During this time, bacteria and viruses are released from the dying parasites and start to invade you instead.

The second seven minute session is intended to kill these newly released viruses and bacteria. If you omit it, you could catch a cold, sore throat or something else immediately. Again, viruses are released from the dying bacteria. The third session kills the last viruses released.

Do Not Zap If You Are Pregnant Or Wearing A Pacemaker.

These situations have not been explored yet. Don't do these experiments yourself. Children as young as 8 months have been zapped with no noticeable ill effects. For them, you should weigh the possible benefits against the unknown risks.

That is all there is to it. Almost all. The zapping current does not reach deep into the eyeball or testicle or bowel contents. It does not reach into your gallstones, or into your living cells where *Herpes* virus lies latent or *Candida* fungus extends its fingers. But by zapping 3 times a day for a week or more you can deplete these populations, too, often to zero.

Killing The Surviving Pathogens

The interior of gallstones may house parasites inaccessible to the zapping. Eliminate this source of reinfection by flushing them out with liver cleanses (page 552).

Although the center of the bowel contents is often unaffected by electric current, which lets bowel bacteria like *Shigella*, *Escherichia coli (E. coli)* and parasite stages survive, sometimes it is nearly all sterilized by zapping. This results in considerable shrinkage of the bowel movement. Eliminate remaining parasites and bacteria with a single dose (2 tsp.) of Black Walnut Hull Tincture, Extra Strength (see page 543).

There is no way of distinguishing between "good" and "bad" bacteria with either of these methods. However even good bacteria are bad if they come through the intestinal wall, so zapping targets mostly "bad" bacteria. The good news is that perfect bowel habits often result in a few days. Evidently, the good bacteria are benefited by killing the invasive ones. Home-made yogurt and buttermilk (see *Recipes*) are especially good at recolonizing the bowel. But it does not seem wise to culture yourself with special commercial preparations and risk getting parasite stages again when you can become normal so soon anyway. If you do decide to take some *acidophilus* bacteria to replenish your intestinal flora make sure you test for parasites like *Eurytrema* first.

When a large number of parasites, bacteria and viruses are killed, it can leave you fatigued. Try to give yourself a low-stress day after your initial zapping. But there are no significant side effects. I believe this is due to the second and third zapping which mops up bacteria and viruses that would otherwise be able to go on a feeding frenzy with so much dead prey available.

To build your zapper you may take this list of components to any electronics store (Radio Shack part numbers are given for convenience).

Zapper Parts List

Item	Radio Shack Catalog Number
large shoe box	
9 volt battery	

9 volt battery clips	270-325 (set of 5, you need 1)
On-Off toggle switch	275-624A micro mini toggle switch
1 KΩ resistor	271-1321 (set of 5, you need 2)
3.9 KΩ resistor	271-1123 (set of 2, you need 2)
low-current red LED	276-044 or 276-041 or 276-045
.0047 uF capacitor	272-130 (set of 2, you need 1)
.01 uF capacitor	272-1065 (set of 2, you need 1)
555 CMOS timer chip	276-1723 (set of 2, you need 1)
8 pin wire-wrapping socket for the chip	276-1988 (set of 2, you need 1) Note: Radio Shack is discontinuing all wire wrap sockets. Find another parts store or use 276-1995 (but the legs are much shorter and harder to attach clips to).
short (12") alligator clip leads	any electronics shop, get 6
Microclip test jumpers	278-017 (you need 2 packages of 2)
2 bolts, about 1/8" diameter, 2" long, with 4 nuts and 4 washers	hardware store
2 copper pipes, ¾diameter, 4" long	hardware store
sharp knife, pin, long-nose pliers	

Hints for absolute novices: Don't let unusual vocabulary deter you. A "lead" is just a piece of wire used to make connections. When you remove a component from its package, label it with a piece of tape. A serrated kitchen knife works best as does a large safety pin. Practice using the microclips. If the metal ends are L-shaped bend them into a U with the long-nose pliers so they grab better. Chips and chip holders are very fragile. It is wise to purchase an extra of each in case you break the connections.

R1 1K
R2 3.9K
R3 1K
R4 3.9K
C1 .01ì f
C2 .0047ì f
U3 MC1455
LED1 2 ma LED Red
Pin 1 ground
pin 8 power

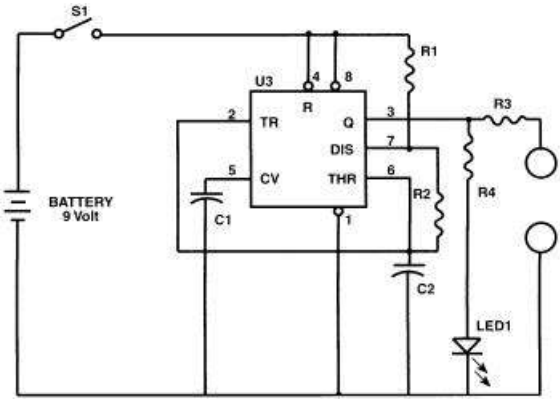

Give this to an electronics person or make it yourself in a shoebox by using the following instructions.

Fig. 3 Zapper schematic.

Assembling The Zapper

1. You will be using the lid of the shoe box to mount the components. Save the box to enclose the finished project.
2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole "grounding bolt" on the inside and outside.

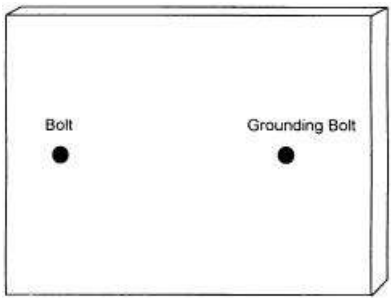

3. Mount the 555 chip in the wire wrap socket. Find the "top end" of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.
4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the "cookie bite" as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1.

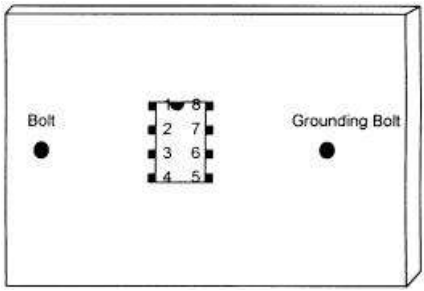

5. Pierce two holes ½ inch apart very near to pins 5, 6, 7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF ca-

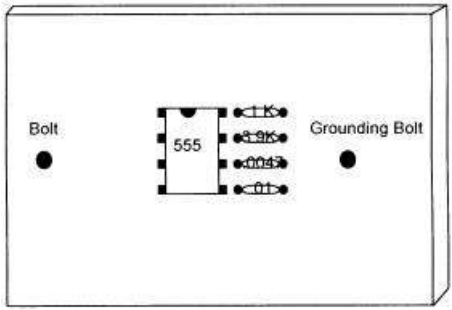

pacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 KΩ resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 KΩ resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 KΩ resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9KΩ resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

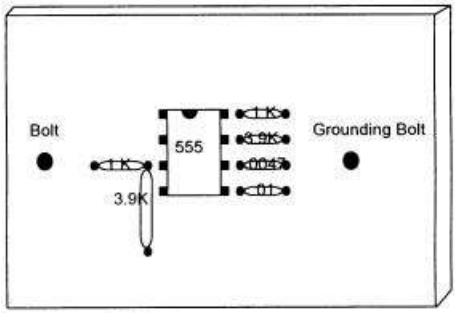

7. Next to the 3.9KΩ resistor pierce two holes ¼ inch apart for the LED. No-

tice that the LED has a positive and negative connection. The longer wire is the anode (positive). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

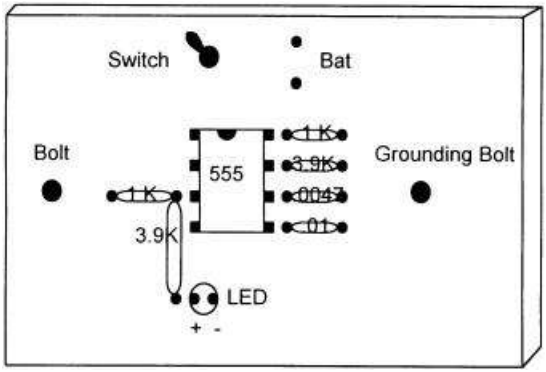

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.
9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Attach the battery and tape it to the outside.

NOW TO CONNECT EVERYTHING

First, make holes at the corners of the lid with a pencil. Slit each corner to the hole. They will accommodate extra loops of wire that you get from using the clip leads to make connections. After each connection gently tuck away the excess wire.

1. Twist the free ends of the two capacitors (.01 and .0047) together. Connect this to the grounding bolt using an alligator clip.
2. Bend the top ends of pin 2 and pin 6 (which already has a connection) inward towards each other in an L shape. Catch them both with an alligator clip and attach the other end of the alligator clip to the free end of the 3.9KΩ resistor by pin 7.

3. Using an alligator clip connect pin 7 to the free end of the 1KΩ resistor attached to pin 8.
4. Using two microclips connect pin 8 to one end of the switch, and pin 4 to the same end of the switch. (Put one hook inside the hole and the other hook around the whole connection. Check to make sure they are securely connected.)
5. Use an alligator clip to connect the free end of the other 1KΩ resistor (by pin 3) to the bolt.
6. Twist the free end of the 3.9KΩ resistor around the plus end of the LED. Connect the minus end of the LED to the grounding bolt using an alligator clip.

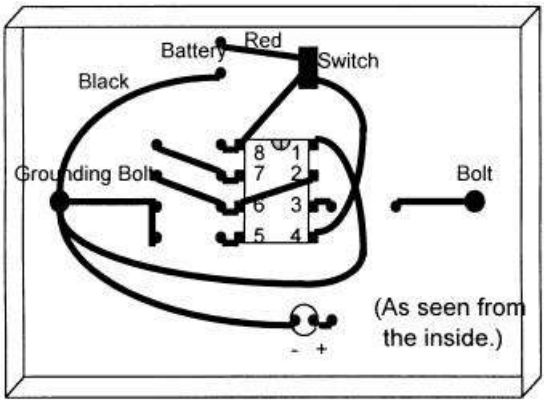

7. Connect pin number 1 on the chip to the grounding bolt with an alligator clip.
8. Attach an alligator clip to the outside of one of the bolts. Attach the other end to a handhold (copper pipe). Do the same for the other bolt and handhold.
9. Connect the minus end of the battery (black wire) to the grounding bolt with an alligator clip.
10. Connect the plus end of the battery (red wire) to the free end of the switch using a microclip lead. If the LED lights up you know the switch is ON. If it does not, flip the switch and see if the LED lights. Label the switch clearly. If you cannot get the LED to light in either switch position, you must double-check all of your connections, and make sure you have a fresh battery.

11. Finally replace the lid on the box, loosely, and slip a couple of rubber bands around the box to keep it securely shut.

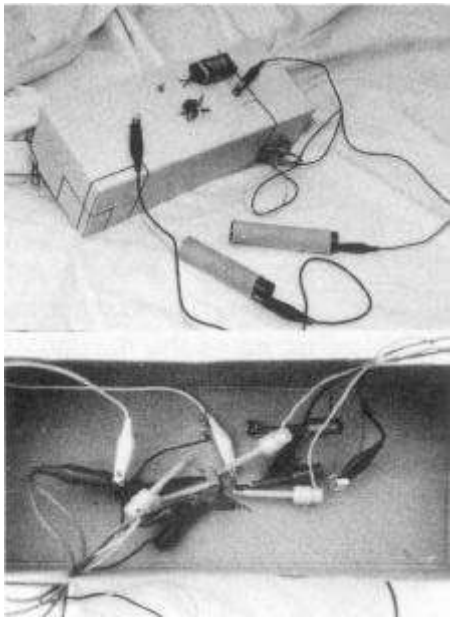

Fig. 4 Finished zapper, outside and inside.

- Optional: measure the frequency of your zapper by connecting an oscilloscope or frequency counter to the handholds. Any electronics shop can do this. It should read between 20 and 40 kHz.
- Optional: measure the voltage output by connecting it to an oscilloscope. It should be about 8 to 9 volts. **Note: a voltage meter will only read 4 to 5 volts.**
- Optional: measure the current that flows through you when you are getting zapped. You will need a 1 KΩ resistor and oscilloscope. Connect the grounding bolt on the zapper to one end of the resistor. Connect the other end of the resistor to a handhold. (Adding this resistor to the circuit decreases the current slightly, but not significantly.)

The other handhold is attached to the other bolt. Connect the scope ground wire to one end of the resistor. Connect the scope probe to the other end of the resistor. Turn the zapper ON and grasp the handholds. Read the voltage on the scope. It will read about 3.5 volts. Calculate current by dividing voltage by resistance. 3.5 volts divided by 1 KΩ is 3.5 ma (milliamperes).

Using The Zapper

1. Wrap handholds in one layer of wet paper towel before using. Grasp securely and turn the switch on to zap.
2. Zap for 7 minutes, let go of the handholds, turn off the zapper, and rest for 20 minutes. Then 7 minutes on, 20 minutes rest, and a final 7 minutes on.

Trying the zapper on an illness to see "if it works" is not useful. Your symptoms may be due to a non-parasite. Or you may reinfect within hours of zapping. The best way to test your device is to find a few invaders that you currently have (see Lesson Twelve, page 492, or Lesson Twenty Seven, page 509). This gives you a starting point. Then zap yourself. After the triple zapping, none of these invaders should be present.

Simple Pulser

If you are ill or want a reliable zapping, make the first model. However, there is another way to make a zapper if you can not afford to build the first model.

An ordinary battery is a source of positive voltage. It is the positive voltage that eliminates so many parasites at once, not a specific frequency. So although the zapper's frequency is about 30 kHz (thirty thousand "zaps" per second), even 5 Hz (five

"zaps" per second), **about as fast as you can tap the battery with your hand, is moderately effective!**

You must be connected to both terminals. One will be marked + (positive) and the other – (negative). If you simply touch these terminals with your wet fingers, nothing much happens. That is because your resistance to the current starts going up right away, so less and less current passes through you.

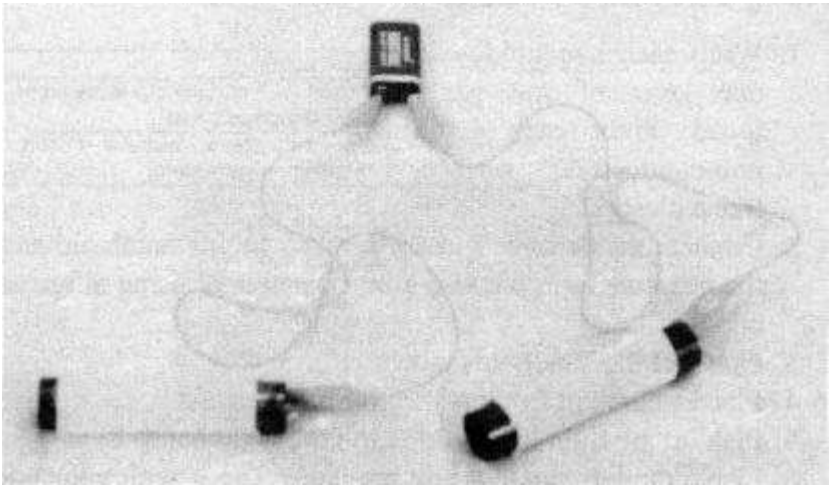

Fig. 5 Simple pulser.

However if you tap the positive terminal with your wet hand, and tap it at a fairly high rate, your body's capacitors come into play. Capacitors only take part in the flow of electricity when they are charged and discharged. Tapping the terminal starts and stops the voltage so capacitors charge and discharge. This kind of resistance to current flow is much smaller.

The faster you tap, the greater the frequency of current pulses and the lower this kind of resistance becomes. Now you can have a considerable sustained current flow through your body.

If you can tap even twice per second (2 Hz) for ten minutes without interruption you can give yourself a zapping that is moderately effective. Remember to take an intermission of twenty minutes and then repeat to avoid catching new viruses. After a second twenty minute intermission repeat zapping a third time.

Using The Simple Pulser

9 volt battery
2 short (12") alligator clip leads (from any electronics shop)
2 copper pipes, ¾" diameter, 4" long (from a hardware store)

1. Wrap each handhold with one layer of wet paper towel. Place each on a non-conductive surface, like a plastic bag.
2. Connect the positive battery terminal to one handhold and the negative terminal to the other handhold using alligator clip leads.
3. Don't let the handholds touch.
4. Place a clock in front of you to time yourself.
5. Pick up the right handhold with your right hand.
6. Leave the left handhold on the table. Tap it with your left hand, preferably the fleshy part of the palm. You may brace yourself with your fingers on the plastic. Keep up a steady pace as fast as you are able.
7. When you get tired pick up the left handhold with your left hand and tap with your right hand. Keep changing off with the least interruption.
8. Repeat a second time 20 minutes later, and a third time 20 minutes after that.

A single 9 volt battery will wear out rather quickly used this way. Put two together, in parallel, for longer lasting power. This requires two more short alligator clips. Connect positive terminals of the batteries to each other, and the negatives also.

Parasites & Pollution

The word “parasites” is used in two senses. Everything living on you or in you, not just to perch, but to take its food from you is a *parasite*. No matter what its size, it can be called a parasite.

But in some way the big worms need to be distinguished from the medium-sized amoebae, the even smaller bacteria and the smallest of all—viruses. So often the term parasite is reserved for the bigger things, from amoebae on up. In this book, the word parasite will be used in both ways as usual. You can easily guess what is meant.

Parasitic worms are divided into *roundworms* and *flatworms*. Roundworms are round like earthworms even though they may be as thin as hairs (threadworms, *filaria*) or microscopically small (like *Trichinella*). Flatworms are more like leeches. They have a way to attach themselves sometimes with the head (*scolex*) like *tapeworms*, sometimes with a special sucker like *flukes*.

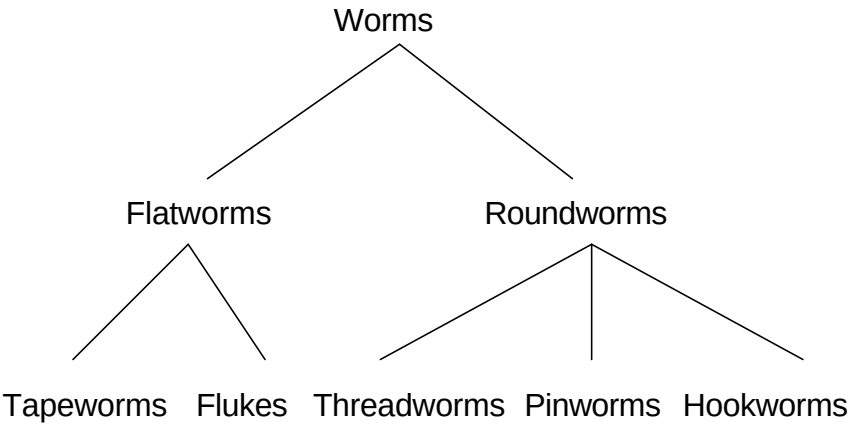

Worm parasites go through stages of development that can look very, very different from the adult.

Roundworms like *Ascaris* (common cat and dog roundworm), are simplest. The **eggs** are swallowed by licking or eating a bit of filth. They hatch into a tiny *larva*. The larva treks to the lungs. You cough it up and swallow it. Meanwhile it has molted a few times. It then crawls to the intestine where it becomes an adult, shedding eggs in your stool.

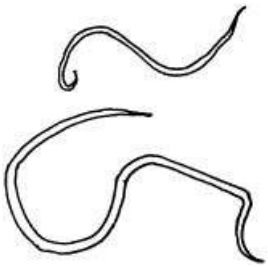

Fig. 6 Ascaris.

Worms usually have preferred locations. The favorite organ for *Dirofilaria* (dog heartworm) is the heart (even human heart). Sometimes the rules can be broken. My tests show *Dirofilaria* can live in other organs, too, if they are sufficiently polluted with solvents, metals and other toxins.

Flatworms like **tapeworms** are much more complicated in their life history. You could eat the eggs accidentally with dirt. After hatching, the tiny larva burrows into its favorite organ. Your body encases it with a cyst. The white blood cells have been taught never to attack your body...and the cyst case is your body! So the tapeworm stage has safe residence for some time. If you are a meat eater, you could eat such a cyst if it happens to be lodged in the meat you are eating! Your teeth break it apart as you crunch. The little larva is swallowed and tries to attach itself to your intestine with its head. Then it grows longer by making segment after segment. The segments with their eggs leave with the bowel contents. I often see dog tapeworm of the small variety in their human family.

Flatworms like **flukes** are also very complicated. The eggs, passed out with bowel contents were not meant to be eaten as such. They were meant to hatch in a pond where snails and minnows eat them. The larva grows up in these new

"secondary" hosts. Later, the snail sheds them and they attach themselves to foliage near the pond. They over-winter in a tough *metacercarial* cyst. An unsuspecting browsing animal now eats them. They come out of their metacercarial cyst as a small adult and quickly attach themselves to the intestine with a sucker. They now have "safe haven" and can go about maturing and laying eggs.

Four common flukes are: **human intestinal fluke, human liver fluke, sheep liver fluke, pancreatic fluke of cattle.** Don't let the terms sheep and cattle mislead you. They are all found in humans.

Fig. 7 (L to R) Human intestinal fluke, pancreatic fluke, sheep liver fluke, and human liver fluke.

The Worst Parasite

Fasciolopsis buskii is the fluke (flatworm) that I find in every case of cancer, HIV infection, Alzheimer's, Crohn's disease, Kaposi's, endometriosis, and in many people without these diseases. Its life cycle involves six different stages:

Stage	Normal Life Cycle	
1 Egg	Expelled with bowel movement onto soil. Washed by rain into ponds.	
2 Miracidia	Hatches from egg in water. Has cilia, can swim vigorously and must find intermediate snail host in one to two hours or may be too exhausted to invade.	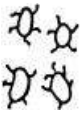
3 Redia	Develop inside miracidia as little balls until expelled. Those are "mother" redia, and each one bears "daughter" redia for up to 8 months, all still inside the snail, and living on the fluids in the lymphatic spaces. Similarly, daughter redia are continually developing cercaria.	
4 Cercaria	Have a tail, use it to exit from snail and swim to a plant. If the snail is feeding on a plant, cercaria can latch onto plant with sucker mouth and start to encyst (form a "cocoon") within minutes. Tail breaks off and swims away to dissolve.	
5 Metacercaria	Two-walled cyst. The outer wall is very sticky. But as you eat the plant it is stuck to, the least pressure will break it, leaving the cyst in the mouth. The "almost unbreakable" inner cyst wall protects it from chewing, and the keratin-like coat prevents digestion by stomach juices. However when it reaches the duodenum, contact with intestinal juices dissolves away the cyst-wall and frees it. It then fastens itself to the intestinal lining and begins to develop into an adult.	

6 Adult	Lives in your intestine and can produce 1000 eggs per bowel movement and live many years.	

Fig. 8 Fasciolopsis' normal life cycle.

Note that the adult is the only stage that "normally" lives in the human (and then only in the intestine). *Fasciolopsis* depends on a snail, called a *secondary host*, for part of its life cycle. **But when your body has solvents in it, the other five stages can develop in you!**

If **propyl alcohol** is the solvent, the intestinal fluke is invited to use another organ as a secondary host—this organ will become cancerous. If **benzene** is the solvent, the intestinal fluke uses the thymus for its secondary host, setting the stage for AIDS. **Wood alcohol** invites pancreatic flukes to use the pancreas as a secondary host. This leads to pancreatic dysfunction which we call *diabetes*. If **xylene** (or **toluene**) are the solvents, I typically see any of four flukes using the brain as a secondary host. If **methyl ethyl ketone** (MEK) or **methyl butyl ketone** (MBK) are the solvents, the uterus becomes a secondary host and endometriosis a likely result.

This is a new kind of parasitism, based on pollution. I call the diseases caused by fluke stages in inappropriate locations **Fluke Disease**; it is discussed in more detail later (page 249).

Are tapeworms and roundworms affected by solvents this way, too? This is a fascinating and very important question. Search for the answer and help others search for the answer. I do not know yet.

Pollution

Pollutants are all the dead things around us that should not get into your body because they interfere with its work. As long as they don't penetrate your tissues, they won't interfere, like plastic eyeglasses and clothing. But if they are invasive, your body must fight to remove them.

Pollutants can invade your body via the air you breath, the foods and beverages you eat, and the products you put on your skin.

The biggest tragedy is not recognizing when a pollutant is harming you.

Two people can use the same face cream. One develops a rash, the other does not. The one who did not assumes the cream is not harmful to them…that they are like a bank vault, impregnable to that product. A better assumption is that the face cream is somewhat toxic, as evidenced by the rash that can develop, and they escaped the rash only because they had a stronger immune system. The immune system is like money, paid out of the bank vault, for every toxic invasion. When the money is gone, the bank (your health) fails.

Solvent Pollution

Solvents are compounds that dissolve things. Water is a useful, life giving solvent. Most other solvents dissolve fats and are life threatening, because fats form the membrane wall around each of our cells, especially our nerve cells.

The solvent that does the most harm is **benzene**. It goes to the thymus, ruins our immune system, and causes AIDS. The next worst solvent is **propyl alcohol**. It goes to the liver and

causes cancer in some distant organ. Other major culprits of disease are **xylene, toluene, wood alcohol, methylene chloride,** and **trichloroethane** (TCE). I'll discuss each one later, with the ailment it's associated with.

Metal Pollution

Biochemists know that a mineral in raw element form always inhibits the enzyme using that mineral. Copper from the meat and vegetables you eat is essential. Inorganic copper, like you would get from a copper bottomed kettle or copper plumbing, is carcinogenic[3]. Unfortunately, the inorganic form of metals is what pervades our environment. We put metal jewelry on our skin, eat bread baked in metal pans, and drink water from metal plumbing.

Another obvious metallic threat is tooth fillings. **Mercury amalgam fillings**, despite the assurances of the American Dental Association, are not safe. And sometimes the mercury is polluted with **thallium**, even more toxic than mercury! **Gold** and **silver** seem to have fewer harmful effects, but no one should have any pure metal in or on their body.

Other prevalent toxic metals include **lead** and **cadmium** from soldered and galvanized plumbing, **nickel** and **chromium** from dentalware and cosmetics, and **aluminum** from food and drink cans, and cooking pots.

[3]Haleem J. Issaq, The Role of Metals in Tumor Development and inhibition. From *Carcinogenicity and Metal Ions*, volume 10, page 61, of a series called *Metal Ions in Biological Systems*, edited by Helmut Sigel, 1980.

Mycotoxins

Molds produce some of the most toxic substances known, called *mycotoxins*. One small moldy fruit or vegetable can pollute a huge batch of juice, jam or other product. Although molds are alive, and can be killed by zapping, mycotoxins are not, and must be detoxified by your liver.

But because mycotoxins are so extremely poisonous, a tiny amount can incapacitate a part of the liver for days!

Aflatoxin is the most common mycotoxin I detect. It is produced by molds that grow on quite a variety of plants. For that reason I am always cautioning people to eat only perfect citrus fruit, and never drink commercial fruit juice. Of the thousands of oranges that go into the batch of orange juice you drink, one is sure to be moldy, and that is all it takes to give your liver a setback.

A heavy dose of vitamin C helps the liver recover quickly. It also helps get rid of aflatoxin before it is consumed, right in the food container. So keep a plastic shaker of vitamin C powder handy and use it like salt on all your food.

There are thirteen other mycotoxins I have searched for in our foods. They are described in the section on moldy food (page 381).

Physical Toxins

Breathing in dust is quite bad for you so your body rejects it by sneezing, coughing, spitting up and out. Imagine breathing in broken glass particles. They cut into the lungs in a thousand places and couldn't be coughed up. They would travel. Imagine swallowing a needle or open pin. If the tip was blunt it could move through the intestine. But because it is sharp it gets caught in your tissue, then works its way deeper and deeper.

Would we ever knowingly breathe in broken glass? We are justifiably afraid of it in our food or under our bare feet. We are unaware that it fills our homes when **fiberglass** insulation is left imperfectly sealed off. Any hole made through the ceiling or wall, even if covered with cloth, lets swarms of broken glass bits into the house air. Air currents flow inward, into your living space. So all holes leading to the attic or insulated spaces must be sealed airtight. Of course, fiberglass should never be used in home construction, draperies, or around water heaters. The best advice is to have it all removed while you are away and then vacuum and dust.

Occasional exposures by house builders working outdoors does much less harm. Chronic exposure from a single small hole in the ceiling does a lot of harm, leading to cyst formation. And that cyst is a perfect place for parasites and bacteria to settle and multiply. When the intestinal fluke settles there it becomes malignant!

Cancer patients with *solid tumors* have either fiberglass or asbestos in them.

Asbestos is another tiny bit, sharp as glass, that moves through your body like a swordfish, impaling your cells until it, too, gets routed into a cyst.

We have been led to believe that we no longer have asbestos in our homes because we have outlawed the fireproofing materials it was used in. While that may be true, the source I find most often is all too prevalent: the clothes dryer belt. As it gets hot the belt releases a blast of asbestos particles that are forced through the seams of your dryer, and also openings in your exhaust hose, by the high pressure formed inside. It is now in <u>your</u> air.

Chemical Toxins

Chlorofluorocarbons (**CFCs**) or **freon** is the refrigerant in your air conditioner and refrigerator coils. CFCs are suspected of causing the ozone hole above the South Pole. All cancer sufferers test positive for CFCs in their cancerous organ! I have preliminary evidence that it is CFCs that attract other pollutants–fiberglass, metals, PCBs–to form a growing tumor instead of allowing their excretion. This would make it a "super carcinogen.". How could you detect CFCs leaking in your home? By the time your air conditioner or refrigerator needs recharging, you have been exposed for a long time. We desperately need an inexpensive, in-home test for this unsuspected killer.

Arsenic is used in pesticide. Why would we poison ourselves along with the cockroaches? Is it because we can't see it happening? Just as we couldn't see the fiberglass floating in the air? Our diligent scientists have studied the mechanism of arsenic poisoning in great detail. Then why are we allowed to put it on our lawns to be carried into our carpets via shoes?

Polychlorinated biphenyls (PCBs), oily compounds with wonderfully useful electrical properties, were originally used in transformers until their inability to break down into less toxic substances in our environment was spotlighted. Banned from use, I find them in most commercial soap and detergents! Is transformer oil being disposed of by selling it to soap makers?

Formaldehyde is used to cure foam. As a result, foam furniture, pillows and mattresses give off formaldehyde for about two years after manufacturing. If you sleep with your nose buried in a new foam pillow all night, you are risking major lung problems.

Every cleanser in your house probably has a toxic warning on its label. Every fluid your automobile uses is toxic. Every pesticide, herbicide and fertilizer you put on your lawn is probably toxic. Every paint, varnish, wax, lubricant, bleach and

detergent will send you to the hospital if even a small amount is ingested. Why do we keep them around? See *Recipes* (page 513) for safe, old-fashioned, alternatives.

If you are ill even after zapping, it is toxins still at work. Getting rid of them is a major step toward being well.

I DON'T THINK WE SHOULD LET HUMANS INTO THE HOUSE. WE'LL GET ALL THEIR PARASITES.
YEAH, I JUST CAN'T GET RID OF THIS MANGE.

How We Really Get Sick

What if you invented a device that could search people for the presence of mycotoxins (extremely toxic substances made by food molds)? And what if you found that although many people had them, those who were sick with a cold always had at least one of them. Would you ask whether a sudden buildup of mycotoxins is what really lets colds develop? Why do some people in the same family get the cold while others do not?

- What if you found everyone with **cancer** had the human intestinal fluke in their liver, and no one else did?
- What if you found everyone with **diabetes** had the pancreatic fluke of cattle in their pancreas, and few others did?
- What if you found everyone with **environmental illness** tested positive for Fasciola (sheep liver fluke) in their liver?
- What if you found everyone with **asthma** tested positive for Ascaris in their lungs?

What if you always found every mysteriously ill person had some unsuspected parasite or pollutant?

The device is the Syncrometer™, and these "what ifs" are all true. They forced me to alter my entire outlook on what really causes some of our "incurable", mysterious diseases.

We used to believe that diabetes was caused by over consumption of sugars, a cold by a virus you caught from some-

body, cancer from carcinogen exposure, depression from poor parenting. This multicausal concept is what made the study of medicine so difficult that only a few could undertake it. And every year new syndromes are added to the list of human illnesses.

But these diagnoses are based on a description of what is happening at a particular place in your body. This is like calling a mosquito bite behind the ears by one name and a mosquito bite behind the knee by another name. If you never see the true cause, a mosquito at work, this system could be excused as somewhat sensible.

And, until now, the profession of medicine has made some sense. The new truths, however, make the old descriptive system obsolete. You can now find the true causes of all your illnesses. And you can find them yourself by building the electronic diagnostic circuit (page 457)!

Once you have seen a mosquito at work on your body you no longer need to go to the doctor for a red, itchy bump. You don't need to search for the correct diagnosis and an appropriate drug. **You put up screen doors and windows!**

Once you have seen how common house dust is implicated in the common cold you get rid of the house dust. Once you have seen the mold in your food facilitate the cold virus you throw out that moldy food. But only seeing is believing. Nothing is left to faith. The electronic resonance method described in this book will let you see all these things for yourself.

You are not a hapless pawn attacked by bacteria and viruses that dart at you from nowhere to make you ill. You are not at the mercy of diseases all around you, hoping, by chance, to escape, like a soldier hoping to come home from the war. Nature and your body make good sense.

There is no disease that can outwit you if you know enough about it. Not even Lou Gehrig's disease! Nor asthma or diabetes. Read how the people in the case histories made themselves

well. Read why some people failed. You have an advantage they did not have. Their instructions were hard to carry out because they had to have faith in them. You don't. You can replace faith with your own hard headed observations by building the diagnostic circuit (Syncrometer). The great convincer is seeing it yourself. When you personally find the mold in your peanut butter, or *Shigella* in your cheese, you have the knowledge, not faith, that convinces and guides you.

All illness comes from two causes, PARASITES and POLLUTANTS.

Only two causes! This is what simplifies the picture to make it possible for you to cure yourself.

We have been taught that illness is largely our own fault. That it is due to "catching something", not eating what we should, like roughage or vitamins, or not doing what we should, like dressing properly, exercising or going to bed on time. Somehow, it's our own fault. Either by doing something we shouldn't or not doing something we should. When absolutely no fault can be found we are told it's in our genes! True inherited diseases are extremely rare. Our genes have evolved over millions of years to produce healthy humans. Nor are genes that mutate during your lifetime at fault. Pollutants, which are known to be mutagens, are the real culprits.

Neither the parasites nor the pollutants in you are "your fault". Notice that other people all around us are doing the same things or not doing the same things, and even share our genes and don't have our illness. The current concepts on disease causation blaming our actions and our genes are simply not logical.

But until now they appeared logical. Suppose 1000 people were bitten by a mosquito or flea, it would always be in a dif-

ferent place, and if you were using the location and effect system to diagnose the problem you could have a thousand diagnoses listed for them, including a defective gene. Could you be persuaded to accept a gene replacement for your red itchy bumps? The new gene might be for antihistamine production so the welts don't become large, red and hot, or lead to impetigo. If you were the research doctor, you might be tempted to alleviate a thousand persons' distress with a new gene. Fortunately, you are not and only need to solve your own problems. You can be more logical.

After you have found the parasite interlopers hiding in your body you can kill them electronically. And after you have identified the pollutants stuck in your organs you can stop eating them, breathing them or putting them on yourself. In response, your body will begin to heal, just as surely as a mosquito bite heals.

Heal from multiple sclerosis, emphysema, myasthenia? Yes!! Some healing will be swift. Some healing will be slow. Healing is not understood. It is much faster in young persons. But fast or slow you know it has begun. It will be an exciting adventure to watch yourself lose your symptoms and get stronger.

Self Health

The entire purpose of this book is to enable you to diagnose and treat yourself for any disease. You have three new approaches that make this wish a reality: the understanding that only pollution and parasites make you sick, the quick and inexpensive diagnostic circuit that lets you find which pollutants and parasites they are, and the zapper or herbal recipe that kills the parasites.

Wouldn't it be nice not to have to go to the doctor for your aches and pains? And not to be dependent on the doctor to diagnose and treat you?

Self health means keeping yourself healthy. Doing it **yourself**.

Suppose your doctor has already diagnosed you as having "Atypical Lateral Sclerosis" or "Shoulder-Hip Girdle Metastable Aplasia." Could you re-diagnose this for yourself so as to treat and cure it? And be successful? Why not? You have already succeeded in many enterprises. You learned to talk, walk, read, get along with people. These skills took a few years to master. Learning to keep well is a new skill. It may take a few years too. After you have learned these skills you may pass them on to your children. And so a new gift is given to humanity, like the gift of music or the art of cooking.

How To Heal

Your body has been trying to rid itself of its parasites and pollutants all your life! It had its own ways. It made stones, it made mucus secretions, it made itself toxic dumpsites. These were good tactics but now of course, they are no longer necessary. Can you help your body get rid of these accumulations and sweep itself clean again?

Sweeping your liver clean is the most powerful way of helping your body to heal itself after the parasites are gone. There are thousands of bits of "trash" accumulated in the liver bile ducts. They will turn into stones (gallstones) if left in place.

The kidney, too, has made numerous small stones in its effort to keep your body clear of lead, cadmium, mercury and

other impassable pollutants. You can assist the kidney to expel all these.

In days, not weeks or months, you can feel the healing effects of clearing gallstones and kidney stones from your body. But there are miles of bile ducts (50,000 ducts) in the liver; the herbal recipes that do this are used over and over, patiently, until all, the "trash" is removed. This can take several years.

So, although you can stop your disease very quickly from progressing, the healing process may not be complete for years.

Nevertheless, you are healthy again. This means your pains are either gone or greatly reduced. Your organs are functioning better. You have a new sense of well being. Your energy is up. Your desire to live and accomplish something is back.

Organs that have been damaged beyond the ability of our simple methods to reverse can be treated with the magic of modern surgery. Cataracts, bunions, old injuries are examples. Possibly, these too, are "stone" formations. But no recipe has been found to clear them up simply and in a useful time frame.

Killing parasites, removing pollutants and clearing gallstones and kidney stones from your body is a powerful combination of treatments. It is so powerful you can change yourself into a new person in half a year. And then go on improving for years more.

Should you stop taking your prescription medicine while you are treating yourself? NO. Wait until you have cured yourself of the condition that required the medicine. Reduce your medicine and eventually go off it. Will your doctor approve? Find one that will. Remember that the medicine is buying you the time to cure yourself, something to be grateful for.

The Road To Wellness

To review our new understanding of health vs. disease:

- We have only two problems: parasites and pollutants. Parasites are things that live on us, using up our food and giving us their wastes. Pollutants are toxic things in us making it difficult for our organs to do their work. These two things are responsible for all our other problems.
- Our bodies have been trying to rid us of these by making stones, making secretions, giving us swellings, inflammations and benign tumors. We develop deficiencies and disabilities.
- Finally, some permanent damage is done. Our hair turns gray, we develop cataracts, the spine bends, nerves and muscles die. We weaken.

Our strategy to undo all this will be a logical one.

First, we will kill all parasites, bacteria, viruses and fungi.

Second, we will remove the toxic molds, metals and chemicals in our foods and body products.

Third, we will clear away and wash away the stones, secretions and debris already formed, that hinder healing.

Fourth, we will use herbs and special food factors to hasten healing, being very careful to use pure products. (These act more quickly when given intravenously but the emphasis in this book will be on oral consumption.)

Finally, for repairs that are beyond our abilities, we will seek help from health and medical professionals.

What could be more exciting than finding the tremor is out of your arm or the pain is out of your shoulder? Won't it be admirable to correct your pulse and your high blood pressure, by yourself? What an adventure it could be to get rid of all your warts.

But getting rid of pain seems like a first priority to me, since pain often undermines our morale, our initiative to do things, even our interest in getting well!

Many of our illnesses are caused by unsuspected sources. I have found pigeon tapeworm in humans, for instance.

Fig. 9 Feed animals out of your yard and away from where children play. Their wastes contain pathogens.

Pain From Toe To Head

I would rather die than endure excruciating, unrelievable pain. That puts **pain** at the very top of my priority list.

Fortunately for us, pain killers are at hand to get us through it and buy us the time it takes to solve the real problem behind it.

The pain killing industry also brought us the addiction industry. As we turn to electrical pain killing the need for addicting drugs should decline. There are other very useful pain killers: acupuncture, massage, listening to music, feedback devices, contemplation, hypnotism, and prayer.

But we will focus on getting rid of the cause of pain and healing the organs that are in pain so none of these methods are needed.

I am not talking about the pain of a broken bone, twisted ankle, bee sting or sunburn. I am not talking about the pain of a misaligned vertebra or stretch trauma in your leg muscles or arm muscles. I am referring to pain that is in one of your organs and refuses to go away. For example, arthritis. Other pains are headache, foot pain, elbow pain, hip pain, chest pain. All of these may have special names like rheumatoid arthritis, cluster headache, fibromyalgia, bursitis, tennis elbow and so on, but they are all the same phenomenon.

Knowing that parasites and pollutants are the real culprits, let us get right down to the job of finding out which they are, where they come from, and how to get rid of them.

The parasites that cause pain are not the large ones, like worms or amoebas. Nor are they the very tiny viruses. They are *bacteria*. Bacteria are the right size to get into the doorways of our cells. Our cells try to keep their doorways tight-shut but, of course, they have to open to let food in, or hormones, or other life-signals. If bacteria are swarming around the outside of cells,

some will manage to slip into a doorway while it is open. A battle begins. The cells refuse to let the bacteria in. The bacteria refuse to let go of the door latch. There is probably a specific electrical attraction between them and an exact physical fit. The body's extra forces, the immune system, are called in to help quell the invasion. The bacteria multiply as fast as they can. There is swelling. There is heat produced. There is pressure against other organs. All together it is called inflammation and infection.

The answer is not to deinflame with drugs (like the cortisone variety). The answer is not to reduce swelling or body temperature. **The answer is certainly not pain killer.** The answer is to kill the bacteria. (Even this is not the ultimate answer. We must stop the source of the bacteria and your body's invitation to be invaded. We will get to this later.)

So **Step One** is to search for the bacteria nibbling at our painful regions and identify them. This gives us the clue to finding their source. **Step Two** is to exterminate them electrically. Within minutes they fall out of the doorways to our cells. Your white blood cells are waiting for them, and will gobble them up in a grand feast.

But, remember, there is another cause of pain, pollutants. **Step Three** is to find the pollutants and identify them because this gives us a clue as to their source. **Step Four** is to eliminate our pollution sources. **And the job is done. Pain is gone.**

An intriguing question will pop into your head as you search your organs for parasites and pollutants. Which came first? Pollutants can jam their way into your cell's doorways too. Does this allow the bacteria to swim in? Or do the bacteria come first, jamming open the doorways so the pollutants can enter? Both seem possible. Maybe both events go on simultaneously. Perhaps that is why bacteria and pollutants are always seen together. Viruses can land on your cell's doorways, too, and cause viral diseases, but they are not as often pain producing.

You will also notice something, as you keep testing and watching over your health. **Your body is very good at killing bacteria and viruses**. Your body kills them faster than a wave of a magic wand! The only ones that get away are those that are stuck in doorways and ‘channels with pollutants in them! This seems like evidence that pollutants do the gate-opening. But it isn't proof and we must keep all possibilities in mind.

Fortunately we do not have to know exactly how parasites and pollution make us sick in order to get well.

Searching For Bacteria

In order to find which organs have the bacteria and which bacteria are present you will need to learn the new technology that makes all of this possible. This technology is a simple electronic circuit that is capable of trapping frequencies in such a way that you can hear them. Your body's frequencies, the frequencies of bacteria, viruses and parasites are all different and can be heard as distinctly as a **mooo**, **baah**, **tweet**, or **oink** coming from a farm yard.

But do you have to do all that?

No! You don't. You could simply electrocute all these tiny invaders. But how would you know what to avoid in the future? If your pain returned how would you know if it was the same old bacteria or a new one?

Learning to test takes the guesswork out of diagnosis.

My hope is that you will find it all so intriguing, so absolutely fascinating, that in spite of some chronic pain, you will feel compelled to make the searches yourself. Find someone willing to help. Trade your information. It is less difficult than learning to use a computer.

What You Will Find

First we will study and cure pains of all kinds, starting with the toes and working our way up the body. We don't need to be very specific about the location of the pain since bacteria and toxins flow over to nearby locations anyway.

For each kind of pain, we will look into the causes so you can eliminate them. Pain could come back in an hour if you didn't know the bacteria were coming from cheese and you had a cheese sandwich after *zapping* (killing parasites electrically). In fact, the pain may not have had time to go away before the next onslaught begins and you might conclude, wrongly, that this method doesn't work.

Parasites might also come back to your specially painful place from a few far away places that are hard to reach by your zapper's electrical current. The inside of your eyeball, the testicle, the interior of gallstones, the middle of a tooth abscess or the bowel contents are such places. Your zapper current, because it is high frequency, prefers to “go around” these items, rather than through them. But with repeated zapping, and herbal parasite treatment, you can decimate them, too, and stop reinfecting the rest of your body.

In fact, it is such knowledge about reinfection and sources of our pollutants that is the most important contribution of the case histories.

After dealing with pains we will turn our attention to the diseases that aren't pain producing, like diabetes, myasthenia gravis and so on.

Toe Pain

The ends of your feet get the poorest "service" from your blood supply. They are the furthest away. The blood here has the most accumulated acid and the least oxygen supply. The body produces quite a bit of *uric acid* and this should, of course, be excreted into the bladder by the kidneys. But if the kidneys are doing a poor job of this, levels in the body and blood stream rise. The blood can only hold so much. It holds even less in acid conditions such as the ends of your feet experience. Uric acid begins to settle out or precipitate at our feet.

Hippuric acid, too, is found where pain is found. Hippuric acid is made in large amounts (about 1 gram/day) by the liver because it is a detoxification product. It makes no sense to consume *benzoic acid*, the common preservative, since this is what the body detoxifies into hippuric acid. Read all labels on food you buy. Don't buy any beverages or baked goods preserved with benzoic acid. *Citric acid* is fine. The joints of the big toes are favorite places for pain to develop. This is made even worse when circulation is poor. Take a *cayenne* capsule with each meal to improve circulation. If you cannot find your pulse just below your inner ankle your circulation is poor.

The accumulation of uric and hippuric acid invites bacteria to feed on them. As bacteria multiply the tissue fights back with

inflammation. Now the stage has been set for **pain**. Some people do not have pain although these acids and other deposits are present making their joints knobby and unbending. Bacteria have not found them yet or haven't multiplied sufficiently in them to invade your tissues. Perhaps there are other reasons as well.

If you have **toe pain** your course of action is this:

1. Kill all bacteria possible with your zapper. Repeat daily until no further benefit is seen.
2. Dissolve the deposits away. An herbal recipe, quite elaborate, is capable of doing this. It is called the Kidney Cleanse (page 549). Toe deposits are made of the same crystals as kidney stones, which is why the Kidney Cleanse works for toe pain. But because these deposits are far away from the kidney, it takes longer than merely cleaning up kidneys. It may take six months to make a significant dent on these deposits. This will at the same time remove kidney crystals so that these are no longer a source of bacteria.
3. Get teeth cavitations cleaned (cavitations are bone infections in the jaw where a tooth was pulled; it never healed; see Dental Cleanup page 409). This can "magically" stop the toe pain the same day as they are cleaned. The effect lasts for days afterward showing it is not the dental anesthetic that is responsible. It also teaches you that the bacteria in the toes can come from the teeth. But pain may return as other bacteria find the deposits.
4. Clean the liver of stones using the Liver Cleanse (page 552). This, too, can give immediate pain relief in the toes showing you they are a source for bacteria. Liver cleaning may take you two years to complete! Meanwhile your toe pain is receding. And, of course, this pays extra dividends in health for your body.

5. Reduce the acidity in your toes. First, check your acidity with pH paper meant for testing urinary pH, called Nitrazine™ paper. Ordinary pH paper, as for fish tanks, is almost as accurate and will serve as well. Tear a ½inch piece and hold it in the urine stream. Early morning is the time your urine is most acid. If this reads below 5.5 your feet must have been even lower in the night (lower is more acid).

Once deposits start, it is hard to stop them. If they start forming at 2 a.m., they are likely to continue for several hours even if the pH goes back up to normal. Your tactic will be to go to bed with an alkalizing action. Taking a calcium and magnesium supplement at bedtime, drinking milk at bedtime, using baking soda at bedtime are all remedies to be tried. They should raise your urinary pH to 6 in the morning.

Balance Your pH

Most persons with painful deposits anywhere in their feet have a morning urine pH of 4.5! At 4.5 it is safe to guess that a lot has precipitated again in the night. During the day, your body's pH swings back and forth. The urine gets quite alkaline right after a meal; this is called the *alkaline tide*. Three meals a day would bring you three alkaline tides. During these periods, lasting about an hour, you have an opportunity to dissolve some of your foot deposits. But if you allow your pH to drop too low in the night you put the deposits back again. The net effect decides whether your deposits grow or shrink.

To alkalinize yourself at bedtime, choose one of these options:

1. Two oyster shell tablets, equaling 750 mg. of calcium plus a magnesium oxide tablet, 300 mg (see *Sources*). The magnesium helps the calcium dissolve and stay in solu-

tion. Taking more calcium at one time is not advised because it cannot be dissolved and absorbed anyway and might constipate you. For the elderly only one calcium tablet is advised. Take calcium tablets with vitamin C or lemon water to help dissolve (¼ tsp. vitamin C powder; adding honey is fine).

2. One cup of sterilized milk or buttermilk, drunk hot or cold, plus 1 magnesium oxide tablet, 300 mg. (adding cinnamon is fine).

   If these two remedies work for you, your morning urinary pH will come up to 6.0 but if for some reason they don't, you need to take more drastic measures. Take the supplements and milk earlier in the day and reserve bedtime for:

3. ½tsp. baking soda in water. This is *sodium bicarbonate*. But don't use baking soda from a store because most brands I have tested are polluted with benzene! (See *Sources* for safe baking soda.) Using a combination of sodium and potassium bicarbonate in a ratio of 2:1 is actually a much more healthful potion. You can make your own or ask a pharmacist to make it for you. Mix two parts baking soda and one part potassium bicarbonate (see *Sources*) in a jar. Keep tightly closed. Label it **sodium potassium bicarbonate alkalizer** (this potion is also very useful in allergic reactions of all kinds). Take 1 level tsp. in water at bedtime. If your pH reaches 6 in the morning continue each night at this dose. If it does not, take 1½tsp. Keep watching your pH, since it will gradually normalize and you will require less and less. If you are using plain baking soda, instead of the mixture, watch your pH each morning, also, so you can cut back when the pH goes higher than 6.

Persons with a limit on their daily sodium intake must carefully count the grams of baking soda consumed in this way.

Each tsp. weighs about 2 grams, of which half (1 gram or 1000 milligrams is sodium. The sodium/potassium mixture would only give you half as much sodium (½gram per tsp.). By comparison, the usual daily intake of sodium is about 5 gm., although salt eaters consume twice that amount.

You have done five things to pull the rug out from under the bacteria living in and around the deposits in your toes. Now when you kill bacteria with your zapper, you can expect the pain to go away and stay away.

Locations at the base of toes may be painful due to a *neuroma*. Deposits and bacteria here are even more painful because this is the location of nerve centers. If the build-up is large, you may prefer some surgical help or a cortisone shot rather than wait several years for solid relief.

Foot Pain

This kind of pain does not involve as much deposits as toe pain and is therefore easier to clear up. But trauma to the foot is more important. First, even though your shoes are comfortable, change them. Get wider shoes, longer shoes, lower heels. Alternate two pairs of shoes in a single day. In your home take shoes off.

Keep feet very warm. Wear natural fiber socks, not synthetics. If your circulation is poor, take a *cayenne* capsule with each meal. When circulation is moderately poor, your feet get cold easily. When circulation is very poor, the heart pulse cannot be felt in your feet (take your pulse just below your inner ankle). Again:

- Get teeth cavitations cleaned (Dental Cleanup, page 409).
- Do the herbal Kidney Cleanse (page 549).
- Kill parasites and bacteria with a zapper.

- Then clean the liver (page 552).
- Check body pH in the morning upon rising using Nitrazine™ or other pH paper. Correct it as discussed in Toe Pain. If the urinary pH is 7 or higher, it means you have a bladder infection. Treat it immediately (page 101).

If there is any swelling around the foot or ankle, you are "holding water." It may be called *edema*. This is due to poor adrenal and kidney function. The adrenals are located on top of the kidneys and together they regulate how much salt and water stays in your body. Because they are situated so close together, they share their parasites and pollution. When the kidneys form *kidney crystals* the flow through the kidney tubes is hindered, and less water and salt can leave the body. It stays in your tissues as edema.

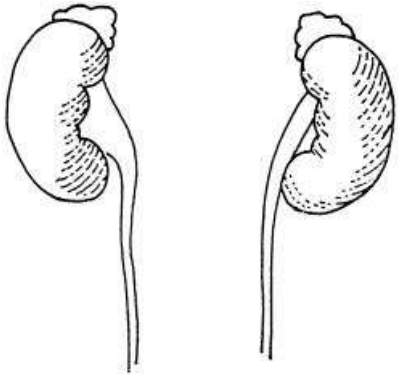

Fig. 10 Your kidneys with the adrenal glands sitting like hats on top. The ureters lead to the bladder.

The kidney herb recipe will dissolve the crystals. But you must remove toxins such as metal from tooth fillings and kill parasites. Continue doing the Kidney Cleanse after the original six weeks is up until all foot pain and edema are gone. Continue killing your tiny invaders with a zapper twice a week. You may need to cleanse the liver several times, too, before all the pain and edema are gone.

The supplement, *pantothenic acid* (see *Sources*), is particularly good for feet. Take 500 mg three times a day for several

weeks to see if it helps. Massage and reflexology are also good for them.

Heel Pain

Sometimes heel pain is due to heel spurs, sometimes it is not. Heel spurs are due to deposits. The usual heel deposits are *uric acid* and various *phosphates*. Uric acid deposits become a breeding ground for bacteria. The phosphates give the deposits a rigid structure that is hard to dissolve. You may have to choose a pain killer, get specially built "orthopedic" shoes, or stop your daily walks to get relief from the piercing pains. These will not cure the problem but may "buy you some time" while you make basic changes in your lifestyle.

Stop drinking tea and cocoa because they contain *oxalic acid*. Stop drinking coffee, decafs, fruit juice and soda pop because they are contaminated with solvents. All of these must be detoxified by your body and eliminated by your kidneys. We should spare the kidneys these extra tasks when we wish them to clean up heel spur deposits. You must first dissolve the deposits, then help the kidneys eliminate them.

To dissolve them, you alkalinize your body's pH, watching over it carefully with pH paper or Nitrazine paper. To help kidneys eliminate them, use the Kidney Cleanse and drink lots of water. Only water, not a beverage, helps the kidneys to eliminate.

> Drink a pint of water upon rising in the morning, and a pint of water between meals.

Do not buy "special" water. Use your cold tap water only. If you don't like the taste of your own tap water, get it from some-

body else's tap. Use only glass or reused polyethylene jugs. Polyethylene is opaque, not clear. It has already lost its plasticizer into the water that stood in it earlier. (Somebody drank it!) Purchased water has traces of solvents from machinery and sterilizing equipment used in its bottling. Your own tap water is not pure (indeed it may have 500 toxic elements), but it never contains solvents in amounts I can detect.

Traces of solvents are worse than traces of other toxins.

Water filters are not the solution. They trap the pollutants and then allow a tiny amount to enter the water on a daily basis. Chronic toxin consumption is much worse for your health than periodic surges of toxins. You can use a small filter, that gets changed every month without much risk. This would dechlorinate the water, at least, and improve the flavor. The pitcher variety (it should be made of hard, inflexible plastic) and the faucet variety are listed in *Sources*.

Bottled water is popular,

and tasty, and has appealing advertising, but it is just not safe.

Why is it easier for everyone to spend dollars per day, for the rest of their life, buying water instead of insisting that their water pipes are metal-free?

Another reason not to drink water from bottles, however convenient, is that it is stagnant and is soon contaminated with our own bacteria from contact with mouth or hands. *Staphylococcus (Staph)* and *E. coli* are commonly seen. The solution is not to add still more chemical disinfectants, the solution is to drink from a flowing source, such as our faucets. If you must carry water, use glass containers; plastic is porous and much

more difficult to wash clean (sterilizing in a dishwasher is effective, though).

By drinking a total of four pints of water in a day, the kidneys will notice the assistance. (Any single herb tea without added salt or sweetener counts as water.) The urine will stop having any odor and will become very light colored. This is especially important while you are dissolving the heel deposits since your body is now carrying these in the circulation.

Killing bacteria with a zapper may give you instant pain relief and is, of course, beneficial to your body. But you can't expect the pain to stay away until the deposits are gone and the source of bacteria is also removed. Go after the usual sources: teeth and stones. Another source is dairy food contaminated with *Salmonella* and *Shigella* bacteria. Sterilize all of it by boiling. Even the amount put on cereal in the morning or used in scrambled eggs is enough to reinfect you! Butter and heavy whipping cream also need boiling. Stop eating yogurt and cheese which can't be boiled.

Phosphate deposits are a mixture of three phosphates: *monocalcium phosphate* ($CaH_2\ PO_4$), *dicalcium phosphate* ($Ca_2H\ PO_4$) and *tricalcium phosphate* ($Ca_3\ PO_4$). They are formed by eating too much (way too much) phosphate relative to calcium.

Our high phosphate foods are meats, carbonated beverages and grain products like rice, cereals, breads, pastas and nuts.

The body's normal elimination tactic for phosphate is to combine it with calcium and magnesium in order to neutralize it first. Unneutralized phosphate is very acidic and would burn the delicate kidneys. But where shall the calcium and magnesium be taken from? Magnesium is often in very short supply since it comes from green vegetables in the diet and is not stored up in any special organ. So it falls on calcium to be used for this purpose since it is stored up (in your bones and teeth).

The acid condition created by phosphates dissolves your bones and allows large amounts of bone structure to be washed out with the urine: this can be directly seen with an analysis of urine (you can ask your doctor to order this at a lab). If you catch all the urine in a 24 hour period you can measure all the calcium you have wasted. You should not lose more than 150 mg calcium in a day because this is all you can absorb in a day![4] If you do lose more than 150 mg in a day, you are dissolving your bones at a fast clip. This also means there is too much calcium in your blood and lymph, from dissolving so much bone so quickly.

Once you have dissolved your bones it is not so easy to put the calcium back into them. Your body will try to put it back as soon as possible—as soon as your acid condition is gone. But your bones can't do this without *vitamin D*. Vitamin D may "come from" sunshine and from vitamin D in milk but it isn't that simple. Vitamin D must be activated by your kidneys before it can go to work! Remember, though, it was the kidneys that had a problem in the first place, allowing deposits to form! With old kidneys, clogged with crystals, hampered by heavy metal and mold toxins, and beleaguered by bacteria and parasites, is it any wonder that sunshine and vitamin D fortified milk don't supply large amounts of activated vitamin D? It takes large amounts to put back into your bones the large amount of calcium that dissolved out during the acid state you put yourself in by over consuming phosphate food.

If you can't put the calcium back into your bones promptly where is it to go? It may attach itself to tissues that were never meant to be used this way. Your arteries fill with "scale," your

[4]You absorb 5 to 10% of what you eat. If you eat 1 gram (1000 mg) you absorb 50 to 100 mg. But you absorb 25-40% if it comes from milk!

kidneys form calcium phosphate crystals, heels form spurs, joints become knobby with deposits.

Young persons and children, with healthy unclogged kidneys, make–that is, activate–ample vitamin D, so even if they consume too much phosphate and develop an acid condition that dissolves their teeth and bones, **they can put the dissolved calcium back in its proper place.** They don't develop hardened arteries, heel spurs, and knobby joints, at least not at first. Their bodies can take a considerable amount of abuse without showing it.

In general, people eat way too much phosphate. Meat eaters eat too much meat. Vegetarians eat too much grain. Most everyone drinks phosphated beverages. In this way we set the stage for hardened arteries, joint disease, calcified tissues that no longer have flexibility. We all get kidney crystals that become stones. This is *aging*. All these deposits invite bacteria to live in them and on them, creating pain.

Old age and pain go together as if they were true partners. Yet it is just the result of bad food choices.

Try to undo as much of this false aging as possible.

1. Reduce your meat consumption. Switch to fish which supplies calcium in the tiny bones. It is true, these bones are made of calcium phosphate and one might expect, logically, to be getting a less effective calcium source. Logic isn't necessarily biologically correct. The bones of fish work nicely as a calcium source and their phosphate content is not too great. Such a diet has worked for many primitive societies. Further, I have never seen a case of mercury toxicity from eating fish; amalgam tooth fillings are our truly significant source.

2. Reduce your grain consumption. Instead of cereal for breakfast, add fruit and reduce the cereal to half. Cut bread consumption in half. Cut pasta consumption in half. Cut rice and corn consumption in half. Eat more bananas and other fruits. Eat more vegetables; always choose potato (not potato chips) instead of rice or macaroni. Always choose a leafy salad instead of pasta salad. At any restaurant or salad bar ask yourself: is this wheat, rice or corn? If so, choose potatoes or other vegetables. Choose coleslaw. Choose mixed fruit. You don't need to go off the grains, only reduce them to improve your condition.
3. Take vitamin D as a supplement. Nothing less than 40,000 units has any real impact by the time there are problems. This strength is available by prescription only (usually 50,000 units, which is close enough). To avoid getting a polluted product, ask your pharmacist to follow the recipe on page 560. (In the past some cases of poisoning by overdosing resulted in this regulation. If you overdose you will get joint and muscle pain and nausea but it is reversible.) Take one a day (not more), for the first three weeks, then two a week forever after.
4. Finally, toss the carbonated beverages right out of your diet or make your own (see *Recipes*). It is not the carbonation that is harmful, it is the added phosphate. Drink water, herb teas, homemade fruit and vegetable juices, milk or buttermilk.

Milk, like fish, is full of calcium in the form of calcium phosphate. Again, logic might speak against the effectiveness of this form of calcium. Again, logic is wrong. Evidently, the calcium and phosphate story must be much more complex than I am depicting here.

Milk works best as a calcium source, in spite of its phosphate content. Possibly the *lactose* and other complexities of its

composition contribute to this. My recommendation when deposits have formed anywhere in the body, such as heel, toe, arteries, joints, is to switch to milk as a beverage. Compare the calcium level of your urine before and after the switch (allowing several weeks first). Also compare calcium levels in your blood serum. It should move towards normal. This means **up** if it is too low (below 9.2). It means **down** if it is too high (10). If you are monitoring the effectiveness of the kidney herb recipe in dissolving away your phosphate crystals, notice that drinking milk keeps them from reforming. Taking calcium tablets does not! Taking nothing lets them reform the quickest.

The milk must be 2% or higher in butter fat to be effective.

With your body fluids at their proper acid level, with your kidneys able to flush out acids, with heavy metal toxins no longer settling in, with your bone-dissolving stopped, your heel deposits can shrink. Bacteria have no place to feed and breed. You can kill them several times more with your zapper to catch stragglers. And your heel pain becomes history. Be careful not to bruise the sensitive tissue with too much walking or running immediately after the pain is gone. Wear cushioning socks and well cushioned shoes.

Names in the case histories have been changed to ones of the same sex, picked at random from a telephone directory. Other facts may have been altered in non-essential ways.

Walter Jones, a man of 67, was diabetic for 14 years. His feet and upper legs hurt so much for the past 13 years he could barely shuffle along now. They were also cold and clammy. The herb, juniper berry was added to the Kidney Cleanse recipe to make it even more effective for him and he was advised to stop smoking, using alcohol, and caffeine. He also started the parasite killing program (at that time an herbal parasite program was being used

instead of a zapper) and a liver cleanse that yielded several hundred small gallstones. Three months from his first visit his legs were better and feet OK, although he still had some trouble walking due to pain in upper thighs.

Dinah Sagun, a minister's wife, had a lot of walking and standing to do besides traveling a lot. She had knee surgery 15 years ago to remove deposits but now they were getting bad again. Also her heels were sore. My tests showed she had phosphate and oxalate deposits in her kidneys. She was started on the Kidney Cleanse followed by the parasite program. She stopped using benzene polluted items, especially her Chap Stick™. Her diet was changed to include milk and leave out store-bought beverages. In 4½ months her heel pain was gone along with the bad headaches we had not even started to work on.

Julie Fernandez came with a list of 10 serious problems including foot pain and ankle swelling. Her urinalysis showed crystals. My test showed they were uric acid crystals. Her parasites included *Trichinella*. There was a house cat. Her toxic metal test showed tellurium and platinum accumulation from metal dentalware and arsenic from pesticide. She was to start on a Kidney Cleanse and add the parasite program two weeks later. She was to remove all roach hives and other pest killers from her house and arrange for dental metal replacement. At her third visit, four weeks later, she could walk without pain although she still had *Trichinella* and arsenic problems. Two months later she was aching all over again and her kidneys hurt. She still had *Trichinella* and some dental work to do. She was to do a 5-day high dose parasite treatment and treat the cat also and repeat the kidney cleanse. This relieved her pain.

Dorothy Shelley had numerous pains including foot pain in the arch, lower back pain and cramps with her period. She had oxalate and uric acid crystals in the kidneys so was started on kidney herbs. Three weeks later her foot pain and low back pain were gone.

Paul Longtin had toe cramps, calf cramps, and heel pain. After cutting down on smoking, quitting caffeine and soda pop and taking niacin (250 mg time release; 1 capsule each meal and upon rising in morning) and doing a kidney cleanse, all in three weeks, he was much improved and didn't even need his arch supports.

Juan Onley, age 58, came for his gout in both feet and one hand. He could hardly walk, in spite of soft shoes and pain killer. It started 7 years ago. He also had prostate pain and couldn't sit comfortably. My tests showed his kidneys were full of uric acid, oxalate and cystine stones. His prostate was full of *Gardnerella* and *Campylobacter* bacteria. His wisdom teeth were harboring *plantar wart #4 virus* and *Coxsackie B4* virus. *Gardnerella* often comes with fluke parasites and indeed he had intestinal flukes in his kidney! He began with the kidney herb program, then the parasite killing program. It took five months to clear them all. Then he could walk and sit without pain.

Leg Pain In Children

It is commonly accepted as normal(!) in children to have pain in the shins or calves of the leg. They may even be called "growing pains." Children may cry with the pain and never tell anyone the reason for crying. It happens mostly after napping. This may be caused by cramping of the leg or spasms of the blood vessels. *Lead toxicity* is a common cause of both. Test for the presence of both **lead** and **cadmium** in the tap water. Only your own electronic tests are helpful. Water department tests are much too crude.

Fig. 11 All disposable diapers I tested had mercury and thallium! These toxins can be absorbed through babies' skin.

If either poison is

found, test the water supply from each faucet in the house, in the morning, before it has been run. Find the offending sources, change the water pipes to polyvinyl chloride (PVC).

Also search for thallium or mercury in the child's saliva. If it is there, remove all dental metal. Stop using all commercial disposable diapers, dental floss, cotton swabs and bandages; they are polluted with mercury and thallium probably from manufacturing them in foreign countries where it is legal to sterilize with mercuric chloride. Test again, several times, after plumbing or dental work has been completed. To relieve pain:

- immerse legs in warm water
- massage legs gently
- give 25-50 mg niacin, not time-release, to dilate blood vessels.

Leg Pain In Adults

Leg pain in adults is usually associated with *cadmium* or *thallium*. Cadmium is present in tap water that runs through corroded galvanized pipes. The cadmium is probably a contaminant of the zinc used for galvanizing. Test the water, electronically, for cadmium. If you have all copper pipes but there is cadmium in the water, there must be a short piece (a **Y** or a **T** joint) made of old galvanized pipe lurking somewhere. Track it down by testing water from all your faucets.

Cadmium causes the blood vessels to spasm and it is made worse by smoking, that's why the condition is sometimes called **Smoker's Leg**. But extremely painful legs are due to chronic thallium poisoning more than any other cause!

It is very important to know exactly how toxic thallium is. Read the clipping on page 417 right now!

Where would you ever get thallium? From your very own mouth! The mercury in fillings is often itself polluted with thallium! Replace your amalgam fillings with composite.

Bandages

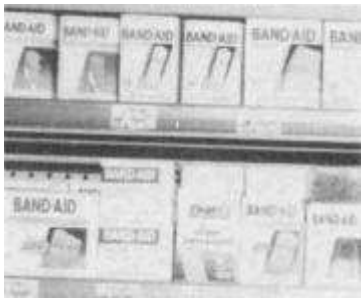

Sanitary napkins and tampons

Cotton swabs

Cotton balls

Floss

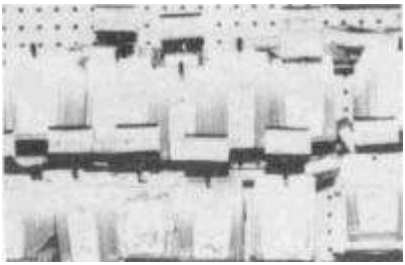

Toothpicks (the one on the right is ten years old and had no mercury or thallium)

Fig. 12 Do not use any commercial personal products, the risk of pollution is too great.

Thallium has another source: it is riding along as a pollutant in cotton swabs, cotton balls, commercial bandages, toothpicks, floss, gauze, sanitary napkins, tampons, disposable diapers, and paper towels. Evidently these are being sterilized with mercuric chloride which, in turn, has thallium pollution.

- Line **disposable diapers** with a tissue
- Line **sanitary napkins** and pads with a tissue
- Use the **polyester puff** in the top of vitamin bottles in place of cotton balls. Twirl some around a plastic stirrer for a swab.
- Use pieces of **tissue and masking tape** for bandages.

Use cheesecloth in place of gauze.

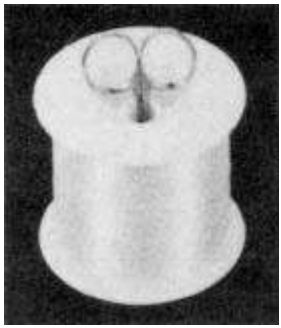

Use monofilament fish line (2 or 4 lb. test) for floss

Fig. 13 Safe substitutes for personal products.

If you do have thallium in your white blood cells and you haven't used toothpicks, etc. earlier in the day, then it is in your tooth fillings and **you have no higher priority than getting the**

amalgams out. Find a dentist immediately who will remove them, drilling deeply and widely not to miss a speck of it, thereby getting the thallium out, too. You cannot cure your leg pains without removing thallium.

Leg Pain Protocol

1. Stop smoking.
2. Repair plumbing.
3. Do dental cleanup and chelate out the mercury and thallium that has gotten into your tissues with EDTA (see *Sources*). You will need to find a chelating doctor; ask a friendly chiropractor to help you locate one. Or at least take thioctic acid 100 mg, (2 three times a day) and vitamin C (5 gm or one teaspoon) daily for a month.
4. Take magnesium oxide 300 mg (take 1 twice a day).
5. Take niacin, as much as you tolerate—time release varieties are less effective. Try 50 mg with each meal.
6. Change your diet to reduce phosphate and include milk (sterilized).
7. Do the herbal Kidney Cleanse (page 549) followed by a Liver Cleanse (page 552).
8. Zap yourself on alternate days at bedtime. If this zapping makes no difference whatever, your problem is purely spasms. But if you get relief, even if it's very short lived, you must have killed something. Bacteria must come from somewhere. Concentrate your efforts on dental health and better diet.

Jean Booth, age 30, had sore, tired legs and severe three-day headaches. She would get stabbing pains in back of her thighs. After we found thallium and mercury in her kidneys she did a Kidney Cleanse and got all her metal tooth fillings replaced. She then felt fine for one year. Suddenly she got fatigue and heavy legs again with stabbing pain at the outer thigh. She had seen a neurologist. Her chiropractor suggested it was leftover mercury so she came

back to us. Indeed, she was toxic with lead, mercury, thallium, but her dentist could not find the leftover metal in her mouth. Three cavitations were cleaned; she was put on thioctic acid; eight varieties of bacteria and viruses were killed with a frequency generator and her legs became well again. Our test showed thallium at 4 teeth, but it was not a big enough deposit to show up on dental X-ray. She may eventually choose to have these redrilled.

Charlie Snelling was a picture of pain: pain in arms, elbows, shoulders, wrist, hands, chest, low back, legs, knees, and feet. He was started on kidney herbs and a few pains were reduced. He was toxic with cadmium so he changed his plumbing to plastic. However, he continued to be toxic with cadmium and thallium throwing suspicion on his numerous old tooth fillings. He got them all replaced and cavitations cleaned. He used our frequency generator to kill *beta Streptococcus*, *Pseudomonas*, *Troglodytella* and *Staphylococcus aureus* all of which were under one tooth (#15). A year later he still had bouts of leg pain. He still had numerous bacteria under his teeth because the jaw bone was not healing. He had not been taking vitamin D, nor magnesium nor drinking milk for the necessary calcium. But he had improved enough to go back to work full time.

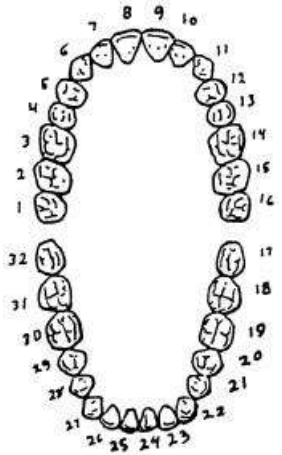

Fig. 14 Tooth numbering system.

Victor Abhay, age 16, could no longer play in high school sports because of knee pain. It began "with a virus" and high temperature two years ago. His knee started to bother him after that. He had *cysteine* kidney crystals and four parasites: *Cryptocotyl*, human liver fluke, *Echinococcus granulosus* cyst and *Echinostomum revolutum* in his white blood cells. He was to start the kidney herb recipe and follow this with the parasite program. Five months later, when we next saw him, his knee was fine.

Kim Murphy, 45, had painful legs, feet and knees. They also were swollen and itched. She was parasitized by *Trichuris*, (dog whip-

worm). She also had tapeworm stages (*Taenia pisiformis*) and intestinal fluke in the intestine. She started on the kidney herbs, followed by the parasite program. She stopped using zirconium-containing products (deodorant) and barium (lipstick). She stayed out of bus exhaust. (She knew she was allergic to diesel exhaust.) In one month her leg pain and itching were gone; slight swelling remained.

Nancy Tong, 80's, had edematous legs. In fact she could get no stockings on. They appeared like pillars with no taper at all. She was on diuretic medicine from her doctor. It kept her blood pressure down but she was losing ground with water excretion. This raised her general toxicity (blood BUN[5]) which made her feel bad most of the time. Yet she drank enough water, curtailed her salt, used no caffeine and had no really bad habits. She had to wear several pads for incontinence. We found she was toxic with cadmium and lead, which were probably responsible for her huge accumulation of kidney stones. The metals were in her tap water and she was unable to resolve this problem since she lived in a senior citizen center. We advised her to move, or to have her tap water carried in, but she could do none of these. Although the situation was hopeless, she did the kidney cleanse, parasite killing program and changed her metal rimmed glasses and wrist watch to plastic. She gained enough ground from these improvements to be able to wear elastic hose and thereby give some physical assistance to her body. This encouraged her to do a liver cleanse. She had a headache with the cleanse but immediately afterwards she fit into a smaller size “Keds” (elasticized stockings). A half a year from the beginning, her legs had taper to them; she didn't even mind wearing a dress.

Fibromyositis and Fibromyalgia

When pain is widespread, not just in joints or legs but in many muscles and soft tissues of your body your doctor may call it *fibromyositis* or *fibromyalgia*.

[5]BUN stands for blood urea nitrogen. It is a body waste and is normally kept low by the kidneys.

For bacteria to get all over your body, they must be riding along with parasites that get all over your body. Microscopically tiny roundworms can do this.

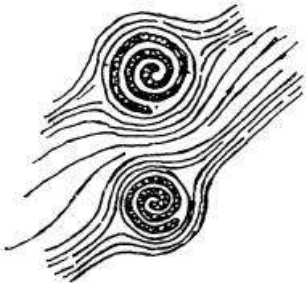

Fig. 15 Trichinella larvae settled in muscles.

Trichinella is the most common cause of these diseases, but sometimes *Ascaris* larvae or *hookworms* or *strongyle* larvae are the main culprits. These wormlets bring hosts of **bacteria** with them, mainly *"Streps"* (*Streptococcus* varieties) and *"Staphs"* (*Staphylococcus* varieties), but also *"Clostridiums"* (*Clostridium* varieties) and "Campyls" (*Campylobacter* varieties). The bacteria are probably the pain causers. By killing all bacteria—*Staphs*, *Streps*, *Clostridiums* and *Campyls*—using a zapper, you may get relief for one hour!

By killing *Trichinella* and *Ancylostomas* (worms) first, followed by the bacteria, you may get relief for several hours. By killing the parasites and bacteria in every household member and the pets at the same time and by never putting your fingers to your mouth, you can expect permanent pain relief. It is interesting to speculate why the other family members, who are also infected with these tiny roundworms don't develop *fibromyalgia*. Perhaps the larvae stay in the intestine or go to the diaphragm (causing coughing) or the eyes (causing "lazy" eye muscles). Perhaps they merely cause **anemia**. *Trichinella*, hookworms and *strongyles* are extremely difficult to get rid of in a family.

These roundworm larvae undoubtedly cross the placenta into the unborn child during pregnancy, too. So they can be "inherited." Try to clear up the whole family before the next pregnancy.

Clearing up pets of these parasites is even harder. The best advice is to give your pets away. They will continue to harbor them even though they are on a pet parasite program. It is impossible to stay free of the parasites your pets have: they will move to your soft tissues immediately, giving you the bacteria and inflammation again.

The next most important advice is to keep fingers out of your mouth (read Hands, page 397). None of these parasites enter through your skin (this is in spite of teachings that hook-worms enter this way), you must put them into your mouth somehow! Consider your mouth off limits to anything but food and kissing.

Finally, if there is a baby in diapers in the family, be patient. When diapering days are over you will have less bowel contact, giving you an opportunity to finish your own treatment. Meanwhile, wash fingernails in Skin Sanitizer (see *Recipes*) after cleaning up children's bowel movements, diapers and yourself. Use borax liquid for soap to leave an antibacterial residue on the skin.

Try to identify your parasites before killing them so you can be on the lookout for them in the future. Get slides or dead cultures of various pathogens and search in your white blood cells. If you can't do this, at least save a saliva sample of your own; keep it frozen or preserved. Also make a saliva sample for your pet. This gives you specimens to test yourself for later. You won't know which parasite is in this saliva specimen, but if you ever test positive for it again you will know you got it back. Then zap yourself.

Brenda Byrd was diagnosed with myofibrositis two years earlier at the age of 36. Her blood test showed triglycerides slightly high (152 mg./DL), indicating the beginnings of urinary tract problems. Her urinalysis stated “hazy” (hazy with bacteria or crystals) instead of clear urine. It also listed white blood cells, red blood cells, and a few bacteria present in her urine. Our tests revealed mercury and numerous other heavy metals distributed in her thyroid, stomach,

kidney, lungs, bones and bone marrow. She was also full of beryllium (usually from "coal oil") contained in the hurricane lamps she kept in every room. She had numerous parasites, including *Strongyloides* and hookworms spread through her body tissues. She was thrilled to learn how to get her health back and started with the dental problem.

Marcia Cochran, 36, had muscles twitching all over her body. It was diagnosed as fibromyalgia. Her joints were tender and her chest felt "tight." She had bronchitis twice a year. She was on Amytryptaline™ for muscle twitching and Bentyl™ to calm the intestine (spastic colon). She had depression with it and was on medicine for that. It all started with fever and chills that she thought was the flu but after they went away, she was left with a tremor. Sometimes she felt that little electric shocks were going through her. She had *Ascaris* and hookworm larvae widespread in her body. She had sheep liver flukes in her liver. She was started on the parasite program. She was also toxic with PVC and tellurium (dental metal). The PVC was traced to plastic storm windows applied to the inside of the window and to new shower curtains. Two months passed and she had not solved any of her problems. Then she did her first liver cleanse and got over 100 stones out. This instantly reduced her fibromyalgia to occasional attacks. She was so encouraged she decided to go ahead with dental cleanup.

Joint Pain or Arthritis

Two main kinds of arthritis are recognized clinically, *osteoarthritis* and *rheumatoid arthritis*. In osteoarthritis the joints have bacteria living on the deposits left there. In rheumatoid arthritis the bacteria come from larger parasites—wormlets actually living in these joints. The worms are the common little roundworms whose eggs hatch into microscopic wormlets that travel.

Fig. 16 Hookworms, strongyles, and whipworms.

We have four common roundworms: *Ascaris*, *hookworm*, *Strongyloides*, *Trichinella*. Their life cycle normally directs them to travel to the lungs but in some people they travel through the entire body, including brain, muscles and joints. More research is necessary to explain this. My suspicion is that there are toxins, like **mercury**, **thallium**, **cadmium**, **lead**, as well as **solvents**, distributed through the body, lowering immunity and allowing the tiny larvae to reside there. Once the pathway (routing) to these organs has been established, it continues to be used by other parasites as well. Soon a variety of parasites, their bacteria and viruses, and pollutants are all headed toward these organs.

Osteo or Common Arthritis

When joints are painful it is a simple matter to kill the bacteria with an electronic zapper. Treat yourself with a zapper daily until the pain is gone. Maybe it will stay away, but chances are the bacteria have a steady source.

The most common source for *Staphs* and *Streps* are small abscesses in the jaw bone, under and beside old extractions, root canals and mercury fillings. You may get immediate pain relief just from a dental cleanup, and again disappointment may follow. *Staphs* and *Streps* are such ubiquitous bacteria, they may come not only from jaw bone infections but from gallstones, kidney stones and other parasites. The correct treatment for ar-

thritis is a complete overhaul of body health: a diet cleanup, a body cleanup, and environmental cleanup.

Start with the herbal parasite program and zapping. Follow this with a kidney cleanse, then liver cleanse. If any toxin is overlooked, especially asbestos and fiberglass, it is sure to find your joints and permit bacteria to return and cause pain. Make sure to correct your body acid levels after doing pH measurements of the urine (page 57).

Arthritic deposits contain a large amount of phosphates combined with calcium. This calcium came from some other bone, such as the base of your spine or the wrist. Here the bones are getting weaker due to this calcium loss. Calcium was taken out of your bones for the simple purpose of neutralizing the excess phosphate in your diet. Reduce phosphate consumption (meats, soda pop, grains) by half, eating fish, milk, vegetables and fruit instead. Drink three cups of milk a day. If you are allergic to milk, do several liver cleanses, switch brands of milk, use milk digestant, and use it in cooking and baking. Cheese and cottage cheese are not substitutes for milk (the calcium stayed in the whey). Dairy products must be boiled before consuming and should be no less than 2% butter fat. It takes bile to make calcium absorbable, yet milk with less than 2% butterfat does not trigger the gallbladder to empty it's bile at mealtime.

If you are not used to dairy products, start slowly and work up gradually to the 3 cups a day needed.

Carol Lachance was diagnosed with arthritis of her back and knees. (She had spurs in both places.) She was positive for *Trichinella*, *Ascaris* and *Dirofilaria* (she also had pain over the heart). They had an outdoor dog. Her blood test showed a high phosphate and alkaline phosphatase level showing she was dissolving her bones. After changing her diet to include milk, extra oyster shell calcium (one a day), magnesium oxide and vitamin B_6, and reducing her meat and grain consumption her phosphate level went down to normal (below 4). She did the kidney cleanse and liver cleanse as well as parasite program but still had pain. A toxic element test

revealed lead in her bones. It was traced to a drugstore variety multivitamin tablet she had taken daily for years. When she stopped these and added prescription vitamin D (50,000 units) for three weeks to help her bones heal she got relief.

Gail Hildebrand, age 62, had painful arthritic hands and gum disease. She had 12 parasites free-loading on her and was toxic with asbestos. This was traced to her clothes dryer. Four months later, after killing parasites, her hand pain and gums were much better. She had the dryer vent taped up tighter and this got rid of her asbestos problem. She started on kidney herbs and in one month saw that her enlarged knuckles were beginning to go down.

Norma Littrell, age 53, came in for her severe arthritis of six years. Her knees, shoulders and hands were painful. I explained to her that painful shoulders did not belong to the arthritis picture but had a gallstone etiology which she could easily fix in a single night at a later time (liver cleanse). She also had mid-back, upper back and lower back pain; again the upper back pain belonged to the liver problem. She had tricalcium phosphate kidney crystals as well as uric acid crystals. She was told to go off coffee (no decaf either), decrease her meat and grain consumption (phosphate) and increase milk and use stone ground cornmeal products (genuine stone ground tortillas as well as pickled pigs' feet are high in utilizable calcium). She started on the kidney herbs. In 33 days her low back pain had improved a lot, she could wash her own hair again and she could sit down and get up from her living room floor without pain. She was elated but we recommended less stress than such exercises for her joints.

Fig. 17 Stone ground corn tortillas, high in calcium.

Patricia Robinson, age 76, had pain in her knees, feet, lower back, hands and wrists. Also in her shoulders and upper back which is not part of the arthritis

picture. She had swollen puffy eyelids which is a telltale sign of Ascaris. She had heartburn, cold feet and insomnia as well as high blood pressure. She was on several medicines. We started her on the kidney recipe and ornithine (four to eight as needed at bedtime) for sleep. We hoped she could stop her Ativan™ drug soon. She was to go off coffee, tea and decafs. Her hands were knotted and misshapen at the joints, also tender. Two months later there was little change; her doctor had put her on Prozac™ and she hoped that would do a lot for her (so she stopped the kidney herbs) but it didn't. The parasite test still showed *Ascaris* and she was started on the parasite program. We also found fluoride (from toothpaste), iridium, samarium and palladium, all from her tooth implants. She was to remove as much metal as the dentist could replace, clean cavitations, and take thioctic acid, 2 a day, to help clear metal from her body. In four weeks the sharp pain in her back was gone and in three more weeks the pain in her hands was gone.

Lynne Snyder, 72, had pain in every joint and had to be on pain medicine to keep moving. Her potassium level was very low (3.6—an adrenal/kidney problem), and she was started on kidney herbs, carrot juice, vegetable juice and bananas. In ten days she could feel some new energy but her pains were terrible, especially her knees. She was taken off tomato juice, cranberry juice, citrus, pepper (she was using a lot), and given buttermilk as a beverage which she enjoyed. After three weeks of kidney herbs she was started on parasite killing herbs. In another month her arthritis was much better. She was not on any pain medicine and could get to sleep without it. She thought it was mostly going off pepper that helped.

Rheumatoid Arthritis

When inflammation and swelling affect your joints, besides pain, it is called *rheumatoid arthritis*. In addition, a blood test may reveal "rheumatoid factor" to be present. In this case, the common tiny round worms have invaded your joints. These are *Ascaris*, *Ancylostomas*, *Strongyloides*, and *Trichinella*. Their eggs are everywhere around us, in dust and dirt and the filth under fingernails and our own bowel movements.

Superior sanitation is your first defense. Rinse fingernails in alcohol after cleaning up bowel movements or changing diapers. Never, never, tolerate long fingernails in any family member. If this discipline can't be enforced, do not allow food preparation by "long nails" unless gloves are worn. He or she may not be getting ill (yet) from the family parasites, but you are. Of course, you can kill them with a zapper (internally, not the ones under the nails) but that is after you have been infected. They are easily picked up again. It would be wise to zap for roundworms every week, just in case.

Make sure your pet is treated with parasite herbs or by zapper as well. A pet that goes outdoors will quickly (the very next day) bring these roundworms into the house again. Give away your pets if possible.

Check for dental problems. Do the Dental Clean-Up (page 409). Then do a Kidney Cleanse and Liver Cleanse.

You may relieve your pain and begin to heal immediately after zapping but it is wise to do all the health programs, anyway. Change your diet. Reduce phosphate, start using sterilized milk for calcium. Switch to fish from meats. Drink much more water. Use only harmless beverages (see *Recipes*) and foods. Switch to toxin-free body products. Live in a non-toxic house. Stay on a maintenance parasite program of herbs, and zap regularly. Stay on the kidney cleanse for three to six weeks and repeat a one-week session every few months to keep removing deposits which may also choose these sick joints to settle in. Knees are a favorite location for rheumatoid arthritis. Knees are very dependent on kidneys.

To summarize, do everything as for osteoarthritis, emphasizing the roundworm parasites for elimination.

Allergic Arthritis

A prominent food toxin that is said to affect knees is *piperine*, found in the pepper family which includes black and white pepper (not cayenne). The *Solanaceae* family of plants (potatoes, tomatoes, eggplant, tobacco!) also has a common "allergen" that produces joint pain. Try going off these for two weeks to see if it helps. Two more chemicals that can trigger arthritis-like pain are *hippuric acid* and *phenylisothiocyanate* (PIT).

Your body makes large amounts of hippuric acid, up to a gram a day. It is the product of benzoic acid detoxification by the liver. Quite a few fruits contain natural benzoic acid. But we can easily triple and quadruple our benzoic acid intake by consuming commercial beverages and pastries where benzoic acid is used as a preservative. It is indeed a "natural" preservative. All of it must be detoxified, though, and this gives us way too much hippuric acid. The kidneys are unable to excrete such overloads of hippuric acid, so it distributes itself in our organs. I suspect a simple mechanism could explain its pain-triggering action: hippuric acid molecules could attach themselves to our cell's conductance channels keeping the gates jammed open. This might invite bacteria and viruses to enter there. But there are also hippuric acid-loving bacteria that feed on it. Perhaps hippuric acid can cause pain without the help of bacteria. This requires further study. It is only sensible for persons with chronic pain not to consume benzoic acid (or benzoate) preserved foods.

PIT is a food chemical found especially in chicken, eggs, the cabbage family, peas. PIT is also part of the body's own chemistry, taking place in the liver, and involving detoxification of *cyanide*-containing foods. Many vegetables, notably the cabbage family, contain such cyanides, giving them protection from insects, disease, and grazing animals. It can take the liver a

week to detoxify a meal full of these cyanides: in the meantime, PIT levels are higher in the body. PIT is very reactive. In fact, it is the chemical used as a general reactant with amino acids in the well known **Edman degradation** reaction. But now, your body is the reaction flask, supplying the amino acids. Since all organs supply amino acids, it is no wonder they can all react to PIT, giving you multiple allergic reactions and pains.

If you have any kind of arthritis, stop eating the high-PIT foods and clean the liver until you are free of all allergies you are aware of. This suggests that the liver is capable, again, of detoxifying the cyanides for you in a reasonable time and you may eat them again. These foods do have many benefits, of course.

Joint pain, or arthritis, was known in antiquity long before dogs and cats were household pets and giving us their parasites. Pigs and horses harbor these roundworms too and may have been the source at that time.

Herbs and treatments that help arthritis are, therefore, plentiful. Maybe they act by killing roundworms, bacteria, and viruses, or help metabolize hippuric acid and PIT. Homeopathic treatments, as well as massage, heat and electronic devices also help. With this wide range of effective treatments dating to the distant past, why is none of them a permanent cure? The answer is simple. The common roundworms are everywhere about us, sanitation is poor, and our civilized lifestyle leads to deposit formation that invites bacteria. But knowing this, you can stop your pain and remove the causes to become one of the first humans to achieve a permanent cure.

Verna Plumb, age 46, was diagnosed with rheumatoid arthritis four years earlier. Since then she had been continuously on methotrexate™ and prednisone.™ This had caused her to gain a lot of weight from water retention. The drugs were no longer effective and she would need to do something else very soon. She had the typical causes: her body was toxic with mercury and nickel from tooth fillings. Her kidneys were full of five kinds of

stones. She had numerous roundworm parasites including two kinds of *Ascaris*, two kinds of hookworm, *Strongyloides* and *Trichinella*. She would have to clean everything up to get relief. She started on the kidney herbs, killed parasites with a frequency generator and in two months noticed her swelling was receding.

Camille Franklin had hands that were swollen and hot and painful. She also had "arthritis" in shoulders and knees. We explained that shoulders were not part of the arthritis picture. She could deal with that in a single evening, soon. She also had bone spurs at sinuses which needed surgical removal. Her kidneys revealed tricalcium phosphate crystals. She was given a diet change; onto milk, fruits and vegetables, off other beverages, less meat and grains. She was started on kidney herbs. In five weeks all the swelling and redness and heat was out of her finger joints.

Thigh Pain

Inner thigh pain often stems from the *sciatic nerve* which is suffering pressure at the lower back. If this is so, chiropractic adjustments should help. The correct treatment, after killing bacteria electronically, is to clean up the entire kidney area using the kidney herb recipe.

If this is not the correct explanation, (and you're not getting pain relief) you may have a trauma—perhaps you overstretched your leg in some exercise. The minor trauma invited bacteria to settle there and give you pain.

If the pain recurs after clearing it several times, there must be a chronic source of bacteria. Since the kidneys are already cleaned, consider the teeth, as well as recurring parasites, and the liver. Clean the liver every two weeks until 2000 or more stones have appeared and no more appear. This could take 1-2 years. Be patient. Do a dental clean up. Keep killing the bacteria so they can't spread. And, of course, let the painful leg rest.

Hip Pain

Hip pain is always due to bacteria. In fact, these bacteria regularly come from two sources: the kidneys and the teeth. This simplifies the treatment since neither of these places takes a long time to clear.

Start yourself immediately on the kidney cleanse (page 549) to clean your kidneys. Continue on the recipe until the dental cleanup has been completed. Both must be clean together to stop exporting bacteria to the hip.

The dental cleanup could take several weeks if extensive work is required. During this time, kill all parasites electronically. Keep killing bacteria, especially *Staphs*, *Streps*, *Clostridia*, *Campyls*.

The dental problem is not always on the same side as the hip pain. The jaw may be very fragile and porous, full of invading bacteria. Cleaning these cavitations may give immediate pain relief in the hip (proving the bacterial source). But getting the jaw bone to heal by taking up calcium again is not guaranteed by the cleaning process.

Give your jaw bone every chance to heal:

- Start taking vitamin D (40,000 to 50,000 u.), every day for three weeks from the day of the dental work or before. After this, take it twice a week forever. **Do not take more.**
- Take vitamin C (1+ gm a day) and B_6 (250-500 mg a day) for healthy gums.
- Get one gram of usable calcium in your daily diet.

Bone Strengthening

Vegetable calcium can't be dissolved by our stomachs (*ruminants*, like cows, can dissolve it—they have an extra stomach loaded with special bacteria who do the actual retrieving of calcium). Tablet-form calcium can't be dissolved well

either, especially as we age. We need predissolved calcium if a little is to go a long way.

Primitive people who lived on fish or stone-ground meal ate 4-6 grams of calcium a day.[6] Even if only 20% of this got dissolved, they would still have about 1 gram of utilizable calcium for themselves. Chances are good they dissolved even more, since they were young (life expectancy was less than 50 years). Their skull remains show beautiful, cavity-free teeth. They lived outdoors, mainly, so getting enough sunshine-derived vitamin D was not a problem. Their natural diet supplied enough vitamin B_2 to protect them from UV (ultraviolet) damage from sunshine exposure.

But these are civilized times. Our lives are stretched into old age, when our stomachs no longer produce enough acid to kill bacteria, nor to dissolve the minerals in our food. So they need to be dissolved for us. Milk is a beverage where the calcium has already been dissolved by the other ingredients. The lactic acid in milk formed during digestion gives the calcium the correct chelated structure for absorption by the intestine. Even the bile participates in calcium absorption. Milk also contains phosphate, but not too much to be useful. I recommend milk as a calcium-source to heal the jaw bone after and before dental work. You need 1+ grams a day. One quart of milk has 1 gm (1000 mg) of utilizable calcium. You absorb only 250-400 mg. The rest is excreted and eliminated. Only the absorbed calcium can heal your jaw bone. Use milk in cooking as well as a beverage. The calcium in it is indestructible.

Bones are not made of calcium alone. **Magnesium** is essential. Since magnesium is more soluble and easy to assimilate than calcium, the tablet form (magnesium oxide, 300 mg, see

[6]Read Nutrition and Physical Degeneration by Weston A. Price, DDS first published in 1939. At least, gaze at the pictures. Ask your library to buy a copy, available from Price-Pottenger Nutrition Foundation, (800) 366-3748.

Sources) will do. If you are not absorbing the magnesium it will stay in your intestine and act as a laxative. If this happens acidify your stomach during meals: always add fresh lemon, vinegar, or vitamin C to your food or drink to help digest milk and dissolve minerals for you. **Boron** (3 mg. once a day) and **manganese** (15 mg. once a day) are additional bone hardeners.

When your diet is improved, your dental problem is cleared, and your kidneys are clean, your hip pain will stay away and you can stop thinking about hip replacement surgery.

Mary Hammond, 48, had two painful hips. She was diabetic and drinking five cups of coffee a day. She had *Staphylococcus aureus* infections under three teeth that she no longer had. After going off caffeine (caffeine may spread bacteria by making tissues more permeable) and getting some dental work done, her right hip stopped hurting. When cavitations were cleaned, her left hip stopped hurting too, but after a week the pain returned. She still had parasites and their bacteria to kill. She had solvents to eliminate and a kidney cleanse to do but she was quite enthusiastic and enjoyed showing off how well she walked.

Groin Pain

Lymph nodes are situated here, as well as in armpits and around the neck. Lymph nodes are your best friends. They are hives of activity. Your white blood cells "nest" here. Lymph nodes sample your body fluids (lymph) at these locations, much like the water department and health department sample our milk and water, making sure they are pure and sterile. Of course, they never really are. But your white blood cells keep working at it. They are busy removing impurities like zirconium and titanium and pathogens like bacteria and viruses.

When an especially challenging dose of parasite or pollution arrives at the node, it enlarges, in order to handle the bigger sized task. This enlargement can be felt. It may press against other organs and you feel the pain of pressure in the groin. This should alert you, of course, to the danger. Kill the parasites and pathogens immediately with your zapper. Start the kidney cleanse. Stop using toxic products and eating toxic food. If you are being effective, the lymph nodes will begin to shrink in a few days, relieving the groin pain. If it does not come back, you probably eliminated the main cause. But if it recurs, try to diagnose it accurately. Test yourself for HIV and AIDS and then to pet saliva, dairy products and other disease specimens. Stop reinfecting from humans or pets or dairy food. Assist your body by cleaning up your dentalware, and environment. Check all supplements for toxins before using them on a daily basis. (If they show up in your white blood cells a few minutes after eating them, there is a toxin.) If your groin pain doesn't go away, you probably missed something!

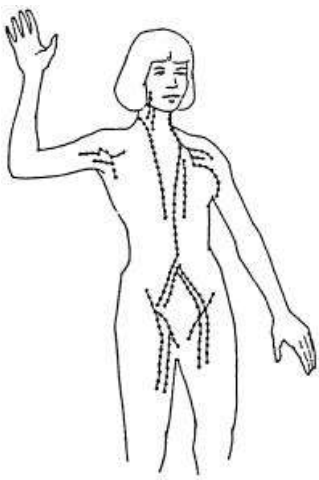

Fig. 18 Your lymph nodes are your best friends.

There are other causes of groin pain, though, such as **hernia**. A physician will help you identify it. Have it surgically repaired. The Shouldice Hospital[7] has the best surgical record and will disclose their statistics! You won't even need full anesthesia there.

Pain from the **ovaries** is often felt near the groin. Sometimes a large cyst in the ovary puts pressure on the sensitive nearby

[7]Shouldice Hospital, 7750 Bayview Ave. Box 370, Thornhill, Ontario, Canada L3T-4A3, telephone (416) 889-1125.

organs. The formation of cysts, *cystic ovaries*, is a common condition of cats, too. Obviously, something is not right in the ovaries.

Ovaries make hormones: **progesterone** and **estrogen**. If bacteria (like *Gardnerella*, *syphilis*, *gonorrhea*) are living there, the ovaries are handicapped and may under-produce or over-produce some hormone. The first treatment should be to kill parasites, especially the flukes. Then kill all other parasites and bacteria, especially *Gardnerella* and enteric bacteria which can migrate easily from intestine to ovary. In spite of all this, the cyst may not shrink. In order to shrink the cyst you must determine what is filling the cyst. Then stop filling it. The cyst will eliminate itself and shrink.

Many kinds of pollution can fill an ovarian cyst. Test for CFCs and PCBs. Gold is another favorite. Particulate pollutants like asbestos and fiberglass are often put into cysts by your body. Your body is wise. If these can't be eliminated through the kidneys or bile, it will at least keep them all together (in the form of a cyst) the same way a toxic dump spares the rest of the landscape. As long as you are adding to it, it cannot get smaller. Fortunately, your loyal white blood cells are trucking toxins away from your cysts every minute of every day and night. All you need to do is stop adding. Remove dental mental, clean up your body, diet, and environment.

You will notice shrinking of cysts in three weeks. What you actually notice is absence of pain, implying shrinkage. Meanwhile pain relief by killing bacteria, herbal ovarian assistance (try wild yam), chiropractic, pain killers are all useful. Decongest the area by means of a kidney cleanse. If your cyst does not shrink you have missed the pollutants. After it does shrink, stay on a regular program of parasite killing, herbal or electronic, and improved lifestyle.

Ovaries may be giving you pain even without a cyst present. By cleaning up parasites and pollutants you can eliminate it quickly; much more quickly than when a cyst has formed.

Synthetic hormones (Provera,™ Premarin,™ Ogen,™ etc.) are often used to clear up ovary problems of various kinds. Don't continue to use them when the need no longer exists. Although they have low toxicity, there are disadvantages such as the need for liver detoxification, and risk of heavy metal pollutants. Cancer acceleration has been seen when taking estrogens.

Low Back Pain

We have been told that lower back pain originates in an inherited weakness of the spine at its base because we humans walk upright instead of on four legs. And we have been told that the bony hooks that keep the spine aligned are flatter in some families, making it harder for them to hold the spine together. We are also told that "proper exercises" could have kept this part of our bodies strong so lower back pain could be avoided.

These theories become obsolete when, without surgery or exercise or change in posture, lower back pain can be made to disappear quickly and permanently.

Acupressure massage and chiropractic can bring "miraculous" relief. The most severely crippled lower back pain sufferer can shuffle lamely into a chiropractor's office and walk out normally, without pain or painkiller after treatments. So al-

though there has been slippage of disc or spine, apparently it goes back into place rather easily.

If muscle relaxation is the clue, we must ask why these muscles spasm so easily. Any muscle spasms if you irritate or injure it suddenly. In fact, your whole body spasms and flinches if a sliver or bit of broken glass is in your shoe. If you remove these objects, the leg can walk normally.

Oxalic acid crystals are as sharp as broken glass. Use the kidney cleanse (page 549) to dissolve them and other stones. All lower back pain can be cured by removing the sharp crystals in the kidneys. It takes about three weeks to dissolve them. In some very severe cases, it may take six weeks.

Whether you have suffered a year or 20 years, the permanent cure is only weeks away.

Our bodies make eight or more different kinds of kidney "stones." The oxalic acid variety is associated with sharp stabbing pains. In its effort to eliminate this extremely vicious acid your body neutralizes it with calcium first to make calcium oxalate. Your kidneys can keep a bit of calcium oxalate in solution but not a lot. The excess hardens into crystals. A glass of regular or iced tea (not herb tea or green tea) has about 20 mg[8] of oxalic acid—way too much for kidneys to excrete. Tea is a toxic drink, not to be considered a beverage. Chocolate is very high in oxalate, too, and should not be used as a beverage (as cocoa).

Children should never drink tea or cocoa. Their delicate kidneys should not be faced with the daily burden of excreting large amounts of oxalic acid. And calcium used to neutralize

[8]Taken from Food Values 14th ed. by Pennington and Church, 1985.

oxalic acid is wasted. Calcium is a precious nutrient. It should be conserved for children's bone development.

It isn't necessary to find which variety of kidney crystals are causing your muscle spasms. Different herbs dissolve different kinds. And by combining them into a grand herbal mixture you can be dissolving all varieties at the same time.

Wherever oxalate crystals have formed, a particular bacterium, *Proteus vulgaris*, can be found. Does that bacterium somehow thrive on oxalate crystals? Or even help them form? Does *Proteus* itself contribute to lower back pain? Is lower back pain in reality two pains in one—the sharp jabbing of glass-like particles plus the inflammatory effect of bacteria? Fortunately, you can kill *Proteus vulgaris* electronically.

By using your new diagnostic skills, you can test your kidneys for crystals. The kidney stone varieties I have tested for are: **calcium oxalate, uric acid, cysteine, cystine, monocalcium phosphate, dicalcium phosphate, tricalcium phosphate.** All these varieties can be dissolved by the herbal mixture. But all can be formed again in a week!

To prevent **oxalate** formation stop drinking oxalic acid (eating oxalate rich vegetables is not significant—spinach, chard, rhubarb and sorrel all have their place in the diet). Also take magnesium and B_6 supplements (as directed in the kidney cleanse).

To prevent **phosphate** crystals from forming, reduce phosphate consumption and drink milk as a calcium source. Keep your kidneys squeaky clean with herbs and copious water drinking. After drinking one quart of sterilized milk, two pints of water, one-half glass of homemade fruit juice and one-half glass of vegetable juice, there is little desire for additional beverages.

I have no understanding of what may cause **cysteine** or **cystine** stones (the genetic theory does not explain them either, considering that people without *cystinuria* make these stones).

Since they are sulfur-containing, and I have seen them appear after taking sulfa-drugs, it may be wise to avoid use of sulfa-drugs if you have a choice, or go on the kidney cleanse afterward.

If you have severe lower back pain you probably have several kinds of stones. Some persons have all seven kinds!

Rosie Zakar, age 30, came to see us because her mother was cured of lower back pain so severe she could do no housework for 30 years. Rosie had the usual crystals in her kidneys: oxalate, urate and phosphates. She was started on the kidney herb recipe. In three weeks she was so much better she would have missed her appointment if she had not wanted to cure her digestive problem and fatigue too.

Vera Vigneault, age 32, came mainly for help in getting pregnant but she already had lower back pain and mid-back pain. If she had gotten pregnant before clearing this up, she might have developed eclampsia and high blood pressure which are kidney-related disorders. She was started on kidney herbs for these. She chewed gum a lot and had bleeding gums. She stated her bad teeth were hereditary (meaning other family members had bad teeth also). For this she was instructed to stop chewing gum, start drinking three glasses of 2% milk a day and take a vitamin A&D perle. She was to floss her teeth once a day. (All floss varieties are polluted with mercury and thallium. Use monofilament fish line, 2 to 4 lb. weight.) Immediately after flossing she was to brush them with a new very soft toothbrush with five drops of 17½% food grade hydrogen peroxide. She was to avoid brushing teeth with metal fillings to reduce erosion. She was to brush them a second time without flossing first, this time with five drops of white iodine (potassium iodide) made up by the pharmacist, again avoiding the metal. She had only oxalate kidney stones and was to stop drinking regular tea, replacing it with single-herb teas. In five weeks her gums were better although she was still chewing a little gum and the "peroxy" had been too painful for her to use. Her low back and mid-back pains were gone too.

Gerhard Rogers, age 39, came for his lower back pain and leg cramps. He had mono, di and tricalcium phosphate crystals in his kidneys. His diet was changed to reduce phosphate (meat, cereal,

breads, pasta, carbonated beverage) and increase calcium and minerals. He was to drink three glasses of 2% milk a day and to start the kidney herb recipe. In 25 days he had only minor improvement. He still had phosphate crystals. He was afraid to drink milk because he had heard so many bad things about it. He was told to boil it first to eliminate these "bad things". A toxic element test showed a buildup of copper, arsenic, cobalt, cadmium, lead, thallium, vanadium and radon. This could easily explain his leg cramps, headaches and sleep problem, too. The arsenic came from pesticide, cobalt from detergent, thallium and copper from tooth fillings. The vanadium was fixed by having the gas pipes tightened, and radon could be reduced by improving ventilation under the house. He was thankful for the information and set about cleaning up his body and environment.

Alberta Mellos age 52, came in for lower back pain and upper back pain. It was explained to her that lower back pain was simply due to tiny stones cutting into her tissues but upper back pain was due to gallstones. She could clear her low back pain first. The kidney test showed she had oxalate and cysteine crystals. She was started on the kidney herb recipe. Nineteen days later she arrived with a cold but stated that her low back pain was gone.

Glenn Dirk, age 62, called on the telephone to say his urination had stopped, probably due to kidney stones. This had happened once before and now he was in a panic. He started our kidney herb recipe the same day and passed 117 stones the same night without bleeding or enough pain to need painkiller. After this, he could focus on his prostate enlargement and pain with sitting. He had intestinal flukes and other stages in his prostate gland as well as in his intestine. He also had *Clonorchis* (human liver flukes and their eggs) in his prostate. He had carbon tetrachloride methyl butyl ketone and TC Ethylene from food pollution accumulated there too. After stopping grocery store beverages and killing parasites with a frequency generator, he could urinate normally, freely and without pain.

Lower Abdominal Pain

The lower abdomen on the left side has the sigmoid colon as it comes down and bends. This is a favorite location for larger parasites to settle permanently. Flukes, roundworms, parasites of all kinds and their attendant bacteria and viruses can be felt if they produce gas and pain. Sometimes they live perfectly quietly, seemingly in harmony with us.

Moving the bowel more frequently expels them repeatedly and prevents their numbers from getting very high. Nature may help you with this by setting up diarrhea. Diarrhea is your clue that intestinal freeloaders are present.

The small intestine leads into the colon at your lower abdomen on the right side. At the junction is the ileocaecal valve that prevents backwash, and the appendix. The ascending colon goes up your right side then becomes the transverse colon that crosses your abdomen at the belly button level. The colon descends on your left side, leading into the sigmoid.

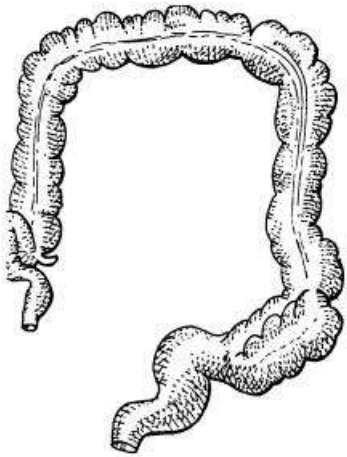

Fig. 19 Colon.

E. coli and *Salmonella* and *Shigella* are "enteric" (they live in your bowel) bacteria that can give you severe abdominal distress and pain. In fact, you can become a chronic sufferer. They can live on hands and under your fingernails, so reinfection from yourself is the most important source. Never, never touch your fingers to your lips. Most importantly, don't try to stop

your frequent bowel movements. They will stop on a dime when your parasites and bacteria are dead and gone.

Other sources of *E. coli* are personal water bottles, other people's hands, hands that have changed baby diapers or cleaned bathrooms.

Hands do everything. To eliminate their threat of reinfection, cut out the section on hands (page 397) and paste it on your refrigerator.

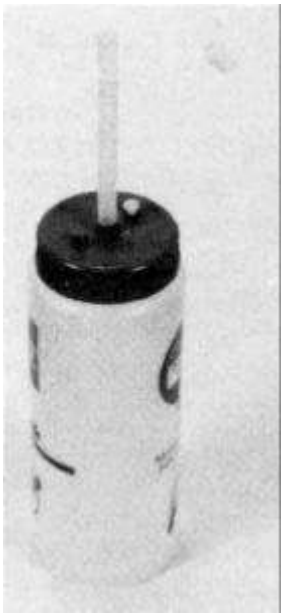

Fig. 20 Keep personal water bottles sterile.

Stomach Pain

Our dairy foods are polluted with *Salmonella* and *Shigella* bacteria. It is impossible to operate a dairy without getting some cow manure into the milk. Although udder wash contains antiseptic it does not kill all manure bacteria. Later, when milk is pasteurized, many heat sensitive bacteria are killed like the "friendly" *streps* and *staphs*, but not all the harmful *Salmonellas* and *Shigellas*. Some survive to colonize the milk, then later infect the consumer. Only milk that is sterilized is safe. A commercial source of sterilized (safe) milk can sometimes be found on the shelf (unrefrigerated). If it had any bacteria, it would not survive shelf life for more than one day!

You may not notice any discomfort from drinking milk, buttermilk, or eating yogurt without sterilizing it. Your stomach acids may be strong enough to kill them, or your liver able to strain them out of your body fluids and dump them, dead, into your bile ducts. Or they may live quietly in some part of the

bowel where you feel no effects. Sterilize all your dairy foods by heating at the boiling point for 10 seconds, even if you have no symptoms.

If you are intolerant of milk it doesn't mean that you are lactase deficient, but that you are unable to kill any *Salmonellas* and *Shigellas*. These, in turn, can make you lactase deficient via frequent diarrheas. You can correct this situation by not eating any more bacteria. Give your body clean food, as intended by nature. Don't eat any deli foods, don't eat salad bar food or restaurant food unless it has been baked or cooked. Never eat chicken or red meat at restaurants. They are not thoroughly cooked.

As soon as a new abdominal pain or discomfort, or a gassy condition appears, zap bacteria and try to eliminate your bowel contents. Use the herb, *Cascara sagrada* (follow directions on label) as a laxative, or Epsom salts if necessary. Also start the Bowel Program (page 546).

If you have chronic abdominal problems, make sure you eliminate the bowel contents two or three times a day. There are herbs that can kill enteric bacteria, known to our ancestors of various cultures. **Echinacea** was a treasured herb of American Indians. **Goldenseal** is another favorite. **Turmeric** can kill *E. coli* and some *Shigellas*. **Fennel** can also kill some. But a single dose of Black Walnut Tincture Extra Strength seems to do the most. Make it yourself if possible (see *Recipes*, page 543).

If your body has lost its ability to kill *Salmonellas* and *Shigellas*, all the antibiotics and herbs and good bowel habits cannot protect you from these ubiquitous bacteria. You could ask how you lost your natural protection from them. There is evidence that common **antibiotics** that kill *Streptococcus* and *Staphylococcus* varieties are responsible.

A fraction of your bowel bacteria should be the friendly *Strep. lactis* and *Staph. epidermidis*. After repeated doses of penicillin-like antibiotics (that you may be taking for your strep

throat) they are eradicated along with the "bad" *Strep. pneumoniae* bug. No amount of acidophilus culture (which contains active *Lactobacillus*) can replace these *Streps* or *Staphs*.

In mice, it takes a million Salmonella bacteria to start an infection. After giving them streptomycin, it only took 10 bacteria to infect them![9] Your intestines are similarly handicapped after antibiotics, and allow even very small amounts of *Salmonella* and *Shigella* to escape and multiply!

Try to get some natural killing power back. This means improving the stomach's ability to produce acid and the liver's ability to make bile. In turn, this means getting the toxins out of the stomach and cleaning the liver. Certain toxins accumulate in the stomach when the liver and kidneys can't keep up with elimination. Arsenic is a prominent stomach toxin. Get all sources of arsenic removed. Freon is another stomach toxin. Switch to a non-Freon containing refrigerator.

The metals from dentalware: mercury, silver, copper, thallium, first are swallowed and then land in the stomach. Clean up your dentalware. Toxins you inhale such as asbestos, formaldehyde, fiberglass, also are coughed up and swallowed to accumulate in the stomach. Test for them and clean up your environment. Any stomach can recover a significant part of its function by cleaning it up. Even though you regain your tolerance toward minute bits of filth in dairy products, do not go back to unsterilized milk products.

Appendicitis

The lower abdomen on the right side has the valve that separates the small intestine (*ileum*) from the large intestine

[9]Sherwood L. Gorbach, M.D., Perturbation of Intestinal Microflora, Vet Human Toxicol 35 (Supplement 1) 1993.

(*caecum*) called the *ileocaecal* valve. It is a common trouble spot because large parasites can attach themselves behind it and keep themselves safe from elimination. (A parasite's biggest worry is your elimination.) It is a favorite location for pinworms in children. It is near this point where the appendix attaches and this, too, is a favorite location of pinworms. With an appendix full of pinworms and their bacteria, is it any wonder when it gets inflamed and causes pain?

Appendicitis refers to inflammation of the appendix. Often, the pain isn't felt over the appendix but over the navel (this is an example of pain being caused at one location but felt at another; it is called *referred pain*). If there are any suspicions of appendicitis, zap pinworms and all enteric parasites and bacteria immediately. Because the current does not penetrate the bowel contents very well, zap every day for two weeks and take 2 tsp. (½tsp. for children) Black Walnut Hull Tincture Extra Strength one time. Make sure bowel movements are regular after this (see the Bowel Program, page 546, for hints) and hands are washed after bathroom use and before eating. Keep fingernails short for the whole family.

If appendicitis does not clear up it can lead to a burst appendix, spewing the dreadful contents into the abdomen. Kill pinworms and roundworms and enteric parasites regularly (once a week) in children. Keep pets on a regular diet of parasite-killing herbs.

Urinary Tract Pain

Urinary tract infections, including bladder, kidney, and urethral infections, are easier to clear up than to test for. Start by drinking a half gallon of water a day. Put yourself on the kidney herb recipe (page 549). This will dissolve the tiny crystals where bacteria hide and multiply.

Common urinary tract pathogens are *Gardnerella*, *Proteus*, *Trichomonas*, *Campylobacters*, *E. coli*, and *Salmonellas*. Sex will give you an instant dose of your partner's urinary tract bacteria. Make sure both of you clean up the urinary tract by zapping and doing the Kidney Cleanse.

Irritable Bowel Syndrome(IBS), Colitis, and Spastic Colon

are all conditions that combine parasite and bacterial problems plus an allergic trigger. If dairy foods trigger yours, you can guess it is not allergic at all but simply *Salmonella* or *Shigella* infection. Boil all dairy foods, stop eating ice cream, cheese and yogurt which you cannot boil. If eating lettuce triggers your intestinal attack, but other roughage does not, it may be a true allergen and cleaning the liver will eventually cure it. Apples, cinnamon and other "allergic" foods can be salvaged the same way. Wheat "allergy" is due to the pancreas being full of pancreatic flukes, wood alcohol, Kojic acid (a mycotoxin), and gold.

All these bowel diseases are quite easily cured by killing all parasites, bacteria, and viruses. Since reinfection is such a big problem, give your pet away until you are completely cured. Have your pet on the herbal parasite program before bringing it back. Clean up your diet, dentalware and environment. Your abdomen will be happy once more and grateful to you for your kind attention. Remember that zapping does not penetrate into the bowel contents. It kills only the outside layer of pathogens. For this reason you should zap daily for several weeks. For this reason, too, I recommend the Bowel Program (page 546) and Black Walnut Hull Tincture Extra Strength even though you may have gotten immediate relief from zapping alone.

Crohn's Disease

is somewhat more serious because the sores are higher up in the digestive tract. This is because sheep liver fluke and pancreatic fluke are commonly the main parasites and these live in the pancreas and liver. They often spill over into the upper intestine. *Salmonella* and *Shigella* are always part of the picture, too, as are various amoebae and fungi. The treatment is the same, kill all parasites and remove all pollutants, especially wood alcohol in commercial beverages. Healing of the digestive tract is very quick, often in a week. Reinfection is very quick too, if the rule about cooking dairy foods is not observed. Keep up meticulous hand sanitation.

Michelle Whorton had stomach pain at the middle of her abdomen, not related to eating. She had occasional very bad diarrhea and also daily headaches. She was started on the kidney herbs for other reasons. Her diarrhea disappeared! We found she had *Ascaris* (probably in her stomach where they cause indigestion and inflammation). She zapped them with a frequency generator set to 408 KHz for three minutes at 10 volts. She was to be very careful with sanitation since they owned a number of farm dogs. Next seen after six weeks, she stated that all her previous problems were gone but she had a different pain in the mid-lower abdomen that got worse during her period and sent pain shooting down both legs.

This turned out to be uterine in origin, but not endometriosis. Her uterus was full of asbestos, arsenic, gold, silver, titanium, propyl alcohol, benzene, styrene, toluene and carbon tetrachloride. This would invite any bacteria toward it!

Mark Lippman, age 51, came in for his irritable bowel syndrome, hoping we would find *Giardia* and put an end to it quickly. Actually, he had intestinal flukes, beginning to invade the liver. He also had propyl alcohol built up in his body giving him a precancerous condition that needed immediate attention. The flukes were killed in twenty minutes, along with *Ascaris* (he had swollen eyelids). He was allergic to milk as could be expected with so much interfer-

ence with digestion. He was immediately better and did not need to come back.

Billy Henry, a 9-year-old boy, had diarrhea daily and stomach aches. He also wet the bed. There was an indoor pet dog and a bird. Electronic testing showed he had two kinds of *Ascaris* and pinworms. His young body also had a buildup of benzene, moth balls and carbon tetrachloride that he was eating, drinking, and breathing. His bed wetting stopped after killing parasites with the herbal program. His other problems recurred until he was older and could stop licking his fingers when eating.

Tom Ochs, age 36, had chronic stomach problems, alternating constipation and diarrhea, was labeled "lactose intolerant" after an elaborate test, and finally had been diagnosed with irritable bowel syndrome. Actually, he had *Ascaris*, besides other smaller parasites. He was also toxic with cesium from drinking beverages out of clear plastic bottles. This frequently causes depression and he was happy to understand his mood changes. After changing to purer food and products and killing his parasites, he did not need to come back. Five months later he was able to drink all the milk he wanted, no longer had sinus problems and lost his IBS.

Rex Callahan, age 5, had dark circles under his eyes, numerous ear infections until tonsils were removed and tubes put in, and many strep throat infections. Clinically, he was found allergic to dust mites, pollens, and animal dander. His skin got "rashy" if he drank too much fruit juice. He had frequent diarrhea. We found he had *Ascaris* parasites. They were not difficult to clear and he was soon a new person.

David Falls, age 52, had stomach pain and numerous health problems stemming, no doubt, from his diagnosed Crohn's disease. He became allergic to the sulfa drugs commonly used in this disease. We found he had sheep liver flukes and all their developmental stages in his blood and intestine. He was put on the herbal parasite program which he found difficult to follow. Nevertheless, in three months his bowel was nearly normal and the pain in his intestine much less.

Edward Marsili age 7, had bouts of stomach pain. He had intestinal flukes and a build-up of benzene in his body. This would seriously lower his immunity and ability to fight off tiny parasites. He was

using a product containing an herbal oil that was polluted with benzene. His parasites were quickly killed with a frequency generator and he was put on the herbal parasite program. One month later his stomach felt much better, but he still had an occasional stomach ache. Testing showed hookworm and rabbit fluke. His benzene was now gone so the tendency to "pick up everything" was gone too. Staying on a child's maintenance parasite program would protect him.

Kim Johnson, almost two years old, had lots of ear infections. It started at eight months so the mother took her off cow's milk and wheat. This stopped her ear infections until mid-winter. She had to be back on antibiotics and a few months ago the doctor began discussing tube implants with her since she was still on antibiotics (six months). Another ear, nose and throat doctor agreed with this opinion, but was willing to wait until Autumn. The baby had been passing a lot of undigested food and was unhappy. They were vegetarians. The baby nursed. Our test showed pancreatic fluke infestation; this would easily lead to bad digestion, especially of milk and gluten in wheat. Fortunately, she was nursed throughout, in spite of going to daycare. Simply killing the parasites (in both mother and baby) solved both problems and she did not need to come back. The ear infections were probably caused by bacteria and viruses brought in by the parasites.

Cynthia Prout, age 36, brought her three children because of their poor health. They all, including herself, had stomach problems, a lot of allergies, asthma, ear infections, and milk intolerance. One boy, age 8, was intolerant of both milk and wheat and hadn't had them for years. He was infested with two kinds of *Ascaris* and pancreatic flukes. His sister, Nola, had itching legs and headaches besides; she was toxic with bismuth and antimony (from shampoo fragrance and laundry fragrance). She also showed a build up of vanadium, implying a gas leak in the home. The youngest, age 5, had frequent stomach aches and vomiting. It was a simple matter to kill *Ascaris* electronically at 408 KHz and the pancreatic fluke with all its stages (421 through 434) after which the children did fine.

Sofia Sobel had extreme ulcerative colitis although she came for her headache. She had been on Prednisone for a month with no relief. We found she had the three large flukes plus *Chilomastix*, dog whip worm, and amoebas in her intestine (but not in body organs).

There were several house dogs. Her stomach and intestines were much too sensitive to accept parasite herbs, or in fact, anything—anything except slippery elm powder. This herb (1 tbs. made into a paste first with water and then drunk as a beverage three times a day) paved the way for acceptance of two oyster shell calcium, one magnesium and one zinc tablet. Her blood test showed high phosphate levels since she was dissolving her bones to get calcium. She added sodium alginate (¼ tsp. to a cup of vegetable broth soup) twice a day to help her tolerate the parasite killing herbs. Her children were given VMF (vermifuge or parasite killing) syrup. By the 12th day of the parasite program she no longer needed colitis medicine; her bowel movements were down to twice a day, soft and formed, but still with a little blood streaking. She loved the alginate mixed with slippery elm. She was able to eat fruits and vegetables but agreed to stay off wheat and corn until her liver was cleansed. In another week she was free from all abdominal complaints except a heaviness over the uterus, possibly due to two missed periods. The thought of pregnancy put her in a panic. She was instructed to induce her period (Emmenagogue, see *Recipes*). She was sure she wanted her period, not a pregnancy and this seemed to be her God-given right. Three weeks later she had a flare up of colitis due to *Salmonella* in food; it also gave her a urinary tract infection. This time she took Quassia herb to kill invaders in addition to the maintenance parasite program which she had begun to neglect. She had been very busy, had lots of energy and wasn't on medications. She treated her urinary tract infection with betaine-hydrochloride (to acidify the stomach), began using plastic utensils to reduce her nickel intake (see Prostate Pain, page 124)) and drank a lot of water. This experience taught her valuable lessons that she was eager to learn, benefiting her family and herself immensely.

Rebecca Goetz, age 53, had ulcerative colitis and her husband had Crohn's disease. She had been on Azulfidine™ and Flagyl™ frequently. Her parasites were only intestinal flukes and their stages, and *Endolimax*, an amoeba. It was a simple task for her to clear her problems by killing them and by sterilizing her dairy foods. Wes, her husband, had three surgeries to remove sections of bowel due to Crohn's disease. He now had a colostomy but was on Advil™ for pain in the rectal area. He could hardly sit. He had been tried on anti parasitic medicine (Cypril™ and Flagyl™) but

they did no good. He had intestinal flukes and all their reproductive stages in his body, also pancreatic flukes, *Capillaria* roundworm, and *Diphyllobothrium erinacea* scolex. We interrupted his testing at that point. His kidneys were full of phosphate crystals— he ate no dairy products. He was started on half-doses of kidney herbs and only part of the parasite program in view of his colostomy and possible diarrhea. Two weeks later we continued testing, finding pinworms, *Haemonchus*, *Leishmania tropica*, *Paragonimus*, *Sarcocystis*, *Stephanuris* and *Trichuris* (whip worm.) Quassia was added and doses increased. His blood test showed a high thyroid hormone level (T4), contributory to over activity of his bowel He was started on goat milk, vitamin C (3 gm. daily) and B_{12} shots. He was given magnets to sit on for pain. He was toxic with cadmium, from his old tooth fillings. But in five weeks he could sit comfortably without pain pills. There was less blood in the stool. Dental work would bring him his next big improvement.

Benito Villamar, a middle age man, had severe side pain for several weeks. He was also gassy. He had sheep liver fluke and stages in his thymus and intestine. The thymus is under the top of the breastbone and is a very important organ of immune function. It is easily damaged by benzene. He did, indeed, have benzene accumulated there. He was given a list of benzene-polluted products to avoid and was started on the parasite killing herbs after killing the flukes instantly with the frequency generator. Two weeks later his side was very much better, his benzene was gone and he was eager to rid himself of lower back pain, which he also had.

Al Vickers, age 9, had stomach aches, headaches, a constantly runny nose and asthma. He was on Slo-Bid™ medicine and allergy treatment. He had a sleep problem. He also had two dogs, one rat and two hamsters. The dogs and he had high levels of *Ascaris*. He was zapped for *Ascaris* and the four common flukes (without testing). He was put on vermifuge syrup and Rascal capsules. This ended his problems and began a new chapter of better care for his health by his parents.

Tim Melton, age 16, had several colitis attacks yearly, requiring hospitalization, from third grade to the present. He also drooled constantly, needing to spit a lot. (This is due to mercury toxicity from amalgam fillings. It is better to spit out the mercury than to swal-

low it.) He had intestinal flukes at a high level for which he was started on the parasite program. One month later he was very much better. He had only one diarrhea session since the last visit. But he still had sharp pains under both buttocks (probably due to kidney stones). He had been an iced tea drinker and had numerous oxalate and cysteine crystals deposited. He was appalled that a common beverage could be so harmful.

Central Abdominal Pain

can be coming from the uterus, bladder, or bowel. It is difficult to tell which is the source. The first step is to simply kill enteric (bowel) free-loaders and get into good bowel habits. Gas and bloating should be gone. If this isn't the solution to the pain there may be special bladder parasites with their bacteria. *Schistosomes* prefer to invade the bladder wall. In fact, very many parasites temporarily invade the bladder because the body is trying to excrete many of them. The whole family should be cleared of these same parasites. Kill them by zapping. Pets should not be kept indoors since they have many of these parasites, too, and they are easily transmitted to us.

Interstitial Cystitis

is one of the most painful conditions described by clients. *Schistosomes* are the real perpetrators but after the bladder wall is weakened, other parasites and their bacteria and viruses accumulate here too. To regain your bladder's health <u>all</u> toxins must be cleared as well. Dental metal, environmental toxins, including radon, asbestos, formaldehyde, must be cleaned up. The diet, body products and home should be carefully searched for toxins. *Schistosomes* are easily zapped but easily picked up

off toilet seats and doorknobs. Always wash hands after toileting: a single droplet reinfects you!

Uterine Pain

Endometriosis

Many a woman's dreams have been shattered by her inability to have a child. Endometriosis is often the cause. It starts with painful cramps at period times. They get worse and worse until pain killers are necessary just to get out of bed and move about the house. There are flukes in the uterus! Large intestinal flukes in a rather small organ! Did they migrate to the uterus from the intestine or did they develop there from eggs?

Sometimes sheep liver fluke is seen there. Once an avenue to the uterus is established, numerous other parasites move in the same direction: *Clonorchis*, the human liver fluke and even *Eurytrema*, the pancreatic fluke, can invade the uterus wall. Why have they taken up so abnormal a living place? Because the uterus has solvents in it! This is the green light for flukes. This disarms your organs so they are left helpless against fluke stages left there by the blood and lymph. Stop eating solvent-polluted foods. There are solvents in all cold cereals. Make cooked cereal. There are solvents in purchased drinking water. Drink from your cold kitchen faucet. There are solvents in grocery store bread, grocery baked goods and cholesterol-reduced foods. Eat none of these. Buy baked goods and bread at your local bakery. Stay away from “low cholesterol” foods. There are solvents in decaffeinated and other powdered mixes for beverages. Drink nothing except milk from the grocery store (sterilize it). Milk does not have solvent pollution. The hormones, antibiotics and udder wash can be tolerated—solvents cannot.

Beverages and powdered mixtures sold at health food stores are no exception. Use no powdered mixture intended for weight loss or weight gain, nor vitality supports, nor dietary supplements. They are all polluted. Some solvents (I often see methyl ethyl ketone and methyl butyl ketone) choose the uterus to accumulate in. This sets the stage for endometriosis and fertility problems. Where there are large parasites, smaller ones soon crowd in. All bring their own bacteria and viruses. *Gardnerella*, especially, is found in cases of endometriosis, ovarian cysts and menstrual problems. The flukes evidently travel from the uterus to other parts of your body cavity, distributing bits of the uterine lining as they go. Once this distribution has occurred, can the bleeding (regular menstrual bleeding) at these extra sites ever be stopped?

It stops immediately when the flukes are dead!

Your body knows how to clean up after dead flukes and does the job perfectly. You can be free of pain in time for your next period. Zap to kill the four common flukes, *Gardnerella*, all other common parasites, and urinary tract bacteria (common ones include *Proteus*, *Salmonella*, *Campylobacter*, *Chlamydia*, *Trichomonas*). Avoid reinfection by avoiding solvents! It is impossible not to pick up parasites. If your uterus has solvent in it, they will find their way to it in a day. Without solvent, they will not.

The solvents will leave by themselves. Help your body get rid of them with vitamin C and B_2 (3 grams and 300 mg. respectively, daily, see *Sources*).

To heal the uterus so it no longer attracts parasites, clear up its internal pollution besides solvents. This means mainly the dental metal that has piled up and environmental toxins such as asbestos, arsenic, fiberglass, and formaldehyde. Gold and silver

are especially attracted to the uterus. Don't wear gold rings or any metal jewelry touching your skin anymore, and, of course, get all metal out of your teeth. Never try to get pregnant before you have cleared up endometriosis.

The advice given by obstetricians to get pregnant to solve your pain problem is most unwise. Indeed, pregnancy changes your body's metabolism and without periods you get pain relief. But it seems much too risky to grow a baby in an infested, polluted uterus. Fear of birth defects is an intelligent fear. Be careful not to get pregnant while you are killing parasites and getting mercury removed from your teeth.

Healing starts as soon as all the parasites and pollutants are gone.

Joanne Biro, age 22, had severe cramping pain with her periods, diagnosed as endometriosis. She had adult intestinal flukes and the *cercaria* stage in her uterus. She had a xylene (solvent) buildup in both her brain (cerebrum and cerebellum) and uterus. She was started on the herbal parasite program following the kidney cleanse. Her next period was pain free. A check up showed she was free of flukes but had thallium in her immune system. Dental cleanup was next on her agenda.

Denise Leyva, 22, was on birth control pills to control the growth of endometrial tissue. She had laser surgery previously. She had hexanedione and methyl butyl ketone buildup in her uterus supporting the intestinal fluke and its eggs in the uterus. There were also some sheep liver flukes and human liver fluke stages there! She was advised to stop eating cold cereals and commercial beverages and kill the parasites immediately. She had no recurrence.

Anita Pierce, age 32, had numerous surgeries for her endometriosis. She also had chronic fatigue syndrome, and several allergies. She had two beautiful poodles in her home. She could not part with them so she gave them the pet parasite herbs faithfully. She had intestinal flukes, tapeworm stages, *Ascaris* and various other

flukes in the uterus. She had all her dental metal removed and home detoxified. Her body was teeming with *Nocardia* and Epstein Barre Virus (EBV). In spite of repeatedly killing the flukes and bacteria with a frequency generator and making herculean efforts she was no better off eight months later. She was unable to solve the problem of reinfection from her dogs.

Christine Solton, age 27, had extremely heavy and painful periods and didn't stop bleeding between periods. A large cyst had been seen by X-ray in the uterine wall. She also had constant bladder pain. Both problems kept her in the bathroom most of the time (90 visits/day). She had the intestinal fluke in her uterus (probable cause of cyst) and *Schistosoma haematobium* (bladder parasite) throughout her body. She was started on the parasite program and in one week her bladder pain was under control but bleeding (from the cyst in uterine wall) continued. *Schistosomes* are very contagious, probably even from toilet seats and the house dust of an infected person. She had them again three weeks later. This time she zapped them and got instant relief. Her bladder and uterus were both full of propyl alcohol, tooth metal, fluoride, cobalt, zirconium, aluminum, antimony, cadmium, and formaldehyde. She was delighted, though, to understand her problem and made the dental appointment.

Contraception

There is an excellent pamphlet available at health food stores, called Wild Yam for Birth Control Without Fear[10] that informs that 3 capsules taken two times a day provides reliable (perfect) contraception provided you give it a two month head start. Also, an emmenagogue recipe is on page 546.

The Silent Cervix

The cervix is a big "trouble spot" for women just as the prostate is for men. It seldom lets you know with pain, however,

[10]Willa Shaffer, published by Woodland Health Books, PO Box 1422, Provo, Utah 84603.

that bacteria or parasites or toxins are present. Sometimes a brief needle-like pain does alert you to something going on there, but it is easy to miss. The cervix is constantly secreting a little bit of mucous and this helps it stay clean but why give it mercury and copper and gold to secrete? Many a fertility problem has been solved by stopping the toxic pollution of uterus, ovaries, and cervix. Clean up your dentalware and clean up your diet and environment.

Kill parasites and bacteria regularly, every week, with the herbal recipe or by zapping. You should have no pain with menstruation, no bloating, fatigue or headaches. A PAP smear test should always be "good". If it isn't, hurry to the rescue of your cervix.

Menopausal Symptoms, Hot Flushes, PMS

Insomnia, irritability, PMS (pre-menstrual syndrome), depression, anxiety, nervousness, are all not to be expected at and after menopause. They may certainly be caused by hormone imbalances. It is these imbalances that are not normal.

NO menopausal symptoms are normal

After the ovaries are done with their cycles of estrogen and progesterone production, the **adrenal glands'** hormone production was meant to "kick in" and make up any deficit.

During your fertile years, you were meant to have a peak of 100 picograms/milliliter (pg./ml) of estrogen on day 9 and day 22 of your cycle. Progesterone, on the other hand, only peaks once, on day 22, and it should reach a level 20 to 100 times as high as estrogen! After this ends, your adrenals can still keep your hormone levels regulated. Typical values are 20 pg./ml

estrogen and, again, 20 to 100 times as much progesterone. Keeping these two hormones in balance is just as important as the actual amounts. **20 pg./ml estrogen is enough to prevent menopausal symptoms** including hot flushes, and to give you heart protection and bone density protection. Taking synthetic hormones usually gives you exactly such levels. But if your own adrenal glands can supply them, surely it is a better approach. (A blood test can tell you your levels; do it on day 21, 22 or 23 before menopause, after menopause the day is not critical.)

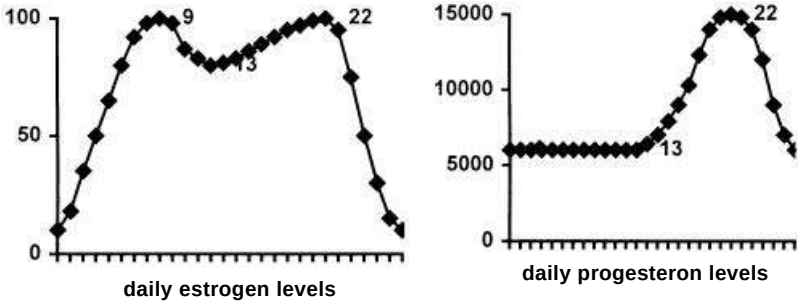

Fig. 21 Estrogen and progesterone levels (pg./ml).

Why aren't your adrenals producing them? Because they are hampered by parasites and pollutants! Kill all the parasites, bacteria and viruses, especially *Gardnerella*, *Proteus*, *Chlamydia*, *Campylobacter*, *Neisseria*, *Treponema*, *Salmonella*. Use the zapper.

Notice that these are also the favorite urinary tract bacteria! This makes good sense, because the adrenal glands sit right on the kidneys and would be geographically close to the kidney bacteria. To avoid getting them back, do a kidney cleanse (page 549) to remove all crystals where they might hide.

After this, hot flushes can be suddenly gone. If not, continue the cleanse. Meanwhile, do some permanent lifestyle improvement. Start drinking two pints of water between meals plus water and milk (sterilized) at mealtime.

Don't drink cranberry juice with its copious *hippuric acid* and its solvent pollutants. You won't need such insufficient help after cleaning up your body, dentalware, and environment. Besides giving you a better hormone supply, your newly revitalized adrenals will get you through stress in better shape and keep your blood pressure normal.

If bacteria are not kept down they will begin to invade other organs. *Gardnerella* goes to ovaries to feast on the corpus luteum after ovulation. This keeps the corpus luteum from making enough progesterone and PMS results.

Menstrual problems and PMS, in general, although they may not be pain-causers, are a sign that all is not well with the uterus and ovaries. Go on a cleanup program. Kill your invaders with herbs or the zapper. Clear up your toxic accumulations from dental metal and environmental sources.

Don't be surprised by a pregnancy! This is not the time to get pregnant, though. If you wish to get pregnant, clean up your body first, being very careful to prevent pregnancy during this time. If this is not under your control do your dental work first. Since every cleanup job increases your fertility, it is best to get the mercury, thallium, copper and nickel out of your body before your risk of conception is raised further by making other improvements. Many an amalgam replacement job had to be halted in the middle due to pregnancy! Couples just couldn't believe they could have a child as a result of cleaning up their bodies so they were careless in spite of my warnings! **A dentist will not take out mercury during pregnancy.**

Nicole Truett, 40ish, had PMS before her periods. She was a returning student and couldn't afford to feel emotionally upset. She also had recurrent yeast infections, *Herpes* and panic attacks. She com-

plained that her thinking was weird, although she was an excellent student (she got her birth date wrong on our office forms!) She had high levels of mercury and we suggested dental work immediately. Two months later she was feeling much better and had all metal removed but was experiencing a slight return of symptoms which panicked her. She still had *E. coli* and *Bacillus anthracus* at four tooth locations, giving her chronic sinus symptoms. She needed her cavitations cleaned. Four weeks later she described how she had gotten immediate emotional relief after two cavitations were done. Our solvent test showed methyl butyl ketone, benzene and carbon tetrachloride (which we found in her Mountain Valley Arkansas Spring Water). They were lowering her immunity giving recurrent Herpes and yeast problems. These disappeared in a week. She was so happy to find the cause of her problems and yet so angry at the nature of the cause that she planned to write to the water company. We need more such environmental activists.

Monica Koziol was on Ibuprofen™ for menstrual cramps. She also got a severe sugar craving and minor depression and headache with her period. She was toxic with silver, copper, platinum, mercury and lead. She also had hookworms, pinworms, human liver fluke and cat liver flukes infesting her. A hormone test showed very low estrogen (57.6 pg/ml) probably due to all these interfering factors. She had all the metal from her fillings replaced and killed parasites with the herbal recipe. This gave her regular normal periods for several months. She decided to get pregnant but couldn't. A follow-up showed she was full of parasites again. She had stopped the maintenance parasite program. She resumed it and began kidney and liver cleanses to get longer lasting benefits.

Barbara Ashby, age 43, had suffered for 1½ years from menstrual pain. She had oxalate crystals in her kidneys and was started on the kidney cleanse. She followed this with the parasite program and dental metal replacement. Then she cleaned her liver and after three cleanses (she got over 1,000 stones the first time!) she said she felt great again.

Terri Entzminger, age 16, had a long list of health problems including painful ovaries and painful periods for which she was put on birth control pills by her doctor. She had several bacteria in her genital tract: *Neisseria gonorrhea*, *Plasmodium cyano*, *Staphylococcus*

aureus (also at tooth #28 which had a plastic filling), *Streptococcus pyogenes* (also at tooth #28). A parasite test showed intestinal fluke adults in the uterus, not in the intestine or liver. There were also fluke *cercaria* here. She was started on the parasite herbs. Three weeks later there was no improvement. She had a rabbit, a dog and a hamster. She was to get them all onto the pet parasite program. Her diet was changed to exclude solvents. Six weeks later her periods were "great", she did not need the pill and she was keeping the whole household on a maintenance program killing parasites. Three weeks later she had cramps again. This time it was sheep liver fluke in the uterus. She probably got them from the snails in her fish tanks. She was off the maintenance program and drinking caffeine free cola again. This would fill her with solvents that make fluke disease possible. She killed them all with a frequency generator and decided to be more vigilant over parasites as long as she was such an ardent animal lover.

Azar Moya, 57, was on Premarin™ and Provera™ for hot flushes and emotional extremes, Synthroid™ for the thyroid, Xanax™ for nerves and sleep problems, something for diarrhea and something for depression. In five months she needed none of it. She had done a liver cleanse by then and got a commode-full of stones (about 1,000), she had changed her plumbing, got rid of the water softener, killed parasites and cleansed her kidneys. She still had sinus problems and some arthritis and was planning dental metal replacement and cavitation cleaning to clear them up too.

Infertility

An ominous sign in any species, infertility is not just another disease or "problem."

When birds' eggs don't hatch their species is doomed. So we learned from the DDT experiment humans did with birds in the 1960's. The DDT changed the thickness of their egg shells so they cracked when the mother bird sat on them. All changes are experiments whether intentional or unintentional. Nature by itself produces sweeping changes, too, such as droughts, wind

storms, fires, ice ages, but usually living things had time or mobility to adapt to them. When there wasn't time, and they couldn't run away, the species went extinct.

Are we humans an exception to this rule of adapt or perish? Nobody feels more helpless and hopeless than the infertile couple. They can not run away, time is limited, and obviously adaptation is not occurring. More likely their lineage will perish. The couples' only wish is "Give us one child, now." Surely, it is their birthright, as it is any living creatures', to reproduce.

Can we relax with the assurance that our intelligence, through the arm of science, will always rescue us? Are test tube fertilizations, fertility drugs, Cesarean sections, incubators for premature babies all triumphs for science? No, they are signs of reproductive failure for the human species.

When the concern is overpopulation of this planet, reproductive failure might seem less ominous. Maybe it's no worse than the natural way any species curbs its growth rate. Maybe only those who can survive parasitism, pollution and immune deficiency should survive in order to strengthen the species. But when reproductive intervention becomes a necessity, not an option, surely the danger signal is present as it was for the DDT'd birds who saw cracks develop in their eggs. The solution to our reproductive failure is not to find ever more artificial ways to conceive, to give birth, and to care for damaged babies. The solution is to fix the old fashioned way; to safeguard the natural way.

If you are unable to conceive or to provide viable sperms use an intelligent approach. Remove the obstacles. **The obstacles are parasites and pollutants, the same enemies of health we have seen before.**

Kill all large and small parasites with a zapper and the herbal parasite killing program. Don't try to keep a pet parasite free, give it away. Living close to another species is a luxury you can't afford at present. The pet can live with its parasites,

you can't. Remember to kill bacteria and viruses too, especially *Gardnerella*, *Neisseria*, *Treponema*, the ancient enemies of human reproduction.

Is it safe to kill parasites if you might be pregnant?

The electronic way of killing parasites is safe if you use a frequency generator. The frequencies of parasites and bacteria are far away from human frequencies. The treatment with each frequency is short. There are no side effects.

The zapper has not been tested and should not be used during pregnancy.

The herbal way of killing parasites has been used by pregnant women without bad effects but this is not enough safeguard. I recommend waiting until the baby is born if at all possible. The treatment is long and intense. The growing baby is exposed continuously to herbs. Perhaps this is preferable to the toxins produced by parasites. You must use your own judgment. Obviously it is wiser to take a chance on herbs than to take a chance on inheriting AIDS or "genetic" diseases.

Part two of regaining your reproductive freedom to have a child is removing pollutants. Gold, silver, copper and mercury can accumulate in the reproductive organs, wrecking the delicate hormone balance between estrogen and progesterone, or wrecking the motility of sperm. Research has not been done to search for dental metal in the uterus, ovaries and testicle of infertile couples. You can do this research yourself. Slides of ovary tissue cost less than $10.00 as do other parts of the reproductive system. Search for dental metal yourself. Remove all dental metal from your mouth, and replace it with metal-free composite. Extract teeth with root canals.

A Word Of Warning!

Be extra careful with contraception during the dental cleanup. You could get pregnant the very next day! **This is no joke.** It is a serious hazard to conceive a child while mercury is loose and rampant in your body from the removal process. It may be a higher risk than leaving it untouched. If you are pregnant no dentist will want to finish the job of mercury removal! **Don't try to get pregnant yet.**

You may have tried fertility pills, in vitro fertilization, and other methods for getting pregnant over a ten year time period, all to no avail. Then you start cleaning up your body and taking your mercury out and suddenly you are pregnant before the job is complete! It may seem unreasonable and illogical to have to be careful after ten years of no worries, but play it safe.

If you fail to observe this warning and do get pregnant too soon, you may pray for miscarriage. Otherwise, take vitamin C and thioctic acid and hope for the best. Men should add daily zinc and arginine (60 mg. and 450 mg, respectively) to their diets. Both men and women should add vitamin E (200 mg.), a prenatal multivitamin and multimineral tablet, eat freshly grown vegetables for folic acid, and add vitamin C (at least a gram daily, see *Sources*). **No other supplements**! Supplements polluted with heavy metals or solvents do more harm than good. If you are not sure of their purity, test one by eating it and searching for it in your immune system five minutes later. If it is there, it is harmful; eat no more.

Nausea

of pregnancy is the scourge of expectant parents. After waiting hard and long for the desired pregnancy, the mother-to-be feels rotten, salivates and gags at the thought of food, and wants no more sex. Maybe sex is ill-advised during pregnancy, no matter how reassuring the male or male-oriented obstetrician is! Maybe salivation is actually mercury excretion being attempted by the body. Maybe nausea is all about keeping toxins out of the body and away from the developing child. These are intriguing possibilities, worthy of your research expertise.

A few decades ago the treatment for nausea was a weekly B_6 and B_{12} shot. Ask your obstetrician for this to see if it helps.

An older, herbal remedy was cinnamon tea: 2 tbs. cinnamon (bark or powder) in 2½cups boiling water, steeped for 10 minutes. Strain and add honey to taste. Dose: ¼ cup three times a day before meals.

Nausea invites starch eating—pasta, potatoes, rice and bread. Starches can absorb. Perhaps they absorb the noxious substances causing nausea. Make sure you add vitamin C to grains. In any case you must still eat additional nutritious food to grow your baby. In spite of craving a pickles/chocolate pudding/carbonated beverage lifestyle, you must eat mainly good food. Craving can take strange turns. Search for the taste you crave in good food and in long forgotten childhood foods.

These are all the fertility cases I saw in a year's time. None were left out in order to hide failure. Assess the success rate yourself:

Domilita Renshaw and her husband had been trying for six years to get pregnant. Both had been tested and treated in assorted ways. Domilita's period was irregular, a sure sign that all is not well in

the area of reproduction. I gave them the usual warning about not risking pregnancy during their deparasitizing and depolluting procedures they both would be going through. Her hormone test showed slightly high (125 pg/ml) estrogen levels for day 22 (if it really was day 22!) and higher still if it was not yet day 22! Obviously, something was irritating the ovaries into overproduction of estrogen. She had oxalate and urate crystals and was put on the kidney herb recipe. She was switched to milk (3 glasses 2% a day) as her primary beverage besides water. She was toxic with nickel (dental metal) which would invite hordes of urinary tract bacteria, dangerously close to the ovaries. She made her dental appointment. She had sheep liver flukes and was started on the parasite program. She broke out in hives from a new hair spray polluted with praseodymium which got into her ovaries. She prepared to clean her liver for her frequent hives. Then she called to cancel her next appointment because she was pregnant (four months from first visit). Fortunately she had one visit with dentist completed. Nine months later she had a beautiful perfect baby.

Lindy Maloy and her husband had been trying for eight years to have their second child. They all had *Ascaris*, including, of course, their house dog. They wormed the dog monthly and did not want to part with it since they did not believe it mattered. They used the pet parasite program, but five months later she had higher *Ascaris* loads than ever. She also could not rid her uterus of intestinal fluke stages in spite of killing them with a frequency generator and using the parasite herbs. She remained full of solvents, bacteria and platinum from dentalware. Her endometriosis continued. They gave up.

Rosemary Peterson, age 33, had been trying to get pregnant for fourteen years. She had seven laparoscopies for endometriosis and very hard cramps with her period. She had intestinal flukes and sheep liver flukes in her uterus. There were sheep liver flukes and human liver flukes in her liver. There were intestinal fluke redia and cercaria in her saliva. The solvents in her uterus were methyl butyl ketone, acetone, carbon tetrachloride (from drinking store bought water), styrene (from drinking out of styrofoam cups), xylene (from carbonated beverages) and decane (from cholesterol-reduced foods). She also had a chronic yeast infection, treating it constantly with Nystatin™. She killed the flukes and yeast electronically before leaving the office and started her-

self on the parasite program and diet restriction. She got pregnant immediately, and did not return.

Elisabeth Tran, age 37, had tried to get pregnant for five years. She did get pregnant recently, on a special "gift" surgery program, but lost it. Her ovaries and uterus were toxic with mercury and thallium from polluted dental alloy. She also had barium and titanium in them, probably from lipstick. We did not see her again, we hope she solved these problems.

Christopher Gravely, a young man of 26 and Frederica, 22, promised faithfully not to get pregnant until their cleanup was complete. He was found by his doctor to have slow moving (low motility) sperm. He was robust and healthy looking but suffered a lot from low back pain—a clue to swarms of bacteria in the lower abdomen. An electronic search of his testicles and prostate (which had been infected once) revealed iridium, platinum and yttrium. This implicated tooth metal. He was also started on kidney herbs. Eight months later he had completed all his tasks, his low back and pain with urination had stopped, and this encouraged him to continue with his fertility program. We started him on thioctic acid two a day and zinc (60 mg.) two a day, switched him to an electric razor so he wouldn't have to use any chemicals on his face, and recommended that he ventilate his garage which was attached to the house, to reduce fumes in his home.

Meanwhile, Frederica, his wife, was also checked for toxic elements. She had antimony (from mascara) in her ovaries and breasts. She had sensitive painful breasts during her periods which were quite irregular. She also had indium and gallium, dental alloys in the ovaries and breasts. She, too, was started on the kidney herbs and instructed to get metal tooth fillings replaced. After two months they canceled their appointment. Frederica was pregnant! Not for long, though, and a wiser couple returned a few months later. Frederica finished her dental work. Both started the parasite program. Frederica's periods became regular. She was started on thioctic acid (one a day) plus zinc, (one a day), until her first missed period. Twelve months later they sent me their baby's picture: he was two months old.

Ginger Hart had been trying for three years to get pregnant. After an endometrial biopsy, a D&C,[11] and laparoscopy she was diagnosed with "inadequate corpus luteum." We found her ovaries toxic with nickel and europium from tooth fillings and strontium from toothpaste. She was delighted to understand her problem and set about correcting it.

Marjory Davis, age 28, had been on the "pill" (synthetic hormones) a long time but was off now and couldn't get pregnant. She actually got pregnant about one year ago but lost it at one month. A toxic element test showed her ovaries and uterus were full of beryllium (gasoline and coal oil), gadolinium and gallium. The metals are alloys of gold used in dentistry. She wore a lot of jewelry, just loved her chains, necklaces, rings, etc. But she agreed to go off all except two rings which did not have these alloys. To reduce fossil fuel fumes in the house she removed all gas cans and the lawn mower from the attached garage. They parked the cars outside. She was started on kidney herbs and promised to use contraception until she was done. She was to drink three glasses of 2% milk a day and take a magnesium tablet and stop drinking other beverages. Three weeks later her husband canceled her appointment because she was too embarrassed and delighted to call herself.

Prostate Problems

If urination is not complete, so you must soon go again, especially in the night, it is suggestive of pressure on the urethra from an enlarged prostate gland. Keeping a little urine from being voided is conducive to bladder and kidney infection, too, because bacteria soon find this "free food."

The prostate collects toxins as if it were a designated dump site, especially for nickel. Urinary tract bacteria quickly find "their" metal, nickel. Any supply of nickel will attract bacteria

[11]A surgical procedure, called *dilation and curettage*, meaning dilate the bladder with air and scrape away the inner lining.

as quickly as crumbs and cheese attract mice. Urinary tract bacteria are making use of your urea as their food. To digest it, they first break the urea molecule apart into two ammonia molecules. It is the ammonia smell of the urine that gives away their presence. The urine should have no ammonia smell. Our bodies do not make ammonia. Only bacteria can do this! Their digestive enzyme is called *urease*. In order to do its job, this enzyme requires the element nickel.

Nickel is plentiful in the soil which is undoubtedly where these bacteria belong, breaking up and utilizing the urine and droppings left there by animals. They perform an essential task in our environment, destroying animal excrement and thereby cleaning-up the soil around us. What folly it is to load ourselves up with nickel so that in one short hop from the earth they are residing in us! Bacteria are all around us doing their valuable jobs. We cannot stop associating with bacteria. We were not meant to feed them, however. If we did not supply them with nickel, as if we were just another patch of earth, they could not gain a foothold in our urinary tract and then to the prostate.

How can we rid our bodies of nickel? This is the challenge. Are we eating dirt? A small amount of dirt can't be avoided on our food. But we can stop sucking on nickel as if it were a lollipop. Our spoons, forks and knives are made of nickel! Stainless steel is 8% nickel! Does it really come off as you eat? When you stick a knife into the mayonnaise jar, it is stained in a few minutes. Try it. The mayonnaise has reacted with the metal loosening the nickel. When you smear the knife over your bread, this film comes off and you eat it. If you were to put the knife in your mouth, now, you could taste the metal. You will later wash the knife but not before you have eaten enough nickel to supply all the bacteria in your body with the daily allowance of their essential element, nickel. Nickel is not our essential mineral. Even plants keep their nickel levels very low. But due to pollution of animal feed with it, even a hen's egg now has 3

mcg/100 gm of nickel in it.[12] To produce a nickel-polluted egg, the chicken must be polluted.

Especially infants and children should never be given metal cups or cutlery. They need all their immune power to combat the barrage of new bacteria and viruses that is emerging in this age of AIDS. Nickel is part of dirt and belongs there, not in our pots and cutlery.

Another large source of nickel is metal dentalware. It is used to harden gold! If you suffer from prostate problems, remove metal from your dentalware. Nickel is used to make bridges, gold crowns, retainers, amalgams. Exchange it all for plastic ware and composite buildups (see *Sources* for more dental information). Stop eating and cooking with metal utensils; use old fashioned wooden or sturdy plastic cutlery instead. Always use a plastic knife for butter or mayonnaise. Never buy foil-wrapped butter.

Nickel is fat soluble and is stored in your skin fat temporarily when a surge of it enters the body. Your skin oils may be loaded with nickel causing "allergies" in the skin. Male pattern baldness is such an allergy. The sweat tries to excrete it for you. Always wash off your scalp sweat to help with this excretion. The skin oils dissolve nickel from metal jewelry (sometimes leaving your skin with a greenish black color) and transport it into your body. Don't wear metal jewelry. Earring posts should be plastic. Metal watches and metal rimmed glasses should be replaced with all plastic types. Metal rings should be replaced. After lowering your total body nickel levels and your prostate disease is only a memory, you might notice scalp hair returning to sparse areas. Search around the edge of the hair line for the first returnees.

Bacteria cannot live in the prostate without nickel being present. You can cure your prostate problems with the simple tactic

[12]Food Values by Pennington and Church, 1985

of stopping nickel pollution of your body. Notice that you get a fresh attack after accidentally using metal cutlery in a restaurant or eating mayonnaise-style salad with a metal spoon stuck in it. It might be wise to take a **histidine** capsule (about 500 mg., one a day for three weeks, see *Sources*) when this happens. Histidine is a nickel chelator. Taking **zinc** is helpful too (60 mg. two times a day for a month). Possibly, the nickel was poisoning zinc enzymes. Read about the benefits of **flaxseed**, too, but remember to test every product for pollutants before accepting it as a supplement.

Prostate problems of all kinds clear up when bacteria are zapped, the Kidney Cleanse is done, dental cleanup is done, and the Bowel Program is followed.

Richard Traylor, age 71, had suffered from prostate and urinary tract disease for three years. Scar tissue had to be removed occasionally from prior treatments of them. He was started on the kidney herbs and in two weeks (13 days) he had a considerable improvement in urine flow. At his follow-up visit we searched for toxins. He had radon, chromate, yttrium and strontium in his genital and urinary tract. He got rid of his water softener (such salts are polluted with chromate), toothpaste (strontium source) and opened the crawl space vents (source of radon). This cured these problems in less than two months. It also cured his stomach ulcers for which he had to take medicine. He was so pleased he decided to install a crawl space fan and pursue a parasite program and dental health just to see what extra health improvements he might get.

Omer Whitney, age 45, had always been a strong, healthy, hard worker. He could now barely walk, due to weakness and pains of several kinds; his prostate problems began several years ago. Our tests showed 4 kinds of kidney stones. He was started on only half a dose of the herbal recipe to give them a chance to dissolve more slowly. One month later he still had some stones although his leg cramps were already gone. At this time we found *Ascaris* (both kinds) which he killed with a frequency generator. We also found carbon tetrachloride and pentane (in decaf beverages) built up in him; also gasoline and TCE. He was considera-

bly improved five weeks later and was quite eager to improve further. A toxic element test showed he was full of copper, antimony (from mineral ice massages), cobalt (aftershave), zirconium (deodorant), thulium (vitamin C fortified orange drink) and mercury (very high, from tooth fillings). He planned on cleaning all of it out of his body and regaining his lost strength.

Harvey Van Til, age 35, came in for his prostate and testicle swelling which began shortly after a vasectomy. He ached over the front right side of his abdomen. He was started on the kidney herbs and in four weeks he had eliminated his oxalate crystals and felt considerably better. We next found the adult intestinal flukes and human liver flukes in his prostate gland! After killing them immediately with a frequency generator and getting instant relief of pain, he got his own device and did not need to return.

Clayton Gamino, 26, had pain during urination which he interpreted as a left-over from a prostate infection he once had. He got all the metal out of his mouth, and did a kidney cleanse. A half year later he had no remaining pains and was able to father his first child.

Side Pain

Pain on the right side can come from problems at the ileocaecal valve or the appendix or the large intestine itself. It can also come from the liver which is higher up but is sending its pain message to your side. Pursue it as an intestinal problem first, killing parasites and bacteria and normalizing bowel movements with the Bowel Program. If the pain persists, especially if it reaches up the side to the

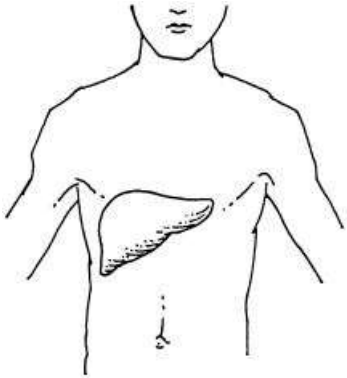

Fig. 22 The liver has a large lobe on your right side with the gallbladder tucked inside. The left lobe is smaller.

middle of the waist, it is probably due to the liver.

The liver is a large organ, mostly on the right side of the body, but with a smaller lobe on the left side. It is the chemical manufacturing plant for the body. It pulls in the food from the intestine (that you ate hours ago) and makes your body's chemicals from them. Toxic items are changed chemically into non-toxic items that the kidney is able to excrete into the bladder. Fatty things must be made water soluble for them to leave with the urine. The liver also makes bile and sends toxic items along with it to the intestine through the bile ducts. The bile enables calcium and fat to be absorbed. If the liver isn't getting much bile to the intestine, fat is left in the bowel contents and the feces will float in the toilet bowl. That is your clue to bile duct blockage.

Bile is bright green. Mixed with intestinal contents it turns the bowel movement dark brown. If the bile is not arriving in the intestine the bowel movement will stay light colored, even yellow or orange. This is another clue to bile duct blockage. Over a quart of bile should exit the body each day. Since bile is loaded with cholesterol this daily excretion of bile is a major method of keeping cholesterol levels low. If the bile ducts are choked with debris so only half as much (often only a cup instead of a quart!) bile is produced and excreted you can expect cholesterol levels to rise, and digestion to be bad. When food isn't promptly digested and absorbed the ever present, ever-ready bacteria will grab it for themselves.

Taking cholesterol-lowering drugs should be reserved for cases where natural excretion cannot be regained.

E. coli and other intestinal bacteria, which do no harm in moderate numbers, can overgrow in a few hours to give you bloating, gas and pain. Your body produces no gas. Only bacte-

ria can produce gas. If your side pain is accompanied by bloating and gas, you know you have a digestive problem. And that this digestive problem stems from a congested liver if the pain is directly under it or over it, or if the feces are light colored or your cholesterol levels are high. Not everybody has all the symptoms.

To clear the clogged passages of the bile ducts, you simply do the liver cleanse (page 552) over and over until the problem is gone. There is one catch. If there are living parasites in the bile ducts, they will not let the bile ducts clear themselves. They are stuck fast to your ducts as a tick can be to your skin. They must be killed before they will let go. Zap them all, or you may use the herbal parasite program, staying on a twice a week maintenance program. Only after parasites are dead (after day 20 if using the herbal program) will you get a lot of "green stuff" and be able to clear "stones" out of your bile ducts. Only one large duct at a time will clean itself. We have hundreds of larger ducts and thousands of tiny ducts feeding into the larger ones! Stay on a schedule of cleansing the liver every two weeks (unless you are ill) until your side pain is gone, your digestion is normal, and you are bouncing with energy. You may also lose some weight, but only if you are overweight.

Remember that a clogged liver does not necessarily give you pain by itself. It is more likely the bacteria in the gall bladder and bile ducts, causing inflammation there and in your intestine, that cause pain. Don't wait till pain occurs over the liver. Use whatever clues you can to diagnose your clogged condition. Or just assume it is clogged. Do the cleanse, and see if you get any stones out. It can never hurt and can help a lot.

Fig. 23 Gallstones.

Bruce Hearn, 40ish, had severe side pain for several weeks and was rather gassy. He had seen a clinical doctor who found him in good health. But we found sheep liver flukes in the intestine and in the thymus! The thymus is an immunity-giving gland, so anything in the thymus is a very serious matter. He also had benzene in his thymus (inviting AIDS). He quickly switched from drinking soda to drinking milk. He went off everything in the benzene list. He killed the flukes electronically and started on the parasite program. Three weeks later the benzene was gone, his side was very much better and he could begin a kidney cleanse for his low back pain. He hadn't cleansed his liver yet! His improvement was probably due to improving his immunity which then controlled the bacteria.

Midabdomen Pain, Stomach Pain

The colon crosses over from your right side to the left side at the midabdomen. This is also the location for the bile duct to join your small intestine. Most midabdomen pain comes from either the colon or the bile duct connections. Kill parasites and bacteria by zapping or with the herbal recipe. Improve your digestion with diet clean up (off moldy food, boil dairy products). Sometimes the midabdomen pain stems from the stomach itself. The valves at the top and bottom of the stomach are meant to keep the food in. The valve at the top where the stomach joins the esophagus is a favorite location for bacteria.

You seldom feel them here though. This is just under your breastbone. They do their work quietly. Eventually, the tissue there is so weakened, the valve can't shut tightly and food is allowed to go back up the esophagus. This is called *reflux* and you may be told to sleep with your head elevated and to eat small meals, especially at bedtime. You may be given Reglan,™ a drug to help empty the stomach faster. Digestive enzymes will help empty the stomach, too, but may harbor molds. The real solution is to kill the bacteria in this area and

keep them from reinvading it. Start by killing the *Salmonellas* and *Campylobacters* (zap them).

Within a day or so, however, the area can be re-invaded. Some bacteria are coming from your teeth! Some come from the liver! Often both sources are supplying bacteria to the stomach. The stomach allows a little bile to enter at the end of each meal, this is normal. But if the bile is full of live parasite stages and bacteria they may try to colonize the stomach, too. If there is insufficient stomach acid to kill them or if there is an accumulation of toxin in the stomach, they will get a foothold. Then they can burrow down deep to escape acid. Eventually, an ulcer can develop.

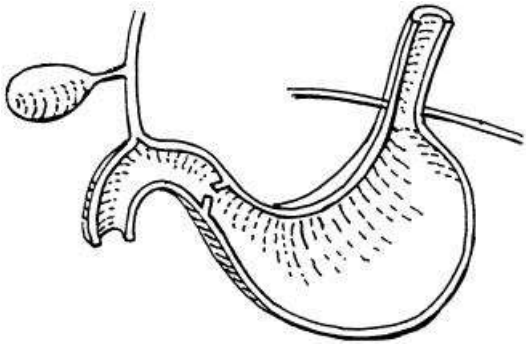

Fig. 24 Stomach, esophagus, diaphragm, gallbladder.

Stomach Ulcer

Often, such an ulcer is painless.

You are, therefore, not alerted to the parasites' presence until they have established themselves in good hiding places. Taking antacids, of course, works in their favor. The solution for both stomach pain and stomach ulcers is to kill parasites and bacteria, followed by dental and liver clean ups. One very common toxin that accumulates in the stomach is the pesticide **arsenic**. You inhale it right along with the flies and roaches you may be trying to kill with arsenic-laced pesticides.

Other inhaled toxins are fiberglass, asbestos, formaldehyde and freon. Your nose and mouth mucous traps a lot of these whereupon you swallow them and they glide into the stomach. Tooth bacteria and tooth metal get into the stomach the same way. You simply swallow them.

Clean up your air, don't use any pesticides (see other methods in *Recipes*). Your dentalware may be cleaned up in a few dental visits but the liver cleanses must go on for a year or two before it is reasonably clean. You may get pain relief in a few weeks but this should not derail your intention to revitalize yourself completely with a cleaned liver and stomach.

Hiatal Hernia

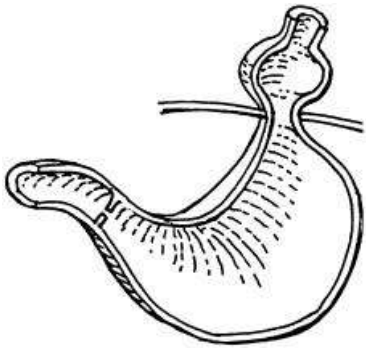

Fig. 25 Hiatal hernia.

When bacteria have spread to the diaphragm and weakened it, along with the upper-stomach valve, food is allowed to get pushed up right through the diaphragm. Pressure in the abdomen from overeating or sitting in an easy chair pushes it up. Walk after eating. Empty the stomach before going to bed. Don't sit in recliners. Very many of us, about 25%, have a small hiatal hernia. It only hurts if it is inflamed. Work at clearing the inflammation first, to get pain relief. In time, the area will strengthen and the hernia itself may get smaller.

Jeffy, 3½ months, had been screaming a lot ever since birth. He was very gassy. He could not be put down without starting to cry. He was congested and had colds. He was on mother's milk exclusively so his chronic *Salmonella* infection must have come from someone who was a carrier, possibly his mother, although she

had no symptoms. The mother had platinum and tellurium in her milk (*Salmonella* can be transmitted in milk but this was not checked). The solution was to clean up the mother's milk by getting the dental metal out of her mouth, and washing hands before nursing. Jeffy's father had an *Ascaris* and intestinal fluke infestation. It is quite possible the baby had these also, giving him a nasty tummy ache in addition to the gas pains. The baby's older sister had screamed and cried the first nine months, too, so the parents were told it was a "familial thing." She also had ear infections, colds and a flaky patch of skin occasionally. She, too, had *Ascaris*. They were very pleased to be able to clear up the whole family's problems by killing parasites and removing toxins.

Ruby Adair, age 14, filled a page with her symptoms. She was also chronically fatigued and had consumed enough antibiotic "to fill a room." She had shooting pains from under her feet up her legs. A quick check revealed mercury and thallium in her immune system. Instead of being dismayed, this news filled her with hope for recovery. She arranged for dental metal replacement. Then she related her stomach "story". While at a wedding, a year ago, she began vomiting with diarrhea. She thought it was the stomach "flu" but she didn't recover for six months and had to miss school. The psychologist thought it was emotional. She was still only attending school one hour a day. We found *Fasciolopsis*, the intestinal fluke, in her stomach wall as well as in her intestine. She started the parasite program and in three weeks her appetite was back, insomnia was gone, fatigue was better and a significant improvement was evident.

Respiratory Illness

Asthma

is a very old disease described in the ancient literature. The only progress we have made to date with this disease is to give drugs to soothe the symptoms.

Asthma is associated in **all** (100%) cases with tiny *Ascaris* larvae. As soon as eggs hatch (in the stomach, immediately after

swallowing filth) the microscopic larvae travel to the lungs, not the intestines. Imagine the distress of lungs full of tiny worms! One tries to cough them up, of course, but in our misguided effort to be polite we teach children to swallow anything they cough up! Some swallowing is inevitable and the young worms are back in the stomach, this time to set up their housekeeping in the intestine. Some never leave the stomach, causing children stomach aches and, of course, a large entourage of bacteria which, in turn, have their viruses.

Most cases of *Ascaris* infestation also show *Bacteroides fragilis* bacteria which, in turn, carry the *Coxsackie* viruses (brain viruses). Whether or not these bacteria or viruses will thrive in you depends on whether you make a good home for them, namely have low immunity in some organ. The preferred organs for *Bacteroides* are liver and brain (brain tumors always show *Bacteroides*). The preferred organs for *Coxsackie* viruses appear to be tooth abscesses and brain.

Not everybody with *Ascaris* develops asthma, even though they always go through a lung stage. Does it depend on the age of the person when the infection develops? Or how many *Ascaris* are present? Or the time of year when lung infection is present?

That innocent cough of early childhood should not be neglected, as simply "croup." At the first sign of a cough, use a frequency generator set to 408 KHz, the frequency for *Ascaris*, or use a zapper. Pay extra attention to washing hands before meals. Pay extra attention to the animals nearby. Kill their *Ascaris* with a zapper and keep it up daily or put parasite killing herbs in their food.

Asthma sufferers become **allergic** to many air pollutants such as pollen, animal dander, smoke. The production of histamine in the lungs and the vast interconnectedness of histamine to allergies has been well studied scientifically. Although invasion by worms is known to result in both histamine production

and high eosinophil counts (over 3), and **asthma clients typically have both**, they are not routinely checked for worms clinically! They are simply given drugs to enable better breathing. More and better (though toxic) drugs have been developed.

But you can put an end to your asthma by terminating your *Ascaris* infection. Then wash your hands and fingernails with grain alcohol, and let no more filth past your lips. Wear plastic gloves for a week to break a nail biting or finger sucking habit. For children wash hands before eating anything, even between meals; keep fingernails short.

Dogs, cats, pigs and horses all get *Ascaris*. Never, never let a child clean up any vomit or mess left by an animal. This could lead to massive infection, the kind that could result not only in asthma but **seizures**. Kill the worms in animal messes before you clean them up too. Never use your dustpan or broom. Use cardboard, newspaper or anything that you can afford to throw away with the mess. Squirt povidone iodine (available at drug stores) on the mess–even if it's outside–and cover with salt before cleaning up. Discard it in outside trash. Wash your hands with grain alcohol, paying special attention to fingernails. If you are a food preparer, you could infect the whole family if you don't wash carefully.

If there is an asthmatic in your family, the whole family should be treated for *Ascaris* with a zapper or with the herbal parasiticides. Even after everybody including the pets have been treated, pets should not be allowed in the bedroom of the asthmatic person. Asthma is more than parasitism. It is also an allergic reaction, to the pet and to other inhaled bits of matter.

Clean the air. Smoke of any kind, fragrance and chemicals of any kind, all household cleaners, polishes, and so forth should be removed. Store essentials in the garage, not the basement, since basement air rises. Clean up the whole house. Persons who must use hair spray or nail polish should do so outside in the summer and in their own rooms with the doors closed in

winter. Use a chlorine filter for the water, especially at the shower. Install central air conditioning if possible, with maximum filtering (but never with chemicals added to the filter and never with a fiberglass filter) at the furnace. A room air filter (not fiberglass) is next best. Use it for an hour in the bedroom ahead of bedtime so the air currents can cease. Just moving dust around is worse than leaving it there. Never do dusting when an asthmatic is in the house. Lungs heal quickly when the air is clean and there is no reinfection. The best place to recover is outdoors away from trees and bushes or indoors with total pollution-free air conditioning (free of asbestos, formaldehyde, arsenic, fiberglass, pet dander).

As your asthma lessens, reduce your inhalers, but always keep them on hand. When you suddenly need them, try to identify your source of reinfection or allergens. Use this experience wisely. Try to understand the recurrence of your asthma. Keep notes. It may take half a year with a dozen recurrences to finally learn and conquer! It will feel great to breathe without spraying yourself and taking medicine. If it comes back a year later, figure out what is happening that's seasonal. A pine tree near the house, a flowering bush, the first mown grass? Stay away from these until you are completely healed.

There are traditional herbs for helping lungs. Grow your own **comfrey** and **garlic**. Make **mullein** tea from the dried herb (see *Sources*). Read herb books for more help. Dry some for winter use, being careful to do it right and not let it mold.

Suzanne Carlyle, 45, had asthma from infancy. She was currently on Albutesol™ spray and tablets daily. Now she was beginning to have arthritis too. She was given arginine to replace caffeine. She had two species of *Ascaris* and was allergic to cats and other animals. She was started on the herbal parasite program after killing *Ascaris*, *Bacteroides* and *Coxsackie* viruses with a frequency generator. Her lungs showed kerosene, carbon tetrachloride, mineral oil, benzalkonium (from udder wash, she was also milk sensitive), aluminum from her cookware, and aluminum sili-

cate from her salt. She had two extra lung parasites: *Paragonimus*, a lung fluke, and *Pneumocystis*. She was immediately improved after cleaning up these sources and canceled her future appointment.

Cay Wenkert, 63, had asthma for many years for which she took Proventil™, but this gave her such bad side effects she had to stay home now and not venture out. Her lungs were full of benzalkonium (toothpaste), arsenic (ant poison under kitchen sink), zirconium (deodorant), and nickel from tooth metal. She had dog heartworm in her lungs(!), in addition to her heart where she sometimes felt pain. She had *Ascaris* and *Naegleria*, *mycoplasma*, *Endolimax* and the intestinal fluke in her lungs! She coughed up blood, after her doctor had diagnosed *bronchiestasis* recently, meaning her lungs were not capable of sweeping out the daily refuse we all breathe in. In spite of killing these and cleaning up her environment she got no improvement. She repeatedly got parasitized. She had four or five root canal teeth which she was unwilling to have pulled. Hopefully, the tradeoff between teeth and health will soon begin to look poor.

Amy Newberry, 41, had recently begun to have asthma attacks. She had been on cortisone but now was on inhalers through the day (two puffs Ventillin™ 3x/day, plus three puffs Intel™ 3x/day plus four puffs Asthmacort™ 3x/day). She was often hospitalized for attacks. She also had stomach trouble and sinus problems (had pneumonia recently). She had *Ascaris* larvae, *Endolimax*, *Naegleria* and *Acanthocephala* in her lungs! She also had arsenic and palladium (tooth metal). Going onto homeopathic medicine for stuffiness helped her avoid some hospital visits. It took several months (5 visits) to track her arsenic source to the bedroom carpets (stain resistance!). After steam cleaning it herself and doing a liver cleanse (after first killing parasites) she was amazed at her improvement. She had not been to the hospital in a month and was only using inhalers preventively. She planned to get dental work done. She got all her former health back.

Laura Brewster, 25, lived in a very old house. The slightest exertion would give her an asthma attack. She frequently got pneumonia, too. Her lungs had beryllium (coal oil) and asbestos, and two parasites, *Paragonimus* (lung fluke) and *Ascaris*. She got rid of all the old fashioned lamps and candles in the house, but could not

find the source of asbestos. She got rid of the attacks but her cough and pneumonia bouts will continue until she moves from that house.

Brett Wilsey, 70, was congested most of the time, had chronic sinus problems, was getting allergy shots for dust and mold, and was on several inhalers for his asthma plus emphysema. He had asthma for eight years. He had oxalate, urate, and all three phosphate variety crystals in his kidneys. He was started on kidney herbs. His blood test showed high "total carbon dioxide" or "carbonate" showing that his air exchange was not good. His potassium was low, showing that his adrenals couldn't keep his electrolytes (sodium, potassium and chloride) regulated, in turn, giving him muscle weakness. His LDH was very high, showing that his heart muscle) was in distress, too. Fortunately, his RBC was slightly elevated, to help with oxygen delivery. (See Anemia page 285). His eosinophil count was high, as is the rule for asthmatics since they all have *Ascaris* worms. Besides *Ascaris* he had pancreatic and intestinal flukes in his lungs(!) plus *Heterakis* (a chicken roundworm), human hookworm, and *Prosthogonimus*, another fluke. He was started on the parasite herbs. Two weeks later he felt a lot better although he still had some *Ascaris*. He was toxic with barium and hafnium (which were traced to his dentures) nickel, tin, rhenium. He stopped using commercial "denture-soak." His wife stopped using hair spray and they started leaving the car out of the garage and walked around to the front door, instead of using the attached garage. He also started drinking homemade comfrey tea. This made him feel still better.

When he removed his watch he got rid of his nickel source. Nickel has an affinity for lungs (as well as prostate and skin). He was now down to one puff of inhaler instead of two, only four times a day instead of hourly. He could breathe deeper than before. Then the lead in his water was found and traced to a single "sweated" joint in the pipes. He was started on food grade hydrogen peroxide, working up a drop at a time; now his cough became "productive", he was coughing up a lot.

He got the plumbing fixed and did a liver cleanse after which his fatigue lifted. He couldn't stop laughing and joking about the "emphysema" he was so worried over earlier.

Bea Karnes, 49, had asthma from childhood when she also had eczema. She was presently on several medicines plus allergy shots and antibiotics for it. She was toxic with antimony although she used no eye makeup and europium, tantalum, and gadolinium from dental metal. She also had hand swelling in the morning and was started on kidney herbs. She killed her intestinal flukes (in the intestine) and *Ascaris* in her lungs and was not seen for half a year. When we eventually saw her, she said her asthma had been "wonderful." She was faithfully controlling parasites with the maintenance program and occasionally drinking kidney herb tea.

Cynthia Prout's whole family (mentioned previously) had asthma. She was told it was inherited. The three young children and herself were on inhalers, nose sprays, cough syrups and antibiotics. Nola, age 10, also had ear infections and numerous allergies. Lewis, age 8, was a slight, nervous boy; he had been off wheat and milk for many years due to intolerance. Irwin, age 5, seldom went with the family due to his frequent stomach aches and the fact he could vomit without notice. The mother and two children who were with her (Irwin stayed home) had *Ascaris* infection and Lewis also had pancreatic flukes. Their home was toxic with vanadium, namely, a gas leak. The parasites were quickly killed and gas leak repaired. The whole family got well and canceled their next appointment. Some inherited disease!

Asthma is just one of our common respiratory problems. The causes are always a combination of *Ascaris* and other parasites with pollutants (allergies).

Bronchitis, Croup, Chronic Cough

- In **bronchitis** the bronchioles are the site of the problem.
- In **croup** it's further down.
- In cases of **chronic little hacky coughs** it may be heartworm!

Bud Portillo, 62, worked on earth moving machines. He frequently had a "bronchial virus" or "bronchial infection." He was always cough-

ing. He had *Ascaris* infestation and arsenic pollution in his home. He also had palladium toxicity from tooth fillings. As soon as they removed the mouse bait from their home, tore down the hallway wallpaper (arsenic source) and changed wells (the well water had arsenic in it from seepage!) and killed parasites, his cough was gone. He also finished his dental work. All this took six months.

Gene Mizell, age 4, was constantly clearing his throat. His parents wondered if it was a "nervous habit." He had two species of *Ascaris* living inside his small body. He was started on a small dose of parasite herbs immediately, stirred into a daily dose of VMF syrup (see *Sources*). He also had PCBs, aluminum silicate, lutetium from recent painting in the house and xylene and toluene solvents. He was switched off soda pop and onto milk. We saw him five weeks later. He had gone through three treatments with vermifuge syrup. His throat clearing was gone, as well as his hacky cough and the blue circles around his eyes. He still had PCBs, which they later cleared by switching off detergent.

Carmen Castro, 30ish, had a chronic cough without being ill. She also had some heart irregularity. She had *Dirofilaria* (dog heartworm) and *Loa loa*. There were no indoor pets. After killing the parasites with a frequency generator and starting on the parasite herbs she was still coughing a bit but her pulse was down to 80 (from 120). She still had toluene, TC Ethylene solvents and mercury, platinum and lead in her body. Then a gas leak developed in their home. She used moth balls and painted a room. After this she had to be on antibiotics for her extreme cough. This time she had *mycoplasma*, *Haemophilus* and *influenza*. She killed these electronically and her coughing stopped. Until she gets the dental work done she will continue to pick up new infections.

Hope Feldman, 57, had been coughing for half a year. She had seen many doctors including a reflexologist. She had *mycoplasma* and *alpha strep* at tooth #17 (lower left wisdom tooth). As soon as these were killed with a frequency generator her cough stopped. She was advised to wear turtleneck sweaters for extra warmth over her bronchii and get a cavitation cleaned at tooth #17.

Teresa White, 37, had bronchitis several times each winter and was put on antibiotic for the whole season to keep it from breaking out. Her lungs were loaded with tantalum from dental metal, cobalt from detergent and thulium from her vitamin C. She had taken

herself off milk, thinking it might be a factor, and used an air cleaner but without results. As soon as she had the tooth metal replaced with plastic (in less than a month) she could go off antibiotics and also was rid of a chronic sinus condition, but still had a bronchitis bout. She had *Ascaris* larvae in her lungs and phosphate and oxalate crystals in her kidneys. Her diet was changed to include milk and fish, magnesium, lysine (500 mg one a day), vitamin B_6 and a vitamin A+D capsule. She started on the kidney cleansing herbs and then the parasite program. In another month the whole problem was gone. Wisely, she got ready to cleanse her liver.

Craig Stewart, 2, had a history of respiratory problems. He had been on Ceclor™ and Ventilin™ for a long time; he had pneumonia the previous year. He had whip worm (*Trichuris*) infesting his intestine which was promptly killed with parasite herbs (as much as his parents could get down him was effective). He was toxic with asbestos. When the clothes dryer belt was changed to a U.S. variety (imported belts contain asbestos which flies into the air when the dryer is used), Craig's health turned around.

Doris Gumb, 26, was on Isoniazid™, Tussionex™ and Rifodin™ for tuberculosis. It started with coughing. She was down to 98 lb. in weight. Her lungs were toxic with beryllium (coal oil fuel), mercury, uranium, and tellurium. She began by clearing all toxic items from her house and basement and then bringing an air sample for testing. She also had *Ascaris* larvae in her lungs and pancreatic fluke in her pancreas. In three weeks she was coughing less and producing less with each cough. The “clean” air sample still had uranium, tellurium, mercury and beryllium. She had no metal tooth fillings, though. In the next three weeks she found a hole in the floor to the crawl space. It was letting up uranium dust and radon. The mercury was traced to the carpet in a child's bedroom. After throwing it out, her sputum cleared up and she was on the way to recovery, although we never found the source of tellurium.

Breast Pain

Although lumps and cancer in the breast produce no pain, they sometimes do give you little warning twinges. These

twinges cross into the breast from the armpit or from any direction. It is gone in a second, leading one to believe it couldn't be serious. If the breast has any unusual sensations, painful or not, investigate immediately.

Test yourself for cancer. (You may use a specimen of mother's milk as a cancer test since this has mitotic stimulants in it—see Curing Cancer page 331). If you have purchased a slide of breast tissue (mammary gland) you can search your breast for cancer. If not, but you find "mother's milk" in your white blood cells, assume it is cancer and clear it up immediately.

If you don't have cancer, search for the pollutants giving you these twinges of pain. Search for your deodorant, cosmetics, and soap in your white blood cells. Search for dental metal. The breasts are often full of nickel. Nickel is quite soluble in fat and the breast is mainly fat. Nickel is one of the top carcinogens listed by researchers. It could even explain the high incidence of breast cancer. But titanium and barium from cosmetics, as well as asbestos and fiberglass are also quickly accumulated in the breast. Clean up your dentalware and body products. Check for exposed fiberglass. Change your dryer belt. Buy a new non-CFC refrigerator. Never try to get rid of these pains with pain killers; let the pains show you whether the clean up has been complete.

Breast Sensitivity

Breast sensitivity can be quite uncomfortable to the point of not being able to wear a bra, especially near period time. It may be due to high estrogen levels; this is also conducive to breast lumps and breast cancer. Most of your estrogen is produced by the ovaries before menopause and later by the adrenal glands. Too high estrogen levels plague the modern woman. Certain

food molds, particularly **zearalenone**, causes over-estrogenization. It affects men too. I have found it in popcorn and corn chips! And brown rice. Stop eating these. Eat white rice. If you make cooked cereals be sure to add vitamin C to them before cooking (1/8 tsp. per cup), to detoxify food molds. I do not know whether taking vitamin C with your popcorn would detoxify zearalenone. Don't risk it. The excess estrogen compounds must be detoxified by the liver. Yet, the liver may be incapable of this because you ate yet another food mold! See the section on moldy food (page 381).

Over-estrogenized women are over-emotional, seemingly on a roller coaster of enthusiasm and despondence. They can develop a high pitched voice, that almost sounds squeaky. High enough estrogen levels are important for fertility but too high levels can cause infertility. Your body is eager to set the level just right, if only you will clean up the ovaries of parasites and pollution. Don't stop your clean up until the breast feels normal again throughout your cycle and you don't feel over-emotional, even just before your period.

Breast Lumps

Breast lumps may or may not be painful. If you feel one, don't wait to be more certain, don't wait to analyze it with tests, don't wait for a doctor's diagnosis or a mammogram. Obtain a frequency generator or zapper and zap yourself immediately. Also do the herbal parasite program immediately (page 338).

Your body often turns the breast into a collecting station for toxic wastes that have been drawn downward from the top of your body. From your head where shampoo and hair spray and cosmetics leave their daily deposits, from your dentalware with its constant supply of heavy metals, from neck and armpits where cologne, deodorant and soap leave their toxic residues. The lymph nodes under the armpit and the region above the

breast, collect it all and let it slip into the breast where it is bundled up in a cyst. Perhaps the kidneys are clogged so toxins are forced to go to a designated dump site instead of out through the bladder. Do a kidney cleanse. Don't rest until all your breast lumps are gone. They will begin to shrink in three weeks if you are removing the correct toxins. Even radon and asbestos go to the breast, so be meticulous with your cleanup.

When the platelet count (in a blood test) is very high (over 400) there is quite a tendency to form cysts or lumps since platelets make your blood clot. The platelet count goes up when parasites are present. Maybe your blood is attempting to clot them! These clots make “nests” for fluke stages which may be why breast lumps often become cancerous. If yours is over 300, (it should be 250,000/cu mm) start patrolling parasites regularly. Stopping the use of caffeine and taking vitamin E (400 u. a day) are helpful in recovery but don't rely on these minor measures. Breast lumps definitely invite breast cancer.

Leslie Yeager, age 37, had breast soreness and "fibrocystic lumps”. She had cerium and nickel accumulated in her breasts. They cleared up in weeks after her dental metal was gone (she simply took out her retainer). Later she replaced it with a partial made of plastic.

Kari Pfeifer, age 36, had numerous cysts in both breasts and uterus. Her estrogen level was too high (187 pg/ml on day 22 of her cycle; the day of testing is important since it varies through the cycle). Her breasts were full of beryllium (coal oil from hurricane lamps) and radon. After these toxins were removed, all her breast lumps got smaller. After she did the kidney and Liver Cleanse, the lumps got softer and breasts were no longer painful. She had several root canals which filled her breasts with numerous bacteria, mainly *Histoplasma cap* (root canals develop infection around themselves). After starting her dental cleanup and killing bacteria with a frequency generator, all her breast lumps disappeared.

Claudia Davis, age 41, had breast soreness ever since a mammogram two years earlier. She had numerous other pains and indigestion. She had intestinal flukes in her intestine and fluke eggs in

her blood: a dangerous situation. They might land in the breasts and start developing there. This is how cancer begins. But she did not have cancer yet. She had a buildup of niobium from polluted pain killer drugs and thulium from her vitamin C. She had *Salmonella* and several other bacteria in her white blood cells, which accounted for digestive problems. In eight weeks she had cleaned kidneys, killed parasites and gotten rid of her heavy metals. Her breast pain was better and a lump on her eyelid had also disappeared.

Stephanie Nakamura, 68, had six surgeries to remove breast lumps, going back to youth. Her recent mammogram was O.K. Her breasts were toxic with cadmium, lead, gold, radon, uranium, gallium, silver. Our tests showed she had kidney crystals and she was started on the kidney cleanse. She was given vitamin E, (400 units daily), sodium selenite (150 mcg daily) and vitamin C (1 or more grams daily). Her triglycerides were also very high showing again that she had kidney problems. She was given magnesium (300 mg daily), vitamin B_6 (250 mg daily) and lysine (500 mg daily). She killed parasites and cleaned up everything except gallium, silver, mercury, gold, cadmium. These must have come from her gold crowns. Her dentist advised against removing these and proclaimed they had nothing to do with her developing glaucoma, arthritis and stomach ulcers. It was a tough decision for her and she made the wrong choice. Perhaps if she had been up for the next breast surgery she would have gotten those "gold" crowns replaced with composite too.

Heart Pain

Pain over the heart region is usually quite real, even though an EKG does not find any abnormality. The most common cause is *Dirofilaria*, heartworm of dogs. It often begins as a pain just above the heart but spreads itself over the whole heart region. Kill it with your zapper. Parasite herbs can also be effective. If you did kill them, the pain often intensifies for a day before it leaves. Then the pain should be completely gone.

Heartworm is very easy to pick up again. If you have had heartworm, you should no longer keep a dog for a pet. Give it away.

Another heart parasite, *Loa loa*, is also a filarial worm and may be the causative factor. Both *Dirofilaria* and *Loa loa* can be obtained as slide specimens to use for testing yourself. Heart muscle can also be obtained as a slide specimen, but a chicken heart from the grocery store or snippets of beef heart (make sure to sample all 4 chambers) will do.

Follow up on your heart, even when no pain remains. These tiny heart parasites have stages that you may not be able to purchase in slide form and therefore can't test for. These stages, if not killed, will become adults so a maintenance parasite killing program, herbal or electronic, is essential. Virtually all dogs have *Dirofilaria* in spite of monthly medicine to kill it. They pick it up immediately after their last treatment for it and can give it to you again. The only way to live safely with pets is to give them parasite killing herbs daily in the feed.

Other heart problems such as irregular beat and mitral valve prolapse can clear up along with the pain. Or they may be due to bacteria (see Heart Disease, page 318).

Meredith Zackman, age 53, came for her diagnosed cardiomyopathy (heart disease). She owned a beautiful, old, very big dog, and of course she would never part from him. We knew she would lose her battle against heart disease. She had both *Dirofilaria* and *Loa loa* which we killed instantly with a frequency generator. She was on Lanoxin™, Furosemide™, Captopril™ and Metoprolol.™ We found she also had *Cytomegalovirus*, *Staphylococcus aureus*, *Streptococcus pneumonia* in her heart. The *Staph* bugs were also in tooth #17. She had copper in her heart (from tooth fillings) and cobalt and PCB from her detergent. There was zirconium from her deodorant and fiberglass from somewhere. Her pulse was typically in the 90's. Eight days later, after her dental work to replace metal was done her pulse was normal (low 70's), both worms were gone and she felt much better. But she still carried four bacteria, five viruses and two tapeworm stages: *Taenia solium*

scolex in the spleen (she had chronic pain there) and *Taenia pisiformis* in the liver. She was started on Rascal (an herbal combination) for these. Six days later she had all of her problems back including *Loa loa*. She repeated everything, then she had to go off her heart medications because they lowered her blood pressure and pulse too much. She started the dog on the parasite program but continued to be heavily laden with parasites and bacteria that always found their way to her heart. She purchased her own frequency generator and was quite faithful with dog treatments. She may outlive her dog and then regain her health, finally.

Bruce Walby, age 42, had chest pain for three years. We found he had *Dirofilaria* and *Loa loa* in all four chambers of his heart. When he zapped them, the pain left a day or so later.

D'Ann Fonties, age 22, had a lot of chest pain but was told by her doctor it was simply "gas bubbles". She also had a serious digestion problem. She had *Dirofilaria*, high levels of styrene (from styrofoam drinking cups) and benzene. This information delighted her and she planned to change her habits.

Sheila Osborn, age 27, had chest pain when she lifted objects. Her pulse was slightly elevated (81) and slightly irregular. She had *Dirofilaria*. Five weeks after starting the parasite program she was feeling much better but still had the chest pain. This time she had *Loa loa* (but not *Dirofilaria*).

Wendy Lewellen, age 28, had a chronic cough and chest pain at midsternum (the sternum is the bone attached to the ribs and runs up the middle of the chest). She had *Dirofilaria* in one chamber of her heart (right auricle). She had xylene and toluene solvents which came from her daily beverage, Mountain Dew.™ She was also full of asbestos from her trips to do laundry nearby (this could not be proved, but when she switched laundromats, the asbestos went away). Two months later, after killing parasites, she was free of heartworm and her cough and chest pain were almost gone. She was probably healing very slowly due to the asbestos which was still present.

Lupita Cline, a young mother, had a chronic hacky cough and irregular heart beat. She had *Dirofilaria* in all chambers of her heart and *Loa loa* in her blood but not in her heart. She had carbon tetrachloride, propyl alcohol, hexanedione, toluene, and TC Ethylene

buildup from drinking Pepsi™ and Mountain Dew.™ Her pulse was slightly elevated at 80. There were no pets in the house. She was started on the parasite program and two months later was rid of her heartworm but now had *Loa loa* in her heart and was still coughing a bit. She was full of platinum, mercury and palladium from tooth metal as well as vanadium from a gas leak in her home and paradichlorobenzene from using moth balls. She was on antibiotics for a "bronchial infection" and was happy to learn about a better solution.

Slow Pulse/Syncope (Passing Out)

Mason Heckler, 30s, was a mechanic by trade and could not afford to pass out on the job. Yet, it had been happening off and on for 10 years. He had acquired high blood pressure in his teens! This was soon followed by an extremely slow pulse (50 beats/mm). No medicine worked (he had been tried on many) so he was on none. Then he got high blood pressure, it was 160/80 currently. He also had constant chest pain around the left nipple. He had heartworm and was started on the herbal parasite program. He never had a dog. In five weeks his pulse was 72; the parasite was gone. I presume his syncopes were due to sudden blood pressure changes or missing a few heart beats in a row. He began the kidney cleanse next to lower his blood pressure.

Chest Pain

When there is a tightness or just a little pain at the middle of the chest, especially under the breastbone, you may be merely having an allergic reaction. You might be feeling little spasms coming from the esophagus, and reaching up toward the throat from gallstones. You might also have HIV/AIDS disease which has a similar symptom over the sternum. So it is very important to pay attention to even a minor symptom in the chest.

Ruling out HIV disease ranks first in importance. Search for its emission at 365 KHz, or purchase a microscope slide with

the dead virus on it as a test specimen (see *Sources*). Or purchase a set of slides representing all the stages of *Fasciolopsis buskii*. Without this parasite you can't get the HIV virus. Purchase a slide of the thymus gland or make your own specimen of throat sweetbreads. Check yourself for benzene buildup in the thymus. (See Using The Syncrometer page 462.)

If you have neither the benzene nor the parasite stages, you have no risk. Your chest distress is due to something else. Improve your air quality so that your lungs are not in distress. This includes radon, chlorine (from the bleach bottle under the sink), colognes, room fresheners as well as the usual pollutants (asbestos, arsenic, formaldehyde, fiberglass, freon).

If you feel waves of pain reaching up to your throat, you probably have a gallstone stuck in a bile duct. Epsom salts can relax that bile duct in 20 minutes. Take a tablespoon in ¾ cup water but only on an empty stomach or you may feel quite ill. Taking a large dose of valerian herb (6 to 8 capsules) may also buy you a little time by relaxing the duct. If you do get relief, you can be sure it was a spasm of some kind. The magnesium in Epsom salts relaxes spasms. I would recommend cleaning the liver (page 552) a number of times to try to dislodge the sticking gallstone. The instructions for liver cleansing advise you to kill parasites and cleanse the kidneys first. But if your throat pain is severe enough, you might just zap and go ahead with it at once.

Upper Back Pain

The main pain may be a dull ache over a shoulder blade, or between the shoulder blades or running right through you from the front to the back of the chest. These are all gallstone pains coming from the liver! Get yourself ready to clean them out. Clean the kidneys first, kill all the parasites that might be re-

siding in the bile ducts and blocking them (flukes, pinworms and roundworms) and get onto a maintenance parasite program. Then mark your calendar for your first liver cleanse. Even if your first cleanse gives you only a dozen bits of green "stuff" you have done well; you have accessed the bile ducts. The pains will probably be "magically" gone the next day, but they might start to return in two days. The bile ducts are having spasms again due to the remaining stones.

After you have cleaned out 1,000 or more, you will get permanent relief. Repeat every two weeks, unless ill, until the upper back pains are gone, permanently. If chest pain or upper back pain is severe, try going off your favorite high fat food (ice cream, butter, cheese). Also try taking 6 valerian capsules, 4 times a day including bedtime to relieve the spasms.

Shoulder Pain

Some shoulder pain is called *bursitis* and some is called *arthritis*. But it always derives from stuck gallstones in the bile ducts of the liver! You can prove this by taking a tablespoon of Epsom salts in ¾cup water at 6 p.m. instead of supper and on an empty stomach (or you may feel quite ill). If some of the pain subsides then you have evidence as to its true cause, because Epsom salts relax the bile duct valves.

Get started cleaning the liver (page 552). By the time you have chronic or acute shoulder pain you have about 3,000 Stones! Count them roughly, as they float in the toilet after the liver cleanse so you know how much progress you have made toward the final goal. Don't start cleaning the liver until you have killed parasites and spent three weeks cleaning the kidneys though. This improves elimination of liquid toxins so a liver cleanse is promptly cleaned up for you.

What emerges from the liver is the most contaminated mess imaginable, full of bacteria and viruses and parasite eggs and stages (all dead we hope) of every kind. It needs prompt clearing from your body. The diarrhea sees to the bowel elimination. But some toxins can only pass through the kidneys. Kidneys should be clean and capable of doing the job. Remember it is unwise to clean the liver before all parasites are dead, especially flukes, because they produce a substance that inhibits any action of the bile ducts!

You are only one day away from freedom of shoulder motion and sleeping on your side again. Permanent improvement, though, depends on progress with your total stone count. Your bursitis can return in a few days or a few weeks. Be patient. You may only cleanse once in two weeks, and not if you are ill. After six cleanses you can be quite sure of being relatively pain free.

Between cleanses use valerian capsules to stop the spasms. It takes 6 capsules 4 times a day to be effective.

Typically only some bile ducts are spasming, and typically those ducts have a single fatty food trigger. Stop eating the high fat food you consume the most (it's probably your favorite). If that hasn't helped in two days choose a different high fat food to omit. The most common culprits are ice cream, potato chips, salad dressings, cheese, butter, cream, and milk.

Perhaps the pain is actually caused by bacteria living in the blocked bile ducts and invading the shoulder. This point has not been clarified. Using your zapper or frequency generator does no good for this pain. Only liver cleaning brings your shoulders back to their youthful mobility.

Upper Arm Pain

Excruciating pain in the upper arm soft tissues can keep your arm hanging straight down for fear of worsening it with motion.

Magnets of high strength (2x5000 gauss) taped to your arm, under your sleeve, can get you through the day. Also try valerian capsules (6 capsules four times a day). Go off all fat in the diet to let the spasm subside. Then start your liver cleanse at 6 p.m. If you used pain killer drugs during the day, the cleanse may not yield anything but it's worth a try anyway. You might be lucky and pop out the chief culprit stone. If not, you should wait several days before trying again; this time avoid pain killers the day of the cleanse. Be sure to zap parasites the day before or earlier.

Peggy Patton, age 60, had shoulder pain and painful feet in addition to aching all over. The aching was due to *Trichinella* which both she and her husband had. It took six months on the parasite program before it stayed away. She had clay colored stools, evidence of bile duct blockage. Then two liver cleanses cured her shoulder pain, nausea and remaining pains. She started gardening again and immediately picked up hookworms and *Trichinella* again. But she learned to sanitize her hands with grain alcohol after washing away dirt and this kept her parasites in check.

Jessica Atkinson, a middle age school teacher, developed a pain in the right cheek quite suddenly. She also had pain over the right mid abdomen and right side at the waist but X-rays and scans showed nothing (she had been X-rayed three times). She struggled for seven years to stay employed. She was having severe pain attacks over the liver and described her stool as almost white after these attacks. She cleaned her liver at least 30 times before she related, one day, that her joy in living had returned. Her gallstones were exceptionally large (½ x ¾ inch). Eventually the abscesses in her upper teeth were found, clearing up her cheek pain and protecting the liver from recurrent infections from these bacteria. Only then did she get permanent and complete pain relief.

Lisa Mattie, 72, had her right arm hanging limply by her side. It was so painful she bent forward to let it hang straight down. But in seven months she had done 6 liver cleanses, getting over 3,000 stones out. All pain was gone although some numbness in that arm persisted. She could also stop using Tums™, stop coughing, and no longer was bothered by her hiatal hernia.

Elbow Pain

One variety of elbow pain is due to an inflamed tendon there; it is sometimes called "tennis elbow." It is not due to playing tennis or any other arm use. The inflammation is caused by a liver full of stones and parasites, especially flukes which manufacture a chemical that affects tendons. Kill all flukes and cleanse the liver for quick relief. Using your elbows while they are inflamed is traumatic to them, like working with a sore thumb. Don't play tennis or do other arm exercises until they are pain free.

Parasites consume large amounts of your vitamins and minerals. Give yourself vitamin A (25,000 u daily), zinc (60 mg. daily), and B_6 (250 mg twice a day) until the pain is gone.

Wrist Pain

Tendons passing through the wrist can become inflamed from the unnatural chemicals produced by fluke parasites in the liver. Using the wrists to work further traumatizes them (injures them) making it harder for them to heal. A small hole between the tendons lets the nerve and blood vessels through into the hand. Fluke parasites also make chemicals that thicken tendons. When tendons at the wrist thicken, they can squeeze down on the nerves and blood vessels until the hand or fingers feel numb. If you have pain at the wrist or numbness in your hands, killing

parasites and cleaning the liver may give you the permanent cure. Wearing a wrist bandage or support can help reduce trauma damage to the wrist while it is healing.

Numbness of hands, without wrist pain, is more often due to a brain problem with parasites and pollutants. Lead, mercury, fluke parasites are the usual culprits.

Thumb Pain and Hand Pain

can be due to liver parasites. Get yourself ready for a liver cleanse. If the pain goes away beforehand, while you are on the kidney cleanse, it shows you had deposits in your joints. You were headed for arthritis in your hands. Read the information on arthritis (page 78) to protect yourself.

Finger Pain

This is pain in a joint, often accompanied by some enlargement or knobbyness of the joint. It is not hard to recognize these as deposits of the same kind as we saw in the toes. You can test yourself to identify the variety. **Uric acid** and **phosphates** are the commonest types. Read the section on toe pain (page 55) for detailed instructions. You can greatly reduce your finger joint deposits and the size of the knobs. In six weeks after starting the kidney cleanse and changing your diet, the knobs may already be shrinking. A large magnet (5000 gauss—used only as directed) may bring pain relief but only dental cleanup and environmental cleanup will give you lasting improvement.

Back Of Neck Pain

The back sides of the neck seem to be highways that run between the teeth and liver. Both contribute to pain at the back of the neck. Pulling an infected tooth or cleaning a cavitation can bring complete relief, only to return the next time a tooth is extracted. Extractions should be followed by cleaning out the cavity created so an infection can't start here. Cleaning the liver can also bring immediate relief, only to find pain and stiffness to return months later. You must cleanse many times for permanent relief.

An allergic reaction to potatoes and tomatoes can express itself in neck pain too. When the liver can no longer detoxify the chemicals (solanine, etc.) in this food family they are free to roam the body with the circulation. Perhaps they prefer to attach themselves at a particular neck site and cause inflammation here. Perhaps an injury was already there, beforehand. Whiplash is often blamed for back-neck pain and indeed chiropractic adjustments can bring total relief. Perhaps the trauma of whiplash first invited all of these contributors. Merely killing bacteria with a zapper is not long lasting. But dental cleanup plus liver cleansing is.

Front Neck Pain

Lymph nodes under the jaw strain your body fluids of the head, removing bacteria and toxins. They are sometimes called "neck glands." If the stream of bacteria is endless such as when they are coming from a hidden tooth infection, the lymph nodes will enlarge to do a better job. They will also try to remove toxic metals, mouthwash, and toothpaste for you.

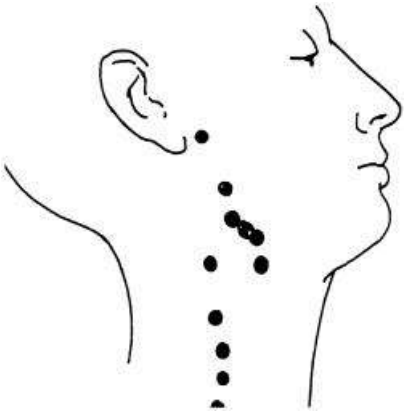

Fig. 26 Lymph node neck glands

To see what is affecting your lymph nodes, purchase a slide of lymph nodes. Since we have lymph nodes in many locations in the body, you can't single out the neck nodes for study. So you will get to see all the toxins affecting lymph nodes everywhere: PCBs in your underwear being removed by groin lymph nodes, lead in your intestinal lymph nodes from the water you are drinking, mercury in your neck lymph nodes from amalgam fillings. Eliminate all these. Don't rest as long as any of your glands are enlarged.

Roland Sanford, 23, had minor pain and a lot of stiffness along the sides of his neck. His arms had some numbness. He only had one metal tooth filling but his whole body was toxic with samarium, beryllium, indium, copper, cesium, and mercury. When it was replaced, his neck pain and numbness got better.

Audrey Doyle had severe neck pains she attributed to sitting all day and sleeping in her wheelchair. She had to take pain killers to get to sleep at night because they were so bad. She knew eating cream and butter made it worse but she had no will power, she said. After a liver cleanse, getting “thousands” of tiny stones, she was free of it.. for one day! But it was enough to convince her and she was determined to be off pain killers.

Temporal Mandibular Joint (TMJ) Problems

Pain at the angle of your jaw is not due to a poorly fitting joint. It fits perfectly but the muscles nearby are pulling it out of

joint with their frequent spasms. There is always a hidden tooth infection present. Ask the dentist to search for hidden tooth infections and to clean your cavitations (you will need to find an alternative dentist, and read Dental Cleanup, page 409). Begin immediately to heal these bone lesions with vitamin D (40,000 to 50,000 units once a day for 3 weeks, followed by 2 such doses per week forever), milk-consumption for calcium, and a magnesium oxide tablet. (See bone healing, page 87).

Kill pinworms with a zapper or frequency generator in yourself and family members twice a week and keep everyone's fingernails short for extra hygiene in the family for a month to prevent reinfection. Pinworms can cause tooth grinding and contribute to TMJ dysfunction. For extra muscle relaxation, take two magnesium tablets at bedtime and valerian capsules.

Tooth Ache

Before the pain becomes acute and excruciating, kill bacteria of the mouth, including "tooth decay" and "tooth plaque" frequencies (see frequency list, page 561). Make your dental appointment immediately. If zapping bacteria several times in a few hours relieves pain enough to get you through the night or past the weekend, do not delay a single day. Zapping does not reach into the middle of an abscess—it circles around, so some bacteria are left to repopulate.

Try to understand the problem. If there are teeth with root canals near the location of pain, extract them. The toxic materials of the root canal jeopardize your total body health. Removing them always helps and may let the jaw heal normally where they were extracted. Since the pain is caused by a bulging infection pressing on a jaw nerve, and because each tooth has a related organ(s) it is especially important to clear up all infections to protect these organs.

These relationships are not understood yet. Finding that teeth have the same tissue frequency as some distant organ sheds a little light on the situation. Until the meaning and function of these frequencies is understood we can only guess that they interact somehow. Bacteria have taken advantage of this common resonance and have invaded both organs.

Heart infection by *Staphylococcus aureus* is an example. It is a common heart bacterium, causing much of our heart ailments, particularly mitral valve disease and irregularity problems. They always derive from teeth, whether present or missing! After wisdom teeth are extracted, the hole left in the jaw frequently does not heal, it picks up *Staphylococcus aureus* from the mouth and a chronic infection is started. For this reason it seems ill advised to pull wisdom teeth if it isn't necessary.

Another heart bacterium, *Nocardia,* can originate in the teeth. *Nocardia* can also invade the brain and nerves. Persons with Parkinson's disease always harbor quite a population of *Nocardia*. Zap all these bacteria before and after your dental visits. Remember that killing bacteria in itself is not a panacea. Pain and body damage will return unless you do the proper repair and cleanup work.

Throat Pain

Recurring sore throats are always improved by removing dental metal and root canals, and by cleaning up hidden tooth infections. This is essential for a permanent solution. Bacteria and viruses that cause sore throats are thriving in hiding places under and around dental metal. It is quite difficult to reach the center of such places (abscesses) with electric currents. Even if you could, you would reinfect the very next time you ate non-sterile food! Zapping is not a substitute for cleaning up your dentalware.

Keep your neck warmer than would be perfectly comfortable, gargle with hot water to bring in extra circulation. Use zinc tablets (60 mg. see *Sources*) twice a day; suck on them before swallowing. After cleaning up dentalware you may never have another sore throat!

Children with recurrent sore throats usually do not have a dental problem. They invariably have an air pollution problem. Asbestos, formaldehyde, fiberglass, Freon and arsenic are the chief culprits. Clean these out of the house. Eating moldy food is especially conducive to respiratory illness. The immunity drop can last for weeks! Go off the moldy suspects to raise your family's resistance.

Eye Pain

is caused by parasites.

The eye is a favorite location for many parasites, including *Giardia*, *amoebas*, *hookworm*, *schistosomes*, *Toxoplasma*, and innumerable others. The eye has two large bodies of watery fluid: the *aqueous humor* and *vitreous humor*, where no blood traverses to bring in extra white blood cells when the need arises. It has its own protective devices, like tears, but some parasites, like *Toxoplasma*, have overcome all the body's

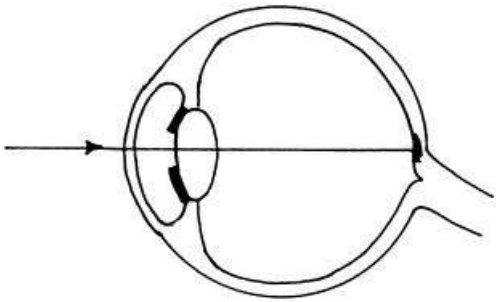

Light travels through the cornea, through the aqueous liquid, the lens, and then the vast vitreous humor, finally striking the super sensitive spot on the retina, called the macula.

Fig. 27 Eye.

defenses and regularly invade the eye if they get into the body somewhere.

We get *Toxoplasma* from cats; the infectious stage is in cat feces.

Toxoplasma infection could be the beginning of a lifetime of eye disease due to weakening of the eyes at an early age. *Toxoplasma* also invades the brain, frequently causing a dull ache or pressure at the back of the head. *Trichinella* is another common eye parasite, invading the eye muscles, so that a muscle is weakened and doesn't allow perfect alignment of the two eyes. Dogs and cats are the source of these.

There should never be a cat box in the house. Never let a child near a cat box.

By killing all the large parasites plus a few bacteria (*Staphylococci*, *Chlamydias*, *Neisserias*) the eye can become pain free in a few days. If pain returns, you missed something or reinfected yourself. Everyone in the family including pets needs to be treated for all the parasites. No indoor pets should be kept by a person of low immunity, since infecting yourself daily and then killing parasites daily is not a solution.

Herpes of the eye is not a single actor. The true host of this virus is a larger parasite, possibly a tapeworm stage. Tapeworm stages should be killed with an herbal preparation, Rascal, or with a zapper. (Not with a frequency generator. Only a zapper can kill all the segments and eggs at once, leaving nothing alive to wander about and find a new tissue to invade.)

Mary Rauch, age 60, filled a page with different pains and problems. Even her eyes had a dull ache around and behind them, sometimes reaching to the back of the head. Her teeth hurt when she ate and she had been getting B_{12} shots once a week for 36 years

for pernicious anemia. She was full of *Ascaris*, amoebas and pinworms which kept her legs twitching and jerking in bed at night, even waking her up. She was so much better after the kidney cleanse and parasite program she was eager to cleanse her liver. Before two months had passed her eye pain was gone.

Jessie Healy, middle aged and in good health otherwise, had carried the anxiety of having inherited *retinitis pigmentosa* for forty years. Now her drivers' license was in jeopardy due to fast progression of her disease. Numerous heavy metals had accumulated in her retina, including cerium from dental floss, arsenic from pesticide, tin from health food brand deodorant, PCB from skin salve, cobalt from dish detergent and indium from tooth metal. She had eight parasites in the retina including *Toxoplasma* from association with cats years ago. Removal of dental metal alone arrested the disease process. Two years later she was slightly improved and still driving her car.

Macular Degeneration

Dolores Bollapragada, 50ish, had suffered from clinical ergot poisoning in the past which put her in a coma for several weeks. Ergot is a grain (especially rye) fungus, very toxic to the liver. Its byproducts are used in migraine medicine. She had overdosed, somehow. Perhaps her liver never recovered. It no longer detoxified solvents for her, allowing them to accumulate in her retina. There she had propyl alcohol, benzene, carbon tetrachloride acetone, butyl nitrite, styrene, gasoline, wood alcohol, paradichlorobenzene (moth balls), pentane, methylene chloride and decane. She stopped snacking on cold cereal through the day. She had many habits and products to change. But she was determined to salvage her sight. She did.

Headache and Migraines

Headaches can take the joy out of living. They can lower your motivation level so low that you don't even want to do anything about them! People with daily headache deserve our

deepest sympathy since they must carry on with life's daily duties in spite of it. Often, no medicine helps. Although there are common headaches, sinus headaches, migraines, and others, the causes of all overlap a great deal.

Tooth infection, urinary tract infection, bowel problems, and a wormlet, *Strongyloides* are the common causes.

There are also allergic connections which include milk, eggs, citrus and salty foods. But the allergy-approach is difficult to put into practice. It is almost impossible to stay off these foods for long time periods. Eliminating bacteria and *Strongyloides* leads to a permanent solution.

Possibly the parasite wormlet comes first, since even young children can suffer with migraines. *Strongyloides* is a microscopically small threadworm that horses are plagued with, but humans and our pets pick it up easily. Every migraine sufferer (100%) has high levels of this tiny worm. Perhaps it is really the special bacteria it brings with it that cause the blood vessels to seep or to spasm in the brain, causing pain. Zap it immediately.

Bacteria hidden under a tooth filling or root canal or in a space where once a tooth was pulled can be the cause. *Staphylococcus aureus* is a favorite, but various *Clostridia*, *Streps* and others are often seen, too. You don't feel pain from this small abscess because the pressure isn't building up inside it. It has found a way into your body–namely, your brain!–so no pressure builds up to alert you. Find an alternative dentist with experience cleaning cavitations and finding small hidden abscesses. If you get immediate relief from dental work, only to lose ground again later, the abscess may have formed again (they are notorious for forming again). Go back to the dentist. Irrigate the dental wound site with white iodine (potassium iodide, 12 drops) or Lugol's (6 drops) to ¼ cup water using a curved-tip syringe.

Do not use iodine if you know you are allergic to it.

The colon is always a thriving mass of bacteria. It should be emptied at least twice a day to keep their levels down. Use the simple herb, *Cascara sagrada*, senna tea, or magnesium oxide tablets (2 to 3 a day) to help you eliminate frequently if your own regularity is lacking.

Gallstones in the liver and a congested liver are sources of bacteria, too. Do several liver cleanses and note the effect.

Is it the toxins made by bacteria or the inflammation from the bacteria or wormlets themselves that produces the headache? Certainly, one can eat the toxins by themselves in foods like yogurt, cheese, wine, sour cream and develop "royal" headaches. Stay away from these **tyramine** containing foods. Boil all your dairy foods to prevent *Salmonellas* and *Shigellas* from swimming into your beleaguered brain. Don't eat dairy foods that can't be boiled for ten seconds.

Begin by killing all *Strongyloides* and other parasites, bacteria and viruses with a zapper. Hopefully, this will only leave a few stragglers behind in abscesses, gallstones and the colon contents. If the colon bacterium, *E. coli*, is your headache cause, start the Bowel Program. Search for the source of your *E. coli* in food or polluted water. Stop reusing water bottles. Most people get their *Strongyloides* back in a few days from pets, other family members, and themselves! Zap every day for three weeks. Try to "clean up" family members and pets. Never let a horse or pet salivate on you. Never put your fingers in your mouth. Always sanitize your hands with grain alcohol after using the bathroom.

To summarize the steps to cure migraine headaches:

1. Kill *Strongyloides* and bacteria by zapping.
2. Do the herbal kidney cleanse.
3. Clean up dentalware.
4. Do the Bowel Program.

5. Boil all dairy foods.
6. Do liver cleanses.

This has never failed to substantially reduce migraine intensity and frequency.

Headaches are also caused by toxins in your environment; especially things you breathe in. Household gas is the most common offender. You don't smell it after you get used to it! Gas pipes are notoriously leaky. Conducting gases through pipes with joints in them, where gases could escape, must be the most ludicrous of all modern "conveniences". Would you try to conduct water through pipes with holes in them? You would soon see the water on your kitchen or bathroom floor. But gas doesn't land on the floor, it doesn't make a puddle, so you, the consumer, are left helplessly believing you don't have leaks. Every gas pipe that has a seam should have a clear plastic boot around it containing indicator compound to let it be known when gas is escaping. Other methods could be invented to make the gas utility safe. As you will see from the case histories, very many persons are living in a cloud of poisonous gas.

The telltale element is **vanadium**. When your vanadium test is positive, you have a gas leak that your body found, even though the gas company may not. Many gas companies use outmoded equipment to search for it. Four out of five gas companies miss the gas leak. Health Departments and building contractors use modern equipment that detects even the tiniest leak; call them.

If you are a headache sufferer, fixing the pipes is not good enough. Switch from fossil fuels to electric. There will be many dividends. (Remember not to use candles as part of your lifestyle, nor to be a smoker.) Your air needs to be clean: clean of perfumes and colognes, clean of potpourri and air fresheners, clean of air sprays, pesticides, formaldehyde, freon, carpet and car odor, fireplace lighter, and of wood smoke.

Janette Donovan, age 52, had migraines every day but could not tolerate any medication for it. She walked about “like a zombie” most of the time. She frequently had vomiting with them. She was gassy, had pain in her right groin for many years and chronic bladder leakage. Our kidney stone test showed urate crystals. Her urinalysis also showed urate crystals and a slight amount of blood, obviously chronic urinary tract infection. The parasite test showed *Strongyloides*, *Trichuris* and *Fasciolopsis buskii* in the intestines. Her heavy metal test showed beryllium. This was tracked down to hurricane lamps that once held coal-oil in them— it filled her house air unbeknownst to her. Thirty five days later she had done an herbal parasite killing program, done the kidney cleanse, cleared out the hurricane lamps and all fuel containers. Her headaches were “more like pressure” now than pain. She still had *Strongyloides*. Four months later she had some headaches still but not migraines. They were down to once a week. Three months after that she had done a liver cleanse and gotten abut 3,000 stones out! She was still getting some headaches. She tested positive to *Histoplasma* and *Coxsackie virus #4* (a common brain virus) probably stemming from dentalware. She had many root canals and couldn't decide what to do. Keep her teeth and risk return of migraines; or get partial dentures. After eight months of indecisiveness she was back up to ten headaches per month, although not migraines.

Patsy Olsen, age 30, had migraines daily, frequently with vomiting. She had *Strongyloides* as well as *Ascaris*, and other bowel parasites as did her husband and two children. She couldn't tolerate any medication and had to give herself an enema daily for constipation. The whole family was put on parasite killing herbs. A gas leak was found and fixed and the baby's diapers were changed to non fragrant. Ten months later, the whole family still had *Strongyloides*. By one year she was experiencing a couple of good days a month although she still had *Ascaris*, *Coxsackie* viruses, and various tooth-related bacteria. Her two and a half year old had swollen neck glands, was toxic with bismuth from disposable diapers but did not have *Strongyloides*. The eight year old was also toxic with the lotions and fragrance of baby-stuff in the home; she was constantly congested and coughing but became free of *Strongyloides* in six months. After another ten months (the baby had been

potty-trained meanwhile) the mother began to have headache-free days.

Donald Schaible, age 14, had migraines, learning disabilities and severe acne. The parasite test showed *Strongyloides*, *hookworm* and *Ascaris*. In spite of being on the parasite program two weeks and zapping, he still had *Strongyloides*.

Kenneth Jones had migraines for thirty five years and had tried all the new medications. They worked for a while, then stopped helping, but he continued taking them anyway. He usually went to the emergency room for the really bad ones, once a week but lived with the constant daily variety. There were two house dogs. They and the whole family had *Strongyloides*. After cleaning up an asbestos problem, killing parasites for five months and clearing kidneys of urate stones, he was down to two to three mere headaches a week. Two months later, he was getting migraines again; they all had *Strongyloides* again. With renewed efforts, one month later his bad headaches were down to one a month, although his low level chronic headache persisted: they had the dogs on a strict schedule of parasite killing herbs as well as themselves. He had not been to the emergency room for a month.

Angelina Gander, age 46, had daily headaches, not migraines. She also had persistent urinary tract infection and sinus infection. She was put on the herbal parasite program and four weeks later was much better. She also lost her chest pain due to heartworm and regained her milk tolerance.

Gracie Arlington had a boy age 6 who wet the bed, a girl age 8 with a behavior problem at school. She was stressed by an unfaithful spouse and thought she should go back to school for a Nursing degree so she could support the family. But she was getting two or three migraines a week in addition to colitis attacks which she feared would make her unable to study. The two cats, a dog, the children and herself all had *Strongyloides*, *Ascaris*, and a variety of other intestinal parasites. The humans were promptly zapped for parasites and the boy was dry that night for the first time in his life. A few nights later he was wet again. This time the animals were zapped and put on the pet parasite program and the children's toileting was carefully supervised. When she dropped her extreme vigilance over all, they all relapsed. After a year of trying, they gave away their beloved dog, put the cat box in the porch

and the mother did the cleaning herself but nothing prevented relapses. A half year later, her six year old son asked if he could launder his own sheets and blankets. This request broke her heart and she planned to give away one cat. Even with only one cat, the girl's behavior and grades fluctuated extremely, the mother had a migraine a week and the boy wet. During a vacation the mother loaned the last cat, (her cat) to which she was very endeared, to a friend, to see if it made a difference. The boy never wet again, the girl made straight A's, and the mother's headaches became sinus headaches. Some intensive dental work cleared these up. She brought her Nursing diploma to our office two years after beginning. She should have had another diploma for **Intelligent Parenting.**

Earache

Earache is particularly common in children. Bacteria, mainly *Streptococcus pneumoniae*, have built up to a high level. Zap them. They were probably introduced by some larger parasite. But why did they multiply and thrive in your child's ear? There must have been food for them and protection from the immune system. Probably the Eustachian tubes are full of mucous, providing habitat. The mucous is present because some air toxin is irritating the sensitive linings. Clean up the air: not just asbestos, fiberglass, formaldehyde, freon, and arsenic, but perfumes, fragrant school supplies, potpourri.

Being housebound, as in winter, makes the air-toxin problem worse. Use summer time to strengthen your child for the winter—spend summer outdoors. Always wash hands a lot. Stay away from moldy food. Give small doses of niacin (25 mg., niacin thins mucous so it can run away) along with vitamin C (250 mg.) at bedtime.

Putting in “tubes” is a short term solution that is better than perpetually staying on antibiotics, but neither should be necessary.

To hasten healing, as soon as earache is suspected put room temperature olive oil in both ears, tug the earlobe to let bubbles out, and stopper them with cotton wool salvaged from vitamin bottles (other types are polluted with mercury). Put on a light bat that covers the ears.

When adults get earache, the *Streps* are hiding under tooth fillings and in gallstones. Clean up these two sources and zap.

Drinking non sterile milk adds *Salmonellas* and *Shigellas* to the *Strep* ear infection! Small wonder milk is thought to make people mucousy. The ears must now battle them, too. Even a few bacteria consumed in milk can start a whole colony if bowel bacteria have been disturbed by antibiotics. If your child has become "allergic" to milk or gets mucousy, remove cheese and ice cream–not milk–from the diet. Even cheese can be eaten if baked as in pizza or casseroles. Milk must be boiled. Try to reduce the child's *Salmonella* sensitivity by avoiding unnecessary antibiotics. Keep immunity high by avoiding moldy food!

Ear Noises And Ringing

This is also called *tinnitus*. A hissing or buzzing sound is heard in one or both ears. It can be continuous or pulsing off and on. It can be as loud as roaring.

Tinnitus is caused by three things acting in partnership: toxic elements, an allergy to *salicylates* (the aspirin family) and a bacterium *Streptococcus pneumoniae* (the pneumonia bug). This "bug" can be carried in the chronic state after a bout of pneumonia or what seems to be a head-cold. It is always present in earache. It is easily activated by exposure to cold wind or drafts and certain toxic substances. For this reason I recommend keeping the ears warm in winter by keeping them covered or wearing a cotton plug or ear-muffs. The *Strep* bug can also cause *Meniere's syndrome*, congestion, loss of balance and

chronic sinus problems. Often an antibiotic of the penicillin family helps immediately, then loses its effectiveness. This shows you that bacteria are involved but cannot be truly vanquished with antibiotics.

Streptococcus pneumoniae often hides in pockets under infected teeth and in holes left where teeth have been pulled—especially wisdom teeth. These can be found by alternative dentists who clean these cavitations. *Strep* also resides in the liver; clean them out with liver flushes.

Certain foods and many medicines, especially cough medicine and lozenges contain salicylate.

To cure the tinnitus we must stop using aspirin or any high level source of salicylates. We must also stop the exposure to certain toxic elements—lead, beryllium, zirconium, benzalkonium. They are present in the air at gas stations and in many of our body lotions, soaps and salves. Switch to safe varieties. Niacin tablets, such as 100 mg, taken three times daily is another treatment, intended to increase the blood supply to the inner ear. Taking a thyroid tablet, by prescription, often helps too.

These methods never fail to improve tinnitus but a complete cure is seldom possible.

William Thall, 47, had a headache daily and was on pain medicine for it daily. He had tinnitus, a loud humming noise in the right ear. He had *Shigella* (producing nerve toxins) and *Borellia* (Lyme disease virus). He had *Gaffkya*, a respiratory bacterium under two wisdom teeth (right side). He also had *Campylobacter* and *Anaplasma* growing on him somewhere. He had *Strongyloides* too. He was toxic with vanadium (gas leak) and asbestos. After ten weeks he had two cavitations on the right side of his jaw cleaned, he had been on the parasite program and his tinnitus was gone, (he still had occasional headaches indicating he still had some *Strongyloides*).

Billie Scott, 26, had a history of ear problems, and lots of headaches. She was started on the kidney cleanse. Then she added the parasite program including their two dogs. She had a cyst in her

left buttock, due to PCBs traced to the well water. She stopped using this well and switched off detergents for laundry and dishes. She switched off soda pop, onto milk. In 3½ months her tinnitus was gone and the cyst was shrinking.

Larry Pelegrini, 59, had tinnitus in both ears but was otherwise a strong, tall, intelligent person, who cared for sick people, whether family or not. As soon as he saw how simple it was to kill invaders with a frequency generator, he bought one. Preventing their recurrence was his big challenge since he had neither the means nor insurance to do dental work. He was toxic with aluminum, copper and PCBs. After switching to borax for all washing purposes, he got rid of aluminum and could feel his memory improve. The kidney herbs cleared him of uric acid and oxalate and he felt more supple. He had to go off his favorite beverage to get rid of pentane and methyl ethyl ketone. Twice a week he killed two dozen parasites and bacteria, that just seemed to pop up from nowhere, in order to feel better and reduce his tinnitus. But he lived alone, had to cook, garden, take care of animals and his sick friends which gave him a lot of parasite exposure. Sometimes he would be toxic with arsenic (a new pesticide he tried out) or vanadium (gas leak) but mainly it was tooth filling metal. If only this wonderful man could afford his dental work: what a blessing to society he could be for a long time to come.

Scalp Pain

Infection anywhere in the head can cause sensitive scalp and scalp pain. Even a common cold can cause bouts of scalp pain. Clean up your dentalware and environment.

Lumps on the scalp are often called *sebaceous cysts*, actually this is where your body has sequestered PCBs (polychlorinated biphenyls, extremely hazardous, now banned in the U.S., but often a pollutant in detergents.) Get rid of them by switching off detergents for all purposes. See *Recipes* for dishwasher liquid, dishwasher detergent, and laundry detergent replacements.

Non-Painful Diseases

Explanations for many of these "mysterious" diseases become rather obvious when you see a **common parasite, or pollutant, or both** consistently show up in case after case.

Diabetes

All diabetics have a common fluke parasite, *Eurytrema pancreaticum*, the pancreatic fluke of cattle, in their own pancreas. It seems likely that we get it from cattle, repeatedly, by eating their meat or dairy products in a raw state. It is not hard to kill with a zapper but because of its infective stages in our food supply we can immediately be reinfected.

Eurytrema will not settle and multiply in our pancreas without the presence of **wood alcohol** (methanol). Methanol pollution pervades our food supply—it is found in processed food including bottled water, artificial sweetener, soda pop, baby formula and powdered drinks of all kinds including health food varieties. I presume wood alcohol is used to wash equipment used in manufacturing. If your child has diabetes, **use nothing out of a can, package or bottle** except regular milk, and no processed foods.

> By killing this parasite and removing wood alcohol from the diet, the need for insulin can be cut in half in three weeks (or sooner!)

Be vigilant with your blood sugar checks. The pancreas with its tiny islets that produce insulin recovers very quickly. Even if 90% of them were destroyed, requiring daily insulin shots, half

of them can recover or regenerate so insulin is no longer necessary. The insulin shot itself may be polluted with wood alcohol (this is an especially cruel irony—the treatment itself is worsening the condition). Test it yourself, using the wood alcohol in automotive fluids (windshield washer) or from a paint store, as a test substance. Try different brands of insulin until you find one that is free of methanol.

Artificial sweeteners are polluted with wood alcohol! Instead of helping you cope with diabetes, they are actually promoting it! Do not use them.

Drugs that stimulate your pancreas to make more insulin may also carry solvent pollution; test them for wood alcohol and switch brands and bottles until you find a pure one. You may not need them much longer, so the extra expense now may soon reward you.

Many persons can detoxify the amount of wood alcohol that pollutes our foods. They do not have a food mold, **Kojic acid**, built up in their bodies as diabetics do. I have found Kojic acid in coffee, and potatoes with gray areas inside. Do not eat discolored potatoes or peels, even if cooked or baked. Being able to detoxify a poisonous substance like wood alcohol should not give us the justification for consuming it. All poisons are bad for us. Do not consume them.

All diabetic persons also carry a virus, *HA virus* in the pancreas. This virus grows in the skin as a wart but is spread quite widely in the body such as in the spleen or liver besides pancreas. It is not necessary to kill this virus since it disappears when the pancreatic fluke is gone. The HA virus undoubtedly belongs to the pancreatic fluke. The question can be asked: Does the fluke or its virus cause diabetes? There might even be a bacterium, so far missed in our observations, that is the real perpetrator.

While recovering from diabetes, it is very important to check your blood sugar every day. Improvement is so rapid, you may suddenly be over-insulinized by your next shot. Cut down your dose to suit your actual need.

There are additional aspects to diabetes that have been studied by alternative physicians. For instance, allergy to wheat and other grains containing gluten is common. Perhaps the pancreas and its islets would heal much faster if grains were out of the diet for a while. Perhaps the 50% improvement that is consistently possible just by killing parasites and stopping wood alcohol consumption could be improved further by a month of grain-free diet. Eating **fenugreek seeds** has been reported to greatly benefit (actually cure) diabetes cases. Are they a specific fluke killer, virus killer, or neither? It seems like a good idea to add this to your diet if you are a diabetic. Wood alcohol also accumulates in the eyes, and there is a connection between diabetes and eye disease. **Bilberry leaves** are an herbal treatment for both diabetes and weak eyes. Do they help by counteracting wood alcohol or detoxifying Kojic acid? Make a tea for yourself, using ¼ cup leaves to three cups water. Drink ½ cup a day. Chromium is another must for diabetics (200 mcg three times a day). It helps insulin enter your cells.

Gold is attracted to the pancreas. Heavy metals should be removed from dentalware including all gold crowns and no metal should be worn next to the skin as jewelry, including all gold items.

Blythe Jenkins was on Micronase™ (5 mg) daily for her diabetes but she still had a morning blood sugar of 183. She had pancreatic flukes and sheep liver flukes in her pancreas, vanadium (a gas leak) in her home and cadmium in her water (old pipes). After killing parasites and cleaning kidneys her morning blood sugar was down to 148. She also got rid of her hot flushes, groin and leg

pain. This encouraged her so much she did the rest of her body cleanup and could go off her medicine completely.

Robert Greene, age 65, had been on insulin five years already, getting two shots a day (25 u each), and even this was not controlling his blood sugar which was 288 in the morning. He was raised to 30 units without much improvement. His legs and feet were too painful to walk without a walker to lean on. He had *Loa loa* in his pancreas. (This is another example of a parasite going to the "wrong" location, this time the pancreas instead of the heart. I believe the solvent makes this possible.) Also *mumps virus*, *HA wart virus*, *mycoplasma*, *flu virus*, *chicken pox virus*, *Adenovirus* and *Shigella*, all making their home in his pancreas! This was possible because he had wood alcohol accumulated there, from drinking various beverages and using artificial sweetener. As soon as he stopped this practice and killed everything with a frequency generator his blood sugar fell below 100 in the morning and he had to reduce his insulin to 20 units. He was also on chromium 200 mcg (2 three times a day). Meanwhile, he cleared 2,000 stones out of his liver. He could now walk well again and decided to take a part time job. The whole process took one year.

Ralph Dixon, age 72, had been switched to 30 units of insulin, once a day, after six years on pills for his diabetes. He still had a fasting blood sugar of 242. He had the pancreatic fluke and a host of bacteria and viruses in his pancreas. He had a poodle. After killing the pathogens and cleaning his kidneys, his blood sugar dropped so he cut his insulin to 25 units (blood sugar was at 111) Soon he had to cut it to 20 units. He was also on chromium 200 mcg (2 three times a day), manganese 50 mg. (one a day), fenugreek capsules (2 a day), and bilberry leaves, each supplement by itself. He also lost his angina and fatigue with all this body-cleaning. But if he went off the maintenance parasite program he would promptly get a spike in his blood sugar, showing how easy it was for him to reinfect and how new parasites would immediately find his pancreas.

Melissa Bird, 54, had major illnesses including heart disease (2 angioplasties), numerous other surgeries and diabetes. She took 15-18 units of insulin once a day. Besides pancreatic flukes in her pancreas, she also had intestinal flukes there(!) plus widespread *Ascaris*. She also had warts and candidiasis. Fortunately there

were no pets. Her parasites were instantly eliminated with a frequency generator and she was started on kidney herbs for her other problems. Seven weeks later she stated she had to cut down her insulin because her morning blood sugar had dropped to 90. Then she eliminated the decafs and artificial sweetener that were giving her wood alcohol, started the parasite herbs and did a liver cleanse. The day after the liver cleanse her blood sugar went up to 164 but was completely normal after that (under 100) and she did not dare take any more insulin or pills. We advised her to keep monitoring her blood sugar and be very, very vigilant and to please stop smoking.

John Angert, 65, was not on any medicine in spite of his diabetes. He was too embarrassed to tell us his blood sugar. He had a long list of other health problems, too. He was toxic with thulium (vitamin C) and palladium (from tooth fillings). He had a variety of parasites. After doing some dental work and parasite killing his fasting blood sugar dropped to a normal 98. But his leg cramps kept returning in spite of doing a kidney cleanse. Only after changing his diet to include milk did the phosphate crystals stay away and eliminate his cramps.

Cornelius Edens, age 33, came for his diabetes, although he also had fatigue, digestion problems, and headaches. He had numerous other minor symptoms like chest pain over the heart, soreness in testicles, etc. His diabetes was only diagnosed one year ago. he was on insulin (Humulin™ 20 long acting plus 6 regular units) in the morning. He often omitted the evening dose which should be 14 long plus 6 regular. This brought his fasting blood sugar down to 166 in the morning.

He had pancreatic flukes in his testicles besides in his pancreas. His aflatoxin level was very high; he was told to stop eating grocery store bread, eat bakery bread only. He had silver, nickel and very high levels of gold–probably all three coming from his gold crowns–he was to have them all replaced with composite. He had fiberglass in his pancreas. Wood alcohol was present in large amounts in his pancreas as expected. He was to stop drinking all store bought beverages, whether frozen, powdered, or ready to drink. He did not test positive to benzene, propyl alcohol, *Salmonellas*, *Shigellas*, or *E. coli*. But he had *Staph aureus* growing at high levels in his pancreas. The usual source for this is in teeth,

so he was told to ask his dentist to search for cavitations and clean up hidden tooth infections while replacing the gold crowns. He was to find the exposed fiberglass and seal it off. He was to zap parasites every other day for 1 month. His supplements were vitamin C (1 tsp. with each meal for constipation; then 1 tsp. daily), vitamin B-50 complex (2 per day), thioctic acid (2 per day). He was to start the Kidney Cleanse recipe for his testicle problem, and after 6 weeks do a Liver Cleanse. He was to follow up with us in 3 weeks, after dental work was completed. He never returned. Four months later we received a phone call he was too embarrassed to make himself. He needed no insulin and was doing fine. Another 3 months later he was still doing well, and off insulin.

Prediabetic

Alyce Dold, 64, came because she was worried about her blood sugar and chest pain. Indeed, a blood test showed her fasting blood sugar to be 136, just beginning to show insufficient insulin production by her pancreas. She had pancreatic flukes and wood alcohol there. Also *mumps virus* and *HA virus*. She had six more solvents accumulated due to eating raisin bran and other cold cereals each day. She was glad to be forced off this routine: she switched to 2 eggs every other day with biscuits or bread (not toast) and cooked cereal in between. Her chest pain was due to dog heartworm and *Staphylococcus aureus* bacteria that originated at teeth #16, 17, 1, 32. The worms and *Staph* were killed with a frequency generator. She was referred to a dentist for cavitations and started on kidney herbs. Two weeks later, there was still a little residual heart pain due to *Staph*; dental work was not yet done. She was given chromium (600 mcg per day) to help her insulin regulate sugar. Her LDH (See tests) was still high from the recent heart stress, no doubt. But she had accomplished a lot and planned to get it all done.

Diabetes Of Childhood

The problem is the same for diabetes of childhood as for diabetes of later onset, but much easier to clear up, provided the whole family cooperates.

Wesley Evanco, age 6, had his onset at age 11 months. Prior to that he had chicken pox and his baby shots. He had pancreatic flukes and their reproductive stages in his pancreas as well as wood alcohol. He had no other solvents accumulated. The problem was clearly due to these two enemies of his small body. Wesley's father did not have pancreatic flukes but his mother had very high levels, along with wood alcohol. She had to clear hers up before Wesley could recover. She chose not to. She couldn't believe the connection. Our most persuasive efforts were not successful. We hope Wesley can forgive us all in due time.

Herpes

The *Herpes* family of viruses includes *Herpes Simplex Virus* (HSV) 1 and 2, *Epstein Barre Virus* (EBV), *shingles or Chicken Pox* (*Varicella zoster*), *Cytomegalovirus* (CMV) and some newly discovered ones.

Herpes simplex virus 1 is the virus that breaks out around or inside the mouth. We call it a cold sore because it often follows a cold in childhood. As children, we may get HSV 1 once or twice each winter. When they come more often the child's immunity is low. Adults who get repeated attacks also have low immunity (this is obvious from a blood test where the white blood cell count is less than 5,000 per cu mm).

Herpes simplex virus 2 breaks out in the genital area. It is often blamed on promiscuous sex but I believe it has quite different origins.

I believe the virus is introduced to our bodies by another large parasite. Perhaps it is pinworms, or *Ascaris*. Perhaps it is a tapeworm stage, picked up from dust and dirt.

I have some evidence that it is released from dog tapeworm stages when these are being killed by your immune system. It is probably the same tapeworm stage as releases the *Adenovirus* (cold virus) which would explain why children frequently get

"cold sores" during or after a cold. (See Curing The Common Cold, page 357.)

Nevertheless, you would not get sick from these viral releases unless your immunity was lowered.

Herpes lives in your nerve centers (*ganglia*) and it is from here that you can be attacked after the initial infection. Evidently your immune system can destroy them as quickly as they emerge. But a meal of **aflatoxin** or other **moldy food** suddenly "gags" your white blood cells and lets a viral attack happen.

The viruses can also be "triggered" which lets them out of hibernation (latency) to multiply and travel along the nerve fiber to the skin. Triggers are things that put these nerve centers to work: sudden cold and heat, trauma from chafing and friction. Never drink water with ice cubes in it. Never eat hot soup with a metal spoon. Don't tweeze hairs.

Begin your prevention program by raising the immunity of your skin; this means removing all toxins from the skin. Use only natural lotions, softeners, cleansers on your skin made from recipes in this book. Health food brands are <u>not</u> superior. This will get rid of nickel, chromate, titanium, zirconium, aluminum, and benzalkonium from your skin and probably your whole body! Do laundry with borax and washing soda, only, to eliminate commercial detergent as a source, too.

As soon as you feel that warning tingle or sensation of *Herpes*, zap or use a frequency generator at 293 and 345 KHz (HSV 1) or 360 and 355 KHz (for HSV 2). Immediately take a **cayenne** capsule and 8 **lysine** tablets (500 mg each). The cayenne slows down travel of the virus along the nerve.

Attacks probably occur when the triggers act at the same time as an immune drop occurs. Immune drops happen frequently due to eating moldy food. Of course, mercury in amalgam tooth fillings keeps immunity chronically lowered. Many persons report they stopped breaking out with *Herpes 1* after

replacing their amalgams. Stopping wearing tight synthetic underpants helps reduce *Herpes 2* out breaks.

When you get an outbreak, mop up a droplet of the blister fluid and prepare it as a specimen for yourself. If you search for it in your white blood cells when your attack is over, it will not be found because it is in hiding inside your nerve cells. Zapping does not reach them inside your own cells. Nevertheless, you can totally eliminate them by repeated zapping provided you kill them at their earliest warning. Evidently, they haven't multiplied yet, so gradually their numbers go down.

Even after you have been *Herpes* free for a long time, stick to your preventive principles. Avoid the trigger foods, peanuts, and chocolate, or be ready to zap. Avoid cold wind or direct sunlight on your face. Don't eat abrasive or acid foods like popcorn, nuts, toast, crackers, candy, citrus. Although you may stop the virus in its tracks by zapping, healing the lesion takes time. Keep the skin softened with a cornstarch or sodium alginate recipe (see *Recipes*).

A lysine mush helps too: crush a lysine table with a large wooden spoon, add a pinch of vitamin C powder and a pinch of zinc oxide. Save part of this mixture for later use. Wet a small bit of it with a few drops of water to make a paste. Apply to lesions.

Bazezew Hailey, 38, started breaking out in the genital area after a period of antibiotic use. She was started on lysine (500 mg, 8 a day), cayenne caps (one with each meal). She was to fill her prescription for Zovirax™ from her doctor, though. By the time she had it filled, the next day, her lesion had stopped enlarging, and she could reduce her supplements. Her skin was full of mercury, lead, strontium, aluminum. Her white blood cell count was low, showing low immunity. Her ratio of segmental to lymphocyte white blood cells was low, evidence for a chronic viral condition. Her bone marrow contained lead and radon. She stopped using toothpaste (strontium), salt, deodorant, detergents (aluminum). She got the metal out of her mouth and eliminated her radon problem by opening crawl space vents. The lead source was never found, but

after she moved to a new house it went away. *Herpes 2* stayed away. A year later she still hadn't opened the Zovirax™ bottle.

Fatigue

Fatigue, whether minor or extreme, is always associated with blood sugar disturbances. The more disturbance, the more fatigue. We have three organs that do most of the sugar regulating: our **adrenals**, the **liver**, and the **islets in the pancreas**. In severe fatigue, that keeps you partly bedridden, all three organs are heavily parasitized. *Epstein Barre Virus* (EBV) is running amok in your body, as a rule, even when clinical culture techniques cannot find it. With your frequency generator and Syncrometer you can find it emitting at 380 KHz. Killing the viruses is not as important as killing the larger parasites and getting your organs functioning for you again. The viruses will go away by themselves.

The liver's role in blood sugar regulation is to get it out of storage when needed. When sheep liver flukes have taken up residence they're spewing their chemicals as well as their own bacteria and viruses into your circulation; it is surprising that the liver has any sugar in reserve and can function at all. Sheep liver flukes are commonly seen in fatigue syndrome cases.

The adrenals (the outer layer called the cortex) help to regulate the blood sugar in a complex way. Some adrenal factors influence the thyroid which is another energy-related organ. Both adrenals and thyroid have toxic buildups in fatigue cases! Their work is hampered.

The heart of sugar regulation is in your pancreas in the tiny islands of cells that secrete insulin, called the *islets of Langerhans*. Here we always find the pancreatic fluke in residence. It actually breeds there when wood alcohol accumulates in it. Wood alcohol is a common pollutant of food, even in artificial

sugar which is often recommended to replace real sugar and spare the pancreas. There is wood alcohol in store-bought drinking water, fruit juice, powders meant to be stirred into beverages, even if they are health food varieties. It's probably being used to clean tubes and hoses in the manufacturing plant. The only beverage you can safely buy (not safe unless you sterilize it, though) at a grocery store is milk. Make your own beverages using recipes in this book.

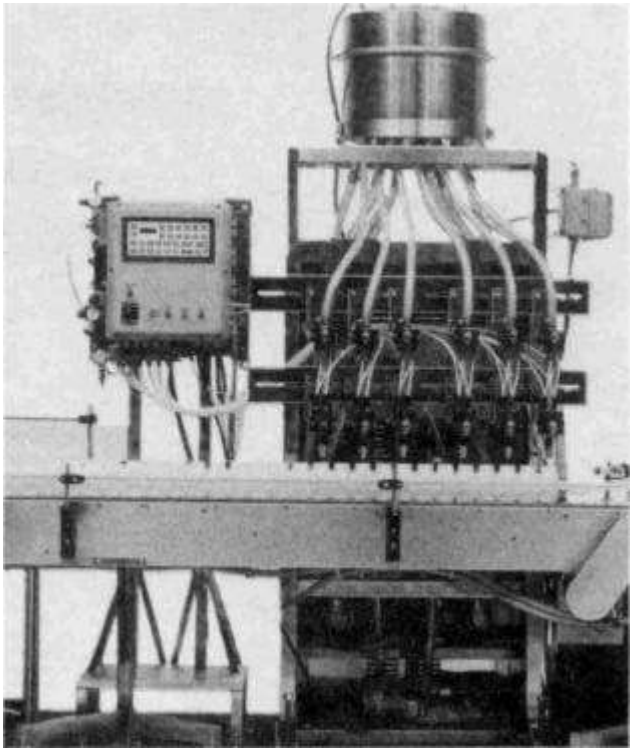

Fig. 28 Bottling equipment should be rinsed with ethyl (grain) alcohol, not propyl alcohol or wood alcohol.

Your first step toward curing your fatigue syndrome is to kill the pancreatic fluke and all other living invaders of the pancreas, liver, adrenals and thyroid. Use a zapper. Drink milk or

buttermilk for several days afterward to provide lactic acid for the "good" bacteria to feed and recover on.

Your second step is removing metal from your mouth, particularly gold. Gold from teeth and jewelry readily goes to the pancreas! Do everything in the *Easy Lifestyle Improvements* chapter.

Your energy can bounce back in a few weeks by attending your liver, adrenals and pancreas. Help these organs heal and grow strong again. Avoid food molds (read Moldy Food, page 381). The most powerful assistance to the liver is a cleanse. This will eliminate liver viruses such as EBV and *Cytomegalovirus* (CMV). Be patient. Do it on a schedule until you have over 2,000 stones out. Take **vitamin C** at least 3 gm/day, to help both liver and adrenals. Take **B_2** and **B_6** to help adrenals and kidneys. Take glucose tolerance factor, **chromium** (two 200 mcg tablets 3x/day). See *Sources* for all of these. Take these supplements for three weeks, then cut the dose in half, and take on alternate days only, as a hedge against possible pollution in these.

Although your energy may be normal in three weeks, you are at higher risk for fatigue than the average person. Reinfection with anything will put the new parasites right back where the old ones were. Other bacteria, solvents and toxins will head for the pancreas, liver and adrenals again because these are weakened organs. It could take two years to build your health to its previous level, but is well worth it to have youth, initiative, and a beautiful appearance again. Going back to school is a good use of your time when your initiative has returned but your physical strength is still not up to housework or a job. When your energy comes back to you, it is tempting to overwork: to clean the whole house or to get into some gardening.

It is better to be moderate today than in bed tomorrow.

Anyone who has suffered from Chronic Fatigue Syndrome (CFS) or recurrent EBV has learned that lesson well.

June Timony, age 38, was diagnosed with Chronic Fatigue Syndrome), EBV and *Candida* around 1½ years ago by her family doctor. She also had a thyroid problem and a high estrogen level (165 pg/ml). She had severe depression at times. Our test showed her body was full of bismuth (fragrance) and silver (tooth fillings) especially in the ovaries. She cleansed her kidneys and killed parasites but could not make up her mind to do the expensive dental work.

Janice Brown, age 21, had EBV with chronic fatigue and depression along with a dozen more symptoms. Her skin, kidneys, breasts, brain, ovaries and pancreas were all loaded with mercury, platinum and other metals. She was full of radon and bus exhaust and the plumbing was shedding cadmium. Rather than do all this she and her husband decided to move. Before the moving date arrived she had cleansed kidneys, killed parasites and done dental work and was feeling noticeably better. Then they moved. She immediately was very fatigued again and worried that the move had been in vain. This time she had a liver full of Salmonella and a return of phosphate crystals in her kidneys. But it was easy to clear up and it was a very useful lesson to her to avoid unsterilized dairy products. She was much more careful after this.

Dee Safian, age 36, came especially for her low energy. She had EBV once. It left her extremely nervous. We advised going off caffeine but not substituting for it by drinking decafs. Her tissues were full of arsenic from pesticide; her urinalysis showed kidney crystals and her eosinophil count was high 5.5% (parasites). She had sheep liver flukes and stages in her pancreas due to a buildup of wood alcohol there. In four months after killing parasites and doing a kidney cleanse she was much improved.

Josefina Linzer, age 32, came for her fatigue and depression. Her tissues were full of arsenic, PCBs, chromate (eye makeup), mercury, yttrium, radon and terbium. She needed tooth metal replacement but could not schedule it immediately. She had *Ascaris* and pancreatic flukes in her pancreas and reacted to sugar in her diet quite strongly, so avoided it. She also had *Strongyloides* and *Trichinella*. She killed all these with a frequency generator and started on the kidney herbs. Her wood alcohol buildup was coming from carbonated beverages. She went off. In 6 weeks she had done everything except the mercury removal and was feeling much better.

Brigette Dawn, age 21, had Chronic Fatigue Syndrome with EBV, along with other problems. She cleaned her home and cleansed kidneys, killed parasites, and did two liver cleanses. Still the fatigue would return two days later. Meanwhile, though, her infertility problem got solved (she got pregnant) and this encouraged her to continue the battle against fatigue after the baby was born.

Hector Garcia, age 14, was getting gamma globulin injections every three weeks for his chronic fatigue syndrome. He had pancreatic flukes in his pancreas, sheep and human liver flukes in his liver and intestinal fluke in his intestine. He had a buildup of benzene, propanol, and carbon tetrachloride as well as aflatoxin from his granola breakfasts. He also had *Candida* and measles in his white blood cells. He killed parasites with a frequency generator and went off the solvent polluted items in the propyl alcohol and benzene lists. He immediately (in 20 days) felt much better.

Dana Levi, age 16, had chronic fatigue syndrome and dizziness; he was not in school. He had pancreatic fluke in his pancreas, sheep, human and intestinal flukes in his liver! Both benzene and propyl alcohol were present in his immune system. As soon as the parasites were killed (with a frequency generator) and he changed a lot of his products, he felt better but soon lost his improvement. At the next visit, our tests showed a buildup of vanadium (from burning candles in his bedroom). When he stopped this, he was better again for a while only to relapse again. His propyl alcohol level was up as was aflatoxin. But getting a taste of normal energy gave him the determination to get himself well! He embarked on a liver cleanse program and still more careful food selection.

Dennis Dillard, age 16, was beginning to do poorly at school due to fatigue. He had to stop athletics although his regular doctor pronounced him well. He was also getting chronic sinus infections. His lungs and trachea had accumulated seven heavy metals: vanadium, palladium, cerium, barium, tin, europium, beryllium. His fasting blood sugar was low (73 mg/DL) and LDH very low (90 u/L; it should have been 160). The body makes LDH in response to lactic acid levels. When the muscles aren't making much lactic acid from their normal metabolism, LDH levels will fall too. Was he developing a muscle disease? The gas leak was fixed (vanadium), the garage was sealed off from the house to eliminate barium and beryllium but the other toxic elements came from his dental retainer. As soon as his retainer came out, and they stopped using flea powder on their dog, his energy became normal and sinuses cleared up. A year later he still had not been ill.

Evelina Rojas, age 12, was having extreme fatigue with mood problems and sudden fevers. She killed *Ascaris* and sheep liver flukes with the parasite program but promptly got them back due to a benzene buildup I believe due to using products containing an herbal oil. Her high levels of *Streptococcus pneumoniae* (cause of fevers), *Staphylococcus aureus* and *Nocardia* could not be eliminated until her three baby teeth (with root canals) were pulled. After that, she was well.

Elaine Perkins, 48, came specifically for her low energy and nervousness. She was toxic with arsenic, a substance that replaces energy with nervous excitement and exhaustion. She also had a backlog of antimony (using baby oil), aluminum, rhenium (hair spray), benzalkonium (toothpaste) and radon. In four months, she had the arsenic and three other toxins eliminated and already had more energy.

Neil Youngblood, 53, was so fatigued, he had to brace himself even while sitting. A blood thyroxin level (T_4) of 1.0 instead of the normal 7.5 mcg/DL explained his fatigue. He had a mouthful of assorted dental metals which were accumulating in the thyroid, inviting viruses, particularly CMV, into it. He had to be on four grains of thyroid to feel near normal. After he had all his tooth metal removed, he only needed one grain to feel O.K. This encouraged him to clean up more of his body.

Scott Pennington, 50ish, was on thyroid medicine for his hyperthyroidism. He had been on iodine-radium earlier. He had the *miracidia* of the intestinal fluke, sheep liver fluke, and pancreatic fluke in his thyroid! Adult human liver flukes were also there! His thyroid was toxic with iridium, nickel, tellurium and mercury (metal tooth fillings) and decane, TC Ethylene and pentane solvents. He had been drinking a great deal of regular tea, which let oxalate crystals deposit in his kidney and slow down the excretion of toxins. The parasites were killed with a frequency generator, he changed his diet to get rid of solvents. In two weeks he was feeling better, had more energy and better sleep. This encouraged him to do the dental work.

Skin Problems

Sebaceous Cysts

Your body, in its wisdom, keeps toxins together and out of harm's way by making a cyst out of it. All the *sebaceous cysts* I have seen are filled with *polychlorinated biphenyls* (PCBs).

Get rid of PCB sources in order to clear PCBs from your body. This can take 6 to 12 months. Change all detergents (for dishes, laundry, and body use) to borax and/or washing soda.

Commercial detergents are wonderful cleaners...

but are unquestionably toxic. Whether you have cysts or not, it is always a good idea to use borax and washing soda instead.

If you have a particularly visible cyst, try to poultice it to the surface. Washing away some of it would be a great help to your body. Read herb books on poultices or just take whatever wild

leaves you can gather; make a mush out of them with a blender, mix with honey or homemade skin softener to make it spread like peanut butter and cover the cyst with it night and day, covered with a piece of plastic. The wetness has drawing power. The plant juices have other benefits. If you can't poultice and must rely on kidney excretion, be sure to take kidney herbs at the same time.

Skin Rash

Rashes can be caused by many things. To find the cause, follow a logical pattern. It may be due to:

- HIV
- Yeast and Fungus
- Allergy
- Childhood Diseases (rubella, etc.)

HIV is the most alarming possibility. Eliminate it first by testing for it. It's often too early for a clinical test to be positive for HIV, so use the Syncrometer (page 457). I often see the rash disappear within days of eliminating the virus.

Probably the most common cause of rash is **yeast**. *Candida* has a resonant frequency of 384-388 KHz. If you test positive for it, stop all commercial soap and detergent for all possible uses. Zapping *Candida* may drive it away for a few days. The fungus is hosted by another parasite but finds your skin quite satisfactory for a home, at least while your skin immunity is low. It may be low from wearing metal jewelry, having metal tooth fillings, aluminum (from lotions and soaps), cobalt (from shaving supplies), and zirconium (from deodorant.). When all these are removed, the skin will dry up quickly in open air or under a heat lamp.

In babies' skin, immunity is low from diaper chemicals (mercury and thallium), wipes, and soap and detergent chemi-

cals. Tight fitting, mercury treated diapers are a modern atrocity. Always line them with a tissue and keep them loose fitting.

The skin that has rash or fungus should be dried with paper towels, unfragranced and uncolored, in order not to contaminate the cloth towels, and thereby transport the tiny infectious spores to other skin locations. You may use skin healers.

Only the skin healers given in *Recipes* are safe to use. Keep them refrigerated when not in daily use. Commercial lotions, including health varieties, all contain toxic ingredients.

Fig. 29 Tight diapers are a modern atrocity, forcing mercury and thallium into the baby's sponge-like skin.

Many adult rashes are due to **allergies**. Allergy to nickel is common, the reaction is easiest to see under rings or watches. The metal is pulled into the body for elimination. Since nickel is used by so many bacteria, especially urinary tract bacteria, it doesn't get eliminated, it gets taken up by bacteria. It also piles up in kidneys, adrenals, bladder and prostate where bacteria thrive on it. Strangely, it also accumulates in the male scalp (and in women's scalps who have male pattern baldness).

Allergy to strawberries, perfume, deodorant or chlorinated water, however different they are, can all be expressed the same way, in a rash. The liver has refused (been unable) to detoxify the chemicals in these items and allows them to circulate in the body. Not for long, though, since great damage could be done to brain and other tissues. Mercifully, the skin grabs these chemicals into itself. Ultimately, it must still be removed. The allergic reaction and your immune system come to your skin's rescue, although bringing you discomfort.

Why didn't the liver detoxify the chemicals given to it? The answer is based on a simple experiment. Try cleaning your liver (page 552) several times or until 1,000 bits of refuse have been washed out of the bile ducts. This relieves the back pressure on that part of the liver, and allows it to do its work again. The physiological details are not understood. Fortunately, the results are instantaneous. The day before the liver cleanse you would never eat a strawberry or peanut for fear of a reaction. A few days after the cleanse, your body "knows" which food it might tolerate and as you try a bit, you notice no reaction, no rash This simple experiment suggests that the liver couldn't detoxify these foods because of the refuse in its ducts.

Each liver cleanse "cures" a different set of allergies suggesting that the liver is compartmentalized—different parts having different duties. It follows that by getting all the stones out all your allergies will disappear. Experience shows this to be true, although it can take two years to carry out such a program.

Meanwhile, avoiding the offensive food or product is very important. It is quite destructive to bathe the brain in strawberry chemicals or your toes in maple syrup chemicals. Stay off allergy-producing foods and products even if you can tolerate a little or can be "desensitized" to them with shots or homeopathic methods. Use these methods for relief, not license to continue using items that tax your body.

Certain **childhood diseases** produce a rash and this can be diagnosed by testing for the suspected disease with a slide or culture of it. Then use a zapper to kill both the bug and any larger parasites that may have brought it in.

Hives

Sometimes your body will break out in hives instead of a rash. Again, gallstones in the liver and gallbladder are responsible. Do the Liver Cleanse.

Acne

The more severe cases of acne cover parts of the body as well as face and can pit the face so badly there is hardly any clear skin left.

In ten days you can reverse this, so most of the skin is beautifully clear. There are bacteria involved and skin oils of youth feed these bacteria. Acne has been extensively studied by scientists. Perhaps the true culprit was too big to be seen with a microscope or too small (antigen) to be recognized or just too unimaginable. I inevitably find *Trichinella*, one of the four common roundworms that infect humans.

Test yourself to *Trichinella* with the slide called "larvae in tissue." Search for it in your skin. It is generally believed to reside in muscles, especially the diaphragm, but in acne cases it is in the skin.

If you only have a frequency generator, set it at 404.5 KHz and at neighboring numbers, extending 5 KHz on each side, to be sure to include all eggs and other molt stages. Or zap.

Psoriasis, Eczema

Psoriasis and eczema are both caused by *Ascaris*. Their molting chemicals are quite allergenic; perhaps it is these that are affecting the skin. Since pets pick these worms up daily, there is chronic reinfection in families with pets. Keep zapping.

Bernadette McNutt, 34, had acne on her back, chest and face. She had been treated since teen age with ultraviolet light, Retin A, and antibiotics. She already had a history of shingles and fungus, two more skin conditions. Her skin was toxic with strontium and her kidneys had cadmium, silver and beryllium deposits inhibiting excretion. She had only one parasite, extremely high levels of *Trichinella*. Her children were also infected as was the cat. In spite of using parasite herbs for months she got no improvement until the baby was out of diapers. Then she cleared up.

Royce Hamilton, 17, had acne so dense on his face there was no good spot the size of a dime anywhere. He had it about one year. His urinalysis showed “amorphous” crystals (stones of all kinds) and a trace of protein. He had *Trichinella* worms throughout his organs. He was very fatigued. He was started on kidney herbs so there would be good excretion after killing the *Trichinella*. His thyroid and kidneys were full of zirconium and titanium from all the lotions he used for his skin. He didn't need deodorant. Evidently even his armpit bacteria had been affected. It took four months to clear his *Trichinella* although there were no young children or pets in the house. His face was beginning to heal, but three months later he had a recurrence, although his parent was not a carrier. After this, he cleared it up again and his face looked as beautiful as a child's.

Evan Knight, 36, had psoriasis at elbows and knees from age 9 but now it was spreading to his fingers and scalp. He occasionally had bronchitis and puffy eyelids, indicative of *Ascaris* but at the time of his visit he had *Trichinella* fluke stages and *Echinostomum* in his skin. He was started on the parasite program and in three weeks it was clearing instead of advancing. He switched to milk for his beverage to raise his immunity and removed the arsenic, formaldehyde and thulium (from his vitamin C) by doing the necessary cleanups.

Gerry Chastain, 41, had a red nose, erupted along the sides. He had been on sulfa drugs and Emycin.™ He had *Leishmania tropica*. He killed it in the office with a frequency generator and got immediate improvement but four weeks later it was back. He had four solvents built up in his body: benzene, TCE, TC Ethylene and hexanedione. This situation would make recovery impossible since he was no doubt reinfecting himself. He also had titanium, platinum and silver accumulated in his tissues and needed to replace his dentalware before expecting a permanent cure.

Floyd Oldham, 50s, was getting pimples on his nose. His whole face was red and flushed looking. His bowels were loose and he had some urinary urgency. He harbored two kinds of *Leishmania* (*braziliensis* and *tropica*). He killed the *Leishmanias* with a frequency generator and started himself on the kidney herb program. Five weeks later the pimples were gone but general redness had

reappeared. The *Leishmanias* were still gone but this time he was toxic with cobalt.

Cobalt is known to promote skin cancers and also heart disease. This was discovered decades ago when an outbreak of heart disease occurred in England. It was traced to a pub (where they all partook) where cobalt was added to the beer to make the foam rise higher! In fact, the foam will just stay in place like a hairdo, if you add cobalt. It was made an illegal additive. Gradually, it has crept back into consumer's products: first toilet cake (blue), then window washer (blue), then dishwasher detergent, and now even mouthwash. If you see a blue colored product, **stay away from it**. It accumulates in the heart and skin. People with skin cancers often have cobalt build up.

Floyd stopped using all these products and cleared up again.

Grethe Driscoll, middle aged, wore tons of make up, so skillfully applied that scars from a face lift could never be detected. When she had minor breakouts, which usually occurred while away on a trip, it seemed like a catastrophe. She tried everything available but could not get to her parasite herbs until she was back home several weeks later. After one week on them (5 day high dose plus maintenance) her complexion was perfect again.

Crofton Thornton, 15, had an embarrassing case of acne. He had *Ascaris*, hookworm and *Strongyloides* (he also had migraines) all reacting in the skin. He stopped drinking commercial beverages that gave him solvents. He killed parasites electronically and with herbs and got a considerable improvement. But he still had *Strongyloides* one month later. Nevertheless, he had seen the connection and he knew it was just a matter of persistence to a clear complexion. Note, he should have had *Trichinella*—did I miss testing for it?

Warts

Could we get warts from playing with toads in childhood? We don't play with toads anymore. Yet we get warts. We don't know how we get them. But after learning how to get rid of them, you will probably know how you got them. Not all warts are the same. In fact, they might all be different: each one is made up of 5 or 6 different viruses, not just one as we had believed.

Peel a tiny fragment off one of your warts. Prepare it for testing by placing it in a small bottle. Add a few tsp. filtered water and a ¼ tsp. grain alcohol, Label it with the location you got it from: like "left middle finger knuckle. "First, search your body for other locations of this wart (organs that test positive to your sample). You can easily find them in your skin, of course. But also search electronically in your liver, spleen, muscles, stomach, heart, pancreas. **Notice how often they are present in the pancreas**. The pancreas seems to be a wart-virus heaven. Are they in the islets or the rest of the pancreas?

Without a zapper, you will need to find the frequency of each virus to completely destroy it. Attach your frequency generator and search between 400 and 290 KHz. When you find its resonant frequency, kill it by treating yourself for three minutes at 10 volts from a frequency generator. Will your warts fall off?

In a few days one or two of your warts will begin to shred. After a week you may lose one or two completely, and find that several more have become smaller. The remainder are unchanged. Continue to identify and kill them. Notice that they are not necessarily gone from the pancreas or other organs at the same time as they are gone from the skin. Perhaps warts are not the benign entities we have believed them to be. They may, in fact, ride into the body on some common bacteria, like *Salmonella*, or common parasite like pinworms or tapeworm stages.

Zapping doesn't reach all the viruses in a wart either. It takes repeated zappings to start the shredding and gradual killing of warts.

Guy Laird, age 11, had warts on his lips besides fingers. His job was feeding the three outdoor dogs. He was full of *Ascaris*. He had *Taenia pisiformis* and *Taenia solium* bladder cysts in his liver. These were shedding viruses into Guy. He was started on Rascal for six weeks (this was before the zapper was invented). Maybe his benzene buildup was responsible for letting so many parasites (and their viruses) survive and multiply in his body. He stopped using toothpaste, killed *Ascaris* (408 KHz) and some flukes (434 to 421 KHz) and improved his diet. All except one wart came off (without bleeding). He was given different chores, too, to reduce his contact with animals and their parasites.

Georgianna Mills, a middle age music teacher, broke out with warts all over her hands, at least 30 in total. A few months later she was diagnosed with bone cancer; she always wondered if there was a connection. She cleared up her cancer and killed her viruses and bacteria with a frequency generator. Nearly all her warts disappeared. But her indoor pet brought new parasites daily, especially *Moniezia* tapeworm stages. With each *Moniezia* infection (about once a month) she got new warts. She was never able to clear them completely.

I concluded that each wart is actually composed of 3 to 6 viruses and these viruses are distributed throughout our bodies! How satisfying to be able to rid our bodies of them, once and for all even in internal organs. There is a catch. Small remnants of some warts do not disappear in spite of killing most of them. More accurately, they disappear and then reappear in our internal organs. Could this suggest to us their true origin? Could it be a tapeworm stage?

Tapeworm Stages

Our bodies harbor numerous stages of tapeworms. But not the tapeworm itself, which may belong to a dog, cow, or pigeon. Tapeworms lead complicated lives, much like insects with their caterpillars, larvae, larval molts, pupae and eventual adults. Tapeworms shed eggs with the bowel movement of the animal host. The eggs blow in the dust and reside in the earth. A vegetarian animal nibbling vegetation near this filth, or licking dirt and dust off its coat, swallows the eggs. Humans, too, eat plenty of filth by licking their fingers. As children we all eat dirt simply by eating with unwashed hands.

The Jewish society discovered the great importance of washing hands before eating, thousands of years ago. But many of us choose to ignore truths that seem old fashioned. In our own relatively short life times we cannot see the whole picture as well as the prophets and seers of ancient cultures could. We eat plenty of dirt and along with it, the eggs of tape-worms. Dog and cat tapeworms are most prevalent, but sheep, cow, pig, and sea-gull tapeworms are also common.

There is hardly a predator species in existence that doesn't have its own characteristic tapeworm. Whatever animal species you live near, or once lived near, you probably swallowed some of its filth and some tape eggs. The **eggs** hatch in your stomach and the tiny **larvae** burrow into a neighboring organ without any consideration that this is your stomach wall or spleen or muscle. The larva's plan is not to grow into a long worm—that can wait. The larva must simply

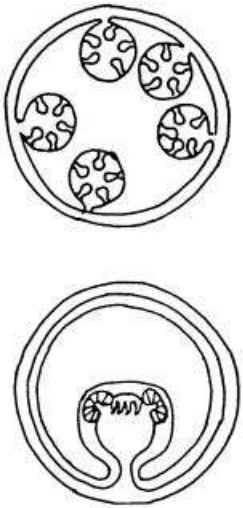

Fig. 30 Some cysticercus varieties (types) have multiple heads.

survive until you can be conveniently eaten! A wolf or a tiger will surely come along! In bygone days it did.

The larva is about ¼ inch long, surrounded by a "sac of waters," like a tiny water balloon. Looking very closely at this sac, called a **cysticercus**, we see a head (scolex), complete with hooks and suckers, turned inside out, inside a bladder.

As the tiger's teeth bite down on the cysticercus, the pressure pops it out. The head is now right side out with hooks and suckers ready for action. Now it grows in the tiger!

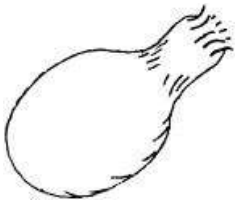

Fig. 31 Emerged cysticercus.

It quickly hooks into a loop of intestinal wall so it can't be swept away and begins its growth into a regular long **adult** tapeworm. The tiger is the true or **primary host**. We were merely the secondary or **intermediate host**. Why does the adult tapeworm prefer the tiger instead of us? Only Mother Nature knows. But the best way to get to a carnivore is through its prey.

You can find these larval cysts in your organs using slides of the *cysticercus* stage of various common tapeworms. Search in your muscles, liver, stomach, pancreas, spleen, intestine and even brain. **You will not find even little bits of them in your white blood cells**. My explanation for this curious finding is that the tapeworm leaves no debris to be cleaned up by your white blood cells. Evidently your body builds a cyst wall around the larva to tightly encase it and prevent toxins and debris from entering your body. Thus your white blood cells are not alerted in any way. Of course, the larva is much too big to be devoured by tiny white blood cells anyway. Yet, it seems that if a pack of white blood cells had attacked the larva just as soon as it hatched from the egg they would have been able to devour it. Perhaps it enlarges too rapidly. Perhaps our white blood cells are preoccupied. In any case, we begin to load up on tapeworm

stages from infancy and by the time we are middle aged we have dozens tucked away in our organs.

Some do die in the course of time. Perhaps their true secondary host is a rabbit or a mouse instead of a human. The short life span of these other hosts might mean that the life span of the *cysticercus* is also quite short, not 40 years! When they die, the white blood cells do clean them up and we can see them in our white blood cells at this time. It can take several weeks for the *cysticercus* to be completely gone by this natural method. During this time, we become ill! Numerous bacteria and viruses spring up, as if from nowhere, in our organs.

Don't be surprised if you are testing yourself during illness to find a tapeworm or two in your white blood cells! It is well worth searching for at such a time. Help your body dispatch the tapeworm stages all together with your zapper. A frequency generator is bound to miss some. Some cysticercus varieties consist of many heads, and each head has even more heads inside it! These might have different resonant frequencies. Only killing them together has the desired effect. Remember bacteria and viruses are released by killing tapeworms, so always follow with a second zapping in 20 minutes, and a third zapping 20 minutes after that. Only then can your tapeworm-related illness disappear.

If you do nothing, your body will be kept busy killing bacteria and viruses as the tape cysticercus wears down and eventually dies. You may not wish to identify all of them (but at least search for *Adenovirus*, the common cold) and just note where you are being attacked: your nose, throat, ears, lungs, bronchi. Internal organs are attacked too. It seldom takes more than three weeks, though, for your body to clean up a tape stage even without any help from a zapper. The attendant illness will be gone by then, too.

Watching these events in your body gives you insight into the very powerful forces at work, called immunity or body de-

fense. The body "knows" a great deal more than we have surmised. There is yet so much to discover.

What initiated the death or dying process of the tapeworm stage in the first place? Has your body been trying all along and finally succeeded? Has the *cysticercus* reached the end of its life span naturally? Have its (the tapeworm's) own viruses and bacteria gotten the upper hand and killed it? Did it accidentally absorb something that killed it?

By taking a herbal combination, Rascal, you can soon find a tapeworm stage in your white blood cells where you could not find it earlier. It is now dead or dying. This proves the effectiveness of Rascal, even though it is slow.

Since we all eat dirt and inhale dust that is laden with dog feces or other animal excrement, we all harbor tapeworm stages, although none may be present in our white blood cells. **Are they harming us?** Perhaps they are living out their lives as quietly as they can in our organs, the way mice or ants try to live in our dwellings. Yet, when tapeworm stages are being killed, either spontaneously by your body or with a zapping device, we see an assortment of bacteria and viruses spread through the body, including the common cold.

Getting rid of the tapeworm stages in your organs seems a very worthwhile goal. Since each of us has been associated with dozens of animal species in our past, we probably have dozens of varieties of tapeworm stages in us. I cannot identify more than a handful due to lack of prepared slides. You can find them without identifying first, though, by listening to their emission frequencies. Their emissions are often extremely weak, possibly due to being encased in a cyst. Search between 510 KHz and 410 KHz. You may wish to "track" them for a while before killing them. You may wish to search for identical frequencies in your pet's saliva. Or you may wish to dispatch them as rapidly as possible. Use the zapper, not a frequency generator. Remember to "mop up" after your tapeworm killing by zapping

again to kill bacteria and viruses that have been released from the tapeworm.

You may be disappointed not to feel any different after ridding yourself of numerous tapeworms and their pathogens. Evidently, the tapeworm stage itself doesn't make you sick; it is simply there like a wart is there, without making you sick. Its viruses can make you sick. Depending on which virus it is, it can make you very sick or not sick at all. Different viruses invade different organs. And some of these turn into warts!

The Flu

Influenza is a virus that can cause "the flu." Does it belong to us as humans or to a larger parasite we are hosting? It is easily transmitted from person to person and in less than a year can spread across the planet. Some flu examples are Influenza A, B, C and Swine flu.

However, much that is called "flu" is actually caused by a bacterium, either *Salmonella* or *Shigella*. If someone in your family is "catching" a flu, test their saliva for the presence of dairy products, implicating the *Salmonellas* and *Shigellas*. Also test for influenza A, B, and C. Children's "flus", especially when there is a fever, are usually due to *Salmonellas*. Even after zapping it can take an hour for the symptoms and fever to go away.

Go straight to the refrigerator and throw away all dairy products. Throw away all milk, cheesecakes, buttermilk, cream, butter, yogurt and cottage cheese, deli food and leftovers. You may wish to identify the food source of your family's bacteria first, and save the uncontaminated food. Use the sick person as a subject, searching for foods that appear in her white blood cells (or search their saliva sample for the food offender). If the flu is "going around" your neighborhood, you might wish to tell

some of your neighbors which foods you found were contaminated. They may have purchased the same food! Obviously, when a contaminated shipment of dairy products arrives in your grocery stores, quite a few people will be consuming it, setting the stage for a "bad flu" that "goes around".

Why can some people eat contaminated food without getting sick? Maybe their *Salmonellas* don't multiply rapidly. Maybe their stomach acid is strong enough to kill most of them. Maybe their bowel movements are frequent enough to expel them quickly. Maybe they haven't been on frequent treatments with anti-strep antibiotics. The answer is not known yet. After a serious bout with *Salmonellas* or *Shigellas* the body does not completely clear itself of them. They stay in hiding somewhere. When a new batch of bacteria arrives, even though very sparse, as in 1 tbs. of milk, the two subtypes can hybridize and produce a much more vigorous offspring. This is called *virulence*. You are made much sicker by more virulent subtypes of bacteria. You may have diarrhea, vomiting, illness. Especially if you believe you have "lactose intolerance," pay attention to *Salmonella* and *Shigella*.

If your flu is due to an influenza virus, kill it with your zapper. Some family members may prefer to take a homeopathic flu "remedy" such as Oscillococcinum™ or Flusolution.™ Others may take herbs. These probably act by prying the viruses out of your cells' gateways and channels so the white blood cells can easily devour them.

But flu due to *Salmonella* is not easily zapped away. Remember, the zapper current does not penetrate the bowel contents, which is exactly where *Salmonella* lives! Besides zapping to clear them from your tissues, you must eliminate them from the bowel by using the Bowel Program (page 546).

Lugol's iodine solution (see *Recipes*) can quite quickly get rid of Salmonella throughout the body. Use 6 drops (small drops from an eyedropper) in ½glass of water four times a day. If no

more *Salmonella* is consumed, it will be vanquished in a day or two.

If your flu brings you a fever, use Lugol's.

Fever

Fevers are there to help your body fight the invaders...up to a point. Don't use a fever medication unless the body temperature goes over 102°F, and then only enough to bring the fever down a bit.

Most fevers, especially **"fevers of unknown origin"** are due to *Salmonellas* and *Shigellas*. Your body may be young and strong enough to kill them but not strong enough to kill an everlasting supply of them coming from dairy foods you eat on a daily basis. Stop eating salads at restaurants immediately. Stop eating food made by others' hands unless it is sterilized. Stop eating dairy foods until you have cooked them. Stop eating those that can't be cooked.

Sam Ellis, age 7, had two episodes of severe abdominal pain with fever lasting two weeks. He got hyperactive with milk products, had a frequent cough and stuffy nose. (Here the picture is quite clear. The milk products were bringing him *Salmonellas*, *Shigellas* and other bacteria which grew in his intestine to produce pain. But why only Sam and not his brothers?) Sam had a buildup of benzene from using bathroom soap containing a special herbal oil. Sam also had hookworms, intestinal fluke, and rabbit fluke, probably due to his lowered immunity from the benzene. Then his mother boiled Sam's milk, removed the polluted soap (she planned to use it herself!) and killed his parasites with the parasite herbs. His fever went away and stayed away. He said he enjoyed all this because now he "could play after school" without a stomach ache and he wasn't being sent to the nurse's office because of a fever. Notice the bacteria causing the temperature went away by themselves, probably due to the return of his normally strong immune system.

Jalene McCormick, 46, had been passing lots of kidney stones (hundreds) for years and had a temperature most of the time for which she was on antibiotics. It took her six months on our kidney herb recipe to dissolve and pass so many they no longer showed up on X-ray, and to stop making them. Then her fever left, not to return.

Kristen Jane Johnson, a young mother, had recurrent fevers and fatigue but, besides EBV, her doctors found no cause. We found HIV virus and a lot of bacteria and parasites. The fever-causing bacterium was *Salmonella*. To stop her *Salmonella* attacks she had to raise her immunity besides boiling all dairy products. Moldy foods (pasta) and lunch meats (benzopyrenes) were the source of liver toxicity. Each new *Salmonella* attack immediately invaded the liver so a vicious cycle was set up. When she stayed meticulously on the parasite program, meticulously off unsterilized dairy products, and meticulously off benzene-polluted items, she cured herself of fevers and night sweats and the HIV infection. Perhaps in two years the liver will have recovered enough to kill *Salmonella* that enter it, but she is not taking any chances till then.

Although Kristen was eating food polluted with both *Salmonellas* and *Shigellas* she only "picked up" *Salmonella*, never *Shigella*! Why is that? In contrast, people with multiple sclerosis "pick up" *Shigellas*, not *Salmonellas*.

Multiple Sclerosis & Amyotropic Lateral Sclerosis

Multiple sclerosis (MS) is a disease of the brain and spinal cord. It is called *lateral sclerosis* if the disease is mainly in the spinal cord.

It is caused by fluke parasites reaching the brain or spinal cord and attempting to multiply there. Any of the four common flukes may be responsible. Kill them immediately with your zapper or a frequency generator (434 KHz to 421 KHz). They

cannot return unless you reinfect yourself. Stop eating meats, except fish and seafood. All meats are a source of fluke parasite stages unless canned or very well cooked. Pets and family members are undoubtedly carriers of the same flukes, although they do not show the same symptoms. Give away your house pets. Don't kiss your loved ones on the mouth. Make sure your sex partner has also been freed of fluke parasites.

The most important question you must be able to answer is why did these parasites enter your brain and spinal cord? When the brain contains solvents, it allows flukes to multiply there. The solvents, **xylene** and **toluene** are common brain solvents always seen in MS cases. Evidently these solvents accumulate first in the motor and sensory regions of the brain, inviting the parasites to these locations.

Xylene and toluene are industrial solvents used in paint and thinners. It is also a pollutant of certain carbonated beverages (I found it in 7-Up,™ ginger ale and others that I tested). Stop drinking them.

All MS cases I have seen also harbor *Shigella* bacteria in the brain and spinal cord. These come from dairy products. They are manure bacteria. Be absolutely meticulous about sterilizing dairy products. Even one tsp. unsterilized milk added to scrambled eggs could reinfect you. Not even heavy whipping cream or butter is safe without boiling. Kill bacteria every day with a zapper. *Shigellas* produce chemicals that are toxic to the brain and spinal cord. Eliminating *Shigellas* brings immediate improvement.

All large parasites like flukes have their own entourage of bacteria and viruses. Perhaps it is these that initiate the brain's reaction, which is inflammation and scar tissue formation in the outer covering of brain cells and nerve fibers. Perhaps it is the fluke stages themselves. Your brain is trying desperately to heal these lesions, only to be assailed by a fresh batch of solvent and *Shigellas* and another generation of parasites and pathogens.

The other pollutant associated with MS is **mercury** from dental metal. The mercury that is constantly released in the mouth does not all get excreted by the kidneys or eliminated by the bowels. Some of it travels up to the brain and gets into the spinal cord as well. You will be able to eliminate and excrete more mercury by doing a kidney and liver cleanse. The mercury may itself be polluted with **thallium** which is even more toxic. For this reason mercury removal should be done extra thoroughly to be sure no thallium has been left behind.

If you are concerned about MS-like symptoms, purchase slides of the brain regions, cerebrum, and cerebellum. Or purchase pork brains at the grocery store and snip out a portion of the sensory lobe and cerebellum. Prepare these as test substances (sterilize your hands afterward). Test your daily foods and body products for their presence in these brain areas. Also test for parasites, bacteria (especially *Nocardia* and *Shigella*) and other pollutants such as arsenic and pesticides. If the disease (tremor and lack of sensation) has not progressed too far, you can cure it. In all cases you can stop it from progressing further by cleaning up dentalware, the environment and diet.

Brandi Rainey, age 34, of Amish religious culture, was diagnosed with MS four months earlier after an MRI confirmed it although she had symptoms for many years. She was told she had inherited a gene for it and that Amish folk are particularly susceptible to MS for reasons of inbreeding. She had a constant pain running down the side of her neck, and headache. Her legs were getting too heavy to get up stairs. Our tests showed her brain was full of scandium (tooth metal alloy) and fluoride (toothpaste). Her vision was getting worse; her eyes were full of wood alcohol. She lost no time in getting dentures: there were no teeth that could be saved. She had several bacteria growing in her jaw bone: *Strep G* (sore throat bacteria), *Staphylococcus aureus* (this was raising her pulse to over 100), *Clostridium tetani* (causes great stiffness), and *Shigella* (produces nerve toxins). She killed these with a frequency generator. Five weeks later the pain and stiffness in her neck were gone, her pulse was down to 100, her periods were free of pain

and her hands seemed to shake less. She was put on the parasite program plus thioctic acid (2 a day) and histidine (500 mg, one a day to keep nickel levels down)and advised to cook and eat with non metal. Four weeks later her pulse was down to 80, her legs were much better. She zapped four remaining bacteria. Two months later the numbness and tremor had left; her legs still felt tired and her hands sometimes shook but she was quite reassured that MS would not claim her life. Nor had a gene betrayed her. A half year later she was walking and working normally, doing liver cleanses and keeping up her vigilance against parasites and pollutants.

Kendra Welch, 56, was diagnosed with MS a year ago, by MRI. She went to a chelating doctor and this cleared up her temporary ischemic attacks (T.I.A's) which were occurring daily. But she had lost her balance, eyesight was getting worse, her feet and hands stung. Her sister also had MS but nobody else in the family did which baffled her doctor. Her brain tissue was full of barium, europium, gadolinium, and platinum. These are dental alloys, although barium could come from bus exhaust (she wore no lipstick). She was advised to have all metal removed from her mouth immediately. Two days afterward she came into the office without any neurological symptoms. She stated she was afraid to stop her new health program, though, and this was good policy.

Lynne Ceretto, age 15, was diagnosed with an “MS-like syndrome” by MRI. She had intestinal flukes and stages, human liver flukes and *Trichinella* in the brain. She had no tooth fillings. But there was benzene in her thymus keeping her immunity low. She also had propane and asbestos in her brain from leaky pipes and a worn washing machine belt. She, too, was told she had a “bad” gene. She was barely able to walk with help. It took several months to track down the source of benzene—the drinking water. Sometimes it was polluted; sometimes it was not! When the pump was oiled, some of it dripped onto the cement platform. Rain washed it to the center and down the pipe in the well. They eagerly removed the platform, found the oil on the water surface, cleaned everything up carefully, until no benzene could be found which put her on the road to recovery. A year later she had recovered further.

Norma Luellen, a young mother, had tingling, numbness and weakness on the entire left side of her body. She was in process of

clinical tests for MS. Her body was full of pentane, possibly from her workplace since 12 other persons working there also had MS (such a situation should make our government eager to jump at investigations)! She had intestinal flukes and their stages, not in the intestine or liver or thymus, but in her brain! We found her home air toxic with bismuth too, probably from cosmetics. In spite of staying on the parasite program she got reinfected with sheep liver fluke, probably from eating hamburgers. She was not able to stop her carbonated beverage habit and frequently showed xylene, acetone, methylene chloride in addition to pentane in her white blood cells.

Shannon Synder, age 44, had been getting more numb over her whole body for several years and was presently considered by her doctor to have MS. Her muscles twitched all night, making sleep impossible, and her hands shook. She had intestinal flukes in the brain (cerebrum and cerebellum) but none in the intestine! The brain also had wood alcohol from drinking Diet Coke.™ She also had bismuth (cosmetics), palladium, copper, samarium, and tellurium (tooth alloys) in her brain. She began to improve enough to be off Prednisone by her 10th day of the parasite program.

Erica Blake, age 41, was diagnosed with MS two years earlier although her symptoms went back 13 years. She was on Prednisone™ but her balance was getting so bad she had to be in a wheelchair. Chelation treatments kept her from deteriorating further. Her brain was full of gasoline; she used to work at a gas station and now was getting it from the attached garage. Her hands and feet were completely numb. She had 5 root canals extracted and a few days later was able to stand. She could now walk with a cane. She had human liver flukes, sheep liver fluke and *Trichinellas* and dog tapeworm stages in her cerebellum (motor control center). After killing parasites and starting to take thioctic acid (4 a day) and cleaning up her environment she improved enough to drive a car again, walk without a cane in her home. She regained enough feeling in her hands and legs to do her housework, too.

Kurt Nielsen, age 43, was told he had peripheral neuropathy. His feet were so numb he had to look at the clutch to drive. Also both hands were numb. He was full of kerosene and benzene possibly from fuel oil that he pumped for a living. There were fluke stages

in his brain and a dozen bacteria and viruses. He also had mercury and thallium in his immune system which came from tooth fillings. However, he had all his metal fillings replaced two years earlier! He thought there was no mercury left in his mouth! Actually, he had little bits (called tattoos) left somewhere. And they were giving him the classical symptoms: numbness of hands and feet and gradual destruction of his nervous system. His peripheral neuropathy was due to thallium poisoning. The dentist couldn't find tattoos, and he was left in his predicament. (This was before I found mercury and thallium sources in many personal products.)

Duncan Wood, a middle age father of 5 young children, could still slowly shuffle along when he arrived. He could not raise his arms to eat. He had uncontrolled inappropriate laughter every minute. He was diagnosed with MS two years earlier and told he had a "bad" gene. The fact that one child was beginning to show similar symptoms strengthened their belief in the gene theory. Ten days later his inappropriate laughter stopped; he could get his right hand to his face, he walked twice as fast and had very little tremor remaining. Strong chelating treatments obtained at a Mexican clinic had drawn much of the mercury and thallium out of his brain. He killed the flukes and *Shigella* bacteria electronically and stopped consuming unboiled milk. The brain solvents, xylene and toluene were removed quickly, too, as well as asbestos. His fast improvement showed them how important it was to remove the source of these pollutants in his home.

Two days later he regressed considerably which made him feel quite depressed, since his chelating treatments had not stopped. Was there still an unknown factor? It was a return of *Shigella* bacteria! He had inadvertently eaten a non-sterile dairy food: milk added to soup when it was already done cooking! This was a valuable lesson. Nothing else had returned. He was away from the asbestos and xylene from the workshop at home. He zapped the bacteria again and applied greater vigilance to eating only sterilized dairy foods. He recouped his losses in one day.

Then they scheduled their dental work, which had already been done once two years ago! He had leftover mercury and thallium. Now, selecting a dentist with experience in finding tattoos and cleaning cavitations made much more sense to him than it had before. He also planned to do a kidney and liver cleanse after re-

turning home. And to stay out of the workshop until the asbestos-containing belt had been replaced and the furniture painting had been moved to a different building.

Shigella also causes irritability and depression, a frequent problem for MS cases.

High Blood Pressure

High blood pressure is one of the easiest problems to correct without resorting to drugs.

The most important change to make is to stop using caffeine as in coffee, tea, or carbonated beverages. Don't use decaffeinated coffee or tea either because of the solvent pollution in them. Switch to hot milk or hot water if a hot beverage is desired, or any of the beverages given in the recipe section. If being without caffeine leaves you fatigued, take an arginine tablet in the morning (500 mg).

Blood pressure is mainly controlled by the adrenal glands which sit like little caps on top of the kidneys. Whatever is affecting the kidneys is probably affecting the adrenals, too, since they're so close to each other. You must find out what it is.

You could do your search in the kidneys since kidney tissue is available in grocery stores. Adrenal tissue is available on microscope slides. What will you find? Probably **cadmium**.

Search for the cadmium source in your drinking water! Cadmium comes from the metal pipes. In fact, you could scrape a galvanized pipe to get a cadmium test substance. Conducting or storing drinking water in containers of metal is as foolish a practice as eating food off the floor. Water picks up everything it touches simply because it is wet! You may not see what it picked up any more than you can see if it has picked up sugar or salt. The cadmium and other metal is dissolved in the water. The older the pipes the softer, more corroded they are, and the

more metal is picked up as the water rushes by. If you find cadmium in your hot or cold water, you will never be able to filter it out. Nor should you switch to bottled water. The amount of cadmium in your clothing from doing laundry with this water is already too much for your adrenals and kidneys.

Change your galvanized pipes to PVC plastic. If you believe you already have plastic pipes or all copper (which leads to leukemia, schizophrenia and fertility problems) you will need to search every inch of plumbing for a very short piece of galvanized pipe left in the system! A piece as short as a 2 inch T or Y can be causing all the trouble.

The toxicity of cadmium, in fact, the high blood pressure connection, has been known a long time. After finding the cadmium start on the kidney cleanse. You might miss the cadmium problem if you don't attend to it first. Also remove all metal from your mouth.

All (100%) cases of high blood pressure I have seen could be easily cured by eliminating cadmium and other pollutants, followed by cleansing the kidneys.

To test whether you still need your blood pressure medicine, wait until your pressure is down to 140/90 or better. Then cut the dose in half. Check it again next day. If it has climbed back up you are not ready; go back to ¾or a full dose of medicine. Try again a few days later. If your blood pressure stays down, cut your medicine in half again (you are now down to ¼ the regular dose) and see if your blood pressure stays improved.

When you are down to 130/80 go off completely. But stay on the kidney herb recipe. At 120/80 try yourself on a few shakes of sea salt. The amount of salt eaten, once the pressure is down, has little influence. In fact increasing salt intake improves energy without raising blood pressure. Take no more than one teaspoon a day (2,000 mg sodium), total, including cooking. Better yet, make a salt that is a mixture of sodium and potassium chlorides (see *Sources*). Mix it for yourself in a 1 to 1

ratio or whatever your taste can accept. The sodium portion could be sterilized sea salt (test and make sure it has no aluminum silicate in it first).

Mold toxins have specific kidney effects! Especially **T-2 toxin**, found mostly in dried peas, beans and lentils. Rinse these thoroughly first, throw away shriveled ones, and add vitamin C to the cooking water. All cases of serious kidney disease show a build up of T-2 toxin. Be extra careful to avoid moldy food (read Moldy Food, page 381).

Bala Cuzmin, age 72, had high blood pressure for ten years but the upper (systolic) pressure remained high in spite of various medicines that were tried. She had three kinds of kidney stones and only one functional kidney. She stopped using caffeine, switching to arginine tablets to get over the let-down. Her diet was changed to reduce phosphate and add calcium, and she took magnesium and Vitamin B_6 to assist the kidneys. She was very anemic and her mean cell volume (MCV) was high due to *Ascaris* infestation. She killed parasites, cleansed kidneys but saw no drop in blood pressure which stayed at 150 to 170 systolic. Her adrenal glands were choked with copper and platinum. She had all the metal in her mouth replaced and promptly saw a blood pressure drop to 145-1 50. Three months later it was at 128 to 133 on half her medicine. She had not been tested for T-2 toxin yet, nor changed her copper water pipes.

Sabrina Patton, 66, had a long list of health problems, including high blood pressure for six years. She was on Corgard™ and diazide drugs which kept it down to 140-160/74-80. She had phosphate crystals in her kidneys and was started on kidney herbs and a diet change to include milk and exclude soda pop. She had high levels of mercury and copper in her immune system. She was feeling so much better after the kidney cleanse that she decided to remove her last fillings and replace her bridge, too, since it was shedding ruthenium. On her way home from the dentist, her ears stopped ringing and soon her blood pressure was down to 126/68. She was still on half a dose of drugs because she was too afraid to go off entirely. But when her pressure stayed down she found the courage to go off completely. This gave her the energy she wanted to play basketball with the grandchildren again.

Rolf Ehrhart, 61, had 80% blockage of heart arteries and high blood pressure for which he was on a Hydropres™ patch, Tenormin™, and Logol™ (diuretic). He had phosphate and uric acid crystals in his kidneys. He was started on kidney herbs followed by the parasite herbs. His *Ascaris* and flukes were zapped. He stopped using store-bought beverages. Then he could cut back on his medicines, measuring his blood pressure daily to guide him. After seven weeks it was down to 140/85, so he decided to do without medicine, a bit early. He was also getting chelation therapy and was now able to walk 2-4 miles a day. His next chore, which he approached gladly, was removal of all metal from his mouth.

Len Gerald, 45, was on Vasotec™ for high blood pressure. He was constantly sleepy; his blood test showed a low thyroid level in spite of being on Euthyroid.™ He was started on kidney herbs followed by parasite herbs. In two weeks, barely into his program, his blood pressure dropped. He had to go off his blood pressure medicine. It stayed at 126/80. He still had some *Ascaris* and other health problems but was highly motivated to clean them up, too.

Glaucoma

In glaucoma the pressure in the eyeball gets too high, putting pressure on fragile retina cells that do your seeing. The first question to ask is: "Is my blood pressure too high?," because there is a link between high blood pressure and elevated eyeball pressure.

Your blood pressure should be 120/80. Your doctor may say 140/85 is "not high." He or she is kindly refraining from giving you drugs until this level of pressure is reached. It is your tip-off, though, that something is not right and you should correct it now, when it is easy, and before other damage is done. Read the section on high blood pressure (page 210) to learn how to reduce it by going off caffeine, checking for cadmium poisoning from your water pipes, and cleansing the kidneys (page 549). Even though your doctor has explained how the tiny tube draining your eyeball is too narrow, you should ask: was it not

too narrow before high blood pressure struck? Simply getting your blood pressure to normal is sufficient help for beginning glaucoma.

Antonia Guerrero, age 51, had glaucoma for five years and was deteriorating rapidly. She cleansed her kidneys, killed parasites and changed her diet to the anti-arthritic one since she also suffered from arthritis in her hands for ten years with painful enlarged knuckles. She didn't get relief from taking aspirin. She got rid of her asbestos toxins by bringing her own hair blower with her to the hairdresser. After seven months she had pain relief for her arthritis (without aspirin) and her glaucoma was pronounced stable by her ophthalmologist.

Tooth Decay

The strongest part of our body structure is our bones. The strongest bones are our teeth. How can they decay? We must look at the **enamel**, **dentine** and **root** of the tooth as well as the bone they rest in for some answers.

Scientists have already searched very hard and long for answers. But their work is hampered by commercial interests that try to shape the results. Since commerce determines which research can be done (that is, paid for) sacred territory can be ignored. For example, the effects of sugar-eating, gum-chewing, tooth brushing, fluoridation, tooth filling materials and diet can be ignored if it interferes with product sales. Trivial studies such as comparing shapes of toothbrushes, studying the chemical composition of plaque, and studies of bacterial structure and genes are done instead. Studies “at the molecular level” do not threaten existing industries.

Important research has lapsed since the 40's and 50's. Perspective on tooth health was sound and clear in the mind of Dr. Weston Price in the 1930's. His scientific studies stand as a beacon even today because truths, once found, do not change. He

traveled the world over in search of good teeth. Anywhere and anytime he found them, he described the people who had them. This is excellent science. It lets you draw the conclusions. He described what he saw in a book, titled Nutrition and Physical Degeneration.[13] They came to these conclusions from the following observable facts:

1. Skulls of primitive peoples who lived along coastlines, such as Peruvians, Scandinavians and various islanders, and whose staple foods included fish daily, showed perfect teeth; not a single cavity in a lifetime. They had strong bones that didn't break even once in a lifetime of 45 years. Skeletal structure was fully developed, meaning the jaw bone was not undershot or cheek bones squeezed together, forcing the teeth to grow into a smaller than ideal space. Consequently, there was room for the wisdom teeth, and no need to crowd the remainder. They saw no crooked teeth or unerupted wisdom teeth. The authors estimated a daily consumption of **4 to 5 grams of calcium** in their fish containing diet.

Our daily consumption of less than 1 gram calcium daily is small by comparison. Our wisdom teeth erupt poorly, our other teeth are often crooked. But today bad teeth go shamefully unheeded because we don't need to chew our food, we can lap it (ice cream) or suck it, or gum it (applesauce).

2. These primitive peoples got all the calcium, magnesium, phosphate, boron and other bone builders they needed simply from eating (fish) bones. Mexican peoples got 4 to 6 grams of calcium a day from **stone-grinding** of corn for their staple, tortillas, instead of from fish.

[13]It is still available from the Price-Pottenger Nutrition Foundation, a non-profit organization that seeks to keep his observations alive. Their address is PO Box 2614, La Mesa, California 91943, (800) 366-3748.

Where do we get our calcium? Milk is our only supply. One quart supplies one gram. There is little excuse for a carnivorous society like ours to regularly throw away the bones of its food animals in view of our dire shortage. It leaves us dependent on milk alone. Milk has so many disadvantages. It is impossible to milk a cow by machine and not get a few manure bacteria, *Salmonellas* and *Shigellas*, into the milk. These bacteria are not completely killed by pasteurization the way more susceptible bacteria are. It takes boiling temperature to kill all of them. Why isn't milk sterilized? Water was sterilized for human consumption in distant decades. Chlorination of water is not ideal but it did sterilize the water. Milk could be sterilized by boiling or flash-heating.

Milk has other disadvantages: dozens of antibiotics, both by feed and by shot, bovine growth hormone, chemicals added in milk processing, the bad effects of homogenization, and allergy to milk. Yet, in a choice between milk drinking and bone loss, one must choose the milk. This would not be necessary if bones were properly salvaged–ground to powder and added back to the meat where it belongs–to offset the acidifying effect of the phosphate in meat. One gram of calcium is not much bone (½tsp.) but it requires a whole quart of milk. Bone powder added back to ground meat, soups, stews could greatly improve our tooth decay problem, bone density problem, and skeletal growth problems.

Softened teeth set the stage for decay; bacteria do the dirty work.

Zapping bacteria does not kill them all. The zapper current does not reach into abscesses under metal filled teeth or around root canals. *Staphylococcus aureus*, which we are constantly

stuffing in our mouths as we lick our fingers, finds an immediate hiding place in a crevice where it can't be zapped. Many other bacteria hide here, too: those that cause ear ache, sore throats, bronchitis, stiff knees, joint disease. You can try zapping all the *Clostridia*, *Streps* and tooth decay or plaque bacteria. But the only way to successfully eliminate them is to pry them out of hiding and wash them away. This is a job for the dentist (see Dental Cleanup page 409).

Strep. mutans is considered to be the bacterium that causes tooth cavities. I have found it in milk, evidently another pasteurization escapee. All the more reason to sterilize dairy products.

Frannie LaSalle, 52, was getting compression fractures in her spine, but the weak bone condition was evident in her mouth (many teeth were loose—they could be jiggled!). Her gums were red and inflamed. A low thyroid condition (she needed 2½ grains a day of thyroid—in one day the normal body goes through 5 grains of thyroid products) contributed to this. Her blood phosphate level was high (4.7 mg/DL—should be below 4.0) and her alkaline phosphatase was 205, also high, showing she was dissolving her bones (including tooth sockets) at a rapid pace. Her whole system was too acid, as could be seen in elevated CO_2 levels (28, when 23-30 is normal).

Only the major minerals, sodium, potassium, calcium and magnesium can have an impact on this major disturbance. The dentist said she had to have all her teeth pulled and replaced with dentures. Her kidneys showed all three types of calcium phosphate crystals. She drank no milk. She had only three weeks before her oral surgery appointment. She was started on ½ cup 2% milk, 6 times a day plus 50,000 units of vitamin D (a prescription dose) to make sure she absorbed all the calcium. She also took magnesium oxide (300 mg. once a day) and vitamin B_6 500 mg (one a day).

She was started on the kidney cleanse to help activate the vitamin D and to help the adrenal glands make *estrogen*. Her estrogen level (5.2 pg/ml) was too low to get the calcium deposited back into her bones. She was also given licorice herb for their estro-

gen-like action to help with this and vitamin C, 1 gram (1,000 mg) 2 to 3 a day.

Her mouth care was to be as follows: potassium iodide (white iodine, made up by dissolving 88 gm potassium iodide in one liter/quart water). Purchase a new very soft toothbrush. Use no toothpaste or store bought floss. Use 2 lb. or 4 lb. (the 4 lb. is coarser) fish line (rinse first). Brush twice a day; floss only once at bedtime before brushing. Use 6 drops of food grade hydrogen peroxide for daytime brushing. Use 6 drops of potassium iodide for nighttime brushing. Use no mouthwash, chewing gum, candy. In three weeks her teeth could not be jiggled. Her dentist was astonished (but was not interested in how she achieved this). In six weeks her mouth looked normal and she could chew some foods. Her vitamin D was tapered as follows: Take 6 a week for the first week (miss one day). Take 5 a week for the second week (miss two days). Take 4 a week for the third week. Then 2 a week indefinitely. She never lost a tooth.

Muscle Diseases

There are a variety of muscle wasting diseases, thought to be genetic in their cause. Yet, what could be more easily inherited than a parasite? Persons living together share food, living habits. refrigerators, and parasites. Their shared genes indeed give them similar susceptibilities but if we take muscle parasites away, muscle diseases “magically” disappear.

Of course, there is no magic involved. It is actually hard work. Hard work to rid the whole family of parasites that are shared and possibly were present even at birth. Parasites that normally don't go to the muscles. For example liver flukes and intestinal flukes. They belong in the liver and intestine! Yet, in muscle disease they show up and reproduce themselves in the muscles. The reason for this becomes clearer when you see that certain solvents have accumulated there. Heavy metals, bacteria, and viruses have accumulated there, too. The host's muscles,

instead of kidney and bowel, have taken on the duties of toxic dumping grounds. Could it be that the regular routes of elimination were overwhelmed? Or did the muscles, traumatized by these unusual parasites, invite the toxins? A tantalizing question.

But in seven minutes you can methodically kill everything and anything that is alive in your muscles and shouldn't be there. Zap until you are free of all parasite invaders. Your muscles will feel lighter afterward.

Muscular Dystrophy

In muscular dystrophy the solvents, **xylene** and **toluene** are seen to accumulate in muscles. These also accumulate in brain and nervous tissue! (See Alzheimer's page 269 and multiple sclerosis, page 204). Could it be that these solvents are actually present in the nerves of the muscles?

Fortunately these solvents will leave your body, by themselves, in five days after you stop consuming them! Stop drinking all store bought beverages, including water and powders that you mix, and including health food varieties. Water claims and health food powder claims sound as convincing and strong as a twelve inch plank to walk on. But if the plank leads out over the side of a ship, would you walk it?

Throw all your possible sources of solvents out. Flavored foods are the chief offenders (cold cereals, sweets and candy too). But of course, you should check in your basement or attached garage for cleaning solvents. Places where painting is done or automobiles are worked on should be off limits to you.

If you've been wondering whether you have muscular dystrophy, which I consider to be a fluke disease, search your muscles electronically. Use prepared slides of flukes along with a sample of hamburger meat to represent your muscles. If flukes have already taken up residence in them, you should diagnose

yourself as "Positive". If not, but other parasites and toxins are present, you have pre-muscular dystrophy.

Also, the likelihood of finding thallium is quite high, judging by the case histories.

Mel Rickling, age 18, had been seeing a specialist for bouts of muscular weakness for several years, but no diagnosis was given. His condition was not yet severe enough although it was difficult for him to raise an empty glass or get upstairs. It began at puberty, not too long after his first mercury tooth filling. He had asthma in childhood. The flukes attacking his muscles were liver fluke, intestinal fluke, and pancreatic fluke. Other parasites in his muscles were *Leishmanias*, several dog tapeworm cysts, and pinworm.

He also had assorted bacteria in his muscles. The solvents propyl alcohol, benzene, toluene, and xylene were accumulated there too. Ortho-phospho-tyrosine (cancer test) was already positive. His doctors had not searched for cancer in their biopsies. His drinking water contained lead and since he had lived in one house since birth he was probably drinking lead every day of his life. He also had high levels of mercury and some thallium accumulated in his muscles; these came from the tooth fillings in his mouth and could explain why his problems began after his first filling was put in.

His flukes and other large parasites were killed immediately with a frequency generator. He was started on the herbal parasite program to prevent reinfection. His diet and body products were changed to exclude solvent pollution. He could have no commercially prepared beverages except milk which needed to be boiled to kill bacteria. In twelve days his daily stomach pains were gone, so he was able to eat more and gain some much needed weight. The rash on his face was gone, the pain at his right side was gone, his muscle twitches were gone, his joints no longer ached and his mood was much better. The whole family was put on the parasite program and Mel was scheduled for dental cleanup. The plumbing repairs removed lead from the water and he was soon able to walk upstairs, in fact <u>run</u> upstairs.

A young man, seeing himself regain normalcy, wants nothing more than to lead a normal life" which includes reckless behavior. But after several warnings from his muscles he stuck to his re-

strictions and gained the weight he wanted in order to participate in athletics.

Myasthenia Gravis

is probably a fluke disease. Some chemical, possibly coming from the fluke, may affect the acetylcholine receptors, thereby causing an allergic reaction so they become inefficient. This is most noticeable in the eyelids. They droop from lack of strength to lift them.

The thymus is often involved, too. The thymus is extremely sensitive to benzene and with so much benzene pollution in our products and foods (pollution from gasoline is negligible by comparison), you will probably find benzene accumulated there. Search the thymus and the muscles for parasites, bacteria and tooth metal as well as toxins in the foods eaten daily. Kill invaders twice a week with a zapper or stay on an herbal parasite program until all danger of recurrence is past (one to two years).

Clean up dentalware, diet and environment. Keep no indoor pets since any new parasite, however tiny, will surely find the niche left behind by the flukes and give you a new myasthenia gravis-like disease. The whole family must be parasite-free to protect the member with myasthenia gravis. But it is a task easily accomplished and desirable in its own right, so discuss your plan immediately with family members. Don't delay. The flukes don't waste a single minute. They go right on feeding and breeding.

Carmen Opsal, age 37, was told by her specialist she had her myasthenia from birth since she didn't have the strength to nurse. She had pancreatic fluke stages throughout her body. Her plan was to start on the parasite killing program, clean her kidneys, remove toxic elements, kill bacteria and clean her liver. Long before she accomplished this, in one month, she was feeling better and had return of her strength on some days. She still had the solvent, methylene chloride, from drinking “pure” orange juice and praseodymium from eating foil-packaged foods, also thulium from her

brand of vitamin C. She was full of auto exhaust and nickel from dental metal. There was hafnium from nail polish and hair spray and zirconium from deodorant. She planned to get rid of it all, and never need to return.

Universal Allergies

If minor allergies are due to a disabled liver, then extreme allergies must be due to an extremely disabled liver. This is the case for persons suffering from “universal” allergies, namely “everything”, like the lacquer on floors, plastic chairs, the neighbor's flowers, and the grocery store.

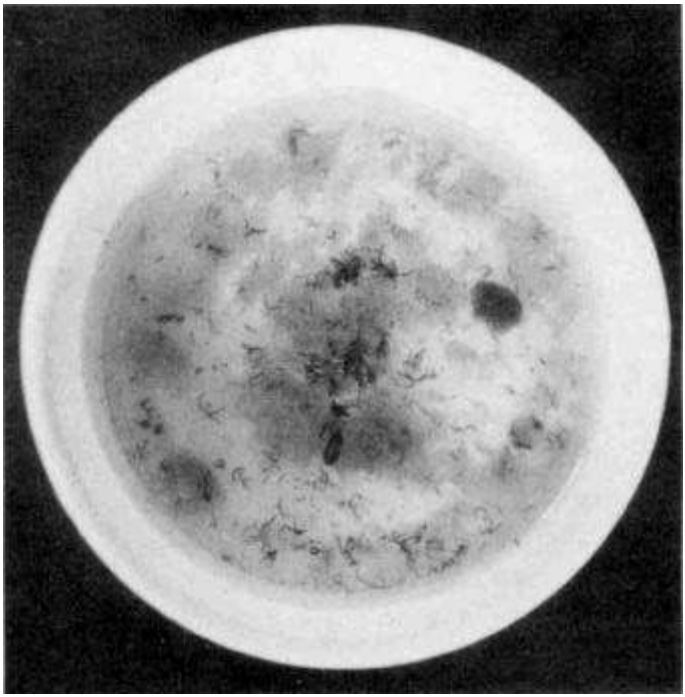

Fig. 32 Sheep liver flukes. Black threads in toilet are indicative of fluke remains.

They have more than merely clogged bile ducts. They have the sheep liver fluke living in the bile ducts! A tip-off to this situation is allergy to wool and wool fat (lanolin). A few flukes might not be noticed but a liver full of flukes that spill over into the intestine can give the worst case of allergy imaginable.

Sometimes the body manages to kill them with its own resources (maybe you ate something even too toxic for them!) They come through the bowel in a torrent. In the water of the toilet bowel they explode, spewing their infectious eggs all over in little black threads. Because these look like hairs, you may believe you passed "things with black hairy legs." These are actually burst flukes with black strings of highly infectious eggs. Why some people are literally taken over by these flukes is unclear. Amongst sheep, only certain sheep will be severely affected, being called "liver-rot." The disease in animals has been extensively studied.

Kill flukes with a frequency generator (434-421 KHz) or zapper. Come to the aid of the liver by avoiding food molds, removing dental metals, stopping chronic *Salmonella* infection and finally cleaning the kidneys and liver.

Environmental Illness

is another name for "universal" allergies. When more than a few flukes are present in the liver, they keep the liver from doing its major job: detoxifying all the food and chemicals that are taken into your body.

Different parts of the liver have different detoxifying jobs. One part detoxifies plastics and solvents, another part detoxifies perfumes and another newsprint ink, and so on. Foods have natural chemicals that need detoxification. By changing our food constantly we avoid overburdening any one of our detoxifying mechanisms. This is probably the basis for wanting differ-

ent food at each meal and different meals each day. We somehow "know" when we're ready for the same food again.

Less extreme forms of allergy can be due to other flukes in the liver, such as human liver fluke (*Clonorchis*), or just plain clogging with numerous cholesterol crystals.

Anything that is lodged in the bile ducts obstructs the flow of bile. This causes back pressure in that part of the liver so it produces less bile.

The bile duct system is a gigantic tree with lots of interconnecting branches. Remember how "stringy" liver can be when you buy it in the grocery store. These strings are bile ducts. When one is obstructed, others take over its job. But when a whole section of the liver gets obstructed and it can't detoxify a whole set of chemicals you dare not get those chemicals into you again.

What if you do? These chemicals go coursing all over your body! They are taken up by various organs. The brain has special protection, called the *blood brain barrier*. But this can get broken by parasites that burrow. Now chemicals can roam through the brain. Some attach themselves and cause an "allergic reaction". Beryllium, from "coal oil," kerosene and gasoline attaches itself to the brain easily. Then other things attach themselves to the beryllium!

The extreme form of allergies simply requires killing the sheep liver fluke and other flukes inhabiting the liver. They tend to overflow the liver and inhabit the intestine, too. In this case, you might actually see some in the bowel movement after killing them. They won't let go of you as long as they are alive.

They have two attachments to hold onto you, yet, they are not difficult to kill, even with herbs. Use the herbal parasite recipe (page 338), zapper, or a frequency generator.

Sheep liver flukes might actually be breeding, that is, multiplying in the liver of the hyperallergic person. This is not normal. Sheep liver flukes "should" only spend their adulthood in

our bodies. When the baby stages are also found in our bodies, (instead of in minnows or snails) there is undoubtedly a specific solvent involved. Environmentally ill persons have quite a few solvents accumulated in their organ tissues. Which one enables the sheep liver fluke to go through all of its development in the human is not known yet.

Obviously, the extremely allergic person, should remove all solvents from their diet and environment. Begin with eliminating propyl alcohol and benzene. The same products have other solvents too. It is processing of foods that puts solvents into them. Go completely natural. Dairy products are free of solvents, except for some cheeses. Remember to boil them to get rid of bacteria. Salt, olive oil, butter, and honey are free of solvents. With electronic technology, you can find solvent free products. Otherwise, if it didn't grow or you didn't make it from scratch, you must assume it has solvents! Cook from scratch, make your own pasta, bread, fruit juices, beverages.

Often, but not always, persons with sheep liver fluke, have a specific allergy to lanolin, a sheep product. Since lanolin is widely used in other products, this becomes a very broad range allergy. Such persons "can get no fat" at mealtimes or wear no wool without a considerable reaction. The allergy to lanolin does not disappear the day the flukes are all dead. But cleaning the liver with several liver cleanses (page 552) after killing parasites will start the recovery process.

Which comes first, the flukes or the solvents? That can't be answered. But what happens next is easily seen. The more flukes, the less able the liver is to detoxify solvents. The more solvents the better able the fluke is to multiply. A vicious cycle is set up that accelerates the illness.

Perhaps neither of these came first. Perhaps something else poisoned the liver so both solvents and flukes are given a home in your liver! Such a powerful liver poison would be a food mold: *aflatoxin, cytochalasin B, sterigmatocystin, zearalenone,*

ochratoxin, sorghum mold, griseofulvin, citrinin, T-2 toxin, Kojic acid, ergot and others. Avoid food molds—see Mold Free Diet, page 365. The diet must be quite limited at first, to allow the liver time to "regain" its detoxifying capability.

Of course, it is assumed that environmentally ill persons have had their dental metal replaced by metal free composite. This includes gold. Gold accumulates in the pancreas, another organ of digestion. This may mean choosing partial dentures. Read the section on healing the jaw and Bone Strengthening (page 87) to ensure this move brings you success.

The liver is a versatile organ. It can regenerate itself but it won't if food molds block regeneration. Given half a chance it will become like new. After killing parasites do the liver cleanse (page 552). If it has been a month or more since you killed parasites, then go on a high dose parasite herb treatment the week before, or zap. Don't use the herbs the day of the cleanse. With one major allergy gone after each cleanse and by timing liver cleanses two weeks apart, it takes only six months to have a reasonably normal life again. You can endure indoor air again, sit on plastic chairs, read newspapers, wear cotton clothing and leather shoes without reacting. You must still be patient and careful as you take back the world for you to live in.

Delores Flores, 53, was brought by her husband to the driveway in front of the office. There she put on her mask and advanced to the outdoor bench. She did not dare to come in. Without doing any testing her condition was obvious. She must start killing liver parasites. But it seemed too simple to be believable. And she knew she'd be allergic to the parasite killing herbs (this was before the zapper). She decided to do nothing.

Patricia Humphry arrived wearing an industrial painters' mask. It smelled rubbery. Her winter boots smelled moldy. And a faint scent of mothballs came from somewhere. Even her car had an engine problem, spewing exhaust fumes into the driveway. I suggested she begin with some basic reading material on allergies. She did not return either.

Arlene Kelly, 50ish, could eat no fat—not the tiniest snippet. But at Thanksgiving she allowed herself a little gravy. The consequences were swollen eyelids, swollen face, swollen throat: quite a dangerous situation. After killing *Ascaris* and the flukes, and cleansing the liver (all in time for Christmas) she dared a little pie—and got along quite well!

Alcoholism

When the portion of liver that detoxifies ethyl alcohol (the drinking kind) is hampered you are at risk for alcoholism. The other contributors to alcoholism are **beryllium** and **ergot**. Perhaps there are even more contributors.

Beryllium is plentiful in coal products such as "coal oil", and in gasoline to which kerosene or coal oil has been added. Fuel for "hurricane lamps" is a common offender, filling the air with beryllium. Liver blockage can force beryllium to circulate through the body; if it happens to attach itself to the addiction center of the brain, you're in a heap of trouble. Beryllium is very reactive. Any other allergen coursing by can react with it. If this happens to be alcohol–the drinking kind–you will be alcoholic unbeknownst to you.

When the liver is quite disabled, there may still be alcohol coursing through your body the day after you drank even a little bit! It is bound to find the beryllium stuck to the addiction center. Together, they turn the brain into a uncontrolled machine. Neurotransmitters are released that shouldn't be; others not released that should be. Mood is affected in a typically "alcoholic" way. Depression may be lifted—or caused!

Alcoholic persons should remove all fossil fuels from their environment, and never choose a career that exposes them to paint, cleaners, or automotive products. They should do liver cleanses until 2,000 stones or more are out.

Of course, they should never touch a drop of alcohol: not even the Black Walnut Hull Tincture in the herbal parasite program. The aqueous recipe should be made for them. Since alcohol is produced anyway, in the body, the liver should never be poisoned by molds, especially ergot: the very mold that is so abundant in alcoholic beverages! Alcohol and ergot interact to make each more toxic.

To help the brain recover its neurotransmitter status, take glutamine (500 mg.), a B-50 complex, and niacinamide (500 mg—to help detoxify ergot), with each meal.

To prevent alcoholism, protect your liver from food molds, especially ergot. Add vitamin C to nuts, pasta cereals, grains and even alcoholic beverages! Avoid fossil fuel pollution of your home by switching to all electric utilities.

Alcohol Addiction

There are many definitions of addiction. My definition is based on the special brain toxins, *beryllium* and *ergot*.

The brain has a region called the addiction center. If this center is stimulated it produces pleasure-chemicals. It is carefully controlled so that not too much pleasure or happiness can be experienced.

When a toxic substance, beryllium, is inhaled it circulates with the blood to the brain and may land at the addiction center. The more beryllium is inhaled the bigger the chance that it will occupy the addiction center. The brain cells in the addiction center have receptor sites for *glutamate* (the same glutamic acid that comes from the protein in our food). Normally, glutamate activates the addiction center. But when beryllium has "stolen" these seats, the glutamate is powerless to activate the joy and happiness center. The result is a low level chronic depression. The more beryllium there is to clog the receptors the worse the depression. Giving glutamic acid does not help but giving **glu-**

tamine does! Addicted or depressed persons should take glutamine, no less than 3 grams (3000 mg) a day. It comes in 500 mg. tablets. It is completely harmless.

When we drink alcohol or put it on the skin (as in mouthwash, tinctures, medicine) or produce it by fermentation in the intestines (*Candida* produces alcohol) a substance, *salsol*, is formed. Salsol reacts with beryllium. If the beryllium is in the pleasure center it reacts with it there. This reaction has the effect of activating the cells! Now a large amount of pleasure-chemical can be released. The amount is larger than normal because so many clogged cells are activated together. This explains the alcohol "high". In all the alcohol-addicted persons I studied, salsol was present, along with beryllium, on the receptor sites normally activated by glutamate (or NMDA or kainate). As we removed the beryllium we saw that the salsol also disappeared.

The solution to alcoholism is to avoid ergot contaminated food and avoid beryllium inhalation. We also remove the brain beryllium using **thioctic acid**. Stopping the use of alcohol may save a life or career but does not correct the problem. Even after 30 years of abstinence, I still see the beryllium present in the addiction center and the salsol, derived no doubt from endogenous sources, still attached to the beryllium. This is why the addiction is never gone even after years of abstinence.

If any member of the family is, or was, addicted to alcohol the house should be searched for beryllium sources. Hurricane lamps or antique lamps are the most common sources. Remove them permanently. Washing does not clean them. Remove all solvents, cleaners, lighters. Switch to a butane lighter. The air should be tested for beryllium. The garage door to the house should be permanently closed, and the car and lawnmower kept out of it. Addicted persons should not be painters! Nor walk into a dry-cleaning business. Soon you will see a more cheerful

disposition in the addicted person and this will be rewarding for the whole family.

Miguel Alcorn's wife cleaned up the environment for Miguel, whose alcoholism was 30 years long. Even lighter fluid was removed. The garage was sealed off from the house. She added vitamin C to his meals so he didn't have to “take anything”. She was very careful about moldy grains. He lost his preoccupation with drinking after killing parasites. She believes he is not sneaking any. Our hats are off to her.

Seizures

are always caused by tiny *Ascaris* larvae in the brain.

I suppose they find their way to the seizure center by accident. It is not normal for them to be in the brain, they typically travel between the stomach and lungs. *Ascaris* eggs are present everywhere in animal filth. Dogs, cats, horses and pigs all get *Ascaris*. Their excrement dries and flies about in the dust, but mostly it resides in the soil. Children playing in the dirt cannot help but pick up *Ascaris* eggs. The eggs hatch in the stomach and the tiny larvae, microscopic in size, travel first to the lungs. Here they go through a *molt*. This causes some coughing.

Whenever a child coughs for part of the day do not assume it is harmless. Use a frequency generator set to 408 KHz, or use a zapper. Children should be treated for *Ascaris* anyway, whether coughing or not, once a week. The tiny larvae are in the cough up. Children should not be taught to politely swallow this. They could be swallowing their own future seizures, asthma, or eczema. Teach children to use tissues for all spit up. The lungs are doing what they can to rid the body of these invaders. Your intelligence must cooperate with your lungs.

Ascaris do not come sweet and clean in themselves. They bring their own bacteria and viruses. One of these bacteria is *Bacteroides fragilis*. *Bacteroides* needs a host like *Ascaris* so it

can be oxygen-free. Such a requirement is termed *obligatory anaerobic* meaning "must have absence of air."

Being transported to the brain inside *Ascaris* larvae is probably the means by which *Bacteroides* gets into the brain. Brain abscesses and brain tumors usually have *Bacteroides fragilis* growing there. Brain tumors will not shrink unless all the parasites, bacteria and viruses are dead. *Bacteroides*, in turn, are big enough to house thousands of viruses. Two common viruses seen with *Ascaris* are *Coxsackie* B_1 and *Coxsackie* B_4. Perhaps it is the toxins of the *Ascaris* larvae or *Bacteroides* or *Coxsackies* that induces the seizures. Maybe it is something else about the infestation that induces them. But by killing *Ascaris*, *Bacteroides* and *Coxsackies* (zapper or frequency generator at 408, 325, 364, 362.5 KHz) you have eliminated the first essential link in the chain of developments that causes seizures.

The brain does not quietly tolerate these invaders. It fights back with its immune system. But the wormlets are already too big to be eaten by white blood cells. The brain fights back by producing **inflammation**.

Inflammations are intended to attract calcium so a wall can be built around the intruders. Inflammations are negatively charged regions so the positively charged calcium can find its way to the inflamed site. But lead and mercury are also positively charged! Perhaps this is how these **toxic metals** are attracted to the brain. All metals are positively charged. Perhaps this is their fateful poisonous attraction to living things. Perhaps they do not poison when no inflammations are present! In seizure cases we see many tooth metals in the brain. These must be removed so the inflamed site can heal.

Other toxic substances have also found their way to the inflammation at the seizure center: **vanadium** from leaking household gas; **PVC** from new carpets; **titanium** from face powder; **zirconium** from deodorant; **asbestos** from the clothes

dryer belt or hair blower; **lead** from tainted drinking water. Do a good clean up of your environment.

Solvents accumulate here, too. Especially **toluene** and **xylene**. These are found in paint (persons with seizures should never be around fresh paint) but are also found in trace amounts in carbonated beverages. A person with seizures should drink no commercial beverages: see the Recipe section for homemade carbonated and other beverages. There are several other specific brain irritants that accumulate at the seizure center.

The food fungus, **ergot**, is always seen in seizure cases. Perhaps it can act alone to produce seizures. After all, seizures are an ancient malady, existing long before chemicals and solvents were manufactured.

MSG, which is *monosodium glutamate* should never be used in food. It was already banned in infant food in Europe a decade ago. Why are we still allowing it? Are our children not as precious? Healthy adults may tolerate it better than young children. But what about sick adults? Specifically, adults with a brain illness? Glutamic acid is a natural constituent of protein in our foods. And the sodium glutamate it must form in the body does no harm. But MSG is not biologically produced. It is lab-made. Lab-made amino acids are not the same as biologically made. Perhaps it is these "isomers", perhaps it is the simple overdose of a natural thing that is brain-toxic. Whatever the mechanism, MSG should not be consumed by anyone, let alone a seizure sufferer. Fortunately, you can ask at restaurants, where (not whether) MSG is used so you can avoid these foods.

BHT and **BHA**, standing for *bishydroxytoluene* and *bishydroxyanisole* are food preservatives and also seizure triggers. They are often put on the boxes of cereals, rather than the cereals themselves, so the cereals can be pronounced preservative-free. Imagine how much the box must be drenched with to prevent oxygen leakage into the interior?

A more insidious seizure trigger is a perfectly natural substance, **malvin**. Malvin is the natural dye found in grapes, strawberries, plums and blueberries. Stop eating strawberry and grape jam or juice. Chickens and the eggs they lay, have lots of malvin too, stop eating chicken and eggs.

Here are foods relatively free of malvin: artichokes, asparagus, almonds, barley, beans of all kinds, green beans, broccoli, Brussels sprouts, cantaloupe, celery, nectarines, citrus, dates, mango, pears, kiwi, pineapple, Granny Smith apples.[14]

To Summarize

To stop your seizures on a dime, and not have another one:

1. Avoid malvin in food. Eat nothing colored red or blue, chicken, eggs, MSG, BHA & BHT. Boil all dairy products or don't eat them.
2. Avoid ergot in food. Eat no whole grain products; take niacinamide 500 mg three times a day to help the liver detoxify tiny bits in other foods.
3. Kill *Ascaris*, *Bacteroides* and *Coxsackie* virus and stay on a maintenance program of killing them. Avoid reinfection. It would be wise to have only outdoor pets.
4. Replace dental metal with metal-free plastic (See Dental Clean-up).
5. Clean up the home environment and body products of toxic substances.
6. Keep your fingers sanitary: spray them with 10% grain alcohol or vodka after bathroom use.

You can often tell by how you feel whether you are near to having a seizure. But some people get no warning. Don't take

[14]Taken from *A Guide to the Identification and Treatment of Biocatalyst and Biochemical Intolerances*, 1988 by J. A. Krohn, Los Alamos Medical Center, 3917 West Road Suite 136, Los Alamos, NM 87544.

chances. Keep your drugs with you, even though you no longer need to take them. Drugs like Tegretol™ and Phenobarbital™ are not harmless. Once you can tell that you're better, try reducing your drug dosage slightly. See how you manage. If you have a breakthrough seizure you could fall and break a bone. Don't take chances. Even a year after your last seizure you should carry your medicine with you and have some in your house. This is because it is so easy to pick up *Ascaris* again. The highway to the brain–its seizure center–is still open. They will travel it again. It might only take two days from the time of accidental swallowing of animal filth, to having little larvae in the brain. Use a frequency generator every day at first, or zap daily to guard against this. Notice that killing parasites the first time may actually start a seizure coming. Simply stop zapping if you feel one coming. Do shortened zapping until you can tolerate a regular treatment. Have someone with you while zapping.

Say good-bye to seizures forever. But don't forget your susceptibility. I believe you should be extra careful for two years. If you have a recurrence, repeat the whole procedure. This time it should be curable in a single day.

Doug's mother was distraught when she brought him, age 8 months. Her doctor only seemed sympathetic with her purpose to keep the baby's temperature down the next time he catches a cold. But her doctor had referred her to the county social worker. She had been completely honest with her doctor, because she was that kind of trusting person. Since her baby had only experienced one seizure (which was during a fever), she didn't see why her beautiful first born child should be on medicine “the rest of his life”. She wanted her baby to be perfect. But the social worker had called her, talked about “the law” and being an unfit mother. She was all apart. The baby was supposed to be on Phenobarbital™ twice a day. Our tests showed Doug had *Ascaris* plus lead toxicity. He was also getting home made strawberry and grape juice. She promised to put the three cats outdoors, keep the baby off the floor, keep Doug's fingernails short and always wash his hands before eating. The parasites were easily killed. The lead was spo-

radically present in the water. She planned to move, and until then would filter all the drinking water so her breast milk would be free of it too. His diet was changed to eliminate eggs, chicken and the red and blue fruits. We recommended leaving the state in order to be able to peacefully raise her child. We promised to treat her child free of charge if another seizure should occur. Two years passed and we heard she was doing fine with her child.

Clara Scruggs, 50ish was losing control over her seizures and had to be hospitalized while a new medicine was tried. It changed her personality (again!) which upset her husband, too. She was started on the herbal parasite program but could only increase by one drop of Black Walnut Hull Tincture a week, instead of daily, since each new increase would give her a seizure. In half a year she was fairly free of seizures in spite of being off drugs. After each seizure, a checkup showed she had picked up *Ascaris* again sometimes with additional parasites. She could not bear to put her cat outside; Boots had been a friend in need many times. When she finally got Boots onto a regular parasite program she improved enough to go to church and church events again. When Boots finally "wanted out" she didn't mind. She decided to do a liver cleanse—this, too, gave her two seizures the next day but paid big dividends in other ways. She eventually improved to an incidence of one small seizure ("spacey" time or incoherent speech) in two weeks.

Chun Yee, age 28, has been on Dilantin™ from age 15. Now he was up to five pills a day and it didn't control his seizures. Any activity would trigger it. He was put on a low malvin diet and started on the kidney cleanse. His blood test showed he was anemic with a high MCV (104 cu microns), suggesting the *Ascaris* worms were using up all his vitamin B_{12} too. In six weeks he was down to one or two seizures per week, although he had not yet started the parasite program. He had beryllium built up in him, probably from a kerosene heater. When the pets and family were all treated for parasites he had no more breakthrough seizures and could cut his medicine in half which gave him much more energy. He was no longer in danger of losing his job.

Shiresse Nobel, age 7, was having minimal seizures but the mother did not want to start her on medicine. Shiresse had high levels of mercury in her body, although she had no tooth fillings. The whole

family cleared their Ascaris infestation and in three weeks the seizures were gone but aggressive behavior remained. There was mercury in the air of some rooms but it was not in the paint. The bathroom was the worst. When everything in the bathroom was removed, the air cleared and so did Shiresse's behavior problem.

Drew Seaton, age 8, had his first seizure lasting nearly a minute. The parents were very fastidious and extremely conscientious about diet and habits. They were distraught. They all had *Ascaris*. A baby was still being diapered. Drew had arsenic (pesticide under kitchen sink), formaldehyde (some remodeling) and PVC (a new carpet) accumulated in his body. The carpets had to be steam cleaned to get rid of the arsenic. He was started on parasite herbs at once, since he was on medication that would shield him from having another seizure while killing *Ascaris*. Two weeks later everybody, except the mother, was free of *Ascaris*. In another two weeks they were all free and had cleaned up house toxins. They dared to stop his medicine. This let Drew's former happy personality come back to everyone's delight. Two years later there was still no recurrence.

Cosmo Maser, 30ish, was in a hospital across the country. He was having continuous seizures, although he had been there a week. It seemed impossible to transport him but, against doctor's orders, they got him into a station wagon. He had nothing to eat or drink that had any malvin in it (he ate four very well done hamburgers, plain, with lettuce on his trip) and his seizures stopped immediately. They felt a bit sheepish upon arrival 20 hours later since he could sit up, could tell his own story and no longer looked ill. He was without medication, too. They had left in a hurry. They immediately removed all the metal from his mouth; this cleared his mercury problem. He was started on parasite medicine and weathered the small seizures each increase gave him. He could return home in five days with his new diet and thioctic acid daily as a supplement. He occasionally had a seizure (2 a month) until they moved away from the busy street below their apartment. About a year later he could hold a job and go off Social Security support.

Weight Problems

Overweight is not the same problem as *obesity*. In fact, I do not have the answer to either problem, only a part of the answer.

In **obese** women, the ovaries, pancreas and thyroid are all involved. Perhaps the adrenals, the brain satiety center, and the liver are also involved. Maybe it's as simple as gold accumulation in all these places. Perhaps it is bacteria in all these places. When you weigh close to 300 pounds obviously some organ isn't working right. Try several things, but not a starvation diet.

The cause is not eating too much. Try removing all gold: gold teeth, gold jewelry and gold rings. Replace them with non metal varieties. After removing the gold, pull the remaining gold out of your tissues with thioctic acid (2 or 3 a day for several months). Make sure kidneys are able to excrete the gold instead of making crystals by doing a kidney cleanse. Gold accumulates in the pancreas, the brain (possibly in a control center here) and the ovaries (causes some infertility here). Also try clearing the body of all bacteria and parasites by regularly using a zapper. Use the Bowel Program (page 546) to evict the last of the *Shigellas*. Be very careful to avoid nonsterile dairy products. Try cleansing your liver by doing liver cleanses. Get 3,000 stones out.

Make sure you are getting enough nutritious food; make carrot and vegetable juice; use no commercial beverages. Avoid moldy food—don't take risks. If all these measures bring your weight down to the level of mere overweight give yourself good grades.

Overweight is a low energy condition. Your food is being turned into fat instead of energy. The decision not to make energy is being made in the liver mainly, but perhaps other organs as well.

Try cleaning the liver (page 552) until no more stones come out: get at least 2,000 stones. Notice that as the liver gets

cleaner you get more and more energy right after each cleanse. Some cleanses have a dramatic effect. Others do not. This suggests that a certain part of the liver is the responsible part. Soon after the cleanse–within a week–the same old lassitude sets in. But during these few days notice how your body feels. It feels light. Your abdomen feels tight, like it's a part of you again. You're mind isn't on food throughout the day. It's very easy to lose weight, in fact you may lose five pounds in these few days without dieting or exercising. Definitely, your long-lost weight regulation is back in force. But then it vanishes. Fortunately, a bit of the weight loss stays with you, and by repeating cleanses (only once in 2 weeks, though) you can shed the pounds you want and gain energy in a permanent way. It is probably the way nature intended.

Try increasing your bowel movements. Notice how cats and dogs seem to derive energy from emptying their bowels. A cat walks to its litter box; after emptying its bowels and carefully covering it up, it jumps from the box and runs away. It now has its playful mood. A body chemical, *acetylcholine*, plays a role in emptying the bowels. Acetylcholine is a necessary operator for many of our muscles. Is there a disturbance in our acetylcholine metabolism in overweight conditions?

Coax your body to release more acetylcholine, at least in the intestines, by using a herbal laxative like Cascara sagrada. Other varieties are useful, too, but don't use a drug laxative: it burdens the liver more. Try to have three bowel movements a day.

Shigella bacteria can cause dreadful constipation. Immediately, the body feels sluggish, abdomen feels disconnected or hanging out. A nameless hunger sets in. Keep a close watch on dairy foods to make sure they are sterile. Zap when in doubt and do the Bowel Program.

Exercise helps as long as you keep at it. Strict dieting works as long as you keep doing it. But there's the problem. When you

stop, you lose ground. It doesn't solve the problem of an inefficient body metabolism.

Raising thyroid levels helps but this can be dangerous. Raising thyroid levels naturally, by removing toxins is a very effective method—provided it was low to begin with. Overweight people often have a low body temperature, showing that the thyroid is involved: it is under producing. **But giving the body extra thyroid doesn't solve the thyroid's problem. It only temporarily solves the rest of the body's problem.** The thyroid will have viruses and heavy metals in it. The metal in your mouth drains downward to the stomach passing very close to the thyroid. Perhaps its iodine uptake is inhibited. The chlorine in water and bromine in bread may inhibit iodine uptake by the thyroid, too. After all, they are all halogens. Stop eating bleached bread and filter out the chlorine in your water. If this raises your body temperature you could expect better weight control.

The traditional herb, *Fucus*, was used to treat thyroid problems (and overweight) in days when herbs ruled medicine. Herbalists made a point of discouraging use of plain iodine. Fucus, they said, was much more effective. See *Recipes*.

If all these measures don't work for you, at least you have improved your health trying.

There are some advantages of being overweight. Overweight people seem to weather illness better. They laugh more. But one look in the mirror or at the scales ruins it. Put away the long mirror and scales. Don't ruin your whole life over it. Make a reasonable effort and then let go. Enjoy your stay on this planet.

Underweight can be just as difficult as overweight to correct. Once the stomach has been trained to say “full” or “full enough,” even after a few mouthfuls, it is difficult to heal. *Salmonellas* in the stomach wall are often seen. *Giardia* and other

common parasites, that don't belong in the stomach, are seen here in cases of underweight.

The stomach is invaded by bacteria and parasites when its immunity is low. The common culprit is tooth metal draining down continuously into the stomach. Remove every bit of mouth metal. Don't cook or eat with metal. Stimulate your appetite with B-vitamins. And, again, the liver plays a role. If it is toxic with mold, it may say "eat no more" and the body obeys.

A stage of cancer illness is weight loss. This is called *cachexia*. The victim believes he or she is eating enough. They may not even have a poor appetite. Yet weight drops steadily. This metabolic problem has been studied scientifically. A chemical, **hydrazine sulfate** (prescription only), can reverse it to some degree. Use 65 mg three times a day for 30 days. Perhaps a lesson taken from cachexia metabolism could be applied to obesity. For the cachexia sufferer, life would end sooner if high calorie supplements were not used. But don't use canned "calorie boosters". They are polluted—often with the very solvent that makes the condition worse. Instead, make an eggnog: ½cup boiled milk, ¼ cup boiled whipping cream, a raw egg (exterior carefully washed), 1 tsp. olive oil, a banana, honey, cinnamon, cloves, nutmeg to taste. Mix all in a blender. Drink 1 cup a day. Vary it daily to keep it interesting.

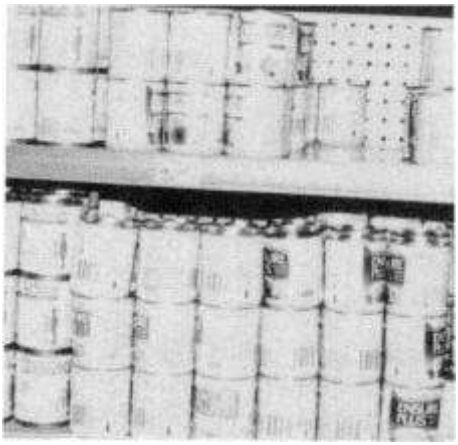

Fig. 33 I found all calorie boosters to be polluted with wood alcohol. Make your own.

If all this fails, give yourself credit for achieving health improvement and shift your focus to a different project. Underweight is not all bad either.

Sleep Problems

All big animals sleep, but some sleep by day instead of night. When humans do this, that is, work the night shift, they don't feel as well. Humans need about seven hours of sleep out of the twenty-four. Younger ones sleep more; newborns sleep much more. When we are deprived of sleep we are grouchy, think less clearly next day and have less energy. In spite of lots of research at "sleep labs" sleep problems are not understood, except for sleep *apnea*. Breathing should be even. When breaths are missed it is called apnea. It is especially disturbing when a baby shows apnea.

Sleep Apnea

Since breathing is regulated by acid levels in the blood and this is influenced by air quality, air toxins should be searched for first. **Cigarette smoke** is an air toxin. **Vanadium** from a gas leak is a very serious air toxin and can go unnoticed. Do your own checking since gas companies give wrong answers four out of five times. Ask a home construction company to check for gas leaks or the Health Department. **PVC** from new carpeting may be polluting the air. **Arsenic** from "treated" carpets and drapes and furniture also pollutes. **Asbestos** from clothes and hair dryers may be the toxin responsible. Perhaps even **fiberglass**, **formaldehyde**, or **freon**.

Adults with sleep apnea show swollen throat tissues: not necessarily pain. This makes the air passage smaller; long gasps

of air are taken to try to make up for the missed oxygen and the carbon dioxide build up.

Swelling of the throat is a common allergic reaction. The possibility of allergy should get second consideration after air quality. Drug reactions, even in a nursing baby, where only the mother is using a medicine could be the problem. Allergy to food, chemicals has been suggested, as well as a simple lack of vitamin C (implicating mold and medicine which consume vitamin C in the detoxification process).

A third possibility is infection. Many bacteria and viruses can cause throat swelling. Redness of the throat is a telltale sign. It doesn't necessarily hurt. Kill all invaders with a zapper and try to understand the basis of low immunity in the throat.

Keeping metal in the mouth constantly, is a cause of low throat immunity since it must drain past the throat.

If you snore, you can deduce that your throat is swollen, even if you don't have sleep apnea. Pursue all three possible causes (air toxin, allergy, infection).

Overweight and obesity have been emphasized as causes. This may apply to some cases but certainly not to babies.

Whatever you do, <u>don't do nothing</u>. Keep removing bad things until you find the cause of irregular breathing.

Chester Fannon, 5Oish, was quite overweight and wore a mask at night with an air blower to assist his breathing. He had been referred to a sleep center for sleep apnea. He had extreme dryness of his throat at night and some hearing loss in one ear. He was toxic with arsenic (roach killer), bismuth (cologne), tin (toothpaste), and thallium (polluted dentalware). He was infested with both species of *Ascaris* and had a hacky cough. He had four solvents accumulated in his tissues. He was growing nine pathogens: *Mycoplasma*, *Haemophilus inf.*, *Streptococcus pneu*, *A-strep*, *Nocardia*, *Staphylococcus aureus*, *Bacillus cereus* and Flu virus, over half of them in his throat. These were killed with a frequency generator and a general cleanup was done. After two teeth were pulled he no longer needed his mask, he no longer had apnea.

Peter Day, middle age, was set for throat surgery in a few days. He had a couple of scary nights when he thought he was dying and couldn't risk many more nights with his obstructed airways. He was overweight. His throat was red and swollen, although he felt nothing. He never even had colds. His diet was completely changed, to things he rarely ate (bananas, milk, soup, oatmeal) and off things he ate daily (hamburgers, fries, tea, pancakes with genuine maple syrup). In two days, his throat was quite clear, the tissues having become unswollen. Maybe it was the molds in the maple syrup, maybe it was the oxalic acid in the tea, or something else he could not detoxify in these foods. He was certainly happy not to live the rest of his life with an artificial voice box.

Insomnia

Another sleep disturbance is waking in the night and not being able to go back to sleep for hours. Or not being able to get to sleep.

I believe these problems are caused by a high ammonia level in the brain. This belief is based on two observations. **Ornithine**, an ammonia reducer, induces a wonderful sleep in sleep-deprived persons. It is also observed that after killing parasites, which produce ammonia, sleep is much improved. Our metabolism does not produce ammonia. We produce urea which is excreted by the kidneys along with water and then called urine. When we are parasitized, our metabolism is burdened with ammonia, though, made by the parasites. We have to turn it into urea in the liver and kidneys so we can excrete for them. But this can't be done in the brain! The brain lacks an essential enzyme, *ornithine carbamyl-transferase*, for this bit of biochemistry. The brain was never meant to be parasitized or infected and has no defense. Most of our parasites come from animals we associate with. We weren't meant to live with horses, cows, sheep, pigs, monkeys, guinea pigs, cats, dogs and chickens nor to come in contact with dozens more at a zoo. We do so at our own peril.

It is known that ammonia is a strong brain irritant. In fact, a person can be awakened from a coma by being made to smell ammonia "smelling salts." Ornithine reacts with ammonia, mopping it up like a sponge. **Arginine**, another amino acid, also reacts with ammonia, but does not put you to sleep. So there is more to insomnia than mere inability to reduce ammonia levels. Arginine results in alertness and therefore should be used in the morning, when needed. Ornithine, given at bedtime, may take ½ hour to do its magic. Both are perfectly safe, since they are natural to your body, and a food constituent.

Start by taking two ornithine capsules (each 500 mg.) on the first night. Take four the next night. Take six the night after and choose the dose you like best. Sometimes it takes five days to "catch up" on everything that needs to be done for the brain and get you sleeping. Meanwhile, of course, you are planning to kill your parasites and be done with insomnia in the most effective way of all.

Another sleep aid is herbal. A couple of herbs, **valerian** and **skullcap**, are known for such action. The mechanisms are not understood and this makes for nonuniform action. Some persons sleep well with them, others do not. Simply try them to find out. We are all so different in our metabolism details, we respond differently to herbs. But it is a blessing that the mechanism is <u>not</u> understood. Herbs, a tradition that precedes civilization, need to be forever off limits for intervention by government agencies.

Tryptophane, another amino acid, is about twice as powerful as ornithine, but was taken off the market a few years ago. Some persons taking it daily were seen to become quite ill and some deaths ensued. Since tryptophane had been used in prior years without noticing toxicity, something unusual should have been suspected. My tests showed extreme pollution of tryptophane capsules. They contained PCBs, mercury, ruthenium, strontium, praseodymium, aluminum, and benzalkonium. I can

only speculate that a mixing vat broke, dumping its precious load onto the floor—but it was salvaged. Or that the mixing vat wasn't cleaned thoroughly from it's last use.

Persons with illness due to taking tryptophane developed an extremely high eosinophil count in their blood test—an index of parasitism, too. Parasitism, that would have led to insomnia in the first place! Were these unfortunate victims seeing the cause or the result of their tryptophane use? This tragic event should have led to a discovery of the heavy pollution, a revelation of the industrial manufacturing process, and a safeguarding against any repetition. It has not been done (certainly not publicly).

Foreign countries' manufacturing processes do not come under U.S. scrutiny or jurisdiction, although some imported products must pass tests. There are no safeguards against repetition of the tryptophane experience. It behooves us to demand safe supplements and medicines. It is not the list of ingredients that informs. Lot analysis, after bottling, would give us the necessary safeguard. The presence of filth contamination and toxins cannot be completely avoided but the consumer can make informed choices if he or she knows it is there. Disclosure, of course, is the bane of the manufacturing business. Interest rate disclosure was the bane of the money lending business. Such important matters can't be left to "self-regulation" policies. The consumers must simply demand to know what they are consuming.

Ruby Adair, 14, ached all over, had ringing in her ears, sinus problems and chronic fatigue. She couldn't get to sleep, ever; and had been half a year out of school already. She had intestinal flukes in her stomach. In three weeks she had eliminated them with parasite herbs and she could go to sleep naturally.

Yeast Infections

The most common yeast in humans is *Candida albicans*. *Candida* has always been around. It flies in the air, searching for a place to land and reproduce. It can invade a variety of human tissues like the mouth (called thrush), skin (including some kinds of diaper rash), vagina, and the digestive tract. We all have some yeast in our digestive tract, but when it gets out of hand, it's called *candidiasis*.

Yeast is a **fungus**. It needs dampness to survive and sugar to grow.

Our immune system, white blood cells, are capable of eradicating yeast provided it isn't growing too fast. And provided the white blood cells aren't immobilized or preoccupied with something else.

Diaper Rash

A baby's rash is an example of the white blood cells being preoccupied. When chemicals are used in the diaper, the white blood cells go after the chemicals and let the yeast grow. Drying the baby's skin helps since the yeast must have dampness. This should be done with air, sunlight and a heat lamp, not with more chemicals! Certainly not with cortisone containing salves that further reduce the immune competence of white blood cells.

Use a heat lamp for five minutes at a time, several times a day. Switch to cloth diapers; do not bleach them with chlorine bleach, the residual chlorine trapped in the cloth is a chronic irritant, setting the stage for another rash and future chlorine-allergy. Cloth diapers should be sterilized, not bleached. Use the hottest water your laundry system is capable of producing. Add ½ cup borax for the washing process. If you have homemade Lugol's iodine (made by your pharmacist or by yourself, see *Recipes*), add a tsp. to the wash or rinse. Vinegar is a yeast in-

hibitor, add it to the rinse. Dry diapers at the hottest setting. Dry to kill. Kill all the yeast spores in the diapers.

To strengthen the baby's skin against future infection, do not put chemicals on the skin. Do not use any soap, fragrance, bath oil, ointment or lotion. Do not use cotton balls or baby wipes. Do not give a daily bath. Wash bottoms gently, with borax followed by a vitamin C rinse. Vitamin C is acid and is our natural healing agent but it will sting on a broken skin surface. Use it as dilute as necessary to be tolerated. Zinc oxide is another natural healer because it competes away the iron that fungus and bacteria need for their reproduction. Never use commercially available zinc compounds though, simply purchase your own zinc oxide powder, mix it with cornstarch and keep in a large old salt shaker, dust it wherever there is moisture or fungus growth.

Treat Yeast or Fungus the Same

Other fungus growths, like *Tinea* (crotch itch), ringworm (not a worm at all), athlete's foot, along with *Candida*, can be similarly eradicated:

1. Deprive the fungus of moisture.
2. Deprive the invaders of iron.
3. Deprive the fungus of sugar.
4. Strengthen the skin's immune power.
5. Strengthen the skin's healing ability.

It may be impossible to deprive the fungus of moisture, for example if your feet sweat and you must wear socks. Take your socks off as soon as you are at home, treat your feet with a heat lamp. Use zinc oxide or cornstarch to powder and dry the skin. Boil your socks when laundering. Dry them to tinder-heat (too hot to touch). Launder with borax only (soaps and detergents contain aluminum which pollutes the skin). Rinse skin with vitamin C water. It takes <u>all</u> these measures used simultaneously

to clear up athlete's foot fungus. And great persistence. They may have developed a foothold underneath the toe nail where a steady supply of moisture, iron and sugar is available to them. Nevertheless, your white blood cells will eventually gobble them up if you let them.

In thrush (yeast infection of the mouth) you must again outwit its growth by doing everything possible at one time. Eat no sugar, drink no fruit juice, stay off antibiotic. Avoid trauma like eating abrasive foods (crusts, popcorn, nuts, lozenges) or sucking on things. Floss teeth only once a day (using monofilament fish line), followed immediately by brushing with white iodine (or Lugol's, but this may temporarily stain). Hydrogen peroxide is not strong enough. Remember to sterilize your toothbrush with grain alcohol or iodine. You may also rinse your mouth with Lugol's (6 drops to ¼ cup of water). Or apply 6 drops directly to the tongue and rub it in lightly with your lips.

Do not use Lugol's iodine if you have been told you are allergic to iodine.

Kill *Candida* daily with a frequency generator or zapper. Since reinfection is constant, you must continue to do all the treatments given to permanently cure yourself of fungus disease.

Since *Candida* grows right into your living cells (which you are not attacking!) you cannot kill it all at once. Only surface fungus can be accessed by either Lugol's or electrical "zapping". But as the top layer is killed, exposing the next layer, you will make progress. It will take a month of daily treatment to clear it.

Clearing up fungus at one location but not another will not bring you a permanent cure, either. Damp locations like under the breasts, under the belly fold, groin and crotch need to be

kept dry with cornstarch daily. Keep it up long after it seems to be cured.

Fluke Disease

Flukes, or flatworms, have a complex life cycle with many stages. Although sheep, cattle, pigs and humans can be "natural" hosts to the **adult** stage, the other stages are meant to develop outdoors and in secondary hosts. When fluke stages other than the adult are able to develop in us, I call it *fluke disease*.

Or, when an adult that "normally belongs" to another species is able to develop in us, I also call that fluke disease. Or even with adult flukes in their "normal" host, when they move from the organ that they "normally" colonize to other organs in the body I call this fluke disease, too.

Four fluke varieties engaged in this extra territorial pursuit are the **intestinal fluke**, **sheep liver fluke**, **pancreatic fluke**, and **human liver fluke**.

As you can see from their names, scientists have studied them well, and know exactly which animals are the "normal" hosts, and which organ in that animal is the adult fluke's "normal" home. Fluke disease is when any of these is "wrong."

Flukes don't have eyes to see with or legs to walk with, so how can they find and travel to the organ they want in the middle of your body? Scientists do not know for sure. However it's concluded from many scientific studies that the liver fluke, *Fasciola*, for example, has no trouble seeking out and colonizing the liver.

Here are some examples of what can happen when flukes go "wrong:"

- Adult flukes (any of the four mentioned) in the uterine wall causes cramping and bleeding when it is not men-

strual period time. If an adult crosses the wall to the inside and then manages to get out through the fallopian tubes to the abdominal cavity it takes some endometrium with it—causing **endometriosis**.

- If adults develop in the kidneys, it can cause **lupus** or **Hodgkin's disease**.
- If adults complete their cycle in the brain, **Alzheimer's** disease and **multiple sclerosis** result.
- If the intestinal fluke (*Fasciolopsis buskii*) becomes adult in the liver it causes **cancers** of many (hundreds) kinds.
- If the pancreatic fluke completes its cycle in the pancreas it leads to **diabetes**. This is not an example of flukes straying into the wrong organs, but of having its stages reproducing where they never could before.
- If flukes develop in the thymus, immunity is lowered. If it happens to be the intestinal fluke, **HIV** (Human Immunodeficiency Virus) is released there. In turn, HIV invades other tissues, like penis and vagina.
- These four flukes can also invade the muscles, causing **dystrophies**.

As dissimilar as we always thought these diseases to be, it's obvious to me that they are but one disease—fluke disease

Considering the size of these flukes (adults are easily visible), it is not surprising that they can quickly lay waste a human's organs. Yet a human is big and makes a valiant effort to kill the stages, block access to tissues and otherwise battle them.

But only the human's intelligence can be counted on to defeat them. The intelligent approach is to discover what enables these mighty monsters to do their reproducing in our bodies instead of the pond with its snail/minnow secondary hosts.

Flukes and Solvents

The explanation I have found for two of these flukes is the presence of solvents in our bodies. The presence of *isopropyl alcohol* is associated in 100% of cancer cases (over 500 cases) with reproduction of the intestinal fluke stages in a variety of organs causing cancers in these organs.

The presence of *benzene* is associated in 100% of HIV cases (over 100 cases) with reproduction of intestinal fluke stages in the thymus.

The presence of *wood alcohol* is associated in 100% of diabetes cases (over 50 cases) with reproduction of pancreatic fluke stages in the pancreas.

The presence of *xylene* and *toluene* is associated in 100% of Alzheimer cases (over 10 cases) with the reproduction of intestinal fluke stages in the brain.

Much more work needs to be done to examine the relationship between fluke reproduction, the solvent and the chosen organ. But it seems probable that the solvent allows it all to happen. And our intelligence, to save us, must find a solution.

Stopping use of these solvents seems to me to be the most urgent advice. Finding which foods and products are polluted with them is the first step. It is imperative that you test everything you use or eat for solvent pollution. The Syncrometer makes that an easy task. Ideally, we should all pool our results, adding to the body of knowledge I have begun.

In my observations, when the big sources of solvents are stopped, the body's levels go back to zero. In other words, the minute amounts that we inhale here and there do not accumulate to the point of serious damage. We have to eat, drink or absorb them on a daily basis to injure us! So where can they come from?

The sources of benzene and propyl alcohol that I found are given in special lists (page 354 and 335). The sources of wood

alcohol are not as well known, but include commercial beverages, cold cereals, artificial sweetener, vitamins, and drugs. Other solvents are even less studied. But a pattern is emerging: foods and products that require sterilization of bottles and machinery to fill these bottles are polluted with propyl alcohol or wood alcohol. Foods and products containing flavorings or oils are polluted with benzene. Let the buyer (you) be wary! Test your own products if possible. If not, do not purchase them.

There are many other flukes and many other diseases. Are there other fluke/solvent/disease trios? Has fluke disease been going on for a long time or is it a recent phenomenon? Certainly cancer is 100 years old, so is the use of propyl alcohol. Diabetes is quite old as an illness, too, and so is its associated solvent, wood alcohol. But HIV, AIDS and Alzheimer's are recent diseases. Should we conclude that benzene, xylene and toluene were used much less in the past?

Fluke diseases could be eradicated with some simple actions: monitoring of solvents in foods, feeds and products. Hopefully, this will begin. It is in the interest of the consumer to have her or his own independent way of monitoring too. Chemical ways can be devised, besides the electronic way presented in this book. Imagine a small test strip like a flat toothpick which turns color when in contact with propyl alcohol. Keep a pack in your pocket and never be unknowingly dosed again...all in tomorrow's world.

Flukes Not Alone

There are other families of parasites. The roundworms and tapeworms are gaining ground too. Are they associated with solvents? Or with yet undiscovered factors? Are they changing their life cycles to take advantage of our lowered immunity? These are important questions. But you are armed with excellent technology. The answers will be found.

And along with answers there will surely develop a new industry. An industry that not only proclaims purity for its products but provides the proof to your satisfaction.

Burning And Numbness

Burning sensations in the skin let you know that nerves are involved. Mercury is the most common offender. Mercury may have started the trek of a host of other toxins as well into your nervous system: pesticide, automotive chemicals, household chemicals, fragrance and even food chemicals. Some people can get a burning sensation after a car trip, some when exposed to perfume, some when walking down the soap aisle in a grocery store. When the affected nerves don't go to skin but instead go to an organ like toes, you might feel a toe cramp or finger cramp instead. Remove your mercury sources.

Burning skin is an ancient malady—maybe even the basis of concepts like "hell." St. Anthony's fire was caused by *ergot* (food fungus) ingestion. Molds don't necessarily come singly. Maybe other mold toxins can go to your nerves, too (see Moldy Food, page 381). Maybe the mold toxins interfere with **pantothenic acid** used by your body, because giving pantothenate (500 mg three times a day) can sometimes relieve the condition and, of course, this is good for your body.

Monosodium glutamate (MSG) can cause burning, especially of the face and lips. Sometimes swelling occurs too. MSG is used as a flavor enhancer. It was found decades ago to be a brain toxin and was taken out of baby food. But what about adults? Especially those who already have a brain problem. Throw it all out of your kitchen. Ask at restaurants which foods have it.

Numbness has a similar cause. Numbness of fingers or feet has become quite common since thallium and mercury toxicity has spread so widely.

If you have burning and numbness, can multiple sclerosis (MS) be far away? Remove all the metal in your dentalware immediately, replacing with composite (see Dental Cleanup, page 409). Hopefully, your immune system is still strong enough to clear the bacteria growing around the metal and in pockets in the jaw. Check and clean cavitations. Start your jaw healing with the milk, magnesium, vitamin D diet. Use thioctic acid to help clear your tissues of remaining metal (3 to 6 a day).

The most common nervous system bacterium is *Shigella*. Its beginning can already be seen in cases of burning and numbness. It is deeply entrenched in cases of MS. Three kinds of *Shigella* are readily obtainable on slides: *Shigella dysenteriae, Shigella flexneri, Shigella sonnei*. *Shigella flex* causes depression and irritability. All can cause gas and bloating. Zapping doesn't kill all of them because they inhabit the bowel. You must empty your bowels frequently, two or three times a day. And do the Bowel Program until all symptoms are gone. Be very careful not to put contaminated dairy food in your mouth again. Boil all milk products. They must be at boiling point for 10 seconds. This includes cheese, cottage cheese, buttermilk and regular milk. Eat only home made yogurt or home made buttermilk. Butter and whipping cream need this treatment, too. Never use raw dairy products.

Nana Hughes, 48, had numbness of the whole right arm, hand and right side of her head; it was particularly bad in the last four months. She was toxic with PCBs, titanium and dysprosium (paint). She was on thyroid, Xantac™ (for stomach) and chlorazipate medicines. We also found dog heartworm (she had chest pain over the heart). She started on the parasite program, stopped using nail polish, and stopped all detergents for dishes or laundry. In three weeks her numbness was greatly reduced. She still had titanium buildup from dental metal (a partial bridge). See-

ing she was on the right track, she stopped use of MSG in her food, switched from concocted beverages to milk and cut down on her smoking. She brought her arm pretty near to normal.

Maria Santana, 45, had numbness in both arms; they would tingle and "go to sleep" a lot. It was spreading to one leg. Her muscles were toxic with thallium. It was in some very old pesticide, still effective and still in use in the house. It was also in the well water, probably, from pesticide seepage. She went off all commercial body products, did a kidney cleanse and killed parasites. She had difficulty getting rid of *Prosthogonimus* but in two months she had everything cleaned up. Her legs, arms, sleep problem, urinary tract problems were all gone and she could focus on her last problem, digestion.

Candy Donaldson, 44, had numbness from her shoulder to the wrist of one arm, it started a year ago. She was toxic with iridium, lithium and vanadium from a gas leak. She was advised to stop caffeine use and switch to milk (her calcium level was low: 9.0 mg/DL) and a magnesium tablet (300 mg daily). Her triglycerides were high, implying a kidney problem. She had urate and phosphate crystals in her kidney. She decreased the phosphate in her diet (meat, nuts, grains, soda pop) and started the kidney cleanse. When the gas leak was fixed, both her lithium and vanadium toxicity disappeared. In six weeks she had also killed parasites and her periods became regular for the first time. An ovarian cyst had disappeared, too, as checked by ultrasound. Soon her PMS was gone, including hot flushes. After four months she had done three liver cleanses and suddenly her numbness improved. After a few more there was no numbness at all.

If cleaning cavitations brings you immediate improvement you know that these bacteria were part of the problem. Have them checked again if problems return; dental bacteria are notorious for returning. If kidney cleansing makes it worse for a day and then better, you know kidney bacteria are partly responsible. If liver cleanses (page 552) make matters worse for a day and then better, you know bacteria are entrenched in the liver. Continue cleansing until none of these sources exist any longer. Kill all bacteria at least once a week electronically. Burning and

numbness can be cured, not just arrested. In other words, your nerves can be cleaned up and healed.

Depression

All persons I have seen with clinical depression had small roundworms in the brain. Is it any wonder the brain can't make enough neurotransmitters or gets them out of balance? The usual worms are hookworms (*Ancylostoma*), *Ascaris* of cats and dogs, *Trichinellas* and *Strongyloides*.

Although it is commonly believed that hookworms penetrate the skin when walking barefoot on earth, this appears to be a negligible route. The important routes are eating animal filth and inhaling filthy dust. Our pets pick these worms up daily. We get them and give them in constant exchange with our pets and family members. Diapering babies is an especially hazardous, though necessary, business. Letting little children clean up after their own bowel movements is even more hazardous. Hands should be sanitized with grain alcohol after dealing with bowel contents, whether your own, your child's, or an animal's. If you clean up a messy diaper and then your hands well with soap, then go to make the chopped salad for dinner, you're sure to give each family member a dose of whatever the baby has. It was hiding under the fingernails. Animals clean up the easy way: they simply lick the youngster's bottom. But, we humans are not strong enough to take on a dose of bottom with each meal. **We must sanitize our hands**.

Cleaning bathrooms is also dangerous. Wear gloves. If nobody suffers from depression, you can use bleach (stored in the garage) to disinfect the stool, otherwise use alcohol (50% grain alcohol). Keep doorknobs and faucet handles wiped with alcohol, too.

If you suffer from depression use your zapper to immediately kill these four roundworm species: *Ancylostoma*, *Ascaris*, *Trichinella* and *Strongyloides*.

Other family members should be cleared of these four worms on the same day or as close to it as possible. Reinfection always occurs. In the depressed person, the microscopic parasites travel immediately to the brain. In others, they may simply reside in the intestine or lungs or liver, or other organs. Pathways (routes) to the brain have become established for the depressed person. These must heal before there is any tolerance to reinfection.

Solvents and other toxins, also in the brain, slow down or prevent healing. For this reason the depressed person should do the *Four Clean-ups*.

The bacteria of the *Shigella* family are always seen in depression cases. Kill all *Shigellas* and avoid reinfection by boiling dairy products and not eating those that can't be boiled. Go on the Bowel Program (page 546). Do not eat deli food or hand prepared salads at salad bars. Finally, do the Liver Cleanse, repeating every two weeks. Depression, even of long standing, can lift within days after the brain finally has its territory to itself. Look in the mirror and smile at yourself for your success in vanquishing your invaders. Never again, let these creepy crawlers into the happiness-center of your brain.

Manic Depression

This variety of depression is associated with *Strongyloides*, as the main parasite in the brain. Plus **chlorine** as an allergen! *Strongyloides* is the same worm that causes migraines and other severe types of recurrent headache. It probably depends on where these tiny worms have set up their “housekeeping” which

symptoms you get: manic depression or migraines. Maybe chlorine is the deciding factor.

These tiny wormlets can pass the placenta into the unborn fetus. Is it any wonder that these brain disturbances seem to be inherited? Of course, there is ample opportunity to simply eat them off hands, other people's hands, and off floors during childhood. The amazing truth is that some family members do not get infected with it or at least do not get brain symptoms! It is very difficult to eradicate *Strongyloides* in a whole family and thereby let the depressed person get well. It is, in fact, impossible if there is a pet or other animal connection. Getting rid of the chlorine allergy is also very challenging. Step one is to zap all parasites.

I usually see an accumulation of **bromine** as well. Since bromine, fluorine and chlorine are all *halogens*, maybe getting too much of any one could saturate the liver's ability to detoxify chlorine. Stop eating brominated (bleached) bread. Stop taking drugs containing bromides. That is the easy part. You must also stop even washing your face in chlorinated water (use a pure carbon filter system). You inhale it as you wash. Never drink it or use it for any purpose. Of course, there should be no bleach container in the house, even when tightly closed; nor should bleached clothing be worn.

Do the *Four Clean-ups*. Sometimes the cloud lifts and the mind clears on the way home from the dentist. Recovery can be very rapid—less than a week. And recurrence just as rapid when a tiny bit of chlorine is inhaled or drunk. But your careful vigilance pays off. In half a year you can expect no recurrence.

Humans, it seems, must lick fingers with the same compulsion that cows lick their noses and cats lick their rears. The single, most significant advance in human hygiene would most assuredly be stopping the hand to mouth habit. We must <u>always</u> eat with utensils. And never leave a bathroom without washing. These are difficult changes but the new age of parasitism makes

it necessary. Together with the new pollutants, solvents, and heavy metals, parasites will overtake us unless we change.

Don't go off lithium and other medicines until your doctor agrees you are ready, about a half year. After this, make sure you still keep it handy. Although you may be free of manic depression in a day, reinfecting yourself weeks later will attack your brain like a hurricane; it has not yet healed, the routes are open. Be patient; healing will happen as it did for these happy persons.

Lena Constantine, age 39, had a history of migraine, TMJ, heavy clotting with periods and numerous pains but it shouldn't have made her try suicide 1½ years ago. She was put on Prozac™ afterward. She was parasitized by intestinal flukes (in the intestine), dog whipworm, *Strongyloides* and human liver flukes. She was started on a parasite program and kidney cleanse. This made her feel so good she took herself off Prozac™ and landed in the hospital for reasons she couldn't remember. After 42 days spent there she got out, wiser than before. She set to work again, leaving no detail undone, because she could remember how good it felt to be free of depression (not drugged out of it). Three months later she still had *Strongyloides* (she had a cat) but she did her first liver cleanse anyway. She got over 500 stones out. Her depression was gone. She substituted 4 ornithine and 2 ginseng capsules daily (more if tension was not relieved) for Prozac and cured her problem.

Mona Zabala, 33, was extremely depressed over her job. She was full of mercury, arsenic, PCBs, chromate from eye liner, wood alcohol from drinking colas and she had *Ascaris*, pancreatic flukes, *Trichinellas* and *Strongyloides*. She thought she was a hopeless case. But in less than three months, when only half her clean-up chores were done, she was already saying positive things about her job.

Acey O'Hara, a young graduate student, was very careful to avoid junk food, caffeine, fragrance, and body products because he had learned the hard way that he didn't tolerate them. When “crying” depression hit him he was not only surprised but angry that his good health habits “hadn't paid off.” He was buying his drinking water; it came in clear plastic containers. He had cesium in his

tissues and brain. When he switched back to plain tap water (filtered in small quantities) the depression lifted in a week and he was no longer crying over anything.

Leisa Underwood, 46, was clinically depressed and in therapy. She believed it was due to going through menopause. She had a heavy burden of *Strongyloides* but no other worms. Only one of her two dogs had *Strongyloides* (saliva test) and the cat was free of them also. She was full of cesium (from drinking refrigerator water) and vanadium (from a gas leak). In two months she had accomplished the impossible: all pets and herself were free of *Strongyloides*, they had repaired three gas leaks and her depression was just a memory.

Roland Greeley was diagnosed as manic depressive a few years ago and was put on Ativan™ and Prozac.™ This controlled him but did not relieve depression. He had a prominent tremor. He had *Ascaris* and sheep liver fluke stages in the brain. Also *Trichinella*, *Strongyloides* and human liver fluke stages. Styrene (from styrofoam cups), methyl ethyl ketone (beverage) and carbon tetrachloride were in his brain also, probably setting the stage for parasite reproduction. He had high levels of mercury and silver but highest of all–throughout his body–was chlorine (from bleach and tap water). In four weeks he had all the metal removed from his mouth. He stated that this "unchained" him. He could already tell on his way home from the dentist that something special had happened. His depression was simply gone "the way you lift a blanket off a bed". He resolved to clean up his whole body and recover from his illness using logical methods, like ours. Staying away from regular chlorinated water was a fine challenge to his resolve but with whole house filtering now available he may have done it.

Darren Knox, age 48, had been on Thorazine™ for 36 years but was recently changed to Desyral™ and Valium™ and lithium. He had *Ascaris* and hookworm and two dozen more assorted parasites including fluke stages. His brain was also hosting *Bacteroides* and *Nocardia*. All parasites were killed in half an hour by frequency generator at his first visit whereupon he immediately announced himself free of depression; better than the last eight years. He had many metals in his brain, also chlorine. In four weeks his tremor

was way down, after dechlorinating his tap water. His depression never came back after dental work was done.

Schizophrenia

Much more mold toxin was seen in schizophrenic families than in other kinds of illness. They usually had four or more kinds of mold toxins at the same time, meaning that one toxin was not detoxified before the next was already eaten. It may reflect on the liver as much as the food selected. The initial injury, though, to the liver may have occurred in early childhood.

Schizophrenia does not require mercury or other dental metal pollution for its expression. This pattern is logical when it is seen that young children can have schizophrenia. Schizophrenia is an ancient illness, being described in some very old literature, before dentistry existed. But parasites existed. And moldy food existed. And copper existed!

Ergot is always seen in sick persons. Other mycotoxins are also present, including *sterigmatocystin*, *cytochalasin B,* and *aflatoxin*. As the mycotoxin panorama changes, brain symptoms can change from compulsive hand washing to paranoia or from hearing voices to meanness in disposition.

It is my belief that the current increase in violent crime in U.S. society can be attributed to the especially high levels of mold consumption in foods and beverages, with the resultant effect that behavior erupts into violence with almost no provocation, merely some frustration. It would not be difficult or expensive to experiment with a mold-free diet in our prisons.

A bacterium, *Mycobacterium phlei*, may also be a cause because I have seen a high correlation between it and schizophre-

nia cases. What its specific effects are, I don't yet know. This bacterium may be hiding under teeth. It is also seen in dogs.

Shigella bacteria from nonsterile dairy foods are part of the problem, too. They produce brain and nerve toxins resulting in irritability, depression, anger. In fact, anger can be so intense, it erupts in violence.

Lead and copper are commonly seen in schizophrenia sufferers. The usual source for these is the household water (household plumbing may have lead solder joints). Change plumbing to PVC, then take thioctic acid (100 mg, twice a day).

Parasites always found in schizophrenia are hookworms (4 *Ancylostoma* varieties) in the brain.

Instructions:

1. Stop eating all grain products, nut products and syrups immediately.
2. Sterilize all dairy products.
3. Search for lead and copper in the water.
4. Stop drinking commercial beverages, including bottled water.
5. Zap the parasites in the whole family for three days, followed by repetitions twice a week.
6. Eliminate *Shigellas* with the Bowel Program (page 546).
7. Give away pets. Schizophrenia is too serious to risk reinfection.
8. Do the dental cleanup (page 409).

The need to zap repeatedly arises from reinfection. Nothing needs to be killed twice. But reinfection from self, family members, pets and food happens every hour. One cannot rely on zapping to stay well. Do a thorough diagnostic search of all foods eaten at the last meal, the water drunk, the air breathed. Only when all these are clean, will the brain heal.

When can you eat grains again? When you are well. Find a cereal or pasta that has no mold. Test it for the mold frequencies (77, 88, 100, 126, 131, 177, 188, 232, 242, 277, 281, 288, 295

KHz). Search especially for ergot (295). Remember, ergot makes *lysergic acid diethylamide* (LSD), not a good thing for a schizophrenic brain. Honeys, too, have ergot. Ergot takes longer (up to 20 minutes) to detoxify with added vitamin C. (Read the section on Moldy Food, page 381). If you become ill again after starting grains, go off again. Take 500 mg. niacinamide 3 times a day to speed up ergot detoxification by the liver. Avoidance is much easier.

Healing of the brain is very rapid; in less than one week feelings and behavior are more normal. Perhaps there are herbs that hasten healing; considering how old the illness is, there must surely be several useful herbs. But considering that herbs, too, can be moldy, be very careful to search for molds electronically before using any herbs. Blue vervain, sage, and ginseng are herbs worth trying.

A question may have popped into your mind as well as mine. If the whole family is eating moldy food, why aren't they all schizophrenic? In fact, family members usually do suffer from some symptoms that are similar to the victim. But every person's collection of parasites and pollutants is unique. Certainly, the whole family should obey the moldy food rules, in order to function better.

Autism

Childhood brain disorders suggest an inherited genetic defect. Yet numerous parasites and pollutants are able to pass into the unborn child through the placenta. Even some bacteria and viruses can.

Lead accumulation is always seen in children with autism. Was it acquired before birth?

Mercury can be transmitted from mother to child, too. If mercury fillings were not removed before pregnancy, have them

replaced as soon after delivery as possible (never during pregnancy since the removal itself causes a surge of heavy metal to enter the body).

The common tiny worms such as *Ascaris*, hookworm, *Strongyloides* and *Trichinellas* easily enter the brain. They are present in dirt. Dirt enters buildings via shoes. Shoes carry animal filth. Don't let children put their own shoes on until they have learned to avoid touching the soles. Don't let your child crawl on the floor of a public building, even though it looks glossy. Don't set shoes on furniture or table! A preferred habit is to leave shoes at the door.

Once wormlets have found a pathway to the child's brain it is difficult to reroute them. They must all be killed repeatedly since there is daily reinfection from putting hands in mouths. All family members should kill these parasites weekly to protect the child with autism. When lead and parasites are gone consistently for several weeks the pathway to the brain heals and reinfection no longer sends them to the brain and your child can resume a normal life.

I have not treated enough cases to point to a particular parasite or pollutant. For this reason you must do a total cleanup: body, environment, dental, diet (especially solvents and molds).

Leon Dickson, age 10, appeared normal at birth but he crawled and walked late. At age 3½ he began having seizures and was also diagnosed with autism. (Seizures are caused by *Ascaris* larvae, they probably began the routing to the brain). He was started on Phenobarbital™ by his clinical doctor; switched to Dilantin™ then two other drugs were tried. Now he was on Tegretol™ plus Depacote.™ The mother used no anti nausea medicine during pregnancy, no caffeine, no alcohol or nicotine, not even a single aspirin. In spite of his medicines he seemed to have headaches, continued to have seizures which disturbed his sleep and he wasn't trying to talk. He vomited a lot. He would take no pills or drops (no herbs even mixed with honey) and our frequency generator method was not discovered at that time. He couldn't kill his parasites and *Shigellas*. His brain was full of thallium (not mercury!)

besides the roundworm larvae. He must have gotten this from Q-tips™ or cotton balls or some other mercury-sterilized product. Leon's favorite food was grilled chicken which he ate nearly every day, as well as two eggs a day.

His diet was changed to exclude chicken, eggs, bacon, chips, preservatives and colors in foods, grape jelly and strawberry jam. One month later he had not improved, nor had they been able to kill his parasites with the herbal recipe. The diet change was extremely difficult; he was screaming for his favorite junk food and the whole family was upset over his restrictions. But we encouraged the mother to stick to her purpose, get a different baby-sitter who would obey her, and to try to get some parasite herbs and thioctic acid (100 mg. daily, stirred into honey, to take out lead) down him. The first week the new baby-sitter succeeded in getting him to take thioctic acid. He had only one seizure that week. This encouraged the mother to enforce the parasite program and the diet rules. He became attentive in one month and tried to voice sounds.

The problem with eggs is that they are contaminated with *Salmonellas*. I find, however that it is the outside of the eggshell and the carton that is contaminated. The safe way to handle eggs is to remove them and return the carton to the refrigerator, then wash the eggs and your hands before cracking them. Eggs also contain malvin, a known seizure trigger.

Kirk Peeples, age 5, did not have any words yet but he would point to something and voice M-M-M to mean he wanted it (usually food). He was in a special school and "doing well." He had the brain toxin MSG, and antioxidants BHT and BHA accumulated in him. In other words, his liver was not able to detoxify these common food chemicals. At that time, I had not found the mold toxins yet; I would now surmise that they were responsible for the liver's disability. Besides going off these food additives he was "desensitized" to them with homeopathic drops by an alternative allergist. The result was immediate. In one week he tried several new sounds and managed his first word: "box." After killing parasites with the herbal program over a four week time period he could speak 19 words. The parents were bewildered with joy. They cleaned the toxins out of their home so thoroughly, there

was no place to sit and nothing familiar to eat. But their son could say things and the parents loved each new sound as if it came from a newborn baby. In two months he was saying two-syllable words and putting phrases together. He needed us no more (he was on homeopathic thyroid drops, too).

Geoff Berkely was diagnosed autistic. He went about his business of examining everything in the office without a word. He was infested with both species of *Ascaris* (there was a pet dog) and was started on the herbal parasite program: just a little less than the adult doses. (Children's' syrups are not as effective.) He was toxic with mercury, too. He had 2 or 3 “baby” root canals. These were to be pulled out. He was also taken off food color, MSG, chicken and eggs. The parents accomplished all this very quickly and called to say their child had become normal but they didn't want us to spread the good news to the “autism” club they attended for fear of criticism for doing unorthodox things. Only in the USA could such thinking occur!

Digestion Problems

Burping, bloating, and being gassy are signs that your digestion isn't perfect. What has gone wrong? Burps are gases escaping upward. Bloating is due to bubbles of gas causing pressure. Your body does not make gas! Gas can only be made by bacteria. The immediate conclusion is that bacteria are growing in your digestive tract (stomach and intestines) that should not be allowed to do so. They are likely to be the common enteric (digestive tract) bacteria: *Salmonellas*, *Shigellas*, *E. coli*, *Bacteroides fragilis*.

You may wish to identify them before killing them with the zapper. Or you can sweep through the whole bacterial and viral range killing all with a frequency generator. The good effects can be felt in an hour, although the last gases may take days to get rid of. *Salmonella* and *Bacteroides fragilis* are two bacteria that can eat bile, and can do without oxygen, so they are com-

monly seen in the liver. *Bacteroides* probably escaped from its roundworm host, *Ascaris*. *Salmonella* probably came with non-sterile dairy food.

If you have an intestinal problem involving digestion or pain, start immediately to boil all dairy foods. Stop eating those that can't be boiled: cheese sandwiches, yogurt, ice cream. It must be boiled for 10 seconds. The bacteria are in the liver because your liver attempted to strain them out of your blood and lymph in order to kill them with bile. Instead, they turned around and "ate" the bile, turning it brown as evidence. Now, every time the liver lets down bile into the intestine (and stomach), a population of these bacteria goes with it. The intestine becomes a seething mass of bacteria, bubbling away as they produce CO_2, SO_2, H_2S, CO (carbon dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide). Some of these gases are quite toxic.

Help your liver expel its bacterial overload with liver cleanses (page 552) until all the bile is a beautiful bright green. This is evident as dark brown bowel movements. Without the green color of bile added to your intestine, the bowel movement remains light colored, such as tan, yellow or orange! By stopping eating polluted food, killing bacteria and cleansing the liver, digestion becomes normal again.

Of course, there must be enough acid in the stomach and digestive enzymes produced to make good digestion possible. Otherwise, leftover food goes to feed the waiting bacteria.

Persons with a chronic digestion problem may also find they harbor lead, cadmium, or mercury in the intestine! This is very good in a sense. Your body has kept these toxins in the intestine, preventing it from getting into your vital organs. The bad news is that their presence in the intestine could start an intestinal disease. Toxins in the intestine would inhibit your immune system (here the white blood cells are in clumps called *Peyer's patches*), from gobbling up the "bad" enteric bacteria. Maybe

the "good" bacteria found your intestine too toxic to live there. Clean up your dentalware. Search for lead and cadmium in your drinking water. After improving your lifestyle, continue to do liver cleanses. Keep your goals high: a flat tummy that feels energetic, no burps or gas.

Stomach ache (page 98) and **hiatal hernia** (page 133) are also digestive problems but are dealt with under pain. (See also lower abdominal pains, page 97, and appendicitis, page 100).

Alan Barth had his two young sons with him. One of them had a very sensitive stomach, a poor appetite, wanting nothing but sweets or chips to eat. The 16 year old had aches and pains that were keeping him out of sports. The father had a tonsil problem; they swelled if he drank milk. One problem was obvious. Their milk was tainted with *Salmonellas* and *Shigellas*, setting up throat problems for the father, stomach problems for one child and a pain syndrome for the other child. Boiling all their milk, not bringing raw chicken into the house (*Salmonella* Source) and stopping eating yogurt and cheese was the solution. There were traces of lead in their tap water and the house air had vanadium in it, announcing a gas leak. They were all heavily parasitized. When these problems were cleaned up, the whole family's health improved.

Kae Nakajima, middle age, had a history of ulcers and stomach problems. She took a lot of Zantac™ and Tagamet™ over the years. She was drinking coffee, tea and colas. She had *Ascaris* and cadmium in her stomach. Five months later she had cleaned up everything except dentalware and was feeling very good. She didn't need any medicines. She still had arthritis and sinus problems but felt so encouraged she had the dental work scheduled.

Sven Lippencott, age 4, had been tube fed for several years due to weak stomach action. He was quite underweight for his age. He had a population of intestinal fluke in his stomach along with arsenic (pesticide). The rest of the family also had intestinal flukes. After killing parasites and washing the upholstered furniture, Sven's appetite went up so he ate more by mouth and grew immediately. But he soon picked up *Ascaris* and cat liver fluke (there was an indoor cat). Then the whole family got intestinal flukes again. They all, including Sven, drank carbonated beverages *ad*

libitum (whenever they wished). With both parents working it would not be possible to discipline the habit. Sven had wood alcohol, methyl butyl ketone, hexanedione, methylene chloride and toluene buildup making his recovery hopeless.

Alzheimer's

What was once a rare disease has become a household word because it now affects so many. Two new pollutants of the brain, inviting an old parasite to a location it would not normally be, is the explanation. The new pollutants are solvents that seek the brain.

Xylene and **toluene** are pollutants of popular beverages, decaffeinated powders and carbonated drinks. At first, the body can detoxify these but with a steady stream of solvent arriving, detoxification slows down and parasites begin to build up in the brain. Common fluke parasites which we eat in undercooked meat and perhaps get from our pets, can now reach the brain and multiply there.

Other toxins are also present, such as aluminum, mercury, freon, thallium, cadmium. Aluminum buildup is seen in all Alzheimer's sufferers (100%). This is undoubtedly part of the true cause. Did it come before or after the parasites?

Whatever the answer, your job is clear. Remove every bit of aluminum from the food and environment. Throw out the pots, the aluminum foil, the cookie sheets, the tea ball. Throw out the kitchen salt, the pickles, the baking powder. Buy things made with baking soda (not baking powder), use a plastic salt shaker, buy salt without added aluminum. Stop using commercial soaps and lotions. Make the soap recipes in this book. Finally, tape over all aluminum handles in the bathroom and elsewhere (e.g. the walker) with masking tape. Then find a chelating doctor to help remove aluminum from the brain. Also use thioctic acid (100 mg; take 2 three times a day).

Kill the four common flukes with the first frequency genrator or zapper you can get your hands on. Prevent reinfection from meats and pets. Stop all commercial beverages, including water. The processing has left xylene and toluene in them. They are not put in intentionally. For the same reason, health food beverages are similarly polluted. Only milk is safely bought from the store. You must still sterilize it, however. Make your own fruit juices. Select beverages from the list of recipes given. Drink water from your cold water tap, filtering it with a small pure carbon filter as in a filter pitcher (see *Sources*).

As much as xylene and toluene are brain-seeking solvents, *Shigella* is a brain-seeking bacterium. The symptoms it causes are not always the same since they depend on the location of infection. Sometimes they cause tremor, sometimes loss of balance, sometimes speech problems. But they are very serious problems. Kill *Shigellas* every day at bedtime with your zapper. Start the Bowel Program (page 546). When improvement is lasting you know you have stopped reinfecting from your own bowel or from polluted dairy products.

Remove dental metal and use thioctic acid as a help to clear tissues of metal. Use vitamin C (3 grams) and B_2 (300 mg) to assist the liver with detoxification. Use B complex (2 a day) to assist the liver generally. Avoid food molds; ergot especially has strong mental effects (see Moldy Food, page 381).

Start a kidney cleanse (page 549) as soon as you can. Follow this with a liver cleanse (page 552). Clean up environment and diet. Your beloved family member or friend with Alzheimer's can regain her or his mental function to a considerable degree. **Most important is stopping the mental deterioration** before it is not reversible.

Lisa Anne Reed, 60ish, was tentatively diagnosed with Alzheimer's 10 years ago. She needed complete care at present but was able to walk (could disappear quickly) and eat. She could occasionally say her name. Her brain had intestinal flukes and their eggs and

was toxic with aluminum (cooking pots) and aluminum silicate (salt). One week later she still had the parasites because nobody could skillfully give her the parasite program. She was also toxic with benzene so reinfection was occurring. In addition she was toxic with bromine (from brominated bread?), chlorine (chlorinated water?) lithium, bismuth, vanadium, and tungsten, all known to have strong brain effects. She was also toxic with moth balls and iridium. She harbored *Naegleria*, another brain parasite. In another week there still were no changes due to inability to administer the treatment.

Isabelita Ufford, 77, was in a wheelchair, brought by her two daughters who took turns caring for her. She was on Clanopin™ medicine, did not try to speak and needed total care, including feeding. She had been ill about seven years. She had intestinal flukes and their stages in her brain (the cerebrum) as well as intestine. She also had isopropanol solvent, aluminum, chromate and high levels of arsenic in her body. She was given the parasite herbs plus instruction to get rid of solvents and metals but the plans could not be carried out. The parasites could not be killed without considerably more help than was available. She was a dear, sweet person. The daughters were highly motivated but were overwhelmed with the size of the task.

Beth Hamm, 60ish, arrived led by her ever-vigilant, ever-caring husband. She was started by medical doctors on EDTA chelation to remove aluminum from her brain. My tests showed aluminum, toluene, sheep liver flukes, asbestos and *Shigella* bacteria. The parasites and bacteria were zapped immediately and her husband began the difficult task of excluding non-sterile dairy products from the diet provided. In four days she was able to walk by herself, knowing where she was going. She could finish a short sentence and comply with directions to sit down and get up. Then she had a set back—she had acquired *Salmonellas* in the brain from a bit of dairy food that had slipped by his attention. She was given Lugol's and she improved further. In ten days she was a new person; an interview of twenty minutes length did not reveal Alzheimer symptoms. Will she be able to hold on to her gains? Only if the aluminum and asbestos are removed from her home environment, his vigilance with dairy food keeps up, and she stays on a maintenance parasite program. But her husband appeared intent

on her recovery. She is a person again. And there seems to be a delightful companionship.

Ruben Camberos was brought by his wife and a friend for Alzheimer's. The first day he arrived, the intestinal flukes in his brain were found and killed. He was started on EDTA chelation. They were warned about non sterile dairy foods. His *Shigella* was zapped. Four days later he spoke his first meaningful sentence: it was three words long. He could pay attention to the appointment proceedings. Two days after that he was reading a newspaper. This was utterly shocking to his wife. In another three days, he could hold a conversation consisting of very short sentences. Larger ones became hopelessly garbled. He was started on ornithine (4) and valerian capsules (6) at bedtime: this produced a beautiful nights sleep (especially for his caretakers!) and his days were less agitated. There were still setbacks later but his wife was determined to get him well.

Dementias, Memory Loss

Memory loss is progressive with age but not due to aging. There are plenty of nonagenarians and centenarians with clear minds and good memories to prove that age is not the deciding factor in the dementias. Why do some people deteriorate much sooner? Could you prevent personal deterioration of mental abilities? You probably can. You will know it by noticing memory improvement. Telephone numbers that left you with no recall, unless you wrote them down, number by number, now form groups as you hear them, and you can jot them down the way you always did! This is a good sign of memory improvement. Your writing can improve. The jagged, crooked, misaligned words can be smoothly written again! You can remember things that happened earlier in the day and talk about it later, at mealtime. You can finish your thoughts in conversation.

Mental deterioration of the elderly is not as complicated as is generally believed. Although circulation and blood pressure play a role, **the effect of toxins is much greater**. The action of toxins is greater in age than in youth. The same polluted water and food causes disorientation in the elderly when it only gives a young person a stomach ache.

The liver's detoxification capability may be the real issue. Indeed, the liver may age, in accordance with the calendar date. Perhaps the liver is the only truly aging organ. It may even determine your life span. The answer, then, is to stop giving it toxic substances and shortening your life span.

As the liver is less able to detoxify them, common toxins are allowed to roam the body with the circulation, doing harm to all the organs. The brain feels disoriented or dizzy; there is memory loss. At first, the liver can "catch up" its work and finally clear the toxin for excretion. But, eventually, it can't catch up or keep up. The body, notably the brain, is bathed in toxic chemicals that interfere with its functioning. Now, the elderly person must use a cane for stability, must walk very carefully not to fall, must write everything down to remember it, calls people by their wrong names, can't "find" the right words to speak with, can't finish sentences, must write on a calendar to keep the days straight, starts talking to themselves to help think of things, develops tremors and unsteady gait, acquires a passive personality, loses weight, gets stooped, stops reading the newspaper.

All these signs of aging (dementias) can be reversed by simply removing the common toxins with which we are already familiar.

Of primary significance are food molds. These cause brain hemorrhages. Clean up diet, mouth, body, environment, very meticulously.

Of course, an elderly person cannot bring these changes to herself or himself. If you have a loved one with symptoms of aging, and this person is willing to cooperate with you, you can honestly promise them numerous improvements. Spend a good deal of your effort on persuasion since living longer or being healthier may not seem worth giving up a coffee and doughnut breakfast. On the other hand, they might respond to the goal of needing fewer pills, getting into their own apartment again or becoming freed from a walker.

Walter Heffern, 64, had been to various neurologists but could not find any help. He appeared to have the same kind of mental deterioration as his mother, but at a much earlier age. He couldn't understand an ordinary conversation; he constantly spoke about winning money, walked hesitantly and had to be left undisturbed to accomplish anything—even eating and dressing. He needed a lot of care. We found he had *Ascaris* larvae in the brain—in the cerebrum, where you think. He also had *Acanthocephala*, *Dipetalonema* (a chicken roundworm), amoeba (*Entamoeba histolytica*) and *Fischoedrius* in the thinking part of his brain. He had been in the poultry business all his life: his mother probably shared this exposure, as well as other lifestyle habits that gave them solvents and pollutants besides parasites. He had constant ringing in his ears, this could affect hearing an ordinary conversation. He had a water softener that would have supplied a daily dose of aluminum to the brain, too. There always were dogs in the house. Perhaps the marvel is that he was no worse off, a tribute to human strength in general.

Pushing Back Age

This chapter is a tribute to Jimmy, Nazy, Michele, Suzanne, Marlena and all the others who achieved excellence with daily care-taking of Mary Austin, deceased at 97.

It's true that we have to die sometime. But why die before our life span is up? If many people can live to 100 years, then surely this is the human life span, not three score and ten. Some scientists think the true human life span is closer to 140 years! And that we all lead shortened lives. The shortening is due to failure of some organ in us. Other organs are dependent on the failing organ and begin to fail also. When the brain fails, death occurs, sometimes in five minutes.

If we knew which organ is failing, we could come to its assistance and prevent the collapse of the whole body. Often it is easy to see which organ is failing. But whether this is the true beginning of the body's problems we cannot know. Before death there may have been appetite loss. Before the appetite loss there may have been a broken hip. Before the broken hip, dizziness. Before the dizziness a blood pressure or blood sugar problem. Before these, an episode of “flu” or a dental “repair.” Sometimes we know what started it all. But often we don't. Just make a guess and begin somewhere.

Diet

If your aging friend or relative is in a home for the elderly, you may be able to persuade him or her to choose a diet that is wiser than the average diet people eat there. This can help a lot. Just stopping drinking the coffee, decaf, iced tea and carbonated beverages that are served, and switching to the recipes in this book could get them off some of their medicines.

The beverages to encourage are sterilized milk and hot water—delicious with whipping cream, honey and cinnamon. This gets them away from solvents, oxalic acid and caffeine.

Old age is not a time when you "no longer need milk." Calcium losses increase in old age. Milk has the organic form of calcium, chelated with lactic acid, and it has the cream to promote absorption. For this reason, milk should never be reduced in fat content (not less than 2%). The cream is necessary to improve calcium absorption.

In old age it is downright dangerous to be taking many calcium tablets. The stomach does not have the acid necessary to dissolve them. They pass into the intestine, disturbing its function and acid levels. With tablets, too, one must be careful with dosages, while food is self limiting. No elderly person would be able to drink more than one cup of milk at a time. This contains 250 mg. of calcium.

Milk, however, requires stomach acid to curdle it as the first step in digestion. If there is not sufficient acid, it will pass undigested into the intestine, causing new problems. We must listen to the elderly when they say milk gives them gas or other troubles.

Having the milk warm to hot helps in getting digestion started in the stomach. Milk served hot with cinnamon accomplishes two purposes: it will stimulate acid secretion and the cinnamon is an insulin aid. Milk served hot with honey adds the nutritive value of honey, displacing the need for other unnatural sweets. The meal should always include something sour to curdle the milk. It does not have to be added to the milk; it can simply be included with the meal somewhere.

Lemon juice or vinegar can be put in certain foods but the most reliable way to get it into the diet is to put 1 tablespoon into the water glass along with a teaspoon of honey. This gives the water a "sweet and sour" flavor, enough to make it interesting throughout the meal. The fresh lemon juice or white dis-

tilled vinegar and a honey dispenser that is easy to use should always be on the table. Bring these two items to your loved one at the "home" if it cannot be provided regularly and reliably. Pop in at mealtime to check up on it. Powdered vitamin C (¼ tsp.) is another useful acid if the first two are not effective enough.

The lemon and honey habit, alone, can add years (healthier years) to an elderly person. The extra acid taken with lunch and supper (the stomach has its own best supply of acid in the morning, for breakfast) improves overall digestion and helps dissolve the calcium, magnesium, iron, zinc, manganese, and other minerals in the food so they can be absorbed.

The habit of using vinegar and honey in water as a beverage was made famous by Dr. Jarvis in his book *Folk Medicine*, circa 1960. He recommended apple cider vinegar for its extra potassium. In those days, vinegar was made of good apples. Now, all the regular vinegars have mold in them. The toxin, *patulin*, in moldy apples has been carefully studied by scientists. It taints the vinegar as well as apple juice and concentrate made from them. I have not tested patulin to see if it can be detoxified by vitamin C. We must use only white distilled vinegar, even though it lacks potassium, aroma and popularity. Using a variety of honeys can make up for the need to vary the flavor. Get orange blossom, linden blossom, buckwheat, wildflower, and sage honey, besides clover blossom.

But honey is not perfect food. It usually has *ergot* mold, a very serious toxin. To detoxify the ergot, you simply add vitamin C to the honey as soon as it arrives from the supermarket. This gives it plenty of time to react with the ergot before you eat it. Bring your "fixed" honeys to the home.

If your elderly loved one has not tolerated milk in years, start with the vinegar and honey beverage, or lemon and honey, and be patient until that is accepted. Then add only ¼ cup milk to the day's diet, (in the morning, on homemade cereal). Go up

very gradually and only when digestion allows it. Of course, the milk must be sterile.

If it is not sterile, the final warming will only increase the bacterial count. You must be sure of its sterility. Boil the milk yourself. Near-boiling is not hot enough. It must be heated until it bubbles up and almost goes over the container for ten seconds. Use a non-metal pot that holds one to two quarts. You may throw away the skin. Then cool and refrigerate. Supply it to the home, too.

Milk that is marketed in paper containers that need no refrigeration has been sterilized; it is safe.

Once the body, even an aged body, finds a nutritious food that does not cause troubles of its own, it asks for more. Your loved one will accept it and drink it without forceful coaxing, if there is no problem with it. As long as your loved one tries to avoid drinking it, your challenge is to find the problem and solve it. It is not a matter of taste or habit. It is a matter of digestibility and lack of toxicity. When your loved one is drinking three cups of milk (or buttermilk or whey) a day and three cups of water, there will be no room (nor request) for the usual coffee and tea and other bad beverages.

We all must die of something. But it needn't be a stroke, or heart failure, or cancer. Choose what seems to be the most pressing problem to work on. Common problems that plague the aged are brain problems, incontinence, bad digestion, diabetes, tremor, weakness, feeling cold, sensitivity to noise, losing the sense of taste and smell, hearing loss, insomnia, kidney and heart failure.

Increase Oxygen

Brain problems include memory loss, communication deficit, dementia (calling things by inappropriate names and saying

inappropriate things). The brain is simply not getting enough oxygen and food to work right. It is like having a pocket calculator with rundown batteries: it will give you wrong answers (without telling you they are wrong). Not enough oxygen to the brain is the main cause of memory loss, inability to find the right words, getting words mixed up and not being able to speak in sentences. You can prove this by providing oxygen from a tank; modern equipment is very easy to use and inexpensive. If your loved one responds well to a few hours of oxygen, you have proof of the problem.

How can you increase oxygen in the brain?

1. Open the blood vessels wider.
2. Increase pressure of blood running through the blood vessels.
3. Raise the oxygen level in the air that is breathed. Less carbon dioxide, tobacco smoke and auto exhaust. All these, including a gas leak from the pipes in the house, compete with oxygen.
4. Increase the oxygen delivery system to the brain by raising hemoglobin levels. Cure anemia and low iron levels.
5. Raise oxygen saturation of blood by keeping body acidity down.
6. Correct a slow and irregular heart beat.

Niacin

Open blood vessels wider by giving **niacin**. Give it early in the morning, upon rising, as soon as the feet are set on the floor. Keep it at the bedside, use small capsules or tablets and combine this chore with water drinking. The water should not be cold and should have nothing added to make it a beverage. (Drinking water within minutes of sitting upright may also move the bowels soon.) A 250 mg. time-release niacin tablet (see *Sources*) is a good choice. The elderly have little side ef-

fects. Even the niacin-flush, which reddens the face and neck is welcomed since it gives a sensation of warmth.

The flush is intensified by giving hot liquids or acids (even vitamin C) to drink. The flush is reduced by giving cold liquids. The opening of blood vessels by niacin only lasts a few hours. If you see it has a good effect on your loved one, give several a day. Do not use a prescription variety, since they are polluted with heavy metals; use only the brand in *Sources*, or a brand that you have tested pure. You can freely experiment with niacin to find the best dosage and variety; it is not toxic in this amount; but the size of the tablet should not turn it into an unpleasant chore. Reduce it if it seems too large to swallow. Don't cut tablets in half, the rough edges can scratch the throat.

Hawthorn berry is an herb that opens blood vessels, particularly to the heart. Carefully watch the effect on blood pressure when using it.

Food mold, particularly ergot, has the opposite effect of niacin. Brain blood vessels are made narrower, cutting down the oxygen supply. Ergot is a common contaminant of grains: don't provide rye or pumpernickel breads or crackers. Don't provide wine or other alcoholic beverages; they are too contaminated with ergot and aflatoxin. Narrowing the blood vessels in the brain can lead to stroke. If you notice an attack of dementia coming, try a niacin tablet (100 mg, not timed release) immediately.

Fig. 34 Alcoholic beverages contain ergot and aflatoxin. Add vitamin C (1/8 tsp.) upon opening and wait 10 minutes for it to act.

TIA's, Strokes and Purpura

Sometimes, the elderly person is aware of the onset of a brain attack; they may see stars or peculiar shapes or lose vision temporarily. These are called *temporary ischemic attacks* (TIA's). Immediately give a 100 mg tablet of niacin, 1 gram vitamin C, and a B-complex in this order of importance.

TIA's are caused by spasming in the brain blood vessels. If this causes them to spring a tiny leak somewhere, a part of the brain will not get its usual oxygen and nourishment. A stroke results.

The spasming was probably caused by sorghum molds. Cooking during the manufacturing of sorghum syrup kills the mold but its toxic byproducts (mycotoxins) are still present. Other syrups may have sorghum added, polluting them. Brown sugar is also polluted with sorghum molds, but fortunately you can detoxify this mold with vitamin C as usual. Mix <u>well</u> ¼ tsp. powdered vitamin C with each new (1 lb.) box of brown sugar.

Purple patches, like bruises, on the hands or arms of an elderly person are called *purpura*, and is also caused by sorghum molds. It weakens blood vessels so they break easily.

When an elderly person has purpura or TIA's and the mold source isn't obvious, you must track it down. Test in a saliva sample for all the sweetenings used recently (at least an hour ago). At the very least, keep notes on all the sweeteners being used. Look for a common one at the next attack. Never let the trigger food be eaten again.

Blood Pressure

<u>Increase</u> blood pressure if it is habitually too low. Blood pressures below 110 may prevent strokes but ruin the quality of life. Low blood pressures are often due to toxins from foods. But severe salt deprivation in the diet can also cause this. If the adrenal glands are not conserving salt properly, too much so-

dium is allowed to leave the body with the urine, resulting in low sodium levels in the blood and a blood pressure drop. Adrenal performance is improved by taking the kidney herb recipe.

The kidney herbs (page 549), at half dose level (½cup a day instead of a whole cup) can be given daily for three weeks and then on alternate days indefinitely. Be very careful to keep the herbal tea sterile by reheating. Elderly people seem to sense the improvement given by kidney herbs. Try other kidney herbs from time to time: **shave grass, cedar berries, juniper berries, butcher's broom, cornsilk**. None interfere with drugs. Remember, they also have a diuretic effect. Be prepared to use extra paper padding in underwear to help catch the extra urine output. The first few nights may be disturbed by extra urination. Interpret this positively.

After the blood pressure comes up to 115 (systolic) mental performance will be greatly improved. Don't try to bring it up to 120 since this raises the stroke potential without giving you much improvement in performance. Use an electronic device to measure blood pressure, one with a finger cuff, not an arm cuff which can itself induce broken blood vessels. Purchase a device that needs no adjustments of any kind and has automatic cuff tension control (see mail order catalogs if your pharmacy does not have one).

Air Pollution

Improve the quality of the air by lowering the pollution level. Check into carbon dioxide, carbon monoxide, fumes from a gas stove pilot light, auto exhaust from an attached garage or nearby highway, arsenic from household pesticide, PVC from new plastic curtains or carpeting, formaldehyde from wearing new clothing before washing it, asbestos from hair dryers, freon from a refrigerator, fiberglass, and chlorine from running tap water. Some of these displace oxygen, some are simply toxic to

the body and lungs. Clean up the air according to the general principles of environmental cleanup (see Four Clean-ups, page 409).

For the elderly pay special attention to **chlorine** in the air. Shower water puts a lot of chlorine into the bathroom air which then distributes itself through the rest of the house. Notice whether your elderly person goes into the bathroom in fair shape mentally but comes out confused, unreasonable. Not every day's chlorine exposure will have the same effect. Trust your judgment. Attach a carbon filter to the shower head (see *Sources*). Purchase a variety that has very simple-to-replace cartridges. Figure out how long it should last and write the date for replacement on the outside of it for your own convenience.

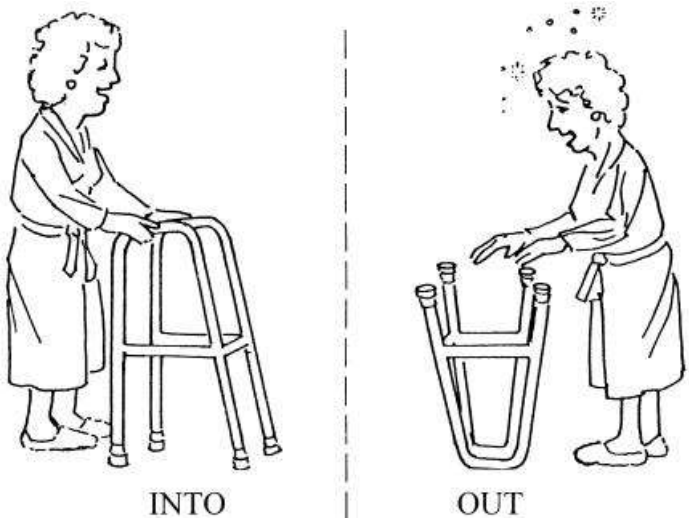

When into and out of the bathroom is a different performance suspect chlorine. Put a filter on your faucets.

Fig. 35 Chlorinated water can cause mental problems.

Washing hands and face in chlorinated water can give off enough chlorine to trigger a manic episode in a manic-depressive person. Certainly, it is enough to cause mental ef-

fects in an elderly person. Of course, the chlorine bleach bottle should not be kept under the sink. It should be kept in a closed plastic bag in the garage. It should not be used while the elderly person is in the house and never for his or her laundry. Use chlorine-free bleach.

Don't pollute the air with fresh flowers, potpourris, or room fresheners. These can induce a dizzy spell.

Room air conditioners may have a fiberglass filter! This fills the house with tiny particles of glass to be breathed by everybody. The body makes tumors out of them in order to stop them from cutting through your tissue. Replace the filter with a foam sheet. This sheet is 1/8 inch thick and washable. I have not found these types of foam filters to emit formaldehyde.

Room air filters are not the answer to polluted air. Removing the pollution source is. Air filters may remove some of the toxic elements but by blowing the air (and dust) around vigorously the remaining toxins are made much more vicious in their effect. The noise of a filter motor and fumes it may put out itself adds misery to the simple job of breathing. Using a non-fiberglass filter at the furnace is a better idea.

Make sure all fragrances are removed from the air, even though family members “like” them. They don't belong in air. The lungs treat them like toxins to be coughed up or removed by the kidneys and immune system. This includes colognes, scented tissues, soap and shampoo and shaving supplies. If you can walk into the bathroom blindfolded and know you're in the bathroom, it's not clean enough. Everything in the bathroom pollutes the air of the whole house. People who must use fragrance should apply it outdoors to keep the indoor air less polluted.

Anemia

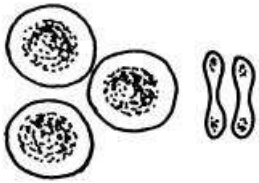

Fig. 36 Red blood cells, top and side view.

Oxygen gets to the brain on a carrier system of tiny rafts called *red blood cells*. They were meant to be an exact shape and size to fit the most oxygen molecules onto them.

Each red blood cell is shaped like a doughnut without the hole. This fits a lot more oxygen, O_2, than round balls would. Yet, if there isn't enough vitamin B_{12}, the dimple isn't put into them to make them doughnut shaped. This reduces the body's oxygen supply and the disorder is called *"pernicious" anemia*. The changed shape of the red blood cells is reflected in a bigger volume called *mean cell volume* (MCV). The correct volume for red blood cells is about 90 cubic microns. Many elderly persons have a MCV over 100!

I have seen pernicious anemia to be associated with *Ascaris* infestation. Kill *Ascaris* on a frequency generator (408 KHz) or zap. The source of *Ascaris* is usually a pet, owned in the past. Once infected, the tiny worms do not leave your body on their own. The infestation may date back to childhood. What a relief for the bone marrow whose job it is to make red blood cells to have enough vitamin B_{12} again! What does *Ascaris* do with your B_{12}? B_{12} is a beautiful rose colored vitamin. Some worms are actually pink from absorbing your B_{12}! Giving B_{12} shots is the current clinical treatment for B_{12} deficiency. Killing *Ascaris* twice a week by zapping and taking B_{12} lozenges (see *Sources*) is a better solution. (If your loved one is getting shots, make sure that no isopropyl alcohol is used on the skin beforehand. Provide vodka yourself in a small pocket flask or 70% grain alcohol for this purpose. Unfortunately, the shot itself may contain traces of this harmful solvent—take a sample home for testing.)

Other kinds of "anemia" can deprive your elderly person of oxygen. A low red blood cell count (under 4.4 million/mm^3) is the "garden" variety. Sometimes iron levels are low and can explain the low red blood cell count. Sometimes they are not.

Most regular anemias, including low iron levels, are associated with hookworm infestations.

Kill all *Ancylostomas* along with *Ascaris* twice a week. It is not wise to take iron pills, even if they do raise hemoglobin levels, except in life-threatening situations. Remove the tiny creatures that cause microscopic bleeding instead. Iron in the form of pills is too easily snatched up by bacteria who also need it, making them more virulent to the body. Use grain alcohol rinse in the bathroom to kill *Ascaris* and hookworm eggs under fingernails. Don't have pets in the house or keep them on daily parasite killing herbs.

It takes nutritious food to build the blood back up to its normal hemoglobin level. Eggs and meats (all very well cooked) are the richest sources of iron and other minerals used in blood building. B_6 and other vitamins are also involved and can be given as a B-complex (see *Sources*). Do not use black strap molasses as an iron source, or any molasses, since it contains toxic molds. (The molds could be detoxified with vitamin C the same way as honey. However, I have not tested enough molasses for solvents and you cannot risk these.) In the past, when the nutrient properties of molasses were discovered, the molasses manufacturing was a small, carefully conducted business. Now it has molds which cause platelet destruction, (purpuric spots) internal bleeding, and immune failure.

Acid Levels

Oxygen must first jump onto its raft, the hemoglobin, in the lungs. Later, in the brain, oxygen must jump off again to enter the brain cells. A difference in acid levels makes this possible. Acid levels operate the latching system that decides whether oxygen will be attached to hemoglobin or let go! Acidity unlatches oxygen. There should be no acidity in the lungs so oxygen can attach here. Sometimes, the entire body is too acid! Diabetics, asthmatics, arthritics, especially, suffer from total body acidity.

Acid was meant to be removed from the blood and loaded into the stomach at mealtime for digestion. When this isn't happening, it was meant to be shipped out of the body with the urine. But the kidneys may be doing a poor job because they are clogged with tiny crystals and because not enough water is drunk, so the body's acid levels rise. You can test total body acidity by measuring the pH of the morning urine. It should not be under (more acid than) 5.5. If the body acid level is too high, help the kidneys excrete it by adding more water to the diet and more minerals to neutralize the acid. The main minerals for this purpose are calcium and magnesium.

Increase Minerals

Adding water to the diet could be the most difficult of tasks if your elderly loved one “doesn't like it.” Calcium should be in the form of milk, magnesium as a tablet. When tablets cannot be swallowed; use magnesium oxide powder (see *Sources*). Use 1/8 tsp. added to cooked cereal, soup, stew, pudding. Magnesium, being a mineral, does not get destroyed as vitamins may. You can add it anywhere in the diet where it won't be tasted. Notice how calming it is to have extra magnesium in this gradual way. And how much better the sleep is at night.

When water "doesn't taste good," there is probably a valid reason. The body may be trying to reject chlorine or other toxins in it. In this case, filter it with a small all-carbon unit that is changed right on schedule. A plastic pitcher (not clear plastic or flexible plastic) with a carbon pack fitted into the top is best. Sterilize it once a week by putting a cup of water and one tbs. of grain alcohol in it and turning it upside down so the filter can soak for 15 minutes. Flush out the alcohol with two pitchers of water. Make sure the temperature suits the person. Temperature can mean everything to the never-thirsty person. Don't allow ice cubes, however, nor beverage making, with the essential water. Adding lemon or vinegar (white distilled) and 1 tsp. honey is probably the best way to stimulate both thirst and appetite.

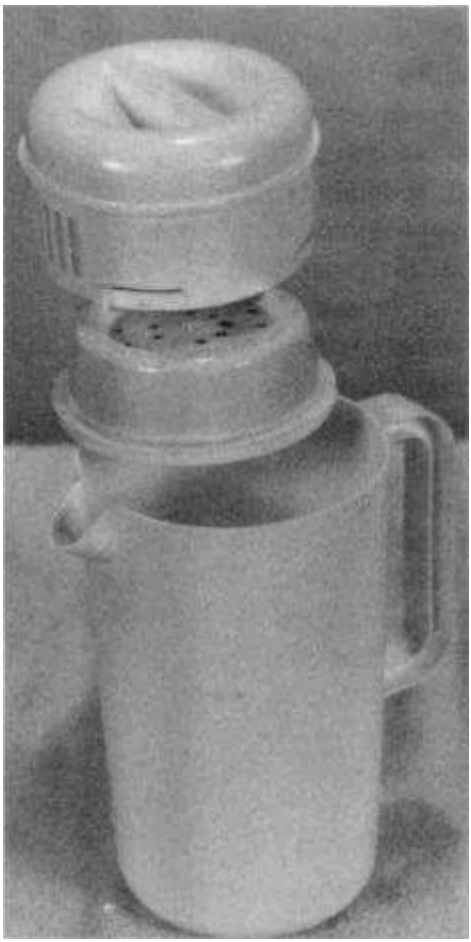

Fig. 37 Water pitcher with filter.

When blood is properly oxygenated it takes on a bright red color, unoxygenated blood is more purple. A chelation doctor can easily see the state of oxygenation.

Chelation

Chelation is a powerful way to quickly improve oxygenation of blood. The most important rule to observe, though, is to take the treatment slowly. Especially if *ethylene diamine tetra acetate* (EDTA) is being used to remove heavy metals, it is important to take the treatment over a two hour time period. Mini doses may be given in a shorter time. Generally, you are in charge of the flow rate. Discuss it with the nurse. Weekly chelations can correct many problems of the elderly that no other treatment could.

Because of hostility from insurance companies who do not wish to add another cost to their ledger and doctors indoctrinated with misinformation, bad publicity is given to this wonderful, life-prolonging mode of treatment. Clinical doctors who have no time to really investigate the statistics of chelation treatments and for whom this is purely competition may feel antagonistic to these treatments. Your loved one should not be the one who must suffer from medical politics. Go to see for yourself what chelation is all about. The receptionist should be glad to show you around. The secret is to talk to the patients themselves. They are usually sitting around a room, eating their lunch and reading as their IV's drip. The pulse, blood pressure and blood chemistry is also carefully monitored. Sit down with them to find out their stories. Get a realistic picture of benefits and costs.

Pulse

The pulse reflects the heartbeat. A **slow pulse** can give weird brain symptoms besides great fatigue. The cause is usually a drug that is being taken to correct a **fast pulse**! Check with the nurse. Read the insert included with packaging for all drugs used. The drugs responsible are usually “beta blockers”,

used for the purpose of smoothing out the heart beat, that is, making it regular. Often the drug can be changed.

Less than 60 beats per minute will lead to trouble. For a young person it is a good sign to be as low as 60, provided no drug is involved. But for the elderly it does not reflect a strong athletic heart beat.

The heart is made of four separate “chambers” or compartments each pulsing in turn. They are like four horses pulling a wagon. Unless they pull evenly, the wagon feels jerky, and irregular. The wagon will wear out sooner with jerky pulling. To smooth them out you simply slow them down. Apparently they sense each other better and can pull evenly now.

A heart that is beating 100 times per minute, not unusual for a weak old heart, can be so irregular that it misses every fourth beat. That creates a terrible deficiency of oxygen. Imagine your four cylinder car or lawnmower missing one out of four engine strokes! Beta-blockers have some quite undesirable side effects but heart regularity has a higher priority. So drugs are the immediate choice. Later, when heart health is improved, the heart will beat regularly without drug use. In the meantime, watch over the pulse. When the pulse drops below 60 the new danger is slowness. Take the pulse daily when a new drug has been added, or when you are working on heart health, without getting your loved one anxious about it.

Heart Health

To improve heart health, the first steps of course would be to go off caffeine and to kill parasites and bacteria. This alone could drop the pulse from 120 to 80 in a few days. Obviously, the need for a drug is gone. Cut the drug dosage in half immediately. Don't wait for a doctor's appointment to O.K. it. If you waited another day the pulse could be below 60.

Many common bacteria, especially *Staphylococcus aureus*, choose the heart as their favorite location. Their nesting place, though, will be under a missing tooth in the jaw (cavitation). Heartworm and *Loa loa* are two very common heart parasites. You can have all these killed in a day, without side effects and your heart is once more free to beat regularly. Don't take a chance on over-medicating. As soon as the beat is regular and under 100 per minute, reduce your heart drugs. Stop them when you are regular and under 80. Fatigue will leave and the brain will work better.

Raising potassium levels slows the pulse. Try to do this with diet by eating more potassium rich food and by conserving on potassium losses. The adrenals are in control of losses. Give them a thorough cleaning. The adrenals are situated right on top of the kidneys where all toxic things are being excreted. Being this near to the urinary tract will result in shared toxins. Urinary tract bacteria, small kidney stones, moldy foods and metal from dentalware are the chief offenders. Switch to composite tooth fillings. Use non-metal jewelry. Cook and eat with non-metal ware. Don't handle metal unconsciously throughout the day. Aluminum objects that must be touched should be wrapped in masking tape: this includes walker, shower door, bathroom supports.

Door knobs, taped walker handles, and cane handles should be wiped daily with a grain alcohol solution.

Treat the adrenal glands to 5 supplements

1. **Vitamin C:** shake some into all foods that can absorb a bit of the sour taste, even cooked cereal and vinegar water.
2. **Pantothenic acid:** 500 mg., one daily.
3. **B_6:** 250-500 mg. daily.

4. **Folic acid:** 800 mcg. daily.
5. **B_2:** 150 mg. daily. These are minimum dosages.

If no capsules or tablets can be swallowed put a three day supply in a heavy plastic bag. Pound with a hammer; then roll finer with a big glass jar. Use about 1/3 of the mix each day. If you are trying to do all this in a nursing home, feed it to your loved one while visiting. Put the powder mix in a plastic (not styrofoam) cup, add honey and stir until you get a paste. Feed the paste directly by spoon. Often the elderly prefer it this way in order not to bother with pill taking at meal time. Remind them it will turn the urine yellow.

When the brain problems are corrected for an elderly person, be sure to relate the improvement to him or her. Improvements should not be dismissed lightly. Keep notes. This encourages the elderly, letting them know their existence and quality of life is important to you. Improvements are not merely steps to yet further improvements. Enjoy each bit of progress; it is often too subtle for your loved one to notice even when it is glaringly obvious to you. Before and after a chelation treatment can show a dramatic change in mood, energy, appetite and communication ability, yet get no comment from your loved one. Point it out explicitly so your loved one can look forward to it, too.

Aging is no fun. The elderly long for a brisk gait, laughter, and a picnic at a park again. They dwell on dying, though, because they know it isn't far away and wonder what to do about it. They dare not talk about it because it is too painful a subject for the loved ones. And the immediate problems are too pressing to allow much contemplation of future problems. Talk about aging in its positive aspects. Let your loved one express feelings about it.

Incontinence

plagues most elderly persons. It begins to plague women much earlier—after childbirth, for instance. Surgically shortening the bands that hold the bladder in position (called bladder "lifting") can give temporary relief, but the surgeon may be the first to tell you that it is a temporary fix. Still, it is so shocking not to be able to run a few steps or sneeze or cough without wetting the underwear, that anything seems better than doing nothing. Surgeons will tell you that the bands have been "overstretched."

The real reason why nothing, not even surgery, is permanent is that the support bands are weak. Bacterial invasion causes most of this weakness. Low potassium levels (due to excess potassium losses by the adrenals) causes more weakness. When you kill bacteria (and *Schistosomes* and *Ascaris* and other parasites that bring in bacteria) and blood potassium levels go up, the problem is solved. Overnight you may throw those pads away. Even though you needed three pads to be "safe" you will not need any. Whether you have killed bacteria permanently determines whether you have permanently cured the condition. Make sure all dairy foods are absolutely sterile. Ask that the milk be boiled for ten seconds and other foods that can't be sterilized are not on the menu, like sour cream. Sour cream has too much *tyramine* to be safe. Tyramine is a bacterial by product that is quite toxic; it is rather high in aged cheese, also. With the food bacteria, *Salmonellas* and *Shigella*, out of the way and parasites being killed regularly, you can focus attention on the adrenals which control potassium levels.

Be careful not to rave about the foods that your loved one cannot eat.

Eating more potassium in food is a good nutrition project. Bananas are the top choice. Fresh fruit salad and baked potatoes and soup also provides a lot. Mixing potassium salt with regular salt, half and half, for the shaker is another easy trick, even if you only use it in cooking where the taste cannot be detected. Potassium by prescription is often used by clinicians to conserve body potassium during diuretic use. This need not be stopped (if the pills are not polluted) although taking potassium pills is less useful than salting it in because the adrenals will let any big dose escape anyway. A sign of too much potassium is a slow pulse.

It may be necessary to wear some kind of incontinence underwear. Try to avoid them at night, though, so the skin can breathe freely. Bring a commode near the bed for the night, rather than diapering your loved one (but don't call them diapers; say "underwear"). Absorbent pants of all kinds are heavily chemicalized. This is absorbed by the skin and adds to the toxin level. Less will be absorbed if you powder the skin with cornstarch first. Use them minimally and line them with tissue or paper towel. Chair and bed pads, too, are chemicalized. Don't sit on them with bare skin. To facilitate getting to the commode quickly in the night, dress the elderly in a short night shirt, no pajamas or long gown. Bed socks on the feet help with warmth.

Wash the body parts daily, around the urinary and rectal outlet, using borax water. Follow with 5% grain alcohol. Put washcloth in laundry after a single use. Nothing, not even brain improvement, impresses and encourages an elderly person as much as seeing the incontinence lessen. This bit of progress will put him or her solidly on your side. When they believe in you, it makes your task more rewarding. Remember to enjoy and celebrate your achievements together; don't make a grim business out of it.

Bad Digestion

with its excessive gas and burping is another plague of the elderly. They would rather not go to church nor visit a friend than embarrass themselves in that way.

Chewing

It all begins with the stomach although chewing food well is essential for really good digestion. Dentures should fit perfectly so the mouth does not develop sores. Using denture cream is not a good substitute for correct fit and is toxic. Denture plastic is often toxic, even containing mercury in its composition! Toxins in plastic can seep! Such toxins lower the immunity of the mouth and throat and stomach since it all flows down into the stomach. Low immunity in the mouth permits throat infections to be chronic. If your elderly loved one has a red-looking mouth or throat, instead of pink, an infection is going on in spite of no coughs and no complaints.

It will do no good to keep zapping bacteria when reinfection is so easy. First kill the bacteria in the dentures by soaking in 70% grain alcohol. Then test the dentures for toxins. Soak the dentures in water for several hours. Rinse and soak again in fresh water. Repeat a third time to insure that any toxin found came from the dentures, not the saliva. Save this water for testing. Search for heavy metals in the denture water. If you find any, you know the dentures are toxic! Get new ones, made of uncolored methacrylate (see Dental Cleanup, page 409).

The denture-soak should kill bacteria each night. Plastic has tiny pores where bacteria can hide. Use 70% grain alcohol which you make yourself or plain vodka which is about 50% alcohol. Since alcohol evaporates and is expensive, use a wide mouth jar with close fitting non-metal lid for all this. Fish them out with your toothbrush so it gets sterilized too. It only takes

minutes to kill everything. Commercial denture cleaners are much more toxic than grain alcohol; don't use them.

Use food grade hydrogen peroxide or salt water to brush teeth in your mouth, never **toothpaste**. Toothpaste has toxic metals (tin, fluoride, strontium) besides benzene pollution. See the section on brushing teeth (page 532) for details and sources. If you are responsible for this daily chore, use homemade floss (2 pound to 4 pound nylon fish line) first; then brush. If your loved one is seated they may be able to handle the brush by themselves, giving them pride in the achievement.

If an elderly person refuses or can't wear dentures, provide food that is soft and without chunks since this decides whether the stomach can digest it. The stomach is the weak point of the digestive process for the elderly because nearly all don't produce enough acid to get the job done.

Stomach Acid

The body produces hydrochloric acid (HCL) which gets pushed into the stomach from the blood! The enzyme, *carbonic anhydrase*, a zinc enzyme, is involved. Not many ways are known to stimulate this whole process. Drinking water before meals stimulates it in unknown ways but is hard to do for the elderly. Next best is to provide acid.

Because strong HCL would dissolve teeth it is not available as a solution to aid digestion. Ask a pharmacist to make a 1% HCL solution and use 10 drops of it in a beverage at mealtime once a day. HCL as a tablet ("Betaine HCL") is available but doesn't have enough HCL in it.

Using a lemon or vinegar and honey beverage helps with digestion although this provides citric or acetic acid, not hydrochloric. These acids are completely metabolized so they don't add to the body acid level. But the fact that it is not hydrochloric means that it can't kill bacteria and parasites in the stomach

like regular hydrochloric acid could. The stomach becomes a haven for *Salmonellas* and other bacteria and this is **the biggest digestive plague of the elderly**. *Salmonellas* dig deep into the stomach wall, safe from antibiotics and stomach acid and aren't washed away with the food. When they take over the region near the top of the stomach, it weakens the esophageal sphincter and food keeps coming back up a bit—a most uncomfortable development, especially after supper or when lying down.

When the Salmonellas spread out further to invade the diaphragm around the sphincter, the diaphragm weakens, and lets a bit of the stomach up through the hole.

This causes *hiatal hernia* distress. Don't settle your loved one in an easy chair after supper. This presses the stomach upward and the food up, too. Leave them sitting at the table a while, then walk a bit, to get the food down lower. The food will sink lower if some of it can leave the stomach at the lower pyloric end. But if *Salmonellas* are entrenched here, too, the lower end does not have enough action to push the food through the valve. Drugs like Reglan™ are given to speed this up.

What helps most is getting digestion completed. This sets up the natural cues for emptying. Digestive enzyme tablets have been in popular use to help digestion. But they may not be safe since they have not been sterilized. Always try the vinegar and honey method first. Coughing during eating is a sign that the diaphragm is irritated (by a hiatal hernia). If drinking water starts the coughing, omit it at the beginning of meals. Work in sips during the meal.

Salmonella and Shigella

Some *Salmonella* infections can bring dizziness to your elderly person. Dizziness is another plague of the elderly, keeping them from going shopping, getting to church and even from getting around their own homes. Drugs such as Antivert™ are

given but only take the edge off the problem. Feeling dizzy can make your loved one home bound and stuck to a walker for every move.

Salmonellas, along with *Shigellas*, produce very toxic substances that cause dizziness. There are three common *Salmonella* varieties: *Salmonella enteriditis*, *Salmonella paratyphi*, and *Salmonella typhimurium* (386, 380, 354 KHz). Kill *Salmonellas* daily for a month by taking Lugol's iodine (6 drops in a half cup water, after meals and bedtime, see *Recipes*). Unfortunately, this will not kill *Shigellas*; follow the Bowel Program (page 546) to get them.

During this time set up a system of sterilizing all dairy products (see Milk, page 425) since this is the source of reinfection. Set up a system of rinsing fingers (and fingernails) in 10% grain alcohol in the bathroom. Deli food and restaurant salads carry *Salmonellas* and *Shigellas*, too. Kill them, routinely, after eating such food due to necessity. A warm stomach full of food at a neutral pH is just the right culture condition for these bacteria. It's like putting yeast into a bowl of warm water, flour and sugar. In half an hour it is overflowing with growth.

Once *Salmonella* is entrenched in an organ it is difficult to eliminate. Only an electric zapper can kill them all (in an organ, not the bowel). If your body has the right conditions (like a low acid stomach) to let them grow you dare not swallow another one! *Shigellas* arrive with dairy foods, too, but prefer the lower intestine as their headquarters. Indigestion that starts right after eating is probably due to *Salmonellas*. If your indigestion comes in the night, this suggests *Shigellas*, since they've had time to reach their favorite place further down.

Campylobacter and *E. coli*, other digestive bacteria, are sometimes the culprits. The Bowel Program is effective against these also. Besides getting digestive improvement you get mental improvement, less depression, less dizziness, less irritability after clearing these up. Remember that eating bacteria and

killing them later will not solve the problem. Stopping eating them will.

Other Clues

Digestion problems that remain after eliminating bacteria can be diagnosed in a rational way. Ask these questions:

- Is the stool orangish-yellow, or very pale, instead of greenish brown? If so, bile isn't getting delivered to the small intestine from the liver.
- Is there abdominal pain? (More about this on page 97). It may be due to *Ascaris*, flukes, or other parasites.
- Is there constipation? This will let wastes accumulate, all the longer for bacteria to thrive on them.
- Is there bloating? This is due to gas made by bacteria.
- Does the stool float? If so, it must be lighter than water and contain fat or a great deal of undigested material.

Liver Bile

Bile is necessary for digestion. Absorption of fat and calcium depends on bile mixing with the food. When fat isn't absorbed, it stays in the intestine. Fat is lighter than water; it makes the stool float. Feces should not float. When the stool floats you can assume that calcium isn't being absorbed either, leaving the blood in a deficit which will be taken from the bones.

If the stool floats or is orangish in color prepare your elderly person for a liver cleanse (page 552) to clear a bile duct of obstruction. They get quite fond of these cleanses and will ask to have one. Liver cleanses are completely safe, even for persons in their 80's. One of the stones pictured on page 554 came from a woman age 97. The general rules apply to the extremely elderly: kill all parasites first by zapper if possible, otherwise by

herbal parasite killing. Do a kidney cleanse (page 549) first, using half a dose instead of the regular dose, for three to six weeks. Attend your loved one in person for the liver cleanse, have a commode at bedside, protect bedding from accident: use paper underwear if necessary. Share the joy of getting gallstones out painlessly with your loved one; let them see and count them if they wish before you flush them (use a flashlight).

Be extra careful with the skin cleansing. Hot water soothes and heals. Use starch skin soother to dispense onto the wet paper towel, besides borax solution and alcohol. Don't use ordinary soap. The starch skin softener gives the smoothness of soap, and prevents the pain of friction. An elderly person may have no diarrhea at all with the Epsom salts! Evidently the body absorbs all the magnesium so eagerly, none is left in the intestine to absorb water and create diarrhea. It is especially important though to rehydrate your elderly person after a diarrhea. This time they do not balk at water consumption. The liver cleanse, it seems, gives them new thirst as well as new appetite. But it doesn't last long. As the stones from the far corners of the liver move forward, they compact into larger stones and plug the ducts again. Their previous symptoms return. Try to give a cleanse once a month until the dark color of the stool returns and it no longer floats.

The benefits of a liver cleanse will last longer if **valerian herb** is taken the day after the cleanse and from then forward. It may be preventing spasm of the bile ducts. Use 2 oz. of the herb (cut) in 3 cups water. Simmer for 5-10 minutes, let settle or strain. Add honey to sweeten. Give a few tbs. every 4 hours (or 6 capsules) for several days followed by a daily dose at bedtime.

Constipation

If constipation is a problem, use an herbal product rather than a drug until you have removed the cause. **Cascara sagrada** (half dosage) or **prunes** work for many people. Adding **roughage** to the diet is a good solution but often doesn't work. If you try bran, you should add vitamin C and boil it, first, because it is very moldy. But even eating tree branches for supper won't move a bowel that has the wrong bacteria in it.

Bacteria are part of the cause; and part of the result! Constipation increases the bacteria level which causes further constipation! You may solve the constipation problem immediately by zapping. Even though this kills some "good" with some "bad" bacteria, no harm is done. The stool is recolonized in one to two days.

Poop Your Troubles Away

Two bowel movements a day are the minimum necessary for good health. The first one should be in the morning. The morning cup of water, drunk at the bedside has the magical ability to move the bowels. Cold water may fail. But the water effect only works in the early morning. Waiting until after breakfast may not work. Notice the energy lift your loved one gets from this most primitive body cleanse. Take advantage of this to exercise them. Go immediately for the morning walk. This might be the only time of day they can enjoy their walk.

Walking and **liver cleansing** are the most health-promoting activities you can do for your loved one.

Make walking as essential as eating. Walking is not merely walking about the house or shopping. Walking should be done outdoors. Walking is a brisk exercise, done as speedily as possi-

ble and lasting at least ½hour. Only if the weather doesn't allow outdoor walking can an indoor walk be substituted. Don't let your elderly person choose whether they will walk that day. To overcome resistance, find a cheerful neighborhood person willing to do this task for pay. The need to respond to a new stranger energizes the elderly more than your persuasion can.

Sugar Regulation

Diabetes is a common development in the elderly. If your loved one is already on a pill for beginning diabetes, take this as your challenge never to let it get worse. It is not a chronic metabolic deterioration. It is a destruction of the pancreas (specifically the islets) by the pancreatic fluke which is attracted to the pancreas by wood alcohol. Zap flukes and eliminate wood alcohol as described in the section on diabetes (page 173).

Use no artificial sweetener and no beverages besides milk, water and the recipes given in this book. This is one regimen your loved one will not resent. They are well motivated to prevent the need for giving themselves daily shots of insulin. Use this motivation to acquire the taste for new foods and beverages.

Elderly Person's 7 Day Diabetic Diet

Daily supplements: 4 chromium (200 mcg. each), 1 or 2 B-50 complex, vitamin C (1,000 mg. or ¼ tsp.). Take with food.

Breakfast

Choose any one; they need not be in order.

1. Two eggs, (replace carton and wash hands and eggs before cracking), wheat-free, corn-free bread, not toasted (special breads can be found in the freezer section of natural food

stores), with butter and 1 tbs. orange blossom honey. 1 peeled pear, raw, with whipping cream. One cup hot milk with cinnamon.

2. Old fashioned oats, with 1/4 tsp. cinnamon and 1/8 tsp. vitamin C, stirred in just before serving. Mix whipping cream with sterilized milk to make a "half n half" for the cereal. 1 tbs. honey. 1 banana. One half cup milk, one half glass water with honey and vinegar.
3. Fried potatoes with 2 eggs (use only butter, olive oil or lard), 1 cup hot or cold milk. A quartered orange (wash the orange before quartering).
4. Cream of rice, with homemade "half n half" or whipping cream, cinnamon and vitamin C stirred in. 1 cup milk, 1 banana.
5. Cottage cheese, cooked in covered skillet to sterilize. Add chives or peeled fruit (not canned). Wheat-free, corn-free bread, or rice bread with 1 tbs. honey. 1 nectarine or piece of melon. 1 cup hot milk. Water with vinegar and honey.
6. Pancakes or waffles with butter and eggs (no sweetening). Fruit (peeled), hot milk, water.
7. Fruit cup, large bowl of peeled, chopped mixed fruit with whipping cream and 1 tbs. honey and rice bread or other wheat-free, corn-free bread with unsalted butter. 1 cup hot milk with cinnamon.

Remember, all honey must be pretreated with vitamin C. All fruit is peeled and free of blemishes and soft spots. All milk, cream, butter must be sterilized for 10 seconds at full boiling point. Butter must not be "raw". Get wheat-free, corn-free bread at a natural foods store.

Lunch

It is better to have most of the day's calories in the middle of the day than at the end. Arrange for dinner at noon if possible.

Dinner

Choose any one.

1. Green beans with potatoes, meat dish, cabbage apple salad, water with lemon juice and honey, 1 cup hot milk. Water.

   Fresh green beans, especially fava beans contain a substance that is described in old herbal literature to be especially beneficial to diabetics. Don't overcook them—it might harm this substance.

   For the same reason, don't use canned green beans. If "fresh" isn't possible, choose "frozen" but rinse the chemicals off before cooking. Potatoes (not overcooked), peeled to make sure there are no blemishes (contain mold and pesticide) can be cooked with the beans. Cook with onions and oregano for flavoring. Add fresh chopped parsley to the sauce or butter for both green beans and potatoes. Fresh parsley has special herbal goodness (high magnesium, high potassium, diuretic.)

   The meat dish should be overdone. "Fast food" is plopped from the freezer into the boiling grease which browns the outside nicely but can easily leave the inside undercooked. Meat must never be "rare." There should be no redness near bones! Canned meat is safe from parasites but may have smoke flavoring added (contains benzopyrene) or nitrates. Avoid these chemicals. Avoid MSG too. Whenever a meat dish is not accepted, substitute sardines. Let them choose from a display of six kinds. Purchase the flip-top cans to avoid eating metal grindings from the can opening process.

   Cabbage for salad should be chopped fine enough to be digestible. Add finely chopped apples (peeled) and a few apple seeds and whipping cream for the dressing.

Sweet things are reserved for dessert. Since a diabetic's tissues are not absorbing sugar, they crave it more and more. As the diabetes improves they crave it less. For dessert, serve 1 tbs. of honey to satisfy this craving without endangering their blood sugar regulation. It can be used in the hot milk or in other ways. Undercooking the vegetables also helps slow down the sugar release. Never serve mashed potatoes for this reason.

The drinking water should always have a little vitamin C, lemon juice or vinegar added, and 1 tsp. honey if desired.

2. Asparagus, potato, raw salad, fowl dish, fruit, water with vinegar and honey, 1 cup hot milk.

   The asparagus can be fresh or canned. Bake the potato: not in aluminum foil, not baked until fluffy. Don't let the skin be eaten. Use genuine butter, only, or a homemade sour cream dressing (see *Recipes*). Fresh chopped chives may be added but no regular sour cream since this is very high in *tyramine*, a brain toxin.

   The raw salad should be chopped small enough to be edible by dentures. Use homemade salad dressing with a preference for oil and vinegar styles.

   The fowl dish should be very well done, never “fast food”.

   For dessert, fresh fruit chunks dipped in a homemade honey sauce (honey, water and cinnamon). Less sweets are consumed if you dip the fruit rather than pour the sauce over. Limit the total to 1 tbs. honey. Don't serve grapes or strawberries due to the intense mold problem.

3. Soup, sandwich, fruit, hot milk, water.

   Soup should be homemade from scratch. Add bones and 1 tbs. vinegar (white distilled) or a tomato to the kettle to ensure some calcium leaches out of the bones. A fish chowder serves this purpose very well, too.

The sandwich has lettuce, real butter, and whatever else tastes good (no cheese, bacon bits or condiments). The bread is wheat-free, corn-free, stored in freezer. Home-made salad dressing can be added.

The fruit may be chopped with whipping cream, cinnamon and honey sauce (not more than 1 tbs. honey).

The water may be plain if there was vinegar in the soup.

4. Fish, green beans, potatoes, other greens, fruit, hot milk, water.

   Fried or baked fish is served with lemon or lime. Green beans are served with a cheese sauce so a lot will be eaten. (Cheese sauce: add milk, olive oil to a block of cheese. Melt and cook at least 10 seconds.) Serve au gratin potatoes or scalloped potatoes or any kind of potatoes that will be enjoyed. The extra greens can be beet greens, collards, mustard greens or spinach served with a favorite dressing to make sure it's eaten. (No croutons or bacon bits, though.)

   Never serve dessert if the plate has not been cleared. Your loved one isn't hungry enough. If appetite is very poor, sweets will only worsen the problem. Try to change the menu to stimulate the appetite. Acid foods stimulate; spices and B-vitamins (especially B_1) stimulate; hot foods stimulate. Much appetite is controlled by the liver and brain. Toxins at either location (especially food-derived toxins) tell the body to stop eating. Suspect food molds first, bacteria and chemical additives next.

5. Asparagus, meat dish, white rice (brown rice contains mold), coleslaw, milk, water, ice cream.

   A hot meat dish (no pasta, no wheat flour, no regular gravy) can be fried, cooked or baked, but not grilled. Asparagus is fresh, frozen or canned. Rinse if frozen. Fix it differently than last time. Season rice with parsley and minimal salt and pure herbs like thyme; no MSG or mixed

seasoning, make butter sauce. Dessert is homemade ice cream (see *Recipes*).

6. Fish or seafood hot dish. Green peas or peas and onions. Peeled sweet potato with butter (not canned). May switch sweet potato with rice on asparagus day. Sliced tomatoes or cucumber or other raw vegetables with or without dressing. Milk, 1 tbs. honey (can be used on sweet potato).
7. Chili or stew with unlimited rice-bread and butter. If chili produces gas, stay away from it. Serve no canned varieties. Grated carrot salad with stewed raisins added and heavy cream. Milk, water as usual. Blueberry pie, sweet potato pie, custard pie.

If more bread is requested, provide a wheat-free, corn-free variety; but limit bread eating to "after main dish" eating. If not enough milk is drunk: make custard pudding or rice pudding so the daily amount (3 cups) is consumed.

Supper

1. Tuna with salad dressing or tuna salad (no pasta). Non-wheat raisin bread (from natural foods store) and butter. Milk, water.
2. Custard, cooked greens, baked potato. Rice-bread and butter. Herb tea with milk added (single herb only, not mixed herbs).
3. Vegetable soup, homemade, from scratch. Leftover meat sandwich with rice-bread (no deli or cold cuts or luncheon meat). Milk, water.
4. Baked squash with butter, rice pudding with cinnamon, raisins, and honey. Canned salmon or sardines with wheat free, corn free bread. Milk, water.
5. Chili or stew leftovers with wheat free, corn free bread. Custard pudding sweetened with honey, and nut-meg/cinnamon mix. Milk, water.

6. Sardines and rice bread or other wheat free, corn free bread. Homemade tomato juice with celery, strained. Milk, plain water. Pie a la mode (homemade pumpkin or squash pie and homemade ice cream).
7. Potato salad. Leftover meat dish and beans, stewed tomatoes, squash. Baked apple with cinnamon, cream and honey. Milk, water.

Many diabetics lose 50 points (mg/DL) of blood sugar in a few days on this diet. This is why: there is less bread than a diabetic would prefer. There is very little cheese (it must always be boiled in a sauce to sterilize). There is no fruit or vegetable juice except homemade, and not much of that because it crowds out milk and water. If your elderly loved one can't eat all this, make sure there are no snacks consumed between meals that are forbidden.

There is no pasta anywhere. Pasta is mold-ridden. Even after cooking, it may be toxic. There is no wheat or corn bread. The menu is heavy on green beans and asparagus and cinnamon. If by chance, your elderly person hates these and starves themselves to get your sympathy, add a lot more potatoes and rice (never brown) to raise calories.

There is no sweetening other than honey (5 kinds). There are no syrups or sugars. Honey is self limiting—the taste for it is all gone after 1 tbs. Not so for other sugars. The heavy use of cream and butter is offset by no deep fat fried food and little cheese.

Keep in mind that this diet may reduce the need for insulin almost immediately. You may have to cut it in half! But how would you know this? The morning blood sugar test is essential to keep track of changing circumstances. Don't neglect it. Be careful <u>not to use rubbing alcohol</u> when making the finger stick (use vodka or grain alcohol). Your elderly person will feel it is all worthwhile (doing without coffee or pie) if one less insulin shot is needed or if they can go back on tablets instead of insu-

lin. Or even just the knowledge they are staying well controlled and will never have to take insulin shots. Remember to give yourself the credit for a fine accomplishment when your loved one's diabetes improves.

Diabetic Supplements

Several supplements are especially good for diabetics:

- Fenugreek seeds, 3 capsules with each meal.
- Fresh vegetable juice made of raw green beans and carrots (½cup total).
- Bilberry leaves. Maybe they have something in them that helps detoxify wood alcohol, since bilberry leaves are good for eyes, too. Get in capsules or make a tea.

Diabetic Eating Out

Since the rules are always somewhat relaxed when "eating out" a diabetic loved one will badger you to go out with them. If rules are sure to be broken, calculate it into the rest of the day so you can compensate for it.

Extra Diet Tips For The Elderly

Food should taste good.

Eating is a fundamental pleasure of living. In old age there is no other pleasure that can equal enjoyment of food. It is a time when we long for the foods of our own childhood, too. Ethnic foods often had to be given up when children were raised (switched to hot dogs and pizza) but with this diversion gone, a return to family food would be most welcome and most healthful. Ethnic foods were made from scratch. And they certainly were made at home where cleanliness and "persnickitiness" are at their finest! A speck in the batter gets noticed. Not so in a

commercial mixing vat. Pots and pans are sanitized with hot water, not chemicals.

Good advice is to return to old fashioned home cooking: with its flour and butter, lard and cream, homemade pasta, olive oil and soup, coarse cereal grains and plain fruit. Gone are the fruit juices, flour mixes, crackers and sweets that fill grocery shelves. What about convenience? Old fashioned cooking took most of the day. It does take 3 or 4 hours to make a soup from scratch. But you then get 3 days off! Each day you reboil it, it is sterile again. Or freeze half of it (take the potatoes out first). It does take a whole morning to make pasta or some ethnic dish. Freeze it in plastic sealed containers so the delicate flavor isn't spoiled. Baking homemade bread is automated now. Do at least this much to get away from the mold-ridden grocery store loaves. Make your own ice cream and nut butters. They last many days and free your schedule.

Time is the great inhibitor but if you have the means or the help, the best advice, nutritionally, is a return to old-fashioned cooking and recipes. Use your new insights to improve them where you can. Don't use your mother's aluminum ware; use her enamel ware or the new glass and ceramic ware. Don't use her copper-bottomed tea kettle or gold-rimmed cups or “silver”. Use her wooden spoons, glass glasses, and plain dishes, her wooden and straw bowls and enamel pots and pans.

Salt

Should you avoid salt? No. But a good salt rule is to either cook with it or have it on the table, but not both. Use aluminum-free sea salt, and make sure the salt is sterilized by heating five minutes at 400°F in a glass pie plate to kill mold. (Sea gulls fly over the salt flats where sea salt is gathered. Their droppings provide a medium for mold.)

Fig. 38 Sea salt flats are often roosting places for sea gulls.

The best salt is a mixture of 1 part of your aluminum-free, sterilized sea salt and 1 part potassium chloride (another kind of salt, see *Sources*). Potassium ousts sodium (salt) from your body, so you can use twice as much of this kind of salt! Also, the extra potassium helps lift fatigue and has other benefits.

Always use a non-metal salt shaker with a closable lid to keep out moisture. Don't put rice in your salt because it invites mold.

Since you, the cook, know where the salt is, (mostly in soups and stews), don't serve as much of these when there is heart and kidney illness or high blood pressure. Don't put salt in cereal, cooking vegetables, or other dishes. Just leave it out! Use herbs instead. **Tip:** encapsulated herbs stay fresher and are more potent. Fenugreek and thyme are the most beneficial of the common cooking herbs. Just open a capsule and season.

Tremor

Tremor is a symptom, not a natural part of aging. The nerves controlling the hands and arms are poisoned. The nerves originate in the brain where the poison has accumulated. What is the poison? Did it happen long ago? No! It could have happened as long as two weeks ago but not longer!

Tremor is the result of ongoing poisoning! It is important to find the poison as soon as you can since the rest of the body will soon be affected, too. Search your memory for the new things that happened in the last two weeks. It is a herculean task but only gets harder each day, so keep notes as you ask: Is there new carpeting? Is there a new furnace? Is there a different water supply? Is there a new hair dresser? Did somebody bring a vase of fresh flowers? Is there a new laundry person? Was the place sprayed for insects? Is there a new medicine (drug) or supplement? Was remodeling done? Is there a new food?

The list is endless and the situation looks hopeless because so many new things can happen in two weeks.

Rather than asking individual questions like these, let's ask only **five general questions** and have the assurance that one of them will catch the culprit.

1. Is it in the **air**? This will catch insecticide, flowers, carpets all together.
2. Is it in the **water**?
3. Is it in the **medicines** or **supplements**?
4. Is it in the **clothing**?
5. Is it in the **food** or on the dishes?

To answer each question, test the item using your Syncrometer searching technique. Make a test substance. Then search a saliva sample for it.

To test the air, take a dust sample off the kitchen counter or table (this gives you fresh dust). Pick up the dust with a few

wipes by a small, two inch square of damp paper towel. Place in a resealable baggy.

To test the water, make samples by putting about a tsp. of hot, cold, or filtered water into a resealable baggy with a bit of paper towel in it. Try to get the first morning water before it has run.

To test the medicines and supplements put one of each in resealable baggies.

To test clothing (laundry) use a bit of it, (such as a sock) rolled up tightly.

Testing food is the biggest job. If there are leftovers in the refrigerator or freezer, this helps. You can combine all the leftovers in a single baggy. Frozen things don't need to be thawed for testing. Still, the chance of missing a food culprit is quite high. Be sure to test everything eaten in a two week time period: unusual things like popcorn, candy, crackers, cookies, health foods and special powders. A consolation is that you will find a number of bad foods that are not necessarily the tremor causes but which cause other health problems.

Tremor Remedies

1. Let us imagine that the air (dust) sample proves toxic (resonates with the saliva sample). What is it in the air that is toxic? These are the biggest suspects:

- CFCs (from leaking refrigerant, check refrigerator and air conditioner by removing them from the house and retesting the dust after three days, or simply buy a non-CFC variety)
- vanadium (from leaking house gas from a fuel line—repair)
- arsenic from pesticide (switch to boric acid)
- solvent from a lamp or can of lighter fuel (take them out of the house)

- chlorine from water (use carbon filters; remove bleach bottles)
- asbestos (clothes dryer belt)
- paint thinner, carpet cleaner (remove from house)
- fiberglass from bare insulation somewhere (fix holes in ceiling or wall)
- formaldehyde (new foam bedding, new fabric or clothing)

2. Suppose the water proves toxic (appears in your white blood cells); search for lead, copper, and cadmium. Although municipal water tests occasionally detect small amounts of propyl alcohol, benzene, or wood alcohol, I have never detected them—you need not search for them.

3. If the medicines are toxic just change brands. Your pharmacist can help you find a replacement brand. Find which ones are toxic and stop using them. (Don't use up any of the polluted pills or supplements.) They do more harm than good.

4. If the clothing or dishes are toxic (appear in the saliva), suspect

• cobalt • PCB • aluminum

Stop all detergent use. Use borax, or washing soda, or use paper plates and plastic cups (not styrofoam).

5. If the food is toxic, suspect

• food molds • aluminum • bacteria

Don't eat that food any more.

6. Any bacterium or toxin that invades certain brain centers can cause tremor. The most common culprits are *Shigella*, mercury, thallium and arsenic. Try to identify these for your sake as well as your loved one.

The *Salmonellas* and *Shigellas* will have come from some food. Be sure all dairy foods, including butter and whipping cream, are sterilized. Parasites come from meats. Be sure no undercooked or fast food meats are eaten. Kill all bacteria, viruses and parasites with a zapper. Sterilize fingernails with grain al-

cohol to prevent reinfection. Use Lugol's (see *Recipes*) and the Bowel Program (page 546) to clear them up.

Bacteria, coming from teeth and jaw (bone infections, called *cavitations*) may not seem as recent as two weeks. Indeed, they may have been there for ten years. But something recent may have aggravated them, so they now can enter more easily into the blood and brain. You may never find out what caused this. It is wisest to check this possibility with a dentist before doing weeks of other testing. See a dentist who can find and clean cavitations. Do dental repair according to the principles described in the dental section.

Going after a tremor problem in this logical way always finds the cause of tremor

whether its a simple short attack or a situation of long standing tremor with head shaking and drooling. If your situation is extra difficult, you will at least improve it and stop its progression. **This includes Parkinson's cases.**

In cases of Parkinson's disease I often find the bacterium *Clostridium tetani*, well known for causing stiffness. It hides under tooth fillings, too.

Remember, there is a consolation for doing all this work. When you find the culprit, you not only will be stopping the tremor, you will be improving a lot of other conditions along the way. Conditions like hesitant speech, shuffling walk, getting up stiffly and slowly from a chair. These are extra dividends for your loved one. And you have learned which things to avoid for yourself too.

One more thing, don't take no for an answer.

If the problem is a drug, don't accept "No, it can't be changed." Everything can be changed. Go to higher levels of authority. Doctors are very understanding and sympathetic with your intent. If the problem is leaking house gas, don't accept "We can't find a leak," implying there is none. Go to a building contractor or the Health Department. Their equipment is better. If you get nowhere, change to electric utilities. If the problem is auto exhaust, don't accept "But we have to use the kitchen door to the garage, because it's cold outside." Conveniences vs. tremor is no contest. Everyone benefits by excluding auto fumes from the house. Lock the door and cover it with plastic. By the time you have identified the culprits (probably 20 hours of work) surely you have won the right to make changes.

Often others are not impressed. Even when the tremor lessens and the elderly person plainly states they feel better, family members may disregard your recommendations. **Get tough!** It's your loved one. You have something at stake too. Be sympathetic with negative responses. But very firm. Make their choices clear:

- Either the inside door to the garage gets sealed off or the cars and lawn mower get parked outside and anything containing gasoline or solvents gets put in a detached shed.
- Either the girls use their hair dryers in their bedrooms with the door closed or you'll get them all new ones that don't contain asbestos.
- Either the clothes dryer gets a new belt or it is taped securely shut and the laundry is dried on the line or taken to a Laundromat.
- Either the plumbing gets changed (to plastic) or each faucet in the house gets a filter. (If your plumbing is corrod-

ing, not even filters are a good idea—you would have to change them every week!)

Weakness

should not be taken for granted in the elderly. Especially if they themselves complain about it. It isn't normal for them. Sometimes they will describe “spells” of weakness. This is an important clue. Check the pulse immediately. Count for 30 beats at least. Are there missing beats? There should not be! Missing two beats in a row certainly can produce a weak or “sinking” spell. The brain and body need every pulse of blood sent out right on time.

Check into caffeine use first. Take it all away. Caffeine speeds up the heart; then the overworked heart has to “take time out” for itself by missing a beat. Don't switch to decafs because this introduces solvents and new problems. If no other natural beverages appeal, serve hot water with cream and cinnamon. After stopping caffeine use ask: Is the pulse too slow or too fast? The pulse should be between 60 and 80 beats per minute.

If it is lower than 60, a medicine may be at fault. Ask the clinical doctor about it immediately. A slow pulse could certainly bring about weakness. A young athlete may have a slow pulse legitimately, due to having a very strong efficient heart, but your elderly person does not fit this category. The cause must be found.

If the pulse is quite high, over 100 perhaps, this will wear the heart out much sooner than necessary. Ask why it is beating so fast? A probable answer is that it is so weak that it has to beat faster to keep up with its job of circulating the blood. What is making the heart so weak?

Heart Disease

When the heart is enlarged, the valves don't quite close where they should, making the work harder for it and weakening it. It may be called "congestive heart failure." Why is it enlarged? Possibly because it is so weak! Yes, it becomes a vicious cycle, getting worse and worse. But you can break into this cycle and get it all reversed again. The real culprit is parasite invaders and toxic pollutants.

The most common parasite heart invaders are *Dirofilaria*, heartworm "of dogs" and *Loa loa*, another small filaria worm. At one stage these worms are so tiny that they can slide through the smallest blood vessels. They are very contagious. Even persons who don't live with a house dog can pick up heartworm. *Loa loa* is thought to be a tropical parasite but it is alive and thriving in the USA! The source of *Loa loa* seems to be tapeworm stages; this is not a certainty.

Both heartworm and *Loa loa* are very easy to kill with a zapper and both are very easy to pick up again. Treat your elderly person twice a week if there is any heart problem. It makes no difference that the house dog is getting monthly preventive treatments for heartworm. They pick it up daily and have thirty days to develop it and give it to others between treatments. Killing the dog's parasites twice a week with a zapper would be very helpful to you. These heart parasites may not cause any pains, yet disturb the rhythm or the pulse of the heart and cause it to enlarge.

Staphylococcus aureus is a bacterium hiding out in far away places like pockets left under teeth when they were extracted or along root canals. Make sure extractions heal and don't leave permanent cavitations where bacteria can live. Ask a dentist familiar with cavitations to do a mouth search. Once the mouth source is cleaned up, the bacteria do not come back to the heart (after one last zapping). If they do, go back to the dentist!

Killing these three invaders (heartworm, *Loa loa*, *Staphylococcus aureus*) should cure an irregular heart beat immediately (within a day).

If the elderly person is on a heart-slowing drug, check the pulse twice a day after zapping to make sure it doesn't drop too low. They may need to be off their heart medicine. Nobody will notice the relief of going off this medicine as much as you. The sunshine breaks out! Your loved one can smile again at little things! Even interest in sex returns so watch out! Life is normalized when drugs, especially beta blockers are gone. (Other heart medicines, such as Digitoxin,™ don't have this depressive effect. They are used to make the heart beat stronger, not to affect the rate of beating.)

The pulse should be around 70 beats per minute and perfectly regular.

If it isn't, there is still something wrong. Get rid of toxic body products and house pollutants. Test your air for gas leaks frequently. Gas heat, gas stoves and gas water heaters are notoriously leaky. Weather changes, namely temperature changes make pipes expand or shrink—leaving cracks! The gas is toxic and a small amount can't be smelled. What a predicament! Delivering poisonous house gas to our homes in pipes that are not fail-safe is an archaic practice. Especially when the blood test shows a high "total CO_2" level, near the upper limit, search for an air pollutant like house gas or auto fumes. And read the sections in this book on pulse (page 289) and brain problems (page 278) very closely for more things to check.

With the heart regular again, it will be much stronger, too, since it doesn't have to work against itself. This strength is necessary to push the blood into the farthest "corners" of the body, especially the hands and feet, and warm them up! If your loved

one constantly has cold hands or feet, try to improve circulation. Dissolve phosphate crystals with the kidney herb recipe. Give niacin (page 279). Give cayenne capsules (one with each meal). Blood thinning drugs to improve circulation are dangerous—use only if the doctor insists. Monitor blood clotting time if your loved one is on a thinner.

Heart/Kidney Relationship

A strong heart is necessary, too, to push the blood through the kidneys. Often a kidney problem is linked to the heart disorder. Kidneys are made of tubes that get finer and finer. It takes pressure, namely strength, to push the blood through them so wastes and extra water can be let down the kidney tube. Think of the kidneys as a colander full of tiny holes of various sizes that let certain things through them but not bigger things. These holes are constantly being adjusted by the adrenals which sit right on top of the kidneys and "supervise".

If the elderly person is not producing four cups of urine in a day (24 hours), it is not enough. The body cannot get enough cleansing action from less than four cups. More liquid must be consumed. If most of the urine is passed in the night this reflects on unhealthy kidneys. Use the kidney herb recipe—but only half a dose (so it will take six weeks instead of three to see good effects). As the tiny "colander" holes open up there is freer flow and many more trips to the bathroom result. The urine loses its awful odor (no ammonia, acetone and bacteria!) and gets a clear look that shows no sediment. Now that water and wastes (urea and uric acid and other acids) can leave the body quickly through more holes, it takes less pressure from the heart to get blood pushed through the kidneys. This brings relief to the heart because its work is easier. The heart and kidneys work <u>together</u>. Like horse and wagon the heart provides the power and the kidneys follow.

This is why heart medicine and diuretics are commonly given together. *Diuresis* (urine flow) helps the heart and a stronger heart helps the kidneys. Similarly, they fail together. In the old days this was called *dropsy*. Urine that should have left the body is backed up in the tissues. Sometimes it shows up in pockets that hang like giant oranges from the skin.

Even (especially) when the strongest diuretics (Maxzide™, Lasix™) fail to work, even when coupled with strong heart medicine (Digitoxin™), the kidney herb recipe can bail you out of the emergency.

The secret is in the varied actions of different herbs. This makes them work together. Be very careful to keep the herb tea sterile by reheating every fourth day. Freeze unused larger amounts. If too much is drunk at once, especially on the first day, a stomach ache can develop and a pressure felt in the bladder that is most uncomfortable. Go extra slow on the first few days, even though you find it quite tasty, so there is no discomfort (only lots of bathroom visits).

Diuretics

As soon as urine is flowing better, blood pressure may drop. Keep track of this twice a day with a modern electronic finger device (not an arm cuff that itself can break blood vessels). Cut down on drug diuretics gradually, using only ¾dose the first day, then ½dose, then ¼ dose. The amount of urine produced or the weight of the person can be used to assess how effective your method is. **Your goal is to not need any drug diuretics.** Again, mood will improve dramatically when diuretic drugs are removed for your loved one. The sense of humor comes back:

be prepared for some new jokes and new laughter. Give yourself good grades for this accomplishment.

Don't throw out the drug diuretics. After being off them for a while, they become more potent again. So if an emergency (sudden edema) should arise they could again be useful.

With a parasite and pollution-free heart and a low-resistance, freely flowing kidney, some reserve strength will soon be built up. Weak spells are gone and forgotten. Your loved one is walking better, needing less sleep, and a "golden age" finally arrives. It is free of pain, free of medicine, free of shots and doctor visits, free of dementia, free of the dreadful weakness that demands so much help. They are free to enjoy family and friends again. Seeing themselves gain strength and be able to do more for themselves gives the elderly a sense of pride.

Give them the credit for improving their health. When they balk at having to take herbs or vegetable juice, remind them of the days they were on a handful of pills and still had heart failure, pain and kidney disease.

Feeling Comfortable

If all this improvement doesn't warm up their feet or hands (feel them yourself) put extra socks on. Warming up their feet might have the effect of warming up hands, too. But if it doesn't, raise the room temperature.

Being forced to feel cold is an undeserved misery of the aged.

Others must accommodate to the elderly's need for body warmth. The thermometer does not tell all. Comfort is paramount for each of us. Younger persons can undress for comfort. The elderly can't make changes for themselves. Usually, by the time they are complaining of cold, they have suffered a long

time, feeling too guilty to request a temperature hike. Ask your loved one. They will appreciate it. A shawl, a lap-blanket, woolen sweater, long underwear and fleecy thermal outerwear help a lot. But if your hand still senses cold feet, the thermostat must still go higher. Cold body temperature is an invitation for fungus and viruses to multiply. Viruses escape into the body daily. Don't give them the advantage.

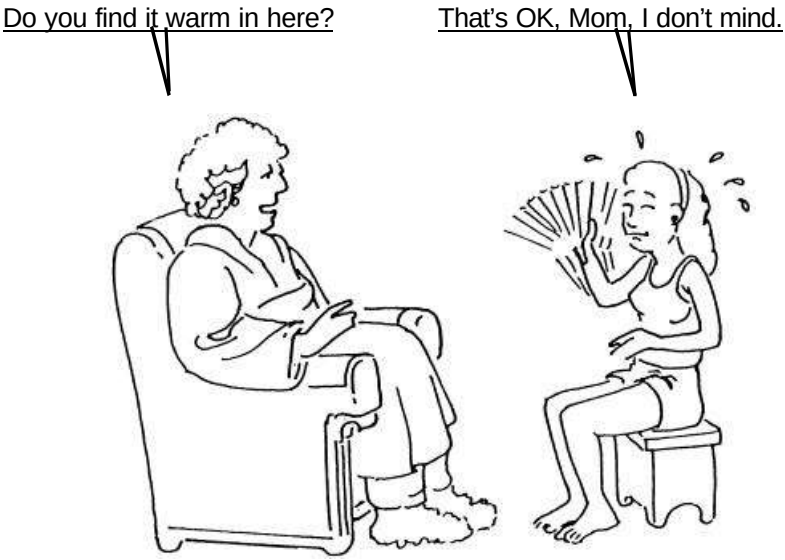

Fig. 39 Too hot and too cold.

But unless all these things are tried, don't raise the temperature. It is much healthier to be warmly dressed and breathe cool air than to be lightly dressed in an 80°F room. The heart, especially, benefits by the cooler air temperature.

For this reason, it is important to have air conditioning during the hot season. Keep your elderly person warmly dressed, away from air conditioner or fan drafts, but keep it cool. As cool as their body temperature and comfort will allow. Don't seat an elderly person under a fan in restaurants. The blowing air not

only chills them, but brings filth in dust that blows in the air currents. Bacteria and viruses are soon to follow.

Being comfortable, knowing you are there to care for them, brings out the best in your elderly person. They might get well enough to long for a genuine relationship again. And put you to the test. The test of listening. This can be very rewarding if they are still able to communicate and distill their life experience into wisdom for you. If you can listen and be interested in their distillations or their ramblings their longing for relationship will be fulfilled. There's just one catch, if the new found interest in communication can't be expressed. If they haven't communicated much for a long time, it would be easy for you to miss a simple fact. They can't hear!

Hearing Loss

The hearing deficit in an elderly person is always much greater than they or you realize. Try to understand these communications:

What you (caregiver) say	What the elderly person hears	What they think	What they respond
"Look at the sunshine, isn't it a nice day?"	"Look at something, isn't it a nice bay?"	What a stupid sentence. But she wants an answer. So here goes,	"MmmHmmm" (Meaning, "yes.")
"We'll have such a nice walk."	"Have a…rock."	Rock what? I'm not in a rocking char. I better not say anything.	
"What kind of soup should I make?"	"What kind of hoop should I make?"	I haven't used a hoop for embroidery for a long time. Why is she digging that up. I better say I don't know.	"I don't know."

Don't let this ruin your relationship. It takes the fun out of their life as much as yours. **Get hearing aids**.

Don't ask your loved one if they need a hearing aid. The answer may be "I'm not deaf." You can go about it more persuasively. Every time you talk, come quite near to the person's ear and speak loudly. They can see that you must come near. If they are fighting against the whole business, they will say things like, "You don't have to shout. I can hear you." (It's what you're saying that's wrong!)

Arrange for a hearing test. It is free. That will appeal. The results of a hearing test, as it is told by a salesperson, is much more persuasive than you can be. Let the salesperson use his or her special talents to sell your loved one on hearing aids. But you make the choice on quality. Both you and your elderly person deserve the best tone quality that is made. Plus a regular cleaning service. Most companies do offer this but don't tell the customer because of the dreadful amount of time it would take if everybody took advantage of it. You take advantage of it. Clogged hearing aids are the most troublesome feature of any of them—and never mentioned! Make it a rule to buy your batteries at the same hearing aid office where they are cleaned free of charge. This repays them and serves the elderly best. Hearing loss is too subtle to leave to chance; have the hearing aids cleaned each time you buy fresh batteries (about three months). Take your loved one to a nurse for ear cleaning every six months after hearing aids are begun. Wax and debris accumulate behind the aid because the channel is stopped up.

With hearing aids that hear, and kidneys that flush and a heart that beats strongly, your elderly person may choose to attend concerts again, go to church or gatherings—and leave you out of the picture. Give yourself good grades for this achievement. Get them incontinence pants, get regular taxi service. **Do whatever it takes to get your loved one out into the world again!**

If the excitement of a night out keeps him or her from sleeping use **ornithine** and **valerian** capsules. They are good

for the health anyway. Hot milk and a piece of cake (homemade, never chocolate) may do as much.

But if insomnia is the rule, not the exception, you need to go after it as a special problem.

Insomnia

is always associated with high levels of parasites and bacteria. This leads me to believe it is their waste products, namely ammonia, that really causes insomnia. Read the section on Insomnia under Sleep Problems for more on this (page 243).

A sound sleep refreshes as nothing else can. Your elderly person will have more energy throughout the day and a better mood if sleep was good.

Of course you must guard against daytime napping if nights are sleepless. Sleep at night is more important than sleep by day. They are not equal. Try to turn your loved one's cycle back to night-time sleeping if it has become turned around by bad kidney function (frequent urination at night) or too much daytime napping. Sleep can be disturbed by taking vitamins at bedtime too. Sleep is enhanced by taking magnesium. Limit bedtime supplements to magnesium, ornithine, valerian (6 capsules) taken with hot milk.

Healthful Habits

If your loved one had his or her way, they would drive the car forever, wear the same cosmetics forever, smoke or chew tobacco forever and eat their favorite dessert forever.

But if you are the caretaker, you know that some things must stop. You also know that gentle persuasion is useless; it merely erodes your relationship. Here are a few tips.

1. Ask your loved one to ask their doctor (clinical doctor or trusted medical advisor) the following question: "Would it be better for my lungs to stop smoking?" Be present so the question does not turn into "Will smoking a few cigarettes once in a while kill me?" Hearing it from the doctor is what's needed.
2. Don't ever purchase something you believe is detrimental to your elderly person. Whether it's coffee, cigarettes, beer or lipstick, say "That is something I can't buy for you; it's against my principles." Don't be surprised if you cave in a few times to some super ruse they use on you. But the next time, have your answer ready.
3. Let your family and other caretakers know you are no longer supplying these items (the car keys, the wine bottle, the codeine-containing pain pills). Try to get cooperation. Discussing it with your loved one may do more harm than good. If they start the discussion, you end it. This is not a task for the timid! After it's done, you'll wonder what was so difficult.
4. Don't buy a wheelchair if your loved one can still walk with your help. Stay with a cane as long as possible. Then the walker. Stay with a walker as long as possible. Then your personal help. Once a wheelchair has been accepted, the last bit of exercise, walking, is lost. Fight against it. Hide it in a far away closet.

Aging is necessary but chronic illness and pain are not.

If you have managed to free your loved one from having to take pills or from certain disabilities that would soon require pills, you can give yourself great credit. Perhaps you, too, will find the needed natural help when you are aged and have lost your authority and your way mentally. Our lives are all fore-

shortened, much like the life of a domestic steer's. Does a captive animal learn from seeing its companion disappear? It does nothing to escape its fate. Should we accept our fate with the same docility? None of us can remember how things were in precivilized times. We are eager to believe the present is the best time that has ever been. The steer, too, has its feed provided, its water provided, its shelter for the night provided, seemingly the best time it ever had. Perhaps the price we pay for civilization, like the steer's price, is simply too high. There must be other ways. As a society, we should search for our lost longevity.

Not Old Yet

For persons merely over 40 and not ill a most important rule is: **don't overdo**.

It's easy to injure tendons and muscles by pulling or stretching them too far. Don't try, with almighty determination to open a jar. Leave it for stronger hands. Don't try to stretch a gigantic stretch to reach something on a high shelf. Wait for someone taller to come along and reach it down for you. Don't do exercises, that have left you with strains in the past. Do different exercises. Don't do new exercises, with a determined approach; start moderately; stay moderate. If you start a new job that uses a foot, leg, hand or wrist a lot, more than it was used before, even though it's in ordinary use, it can feel injured. These stresses and strains invite bacteria toward themselves. Bacteria from the liver or your own intestines find these strained tissues immediately and intensify the pain. Kill the bacteria with a zapper, cleanse the liver, and start the Bowel Program if this has already happened to you.

Don't kneel on the floor to do some cleaning job. Don't sit on the floor at a gathering. Don't let your grandchildren take "rides" on you. Don't bend over as far as you can to pick something up. Let your family know you are aiming to reach 100 years in healthy condition.

Super Longevity

We should be able to live to 140 years of age. Middle age might begin at 65, old age at 90. What is the clue to long life? Surely it is keeping all your cells healthy so they can coordinate the constant tasks of nourishing themselves, removing their wastes, plus whatever job that cell was meant to do.

Since your cells divide and therefore start again at age zero, even though you are 90, why do you age at all? Only the nervous system does not divide. Is it the nerve that ages then, and decides death for each of us?

It would never do to live forever. It would clutter the planet. Are evolutionary forces at work preventing this? But we have never cluttered the planet yet. So how could evolutionary forces have "learned" to establish death to prevent overpopulation? Living to age 140 is not living forever. Wisdom comes with age. Wisdom would serve our society well. Perhaps wisdom is needed more than ever for humans to survive. Part of the human tragedy is war. Wisdom gathered from a knowledge of history, might help end wars! But history can't be gathered and understood in less than 100 years. If centenarians can't think well or express themselves, their perspectives are lost. Longevity seems a very useful trait if only it were accompanied by health!

Dying

Although it can't be avoided it can be helped. Dying alone is the most barbaric of all society's practices.

It is still like death in the forest amongst chimpanzees. Unable to feed, to run, to call for help brings pain, fear, loneliness and finally, death. When your loved one is in the mood to talk about dying, listen. Especially if it is about their own imminent death. This doesn't obligate you to carry out any of their wishes. When death approaches the important thing is simply to be there. They may not have requested this, out of a sense of guilt or masochism, or plain dementia. But it is the most primitive of needs, the same as having a loved one nearby during childbirth. It is just a presence that counts. How can you be there if you have a job or are attending a family's needs? It is a time of great frustration for you. All your hard work and successes are culminating in one grand failure!

The good news is that it need not be you who attends your loved one every minute of the last week. Pay for someone to sit—someone who is recognized. But arrange for immediate privacy when you return. No matter how much your loved one admonishes you to go about your business, you will know when you share the final minute that your presence helped. The loneliness of the last coma, the last silence is unspeakable. Give yourself the reward of knowing you shared the pain, fear and silent cry for help.

Curing Cancer

Cancer is no longer the deadly disease it once was. In fact, you can clear it up in less time than it takes to get a doctor's appointment for a check up. If you notice a lump or think you might have cancer, don't rush to see a doctor first. Rush to clear it up, yourself, first. By the time your doctor's appointment arrives, you can be sure of a negative test.

Another Fluke Disease

Cancer is so easily cured because it is a parasite-caused disease. Kill the parasite and you have stopped the cancer. This does not mean you have also stopped being ill. If the cancer damaged your ovaries or prostate, you still must heal these organs. The Ca-125 or PSA test will not drop to normal unless you begin to heal them. These markers reflect the condition of the organ, not its malignant nature. Remember that killing a mosquito does not remove the lump it caused. That will take its course. It will heal beautifully if you let it. But if you scratch it mercilessly, it will take longer. Removing toxins from the affected organs lets them heal.

Fortunately for us, **cancer is not like a fire, unstoppable once it has started**. It takes only 7 minutes to zap all the parasite adults and their stages which cause your cells to multiply.

The responsible parasite is *Fasciolopsis buskii*, the **human intestinal fluke**, a flatworm. It is a human parasite although it can also parasitize other species. It normally lives quietly in the intestine. (The goal for all larger parasites is to live quietly. After all, your demise is their demise.) They were meant to pass their thousands of eggs with your bowel movement, outside, to some pond where snails live. But when the eggs hatch before

they leave your body and are allowed to continue their development inside you, the setting is right for cancer to develop.

If the fluke eggs and other stages go through their development in your breast it can become breast cancer. If it is in the prostate it can become prostate cancer. And so on. Each different kind of cancer means the developmental stages of the intestinal fluke are present there. Only one more thing is needed to bring about an avalanche of reproduction, so that hundreds of little larvae turn into hundreds more in a short time: a growth factor. It makes them multiply and your cells are similarly affected. This growth factor, *ortho-phospho-tyrosine* (and possibly, also, *epidermal growth factor* and *insulin-dependent growth factor*) really begins your cancer.

Teamed With A Solvent

The good news is that this growth factor, which is essential for cancer to develop, cannot be made, without the presence of an abnormal solvent, **propyl alcohol** (or more exactly, isopropyl alcohol).

Without taking in propyl alcohol you could never get cancer. It takes two things, together, to give you cancer: propyl alcohol and the human intestinal fluke parasite.

Since it takes a frequency generator (3 minutes at each of 434, 432, 427, 425, 423, 421 KHz) or zapper mere minutes to kill the fluke and its stages you will be stopping the production of growth factors immediately.

Zap yourself every day for three seven minute periods, until after you are completely well.

After killing the flukes, those growth factors already formed will disappear in one hour. Your malignancy is stopped. It cannot return unless you infect yourself with the parasite again!

Getting rid of propyl alcohol is also a simple task. Once you have stopped using it, the last remnants leave your body within three days.

We must marvel at the body's wisdom and capabilities for restoring health. You are not permanently damaged by this large and hungry parasite. Given half a chance your body will throw the rascals out and restore order in your tissues.

Read the list of foods and products that are polluted with propyl alcohol. It is not, of course, usually on the label. If it is used as an ingredient, it is on the label, easy for you to avoid. It is the pollutants not appearing on the label that pose sinister hazards.

All the store bought shampoo I tested had propyl alcohol. Health brands were no exception

All bottled water is polluted with antiseptics from the bottling procedure. This is a main source of propyl alcohol.

Cosmetics are laced with propyl alcohol. Use the recipes in this book to make your own.

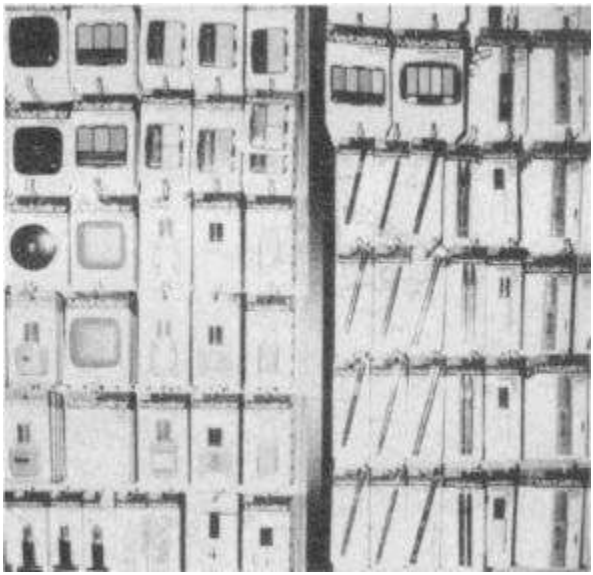

Fig. 40 Products with propyl alcohol.

Propyl Alcohol Polluted Products

THROW THESE OUT

even if propyl alcohol is not listed on the label!

- **shampoo**, even health brands
- **hair spray** and **mousse**
- **cold cereals**, even "natural" granolas
- **cosmetics** (make your own)
- **mouthwash**
- **decaffeinated coffee**, Postum™, herb tea blends (single herb teas are OK)
- **vitamins, minerals and supplements** (unless you test them)
- **bottled water**, distilled water, or spring water
- **rubbing alcohol**
- **white sugar** (brown is OK if detoxified)
- all **shaving supplies** including aftershave
- **carbonated beverages**
- store-bought **fruit juice**, including health food brands

Tear out this page, put it on your refrigerator, and make a copy to stick on your medicine cabinet. Remember propyl alcohol is also called propanol, isopropanol, isopropyl alcohol and rubbing alcohol. You won't drop dead from getting propyl alcohol, but your cancer will flare up with each small addition.

Avoid the entire list, meticulously. Even using one of these, **like your favorite shampoo or bottled water**, will result in failure. Your body will continue to make *human chorionic gonadotropin* (hCG) and the pathology will remain "indeterminate"—not cancerous but not well, either. If you have learned the new bioelectronic technology described in this book, you can test all your foods and products for isopropyl alcohol.

When you find a beverage that is free of propyl alcohol, it may have other pollutants. Xylene and toluene invite parasites to the brain. Wood alcohol invites them to eyes and pancreas. The diseases caused by these are not as frightening, perhaps, as cancer, but entirely avoidable. For this reason, I suggest in this book that you go back (actually "forward") to self made products, unprocessed food and a limited number of tested supplements.

Getting Well After Cancer

The ravages of cancer must be healed once the malignancy has been stopped. This is where *carcinogens* play a role. The lung lesions will not heal unless cigarette smoking, freon, asbestos, and fiberglass exposure is stopped. Carcinogens were thought to be the cause of cancer. Actually, they drew the cancer to the organ. Nickel draws cancer to the prostate. Barium found in lipstick draws cancer to the breast. And so on.

The following toxins can be present in any organ! I consider these to be our most serious threat. Starting with the worst, they are:

1. **Freon** (same as **CFCs** or refrigerant). I have not found a single person to be entirely free of it, including persons without cancer or disease. But in cancer sufferers it is always concentrated in the cancerous organ, and facilitates the accumulation of other toxins. This makes your refrig-

erator, if it leaks even microscopically, the top cancer hazard in the country!

2. **Copper** from water pipes. All cancer sufferers have an accumulation in the cancerous tissue. This makes plumbing the second greatest hazard.
3. **Fiberglass** or **asbestos** is present in about 25% of the cancer victims I see.
4. **Mercury** as in tooth fillings.
5. **Lead** from solder joints in copper plumbing. All colon cancer sufferers test positive.
6. **Formaldehyde** as in foam bedding and new clothing.
7. **Nickel** usually from dental metal. Most prostate cancer sufferers test positive.

At first, tumors are benign—what a relief to find your tumor was benign. Its true nature is still unknown, but it contains freon, other toxins, and later propyl alcohol! Since tumors are often large, many centimeters in diameter, and toxins do not occupy much space, there is much unidentified substance. These tumors can multiply and enlarge, as in fibrocystic breast disease, all without being malignant. But what a convenient place for baby stages of the fluke to hide out and multiply, safe from your immune system. After being colonized by fluke stages, the tumors become malignant. Eventually they also become infected when metastasis sets in.

All malignancies have the same two fundamental causes: intestinal flukes and propyl alcohol. Whether you have a rhabdomyosarcoma or a mesothelioma or melanoma, you can cure it quickly, never to return.

Herbal Parasite Killing Program

Flatworms, roundworms, protozoa, even bacteria and viruses are remarkably easy to kill using a combination of zapping and this herbal program. Thus it is not just for cancer, but a general treatment that can benefit almost every illness

1. **Black Walnut Hull Tincture Extra Strength** (see *Recipes*, page 543):
   Day 1: (this is the day you begin; start the same day you receive it)
   Take one drop. Put it in ½ cup of water. Sip it on an empty stomach such as before a meal.

   Day 2: Take 2 drops in ½ cup water same as above.
   Day 3: Take 3 drops in ½ cup water same as above.
   Day 4: Take 4 drops in ½ cup water same as above.
   Day 5: Take 5 drops in ½ cup water same as above.
   Day 6: Take 2 tsp., all together in ¼ cup water. Sip it, don't gulp it. Get it down within 15 minutes. (If you are over 150 pounds, take 2½ tsp. Do not take more than 3 tsp. because no additional value has been observed.)

   This dose kills any remaining stages throughout the body, including the bowel contents, a location unreachable by electric current. The alcohol in the tincture can make you slightly woozy for several minutes. Simply stay seated until you are comfortable again. You may put the tincture in <u>lukewarm</u> water to help evaporate some of the alcohol, but do not use <u>hot</u> water because that may damage its parasiticide power. Then take niacinamide 500 mg to counteract the toxicity of the alcohol. You could also feel a slight nausea for a few minutes. Walk in the fresh air or

simply rest until it passes. You may add more water or honey or a spice to make it more palatable.

For a year: take 2 tsp. Black Walnut Hull Tincture Extra Strength every week or until your illness is but a hazy memory. This is to kill any parasite stages you pick up from your family, friends, or pets.

Family members and friends should take 2 tsp. every other week to avoid reinfecting you. They may be harboring a few parasite stages in their intestinal tract without having symptoms. But when these stages are transmitted to a cancer patient, they immediately seek out the cancerous organ again.

You may be wondering why you should wait for five days before taking the 2 tsp. dose. It is for your convenience only. You may have a sensitive stomach or be worried about toxicity or side effects. By the sixth day you will have convinced yourself there is no toxicity or side effects.
***Going faster**. In fact, if you are convinced after the first drop of the restorative powers of Black Walnut Hull Tincture Extra Strength, take the 2 tsp. dose on the very first day.*
***Going slower**. On the other hand, if you cringe at the thought of taking an herb or you are anxious about it's safety, continue the drops, increasing at your own pace, until you are ready to brave the decisive 2 tsp. dose.*

2. **Wormwood** capsules (should contain 200-300 mg of wormwood, see *Sources*):

   Day 1: Take 1 capsule before supper (with water).
   Day 2: Take 1 capsule before supper.

Day 3: Take 2 capsules before supper.
Day 4: Take 2 capsules before supper.

Continue increasing in this way to day 14, whereupon you are up to seven capsules. You take the capsules all in a single dose (you may take a few at a time until they are all gone). Then you do 2 more days of 7 capsules each. After this, you take 7 capsules once a week forever, as it states in the Maintenance Parasite Program. Try not to get interrupted before the 6th day, so you know the adult intestinal flukes are dead. After this, you may proceed more slowly if you wish. Many persons with sensitive stomachs prefer to stay longer on each dose instead of increasing according to this schedule. You may choose the pace after the sixth day.

3. **Cloves**:
   Fill size 00 capsules with fresh ground cloves; if this size is not available, use size 0 or 000. In a pinch, buy gelatin capsules and empty them or empty other vitamin capsules. You may be able to purchase fresh ground cloves that are already encapsulated; they should be about 500 mg. Grocery store ground cloves do not work! Either grind them yourself or see Sources.

   Day 1: Take one capsule 3 times a day before meals.
   Day 2: Take two capsules 3 times a day.
   Days 3, 4, 5, 6, 7, 8, 9, 10: Take three capsules 3 times a day.
   After day 10: Take 3 capsules all together once a week forever, as in the Maintenance Parasite Program.

Take **ornithine** at bedtime for insomnia. Even if you do not suffer from insomnia now, you may when you kill parasites.

Parasite Program Handy Chart

Strike out the doses as you take them.

	Black Walnut Hull Tincture Extra Strength Dose	Wormwood Capsule Dose (200-300 mg)	Clove Capsule Dose (Size 0 or 00)
Day	drops 1 time per day, like before a meal	capsules 1 time per day, on empty stomach (before meal)	capsules 3 times per day, like at mealtime
1	1	1	1, 1, 1
2	2	1	2, 2, 2
3	3	2	3, 3, 3
4	4	2	3, 3, 3
5	5	3	3, 3, 3
6	2 tsp.	3	3, 3, 3
7	Now once a week	4	3, 3, 3
8		4	3, 3, 3
9		5	3, 3, 3
10		5	3, 3, 3.
11		6	3
12		6	Now once a week
13	2 tsp.	7	
14		7	
15		7	
16		7	
17		Now once a week	
18			3

At this point you do not need to keep a strict schedule, but instead may choose any day of the week to take all the parasite program ingredients.

Continue on the Maintenance Parasite Program, indefinitely, to prevent future reinfection.

Maintenance Parasite Program

YOU ARE ALWAYS PICKING UP PARASITES! PARASITES ARE EVERYWHERE AROUND YOU! YOU GET THEM FROM OTHER PEOPLE, YOUR FAMILY,

YOURSELF, YOUR HOME, YOUR PETS, UNDERCOOKED MEAT, AND UNDERCOOKED DAIRY PRODUCTS.

I believe the main source of the intestinal fluke is undercooked meat. After we are infected with it this way, we can give it to each other through blood, saliva, semen, and breast milk, which means kissing on the mouth, sex, nursing, and childbearing.

Family members nearly always have the same parasites. If one person develops cancer or HIV, the others probably have the intestinal fluke also. These diseases are caused by the same parasite. They should give themselves the same de-parasitizing program.

Do this once a week. You may take these at different times in the day or together:

1. **Black Walnut Hull Tincture Extra Strength**: 2 tsp. on an empty stomach, like before a meal.
2. **Wormwood capsules**: 7 capsules (with 200-300 mg wormwood each) at once on an empty stomach.
3. **Cloves**: 3 capsules (about 500 mg. each, or fill size 00 capsules yourself) at once on an empty stomach.
4. Take **ornithine** as needed.

	Black Walnut Hull Tincture Extra Strength Dose	**Wormwood Capsule Dose (200-300 mg)**	**Clove Capsule Dose (Size 0 or 00)**
Day	1 time per day, on empty stomach	capsules 1 time per day, on empty stomach	capsules 1 time per day, on empty stomach
1	2 tsp.	7	3
2			
3			
4			
5			
6			
7			
8	2 tsp.	7	3
9			
10			

11			
12			
13			
14			
15	2 tsp.	7	3
and so	**on...**		

The only after-effects you may feel are due to bacteria and viruses escaping from dead parasites! Be sure to zap after taking your maintenance parasite treatment. After-effects also let you know that you did indeed kill something. Try to discover how you might have picked up parasites and avoid them next time.

Pet Parasite Program

Pets have many of the same parasites that we get, including *Ascaris* (common roundworm), hookworm, *Trichinella*, *Strongyloides*, heartworm and a variety of tapeworms. Every pet living in your home should be deparasitized (cleared of parasites) and maintained on a parasite program. Monthly trips to your vet are not sufficient.

> You may not need to get rid of your pet to keep yourself free of parasites. But if you are quite ill it is best to board it with a friend until you are better.

Your pet is part of your family and should be kept as sweet and clean and healthy as yourself. This is not difficult to achieve. Here is the recipe:

1. **Parsley water**: cook a big bunch of fresh parsley in a quart of water for 3 minutes. Throw away the parsley. After cooling, you may freeze most of it in several 1 cup containers. This is a month's supply. Put 1 tsp. parsley

water on the pet's food. You don't have to watch it go down. Whatever amount is eaten is satisfactory.

All dosages are based on a 10 pound (5 kilo) cat or dog. Double them for a 20 pound pet, and so forth.

Pets are so full of parasites, you must be quite careful not to deparasitize too quickly. The purpose of the parsley water is to keep the kidneys flowing well so dead parasite refuse is eliminated promptly. They get quite fond of their parsley water. Perhaps they can sense the benefit it brings them. Do this for a week before starting the Black Walnut Hull Tincture.

2. **Black Walnut Hull Tincture (regular strength):** 1 drop on the food. Don't force them to eat it. Count carefully. Treat cats only twice a week. Treat dogs daily, for instance a 30 pound dog would get 3 drops per day (but work up to it, increasing one drop per day). Do not use Extra Strength.

If your pet vomits or has diarrhea, you may expect to see worms. This is extremely infectious and hazardous. Never let a child clean up a pet mess. Begin by pouring salt and iodine[15] on the mess and letting it stand for 5 minutes before cleaning it up. Clean up outdoor messes the same way. Finally, clean your hands with diluted grain alcohol (dilute 1 part alcohol with 4 parts water) or vodka. Be careful to keep all alcohol out of sight of children; don't rely on discipline for this. Be careful not to buy isopropyl rubbing alcohol for this purpose.

Start the wormwood a week later.

[15] "Povidone" iodine. topical antiseptic, is available in most drug stores.

3. **Wormwood capsules:** (200-300 mg wormwood per capsule) open a capsule and put the smallest pinch possible on their dry food. Do this for a week before starting the cloves.

4. **Cloves:** put the smallest pinch possible on their dry food.

Keep all of this up as a routine so that you need not fear your pets. Also, notice how peppy and happy they become.

Go slowly so the pet can learn to eat all of it. To repeat:

- Week 1: parsley water.
- Week 2: parsley water and black walnut.
- Week 3: parsley water, black walnut, and wormwood.
- Week 4: parsley water, black walnut, wormwood, and cloves.

	Parsley Water	**Black Walnut Hull Tincture Dose**	**Wormwood Capsule Dose**	**Clove Capsule Dose (Size 0 or 00)**
Week	teaspoons on food	drops on food, cats twice per week, dogs daily	open capsule, put smallest pinch on food	open capsule, put smallest pinch on food
1	1 or more, based on size			
2	1 or more	1		
3	1 or more	1 or more, based on size	1	
4	1 or more	1 or more	1	1
5 and onward	1 or more	1 or more	1	1

Parasites Gone, Toxins Next

Healing is automatic when you clean up your body tissues. Killing parasites and bacterial and viral invaders is fundamental. Removing toxins which invite them into your organs is even more fundamental.

How do you know which toxins are responsible for your cancer? Unless you use a Syncrometer to test, you can not know. So learn to use a Syncrometer, it will save your life.

The only other alternative is to move to a safer environment. Go on vacation. Stay in hotels less than ten years old (so the plumbing hasn't started to corrode) but not in new construction (give the carpets time to outgas). Do not have a freon containing refrigerator in your room. Do not use the hair drier they supply. Do not let them spray your room with anything. Launder the sheets and towels yourself at a Laundromat with borax and/or washing soda. Don't hesitate to drink the municipal water. Get busy with your dental cleanup.

When you get better on vacation, let that be your inspiration to move from your home. All of the toxins come from a civilized lifestyle. Resolve to leave it behind. Select a warm climate where you can spend your time outdoors in the shade most of the day. Have no refrigerator, air conditioner, clothes dryer, hair dryer, new clothing, detergent. Check that the plumbing is relatively new and that no pesticide is being used. Make the Easy Lifestyle Improvements (page 397). Throw away non-essential health supplements (unless tested) and drugs. The risk is greater than the benefit.

Watch For Bacteria

In the later stages of cancer the tumors are more and more infected with the common bacteria *Salmonella*, *Shigella*, and *Staphylococcus aureus*. Killing parasites prepares a feast for these ubiquitous bacteria. Now, more than ever, must you stay off dairy products (except for boiled milk), do the Bowel Program, take Lugol's. Remove *Staphs* by doing the dental cleanup (page 409). Don't delay.

Help Your Family, Too

If you had cancer, your whole family should be freed of intestinal fluke parasites to protect you! They may not be getting cancer (yet!) but your closeness puts you at risk. Kissing on the mouth could reinfect you. Request that family members zap themselves and take at least one 2 tsp. dose of Black Walnut Hull Tincture Extra Strength while living with you.

Pets, too, can be a source of cancer fluke stages (in their drool). They get propyl alcohol from their feed. Use unflavored, uncolored feed for them to minimize pollution from processing. Add 1 tbs. vitamin C powder to the top of a 5 lb. bag; it will stick to the pellets as they pour out. Zap your pet along with yourself by holding them and touching a bare spot such as nose or paw.

Never eat rare meats or fast food chicken. Parasite stages survive heat up to the boiling point. If you have taken a risk, zap yourself as soon as you get home to minimize the damage.

Cancer could be completely eliminated in the entire country if laws required testing for solvents in animal feeds and human food and products. Presently it is allowed in the United States Code of Federal Regulations (CFR) (see page 428)!

Another reason for propyl alcohol pollution (and other pollutants) in our food are the chemicals used by manufacturers to sterilize their food handling equipment.

> **21 CFR 178.1010 (4-1-94 Edition) Sanitizing solutions.**
>
> Sanitizing solutions may be safely used on food-processing equipment and utensils, and on other food-contact articles as specified in this section, within the following prescribed conditions:
>
> (a) Such sanitizing solutions are used, followed by adequate draining, before contact with food. **[Note rinsing or drying is not required!]**

(b) The solutions consist of one of the following, to which may be added components general recognized as safe and components which are permitted by prior sanction or approval.

[Now comes (1) through (43) permissible sterilizing solutions, including several with isopropyl alcohol, like:]

(25) An aqueous solution containing elemental iodine (CAS Reg. No. 7553-56-2), potassium iodide (CAS Reg. No. 7681-11-0), and isopropanol (CAS Reg. No. 67-63-0). In addition to use on food processing equipment and utensils, this solution may be used on beverage containers, including milk containers and equipment and on food-contact surfaces in public eating places.

[Then in paragraph (c)(19) the exact concentration of the iodine is specified. Nowhere is the concentration of the isopropanol specified. It can be as strong as desired.]

Fig. 41 U.S. regulations on sterilizing solutions.

Even if there were regulations governing removal of sanitizing solutions, the overwhelming truth is missed: that **nothing can ever be completely removed after it has been added**. Or perhaps the lawmakers didn't miss this fact. Perhaps they believed that small amounts–too small to measure with an ultraviolet spectrophotometer–could surely do no harm.

Meanwhile, protect yourself by avoiding propyl alcohol. And by observing 2 extra rules:

1. Never eat moldy foods. **2. Always take vitamin C.**

Aflatoxin

A common mold found on bread, nuts and fruit and in beer, apple cider vinegar and syrups, produces *aflatoxin*. This is what prevents you from detoxifying tiny bits of propyl alcohol that get into your body!

Buy bakery bread or bake your own. Roast nuts after washing in vitamin C water to destroy aflatoxin and then store in re-

frigerator. Keep moldy fruit out of the refrigerator where the spores can spread. Use only white distilled vinegar. Use honeys instead of syrups and even add vitamin C to them.

Vitamin C helps your body detoxify all the mold toxins I have tested, including aflatoxin.

Keep powdered vitamin C in a salt shaker. It belongs on the table with salt and pepper, and at the stove. Put it in everything possible, from cereal to soup to rice (1/8 tsp. is enough). Besides this take 1/8 tsp. powdered vitamin C with each meal (500 mg).

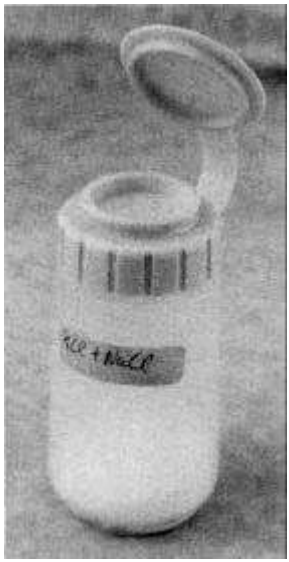

Fig. 42 Keep both salt and vitamin C powders in closable plastic shakers.

Developing cancer is a chain of events. This explains why it is a disease of aging. For ten years or more you poisoned your body with freon, fiberglass, asbestos, mercury, lead, copper, etc. You continually ate moldy food (chips, nuts, etc.) which was toxic to the liver. But the liver regenerated the pieces that died. Eventually a mold toxin prevents the liver from regenerating. Your aflatoxin-ed liver then lets propyl alcohol build up after using it. You use more and more propyl alcohol. Somewhere, over the years, you pick up the intestinal fluke in a hamburger or from a pet or person. The stage is set and cancer is inevitable.

But pull out any one of the links in this chain and cancer is impossible. **Pull them all out for a return to good health**.

So cure yourself, prevent reinfection, heal the damage and go through life without this sword hanging over you.

Over 100 consecutive case histories of cured cancer victims are the subject of another book[16] along with more detailed instructions and suggestions.

[16] *The Cure For All Cancers*, by the same author, New Century Press 1993.

Curing HIV/AIDS

HIV and AIDS disease are very similar to cancer. That is why cancer is so often seen with HIV/AIDS. It is caused by the same parasite but the solvent is **benzene** instead of propyl alcohol.

HIV stands for
Human Immunodeficiency Virus

AIDS stands for
Acquired Immune Deficiency Syndrome

Many researchers believe HIV causes AIDS. I observe them both caused by parasites and solvents!

When the body can no longer detoxify benzene it soon may not be able to detoxify propyl alcohol. Food mold, at the base of the propyl alcohol problem, is also at the base of the benzene problem. Zearalenone, a mycotoxin I find in popcorn, corn chips, and brown rice specifically inhibits detoxification of benzene. None of us should be eating these foods untested.

Several common mold toxins inhibit the immune system, too, specifically those white blood cells that are supposed to eat and destroy viruses. Consequently, the HIV virus cannot be checked once it is introduced in the body.

Benzene goes to the bone marrow where T-cells are made, and to the thymus where T-cells are programmed, two big blows to the immune system.

Benzene, a most unthinkable pollutant, is widespread in extremely small amounts. But when **benzopyrenes** are added, the

total is entirely too much for the liver and it begins to accumulate in your thymus.

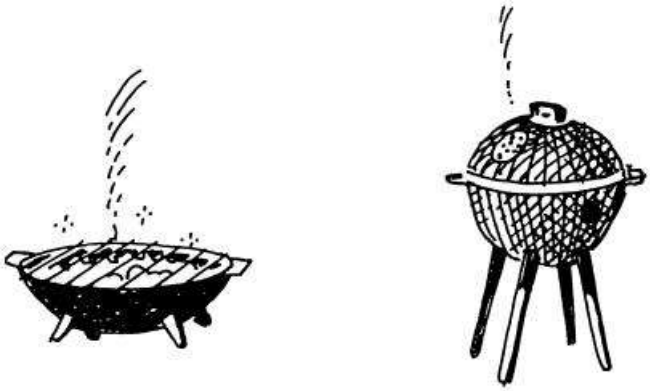

Fig. 43 Grilled food has benzopyrenes as do hot dogs and "smoke flavored" foods.

Benzopyrenes are made right in your food by direct flame-heat. Grilled food, smoked food, hot dogs and lunch meats with "smoke flavor" all have benzopyrenes—even toast has it. Food fried in a skillet does not (even if you burn it black!). As the thymus deteriorates from its benzene burden so does your immunity.

Without benzene in your body
you can't get AIDS.
Without the intestinal fluke in your body
you can't get HIV.

After killing the parasite and its stages the HIV virus will be gone in 2 hours, almost as quickly as the cancer marker, ortho-

phospho-tyrosine. It is not necessary to zap the virus itself at 365 KHz.

But the AIDS is not gone. This depends on removing benzene from your body and keeping it out of your body. Keeping it out on alternate days or 5 days of the week will not suffice. It must be out consistently. Only then can your thymus and bone marrow recover.

As your thymus recovers your immunity returns. Immunity to all the diseases that lurk at very low level in our bodies. They are already in us. We have accumulated them in a lifetime. Mumps, measles, chicken pox, CMV, *Staphylococcus aureus, E. coli,* are all there. Until now they have been controlled–kept down–by an ever vigilant immune system. If this system fails you are an easy target for any and all of these invaders.

Method Of Treatment

As soon as you find you are HIV positive, don't panic. It was inevitable. It is also inevitable for many others with unexplainable risk factors. If you have a source of infection with the intestinal fluke and at the same time a source of benzene, HIV and AIDS are a logical result. You must stop the source of both.

Purchase or make a zapper or use somebody's frequency generator (434 KHz to 421 KHz giving 3 minutes to each KHz). Kill your flukes immediately. Take vitamin B_2 immediately to help detoxify benzene (three 100 mg. tablets 3 times a day, 9 altogether). Zap daily until you feel completely well: no night sweats, no coughing, no symptoms of any kind.

Remember parasites are all around us. We pick them up daily. And your weakened immune system lets everything gain a foothold in your body. Avoiding benzene will restore your immunity. Use the benzene pollution list to guide you.

Benzene Polluted Products

THROW THESE OUT

Your health is worth more than the fortune you spent on them!

- **Flavored food**, yogurt, jello, candies, throat lozenges, store-bought cookies, cakes
- **Cooking oil** and shortening (use only olive oil, butter and lard)
- **Bottled water**, whether distilled, spring, mineral, or name brand. Bottled fruit juice.
- **Cold cereal**, including granola and health brands
- **Toothpaste**, including health brands
- **Chewing gum**
- **Ice cream** and frozen yogurt
- **Pills and capsules**. At least a third of all I test are polluted. This includes herbal extracts and prescription drugs. Test yours and switch brands until you find a safe one.
- **Vaseline products** (Noxzema™, Vick's™, Lip Therapy™), chap stick, hand cleaners
- **Vitamins** and other **health supplements**, unless tested.
- **Rice cakes**, even the plain ones
- **Personal lubricant**, including lubricated condoms
- **Baking soda and cornstarch** (see *Sources*)
- **Soaps, hand creams**, skin creams, moisturizers
- Flavored pet food, both for cats and dogs
- Bird food made into cakes

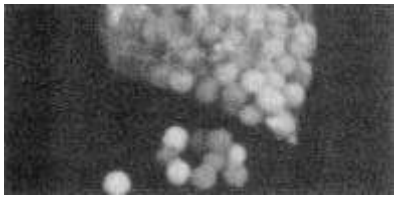

Fig. 44 Mexican made candy with no benzene.

It is impossible for me to have tested every batch of every food and product, but so many test positive you simply can not risk any of the foods and products on the list.

Fig. 45 Pollutants are in unlikely places

Learn to use the Syncrometer to do your own testing. While you are learning, observe the rules perfectly. There is no half way measure with benzene. Take an attitude of over-compliance, not "getting away" with as much as possible. Over-compliance can bring back radiant health, strength you never knew you had, a beautiful normal body again! You will be able to resume your plans for education, professional life, personal relationships, free of the sword hanging over you. You will not be infectious to anybody. Let over-compliance enthuse you.

Fig. 46 Every brand of popcorn and corn chips I tested had zearalenone contamination.

There are 2 extra rules that help eliminate benzene buildup:

1. Never eat moldy or grilled foods including popcorn, corn chips, grocery store breads, pasta, nuts, alcoholic beverages, toast, brown rice (white is OK).
2. Always take Vitamin B_2 (three 100 mg tablets three times a day) and vitamin C (1/8 tsp. with each meal).

Plan For The Future

After you are well again, you may wish to indulge in some philosophy. How did an obscure virus–a snail virus!–become a human virus? This is not so bizarre. After all, rabies virus comes to us from animals, and many encephalitis viruses come from mosquitoes. How did HIV spread so rapidly? How did a pollutant as dangerous as benzene get to be in our very food? Are other parasites getting set to spring on us? What must be done to protect ourselves and loved ones from future disasters? Would getting away from fossil fuel be a big answer? Would getting away from preoccupation with chemistry be a big answer? Would more disclosure of industrial practices be an answer? Should the government agencies responsible for food and product safety be depoliticized? Should public inspection of food manufacturing be a right? Should disclosure of foreign origins of food ingredients be mandatory? Would communicating with other cancer and AIDS survivors be useful? The computer age would make communication possible. Communication leads to answers. Answers might lead to new policies. Policies supported at the grass roots level can bring about change.

Over 50 case histories of cured HIV victims are the subject of another book[17] along with more detailed instructions and suggestions.

[17] *The Cure for HIV and AIDS*, by the same author, New Century Press, 1993.

Curing The Common Cold

Sometimes you can zap *Adenovirus*, the common cold virus, at 393 KHz for three minutes with a frequency generator and be rid of your cold, magically, in five minutes. But magic and luck are not really responsible for this. And most of the time the cold will reappear a few hours later.

Homeopathy, too, can immediately banish your cold symptoms. The reason is not mysterious either. But, this time, the cold reappears later in a different location. Choose the right homeopathic remedy for that, and you can chase it away again.

Tapeworm Stage or Mites

The fascinating story of how we really "catch" a cold kept me spellbound for a year. I was hot on the heels of *Adenovirus* wherever it might be in my body. Sometimes I saw it; sometimes I didn't. Sometimes I had cold symptoms; sometimes I didn't. Sometimes I could zap it; sometimes it did no good.

It is now apparent to me that *Adenovirus* isn't our (a human) virus at all! It belongs to other parasites. Parasites as varied as tapeworm stages and mites. Perhaps it belongs to many other parasites, as well. My evidence comes from a tapeworm stage, cysticercus of *Diphyllobothrium erinacea*, the mites *Sarcoptes* and *Dermatophagoides*, and our own colon bacteria, *E. coli*.

The tapeworm stage flies in the dust as eggs, you can trap these by setting out a pint jar with a little water in it. In three days' time you are likely to find its frequency near 487 KHz in your jar. You are also likely to find it on your kitchen sponge,

since you wipe up dust each day. To test it, place it in a plastic bag, wet it thoroughly and search from 510 KHz downward, one KHz at a time. The various tapeworm stages emit between 510 and 440 KHz.

If you have a household pet, you will always be able to find a tapeworm stage in your sponge or in a dust sample you collect from the table or kitchen counter in the morning. Gather dust with a damp bit of paper towel, put it in a plastic bag. Then wash your hands or you may accidentally eat some.

This, of course, happens to every household member. Eating the dust off the tables, inhaling the dust, and eating off surfaces wiped by the kitchen sponge happens to everyone. And everyone "catches" colds. If you search for *Adenovirus*, though, in your dust sample, it isn't there!

Similarly, you can search for the mites in your house dust. Search near the frequencies given for them. There is a good chance you will have one that is not given, because the list is so incomplete. Name it after yourself. Compare notes with others; maybe it is common, maybe it's a rare one. Again, you will not find *Adenovirus* beeping its characteristic frequency out of your mite specimen. Why not? Possibly, it is too faint; it must multiply and create a loud chorus before you can hear it. But multiply it will, if given a chance, in you. You must, of course, first eat or inhale the dust.

Then the tape eggs hatch into the *cysticercus* stage, which promptly gets to the liver. Sometimes it gets to other organs, like the muscles, the spleen, the pancreas. Presumably the liver screened it out of the blood originally.

Soon you will zap them, wherever they are. If you are using a slide specimen of *cysticercus* you can locate it in your body. If you are only listening to its beeps, you can't. If you can do both, you may be able to see which organ allows the virus to replicate after it emerges. Maybe only the respiratory organs do; maybe they start to replicate in the organ where they emerge, such as

the liver and then get to the respiratory tract. This is a fascinating avenue I have not yet explored.

Mites are inhaled or swallowed or both, just as tapeworm eggs are. They are on your kitchen sponge, and in any food or dishes that stand uncovered anywhere in the home. Never drink water from a glass that has "stood out" all day. After finding one, you will notice it beeping in you for several days. Then the beep disappears; presumably the mite is dead.

The tapeworm stage beeps may disappear in a few days, too, presumably dead. Except in cases of disease. Muscles that are diseased will take in the newcomer and allow it to survive adding to the parasites and pollutants already there! Evidently the immune power of such diseased locations is way down.

On the day that the mite stops beeping, the day it dies, *Adenovirus* appears!

Not many *Adenovirus* at first. You will need to search several times during the day to find it in your white blood cells. (And you have no symptoms, yet, either!) Is it a coincidence that *Adenovirus* appeared directly after a tapeworm stage or mite died?

You can find out by waiting until a time when you have a tapeworm stage or mite and no *Adenovirus*. Then kill your tapeworm stage or mite by zapping for seven minutes. Within minutes after that, the beeping of the tapeworm stage or mite is gone and *Adenovirus* can be heard, loud and clear at 393 KHz! And minutes later you may feel a stuffy nose, a slight congestion developing, a certain head feeling that is different. You are "catching" a cold!

Will you really get this cold? Will it become a full blown cold of the usual kind? After seeing this happen dozens of times

after killing a mite or tapeworm stage I concluded that *Adenovirus* really belongs to them; the virus is scuttling its dying host like people jumping off a sinking ship into the ocean. Our bodies are the ocean for them. They too, immediately swim and search for a hospitable island. Our respiratory tract is such an island; perhaps other organs, too.

Yes, this "baby cold" will develop into a full blown cold if, but only if, you have a mold in you!

Molds and Colds

This is part two of the cold story. You may have *Adenoviruses* quietly slipping into your blood stream and tissues from a tapeworm stage or mite you inhaled, or *E. coli* bacteria that strayed into your tissues, and which is being slowly killed by your immune system. Your immune system can keep up with them quite easily provided you don't have a mold in you at the same time. The significance of the mold is that it lowers your immunity, specifically and generally.

Mold eluded, is health improved.

This has already been studied extensively for a number of food molds. There are a variety of ways that mold toxins lower immunity. Some simply kill white blood cells. Others seem to "bind and gag" them so they just can't go about eating viruses.

So with mold toxins present, *Adenovirus*, fleeing the dead tapeworm stage, mite, or *E. coli* is not gobbled up. It has time to get to its favorite organ and enter the cells there. It may get in

your lungs if they're full of arsenic or formaldehyde, in your throat if it's full of mercury from your fillings, in your spinal cord if it's full of thallium. Sometimes you feel the viral attack, sometimes you don't.

When *E. coli* is the source of your *Adenovirus*, a question pops up. Why don't you have a perpetual cold, since these bacteria are always in your colon...and should be! As long as *E. coli* stays dutifully in your colon, no *Adenovirus* is seen. But as soon as any cross the colon wall to invade your body, your white blood cells pounce on them. After this, *Adenovirus* appears and again you are catching a cold. They may go to your internal organs where you don't feel them.

One place <u>you do</u> feel an attack is in your respiratory tract: lungs, bronchi, sinuses, nose, Eustachian tubes, inner ear, eyes or head. And the size of the attack depends on whether you recently ate moldy food.

Human food (in general, in the U.S.) is very, very moldy. We do not taste it because manufacturers have been using more and more flavorings in food. This covers up small amounts of mold or "off" flavor. Measures to reduce mold are not effective enough.

Bread is a good example. Calcium propionate is added to bread-stuff to inhibit molding. That's fine. But then the bread is encased in plastic to hold in moisture and keep it "fresh". The moisture acts to incubate mold spores and overwhelms the inhibitor. Vinegar is used instead of calcium propionate in some breads but, again, the plastic ruins its effectiveness.

Another good mold inhibitor is lime water. This is used in making tortillas. None of the old fashioned tortillas (made with just corn, water, lime) that I tested had any mold, even without propionate added! Other tortillas made of flour and calcium propionate frequently had molds.

Fig. 47 This Mexican bread has no molds. It is made from white, unbleached flour and is not wrapped in plastic.

Bread is such a staple we must correct its mold problem immediately. The two likely sources for the mold spores are: in the flour to begin with, or just flying about the bakery and landing on the newly baked loaves. Bread flour in the grocery store is quite free of mold spores, so maybe it is the bakery that needs to change. Perhaps it is not possible to bake 24 hours a day in the same building, year after year, without bits of flour and moisture accumulating in the millions of tiny cracks and crevices that all buildings have and germinating mold. Yet bread from small neighborhood bakeries does not have mold!

Only buy fresh bread not wrapped in plastic.

As soon as you feel a cold coming, ask yourself: what did you eat recently that might have been moldy? Cold cereal, hot cereal, bread, crackers, cookies, rice, other grains, fresh fruit, store bought fruit juice, nuts, syrups, pasta, honey? This takes up a large part of any person's diet, even in a single meal. The answer is yes, no doubt you ate moldy food recently.

So you can't catch a cold directly from some sneezy companion, or *E. coli*, or tapeworm stages, or mites. You have to eat moldy food first. This lowers your immunity, allowing any *Adenovirus* to invade your weakest tissues. If that happens to be your respiratory system, you get classic symptoms. (Those same "cold" symptoms can be caused by bacteria, for which I have preliminary evidence of arriving in a similar fashion.)

As fascinating as this whole story is, the bottom line is: how can you stop a cold, in record time?

The Cure

Remember, zapping does not kill your cells. So anything hiding in them will not be harmed by the electric current either. Viruses live inside your cells while they reproduce. You can only kill the outsiders: those stuck in your cell gateways. The rest will be killed by your own cells in time. Not much time. Five or six hours at most. Your cells do it with mucous secretion, inflammation and other unknown ways. So zapping is an imperfect solution.

Using a frequency generator to electrocute *Adenovirus* (393 KHz for three minutes) is not effective either because you are

not killing the mites and tapeworm stages at the same time, and the *Adenoviruses* are coming from them.

The best advice to stop a cold is to:

1. **Eat sterile food for 24 hours.** Follow the Mold Free Diet on page 365. Do not eat one questionable item.
2. Take **vitamin C** (10 grams or 2 tsp.), a **B50 complex** (2 tablets), and niacinamide (3 500 mg tablets) to help detoxify the mycotoxins already in you. See *Sources*. It will still take five or six hours for your white blood cells to recover their ability to capture viruses, for the "gag" to wear off.
3. **Zap** for seven minutes, killing all viruses, tapeworm stages and mites together. **Wait** twenty minutes to let viruses and bacteria in the dead larger parasites emerge. **Zap** a second time for seven minutes to kill those viruses and bacteria. **Wait** twenty minutes to let any viruses infecting the killed bacteria emerge. **Zap** a third time for seven minutes to kill the last viruses.
4. Now you need only wait for your tissues to decongest and stop making mucous, etc.
5. Immediately start the Bowel Program (page 546) in case yours is an *E. coli* cold. You can't, and wouldn't want to, kill all the bacteria in your bowel. Zapping kills the escapees, though, to give a bit of relief, and the Bowel Program stops the invasive *E. coli*.
6. Do additional zapping as time permits until the Bowel Program has stemmed the invasion.

In five or six hours your cold could be gone.

Of all these measures, stopping mold consumption is the most important. If you eat peanut butter now, your cold will

return with a vengeance. If you eat cheese it will add *Salmonella* to your illness and you may develop a fever. Your own immune system is the most powerful cold killer, so stop handicapping it.

Test yourself for the presence of molds to see if you are accomplishing your goal. The various molds I have tested had these emitting frequencies: 77, 88, 100, 126, 133, 177, 181, 188, 232, 242, 277, 288, 295 KHz.

In about five hours, some relief will be felt. The time it takes depends on how much mold you ate. But if you stop immediately and eat only perfectly safe food, your illness will be over in the shortest time. Shorter than merely zapping.

Mold Free Diet

Stick to this for 24 hours, even if you feel better much sooner.

Before starting to cook sterilize your kitchen sponge (microwave it for three minutes), and wash hands.

Breakfast

- 1 or 2 eggs any style. The egg carton and egg exterior have *Salmonella* on them, so remove the eggs, replace the carton, wash the exterior of the eggs and then your hands again before cracking them. You don't want a *Salmonella* infection added to your cold.
- Hash brown potatoes
- Pancakes or waffles with artificial maple syrup made with brown sugar and vitamin C.
- 1 cup herb tea with vitamin C, cinnamon, or other spice.

- Water with a tsp. of vinegar and honey.

Lunch

- Soup without noodles, without rice or any grain product.
- Homemade biscuits or bakery bread with butter.
- Homemade pudding or custard, all ingredients well cooked.

Supper

- Well cooked fish or seafood (canned O.K., like sardines, salmon and tuna).
- Fresh green vegetables, in perfect condition.
- Cooked vegetables with olive oil and salt (pure, see *Sources*).
- Canned beans, any variety.
- Baked or boiled potato (don't eat skin) with olive oil and salt as described on page 310.
- Hot water with whipping cream and cinnamon.
- A perfectly unblemished banana.
- Water with lemon.

You can "mix and match" these safe foods. If you get a hefty dose of mold at the outset of your cold, the toxicity lasts quite a long time. Repeat the diet the next day and the next until you are well. In animal experiments reported by scientists, toxicity from mold usually lasted three weeks. Sometimes the real damage was only seen after three weeks! Keep up your vigilance. When you decide to take some risks, make sure vitamin C has been added to the new food and mixed with it thoroughly.

Fig. 48 Goods baked in a panaderia (Mexican style bakery) never tested positive to molds.

Prevention

What is the best way to prevent a cold? Stop eating moldy food. We were never meant to eat rotting, spoiling food. We were meant to be repelled by the bad odor, the bad appearance, the bad taste. Our parents were supposed to teach us in childhood to distinguish between good and bad food. This system no longer works. By mixing spoiled food with good food, by adding flavors and changing the food consistency, parents can't distinguish substandard foods, nor teach their children to.

We rely on government agency assurances, like beef grades, expiration dates, approved food colors and additives. And when they fail? We land in a debacle such as the present one, where large segments of society are ill with uncontrollable behavior (called crime), suffer from hormone imbalances and sexual disturbances, are sidelined by chronic fatigue and new illness. But the greatest social disaster is lowered immunity—AIDS.

We cannot individually control the destiny of our species. But we can get ourselves out of the path of the falling human tide. We can dissent. We can say **NO** to rotten moldy food.

What about exposure to a cold? Won't you catch one if you're in a roomful of coughing, sneezing people? Or you shake hands with a coughing, sneezing person? Or you drink from the same glass as a person with a cold? Or your child plays with the same toys as sick children?

Yes, you will catch the virus, but you won't get sick. If you are tracking *Adenovirus* using the electronic techniques in this book, you will see that it infects you immediately after eating coughed-on food. It stays in you about twenty minutes. Then it disappears, evidently eaten up by your white blood cells, **provided there is no mold toxin in you**. But if you do have a mold toxin in you, the virus spreads, multiplies and gives you a cold! I have only followed *Adenovirus* behavior. There are numerous

other "cold bugs" left for you to track. Each illness in your family could provide you with a specimen to research.

This throws light on self infection, too. When we cough into our hands and then eat with them, we self-infect. But it only makes us sicker if we harbor molds.

Curing Symptoms

Cold symptoms alone can be cured much faster than the cold. Taking drugs proves that. Most of the drugs on the market can cure some symptoms in less than one hour. But not without a price, such as a harmful side effect.

Homeopathy can cure cold symptoms too, without side effects. There are three or four favorite homeopathic remedies for colds and eight or nine less common ones. To use them you read the symptoms listed and take the remedy with the closest match.

Homeopathic Remedy	For These Symptoms
Aconitum	early cold with fever, headache, hoarse cough
Allium	clear runny nose with burning of lips or eyes
Arsenicum	sneezing cold, frontal headache, tickling cough
Belladonna	high fever cold with flushed face, throbbing head
Kali bi	thick post nasal drip, colored discharge, sinus headache
Spongia	croupy cough

Fig. 49 Starter set of homeopathic remedies.

There are lots more remedies with fascinating symptoms to try to match with your own. Books suggest that you start with a 6X or a 12X remedy, but success is more certain with 30X. Use three remedies simultaneously. If you get total relief at some point, stop. If the cold has moved or won't budge, try another set of three after an hour. Don't take them within 15 minutes of

food or anything else. Homeopathy makes very interesting reading.

Homeopaths say they stimulate the immune system specifically. My results show they do much more. They go right to the gateways of your cells and evict the tiny parasite, bacteria or virus stuck to the latch and trying to get in. Your immune system would be able to gobble them all up if they weren't gagged by the food mold you ate.

Different homeopathic remedies go to different tissues, so you can only clear one tissue at a time. If you plan on trying this for yourself, order the set of cold remedies listed above (see *Sources*). The homeopathic method would be a beautiful cold cure if it weren't for the mold intrusion.

Herbs, too, can cure symptoms rather quickly. **Elderberry tea** mixed with **peppermint** is cited in herbal textbooks and it could probably do a lot if it weren't for the mold immunosuppression. If you plan on trying these start with a set of **thyme**, **fenugreek**, **sage** (for throat). Since both herbs and homeopathic remedies work on the principle of ejection, they could eject each other. Maybe the last one to arrive takes over. This is an exciting field for you to explore.

Ultimately, the length of time your own white blood cells are bound and gagged decides how soon you are really cured of your cold. Remember taking vitamin C (10 grams or more) helps detoxify the molds. If you find a recipe that works for everybody in less than five hours, be sure to let everybody know.

True Origins Of Viruses

Your body can eliminate any virus in a short time, such as hours or days. It can even keep up with a steady stream that is coming from tapeworm stages!

Let us apply these new insights to several diseases we are familiar with. Let us speculate what could really be happening.

Epstein Barre Virus (EBV) is a mysterious disease because in spite of building up antibodies, it attacks repeatedly. I only see EBV if the person also has *Eurytrema* (pancreatic fluke) in the pancreas. When the fluke is gone, I no longer find EBV in the white blood cells. This suggests that the virus comes from the fluke. As each fluke dies and is finally removed, the body's white blood cells can catch up with the viruses and you begin to feel better again, which can be as quick as one day. But reinfection with an EBV-carrying *Eurytrema* (plus a wood alcohol containing beverage to allow the fluke to go to the pancreas) can spark the next recurrence.

Shingles is a recurrence of chicken pox. I always find *Ascaris* in persons with shingles! Unfortunately, killing the *Ascaris* does not cure shingles. *Herpes Zoster* (the shingles/chicken pox virus) is known to hide in nerve cells. Perhaps *Ascaris* facilitates it's release, or simply suppresses the immune system in a way that allows it to suddenly multiply.

Polio was once a scourge. At that time, we can theorize that a new large parasite was making its appearance. Was a new animal association taking place in the early 1900's? Life was indeed becoming more urban with horse manure on all streets. Owning a dog for a house pet was becoming an acceptable life-style. Could the tapeworms of these animals give us a tapeworm stage that hosts polio virus? Many polio sufferers also had migraines. These are caused by *Strongyloides*, a horse threadworm. Does *Strongyloides* host polio virus?

The **HIV** virus infects us during the time the intestinal fluke, *Fasciolopsis buskii*, is being hosted. Persons test negative to HIV shortly after the fluke and its stages are eliminated.

Coxsackie viruses give us some of our encephalitises. I never see *Coxsackie* viruses without the bacteria, *Bacteroides*

fragilis, and I never see *Bacteroides fragilis* without *Ascaris* (a roundworm.) I conclude that one lives inside the other!

We may be deriving viruses from all the roundworms, flukes, tapeworms and bacteria that infect us! It would be a fascinating study, simply to examine each of these parasites singly, searching for their viruses with an electron microscope. They could also be searched for using immunological methods.

Fortunately, your health improvement does not need to wait on such studies. Your electronic technique can detect them in your body long before you are made ill by them. You don't need to know their hosts in order to stop hosting them yourself.

It is a time of great change for this planet as pollution spreads from pole to pole. The growth of industrial activity, mining, chemical manufacturing, the food "industry", and personal habits like smoking have spread new chemicals to every corner of the globe. The element *polonium*, which is radioactive and in tobacco smoke, is harmful to human lungs, but may not be harmful to a small lung parasite, like *Pneumocystis carnii*.

Benzene, which is a solvent and extremely harmful to humans, may not be harmful to fluke parasites living within us. Propyl alcohol facilitates the intestinal fluke but is toxic to us.

Parasites are doing abnormal things. Is this because of pollution?

The tables are gradually being turned against us in favor of our parasites and pathogens. Such large changes are called evolutionary. Is the human species doomed, or will some of us "adapt". Will some of us survive to pass on our "better" genes to a new population of cancer-resistant, AIDS-resistant, Alzheimer's-resistant, etc.-resistant humans? How many of us will die trying?

The common cold should not be so common!

Body Wisdom and Why Bad Food Tastes Good

Don't let yourself eat junk food just because your body craves something in it. Try to figure out what it is your body craves. Could it be fat? Could it be salt? Could it be starch?

Salt

If it's salt, you might also love popcorn and other salty food. This implicates the adrenal glands. Maybe they're letting too much salt (sodium chloride) leave the body through the kidneys. Maybe they're letting too much potassium chloride through, too. A diuretic pill could certainly have a similar effect.

Help the adrenal glands do their job of regulating sodium and potassium chloride by cleaning them up. Let salt-hunger be your signal to do a kidney cleanse (page 549). This will clean adrenals too. Even a slight drop in sodium and potassium chloride in the blood (body fluids) can make you too fatigued to tie your own shoelaces.

Remember, when your body craves potato chips, it craves something in the potato chips. If you let yourself eat highly salted food while you're giving the adrenals a clean up, at least add potassium chloride to your diet. Make yourself a mixture of equal parts of sodium chloride and potassium chloride. Part of salt hunger is actually potassium hunger. Let your body (your taste) decide on the amount of potassium chloride to add. Maybe one part potassium chloride to two or three parts sodium chloride is a better mixture for you. After mixing, store it in the original containers (re-label them) to prevent caking. If you put

it in an ordinary salt shaker, it will cake soon. Use a shaker with a lid that closes.

Fats

Maybe you like French fries because of the fat. If you deprive yourself of the “good” normal greases that come from plant or animal sources which would ordinarily make up 25% of your calories, of course you'll crave grease. But what a bad trade it is. Now you are getting lab-made (hydrogenated) grease with a non-biological structure, and loaded with the carcinogen nickel.

So if you're body tells you that you need grease, go back to olive oil, butter, cheese (baked only), lard, avocados, nuts and nut butters (homemade only) and seeds. Humankind has been eating these natural fats long before cholesterol was vilified. The key to cholesterol control is not fat avoidance, but a liver cleanse!

Starch

If switching to natural greases doesn't satisfy your “fat-tooth”, maybe its the potato in the French fries that your body craves. Plain, pure starch. Do you also love bread and pasta (more pure starch though very inferior to potatoes)? Pure starch is very easy to digest and has a large adsorptive capability for toxins. In fact, if any family member should accidentally eat something poisonous, drinking cornstarch will quickly mop it up and keep it stuck so it can't enter your tissues. (This doesn't work for all poisons.) By craving pure starches, your body could be telling you about a need to improve your digestion (liver disorders) or to eat and breathe less toxic things.

Maybe a stomach-full of baby *Ascaris* is telling you to eat only food that doesn't need a lot of acid: "just potatoes, bread and pasta, please, and skip the sauce." *Ascaris* inhibits acid production by the stomach. This can result in an aversion to meat.

It doesn't take much acid to digest pure starch and get it on its way out of the stomach. And out of the stomach means relief: relief of the pressure on the diaphragm and liver, heartburn, that too-full feeling, and other digestive disturbances.

Sugar

Your body runs on sugar. If you are short on sugar it will turn fat into sugar. If you are short on both, it will turn your muscles into sugar. However eating more sugar doesn't cure the craving. You have to find out why you are so short, in spite of eating it.

The first thing to try is 1 mg chromium (five 200 mcg tablets, see *Sources*) per day. If you still crave sugar after a week the problem is something else. Perhaps you have pancreatic flukes upsetting your sugar regulation. Kill them and go off commercial beverages that may contain wood alcohol. Sugar regulation is very complex, but these two approaches help most of the time.

Dislikes

Respect your body's opinion when it says, "No, I don't want to eat that." Our education about nutritive value of food may be sound but there are other facts to consider. We should take a lesson from nursing babies: when they refuse to nurse, there is something unpalatable in the mother's milk. Usually the mother has eaten onions or members of the cabbage family. The baby

tries it once, and learns to reject it immediately. The baby's liver, in its wisdom, does not want the baby to eat what it can't properly digest. The mother may feel: “Now, this breast milk is good for you and drink it you must, or you shall go hungry.” Unfortunately, this works for 2-year-olds and up. They are forced to eat carrots, peas, and other vegetables; vegetables that taste terrible, (modern agriculture has ruined the flavor). They alone taste the bitterness of PIT, a cyanide-related chemical, and very difficult for the liver to metabolize. Broccoli and onions may burn the tongue with its sulfur-containing acids. Green beans, onions, garlic, eggplant, all have unique chemicals in them. If you or your child are not ready to eat them, avoid them carefully, so you don't get a surprise dose of the toxic chemical.

The more mold a child eats, inadvertently, in peanut butter, bread, potato chips, syrups, the less capable the liver is of detoxifying foods. This will certainly increase the “pickiness” of a child's appetite. If your child has too many foods on her or his personal “off list”, let this signal you to improve liver function. Stop the barrage of chemicals that comes with cold cereals, canned soup, grocery bread, instant cheese dishes, artificially flavored gelatin, canned whipped cream, fancy yogurts and cookies or chips. Move to a simpler diet, cooked cereal with honey, cinnamon and whipping cream (only 4 ingredients), milk (boiled), bakery bread, canned tuna or salmon, plain cooked or fried potatoes with butter, and slices of raw vegetables and fruit without any sauces, except honey or homemade tomato sauce, to dip into.

It is frustrating to cook “a fine meal” for the family and find everybody likes it except Ms. Picky. The good news is that she can usually think of something she would rather eat. If it's nutritious, be thankful. If it's not say No.

Adults should hide their junk food, including everything off limits to children. Don't “hide” your junk food in the refrigerator and lower level cupboards! Treat yourself as well as your

child. If a food tastes bad, don't eat it. If you crave it, try to understand the message.

Outwit The Cravings

Here are some examples. Suppose you crave these items:

- **Pickles**. They supply vinegar and are often loved by persons with little acid in their stomachs or a lot of yeast (vinegar is a yeast inhibitor). Start drinking water with lemon juice or vinegar and honey.
- **Bacon**. The fat soothes the stomach and slows down digestion. Switch to butter and cream, with meals.
- **Sugar coated cereals**. Loved by persons with disturbed sugar regulation. Kill parasites, avoid wood alcohol, use chromium tablets and a lot of cinnamon.
- **Crunchy munchies**. Your jaw and teeth want some work to do. Try salads, an apple, raw sunflower seeds (beware of moldy seeds, nuts and dried fruit).
- **Ice cream**. Ice cold food stimulates the thyroid; loved by low thyroid persons. Clean up the thyroid by doing dental work and liver cleanses.
- **Caffeine**-laced beverages. Stimulate many body tissues, raise blood pressure. Loved by low energy people. Do a general body and environment cleanup. (There are people who say coffee puts them to sleep. Insomnia has better solutions than caffeine, though.)
- **Candy**. The more you eat the more you crave because chromium is being used up as you eat it and yet it is necessary to utilize more sugar. Give yourself chromium (GTF) tablets totaling 1 mg. (1,000 mcg.) a day and watch your sugar craving shrink.
- **Pretzels**. You want salt plus crunch.

- **Potato chips**. You want salt, grease, starch and crunch. No wonder they are so popular!

If your body still has its wisdom, or most of it, why can't it detect the mold in peanuts, crackers and bread for us? There is a very sound reason. Our food manufacturers have gone to great lengths to fool our native senses. Salt and sugar, roasting and flavoring, do most of it.

Your body is accustomed, natively, to interpret sugar, salt, and flavors as "good, good, good." Of course, the mold is "bad, bad, bad." But when you mix them, what is your body to read? The "goods" always win; manufacturers don't stop until they do. More flavorings are added. The result is that you can be eating rotten moldy food without knowing it.

Food that is predominantly concocted can't be interpreted by your body wisdom. You must use your second-best ally, your intelligence.

How would you interpret these situations, taken from real life:

- An elderly person can't stand butter, wants and enjoys margarine.
- A child prefers canned spaghetti for the real thing.
- A child wants to eat only sweets, everything else must be coaxed down.
- A young man needs "his" beer to enjoy a cook-out.
- A young man with serious mental illness drinks half a gallon of Mellow Yellow™ a day.
- A child wants ketchup on everything.
- A pregnant woman puts herself on a pickled pigs feet and white bread diet.

Back To Normal

Body wisdom was not meant to substitute for parental teaching. They must both be there. But when there is conflict, trust your wisdom. Will you ever get your primitive body wisdom back and enjoy vegetables, fruit, simple styles of cooking and baking them? Yes, to a considerable extent. You'll hold your nose at all seeds and nuts and most flour (they smell so rancid). You'll back away from cookies and cakes, especially icing (they taste like you imagine shortening tastes). You'll retreat from deep fat fried foods: the dripping grease will just undo the appetite. You'll say "No thanks" to canned food and metal cutlery (you can taste the metal now). You'd have to force yourself to eat grocery bread (it's so doughy and sour smelling). Wheat germ smells terrible (rancidity). Even vitamin tablets may smell awful.

Has life been ruined, now that plain potatoes and butter taste good? Your body wisdom has returned. You are the true gourmet. It is as different as corn on the cob is from the canned variety. Perhaps you are "spoiled" now by eating un-rotten food. Accept the charge with humor and dignity—as long as you're not expected to eat any more spoiled, moldy food.

Toxic Food

Grilled food develops *benzopyrenes* in it that are very toxic. In an age of lowered immunity, it makes little sense to deliberately poison the food with benzopyrenes. Especially for children, who will be faced with new viruses and parasites in their lifetimes. Will they be able to overcome them or succumb at middle age? Only the strength of their immune system decides this.

Benzopyrenes must be detoxified using the liver's valuable benzene-detoxification system. With so many benzene-polluted items, there is hardly enough detoxification capability to get it all taken care of. NAD enzymes (the N stands for niacin) come into play too. These are essential for alcohol detoxification. If you have consumed alcohol, like a can of beer, NAD enzymes must be shared between the alcohol in the beer and the benzene in the beer. It takes longer to detoxify both the benzene and alcohol. The time delay is a time of lowered immunity and facilitates a growth spurt for parasites and pathogens.

Foods that are raised to very high temperatures, made possible with a microwave oven, produce benzopyrenes. Ordinary bread-toasters can do this too! Old fashioned toasters had a layer of metal separating the bread from the wires. Toasting bread in a frying pan or a stove top surface protects it too. But your stove grill, whether electric or flame, will produce benzopyrenes in your food unless there is a separating wall between them.

It does not matter what kind of fuel is used, the benzopyrenes develop due to lack of shielding between the food and heat source. A metal wall between them absorbs some of the heat.

Do not burn your food in a microwave oven. Since the temperature may go higher than your regular oven, you can produce benzopyrenes. Your regular oven is thermostated so that it cannot go higher than it states. Baking and browning is never done above 425°F. This is your safety feature. If anything in your microwave has turned dark brown or black or has melted plastic, throw it out!

Supplements that help your body to detoxify the benzopyrenes are:

1. Niacin or niacinamide. These are NAD-builders. Take 50 mg with each meal.
2. Vitamin B_2 (riboflavin). Take 50 mg with each meal.

For unpolluted vitamins see *Sources*.

It would be wise to teach children the habits that maximize their immune strength. Avoiding food toxins that are specifically immune-lowering is most important. Besides the benzopyrenes, certain mold toxins and solvents do this and are found in foods.

Moldy Food

Everything that's animal or vegetable can get moldy. While living things are alive, the mold attackers can be held at bay. As soon as they are dead, molding begins. First it molds; then bacterial action sets in. This is what makes things biodegradable. It is a precious phenomenon. It does away with filth—in an exquisite manner. Without mold and decay the streets of New York would still be full of horse manure from the days of the horse and buggy and our lakes too full of dead fish to swim in.

Every grain has its molds; every fruit has its molds; tea and coffee plants have their molds; as do all herbs, and vegetables. Nuts have their molds; nuts grown in the ground (peanuts) are especially moldy because the earth is so full of mold spores. But the wind carries these spores high up into trees, and even up to the stratosphere. Molds are not very choosy. They have their preference for certain plants and conditions. But the same molds can grow on many plants. This is why aflatoxin, for instance, is found not just in your cereal, bread and pasta but in nuts, maple syrup, orange juice, vinegar, wine, etc. Where is it not? It is not in dairy products or fresh fruit and vegetables, provided you wash the outside. It is not in meat, eggs, and fish. It is not in water.

Although I find aflatoxin in commercial bread, I do <u>not</u> find it in carefully screened wheat that has had its discolored, shriveled seeds removed before using it for making bread, cereals

and noodles. It is not in baked goods bought at bakeries, left open to air. Evidently the system of wrapping baked goods in plastic keeps moisture trapped and starts the molding process. In spite of adding mold inhibitors, American bread-stuff is far inferior to Mexican baked goods in which I do not find aflatoxin!

Here is some good news for cooks: if you bake it yourself, adding a bit of vitamin C to the dough, your breads will be mold free for an extended period (and rise higher).

Aflatoxin

What is so important about molds? Some of them produce very, very toxic chemicals wherever they grow. They produce some of the most toxic chemicals known to exist. Aflatoxin is one of these. My tests show it is always present in cancer patients; in other words it has built up due to the body's inability to detoxify it in a reasonable time. A great deal of research has been done on aflatoxin. Any library would have more information.

Aflatoxin reaches the liver and simply kills portions of it. After a hefty dose the liver is weakened for a long time—possibly years. Hepatitis and cirrhosis cases always reveal aflatoxin. The liver fights hard to detoxify aflatoxin and manage its own survival. It manages for 2 to 3 weeks; then a portion of it succumbs. So the toxic effects of a dose of aflatoxin aren't even noticeable for several weeks! And without a taste or smell to guide you, how would you know to stop eating the moldy peanut butter or spaghetti? The answer is:

1. make and bake things for yourself
2. test the things you dearly love but can't make
3. treat things that are treatable for molds
4. throw the rest out of your diet

Treatments mentioned in the industrial research journals are hydrogen peroxide, strong alkali such as lime-water, metabisulfite (a common reducing agent) and high heat. I have tried heat and vitamin C, which is also a reducing agent.

Just heating a food to the boiling point does not kill the molds. Boiling for many minutes at a higher temperature or baking does kill them (but not ergot, another mold) and also destroys aflatoxin they produced and left in the food. For foods you can't heat that high, for example nuts that are already roasted, or vinegar, vitamin C comes to the rescue. I suppose it acts a lot like the bisulfite; chemically destroying the mold toxin molecules.

Eradicating Aflatoxin

Simply sprinkling vitamin C over **roasted nuts** is not effective because the molds have penetrated the surface. Rinse the nuts in water first (a lot of mold is removed in this simple way). Cover the nuts with water, add about ¼ tsp. vitamin C powder (for a pint of nuts) and mix. Let stand for 5 minutes. The water penetrates the nuts, taking the vitamin C with it and detoxifies them. Pour off the water and dry the nuts in the oven at low heat. (Don't burn them or you will make benzopyrenes.)

Rice and **pastas** can be demolded partly by cooking and partly by adding vitamin C before or after cooking. There is no need to add so much it affects the flavor. Brown rice is especially moldy.

Vinegars can simply have vitamin C added and placed in the refrigerator.

Honey can be warmed and treated the same way (¼ tsp. per pint).

Bread cannot be salvaged. Switch to bakery breads or homemade. Use it up in a few days, left in its paper bag. Or slice and place in a plastic bag in the freezer.

Since all foods have both their own and others' molds, there must be thousands of molds. Very many have been studied besides aflatoxin producers.

Zearalenone

> Zearalenone, an anabolic and uterotrophic metabolite, is frequently found in commercial cereal grains and in processed foods and feeds, and is often reported as causative agent of naturally occurring hyperestrogenism and infertility in swine, poultry and cattle.[18]

What this means is, in animals, "zear" looks likes extra estrogen to the body. Does it affect humans the same way? Are high estrogen levels a problem for us? I find nearly every breast cancer case shows a too-high estrogen level for years before the cancer is found! It starts females maturing too early, too. It could cause PMS, ovarian cysts and infertility. Not everybody gets all of these effects. And what is the effect on men and boys of eating an estrogen-like mycotoxin in their daily diet? This female hormone could have a drastic effect on the maturing process even in small amounts.

Zearalenone ("zear") and aflatoxin both have immune lowering effects. Zearalenone can induce thymic atrophy and macrophage activation.[19] If you have low immunity (low T-

[18] Bottalico, A., Lerario, P., and Visconti, A., Production of Zearalenone, Trichothecenes and Moniliformin By Fusarium Species From Cereals, In Italy. From *Toxigenic Fungi, Vol 7*, edited by H. Kurata and Y. Ueno, copublished by Kodansha Ltd, Tokyo and Elsevier Science Publishers B.V., Amsterdam, 1984, page 199.

[19] Luster, M.I., Boorman, GA., Korach, K.S., Dieter, M.P., and Hong, L. 1984. Myelotoxicity toxicity resulting from exogenous estrogens evidence for bimodal mechanism of action. Int. J. Immunopharmacol. 6:287-297.

cells, low white blood cell count, and so forth), immediately go off moldy food suspects.

"Zear" is the mycotoxin that prevents you from detoxifying benzene. Every AIDS sufferer I see has a crippled ability to detoxify benzene; they also have zear!

The main zear sources I have found so far are popcorn, corn chips, and brown rice. But it was absent in fresh corn, canned corn, corn tortillas, and white rice, making me wonder how it gets in our processed corn products.

Sterigmatocystin

Sterigmatocystin ("sterig") is plentiful in **pasta**. Emphasize baked pasta dishes, not boiled. This raises the temperature much higher than boiling. Better yet, make your own pasta with a pasta maker. U.S. bread flour is quite free of mold; the mold in our pastas must come from using inferior quality flour. Always add vitamin C to pasta before or after cooking.

Fig. 50 All U.S. brands of pasta I tested had mold, including health food brands like the one shown here (left). No Mexican brands of pasta, like the one pictured (right), had any molds.

Ergot

A food mold that causes strange feelings and behavior is *ergot*. Although laws regulate the amount of ergot allowed in

foods,[20] this is not enough protection. Ergotoxins, for example LSD, are active in extremely minute (less than a microgram, about one thousandth of a fly speck) quantities. They are not destroyed by heat and are especially toxic to children. I found traces in cereals, whole grain breads, wines, and honey. It can be detoxified by adding vitamin C but takes longer; about 10 minutes. Detoxify all your **honey** as soon as it arrives in your house. Warm it slightly and add vitamin C (1/8 tsp. per cup). Stir with wood or plastic.

Ergot toxicity could explain "Jekyll and Hyde" behavior in children, commonly attributed to "allergies". In fact, the mechanism, inability by the liver to keep up with detoxification, fits well into the "allergic" concept. If your child has undesirable behavior, try going off the moldy food suspects for three weeks (cold cereals, nuts and nut butters, store bought breads and baked goods, syrups). Substitute cooked cereals, bakery breads, potatoes, and honeys. Add vitamin C to honey, pasta and cooked cereals. Pancakes and waffles made from scratch would be O.K.

Combining alcohol with ergot is more toxic than either is alone. Alcohol seems to drive the toxin deeper into your tissues. I have found ergot and aflatoxin in beer and wine! Perhaps some of the bizarre behavior and speech of intoxication is really due to the mold-alcohol combination. By delaying alcohol detoxification, the mold could even be responsible for deaths "due to" alcoholism. It would be safer to brew your own alcoholic beverages. Start with pristine fruit. Or at least add vitamin C (1/8 tsp. per cup) to the store bought container you are consuming.

Older children and adults are quite susceptible to ergot too. If bizarre behavior shows up, such as saying mean and cruel things, expressing unusual, irrational thoughts, feeling emo-

[20]Canada allows one ergot grain per 300 grains of #3 or #4 wheat.

tionless or unreal, try the same diet changes, but put alcoholic beverages, soy sauces and other sauces, and other grain derived foods on the "off" list. Try this diet on yourself if you have a temper or crying spells or frequent colds! Ergot can make you super religious, hearing voices of command or threat. Ergot also

Fig. 51 All cold cereals I tested were full of mold toxins (besides solvents), health food varieties were worst.

causes seizures!

Cytochalasin B

Cytochalasin B ("cyto B") is another immune lowering fungus. I find it mostly in pasta. It stops cells from dividing. Dead portions of the liver cannot regenerate as they otherwise would after a toxic encounter!

Kojic Acid

Kojic acid is a mycotoxin that appears to be responsible for wood alcohol build up. In other words, the toxic effect prevents you from detoxifying wood alcohol. This leads to pancreas damage, invites pancreatic fluke infestation, and typically results in diabetes. I find it in potatoes; don't eat potato skins. If you are a potato lover fix your own so you can peel them and remove any gray parts. I have also found it in regular coffee.

T-2 Toxin

T-2 toxin is a mold I have found in all cases of high blood pressure and kidney disease. It is present on dried peas and beans but it can be detoxified in 5 minutes by adding vitamin C to the water they are soaked in. Remember to throw away imperfect ones, first.

Sorghum Molds

Sorghum and millet carry these. Don't buy sorghum syrup. Rinse millet in vitamin C water before cooking, or add vitamin C to the cooking water.

These mold toxins cause hemorrhaging, appetite loss, and inability to swallow. Elderly people are more easily poisoned than others; their hemorrhages show up as strokes and purple blotches on the skin.

Patulin

is the major fruit mold toxin. It is present in most common fruits if they are bruised. It is particularly hazardous since the mold that produces it can actually grow in your intestine in patches. At these locations, bowel bacteria, *E. coli* and *Shigella*,

can climb through the colon wall to invade you. These bacteria are then free to spread to regions of injury and tumors.

If you have cancer or bowel disease go off fresh fruit (bananas and lemons are OK) for a few weeks. Then choose your fruit meticulously. Peel everything so you can see and avoid every bruise. Also take a 2 tsp. dose of Black Walnut Hull Tincture Extra Strength. This kills these bowel fungi. But you can reinfect with a single soft grape.

Mold Avoidance

We should be much more critical of our food.

Crackers are notoriously moldy. Never let your child eat crackers. Make crisp things in the oven from left over bakery goods. Just sprinkle with cinnamon.

Dried fruits are very moldy. Soak them in vitamin C water. Rinse and bake to dry again. Then store in the refrigerator or freezer. When fresh fruit gets overripe, don't quickly bake it or preserve it. It's too late.

Peanut butter (store bought) and other nut butters can't be detoxified by adding vitamin C due to the mixing problem, even if you stir it in thoroughly. Make your own. Making your own peanut butter is a great adventure (see *Recipes*). Mix it with home made preserves, honey, marmalade, not very homogeneously so the bright colors and individual flavors stand out in contrast. Having three or four such spreads in the refrigerator will give your children the right perspective on food—homemade is better. Store bought jams are sweeter and brighter in color but strangely low in flavor and often indistinguishable from each other. Let your children eat the polluted foods that friends and restaurants serve (but not rare-cooked meats) so they can experience the difference. Their livers are strong enough to detoxify occasional small amounts.

Tea is quite moldy if purchased in bags. Although I used to recommend single herb teas (tea mixtures have solvents), I can now only recommend single herb teas from fresh sources in bulk (see *Sources*). This also gets you away from the benzalkonium chloride and possibly other antiseptics in the bag itself. When you get them, store them in their original double plastic bag. These herbs are so fresh, you'll only need half as much to make a cup of tea. Use a bamboo strainer (non metal). Bake the strainer occasionally or put through the dishwasher to keep it sterile.

Fig. 52 Packaged herb tea is moldy and polluted with solvents. Get yours in bulk from an herb company.

It comes as a surprise that pure, genuine **maple syrup** has the deadly aflatoxin and other molds. You can often see mold yourself, as a thin scum on the surface or an opaque spot on the inside of the glass after the syrup has stood some time, even in the refrigerator. Some mold spores were in it to begin with. Others flew in. After some time they grew enough to be visible. In my testing, aflatoxin can be cleared with vitamin C but sterig and others need to be treated with a high temperature as well. Fortunately, this is easy to do with a syrup. Heat to near boiling

while in the original jar with the lid removed. Keep refrigerated afterwards.

Fig. 53 Three safe flavorings.

Artificial maple flavor did not have benzene, propyl alcohol or wood alcohol, nor molds. **Turbinado sugar** had none of these contaminants either. **Brown sugar** had sorghum mold. **White sugar** had propyl alcohol pollution. You can make your own syrup, safely, with artificial flavor and turbinado sugar. Of course, you'll be missing the taste and nutritional minerals provided by the natural maple product but in a contest between nutritional value and toxicity, always choose the safe product.

The mold in our **hot cereals** can be spotted. Pick out all dark colored, shriveled bits. This represents most of it. Add honey, and salt while it's cooking—this raises the boiling temperature and detoxifies more. At the end, turn off heat and add a sprinkle of vitamin C powder. Rolled oats never showed molds in my testing, although they have their characteristic fungi, too. Don't let grains mold on your shelves simply from aging. Nothing should be more than six months old. Remember you can't see or smell molds when they begin. Molds must have a degree of moisture. As soon as you open a cereal grain, put the whole box in a plastic bag to keep moisture out. This keeps out Weevils too, so you won't have to put the box in the freezer later to kill them.

Anything that is put in the refrigerator or freezer and then taken out develops moisture inside. Store cereals in kitchen cupboards or the freezer.

No government agency can test for all of these mycotoxins in all of our foods. Production and storage methods must be better regulated so as to be fail-safe. Simply sending inspectors out to look into the bins at grain elevators is not sufficient. Crusts of mold, sometimes several feet thick, that form on top of grain bins can be simply shoveled away before the inspector arrives. The humidity and temperature of stored grain should be regulated, requiring automated controls. This would soon be cost effective, too, in terms of reduced spoilage losses and higher quality prices earned. I believe that zear, aflatoxin and ergot require special regulations. Products that are imported should be subjected to the same tests as ours. Test results should be on the label.

Getting Away From Grains

In view of the many molds that are grain-related, and because these cannot be seen or smelled in pastas, breads, cold cereals, it would be wise to steer away from grain consumption. Always choose potatoes, because it is a vegetable instead of a grain, if you have a choice. The potato appears on your plate the way it was harvested. Whereas grain was hulled, stored for quite a long time, perhaps degerminated (the bran and germ picks up

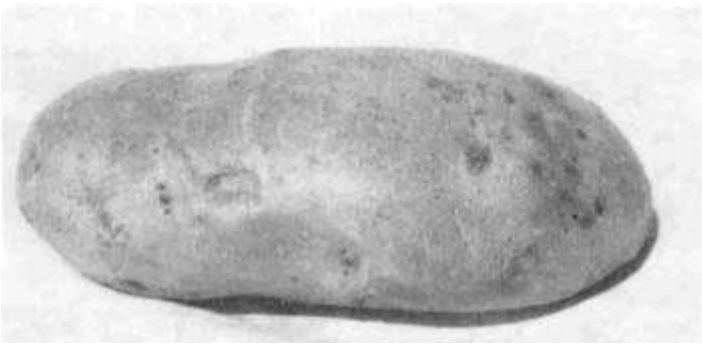

Fig. 54 Don't eat the green on the potato.

mold the fastest). Then it was mixed with assorted chemicals (fumigation, anti oxidants), each polluted in its own way, packaged again and stored again. Grains have a more tortuous history than potatoes that simply get sprayed.

The spray isn't simple, of course. Scrub it off under the tap. If potatoes weren't heavily sprayed they'd be sprouting in the stores. The spray accumulates in the eyes. Cut away all the eyes. By the time you have done this you may as well have peeled them. But no blemish, no cut, no dark spot inside may be left for you to eat. Don't buy potatoes that show a tint of green on them (the green color is due to *scopolamine*; it is toxic). Red potatoes have different chemistry that doesn't produce the green toxin, buy these often. Store potatoes out of the light, to slow down the greening process. They are still a nutritious, vitamin C-rich food—provided you don't fry them in benzene-polluted, hydrogenated grease!

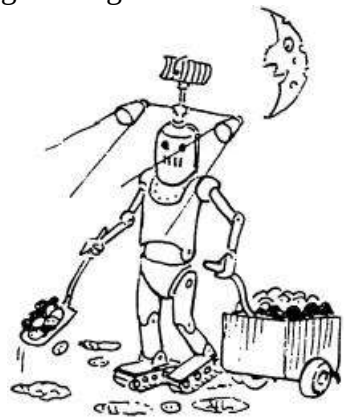

Fig. 55 Potato harvest of the future.

Potatoes have their molds but they are nicely visible. And washing and peeling does away with them. Old literature advises that potatoes should be harvested by moonlight so the green drug isn't produced in the white varieties. With modern mechanized harvesting this should pose no problem. But perhaps this must await the age of robots.

Pets Teach Health Lessons

Dogs don't eat hay and cats don't eat fruit. This is not simply due to their inability to digest them. Nor to training. Their body wisdom guides them. But we can trick them into eating corn and soybeans by adding the flavors they like and thereby defeat their wisdom the same way we defeat ours. A concoction is made for them that is called “complete nutrition” and we feed this meal after meal, day after day, a most unnatural situation. The liver is deluged with the same set of pollutants time after time and never gets a rest. Humans still obey their body wisdom about varying their meals. This gives the liver a chance to catch up with detoxifying one pollutant while the new one builds up. If the liver is absolutely unable to handle something, you are informed quite quickly with an allergic reaction to the food.

Cats and dogs with their monolithic diet get no opportunity to reject food (except by vomiting or starvation). It is not surprising they are getting cancer with increasing frequency, a situation where the liver can no longer detoxify isopropyl alcohol, a common pollutant in their food.

Should we go back to the old days and make their food for them? Yes, they deserve pure food, they deserve variety. Table scraps would be much less toxic for them than their commercial feed. But what if they like and prefer their monolithic “scientific”, “complete”, polluted diet? If our food was doused with sugar for breakfast, lunch and supper, we wouldn't care much about what was under the sugar either. And we'd continue wanting sugar, sugar, sugar the way a pet might want its favorite food and nothing else. Such is the deception of flavorings.

All change should be brought about slowly and with kindness for animals and humans alike. Learn what makes a good pet diet. Cats and dogs are both meat eaters. Cook chicken in a pressure cooker to kill all parasites. Put portions in the freezer. Add table scraps, dressed with a little butter, cheese or lard.

Don't wash the pet dishes with your own—dishwashers don't reach the boiling point. Serve fresh water daily. Standing water picks up bacteria. Don't let food get more than a day old in the dishes. It picks up molds. Don't feed pets at the table, keep them outdoors during mealtime.

After your pets have stopped eating propyl alcohol polluted food and are not getting propyl alcohol in their shampoos, there is no way they can get cancer. Whatever cancer they have will clear up by this change in diet and by giving them the pet parasite program.

Now they are back to a natural state and do not host human flukes. What a relief it is not to worry about reinfection from your pets.

Easy Lifestyle Improvements

None of us likes to change a habit. But once it is changed you are back to an automatic way of doing something. By selecting wise habits your improved lifestyle pays you back for the rest of your life.

Living Hand To Mouth

Hands do everything. They pick up things from the floor. They handle money. They touch other peoples' hands. They clean up bottoms. They touch all kinds of door knobs. And then they pick up food to eat. Some people even lick their fingers when they're sticky or just to turn a page!

What is on the hands that you don't want to eat but can't see? **Bacteria** and **viruses** from coughing and sneezing into your hands! And **cysts**! Cysts are the "eggs" made by parasites. Cysts are so tough not even bleach kills them. They hide under our fingernails when we wash our hands. Then we eat them along with our food. This is called *oral-fecal route*. They hatch in the stomach and go to the intestine to live.

To stop reinfecting yourself the little cysts under the nails need to be killed. Food grade alcohol solution kills them. Buy Everclear™ or Protec (potable) alcohol and make a 5% solution (add ¼ cup of 95% alcohol to a quart of water). Keep it in a small pump bottle at the sink. After using the bathroom and washing your hands, treat your fingernails with alcohol. Pump alcohol into one palm. Put the fingernails of the other hand into

it. Scratch a bit. Pour it into the other palm and do the remaining fingernails. Rinse.

- **Don't** eat with your hands! Use a fork.
- **Never** eat food off the floor!
- **Always** wash hands after petting an animal!
- **Never** touch the bottoms of shoes! Keep shoes off couch or bed or chair.
- **Always** cough or sneeze into your clothing or a tissue, not your hands.
- **Keep** your fingers out of your mouth. Don't lick your fingers to turn pages or open plastic bags.

Sick persons need a 50% alcohol solution. Add ½cup 95% alcohol to ½cup cold tap water or buy plain vodka, 80 to 100 proof. Pour the vodka into the pump bottle. Be careful that nobody tries drinking it. If there are teenagers in the house, add a hefty dose of cayenne to it.

Lugol's iodine will also sterilize your hands. However most commercial Lugol's is polluted with isopropyl alcohol. Ask your pharmacist to make it from scratch for you (there are only two ingredients and water, see *Recipes*). Then make a solution to wash in (1 tsp. to a quart of water). This can stain some things. Do not use "tincture of iodine."

Better Laundry Habits

Boil your underwear. In long-ago days, all sheets, towels, table cloths, and underwear were separated and boiled.

With the convenience of our electric washing machine, we tend to overlook the fact that underwear is always contaminated by fecal matter and urogenital secretions and excretions. Mixing these with socks and towels and dishcloths is all right if you are

going to kill everything anyway. But if you don't kill them, as in cold water washes, you are mixing the yeast, parasite eggs, bacterial spores, and fungus from underwear with all the other clothing you and your family wear. An enlightened system would be to add an antiseptic to the wash or rinse cycle. Lime water (calcium hydroxide) or iodine based antiseptics seem obviously simple methods to accomplish this. In the absence of this protection, use dryer heat to do your sterilizing. Underwear should be dried until too hot to handle.

Bleach can kill a lot, but doesn't kill *Giardia* spores and a lot of types of fungus. Don't rely on bleaching. Besides, your skin absorbs it from clothing, it is quite toxic to you, and can cause mental effects.

Commercial detergents are polluted with PCBs and have cobalt added. Both of these are easily picked up through your skin. Use **washing soda** and **borax** in the wash cycle. They do not clean quite as well as modern detergents, but there is less static cling, eliminating the need to put more chemicals in your dryer. For spot removal use homemade bar soap.

Better Kitchen Habits

Once a day, sterilize the sponge or cloth you use to wipe up the table, counter tops and sink. This little piece of contaminated cloth is the most infectious thing in the house, besides the toilet. It's more dangerous than the toilet because you do not suspect it. Sometimes it has a slight odor at first, which may warn you, but most pathogens do not have an odor! As we wipe up droplets of milk, we give the milk bacteria, *Salmonellas* and *Shigellas*, a new home to multiply and thrive in. We add crumbs, picking up molds this way. We add dust, picking up parasite eggs and stages. They all feed on the milk and food residue.

As the counter and table and stove get wiped "clean" a film of contamination is left everywhere. A few varieties may die but most of them don't. The general moisture in the kitchen is enough for them to survive. The cloth or sponge recolonizes the kitchen and dining room table several times a day.

No doubt, the last thing you do before leaving the kitchen is squeeze it dry with your hands. Now all the pathogens are on your hands!

Where do your fingers go? To your mouth to remove a hull or bit of something from your teeth. Or to eat a last bite of something. Or to turn a page of the telephone directory. You have just eaten a culture sampling from your own kitchen sponge. In two hours they are already multiplying in the greatest culture system of all: your body! You have given yourself your next sore throat, or cold or headache. The worst possible habit is to wipe a child's face and hands with the kitchen cloth. Or to have a handy towel hanging from the refrigerator handle.

To sterilize the sponge: **drop it into a 50% solution of grain alcohol** at the end of each day. Keep a wide mouth glass quart jar handy just for this. Keep the jar tightly closed and out of the reach of children. Dunk your sponge and plop it onto the sink. If you stand it on end in the sink it will partly dry overnight.

Another way to sterilize the sponge or cloth is to **microwave it**, after wetting it, for 3 minutes. Any shorter time simply warms and cultures the pathogens and multiplies them. Or **boil the cloth** like our grandparents did. Drying out the dish cloth helps kill many–but not all–pathogens. It takes three days of drying to kill all! Another strategy is to **use a fresh cloth** or sponge each day, putting the used one to dry until laundry day.

During the day, set the sponge on end to start drying and slow down culturing.

Don't eat food directly off the counter top or table top. You wouldn't slice a tomato or egg directly on the counter top. It would pick up something: some little particle of dust or dirt. Treat bread the same way. Always on a new clean surface, such as a plate. The counter and table top have on them whatever is in the kitchen dust and on the wipe cloth. Dust is always falling! And the sponge is always culturing. Don't eat the dust!

Keep the cutting board sterile like dishes. Wash it the same way and keep it in the cupboard.

Keep food containers closed. Milk or water glasses are picking up dust as soon as you set them out. Dust is everywhere. Every step on the carpet sends up a puff of dust. Vacuuming sends up a hurricane of dust and distributes bathroom dust to the kitchen and kitchen dust to the bedrooms. So if one person has brought in a new infection, the whole family is exposed to it in hours via the dust.

It is very helpful not to eat the new infectious pathogen. Breathing it is not so damaging. Our noses collect such pathogens and we blow them out again. Touching the infected person is not very damaging either; the pathogens can't get through our skins and since we wash hands before eating we are not at great risk of infection this way. But eating the pathogen is 100% effective in infecting us. The new pathogen is in the dust. The newly contaminated dust drops into your ready and waiting glasses on the table and the open foods. Of course, there is no defense if somebody should cough or sneeze at the table.

Teach children to cough and sneeze into a suitable collecting place like a tissue, not their hands. Pathogens live bountifully on hands. Hands not only provide moisture but often food from the last meal. Hands are second only to the dish cloth in contamination level. If you must cough or sneeze and a tissue is not within reach fast enough, use your clothing! That's what clothing is for—to protect you. Cough and sneeze into your own clothing; this protects the cougher and sneezer, as well as eve-

rybody else. A sleeve is handy for children. The inside of your T-shirt for T-shirt wearers. The inside of coat for suited persons. The inside of the neck line for dresses. Of course, paper is best, but in emergency use cloth. Never, never your hands unless you are free to immediately dash into the washroom and clean the contamination off your hands.

Teach children this old rearranged verse:

If you cough or sneeze or sniff
Grab a tissue, quick-quick-quick!
And if you're sitting at the table
Do it in your sleeve if able.

Better Housekeeping

Throw out as much of the wall to wall carpeting as you can bear to part with. It is injurious to everyone's health, even though it's comforting to bare feet and looks pretty.

Carpets clean our shoes. Modern shoes, with their deep treads, bring in huge amounts of outdoor filth which settles deep down into the carpets. In spite of vacuuming every week, the filth accumulates.

Vacuum the carpets when the children, the sick and elderly are out of the house. The dust raised and distributed throughout the house isn't just dirt, it's infectious dirt. It lands on tables and counters. These get wiped with a cloth or sponge and then applied to dishes. The dust in the kitchen falls on open food and into open containers.

Clean carpets with a “steam cleaner”. When you see how much filth is in the water and realize how much dirt you were living with, you might be willing to trade in the “beauty” of carpets for the cleaner living of smooth floors. Don't add chemicals (commercial cleaning solutions) to the steam cleaning machine; these chemicals leave a residue in the carpet which dries

and flies up into the air to add to the dust. Popular stain resistance treatments contain arsenic. Cobalt, which adds "lustre" to carpets, causes skin and heart disease after it has built up in your organs. Use borax instead of detergent. Use boric acid to leave a residue that kills roaches and fleas (but not ants). Add vinegar that leaves a residue to repel ants. Nothing controls fleas reliably, except getting rid of the carpets and cloth furniture (keep pets out of bedrooms). Removing all the borax is what brings luster to the carpet. Use citric acid in the rinse water for this purpose. Adding lemon peel to the rinse also adds luster and ant deterrence. Just drop the whole lemon in the tank so it can't block the hoses.

Fleas and other vermin in the carpet simply crawl below the wetness level when you wash the carpet. Spraying a grain alcohol solution with lemon peel in it (it needs to extract for a half hour) on the damp carpet will reach and kill a lot of these, together with the residual bacteria. The damp carpet lets it spread evenly and reach all the crevices.

We are trapped in our dwellings. Primitive peoples were mobile. This got them away from accumulations of filth and rubbish in their living space. Much living was done outdoors, the cleanest space of all.

Now, air conditioning has made indoor living more comfortable. But also has added new hazards. The strong currents of air blow the dust about continuously. Molds and bacteria that grow right on the air conditioning unit get blown about for all to inhale. Never, never use fiberglass as a filter or to insulate your air conditioner around the sides. It is a carcinogen. And the danger of freon escaping from a tiny leak is another major health hazard.

Forced air heating systems are undesirable, too. All dirt brought into the house by shoes gets circulated throughout the house by forced air systems of heating or cooling. Old fashioned radiant heat from radiators or a stove did not distribute the

dust so effectively. A return to linoleum floor covering for kitchen and bathroom and hardwood for other rooms would be a good step of progress for a health conscious society. Mopping, instead of the vacuum cleaner, keeps dirt to a minimum. Throw rugs at doors and bedside, easy to clean, would "catch the dirt" as was the original intention. Carpets were intended to help keep filth out of the air. These smaller rugs should be laundered weekly.

Furniture should be wood, cane, or plastic, with cushions to soften the impact. These can be washed weekly if the covers are removable. Modern cloth furniture with its foam interior is a repository of filth and fumes and a constant source of infectious dust.

This old fashioned setting is more progressive than our carpeted, modern homes.

Fig. 56 Smooth floors allow every bit of dust to be removed.

Dust your furniture with a damp paper towel. You are picking up and removing highly infectious filth (*Ascaris* and pinworm eggs, pet parasites, "dander" and house mites). Instead of

distributing these from room to room, throw the paper towel away after each room is done. Use plain water or vinegar water (50%), not a chemical combination which further pollutes the air.

Clean windows with vinegar water, too. Use a spray bottle.

Keep your dishes in cupboards. This keeps them free of dust. This principle is ancient. It is tempting to leave some of them out. If you must keep the juicer or dishes outside of cupboards, keep them covered or placed upside down so they don't catch dust. Even inside cupboards, store them upside down. When using the "good" dishes or glasses, that haven't been used in a while, wash them first.

Windows Open Or Closed?

In places like Chicago where you can smell the air as you approach the city, it is wiser to keep your windows shut. You can't breath the industrial "soup" all day and night and expect to stay healthy. Of course, it all enters the houses anyway. Central air conditioning and a plain carbon filter at the furnace location (see *Sources*) may be the best solution in spite of blowing dust around the house. Keep the vents to the bedrooms closed to reduce the air turbulence there but leave the cold air return open. Clean the vents in other rooms each week along with floors and carpets by pulling up the grating and reaching down the passage as far as possible.

If you believe the air is free of highway exhaust and industrial smoke open the windows every day. This will let some of the indoor toxins blow away. Asbestos, fiberglass, freon, radon and plain dust can be reduced to a minimum by keeping windows open. If you are ill, sit outdoors (on the porch) as much as you can. Escape to a suitable climate that makes this possible.

Just a few decades ago, many people had summer living quarters that were different from winter living quarters. Gone was all the accumulated infectious dust of half a year of habitation.

Fig. 57 Moving into the summer kitchen got you away from the accumulation of filth from winter!

Don't have a basement where you stockpile toxic items. Basements invite mold, mice and radon besides toxic things. Fumes travel upward where you live! Keep your toxic things in the attic. If there is no attic, store them in the utility room. Close off the ventilation between utility room and the rest of your house. If you have none of these, perhaps because you live in a senior citizen community or condominium, don't keep any toxic things stored anywhere. Don't save any leftover paints, solvents or cleaners. Buy such small quantities that you can afford to throw it all away when you are done with them.

Live on top of the earth as was intended by nature.

Never have a basement room “finished” for actual living space. Don't buy a house that has a “lower level” built into the

earth. This will be the most polluted and dangerous room in your house. If you are ill, move out of such a room. There is no way that it can be “cleaned up”. Move to the other end of the house and furthest away from an attached garage door.

What Kind Of Heat

The worst is coal. The best is none. Breathing coal fumes during the beginning of the industrial age may have brought the new lung diseases: tuberculosis (TB), and pneumonia. It may also have worsened alcohol addiction (beryllium toxicity). Choose electric heat if possible. Even though electricity is based on other fuel consumption, you don't have to breathe those fumes directly.

Wood stoves can be made safe by making sure the chimney works properly. Never use a lighter fluid. Don't fill the house with smoke when stoking.

Minimize your use of fossil fuels in every way you can.

Getting Rid of Mites

We do not tolerate external parasites like bedbugs, lice, ticks, leeches. Bedbugs were once a scourge amongst northern Europeans. I remember our parents spraying for them (kerosene) in the bedroom. This only “controlled” them. What eliminated them was a law against sale of used mattresses. Lice were originally “controlled” by frequent washing, louse combs, and ironing the seams of clothing. What eliminated them was the cutting of long hair as a societal practice. But what about **mites**? They live with us and other animals.

Mites are too tiny to see, tiny enough to ride on a dust particle as if it were a magic carpet. They resemble insects. Chiggers are really mites. Mange in animals is a mite infestation. Dust mites live on our dander (scales of dead skin).

Fig. 58 Mite.

Get rid of their breeding places: beds, cloth covered chairs and soft sofas. Humans leave enough dander behind in these places to support these ultra small insects. Cover mattresses with plastic covers. Use throws on easy chairs and sofas and wash them often. Never allow a pet into the bedroom or the dust will have tapeworm eggs as well as mites. Throw out rugs that have been pet-beds. Spray the air with a mist of 50% grain alcohol before vacuuming. If you have an illness wear a mask to vacuum. Deep, soft, wall to wall carpets compromise an ancient concept: everything should be washable and cleanable, without throwing the dirt into the air for humans to inhale. Vacuuming a carpet blasts mites and tape eggs into the air. Never shake bedding or rugs where the dust will blow back into the house behind you.

Mites don't bite us but we inhale them as they float in the ever present dust in our homes. The mucus in our lungs traps them and in a few days they die, only to release a drove of *Adenoviruses* (common cold virus) in us.

Four Clean-ups

Chronic health problems are not due to exposures of the past. They are ongoing. Your body is constantly fighting to remove pollutants. In order to stay sick, you must be constantly resupplied! These four clean-ups–dental, diet, body, home–are aimed at removing parasites and pollutants at their source. Only then can your body heal.

Dental Clean-up

(This section on dentistry was contributed by Frank Jerome, DDS)

Dr. Jerome: The philosophy of dental treatment taught in America is that teeth are to be saved by whatever means available, using the strongest, most long lasting materials. Long-term toxic effects are of little concern. The attitude of the majority of dentists is: whatever the American Dental Association (ADA) says is OK, they will do.

A more reasonable philosophy is that there is no tooth worth saving if it damages your immune system. Use this as your guideline.

The reason dentists do not see toxic results is that they do not look or ask. If a patient has three mercury amalgam fillings placed in the mouth and a week later has a kidney problem, will she call the dentist—or the doctor? Will they ever tell the dentist about the kidney problem or tell the doctor about the three fillings? A connection will never be made.

It is common for patients who have had their metal fillings removed to have various symptoms go away but, again, they do not tell the dentist. The patient has to be asked! Once the patient begins to feel well they take it for granted, and don't make the

connection, either. If everybody's results were instantaneous, there would be no controversy.

Find an alternative dentist. They have been leading the movement to ban mercury from dental supplies. Not only mercury, but all metal needs to be banned. If your dentist will not follow the necessary procedures, then you must find one that will. The questions to ask when you phone a new dental office are:

1. Do you place mercury fillings? (The correct answer is NO. If they do, they probably don't have enough experience in the use of non-metal composites.)
2. Do you do root canals? (The correct answer is NO. If they do, they do not understand good alternative dentistry.)
3. Do you remove amalgam tattoos? (The correct answer is YES. Tattoos are pieces of mercury left in the gum tissue.)
4. Do you treat cavitations? (The correct answer is YES. By cleaning them.) The complete name of *cavitations* is *alveolar cavitational osteopathosis*. They are holes (cavities) left in the jawbone by an incompletely extracted tooth. A properly cleaned socket which is left after an extraction will heal and fill with bone. Dentists routinely do NOT clean the socket of tissue remnants or infected bone. A dry socket (really an infected socket) is a common result. These sockets never fully heal. Thirty years after an extraction, a cavitation will still be there. It is a form of *osteomyelitis*, which means bone infection.

Ninety percent or more of dental offices will not be able to answer ANY of the above questions correctly. If you allow the work to be done by a dentist who does not understand the importance of the above list, you could end up with new problems. Find the right dentist first even if you must travel hundreds of miles. There are 6,000 to 10,000 dentists who should be able to

help. Some can do part of the work and refer you to a specialist for the rest. Five hundred to one thousand of these dentists can do it all.

Normal treatment cost is about $1,000 for replacement of 6 to 8 metal fillings including the examination and X-rays. For people with a metal filling in every tooth, or for the extraction of all teeth (plus dentures), it may be up to $3,000 (or more in some places).

Remember, the simpler the treatment, the better. If the dentist says that he or she can change your metal fillings to plastic but it would be better to crown them, say "NO!"

Guidelines For A Healthy Mouth

If you have	What to do
Metal fillings	change to plastic fillings
Inlays and onlays	change to plastic fillings
Crowns (all types)	change to plastic crowns
Bridges	change to plastic crowns, partials
Metal partials	change to plastic partials(Flexite™)
Pink dentures	change to clear plastic
Porcelain denture teeth	change to plastic denture teeth
Badly damaged teeth	become extractions
Root canals	become extractions
Braces and implants	avoid
Cavitations	need to be surgically cleaned
Temporary crowns	use plastic
Temporary fillings	use Duralon™

Fig. 59 Dental replacements.

The guidelines can be summarized as:

1. Remove all metal from the mouth.
2. Remove all infected teeth and clean cavitations.

Dr. Clark: *Removing all metal means removing all root canals, metal fillings and crowns. Take out all bridge work or partials made of metal and never put them back in. But you may feel quite attached to the gold, so ask the dentist to give you everything she or he removes. Look at the underside. You will be glad you switched.*

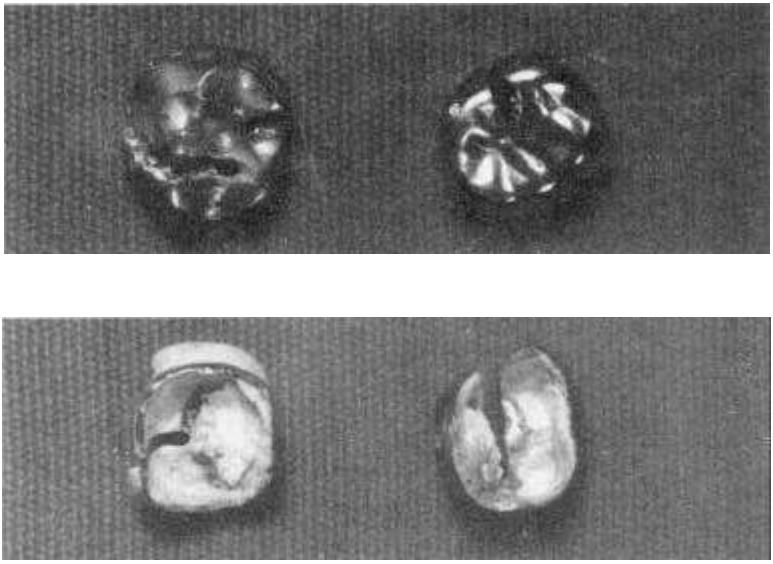

The top surfaces of tooth fillings are kept glossy by brushing (you swallow some of what is removed). Underneath is tarnish and foulness. Ask to see your crowns when they are removed.

Fig. 60 Tops and bottoms of some metal crowns.

The stench of the infection under some teeth may be overwhelming as they are pulled. Bad breath in the morning is due to such hidden tooth infections, not a deficiency of mouthwash!

All metal must come out, no matter how glossy it looks on the surface. Metal does not belong in your body. It is an unnatural chemical. Do this as soon as you have found a dentist able to do it. Find a dentist with experience and knowledge about this subject. It is more than replacing acknowledged culprits like mercury-amalgam fillings. This is metal-free dentistry. Only metal-free plastic should be put back in your mouth.

Dr. Jerome: If your dentist tells you that mercury and other metals will not cause any problems, you will not be able to change his or her mind. Seek treatment elsewhere!

Your dentist should do a complete X-ray examination of your mouth. Ask for the *panoramic* X-ray rather than the usual series of 14 to 16 small X-rays (called full mouth series). The panoramic X-ray shows the whole mouth including the jaws and the sinuses. This lets the dentist see impacted teeth, root fragments, bits of mercury buried in the bone and deep infections. Cavitations are visible in a panoramic X-ray that may not be seen in a full mouth series.

The cost of removing metals should be viewed in the proper light. It took years or decades to get into your present condition. When you do a lot of dental repair in a short time, it can seem to be costly. Unfortunately, many people are in a tight financial position because of the cost of years of ineffective treatment, trying to get well.

Your dentist may recommend crowning teeth to "protect" or strengthen them. Unfortunately, the very concept of crowning teeth is flawed. First, the enamel is removed from a tooth to prepare for the crown. This is permanent and serious damage! Many teeth, up to 20%, may die after being crowned and will need to be extracted. For this reason, you should only get REPLACEMENT crowns and NO NEW crowns. Your metal

crowns can be changed to plastic. (Remember, no metal must be left under the crown.)

If you have many crowns, you should have them all removed as quickly as possible. But you should not spend more than two hours in the dentist's chair at any one time. That is too much stress for your body.

Dr. Clark: *Don 't accept intravenous (IV) treatments during amalgam removal. Both IV bags and the supplements used in them are polluted with propyl alcohol, benzene, and wood alcohol.*

Dr. Jerome: It is quite all right to have temporary crowns placed on all teeth that need them in the first visit. You may then go back and complete treatment over the next 6 to 12 months. It is common to find a crowned tooth to be very weak and not worth replacing the crown, particularly if you are already having a partial made and could include this tooth in it.

Dr. Clark: *We are accustomed to thinking that plastic is metal-free. This is wrong. The original dental plastic, methyl methacrylate was metal-free. But modern plastic contains metal. The metal is ground up very finely and added to the plastic in order to make it harder, give it sheen, color, etc.*

Dr. Jerome: Dentists are not commonly given information on these metals used in plastics. The information that comes with dental supplies does not list them either. Most dentists never look at a dental materials book after they graduate. The ADA, however, has a library full of such information.[21]

Dr. Clark: *There are many lanthanide (Rare Earth) metals used in dental plastic. Their effects on the body from dentalware*

[21] Call the American Dental Association at (800) 621-8099 (Illinois (800) 572-8309, Alaska or Hawaii (800) 621-3291). Members can ask for the Bureau of Library Services, non-members ask for Public Information.

have NOT been studied. Yet their cancer-promoting ability is known in many cases.[22] *Only metal-free plastic is safe.*

Dr. Jerome: These are the acceptable plastics; they can be procured at any dental lab.

- Plastic for dentures: Methyl Methacrylate. Available in clear and pink. Do not use pink.[23]
- Plastic for partial dentures: Flexite™ Available in clear and pink. Do not use pink.
- Plastic for fillings: Composite Materials. This is the material that has been used in front teeth for 30 years. It has been used in back teeth for 10 years. There are many brands and there are new ones being marketed constantly. The new ones are very much superior to those used 10 years ago and they will continue to improve. They do, however, contain enough barium or zirconium to make them visible on X-rays. There are no alternatives available without these metals.

Dr. Clark: *Composites with barium are not good, but I haven't seen enough barium toxicity from fillings at this time to merit advising extraction instead. Hopefully, a barium-free variety will become available soon to remove this health risk.*

Dr. Jerome: Many people (and dentists too) believe that porcelain is a good substitute for plastic. Porcelain is aluminum oxide with other metals added to get different colors (shades). The metal DOES come out of the porcelain! It has many technical drawbacks as well. Porcelain is not recommended. Some-

[22] Thulium and ytterbium have been studied for their tumor-seeking ability. See page 321 in the book *METAL IONS In BIOLOGICAL SYSTEMS, Vol. 10, Carcinogenicity and Metal Ions*. Editor Helmut Sigel 1980.

[23] The pink color is from mercury or cadmium which is added to the plastic.

times the white composite fillings are called porcelain fillings but they are not. They also require more tooth structure to be removed.

If you have a large bridge, it cannot be replaced with a plastic bridge because it isn't strong enough. A large bridge must be replaced with a removable partial (Flexite™).

The methods used to remove metals and infections are technical and complicated. See dental information in *Sources*.

Dr. Clark: *I'd like to thank Dr. Jerome for his contributions to this section, and his pioneering work in metal-free dentistry. I hope more dentists acquire his techniques.*

Horrors Of Metal Dentistry

Why are highly toxic metals put in materials for our mouths? Because not everyone agrees on what is toxic at what level. Just decades ago lead was commonly found in paint, and until recently in gasoline. Lead was not less toxic then, we were just less informed! The government sets standards of toxicity, but those "standards" change as more research is done (and more people speak out). You can do better than the government by dropping your standard for toxic metals to zero! Simply remove them.

The debate still rages over mercury amalgam fillings. No one disputes the extreme toxicity of mercury compounds and mercury vapor. The ADA feels that mercury amalgam fillings are safe because they do not vaporize or form toxic compounds to a significant degree. Opponents cite scientific studies that implicate mercury amalgams as disease causing. Many dentists advocate mercury amalgam fillings simply because they are accepted by the ADA, which they believe protects them from malpractice litigation. Why risk your health and life on their opinions? Remember everything corrodes and everything seeps, so amalgams must too.

Cadmium is used to make the pink color in dentures! Cadmium is five times as toxic as lead, and is strongly linked to high blood pressure.

Occasionally, thallium and germanium are found together in mercury amalgam tooth fillings. Thallium causes leg pain, leg weakness, and paraplegia. If you are in a wheelchair without a very reliable diagnosis, have all the metal removed from your mouth. Ask the dentist to give you the grindings. Try to have them analyzed for thallium using the most sensitive methods available, possibly at a research institute or university.

I was astonished to find thallium in mercury amalgams! It couldn't be put there intentionally, look how toxic it is:

TEJ500 ***HR: 3***

THALLIUM COMPOUNDS

Thallium and its compounds are on the Community Right To Know List.

THR: Extremely toxic. The lethal dose for a man by ingestion is 0.5-1.0 gram. Effects are cumulative and with continuous exposure toxicity occurs at much lower levels. Major effects are on the nervous system, skin and cardiovascular tract. The peripheral nervous system can be severely affected with dying-back of the longest sensory and motor fibers. Reproductive organs and the fetus are highly susceptible. Acute poisoning has followed the ingestion of toxic quantities of a thallium-bearing depilatory and accidental or suicidal ingestion of rat poison. Acute poisoning results in swelling of the feet and legs, arthralgia, vomiting, insomnia, hyperesthesia and paresthesia [numbness] of the hands and feet, mental confusion, polyneuritis with severe pains in the legs and loins, partial paralysis of the legs with reaction of degeneration, angina-like pains, nephritis, wasting and weakness, and lymphocytosis and eosinophilia. About the 18th day, complete loss of the hair on the body and head may occur. Fatal poisoning has been known to occur. Recovery requires months and may be incomplete. Industrial poisoning is reported to have caused discoloration of the hair (which later falls out), joint pain, loss of appetite, fatigue, severe pain in the calves of the legs, albuminuria, eosinophilia, lymphocytosis and optic neuritis followed by

> atrophy. Cases of industrial poisoning are rare, however. Thallium is an experimental teratogen [used to induce birth defects for study]. When heated to decomposition they [sic] emit highly toxic fumes of Tl [thallium]. See also THALLIUM and specific compounds.[24]

Fig. 61 Thallium excerpt.

Thallium pollution frightens me more than lead, cadmium and mercury combined, because it is completely unsuspected. Its last major use, rat poison, was banned in the 1970s. Every wheelchair patient I tested was positive for thallium! One current use for thallium is in Arctic/Antarctic thermostats. When added to mercury the mercury will stay liquid at lower temperatures. Are mercury suppliers then providing the dental industry with tainted amalgam?

The cancer causing or carcinogenic action of metals has been studied for a long time, although it doesn't get attention by our regulatory agencies. A scientific book on this subject was published in 1980.[25] One table from this book is shown on page 431. We can see that chromium and nickel compounds are the most carcinogenic metals. Nickel is used in gold crowns, braces, and children's crowns!

Note that the form of the metal is very important. For instance chromium is an essential element of *glucose tolerance*

[24] *Dangerous Properties of Industrial Materials*, 7th ed. by N. Irving Sax and Richard J. Lewis Sr., Van NOSTRAND, Reinhold N.Y. 1989.

[25] The title is *Carcinogenicity and Metal Ions*. It is volume 10 of a series called *Metal Ions in Biological Systems*, edited by Helmut Sigel. A university chemistry library should have this book. It has a fascinating chapter on the leukemias by two scientists from the Academy of Sciences of the USSR, E. L. Andronikashvili and L. Mosulishvili. Their brilliant work and discussion was largely responsible for my pursuit of the whole subject of cancer.

factor, but most of its other compounds are extremely toxic. In general, xenobiotic compounds (foreign) are to be avoided! Metal doesn't belong in our foods or in our bodies.

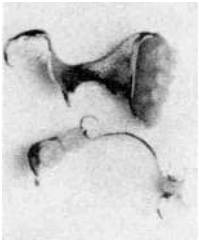

Fig. 62 More dental metal.

Dental Rewards

After your mouth is metal and infection-free, notice whether your sinus condition, ear-ringing, enlarged neck glands, headache, enlarged spleen, bloated condition, knee pain, foot pain, hip pain, dizziness, aching bones and joints improve.

Keep a small notebook to write down these improvements. It will show you which symptoms came originally from your teeth. Symptoms often come back! So go back to your dentist, to search for a hidden infection under one or more of your teeth, or where your teeth once were! That infection can be the cause of tinnitus, TMJ, arthritis, neck pain, loss of balance, and heart attacks!

Dentures can be beautiful. Of course, plastic isn't natural, but it is the best compromise that can be made to restore your mouth. At least it isn't positively charged like metals; it can't set up an electric current nor a magnetic field in your mouth, all of which may be harmful.

Do not be swayed by arguments that plastic is not as strong as metal. You see dentures everywhere and they seem strong enough to eat with. You will be told that "noble" metals like gold and platinum

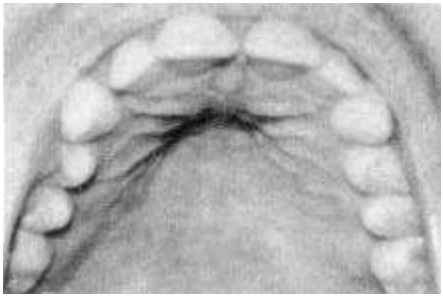

Fig. 63 Beautiful plastic mouth.

and silver are OK, that they are "inert" and do not corrode or seep. Nothing could be more untrue. You may be keeping them glossy by the constant polishing action of your toothpaste. But if you look at the underside, the view is frightful. **Everything tarnishes and everything seeps.** You wouldn't expect even a gold or silver coin that was dropped in a fountain 50 years ago to be intact. As metal corrodes your body absorbs it!

Fig. 64 Ugly metal in mouth.

In breast cancer, especially, you find that metals from dentalware have dissolved and accumulated in the breast. They will leave the breast if you clear them out of your mouth (and diet, body, home). **The cysts shrink and are simply gone.** No need to do surgery!

Diet Clean-up

Breakfast

Cook your cereal from scratch. Don't eat cold cereal; it has numerous solvents and molds. Buy hot cereals that say "no salt added," like cream of wheat, steel cut oats or old fashioned oats,[26] millet, corn meal, cream of rice, or Wheatena. Cook it

[26] Rolled oats have 235 mcg nickel per serving of 4 ounces, picked up from the rollers, according to *Food Values* 14th ed. by Pennington and Church, 1985. I have only found nickel in the "one-minute" or "instant" variety of oats, however.

with milk to add nutritive value. Add your own (non-aluminum) salt and a pinch of vitamin C before cooking. Make granola from a recipe (see *Recipes*). Use honey, or brown sugar. Add raisins that were soaked for 5 minutes in vitamin C water. Use whipping cream or butter (both boiled) if you need to gain weight. Isn't this a delicious way to start your day! Add cinnamon to flavor, or frozen fruit and honey.

Fig. 65 Unpolluted breakfast cereals.

Or start your day with fried potatoes, an egg, and glass of milk. Don't worry about cholesterol since you will be doing liver cleanses anyway. (We have been told that eggs carry *Salmonella* bacteria. I found *Salmonellas* only on the outside shell and the egg carton—never inside! Could the researchers have accidentally transferred the bacteria from the shell to the inside while they were testing?)

The milk should be 2% or more butterfat because the calcium in milk cannot be absorbed without at least this much fat. Eat homemade yogurt and add honey or homemade preserves yourself. You need 3 cups of a milk product each day. Homemade buttermilk is fine. If you don't tolerate milk, and get diarrhea from it, try a milk digestant tablet to go with it. Start with only ¼ cup at a time. Do not choose chocolate milk. There is no substitute for milk; calcium tablets are not satisfactory. Vegeta-

ble matter, although high in calcium, does not give you *available* calcium either, unless you buy a juicer and make vegetable juice out of it. Eating fish can give you a lot of calcium, but it is in the tiny bones hidden in the fish. Don't try to remove them. Canned salmon has a lot of calcium; tuna does not. On a day that you eat fish, you would not need milk. Goat milk is probably better than cows' milk, but more difficult to get used to.

Lunch

Cook your food from scratch. Don't start with cans or packages or frozen items to make some recipe. In fact, don't bother with any fancy recipes. Just cook two or three vegetables for lunch and eat them with butter and salt or homemade sauces. Bread and milk rounds it out, plus fruit (not canned or frozen). Soup is a nice change. Cook it with all the vegetables you can find. Don't start with a can or packet or cube. Use a bit of onion and genuine herbs to give it zest. Thyme and fenugreek, together, make a flavorful combination you can purchase in capsules. Just pull apart and season.

If all this is too much work, make fresh vegetable juice once a week and freeze enough so that you can have a daily nutritious meal just by pouring a glass of it, together with bread and yogurt or milk.

Never diet during illness

This is a rule based on common sense. A weight-loss diet must wait at least two years.

Bake your own bread! I found aflatoxin in commercial bread after just four days in my bread box, but none in homemade bread even after two weeks! Aflatoxin is a most potent

carcinogen and immunosuppressant. Aflatoxin is the toxin in your diet that keeps you from clearing propyl alcohol from your body (see 382)! Aflatoxin is a substance made by mold; bread starts to mold on the grocery store shelf. Don't buy plastic-wrapped bread. Don't ever salvage moldy food, whether it is fruit, breads or leftovers in the refrigerator. Throw them out. Buy a bread maker. It can do everything, including baking the bread. Use unbleached (unbrominated) flour and add ½ tsp. vitamin C powder per loaf to help retard mold further (it also makes the bread rise higher).

Supper

Cook your supper from scratch. Emphasize fish for animal food, not beef, pork, turkey or chicken. Don't buy bread crumbs, use your own. Don't buy batter, make your own. Use genuine eggs, not substitutes. Wash your hands after handling raw meat or eggs.

Make your own salad and salad dressing out of olive oil, fresh lemon juice or white distilled vinegar (apple cider vinegar has aflatoxins), honey, salt and herbs to flavor. If your digestion isn't strong enough for raw vegetables or fruit, make juice. Get a sturdy juicer and make your juice about half carrot juice and half from vegetables like celery, squash, lettuce, and broccoli. Make your own tomato sauce with pure herb seasoning, not from ajar or can (home canned foods are fine, of course, as long as they are not made in a big aluminum pot with aluminum-containing salt).

Cook real potatoes, not instant varieties. Peel them to get rid of Kojic acid (mycotoxin) and scopolamine (the green part). Make mashed potatoes from scratch, with milk, not box potatoes, nor chips nor French fries. Chips and fries were made in chemical grease called “hydrogenated.” There is a large amount

of nickel in hydrogenated fats.[27] Fry your potatoes in butter, lard or olive oil. Find butter that is not wrapped in foil and is not salted. Salt your own butter, using aluminum-free salt.[28] Don't wrap potatoes in foil to bake, coat with butter or olive oil. Don't eat the peels.

Eat no meat that hasn't been cooked as thoroughly as if it were pork.

Other animals are as parasitized as we, full of flukes and worms and *Schistosomes* in every imaginable stage, and if the blood carries these, would we not be eating live parasites if we eat animals in the raw state? We have been taught to cook thoroughly any pork, fish or seafood. Now we must cook thoroughly any beef, chicken or turkey. It must be at cooking temperature (212°F or 100°C) for 20 minutes. Freezing is not adequate. Canned meats are safe from living parasites, but are not recommended due to added chemicals.

Beverages

Drink 6 kinds of beverages:

- milk
- water
- fruit juices
- vegetable juices
- herb teas
- homemade (see *Recipes*)

[27] 114 mcg/100 g. Taken from *Food Values* 14th ed. by Pennington and Church, 1985.

[28] Salt has aluminum in it to keep it from caking. Buy salt that has magnesium carbonate as its anti-caking agent. Sea salt must be baked for 5 minutes at 400°F to destroy molds. Or buy chemically pure salt (see *Sources*).

This means getting off caffeine. And if you are already fatigued, this means you might be even more fatigued for a short time. You might have headaches from withdrawal, too. But they will only last 10 days. Mark your calendar and count off the days. Take headache medicine, if necessary, but make sure it does not contain caffeine. For energy, to replace caffeine, take one arginine (500 mg, see *Sources*) upon rising in the morning and before lunch. Soon you won't need it.

Cutting down on coffee, decaf, soda pop and powdered drinks won't do. You must be completely off. They contain very toxic solvents due to careless, unregulated production methods. Much is imported and can't be sufficiently regulated.

Even though grain (drinking) alcohol is the recommended substitute for propyl alcohol, that doesn't mean you may safely drink it. It is inadvisable to drink any form of alcohol at least until you are fully recovered.

1. Milk: 2% or higher, drink three 8 oz. glasses a day. Alternate brands. Buttermilk will do. Homemade yogurt is fine. Goat milk is also fine. Start with ¼ cup and increase gradually, if you are not used to it. If you do not drink milk because it gives you more mucous, try to drink milk anyway. If you have other reactions, like diarrhea, try milk digestant tablets (available at health food stores). Milk is too valuable to avoid: there are many unwanted chemicals in most brands of milk, but it is solvent-free, mold-free and very nutritious. The only exception should be for serious symptoms, like swelling, colitis, flu, or chronic diarrhea.

But all milk, whether goat or cow, is contaminated with *Salmonella* and *Shigella* bacteria as well as fluke parasite stages. Cattle are immunized against *Salmonella* but it does not prevent its persistence in the bowel. All these are very harmful. Pasteurization does not kill all of them. Only heating to a rolling boil makes milk safe. To do this in the easiest way, pour 1 or 2 quarts milk into an enamel double boiler or microwavable glass

jar. Stay in the kitchen while the heat is on. When the bubbles have risen to indicate boiling, turn off the heat. You may throw away the "skin". Pour into glass jar and refrigerate. Another easy way is to use a pressure cooker that holds several pint jars of milk. All dairy products that have only been pasteurized are still contaminated. Ultrapasteurization does not improve matters. Dairy products that cannot be sterilized should not be consumed. It may be possible to find sterilized milk in paper containers on the store shelf—not in the refrigerator; if it wasn't sterile it would go foul in a day! Canned milk has solvent pollution. Powdered milk has both solvent and bacterial pollution.

2. Water: 2 pints. Drink one pint upon rising in the morning, the other pint in the afternoon sometime. The cold water faucet may be bringing you cadmium, copper or lead, but it is safer than purchased water, which inevitably has solvents in it. Let it run before using it. Filters are rather useless because water pollution comes in surges. A single surge of PCB contaminates your filter. All the water you use after this surge is now polluted, so you will be getting it chronically, whereas the unfiltered water cleans up again after the surge passes. Until you can test your own water for solvents, PCBs and metals, no expensive filter is worth the investment. An inexpensive pure carbon filter that is replaced every month may improve your tap water. Inflexible plastic pitchers fitted with a carbon filter pack are available (see *Sources*). Never buy filters with silver or other chemicals, even if they are just added to the carbon. Keep the filter sterile by soaking in diluted grain alcohol weekly.

3. Fruit juice: fresh squeezed only. Some stores make it while you wait. If they freeze some of it, you could purchase the frozen containers. Bottled fruit juices have traces of numerous solvents, as do the frozen concentrates, as do the refrigerated ones, don't buy them. You have to see it being made, but watch carefully: I recently went to a juice bar where they made everything fresh, before your very eyes. And I saw them take the fruit

right from the refrigerator and spray it with a special wash "to get rid of any pesticides," then put a special detergent on it to clean off the wash! So instead of getting traces of pesticide, I got traces of propyl alcohol![29] Another grocery store had a machine that squeezed the oranges while you watched. But if you did not watch them filling the jugs, you missed seeing them add a tablespoon of concentrate, from a bottle out of sight, to give it better flavor. It still qualifies as "Fresh squeezed 100% orange juice," but thanks to that concentrate it now has toluene and xylene in it! Best of all, buy a juicer, select completely unbruised fruit, wash with plain water, and make your own juice (enough for a week—freeze it in half pint plastic bottles). For stronger flavor, leave some of the peel in the juice.

4. Vegetable juice: fresh or frozen only. If you or a friend would be willing to make fresh juice, this would be much better than purchased juice. Start with carrot juice. Peel carrots (don't scrape them, it's too easy to miss small dirt spots) and remove all blemishes carefully, then rinse. Drink ½glass a day. After you are accustomed to this, add other vegetables and greens to the juice to make up half of it. Use celery, lettuce, cabbage, cucumber, beet, squash, tomato, everything raw that you normally have in your refrigerator. Then drink one glass a day.

5. Herb tea: fresh or bulk packaged. Tea bag varieties are moldy. Buy a non-metal (bamboo is common) tea strainer. Sweeten with honey or brown sugar with vitamin C added.

6. Homemade beverage. If you will miss your coffee or decaf, try just plain hot water with boiled whipping cream. Sweeten with honey. Please see *Recipes* for many more suggestions.

[29] Yes, I took a sample of the wash to test.

Horrors In Commercial Beverages

Commercial beverages are especially toxic due to traces of solvents left over from the manufacturing process. There are solvents in decaffeinated beverages, herb tea blends (not single herb teas), carbonated drinks, beverages with Nutrasweet™, flavored coffee, diet and health mixes, and fruit juices, even when the label states "not from concentrate" or "fresh from the orchard," or "100% pure."

It is allowable to use solvents to clean machinery used in bottling (please look again at page 347)! It is also allowable to use solvents to make spice oleoresins, which are used as flavoring.

> **21 CFR 173.240 (4-1-94 Edition) Isopropyl Alcohol.**
> Isopropyl alcohol may be present in the following foods under the conditions specified:
> (a) In spice oleoresins as a residue from the extraction of spice, at a level not to exceed 50 parts per million.
> (b) In lemon oil as a residue in production of the oil, at a level not to exceed 6 parts per million.
> (c) [Discusses its use in hops extract.]

Here is a summary of other solvents mentioned:

Solvent	Allowable residue in spice oleoresins	Paragraph in 21 CFR
Acetone	30 PPM	173.210
Ethylene dichloride	30 PPM	173.230
Methyl alcohol	50 PPM	173.250
Methylene chloride	30 PPM	173.255
Hexane	25 PPM	173.270
Trichloroethylene	30 PPM	173.290

Fig. 66 Lawful uses of solvents in food.

I have found all these solvents and others in commercial beverages! Some of the solvents I have found are just too toxic to be believed! Yet you can build the test apparatus yourself

(page 457), buy foods at your grocery store, and tabulate your own results. I hope you do, and I hope you find that the food in your area is cleaner than mine! Remember that the Syncrometer can only determine the presence or absence of something, not the concentration. There may only be a few parts per billion, but a sick person trying to get well cannot afford any solvent intake. For that matter, none of us should tolerate any of these:

- **Acetone** in carbonated drinks
- **Benzene** in store-bought drinking water (including distilled), store-bought fruit juice (including health varieties)
- **Carbon tetrachloride** in store-bought drinking water
- **Decane** in health foods and beverages
- **Hexanes** in decafs
- **Hexanedione** in flavored foods
- **Isophorone** in flavored foods
- **Methyl butyl ketone** and **Methyl ethyl ketone** in flavored foods
- **Methylene chloride** in fruit juice
- **Pentane** in decafs
- **Propyl alcohol** in bottled water, commercial fruit juices, commercial beverages.
- **Toluene** and **xylene** in carbonated drinks
- **Trichloroethane** (TCE), **TC Ethylene** in flavored foods
- **Wood alcohol** (methanol) in carbonated drinks, diet drinks, herb tea blends, store-bought water, infant formula

If you allowed a tiny drop of kerosene or carpet cleaning fluid to get into your pet's food every day, wouldn't you expect your pet to get sick? Why would you not expect to be sick with these solvents in your daily food? I imagine these solvents are just tiny amounts, introduced by sterilizing equipment, the manufacturing process, and adding flavor or color. Flavors and colors for food must be extracted somehow from the leaves or

bark or beans from which they come. But until safe methods are invented, such food should be considered unsafe for human consumption (or pets or livestock!).

Fig. 67 Some unsafe beverages.

Food Preparation

Cook your food in glass, enamel, ceramic or microwavable pots and pans. Throw away all metal ware, foil wrap, and metal-capped salt shakers since you will never use them again. If you don't plan to fry much (only once a week), you might keep the Teflon™ or Silverstone™ coated fry-pan, otherwise get an enamel coated metal pan. Stir and serve food with wood or plastic, not metal utensils. If you have recurring urinary tract infections, you should reduce your metal contact even further; eat with plastic cutlery. Sturdy decorative plastic ware can be found in hardware and camping stores. Don't drink out of styrofoam cups (styrene is toxic). Don't eat toast (many toasters spit tungsten all over your bread and make benzopyrenes besides). Don't buy things made with baking powder (it has aluminum) or

baked in aluminum pans. Choose goods made with baking soda and sold in paper or microwavable pans. Don't run your drinking water through the freezer or fountain or refrigerator. Don't heat your water in a coffee maker or tea kettle. Don't use a plastic thermos jug (the plastic liner has lanthanides) the inside must be glass. Don't drink from a personal water bottle (it begins to breed bacteria) unless you sterilize it daily.

Why are we still using stainless steel cookware when it contains 18% chromium and 8% nickel? Because it is rustproof and shiny and we can't see any deterioration. **But all metal seeps!** Throw those metal pots away. Get your essential minerals from foods, not cookware.

Never, never drink or cook with the water from your hot water faucet. If you have an electric hot water heater the heating element releases metal. Even if you have a gas hot water heater, the heated water leaches metals or glues from your pipes. If your kitchen tap is the single lever type, make sure it is fully on cold for cooking. Teach children this rule.

Food Guidelines

It is impossible to remember everything about every food, but in general do not buy foods that are highly processed. Here are a few foods; see if you can guess whether they should be in your diet or not.

breads	Yes, but only from a bakery, and never wrapped in plastic.
toast	No. It has benzopyrene and tungsten. Yes, if made on a cookie sheet or in a frying pan.
cheese	Yes, if used in baked dishes.
chicken	Only if cooked for 20 minutes at boiling point, as in soup, or canned (never prepare raw chicken yourself).
wine with dinner	No.

peanut butter	Yes if you grind it yourself and add ¼ tsp. vitamin C powder as you grind.
cottage cheese	No, it can't be sterilized easily.
desserts	Yes, but again, only if flavored with safe extracts.
rice	Yes, if vitamin C is added before cooking. Use white only, brown is too moldy.
pasta	Yes, with homemade sauce and vitamin C.
Jell-O™	No, it has artificial flavor and color.
egg dishes	Yes, but not “imitation”, cholesterol-free or cholesterol-reduced varieties.
fish, seafood	Yes!
soy foods (tofu)	No. It's the extensive processing that taints it.
soup	Yes, if seasoned only with herbs (no bouillon cube).
sugar	Yes, turbinado or brown if treated with vitamin C.
herb tea	Yes, if not in a bag and not in a mixture of herbs.
cheesecake	Yes.

Fig. 68 Some good foods.

Choose brands with the shortest list of ingredients. Alternate brands every time you shop.

Fig. 69 All breads I tested had mold if they were in plastic.

Dining Out

Restaurants (excluding fast food) are generally quite safe to eat at. Here are some do's and don'ts;

Do carry your own aluminum-free salt and vitamin C powder with you.

Do ask for plastic cutlery.

Do drink the water if from the tap.

Do ask for boiled, not just steamed, milk.

Don't eat or drink from styrofoam. If getting food "to go," get it in clear plastic containers, or ask them to line the styrofoam container with paper or plastic wrap, and line the styrofoam cup with a plastic baggy.

Don't use their ketchup and condiments (they have been standing out too long).

Here is a list of things that are generally safe to order:

pancakes, French toast, waffles	Don't use their imitation syrup (has benzoate), use honey instead.
eggs	Any style except soft boiled and scrambled. The white should be solid.
hash browns	If lightly fried, not deep fried.
soup	Only if nothing else is available. (It probably came in a can and was cooked in an aluminum pot and is full of aluminized salt.)
vegetarian sandwiches	But no soy products (too processed).
baked or boiled potatoes	Use only cheese sauce, bring your own salt, don't eat the skin.
cooked vegetables	Broccoli, Brussels sprouts, beets, corn, squash, and so forth.
vegetable salads	Don't eat the croutons, bacon bits, and anything that doesn't look fresh.
vegetarian dishes	But no soy ingredients and or sauces. Fresh ketchup OK.
bread and biscuits	White only, not toasted, not "cholesterol-free" varieties.
fish and seafood	Anything but deep fried (the oil may have benzene) is fine: baked, steamed, fish cakes, seafood cocktails, etc.
Mexican food	Any of the numerous baked dishes.
Chinese food	Except dishes with tofu or MSG.
fruit cup	With honey and cinnamon.
fruit pies, cobblers	But not with ice cream (every flavor has benzene).
lemon or lime meringue pie	Indulge yourself.

Fig. 70 Good restaurant foods.

As you see your symptoms disappear, one after another, you will feel the magic of healing. Many sick persons have 50 or more symptoms to start out! They could fill two sheets of paper,

one symptom to each line. It can be quite shocking to see a list of all your symptoms.

Sometimes a new symptom appears as fast as an old one disappears. The coincidence makes it tempting to believe that one symptom turns into a different one. But it is not so. If a new symptom appears, it is because another pathogen has become activated due to a new toxin. Try to identify the new item. Stop using any new food, supplement, or body product, even if it is a health variety, and see if it goes away.

Body Clean-up

We are living in a very fortunate time. We are not expected to all look alike! The 60's brought us this wonderful freedom. Freedom to dress in a variety of styles, use make-up or no make-up, jewelry or no jewelry, any kind of hair style, any kind of shoes.

You will need to go off every cosmetic and body product that you are now using. Not a single one can be continued. They are full of titanium, zirconium, benzalkonium, bismuth, antimony[30], barium[31], strontium[32], aluminum, tin, chromium, not to mention pollution solvents such as benzene and PCBs.

Do not use any commercial salves, ointments, lotions, colognes, perfumes, massage oils, deodorant, mouthwash, toothpaste, even when touted as "herbal" and health-food-type. See *Recipes* for homemade substitutes.

[30] Breast cancer cases show titanium, zirconium, benzalkonium, bismuth and antimony accumulation in the breast.

[31] Barium is described in the *Merck Index* as "Caution: All water or acid soluble barium compounds are POISONOUS." 10th ed. p. 139 1983.

[32] This element goes to bones.

People are trying desperately to use less toxic products. They seek health for themselves. So they reach for products that just list herbs and other natural ingredients. Unfortunately, the buyers are being duped. The Food and Drug Administration (FDA) requires all body products to have sufficient antiseptic in them. Some of these antiseptics are substances you must avoid! But you won't see them on the label because manufacturers prefer to use quantities below the levels they must disclose. And by using a variety of antiseptics in these small amounts they can still meet sterility requirements. The only ingredient you might see is "grapefruit seed" or similar healthy-sounding natural antiseptic. This is sad for the consumer of health food varieties.

- I have seen rocks sold as "Aluminum-Free Natural Deodorant". You rub the rock under your arms. It works because the rock is made of magnesium-aluminum-silicate.
- Men's hair color has lead in it.
- Lipstick has barium, aluminum, titanium.
- Eye pencil and shadow have chromium.
- Toothpaste has benzene, tin, and strontium.
- Hair spray has propyl alcohol and PCBs. BEWARE! Stop using it today.
- Shampoo, even health varieties, has propyl alcohol! BEWARE! Stop using it today.
- Cigarettes have lead, mercury, nickel and *Tobacco Mosaic virus*.
- Chewing tobacco has ytterbium

Some of the unnatural chemicals listed are present because of residues in the manufacturing process, but others you will actually see listed on the label!

Propyl alcohol and wood alcohol are present because the tubing used to fill the bottles is sterilized and cleaned with them. Ice cream machines are "oiled" with a gel containing pe-

troleum products. This could explain why I always find benzene in ice cream.

Fig. 71 Examples of commercial "food lube."

How can propyl alcohol in shampoo get into your body in significant amounts? The skin is more absorbent than we realize, and time and time again I see cancer victims who have gone off every body product except their favorite shampoo. They harbor propyl alcohol until they make that final sacrifice. It is better to switch shampoos than to not need any due to radiation and chemotherapy!

See *Recipes* for easy-to-make, natural cosmetics. But you might consider just stopping them all. Especially if you're going on vacation.

Use nothing that you wouldn't use on a new-born baby. This is a permissive age. You will be the only one feeling "naked." Others won't even notice. Don't forget advertising is aimed at you, even if other people's eyes are not!

Don't even use soap unless it is homemade soap (see *Recipes*) or borax straight from the box. Borax was the traditional pioneer soap. It is antibacterial and can be made into a solution. It is also a water softener and is the main ingredient in non-chlorine bleach. Borax can remove grease, too, and some stains.

But even borax is not natural to your body and it is therefore wise to use as little as necessary. See *Recipes* for anti-bacterial borax soap.

Dishes and clothing are primary source of PCBs.

Fig. 72 Detergents with PCBs.

homemade soap pure borax

Fig. 73 Safe soaps.

Don't use toothpaste, not even health-food varieties. To clean teeth, use plain water or chemically pure baking soda (see *Sources*)—but dissolve it in water first, otherwise it is too abrasive. Or brush with hydrogen peroxide food grade, not the regular variety (see *Sources*). Don't use floss; use 2 or 4-pound monofilament fish line. Floss has mercury antiseptics (with thallium pollution!). Throw away your old toothbrush—solvents don't wash away.

Don't use mouthwash. Use saltwater (aluminum-free salt) or food grade hydrogen peroxide (a few drops in water).

Don't use hair spray.
Don't use massage oils of any kind. Use olive oil.
Don't use bath oil. Take showers, not baths, if you are strong enough to stand. Showers are cleaner.
Don't use perfumes or colognes.
Don't use commercial lotions or personal lubricants.

Stop Using Supplements

Stop using your vitamin supplements. They, too, are heavily polluted. This is the saddest, most tragic part of your instructions. I have found solvents, heavy metals and lanthanides in 90% or more of the popular vitamin and mineral capsules and tablets I

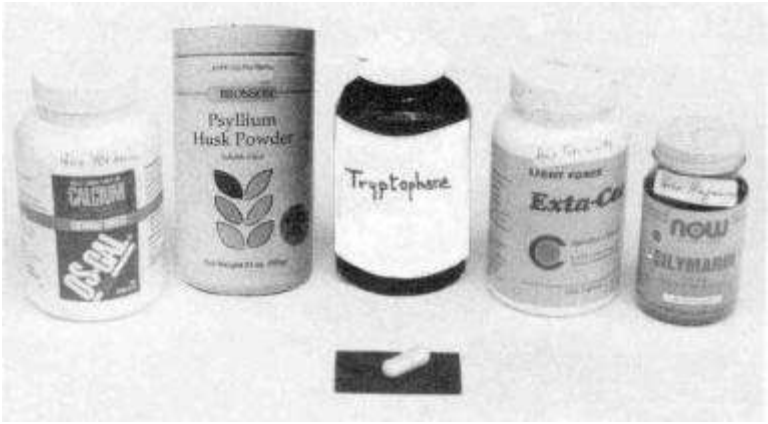

The capsule in the foreground is a notorious tryptophane capsule. It had the following pollutants: PCBs, mercury, ruthenium, thulium, strontium, praseodymium, aluminum, benzalkonium.

Fig. 74 Some polluted supplements.

test. These substances will do more harm in the long run than the supplement can make up for in benefits.

Most of the varieties of vitamin C that I have tested are polluted with thulium! Until all vitamins and minerals and other food supplements have been analyzed for pollutants, after they are encapsulated or tableted, they are not safe. We need more disclosure on our products. No manufactured product is pure. We can't expect that. But at least we should be able to tell what impurities we are getting, and how much.

It is possible to do detailed analysis of foods or products at a reasonable price. Look at the bottle of common table salt, sodium chloride, that is used by beginning chemistry students to do experiments. It must be thoroughly analyzed for them because minute impurities affect their results. (Those minute impurities, like lead, affect you, too.) Look at the label on the bottle in the picture. Even after all these tests, the cost of laboratory salt is only $2.80 per pound.[33]

Fig. 75 Pure salt.

It is most important not to be fooled by ingredient claims, like "made from organically grown vegetables". Sure that's great, but the analysis *I* trust would be done on the final, cleaned, cooked and packaged product on the shelf. The package is a major unlisted ingredient.

Toxic solvents like decane, hexane, carbon tetrachloride and benzene will get more flavor or fat or cholesterol out of things than metabolizable grain alcohol. Of course, the extraction process calls for washing out the solvent later. But it can't all be washed out, and a detailed analysis on the final product would

[33] You will pay about $8.00 per pound (Spectrum Chemical Co.) for USP (United States Pharmaceutical) grade. But the same analysis is done on the cheaper grades, and my point is that the analysis is cost effective enough that it should be done on our daily foods.

give the public the information they need to make informed choices.

All supplements must be tested for purity by yourself. If this cannot be done, don't take them.

Polluted supplements do much more harm than good. Get your super-nutrition by juicing vegetables of all kinds and making herbal teas.

Safe Supplements

There are, no doubt, lots of safe supplements to be had. The problem is knowing which they are. The nature of pollution is such that one bottle might be safe, while another of the same brand is not. In view of this, as I found a polluted bottle, I stopped using any more of that brand. That is why I am reduced to recommending only the ones in the *Sources* at this time.

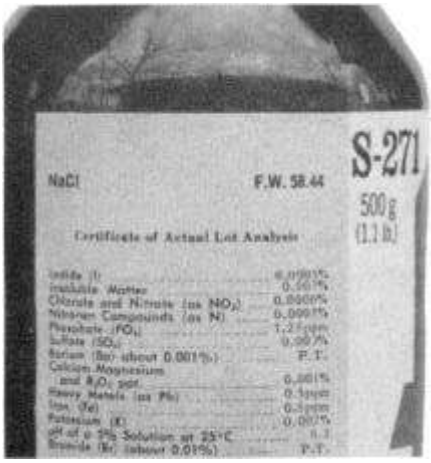

Common salt for student use is thoroughly analyzed for pollution. The label gives you the final "Actual Lot Analysis" of the product. It is not expensive.

Fig. 76 Laboratory salt label.

Vitamin C, in crystal form, is a must in your lifestyle. It helps the liver, and possibly other organs, detoxify things. It also helps retard mold, and perhaps even destroys aflatoxins! Keep some next to your refrigerator so it is handy when you put away groceries. Add 1/8 tsp. to maple syrup, vinegar, cooked

cereal, fruit juice, leftovers. Have ¼ tsp. (1 gram) with each meal.

Vitamin B_2, 100 mg. This is the vitamin that helps detoxify benzene! Take one to three a day. While recovering from AIDS you need 3 tablets three times a day.

Vitamin B_6, 250 mg, and B-complex, 50 mg. Undoubtedly these help the liver and kidneys in many ways. One a day.

Magnesium oxide, 300 mg., is another must. Take one or two a day. It is a major mineral; all of our cells need lots of it. Only leafy vegetables provide it.

Hydrogen peroxide, food grade. It is advantageous to kill bacteria and viruses to some extent every day. Hydrogen peroxide lets you do this. It should never come in contact with metal, including its container or metal tooth fillings. If you get a few drops on your skin it may turn white and sting, but does no harm, so simply wash it off. Instructions for its use come with the product.

Herbs. These are excellent supplements, both in bulk and capsules, but not extracts, concentrates, or concoctions. There are many books that describe their uses.

Thioctic acid or lipoic acid. Presumably this chelates (traps and prepares for elimination) heavy metals, and helps the liver in detoxifying obscure and deadly poisons. Everyone would benefit from 100 mg. per day. I find it outstanding, and give it to many ill persons, even when not mentioned in the case histories. It comes as a 100 mg. capsule (see *Sources*). I use it at doses from one capsule, 3 times a day, to 2 capsules, 5 times a day. I have seen no side effects at these dosages, even in very sick persons.

Lugol's Iodine Solution (see *Recipes*) is old-fashioned "iodine." Iodine has a distinctive trait: it hangs up on anything and everything. In fact, it attaches itself so quickly we consider everything it touches as "stained." This is just the property we want to make it safe for use. The amount you use is immedi-

ately hung up, or attached, to your mucous and can not be quickly absorbed into the blood or other organs. It stays in the stomach. And for this reason it is so useful for killing vicious bacteria like *Salmonella*.

Do not take Lugol's iodine if you know you are allergic to iodine. It could be fatal.

Six drops of Lugol's solution can end it all for *Salmonella*. If you have gas and bloating, pour yourself ½glass of water. Add 6 drops of Lugol's (not more, not less), stir with wood or plastic, and drink all at once. The action is noticeable in an hour. Take this dose 4 times a day, after meals and at bedtime, for 3 days in a row, then as needed. This eradicates even a stubborn case of *Salmonella*.

Notice how calming 6 drops of Lugol's can be, soothing a manic stage and bringing a peaceful state where anxiety ruled before.

Lugol's is perfectly safe (if not allergic) to take day after day, when needed, because of its peculiar attaching property. It arrives in the stomach, reattaches to everything in proximity. Doomed are all *Salmonellas*; doomed also are eggs of parasites that might be in the stomach (cysts).

Naturally, one would not leave such medicine within the reach of children. Also, one would not use anything medicinal, including Lugol's unless there were a need, like cancer, AIDS, or bowel disease. When the gas and bloating problem has stopped, stop using Lugol's. If one or two doses of Lugol's cures the problem, stop. Store it in a perfectly secure place. In the past, 2/3 of a teaspoon (60 drops) of Lugol's was the standard dose of iodine given to persons with thyroid disease. Six drops is small by comparison.

Turmeric and **fennel** are herbs also used as cooking spices. They can eradicate invasive *E. coli* and *Shigella* bacteria! They are completely harmless, and are part of the Bowel Program.

Other supplements. The concept of supplementing the diet is excellent, but the pollution problem makes it prohibitive. Use only supplements and brands recommended in *Sources*, although the best approach is to test them yourself with your Syncrometer. I can't guarantee the brands in *Sources* will stay pure. If in doubt, leave it out.

Home Clean-up

This is the easiest task because it mostly involves throwing things out. Hopefully your family and friends will jump to your assistance.

- The basement gets cleaned.
- The garage gets cleaned.
- Every room in the house gets cleaned.

Your Basement

To clean your basement, remove all paint, varnish, thinners, brush cleaners, and related supplies. Remove all cleaners such as carpet cleaner, leather cleaner, rust remover. Remove all chemicals that are in cans, bottles or buckets.

You may keep your laundry supplies: borax, washing soda, white distilled vinegar, bleach and homemade soap. You may keep canned goods, tools, items that are not chemicals. You may move your chemicals into your garage. Also move any car tires and automotive supplies like waxes, oil, transmission fluid, and the spare gas can (even if it is empty) into your garage or discard them.

Seal cracks in the basement and around pipes where they come through the wall with black plastic roofing cement. In a few days it will be hard enough to caulk with a prettier color. Spread a sheet of plastic over the sewer or sump pump.

Your Garage

Do you have a garage that is a separate building from your home? This is the best arrangement. You can move all the basement chemicals into this garage. Things that will freeze, such as latex paint, you may as well discard. But if your garage is attached, you have a problem. Never, never use your door between the garage and house. Walk around the outside. Don't allow this door to be used. Tack a sheet of plastic over it to slow down the rate of fume entrance into the house. Your house acts like a chimney for the garage. Your house is taller and warmer than the garage so garage-air is pulled in and up as the warm air in the house rises. See the drawing.

In medieval days, the barn for the animals was attached to the house. We think such an arrangement with its penetrating odors is unsavory. But what of the gasoline and motor fumes we are getting now due to parked vehicles? These are toxic besides! This is even more medieval.

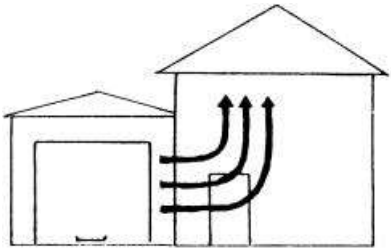

Fig. 77 Garage fumes.

If your garage is under your house, you cannot keep the pollution from entering your home. In this case, leave the cars and lawnmower outside. Remove cans of gasoline, solvents, etc. Put up a separate shed for these items.

Special Clean-up for Freon (CFCs)

Because I consider Freon to be the top health hazard in our home, I recommend turning in your refrigerator for a non-CFC variety. Dispose of all spare units. Remove window air conditioners or test the dust in your home (page 485) for Freon. Have your car's air conditioning system checked. Dispose of old pressurized cans. Even one whiff is too much. It never leaves the body because the body has no detoxification methods for it!

Only one useful reaction with Freon comes to mind. Freon is thought to be responsible for the ozone "hole" at the South Pole. Would Freon react with ozone supplied to your body and thereby become biodegradable? Indeed, it does! But only if you drink it as ozonated water. Other ozone routes, as intravenous or rectal, have not been observed to be as effective.

If you are following your progress with the Syncrometer, you will see that Freon now appears in the liver for the first time. (Before this, it was marooned in the parathyroids, thymus, and other organs.) You may also detect a feeling like indigestion. You must come to the assistance of your liver. Even ozonated Freon is extremely burdensome to the liver.

A combination of herbs (Liver Herb Drink in *Recipes*, page 552) rescues the liver from its plight, and prevents the indigestion. After drinking liver herbs you will see that the Freon now appears in the kidneys. Yet it is marooned there unless you assist them. Take the kidney cleanse to assist the kidneys so they can finally excrete the Freon into the urine.

It's an elaborate detoxifying program and usually takes six to eight weeks to get most of the Freon out. Afterward, continue the programs at one fourth dosage for half a year.

Forane is one of the new refrigerants. Although toxic, at least I observe it in the liver directly, suggesting that your body is capable of handling it. Remember your new refrigerator will

still be using a toxic coolant, and it would be best to keep it outside or at least vented to the outside.

Special Clean-up for Fiberglass

Fiberglass insulation has microscopically small bits of glass that are free to blow into the air. When house drafts pull it into the air you will inhale them. They cut their way through your lungs and organs like millions of tiny knives, spreading through your body, since there is no way out for them. You smell nothing and feel nothing. This makes it a very sinister poison. Your body, though, recognizes these sharp, pointed bits and tries to stop their spread by sequestering them in cysts.

Most solid malignant tumors contain fiberglass or asbestos, another glass-like particle. In nearly all cases a hole can be found in the ceiling or walls, leading to fiberglass insulated parts of the house. When these holes are sealed in an air-tight manner the house air no longer is positive for fiberglass. Covering with paneling is not sufficient. Check your dwelling for uncovered fiberglass. Repair immediately. Search for small screw holes intended for pictures, or electric outlet plates that are missing.

Also remove fiberglass jackets from water heater and fiberglass filter from furnace. Replace with foam or carbon. Best of all, hire a crew to remove it all from your home, and replace insulation with blown-in shredded paper or other innocuous substance.

Never build a new house using fiberglass for any purpose.

Special Clean-up for Asbestos

The biggest source of asbestos is not building materials! It is the clothes dryer belt and hair dryer! To be safe, remove the belt from your dryer and check to see if it says “Made in USA” on

the belt itself. If so, it is OK. If not, it is imported, and probably contains asbestos. Exchange it for a USA belt (see *Sources*).

Hair dryers, too, may be imported and shed asbestos. It is especially hazardous to be aiming a stream of hot asbestos right at your face! If you can't find a safe model (see *Sources*), or are unsure, don't use any. If you have cancer or are ill, no one in the house should use an unsafe hair dryer.

Turn off radiators and electric heaters and cover them with big plastic garbage bags, or paint them, or remove them. They give off asbestos if their paint is old.

Your House

To clean the house, start with the bedroom. Remove everything that has any smell to it whatever: candles, potpourri, soaps, mending glue, cleaners, repair chemicals, felt markers, colognes, perfumes, and especially plug-in air "fresheners". Store them in the garage, not the basement. Since all vapor rises, they would come back up if you put them in a downstairs garage or basement.

Do not sleep in a bedroom that is paneled or has wallpaper. They give off arsenic and formaldehyde. Either remove them or move your bed to a different room. Leave the house while this is being done. If other rooms have paneling or wallpaper, close their doors and spend no time in them.

Next clean the kitchen. Take all cans and bottles of chemicals out from under the sink or in a closet. Remove them to the garage. Keep only the borax, washing soda, white distilled vinegar and homemade soap. Use these for all purposes. For exact amounts to use for dishwasher, dishes, windows, dusting, see *Recipes*. Remove all cans, bottles, roach and ant killer, moth balls, and chemicals that kill insects or mice. These should not be stored anywhere. They should be thrown out. Remember to check the crawl space, attic and closets for hidden poisons also.

To keep out mice, walk all around your house, stuffing holes and cracks with steel wool. Use old-fashioned mouse traps. For cockroaches and other insects (except ants) sprinkle handfuls of boric acid[34] (not borax) under your shelf paper, behind sink, stove, refrigerator, under carpets, etc. Use vinegar on your kitchen wipe-up cloth to leave a residue that keeps out ants. Do this regularly. To wax the floor, get the wax from the garage and put it back there. A sick person should not be in the house while house cleaning or floor waxing is being done.

Remove all cans and bottles of "stuff" from the bathroom. The chlorine bleach is stored in the garage. Someone else can bring it in to clean the toilet (only). Leave only the borax soap, homemade soap, and grain alcohol antiseptic. Toilet paper and tissues should be unfragranced, uncolored. All colognes, after shave, anything you can smell must be removed. Family members should buy unfragranced products. They should smoke outdoors, blow-dry their hair outdoors or in the garage, use nail polish and polish remover outdoors or in the garage.

Do not keep new foam furniture in the house. If it is less than one year old, move it into the garage until you are well. It gives off formaldehyde. So does new clothing; it is in the sizing. Wash all new clothes before wearing. If you have a respiratory illness, move all the clothes in the clothes closet out of your bedroom to a different closet.

Do not use the hot water from an electric hot water heater for cooking or drinking. It has tungsten. Do not drink water that sits in glazed crock ware (the glaze seeps toxic elements like cadmium) like some water dispensers have. Do not buy water from your health food store that runs through a long plastic hose from their bulk tank (I always see cesium picked up from flexi-

[34] Boric acid is available by the pound from farm supply stores and from Now Foods. Because it looks like sugar keep it in the garage to prevent accidental poisoning.

ble clear plastic). Also ask them how and when they clean their tank. Best is to observe that it is done with non-toxic methods.

If your house is more than 10 years old, change all the galvanized pipe to PVC plastic. Although PVC is a toxic substance, amazingly, the water is free of PVC in three weeks! If your house has copper pipes don't wait for cancer or schizophrenia to claim a family member. Change all the copper pipe to PVC plastic immediately. If the pipes are not accessible, ask a plumber to lay an extra line, outside the walls. This is less expensive, too.

If you have a water softener, by-pass it immediately and replace the metal pipe on the user side of the softener tank. Softener salts are polluted with strontium and chromate; they are also full of aluminum. The salts corrode the pipes so the pipes begin to seep cadmium into the water. After changing your pipes to plastic, there will be so little iron and hardness left, you may not need a softener. If the water comes from a well, consider changing the well-pipe to PVC to get rid of iron. While the well is open, have the pump checked for PCBs. Call the Health Department to arrange the testing. If you must have softening after all this, check into the new magnetic varieties of water softener (although they only work well when used with plastic plumbing).

The cleanest heat is electric. Go total electric if possible. If you must stay with gas, have a furnace repair person check your furnace and look for gas leaks before the heating season starts. Don't call the gas company even though it is free. The gas company misses 4 out of 5 leaks! The Health Department does not miss any; call them! House builders and contractors are also reliable in their gas leak detection.

Unnatural Chemicals

And where I found them...

in ant & roach hives,
grains of pesticide

ARSENIC

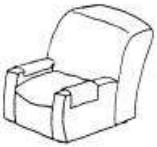

in carpet & furniture "treated"
for stain resistance

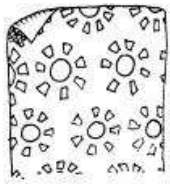

in wallpaper

BARIUM

in lipstick

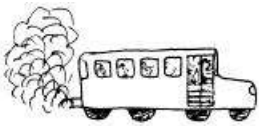

in bus exhaust

MOLYBDENU

in "molys"

COBALT

in laundry
detergent

in dishwater
detergent

in skin bracer

in mouthwash

ANTIMONY

in eye liner

CADMIUM and COPPER

in water running
through old metal pipes

TITANIUM

in face powder &
other powders, and
in metal dental ware

PCB's

in regular and
health store detergents

LEAD

in men's hair
color restorer

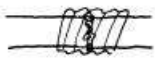

in solder at joints
of copper pipes

CHROMIUM

in eyebrow
pencil

in water
softener salts

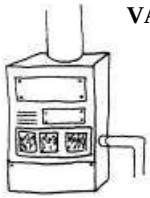

in leaks in pipes to gas
stove, furnace, water heater

VANADIUM

in diesel fuel

in candles
(even when
they're not
burning)

NICKEL

in metal jewelry
worn on the skin

in metal glasses frames

in metal
watch bands

in metal tooth fillings
and retainers

FIBERGLASS

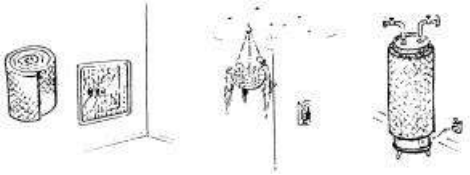

from insulation behind holes in ceiling or uncovered outlets, water heater jackets, stuffed around fans and air conditioners, insulation

CFC's (FREON)

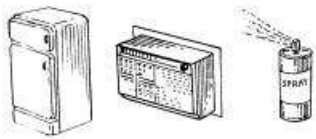

in
refrigerators

in air
conditioners

in spray
cans

MERCURY and THALLIUM

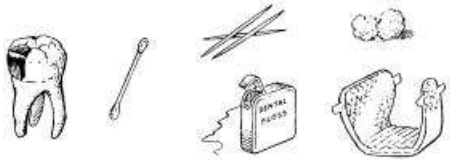

in tooth fillings, sanitary napkins, cotton balls, dental floss, toothpicks, cotton swabs

THULIUM

in most brands of vitamin C I tested

DYSPROSIUM and LUTETIUM

in paint, varnish, shellac

HOLMIUM

in hand cleaners

HAFNIUM

in nail polish & hair spray

RHENIUM

in spray starch

BISMUTH

in cologne and stomach aids

CESIUM

in clear-as-glass plastic

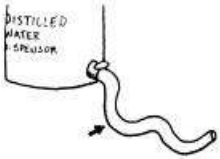

after running through long plastic hose

TIN and STRONTIUM

in toothpaste

YTTERBIUM, ERBIUM, TERBIUM

in foil packaging

in plastic tooth fillings

in vitamins and supplements

PRASEODYMIUM, NIOBIUM, NEODYMIUM, YTTRIUM

in over the counter drugs

in prescription drugs

RADON, URANIUM, THORIUM

in crawlspace without open vents

in holes and cracks in basement

LANTHANUM

in duplicator and copier ink

BENZALKONIUM and ZIRCONIUM

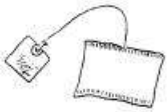

in tea bags

in deodorant

in toothpaste

in mouthwash

in cosmetics

ALUMINUM

in "natural" deodorant advertised as aluminum-free

in salt

in cans

in walkers for the elderly

in lotions

TUNGSTEN

corroded rod in electric water heaters

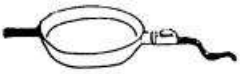

in electric frying pans

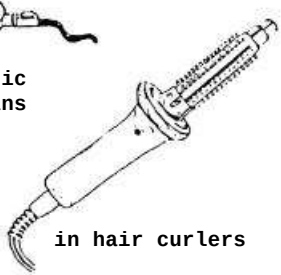

in hair curlers

in toasters

in tea kettles

BERYLLIUM

in hurricane lamps

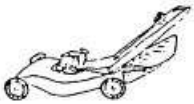

in lawn mowers

in kerosene

FORMALDEHYDE

in foam mattresses

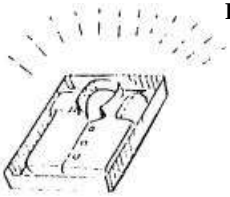

in new clothing

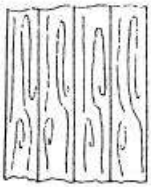

in paneling

in foam chairs

ASBESTOS

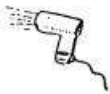

in hair blowers

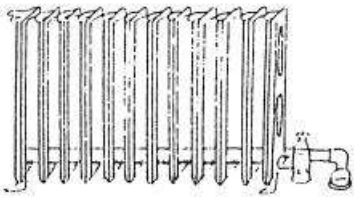

in radiator paint

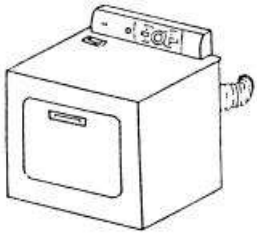

in clothes dryer belts

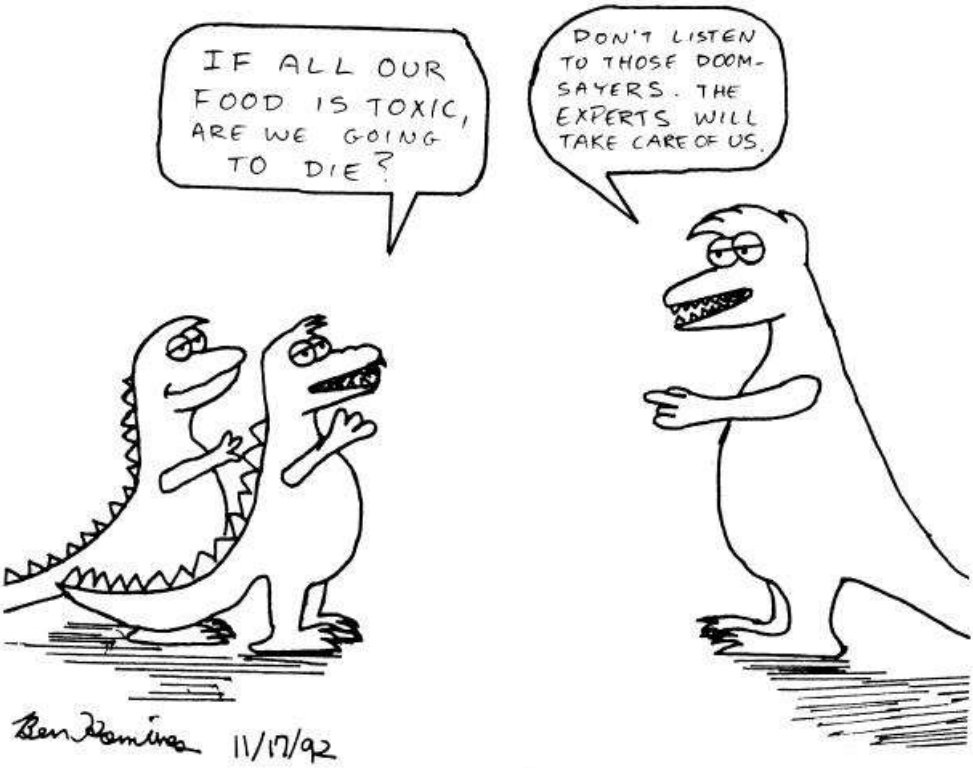

Fig. 78 Our future, unless we act.

Bioelectronics

The most important electronic device to make or buy is a **zapper**—a compact pulse generator operating from a common 9 volt battery whose output is about 30 KHz. It kills all parasites, bacteria, viruses, molds, and fungi even though their individual resonant frequencies are either higher or lower (50 KHz to 900 KHz). Building a zapper is described in an earlier chapter.

The next most useful device to have is a **Syncrometer.™** It lets you diagnose yourself and monitor your progress until you are cured. It consists of an audio oscillator circuit with your body as part of the circuit. Utilizing samples of parasites or pollutants, it lets you test for them in any product or body tissue. I include a design that you can make yourself.

A third very useful device is a **frequency generator**. You can use it to electrocute individual organisms, or together with the Syncrometer™ to find an organism's particular frequency. You need one that operates in the parasite, bacteria and virus ranges, from 50 KHz to 900 KHz. It must also be able to select a particular frequency, like 434 KHz, quickly and accurately. Frequency generators are available for as little as $300.00, but it is worth paying a little more to get a digital display of the frequency.

Making A Syncrometer

This is an *audio oscillator* circuit in which you include yourself by means of a handhold. You listen to the current in your circuit with a loudspeaker. Other oscillator circuits will work, too. A lot of fascinating opportunities present themselves with this concept.

I have previously published three ways to build the Syncrometer circuit.[35] Here is the circuit diagram:

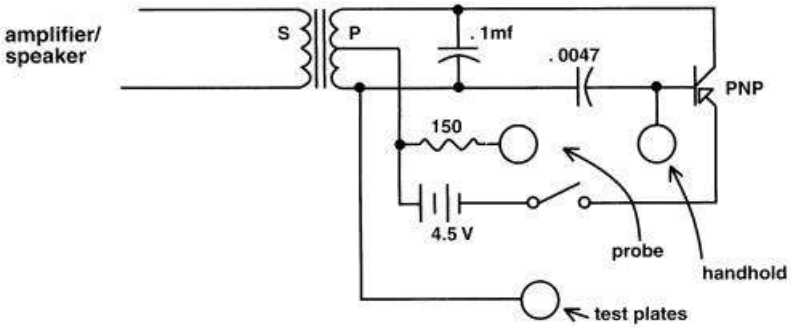

4700pf moly cap
.1 mfd 16v cap
2N2907 PNP
min output transf 8-900Ù
150 .25w res
3 AA batteries
speaker (like Radio Shack 277-1008C)

Fig. 79 Syncrometer schematic.

If you are not an electronics enthusiast, you can still assemble a Syncrometer using a hobby kit. No soldering is required. Here is what you need:

Making a Hobby Kit Syncrometer

Item	Radio Shack Cat. No.
200 in One Electronic Project Lab by Science Fair	28-262
3 AA 1½ volt batteries	

[35]In *The Cure for all Cancers* and *The Cure for HIV/AIDS*.

Alligator clip test jumpers	You need 2.
Handhold. A four inch length of ¾ inch copper pipe, like for plumbing. These dimensions are critical to assure maximum skin contact.	
Probe. A banana plug.	Precision Mini-Hook Test Lead Set (contains two, you only need one) 278-1160A
Pencil, new.	

Fig. 80 Syncrometer parts list.

Build The Electrosonic Human in the *200 in One Electronic Project Lab*. It takes about 10 minutes.

Later, when you use the probe to press against your knuckle you may find getting the right sound is painful. In this case try substituting the .005 microfarad capacitor for the .01 microfarad capacitor in the circuit.

Attach the Probe. The Archer Precision Mini-Hook Test Lead Set has a banana plug for the probe on one end and a mini-hook on the other end for easy attachment to the circuit. Tape a long, new pencil to the probe to make it easier to hold. Connect the Probe to middle post of the primary side of the transformer (it also connects to the negative battery post). You will not be using the two connections the instructions tell you to hold.

Attach the Handhold. Clip the Handhold to one end of an alligator clip test jumper, and clip the other end to the base (B) of the transistor used in the circuit.

Attach an alligator clip to the post of the transformer that connects to the two capacitors. This will go to the **test plates**.

Final test. Turn the control knob on and keep turning the potentiometer to nearly the maximum. (This reduces the resis-

tance. The schematic has a 150 ohm fixed resistor in place of the potentiometer.) Make sure you have good batteries installed. Test the circuit by briefly touching the Probe to the Handhold. The speaker should produce a sound like popping corn. If it does not, check that your alligator clips are not bending the spring terminals so much that other wires attached there are loose. Finally, turn switches OFF.

Making Test Plates

This is the box you attach to the basic Syncrometer circuit. It has test plates to put your test substances and tissue samples on. The wiring in it is arranged so that you can test for a toxin in a product, as well as search in yourself. This means you can search for *Salmonella* in the milk or cheese you just ate, not just for *Salmonella* in your stomach.

Only if the resonant frequency of an item on one plate is equal to the resonant frequency of an item on the other plate will the entire circuit oscillate or resonate! This implies the two plates have something in common. By putting a known pure sample on one plate you can reliably conclude the other sample contains it if the circuit resonates.

You may build a test plate box into a cardboard box (such as a facial tissue box) or a plastic box. Here are the instructions for the cardboard box model.

Test Plates Parts List

- Stiff paper.
- Aluminum foil.
- A facial tissue box is easiest. A plastic project box, about 7” x 4” x 1½” makes a more durable product, but requires a drill, and you should discard any metal lid it comes with.

- 3 bolts (tapered heads) about 1 inch long, 1/8 inch diameter and 6 washers and nuts to fit.
- toggle switch with OFF-ON positions.
- Alligator clip test leads.

Test Plates Assembly

Cut two 3-1/2 inch squares out of stiff paper such as a milk carton. Cover them with 4½ inch squares of aluminum foil, smoothed evenly and tucked snugly under the edges. You have just made yourself a set of open capacitors. Turn the box upside down and draw squares where you will mount them at the ends of the box. Don't actually mount them, to save wear and tear on them, until the rest of the box is complete.

Mount the ON OFF switch on the front of the box, underneath the right hand plate. Line it up so ON is downward and OFF is up. (An electronics shop can determine this for you at the time of purchase.) Label the box with ON and OFF signs.

Two bolts will be reserved for the plates. The third bolt is used as a terminal where the current from the oscillator circuit will arrive. Make a hole on the side of the box, near the left hand plate and mount the bolt so it sticks half way inside and halfway outside the box. It does not matter whether the head is inside or outside. Tighten it there with a nut on each side of the box. Label it TERMINAL. It merely means connecting place.

Mark the center of each square that you drew and each capacitor you built. Pierce first with a pin; follow with a pencil until a round hole is made at the center. Mount each plate with a bolt, fastening it below with a nut. Washers are optional.

The left side connection (terminal) gets attached to the left plate (bolt) with an alligator clip. Use another clip to attach the same left plate (bolt) to the ON OFF switch (there are two connections, use either one). Finally attach the ON OFF switch connection you didn't use to the right plate (bolt). Make sure the

connections at the switch are not touching each other; you might tape them to guard against this.

All these connections should be checked carefully to make sure they are not touching others accidentally. But if you leave the box open so you can see any problems and use clear tape around connections to prevent accidental touching to the wrong connection, it should work OK.

Finally, trace your current. It comes in from the Syncrometer at the main terminal on the left. It is brought to the left plate. When the switch is ON it is simultaneously brought to the right plate. Notice that the plates are not connected to anything else. They are simply capacitors, letting current in and out momentarily and at a rate that is set by the frequency of the oscillator circuit, about 1,000 hertz. This frequency goes up as the resistance (of the circuit or your body) goes down.

The probe and handhold allow you to include yourself in the Syncrometer circuit. You grasp these when testing. This makes you part of the circuit.

The speaker lets you "listen" to the current. As resistance drops, current goes higher and frequency goes up. As frequencies go higher in the circuit, pitch goes higher. You will be comparing the sound of a standard "control" current with a test current.

Using The Syncrometer

Fill a saucer with cold filtered tap water. Fold a paper towel four times and place it in this dish. It should be entirely wet.

Cut paper strips about 1 inch wide from a piece of white, unfragranced, paper towel. Dampen a paper strip on the towel and wind it around the copper pipe handhold to completely cover it. The wetness improves conductivity and the paper towel keeps the metal off your skin.

- Start with the test plate switch at OFF.
- Turn the control knob (potentiometer) on, and to near maximum.
- Touch each plate with the probe, while holding the copper pipe with one hand. Only the left plate should give you a sound from the speaker. Turn the test plate switch ON. Now both plates should give you a sound when the probe touches them.
- Turn the test plate switch OFF again.
- Pick up the handhold, squeeze it free of excess water.
- Pick up the probe in the same hand, holding it like a pen, between thumb and forefinger.

Dampen your other hand by making a fist and dunking your knuckles into the wet paper towel in the saucer. You will be using the area on top of the first knuckle of the middle finger or forefinger to learn the technique. Become proficient with both. Immediately after dunking your knuckles dry them on a paper towel folded in quarters and placed beside the saucer. The degree of dampness of your skin affects the resistance in the circuit and is a very important variable that you must learn to keep constant. Make your probe as soon as your knuckles have been dried (within two seconds) since they begin to air dry further immediately.

With the handhold and probe both in one hand press the probe against the knuckle of the other hand, keeping the knuckles bent. Press lightly at first, then harder, taking one half second. Repeat a half second later, with the second half of the probe at the same location. There is an additive effect and you get two chances to listen to the current. All of this takes less than two seconds. Don't linger because your body will change and your next probe will be affected.

Subsequent probes are made in exactly the same way. As you develop skill, your probes will become identical. Plan to practice for one or two hours each day. It takes most people at least twelve hours of practice in order to be so consistent with their probes that they can hear the slight difference when the circuit is resonant.

For reference you may wish to use a piano. The starting sound when you touch down on the skin should be F, an octave and a half above middle C. The sound rises to a C as you press to the knuckle bone, then slips back to B, then back up to C-sharp as you complete the second half of your first probe. If you have a multitester you can connect it in series with the handhold or probe: the current should rise to about 50 microamps. If you have a frequency counter the frequency should reach 1000 Hz. You should arrive at C-sharp just before the probe becomes painful.

Two things change the sound of the probes even when your technique doesn't change.

1. The patch of skin chosen for probing will change its properties. The more it is used, the redder it gets and the higher the sound goes when you probe. Move to a nearby location, such as the edge of the patch, when the sound is too high to begin with, rather than adjusting the potentiometer.
2. Your body has cycles which make the sound go noticeably higher and lower. If you are getting strangely higher sounds for identical probes, stop and only probe every five minutes until you think the sound has gone down to standard. This could take five to twenty minutes. Learn this higher sound so you can avoid testing during this period.

You may also find times when it is impossible to reach the necessary sound without pressing so hard it causes pain. You may adjust the potentiometer if that helps.

All tests are momentary.

This means less than one second. It is tempting to hold the probe to your skin and just listen to the sound go up and down, but if you prolong the test you must let your body rest ten minutes, each time, before resuming probe practice!

For our purposes, it is not necessary to locate acupuncture points.

Resonance

The information you are seeking is whether or not there is *resonance*, or *feedback oscillation*, in the circuit. If there is the test is **YES** (positive). You hear resonance by comparing the second probe to the first. You can never hear resonance on the first probe, for reasons that are technical and beyond the scope of this book. You are not merely comparing pitch in the two probes. During resonance a higher pitch is reached faster; it seems to want to go infinitely high.

Remember that more electricity flows, and the pitch gets higher, as your skin reddens or your body changes cycle. These effects are not resonance.

Resonance is a small extra hum at the high end of the probe. As soon as you hear it, stop probing. Your body needs a short recovery time (10 to 20 seconds) after every resonant probe. The longer the resonant probe, the longer the recovery time to reach the standard level again.

Using musical notes, here is a NO (negative result): F-C-B-C# (first probe) F-C-B-C# (compare, it is the same sound). Here is a YES (positive) result: F-C-B-C# (first probe) F-D (stop quickly because you heard resonance). In between the first and second probe a test substance will be switched in as described in lessons below.

It is not possible to produce a resonant sound by pressing harder on the skin, although you can make the pitch go higher. To avoid confusion it is important to practice making probes of the same pressure. (Practice getting the F-C-B-C# tune.)

Making Pure Water for Testing Purposes

Since the water you purchase is likely to have solvents in it and since your tap water may be polluted with heavy metals and since your (or a store's) filtration system may be clogged, it is important to make your own pure water.

Purchase a "filter pitcher" made of hard, opaque plastic, not the clear or flexible variety (see Sources). Fill the pitcher with cold tap water, only, not reverse osmosis, distilled, or any other water, since solvents do not filter out as easily as heavy metals. The filter should be made of carbon only. To make test substances, use fresh water in the pitcher and pour.

If your water has lead, copper or cadmium from corroded plumbing, the filter will clog in five days of normal use. So use this pitcher sparingly, just for making test substances and for operating the Syncrometer.

Lesson One

Purpose: To identify the sound of resonance in the circuit.

Materials: Potentized (homeopathic) solutions. Prepare these as follows: find three medium-sized vitamin bottles, glass or plastic, with non-metal lids. Remove any shreds of paper sticking to the rim. Rinse well with cold tap water. Then rinse again with filtered water.

Pour filtered water into the first bottle to a depth of about ½ inch. Add about 50 little grains of table salt using the tip of a plastic knife. This is a "pinch." Replace the lid. Make sure the

outside is clean. If not, rinse and dry. Now shake hard, holding it snugly in your hand. Count your shakes; shake 120 to 150 times. Use elbow motion so each shake covers about an eight inch distance. Shaken samples are different from unshaken ones, that's why this is so important. When done label the bottle on its side and lid: SALT #1. Wash your hands (without soap).

Next, pour about the same amount of filtered water into the second and third bottles. Open SALT #1 and pour a small amount, like 1/4 to 1/2 of a teaspoon (do not use a spoon) into the second and third bottles. Close all bottles. Now shake the second bottle the same as the first. Clean it and label it SALT #2. Do the same for the third bottle. Label it SALT #2 also and set aside for Lesson Four.

These two solutions have unique properties. SALT #1 always resonates. Use #1 to train your ear. SALT #2 shouldn't resonate. Use #2 to hear when you (your body's internal resistance) have returned to the standard level.

1. Turn the Syncrometer ON.
2. Place the SALT #2 bottle on the right test plate.
3. Start with the plate switch OFF.
4. Make your first probe (F-C-B-C#).
5. Flip the plate switch ON, taking only one half second. Brace your hand when switching so it is a fast, smooth, operation.
6. Make the second probe (F-C-B-C#). Total probe time is 2½ seconds. Count it out, “a thousand and one (done with first probe) a thou. (done with switching) a thousand and one (done with second probe).”
7. The result should be a NO (negative). If the second probe sounds even a little higher you are not at the standard level. Wait a few more seconds and go back to step 3.
8. If the first result was NO, remove SALT #2 and put SALT #1 on. Put the test plate switch back to OFF and repeat the test. This time the circuit was resonating. Learn to hear the

difference between the last two probes so that a resonant probe can be terminated early (reducing rest time).

9. The skin must now be rested. When SALT #1 is placed in the circuit there is always resonance whether you hear it or not. Therefore, always take the time to rest the skin.
10. How can you be sure that the skin is rested enough? Any time you want to know whether you have returned to the standard level, you may simply test yourself to SALT #2 (just do steps 3 through 6). While you are learning, let your piano also help you to learn the standard level (starts exactly at F). If you do not rest and you resonate the circuit before returning to the standard level, the results will become aberrant and useless. The briefer you keep the resonant probe, the faster you return to the standard level. Don't exceed one half second when probing SALT #1. Hopefully you will soon hear resonance within that time.

This lesson teaches you to first listen to the empty plate, then to SALT #2, to check for standard state. Then to compare the empty plate to SALT #1 to check for resonance. In later lessons we assume you checked for your standard level or are quite sure of it.

Practice hearing resonance in your circuit every day.

White Blood Cells

Checking for resonance between your white blood cells and a toxin is the single most important test you can make.

Your white blood cells are your immune system's first line of defense. In addition to making antibodies, interferon, interleukins, and other attack chemicals, they also “eat” foreign substances in your body and eliminate them. By simply checking your white blood cells for toxins or intruders you save having to

check every other tissue in your body. Because no matter where the foreign substance is, chances are some white blood cells are working to remove it.

It took me two years to find this ideal indicator, but it is not perfect. **Tapeworms are a notable exception.** They can be encysted in a particular tissue which will test positive, while the white blood cells continue to test negative. Also, when bacteria and viruses are in their latent form, they do not show up in the white blood cells. Fortunately, in their active form they show up quite nicely. **Freon** is an example of a toxin that is seldom found in the white blood cells; but typically, the white blood cells are excellent indicators of toxins.

Making a White Blood Cell Specimen

Obtain an empty vitamin bottle with a flat plastic lid and a roll of clear tape. The white blood cells are not going into the bottle, they are going on the bottle. The bottle simply makes them easy to handle. Rinse and dry the bottle. Make a second specimen on a clean glass slide if available. Squeeze an oil gland on your face or body to obtain a ribbon of whitish matter (not mixed with blood). Pick this up with the back of your thumb nail. Spread it in a single, small streak across the lid of the bottle or the center of the glass slide. Stick a strip of clear tape over the streak on the bottle cap so that the ends hang over the edge and you can easily see where the specimen was put (see photo). Wipe the lid beside the tape to make sure all white blood cells are covered. For the slide, apply a drop of balsam and a cover slip (see *Sources*). Both types of preparation will give you identical results. The bottle type of white blood cell specimen is used by standing it on its lid (upside down) so that the specimen is next to the plate. The lid is used because it is flat, whereas the bottom of most bottles is not.

Lesson Two

Purpose: To add a white blood cell specimen to the circuit and compare sound.

Method:

1. Turn the Syncrometer ON.
2. Start with test plate switch OFF.
3. Place the white blood cell specimen on the left plate. Place some junk food in a plastic baggy on the right plate.
4. Eat some of the junk food.
5. After ½minute listen to the current. Flip the plate switch ON and listen again.
6. If the circuit is now resonating, the junk food is already in your white blood cells. It is toxic.

Take vitamin C and a B-50 complex to clear it rapidly; it may have had propyl alcohol or benzene in it. Test every 5 minutes afterward to see how long it takes to clear out.

Fig. 81 Bottle with white blood cells taped on top.

Lesson Three

Purpose: To determine the purity of the filtered water you are making.

Method: Pour a few tsp. of filtered water into a bottle or plastic bag. Place your white blood cell specimen on one plate and the water sample on the other. Listen to your circuit. Taste your filtered water. After ½minute, listen to your circuit again, just as in Lesson Two. If it appears in your white blood cells at any time you can conclude the water is not pure. You must have pure water available to you before continuing.

Lesson Four

Purpose: To determine your percent accuracy in listening for resonance.

Materials: The SALT #1 and SALT #2 solutions you made for Lesson One.

Method: Move the SALT #1 and SALT #2 labels to the bottom of the bottles so you can not tell which bottle is which.

1. Turn the Syncrometer ON.
2. Start with the test switch OFF.
3. Mix the bottles up, select one at random, and place it on the right plate.
4. Listen to the current.
5. Flip the plate switch ON and make your second probe.
6. Resonance indicates a SALT #1, no resonance indicates SALT #2. Check the bottom. Remember to rest after the SALT #1, whether or not you heard resonance.
7. Repeat steps 3 through 5 a number of times. Work toward getting three out of three correct. Practice every day.

Trouble shooting:

a) If you repeat this experiment and you keep getting the same bottles "wrong", start over. You may have accidentally contaminated or mislabeled the outside of the bottle, or switched bottle caps.

b) If you get different bottles wrong each time, the plates may be contaminated. Wash the outside of the bottles and rinse with filtered water and dry. Wipe the plates very gently too, with filtered water and dry. Or replace the plates.

c) If all the bottles read the same, your filtered water is polluted. Change the filter.

Preparing Test Substances

It is possible to prepare dry substances for testing such as a piece of lead or grains of pesticide. They can simply be put in a plastic bag and placed on the test plate. However, I prefer to place a small amount (the size of a pea) of the substance into a ½ ounce bottle of filtered water. There will be many chemical reactions between the substance and the water to produce a number of test substances all contained in one bottle. This simulates the situation in the body.

Within the body, where salt and water are abundant, similar reactions may occur between elements and water. For example, a strip of pure (99.9% pure) copper placed in filtered water might yield copper hydroxide, cuprous oxide, cupric oxide, copper dioxide, and so forth. These may be similar to some of the reaction products one might expect in the body, coming from a copper IUD, copper bracelet or the copper from metal tooth fillings. Since the electronic properties of elemental copper are not the same as for copper compounds, we would miss many test results if we used only dry elemental copper as a test substance.

Impure Test Substances

It is not necessary to have pure test substances. For instance, a tire balancer made of lead can be easily obtained at an auto service station. Leaded gasoline and lead fishing weights also make good test substances for lead. There is a disadvantage, though, to using impure test substances. You are including the extra impurities in your test. If your lead object also has tin in it, you are also testing for tin. Usually, you can infer the truth by some careful maneuvering. If you have searched your kidneys for leaded gasoline, fishing weights and tire balancers and all 3 are resonant with your kidneys, you may infer that you have lead in your kidneys, since the common element in all 3 items is

lead. (You will learn how to specify a tissue, such as your kidneys, later.)

Using pure chemicals gives you certainty in your results. You can purchase pure chemicals from chemical supply companies (see *Sources*). Your pharmacy, a child's chemistry set, a paint store, or biological supply company can also supply some.

> The biggest repository of all toxic substances is the grocery store and your own home.

You can make test substances out of your hand soap, water softener salt, and laundry detergent by putting a small amount (1/16 tsp.) in a ½ounce glass bottle and adding about 2 tsp. filtered water. (Or for quick testing just put them dry or wet in a sealed plastic baggy.) Always use a plastic spoon.

Here are some suggestions for finding sources of toxic products to make your own toxic element test. If the product is a solid, place a small amount in a plastic bag and add a tablespoon of filtered water to get a temporary test product. For permanent use put it in a small amber glass bottle. If the product is a liquid, pour a few drops into a glass bottle and add about 2 tsp. filtered water. Keep all toxic substances in glass bottles for your own safety. Small amber glass dropper bottles can be purchased by the dozen at drug stores (also see *Sources*). Seal your test bottles with tape for safety and to prevent evaporation.

Aflatoxin: scrape the mold off an orange or piece of bread; wash hands afterward.

Acetone: paint supply store or pharmacy.

Arsenic: 1/16 tsp. of arsenate pesticide from a garden shop. A snippet of flypaper.

Aluminum: a piece of aluminum foil (not tin foil) or an aluminum measuring spoon.

Aluminum silicate: a bit of salt that has this free running agent in it.

Asbestos: a small piece of asbestos sheeting, an old furnace gasket, 1/4 inch of a clothes dryer belt that does not say "Made in USA", or a crumb of building material being removed due to its asbestos content (ask a contractor).

Barium: save a few drops from the beverage given clients scheduled for an X-ray. Lipstick that has barium listed in the ingredients.

Benzene: an old can of rubber cement (new supplies do not have it). A tsp. of asphalt crumbs from a driveway.

Beryllium: a piece of coal; a few drops of "coal oil" or lamp oil.

Bismuth: use a few drops of antacid with bismuth in it.

Bromine: bleached "brominated" flour.

Cadmium: scrape a bit off a galvanized nail, paint from a hobby store.

Cesium: scrape the surface of a clear plastic beverage bottle.

CFCs (freon): ask an electronics expert for a squirt from an old aerosol can that used freon as a cleaner. (Squirt into water, outdoors, put the water in a sample bottle.)

Chromate: scrape an old car bumper.

Cobalt: pick out the blue and green crumbs from detergent. A sample of cobalt containing paint should also suffice.

Chlorine: a few drops of pure, old fashioned Clorox.™

Copper: ask your hardware clerk to cut a small fragment off a copper pipe of the purest variety or a ¼ inch of pure copper wire.

Ergot: a teaspoon of rye grains, or rye bread. Add grain alcohol to preserve.

Ether: automotive supply store (engine starting fluid).

Ethyl alcohol (grain alcohol): the purest "drinking" alcohol available. Everclear™ in the United States, Protec™ (potable) in Mexico.

Fiberglass: snip a fragment from insulation.

Fluoride: ask a dentist for a small sample.

Formaldehyde: purchase 37% at a pharmacy. Use a few drops only for your sample.

Gasoline: gas station (leaded and unleaded).

Gold: ask a jeweler for a crumb of the purest gold available or use a wedding ring.

Kerosene: gas station.

Lead: wheel balancers from a gas station, weights used on fishing lines, lead solder from electronics shop.

Mercury: a mercury thermometer (there is no need to break it), piece of amalgam tooth filling.

Methanol: paint supply store (wood alcohol).

Nickel: a nickel plated paper clip, a washed coin.

Patulin (apple mold): cut a sliver of washed, bruised apple.

PCB: water from a quarry known to be polluted with it (a builder or electrical worker may know a source).

Platinum: ask a jeweler for a small specimen.

Propyl alcohol: rubbing alcohol from pharmacy (same as propanol or isopropanol). Use a few drops only, discard the rest. Do not save it.

PVC: glue that lists it in the ingredients (polyvinyl chloride).

Radon: leave a glass jar with an inch of filtered water in it standing open in a basement that tested positive to radon using a kit. After 3 days, close the jar. Pour about 2 tsp. of this water into your specimen bottle.

Silicon: a dab of silicon caulk.

Silver: ask a jeweler for a crumb of very pure silver. Silver solder can be found in electronics shops. Snip the edge of a very old silver coin.

Sorghum mold: 1/8 tsp. sorghum syrup.

Styrene: a chip of styrofoam.

Tantalum: purchase a tantalum drill bit from hardware store.

Tin: scrape a tin bucket at a farm supply. Tin solder. Ask a dentist for a piece of pure tin (used to make braces).

Titanium: purchase a titanium drill bit from a hardware store.

Toluene: a tube of glue that lists toluene as an ingredient.

Tungsten: the filament in a burned out light bulb.

Vanadium: hold a piece of dampened paper towel over a gas stove burner as it is turned on. Cut a bit of this paper into your specimen bottle and add 2 tsp. filtered water.

Xylene: paint store or pharmacy.

Zearalenone: combine leftover crumbs of three kinds of corn chips and three kinds of popcorn.

This list gets you off to a good start. Since few of these specimens are pure, there is a degree of logic that you must apply in most cases. If you are testing for barium in your breast, a positive result would mean that a barium-containing lipstick tests positive and a barium-free lipstick is negative.

A chemistry set for hobbyists is a wonderful addition to your collection of test specimens. Remember, however, the assumptions and errors in such a system. A test for silver using silver chloride might be negative. This does not mean there is no silver present in your body; it only means there is no silver chloride present in the tissue you tested.

You are bound to miss some toxins; don't let this discourage you. There is more than enough that you can find.

The most fruitful kind of testing is, probably, the use of household products themselves as test substances. The soaps, colognes, mouthwash, toothpaste, shampoo, cosmetics, breads, dairy products, juices and cereals can all be made into test specimens. Put about 1/8 tsp. of the product in a small glass bottle, add 2 tsp. filtered water and ¼ tsp. grain alcohol to preserve it. For temporary purposes use a plastic baggy and water only. If you test positive to your household products in your

white blood cells you shouldn't use them, even if you can not identify the exact toxin.

For a list of toxins and solvents I use, see page 571. To order pure substances see *Sources* for "chemicals for testing."

Making Organ Specimens

To test for toxic elements or parasites in a particular organ such as the liver or skin, you will need either a fresh or frozen sample of the organ or a prepared microscope slide of this organ. Meat purchased from a grocery store, fresh or frozen, provides you with a variety of organ specimens. Chicken, turkey, beef or pork organs all give the same results. You may purchase chicken gizzards for a sample of stomach, beef liver for liver, pork brains for brain, beef steak for muscle, throat sweet breads for thymus, tripe for stomach lining. Other organs may be ordered from a meat packing plant.

Trim the marrow out of a bone slice to get bone marrow. Scrub the bone slice with hot water to free it of marrow to get a bone specimen. Choose a single piece of meat sample, rinse it and place it in a plastic bag. You may freeze it. To make a durable unfrozen sample, cut a small piece, the size of a pea, and place it in an amber glass bottle (½oz.). Cover with two tsp. filtered water and ¼ tsp. of grain alcohol (pure vodka will do) to preserve it. These need not be refrigerated but if decay starts, make a fresh specimen.

Pork brains from the grocery store may be dissected to give you the different parts of the brain. Chicken livers often have an attached gallbladder or piece of bile duct, giving you that extra organ. Grocery store "lites" provides you with lung tissue. For kidney, snip a piece off pork or beef kidney. Beef liver may supply you with a blood sample, too. Always wash hands and rinse with grain alcohol after handling raw meat.

I use ½ oz amber glass bottles with bakelite caps (see Sources) to hold specimens. However, plastic bags or other containers would suffice. After closing, each bottle is sealed with a Parafilm™ strip to avoid accidental loosening of the cap. You may use masking tape.

To make a specimen of skin, use hangnail bits and skin peeled from a callous, not a wart. A few shreds will do. Remember, they must be very close to the test plate when in use; add 2 tsp. filtered water and ¼ tsp. grain alcohol.

Making a Complete Set of Tissue Samples

My original complete set was made from a frozen fish. As it thawed, different organs were cut away and small pieces placed in bottles for preserving in filtered water and grain alcohol. In this way, organs not available from the grocery store could be obtained. The piece of intestine closest to the anus corresponds to our colon, the part closest to the stomach corresponds to our duodenum. The 2 layers of the stomach and different layers of the eye, the optic nerve and spinal cord were obtained this way.

Another complete set of tissue samples were obtained from a freshly killed steer at a slaughter house. In this way the 4 chambers of the heart were obtained, the lung, trachea, aorta, vein, pancreas, and so forth.

Purchasing a Complete Set of Tissue Samples

Slides of tissues, unstained or stained in a variety of ways for microscope study give identical results to the preparations made by yourself in the ways already described. This fact opens the entire catalog of tissue types for your further study. See *Sources* for places that supply them.

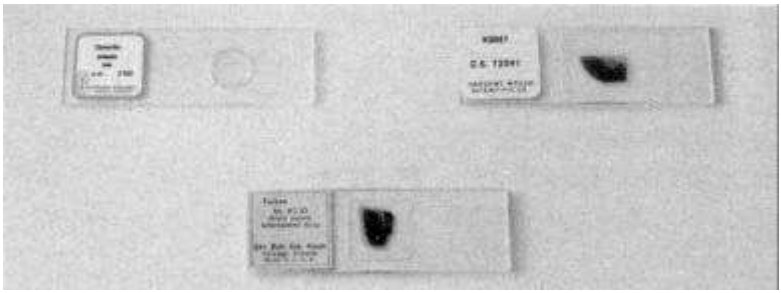

Fig. 82 Some purchased parasite and tissue slides.

You now have a set of organ samples, either fresh, frozen, preserved or on slides. You also have a set of test substances, whether chemical compounds, or elements, or products. Your goal is to search in your own organs and body tissues for the substances that may be robbing you of health.

> Keeping yourself healthy will soon be an easy, daily routine.

Body Fluid Specimens

Each of these fluids should be prepared by putting about ¼ tsp. in a ½oz amber glass bottle. Add about 2 tsp. filtered water and ¼ tsp. grain alcohol for preservation. Undiluted specimens do not work for reasons that are technical and beyond the scope of this book. It is important *not* to shake the specimen, but to mix gently.

Urine. It is desired to have a pure, uninfected urine sample as a tissue specimen. Since this cannot be proved with certainty, obtain several urine samples from different persons

whom you believe to be healthy and make several test specimens in order to compare results. Label your specimens Urine A (child), Urine B (woman), Urine C (mine), and so forth.

Semen. A sample from a condom is adequate. Aged specimens (sent by mail, unpreserved and unrefrigerated) work well also. Use one to ten drops or scrape a small amount with a plastic knife.

Blood. One to ten drops of blood should be used. Clotted or chemically treated blood is satisfactory. A blood smear on a slide is very convenient.

Milk. Cow's milk is too polluted with parasites to be useful. Electronically, a dead specimen is equivalent to a live specimen, so that pasteurization of the milk does not help. A human milk specimen is preferred.

Saliva. Use your own, if you have deparasitized yourself and test negative to various fluke stages. Otherwise find a well friend or child.

Specifying a tissue is the most powerful investigative technique in your arsenal. Any of your tissue samples can be tested for any of your toxic substances.

You Can Now Test Three Different Ways!

When you test with a substance on one plate and nothing on the other, you are searching your entire body for that substance. Such a test is not very sensitive.

By putting a tissue sample on the other plate you are testing for the substance specifically in that tissue, and this is much more sensitive. The tissue need not be the white blood cells. To find mercury in your kidneys you would use a mercury sample on one plate, and a kidney sample on the other. The technique is the same as when you use white blood cells.

If you put a substance on each plate, a resonating circuit means the two samples have something in common. For example, if you have mercury on one plate and some dental floss on the other, a positive result indicates mercury in the floss.

Lesson Five

Purpose: To watch substances travel through your body.

Materials: Prepare a pint of brown sugar solution (white sugar has propyl alcohol pollution) using filtered water. Use about 1 tsp. brown sugar, 1/8 tsp. vitamin C (to detoxify sorghum mold), and a pint of filtered water. Do not shake it; gently mix. Make a sample bottle by pouring about ½inch into a clean used vitamin bottle. Rinse and dry the outside of the sample bottle. Finally wash your hands with plain water.

Method:

1. Test your skin for the presence of brown sugar, using the newly made sample bottle and your skin specimen. It should not be there (resonate) yet.
2. Prepare a paper applicator by tearing the corner from a white unfragranced paper towel. Fold it to make a wick.
3. Dip the paper wick in the pint of sugar water and apply it to the skin of your inner arm where you can rub freely.

Rub it in vigorously for about 10 seconds (otherwise it takes minutes to absorb). Leave the shredded wick on the skin and tape it down with a piece of clear tape about 4 inches long (this increases the time you have to work). Quickly wash your fingers.

4. Place your skin tissue specimen on one plate and the sugar specimen bottle on the other plate.
5. Probe for resonance every 5 seconds. As soon as you hear resonance, implying that the skin has absorbed the sugar solution (which may take a full minute), replace the skin specimen with one of liver and listen for resonance again. There should be none, yet.
6. Alternate between the skin and liver. Soon the skin will be clear and the liver will resonate. Also check the pancreas and muscles to see how quickly sugar arrives there.
7. Check white blood cells and kidneys. It should not appear here (unless it is polluted with a toxin).
8. After five to ten minutes the sugar will be gone from all of these tissues and your experiment is ended. Wash your arm with plain water.

Notice that you have only a few minutes to get all your testing done after the skin has absorbed the test substances.

Lesson Six

Purpose: To verify the propyl alcohol and benzene lists.

Method: We will use the Syncrometer to test for a toxin in a product. Assemble the products named in the propyl alcohol list (page 335) and benzene list (page 354)...as many as you can find. Also make sample bottles of benzene and propyl alcohol.

1. Place the propyl alcohol test substance on one plate and your products, in turn, on the other.

2. Listen to the current with only one of the plates in the circuit. Then listen with both plates in (the test plate switch ON). This method can detect one part per quadrillion in concentration. It is not as sensitive as the skin test (Lesson Five).
3. Repeat, with the benzene test substance.

Even tiny amounts of solvents are toxic! They must not be consumed or be left in our environment.

I have found that too many unsuspected products test positive to benzene. This is such a global tragedy that people must protect themselves by using their own tests. Rather than assurances, regulatory agencies should provide the consumer with cheap and simple tests (dip sticks and papers so we need not lug our Syncrometers around). Even if some test should fail, not all tests would fail to find an important pollutant like benzene. It would come to public attention much faster than the present debacle has.

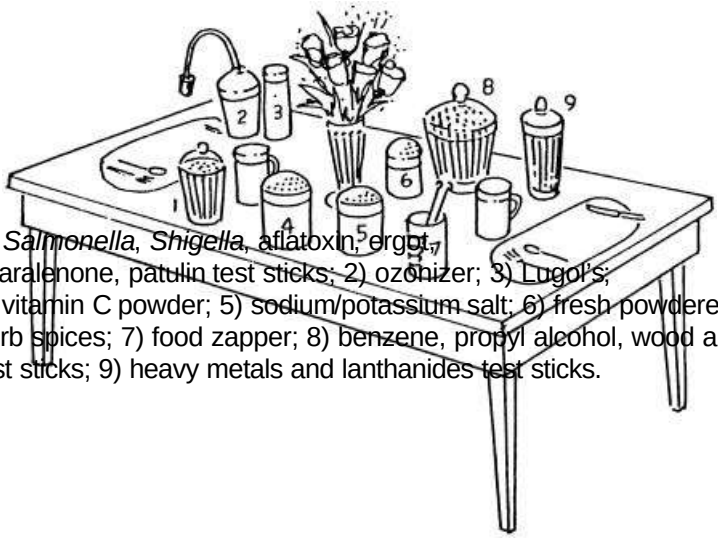

1) *Salmonella*, *Shigella*, aflatoxin, ergot, zearalenone, patulin test sticks; 2) ozonizer; 3) Lugol's; 4) vitamin C powder; 5) sodium/potassium salt; 6) fresh powdered herb spices; 7) food zapper; 8) benzene, propyl alcohol, wood alcohol test sticks; 9) heavy metals and lanthanides test sticks.

Fig. 83 Table of the future.

Lesson Seven

Purpose: To test for the presence of aluminum in your brain and your foods.

Materials: An aluminum measuring spoon, a tsp. of free flowing aluminized salt, a square inch of aluminum foil, a package of pork brain from the grocery store, kept frozen. (Other animal sources will do). Or a stained slide of cerebrum, cerebellum or other brain tissue.

Method:

1. Cut a piece of brain tissue (about 1 tsp.) and place in a plastic bag.
2. Place the aluminum samples in separate plastic bags. Add filtered water to each, about 1 tbs. Keep all surfaces and your hands meticulously clean (do not use soap).
3. Place the aluminum sample on one plate and the brain sample on the other plate.
4. Probe for resonance. If the circuit resonates <u>you</u> have aluminum in <u>your</u> brain.
5. If your aluminum specimen actually has cadmium or copper in it, you are <u>also</u> testing for these in your brain. Repeat the aluminum test with other aluminum objects. If they <u>all</u> resonate, you <u>very</u>, <u>very</u> <u>likely</u> have aluminum in your brain. If you can, test yourself to cadmium and copper, separately. If you don't have these in your brain, the aluminum test result is even more likely to be correct.
6. Of course, it would be desirable to have absolute certainty about this. To achieve this, purchase pure aluminum or an Atomic Absorption Standard. These are available from chemical supply companies.

If you do have aluminum in your brain, where is it coming from?

7. Leave your purest aluminum test substance on one plate, and replace the brain sample with these items, testing them one at a time. Remember to rest after each positive result.
   - a teaspoon of cottage cheese or yogurt taken from the top of a container of a foil-capped variety
   - a piece of cream cheese or butter that was wrapped in foil
   - a chip of bar soap or a bit of hand lotion
   - a piece of cake or rolls baked in an aluminum pan
   - a piece of turkey skin or hot dish that was covered with aluminum foil
   - anything baked with baking powder
   - a carbonated beverage from an aluminum can

Alternative Lesson:

To test for dental metal in your tissues. Use a piece of amalgam from an old tooth filling. This tests for the rest of the alloys in amalgam fillings as well as mercury. If you can't get a piece of mercury amalgam, use a mercury thermometer (don't break it, just put the bulb on the plate). Choose tissues like kidney, nerves, brain, liver, in addition to white blood cells.

I have never dissected human tissues and subjected them to confirmatory laboratory tests. It seems reasonable that because skin and tongue are directly provable, that other tissues work similarly.

Testing the Air

Fine particles and gas molecules that are in the air stick to the dust and eventually fall down onto the table, kitchen counter, and other places. Every night a film of dust accumu-

lates, even though you can't see it. To test for air pollutants, gather some dust. Wipe the kitchen table and counter with a dampened piece of paper towel, two inches by two inches square. Place it in a resealable baggie. Do not get old dust, like from the top of the refrigerator or back shelves, because it does not represent the current air quality.

Testing Someone Else

Seat the person comfortably with their hand resting near you. Choose the first knuckle from the middle or first finger just like you do for yourself. Since you are touching this person, you are putting yourself in the circuit with the subject.

To exclude yourself, you need to add inductance to yourself. A coil of about 10 microhenrys, worn next to the skin, works well and is easily made. Obtain insulated wire and wrap 24 turns around a ball point pen (or something about that size), closely spaced. Cut the ends and tape them down securely. Keep it in a plastic bag, even when in your pocket. A commercial inductance of 4.7 microhenrys, worn touching your skin also works well. It can be worn on a string necklace. (Remember to remove the necklace when testing yourself.) The inductance acts as an RF (radio frequency) choke, limiting the alternating current that can flow through you while testing another person.

Test your inductor in this way. Repeat Lesson One with the coil next to your body. No resonance, even to SALT #1, should occur. If it does, make the coil bigger. Remove the inductor when you are not testing others.

Lesson Eight

Purpose: To detect aluminum in the brain of another person.
Materials: same as previous lesson, you wear the inductor.

Method:

1. Place the aluminum sample on one plate and the brain sample on the other plate.
2. Give the other person the handhold. You use the probe. Hold their finger steady in yours.
3. Probe the other person for resonance. The first probe is with only one plate in the circuit. The second is with both plates in the circuit. Resonance implies there is aluminum in the person's brain.

Saliva Testing

This may become your most useful test. The saliva has in it a bit of almost everything toxic that is in you. But it is not the first tissue to carry the HIV virus or a bit of a tapeworm stage. Nevertheless, *Salmonella* in your liver, mercury in your kidneys, aluminum in the brain all show up in the saliva, too. And saliva can be sent by mail or stored in the refrigerator. It should be frozen for long storage to prevent mold invasion. Or it may have grain alcohol added to preserve it. This test is not as sensitive as having the person present in the circuit, though.

To make a saliva specimen, place a two inch square piece of white, unfragranced paper towel (tear, don't cut) in a lightweight resealable baggy. Hold the open baggy near your mouth. Don't touch the paper towel with your fingers. Drool or spit onto the paper towel until half of it is damp. Zip it shut. Before testing, add enough filtered water to dampen the whole piece of paper.

Lesson Nine

Purpose: To search for shingles or *Herpes*.

Materials: A saliva specimen from the person being tested; they may be thousands of miles away. Also a specimen of the

virus. This can be obtained from someone else's lesions—one droplet is enough, picked up on a bit of paper towel. The whole thing, towel and all, can be pushed into a glass bottle for preserving. Water and alcohol should be added. It can also be put on a slide, *Herpes, homemade*. A homeopathic preparation of the virus does not give accurate results for this kind of testing, due to the additional frequency imposed on it by potentizing. (However, homeopathic preparations can be used if the potency matches the tissue frequency where it resides. Hopefully, some way of using homeopathic sources will soon be found.)

Method: Place the saliva specimen in its unopened baggy on one plate. You may wish to open it briefly, though, to add enough filtered water to wet all the paper and add ¼ tsp. grain alcohol to sterilize or preserve it.

Place the virus specimen on the other plate and test as usual (like Lesson Six). A positive result means the person has active *Herpes*.

The main disadvantage of saliva testing is that you do not know which tissue has the pathogen or the toxin. You can only conclude that it is present. Usually this is enough information to carry out a corrective program.

Surrogate Testing

Although saliva testing is so easy, it is also possible to use an adult as a surrogate when testing a baby or pet. The pet or baby is held on the lap of the surrogate. A large pet may sit in front of the person. The handhold is held by the surrogate and pressed firmly against the body of the baby or pet. It can be laid flat against the arm, body or leg of a baby and held in place firmly by the whole hand of the adult. The paper covering should be wet. For a pet, the end is held firmly pressed against the skin, such as between the front legs or on the belly. The other hand of the adult is used for testing in the usual way. The

adult must wear an inductor for surrogate testing as well as you, tester.

An ill or bedridden person may be tested without inconvenience or stress. He or she rests their whole hand on the skin of your leg, just above the knee. A wet piece of paper towel, about 4 inches by 4 inches is placed on your leg, to make better contact. You must use an inductor for yourself with this method. You may now proceed to probe on your hand instead of the ill person's.

Lesson Ten

Purpose: To test for cancer.

Materials: Ortho-phospho-tyrosine. Here are four ways to obtain some:

1. Order a pure sample from a chemical company (see *Sources*). Place a few milligrams (it need not be weighed) in a small glass bottle, add 2 tsp. filtered water and ¼ tsp. grain alcohol.
2. All persons with cancer have ortho-phospho-tyrosine in their urine as well as in the cancerous tissue. It is seldom found in other body fluids. Obtain a urine specimen from a friend who has active cancer. Freeze it if you can't prepare it immediately. Keep such specimens well marked in an additional sealed plastic bag. Persons who have recently been treated clinically for cancer are much less likely to have ortho-phospho-tyrosine in the urine.

   Urine cannot be considered a chemical in the same way as a sugar or salt solution. Urine is a tissue and has its own resonant frequency as do our other tissues. If combined with another tissue on the test plates, it will not resonate as if a solution of pure ortho-phospho-tyrosine were used. To use urine as an ortho-phospho-tyrosine specimen, you must:

a) Pour a few drops of urine into your specimen bottle
b) Add about 2 tsp. of filtered water
c) Add a few drops of grain alcohol

Gently mix, do not shake. Rinse and dry the outside of the bottle. Label it "urine/cancer".

3. Cancer victims also have other growth factors being produced in their bodies. These are the same as can be found in mother's milk—for example, epidermal growth factor and insulin-like growth factor. Obtain a sample of mother's milk and use it to make another test substance for cancer. A few drops is enough.
4. There is still another way to prepare an ortho-phospho-tyrosine test sample. Common snails from a fish tank or outdoor snails are the natural hosts for *Fasciolopsis buskii* (human intestinal fluke) stages. The stages will produce ortho-phospho-tyrosine when the snails are fed fish food polluted with propyl alcohol. Over half the fish food cans I purchased had propyl alcohol pollution. Buy several brands of fish food. Test them for propyl alcohol and benzene. Obtain some snails, put them in a tank, feed them propyl alcohol polluted fish food. (Feed a separate group of snails benzene polluted fish food to obtain samples of HIV.) After two days put each snail in a zipped plastic bag, and test them individually against someone diagnosed with cancer or their saliva. The snails that the person tests positive to have ortho-phospho-tyrosine. Put these snails in the freezer to kill them humanely, then crush them and place in a specimen bottle with 50% grain alcohol to preserve. The bottles can be kept sealed and at room temperature.

   Similarly, your benzene snails can be tested against someone known to be HIV positive. Any snails that test positive can be used to prepare an HIV test specimen in the same way. The fish food must be tested for both benzene

and propyl alcohol pollution, and separated appropriately, or you run the risk of making specimens that have both ortho-phospho-tyrosine and HIV.

Method:

1. Test for cancer by placing the test sample you just made (any of the four) on one plate and a white blood cell sample on the other plate.
2. If you resonate with both samples in the circuit you have cancer. Immediately, search for your cancer in your breast, prostate, skin, lungs, colon, and so forth.
3. To be more certain, test yourself to the other kinds of test samples. You should not resonate.

As you know by now, you can confirm the cancer by testing yourself to propyl alcohol and the human intestinal fluke in the liver. You should eliminate propyl alcohol from use, and zap all parasites. Keep testing yourself for cancer until it is gone. It should take less than one hour. Also continue to test yourself for propyl alcohol and the intestinal fluke in the white blood cells; make sure they are gone. Also test yourself for aflatoxin and freon.

Lesson Eleven

Purpose: To test for HIV.

Materials: Purchase a few milligrams of Protein 24 antigen (a piece of the HIV virus core) or the complete HIV virus on a slide (see *Sources*). You may use the vial unopened if only one test specimen is needed. To make more specimens, use about 1 milligram per ½ounce bottle. Add 2 tsp. filtered water and ¼ tsp. grain alcohol. Or prepare an HIV specimen from snails as described in the previous Lesson.

Method: Search in the thymus (throat sweet breads), vagina and penis for the virus because that is where it will reside al-

most exclusively for the first year or two. If you don't have those tissue specimens, you could search in urine, blood, saliva, or white blood cells, but only a positive result can be trusted. Also search for the human intestinal fluke and benzene in the thymus. Of course, a positive test in these tissues is very significant. If you are positive, zap parasites immediately. You should test negative in less than an hour. Remove benzene polluted items from your lifestyle. Also test yourself to several varieties of popcorn, brown rice, and corn chips as an indication of zearalenone, which must be eliminated in order to get well. Follow up on yourself every few days to be sure your new found health is continuing. Test yourself for freon.

Lesson Twelve

Purpose: To test for diseases of all kinds.

Materials: Use slides and cultures of disease organisms. Homemade preparations of strep throat, acute mononucleosis, thrush (*Candida*), chicken pox, *Herpes* 1 and 2, eczema, shingles, warts, measles, yeast, fungus, rashes, colds, sore throats, sinus problems, tobacco virus, and so forth can all be made by swabbing or scraping the affected part. A plastic spoon or bit of paper towel works well. Put a small bit on a slide. Add a drop of balsam and a cover slip. Or put the towel in a bottle, add water and alcohol as described previously. Microscope slides can greatly expand your test set (see *Sources*).

Method: Test yourself for a variety of diseases, using your white blood cell specimen first. Then search in organs like the liver, pancreas, spleen. Notice how many of these common illnesses don't "go away" at all. They are alive and well in some organ. They are merely not making you sick!

Lesson Thirteen

To test for AIDS.

Materials: Benzene sample, slides of tissue samples like thymus, liver, pancreas, penis, and vagina. Also a collection of disease specimens such as the ones used in the previous lesson.

Method: Search in the thymus for benzene. If it is positive throughout the day, you are at risk for developing AIDS, although you may not be ill. Search other tissues for benzene. The more tissues with benzene in them the more serious the situation. Immediately search all your body products and foods for benzene.

Stay off benzene polluted items forever.

Tally up the diseases you tested positive for in Lesson Twelve. Test at least ten. If you had more than half positive you already have AIDS. (50% is my standard, you may set your own; an ideal standard for defining a healthy person should be 0% positive.)

Lesson Fourteen

Purpose: To test for aflatoxin.

Materials: Do not try to purchase a pure sample of aflatoxin; it is one of the most potent carcinogens known. Having it on hand would constitute unnecessary hazard, even though the bottle would never need to be opened. Simply make specimens of beer, moldy bread, apple cider vinegar, and any kind of peanuts using a very small amount and adding filtered water and grain alcohol as usual.

Method: Test yourself for these. If you have all of them in your white blood cells and the liver then you very, very proba-

bly have aflatoxin built up. Next, test your daily foods for their presence in your white blood cells. Those that test positive must be further tested for aflatoxin. Notice the effect of vitamin C on aflatoxin in your liver. Find a time when your liver is positive to aflatoxin (eat a few roasted peanuts from a health food store and wait ten minutes). Take 1 gram vitamin C in a glass of water. Check yourself for aflatoxin every five minutes. Does it clear? If not, take 5 or 10 grams vitamin C. How long does it take?

Lesson Fifteen

Purpose: To test for parasites.

Method: If you test positive to your pet's saliva, you have something in common–a parasite, no doubt. You must search your muscles and liver for these, not saliva or white blood cells, because they are seldom seen in these. Zap yourself for parasites until you no longer test positive to your pets' saliva.

Tapeworms and tapeworm stages can not (and should not) be killed with a regular frequency generator. Each segment, and probably each scolex in a cysticercus has its own frequency and might disperse if your generator misses it. Only zapping kills all and is safe for tapeworms.

Be sure to treat your pet on a daily basis with the pet parasite program.

Lesson Sixteen

Purpose: To test for fluke disease.

A small number of intestinal flukes resident in the intestine may not give you any noticeable symptoms. Similarly, sheep liver flukes resident in the liver and pancreatic flukes in the pancreas may not cause noticeable symptoms. Their eggs are shed through the organ ducts to the intestine and out with the bowel movement. They hatch and go through various stages of

development outdoors and in other animals. But if you become the total host so that various stages are developing in your organs, you have what I term *fluke disease*. I have found that cancer, HIV, diabetes, endometriosis, Hodgkin's disease, Alzheimer's disease, lupus, MS and "universal allergy syndrome" are examples of fluke disease.

> You can test for fluke disease in two ways: electronically and by microscope observation.

Materials: Cultures or slides of flukes and fluke stages from a biological supply company (see *Sources*) including eggs, miracidia, redia, cercaria, metacercaria. Body fluid specimens to help you locate them for observation under a microscope.

Method: Test for fluke stages in your white blood cells first. If you have any fluke stages in your white blood cells you may wish to see them with your own eyes. To do this, you must first locate them. Place your body fluid samples on one plate, your parasite stages on the other plate, and test for as many as you were able to procure, besides adults. After finding a stage electronically, you stand a better chance of finding it physically with a microscope.

Lesson Seventeen

Purpose: To see how sensitive your measurements can be. (How much of a substance must be present for you to get a positive result?)

Materials: filtered water, salt, glass cup measure, 13 new glass bottles that hold at least ¼ cup, 14 new plastic teaspoons, Your skin tissue sample, paper towel.

Method: Some of the best measurement systems available today are immunological (such as an ELISA assay) and can de-

tect as little as 100 fg/ml (femtograms per milliliter). A milliliter is about as big as a pea, and a femtogram is 1/1,000,000,000,000,000th (10^{-15}) of a gram!

1. Rinse the glass cup measure with filtered water and put one half teaspoon of table salt in it. Fill to one cup, stirring with a plastic spoon. What concentration is this? A teaspoon is about 5 grams, a cup is about 230 ml (milliliters), therefore the starting concentration is about 2½(2.5) gm per 230 ml, or .01 gm/ml (we will discuss the amount of error later).
2. Label one clean plastic spoon "water" and use it to put nine spoonfuls of filtered water in a clean glass bottle. Use another plastic spoon to transfer one spoonful of the .01 gm/ml salt solution in the cup measure to the glass bottle, stir, then discard the spoon. The glass bottle now has a 1 in 10 dilution, and its concentration is one tenth the original, or .001 gm/ml.
3. Use the "water" spoon to put nine spoonfuls of filtered water in bottle #2. Use a new spoon to transfer a spoonful of salt solution from bottle #1 to bottle #2 and stir briefly (never shake). Label bottle #2 ".0001 gm/ml".
4. Repeat with remaining bottles. Bottle #13 would therefore be labeled ".000000000000001 gm/ml." This is 10^{-15} gm/ml, or 1 femtogram/ml.
5. Do the skin test with water from bottle #13 as in Lesson Five. If you can detect this, you are one hundred times as sensitive as an ELISA assay (and you should make a bottle #14 and continue if you are curious how good your sensitivity can get). If you can not, try to detect water from bottle #12 (ten times as sensitive as ELISA). Continue until you reach a bottle you can detect.

Calculate the error for your experiment by assuming you could be off by as much as 10% when measuring the salt and

water adding up to 20% error in each of the 13 dilutions. This is a total error in bottle #13 of 280%, or at most a factor of 3. So bottle #13 could be anywhere from 0.33 to 3 femtogram/ml. If you can detect water from bottle #13, you are definitely more sensitive then an ELISA, in spite of your crude utensils and inexpensive equipment! Note that the starting error of using 2.5 gm instead of 2.3 gm only adds another 10% error.

If you want to calculate how many salt molecules you can detect, select the concentration at the limit of your detection, and put 2 drops on a square inch of paper towel and rub into your skin. Assume one drop can be absorbed. If you can detect water from bottle #13, you have detected 510,000 molecules (10^{-15} fg/ml divided by 58.5 gm/M multiplied by 6.02×10^{23} molecules/M divided by 20 drops/ml). Water in bottle #12 would therefore have 10 times as many molecules in one drop, and so forth. Even if your error is as much as a factor of 2 (100%), you can still get a good idea of what you can measure.

Atomic absorption standards start at exact concentrations; it is easy to make a more exact dilution series with them. When testing for iridium chloride by this skin test method, I was able to detect 3025 molecules!

Troubleshooting:

Always extend your set until you get a negative result (this should happen by at least bottle #18). If you always "detect" salt, then you shook the bottle!

Never try to reuse a bottle if you spill when pouring into it. Get another new bottle.

Sensitivity of Pollutant-In-Product Testing

Get some slides of *Salmonellas* and *Shigellas* and find some milk that tests positive to at least one. Make a dilution series of the milk up to bottle #14, being careful not to shake the bottles. Start with 2 drops of milk in bottle #1. Use an eye dropper to

deliver 2 drops to subsequent bottles. Begin testing at bottle #14, using the slide that tested positive. You will learn to search by frequency later. My sensitivity was routinely around bottle #12, for a variety of pathogens. It was the same for toxic elements starting with standard solutions, about 1000 μg/ml, showing this method is less sensitive than skin testing.

Microscopy Lesson

Purpose: To *observe* fluke stages in saliva and urine with a microscope.

Materials:

a. A low power microscope. High power is not needed. A total of 100x magnification is satisfactory for the four common flukes, *Fasciolopsis*, *sheep liver fluke*, *human liver fluke* and *pancreatic fluke*.
b. Glass slides and coverslips.
c. A disposable eye dropper.

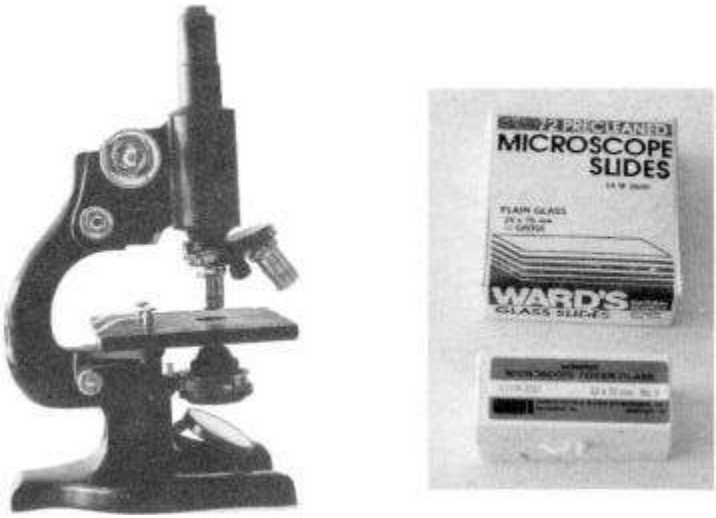

Fig. 84 Microscope, slides and coverslips.

d. For sanitation purposes (wiping table tops, slides, microscope and your hands) a 50% to 70% alcohol solution (not rubbing alcohol!) is best. Dilute 95% grain alcohol 7 parts alcohol plus 3 parts water. Vodka or 76% grain alcohol can be used undiluted.
e. Formaldehyde, 20%. Formaldehyde 37% is commonly available at pharmacies. Dilute this with equal parts of filtered water to get 18½%, which is close enough to 20%, for the purpose of "fixing" (killing) the specimens. Store in a glass bottle in the garage, away from sunlight. Label. Specimens that are fixed properly do not lose their life-like appearance.
f Iodine solution. This is only useful for the urine specimens. Lugol's iodine and tincture of iodine are both useful. Ask a pharmacist to prepare *Lugol's Iodine Solution* for you, as follows:
    - 44 grams (1½oz) iodine crystals
    - 88 grams (3 oz) potassium iodide crystals

    Dissolve both in 1 liter (quart) filtered water. This may take a day of frequent shaking.

Method for saliva:

1. Pour the 20% formaldehyde into a small amber bottle or other receptacle to a depth of about 1/8 inch. Keep tightly closed.
2. The person to be tested is asked to salivate into the bottle so the organisms are immediately "fixed" without undergoing cooling first. The total volume should be about double the original amount of formaldehyde used. Make a mark on the container so the subject knows how much to produce. The resultant concentration of formaldehyde will be about 10%.
3. Shake the bottle a few times. Set it aside for 24 hours to settle (less if testing is urgent).

4. With a dropper, draw up some of the bottom settlings. Put one drop on a slide and apply a coverslip.
5. View under low power of microscope. Compare objects you observe with specimens obtained on slides from biological supply companies.

Note: Persons with HIV and moderate AIDS will show about one to ten parasite stages per slide. It requires several hours of searching. Persons with HIV and severe AIDS show 10 or more fluke stages per slide; this makes the task of finding them much easier. Persons with terminal untreated cancer have many more fluke stages than relatively well persons.

Method for urine:

1. Prepare bottles of formaldehyde fixative ahead of time. Put about ¼ to ½ inch of 20% formaldehyde in each. Keep tightly closed.
2. Add freshly voided[36] urine from cancer or HIV sufferers to the formaldehyde in approximately equal amounts, resulting in a 10% formaldehyde solution. Shake immediately. Let settle several hours. The sediment has a higher number of fluke stages. Cancer victims with cervical or prostate cancer will show higher numbers of stages in urine than other cancer types.
3. Staining the slide is optional. It helps to outline fluke stages slightly. Prepare Lugol's solution as described above.

   Slides may be stained in either of these two ways:

   - Put a drop of "fixed" urine on a slide. Add a drop of 50% Lugol's (dilute 1:1 with filtered water). Apply coverslip.

[36] Urine that has cooled even slightly below body temperature does not show *miracidia* and *redia* in their original shapes.

- Put a drop of "fixed" urine on a slide. Apply coverslip. Add 1 to 3 drops of 50% Lugol's to edge of coverslip and allow it to seep in.

Note: persons who have been treated for cancer or HIV using any of the known drugs may show only 1 to 2 fluke parasite stages per drop of saliva or urine. For this reason, you may need to search through 20 or more slides to find flukes. Very ill persons may show up to 10 parasites per drop (slide).

Taking Pictures Of What You See

You may be unsure of what you see even if you have the microscope slides of labeled flukes and their stages to study and compare. In real life, they vary so much in shape and size that absolute identification is difficult without experience. Unfortunately in a few hours, just as you are getting proficient, your magnificent specimens will be drying out and unfit for observation. To preserve them longer you can seal the edges by painting around the coverslip with fingernail clear enamel. Or dribble hot sealing wax along the edges and then place them in sealed plastic bags (one per bag). Melt sealing wax in a metal jar lid. Make an applicator from a piece of coat hanger wire bent in the shape of a small square to fit around the coverslip and a handle.

Or take photographs. To take pictures of what you see under the microscope you will need a photomicrographic camera, which costs $200.00 and up (see *Sources*). It is easy to use. Remember to label your pictures so you know which slide they came from.

Even photographs do not scientifically prove identity of parasite stages, but it is very good evidence. Proof would require that the saliva or urine sample could be cultured and seen to produce the known parasite stages.

Using A Frequency Generator

Frequency generators come in all sizes and costs and capabilities. If you can purchase one that reads out the frequency for you in numbers (digital type) and lets you produce a fraction of a kilohertz by turning a dial, it meets your most elementary needs. It should also be possible to set it on positive offset (100% positive) and still give you 5 volts. Then it can be used as a zapper. You should also be able to select a sine wave or square wave.

The advantages of having a frequency generator are that you can do your own diagnosing. You can find, in a few minutes:

1. Which invaders you have by dialing in to their frequencies.
2. At what frequencies you are broadcasting to the world.
3. What frequencies are used by other living things.

The Theory

Every living animal and every cell type produces its own frequencies and responds to these frequencies as well. We may speak of frequencies but we really mean waves, waves of energy. All waves have a frequency associated with them, so it's not really misleading to say frequencies when we really mean waves.

When the animal is alive it produces them, when it is dead it still responds to some of them. It is like the opera singer and the glass goblet. The opera singer produces frequencies in the air. The goblet responds to them because of its structure, not because it's alive. The goblet "picks up" on that particular frequency of sound because its own "resonant" frequency is exactly the same. If the singer sings loud enough the goblet

shatters from the vibrations set up in it. An identical goblet, made of plastic, would not have the same resonant frequency.

There is not merely a structural and chemical difference between the living and non living. Living things are transmitting energy of some unique kind. And with your simple device, you will be able to trap this energy. And measure its exact frequency. This is not the same as understanding its makeup and source. We must leave that to others. But we can observe and use our observations to track down bacteria and other parasites. We can track down pollutants. We can measure our health quantitatively and perhaps in the future predict life expectancy.

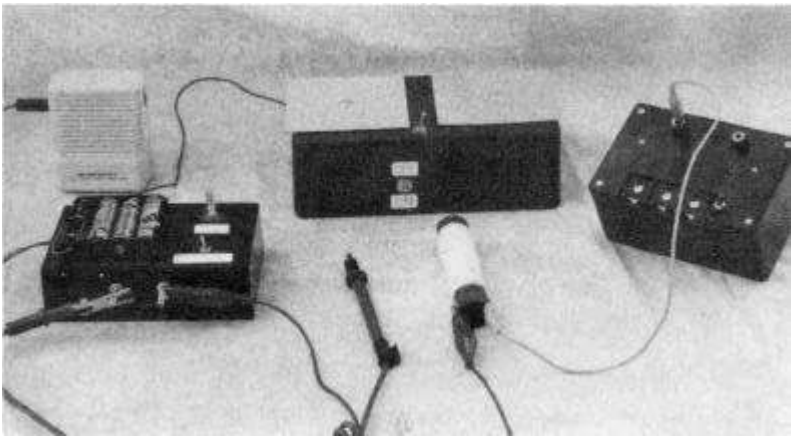

The Syncrometer at left is attached to the handhold. The frequency generator at right is also clipped to the handhold.

Fig. 85 Setup for finding resonant frequencies.

The Syncrometer traps the frequencies that match the ones in the material on the test plates and delivers them to an audio speaker in a range that you are able to hear. **Instead of test tissues or pathogens, we are now going to use pure test frequencies!** Remarkably, few things have overlapping

frequencies, making this technique extremely useful for identification, even without a specimen!

Lesson Eighteen

Purpose: To search for the intestinal fluke in your body by listening to its broadcast frequency at 434 KHz.

Method: Turn on the frequency generator, select a frequency a short distance above the one you are interested in, like 438 KHz, turn the voltage (amplitude) down to less than one volt. Select sine waves. The lead coming from the frequency generator will have two connections, usually red and black (ground). We will not use the black (ground), just tape it out of the way. Pick up the handhold and probe in the usual way. Attach the red lead coming from the generator to your handhold. This makes two wires attached to your handhold. Although there is nothing on the test plates, they must be connected as usual with the switch at OFF (one plate is still ON).

Turn the Syncrometer ON. Probe yourself as usual. Your body's waves are being sent to the capacitor (plate) in the test plate box. The frequency from the Syncrometer is sent there, too. And now the 438 KHz waves from the generator are being sent there as well. Three different frequencies are mingling on the plate! If the two from your body and the generator are the same, the circuit will oscillate, and you will hear resonance. Turn the generator to 437 and probe again. Next, 436.

Sometimes, you can hear the resonance start to build. Continue on.

Next try 435. Then 434.

If your body is emitting a frequency of 434 KHz (coming from a live intestinal fluke inside you) it will be reinforced by the generator's 434 KHz. The reinforcement will put oscillations or resonance in the circuit, the same as you are accustomed to hearing with the Syncrometer. If there was none, you don't have

the intestinal fluke anywhere in your body. Confirm this by starting at 430 KHz and working your way up.

If you hear resonance, you do have it. You may wish to verify this independently using a prepared slide of the fluke. Kill your flukes immediately as described in the next lesson.

Lesson Nineteen

Purpose: Killing the intestinal fluke with a frequency generator.

Materials: A frequency generator, two handholds with alligator clip leads for them.

Method: Wrap a single layer of paper towel over each of the two handholds. Wet them under the tap; squeeze out excess water. Clip them to the red and black wires of the frequency generator. (We use both wires for this purpose.) Dial up 434 KHz. Set the amplitude (voltage) at 10 volts. Grasp the handholds in each hand and hold on for three minutes. That is all. You have killed whatever tiny invader has a resonant frequency the same as the setting on the generator. Remember to zap all the stages, too; see *Pathogen Frequencies*.

If your frequency generator has a **positive offset** capability, you can use it like a zapper, and a single session will kill all pathogens, provided it is 100% offset and can give at least 5 volts at this setting. When using this technique, the generator can be set to any frequency from 2 KHz to 800 KHz, and you should go for 7 minutes. But even a small percentage of negative voltage will ruin this effect and do more harm than good! To be certain your generator is set correctly it would be best to observe the output on an oscilloscope.

Experiment with other voltage settings. Notice that less than one volt is also effective.

Lesson Twenty

Purpose: To find the bandwidth of a small living animal.

Materials: A fly, beetle or other insect, Syncrometer, frequency generator.

Discussion: Persons using a Syncrometer might have already tried putting a small insect on one of the plates. The circuit always resonates when you join the circuit at the handhold and probe. Even the tiniest ant placed in a glass bottle or plastic baggy will resonate the circuit. Unless it is too far away from the plate. If it has climbed up the side you will lose the resonance. At least one foot must be touching the bottom of the bottle. If the animal is dead this ceases. Obviously the living thing is affecting the circuit differently before and after death. Is it some kind of a wave form energy? To find its frequency you must add another frequency that will reinforce or interfere with the frequency already on the plate. Adding the generator frequency does just that.

Method: Use the same method as described in the last Lesson; however for an ant or fly, start at 1,000 KHz and proceed upward in big steps like 10 KHz. Use the right test plate which is controlled by the ON-OFF switch. Always listen to the current with the switch OFF, first, then ON. Move the frequency up and repeat. Continue until you hear resonance. Stop immediately. Rest your skin and go back down to the nonresonant frequency region. Move up in smaller steps this time. Repeat and repeat until you feel sure you know just where the resonance begins. But where does it end?

Start testing well above the suspected range taking big steps downward until you reach a resonant frequency. Rest and repeat until you find the upper limit of resonant frequencies. Record the bandwidth, for example, 1009-1112 KHz.

Lesson Twenty One

Purpose: To see if similar living things interfere with each other when put on the plate together.

Materials: Two identical living insects or very small living things.

Method: Find the broadcast range of each one separately and then together on the plate.

Note: Identical living things do not interfere with each others' frequencies.

Lesson Twenty Two

Purpose: To see if different living things interfere with each other when put on the plate together.

Method: Find the lower and upper end of the broadcast range of two different living things, such as a fly and a beetle or 2 kinds of flies or beetles. Then put them on the plate together. Notice there is no resonance in the accustomed range for either of them. They are interfering with each other on the plate.

Now add the 2 lower ends, then the two upper ends. Also subtract the 2 lower ends, then the two upper ends. For example imagine two insects, one with a spectrum of 1000 to 1090 KHz, the other with a range of 1050 to 1190 KHz. Adding the lower ends gives us 2050 KHz. Subtracting the lower ends gives us 50 KHz. Adding the upper ends gives 2280. Subtracting the upper ends gives 100. Now search for resonance at 50, 100, 2050, 2280 KHz. (These last two may be outside the range of your frequency generator. Choose more primitive life forms which have lower frequency bandwidths to stay within your limit.)

Notice that you hear resonance at exactly these frequencies and not above or below them. This is evidence for modulation of the frequencies: namely fusing them together.

Lesson Twenty Three

Purpose: To find your own bandwidth of emitted frequencies.

Materials: A frequency generator that goes up to 10 MHz. If yours only goes to 2 MHz you can still investigate the lower end of your band.

Method: You do not need to put yourself on the plate, since you are already there by being in the circuit at the handhold. However, if you are measuring someone else, they can simply touch the plate with a finger. Attach the frequency generator to the circuit at the handhold.

Since human adults begin to emit at about 1560 KHz, start searching at 1550, going upward in 1 KHz steps until you hear resonance.

Younger or healthier humans start emitting at a lower frequency and sometimes end at a higher frequency. In other words, they broadcast on a wider band.

Very young infants begin their band at about 1520 KHz. Could you ever regain this ability?

Most adults terminate at 9375 KHz

By eliminating molds from my diet, killing as many parasites and removing as many toxins as I became aware of, I have been able to expand my bandwidth from an initial 1562-9457 KHz in 1990 to 1520-9580 KHz in 1994! I hope this challenges you to accomplish a health improvement reflected in an even broader bandwidth for yourself.

Lesson Twenty Four

Purpose: To find the effect of a variety of things on the lower end of your spectrum, such as body temperature, eating, time of day, rainy weather, feeling sick. Notice that you may not change for weeks at a time, then suddenly see a shrinking of your bandwidth. You may assume you have eaten a mold.

Search for mold frequencies from 75 KHz to 295 KHz. Or test in your liver with mold samples. If this is positive go on a mold free diet—watching carefully for mold in your white blood cells. Even after removing the mold from your diet, so that no molds appear in your white blood cells, notice that your bandwidth does not recover. It regularly takes 2-3 weeks for mine to recover.

Surely, this sheds light on the poisonous effect of eating bad food.

Lesson Twenty Five

Purpose: To find an emission spectrum using a saliva sample.

Materials: A regular frequency generator.

Method: Search for the bottom of the resonant frequency band as in the previous lesson.

You may store it in the refrigerator for a few weeks without seeing a change. After that the band begins to shrink.

Lesson Twenty Six

Purpose: To observe the effect of dying on the bandwidth.

Method: Freeze the insect you tested in Lesson Twenty to kill it humanely. Repeat the search for its bandwidth. Note the bandwidth has become very narrow.

Note the bandwidth also depends on the accuracy of your particular frequency generator.

Lesson Twenty Seven

Purpose: To find unknown invaders of your body.

Method: Start at 900 KHz and proceed down to 77 KHz in 1 KHz steps, to search for all pathogens. If you find a resonating frequency, go to the Pathogen Frequency Chart (page 561) to

identify likely candidates for it. Verify the identity of the invader by using a slide or culture specimen. If your pathogen remains unidentified, add it to the chart. This lets you determine whether the next illness is new or a recurrence of this one. Or just kill it.

Use the frequency generator at one pathogen's frequency. Wait ten minutes and retest all of the ones you found. Only that one will be gone. Now **zap**, wait ten minutes, and test again for all of the ones you found. Notice they are all gone. After one hour, search yet again for the pathogens you had. Any that are back must have come from an internal source not reached by the zapper current, like from the bowel or an abscess.

Lesson Twenty Eight

Purpose: To observe the action of a positive offset frequency on a very small animal. Does the animal die or is it just incapacitated?

Materials: A slug or small earthworm.

Method: Place the small animal in a plastic container like a cottage cheese carton. Add a few tsp. of water to wet the bottom. Attach a metal teaspoon to each of the generator clips. Place them on opposite sides in the carton and fasten with tape. Set the generator to positive offset at a frequency of about 30 KHz and 5 to 10 volts. Experiment with different voltages and compare effectiveness. Measure the time it takes for the animal to seem lifeless. You may try to revive it by keeping it for some time in the presence of food. Retest its emission band.

Lesson Twenty Nine

Purpose: To kill the bacteria in dairy products.

Materials: A glass of regular pasteurized milk, a carton of cottage cheese. A zapper.

Method: Search for *Salmonellas* and *Shigellas* first in the milk and cottage cheese. Search by frequency, using the chart, or with slides of these bacteria. If you don't find any, search different dairy foods until you find some bacteria. Attach metal teaspoons to the red and black leads of the generator. Place them inside the milk glass or cottage cheese carton, across from each other. Secure with masking tape. Attach the zapper. Zap them for 7 minutes. Remove the electrodes and wait 5 minutes. Test again for the same bacteria. They should be gone (but the food is not safe to eat due to the metal released from the teaspoons).

These experiments point to some exciting possibilities. Perhaps water supplies as well as foods and medicines could be sterilized this way. Perhaps sewage could be treated more efficiently, electrically. Best of all, maybe you could protect yourself from unsanitary products. If you do decide to explore this possibility, remember not to put metals in your mouth or food. Nor to use currents greater than 10 milliamps, or for longer than 10 minutes.

There are many commercially available function generators that can meet your needs. Two are shown here.

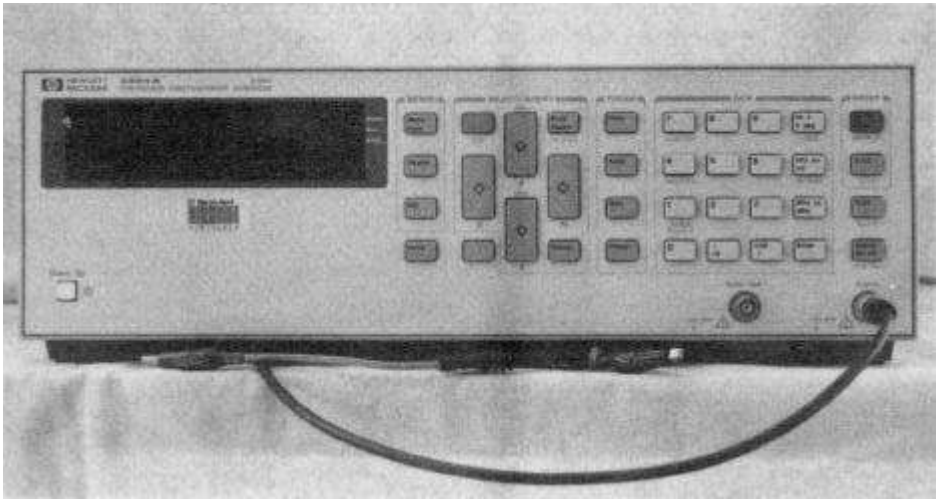

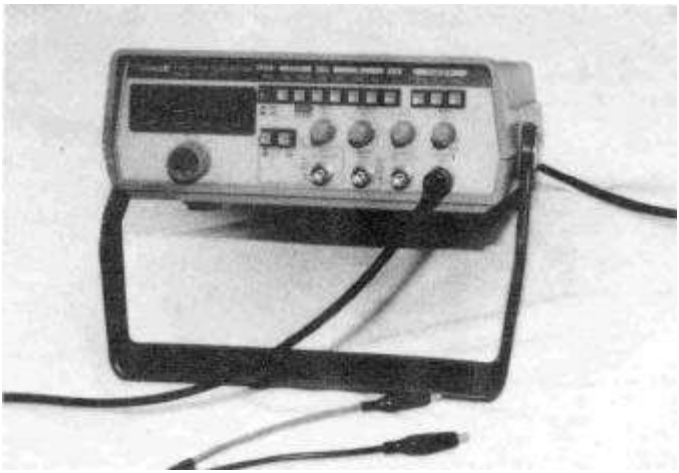

Fig. 86 Function generators.

Recipes

Read old recipe books for the fun and savings of making your own nutritious food. Change the recipes to avoid processed ingredients. Here are some I found:

Beverage Recipes

Anything made in your own juicer is fine. Experiment with new combinations to create different flavorful fruit and vegetable juices. Consider the luxury of preparing gourmet juices which satisfy your own individual palate instead of the mass-produced, polluted varieties sold at grocery stores. Remember to wash all fruit, including citrus before juicing. This removes the ever-present pesticides and common fruit mold.

Lemonade

1 cup fresh lemon juice, 1 cup honey, 1½quarts water. Bring honey and water to a boil if you plan to keep it several days. Then add lemon juice and store in the refrigerator.

All honey and maple syrup should have vitamin C added to it as soon as it arrives from the supermarket. Warm it first; then stir in ¼ tsp. per pint.

Fresh Tomato Juice

Simmer for ½hour: 12 medium-sized raw, ripe tomatoes, ½ cup water, 1 slice onion, 2 ribs celery with leaves, ½bay leaf, 3 sprigs parsley. Strain these ingredients. Season with: 1 tsp. salt

(aluminum-free), ¼ tsp. paprika, ½tsp. honey. Serve thoroughly chilled. Makes about 4 servings.

Fresh Pineapple Juice

Peel a pineapple. Remove all soft spots. Cut it into cubes. Extract the juice by putting the pineapple through a food grinder or a blender. There will be very little pulp. Strain the juice and serve it on ice with sprigs of mint. Makes about 1½cups of juice. Mix the pulp with an equal amount of clover honey and use as topping (kept in freezer) for homemade ice cream (below), pancakes, or yogurt.

Maple Milk Shake

For each milk shake, blend or shake together: 1 glass of milk and 2 tablespoons maple syrup.

Remember, all milk gets boiled.

Yankee Drink

Mix together 1 gal. water, 3 cups honey, ½cup fresh lemon juice or distilled white vinegar, and 1 tsp. ginger.

Hot Vanilla Milk

Add one inch of vanilla bean and one tsp. honey to a glass of milk and bring to a near boil. You may add a pinch of cinnamon or other pure spice. You may even use vanilla extract (see *Sources*).

Red Milk

Equal parts fresh carrot juice (use a juicer) and sterilized milk. Save the carrot pulp for salads and soups.

C-Milk

Milk can absorb a surprising amount of vitamin C powder without curdling or changing its flavor. Try ½tsp. in a glass of cold milk.

My Own Soda Pop

Excellent for stomach distress. Put 1 tsp. citric acid, 2 tbs. vegetable glycerin (see *Sources*), 2 tbs. honey, and 1 lemon, juiced by hand, into a quart jar and fill with cold water. Refrigerate until ready to use. Then add 1 tsp. baking soda (chemically pure only, see *Sources*) and shake a few times, keeping the lid tight. Pour over a few ice cubes. Many variations are possible: other fruit concentrates, made in the blender, can be used along with some lemon juice; for example, 2 blended whole apples (peeled), blended pineapple, orange or grapefruit. Always add a bit of lemon to give it zip. You may add a pinch of ginger or other pure spice.

Note: The amount of sodium in ½tsp. baking soda is .476 grams. If you have heart disease, high blood pressure, or edema, use potassium bicarbonate instead. Ask your doctor what an acceptable amount of sodium or potassium bicarbonate is. I would suggest limiting yourself to one glass of soda pop a day, even if you do not have heart disease.

Another Note: the citric acid kills bacteria, while the carbonation brings relief.

My Own Super C-Pop

An excellent way to get lots of vitamin C into a child and relieve stomach distress at the same time. Squeeze 1 slice of lemon and 1 whole orange into an 8 ounce bottle that has a tight lid. Add 1 tsp. vitamin C powder (ascorbic acid), ¼ tsp. citric acid, and 2 tbs. vegetable glycerin (you may also experiment with honey for sweetness). Fill the bottle to the top with cold water. Then add ½tsp. chemically pure baking soda and close tightly. Shake briefly and serve immediately.

Half And Half

Mix equal parts whipping cream and milk or water. Boil and chill.

Buttermilk-C

Stir 1 tsp. vitamin C powder into a glass of milk. Add a pinch of potassium chloride. Additional seasoning may be pepper and herbs. Stir and enjoy.

Food Recipes

Despite the presence of aflatoxins, benzopyrenes, and solvents in many foods, it is possible to have a delicious and safe diet. Many persons need to gain weight, and with the emphasis in today's society on losing weight, consider yourself lucky in this respect. Help yourself to lots of butter, whipping cream, whole milk, avocados, and olive oil. Make your own preserves and baked goods, including breads. Remember, when you are recovering from a major illness it is essential not to diet to lose weight. You must wait two years after you are recovered to try to lose weight.

Daily Foods

Dairy products should contain at least 2% fat to enable you to absorb the calcium in them.

All milk should be sterilized

by boiling it for 10 seconds. If it makes mucous, you already have a chronic respiratory infection. Try to clear this up.

Change brands every time you shop to prevent the same pollutants from building up in your body.

If frying or cooking with fat, use only olive oil, butter or lard (the BHT and BHA preservatives in lard are OK except for seizure sufferers). Mix them for added flavor in your dishes. Never use margarine, Crisco™ or other hydrogenated fats. Do not cook over flames or grill, even when electric.

Eat lots of **fresh fruits and vegetables**. Wash them off only with cold tap water, not commercial food "wash". Scrub hard with a stiff bristled brush. Then cut away blemishes. Always peel potatoes, apples, and carrots. Modern dirt is full of chemicals and is toxic to you.

Be sure to drink plenty of **plain water** from your cold faucet throughout the day, especially if it is difficult for you to drink it with your meals. If you don't like the taste of your own tap water, try to get it from a friend with newer plumbing. Use a polyethylene (opaque) water jug from a grocery store to transport it. Never drink water that has been run through a water softener or copper plumbing or has traveled through a long plastic hose. Don't drink water that has stood in a container for a day. Dump it and sterilize the container. To further improve flavor and to dechlorinate attach a small faucet filter made of carbon only. Or

buy a filter pitcher (see *Sources*). Don't drink water that has stood in the filter pitcher very long, either.

Because commercial **cold cereals** are very convenient, but have solvents, here are two replacements.

Two Granolas

7 cups rolled oats (old fashioned, not quick)
1 tsp. salt
1 cup wheat germ (fresh, not defatted)
½ cup honey
½ cup sunflower seeds, immaculate quality
½ cup milk (no need to sterilize, it is being baked)
½ cup melted butter
1 cup raisins, rinsed in vitamin C water

Mix dry ingredients together. Mix liquid ingredients and add gradually, while tossing until thoroughly mixed. Place in large ungreased pans and bake in slow (250°) oven. Stir occasionally, baking until brown and dry, usually 1-2 hours. Store in airtight container in freezer.

6 cups rolled oats
½ cup raw wheat germ
1 cup sesame seeds
1 cup sunflower seeds (raw, unsalted)
1 tsp. cinnamon
½ cup melted butter
½ cup honey

Preheat oven to 250°. Toss all ingredients in mixing bowl. Spread thinly on a baking sheet and bake 20-25 minutes. Stir often in order to brown evenly. When golden, remove and let cool. Makes 12 cups.

If you would like to add nuts to your granola recipes, rinse them in cold tap water first, to which vitamin C powder has been added (¼ tsp. per pint). This removes aflatoxins.

Peanut Butter

Use fresh unsalted roasted peanuts—they will be white on the first day they arrive at the health food store from the distributor. (Ask when they will arrive.) Or shell fresh roasted peanuts yourself, throwing away all shriveled or darkened nuts. Grind, adding salt and vitamin C (¼ tsp. per pint) as you go. For spreadability, especially for children, grind an equal volume of cold butter along with the peanuts. This improves spreadability and digestibility of the hard nut particles. This will probably be the most heavenly peanut butter your mouth has ever experienced.

Fig. 87 Light colored, roasted peanuts in the shell had no aflatoxin.

Sweetening and Flavoring

Brown Sugar. Although I am prejudiced against all sugar from a health standpoint, my testing revealed no benzene, propyl alcohol, wood alcohol. However it does contain sorghum mold and must be treated with vitamin C to detoxify it. Add ¼ tsp. to a 1 pound package; knead until well mixed.

Maple syrup. Add vitamin C to newly opened bottle, ¼ tsp. to retard mold. Keep refrigerated and use promptly.

Flavoring. Use maple, vanilla (both natural and artificial), and any pure spice. They are free of molds and solvents.

Honeys. Get at least 4 flavors for variety: linden blossom, orange blossom, plain clover and local or wild flower honey.

Add vitamin C to newly opened jar to detoxify ergot mold (¼ tsp. per pint).

Jams and jellies. They are not safe unless homemade.

Fruit syrup. Use one package frozen fruit, such as cherries, blueberries or raspberries. Let thaw and measure the amount in cups (it might say on the package). Add an equal amount of clover honey to the fruit. Also add ¼ tsp. vitamin C powder. Mix it all in a quart canning jar and store in the refrigerator. Use this on pancakes, cereal, plain yogurt and homemade ice cream too. Use to make your own flavored beverages in a seltzer maker or to make soda pop. If you wish to use fresh fruit, bring it to a boil to sterilize. Use it up in a few days or boil to sterilize it again.

Note for diabetics

Diabetics must not use artificial sweeteners. Nor can they use all the sweeteners listed. Try stevia powder instead.

Preserves

Keep 3 or 4 kinds on hand, such as peach, pineapple, and pear. Peel and chop the fruit. It should not have any bruises. If you use a metal knife, rinse the fruit lightly afterwards. Add just enough water to keep the fruit from sticking as it is cooked (usually a few tablespoons). Then add an equal amount of honey, or to taste and heat again to boiling. Put in sterile jars in refrigerator. Make marmalade the same way, slicing the fruit and peel thinly. Always add vitamin C powder to a partly used jar to inhibit mold. Never use up partly molded fruit by making preserves out of it. Throw it out.

C Dressing

½ cup olive oil
¼ cup fresh lemon juice or white distilled vinegar
1 tsp. thyme, fenugreek or both (capsules are freshest)
1 tsp. vitamin C powder
½ tsp. brown sugar

Combine the ingredients in a clean salad dressing bottle. Shake. Refrigerate. The basic recipe is the oil and vinegar in a 2:1 ratio. After mixing these, add any pure spice desired. Or add fresh tomato chunks for creaminess.

Cheese Sauce

Add milk to cheese in equal amounts. Gradually heat to boiling while stirring. Add more of either to obtain the desired consistency. Boil 10 seconds. Use immediately.

Sour Cream-C

2 cups heavy whipping cream, previously boiled
¼ tsp. citric acid
¼ tsp. vitamin C powder
1 tsp. fresh onion juice or other seasoning (optional)

Stir until smooth, refrigerate 2 hours.

Yogurt

Buy a yogurt maker. Be sure and use boiled milk.

Soups

All home made soups are nutritious and safe, provided you use no processed ingredients (like bouillon), or make them in metal pots. Use herbs and aluminum-free salt to season. Always add a dash of vitamin C or tomato juice or vinegar to draw out calcium from soup bones for you to absorb.

Fish and Seafood recipe

Any kind of fish or seafood is acceptable, provided it is well-cooked. Don't buy food that is already in batter. The simplest way to cook fish is to poach it in milk. It can be taken straight from the freezer, rinsed, and placed in ¼ inch of milk (unboiled is fine) in the frying pan. Heat until it is cooked. Turn over and repeat. Throw away the milk. Serve with fresh lemon and herbs.

Baked Apples

Peel and core carefully. Remove all bruises (this is where the patulin is). Cut in bite-sized pieces, add a minimum of water and cook or bake minimally. Add a squirt of lemon juice when done. Serve with cinnamon, whipping cream and honey.

Ice creams

from the grocery store are loaded with benzene and other solvents. Fortunately there are ice cream makers that do everything (no cranking)! Or try our recipe which uses a blender. Be sure not to add store bought flavors, except vanilla or maple.

5 Minute Ice Cream

(Strawberry) Use 2 half pints of whipping cream, previously boiled, 1 package of frozen strawberries (about 10 oz.), and ½ cup clover honey. Pour frozen strawberries into blender. Pour whipping cream and honey over them. Blend briefly (about 10 seconds), not long enough to make butter! Pour it all into a large plastic bowl. Cover with a close fitting plastic bag and place in freezer. Prepare it a day ahead. Try using other frozen fruits, such as blueberries and cherries. Keep a few berries out of the

blender and stir them in quickly with a non-metal spoon before setting the bowl in the freezer. There are many ice cream recipes to be found in old cook books. Avoid those with raw eggs or processed foods as ingredients. You may add nuts if you rinse them in vitamin C water.

Cookies, cakes and pies

Bake them from scratch, using unprocessed ingredients. Use simple recipes from old cook books.

Seven Day Sample Menu

Because processed foods have many toxins, you must cook as much from scratch as possible. So for convenience sake, keep your meals simple in preparation. You may want to prepare ahead and refrigerate your dressings and toppings. Or you could make a hot soup for dinner, refrigerate, and eat the leftovers for lunch. Don't save leftovers more than two days. Make sure they are covered. Try baking several potatoes at one time, refrigerate and put them in a salad the next night. Variety is the spice of life, so combine the allowed foods in the most creative ways you can imagine. And don't forget herbs and spices; learn to use them from old cook books.

	Breakfast	**Lunch**	**Dinner**
Day 1	Granola and honey with milk, half n' half or whipping cream 1 cup fresh squeezed fruit juice Water Milk	Fresh ground peanut butter and preserve sandwich Soup Milk Water	Orange roughy fish Fresh green beans with butter Baked potato with Sour Cream-C topping or fresh chives Pie (homemade) Milk 1 cup fresh squeezed or frozen vegetable juice Water

Day 2	Egg (limit is 2) Fried potatoes 1 glass milk Peppermint herb tea Fresh orange juice	Bagel (from bakery) Sour Cream-C Tomato 1 cup vegetable juice Water Milk	Homemade bean or lentil soup Sardines Dinner roll and butter Salad Homemade dressing Ice cream (homemade) Water
Day 3	Cream of Wheat™ cooked with raisins and milk Banana Peppermint herb tea ½ cup milk Water	Tuna sandwich with olives and butter Soup Milk Water	Baked sweet potato with butter and sweetening. Fresh broccoli with cheese sauce Bread and butter Chopped, peeled pear and whipping cream 1 cup vegetable juice Milk Water
Day 4	French toast with maple syrup Egg Homemade grapefruit juice Milk Water	Avocado and sour cream sandwich ½ cup vegetable juice Bread and butter Water	Lobster or sautéed shrimp Fresh asparagus Potatoes, any style ½ cup vegetable juice Water Milk
Day 5	Cooked cereal 1 glass milk Sliced banana with whipping cream and honey 1 glass water	Cold potato salad with C Dressing Soup ½ cup vegetable juice Custard Water Milk	1 can sardines or salmon in easy-open can (can openers shed metal) Salad of lettuce, tomato, olives, avocado with homemade dressing Bread with butter Ice-cream (optional) ½ cup vegetable juice Water Milk
Day 6	Egg and homemade biscuit with honey and butter Milk Fruit juice (homemade) Water	Homemade peanut butter sandwich ½ cup vegetable juice Milk Water	Gourmet pizza: home baked bread topped with olive oil, sliced tomato or homemade sauce, grated cheese, sardines or anchovies, chopped vegetables, garlic and onion Salad Milk Water

Day 7	Pancakes Banana or chopped fruit with cream Milk Water	Salmon sandwich (from flip top can) ½ cup vegetable juice Milk Water	Stir-fry vegetables: broccoli, carrots, cabbage, in olive oil and butter Bread and butter Pie (optional) Milk Water

Remember, take vitamin C and B-complex with each meal.

Too Sick To Cook, Too Tired To Eat

Pick three meals from the sample menu that need no cooking and eat them every day.

Recipes for Natural Body Products

You can use just borax (like 20 Mule Team Borax™) and washing soda (like Arm & Hammer Super Washing Soda™) for all types of cleaning including your body, laundry, dishes and your house! You don't need all of those products you see in commercials for each special task!

Even if you have dry skin, difficult hair or some other unique requirement, just pure borax will satisfy these needs. A part of every skin problem is due to the toxic elements found in the soaps themselves. For instance aluminum is commonly added as a “skin moisturizer”. It does this by impregnating the skin and attracting water, giving the illusion of moist skin. In fact you simply have moist aluminum stuck in your skin which your immune system must remove. While borax won't directly heal your skin or complexion, it does replace the agents that are causing damage, so that healing can occur.

Borax Liquid Soap

Empty 1 gallon jug
1/8 cup borax powder
Plastic funnel

Funnel the borax into the jug, fill with cold tap water. Shake a few times. Let settle. In a few minutes you can pour off the clear part into dispenser bottles. This is the soap!

Easier way: use any bottle, pour borax powder to a depth of a ½inch or so. Add water. Shake. When you have used it down to the undissolved granules, add more water and shake again. Add more borax when the undissolved granules get low.

Keep a dispenser by the kitchen sink, bathroom sink, and shower. It does not contain aluminum as regular detergents and soaps do, and which probably contribute to Alzheimer's disease. It does not contain PCBs as many commercial and health food varieties do. It does not contain cobalt (the blue or green granules) which causes heart disease and draws cancer parasites to the skin. Commercial detergents and non-soaps are simply not safe. Switch to homemade bar soap and borax for all your tasks! Borax inhibits the bacterial enzyme *urease* and is therefore antibacterial. It may even clear your skin of blemishes and stop your scalp from itching.

For Laundry

Borax (½cup per load). It is the main ingredient of non-chlorine bleach and has excellent cleaning power without fading colors. Your regular laundry soap may contain PCBs, aluminum, cobalt and other chemicals. These get rubbed into your skin constantly as you wear your clothing. For bleaching (only do this occasionally) use original chlorine bleach (not “new improved” or “with special brighteners”, and so forth). Don't use chlorine if there is an ill person in the house. For getting out

stubborn dirt at collars, scrub with homemade bar soap first; for stains, try grain alcohol, vinegar, baking soda.

For Dishes

Don't believe your eyes when you see the commercials where the smiling person pulls a shining dish out of greasy suds. Any dish soap that you use should be safe enough to eat because nothing rinses off clean. Regular dish detergents, including health brands, are now polluted with PCBs. They also contain harmful chemicals. Use borax for your dishes. Or use paper plates and plastic (not styrofoam) cups.

In The Dishwasher

Use 2 tsp. borax powder pre-dissolved in water. If you use too much it will leave a film on your dishes. Use vinegar in the rinse cycle.

In The Sink

Use a dishpan in the sink. Use ¼ cup borax and add a minimum of water. Also keep a bit of dry borax in a saucer by the sink for scouring. Don't use any soap at all for dishes that aren't greasy and can be washed under the faucet with nothing but running water. Throw away your old sponge or brush or cloth because it may be PCB contaminated. Start each day by sterilizing your sponge (it harbors Salmonella) or with a new one while the used one dries for three full days. Clean greasy pots and pans with a paper towel first. Then use homemade bar soap.

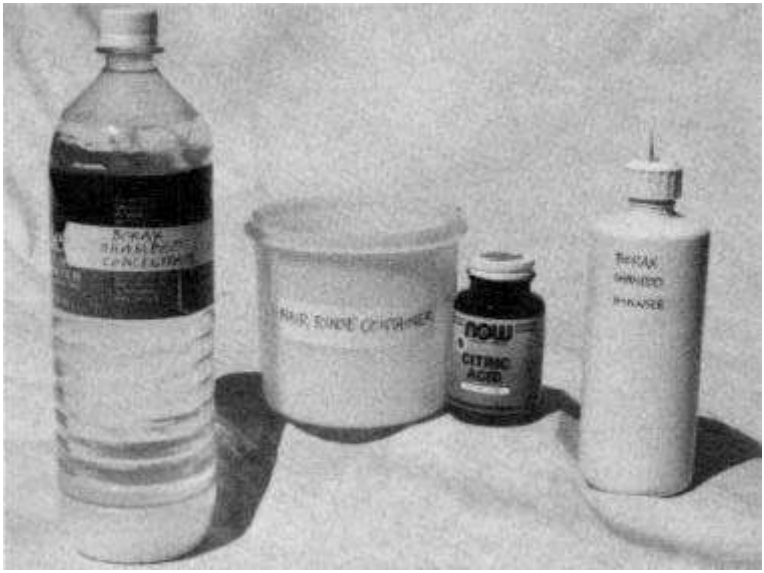

Fig. 88 Make a bottle of borax liquid to fill your soap dispensers and shampoo bottle. Use citric acid to rinse and condition.

Shampoo

Borax liquid is ready to use as shampoo, too. It does not lather but goes right to work removing sweat and soil without stripping your color or natural oils. It inhibits scalp bacteria and stops flaking and itching. Hair gets squeaky clean so quickly (just a few squirts does it) that you might think nothing has happened! You will soon be accustomed to non-lathery soap. Rinse very thoroughly because you should leave your scalp slightly acidic. Take a pint container to the shower with you. Put ¼ tsp. citric (not ascorbic) acid crystals (see *Sources*) in it. For long hair use a quart of rinse. Only **citric acid** is strong enough to get the borax out, lemon juice and vinegar are not. After shampooing, fill the container with water and rinse. Rinse your whole body, too, since citric acid is also anti-bacterial. All hair shampoo penetrates the eye lids and gets into the eyes although you do not feel it. It is important to use this natural rinse to neutralize the shampoo in your eyes. (Some people have

stated that citric acid makes their hair curlier or reddens it. If this is undesirable, use only half as much citric acid.) Citric acid also conditions and gives body and sheen to hair.

Hair Spray

I don't have a recipe that holds your hair as well as the bottle of chemicals you can buy at the store. Remarkably a little lemon juice (not from a bottle) has some holding power and no odor! Buy a 1 cup spray bottle. Squeeze part of a lemon, letting only the clear juice run into the bottle. Fill with water. Keep it in the refrigerator. Make it fresh every week. Spraying with just plain water is nearly as good! For shinier hair, drop a bit of lemon peel into the bottle.

Homemade Soap

A small plastic dishpan, about 10" x 12"
A glass or enamel 2-quart sauce pan
1 can of lye (sodium hydroxide), 12 ounces
3 pounds of lard (BHT and BHA are OK here)
Plastic gloves
Water

1. Pour 3 cups of very cold water (refrigerate water overnight first) into the 2-quart saucepan.
2. Slowly and carefully add the lye, a little bit at a time, stirring it with a wooden or plastic utensil. (Use plastic gloves for this; test them for holes first.) Do not breathe the vapor or lean over the container or have children nearby. Above all use no metal. The mixture will get very hot. In olden days, a sassafras branch was used to stir, imparting a fragrance and insect deterrent for mosquitoes, lice, fleas, ticks.

3. Let cool at least one hour in a safe place. Meanwhile, the unwrapped lard should be warming up to room temperature in the plastic dishpan.
4. Slowly and carefully, pour the lye solution into the dishpan with the lard. The lard will melt. Mix thoroughly, at least 15 minutes, until it looks like thick pudding.
5. Let it set until the next morning; then cut it into bars. It will get harder after a few days. Then package.

If you wish to make soap based on olive oil, use about 48 ounces. It may need to harden for a week.

Liquid Soap

Make chips from your homemade soap cake. Add enough hot water to dissolve. Add citric acid to balance the pH (7 to 8). If you do not, this soap may be too harsh for your skin.

Skin Sanitizer

Make up a 5 to 10% solution of food grade alcohol. Food grade alcohols are grain (ethyl) alcohol or vodka. Find a suitable dispenser bottle. Mark it with a pen at about one tenth of the way up from the bottom. Pour 95% grain alcohol (190 proof) to this mark (for 50% grain alcohol or vodka make your mark one fifth of the way up). Add water to the top. Keep shut. You may add a chip of lemon peel for fragrance.

Use this for general sanitizing purposes: bathroom fixtures, knobs, handles, canes, walkers, and for personal cleanliness (but use chlorine bleach for the toilet bowl once a week). Always clean up after a bowel movement with wet toilet paper. This is not clean enough, though. Follow with a stronger damp paper towel. This is still not clean enough; use a final damp paper towel with skin sanitizer added. After washing hands, sanitize them too, pouring a bit on one palm and put finger tips of the

other hand in it, scratch to get under nails, repeat on other hand. Rinse with water.

Do not use this recipe, nor keep any bottles of alcohol in the house of a recovering alcoholic.

Deodorant

Your sweat is odorless. It is the entrenched bacteria feeding on it that make smells. You can never completely rid yourself of these bacteria, although they may temporarily be gone after zapping. The strategy is to control their numbers. Here are several deodorants to try. Find one that works best for you:

Vitamin C water. Mix ¼ tsp. to a pint of water and dab it on. Then dab on cornstarch.

Citric Acid water. Mix ¼ tsp. to a pint of water and dab it on. Then dab on cornstarch.

Only a few drops of these acids under each armpit are necessary. If these acids burn the skin, dilute them more. Never apply anything to skin that has just been shaved!

Corn starch. Many people need only this. Dab it on.

Use only unpolluted **cornstarch** (see *Sources*).

Baking soda has been deleted as a deodorant because benzene was found in some boxes.

Lemon juice. This acid is not as strong, use what you need.

Pure alcohol (never rubbing alcohol). The food grade alcohols are grain alcohol and vodka. Dab a bit under each arm and/or on your shirt or blouse, then dab on cornstarch. If the alcohol burns, dilute it with water. Be very careful not to leave the

bottle where a child or alcoholic person could find it. Pour it into a different bottle!

Pure zinc oxide. You may ask your pharmacist to order this for you. She or he may wish to make it up for you too, but do not let them add anything else to it. It should be about 1 part zinc oxide powder to 3 parts water. It does not dissolve. Just shake it up to use it. After you get it home, you can add cornstarch to it to give it a creamy texture. Heat 3 tsp. cornstarch in 1 cup of water, to boiling, until dissolved and clear. Cool and add some to the zinc oxide mixture (about equal parts). Store unused starch mixture in the refrigerator. Only make up enough for a month.

Alcohol and zinc oxide. This is the most powerful deodorant. Apply alcohol first, then the zinc oxide, then dab on cornstarch.

Remember that you need to sweat! Sweating excretes toxic substances, especially from the upper body. Don't use deodorant on weekends. Go to the sink and wipe clean the armpits like our grandparents did. Often, just plain cornstarch is enough! These homemade deodorants are not as powerful as the commercial varieties–this is to your advantage.

Brushing Teeth

Buy a new toothbrush. Your old one is soaked with toxins from your old toothpaste. Use only water or chemically pure baking soda if you have any metal fillings. Put a pinch in a glass, add water to dissolve it. Use food-grade hydrogen peroxide (see *Sources*) if you have only plastic fillings. Dilute it from 35% to 17½% by adding water (equal parts). Store hydrogen peroxide only in polyethylene or the original plastic bottle. Use 4 or 5 drops on your toothbrush. It should fizz nicely as oxygen is produced in your mouth. Your teeth will whiten noticeably in 6 months. Before brushing teeth, floss with 4 or 2 pound mon-

ofilament fish line. Double it and twist for extra strength. Rinse before use. Floss and brush only once a day. If this leaves you uncomfortable, brush the extra times with plain water and a second "water-only" toothbrush. Make sure that nothing solid, like powder, is on your toothbrush; it will scour the enamel and give you sensitive teeth, especially as you get older and the enamel softens. Salt is corrosive—don't use it for brushing metal teeth. Plain water is just as good.

For Dentures

Use salt water. It kills all germs and is inexpensive. Salt water plus grain alcohol or food-grade hydrogen peroxide makes a good denture-soak.

Mouthwash

A few drops of food grade hydrogen peroxide added to a little water in a glass should be enough to make your mouth foam and cleanse. Don't use hydrogen peroxide, though, if you have metal fillings, because they react. Don't use regular drug store variety hydrogen peroxide because it contains toxic additives. Health food store varieties contain solvents from the bottling process. See *Sources*. Never purchase hydrogen peroxide in a bottle with a metal cap.

For persons with metal tooth fillings, use chemically pure baking soda or just plain hot water. A healthy mouth has no odor! You shouldn't need a mouthwash! If you have breath odor, search for a hidden tooth infection or cavitation.

Contact Lens Solution

A scant cup of cold tap water brought to a boil in glass saucepan. After adding ¼ tsp. aluminum free salt and boiling

again, pour into a sterile canning jar. Refrigerate. Freeze some of it.

Lip Soother

For dry, burning lips. Heat 1 level tsp. sodium alginate plus 1 cup water until dissolved. After cooling, pour it into a small bottle to carry in your purse or pocket (refrigerate the remainder). Dab it on whenever needed. If the consistency isn't right for you, add water or boil it down further. You can make a better lip soother by adding some lysine from a crushed tablet, vitamin C powder, and a vitamin E capsule to the alginate mix. If you have a persistent problem with chapped lips, try going off citrus juice.

Foot Powder

Use a mixture of cornstarch and zinc oxide poured into a salt shaker with a lid. Add long rice grains to fight humidity. You may also try arrow root or potato starch. If you don't have zinc oxide use plain cornstarch.

Skin Healer Moisturizer Lotion

1 tsp. sodium alginate
1 cup water

Make the base first by heating these together in a covered, non-metal pan until completely dissolved. Use low heat–it will take over an hour. Use a wooden spoon handle to stir. Set aside. Then make the following mixture:

¼ tsp. Vitamin C (ascorbic acid) (You may crush tablets)
¼ tsp. lysine (crush tablets)
2 tbs. pure vegetable glycerin
2 vitamin E capsules (400 units or more, each)
1 tsp. apricot kernel oil (olive oil will do)

1 tbs. lemon juice from a lemon or ¼ tsp. citric acid (this is optional)
1 cup water

Heat the water to steaming in a non-metal pan. Add vitamin C and lysine first and then everything else. Pour into a pint jar and shake to mix. Then add the sodium alginate base to the desired thickness (about equal amounts) and shake. Pour some into a small bottle to use as lip soother. Pour some into a larger bottle to dispense on skin. Store remainder in refrigerator. (See *Sources* for sodium alginate, vegetable glycerin and apricot kernel oil. Sodium alginate is also available in capsule form at some health food stores.)

Other Skin Healers

Vitamin C powder (ascorbic acid, not the same as citric acid). Put a large pinch into the palm of your hand. With your other hand pick up a few drops of water from the faucet. Rub hands together until all the powder is dissolved and dispensed. It may sting briefly. Do this at bedtime, especially for cracked, chapped hands. Include lips if they need it.

Vitamin E oil. Vitamin E oil from Now Foods was not polluted at the time of this writing, but for the future it would be safer to rely on capsules. Snip open a capsule and rub into skin.

50% Glycerin. Dilute 100% vegetable glycerin with an equal amount of water. This is useful as an after shave lotion.

Vitamin C liquid. Mix ¼ tsp. vitamin C powder in one pint water (crushed tablets will do). This is useful as an after shave lotion and general skin treatment.

Apricot Kernel Oil. This is a very light oil, useful as an after shave lotion and general skin treatment.

Cornstarch (see *Sources*). Use on rashes, fungus, moist or irritated areas and to prevent chafe.

Combining several of these makes them more effective.

Dry skin has several causes: too much water contact, too much soap contact (switch to borax), low body temperature, not enough fat in the diet, or parasites.

Massage Oil

Use olive oil. It comes in very light to heavy textures. Pick the right one for your purpose. Alginate mixtures can be used instead of, or added to, oil. Starch solutions are good, too.

Sunscreen Lotion

Purchase PABA (see *Sources*) in 500 mg tablet form. Dissolve 1 tablet in grain alcohol or vodka. Grind the tablet first by putting it in a plastic bag and rolling over it with a glass jar. It will not completely dissolve even if you use a tablespoon of the alcohol. Pour the whole mixture into a 4 ounce bottle of homemade skin softener. Be careful not to get the lotion into your eyes when applying it. A better solution is to wear a hat or stay out of the sun. Remember to *take* PABA as a supplement, too (500 mg, one a day).

Nose Salve

(When the inside of the nose is dry, cracked and bleeding.)

Pour ½tsp. pure vegetable glycerin into a bottle cap. Add ½ tsp. of water.

Applicator: use a plastic coffee stirrer or straw; cut a slit in the end to catch some cotton wool salvaged from a vitamin bottle and twist (cotton swabs, cotton balls and wooden toothpicks are sterilized with mercury which in turn is polluted with thallium). Dip it into the glycerin mixture and apply inside the nose with a rotating motion. Do each nostril with a new applicator.

Quick Corn Starch Skin Softener

4 tsp. corn starch (see *Sources*)
1 cup water

Boil starch and water until clear, about one minute.

Cornstarch Skin Softener

1 tsp. lysine powder or 8 tablets, 500 mg each
1 tsp. Vitamin C powder (ascorbic acid); or 8 tablets, 500 mg each
3 tsp. cornstarch (see *Sources*)
Vitamin E, 1 capsule 400 mg
¼ tsp. apricot kernel oil (optional)
1 cup water

Boil starch and water until clear, about one minute. Add other ingredients and stir until dissolved. Cool. Pour into dispenser bottle. Keep refrigerated when not in use. Apply after washing dishes and after showering.

After Shaves

Vitamin C. ¼ tsp. vitamin C powder, dissolved in 1 pint water.

Apricot kernel oil.

Vegetable glycerin. Equal parts glycerin and water or to suit your need.

Personal Lubricants

Heat these together: 1 level tsp. sodium alginate and 1 cup water in a covered non-metal pan until completely dissolved. Use very low heat and stir with a wooden spoon handle. It takes a fairly long time to get it perfectly smooth. After cooling, pour into a small dispenser bottle. Keep the remainder refrigerated.

Or, mix and heat 4 tsp. cornstarch and 1 cup water until completely dissolved in a covered saucepan. Use non-metal

dishes and a non-metal stirring spoon. Cool. Pour some into dispenser bottle. Refrigerate remainder. This is many person's favorite recipe.

Baby Wipes

Cut paper towels in quarters and stack in a closable plastic box. Run tap water over them, drain the excess. Add 1 tsp. grain alcohol and/or borax liquid on top. Close. Put a dab of the Quick Cornstarch Softener recipe on top of each wipe as you use it.

People Wipes

¼ tsp. powdered lysine (you may crush tablets)
¼ tsp. Vitamin C powder (you may crush tablets)
¼ cup vegetable glycerin
1 cup water

Prepare wipes by cutting paper towels in quarters. Use white, unfragranced towels that are strong enough to hold up for this use. Fold each piece in quarters again and stack in a plastic zippered baggy. Pour the fluid mixture over the stack and zip. Store a bag full in the freezer to take on car trips. If you want to keep them a month or more, add 1 tbs. grain alcohol or vodka to the recipe.

For bathroom use, dampen a roll of paper towels under the cold tap first. Then pour about ¼ cup of the mixture over the towel roll around the middle. Store in plastic shopping bag or stand in plastic waste basket.

Recipes For Natural Cosmetics

Eye liner and Eyebrow Pencil

Get a pure charcoal pencil (black only) at an art supply store. Try several on yourself (bring a small mirror) in the store to see what hardness suits you. You may need to wet it with water or a vitamin E perle first. Don't put any chemicals on your *eyelids*, since this penetrates into your eye. To check this out for yourself, close your eye tightly and then dab lemon juice on your eyelid. It will soon burn! Everything that is put on skin penetrates. Otherwise the nicotine patch and estrogen patch wouldn't work. Not even soap belongs on your eyelids! Charcoal pencils are cheap. Get yourself half a dozen different kinds so you can do different things.

You could also use a capsule of activated charcoal. Empty it into a saucer. Mix glycerin and water, half and half, and add it to the charcoal powder until you get the consistency you like. Use a brush for eyelashes; use a finger for eyebrows.

Lipstick

Beet root powder (see *Sources*)
100% vegetable glycerin

Combine 1 tsp. vegetable glycerin and 1 tsp. beet root powder in a saucer. Stir until perfectly smooth. Then add ½tsp. of vitamin E oil. Snip open vitamin E capsules or buy vitamin E oil (see *Sources*). Very thick olive oil can be substituted. Apply liberally with your finger or a lipstick brush. Do not purse or rub your lips together after application. To make the lipstick stay on longer, apply 1 layer of lipstick, then dab some corn starch over the lips, then apply another layer of lipstick. Store in a small glass or plastic container in the refrigerator, tightly covered in a plastic bag.

Face Powder

Use cornstarch from the original box. You may also try arrow root starch or potato starch. Use your fingers or a tissue to apply because applicators can carry bacteria.

Blush (face powder in a cake form)

Add 50% glycerin to cornstarch in a saucer to make a paste. Slowly add beet root powder to the desired color. Use part of a charcoal capsule to darken it, if desired. A drop of food grade alcohol will also darken it. To make 50% glycerin, add equal parts of glycerin and water. Try to make the consistency the same as your brand name product, and you can even put it back in your brand name container.

Recipes For Household Products

Floor Cleaner

Use washing soda from the grocery store. You may add borax and boric acid (to deter insects except ants). Use white distilled vinegar in your rinse water for a natural shine and ant repellent. Do not add bleach to this. For the bathroom floor use plain bleach water—follow the label. Never use chlorine bleach if anybody in the home is ill or suffers from depression. Use grain alcohol (1 pint to 3 quarts water) for germ killing action instead of chlorine.

Furniture Duster and Window Cleaner

Mix equal parts white distilled vinegar and water. Put it in a spray bottle.

Furniture Polish

A few drops of olive oil on a dampened cloth. Use filtered water to dampen.

Insect Killer

Boric acid powder (not borax). Throw liberal amounts behind stove, refrigerator, under carpets and in carpets. Since boric acid is white, you must be careful not to mistake it for sugar accidentally. Keep it far away from food and out of children's reach. Buy it at a farm supply or garden store (or see *Sources*). It will not kill ants.

Ant Repellent

Spray 50% white distilled vinegar on counter tops, window sills and shelves and wipe, leaving residue. Start early in spring before they arrive, because it takes a few weeks to rid yourself of them once they are established. If you want immediate action, get some lemons, cut the yellow outer peel off and cover with grain alcohol in a tightly closed jar. Let stand at least one hour. Use 1 part of this concentrate with 9 parts water in a spray bottle. Mix only as much as you will use because the diluted form loses potency. Spray walls, floors, carpets wherever you see them. The lemon solution even leaves a shine on your counters. Use both vinegar and lemon approaches to rid yourself of ants.

To treat the **whole house**, pour vinegar all around your foundation, close to the wall, using one gallon for every five feet. Expect to damage any foliage it touches. Reapply every six months.

Flower and Foliage Spray

Food-grade hydrogen peroxide. See instructions on bottle.

Moth Balls

I found this recipe in an old recipe book. Mix the following and scatter in trunks and bags containing furs and woolens: ½lb. each rosemary and mint, ¼ lb. each tansy and thyme, 2 tbs. powdered cloves.

Carpet Cleaner

Whether you rent a machine or have a cleaning service, don't use the carpet shampoo they want to sell, even if they "guarantee" that it is all natural and safe. Instead add these to a bucket (about four gallons) of water and use it as the cleaning solution:

Wash water	Rinse water
1/3 cup borax	¼ cup grain alcohol
	2 tsp. boric acid
	¼ cup white distilled vinegar **or**
	4 tsp. citric acid

Borax does the cleaning; alcohol disinfects, boric acid leaves a pesticide residue, and the vinegar or citric acid give luster. If you are just making one pass on your carpet, use the borax, alcohol, and boric acid. Remember to test everything you use on an unnoticed piece of carpet first.

Health Improvement Recipes

Black Walnut Hull Tincture

This new recipe is four times as strong as the previous one, so it is called **Black Walnut Hull Tincture Extra Strength**.

Your largest enamel or ceramic (not stainless steel, not aluminum) cooking pot, preferably at least 10 quarts
Black walnuts, in the hull, each one still at least 50% green, enough to fill the pot to the top
Grain alcohol, about 50% strength, enough to cover the walnuts
½ tsp. vitamin C
Plastic wrap or cellophane
Glass jars or bottles

The black walnut tree produces large green balls in fall. The walnut is inside, but we will use the whole ball, uncracked, since the active ingredient is in the green outer hull.

Rinse the walnuts carefully, put them in the pot, and cover with the alcohol. Sprinkle on half the vitamin C. Seal with plastic wrap and cover. Let sit for three days. Pour into glass jars or bottles, discarding walnuts, and divide the remaining vitamin C amongst the jars. If the glass jar has a metal lid, first put plastic wrap over the top before screwing on the lid. Potency is strong for several years if unopened, even if it darkens.

You have just made Extra Strength Black Walnut Hull Tincture. It is stronger than the concentrate made with just a few black walnuts in a quart jar (my earlier recipe), because there are more walnuts per unit liquid. In addition, you will not dilute it before use (although when you take it, it will usually be in water).

When preparing the walnuts, rinse only with cold tap water. You may need to use a brush on areas with dirt. If you are not going to use all of them in this batch, you may freeze them in a resealable plastic bag. Simply refrigerating them does not keep them from turning black and useless. The pot of soaking walnuts should not be refrigerated. Nor does the final tincture need any refrigeration.

Exposure to air does cause the tincture to darken and lose potency. To reduce air exposure, fill the pot as much as possible, without touching the plastic wrap, while still keeping a snug fitting lid. Even more importantly, the glass jars or bottles you use to store your tincture should have as little air space as possible, without touching the plastic wrap on top. A large jar should be divided into smaller ones when you are ready to use it. The idea is not to have partial jars, with a lot of air space, sitting for longer than a month or so.

There are several ways to make a 50% grain alcohol solution. Some states have Everclear,™ 95% alcohol. Mix this half and half with water. Other states have Everclear that is 76.5% alcohol. Mix this three parts Everclear to one part water. Yet another method is to buy vodka that is 100 proof. This is already 50% alcohol.

Remember, never use any kind of purchased water to make tincture.

Black Walnut Hull Tincture (Regular Strength)

This is the potency I used originally. It is included here in case you prefer it or wish to treat a pet. The Extra Strength recipe is four times as potent as the original recipe, so it must be diluted in quarters. (Similarly, if you have a lot of the Regular Strength left and want to use it in place of Extra Strength, simply take four times as much.)

Black Walnut Hull Tincture Extra Strength
Grain Alcohol, about 10%

Mix one part extra strength tincture with three parts of the 10% alcohol. Store in glass containers same as described above.

There are several ways to make a 10% grain alcohol solution. Some states have Everclear,™ 95% alcohol. Mix this one part Everclear to nine parts water. Other states have Everclear that is 76.5% alcohol. Mix this one part Everclear to seven parts water. Yet another method is to buy vodka that is 100 proof (50% alcohol) and mix one part vodka with four parts water.

Black Walnut Hull Extract (Water Based)

Because you do not know how commercially available extracts were made, and may not be able to test for solvent pollution, it is wisest to make it yourself!

This recipe is intended for alcoholic persons: cover the green balls in the 10 quart (non-metal) pot with cold tap water. Heat to boiling, covered. Turn off heat. When cool, add vitamin C, cover with plastic wrap, and the lid. Let stand for 1 day. It will be darker than the tincture. Do not dilute. Pour into freezable containers. Refrigerate what you will use in two days and freeze the rest. Add vitamin C after thawing or during refrigeration (¼ tsp. per quart).

For use: in programs calling for Extra Strength Black Walnut Hull Tincture use four times as much of this water based recipe (8 tsp. instead of 2 tsp. Extra Strength).

Important Note: do not use bottled or purchased water to make this tincture or you could pollute it with benzene!

Quassia recipe

Add 1/8 cup quassia chips to 3 cups water. Simmer 20-30 minutes. Pour off 1/8 cup now and drink it fresh. Refrigerate remainder. Drink 1/8 cup 4 times/day, until a total of ½cup of chips is consumed. Flavor with spices.

Emmenagogue (Menstrual Period Inducer)

Here are four herbs that can each bring on your period. They can be started anytime but the most-effective time is before your next calculated period time (count days as if you never missed a period).

1 oz sassafras bark
1 oz rue (cut)
1 oz marjoram herb
1 oz blue cohosh root
4½ cups boiling water

Add the herbs to the boiling water and turn down to simmer, covered, for 20 minutes. Do not boil. Strain and refrigerate in sterile glass jar. Pour one cup for yourself in the morning. Let warm to room temperature, and sip between meals, making it last until supper.

Bowel Program

Bacteria are always at the root of bowel problems, such as pain, bloating and gassiness. They can not be killed by zapping, because the high frequency current does not penetrate the bowel contents.

Although most bowel bacteria are beneficial, the ones that are not, like *Salmonellas* and *Shigellas*, are extremely detrimental because they have the ability to invade the rest of your body and colonize a trauma site or weakened organ. These same

bacteria colonize a cancer tumor and delay healing after the malignancy is stopped.

Another reason bowel bacteria are so hard to eradicate is that we are constantly reinfecting ourselves by keeping a reservoir on our hands and under our fingernails.

- So the first thing to do is **improve sanitation**. For a serious problem, use 50% grain alcohol (100 proof vodka) in a spray bottle at the bathroom sink. Sterilize your hands after bathroom use and before meals.
- Secondly use **turmeric** (2 capsules 3 times a day, this is the common spice) which I find helps against *Shigella*, as well as *E. coli*. Expect orange colored stool.
- Third use **fennel** (1 capsule 3 times a day).
- Fourth use **digestive enzyme tablets** with meals as directed on the bottle. (But only as long as necessary, because these frequently harbor molds.)
- Fifth use a single 2 tsp. dose of **Black Walnut Hull Tincture Extra Strength**. Add it to a ½glass of water and sip over a 15 minute period. Stay seated until any side effect from the alcohol wears off.
- Sixth take **Cascara sagrada** capsules if constipated (start with one capsule a day, use up to maximum on label). Remember to drink a cup of hot water upon rising in the morning. This will begin to regulate your elimination.

It can take all six to get rid of a bad *Shigella* problem in a week. Afterward, you must continue to eat only sterile dairy products. Note that the Kidney Cleanse is often effective with bowel problems. Try it also.

You will know you succeeded when your tummy is flat, there is not a single gurgle, and your mood improves!

Constipation Tea

Constipation is often caused by *E. coli* and *Salmonella* from dairy foods, or from killing "good" bowel bacteria with antibiotics (killing a few by zapping actually restores good flora). Eat foods that restore the body's good bowel flora: vegetables, sterilized milk (the milk sugar is essential), lots of water.

There are a lot of remedies for constipation, but many people enjoy this tea:

1 tbs. senna tea leaves
½ tsp. mint leaves

Boil for one minute in a quart of water, add a dash of vitamin C and brown sugar to taste. Sip through the day to avoid "belly-ache". It can take years for the body's flora to "right themselves" after an antibiotic session, be patient.

Weight Reduction

Here are two ancient herbal recipes for obesity. I have not personally determined their effectiveness.

Fucus

2 oz *Fucus vesiculosus*, cut (see Sources)
3 cups cold tap water

Boil for 15 minutes, covered. Cool. Dose: ¼ cup four times a day on an empty stomach. After one week increase dose to ½cup. You may add any flavoring desired.

Watch the pot carefully as it comes to a boil. If it boils over, you will have a month of stove-cleaning to do. The odor of *Fucus* boiling is wretched. So is the taste. Maybe garlic (fresh) would improve it.

Fennel

1 oz fennel seed (crushed or powdered is fine)

3 cups cold tap water

Boil water, pour over herb. Steep 30 minutes. Strain. Add 4 oz honey (optional). Drink one cup each day.

You could take them both together, along with the Bowel Program, to be more successful, but the best single weight reducer is the Liver Cleanse.

Kidney Cleanse

½ cup dried Hydrangea root
½ cup Gravel root
½ cup Marshmallow root
4 bunches of fresh parsley
Goldenrod tincture (leave this out of the recipe if you are allergic to it)
Ginger capsules
Uva Ursi capsules
Vegetable glycerin
Black Cherry Concentrate, 8 oz
Vitamin B6, 250 mg
Magnesium oxide tablets, 300 mg

Measure ¼ cup of each root and set them to soak, together in 10 cups of cold tap water, using a non-metal container and a non-metal lid (a dinner plate will do). After four hours (or overnight) add 8 oz. black cherry concentrate, heat to boiling and simmer for 20 minutes. Drink ¼ cup as soon as it is cool enough. Pour the rest through a bamboo strainer into a sterile pint jar (glass) and several freezable containers. Refrigerate the glass jar.

Boil the fresh parsley, after rinsing, in 1 quart of water for 3 minutes. Drink ¼ cup when cool enough. Refrigerate a pint and freeze 1 pint. Throw away the parsley.

Dose: each morning, pour together ¾cup of the root mixture and ½cup parsley water, filling a large mug. Add 20 drops of goldenrod tincture and 1 tbs. of glycerin. Drink this mixture

in divided doses throughout the day. Keep cold. Do not drink it all at once or you will get a stomach ache and feel pressure in your bladder. If your stomach is very sensitive, start on half this dose.

Save the roots after the first boiling, storing them in the freezer. After 13 days when your supply runs low, boil the same roots a second time, but add only 6 cups water and simmer only 10 minutes. This will last another 8 days, for a total of three weeks. You may cook the roots a third time if you wish, but the recipe gets less potent. If your problem is severe, only cook them twice.

After three weeks, repeat with fresh herbs. You need to do the Kidney Cleanse for six weeks to get good results, longer for severe problems.

Also take:

- Ginger capsules: one with each meal (3/day).
- Uva Ursi capsules: one with breakfast and two with supper.
- Vitamin B6 (250 mg): one a day.
- Magnesium oxide (300 mg): one a day.

Take these supplements just before your meal to avoid burping.

Some notes on this recipe: this herbal tea, as well as the parsley, can easily spoil. Heat it to boiling every fourth day if it is being stored in the refrigerator; this resterilizes it. If you sterilize it in the morning you may take it to work without refrigerating it (use a glass container).

When you order your herbs, be careful! Herb companies are not the same! These roots should have a strong fragrance. If the ones you buy are barely fragrant, they have lost their active ingredients; switch to a different supplier. Fresh roots can be used. Do not use powder.

- Hydrangea (*Hydrangea arborescens*) is a common flowering bush.
- Gravel root (*Eupatorium purpureum*) is a wild flower.
- Marshmallow root (*Althea officinalis*) is mucilaginous and kills pain.
- Fresh parsley can be bought at a grocery store. Parsley flakes and dried parsley herb do not work.
- Goldenrod herb works as well as the tincture but you may get an allergic reaction from smelling the herb. If you know you are allergic to this, leave this one out of your recipe.
- Ginger from the grocery store works fine; you may put it into capsules for yourself (size 0, 1 or 00).

There are probably dozens of herbs that can dissolve kidney crystals and stones. If you can only find several of those in the recipe, make the recipe anyway; it will just take longer to get results. Remember that vitamin B_6 and magnesium, taken daily, can prevent oxalate stones from forming. But only if you stop drinking tea. Tea has 15.6 mg oxalic acid per cup[37]. A tall glass of iced tea could give you over 20 mg oxalic acid. Switch to herb teas. Cocoa and chocolate, also, have too much oxalic acid to be used as beverages.

Remember, too, that phosphate crystals are made when you eat too much phosphate. Phosphate levels are high in meats, breads, cereals, pastas, and carbonated drinks. Eat less of these, and increase your milk (2%), fruits and vegetables. Drink at least 2 pints of water a day.

[37] Taken from *Food Values* 14ed by Pennington and Church 1985.

Cleanse your kidneys at least twice a year.

You can dissolve all your kidney stones in 3 weeks, but make new ones in 3 days if you are drinking tea and cocoa and phosphated beverages. None of the beverage recipes in this chapter are conducive to stone formation.

Liver Herbs

Don't confuse these liver herbs with the next recipe for the Liver Cleanse. This recipe contains herbs traditionally used to help the liver function, while the Liver Cleanse gets gallstones out.

6 parts comfrey root, *Symphytum officinale* (also called nipbone root)
6 parts tanner's oak bark, *Quercus alba* (white oak bark)
3 parts gravel root, *Eupatorium purpureum* (queen of the meadow)
3 parts Jacob's staff, *Verbascum thapsus* (mullein herb)
2 parts licorice root, *Glycyrrhiza glabra*
2 parts wild yam root, *Dioscorea villosa*
2 parts milk thistle herb, *Silybum marianum*
3 parts walnut bark, *Juglans nigra*, (black walnut bark)
3 parts marshmallow root, *Althea officinalis* (white mallow)
1 part lobelia plant, *Lobelia inflata* (bladder pod)
1 part skullcap, *Scutellaria lateriflora* (helmet flower)

Mix all the herbs. Add ½cup of the mixture to 2 quarts of water. Bring to a boil. Put lid on. Let sit for six hours. Strain and drink 1½cups per day. Put the strained herbs in the freezer and use them one more time.

Liver Cleanse

Cleansing the liver of gallstones dramatically improves digestion, which is the basis of your whole health. You can expect

your allergies to disappear, too, more with each cleanse you do! Incredibly, it also eliminates shoulder, upper arm, and upper back pain. You have more energy and increased sense of well being.

Cleaning the liver bile ducts is the most powerful procedure that you can do to improve your body's health.

But it should not be done before the parasite program, and for best results should follow the kidney cleanse and any dental work you need.

It is the job of the liver to make bile, 1 to 1½quarts in a day! The liver is full of tubes (*biliary tubing*) that deliver the bile to one large tube (the *common bile duct*). The gallbladder is attached to the common bile duct and acts as a storage reservoir. Eating fat or protein triggers the gallbladder to squeeze itself empty after about twenty minutes, and the stored bile finishes its trip down the common bile duct to the intestine.

For many persons, including children, the biliary tubing is choked with gallstones. Some develop allergies or hives but some have no symptoms. When the gallbladder is scanned or X-rayed nothing is seen. Typically, they are not in the gallbladder. Not only that, most are too small and not calcified, a prerequisite for visibility on X-ray. There are over half a dozen varieties of gallstones, most of which have cholesterol crystals in them. They can be black, red, white, green or tan colored. The green ones get their color from being coated with bile. Notice in the picture how many have imbedded unidentified objects. Are they fluke remains? Notice how many are shaped like corks with longitudinal grooves below the tops. We can visualize the blocked bile ducts from such shapes. Other stones are composites–made of many smaller ones–showing that they regrouped in the bile ducts some time after the last cleanse.

At the very center of each stone is found a clump of bacteria, according to scientists, suggesting a dead bit of parasite might have started the stone forming.

As the stones grow and become more numerous the back pressure on the liver causes it to make less bile. Imagine the situation if your garden hose had marbles in it. Much less water would flow, which in turn would decrease the ability of the hose to squirt out the marbles. With gallstones, much less cholesterol leaves the body, and cholesterol levels may rise.

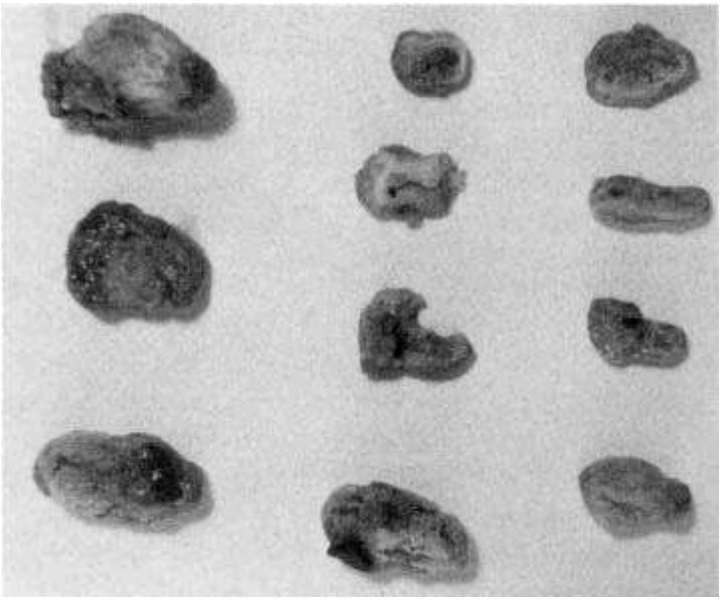

Fig. 89 These are gallstones.

Gallstones, being porous, can pick up all the bacteria, cysts, viruses and parasites that are passing through the liver. In this

way “nests” of infection are formed, forever supplying the body with fresh bacteria. No stomach infection such as ulcers or intestinal bloating can be cured permanently without removing these gallstones from the liver.

Cleanse your liver twice a year.

Preparation.

- You can't clean a liver with living parasites in it. You won't get many stones, and you will feel quite sick. Zap daily the week before, or get through the first three weeks of the parasite killing program before attempting a liver cleanse. If you are on the maintenance parasite program, you are always ready to do the cleanse.
- Completing the kidney cleanse before cleansing the liver is also highly recommended. You want your kidneys, bladder and urinary tract in top working condition so they can efficiently remove any undesirable substances incidentally absorbed from the intestine as the bile is being excreted.
- Do any dental work first, if possible. Your mouth should be metal free and bacteria free (cavitations are cleaned). A toxic mouth can put a heavy load on the liver, burdening it immediately after cleansing. Eliminate that problem first for best results.

Ingredients

Epsom salts	4 tablespoons
Olive oil	half cup (light olive oil is easier to get down)
Fresh pink grapefruit	1 large or 2 small, enough to squeeze 2/3 to 3/4 cup juice

Ornithine	4 to 8, to be sure you can sleep. Don't skip this or you may have the worst night of your life!
Large plastic straw	To help drink potion.
Pint jar with lid	

Choose a day like Saturday for the cleanse, since you will be able to rest the next day.

Take no medicines, vitamins or pills that you can do without; they could prevent success. Stop the parasite program and kidney herbs, too, the day before.

Eat a no-fat breakfast and lunch such as cooked cereal with fruit, fruit juice, bread and preserves or honey (no butter or milk), baked potato or other vegetables with salt only. This allows the bile to build up and develop pressure in the liver. Higher pressure pushes out more stones.

2:00 PM. Do not eat or drink after 2 o'clock. If you break this rule you could feel quite ill later.

Get your Epsom salts ready. Mix 4 tbs. in 3 cups water and pour this into a jar. This makes four servings, ¾cup each. Set the jar in the refrigerator to get ice cold (this is for convenience and taste only).

6:00 PM. Drink one serving (¾cup) of the ice cold Epsom salts. If you did not prepare this ahead of time, mix 1 tbs. in ¾cup water now. You may add 1/8 tsp. vitamin C powder to improve the taste. You may also drink a few mouthfuls of water afterwards or rinse your mouth.

Get the olive oil and grapefruit out to warm up.

8:00 PM. Repeat by drinking another ¾cup of Epsom salts.

You haven't eaten since two o'clock, but you won't feel hungry. Get your bedtime chores done. The timing is critical for success; don't be more than 10 minutes early or late.

9:45 PM. Pour ½cup (measured) olive oil into the pint jar. Squeeze the grapefruit by hand into the measuring cup. Remove pulp with fork. You should have at least ½cup, more (up to ¾

cup) is best. You may top it up with lemonade. Add this to the olive oil. Close the jar tightly with the lid and shake hard until watery (only fresh grapefruit juice does this).

Now visit the bathroom one or more times, even if it makes you late for your ten o'clock drink. Don't be more than 15 minutes late.

10:00 PM. Drink the potion you have mixed. Take 4 ornithine capsules with the first sips to make sure you will sleep through the night. Take 8 if you already suffer from insomnia. Drinking through a large plastic straw helps it go down easier. You may use ketchup, cinnamon, or brown sugar to chase it down between sips. Take it to your bedside if you want, but drink it standing up. Get it down within 5 minutes (fifteen minutes for very elderly or weak persons).

Lie down immediately. You might fail to get stones out if you don't. The sooner you lie down the mote stones you will get out. Be ready for bed ahead of time. Don't clean up the kitchen. As soon as the drink is down walk to your bed and lie down flat on your back with your head up high on the pillow. Try to think about what is happening in the liver. Try to keep perfectly still for at least 20 minutes. You may feel a train of stones traveling along the bile ducts like marbles. There is no pain because the bile duct valves are open (thank you Epsom salts!). **Go to sleep**, you may fail to get stones out if you don't.

Next morning. Upon awakening take your third dose of Epsom salts. If you have indigestion or nausea wait until it is gone before drinking the Epsom salts. You may go back to bed. Don't take this potion before 6:00 am.

2 Hours Later. Take your fourth (the last) dose of Epsom salts. Drink ¾cup of the mixture. You may go back to bed.

After 2 More Hours you may eat. Start with fruit juice. Half an hour later eat fruit. One hour later you may eat regular food but keep it light. By supper you should feel recovered.

How well did you do? Expect diarrhea in the morning. Use a flashlight to look for gallstones in the toilet with the bowel movement. Look for the green kind since this is proof that they are genuine gallstones, not food residue. Only bile from the liver is pea green. The bowel movement sinks but gallstones float because of the cholesterol inside. Count them all roughly, whether tan or green. You will need to total 2000 stones before the liver is clean enough to rid you of allergies or bursitis or upper back pains permanently. The first cleanse may rid you of them for a few days, but as the stones from the rear travel forward, they give you the same symptoms again. You may repeat cleanses at two week intervals. Never cleanse when you are ill.

Sometimes the bile ducts are full of cholesterol crystals that did not form into round stones. They appear as a "chaff" floating on top of the toilet bowl water. It may be tan colored, harboring millions of tiny white crystals. Cleansing this chaff is just as important as purging stones.

How safe is the liver cleanse? It is very safe. My opinion is based on over 500 cases, including many persons in their seventies and eighties. None went to the hospital; none even reported pain. However it can make you feel quite ill for one or two days afterwards, although in every one of these cases the maintenance parasite program had been neglected. This is why the instructions direct you to complete the parasite and kidney rinse programs first.

CONGRATULATIONS

You have taken out your gallstones without surgery! I like to think I have perfected this recipe, but I certainly can not take credit for its origin. It was invented hundreds, if not thousands, of years ago, THANK YOU, HERBALISTS!

This procedure contradicts many modern medical viewpoints. Gallstones are thought to be formed in the gallbladder, not the liver. They are thought to be few, not thousands. They are not linked to pains other than gallbladder attacks. It is easy to understand why this is thought: by the time you have acute pain attacks, some stones are in the gallbladder, are big enough and sufficiently calcified to see on X-ray, and have caused inflammation there. When the gallbladder is removed the acute attacks are gone, but the bursitis and other pains and digestive problems remain.

The truth is self-evident. People who have had their gallbladder surgically removed still get plenty of green, bile-coated stones, and anyone who cares to dissect their stones can see that the concentric circles and crystals of cholesterol match textbook pictures of "gallstones" exactly.

Lugol's Iodine Solution

It is too dangerous to buy a commercially prepared solution. It is certain to be polluted with propyl alcohol or wood alcohol. Make it yourself or ask your pharmacist to make it up for you. The recipe to make 1 liter (quart) is:

44 gm (1½ ounces) iodine, granular
88 gm (3 ounces) potassium iodide, granular

Dissolve the potassium iodide in about a pint of the water. Then add the iodine crystals and fill to the liter mark with water. It takes about 1 day to dissolve completely. Shake it from time to time. Keep out of sight and reach of children. Do not use if allergic to iodine. Be careful to avoid bottled water for preparation.

Vitamin D Drops

1 gram cholecalciferol (see Sources)
10 cups olive oil

Mix in a non-metal container. It may take a day of standing to dissolve fully. Refrigerate. Ten drops contain 40,000 iu. Use within a year.

Pathogen Frequencies

Living creatures emit a range of frequencies, also called *bandwidth*. As they age, the bandwidth shrinks. When they die sometimes all that is left is a single frequency.

Most of the organisms listed below are dead on commercially available and prepared slides (see *Sources* for biological supply companies). However they still exhibit a 5 KHz bandwidth, probably due to testing with a frequency generator that was only accurate to 100 Hz, and also due to using more voltage than necessary (like when a powerful radio station comes in at its own frequencies and ones nearby, too). Some testing was done with a more accurate frequency generator at a lower power level so some bandwidths are reported much more narrowly.

If the same person retests the same specimens with the same equipment within a few days, the results will be absolutely identical (within 1 Hz) 90% of the time. Why a few of the results will not be identical is not known. However different people, and even the same person at different times of the year, can notice that the perceived frequencies shift by as much as 3 KHz (still less than 1% change).

Some specimens have more than one range listed; this may be characteristic of the organism or may be due to having an undocumented organism on the same microscope slide.

Blank locations represent organisms for whom there are prepared slides available, but whose bandwidth has not been determined.

Bandwidth Of Organism Families

In general, the smaller the organism the lower the frequency and narrower the bandwidth. This chart shows the major families studied and where they fall in the spectrum.

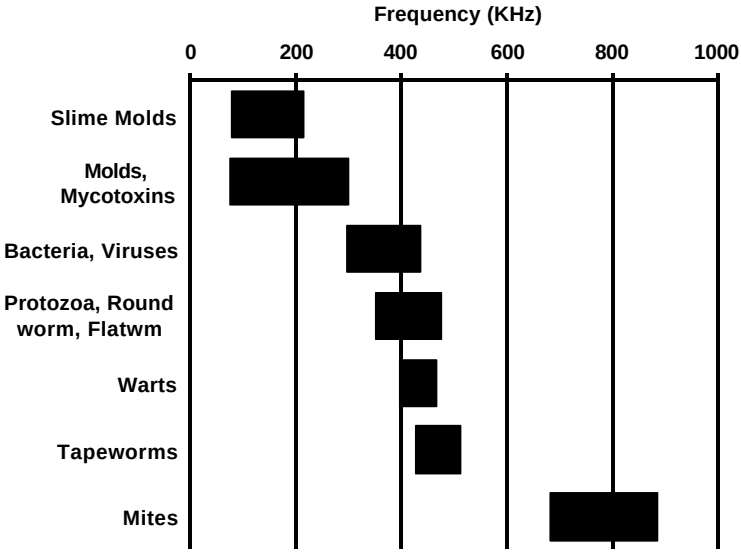

Fig. 90 Chart of bandwidths for organism families.

Mold, Mold Toxin Frequencies

Other molds and mold toxins	**KHz**
Aflatoxin	177,188
Cytochalasin B	77,91
Ergot	295
Griseofulvin	288
Sorghum syrup	277
Sterigmatocystin	88,96,133,126
Zearalenone	100

Slime Molds	**KHz**
Arcyria	81
Lycogala	126
Stemonitis	211

Bacteria and Viruses

Including locations where I commonly found them.

	Low Freq (KHz)	High Freq (KHz)	Use freq gen for 3 min @
Acetobacter aceti			
Adenovirus	393	393	393
Adenovirus (2nd range)	371.45	386.90	
Agrobacterium tumefaciens			
Alcaligenes faecalis			
Alpha streptococcus	369.75	385.4	380,375
Azobacter chroococcum			
Bacillus anthracis causes anthrax in cattle (tooth)	393.5	398.05	395,364,368
Bacillus anthracis (2nd range)	363.2	365.3	
Bacillus anthracis (3rd range)	359.4	370.5	
Bacillus anthracis spores	386.95	391.45	388
Bacillus cereus	373.65	375.85	374.5
Bacillus megaterium			
Bacillus sterothermophilus			
Bacillus subtilis spores			
Bacillus subtilis var. niger	371.85	387.1	385,380,375
Bacteria capsules (capsular strain)	416.05	418.75	417.5
Bacterial capsules	357.6	362.4	360
Bacteroides fragilis found with common roundworm Ascaris	324.3	325.0	325
Bacteroides fragilis (2nd range)	325.7	326.0	
Beta streptococcus (tooth)	380.6	387.4	385
Blepharisma	405.65	407.45	406.5
Bordetella pertussis "whooping cough" (tooth)	329.85	332.25	331
Borellia burgdorferi Lyme disease	378.95	382.0	380
Branhamella (Neisseria) catarrhalis (has hole at 398)	394.9	396.7	396
Brucella abortus			
Cabbage Black Rot			
Campylobacter fetus smear	365.3	370.6	368
Campylobacter pyloridis	352.0	357.2	355
Candida albicans (pure powder) common yeast	384.2	388.4	386
Caulobacter vibrioides			
Central spores (bacillus smear)	372.45	378.65	376
Chlamydia trachomatis	379.7	383.95	381
Clostridium acetobutylicum	382.8	391.15	389,384
Clostridium botulinum (tooth) causes food poisoning	361.0	364.55	362

Clostridium perfringens			
Clostridium perfringens spores	394.2	398.1	396
Clostridium septicum	362.05	365.6	364
Clostridium sporogenes			
Clostridium tetani (tooth) causes tetanus			
Corynebacterium diphtheriae (tooth) causes diphtheria	340	344	342
Corynebacterium pseudodiphthericum			
Corynebacterium xerosis	315.65	316.8	316.0
Coxsackie virus B-1 found with Bacteroides fragilis	360.5	366.1	364
Coxsackie virus B-4 found with Bacteroides fragilis	361.45	363.7	362.5
Coxsackie virus B-4 (2nd range)	363.9	364.9	
Crithidia fasciculata			
Cytomegalovirus (CMV) antigen	408.35	410.75	409
Cytophaga rubra	428.1	432.2	430
Diplococcus diphtheriae	357.95	264.0	361
Diplococcus pneumoniae	351.65	368.45	365,360
Eikanella corrodens	379.5	384.3	382
Enterobacter aerogenes intestinal bacterium	374	374	374
Epstein Barre virus (EBV)	372.5	382.85	380,375
Erwinia amylovora	347.2	352.1	350
Erwinia carotovora	368.1	377.0	373
Escherichia coli (E. coli) intestinal bacterium	356	356	356,393
Escherichia coli (E. coli) (2nd range)	392	393	
Gaffkya tetragena causes respiratory infections	344.85	352.5	350
Gardnerella vaginalis ovarian and genital tract infection	338.0	342.55	340
Haemophilus influenzae bacterial meningitis, infects joints	336.41	336.41	336
Hepatitis B antigen	414.55	420.8	418
Herpes simplex 1	291.25	293.05	292,345.5
Herpes simplex 1 (2nd range)	345.35	345.75	
Herpes simplex 2 (fresh smear)	353.9	362.9	360,355
Herpes Zoster "shingles"	416.6	420.2	418
Histomonas meleagridis (liver)	376.55	378.7	377
Histoplasma capsulatum	298.3	304.85	302
HIV	365	365	365
Influenza A and B (flu shot)	313.35	323.9	320,315
Iron Bacterium Sphaerotilus			
Klebsiella pneumoniae causes pneumonia	398.45	404.65	401,419
Klebsiella pneumoniae (2nd range)	416.9	421.9	
Lactobacillus acidophilus (tooth)	346.05	351.65	349

Leptospira interrogans spirochete	397.05	401.1	399
Lumpy Jaw			
Measles antigen	369.5	373.0	371
Micrococcus luteus			
Micrococcus roseus			
Mumps antigen	377.6	384.65	382
Mycobacterium para TB			
Mycobacterium phlei	409.65	410.65	410.0
Mycobacterium smegmatis			
Mycobacterium tuberculosis (infec nodule) causes tuberculosis	430.55	434.2	432
Mycoplasma	322.85	323.9	323.5,346
Mycoplasma (range 2)	342.75	349.3	
Neisseria gonorrhea causes gonorrhea	333.85	336.5	334
Neisseria sicca			
Nocardia asteroides found in Parkinson's Disease	354.95	355.35	355.1,368
Nocardia asteroides (2nd range)	363.7	370	
Propionobacterium acnes	383.75	389.0	387
Proteus mirabilis	320.55	326.0	324,349
Proteus mirabilis (2nd range)	345.95	352.1	
Proteus vulgaris urinary tract pathogen	408.75	416.45	413,336,328
Proteus vulgaris (2nd range)	333.75	339.15	
Proteus vulgaris (3rd range)	327.2	329.5	
Pseudomonas aeruginosa found in open wounds	331.25	334.6	333
Pseudomonas fluorescens			
Respiratory syncytial virus	378.95	383.15	380
Rhizobium leguminosarum			
Salmonella enteriditis intestinal infection	329	329	329
Salmonella paratyphi	365.05	370.1	368,385
Salmonella typhimurium food poisoning, nervousness, apathy	382.3	386.55	355,386,390
Serratia marcescens	349.45	352.1	351
Shigella dysenteriae intestinal problems	390.089	390.089	390.089
Shigella flexneri depression	394	394	394
Shigella sonnei invades tumors	318	318	318
Sphaerotilus natans	388.4	393.45	391
Spirillum itersonil			
Spirillum serpens	378.35	382.8	380
Spirillum sinuosum			
Spirillum volutans			
Spores in bacteria spore stain			
Staphylococcus aureus (culture)	376.27	380.85	
Staphylococcus aureus (slide) source is tooth infection, causes abscesses, heart disease, invades tumors	381	381	378,381

Staphylococcus epidermidis infects skin and mucous membranes			
Streptococcus lactis occurs in milk	382	387	385
Streptococcus mitis lung infection, tooth infection, abscesses, causes stiff knees	313.8	321.1	318
Streptococcus pneumoniae causes pneumonia and inner ear disease	366.85	370.2	368
Streptococcus pyogenes (tooth)	360.5	375.3	373
Streptococcus sp. group G (tooth)	368.15	368.85	368
Sub terminal spores bac. smear	385.15	385.95	
Terminal spores bacillus smear			
Tobacco mosaic virus (tobacco)	427.15	429.55	428
Treponema pallidum causes syphilis	346.85	347.4	347
Troglodytella abrassari	377.75	385.2	383,419
Troglodytella abrassari (2nd range)	416.9	422.2	
Veillonella dispar	401.75	405.2	403
Vibrio (photobacterium) fischeri			

Roundworms, Flatworms, One-celled Animals

	Low Freq (KHz)	High Freq (KHz)	To kill, use freq. gen for 3 min. at these frequencies
Acanthamoeba culbertsoni			
Acanthocephala			
Anaplasma marginale	386.4	388.0	387,422
Anaplasma marginale (2nd range)	415.3	424	
Ancylostoma braziliense (adult)	397.6	403.25	401
Ancylostoma caninum	383.1	402.9	400,393,386
Ancylostoma duodenale male			
Anguillula aceti			
Ascaris larvae in lung common roundworm of cats and dogs	404.9	409.15	408
Ascaris lumbricoides (m and f)			same
Ascaris megalocephala (male)	403.85	409.7	408
Babesia bigemina			
Babesia canis smear			
Balantidium coli cysts	458.8	462.9	460
Balantidium sp. trophozoites (from guinea pig) parasitic ciliate			
Besnoitia (lung sect.) protozoan	352.8	361.4	358

Capillaria hepatica (liver sect.)	424.25	430.65	428
Chilomastix cysts (rat)	388.95	390.7	389,426
Chilomastix cysts (rat) (2nd range)	425.2	427.3	
Chilomastix mesnili (trophozoites)			same
Chilomonas, whole mount	393.75	400	398
Clinostomum metacercaria			
Clonorchis metacercariae			
Clonorchis sinensis	425.7	428.75	427
Clonorchis sinensis eggs			
Cryptocotyle lingua (adult)	409.95	416.0	414
Didinium			
Dientamoeba fragilis	401.35	406.05	404
Dipetalonema perstans (microfilaria human blood)			
Dirofilaria immitis dog heartworm	408.15	411.15	409
Echinoporyphium recurvatum	418.55	423.9	421
Echinostoma revolutum	425.5	429.65	428
Eimeria stiedae			
Eimeria tenella			
Endamoeba gingivalis trophozoite	433.8	441.0	438
Endolimax nana trophozoites and cysts	394.25	397.1	396,432
Endolimax nana trophozoites and cysts (2nd range)	430.5	433.35	
Entamoeba coli cysts			
Entamoeba coli trophozoites	397.0	400.35	398
Entamoeba histolytica trophozoite	381.1	387.8	385
Enterobius vermicularis	420.95	426.3	423
Eurytrema pancreaticum	420.35	422.3	421
Eurytrema pancreaticum stages			
Fasciola hepatica	421.35	427.3	425
Fasciola hepatica cercariae	423.8	430.6	427
Fasciola hepatica eggs	422.0	427.6	425
Fasciola hepatica metacercariae			
Fasciola hepatica miracidia	421.75	424.7	423
Fasciola hepatica rediae	420.6	427.5	425
Fasciolopsis buskii adult	427.7	435.1	434
Fasciolopsis buskii eggs	427.35	435.45	434
Fasciolopsis buskii eggs unincubated			
Fasciolopsis cercariae	429.5	436.25	434
Fasciolopsis miracidia	427.35	435.2	434
Fasciolopsis rediae	427.3	433.0	432
Fischoedrius elongatus	441.75	443.2	442
Gastrothylax elongatus	451.9	457.1	455
Giardia lamblia (trophozoites)	421.4	426.3	424
Giardia lamblia cysts			
Gyrodactylus	378.75	381.8	380
Haemonchus contortus	386.8	395.5	393
Haemoproteus			

Hasstile sig. tricolor (adult)	448.05	455.1	453
Heterakis			
Hypodereum conoideum	424.45	429.55	427
Iodamoeba butschlii trophozoites and cysts	437.85	448.5	445,402
Iodamoeba butschlii trophozoites and cysts (2nd range)	398.15	404.75	
Leishmania braziliensis	400.05	405.1	403
Leishmania donovani	398.0	402.65	400
Leishmania mexicana	400.2	403.8	402
Leishmania tropica	402.1	407.4	405
Leucocytozoon	397.45	402.55	400
Loa loa	360.551	360.551	361
Macracanthorhynchus	438.85	442.8	440
Metagonimus Yokogawai	437.35	442.1	440
Monocystis agilis			
Myxosoma	409.6	416.95	414
Naegleria fowleri	356.9	364.35	362
Naegleria fowleri (brain sec.)			
Necator americanus (infect larvae)			
Notocotylus quinqeserialis			
Onchocerca volvulus (tumor)	436.3	442.1	440
Paragonimus Westermanii adult	437.8	454.2	452,447
Passalurus ambiguus	428.8	444.15	441,437
Pelomyxa carolinensis			
Plasmodium cynomolgi	417.3	424.5	422
Plasmodium falciparum smear	372.3	373.8	373.0
Plasmodium vivax smear	438.15	445.1	442
Platynosomum fastosum adult			
Pneumocystis carnii (lung)	405.75	409.15	407
Prosthogonimus macrorchis(eggs)	396.85	404.75	401
Sarcina lutea			
Sarcocystis	450.55	454.95	452
Schistosoma haematobium	473	473	473
Schistosoma japonicum eggs			
Schistosoma mansoni	353	353	353
Stephanurus dentalus (ova)	457.35	463.1	461
Stigeoclonium	404.25	415.25	412,407
Strongyloides (filariform larva)	398.4	402.0	400
Strongyloides parasitic females			
Toxocara (eggs)			
Toxoplasma (human strain)	395.0	395.0	395
Trichinella spiralis (muscle)	403.85	405.57	404.5
Trichomonas muris			
Trichomonas vaginalis	378.0	383.6	381
Trichuris sp. (male)	388.3	408.9	406
Trypanosoma brucei	423.2	431.4	429
Trypanosoma cruzi (brain tissue)	460.2	465.65	463

Trypanosoma equiperdum	434.6	451.25	448,442,438
Trypanosoma gambiense	393.75	398.7	396
Trypanosoma lewisi (blood smear)	424.5	426.0	425
Trypanosoma rhodesiense	423.5	428.55	426
Urocleidus	442.35	450.0	447

Wart Frequencies

(Most of these are from homemade slides.)

	Low Freq	High Freq	Use freq gen for 3 min @
Wart BS	402	406	404
Wart CC	426	432.35	430
Wart FR	459.3	464.75	462
Wart HA	434.8	444.1	442,437
Wart HRCm	438.9	448.55	446,441
Wart human papilloma plantar	404.7	406.75	405
Wart human papilloma virus	402.85	410.7	407
Wart JB	418.75	422.4	420
Wart L arm	343.65	345.95	344
Wart papilloma cervix smear	404.05	404.6	404.3

Tapeworms

Tapeworms are segmented. The first segment is the head, called the *scolex*. Tapeworms grow by adding a new segment to their body.

Tapeworms can have very large bandwidths (range of frequencies), and it varies by the length of the specimen! It is as if each new segment has a unique, and slightly lower, frequency.

Do not use a frequency generator to kill tapeworms. If you accidentally kill middle segments instead of working your way up from the bottom, you may conceivably promote dispersion! Use only a zapper.

	Low Freq	High Freq
Cysticercus fasciolaris	436.4	440.05
Diphyllobothrium erinacei (Mansoni) (scolex)	467.25	487.55
Diphyllobothrium erinacei eggs		
Diphyllobothrium latum (scolex)	452.9	472.3
Dipylidium caninum (proglottid composite)	439.55	444.3
Dipylidium caninum (scolex)	451.95	472.15
Echinococcus granulosus	451.6	461.5
Echinococcus granulosus (cysts)	441.15	446.5
Echinococcus granulosus (eggs)		
Echinococcus multilocularis	455.85	458.35
Heterophyes heterophyes		
Hymenolepis cysticercoides	478.0	481.75
Hymenolepis diminuta	445	481.15
Hymenolepis diminuta ova		
Hymenolepis nana eggs		
Moniezia (scolex)	430.35	465.2
Moniezia expansa (composite)	430.35	465.2
Moniezia expansa eggs		
Multiceps serialis	453.6	457.8
Pigeon tapeworm		
Taenia pisiformis (cysticercus)	475.2	482.1
Taenia pisiformis eggs (ova)	465.2	469.7
Taenia saginata (cysticercus)	476.5	481.05
Taenia saginata eggs		
Taenia solium (cysticercus)	475	475
Taenia solium (scolex)	444.0	448.9
Taenia solium eggs		

Mite Frequencies

These are the organisms that cold viruses ride in with!

Mite	KHz
Demodex folliculorum follicle mite	682
Dermatophagoides dust mite	707
Meal mite	718
Ornithonyssus bird mite	877,878
Sarcoptes scabei itch	735

Miscellaneous Frequencies

	KHz
Blue-green Algae	256
Bryozoa cristatalla	396
Mucor mucedo	288
Rhizobium meliloti	330
Rotifer	1151

It's easy to make homemade slides when you or a family member is ill. Finding out the frequencies of these illnesses helps you identify them (use the Pathogen Frequency Chart) and also lets you know if you are chronically getting them back.

Unidentified pathogens	Low Freq	High Freq
A cold virus HRC	395.8	395.8
Fungus EW	362.0	364.9
Fungus JWB	397.2	400.75
Tooth decay	384.3	387.2
Tooth decay (N)	367.9	375.05
Tooth decay (N) (2nd range)	326.95	331.5
Tooth decay (N) (3rd range)	293.2	297.4
Tooth plaque I	378.8	383.05
Tooth plaque I (2nd range)	294.7	298.25
Tooth plaque I (3rd range)	233.1	238.2
Tooth plaque II	384.95	387.05
Tooth plaque II (2nd range)	278.75	284
Tooth plaque II (3rd range)	212.15	218
Tooth plaque II (4th range)	340.15	344.8
Tooth plaque II (5th range)	305.5	310.35

Toxic Elements

Although not living, solvents and toxins must exhibit characteristic frequencies, otherwise how could the Syncrometer detect specific ones? This needs further exploration.

Most of the toxic elements I use are metals, heavy metals and lanthanides. But some are not; examples are PCBs and formaldehyde.

Some important elements are missing, like iron, zinc and manganese. This is because I never could find them present in the white blood cells, and I finally gave up searching for them.

Below is a list of the 70 or so toxic elements I use. Most of them were obtained as Atomic Absorption Standard Solutions and are, therefore, very pure. This prevents mistakes in identifying a toxin. They were stored in ½ounce amber glass bottles with bakelite caps and permanently sealed with plastic film since testing did not require them to be opened (they get close enough to the frequency field). The exact concentration and the solubility characteristics are not important in this qualitative test. The main sources of these substances in our environment are given beside each item.

Toxic Substance	Sources
Aflatoxin B	beer, bread, apple cider vinegar, moldy fruit, nuts
Aluminum	cookware, deodorant, lotions, soaps
Aluminum silicate	salt, water softener
Antimony	fragrance in lotions, colognes
Arsenic	pesticide, “treated” carpet, wallpaper
Asbestos	clothes dryer belt, hair blower, paint on radiators
Barium	lipstick, bus exhaust
Benzalkonium chloride	toothpaste
3,4 Benzopyrene	flame cooked foods, toast
4,5 Benzopyrene	flame cooked foods, toast
Beryllium	hurricane lamps, gasoline, dentures, kerosene
Bismuth	colognes, lotions, antacids
Boron	
Bromine	bleached “brominated” flour
Cadmium	galvanized water pipes, old tooth fillings
Cerium	tooth fillings
Cesium	clear plastic bottles used for beverages
Chlorine	from Chlorox™ bleach
Chromium	cosmetics, water softener
Cobalt	detergent, blue and green body products
Copper	tooth fillings, water pipes
Dysprosium	paint and varnish
Erbium	packaging for food, pollutant in pills
Europium	tooth fillings
Europium oxide	tooth fillings, catalytic converter

Fiberglass	dust from remodeling or building insulation
Formaldehyde	foam in mattresses and furniture, paneling
Gadolinium	tooth fillings
Gallium	tooth fillings
Germanium	with thallium in tooth fillings (pollutant)
Gold	tooth fillings
Hafnium	hair spray, nail polish, pollutant in pills
Holmium	usually found in presence of PCBs
Indium	tooth fillings
Iridium	tooth fillings
Lanthanum	computer and printing supplies
Lead	solder joints in water pipes
Lithium	printing supplies
Lutetium	paint and varnish
Mercury	tooth fillings
Molybdenum	auto supplies
Neodymium	pollutant in pills
Nickel	tooth fillings, metal glasses frames
Niobium	pollutant in pills, foil packaging for food
Palladium	tooth fillings
Platinum	tooth fillings
Polychlorinated biphenyl PCB	detergent, hair spray, salves
Polyvinyl chloride acetate (PVC)	glues, building supplies, leaking cooling system
Praseodymium	pollutant in pills
Radon	cracks in basement cement, water pipes
Rhenium	spray starch
Rhodium	tooth fillings
Rubidium	tooth fillings
Ruthenium	tooth fillings
Samarium	tooth fillings
Scandium	tooth fillings
Selenium	
Silver	tooth fillings
Sodium fluoride	toothpaste
Strontium	toothpaste, water softener
Tantalum	tooth fillings
Tellurium	tooth fillings
Terbium	pollutant in pills
Thallium acetate	pollutant in mercury tooth fillings
Thorium nitrate	earth (dust)
Thulium	pollutant in many brands of Vitamin C
Tin	toothpaste
Titanium	tooth fillings, body powder
Tungsten	electric water heater, toaster, hair curler
Uranium acetate	earth (dust)
Vanadium pentoxide	gas leak in home, candles (not necessarily lit)

Ytterbium	pollutant in pills
Yttrium	pollutant in pills
Zirconium	deodorant, toothpaste

Solvents

This is a list of all the solvents I use together with the main source of them in our environment. These are chemicals, very pure, obtained from chemical supply companies, unless otherwise stated. Those marked with an asterisk (*) were the subject of a recent book *The Neurotoxicity of Solvents* by Peter Arlien-Soburg, 1992, CRC Press.

Solvent	**Source**
1,1,1, Trichloro ethane* (TCE)	flavored foods
2,5-Hexane dione*	flavored foods
2 Butanone* (methyl ethyl ketone)	flavored foods
2 Hexanone* (methyl butyl ketone)	flavored foods
2 Methyl propanol	
2 Propanol (propyl alcohol)	see the propyl alcohol list
Acetone	store-bought drinking water, cold cereals, pet food, animal feed
Acetonylacetone (2,5 hexanedione)	flavored foods
Benzene	see the benzene list (page 354)
Butyl nitrite	
Carbon tetrachloride	store-bought drinking water, cold cereals, pet food, animal feeds
Decane	health food cookies and cereals
Denatured alcohol	obtained from pharmacy
Dichloromethane* (methylene chloride)	store-bought orange juice, herb tea blends
Gasoline regular leaded	obtained at gasoline station
Grain alcohol	95% ethyl alcohol obtained at liquor store
Hexanes*	decaffeinated beverages
Isophorone	flavored foods
Kerosene	obtained at gasoline station
Methanol (wood alcohol)	colas, artificial sweeteners, infant formula
Mineral oil	lotions

Mineral spirits	obtained from paint store
Paradichlorobenzene	mothballs
Pentane	decaffeinated beverages
Petroleum ether	in some gasolines
Styrene*	styrofoam dishes
Toluene*	store-bought drinking water, cold cereals
Trichloroethylene* (TCEthylene)	flavored foods
Xylene*	store-bought drinking water, cold cereals

Pathogen Frequency Chart

Use this chart if you know the frequency and wonder what the pathogen might be.

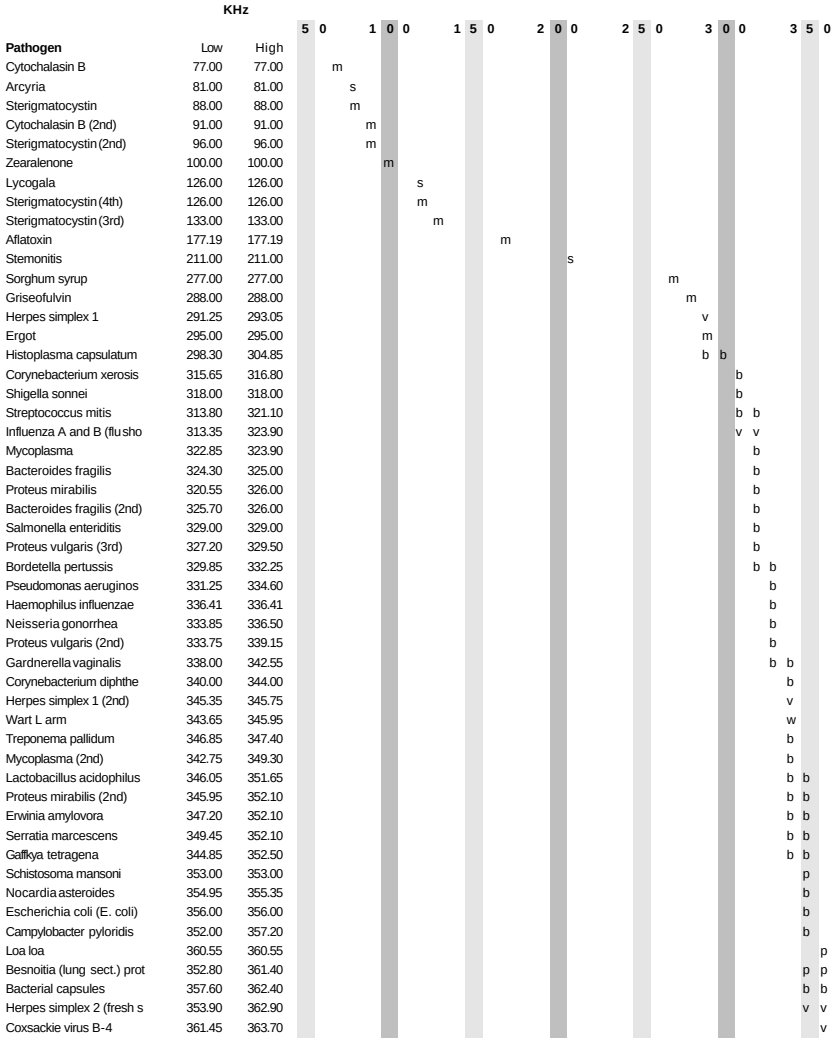

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

Pathogen	KHz Low	KHz High	350	400	450	500
Diplococcus diphtheriae	357.95	364.00	b	b		
Naegleria fowleri	356.90	364.35	p	p		
Clostridium botulinum	361.00	364.55		b		
Coxsackie virus B-4 (2nd)	363.90	364.90		v		
Bacillus anthracis (2nd)	363.20	365.30		b		
Clostridium septicum	362.05	365.60		b		
Coxsackie virus B-1	360.50	366.10		v		
Diplococcus pneumoniae	351.65	368.45	b	b		
Streptococcus sp. group	368.15	368.85		b		
Nocardia asteroides (2nd	363.70	370.00		b	b	
Salmonella paratyphi	365.05	370.10		b	b	
Streptococcus pneumoni	366.85	370.20		b	b	
Bacillus anthracis (3rd)	359.40	370.50	b	b	b	
Campylobacter fetus sme	365.30	370.60		b	b	
Measles antigen	369.50	373.00		v	v	
Plasmodium falciparum s	372.30	373.80			p	
Enterobacter aerogenes	374.00	374.00			b	
Streptococcus pyogenes	360.50	375.30		b	b	
Bacillus cereus	373.65	375.85			b	
Erwinia carotovora	368.10	377.00		b	b	
Central spores (bacillus s	372.45	378.65			b	
Histomonas meleagridis (l	376.55	378.70			b	
Staphylococcus aureus (c	376.27	380.85			b	b
Staphylococcus aureus (s	381.00	381.00				b
Gyrodactylus	378.75	381.80			p	p
Borellia burgdorferi	378.95	382.00			v	v
Spirillum serpens	378.35	382.80			b	b
Epstein Barre virus (EBV)	372.50	382.85			v	v
Respiratory syncytial viru	378.95	383.15			v	v
Trichomonas vaginalis	378.00	383.60			p	p
Chlamydia trachomatis	379.70	383.95			b	b
Eikanella corrodens	379.50	384.30			b	b
Mumps antigen	377.60	384.65			v	v
Troglodytella abrassari	377.75	385.20			b	b
Alpha streptococcus	369.75	385.40		b	b	b
Sub terminal spores bac.	385.15	385.95				b
Salmonella typhimurium	382.30	386.55				b
Adenovirus (2nd range)	371.45	386.90			v	v
Streptococcus lactis	382.00	387.00				b
Bacillus subtilis var. niger	371.85	387.10			b	b
Beta streptococcus	380.60	387.40				b
Entamoeba histolytica tro	381.10	387.80				p
Anaplasma marginale	386.40	388.00				p
Candida albicans	384.20	388.40				y
Propionobacterium acnes	383.75	389.00				b
Shigella dysenteriae	390.09	390.09				b
Chilomastix cysts (rat)	388.95	390.70			p	p
Clostridium acetobutylicu	382.80	391.15			b	b
Bacillus anthracis spores	386.95	391.45			b	b
Escherichia coli (E. coli)	392.00	393.00				b
Adenovirus	393.00	393.00				v
Sphaerotilus natans	388.40	393.45			b	b
Shigella flexneri	394.00	394.00				b
Toxoplasma (human strai	395.00	395.00				p
Haemonchus contortus	386.80	395.50			p	p
Branhamella (Neisseria)	394.90	396.70				b
Endolimax nana trophozo	394.25	397.10				p
Bacillus anthracis	393.50	398.05				b
Clostridium perfringens s	394.20	398.10				b

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

| | KHz | | |

| | KHz | | |

	KHz		550	600	650	700	750	800	850
Pathogen	Low	High							
Demodex folliculorum foll	682.00	682.00				x			
Dermatophagoides dust	707.00	707.00				x			
Meal mite	718.00	718.00				x			
Sarcoptes scabei itch	735.00	735.00					x		
Ornithonyssus bird mite	877.00	878.00							

s = slime mold, m = mold, b = bacteria, v = virus, y = yeast, p = parasite (one-celled animals), t = tapeworm, x = mite

Sources

This list was accurate as this book went to press. Only the vitamin sources listed were found to be pollution-free, and only the herb sources listed were found to be potent, although there may be other good sources that have not been tested. The author has no financial interest in, influence on, or other connection with any company listed, except for having family members in the Self Health Resource Center.

Note to readers outside the United States of America:

Sources listed are typically companies within the United States because they are the ones I am most familiar with. You may be tempted to try a more convenient manufacturer in your own country and hope for the best. I must advise against this! In my experience, an uninformed manufacturer most likely has a polluted product! Your health is worth the extra effort to obtain the products that make you well. One bad product can keep you from reaching that goal. This chapter will be updated as I become aware of acceptable sources outside the United States. Best of all is to learn to test products yourself.

Item	Source
Amber bottles, ½ ounce	Drug store, Continental Glass & Plastic, Inc. (large quantities)
Apricot Kernel Oil	Now Foods

Arginine	Now Foods, Jomar Labs
Artemesia (wormwood) seed	R. H. Shumway
Baking soda (sodium bicarbonate)	Spectrum Chemical Co.
Beet root	San Francisco Herb & Natural Food Co.
Belts for clothes dryer	Three that tested negative to asbestos are: Maytag™ 3-12959 Poly-V belt, Whirlpool™ FSP 341241 Belt-Drum Dr. (replaces 660996), and Bando™ V-Belt A-65. Bando American makes other belts, some of which might be the right size for your dryer. Call for a dealer near you, make sure it says "Made In America", right on the belt.
Black cherry concentrate	Health food store
Black Walnut Hull Tincture	Self Health Resource Center, New Action Products
Borax, pure	Grocery store
Boric acid, pure	Now Foods, health food store, pharmacy
Cascara sagrada	Natures Way, health food store
Chemicals for testing.	Aldrich Chemical Co., Spectrum Chemical Co., ICN Biomedicals, Inc. (research chemicals only, including genistein), Boehringer Mannheim Biochemicals (research only)
Cholecalciferol	Spectrum Chemical Co.
Citric acid	Now Foods or health food store
Cloves	San Francisco Herb & Natural Food Co. (ASK for fresh)
Cornstarch	Lady Lee is the only unpolluted brand found so far
Dental information	Tooth Truth, by Frank J. Jerome, available from New Century Press.
EDTA	Spectrum Chemical Co.
Electronic parts	A Radio Shack near you.
Empty gelatin capsules size 00	Now Foods, or your health food store

Filters, pure charcoal	Pure Water Products (pitchers), Seagull Distribution Co. (faucet, shower, whole house)
Flaxseed oil	Omega Nutrition USA, Inc.
Fucus	San Francisco Herb & Natural Food Co.
Ginger capsules	Now Foods
Goldenrod tincture	Dragon River Herbals, Blessed Herbs
Grain alcohol	Liquor store, as vodka, Everclear™
Gravel root (herb)	San Francisco Herb & Natural Food Co.
Histidine	500 mg from Jomar Labs
Homeopathic remedies	Dolisos America, Inc., and others
Hydrangea (herb)	San Francisco Herb & Natural Food Co.
Hydrogen peroxide 35% (food grade)	New Horizons Trust
Iodine, pure	Spectrum Chemical Co.
Lugol's iodine	For slide staining (not internal use) from Spectrum Chemical Co., and farm animal supply store. For internal use must be made from scratch.
Lysine	Bronson Pharmaceuticals
Magnesium oxide	Bronson Pharmaceuticals
Marshmallow root (herb)	San Francisco Herb & Natural Food Co.
Microscope slides and equipment	Carolina Biological Supply Company, Ward's Natural Science, Inc., Southern Biological Supply Company, Fisher-EMD
Microscopes	Carolina Biological Supply Company, Ward's Natural Science, Inc., Edmund Scientific Co.
Milk Thistle	Herb companies.
Mullein tea	San Francisco Herb & Natural Food Co.
Niacin	100 mg or 250 mg time release, Bronson Pharmaceuticals
Ornithine	Now Foods, Jomar Labs
Ortho-phospho-tyrosine	Aldrich Chemical Co.
Ozonator	Superior Health Products, LLC
P24 antigen sample	Bachem Fine Chemicals Inc.
PABA (para amino benzoic acid)	Bronson Pharmaceuticals
Pantothenic acid	Bronson Pharmaceuticals

Peroxy	See Hydrogen peroxide.
Photo-micrographic camera and film	Ward's Natural Science, Inc.
Potassium bicarbonate	Spectrum Chemical Co., or pharmacy
Potassium chloride	Now Foods, Spectrum Chemical Co.
Potassium iodide, pure	Spectrum Chemical Co.
Rascal	Kroeger Herb Products, New Action Products (as Raz-Caps)
Salt (sodium chloride), pure	Spectrum Chemical Co., get USP grade
Sodium alginate	Spectrum Chemical Co. or health food store
Stevia powder	Now Foods
Tea	San Francisco Herbs, buy in bulk, any single herb variety.
Thallium, homeopathic	Dolisos America, Inc.
Thioctic acid (also called lipoic acid)	Maypro Industries
Uva Ursi	Natures Way or health food store
Vanilla extract	Durkee's™ or Mexican brands
Vegetable glycerin	Now Foods or health food store
Vitamin B Complex	Bronson Pharmaceuticals
Vitamin B_2 (riboflavin)	Nutrition Headquarters (250 mg), or Bronson Pharmaceuticals (100 mg)
Vitamin B_6	Bronson Pharmaceuticals, EDOM Labs
Vitamin B_{12} lozenges	Bronson Pharmaceuticals
Vitamin C (ascorbic acid)	Self Health Resource Center
Vitamin D 50,000iu	From dentist, by prescription, or see Recipes.
Vitamin E capsules	Bronson Pharmaceuticals
Vitamin E Oil	Now Foods
Washing soda (sodium carbonate)	Grocery store
Water filter pitchers	Pure Water Products
Wormwood capsules	Self Health Resource Center, Kroeger Herb Products, New Action Products
Zinc	Bronson Pharmaceuticals
Zinc oxide	Spectrum Chemical Co.

Aldrich Chemical Co.
P.O. Box 355
Milwaukee, WI 53201
(414) 273-3850

Bachem Fine Chemicals Inc.
3132 Kashiwa St.
Torrance, CA 90505
(310) 539-4171

Bando American Inc.
1149 West Bryn Mawr
Itasca, IL 60143
(800) 829-6612
(630) 773-6600

Blessed Herbs
109 Barre Plaines Rd.
Oakham, MA 01068
(508) 882-3839

Boehringer Mannheim Biochemicals
9115 Hague Rd.
P.O. Box 50414
Indianapolis, IN 46250
(800) 262-1640
(317) 849-9350

Bronson Pharmaceuticals
Div. of Jones Medical Industry
1945 Craig Road
P.O. Box 46903
St. Louis, MO 63146-6903
(800) 235-3200 retail
(800) 525-8466 wholesale

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215
(800) 334-5551
(919) 584-0381

Continental Glass & Plastic, Inc.
841 West Cermak Rd.
Chicago, IL 60608-4582
(312) 666-2050

Dolisos America, Inc.
3014 Rigel Ave
Las Vegas, NV 89102
(800) 365-4767
(702) 871-7153

Dragon River Herbals
PO Box 74
Ojo Caliente, NM 87549
(800) 813-2118
(505) 583-2118

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007
(856) 573-6250

EDOM Labs, Inc.
860 Grand Boulevard
P.O. Box 780
Deer Park, NY 11729
(516) 586-2266
(800) 723-3366

Fisher Scientific EMD
485 S. Frontage Rd.
Burr Ridge, IL 60521
(800) 955-1177

ICN Pharmaceuticals, Inc.
Biomedical Division
3300 Hyland Ave.
Costa Mesa, CA 92626
(714) 545-0113
(800) 854-0530

Jomar Labs
251-B East Hacienda Avenue
Campbell, CA 95008
(800) 538-4545
(409) 374-5920

Kroeger Herb Products
(wholesale:)
805 Walnut St.
Boulder, CO 80302
(800) 225-8787
(303) 443-0261
(for retail call:)
Hanna's Herb Shop
5684 Valmont Rd.
Boulder, CO 80301
(800) 206-6722

Maypro Industries
2700 Westchester Ave.
Purchase, NY 10577
(914) 251-0701

Nature's Way
10 Mountain Springs Pkwy
Springville, UT 84663
(800) 962-8873
(801) 489-1500

New Action Products (USA)
P.O. Box 540
Orchard Park, NY 14127
(800) 455-6459
(716) 662-8000

New Action Products (CANADA)
PO Box 141
Grimsby, Ont. L3M4G5 Canada
(800) 541-3799
(716) 873-3738

New Century Press
1055 Bay Blvd., Suite C
Chula Vista, CA 91911
(800) 519-2465
(619) 476-7400

New Horizons Trust
53166 St. Rt. 681
Reedsville, OH 45772
(800) 755-6360
(614) 378-6366

Now Foods
395 Glen Ellen Road
Glen Ellen, IL 60108
(630) 545-9098

Omega Nutrition USA, Inc.
6515 Aldrich Rd.
Bellingham, WA 98226
(800) 661-3529

Superior Health Products, LLC
13549 Ventura Blvd.
Sherman Oaks, CA 91423
(800) 700-1543
(818) 986-9456

Pure Water Products
10332 Parkview Ave.
Westminster, CA 92683
(800) 478-7987

R. H. Shumway
P.O. Box 1
Graniteville, SC 29829
(803) 663-9771

San Francisco Herb & Natural Food Co.
1010 46th St.
Emeryville, CA 94608
(800) 227-2830 wholesale
(510) 601-0700 retail

Seagull Distribution Co.
3372 Baltimore St.
San Diego, CA 92117
(858) 483-0264

Self Health Resource Center
1055 Bay Blvd., Suite A
Chula Vista, CA 91911
(800) 873-1663
(619) 409-9500 (USA)
(780) 475-2403 (Canada)

Southern Biological Supply Company
P.O. Box 368
McKenzie, TN 38201
(800) 748-8735
(901) 352-3337

Spectrum Chemical Co.
14422 South San Pedro Street
Gardena, CA 90248
(800) 772-8786
(310) 516-8000

Ward's Natural Science, Inc.
5100 West Henrietta Road
Rochester, NY 14586
(716) 359-2502
(800) 962-2660

Finale

I hope you have come to the same happy conclusion that I did a few years ago! That we humans don't have hundreds of different maladies and disturbances. **We only have two!** Things that crawl or climb into us. And toxins: unnatural chemicals that we unknowingly inhale or consume.

The living things are both large and small: from worms we can see, to microscopic bacteria, viruses and fungi. The non living things are pollutants in our air, food, dental metal and body products. Taking in a lot of pollutants hampers the body's ability to kill and get rid of the invaders. And so, gradually, as we get older or sicker, the body's invaders get the upper hand and take over. Don't be discouraged if you have lupus, cerebral palsy, cirrhosis, or any complex-sounding disease. Every disease is an example of the same process.

The good news is that our body can reclaim its sovereignty by throwing the rascals out. We must assist by throwing the pollutants out. Fortunately, we don't have to do the whole job ourselves, we only need to assist. Our body has miraculous powers to clean itself up.

By reducing chronic disease to two problems, it becomes manageable. Ill health, even aging, can be reversed. Health comes back and rewards you.

With the new electronic insights and technology, our parasitic invaders can be vanquished with the closing of a switch. Preventing reinfection is the bigger challenge. Similarly, pollutants can be uncovered in as short a time as days, short enough to turn any sick, even terminal, sufferer's verdict around before tragedy occurs.

The tragedies of surgery, organ replacements, radiation, chemotherapies, doses of drugs, even death can be avoided. Reversing illness and turning into a shining example of your for-

mer healthy self could be the most exciting adventure of your life.

Killing your invaders is an easy matter: you simply purchase or build the device that can do that and take the proper herbs. Cleaning up dentalware is under your control, too—a financial expense not beyond your reach, hopefully. Trading your body products for unpolluted varieties is a job but not insurmountable. Cleaning your environment may be the stumbling block. If you can't unpollute your air, water, carpets, furniture, move. Move to a healthier dwelling! Get rid of it all. Like a cat that moves her kittens to a safer place, just move.

The healthiest house is no house. If you have been quite ill, move far enough south to avoid heating and cooling. Sit outside in the shade all day. Use your new wisdom and sharp eye to choose a new dwelling as free of pollutants as you can. No refrigerator indoors. No window air conditioner. No fiberglass insulation. No fossil fuels. No attached garage. No carpets or stuffed furniture, no foam bedding, no fresh paint, no pesticide. Go primitive. Health is primitive. You were born primitive—with health. Even if you weren't, you can undo much of the "inherited" damage.

Don't listen to the new doomsayers, who persuade you nothing can be done unless a gene is replaced. Your genes have been reliable for millions of years. Genes are the most reliable of all biological chemicals in your body. They are not faulty. They are hampered in their tasks. They are commandeered by metals and other species' genes. Those of parasites, bacteria, and viruses. They wouldn't be there if pollutants weren't there. They allow invaders into the most jealously guarded recess of your being: your genes. But now you can throw the rascals out and reclaim your territory. It is not new genes that you need. You simply need your own genes back on the job, directed by your own body, working for you.

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About this electronic book

While creating this electronic version of The Cure for all Diseases, I encountered some inconsistencies and (small) errors in it. Below follows an overview.

Niels Willems, december 2002.
niels.w@hccnet.nl
www.rupa.demon.nl

Page	Line	Hard copy	Electronic version
18	Fig.2	(Di-phyllobothruim e.)	(Di-phyllobothrium e.)
25	last-2	both with a alligator clip	both with an alligator clip
255	last-3	liver cleanses(page 549) make	liver cleanses (page 552) make
360	last-7	health improv-ed	health improved
451	5	furniture"treated"	furniture "treated"
452	last	refigerators	refrigerators
467	14	SALT # 1	SALT #1
519	last	honey	honey.
562	last-7	Argyria	Arcyria
563	16	Bac. antracis spores | 391.45 | 386.95	Bac. antracis spores | 386.95 | 391.45
564	6	Corynebacterium diptheriae	Corynebacterium diphtheriae
565	18	Norcardia asteroides (2nd range)	Nocardia asteroides (2nd range)
570	last-4	folicle mite	follicle mite
575	2	Paradiclorobenzene	Paradichlorobenzene
576	(17)	missing: Aflatoxin (2nd) 188 188	(not corrected)
576	last-19	Corynebacterium diptheri	Corynebacterium diphthe
580	4	folliculorum foli	folliculorum foll

HOW TO CONSTRUCT A BOB BECK BLOOD ELECTRIFIER CIRCUT WITH A BREADBOARD

FOR BEGINNERS

PLEASE VISIT

https://archive.org/details/TakeBackYourPower-BobBecksuppressedMedicalDiscoverieS

TO VIEW THE ENTIRE BOB BECK PROTOCOL HANDOUT

AND WATCH

http://archive.org/details/DrBobBeckVideo-LectureOnCuringCancerAndHiv

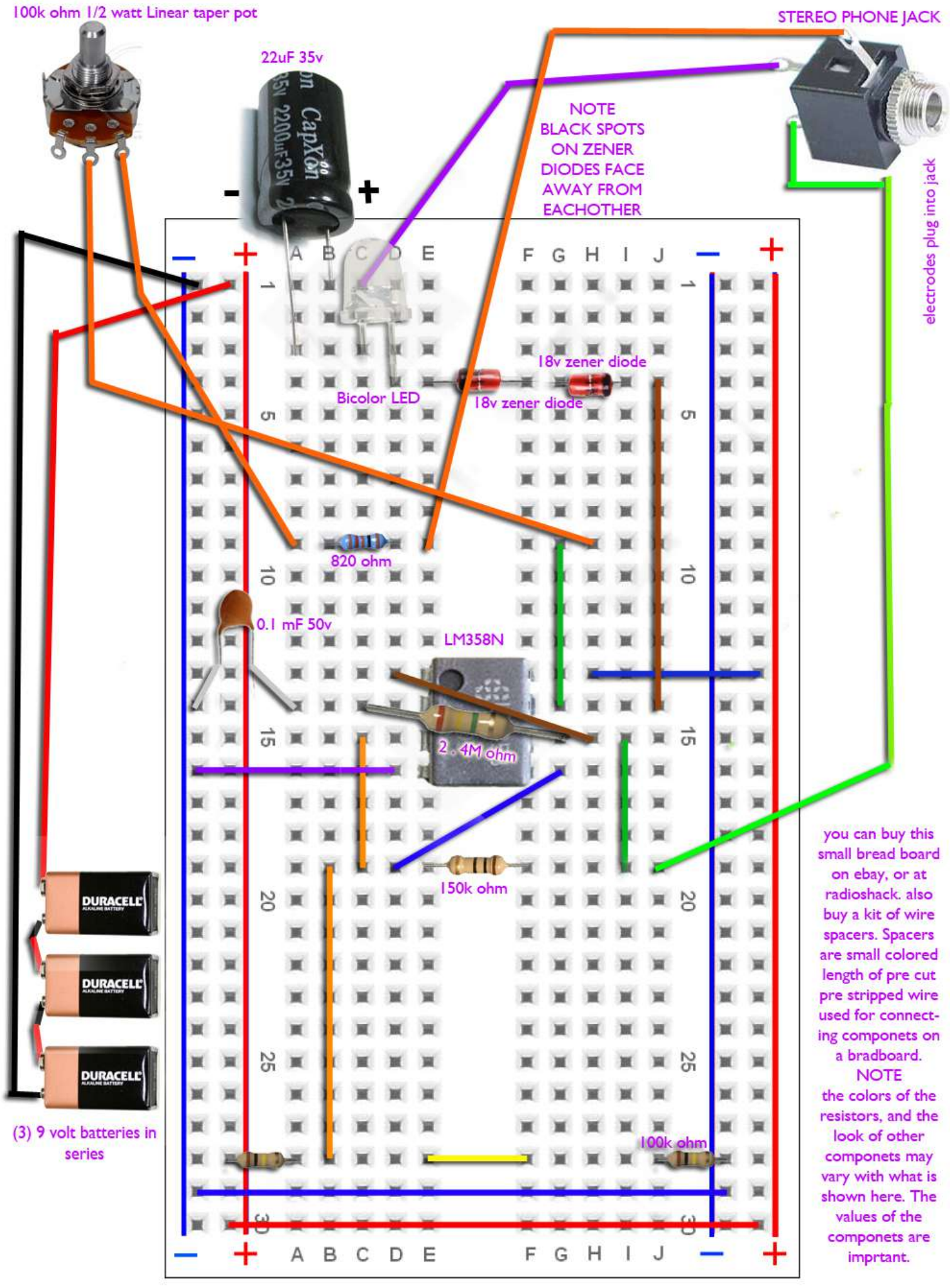
100k ohm 1/2 watt Linear taper pot
22uF 35v
STEREO PHONE JACK
NOTE
BLACK SPOTS
ON ZENER
DIODES FACE
AWAY FROM
EACHOTHER
electrodes plug into jack
18v zener diode
Bicolor LED
18v zener diode
820 ohm
0.1 mF 50v
LM358N
2.4M ohm
150k ohm
100k ohm
(3) 9 volt batteries in series
you can buy this small bread board on ebay, or at radioshack. also buy a kit of wire spacers. Spacers are small colored length of pre cut pre stripped wire used for connecting componets on a bradboard.
NOTE
the colors of the resistors, and the look of other componets may vary with what is shown here. The values of the componets are imprtant.

COMPONENT DESCRIPTIONS, SOURCES, AND CURRENT PRICES

Revision November 24, 1996. Copyright (c) 1991/1999 Robert C. Beck, D.Sc.

Note: These data are for theoretical, informational and instructional purposes only and are not to be construed as medical advice. Consult with your licensed medical practitioner. Hundreds have been built successfully if duplicated exactly as shown.

LM358 CMOS Operational Amplifier (OP-AMP) chip (generic)		U1	$ 1.00
2.4 megohm 1/4 watt 5% resistor		R1	0.07
150 kohm 1/4 watt 5% resistor		R2	0.07
100 k ohm 1/4w 5% resistor	2 required @ 0.15	R3, R4	0.14
100 kohm linear taper pot, 1/2 watt Cattronics P-68		R5	2.56
150 ohm 1/4 watt 5% resistor		R6	0.07
820 ohm 1/4 watt 5% resistor		R7	0.07
0.1 mF 50 V (or higher) ceramic capacitor		C1	0.45
22 mF 35 V (or higher) electrolytic capacitor		C2	0.25
18 Volt Zener diodes (NTE5027A)	% Watt, 2 @ 0.79	D1 & D2	1.58
Bulb, 6.3V 0.075 A	Type 7377	B1	1.34
Bicolor LED Red/Green	RS# 276-012	LED 1	$ 1.19
Jack for electrode leads (3.5mm or 1/8" mono-phone jack)	RS# 274-251 3/$1.59	J1	0.53
Jack for silver wire leads (2.5mm or 3/32" mono-phone jack)	RS# 274-292 3/$1.59	J2	0.53
3 Alkaline 9 V batteries, type 1604 etc.	3 for		3.75
3 x 9 V battery snaps (clip-on connectors)	RS# 270-325 pkg.	5/$1.29	1.29
Misc. wire, solder, etc.			0.50
Box, if used			2.29
Lead wire with 3.5 mm plug, 6 ft., Mouser or Calrad Electronics			0.35
Electrodes, stretch elastic, Velcro, cotton flannel, alligator clips, etc.			
Total Cost **for all** components for improved **do-it-yourself** project			**$22.47**

All components listed above check your local electronics store.

Ensure the IC chip U 1 (LM358) is wired correctly. The location of Pin #1 is shown below:

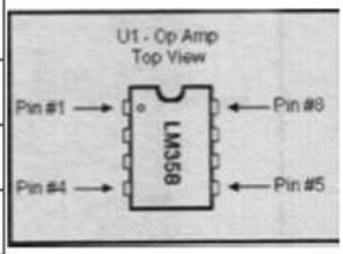

NOTE RESISTOR COLORS NOT TO SPEC. CHECK RESISTOR COLOR VALUES

electrodes:
3/32 x 1
stainless steel cotter pins -hardware store-
Snap pins in half across the curve. and wrap the headphone wires comming from the mono plug around the curve of each half of the pin. then hou glue into place.

		Bids	Price	Time left	Actions
☐	.1 mf 50v Monolythic Capacitor - Lot of 10 hodge16 | 2777 | 100.0% Quantity available: 466	--	$1.99 Buy it Now or Best Offer + $3.49 shipping	2d 01h	Buy it now Make Best Offer More actions
☐	820 Ohm ¼ Watt Metal Film Resistor 1% 5pcs 1/4 FREE BONUS... curtsnovelty | 6212 | 99.8% Quantity available: 4	--	$1.39 Buy it Now Free shipping	4d 03h	Buy it now Add to cart More actions
☐	Enlarge 1ft Pure Silver Wire 9999 Fine 14g Pdxsilverguydotcom colloidalsilverguy | 1052 | 100.0% Quantity available: 572	--	$18.00 ® Buy it Now + $2.00 shipping	5d 22h	Buy it now Add to cart More actions
☐	CTS 100K OHM LINEAR TAPER POT 1" SHAFT k5svc | 15973 | 99.9% Quantity available: 12	--	$6.95 Buy it Now + $5.50 shipping	6d 01h	Buy it now Add to cart More actions
☐	NTE NEH22M35BA - CAP-22MF 35V AXIAL #:NEH22M35BA radioshack | 10790 | 98.9% Quantity available: 100	--	$1.02 Buy it Now Free shipping	6d 19h	Buy it now Add to cart More actions

Blood Electrification

and

Ionic/Colloidal Silver

"White cells (leukocytes) kill bacteria and pathogenic fungi by electrocuting them. Discovered by Jacques Schrenzel and Karl Heinz Krause, Geneva University Hospital, Switzerland, this defense mechanism is triggered as soon as receptors of the white cell detect the microbe's presence. This signal activates an enzymatic system on the leukocyte's membrane, composed of a "sleeping" enzyme (NADP II oxidize) and co-enzyme (NADP II), the reaction begins by the enzyme "waking up", receiving electrons from its co-enzyme, and transporting them through the membrane. Ejected out of the white cell, this electronic flux is focused toward the bacteria with oxygen molecules and the microbe dies. This discovery might open new lines of research on immunity deficiencies in patients who are deprived of this enzymatic system."

Translated from Science & Vie, Issue #972, September, 1998 page 44.
Telephone: 01-46-48-48-48 and Fax: 01-46-48-48-67

Looking at this totally as a "physics" or "engineering" problem, a few structured electrons can act as the equivalent of trillions of white cells and restore function to one's immune system!
The electrons cost pennies.

US Patents

Amazingly similar discoveries have been made by scientists and are a permanent record in the US Patent Office since the 1880's. Why don't we know of these? Many work far more effectively than expensive antibiotics and have no side effects and practically no costs.

Since the Abraham Flexner propaganda funded by pharmaceutical company owner John D. Rockefeller in 1910 eliminated electromedicine from accredited medical universities, researchers have not pursued breakthrough discoveries. They are usually discredited. Instead the public spends billions of dollars annually with "medicines" that may create more side-effects than the original symptoms.

Here is a condensed reference list of US Patents which professional researchers may find interesting:

1 Direct application of electricity to kill or attenuate microorganisms in liquid.

1) Kaali	5,188,738	
2) Kaali	5,139,684	
3) Lathrop	5,133,352	
4) Ellis	4,019,510	
5) Myers	3,753,886	
6) Jones	592,735	(1897)
7) Dawson	3,965,008	
8) La Comme	672,231	(1901)

II Applications of Magnetic Fields to Kill or Attenuate Micro–Organisms.

1) Hofmann	4,524,079
2) Middleton	5,645,697
3) Forrest	5,248,437

III Application of Magnetic Fields in the Treatment of Cancer.

1) Costa	4,665,898
2) Liboff	5,437,600
3) Gordon	4,106,488
4) Gordon	4,303,636
5) Gordon	4,622,952

IV Application of Electricity and Magnetic Fields to produce other Biological Effects.

1) Cadossi	4,683,873 (Fuse Bone)
2) Ryaby	4,266,532 (Modify Cells)
3) Findl	4,428,366 (Reduce Serum Glucose)
4) Chang	4,822,470 (Cell Electroporation)

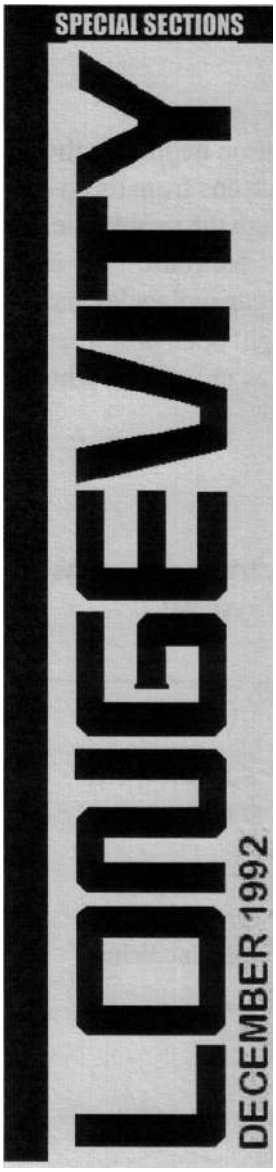

LONGEVITY/DECEMBER 1992, Page 14

OUTER LIMITS

ELECTROCUTING THE AIDS VIRUS

A SAFER-YET BLOOD SUPPLY

Despite official reassurances about the safety of the nation's blood supply, concern lingers that small amounts of HIV—infected blood may be sneaking through, especially since current screening detects only antibodies to the virus, which can take months to form. But now a new electrical process for cleaning blood of viruses may solve the problem.

At the Albert Einstein College of Medicine in New York City, Steven Kaali, M.D., has found that most of the AIDS viruses in a blood sample will lose their infectious capability after being zapped by a very low—level current. Repeated exposure appears to leave blood virtually free of HIV, as well as hepatitis—without harming blood cells.

Kaali cautions that it will take years of testing before a virus—electrocuting device is ready for use. But, ultimately, he predicts, it could be used not just to purify blood, but to treat people with AIDS, by channeling their blood out of the body, exposing it to virus—killing current and then returning it. "By lowering the viral count," he says, "we may be able to lengthen and improve the quality of AIDS patients' lives."

—Sharon McAuliffe

MARCH 30, 1991 Page 207

Biomedicine

Shocking Treatment proposed for AIDS

Zapping the AIDS virus with low–voltage electric current can nearly eliminate its ability to infect human white blood cells cultured in the laboratory, reports a research team at the Albert–Einstein College of Medicine in New York City.

William D. Lyman and his colleagues found that exposure to 50 to 100 microamperes of electricity—comparable to that produced by a cardiac pacemaker—reduced the infectivity of the AIDS virus (HIV) by 50 to 95 percent. Their experiments, described March 14 in Washington, D.C., at the First Inter–national Symposium on Combination Therapies, showed that the shocked viruses lost the ability to make an enzyme crucial to their reproduction, and could no longer cause the white cells to clump together—two key signs of virus infection.

The finding could lead to tests of implantable electrical devices or dialysis–like blood treatments in HIV–infected patients, Lyman says. In addition, he suggests that blood banks might use electricity to zap HIV, and vaccine developers might use electrically incapacitated viruses as the basis for an AIDS vaccine. For scientists working to create contraceptive devices that repel sperm with electricity, the new study also hints at a lifesaving side effect: protection against HIV.

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Scientists say electric current may help fight AIDS

REUTER NEWS SERVICE

NEW YORK — Doctors at a prestigious New York medical center are testing a new way to fight AIDS— using electrical energy to weaken the killer virus— and say their first results are encouraging.

Researchers William Lyman and Steven Kaali of the Albert Einstein School of Medicine said Tuesday that initial laboratory tests have shown electrical current can weaken the virus believed to cause acquired immune deficiency syndrome.

The two men said they plan to move to the next phase of the experiment in April using blood samples from people with AIDS.

If their tests are successful, the researchers hope it could lead to a new way to treat AIDS patients, possibly involving a dialysis—type machine in which an AIDS patient's blood would be treated with electrical current outside the body.

"What we have done is expose the AIDS virus in laboratory circumstances to electrical current and then incubated the virus with white blood cells susceptible to the virus. We found that the virus became much more ineffective," Kaali, a specialist in the medical use of electrical current, said Lyman, an AIDS researcher and associate professor of pathology at Einstein, likened the new technique to chemotherapy.

"You are not going to get rid of the tumor, but you could get rid of enough of it to help the patient lead a normal life. This is not a cure but a new tool," Lyman said.

He added that the use of electrical energy has no toxic side effect and that a similar technique has been used as a treatment for reducing herpes.

US005188738A

United States Patent [19]

Kaali et al.

[11] Patent Number: 5,188,738

[45] Date of Patent: * Feb. 23, 1993

[54] ALTERNATING CURRENT SUPPLIED ELECTRICALLY CONDUCTIVE METHOD AND SYSTEM FOR TREATMENT OF BLOOD AND/OR OTHER BODY FLUIDS AND/OR SYNTHETIC FLUIDS WITH ELECTRIC FORCES

[76] Inventors: Steven Kaali, 88 Ashford Ave., Dobbs Ferry, N.Y. 10522; Peter M. Schwolsky, 4101 Cathedral Ave., NW., Washington, D.C. 20016

[*] Notice: The portion of the term of this patent subsequent to Aug. 18, 2009 has been disclaimed.

[21] Appl. No.: 615,437

[22] Filed: Nov. 16, 1990

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 562,721, Aug. 6, 1990, abandoned.

[51] Int. Cl.[5] B01D 35/06; A61K 41/00

[52] U.S. Cl. ..... 210/748; 128/419 R; 128/421; 128/783; 128/784; 204/131; 204/164; 204/186; 204/302; 210/243; 422/22; 422/44; 604/4

[58] Field of Search ..... 210/243, 748, 764; 128/419 R, 421, 783, 784; 604/4; 422/22, 44; 204/131, 164, 186, 242, 275, 302, 305

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Primary Examiner—Robert A. Dawson
Assistant Examiner—Sun Uk Kim
Attorney, Agent, or Firm—Charles W. Helzer

[57] ABSTRACT

A new alternating current process and system for treatment of blood and/or other body fluids and/or synthetic fluids from a donor to a recipient or storage receptacle or in a recycling system using novel electrically conductive treatment vessels for treating blood and/or other body fluids and/or synthetic fluids with electric field forces of appropriate electric field strength to provide electric current flow through the blood or other body fluids at a magnitude that is biologically compatible but is sufficient to render the bacteria, virus, parasites and/or fungus ineffective to infect or affect normally healthy cells while maintaining the biological usefulness of the blood or other fluids. For this purpose low voltage alternating current electric potentials are applied to the treatment vessel which are of the order of from about 0.2 to 12 volts and produce current flow densities in the blood or other fluids of from one microampere per square millimeter of electrode area exposed to the fluid being treated to about two milliamperes per square millimeter.

31 Claims, 6 Drawing Sheets

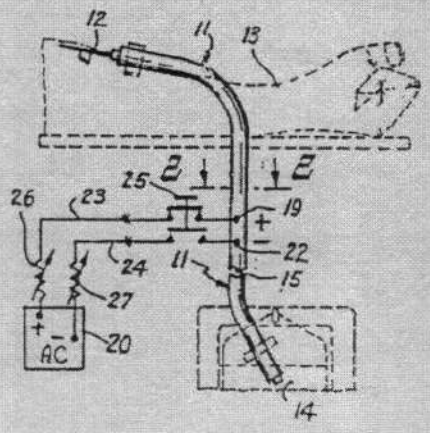

Fig. 1

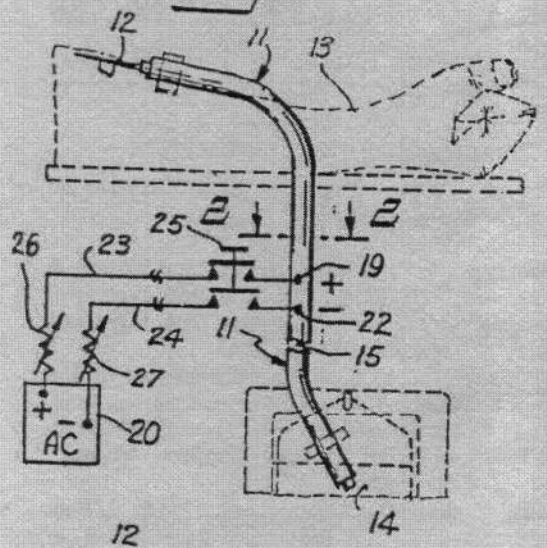

ALTERNATING CURRENT SUPPLIED ELECTRICALLY CONDUCTIVE METHOD AND SYSTEM FOR TREATMENT OF BLOOD AND/OR OTHER BODY FLUIDS AND/OR SYNTHETIC FLUIDS WITH ELECTRIC FORCES

FIELD OF INVENTION

This is a continuation-in-part application of prior U.S. patent application Ser. No. 07/562,721 filed Aug. 6, 1990, now abandoned

This invention relates to novel electrically conductive methods and systems employing electrically conductive vessels provided with electrically conductive surfaces for use in subjecting blood and/or other body fluids and/or synthetic fluids such as tissue culture medium to direct treatment by alternating current electric forces.

BACKGROUND PROBLEM

It is now well known in the medical profession and the general public that blood collected in a blood bank from a large number of donors may be contaminated by contaminants such as bacteria, virus, parasites and/or fungus obtained from even a single donor. While screening of donors has done much to alleviate this problem, the screening of donors can and does miss occasional donors whose blood is unfit for use. When this occurs and the unfit blood is mixed with otherwise usable blood, the entire batch must be discarded for transfusion purposes. Because of this problem, the present invention has been devised to attenuate any bacteria, virus (including the AIDS HIV virus) parasites and/or fungus contained in blood contributed by a donor to the point that any such contaminant is rendered ineffective for infecting a normally healthy human cell, but does not make the blood biologically unfit for use in humans. Similar problems exist with respect to treatment of other body fluids, such as amniotic fluids. The treatment method and system is also applicable to mammals other than humans.

Fig. 6

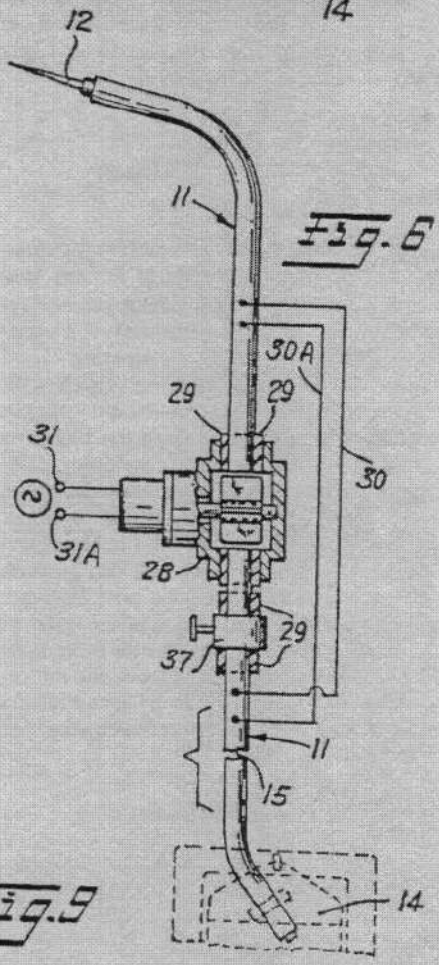

Fig. 8

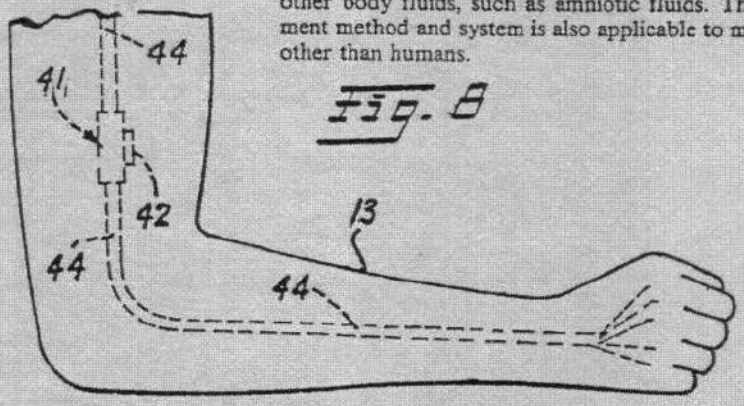

Fig. 9

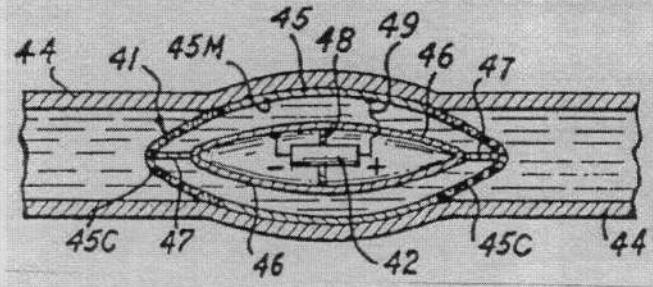

Fig. 10

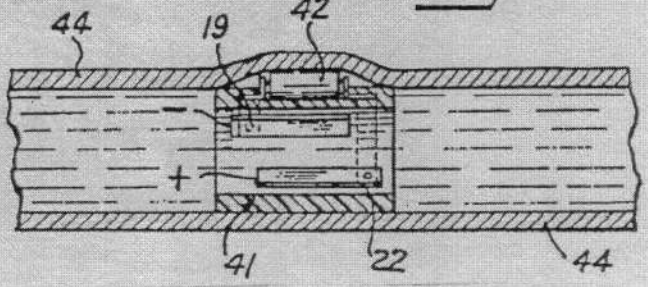

A PROPOSED EXPERIMENTAL/THEORETICAL, NON-INVASIVE, NON-PHARMACEUTICAL, IN VIVO METHOD FOR POSSIBLE NEUTRALIZATION OF HIV VIRUS IN HUMAN SUBJECTS.

Revision March 1999. Copyright 1991/98 by Robert C. Beck, D.Sc.

In a remarkable and startling discovery at Albert Einstein College of Medicine, NYC in 1990, it was shown that a minute current (50-100 microamperes) can alter outer protein layers of HIV virus in a petri dish so as to prevent its later attachment to receptor sites. *(Science News*. March 30, 1991 pg. 207.) It may also reverse Epstein—Barr (chronic fatigue syndrome), hepatitis, Lupus, cancer and many others. HIV—positive users of this enclosed information may expect a dramatic reduction of symptoms after about 45 days. ***This is reminiscent of a well proven cure for snakebite by application of electric current that instantly neutralizes the venom's toxicity.*** *(Lancet,* July 26, 1986 pg. 229.) And there may be several other diseases as yet undiscovered or untested viruses neutralizable with this discovery; perhaps more surprisingly, even the common cold.

This very simple and valid blood clearing treatment proved of great promise as a positive method for immobilizing known strains of HIV still present and contaminating some European and US blood bank reserve supplies. It was further suggested that infected human HIV carriers *could recover* by removing their blood, treating it electrically and returning it by methods similar to dialysis or by surgically implanting electrode arrays with miniature batteries sewn inside blood vessels as described in US patent #5,188,738. Dr. S. Kaali, MD, projected that "years of testing will be in order before such an *in vitro* (blood removed for treatment) device can be made ready for widespread use." *(Longevity,* Dec. 1992, page 12.) This paper reveals an alternate do-it—yourself approach for electrifying/purifying blood *with no dialysis, implants, or medical intervention*.

In the writer's opinion both blood and lymph can be cleared *in vivo* (which means blood isn't removed or skin ever penetrated) simply, rapidly and inexpensively with similar but *non—invasive do—it-yourself techniques* described herein. All are fully disclosed in this paper. Also included are proven schematics, parts lists, electrode construction and complete instructions. Electronic and controlled electroporation approaches may easily make vaccines, antibiotics and pharmaceuticals obsolete.

In a public lecture (Oct. 19, 1991) the writer proposed this theoretical do—it—yourself method for eliminating HIV, parasites, fungi, viral and pathogens *in vivo*. Subsequently, his original modalities and protocols have been refined, simplified and made universally affordable. These three simple treatments used in tandem are offered for research purposes to determine the extent to which they nullify known electro-sensitive pathogens residing in blood, lymph, and other body tissue and fluids. Following is a summary of several years of testing with this non—iatrogenic, do—it-yourself, simple and inexpensive experimental solution to the ever—escalating "incurables" **dilemma.** ***There are no known side effects since milliampere currents applied to skin are much lower than those in FDA approved TENS, CES and muscle stimulators which have been in safe daily use for many years.*** Battery replacement costs are about $10.00 per month per user or about 330 per day for a typical 30 day "spontaneous remission." No pharmaceuticals, shots, or medications appear necessary.

One compact battery—powered blood clearing instrument is basically a miniature relay driven by a timer chip set to —4 Hertz. Its 0 to 33V user adjustable biphasic output minimizes electrode site irritation. The described system delivers stimulation through normally circulating blood via electrodes placed at selected sites on wrist or arm. Optimum electrode positions are reliably located by feeling for strongest pulse (page 19.) Micro-current treatment is of such low amplitude that it creates no discomfort when used as directed and is demonstrated to have no harmful side effects on healthy blood cells or

tissue.

A major obstacle to this simple, proven and obvious solution is disbelief. Treating approximately 120 minutes per day for four to twelve weeks should in the writer's opinion effectively neutralize well over 95% of HIV plus any other electro-sensitive viruses, parasites, bacteria, pathogens or fungi in blood.

In heavy infections, shorter application times will prevent stressing patients with toxins. Simply treat for a greater number of days or also ingest ozonized water. In time, the restored immune system plus silver colloid may handle residual problems. In the special case of diabetically impaired circulation longer treatment times may be indicated. (See expanded instructions pages 22-23). Immobilized viruses may be expelled naturally through kidneys and liver. More rapid neutralization is possible but ***not*** recommended because of potential excessive toxin elimination (Herxheimer's syndrome.) T—cell counts usually drop initially because of lysing and scavenging by macrophages but should recover and increase after a few months. There is too much controversy around the PCR test and it has not been proven as a reliable measurement for HIV.

Latent/germinating HIV reservoirs in body's *lymph* or other tissues and glands may theoretically be neutralized with a second and separate device by the strategy of generating a very high intensity (~20 kilogauss) short duration (-10 uS) magnetic pulse of >~32 Joules by discharging a modified strobe light's capacitor through an applicator coil held against body locations over lymph nodes, thymus, kidneys, adenoids and other possible internal sites of latent infection (see page 43). By the physics of Eddy current/back e.m.f. "transformer action" (Lenz' law) the desired criteria of minimum current induced through infected tissue on the order of >100uA should be readily attained. Several pulses repeated at each site over several weeks may insure a reliable "overkill" for successful disease neutralization. A magnetic "pulser" is very simple to build. Full instructions are on page 41-42.

Subjects must assume responsibility for their own health. In today's society, we are conditioned to look for answers only to a medical establishment. Unfortunately current medical practices have been unable to cure so many illnesses today.

These "theoretical solutions" are being disclosed under constitutional freedom of speech guarantees. ***Data*** **is offered only as theoretical and no medical claims are made or implied.** "See your health professional!" Anyone at his discretion and assumed responsibility should be free to build, use (on himself) and network his "research" results. With this data, someone with a little knowledge of electronics should confidently be able to assemble *both* theoretical blood and tissue clearing modalities in about three hours. Components are widely available. After assembling, the only additional cost is for batteries. If electronically unskilled, "busy" or technically illiterate, call an "Amateur Radio Supply" store (yellow pages) or find a ham radio operator, hobbyist or TV repairman. After "spontaneous remissions" some users may wish to interest their doctors. But be advised that *electronic* cures may be vigorously suppressed or ignored because there is presently no credibility nor drug cartel profit in this inexpensive solution. Also the 1910 Rockefeller—Flexner Report attempted to discredit electro—medicine with intent to give pharmaceuticals a monopoly.

I'm definitely *not* soliciting funds. This was independently developed by me, Bob Beck, at my private expense and offered freely for "theoretical, informational, and educational purposes only" and with absolutely no profit motive.

Non-FDA approved devices are illegal to use within the USA except via little known FDA loopholes. *Researchers* are allowed to use *anything* on patients if safe, they build it themselves and don't sell them. (Code of Federal Regulations 21 § 807.65 subsections {d} & {f} . See actual text in footnote on page 21). Although we will offer technical updates and always welcome feedback from users, please respect the writer's privacy and never attempt to contact him for additional help, advice or information. *Everything* users need to know is included herein.

Feedback: SOTA Instruments Inc. gathers feedback from individuals and health practitioners on the use of The Beck Protocol.

1-800-224-0242 or 250-770-2023
Fax: 250-770-1999, www.sotainstruments.com

IMPROVED SCHEMATIC

This 11/24/1996 schematic describes a **"Plant Growth Stimulator"** improved since my 1991 design. User tested for over two years, it is solid state (no relays), uses three (not seven) batteries, makes colloids, is much smaller, lighter, silent, with battery saving features.

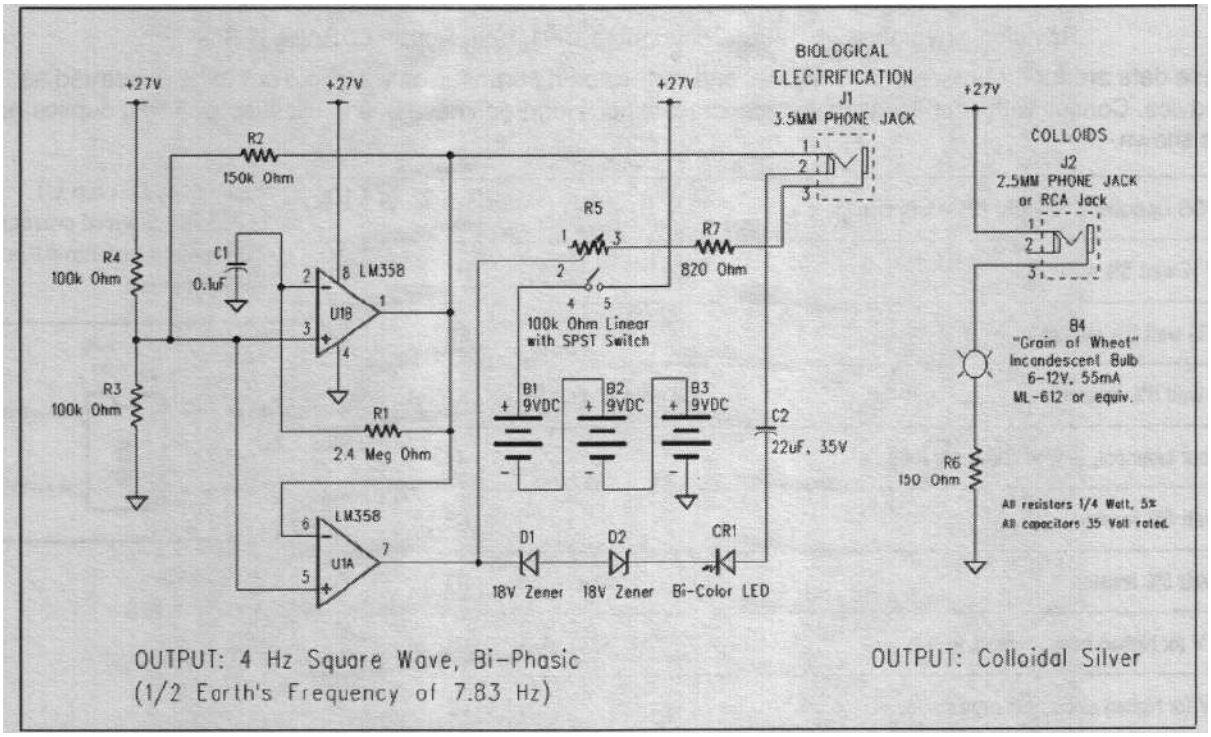

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The first section (U1B) of the LM358 dual op amp is a 50 volt peak to peak square wave oscillator. The second section (U1A) reverses polarity and provides ±27 Volts DC output of low impedance. This delivers a Bi-Phasic, sharp rise time output of Hz (not critical) for the biological cotton covered stainless steel electrodes saturated with salt water before applying. Sharp rise time is considered necessary to provide higher odd harmonics to the stimulus, although "rounded" waveforms will feel different.

The third section is a current limited 27 Volts DC output from a separate RCA (or 2.5mm) jack for rapid generation of excellent colloidal silver in water. A three minute cycle in 8 Oz. of room temperature water makes a ppm concentration.

Op amp section U1B's 4 Hz oscillator frequency is set by C1 (0.1 uF) and R1 (2.4 meg W). It is configured as a comparator with hysteresis determined by R2 (150 kW). Charging and discharging of C1 is done by the 180° out-of phase signal through Rl. R3 and R4 provide a set point 1/2 the V+ to the comparator. This insures a 50% duty cycle square wave with an amplitude of slightly less than the —27 Volt supply.

U1A, the *second comparator,* is used to invert the output of oscillator U1B. A —50 Volt peak to peak signal will be generated between the op amps due to their outputs being 180° out-of phase. U1A's current is limited by potentiometer R5 (100 kW) and R7 (820 W) and is set to individual user's comfort.

The *power indicator* circuit consists of a bicolor (red green) LED (CR1) and the series combination of two 18 Volt Zener diodes, D 1 & D2, with power limited by C2 (22 uF, 35 Volt). This section of the device is automatically disabled when the 3.5 mm plug is inserted into its jack. Therefore the LEDs flash only when batteries sum is over —21 Volts. If LEDs are dim or extinguished, replace with three fresh 9 Volt Alkaline batteries. C2 used as a limiter allows the LED to flicker on at 1/8 second intervals only as the square wave output reverses polarity.

Users find this newer design highly satisfactory, trouble free and most efficient.

IMPROVED SCHEMATIC - Parts List
PROPOSED THEORETICAL IN-VIVO BLOOD, HIV, PATHOGEN, PARASITE AND FUNGI NEUTRALIZING DEVICE

COMPONENT DESCRIPTIONS, SOURCES, AND CURRENT PRICES

Revision November 24, 1996. Copyright (c) 1991/1999 Robert C. Beck, D.Sc.

Note: These data are for theoretical, informational and instructional purposes only and are not to be construed as medical advice. Consult with your licensed medical practitioner. Hundreds have been built successfully if duplicated exactly as shown.

LM358 CMOS Operational Amplifier (OP-AMP) chip (generic)		U1	$ 1.00
2.4 megohm 1/4 watt 5% resistor		R1	0.07
150 kohm 1/4 watt 5% resistor		R2	0.07
100 k ohm 1/4w 5% resistor	2 required @ 0.15	R3, R4	0.14
100 kohm linear taper pot, 1/2 watt Cattronics P-68		R5	2.56
150 ohm 1/4 watt 5% resistor		R6	0.07
820 ohm 1/4 watt 5% resistor		R7	0.07
0.1 mF 50 V (or higher) ceramic capacitor		C1	0.45
22 mF 35 V (or higher) electrolytic capacitor		C2	0.25
18 Volt Zener diodes (NTE5027A)	% Watt, 2 @ 0.79	D1 & D2	1.58
Bulb, 6.3V 0.075 A	Type 7377	B1	1.34
Bicolor LED Red/Green	RS# 276-012	LED 1	$ 1.19
Jack for electrode leads (3.5mm or 1/8" mono-phone jack)	RS# 274-251 3/$1.59	J1	0.53
Jack for silver wire leads (2.5mm or 3/32" mono-phone jack)	RS# 274-292 3/$1.59	J2	0.53
3 Alkaline 9 V batteries, type 1604 etc.	3 for		3.75
3 x 9 V battery snaps (clip-on connectors)	RS# 270-325 pkg.	5/$1.29	1.29
Misc. wire, solder, etc.			0.50
Box, if used			2.29
Lead wire with 3.5 mm plug, 6 ft., Mouser or Calrad Electronics			0.35
Electrodes, stretch elastic, Velcro, cotton flannel, alligator clips, etc.			5.00
Total Cost **for all** components for improved **do-it-yourself** project			**$22.47**

Ensure the IC chip U 1 (LM358) is wired correctly. The location of Pin #1 is shown below:

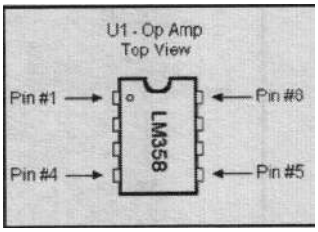

All components listed above check your local electronics store.

Map of Blood Vessels in Extremities for Optimum Electrode Access

Gray's Anatomy pgs. 540, 541, 584, 591

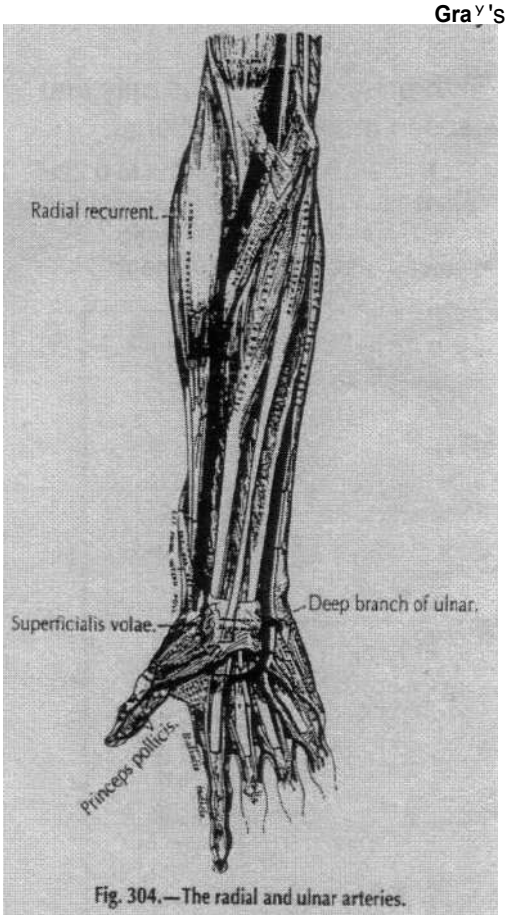

Fig. 304.—The radial and ulnar arteries.

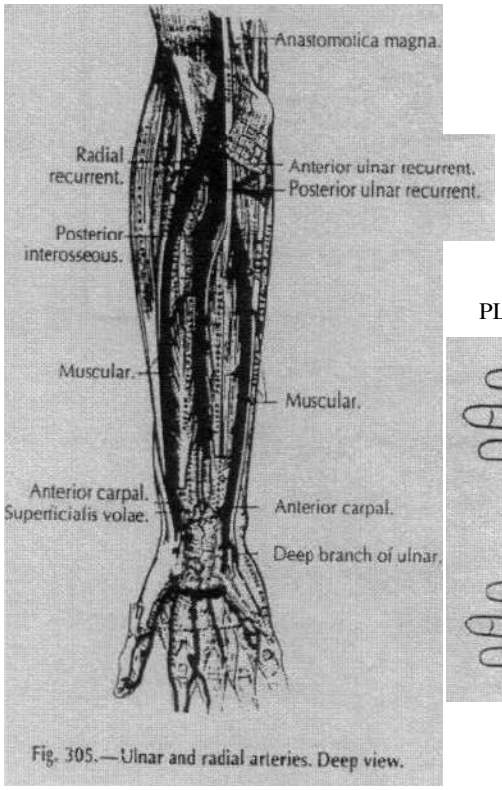

Fig. 305.—Ulnar and radial arteries. Deep view.

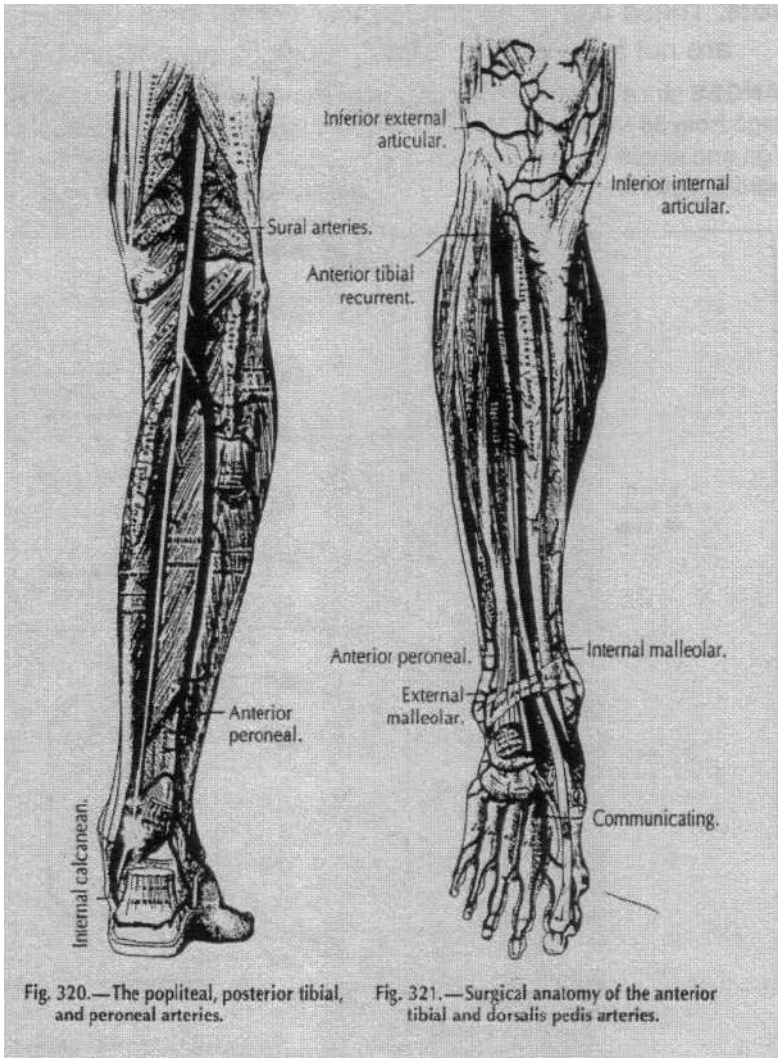

Fig. 320.—The popliteal, posterior tibial, and peroneal arteries.

Fig. 321.—Surgical anatomy of the anterior tibial and dorsalis pedis arteries.

PLACEMENT OF PRO 5 (ELECTRODES): Over *Arteries* not blue veins.

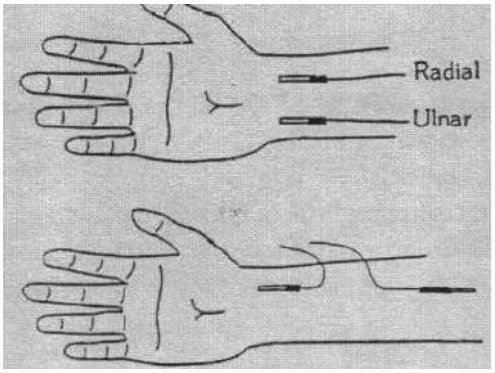

Align Electrodes Parallel to Pulse and Directly Over Pulse Paths

The figure illustrates the hypothetical placement of the two electrodes on the same wrist. It s easier to place the electrodes first place the strap around the wrist and then insert the electrodes under the strap.

This figure illustrates the hypothetical placement of the electrodes on the same forearm and wrist. Position probes about 6" apart on same Artery

Choose from Two Ways to Align Probes Parallel to Pulse

EXPERIMENTAL IN VIVO BLOOD CLEARING DEVICE FOR ELIMINATING VIRUSES, PATHOGENS, MICROBES, BACTERIA, FUNGI, AND PARASITES.

Revision March 16, 1996. Copyright a 1991/1999 Robert C. Beck

Note: These data are intended for informational, instructional, and research purposes only and are not to be construed as medical advice. Consult your licensed medical practitioner.

CHANGES since previous editions: Pulse Repetition Rate from 0.67 Hz to —4 Hz (Not critical). C2 from 1uf to 0.22uF. Voltage from 36 Volts to 27 Volts. Treatment time increased to 2 hours daily for at least 30 days. Improved electrode design and single wrist placement. SW2 added to extend battery life. There are NO "errors" in this schematic. Hundreds have been constructed successfully when duplicated exactly without user attempted "improvements".

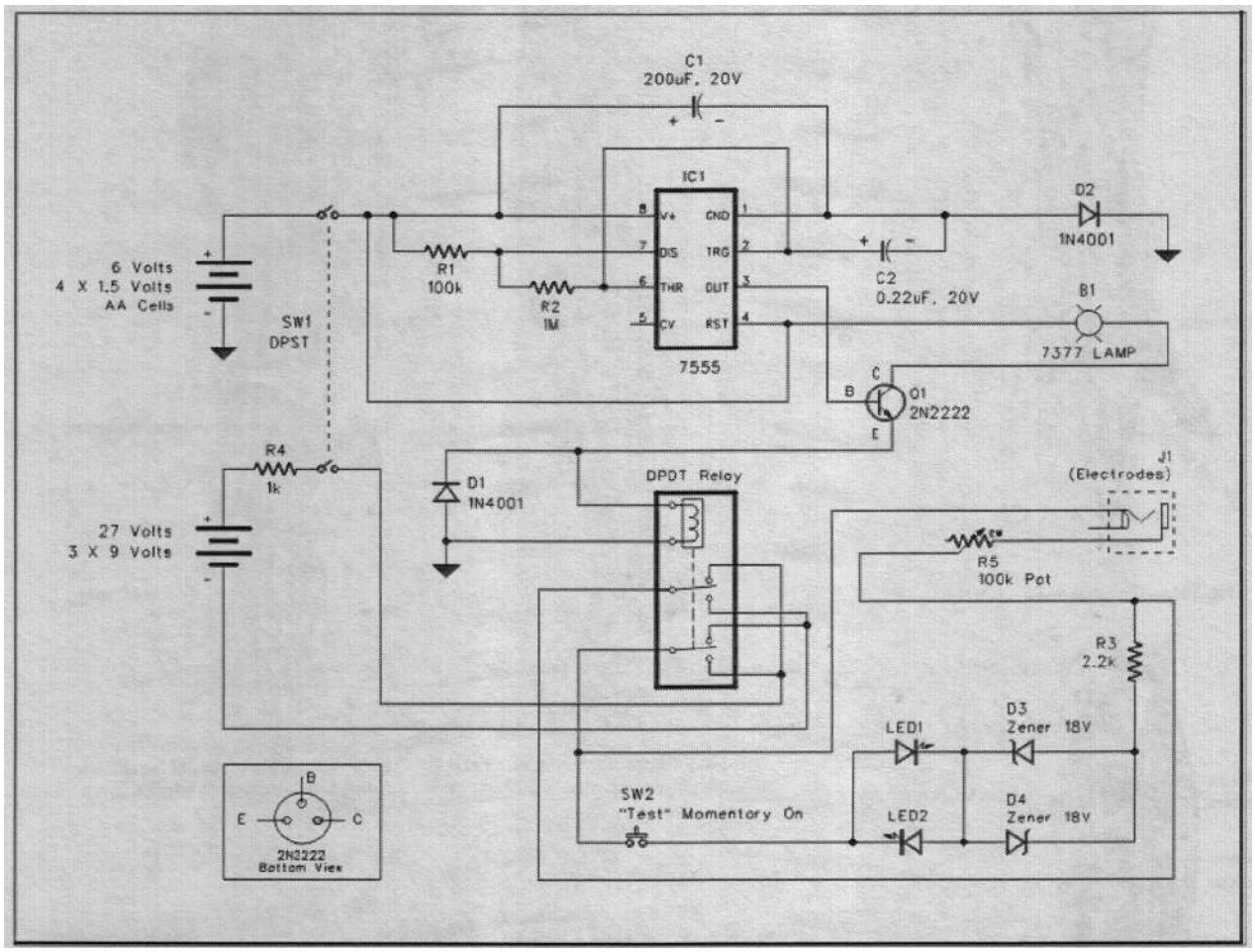

SPECIAL PARTS

B1: Filament type incandescent bulb; 6.3V 0.075A type 7377 (Ballast and current limiter).

Relay: 5V 50 ohm coil, PCB mount DPDT; Selecta Switch SR15P207D1.

D3 & D4: Zener Diodes, 18V ½ Watt; NTE 5027A.

R5: 100 kohm ½ Watt linear potentiometer; Caltronics P-68 or equivalent.

LED1 & 2: Combined as Bi-Color Red & Green in same housing; Radio Shack #276-012

SW2: "Test" SPST Momentary ON subminiature Push-Button; Radio Shack #275-1571

PROPOSED THEORETICAL IN-VIVO BLOOD, HIV, PATHOGEN, PARASITE AND FUNGI NEUTRALIZING DEVICE

COMPONENT DESCRIPTIONS, SOURCES, AND CURRENT PRICES

Revision March 13, 1996. Copyright © 1991/1999 Robert C. Beck, D.Sc.

Note: These data are for theoretical, informational and instructional purposes only and are not to be construed as medical advice. Consult with your licensed medical practitioner. Hundreds have been built successfully if duplicated exactly as shown.

This design is basically a 7555 IC timer chip set for 50% duty cycle and -3.9 Hz. driving a sub-miniature relay.

Electrode polarity continually reverses -1/4 second positive / 1/4 second negative.

Frequency is not critical.

7555 CMOS timer chip (generic)		ICI	$ 1.80
100 k ohm 1/4 watt 5% resistor		R1	0.07
1 meg ohm 1/4 watt 5% resistor		R2	0.07
2.2 k ohm 1/4 watt 5% resistor		R3	0.07
1 kohm 1/4 watt 5% resistor		R4	0.07
100 k W linear taper pot, 1/2 watt Caltronics P-68		R5	2.56
200 mF 20 V (or higher) electrolytic capacitor		C1	0.45
0.22 mF 20 V (or higher) Tantalum capacitor		C2	0.25
1N4001 diode	2 required © 0.15	D1 & D2	0.30
18 Volt Zener diodes (NTE5027A)	1/2 Watt, 2 @ 0.79	D3 & D4	1.58
NPN Transistor	Generic 2N2222	Q1	0.30
Bulb, 6.3V 0.075 A	Type 7377	B1	1.34
Relay, 5 V 50W coil PCB Mount DPDT Selecta Switch	SR15P207D1		5.45
Misc. wire, solder, etc.			0.50
Bicolor LED Red/Green Radio Shack #276-012		LED 1	$ 1.19
Jack for electrode leads	274-251 3/$1.59	*J1*	0.53
DPDT switch, 275-626 or equiv. (used as DPST)		SW1	2.55
SPST Subminiature momentary ON push button switch ER-SW101 "Test"		SW2	0.59
Battery holder, 4-AA cells, Radio Shack	270-383		1.29
4 Alkaline M cell batteries, #23-552	4 for		2.89
3 Alkaline 9 V batteries, type 1604 etc.	3 for		3.75
3 x 9 V battery snaps (clip-on connectors)	270-325 pkg.	5/$1.29	1.29
Box, if used			2.29
Lead wire with 3.5 mm plug, 6 ft., Mouser or Calrad Electronics			0.35
Electrodes, stretch elastic, Velcro, cotton flannel, alligator clips, etc.			5.00
Custom printed circuit board #PS-PCB:			15.00
Total **Cost for all components for do-it-yourself project**			**$49.24**

EXPANDED INSTRUCTIONS FOR EXPERIMENTAL/THEORETICAL BLOOD ELECTRIFICATION *HYPOTHETICAL PROTOCOLS FOR EXPERIMENTAL SESSIONS*

Revision January 15, 1997. Copyright © 1991/1998 Robert C. Beck, D.Sc.

PRECAUTIONS: Do NOT use wrist–to–wrist with subjects using cardiac pacemakers. Any electrical signals may interfere with "demand" type heart pacers and cause malfunction. Single wrist/forearm locations should be acceptable. Do NOT use on pregnant women, while driving or using hazardous machinery.

Users MUST avoid ingesting anything containing potentially toxic medications, nicotine, alcohol, recreational drugs, laxatives, for several days before starting because blood electrification can cause electroporation which makes cell membranes pervious to small quantities of normally harmless chemicals in plasma. The effect is the same as overdosing. See Electroporation: a General Phenomenon for Manipulating Cells and Tissues J.C. Weaver, Journal of Cellular Biochemistry 51: 426-435 (1993.) The blood purifier can cause electroporation. Avoid ingesting alcohol 24 hours before using and keep in mind that high potency, synthetic vitamins as well as junk foods can be a problem when magnified.

Do NOT place electrodes over skin lesions, abrasions, new scars, cuts, eruptions, or sunburn. Do NOT advance output amplitude to uncomfortable levels. All subjects will vary. Never put bare metal on skin. The magnetic pulser should be safe to use anywhere on body or head.

Drink an 8 oz. glass of filtered or preferably ozonated water 15 minutes before and immediately following each session and drink at least four additional glasses daily for flushing during "neutralization" and for one week thereafter. This is imperative. Ignoring this can cause systemic damage from unflushed toxic wastes. ***When absolutely essential drugs must be ingested, do so a few minutes after electrification then wait 24 hours before next session.***

If subject feels sluggish, faint, dizzy, itchy, headachy, light-headed or giddy, nauseous, bloated or has flu–like symptoms or rashes after exposures, reduce pulsing per session and/or shorten applications of electrification. Drink more water—preferably ozonized—to speed waste oxidation and disposal. Use extreme caution when treating patients with impaired kidney or liver function. Start slowly at first, about 20 minutes per day to reduce detoxification problems.

To avoid shock liability, use only batteries with blood cleaner. Do NOT use any line–connected power supply, etc. with blood electrification device. However a.c. supplies are OK with well–insulated magnetic pulse generators (strobe lights.)

Health professionals: Tobacco, the most damaging (41/2 times more addictive than heroin) and deadly substance of abuse known, disrupts normal cardiovascular function. True vegetarian diets are missing several essential amino acids absolutely necessary for the successful rebuilding of AIDS–ravaged tissues. Secondary gains and hidden agendas (sympathy/martyrdom, work avoidance, free benefits, financial assistance, etc.) can play large roles with many seriously ill patients.

SUPERIOR ELECTRODES: Excellent, convenient and vastly superior electrodes, reusable indefinitely, can be user-made by butt–soldering connecting wires to ends of 1-1/8" long by 3/32" dia. blanks cut from type 316 stainless steel rods available from welding supply stores (Cameron Welding Supply, 11061 Dale Ave., Stanton, CA 90680.) Use "Stay Clean" flux before soldering (zinc chloride/ hydrochloric acid.) Shrink–insulate TWO tight telescoping layers of 3/8" long shrink tubing over soldered joints to prevent flexing/breaking and lead/copper ions from migrating.

PREPARATION FOR USE: Wrap three or four turns of 100% cotton flannel around rods. Spiral–wrap with strong thread starting from wire side to end. Tightly pinch cloth over rod's end so as to leave no metal exposed by wrapping 6 or 7 turns of thread TIGHTLY just off end of rod, then spiral wrap back to start and tie with four knots then cut off excess cloth at end close to pinch-wraps. Treat end and knots with Fray Check® (fabric & sewing supply stores) to prevent raveling. Saturate before each use in a solution of sea salt (not table salt). Add a few drops of Colloidal Silver for disinfectant. Store for reuse. Tape soaking wet electrodes tightly over arterial pulse sites with paper masking, Transpore™ or Micropore® tape or make 1" wide stretch elastic bands with tabs of Velcro® at ends to fasten. Electrodes should closely conform precisely along blood vessels, not skewing ever so slightly over to adjacent flesh. This insures better electrical conductivity paths to circulating blood and insures very low skin impedance. (-2000Q) Rinse and blot-dry electrodes and skin after each use. NEVER allow bare metal to touch skin as this will cause burns manifested as small red craters that heal slowly. The objective is to get maximum current into blood vessels, not leak it over to adjacent tissue. Therefore never use any electrode with cotton cover wider than about 1/8 inch.

ELECTRODE PLACEMENTS: Locate blood vessel paths *(NOT* to be confused with acupuncture, Chapman or pressure points) on either wrist (Ulnar to Radial) or else

wrist to forearm by feeling for maximum pulses. Scrub skin over chosen sites with mild soap and water. Position each electrode lengthwise precisely along same branch of Radial artery. A 7" long, 1" wide elastic stretch–band with two l-'/4" lengths of ¾" wide Velcro® sewn to ends of opposite sides makes an excellent wrist band for holding electrode snugly in place. Place wet electrodes between ulnar and radial pulse points on opposite sides on inside of ***same*** wrist. Then with electrode cable unplugged, turn switch ON and advance amplitude control to *maximum*. On original blood electrifier design, push momentary SW 2 "test" switch and see that the red and green light emitting diodes flash alternately. This verifies that polarity is reversing –4 times per second (frequency in NOT critical) and that batteries are still good. When LED's don't light, replace all three 9V alkaline batteries. When the white incandescent bulb dims or appears yellowish, or relay isn't clicking, replace all four AA cells. Zener diodes will extinguish LED's when the three 9V battery's initial 27V drops below –20V after extended use. Never use any electrode larger than 1-1/8" long by 1/8" wide to avoid dissipating current through surrounding tissue. Confine exactly over blood vessels. Apply drops of salt water to each electrode's cotton cover as needed to keep cotton covers damp and insure optimum current flow. Later devices are solid-state, use only one battery and no relays, and are much smaller. Electrify blood 2 hours daily for 4 weeks or longer as indicated. (See diagram on page 19.)

SETTING VOLTAGE: Now rotate amplitude control to *minimum* (counter-clockwise) and plug in electrode cable. Advance dial slowly until feeling a "thumping" and tingling. Turn as high as tolerable but don't advance amplitude to where it is uncomfortable. Adjust voltage periodically when acclimatizing to comfort level after several minutes. It is normal to feel different sensations with time. You may notice little or no sensation at full amplitude immediately, but feeling will begin building up to maximum after several minutes at which time amplitude can be decreased. Typical adapted electrode–to–electrode tissue impedance is on the order of 2000 Ohm. Typical comfortable input (to skin) is ~3mA, and maximum tolerable input (full amplitude) is ~7mA. However, this "reserve" margin although harmless is unnecessary and can be uncomfortable. Current flowing through blood is much lower than this *external* input because of series resistances through skin, tissue and blood vessel walls, but 50 to 100uA through blood is essential.

FREQUENCY OF USE: Apply blood electrifier for about two hours daily for at least 1 to 3 months. Use judgment here. The limiting factor is detoxification. Carefully monitor subject's reactions (discomfort, catarrh, skin eruptions, weeping exudites, rashes, boils, carbuncles, coated tongue, etc.) With very heavy infections, go slower so as not to overload body's toxic disposal capability. Drinking ozone–bubbled water oxidizes wastes and speeds detoxification. With circulation–impaired diabetics, etc., you may wish to *extend* session times. Again, have subjects drink lots of water. Recent changes in theoretical protocol being currently tested suggest continuing the protocol for several weeks. One health practitioner with extensive use of both the blood electrification and magnetic pulsing devices reported to Sharing Health From the Heart Inc. to suggest prolonged use to ensure the stronger pathogens have been neutralized. He points out the danger of stopping too soon if only the weaker pathogens have been dealt with. He has suggested building up to using the blood electrification device for 6 days continuously to neutralize the longest-lived pathogens. Remember to remoisten electrodes regularly. If you absolutely ***must*** ingest prescription drugs, do so immediately ***after*** turning off instrument and allow 24 hours before next treatment to let chemical concentrations in blood plasma decay to lower levels.

Remember, if subjects ever feel sleepy, sluggish, listless, nauseous, faint, bloated or headachy, or have flu-like reactions, they may be neglecting sufficient water intake for adequately flushing toxins. We interpret this as detoxification plus endorphin release due to electrification. Let them rest and stabilize for –45 minutes before driving if indicated. If this detoxing becomes oppressive, treat every *second* day. Treatments are shown to safely neutralize viruses, fungi, bacteria, parasites and microbes in blood. See US patents #5,188,738, 5,091,152, 5,139,684, 5,328,451, 3,753,886, 4,524,079, 4,665,898 and others as well as numerous valid medical studies which are presently little known or suppressed.

SILVER COLLOID: Also, ingesting a few oz. of –5 parts per million silver colloid/silver ion solution daily can give subjects a "second intact immune system" and minimize or eliminate opportunistic infections during recovery phase. This miracle substance is pre-1938 technology, and unlike ozone is considered immune from FDA harassment. Silver colloid can *easily* be made at home electrolytically in minutes and in any desired quantities and parts per million strength for under 10 per gallon plus cost of water. It is ridiculous to purchase it for high prices. Unlike silver proteins, metallic colloid has no side effects. Silver colloids won't produce drug resistant strains as will all other known antibiotics. No reasonable amount can overdose or injure users either topically, by ingesting, or professional medical injection. Refer to page 31 for complete instructions on successfully making your own.

Preparation to Use the Electrodes for Blood Electrification

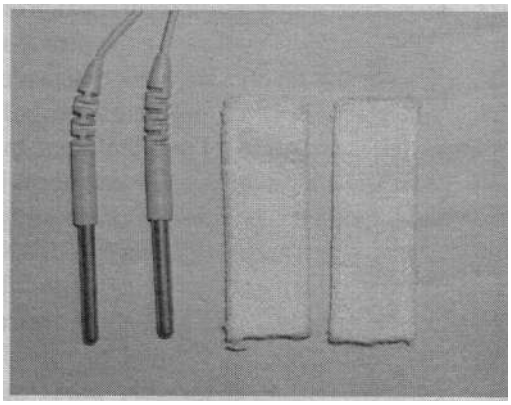

Step 1: Prepare cotton sleeves or cotton covers for the electrodes.

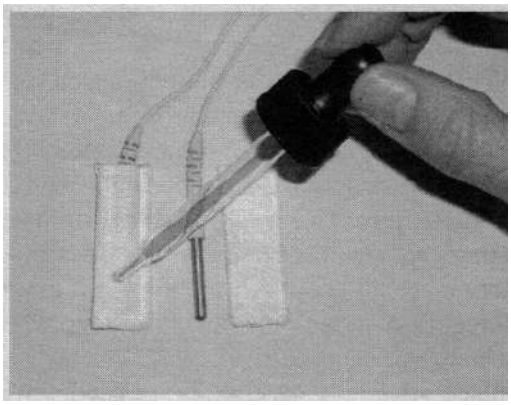

Step 2: Place the cotton sleeves over the electrodes. A dropper bottle is a handy way to wet the cotton and to keep the covers damp during use.

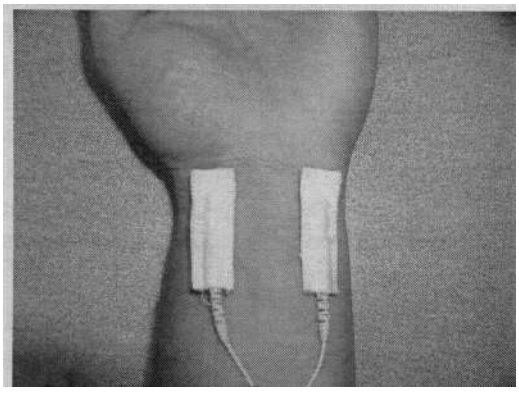

Step 3: Place the covered electrodes directly over the two arteries on the wrist: the radial and ulner arteries.

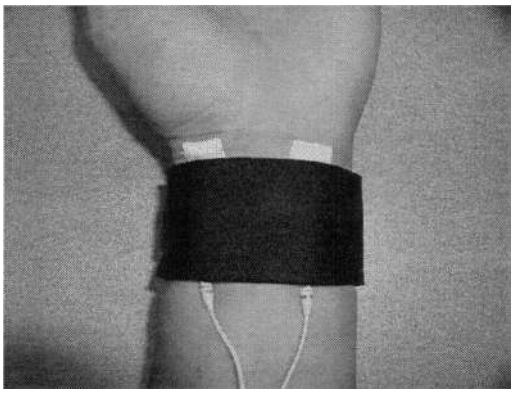

Step 4: Hold the electrodes in place with a wrist strap. This one is made of waterproof neoprene with velcro to hold it firm.

Ensure the wrist strap does not get wet between the electrodes. If it does the current will travel between the two electrodes rather than through the skin to the arteries.

Total Cancer Remissions through Blood Electrification combined with Silver Colloid

Theories Offered for Information and Educational Purposes Only and are the Author's Opinions

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Opinions expressed in this article are based on the author's first hand experience and do not necessarily reflect those of this publication. [Also published in *Explore!* Magazine]

My archives contain a tantalizing report from several decades ago describing an authenticated record of an older man who was struck by lightning, survived, and subsequently grew a third set of teeth and a bushy head of youthful new dark hair. His grossly metastasized, inoperable cancers vanished. He threw away his glasses and cane, and appeared much younger and was totally healthy for the first time ever. This fascinated scientists and years later almost encouraged some highly illegal and bizarre human experiments in an abandoned aircraft hangar in Wendover, Utah where Tesla coil research with ball lightning was underway. The incident generated wide speculation, but few insights at the time. This mystery remained sleeping until 1990 when an astounding discovery was reported at Albert Einstein college of Medicine in NYC by Drs. Kaali and Lyman. Not surprisingly, the revolutionary data were apparently immediately suppressed (See *Science News:* Mar. 30, 1991 pg. 207; and *Longevity:* Dec. 1992 pg. 12.)

As a totally unexpected and unpredictable outcome of the writer's self-funded research into "blood electrification" with micro currents for AIDS (currently showing excellent results), a growing number of users previously unknown to me began independently reporting "spontaneous remissions" of numerous *other* diseases ***including cancer.*** Most involved no doctors, medication, or time off. Recoveries occurred after subjects had self-administered an altered do-it-yourself blood treatment process first described in US Patent #5,188,738 issued to Dr. Steven Kaali in '93. We were puzzled to find explanations as to why this worked. This preliminary report offers a possible theory. Magnetic pulsing success with cancer were independently proven again in 1984 and described in US Patent #4,665,898 plus many other patents dating back to 1890!

The Einstein disclosure describes removing blood from one arm, electrifying it, and returning it to the other arm in a process similar to dialysis. It also describes surgically implanted active electrode chambers containing miniature batteries sewn inside blood vessels. This author's preferred approach leaves all blood in the body, is totally non-invasive, costs practically nothing and is safely accomplished in about a month with –two hours per day exposures as one goes about his normal activities. It handles pathogens while blood flows normally through the –60cc volume of the electrified forearm's ulnar branch artery from wrist to elbow. Without medications, invasive techniques or doctors, most pathogens, viruses, microbes, parasites and fungi just tend to disappear. Progress can be readily observed in blood with dark-field and phase-contrast microscopy. The entire process and simple apparatus with parts list is fully described in my '91 paper reprinted in recent issues of *Explore!* (Vol.7 #1) and in this paper. Also simple instructions for self-made silver colloids of far better quality than you can usually buy are given in Vol. 7, #2 of *Explore!* also *Explore More,* Issue #15. Back issues: Box 11510, Prescott, AZ, 86303, 928-541-1920. You can turn any glass of tap water into a 3 ppm ionic electrolytic silver colloid in about two minutes anywhere with a shirt pocket instrument by simply running 27V (three 9V transistor radio batteries) between two short lengths of pure silver (never "Sterling") wires submerged in water. To date many "spontaneous remissions" of dozens of "incurable" illnesses including HIV have been reported by users and researchers of this "blood purification" when combined with ingestion of pennies-per-gallon instantly self-made ionic silver colloid plus magnetic pulsation and ozonized drinking water. Since none of dozens of friends using these apparent miracles has experienced infections, colds, flu, pneumonia, or lost a single day's productivity in over three years, evidence strongly suggests restored immune systems or dramatically improved blood functioning. It is also fascinating to note that several pet owners report their cats now refuse to drink water if silver colloid is not added. Trips to veterinarians with previously recurring infections were cut dramatically. It is as though the Creator had left a secret "back door" method for mankind to finally conquer the adversary - incurable diseases plaguing us since the beginning of time. To avoid legalities, these data are being offered under first amendment freedom of speech rights and should not be construed as medical advice.

It has long been known that dissections of cadavers dying of natural causes reveal many have had cancer several times during their lifetime resulting in "spontaneous remissions" generally without their knowledge and without ever visiting a doctor. An optimally functioning immune system somehow automatically "handles" diseases of which the subject seldom becomes aware. Several promising broad-spectrum natural immunological agents like interferon and interleukin are produced by healthy immune systems but would cost thousands for patients with already overloaded or "shut down" defenses although many such neuropeptides could speed cures. Other respected researchers describe "pleomorphic" forms of cancer pathogens which evolve through several stages—even mycotoxin involvement—all of which surrender to blood electrification. For persons

unable to self-assemble the simple electrifier (about two hours and –$50), dozens of people are currently custom building them and several companies are providing excellent and reliable combination blood electrification and colloid generators ready to use. Most retail ready-to-use from $135 to $200. But this health breakthrough is politically incorrect and may never be FDA approved because of the millions of dollars and years needed to sort through an approval process and the billions invested in treatment facilities, pharmaceuticals, and in clinical, diagnostic equipment This discovery gi es power over diseases *back to the individual*. The onl dangers lie in too rapid detoxification avoidable by increa ing ozonized water intake for flushing and oxidizing wastes erxheimer's syndrome), plus avoiding potentially tox c substances during blood electrification because of v stly enhanced cell absorption due to electroporation. (See J.C . Weaver: Harvard-MIT in *Journal of Cellular Biochemistry,* 51:426-435; 1993).

All drugs, alcohol, tobacco, pharmaceuticals and coffee *must* therefore be discontinued for at least two days before starting and for the duration of blood electrification or magnetic pulsing. This minimizes substances in your blood plasma which may become toxic at –20X their normal levels.

Electrification is now being successfully used underground around the world. One example—cervical cancer alone kills –1/3 of all victims in the third world, and has long been known to be caused by the papilloma virus. Electrification has the potential to eliminate these toxic "fellow travelers' coexisting in our blood and may handle 'innumerable other diseases previously considered "incurable." Ebola or other possibly genetically engineered biological warfare "designer" plagues may be unleashed someday per some theories of Gulf War Syndrome diseases which are currently immune to all other known countermeasures. Blood electrification, colloids and ozone may be effective against these viruses as well. Unfortunately in today's society, millions of dollars are needed to do the research for more people to be helped.

The most reasonable theory of why electrification is so surprisingly effective for so many conditions lies in the now proven fact that when correctly applied directly into blood *(not* into other body tissue like palms of hands, soles of feet, or organs) the process neutralizes all microbes, pathogens, fungi, parasites, viruses, bacteria, mycotoxins and coexisting foreign life forms and alien invaders and their byproducts. In my opinion, this should never be confused with Royal Rife, Hulda Clark or others' modalities. Effective results are found to require a *minimum* of 27 Volts measurable under load with low impedance output which must deliver up to several milli-amperes measurable current into skin to produce the required 50 to 100 micro-amperes internally through blood after the inevitable series resistance losses through vessel walls plus several layers of tissue. Electrical currents in blood can be measured with an AC microvolt meter by IR drop using partially insulated hypodermic needles inserted –6 inches apart into the same artery. Clark's "syncro-zap" running at her standard 30 kHz (considered many octaves too high to be effective) actually measures only –2.6V peak to peak under load (~2000 ohms) at palms. The syncro-zapper's current is unmeasurable directly in bloodstream and physically *cannot* produce the essential 50 to 100 uA required internally. Using the syncro-zapper may only mask readouts of parasite presence radionically. Unfortunately the live bugs remain undisturbed and are still there and will still be observed in stool and microscopic blood diagnosis. To function at all, electrification requires cotton-covered salt water saturated stainless steel electrodes never over 3/32" wide and 1" long. Electrodes must be carefully positioned directly over and precisely in line with specific arterial pulse points. This maximizes current into *blood* by not diffusing it into surrounding tissue. Square or round TENS, EKG, EEG, EMG; etc. electrodes work only marginally and should never be substituted. Preferred instrument pulse-repetition rate is –3.9 Hz biphasic with steep rise time and 50% duty cycle. Rate is *not* critical although much higher frequencies and certainly higher harmonics of the essential square wave output are degrades by "skin effect" where currents travel around the outside of body instead of internally. This is demonstrated by lighting a bulb in one hand while touching a Tesla coil with the other and not getting shocked.

Careful electrification causes no known harmful side effects to healthy cells or tissue. Blood electrified for 18-24 hours a day for three months were observed to live for well over a month when sealed under cover slips on microscope slides while the average life of "normal" drawn blood is under 4 days. This strongly suggests that even aging bodies may easily and rapidly be made impervious to many hostile, toxic, infectious, antibiotic-resistant and even yet undiscovered invaders.

Like all revolutionary ideas, this incredible breakthrough barely survived initial ridicule and rejection because it is too startling, effective, inexpensive, simple and foolproof to be generally believable. Almost universally, people simply refuse to take responsibility for their own health. They think the "Doctor" should know what's "best" for them. So acceptance of blood electrification, through word of mouth, is just now emerging to enthusiastic acceptance from those who've actually experienced the results. Being profit-motivated, the establishment *must* resist anything like this. But we now have our "hundredth monkey." Skeptics have only to use this technology to directly enjoy immensely better health. ***Take back your power!*** This works! The writer is a researcher, not a practitioner. **I have nothing to gain from this!**

Blood Electrification The Easy In-Vivo Way

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Several years of experimentation and many reports of successes have resulted in simple, fast, proven ways to implement this most important step in self-healing.

Electrify two hours daily for a minimum of four weeks.

1. Build or purchase a ready–to–use device, or put finishing touches on a nearly–completed kit.

2. Prepare and label a sea–salt–in–water solution for electrode wetting. Use 1/8 teaspoon of sea salt in a 2 ounce dropper bottle. Greater salt concentration can cause osmotic skin burns, irritation and rash. Add water and few drops of colloidal silver. Let salt dissolve. Filter through paper towel to clarify this storable conductive interface between cotton covered electrodes and skin. NEVER let bare metal electrode or any small area of metal touch skin directly, or it will burn. Use natural salt only, not table salt containing iodine for goiter and aluminum and silicates to insure easy pouring.

3. For best electrical conductance scrub skin at electrode locations with soap and water to eliminate skin oils, grime, dead skin cells, etc. Rinse and dry. With fingertip rub a drop of salt water into skin at each electrode site.

4. Referring to illustrations on page 19, carefully feel for pulses and trace a line about 1 inch long at each wrist site precisely on top and in line (parallel) with located blood paths. Pulses on Ulnar location opposite thumb are harder to feel. Never place electrodes over new lesions, cuts, abrasions, or sunburn. Muscle twitching in palm and fingers is normal and experienced occasionally.

5. Dip into bottle to saturate initially. Position wet electrodes not over –3/32" wide 1-'/4" long to wrist precisely over traced pulse paths. Slide each from forearm side underneath a snug 1" wide stretch elastic band with Velcro® retaining overlapped ends. One electrode positions on radial (thumb) side, the second on other (ulnar) inside of same wrist. Current is confined to blood in lower forearm. Very little electrification is detectable elsewhere thus making it safer for heart-pacer users. The wrist electrode placements are more convenient and faster than any other positions.

6. Put larger units in pocket and run electrode cord down sleeve or strap the smaller electrifier—single battery units—with stretch–band to forearm. Plug in electrodes, turn on and advance slowly to comfortable level. I prefer the small, convenient, unobtrusive unit that uses one instead of the three 9V battery units. Neither interferes with normal activities.

7. Re-adjust power occasionally to maximum comfortable level. You can now even sleep with it on without fear. When the treatment (about two hours per session daily for a month or more but only after detoxifying) is done, turn it off and put it aside until tomorrow. When red and green LED's flash alternately with electrodes unplugged you know it's working properly. Blood cleansing can be speeded with heat. Example: wrapping forearm with electrodes in heating pad set to high.

8. Keep electrodes wet by re–moistening with drops of salt water occasionally using eye dropper. When finished, rinse wrists. Wash electrodes periodically with soap, water and soft toothbrush to eliminate skin oils and soil. Soaking overnight will dissolve caked salt. Discoloration at ends is normal. When frayed or worn, discard old covers and re-wrap stainless rods with 3 turns of 100% cotton flannel. Wrap tightly with a few turns of thread to end, spiral back to beginning and tie. Electrodes should last for months, but wire leads break and must be replaced eventually.
   [Editor's Note: If skin is particularly sensitive, try using conductive gel on the electrodes or reduce the amount of salt in the water to minimize skin irritation. Apply a healing salve after each session.]

What's inside the box?

Preferred electrifiers must generate a 3.9 Hz (not critical) biphasic sharp-rise-time square wave, ± 27V peak adjustable output, 50% duty cycle, capable of delivering several milliamperes into a low resistance load at skin surface (—S 2000W impedance) which after losses in tissue resistance delivers the necessary 50 to 100 microamperes through flowing blood.

Precautions:

Badly debilitated patients such as full—blown AIDS victims should begin at less than 20 minutes every second day and flush by drinking lots of pure water, preferably ozonized because their systems will go into rapid detoxification causing physical problems called Herxheimer's syndrome.

Users taking ANY medications should minimize such presence in blood for at least two days before starting and avoid irritants including coffee, tea, alcohol, tobacco, recreational drugs, etc., during the several weeks of recovery. "Electroporation" is shown to increase dosage levels up to 20X of anything drunk, shot, or ingested thus causing problems. This documented by J.C. Weaver, Harvard-MIT *Jr. Cellular Biochemistry,* 51: 426-435; 1993. Patients needing essential medications should take them immediately ***after*** turning off electrification and wait 24 hours before next blood cleansing. This lets their residues decay to minimum levels in plasma before re—electrifying.

If detoxing becomes disturbing, proceed even more slowly. Symptoms may include fever, giddiness, dizziness, headaches, light—headed, vagueness, nausea, skin rashes, eruptions, itching, boils, coughing, kidney and liver discomfort, aches, general malaise, inflammations, frequent urination, and sluggishness. Use caution when detoxing patients with impaired liver or kidney function. But remember it's far better to force wastes *out* of your system than leaving them stored where they may have been hiding for years.

Treat slowly if initial discomfort occurs. Electrification will profoundly affect your health and provoke your deepest mind—sets such as everyone's unconscious conflicting death wishes. This generally causes noticeable anxiety and depression.

RECOMMENDED SUPPLIER

For Electronic Parts: Check your local electronics supply store.

For Complete Units:

Robert (Bob) C. Beck, D.Sc. worked closely with Russ Torlage of SOTA Instruments Inc. in the years preceding his passing. He recommended SOTA as a supplier for The Beck Protocol units.

Contact SOTA at: 1-800-224-0242,250-770-2023 Fax: **250-770-1999** or

Write: PO Box 20019, Penticton, BC V2A 8K3

www.PositiveOffset.com

Electronic Kit & Parts for Educators, Researchers & Hobbyists

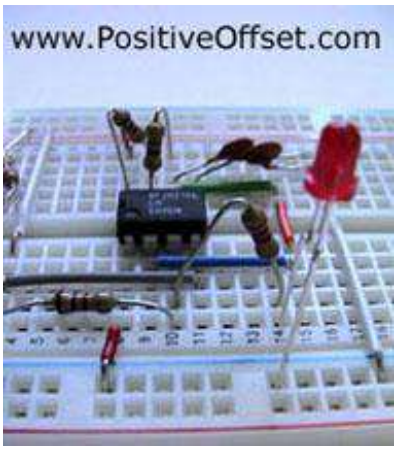

30 kHz / 1 kHz Zapper Kit
with Color Illustrated Instructions
$50.00 Add to Cart

Our Zapper Kit contains all the parts necessary to build either a 30,000 Hz or a 1,000 Hz Positive Offset Square Wave Frequency Generator Unit. This breadboard kit is based on Dr. Hulda Clark's zapper circuit design that was recently updated and published in 2003. Copper Pipes and 9 Volt Battery are not included in kit. For copper pipes and individual electronic parts, click the links in the right column.

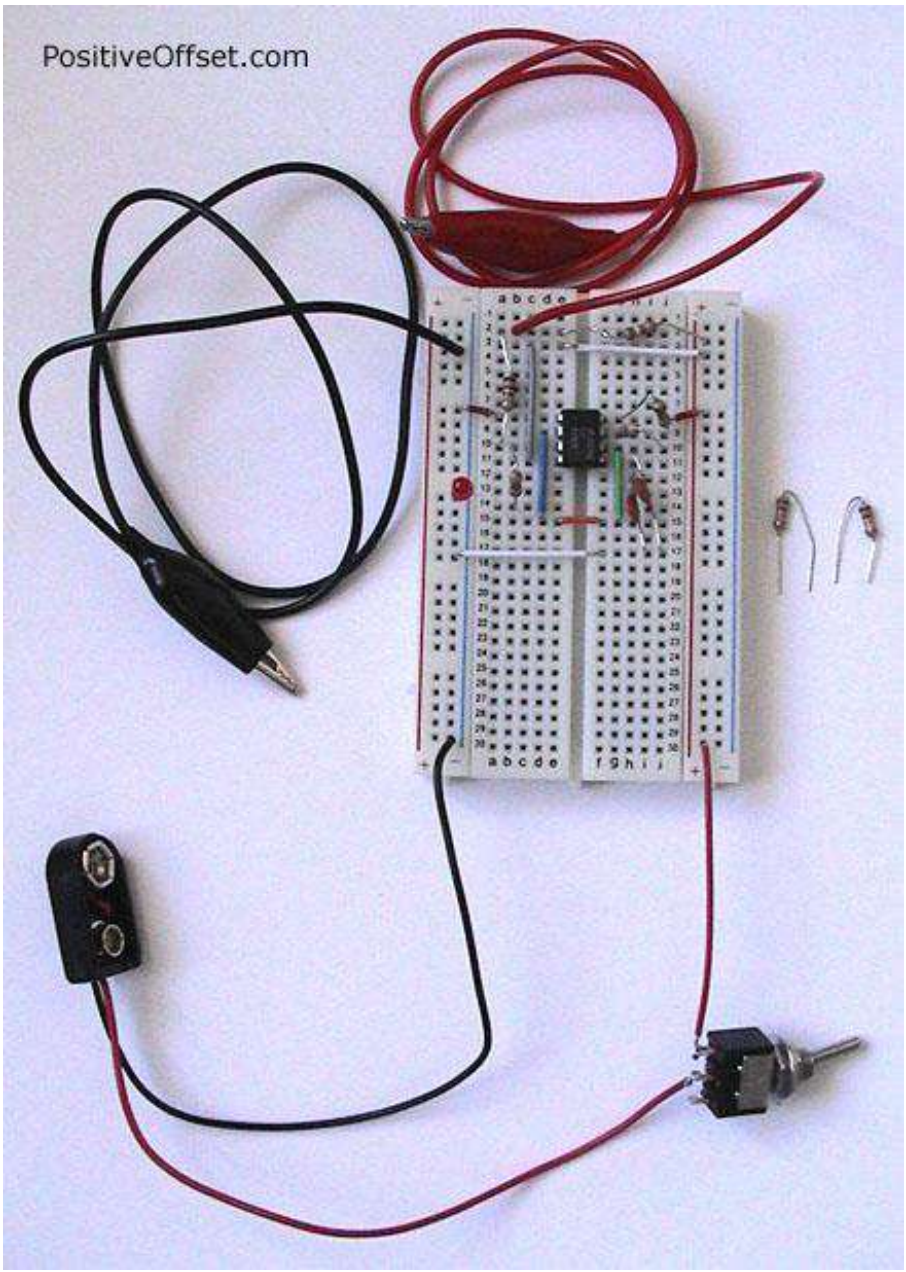

- 30 kHz/1 kHz Zapper Kit
- .0047 uF Capacitors
- 1 uH Inductors
- 1K Ohm Resistors
- 2.2K Ohm Resistors
- 3.9K Ohm Resistors
- 4.7K Ohm Resistors
- 39K Ohm Resistors
- 270K Ohm Resistors
- 555 CMOS Timer
- 8 Pin Wire Wrap Socket
- 9 Volt Battery Snap
- Alligator Clip Converter
- Alligator Leads
- Aluminum Square
- Banana to Alligator Leads
- Breadboard
- Color Coded Jump Wires
- Copper Pipes
- Nuts and Bolts
- On/Off Toggle Switch
- Red Mini LED
- Switching diode 1N914
- Video Instructions

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VIEW CART

Hulda Clark Zapper Kit with Color Illustrated Instructions
$50.00 Add to Cart

Zapper Kit includes: Breadboard, 555 CMOS Timer, (2) 1K Ohm resistors, 2.2K Ohm resistor, 4.7K Ohm resistor, 39K Ohm resistor, (2) 270K Ohm

resistors, (2) .0047 uF Capacitors, Mini Red LED, (9) Color Coded Jump Wires, 9-Volt Battery Snap, (2) Alligator leads, and an On/Off Switch. All this comes in a sturdy little cardboard box you can use to house your finished circuit. The full-color instructions will help you build either a 30,000 Hz or 1,000 Hz circuit.

It's so easy to build. No soldering required! Watch the video instructions right here (36 minutes).

- YouTube video instructions: 9 easy steps to build this circuit
- Build a zapper Frequently Asked Questions and Answers
- Already have electronic parts? Download PDF Instructions

Remember the Hulda Clark Zapper has not been licensed as a medical device by the US FDA. Zapper Kit is sold as an educational tool only, no medical claims are intended by the sale of these electronic parts. Our Zapper Kit is a great project for a school science fair, or to learn the basics of building simple electronics.

Please note that when ordering electronic parts and kits we can assume no liability on the customer's ability to use them. Safety, craftsmanship, experience, and ability are the user's responsibility.

Electronic parts are small and fragile. We can not offer refunds or replacements on electronic parts. Buy electronic parts and kits only if you believe you can accomplish the work. If you experience difficulty with your build, or have little experience in electronics, please order replacement parts along with your kit.

The 555 CMOS Timer is the most likely part to need replacement, so it may be smart to order extras when building a kit.

The 555 CMOS Timer is vulnerable to static electricity. If you walk on a carpeted floor and the 555 receives a static shock it may burn out and need replacement.

555 CMOS Timers are sold separately for those who want to have several at hand during a kit build, or to troubleshoot a circuit that is not working.

If you are new to electronics, or just want to be cost effective, you may want to purchase extra 555 CMOS Timers when building your first kit. We can not offer refunds or replacements on electronic parts.

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Electronic Kit & Parts for Educators, Researchers & Hobbyists

Hulda Clark 30 kHz / 1 kHz Zapper Kit
with Color Illustrated Instructions
Order Zapper Kit Here

Hulda Clark Zapper Kit includes: Breadboard, 555 CMOS Timer, 7 resistors: (2) 1K Ohm, 2.2K Ohm, 4.7K Ohm, 39K, (2) 270K Ohm, (2) .0047 uF Capacitors, Red LED, (8) Color Jump Wires, (2) Alligator Leads, and Soldered Battery Snap/On-Off Switch. All this comes in a sturdy little cardboard box you can use to house your finished circuit. The full-color instructions will help you build either a 30,000 Hz or 1,000 Hz circuit. Kit does not include copper pipes. Click here to order copper pipes.

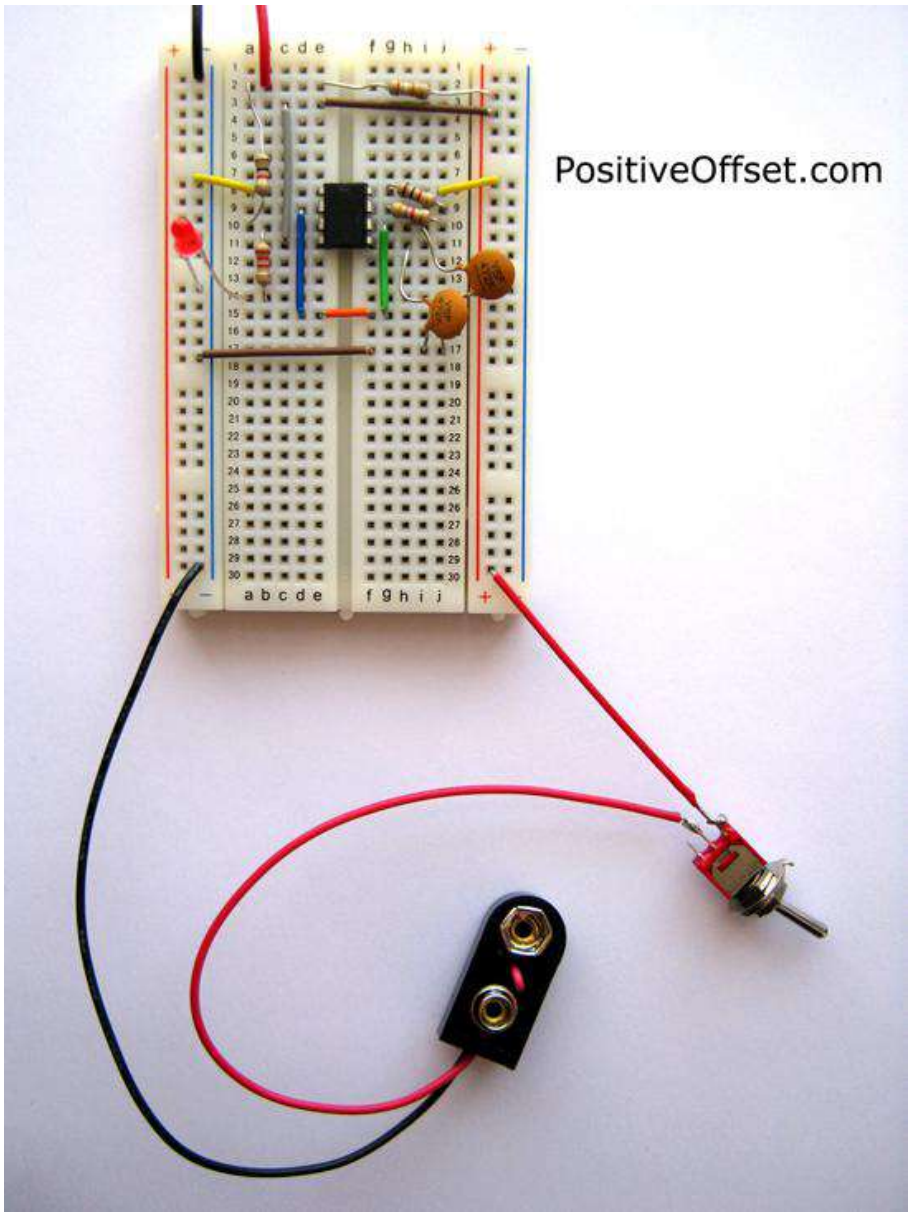

Hulda Clark Zapper Kit with Color Illustrated Instructions
Order Zapper Kit Here

If you are new to building electronics, you may also want to watch the instruction video. The 'Build A Zapper Video' shows how to build this Clark Zapper breadboard kit. Watch the video below. (Note: There are minor updates to the "Build Your Own Zapper" Kit. We have adjusted the jump wires for a

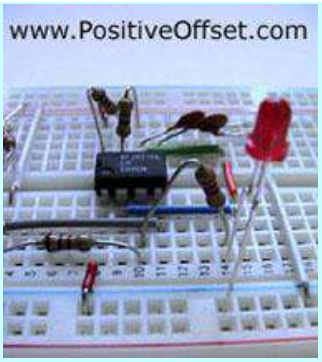

- 30 kHz/1 kHz Zapper Kit
- 555 CMOS Timer
- Switching diode 1N914
- Mini Alligator Leads
- Copper Pipes
- Dial-A-Zap
- Chair Zappicator
- Pet Zappicator
- Video Instructions

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better fit. We have also pre-soldered the 9-volt battery snap to the on/off switch. These updates are not shown in this video, but are clearly described in the kit instructions.)

It's so easy to build. No soldering required! Watch the video instructions right here (36 minutes).

More Video Instructions

- Build a Zapper, Plate Zapper, Food Zappicator, and Toothbrush Zappicator
- Zapper Kit Frequently Asked Questions and Answers
- Already have electronic parts? Download PDF Instructions

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Electronic parts are small and fragile. We can not offer refunds or replacements on electronic parts. Buy electronic parts and kits only if you believe you can accomplish the work.

The 555 CMOS Timer is the most likely part to need replacement, so it may be smart to order extras when building a kit.

The 555 CMOS Timer is vulnerable to static electricity. If you walk on a carpeted floor and the 555 receives a static shock it may burn out and need replacement. If you ever touch the 9 volt battery backwards to the battery snap, it may burn out the 555. You may want to protect your 555 by adding a 1N914 Switching Diode to your kit (diode sold separately).

555 CMOS Timers are sold separately for those who want to have several at hand during a kit build, or to troubleshoot a circuit that is not working. If you are new to electronics, or just want to be cost effective, you may want to purchase extra 555 CMOS Timers when building your first kit. We can not offer refunds or replacements on electronic parts.

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www.ZapperLab.com

Order A Hulda Clark Zapper - Order Dr. Clark's Books - Order Electrical Supplies

Welcome to the Zapper Lab. Here we have the step-by-step instructions for building your very own Hulda Clark Zapper, reprinted with permission from the books by Dr. Hulda Clark. Dr. Clark has improved her original zapper circuit and published this update in 2003. Knowing her readers have varying experience with building electronics, this recent update released several different sets of instructions on how to build a zapper, depending on one's electronic expertise.

- The original published Zapper instructions require soldering or twisting the parts together. It is best when soldered, which does require some special tools and skill. These instructions are found reprinted below from Dr. Clark's 2003 update.
- A newer, easier to build design employs the use of an electronic *breadboard*. A breadboard does not require soldering, as one can push the electronic components into place onto the breadboard to easily build a circuit. Dr. Clark published designs for the 30 kHz Zapper, and the 1000 Hz Zappicator to be built on a breadboard. The instructions for building both breadboard zapper circuits are at ClarkZapper.net along with a nifty on-line video to help guide you through the process.
- And last, for advanced electricians, Dr. Hulda Clark published a schematic for building the updated Zapper (see photo below).

If you do not know anyone who could put one together for you, you can order a pre-built Zapper at the web site, www.ClarkZapper.com. Remember, the Hulda Clark Zapper is not a licensed medical device. It has not been tested by the FDA or AMA for use on humans or animals. The Clark Zapper can be sold and used only as an experimental device, and no claim can be made as to a diagnosis, cure or treatment for any medical condition or disease. Dr. Clark's book states to not experiment with a zapper if you are either pregnant or wearing an electronic pacemaker. Please be sure to read one of Dr. Clark's books before using a Hulda Clark Zapper.

Order A Hulda Clark Zapper - Order Dr. Clark's Books - Order Electrical Supplies

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How To Build A Hulda Clark Zapper

click here to print the 2003 schematic for building a zapper

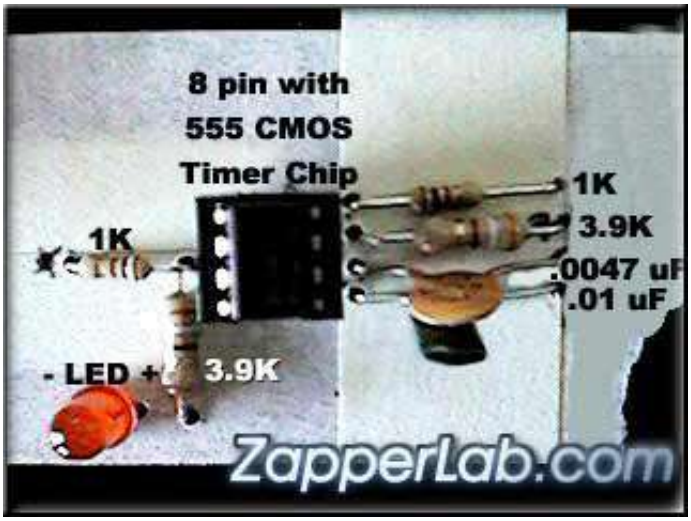

Order A Hulda Clark Zapper

Instructions for building your very own zapper can be found reprinted below from the books by Dr. Hulda Clark. You can get all the parts you need at online electrical supply stores such as: PositiveOffset.com. If you would rather order a pre-built zapper, just click: Clark Zapper.

Dr. Clark has released new devices called the *Food Zappicator* and the *Toothbrush Zappicator.* For the instructions on how to build this new type of zapper, visit: FoodZappicator.com and ToothZappicator.com

NEW! Build A Hulda Clark Zapper Video Instructions
Nine short videos that take you step-by-step through the process of building a Hulda Clark Zapper.

How To Build A Hulda Clark Zapper

***The Cure For All Cancers* © Copyright 1993 by Hulda Regehr Clark, Ph.D., N.D.**
Zapper instructions have been updated for 2003 by Dr. Hulda Clark

Hints for absolute novices: Don't let unusual vocabulary deter you. A "lead" is just a piece of wire used to make connections. When you remove a component from its package, label it with a piece of tape. A serrated kitchen knife works best, as does a large safety pin. Practice using the micro clips. If the metal ends are L-shaped bend them into a U with the long-nose pliers so they grab better. Chips and chip holders (wire wrap sockets) are very fragile. It is wise to purchase an extra one of each in case you break the connections. The "555" timer is a widely used component; if you can't locate this one, try another electronics shop.

The Shoebox Way

This circuit has been improved since the one given in earlier books. A resistor has been added that gives every pulse an added Positive Offset of 1/4 volt. You no longer need to operate your zapper so daringly close

to a Negative voltage.

Get from Radio Shack, (serial number included to make it easy). Order these parts from their web site at: www.RadioShack.com. If any electrical parts are unavailable at Radio Shack, visit another on-line electrical supplier of these items, such as: www.PositiveOffset.com to buy your electrical parts.

Parts List for the 30,000 Hz Zapper Circuit	
Item	**Radio Shack Catalog Number**
Use Shoebox or Buy a Plastic Project Box	270-1809
9 volt battery	
9 volt battery snap connector	270-324 (set of 5 you need 1)
on-off toggle switch	275-624A micro mini toggle switch
If not available, choose any toggle switch with holes in the contact points or Radio Shack 275-612	
1 K Ohm resistor, brown-black-red-gold	271-312 (500 piece assortment) use 2
3.9 K Ohm resistor, orange-white-red-gold	Use 2 from 500 piece assortment
39 K Ohm resistor, orange-white-orange-gold	From 500 piece assortment
low-current red LED	276-044
.0047 uF capacitor	272-130 (set of 2, you need 1)
.01 uF capacitor	272-131 (set of 2, you need 1)
555 CMOS timer chip (TLC 555)	276-1718 (you may wish to buy a spare)
8 pin wire-wrapping socket for the chip	900-7242
If only 16 pin sockets are available, cut one in half OR leave half empty. Editor's Note: These parts have been discontinued at most Radio Shacks. 8 pin wire wrap sockets are available at many other electrical supply stores such as: www.PositiveOffset.com	
short (12") alligator clip leads	any electronics shop, get 10
If not available, use 14" length from Radio Shack, 278-1156	
Micro clip jumper wires	278-017 (you need 2 packages of 2)
If not available, use mini-clip jumper wires 278-016	
2 bolts, about 1/8" diameter, 2" long, with 4 nuts and 4 washers	hardware store
2 copper pipes, 3/4" diameter, 4" long	hardware store
Sharp knife, pin, long-nose pliers, tape, 4 twist ties or rubber bands.	

Editor's Note:

The 8 pin wire-wrapping socket has been discontinued at many Radio Shacks and readers have asked what to do. We know a great electrical supply store where 8 pin wire wrap sockets are available, as well as easy-to-build science kits for making a 30,000 Hz Frequency Generator with all the parts listed above in one simple package.

A Hulda Clark zapper is basically just a common Frequency Generator

set at 30,000 Hz, with a 100% positive offset square wave. The cost for the electrical parts to build one is about $30-$40 for them all. Visit the electrical suppliers at PositiveOffset.com for all your electrical needs. They have everything you'd need to build a basic 30,000 Hz Positive Offset Square Wave Frequency Generator, and their kit is much easier to build than the instructions given below, because it uses a breadboard so there is no need to twist or solder wires, you simply push the electrical parts into place on the breadboard. **-editor.**

Assembling The Zapper

If you have tools such as a drill, needle nose pliers, and small drill bits, buy one of the plastic project boxes on the list, otherwise build your zapper in a shoe box, or a box half the size of a shoe box.

1. You will be using the lid of the shoe box or plastic lid of the project box to mount the components. Save the box to enclose the finished project.

2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole "grounding bolt" on the inside and outside.

3. Mount the 555 chip in the wire wrap socket. Find the "top end" of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.

4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the "cookie bite" as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1. The pins are numbered like this:

1	8
2	7
3	6
4	5

5. Pierce two holes ½ inch apart very near to pins 5,6,7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF capacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the

pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 K Ohm resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 K Ohm resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½ inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 K Ohm resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9 K Ohm resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

7. Next to the 3.9 K Ohm resistor pierce two holes ¼ inch apart for the LED. Notice that the LED has a positive and a negative connection. The longer wire is the positive (anode). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.

9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Do not attach the battery yet.

10. An inch away from the switch pierce two holes 1/4 inch apart. Mount the 39 K Ohm resistor on the outside and label it inside and outside as "39 K, Positive offset." Flatten the wires on the inside.

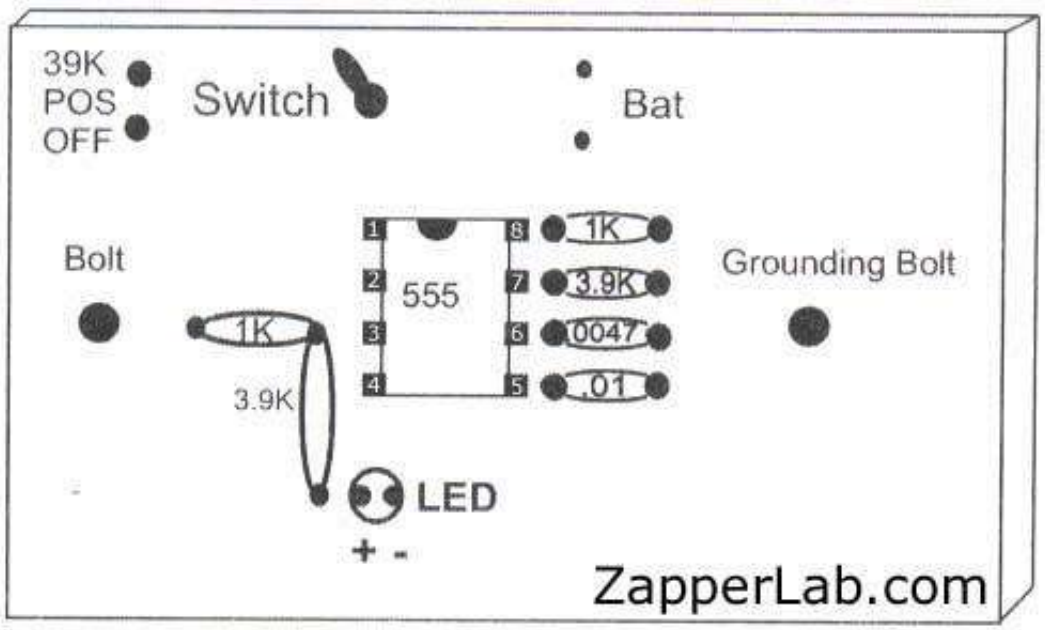

Now To Connect Everything

1. Twist free ends of the two capacitors .01 and .0047 together. Connect this to the Grounding Bolt using an alligator clip.

2. Bend the top ends of pin 2 and pin 6 (which already has a connection) inward towards each other in an L shape. Catch them both with an alligator clip and attach the other end of the alligator clip to the free end of the 3.9 K Ohm resistor by pin 7.

3. Using an alligator clip connect pin 7 to the free end of the 1 K Ohm resistor attached to pin 8.

4. Using three micro clips connect pin 8 to one end of the switch, pin 4 to the same end of the switch, and one end of the offset resistor to the same end of the switch. (Put one hook inside the hole and the other hooks around the whole connection. Check to make sure they are securely connected.) Connect the free end of the offset resistor to the bolt using an alligator clip.

5. Use an alligator clip to connect the free end of the 1 K Ohm resistor (by pin 3) to the bolt. It is the **output resistor**.

6. Twist the free end of the 3.9 K Ohm resistor by pin 3 around the plus end of the LED. Connect the minus end of the LED to the grounding bolt using an alligator clip.

7. Connect pin number 1 on the chip to the grounding bolt with an alligator clip.

8. Attach an alligator clip to the outside of one of the bolts. Attach the other end to a handhold (copper pipe). Do the same for the other bolt and handhold.

9. Connect the minus end of the battery snap connector (black wire) to the grounding bolt with an alligator clip.

10. Connect the plus end of the battery snap connector (red wire) to the free end of the switch using a micro clip lead. Attach the battery very carefully. Before attaching the battery to its snap connector, cover one terminal with tape. After snapping in one terminal, remove the tape to attach the other terminal. This is to prevent accidental touching of terminals in a backwards direction. If the LED lights up you know the switch is ON. If it does not, flip the switch and see if the LED lights. Label the switch clearly. If you cannot get the LED to light in either switch position, double-check all of your connections, and make sure you have a fresh battery. Even if it does light up, check every connection again.

11. Finally tie up the bunches of wire with twist-ties or rubber bands

and replace the lid on the box. Slip a couple of rubber bands around the box to keep it securely shut. For safer storage, place it inside a larger box.

Note: Having gained this much experience, you may prefer to build your next zapper on a piece of cardboard folded and able to fit inside a shoebox or plastic electronic project box for more protection.

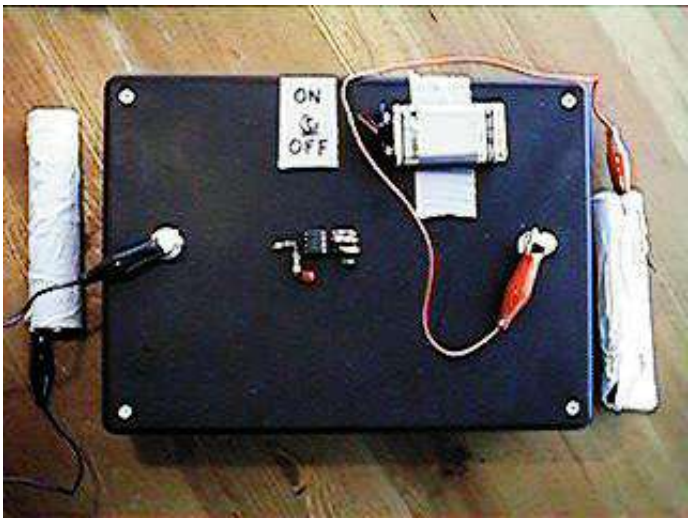

- Optional: measure the frequency of your zapper by connecting an oscilloscope or frequency counter to the handholds. Any electronics shop can do this. It should read between 20 and 40 kHz. The shop can also read the voltage (peak to peak) and the amount of Positive offset (on the .5 volt-per-division scale). The voltage output should be about 8 volts.
- Note: a voltage meter will only read 4 to 5 volts because it displays an average voltage.

Using The Zapper

1. Wrap handholds in one layer of wet paper towel before using. More will reduce the current. Grasp securely and turn the switch on to zap. Keep a bottle of water handy to keep them wet.

2. Zap for seven minutes, let go of the handholds, turn off the zapper, and rest for 20 minutes. Then seven minutes on, 20 minutes rest, and a final seven minutes on. This is the routine for **regular** zapping.

Tell us about your zapper experience at the zapper message board.

To Visit The Zapper Museum - Click Here!

Order A Hulda Clark Zapper - Click Here!

See The *'Build A Zapper'* Video - Click Here!

Learn about Dr Clark's latest zapping technique called: Plate Zapping

Learn about Dr Clark's latest inventions:
The Food Zappicator and The Toothbrush Zappicator

Order Electronic Parts at RadioShack.com and Frequency Generator Kits at PositiveOffset.com

All information is for educational purposes only. These statements have not been evaluated by the FDA. Not intended to diagnose, treat, prevent, mitigate or cure disease. Visit www.HuldaClark.com for more information on Dr. Clark's Syncrometer™ Science, and the Zapper. Legal Disclaimer Privacy Policy

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Simple Zapper Schematic

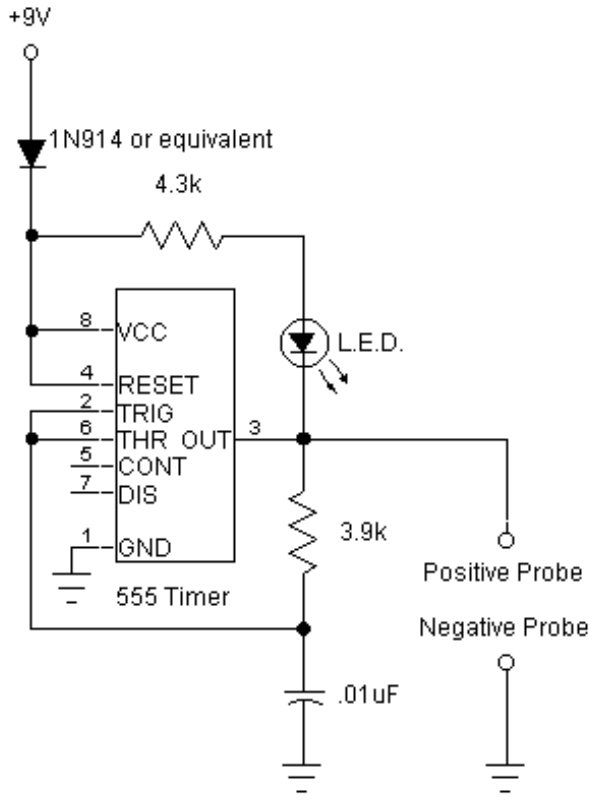

The Research of Dr. Hulda Regehr Clark, Ph. D., N.D.

I have recently (9/15/2000) come across the research of Dr. Hulda Regehr Clark, Ph. D., N.D. In her books, she states that many diseases, among which are cancer and HIV/AIDS, can be cured by the use of, among other things, certain herbs and a frequency generator called a "Zapper" that was invented by her and her son.

Speaking of mothers :), my mother, 62, had fatigue and arthritic symptoms in her hands before I found out about and told her about Dr. Hulda Clark. She is a seamstress, so the arthritic symptoms hindered her work. After doing the Parasite Cleanses and using the Zapper, she doesn't have to take naps like before and her hands are flexible again. She has done the complete Parasite Cleanse only twice but she Zaps practically every day.

Simple Zapper Information

Schematic updated on 12/21/2001

Simple Zapper Information text updated on 12/21/2001.

I forgot to mention that the Simple Zapper that I'm using has a 1 Megohm potentiometer instead of the 2.2k ohm resistor in order to vary the output frequency. If you use a potentiometer with the circuit put it in series with the 2.2k ohm resistor because the chip gets hot when there is too little resistance.

The duty-cycle is pretty consistent with a range of 51% to 57%. With the oscilloscope's frequency analyzer in storage mode, I hold the Zapper probes and put the oscilloscope probes somewhere on my body and then I vary the frequency of the Zapper using the 1 Megohm potentiometer.

When testing my body on a spectrum analyzer while using the Simple Zapper with an output of around 5 Volts (tested on a DC voltmeter), I noticed that the frequencies around 4,000 hz to around 18,000 hz had larger peaks telling me that my body at the time was more conductive (less reactive?) and/or less resistive to frequencies in this range at the given voltage.

With my body being more conductive (less reactive?) at these frequencies, I believe that there is a better dispersal of the Simple Zapper's output within my body. I did this recent test with one Zapper probe in each hand (as opposed to both in one hand) and the oscilloscope probes (RCA to 1/4" phone plug adaptor) in my mouth near my wisdom teeth with my lips around the RCA ground (like a lollipop).

The oscilloscope's frequency analyzer was in storage mode. With the Simple Zapper circuit on this page, change the 2.2k ohm resistor to 4.3k ohm if you want a ~15,000 hz frequency. I have recently built a couple of Zappers with optimized output frequencies of around 11,000 hz. I haven't tested anyone using the Simple Zapper other than myself, so there is the possibility that your body's response may differ.

For more information, check out my Simple Zapper webpage at:

www.members.aol.com/mas1911/index.html

or for really interesting free circuit schematics:

www.members.tripod.com/~mas1911/zappers20011221tripod.html

You can write the Author of Simple Zapper if you have comments or questions.

The following document, written by Luke Parrish, provides instructions on building an astable multivibrator in DC pulse mode, identical in output to the Zapper, described in The Cure For All Diseases by Dr. Hulda Clark.

Plans For Zapper

This page tells how to make a Hulda Clark-style "Parasite Zapper". It's a simpler and more efficient version, but works just as well. We make no theraputic claims for this device. It is for experimental purposes only. We provide a ready made version for those who prefer not to spend so much time building it.

Materials

- A CD4069 hex inverter (Radio Shack link)
- 1 1M resistor, 1 10k resistor, and 1 1k resistor (Radio Shack link) (Resistor color code)
- 1 1000 pF capacitor (Radio Shack link)

NOTE: The size of the resistors and capacitors can vary, because they determine the frequency of the zapper, which doesn't really matter much according to Hulda Clark.

The following parts may be substituted according to preference, though something similar will be needed:
- Solderless breadboard (Radio Shack link)
- 9-volt battery
- 4 alligator clip-leads sets Radio Shack link
- 2 copper pipes (hand-holds)

Instructions

Plug the components into the solderless breadboard according to the following schematic. Make sure none of the wires touch each other. To hook up the power, attach an alligator clip-lead to each side of the capacitor that stretches from hot to ground. Clip the one that goes to hot to the positive terminal on the battery and the one that goes to ground to the negative terminal. The two hand-holds are attached with the other two clip-leads. (One goes to ground, the other to the end of a resistor that goes to pin 12.)

Schematic

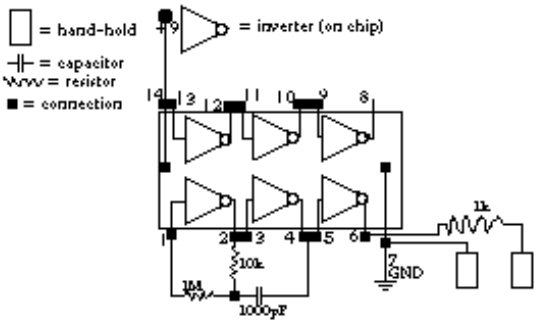

Schematic most recently updated 5-17-2001

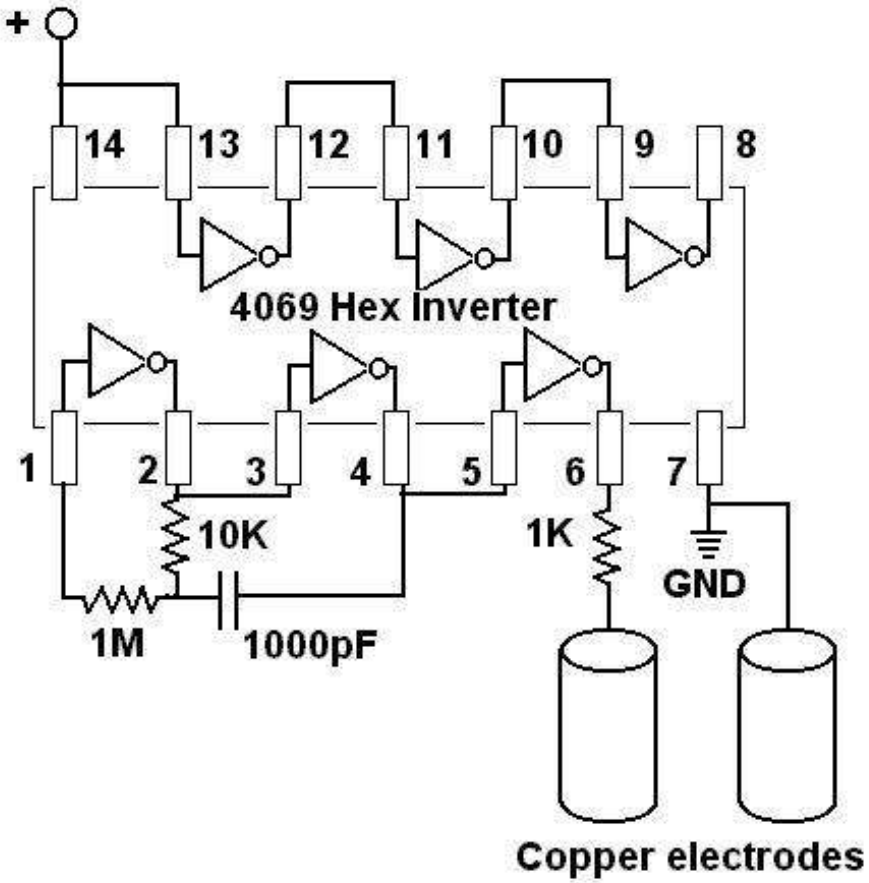

The above instructions are not the only way to do it. You can, for example, solder all the components directly to a 14-pin socket, like we do in our ready made version. This is a lot more trouble and more time-consuming for most people, which is why we recommend a breadboard. The resistors and capacitor don't all have to be the exact sizes mentioned here to make a working Zapper. However, any variation in capacitance or resistivity will change the frequency. (There are certain limits on how high of frequencies the chip can handle, so don't stray too far from the specified values.) If you have an oscilliscope, that's handy to check if it's working.

Ready made Zappers

Free plans from Zapperlab.com

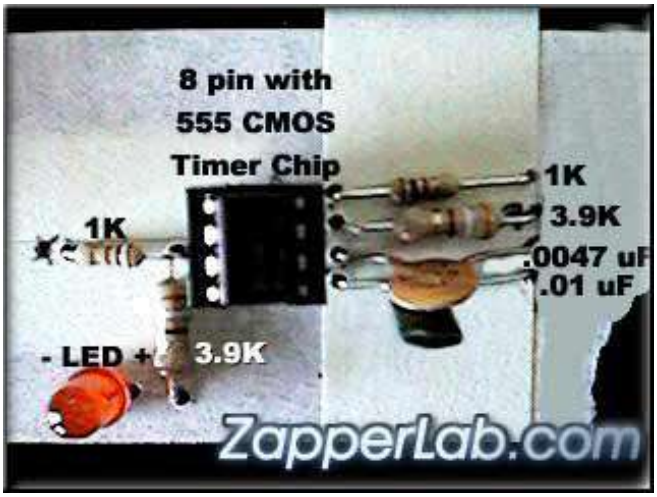

Here we have the easy step-by-step instructions for building your very own Hulda Clark Zapper reprinted with permission from her books (provided below). For advanced electricians there is a schematic for building a Hulda Clark Zapper as well. If you do not know anyone that could put one together for you, you can now order the zapper Hulda Clark uses as described in "The Cure For All Cancers" and "The Cure For All Diseases" at: www.SyncroZap.com. The Dr. Clark Zapper can be sold only as an experimental device, and no claim can be made by us legally as to a diagnosis, cure or treatment for any medical condition or disease.

Build A Dr. Clark Zapper

Order A Dr. Clark Zapper

Instructions for building your very own zapper can be found reprinted below from the books by Dr. Hulda Clark. If you would rather order a pre-built zapper, just click here.

How To Build A Zapper from *The Cure For All Cancers*:

The Cure For All Cancers © Copyright 1993 by Hulda Regehr Clark, Ph.D., N.D.

Get from Radio Shack, (serial number included to make it easy).
Order these parts from their web site at:
www.RadioShack.com

___ Black plastic Project Box Radio Shack # 270-1809

___ 9 volt battery

___ 9 volt battery clips: Radio Shack # 270-325

___ On off switch: Radio Shack # 275-624A

___ 1K Ohm resistor: RS# 271-1321

___ 3.9K Ohm resistor: RS# 271-1123

___ low current red LED: RS# 276-044

___ .0047 uF capacitor: RS# 272-130

___ .01 uF capacitor: RS# 272-1065

___ 555 CMOS timer chip: RS# 276-1723

___ 8 pin wire wrapping socket for CMOS chip: RS# 276-1988

___ two packs of Microclip test jumpers: RS# 278-017

___ one pack of 14" alligator clip leads RS# 278-1156C

Get from any Hardware Store:

2 Bolts 1/8" diameter, 2" long with 4 nuts and washers.

2 pieces of ¾" copper pipe, cut to 4 inches long each.

Editor's Note:

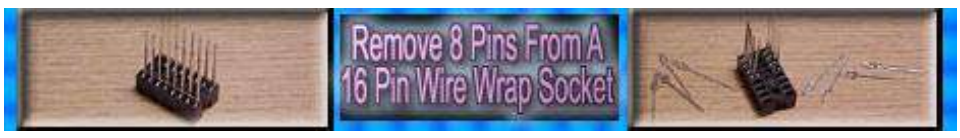

The **8 pin wire-wrapping socket** has been discontinued at many Radio Shacks and readers have asked what to do. Some say it is still available on their website at www.RadioShack.com, if not:

There are a couple options. One can still get the **16 pin wire-**

wrapping socket. Pull out the bottom grouping of 8 pins, and you now have an 8 pin socket. Just make sure when you plug the 555 Timer into it, you line it up with the remaining 8 pins. Very simple.

There is also a **Low Profile 8 pin socket**. The pins are so small one must solder to them.

The wire-wrap socket has long pins for easy twisting onto other wires. The low profile is for those that solder electronics.

If you are soldering your zapper together get the low profile 8 pin socket. Since the socket is just a saddle for the 555 Timer, it is not a vital part of the circuit. It's just a way to put long or short pins on the 555 Timer for easy twisting. If you cannot find one at your local Radio Shack, simply get the 16 pin wire-wrap socket, and pull out 8 pins. -editor.

Assembling The Zapper

If you have tools such as a drill, needle nose pliers, and small drill bits, buy one of the plastic project boxes on the list, otherwise build your zapper in a shoe box, or a box half the size of a shoe box.

1. You will be using the lid of the shoe box or plastic lid of the project box to mount the components. Save the box to enclose the finished project.

2. Pierce two holes near the ends of the lid. Enlarge the holes with a pen or pencil until the bolts would fit through. Mount the bolts on the outside about half way through the holes so there is a washer and nut holding it in place on both sides. Tighten. Label one hole "grounding bolt" on the inside and outside.

3. Mount the 555 chip in the wire wrap socket. Find the "top end" of the chip by searching the outside surface carefully for a cookie-shaped bite or hole taken out of it. Align the chip with the socket and very gently squeeze the pins of the chip into the socket until they click in place.

4. Make 8 pinholes to fit the wire wrap socket. Enlarge them slightly with a sharp pencil. Mount it on the outside. Write in the numbers of the pins (connections) on both the outside and inside, starting with number one to the left of the "cookie bite" as seen from outside. After number 4, cross over to number 5 and continue. Number 8 will be across from number 1. The pins are numbered like this:

1 8

2 7

3 6

4 5

5. Pierce two holes ½ inch apart very near to pins 5,6,7, and 8. They should be less than 1/8 inch away. (Or, one end of each component can share a hole with the 555 chip.) Mount the .01 uF capacitor near pin 5 on the outside. On the inside connect pin 5 to one end of this capacitor by simply twisting them together. Loop the capacitor wire around the pin first; then twist with the long-nose pliers until you have made a tight connection. Bend the other wire from the capacitor flat against the inside of the shoe box lid. Label it .01 on the outside and inside. Mount the .0047 uF capacitor near pin 6. On the inside twist the capacitor wire around the pin. Flatten the wire from the other end and label it .0047. Mount the 3.9 K Ohm resistor near pin 7, connecting it on the inside to the pin. Flatten the wire on the other end and label it 3.9. Mount the 1 K Ohm resistor and connect it similarly to pin 8 and label it 1K.

6. Pierce two holes ½ inch apart next to pin 3 (again, you can share the hole for pin 3 if you wish), in the direction of the bolt. Mount the other 1 K Ohm resistor and label inside and outside. Twist the connections together and flatten the remaining wire. This resistor protects the circuit if you should accidentally short the terminals. Mount the 3.9 K Ohm resistor downward. One end can go in the same hole as the 1K resistor near pin 3. Twist that end around pin 3 which already has the 1K resistor attached to it. Flatten the far end. Label.

7. Next to the 3.9 K Ohm resistor pierce two holes ¼ inch apart for the LED. Notice that the LED has a positive and a negative connection. The longer wire is the positive (anode). Mount the LED on the outside and bend back the wires, labeling them + and - on the inside.

8. Near the top pierce a hole for the toggle switch. Enlarge it until the shaft fits through from the inside. Remove nut and washer from switch before mounting. You may need to trim away some paper with a serrated knife before replacing washer and nut on the outside. Tighten.

9. Next to the switch pierce two holes for the wires from the battery holder and poke them through. Attach the battery and tape it to the outside.

Now To Connect Everything

Twist free ends of the two capacitors .01 and .0047 together. Connect to Grounding Bolt using an alligator clip.

Bend pin 2 and pin 6 together inward, using an alligator clip, catch them and connect to free end of 3.9K Ohm (by pin 7).

Alligator clip Pin 7 to free end 1K Ohm (near pin 8)

Using two microclips Pin 8 and pin 4 to one end of switch (use hole to attach both microclips).

Free end of 1K Ohm (by pin 3) to the Bolt using an alligator clip.

Alligator clip the free end of 3.9K Ohm (by pin 3) to plus end (long) of LED.

Minus end (short) of LED to Grounding Bolt with an alligator clip.

Alligator clip pin 1 to the Grounding Bolt.

Alligator clip Black battery wire to Grounding Bolt.

Micro clip the Red battery wire to free end of switch.

Hook up the battery, and the light should turn on, click the switch if it does not, check connections if LED does not light up.

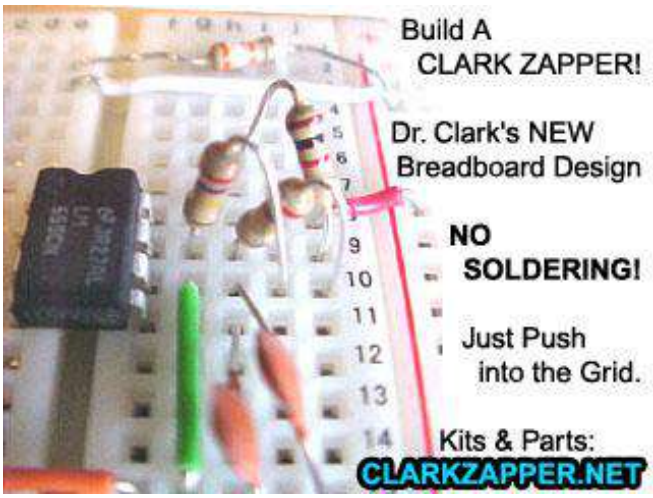

Attach a long lead wire to the grounding bolt & bolt, and then to the copper handles. Wrap handles in paper towel, clip with lead wire, wet handle when you are ready to zap.)

How To Zap

Wrap handles in wet paper towel, or wet cotton sleeves, and hold in each hand. If you have wrist cuffs, run them under water to wet them, attach to each wrist.

Attach handles or wrist cuffs to zapper.

Turn zapper on, zapping for 7 minutes.

At end of 7 minute zapping rest 20 minutes.

Do this a minimum of three 7 minute zapping sessions, with a 20

minute break in between each session. Some people zap five times in extreme cases.

[Order A Dr. Hulda Clark Zapper - Click Here!]

Learn about Dr Clark's latest zapping technique at: www.PlateZapping.com

All information is for educational purposes only. These statements have not been evaluated by the FDA. Not intended to diagnose, treat, prevent, mitigate or cure disease.

This Circuit designed by Geoff Clark and approved by Dr. Hulda Clark

SOTA Instruments Inc. presents...
"The Zapper" as per Dr. Hulda Clark, Ph.D., N.D.

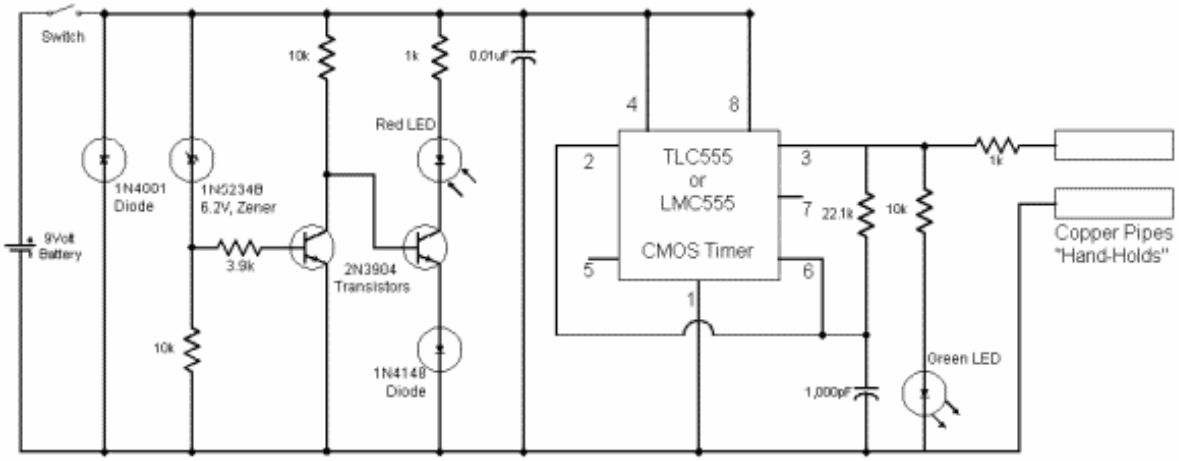

Certified and Approved by Dr. Clark's son Geoff Clark.
Designed & Drawn by Russell J. Torlage, CTech, President, SOTA Instruments Inc.
Model: ZHC3 Rev 4.0
Revised: June 9, 1999

All Resitors are 1/4W, 5% Tol. 22.1k resistor is 1%.

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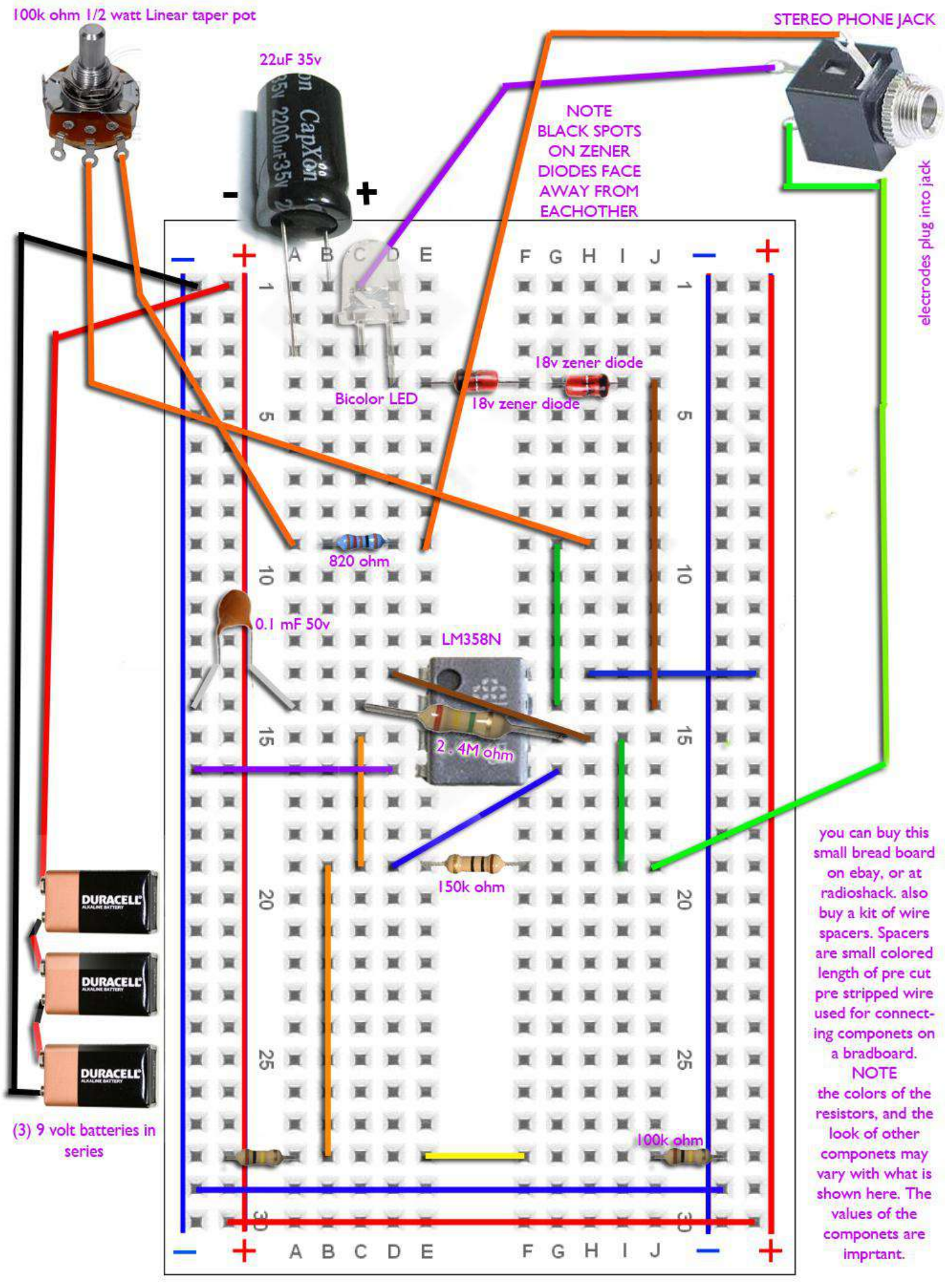
100k ohm 1/2 watt Linear taper pot
22uF 35v
STEREO PHONE JACK
NOTE
BLACK SPOTS
ON ZENER
DIODES FACE
AWAY FROM
EACHOTHER
electrodes plug into jack
18v zener diode
Bicolor LED
18v zener diode
820 ohm
0.1 mF 50v
LM358N
2.4M ohm
150k ohm
100k ohm
DURACELL
DURACELL
DURACELL
(3) 9 volt batteries in series
you can buy this small bread board on ebay, or at radioshack. also buy a kit of wire spacers. Spacers are small colored length of pre cut pre stripped wire used for connecting componets on a bradboard.
NOTE
the colors of the resistors, and the look of other componets may vary with what is shown here. The values of the componets are imprtant.

COMPONENT DESCRIPTIONS, SOURCES, AND CURRENT PRICES

Revision November 24, 1996. Copyright (c) 1991/1999 Robert C. Beck, D.Sc.

Note: These data are for theoretical, informational and instructional purposes only and are not to be construed as medical advice. Consult with your licensed medical practitioner. Hundreds have been built successfully if duplicated exactly as shown.

LM358 CMOS Operational Amplifier (OP-AMP) chip (generic)		U1	$ 1.00
2.4 megohm 1/4 watt 5% resistor		R1	0.07
150 kohm 1/4 watt 5% resistor		R2	0.07
100 k ohm 1/4w 5% resistor	2 required @ 0.15	R3, R4	0.14
100 kohm linear taper pot, 1/2 watt Cattronics P-68		R5	2.56
150 ohm 1/4 watt 5% resistor		R6	0.07
820 ohm 1/4 watt 5% resistor		R7	0.07
0.1 mF 50 V (or higher) ceramic capacitor		C1	0.45
22 mF 35 V (or higher) electrolytic capacitor		C2	0.25
18 Volt Zener diodes (NTE5027A)	% Watt, 2 @ 0.79	D1 & D2	1.58
Bulb, 6.3V 0.075 A	Type 7377	B1	1.34
Bicolor LED Red/Green	RS# 276-012	LED 1	$ 1.19
Jack for electrode leads (3.5mm or 1/8" mono-phone jack)	RS# 274-251 3/$1.59	J1	0.53
Jack for silver wire leads (2.5mm or 3/32" mono-phone jack)	RS# 274-292 3/$1.59	J2	0.53
3 Alkaline 9 V batteries, type 1604 etc.	3 for		3.75
3 x 9 V battery snaps (clip-on connectors)	RS# 270-325 pkg.	5/$1.29	1.29
Misc. wire, solder, etc.			0.50
Box, if used			2.29
Lead wire with 3.5 mm plug, 6 ft., Mouser or Calrad Electronics			0.35
Electrodes, stretch elastic, Velcro, cotton flannel, alligator clips, etc.			
Total Cost **for all** components for improved **do-it-yourself** project			**$22.47**

All components listed above check your local electronics store.

Ensure the IC chip U 1 (LM358) is wired correctly. The location of Pin #1 is shown below:

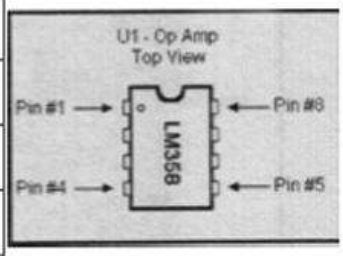

NOTE RESISTOR COLORS NOT TO SPEC. CHECK RESISTOR COLOR VALUES

electrodes:
3/32 x 1
stainless steel cotter pins -hardware store-
Snap pins in half across the curve. and wrap the headphone wires comming from the mono plug around the curve of each half of the pin. then hou glue into place.

Written by
MARK HYMAN, MD

Can Autism be Cured?

TODAY MOST PEOPLE BELIEVE that Autism is a genetic brain disorder. I'm here to tell you that this isn't true. The real reason we are seeing increasing rates of autism is simply this: Autism is a systemic *body disorder* that affects the brain. A toxic environment triggers certain genes in people susceptible to this condition. And research supports this position.

Think about it. Rates of autism have skyrocketed over the years, from an estimated 1 child in 3,000 to just 1 in 150 kids today. Sure, wider criteria for diagnosis and better detection might explain some of it but not an increase of this magnitude.

Dramatic scientific discoveries have taken place during the last 10 to 20 years that reveal the true causes of autism, and turn conventional thinking on its head. For example, Martha Herbert, MD, a pediatric neurologist from Harvard Medical School has painted a picture of autism that shows how core abnormalities in body systems like immunity, gut function, and detoxification play a central role in causing the behavioral and mood symptoms of autism.

Recently I treated a 2 ½ year old boy named Sam. He was born healthy but diagnosed with autism after his vaccination for measles, mumps and rubella at 22 months.

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When I first saw him, this little boy was deep in the inner wordless world of autism. Watching him was like watching someone on a psychedelic drug trip. So we dug into his biochemistry and genetics and found many things to account for the problems he was having.

He had very high level of antibodies to gluten. He was allergic not only to wheat, but to dairy, eggs, yeast, and soy — about 28 foods in total. He also had a leaky gut, and his gut was very inflamed. Sam was deficient in zinc, magnesium, and manganese, vitamins A, B12, and D, and omega-3 fats. Like many children with autism, he had trouble making energy in his cells, or mitochondria.

His amino acids — necessary for normal brain function and detoxification — were depleted. And his blood showed high levels of aluminum and lead, while his hair showed very high levels of antimony and arsenic, signs of a very toxic little boy. His levels of sulfur and glutathione were low, indicating that he just couldn't muster the power to detox all these metals. In fact, his genes showed a major weak spot in glutathione metabolism, which is the body's main antioxidant and major detoxification highway for getting rid of metals and pesticides.

Sam also had trouble with a key biochemical function called methylation that is required to make normal neurotransmitters and brain chemicals and is critical for helping the body get rid of toxins. This showed up as low levels of homocysteine (signs of problems with folate metabolism) and high methylmalonic acid (signs of problems with B12 metabolism). He also had two genes that set him up for more problems with this system.

Finally, he also had very high levels of oxidative stress or free radical activity, including markers that told me that his brain was inflamed and under free-radical fire.

This may all seem complicated, but it really isn't. When I see any patient, I simply work through the 7 Keys to UltraWellness (based on functional medicine) to see how everything is connected, create a plan to get to the causes of the problems, and then

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To create a roadmap for recovery you just take away what's bothering the patient and give his body what it is missing and needs to thrive (based on the individual's biochemical uniqueness). Then the body does the rest. Here is the roadmap I used to help Sam recover.

Step 1: Fix His Gut and Cool the Inflammation There

This step included a number of different tactics including:

- Taking away gluten and other food allergens
- Getting rid of his yeast with anti-fungals
- Killing off the toxic bacteria in his small intestine with special antibiotics
- Replenishing healthy bacteria with probiotics
- Helping him digest his food with enzymes

Step 2: Replace the Missing Nutrients to Help His Genes Work Better

In Sam's case we:

- Added back zinc, magnesium, folate, and vitamins A, B6, B12, and D
- Supported his brain with omega-3 fats

Step 3: Detoxify and Reduce Oxidative Stress

- Once his biochemistry and nutrition was tuned up, we helped him detoxify and

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As I said before, the keys of UltraWellness can help, no matter what the disease or condition. Biology has basic laws, which we have to follow and understand. All the details of Sam's story fit into these laws. We just have to dig deep, peel back the layers, and understand what is going on. When we do this the results are nothing short of miraculous...

After following a gluten-free diet and treating his gut for 3 weeks, Sam showed dramatic and remarkable improvement. He was getting back much of his language skills and showing much more connection and relatedness in his interactions.

After 4 months, he was more focused, unstuck and verbal.

After 10 months, his bowels were back to normal, he was verbally fluent, mainstreamed in school and he "lost" his diagnosis of autism.

After 2 years all his abnormal tests were normal including the high metals, gut inflammation and damage to his mitochondria and free radicals.

And more importantly, the child was totally normal. Not every child has such a dramatic recovery but many improve, and some improve dramatically using the approach of functional or systems medicine.

This is just the beginning. Read the full article on Why Current Thinking About Autism Is Completely Wrong.

To your good health,

Mark Hyman, MD

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Mark Hyman MD is the Director of Cleveland Clinic's Center for Functional Medicine, the Founder of The UltraWellness Center, and a ten-time #1 New York Times Bestselling author.

If you are looking for personalized medical support, we highly recommend contacting Dr. Hyman's UltraWellness Center in Lenox, Massachusetts today.

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Healing the symptoms known as Autism

Second Edition

PDF E-Book

Kerri Rivera

with Kimberly McDaniel & Daniel Bender

Jim Humble • Dr. Andreas Kalcker

Dr. Marco Ruggiero • Robert L. Sands

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Foreword

Autism, not the one described by Kanner in 1943, but the one that we see today diagnosed in 1 of 50 kids is a combination of immune disorders that need to be treated biomedically. There is a lot that we still need to understand about why and how these immune dysfunctions affect our kids' development, causing near complete impairment of their social interaction and communication.

There is a long, hard road ahead to fully comprehend the integrated system that comprises "autism," but our kids cannot wait. It takes more than just medical, professional, or even scientific interests working hard day and night to find a suitable and effective solution to help our kids. It takes drive, passion, and guts to do the right thing; to hear and read the overwhelming stories of parents from all over the world and not turn our backs, but help. It takes an eternal and extreme will to help, even when your own child is on the spectrum.

Kerri's protocols have been indispensible to the full recovery of many of the kids in our Curando el Autismo (CEA) Foundation. These protocols represent a readily available and effective solution to alleviate most of the pathogenic insults to the immune system. Years from now, when "autism" diagnoses do not exist, when we find ourselves fully knowledgeable about the now mysterious immune-brain-behavior connection, I will remember Kerri not only as a friend but as one of the first courageous leaders that dared to change the path for our ill kids. She goes against all odds, sharing knowledge, experience and simply making it happen.

~ Lorna B. Ortiz, PhD.
President of Curando el Autismo, CEA

"Based on parent reports, the prevalence of diagnosed ASD in 2011–2012 was estimated to be 2.00% for children aged 6–17. This prevalence estimate (1 in 50) is significantly higher than the estimate (1.16%, or 1 in 86) for children in that age group in 2007."

US Department of Health & Human Services
National Health Statistics Reports
Number 65, Pg. 2 - March 20, 2013
www.cdc.gov/nchs/data/nhsr/nhsr065.pdf

Preface

by Kimberly McDaniel

Darkness cannot drive out darkness; only light can do that.
Hate cannot drive out hate; only love can do that.
~ Martin Luther King, Jr.

Welcome to the Second Edition of *Healing the Symptoms Known as Autism!* We are absolutely thrilled to share with you the latest protocol updates and everything else that has happened since May, 2013.

You may be thinking: Why a second edition so soon? Our first edition gave us the structure to explain the protocol, and a foundation to build on. This book has already helped many families around the world, and in fact some parents read it and recovered their children without even contacting us until afterwards! Keep in mind that when it was released in May, 2013 it was absolutely up to the minute, but as we mentioned, this protocol will continue to evolve until we have something that is consistently recovering people on the spectrum of all ages. As of January 2014, we again are sharing the latest updates, as well as a whole lot more information that we hope will be as interesting and beneficial to you as it was to us.

Here are some of the exciting new additions:

- Olive Kaiser of www.GlutenSyndrome.net has written a section on gluten and its role in molecular mimicry and autoimmunity. Since many of you are not new to the autism community, a gluten free diet for your children is nothing new. However, you may be interested to find out just how damaging gluten can be for folks who are off the spectrum as well.

- Scott McRae has contributed a chapter on CDH (Chlorine Dioxide Holding [Solution]). A new method of preparing chlorine dioxide that many families are now using with success. This gives us an even wider variety of preparations available to accommodate the needs of our families.

- The Kalcker Parasite Protocol chapter now has some beautiful charts that spell out the timing of all the components for the 18 days a month that a child will be on the parasite protocol. Thanks to Dan Bender, a lot of the confusion surrounding how to make it all fit will be cleared up. You will also find years of lunar calendars to make it easy to see when the protocol is active. You won't have to check Google again to see when the full or new moon is coming.

- The "Worm Whisperer" Robin Goffe shares with us part of her journey towards healing for her 19-year-old son. Her advice is for the Extreme Cases—Self Injurious behavior, aggression, violence, etc. If you are the parent of an older child on the spectrum, or a child who displays these behaviors, or you know someone who is living with a child like this, you owe it to yourself to read Robin's suggestions. They are full of hope and wisdom.

- The one and only Marco Ruggiero, lead researcher on GcMAF, (Gc Macrophage Activating Factor—an immune system supplement) has written an entire chapter on GcMAF and its applications for autism. A must read.

- Last but not least, a whole new crop of testimonials that will make you cry. If after reading this book you still have doubts about giving this protocol a chance, I highly recommend you revisit these testimonials. If I had to pick one part of the book that was absolute favorite, this would be it. It may be because I collect a lot of them, and usually have a little correspondence with the families to get their permission, and genuinely get to feel their excitement, their sense of accomplishment when they see their child start to heal, and not to mention their endless gratitude for being able heal their own children.

  I pray that all of these testimonials find their way to the people who need them and as a result children stop suffering because their parents see them reflected in those words and understand that if other children can heal, their children can as well.

  To me, there is nothing more real than hearing from someone that has walked a mile in your shoes. There is nothing more inspiring that to hear someone say, "I know it's possible, because I did it, I lived it, and I am here to tell you about it."

The families that courageously walked this path and then took the time to share their stories are pioneers and heroes to their own families and to our entire community and beyond. They are blazing a trail for others to follow and countless lives will benefit from their diligence, fortitude and dedication. The stories of healing come from all over the world... from children and adults of all ages. We hope that they move you as much as they moved us. We are eternally grateful for the service these families have provided to humanity and thankful that they were generous enough to take the time out of their lives to pay it forward and share.

- The book now as an extensive index making it much easier to use as a reference.

As of this printing, families are healing their children with autism using this protocol in over 58 countries! Our Facebook groups have over 3,500 members in many of these countries. CD officially knows no borders. It is absolutely thrilling to us that people are coming together with the common goal of healing their children themselves, and to help others do the same! It fills our hearts with joy to be a part of this and to be able to see and feel the love that is shared every single day.

The development of this protocol has been a growing grass roots effort, in sharp contrast to how modern medicine usually works. The reason for this is clear: Modern medicine has not really helped to heal autism and may very well be part of its cause. While we don't have any double blind studies to rest on, we do have a slew of anecdotal evidence, which may not mean much to those in the arena of modern medicine or modern science, that doesn't make it any less real. Time and time again, our *results*—children dropping ATEC points—are being duplicated by families all over the world. For a family who is using this protocol, there is absolutely nothing more real than watching their child come back to them. Ask any autism parent what they would rather have... a long-term double-blind study published in a peer reviewed journal... or a healthy child. My money's on the latter.

As exciting as it is to be a part of this, and as wonderful as it is to hear about gains and read uplifting testimonials, we know there are still families working to heal children that are very sick, and our groups share the highs as well as the lows. Kerri will tell you that some months are better than others and the gains ebb and flow. I urge you to read and reread the testimonials. These are

real stories of real healing and if you haven't already I invite you to believe that your child can be one of the success stories in those testimonial pages.

All of our families are proving what many were told was impossible: Children with the symptoms known as autism can heal! This grass roots movement is creating a paradigm shift in the way the world views healing from autism. The second edition of this book will be translated into at least 13 languages including Spanish, Portuguese, French, Flemish, German, Czech, Norwegian, Arabic, Polish, Italian, Hungarian, Bulgarian and Serbian. This is exciting. This is real. And, this is a living protocol. Every family that uses it every single day is helping to shape the future and heal the children who are affected today, and quite possibly prevent children from becoming affected tomorrow. For this we are eternally grateful.

Here's to you and the continued healing of humanity,

Terminology & Units of Measure

Throughout this book we talk about "CD," which is an abbreviation for *chlorine dioxide*, a well-established oxidizer. Chlorine dioxide is also often referred to as MMS, which is the common name given to it by Jim Humble, the man who discovered various applications of chlorine dioxide. There are many books, videos, blogs and articles using the name, "MMS," which is surrounded by a fair amount of controversy. We choose to not get tangled into that debate since our focus is on helping our children recover from autism. For us, our only concern is that (1) it is safe for our children, and (2) that it works. Based on extensive use of CD on thousands of children with autism, we can confidently say that both those statements are true. If this were not so, this book would not exist.

Units of Measure

Throughout this book we talk about various measured treatment components and containers using fluid volumes and weights. Since this book primarily addresses a US audience, we sometimes talk about measures in the US system of pounds and fluid ounces; while also using the internationally recognized metric system, which is frankly... easier to use.

The common abbreviations of measure you will see throughout this book include:

l	=	liter (volume)
mg	=	milligram (weight)
ml	=	milliliter (volume)
lb	=	pound (weight)
lbs	=	pounds (weight)
ppm	=	parts per million (concentration)
fl. oz.	=	fluid ounce (volume)
net. wt. oz.	=	net weight ounce (weight)

For easily measuring small amounts, syringes (without needles) are a great tool. Don't bother going to a chain store pharmacy... they won't sell them to you without a prescription. Instead, check your local medical supply store, animal

supply store, private pharmacy or protocolsupplies.com. Cost: Surprisingly dirt cheap. The complete set of five below cost about $1.00 in Mexico—less than most candy bars—and not much more in the US. Note: Some brands of syringes have printed on scales that easily rub off, especially if your hands are a little oily. To prevent from losing the markings, cover the scale with some clear tape or clear nail polish.

When it comes to accurately measuring larger volumes, you can buy a set of 7 Polypropylene Graduated Cylinders. Of course this is not a requirement. You can use common kitchen measuring utensils, but these are more accurate and easier to read. If you decide to get them, avoid those with printed on lettering (it rubs off). Raised lettering is best, although sometimes a bit difficult to read. Typical cost on ebay™ or Amazon® for a set is around $25USD. The sizes range from 10ml to 1000ml. You can also buy individual cylinder sizes made of plastic or glass.

Acknowledgements

Gratitude makes sense of our past,
brings peace for today,
and creates a vision for tomorrow.

~ Melody Beattie

Thank you to my Mother who taught me by example the value of volunteerism and to help others who are less fortunate. Thank you for always telling me that I am the best and that I could do anything. I believed you :)

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Thank you to Patrick for bringing to our family a higher good. You are an angel. You have brought light to all who meet and know you. Thank you for choosing me to be your mother. You and your brother have taught me more about myself and about life than I could have ever dreamed. I am grateful to you and I Love You more than words can say. Through me, you have given people their lives back. You have forever changed the face of autism.

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Bob Sands, thank you for seeing something special in me, thank you for taking me to meet Bernie and Mrs. Rimland. That day changed my life forever. Thank you for giving us the best hyperbaric chamber in the world. With that chamber we have seen so many miracles.

Jim, you have brought light to many and hope to all who have had the fortune to know the miracle that is CD (Chlorine Dioxide). I am grateful to you every day of my life. I have witnessed first-hand the miracle that is autism recovery. Thank you for staying the path that has never been easy. But it is as you say, "The right thing to do..." I love you.

Andreas, my dear friend, thank you for your dedication, your research and for your willingness to help. You are the science, the reason and the truth that is chlorine dioxide, the molecule that has the power to save humanity. Thank you to you and Miriam for your unfailing support over the years. Your contributions to the world of autism are changing the way the world views autism forever. And the lives of so many children are now recovered thanks to your contribution to The Protocol. Without you both, these recoveries would not have been so abundant.

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Thank you to all the families on our forums for blazing a trail for others to follow and fighting for the health of your children every single day. You are an inspiration.

To all the Mods; Ginette, Caryn, Joy, Alison, Heidi, Michael, Pam, Katya, Carolina, Nilesh, Mirena, Robin, Debbie, Sue, Susan A., Brandi, Don, Clint, Maggie, Claire, Amber, Dawn, Naomi, Maryann, Susan R., Stacey, Jessi, Lina, Boris and Susanne, Olive, Dana, and Pat, for being the best mods in the world. Your help changes lives for the better each and every day. This is for you:

> *It's in our interest to take care of others. Self-centredness is opposed to basic human nature. In our own interest as human beings we need to pay attention to our inner values. Sometimes people think compassion is only of help to others, while we get no benefit. This is a mistake. When you concern yourself with others, you naturally develop a sense of self-confidence. To help others takes courage and inner strength.*
>
> ~ The Dalai Lama

Thank you Joy for sharing with Alison that you had heard about CD for autism through the seminar that Jim had in the Dominican Republic. That gesture opened the gates to the north and from there to everywhere. You are a special healer.

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The purpose of life is to contribute
in some way to making things better.

~ Robert F. Kennedy

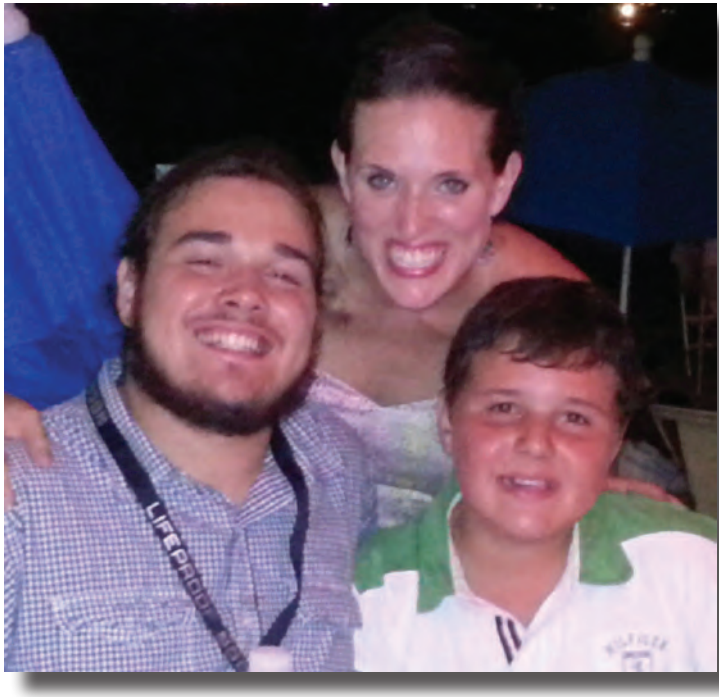

Alex Rivera, Kim McDaniel (Kerri's sister), & Patrick Rivera

Introduction

Autism is Avoidable, Treatable and Curable

Your body's ability to heal is greater
than anyone has permitted you to believe.
~ Anonymous

Congratulations on finding this book, and welcome to the world of autism recovery. This book comes to life as more and more children with an autism diagnosis respond and recover in more than 58 countries around the globe. This book gives families a do-it-yourself guide to an *Autism Spectrum Disorder* (ASD) recovery program with answers all in one place.

I have, on my ASD recovery journey with my son Patrick, personally been frustrated with the lack of information and answers leading to lost time and money. For example, when I first knew that Patrick was no longer developing "normally" (in 2003), I was unable to get a diagnosis. Seven years, dozens of interventions and hundreds of thousands of dollars later I was still searching for pieces to Patrick's autism puzzle.

I learned over the years of many people recovering their children using various protocols and interventions, and I looked into all of them. Some gave us improvements but not recovery (most specifically for Patrick, diet). Some gave us nothing.

My goal with this book is to alleviate that frustration and loss of time and money for other parents.

I became interested in chlorine dioxide (CD) in 2010 but I was unable to find any information about using it with autism on the Internet. Since I knew that almost every child with autism suffers from similar pathogens (viruses, bacteria, candida, and parasites), heavy metal toxicity, inflammation and allergies I researched those conditions in combination with chlorine dioxide—removing "autism" from my vocabulary.

I realized with further research that CD would be excellent for curing the symptoms collectively known as autism. When Patrick was first diagnosed in 2004, his *Autism Treatment Evaluation Checklist* (ATEC) score was 147 and after six years of biomed he was at a 63. (The diets made the biggest difference in

those initial dropped ATEC points). 2½ years of CD later he is at a 21. CD has made all the difference in his life, in my life, and in so many lives around the world.

I brought CD to my *Defeat Autism Now!* style Clinic in Puerto Vallarta in 2010. Today more than 115 children globally have lost their diagnosis of autism (meaning an ATEC score of under 10 points). Additionally, thousands of children around the globe have dropped points on their ATEC and are moving towards recovery. 27 children in less than 1 year in Venezuela alone lost their diagnosis of autism with a combination of diet, CD, and ocean water to the surprise of the doctors who diagnosed them in the first place. Many of those same doctors are now looking at CD for other patients.

It is my dream that every family of a child with autism be given this information so that they can decide for themselves whether they want to give it a try.

This book is a protocol for all of us. Some of you may be completely new to autism recovery; some of you may be a veteran like me and/or parents of older children and adults on the spectrum. This protocol works for even the classic "non-responders" and for those who are so close to recovery yet can't seem to get through the door. This book is for you. CD helps the body heal the symptoms we call "autism" across the board—it is an equal opportunity healer.

I know from experience that an autism diagnosis is devastating on many levels. The initial regression of a neurotypically developing baby takes away eye contact, speech, and the emotional connection between parent and child. Then, when strange new behaviors such as flapping, squealing, rocking, spinning or even self-injurious behaviors appear, you know in your deepest mommy (or daddy)-gut that your child was not born like this. It seems to take forever to get the truth about what happened to your happy, healthy baby. It takes even longer and is more confusing when you have to figure out how to heal that sick child. Far too many "health" providers in the autism field are focused on making money so we can't blindly trust anyone. We must do our own homework. The journey itself is a lot of trial and error coupled with misinformation.

Many supposed "autism experts" don't know much about recovery, or the effective order of treatments and end up costing our children time and the parents money. The less time a child spends chronically ill, the easier and faster it is to recover them. Not to mention the child spends less of their lifetime suffering the physical, emotional and mental effects of autism.

I feel that all parents who begin this protocol should expect a full recovery from autism because this protocol treats what causes this diagnosis. Our research

indicates that every person with a diagnosis of regressive autism has virus, bacteria, candida, parasites, heavy metals (biofilm), inflammation and allergies. This protocol handles every one of these issues, and that's why it has been so successful. Some recover faster than others. But, every day we are one step closer to the end of autism.

How do you know if the protocol is working and how long does it take to see results?

The ***Autism Treatment Evaluation Checklist*** (ATEC) is our measure. The ATEC is an online survey that evaluates the severity of a child on the spectrum. For more information see Appendix 4, page 447. Many families notice changes from day one, while others take longer. You will get results when you correctly apply the interventions in this book in the proper order and without breaks.

What are the results you can expect from the protocols in this book?

I would love to say that everyone who follows the protocol will get their child down to an ATEC of 10 or less—what we call a recovery—and we have 115 of those already. The majority of those I'm in contact with report substantially significant improvements, even if they have not reached recovery. In the case of my son Patrick, he started at 147 in 2004 and has come down to 26. I'm optimistic as I continue to search for further answers, and will continue to share what I find.

If you are not getting results and have gone through this book including the Frequently Asked Questions (FAQs) and troubleshooting, please contact me through the forum at...

www.cdautism.org

...there are always tweaks we can make to keep moving towards recovery.

I recommend you read this book straight through in the order that it is written as that is the order in which it is to be applied. Jumping around the interventions can lose time for your child and waste money for you. Doing interventions in the correct order, when your child is ready for them, is the best to way to achieve recovery. Diligence and perseverance win the race every time.

My mission is to share with whoever is interested, the blessings that I have received. If the information presented here feels right and resonates with you, then please, give it a try. It might just be what your child needs.

This book in a nutshell:

If you want the best chance at recovery, here's the overview of how to do it:

1. The Diet: Eliminating gluten, dairy, soy, sugar, and toxins, to stop inflammation and reduce the overall toxic burden.
2. The CD Protocol to kill pathogens while using a multimineral like ocean water.
3. The Kalcker Parasite Protocol.
4. Explore and implement other potentially synergistic supplements to aid in speech facilitation, neurotypical behavior and/or seizure reduction.
5. Consider gentle chelators.
6. After 3 parasite protocols and consideration of all above steps, find a hyperbaric chamber (1.75ata).
7. Consider adding in GcMAF.

It is important to consider all of the pieces of information in Chapter 14, *Miscellaneous Information You Should Know* (page 323) and apply them from the beginning when they make sense for your child. You also may find the *Summary of Protocols* in Appendix 12 a good resource when you do not have time to reread a chapter to find something specific.

On the right is what we call the *Stairway to Recovery*. Joy Whitcomb, one of our amazing moms, came up with this so you can see just how each step rests on the previous steps, and without them you would not reach the top step… RECOVERY!

Author's Note: It is never my intention to "change someone's personality" or take away their character by healing autism. I see it quite the opposite. When children start to recover, their personality starts to shine through. The behaviors that we saw before (spinning, flapping, squealing, smearing feces, auto aggression, lining things up, tantrumming, etc.) are not personality traits but symptoms of a sick body. These symptoms start to disappear once the body begins to heal and our children can express who they really are through smiles, eye contact, words, gestures, etc. They can show us what they need and want and play an active role in their own lives. It is my dream that every child has the opportunity to mature and choose the life they want for themselves, and be responsible for making their own decisions. I truly believe this is possible for all of our children and adults on the spectrum, and I want families to have the opportunity to offer healing to their children.

Throughout this book we have used the pronoun "he" when referring in general to "a child on the spectrum." This is not to alienate families with girls or women on the spectrum. It is simply a question of fluidity. To use *he/she* or *his/hers* every time we chose to use a pronoun seemed cumbersome, so therefore we are using "he" or "his" throughout the book. We chose "he" rather than "she" because autism is five times more common among boys than among girls. As of March 2013 the CDC revealed the results of a new study conducted during 2011 and 2012 which surveyed 95,000 families and estimated the prevalence of autism at 1 in 50 children.

The acronym DAN! is no longer applicable to *Defeat Autism Now!*, as it belongs to *Divers Alert Network*. The acronym has been used in several places in this book as several of the personal anecdotes are from a time when its use was still appropriate. Today, a "DAN! Doctor" could be defined as a practitioner who received training through the network formerly known as *Defeat Autism Now!*.

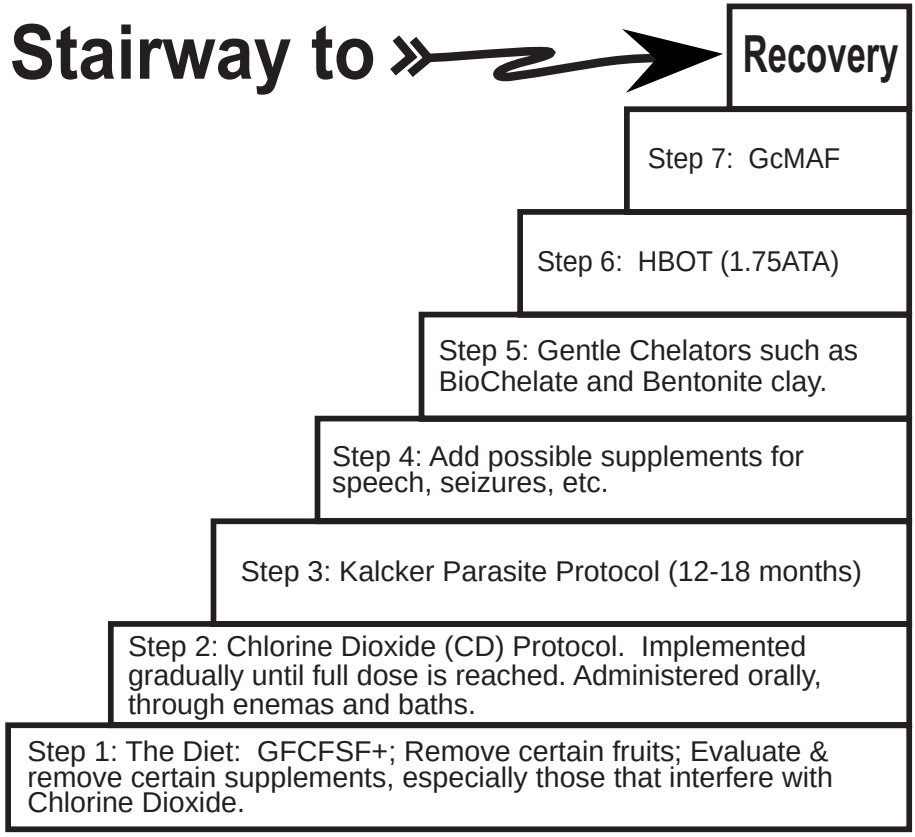

Concept by Joy Whitcomb.

Everything yields to diligence.

~ Antiphanes

IMPORTANT NOTICE

Please keep in mind that the protocols in this book are still evolving, and will continue to be improved as new discoveries are made. We will release new editions to incorporate those new discoveries. The topics of CDS & CDH are particularly new and rapidly evolving. This book is current as of January 2014. Please be sure to check this book's website for important corrections and updated information beyond this and subsequent editions:

HealingTheSymptomsKnownAsAutism.com

Chapter 1

Kerri's Story

"The impossible is now declared possible as soon as you agree to it. It's just a flip of the mind, letting go really, nothing more."
~ Stuart Wilde

"What happened, what did you do to Patrick?" That was the first thing my husband asked me when he first saw our son, after returning from a weeklong trip. This was just five days after our youngest son Patrick received his last vaccine—the DPT (diphtheria-pertussis-tetanus) + Hepatitis B + Influenza B (what is known in Mexico as the *Pentavalente*) on the 13th of August 2002 at two years and one day old.

That question was the first of many to propel us down our path paved with autism. I told Memo (my husband) that we shouldn't worry. The nurse mentioned that we could expect a fever, or he could be listless. These were completely normal reactions. Contrary to what she said, what we observed during those first days and weeks were loss of eye contact, flapping, toe walking, high-pitched marine noises along with excessive drooling—drooling that would soak the front of his clothing.

Patrick had also lost all of the speech he had acquired; Mama, Pa, *agua* (*water* in Spanish), letters of the alphabet, numbers... all of it. The only thing he wanted to do was watch videos while running back and forth in his bedroom squealing the "ambulance sound," flapping and banging his gut, and drooling through all his clothes.

Not being well versed at the time in these problematic symptoms, we chalked it up to a case of the terrible twos. But these particular terrible twos led to loss of sleep for Patrick as well as the rest of the family, antibiotic use for green nose and eye mucous, and raging diarrhea that was so acidic it would burn his skin upon contact. This would be the story for the rest of the third year of his life.

The first of many to associate Patrick's behavior with autism would be my great aunt. She mentioned to me that she believed Patrick had autism after observing him at a family get together in April of 2003 while we were visiting relatives in Chicago. It was the most ridiculous thing I had ever heard.

Nevertheless, I went home that evening and immediately Googled the symptoms of autism. Laid out on the website were symptoms like spinning objects, lining up objects, self-injurious behavior, lack of socialization, and several other factors that I felt in no way described my son. I dismissed the comment, and continued to watch my son display strange behaviors, without understanding why.

I was back in Chicago a few months later in July. While going out for a run, I saw a girlfriend of mine who has a child the same age as Patrick. We stopped to chat and she asked me how he was doing. I said, "fine." She asked me if he was talking yet. I told her he had developed language, but since March he had lost all the vocabulary that he had previously acquired. My girlfriend looked at me and said "Oh…" with a look of concern on her face. I asked her, "What's wrong? What does that mean?" Now I was extremely nervous. "Well," she said reluctantly, "loss of language is a red flag for autism." There was that word again. I told her that we had already gone through all that, because by then I had taken Patrick to a neuro-pediatrician in Guadalajara, a psychologist with a huge center in Guadalajara, and a local psychologist in Puerto Vallarta. All three of these experts had told me that he was fine; they didn't see any problems with his development.

I started on my jog, and about halfway through, it hit me that Patrick did have autism, so I sprinted home, sat down at the computer and went to the *Autism Society of America*'s website and found a checklist of 16 symptoms of autism. The directions said if your child had 12 or more than most likely he has autism, Patrick had exactly 12. Looking back, he most likely had 14 or more, but I wasn't ready to see those just yet.

That same day I called his pediatrician in Puerto Vallarta and I told her I thought my son had autism, and she told me, "No, I have never seen anything like that in your son, but bring him and I will take another look." When we went in she observed him. She said that he didn't line things up, he didn't hit his head, he would still come to me, he was 'playing' with some toys in the waiting room, so therefore my son didn't have autism.

The pediatrician told me to go home that day to wait for him to straighten out. All the experts told me he was the way he was because he was the baby of a bilingual family that—according to them—traditionally produces late talkers; his parents and brother were all late talkers. He was spoiled. He had a nanny. And, he's a boy—boys are late talkers, etc., etc. The pediatrician successfully talked me out of the diagnosis once again.

As nothing was wrong, that fall we put Patrick into a kindergarten. His teacher would tell me Patrick isn't doing this activity or that, and I replied that we had taken him to see all the specialists, and he was just a late talker. She was super sweet about it and every few months she would make a comment to me because she saw him drastically different from his classmates.

Then one day it happened, I got a call from the director of the school saying that her friend, a neuropsychologist was in town from the United States, and she would like her to see my kids. At 6pm on March 12, 2004 I had an appointment with this neuropsychologist. I had already figured that this woman wanted to see Alex, my older son because he hadn't been doing well at school. He hadn't been sleeping well since Patrick hadn't been sleeping, which led to some poor performance in school. I had already gotten the news that Patrick was fine, so when she started focusing on him and his behaviors I was slightly confused. We sat down in his classroom, and she started asking me if he always… runs in circles, flaps, drools excessively, squeals like a dolphin, etc., (we actually used to joke that his mother must have been a dolphin). After that, I told her how we had already gone to all of these specialists and they said he was fine.

I was tired of getting the run around, and then everybody asking me what was wrong with my kid when he was just taking some extra time getting going. That's when she said to me, "I can't believe they didn't tell you your son has autism."

These words changed my life forever. Of course I asked her if she could be wrong, and she said, sure there exists a possibility, but she had done her post grad in autism, had seen hundreds of cases and this diagnosis was her professional opinion. That opened the floodgates for a river of tears that didn't end for years to come.

Being a positive person, I asked her what I should do. She said, "I would like to introduce you to a group of psychologists that are in town." The next day I went with her to a hopeless place, with hopeless people and I asked her if this is something that we can cure, and she said, "No, you can do therapy with these psychologists, and that's it." Children are born with autism and they will die with it, was the basic sentiment. I knew for sure that my son was NOT born with autism. He was the smartest, bright-eyed baby ever, and we had the photos and the videos to prove it. He was not born the ghost of a child that we had now. I knew that I would keep searching until I found something else for Patrick. I became proactive and never returned to that place.

The very next day I saw another girlfriend and she mentioned that she had a book on ADD and autism, so I immediately picked up the book and it was all about diet. Gluten-free, casein-free to be specific, and I decided to start it right away. Truth be told, Patrick's diet was horrible, he had self-restricted to only dairy and wheat. Bread products and cheese were his staple foods, but the good news was he still ate potatoes. Even as an autism novice, I knew I couldn't take him to a fast food chain because those fries were coated in gluten. We started off with just homemade fries with sea salt, because that was the only thing left on his diet that he would eat. After three days of being on the diet he said three words, the first three words he had said in over a year. I knew we were onto something.

The next week I ran into a friend from tennis, I really didn't want to say hi, because I was really depressed, but I heard a voice saying to me "It's not about the road but about smelling the flowers along the way." So, I forced a smile on my face, and went to say hi to her in my great depression. Well, she started to complain about her week, so I listened patiently, and then I told her about my week; Thursday my identity was stolen on the Internet, Friday my son was diagnosed with autism, and Saturday my dog of 14 years had to be put to sleep.

When she heard all this she turned off her car and told me how sorry she was. She said that she would put me in touch with her friend that had opened the *Early Autism Center* in Toronto, Canada. When I woke up the very next morning, I had a long email from Norah Whitney waiting in my inbox. She would turn out to be the first of many autism angels in my life.

I received a lot of precious information from that email, but what was maybe the most important detail for me was that what had happened to my son was an effect of all the vaccines he had received, he wasn't born with autism, as I knew. I also hadn't caused this, and I needed to start letting go of some of my guilt. Norah also told me that we can treat autism and I needed to immediately contact a DAN! Doctor, and Dr. Bobby Newman, Board Certified Behavior Analyst and Licensed Psychologist. Norah said that they were the best, and that this group of DAN! Doctors were curing autism.

I got in touch with everybody and that same month we started our own *Applied Behavior Analysis* (ABA) program. I also took Patrick to the States to see his first DAN! Doctor. When I got back home from that trip I had bought nearly $5,000 (US) of supplements and injectables. That didn't mean I knew how to use them, and by no means was I watching my son improving before my eyes. This was June of 2004, and we went through the rest of that summer with some supplements, other biomedical interventions, and 40 hours a week of ABA therapy.

That fall, some friends mentioned to me that their father was receiving chelation in San Diego, and I had just heard someone else saying that chelation was working for kids with autism, due to their extreme metal toxicity. By the end of the evening I had the phone number for the clinic that was providing his chelation. When I called for information, they told me that they referred all of the children's chelations to Dr. Woeller in Temecula California, so I made Patrick an appointment. In March of 2005, I took the whole family to Temecula to see Dr. Woeller, because basically nothing was happening with the supplements I had been giving to Patrick. I knew I needed to keep exploring other avenues.

Several thousand miles and various tantrums later, we arrived at Dr. Woeller's office. I told the receptionist that we had come to see Dr. Woeller. To my chagrin she said, "No, you have an appointment with some other doctor, Dr. Woeller isn't even in town right now." My husband was sure I had messed up the appointment and was extremely upset with me. Meanwhile, Patrick was screaming, crying and taking his clothes off in the waiting room. They finally let us through to speak with the other doctor and after going through Patrick's autism we explained that we wanted to chelate. We had the understanding at that point that his autism was coming from the mercury in the vaccines. She told us point blank that we couldn't do everything at once, and before we could chelate we would have to clean up his gut. I flew home with my family totally deflated. We started on the impossible journey of cleaning the gut.

My first ever autism conference turned out to be *AutismOne* in late May of 2005. I met a lady who was a rescue angel for *Generation Rescue*, and I told her I wanted to chelate my son with those DMPS drops, which were fashionable at the time. She told me that when it came to my son's recovery I shouldn't take no for an answer. I had to advocate for my son, and not let myself get pushed around. With that wisdom, I called Dr. Woeller's office again and told them I wanted my appointment with Dr. Woeller himself, and I would not be given the run around. The manager listened to me and said that she would put me through to him. After a long c'onversation, Dr. Woeller agreed to take Patrick's case and that he would help me chelate my son. He agreed with me that it was silly to think that we could have the gut completely under control before beginning chelation. Eventually I got the DMPS drops for Patrick that I had so coveted, and I felt we were back on track. However, after about six months of using the drops we still saw no change.

Flashback to that same *AutismOne* conference, where I had attended a lecture about the *Specific Carbohydrate Diet* and the removal of all grains from the diet—a diet that helped Patrick inch forward minimal improvement by minimal improvement.

In November of 2005, I had a phone consult with Dr Woeller, and having been disappointed with the transdermal DMPS I decided to ask if there was anything new in the world of autism. The answer that would end up changing all of our lives was hyperbarics or HBOT (hyperbaric oxygen therapy).

I learned that there was a really nice man by the name of Bob Sands in San Diego who owned a corporation that manufactured hospital grade hyperbaric chambers. I phoned Bob's office because Patrick was going to need 40 sessions right away, and I wanted to check prices and see if there was a package discount for hyperbarics. The answer was yes, in fact there was a discount. I scheduled Patrick's HBOT, and took both of my kids to San Diego, where we stayed for 20 really long days to get Patrick his first 40 sessions of hyperbarics—two a day—everyday, morning and night.

During that time, my husband and mom would call and ask me if Patrick was better, but he was still naked in front of the TV, jumping up and down, flapping and squealing. It wasn't until we got back home that he began to pronounce the first syllables of all of the words for things he wanted, like "ap" for apple. We considered hyperbarics a great success, but like I said that wasn't until a couple of weeks after we finished the 40 sessions. That's when we really began to see the changes in Patrick. Bob always says that HBOT is the gift that keeps on giving; you can see benefits for up to two months after you finish your sessions.

Meanwhile, Bob and I hit it off right away. He had a real jovial and family-oriented atmosphere in the clinic. I told him my story and how I wanted to help people know that autism is avoidable, treatable and curable. I shared with him that there was no information, much less Biomed or autism recovery in Mexico (and most of Latin America). I wanted to help people and to share with people that there is a lot we can do to help our children heal.

The very next day he walked into the office and changed the course of my life forever. He told me that he was in fact friends with Dr. Bernard Rimland, "Bernie," the Grand Godfather of Biomedical treatment for autism, and the author of *Infantile Autism*, *Dislogic Syndrome*, and the founder of the *Autism Research Institute*. I told Bob that meeting Bernie today, would be akin to having met Mick Jagger when I was 15. He then announced that we would be having lunch with none other than Bernie himself and Mrs. Rimland. For the first time in my life, I admitted to Bob that I was so excited that I didn't know what to say. Bob told me that when it was my turn to say something that I should ask Bernie "What can I do for DAN!?"

In a tizzy I ran over to Marshall's, the discount retailer; bought a new suit, hose, and even a pair of high heels. The next afternoon, I put on my new ridiculous clothes, ditched my kids with my friend's maid, and hopped in Bob's Jag to meet Bernie and Gloria (Dr. and Mrs. Rimland)—an absolute dream come true. When we arrived at their favorite restaurant, I was completely overdressed. Gloria ordered a salad, and the guys had tilapia because Bernie didn't really like vegetables. The conversation ranged from Kinotakara patches, to the difference between soft-sided hyperbaric chambers and hard hyperbaric chambers.

I waited until there was a lull in the conversation and I went for it, I asked him what could I do for DAN!, and he said I should translate the DAN! Protocol and take it to all of Latin America. His words left me totally dumbfounded. Had I heard right? Latin America? I was thinking my town of Puerto Vallarta, or maybe Jalisco, (the state we lived in) and maybe in my wildest dreams all of Mexico, but this was much bigger than I had imagined. At this point, though there was no stopping the momentum that we had started. Within months we translated the Protocol to Spanish, and donated it to the Autism Research Institute, for dissemination throughout Latin America. Much later I would find out that one of my dear friends, Yeroline, would heal her son from autism using the translation of the DAN! Protocol, as well as others.

During that same trip my husband and I spoke to Bob about buying one of his chambers for the not-for-profit autism clinic we were planning on opening in Puerto Vallarta. The plan was to run the clinic on a non-profit basis, but anchor the clinic by charging the public for their sessions in the chamber, allowing all the profits to pay for children with autism to go for free in the chamber.

It was a green light all the way. We deposited the money for the chamber in March of 2006, and it arrived on October 31, 2006. AutismO2—Hyperbaric Clinic officially opened its doors on Dec 1, 2006. We threw a party for the inauguration, invited friends, family, Patrick's therapists, and our local priest came to Bless This House. We all wore white, and in honor of Patrick, who was our motivation for opening the clinic, we all had on nametags that said *Kerri—Patrick's Mom*, *Memo—Patrick's Dad*, etc. It was a special evening for all of us, but me especially, as it solidified what would be the path that I would still be walking as I write this book seven years later.

The clinic had a Sand's Hyperbaric Chamber, an allopathic physician with a specialty in Hyperbarics, 2 psychologists, 2 hyperbaric technicians, and me, to initially meet with the parents. As for the chamber, we always knew that it was going to help a lot of kids with autism, but it has helped a lot of others as well. The chamber was what gave language back to Patrick in 2006.

Later that same year we sent our allopathic doctor with our naturopathic hippie doctor to Ixtapa, Mexico for a hyperbaric conference, where they serendipitously met Dr. Giuseppina Feingold, (Dr. Jo) a DAN! doctor using hyperbarics for children with autism. As soon as our guys got back to Puerto Vallarta they started insisting that I had to contact her because she is curing kids with a protocol that included hyperbarics. Never one to waste time, I emailed her immediately, but at the time I didn't know she wasn't an email person and, because I am just not a phone person, we didn't connect.

Fast forward to January 2007, my husband, Memo, was buying a 1951 Desoto on eBay. We had to pay for the Desoto with a check, and therefore started to talk to Bryan, the seller of the car. During their conversation, Memo, my husband, said to Bryan "If you don't want to sell, because it's worth more than your selling price I will understand." Bryan had already decided to let it go, but at the same time he was interested in where the car was going, what Memo did for a living, etc. Memo told him about our life in Puerto Vallarta, and the classified ad magazine business that he owns. That's when Bryan stopped him and said, "I've heard of that magazine!"

It turned out that this Bryan was a nurse who works with a doctor who does hyperbarics and heals kids with autism. Well, that piqued Memo's interest, so he told Bryan about Patrick's autism and then Bryan says you must call Dr. Jo, yes, the very same Dr. Jo that our clinic doctor had met months earlier at the Hyperbaric Conference in Ixtapa. So, I called her immediately and when she answered I said who I was, and I told her Bryan told me I had to call her. I asked her if she believed in God and she said yes. I went on to tell her that in September she had met with my clinic's doctor and how I had emailed, but never heard back. At the time, Dr. Jo had been receiving so many emails that sometimes she couldn't get to all of them.

Finally we had connected, and we hit it off right away. I immediately told her all about the clinic and Patrick, hoping that she could come to Vallarta. She told me that I had to go see her in New York first, and we would get Patrick some treatment. So off we went to freezing cold New York in March of 2007.

We immediately started treating Patrick with IV chelation. The theory at the time was the main factor causing autism were heavy metals coming from vaccines that were damaging the methylation pathways. During my daily treks to Dr. Jo's office I finally met Bryan, the owner of the Desoto that my husband bought on eBay. We started talking about my clinic and what we could do collaboratively if Bryan were to move there. Bryan had already been in nursing for almost 30 years and was an expert in ozone and other alternative

therapies. He told me he was ready for some changes, and we were very interested to have someone of Bryan's caliber and relaxed personality to join us at the clinic.

Within a week of my return to Puerto Vallarta Bryan came for his first visit, to see if he could call Vallarta home. Two months later he came back with all of his equipment to set up his office. We were a great fit, and Dr. Jo would fly down from time to time to help out with patients.

From 2007 to 2008 we were treating Patrick with IV chelation on top of his regular GF/CF/SF, diet, supplements, and hyperbarics. In May of 2008, I met a mom who had recovered her autism spectrum child with homeopathy. Almost immediately I started working with a world class homeopath from June 2008 to May 2009, but I didn't see anything to make me feel that the cure to autism was down that path. That same year I met a doctor doing the Yasko protocol, and she had some ideas, so we gave it a try from August 2009 until the end of May 2010. At that point, Patrick honestly looked worse than before we had started giving him 80 supplements a day.

By now I had become disenchanted with *Defeat Autism Now!* based megavitamin protocols. A precious few of the families that we helped recovered their children with diet, supplements, chelation and hyperbarics. However, the overwhelming majority still had an autism diagnosis after tons of work by their parents, and usually a lot of money spent on supplements and treatments. I started feeling like it was a fraud, telling people to follow this protocol, which I knew wasn't going to be enough to recover most of the kids. That's not to say that we weren't seeing vast improvements, but counting all of the children that we worked with, only two children recovered.

By July of 2010, I was totally disillusioned and befuddled and I didn't want to continue doing what I was doing the way I was doing it. So, I asked the Universe/God/Angels—whoever was listening, for help. If my mission truly was to help families recover their children from autism then I was going to need a tool to work with. One that was available on every continent and that was affordable to everyone, because what we had just wasn't doing the job.

No magic voice came, thank God! Because that would have really freaked me out. However, I started to remember these colorful little bottles of chlorine dioxide that I never used. I decided to research their use on Google. Disappointingly, there was absolutely nothing on the Internet about autism and Miracle Mineral Solution (MMS) aka chlorine dioxide (CD). So I started thinking about what autism is made up of. So, I Googled chlorine dioxide

with virus, bacteria, candida, heavy metals, blood brain barrier, allergies, and inflammation. The evidence was overwhelmingly positive, which showed me that CD could treat all of the components that make up autism. I had hope once again.

I was especially interested because at the clinic, we specialize in oxidative therapies such as hyperbarics and ozone. As chlorine dioxide is more benign than what we were already using, I decided to investigate further.

No side effects except a possible Herxheimer reaction; which is not a side effect of chlorine dioxide itself, but can happen with any detoxification protocol. I decided to speak to my husband and son Alex, who were also excited. The next day at the clinic, my husband's best friend's cousin and his wife were getting out of the chamber. I said, "Hi!" and she immediately said to me, "I'm taking CD." She didn't say "Hi!" or "Kerri!" just, "I'm taking CD." That was the definitive moment for me—my Aha! moment. I told her I had been researching it for weeks, and I was extremely interested. She was having great results, so my husband said he would try it first. If after three days on the drops he was still alive then we would start Patrick on them.

I contacted Jim Humble, discoverer of CD. I was hoping he would help me to better understand how to dose CD for children with autism. I explained to him that there was nothing on the Internet for kids. He helped me do just that. He gave the following recommendations: 1 drop 8x a day for children under 25lbs, 2 drops 8x a day for children under 50lbs, and 3 drops 8x a day for children under 100 lbs. He told me that the more doses that we can get in one day the better, 8 doses are the minimum.

That first week Patrick vomited (classic Herxheimer reaction), because I went too fast with the dosing. On the Internet, the only protocols I found gave high doses a few times a day, and as I found that week low and slow doses all day was the way to go. However, despite the Herxheimer reaction I caused Patrick (through lack of a low and slow dosing protocol) he was still noticeably better. Seven days later my son had improved eye contact and was asking for things that he had never requested in his life. At 9pm he looked me straight in the eye and said, "I want bed." With my jaw hanging open in disbelief, I followed him upstairs to his room. When we got there he turned to me and looked me straight in the eye again and said, "I want take bath." I knew I was not dreaming, and I had really just heard that. After his bath he looked me straight in the eye and said "I want brush teeth" and the whole time we brushed his teeth he was giggling... so I asked him what he wanted and he said, "I want 'kanket'" so I said, "blanket" and he repeated, "blanket, yes" and ran to the bed,

and jumped on it to enjoy the blanket. He had never jumped into the bed in his life before that. This was the first seven days on CD. I was blown away.

By September of 2010, every person that was previously only using herbs or medications to kill viruses, bacteria, candida and other pathogens was about to hear about CD. That's when things really started to happen.

Back in 2007, I learned how Dr. Anju Usman was having great success with her biofilm protocol. She concluded that virus, bacteria, candida, parasites, and heavy metals are all joined together in the biofilm (more on this in Chapter 5, starting on page 117). And when I saw that CD killed pathogens and neutralized heavy metals and so many other things that make up the core of autism, I knew we would kill a lot of birds with one stone. I was also hoping to sidestep a few pharmaceutical pieces of the biofilm protocol, i.e. antifungals, antibiotics, antivirals and be able to use something with no side effects (a Herxheimer reaction is different than a side effect).

I was in the process of discovering how we could use this extremely inexpensive oxidizer that is available all over the world to help the body heal from autism. The other important part of CD is that you don't need to take your child somewhere for treatment, as in the cases of hyperbarics, ozone or IV chelation... there is no doctor needed, or trips to visit doctors in other countries. It's as simple as taking a supplement and you modify your dose depending on what you feel and see. Basically, any family with access to the internet, diet, CD and a few choice supplements can heal their child with autism.

After having limited success with my son on different biomedical treatments, even with the best doctors in the world, it was time for a change. With CD we are attacking the biofilm all day as CD destroys the electron shells of the different molecules making up pathogens, therefore releasing toxins into the bloodstream. This release of toxins is the principal reason one must go slow and build up the dose, to avoid a Herxheimer reaction as so many of these children are very toxic. If we kill too many pathogens at once, too many toxins enter the bloodstream. The body will immediately look to eliminate them, most notably through diarrhea and vomiting. This is unpleasant and totally avoidable.

CD is so benign you can use it on your skin, hair, ears, eyes, orally, rectally, vaginally, inhaled, etc. At the doses we use CD in aqueous solutions; it is not detrimental to healthy cells. It specifically targets pathogens due to their negative charges. Once I understood the basics, and Patrick was still improving, I started to share with others to understand how to use CD. Very quickly we were having success that many other clinicians weren't having. Kids on the

spectrum were improving, some started recovering, and we had to sit up and take notice. I was blown away again.

In November, a child recovered and then in December another child recovered. Their families took them to psychiatrists and their doctors to have their diagnosis removed. These were the very important first steps that convinced me that this is something that we must continue to do. We started to spread the word that this was an inexpensive treatment modality available in every continent of the world.

With my background in biomed I learned that you watch for reactions while you load the dose. *Low and slow* is the rule. We arrived at the one-drop at a time dose and as kids recovered, parents shared their stories with other parents and more and more people started using it. It was very grass roots.

This is when the explosion happened. I started to think that this might be the missing piece of the puzzle that we had been looking for. In all seriousness, there is no one cure for all kids with autism, which is why each child's protocol and path to recovery is different. While we have seen great success with CD today I keep working to discover new modalities that help these children heal as non-invasively as possible. Now that we had had success in the Spanish-speaking world, I needed to share these treatments with families of children with autism all over the world.

Around this time something very interesting started happening with the CD enemas... parasites; more specifically roundworms were coming out with the CD enemas of the parents and their children using the Protocol. Today I have hundreds of photos, which were sent to me from parents all over the world (first world and third world nations) who have seen worms passed in stools.

At the moment laboratory testing is woefully inadequate, but a keen veterinarian can easily check for the presence of parasites in a stool sample using a high-powered microscope. The children who have had stool samples reviewed by microscopy have come back positive. Pinworms, roundworms, tapeworms and hookworms are the most common findings. Stool analysis done by laboratories have consistently come back negative even when worms have clearly been seen and photographed and seen under the microscope. In fact, one mother I know sent in a live, moving worm that her child had passed. The result? Negative for parasites! At this point it is simply not enough to trust a coprological analysis when looking for parasites.

Dr. Andreas Kalcker and Miriam Carrasco have been instrumental in this piece of the puzzle and have designed an amazing parasite protocol that has already helped many children including Patrick. In October of 2011, Andreas gave me the first parasite protocol and families in Spain, Mexico, Venezuela and others throughout Latin America began to use it. We'll talk about it in depth in Chapter 8, page 165 and how it has affected my life as well as the lives of so many other families with children on the spectrum.

In January of 2012, I got in touch with Teri Arranga and I was invited to speak at *AutismOne* in May of 2012. This would be the first time I would present at *AutismOne* in English, and obviously the first ever presentation on CD. After eight years of biomed and six years of helping families in Latin America I would be flying above the radar, knowing full well there would be a tradeoff. While I would reach families all over the US, for the first time I would end up taking a lot of flak in the blogosphere. We survived!

When I first came across CD in 2010 and began to watch it work it's miracles with autism, I expected parents, doctors and professionals who dealt with autism to be excited. I assumed they would begin to do research as to how and why the chlorine dioxide molecule was healing/curing autism. Much to my chagrin, many people were disinterested. Some even went so far as to say that what I had seen was impossible or that CD was toxic. Well, to that I would say that healing/curing autism with a toxic substance is impossible. Since then a handful of some of the best doctors in the world have become interested (that number is growing) and quite a few parents are taking note. Hundreds in fact went to my presentation at *AutismOne*. Several told me in hindsight that they had thought about not attending because the title of the presentation sounded too good to be true... *40 Children Recovered in 21 Months*.

The people who did attend were pleased with the information and many began the Protocol. However, what was to happen the days and weeks after my presentation blew my mind and was absolutely beyond my wildest nightmares. Some parents attacked me in print and on the Internet. I received threatening and accusatory emails filled with hate speech and foul language.

In most cases these emails and blogs were from anti-biomed parents. Others in the biomed movement told me not to worry, that these people were notorious for doing this sort of thing to others. They jump on the newest and brightest intervention in order to get their time in the limelight. Stealing attention away from the treatment, altering the truth, and in some cases lying to people about what is happening just to get other parents up in arms. Never could I have imagined anything like what transpired. However, as time passed, so did the threats, negative blog posts, etc.

Update for 2014

One of my favorite quotes states:

> *"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."*

Fortunately, the 2013 *AutismOne* conference was a totally different experience—which may indicate we are slipping into that third stage. In May of 2013, we were at 93 recoveries, and during my presentation at *AutismOne,* some courageous parents took the stage with me to share their children's stories of healing and recovery. There were no attacks. As the first edition of this book launched at the conference, many of our wonderful moderators were on hand to answer questions, and assist parents who were interested in getting started. I had a book signing along with the pleasure of meeting many parents I had up until then only known through email or Facebook. By January 2014, the first edition had already sold thousands of copies. If you searched for "autism" in the category of "books" on Amazon, it was showing up in various positions of the first two pages of over 10,000+ results, with the majority being five-star reviews. If you changed the order to "Average Customer Review," it was in the top 10, sometimes in position #1.

This has always been a grassroots parent driven movement, and today help is available in 7 languages online to answer questions and offer support. As with anything, if you attract enough attention, you will also attract some "haters," however CD has already earned itself a place in the treatment modalities that are healing the symptoms known as autism.

CDS (chlorine dioxide solution) was introduced in the first edition, as we were still hoping that it was something better than it turned out to be. It was a better tasting and more tolerated form of CD, and still remains an excellent preparation choice for those who are extremely sensitive, and have trouble tolerating even one drop of classic CD. However, we found that over the long haul, only one child so far has recovered with strict CDS use—the other 114 were with classic CD.

In this edition we are introducing *Chlorine Dioxide Holding [Solution]* (CDH). When this preparation technique was introduced it was touted as something similar to CDS… having a better taste, is better tolerated, along with less Herxheimer reactions. However, there is one big difference; CDH still contains a small amount of the raw materials required for the preparation of CD (sodium chlorite and citric/hydrochloric acid). On the other hand,

CDS was chlorine dioxide gas ONLY dissolved in water. That small amount of raw materials in the CDH preparation may be what makes the difference. After 90 days of CDH use with over 70 families, it has not failed. Gains have not plateaued, and parents seem to be having an easier time increasing their children's dose, without any Herxheimer reactions. Another amazing thing about CDH is that the natural sweetener *Stevia* can be added to improve the flavor, while the potency of the dose does not change. This can be a game changer for kids that have taste aversion to classic CD. It should be noted that not all brands of Stevia are created equal and there may be some that can't be used. We are still testing various brands.

CDS and CDH have both earned their place in methods of chlorine dioxide preparation, thus allowing more people to benefit from the healing properties of CD who might not have otherwise been able to tolerate it.

People are always interested to know how my son Patrick is doing, and I am happy to share a little bit about what has been going on in his life lately. This past August 2013, Patrick turned 13. I had expected him to be recovered by now; however, we are still working towards a full recovery. He is better every month and his current ATEC is somewhere between 22 and 24. Patrick is very social, he loves a party. This Halloween, my sister threw a party and it was 11:30pm before he was finally ready to go home. He also loves spending time with his family. Every night he tells me, "I love you Mommy, gimme kissy." That is not only his way of telling me he wants a kiss, but that he wants me to come spend time with him before we go to sleep.

He has been preparing his own food in the kitchen, and while he has always liked to help chop, his being able to place his selection in the toaster oven and heat it himself is new. We didn't show him how to do this. He decided on his own that he would heat and serve himself his dinner one day. Another major advancement is that he is now able to clean himself after toileting, which is something he always asked for help with before. He will even wear headphones when listening to YouTube videos or watching DVDs if someone has to make a phone call.

We don't have any conduct issues, and if no one told you I had a son with autism, and you saw us out, you would never know. Apraxia remains the biggest factor delaying Patrick's recovery. That said, Patrick does communicate more than ever, and attempts more language than ever before.

As far as where I see this movement heading in the future, I believe that if truth does pass through 3 stages then we have finally entered the third stage of "self-evidence." The CD Protocol has now recovered 115 children (as of

December 2013); is used in 58 countries; and has already helped over 5,000 people on the spectrum, with more and more being added every day. The power of social media allows for parents to share with other parents their successes with the protocol, thus forming a stronger bond. Parents in the autism community trust other parents above doctors, and rightfully so.

At this point we are breaking many stereotypes associated with healing autism. For example, we now know that after the age of 9, recovery is still very possible (a 31 year old man is nearing recovery as I write these words). You do not have to be rich to recover your child from autism. You do not have to speak English—there are Facebook groups in 7 languages and this book will be translated into at least 13 languages. We now know that autism is not a psychological disorder. It is biomedical... viruses, bacteria, candida, parasites, and heavy metals cause the behaviors that lead to an autism diagnosis. Once you remove what is causing the symptoms, you can remove the diagnosis.

I witness on a daily basis what was not supposed to be possible: the healing of autism.

The future is bright, and it is up to us to share it!

Best in health,

Alex, Kerri & Patrick Rivera

Jim, Andreas and myself in Venezuela where 2 of the most amazing women in the world have a foundation to help Venezuela heal from the autism epidemic. I am so grateful to Yamileth Paduani and Carolina Moreno for their foundation and hard work. 28 recovered children from their foundation with this protocol in their first year of service. Thank you ladies. I am so proud to be your sister of the heart.

Ty reading and healing

Chapter 2

Yes We Can!!!

Without faith, nothing is possible. With it, nothing is impossible.
~ Mary McLeod Bethune

Before we embark on the path of healing autism, it may provide you some comfort and encouragement to hear from those who have gone before you.

Some of the parents of the children who lost their diagnosis through this Protocol were generous enough to share a photo of their children along with a "thank you note." You will see that a couple of the older children wanted to write their own notes and share their success with the world.

1

My son gets to play little League!

Thanks to ATEC of 4, autism IS treatable!

THANK YOU KERRI!

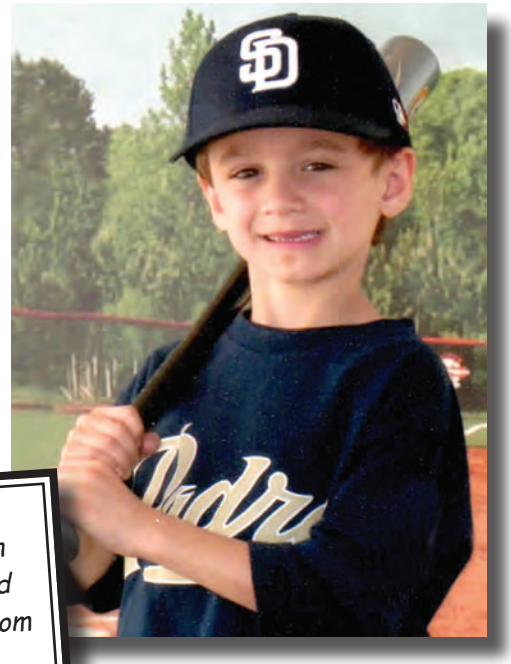

2

OMG! I'm still rubbing my eyes. Nathan just played with cars appropriately! He pushed them along while saying, "vroom vroom!" Until now, he would simply mouth, spin or tap toys.

-Week 5 of MMS

3

Today in my son's school they had an "I Can Run" day for good health and to collect food for families in our community. Last year he couldn't make it 1 mile - they run / walk around a track. This year he ran 2 miles... Whhaattt? 7 months on mms and 6 months treating parasites.

5

Wow! Here is something to be grateful for! It was time to do my son's one year ATEC doing MMS (7 months detoxing parasites) and his score was...drum roll please...15! You read it right, a 15! I am tearing up right now writing this. My son is 14 years, 4 months old. He was at a 27 when we started, then went up to a 34 when we started treating parasites (behaviors worsened), then down to 21 three months ago, and now a 15! Thank you so much Kerri! Without you, who knows where he'd be.

6

Before MMS we were able to get my sons atec score down to a 24. Although he mainly functioned as a "neurotypical" child, he still would have behavioral problems. He was easily agitated and would struggle with some anxiety and OCD. We were constantly battling yeast, constipation, metals and come to find out, parasites! We began MMS very slowly. We noticed his moods were improving. He was smiling more and over all just really pleasant to be around. We decided to retake his atec after only 1 month. It was a shocking 4!!! It dropped 20 points in 1 month!!! We have our boy back and will forever be grateful! We will be starting the parasite protocol this month and looking forward to an atec of 0!!!

7

I just wanted to share that today my daughter said a full sentence!

She normally only makes two word sentences and often stutters and stammers, with a lot of articulation problems.

My husband came home after a week away for work and she walked up to him as he sat at the computer and she said: "I want... to sit with daddy."

And in the bathtub (I'm doing the MMS steambath as both my kids are coughing right now), she turned to her brother and said "Look brother, cup." and she held the plastic cup in front of him. She has never been this coordinated and 'present', nor articulate. I am so grateful.

Even though we still have a long way to go, I feel like a huge weight has been lifted off my shoulders.
Thank you for your hard work.

8

Thank you for helping me to rescue my son.
God bless you
Kerri Rivera!

9

My son is at a three-day camp with 100 NT 5th graders! We have provided all his food, and go up to give supplements twice a day... other than that, he is on his own sleeping with friends for the first time in his life! I have no words other than Praise The Lord for bringing me Kerri Rivera and also for giving me and my family the strength to never give up! Our little bird had taken flight... thanks be to God!

Thank you God for your fidelity, thank you my beautiful girl for giving me your gaze and your smile every day, thank you Kerri McDaniel de Rivera for walking with me.

11

Hello, I'm Silvia, Alejandro's mom, we live in Spain. I was giving MMS to my son for 10 months without seeing any changes. Kerri told me that I wasn't doing something right... and that was correct. Being the warrior she is, she made me tell her everything I was giving Alejandro and she got it, Alejandro drank pineapple juice all day long, he would take more than a liter a day and that made the MMS not work, I stopped giving him pineapple juice 2 months ago, and he is a new child... He pays attention, his comprehension is almost 100% I must say my baby did not speak, but with this he started saying: "Come on, mom!" "My mommy" All this because I started giving him the MMS as I should. I want to say NO juice near MMS because it anulls its effectiveness. I thank God for putting Kerri in my path. My son improves everyday, slowly but you can see that he is saying goodbye to his little world. Thank you Kerri for being in our lives and for making us see the light. Also thank you JIM HUMBLE for giving hope to our lives.

13

My son turned 12 today - hooray!! This is truly the very first time since his 1st birthday that my heart didn't shatter into a million pieces because it's another year down the road, and still so far away from recovery!! He decided that he was staying at home today to play with his birthday toys, he told his teacher (several times over), and when she asked if she could take the day off too, he said "nooooo!!. When his grandpa called from Holland to sing Happy Birthday, he sat quietly listening with a smile on his face - the usual is "no singing!" Besides that - here's my brag for the day - his teacher told me that she had to move him and his best class buddy away from each other because they were copying each other's work!!! YAHOO - we were SO excited - yes I know, we're crazy, but hey - if it's typical, I don't care what it looks like, I WILL TAKE IT!!! If you think this is weird, you should've seen me when he bit a child when he was 3!! I want to encourage you all today, look for the small things, check in with the people who are in contact with your kids and keep a journal of the changes. You will be amazed at how much we miss, because we spend every waking moment watching over them! I feel SO blessed!!

Dear Kerri,

Thank you so much for bringing our son's smile to life. The happiness you see in these eyes comes from listening to you and your amazing protocol.

We were stunned when his ATEC dropped 18 points in 3 weeks, and has now reached a staggering 1 from the original 36 in less than one year.

I thank God every day for having me in that AutismOne lecture in 2012 where you opened my eyes to what else we could do to help him. I want every parent out there to know this is a real Protocol with real results.

Thank you again and God Bless everything you do for our Children.

You Rock! Love Maryann

15

Greetings from Monterrey.

Just to let you know, we went to visit you in Puerto Vallarta on June 21st, and my child started treatment in July with MMS. As of today my son eats almost all on his own, and wipes his mouth whenever he needs to. For about a month now he has been doing funny things; like covering up his cards when we play as if to hide them, if he sees me squatting on the floor he runs over and jumps on me. He shows expectation on his face when he knows that I am coming to tickle him. He hides behind a wall when we play hide-and-seek.

In both of the institutes where he goes they have told me he is able to pay attention for longer periods of time, his way of being has changed, and they have also said that his eye contact is much better. According to his therapist he is now a candidate for speech therapy because he is able to pay attention.

For us, Kerri, this is a miracle come true, to see our son waking up little by little and to see him eat all on his own. Thank you so much for sharing all of this with us.

16

Since starting MMS my daughter's play skills improved, she actually looks into my eyes and gives me eye contact which means a lot. She started answering questions, more engaging and now I started to feel as if the end of the tunnel is not too far. I am so grateful to Kerri for showing me a way to recover my child. GOD BLESS.

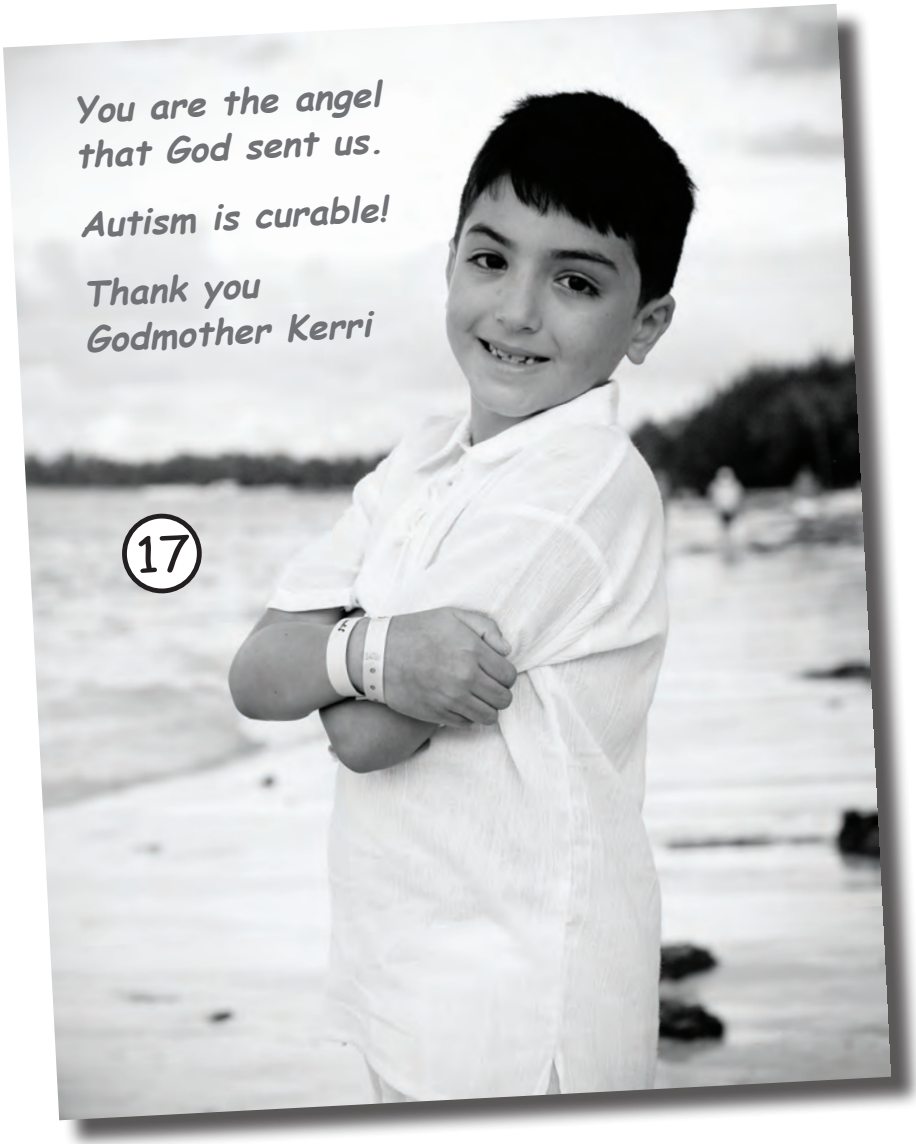

18

Hi Kerri,

I cannot believe it has been 5 weeks since we spoke on the phone.

My son turned 22 yesterday. He actually opened each birthday card, and read the inside. We always knew he could read, but he Never showed an interest in opening cards or gifts. He had some interest in his gifts last night. He has been wearing only light grey shirts for 5 years. This week he wore a blue one and a charcoal grey shirt.

Looking straight at me, and asking for what he wants. No real bad effects yet. We are on 22 drops as of today. 2 enemas a day 300ml - 8 drops - ocean water in the morning.

I have attached 2 pictures from this week, I think these are worms.

Can I hope that he can get better?... After all the treatments we have been through?... well I am. I think, what will I do with my time when he is better (possibly recovered)?... I will yell from the roof tops and dedicate myself to helping other families. Is this what I was meant to do? My purpose? I would love it!

19

My family and I are very grateful to Kerri Rivera for making available the CD protocol to treat ASD which has recovered myself and made a huge difference to thousands of kids and families all over the world.

CD can recover even a teenager like me whom others had given up on. Of all the bio-medical interventions, CD cost the least and made the biggest difference.

Muchas Gracias por salvar mi vida Kerri.

21

This is Benjamin. 4 years 5 months old, current atec of 4 and dropping weekly :) Diagnosis atec at 3 years 2 months was 134. Atec when starting CD protocol was 18 and was stagnant after full on bio-med/ diet intervention. Dropped all supps except melatonin when starting protocol and obviously can't be happier with that decision. Thank you to Kerri Rivera of course for giving me a way to save my baby boy... We will continue with protocol until atec = 0 :)

22

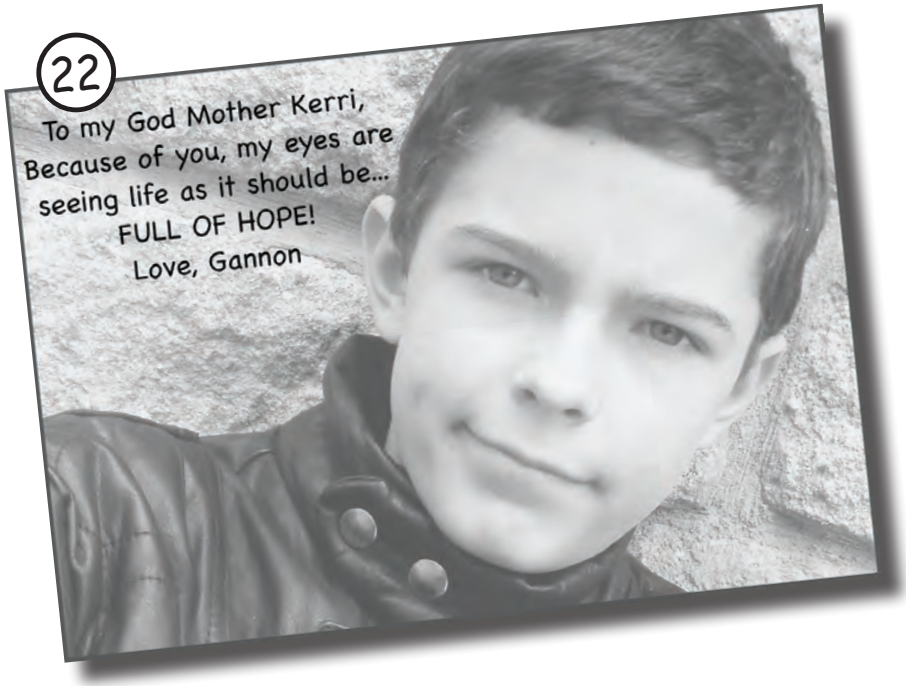

23

My sons started using MMS exactly 2 and a half months ago and we saw improvements almost immediately, my twins attention got better just days after we started the treatment and at 10 days after starting my son Juan Pablo started calling me mom! He has never done that before. (Neither of my twins were verbal, meaning they were not able to speak a single word.) A few days later Jesus Alejandro said "Mom, water" while pointing to the fridge, it was shocking for me.

My two sons can now say 4 or 5 words and their communication skills have gotten a lot better, even if it's not verbal they are very good at expressing what they want. There is a lot of improvement in comprehension, following orders and accomplishing small tasks, they react when you say their names, they are controlling their bowel movements, and in general their whole quality of life has gotten so much better since they started with MMS.

I know we have a long road to go but we are on the right track and I trust that thanks to the science that discovered the great effects of this wonderful formula for our children with autism we will recover them, as it truly does detoxify!

Ing. Artebys Cedeño
Mother of Jesus Alejandro and Juan Pablo

Dear Godmother Kerri,

How can we ever thank you enough for crushing autism out of TJ's life? We now have a smart, happy, helathy boy that has great confidence in himself!

We are forever grateful to you!!!

25

We started using MMS a month ago. We are not even at the full dose yet but have been seeing some amazing gains.

I took my son to the mall about a week ago because it is one of his favorite things to do. When we got home he did something he has NEVER done before. He came up to me, hugged me and said "Thanks". Wow.

Two days ago my husband had to go to the local farm supply store because something broke in the barn. So we asked my son if he wanted to go and he literally jumped off the couch and excitedly came with us. While he was there he picked out a couple of books he was interested in and a couple of small vehicle toys. When we got home I was helping him with his coat and boots he said "you're great mom". Never have I ever had spontaneous comments like this and the only thing I can attribute it to is the MMS because we stopped everything else. This gives me inspiration to continue the protocol and I look forward to what the future holds for my son and our family.

Thank you Kerri!

26

If it were not for you Kerri, my mother would still be worried about my future.

You are my Guardian Angel!!!

Autism is curable!

Thank you Kerri
Gracias Kerri!

27

His speech therapist told me today that his sentences are so much better, more organized, also his ability to converse back and forth and also his concentration have improved!! Soooooooo..... Yay!
Oh, before we went to see his speech therapist he said: Mummy, my speech is getting so much better!
Yup, he said that! He knows!

28

I can't believe it! I just did my daughter's ATEC and in one month it dropped from 72 to 48!!! I am so shocked! Is this a dream? We revised the scores over and over with my husband and accepting that some of our answers could be just very positive feelings, still the improvement is huge!! I am so thankful Kerri Rivera! I have no words!! I am praying this is not a dream!! THANK YOU SO MUCH!!!! I believe there is more to come but right now I am so much in shock!

29

I have to post our Sunday gain, my daughter is and always has been on sensory overload, those of you who deal with this know that teeth brushing, hair combing and showers can be torturous for child AND parent. I literally dread washing her hair. She screams so loud she could break the windows. She smacks her wet thighs so hard that they've been bruised for years. This morning she gets in the tub, sits down and sees me roll my sleeves up (which is usually the moment she loses her mind because she knows I'm about to grab the shower head), she stood up, looked me dead in the eye, smiled at me and said "R. shower". I began to wet her hair down, still convinced that the screaming was about to begin any minute. I started shampooing and she said "well done", I smiled and said "VERY we'll done baby". My husband peeked in to see why it was so quiet and she looked at him and said "Daddy shower", smiling from ear to ear as to say 'I'm taking a shower Daddy'..... what a great way to start our Sunday. HUGE, HUGE deal for her and for us. I feel like I finally exhaled today. MMS rocks and so do all of you!!! Happy Sunday ;-))))

30

Dear Kerri,

Thank you SO MUCH for helping us with our daughter's complicated health issues. The CD/PP protocol allowed my daughter to sleep through the night, for the FIRST time in 7 years! One month on the parasite meds, she began sleeping perfectly and has slept perfectly ever since!

We are FOREVER grateful! Also, the more her pathogen load decreased on the protocol, the more foods she would eat and LIKE!

My daughter eats SALAD now! AND will try any food I give her. I thank you from the bottom of my heart and will be forever grateful!

With love,

The WHOLE Clark Family!

31

I was cured,
Yes we can.

I love you very much Godmother Kerri!

32

My son had a great week - yesterday we went bowling as a family. It's difficult with him to notice gains sometimes because he is really close - his ATEC was a 7 last time I did it and the changes in him may be subtle and harder to notice. While we were bowling he was calm (despite the loud music, lights and commotion) he sat in between his turn watching everyone, (and the music videos playing) knew when it was his turn and cheered for me (I was beating my husband at the time - lol). He carried his ball down the lane and swung it with one arm - omg!! It was the most NT I have seem him! He now is a brown belt in Tae Kwon Do and this was the first time he was able to swing the ball - I used to have to carry the ball to the ramp, help him lift it and count to 3 for him to push the ball. He was diagnosed hypotonic at 3.5 years, MMS and PP are what helped him get some strength, energy and endurance. I increased his MMS by a drop about 2 weeks ago and we are also ramping up on GcMaf.

33

Great FUA moment today. My son took his first ever lesson.... swim lessons. He did amazing!!! Followed all instructions, waited in line, smiled, talked, and let the instructors help him. Amazing.... I cried almost the entire time. At one point he smiled, waved, and said "hi mommy."

35

My son has continued to improve on his handwriting and his anger has melted away. We had an IEP today and we lost 2.5 hours of services because he has done so well he does not need those services. They were surprised at how well he is doing. And he fed his little brother soup tonight to get him to eat his dinner.

Thank you Kerri for helping us to recover our son!

36

I'm Number 102!
Thank you for giving me a chance at a future
Kerri Rivera!

On any given day, I probably rattle out the words I LOVE YOU, directed at my boys at least a dozen times. My NT boy almost always will reply back. My ASD boy usually says, YES YOU DO as his answer. And I have completely accepted that that is his way of receiving my I love yous.

On very rare occasion he will say I love you to me...

Well, by now you know where this is going.

This morning I was walking past him and he said to me.... I LOVE YOU!

I wasn't at first sure what he said as he didn't shout it, So I asked him, what was that?

He repeated, I love you.

I said thank you son, I love you too!!!

38

Wait for it...

Bammity bam bam BAM!!!

Celebrating every little big thing. Appreciating my 3 favorite words. Loving every minute of every day. Even loving those big red lips this morning knowing he is detoxing...

Our son was quickly slipping away from us. We were lost. This protocol gave us direction and ultimately brought our son back to us. He looks at us with smiling eyes and tells us he loves us. He has a full childhood now. Words could never convey the magnitude of our gratitude for Kerri and all who support her efforts to make a future for our kids. See Gunnar's full testimonial on page 378.

Gracias Madrina Kerri!! I now have an ATEC of 10!

We started the DAN protocol when our 10 year old daughter was 18 months old and remained on it for 9 years. Before starting CD, our daughter appeared neurotypical, but she was heavily dependent on supplements and her progress had stagnated for a few years. She had a distended belly, poor growth, severe constipation, anxiety, a touch of OCD, and focus/concentration/ fogginess issues.

Her ATEC before starting CD was 24. Just 26 days later, her ATEC is 7. A 17 point drop in 26 days! We haven't even had time to do a parasite protocol or a 72/2 weekend yet! Her belly is much flatter and her anxiety, minor OCD, and focus issues are greatly improved! We're going to keep her on CD and I plan on starting the protocol myself this week. As a friend said, "DAN got her to third base and CD brought her home!"

42

My son just saw me reading this page, and asked what CD Autism was. I told him it was the medicine he's taking. He said, "I think my autism is gone. How do you know someone has it still?" Soon, baby, soon!

Spiro and Peter (9 year old twins)

After years of doing many interventions for our twin boys, and having moderate success at best, we learned about CD. It took about a year before we felt comfortable enough to try it. I can honestly say that, it is the BEST intervention that we've used. We started CDS in mid July 2013. In the 4 short months that we've been using CDS and now CD, we have had more gains in every area, than in the last 6 years of doing so many different treatments. What I love about this protocol, is the simplicity of it, less is more, and that was a huge change in thinking for me.

Just to give you an idea on how well our boys are doing, here are their ATEC scores so far:

Spiro: He was number 100 to recover on the "Healing Train" and the 1st child to recover using CDS.

ATEC prior to starting CDS - 22.

ATEC one month after starting CDS - 16.

ATEC two months after starting CDS - 9.

Peter: He was pre verbal prior to CDS and now uses single words and the odd 2 word combination to communicate. Well on his way to healing.

ATEC prior to starting CDS - 69.

ATEC one month after starting CDS - 55.

ATEC two months after starting CDS - 46.

We finally know, deep in our hearts, that our boys are well on their way towards "true healing". We don't have that stress and anxiety about what the future holds anymore. We finally feel like we can breathe easier, and that day by day, the gains keep coming consistently. The gains stay, and that feels better than anything.

Thank you, to my FB friends who introduced me to MMS and to Kerri Rivera who we have such admiration and respect for. I thank GOD everyday that we were fortunate enough to find out about this treatment. Our boys are coming back to us and their beautiful personalities are emerging. We now look to the future with such HOPE. Kerri, we will forever be grateful to you.

xoxoxoxoxoxoxoxoxoxo

43
Tim Hortons

44

Whoa... My severe kid walked in the door and wrapped his arms around my neck and gave me a normal hug for the first time in his life (6.5 years). Umm... This is crazy. He wiped his butt for the first time EVER... no prompting, no asking! I wasn't even in the room with him! When I got excited and asked, "Did you wipe???" I swear to GOD... I heard "Yeah, Mom!" Kid's never said a word ever. Could be dreaming, but WOW!!! What a day!!!

Please share your experiences!

Testimonials are one of the best ways to share your experiences with this protocol. Perhaps you learned about it by reading or watching a video testimonial?

If you don't tell us your experiences, we can't share them or take action on issues that need improving or correcting...

Send your testimonials to:

testimonials@cdautism.org

Also, let us know if we are free to publish your testimonial, with or without your name.

More miracles & testimonials starting on page 358.

Chapter 3

Step 1 – The Diet

"Let food be thy medicine and medicine be thy food."
~ Hippocrates

If I could choose the one part of *The Protocol* that would be the single most important piece of the recovery puzzle it would be—*The Diet.* By *The Diet,* I mean the dietary plan that I recommend to all of the families that want to start *The Protocol.* It is a combination of the classic gluten-free, casein-free, and soy-free diet along with the elimination of sugar, corn syrup, coloring, preservatives, and other harmful foods. *The Diet* is the basis for the rest of The Protocol; similar to laying the foundation of a house that the rest of the structure will rest on. Adhering to *The Diet* is critical to the effectiveness of the rest of *The Protocol.*

When a family of a child with autism comes to see me, the first thing they want to know is:

What can I do to help my child?

I always, always start with *The Diet.* In fact, I send them away after that first meeting with hope that they will be able to recover their child, but only if they commit to *The Diet* 100%. I explain to the families that they must think about food the same way their great grandparents thought about food. In generations past, food came directly from the Earth, with little processing. Fruits, vegetables, nuts, and meats were dietary staples for our great grandparents and they should be for our children as well. We must think whole foods and not ~~processed foods~~. There is no point in going from regular junk food to gluten-free/casein-free junk food!

After my first meeting with a family, they leave with the list of permitted foods and I have them email me when they have a week straight with zero exceptions or "errors" in *The Diet.* That is where the parents who are truly hungry for recovery are separated from those who are interested in having someone else "fix" their child for them.

One of two things generally happens during that first week. In the first scenario, I get an email from an ecstatic mother or father saying, "I can barely believe it, Johnny slept through the night for the first time in years," or "Johnny had a normal bowel movement," or "Johnny said two new words yesterday!" That's what I hope for.

The second scenario is... I never hear from the family again. There may have been tantrums, or an adjustment period related to *The Diet* that proved too much for them, and they decided to pursue another avenue. That's not to say that everyone sees a miracle, or that there's no middle ground. Some of the results are less obvious, such as more eye contact or less redness in the face, but generally speaking, we see positive changes. Any change is a good sign. *The Diet* is only the first piece of the puzzle. We must continue from here, layering in interventions until we get the desired, end result.

> Kerri... Bless you! When my son was 3 years old he was prescribed Ritalin®, Risperdol® and Clonazepam... can you believe it? Obviously I never gave them to him, it hurt me to see my child "drugged." 2 days after starting the diet he slept through the night, the sparkle is back in his eyes... I can't wait to start with MMS, I am so happy!!!

Throughout this book "miracles," which are actual emails and forum posts from parents about their children's improvements, have been set in text boxes (like the one above) and placed in the chapters that they accent. Please note that as many of these miracles were collected some time ago the contributors have used the term MMS instead of CD. Due to time constraints it was impossible to request permission from these contributors to change the acronym of MMS to CD in their testimonials. MMS and CD are the same substance. Where the acronym MMS is used please know that chlorine dioxide is the substance being discussed and is responsible for the healing.

Author's note: I'm not against all prescription drugs, especially those necessary to bring about healing. However, I don't condone medicating a child with drugs, masking the symptoms known as autism. So, when I see an email like this, I know we've got a great chance to heal that child because we have a parent who has committed herself to healing her child, and who is excited to see what changes the next tool will bring.

Your child's doctor may not have heard of *The Diet* or may be misinformed of its benefits. The references section at the end of the book lists several studies and articles discussing dietary intervention for ASD's. You can use them as a

jumping off point for your own study. If you are consulting with a doctor, it is important to choose someone who is familiar with autism and the recovery of autism.

Many doctors do not have time to study up on what's new in autism recovery and if they have zero recoveries then they are in dire need of overhauling their protocols. Another major problem in the mainstream medical community is gigantic egos. If what we are doing is not working to recover our children, then we need to look at what we are doing and why we are doing it. Let's check our egos, update our protocols, and look at what has worked for families who have recovered their children.

Researchers at the New Jersey Medical School's Autism Center found that "children with autism were more likely to have abnormal immune responses to milk, soy, and wheat than typically developing children," which is published in a chapter of Cutting-Edge Therapies for Autism 2011-2012, by Siri and Lyons.[1] In addition, interest is growing in the study of the link between autism and gastrointestinal (GI) ailments. Siri and Lyons also relate a study by the University of California, Davis Health System, where they found that children with autism born in the 1990s were more likely to have gastrointestinal problems, including constipation, diarrhea, and vomiting than children with autism who were born in the early 1980s.

If your doctor is uninformed, or tells you there is no evidence to prove that *The Diet* will help your child, do the research for yourself since only you are in charge of your child's diet. Heck, why not do *The Diet*? It doesn't cost you any money and it just might help your child heal. Whether he eats cheesy puffs or fruits and vegetables will ultimately come down to you. You are the one with the money in your pocket. The only way to know for sure if your child is going to be one of the individuals who recovers with *The Diet*, is to try. It can take gluten six months or more to be removed from the microvilli or "shag carpeting" of the small intestine. As I mentioned previously, some children have obvious changes in two to three days, but even if your child's evolution is taking a little longer than most, DO NOT GIVE UP! At the writing of this book, I have helped about 5,000 or more families of children with autism; all of the children who have lost their diagnosis, as well as those coming close to recovery, have used varied protocols depending on their symptoms. The one thing that they all—unequivocally—have in common is: ***The Diet*!**

In my opinion, it makes little difference what other interventions you apply to your child if you can't manage *The Diet* 24/7/365. Hyperbarics, chelation, ABA, etc., simply will not have the desired effects if you are still feeding "drugs" (aka garbage foods) to your child.

Why do I say drugs? Because that is what gluten and casein become in the bodies of our children on the spectrum; more specifically, gluteomorphin (also called gliadorphin) and casomorphin, which are similar to morphine. Gluteomorphin and casomorphin are produced in the gut due to improper digestion of peptides (as we will explain more in detail later). In a person with "leaky gut syndrome" (increased intestinal permeability), they are able to leave the intestine and cross the blood-brain barrier where they act exactly like morphine or heroin. Would you purposely give your child street drugs? NO!

Once we have this information and understand the severity of this issue, we have a responsibility to our children to do better. We must take away the foods that are keeping them ill. Invite your family and your child's school to help heal your child's ailing body. Explain that they can no longer give your child these items, and that if they do, it's like giving them a dose of morphine. If it sounds drastic... that's because it is!

Researchers have found an abnormal amount of these undigested peptides (gluteomorphin/casomorphin) in the urine of children with autism, proving their existence in the body. Among others, Dr. Knivsberg and colleagues in Norway have found that urine samples from people with autism, PDD, celiac disease, and schizophrenia contained high amounts of the casomorphin peptide.[2] Similarly, Gliadorphin (gluteomorphin) has been verified by mass spectrometry techniques to be present in unusual quantities in urine samples of children with autism.[3]

Do *The Diet*!

There are still plenty of food options that are permitted. I promise you—your child won't starve! We have included some recipes in Appendix 15 on page 513 to get you started. *The Diet* is absolutely the most important piece of the puzzle. If we can't remove what is directly linked to brain and gut inflammation, as well as immune-allergic reactions to offending foods, it is nearly impossible to heal a child on the spectrum. I have personally never seen a family recover a child without dietary intervention. That's not to say it hasn't happened, but I have never seen or heard of it.

Like I said before, when we started with my son Patrick, his only legal food was homemade French fries. So that's what he ate. Little by little he began to accept more foods. I assure you, the adjustment period will fade and they do eat. Stop the cycle of inflammation and addiction. Only then will your child begin to heal, and once your child starts to feel better he will accept more foods.

In the case of my own son, his acidic diarrhea and sleepless nights stopped the week we started *The Diet*. From that moment on I was hooked, not only on *The Diet*, but also on biomedical treatments for curing autism. I have never looked back. I strongly encourage you to experience *The Diet* for your child, or even as a family. It is an amazing thing.

I thought the following might encourage some of you who have recently made big dietary changes for your kids and are struggling with all that involves. I put my son on a GF/CF/SF... well, basically, EVERYTHING-free diet when he was 11 months old, following a major vaccine-induced crash. My choice to put him on a diet was criticized by nearly everyone in my life, beginning with his pediatrician who told me I was "just imagining" that he'd regressed and that he "probably wasn't allergic" to what I had taken out; she called a week later with the test results and an apology, and a long list of other things he was allergic to! He's now just a little over seven and doing GREAT. I just delivered a GF/CF muffin to him, and he said, "You know what I love best about you, Mommy? I love that you are so nice to us, and that you always make sure we have food that doesn't make us sick." So, don't feel bad about not giving your kid that ice cream cone when Mr. Softee comes by or not loading their Easter basket up with food dye this weekend. It may take years, but they will see that you loved them enough to NOT give them these things.

Some other tips include the following:

Review Your Child's Supplement List

Is your child taking 30+ supplements a day? We will talk more about this throughout the book, but this protocol is geared towards eliminating excesses and not about supplementing deficiencies. It's important to carefully review your child's supplements. In order to maximize the benefits from this protocol consider removing any antioxidants, (they kill CD—more on that in Chapter 5, page 88), calcium, magnesium (which feeds the biofilm), as well as iron and B_{12} (which are favorite foods of parasites). Supplements for increasing speech, reducing seizures, enzymes, and probiotics obviously have

their place in individual protocols. B_{12}, while known to feed parasites, has also been known to greatly boost speech in some children. If your child saw benefits in speech from B_{12}, it may be worth keeping in. As always, these are decisions that each family has to make for their child on an individual basis.

If a certain supplement proved beneficial to your child, then don't remove it (the exception being antioxidants and the other aforementioned supplements). The goal of this step is to remove unnecessary supplements as they are most likely feeding parasites and creating "excess noise" in the body. Anything that is not serving a purpose needs to be eliminated.

Keep a Journal

Keep a record of the foods you have removed and those you have added in. Then, take note of the types of reactions you observe: rash, more or less hyper, more or less stimmy (self-stimulatory behavior), sleep patterns, frequency and consistency of bowel movements, tantrums, acceptance of new foods, eye contact, language, etc. Write everything down so that you can follow any relationships or patterns that will allow you to identify when something is working, or when it is not. Record these observations in a notebook because it helps guide us, especially those of us who are stressed, frazzled, and sleep deprived.

Don't Stress About Raw Foods or Perfectly Balanced Meals…Yet!

When you are first transitioning, feed your child whatever legal foods he/she will eat. We are taking baby steps. Once your child is on *The Diet* 100%, you can start adding in new foods, bite by bite, if necessary.

Do the ATEC

Keep track of your progress with the ATEC checklist (see page 447), which you can find at...

www.autism.com/index.php/ind_atec

This is an excellent way to see how you are doing. Every time that you begin a new intervention, it's a good idea to do the ATEC, and then repeat it every three months or so to see how your child is evolving. Sometimes our children are recovering right before our very eyes and we don't even know it. The ATEC can be used to measure the effects of all new interventions, not just *The Diet*.

Using the ATEC is a great way to measure improvement. Many of us are tired, burned out, or don't have the best memory. A formal questionnaire can help us to discern when an intervention is working or not, and it only takes about seven minutes to fill out. See Appendix 4, page 447 for a sample survey and more information about ATEC.

Always Read Labels

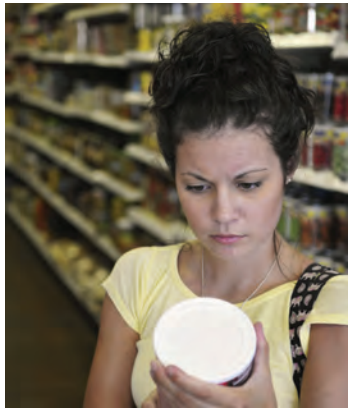

Read the label on the back of all packages—not just the one on the front that says "gluten-free." Many times they have sugar, yeast, carrageenan, or other items that are not allowed. We must know what we are putting into our children's bodies. If you can't pronounce it... you don't want to put it into your child. Be careful of hidden offenders like malt, natural flavors, artificial flavors, whey, and numbers (red 40, E-441), etc.

Have a Support System

It doesn't matter whether it is a friend, family member, rescue angel, or neighbor. Have a shoulder to lean on. Autism recovery is a marathon not a sprint, and no one should have to go it alone. There are so many amazing parents out there who have walked this path and are willing to help newbies! As of this writing we have several public forums open, including...

www.cdautism.org

and

www.facebook.com/groups/AutismCD

This is an excellent resource for finding the latest info, protocol changes, and share hope and/or frustration with parents all over the world who are walking the same path. Don't forget to sign up for our newsletter as well by visiting the home page at www.cdautism.org!

Take it One Day at a Time

Defeatist thinking will only harm your resolve to help your child "I can't do this for the rest of Johnny's life!" or "How will I get through this year?" are defeatist thoughts. Go hour-by-hour or minute-by-minute, and know there are victories every day in the world of autism. We must draw strength from those victories, even when they aren't our own. Both this book and my website have a section of miracles and testimonials (see Chapter 2, page 19 and Appendix 1, page 357), which are real correspondence I have received from parents describing the advances their children have made as a result of doing *The Protocol*. We receive these miracle emails and forum posts every day, but we had to pick and choose which ones to share in the book. You will also see them sprinkled throughout the chapters of this book. Take some time to read them, know that children are recovering every day, and believe your child can be next. If something doesn't go as planned, wake up the next day and know that, *THIS IS the first day of autism recovery.*

Why Does My Child on the Spectrum Need to Go on a Gluten-Free/Casein-Free/Soy-Free Diet?

As I said before I have never seen a child recover without *The Diet*. The following information comes from *www.gfcfdiet.com* and explains why *The Diet* is so important for people with autism.

Scientific studies have shown the presence of high levels of peptides derived from casein and gluten proteins.[4,5] The digestion process is considered "normal" in terms of protein digestion for most people, as they make smaller particles called peptides that are further broken down into amino acids. However, in people diagnosed with autism it is more difficult to properly digest some of these proteins, thus allowing them to enter the blood directly as peptides. This often happens due to a lack of enzymes that help with the optimal assimilation of food and can be a factor in causing exaggerated bowel permeability (aka, leaky gut syndrome). This results in poor digestion, which facilitates the entry of these harmful proteins directly into the bloodstream, where they can cross the blood-brain barrier.

Leaky gut syndrome has been attributed to many causes including viruses; Candida; gluten, which produces zonulin, a protein thought to cause leaky gut; amongst other things.[6]

Gluten-containing foods may destroy the digestive system if they are consumed excessively or are introduced too early into a child's diet. Wheat is hybridized through artificial processing, resulting in inadequately prepared grains. Casein-containing foods may also destroy the digestive system because they are pasteurized and/or homogenized. These processes may result in damage to the enzymes that break down gluten or casein, thus causing incomplete digestion of these proteins.

Recently, Dr. Andreas Kalcker introduced us to the theory that the inability to properly digest these proteins may stem directly from parasites in the intestinal tract. These parasites may contribute to a leaky gut and thereby play a role in the development of allergies towards gluten, casein, soy, etc.

Gluten is found primarily in wheat, rye, barley, oats, spelt, malt, most breads, cakes, muffins, cereals, flour tortillas, pizzas, pastries, and donuts, etc. Gluten is also found in food starches, semolina, couscous, malt, some vinegars, soy sauce, teriyaki sauce, flavorings, artificial colors, and hydrolyzed vegetable proteins. Casein is contained in milk from cows, sheep, goats and any or their derivatives such as yogurt, butter, ice cream, or cheese. No form of cow's milk may be consumed as it causes inflammation and mucous. Even if the product claims to be lactose free, cream free, or casein free—it is not allowed.

Improperly digested gluten and casein fragments can both enter the bloodstream and cross the blood-brain barrier. Because of their opioid properties, these peptides can react with opiate receptors in the brain to cause effects similar to those of an opiate drug such as heroin or morphine.[7] These opiates are called gluteomorphin (or gliadorphin) and casomorphin, and can react with some parts of the brain, for example, the temporal lobes, which are actively involved in the process of the integration of language and hearing. Interestingly, these are two of the areas most affected by autism.

Besides their effects on the brain, opioid-forbidden foods cause inflammation in the gut and brain. When a child has an allergy to a food—in this case gluten, casein, and/or soy, etc.—as it enters the body the immune system sees it as an invader and reacts by trying to protect the body from the substance.

The first time the body is exposed to a food allergen, the immune system makes antibody-specific immunoglobulin E (IgE) against the

allergen. IgE antibodies circulate in the blood and adhere to types of immune cells called mast cells and basophils. Mast cells are found in all body tissues, especially in the nose, throat, lungs, skin, and gastrointestinal tract (GI). Basophils are found in the blood and in tissues that have been swollen due to an allergic reaction.

The next time the body is exposed to the same food allergens, the allergen binds to IgE antibodies that bind to mast cells and basophils. These connections between allergens and antibodies direct the cells to release large amounts of chemicals, one of which are histamines. After the liberation of a histamine by an activated mast cell, the permeability of the vessels near the site increases. Therefore, the blood fluids (including leukocytes, which are also involved in immune response) enter the area causing inflammation. Histamine release also causes the release of cytokines and inflammatory mediators by leukocytes. These chemicals, in turn increase the inflammatory response.

Welcome to The Diet!

Now that we've covered the science behind *The Diet*, it's time to get started. First, make sure you complete an ATEC and save the results so you have a baseline score. Next, prepare a shopping list based on the following allowed items.

Author's Note: Organic products are better but not required.

Permitted Foods List

Proteins:

- Beef
- Chicken
- Eggs
- Fish (small not large size)
- Pork
- Turkey
- No processed meats or cold cuts (hot dogs, bologna, etc.)
- No shellfish (preferably—full of toxins)

Fruits:

- Most fresh fruits are permitted (except citrus, mango, pineapple, kiwi and limit berries).
- Frozen fruit without added cream or sugar.
- NO canned fruit (nothing canned ever).
- Be careful of dried fruit as it may contain sugar.

Author's Notes:

Juice is not permitted on this protocol as it has proven time and time again to annul CD and cost families precious time and money. The amount of fruit necessary to make a glass of juice also causes it to be high in sugars, albeit natural, and they can still affect the immune system. Children on this protocol need to drink water and generally speaking most former juice drinkers transition from drinking flavored beverages to water without much issue. If your child must drink a flavored beverage it would be acceptable to blend and strain or juice one apple, for example, and add it to some water and if you choose you can sweeten it with stevia (SweetLeaf® or KAL® brands are ok).

Fruit should not be consumed after a meal as a dessert due to its rapid digestion. If it is eaten after other more slowly digested foods (i.e. meat, grains, etc.), it can ferment in the stomach, causing bloating, gas, or discomfort. Fruit is best eaten before a meal or separate from meals.

Vegetables:

- All vegetables!!!
- Including French fries, however, not frozen fries or fries from fast food chains; these are often coated in flour.

Author's Note: I don't condone the prolonged use of potatoes, as they convert to sugar in the body. However, it was the only "legal" food my son would eat when we began the GF/CF/SF diet.

Nuts:

- Almonds
- Cashews
- Coconut
- Hazelnuts
- Walnuts
- Plus, they all make great milks!

Grains:

- Amaranth
- Buckwheat
- Corn
- Millet
- Quinoa
- Rice
- Sorghum
- Tapioca
- Xanthan gum

Author's Note: I prefer a grain free diet for autism recovery, especially if your child suffers from "grain brain" (addiction to grains, undesireable behaviors and/or inability to concentrate after eating grains). If your child seems to be addicted to carbs, i.e. fruits and starches, you may want to consider the Ketogenic diet or the Rosedale diet.

Even though these grains are allowed, they can be difficult to break down, and can easily ferment in the intestinal tract due to excessive Candida overgrowth, bacteria, and parasites.

Beans:

- All beans—EXCEPT soy
- Garbanzo
- Lentils
- Navy
- Peanuts

Sweeteners:

- Stevia (This is the best of all the sweeteners, but make sure it does not contain erythritol—a sugar alcohol!)
- Agave syrup
- Honey
- Maple syrup (natural/real—not made from corn syrup)
- Xylitol
- NO piloncillo (unrefined sugar)
- NO sugar

Author's Note: Honey is allowed, however, it can create insulin spikes.

Prohibited Foods List

After working with thousands of families, and conducting independent research, it is my personal opinion that the products on the following list should be avoided if your intention is to heal autism:

- Acetic acid (E260)
- Artificial flavoring
- Artificial sweeteners
- Bouillon cubes
- Bread
- Cacao/Cocoa
- Candy
- Cane sugar
- Carrageenan
- Catsup
- Chocolate milk
- Coloring
- Corn flakes
- Corn syrup
- Cow's milk in any form (even lactose-free milk products)
- Flour tortillas
- Gelatin
- Malt
- Margarine

- Mayonnaise
- Microwave popcorn
- MSG (Monosodium Glutamate)
  (MSG goes by many names—too numerous to mention here. A detailed list is available at www.truthinlabeling.org/hiddensources.html)
- Natural flavoring
- Noodle soup
- Oatmeal (except for Bob's Red Mill GF oats)
- Pasta
- Children´s nutritional shakes
- Play-Doh™
  (Contains gluten—Gluten-Free Dough is available at www.discountschoolsupply.com)
- Preservatives
- Processed meats (hotdogs, ham, sausage, cold cuts)
- Sodas
- Soy/fruit beverages
- Soy milk
- Soy sauce
- Sports drinks
- Sugar
- Yeast

NO Cow's Milk:

- Not casein free
- Not lactose free
- Not organic
- Not raw
- Not evaporated
- No No No cow's milk!
- Sorry, no goat's milk either! It too has casein.
- All cow's milk, regardless of what is removed from it, causes mucous production in the body. This, in turn, provides an ideal environment for pathogens.

If you're thinking that once you go GF/CF/SF + that your child will starve, trust me they won't! The list of foods they eat may get shorter, but they will keep eating. As I mentioned earlier, my son Patrick ate homemade French fries for the first three weeks of *The Diet* until he began accepting different fruits, nuts, and chicken again, but we did it... we transitioned. What I have seen in my own son, and in other children, is that when they begin to get healthier in the weeks and months after starting *The Diet*, they become more open to accepting new "legal" foods.

Wow... quite amazing Kerri...

I have always believed that "you are what you eat" and have been very careful with what I give to my kids, so their diet has been quite healthy, except for the occasional ice cream, etc. My son even spits out candies when someone offers him one because he really doesn't like them. He is not into sweets at all, thank God.

But I must say this diet is just what he needed! Yay!

There are a few loopholes to the above list. If you make your own catsup, mayonnaise, etc. with items from the permitted foods list, then your child can obviously eat those foods. The list refers to those items that come from the grocery store that contain white sugar, preservatives, and other problematic ingredients.

There are many items on the forbidden foods list that don't contain gluten, casein, or soy. Here is the explanation behind a few of those items:

White refined sugar: Refined sugar has been found to reduce immune system function as well as contribute directly to obesity and Type II diabetes.

The following list is excerpted from *Suicide by Sugar.*[8]

- Sugar can suppress your immune system.
- Sugar upsets the mineral relationships in the body.
- Sugar can cause juvenile delinquency in children.
- Sugar eaten during pregnancy and lactation can influence muscle force production in offspring, which can affect an individual's ability to exercise.
- Sugar can cause hyperactivity, anxiety, inability to concentrate and crankiness in children.

MSG: An excitotoxin that can literally "excite neurons to death." We need all of our neurons!

Yeast: Feeds Candida and other fungi.

Carrageenan: Contributes to inflammation in the body and studies have linked it to colon cancer in rats.[9]

Artificial sweeteners containing sucralose: In making sucralose, the chlorine in the sweetener bonds to carbon, producing a chemical known as a chlorocarbon. "According to physician and biochemist, Dr. James Bowen, chlorocarbons are never nutritionally compatible with our metabolic processes and are wholly incompatible with normal human metabolic functioning."[10]

Processed Meats (hot dogs, ham, cold cuts, and sausages): The fats found in these meats may contain high amounts of toxins such as heavy metals, pesticides, and herbicides. In addition, processed meats contain sodium nitrite, which can harm the liver and pancreas. They may also contain corn syrup and flavoring.

Natural Flavoring: The exact definition of natural flavorings & flavors from Title 21, Section 101, part 22 of the Code of Federal Regulations is as follows:

> *The term natural flavor or natural flavoring means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products, or fermentation products thereof, whose significant function in food is flavoring rather than nutritional.*[11]

Basically if you start with a natural ingredient, you can process or manipulate it any way you choose. No matter how many chemicals or solvents are added it will be labeled as a "natural flavor."

Notice they can come from meat, seafood, dairy, and wheat, etc., can also contain MSG.

Coloring: Food dyes have been linked to allergic reactions, hyperactivity in children, and even cancer. Red No. 2, for example, was banned in 1976 after it was suspected to be carcinogenic. Red No. 40, in a number of tests, was shown to damage DNA in mice.

When we are dealing with children on the spectrum, their immune systems are already compromised, and their detox pathways can be blocked or impaired. The idea is to decrease their burden with life-giving, nutritious foods, rather than add more stress to a body that is already maxed out.

Corn Syrup/High Fructose Corn Syrup: Simply because corn is a permitted food does not mean corn syrup/HFCS are "legal." Both of these shut down the immune system, as refined sugar does. They are chemically similar in composition. There is much controversy surrounding the use of mercury in the refining process, and how much if any, is in the final product.[12]

I wanted to update you on everything with my daughter.

We had a mishap 2 days ago. A substitute teacher gave my daughter a regular granola bar and a flavored beverage containing sucralose. You know what Kerri, when she came home from school that day she was in her own world and was ignoring me. I knew right away she had something she shouldn't have had. I was angry and saddened by what I was witnessing. Is there anything we should do since she had those 2 items that she's not supposed to have. Or just continue to move forward??

After a while on the diet it becomes obvious when an infraction happens, if you are present when it happens you can give an enzyme to help break down the food, if not, we move forward and learn how to prevent it from happening in the future.

Common Errors:

"It's no big deal if we break the diet every once in a while."

Not True! Every time you break the diet, further inflammation is caused in the brain and gut. When gluten and casein proteins are not properly broken down, the resulting peptides reach the brain as gluteomorphin and casomorphin. It takes three days for casein to be eliminated by the body, but months for gluten to be eliminated by the body.

"My child can drink milk as long as it doesn't have casein."

Not True! As long as the milk comes from a cow, your child cannot drink it. It doesn't matter how it's labeled. If it comes from a cow it's off limits. Cow's milk can provoke the body to produce mucous, thus providing an ideal environment for pathogens which can cause chronic inflammation.

"The allergy panel says my child isn't allergic to gluten or casein, therefore he can eat them."

Not True! If your child has autism, or is on the spectrum, he must avoid gluten, casein, and soy. You should also observe your child carefully after adding a new food, or a food he hasn't eaten in a while. In one particular case, even though the child didn't test positive for an orange allergy he continued to produce symptoms of an allergic reaction whenever he ate

one. We must remember that the body is changing constantly and that any test is only good for a couple of months, if at all.

I have seen the same story repeated over and over again with mangoes, oranges, bananas, apples, and corn, etc. Observing the conduct of your child after consuming a food you suspect he may have an allergy/intolerance to is the best way to measure whether the food is acceptable or not. As our children move towards healing, foods that at one point produced allergy-type symptoms can be tolerated without an immune system response.

"My doctor says that autism has no cure, and that the diet doesn't work."

Not True! Run from any doctor who says he will take your money even though he feels that autism is incurable. The first question you need to ask a doctor is:

"How many children have your recovered from autism?"

If the answer is zero, keep looking!

The Diet is free—no one earns money if your child is on *The Diet*—so do it! You have nothing to lose, and everything to gain. However, if you choose not to do it, you may further lose the health or your child. Commit 100% to *The Protocol*, and your child may be one of the next recovery stories.

My son had what can only be described as a miraculous reaction to the GF/CF/SF diet. Since starting 2 weeks ago, all the bumpy red areas on his face disappeared, tantrums went from about a 10 to a 2, and diarrhea is all but gone.

"We tried the diet, but Johnny didn't get any better."

***The Diet* is only one piece of the puzzle.** However, it is the foundation of everything we are going to do. Without maintaining *The Diet*, it is difficult to know which intervention is actually helping.

Candida will be dying and a reaction to *The Diet* may be a Herxheimer. We must go beyond the diet to heal autism, but diet is the first piece of the recovery process.

When I receive an email complaining that a child isn't getting better I ask for a detailed list of exactly what the child is eating. I always find errors in parents' application of the GF/CF/SF + diet. What I typically uncover is that *The Diet* did not fail but that the application was flawed.

"I should remove gluten and casein from my child's diet gradually."

Not True!!! Remove them from the diet immediately and watch your child improve before your very eyes. Foods that cause IgG or IgE allergic reactions cause many other problems in the body including inflammation and psychotic behaviors, in response to gluteomorphin and casomorphin. The sooner you can remove these foods the faster your child will recover.

As soon as we started working on the diet, my son received a developmental evaluation, although he was 20 months old, the results were that of a child of 15 months. 4 months after implementing the diet, the changes have been dramatic. My boy smiles again, he speaks in his own way, he points, has eye contact, interacts with others, he is very close to being recovered, although he is still missing a little bit. He is occasionally nervous and sometimes distant, but the most important thing is that the therapist reapplied the developmental test and my son is now reacting like a child of 24 months (his current age), even in some areas surpassing it! And this is only with the diet because he hasn't taken any supplements, just a probiotic that was ineffective.

"A gluten-free/casein-free/soy-free diet is good enough."

It's Not! Like I said before, I always find errors when a parent goes step-by-step with me through their child's diet. The list on page 52 is a detailed list of what our children should not eat under any circumstances. Many of these foods contain neurotoxins/excitotoxins. These foods can negatively affect developing and mature nerve tissue. Keep them out of your child's diet.

Beyond GF/CF/SF +

Sometimes, *The Diet* as explained is not enough and we need to go beyond it. If your child suffers from constipation, diarrhea, or seizures it is recommended to do a period on the Specific Carbohydrate Diet™ (SCD™). The following text was sourced from the website...

www.breakingtheviciouscycle.info

...by Elaine Gottschall. A complete list of references is also available at that website.

The Specific Carbohydrate Diet™ has helped many thousands of people with various forms of bowel disease and other ailments vastly improve their quality of life. In many cases people consider themselves cured. It is a diet intended mainly for Crohn's disease, ulcerative colitis, celiac disease, diverticulitis, cystic fibrosis and chronic diarrhea. However it is a very healthy, balanced and safe diet that has health benefits for everyone. The foods that are allowed on the Specific Carbohydrate Diet™ are based on the chemical structure of these foods. Carbohydrates are classified by their molecular structure.

The allowed carbohydrates are monosaccharides and have a single molecule structure that allow them to be easily absorbed by the intestine wall. Complex carbohydrates which are disaccharides (double molecules) and polysaccharides (chain molecules) are not allowed. Complex carbohydrates that are not easily digested feed harmful bacteria in our intestines causing them to overgrow producing by products and inflaming the intestine wall. The diet works by starving out these bacteria and restoring the balance of bacteria in our gut.

Autism & GI Problems

Altered intestinal permeability was found in 43% of autistic patients, but not found in any of the controls (Harvard University). Intestinal permeability, commonly called "leaky gut", means that there are larger than normal spaces present between the cells of the gut wall. When these large spaces exist in the small intestine, it allows undigested food and other toxins to enter the blood stream. When incompletely broken down foods enter the body, the immune system mounts an attack against the "foreigner" resulting in food allergies and sensitivities. The release of antibodies triggers inflammatory reactions when the foods are eaten again. The chronic inflammation lowers IgA levels. Sufficient levels of IgA are needed to protect the intestinal tract from clostridia and yeast. The decreasing IgA levels allow for even further microbe proliferation in the intestinal tract. Vitamin and mineral deficiencies are also found due to the leaky gut problem.

In a healthy intestinal tract the small intestine and stomach are not inhabited by bacteria. When the flora balance in the colon is lost, the microbes can migrate into the small intestine and stomach, which hampers digestion. The microbes compete for nutrients and their waste products overrun the intestinal tract. One of the toxins produced by yeast is actually an enzyme that allows the yeast to bore into the intestinal wall. The yeast also produce other toxins such as organic acids, which can also damage the intestinal wall.

Bacterial growth in the small intestine destroys enzymes on the intestinal cell surface, which prevents carbohydrate digestion and absorption.

The last stage of carbohydrate digestion takes place at the minute projections called microvilli. Complex carbohydrates that have been broken down by the enzymes embedded in the microvilli can be absorbed properly and enter the blood stream. But when the microvilli are damaged, the last stage of digestion cannot take place. At this point only monosaccharides can be absorbed because of their single molecule structure.

In the small intestine, the body should absorb the nutrients needed from what is eaten. But in the case of malabsorption, the undigested carbohydrates left in the small intestine cause the body to draw water into the intestinal tract. This pushes the undigested carbohydrates into the colon where the microbes can feast on it. This allows for even more proliferation of the unwanted microbes and continued increase in malabsorption problems.

Low intestinal carbohydrate digestive enzyme activity was found in 43% of patients with autism. (Horvath) Recent studies point out that ongoing carbohydrate malabsorption keeps the digestive system constantly weakened, leading to systemic disorders. Suspected carbohydrate malabsorption should be treated to ward off further damage to the body's digestive system. (GSDL)

Most intestinal microbes require carbohydrates for energy. The Specific Carbohydrate Diet™ limits the availability of carbohydrates. By depriving these microbes of their food source, they gradually decrease in number. As the number of microbes decreases so do the toxic by-products they create.

The Specific Carbohydrate Diet™ (SCD™) is intended to stop the vicious cycle of malabsorption and microbe overgrowth by removing the source of energy from the microbes. The SCD™ allows simple monosaccharides that do not need to be broken down in order to be absorbed.

By following the SCD™, malabsorption is replaced with proper absorption. Inflammation is decreased and the immune system can return to normal. Once the immune system is returned to adequate levels, it can begin to keep in the intestines microbes in proper balance.

The SCD™ allows simple carbohydrates, but prohibits complex carbohydrates. The diet is started by following an introductory diet, which consists of a limited selection of foods. After the introductory diet, the next stage of the diet allows many more foods, but requires that all fruits and vegetables be peeled, seeded and cooked in order to make them more easily digested. Raw fruits, vegetables, nuts and seeds are added to the diet later. To properly follow this diet, it is imperative to read Breaking the

Vicious Cycle by Elaine Gottschall. The book details the progression of allowed foods as well as providing many delicious recipes.[13, 14]

Salicylates/Phenols

Phenol is a naturally occurring chemical found in many of the foods we eat, such as fruits and vegetables, nuts, and in bioflavonoids and cartenoids (carotene, lutein, lycopene, xanthophylls, and zeaxanthin), etc. Phenols can be found in toothpaste, hair dye, and disinfectants, etc. Many foods have phenols, and they are impossible to avoid completely. Salicylates are a subgroup of phenols, related to aspirin. There are several kinds of salicylate, which plants make as a natural pesticide to protect themselves from insects, fungi, and harmful bacteria. Foods high in natural salicylates are tomatoes, apples, peanuts, oranges, cocoa (chocolate), red grapes, coffee, all berries, and peppers, to name a few.

You may also need to consider a low salicylate and/or phenol diet, as many children on the spectrum may have issues with these items. The following was sourced from *www.scdlifestyle.com*.

Dr. Feingold is probably the most widely known individual to study this chemical, as he developed what is now referred to as the Feingold Diet. He started out in the 1960s as a pediatrician and allergist studying children's negative reactions to aspirin. Through his work, he found that many other dietary chemicals were causing physical and even behavioral reactions in his patients. He developed the Feingold Diet to eliminate all food additives, colorings, and salicylates.

Why Do People React to Them?

In a normal body that has the correct levels of sulphates and liver enzymes, phenols and salicylates are easily metabolized. The body utilizes what it needs from the chemicals and properly disposes of the rest through the bowels. In those whose levels are not normal or in the case of "leaky gut syndrome", intolerance to this chemical family can occur rather quickly.

Many people with gut issues such as yeast/bacteria overgrowth or digestive diseases can develop salicylate intolerance as a result of "leaky gut" syndrome. Leaky gut is a result of various digestive problems and occurs when the small intestine becomes too damaged to properly filter the size and types of food particles or chemicals that enter the bloodstream. [For more on leaky gut syndrome see http://scdlifestyle.com/2010/03/the-scd-diet-and-leaky-gut-syndrome/] When these improper particles are allowed to repeatedly enter the bloodstream the

body tries to get rid of them by triggering an immune system response. Because phenols/salicylates are so common in most foods, a person with a leaky gut will have much higher than normal levels of these chemicals in their blood and can very quickly develop intolerance´s to these specific particles.

Why Can Phenols Affect Children on the Autism Spectrum More Than Others?

Research by Dr. Rosemary Waring at the University of Birmingham found that children on the autism Spectrum have low levels of the enzyme phenol-sulfotransferase-P (the enzyme that breaks down the phenol and amine families, also known as PST) and the substrate it uses: sulfates. Sulfates are a key tool that the body uses in the process of detoxification and break down phenols such as salicylates. Without normal levels of sulfates in the body, the sulfotransferase enzyme cannot do the task it was created to do: metabolize salicylates. So there are two problems with PST deficiency: low sulfate levels and low enzyme levels. PST deficiency alone can cause problems in children (remember phenols are normal) but factor in any intestinal damage resulting in leaky gut along with it and your child's body can easily be overwhelmed. The end result is a salicylate intolerance and the subsequent physical and behavioral reactions that come with it.

Reactions Caused by Phenols

Salicylates stimulate the central nervous system in people that react to them. This can often bring with it an emotionally extreme high followed by a very low, low. Other reactions to the phenol family can occur anywhere from immediately after consumption up to 48 hours after the consumption of the chemical, depending on the immune response. Physical reactions can include: dark circles under the eyes, red face/ears, diarrhea, headache, difficulty falling asleep at night, night waking, and in some cases excessively tired and lethargic. Behavioral symptoms of a reaction can be: hyperactivity, aggression, head banging or other self-injury, and even inappropriate laughter. Hyperactivity is more common in children's reactions, while adults generally experience symptoms similar to chronic fatigue.[15]

For additional information on leaky gut syndrome you may wish to look at (search for) *Dr. Peter Osborne*:

www.glutenfreesociety.org

If your child suffers from self-injurious behaviors limit these foods that are moderate to high in phenols:

- Almonds
- Apples
- Avocados
- Bananas
- Cacao
- Cantaloupes
- Cherries
- Cider vinegar
- Coconut oil
- Colored fruits
- Dates
- Food coloring
- Honey
- Mangos
- Mint
- Oranges
- Oregano
- Peanuts
- Pineapples
- Powdered chili pepper
- Processed meats
- Raisins
- Strawberries
- Tangerines
- Tomatoes

For more information on this you can visit:

www.scdlifestyle.com

and

www.feingold.org

She's quite the book worm and has an impressive collection which includes classic favorites such as Brown Bear, Llama Llama Red Pajama, Barnyard Banter and Goodnight Moon... But lately, she has been drawn to her Mama's new favorite read... Perhaps she is hoping that someday her story of recovery will be told too...

Gluten Syndrome

For many parents of children on the spectrum, having their children on *The Diet* is something that is second nature to them. However, as more and more people are using the protocol in this book to heal their own health ailments we have decided to include the following section on how gluten can negatively affect many more than just the autism community. You will get a very interesting look into how the immune system works and why so many sufferers have misunderstood gluten syndrome. Thank you Olive for contributing to our understanding of the subject.

Molecular Mimicry
What It Is & How It Relates to the Gluten Syndrome

by Mrs. Olive Kaiser

Who am I?

I am a married stay at home mom, blessed with a wonderful husband and seven fantastic kids. In 2003, after decades of searching, we learned about gluten reactivity through our daughter's nursing school training and eventually confirmed that we are a gluten syndrome family. Our daughter and my husband had the most obvious symptoms, but we all had manifestations and antibodies. Additionally our oldest son reacted to his MMR vaccination and probably other shots, which added high functioning ASD/ADD to the mix, and he developed type 1 diabetes at age 19. Two other sons had various shades of ADD/ADHD. My own school age vaccinations in the 1950's may have led to repeated bouts of strep throat until I reacted to a strep antibiotic injection about age 10. I developed PANDAS from that reaction (Pediatric Autoimmune Neuropsychiatric Disorder Associated with Streptococcus). What a struggle! Decades later it has responded somewhat to diet changes and now the CD/parasite protocol. I give thanks to God for His guidance along the way.

How did I get into this community and this health project?

We tested for gluten syndrome (we called it celiac disease back then) using standard tests recommended by celiac experts and received confusing results. Then, our daughter had a troubling experience with a gluten challenge that did not match the celiac story we'd been taught. I delved into medical literature and networked extensively with the gluten syndrome community looking for help. In that desperate discovery and prayer process I found practitioners and researchers who stepped outside the "villi damaged celiac only" box. They were able to explain why we received, in the midst of obviously gluten-induced

incidents, false negative results from our celiac blood tests and villi biopsy. Those tests significantly led us astray and eventually I put up a website...

www.TheGlutenSyndrome.net

...to warn others of discrepancies we stumbled upon in the diagnostic process.

What is Molecular Mimicry?

Molecular mimicry is a recognized medical theory which explains very nicely why gluten reactions may potentially inflame and damage so many different parts of the body, leading to very different symptoms in different people. It also clarifies why gluten antibodies may cross react with other foods and infections, and why it only takes a small exposure to trigger them.

When we understand molecular mimicry we are better equipped to deal with tempting social situations. Gluten syndrome has its own rules, which do NOT make sense unless this concept is understood.

The following is a brief introduction to Appendix 5, page 449, which goes into much more detail, along with references, about the following questions:

1. How does the gluten syndrome reaction actually damage our bodies?

Molecular mimicry. The molecular structure of gluten resembles the molecular structure of many of our body tissues. When the immune system attacks gluten it may also attack body tissues that "look like" gluten. Even if you do not read the other detailed answers, learn the details for this question on page 450.

2. Does gluten always damage the villi of the small intestine as the celiac story teaches? Many other tissues such as thyroid, pancreas, liver, joint, brain, nerves, heart, bone, blood vessel walls, etc., are involved in this disorder. Does all that other damage only arise from poor nutrient absorption from injured gut villi?

No, according to published research, many researchers and practitioners believe the villi are not always damaged in an autoimmune gluten reaction. Where there is no villi damage, injury to other organs CANNOT be due to nutrient deficiencies caused by villi damage. Molecular mimicry provides a mechanism for direct autoimmune gluten damage to many other tissues and organs when the villi are fine, OR other tissues/organs, *including villi*, may be directly damaged through molecular mimicry.

Dr. Vojdani's abstract in his editorial *The Immunology of Gluten Sensitivity Beyond the Intestinal Tract*, supports that the villi are not always injured. To quote his editorial abstract, "Evidence has been accumulated in literature demonstrating that gluten sensitivity or celiac disease can exist even in the absence of enteropathy [gut/villi damage], but affecting many organs."

3. I don't have damaged villi, and my tTG/gliadin tests were negative, but I feel so much better gluten-free. Why?

The tests were likely false negative. That is very common. As gluten digests, it breaks into more pieces than we have tests developed to check them, and the immune system makes a separate antibody for each piece. Standard tests only check 2-3 antibodies. You may have others (Cyrex Labs tests 28 antibodies). Your villi may be fine, but you may be injured somewhere else—for example: thyroid, nerves, heart, etc.

4. Why do many gluten syndrome patients not only react to wheat, barley, and rye but also at times to other foods, particularly oats, milk, corn, soy, egg, yeast, coffee, sesame, rice, chocolate and others?

These foods "look like" gluten closely enough in their structure that the immune system may mistake them for gluten. This situation may also cause your gluten antibodies to run high after you go gluten-free. The immune system may misrecognize other foods, such as yeast, corn or milk, and others for gluten because they resemble gluten molecularly.

5. The diet seems excessively strict? Why does it take so little gluten to start a reaction?

Our perspectives are skewed. We accept that miniscule amounts of venom injected by a bee sting, or a tiny exposure to peanuts in allergic individuals can set off immediate life threatening allergic reactions. Many medications are contained in very TINY pills, but they have powerful effects in our bodies. Immune gluten reactions are also that sensitive. "Crumbs matter."

6. Why do many people react to gluten, proven by antibody tests, but they have few or no warning symptoms for a long time and then they crash with something serious, usually autoimmune?

Gluten is famous for slowly injuring nerves by molecular mimicry, and in many cases, the nerves are silenced by that injury. The patient does not realize there is a problem until the tissue or organ that those nerves supply begins to fail.

7. Why do so many of us react to gluten today, when for centuries most people appeared to be fine with wheat, barley, rye and oats? After all, wheat and barley are mentioned positively in the Bible and other historical documents.

Today's gluten is altered, violently, by nuclear radiation and chemical mutation within the past 60 years*, plus our toxic and poorly nourished bodies do not have optimal digestive capabilities to break it down. Weak, toxic, leaky body barriers/membranes, particularly leaky gut, set the stage for gluten induced molecular mimicry.

*Nina Federoff, *Mendel in the Kitchen*

8. Why do specialists and researchers insist that the gluten-free diet must be life long? Can't we heal this problem and go back to our beloved wheat bagels, croissants, and brownies?

Our scientists still insist that gluten-free is a strict lifelong commitment. I agree. For me it is not worth playing with today's wheat. There is something strange and unpredictable about it. The memory B cells in the immune system never forget what the enemy "looks like", and fresh exposure retriggers antibodies.

9. Traditional peoples soaked and/or sprouted their wheat berries and then made sourdough bread with them. Does that process alter the gluten sufficiently for gluten syndrome patients to safely consume this bread, particularly spelt or einkorn?

No. These processes and ancient wheat grains do make the bread more digestible, but not gluten-free and still unsafe.

10. Should I substitute all the gluten foods I routinely eat with gluten-free substitutes?

No, not routinely. The gluten-free community finds that they are still mainly expensive high carb processed food (i.e., junk food).

11. What are gluten withdrawals?

Occasionally, gluten breaks into specific "pieces" in the gut that resemble opiate drugs. When a person goes gluten-free, they may experience temporary, but unpleasant, withdrawal symptoms for a few days as these pieces disappear from the blood stream.

12. What are the risks of formal gluten challenges?

Many patients avoid these challenges. Occasionally a patient tries the gluten-free diet for an extended period of time and then the patient or doctor decides to run tests to confirm gluten reactivity. The standard advice to restart the production of antibodies is to consume gluten products 4 x per day for 4-6 weeks, and then run the standard blood test, followed by a villi biopsy if the blood work is positive. This is called a gluten challenge and has created some very dramatically unhappy reactions, some of them neurological/psychological.

Please see Appendix 5 (page 449) and www.GlutenSyndrome.net for more info and references. When we understand molecular mimicry our understanding of the gluten syndrome comes into focus. It explains why gluten-free diets and beyond are important tools to reduce inflammation and promote healing. As time goes on, gluten-free diets are easier to manage in public, tests are better and social awareness has grown. The Just Eat Real Food movement and others play into healthy gluten-free dining with wonderful recipes that avoid processed foods and incorporate healthy fats and nutrient density. This is a happy, encouraging era as we watch our children heal and adults find better stability in the midst of a health crisis. Bon Appetit!!!

The Diet - FAQs

The following FAQ's were printed with permission from gfcfdiet.com:

Slight changes were made to match the formatting of this book; however, the content remains unaltered. Please visit gfcfdiet.com for complete list of the references contained within the following text.

1. My doctor has never heard of any of this and she is extremely skeptical. I'm embarrassed to tell her I'm considering this approach. What do you think?

Skepticism is a good thing in a medical doctor or scientist. However, since there is preliminary evidence to support this safe, non-invasive intervention, it is up to you to educate her, state your wishes, and ask for her support. For a doctor, it is better to wait until all of the data is published in peer-reviewed journals before advocating a treatment. However, for a parent, it is reasonable to want to help one's child without waiting for all of the results of the "double-blind placebo" studies. Because this approach does not include any unusual supplements, invasive drugs, or expensive treatments, your pediatrician should be supportive. Explain that you would like to try this for a few weeks, and agree that you will be objective about recording your child's progress while on the diet.

If you feel that you need to support your case legally with the scientific and medical documentation that is currently available, please see the medical links at www.gfcfdiet.com or at www.autismndi.com.

2. What is casomorphin?

Casomorphin (or caseomorphin) is a peptide derived from casein, a milk protein. Casein is one of the major proteins in the milk of all mammals including cows, goats, and humans. When casein is digested properly, it breaks down into large peptides like casomorphin, and should then be broken down further into smaller amino acids.

However, Dr. Reichelt in Norway, Dr. Cade at the University of Florida, and others found that urine samples from people with autism, PDD, celiac disease, and schizophrenia contained high amounts of the casomorphin peptide in the urine.[4] In its peptide form, casein has opiate properties similar to morphine, and may plug into the same opiate receptor sites in the brain. Researchers have found that these peptides may also be elevated in other disorders such as chronic fatigue, fibromyalgia, and depression based on anecdotal reports of symptom remission after exclusion of wheat and dairy.

3. What is gliadorphin?

Gliadorphin (also called alpha-gliadin or gluteomorphin) is a substance that resembles morphine. Ordinarily, this is a short-lived by-product from the digestion of gluten molecules (found in wheat, barley, rye, oats, and several other grains). Gliadorphin is very similar to casomorphin. Gliadorphin has been verified by mass spectrometry techniques to be present in unusual quantities in urine samples of children with autism, and are believed by many to be a central part of the system of causes and effects that cause autistic development.

The most probable reasons for the presence of these molecules are:

- One or more errors in the breakdown (digestion) process caused by enzyme deficiency and/or
- Abnormal permeability of the gut wall (that would allow these relatively large molecules to enter the bloodstream from the intestine in abnormal quantities).

4. I am confused about allergy vs. intolerance. I understand that our children may be sensitive to corn, soy, and other foods as well as gluten and casein. Does this mean that they will eventually start turning these foods into the morphine-like compounds too? If this were the case, would they show up as an allergy on a RAST test? Or were our children always allergic to these foods (a regular allergy

that may cause behavioral changes in our children), and we just didn't know because the gluten and casein were hiding the allergy?

To a traditional physician or allergist, "allergy" is used to describe a reaction of the IgE part of the immune system, resulting in hives, swelling, or breathing problems. However, the words "allergy" and "intolerance" are often used to describe any inappropriate reaction to foods or substances that should normally be harmless to the body.

There are at least three different ways that a child with autism may have a problem with foods that contain gluten or casein, and it's important to understand the distinction:

1. An IgE ALLERGY commonly results in skin problems, hives, swelling, and breathing problems, etc. This can be tested using a skin test or blood test.

2. An INTOLERANCE (usually mediated by the IgG or IgA part of the immune system, or by an enzyme insufficiency such as lactose intolerance) has more varied or vague symptoms like discomfort, stomach problems, sleep problems, joint pain, ear infections, or hyperactivity and behavior problems. Sensitivity to these substances can be tested with an ELISA blood test.

3. PEPTIDUREA (peptides in the urine) is caused by the inability of the body to properly break down certain proteins. It is hypothesized that certain peptides, notably from milk and wheat proteins, are plugging into the opiate receptor sites of the brain and disrupting brain and nervous system function. Urine testing for this is still experimental, and many parents believe that the best way to find out if this is what is causing a child's autism is a strict trial period on the GF/CF diet.

On the GF/CF diet, gluten and casein are avoided because they are strongly suspected of having a direct pharmacological effect. When these proteins are only partly broken down, some of the resulting fragments can be strikingly similar to morphine, and act in more or less the same manner. (This type of reaction can co-exist along with a classic type of allergy towards the same foods.)

Recent research indicates that protein from both corn and soy may also contain some molecular sequences that could, if the patient has an enzyme deficiency, be broken down into something closely resembling opioid peptides. Even spinach protein has been found to have some opioid activity.

Products made from soy or corn will also often contain metabolic end products made by microscopic organisms like bacteria, molds,

or other fungi. Some of these are suspected of being harmful to a small number of people who are genetically predisposed to autism. The amount of danger will depend on individual conditions AND on the quality of the corn or soybeans used in the production process. Soy OIL (lecithin) may be worse than most other soy products since this product will look and taste okay, even when made from moldy raw material, and since it is commonly made from the "bottom grade" of the harvest.

Some people also think that one of the natural pigments in corn (lutein) may cause problems for reasons that are not properly understood (see: "Sara's Diet"). This must be regarded as highly speculative.

5. I don't think my child has allergies, or that allergies could cause autism. Why should I try removing foods from his diet?

Although parents have been reporting a connection between autism and diet for decades, there is now a growing body of research that shows that certain foods seem to be affecting the developing brains of some children and causing autistic behaviors. This is not because of allergies, but because many of these children are unable to properly break down certain proteins.

6. Milk and wheat are the only two foods my child will eat. His diet is completely comprised of milk, cheese, cereal, pasta, and bread. If I take these away, I'm afraid he'll starve.

There may be a good reason your child "self-limits" to these foods. Opiates, like opium, are highly addictive. If this "opiate excess" explanation applies to your child, then he is actually addicted to those foods that contain the offending proteins. Although it seems as if your child will starve, if you take those foods away, many parents report that after an initial "withdrawal" reaction, their children become much more willing to eat other foods. After a few weeks, most children surprise their parents by further broadening their diets.

7. Isn't milk necessary for children's health?

Americans have been raised to believe that this is true, largely due to the efforts of the American Dairy Association, and many parents seem to believe that it is their duty to feed their children as much milk as possible. However, lots of perfectly healthy children do very well without it. It is calcium children need, not milk. Cow's milk has been called "the world's most overrated nutrient" and "fit only for baby cows." There is even evidence that the cow hormone present in dairy actually blocks the absorption of calcium in humans.

Be careful. Removing dairy means all milk, butter, cheese, cream cheese, and sour cream, etc. It also includes product ingredients such as "casein" and "whey," or even words containing the word "casein." Read labels—items like bread and tuna fish often contain milk products. Even soy cheese usually contains caseinate.

For more information on dairy-free living, there's a very good book called *Raising Your Child Without Milk* by Jane Zukin. Another great book called *Don't Drink Your Milk* by Frank Oski (the late head of pediatrics at Johns Hopkins and author of *Essential Pediatrics*). This book cites the results of several research studies that conclude that milk is an inappropriate food for human children. It is available for $4.95 from Park City Press, PO Box 25, Glenwood Landing, NY 11547, ISBN #0671228048.

8. How do I know which foods he's allergic to?

Try an allergy elimination diet. For example, keep common allergens out of his diet for a few days and then re-introduce them, one-by-one. If you see symptoms, either physical or behavioral, try again in a few days. By being systematic you will be more certain of which foods are causing problems and correctly rule them out. Two excellent resources, probably available at your library, are Doris Rapp's book, *Is This Your Child*, and William Crook's, *Solving the Puzzle of Your Hard to Raise Child*.

9. Aren't eggs dairy?

Many years ago, most of us were taught that eggs and dairy were part of the same section of the food pyramid under "dairy." However, they are not. Eggs are free of any dairy. Dairy can be from cows, sheep, or goats. The eggs we eat are normally from chickens. Dairy and eggs happen to be side-by-side in the refrigerator section of the grocery store, which may add to the confusion.

10. What do I do when we go to a party or out to another person's house and are trying to maintain my child on a GF/CF diet? At times we find it impossible to catch him before he ingests something he shouldn't.

It is a good idea to bring some favorite GF/CF goodies with you. Keep them hidden until that moment of "competition." Show the surprise treat to your child before your child eats one of the gluten and/or casein laden foods. Bring more than one goodie to be on the safe side. Also, there are two small pamphlets that are great for handing out to friends and family members that give a simple explanation for your child's special dietary requirements. These are: "Alternative Treatments for Children Within the Autistic Spectrum: Effective, natural solutions for learning disorders, attention deficits, and autistic behaviors," by Deborah Golden Alecson, and "Leaky Gut Syndrome: What to do about a health threat that can cause arthritis, allergies, and a host of other illnesses," by Elizabeth Lipski, M.S., C.C.N. Both of these books cost $3.95 each and can be found at health food stores.

11. Do we need to worry about gluten-containing lotions, shampoos, and toothpaste being absorbed through the skin?

Nicotine patches, birth-control patches, and other transdermal applications of medications are proof that the skin does absorb many things (and pass them to the bloodstream). However, the molecules in gluten are too large to pass through the skin, according to John Zone, MD (a dermatologist quoted in the Spring 2003 issue of *Living Without* magazine).

Most often the problem occurs from hand to mouth (i.e. touching colored modeling dough and then touching one's face), which is a good reason to avoid giving our kids much access to anything that poses a threat. If your child's school has a sensory table, you can request that it be filled with rice or dried beans, instead of macaroni or gluten grains. Likewise, we suggest that you volunteer to be the "Play-Doh™ parent" and keep the classroom supplied with a safe version that you don't have to worry about.

We are not too concerned about shampoo, unless you have a child who is likely to try to drink the stuff. But toothpaste is an entirely different matter, since some of it is likely to be ingested, rather than spit out.

12. I'm already worried about my child's nutrition, and his "allergies" are causing me to further reduce his choices. If apple juice and bananas are the only fruits he will eat, and he's reacting to them, how is he supposed to get by?

Fruit contains water, sugar, fiber, and vitamins. If he will not eat other fruits then he needs to get these things from other sources.

13. I am wondering if anyone else is having problems with school and keeping them on the diet? I have sent a note saying: "Please don't give my son dairy, wheat, corn, or soy." Today I came in and they were giving him Popcorn!

My kid doesn't eat ANYTHING that isn't sent from home. He's almost ten now, and this policy has been good for him because succumbing to temptation outside of the house has simply never been an option. I don't think it would occur to him to take food from anybody without our permission.

We always made sure there are backup snacks and birthday party treats at school for emergencies. I think the school has always taken this seriously because they can see how seriously we take it.

We once got a note from a mom who said that her son had been strictly GF/CF for months without an improvement. I asked what he was eating, and she gave me a long list including expensive GF pre-packaged products. Then she ended her letter by saying, "Of course, that's just what he gets at home. I have no idea what he gets in his school lunch, or what they're using for food reinforcers in his ABA program."

Definitely try this—you might see a real difference.

14. What percentage of children will respond to dietary intervention?

DAN! doctors used to try to be conservative about this, and say at least a third of children, and then, after seeing more patients, they said two thirds. Now that they have seen hundreds or thousands of patients, most tell us that they believe that almost every ASD child will benefit from this diet. Many will need further modifications (i.e. removing grains or sugar) before the full benefits are realized.

However, age plays a big part in how quickly results will be seen. We can probably say that the response will be dramatic in more than two thirds of the children under three, and perhaps more subtle, but still helpful, in at least two thirds of older children. We think those are pretty good odds.[3]

Some Additional FAQs...

Kerri, yesterday the therapist was playing with Play-Doh™ with my daughter. She could not resist eating it. We tried very hard to stop her with no luck. In the end we had to stop her from playing with it. People say this is due to a zinc deficiency. Do you know if this is correct? Will giving her Zinc stop her from wanting to eat Play-Doh™? If yes, how much should I give?

She is not eating Play-Doh™ because of a zinc deficiency. Play-Doh™ contains wheat. She is addicted to gluteomorphin, a by-product of her eating gluten, which is contained in Play-Doh™. So, she broke her diet. She cannot touch nor eat Play-Doh™.

What exactly is Candida?

Candida albicans is an opportunistic fungus (or form of yeast) that is the cause of many undesirable symptoms ranging from fatigue and weight gain, to joint pain and gas.

The Candida yeast is a part of the gut flora, a group of microorganisms that live in your mouth and intestine. When the Candida population starts getting out of control it weakens the intestinal wall, penetrating through into the bloodstream and releasing its toxic by-products throughout the body.

What Causes Candida Overgrowth?

Candida is an opportunistic pathogen that can rapidly take over when a person is under a course of antibiotics. Antibiotics destroy beneficial gut flora but have little effect on Candida, giving this normally harmless yeast the chance to take over dominance of the gut environment very quickly.

Babies born via C-section, or to mothers who were treated with IV antibiotics during labor are especially vulnerable to the ravages of Candida overgrowth. This is because they are not exposed to a healthy balance of gut flora on the way through the birth canal prior to the moment of birth.

…disaccharides, or double sugars, are present in many carbohydrates including ALL grains—not just gluten containing ones. An inflamed, imbalanced gut overridden with Candida is unable to digest double sugar molecules completely because the lack of beneficial gut flora has compromised the function of the enterocytes.

According to Dr. Natasha Campbell-McBride MD, author of *Gut and Psychology Syndrome*, and one of the key scientists at the forefront of gut restoration research today, enterocytes are the cells that reside on the villi of the gut wall and produce the enzyme, disaccharidase, which breaks down the disaccharide molecule into easily absorbed monosaccharide molecules. When the enterocytes are not nourished and strengthened

properly by adequate beneficial flora, they become weak and diseased and may even turn cancerous. Unnourished, enterocytes cannot perform their duties of digesting and absorbing food properly.[16, 17]

The critical importance of the enterocytes to health cannot be overstated!

Weak and diseased enterocytes also have trouble digesting starch molecules, which are very large molecules that consist of hundreds of monosugars, connected in long branchlike strands. People with weak digestion due to Candida overgrowth and messed up enterocytes have a terrible time digesting these complex molecules leaving large amounts of it undigested—the perfect food for pathogenic yeasts, bacteria, and fungi like Candida to thrive upon. Even the starch that manages to get digested results in molecules of maltose, which is—you guessed it—a disaccharide! This maltose also goes undigested due to a lack of the enzyme disaccharidase and becomes additional food for Candida.

We are a few days into the diet. Can someone comment on what they send to daycare with their kids for snacks? Our daycare is nut free as well. We are ok for lunches but what should we take for snacks. The gluten-free pretzels, etc. we were taking he can't have now because of yeast and soy.

Here a few suggestions: Hard boiled eggs, cut up raw veggies and fruit, air popped popcorn, apples, bananas, dried fruits (with no sugar added). Also you can join "CD/CDS MOMS WHAT IS MY KID EATING TODAY" Facebook group. You can find more ideas there.

Chapter 4

An Introduction to Chlorine Dioxide

by Jim Humble

"Condemnation without investigation is the height of ignorance"

-Albert Einstein

Jim Humble, the man behind chlorine dioxide for healing, was kind enough to write the following introduction to our CD section...

I just can't tell you how pleased and proud I am that Kerri has developed protocols using chlorine dioxide as the main ingredient to bring health and normalcy to many children who had the symptoms called autism. Their resulting healing is one of the greatest stories of this and the last century. Kerri's ability to look at something new and to evaluate the value of the new item without being totally affected by the dictates of present established medical science is truly rare. Kerri decided to do something since modern medicine has yet to come up with a reasonable priced globally available solution to the problem of autism that yielded good results. Medical science says that autism is incurable, that millions of children have to be left to suffer and live without reaching their potential. At this writing 115 children have recovered, hundreds more are near recovery and thousands have had documented improvements as a result of being treated with Kerri's protocol.

Here are some basic points:

Chlorine dioxide (the molecule) was discovered in 1814, with many giving credit to Sir Humphrey Davy for its creation, and today several patents exist for healing various ills with it (see list on page 85).

MMS (Master Mineral Supplement) – I rediscovered chlorine dioxide in 1996 and since then more than 1,020 people have traveled from more than 95

countries to the Dominican Republic, Mexico, and other countries, to be trained in its use. By our estimation, more than 10 million people worldwide have used chlorine dioxide.

The highest cost of a set of bottles of sodium chlorite + activator is less than $25 for 4 ounces of each. This means that almost any place in the world the average dose of chlorine dioxide is less than 4 cents, or less than $.40 a day or $25 for 2 months. In most places it is even less than that. So far there is no one in the world who can't afford it or who wouldn't be able to get it merely by asking if they can't afford it.

The chlorine dioxide molecule is the weakest of all oxidizers used in the human body and thus has very little effect on human cells. This molecule has the unique ability to recognize and oxidize (kill) harmful bacteria. Hans Christian Gram, a scientist of the 19th century, discovered that most harmful bacteria have a negative charge. He was able to dye positive and negative bacteria two different colors. His techniques are still used in laboratories and universities. All oxidizers, including chlorine dioxide, have a positive charge that will attract and kill negatively charged bacteria while repelling positively charged bacteria. Chlorine dioxide is thusly able to kill bad bacteria without destroying the good bacteria. This is simple high school science; like charges repel and unlike charges attract.[1]

Most chemicals and many foods in this society are tested to determine their poison index, which is designated by giving them a toxicity number known as LD_{50}. Sugar, table salt, butter, arsenic, cyanide, vinegar, wine, Clorox, window cleaner, and dozens of other household and industrial chemicals are rated as to their toxicity by force feeding 10 rats with the food or chemical in question until ½ of them die. The amount of chemical or food that it takes to kill 5 of the 10 rats determines the LD_{50} number. Every chemical has a toxic rating and is indicated as an LD_{50} number. All chemicals are toxic in large enough quantities and there are a lot of unlucky rats in our society.

There has never been a recorded death caused by ingestion of chlorine dioxide or sodium chlorite in humans. In the case of chlorine dioxide, it would take 1000 times more chlorine dioxide than is used in a daily treatment dose to reach a toxic dose for a human being. The following information is from the *Toxicological Profile for Chlorine Dioxide and Chlorite* (published by the U.S. Dept., of Health & Human Services) which contains LD_{50} toxic numbers for chlorine dioxide along with documentation that no deaths have been caused by chlorine dioxide (Emphasis in italics is the author's):

> *No information was located regarding death in humans following oral exposure to chlorine dioxide or chlorite. Shi and Xie (1999) indicated that an acute oral LD_{50} value (a dose expected to result in death of 50% of the dosed animals) for stable chlorine dioxide was > 10,000 mg/kg in mice.*[2]

I should say something about bleach as a number of critics insist that MMS (chlorine dioxide) is a bleach and thus is a poison. Chlorine dioxide, the chemical that is MMS, has never been used domestically as a bleach for cleaning toilets. It is an industrial bleach when used 4000 times more concentrated than MMS. It is never used for bleaching purposes in the homes of people of this world.

Legally, ethically, morally, and logically, if any item does not have the characteristics of a particular item, it cannot be said to be that kind of an item. This means that a chemical that does not have the characteristics of bleach cannot be called bleach. So a chlorine dioxide solution being 4000 times weaker than that of bleach cannot be called bleach. This is a fact accepted in courts of law of the world.

I sincerely hope you will take the time to understand the basics of chlorine dioxide as explained here. Any time one has helped someone overcome the symptoms of autism he has helped save a life, as those suffering from the symptoms of regressive autism are not living their full lives. The end result of learning this data is that the time may come when you will need chlorine dioxide to save your own life or that of a loved one.

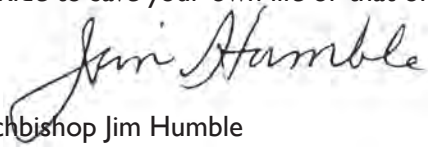

Archbishop Jim Humble

A message from Kerri to Jim Humble

"With all my love, respect and gratitude. You have swum against the current for so long, and I am so fortunate that you waited for me. I will continue to recover these generations of children that are the victims of a senseless epidemic. As you have done, I will do. We can't change the past, but the future is ours. You have brought light to where there once was none."

Chapter 5

Step 2 – Chlorine Dioxide (CD)

"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."
~ Arthur Schopenhauer

CD (chlorine dioxide) is the most amazing intervention that I have ever tried with my son. It by far packed the biggest punch in the shortest amount of time—we saw the positives in under a week with no side effects! (A Herxheimer reaction is not a side effect.) After seven days on CD, my son was looking at me in the eyes and requesting non-preferred activities using four word sentences. I have never, with any other intervention, seen a change in my son come about so quickly, especially since Patrick was your typical non-responder before CD.

The chlorine dioxide molecule (CD).

Why CD for Autism?

We know that the symptoms known as autism are caused by:

- Viruses
- Bacteria
- Candida (yeast)
- Parasites
- Heavy Metals
- Inflammation
- Food allergies

CD catapults children into recovery because it kills these exact things. As of this writing, over three years since we started using CD in our protocol to heal autism, 115 children have lost their diagnosis. Thousands of children around the world are healing, and that means their families are healing as well, and for this I am eternally grateful.

CD has confirmed my faith and has shown me time and time again that autism IS curable. My life has changed since the day my son was able to look me in the eyes, smile, and request things. I could not keep information of this magnitude a secret. I absolutely had to share it with anyone who would listen.

CD is very affordable as you can purchase a two to three month supply from multiple worldwide suppliers on the Internet for around $25USD. The cost difference between the CD Autism Protocol and a megavitamin/supplement based biomedical protocol for a family living without insurance (or in a third world nation) could be the difference between recovering their child and not recovering their child. The results are also vastly different.

You can think of CD as a shortcut to recovery because it kills all pathogens with one shot. Hypothetically, you could use antibiotics, antifungals, and antivirals to get the same results; however, you could also cause damage due to harmful side effects from these products (liver and kidney stress, etc.). Also, antibiotics, antifungals, and antivirals can only target certain bacteria, viruses, and fungi. CD targets all types of pathogens based on their electrical charge and pH. The particular strain is irrelevant.

CD causes no side effects, leaves no toxic residues, and causes no liver damage. It causes no new stress to already stressed bodies. Everything else we use to kill pathogens leaves something behind. For example, antibiotics also kill your beneficial bacteria, and antiviral use comes with contraindications and side effects. CD is gone from the body one hour after your last dose, leaving no trace behind. We dose hourly throughout the day because CD is only active in the body for up to one hour. We must continue to dose if we want to stop the proliferation of pathogens and eliminate them from the body.

A few children with autism in Venezuela recovered using only CD, The Diet, and a probiotic. That doesn't happen every time, but it can.

False Information and the Fear it Creates

The most common reason that families have told me they are afraid of trying CD is because of false propaganda. The FDA, anti-biomed parents, and others have claimed that MMS (Jim Humbles term for a weak concentration of chlorine dioxide in aqueous solution) is a "poison," comparing it to chlorine or chlorine bleach, which it is not.

If you are interested in a deep dive into the science behind chlorine dioxide therapy (also known as MMS), please spend some time on Dr. Andreas Kalcker's websites...

www.medicasalud.com

...mostly in Spanish, though it has a few pertinent documents in English, and...

www.andreaskalcker.com

Also check Jim Humble's website:

www.jimhumble.org

There, you can also find a forum (G2Cforum.org) of people discussing the use of CD (MMS) for the healing of a multitude of ailments.

In a nutshell, chlorine (Cl) and sodium hypochlorite (NaOCl, aka chlorine bleach) are as different from chlorine dioxide (ClO_2) as "required-for-life" oxygen (O_2) and "will-damage-the-lungs" ozone (O_3) are different from each other. Chlorine (Cl) and sodium hypochlorite (NaOCl) destroy pathogens through "chlorination," while chlorine dioxide (ClO_2) destroys pathogens by "oxidation." The by-products of chlorination can bond with other molecules and form potentially carcinogenic trihalomethanes. The only byproducts of oxidation by chlorine dioxide are two neutral oxygen atoms and a chlorite ion, which can bond with sodium in the body to form table salt (NaCl).

Chlorine Dioxide

IS NOT

Laundry Bleach

OR

Pool Chlorine

Your doctor is most likely not a chemist, and may or may not be fluent in the language of oxidizers. If you are working with a doctor, please take the science to them when you speak with them about adding CD to your child's protocol. The best thing we can do for our sick children is to make informed decisions. Understanding the difference between chlorine and chlorine dioxide, or chlorine bleach and chlorine dioxide may mean the difference between your child recovering or not.

I have shared this with thousands of families around the globe whose children have used chlorine dioxide in very dilute aqueous solutions, and NONE have had any injuries from CD. Sure, we have had discomfort in the form of a Herxheimer reaction. This is something we have learned to minimize, and can often be prevented by going low and slow. I have learned that what may appear negative at the outset, often turns out to be a healing crisis that leads to incredible gains in the long run.

Many of the first world children who have done the CD protocol have done it in parallel with other autism protocols. They have had regular blood, urine, and stool tests and generally test healthier while using CD than before they started. CD is fortifying immune systems, improving liver function, reducing bacterial and viral loads, *Candida* markers, and inflammation.

> Just did round of blood tests on my son,
> Liver Function Test best ever after 7 months of MMS.

Critics also frequently cite the fact that sodium chlorite and chlorine dioxide can be used for industrial bleaching processes, as a way to frighten parents out of using it. Just because a substance has the power to remove color, or bleach something, doesn't mean it's "bleach." Lemon, sunlight, hydrogen peroxide, and toothpaste all remove color from textiles. We would never call toothpaste bleach, even though it's capable of removing color, nor would we call sunlight bleach, even though that's what it can do to your clothes if you leave them outside long enough. From here we can draw a very similar analogy to using chlorine dioxide for health. The dilutions we are using for internal consumption in aqueous solution (water) are very weak. Day one starts with just one drop in eight fluid ounces of water.

The 1984 study, *Controlled Clinical Evaluations of Chlorine Dioxide, Chlorite and Chlorate in Man*, found no deleterious effects when taking a concentration of up to 50ppm over several hours a day for three weeks.[1] As Jim Humble

mentioned (see page 79), the concentrations used for industrial purposes are are thousands of times more concentrated than what families have been using for their children on the spectrum.

Any substance can become toxic if taken in too high a concentration—even water.[2,3] Chlorine dioxide is no exception. We always increase CD dosages, *low and slow*, and have a respect for the power that chlorine dioxide can have over pathogens, always resisting the urge to ramp up our dosing too quickly.

> We started MMS 68 Days ago and my son's ATEC has dropped from 50-23... Now that's a MIRACLE!!! He is So much more "with us" and I'm seeing improvements daily. He is just so much more fun to be with now:) He did have a plateau, but is back on track. We have only done 4 enemas to date, but they made a big difference! Baths do as well:) I can't wait to see what he is like on his 4th birthday (still 39 days away).

Chlorine Dioxide was discovered in 1814 by Sir Humphrey Davy as an effective disinfectant. Since then, numerous companies have patented its use for countless applications, including food and health.

The following is an excerpt from Jim Humble's Nov 21, 2012 newsletter:

> Dr. Andreas Kalcker spoke of patents obtained by different multinational pharmaceutical companies, to cash in on this product or to prevent it from being marketed.
>
> Some of those patents include:
>
> - Nontoxic Antiseptic (Pat 4035483/1977)
> - For combatting human amoebas (Pat.4296102/1981)
> - Against dementia caused by AIDS (Pat.5877222/1999)
> - For curing all types of illness of the skin (Pat 4737307/1988)
> - For disinfecting live blood (Pat. 5019402/1991)
> - For curing injuries more rapidly (Pat. 5855922/1999)
> - For all types of oral care (Procter & Gamble) (Pat. 6251372B1/2001)
> - Against infections caused by bacteria (Pat. 5252343/1993)
> - For treatment of severe burns (Pat.4317814/1982)
> - For the regeneration of bone marrow (Pat. 4851222/1989)
> - Treatment of Alzheimers, dementia etc. (Pat. 8029826B2/2011)
> - To stimulate the immune system in animals (Pat. 6099855/2000)
> - To stimulate the immunological system (Bioxy. Inc.) (Pat. 5830511/1998)

> ...The danger that may occur is if one mistakenly used a highly concentrated form. Highly concentrated forms of virtually every substance can cause death. In his conference, Dr. Andreas Kalcker points out that 70g of even plain table salt can cause death.
>
> There have been thousands of reports worldwide of excessive doses of MMS being ingested, however, with the hundreds of millions of tons of this substance used each year worldwide for water purification, preservation of vegetables, sterilization of slaughtered meat, and hundreds of other uses, there has never been a report of a death caused by ingestion of chlorine dioxide.
>
> This proves chlorine dioxide to be one of the safest products known.

There are many products that contain chlorine dioxide (ClO_2) that are currently approved by the Food and Drug Administration (FDA) in US. They are manufactured by *Frontier Farmaceutical*, *Alcide*, *Bioxy*, and others for skin and oral care. A number of these product names are listed below: [4]

- DioxiRinse™ Mouthwash
- DioxiBrite™ Toothpaste
- DioxiWhite™ Pro Teeth Whitener
- WhiteLasting™ Maintenance Gel
- BioClenz™ Dental Unit Waterline Cleaner
- Penetrator™ Periodontal Gel
- Simply Clear™ Acne Treatment
- DioxiWhite™ Home Teeth Whitener
- Cankers Away™ Canker Sore Cure
- DX7™ Skin Protectant Gel
- Periodontitis Treatment
- DioxiSmooth™ Facial Exfoliant
- Gingivitis Treatment Surface Disinfection
- Fire Fighter™ Burn Pain Reliever
- DioxiGuard™ Spray Disinfectant
- Nail-It™ Nail Protector

Chlorine Dioxide is an Oxidant… But aren't Antioxidants Good for Us?

In 1954, Denham Harman published an article called the "Free Radical Theory of Aging,"[5] claiming antioxidants would slow the aging process. However, he later found that mitochondria determined life span, and that antioxidants do not enter the mitochondria, and subsequently published the

"Mitochondrial Theory of Aging,"[6] in 1972. The "Free Radical Theory of Aging" is still responsible for billions of dollars in antioxidant supplement sales a year. While writing this book, a fascinating article was published in the journal *Open Biology* by Dr. James Watson (of Watson and Crick) called "Oxidants, antioxidants and the current incurability of metastatic cancers."[7]

Watson sets forth a hypothesis that links the presence of antioxidants in the body with late-stage (metastatic) cancer. He points out that some successful cancer treatments use "free radical" molecules to treat cancer—the very same molecules that antioxidants attack and kill. Watson urges his readers of the new paper to consider the following: "Unless we can find ways of reducing antioxidant levels, late-stage cancer 10 years from now will be as incurable as it is today."[8]

The following was excerpted from the same article in *Open Biology*.[8] Please see the original document for references contained within the text.

> Free-radical-destroying antioxidative nutritional supplements may have caused more cancers than they have prevented.
>
> For as long as I have been focused on the understanding and curing of cancer (I taught a course on Cancer at Harvard in the autumn of 1959), well-intentioned individuals have been consuming antioxidative nutritional supplements as cancer preventatives if not actual therapies. The past, most prominent scientific proponent of their value was the great Caltech chemist, Linus Pauling, who near the end of his illustrious career wrote a book with Ewan Cameron in 1979, *Cancer and Vitamin C,* about vitamin C's great potential as an anti-cancer agent [52]. At the time of his death from prostate cancer in 1994, at the age of 93, Linus was taking 12 g of vitamin C every day. In light of the recent data strongly hinting that much of late-stage cancer's untreatability may arise from its possession of too many antioxidants, the time has come to seriously ask whether antioxidant use much more likely causes than prevents cancer.
>
> All in all, the by now vast number of nutritional intervention trials using the antioxidants β-carotene, vitamin A, vitamin C, vitamin E and selenium have shown no obvious effectiveness in preventing gastrointestinal cancer nor in lengthening mortality [53]. In fact, they seem to slightly shorten the lives of those who take them. Future data may, in fact, show that antioxidant use, particularly that of vitamin E, leads to a small number of cancers that would not have come into existence but for antioxidant supplementation. Blueberries best be eaten because they taste good, not because their consumption will lead to less cancer.

Don't Oxidants Cause Oxidative Stress?

Not necessarily. Dr. Andreas Kalcker presented us with another theory explaining why oxidative stress is caused by pathogens and parasites rather than oxidants. If you take an oxidant such as CD, it is likely to upset the parasites living in the intestinal tract, causing them to defecate. Waste from worms can contain many toxic substances including MDA (malondialdehyde), formaldehyde, and ammonia. These toxins are known to cause oxidative stress.[9,10,11,12] When parasites are present in the body they are releasing these toxins, even if we don't kill them. Parasitic presence in the body is responsible for many of the symptoms known as autism.

Oxidants themselves are not directly responsible for oxidative stress in the body. However, they can exacerbate oxidative stress, which can cause parasites in the body to release toxins. The solution is to get rid of the parasites. Please see Chapter 8 for an effective Parasite Protocol.

Chlorine Dioxide & Antioxidants

Although antioxidants have their place in personal health and are common in many foods and supplements, they cannot be taken at the same time with chlorine dioxide—they negate each other. This is why vitamin C, juices, and other antioxidant containing foods are prohibited in *The Diet*.

Just a testimonial to MMS: For those of you new to the group and still unsure of the MMS protocol I wanted to tell you about us. I was afraid at first, but we decided to try MMS. Within 3 weeks my son went from an ATEC of 36 to 18! That was amazing. Then we were afraid of the enemas. We said no way, we would just do oral MMS. Of course, after seeing others progress here we decided to do them. He would calm down! Then for months we agonized over the PP. We were afraid of it. We were scared of the meds, everything. Finally we decided to try it too. We are in the middle of our first PP and our son, who used to hit, kick, bite and scream at me over the smallest things all the time, has now been a perfect joy. When he gets mad it is over quickly and does not escalate into world war 3. Also these bumps he had on his face have cleared up along with his attitude! So if you are unsure of MMS like I was, here is one more testimonial of just how good the protocol really is. Thanks Kerri, and all the other moms that came before me!

Herxheimer Reaction (Die-Off Reaction)

There are many stories on the Internet about the "side effects" of CD. The definition of a side effect is:

The unintended or secondary effects of a substance.

When people describe what they believe to be side effects of CD, they are actually talking about a Herxheimer reaction. Jim Humble's original chlorine dioxide (MMS) protocols called for higher doses per hour ramped up much faster than we titrate up for autism. In some cases that resulted in nausea, vomiting, and/or diarrhea. Critics of CD claim that a Herxheimer reaction, which is the result from ramping up too quickly, is the body's reaction to being 'poisoned' by chlorine dioxide.

This is absolutely not the case, as the aforementioned study by Judith R. Lubbers and colleagues found that when healthy individuals were given minimal doses of chlorine dioxide in increasingly higher concentrations, no deleterious effects were noted.[2]

A Herxheimer reaction indicates that the patient is suffering from an overload of pathogens/toxins. If the person taking CD has a fair amount of pathogens, the rapid killing of these invaders produces excess toxins in the bloodstream. It is these substances that the body wants to rid itself of in short order. People with autism often have impaired methylation cycles that reduce their ability to eliminate toxins, making it even more difficult to handle an influx of toxins. So LOW AND SLOW is the way to go.

Children with autism typically don't (or can't) tell you they have nausea. However, discomfort may be visible from seeing that they're eating less, their eating habits have changed, or they're more listless than usual. That's usually a sign of detox, and in which case, we won't give the child any more CD that day. Detox is great, it's what we want, but without stressing the body further. We need to stay just beneath a Herxheimer reaction.

A Herxheimer reaction can present itself in many forms including:

- Blisters
- Bloating
- Burping
- Chills
- Diarrhea
- Fatigue
- Flatulence
- Flushing
- Headache
- Heart Burn
- Hiccups
- Nausea
- Runny nose
- Sleep changes
- Vomiting

If any of these symptoms appear, suspend the remaining doses of CD for the rest of the day. The following day, return to the number of doses given when the child was stable, which is usually the dose that was given the day prior to the Herxheimer reaction.

To mitigate a Herxheimer reaction from chlorine dioxide, you can give vitamin C or orange juice, as either one of these will cut the effects of CD immediately. To help bind the excess toxins you may want to try activated charcoal, bentonite clay, (be aware that these both can cause constipation), or burbur (a liquid detox extract).

Using Chlorine Dioxide for Autism

As I developed this protocol, it became clear to me that we needed to focus on excesses causing the symptoms of autism, rather than deficiencies caused by them. In the autism biomed world, we are accustomed to supplementing deficiencies (low iron, low B_{12}, low calcium, etc.), without questioning why the deficiency exists in the first place (i.e., presence of pathogens/parasites).

As soon as a family completes one week on *The Diet*, we get right into CD. Everyone starts with the "baby bottle" method, one drop of CD in eight fluid ounces of water, which makes the first day's dose 1/8 of a drop at a time. We have greatly minimized Herxheimer reactions by using this method, but it remains very important to monitor your child while they are using chlorine dioxide. It's very important to go low and slow. Every drop we give is helping to heal our children.

What is Chlorine Dioxide (CD)?

Refer to the diagram on the right for a visual overview.

You can't actually buy CD. You have to make it. Fortunately, it's not a big deal. If you can make coffee... you can make CD, which stands for *chlorine dioxide*.

Chlorine dioxide (ClO_2), is a gas produced through a chemical reaction when two liquids, sodium chlorite ($NaClO_2$) and an acid (such as hydrochloric acid (HCl) or citric acid ($C_6H_8O_7$)), are mixed. The acid brings the combined pH level below five, causing the sodium chlorite to become unstable and release chlorine dioxide (ClO_2).

If any of this sounds complex, it isn't. Go through the following explanation and don't get bogged down by the chemical symbols.

Conceptual Overview of Chlorine Dioxide (CD)

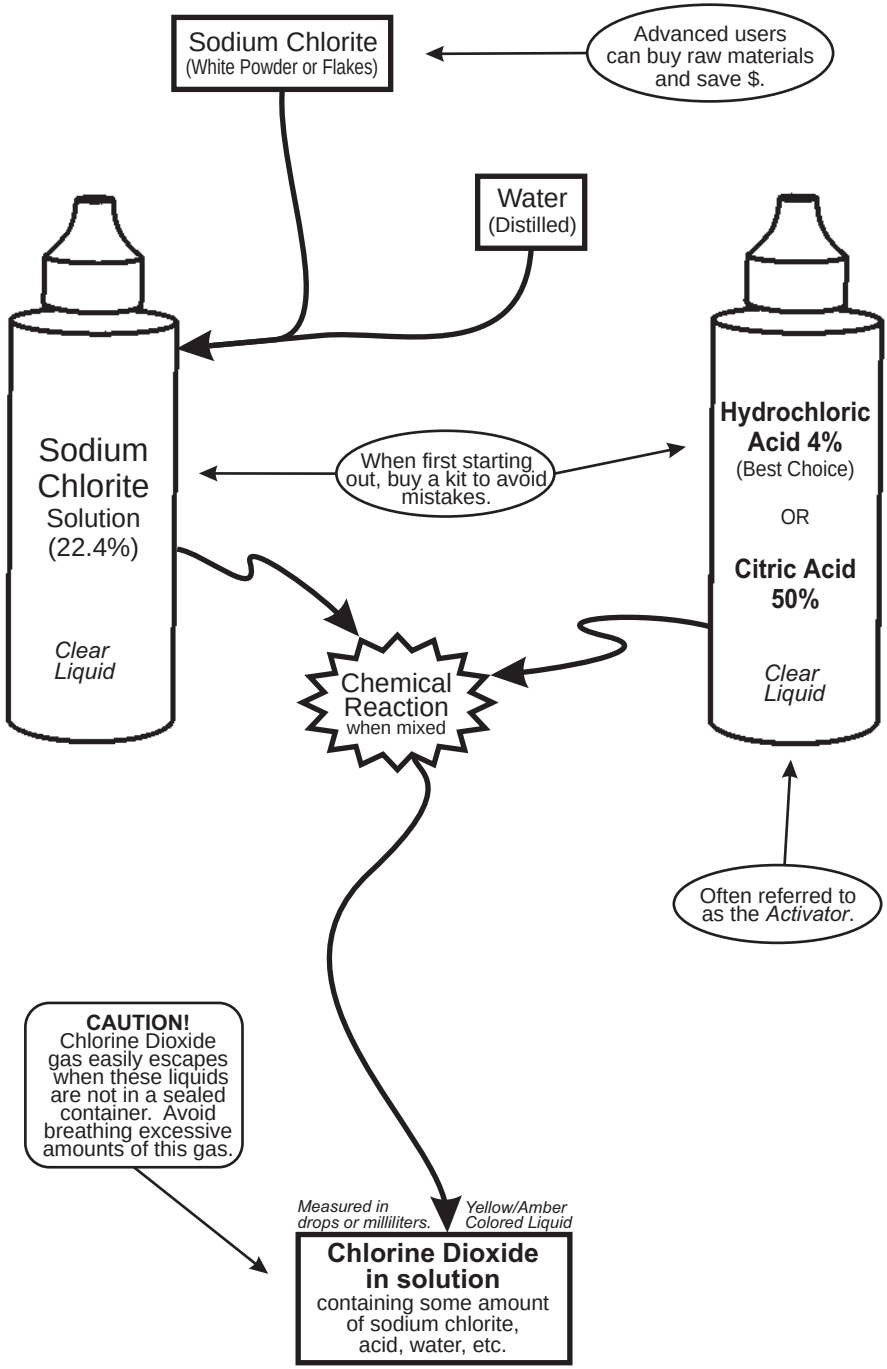

Sodium Chlorite ($NaClO_2$)

This is the first chemical you must have to make CD.

You can get it in one of two forms:

- **Sodium chlorite liquid in water:**
  - If you are beginning, get a starter kit of this.
  - Expect to pay about $20-$30 for a 4 fl. oz. bottle set (usually includes acid activator).
  - 22.4% sodium chlorite solution (from 28% technical grade sodium chlorite salts).
  - Recommended: Buy quart or liter sized quantities of liquid once you understand the principles.
- **Sodium chlorite powder or flakes:**
  - FOR ADVANCED USERS ONLY!
  - Cheaper in the long run.
  - Recommend buying 5 lbs. of flakes/powder for a cost of about $100-$200.
  - Look online or check with your supplier for mixing instructions.
  - Avoid buying 90% sodium chlorite flakes. You want 80%. Most suppliers that sell liquid also sell flakes.
  - NEVER mix any acid directly with powder/flakes!

What's the 28%? 22.4%?

This is not a critical thing for you to worry about unless you are mixing your own. But here is the jist: sodium chlorite powder is not 100% sodium chlorite. It's usually 80% sodium chlorite and 20% salt and other inert ingredients. When diluted in water, you end up with 28% solution of powder, but only 22.4% is sodium chlorite. Labels usually show one or both of these numbers.

Sodium Chlorite Flakes vs. Powder

Sodium chlorite flakes and sodium chlorite powder are the same thing. The resulting physical consistency may vary by different manufacturers. We've even seen clumps of powder. It's still the same chemical. The important part is that it is technical grade, and 80% of the powder/flakes should be sodium chlorite ($NaClO_2$). Mixing info is at: *www.youtube.com/watch?v=t0C8XVm9QVE*.

Acid - The Activator

To produce CD, you must add the second chemical, which is a food acid, to the liquefied sodium chlorite (22.4% solution in water). Chlorine dioxide gas is produced when the pH of the sodium chlorite goes below five. We call the acid used to lower the pH of sodium chlorite an "activator" because it activates the sodium chlorite to produce the chlorine dioxide.

There are several activators to choose from. These are food acids in that they are commonly found in food preparations, or are actually food:

- **Hydrochloric Acid (HCl)**
  - The same acid found in your stomach, and therefore, the most biocompatible option.
  - Working concentration is between 4% and 10%.
  - Available on the market in liquid concentrations of 4%, 5%, 10%, 32%, 35%, and 37%.
  - Any concentration over 10% must be reduced to a working concentration of between 4% and 10%. See Appendix 7, page 471. (Note: We use 4% for CD and CDH; & 10% for CDS.)
  - Only available in liquid form.
- **Citric Acid**
  - Commonly available around the world.
  - Often found in soft drinks to give them a tangy flavor.
  - Some people have problems tolerating this acid.
  - Usually used in 50/50 concentration by weight mixed in water.
  - Available in liquid and powder form.
  - Inexpensive; can be purchased online.
- **Lemon or Lime Juice**
  - Consider this an emergency alternative to be used if the first two choices are not available.
  - Can be found in most stores carrying produce.
  - Should be from pure, organic and freshly squeezed lemons (or limes).
  - Relatively weak acidity requiring five drops of lemon juice to every one drop of sodium chlorite solution.
  - Substantially longer activation time.
  - Lower ClO_2 output.

The amount of acid used, and the length of time you wait to dilute the mixture, will depend on the acid activator and its strength. The following chart gives you an idea.

Activator	Strength	Ratio	Time
Hydrochloric Acid	10%	1:1	40 secs
Hydrochloric Acid	4%	1:1	60 secs
Citric Acid	50%	1:1	60 secs
Citric Acid	33% or 35%	1:1	60 secs
Lemon Juice	Pure	1:5	120+ secs

You are unlikely to be using lemon juice, but we've included it here for completeness.

Families should use whichever activator is available to them depending on where they live and what they have access to. All kids are different, so if yours doesn't respond well to 4% HCl, by all means, try citric acid, or vice versa.

If the HCl you purchased is anything other than 4% or 5%, then see Appendix 7 for instructions on reducing concentration.

If you are using one of the two most commonly available activators, then you are likely to be using a 1:1 mixing ratio (1 drop sodium chlorite + 1 drop activator).

In the case of 10% citric acid or pure lemon juice, you would be using five drops of activator to one drop of sodium chlorite, and waiting about three times as long as if you were using one of the newer, more concentrated activators.

Purchasing Product

When you first start out, you should buy a starter kit and get familiar with the chemistry. A starter kit usually comes in two bottles of four fluid ounces each.

1. Sodium chlorite, (4 fl. oz.)
2. Activator (hydrochloric acid or citric acid), (4 fl. oz.)

The bottles look something like those shown in the diagram on page 91. Getting the hydrochloric acid activator is slightly preferable.

You will also need an 8 fl. oz. baby bottle. This is a handy tool for storing a day's worth of CD doses with the added benefit of having marks that show how much it contains. Glass bottles are much better than any kind of plastic bottle. Lifefactory.com (shown on the right) produces a bottle we especially like. It is made of silicon-covered glass and has a reliable top. This particular bottle is marked as having a capacity of nine fl. oz., but we use it up to only eight fl. oz. Plastic should only be used for lids; avoid bottles with metal tops. Over time, CD will oxidize metals so they can't be used.

Another item that most people have at home is a shot glass or wine glass that tapers down in the middle like a "U" shape. This will be used to mix the chemicals and the tapered shape insures that even as few as two drops will find each other. You can also use a cup with a flat bottom, but must tilt it so both solutions pool together.

A standard shot glass with a "U" shaped bottom is the preferred mixing container for CD & activator. A glass baby bottle, such as the one made by Lifefactory®, is the ideal dosing bottle.

Terminology of Available Products

There can be a bit of confusion for some as to what to look for and buy. The following chart shows the actual chemical, and some of the common names found on the label. There may be other names we are not aware of. In most cases, the chemical and its strength are identified on the bottles.

Common Activators & Their Various Names on the Market	
Chemical	**Common Names**
Sodium Chlorite	Chlorine Dioxide – Part 1 (Purifier) Master Mineral Solution Miracle Mineral Solution Miracle Mineral Supplement MMS MMS Drops MMS Solution MMS Water Purification Drops MMS1 NaClO2 Natriumchlorit (German) Pathogen Biocide Sodium Chlorite 28% Water Purification Drops Water Purificator
Hydrochloric Acid	Activator Chlorine Dioxide – Part 2 (Activator) MMS Activator
Citric Acid	Activator Citric Acid – 20% Citric Acid – 50% MMS Activator

Checklist for Preparing a CD Dose

Assuming you have received the starter kit, it's time to make your first dose. Here's the check list of what you now should have on hand before you begin:

- ❑ Bottle of sodium chlorite solution (28% sodium chlorite salts / 22.4% sodium chlorite)
- ❑ Bottle of acidic activator (hydrochloric acid or citric acid)
- ❑ A clean and dry shot-glass with a "U" shaped bottom.
- ❑ 8 fl. oz. glass baby bottle.
- ❑ Distilled or reverse osmosis water (filtered water will do, but no alkaline water!).

A Few Points Worth Noting!

Looking at the short checklist above, it should be apparent that this is not going to be rocket science. Nevertheless, a few pointers are in order:

- In the past, people who used CD for various things would mix a fresh batch each time they took CD. This involved a lot of extra work that could be avoided by producing one batch big enough to last the entire day. For this exercise, we are assuming you are starting out and going to do things low and slow. We are going to produce 8 fl. oz. of water solution

containing one drop of CD, with the intention of your child consuming one fl. oz., of water (containing 1/8 drop of CD) eight times throughout the day.

- When you mix sodium chlorite solution and the acidic activator, you are mixing equal drops of each substance (unless you are using one of the less concentrated activators mentioned earlier).
- CD doses are measured in drops of sodium chlorite. So one drop of sodium chlorite + one drop of activator = one drop of CD.
- On your first day, start with one drop of sodium chlorite and one drop of activator (in other words—ONE drop of CD).
- If you put in too many drops of one solution or the other, start over with a clean and dry shot glass.
- A batch of CD is good for 24 hours. <u>However, you must keep the cap on tight!</u>
- Keep the bottle with the daily CD batch out of direct sunlight. A brief exposure won't ruin it, but it will become weaker. Why? The chlorine dioxide gas will come out of the water and sometimes form a cloud in the air pocket of the bottle. No need to worry if you see the cloud—it's a common occurrence.

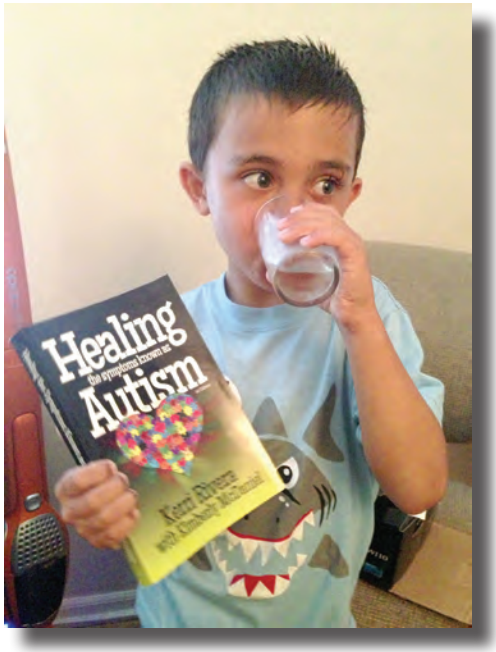

Vincent taking his hourly dose.

Preparing Your First One drop CD Batch for the Day

1.	Start by filling the baby bottle with 8 fl. oz. (237ml) of water (distilled or reverse osmosis). NO alkaline water!	
2.	Place 1 drop of sodium chlorite solution into the CLEAN and DRY shot glass.	
3.	Add 1 drop of acidic activator (hydrochloric acid or citric acid) to the shot glass containing the drop of sodium chlorite. The number of drops may be higher if you are using a weaker activator. See chart on page 94.	
4.	Now wait the appropriate time for the mixture to react (see chart on page 94). You should see the color change from clear to slightly yellow. If there were more drops in the shot glass, the color change is more noticeable. You are also likely to notice the chlorine-like smell coming from the shot glass. Remember, this is NOT chlorine, but rather chlorine dioxide.	
5.	After the activation time has passed, pour a little water from the baby bottle into the shot glass and let it mix. This mostly stops the chemical reaction and insures you get most of the mixture out in the next step.	
6.	Lastly, pour all of the watered down mixture in the shot glass back into the baby bottle, and seal it tightly with the cap—don't leave it sitting open for any length of time. Think partially used soda pop and how you would want to keep that closed.	

Voilà! You have just produced your first batch of CD!

This is now a ONE drop batch, that makes EIGHT hourly doses—each 1/8 of a drop in strength. If your batch is larger; your hourly dose is stronger:

- 2 drop batch = 8 hourly doses of 1/4 drop
- 4 drop batch = 8 hourly doses of 1/2 drop
- 8 drop batch = 8 hourly doses of 1 drop

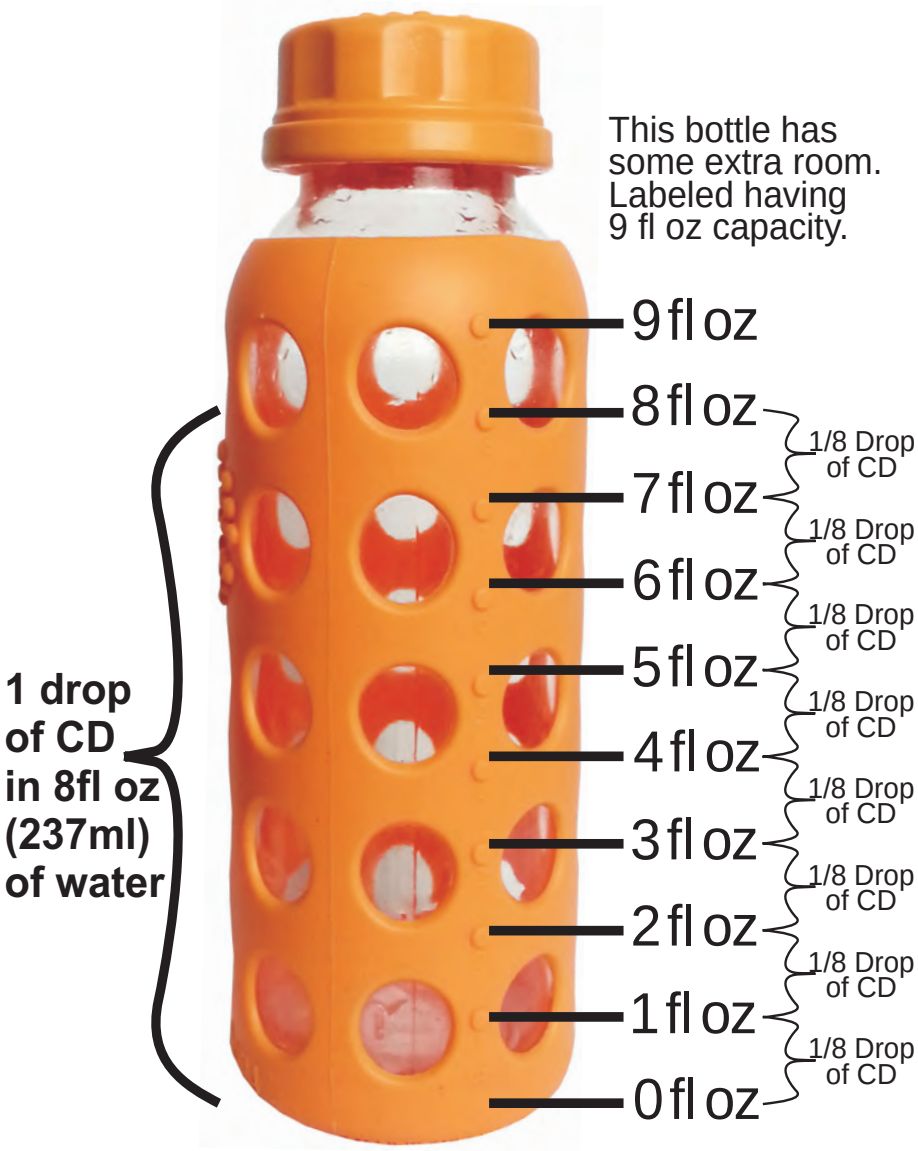

Oral Protocol for CD in Autism Spectrum Disorders (ASDs)

In the previous exercise, you learned how to prepare the dose for Day One. Children and adults all start by taking only one drop of CD divided into eight hourly doses. On Day Two, you make a batch of two drops sodium chlorite plus two drops activator and mix that into eight fluid ounces of water. Increase this dosage by one drop per day, unless you see a Herxheimer reaction (see page 89 for more information).

The chart on the right allows you to determine the estimated full oral CD dose based on the weight of the individual. This gives you an idea of the maximum goal number of drops per day for your child. Once the child has been at the full suggested dose for several months, we may need to increase again, by a few drops, to prevent a plateau.

Important Note: Some children can't go up by one drop each day and need to go slower. A child may have a relatively higher toxic load, or he may be extremely sensitive. Whatever the case, resist the urge to try to get to full oral dose as quickly as possible. This is not a race! Some children need to spend a few extra days at the same dose to avoid a Herxheimer reaction. Even if you must remain at one level for a few days or more does not mean you are making no progress. Whatever the level of dosage, you are detoxing the body.

When you get within two to three drops of your child's maximum dose by weight, go ahead and spend three days at each dose, while carefully observing your child, moving up only when your child is stable. For example, if the full dose is 16 drops in the 8 fl. oz. (237ml) baby bottle, stay at 14 drops for a few days to see how that dose level is tolerated, and then increase every third day till reaching the full dose. If the person is better at a drop or two below the calculated full dose, go back to that lower dose that they tolerated best.

Just had a fascinating appointment with my son's functional neurologist. My son had this third Qeeg today, which clearly showed that previously under-stimulated parts of his brain are 'waking up'. I told our doctor about CD very early on and he believes that it is THIS that is having such a huge impact on his brain. He got quite emotional and said 'every time you get a worm, you are saving your son. Keep doing what you're doing, cause he clearly isn't autistic. He's poisoned'. Goosebumps!!

Estimated Full Oral CD Doses by Weight

Use these numbers as a guide only. You may need to go up by as much as 50% or more over the indicated drops. Read chart as: **POUNDS / KILOGRAMS → DROPS OF CD (per 8 fl. oz. water)**

25/11→8	62/28→17	99/45→24	136/62→29	173/78→33	210/95→37
26/12→8	63/29→17	100/45→24	137/62→29	174/79→33	211/96→37
27/12→9	64/29→17	101/46→24	138/63→29	175/79→34	212/96→37
28/13→9	65/29→18	102/46→24	139/63→30	176/80→34	213/97→37
29/13→9	66/30→18	103/47→24	140/64→30	177/80→34	214/97→37
30/14→9	67/30→18	104/47→25	141/64→30	178/81→34	215/98→37
31/14→10	68/31→18	105/48→25	142/64→30	179/81→34	216/98→37
32/15→10	69/31→18	106/48→25	143/65→30	180/82→34	217/98→37
33/15→10	70/32→19	107/49→25	144/65→30	181/82→34	218/99→38
34/15→10	71/32→19	108/49→25	145/66→30	182/83→34	219/99→38
35/16→11	72/33→19	109/49→25	146/66→30	183/83→34	220/100→38
36/16→11	73/33→19	110/50→26	147/67→31	184/83→35	221/100→38
37/17→11	74/34→19	111/50→26	148/67→31	185/84→35	222/101→38
38/17→11	75/34→20	112/51→26	149/68→31	186/84→35	223/101→38
39/18→12	76/34→20	113/51→26	150/68→31	187/85→35	224/102→38
40/18→12	77/35→20	114/52→26	151/68→31	188/85→35	225/102→38
41/19→12	78/35→20	115/52→26	152/69→31	189/86→35	226/103→38
42/19→12	79/36→20	116/53→26	153/69→31	190/86→35	227/103→38
43/20→13	80/36→21	117/53→27	154/70→31	191/87→35	228/103→38
44/20→13	81/37→21	118/54→27	155/70→31	192/87→35	229/104→38
45/20→13	82/37→21	119/54→27	156/71→32	193/88→35	230/104→39
46/21→13	83/38→21	120/54→27	157/71→32	194/88→35	231/105→39
47/21→14	84/38→21	121/55→27	158/72→32	195/88→36	232/105→39
48/22→14	85/39→21	122/55→27	159/72→32	196/89→36	233/106→39
49/22→14	86/39→22	123/56→27	160/73→32	197/89→36	234/106→39
50/23→14	87/39→22	124/56→28	161/73→32	198/90→36	235/107→39
51/23→15	88/40→22	125/57→28	162/73→32	199/90→36	236/107→39
52/24→15	89/40→22	126/57→28	163/74→32	200/91→36	237/108→39
53/24→15	90/41→22	127/58→28	164/74→32	201/91→36	238/108→39
54/24→15	91/41→23	128/58→28	165/75→33	202/92→36	239/108→39
55/25→16	92/42→23	129/59→28	166/75→33	203/92→36	240/109→39
56/25→16	93/42→23	130/59→28	167/76→33	204/93→36	241/109→39
57/26→16	94/43→23	131/59→28	168/76→33	205/93→36	242/110→39
58/26→16	95/43→23	132/60→29	169/77→33	206/93→37	243/110→39
59/27→16	96/44→23	133/60→29	170/77→33	207/94→37	244/111→40
60/27→17	97/44→24	134/61→29	171/78→33	208/94→37	245/111→40
61/28→17	98/44→24	135/61→29	172/78→33	209/95→37	246/112→40

Serving Cup Dilution

Don't have your child drink out of the baby bottle. Pour the hourly dose into a separate cup and add extra water if needed. Make sure to add water to each dose to ensure that there is a **minimum** of one fluid ounce of water per activated drop of CD. However, there is no maximum amount of water for dilution. To be absolutely clear about this, note the following chart which assumes eight fl. oz., daily batches containing eight hourly doses.

Drops of CD in Batch	Hourly Dose	Min. Water Dilution
1	1/8 drop	1 fluid ounce
2	2/8 drop	1 fluid ounce
3	3/8 drop	1 fluid ounce
4	4/8 drop	1 fluid ounce
5	5/8 drop	1 fluid ounce
6	6/8 drop	1 fluid ounce
7	7/8 drop	1 fluid ounce
8	1 drop	1 fluid ounce
9	1 1/8 drops	2 fluid ounces
10	1 2/8 drops	2 fluid ounces
11	1 3/8 drops	2 fluid ounces
12	1 4/8 drops	2 fluid ounces
13	1 5/8 drops	2 fluid ounces
14	1 6/8 drops	2 fluid ounces
15	1 7/8 drops	2 fluid ounces
16	2 drops	2 fluid ounces
17	2 1/8 drops	3 fluid ounces
18	2 2/8 drops	3 fluid ounces
19	2 3/8 drops	3 fluid ounces
20	2 4/8 drops	3 fluid ounces
21	2 5/8 drops	3 fluid ounces
22	2 6/8 drops	3 fluid ounces
23	2 7/8 drops	3 fluid ounces
24	3 drops	3 fluid ounces
25	3 1/8 drops	4 fluid ounces
26	3 2/8 drops	4 fluid ounces
27	3 3/8 drops	4 fluid ounces
28	3 4/8 drops	4 fluid ounces
29	3 5/8 drops	4 fluid ounces
30	3 6/8 drops	4 fluid ounces
31	3 7/8 drops	4 fluid ounces
32	4 drops	4 fluid ounces

CD is active in the body for about one hour and, as result, hourly doses give us the best progress. This is difficult on school days, but we recommend that you dose two to three times before school and the rest after to distribute the pathogen-fighting more evenly. Eight doses a day is the minimum requirement, but the more you can fit in the better. Try to dose every hour as much as possible.

Special Cases: "The Double Dose"

As a child goes through the detox process, they may exhibit conduct which can include hyperactivity, anxiety, OCD, aggressiveness, and night wakings. In these cases, a double dose is 2 fl. oz. (60ml) of the baby bottle given at once. For example, if your child receives one drop per fluid ounce of the baby bottle method, they will be receiving 2 drops. Let's say for example your child wakes up at 1am, give them a double dose. If your child is still awake at 2am, give another dose. The most common scenario is that after 1 or 2 double doses, the child will fall back asleep. This helps oxidize the toxins from the die-off. During the day if your child has a tantrum or other issues with conduct, we can double dose every hour as well.

CD has two functions with pathogens; one is that is oxidizes the pathogen itself, and the second is that it oxidizes the toxins released by the pathogens while they are living, dead, or dying.

Advanced Protocol – The Enema!

In early 2011, we added enemas to the protocol to kill the pathogens causing dysbiosis in the large intestine (we didn't know about parasites yet). We wanted to get the chlorine dioxide into the blood stream so it could kill the biofilm that exists in the blood. In this way, the blood can carry the CD past the blood-brain barrier to kill pathogens in the brain

When we are detoxing, it is absolutely critical to keep the colon moving and avoid the reabsorption of toxins through the intestinal walls. Enemas allow us to do just this. Some toxins can exit the intestine through the intestinal wall (more so if leaky-gut syndrome is present), and cross the blood-brain barrier, therefore affecting cognition and behavior. When we cleanse the colon, we get those out before they can cross into the brain, and we detoxify the lymphatic system, liver, and gallbladder.

The Enema Stigma

When I say the word enema to a family new to the protocol, I often hear things like "*I could never do that!*," or "*My son would never let me do an enema.*" I assure you it's not traumatic as it has been hyped up to be. Modern society has gotten away from it, but for millennia, cleansing the colon was considered part of daily hygiene. Enemas were mentioned in the Vedas, the Bible, and by the Mayans. The reason for doing CD enemas is NOT for relief of constipation. Of course, when constipation is present, CD enemas can relieve the cause of constipation.

> Great news! First enema today...
>
> My son was so happy that we did and the first thing he said while sitting on the toilet was: "Mommy! IT WORKED!!!" hahaha He is so used to sitting on the toilet and having such a hard time. Poor thing, he was so happy that IT WORKED!
>
> And he even said he wants to do it again tomorrow. He felt so much better and ate so much more for dinner with an empty stomach. I think he got rid of stuff that was there for ages! His tummy is now soft and not hard as usual. Quite amazing and it didn't bother him at all.
>
> Today his molar hasn't bothered him so a perfect day to start the enemas! His appetite has gone up quite a bit. He has seldom asked for food before and now he asks a few times a day for something to eat. The diet is going wonderfully and he is now used to the change of foods. He asks about cheese and milk but I try to talk about something else to distract him so he eventually stops asking. hahaha He hasn't gotten upset about food he wants (that he can't have) not even once. YAY!

I would like to clear up one thing here before we get in the mechanics of the enemas. More than one person has asked in the blogosphere, "*If Kerri Rivera loves enemas so much, why doesn't she do them on herself???*" As a matter of fact I do! I have done my own enemas for years, so has my husband, my sister, and plenty of the parents using this protocol for their children. We understand the benefits of a fit colon, and have no problem applying our own enemas or going for a colonic from time to time.

Actually, I would strongly advise you to practice on yourself. That way you know from first-hand experience that this is really no big deal. You will also

discover how much better you feel after cleaning out your colon, and you will understand when your child feels better as well.

When to Start Giving Enemas

Enemas should be started when the child reaches full oral dose.

However, if your child suffers from constipation you can add enemas and baths on day one (see page 113), before you get to the full oral dose. However, alternate them on opposite days or opposite ends of the day.

Frequency of Enemas

I recommend enemas no less than once every other day. You may need to do them more often, particularly if you see parasites coming out. Doing as many as four in a day is not uncalled for if each one results in parasites being released. Some of the older children seem to pass a lot of parasites in one day, typically in or around a full or new moon.

Timing of Enemas

If your child is going to school, avoid giving an enema in the morning since they may need to visit the toilet a few times after. If the child is homeschooled or too young or sick to attend, the timing is up to you. Ideally, do the enema after the child has a bowel movement.

Enemas — What You Need

The first thing you are going to need is some kind of a large plastic, liquid measuring container. Glass is not recommended since it can get knocked over and break in the confines of a bathroom.

You will also need all the same things you used for making CD batches:

- Water. Use reverse osmosis, filtered, or distilled. DO NOT use tap water or alkaline water!
- Sodium chlorite solution
- Acidic activator
- Shot glass
- Natural lubricant (coconut oil or any other simple food oil). NO perfumed baby oil or chemical lotions such as Petroleum Jelly or K-Y® Jelly.
- Enema kit (see your options on the following page)

Enema Options (Most to Least Preferred)

Gravity Bag or Bucket with hose

Pros:

- Holds plenty of liquid
- Can be refilled without taking it down
- Flow is easy to control
- Can be hung on a door
- Can be used for both enema and douching
- PIC Indolor: Folds for easy travel
- PIC Indolor: Has valve
- PIC Indolor: Two sizes of cathetors

Cons:

- Bucket doesn't fold for easy travel

Enema / Douche Bag / Hot Water Bottle

Pros:

- Holds plenty of liquid
- Flow is easy to control
- Can be hung on a door
- Can be used for both enema and douching
- Easy travel
- Has two sizes of cathetors

Cons:

- Can't be refilled without taking down
- Usually made of rubber, which tends to dry out quickly, especially from CD.

Syringe & Catheter

Pros:
- Flow is easy to control
- Can be used for both enema and douching
- Good for small children

Cons:
- Holds only 60ml-140ml
- Need more than one.
- Have to swap them out to go beyond the capacity of one syringe.
- The graduations rub off easily (suggest putting clear shipping tape over them to protect the markings if they are important to you).

Enema Bulb

Pros:
- Portable
- Can be used for both enema and douching
- Good for “implants” of mebendazole

Cons:
- Volume too small for an effective treatment.
- Hard to clean inside
- Can’t tell if dirt is on the inside.
- Holds only about 200ml.

Fleet Enema (Last Resort)

Pros:
- Cheap
- Can find it in most pharmacies
- Portable
- Can be used for both Enema and Douching

Cons:
- Volume too small for an effective treatment.

Enema Kits

As shown in the previous two pages, here are your enema kit options listed from best to less than good. Prices are estimates in US Dollars and are likely to be higher outside the US:

★★★★★ PIC Indolor Gravity Bag (~$15-$30)

★★★★☆ Enema Bucket (~$5-$10)

★★★½☆ Multipurpose Enema/Douche Bag/Hot Water Bottle (~$15-$30)

★★★☆☆ 100ml+ Syringes plus Catheter (~$5-$10)

★★☆☆☆ Enema Bulb (~$5-$15)

★☆☆☆☆ Fleet Enema (emptied out) (~$5-$15)

You must have a separate enema kit for each person doing enemas. This insures that you are not cross-contaminating parasites.

In my own home we have recently started using the PIC Indolor enema/douche bag. This has made the process faster, and we can tolerate more water before feeling full and desiring to release the enema. This is probably the most practical kit, especially because of the built-in shut-off valve. The enema bucket is a close second, but the sliding clamp that comes with it doesn't last long and breaks easily. You can always just kink the hose and control the flow that way.

The multipurpose enema/douche/hot water bottle type is a good option, but it is usually made of rubber. This material often goes bad over time and CD just speeds up that process. Rinse it out several times before and after use to insure that no breakdown or CD residue is left. Don't use if you notice the rubber becoming brittle.

Even two-year-olds still use about 400 to 500ml in an enema. The intestine is long. Parents with small children sometimes like the 100ml syringe/catheter method. The enema bulb or fleet enema are not really practical for our purposes due to the small volumes they hold. However, if you want to get started right away, they are usually available in most major pharmacies.

You can find syringes, catheters, gravity bags, multipurpose enema/douche bags on various online sites, pharmacies and medical supply stores around the world.

Preparing and Administering the Enema

Make all your supplies easily accessible in your work area before bringing your child in the bathroom. If this is your first time and you are working out the process, you may wish to ask your spouse or someone else for assistance. It's a good idea to do a dress rehearsal without the child, to insure that it goes smoothly when the child is present. Once you and your child have the process down, it will be easy. Being prepared is the key to success.

Please note: The eight fluid ounce baby bottle is NOT involved in any way with enemas!

1. Ideally, time the enema just after a bowel movement.
2. Start by washing your hands to insure you are not introducing any new bacteria into the colon. Everything you are working with should be clean. Wearing gloves and a face/surgical mask is HIGHLY recommended.
3. Assuming you are using one of the suggested gravity bags, find a good and stable location to hang it up. The best location really depends on your particular bathroom's layout and where you are going to place the child during the procedure. I hang mine from a towel hook in the bathroom, or you can use the shower curtain rod. The idea is to have the bag/bucket about three feet (~one meter) over where the enema will be administered. Most parents put a towel on the floor of the bathroom and lay their child on the towel (smaller children can lay across your lap).
4. Refer to the chart below and measure out the appropriate amount of water for the individual receiving the enema. The ratio is two drops of CD per 100ml of filtered warm water.

Age/Size	Water Volume	Drops of CD
Child	1/2 Liter (500ml)	10
Adolescent	1 Liter (1000ml)	20
Teen/Adult	up to 2 Liters (2000ml)	40

5. Don't add any CD yet. The next step is to heat the water to body temperature (98°F / 37°C). The water should feel warm to the touch—NEVER hot! Similar to the temperature of milk in a baby bottle... test it on your wrist. If you are concerned about getting the temperature right use a quality thermometer. Be aware... many cheap thermometers are notoriously inaccurate!

6. After the heating step, pour the water back into the big measuring cup.

7. Referring again to the chart on the previous page, prepare a CD mixture in the clean dry shot glass that's appropriate for the volume of water needed. For example, if you have an adolescent and are preparing one liter, then you will need to mix 20 drops of sodium chlorite and 20 drops of acidic activator to end up with 20 drops of CD! Note: The most important part of the enema is the ***water***. Resist the urge to add more than two drops per 100ml of water.

8. After the appropriate activation time, pour the concentrated CD from your shot glass into the large measuring cup. You may want to rinse out the shot glass with some water from the large mixing cup so you get all the concentrated CD solution into the water.

9. The bag/bucket should now be in its working location with the hose firmly attached, Place the end of the hose so it is over the top of the bag/bucket. A clothes pin can come in handy to hold it up over the bag/bucket. Now, fill the bag/bucket about 3/4 full with the CD water mixture you just prepared.

10. Make sure the hose is filled with water. You may want to let a bit run out into the sink or some other container and then clamp it. The bucket type enema has a plastic clamp for this purpose. The bag type has a valve where the catheter attaches. What you don't want is for there to be a bunch of air in the hose that then is transferred into the colon.

11. If all of the above is ready, it is time to bring your child into the bathroom.

12. Explain what you are going to do. Some parents say that they are going to put the catheter in his bottom, and that it has "special water" in it to help him feel better. One little boy called it "butt medicine" while another called it "butt wash." We recommend you say that you are the only person who is allowed to give this to him. Just say whatever you need to say to explain what is happening.

13. If the child is on the floor (on a rug or towel), they should lie on their stomach. If the child is small then laying them on your lap is best. You can also have them in a doggy position on the floor.

14. Place one or two drops of coconut oil (or similar) on their anus so the area is well lubricated.

15. Now take the hose and gently insert the tip, (one to two inches is plenty—more is not necessary) as the sphincter muscle will hold the tip of the catheter in place. If you are having any problems getting the catheter in, then you may need to add a bit more oil and/or adjust the angle.

16. Release the clamp or open the valve to allow the liquid to flow. The goal is *fill & release*.—NOT *fill & hold*. We are imitating the colonic process that is made up of gallons of water, yet in the home environment.

17. Your child will most likely hold the contents on their own—they will squeeze hard so as not to "go." This kind of happens naturally.

We do a fill and release method. The first part of the enema is usually stool. After that, we usually see parasites and or biofilm.

It's a learning experience and as time goes on, you will get the hang of it.

> Quote from a teenager using the Protocol: "I like the enemas. Before them I am mad. But then when I get one, I feel better. My mad leaves in my poop.

Syringe/Catheter Method

Before I started to use the gravity bag, the syringe/catheter method was my favorite. We have a YouTube video on our channel that shows how to fill the syringes and switch them out while using the catheter. If you don't have access to that video here is an explanation on how to do it:

1. Fill a bowl with body temperature filtered water and fill your syringes. If your child uses 500ml for an enema, fill all five syringes and dump out whatever water is still left in the bowl.
2. Squirt all the water from the syringes back into the bowl. You now have exactly 500ml of purified water.
3. Activate your drops of CD in a clean dry shot glass. If you are using ten drops, activate them and then use the water from your bowl to stop the activation process.
4. Pour the contents of the shot glass back into the bowl.
5. Refill your syringes with the activated CD solution.
6. Lubricate the tip of your catheter with coconut oil, and attach the first syringe.

Note: If you wish to preserve the graduation marks on the syringes, cover them with some clear plastic shipping tape. The printed on marks are often easily rubbed off and the tape will prevent that.

Fleet Enema Method

The third option for enemas is to use a Fleet enema, which can be purchased at any drug store. This method is acceptable if you don't have access to the other items but want to start immediately, as, generally speaking they are easy to find. An enema bulb is a fancy fleet enema without being prefilled with saline solution. Skip step one if that's what you are using:

1. Dump out the contents of the enema (basically saline water). Since a Fleet enema only holds 137ml, two drops of CD are the maximum number you can add. To use more water, empty additional Fleet enemas.
2. Activate your two drops of CD and dilute them with filtered water (not tap water).
3. Funnel the activated CD solution back into the Fleet bottle. Insert the applicator and squeeze the bottle until all or most all of the contents are empty.

Comments & Suggestions from Parents

Most people are surprised at how well this goes. Some parents have asked if they can do the Protocol without the enemas, and I say yes, but why? The results are just that much better with them. Enemas have, in fact, been around for thousands of years, and colon hydrotherapy is becoming a growing trend in autism recovery.

I was really intimidated at first by the enemas. The syringe/catheter system, however, is brilliant. I lube the tip up with coconut oil, attach a filled syringe, and ask my son to put it in. He's 7 and very low verbal. He started inserting the tip by himself maybe on our 3rd or 4th enema with this system and I would depress the syringe. A few months later of every other day(ish) enemas, and he's doing the syringe depressing part himself. All I do is fill and swap syringes out. We are now to 11 100ml syringes, with 3-5 releases per enema (4 months into enemas). He requests enemas frequently on days I don't plan to give him one by getting the box of supplies and handing it to me.

Here are one mom's enema guidelines:

> *Be low-key about it, your attitude sets the tone. Have all your enema gear ready to go and in the bathroom for when the moment strikes. Put a nice, fluffy, washable blanket on the floor; bring in iPad, iPhone, whatever occupies your child for a few minutes. I've been doing my son's enemas after an afternoon poop if I get one because I figure it is easier as he is already in the bathroom, the bowel should be emptier, leaving more room for CD. Also the one time I did an enema close to bedtime, I swear he was up for an extra hour, however, another child might have the opposite reaction. I kneel on the floor, lay a beach towel over my lap, lay my son across me so he's on the ipad, pull his knees up a bit and then in it goes. You can put coconut oil on the anus or on the tip of enema. I ask my son to count to try to hold it in. (On the 4th enema, we only got to 40 seconds.) Then plop them on the toilet, and there you go.*
>
> *If possible, start the enema while lying on the left side, then rolling to the right. In this way, more water is able to reach the colon. (However, this may not be possible for all children.)*

CD Baths

Taking a bath with CD is another good way of detoxing your child. The CD gets into the pores and helps with skin rashes common with autism detoxification. This additional process can be added when you start with the enemas after reaching full oral dose, but avoid giving the child a CD bath right after an enema.

CD baths are done on non-enema days, unless you are doing daily enemas, in which case they are done on opposite ends of the day.

Enemas Every Other Day						
Sun	**Mon**	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**
Enema	Bath	Enema	Bath	Enema	Bath	Enema

Enemas Every Day (Enemas can also be in the morning and baths at night.)						
Sun	**Mon**	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**
Morning Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath	**Morning** Bath
Evening Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema	**Evening** Enema

The CD baths can go from as low as 10 drops to as high as 80 to 100 drops; it just depends on the person, and the size of your tub. With younger/smaller children we start with ten drops. Since we're doing baths every other day, start with ten drops on Monday, 11 drops on Wednesday, and 12 drops on Friday. Just keep going up until you get to 20 drops. The bigger and older the person is, the more drops they can tolerate.

Fill the tub to a level that maximizes skin contact.

If they start getting nauseous/listless or have loose stool, you should back down and find out what their signature dose is on the baths. Some people who have suffered from chronic constipation have done CD baths with up to 100 drops and had a BM during the bath or immediately after, without the use of drugs, laxatives, or suppositories.

CD Steam Bath

Inhalation of CD for children is generally impossible, because you just can't tell a child, especially a child with autism, "just inhale a little bit." That's not going to work. So we do the following:

In a bathtub, with the bathroom door and windows closed, plug the drain, put 20 activated drops on the floor of the tub, and turn on a hot (to tolerance) shower water. The steam will bring the CD into the air, making a really nice steamy bathroom.

When the tub is full, turn it off and place the child to soak in the water for 20 minutes. This way, the child is absorbing it through their skin as well as inhaling it through the air. This technique creates a very dispersed, low concentration dosage. I've seen a lot of children that were going back and forth to the hospital, getting steroid injections and lots of antibiotics due to bronchitis, coughs, asthma, etc., and it was rounds and rounds. This is how this particular method of steam baths came to be a very gentle way of inhaling the CD. It works beautifully; particularly if the child has a really bad cold and is congested, do the oral, enemas, and steam baths. Steam baths are great for asthma, flu, first signs of a cold, runny nose, coughing, etc., putting an end to running to the hospital or pharmacy.

CD Foot Baths

Sometimes it is impossible to give a CD bath, and in some places not all homes have bathtubs. To remedy this you can use a CD foot bath. Fill a small plastic container with hot (to tolerance) water and add your activated drops of CD.

If you have a smaller child, start with ten activated drops, and work up from there. If you have a larger child or an adult, start with 20 drops and go up. Soak feet for 20 minutes every other day, alternating with enemas, or opposite ends of the day if using daily enemas.

72/2 Protocol (Weekend Protocol)

When we give a child eight oral doses of CD throughout the day we are killing more and more pathogens. But at night when we sleep, the pathogens don't. So in order to get ahead of them, we can dose throughout the night. Imagine the progress we can make if we don't give them the chance to gain strength overnight!

Hence, the 72/2 Protocol, which involves giving one dose of CD every two hours for 72 hours straight—including the middle of the night. Here are some additional thoughts and guidelines:

- Start protocol when you pick up your child from school on Friday.
- Give them the last 72/2 dose when you drop them off at school on Monday.
- Avoid giving CD enemas or CD baths during this protocol, UNLESS they are dumping parasites, in which case you might need to reduce the amount of CD on both the oral and enema dose to insure the child doesn't have a Herxheimer reaction.
- Why not give hourly doses during the day at the usual dose? It's simply too much if you are doing it all night as well.
- Watch for improvements on Tuesday or Wednesday each week.
- Ideally, get your spouse or significant other to help with every other nightly dose.

The key is to observe your child and their reactions to the various treatments while keeping the pressure on eliminating the pathogens. You can do this every weekend or not at all. Some families are so happy with the results that they dose throughout the night for months on end.

Ocean Water

This protocol concentrates on excesses and not deficiencies. While we are using CD to reduce pathogen populations and heavy metal toxicity in the body, we need to remineralize the body. Remineralization is extremely important as vital nutrients may be lost along with toxins while detoxing. Children with autism are often mineral deficient to begin with due to these same pathogens and parasites, as well as gut dysbiosis which can prevent adequate nutrient

absorption. We need to fortify our cells and tissues so that they can overcome the deficiencies and eventually return to a state of vitality.

Ocean water has helped us achieve mineralization and has led to increased brain connectivity; not to mention the parasites hate it. The importance of ocean water to this protocol cannot be understated. On page 388 of the Testimonials appendix you will see before and after lab tests proving that this protocol, when used correctly, can correct imbalances. More than one family has reported healthy nails, hair and skin as well as appropriate growth and weight gain.

We've all been taught that drinking salt water from the ocean is dangerous. Let me make it clear: We are not advocating drinking glasses full of straight ocean water nor water mixed with table salt. That would most likely make anyone sick, since it would be too much salt for the body. Rather, we are talking about diluted ocean water. Also, there is no comparison between real ocean water and just taking plain salt and mixing it into a glass of water!

The ocean is a complete source of minerals that are bioavailable to the human body. I prefer ocean water to any synthetic minerals, since the body easily recognizes and assimilates it.

Ocean water contains trace amounts of over 74 bioavailable elements including:

- sodium
- iron
- selenium
- sulfur
- calcium
- molybdenum
- cobalt
- boron
- silver
- fluorine
- potassium
- chromium
- zinc
- silicon
- chlorine
- vanadium
- nickel
- lithium
- iodine
- magnesium
- manganese
- copper
- phosphorus
- bromine
- gold
- etc.

We can use water directly from the ocean (diluted to 25%) and drink this to remineralize ourselves. However, the water must be from clean locations where schools of small fish swim and/or near ocean vortices. These locations provide safe and clean ocean water from which we can harvest. Most of us do not have access to oceans. Fortunately, clean ocean water is available commercially from multiple vendors online.

For further information about how and why ocean water is specifically beneficial to all of us, please research Rene Quinton's work on how he healed the sick using ocean water.

Using Ocean Water with CD

You can add ocean water in before starting CD, or after reaching full CD dose. We use a one part ocean water plus three parts drinking water mixed together (1:3). If we take too much ocean water, we can get loose stool. Start low and slow, 5ml ocean water mixed with 15ml drinking water and go up to tolerance.

Use the following chart as a rough guide:

Ocean Water Dosing				
Size	**When**	**Pure Ocean Water**	**Purified Water**	**Total Volume**
Child	Start at	5ml	15ml	20ml
	Go to	30ml	90ml	120ml
Adolescent	Start at	10ml	30ml	40ml
	Go to	50ml	200ml	250ml
Teen / Adult	Start at	15ml	45ml	60ml
	Go to	75ml	225ml	300ml

Ocean water should be given three times a day, with the first dose being given in the morning, after the first dose of CD. You want to separate the dose of ocean water from doses of CD by at least five minutes. Larger children can take anywhere from between 70 and 120ml, depending on the child. Some adults take up to a cup (plus dilution water) per day. It is important to watch for loose stool/diarrhea when you are increasing the dose of ocean water, as that will be an indicator that the person is at their upper limit. The ratio of ocean water to drinking water is 1:3 (one part ocean water to three parts drinking water). It is important to stay under diarrhea. So we need to add slowly, and to tolerance. If someone suffers constipation, with the right amount of ocean water that will quickly change. So low and slow as we increase the ocean water.

Some parents have reported that their children will not drink ocean water, even when diluted, due to its salty taste. You can try adding a little flavored SweetLeaf® Stevia, or if necessary adding it into a beverage or soup. As some ocean water purists say, heating it kills some qualities of the ocean water. Nevertheless, your child will still be receiving all of the minerals.

Biofilm

One of the pioneers in autism recovery, Dr. Anju Usman gave the autism community one of the critical pieces of the puzzle—biofilm. The following information is used with permission from her presentation, *Gut Biology and Treatment*.

What is Biofilm?

A biofilm is a collection of microbial communities enclosed by a matrix of extracellular polymeric substance (EPS) and separated by a network of open-water channels. Their architecture is an optimal environment for cell-cell interactions, including the intercellular exchange of genetic material, communication signals, and metabolites, which enables diffusion of necessary nutrients to the biofilm community.

The matrix is composed of a negatively charged polysaccharide substance, held together with positively charged metal ions (calcium, magnesium, and iron). The matrix, in which microbes in a biofilm are embedded, protects them from UV exposure, metal toxicity, acid exposure, dehydration, salinity, phagocytosis, antibiotics, antimicrobial agents, and the immune system.

Ok, so in layman's terms, these are microbial (bacteria, Candida, virus, etc.) communities that have a protective layer around them, which makes them 100 to 1000x harder to kill than if they did not live in these protected communities.[13]

Why are they so hard to get rid of?

- Microbes impart genetic material to one another to maintain resistance.
- Colonies communicate with one another through the use of quorum sensing molecules.
- Colonies fail to express OMP (outer membrane proteins).[14]

These colonies are fairly amazing in their development. They communicate with each other, share genetic material to prolong their own survival, and don't express outer membrane protections. This last statement is very important to understand. This is the main reason that the immune system doesn't attack these colonies, they don't express themselves as a threat, and therefore the immune system, which in many children with autism is already compromised, is not able to detect or eliminate them.

In addition to this we must be careful with what supplements we choose to give to our children. Some supplements and nutrients may inadvertently feed the biofilm. "When trying to kill bugs, if you take calcium, you may not be making headway," Usman said. "Calcium, iron, and magnesium block our efforts to dismantle the biofilm."

Why CD Works on Biofilm

The microorganism communities attach to surfaces (in many cases the gut), and are held together by polysaccharides (sugars/carbohydrates) and by iron, calcium, and magnesium. EDTA is a known chelator, and can therefore break the bonds (iron, calcium and magnesium) that hold the matrix together. Neither an antibiotic alone nor a chelator alone was effective against a staph (bacterial) biofilm. However, when combined, EDTA broke the bonds exposing the bacteria to the antibacterial agent, allowing the body to expel the biomass.

Chlorine dioxide oxidizes inorganic compounds by effectively removing their charges. Here is how it works: Fe_2+, Ca_2+, and Mg_2+ are positively charged ions that hold the negatively charged matrix together. When these substances are oxidized by CD, the bacteria are then exposed to the CD which can oxidize (kill) the bacteria, allowing the body to finally expel the biofilm mass.

Many parents using chlorine dioxide orally, and with enemas, have found biofilms in their children's stool. Biofilm can look thick, mucousy, cloudy, whitish, greyish, sometimes like pantyhose, etc.

There is some more interesting information available through the AutismPedia about Dr. Usman's work with biofilm.[14]

> We had our appointment yesterday and to all our surprise when he tested her for Lyme it was negative. Just 3 months ago and before starting MMS she was testing very positive for it. He was pleased with the outcome. Thank you so much for your guidance and we owe this to the miracle of MMS and your dedication to helping me with my questions. I really, really appreciate your help in bringing us one step closer to the cure.

Also, this article "Lyme-Induced Autism Conference Focuses on Biofilm and Toxicity"[15] by Mary Budinger discusses the effects of pathogens present in the biofilm for Lyme disease and autism. The following is a notable quote from the aforementioned article by Dr. Stephen Fry of Fry Labs, which explores the possible pathogenic causes of chronic disease.

> *I could be barking up the wrong tree, but maybe not. Remember that we used to think stomach ulcers were caused by too much acid production. Then Barry Marshall and Dr. Robin Warren turned medical dogma on its head by proving that a bacterium was the cause. The pair identified*

the bacterium H. pylori and proved how it causes inflammation, then ulcers. Maybe in 10 years we will be smart enough to know that the 'auto' in 'autoimmune' actually means pathogen and the whole concept of autoimmunity will change. Chronic inflammation is chronic infection. In autoimmune disease, my model is that there is a chronic infection that cannot be eliminated, thus the immune system is always switched on. The self antibodies are due to apoptosis and death of host cells with host immune response.

I couldn't agree more, and am so grateful that we have CD to combat pathogens, and restore the body to a state of health.

Mitochondrial Dysfunction

Children on the spectrum are also more likely to have mitochondrial dysfunction than neurotypical children of the same age group. The following is an excerpt from *Science Daily*.[16]

> Children with autism are far more likely to have deficits in their ability to produce cellular energy than are typically developing children, a new study by researchers at UC Davis has found. The study, published in the Journal of the American Medical Association (JAMA), found that cumulative damage and oxidative stress in mitochondria, the cell's energy producer, could influence both the onset and severity of autism, suggesting a strong link between autism and mitochondrial defects.
>
> "Children with mitochondrial diseases may present exercise intolerance, seizures and cognitive decline, among other conditions. Some will manifest disease symptoms and some will appear as sporadic cases," said Cecilia Giulivi, the study's lead author and professor in the Department of Molecular Biosciences in the School of Veterinary Medicine at UC Davis. "Many of these characteristics are shared by children with autism."
>
> Dysfunction in mitochondria already is associated with a number of other neurological conditions, including Parkinson's disease, Alzheimer's disease, schizophrenia and bipolar disorder.
>
> Mitochondria often respond to oxidative stress by making extra copies of their own DNA. The strategy helps ensure that some normal genes are present even if others have been damaged by oxidation. The researchers found higher mtDNA copy numbers in the lymphocytes of half of the children with autism. These children carried equally high numbers of mtDNA sets in their granulocytes, another type of immune

cell, demonstrating that these effects were not limited to a specific cell type. Two of the five children also had deletions in their mtDNA genes, whereas none of the control children showed deletions.[10]

In our MMSAutism webinar, Dr. Andreas Kalcker mentions that CD changes the mitochondrial membrane electrical potential.[17] This leads to increased power in every cell in the body, including immune system cells. The mitochondria are the electric generator or "powerhouse" of each cell. When we turn off this electrical generator, cancer can develop. If the cell cannot produce electrical energy through oxidation it will use fermentation.

In practice, what I have seen is that children who suffered from lack of energy, listlessness, and other symptoms that can be related to mitochondrial dysfunction have perked up with the use of CD. They are able to do exercise again, walk without having to be carried, and can cognitively sustain activities without tiring. You will see a few testimonials mentioning "mito issues" at the end of the book. It is wonderful to think that this is another means by which CD can help people on the spectrum heal.

ATEC Statistics

Through some of our Facebook groups we have been collecting ATEC data for the past year. Just to give you an idea of what others are experiencing in terms of test results, here are some statistics:

- 246 parents have given us 2 ATEC scores. Of those, the average drop between ATEC1 and ATEC2 is 15 points. We take ATEC data quarterly, so in general that drop is in three months or less. The more impacted a child is the bigger their initial drop – kids starting with an ATEC over 100 averaged a 26 point drop between ATEC1 and ATEC2.
- Of those 246 ATEC reports, we had 32 children (13%) gain in points in the first quarter. The average gain among those 32 was 7 points. All 32 reported ATEC scores three months later, and 29 of them dropped points between their ATEC2 and ATEC3 scores. Further, 13 of those 29 dropped enough points to put them at or below their ATEC1 starting number. Which means at the 6 month mark, only 19 out of 246 (or 7%) had gained points. 93% of children who do this protocol have improved their ATEC score at the six month mark.
- We have now had 163 parents provide four consecutive ATEC scores (encompassing one year on the protocol). Of those 163, the average ATEC drop between ATEC1 and ATEC4 was 24 points.

- Of those 163, a total of 9 or 6% reported an increase in ATEC score between ATEC1 and ATEC4. The average increases was 6 points. 94% of children who do this protocol have improved their ATEC score at the one year mark.

- In a Facebook group collecting ATEC data, we have 25 recoveries as defined by the ATEC dropping to 10 or under in a year. So we have a rate of 15% recovery as defined as ATEC score under 10 in the parents who have taken this protocol through one year.

Thus showing that the longer they are on the protocol the more points they lose.

Although we all would like to see "high level" statistical research done, this is no doubt a major step in the right direction, and demonstrates that the protocol does work. But, research takes money.

DOs & DON'Ts of CD for Autism Recovery

DO review all current supplementation that your child is taking and remove all supplements which contain any antioxidants including vitamin C, vitamin E, vitamin A, vitamin K, ALA, Coenzyme Q_{10}, and colloidal silver as these will neutralize the CD, rendering it ineffective.

DO consider removing supplements that include iron and vitamin B_{12}. These are principal foods for the parasites, which explains why many children are low in them. If you are seeing a chronic iron or vitamin B_{12} deficiency, revisit the parasite chapter. These levels should normalize when parasites are no longer consuming nutrients.

DO use the Baby Bottle Method in an eight-ounce glass bottle with a completely sealing lid and start at one drop, regardless of weight. Increase by one drop/day, until you reach the optimal dosage.

DO dose frequently throughout the day. The less time we leave the pathogens to proliferate the better. Do a minimum of eight doses a day, but try to get in more doses if possible. Go for 16 in cases of PANS/PANDAS and acute situations like colds and flu.

DO activate CD for the proper amount of time for the acid you use. HCl and citric acid both activate sodium chlorite in 60 seconds.

DO supplement minerals using ocean water.

DO completely avoid the following: citrus fruits, corn syrup, fruit juices, green tea, pineapple, vitamins C, E, A, and K. Only give coconut milk and coconut water a minimum of one hour after the last CD dose at night so they will have no chance of affecting the CD. Coconut milk and coconut water are very alkaline.

DON'T give fruit juice of any form—not fresh, organic, homemade or store bought.

DON'T give highly antioxidant foods including chocolate (cacao/cocoa), coffee, green tea, kombucha, citrus fruits, pineapple, mango, or kiwi. Berries (if you have to give them at all) can only be given at night, one hour after the last CD dose.

DON'T mix anything but water with your CD drops.

DON'T give CD with food.

DON'T use a vitamin C shower water filter—yes, there is such a thing to neutralize chlorine in tap water. Unfortunately, it also neutralizes chlorine dioxide.

CD Troubleshooting Checklist

Before you decide that CD isn't working for your child please take a look at following list of common errors. If it looks like you are doing everything right, but you aren't seeing gains, please, before giving up, use one of the support options shown in Appendix 17, page 521. You are NOT alone! We have a network of parents who are ready and willing to help you.

- ❑ Are you preparing your CD in a clean, dry shot glass, or other type glass container that insures both chemicals are mixing?
- ❑ Is the CD mixture turning yellowish brown? There should be a chlorine-like smell. If there isn't, something is not right. Perhaps you have bad or incorrect chemistry? Maybe the supplier did something wrong in preparing the solutions.
- ❑ Are you using the correct ratio of sodium chlorite to acidic activator drops? See chart on page 94 for the correct mixture ratio depending on the type and concentration you are using.

- ❑ Are you allowing the correct activation time before dilution with water after mixing the sodium chlorite and acidic activator? See chart on page 94 for the minimum activation time you must wait for the chemical reaction to occur.

- ❑ If you question the potency of your CD, then you may wish to test its strength. See Appendix 6, page 467 for testing information.

- ❑ Is your CD or activator cloudy or not changing color after they are mixed? If so, there is something wrong with one or both chemicals. Check with your supplier.

- ❑ Did you leave your baby bottle solution in direct sunlight? A brief exposure to light is no big deal, but if you left it in a hot car for an hour, it may have lost potency.

- ❑ Are you keeping the same baby bottle solution for too many hours? It should be used on the day it was prepared.

- ❑ Are you giving antioxidant supplements or a multivitamin containing antioxidants? Vitamin C, vitamin E, etc., should not be given. Cod liver oil and fish oil supplements in general have lots of antioxidants to keep them from spoiling. Make sure those are out as well. Mixing any of these will cancel out the effect of the CD—and the vitamin. You CAN give them a few hours apart.

- ❑ Have you checked all your labels of supplements and foods to make sure they don't contain antioxidants?

- ❑ Have you removed all juices and all citrus fruits from the diet (including oranges, pineapple, mango, kiwi)? Berries (if you have to give them at all) can only be given at night, no less than one hour after the last CD dose.

- ❑ Are you dosing CD 30 minutes apart from food, as a minimum (one hour is optimal, but not always possible)? Grazers do 15 minutes and we dose CD 16 times a day.

- ❑ Are you mixing anything with your CD, such as baking soda, juice, etc.? The only thing you can add into your dose of CD is more water!

- ❑ Are you using alkaline water to prepare your CD? Alkaline water kills CD. Some expensive water filtration systems are designed to produce alkaline water, which we must totally avoid!

- ❑ Are you breaking The Diet? Could there be dietary infractions at school or with relatives while you're not there?
- ❑ Are you dosing so high that you are detoxing your child too fast and getting a Herxheimer reaction? Some people need to increase every three days—NOT every day.
- ❑ Are your doses too low to accomplish anything?
- ❑ Are you giving too few doses of CD? We need a minimum of eight doses per day or more.
- ❑ Have you started the Kalcker Parasite Protocol? If you have done three Parasite Protocols (PP) it is time to start looking into supplements, chelation, HBOT, GcMAF, etc.

Frequently Asked Questions (FAQs)

Can I use less than one ounce (30ml) of water to administer a dose of CD?

One ounce of water, or more, is best. You can always add more water, but at least an ounce is the minimum per drop.

We have been on the Protocol and are at five activated drops of CD in the baby bottle. My son's "usual" autistic symptoms got exacerbated to the maximum. He has horrible constipation, stimming, scripting, and he seems to be in a bad shape. Our target dose is 15 drops. What should I do?

The general protocol is to wait with CD enemas and CD baths until one is at their full target oral dose. His negative symptoms are probably from reabsorption of toxins from his unpassed stool. You need to resolve his constipation to stop this vicious cycle. You can administer CD enemas and CD baths on consecutive days. This should help the constipation, and flush the toxins out of his system. Then, once he is stable you can resume slowly titrating up to full dose.

What should I do if my child can handle "double doses" (two ounces of the baby bottle) all day with no herxing?

If your child is taking "double doses" all day, then it is NOT a double dose—it's his actual dose! Depending on his gains and what else you are folding into your protocol you can consider going up from there.

Is 72/2 only if you have done the parasite protocol? We are full oral dose but won't do PP until next full moon.

You can do 72/2 protocol before the Parasite Protocol, but you must have reached full dose of CD.

We are really struggling to get in enough doses of CD with school. We do well to get in 8; we really need more (way, way more). Night dosing is not an option (he won't go back to sleep; our mornings start early enough around here as it is), nor is coming to school during the day to dose him (we both work). Advice?

Some parents are dosing every 45 minutes to get in their doses when they are with their children. However, we need to be killing pathogens around the clock. It is not possible to be effective at killing pathogens when we are giving them 16 hours without a dose of CD. You need to get 1 to 2 doses in before school starts. Then get the other 6 (ideally more) in after school is over and in the evening.

My child hates the flavor of CD. Can I give Stevia with CD to improve the taste?

We recently discovered that some brands of Stevia are compatible with CD, CDS and CDH (i.e., SweetLeaf® & KAL® brand)—it doesn't reduce the potency. However, past tests were not so positive. Some added ingredients may be why this was so in our initial tests. Try to use only pure Stevia or check with the Facebook groups on what others are using successfully.

Preliminary tests show that some brands of Stevia can be used with CD to improve taste without losing potency. The two brands we have tested in-house are SweetLeaf® and KAL®. Some of our moms report having successfully used flavored versions of SweetLeaf®.

When you say do two back-to-back baby bottles of 11 drops... you mean do a total of 22 drops in 16 hours? Correct? I'm going slowly up on oral CD because of behaviors. If I go from 11 to 22 drops overnight, won't he have strong detox and behaviors?

This is spread out over 16 hours or more, such that every 60 minutes it is the same amount. It is different than putting 22 drops in 8 fl. oz. Behaviors associated with bacteria (PANDAS/PANS) are often reduced with the tolerated dose spread over longer periods of time. Remember that CD is only active in the body for about one hour.

My child seems very uncomfortable. What should I do?

If you see a detox like this, stop dosing for the day. The next day, return to the last dose when the child was stable. Pathogens are dying and toxins are being released into the bloodstream on their way out of the body. This causes discomfort in some people.

How do you know if I should go past full oral dose of CD?

A Herxheimer reaction will be your biggest indicator if you have gone too far. If you have reached full oral dose and it seems like your child has plateaued, please schedule a consult with Kerri to discuss your options. Note: The full oral dose chart (page 101) is only a general guide and not a one size fits all.

Is an hour enough time to separate CD neutralizers from the CD dose?

CD is only active in the body for about one hour, however, supplements like vitamins A, C, E, K and ALA, CoQ10, and GSH (glutathione) need to be avoided. Also, orange juice, pineapple juice, and other high antioxidant fruits are a problem even after one hour. So, the best thing to do is eliminate everything that kills the CD. If not, it is pretty much like not using CD. I have seen it too many times and it's not worth it. Antioxidants destroy CD. There is no period of time that is safe to use antioxidants with CD.

I know you have to start the parasite protocol on a certain day of the month, but how about the first dose of CD?

You can start giving CD any day of the month. That said, it might be easier to start on a weekend, or a day when you will be with your child all day to make sure to get in all of their doses, and keep an eye on them to make sure they tolerate it well, i.e. no Herxheimer reaction.

What is 72/2?

72/2 is when you give a dose every two hours around the clock for 72 hours. We use a baby bottle and a half to get through the night hours. This can be added in once you are comfortable at your full oral dose and have added in enemas and baths. See page 115 for more information.

Do you recommend 72/2 for everyone?

Once a child is at 100% of their target oral CD, enema, and baths then they can do a 72/2 weekend. They are exhausting for the parents, but some kids do wonderfully. A lot of families get a nice boost. But, if you do a couple of weekends and you don't see anything afterwards, then forget it. The benefits are usually seen two to three days after the 72/2 is over.

My son suffers from constipation. Can I start the enemas before I get to his full oral dose?

Anyone who suffers constipation needs enemas right away. These can be combined with oral doses. Still start low and slow, but it is important to get the bowels moving with any detox protocol. When constipation is present, we do not wait to start enemas.

What is the maximum amount of water to use with enemas? How many times do you hold and release?

First of all, we don't encourage holding. Rather we do a fill and release, which is kind of a home colonic. If your child can hold for a few seconds without fuss, then great. The number of cycles depends on the results of each. If all you are getting out is water, you may be finished, unless the person is seriously constipated. The amount of water really depends on the individual's size and the number of cycles administered. My basic philosophy is: *Any enema is a good enema.* So, even if not much comes out, you are still getting some water and CD in.

Is it possible that my son has been getting rid of mucous after his CD enemas? What is up with the mucous? Why is it there in the first place? And, is it a good or a bad thing that it is coming out?

Mucous is always a sign of inflammation and can contain pathogens and parasites. Mucous gives a home to pathogens. The inflammation and mucous can be caused from the allergies and pathogens. It is common to see mucous come out in the beginning of the enemas since our children have so much intestinal dysbiosis.

What is a good enema method for a 17 year old boy? I am having trouble understanding the enema part of the book. The video in the file really helps, but I am having a hard time imagining doing it on my son. How do other people with older children do it? Can it be self-administered eventually? Kerri mentioned a gravity bag, so you don't have to keep changing syringes. Has anyone tried that? Where do you get the bag?

Here is some advice one mom gave to another mom on one of our boards:

My son is 14 and tends toward constipation. I had done suppositories in the past to help him have a bowel movement. So, I told him that the enema was "fanny medicine" to help him have a BM and make him better. I started with just showing it to him after a BM after I wiped him. Then, I just put it next to his anus the next day. Then closer every day. He was still constipated so just inserting the tip would help him poop and then later I was able to push the liquid with him standing next to the sink and it would run all down his leg. After several weeks of this, it was a full moon and he could not poop at all and was lying on his bed in pain. I said let's try it here because it will really help you. I got out a hundred towels and did it right there and he pooped. It was a slow process over two months but now we do them AM and PM always right after the shower. I counted over 20 feet (of parasites) coming out this last PP. And that is just what I could see. I don't dig, just pull out obvious ones that are a foot long. Main advice is keep calm with soothing voice and have tons of patience and keep telling your son how much you appreciate his patience too. I also tell him this will get rid of his autism. He is non-verbal but said with RPM that he is mad he has autism. Also, the soft tip is key. I use syringes because they go fast.

My son is not having daily bowel movements. What should I do?

Do CD enemas every day until the stools normalize to daily. If you absolutely cannot do enemas, use CD baths in high doses (50+ drops depending on the size of the tub). Ocean water in high doses will move the bowels as well. Castor oil also helps.

I am scared of the CD enemas. Will CD harm the intestinal lining?

CD stays active only for about one hour and can gently, but effectively remove biofilm and kill pathogens in the intestine. Our society has shied away from this healing method in the last few decades. However, CD enemas have been proven to be positive turning points in the treatment, time and time again. Lots of kids will actually ask for enemas, as they provide them relief and comfort. If you are nervous, apply an enema to yourself first. You will see it is no big deal, and feel more at ease applying one to your child. Some parents have shown their higher functioning children how to apply their own enemas, so no one has to be there, and to make them feel more comfortable.

What is the difference between colonics and enemas?

Colonics cleanse the entire length of the colon while enemas cleanse the lower part of the colon. Colonics involves multiple infusions of water into the colon, while enemas involve a single infusion of water into the colon (which can be repeated). With colonics, fecal material leaves the body via a tube. Colonics normally involves going to an office and receiving assistance by a trained colonics hydrotherapist, while enemas are free and done in the privacy of your own home.

I have never done an enema before. How do you administer it?

There are several positions that work well, but there will be one that works best for the individual. The enema instructions are on page 109. Some examples would be on all fours or lying on your left side on a towel, or a small child could lay across your lap.

Enema clean up question: What are we boiling? What are we spraying with *Everclear*? What are we throwing away?

After you are finished looking for worms you can throw away any plastic plates/forks you may have used. Pour boiling water on your specimen collector, enema nozzle and catheter. Then spray with *Everclear* grain alcohol. If you are using syringes, you may pour boiling water over them as well.

How far do I need to insert the catheter for an enema?

Not very far at all; one to two inches is plenty. The anal sphincter is about one inch past the anus. As soon as the catheter passes this muscle, it will hold it in place and there is no need to go further.

What is intestinal biofilm supposed to look like?

Biofilm is fluffy, cloudy, and mucousy in appearance. There are no rules on the color. It can look like pantyhose. But, it is usually mucousy and a cloudy whitish/grey color.

How far away should we be doing enema from food? If we miss the morning enema, can I give it right after lunch?

They can go together; there is no need to separate enemas from food. Any enema is a good enema.

I'm having trouble with my syringes (for enemas). One plunges really smoothly, but the other two are almost impossible to move. Do I need to grease them up somehow before each use? How do you clean them?

I use *Everclear* grain alcohol to clean them, but note, it will dry out rubber parts. You can use coconut oil to lube the plunger gasket.

Is it normal to see black specks coming out after using enemas? We saw white specks for a couple of days too.

Black specks can be heavy metals. Oxalates are known to bond to metals and would come out with metals. White dots are generally parasite eggs.

Does ocean water need to be refrigerated after opening?

No it does not, it is fine at room temperature.

If I harvest my own ocean water do I have to sterilize it?

No. Sterilizing is not necessary or desirable in our experienc—we don't want to denature it. Pouring it through a coffee filter to remove any potential particulate matter is fine. Do NOT use charcoal filters (such as a Brita® water filter), because they will alter the characteristics of the natural ocean water. Just make sure to collect the water far from any harbours or large river outlets.

I bought pure sea water in Australia. It sounds like a great mineral drink. Would this be beneficial for killing parasites or just putting goodness back into the body?

Actually, it does both.

How do I avoid feeding the pathogens?

CD kills pathogens. I would use CD to rid the body of pathogens rather than try not to feed them.

Is it possible to use CD, CDS, or CDH during pregnancy? If it is ok, how much can be used?

CD/CDS/CDH are not advisable during pregnancy or nursing.

Can I add CD to breast milk to the bottle to help the baby detox?

CD must be given in water. Mixing breast milk and CD will reduce or potentially cancel out the potency of the CD.

How many drops go in a CD bath?

It depends on the weight of the child (20-100 drops). If he is a little guy I might start at 10 or 15 activated drops and work up over the course of the following couple of weeks. The size of your tub also plays a part. The bigger the tub, the more CD you are going to need. See page 113 for more information.

I've heard that some people mix CD directly in capsules and then swallow them. Can we use that on our children?

NO! Not a good idea! Since many children with autism can't speak, they won't be able to tell you when the capsule gets stuck. CD needs to be diluted in water before taking as instructed in this chapter.

Can I use warm water instead of cold water to store CD and how long will it remain potent mixed in the baby bottle?

CD is a gas dissolved in water and therefore has to be preserved in a sealed container. If not, it will lose its potency, similar to how soda goes flat if the cap to the bottle isn't screwed on tight. Colder is better because the CD will gas out quicker at higher temperatures. If you have doubts about CD potency, get the Lamotte ClO_2 test strips to be sure. See Appendix 6, page 467 for more information.

Are purified, distilled and filtered water all the same thing?

They are different. However, we can use purified, distilled or filtered water. But, alkaline water should never be used!

Must the activated CD water mix be stored in a glass bottle, or is a no-BPA plastic bottle with an airtight cap ok?

I prefer glass to any plastic. Over time, chlorine dioxide can degrade plastic, and that means you or your child will be consuming it. Yes, the bottle needs to remain sealed. Plastic is acceptable for lids only! Metal lids should never be used because they quickly rust, even if covered with a plastic coating.

Is it a problem to transfer one ounce of CD to a steel bottle briefly before drinking it?

That is fine for a transfer, but I wouldn´t store CD in a steel bottle.

Is the GF/CF/SF "clean" diet essential to the CD protocol? My son doesn't have bad reactions and I just do not see how we could implement it.

A healthy, clean diet is very important to the healing process. Unfortunately, our "standard diet" is filled with preservatives, colorings, and other potentially harmful chemicals. When the goal is to heal, the diet is necessary. Dairy especially can cause inflammation and mucous production. Mucous provides protection to parasites.

What is a good CD-friendly multivitamin?

All multivitamins have antioxidants. What we need to supplement during detoxification are the minerals. Ocean water has 90 bio-available minerals, and it is what I prefer for this protocol.

Are there other specific foods, veggies or fruits that need to be avoided in addition to juices?

When you are following the CD Protocol, all antioxidants need to be avoided. Chocolate is a strong antioxidant. As far as vitamins are concerned; A, E, K, and ALA are off limits. High antioxidant supplements such as curcumin have also been a problem for many people. In the case of vitamin D, it is not an antioxidant, but it has caused aggression in previously calm children. Therefore, as a supplement, it must be used with care, if at all.

Vegetables and legumes which are high in antioxidants have not shown to be very detrimental to the effects of CD. However, citrus fruits, pineapple, mangoes must be avoided. Berries are best given at night, one hour after the last dose of CD, if you must give berries. Juice, any sort of fruit juice, is completely prohibited. Not only can the antioxidants involved kill CD, but the high sugar content (albeit natural) shuts down the immune system, which is already impaired in children with autism.

Can our kids drink anything other than water for the duration of the CD protocol or just not drink juices down with the CD?

Some people are not used to drinking water and find it difficult. Some people drink nut milks or rice milk. On occasion, some folks put a piece of fruit in the blender with an apple and blend it, strain it, water it down and have that sometimes. Juicing is taking 5 apples to make a glass of juice and that is a lot of sugar (albeit natural) as well as a lot of antioxidants. Antioxidants kill CD and sugar slows the immune system. You want to totally avoid alkaline water.

Can I use rice milk to give the CD instead of water?

Water is what we need to use to give the CD. If you are giving CD mixed with another beverage you are reducing its potential. By combining CD with liquids other than water we will not get the desired results. Rice milk might be okay, but you would need to test how it affects the potency of the CD. You can get the *LaMotte High Range Chlorine Dioxide Test Strips* (#3002) at www.amazon.com. This way you can see for yourself how mixing CD with any beverage affects its potential. However, I do not recommend putting CD in anything but distilled/purified water.

Can I give my child fresh pressed green juices (celery, kale, cucumber, apple)?

Anything that is very nutritious to the human body is nutritious for the pathogens/parasites. So, a healthy green drink is very healthy for the pathogens. If you are giving "green" juices make sure they are not loaded with sugar from apples, carrots, etc. In my opinion, it is preferable to avoid these for the first few months of the Parasite Protocol (PP), at least.

Can I use coconut and almond milk with CD?

You can drink coconut and almond milk 60 minutes after your last dose of CD, but I would not combine anything other than purified water with the dose of CD.

Can my child drink coconut water if he is taking CD?

If you want to give your child coconut water, give it one hour after your child's last dose of CD, at night, before bed.

Does lemon interfere with CD, even after it is cooked?

Yes, in some cases. A family of a child who suffered from SIB noticed a direct correlation with lemon use in their meals with the return of his SIB. I would avoid it at all costs.

My son barely drinks anything, especially all at once. This is why we have been unsuccessful with detox programs. Is CD different?

You should make sure that your child is well hydrated, but for the CD alone one ounce (30ml) of water is sufficient. I find that it is easier to drink CD cold rather than at room temperature. Also, if the smell is a problem, put the dose in a plastic syringe and squirt it right into your child's mouth. This prevents them from having to smell it before they swallow it. Enemas are a great tool for hydration.

My child's appetite has changed since starting CD. Is this normal?

Yes. On average larger kids tend to slim down, while thinner kids tend to gain some weight.

Can I give green tea or kombucha while taking CD?

That is out of the question in my humble opinion. Green tea is high in antioxidants and caffeine. Kombucha is similar. I don`t know exactly how long the antioxidants in either one are active in the body, so with autism, if we are looking for healing, avoid them both.

Can I use original Nutriiveda™ with CD?

Nutriiveda™ is derived from whey, a dairy product. In humans, all dairy causes inflammation and mucous, which provides a protective refuge for pathogens. That makes this product contraindicated for this protocol, plus it contains antioxidants.

Can I use Chia seeds with CD?

Yes. But do not mix them directly into the CD.

How do I dose my child when he/she is at school from 8:30 am to 3 pm? I work full time so "dropping in to dose" is not an option.

Give a dose upon waking, one at the door of the school at 8:30 and the third dose of the day at 3pm at the door of the school. The last dose of the day is at bedtime, there should be at least four hours between school pickup and bedtime to get in the other four doses. Once you get the hang of it, it is not that hard, it just takes a little getting used to and some prior planning.

What should I do if my son goes away for 5 days with school? Do you think it is possible to prepare a bottle of CDS for 5 days and he takes only one portion each evening?

It's not ideal, but better than nothing.

My son is refusing the CD. What do I do?

Have you tried adding more water with the dose, using cold water, using a syringe or a straw? Here is some advice from a Mom whose daughter refused oral CD:

We just went through a REALLY rough patch with my daughter when she absolutely refused to take oral CD, and I know it gets super stressful for both you and your child if you try to force it… I had to respect her as clearly she was telling me in her own way, "Mom, this does not make me feel good!" for whatever reason and after maybe a week we were back on track. During that time I was able to give her a few doses (dropped from 14 drops of CD to 5) here and there, during really good moments. For example, in the bath or swing that she loves and I think that helped her associate CD with feeling better again. You WILL be back on track in no time!!!!! Good luck! Keep calm and dose on!

I am on 30 activated drops/day with my teenage boy. The taste is simply horrible. He refuses to drink his doses. What should I do?

You can dilute your baby bottle as far as a liter bottle if necessary; it will not impact its effectiveness. Obviously, one dose will be more like a half a cup or a full cup in this case. However, be mindful of your conversion rate so that you get your dosage right. Cold water helps with the taste. You can add approved Stevia brands to cover the taste of CD. See page 126.

If the country I live in doesn't have glass baby bottles, can I use a plastic bottle?

No, do not use plastic for storing CD. If the cap is plastic, we can live with that. In almost any country you can find a glass water bottle (with a plastic cap). You can use a shot glass to measure out eight ounces, and even mark them on the outside of the bottle with permanent marker. Many

parents in Venezuela do this, as neither glass baby bottles nor LifeFactory® bottles are available in their country. NEVER use a Stainless steel (or other metal) bottle or container!

Do you think this Protocol could work for a child who already has a low ATEC score (18)?

Yes. I started with a 12-year-old, who last February 2012 had an ATEC of 18. He did not budge from there after years of biomedical interventions. He could not stop with fears, phobias, anxiety (all parasitic in nature) and we started him on CD in February 2012 and the Parasite Protocol in June 2012. His ATEC is now a one!

My son's ATEC is not going down as I had hoped it would by now. It has hovered around 65 the past few ATEC's. I think it is probably due to the fact that if I am not home my husband often forgets to give him his doses or his PP meds. Does anyone have any suggestions on how to stress the importance of this protocol to him?

The following responses are from moms on our public Facebook group:

You will never know what following the protocol will do for your son until you follow the protocol. When I first started the protocol a little over a year ago, I remember I had been using a special juice that so many people were raving about and I was paying $140 monthly for this miracle juice and I really wanted to keep in in my son's protocol. I asked my husband to give it to my son at 4 am when he got up, and that was 4 hours before he would get any CD doses... how could that effect our results? The juice was given 4 hours before starting CD for the day, we were following the protocol exactly otherwise, and even doing the enemas. Well, nothing happened, nothing, until about 3 weeks later when I said, well let's stop the juice and see... BAM! Immediately my son's ATEC results dropped and he blossomed. I mean not only did his constant pacing stop, but his eyes lit up, he not only started talking more, more, more but even his laugh changed to a typical sounding teenager's laugh. It was incredible. His ATEC dropped instantly and kept dropping, 68, 25, 13, 7, 5, 3. It's a 6 today but this a super bad new moon for him. You will never know until you follow the protocol.

We have also seen our son stop pacing, stop suffering minute to minute, in the beginning we made our mistakes, missed a dose, didn't get this or that done, we now stick to it, the cumulative effect of staying on protocol means the difference in drops in ATEC scores and staying the same or going up, it did for us anyway. I could feel the slipping, we are still working on getting this right, it is an evolving protocol that requires the entire family's buy in. I have kept my son home from school to make sure he is dosed properly but that's just us. In November he is supposed to begin going to school full days, if they do not dose him correctly, I will hire a homeschool teacher, that's how important this is. You will not get your child well, Kerri told us 16 doses a day, he got better, she told us to start

enema's early, that made a big difference, we started our first PP before he was at full dose, it's all made a huge difference, email her, keep watching your child to see what's working, this protocol works, it may take time, but what is the alternative????

My husband is not good about giving meds either. When I'm gone my older girls give it. I text them reminders. Sometimes setting a timer can help. I also set all of the meds that go along in a morning and night dose daily case. Often when I organize it all for them it's much easier for the meds to be given properly and in time.

My child has horrible nasal congestion. Can CD help?

Yes, you can use CD and make nose, eye, and eardrops. Put one activated drop of CD into one ounce of water. Use one drop of the mixture in the nose (eyes or ears) every 15 minutes till symptoms disappear. NOTE: DO NOT USE PURE ACTIVATED CD WITHOUT DILUTING IT!

You can also do a steam bath, which is done by closing off the bathroom (windows and door shut), and putting 20 activated drops on the floor of the tub. Run hot shower water on top of the drops until the tub fills; the air will be full of CD smell. Now, turn off the shower, put the child in the water to soak for 20 minutes, where he will breathe the light CD air.

Is there a seasonal-allergy protocol for using CD? I suffer from extreme itching in my eyes, redness, puffiness, sneezing, sinus congestion etc. Will CD provide relief quickly or does it need to be used over a long period of time?

Being on full CD, ocean water and the parasite protocol the allergies should begin to fade away.

Can I try the CD ear protocol if my child has not started oral doses?

Yes!! Please start the eardrops, if there is an infection, every hour until the symptoms disappear. If you catch an infection at the onset of its symptoms, give one drop of the mix every 15 minutes. We have seen earaches clear up in a couple hours. In any case, work towards a full oral dose, at least one drop eight times a day to combat the infection on all fronts. The eye, ear, and nose protocols are all the same: one activated drop of CD in one ounce of water in a sealed dropper bottle. Apply one drop of this mix every hour until symptoms diminish.

Can CD help arthritis?

Absolutely! CD is amazing for arthritis. Include CD baths in your routine. Use CD in conjunction with DMSO.

Our son has a runny nose and sneezes a lot, but has no fever. He hasn't been sick in well over a year! I'm wondering if it is from doing CD.

This sounds like a very typical die-off reaction. Monitor his progress, make sure he is hydrated, and continue with the Protocol. If his reactions remain manageable, you don't need to back down or change much. This could also be parasites, depending on whether the symptoms are chronic, etc.

Has anyone seen kids who had never been sick start getting sick as they heal?

Yes, it means immune system is waking up and fighting back against the crud they've been carrying around for a long time. It's called a healing crisis and is not uncommon and is actually a good thing.

Does CD, CDS or CDH work on HIV? Also, are there any contraindications of CD and HIV drugs?

We do not focus on HIV or its treatment and therefore we cannot give you a definitive answer. Anecdotally, there are many testimonials that indicate CD having a positive impact on the disease. In addition, we have spoken to doctors in various parts of the world who use CD to treat their HIV/AIDS patients and have positive results from what we understand.

Can I use CD in a Netti pot when doing an ear, eye or nose wash?

No. Do not use a Netti pot with CD. Instead, use the steam bath method. See page 114 for more information.

I´m wondering if CD can be used in a nebulizer? With our daughter's chronic mycobacterium issues, we can never get rid of the cough. I thought maybe it would be helpful to get it into her lungs or is this not safe?

Try a steam bath. Inhaling CD directly has to be done very delicately. This is why the steam bath is recommended, as the particles have time to disperse into a very large area rather than being inhaled directly. Some people are using humidifiers with 35 drops of CD per gallon. See page 114 for more information.

What supplements do I need to avoid while using CD?

Antioxidants (vitamins C, E, A, K, ALA, and CoQ10) need to be avoided because they kill CD. We avoid iron and vitamin B12 because parasites feed on these. So if you do not have something in place to kill pathogens/parasites, like CD, then the majority of your supplementation goes to strengthening the parasites instead of your child.

I really don't understand something basic... Vitamin C in food. I know not to give citrus or mangoes. Also, kiwis are rather high in vitamin C. If my child eats a kiwi or other high vitamin C containing food, how long does this impact CD? When will it wear off?

Kiwis and other fruits high in vitamin C are a tough call. We do our best to avoid the biggest offenders. Unfortunately, I have seen families lose months because they continued to give fruit juice or supplements high in antioxidants. As soon as these were pulled, their children began to improve. A few years ago, a popular omega high in antioxidants became popular for autism. Families that I was helping all over the world noted regression in their children. As soon as we figured out what the common thread was, and pulled that supplement, the improvements began again, but it was a nightmare. To answer the second part of your question, I don't know exactly how long vitamin C from a natural fruit source lasts in the body. A few different websites estimate up to 24 hours.

We have been using gluthatione every day and modified citrus pectin as a binder. Are those compatible with CD?

Gluthatione is a very powerful antioxidant and cannot be used as a supplement with CD. Modified citrus pectin is fine.

I have heard that CD helps with oxalate problems. Is that true?

Rompepiedras (RP) is very effective against oxalate-crystal formation. There are connections between parasites and oxalate problems, which this protocol seems to be helping. Ridding the body of parasites helps with high oxalates.

I know that CD neutralizes heavy metals. What does that actually mean? What is the difference between chelating and neutralizing?

The mechanism of how CD neutralizes and removes heavy metals such as mercury is not clearly known (or understood). However, a number of recovered children have had heavy metal burden tests performed before and after the use of CD, and their heavy metal burden dropped. We also know of an adult in our circles who was extremely toxic with mercury and was able to normalize his levels after all other medical interventions had failed him.

So is CD enough and we don't need to chelate?

For many it is not necessary to chelate while on CD. There are some children though who do IV chelation and CD at the same time. This method seems to have good results; there are big metal dumps, when administering chelation challenge testing. As time goes by, we add interventions until we reach recovery.

Are all chelators compatible with CD?

In many cases there is no need to do both. To answer your question, EDTA is fine as well as DMSA and DMPS with CD.

You may want to consider Bio-Chelat™, bentonite clay or zeolite clay. These are great light chelators.

We have tried every biomed option available, but nothing has helped. What makes CD different?

Biomedical treatments in general provide large amounts of antioxidants. CD is an oxidizer and kills all pathogens in the body. The premise is that once your body does not have to feed and house pathogens, it will work much better and will heal. This protocol focuses on excesses and not deficiencies, which in itself makes it different from many other biomedical interventions. With CD and the Parasite Protocol we are eliminating the pathogens and parasites that cause the symptoms known as autism.

Most biomedical interventions seem to be only applicable to small kids. Does CD work on "older" kids, teenagers or young adults?

Of course! Families with older teens and adults have had success. The body wants to heal at any age be it 7 or 70! This year, two 17-year-olds lost their diagnosis through the use of CD as part of their biomedical protocols. A 32-year-old male is doing excellent on the Protocol as well. Time will tell, and parent/caregiver dedication is the key to success.

How long should I do the protocol to see if it is working for us?

Within 30 days you will know. If you do the Protocol 100%, and in the order laid out here you should see improvements. Some see improvements with their first dose!

Has anyone had an increase in PANDAS/PANS stuff while on CD? Our ATEC didn't budge this time around and it is mainly due to the OCD and other PANDAS stuff that has increased. I get in 16 doses on weekends, but not on weekdays—maybe I get in 12 on a good day during the school week. Has anyone done anything to treat this PANDAS stuff?

Parasites typically coexist with bacteria, so it is very important to treat bacteria and parasites at the same time. It is extremely important to get in 16 doses a day, whether you get in doses earlier in the morning, or send doses to school. Also, many children with PANDAS/PANS need to be treated month long for parasites. If you are giving a probiotic, you can try doing a period without it and see if you child does not improve. We must keep in mind that if you are seeing parasites coming out with the enemas, we may not be seeing gains until we have eliminated a good number of the parasites living in the body. The toxins that they excrete—living and dead—can also cause some of the behaviors we relate with PANDAS/PANS.

Has anyone seen elevated liver enzymes while on CD?

Liver enzymes will not be high from CD. I have watched people do the liver enzyme tests for two years and the kids are in the normal range. However, when they are dumping worms or doing parasite meds is when we may see the enzyme levels go up. Within a couple of weeks they go back to normal, in the handful of times that I have seen them go up. Mebendazole and Combantrin® are non-systemic, and therefore are not absorbed; they basically travel through the intestinal system and are eliminated in the stool and urine.

My son still has a lot of mercury (DMSA provocation). Is it possible that the level can go down from using this protocol? How long should I wait before testing him again?

It is very common for the heavy metal load to go down. If you want to do labs, you can do them in three to four months.

How young is too young for CD?

There is no age that is too young. If a baby is showing signs of cold/flu, etc., you can start with the baby bottle method, one drop in 8 fl. oz. of water, so they are getting 1/8 of 1 drop per dose. The protocols are based on weight.

Ok we have had my son on this protocol for 11 months now. We started at an ATEC of 82 and had a dramatic decrease right away. Our second score was 26! Now we have had 3 consecutive ATECs of 33, most points being in the speech category. Where should I go from here? More diet changes and or supplements? We have been GFCFSF for years, considering going grain free next. We already use omegas and ocean water, and have done nine parasite protocols.

It may be time to look into hyperbarics or GcMAF, as you have *The Diet*, CD and parasite protocol firmly in place. If these 2 options are not financially possible, you need to look at the speech supplement list. Go in order, and see if your child doesn't see gains from some of those. You can also look at chelators. Also, please check that your omega does not have any antioxidants in it, as that will be killing your CD.

Is it normal to see diarrhea in the beginning of the CD protocol?

I consider there to be two types of diarrhea. One is the water faucet, which we want to avoid. If you see water faucet diarrhea, stop for the day, and give a lower dose of CD the next day, when you start up again. The other type of diarrhea is loose, unformed stool, which is normal during detox. As the body is attempting to eliminate the excess toxins quickly, the digestive process will speed up, and not all of the excess water will have a chance to be absorbed through the intestinal tract, causing loose stool.

How do you move CD through inspections at the airport?

Don't carry concentrated sodium chlorite and activator bottles into the cabin. They must go into your checked luggage. Make sure each bottle is tightly sealed. Double bag each bottle SEPARATELY and place at opposite ends of your luggage but not right up against the sides. You may wish to stick each bottle into a pair of socks as extra protection. Surround each bottle with plenty of clothes to insure they will be protected if the bag is roughly handled. According to TSA regulations, you can bring aboard up to 3.4 fl. oz., (100ml) of a liquid in your carry-on luggage, which can hold 3 doses from your baby bottle batch.

Can I use CD as a toothpaste? Should I use regular toothpaste in addition?

I use CD spray (ten drops of activated CD per ounce) on the toothbrush first. Then, brush the teeth, and follow with fluoride-free toothpaste. CD is great for healthy teeth, tongue, and gums.

Is it okay to go swimming when on CD? I worry about the chlorine.

They do have a molecule in common; however one has nothing to do with the other. Some doctors don't let ASD kids swim in chlorinated pools. But, as far as taking CD goes, the chlorine in the pool will not deactivate the CD in your body, nor react with it. A child on CD can swim in a chlorinated pool, just as a child not on CD can swim in a chlorinated pool.

Can I give colloidal silver with CD?

No. Colloidal silver is active for up to 24 hours in the body, and will lower the potency of CD. Therefore the two are not compatible.

Where is the autism clinic in Venezuela?

Puerto Ordaz, Fundacion Venciendo el Autismo. Carolina Moreno is the president and one of my best friends. Her email is venciendoelautismo@hotmail.com. We have over 36 recovered children there. It is wonderful.

My son has been sick and has really bad diarrhea. Can we skip the enemas for a few days or still do them?

We don't use enemas just for constipation, but for overall colon irrigation and health. CD kills pathogens in the colon, and thereby helps heal autism. As the sickness causing the diarrhea is most likely pathogen induced, CD enemas will continue to kill these pathogens and help your son get over this acute situation faster.

My daughter just drank undiluted CDS. What do I do?

First, get her to drink plain water right away. Next, give orange juice or vitamin C to neutralize the CDS. Give burbur or activated charcoal to mop up the toxins that were released. Considering the strong taste, it is unlikely she would have consumed very much.

Can CD be harmful?

In the past 3 years that families have been using CD for autism, we have not seen any children or adults harmed by using this protocol correctly. Liver enzyme tests, nutritional tests, metal porphyrins tests, etc., have consistently shown improvement in the health of the children. Since Jim Humble started using chlorine dioxide for health, no one has died from ingesting CD (or MMS). The story that is often shared around the internet from Vanatu, concerning a woman who unfortunately passed away, was not attributed by the coroner to be the result of ingesting chlorine dioxide. There was another case of a 25-year-old male who attempted suicide with 10g (nearly the contents of a four ounce bottle of sodium chlorite at 22.4% solution) of sodium chlorite (inactivated CD). He developed methemoglobinemia, which he received treatment for, but survived his suicide attempt. That said, as we have mentioned before... anything used incorrectly or recklessly can harm you. Water, table salt, etc. The reason we outlined the protocol in such detail is to prevent mistakes and help families use it responsibly to recover their children with autism.

Does clay or bentonite clay interfere with CD? How far apart should it be taken from CD?

One hour apart from CD is fine. I use diatomaceous earth about ten minutes apart from a CD dose.

Is ibuprofen ok to take while doing CD protocol?

We have never seen a drug that was contraindicated with CD. Always consult your physician for prescription contraindications.

Is it ok to add Epsom salts to a CD bath?

We do not use epsom salts baths in this protocol. We use CD baths. See page 113.

Is it ok to take SAMe (S-adenosylmethionine) with CD? I took out all antioxidants, but not sure about SAMe.

No, it contains magnesium and vitamin C. For a mineral supplement, we take Ocean Water. Vitamin C kills the CD. Magnesium feeds biofilm, and therefore is counterproductive to our goals of healing.

Can I use DMSO in a CD enema to help drive the CD into the parasites?

Warning: Never use DMSO in an enema! Never introduce it into the body rectally. If it is applied rectally, it will carry toxic fecal matter into the bloodstream through the intestinal wall.

How do I use DMSO?

Every chance you can, apply DMSO to a clean body for 20 to 25 minutes and let it soak in. Apply it to affected parts first then remove rings/jewelry to cover all parts of the hands. Allow it to dry while applying to another body area (i.e. right arm, left arm, right leg, left leg). Apply to clean skin with clean hands. Use natural fiber clothing if it is going to come in contact with the DMSO, which can dissolve synthetics. Dr. Stanley Jacob has proven that DMSO brings about healing of rheumatoid arthritis, and it is great for migraine headaches, etc. You can research his work at...

www.dmso.org

...or find a DMSO retailer at...

www.protocolsuppliers.com

The 99% pure stuff is best, but never use that strength on the skin directly. It must be diluted to 70% or less for topical use.

Does DMSO neutralize CD?

No, it does not. However, DMSO has not proven itself to be a tool for autism recovery. In general, we use it for self-injurious behavior (SIB). The "S" in DMSO (dimethyl sulfoxide) is "sulf" as in sulfur. Many children with autism have a spirochete (amongst other pathogens), which feeds on sulfur. We saw many setbacks when adding DMSO. It is used on a case-by-case basis.

Chapter 6

CDS
Another Way of
Delivering Chlorine Dioxide

There is more than one way to skin a cat.
~ Seba Smith

In October 2011, I received an email from Jim Humble. After a visit with Dr. Andreas Kalcker, he had some fantastic new information for healing autism. Jim wanted me to fly to the Dominican Republic to see him yet again that year so he could share this new information.

The big news surrounded the creation of *Chlorine Dioxide Solution* (CDS)—a new method of producing and using chlorine dioxide; substantially different from the CD mixing process we were using (described in Chapter 5). Jim was excited about all of the great things that Andreas was developing.

Andreas was contacted by a cattle farmer who was frustrated by the health problems of newborn calves he was receiving. These calves were suffering from infections, diarrhea, ear problems, cysts, coccidiosis, bovine respiratory syndrome, etc. His yearly veterinary drug bill was around €28,000, not including the cost of feed. The farmer had heard about the wonders of MMS in humans and wondered if it might help his animals as well.

Andreas thought, "Sure! Why not?" However, he quickly learned that cattle were very different from humans when it came to their digestive system. Cattle digest through fermentation, which CD disrupts, so he had to find a way to bypass their digestive system and go directly to their blood stream. But, that idea had another big problem. The pH of standard CD was too acidic and therefore not compatible with the calves' blood stream. Injecting even dilute CD caused great pain and could result in damage to the veins. There had to be another way!

After much thought and research, Andreas came up with a distillation process to extract the chlorine dioxide—the key ingredient—from the CD mixture

so it would not contain any sodium chlorite or acidic activator. He named the resulting liquid *Chlorine Dioxide Solution* (usually abbreviated CDS). Note: CDS can still contain trace amounts of sodium chlorite and whatever acidic activator used to produce it, but usually not enough to be an issue.

This new CDS solution was injected into the 800 cattle with very positive results. The animals health improved and the vet bill dropped like a rock.

In one case, the farmer called Andreas about a particularly sick cow. He advised him on a dosage, but apparently the farmer misunderstood the instructions and gave the cow 10 times the recommended amount. The result? The cow was a bit "high" with ears and tail standing up, but subsequently became healthy with no ill effects from the accidental overdose.

On the human side, CDS also solves the problem some people have with sensitivity to citric acid as well as the taste of CD. Not having the original chemicals (sodium chlorite/citric or hydrochloric acid) in CDS makes a big difference for some. Another advantage of CDS was a drastic reduction in Herxheimer reactions.

After a long weekend in the Dominican Republic, we went home with new information to try out with Patrick.

I began by swapping out drops of CD for milliliters of CDS. Initially, I didn't notice improvements or regression, but I did notice that Patrick was waking earlier and having a less profound sleep. After about 30 days of trying the new miracle I began to think that, "If it ain't broke, don't fix it." So we went back to the original CD that had given us all of the recoveries and improvements. Patrick went back to sleeping very well and I never looked back. I was a confirmed CD user and CDS, for me, had no obvious advantages.

A little over a year later, Jim was at our home, and on December 26th, 2012, his new assistant showed up from the Middle East to help him. She could be called the "CDS poster child." We differed on this topic right away. But, she was very insistent. She asked me why I didn't like CDS and I told her. So, she told me that I had been using "unstabilized" CDS and now they "stabilize" the CDS.

When the CDS is "stabilized" (with some sodium chlorite added back into the CDS liquid), it gives an extra kick, such that when the chlorine dioxide molecule oxidizes a pathogen, there is sodium chlorite on hand to react with the acid that is created by the death of the pathogen. The result is more chlorine dioxide released on the spot.

I decided to try stabilized CDS with Patrick. We arrived at his full dose based on tolerance. His sleep has been perfect. He sleeps as any pre-teen should—like a rock. And, he has great energy all day long. I can say that there was no noticeable difference over the four months that he was taking CDS, from the days when he took CD. However, he is a little bit "lighter," as if he has no cares in the world. It seems as if something that might have made him uncomfortable no longer bothers him. Little by little, a few families switched to CDS to see if their children did better, worse, or as well as they did with CD.

After a couple of trial months with about 20 families, I think that it is safe to say that CDS has its place in the buffet of different methods of chlorine dioxide administration. We still have the original CD, made with citric acid or HCl. Now, we have CDS and CDH (Chapter 7). Today, we no longer use stabilized CDS, as I feel that CDS is only for hypersensitive individuals and to be used only until they can switch over to CD or CDH. Whatever formula we choose, it will help to heal the body of unwanted pathogens, and helps with parasites as well as heavy metals. Each person is different, and it is up to us as parents to observe and decide which method of chlorine dioxide administration is best.

You are in no way encouraged to switch to CDS if what you're doing with CD is working for you. For some people it may be better, but as of now, only one of our recoveries has come from CDS—all the rest are from CD. Some children may try CDS and come to realize that CD is still better for them.

When to Use CDS

CDS is used when someone just can't get past 1 drop divided in 8 fl. oz., over a day without experiencing a Herxheimer reaction. This allows us to get past the road block and still detoxify the body. Eventually, we want to go back to the standard CD Protocol which I believe to be more effective.

This is not a common situation, but it does occur.

Making vs. Buying CDS

Most people are a bit concerned about making CDS since it involves a distillation process where you produce chlorine dioxide gas and then cause it to go into water. When Andreas first came up with making CDS, it involved two containers, a hose, heat and lots of ventilation. There are still lots of

videos on YouTube explaining that original process. However, there is now a much better, easier and safer way to produce CDS at home. So, if you see a CDS making video or read instructions that talk about using a hose—forget it! The new process is much easier and safer and doesn't involve any heat nor hoses.

There are some online sellers of CDS, but the cost of it is high and making your own is simple. It just takes a little effort in learning the process and having the right equipment. In addition, by making your own, you will have a better understanding of the behavior of chlorine dioxide.

Some Important CDS Points

When it comes to CDS, it is all in the concentration of chlorine dioxide in water; measured in *parts per million*—abbreviated **ppm**.

When buying or making your own, the goal is to end up with a bottle of CDS having a concentration strength of 3,000ppm. This bottle should ideally be made out of glass and kept in the refrigerator. You never use this concentrated solution directly. It must be diluted.

When we say, for example, use 10ml of CDS, we mean mix 10ml of 3,000ppm CDS with whatever indicated amount of water, and use that diluted mixture for the indicated purpose.

Make sure you read and understand Appendix 6, page 467 which explains more about concentration and measuring ppm.

There are several names attributed to this new, better and simpler method of making CDS, such as:

- The Shot Glass Method
- The Overnight Method
- The New Method

There are some demonstrations on YouTube showing this new method along with write-ups on various forums. These methods use a plethora of different containers having different shapes and sizes. The specific tools used to produce CDS can have a significant impact on the concentration.

It should also be noted that the concentration strength is reduced every time you open the CDS source bottle as chlorine dioxide gas escapes the liquid

and evaporates into the air space above the liquid. When you open the source container, some of the chlorine dioxide gas escapes. So, the strength of a half full CDS bottle can be substantially less than what you started off with when the bottle was full. This is similar in concept to a pop bottle that loses its fizz if not used up quickly.

To substantially reduce the evaporation of the chlorine dioxide gas, the CDS source bottle should be stored in the refrigerator, which stabilizes and significantly reduces the amount of CD gas escaping the CDS solution. But, no matter what the temperature, some gas will always escape and reduce the concentration each time the bottle is opened. A narrow neck bottle helps maintain the integrity of the CDS for longer periods.

It is better to store the concentrated source CDS in smaller 300ml bottles than keep it in a larger one liter bottle. That way you use up what is in one bottle faster with less concentration loss. A good storage bottle is shown and described on page 160.

The New CDS Making Method — The Basic Concept

First, let's go over the basic principles of the CDS making process and then we will go into details.

We start with two containers (both ideally made of glass). One container is larger and has some kind of a lid that can be tightly closed. The other is a smaller container having NO lid. The relative size of each container is such that the smaller container fits comfortably inside the larger container while allowing the lid to properly close on the larger container when the smaller one is inside. See page 151 for an example of a well-made glass kit distributed by wps4sale.com.

The large container is then partially filled with filtered/distilled water. The level of water must be low enough so as to not overflow into the smaller container if it is placed into the partially filled larger container. The photos on page 151 show the concept of the two bottles visually.

Now that you have the basic idea, let's make some CDS...

Using the Overnight CDS Generating Kit

The following directions assume you have the glass *Overnight CDS Generating Kit (1000 ml)* from wps4sale.com (as shown on page 151). You are of course not required to use their kit. However, based on our own experience of looking high and low for a good one, theirs has the key features:

- Made of glass
- Smaller glass fits inside of larger container AND 1000ml of water inside the big container will not flood into the smaller container once placed inside.
- Lid fits tight and no gas escapes during the chemical reaction time.
- Lid is plastic—NEVER USE METAL LIDS!

Note: There are plastic CDS kits that work. You may be able to find a combination of containers made of plastic but not glass where you live. In fact, I made a YouTube video where I show how to make CDS using a plastic container. Just understand that chlorine dioxide will deteriorate plastic containers over time, so it should be avoided. Even if you have to use a plastic jar to make the CDS, store the final product in glass. The less time the CDS is in plastic, the better! As for lids, we have no choice. Only use plastic lids. Metal lids will oxidize VERY rapidly! Even metal lids with a plastic coating on the inside will deteriorate.

Steps to Making CDS:

1. Start by pouring one liter of distilled or reverse osmosis water into the large glass container. The water should be around room temperature.

2. Place the empty dessert cup inside the large container making sure no water spills into the cup.

3. Measure 75ml of sodium chlorite solution (22.4% $NaClO_2$ in water) and pour into the dessert cup, while being careful not to spill any sodium chlorite into the water surrounding the cup.

4. Measure 75ml of 10% HCl or 50% citric acid solution and pour into dessert cup.

5. IMMEDIATELY screw on the lid to the large container while being careful to not jiggle the container which could potentially cause the CD solution

wps4sale.com sells this Overnight CDS Generating Kit that produces 1 liter of CDS at 3,000ppm from 75ml of sodium chlorite plus 75ml of activator. The only part not made of glass is the plastic lid. The glass dessert cup is sized just right to fit inside the larger glass jar with enough room left over for 1 L of water that won't overflow into the dessert cup.

to mix with the surrounding water. Make sure the cover is tightly screwed down so as to not have any leaks. If you smell chlorine dioxide (beyond the little that escapes while you are putting on the lid) then something is wrong with the lid and/or container.

6. If you did everything correctly you should see the CD solution turn a dark amber/brown within about a minute (see below) and notice that the water starts to turn a light yellow several minutes later. It is also normal to see bubbles form in the dessert cup. It is normal for the pressure to change during the chemical reaction. We find that citric acid produces a vacuum and HCl can produce a pressure at first and then a vacuum.

7. Cover the kit with a towel to reduce its exposure to light. It doesn't have to be in a pitch black location, but it definitely should not be in direct sun light. Feel free to check it from time to time and see how the colors change. Of course keep this kit out of the reach of children or anything that could disturb it. I keep mine in the cabinet overnight with a towel on it.

8. When the color in the dessert glass matches that of the surrounding water, the chemical reaction is complete. There is no harm in waiting a bit longer—nothing more will happen. This usually takes from 12-24 hours depending on room temperature and the strength of the acid used.

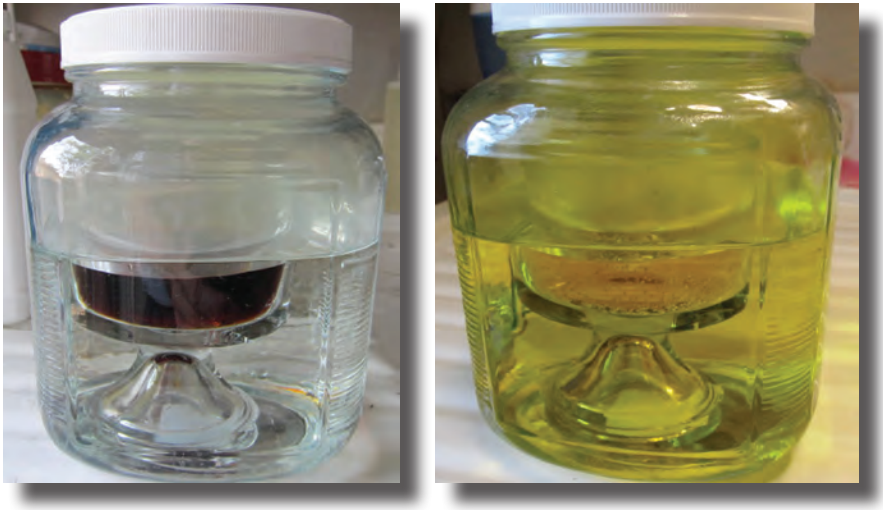

After the sodium chlorite and activator mix, the color will quickly turn a dark amber, almost black color (left). After about 12 hours, the color of the solution in the dessert cup and that of the water surrounding it should be identical (right), which indicates the chemical reaction has completed and the CDS is ready to be poured into a storage container.

9. Have your glass storage bottle(s) clean and ready to receive the CDS solution.

10. Before opening the kit make sure your work area is well ventilated. Perform the steps that follow outside or have the door and/or window open nearby. Having a fan lightly blowing any gas that escapes away from you is a good idea.

11. Slowly open the container being careful to not jostle it which could cause the CD solution to mix with the freshly made CDS. If the chemicals mix, you will have to start over again, so be careful! You will most likely smell the chlorine dioxide gas that was sitting in the air space when you first open it. This is normal, hence the need for good ventilation.

12. Slowly remove the dessert cup while being careful to not spill its contents into the CDS. Immediately dispose of the contents in the toilet and rinse off the dessert cup.

13. Now pour the CDS into the storage bottles while being aware that some chlorine dioxide gas will come out of the water into your working area.

14. Tightly seal the storage bottle(s) and place in the refrigerator.

Note: 10% HCl is the recommended activator when making CDS. However, you can also use 4% of HCl, but the reaction time will be slowed down. It may take as much as a full day before the color of the CD solution and the water match.

Dosing CDS

As mentioned earlier, CDS is particularly well-suited for unusually sensitive individuals who cannot tolerate even low doses of CD.

Start with a baby bottle filled with 8 fl. oz., of water and add 1ml of CDS. This will provide eight doses of 1/8ml. If all is well on the first day, increase to 2ml on the second day. Each day you increase by one milliliter. Increase the amount based on tolerance. If the person is having a problem with a certain level of CDS, then go down to where they were fine and stay there a few days before increasing again.

Tolerance is the key here. Once you can no longer increase you have reached that person's full oral dose of CDS.

Slowly Switching Back to CD

Once you have found the full oral dose where they are stable and cannot go higher, it is time to fold CD back in.

The goal of using CDS is not to replace CD, but rather do some fundamental detoxing so you can bring CD back and reach full oral dose of CD.

This is accomplished by taking out one milliliter of CDS and replacing it with 1 drop of CD. For example, if the individual can tolerate 20 milliliters of CDS, then an ideal transition would be represented in the chart on page 154.

Of course this chart represents an unlikely scenario where everything goes exactly as desired. However, it does demonstrate what we are striving for—switching out CDS for CD and continuing to increase the dose of CD as described in Chapter 5 (page 81).

To accomplish this process effectively requires careful observation of your child and making decisions as to when you can go up; when to hold; and when to back down.

Hypothetical CDS to CD Transition			
Transition Day	**CDS in milliliters**	**CD in drops**	**Comments**
1	20	0	Last CDS only day.
2	19	1	Transition starts
3	18	2	Transition continues
4	17	3	
5	16	4	
6	15	5	
7	14	6	
8	13	7	
9	12	8	
10	11	9	
11	10	10	
12	9	11	
13	8	12	
14	7	13	
15	6	14	
16	5	15	
17	4	16	
18	3	17	
19	2	18	
20	1	19	
21	0	20	Transition completes
22	0	21	CD increases each day
23	0	22	
24	0	23	
25	0	24	

CDS Enemas

CDS enemas can be useful for sensitive individuals when starting the protocol. Follow the same enema instructions in Chapter 5, page 103, keeping in mind that 1ml of CDS has a relative strength of approximately 60% of 1 drop of CD. With that in mind you can work up to 40ml of CDS per liter of enema water.

Chapter 7

CDH - Going Beyond CD & CDS

"The progressive development of man is vitally dependent on invention. It is the most important product of his creative brain."
~ Nikola Tesla

This protocol is constantly evolving, and until every person with autism recovers, we will continue to search for things to add or tweak to the protocol so we reach that goal. A few months before the release of this second edition, I was made aware of a new method of CD preparation, known as *Chlorine Dioxide Holding (solution)* or simply CDH.

CDH can almost be described as a hybrid between classic CD and CDS. Where CDS has no raw material left in the final product, but only chlorine dioxide gas dissolved in water, CDH contains some raw material (similar to classic CD) along with the chlorine dioxide in the final product. This new process allows the sodium chlorite to react with the acid for a significantly longer period of time, thereby reducing much of the remaining amount of unactivated sodium chlorite and activator. Some people cannot tolerate citric acid so CDH is usually made with 4% HCl. Initial reports indicate that CDH is better tolerated than CD.

Another interesting benefit of CDH is that it appears to mix well with the permitted natural sweetener stevia (SweetLeaf® brand) without reducing the potency of CDH. This can help children who have an aversion to the taste of CD. Many families have also reported that they were able to increase their child's dose without producing a Herxheimer reaction, in contrast to classic CD. Older children and severely affected children have benefitted as well from the CDH preparation; you can read more about that on page 221.

Currently, this new method is being used by a relatively small group of families (around 70 as of November, 2013). Many of them are reporting that CDH continues to produce results for their children on the spectrum, and they are seeing even better things than before.

As with all new things, it is important to test with a diverse group of families over a long enough time period to make sure that gains are sustained. So we ask that you please keep in mind that CDH is literally the bleeding edge of this protocol. While we are excited to share a new option with you, the decision to use CDH must not be taken lightly. If you are doing well with classic CD you may never need to use CDH. Consider the old saying, "If it ain't broke, don't fix it." Of the 115 children who have lost their autism diagnosis, 114 have done so with CD and 1 with CDS. So far, 0 with CDH (4 months in use for ASD). I expect this number to change soon as we are seeing good things from CDH. Time will tell. Stay tuned.

Scott McRae, his wife Brenda, and Charlotte Lackney have been pioneers in developing the CDH method. The following section is written by Scott where he discusses how CDH evolved along with detailed instructions on how to prepare and use it.

My wife, Brenda, and I first learned about CD early in 2009, through Bhante Vimalaramsi, an American born Buddhist monk. He's now a very close friend of ours, and even as I'm writing this, I'm at a meditation retreat which is based upon his understanding of the open-minded, experiential teaching of the Buddha.

After receiving our first set of CD bottles from an online seller, we started by trying to get to 15 drops of CD activated with lemon juice for 3 minutes, twice a day, which was the protocol at the time. Though we gave it a good effort, we couldn't get past 6 drops before vomiting and having diarrhea, and this caused us to initially stop taking CD. Then, after moving to Jakarta, Indonesia (Brenda's home town), I experienced almost monthly illnesses, which I believe was due to being in a new and tropical part of the world (I'm from San Diego, CA), riding in public transportation twice a day and teaching in a school of over 300 students. After a year and a half of constantly being sick, I remembered our bottles of CD which we had fortunately brought with us from the US, and I started on Protocol 1000. By that time, *Protocol 1000* had been developed to be what it is now—3 drops of CD (activated for 20 seconds with 50% citric acid) per hour, 8 times a day—and so I decided to do the 3 week cleanse. By doing the cleanse, I experienced a huge improvement in my health. Not only did I immediately stop getting sick, but I also felt that my energy level had increased by about 25%! Obviously, I was excited by these great results and so was my wife because she had started taking CD again as well. However,

Scott & Brenda McRae from Jakarta, Indonesia

even though our results were great and our experience was far better than before with the old, "try to get to 15 drops twice a day protocol," we still were having some nausea and bouts with diarrhea when we took CD. This was especially true at the times when we felt the symptoms of a cold or flu and tried to take more than the 3 drops doses in order to overcome it. Still the results we were getting with CD on Protocol 1000 outweighed the nausea and diarrhea that we experienced and so we continued using it, especially when we felt some sickness coming on.

After taking CD for about a year in this way, CDS hit the CD world. Being the experimental type, I decided to give it a try. After searching all over Jakarta for the plastic tubing for a couple of days and finally finding it, I made our first batch of CDS. We both tried CDS for about six months but found it to be less effective than CD, so we stopped with CDS and went back to CD and Protocol 1000.

Nevertheless, there were 2 things I really liked about CDS: (1) it NEVER caused us any nausea or diarrhea, and (2) it was so easy to use since it was pre-made (no mixing of chemicals before each use). The main thing for me was not having any more nausea because I really disliked feeling sick. So, I started thinking about CDS and my experience with making it and I came to the conclusion that possibly, the reason why CDS wasn't nauseating was because there wasn't any unactivated sodium chlorite in the solution—it was

just chlorine dioxide dissolved in water. I remembered that when I made CDS myself, even after the activation process had gone on for an hour in a heated condition, if I stirred or swirled the activation chamber bottle, more ClO_2 would still come out of it. This got me to thinking... if the chemical reaction between the sodium chlorite and the 50% citric acid solution used to make the CDS was still able to produce more chlorine dioxide after an hour in a heated condition, then surely the 24 drops that I was using to make my daily CD dosing bottle weren't being fully activated after just 20 seconds.

Therefore, I decided to increase the activation time and tried it out on myself first and then my wife (aren't I considerate?). We both found there was no longer a nausea problem, even when taking more drops per hour than we had ever taken before.

Since I was in an experimental mode, I decided to see if I could make larger quantities of concentrated CD all at once to make it more convenient. I mixed equal amounts of sodium chlorite and 50% citric acid in a bottle, let it activate for about a minute, and then added a specific amount of hot water to further encourage the activation process. In the end, I had a total of 140 ml of this concentrated CD solution. Later, I found that hot water wasn't necessary and that room temperature water worked even better because there was less CLO_2 gas lost in the process.

The finished chemistry was indeed very strong and still didn't cause any nausea, so I was compelled to post my discovery on the Genesis II Forum. I named it *7 Day Fridge MMS (CD)* because it provided a 7 day supply of Protocol 1000. The ingredients added up to 140 ml, so each 20 ml was 1/7th of the total, or a one day supply of "pre-activated" CD similar to Protocol 1000. This made taking CD every day really easy. Just pour out 20ml of the new concentrated solution into a water dosing bottle, and then pour out 1/8th of the bottle every hour into some water in a glass, and drink it.

The *7 Day Fridge MMS (CD)* method worked great for my wife and me. Others on the Forum also tried it and liked it. In addition, I gave it to some people at the school where I work to overcome their colds (usually overnight) as well as other diseases within a short time.

About 18 months later, Charlotte, my Forum friend, began testing the *7 Day Fridge MMS (CD)* process to determine the actual ClO_2 content using her *Sensafe*™ Chlorine Dioxide Photometer. Over several months, we worked together to further refine the 7 Day Fridge method. The result of all of our testing and refinements is this new and exciting CDH product.

The final formula to produce CDH using the 1 Bottle Method came out to be:

22 parts water	91.6%
1 part sodium chlorite	4.2%
1 part HCl (4%) or Citric Acid (35%)	4.2%
Total Solution	**100%**

I believe this new way of making CD will be of great benefit to humanity because it will allow people to gradually double or even triple the amount of CD they can take with little or no stomach upset. By increasing their doses to higher levels, people will be able to overcome CD treatable diseases more quickly than ever before.

As with any new technology, more changes and developments are likely. For example, we now know that CDH tastes much better if activated with hydrochloric acid instead of citric acid.

Producing CDH Using the One Bottle Method

Making CDH is really quite simple. You can use any size of bottle, and produce any quantity you wish, as long as you follow the basic instructions and keep the proportions the same. However, before diverting into different quantities, it is recommended you follow these directions exactly to insure you have the process down correctly.

Note the following volume equivalents:

Fluid Ounce (U.S.) Approximate Equivalents

30ml = 1 fl. oz. US (2 Tablespoons)

660ml = 22 fl. oz. US

720ml = 24 US fl. oz. US

750ml = 25 US fl. oz. US

Equipment Needed

- One 750ml (25 fl. oz. US) glass bottle with an airtight cap. DO NOT use a metal cap (even if it is lined with plastic). The best caps are plastic or even a synthetic cork in good condition. A common 750ml wine bottle is ideal for this as you can get them colored to reduce possible UV exposure (the darker the better). But, a colored bottle is not absolutely necessary and using a clear one will allow you to actually see the chemical reaction as it turns from clear to yellow.

- Three 240ml (8 fl. oz. US) bottles ideally made of colored glass to protect the CDH from UV light (the darker the better), but colored bottles are not absolutely necessary. You can also use smaller bottles if you like—these are just used to divide up the resulting 720ml of CDH into smaller bottles to help retain the ClO_2 concentration while opening and closing the bottles during dosing. *Schweppes*™ sells 6-packs of Ginger Ale, Club Soda and Tonic Water in 10 fl. oz. glass bottles with plastic lids that are great for this purpose, and hold 300ml easily. Only the Ginger Ale is in a colored bottle (green), the others are clear.

- One measuring cup or graduated cylinder to accurately measure liquid in either milliliters or fluid ounces.

Ingredients Needed

Ingredients should be at room temperature—not cold. If CD and/or activator are right out of the refrigerator make your water warmer to offset, or allow ingredients to warm up before using.

- 660ml of distilled or purified water at about 70° - 90°F (21° - 32°C).
- 30ml of sodium chlorite (22.4% solution) near room temperature or slightly above.
- 30ml of 4% Hydrochloric Acid (HCl) or 35% Citric Acid ($C_6H_8O_7$) near room temperature or slightly above.

Note: The amounts indicated above add up to 720ml, while the wine bottle easily has room for an additional 30ml and more. Refer to the chart on right if you wish to produce a different batch amount.

The CDH Formulation Table and Different Acid Concentrations

What if you have 10% Hydrochloric acid or 50% Citric Acid (very common)? Or, you wish to use a different size of bottle? Not a problem. These acids can still be used. However, the formula changes accordingly.

The table below is a great tool for determining the formula for a given bottle size. To use the table, start by circling the size of the bottle you wish to fill in the left most column. Next look at the acid you have and its labeled concentration. Match that with one of the 4 options across the top. Below the matching acid/concentration you will find the 3 formulation numbers for water, sodium chlorite (labeled "SC"), and whatever acid you are using. Just go down the appropriate 3 columns to where the bottle size line intersects and you will have the numbers you need. Substitute these numbers in the following preparation instructions if your situation calls for it.

CDH Formulation Table

(Applies to the One Bottle Method of making CDH ONLY!)

SC=Sodium Chlorite / HCl=Hydrochloric Acid / CA=Citric Acid

Water Bottle (ml)	Hydrochloric Acid 4%			Hydrochloric Acid 10%			Citric Acid 35%			Citric Acid 50%		
	Water (ml)	SC (ml)	HCl (ml)	Water (ml)	SC	HCl (ml)	Water (ml)	SC (ml)	CA (ml)	Water (ml)	SC (ml)	CA (ml)
10	9.2	0.4	0.4	9.4	0.4	0.2	9.2	0.4	0.4	9.3	0.4	0.3
20	18.3	0.8	0.8	18.8	0.8	0.3	18.3	0.8	0.8	18.6	0.8	0.6
30	27.5	1.3	1.3	28.3	1.3	0.5	27.5	1.3	1.3	27.9	1.3	0.9
40	36.7	1.7	1.7	37.7	1.7	0.7	36.7	1.7	1.7	37.2	1.7	1.2
50	45.8	2.1	2.1	47.1	2.1	0.8	45.8	2.1	2.1	46.5	2.1	1.5
60	55.0	2.5	2.5	56.5	2.5	1.0	55.0	2.5	2.5	55.8	2.5	1.7
70	64.2	2.9	2.9	65.9	2.9	1.2	64.2	2.9	2.9	65.0	2.9	2.0
80	73.3	3.3	3.3	75.3	3.3	1.3	73.3	3.3	3.3	74.3	3.3	2.3
90	82.5	3.8	3.8	84.8	3.8	1.5	82.5	3.8	3.8	83.6	3.8	2.6
100	91.7	4.2	4.2	94.2	4.2	1.7	91.7	4.2	4.2	92.9	4.2	2.9
150	137.5	6.3	6.3	141.3	6.3	2.5	137.5	6.3	6.3	139.4	6.3	4.4
200	183.3	8.3	8.3	188.3	8.3	3.3	183.3	8.3	8.3	185.8	8.3	5.8
250	229.2	10.4	10.4	235.4	10.4	4.2	229.2	10.4	10.4	232.3	10.4	7.3
300	275.0	12.5	12.5	282.5	12.5	5.0	275.0	12.5	12.5	278.8	12.5	8.7
350	320.8	14.6	14.6	329.6	14.6	5.8	320.8	14.6	14.6	325.2	14.6	10.2
400	366.7	16.7	16.7	376.7	16.7	6.7	366.7	16.7	16.7	371.7	16.7	11.7
450	412.5	18.8	18.8	423.8	18.8	7.5	412.5	18.8	18.8	418.1	18.8	13.1
500	458.3	20.8	20.8	470.8	20.8	8.3	458.3	20.8	20.8	464.6	20.8	14.6
550	504.2	22.9	22.9	517.9	22.9	9.2	504.2	22.9	22.9	511.0	22.9	16.0
600	550.0	25.0	25.0	565.0	25.0	10.0	550.0	25.0	25.0	557.5	25.0	17.5
650	595.8	27.1	27.1	612.1	27.1	10.8	595.8	27.1	27.1	604.0	27.1	19.0
700	641.7	29.2	29.2	659.2	29.2	11.7	641.7	29.2	29.2	650.4	29.2	20.4
720	660.0	30.0	30.0	678.0	30.0	12.0	660.0	30.0	30.0	669.0	30.0	21.0
750	687.5	31.3	31.3	706.3	31.3	12.5	687.5	31.3	31.3	696.9	31.3	21.9
800	733.3	33.3	33.3	753.3	33.3	13.3	733.3	33.3	33.3	743.3	33.3	23.3
850	779.2	35.4	35.4	800.4	35.4	14.2	779.2	35.4	35.4	789.8	35.4	24.8
900	825.0	37.5	37.5	847.5	37.5	15.0	825.0	37.5	37.5	836.3	37.5	26.2
950	870.8	39.6	39.6	894.6	39.6	15.8	870.8	39.6	39.6	882.7	39.6	27.7
1000	916.7	41.7	41.7	941.7	41.7	16.7	916.7	41.7	41.7	929.2	41.7	29.2

Preparation Instructions

Follow the steps of mixing ingredients in this order (assuming you are using the 750ml glass bottle):

1. Pour 660ml of purified water into the 750ml glass bottle.
2. Add 30ml of sodium chlorite to the 750ml glass bottle.
3. Add 30ml of 4% HCl or 30ml of 35% citric acid to the 750ml glass bottle.
4. Immediately cap/cork the bottle tightly so that no ClO_2 gas can escape and give it a good shake to thoroughly mix the ingredients (and a few more times later on if possible).
5. Store the bottle in a dark place with a temperature of 70°F to 90°F (21°C to 32°C) for 12 to 24 hours or more (24 hours or longer if you're in a cold environment—below 70°F (21°C)).
6. After the storage time has passed, place the bottle of CDH into the refrigerator (not the freezer) and allow it to cool down for 3+ hours before opening it for the first time. The temperature of the solution should be no more than 51°F (10.5° C). Note: If you are using a significantly smaller bottle, cool down time can be reduced because the smaller volume of solution will cool faster.
7. Finally, pour the CDH from the 750ml bottle into the smaller bottles, cap tightly and keep refrigerated until ready to use. The smaller bottle are easier to dose from and they also help reduce the number of times gas can escape and reduce the potency of the solution.

Using CDH

The CDH is now ready for use. Each milliliter of CDH solution contains 1 pre-activated drop of CD. It can be used for ANYTHING that CD is used for; viruses, bacteria, yeast, parasites, heavy metals, enemas, tub baths, gums & teeth, skin care, infections, etc.

When used orally, each 1ml of CDH should be added to at least 30ml of water. You can add even more water if you notice slight throat irritation with higher doses. If taste is an issue, a little bit of stevia may be added to each dose to improve taste by sweetening it. Some of the moms are adding SweetLeaf® Natural Stevia Sweetener to their daily bottle and report no negative impact on ppm level.

Although CDH is strong, it has shown to be gentler on folks who have issues with nausea when using traditional CD. You should be able to start at whatever drop dose you were on with CD and switch to an equivalent milliliter dose of CDH and gradually increase to tolerance. Typically, people are able to take 2 to 3 times as much of CDH as traditional CD, without experiencing nausea.

The CDH bottle should be kept refrigerated and only taken out to extract doses. Since 720ml is a fairly large quantity that may take many days to finish, it's a good idea to take the 720 ml and divide it up into 3 smaller 240ml bottles (720ml ÷ 3 = 240ml) so you won't lose much of the ClO_2 each time you open the bottle. By doing this, you will conserve as much of the ClO_2 as possible. It's also easier to extract doses from a smaller bottle using a syringe or pipette.

Also, keep the CDH bottle out of direct or indirect sunlight to prevent loss of ClO_2. If you make a dosing bottle for the day, it's best to keep it cold, but it is not absolutely necessary.

A little note about taste: Most people who complain about the bad taste of CD, CDS or CDH (which does not have any taste at low doses) are actually reacting to the smell of the ClO_2 which can lead to developing a long-term aversion to any of the treatment solutions. So, if you can minimize the gas floating around your nose, you will have an easier time with drinking the CD, CDS or CDH dose. To accomplish this, Charlotte suggested avoiding the use of a cup or wide mouth drinking bottle. Instead, use a bottle with a small opening such as a common water bottle (preferably made of glass). Of course, if the smell doesn't bother you, this is a moot point, but at least you have this little trick if it does.

Well, that's all you need to know to get started on this great new way to make and use CD. May this new CDH formulation bring you and your family much health and happiness.

Scott McRae
Jakarta, Indonesia
November, 2013

We appreciate Scott, Brenda and Charlotte's contribution to the variety of ways to produce and use chlorine dioxide. Be sure to check the Facebook groups and forums for the latest developments on CDH.

Some of you may feel overwhelmed by what you just read. So, let me give you my "Easy-Peasy" single paragraph method of making CDH: I take a 600ml Lifefactory™ bottle, put in 550ml of water; add 25ml of sodium chlorite; followed by 25ml of 4% HCl (or 50% citric acid). Leave it 12 hours in a cabinet, after which it goes in the fridge for 2 or more hours. Done! ☺

Healing & beating autism.

Chapter 8

Step 3
The Kalcker Parasite Protocol

All of our fathers had a treatment for parasites as a part of their cultural practice. We have gotten away from this because of our reliance on modern practice. We would do quite well to relearn the ways of our ancestors in this area and keep ourselves in relatively good health always.

~ Chief Two Trees

The word "parasite" comes from the Greek word meaning, "one who eats off the table of another." Parasites, to Ancient Greeks, were those who sat at another's table, and paid for their meal with flattery.

As I mentioned earlier in the book, a very interesting thing started happening with the CD enemas. What we had previously believed to be mucous or biofilm coming out with the enemas, turned out in many cases to be worms (helminths) (aka parasites)—in rare cases they were still alive and wiggling in the toilet! We believed the most common were *Ascaris lumbricoides* (roundworm). However, what we are now seeing more and more appear to be rope parasites, a potential new species of helminth discovered by Dr. Gubarev, Dr. Alex Volinsky, and coworkers (submitted January 14, 2013). DNA testing is the only way to definitively say, but at $25,000 USD for each analysis, with a minimum of 100 test cases, it is rather cost prohibitive at the moment.[1]

In addition to Ascaris and rope parasites, parents have also seen hookworms, pinworms, tapeworms, and flukes, among others. This is an extremely important piece of the puzzle for so many of our children. We have been led to believe that in first world nations, parasites are not a problem. This is absolutely not the case.

A well washed parasite. You can almost feel the texture.

Andreas Kalcker, co–author of the Kalcker Parasite Protocol

Miriam Carrasco Maceda, co–author of the Kalcker Parasite Protocol

I was honored to have Dr. Andreas Kalcker and Miriam Carrasco Maceda share a chapter from their upcoming book, *Parasites: The Silent Enemy*. Andreas explains the importance of lifelong deworming, and shares with us a protocol that has helped many children and adults become healthier; and for some children on the spectrum was the last piece added that led them to recovery. The version included here has been tailored specifically for children and adults with ASDs. The original protocol can be found at:

www.andreaskalcker.com/ index.php/en/health/parasite

Very few details have been changed, but it is important to note that the Parasite Protocol here is what has been proven to help many of our children on the spectrum, including many of the recovered children.

Thank you Andreas and Miriam for your valuable contributions to this movement, selflessly sharing your findings, and for always taking the time to help.

HOW TO DETECT AND TREAT A PARASITIC INFECTION

Parasitic infections are more common than most people think, and may or may not result in serious health problems. We may be infected with multiple types of parasites, which vary in size and location, on or in the body.

Parasites can be classified as either microparasites, such as malaria that are only visible under the microscope, or large macroparasites such as round or flat intestinal worms (roundworms, tapeworms, etc.). These can be seen by the naked eye, and can reach great sizes. Internal parasites are found, not only in the intestines, as is generally thought, but anywhere in the body, including the lung, liver, muscle, stomach, gallbladder, brain, blood, skin, joints, and even in the eyes.

In recent history, the great migratory movements of the human population via rapid transportation and widespread trading have shortened the distances that previously had separated people and diseases. Formerly localized diseases have thus become universal ailments. Parasites previously confined to very specific geographical areas now appear in other locations, far away from their initial homelands. Unfortunately, conditions typical of the lower socioeconomic strata, (under which a large percentage of the global population lives) tend to favor the transmission of diseases and parasites.

A high percentage of the world population suffers from infections by parasites, which the WHO (World Health Organization) estimates are responsible for 15 million child deaths annually. In addition to the great cost represented by deaths, chronic and persistent infections have increased as parasites have developed multiple mechanisms of evasion and resistance to specific immunity. This allows them to circumvent and cancel the host immune response.

Persistent parasitic infection in human hosts leads to chronic immune reactions, which can result in tissue damage and altered immune regulation. Ninety percent of the world population is infected with one or more parasites, and up to five different types may coexist in the same host.

This situation becomes dangerous when the internal balance within the host is upset, the number of parasites skyrockets, and the host begins showing signs of serious illness that may even result in death. However, in some cases, parasitic worm infections do not result in disease, in fact, a number of carriers are found to be healthy.

A really good look into a parasite. You can see the actual intestines of the parasite. Also known as a helminth.

The same parasite (as above) from a different angle.

Considering that most people are not even aware of their infections, parasites have become silent killers, claiming the lives of many unsuspecting victims going about their lives oblivious to the danger. Some doctors in Western Europe and the U.S. seem unwilling to even contemplate that we may be infected.

Taking into account the recent increase in travel, immigration, and trade across continents, it is not hard to see how the problem has now become magnified to an alarming level. Parasites, especially the modern "toxified" versions, may well be causing many of the rare diseases now becoming more prevalent, as well as other recently identified or growing problems such as chronic fatigue, fibromyalgia, and arthritis.

The most common verminosis (infestation with or without obvious symptomatology of disease caused by parasitic worms) is intestinal. People who have them not only suffer from a large quantity of lost nutrients (absorbed by the parasites), but also from perforations made by worms in the digestive tract that can open the door to various infections and possible autoimmune deficiencies. Intestinal worm infections are very common and can affect everyone, not only people with poor hygiene habits. Helminths (worms) are transmitted by ingesting the eggs or larvae of parasites, which then hatch in the intestinal tract.

A parasitic infection or reinfection can be acquired through one or more of the following avenues:

- From more or less direct contact with an infected person (fecal or sexual).
- From self-infection, for example, through anal-hand-mouth contact. By scratching the anal area, eggs can become lodged under the fingernails.
- From congenital transmission (mother to fetus).
- From commonly contaminated objects.
- From soil contaminated by human or animal excrement.
- From eating contaminated raw or undercooked meat.
- From eating raw fish.

In some countries, raw fish is included in traditional foods. We can avoid the consumption of the larvae or worms by freezing the meat or fish for at least twelve hours, depending on temperature.

A great photo of a dead parasite, believed to be the Ascaris lumbricoides, or possibly a rope worm in the "seaweed" stage.

A very good look at how long some helminths are. The more worms the people pass, the healthier they get, and the improvements come faster and faster. This child passed a lot of parasites in the beginning. Then after a few months was no longer passing them and now has an ATEC score of 5. Meaning, he no longer has the diagnosis of autism.

This is the parasite that measured 32 inches.

Another long, well washed parasite for the collection. The road to recovery is paved with many dead parasites. Adios Autism…

This is a 32-inch parasite that a young boy passed. He went on to have a great day after getting this out.

These are rope parasites as confirmed by Dr. Alex Volinsky.

60cm long worm (Oct 1, 2013) from child; 6 months on CD; 2 drops every 1-2hr; no parasite protocol; 1tblsp DE; 2-3 vials of Quinton.

This 33 inch parasite (aka "Chester") was discovered by a woman using the protocol on herself.

The bubble visible in this photo leads us to believe this is a late stage rope worm.

After passing this parasite, the child went on to have a fabulous day at school. It is so great to feel good and healthy.

The FDA recommends freezing and storing [fish] at -4°F (-20°C) or below for seven days (total time), or freezing at -31°F (-35°C) or below until solid and storing at -31°F (-35°C) or below for 15 hours, or freezing at -31°F (-35°C) or below until solid and storing at -4°F (-20°C) or below for 24 hours is sufficient to kill parasites. FDA's Food Code recommends these freezing conditions to retailers who provide fish intended for raw consumption. Note: These conditions may not be suitable for freezing particularly large fish (e.g. thicker than six inches).[2]

▶ From drinking contaminated water.

▶ From consuming contaminated vegetables or fruits. Often we eat poorly washed (parasite infested) vegetables or fruits. There is a common misconception that vegetables from organic farming are free from any problems, pesticides, or chemicals. The danger is that the eggs or larvae of the worms reach the farm soil through animal waste, decomposed forms of natural compost, and manure (fertilizer) added to the field. There are eggs, such as Ascaris lumbricoides, which can survive in soil under extreme temperatures for five years. It is very important to perform a thorough cleaning of fruits and vegetables, and never eat anything raw and straight from the ground, however healthy it may seem.

▶ From parasite infested animals. Parasitic infections are very easy to spread by contact with pets. Veterinarians are quick to insist upon the quarterly deworming of our animals, but there are steps we must take on our own to avoid contamination.

Parasites come in all shapes and sizes. Of course, they can also come out in pieces.

Suggested: Deworm your pet at least every three months for life, as directed by your veterinarian. During the first month, it should be done every week. Prevent pets from eating raw viscera. If animals eat raw meat or raw bones the best option is to freeze the food in advance for at least 12 hours (See citation above). If the deworming treatment is working, the animal will expel the worms in the feces or vomit, which must then be burned or buried, during the eight-day treatment.

Avoid being licked in the mouth by animals as they are in direct contact with feces, soil, and their own anus. When petting an animal, wash your hands with soap and water before eating or handling food, as the eggs of the parasites remain in the animal's hair.

- Do not walk barefoot or with open toe shoes in soil or sand.
- Avoid Hippotherapy (horseback riding)

Symptoms of Parasitic Infections

The different types of worms and toxic waste produced by parasites in our body may cause the following common problems:

Parasites come in all sizes. Some are very long. These get washed with hot water for photos. This way we get the best look at them.

Blood Disorders & Blood Parasite Diseases

Parasites absorb essential nutrients from the body, such as iron, vitamin B_{12}, and sugars, which may result in certain blood disorders. In addition, some diseases are known to be caused by blood parasites:

Blood disorders:

- Anemia
- Dizziness
- Hypoglycemia
- Weakness

Blood parasite diseases:

- African Sleeping Sickness
- Babesiosis
- Chagas Disease
- Malaria

Fatigue:

The toxic waste produced by the parasites themselves (including ammonia and psychoactive substances), can stress the detox organs and cause disorders of the central nervous system such as:

- Chronic fatigue syndrome (CFS)
- Cold in the extremities
- Dizziness
- Extreme weakness
- Internal cold
- Lethargy
- Low energy
- Night waking
- Restless sleep

Gastrointestinal Symptoms

- Abdominal pain or tenderness
- Blood in stool
- Burning in the stomach
- Chronic constipation
- Chronic diarrhea or diarrhea caused by poor absorption of food
- Colitis
- Cramping
- Cravings for greasy foods and sugary foods, lots of carbs and bread, fruit, fruit juices, alcohol, or vinegar
- Digestive problems
- Distended belly
- Eating more than normal but still feeling hungry
- Excessive bowel movements
- Fever
- Frequent vomiting and nausea
- Gas and bloating (noted after eating)
- Hemorrhoids
- Irritable bowel syndrome (IBS)
- Intestinal irritation
- Intestinal obstruction
- Leaky gut
- Malabsorption syndrome
- Mucous in stool
- Pancreatitis
- Passing a worm in stool

Growth Problems, Weight, & Appetite

Parasites usually live without being detected by the host. They rob the body of many of the essential nutrients in the food consumed. Many overweight people, who are infected with parasites, go hungry for lack of essential nutrients, causing them to eat in excess due to their parasitic infection. Furthermore, depending on the type of infestation, many people are malnourished and cannot gain weight. The following is a list of some possible symptoms:

In children:

- Poor growth
- Poor physical and intellectual development consistent with their biological age

In children and adults:

- Chronic burping
- Craving white flour products; cookies, cakes, pastries, etc.
- Feeling hungry after a meal
- Inability to gain or lose weight
- Long-term obesity
- Loss of appetite
- Obsession and/or compulsion to eat sweets or very specific foods (wheat, sugar, dairy)
- Ravenous appetite
- Uncontrollable hunger to eat more than usual
- Weight gain (specifically around the time of the full moon)
- Weight loss

Mood Problems & Anxiety

Toxins that are released by parasites can irritate the central nervous system. Anxiety and nervousness are often caused by parasites that migrate throughout the body. Some of the problems caused are:

- Anger and irritability
- Anxiety
- Confused thinking (brain fog)
- Depression
- Disorientation
- Forgetfulness
- Lack of coordination
- Mood swings

- Nervousness
- Obsession
- Restlessness
- Slow reflexes

Muscle & Joint Pain

Parasites can travel almost anywhere in the body. When they migrate to the joints and the muscles they can cause cysts and inflammation. These can often be mistaken for arthritis and/or muscle pain.

Toxins from parasites can also accumulate in the joints and muscle tissue causing:

- Chest pains
- Fibromyalgia
- Joint pain
- Muscle cramps
- Muscle spasms
- Numbness of the hands or feet
- Pain in the back, thighs, or shoulders
- Pain in the navel
- Rapid heartbeat
- Restless leg syndrome
- Seizures

Parasites in Children (including children with ASDs)

Parasites can be found in the body in asymptomatic and symptomatic stages. The former are usually found in adults. Symptomatic stages occur mainly in children, in whom we can often observe the following:

- Anorexia
- Anxiety
- Bruxism (teeth grinding)
- Cramping
- Diarrhea that alternates with periods of constipation
- Excessive Flapping
- Growth retardation
- Headaches
- Inability to gain weight
- Itching/Burning/Picking of the anus
- Nasal itching and/or anal urticaria (hives/rash)
- Nervousness and irritability

- Nose Picking
- OCD (Obsessive Compulsive Disorder)
- Rage
- Smearing feces
- Unexplained laughter or weeping
- Verbal stims
- Weight loss

Tapeworms, and some other parasites, have an affinity for B_{12} and iron. Therefore, lab results that show deficiencies in B_{12} and/or iron can be indicators of parasitic infections.[3,4] Due to its size, the tapeworm consumes enormous amounts of food that it obtains by taking the child's food. This can affect the child's normal development.

Treatment is simple, but it requires that the head of the tapeworm be removed, otherwise it will continue to grow. Tapeworm treatment is separate from this protocol and usually requires niclosamide. However, the only way to be sure the head has been removed is to identify it in the stool.

Respiratory Disease

The passage of larvae through the respiratory system or larval invasion in the lungs may cause symptoms such as:

- Acute bronchitis
- Asthma
- Drowsiness
- Dyspnea (shortness of breath; air hunger)
- Chronic/irritative cough
- Pneumonia
- Shortness of breath or respiratory failure

Sexual & Reproductive Disorders

Immune dysfunction as a result of a parasitic infection can lead to:

- Candida - yeast infections
- Cysts and fibroids
- Erectile dysfunction
- Fluid retention
- Male impotence
- Menstrual problems
- Premenstrual syndrome
- Prostate problems
- Urinary Tract Infections

Skin Disorders & Allergies

External parasites (lice, bedbugs, scabies, etc.) that penetrate the skin can cause itching, redness, and/or rashes etc. However, internal parasites can be responsible for skin disorders as well. Parasites create toxic metabolic waste, and because the skin is the largest organ, the body tries to eliminate them through it, resulting in many skin problems.

Some symptoms may include:

- Allergies (to foods, dust, mold, etc.)
- Anal itching
- Brittle hair
- Crawling sensation under the skin
- Dermatitis
- Dry hair
- Dry skin
- Eczema
- Eruptions
- Hair loss
- Itchy nose
- Itchy skin
- Jaundice
- Psoriasis
- Skin ulcers
- Sores
- Swelling
- Urticaria (hives; skin rash)

Sleep Disorders

The body reacts to parasites during rest periods because at night is when parasites are most active. Nocturnal awakenings are common, especially between 2 and 3am, when the liver tries to rid the body of toxins produced by parasites. This in turn may produce:

- Insomnia
- Teeth grinding
- Bedwetting
- Drooling while sleeping
- Sleep disturbances - multiple awakenings during the night
- Restless sleep

Other Problems Associated with Parasites

- Bad breath
- Blurred vision
- Body odor
- Breathing problems
- Chronic infections: viral or bacterial
- Circulatory problems, numbness in the extremities, difficulty in moving
- Cough or coughing up blood
- Difficulty swallowing
- Excessive salivation
- Fever
- Fluid build-up or retention during the time of the full moon.
- Low immune response
- Peritonitis
- Sensation of a foreign body or discomfort in the throat
- Swollen eyes
- Weight gain during the full moon.

Blood Analysis

The following markers may be present when a person is suffering from a parasitic infection or the resulting allergies:

- Anemia/low iron
- Elevated immunoglobulin (IgE)
- Elevated eosinophils (The eosinophil is a specialized cell of the immune system, more specifically it is a proinflammatory white blood cell. According to the Registry for Eosinophilic Gastrointestinal Disorders (REGID), their known functions include movement to inflamed areas, trapping substances, killing cells, antiparasitic, and bactericidal activity, participating in allergic reactions, and modulating inflammatory responses.)
- High ammonia
- High oxalates
- Low vitamin B_{12}

Measures in the Home Environment to Prevent Reinfection

It is important to treat all people and pets that live in the same environment to prevent someone from infecting others. Reinfection occurs via underwear, bedding, towels and household items such as children's toys or animals that have been in contact with eggs. It is important to wash all clothing that has contact with intimate body areas at a temperature not below 60°C (140°F).

All bed linen and underwear must be washed daily (or to the extent possible) while performing anti-parasitic therapy. Affected individuals should not share their swimwear with other members of the family, and should use a separate cloth to wash his anal area. It is best to sleep wearing both underwear and pants to avoid involuntary scratching during the night. This will prevent infection through anal-hand-mouth contact because by scratching the anal area, eggs can become lodged under the fingernails. Keep pets away from the place of rest of their owners, such as beds, sofas, blankets, and cushions.

Thoroughly wash fruits and vegetables in water and soak them in CD or CDS solution for a few minutes. Clean the sink with alcohol, as the eggs of many parasites are immune to the pH of normal cleaning products such as soap or bleach. It is important to note that parasites do not leave any kind of immunity behind in the host, therefore, once cured, the person who has suffered can suffer from them again. The only surefire method of killing the eggs of *Ascaris lumbricoides* is in water above 60°C (140°F) or with 96% grain alcohol (Everclear).

Evolutionary Cycles of Intestinal Parasites

Although there are many more, here is a description of the three most common types of intestinal parasites that can be found in developed countries:

Ascaris Lumbricoides (Roundworm)

Ascaris reproduce quickly, as a single female can lay up to 200,000 eggs each day. This parasite is very common, especially in damp conditions, and when hygiene measures are inadequate. It can affect the entire population, but mostly affects children, seriously disrupting their development and growth. It's so infectious that the WHO estimates that there are about 700,000,000 people infected worldwide, of which around 60,000 cases end in death per year, mainly children.[5]

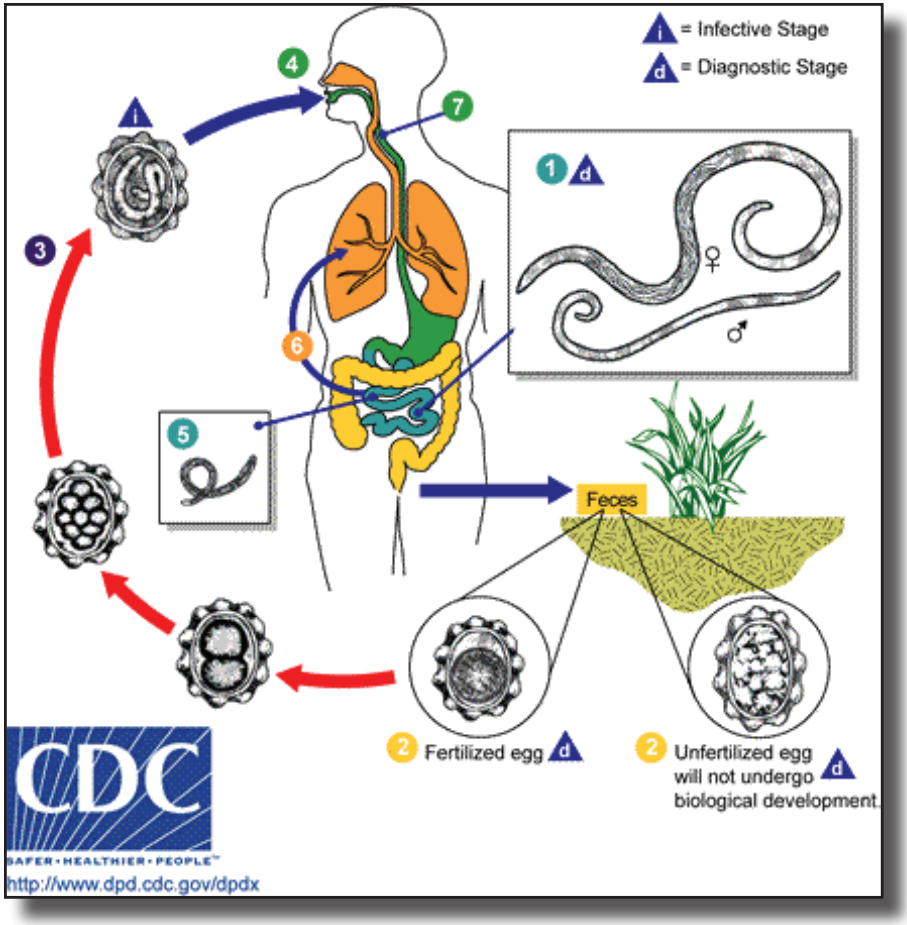

Parasite eggs reach the duodenum through the mouth of the host. Gastric juices rid the eggs of their shells and release the larvae. These larvae, which are highly mobile, penetrate the duodenal mucosa and migrate to the liver. From there, they continue their migration to the heart, reaching the lungs through pulmonary circulation, and finally become trapped in the pulmonary capillaries. Here, the larvae break the thin walls of the capillaries and penetrate the alveoli, bronchioles, and bronchi at which point they are able to travel up through the pharynx. Once the eggs pass the epiglottis (see diagram above), the larvae are swallowed such that they return to the duodenum, where they complete their maturation process. This process takes approximately two to three months to complete; therefore we calculate that to find ourselves completely parasite free, the initial treatment should be done for at least 12-18 months, possibly longer. From there on out, you may only need to follow a routine deworming two to four times a year.

Keep in mind that eggs are expelled through the feces (human or animal) into the environment where they can survive even in harsh conditions, favoring the persistence of the parasite. They are resistant to low temperatures, desiccation, strong acids, soaps, chlorine, formaldehyde (pH between 2 and 11.5), and can live in planted soils for five or more years, creating a "parasite hotbed" that makes them almost indestructible. Once dry, they are transported through the air, fly in air currents like dust that can be inhaled and/or swallowed. We have recovered eggs from nasal mucus, paper currency, potting soil, dust, and in indoor airborne particles, etc.

Taenia Saginata and *Taenia Solium* (Tapeworm)

Taenias reach humans when humans eat their eggs, by the consumption of tissue from infected cattle or pigs. In infected animals, the larvae are encysted in the muscle tissue. If the infected animal is consumed, development may proceed in the human digestive system. Humans are hosts for *T. saginata* (beef tapeworm) and *T. solium* (pork tapeworm). The tapeworm is considered to be solitary, because usually no more than four species are found in any one individual host. The danger of this parasite is that the larvae can migrate to the brain, or other vital organs (cysticercosis). Tapeworms may be detected by identifying segments in the host's stool that the worms discard as they grow. However, tapeworms may go undetected for many years, living asymptomatically within their host.

According to classification, they can vary in size ranging from 2 to 12 meters in length. They consist of a head called the scolex, which attaches to the intestine by means of suction cups, and a body consisting of repeating units called proglottids. A single Taenia can grow from 1,000 to 2,000 proglottids, depending on the type. A tapeworm produces an average of 720,000 eggs per day.

Pinworms (*Enterobius Vermicularis*)

Humans are considered the only host of what are commonly called pinworms (*Enterobius vermicularis*). This type of worm is the most typical in the family because it propagates easily. It is common for children to become reinfected in schools, through contact with others, or through anal-hand-mouth contact. Pinworms have an elongated shape, are whitish in color, and are about 1cm long. They inhabit the large intestine of humans. Female pinworms leave eggs around the anus. Once deposited, the eggs are infectious for a period of up to 20 days. Once in the intestine, it takes between five and eight weeks to

develop into adult worms. The most important symptom is intense itching that occurs in the anal area, especially at night. In women, inflammation of the vulvar area is very common.

A pinworm infection is, generally speaking, not very serious. Unlike other parasites, they infect only humans. Transmission from person-to-person happens by handling clothing, bed sheets, towels, and environmental surfaces (such as curtains, carpeting) contaminated with pinworm eggs, which are so light that they are able to become airborne. A small number of eggs can be integrated into air particles that when inhaled follow the same developmental process as ingested eggs. Enemas are extremely useful in removing this parasite from the large intestine.

Graham's method is a simple method of detection. Just after waking and before a bowel movement, press a piece of tape against the anal folds. The tape will catch the remains of eggs and/or parasites that are situated there. With the naked eye we can see small worms no more than an inch long, but with a microscope, many transparent eggs from females and even other species may be seen.

The Importance of Lifelong Deworming

Once we begin the process of deworming, we should recognize that we must maintain this habit of cleaning for the rest of our lives to enjoy good health. It is common among people who have pets, to follow the recommendations of their veterinarians, and deworm their pets every three months. It is interesting to ask why family physicians do not give the same advice to humans. Perhaps some physicians ignore this information, or simply do not consider it important to eliminate these pests, which are just as harmful to people as they are for animals.

It is true that many parasites are not endemic or common outside certain climates, but human migration and global marketing of food products have facilitated the spread of many parasitic pests silently. It is important that we understand the lifecycle of each parasite, from birth to death including reproductive and death stages. This information is crucial for the complete elimination of the parasite. For example, in the case of intestinal parasites treated here with this protocol, some can live in the host for up to ten years, as in the case of a single Taenia, while others may remain in the host for a lifetime, reproducing again and again, as in the case of the pinworms or the well-known Ascaris.

The Kalcker Parasite Protocol & Lunar Cycle Timing

In the modern civilization in which we live, we have lost touch with much of the ancient wisdom of the past. One of the things we have forgotten is how the natural cycle of the moon influences many of nature's routines. This is especially true for the behavior of parasites. They are known to sync their life-cycle with that of the lunar cycle. Your child may demonstrate extreme behaviors on certain lunar cycle days… especially on the full moon and sometimes even the new moon.

Therefore, to maximize effectiveness, this Parasite Protocol is specifically timed to the lunar cycle. Appendix 10, page 477 provides an easy reference for you to look up the days to perform the Parasite Protocol, which is administered over 19 days—numbered 0 to 18—each month; starting three days prior to the full moon and continue during the waning moon. This period of the moon's cycle is very effective for deworming because many nematodes (parasitic worms) travel back into the intestine to mate at this time.

Length of Treatment

This protocol is not a one-time treatment. You should plan for at least 12 to 18 months to insure you have purged multiple parasite life-cycles and continue beyond 12 months if your child is still expelling parasites.

Building on CD

This protocol builds on what you have already learned using CD. During treatment, it is absolutely necessary to continue CD dosing, CD baths and CD enemas.

Tape Worms

This protocol is specifically designed for the deworming of large intestinal parasites, especially round nematodes such as Ascaris. It is effective for most nematodes, but may not be effective against tapeworms. In the case of infestation by Taenias, the recommended treatment is Niclosamide, the preferred medication due to its low toxicity.

Components of the Kalcker Parasite Protocol

This protocol uses some of what you have already learned and should already be doing, along with a set of ingredients you will need to have on hand before you start (shown in bold below). Here is an overview list of the items you

will need to have on hand, and the items are described in detail on the pages that follow:

- Meal time (1, 2, 3)
- CD / CDS (4-19)
- CD Baths (20)
- CD Enemas (21, 22)
- Ocean Water (23, 24, 25) (see page 115)
- **Diatomaceous Earth** (26, 27)
- **Lepidium Latifolium Extract (Rompepiedras)** or **Chanca Piedra (Stone Breaker)** (28, 29)
- **Pyrantel Pamoate (Combantrin®)** (30, 31)
- **Mebendazole** (32-36)
- **Castor Oil** (37)
- **Neem** (39, 40)
- **Probiotic (usually THERALAC®)** (41)

Check the following website for the latest information on where to find these products:

www.ProtocolSuppliers.com

You may have noticed one or more numbers in parenthesis following each of the previous items, such as "(40)" for the probiotic. The timing of what to give when, is covered in great detail in the daily charts starting on page 198. These numbers match those found on the daily sample charts to make it easier for you to connect the dots and also be able to identify related notes under each chart. They have nothing to do with the quantity/dosing of any substance. The use of these numbers allows us to comment on specific items and when and where they come into play as shown on the daily sample charts.

We now detail each one of the items on the list above and discuss what you need to know about them and how to acquire them (including their associated numbers on the charts).

Meals (1, 2, 3)

Obviously meals are part of everyone's day. The purpose in mentioning them here is that many of the following steps are related to meal timing. Some actions or ingredients are taken before breakfast, others during or after.

In our example charts, we make some assumptions which include:

- Breakfast (1) is at 7:30am
- Lunch (2) is at 12 noon
- Dinner (3) is at 5pm

CD, CDS or CDH (4-19)

As you learned in Chapter 5, you continue to dose CD (or CDS/CDH) as before during the Parasite Protocol. Nothing changes in that regard with the Parasite Protocol building on top of those steps already in place.

The sample charts assume your child is going to school, and so you may not be able to administer doses of CD during his school day (7-12) unless you are home-schooling, in which case you are encouraged to give hourly CD doses, even if the total exceeds 8 for the day.

CD Baths (Optional) (20)

Our sample charts assume you administer a CD bath just before bedtime. See pages 113 for more information about CD baths.

CD Enemas (21, 22)

Ideally, give your child a CD enema in the morning (21) and another one in the evening (22). However, if your child is going to school, a morning (21) enema may not be a good idea due to the possibility of an "accident." Therefore, consider the morning enema optional, but the night time enema a must do! See page 103 for more information.

Ocean Water (23, 24, 25)

Supplementing ocean water minerals is important to support the body through the detoxification process. See page 115 for more information on ocean water.

Dosing:

(23) A dose of ocean water should be administered upon waking, but five minutes apart from CD dosing.

(24) One dose of ocean water immediately after school (or at lunch time if at home).

(25) One dose of ocean water, 15 minutes before or after dinner.

Diatomaceous Earth (DE) - Food Grade (26, 27)

Diatoms are unicellular plants that existed by the trillions in our oceans over 300 million years ago. They are encased by a cell wall that is made of silica. When diatoms die, this microscopic coating deposits at the bottom of oceans. Over time, they pile up in banks forming deposits thousands of meters in size. With the receding of the oceans, these deposits have been uncovered. Through compression, and ultimately fossilization, these silica deposits have given rise to a chalk rock called diatomaceous earth.

DE is an inert, nontoxic compound, which contains a number of minerals such as manganese, magnesium, iron, titanium, calcium silicates, and others. Properly ground, the skeletons of microscopic diatoms become sharp silica needles, harmful to parasites, fungi, yeast, worms, and amoebas. However, these needles are harmless to humans and other warm-blooded animals. Although it is safe to consume diatomaceous earth continuously, the best method (as with everything else) is to allow for periods of rest. During the 18-day treatment, take two teaspoons (5ml) twice a day.

Dosing: ½ to 1 teaspoon twice a day for smaller kids, 1 teaspoon three times a day for adults and bigger kids. Mix with a little water and drink. Given on days 1 through 18. DE mixes well with water but never dissolves. Stir the DE/water slurry vigorously and drink immediately before the DE settles to the bottom. Some people take heaping tablespoons in water, but larger amounts are not necessary. DO NOT take dry!

Note: In rare cases, DE can cause constipation, which can usually be managed by reducing the dosages to 1/2, 1/4 or even 1/8th of a teaspoon. If that doesn't resolve the issue, remove DE from the protocol and continue with all other directions.

Source & Cost: Search online for "Food Grade Diatomaceous Earth." Buy at least 1 pound and expect to pay about $20 more or less. Better yet, buy a five pound bag, which will reduce your cost per pound. DE does not expire or degrade, but should be kept in a dry container. Note: Diatomaceous Earth

is often used as non-toxic element in pool filtration systems. You DO NOT want to use this kind of DE since it has been processed. Only get "Food Grade" Diatomaceous Earth!

Lepidium Latifolium Extract (aka Rompepiedras or Pepperwort) or Chanca Piedra (aka Stone Breaker) (28, 29)

Lepidium Latifolium (Rompepiedras) and Chanca Piedra (Stone Breaker) both break up hard substances in the body. The reason we use it in this protocol is two-fold: It breaks up the protective outer coating of parasites, and annihilates oxalates, which many of our kids have an abundance of because oxalates are produced by parasites.

Note #1: It is often simply referred to as "RP" in our discussion forums.

Note #2: If you are having trouble finding this particular ingredient, don't let its absence stop you from starting the protocol with all other ingredients.

Dosing: 15 drops for a 100 pound child mixed in with the diatomaceous earth/water. Use seven drops for smaller children.

Source & Cost: You have a choice of two herb extracts; Lepidium Latifolium Extract (aka Rompepiedras or Pepperwort) and Chanca Piedra (aka Stone Breaker). One US source is www.mightyguts.com, which sells a 50ml dropper bottle of Pepperwort for about $30. A primary manufacturer in Europe is Soria Natural from Spain that labels their product Rompepiedras, while they also have an English labeled box that says Pepperwort. They both show Lepidium Latifolium on the box.

Pyrantel Pamoate (30, 31) (Trilombrin/Combantrin®)

Pyrantel pamoate is a broad spectrum anthelmintic, which works by causing a neuromuscular block that produces spastic paralysis of the parasite, and its subsequent expulsion by intestinal peristaltic action, without excitation of the parasites or encouragement of their migration. Pyrantel pamoate acts over a short duration, and tends to be completely eliminated from the body in the feces and urine within three to four days. Pyrantel pamoate is poorly absorbed from the gastrointestinal tract, and approximately 6 to 8% total is found in the urine, with the remainder in the feces. The recommended dose is one daily dose of 10 mg per kilo.

Pyrantel pamoate is incompatible with the use of piperazine, because the two substances neutralize each other. Thus Pyrantel pamoate should not be combined with pumpkin seeds, which contain piperazine, or with antiparasitic drugs that contain piperazine in their formulation.

Dosing: Pyrantel pamoate is given only twice during one cycle of the parasite protocol; once during breakfast on day one (30), and again during breakfast on day five (31). Dose is based on weight and calculated by multiplying your child's weight in kilograms times 10mg of pyrantel pamoate. To make it easy, refer to the following chart:

Pyrantel Pamoate (Trilobrin/Combantrin®) Dosing by Weight		
Pounds	**Kilograms**	**Dose in mg.**
20	9	91
40	18	181
60	27	272
80	36	363
100	45	454
120	54	544
140	64	635
160	73	726
180	82	816
200	91	907
220	100	998
240	109	1089

Pyrantel pamoate (often just referred to as Combantrin®) is available in three forms:

- **Liquid:** where each milliliter contains a certain number of milligrams. For example, one available formulation contains 144mg/ml. So a 100lb child would take 3ml.
- **Tablets:** where each usually contains 250mg.
- **Capsules:** where each usually contains 250mg.

You will have to read the label or the particular product you acquire and determine the milligrams to use.

Source: Combantrin® is available by prescription in the US. Most other countries have it available over the counter.

The preferred source of pyrantel pamoate is a compounding pharmacy, as to avoid coloring and flavoring. If you are unable to find it without coloring/flavoring then I would personally use mebendazole for the entire 18 days rather than risk giving your child an ingredient which may cause regression.

Note #1: Some brands of Combantrin® include mebendazole. You want the stand-alone Combantrin®!

Note: #2 Pumpkin seeds should not be consumed with pyrantel pamoate because they neutralize its effects.

Mebendazole (Vermox®/Lomper®) (32-36)

Mebendazole is a drug used in treating diseases caused by helminths (parasites of the gastrointestinal tract). This drug prevents the parasite from using glucose, which results in a decrease in energy and therefore death of the parasite.

Mebendazole is a non-systemic drug which means it is only absorbed, to a limited extent, in the gastrointestinal tract (approximately 5 to 10%). However, if it is consumed with fatty foods then more absorption occurs.

Approximately 2% of the administered mebendazole is excreted in the urine, while the remainder is excreted in the feces. The appropriate dose of mebendazole may be different for each patient as it depends on the type of parasite causing the infection.[6] The most frequently recommended dose is 100mg for children, 200 mg for adults, two times a day for seven of the first nine days of the Protocol.

Adverse effects from mebendazole are generally rare due to its poor absorption. However, it may cause nausea, vomiting, abdominal pain, and diarrhea. Normally these effects are in fact a result of the release of toxins from the very death of

the parasite itself. Anti-parasitic drugs can be administered very effectively by diluting them in water, putting the mixture in a small bulb enema, and inserting the anally. This is especially suitable in the case of oxyuriasis (pinworms). Read more about this "implant method" on page 220.

Dosing:

Note: Indicated weights should only be considered a rough guide.

Small Children (20-40lbs.): Days 2, 3, 4, 6, 7, 8 & 9 — Take as little as 25mg of mebendazole with breakfast and dinner, and do NOT do a blitz on Day 9.

Children (41-70lbs.): Days 2, 3, 4, 6, 7, & 8 — 50mg with breakfast and dinner. On Day 9 they can take 50mg, 50mg and 25mg.

Adolescents (71-100lbs.): Days 2, 3, 4, 6, 7, & 8 — 100mg during breakfast and 100mg during dinner. Day 9 is "Mebendazole Blitz Day" where you administer ONE 200mg dose during breakfast; ONE 200mg dose at lunch; and a final 100mg dose at dinner.

Teens & Adults (101 lbs. and up): Days 2, 3, 4, 6, 7, & 8 — 200mg during breakfast and 200mg during dinner. Day 9 is "Mebendazole Blitz Day" where you administer ONE 500mg dose during breakfast and no dose at lunch or dinner for the remainder of the current cycle.

Source: Mebendazole is available by prescription in the US and over the counter in other countries.

Note #1: Some brands combine mebendazole with Combantrin®. You want the stand-alone mebendazole!

Note #2: Mebendazole is mostly sold in tablet form, but it is also available in liquid. DO NOT buy the liquid form—stick with the tablets! I have seen horrible reactions from the "inert" vehicles used in the liquid products.

Castor Oil (37)

Castor oil is extracted from the seed of a plant called Ricinus communis ("Higuera del diablo"). Its seeds contain between 50-80% oil, which has a high content of ricinoleic acid, which has excellent laxative and purgative properties. Once you begin anti-parasitic treatments, spastic paralysis may occur in some parasites and many together may form a "knot" of worms that can cause intestinal obstruction. It is important to help your body

purge them by using castor oil. Castor oil should be taken in the morning, two hours after breakfast and other medications. If your child goes to school they take it as soon as they walk in the door from school. A typical dose for a child is 1/2 tsp to 1 tsp, or up to tolerance. The adult dosage is 15 to 30ml (two tablespoons), two hours after breakfast and other medications. If you experience any intestinal distress, mineral purgatives such as Epsom salts, or vegetable purgatives such as senna leaves, can be used.

Castor oil is also available in gelcaps for those who dislike the taste.

Dosing: The amount to administer varies and really depends on the individual's tolerance. A good starting point is ½ teaspoon for smaller children and up to two tablespoons for larger children and adults. Only experimentation will determine the right amount, if castor oil causes diarrhea.

Source & Cost: Readily available in liquid form at most pharmacies in the laxative section. Usually under $10 for 16oz. Also available online.

Neem (Azadirachta indica), Caps or Tea (38, 39)

The neem tree is a great natural inheritance of mankind. References in Sanskrit scriptures and ayurvic medicine practices indicate the use of neem since ancient times in Hindu medicine. Even today, Hindus living in rural areas call the neem tree the "village pharmacy" for its ability to alleviate many diseases and is currently endorsed by authorities in India for its use in medicinal preparations. Neem is one of the purifying and detoxifying plants

with the greatest potential. Neem has been used to combat all forms of body parasites, external and internal parasites alike. To prepare neem, boil four leaves (normally the contents of an envelope) in one liter of water for five minutes. Drink the tea throughout the day over the course of each parasite protocol.

Dosing: Neem is given each parasite protocol from day 10 through Day 18.

You have a choice of caps or tea. I prefer caps over tea because the taste is strong and unpleasant, so some kids will buck drinking tea.

Caps (assuming 475mg each): An adult takes six in a day, three times two caps at meal times.

Follow the directions on the bottle. Give a full dose for teens and adults 100 lbs. and over. Small children receive ¼ to ½ dose.

If using caps, give one dose during breakfast and one dose at dinner.

Tea: Give four doses throughout the day. Prepare a tea from the leaves, one tea bag in one liter of water (add stevia if needed to cover some of the bitter taste). One tea bag usually contains approximately four leaves. If using loose leaves, then make one liter of tea with four neem leaves. If using crushed leaves, then use approximately one slightly heaping teaspoon.

Neem Tea Dosing	
Weight of Person	**Total Daily Amount (To be split into 4 doses)**
20-34 lbs	100 ml
35-49 lbs	200 ml
50-64	300 ml
65-84	400 ml
85-109	500 ml
110 and over	600 ml

Source & Cost: Neem capsules cost about $8 for 100x 475mg caps. Look in your local health food store. One popular brand in the US is Nature's Way®. BioPure™ sells a product called *Neem Synergy* which contains a few additional herbs that do not affect the neem.

Neem tea can be purchased in bags or as dried leaves.

THERALAC® (Probiotic) (40)

THERALAC® is a probiotic that should be given during the parasite protocol to help reestablish good gut flora. Ideally, it is rotated every other month with THERALAC® TruFlora®.

The key reason for recommending THERALAC® over other probiotics is explained in this paragraph excerpted from their website:

> *THERALAC® probiotics survive transit through the harsh acidity of the stomach and arrive alive in the intestinal tract. THERALAC's ACID PROOF™ technology utilizes sodium alginate from seaweed in a unique formulation that assures survival at pH 1.6 for 90 minutes, the most severe stomach acid conditions normally experienced. Other probiotics that claim acid resistance are tested at pH 2.5 – 3.0, or >10 times less acidic than pH 1.6 – not a fair test. THERALAC's ACID PROOF® technology is protected by US Patents 7,122,370 and 7,229,818. This technology goes beyond resisting stomach acid and involves keeping the probiotic cells together in a viscous alginate-gel moving in group-force, not as separate individual cells like other probiotics, deep into the intestinal tract while retaining key formula ingredients, LactoStim® and Sodium Alginate in close proximity.*

Dosing: One capsule of THERALAC® is given each and every night at bedtime, irrelevent of age/weight. This probiotic is also to be given outside of the 19 Parasite Protocol days.

THERALAC® can be given at the same time as CD if your child swallows capsules. However, if you are using the THERALAC® powder form then give it at least five to ten minutes after the last CD dose of the night. See their website for more information about the powder form.

Special exception: Some people do not tolerate probiotics, in which case we have no choice but to leave them out. In some of these cases, sauerkraut and fermented veggies may help to cultivate beneficial bacteria.

Source & Cost: Amazon carries "THERALAC® 30 caps by Master Supplements Inc." for $37.

Sample Parasite Protocol Daily Calendar

To assist you in understanding the Parasite Protocol and how it changes from day to day, we have prepared the following visual set of daily charts showing how all the pieces fit together. To prepare this set of charts, we made up the following times for example purposes only:

- Your child's awake time is between 6am and 10pm.
- Breakfast is at 7:30am
- Your child goes to school, which starts at about 9am
- School is out at about 2:30pm
- Dinner is at 5pm

As stated earlier, each dose or activity is labeled with a unique number. Those numbers relate to notes below each chart AND they match longer descriptive notes in the previous pages.

You are encouraged to copy/enlarge the blank chart in Appendix 9 (page 475) and workout your real-life schedule based on these example charts.

Refer to the lunar calendar (Appendix 10, page 477) for the exact days the protocol should be followed, as well as to get an idea of behaviors related to parasites around the full and new moon.

After four years of biomed and no major gains, we decided to try mms/cd protocol. We started in April and are currently on our second parasite protocol. Initially, we were really intimidated by the enema part but realized if we were apprehensive our 7 yr old daughter would pick up on that. We told her that what we were about to do would help her feel better we gave her the iPad right before the procedure and a new fav toy (beanie boos) and she was game. After it was over she said "no more booboo in my tummy". We all cried. To make a three-month adventure short and sweet, her team at school cannot figure out how her fragmented speech has gone from 2-3 word utterances to long, drawn out sentences. Her expressive language and receptive have increased. Her auditory processing speed has quadrupled. The most amazing part thus far has been the increase in social skills. Or just the fact that she is interested in engaging. Socially she was nonexistent and is now at a four year old level. We just spent a week with family and she was saying hi and engaging without being prompted!!! She now has a million questions, wants to know when and where we are going and the sequence in which events will take place. All this from a girl who never asked questions before mms! STOP thinking about trying! Just Do It!! For the first time in seven years, I can hear the bells of freedom ringing!!!! Thank you Kerri Rivera !!!!!

Day 0 (3 days before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1											
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3											
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 0 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
40	Probiotic at the end of the day

Day 1 (2 days before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28	30				
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29					
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 1 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
30	Dose of Combantrin with breakfast
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 2 (1 day before Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 2 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 3 (Full-Moon)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
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Day 3 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 4

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrante/ Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
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7:00 PM		17			25							
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8:00 PM		18										
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9:00 PM		19	20									
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Day 4 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 5

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28	31				
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
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3:00 PM		13			24					37		
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4:00 PM		14										
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5:00 PM	3					27	29					
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6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 5 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
31	Dose of Combantrin with breakfast (NO Mebendazole today!)
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 6

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
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5:00 PM	3					27	29		33			
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 6 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 7

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
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5:00 PM	3					27	29		33			
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6:00 PM		16		22								
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9:00 PM		19	20									
9:30 PM												40

Day 7 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 8

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		32			
8:00 AM		6										
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5:00 PM	3					27	29		33			
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8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 8 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
32, 33	Small Child Dose: 100mg Mebendazole with breakfast and dinner. Teen/Adult Dose: 200mg Mebendazole with breakfast and dinner.
40	Probiotic at the end of the day

Day 9 (Mebendazole Blitz Day)

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28		34			
8:00 AM		6										
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9:00 PM		19	20									
9:30 PM												40

Day 9 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
34	Blitz Day - Small Child Dose 1: 200mg Mebendazole with breakfast. Teen/Adult Dose: 500mg Mebendazole with breakfast ONLY!
35	Blitz Day - Dose 2: 200mg Mebendazole with lunch (or right after school) Teen/Adult Dose: N/A
36	Blitz Day - Dose 3: 100mg Mebendazole with dinner. Teen/Adult Dose: N/A
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
40	Probiotic at the end of the day

Day 10

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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4:30 PM												
5:00 PM	3					27	29				39	
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6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 10 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Start dosing Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 11

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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9:00 AM		7										
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3:00 PM		13			24							
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4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 11 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 12

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrante/ Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM										*		
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4:00 PM		14										
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5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
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8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 12 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 13

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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9:00 AM		7										
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4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
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7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 13 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 14

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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3:00 PM		13			24							
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4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 14 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 15

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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4:00 PM		14										
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5:00 PM	3					27	29				39	
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6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
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9:00 PM		19	20									
9:30 PM												40

Day 15 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 16

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
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11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 16 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 17

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrante/ Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM												
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24							
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 17 - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Day 18

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM		4		21	23							
6:30 AM												
7:00 AM		5										
7:30 AM	1					26	28				38	
8:00 AM		6										
8:30 AM										*		
9:00 AM		7										
9:30 AM												
10:00 AM		8										
10:30 AM												
11:00 AM		9										
11:30 AM												
12:00 PM	2											
12:30 PM												
1:00 PM		11										
1:30 PM												
2:00 PM		12										
2:30 PM												
3:00 PM		13			24					37		
3:30 PM												
4:00 PM		14										
4:30 PM												
5:00 PM	3					27	29				39	
5:30 PM												
6:00 PM		16		22								
6:30 PM												
7:00 PM		17			25							
7:30 PM												
8:00 PM		18										
8:30 PM												
9:00 PM		19	20									
9:30 PM												40

Day 18 (Last Day!) - Notes:	
1, 2, 3	Breakfast, Lunch & Dinner
4 - 19	At least 8 CD doses throughout the day, preferably more, at least 30 to 60 minutes away from food.
20	CD Bath at the end of the day.
21, 22	Enema in the morning (optional) and in the evening (mandatory).
23 - 25	3 doses of ocean water at least 5 minutes away from CD.
26 - 29	Diatomaceous Earth and Lepidium Latifolium with breakfast and dinner.
*** 37**	Castor oil 1 hour after breakfast or immediately upon return from school.
38, 39	Neem Caps with breakfast and dinner. If using tea, 4 doses throughout the day.
40	Probiotic at the end of the day

Parasite Protocol *Off Days*

Days "19" through to the next "Day 0" are "Off Days" where you discontinue parasite meds and herbs. Here's a simple chart showing what to continue doing and what to stop during this *off* time:

Continue with these:
CD / CDS / CDH Dosing
CD / CDS / CDH Baths
CD / CDS / CDH Enemas
Ocean Water
Probiotic

Stop these:
Diatomaceous Earth
Lepidium Latifolium
Pyrantel Pamoate (Combantrin®)
Mebendazol
Neem
Castor Oil

Of course this represents a hypothetical case and your situation may call for taking other meds or supplements.

Detection of Parasites in Stool

It is necessary to detect the parasites by observing the stool carefully. For that we use a small plastic basin, and a plastic stick or fork for examination.

Author's Note: One of the moms who is a part of our forum came up with some guidelines for processing your child's stool for parasite identification. She calls it, "Everything You Wanted to Know About Sorting Through Poop." Here are her suggestions:

Supplies:

- rubber gloves
- paper plates
- plastic forks (plastic sticks, chop sticks, or plastic back scratcher)
- a pen
- a coin
- toilet hat

I like to use a plastic "toilet hat" also known as a specimen collector or a specimen collection unit, which goes under the toilet seat and collects the stool before it sinks into the bottom of the toilet (available on Amazon.com).

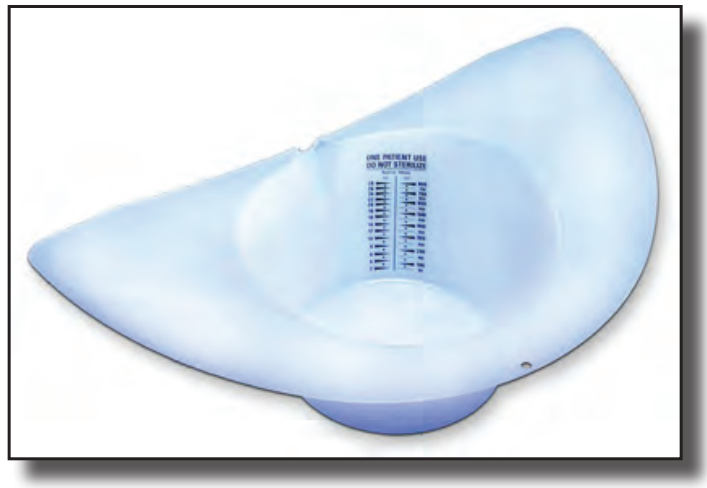

The Collection:

When your child poops, it is collected in the toilet hat (specimen collector). After I get my child cleaned up and taken care of, I remove the toilet hat from the toilet and put the specimen on a paper plate with my plastic fork. I have a look for anything interesting and then transfer that part to a clean plate using my trusty plastic fork. I discard the remainder of the specimen into the toilet, flush and put that dirty paper plate in the bathroom garbage. (We now line with kitchen garbage bags, and I change it after each of these poops.) On the clean plate with the suspected worm, I may add a bit of water and swish it around to get the worm cleaner. I then may transfer the worm to a third plastic plate to get a clear picture. On the clean plate with the washed worm, I write the date, and the initials of the person the worm came from. If you need help identifying the worm, place a penny next to the worm (for size context), snap a picture, and mail the image to kerri@cdautism.org, (Kerri collects the photos for documentation purposes, so send those worm pictures). Then flush the worm and put all paper plates, gloves, and fork in garbage and take it outside. Now, you can go find out what your child has gotten into while you were doing all this.

Clean Up:

Use HOT water (60°C/140°F), and sterilize with 96% (180 proof) grain alcohol (Everclear).

Microscope

It is very useful to have a microscope for diagnosis because it enables you to see both the small parasites that may appear in the blood, as well as eggs or larvae in the feces. This way we are more accurately able to determine if the number of parasites decreases. A simple microscope that costs about $100 is suitable for this kind of identification. The easiest method to determine what you see is to compare your sample to images you find on Google. This way you can enlarge the images, see various samples from different angles, and get a much wider variety of samples than if you were comparing a sample with many textbooks.

Bulb Enemas (aka "Implant")

To prevent anal itching from pinworms, night wakings, etc., you can use a bulb enema or small catheter/syringe with a dilution of 50mg of mebendazole in 10 to 15ml of water for small children, or 100mg of mebendazole in 15 to 20ml of water for larger children/teens/adults. The best way to do this is to introduce the medication together with the water in the rectum immediately before bedtime and hold overnight. If you are using the "implant," a morning enema is mandatory.

So we did the 100mg of Mebendazole with 20ml of water. He kept it in and we did it right before bed... Next day a ton of worms came out!!! Better yet he started singing songs with a tune - 3 different songs over the last 2 days and counting on his fingers very purposefully! His aide at school said he did amazing today - no behaviors, very focused, better articulation and better social interest.

The Worm Whisperer

The following words of wisdom are from a mom who has earned the nickname *The Worm Whisperer* (although her ability to destroy parasites may make the *Worm Ninja* more apropos). Her dedication and diligence have not only made the difference in the life of her son, but countless other children who are what she calls "extreme cases." The information presented here may be the difference between an older/aggressive child living with their family or going to a group home for the care that their family is no longer able to provide them. Thank you Robin, for being a pioneer and for never giving up. Thank you for having the guts, the know-how, and the generosity to share what you have learned with those who need it most.

Extreme Cases by Robin Goffe

This section is for older children who may be violent, self-injurious, destructive, physically aggressive, high risk and/or bedridden.

Some families have children who are older when they first start treatment. My son was 18 years old. We call ourselves the "last chance" group. We say this because our children have lived their whole lives infested, unbeknownst to us. Our children lived as happy, relatively easily manageable, learning-disabled children: perhaps slightly annoying with their routines of movie dialogue scripting or attachment to Disney movies, maps, or little known facts. They were mostly friendless but pretty easy to take care of. However, during the hormonal teen years, things took a grave turn. We may have chalked up their newfound solitude to just giving up socially for lack of friends. They did not fit in. We had no idea that something else was brewing. The hormones within them began to have a bitter war with the parasites living inside them, and a war would soon break out. Their mental state would diminish considerably. What we are faced with are grown, strong children who are mentally ill and violent, self-injurious, and destructive. Some have even become so ill that they had to stay in bed.

This "last chance" is an opportunity to try ONE MORE THING before putting them in a group home; to give them away—for their own safety and the safety of their families.

These things that I am going to share with you are unique to the standard treatment outlined in the book. It is a more aggressive treatment because it is needed. Our children are so highly infested that it is shocking to tell you what we have found. There is a lot to do, but there is a method. It is time

The Goffe family.

consuming and it is a lot of work. But here I will outline what we did to get our son from an aggressive, self-injurious, destructive young man to one who has regained patience, language, understanding, and reasoning; but best of all, the opportunity to remain in our home. With continued treatments, he has the hope for a future: a job perhaps, and maybe even a family of his own.

Beginning treatment for the older child and especially one who is aggressive, self-injurious, violent, and destructive is one done starting low and slow.

Day one = one drop.

I kept a very detailed journal, and I will simply tell you what we did. I will tell you what worked for us and what did not. I will also tell you what I shared with others that worked for them as well. I am not a physician. I am not a chemist. I am a mother in love with my son and his utmost comfort was my main concern. My only goal was to clear his parasites. I had no idea that the things I learned by digging through his stool for 9 months would eventually give me the nickname, "The Worm Whisperer." Although intestinal parasites have been around longer than man, and they are smart enough to live within a human being lifelong, they can go completely undetected. I was ready to plot out a war against them. By the beginning of our 9th month of treatment, I estimate that I had cleaned and examined 35 pounds (16 KG) of solid parasites. Hard to believe? I have 80% of them photographed. The last two months in

jars total seven pounds and a running total of the combined length will be at over 200 feet (61 meters), at the publishing of this book. There is not a classroom in the world that can teach what I learned in my bathroom day after day in latex gloves and a hospital mask. There was a fan blowing on me to manage the stench and by the third week my gag reflex was under control.

I examined the parasites, the pieces, how did it die? What was my son feeling at the time? Was he violent? Sweating? Slapping his legs from the pain of the parasites moving around and torturing him from the inside? I needed to eliminate these worms without allowing them to cause my son pain as they were killed. I had no idea the monsters I was to face.

In March of 2013, we started our son on one drop of chlorine dioxide. One of the most feared things that the parents of adult sized children face is the dreaded enema. It is just not something that most of us grew up with as standard care. But even so, my husband and I knew it was something that made sense. There are toxins inside these kids. They must be flushed out. The bowel is the way out. So on the very first day and the very first drop, we also explained to our severely autistic child that we were going to help his belly feel better. Our son, by this time, was so severe in regression that I can only best explain him as non-human. He was no longer speaking, unable to react to us, had stopped answering to his name, and could no longer contain the saliva in his mouth. He walked with a 12-inch drool hanging from his mouth. He ate like an animal, glaring at us. He was frequently violent: jumping on cars and denting them in, kicking down fences and destroying property.

This was the child that we were going to start giving enemas to. If we could do it, anyone can.

Each day we went up a drop; two drops on day two, three drops on day three, and so on. He was edgy and tired. We went for walks, as per usual, to deal with his aggression, but by day seven he began to have a runny nose and had a great deal of fatigue. We were so happy since we knew this was a sign to look for; that the immune system was kicking in. He slept for about 15 hours as we woke him and dosed him every hour and by the next morning there were about 25 white, hairy, thin looking objects in his stool. We knew these were worms and that we had our answer. After three weeks we began to see 4-6 inch parasites in all shapes and sizes, yet the aggression continued. It was here that I learned that what we were experiencing was POWS (Pissed Off Worm Syndrome). By this point we were at 13 drops, and while we were killing the smaller parasites, we were only pissing off the larger ones. The parasites do not like their environment disturbed, and subsequently they

cause distress to the host. Parasites excrete ammonia, (possibly, leading to hyperammonemia and possibly seizures), morphine, and a meth-like substance. As these toxins enter the body, they can also cause aggression and anger. We had many possessions broken during these tantrums. We stopped valuing material objects.

It was here that we were told about—double dosing. So even though our son was getting about the equivalent of two drops an hour, if we saw increased aggression, OCD or self-injurious behavior we would give him four (see page 103 for an explanation of double dosing). If he did not calm down, we gave him another four drop dose. This was the perfect return attack for the parasites. Within a few moments the aggression settled. His red face and wild eyes diminished, and we had made it past another hurdle.

We used the double dose method dozens and dozens of times over the following months, and this helped tremendously to curtail the aggression caused by the parasites.

By the third week of treatment, we were concerned about the time during the night that our son would not be getting doses. So for the next six months our family had a dosing schedule, dosing additionally at midnight, 2am, 4am and picking back up to hourly doses from 6am to 10pm. This schedule was shared by not only my husband and I, but also our son's siblings,who would also set their alarms and take their turns, while we all rotated lack of sleep.

By the second month we found that our son's behavior not only changed around the full moon but the new moon as well. The standard protocol uses mebendazole over the full moon. However, with the older, more aggressive children we have had success with including mebendazole over the new moon cycle as well. These mini mebendazole courses feature shorter bursts of 5-6 days each, over the new and full moons beginning four days before each. We also deemed it necessary to start earlier in the moon phase than with the younger kids, since the infestation was greater, and the parasite movement occurred earlier, causing behaviors sooner.

For the child that has aggression, every parent must remember that the behavior is parasite related. During treatment you will see a variety of behaviors stemming from the parasites attempting to control their environment aka—the host. We found that increasing the frequency of the dose dampened the violence and aggression. It can be difficult to trust your child who is lost in a rage. You feel deceived and hurt. Those were our frequent emotions as well. It does pass. It took about 4-5 months for the rages to stop. They happened

everywhere and were happening even on the toilet while trying to expel the parasites. Have a plan. Music worked very well for us. So did reading books. Find something to distract, and always give soothing, comforting tones. We frequently told our son how much we loved him and we rubbed his head and back. These herxing behaviors may be avoided through the use of a new method of preparing CD called CDH (see Chapter 7, page 155 for more info on CDH).

CDH: This new preparation method has really been a huge asset for the older kids that need to go higher in drops. At around 20 drops, the volume of the regular CD became unpleasant, making some children nauseous. My son was one of them. With the CDH preparation, I firmly believe that the older, tough-nut children will have more success with getting to the appropriate levels needed to start expelling the larger parasites. It is my personal belief that the amount needed in many of the non-seizure older kids with aggression, violence, self-injury, and destruction to be between 75-100ml of CDH daily. This amount may have a connection to the voltage needed in order for the mitochondria in the white blood cells to be given the power to not only kill the parasites, but to also destroy the bacteria. The job is two-fold, and must be done quickly as once the parasite is dead, the bacteria want to devour them immediately. I say these things because I have seen the condition of the parasites every day. I found that if I can kill the parasite with the least amount of disturbance or preparedness by the parasite, then there is no time for them to fight back and cause herxing. The bacteria also come into play and must be dealt with. Higher amounts of CDH kill both, without so much as a frown or a concern on the face of my son.

Stevia: I found that by adding the sweetener stevia to the CDH, the process can be more pleasant and does not affect the properties or effectiveness of the dose. As proven by Lamotte ClO_2 test strips (see page 467 for information on using the test strips).

Humidifier: In the beginning months, the infestation level is so high that nightly doses may have to be sacrificed in order to start breaking down the will of the parasites. It is not about seeing them every day, but slowly and consistently breaking their will. The constant aggressive irritation of the CDH will kill parasites, stopping them from making gains. There is another layer of nighttime treatments, and that is the humidifier. We fill a cool air humidifier that holds one gallon of water, and put 35 drops of activated CD (NOT CDH) and let it run all night near our son's head. This too was a method we used for maximum parasite elimination.

Spices and Herbs: It is urgent that we work constantly with our older kids to rid the body of parasites and pathogens. We have found that for kids that can easily swallow pills, filling empty gel capsules with the recommended herbs and spices in this chapter under Other Medicinal Plants (page 231) helpful. We have found great results by filling the gelcaps with the variety mentioned there: black walnut, ginger, rue, wormwood, and yarrow and giving two to four different ones with each meal as a toxic feast to the parasites. Don't narrow your selection to those mentioned here—get them all. There is no plan or pattern. Use any combination.

Colonics: Professional colonics have been an important addition to healing and cleansing parasites in our older kids. We started these a few months after our son was accustomed to the routine enemas. This has been a wonderful addition, and we try to do at least one weekly. Some places will allow you to do inserts, and we have taken our CDH there working up to 50-100ml CDH with great success.

Limiting Undesirable Behaviors

Probiotics: If you are using probiotics and your child is aggressive or becomes aggressive after restarting the probiotics, consider removing them as a first step. There could be such a high infestation rate that the child's system does not distinguish between good bacteria and bad bacteria.

Enemas: CD enemas should start on day one of treatment for the aggressive/older child. Since they have such a high rate of infestation, it is necessary to clear the pathogens on a continuing cycle from the very beginning. Please follow instructions for enemas starting on page 103.

Diatomaceous Earth (DE): In some children, the DE may shred the larger parasites to death, causing them to spew additional toxins into the child's body, which results in herx symptoms. Discontinuing DE for a few months may help to ease the distress, and give a cleaner kill.

Salt Baths: There are times that the body is unable to pull out the toxins fast enough. Be careful about killing too fast (dosing without or not enough enemas). If you have done enemas, and there still seems to be distress, you can buy a 40-pound bag of plain pool salt, take 9 pounds of salt and put it into a hot bath. Allow the salt to dissolve and have the child soak for one hour. If the child sweats during the bath, this is a good sign, as it shows toxins are being pulled out. Do not use Epsom salts. They contain magnesium. Magnesium feeds parasites as well as biofilm. Plain pool salt is cheap, and helps to remove toxins.

Dandelion Tea: This is an incredible detoxing source as well. There have been times that our son was in and out of a salt bath all day drinking dandelion tea to get the built-up toxins out. This is a tea ready made by Traditional Medicinals® (traditionalmedicinals.com).

Tips on What to Expect During the Parasite Elimination

Intestinal parasites have been on Earth longer than humans. Their plan is to find a host, and to continue to create life. They have the home advantage by living inside of your child. There are many things that I have learned while at war with them. They have a plan and so should you.

Situations We Have Come Across

Peetox: As you kill the parasites, they are alerted that you have taken away their joyful life. As a result, they do things to the host to show their displeasure. One of the things the parasites do is to spew toxins, including a morphine-like substance that can cause your child to not feel that he needs to urinate or that he is urinating. Naturally, this can lead to accidents. This is not the child's fault, but only a part of the parasite elimination process. One of the most difficult things we did was to put our 18-year-old son in adult diapers. It was heart breaking because it felt that we were moving backwards instead for forwards. However, this was only temporary, and for his own dignity. Especially if they go to school; perhaps being in diapers for a while is the answer. Our son was in and out of them for about two months. This does end.

Sleepytox: As you are going higher in drops, the CD is assisting the immune system to get the parasites out. It will take a lot of energy to do this. Remember, your child is the host and there is a war going on! Sometimes, your child may be tired for days. Our son slept for nearly the entire summer at the beginning of his treatment. Allow the rest they seek. Now our son gets higher doses of CD on the weekends, and he is very tired and sleeps then, too. By Monday morning, we can usually get a big fat rope worm after our efforts. Sleepytox is great because you can get a lot done on your home "to do" list.

Behaviors/OCD/Tics: Some may become alarmed because their child starts having behaviors that they did not have before treatments, or they feel that the behaviors have gotten worse. Parasites have a plan. It is to stay alive and to procreate. They want their eggs to return back into a host to repeat the cycle. So, you may see behaviors of playing with feces, touching their anus to their mouth, trying to put their fingers into your mouth or another person. There are finger and nail chewing, and spitting. These are all parasite controlled behaviors. We have found that eliminating parasites helps to minimize this behavior and it will eventually subside. There may also be

a mineral deficiency attached as well. We have found that giving PLENTY of ocean water can help to tame these behaviors. Our 19-year-old son gets over 200ml OW mixed with 400ml spring water per day.

POWS (Pissed-Off Worm Syndrome): POWS presents itself when you have been dosing, and your child seems weepy, is pacing, and/or unhappy. Sometimes it is really that you have pissed off the worms, but are not killing them. Always check with Kerri regarding your concerns. But many times the answer is to go up in drops not down. You need to kill them—not piss them off, or they will fight back.

Clear Zone: This time period can be about five to seven days before the full moon; once infestation is brought down after six months or more of treatment. You may be able to start seeing glimpses of your child being lucid. This is a good time for an ATEC test.

High Volume Eating: Often times, the kids reach a point where they realize that they have been starving. The parasites have been taking a bulk of their nutrients, causing their mental deficiencies. They may even be eating non-stop all day. It is tough to juggle the timing and effectiveness of the CD with the continued eating. Allowing the child to eat high volumes of food while dosing with CD will still kill the parasites, but the CD levels may not be high enough to avoid a herx. Though the parasites may be killed the CD level may not be high enough to also kill off the bacteria eating the dead parasite. One solution we found was to give our son homemade bone broth with ocean water many times a day. This will help to replace the lack of nutrients, meanwhile reducing the overeating enough to continue the CD without risking a herx reaction.

Weight Loss: Our son lost 50 pounds during the first seven months of treatment. He was very over weight at 5'9" and 200 pounds. The weight loss brought concern to people who had not seen him for long periods. During this time I estimate that 35 pounds was solid parasites. His stomach was very bloated, as was his face. Our children are full of parasites and pathogens (i.e., yeast, bacteria, etc.), and all of these things can make them gain weight or be bloated. Our son is now in the normal weight range for his height, and has a flat stomach.

Night Terrors: During the night you may see that your child has trouble settling down, or they may wake in the night screaming your name. They may even do night walking, possibly leaving out the front door in a sleepwalk state. We saw these behaviors years ago, as our son was heading into a higher infestation level. Now that we are on the healing end, many of the behaviors return as sort of a rewind. The behaviors that came into play going down the ladder are sometimes repeated heading back up the ladder to wellness. We feel that our son was experiencing separation anxiety, and the recognition that

he had total control again. This new gained independence may be frightening. At a point, our son entered the peetox stage (see above). He had no feeling or sensation to urinate, so he was put into adult diapers. As our son's infestation rate decreased, the normal behaviors like waking in the night and feeling the urge to urinate returned. Then, as he would get up to go to the bathroom, he would suddenly stop, and feel perhaps lost and afraid to continue this task alone. He would scream out or wander around whimpering. Although night wakings were disturbing, we found them to be a necessary passage for bringing our son to reality. In order to give comfort, at night we continued the CD humidifier, as well as CD ear and nose drops. Many times a CD bath before bed was calming as well.

Emotional Blindness: Because the toxins that the parasites excrete are substances that have the effects of morphine, ammonia, and histamine, these toxins can cause emotional confusion in your child. They may be confused by your laughter, smiles, and affection. Your positive and loving encounter may be perceived as threatening or challenging. Your smile may bring a rage. Any spoken words by you no matter how soothing they may be, could be perceived as a confrontation. This is difficult on both parent and child, as the child may see you as a threat and perhaps even as mocking them; while you as the parent feel rejected in your affections. Many times the child's behaviors evolve into a stoned-out loss of reality and presence. These are all related to the toxic build up and defense of the parasites. Their motivation is to remain in the host; they show their displeasure to the discomforts we have given them in our elimination attempts. Many times during these episodes, we have found it best to avoid words or eye contact, but rather to offer double doses as outlined by Kerri, and keep a calm environment. We have found that these toxic levels can be lowered through salt baths and dandelion tea.

Despite the behaviors that may be brought on by a parasite protocol, the results are amazing. In our family we are finally getting our son back. I would recommend staying the course. As we know, these kinds of parasitic infestations in immune-comprised children will not go away on their own. Children do not "grow out of" worms. In fact, the worms will continue to grow inside of them. The following parasites were expelled by my older son, by making the aggressive modifications aimed at older children. By removing these parasites we are seeing the first stages of recovery. The jars on the following page represent seven pounds of worms in less than two months.

Yours in healing,
Robin

7 lbs. of 35 lbs. (total) of the parasites extracted in 9 months (160 feet in total above).

39+ inch long worm.

Other Medicinal Plants

Author's Note: The following information is extremely powerful for our continued health and well-being. However, these plants and foods ALONE have NOT been proven to heal autism. Rather, follow the 18-day deworming protocol presented starting on page 187. When this is done for 12-18 months it has proven to be an important part of the protocols that have led to the recovery of many children. With that in mind, some parents of older children, and aggressive/self-injurious children have started to implement a few of the plants and foods listed below, in addition to the aforementioned 18-day protocol. In many cases, these additions have led their children to increased gains through increased parasite elimination.

A number of other plants are also effective for deworming. If, after three months of treatment, the problem persists we can change the type of plant, or repeat any plant that was effective in previous months. We can use them in combinations, mixing several plants at once, or take them individually. Plant formulations that should be considered are alcoholic extracts, in oil or by infusion, and include the following plants:

- Clove (*Syzygium aromaticum*)
- Common Rue (*Ruta graveolens*)
- Dandelion (*Taraxacum officinale*)
- Gentian Root (*Gentiana lutea*)
- Mint (*Mentha sativa*)
- Mugwart/Common Wormwood (*Artemisia vulgaris*)
- Pomegranate Root Bark (*Punica granatum L.*)
- Southernwood (*Artemisia abrotanum*)
- Sweet Wormwood (*Artemisia annua*)
- Sweetflag/Calamus Root (*Acorus calamus*)
- Tansy (*Tanacetum vulgare*)
- Walnut shell (*Juglans*)
- White Fraxinella (*Dictamnus albus*)
- Yarrow (*Achillea millefolium*)

Preventative Food & Diet

There are groups of foods that should be avoided if you have a parasitic infection. For example, dairy products in general, refined sugars (sucrose, fructose, corn syrup), flour (especially refined), and overly sweet foods in general. The list of foods and plants below promote good internal balance of the body, hence becoming our allies. With good production of stomach acid, a normal level of healthy bacteria, and proper bile production, it is impossible for parasites to survive for long. Worms need an acidic environment that comes from the breakdown of sugars and putrefaction from the ingestion of unhealthy or processed foods. It is very important to eat raw vegetables and

fruit juices, which provide us with enzymes and other elements necessary to protect us.

Choucroute/sauerkraut (fermented cabbage in salt).

Many people have low levels of stomach acid, which is the cause of many intestinal problems, because the body is unable to defend itself against intruders. Sauerkraut juice or cabbage/sauerkraut is one of the most powerful stimulants for your body to produce stomach acid. The use of unpasteurized fermented foods (water kefir, soy sauce, miso, etc.) is highly recommended for its stimulation of the beneficial bacterial flora that is responsible for generating control over parasites. Take a few spoonfuls of cabbage juice before meals, or better yet sauerkraut juice, because it will do wonders to improve your digestion.

Author's note: I do not recommend soy, in any form, for anyone with an ASD.

Garlic

Garlic, eaten regularly, turns the stomach and intestine into a lethal environment for parasites, providing constant protection. Garlic is the quintessential home remedy to eliminate intestinal parasites naturally. It has been used by many different cultures such as Chinese, Greek, Roman, Indian, and Babylonian.

Garlic is still in use today by practitioners of modern medicine. It is used both fresh and as an oil. The simplest treatment is to eat three cloves of garlic every morning, or take a teaspoon of garlic oil. Alternatively, mix crushed garlic in a little cold water and drink the mixture immediately. Another recipe is to cut and crush four cloves of garlic, place them in milk, and allow the mixture to sit overnight. Take the liquid while fasting the next day.

Pumpkin Seed

Pumpkin seeds contain a substance called piperazine. It acts by paralyzing the parasites, which allows them to be removed easily.

We can find piperazine commercially in pharmacy drug formulations or naturally, as we said, in the seeds of the pumpkin. This traditional method of deworming has been used around the world since man can remember. There are several effective traditional formulas, below we describe one of them:

Use one cup of peeled and mashed pumpkin seeds (about 80 seeds). Mix them with coconut water and two tablespoons of honey. Take the mixture

over three hours on an empty stomach. Do not eat during this three-hour period. At the end of the three hours, take castor oil in order to quickly eliminate the parasites.

Papaya and Papaya Seeds

Papain is a digestive enzyme contained in papaya that is capable of breaking down the outer layer of adult parasites. The milky juice of unripe papaya is a powerful agent for destroying roundworms. The adult dose is one tablespoon of fresh green papaya juice, an equal amount of honey, and three or four tablespoons of hot water. Two hours later, administer a dose of castor oil mixed with warm milk. This treatment should be repeated for two days if necessary. For children seven to ten years of age, half of this dose should be administered. For children under three years of age, one teaspoon (5ml) of the mixture is sufficient.

Papaya seeds are also useful for this purpose as they are rich in papain and caricin. For every tablespoon of crushed, fresh seeds, add an equal amount of honey. Take the dose of one teaspoon (5ml) daily in the morning or at night on an empty stomach for ten days, rest five days and repeat the cycle three times. We recommend the use of a purgative.

Ginger

Ginger not only helps to combat intestinal parasites but also reduces nausea and can help calm nerves. For hundreds of years, fresh ginger has proven to be highly successful in destroying intestinal worms. The most common way to consume ginger is raw or by infusion. Ginger extract may also be sprinkled on a variety of foods.

Propolis

Propolis is a resin like substance gathered by bees from the bark and leaf buds of trees, to help disinfect, build and maintain their hives. Propolis has been used for at least 3,000 years. Its use dates back to the Egyptians and the Romans, and remains in use today. To the Greeks we owe the name pro, meaning "before" and polis, meaning "city." This translates as "defenses before the city," or "defender of the city." Thanks to the antibiotic action of propolis, which protects against the activity of viruses and bacteria, the hive is one of the most sterile places known to nature.

Many scientific studies have proven the antiparasitic activity of propolis, therefore it is recommended for treatment of: *Giardia*, amoebas and roundworms, and also for intestinal infections caused by gram-positive bacteria.

Take propolis, diluted in water or fruit juice, for treatment of parasites, for seven days, on an empty stomach. Use Propolis standardized at 30% in either propolis tincture or capsules. Take three drops per kilo of weight, or three capsules one half-hour before each meal. A seven-day treatment cycle should include seven days on, followed by seven days off; repeat three to five times to ensure complete elimination of parasites or bacteria. Repetition of the treatment is essential to halt bacterial reproductive cycles. By repeating the treatment at least three times, the effective elimination of parasites is ensured. The benefits of propolis are that it has no side effects, is well tolerated, and is highly effective.

Pomegranate Bark

Pomegranate bark contains an alkaloid known as punicine, which is highly toxic to earthworms. It is used by decoction of the root bark, stem, or fruit. The root bark is preferable because it contains a greater quantity of the alkaloid than the bark of the trunk. This alkaloid is also highly toxic to tapeworms. A cold decoction of root bark, preferably fresh, should be given in quantities of 90ml to 180ml three times per day (for adults), with one-hour intervals between cups. A purgative should be taken after the last glass. For children, a dose of 20ml to 60ml is appropriate. A decoction is preferably used to eliminate solitaires (tapeworm, *Taenia Solium*).

Carrots

Carrots are another effective home remedy for eliminating intestinal parasites in children. The chemical constituents of carrots attack pests by preventing their development. It is one of the most effective natural treatments for children, when given a small cup of grated carrots each morning until the problem desists.

Condiments

Seasoning plants are also powerful weapons to keep in mind in our everyday cooking. Since time immemorial, mankind has used them to control parasitic diseases. The following are most interesting because of their effects:

- Cayenne
- Cinnamon
- Cloves
- Paprika
- Pepper
- Tarragon
- Thyme
- Turmeric

Thank you Andreas and Miriam for sharing what I know will be very enlightening, not only to the families of children with autism, but to people all over the world suffering from mysterious symptoms consistent with parasitic infections. I want to share one interesting tidbit about parasite infections before we get into the FAQs on parasites and the parasite protocol.

"We have a tremendous parasite problem right here in the U.S. It is just not being addressed."[5] - Dr. Peter Wina, Chief of Patho-Biology in the Walter Reed Army Institute of Research in 1991. (The problem existed in 1991, and with modern globalization parasites are more prevalent than ever, yet they still not being addressed.

Parasite Protocol FAQs

I showed my family practitioner pictures of the worms we have found. He thinks they are not a parasite, but just mucous. How can I be certain?

It can be difficult to identify parasites, and most general practitioners are not trained to do so. Some parents have success with a local vet, who analyzes samples in their office. As a crude test, you can pour boiling hot water onto your specimen. If it falls apart, it is probably biofilm or mucous. If it withstands the wash, it is probably a parasite. Unfortunately, most stool analyses are notorious for false negatives. If you put hot water on parasites, they do not dissolve. Mucous dissolves in any water—hot or cold.

Is it ok to do the Kalcker Parasite Protocol during pregnancy?

No. Don't do any kind of detox or parasite protocol while you are pregnant or nursing. Any detox will release toxins into the blood stream that could potentially negatively impact the developing fetus or nursing baby. If you are planning on getting pregnant, it would be advisable to do whatever detox or deworming procedure before pregnancy.

When is it appropriate to stop the parasite protocol? In other words, does every child on this protocol need both the CD and the other parts of the Parasite Protocol or are there some that only need CD? This is a critical question since these are two protocols joined together and not every child may need both. We have done the Parasite Protocol and have never passed parasites so I am uncertain about my child.

Usually the Parasite Protocol is repeated for 12-18 months, sometimes less. The most important thing is to make sure that there are no fertilized eggs left that could hatch at a later date. As it is very difficult to know if there are remaining eggs, it is important to complete the 12-18 month

treatment. The Parasite Protocol is a complete protocol heavily researched to achieve the best results. The Parasite Protocol in conjunction with CD has been shown to be one of the most effective methods to heal regressive autism. Parasites are cyclical and need to be treated as such. You continue with the parasite protocol until no more parasites are seen—be that in behavior or actually in the stool.

What does the process of worms toxifying the brain look like?

Ascaris lumbricoides (roundworm), for example, produces at least five different toxins: Malondialdehyde, ammonia, histamine, formaldehyde, and morphine. Malondialdehyde is responsible for oxidative stress, and is mutagenic.[7] Ammonia, which can lead to hyperammonemia, can be responsible for seizures, tremors, flapping, poor coordination, growth retardation, combativeness, lethargy, and other symptoms. Comparing hyperammonemia with the symptoms known as regressive autism yields overwhelming similarities. Formaldehyde has been shown in some laboratory studies to affect the lymphatic and hematopoietic systems. Morphine inhibits nerve reactions and slows intestinal peristalsis. It also keeps the immune system from finding parasites, and from doing anything about them. This is a reason we often can't identify parasites. We only find parasites when the infection is acute, not chronic. This is because IgE or IgM reactions are altered by morphine. Histamine can lead to chronic inflammation in the body.

As a family, we expect to be doing the CD and parasite protocols for some time. How do we know when to stop? Should we wait until we have a few months of no symptoms?

We do it until full recovery is reached.

We have been doing full oral dose CD and the Parasite Protocol. We are seeing some amazing changes, but we don't see worms. Are we doing something wrong?

CD affects parasites of different sizes. You may be clearing parasites that would be undetectable to the naked eye, or nematodes that are very small and therefore hard to detect in the stool.

Why is my child so deficient in vitamins?

As a general rule, most children with autism are deficient in vitamins. In the first place many pathogens feed off of vitamins intended for the host, and helminthes especially love B12 and iron. Since many of us, especially those of us living in cold climates, do not receive enough sun, we are deficient in vitamin D. Calcium is used by the body as an antagonist for acid inflammation; all acidity in the body is compensated by calcium, and therefore it is usually low with the kids on the spectrum. As our children heal, these deficiencies fade and homeostasis returns.

I just gave mebendazole, Not pyrantel this AM. What should I do?

Don't stress. Tomorrow is a new day, and you can begin again. Give mebendazole tomorrow as that is tomorrow's scheduled dose.

Aren't there some parasites that are good for us and help our immunity and gut healing?

A parasite is defined as a living being that is dependent on a host for survival, to the detriment of that host.

For those of you that continue the parasite protocol thru the new moon, how many days do you stay on it? We are now 3 days past the new moon.

Some people treat month long. The Kalcker protocol itself is 18 days long. Each family has to find a protocol that suits them. Some folks use mebendazole 3 days before the new moon, the day of, and three days after. Other families use herbal remedies on the off days. If you consult with a healthcare provider, this would be a question to ask them. Each child is unique and has different needs when it comes to treating parasites.

Why are live worms not digested? Poisons?

Live helminths are protected by a glucosoid mucous with positively charged ions, making them resistant to stomach acid, or digestive fluids. When they die, the mucous separates from the helminth, leaving them open to digestive enzymes. We often see the mucous, as well as semi-digested helminths, in the stool of people using the protocol.

Does everyone in the family need to do the parasite protocol at the same time? With or without CD, enemas, diatomaceous earth, Rompepiedras/stone breakers, and castor oil? My (neurotypical) daughter will take the anti-parasitic drugs, mebendazole, and pyrantel pamoate, but not these other parasite protocol ingredients, which is why I ask.

Your entire family needs to do the protocol at the same time, or you risk reinfection. Neurotypical family members should do as much of the protocol as possible. If someone will only take the meds, so be it. However, I feel the more the better.

Do I need to separate the neem from CD?

Yes, I give neem with food, and would separate from CD by at least an hour.

If I don't see any worms, does that mean my child doesn't have parasites, or are we just missing the eggs?

Just because you don't see parasites doesn't necessarily mean you don't have any. For example, *Toxocara canis* or *Toxocara cati*, which are very common in our pets (and can infect humans as *Toxocariasis*), are not expelled in fecal matter. Some families on the protocol did not see actual worms until month seven.

To what extent do the rest of us need to do the CD protocol? Is it the same as our ASD children? And, is it necessary to do the whole nine yards with the full Parasite Protocol for the whole 12 months? Are there any shortcuts for healthier individuals?

All of the family members, including pets, need to be on anti-parasite treatment for a year and thereafter lifetime maintenance is best. As mentioned before, with neurotypical family members, you do as much as you can, but the anti-parasitic medications are crucial to preventing reinfection.

Is diatomaceous earth a binder and therefore must it be given apart from food, medication, and supplements?

No. It is not a binder. It is fine to give with or without food, and does not affect medication or supplements.

Do you have to do the Protocol forever if you are fully recovered or is there a maintenance plan?

When the child gets to where you want him, you can start to pull things. Then, we do maintenance dosing of CD; one dose on Monday and one on Thursday. We do the Parasite Protocol for a week every three months since we live in a world of parasites. It is good preventative medicine for all. Ocean water is also good for all of us. See Chapter 13 (page 319) for the complete maintenance plan.

Does CD kill parasites?

Yes. CD kills amoebas, *Giardia lamblia*, and other smaller parasites. CD does not kill the larger macroparasites due to their higher oxidative stress resistance.

When is it ok to start the parasite protocol prior to reaching full dose of CD?

Healing autism is a marathon not a sprint. The point is to heal with the least amount of aggravation. Therefore, you should be at a full dose of CD before starting, and have added in enemas and baths. If you are seeing Herxheimer reactions then don't start yet. Obviously, everyone must make his or her own decisions.

Where in the gut do helminths live? Do CD enemas (300 ml) reach them?

It depends on the type of helminth. There are more than 300 different helminths so they could be in many different places. However, most live in the small intestine. Some lay their eggs in the rectum. The size of the person will dictate how high an enema will reach.

Do you tell your kids that they have worms? Do you show them? Are they scared? My son is very interested about everything in the world and asks 4,000 questions a day. What do I tell him?

How to handle this situation is unique to each and every family. There is no right or wrong answer here. The following are some suggestions we have received from families on the protocol:

Nope. My husband was just telling me a story from when he was a kid about another kid who got teased all the time about having worms. He still remembers it. So, no I will not tell my kids.

My kids (ages 10 & 7) know about worms because we have talked about their Lyme disease and other symptoms for a long time. I think it helps them understand why they feel grumpy or sick and why the enemas help. But, I think every child is different. The risk is that they might tell their friends. I tell them that it is private information and that pretty much everyone has worms but some people have more and get sick from them. And, I told them that even most doctors don't know this but slowly people are learning and getting smarter about this and a good diet, etc... My boys like to see the big ones, and try for new records. They like to show their brother the records. I think that's a boy thing.

I have a 10 year-old, and I tell him that we have parasites. I have not showed him anything, I ask him to leave the room before I start to sort the poo. ;)

My son had another bowel movement FULL of worms, pinworms—and I mean hundreds. This is only our second day on CD (1/2 drop in 8 fl. oz.) so a bit thrown to the deep end. Has anyone else had a start like this? How did everything go from there on?

I have seen it a handful of times. I get VERY excited about this. Everyone has autism a bit differently. But, if we see worms early, in many cases the recovery begins early too. That may be the case for your child.

I understand that even organic produce needs to be washed properly. What is the best way to wash my fruits and vegetables?

The Ascaris eggs are resistant to UV, and can withstand a pH from 2 to 11.5. Eggs are killed by heating to approximately 60°C (140°F). Spray your fruits and veggies with CD spray. 10 drops per 1 fl. oz., of water, no need to rinse off.

Anyone notice a huge growth spurt after starting the parasite protocol?

Many parents have reported their children resumed growth as well as weight gain. No real surprise considering they are getting back what the parasites were taking from them.

Do we need to treat our pets if they are taking heartworm medication?

Yes, heartworm medication does not address intestinal parasites, which can infect us and our children. We need to deparasitize our pets, as well as ourselves.

We put "cascara sagrada" in place of castor oil because for my son and me, it is difficult to take the oil. Is it ok?

Cascara sagrada is not the same thing as castor oil and is not part of the protocol. An alternative solution to liquid castor oil is to buy castor oil in softgels. You will need many but it does solve the taste problem.

My son is very high in Trichinella spiralis, which is a roundworm from undercooked meat or pork. It's supposed to be rare in the US, so I'm wondering how my child would have picked this up. Any ideas? No undercooked meat here for the kids, and we don't eat pork.

At this moment we have not seen a relationship between *Trichinella spiralis* and autism. It may be a multi-parasitic infection, or a misdiagnosis. Apart from the standard protocol, your child might need something else. I would consult the practitioner for the appropriate dosage, and only if your child has a definite Trichinella spiralis diagnosis.

How do we know if there are parasites in the brain, and what can we do about it?

Parasites in the brain are very rare. (According to the CDC, *Cysticercosis* is a parasitic tissue infection caused by larval cysts of the pork *tapeworm*. These larval cysts infect brain, muscle, or other tissue, and are a major cause of adult onset seizures in most low-income countries. An individual acquires cysticercosis from ingesting eggs excreted by a person who has an intestinal tapeworm.)[6] Larvae can be seen on a scan. Many people assume that the problem causing behavioral issues, or mental issues, must be located in the brain. However, the problem likely exists elsewhere. If the blood contains toxins, this will affect the brain. For example, if you ingest too much alcohol, your brain, nervous system, etc. will be affected, but the problem is not in the brain itself. We can think the same way about parasites. The chemicals that they produce will have effects on the brain, however, rarely will the parasites be located there.

Do parasites cause autism? If so, why doesn't every child with parasites have autism?

Regressive autism has been called parasitological vaccinosis by Dr. Andreas Kalcker. This is a cross reaction between a child with parasites that receives certain vaccines. Further research is needed for a definitive answer.

Why don't normal lab tests find parasites?

Generally speaking, lab tests need to find living creatures or eggs. The eggs are only present certain days of the month, and even on those days they won't necessarily be present in a particular stool sample. Living worms are extremely rare in stool because they are generally passed only once they die. They are very good at avoiding being excreted in stool. Furthermore, if they die internally, they can be partially or fully digested within our bodies before being expelled.

Are some labs better than others? Is it worth taking a stool sample to a vet if they send it out, or only if they look under a microscope?

We haven't found a lab that consistently finds parasites. Metametrix™ has identified parasites, but in our experience and the experience of the families I have helped, we have not found a lab that is consistent. It is only worth sending a sample to a vet if they are identifying parasites with a microscope.

Combantrin® is available in tablet and liquid form. Which is better?

I hate the liquid and never use it. It may have added colors and flavors. If you absolutely can't find it without additives, I would use only mebendazole instead of using pyrantel with additives.

Why are there no systemic drugs in the protocol?

They are not needed with this Protocol. Treating parasites without systemic drugs is much safer and easier on the body. The suggested treatments using mebendazole and pyrantel pamoato are nearly unabsorbed by the body, meaning that we do not add more toxins to an already overloaded body.

When does a child need systemic drugs?

This is necessary only for certain parasites like cysticercosis, which is caused by tapeworms, hookworms, Trichinella spiralis (from pork), or other hard to kill helminths. These may be identified by a blood test. The practitioner may prescribe systemics depending on the situation.

Should I start on the new moon if my child's behavior declines then?

The full 18-day Kalcker Parasite Protocol always starts before the full moon. However, some parents have found that by treating parasites for 3 days over new moon that they are able to get through the new moon as well as the full moon with limited issues if any.

Is there a time in the moon calendar, where it is normal that there are no worms in the stool? (We don't have any at new moon.)

Further research is necessary to determine this definitively.

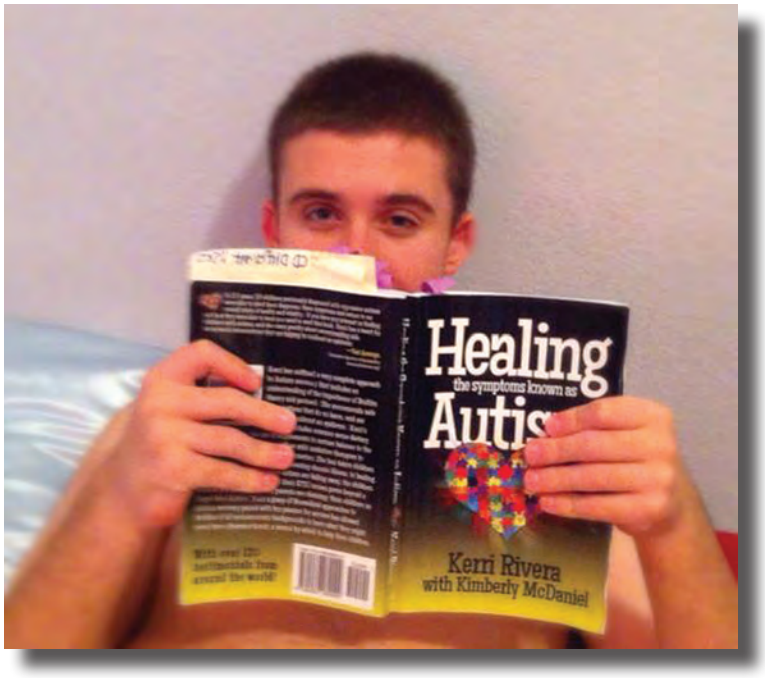

Hero Guy taking a peek at *The Protocol.*

Chapter 9

Step 4 - Other Supplements

"One of the first duties of the physician is to educate the masses not to take medicine."
~ William Osler

Most of the families that followed this Protocol, and recovered their children, used a combination of these additional supplements along with CD. Each supplement combination is completely unique, depending on the symptoms of the child, and how the child reacts to each intervention. If after *The Diet*, full *CD Protocol*, and three *Kalcker Parasite Protocols* we are still dealing with an autism diagnosis, then families start adding in supplements. This section is about "unfinished business." I like to do three Kalcker Parasite Protocols before adding back in supplements because parasites love supplements, especially vitamin B_{12} and iron.

I feel when we supplement deficiencies in children with underlying parasitic infections, it can result in resistant parasites. We aren't making the child healthier; we're making the parasites healthier and stronger. If significant supplementation does little or nothing to change lab values in subsequent blood, urine, and stool tests, then it's fair to say that we have a flaw in our approach. Pathogens and parasites can cause vitamin/mineral deficiencies. By killing them, instead of feeding them with additional supplementation, we are focusing on the root cause of the symptoms that we call autism.

When I came back from our first *Defeat Autism Now!* doctor visit, I had thousands of dollars in supplements that I did not know how to use. We kept going to different doctors hoping to find the one that had the answer. At one point, Patrick was on a protocol, given to me and supervised by a doctor, which called for 70+ different supplements a day. He looked worse during the entire nine-month period that we followed that protocol. In hindsight, all those years of supplementation made it harder to eliminate Patrick's pathogens.

That is why this protocol focuses on the excesses instead of the deficiencies for children with an autism diagnosis. If by eliminating the excesses of viruses, bacteria, candida, parasites and heavy metals, we can see a reduction in the symptoms known as autism, then eventually we can reach full healing.

Commonly, when a new family contacts me, they send me a list of all the supplements their child is taking. I frequently see lists of 30+ supplements that may be combined in ways that negate their effects. For example, probiotics are given in the morning with breakfast, or GABA with food. Both are incorrect, probiotics go alone at night right before bed, and GABA is always taken without food. If there is a legitimate reason for a certain supplement, then it absolutely must be given correctly or it's just excess noise in the body, and more stress on the detox organs.

The following list of supplements can be considered after *The Diet*, ocean water, CD, and three months of the *Kalcker Parasite Protocol* (except probiotics and enzymes which may start day one). This chapter is to be used as a starting point for your own research on these supplements. This list contains references and the websites used in this research with some of the more pertinent information about products.

Probiotics

The vast majority of the families who have recovered their children with this Protocol have used THERALAC® brand probiotic. It is a prebiotic plus probiotic in a capsule that can withstand stomach acid, which allows it to pass to the small intestine, where the beneficial bacteria are needed. THERALAC® contains three *lactobacillus* and two *bifidobacterium* strains.

The paragraph below was slightly modified from www.theralac.com where you can find more information. Please visit their site for details on references contained within the text.[1] The following two paragraphs were taken from different sources, and help explain benefits of THERALAC®, specifically for children on the spectrum.

> Probiotics are defined as: "Live microorganisms that when administered in adequate amounts confer a health benefit to the host" (World Health Organization 2001). According to the International Probiotics Association (IPA), the benefits of probiotics can include reduction in diarrhea caused by antibiotics and rotavirus, alleviation of symptoms of lactose intolerance, alleviation of symptoms of food and skin allergies in children, reduction of recurrent ear and bladder infections, and other positive indications.

How Does THERALAC® Benefit My Immune System?

> THERALAC®'s five probiotic strains work in unison to support the mucosal immune system on the intestinal surface; activation signals are then sent to the body's systemic immune system. This is a gentle and controlled process because THERALAC®'s strains are beneficial. Essentially, the immune system is put on alert so that it is ready to act quickly if there is an appearance of pathogenic microorganisms.[2]

> Many children with autism have chronic digestive problems. In fact, gastrointestinal symptoms in autistic children often first appear in conjunction with initial changes in emotion and behavior during the onset of autism, leading researchers to suspect a gut-brain connection.[3]

Normally, proteins are digested in stages by enzymes; first to peptides, and then to smaller amino acid components, which are absorbed into blood capillaries in the gut mucosa. The larger peptides are generally unable to cross this mucous membrane barrier, if they do, however, they can act as opioids affecting neurotransmitters in the brain causing abnormal behaviors and/or activity. These incompletely digested peptides—known as exorphins, casomorphins, and gluteomorphins usually come from milk proteins such as casein, or from wheat (gluten), and are structurally similar to morphine. The formation of excess peptides in the gut is possibly associated with sub-optimal enzyme activity, or an insufficient supply of enzymes required to breakdown these peptides. So if we repair the imbalance of beneficial bacterial organisms in the gut and the gut lining, while killing the pathogens causing the dysbiosis, we have the opportunity to heal children with autism. Probiotics can be used to improve the quality of the gut mucosa.[2]

In addition to aiding in the repair of the gut lining and improving digestion, there is also evidence that probiotics can help with detoxification of heavy metals such as toxic mercury.

The paragraph below was taken from the presentation "Gut biology and Treatment" by Dr. Anju Usman:

> Emerging literature is showing the beneficial effect of oral probiotics on mood and anxiety symptoms. In a double-blind, placebo controlled randomized parallel group study, daily use of probiotics reduced psychological distress.[5] A number of studies have shown the anti-anxiety effects of probiotic use in patients with medical conditions.[6]

> Dr. Vincent Young, University of Michigan (2009): "the gut ecosystem needs to be preserved and that changing the ecosystem through stresses such as antibiotics could irreversibly change the ecosystem, with deleterious effects." Dr. Young has studied the effects of antibiotics on the microbes in our gut. He found that mice when given particularly strong antibiotics completely wiped out all their normal gut microbes. Even more striking, clostridium species and fungal species are then able to overgrow without the bacteria there to fend them off.

There is no doubt in my mind that probiotics helped get my son's gut back in order, helped improve my own health, and that of thousands of families of children on the spectrum. Probiotics should be given without food, directly before bedtime. This way, they have the entire night to proliferate in the small intestine where they are needed.

Special note for those with PANDAS/PANS: We have received some reports where some PANDAS/PANS and/or older children were becoming violent and having more SIBs while on probiotics. Be observant and watch for behavior changes when adding probiotics. In addition, know that we may need to remove them for a period of time!

Omega-3 & Omega-6 Fatty Acids

Omega-3 and omega-6 fatty acids are polyunsaturated fatty acids and are considered essential fatty acids. Essential fatty acids must be consumed because your body cannot produce them. They are important for brain development, immune system and cardiovascular function, and normal metabolism. Omega-3 and omega-6 fatty acids are commonly found in marine and plant oils. While a healthy diet often provides adequate supplies of both, supplementation is sometimes necessary.

Omega-3 fatty acids also help to regulate energy levels, as well as normalizes blood sugar levels. They help improve concentration as well as mental vividness. Using omega-3 fatty acid supplements helps with anxiety, mood swings, and depression. They are especially significant in the treatment of autism. The entire body benefits from ingesting omega-3 fatty acids; from physical development, to relaxation from anxiety and jitteriness, to developing brain cells; all of these aspects can aide in the treatment of autism.[6]

Omega-6 fatty acids promote healthy brain function and assists with skin and hair growth, bone development, and metabolism. A healthy balance of omega-3 and omega-6 fatty acids promotes heart health and minimizes inflammation. Omega-6 may also be used to treat allergies, eczema, osteoporosis and premenstrual syndrome.[7]

Unlike omega-3 fatty acids, excessive consumption of omega-6 fatty acids can have negative effects. Therefore, their consumption must be monitored. Omega-6 fatty acids, in large quantities, can promote inflammation in the body that may lead to flare-ups of eczema, acne, and the aches and pains associated with arthritis. It is recommended that you maintain about a 4:1 ratio of omega-6 to omega-3 fatty acids.

Some research has been done that suggests improvements in overall health, cognition, sleep patterns, social interactions, and eye contact when children on the spectrum were given an EFA (Essential Fatty Acid) supplement.[8]

Furthermore, another study showed the positive effects of EFA's on dyspraxia (a motor disorder frequently associated with cognitive, behavioral, and social challenges). The participants showed improvements in reading, spelling and behavior during the treatment period.[9]

I have personally found that I really like omegas from YES™ Supplements. Dr. Brian Peskin has some very informative videos on YouTube discussing the merits of vegan versus animal based omega sources. I highly recommend you have a look for yourself. My own son, and many other children have built up to taking one tablespoon, two times a day.

L-carnitine

L-carnitine is a vital amino acid that promotes healthy neural levels of acetylcholine, an important neurotransmitter that aids memory and proper brain function. Research suggests that an L-carnitine deficiency may be implicated in a number of conditions, including ME/CFS (chronic fatigue syndrome), diabetes, Alzheimer's, dementia, and autism.

L-carnitine is composed of two essential amino acids, lysine and methionine. It is produced in the liver and kidneys and is contained in most cells of the body. It is required for the proper metabolism of fat and helps with mental concentration, and energy production. It transports long-chain fatty acids across the mitochondrial membrane so that they can be burned to produce energy.

A clinical trial studying the use of L-carnitine as a potential therapy for autism demonstrated the children taking L-carnitine showed improvements in their ability to relate to people, body use, adaptation to change, listening response, verbal communication, sociability, sensory/cognitive awareness, and health/physical behavior. There are a few articles that may be helpful for a better understanding of the importance of this amino acid. Check out an article by Henke Schultz, "L-carnitine helps kids with autism, study finds" and another by Emily Singer, "Defects in carnitine metabolism may underlie autism."

The average dose for L-carnitine is anywhere from 250-1000 mg per day with food, depending on weight and reactions.

GABA

GABA (gamma-aminobutyric acid) is an amino acid and a neurotransmitter (a type of chemical responsible for carrying information from one cell to another). It is produced naturally in the body, but is also widely available in supplement form. Manufacturers claim that GABA supplements can help boost the brain's GABA levels and, in turn, treat anxiety, stress, depression, and sleep problems.

The GABA system acts as something of an information filter to prevent the nerves from becoming over stimulated. It has long been suspected that this filtering process is compromised in many autistic children. Impairment of the GABA system could overwhelm the brain with sensory information, leading to many of the behavior traits associated with autism. GABA is also believed to play a key role in the early development of the brain.[10]

GABA is also involved with the production of endorphins in our brain, which make us feel positive and upbeat. GABA can reduce stress, relieve anxiety, and increase alertness. GABA can be helpful for behavior, language, and possibly even seizures.

GABA is used for control of seizure activity and works on the same receptors as the drug Keppra®. GABA is also useful for speech, helps facilitate language in nonverbal children, and improves language in children that are beginning to speak.

If you are going to give GABA to your child, the max is 5,000 mg per day, divided into two doses, one in morning and one at night, always on an empty stomach. In the evening, GABA can be given 15 minutes after your last dose of Chlorine Dioxide, with your probiotic. I start at 250 mg two times a day, one in the morning and one at night. I then titrate up the dose daily or every other day if everything looks good. If you observe sleepiness or irritability it is a good idea to back down.

5-HTP (5-Hydroxytryptophan)

5-HTP, also known as oxitriptan, is a naturally occurring amino acid. It is a chemical precursor to the neurotransmitters, serotonin and melatonin from tryptophan. 5-HTP works in the brain and central nervous system by increasing the production of the chemical serotonin. Serotonin can affect sleep, appetite, temperature, sexual behavior, and pain sensation.

From *Saving Eli: One Family's Struggle* - Vitamin Research Products website:

> While not clearly understood, researchers know that serotonin pathways are disturbed in autism, contributing to sleep disorders and mood. Tryptophan has been shown to help but has been banned by the FDA since 1989. We found that 5-HTP helped immensely, calming tantrums and increasing communication with our son.[11]

5-HTP is used between 50 mg and 200 mg, divided into two doses, morning and evening with food. I have seen it help children with autism for attention, focus, sleep, and cravings.

L-theanine

L-theanine or gamma-glutamylethylamide or 5-N-ethyl-glutamine, is an amino acid commonly found in tea. Theanine is able to cross the blood–brain barrier, and is reported to have positive effects on mood, stress, and cognition.

The following is excerpted from the L-Theanine website:[12]

> Many people experience stress on a daily basis and are looking for natural and safe ways to manage it. For thousands of years, it has been suggested that drinking green tea will make one relaxed. Recently this relaxation effect was found to be true and works because of an amino acid called L-Theanine which is found in the tea. Clinical research will show that ingesting up to 200mg of L-Theanine will promote the creation of the very important "anti-stress" neurotransmitter in the brain called GABA or gamma-aminobutyric acid. This results in a relaxed, clear and alert mental state.
>
> When used in the correct amounts in supplemental form, L-Theanine may:

- Reduce Stress
- Reduce Occasional, Simple Nervous Tension
- Promote Relaxation without Drowsiness
- Promote Mental Clarity and Focus
- Promote Positive Mood
- Promote Alertness
- Promote Learning and Memory
- Help Prevent Jitters Caused By Caffeine

I have found that when we can reduce these symptoms in individuals with ASDs we can get an increase in speech, learning, focus, concentration, and attention. L-Theanine is given with GABA upon waking, and can also be given at bedtime if needed, always without food. You can work up to 200 or 250mg/day.

Pycnogenol®

Pycnogenol® (pic-noj-en-all) French maritime pine bark extract acts as a potent blend of antioxidants, it is a natural anti-inflammatory, stimulates generation of collagen and hyaluronic acid and help with natural dilation of blood vessels by supporting production of nitric oxide.[13]

Pycnogenol® is not a supplement I tend to use very often, because it is an antioxidant, and therefore cannot be combined with chlorine dioxide. However, in some people it has proved necessary and helpful for speech and reduction of seizures. It should be given in the morning with food at a dose between 25 and 400 mg/day depending on need. Pycnogenol® may not be suitable for children who are sensitive to phenols.

L-Carnosine

L-Carnosine is a dipeptide of the amino acids beta-alanine and histidine. It is highly concentrated in muscle and brain tissues.

L-Carnosine is believed to stimulate the frontal areas of the brain, resulting in overall improved levels of functioning. More and more research shows that the frontal lobes and temporal lobes in the brain control emotion, epileptic activity, cognitive, expressive speech, and abstract thinking. Studies have shown Carnosine to improve language, socialization, and overall level of functioning in individuals within the autism spectrum. It has also been shown in studies

to have anti-seizure properties without the side-effects of prescription anti-seizure medications.

Research indicates it prevents the formation of the beta amyloid plaque that is found not only in neurological conditions such as Alzheimer's, Parkinson's and autism, but also in the eyes in degenerative eye conditions and in the pancreas in diabetes. It is a neuroprotectant, with a study indicating it reduced severity of damage in stroke patients.[14]

Chez and coworkers found that after eight weeks on L-carnosine, children showed statistically significant improvements on the Gilliam Autism Rating Scale (GARS). They relate this to the likely ability of L-Carnosine to enhance neurological function, perhaps, in the enterorhinal or temporal cortex.[15] This enhancement in neurological function has led to speech in many of the families that I have worked with.

I have also seen L-Carnosine help reduce seizures in some children and increase language in others. It is given twice a day with breakfast and dinner at a dose of 200 to 400mg, 2 times a day. If you note hyperactivity, remove it.

Taurine

Taurine is an amino acid, a chemical that is a required building block of proteins. Taurine is found in large amounts in the brain, retina, heart, and in blood cells called platelets. It can be consumed through eating meat and fish.

Autism and Low Taurine

"Are You Dangerously Deficient in Taurine"[16] explores possible problems associated with a taurine deficiency. Among the problems noted in the article is autism and low taurine levels. In the article, Leonard Smith MD writes about the benefits of taurine, some of which can be of interest to people dealing with autism spectrum disorders:

- Brain and nervous system function
- Helps eliminate toxins
- Stabilizing the brain (can be effective in treating seizure disorders)

Taurine, like all amino acids, must be given without food. The maximum dose is between 500 and 1,500 mg.

DMG

DMG, or dimethylglycine, is an amino acid that can be found in many common food items like meats (especially liver), various grains, and beans. It has been classified as a type of amino acid that is closely linked to vitamin B.

There have also been interesting developments in the use of a DMG supplement for children with autism. Because many children who have autism are unable to tolerate eye contact, and some have problems forming complete sentences and thoughts studies investigated whether an increase in DMG consumption could help to alleviate many of these problems. In fact, the study found that when children with autism were given supplemental DMG they appeared less frustrated and showed a marked increase in their speaking and cognitive abilities.[17] At present, this research remains novel and therefore further investigation is necessary to determine what the long-term effects of DMG supplementation might have on children on the spectrum.

The following paragraphs were excerpted from *Defeat Autism Now!*[18]

Dimethylglycine (DMG) for Autism

> For over 20 years ARI has been hearing from parents who have tried DMG on their autistic children. In many cases remarkably good results have been seen, especially in enhancing speech. In some cases, drug-resistant seizures have been stopped by DMG. (See New England Journal of Medicine, 10-21-82, pgs 1081-82).
>
> There is an extensive research literature on the safety and health benefits of DMG. Many studies have shown that DMG enhances the effectiveness of the immune system, improves the physical and athletic performance of humans and other animals (e.g. race horses) and has, all in all, a very wide range of beneficial effects. It is very safe. I have seen no evidence of any toxic or significant adverse effects.
>
> Many parents have reported that, within a few days of starting DMG, the child's behavior improved noticeably, better eye contact was seen, frustration tolerance increased, the child's speech improved, or more interest and ability in speaking was observed.

A full dose of DMG is 900 mg per day, taken without food upon waking. However, it is best to start at a lower dose and slowly work up to 900 mg over a week or so. If you see an increase of hyperactivity (which is rare), reduce the dose. If no improvement is seen within a month I would switch to TMG.

TMG - Trimethylglycine (Betaine Anhydrous)

TMG (Betaine anhydrous} is a chemical that occurs naturally in the body, and can also be found in foods such as beets, spinach, cereals, seafood, and wine.

How does it work?

A form of betaine called betaine anhydrous helps in the metabolism of homocysteine, a chemical involved in the normal function of many different parts of the body, including blood, bones, eyes, heart, nerves, and the brain. Betaine anhydrous prevents the buildup of homocysteine seen in people who have problems with its metabolism from birth.[19]

The following is excerpted from the *Autism Canada Foundation*.[20] Please visit their site...

www.autism.org

...for full references contained within the text.

The benefits of taking DMG or TMG range from behavioral changes, reduction of seizures, and decreased obsessive-compulsive behaviours to improved language. DMG and TMG have been reported from thousands of families to be quite beneficial to many individuals with autism.

Research on humans and laboratory animals has shown that DMG and TMG enhance the effectiveness of the immune system. Some children and adults with autism have seizures, and there are published reports of decreases in seizure activity as a result of DMG. A double-blind placebo-controlled study by Drs. Shin-siung Jung, Bernard Rimland, and Stephen M. Edelson involving 84 participants documented a significant decrease in behavioral problems.

It should be noted that some kids tolerate DMG but not TMG. TMG is given upon waking without food, in a dose of 500mg. If DMG didn't yield improvements in language, then we switch to TMG.

FAQ's

There are times when I do see undigested food in my son's stools. I am particularly concerned. He never complains of stomach pains. But I do see some at times, especially cashews. Should I bother with an enzyme? Or is it better without one. If so, which brand?

I love enzymes. Kirkman has one with Isogest®, 851/180 is the number, and it's broad spectrum. Also, Biofilm Defense® is great for dissolving the biofilm. A number of the parents online have used Ness® enzymes Gastric comfort formula #601 very successfully.

How should I administer THERALAC®?

The best time to administer probiotics is at bedtime. Children's THERALAC® is a granular formula so you can sprinkle it on yogurt or mix it into a smoothie and still obtain the same benefits! So how do you take it? We recommend that you take a level 1/4 teaspoon and fold it into yogurt, applesauce, or food of a similar consistency and let it sit for a minute. This is to keep the granules as close together as possible, thus allowing our acid proof gel matrix to form around the product. Visit the THERALAC® website for more info:

www.theralac.com/childrens-theralac.aspx

Supplement Dosing Overview

Supplement	Dose	Time of Day	Empty Stomach (ES) or With Food (WF)
Probiotics	1 cap	Before Bed	ES
Omega-3/ Omega-6	1 Tbsp	With any meal 1-3x / day	WF
L-Carnitine	250-1000mg/day	With any meal 1-3x / day	WF
GABA	Up to 2,500mg 2x/day	Upon waking & at bedtime	ES
5-HTP	50-200mg	Morning & Evening	WF
L-Theanine	Work up to 200-250mg/day	Mornings or Mornings & Nights	ES
Pycnogenol	25-40mg a day/as needed	Morning	WF
L-Carnosine	200-400mg 2x / day	Morning & Evening	WF
Taurine	500-1500mg/day	Morning, Noon & Night	ES
DMG	900mg/day	Morning	ES
TMG	500mg/day	Morning	ES
Enzymes	1 cap w/meals	Morning, Noon & Night	WF

Chapter 10

Step 5 - Chelation

So, let's say we're clipping along; full Diet, CD, Kalcker Parasite Protocol, and we've added in whatever supplements the child specifically needs and the child still has autism. Recovery is still not a reality... yet! At this point, it's time to look at chelation.

Why use Chelation for Autism?

Chelation became very popular in the world of autism about a decade ago, when things were heating up around the Thimerosal/Autism connection. Today, many of our children are still metal toxic. Metal challenges (testing that shows metals in urine) from any of the thousands of children whose families I have helped show the same thing—extremely high levels of mercury, lead, aluminum, as well as sometimes tin, cadmium, and other metals.

These heavy metals can come from various sources such as:

- Coal burning power plants. According to the EPA, coal-fired power plants in the United States emit about 48 tons of mercury into the air every year, where more than half of this mercury falls within five miles of the plant itself. When it reaches the water, microorganisms consume it and convert it into a substance called methyl mercury.
- Drinking water
- Our food supply
- Cookware
- Deodorant
- Beauty products
- Dental amalgams
- Vaccines, etc.

Heavy metals are known to accumulate in different parts of the body including organs, bones, joints, and the brain, etc. Metal toxicity can provoke

inflammation, kill neurons, cause behavioral changes, affect the thyroid and other master glands, lower T-cell counts, and cause a myriad of other symptoms. Furthermore, new research shows that fluoride in drinking water makes the aluminum that we ingest more bio-available. As was reported in the journal *Brain Research*, the combination of aluminum and fluoride causes the same pathological changes in brain tissue found in Alzheimer's patients.[1]

Many children with autism also have impaired methylation cycles. The result of this impairment is an inability of the body to rid itself of excess metals, thereby prolonging chronic illness.

What exactly is methylation?

Methylation reactions are those that involve the transfer of a methyl group from one compound to another. The methylation cycle is the name given to a biochemical pathway that contributes to a range of crucial bodily functions, including:

- Detoxification
- Immune function
- Maintaining DNA
- Energy production
- Mood balancing
- Controlling inflammation

Impairments or mutations on the methylation cycle can lead to problems with:

- ASD's
- Alzheimer's
- Diabetes
- Allergies and Asthma

An overload of toxins (including heavy metals), can contribute to the impairment of the methylation cycle, and if the methylation cycle is impaired the body is unable to detoxify as needed, therefore creating a vicious catch 22.

We need to help our children's bodies rid themselves of their excess metals as part of the healing process. Dr. Usman has shown us that heavy metals are present in the biofilm, and Dr. Klinghardt has shown that removing mercury can be directly related to a reduction in chronic infections.[2]

Let's get those metals out!

What exactly is Chelation?

Chelation is a process used to rid the body of heavy metals. It is described as a chemical process in which a substance (chelator) is used to bind molecules, such as metals or minerals, and hold them so that they can be removed from the body.

Some of the most common chelators used in the world of autism are:

EDTA

This is an amino acid that attracts lead, other heavy metals, and some minerals from the bloodstream and expels these toxic elements in the urine. EDTA works to remove excess lead from the body, but it is not specific to mercury or methyl mercury as are DMSA or DMPS. It can be taken orally, by rectal suppository, or IV.

DMSA

This is an FDA approved drug that can be used in children when lead toxicity is suspected, however it can also be effective at removing other heavy metals including mercury and arsenic. It can be taken orally, transdermally, or given as a suppository.

DMPS

DMPS is given to remove mercury from the body. It can be given IV, intramuscularly, subcutaneously, transdermally, or by suppository.

Patrick has been prescribed all of these at different points of his life, and I can't say that I saw miraculous results during the time that I used them. However, some families have seen results, and this is something you may want to discuss with your doctor. After years of using chelators, and seeing other families use chelators, I have opted for a gentle approach. I like to use two products: bentonite clay baths and Bio-Chelat™. These products are strong enough to help the body rid itself of heavy metals, but have not been shown to stress the liver or provoke undesirable detox symptoms.

Knowing now that metals are in the biofilm, I feel it is short sighted to focus solely on metals or heavy metals rather than all the pathogens in the biofilm.

Bentonite Clay Baths

Bentonite clay is sedimentary clay composed of weathered and aged volcanic ash. Bentonites are more widely known as healing clays used for detoxing, cleansing, and drawing out impurities. They are used in many everyday products such as toothpaste, antacids, and cosmetics.

Indigenous people have used bentonite clay for centuries; Dr. Weston A. Price in his book, "Nutrition and Physical Degeneration,"[3] stated that when studying the diets of native tribes he examined their knapsacks. Among the tribes examined in the High Andes, in Central Africa and the Aborigines of Australia, Dr. Price reported that some knapsacks contained balls of volcanic ash clay, a little of which was dissolved in water.

Bentonite is known as "swelling clay." When bentonite clay absorbs water and swells up, it is stretched like a sponge. Toxins are drawn into these spaces through electrical attraction and bound. In fact, according to the Canadian Journal of Microbiology, bentonite clay can reportedly absorb pathogenic viruses, as well as herbicides and pesticides.[5]

One of my personal favorites has been *Even Better Now*®'s product available at:

www.evenbetternow.com

> "EBN® Cleansing Clay is 100% pure sodium bentonite clay which has the highest cation exchange capacity (CEC of 98-107 meq/100g) of any bathing clay that we tested on the market. This clay is high purity air-classified sodium bentonite, selectively mined, consisting of micronized particles, which is a free-flowing powder. EBN® Cleansing Clay is 100% pure, hypoallergenic, and free of viruses, bacteria, yeast, and mold, as well as having a high cation exchange capacity."

There are other quality clays on the market, but EBN® tests every batch for heavy metals when it comes in. No, I do not receive financial gain from the company.

Bio-Chelat™

Another product I really like for gentle (low and slow) chelation is Bio-Chelat™. This is a German product containing a minimal amount of EDTA, which is FDA approved as a food substance. According to a clinical trial carried out in Germany:

> The therapeutic value of the Bio-Chelat™ in the context of other chelators that are currently on the market is seen as follows: Chelators work relatively fast, but they are also very strong with a relative high washout of important trace elements and a high degree of specific side effects. Bio-Chelat™ works much gentler than most common chelators.

> Although during the treatment a significant decrease of the body's heavy metal ion load was seen, this is accomplished without greatly disturbing the mineral and trace element relationships. The reduction of zinc should be looked at with caution and may easily be corrected throughout the treatment.[5]

I have seen very positive changes in many of the children who added in either bentonite clay baths, Bio-Chelate™, or both. As with any other intervention, add them separately while closely observing your child. Keep a log to record any changes, progress, or reactions you observe. Even if you don't see anything right away, I would keep using the products for a minimum of three months. Again, since they work LOW and SLOW changes may not be apparent at the outset, but that doesn't mean they are not helping to heal your child's body.

I use the CD baths every other day and then two times a week I do bentonite clay baths. I don't do the CD bath and the bentonite clay bath on the same day. I do them at opposite ends of the week.

Three days or so later, we'll add in the Bio-Chelat™. Again, follow the instructions on the package, and you can always start low and work your way up. Since Bio-Chelat™ doesn't alter the CD, the drops can be added to a single dose of CD. In addition, since the drops have no flavor, it is suitable to add them to water or any other drink your child might consume throughout the day.

Common Errors in Chelation:

Urine analysis without provocation:

Many families will do urine analysis to see if there are heavy metals present. If you have not done any chelation (oral or intravenous) you really don't get a good picture of what kinds of metals are actually in the body. Simply because the metals don't show up in urine, doesn't mean they are not present in the bones, the intestinal tract, the brain, and organs, etc. If we don't do any sort of provocation, we may end up with a false negative, leading a family to believe that their child is not metal toxic, when in fact they are. Bentonite clay baths and Bio-Chelat™ are gentle enough that they will not cause any harm to a child (metal toxic or no) but can greatly help reduce the heavy metal load, as well as other toxins in the body.

Healing the gut before starting chelation:

A doctor once told me that we had to heal the gut before we could start the chelation process. However, in the children that I have seen recover, probably up to the last month before they recover, their gut might still not yet be perfect. For example, one of the little girls that recovered continued to suffer from constipation at 30 days before she lost her autism diagnosis. However, at this stage something seemed to switch, she started having regular bowel movements and within 30 days she lost her diagnosis.

Basically we're healing the intestines as we're chelating, as we're healing everything else. They are all parts of the puzzle. I would never put chelation before the CD or parasite protocols. However, it's definitely something that's part of our road when, after these other approaches, children have not yet recovered. At some point after we have the CD, ocean water, parasite protocol and some supplements is when we can add in chelators. It's not like I'm saying, "Oh we'll talk about that in a couple of years." We want our children recovered in less time. It's like a marathon, we keep the pace, never lose our heads, or break into a sprint.

Do not chelate with constipation:

If the child suffers from constipation, it's really important that we start moving the intestines when we're using chelators. There are a few options open to us for moving the intestines. I have found that the most effective is through the use of CD enemas. If your child isn't having a daily bowel movement, I would do an enema once a day. If you absolutely can't do enemas, get that child in a CD bath. We're finding that 50 to 100 drops in a bathtub is allowing children who previously had constipation to have bowel movements.

There are a few children/adults on the protocol that will not do enemas, or the parent will not. Whatever their situation may be, we have to get the bowels moving again. In this case, we do 50 to 100 drops in their bath water along with their max oral dose every day. The result has been that they're having regular bowel movements. That's one way we can move it along and then you can keep chelating. It's really important to have a daily bowel movement with any kind of chelation because otherwise the toxins are simply reabsorbed through the intestinal wall, whether they're heavy metals or other pathogens.

IV chelation is not the only means by which to cure autism:

I think at one point between 2006-2008, we were all focused on the problem in the world of autism being the heavy metals, because there was mercury/Thimerosal in the vaccines. We had to get the mercury out of our children. Well, part of the problem is they're not detoxing. As mentioned before, methylation cycles are impaired in children on the spectrum. I met a young girl whose parents were both allopathic doctors and they really believed at that point, as most of us did, that heavy metals were the problem with autism. If we could get the heavy metals out then they would recover. The parents did 122 IV chelations and their child never improved. At this point I have lost touch with them, but these are things that we have to learn along the way. I know now that it is NOT just about chelation, and why metals are NOT the only important piece. All of the pieces play a role and likely interact to cause autism in our children. There is a symbiotic relationship between the viruses, bacteria, candida, and parasites that exist in the biofilm. Since CD can break down biofilm and kill the pathogens living in it, as well as neutralize heavy metals, it has been a very powerful tool for us.

Doing a blood test to look for heavy metals:

Generally speaking, within three days of heavy metals entering the bloodstream, the body will deposit the heavy metals into tissues, organs, and eventually bones. For this reason, a blood test is not the best place to look for heavy metals in children with autism. Unless the child has very recently been exposed to heavy metals, we are unlikely to see elevated levels of heavy metals through a blood analysis.

The articles at the end of this book (Appendices 13 & 14) will provide further insight as to why chelation can be so important for our children on the spectrum.

Luca

Chapter 11

Step 6 - Hyperbarics

by Bob Sands (Introduction by Dr. Beatrice Golomb)

"What Oxygen is to the lungs, such is hope to the meaning of life."
~ Emil Brunner

We were fortunate enough to have the amazing Bob Sands write this chapter on hyperbarics explaining its importance in healing ASD's.

Note: Throughout this section of the book, the author, Robert Lyne-Sands uses the actual names of the people with whom he came in contact with. In some instances it is with their permission, in others it is not. The accuracy of quotations, opinions expressed within this chapter, and the names used are solely the responsibility of Robert Lyne-Sands. Great care has been taken to remain within the bounds of current journalistic integrity and practice.

Robert Lyne-Sands new book, *OXYGEN: The First Medicine, Volume 1 CANCER*, is expected to be released January 2014.

Robert Lyne-Sands author of the Hyperbaric section of the book, with one of his young patients, getting ready for a session.

Robert Sands is one of only about five licensed manufacturers of hyperbaric oxygen therapy (HBOT) machines in the US, with extensive experience in clinical hyperbaric treatment, whose expertise will be an exceptional asset to this project. He has designed and manufactured HBOT machines for the US, Australia, Britain, Thailand, and many other nations, for naval/military use, civilian diving use, and medical use. He has the theoretical understanding of HBOT therapy that derives from intimate involvement in the process of designing and manufacturing these machines. He has the practical experience that derives from running a set of HBOT centers, and personally overseeing greater than 20,000 hours of HBOT sessions over 35 years.

~ Dr. Beatrice Golomb, MD, PhD.
Professor of Medicine. UCSD 2011.

Beatrice Alexandra Golomb, MD, PhD (PI) is singularly qualified to lead this study. She has expertise in GWI including authorship of four RAND reports related to GWI29-31, and work in the scientific literature. She has been a member, since its inception, of the Department of Veterans Affairs Research Advisory Committee on Gulf War Veterans' Illnesses, and served as Scientific Director of this Committee. As a licensed internist, she is a primary care physician for a panel of ~280 veterans, including GWV, at the VA San Diego Healthcare Center.

Recently, I sought the answer to something that was puzzling me. My friend, Dr. Bernard Gunter, is a revered and renowned psychologist in his eighties and, if anyone would know the answer, Bernard would.

"Does God, Great Spirit in the Sky, The Universe or whatever unseen deity you worship give you freedom for personal choices or is everything predestined?"

Bernard's eyes twinkled. He was never in a hurry to answer a question. In my mind, Dr. Bernard Gunter is sort of the American version of the Dali Lama.

He thought for a moment, selecting his words carefully, and then replied, "Funny you should ask that—just the other day I was talking with Eckhart Tolle and asked him that very same question. Tolle replied, 'God allows you to think that you have free will and free choice—and you do, by and large. However the roadmap is laid out for you beforehand.'"

Just as I suspected.

Dr. Bernard Rimland, Kerri Rivera, and the Hand of God.

On January 20th, 2006, a tall, glamorous woman walked into my San Diego clinic; her name was Kerri Rivera. She had brought her small five-and-a-half-year-old son, Patrick all the way from Mexico for hyperbaric oxygen therapy. The little fellow was absolutely gorgeous, but had a vacant stare and made no eye contact with any adult, rarely even with his mother. Day after day Patrick spent time in the chamber.

Kerri explained to me that Patrick developed normally for almost the first two years of his life. Then, to comply with vaccine regulations, Patrick received the DPT, HepB, and Influenza B (Pentavalente) vaccines in one day. Patrick fell into a complete zombie-like state after the injections. By the time Kerri arrived in San Diego, she had already done her homework. She blamed the vaccinations and had already undertaken the task of healing her son.

After her own experience with autism, Kerri wanted to help people and she was already doing the DAN! Protocol, etc., as Dr. Rimland has done so much for the children and she had a lot of respect and admiration for him and his work.

One day, I walked into the clinic and told her, "We're having lunch with Bernie tomorrow. Get a babysitter." At that point, totally shocked, she said, "Oh my God, yes, but I don't have anything to wear!"

"Trust me, what you have on would be just fine." A flustered Kerri rushed off to purchase some dressy clothes—she was, after all, a woman originally from Chicago. The very next day, we were sitting with Bernie and his wife Gloria in a quaint little restaurant, *The Green Tomato*. If the reader wishes to see that day, just go to your computer and look up Bernie on Wikipedia and there you will see Kerri in her black business suit (http://en.wikipedia.org/wiki/Bernard_Rimland).

Over lunch, Bernie and Kerri bonded immediately. None of us at the table realized that Bernie was suffering from cancer and had less than a year to live. Driving the short distance back to my clinic I made the observation to Kerri that I suspected she was about to become a scientist, and no longer just a trophy wife. "Be careful," I warned her, "Bernie Rimland's mantle will be heavy on your shoulders."

Kerri turned her face toward me and said, "I will carry that mantle willingly and with honor."

After a few days, Bernie told me that he thought Kerri had what it takes to carry the torch and help families heal their children with autism. I saw a lot of Bernie in the next nine months. He would come down to the clinic for regular hyperbaric treatments because it eased the pain of his cancer. Just before his death, he told me, "I will not die before I have found the reason for and defeated autism." But die he did on November 21, 2006, at the age of 78.

As I drove to Bernie's grave, I anticipated many, many people lining the way with some hundreds even thousands thronging the memorial park, similar to Giuseppe Verdi's funeral, in 1901, where 200,000 people gathered. At his graveside, the thousands of mourners spontaneously burst into the "Slaves Chorus" from his Opera, Nabucco.

I was stunned upon arriving. Probably less than thirty or so weeping caregivers of children with autism were present at the burial, along with Gloria and Bernie's three children. WHERE WERE ALL THE PEOPLE, THE MOTHERS AND FATHERS, THE RESEARCHERS AND SCIENTISTS? I asked myself. It was my first Jewish funeral and I think that the booming sound of the shovel full of earth that I threw down onto his plain casket made me look heavenward and ask, "God, where are you now?"

I drove home, eyes unfocused with tears, and stone eggs of the birds of unhappiness in my heart, stopping only to purchase two fine bottles of wine to toast Bernie. I knew one would not be enough. Arriving at my house, I found the fine crystal goblet my Mom had left me, filled it, and played Neil Diamond's, Morningside over and over, with each playing, another glass, held high to Bernie...

Morningside
The old man died
And no one cried
They simply turned away

And when he died
He left a table made of nails and pride
And with his hands,
He carved these words inside
'For my children'

Morning light
Morning bright
I spent the night
With dreams that make you weep
Morning time
Wash away the sadness
From these eyes of mine
For I recall the words an old man signed
'For my children'

And the legs were shaped with his hands
And the top made of oaken wood
And the children
That sat around this great table
Touched it with their laughter
Ah, and that was good

Morningside
An old man died
And no one cried
He surely died alone
And truth is sad
For not a child would claim the gift he had
The words he carved became his epitaph
'For my children'

In fact, as I sit here writing this, I play Diamond's melody and listening to the words makes my heart swell and my eyes become damp.

The morning after Bernie's funeral, hung-over and miserable, I pondered: Did my beloved friend Bernie die feeling that he failed? I now doubt it for he had passed his mantle to carry on his search for the cure without fear, without the need for accolades and rewards and to do so with integrity. I did not know it, but before his passing, Bernie and Kerri had been in communication. Bernie had given her permission to translate his *Defeat Autism Now!* Protocol into Spanish, Kerri's other language, as well as other tasks.

In review, I now see God's Hand at work—and it started one afternoon at the Green Tomato. Thus, my question to my friend on free will versus predestination right at the start of my notes on this section.

Brain overload and frozen fingers.

At the time, when Kerri asked me to write this section of her book about hyperbaric oxygen therapy and the treatment of challenged children, my mind went into overload. Why? Kerri was (in my view and that of others) the most efficient and effective health scientist with a high normalization rate of challenged children (autism, etc.). With her own hospital-quality hyperbaric oxygen center, Kerri had first-hand knowledge that to normalize such an afflicted person required a lot more than some trips in a oxygen chamber or some Silver Bullet response from a pharmaceutical company.

My brain whistled like an express train rushing through a tunnel. I thought of the dozens of children that hyperbaric oxygen therapy has helped at my different centers. Some of the little guys were so badly damaged they would repeatedly punch at their own head, or chewed on their own wrists. I'm thinking of Marco as I write this. Ten years later, he still punches. A clearly defined casualty of a hotshot thimerosal vaccination, normal until three, his parents won a multimillion-dollar lawsuit against Big PHARMA. There has

been some progress over the years; but it will be a matter of unrelenting attention to Marco.

I remember another little guy; a handsome, articulate smiling boy of about 12 years of age named Chase. Meeting him and his parents, you would never know he had autism or ADHD. Chase was a "runner." When his treatment in the chamber was over, he would promptly disappear out of the clinic doors. Eventually, Chase would be carted back down by one of the upstairs nurses. "Chase" by name and chased by nature.

After one such session in the chamber, he rocketed out and into the restroom of the clinic. I was sitting at the controls when he came back. Chase climbed up onto my knee and said, "I love you Bob," and he rubbed his hands across my face. From the terrible odor I knew in an instant what was all over my face and my lips. Chase had used his hands instead of toilet paper and bypassed the washbasin on the way out.

"Oh goodness," came from his horrified mother. "He got you. I am so sorry. It is one of his favorite jokes."

"Not to worry," I said, "I have eaten and tasted this in a variety of forms most my life." So, whenever I hear somebody say, "Sands is not a Doctor so he doesn't know s—t from Shinola," I think of Chase.

Normalizing kids is so rewarding, but you have to take a chance on s**t.

My fingers were not ready for the keyboard as I tried to wade through dozens of experiences with these children, my own personal experiences, and finally adding input from experts in the field of pediatric abnormalities. (Many of these experts became my close, personal friends as the years went by.)

For any parent or caregiver to delve into all of the opinions and conclusions of the so-called experts, it is a bewildering journey through a lot of contradictory and self-serving educated guesses and erroneous assumptions. To arrive at something that the reader will identify with, and believe in, I have to go way back. After 70 years on the face of this planet, I have reached certain conclusions about the treatment of children that enables me to write this section. Mind you, I'm not stuck in my ways and I am open to change my thoughts and conclusions as the science improves on treating children with autism.

Little Patrick Rivera, Little Bobby Sands Something in Common?

Here is something that I doubt my adult children even know about. In 1947, polio was raging throughout Australia. I was seven years of age and had developed a sore throat and fever. My father, a wealthy man, called the very best doctor to my bedside—yes physicians did make house calls in those days. I can even remember the doctor's name, Dr. Bradfield. His father had been the engineer that designed the Sydney Harbor Bridge. My dad, with all of his money drew a lot of water in those days and could get almost anything he wanted. Bradfield came in and examined me briefly; after all he had other house calls that night.

Bradfield told my Mom and Dad that he did not think I had polio, but perhaps diphtheria and that I should spend time in isolation in the infectious disease hospital overlooking Botany Bay, "just in case." The next morning an ambulance came and, in spite of my fear, pleading, misery, and tears they carted me away. The three-hour journey became a six-hour journey. The ambulance broke down outside the Sydney airport. I remember looking out of the rain spattered window and seeing the aircraft clearly visible over the fence. We sat on the side of the road for almost two hours before the replacement ambulance came to transport me, and my journey continued to a huge colonial building complex, built by convicts and perched on rolling, green lawns that looked down onto the Pacific. The complex was known as, The Coast Infectious Disease Hospital, which later became Prince Henry Hospital. I was terrified and clutched my teddy bear, *Threadbare*, under the blankets. Threadbare became my only friend for the next four months, and a glimpse of airplanes over the fence became an enduring memory of the trip.

My parents were already there and had obviously filled out all of paperwork. I never got to say goodbye to them since it was an infectious disease hospital. As they walked past a big hopper window, they paused momentarily and Mum waved through the window. I saw them maybe three times in the next four months when the nurses wheeled my bed up against the window that looked out into the hall. They would tap on the glass and smile at me but because my father was quickly bored, after about five minutes they would wave and be gone for another couple of weeks. It was a long way for them to travel.

The night of my arrival, a team of doctors and nurses arrived and they rolled me onto my side. Full syringes lay on a tray; in those days they were glass with little thumb and finger holes on each side and each needle was reused and supposedly resharpened before their next use. This meant that the needles

were thick and long. One-by-one these needles were inserted into my upper thigh on the left-hand side. The pain was agonizing and I'm sure I screamed and screamed. I remember at least three nurses holding me down. At seven, I was just a little fellow. There had to be at least 20 of these very large syringes. Checking the history books, I believe that they were mostly penicillin and sulfa drugs. I might add, it was already known to Doctor Bradfield that I was highly allergic to sulfa and remained so for my entire life.

The next morning, when I awoke, I found that I was paralyzed from the feet up to just under my arms. Threadbare was my only friend for the next four months. The days all blurred together. One thing I do remember vividly is that I used to deliberately wet the bed. I did so only when a lovely red-haired nurse with a band of freckles across her nose was on duty. This nurse was kind and gentle, probably in her twenties. After she had changed the sheets, she would stroke my cheek and tell me that everything was going to be okay and not to worry about wetting the bed. The other older nurses scolded any of the other pediatric patients if they had an accident. At some point later, my gentle nurse told me that I really did not need to wet the bed to get her attention. I soon stopped and I still got a cuddle from her. Such a display of care and affection was unknown to me from my parents back at home.

After that stay in the hospital, I was never the same. I know that there was constant discussion amongst my family members that I should be placed in some sort of an institution because my behavior was "contrary and stubborn." I was either talking my head off, trying to make my family love me, or distant, and as such, I was said to be "uncooperative." Soon after, I was placed in a Hogwarts-style boarding school.

Could that childhood experience have made me what I am today, forever alone, but rarely lonely? As the years ticked by, to my surprise (and I think everybody else's), the school counselors found that I had a genius IQ. Amongst the 1,200 boys, I was second from the top.

After seventeen years of treating so-called challenged children, I have yet to find one that was not as smart as a whip in something.

I managed to burn every social bridge at the boarding school, thrown out of every special social club at Newington. On Saturday afternoon, after mandatory sports such as Cricket or Rugby, the other boarders would get to do things they wanted like billiards, photography, or gardening (these were clubs that you had to apply for and join). However, I had been expelled from

each of them so I wandered alone each Saturday afternoon and finally picked the lock on a large room-sized cage full of Sulfur-Crested Cockatoos and other Australian parrots. I would sit alone with them and be jeered at by the boys in the garden club that were planting and weeding. Within weeks, these birds would happily climb all over me, enjoying my company. The birds loved me, but the boys and masters did not. To me, it was a two-way street. Animals made better friends than people. Eventually some of the other boys would come and beg to be allowed to accompany me into the cage so they too could have that same privilege.

Do not get the wrong impression of my beloved Newington College in Sydney Australia; even today I dream of the sanctuary of that place. It was better than what I had with my family back home.

The really curious thing is that my mind had blotted my hospital stay out, or had hidden it in some black cabinet in my brain where the really bad things are kept to allow me to get on with the reality of NOW. I remembered the illness and isolation only when Kerri asked me to write this. The details have returned with clarity: the old iron beds, the smiling face and freckles of my favorite nurse, being cold at night, the colors on the wall, the distant sight of the ocean through a window on the other side of the big ward, the frame of the window so far away that it looked like a painting hanging there. If I close my eyes as I write I can see it now.

I now ask myself, "Is this the way children with autism feel?"

I don't know. What I do know is that my old friend and confidant, teddy bear, is sitting on the desk as I write this. I reach out to rub Threadbare's head and a great calmness washes over me. The little fellow is 64-years-old now and there is a great competition amongst my adult children to see who gets him after I die.

Botched diagnosis
The incorrect pharmaceutical response.

With almost 40 years of working in medicine behind me, and now in my retirement, I do know that neither diphtheria nor polio were the problem. The suffocating "Bull Neck" or the "Strangling Angel of Children," diphtheria, had not happened to me, nor did the withered limbs of poliomyelitis set in after paralysis.

Simply put, Dr. Bradfield cocked it all up in a big way by guessing, not taking enough time and arriving at the wrong medical response on his visit. The relentless attack on me with sulfa drugs caused paralysis, which was probably what is commonly known today as Guillain–Barré Syndrome, a disorder affecting the peripheral nervous system. Ascending paralysis, weakness beginning in the feet and hands and migrating towards the trunk, is the most typical symptom; the disease is usually triggered by an infection.

It sure sounds similar to what happened to little Patrick, and probably to the reader's challenged child as well.

Migrating to America in 1990 with my tribe of offspring.

I arrived in the United States over twenty years ago. If the reader is interested enough, a quick look at a funny but classy "roast" presentation is on YouTube. You can find it by searching "Robert Lyne-Sands" on YouTube.

After completing the United States Navy transportable chamber development project, I arrived in swank, Pacific Palisades, on the outskirts of Los Angeles; living amongst all of the Hollywood greats. I was going nuts with boredom and became the "Bob Clampett" of the area; jogging down the leafy streets I always said Gudday to any celebrity. I rarely remembered their names but knew their faces. They never replied on the first go past, but then I would jog backwards, keeping pace with them (big stars like Madonna always ran with a group of minders) and I would yell out "I said Gudday. My goodness, your manners are appalling." I might add, it was not just me; they never ever nodded to each other when their paths crossed either.

Around this time, I opened the very first freestanding hyperbaric oxygen therapy center. It was more or less hidden away in Santa Monica on 6th Street. Tucked away in what used to be an old motel, you could almost refer to it as a "speakeasy" center, akin to something from the days of prohibition, where you had to knock on the door three times before being let in. I would only treat people who had been referred by another patient. Most of these people were from the entertainment industry in Hollywood, many with the HIV virus, and lots of folks with chronic fatigue syndrome.

The kiss of death in Hollywood is to be known to be ill. Hyperbaric oxygen therapy works so well that the word soon got around, and I was inundated with patients, some famous and well-known, and others just hardworking folk in the movie industry. Thus, I ended up being known for some years as "Mr. Oxygen," and because of the remarkable effects of HBOT, I befriended many of these celebrities, who subsequently invited me as their guest to many of

the big Hollywood functions (the only one that I missed was the Academy Awards).

One of the first of these talented people that became my close friend was Harold Michelson. Harold was an award-winning art director working out of DreamWorks. He was suffering the aftermath of a mild stroke. His wife Lillian had told me that her Harold loved crossword puzzles, but since his stroke he would put the across answer in the down column. This caused him immense frustration since his answer was usually correct, just in the wrong place. Five treatments in the little chamber were all it took for Harold to get his verticals and horizontals in the right place. The big thing that he noticed was that his blood pressure stabilized, his lung problems normalized, and he needed less medication for his diabetes.

Harold still stood well over 6-feet–tall, though stooped with old age. We hit it off immediately because Harold had a quick wit and loved a good laugh. The stories and banter between us were constant. Harold was extremely talented yet self-effacing. He really was a hero in the truest sense of the word. As young man, he made over 40 flights across the English Channel to bomb Germany. As navigator, Harold sat in the nosecone of the B-17 and either froze with the cold on the trip or froze with fear when making the lower-level bombing run. "Bob, I was so frightened of the flak from the antiaircraft fire from the Germans on the ground. As the puffs of smoke would erupt around the front of the aircraft, shrapnel would pierce plexi-glass windows in front of me. I would hold the navigational map in front of me and try to believe that the thin paper would stop the lethal fragments."

The first challenged child to be treated in a hyperbaric chamber—Emily.

I need to jump forward in time for a moment before getting back to Harold Michelson and his wife, Lillian. I went back into production of hyperbaric chambers after I realized the great need for hospital-grade dispensing of oxygen to the public. There were no rules preventing me from doing this even though I'm not a physician. All my patients needed was a prescription from a registered physician; that was the easy part. My first center was in San Diego.

In the first few months of patient treatments we received a call from a father in Canada. His daughter, Emily, had cerebral palsy. The father had read that hyperbaric oxygen therapy would perhaps help his little girl normalize, and so when he asked me what I thought I gave him my usual answer, "I do not know, I am not a physician." And then I added, "I would hate for you to waste your money on a trip from Canada to San Diego if it doesn't work."

The father replied, "I have two choices. I can go to England where there is snow on the ground or I can come to San Diego. It is an easy choice to make."

So father and daughter duly arrived. Emily was the most delightful child. When she walked through the door she had a crash helmet on, knee guards, and wrist-guards to prevent serious injury when she would crash, face first, into the floor. We learned a lot in the first ten days of treating Emily. One of the first things was the fact that fathers can never properly do a good job on their daughter's hair. I felt for the father since Emily had lots and lots of hair and was never still for a moment (I have a few daughters myself). Emily would arrive looking like a rag doll; her little blonde head would have pins, bits of string and ribbon through it. So the very first task of our nurses would be to grab Emily (usually tearing around the clinic), and comb her hair out to make her more presentable.

Now, the really big thing that we noticed was that on day ten she arrived at the clinic without any of her body armor. Yes, she still "toe-walked" because her heels did not touch the floor. To compensate, she would park her little fists against her chest, push her elbows out to keep a center of gravity, and rush around the clinic. On day 11, father and daughter spent five hours at the San Diego Zoo without the usual body protection. Emily never lost balance or tumbled even once. Follow-up visits over the last 17 years find that Emily is living a normal life. Yes, she still has some walking problems, but never needed to undergo the mutilating surgery that was recommended to her by her Canadian doctors. During 20 days of hyperbaric oxygen treatments in San Diego, something had changed in Emily's brain.

Likely the most important introduction in my life... The Great-Spirit-in-the Sky's (God's) hand at work.

Listening to the improvements that little Emily had made, Harold Michelson was both enchanted and excited.

"Did you know that Lillian and I have an autistic son? We need to introduce you to a couple of people in San Diego. Dr. Eric Courchesne, who runs the autism research center for the University of San Diego, known as the Autism Center of Excellence or ACE."

Lillian chimed in and said, "I really must call them about you. Eric is a gem and his wife Rachel is also a research doctor. They work side-by-side and will be so helpful."

With Emily's positive results, and more children making gains at the center, I called the Courchesne couple at the ACE and offered to provide them with the use of a $150,000 hospital-grade hyperbaric chamber for one full year. There was no response to my offer.

While you may imagine that the UCSD-ACE Research Center is located in some lofty center of learning, it is in fact to be found in a delightful millionaire's village known as La Jolla in Southern California, a block or so from the Pacific Ocean. On the top floor of a three-story building, an elegant balcony ran across the front of the building, while red and white umbrellas and tables make it look more like a posh restaurant than a research center.

I waited about a month and called again and repeated my offer of a hyperbaric chamber, operated by trained technicians for a year, or whatever time it took to make a decision on efficacy, at zero cost to the ACE. About an hour after making the second call, my secretary told me that a Dr. Rachel Courchesne was on the line and needed to speak to me on an urgent matter. I picked up the telephone, anticipating a good conversation but this is the way that it went, all one-way at me. Dr. Rachel was in fine fury and, looking back, the only way I could have put a word into that conversation would have been to fold the word flat and slip it into the tirade, sideways. She told me that it was amateurs such as myself that muddied the scientific waters of autism research and that, essentially, I should crawl back into whatever hole I came out of.

She made it clear to me that the mission of the ACE was to perform research to find a cure with pharmaceuticals. In fact, the ACE receives funding from drug companies, and that I should not bother them again. I was taken aback, to say the least.

A decade later, Dr. Eric is apparently doing fine work. For example, in his recent research, quoted widely in the media, he has found that the frontal lobes of an autistic child's brain is abnormally large. This is an observation, perhaps useful in the future, but only time will tell. But does it matter to you the reader whether this is so? Maybe yes, maybe no, so let's hold off on that sort of thing until we get into the scientific part of the book.

Let's get back to Dr. Rachel's harangue of me. In my mind, there is no doubt about the fact that for her, at least, it was all about the money and the potential for a patented silver bullet for Big PHARMA. If successful, a drug company could charge you a huge amount of money to heal your child with autism. At worst, there would be the ability to raise more money for research despite scant evidence of clinical results on children.

An example of this ability to raise money on a potential medical marketplace is the fact that in the year 2012, the National Institute of Health (NIH) allocated $100 million over a five-year period to a bunch of ACE research across the United States. So much for Lillian's glowing endorsement of Dr. Rachel.

However, the Michelson's other introduction proved to be a link in the chain.

Autism research with integrity—Dr. Bernie Rimland.

"A dear friend of ours, Dr. Bernard Rimland, also has a research center in San Diego which he calls *Defeat Autism Now!*, or DAN! for short. Bernie's son, Marc, is a true autistic savant. The movie with Dustin Hoffman and Tom Cruise, Rain Man, was modeled around Bernie and Gloria's son. Bernie was the technical advisor for the film. You must meet Bernie."

Lillian was especially grateful and fond of Bernie and his wife, Gloria. Back in the early 1950s, autistic children were attributed to cold, hard, heartless mothers. Many psychologists and psychiatrists agreed with the "Emotional frigidity" hypothesis, which suggested that the mothers were the cause of what we now know as autism. A lot of children in the United States were taken by force from their parents, and placed in isolated institutions to "protect" them from their parents. Bernie Rimland alone stood against this hypothesis; after all Bernie did have degrees in psychology, including a PhD. In fact, it was Bernie that took away the shame, the blame, and the guilt of many loving parents who were bullied into believing labels put upon them by the so-called "learned."

Driving forces behind autism research centers.

Unlike the La Jolla location for the ACE, Bernie's Autism Research Institute (ARI) was about five minutes drive from my San Diego hyperbaric oxygen dispensary; two minutes of freeway, a quick turn into Adams Avenue, and I had arrived. Again with an erroneous assumption, I had thought that Bernie's ARI would be similar to the ACE La Jolla location. In fact, I drove past Bernie's place three times before I found it. An unassuming, clay-colored, converted storefront, with a little sign on the front door that said, "Autism Research Institute." I knocked on the door and walked in. Instantly, the smell of antiquity and old books overwhelmed me and beguiled me, like something out of a Harry Potter movie. Stacks of papers were high on the floor almost in a willy-nilly fashion. A gentleman dressed in a checkered shirt came towards me. "Bob Sands? The Michelson's said to expect you." He peered over his glasses and gray whiskers at me. In that one glance, we created a bond of

friendship that lasted for more than a decade. At least once or twice a month we would lunch together along with his wife, Gloria; always two blocks from his Center, at the *Bleu Boheme*. Bernie and Gloria would carefully examine the menu and then they would both look out and recommend, "Let's all order the fried green tomatoes."

Bernie was interested in clinical results. He would turn over any stone that would perhaps unlock the mystery of autism. When I first met Bernie, 1 in 850 children born in the United States was afflicted with this mysterious and terrifying disorder. As I write, autism spectrum disorders have spiked to 1 child in every 88. So when the phone rang at the ARI, Bernie would often answer it and ask many questions, if the person believed that they had found a cure or a clue. He never discarded anything, in stark contrast to my encounter with Dr. Rachel at the ACE in La Jolla. I once listened in when he spoke with a lady who believed that you could cure autism by filling crystal glasses to different levels and rubbing your fingers around the edges to create pure tones.

Bernie put the telephone down and said to me, "It could be worth looking into. Music does create new neuronal wiring in small children, for example, or a mother singing to a child." I had already mentioned to him that when a child with autism was in the chamber, if you played unfamiliar sounds such as whale songs, or bagpipes, the unresponsive child would often brighten up and look around.

"Maybe new neuronal connections are being established," Bernie pondered as he rubbed his whiskers.

In those days, I worked on weekends. If I wanted to chat with Bernie, Sunday was the best day. No staff to answer the telephone, so he always did. I once asked him whether he took a day off and his response was succinct:

"When autism takes a day off so will I."

Bernie, a $2.6 million donation and his ARI.

Now, here is the most interesting of Bernie Rimland's driving forces—to me at least. It was not about dollars or ego, not in the slightest.

At that time, I was also friends with another Bernie, the renowned anthropologist, Dr. Bernard Aginsky. To avoid confusion between the two Bernie's I will refer to him as Dr. Aginsky. He was in his late 90s at the time, as

rich as Croesus. For many years, he had leased the penthouse of the La Jolla Shores Hotel, right on the beach of one of the most desired parts of Southern California. Again, like most of my friends, Dr. Aginsky was a humble man and thought nothing of his wealth other than as a means of accomplishment. Out of the blue, one day in my office, Dr. Aginsky looked at me thoughtfully and then asked, "I have $2.6 million and I want to give it to somebody that would make a difference. Can I give it to you?"

I immediately thought of Bernie and the children with autism and the nonprofit status of the Autistic Research Institute. "Hold that thought Dr. Aginsky. I will give you an answer in a couple of days."

A couple of days later, Bernie and I were traveling to take part in a medical internal review board. I was wearing a shirt with French cuffs and a silk tie. Bernie had on his usual checkered shirt. He confided in me once that he had to make a choice between wearing a tie or trimming his Santa Claus-gray beard. The beard always won. Wondering about his shirts, I respectfully asked him whether he ever received a salary from his ARI.

"Good gracious. I could never pay myself a salary from ARI funds and donations. You must remember that I am on a full Navy pension so it would be wrong to double dip."

After the meeting, as we traveled back along the I-405 to San Diego, I broached the subject of Dr. Aginski's offer of a $2.6 million donation for the Autism Research Institute. Bernie looked out the window for a few moments and fiddled with his beard. I could see he was calculating in his head. He turned to me and said, "We have so much money in the ARI at this time, donations and such, that I think that amount of money could be used elsewhere. Find another recipient."

Dr. Bernard Aginsky, a widower, passed away in January 2000. I have no idea where his donation ended up. I do know whether Bernie Rimland ever had a second thought about not taking that money. He never mentioned our conversation again.

DAN! changing to parallel other autism research.

Research costs money. Bernie used his resources wisely and was not interested in empire-building. He just wanted to find the cause and the answers. Bernie cured kids.

On the anniversary of his death, I went to his Kensington ARI center. I had two bottles of good wine, a bunch of wine glasses, and a whole lot of chocolates. I walked in and was astonished. The whole tenor and tone of the place had

changed. The clutter was gone. Bookshelves were neat and organized. The smell of scholarly interest in documents and old books had evaporated. It was as if the ghost of Dr. Bernard Rimland seemed to have moved to another place completely. The staff were delighted to see me, and happily munched on the yummy chocolates that I had brought for them. I commented on the neatness and the vast changes that I observed. One of the staff shrugged her shoulders, grimaced, and said,

"You have no idea just what changes have taken place, and what is about to happen."

An example of the transformation in attitude is exemplified by an offer for inflatable, aka soft-sided, chambers for DAN! while Bernie was still alive. One day, he called me up and explained to me that a group was coming to do a presentation on these soft chambers, and suggested that I plant one of my staff at the ARI to listen to the blurb from the manufacturer, Oxyheal. My secretary, Crystal was waiting amongst Bernie's staff to greet the technicians, doctors, and such that accompanied the owner of the company. They arrived at the ARI, set up the inflatable chamber, and gave their sales pitch, extolling the virtues of hyperbarics at low pressure and at a low cost.

Crystal reported back to me that Bernie looked dour during the presentation and asked, "What would happen to this with a razor blade?" Bernie and I discussed the concept of inflatable chambers the next time he was at my center, after he had finished his treatment in a chamber. He was not convinced about the soft-sided chambers.

"I worried that the scientific data that they quoted was all from hospital quality chambers. I think you are correct Bob, the physics do not hold up. I could not recommend this device to parents for their children."

The "discovery" (observation) of God's gunpowder + Bernie Rimland and Kerri Rivera.

Throughout history, air was taken for granted. You just breathed in and out and there it was; bugs and birds flew in it, mostly useful to keep your floors and ceilings apart. Even in this day and age, many folks think of it in the same way.

Let´s revisit what is now called the Age of Enlightenment, the 17th and 18th Centuries. About 1774, the kindly and soft spoken clergyman/scientist Joseph Priestly and his close friend Benjamin Franklin. They spent time drinking coffee together once a week in a London coffee house along with other scientists. Together they realized that air was actually a mixture of gases, but mostly nitrogen and oxygen. Priestly and Franklin could kill a mouse in a glass jar

in less than five minutes by depriving it of one of those gasses. Put the poor little mouse in a glass jar with a lit candle (which consumed the oxygen) and the flame of life in the mouse departed by about the time the candle went out.

Using precise scales, Joseph Priestly and the French chemist Antoine Lavoisier, gave oxygen its name. It could be weighed on a scale just like you would weigh out a cup of rice. Each unseen gas has a weight. Baros is the Greek word for weight. Words that we are familiar with come from this: barometer, barometric pressure, and hyperbaric (as in hyperbaric oxygen therapy, hyper meaning more than and baric meaning weight of the gas).

Weigh oxygen?

The weight of air (mixed oxygen and nitrogen) is 14.7 pounds per square inch at sea level. Most folks like me would prefer to use the word pressure, however, the math is easier if we use the doctors measure (the same as that used in measuring blood pressure – millimeters of mercury or mmHg). An average blood pressure measure is typically 120/80 mmHg. Let's look at it this way; if air at sea level is 760 mmHg, then 20% of that air (oxygen) is 20% of that amount. So multiply 760 by 0.20 and you will realize that vital, life-giving oxygen going into your lungs is about 150 mmHg.

Oxygen - You cannot see it, or smell it but you have to "eat" a kilogram of it each day to stay alive.

Make no mistake. If you take a substance into your body, ALL of your 60 to 90 trillion cells will be affected. Snort it, chew it and swallow it, breathe it, or inject that substance and it will have a positive or negative effect on your whole body. Cells "consume" the substance. Another word for consume is "eat." We will discuss this process, known as oxidative metabolism shortly and, especially how to produce stem-progenitor cells.

Eat oxygen?

Oxygen is a cellular food. The adult human consumes approximately 0.6 kg of oxygen each day (about 1.2 pounds). We can live about three weeks without the food that we chew and swallow, survive three days without water, but we can only live approximately three minutes without oxygen. Body cells start to die—the brain is the most vulnerable. Even a minute or so without oxygen can cause permanent damage.

Don't worry about the earth running out of oxygen. Back in the 1700s Ben Franklin and Joe Priestly also discovered the fact that sunlight on green

vegetation produces oxygen—a process called photosynthesis. They showed this with the mouse and candle in the glass jar. As the candle flame seemed to flicker, about to go out and the mouse lay, apparently dead, if there was a sprig of a green plant, both the candle and mouse came back to life. All of the oxygen that you are going to eat in the next 24-hours is replaced by just one square meter of grass producing oxygen through photosynthesis during that same length of time. In populated areas, where there is not much greenery, life-sustaining winds carry oxygen over the oceans and hills to all humans and animals.

Captain Cook, Joseph Priestly, Bernie Rimland, and Kerri Rivera—Explorers

Before we stop talking about Joseph Priestly, he made another observation about gas and this applies to our subject of autism, Bernie, and Kerri.

Living next door to a brewery, Priestly was intrigued about the gas given off by the fermentation of beer in the barrels. He put a dish of water under the vent-pipe coming out of the barrel. When he tasted the water it was full of refreshing bubbles we now call fizz. In 1767, Priestly discovered how to carbonate a liquid. He taught the Navigator, Captain Cook, how to carbonate water and, thinking that drinking that bubbly water would prevent scurvy, Cook set sail with it in 1772. It did not prevent scurvy, but, just like Bernie and Kerri, everything is worth investigating.

We now know that any gas becomes soluble if it is concentrated or made thick. In this instance, the gas was an extremely light gas known as carbon dioxide (yes, the stuff we breath out and, unlike the 21% oxygen, there is only about .033% of carbon dioxide in the air we breathe). However, if you concentrate it to 100% some of it melts into the water and becomes carbonic acid, as is the case with soft drinks. Pop the lid and the acid turns back into carbon dioxides gas, forming little bubbles in the liquid. Joseph Priestly should have patented his observation. Ten years or so later, Joseph Schweppes patented the process in Germany and most folks think of him, not Priestly, when they have a gin and tonic.

Thereby hangs another Newtonian rule about gas that cannot be changed. "Gas under pressure becomes soluble in a liquid according to its density (or thickness)." – Henry's Law.

And this is how oxygen works in a hyperbaric chamber – Newtonian Gas Laws

Stay with the soda can thought and the thicker gas melting into the sugary drink. When a human climbs into a hyperbaric oxygen chamber, we substitute oxygen for carbon dioxide. Believe it or not, you do not feel squashed by the pressure other than you have to "pop" or equalize your ears. Humans are mostly water and other fluids that cannot be compressed like a gas. What is happening in the chamber is that the oxygen (it should be 100% oxygen) is being made thicker or concentrated. And, just like the soda, Henry's Law kicks in. The oxygen melts and the body supersaturates with oxygen.

Another curious thing about a well-oxygenated body is that it becomes slightly alkaline. Your powers of hydrogen (pH) read about the same as seawater, which is alkaline because of the dissolved oxygen in it. Yes, even fish need their daily meal of oxygen!

The word "saturate" comes from the Latin word meaning "to completely fill." Since only our red blood cells (RBC) carry oxygen, they are almost always full of oxygen in a healthy human. The little pulse-ox device that clips on your finger when you are in hospital almost always reads 99% unless you are anemic.

It takes between one and three minutes for each RBC to leave your heart, make its complete circuit, and be back in your lungs for its next load of oxygen. Remember that Henry's Law also applies here, therefore, oxygen is a gas in your lungs but turns into molecular oxygen when it enters your body's fluids. This is so complex that there is no chemical symbol for it, but rest assured, your body's cells feed on it with a great appetite. (More on oxidative cellular metabolism shortly.)

Supersaturate?

When you fill a glass of water to the brim, it is full or saturated. Right? Yes. Holding it under the faucet and running more water into the glass will only mean that the water slops over the edges. The glass is still full. However, this is not the case with any gas, particularly oxygen breathed in by a human. Sure, just like a glass of water, oxygen can be measured by volume, but there is plenty of room to over-fill our bodies with oxygen—supersaturated.

To illustrate a complex process, let's paint a simple picture—An underground subway system.

Think of your lungs as a subway station. Passengers get off the carriages and others get on. In this instance, remember that air is made up of (for easy math calculations) 80% nitrogen and 20% oxygen. Visualize each gas molecule of either type as a gas-person. The body is already full of nitrogen at sea level and since it does nothing at all (it is inert), the nitrogen-people just come in and out your lungs. However the oxygen-people are dynamic and bustle to climb on board the little red-blood-cell carriage (which has a special oxygen-people magnet—an iron molecule), and away the red blood cell rushes with the oxygen-people ready to jump off to the hungriest of the body's cells.

Since Henry's Law allows a gas to melt into clear fluids (and our body has lots of clear fluids), there is a whole lot of room to add more oxygen-people. For example, if we barred entry to our lungs of the nitrogen-people (simple to do—just put on a mask and breath oxygen out of a 100% oxygen tank), then our lung-subway station would have five times more oxygen-people and that would mean that we increased the oxygen-people with each breath from 160 mmHg to 760 mmHg. Remember that they are dynamic, and that each red-blood-cell carriage has an oxygen magnet in it. The thick crowd oxygen-people all bustle to get onto that carriage, through the wet soapy surfactant in the wall of your lungs, even though it was already full.

Essentially, the oxygen-people fill the red-blood-cell carriage, and into the plasma where they are quickly swept along in that clear plasma fluid. Then, when even more oxygen-people continue to crowd on back at the subway station (i.e. the lungs), the plasma, which normally does not carry oxygen-people (molecular oxygen), then needs to put the overload of oxygen somewhere. From here the oxygen-people go out through the rail tunnels (i.e. the circulatory system) and into the clear fluid (i.e. interstitial fluid) that bathes our body cells. As this fluid fills with oxygen, it dumps it off into the body's largest water compartment—the body's cells (the intra-cellular compartment). These cells now have a veritable feast of oxygen available.

About 90 minutes after you start breathing 100% oxygen, you are supersaturated with five times the normal amount of molecular oxygen. No, you do not swell up since we are talking about molecules in existing body fluid, not added fluid. Curiously, if you put the little pulse-ox back on your finger, it would still only read 99% since it is just measuring the oxygen in your red blood

cells. However, using high-tech oxygen measuring equipment (transcutaneous oxiometry), you can even measure molecular oxygen in your urine, saliva, and tears—something once thought impossible.

Now comes the hyperbaric chamber part. You climb in, the door is shut, and 100% oxygen floods in. The technician can look at the physician's prescription and increase the thickness of the gas in that chamber. Double the thickness (i.e. weight or pressure) to 1520 mmHg; ninety minutes later you will climb out of that chamber with ten times the number of oxygen-people (molecular oxygen) in your body. Or, put another way, since your body's cells are going to consume (eat) that additional oxygen, this is the only way you can increase the weight of oxygen-food available in a 24-hour period. One hundred percent pure oxygen at sea level and you will "eat" between just under half a kilogram to just over one kilogram of oxygen.

The deeper/thicker the oxygen is in the chamber the more you get. In fact, following Dalton's Universal Gas Laws, by doubling the pressure, you can actually get your daily oxygen meal at almost two kilograms.

Now the nifty thing about oxygen supersaturation.

Unlike many pharmaceuticals that are weight dependent, (too much of a certain drug will sicken or kill a smaller patient, not enough of the same drug and there will be no therapeutic benefit to the patient) with hyperbaric oxygen no individual can suffer from an "overdose" of oxygen, regardless of whether the patient is a mouse, rabbit, horse, or human. All climb out of the chamber, (depending on the pressure/thickness of oxygen they were treated at) with the same amount of molecular oxygen in their body. Not one person has suffered from an "overdose" of oxygen.

Our oxygen dispensary centers have treated, according to their physician's prescription, tiny babies, the elderly, and everyone in between; we have never seen a negative side effect. Instead, we have observed clinical positive effects for all.

What happens when we actually give people an extra "oxygen feast" by putting them in the chamber? Again, an extremely complicated process has to be simplified for understanding. However, before making things simpler we must first look at the science. Chatelier's principle predicts the effect of a change in conditions on a chemical equilibrium. The principle is named after Henry Louis Le Chatelier, who observed that if a chemical system at equilibrium has a change in concentration, temperature, volume, or partial pressure then the

equilibrium shifts to counteract the imposed change and a new equilibrium is established. Any change in the status quo prompts an opposing reaction in the responding system.

Time to change just a couple of words for better understanding. Let us start with the word equilibrium and now call it "the way it was." We can also use that term for status quo and counteract can be changed to "pushing back." So what is really being said here is, if we change something in any chemical environment it will push back hard to be the way it was. Now it is time to make things even easier.

We are all chemical systems.

We have already mentioned cola in a can and advised against giving it to anybody, your child or yourself, because of the acidity of the liquid in the soda. But there is an even more compelling reason—the sugar. There are 39 grams of sugar, about ten teaspoons of sugar, in one can of soda. Would you feed your child that much dry sugar?

"Come on," you might think to yourself, "No way. It does not taste that sweet." It is true. The manufacturers of sodas use a lot of phosphoric acid to disguise the sickly sweetness of the drink. If you still doubt this, take an ordinary penny, or an egg and put it in a glass full of cola overnight. Within a few days, you will find all tarnish removed and instead a bright, shiny penny; the eggshell will be soft and pliable, all its protein dissolved.

Visualize what happens when you allow your small child a glass of cola (or any soda drink). Your little kid becomes supercharged, bouncing off the wall, and for some time you cannot get the child to sit still. In other words, your child has become hyperglycemic. Too much sugar, of any sort, whether it be corn fructose, beet or cane sugar, the results are the same according to Chatelier's principle. Remember, we are all chemical systems and by adding all of the sugar to a small child's body, all of the cells in that body will push back to return to the way they were before the additional sugar. The most efficient way to return to this state is to increase physical activity, causing cells to consume all of the additional added sugar.

Run, baby, run!

Another way, of course, is to rely on the body to use its own chemicals to burn off the sugar. This is predominantly the job of the hormone insulin. If an adult drinks a lot of soda each day (or even has one gin and tonic, which

has about half as much sugar as a soda) and does not increase physical activity, diabetes eventually sets in as the body become insulin exhausted, unable to produce more. Then the risk of blindness in old age, amputations, and other terrible consequences may become a reality.

The process of cells using the nutrients we consume is called cellular metabolism. Overloading cells with nutrients that we do not need such as excessive raw sugars (or even food that is easily converted by the body into glucose) and fats, results in obesity; your brain will become sluggish. Now, add extra oxygen and your body will certainly consume it. This is called oxidative metabolism. The added oxygen will push all cells into overdrive; repair cells use the added oxygen to work harder in an effort to restore their state prior to entering the hyperbaric chamber. Repair cells help get rid of the toxins, acids and, excess/unneeded sugars.

After people have been in a hyperbaric chamber, healthy adults comment on the fact that their brain is working more efficiently. Memory becomes vivid and problems are easier to solve. This state is commonly known as the "cappuccino" effect or "brain brightening."

As for small children with autism, almost all of them have a neuronal oxygen transport problem. So the additional feast of oxygen actually makes the good cells, the repair cells, work harder for just a little while after the treatment. This increase in oxidative metabolism dissipates after a couple of hours, but that little bit of improvement lasts: brain cells wire up into complex circuits, blood vessels within the brain become robust, and stem cells are produced. (More on that shortly.)

This is why all oxygen treatments need to take place over consecutive days. There is no point in attending one hyperbaric treatment and then not following it up for another week. Sort of like a seed sprouting from the earth. With each treatment, the positive changes begin to accumulate, and positive results are visible with the passing days.

Can oxygen therapy alone cure autism?

The short answer is no; it cannot. I make this statement based on the treatment of scores of challenged children that have come to my centers across America, and in other parts of the world. Something more is needed—an interdisciplinary approach.

How many treatments in the chamber does a challenged child need to be part of that recovery program?

As noted earlier, we treated our first challenged child, Emily, in one of my centers in the United States. Just one treatment per day at 2 ATA, the pediatrician's decision, made a vast difference to little Emily. Then along came a physician, Dr. Paul Harch, a very bright health scientist. He came to the conclusion 15 years ago that two 60-minute treatments each day at 1.75 ATA for 20 days could cure children with autism. He was so sure of himself that he even took out a patent on that protocol.

I was nonplussed and puzzled. I did not think that you could patent a natural phenomenon such as the effects of hyperbaric oxygen therapy or gravity. Of interest is the fact that the Supreme Court came to the same conclusion in 2012 with what is now known as the "Prometheus" ruling. In essence, the courts had taken all of the enforceable teeth out of Dr. Harch's protocol. This is not to say that there isn't some merit in the treatment pressure, nor is it to imply that Dr. Harch was ignorant of the science of hyperbaric rights in the therapy. So my centers took notice of the fact that he is a physician, and for a little while at least, we did use the Harch protocol on children.

While our little patients saw useful and positive results, there was never a normal recovery by any of the children in that 20-day double ride. This left a lot of the parents disappointed, some angry at what they felt were false claims about hyperbaric oxygen therapy, and rightfully so.

It is significant to note that Dr. Harch, and other clinicians, no longer use the two treatments a day protocol for challenged children, and he no longer claims that recovery is possible in just 20 days.

Now, onto our wonderful Jennifer; the ballet dancer and champion ice-skater. Her mom, Vickie, a bright spirit and highly intelligent woman (actually that describes the whole family), independently arrived at the conclusion that diet was a most important part of the normalization program. All together, over a 12-year period, Jennifer had 135 rides in the hyperbaric chamber. She ice skated at 2am (when the rink was clear), and focused on diet. In a nutshell, while the extra oxygen was feeding one side of cellular metabolism in spurts of 20 treatments at a time, Jennifer's cells were getting the correct diet of nutrients on the other. All of Jen's cells were giving off the right amount of heat and energy, particularly her repair cells.

Bernie and Kerri proved scientifically that the addition of proper nutrients, combined with the removal of deleterious/toxic foods is probably more important than hyperbaric oxygen therapy for children and young adults on the spectrum. Yes, the oxygen boost helps propel the patient to "normal," but the other nutritional changes are really the rocket fuel. It is a long journey, not all that expensive, and certainly worthwhile.

When a hyperbaric chamber is not a hyperbaric chamber.

One final comment about treating neuronal disorders at 1.75 ATA pressure is of utmost importance; this is that 100% oxygen is essential to the protocol. Since Dr. Harch arrived at this treatment depth, there have been thousands of inflatable chambers, so-called mild hyperbaric chambers, sold in the United States and around the world. These are not the same as hospital grade, hard-sided chambers. These bag-chambers do not deliver the needed 100% oxygen. In my opinion, at the very best, if you modify them (against FDA rules) you will only get 34% oxygen.

What have we learned thus far? Time for a review and then THE BIG SECRET REVEALED!

- Oxygen cannot be seen, but we can weigh it.
- Our bodies "eat" oxygen every day because it is a food for our cells.
- The only way we can get additional oxygen is in a hyperbaric chamber.
- This is because any gas becomes soluble and melts into a fluid (i.e. Henry's law); the same reason we can carbonate soda drinks.
- In a single treatment in a hyperbaric-oxygen-therapy chamber, we cannot overdose (and I have never witnessed any negative side effects).
- With the extra oxygen feeding the cells, our bodies get a boost of energy, particularly the repair cells.
- For oxygen in the chamber to be effective, it must be 100% oxygen. Inflatable chambers do not deliver 100% oxygen.
- Hyperbaric oxygen therapy alone will not cure autism, but it does make a big difference.
- There is no such thing as a "one-size fits all" treatment protocol in a hyperbaric chamber that works for all patients. For example, twice a day in the chamber for 20 days will make some difference but not necessarily "normalize" a challenged child.

Did you miss the big secret?

It was already mentioned about one page back—the discoveries of Bernie and Kerri. Let us repeat the secret for you and then push the edges of their really stunning discovery that is backed up by the latest science.

Bernie and Kerri proved scientifically that the addition of the proper nutrients, in the absence of offending foods, in addition to eliminating pathogens and parasites, are most likely more important than hyperbaric oxygen therapy for children and young adults. Yes, the oxygen boost helps propel the patient to "normal" but the other dietary interventions are really the rocket fuel. Not to mention freeing the body of offending pathogens/parasites which wreak havoc on the body. It is a long journey, not all that expensive and, certainly worthwhile.

Nutritional "padding." Hyperbaric oxygen therapy and the production of progenitor and stem cells.

When a baby is growing inside its mother, it has progenitor cells and stem cells. The function of these cells is considered to be, as yet, undecided. Although studies continue to elucidate exactly which mechanisms are involved in determining the fate of these cells, it is generally accepted that their surrounding cells will dictate their development. For example, the big arteries that crisscross the chest area make a decision sooner or later to turn into a heart with all of its compartments. Then, as development moves on different parts of the baby appear. These are called progenitor or stem cells.

There are various estimates on how many different types of cells the developed human has in total; however, it is predicted there are somewhere between 210 and 300. Mind you, when the baby takes its first breath of air, all but about four of these different cell groups stop reproducing. For example, the brain, with all of its neuronal pruning and circuitry needs about 20 year's worth of stimulation to properly wire all of the connections. Surprisingly, a lot of the neurons will be shed or "pruned" since they will not be put to use in the adult. However, neuroplasticity allows new skills to be added or repairs to be made to and by the brain in a lifetime.

However, medical scientists have now realized the great need for progenitor or stem cells (cells that can make decisions to replace worn or damaged cells within the body), and the search is on for these decision-making cells. Many scientists are looking for something they can patent and as a result are missing the point that it is already here. Or they are ignoring it, because but they cannot patent it.

It is called hyperbaric oxygen therapy.

> Penn Study Finds Hyperbaric Oxygen Treatments Mobilize Stem Cells
>
> **Science Daily** — According to a study to be published in the American Journal of Physiology-Heart and Circulation Physiology, a typical course of hyperbaric oxygen treatments increases by eight-fold the number of stem cells circulating in a patient's body. Stem cells, also called progenitor cells are crucial to injury repair. The study currently appears online and is scheduled for publication in the April 2006, edition of the American Journal.
>
> Stem cells exist in the bone marrow of human beings and animals and are capable of changing their nature to become part of many different organs and tissues. In response to injury, these cells move from the bone marrow to the injured sites, where they differentiate into cells that assist in the healing process. The movement, or mobilization, of stem cells can be triggered by a variety of stimuli including pharmaceutical agents and hyperbaric oxygen treatments. Where as drugs are associated with a host of side effects, hyperbaric oxygen treatments carry a significantly lower risk of such effects.
>
> "This is the safest way clinically to increase stem cell circulation, far safer than any of the pharmaceutical options," said Stephen Thom, MD, PhD, professor of emergency medicine at the University of Pennsylvania School of Medicine and lead author of the study." This study provides information on the fundamental mechanisms for hyperbaric oxygen and offers a new theoretical therapeutic option for mobilizing stem cells."
>
> "We reproduced the observations from humans in animals in order to identify the mechanism for the hyperbaric oxygen effect," added Thom. "We found that hyperbaric oxygen mobilizes stem/progenitor cells because it increases synthesis of a molecule called nitric oxide in the bone marrow. This synthesis is thought to trigger enzymes that mediate stem/progenitor cell release."[1]

Nutritional padding: It has long been known that when hyperbaric oxygen therapy is applied, existing cells, the good ones, the repair cells, turn the body into its own pharmaceutical company, providing the right sort of chemicals at the right time. Above all, there is a dramatic increase in the production of the molecule called nitric oxide from the bone marrow. Probably the best way of describing the addition of hyperbaric oxygen therapy, as an adjunct to the correct nutritionals, is simply by putting fuel onto an already existing smoldering fire. Out of the glow of embers and smoke you will see a vigorous combustion as your fireplace heats up and the flames appear.

Now imagine other ingredients that have yet to be discovered as beneficial. For example, stem cells that repair the damaged brain of a person with autism. It could be that adding external stem cells to the recipe of recovery and normalization, with simple nutritional low-cost padding, and putting the little patient in the chamber would be a faster way of achieving what all parents want for their children—to eventually become fully functional and independent adults.

All of this by just a little bit of nutritional padding and helping the body to rid itself of pathogens/parasites.

Now, it is time to turn back to Kerri so she can tell you what she has seen when hyperbaric oxygen therapy is added to the correct nutritional padding, along with chlorine dioxide to keep pathogens under control. That is the big secret to helping your child through the challenges that living in this century have visited upon you.

As Bob mentioned, I have seen miracles happen when hyperbaric oxygen therapy was applied to a child who is ready. Two girls, in particular, lost their diagnosis completely within weeks of completing treatment in the chamber. As I mentioned before, hyperbaric oxygen therapy gave my own son his speech back. Before his first 40 dives he had several single-syllable sounds, but after, he began stringing words together to request his favorite foods.

Today we are seeing that one dive a day at 1.75 ATA (atmospheres absolute) for 90 minutes at depth is better than two 60-minute sessions were first prescribed for Patrick seven years ago. Every three months after the first treatment of 20 sessions, apply ten sessions of 90 minutes, each at 1.75 ATA, until your child is recovered.

A lot of parents ask when is a good time to do hyperbarics. To this I reply that we must first have diet and chlorine dioxide totally under control, and be at least three months into the Parasite Protocol. At that point it's time to start looking for a chamber.

Make sure to do an ATEC before your child's hyperbaric oxygen therapy sessions, and repeat two months after the sessions are over; the results will be obvious.

This is my Asperger son Tobias, 10 years old, and me... when we received the book this summer.

Chapter 12

Step 7 - GcMAF & Autism:
State of the Art & Future Perspectives for a Natural Cure

by Marco Ruggiero, MD, PhD.
Specialist in Diagnostic Radiology
Full professor of Molecular Biology
Dept. of Experimental & Clinical Biomedical Sciences
University of Firenze, Italy

"The voyage of discovery is not in seeking new landscapes but in having new eyes."
~ Marcel Proust

My family and I have been in biomed for so long, that there aren't too many interventions we haven't already tried. A few years back, Dr. Usman mentioned to me that GcMAF might be something good for Patrick. She explained that GcMAF is a human protein that occurs naturally in a healthy body. It is a special supplement that replaces the missing part of the immune system, and also acts as the body's own internal medicine.

Based on her recommendation, we ordered a vial, and applied it for about two and a half months. I saw less obsessive compulsive eating, but when the vial ended and I hadn't seen amazing results, I wasn't extremely motivated to continue. Not only that, funds were scarce, so continuing really wasn't an option.

Two years went by and I spoke to Dr. Usman again. She said we really should give it four to five months before making a final decision. So, we scraped together the money for a second order. We started again in November of 2012, and reached full dose by December, 26th 2012. Seemingly, as time went on, Patrick started to do new things.

By springtime of 2013, Patrick's BFF's mom was saying how well he was doing, and reminded me that during the prior month Patrick had not been doing the things that he was now doing. As I write this in October of 2013, all of my money now goes to GcMAF. ☺

One of the things that I feel makes GcMAF so exciting is the fact that it helps regrow dendrites in a matter of hours after it is injected. The dendrites are the very things that got fried when mercury entered our children's bodies. With the help of GcMAF, we are now able to restore what was lost. Not to mention, GcMAF boosts the immune system, which we have come to find is often sorely lacking in people with ASD's.

Many people have asked me if GcMAF is now an official part of the protocol. When working towards recovery, I feel that we need to try everything at our disposal that has been proven to heal autism—in the correct order, or course. GcMAF fits that description. According to www.gcmaf.eu, "As of February 2013, on the American National Library of Medicine alone, 142 eminent scientists from 8 nations have published 59 major GcMAF research papers, which can be viewed on the US Government's Pubmed system." There is now enough research to prove that GcMAF has secured its place as a powerful biomedical intervention for healing autism. Therefore, after three months on the Kalcker Parasite Protocol, it is time to start thinking about adding in supplements, HBOT and GcMAF.

We are blessed to have the one and only Dr. Marco Ruggiero, the lead GcMAF researcher, write the remainder of this chapter about this substance, it's benefits and applications in autism and beyond.

The information he presents is extremely important because I feel that GcMAF is the future of medicine—today. What other intervention boasts a cancer recovery rate of 80%? None! Dr. Bradstreet is reporting 85% responders and 15% recovery rate from autism with GcMAF.[1]

Imagine adding GcMAF to the protocol already outlined in this book at the right moment (after working down some of the pathogen load), we should start seeing even higher rates of recovery than 15%. I look forward to seeing what transpires during the upcoming year as more families add GcMAF to their children's protocols. I am excited for more and more people to lose their autism diagnoses.

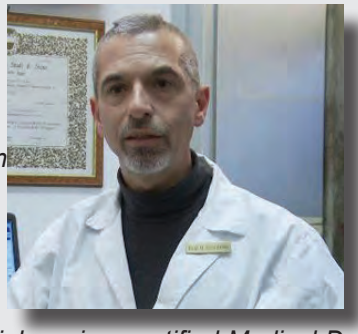

In For the past 20 years, Dr. Marco Ruggiero has worked on the vitamin D axis, a metabolic pathway that includes the vitamin D binding protein-derived macrophage activating factor or GcMAF. the past 3 years he has published studies on the immunotherapeutic effects of GcMAF in cancer, HIV/AIDS, chronic fatigue syndrome and neurological conditions.

Marco Ruggiero holds a PhD in Molecular Biology, is a certified Medical Doctor specializing in Clinical Radiology and is a professor of Molecular Biology at the Department of Experimental and Clinical Biomedical Sciences of the University of Firenze, Italy.

He served in the Army as Medical Lieutenant with specific training in chemical, biological and nuclear warfare. He worked at Burroughs Welcome Co. North Carolina, USA publishing a seminal paper with Nobel Laureate Sir John Vane and, subsequently, at the National Cancer Institute of the NIH in Bethesda, working with Dr. Stuart A. Aaronson and Dr. Peter Duesberg.

Since 1992, he holds the chair of Molecular Biology at the University of Firenze where he leads a research group of about 10 researchers. He has published more than 150 peer-reviewed scientific papers on signal transduction in a variety of experimental and spontaneous pathologic system related with cancer, chronic kidney disease, chronic fatigue syndrome and neurological conditions.

The role of nutrition in the treatment and eradication of the symptoms of autism is well established and other chapters of this book treat this topic in detail. What is far less known is the fact that certain natural components of the diet, certain nutrients, have profound effects on all the systems that are affected in autism and in particular on the brain and the immune system. Their effects are so dramatic that for about 20 years, these natural components have been labelled as "drugs" even though they are essential parts of our bodies, just like hormones or neurotransmitters. I am referring here to the family of molecules that is known as GcMAF, an acronym that stands for Gc-protein-derived Macrophage Activating Factor.

GcMAF has been the object of intense research in the past 20 years for its therapeutic role in cancer, autoimmune diseases, and HIV infection (for review, see: Anticancer Res. 2012 Jan;32(1):45-52). But, only one year ago, in 2012, its dramatic effects on the eradication of the symptoms of autism were published in a prestigious peer-reviewed scientific journal (Autism Insights 2012:4 31–38).

In this chapter I shall provide an overview on GcMAF with particular reference to its therapeutic role in autism and to the future perspectives deriving from the basic and applied research that is revolving around this fascinating molecule.

A Brief History of GcMAF

The first publication on GcMAF in a peer-reviewed journal indexed in the US National Library of Medicine is dated 1994 (J Immunol. 1994 May 15;152(10):5100-7). In this article, a group of researchers from the Department of Biochemistry at the Temple University School of Medicine in Philadelphia, USA, described the effects of a protein, defined as GcMAF, on rat macrophages. Macrophages are key elements of the immune response and the research group led by Dr. Nobuto Yamamoto, the first author of this paper, showed that GcMAF activated these cells. Given the central role of macrophages in the control of all immune responses, GcMAF was considered a powerful regulator of the immune system and the research on GcMAF initially was focused on its immune-stimulant properties. In fact, one year after the initial observation on rats, Dr. Yamamoto, who in the meantime had moved to the Laboratory of Cancer Immunology and Molecular Biology of the Albert Einstein Cancer Center in Philadelphia, authored a paper suggesting that a defect in endogenous GcMAF production contributed to immunodeficiency in AIDS patients (AIDS Res Hum Retroviruses. 1995 Nov;11(11):1373-8.). Consequently, he provided GcMAF to Medical Doctors treating HIV patients and, 14 years later, after 7 years of follow-up, he published a seminal paper describing eradication of HIV infection through GcMAF administration (J Med Virol. 2009 Jan;81(1):16-26).

Immunodeficiency, however, is not unique to HIV/AIDS and, back in 1996, Yamamoto and colleagues, hypothesized that deficient endogenous GcMAF production was responsible for the relative immunodeficiency that is typically observed in cancer patients (Cancer Res. 1996 Jun 15;56(12):2827-31). Quite logically, this observation of 18 years ago, led to the proposal of administering GcMAF to cancer patients with the goal of empowering the immune system that in turn would fight the cancer growth. This approach is known as "immunotherapy" and it is much older than GcMAF since, in modern times, it stems from the observation of Dr. William Coley in 1891. However, it could be argued that the idea of stimulating the immune system to fight diseases is even older since, as it is stated in this recent article, "…cancer regresses when associated with acute infections such as bacterial, viral, fungal, protozoal, etc. Acute infections are known to cure chronic diseases since the time of Hippocrates…" (Indian J Cancer. 2011 Apr-Jun;48(2):246-51).

Whatever the case, administration of GcMAF to patients with metastatic advanced cancer proved efficacious and there are now scores of papers published in the peer-reviewed literature describing the dramatic therapeutic effects of GcMAF in all types of experimental or spontaneous tumors.

Nowadays, the interest for GcMAF in the immunotherapy of cancer is so high that the prestigious scientific journal "OncoImmunology" dedicated the cover of its August 2013 issue to GcMAF. The molecular rendering of GcMAF is on the left of the cover with a caption linking it to an article by Thyer and colleagues published in the same issue and describing successful treatment of advanced cancer patients (Figure 1).

Figure 1

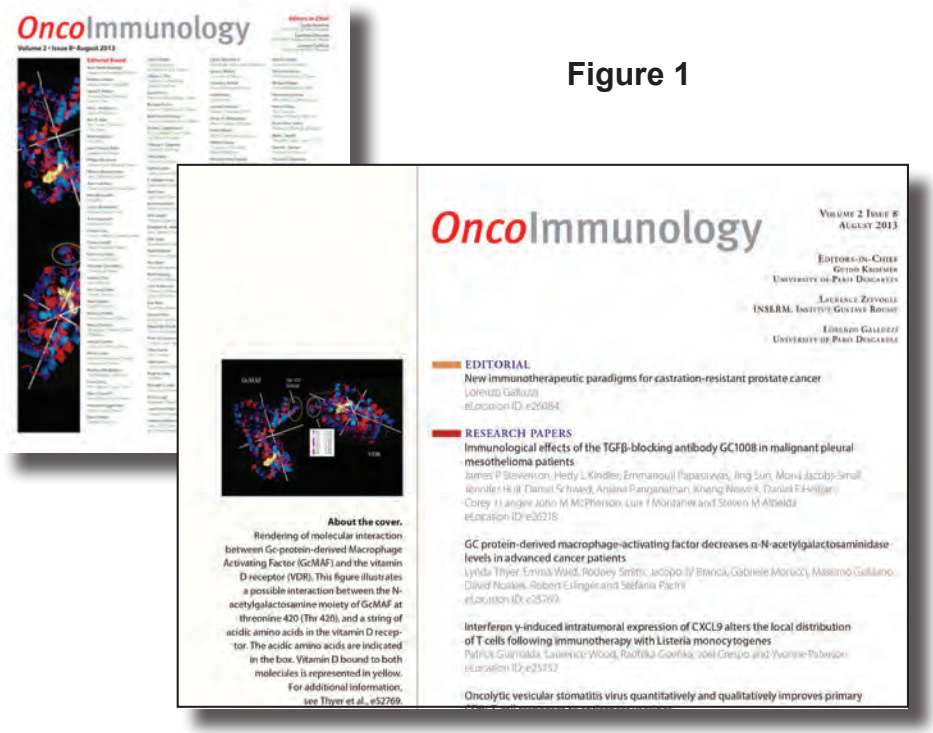

Source: https://www.landesbioscience.com/journals/oncoimmunology/oncoimmunology_2-8.pdf

Consecration of GcMAF in the Olympus of science, however, occurred a few days later, on September 14, 2013, when another article by Thyer and colleagues was published in "Nutrients", an international, peer-reviewed open access advanced forum for studies related to human nutrition (Nutrients. 2013 Jul 8;5(7):2577-89). In fact, this article describing the effects of GcMAF on human breast cancer cells, was ranked in the top 5% of all articles ever tracked by Altmetric. The Altmetric score is a general measure of the attention that an article, book or dataset has received online and reflects the quantity of attention received as well as the quality of that attention. By the time that the GcMAF was ranked in the top 5% of all scientific articles ever tracked, Altmetric had analyzed 1,510,524 articles across all scientific journals. Therefore, we may safely state that in this chapter we are describing one of the hottest topics in today's world science (Figure 2).

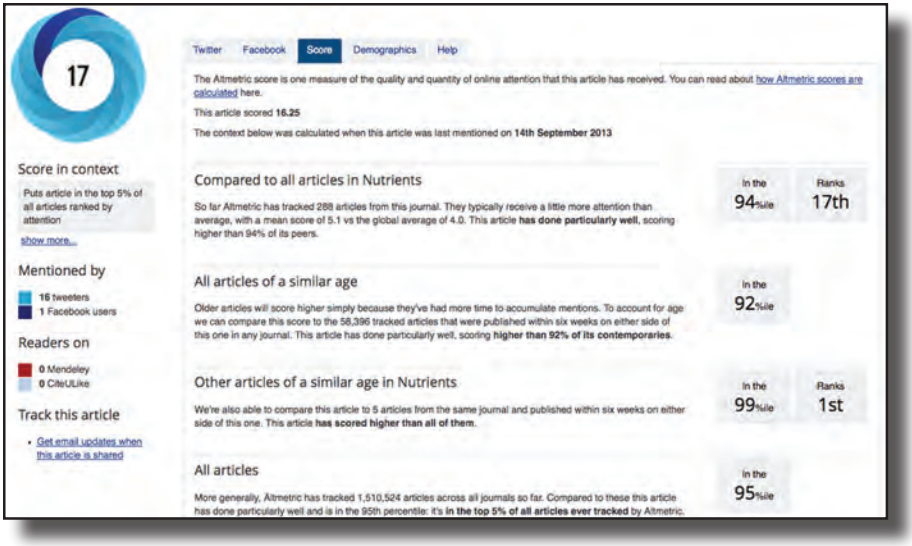

Figure 2

The interest for the therapeutic effects of GcMAF in a variety of conditions derives from the early observation by Yamamoto and colleagues in 1995, who showed elevated level of serum alpha-N-acetylgalactosaminidase (Nagalase) in the serum of AIDS patients. Nagalase is an enzyme that deglycosylates (degrades) the precursor of GcMAF that is the circulating Gc-protein, also known as vitamin D-binding protein (AIDS Res Hum Retroviruses. 1995 Nov;11(11):1373-8). This results in the loss of GcMAF precursor activity and consequent dysfunction of the immune system. Increased Nagalase activity, however, is not observed uniquely in AIDS patients. For example it was demonstrated that the increase of Nagalase activity in the serum of cancer patients is due to the fact that cancer cells release Nagalase and, therefore, Nagalase activity reflects tumor burden, aggressiveness and progression of the disease. Consequently, determination of Nagalase activity is currently proposed as a reliable way of evaluation of cancer severity (Cancer Lett. 2009 Oct 8;283(2):222-9).

In short, in cancer, HIV/AIDS, and in many other chronic conditions, elevated serum Nagalase, degrades Gc-protein that is the precursor of GcMAF. Therefore, GcMAF is not produced inside the body to a sufficient extent and this leads to immunodeficiency. Serum Nagalase, however, does not degrade GcMAF, and this justifies the administration of exogenous GcMAF in all those conditions where its endogenous production is insufficient due to elevated Nagalase activity.

Until 2002, it was thought that GcMAF exerted its effects only on macrophages and that its therapeutic efficacy was due to stimulation of macrophages that in turn would attack and destroy cancer cells as well as virus-infected cells. In 2002, however, a novel effect of GcMAF was described. Kanda and colleagues, working at the Department of Molecular Microbiology and Immunology, Division of Endothelial Cell Biology, Nagasaki University Graduate School of Medicine, Nagasaki, Japan, published a paper, co-authored by Yamamoto, describing the inhibitory effects of GcMAF on angiogenesis (J Natl Cancer Inst. 2002 Sep 4;94(17):1311-9.). Angiogenesis is the process of building new blood vessels that provide the tumor mass with the required supply of blood and nutrients that it needs to grow and metastatize. Therefore, since 1971 it was postulated that inhibition of angiogenesis could be a successful strategy to deprive the growing tumor mass of its supply of blood and nutrients (N Engl J Med. 1971 Nov 18;285(21):1182-6). While there are scores of inhibitors of angiogenesis, some of which in use in the therapy of cancer, GcMAF offers the advantage of performing more than one anticancer effects; in fact, not only it inhibits tumor-induced angiogenesis (Cancer Immunol Immunother. 2011 Apr;60(4):479-85), but it also stimulates macrophages that attack and destroy the cancer cells (Nutrients. 2013 Jul 8;5(7):2577-89).

If these combined anticancer effects were not enough, in 2010 Gregory and colleagues, working at the Department of Ophthalmology and Visual Sciences of University of Kentucky in Lexington, Kentucky, USA, demonstrated that GcMAF directly inhibited proliferation and metastatic potential of human prostate cancer cells (PLoS One. 2010 Oct 18;5(10):e13428). Slightly more than one year later, we were able to demonstrate that GcMAF not only inhibited proliferation and metastatic potential of human breast cancer cells, but it also reverted their neoplastic phenotype; in other words, cancer cells treated with GcMAF became normal (Anticancer Res. 2012 Jan;32(1):45-52).

On the basis of the peer-reviewed scientific literature quoted above, we can now state that GcMAF exerts multiple effects that are responsible for its efficacy in anticancer therapy:

1. It stimulates macrophages that attack and destroy cancer cells, as originally postulated by Yamamoto and colleagues.

2. It inhibits tumor-induced angiogenesis thus depriving the growing tumor mass of blood and nutrients.

3. It directly inhibits cancer cell proliferation and metastatic potential and it retro-transforms cancer cells into normal healthy cells.

Given this plethora of effects on cancer, it is no wonder that the majority of GcMAF research has been focused on its anticancer properties. There are, however, a few research articles suggesting that GcMAF might exert also other biological actions with therapeutic implications. In addition to the studies on HIV and AIDS quoted above, GcMAF has received attention for its potential role in the therapy of bone disorders (Blood. 1996 Oct 15;88(8):2898-905), and autoimmune diseases such as Lupus Erythematosus (Clin Immunol Immunopathol. 1997 Mar;82(3):290-8).

Despite these scanty evidences on the possible role of GcMAF in conditions other than cancer and AIDS, it was not until 2012, however, that GcMAF proved dramatically effective in the therapy of autism.

GcMAF & Autism

GcMAF, being derived from Gc-protein, also known as vitamin D binding protein, belongs to the so called "vitamin D axis", a nutritional metabolic pathway described in detail in a recent review (European Nephrology, 2011;5(1):15–9). My research group had been working on the vitamin D axis since 1996 (Epidemiol Prev. 1996 Apr-Sep;20(2-3):140-1), that is since the beginning of GcMAF research. Just like our colleagues in the USA and Japan, we were mainly interested in the role of the vitamin D axis in bone metabolism and cancer (Radiol Med. 1996 Nov;92(5):520-4. Oncol Res. 1998;10(1):43-6). Therefore, it came as a surprise when Dr. Nobuto Yamamoto first mentioned to me the effects of GcMAF on neurodegenerative diseases such as Parkinson's and Alzheimer's diseases.

In the hot summer of 2010 we visited Dr. Yamamoto in his hometown of Philadelphia, and we had the honor and the pleasure to spend two very intense days with this old-style exquisite gentleman. Dr. Yamamoto gave us a detailed history not only of his decade-long research activity, but also of the entire field of immunotherapy, starting with the pioneering work of Dr. William Coley at the end of the nineteen century. During these intense and fruitful talks, Dr. Yamamoto mentioned the dramatic effects that he had personally observed by administering GcMAF to a patient suffering from Parkinson's disease. According to Dr. Yamamoto, the effects had been almost immediate and dramatic up to the point that he himself was amazed. Regrettably, he

had been unable to clinically document the case and, therefore, this remained an anecdote. From this anecdote, however, an entire new field of GcMAF research was about to rise; that is the study on the role and implications of GcMAF in treating neurologic and neurodegenerative disorders.

The first solid evidences for a role of GcMAF in treating a neurodegenerative disorder were simultaneously presented by Dr. Paul Cheney and Prof. Kenny de Meirleir at the meeting of the International Association for Chronic Fatigue Syndrome and Myalgic Encephalomyelitis (CFS/ME) held in Ottawa in September 2011. A few days later, in collaboration with Dr. Paul Cheney, we presented in Padova, Italy, a study demonstrating that food-based GcMAF dramatically improved the symptoms of CFS/ME, and this work was published in the official journal of the Italian Society of Anatomy and Histology, one of the oldest and most respected European scientific societies, founded at the beginning of the twentieth century (It. J. Anat. Embryol. Vol. 116, No 1, 2011).

CFS/ME is a complex disorder that shares many features of autism. In fact, it is characterized by immune system dysfunction, widespread inflammation, and multi-systemic neuropathology (J Intern Med. 2011 Oct;270(4):327-38. In Vivo. 2013 Mar-Apr;27(2):177-87). Dysfunction of the immune system involves abnormal functions and distributions of T lymphocytes, B lymphocytes, natural killer cells, and monocyte/macrophages (Nihon Rinsho. 1992 Nov;50(11):2625-9. Brain Behav Immun. 2012 Jan;26(1):24-31). The etiology of CFS/ME, just like the etiology of autism, is still unknown and multiple factors are thought to be responsible for its onset and progression, thus lending credit to the hypothesis that both etiology and pathogenesis are multifactorial (J Intern Med. 2011 Oct;270(4):327-38). Heavy metal exposure and viral infections are among the factors that contribute to CFS/ME etiology and pathogenesis, and a role for human endogenous retroviruses has been recently hypothesized (In Vivo. 2013 Mar-Apr;27(2):177-87). Both chronic heavy metal exposure and viral infections are considered responsible for the immune system dysfunction and neuropathology that are typical of CFS/ME (Med Hypotheses. 2012 Sep;79(3):403-7. In Vivo. 2013 Mar-Apr;27(2):177-87).

In addition to these areas of overlapping, it had been noticed by Doctors treating autism and/or CFS/ME, that in several families the two conditions are often associated with parents of autistic children suffering from CFS/ME. Interestingly, this happens also in families with adopted children with autism, thus lending credit to the hypothesis that environmental or infectious factors may contribute to both conditions.

Whatever the case, it had been observed that CFS/ME patients had elevated levels of serum Nagalase together with a number of immunological alterations, and it was hypothesized that they could benefit from GcMAF treatment. The results presented in Ottawa and in Padova confirmed this assumption and ever since immunotherapy with GcMAF is a stronghold of CFS/ME treatment.

At about the same time, Dr. Bradstreet, a leading authority in the field of autism, began to study the levels of Nagalase in autistic children and their responses to GcMAF treatment. The results obtained in a first cohort of 40 subjects were reported in a seminal paper published in 2012 (Autism Insights 2012:4 31–38). This paper represents a turning point in the understanding of autism pathogenesis and treatment.

The first significant finding is the observation that the average level of Nagalase in autistic subjects was more than two folds higher than the normal level, thus lending credit to the hypothesis that immunodeficiency or immune system dysfunction is a hallmark of autism. The second finding, probably the most important in recent years, is the observation that GcMAF treatment significantly improved the symptoms of autism and this improvement was associated with a decrease of Nagalase levels.

The therapeutic response to GcMAF was statistically significant and showed the typical bell-shaped curve that is expected when a biologically effective treatment is at work. About 15% of subject did not respond; this means that their symptoms were not ameliorated by GcMAF treatment. However, more than 15% of children responded so dramatically that all the symptoms of autism were eradicated in a matter of weeks up to the point that the children could no longer be defined as "autistic." According to the very word of the authors, in the children in this group, "This response was demonstrated at school, during therapies, home and outside the home as substantial improvement to the point that many or most of the criteria of autism were no longer present."

The remaining 70% of children were distributed according to the so-called Gaussian distribution in the groups showing "slight," "moderate," or "considerable" improvement.

This paper demonstrated for the first time that GcMAF treatment was able to eradicate the symptoms of autism in a matter of weeks, thus reinforcing the

idea brought forward in many chapters of this book that autism is a curable condition indeed.

Quite obviously, the dramatic results obtained by Dr. Bradstreet did not go unnoticed and, in April 2013, he presented further results at the First GcMAF Immunology Conference held in Frankfurt, Germany. According to Dr. Bradstreet, as the time of follow-up and the number of subjects increased, a shift toward the right (that is the "best") part of the curve could be observed. This means that the percentage of those showing "considerable" to "very considerable" improvement increased.

From the point of view of the general practitioner, the issue could be considered closed: GcMAF cures a significant percentage of autistic children now and that figure is rising.

However, since I am a researcher in addition of being a Medical Doctor, the successes of Dr. Bradstreet in treating autism and the research papers published by Immuno Biotech laboratories are in the middle of an exciting series of observations that are leading to a completely new understanding of how GcMAF works and what autism truly is.

In fact, the undisputable efficacy of GcMAF in treating autism raises a number of questions on the mechanisms involved at the cellular and molecular levels. The most important questions are:

1. The efficacy of GcMAF in curing autism is due only to its immune-stimulating effect?
2. Or, is GcMAF acting directly also on neurons as it does on cancer cells?
3. Does GcMAF revert the neuro-anatomical alterations that are typical of the autistic brain?
4. Why a certain number of autistic subjects do not respond to GcMAF?
5. Can we devise strategies to have these non-responders respond?
6. Can we devise strategies to further improve this already dramatic therapeutic effect?

The Effects of GcMAF on Human Neurons

GcMAF is a protein and, as such, it was thought that it would stimulate cells from the outside. In other words, until 2013, it was conjectured that, on their external surface, cells had a receptor that bound GcMAF and conveyed the signal to the inside of the cell and, ultimately, to the nucleus and the DNA, thereby modifying the cell behavior. However, despite 20 years of research, such a receptor for GcMAF had not been identified. And this might appear truly odd considering that the entire human genome had been sequenced, that is studied in every single detail, more than 10 years ago.

In our first publication with Dr. Yamamoto, presented at the XVIII International AIDS Conference in Vienna in 2010, we had demonstrated that the response to GcMAF in human mononuclear cells (that is macrophages) was dependent on polymorphisms (that are the individual variations among humans) of the vitamin D receptor (VDR) gene. This observation was not surprising considering that vitamin D, its receptor, and GcMAF all belong to the vitamin D axis.

In order to further investigate this relationship between GcMAF and the VDR we began studying the molecular assembly of GcMAF that is the "shape" that the molecule assumes in its physiological conformation. Having done this, we looked for complementary areas in the GcMAF and VDR molecules and… voilà! The two molecules complemented each other as two elements of a puzzle.

We published this observation in the "Nutrients" paper that is now in the top 5% of all articles ever tracked, and the picture of the two molecules interacting with each other is in the front cover of the OncoImmunology August 2013 issue. The molecular mechanisms through which GcMAF and VDR interact and the consequent complex web of intracellular signaling are topics for specialists and rather difficult to divulge; the basic point, however, is that we had demonstrated how is it possible that GcMAF exerted so many different effects that can be exploited to treat a number of diseases so different from each other.

From this observation we deducted that all cells having the VDR would have responded to GcMAF and, given our interest for the effects of GcMAF in neurological conditions such as autism and CFS/ME, we began our study on human neurons. In fact, human neurons express (i.e. "have") the VDR and therefore, they are candidate to be stimulated by GcMAF.

We cultured human neurons in Petri dishes and we challenged them with ultra-pure GcMAF; in this type of experiments there were no other variables. That is, there were only neurons and GcMAF; the cells of the immune system or other molecules were not involved. By doing so, we would have been certain that whatever effect we observed, this was due uniquely to GcMAF.

As I have shown at the congress "Curando el Autismo" in San Juan de Puerto Rico in August 2013, GcMAF at extremely low concentration significantly increased neuronal cell viability and metabolic activity. These effects on cell viability were associated with dose-dependent intracellular cAMP production (cAMP is an intracellular second messenger). This means that GcMAF increased the production of energy inside human neurons and made them more active, more viable. Increased viability and metabolic activity following GcMAF stimulation as well as cAMP formation were accompanied by morphological changes, meaning that stimulated neurons changed their shape.

In the absence of GcMAF, human neuronal cells under the microscope appeared as small, relatively undifferentiated cells with large nuclei. After 24h stimulation with GcMAF, neurons showed a significant change in morphology that was consistent with the induction of neuronal differentiation and increased connectivity. The cytoplasm was enlarged and cytoplasmic elongations could be observed. After 72h incubation with GcMAF, these morphological changes were more evident and well differentiated cells could be observed.

After incubation with GcMAF, the cells appeared to establish contacts with each other. Taken together these results indicated that GcMAF increased neuronal cell viability, metabolic activity and differentiation, with the first effects being observed at 24h. It is worth noticing that the assay that we used to determine cell viability, measured mitochondrial activity, and mitochondrial dysfunction is known to be hallmark of ME/CFS (Int J Clin Exp Med. 2012;5(3):208-20), and possibly of autism as well. Therefore, the effects of GcMAF that we observed explain the reason why GcMAF is so effective in CFS/ME and autism; it counteracts the molecular alterations that are the pathogenetic basis of both conditions.

I wish to spend a few words here on the effects of GcMAF on neuronal connectivity. It is well assessed that this is one of the basic alterations in the brain of autistic subjects; neurons do not establish contacts with each other and therefore the neurological signal cannot be transmitted from one area of the brain to another thus causing a "disconnection" (Rev Neurol. 2012

Feb 29;54 Suppl 1:S31-9). GcMAF re-establishes neuronal connectivity by stimulating the formation of what are called "cytoplasmic elongations" that are like small "arms" that protrude from the neurons and establish contact with each other as if neurons were tending arms to "touch" each other and exchange information.

In Figure 3A, human un-stimulated human neurons in culture can be observed; they are small and roundish. After stimulation with GcMAF (Figure 3B), they are much larger because increased energy production leads to increased protein synthesis in their cytoplasm. But, perhaps more important, they have a highly irregular, elongated, triangular, shape with spikes that touch each other. The areas of contact between the two neurons can be clearly observed in the central part where they establish connecting bridges. Please notice that both pictures were taken with the same magnification.

Figure 3

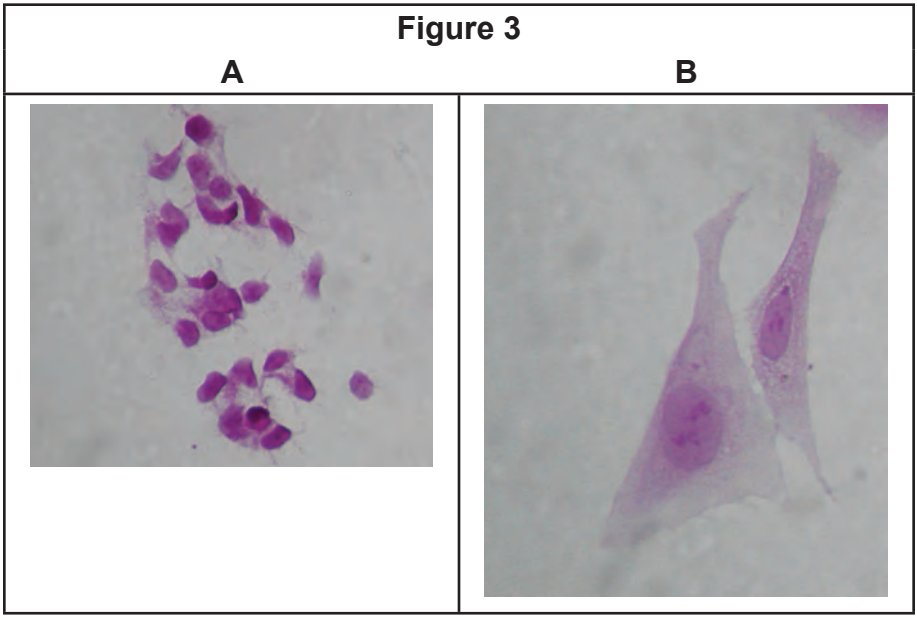

These observations provide an answer to the first two questions raised by the article published by Dr. Bradstreet: the therapeutic effects of GcMAF in autism can be ascribed to at least two different actions of GcMAF. On one side, it rebalances the immune system that is typically dysfunctional in autistic subjects; on the other side, it directly stimulates human neurons increasing their metabolic activity and their connectivity. But, as it always happens in research, these "answers" led to other "questions": does GcMAF cross the blood brain barrier? That is, does it arrive to the neurons of the central

nervous system? Before challenging this question further, however, let's proceed with order and let's try to provide an answer to the other questions that were raised by the Bradstreet's paper.

GcMAF and the Neuro-Anatomical Alterations of the Autistic Brain

If the etiology of autism is still undefined, the pathogenesis and the brain alterations associated with autism are better understood. Several studies using sophisticated imaging techniques demonstrated that there is atypical structural brain connectivity within cortical white and grey matter and it is postulated that such an alteration of brain connectivity may represent one of the principal neural substrates underlying autistic symptoms (PLoS One. 2013 Jun 18;8(6):e67329. Proc Natl Acad Sci U S A. 2013 Jul 22.).

The observed atypical brain connectivity is localized to particular areas of the brain and the alterations in the fronto-temporal regions are associated with the severity of social and repetitive symptoms of autism (Proc Natl Acad Sci U S A. 2013 Jul 22.). Atypical brain connectivity in autism is also associated with reduction of grey matter volume in different areas of the brain (Cerebellum. 2013 Apr 10.). In the bilateral superior temporal gyrus significantly decreased functional connectivity was accompanied by the strongest trend of grey matter volume decrease (PLoS One. 2013 Jun 18;8(6):e67329), thus reinforcing the hypothesis that study of grey matter volume may provide indication of functional connectivity.

However, the studies on brain connectivity and grey matter reduction quoted above were conducted with sophisticated Magnetic Resonance Imaging (MRI) equipments using complex softwares. Because of their cost and complexity, these techniques are not suitable for routine examination and this appears to be in contrast with the need to provide the general practitioners with the instruments to study autism. In fact, given the current epidemiological trend, it is highly probable that even primary care providers will see with increased frequency a patient with autism spectrum disorder in their clinic (Curr Probl Pediatr Adolesc Health Care. 2013 Jan;43(1):2-11). This consideration prompted us for the search of accessible methods to study brain alterations in autism and to study the response to different treatment including GcMAF.

To this end, we developed an easily accessible method to study the brain cortex using transcranial ultrasonography. This technique was first applied to the diagnosis and treatment CFS/ME a syndrome that, as we know, share

neuropathological similarities with autism (Toxicology. 2008 May 2;247(1):61-72). In particular, we proposed to use ultrasounds to study the grey matter in the temporal lobe, and to evaluate signs of neuronal layer disorganization and brain inflammation (Med Hypotheses. 2012 Sep;79(3):403-7). It is worth noticing that these same neurological alterations, i.e. minicolumn structural changes and inflammation are frequently observed in autism (Front Immunol. 2013 Jun 10;4:140. doi: 10.3389/fimmu.2013.00140. Print 2013). Therefore, we hypothesize that ultrasounds could be used in autism in order to study the brain alterations that have been described using more sophisticated and less accessible techniques.

First of all, we assessed the safety of the technique; to this end we used sub-thermal ultrasounds. These are considered inherently safe and have been used for fetal imaging in utero, and virtually every part of the body, including brains of newborn babies through fontanelles. Their inherent safety and any lack of correlation with the onset of autism have been confirmed by meta-analysis of thousands of cases. A recent randomized controlled trial on over 1.400 cases demonstrated beyond any reasonable doubt that there is no link between the prenatal ultrasound scans and the autism phenotype (J Autism Dev Disord. 2012 Dec;42(12):2693-701).

Then, in a collaborative work with Dr. Bradstreet, we decided to focus our attention on the temporal cortex in order to compare our results with those already published by Hameroff and colleagues and by ourselves using this technique (Med Hypotheses. 2012 Sep;79(3):403-7. Brain Stimul. 2013 May;6(3):409-15). In addition, having to choose a particular area of the brain for this initial study, the temporal lobe was particularly interesting because of its accessibility to ultrasounds and its involvement in the pathogenesis of autism (PLoS One. 2013 Jun 18;8(6):e67329. Print 2013).

In the typical adults subject, meninges appeared as a well-organized array of layers of about 2.6 mm thickness. The meninges were separated from the cortex by a structure that shows echogenic and morphological feature consistent with the sub-arachnoid space. The cortex of the temporal lobe appeared as a well-organized array of alternate, hyper-echogenic/hypo-echogenic, layers. The thickness of the cortex was 5.0 mm. This value of thickness and the anatomical positioning of the probe led us to hypothesize that we were observing the temporal areas designated by von Economo as TG and TE, i.e. those areas involved in the control of eye movements and balance in standing position (area TE), social behavior, mood and decision making

(area TG) (von Economo C. Temporal lobe. In: Triarhou LC, editor. Cellular structure of the human cerebral cortex. Basel; 2009. p. 114-132). It is worth noticing that the layers within the column-like structure of the healthy subject appeared well-organized and parallel to each other.

However, the images obtained in a representative autistic subject showed that the thickness of the cortex of the temporal lobe was significantly reduced, as it had been observed with MRI (PLoS One. 2013 Jun 18;8(6):e67329. Print 2013). Other images showed a concomitant increase in the spinal fluid in the sub-arachnoid space that was twice as much as in the healthy subject. These findings are consistent with the very recent observation that infants who developed autism spectrum disorder had significantly greater extra-axial fluid characterized by excessive cerebrospinal fluid in the sub-arachnoid space (Brain. 2013 Jul 9.).

Taken together, the results obtained in autistic subjects demonstrate that our technique was able to visualize the excess extra-axial fluid in a manner comparable to MRI; however, at variance with MRI, the observation with ultrasounds was immediate and intuitive and could be easily performed with no discomfort during a routine examination.

Another finding that we observed was a relative disorganization of the neuronal layer arrangement in the temporal cortex of autistic subjects. It was possible to observe that the neuronal layers had a different orientation and that there were black areas of about 0.4 mm that could represent areas of poor connectivity.

Since this technique has been applied only recently to the study of autism, there is no statistical analysis indicating whether GcMAF or any other effective treatment can reverse the anatomical alterations that we have observed in the brain of autistic subjects. Therefore, there is no sound scientific answer to this question; there are only some anecdotic evidences suggesting that this might indeed be the case. Autistic subjects treated with GcMAF and showing considerable clinical improvement showed a normal brain anatomy. Future observation will tell whether these anecdotic evidences have a statistical meaning.

Ultrasounds, however, in addition to their role in early diagnosis and follow-up, might also have a role in the therapy of autism and in particular in improving the response of those subjects who do not appear to benefit from GcMAF treatment.

GcMAF Non-Responders

As odd as it may appear to non-researchers, the presence of non-responders is often the best assurance that we are dealing with a real biological phenomenon and not with placebo effects or worse. In fact the bell-shaped curve presented in the article by Bradstreet and colleagues it typical of any effective treatment and it confirms the validity of the results. This having said, however, there is the need to provide an answer to those who do not respond. And, in the effort of providing an answer to non-responders, improvements in the overall efficacy of the treatment for everyone will eventually follow.

At the moment, there are two hypotheses that could help explaining why certain subjects do not respond to GcMAF in terms of improvement of symptoms of autism.

The first hypothesis is related with the VDR gene polymorphisms. As we proposed at the AIDS conference in Vienna in 2010, and later published in 2012 (J Nephrol. 2012 Jul-Aug;25(4):577-81), the individual responsiveness to GcMAF depends on the individual variations (polymorphisms) in the VDR gene. In other words, there are subjects harbouring variants that are associated with little or no response. However, this lack of response is relative and not absolute. In fact, it has been observed with vitamin D that these individuals respond to higher doses of the vitamin, thus indicating that the VDR is "less" responsive, but still functioning. This would mean that the so-called non-responders might need a higher dose or a longer time of GcMAF treatment to obtain the desired therapeutic effects. Prolonged observation of a higher number of cases will tell whether this hypothesis is correct.

The second hypothesis is closely associated with the first one as well as with the question briefly outlined in a preceding section: "does GcMAF cross the blood brain barrier?" In a recently submitted paper, we proposed that the interconnection between GcMAF and VDR signaling is responsible for the transport of GcMAF through the blood brain barrier. In fact, transport of macromolecules across the blood brain barrier requires both specific and nonspecific interactions between macromolecules and proteins/receptors expressed on the luminal and/or the abluminal surfaces of the brain capillary endothelial cells (Int J Cell Biol. 2013;2013:703545. doi: 10.1155/2013/703545). Since VDR signaling appears to enhance brain to blood transport at the blood brain barrier through both genomic and non-genomic actions, it can be hypothesized that the interaction between GcMAF and VDR (Nutrients. 2013 Jul 8;5(7):2577-89. doi: 10.3390/nu5072577) may favor GcMAF transport

into the brain. This means that subjects with a less responsive VDR because of unfavorable genetic variants, would also have a less efficient transport of GcMAF to the brain.

This latter consideration, however, opens the way to a possible solution that might also help increasing the effectiveness of GcMAF in those who already respond to it.

In fact, now that we know the physiological molecular assembly of GcMAF, we can design specific GcMAF molecules that are more efficient in crossing the blood brain barrier and, therefore, are more effective in treating neurological conditions such as CFS/ME and autism. These molecules exploit the fatty acid binding site in the GcMAF molecule, and use one of the most beneficial fatty acids, oleic acid, the basic component of olive oil, to target brain cells.

Most interestingly, GcMAF/oleic acid molecules do not only stimulate human neurons with a much higher efficiency than GcMAF, but they also regulate glial cell metabolism. Glial cells are the connective tissue of the brain and glial cell dysfunction is involved in the pathogenesis of autism. In particular, glial cell dysfunction seems to be responsible for the neuronal underconnectivity typical of the autistic brain (Neuron Glia Biol. 2011 May;7(2-4):205-13). In short, we can postulate that the development of these novel GcMAF/oleic acid molecules will prove beneficial not only for the GcMAF non-responders, but also for improving the therapeutic efficacy of GcMAF in all neurological conditions where GcMAF treatment is indicated.

In addition to these novel, more physiological, brain-targeted, molecules, there are other strategies that can improve GcMAF transport into the brain with consequent increased therapeutic efficacy. Just a few days ago, in a journal dedicated to advanced radiological research, it was published a report demonstrating that ultrasounds, just like those described in the preceding section, transiently open the blood brain barrier. This phenomenon is exploited to favor transport of chemotherapeutic drugs into the brain of individual with brain tumors and it proved safe and efficacious after extensive testing.

On the basis of this observation, one could devise a simple treatment protocol using the same ultrasound system that is currently used for transcranial ultrasonography. In analogy with what is performed to deliver chemotherapeutic drugs to brain tumors, ultrasounds could be used to facilitate the transport of GcMAF through the blood brain barrier and to focus its delivery into those areas of the brain that are known to be altered in autism.

In this manner, during a regular examination, the health professional could exploit our technique to assess the neuro-anatomical alterations in the autistic brain and to deliver GcMAF to those areas. The use of more physiological, brain-targeted GcMAF molecules that can be administered sublingually, would greatly improve the efficacy of the treatment and it will most likely reduce the percentage of the so called non-responders to GcMAF.

As noted above, however, the use of ultrasounds to treat neurological conditions is not completely new. In fact, we and others have demonstrated that non-thermal ultrasounds have significant effects on mental states (Brain Stimul. 2013 May;6(3):409-15), modulate neurotransmission (Neuropsychobiology. 2012;65(3):153-60), cardiac frequency and blood pressure and improve skeletal muscle strength (The Journal of IiME, vol. 6 (1), p 23-28, 2012). These effects can be observed with ultrasounds alone, that is in the absence of other treatments.

In a protocol for the treatment of autism and CFS/ME, we propose to use our ultrasonographic technique together with timely administration of sublingual GcMAF/oleic acid molecules. In this manner, we are able to exploit the direct effects of ultrasounds on the neuronal microtubules (Brain Stimul. 2013 May;6(3):409-15), together with the ability of ultrasounds to favor the transport of GcMAF/oleic acid into the brain and, more precisely into those areas where the neuroanatomical alterations are observed.

What is GcMAF?
A drug, a hormone, a natural component, a nutrient?

How to define a molecule that is formed every time a wound is licked? This is the most evolutionary conserved protective behavior in animals, humans included. The enzymes in the saliva convert the Gc-protein in the blood that is on the wound into active GcMAF that prevents infection of the wound and promotes repair (PLoS One. 2013 Jul 18;8(7):e69059).

For many years researchers considered GcMAF only a key regulator of the immune system because of its activity on macrophages and its denomination reflects this early conjecture. However, as it often happens in science, the original denomination of a molecule proves incorrect with the passing of time and the accumulation of scientific evidences. Vitamin D is a notable example; it is not an vitamin and it does not contain any amine group (even though the suffix "vita" applies, in that it is indispensable for life). Now it is rightly considered a hormone produced by the body and, to be more precise,

a secosteroid hormone that has a mechanism of action similar to that of classical steroidal hormones. GcMAF, being a part of the vitamin D axis might soon become another example of scientific mislabeling. In fact, we now know that it exerts its actions in many other cell types in addition to macrophages and that its role go well beyond activation of macrophages.

And even though there are no doubts that it is a powerful stimulant of the immune system, it would not be surprising to realize that this might not be its most relevant physiological role. In this respect, GcMAF shares the destiny of its precursor, the Gc-protein. Gc-protein is a serum alpha 2 glycoprotein composed of a single polypeptide chain, structurally related to serum albumin, that performs a variety of actions in several cell types. It is synthesized in the liver and has been detected on the surface of several cell types, yolk sac endodermal cells, and some T lymphocytes. In B cells, it participates in the linkage of surface immunoglobulins. In addition to vitamin D, it binds actin and acts as an actin scavenger. These characteristics are of paramount importance in human pathology since actin is the most abundant protein in eukaryotic cells and it is a major cellular protein released during cell necrosis that may cause fatal formation of actin-containing thrombi in the circulation if the actin scavenging capacity of Gc-protein is exceeded. Not surprisingly, therefore, several studies suggest an association between Gc-protein and resistance or susceptibility to chronic obstructive pulmonary disease, thyroid diseases, diabetes, multiple sclerosis, and sarcoidosis (for a review on Gc-protein and the vitamin D axis, see: European Nephrology, 2011;5(1):15–9).

From these considerations it derives that the potential indications for GcMAF treatment might be far too numerous than those currently envisaged. And also this parallels the fate of vitamin D, once thought only to prevent rickets and now involved in almost all aspects of human physiology and pathology up to the point that a (serious) scientific article on this subject was entitled: "Does vitamin D make the world go 'round'?" (Breastfeed Med 2008; 3: 2392–50.).

Apart from issues of biomedical terminology, it is now emerging the concept that GcMAF is an essential component of that nutritional pathway that is the vitamin D axis. It is not a case or a coincidence that the article on GcMAF that has received the greatest attention was published in a scientific journal named "Nutrients". With the proceeding of research it is becoming apparent that GcMAF participates in such a variety of physiological events that each proposed definition is limited.

But, if we accept the concept that GcMAF is a natural nutrient, indispensable for brain and immune system development and function (and possibly for

many more essential physiological events), two questions spontaneously arise: "Where do I find it in nature?" and "How can I consume it?"

The second question already has an answer: now that the physiological molecular assembly of GcMAF is known, there are on the market several GcMAF products that can be used sublingually or simply eaten. Modern biotechnology has reproduced the physiological conformation of GcMAF so that it can be absorbed in a natural way without recurring to intravenous or intramuscular injections. GcMAF injections are reserved for those cases where a strong and rapid stimulation is required.

The other question is more intriguing and leads to the final section of this chapter.

My Own Personal Experience with GcMAF

As it happens in many people of my age exposed to the radiations from the Chernobyl incident, I have several thyroid nodules. Being a radiologist, it was easy for me to perform ultrasonography on my thyroid and what I saw on the screen was not nice. In addition to small lesions in my right lobe, in my left lobe I observed a massive mixed (solid and cystic) protruding nodule substituting for most of the lobe. The anterior-posterior diameter was about 3 cm, whereas the longitudinal diameter was greater than the length of the probe (4 cm). The structure was grossly inhomogeneous with cystic areas and hypo-reflecting areas alternated with iso- or hyper-reflecting areas. The margins bordering the residual normal thyroid tissue appeared well defined with an area of edema (inflammation) surrounding the nodule. The blood vessels were located around and inside the nodule and few or no blood vessels could be observed in the large hypo-reflecting areas suggesting the presence of metabolically inactive tumor tissue. Consistent with these findings, laboratory tests showed signs of immunodeficiency and anemia. And, it has been reported that anemia is among the predictive elements of malignancy in thyroid nodules (Tunis Med. 2002 Sep;80(9):536-41).

It was immediately clear to me that I needed a powerful stimulant of the immune system as wells as an anticancer agent, and GcMAF was my first thought. However, at that time, GcMAF was synthesized only in academic research laboratories and it was not available on the market as the pure, highly active, quality controlled product that we know today. Therefore, we decided to look for natural sources of GcMAF.

We already knew that GcMAF is naturally formed when a wound is licked because saliva contains the enzymes that convert blood Gc-protein into active GcMAF. Licking my thyroid, however, quite obviously, was not an option.

Because of these hindrances, we hypothesized that GcMAF could be obtained through a natural food fermentation process that exploits the characteristic of certain microbial strains to produce the enzymes that convert food Gc-protein into GcMAF (Hollis and Draper, 1979). According to our hypothesis, fermented food-derived GcMAF would activate the macrophages widely diffused in the walls of the entire gastrointestinal tract and, in particular, in the Waldeyer's-Pirogov tonsillar ring (or pharyngeal lymphoid ring). Our first goal was to assess the feasibility of obtaining natural GcMAF through home-made food processing procedures. To this end, we devised a strategy to prepare a fermented food product using those microbes, known to mankind for their healthy properties for millennia, that express the enzymes involved in GcMAF synthesis (Hollis and Draper, 1979).

After having prepared this fermented food at home, I began consuming it on a daily basis.

Since at that time we too considered GcMAF mainly for its immune-stimulating properties, the first objective was to assess the efficacy of this procedure on certain markers of immunodeficiency, the so called CD4 lymphocytes. The general public became familiar with CD4 lymphocytes because of their involvement in HIV infection and AIDS, and CD4 cell number is considered a reliable marker of immune system function. The role of CD4 cells in the immune system has been widely popularized up to the point that the webpage of the AIDS Authority of the Government of the United States of America states; "CD4 cells or T-cells are the "generals" of the human immune system. These are the cells that send signals to activate your body's immune response when they detect "intruders," like viruses or bacteria. Because of the important role these cells play in how your body fights off infections, it's important to keep their numbers up in the normal ranges..."

In our observation, the reference laboratory considered normal value for CD4 cell count 500 - 1500 cells/μL. Before consumption, my CD4 count was low, close to the threshold of AIDS definition (372 cells/μL). CD4 count rose from the abnormal value of 372 to the normal value of 609 cells/μL after three weeks of consumption of the fermented food that I had prepared. Such an increase continued up to eight weeks with CD4 cell count reaching 853 cells/μL. After many years, they are still in the normal range.

The trend toward normalization of blood parameters was observed also in other abnormal haematological values. My values (low or abnormal) changed as follows:

	Before Consumption	After 3 Weeks	Normal Values
Red Blood Cells			
(x106/uL)	4.55	4.85	4.6 - 6.2
Haematocrit, %	42.9	45.9	40 - 52
Haemoglobin, g/dL	14.8	15.6	13 - 18
Platelets/uL	165,000	206,000	140,000 - 440,000

The neutrophil cell count decreased from 77% to 55% in about 12 weeks, indicating a normalization of parameters suggestive of a pro-inflammatory state. Overall, the observed changes in haematological parameters were consistent with those positive modification of immune responses in humans that might represent the potential mechanism by which food fermented by probiotic bacteria confer health benefits.

Being a researcher, I am very well aware that this report is a mere anecdote that, in the era of evidence-based medicine, has low value or is not even considered to be medical evidence. However, a very recent study on the evaluation of clinical practice challenges the deprecation of stories like that reported above. Thus, it is well known that some studies present large and impressive statistics obtained from many observations while others report a small number of noteworthy events, as we did in this study. However, according to this authoritative epistemological approach, "all of these stories become evidence of what works in medicine" (J Eval Clin Pract. 2011 Oct;17(5):920-6).

Conclusions

In August 2013, a paper published in the very prestigious American Journal of Immunology reported a series of clinical cases successfully treated with GcMAF (Am. J. Immunol., 9: 78-84. 2013). Among these, there were pathologies already known to be responsive to GcMAF treatment, such as cancer, autism, and CFS/ME. Other neurodegenerative diseases such as multiple sclerosis and amyotrophic lateral sclerosis, however, had not been treated with GcMAF before, and this is the first report on such a successful treatment. This paper, together with all the other recognitions reported above, places GcMAF as one of the most effective tool to fight diseases that were considered incurable until very recently.

In other chapters of this book it is clearly stated that autism IS curable, and the successes of GcMAF in curing autism further strengthen this concept. What is emerging and what I hope to have been able to convey, is that GcMAF is not an exogenous drug that "fixes" some problem, but rather a very natural component of our body that is essential for, at least, brain and immune system development and function. In many conditions, including autism, GcMAF is not produced to a sufficient extent and therefore it has to be administered from the outside. With the advent of a courageous little biotech company that has perfected the synthesis of natural, fully physiological, GcMAF molecules that can be eaten, GcMAF treatment will become all the more and flexible to fit the individual needs. Eventually, GcMAF will become part of an integrated nutritional plan as it was intended by nature during evolution.

Consistent with this concept, I wish to conclude with an example from the realm of nature.

According to the Genetic Science Learning Center of the University of Utah, "Some mother rats spend a lot of time licking, grooming and nursing their pups. Others seem to ignore their pups. Highly nurtured rat pups tend to grow up to be calm adults, while rat pups who receive little nurturing tend to grow up to be anxious. It turns out that the difference between a calm and an anxious rat is not genetic—it's epigenetic. The nurturing behavior of a mother rat during the first week of life shapes her pups' epigenomes. And, the epigenetic pattern that mom establishes tends to stay put, even after the pups become adults."

It seems that licking their pups while breastfeeding in the first week of life is the decisive factor; in the saliva there are the enzymes that convert milk Gc-protein into GcMAF. What is more natural than this?

Subcutaneous GcMAF has been available through FIRSTiMMUNE for several years. Their website is:

www.gcmaf.eu

They now also produce a sublingual version of GcMAF called GOleic. They also have Bravo probiotics, and more. Please visit their website for more information.

"If you're not stubborn, you'll give up on experiments too soon. And if you're not flexible, you'll pound your head against the wall and you won't see a different solution to a problem you're trying to solve."

~ Jeff Bezos
Founder of Amazon

Chapter 13

Beyond Recovery: The Maintenance Plan

"Success is not final, failure is not fatal:
it is the courage to continue that counts."
~ Winston Churchill

We see these questions on our boards from time to time:

Will my son have to take CD for the rest of his life?

or

Will we be sorting through poop forever?

The answer is No!

Once your child has recovered, you can move to the maintenance phase. Since we live in a toxic world, it is important to continually detox the system, and keep the body free of parasites. While this can look different for every child and every family, the following are some general guidelines designed to keep our kids healthy once they are recovered.

Diet

While some families go back to giving their children foods that aren't permitted here, many do not. Wheat, dairy, and soy aren't "healthy" foods for any of us to be consuming. After reading Olive Kaiser's section on gluten, you may have a tough time giving your child any bread products ever again. That said, once the gut is healed, it should be able to tolerate many of these foods again, to the extent that a "healthy" person would.

CD

Even into the recovered stage of autism, many of the families keep using CD (oral, baths, enemas) to reach an ATEC of zero... or until there are no behaviors left from the autism. Once that is accomplished, then a maintenance

plan of one oral dose on Monday and one oral dose on Thursday is enough. Typically, such a dose is 3 drops for children and 6 drops for adults—all in one dose on each of those 2 days. However, each family does this a little differently depending on weight and what the optimum dose was while on the full protocol.

The more I learn about how toxic our planet is (i.e. GMOs, toxins in the air, drinking water, parasites in the environment, etc.), the more I realize how critical it is to be on a at least a limited long-term detoxing program. This is especially true for someone who was, or may still be immunocompromised. I do believe that once a child recovers from autism, their immune system can do the job that it was designed to do. However, healing takes time, and every case is different. Some people ask me if recovered children still take CD once recovered—and to be honest—many do not.

Parasite Protocol

It is impossible to avoid parasites in our world. As Andreas and Miriam explained to us, their larvae are nearly indestructible in nature and can live for years. A strong immune system, as well as sufficient stomach acid, may prevent a parasitic infection from taking hold in the body. To make sure, it is best to do a "mini protocol" every 3 months. You can do the full 18 days every 3rd month or a 1-week mini version—whichever you prefer.

Other Supplements

While ocean water is necessary when detoxing with CD, it is extremely beneficial to all of us as our soils are almost completely devoid of nutrients and are contaminated with heavy metals and toxins. Also, it has been theorized that many GMO crops are lacking in nutrition as well. The 90 bioavailable nutrients in OW can certainly go a long way in keeping our bodies healthy. I especially love that it helps with conductivity in the brain. And, it is conducive to speech and cognitive function as well.

Depending on each individual's needs it may behoove a family to keep giving MCT oil or Vegan 3,6,9 omegas. Certain supplements may still be required if there is a history of seizures.

Chelation

Gentle chelators like Bio-Chelate™ can continue to be used into the recovery phase as heavy metals are present in our air and water.

Hyperbarics

Nothing brings down inflammation quite like a hard hyperbaric chamber. However, 10 to 20 sessions can be very cost prohibitive for some families, making it a very personal decision as to whether or not to continue with HBOT after recovery.

GcMAF

I never felt better than when I did a course of GcMAF injections on myself. Energy went up and so did my ability to concentrate. Again, GcMAF is a fairly expensive intervention and that will factor into each family's decision as to whether to keep using it. or not

In a nutshell, I would at least continue with CD two times a week, and a mini parasite protocol every 3 months, just as a preventative. Staying healthy is as important as getting healthy.

Um, YEAH so just took an ATEC. We have officially been on the protocol for 12 months now and finishing up our 11th PP. ATEC of THREE!!!!!!!!!!!!! 57 to 3 in 12 months. Henry's speech is what is keeping us from 0. He has great conversation with people that are patient and don't interrupt him so we are so close to a BIG ZERO!!! 57 to 3 in 12 months!!!! Far cry from the severe autism diagnosis he got at 2.5 years old. Here is to the doctor that told me my son should be medicated, would never speak, and will probably need to be institutionalized. I hope YOU never say those things to another person!!!!! All you need is hope, determination, and LOVE.

Healin
the symptoms kn
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Chapter 14

Miscellaneous Information You Should Know

"Always bear in mind that your own resolution to succeed is more important than any one thing."
~ Abraham Lincoln

Seizures

An estimated 40% of children with autism suffer from some form of seizures. Seizures can be absolutely terrifying for both child and family and deleterious to the health of a child who is already suffering from various issues. I have talked to many different professionals about seizures and in turn have heard just as many different opinions on why this happens. Many doctors are unsure, while some simply don't express their opinions. Some say it is a virus in the brain or heavy metals, inflammation, or pathogens/parasites. In a presentation by Dr. Andreas Kalcker, he stated that high levels of ammonia in the body can cause seizures and the high levels of ammonia in the body come from parasites. Since we know that CD kills pathogens/parasites, neutralizes heavy metals, and helps to reduce inflammation, it is not surprising that we have noticed reduced, or even eliminated seizure activity in children with seizure disorders that use CD in combination with the Parasite Protocol.

MCT (medium chain triglyceride) oils, which come from the Ketogenic Diet out of UCLA, are also a very important piece to healing the body and eliminating seizure disorders. There is plenty of information on the Internet that discusses the results of people (on the spectrum and otherwise) using MCT oils for seizure disorders.

The following is a list of things that parents on The Protocol have used successfully to reduce/eliminate seizures in their children.

- CD
- Parasite Protocol
- MCT oil

- GABA
- Hyperbarics at 1.75 ATA
- Ketogenic diet
- SCD diet (grain free)
- L-Carnitine
- P5P with magnesium
- L-Carnosine
- Taurine
- DMG
- Pycnogenol®

The first four in this list have proven to be the most important and have shown consistent results. If you have a child suffering from seizures, you would be wise to review and consider these interventions immediately. The others have also proven very helpful and can be added in one-by-one, (always leaving three days between each new supplement) while you watch for a decrease in seizures.

When we introduce GABA, we increase the dose daily in search of the appropriate dose for the individual. While establishing the correct dose for one intervention it is not appropriate to add in other supplements. Watch out for sleepiness or undesired behavior with GABA. In these cases, I would personally discontinue its use, as with everything there is not one formula that is right for every child. Similarly, if you see hyperactivity or undesired behavior with DMG discontinue its use.

All of the above supplements/interventions have proven very important for eliminating seizures, in different combinations, for different families. Whether the seizures are grand mal (tonic clonic) or petit mal (absence), they start to fade away as a result of the Protocol.

Sometimes, when a family starts corresponding with me, their child may already be taking some of these supplements, and they continue to do that. They may have already taken some of these and seen no improvement. Some other families live in parts of the world where these supplements are unavailable, and in that case we focus on CD and killing parasites.

As I mentioned, a critical piece for some of the children with seizures has been the implementation of the Parasite Protocol. This has also led to a reduction or cessation of seizure activity in many children with seizures.

Interestingly, once some moms were made aware of the parasite/seizure connection it was easy to time seizure activity/anxiety/aggression to full and/or new moons. As Dr. Andreas Kalcker talked about in the parasite section,

the full moon period is when parasites are mating, many in the gastrointestinal tract, and therefore "wormy behaviors" (anxiety, SIBs, depression, tantrums, aggression, and teeth grinding to name a few) will generally be higher around that period. New moons can also cause an increase in these behaviors.

Children who have a seizure disorder or are self-injurious need to avoid food coloring, eggs, tomatoes, pork, and chocolate. When adding in the supplements for the seizures that we listed above, follow the same rules as before, never adding more than one supplement every three days, and always carefully observing and keeping track of any and all changes in your notebook so we know what causes what.

After starting anti-parasitics with the help of her daughter's doctor, one veteran mom introduced the CD protocol; a combination that has been extremely beneficial for her daughter, who suffered from frequent grand mal (tonic clonic) seizures.

Her Advice:

Most of my understanding of how parasitic infections can lead to seizures involves my own tracking of seizure activity patterns in my daughter, which coincided with new moon and full moon periods. Then, since MOST doctors want references to what they feel are 'reliable sources,' I started by Googling "NIH parasites seizures," which brought me to:

ncbi.nlm.nih.gov/pubmed/18754958
Helminthic parasites and seizures. [Epilepsy. 2008][1] - PubMed - NCBI

I would strongly suggest that you document patterns of seizure activity against the Farmer's Almanac of Full Moons (you can even look up past Full Moons) and marry that information with info from sites like the one above. Also, I would highly recommend you hunt down a pediatric infectious disease specialist in your local area (start by researching pediatric staff at local hospitals) and bring with you all information/insight to your first appointment.

Her Testimonial:

From her very first drop of activated CD in early July 2012 (actually her very first one-eighth drop to be exact), I witnessed an improvement in my daughter. Within about two hours of drinking her first ounce of the activated CD water solution (one activated drop of CD mixed into eight ounces of water), I witnessed her sitting still in our kitchen and observing me in such a way unlike she had ever done before. She was calmly observing me instead of running around the kitchen. She was taking my actions in. She was studying me. Her eyes were focused on me, rather than constantly scanning everything else in the room. Both her facial expression and her body language were calmer than I had ever witnessed before. She was more focused, more centered. She appeared content.

This change that I witnessed in her was so noticeable and so sudden, that I couldn't help but think to myself, "So this must be why the first word in MMS is Miracle." It was that amazing of a change in those moments.

Shortly after those incredible moments, my daughter went on to eating contently and then jumping on the neighbor's netted trampoline. She has enjoyed the neighbor's trampoline for years; yet on that particular day, only a few hours after her first drink of a tiny amount of CD, I noticed something quite different in her behavior. As I observed her from the windows of our house, I could see that she was jumping less than usual and instead looking around a lot more. She was calmly looking around at the neighbors' houses, down at some birds in the grass, up at the trees, the clouds, etc. It was all as though she was perhaps truly noticing them for the first time. She had glanced at these things before that day, sure, but she never before appeared to be studying them in the manner she was in those moments on the trampoline that July afternoon. She did engage a bit in some of her tic-like spitting movements with her mouth while on the trampoline, but to nowhere near the intensity, nor duration that would more typically have consumed her prior to that day.

When she came back into the house after using the trampoline and observing her world, I asked her, "why were you spitting out there?" To my surprise, she then very calmly replied, "because it's sensory." Wow! She truly was more connected somehow to her world than ever before. Something good was happening to my girl—only hours after drinking one-eighth of a drop of activated CD with one ounce of water. From those moments on I felt encouraged in my heart and soul that CD could possibly be a very important catalyst toward improving my daughter's health and well-being.

With the help of a caring local doctor, we had already begun some trials of anti-parasitic medications on our daughter in early May 2012, prior to starting CD, in response to behavioral struggles that had been consistently intensifying around full moons every month. (Later, we noticed new moon behavioral intensities as well). We had seen some improvement with anti-parasitic medication, yet CD seemed to somehow boost our daughter toward further improvements that much quicker. In fact, our daughter's ATEC score before starting CD measured 79 on July 8th, 2012 (the day before starting CD), but as of September 30th had dropped down to 55 (only two and a half months later).

Now, in early December 2012, our daughter still appears to be on an overall upward trend of improving health and stability, attributable to the synergy of CD and anti-parasitic medications. Natalie's interpersonal skills have improved, her growth rate has improved, her focus has improved, and her frequency of seizures has lessened.

In fact, at this writing she is 53 days seizure free, which is quite an improvement considering before she was on a terrifying pace of grand mal (tonic clonic) seizures occurring every 2-3 weeks. These are very dangerous, life-threatening events. Her seizures were rapid onset, heading toward grand mal within seconds. They could happen anywhere, i.e. while in her car seat coming back home from a Dr.'s appointment, while driving away from Costco, while running in the backyard playing with the dog, or swinging high on the swing set in the backyard with a neighbor girl. Yet another occurred while wading in the lake (with life vest on), another hit while in our neighbor's four-foot swimming pool with me and her brother. She was right next to me, walking around and then suddenly, she was in the throes of a rapid-onset grand mal seizure that required me to lift her out of pool into her NT (neurotypical) brother's arms. May these be the last my daughter ever knows of seizures.

It is our hope that, in time, CD will be able to take on the lead role as the primary health-support for our daughter, if not, perhaps even someday the sole healthcare support to her. We're looking forward to the days when we may be able to remove or reduce many, or perhaps even almost all, of her current supportive medications (i.e. antibiotic, antiviral, anti-seizure, etc.). With the caring support of parents of The Thinking Moms' Revolution, as well as some excellent local doctors, we suspect that our daughter's life will continue to improve. In the almost 14 years of caring for our daughter in her various states of medical fragility, we have never ever had this much Hope. We feel fortunate to have been swept up into this Revolution and embraced warmly by so many Thinking Moms who are also in the process of working toward more healing for their children. Working to heal illness is so much nobler than working to mask illness, wouldn't you agree? God Bless Jim Humble, Andreas Kalcker, Kerri McDaniel de Rivera and all the TMR families!

UPDATE: January 30th, 2013

I too am so thankful for Kerri and her whole 'crew'. Thanks to Kerri for bringing CD to all of our kids on the spectrum worldwide. My Natalie is now OFF of her former roller-coaster ride of prescription anti-fungals, OFF of her former roller-coaster ride of prescription antibiotics, OFF of prescription antiviral, OFF of prescription low-dose naltrexone, etc. Her belly distention has disappeared, she's gained weight, she's gained height and she's now almost 103 days seizure free (as of 6:16pm tonight). She still has a ways to go toward more improvements, but she's happily climbing up from bottom of the trenches; she's climbing up from what seemed like the very bottom of the abyss that vaccine injury/injuries had placed her in. Thank you Kerri, Andreas Kalcker, Jim Humble and all of the moderators on the supportive websites!!!

UPDATE: February 1st, 2013

My Natalie's long run of 105 seizure-free days has ended. After being off of Albenza® less than 24 hours, BOOM! a grand mal (tonic clonic) seizure occurred yesterday evening. This same thing happened the last time we stopped Albenza®, sooooo we're not sure if it's withdrawal related or parasitic activity related. We're going to closely watch her behaviors this week for signs of parasitic burden. We put her on Alinia® now, just to give her some sort of parasitic coverage while we wait to likely restart Albenza®, soon. She did fine on Alinia® 200mg BID in the past. I'll keep you all posted, but for now we unfortunately need to restart the clock on my Natalie's 'seizure-free days' tracking. I'm bummed, but thought I should keep you in the loop on this; as I've been soooooo excited over the past three months about her freedom from seizures, which I believe was due to the synergy of CD and Albenza®. I'll touch back if/when we learn more.

UPDATE February 2nd, 2013

O.K. so, I just wanted to kind of round out this long thread a bit with my thoughts, for whatever they're worth: I really truly suspect that perhaps too sharp of a drop off (lack of weaning) from the systemic med, Albenza® lead to the seizure. Natalie is stable right now on a low-dose interim of Alinia® 200mg BID for now until all insurance approvals are in for the delivery of more Albenza®. This leads me to believe that the several courses of Albenza® over the past months likely HAS lowered her overall parasitic load/burden fairly well thus far (it's a pretty broad-spectrum anti-parasitic, from what I understand). However, I don't think for a

minute that Natalie's broad spectrum anti-parasitic medicine needs are finished. For this reason, we'll resume Albenza® as soon as we're able.

Although further discussion/negotiation between myself and Natalie's pediatric infectious disease doctor is required, my thought is that she may need an entire year on Albenza. However, certainly in the future, whenever we stop Albenza®, I'm going to plan for a slow weaning off period so as not to disrupt Nat's delicate nervous system. Also, I'm kind of thinking that perhaps if our kids 'wig out' when CD is eventually dropped that maybe we've not lowered the overall parasitic burden enough, as yet to allow their immune system to 'kick in gear' and properly function??? I don't know, obviously, just theorizing with the brain matter God has given me.

SUMMARY & UPDATE FOR SECOND EDITION: December 1st, 2013

From birth to age 7 years, my daughter Natalie unfortunately had her share of health and developmental struggles. Her diagnoses began with 'Failure to Thrive' shortly after birth, followed thereafter by a Mitochondrial Encephalopathy Partial Complex III Deficiency diagnosis by age 7 months, then Hypothyroidism as well as global developmental and cognitive delays obvious from there. Despite significant medical and developmental challenges, Natalie entered a Kindergarten designed for the 'mild cognitively impaired' (formerly referred to as educatably mentally impaired 'EMI') with daily opportunities for mainstreaming with the typical Kindergarten classroom next door. After a fall 2005 Flu shot early in that same Kindergarten year, however, all bets were off. She regressed very rapidly in every way: medically, developmentally, and behaviorally. Within months of that shot, a laundry list of additional diagnoses began to form: Sensory Integration Disorder, Autism, Epilepsy, P.A.N.D.A.S., P.A.N.S., and Combined Immune Deficiency, to name a few. After much study by a large team of educational specialists, Natalie was reclassified by school professionals by the following April of 2006 to the 'SXI" category of disabilities (Severely Multiply Impaired), having deteriorated terribly from her former classifications of POHI (Physically or Otherwise Health Impaired) and 'CI' (Cognitively Impaired) within only months of that Flu shot. Her significant healthcare needs and behavioral challenges since have necessitated assignment of a one-on-one Para-educator to her case, even while she's been schooled within high adult-to-student ratio basic education special- needs classrooms over the past several years.

In 2011, between the ages of 12 and 13, I began to notice patterns of apparent P.A.N.S. flares in Natalie, which seemed to coincide with the New Moon and Full Moon weeks. When I began to study this phenomenon a bit more closely, I also recognized a pattern of seizure activity that tracked these timeframes as well. In reading about potential parasite activity that is thought to link to the New Moon and Full Moon timeframes, I requested anti-parasitic medications for Natalie. Thankfully, a local Pediatric Infectious Disease doctor kindly accommodated my request. Each time that the doctor prescribed various anti-parasitic medications for Natalie, she would improve. The improvements were noticeable both at school and at home. It was incredible to witness. However, each and every time that she was off of such medications, she would regress back to her former state of illness (displayed primarily by significant behavioral regressions). So, we found that we needed to try to keep her on various anti-parasitic medications more often than off of them, in order for her to enjoy overall improved health and neuropsychiatric stability. Even so, there was still some sort of physiological strain that she was very

definitely experiencing, but we were unable to decipher what it could be. This was frustrating, of course; to witness her continued rollercoaster of ups and downs in health and her various psychiatric disturbances each month.

It wasn't until a friend suggested we get Natalie started on CD, that the health and behavioral 'rollercoaster ride' began to show signs of smoothing out. In July 2012,

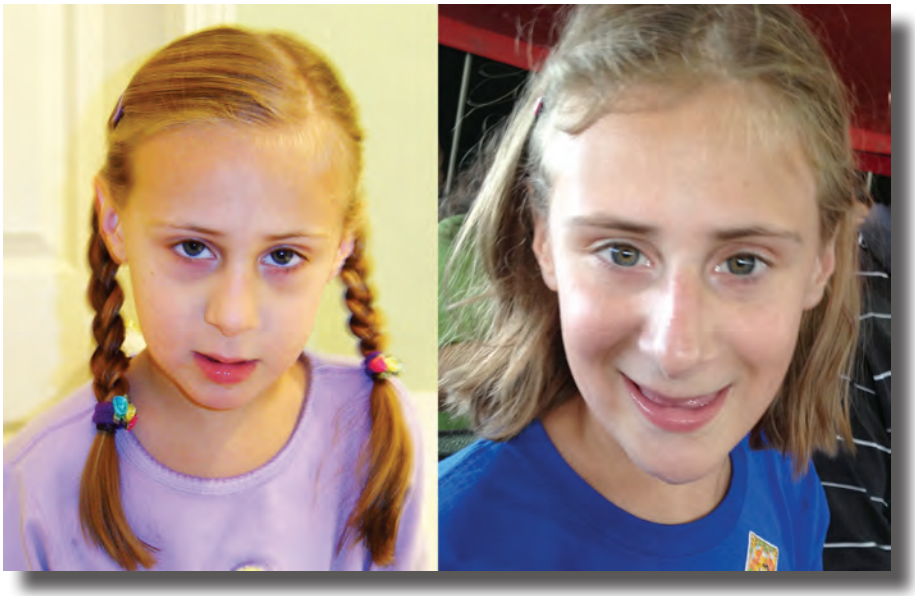

Natalie in 2006 (left) and in 2013 (right)

after her first drink of CD (only one-eighth of a drop), Natalie began to show initial signs of relief from whatever it was that was still ailing her. Her connectedness and overall psychological state of being changed within hours of that first one-eighth drop of CD. After that first day, we of course then continued with a very slow and conservative ramp-up of CD (orally, then baths, then enemas) alongside various anti-parasitic medications and all of the components of the Kalcker PP (with frequent swap out of Mebendazole with Albendazole, predominantly). With each passing month over the past sixteen months, we've been able to witness improvements in Natalie; perhaps a bit more slowly than some of the younger and/or potentially less health-compromised kids that Kerri's protocol has healed, but improvements nonetheless. Before CD, Natalie's ATEC score was a 79. As of this writing, her ATEC score is a 39. Even more astounding to us than that improved ATEC score have been the changes witnessed thus far in her overall health status and health regimen. Here is a list of some of the improvements that I can very easily recall as I write this (there are likely many more that I could comment upon, if I had more time):

1. *Daily prescription anti-fungal medications no longer needed.*
2. *Daily prescription antibiotic medications no longer needed.*
3. *Daily prescription antiviral medication no longer needed.*
4. *Daily prescription LDN (low dose naltrexone) immune modulator removed.*

5. *Daily prescription Leucovorin removed without ill effects noticed, as well as several other daily supplements that might have been ultimately not helpful.*
6. *Prescribed Immune Globulin (weekly subcutaneous, formerly monthly intravenous for years) removed.*
7. *Distended belly gone & improved posture (no longer hunched over).*
8. *Formerly very frequent tongue sores/lesions lessening more & more.*
9. *Seizures formerly as high as every 17-21 days in her worst times; now she's enjoyed seizure-free stretches as high as 105 days (3.5 months) followed shortly thereafter by a seizure-free stretch of 168 days (5.5 months). Prescription anti-seizure medication reductions have also been enjoyed as well as fewer headaches resultant of those reductions.*
10. *P.A.N.S. flares controlled with the combination of CD and anti-parasitic meds. Neuropsychiatric symptoms of flares very dramatically declined.*
11. *Overall appearance of improved health, improved language and interpersonal skills, improved attentiveness (per Neurology's opinion at recent appointment).*
12. *Improved stamina and strength (core, legs, etc.) noticed at Special Needs Performance Cheerleading practices, physical therapies, etc. Her ability to peddle adaptive bike has also improved.*
13. *No more nose bleeds, no more ear infections, no more apparent seasonal allergies, fewer headaches (as noted above).*
14. *Incredibly improved sleep and need for naps only once in a while now (as opposed to formerly daily).*
15. *Improved growth rate and normalized appetite.*
16. *Improved language (more descriptive words, more sentences).*
17. *Healthier-looking skin overall; softer, less dry, improved color & ability to tan.*
18. *Improving oral muscular abilities, able to swallow pills/capsules.*
19. *Capable of successful dentist appointments and now even Orthodontist appointments, with calm and ease.*
20. *Increased success rate during therapies (Speech Therapy, Occupational Therapy, Physical Therapy, etc.).*
21. *Less rigidity overall, fewer transition issues, cooperates more often than she ever used to.*

With all of the well-documented improvements noticed in Natalie at home, at school and in doctors' offices, I don't have the same level of fear as other parents might surrounding our open use of CD, as Natalie's doctors are all well informed and quite supportive. We've also formally notified her social worker (both verbally at a home meeting and in writing) of our use of Kerri's CD Protocol (including Kalcker's Parasite Protocol and of course a GFCFSF/low sugar diet) while under Natalie's local medical team's support and medical monitor. We're 'out of the closet', so to speak, when it comes to our use of CD for improving Natalie's health. It's been quite obvious to Natalie's doctors; actually, that Kerri's protocol has been extremely complementary to their medical efforts for improving Natalie's health and overall quality of life.

There's of course no way to predict with certainty how far my sweet Natalie will be able to ultimately improve via this protocol, but based upon what we've witnessed thus far, I do feel that her current best hope for continued improvement lies within the pages of this book; as these healing strategies of Kerri Rivera's have brought Natalie toward more health (physical, neuropsychiatric, emotional and even some initial cognitive improvements) than any other medical effort attempted since her 2005 Flu shot injury. All other medical efforts for Natalie over the years, I feel, perhaps only temporarily patched her severe illness. Kerri's methods actually work to attack disease, kill it and remove it. Yes, that's right. Eight years after Natalie's tragic rapid spiral downward, it's now finally a time of healing for Natalie. Thank you, Kerri Rivera, for all of your help given to our girl and to so many children around the world.

Self-Injurious Behaviors (SIBs)

Self-injurious behaviors (SIBs) can be absolutely devastating for families with children on the autism spectrum. Common self-injurious behavior includes: headbanging, hand biting, pinching, slapping head/ears, eye poking, hair pulling, scratching/rubbing, throwing one's body on the floor, etc. The horror of watching your own sick child further inflict pain onto himself, and the helplessness of not knowing what to do to help him is heartbreaking. I have met with families through the clinic who have had terrifying episodes of SIBs in front of me as well as at home, and many of these families as well as others are now using the Protocol to help their children with very good results.

There are many theories as to why some children have SIBs. The article "Self-Injurious Behavior" by Stephen Edelson on ARI's website discusses several different theories and supporting research.[2] The theory that most fits what I see on the ground is that of pain alleviation. Many of our kids are in chronic pain and cannot tell us. Sadly, we haven't always had answers to help them.

If we follow this thinking, and assume that many of these children suffer from severe gastrointestinal pain, or headaches (supported by head banging, gut clutching, etc.) we can hypothesize that much of this pain can come from pathogenic overload, parasites wreaking havoc on the body and the resulting inflammation.

Families applying CD in combination with the Kalcker Parasite Protocol are reporting a dramatic reduction in SIBs in their children. I believe there is

an important connection to be made here, as we eliminate pathogens and parasites SIBs decreases. More research is needed, but for families facing the horrors of self-injurious behavior, this combination could be of great value. (More testimonies on decreased SIB's can be found in Chapter 2, and the Miracles and Testimonials section at the end of the book starting on page 357.)

Prior to starting CD, we had tried almost every autism biomedical protocol. We saw several DAN and GI specialists and numerous other practitioners. We spent tens of thousands of dollars on consults, supplements, diets, medicine and medical procedures not covered by insurance. My daughter either had no response or negative ones and she continued to get worse. She developed extreme self-injurious behaviors that progressed to the point of her needing to be restrained several times a day in an attempt to prevent her from pinching or biting herself until she drew blood. Her body was covered with bruises and cuts. She would also pull out big clumps of her hair. She would be up for hours screaming in the night with these behaviors. She was severely malnourished despite the fact that two registered dieticians had deemed her daily caloric intake adequate. She was 14 years old and weighed a little over 70 pounds. I honestly did not think that CD would be any different than anything else we had ever tried but figured things could not get much worse.

Since starting CD her self-injurious behaviors are almost entirely gone. She went from having to be restrained almost daily to once in the last 5 months. Her former multiple daily 45 minute self-injurious tantrums are now a few minutes of crying or protest and happen once a week if at all. We have noticed gains in language and cognition (20 point drop in her ATEC score). After years of fluctuating between loose stools and constipation, she is now regular and has gained almost 10 pounds. She sleeps through the night and we are able to take her places that we would have never dared to before. If my daughter can make gains this drastic in 5 months at age 14, I can't wait to see what the future holds.

Julie, Colorado, USA

PANS, PANDAS and PITAND

PANS stands for *Pediatric Acute-onset Neuropsychiatric Syndrome*. It encompasses PANDAS (Pediatric Autoimmune Neuropsychiatric Disorder Associated with Streptococcal Infections) and PITAND (Pediatric Infection Triggered Autoimmune Neuropsychiatric Disorders), where PANDAS is a subset of PITAND. Dr. Susan Swedo, Chief of Pediatrics & Developmental Neuroscience Branch at the National Institute of Mental Health (NIMH), and her research team identified a subtype of OCD in children during the 1990s that is triggered by infection. Streptococcal infection has been most studied; however, any infection can trigger this condition.[3]

I have run across these diagnoses a lot since I have started helping families in first world nations. There seems to be an overlap in some autism and PANS/PANDAS/PITAND cases. I have heard that around 25% of children with ASD's also suffer from PANS/PANDAS, and/or PITAND. Some practitioners would put that figure even higher. However, since further research is needed, and this field is still developing it is impossible to say for certain at the moment.

According to the International OCD (Obsessive Compulsive Disorder) Foundation some of the symptoms of PANDAS/PANS may include:

- Acute sudden onset of OCD.
- Challenges with eating, and at the extreme end, anorexia.
- Sensory issues such as sensitivity to clothes, sound, and light.
- Handwriting noticeably deteriorates.
- Urinary frequency or bedwetting.
- Small motor skills deteriorate - a craft project from yesterday is now impossible to complete.
- Tics
- Inattentive, distractible, unable to focus and has difficulties with memory.
- Overnight onset of anxiety or panic attacks over things that were no big deal a few days ago, such as thunderstorms or bugs.
- Suddenly unable to separate from their caregiver or to sleep alone.
- Screaming for hours on end.
- Fear of germs and other more traditional-looking OCD symptoms.

I know several moms who have been able to reduce/control/eliminate their children's symptoms with CD. In fact, families began to eliminate the antibiotics that they were using as they reached full dose of CD. I am by no means suggesting anyone reduce or remove a prescription medication without a doctor's supervision. I am simply reporting on what I have witnessed.

We know that CD kills bacteria, so we could hypothesize that CD could have a similar effect on the PANS/PANDAS/PITAND symptoms that an antibiotic would. What has worked in these cases is upping the number of doses of CD given a day so as to kill pathogens around the clock. For PANDAS/PANS/PITAND use two baby bottles a day. If your max dose is eight drops in an eight ounce bottle, and a PANDAS flare presents, prepare two baby bottles with eight drops in each and give one dose every hour over the course of 16 hours. Some families are doing 16 doses a day even if there is no flair and the child is doing excellent.

As noted previously, in the absence of research, we cannot recommend doing nothing for these children. Their suffering is intense and the risk of long-term damage cannot be ignored. We also do not know if some of these children remit spontaneously later in adolescence. We do not know if some of them grow into adults with the most treatment resistant OCD due to permanent basal ganglia damage. While we research those questions, offering treatment options at the local level, especially in the first few months after onset, could be critical to the long term success for these kids.[4]

We parents are pioneers in the research surrounding PANS/PANDAS/PITAND, so it is critically important that we document what we are doing with our children and what is working for them. In fact, A MOM was the first to discover the connection between strep and OCD/tics. Her child was the first documented PANDAS child. Dr. Susan Swedo reinforces that physicians should listen to what the mothers have to say![5] Speak up to your doctor, share your findings, join our forum to learn, and share what is working for you. Parents are driving the biomed movement (and always have) for ASDs as well as PANS/PANDAS/PITAND. In fact Dr. Bernard Rimland was a parent and the first to suggest biomedical interventions for people on the spectrum. We as parents can help countless other families by sharing our experiences.

You will find more info on PANS/PANDAS/PITAND at:

www.pandasnetwork.org

and

ocfoundation.org/PANDAS

Fever Therapy

Dr. Kenneth Bock and Nellie Sabin, in their groundbreaking book *The Road to Immunity: How to Survive and Thrive in a Toxic World*, explain how to use fever therapy and how it is an incredible tool for healing.[6] When a mom emails me to tell me her child has a fever, it tells me that the immune system is reacting to an invader, and we have an excellent opportunity to kill pathogens in the body. Having a fever is part of an effective immune response. This is also true in infants as well as small children. Using over-the-counter (OTC) fever reducers interferes with the body's own ability to fight infection.

This section was excerpted from the aforementioned book.

> Fever has long been recognized as an important tool in the process of healing. The process of heating the body is called "hyperthermia." Hyperthermia, or ordinary fever, can be very effective against cancer cells, various pathogens, or invading organisms that cannot "tolerate the heat." Hyperthermia may not kill all pathogens in the body, but may reduce the number of invaders in the body to a manageable level for the immune system. Hyperthermia may also be responsible for stimulating the immune system to produce cytokines i.e. antibody production, and release of toxins from fat cells.

What Temperature Constitutes a Fever?

According to Dr. Robert Sears, the following are normal temperatures in children over 3 months:[7]

Normal temperature:	97° to 99° F (36° to 37.2° C)
Low-grade fever:	99° to 100.9° F (37.3° to 38.3° C)
Common fever:	101° to 103.5° F (38.4° to 39.7° C)
High fever:	103.6° F (39.8° C)

Fever Therapy in Practice

If your child develops a fever, it is not a failure of the body that needs to be corrected, but a mechanism that brings the body closer to healing. Rather than administer an OTC remedy to reduce fever, apply a cool, damp washcloth to the forehead and neck, replace them as they warm, and let the body do its job. Some parents put damp socks on their child's feet.

During a fever you can dose orally, as well as do one CD bath and one CD enema in one day. Keep dosing CD every hour (16 to 24 doses a day), unless the person stops eating. Even if you must reduce the number of drops, even if you are only giving one drop, keep dosing every hour. CD baths, as well as baths in general, are also your friend if your child has a fever. Some parents have given several baths throughout the day while a fever is present with great results. Bath the child if the fever spikes. Always be vigilant that the temperature does not rise too high or too fast so as to cause febrile seizures, we have to use common sense and trust our instincts. Bath and keep a cool damp wash cloth going 24/7 until the fever pases.

According to the National Institute of Neurological Disorders and Stroke febrile seizures are convulsions brought on by a fever in infants and small children. The majority of children with febrile seizures have rectal temperatures greater than 102° F. Approximately 1 in 25 children (4%) will have one febrile seizure. Although febrile seizures can be frightening to parents, the vast majority of febrile seizures are fast and harmless. There is no evidence that short febrile seizures cause brain damage. Large studies have found that children with febrile seizures have normal school achievement and perform as well on intellectual tests as their siblings who don't have seizures.[8]

If your child has a febrile seizure, experts recommend that you try to stay calm, keep the environment around your child safe (place them on the floor if they are not, and clear objects out of the way), and allow the seizure to

resolve spontaneously without restraint. Try to look at your watch so you will know how long the seizure lasted. Do not put anything in your child's mouth as it may break, obstructing their airway.

Skin Issues

I have been hearing about skin issues right and left: rashes, hives, redness, acne, eczema, psoriasis, pustules, etc. It is very easy to assume that since skin is on the outside of our bodies that these reactions are caused by exterior factors (i.e. irritation from a detergent, mold, etc.). However, the skin is our largest detox organ, and many pathogens seek exit through the skin causing many of the above conditions.

The scenario that I keep hearing is the following: We just started the Kalcker Parasite Protocol. Little Johnny has a rash with white heads on his legs. What do I do? When the families keep up with the parasite protocol, and continue dosing daily with CD these eruptions disappear, and this is generally accompanied by improvements in behavior, or hyperactivity/anxiety.

We need to think about skin issues as outward manifestations of inner toxicity, and use our protocols accordingly. Skin issues can be a good indicator that something is being flushed from the system, or something needs to be flushed from the system. The Kalcker Parasite Protocol combined with CD tends to eliminate skin issues at the root.

The following paragraphs were excerpted from leakygut.co.uk, written by Dr. Gloria Gilbere ND DA hom PhD[9]:

> Experts agree that most chronic skin disorders, specifically psoriasis, is the external manifestation of the body's attempt to eliminate internal toxins that have accumulated within the lymphatics and blood stream by "seeping" through intestinal walls in a condition known as leaky gut syndrome.
>
> In working with clients around the world, the protocols that have been most effective are those that include repairing the intestinal walls by first beginning a protocol to eliminate candida yeast and parasites.
>
> The most effective cleansing protocol is obtained by clearing out these "uninvited" health-depleting microorganisms in order to release the accumulated pressure on the liver and the intestines—allowing free passage and thus reduction of overall toxic load.

The following paragraphs, authored by Dr. Edward F. Group III, DC, ND, DACBN, DABFM, were excerpted from parasite-cleanse.com/intestinal-parasite-symptoms.html[10]:

> **Symptoms of Intestinal Parasites Related to Skin**
>
> The presence of intestinal parasites, at times, manifest as allergies, tumors, and various other skin conditions.
>
> Intestinal parasites cause the human body to release hormones and immune system defenders, which in turn irritate the skin and cause various skin conditions such as acne, hives, rashes, itching, weeping eczema, ulcers, swelling, sores, lesions, blisters on lips, and dermatitis. It also deprives the skin of its usual glow.
>
> Intestinal parasites cause irritation and inflammation in the stomach making it difficult to digest certain types of foods. The presence of undigested food particles in the stomach causes the body to produce increased levels of eosinophil, an immune system defender. These eosinophils inflame the body's tissue and cause skin rashes.
>
> Intestinal parasites trigger the body's immune system to develop a tumor-like mass known as granuloma to encase parasitic larvae or eggs. Granulomas usually develop in the colon, rectal wall, lungs, liver, peritoneum, and the uterus.

Btw, you were bang on re his allergies and PP (parasite protocol). He had this horrible red lip thing because of food allergies. He would make it worse by rubbing it. It would get really bad. After first PP (Parasite Protocol) - NO MORE RED LIP ISSUES!

Families often tend to panic when dealing with sudden "unexplained" skin issues. If you are seeing chronic or acute skin issues I think there is enough evidence to look towards parasites as the main or at least a contributing culprit. Therefore, if we work towards removing the parasites causing the symptoms, rather than treating the symptoms topically we can expect an alleviation of the symptoms.

If you are seeing acute or chronic skin issues and you have not started a Parasite Protocol, I would suggest you revisit the parasite chapter and go over the recommendations with your healthcare provider. Keep dosing CD, in

some cases upping the dose has helped resolve the issue faster, and in the case of severe irritation using a CD spray topically can provide relief (10 activated drops per ounce of water in a spray bottle) and a CD bath can also help. I have seen most, if not all skin issues resolved with CD and/or the Kalcker Parasite Protocol.

Healing Adults with Autism

Common thinking in the biomed community and the autism community at large is that autism is only "curable" or "recoverable" up to a certain age. I have heard that two to nine years old is the "golden window" for autism, and that after nine years of age improvement would be possible, but not recovery. The neural pathways would be set, the damage done, and the child would retain the autism diagnosis for life.

Not anymore. This year a 15-year-old recovered from autism, as well as two 17-year-olds. In addition, I am helping an amazing mother of a 31-year-old with autism that began the Protocol and for the first time in 28 years was seeing real progress with her son. In fact that young man's ATEC score dropped from a 65 to somewhere in the 20s in his first three months on The Protocol. I want to prove that autism recovery is possible at any age. It may take longer, and the road may prove more challenging, but it's already happening. Families that have been using biomedical interventions for more than ten years are finding the Protocol and sharing their gains.

Older children and adults on the spectrum start the same way as the little kids—clean up the diet first, and then on Day one of CD, give one drop in eight ounces of water over eight doses throughout the day. It is so important to start low and slow even with adults because they have often been chronically ill much longer than young children and have deep rooted pathogenic and parasitic infections. This means that when we start giving CD they might experience a detox reaction considering the amount of pathogens that will be dying.

Working with Neurotypical Adults

Can CD benefit parents and other adults not on the spectrum? Absolutely. You can literally find thousands of testimonials on the Internet (Jim Humble's website, www.jimhumble.org or www.curezone.com, etc.) on people who successfully detoxed, or healed a myriad of illnesses using CD.

Many parents who have seen improvements in their children have decided to use CD, or the Kalcker Parasite Protocol for themselves. I have done CD oral, baths, and enemas on myself, especially when I feel "something coming on" and with great results.

It's important to keep in mind that just because we weigh more than our children doesn't necessarily mean we should jump in and go to full dose from one day to the next. The best way to start an adult who may have 40 or 50+ years of accumulated toxins/pathogens/parasites is low and slow. Use the baby bottle method and start day one with one drop spread out over eight doses and go up from there. Chart your progress, see how you feel, go low and slow. When we as adults use the protocol it can be great for us, but also a window into how our children are feeling.

I love to see a mom or dad begin CD with their child. Both begin at one drop on day one in eight ounces of water, 1/8 or a drop per dose, for eight doses throughout the day. Starting with our children gives us a much better understanding as to how our child is feeling, and when we up the dose how that feels as well. This includes enemas. Once parents see how good they can feel after an enema, it helps garner confidence, if we had doubts about using them for our children. Applying our own enemas can help to remind us just what a powerful tool they are for healing.

Many of the parents doing the protocol for themselves write me to tell me about their remission from fibromyalgia, chronic fatigue syndrome, Lyme disease, life-long constipation, etc.

We all do the parasite protocol in my house so as not to re-infect my son, as parasites can be highly contagious. Last year I did a round of parasite medications prescribed to me by a doctor. During the course of treatment I felt a tremendous amount of anxiety and some depression (feelings I had never felt before) right before I passed worms, I can assure you it felt awful. That experience motivated me to encourage parents to get these invaders out of their children's bodies.

As soon as I started passing worms and detoxing more with CD, I started to feel good again. The cough that I had had on-and-off for years miraculously disappeared. Seriously, go low and slow, a toxic body can only process so much at a time. Too much too fast can cause headaches and diarrhea. The way I see it, there is no need for that, listen to your body and go at whatever pace you need. Don't just "push through," low and slow wins the race. Always remember to drink water when doing any sort of detox!

Tax on a Marriage

During the first five years after an autism diagnosis married couples face an estimated 80% divorce rate, and a 90% chance of divorce beyond the tenth year of marriage. My family was almost a statistic. Even before we had a diagnosis, our family was suffering. Due to Patrick´s constant screaming and tantrums, he wasn't sleeping at night, and that meant that no one else was sleeping either. He had also stopped being the affectionate baby that he was for the first two years of his life, which was emotionally challenging for all of us. We were all over stressed and sleep deprived, not to mention having symptoms of post traumatic stress disorder (PTSD).

If I could give any advice to families dealing with a new diagnosis it would be to start The Protocol and CD immediately. The sooner the affected family member starts to heal, so will the rest of the family, similar to the sun coming out after a storm—this too shall pass.

Financial Stress

Not only is an autism diagnosis emotionally stressful on a marriage, but it can be extremely financially stressful as well. The Protocols outlined here can be extremely cost effective, even if including ocean water. Recently, one of the moms using The Protocol did some calculations comparing what she spent previously (see table on page 342) using another biomedical intervention with many supplements, etc., to what she spends now (see table below).

The Protocol - Estimated Cost

Product	Size	Price	Reorder Schedule	Current Cost per Month
CD	1 bottle	$22	1/mo	$22.00
Diatomaceous Earth	2.5 lb	$15	1/3mo	$5.00
Rompepiedras	50 ml	$24	1/2mo	$12.00
Vortex Ocean Water	1 L	$40	1/mo	$40.00
THERALAC®	30 caps	$36	1/mo	$36.00
Natures Way® Neem	100 caps	$4.09	1/5mo	$0.75
Pyrantal Pamoate (Combatrin®)	32 oz	$35	1/6mo	$5.00
NOW® Castor Oil	16 oz	$8.23	1/6mo	$1.38
Mebendazole	90 tabs	$28	1/5mo	$5.60
TOTAL				**$127.73**

Defeat Autism Now! based Protocol - Estimated Cost				
Product	**Size**	**Price**	**Reorder Schedule**	**Current Cost per Month**
Actifolate	60	$15.00	1/2mo	$7.00
Calm PRT	120	$89.00	1/5weeks	$78.00
Caprilex™	90	$16.00	1/6weeks	$10.60
Cytoflora™	4 oz	$79.00	1/mo	$79.00
Designs for Health Lithium Synergy	120 caps	$22.00	1/mo	$6.00
DMG	90	$16.00	1/5mo	$10.60
Douglas B-Complex	60	$21.00	1/6mo	$21.00
Douglas CoQ10	60	$49.81	1/6mo	$12.50
Enhansa™	150 caps	$58.00	1 / 75 days	$29.00
Enzymedica Virastop™	120 caps	$32.11	1 / 4 months	$8.00
Garden of Life Probiotics	81g	$32.17	1/mon	$32.17
GI Revive	225g	$52.00	1/mon	$52.00
Homocycsteine Supreme	60 caps	$20.00	1/4months	$5.00
Kirkman Digestive Enzyme	200 caps	$60.00	1/3months	$20.00
Kirland Vit E	500	$13.65	1/16months	$0.84
Klaire Multivitamin	180	$28.00	1/3months	$9.00
Liver Life	4 oz	$50.00	1/2months	$25.00
Magnesium	240	$13.25	1/6months	$7.00
Metagenics Adreset®	60	$33.00	1/4months	$8.00
Milk Thistle	100	$25.00	1/3months	$8.00
NDF+	1 oz	$80.00	1/6months	$15.00
NeuroProtek®	4 bottles	$140.00	4/4months	$35.00
NeuroScience Avipaxin	60	$58.00	1/2months	$28.00
NeuroScience EndoTrax	1 bottle	$27.00	2/month	$54.00
NeuroScience Kavinace	120	$65.00	4/4months	$32.50
New Beginnings Copper	50 ml	$20.00	1/year	$1.75
NOW MCT	32 oz	$17.00	1/6months	$2.80
Nutribiotic GSE	4 oz	$16.99	1/6months	$3.00
OSR	30	$60.00	1/2months	$30.00
Oxycell Glutathione Cream	1 jar	$33.00	1/2months	$16.50
Pharmax Cod Liver Oil	8 oz	$13.33	1/mon	$13.33
Source Naturals B6 (p5p)	240	$15.00	1/6months	$2.60
Source Naturals Evening Primrose Oil	90	$7.45	1/6weeks	$4.97
Source Naturals Gaba	100g	$18.00	1/4months	$4.50
Source Naturals Lysine	200	$10.00	1/mon	$10.00
Source Naturals Quercitin	200	$25.80	1/3months	$8.25
Speak EFA	60	$42.00	1.5/month	$63.00
TheaNAQ	90	$54.00	1/month	$54.00
Therabiotic	120	$69.00	1/2months	$35.00
TravaCor Jr.	120 caps	$24.00	1/4months	$7.00
Vit B12 shots	1 refill	$45.00	1/3months	$15.00
Wobenzyime®	120	$60.00	1/2months	$30.00
TOTAL				**$894.91**

Tips for a Non-Toxic Home

Many of our children on the spectrum have chemical sensitivities, and even if they don't, it's wise to limit their exposure to toxins during the healing process as much as possible. Toxins are not good for anyone at any point in their life. The benchmark investigation "Bodyburden: The Pollution in Newborns" by the Environmental Working Group[11] (see Appendix 13, page 499) explains why this is so important for children with developing brains and immune systems. The following is a list of products to use instead of toxin filled, name brand cleaning products.

Floor cleaner: Add one cup of white vinegar and baking soda to a bucket of water (add a squirt of liquid soap if you like).

Air Freshener: To remove odors from carpets spread on baking soda and then vacuum the carpet. Simmer cloves and cinnamon as air freshener.

Removing Toilet odors: Borax

Trashcans: Spread baking soda in the bottom, then spray to disinfect with a solution of borax and water.

Dish soap: I use liquid dishwashing soap and white vinegar to cut grease. If you buy dish soap make sure it's biodegradable.

Disinfectants: Borax with water is an excellent disinfectant, or spray CD.

Laundry detergent: Soak the clothes for an hour in borax soap before putting into the washer.

Oven Cleaner: Dissolve two teaspoons of liquid soap (not detergent) and two teaspoons of borax with enough warm water to fill a spray bottle.

Windows and Mirrors: Club soda in a spray bottle

Toilets and Tubs: Baking soda with apple cider vinegar

96% Alcohol: Kills parasites on enema catheters, etc., and is great for cleaning bathrooms.

Videos

I have had many parents ask me if I think it is a good idea that their child watch "Genius Baby" or other videos that are supposed to help with their development. I do not believe these videos to be appropriate for a developing brain. Studies were done in Cuba that found that excessive TV watching before three years of age can cause the symptoms of autism. When the TV

was removed from the children that presented symptoms of autism, the symptoms disappeared. They also reported that TV watching could cause neurological discharges in the brain.

I can also tell you that the only time my son stims or flaps is when he is allowed to watch TV. When he was younger, and deep in the throes of autism, the only thing he wanted to do was watch TV, while running back and forth and squealing. Any other activity was met with screaming and tantrums. He is much more interested in other activities now, and easily transitions from one to the next, including school. However, he still requests to watch YouTube in the evenings when all of his activities are complete, and that is truly the only time he flaps his hands anymore. To me it is very obvious that TV is a source of over stimulation for him. However, it is hard to deny him a truly preferred activity, especially when he enjoys videos on cooking and foreign language! The least amount of screen time (TV, computer, iPad, etc.) the better, however, we do what we can.

Therapy Options:

ABA is not the only therapy for children with autism.

Many parents worry because ABA/IBI is either not available, or not affordable to them. I firmly believe that something is better than nothing. At the same time, I have seen many children recover without any ABA or IBI. Here are some of the options that have worked for families in conjunction with the protocol:

- ABA - Applied Behavior Analysis
- Occupational Therapy
- DIR® Developmental - Individual Difference, Relationship-based Model
- Floortime Therapy
- TEACCH - Treatment and Education of Autistic and Related Communication Handicapped Children
- Son-Rise®
- PROMPT - Prompts for Restructuring Oral Muscular Phonetic Targets
- Sensory Integration Therapy
- RPM - Rapid Prompting Method
- Supportive Typing

There are many other options not mentioned here. Human interaction is key for our children on the spectrum to find joy with us in our world.

I have known many families to have varying degrees of success with all of the above therapies. Some are better for younger children and some for older children. Depending on the areas most lacking in your child's development, you can investigate any one of these types of therapies. Families in many countries where insurance doesn't cover any type of therapy have had to be trained themselves in how to apply therapy. Sometimes an aunt, sister, cousin, or neighbor steps up to help out. No ONE therapy has been fundamental to all of the recovered children and for that reason I say something is better than nothing when it comes to therapy.

Even household chores can be therapeutic and task oriented. Simply because a person has autism doesn't mean they can't have responsibilities and learn new skills while helping out in the home.

A word on laboratory testing

I can't stand to watch people waste money that they could be using for healing their children through various interventions on laboratory testing. If you have all the money in the world, and want to chart your child's progress through laboratory testing, so be it. However, the rest of us sometimes have to choose between expensive testing and treatment. So many families have come to me after spending thousands of dollars they didn't have on testing to tell me their child has viruses, bacteria, and candida. Am I surprised? Never. I have yet to see a child with regressive autism that does not have pathogens/parasites. No matter which pathogens are present, we use CD.

Testing for parasites is woefully lacking at this time, and in fact, the only practitioners who have consistently diagnosed parasites have been veterinarians and practitioners of alternative medicine (also Metametrix labs have identified parasites in some cases).

Generally speaking, if a child doesn't have viruses, bacteria, yeast, parasites, heavy metals and allergies they don't have autism.

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Chapter 15

Final Thoughts

If you knew how powerful your thoughts were
you would never think a negative thought again.
~ Peace Pilgrim

What would be your message to families of children with autism who have just read the book, but not started the protocol?

Do not wait! Get started now! Autism is Avoidable, Treatable and Curable! You don't have to spend fortunes on lab testing, imported foods nor supplements. Even if the medical community can't decide if your child has autism, PDD-NOS, ADHD, Asperger's, PANDAS, etc.... don't wait! Start the diet. Even if you cannot do more than that, it will help. Some children have lost their diagnosis with just diet. There are parents all over the world doing biomedical protocols for autism, get together with them, join the forum at...

www.cdautism.org

...or the CDAutism Facebook group. The Internet helps us all to be close and share information. Don't let anyone tell you the diet doesn't work, just keep going and don't stop. There is never an excuse to not do what is right for your child. "Their future depends on our courage."

The final chapter of this book is yet to be written. Until the day we have recovered every victim of regressive autism, there is no success. Just progress. Here I have expressed what I have seen and what the road of autism recovery has brought to me. I have learned a lot and continue to learn. Our children need us to keep learning and searching until we find what unlocks them from their autism. Not everything works for everyone. However, I have seen that this protocol works for most. Especially when it is done exactly as it should be. If you have found this book you have an advantage that I did not have with my son. When I first learned of Patrick's diagnosis I lost precious time and money that I didn't have to lose, trying interventions that didn't yield results. In the nine years that my son has been in recovery I have yet to come across another protocol that has helped as many children to recover from autism

in such a short amount of time—less than three years, to be exact! As of the date of this writing in May of 2013, 93 children have lost the diagnosis of autism and every month more and more are recovering.

Please remember that if your journey is autism you will never walk alone. I am here too. Just one click away...

www.cdautism.org

I wish everyone who is ill to have the fastest recovery possible from whatever it is that ails them.

To be continued…

Dr. Andreas Kalcker, Kerri Rivera, Jim Humble, in Puerto Vallarta, Mexico 2012.

Chapter 16

Healing Beyond Autism...

When TRUTH is found, understood and accepted is when we realize it was not even close to what we thought it would be...
~ Miriam Delicado

As Jim Humble has been proving for many years, chlorine dioxide is a molecule capable of healing many common ailments. When combined with the other elements of this protocol, in the correct order, it has shown to be even more effective. We have decided to include this bonus chapter because it is time to start sharing this information with everyone, as pathogens and parasites are the root cause of many of the diseases that are causing suffering in our world today.

As parents saw improvements in their children's health from the protocol, some of them decided to use it on themselves as well. Similarly to when the flight attendant tells you to put on your own oxygen mask first before helping others, it is important to take care of yourself if you want to be able to help your children heal, grow, learn and mature.

Over time, parents who followed in their children's footsteps started to have some undeniable gains in their own health. This was an added bonus many didn't expect, and we couldn't resist sharing their stories with you.

After reading the parasite chapter, you may have been surprised to see how many common symptoms can be caused by parasitic infections. Imagine what would happen if we could get this information into the hands of people who have seen many doctors, used various drugs, and applied countless protocols for years while only masking the symptoms of the underlying cause. So, there should be no surprise if going after the real cause was life changing in real ways.

The following testimonials are a small sample of how some of these people's lives have been changed. Serious afflictions such as Lyme disease, fibromyalgia, chronic fatigue syndrome (CFS), depression, cancer, and chronic infections, are just some of the conditions that improved or completely cleared

up. By cleaning up toxic pathogens and parasites, as well as removing foods that feed these invaders, it should be no surprise that disease triggering inflammation is reduced so true healing can take place.

I am so excited for you to read these, and I know that some of you will recognize yourselves here. Please know that healing is possible! We have a public Facebook group called *CD Health* where adults using the protocol for themselves can share questions, doubts and success stories. I highly recommend that you check it out if you are looking for support or some guidance getting started.

Testimonials Beyond Autism

After we saw our son recover from ASD using CD, I tried CD myself and it helped me recover from Lyme and its co-infections. Some of our extended family heard about our success and they have had very good results using CD for treating Hypertension, Diabetes and Liver problems. My younger NT son used to bang his head in sleep since he was born, CD has now resolved the problem. I think anyone who tries CD sincerely, can only benefit in treating so many hard problems. One very beneficial side effect I have seen with CD is the resolution to seasonal allergies and improvement in the immune system to the point where kids do not fall sick or catch colds. In this regard CD is much better than yearly flu shots which have so many toxic elements in them and still do not protect adequately.

—Nilesh

To say I was anxious about the impending birth of Baby #2 is an understatement. I felt like I had failed our first born on so many levels and was a mess believing that I'd do the same for our new daughter.

But alas, she was born a perfect and healthy baby girl. So was Callum, our son, but unlike Lila who had zero interventions, Callum had antibiotics from my labor, the Vitamin K shot, HiB, and DTaP. And it was the DTaP vaccine at 15 months that took the shine from our sweet boy's eyes.

We discovered Kerri's protocol when Lila was 3 months old and more worries cropped up about how to best protect her from the die off that was going on in our house.

At 5-months, she developed an eczema patch underneath her chin, became chronically constipated, and her normally cheerful disposition became irritable.

As soon as she hit the 20-lb mark, I started giving her 20 drop CD baths, low dose oral CD, and 3 drop CD/150 mL water enemas. To my horror and surprise, Lila started passing 1" baby roundworms almost daily.

In a family with both NT and ASD children, the NT child always has some type of quirky behavior. Now we know why! Parasites do not only affect the ASD

population, they affect everyone. Having CD in my tool chest gives me the power to prevent so many things that may have been in my daughter's future.
Don't be afraid to treat your babies! Her eczema is gone and she's pooping regularly once more.

I write and share my story in that it might help or save someone else's life. That it may just be the key to help someone see what may be what is happening for them as it was and is happening to me. If it helps just one person onto their path to recovery and health then it will have been worth sitting down at this computer and sharing it.

For the past 10 years or so my world has been collapsing in on me, and getting smaller and smaller, and accelerating the past 5 years. I have felt as if I were under a thick coffee mug on the edge of a table about to fall off. On a scale of 0 to 20 with 0 being death and 20 being fully alive and cognizant, I felt as thought I was at 3 staring at 0. For the past 5 years at least I have done so much research, listened to so many radio interviews, done so many different modalities, bought so many products, paid a lot of money to different therapists, ate weeds, made my own concoctions, etc. My mother would always say to me wow you should be so healthy to which I would reply no mum, actually I am not. I began feeling like a phony. I ate real good took all the right stuff, got plenty of rest foraged for my own food and spring water, got exercise, walked barefoot, etc, but always felt exhausted and looked worse and worse. I was fighting with everyone it seemed and chasing people away including family.

Four months ago my wife decided we should go away on a weekend getaway and relax. We fought the whole drive up there and when we got there she threw me my room key and said you're on your own. I spent the whole weekend in bed and on the trip home we both decided to end our 20 year relationship and marriage. I was good with that and looking forward to being on my own. I was finally chasing the last person who mattered to me away.

A week later an angel came into my life. I have been listening to oneradionetwork.com for the last 5 years and on this day Patrick Timpone had a lady by the name of Kerri Rivera on and she spoke about how she was curing kids with autism and that the kids had parasites. I looked up the symptoms of autism and realized I had quite a few of them. I immediately began the mms enema protocol which she recommends. I could not believe what then came out of me. I kept this up for a week and still there was no let up with the amount of parasites, biofilm, and who knows what coming out of me. After a week of this and seeing no let up on what was coming out of me, and having just done an mms enema I laid on my bedroom floor and the grief just poured out of me. My wife came in and lay down next to me and just held me. I knew then that something had changed, that my life and my marriage were now on a healing path. That the pain, the toxins and parasites were now leaving my body.

It has now been just over 3 months and there has been no let up on what has been coming out of me. If I were to have scooped it all up and put it in a jar I am sure it would fill a one gallon jar with hardly any water in it. I now feel I am at about a 9 with 20 in my sights. I thank God that this info came into my life and I took action on it. It has saved my life and my marriage. I love my wife, and cannot imagine not having her with me. And I love my life and am looking forward to not only getting

to the 20 mark but what is beyond the 20. What is possible when one's brain is at full capacity and not being inaundadated with toxins? Much love and appreciation goes out to Patrick Timpone at oneradionetwork.com, Kerri Rivera and her work with autistic kids (adults too Kerri), and to Andreas Kalcker. Thank you all for showing me and pointing to the keys I needed to free myself from what has been a nightmare.

A big part of my healing has been reviewing my life and realizing that this has been going on for most of it and answers so many questions I have had. As a child growing up I had pain in my stomach and what the doctors eventually did was take out my appendix, which most of us know now is needed to keep the healthy flora in our intestines. And they told my parents that it was all in my head. So whenever I complained about stomach aches and pains was told that it was all in my head. School was a nightmare for me, as socially I felt I didn't fit in or belong, and a lot of easy concepts that most others got, I just couldn't get. I always had the feeling like I was missing something. I felt as though I was stupid or something just wasn't right with me. I now know there are many just like me. The words Autism, add, adhd, ocd, etc were not a reality back then. And I know those are just words or diagnosis of toxins and parasites. Get rid of the toxins and parasites and the diagnosis goes away. Easy peasy. Thank you all for listening to this chapter of my story. I look forward to many more chapters in my life story. Please feel free to pass this along to anyone who it may help. Much love.

—Bruce

When starting the protocol for my son's Autism, I decided to do it along with him.
I was suffering from Hypothyroidism, Adrenal Fatigue, a Hormonal Imbalance, and Severe Anemia. My cortisol was at a 3. One week into the protocol, my cortisol was at a 14, and my iron levels were normal without supplements. My thyroid medication dosage was decreased twice. My vitamin levels were all normal. My uterine fibroid cysts were completely gone after a few months on the protocol. I continue to see improvement in my health. This protocol has been a Godsend for my family.

—Maggie Kaye

CD has been life changing for my 18 year old son who has autism and Lyme, although his ATEC today is only a 3, down from a 68 at the start of cd, but I never thought it would be so instrumental in my dad's life also.

My dad, William, has a malignant melanoma in his eye and has received radiation for treatment for the last few years. I talk about cd all the time but they never took this treatment seriously, at least for anything besides autism until now. My dad gets terrible ear infections that he sometimes has to go to the hospital for. They tell him each time that he has "swimmers ear" and they give him abx, sometimes it seems to work, sometimes not, and he goes back to the drs or hospital for more abx....over and over. Recently he was leaving here for his 7-hour trip home, and he was very worried that he would not make it home with the painful infection that had begun,

and he would have to stop on the way and visit a strange hospital. So I mixed up some cd, and told him to drop a few drops of the cd mixture in his ear periodically on his way home. To his surprise, the infection cleared up by the time he got home and there was no need to even call a doctor.

Of course, my secret plan is to get him on the cd protocol to finally deal with the tumor in his eye and that's the plan we have started. Whether he uses it and shrinks the tumor and saves his life with cd or not, he's a true believer now that cd cures infection.

I have been taking CD and the parasite protocol for 5 mo., and here are my observations. I have had long-term chronic sinus issues which has caused sever sleep problems. Also, a few months ago, I had a severe toothache in the upper left area. The dentist examined and found no fault with the tooth, even though there was severe swelling in the area. The infection originated from my sinus, and by taking my CD regularly hourly, was quickly solved. (My hourly CD doses were compromised by travel) I have also noticed improvement in my sinus condition, resulting in better sleep, although I have not fully recovered yet. Right now my sleep is somewhat interrupted by peetox. I will continue CD and PP for the 18 mo. Previously; I had used several naturopaths, with either negative results or limited results that disappeared when the medications were discontinued. So far I am happy with CD and would recommend it to people to try.

—Ed Canada.

A friend started eardrops with her 13-year-old pug 3 weeks ago. The pug Lucy was almost deaf from ear infection after ear infection, on constant drops, had seizures. After 3 weeks on CD eardrops, went to the vet, no ear infection, hearing is improving!! Winning!!

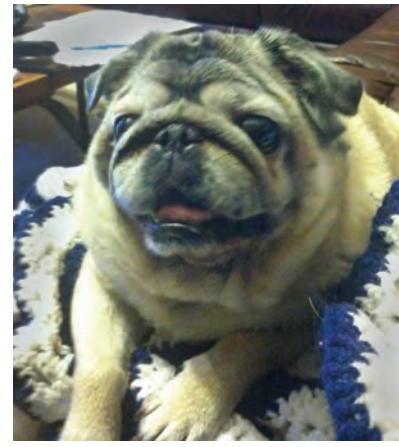

Since I was a child, I had been anemic and reading the book "Healing the symptoms known as autism" on the Parasite chapter, I saw that anemia is a sign of parasite infection. Since my son is taking CD I also took CD to know how my son feels and maybe cure my anemia. I had no problem going up to 24 drops in less than 2 weeks. I stopped taking my iron pill after 1 month of taking CD. I also did parasite protocol as I do not want to reinfection my son. Since, I stopped taking my iron pill I never had any dizzy spells and I feel great.

I used to wake up at night too to use the bathroom, now with CD no more night waking. In 2009, I was informed by my Doctor that I need to go and see a specialist as there was some suspicious stuff in my Pap Test and if not removed it

can lead to cervical cancer. I was booked in the hospital for the procedure. After taking CD reaching full dose, I had been discharging this horrible smell, like rotten egg, whenever I urinate. It took about a month before it stopped. Whatever that was, CD cleansed me and I think that discharge is related to my diagnosis on the pap test result. I am very grateful for CD for giving me my health back. I am still continuing taking CD as I want to be healthy and I will also try to complete the Parasite protocol for 12 months, I just finished my 5th PP and have been seeing lots of parasites mainly pinworm and ascaris. Now, I know the root cause of my anemia especially. I would encourage people to try the Protocol and see where the healing leads you. Thanks to Kerri Rivera, Jim Humble, Andreas Kalcker and people who used the CD before me as you gave me courage to use the CD.

—G.M, Canada.

Two days before our first set of cd bottles arrived (we bought it to start Kerri's protocol with our autistic daughter), our son (6) got sick with scarlet fever. We didn´t give him antibiotics because we just finished our research on cd and were excited to use it instead. My sons face was swollen and red, he had a moderate fever and rash all over his body. After the first dose of 1 activated drop of cd within one hour his swollen red face subsided completely and in the evening the fever was gone. His rash got dry and after 3-4 days it was not visible anymore. Our physician told us that scarlet fever without antibiotics lasts up to three weeks. We were done within 4 days, without damaging his gut flora, as it would have using antibiotics. CD has taken care of many infections in our family since then and most important - brought our daughters ATEC down from 100 to 46 in nine months. I´m beyond grateful for its discovery.

For the past six years, my life has been plagued with anxiety/fear, depression, pressure in my chest, making it difficult to lay flat and sleep, bloating which caused me to look 7 months pregnant and which made my abdomen very tight and uncomfortable. Headaches, weight gain, sore joints, no energy, fibromyalgia pain, and dizziness causing me to feel drugged and off balance.

The anxiety and fear were debilitating literally making it impossible for me to sleep. I would go night after night not sleeping, just dead on my feet suffering with so much anxiety and very frightened wondering what in the world was wrong with me.

When Kerri's book, Healing The Symptoms Known As Autism came into our lives, I read it wanting to help or autistic son. I soon realized I had so many of the symptoms that I needed to do the protocol.

I started on the cd taking a very small amount, 2 drops every hour, about 12 doses per day, and worked up to between 60 and 90 drops a day, I also took cd baths and did enemas. I increased the cd every day by just a drop or two. Very soon I started to calm down significantly. I started sleeping! I started losing weight! For about 5 weeks I thought I had died and gone to heaven. In two months I lost 20 lbs.

But when my anxiety started coming back I set up a consultation with Kerri. I learned I needed to begin the parasite protocol to kill the parasites. The cd just killed the little ones.

With Kerri's help in several consultations I was able to tweak the protocol in her book and apply it to me for my personal needs. I started on low doses and increased it for what I needed to sleep.

As of today I have only been taking Mebendazole, the medication that kills parasites, for 3 and a half weeks. I sleep at night. Some nights are a little choppy but I get 4-5 hours of sleep. I am not depressed. My emotions are not all over the place. I am coping. I'm functioning without sever headaches, only mild ones. I still have bloating but not as severe. I feel like I will live and that I am not dying anymore. I hardly ever feel depressed.

To date I take 200mg Mebendazole at breakfast, lunch, dinner and bedtime, plus a 200mg implant right before I get into bed. The implant has been the turning point in my healing. (Consult with Kerri for directions regarding the implant.) I also take 2 neem tea capsules with each meal. Also, one dose of Combantrin everyday at lunch. I take castor oil as needed each day 1-2 Tablespoons to keep things moving, plus a cd bath at bedtime, 150 drops soaking for 20 minutes.

Trying to differentiate what is die-off and what are actual symptoms from the parasites is challenging. Pay close attention to how you feel after you do or take something. After an hour note how you feel. Worse, better? You have to listen to your body. Consult with Kerri often and keep her informed by email. You may have to tweak the protocol every few days so write everything down, day, time, how much, how you feel etc.

All of my symptoms are not gone 100% but they have greatly improved. The anxiety, which was the worst and most debilitating symptom, is the greatest improvement I have had. I know I will be able to heal completely and get my life back. I have just begun!! I have had so much progress in just a few short weeks that I still cannot believe it!! And...I have lost 2 more pounds!!

Thank you Kerri for all of your love, support and guidance!! I could not have attempted this without your knowledge and help!! You are an angel!!!! I AM HEALING!!!!!!

Your devoted friend, Marcie

My mother 84 yrs of age- who has dementia was very, very serious last week. Her lungs were filled with mucous and she could not spit it out. We thought this was the end and my sister invited the priest to bless her. The doctors suggested that I place her in a hospice, but I refused! They also offered antibiotics, but I bought some CDS and gave it to her every hour. I placed a humidifier with 40 drops of activated CD by her bedside day and night. And massaged different parts of her body with CD and DMSO. soaked her feet just once in CD as it is difficult. She cant sit straight. To everyone's surprise she made it through. Just a little bit more to clear up! Thank you everyone for sharing wonderful tips on loving and caring for our loved ones! This is a wonderful extended family! love the CD!!!!!!!!!!

I want to thank all of those who were kind enough to share their personal stories with us. There are many more, but you get the idea. I am so excited for you to read them, and I know that some of you will recognize yourselves here. It just goes to show that healing challenging illnesses is possible. We have a public Facebook group called *CD Health* where adults using the protocol for themselves can share questions, doubts and success stories. I highly recommend that you check it out if you are looking for support or some guidance getting started.

Appendix 1

More Miracles & Testimonials...

The only limits you have are the limits you believe.
~ Wayne Dyer

To date, 115 children have lost their diagnosis of autism by using CD and some or all of this Protocol. Autism IS curable!

This section is comprised of testimonials, miracles, and short blurbs on gains made by children using The Protocol. In many cases, these are candid emails from parents to Kerri sharing their joy at their child healing. These were gathered over the past 3 years, and have come from families all over the world. Some were translated by the parents of the child to English, and some were translated by my sister or I. We have done our best to honor these exactly how they came to us, unless a correction was needed for clarification, these were not edited. Many are anonymous for the protection of the families and their children. Names were used when permission was given. These families were generous enough to share their experiences with all of us to spread hope and joy, as well as to prove that children all over the world of all ages are healing from the symptoms know as autism. Please enjoy and share.

Please note that many of these testimonials were collected some time ago and therefore some contributors use the term MMS instead of CD. Due to time constraints it was impossible to request permission to change the acronym of MMS to CD in their testimonials. As we mentioned previously, MMS and CD are the same substance. Where the acronym MMS is used in the following testimonials please know that chlorine dioxide is the substance responsible for the healing.

We have added many new testimonials since the first edition came out. Those new testimonials are located at the end of chapter 2 and continue on the next page, followed by those appearing in the first edition.

(continued from Chapter 2, page 40)

45. *Things I wish I'd known before starting this protocol:*
    - *My son would drop juice and pick up a water regimen immediately.*
    - *My son would sleep through the night every night.*
    - *My son would not be constipated again.*
    - *My sons ATEC score would be halved in 7 weeks.*
    - *My son's speech would be at age level.*
    - *My son wouldn't need his daily rx med again.*
    - *My son would be excited about and participate in his birthday celebration.*
    - *My son would come into the bathroom and say, "I'm ready to wash my butt" unprompted.*
    - *My son would drink ocean water.*
    - *My son would get acclimated to school and would initiate conversation with his peers.*
    - *My son's dark circles under his eyes would disappear. He would start to look and act like a healthy boy, and others would take notice.*
    - *My son would be affectionate, tell me he loves me, crack jokes, and be connected to me like never before.*
    - *The people who opposed our diet and protocol choices would be unable to deny that this works and we're on the right track.*
    - *My marriage would be saved by rolling our sleeves up and tackling this together.*
    - *I would find a way to heal my own ailments.*

    The future is bright

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46. *My son with autism is 31 years old. Although he is fully verbal, he had a lot of issues: SIB, Aggression, he was not able to sleep. We have been trying different kinds of protocols since he was 3 years old. Unsuccessfully. I heard about Kerri Rivera and the CD Protocol last September. We started right away. We were continuously in touch with Kerri who kept giving us the faith, that even at that old age it is possible to heal and even recover. In September, when we stared CD he had an ATEC of 87, 4 months later we measured 63, and now, after 8 mounts, he has an ATEC of 28. There are some SIB's and aggression left, but it happens only rarely. If we could get rid of it, my son would be recovered. He became an interested young man, his memory improved. He keeps giving proper answers to my questions, something he never did before. I can see his real personality now: he became a nice, lovable, open-minded young man from a very sick raging, roaring, screaming, suffering boy. There are no words to say thank you to Kerri to show us the end of the tunnel. I think I'm on the best way to recover my 31-year-old son!*

    Mark, 31, Hungary

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47. *Dear Kerri, I am very grateful to you for your benevolent service of helping to recover kids with Autism like myself. You have really improved the quality of lives of many hopeless kids. I really feel the difference now that my ATEC score is a*

1 and I am still making inroads in executive functioning and social skills. Without someone like you, we would have not known about CD and it would have taken several years to cure me solely with chelation. By that time, I would have been out of high school and probably in a community college taking rudimentary general education courses and would have had a bleak future ahead of me. But now, I am doing well in school and am taking college level courses. And I am not the only one in my family that has had benefitted from using CD. My brother used to have mild seizures in the form of head banging and most of that has now stopped. My father has used it because he contracted Lyme's disease twice. And my grandparents have used it to treat Alzheimer's, Diabetes, Blood pressure and Hepatitis C. So again, I cannot thank you enough for everything you have done that has not only changed my life forever but has made a profound difference in the lives of others afflicted with Autism.

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48. *My seventeen-year-old son was a healthy happy baby until he received vaccinations at age three. The day after the vaccinations he began having horrible anxiety problems. Day by day he lost skills and regressed. He developed problems with fine and gross motor skills, and social skills, memory and sensory integration. He also had multiple learning disorders and struggled in school. He spent all of his time in his room by himself and he did not make eye contact.*

    We tried many interventions to try and help him. Biomedical interventions, antibiotics, therapies homeopathy and Biofeedback all had limited benefits for my son. The only thing that helped him some was a gluten free, casein free, sugar free diet. While reading Healing the Symptoms Known as Autism we learned that most of the interventions we tried did not work because we were feeding the parasites that were causing my son's autism with vitamins and supplements.

    While I was watching videos about Chlorine Dioxide I came across a video of Kerri Rivera talking about the protocol she uses with autistic children. As I watched the video everything began to make sense and I knew the protocol would help my son.

    We bought Kerri's book Healing the Symptoms Known as Autism, gathered the supplies and my whole family started the protocol. To our amazement we saw improvements in my son overnight. We had taken the ATEC test for my son right before we started the protocol and it was a 43. In just one month of Kerri's protocol my son's ATEC dropped to a 5! We will continue with the protocol for the recommended time and we expect to see my son's ATEC drop to zero before we finish.

    His social skills, motor skills, thinking, behavior, attention span and stimming have all improved immensely. His sleep patterns, digestion, physical appearance and weight have also improved tremendously.

    Kerri Rivera's book gave us the tools we needed to reach in and pull my son away from the grip that autism had on him. We will forever be grateful to Kerri. She devotes her life to helping children with autism and always has an open line of communication for anyone who needs help. She is the voice for so many children that don't have a voice. Thank you from the bottom of my heart!

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49. *FUA!!!! BIG moment... crazy morning, ughhh we miss the Bus I was so mad because my other daughter had preschool at 9:30 so my morning was a mess, I had to leave in Pj's and make them eat breakfast in the car....but then in our way to school my son saw a School Bus passing by our side and said "school Bus is gone, L is sad" OMG OMG OMG.....did he just said this 30 words sentence?????*

(actually 7 words but seems like 30 to me!!!) Ok...WAIT then I get to school not mad anymore, I walked with him still in shock, I couldn't believe what I just heard....and when he saw the line of kids by the wall he point at them and said "my friends" OMG OMG OMG....ok WAIT....then we get there and he takes the teacher hands, gives me a kiss and said "bye mommy" OMG OMG OMG .... WAIT then the teacher ask him L, remember back pack by the wall, so he goes to the wall with his back pack in his back and does exactly what he was ask to do!!!! O M G

FUA...THAT'S RIGHT.... 223 days in this Protocol, searching poop, dosing, enemas, writing in his food diary every little thing he eats, therapies ABA, speech, occupational, hours hours of work, hard work...all just to witness this miracle of healing...to see him think, react, analyze a situation, be happy, spontaneous and smart by himself (no prompt or reinforcer necessary)....THANK YOU Kerri Rivera since the first day I found you in YouTube I have never stopped believing....I LOVE YOU WITH ALL MY HEART!!!! YES COMADREEEEE!!!!! I can feel it...we are close...it's happening.... so happy I missed the Bus this morning... this is the best day in my son's way to recovery so far!!!!!

HOPE FOR ALL!!!!

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50. *My son is 23 and we have tried many, many approaches to heal him over the years. Typically we would see some initial progress, but then the rate would slow down and he would plateau again, slipping further and further behind. Lyme disease and co-infections, as well as various viral, fungal and metabolic issues complicated everything. We had to resort to psych meds, even, for his depression, anxiety and mood disregulation.*

    We started Kerri's protocol in the summer of 2012, and had to cut the number of drops again and again to something he could tolerate, since he has MTHFR genetic issues with detoxing, until he was at 1/64th of a drop per dose. By October 2012, he was at full dose and after two weeks, began to talk about learning to drive, to offer to do a chore at home, to draw again. So it has been about a year for us, and the improvements are continuing, his ATEC score went from 77 pre-meds to 11 now, and our lives are all much better thanks to this book and Kerri's dedication to the cause of healing the children. Please, if you are reading this, don't be afraid to try one more thing!

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51. *My son started Kerri's protocol 10 months ago. At the time we started the protocol he was doing a home based therapy program for 60 hours a week. We did not send him to school because he was not able to handle all of the outside stimulus, unable to follow directions, and unable to communicate effectively. He stimmed most of his day and only spoke in 2-3 word sentences to get needs met only. When he started the protocol his ATEC was 57. It quickly dropped and the improvements were mind blowing. In 5 months time his ATEC was a 9. Today at 10 months after starting the protocol his ATEC is a FIVE!!!! He now attends school with out any kind of extra support and exceptions made for him. He is truly just one of the other children. I have been volunteering in his school and I have had 5 different office people tell me that he stops and greets them on his way to different specials (p.e, library, art, gardening). They told me he initiates the greetings and says: hello, good morning, buenas noches, and all with a big smile on his face. I have even been told by 2 of them that he greets them by name. Did I mention that he leaves the classroom on his own to go to specials??? Yep, my one time *severely autistic* child finds his name and places it in that specials category*

basket, leaves the classroom and goes to specials on his own???? When he is done with specials he goes back to his classroom and does his work. Holy CRaP!!!! A dream come true.

Thank You Kerri!!

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52. *My 6 year old son's ATEC went from 45 to 22!!! Wow I knew he was doing better but more then half!!*

    Thanks Kerri Rivera!!

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53. *I don't know what to chalk it up to--we just finished our 3rd PP and did our 2nd shot of GcMAF on Saturday--but my 9 y/o son has started taking pictures with my iPhone. They are not just random shots; he is finding objects or angles and taking pictures. They are FASCINATING! He has also figured out how to use the reverse feature, and has taken a series of self-portraits, which he flips through and says to himself "Who's that?"*

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54. *My 16-year-old son is doing great on your CD protocol. ATEC down from 89 to 37. Best thing that ever happened after doing 8 years biomed with him.*

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55. *We started CD with my precious 5 year old 'O-ster' in June 2013. Some of the completely new developments we have seen since we started..... He is aware of how to burp and toot, and thinks it is funny. He is apologizing for things he does wrong. Even a day later, he will remember and apologize. He goes to the bathroom on his own. He is completely pottytrained, even at night. He does household chores happily. He sent people on my contact list emails that said 'I love my mommy.' He has better problem-solving, more motivation to draw pictures. If he gets messy, he just goes to the bathroom and washes his hands and wipes off his shirt by himself without saying anything. He dresses himself. He does somersaults (just a few months ago, it was impossible for him to even get in somersault position), can open baby gates, can get in crab walk position, can jump off of furniture with both feet. He greets us when we come home and is excited to see us. He MISSES us when we are gone and talks about it during the day. He's making up 4 line rhymes. He cares what he wears and picks out his clothes! He is not running back and forth as much. We have normal trips to restaurants. I can leave our front door open now, and not worry that he will run away. He tries to help put our dog in his crate and fetches with him. He wants to come with me if I leave the house to go somewhere. He will now eat almost anything I put on his plate. He used to vomit at the mere thought of things like GF pasta or rice, and he wouldn't allow any food on his plate to touch another type of food on his plate. He will now eat bowls full of tomato sauce, onions, burger, rice, garlic and peppers all mixed together. Our family can eat dinner together now. I no longer have to make separate meals. He even eats raw peppers! He yells 'watch me!' and does things like diving onto the bed or jumping off of something. He looks at cloud formations to see what pictures he sees in them. Last week he heard a toddler crying in Target. He wondered why the child was crying and wanted to go find her. He misses his little sister when she is not at home. He wants her to play with us when we are playing. He is completely aware of what is going on now. He is much more aware of danger. He notices the weather. There is a sense of calmness about him that he did not have before. His tantrums are much less severe and much less frequent. I was supposed to be his aide this year in preschool, but I have been able to just drop him off at school. There are many more new things that he is saying and thinking and doing.*

Our quick biomed history- He regressed after vaccines at 12 months. Starting at 18 months of age, he was gfcfsf for 1 year, then scd for almost 3 years. It feels like we have tried everything with supplements over the last 4 years. Some things helped a little, but nothing really tackled his pathogen load, even though he was on an awesome diet. His ATEC was 66 in Dec 2010. Low dose chelation brought it down to 33 in 3 months. The ATEC stayed at 33 for 2.5 years. We did 112 rounds/weekends of low dose chelation during that time. ATEC June 2013 was 34 (before starting CD), July 2013 was 30, October 2013 was 20! We are on our way down. This is the first time that I have physical proof that we are getting rid of the pathogens that have controlled and poisoned his body and brain for most of his life. It feels so good to finally help him. I am hoping to write our complete recovery story in Kerri's next book. I thank God that we saw Kerri at AutismOne.

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56. *Nick texted me yesterday for the first time, on his own. "Hi from Nick" - that's a 2013 FUA fo sho. – Alison*

    (this text was accompanied by an ATEC drop from 69 at 6 years old to 14 at 8.5 years)

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57. *Yesterday my son told me I worried too much, I said you worry too much Too Noah! He responded, my hair is red, yours is gray, so who is the worrier, hahaaa! The windshield wipers keep wiping away the autism, what's staying around it seems, is completely lucid speech and unbelievable comebacks! He never could say things like that before, not at all, he really was in there somewhere.*

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58. *Something really beautiful is going on in our household right now...Caleb is totally blossoming socially on every level. There is a calmness in his body. He is alert, responding to his name, sharing his toys with other kids, wanting to give affection without prompting, soothing Lilia when she is crying rather than batting at her. We even have gotten a few spontaneous silly phrases!!!! Oh baby, oh baby, oh baby!!! We are on our way!!!!!*

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59. *We started the diet on the 1th of March, CD on the following week. Adam started to ask questions in April. Since then he keeps asking continuously…His ATEC dropped down from 49 to 38.*

    Tunde, Hungary

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60. *OMG OMG OMG!!!!! My son is singing!!! He was ZERO verbal... I mean ZERO!! His shadow teacher told me a week ago that he started to mimic, I said to myself "yeah he was babbling and she thought he is mimicking!..." Yesterday she told me he started to sing and I said to myself, "Yeah right, she is absolutely illusionist or exaggerating!!!" She knew I will not believe her because he is just humming at home! So she sent me a video which was a shock for us. He is singing the song "A is for apple, a a apple... B is for ball, b b ball... C is for cat, c c cat... D is for dog, d d dog..." I don't have enough words to thank you and thank Kerri Rivera and this incredible protocol!!! Thank you for saving my child. xoxo*

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61. *...My son is doing his first CD PP. We picked him up from preschool he was extremely happy. Hugs & kisses. Then...runs up to a classmate and touches his shoulder and says, "bye Johnny", runs to another classmate and says, "bye Kevin." Then he skips to the car. These improvements in his socialization is new. We are so pleased and I wanted to pass along these social gains with you all. His atec at start is 58.*

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62. *My little sweetpea is almost 4...and completely NON VERBAL...upon picking her up from therapy today, her teacher said she was having a great last few days... and both therapists said her eye-contact has been different...like in a really good way!!! I've also noticed her looking at me...straight into my eyes for what seems like forever...almost as if she has never seen me before?! They also said that she has been looking at them and has been opening her mouth trying to make sounds...as if she wants to say something very badly...but can't...but with a lot of prompting...she did say "Hi!"...all I know is that somewhere in there is this amazing person waiting to be let out! I often worry if we are ever gonna make it...finances and healing your family can be very overwhelming...especially on one income. But for the love of my daughter we just cannot give up...feeling very hopeful and blessed today...and very grateful that something is finally working.*

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63. *Hi Kerri,*

I wanted to write and thank you for discovering and sharing your protocol. This protocol has saved my almost 5-year-old son.

My son suddenly started having absence seizures that would freeze his breath. From the day he had his first noticeable seizure, he was hospitalized every seven weeks for uncontrollable status epilepticas, a life threatening condition. They would pump him with seizure meds, Ativan, and Valium for hours before the seizures would finally stop.

Since starting CD five months ago my son has not been hospitalized once. He went ten weeks seizure free. He had a few mild seizures that he brought himself out of without any extra medications. He currently broke this record and has made it another thirteen and a half weeks seizure free. I true miracle.

Everything we searched for to treat his Lyme disease in the past would either cause seizures or not help to prevent them and I now know why. As you predicted after starting your protocols we discovered that he not only has Lyme, he is also incredibly loaded with parasites. So much so, that it scares me to think of what may have happened to him if we didn't find you.

I'm so amazed to watch him subtly emerge. Since we started, he went from saying about 20 words to saying 69 words, along with two and three word combinations, and over the past month he has begun to answer simple questions. His vestibular system has gotten much better; he'll actually swing. He just started jumping off curbs. His eye contact is perfect. He's gained two pounds in the past three months, something he hasn't' done since being diagnosed with failure to thrive at a year old. He is playing with his three year old sister; it's so adorable to watch them chase each other around the house, hug, chase each other, hug, get in the dog crate together, hug, take turns pushing each other in their wagon, and kick the ball back and forth. Last night the three of us played catch together for over 10 minutes. I'm so happy for her to have her brother to play with.

This protocol changed his life, my life, and our family's life.

There are no words to thank you enough for all your help along the way – he's on his way…

Love, Love, Love

Update: as of December 3rd, 2013 this little guy is 18 weeks seizure free!

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64. *My name is Dawn. Below is a shortened version of what we've been through prior to and since Kerri Rivera coming into our lives and changing our family forever.*

I am Noah and Eli's mom, caregiver, advocate etc., that's been my job for 17 years. Prior to having children with special needs I had a career that I loved and my plan was to continue my career, how deluded I was, my life has been forever changed by my children and their symptoms as my entire existence over these years has been to save my son.

My son Noah born August 19, 1996 has struggled and suffered with what is now known as the symptoms of autism. His symptoms began at 8 months of age with a rare blood disorder known as neutropenia, he had a low white blood count. As he continues to improve, I too, along with our entire family seem to be healing as we bore witness to his daily struggles of self injurious behaviors, aggressions and rages, learning disabilities, speech and auditory delays, 2 steps forward and 4 steps back.

Healing the symptoms know as autism with the Chlorine Dioxide and Kalcker Protocol have been a cathartic exercise for me as well, no amount of therapy would have soothed my soul like witnessing my son's return from the daily brink of death.

My hopes and dreams for my son dashed with vaccines before he was old enough to speak. I'm 50 this year, however I'm older then those years, and my views and outlook on life have changed forever. Imagine fighting for my son's life against those trusted factions of our society supposedly put in place to protect us, i.e., government agencies, churches, schools, teachers, principles, school boards, doctors, hospitals. I'm changed forever by the daily battles, but somehow they are small now in comparison to the beast of the symptoms that ravaged my boy with red hair, often referred to by me as my favorite Martian. As he continues on his healing path, so do those of us who have loved him so dearly, despite his outwardly awkwardness, he is the innocent victim left to suffer for what is often referred to as the "greater good", he's responsible for so much more in my life then just the symptoms known as autism.

It was a Saturday morning in May of 2003. Noah, at the time 6 yrs. old, had slept with us because of seizures on and off through the night. Like so many times before, I was very concerned he would go 'status epileptus', a state of continuous seizures. He ate cantaloupe for breakfast that day. I remember it vividly even 11 years later. His seizures would come about every 20-25 days. First he would complain of a stomach ache, and I could hear the gurgle of his stomach. They usually lasted a few minutes and then went away. This day, the Saturday before Mother's Day, he didn't come out of the seizure. We administered his anti-seizure medication but it didn't work. We called 911, the fourth such call in Noah's brief life. When EMS arrived, Eli, then 3 years old, ran to his bedroom upstairs. I remember the technicians working on stabilizing Noah. They ripped the shirt from his body as they worked on him and carried him out to the ambulance. As I followed them to the ambulance I happened to look back to see Eli watching from his upstairs window as they placed his brother in the ambulance. He stood motionless. Darryn scooped him up and followed us as we drove swiftly through traffic to Texas Children's emergency room, about 25 miles away. I remembered thinking, why don't people heed the right of way? I looked back as they worked on Noah. His seizures continued until we arrived at the hospital. Once we arrived he was taken straight to the ER, ICU room, where

four doctors began to work on him. Darryn and Eli arrived as I stood next to the bed while the doctors worked to save his life. I took Eli out of the room and we sat in a chair looking in at what was happening. His eyes were as big as I have ever seen them and he sat perfectly silent in my lap, we colored. I overheard the doctors explain to my husband that they were having problems stopping the seizure. They wanted permission to use a drug that could stop his heart. Darryn asked if there were any other options. The doctor shook his head. He asked what they would do if the heart stopped. The paddles. So he was given the drug. No heart stoppage. His breathing became shallow and the seizures finally stopped after 6-7 straight hours. A couple of hours later Noah woke up in his hospital bed, connected to monitors and the like, in a drugged stupor. By this time my parents had arrived (like so many times before) and had taken Eli home. Darryn stood next to Noah's bed rubbing his chin nervously. Noah asked if he could use the restroom. Darryn said yes, and in the next second Noah leapt from the bed, almost a perfect swan dive, toward the floor. Luckily, Darryn was there to catch him. Noah's life was saved twice in the same day. After the drugs wore off, he was released from the hospital. Noah missed a week of school while he learned to walk again.

I never knew the impact this had on Eli until Father's Day that same year. About a month after the seizure we planned to attend with some friends one of those workshops at Home Depot where the kids make a gift for Dad. He was excited to do the workshop. As we approached the store we noticed the local fire station had an area of the parking lot roped off for tours of ambulances and fire trucks. Eli became frightened and started crying, and began backing up, finally screaming and contorting. This from a child that hadn't given us a peep of trouble before. I had to leave our friends standing in the parking lot as my second son became inconsolable. At the time it hadn't occurred to me that he remembered the incident with his brother just a month prior. He too suffered, and sadly he was 3 years old at the time, unbeknownst to me, Eli has probably remembered more then I realize even today.

Noah had his first seizure in March 1998 at 18 months of age, shortly after a round of vaccines. (His doctors continually assured us that vaccines had nothing to do with Noah's problems, but I know otherwise.) Seizures were not Noah's only problem, however. He was diagnosed with neutropenia (the lack of neutrophils or a type of white blood cells) in 1997. He has suffered from acid reflux for as long as we can remember. He was hospitalized for 4 days at 4 years old for a roto-virus infection, something most children get through at home in a couple days. He had a cyst removed from his thyroid. His tonsils were removed due to frequent infections. In 2005, he was diagnosed with Lyme disease. In 2008 his pediatrician discovered his blood was missing carnitine, a key component for the body's metabolism. We took him to a specialist who diagnosed him with mitochondrial disease. His seizures stopped after we started giving him medication for the carnitine deficiency. But his behavioral symptoms continued and even worsened which always indicated a deeper underlying illness plaguing Noah. But what?

Early in 2013 Noah began to show some psychiatric symptoms that frightened us to the point we had to consider putting him in a home. He had frequent panic attacks (all day, minute to minute), tics, and sudden bursts of outrage over insignificant things. He often didn't make sense while speaking, and secluded himself in his bedroom. He fantasized uncontrollably about his videos, and spoke over and over about what we were going to do about the characters (not what

we would do if we were in the stories). He had repeated events of unrealistic fears. We took him to see an energy medicine specialist. The energy medicine protocol involved various supplements and dietary changes, as well as electrical pulses to adjust his body voltage (an approach similar to acupuncture). During one of our visits we learned of MMS, which this doctor indicated could be used in small doses to treat colds. Symptoms improved, but very little. But then they worsened again dramatically. We took him to his pediatrician who diagnosed PANDAS, and prescribed antibiotics. This helped but only temporarily. His psychiatrist prescribed anti-anxiety medications, with only marginal results. He was unable to attend school through all of this, and needed someone by his side constantly. His pediatrician prescribed Albenza thinking parasites may be involved (despite a negative stool test). This improved his behaviors some but only marginally. There was also the side effect of hair loss. Noah became completely bald, like a cancer patient.

To see your son regress into psychotic behavior is something no human can ever imagine. Facing people everyday as they watched Noah regress and comment, it was a slow slip and then suddenly he was in a dive toward insanity. I felt he was slipping away. I scoured the Internet for answers. I had heard of Kerri Rivera but thought antibiotics were the only treatment for my son, like the vaccines, I had been told by doctors that the only treatment for Lyme was antibiotics. I emailed her and she answered immediately to "start the protocol." We began the CD protocol in June 2013. The protocol takes complete dedication, it requires steadfast commitment, and it's the best gift I have ever given Noah. I have learned so much about illness and it's roots through treating my son with the protocol.

Noah's behavioral symptoms started to improve immediately. He had fewer and fewer tics and outbursts. He was noticeably calmer. He now answers the phone, takes messages, and helps me scan food items at the grocery store. He even got behind the wheel of our car for a practice drive in the school parking lot. He asks a lot of questions. So much has improved in such a brief time. Prior to the CD protocol I scored Noah as a 38 on the ATEC test. Since then, he has improved to an 8. Darryn (Noah's Dad) scored Noah a 55 before we started, and two months after beginning it was a 22. It's amazing that a few brief months ago we were considering having him put him into an institution. Although we try not to think too far in advance, now we can hope our son can someday lead the normal life he was meant to.

I can't help one final story about Noah. Yesterday he asked me what autism was. We've never explained to him that he has it, because he would not have been able to understand it even if we tried. While I searched for an answer, he said "you know, Mom, Sponge Bob couldn't get his boating license because of his autism." I belted out a loud laugh and said "Ok. Noah, you know you have a little bit of autism too." And he said "Yes Mom, I know that," and smiled.

While he still has much to make up, years of life to regain, experiences to live, we're so pleased and grateful to Kerri and the others responsible for these protocols for these improvements, his life is being restored. I would encourage anyone to follow the protocols as closely as possible and do not delay. It is so fitting that the only opportunity I've ever been given to tell a little of what my family has been through would be afforded to me by the very person that actually saved my son…she gains nothing from what she has done for us, except the knowledge that she saved a boy's life that she has yet to meet, by saving my son, she has saved my family.

65. *Shay is doing so well it's surreal. In the past week the balance has shifted so that he is now recovered more of the time than not. He is having a 2-4 hour block every day or two where he is back in his old state (weeping, raging, zero-to-flipout, shrieking, obstinate, defiant, OCD, mean, potty-mouthed, etc.). The rest of the time he is lucid, has perfect mental clarity, is as funny as can be, does his math quickly, has perfect handwriting, gets along with his sister, is generous, expresses himself clearly, plays well, understands how others feel, etc. It is a mind blower Kerri.*

    Although Shay doesn't have the awareness to know when he is in the autistic state, he is now clearly aware when he is in the recovered state. He comes up to me and says quietly, "Mom, it's gone again. Do you think it will come back?" I tell him yes, that it will be like this for a while, coming and going, until one day it will be gone and it won't come back. Shay and I have been discussing which "number" he is going to be in the line of children that recover. :) He is also planning a big "Goodbye Autism" party for himself.

    Bella is getting over her meltdowns much more quickly. Sometimes I say "no" to something and then flinch, waiting for the screaming, but it's small, or sometimes she cries and gets over it within minutes. This is a big improvement for her. In her own words, she has noticed that she feels less anxious.

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66. *We started the protocol 9 months ago. My son had 2, 3 horrible days every month. He wouldn't stop crying all day long, and he could not get any sleep at night. After talking to Kerri, we realized that these terrible days were always the days of the full moon. We saw improvement straight after the first PP. After 6 months, all of the bad behaviors were gone. I realized that the PP helped my child to improve month by month.*

    And to prove that it is not only me who can see the changes, my son's therapist from school told me the other day: "Well, when is full moon again? So that you would start the Mebendazol? I love when he gets it, he is doing so well with it".

    Staring atec in February was 50, now his atec is 34. Thank you so much, Kerri!

    Betti, Hungary

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67. *We are celebrating 3 months on CD and 2 PP's done! Our little angel has (or I should say had) extreme ADHD...we are not seeing much of that anymore. Our life altering issue is her lungs. This child has undergone over 35 surgeries in 8 years. 17 of those to surgically remove mucous from her lungs. She is hospitalized every 6 weeks with pneumonia. We have O2 in our home. She even had a port placed for IV meds at home. Our life has revolved around illness. In 8 years the docs have done every test in the book to figure out the cause. We've turned up nothing. In July, we flew to NYC to see a medical mystery doctor. He told us it's all nutritional and had us do some parasite testing. The testing turned up zilch, but thanks to Jean Marie, we ended up here. Long story short, we are making huge strides. We are not there yet, but to give you an idea, normally her pneumonias take 4 months to clear, this time it was only one month! She's only needed one antibiotic in 3 months, normally it's 8 antibiotics in 3 months. She's doing better in school too, which is just a bonus. Today she came home and told me she was able to run in gym, something she hasn't done for years! Thank you Kerri Rivera and Jean Marie and all the mods for welcoming us to this group and for helping us to take back this child's life. Bless it! Bless all of you!*

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68. *30 days of gratitude, Day 4...I am thankful for an evening alone with my son. It's rare that we have time together alone. He jumped on the bed and danced around while I packed for my trip in the morning, talking and singing the whole time. The dinner table was lonely by ourselves so we decided to eat in front of the fire. I said, "This is fun, isn't it?" and he said, "I love this and I love you, Mom" Moments like this were non-existent before our journey brought us to Kerri Rivera who is an angel on earth. She gave us the direction we needed to heal our son.*

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69. *I observed my kiddos at school today. Get this.....my once severely autistic 6 year old choose and received a Spanish lesson that lasted 27.5 minutes (I timed it). The whole lesson he was sitting on his bottom, following instructions, answer questions correctly (in Spanish), smiling, great eye contact, and really enjoying his time with the Spanish teacher. FUA to the max! This time last year Henry was speaking in 1-2 word sentences to get needs met. Now he is talking in complete sentences in English and Spanish!!!!!!!*

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70. *In the past, if I gave Nate a hug and told him I loved him, he would sort of hug me back, awkwardly jutting his backside out (to reduce physical contact) and patting me on the back and saying, "I love you, too." He would then escape as soon as possible.*

    After a few days of being on 7 drops (last week) Nate approached me with full eye contact, threw his arms around me, gave me a prolonged bear hug and spontaneously said, "I love you, Mom". I hugged him back and we stood there, just enjoying the moment, while I quietly balled my eyes out.

    Thirteen years. I had waited 13 years for that moment.

    And now he has been doing it almost every day since that first hug.

    This alone is the world.

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71. *There's a lot of people jumping on the "Thankfulness Train" this time of year. Here's my contribution. There's only one major thing I can think of this year that I am thankful for. Of course, there's so much to be thankful for, but one thing that really stands out. That would be this protocol. God led us to see Kerri Rivera at Autism One this year. I only went because it was basically the one thing I didn't know much about. The day before Kerri presented, I saw my friend Laura at Karaoke Night (so fun by the way!). She told me she was doing CD and I'm pretty sure I looked at her like she was crazy! Saw Kerri the next day and I was hooked. We started the protocol June 3rd. Laura got me in this group. Thank you Laura, for your patience with me and for letting me know about this group! Thank you, Debbie who has talked to me many times about the protocol, about my son's aggression, reassuring me that things will get better and they have! Much, much better. We still have further to go, but there is light at the end of the tunnel. My four kids and myself are doing the protocol. We all have Lyme. We are all feeling so much better. We are no longer spending thousands of dollars a month on empty treatments. We are getting our lives back; our finances under control, and my son with autism went from an ATEC of 47 to 20 in four months. Thank you and love you all. And to Kerri Rivera, there are no words. Thanks and love isn't enough. You can be assured of my prayers for you, Patrick and your family for life. That's the least I can do for all you have done for all of us.*

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72. *Small progress this week! My son had his ABA therapy yesterday and at the end the therapist gives him a "high five" before he leaves. The therapist asked my 3-year-old normally non-verbal son for a "high five". My son looked at him, gave him a high five and said "HIGH FIVE!" plain as day. My husband almost fell over sideways in shock! He also put his toys away without being asked to, and that too is a big change. CD is the best!"*

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73. *We have been on the protocol since Aug 30th of this year. We've done one PP. My DS is 8 with severe apraxia and autistic.*

    ATEC: 4/2013: 62 starting some biomed

    ATEC: 8/15/2013: 51 before CD

    ATEC: 10/6/13: 24

    Some WOW moments for us so far:

    * *Playing soccer with other kids at school three weeks after the start of the protocol. *Really "on" in conversations...adding information when we didn't think he was listening because he was playing on his iPad.*
    * *Talking about other things in his day besides Minecraft or Plants Vs Zombies.*
    * *Going from a battle with homework that would last over three hours to picking him up at daycare with his homework already finished. And correct. That he did on his own.*
    * *His ST saying he is able to follow three step directions better and was able to talk/ask Who and What questions for nearly the entire hour...I actually had to tell the ST what we are doing because it was obvious to her it was more than just diet.*

    He's just happier. We're all just happier.

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74. *We came back from our Intensive in December of last year on a high. After a week with the Son-Rise® team, Jordan was saying 20 different words; he was more confident, and more mature. He had such an amazing time learning and growing. Every morning he would take his facilitator by the hand and walk him/her into the playroom. He really grew up that week. I loved watching him grow through love and laughter. What an amazing, wonderful thing to witness.*

    We, also, learned at our IAHP appointment that Jordan was reading at about a third grade level. What a trip! The evaluator held up a paragraph for Jordan to read. It was so fast I didn't even have time to read it. Then, she held up a question for him to read, then, a sheet with the answers. She, then, asked him to point to the answer and he did. He was three for three. My son taught himself to read. What?! We were, also, very surprised to find out that between running our Son-Rise® program and incorporating exercises from IAHP, Jordan improved 433% from September to December. WOW!

    Between the two experiences on the east coast, I felt like I didn't know my own son. I always believed he can accomplish anything and yet I had tremendously underestimated his ability. I was so excited to get home and start his program. I knew that if we focused and put everything into his therapy for two years, he would be ready to go to mainstream kindergarten.

    I was so excited; I was beyond hopeful; I believed he was on his road to healing.

    On Christmas Eve, Jordan was crouching down and just froze there. I called his

name, no response. I ran over to him and noticed his lips were turning blue. Immediately, I tipped him over, hit him on the back and did a swipe in his mouth to get out what he was choking on. There was nothing there, but he gasped for air and began breathing again. Did he just have a seizure?

January 15 has become a day I will never forget. We woke up to Jordan throwing up and he didn't want to get out of bed. He just wanted to sleep; he must have caught the flu and needed to sleep it off? Finally, around 10am he got up and ran around the house like nothing was wrong so we began therapy. While I was in the playroom with him we were jumping on the trampoline and he suddenly stopped and looked at me with a panicked look on his face and reached out for me. Clearly, jumping was too active for his upset stomach so I brought him to the family room with Kaiyan and my helper.

Suddenly, he looked off and froze again. He then threw up again and passed out. Oh shit, he just had a seizure, and another one, and another one, and another one. All the while staying unconscious. I brought him to the ER where he slept and had another mild seizure. While he was passed out they gave him a CT head scan to make sure there wasn't a bleed or something in his brain. Everything was fine.

Shortly after, he woke up. He was playing, running around the ER as if nothing had happened. He went through what little water I had brought and was asking for food and water. A good sign, I thought. The ER wouldn't allow him to eat or drink anything "just in case". Anyone who knows anything about seizures knows that no food and drink could very well cause a seizure…and it did.

This time the ER Doctor went into full-blown panic mode, probably because she saw what happened. They began trying to get blood out of him. On a good day this is almost impossible. Now, they are trying on a kid that didn't have any fluids in his system to help expand the veins.

And so it went, needle poke, dig around in the arm searching for a vein, Jordan would hold his breath from the pain and have a seizure. Seizures are typically the brains way of trying to get oxygen; the pinpricking was inadvertently inducing seizures because of the breath holding. This went on for two hours: needle poke, dig, hold his breath, seizure. They poked him 27 times: in his neck, head, ankles, thigh, anywhere they could think of.

This of course wasn't enough. They insisted on doing a spinal tap to check for meningitis, which we had been declining all day. Now they are telling us that the way he had been seizing for the past two hours is classic for meningitis and not doing it could be fatal. They crunched him in the tightest ball they possibly could and held him so tight he couldn't move…or breath. After the fifth poke, I began to get faint and had to sit down. They didn't know what they were doing. When I sat down I could really see how they were holding him and asked if he was breathing. The nurse looked down and said, "he's blue, get the oxygen" and they put oxygen near his face.

I immediately thought, "they're killing him. They don't know what they're doing." That's when I reached out to every FB group I'm on and asked for prayers. That was the only thing that was going to save him.

When they, finally, let him go he had the worst seizure he's had to date. He was actually convulsing. As they went for blood the 28th time, I told the nurse that's enough. This has gone on far too long. She agreed, ran and got the Dr., they wheeled him into to the CPR room, and called for a crash cart. I think I said, "what the fuck?" She said it's "just in case".

They proceeded to get a drill and drill a hole through his shin and into his shinbone so they could put in an IO (IV into the bone). They pumped him full of all kinds of drugs and, at long last, drew blood.

He looked up at me with a longing in his eyes and reached out for me. I went over and put my hand on his chest and he passed out. He was transferred by ambulance to our local children's hospital; we were allowed to follow the ambulance, but couldn't ride with him. He remained unconscious until he arrived into his private room at the hospital.

The first thing he did when he woke up was reach out for my hand and give me a kiss. My little boy!

The blood they had finally taken revealed low electrolytes and bicarbonate at a life-threatening low level. Screaming and crying can drop bicarbonate, which he did for two hours in the ER; lack of food and drink can drop bicarbonate levels, which he wasn't allowed to have in the ER. Low bicarbonate levels can cause seizures. What a recipe for disaster!

The hospital ran every test they could think of and no reason was found for the low bicarbonate or the seizures. We came home after five days, followed by several follow up appointments over the next two weeks. Everything seemed to check out fine until I brought his labs to his DAN (Defeat Autism Now) Dr., she looked at the blood test, pointed to something and said, "Lyme, every time I see this in one of my kids, it's Lyme."

We had the (one of many) $800 test at the best lab in hopes we wouldn't get a false negative, which is very common with Lyme. Jordan came back positive! Now we had something to go on. I was excited to finally have an answer to what was going on with my little boy. Lyme is known for seizures and abnormal electrolyte levels.

We scheduled an appointment with a Lyme Literate Medical Doctor (LLMD) and were ready to start healing our guy. Two days before the appointment, we woke up to Jordan vomiting. He didn't want to get out of bed. He finally did and ran around like nothing was wrong and then he had another seizure. We were told to take him for blood tests immediately the next time he had a seizure. We took him to his DAN Dr. an hour away, but knew they would be able to get his blood without difficulty. We went to lunch, came home, he had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, passed out. His DAN Dr. just happened to call to check on him in the middle of this and told us to get him to the hospital before he had a heart attack. We went to the ER...

And so the story goes every seven weeks TO THE DAY, seizure, turn blue, vomit, pass out, seizure, turn blue, vomit, pass out, admitted to the hospital where he was pumped full of drugs for hours to try and stop the seizures, and they ran the same tests over and over again. The hospital didn't think he had Lyme even with a positive test and thought that seizures every seven weeks to the day was a coincidence, although, they could still not offer any explanation.

We tried treating him with ABX that the LLMD prescribed. One teaspoon and he had a seizure, turned blue, threw up, passed out, had a seizure, turned blue, threw up, and passed out. This time the Valium I administered did stop the seizure cycle, most likely because it was induced from the ABX and not part of his regular seven week seizure cycle. He had multiple mild seizures every day for two weeks from that one-teaspoon.

Clearly, ABX were not going to work. I emailed with a woman who coauthored the book, "The Lyme Autism Connection" and tried the homeopath that she used down in San Diego. This was definitely working with detoxing, but it wasn't helping with the seizures. He went from seven weeks to the day to three weeks to the day. This treatment was working on opening Jordan's detox pathways so his body could rid itself of the Lyme. I liked the idea of treating this way, but the process could take four years. I didn't want Jordan having what the neurologist told us were life-threatening seizures for four years. I was desperate to find something to help him.

We knew what was wrong, but needed something safe to treat him. Nothing was covered by insurance and we were running out of money. I had lost hope. Every treatment seemed to make him worse and I couldn't bear to see my boy suffer the way he had been for the past six months. I didn't know what to do.

I, literally, got on my knees and prayed for help every night. In the same week, a woman who attended the same Son-Rise® start-up emailed me about a newly discovered treatment she was doing. I had signed up for a Lyme conference that mentioned the same treatment, and I had signed up for an autism telesummit that unbeknownst to me had Kerri Rivera as one of the speakers. (Kerri is the woman who discovered this treatment for autistic kids.) I emailed back and forth with Kerri, I posted on the FB group, trying to get all my questions answered. I was terrified to treat Jordan with anything given his seizure history.

Then, he was hospitalized again for uncontrollable seizures and I realized I couldn't let fear get in the way of helping him. I started the day we were home from the hospital at a really low dose that Kerri recommended. She has held my hand through this process to help prevent him from having any seizures.

Since we started in May, he went 10 weeks seizure free and had several mild seizures that he brought himself out of without any extra medication and NO hospital. He is currently at a record-breaking 15 weeks seizure free.

Through this treatment we have learned that in addition to Lyme he has three different visible parasites. He is loaded—he passes more parasites than most of the teenagers in the FB group. It scares me to think what would have happened to him if we weren't led to this treatment. Thank God for Kerri Rivera sharing what she has learned and being so gracious and generous with her time.

I'm incredibly grateful we attended the Son-Rise® Intensive before all of this began. His team of facilitators created a base for him that continued to blossom even through this tumultuous year. Coupled with the parasite treatment, Jordan has gone from 20 to 90 words—he's picking up new words almost daily. His balance is amazing, his muscle tone is getting better, and he understands everything. Even more exciting, he's playing interactively with his sister. He is on the road to recovery.

We are finally able to start picking up the pieces of where we left off back in December. I felt stuck; I had PTSD; I needed help believing we can move past (what I had deemed) the horror of this year. The first thing I did was turn to Son-Rise®; I started having monthly dialogue sessions with Bears (Barry Neil Kaufman)—the co-founder of Son-Rise®, which has been incredible. This is one of those times that happen in life that can make you a better person or break you. Bears is guiding me to be better. I just arrived back from another Son-Rise® training where I realized that staying in fear and being nervous about getting excited or anxious about feeling hopeful again will prevent me from being the

bridge to healing that I want to be for Jordan. I felt a relaxation that I haven't felt all year. I've been wound real tight, waiting, being on the look out for that next seizure.

This year has had a huge impact on Kaiyan as well. She'd see her brother sick and then her mommies would disappear. I'm noticing she's wound pretty tight as well. Her favorite moments are when the entire family is together. I'm hoping talking with her about what happened and spending more one on one time with her will help. She asks daily is Jordan throwing up, is he having a seizure? She doesn't really know what it all means, but is really aware it's not good. She, recently, said she wanted to have autism. After I explained to her that autism is why Jordan isn't talking or riding a bike, she decided she didn't want autism. She wants to be a boy and insists on wearing Jordan's clothes almost daily. I think it's her way of healing and feeling included in the process.

We've been doing Son-Rise® again and it feels great. I do feel like we have some time to make up for since this year has been spent dealing with health issues rather than cognitive issues so we are working up to having a full time program, having quarterly consultations, and doing another Intensive.

Son-Rise® and Kerri's protocol's are not only bringing our son back, they're bringing me back.

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75. Healing From Autism

Hospital birth, bottle fed, fully vax until age 4. Digestive disorders beginning at age 1. Low tone, speech and language delay. Mild early education interventions. GF since age 2, GF, Soy free, sugar free since age 4. Majority of autism symptoms presented in 2013; in the fall of 2012, our son did not qualify as being in need of special education, and thus, could not attend school in our district at all.

Long winter days in a tiny home had me sending him out to play, in our tiny backyard, which had a patch of grass and a bush, under which small animals and birds lived. In his boredom, he sprinkled the dirt all over himself; his head, face, clothes, shoes, on several different days.

Later in the early spring, the symptoms of autism appeared more and more obvious: disobedience, disinterest in sitting for a story or coloring, lost interest in puzzles of more than 24 pcs, jumping on and off furniture for hours, despite scoldings and time-outs. Sudden relapse in bedwetting. Then by summer, the symptoms were very obvious: longer tantrums, rages, anger issues, hitting, fighting, a mean spirit; running out of the house without permission, with no respect for danger or regard for safety. Weepiness, hypersensitivity to touch, suddenly repeating the same phrase, over and over all day. Lost balance and coordination, bumping into walls and furniture, stubbing toes. Shoulder shrugging, all day, but not able to stop or say why he was doing it. Lost dexterity—could not put cards in a box. Lost organizational skills—could no longer put toys or clothes away. Extreme nighttime drooling and bedwetting. The need for sameness, and to have all food served cold. He frequently did not seem to be in his right mind.

In desperation, I asked a group of special needs moms for advice, and ordered a handful of books on Autism, including Healing the Symptoms of Autism by Kerri Rivera.

It was the best money I ever spent.

I read the book thoroughly, ordered the supplies and began the CD Protocol on July 8, 2013. Starting ATEC: 46. We ramped up slowly on drops, serving doses 8 times per day. My son has had two low dose/partial PP's, to minimize the emotional meltdowns, the gas and discomfort. I did not realize how very deficient in minerals he was, and did not give him enough ocean water. Now I order the big 10-liter jug of ocean water, so I am not tempted to be stingy. He needs more than 100 ml ocean water per day for his digestive system to handle the parasite dumping during the PP. His previous digestive trouble was unexplained chronic constipation, since age one, and that is really linked to his high need for the OW. Interestingly, his doctors had all said to keep giving Miralax, and that he might possibly need that laxative every day for the rest of his life. We stopped the laxative when we started the CD program, and began the enemas right away. When I sifted the stool and saw the number of parasites, I understood finally why he couldn't poop well on his own for the last 4 years, despite diet interventions. We are looking forward

to PP #3, in which I hope to ramp up to full dose on all components.

Poop sifting revealed what 6 pediatricians and 2 GI specialists could not tell us. Our son is infected with at least 6 different kinds of parasitic flukes and 3 kinds of parasitic worms. His stool has had a very large amount of sediment, with odd, tiny, but defined shapes. A search for "rodent and avian parasites" reveals photos of very tiny creatures.

I just completed his ATEC at Kerri's request: November 12, 2013: he now scores a 10, with a 1 in language, 2 in social, and 7 in health.

What does his recovery look like? We enrolled our son in a small private school this fall, with one teacher for 6 students, no aide. He now memorizes poems, Bible verses, and songs. He sings, knows his alphabet and all the sounds of the letters, and can count to 47 with precision. He shows kindness to others, is mindful of safety, and has glowing reports from his NT school. He sits with me for stories, and brings books to 'read' to his baby sister. He is not literate quite yet, but enjoys word search games, where he can complete levels and advance to more challenging puzzles. Twice now he has played the word search game on Leap Frog for 45 minutes. He has regained his balance and coordination. The rages, anger, and shoulder shrugging disappeared within the first 10 days on CD. He identifies printed numbers and letters, and does well in math, phonics, penmanship and reading class. He is learning to write numbers and letters in cursive, and follow directions on drawing worksheets. He operates the TV and DVR unaided, recording and watching programs he chooses.

He is happy; he has a patience and joyfulness about life that was previously lacking. He tells me jokes, and now has the coordination to operate a hand puppet while speaking for the puppet!! He is thoughtful and obedient. He has regained fine and gross motor skills, and motor planning skills.

There are still improvements we hope for: further speech, language, and vocabulary improvements. Social graces. More improved digestive health; I can see that he still has parasites in his stool. We will continue the CD Protocol, and we look forward to further healing. Thank you all for your support and encouragement.

The CD Autism Program has done more than cure our son of his brief affliction with Autism; it addresses the pervasive, underlying gut disorder and parasite issues that have plagued him all his life. Where complex testing in expensive medical centers has failed, a simple home health program succeeds. Thank you Kerri Rivera!!

76. *Well...we too did an ATEC! Our son was 11.5 when we started the CD Protocol July 2012 First fully loaded (All PP meds on board) was November 2012*

VERY First ATEC: Jan. 2006= 124

ATEC in July 2012: 64

ATEC August 2012: 52

ATEC Oct. 2012: 48

ATEC Dec. 2012: 45

ATEC May 2013: 40

ATEC August 2013: 39

ATEC NOV. 2013: 33

I actually did one myself as I have done throughout all the previous, but I had hubby do one and combined and divided by the 2! Resulting in the 33! Oddly, it's the "SPEECH" that remains consistently around 14 & 15 throughout ALL of these! All the others continue to go down! We've had some ups and downs, but with continued evacuation of some MIGHTY big worms...we continue to see major gains!

This is the ONLY Protocol that has EVER given us the progress we've seen in one year's time let alone in 6 months! Thank you Kerri Rivera and especially Patrick Rivera for being such pioneers in this journey to recovery! You are SOOO loved and appreciated beyond words! Thank you for never giving up! Thank you for giving so much, and bringing healing to our son! He's come a long way, but we have a ways to go! But with the progress he's making...I honestly feel it will seem like nothing from where we've come!

Again THANK YOU! XOXOXO!

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77. *We had a great day today. For the first time, he joined me in throwing something at a target (blocks at carpet circles). He laughed and smiled and pulled me to play with him better than he has in weeks. I heard a lot more sounds and approximations today. When I couldn't figure out what he was saying, he kept trying until I did.*

My favorite part of the day, and I know this is odd, was when his head collided with my mouth. I exclaimed in pain and he was clearly worried/empathetic. He kept trying to get close to see my lip and giving me kisses. I've seen him concerned before but never that clearly empathetic.

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78. *Just wanted to share that on 21/8/13 my sons ATEC was 46, just redid because we're at the start of our first pp & his score has come down to 31! The big improvement came after introducing CD enemas 3 weeks ago. Although he's been on oral CD for about 2 months, it was always the case that if I missed a dose within 1/2 hour he'd be sensory, inflexible, super-anxious, shouting, aggressive etc & I'd have to syringe it down him but within 10mins of dosing the lightswitch would flick on & he'd be in control & a calm, loving boy again. Since the 3 enemas I gave him 3 weeks ago (only 3 because then his brother had one, panicked, screamed & totally freaked out my 4yr old who up til then had said he liked them bc they made him feel good afterwards) his personality has been shining through again, there's less panick/anxiety, less sensory issues & there's no 'reaction' if I miss a dose or more of CD. I've seen more improvements this week, on Monday he decided to sit down & colour & proceeded to colour neatly,*

inside the lines - he was so pleased with himself! (He used to colour so neatly but about 6 months ago his colouring became scribbly & he frustrated that he couldn't do it neat anymore). Then tonight, when I asked him to hop out of the bath, HE DID! He stood up, stepped out & as I handed him a towel he took it & said 'thank you mummy' and wrapped himself in it & walked out - all completely relaxed - like it was usual!!! WWWOOAHAHH! Yes! He has never done this, it's always tantrums, always arguing, needs to bathe longer, has to be made to get out, refuses to step out, has to be lifted, needs me or hubby to wrap & dress him, & usually all while panicking, crying, demanding, arguing or screaming because it's cold, different, he doesn't want to, it's not right etc. I just can't believe what happened tonight! I'm still astounded. It's like the Finlay we 'know' isn't Finlay & now we're beginning to see who he really is!

So I'm REALLY excited about our 1st pp. We're already seeing full moon behaviours & although tough it's been great to see them because it's a reminder of what Finlay was like every day until 3 weeks ago!

He's already healing. It's soooo exciting! Thank you Kerri - may God bless you & all the children on this protocol. Healing, here we come!

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79. True Hope by Maggie Kaye

Most people don't know that babies are born with about 100 million brain cells. That is more cells with more connections than there are stars in the galaxy! This is difficult to picture when you consider an infant's brain only weighs about 12 ounces at birth, about 25% of it's full size. But, there is a logical explanation for this: Brain cells; like the brain itself, have yet to grow. As neurons (brain cells) mature, they become larger, stronger, and form tentacle-like branches that form synapsis (connection and communication) with other brain cells. Brain growth is directed by neural activity. The neural activity of the cerebral cortex (the largest, most complex part of the brain) molds the way a child will think, behave, and acheive.

Conventional wisdom long held the belief that the human brain cannot change… that it is hard-wired at birth. Scientists today have proven that this is not the case. They have found that the brain is malleable. It has the ability to change shape, size, number of branches, number of connections, and even the strength of it's connections over time. The potential growth, or neuroplastisity (neuro means neurons or brain cells, plastic meaning changable) is far-reaching. At birth, the brain is simply a blueprint of what it will become. No one can predict the amount of growth that a brain has yet to acheive.

For the parents of a child with Autism, the diagnosis can be devastating. But, the biggest and most harmful blow can come from the prognosis: There is no cure. Kenn and I were given a diagnosis of an Autism Spectrum Disorder for our son, but we were not given this prognosis. In fact, the word "Autism" was avoided at our son's diagnostic evaluation until the therapists heard us say it first, and realized we were comfortable with the word. For many parents, a diagnosis is the end all, be all. For far too many parents, the words "No cure" are scary and harmful. We did not hear these words nor would we have accepted them as truth if we had. We do not want to change our son. We want him to be his best self. We are not looking for a cure. We are in search of treatment and

healing for his symptoms. We know and understand that a Therapist is not God. A Therapist cannot predict the future for our son. He or she can simply assess where Gunnar is developmentally and give us options for a treatment plan for a healthy, successful future. Our son's diagnosis was not an ending. It was simply the begininning of a journey through a world of strength, challenges, support, opposition, and the love of a parent that cannot ever be fully defined.

Our son, Gunnar was born with an Autoimmune disorder, Hypothyroidism. He was tested at birth, was diagnosed, and has been treated by an Endocrinologist since he was three days old. We were not upset by the Hypo diagnosis, but rather ready for the course of action to regulate all of Gunnar's bodily systems. What did surprise us was the constant shrugging off of our concerns over our son's developmental delays and gastrointestinal symptoms over the last few years. We were continually disappointed by the compartmentalization of our son's physical and mental challenges by every Pediatrician and Specialist we saw. To us, Gunnar's symptoms all had to be as connected as are all of his body parts. But, we were treated as if our concerns were dumbfounded…as if digestive, behavioral, and physical challenges were not intertwined.

Let's be clear...The brain does not function in isolation. It is a team player. It needs vital nutrients and informational input to perform at optimum levels. To fill these needs, the brain relies heavily on complex interactions between the immune, endocrine, and gastrointestinal systems. Gunnar, like so many other children on the Autism spectrum, suffers from gastrointestinal issues uncluding chronic constipation, diarrhea, and abdominal discomfort. Scientific studies and countless parent reports are pointing to gut inflammation caused by casein, gluten, and soy in our foods. Gunnar has shown clear physical and behavioral reactions to these foods, and improvement in these areas with the removal of Gluten, casein, and soy from his diet. This is not an allergy from the perspective of a traditional allergist. This is what is called a T Cell Inflammatory response.

The use of a gluten, casein, and soy free diet as a means of treatment for Autism symptoms has gotten mixed responses. Many parents and doctors who deal with Autism, Immune, and Endocrine disorders rave about it's benefits, including me and my husband. Still, others call it "junk science". Clearly, if someone is looking purely at one body part at a time, they will not be open to the truth that the body and brain are codependent. I, personally, have been challenged by the choice to follow this diet for my own thyroid disease and for my son's Autism. I was even told on an online support forum that the GFCFSF diet is "fake science" and is causing "false hope" for parents of children on the Autism Spectrum.

False Hope?

This may be one of the biggest oxymorons I've ever heard. This ranks right up there with "God Hates". I cannot say what causes people to be so oppositional to our choice to follow this eating plan. Perhaps the resistance to this way of eating is due to a simple misunderstanding of the leaky gut syndrome that plagues so many children on the Autism Spectrum. This leaky gut syndrome does not cause food allergies. It causes food sensitivities.

In food allergies that many parents are famililar with, the symptoms arise immediately in the form of hives, watery eyes, sneezing, or difficulty breathing. They can even produce life-threatening anaphylactic shock. Only about 10% of

autistic kids have this type of allergy. Some 85% of children with Autism have food sensitivities. Rather than immediate physical symptoms, these sensitivities produce and inflammatory response that results in more subtle mental and behavioral symptoms that can take anywhere from 6-72 hours to appear. The brain's primary fuels are oxygen and glucose which are manufactured from nutrients in our food supply. It only makes sense that we get out of our brains what we put into our bodies.

When it comes to the treatment of any neurological disorder, many parents and doctors focus solely on the obvious cognitive impairments and fail to realize that correcting their child or patient's underlying intestinal imbalances can; and often does, lead to significant overall improvement. Leaky gut syndrome which is so prevalant in children with Autism Spectrum Disorders causes a long list of vitamin and mineral deficiencies because the inflammation process damages the various carrier proteins normally present in healthy GI systems. Our plan is to treat our son from the inside out; Reduce the inflammation, test for vitamin and mineral deficiencies, provide necessary supplements, test for toxin poisoning and remove if necessary, provide therapy as needed, and set Gunnar up for the best possible outcome. When you feel better, you perform better. Who can argue with this rationale?

Many people have differing opinions on what does and doesn't work for families facing Autism. There is a saying in the Autism community, "If you have met one child with Autism, you have met one child with Autism" There is a broad spectrum with severe to mild physical and behavioral symptoms. One person's treatment protocol might not work for another person. I am not judging what others choose to do to treat their child, I am simply sharing what has worked for us thus far. I am not searching for or promising a cure, I am finding a treatment for and healing the symptoms that affect our son. Whether or not you agree with how my family and I choose to approach this journey does not change the outcome. If we have helped one person understand this complex neurological disorder, we have helped spread understanding, and that makes us happy. And, if you are a family facing Autism and don't know which avenue of treatment to pursue first, our advice is: Go with your gut.

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80. Recovery #107

Having a sick child is a full time job. Even when they are well, your mind is filled with ways to keep them from getting sick again, ways to improve their current state, ways to help others who were where you were just a short time ago. It is my hope to do all three.

Autism entered my life a few years ago, but I didn't recognize it. My son, Gunnar was three when my husband and I realized he wasn't progressing as he should. He wasn't asking why, what, where, or when questions. He wasn't growing. He was lining up his trains and cars, screaming if we touched one of them. Gunnar was oppositional and refused to go into a crowded place. He didn't look anyone in the eye, and it seemed to make him uncomfortable to try. He had several sensory issues such as covering his ears when music played, even when the volume was low. He had an aversion to touch and would often yell, "ouch!" when someone touched his arm softly. He was constipated. He smeared his feces on the wall. He often woke in the middle of the night screaming. My husband or I

would find him in the fetal position and he couldn't or didn't respond when we asked what hurt. Gunnar went ballistic when we tried to wash or cut his hair or brush his teeth. He was indifferent to me leaving for work, and what was most painful for me, he ran and hid when I returned. He didn't much care for his own mom and that was heart breaking for me.

We also noticed some regression. Gunnar stopped showing interest in potty training. He went from saying, "Gotta go pee pee!" to not even recognizing he'd soiled his pants. He started refusing foods he previously enjoyed. He went from using several words in succession to not speaking more than two words strung together. He started to be extremely picky when it came to the foods he would eat and spent most of his time at the dinner table staring out of the window. We were losing our son.

Our son was born with an autoimmune condition, Hypothyroidism. He started taking medication just three days after he was born. Initially my husband and I interpreted some of our son's Autism symptoms as side effects from his medication dosage fluctuations. After all, we voiced our concerns to his Pediatric Endocrinologist, and she assured us he was fine. She said the medication was likely making him lethargic. She said boys took longer to potty train. As time went on, Gunnar's symptoms multiplied and worsened, and other caregivers took notice and shared their concerns. At our son's next Endocrinologist appointment, I insisted on a referral for a developmental evaluation.

Our son was diagnosed with an Autism Spectrum Disorder in January of 2013. He was 4 years old. I immediately went into research mode reading everything I could get my hands on that was related to healing Autism. Two weeks after his diagnosis, we started a gluten, dairy, soy free diet and saw digestive issues disappearing. The night-waking was going away. He turned toward us when we called his name. He spoke in short sentences, requesting to watch a movie or eat a snack.

A month after Gunnar's diagnosis we had further testing done to see where he was on the spectrum. When we showed up for the appointment, the diagnostic team was impressed with our son's progress. He responded when they asked him to point to specific items, and he had no trouble matching items together. I remember thinking he was much smarter than I'd realized. Clearly the problem with our son was physical.

The test results showed Gunnar's speech and language to be at a 23 month old's level with his gross and fine motor skills not much further along. We were determined to heal our son and scheduled an appointment to have all kinds of testing done including food allergies, comprehensive stool analysis, and genetic mutation tests. These results showed that our son was sick with food allergies, leaky gut caused by an overgrowth of bacteria, and pathogens. We knew what we were up against. We were on the right track with diet, but had to find out how to get rid of the bacteria and pathogens. In my research, I stumbled upon the CD forum. It was the first treatment program that made complete sense to me.

We received the book in June. It was the first book our son ever showed interest in. He kept saying, "This is it!" and, "This book is the best!" He didn't want to put the book down. My husband and I looked at each other with tear-filled eyes. We knew Gunnar was right; this was it.

We started the CD Protocol immediately...just five months after our son's diagnosis. His starting ATEC was an 80. Immediately we saw regular bowel movements, diminished dark circles under his eyes, and healthy skin coloring. Gunnar began to sleep through the night. Four days into the protocol, our son started taking turns and sharing with other kids. That night, he danced at a graduation party. Every day, his vocabulary improved.

Four weeks into the protocol, our son no longer needed his thyroid medication he'd been on his entire life. He started using the bathroom unprompted. He dressed himself unprompted. He brushed his teeth on his own. Gunnar didn't mind getting his hair cut. He began to engage in reciprocal conversation.

Seven weeks into the protocol, we saw so many behavioral improvements; we decided to take the ATEC test again. Gunnar's score was a 40. It was cut in half in seven weeks!!! Eight weeks into the protocol our son celebrated his 5th birthday. It was the first time he showed anticipation for a party. He was excited to open his gifts and thanked everyone individually. Normally, Gunnar would run and play by himself when guests came over. He had always covered his ears and yelled, "Stop singing!" at previous parties. Gunnar was happy when everyone sang Happy Birthday to him. He was healthy and present. It was one of the happiest days of our lives.

Twelve weeks into the protocol, our son started mainstream preschool. All previous attempts to take him to school resulted in anxiety and complete meltdowns. He started speaking in complete sentences and his speech was relevant to the situation. He started showing interest in books. Fifteen weeks in, our son read his own bedtime story with no help. He picked out his own Halloween costume. He brought home his artwork and proudly showed it to us. His teachers continually voiced their pleasure at his progress. His speech therapist said he was at age level for speech and language. (that's 3 years worth of progress!)

Twenty-four weeks into the protocol, our son's ATEC score is a 10. He continues to go to mainstream preschool and is interested in learning. He is reading a variety of books. He is counting in English and Spanish. He knows his US geography, and does puzzles that are advanced for his age. He asks questions. His speech is appropriate and relevant with continued improvement in vocabulary and articulation. He loves to sing, dance, and paint. Our son is smart, funny, and very affectionate. He spontaneously hugs and kisses me and tells me he loves me. And the best part of all? When I come home from work, Gunnar yells, "Moooommmmyyyy!", runs up to me, jumps into my arms, and wraps his little arms around my neck. I have my son back.

I could never sufficiently thank Kerri Rivera for all of her selfless help. She and her team of parents give freely of their time and energy to bring kids and their families out of the depths of Autism. It is my hope to pay it forward. All children deserve a healthy childhood. If you are holding this book, you are likely in the position my family was in just 10 months ago. This is the way to turn your feelings of desperation into determination. This is the way to change the future for your family. This is the way out of Autism.

—Maggie Kaye

81. *Ok, my brother is 17 and started CD at the end of october. We are on 9 drops as of today. Non verbal. My mom called me crying and my brother said "I want snack please." My mom asked if he wanted something and he "no, no, no." He got his yogurt (df) out and said "thank you." This is just so amazing. Thank you God for putting us on this path and around so many amazing warrior parents to help us with our journey. Happy healing to all!!!*

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82. *At the age of 3 our son was absent. He talked a lot... to himself. Scripting. It was almost impossible to get him to look into our eyes when we spoke to him. He almost never answered back, and when he did, it was scripting again (from a show on TV or a movie he was into.) He played by himself. He refused to potty train. He would wake up in the middle of the night crying and holding his stomach but was unable to tell us what was wrong. He stopped eating whatever we put in front of him and seemed to only want fruit snacks, American cheese, hot dogs, chicken nuggets and fries. And thats it. He didn't seem to be growing anymore, both physically and mentally. He seemed to be slipping away from us. You could see it in his eyes. Those eyes that were pointed off in a different direction. It was gradual...hard to notice right away. But definitely a change, and not one we were happy with.*

Up until this time he was progressing like any other child. He ate well. He slept well. He played well. Was even starting to potty train. A typical child. But not anymore. Then there was the diagnosis. Autism. No parent wants to hear that, but we knew. Every parent knows what I mean. You just know. And at this point we (as parents) have to make a choice.

We can choose to do nothing. Just live with it. We can listen to our doctor, or a specialist in the field. You know, someone who claims to know everything about you and your child in the 5 minutes they spend with you. Or you can talk to other parents. Parents that spend every moment with their children. Not just a few minutes every six months. You can network. You can research. Ask whats working for them, or more importantly what's not.

We chose the latter, and because of this our son is recovering. He looks into our eyes. He asks questions. He sleeps at night. He's potty trained. He sets the dinner table with his older sister and asks to be excused when he's done eating. He's in pre-school now and plays with all of the other kids. He calls them by name. He draws. He paints. He reads books. He does all of the things a typical five year old does.

Our son is recovering, and I need to give two heartfelt thanks for this. The first to my wife for the countless hours of reading and research she did immediately following our sons Autism diagnosis. She is an incredible woman who refuses to give up on anything. Ever. She refused to believe that we had to accept what was handed to us. She knew in her heart and mind that we could make a difference. We just had to do it. Because of this determination, she found Kerri Rivera, whom is the next person I want to thank. She is a true pioneer, someone who refused to keep thinking inside the box, someone who is helping families like ours all over the world.

"We have the world at our fingertips. Every book, every encyclopedia for us to read at our local library, in our own homes, and now on (most) of our cell

phones. It's a beautiful tool for us to use. Use it. Do your own research. Talk with parents. Find out what works and do it.

The only thing I really have to say about Kerri's book and the protocol it explains is that it works. We have our son back.

—Kenn Kaye, Father of Gunnar Kaye

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83. Last night, my 19 year old son came out into the kitchen, picked up a purple straw from the dish drainer, and pretended to play it like a clarinet with great enthusiasm. Pretend play. For the first time in 19 years.

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84. We've been playing the "healing game" with my son for some time, (7 years 11 months old) but we've never really healed anything. To be honest we've never known what we were up against...until now. Like everyone here, my child is very sick. He doesn't grow, he has maldigestion and malabsorption issues and he's chronically constipated. His history of constipation is long and extensive. ANYTHING that disrupted his gut flora would result in this extreme constipation; whether it was a cold, a new food, treating the GI. To say he has leaky gut is a tremendous understatement. So, when we started Kerri's protocol 6/15 my biggest health markers for initial healing were growth and for him to poop daily on his own. With his history being what it is I wasn't surprised to see he was instantly constipated. How could he not be? We are killing pathogens and parasites like gang busters. We started enemas on day two and have done them daily. But, an amazing thing is happening! He is healing. He has grown two inches in these last three months and he starting to poop on his own. BTW, these aren't just lame little poops they are total TROPHY poops. They are soft, formed, have no undigested food and there is lots (I'd show you a picture but we barely know each other)

Yep... It's taken 3.5 months to get here, but his little; fragile and damaged body is doing what it is supposed to do.

Trust the process... It's not easy; it's not always fast. There will be ups and downs. But, my gosh, watching the body heal is an extraordinary thing. It's nothing short of a miracle.

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85. Hi Kerri,

I started my son on the CD last night. I'm taking it with him.

Well, I for one, feel fabulous. My lungs are clearing up, the low-level depression I felt is evaporating. Wow!!!

I've noticed some subtle changes in my son. He is more "with us" in the world and not looking out the window at cars quite as much. Also, a little less flapping his hands.

He and I have been doing a ketogenic version of the GAPS diet (no sweet vegetables, no dairy, no sweeteners) since January of 2013, and I think that's why we've been so successful with the CD! :)

I was thinking of upping it to two drops per 8 oz bottle--one for him, one 8 oz bottle for me.

I am hoping that Sulfur is Ok to still give him. We used to cut it with Kombucha, but that is now a no-no.

Thanks and Huzzah!

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86. *Ryan is the first of our 3 children to recover. Ryan was not considered autistic by most standards but did score a 19 on the ATEC test prior to starting the CD protocol. He is 9 years old and has been in mainstream classes without an IEP. We did hold him and his twin brother back one year prior to starting kindergarten so they could have more time to heal from Lyme Disease which we had been treating since they were 4.*

    Ryan was a healthy baby but I did notice after saying his first words at the appropriate age, he stopped talking a few months later. (I now know that is a symptom of autism!) And both he and his brother were very late with language despite knowing their alphabet at a very young age. Ryan did eventually talk but was often hyperactive and had a hard time sitting still in class or at the dinner table. It was often hard to get his attention and to get him to listen to requests. He was constipated since he was a baby and was a very picky eater. I dreaded mealtimes because it was so hard to get him to eat. We often had to spoon-feed food into his mouth even when he was 7 years old. Treatment for Lyme Disease helped many of his symptoms but he still had some remaining symptoms such as weakness, stomachaches, seeing orange and blue spots at night (more noticeable in the dark), nightmares, bedwetting, difficulty falling asleep and early awakening, and overly emotional and irrational behavior. These symptoms worsened dramatically when our house well water became contaminated with parasites and bacteria. It took us two years to figure out that the water was the cause of our deteriorating health. During this time, Ryan became unable to play sports or have play dates without melting into irrational tantrums when things didn't go his way. When playing mini golf, he refused to finish the round after getting a score of "10" on one hole and had a crying tantrum. In tennis class, he would sit down on the court and start crying if he didn't get to hit as many balls as the other children on the court with him. We didn't even attempt to put him in team sports for fear that he would melt down and storm off, refusing to play the rest of the game.

    Then we discovered CD and Kerri's protocol, and his and our lives changed forever. Within three weeks of taking CD, Ryan's ATEC dropped to an 8. This improvement was the difference in Ryan being able to play sports. He was able to play on a baseball team and while he did get angry if he struck out or made an error, I was there with a dose of CD and that would keep him from a complete meltdown. As the season continued, Ryan's emotions became more and more stable and normal. His energy increased greatly and now after 6 months on the protocol, Ryan is playing three different sports, taking piano lessons and excelling in above grade level reading and math. His ATEC is a 3 but we will continue until it is 0. His first report card since starting the protocol was the best of his life. We were most excited to see that his scores for behavior and attention were above expectations. Last year, these same scores were all below expectations because Ryan was so hyperactive and unable to focus due to the parasites. Ryan still sees a few orange spots at night but they are diminishing and we know they will be gone so long as we stick with this protocol until he is completely healed. We are so grateful that Kerri blazed the way for us all by developing this protocol. I have been searching for the past 7 years for a way to fully heal my children and the CD was the last but most significant piece of the puzzle for us. We will be forever thankful to you Kerri!

87. *I first heard about CD, then called MMS, to treat autism in May 2012 and wanted to try it out with my then 10-year-old son. I bought supplies, and did the then-current protocol for a few months, but then school ended and summer vacations started and I put CD on the back burner or did it very sporadically. My son was verbal and high functioning, but still had lots of autistic behaviors. His ATEC score in 2012 was 27.*

    I started reading about CD again in the summer of 2013. This time there was more information out there. Kerri had written her breakthrough book and lots of facebook friends in the autism community were mentioning it. I bought the book and dove in, first using my old supplies (CD with citric acid) then buying HCl and trying that. My son did very well with the new protocol, starting low and getting to full dose around the time of his 12th birthday at the end of August. I started seeing worms before we even started our first Parasite Protocol! When I started the Parasite Protocol and added in ocean water, things kept getting better! No set-backs or regressions. School was seemingly much easier for my son. He was in a mainstream class with resource room help for reading and writing for the second year, but this year, math homework was no longer taking several hours, but 20 minutes! His reading comprehension was improving as well, and more importantly, I didn't worry about hearing about behavioral issues anymore!

    I wanted to complete three months of CD before I took another ATEC. When I filled in out in November, at the start of our third Parasite Protocol, I was shocked to see a score of 7! My son had dropped 20 points from his 2012 score! Seeing the single digit score was so amazing! My son had been diagnosed with autism at age 2 ½ and there were no options given to me at the time. An early IQ test given by a speech therapist had shown he was mentally retarded and that was that. However, I looked into everything I could, and was not going to give up on my son. So glad I didn't! Nine years of autism, but the beginning of his 12th year marks the end of it! I know his ATEC score will be 0 soon!

---

88. *"thank you for your help in recovering me"*

    This is what my son just typed to me this morning on his iPad with the app we use for supportive typing!

    Thank you Kerri & Patrick for all you have done and continue to do!

    Without you BOTH, we would NEVER be in the place we are right now... HEALING & RECOVERY!

    Just know you are LOVED!

    —Melissa in Indiana

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89. *Sophia was born on March 9, 2006. She was a typical happy baby who slept well and seldom got sick. She met all of her developmental milestones and laughed and made great eye contact. When she turned one just after her vaccines she became violently ill and vomited with fever for 2 days straight. After that she was never the same, her smile was rare and words were gone. When she was nineteen months after more shots, we took her to an ear doctor out of concern that she was not responding to her name or speaking clear words. Her hearing was tested and we were told she was fine and to give her time. After a few months of no change her pediatrician determined that she was developmentally-*

delayed and had all the symptoms of Autism. We were stunned and unprepared for this news. I went into warrior mode and ended up with a DAN dr, who started her on lots of supplements after initial lab results showed heavy metal toxicity and high amounts of intestinal yeast. We followed the program and advice of this doctor for the last 4 years with the only change being dietary fluctuations. Sophia did improve but hit a plateau where no new gains were made in the last year or so, so in May 2013 her DAN doctor suggested that we do another round of stool testing after a urine acid test showed bad bacteria overgrowth and terrible mito issues. Her comment to me was "this kid's DNA is so messed up, I haven't seen a test this bad since the 1990's." This was after thousands of dollars and too many supplements to count. I was done at that point. There were no answers there obviously. I came across this protocol on a Facebook page for autism parents and purchased Kerri's book in September 2013. I immediately knew that this was the answer for my daughter. I had a gut instinct that she would be healed . We started the diet immediately and CD just after. My daughter had been a juice addict before this and I was worried about her taking the CD and being able to drink the water. This was only an issue for a day or so. I have not missed a day of giving her 8 or more doses. We get up very early and dose her ocean water and 2 CD doses before school. On weekends we are doing 16 doses/day. In the second week we started seeing some herxheimer/ die off, very sleepy followed by fevers. This is when the transformation started! I followed the fever protocol and did enemas and she got better. She also had an episode around week 7 of very red throat and fever which we double dosed for and resolved. We have seen a withdrawn, self -focused child with little interest in the world outside of herself disappear and turn into a child interested in friendship with peers, reading books and understanding the story (huge!), and having relevant conversation with great eye contact. She gets all A's at school and has made a complete turnaround with behavior. We have so much hope for her future and she is blossoming into a beautiful, happy girl!

---

90. *Here are a few of the emails I mentioned from my son's therapist in regard to what's happening at therapy! :)*

    This is an email from the exact day I restarted the CD, which was August 21 of 2013.

    We discovered a new game today. He was being a turkey and running up the hall to try to get around me to get places he wasn't supposed to go. I started singing (to the tune of rolling down the river) about whatever he was doing "walking, walking, walking down the hallway" "jumping, jumping jumping down the hallway" climbing, climbing, climbing up the ladder. He thought it was hilarious, especially when I'd change in the middle of a verse "running running, jumping down the hallway.

    —Your son's therapist

    Great day today! Vail seems to be understanding first, then sequencing and I think I finally have a bribe for him--he loves our fish.

    Also, he made a friend today. One of our other pt's was playing in the gym and he was watching him, imitating him a little and said his name 2x!

    —Your son's therapist

    We tried to play the game and he wasn't interested. Instead we ended up

pushing the fisher price horse, sheep, goat, and cow off the treehouse. He would "randomly" produce sounds which we took for requests for the animal associated. Then we would give him the animal "requested." Reviewed his sound cards and he produced the /n/ and /h/. Coulda sworn he said go a couple of times, and mom said she heard a whispered "home." Listen and be watchful for whispers! Oftentimes children with apraxia can get one system working but not the other, ie. articulate with no sound, or vocalize with intonation and no articulation, like when he says "ah uh oo" for "I love you." Yep, he does that!

Cheers!

---

91. *Hi had to share this moment today, just wish daddy wouldn't have missed it!*

Well, we were seeing daddy off for work this evening, when Vail decided that he wanted to go run around in the grass. I told him we needed to put on socks and shoes and then we could play outside. He walked straight to the door, we walked in, I pointed at his socks and shoes, and FOR THE FIRST TIME EVER (always knew he could, just to stubborn to do it unless he really wants too!) he promptly walked over, picked up his socks and shoes and turned and handed them to me!!! (all the while doing it with an attitude!!!"lol)

This is Just from MOM to therapists. :)

CD and Kerri have been life changing for our entire family. We now can give Vail choices, usually of two items. For example I showed him two pairs of pants and asked which he wanted to wear, and he grabbed one pair and started to put them on even though he was still in his pj's. I showed him two shirts, and he picked a shirt. Same thing with his shoes and socks, he is able to choose now on his own. I look forward everyday to him doing something differently or completely new, and he almost always does now!!! This was not possible for CD!!! THANK YOU KERRI !!! WE LOVE YOU FOR SHARING AND FIGHTING THE FIGHT!!!

LOVE,

—The parents of Vail

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92. *Best day of the entire school year! My son initiated verbal interactions 5 times today and responded to his teacher in a group over 5 times, WITHOUT A SINGLE PROMPT! Most days his TA is poking him to pay attention and ask other kids for directions, rather than an adult, all day long! She is tracking these interactions as they are his IEP goals.*

---

93. *Casey is a young man who is 17 years old today, and the estimated ATEC score from 2006 is from when he was 10 years old. Proving once again that recovery is possible at any age.*

Casey H. ATEC History	ATEC Estimated	Start CD	3 months	6 months
	10/12/2006	5/6/2013	8/6/2013	11/6/2013
I. Speech/Language/Communication	6	1	1	2
II. Sociability	14	11	3	0
III. Sensory/Cognitive/Awareness	25	13	6	5
IV. Health/Physical/Behavior	39	28	8	5
TOTAL ATEC SCORE:	84	53	18	12

94. *Daniel - beginning ATEC June 2013 - 101. Today ATEC Nov 12, 2013 - 44! We are thru our 3rd PP and starting speech supplements. Speech, by far, has been the hardest thing. In all other areas he is under "10" on the ATEC! Kerri Rivera words are coming. This week alone he is saying "Hi" and "Bye" and trying to say others. I can't wait to hear "I love you Mom"! You are the Bomb Diggitty Kerri. We all love you!*

    UPDATE: December 3rd, 2013

    I officially want to tell the world that my son, Daniel, who has autism is nonverbal no more! He is starting to talk. Praise God! This battle has been the struggle of my life, but i have learned to trust God, be patient, and enjoy the journey! Where some take a lot for granted regarding their children, I have been waiting almost 7 yrs to hear his beautiful voice! And thank God he has one! Autism is treatable and there is hope!

---

95. *We had a super exciting trip, we went to a therapist on the 28th who teaches Rapid Prompting Method. We have tried since by daughter was diagnosed to get her to speak, but haven't had any luck yet, she is now 11. We thought we would give RPM a try to see if the therapist could get her to communicate.*

    We not only found out that she is able to make correct choices, but can actually SPELL! Her very first word that she spelled was CLOUD!

    Later on in the session the therapist asked her what her favorite color was... she spelled out PINK!

    I was sitting on the floor in awe... For the first time in 11 years, I finally know what my girl's favorite color is... it was surreal... it was amazing... she is so smart, but had no way of letting us know... I am soooooooo proud of her!

---

96. *Diagnosed at 20 months old in August 2011*

    Started supplements under Dan in September 2011

    Started CD / PP on July 1, 2013, after seeing rope in stool

    Starting ATEC on July 1, 2013, was 46

    Present ATEC 22

    Gained 5 pounds from July 1st to present!

    Too many improvements to list!!!!!

    Also doing GcMAF which has also helped……but, I believe GcMAF may have helped more with the viral load. I suspect this because we actually started IV GcMAF in January 2013, before CD . Huge gains with GcMAF but after 35 shots, her gut was still a mess and GcMAF definitely didn't help with the gut. Found Kerri in July 2013, and began our healing journey.

The following lab results are proof of just how well the child described above is doing since starting the protocol. Here is what her mom had to say:

> *"The original test was taken last August of 2012, which showed a deficiency in almost everything despite the fact that my daughter had been on supplements for over a year at that point. The re-test was just taken October 2013, only 4 months after CD / PP and removal of ALL supplements. Wow!"*
>
> *You can see in the second test that her high viral titers were reduced as well.*

Patient Copy

Genova Diagnostics
Improving Healthcare for Chronic Disease

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Asheville, NC 28801
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ONE FMV
Optimal Nutrition Evaluation

Patient: B
DOB: November 18, 2009
Sex: F

Completed: August 27, 2012
Received: August 21, 2012
Collected: August 13, 2012

ONE Results Overview

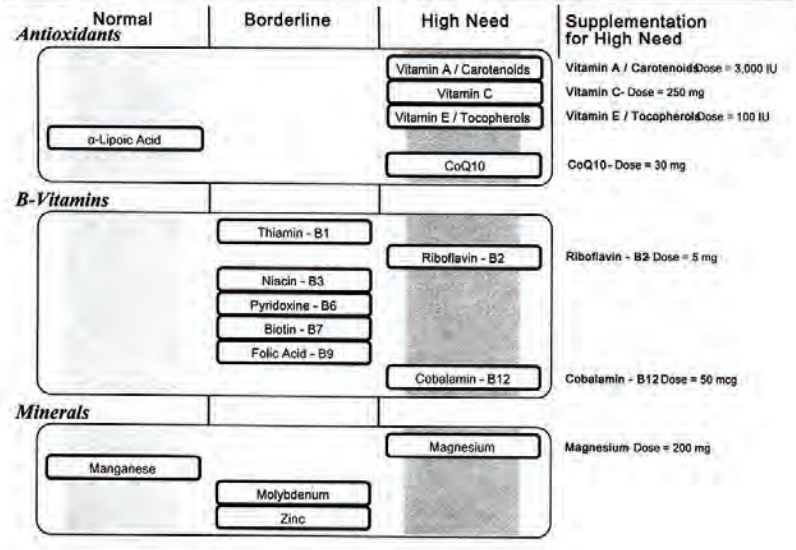

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Patient Copy

GENOVA DIAGNOSTICS

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ONE FMV®
OPTIMAL NUTRITION EVALUATION

Patient: B
DOB: November 18, 2009
Sex: F

Completed: October 28, 2013
Received: October 18, 2013
Collected: October 17, 2013

ONE Results Overview

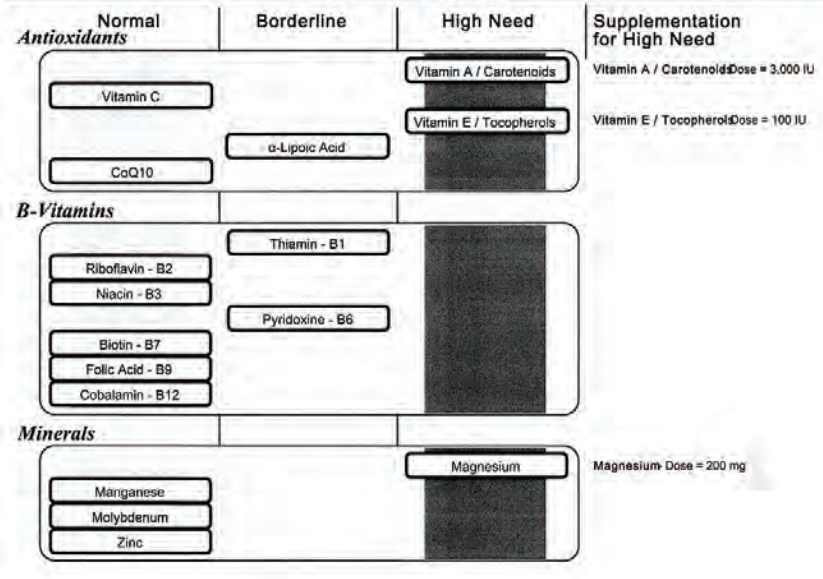

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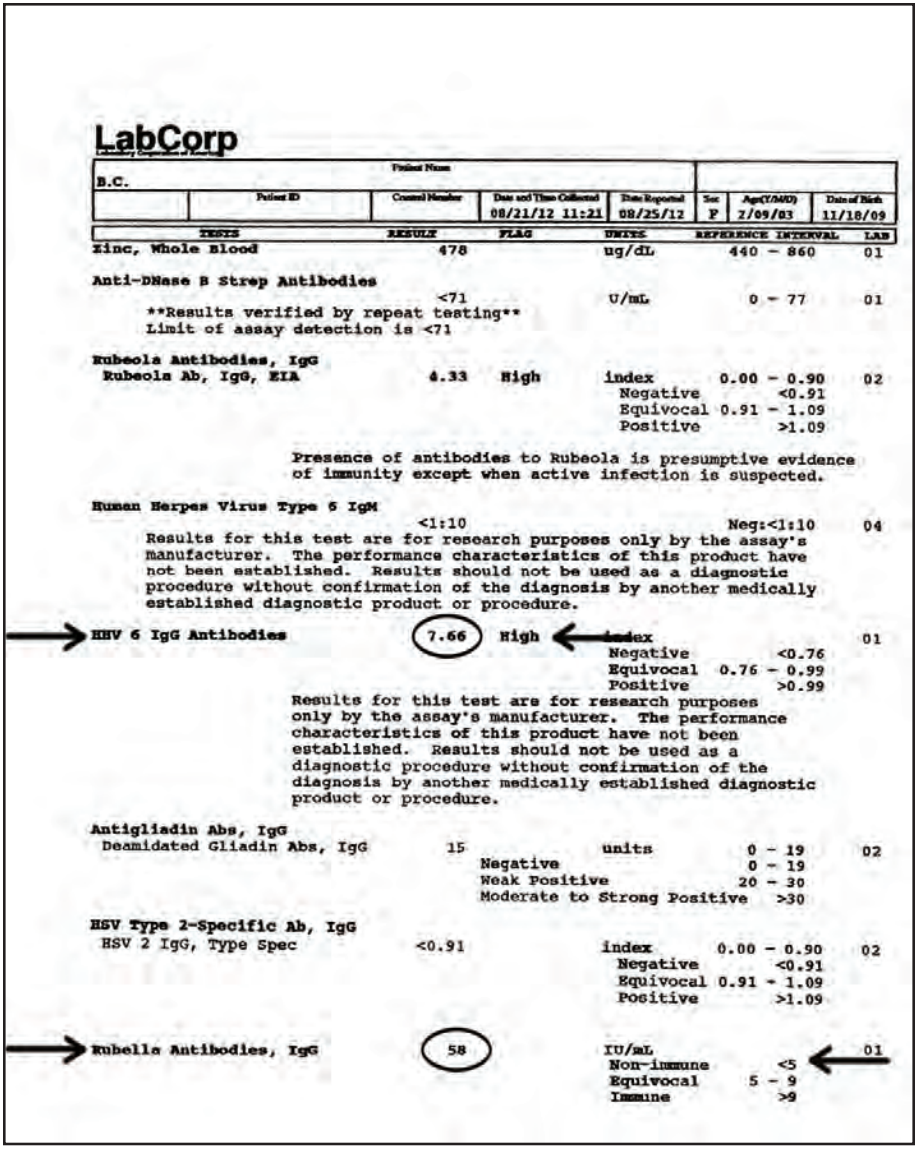

LabCorp

Patient Name							
B.C.							
	Patient ID	Control Number	Date and Time Collected	Date Reported	Sex	Age(Y/M/D)	Date of Birth
			08/21/12 11:21	08/25/12	F	2/09/03	11/10/09

TESTS	RESULT	FLAG	UNITS	REFERENCE INTERVAL	LAB
Zinc, Whole Blood	478		ug/dL	440 - 860	01
Anti-DNase B Strep Antibodies	<71		U/mL	0 - 77	01
Results verified by repeat testing Limit of assay detection is <71					
Rubeola Antibodies, IgG					
Rubeola Ab, IgG, EIA	4.33	High	index	0.00 - 0.90	02
			Negative	<0.91	
			Equivocal	0.91 - 1.09	
			Positive	>1.09	
Presence of antibodies to Rubeola is presumptive evidence of immunity except when active infection is suspected.					
Human Herpes Virus Type 6 IgM	<1:10			Neg:<1:10	04
Results for this test are for research purposes only by the assay's manufacturer. The performance characteristics of this product have not been established. Results should not be used as a diagnostic procedure without confirmation of the diagnosis by another medically established diagnostic product or procedure.					
HHV 6 IgG Antibodies	7.66	High	index		01
			Negative	<0.76	
			Equivocal	0.76 - 0.99	
			Positive	>0.99	
Results for this test are for research purposes only by the assay's manufacturer. The performance characteristics of this product have not been established. Results should not be used as a diagnostic procedure without confirmation of the diagnosis by another medically established diagnostic product or procedure.					
Antigliadin Abs, IgG					
Deamidated Gliadin Abs, IgG	15		units	0 - 19	02
			Negative	0 - 19	
			Weak Positive	20 - 30	
			Moderate to Strong Positive	>30	
HSV Type 2-Specific Ab, IgG					
HSV 2 IgG, Type Spec	<0.91		index	0.00 - 0.90	02
			Negative	<0.91	
			Equivocal	0.91 - 1.09	
			Positive	>1.09	
Rubella Antibodies, IgG	58		IU/mL		01
			Non-immune	<5	
			Equivocal	5 - 9	
			Immune	>9	

Quest Diagnostics Page 2 of 4 10/17/2013 04:07:42 PM **Report Status: Final**

Patient Information	Specimen Information	Client Information
B.C. **DOB: 11/18/2009** **AGE: 3** Gender: F Fasting: U Patient ID: NG	Collected: 10/07/2013 Received: 10/07/2013 / 21:37 EDT Reported: 10/17/2013 / 14:42 EDT	

Test Name	In Range	Out Of Range	Reference Range	Lab

A positive result indicates that the patient has antibody to CMV. It does not differentiate between an active or past infection.

RUBELLA IMMUNE STATUS QHO
RUBELLA ANTIBODY (IGG) 3.13

Value	Interpretation
< or = 0.90	Negative
0.91-1.09	Equivocal
> or = 1.10	Positive

The presence of rubella IgG antibody suggests immunization or past or current infection with rubella virus.

EPSTEIN BARR VIRUS VCA AB (IGG) QHO

< OR = 0.90 index

Index	Interpretation
< or = 0.90	Negative
0.91 - 1.09	Equivocal
> or = 1.10	Positive

DNASE B ANTIBODY <95 < 251 U/mL SLI
MEASLES ANTIBODY (IGG) 4.09 index QHO

Index	Explanation of Test Results
< or = 0.90	Negative - No Rubeola (Measles) IgG Antibody detected
0.91 - 1.09	Equivocal
> or = 1.10	Positive - Rubeola (Measles) IgG Antibody detected

Positive results suggest recent or previous infection with Measles (Rubeola) virus and imply immunity. Patients exhibiting equivocal results should be retested in one month, if clinically indicated.

HERPESVIRUS 6 ANTIBODIES (IGG,IGM) XE
HERPESVIRUS 6 IGG 1:80 H
HERPESVIRUS 6 IGM <1:20
INTERPRETATION PAST INFECTION

REFERENCE RANGE: IgG <1:10
IgM <1:20

Human Herpesvirus 6 (HHV-6) infects T-lymphocytes, and has been identified as an etiologic agent of exanthema subitum. Rises in antibody titers to HHV-6 have been detected during infection with other viruses. In seroepidemiology studies of the prevalence of exposure using serum screening dilutions of 1:10, the detection of IgG antibody in a mid-life population approaches 100%. Due to this high prevalence of HHV-6 antibody.

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Testimonials from the First Edition Continue Here...

97. Meeting a Rescue Angel

The way OUT of AUTISM

My 5 year old little daughter, Anna's story has been long and paved with lots of suffering and doubt, compared to her age, but prayers have always helped us in our journey. We are aware that it may take years to get out of the dark depths of Autism but now we know we are going in the right direction. Finally! Thanks to Kerri Rivera, the Rescue Angel of so many suffering children. She showed us the way out!

We have wasted so much time by trying to face the fact, that unfortunately there is a problem with our perfectly healthy-born daughter. After the consultation with many doctors, they first suspected a hearing problem. As the result of this, she went under many surgeries and antibiotic-treatments, which made her state worse mentally and physically as well. The medical professionals could not find any evidence of physical abnormalities, so they choose the easy way out, the one word diagnosis of Autism! Dear Mom, please accept it, you cannot do anything about it. Try some developmental therapies, but do not put your hopes high!

It is very hard to accept the unexplainable. What does autism mean? If you google it, you will find the verdict immediately: "Autism is a lifelong developmental disability characterized by impaired social interaction and communication, and by restricted and repetitive behavior" How is it possible that a perfectly developing child changes overnight? She stops saying the words she said before; she stops paying attention when called by her name and simply forgets some of her skills she knew so well before. How can one accept that? For us, it was impossible. We took up the gauntlet!

We spent so many sleepless nights on the Internet searching for solutions, to be shortly shocked to learn that in the US, there is a totally different concept and approach to autism. A group of medical professionals and scientists are proving the crucial role of environment and vaccines in the rapid rise of autism, accepting genetics as not the single cause but a factor of susceptibility to the disease. More and more so called DAN (Defeat Autism Now) clinics and practitioners are treating children on the spectrum all over the world with different biomedical interventions with various success rates. Whichever method one chooses in their realm, the base line to all is a strict diet, especially free from gluten, casein and sugar. There is no way out without eliminating these from the diet of an autistic child.

We immediately changed her diet from a bread and butter with chocolate milk style to a much stricter one. The first items to remove were sugar, gluten and casein, but these were shortly followed by potato, rice, corn and all artificial additives. We slowly changed to SCD (Specific Carbohydrate Diet). A few days into the diet and Anna slept through the night, and what's more, the painful eczema spots that had been on her face since she was a baby have shortly disappeared. Parallel with the diet modifications we also started the DAN interventions. We spent a fortune on lab testing, supplements and to see a DAN practitioner in Germany. Unfortunately none of these brought us significant improvements.

But I knew and believed that there has to be a solution.

And yes! I cannot keep it to myself and I would like to spread the word happily, powerfully and self-confidently, that there is a solution! This year in August, I have found the presentation of Kerri Rivera on the internet. Autism is preventable, avoidable, treatable and curable."

At the beginning "Kerri Rivera rose against the wind rather than with it when, after a frustrating slew of hits and misses, her youngest son, Patrick, was diagnosed with autism nine years ago. He was two at the time. Surrounded by literally no local expertise or any type of peer support circle, she did what most mothers would do: She became informed and involved in the biomedical community. It was through the Autism Research Institute (www.autism.com), a non-profit organization dedicated to autism research, diagnosis and treatment for the past 40 years, that she learned about a specialized biomedical protocol involving a special diet and supplements, physical therapy, applied behavioral analysis, chelation and hyperbaric treatment. There was light for Patrick, Kerri's son at the end of the tunnel."

But Kerri did not stop here! As she told me, she felt that there was a missing piece to the autism puzzle. A huge piece! It shortly turned out to be the MMS piece. She developed MMS protocol which can be done at home. Following Kerri's protocol, 68 children lost their autism diagnosis in the past two years! This result is outstanding, considering the fact that this is said to be an incurable disease.

The day I saw her presentation I e-mailed her and I got an answer within a half an hour. Kerri Rivera's MMS protocol is the missing piece of the puzzle to cure autism, ADHD, asthma, allergies, seizure disorders. Even mothers of children with Down Syndrome have reported improvements with this protocol.

My whole family was in Mexico in August. We spent two months with the person, who is also a mother of a child with autism, who sacrificed part of her life to help others. For free, out of faith, humanity and love. Approximately 8-900 children are following Kerri's protocol currently all over the world. The protocol is available for everybody and can be done at home (www.mmsautism.com).

Anna is getting better every day. Although we have heard very promising sounds from her, speech is not developed yet. However she has improved a lot in the last 3 months in many other areas like mood, communication, learning ability, focus and attention span are all better and she started pointing. There were no signs of these at the beginning of the summer.

We are fully aware that there is still a long journey ahead of us, but now we know we are on the right track. Thanks to God and Kerri Rivera to guide us to recovery!

---

98. *Hi Kerri,*

PLEASE use our testimony. MMS kept my daughter's PANDAS under control after switching from Silver Hydrosol BUT the biggest is the PP's (parasite protocols) in combo with MMS. She began sleeping through the night, THEN, sleeping in her own room after sleeping in our room for 9 months. THEN she began putting herself to sleep for the first time in 7 years. We always laid with her--her WHOLE life--I KNEW it was NOT "behavorial", knew it was due to

something going on interally, AND NOW, we read, kiss, and WALK OUT of her room! It's SURREAL really. Seriously SURREAL!

Also, she was a chronic chewer, nose picker. Almost GONE! Peaks at new and full moon, BUT goes away. She was chewing about 20 straws a day before PP! Mangling them! UNREAL! I have pics of the straws... cant even recognize them as a "straw" once she was done with them. CLEARLY parasites. CLEARLY on the right track. NO other interventions. Except for how the MMS PP protocol is outlined MINUS Rhompe etc.. and Neem. NO sleep intervention supps etc.. None.

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99. *Favy is my God sent angel. He is 4 years old and since he was born he came to change lives, to make families stronger and to help others forgive. As many of your stories, everything was "perfect" (besides of milk intoleration, delay speech and sleeping problems) the rest was great, milestones on time.. Then gradually after 13to 18 month something was clearly wrong, we loose him and then the bomb!: diagnosed in Puerto Rico by a developmental pediatrician and a neurologist as PDD-NOS on December 6, 2010.*

We moved fast and start the diet GFCFSFYF no sugars.. Etc Thanks to CEA non- profit organization who help parents with kids with autism. Soon we saw positive changes, then probiotics and a natural anti fungal. Difficult days... But always seeing little good things. On march 2011 I met an angel: Kerri Rivera and we start MMS protocol!!! Then we start to see the light! We moved to FL and they diagnosed him (now I know he was having a die off when reevaluate) he was diagnosed as Autism. For me , not a big differences, still in the spectrum and he still sick!!! We need to cure him!!!

After MMS the big changes came ,and still coming!!

first from 2 to 4 hours straight per night to 6to 9 straight during night plus a nap during day!!!!! Eye contact was much better and he had less tantrums. He learned fast 3 signs to communicate. He was more happy. I didn't see more great results because I was using Mms incorrectly for almost a year (with juice, antioxidants and vit c) When a couple of months ago I started doing it right (just water and no vit c nor antioxidants etc) he started to improve again and better.. After a lot of efforts, dedication, patience and hours of hard work, with Kerri Rivera MMS protocol Favy to improved in many areas.

This is all he have improved:

Educational:

* *Respond to his name when called and say his name when ask.*
* *Recognize people: Mommy, Daddy, Sister, Teachers, Therapists, friends*
* *Name and identify some body parts: eyes, nose, mouth, ears, belly, feet*
* *Recognize some animals (Ipad application or tv) : cow, horse, duck, chicken, zebra turtle.*
* *Recognize some colors: blue, yellow, purple, red.*
* *Recognize and count 1-10 (can repeat 11, 13)*
* *Recognize and/ or use some common objects: plate, spoon, fork, bottle, chair, pants, shirt, shoes, backpack, lunch box, blanket, pillow, tv, books, some toys, ball, cars.*
* *Stack objects like blocks, books*

* *Match pictures, objects or things.*
* *Color independently but refuses, he can trace but hand over hand.*

Social / Emotional:

* *He enjoyed for the first time his birthday Party, he was happy! He opened his presents and show emotions!!!*
* *He is beginning to interact more with others.*
* *He can follow direction of 1 step and some cases of 2. (clean up your plate to the sink and push your chair.)*
* *He is affectionate : kisses, hugs, eye contact is better.*
* *Wave and say bye.*
* *Greet with a good morning or good night.*
* *Play around and with others: chase, tickles, peek-a-boo,*
* *Dancing and imitating some song rituals like: The wheels on the bus, If you are happy, head shoulders knees and toes, and some in Spanish too.*
* *Throw, push, blow, pull, jump, run, walk, go up and down stairs, climb, open, close, zip, unzip,*
* *He can watch an ABC DVD seated or lay down , dancing or repeating.*
* *He can be seated for almost 5 to 8 minutes with his favorite books.*
* *He enjoys to go to playgrounds, go up and down slide or swing.*
* *He enjoyed the trick or treating this year, going house to house picking candy and wore all night his costume.*

Comunication:

* *I think this is the area of more improvement. From 0 to almost 35 words and different ways to label, request, interact and communicate!*
* *He can answer questions with yes or no (yeah- nah)*
* *He signs (modified) more, all done, juice*
* *He can use 3 words at a time (mommy water please, mommy come here, I love you, mommy ipad please, mommy hungry, eat)*
* *Say independently—not all of the sound clear but very similar sounds.*
* *Mommy*
* *Dadda*
* *On*
* *Yes(yeah)*
* *No (nah)*
* *Please (peas)*
* *All done (ah dah)*
* *More (mor)*
* *Water (at-ter)*
* *go*
* *Four*
* *Three*
* *Tickles*

* *Zebra (eebah)*
* *Turtle (totlo)*
* *Uh oh!*
* *Oh No!*
* *I Love You!*
* *Under*

When Prompting or Repeat:

* *Tv (tetete)*
* *Dvd (dededah)*
* *Off*
* *Come (she)*
* *Itch (each)*
* *Scratch (ach)*
* *Bubbles (babah)*
* *Bye (bah)*
* *Swing (win)*
* *Push (pah-sh)*
* *Five (hi)*
* *Nine (nun)*
* *Ten (ttn)*
* *Baby*
* *Ble (buh)*
* *Purple (por-po)*
* *Yellow (ye-yo)*
* *Chase (ch sound)*
* *Play (ay or pah)*
* *He can imitate some animal sounds like tiger, horse and wolf.*
* *He make choices between to objects . (playing, dressing, eating)*
* *Independent Functioning (he needs some prompting)*
* *He eats independently with spoon and clean up after finished.*
* *He can drink of a regular cup.*
* *With pictures or social stories he can transition to different activities.*
* *He is showing understanding of routines and rules. (dvd or toy stay home, 2 minutes and we are all-done)*
* *He can pull up and down his pants (multiple prompt)*
* *He can put his shirt on but need assistance to take it off.*
* *He can pick up and put on hamper his clothes.*
* *He can put his shoes (crocs) independently and cooperates with other type.*
* *He move furniture to reach what he wants.*

Health:

Favy still in the Gluten, Casein, Soy, Yeast, Antibiotics and Hormones free diet. He is trying new textures, flavors and consistency in a variety of food allowed.

He is drinking more water. MMS help us every time he have a cold, a mosquito bite aor nasal allergies. Is the best product we can ever find!

We are excited about all he learned, do and know during this last year because of the use of the protocol of MMS. We are proud of his efforts, but we still have areas to improve. We will continue with MMS, diet and wil start the parasite protocol with faith because MMS Rocks!!!!

We love you Godmother Kerri! God Bless you and your Family.

---

100. Conversation at pick up:

Aide: "What did you spike his breakfast with this morning? I've never seen him like this!"

*Me: *smile* "Oh glad he had a good day"...in my head...'three doses of MMS before drop off'...*

This child is going to figure out he has wings and start to SSSSOOOOAAAARRR!!!!

---

101. I have a 4-year-old son on the autism spectrum and MMS has been the most effective treatment we have tried for him. He had bad eczema on his legs for over a year that I was never able to get rid of. We tried diet, medication, cream and nothing seemed to clear it up. Within 2 weeks of starting MMS it was completely gone and has not returned. My son has made great strides in the past 5 months of being on MMS and the parasite protocol. He is more interactive with all the members of the family, talking more, and becoming more successful with his OT goals.

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102. Kerri; Thank you all for your great job. Because through the Webinar—Autism and MMS—the information has come to me and gave me the strength to start a treatment.

---

103. Hi Kerri,

My wife and I did an ATEC on 8 year old son and it came in at 7. Wow.

We're learning so much from you about how this whole recovery thing works. The child's health takes three steps forward then two steps back then three steps forward then two steps back...but over time that one extra step forward seems to slowly add up. His pee is smelly again but, as you taught us, it's pee-tox and this is a good thing. His focus is still a bit of a challenge at school and he still won't shut up :-) but we are feeling that he truly is slowing getting better.

We've got a ways to go yet but we feel that we are truly moving forward. Thanks so much for all of the help you've given us and any help you might be able to give in the future.

---

104. My son is 19 years old. We started MMS in July. For 2 months my son did not sleep. The end of August at full oral dose we started the baths. At night you could see he was uncomfortable. I don't know how we did it but we talked him into doing enemas. My husband does it. They induce him to have a bowel movement.

Before enemas my son would have nights where you heard him walking back and forth from his bed to the toilet. In the morning I would say you had a bad night

last night, what was your problem? He would spell constipation. He doesn't seem to be doing this since the enemas.

On Saturday 11-10 our son went to the first day of the season Special needs Ice Hockey. He is just learning. There were no problems with him about anything. In fact for the first time he put on his hockey gloves without objecting, which we have been trying to do the last 2 years. He followed directions from a volunteer on the ice, using his hockey stick to hit the puck back and forth to him and towards the goal. When hockey was over we went outside and hung out at the car and did nothing for about 20 minutes and had a dose of MMS. He did not care one bit. He entertained himself by watching the sea gulls. He was not impatient.

Next we walked over to the bowling alley, which is next door to the ice rink. He participated in special needs bowling. They have the bumpers up so the kids don't get gutter balls. My son actually threw some balls that didn't hit the bumpers. There were times in the past where every ball he threw hit the bumpers. Again there was not a single problem, incident, or signs of agitation from him while we were there. This is the first time in his life where we were able to go from one activity to another and not have an upset. He enjoyed himself.

What was really interesting was that he usually stims with a container of pumpkin seeds when he is in the car or at the bowling alley. This Saturday he left the container of seeds at home and not once did he even ask for them while we were out.

My son asks for a heating pad, which he has been doing for years. We wonder is it worms that have been causing all this pain for him? We would love to eliminate the pain, the repetitive behaviors, and the prompting through self-help and activities. He does lay around a lot. Everything he does is at a slow pace. He lacks stamina and speed for appropriate activities.

---

105. Hi Kerri, my daughter's first atec was 85. We just did it again and it is now 55! :) :) (approximately 2 months on MMS)

---

106. Hi Kerri,

I just wanted to let you know that we are up to 30 drops per 8 oz bottle and now I'm seeing some new things. He used future tense this morning (he sticks larry boys super suction ear to his window and waits for him to fall) This morning he said "Larry boy will fall." Usually when he falls he says in his high pitched voice "are you ok". Today when Larry Boy fell he said in a deep 11 year old voice "ouch". I just burst out laughing.

---

107. Dear Kerri,

In the spirit of giving thanks, I wanted to say how deeply grateful I am to you and your amazing work with mms and recovering children. I have never felt such hope for my son and such joy sifting through poop!!!

What a truly tremendous gift you have given us all...

Sending love and Thanks

---

108. My son is getting tiny bit more normal every day!!! I could kiss you!!!!!

---

109. There was once a day not too long ago when all my son would do is scream and cry. No words at all. No communication. Today he asked me "mommy who holds up the clouds so they don't fall?" :) xoxo love that question! It means so much!! Autism is big. But God is bigger!! Don't give up ladies!! God led us to mms & to Kerri for a reason!!

---

110. Kerri is fabulous. She is very loving and supportive and will do anything to help our daughter recover. Using her MMS and parasite protocols have resulted in our eleven year old girl's ATEC scores dropping by half in less than sixth months. She is fully connected and much more responsive and affectionate. She herself is now motivated to succeed! We look forward to full recovery through Kerri's guidance.

---

111. I think we are over the initial die off hump!!! We are getting good reports from school about better focus and independence. Also, my son shampooed and combed his hair independently this morning. He even used a Q tip in his ears! I only asked him to try and shampoo by himself. He rewarded me with the combing and Q tip! Awesome mms!

Thank you again!

---

112. I am so grateful to have found you!! MMS here in our house is a MUST and my boy gets better by the day because of it.

---

113. 6 months ago, my son was on antibiotics for PANDAS, he was suffering with OCD and anxiety, as well as completely distracted - like a zombie.....his teachers came out one day with tears in their eyes because my son said he feels like monsters are inside his head and they are scaring him! They were so worried about him, as we all were!

We started MMS in April. My son got up to full dose relatively quickly and we added in MMS baths and MMS enemas and then I pulled the antibiotics—cold turkey! I was emailing Kerri at the time and was afraid to stop the antibiotics. She guided me and gave me the confidence that was needed! As suggested by Kerri, we also did night dosing of MMS. This really helped my son. Keeping a constant flow of MMS was the key.

My son is flourishing!! He is HAPPY and confident. His focus has increased greatly! Since the start of the new year, he has had great day reports everyday in school! SO many gains in all areas! His coordination and strength have improved - he can do 11 sit ups (In June he couldn't do 1) He was chosen as Student of the Month in his Tae Kwon Do school (he is now a purple belt). The best news to report is his ATEC is now a 10!!!!

Our family is so grateful to Kerri!!! This protocol has made the BIGGEST impact on my son's recovery!

Thank you so much Kerri - My son's Fairy Godmother!!!

Xoxoxo

---

114. I was praying for a new direction to go in to heal my boy. I literally woke up the next morning with a link to Kerri's presentation in my inbox from a friend whose daughter is making beautiful gains with mms. We are on day 3 here and things are going great, I am so excited! Thank you!!

---

115. Yes, my son is making real progress - slow and steady but real progress. The MMS & Parasite Protocol has been very beneficial for him...that's why I am trying to stick to it very closely. Also, I have wanted to tell you that one of the best things that we have ever done for my son is the enemas!!! He is a gut kid with chronic constipation and your enema program has really improved his daily life.

Thanks again for all of your help and guidance—always truly appreciated!

---

116. Hi, I'm the mother of Lizbeth Hernandez Saray Miramontes and I want to share my testimony in case it is useful to you.

My 13-year-old daughter started The Diet in January 2012, in June the full moon protocol to deparasite and withinin two months, she expelled a worm. This helped her regain 8 kilos of weight. (She was 10 kilos underweight when beginning the protocol) Her attitude has changed completely, from being very passive and low energy, she began to smile and be more active.

Thank you and God bless!

---

117. From the ATEC at www.autism.com

Total Score: 5

I. Speech/Language/Communication: 1

II. Sociability: 1

III. Sensory/Cognitive Awareness: 2

IV. Health/Physical/Behavior: 1

Started at 56 score in March.

I´m still having problems in environmental awareness, because in his mind sometimes he is Super-Hero (he wants to help to all the people in disasters, his own words). Sometimes he is eating portions like me, not such big portions but he is burning calories in the swimming classes. His meals are so healthy.

So, my homeopathic doctor told me (and recommends me) to wait until January next year to start the PP. He wants to see the effects of MMS, Probiotics and some homeopathy that he will provide at the end of this month.

We continue using as I said MMS, Theralac, GFCFSF diet, NAET and A.B.A therapy. I am so happy to share it with you.

Hugs my dear God Mother

---

118. My daughter is doing well on the MMS. Her ATEC went from 53 to 26

in three months. The special education teacher at her school was very impressed with how well she is doing. She told me to keep doing whatever it was that I was doing, because it is working!

Thank you for your help.

---

119. Kerri, good day

I want to tell you about the progress of my child, the treatment began in July and the progress that we have seen is:

-He has gone from not wanting to eat ANYTHING, TO EATING BY HIMSELF, SITTING DOWN he grabs his spoon and he cleans his mouth every time he gets dirty

- *He has stopped wearing a diaper, and goes to the bathroom by himself, almost like any other typical child.*

* *He lets people other than my wife and I hug him.*
* *He now gives hugs and has started imitating a few other things.*
* *He can now obey simple instructions that he couldn't before.....no, pick it up, get down, get up, give me your hand, etc.*
* *At the institute where he receives therapy they have told us that they are seeing great improvement in his eye contact, as he now focuses his vision more clearly on an object.*
* *He still will not play with other children, but at least he is where they are.*

Thank you for everything and we are together in this fight day after day, winning small battles everyday to win the war.

God bless

---

120. *My son was a non responder. We worked with a DAN! Dr. for 14 years. We did the DAN! protocol tirelessly with very, very little gains. Did 3 years of ABA and 2 of SonRise. Did the diet. Still do the diet. We started the MMS protocol in April of this year. My son has had more gains since April of this year than with 14 years of DAN protocol combined. My local children's hospital specialist told me to put my son in a home and forget I ever had him. What a jerk. We pressed on and I could write a book about the gains since April. My son's Dr said he had two near impossible "tough nut kiddos to crack open...one being my son." Well, MMS works. If my son can improve I know yours can too. Whatever you have to do to do enemas, and get him to drink it...do it. My son is drinking 35 drops a day. Trust me, it is yuck. But he understands that if he drinks it, it makes the autism go away and he slams it down and says, "yuck." He totally knows I am helping him and cooperates. Be encouraged.*

---

121. *Hi Kerri,*

We're now at 1/4th of a drop per oz and today my daughter for the first time EVER answered a 'Where is...' question. I was putting out the garbage and when I came back in I remembered I had forgotten to put away a black marker

and when I found it was missing, I could only hope the property damage would not be too bad this time. I checked the living room and the kitchen but could not find any traces and meanwhile my daughter had taken the photo camera

and was taking pictures of herself in the mirror. Amazingly she seemed to have a way better understanding of the thing. I asked her twice where the black marker was, and after the second time she pointed towards the kitchen and said "There."

SHE HAS NEVER DONE THIS BEFORE! I checked the kitchen and found the black market next to the fruit. The pears, melon and mango all had black circles and stripes. I was a bit overwhelmed I should say.

Thank you, thank you, thank you for never having given up your search!

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122. *My son Fernando Latin is 8 years old and was diagnosed at age 3 and half. When I started this struggle with autism all the relevant studies were performed. We visited a neurologist, psychologist and a gastroenterologist, he began taking the supplements according to DAN! protocol, but the list of pills he was taking was increasing and my boy was restless. Then I went to a homeopath,*

the treatment worked a little but it was so expensive I couldn't continue, it is needless to say how much money and time I spent on appointments and tests, plus the hyperactivity problem was growing each day. Until God put in my path an extraordinary friend MARIA CAMPERO and she talked to me about a foundation in Port Ordaz "VENCIENDO EL AUTISMO" FOUNDATION (Carolina, Yamileth and all that beautiful team) they brought Kerri Rivera to lecture here in Venezuela, on 04/02/2011. I will never forget these words AUTISM IS PREVENTABLE, TREATABLE, AND CURABLE. A new hope that a mother's heart never looses… In that conference she also talked about MMS and its benefits I was lucky Kerri evaluated my child, I started giving him MMS plus some supplements and have won this since:

* *Better pronunciation, for example he used to say Dowg and now he says Dog.*
* *He obeys orders.*
* *Spends more time sitting.*
* *Evacuates normally with no bad smell.*
* *He stopped biting his clothes.*
* *He stopped making noises like: wiiiii yiiiii.*
* *He stopped playing with his hands.*
* *We go somewhere and he is relaxed.*
* *If we take a picture, he looks at the camera.*
* *He is more aware of his environment.*
* *He is improving a lot and really fast with his ABA therapy*

These are all the benefits I've seen with my son after starting with the MMS, I know there is a lot to do but know a have real hope. Some advice for parents that are starting this road: please accept what is happening, inform yourselves. I always think that to get your children through this you need the four-legged table:

* *Diet*
* *MMS, Supplement treatment*
* *Therapy*
* *Help at home*

I've always asked God to give me enough wisdom to help my child and to put me in a direction were I could find people that can help me, and believe me he has listened: Venciendo al Autismo Foundation, Kerri Rivera, my sons therapist Milagros Alcanta, Danny her teacher-shadow, Maria Campo, a woman not only committed to her son but to all of those who she can help and guide me, including Marilyn Aparcedo and her team. All of them are my bases to keep going and as Kerri and Carolina say: This is an endurance test and there is no giving up!

I have nothing but thanks these wonderful and professional people, Thank you!

Norkis Pinto, El Tigre—Venezuela.

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123. Alexander was a normal baby until he was 6 months old, after that he suffered a change that, when we got home from work it was like no one came in, he was very uneasy, we talked to him but he didn't seem to care, first we thought that he didn't listen, the pediatrician and neurologist recommended hearing tests,

we did them and his results were normal. The pediatrician also recommended a psychiatrist but I thought it was very early for that so I took him to a psychologist, but he didn't diagnosed him, instead he referred me to a psychiatrist specialized in autism, and with a simple test he confirmed the suspicions: your child has autism and this has no cure, take him to special classes and therapy. I quickly signed him to a special camp and school, but they they just took my money and my sacrifice to travel 60 kilometers daily, they didn't do what they promised, they charged me triple just to give me a diagnosis and I believe he didn't even receive therapy. In my despair I went to the internet, I made an email account, a facebook page and started to look for parents that were going through the same things I was, then I contacted a Dominican mom living in Puerto Rico and she told me about Kerri Rivera and the diet. She told me that Kerri was the person to go to about this and Kerri answered immediately and asked me if my boy was on the diet and I said he was only 50% and she told me that if I wanted my boy to get better I had to do 100% so I wrote her back when I was doing the diet entirely. She gave me the first three supplements MMS1, THERALAC AND QUINTON WATER. Everything has been so difficult to get but if you persevere you get want you're looking for. I got the MMS1 but I was scared because of the strong smell of chlorine but I gave it to him with faith, I took it and my youngest baby girl started taking it. She had had a cold for about a month and it disappeared, Alex started to get better in every aspect but the biggest changes began 15 days ago, since I give him his MMS1 treatment. I start at 3 o'clock and finish at 12 at night. On weekends I start at 1 and I complete 12 doses of one drop mixed with citric acid and give him that daily. My 3 year and 4 month old baby boy is saying his first words. He is more connected, pays attention, he is aware of what happens to him and he is more loving than ever. I am so happy; I thank God, Kerri Rivera, Zeneida, Cynthia. But I mainly thank MMS1, because with a supplement so cheap, I'm getting my son back, the one that Autism wanted to steal from me.

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124. Juan Eduardo is 9 years old and he was diagnosed with Autism at age 2. It has been a long road in which we have tried everything. 7 years after trying and failing, in April of this wonderful 2011 we started in the right way. MMS came to our lives. Juan Eduardo was a self-centered boy and with a lot of fixations to objects. His improvement in school has been slow, but in 5 months he has improved what he improved in 5 years. MMS in our lives has been wonderful, despite the hyperactivity and lack of sleep at the beginning of the protocol, the life of Juan Eduardo and our lives have changed drastically in a very positive way. He will start regular school at the beginning of next year. He is a happy boy, he sleeps all night, he talks a lot more even if there is a long way to go, his quality of life is so much better. He shares with whoever is around him, a lot of times he surprises us with his qualities. He has adapted to the MMS in a great way. We took the panel viral test and the results were amazing, there was no virus. When I saw the great positive effects the MMS has made, I started to do protocol 1000 for maintenance with 100% success. Last year I suffered from several episodes of flu in which I had to take antibiotics, but this year I feel excellent, Thank God and Kerri and MMS I haven't been ill. I thank God, Kerri for putting you in our lives; I'm sure he has given back everything you selflessly have done for everybody. The smiles and looks in our children's eyes are priceless. Thank you Kerri and Jim Humble. A big hug.

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125 Yes, I have increased the drops. Honestly, since we last spoke, he has had some of his best days...super happy. He actually read a book on his own on the way to school this morning. Seems very calm. Thank you.

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126. *Hello Kerri! I have not written you in some time. I must tell you I have already been using MMS for two months. We have seen a lot of improvement. He suddenly speaks, says single words. If I sing a song or the vowels, he tries to imitate me, although it is still not very clear. But he tries to imitate. He smiled back at me when I smiled at him. And so those are several things. Tantrums are also less.*

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127. *She is doing excellent! Every day we see small but important progress. I am not sure if she has noticed the changes in herself, the best will be when she starts school and classmates and teachers can give me their opinions. Family members have also commented on the changes we have seen in her.*

    She is also answering questions about what she wants... With yeah, nah or the sign for all done with and then says dddon!

    Now she wanted to see Mickey and told me tttttiii and I showed her the movies and she said "ickey!" ;) We are communicating!!

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128. *We are a family that lives in a country where living is not easy at all. The maternal death rates and child deaths are very high, and there is hardly any chance of getting access to special medical treatments and therapies. Our son started to show signs of autism since he was 2 years 8 months old. He had begun speaking but at that moment he stopped talking, he started to show no expression with his eyes, to roll around trees, to scream and to tantrum, and to not allow contact with anyone. Little by little he started to be very hyperactive and to have serious sleeping problems (he didn't want to wake up and he could not go to sleep at night).*

    The start of my son's autism went along with colds, severe coughing and infectious diarrhea. Our son's teacher had always had excellent reports about our son's behavior, but since this severe cold with synovitis in his hip, the transformation begun. Since then, the awful diagnosis and the absence of guidance led us to an abyss. Our son presented total absence of self, almost no language, hyperactivity and many sicknesses. 6 months went by in which he met with a real parade of doctors and therapists that gave us bad treatments, bad diagnoses and almost no information, our life became a living hell. We went into a state of denial in which we didn't want to see anything on the Internet regarding Autism. In that time our son had been diagnosed with severe sinusitis, complications with his adenoids, and limitations that he developed because of his hearing capacity.

    By the end of the year 2007, I alone broke the pact I had made with my husband, and started to search the Internet and found Yeroline Ruiz's page where she commented about the biomedical protocol through which she had gained her son back in months. Little by little I tried to convince my husband, who at the beginning was completely reluctant to the possibility, but by December 2007 we made our first order of supplements and quelators (magnetic clay from the United States). The supplements took forever to get to us and when they arrived we gave them to our son without any clue or guidance and hardly any diet. The results were horrible, he got worse and worse, and this lasted about 8 months. During this time the therapists gave us a terrible prediction about our son's future. Our family problems were also getting worse and the only guide we had was Yeroline and the Curando el Autismo foundation. Thank God we didn't give up and we passed the hard times.

We eliminated some of the food that is forbidden in the protocol and we started to use Enzymes. Our son started to improve, his health got a lot better and we stopped visiting traditional doctors and I decided to take care of his treatment, the process was not easy because there aren't even the basics for the protocol in my country, from the flour to the milk, everything is really hard to get. Obviously a DAN! doctor or supplements are unthinkable. However even if his health had improved, the Autism symptoms were still present, the speech therapy did not help and sometimes even made it worse. With a lot of effort we brought Rosa Dominguez (Tomatis Therapist) and we begun applying this technique to our son. The economic effort was very big but the results were worth it, he was more in control of his body, the clearest sign of this was the control of his sphincter that happened almost magically. His language also improved even if he still didn't use it socially, but little by little we verified that our son had no sign of retardation compared to other kids his age. Even with the improvement, the tantrums, frustration and limitations of his language remained, we decided then to make a new effort and traveled to Panama to the Stem Cells Institute to make a stem cell transplant.

Our debt was huge, and despite the effort our baby showed two contrary signs: a positive one that was that our boy was completely connected to his environment (he is never outside of the world anymore) and a negative one: he became aggressive. He had never shown aggression, auto-aggression or violent behavior, but from the moment the anesthesia was applied these began.

Our child started hitting himself when things didn't go his way and he bit other people out of frustration. We remained on our path with despair because we could not see the light. We tried hyperbarics for 70 days in a row, eqinotherapy, and others. In 2011 we came across Puerto Rico's CEA conference and we found Kerri's topic and the SCIA topics very interesting. We decided to do the SCIA tests and we confirmed that our boy also had virus and an inflammation even though his immune system didn't seem very affected. Because of our country's limitations we couldn't complete the SCIA tests but then we had a lead on how to start a new journey. All we needed was a doctor that could apply the SCIA protocol.

But then there was a miraculous day in which we saw Kerri's talk and hope grew inside us, we contacted her immediately and she answered immediately too, with good will and all the indications as to how give him MMS and how to apply the protocol. After two weeks we started seeing a change in our son. Eye contact was way better; he speaks fluid sentences and gives structure to his words.

We are now three weeks into the protocol, we can see almost no aggressions and tantrums, we teach him letters and he recognizes them, reads and writes his name (he does it with some difficulty) his receptive language is %100 active, he is very loving, specially with me. (His mom), he hugs me and kisses me and tells me he loves me. We know we still have a lot to go but I'm certain that we will make it. My son has now Borderline Autism; his connection with the world is total. We are still thinking about doing all the SCIA tests but just to find out our child is cured. The light and hope that Kerri and the MMS have given us does not compare to anything. Thank God! Kerri is a blessing in our lives!

129. This email was after an ATEC drop of 64 to 44:

This is truly AWESOME!!! He lacks in the "Speech/Language/Communication" area the most!!

I honestly thought when I was filling this ATEC out that he would have regressed because I just thought he might have...it seems everything else we have EVER done it is always too good to be true! It actually is not this time!! Praise the Lord Jesus Christ! \o/ I even had my oldest daughter give her thoughts on the questions too so that I doubled checked myself regarding his behavior etc...you know to make sure I was not out of touch! :)

We definitely have a ways to go, but I have never had my son at this level of 'awareness' before! We are doing RDI (Relationship Development Intervention) and have been since Feb. 2011...he's made great gains with it, but he is FLYING now only because of the MMS!!

~Melissa, IN, USA

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130. Hello, my name is Silvia and I have a 5-year-old son named Ricardo who was diagnosed with Autism 2 ½ years ago. From that moment he has been on a gluten and casein free diet and a therapy routine that help him day by day. Three months ago I met Kerri Rivera and the Venciendo el Autismo Foundation, and started giving Ricardo MMS. From that moment on he has improved significantly, his language is better and his behavior is a lot more controlled, plus with the biomedical treatment he goes to the bathroom regularly, this makes me very happy because he was always constipated.

Silvia Morales — Caracas.

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131. Since I was a baby I was a very sick child ... I remember I had many gastrointestinal problems, I made my mom's life miserable with all the diarrhea and vomiting ... I couldn't gain weight and I had no appetite. All this accompanied me for many years; the diarrhea became chronic constipation, fluid retention and dry skin.

All of this without knowing I had a serious problem, until I gave birth to my first child. The constipation was a nightmare, my baby got ill, when I fed him breast milk he would get a rash, and then he had convulsions for about 20 seconds, when I fed him again the same would happen but now the convulsions lasted for nearly a day. The doctors didn't know what was going on either. In one of my researches I ran into a page that talked about Autism and Candida being one of the main causes, this is when I find out that my son had chronic candidiasis and that he got it from me when I breast fed him. I tested my child and myself and we both had Candida, and I have had it since I was a baby.

One day I heard about the existence of a woman named Kerri Rivera who is devoted to helping children with Autism and I contacted her and she gave me all the help to treat my child. I will be forever grateful. She talked to me about the MMS and how to give it to my son. I also started taking it and in a matter of days I had a white layer in my tongue, it was the Candida getting out. I have gained my energy back, the headache I had in the mornings is gone, I feel vivid and almost all the Candida is gone. I've been with MMS for a month and I've never felt so satisfied with a treatment. This simple and yet powerful remedy has given my health and family back and with this I can assure, by my own experience that MMS works.

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132. *Hi Kerri, I want to tell you that Erik has started with the speech therapist, and psychologist, when she finished the session with Erik, I asked if she thought that Erik could still be diagnosed with autism. She looked me in the eye and said, autism? Are you sure that he was correctly diagnosed? I found her the forms and she told me today Erik has eye contact, he socializes, and is cooperative. She said he does seem small for his age, and that we were going to have to work on strengthening the muscles of his mouth and the tongue as well because they are very week. She said that not chewing would affct the development of one's language, and Erik has only been chewing for 8 months, which started after we did the chamber with you in Mexico. That was the answer she gave me, and that's something, the fact that she told me that this is not autism is really something, even though she doesn't want to contradict the diagnosis they gave two years ago. The truth is, I am so glad he has come to improve, and that is since you KERRI have started to help my child. It's been a year since we started with the MMS protocol and the improvements have been incredible, he still lacks language as he mispronounces many words, but the worst is over. You can publish this if you want, thank you very much for all your help.*

    Kisses

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133. *We had first formed stool at 4 drops. It was so inspiring. Since then somedays we have formed stool, some days we have loose stool but I relate this to detox - I can clearly see his gut healing. His expressive speech hasn't changed yet but he obviously understands much, much better and is able to follow complex comands like "come and give me one teaspoon from the drawer" or "go and put this in the dishwasher" or "wait for daddy to get out the baby from the car and then you can lock the door and put on the alarm". Things like that, that were unthinkable before. I hope he will go beyond his few words soon and will begin to talk.*

    Although speech is the thing that interests me most of all, perhaps the most impressive thing that MMS brought to us all of a sudden is the sense of smell - our boy never seemed to feel any smell, good or bad, in his entire life. He got this sense a week ago. We are thrilled - something is waking up in his brain, perhaps some pathogens in some part of his brain or in his nose or whatever died and now he is able to sense a smell. Things are getting moved.

    Thank you Kerri.

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134. *My son is 8 1/2 years old. I have spent six years and well into six figures to help my son. While I would see gains, nothing was really moving him forward. Three months with MMS, DE and ocean water; the junk that is coming out of him is both horrifying and thrilling. I think he is finally starting to feel better, and because he feels better he is more with us. He is trying so hard to speak and everyday he is saying at least four new words. He also watched a movie and laughed at a funny part!*

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135. *We started MMS 68 Days ago and my son's ATEC has dropped from 50-23... Now that's a MIRACLE!!! He is So much more "with us" and I'm seeing improvements daily. He is just so much more fun to be with now:) He did have a plateau, but is back on track. We have only done 4 enemas to date, but they made a big difference! Baths do as well:) I can't wait to see what he is like on his 4th birthday (still 39 days away).*

    Kelly, CA, USA

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136. *Is it just an amazing day or is the MMS already working? Its just day 1! I know people say that once your child starts talking, they never stop, but holy cow... Today in the grocery store, it took me 3x's longer to shop because he was talking about everything he saw around him and needed a response on all of it from me! So unlike anything we have ever experienced with him before. Could it really be the MMS already? Also, potty training has been going well (slow & and steady), but today, he didn't need much prompting! Many times, he just stopped what he was doing and ran to the bathroom to go all by himself! This is amazing, because he never stops a preferred activity to go potty! When i thought it had been too long since he went last and said "its time to go potty." he just ran in there and peed, washed hands etc. No tantrums or weight dropping, he just ran in and went! God is answering my prayers! :) I'll keep you posted on what happens tomorrow!*

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137. *You know Kerri, I had to email you directly I waited until today to retake my son's atec...just did his first Parasite Protocol and did the 72/2 hr this weekend, so waited a few days to pass by before we did...so this atec was based SOLELY on this past monday, tuesday & today. I got an 11, hubby got a 13. so average: 12. (he was 32 before MMS, then 27 after 3 weeks of MMS...now 12) I had to email you to thank you b/c well...because. What is there really to say :) cant think of the right words really :) thank you?? not really enough if u know what i mean :) ...But to think i was going to skip your presentation at A1 b/c I thought it's too good to be true. But you caught my attention when you started tearing up as you got up on stage :) you were the only person/speaker to show emotion like that. AND have NOTHING TO SELL ON YOUR TABLE :) You were there only for our children...getting nothing back in return! :) I know I've been emotional, but I'm prego and my sons getting better so cut me some slack :)*

I'm SO grateful for all you do Kerri. If there is something I can do in return, Please let me know. I know you have a lot on your plate. You have a heart of gold; such a giving, compassionate person. a "rare-ity" (this word is in my dictionary!!) You & Patrick are always in our prayers. I seriously want to go visit you in Mexico w/my family so my son can meet you when he's recovered. I told my hubby & he's up for it hehe :)

Anyways, long email but really just wanted to let you know how well he's doing and to 'thank you'. It blew my mind after I got the results. He still has issues in socialization and getting his vocab/speech up to his 4 year old level. I think much of that will change as he learns English better: he'll interact better with his peers.

Thank you Kerri from the bottom of me & husbands heart :) You are loved & covered in prayer. :)

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138. *We started to see a setback in January with our 1 year 8 month old girl. Until this date she had had a normal development, like her sisters (she is our third child) but then, she stopped talking, she just screamed and twirled. She would twirl like 20 times a day for no reason until she got dizzy and she fell to the ground. She didn't look at anybody in the eyes and could be behind a curtain hours comparing her toothbrushes; she wasn't hungry nor asked for her milk, we had to push the food into her mouth so she would eat it. I was desperate so I went in to a forum and a friend from Venezuela told me to look for Kerri Rivera in my country so I did. She immediately answered and gave me hope, since the*

three doctors I had seen before told me that Autism had no cure, that all we could do is to teach her how to survive and be a little bit more independent.

I found my hope in Kerri, I read the testimonies on her page and sent her a message that she answered right away. She told me to do the diet, remove milk and everything else, I went to her clinic and within a week of the diet Abby could look at me and smile (she had stopped doing that long ago) When I went to her clinic Autismo2 in Puerto Vallarta she looked at Abby with all the patience in the world, she gave me MMS, the supplements and all the hope in the world. Everything was new to me but I had faith that I was in the right place and from that moment on, while always counting on Kerri's advice, my baby girl started to get much better. Her first ATEC was 95 and a year and a half after it's a 15. My girl now smiles, talks, dances, she obeys and stopped screaming, her only tantrums are of a normal girl her age. I did hyperbarics and am still doing MMS, supplements and deworming her. She is now diagnosed with Pervasive Developmental because the Autism symptoms are gone. She doesn't run from one place to another, she plays, looks for other kids to play with and has friends. The only thing left is for her to establish a conversation, and to put together the words to make sentences, but I know she is going to make it.

Once she sat down on ant hill and a bunch of ants bit her, we had to go to the hospital and the doctors gave her cortisone and she was seriously ill, now when a bug stings or a mosquito bites she tells me where it bit her, and she asks me to apply a calendula ointment that I use for the mosquito bites. She sets the table and can eat by herself, she doesn't use a diaper anymore, we can go shopping or to parties and she is well behaved, there is no more tantrums or fixations, this is wonderful! I know there is a long way to go, I've been in this fight for a year and a half, but with KERRI RIVERA'S HELP I will rescue my baby from autism, even though some say that Autism has no cure I know it does. Kerri has been a blessing for our lives and I thank God for putting her in my path.

Thank you Kerri, I have no way to repay what you have done for Abby.

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139. Our 10 year old son, Ben, showed symptoms of autism since he was an infant. Until he was 6, he never connected normally with family or peers. As his mother, I ached for a hug, to be called "Mommy," or for a lingering look of love. I never got them.

Until he was diagnosed with autism at age five, I was utterly befuddled. What had I done? What was wrong with Ben? Why didn't he want to play with other children? Why did he drool endlessly, laugh constantly for no reason, and bolt from play dates and parties with no warning? Why was he constantly lethargic, to the point where we called him "the playdough boy?"

Ben was always happy, dwelling far from us, in his own perfect little heaven. My husband and I were depressed, even despondent, despite attempts at gluten-free, casein-free diets, ABA therapy, and many supplements, because we saw no substantive and lasting changes in our child.

Finally we found the Son-Rise Program®, which brought Ben back to us. After three-plus years of a mostly full-time Son-Rise Program®, Ben became highly interactive, engaged, and interested in his peers. That alone was a palpable miracle. As we say in Hebrew, Dayeinu! That would have been sufficient. But we constantly experienced regressions back into autistic symptoms. For no apparent reason, and despite endless biomedical interventions, including the DAN!

protocol—to the tune, I might add, of tens of thousands of dollars, multiplied over four to five years—Ben would suddenly revert to autistic behaviors, and we would lose contact. He became once again non-responsive, uninterested in family or peers, and seemingly unable to connect. Only the day before, he had been totally connected.

After being on the SCD and GAPS diets, and finding even them ineffective to alleviate these regular and devastating returns to autism, we were advised by Dr. Campbell-McBride that it sounded to her as if Ben had parasites. A friend of mine who was also a Son-Rise mom had mentioned to me that she and another Son-Rise mom friend of ours were trying something called "MMS." When I heard the words for which the acronym stood, I gave an internal scoff. "Master Mineral Solution? Is this a joke?"

I can tell you, in all seriousness, that now, five and a half months into our MMS autism protocol, MMS is definitely no joke. Since starting MMS, we have seen nothing but progress in Ben. We are still doing GAPS, but avoiding foods we know Ben cannot yet digest. Ben's ATEC score has dropped from 43 when we started MMS to a startling 20. We are seeing sustained, natural, unsolicited and consistent eye contact, like never before. Ben is consistently responsive, certainly on par with most 10 year old boys. He is playing hockey in our driveway with friends. He is solicitous of others, and compassionate when others are hurt in any way. He is funny, expressively loving, and eager to please and be loved. It makes me cry to write this. I wanted this so badly, and now, with MMS leading the other interventions, I have what I prayed for.

We are not perfect on the MMS. Ben is in his first year of school post-Son-Rise, and dosing during the school day is not easy. But we are tremendously hopeful and excited.

I truly believe, as Kerri Rivera has often said, that parasites are the missing piece of the autism puzzle. Like so many other warrior parents, we have done everything. But everything minus one was not enough for Ben. Now, I think we truly have the tools, and it is only a matter of time, faith, and love, to fully and permanently recover our beloved Ben.

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140. Caitlin has been on the MMS protocol for 3 months now. Caitlin is now off her 100 plus supplements a day that were the glue holding her together so to speak, with no regression. She is happier, more affectionate and focused. She no longer has a distended belly. She used to have terrible smelling gas on a daily basis and very foul smelling bowel movements. This is gone! She has increased muscle tone (has a diagnosis of low muscle tone and bilateral hip anteversion). She has been seizure free as well! She continues to make slow but steady gains in her reading and math skills at school. She isn't conversational in her speech yet but can comment on things and express her wants in longer and more elaborate sentences. She is falling asleep faster and sleeping longer.

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141. Eczema!!

At last my son (4 yrs) is living now without eczema, he was born with severe eczema all over his body, we used every allergic cream and med and even the magical Dead Sea Clay but it didn't work, but now after using mms and pp (parasite protocol) for 2 months... ITS GONE!! Thank you MMS!!"

Thank you!

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142. *This is the story of our son who is 4 years and 9 months old today. Our story is a desperate struggle to defeat Autism, the same struggle that a lot of families are going through to free their sons and daughters. Guillem started to have ear inflammation and laryngitis when he was a few months old and we medicated him with antibiotics, he had his vaccines according the vaccine calendar, and by the time he was 9 months old he was showing signs of Autism. He would put his fingers in his throat until he choked, he would hit his head on the wall and he was always mad, his tantrums were frequent, longer and more intense, he started to look at the lights and to twirl with no sense, he showed less interest in people day by day and he would get really mad if someone said anything to him. He was hyperactive, couldn't stop running and going up and down the stairs. The nights were terrible too, he didn't sleep well and woke up screaming as loud as he could plus he could not say a word.*

    My father and my brothers blamed me for this; they said that my boy wanted to dominate me and to get my attention. I had a hard time recognizing that it wasn't this, that my boy had something else. Once I accepted it I spent hours and hours reading on the Internet, and I read about the gluten-free diet and that was our first step. When Guillem was 2 and half years old we changed the diet and it worked. Guillem started to respond to orders, there was less screaming and his first words appeared. Three months into the diet we contacted Kerri, this has been a key moment in our history, because she has been our guide to get our son out of this long tunnel. The first thing she did was to check what our son was eating, I thought that I was doing a perfect diet but I wasn't, there were some foods with sugar, soy and additives, the next thing we did was to talk about the supplements and MMS, but I was very scared to use it and it wasn't until three months later, the day Guillem turned 3 that I started giving it to him. Now we have been using MMS for a year and 9 months. We give him MMS daily and every weekend we can but minimum one weekend a month we do the 72/2. His improvement was amazing, his language got better, his dressing skills, he learned how to use the bathroom, his sleep was normal, and the screaming was almost gone. The next step was to start with the MMS enemas, every enema made Guillem more alert, more present, we started with the enemas 4 months after starting with the MMS. We saw that the enemas expelled a great amount of biofilm and the more he expelled it, the more abilities Guillem gained back, I saw the importance of healing the intestine and that has been my obsession since.

    The next important step was the sessions in the hyperbaric chamber, his first sessions were at age 3 and 9 months, and the changes we saw were mainly in the obsessions he had, he paid much more attention to everything, his social skills were very affected but after this he made his first friend. Now we do hyperbarics with seawater every three months. Another piece in the puzzle were the parasites but with Kerri's help we've been on the protocol against parasites for 7 months and every deworming cycle our son improves. I know that we have to keep fighting but I also know that we are closer to the exit. Now Guillem sings, he plays with his brothers, we go to the movies, we do puzzles, we paint, and he is very happy, he has learned to spell his name and he walks joyfully down the street telling you about his day. He goes to school, plays football and more importantly, we are a family again.

    For all of this we are deeply thankful to Kerri, because she has always been there for us, without Kerri and MMS our story would be completely different, so we owe them EVERYTHING. I know that we will someday say Guillem is cured, and all the other children with Autism can say that too.

UPDATE: As of December, 2012 Guillem no longer has a diagnosis of autism, here is an email his Mother sent to Kerri when she knew he had recovered:

KERRI!!!

My son has an ATEC of 10!!!!

I have it repeated several times because I did not believe it...

I have copied it below...I'm going to have it framed!

The truth is that this Christmas we have enjoyed our whole family, we've been to the Zoo, to the fair, and during family meals he was very well behaved and enjoyed the Magi and the magic of Christmas. Christmas last year was totally different. For all this we give infinite thanks! There are not enough words to tell you how we feel! Without you our story would be different. We will continue working to get to zero!

A big hug!

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143. I started with MMS on April 2012, I was afraid but had a lot of faith. I did the ATEC for my son and it was 92. He could not use the bathroom alone nor say a single word. The day I started I thought there was nothing different, but when we were at the beach on vacation I noticed that when I called his name he would turn, and come to where I was. All this with one drop! Before that day I always had to stand up and find him so he would pay attention to me. He wouldn't look at me but he would listen to instruction. Days went by and when we came back from the beach he went straight to the bathroom… I couldn't believe it; I sat down and asked my self WHAT IS THIS? What happened? And I silently thanked God and Kerri. This was decisive for me to continue. After this he improved day by day, after 5 weeks his ATEC had gone down to 76 points.

I made a few mistakes at the beginning because I didn't know the protocol very well, and wanted to rush things. Again, Kerri with her infinite patience and love for others led me to the right path, and I started to see more, way more.

My son started writing, he knows his letters, he reads some words (he has memorized them) he is great in the bathroom, he listens, his eye contact has improved significantly, his last ATEC was last month and it was 60 points. I know we have a long way to go, but I every month there is improvement and even though there are some bumps and setbacks the good things overcome the bad.

My son has also started saying words, names of movies, he can say over 100 words (names of movies or things he likes). Some will think it doesn't mean anything to know the name of a movie but for me, it is to know how my son's voice sounds and that, is priceless. Now my next goal is to hear him say "MOM"

~Myrna Sterling, Mother of Gianmarco, age 5.

Myrna is the president of the GM foundation for Autism

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144. My wife and I have always been fond of traveling, getting to know different cultures and people, this is why we had our little one we decided t o keep traveling but to adapt to his rhythm.

When he was 9 months old he went on his first international journey. Everything was perfect, he was the happiest baby on the plane, he played with the people in the seats behind us, the stewardess wanted to stay with him to play, all the plane ride went along perfectly.

Something happened between his 15th and 18th month, his smile was gone, we no longer had happiness in our home, only nerves and less language. Maybe the excessive vaccines were destroying his immune system and leaving the door open for parasites to take hold.

When he was 18 months we went on a second trip and it was an absolute nightmare. He wouldn't stop crying and screaming on the plane, he didn't want to play with anybody. We spent a few days getting to know this new place while our baby fell further into this abyss in front of our astonished eyes.

Something was wrong, and after an episode of auto aggression we knew that this was not normal. After watching a couple of videos on the Internet we started to understand, and we went to a psychologist who didn't give us a diagnosis because our son was so young.

Later on we went to a neuro-pediatrician who also used the excuse of our son's young age to dismiss us, and finally a last doctor who didn't explain anything either.

Not even our family listened because they thought we were exaggerating. We were left alone and our biggest ally was and still is the Internet.

After the medical failure and their "anti-diagnosis" we took the best and most important decision of our lives, that was not to listen to any of the diagnoses, or to wait another 6 months to be called by the neuro-pediatrician again. We started down this road without an official diagnosis but with all the symptoms and behaviors that define autism.

We started with the casein, gluten and soy free diet with no experience on how to do it and our baby suffered awful withdrawal symptoms. We couldn't believe what we were seeing, his nervousness and aggression took us to our limits. After a few days on the diet his tantrums went down little by little until he was stable. But we needed something else because everything was out of control; this is when we went back to the Internet.

After three months of false doctors and pseudo medical experts we found Kerri Rivera.

She gave us hope, and filled us with confidence, but most importantly she was clear with us from the beginning. Everything she told us was logical and everything made sense as to why it was done so we trusted her without a moment's doubt.

He got better and better everyday. Kerri told us how to do the ATEC and what it meant. Our first result was 57 points when he was 2 years old, which was very high for us because of his young age. We have been doing everything Kerri suggests, improving the diet, and using everything she recommends, and the results have been spectacular, right now he is 2 years and 10 months old, his ATEC is 8 and he is doing great. Our goal is to have him at 0, and I'm certain that once we free his intestines of all the parasites, he will be a strong, healthy and happy boy.

He doesn't have any behaviors like the ones he had one year ago, now he smiles again, he talks and asks for things, he plays a lot and he is happy.

This was possible thanks to his Godmother Kerri.

Kerri, you have done and given us everything in exchange for nothing, and that is your defining quality as a human being and as a person.

Every day you give hope to all that YES WE CAN defeat Autism and now we have a lot of puzzle pieces to complete our puzzle. We may find a new one soon because there are a lot of people investigating and that makes us feel alive, to fight against the entire circus that has sprung up around this problem.

I would recommend that if anyone is not seeing progress in their children, to come to Kerri, and try everything she says word for word. She has done it all and has the best investigators and doctor on her side. The ones that aren't intimidated by the absurd laws of the upper echelon, those who only want our children to be sick all their lives so they can sell medicine to us.

We will keep up the fight.

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145. *Hi Kerri, I just got the third MMS Autism newsletter, and I tell you it couldn't have arrived at a better moment. For the last few days my nephew has had a strange infection, he was hospitalized and the doctors couldn't figure how to fight it because it was resistant to many antibiotics. I told my brother-in-law about MMS and he started using it. After two days my nephew was healed, the doctor asked me for a little so he could examine it, and his answer was that the way MMS functions is amazing, he couldn't believe that such a simple and powerful product hasn't come out to the public eye.*

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146. *My husband and I were on the couch having our morning coffee and my son came bolting out of the room and ran up to my husband's face and said..."Oh Hi Daddy, I'm back!" And then ran back to his room...this is our once in a while "word" little man. After 3 non-progressive PPs (parasite protocols) the 4th one was a charm. A nightmare, but quite an eliminator... Lots of Worms Gone! And he is slowly coming back...we are seeing it in fact he is even reassuring us that he "is back".*

~The previous email was accompanied by an ATEC drop from 95 to 35 in 6 months.

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147. *Dear Kerri,*

It's a pity I don't speak English and that's why I can't write you on my own. Currently, a lot of good things are happening to my son (31 years old). I have followed all your advice and as a result he has completely calmed down. I have learned to prepare CDS at home with the help of Jim Humble's video. The CDS is a 600 ppm solution; my son drinks 30 ml per day with the feeding bottle method. I suppose this is the daily dose for a person of his weight. We are past the third PP and preparing for the fourth one.

Unfortunately I won't be able to attend the congress in Prague, since I can't find anyone to look after my son. If it were in the summer I would risk going by car and taking him with me.

I am very grateful for your attention to our life and progress and for your help in curing my son. God bless you for helping children with autism by sharing your knowledge and experience with the world. I will try to give a regular account on the progress of my son. I have no doubt he will be cured, too.

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148. *Three more tiny little gains on our step by step path to recovery....yesterday Nick got a haircut and did not cry at all AND was relaxed enough that it was the first time it wasn't like a sheep shearing, he actually got to get a little style (so cute!). Also, he was doing some pretty terrible screaming in the car in the parking lot at Whole Foods while I tried to find a parking space (I wanted to scream too) and I let him know he scared me. When we got into the store he spontaneously said "I'm sorry" -total first! Lastly, He has requested a hug from me three times recently - HUGE new thing and I love it. Thank you MMS and Kerri.*

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149. *Thank you Kerri. For all of your help, answering my emails, and for all that you're doing to help all of us, help our kids!!! I was at a breaking point. Nothing was helping her anymore, her organs continuing to get worse, hadn't grown in 4 years, and had become Jeckyll/Hyde this past 4 years...A violent, raging Hyde being increasingly present more and more each year, each month. I knew something had a hold of her all these years. And it amazes me how 2 endocrinologists, 3 pediatric GI specialists, and many other doctors had no clue.*

    Thank you for ALL you are doing to get the truth out there. You are an angel!!!

    Merry Christmas - xoxo

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150. *Puerto Ordaz, November 4th, 2011*

    My name is Carolina Moreno and my husband is Rafael Colmenares, we are the lucky parents of a little 6 year-old whose name is Ana Victoria, she came to this world to give us the world's greatest lesson, through her we have learned the real value of life, to be steadfast, and brave. We learned that it's our job to fight for our dreams if we want to accomplish them, and over all we've learned that God is who holds us up and gives us the strength and tools to move forward.

    My journey with Autism began the 27th of march of 2007, my daughter Ana Victoria was 23 moths old, her initial development was normal, but little by little she stopped talking, she didn't understand anything, she didn't miss her parents, she didn't play with other children or even her toys, she didn't like to be kissed or hugged, she acted as she was deaf but we didn't know that all this were symptoms of autism. It wasn't until the day that we went to a neurologist in our area, that someone told us that this was Autism, an incurable condition, and that our daughter would have it all her life. It was a very hard moment for us; all of our plans to be a happy and healthy family went down in a matter of hours.

    As parents we didn't want to give up, after recovering from the horrible news, we began looking for information on how to help Ana Victoria. In our country of Venezuela there were 4 specialists in Autism and they were all using the gluten and casein free diet, vitamin therapy, as well as expensive tests performed in the United States to check candida and bacteria. Thanks to them I learned how important the diet was to get Ana back from Autism, without it, recovery would be impossible.

    We did some testing through Great Plains labs, and the results indicated candida, bacteria, inflammation and much more . We started with Ketazol and Flegyl. My daughter was taking up to 400 mg of Ketazol even though she was barely three years old. Now with everything I've learned I can not believe that a physician could prescribe such a high dose to a child who is only 3 years old and weighs only 16 kg. That alone should be punished and criticized

However, I felt that I wasn't doing the right thing, years passed, Ana Victoria was 5 and her comprehension and attention levels were very low, my husband always thought there had to be something else we could do!

One day my dear friend Carolina Garcia talked to me about Kerri Rivera's blog, she told me that it explained the reason for the supplements and the hours they had to be taken, for example that the antifungals had to be given away from food and the pro-biotics worked better if they are given at night. After I read her blog and visited her website in July 2010 I called the Clinic Autism02 and Kerri Rivera herself answered me. I explained my daughter's case, and she asked me to give her an opportunity to help, and if in 2 months we didn't see anything different with our daughter we could continue doing what we always did. I told my husband and we agreed to try. I felt a great sense of peace when when Kerri told me, "I'm here, and I promise I will walk with you until we recover your daughter"

In August Ana Victoria was on Kerri's full protocol and in November God gave me the opportunity to go to Puerto Vallarta, México. An entire month in this city were my daughter received the hyperbaric chamber treatments, we started with MMS, plus we got together with Kerri at her home every night with pen and paper, she explained to us step by step how we could heal our children. From that moment a beautiful friendship was born between Kerri and I.

This is when I understood that Autism is caused by a weakness of the immune system and this brings as consequences; viruses, bacteria, candida, intestinal and brain inflammation, food allergies and contamination with heavy metals, and that it is necessary to attack every aspect to be able to heal autism.

The 23rd of November Ana Victoria Started to take MMS and in 30 days of treatment we noticed the firsts changes. My daughter's stools were consistent; there were no food residues or foul smells. When I came back from Vallarta I was full of new knowledge and a lot of MMS bottles, Ana Victoria had already a very well defined protocol and the best thing was that it wasn't a long list of supplements, only 7, MMS and Theralac. Everyone in my family noticed a great change in our daughter, better eye contact, controlled hyperactivity, she started saying her first words with sense and purpose; I want park please, I want food please, I want to sleep. She was doing much better in therapy and at school. Anita had begun her way back to the world she left when she was 1 and half years old.

When I saw this improvement in my daughter I decided to share my experience with other members of my community and it was there with my dear friend Yamileth Paduani and her husband Alejandro Teran that Fundación Venciendo el Autismo was born. Mr. Alejandro asked if Kerri could come to Venezuela and talk to parents in a simple way so everyone could understand that Autism is curable. Kerri was delighted to accept the invitation and in only 7 moths of work we had 2 conferences and many evaluations and nowadays there are 700 kids on Kerri's protocol that is: casein, soy, gluten and sugar free diet, some supplements depending on every child, MMS and Theralac. The results are very positive and there hundreds of families that have started with their children's recovery.

Then came the great discovery of the parasite protocol, for me, it was the missing piece in my daughter's puzzle. The first few months of the PP were severe (fever, laughter, hyperactivity) and many worms in her stool. However, after all these worms came out out I saw how her mind cleared, and month by month we waited for the full moon to deworm ...

Ana Victoria is now improving very quickly, she is a girl that enjoys being with her family, the park, a day out, she goes to school and she says to me that at school she now does her work in silence without crying, when I arrive home she greets me with a smile, she runs to me and calls me Mom, she tells me what she wants and what she doesn't, she can use the computer like an expert, she takes her own shower and dresses herself, she even picks out her clothes, she knows when Christmas is coming and that there will be gifts. Her therapists and her shadow teacher are really happy to see how Anita is progressing day by day.

Yesterday we were all at the table eating lunch ... and she points with her finger …"Papa's food, Mama's food and Ana Kikota's (Victoria's) food…yummy… heeheehee. My husband and I were laughing with excitement and happiness. Some time ago we felt that speech would be nearly impossible for Ana Victoria.

My advice: do not be afraid of MMS ... be afraid of autism; that which is unforgiving and has the power to destroy lives and families if we don't attack it on time.

We are grateful to God because He has never abandoned us and has always given us the strength and tools to fight and to believe that it is possible to recover our children. We thank God for putting Kerri in our path and we ask God to bless her everyday for having such a big and noble heart, she who is always helping others in a selfless way. We also thank Jim Humble and Andres Kalcker for helping us find the missing piece in this great puzzle that is Autism. We can do it!!!

To all of you, many sincere thanks for helping the children in my country.

Blessings,

Carolina Moreno, President of Fundación Venciendo el Autismo. (The Defeat Autism Foundation)

Venezuela.

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151. *Good Day, first of all I want to thank God for giving me all the necessary tools to be able to help my son, Jesus Soto who is 8 years old today. Jesus was born normally with no complications, loved by his parents and family, everything was going fine, but when he turned 18 months old he became ill; laryngitis, and fever, amongst other things.*

    He was diagnosed with Autism at age 3. As a worried mother, I took him to the psychologist because I observed several behaviors that were not normal. After the terrible diagnosis we started to take him to a specialist after specialist, they were all very good doctors, his DAN! doctor in Venezuela, and my sons gastroenterologist were very helpful. I met a very special friend Mayerling Aparcedo who brought the ABA method to Venezuela. My son had many improvements but we still felt that we needed something else. I spent my time on the internet finding out as much as I could until I found Kerri Rivera that without even knowing me helped me via Internet, talked to me about MMS and about the supplements and how to take them. My friend Carolina Moreno had the joy to travel to Puerto Vallarta and wrote to me from there, telling me that MMS was helping a lot of children. The 14th of December I ordered my first MMS and the 27th of January it arrived to my country, from that date on my son is taking MMS.

    The 2nd of April Kerri arrived to Venezuela and I went to see her, I took all the tests I had and she checked them, after only two months of taking MMS his viral

load went down to near normal levels, and his liver profile showed no problems. I made some adjustments that day and I continued with the treatment seeing a lot of improvement in his language, socialization, understanding of things, his hyperactivity has gone down and the laughter for no reason stopped. I'm very happy with the results and now all the family is taking MMS.

I'm very grateful to God for putting my husband in my life, as he has been a very special part of this battle that we are winning, I also want to thank our family, Kerri, Carolina, Yamileth, Mr. Alejandro and everyone from the Fundación Venciendo al Autismo.

Yours truly,

Maria Campero

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152. My baby girl Yuliangel Nazareth Quijada Montero was diagnosed with autism when she was one and a-half years old. From that moment she was given a treatment to allow her to sleep and to control her tantrums: "Risperdal" which had absolutely no effect, I gave her up to three pills before bed and even them nothing happened, I was just damaging her brain. She didn't sleep night or day, I was worried because she screamed all the time and she hit herself.

The 2nd of April 2011 I attended the conference of Fundación Venciendo el Autismo, where I heard for the first time that Autism had a cure. Kerri explained in a very simple way how I could cure my girl, even though I didn't have all the economic resources necessary for her treatment, the Foundation helped me with a part of the treatment, MMS and multivitamins. From there I started noticing changes, with a lot of sacrifice and effort my girl was on a strict casein, soy and gluten free diet. When I started giving her the MMS I would give her 72/2 on weekends and then I noticed that there was a lot of mucus in her stool, from there she started talking, she slept the entire night, and took naps in the afternoon, she pays attention, she knows how to count and all the colors with only three years of age. For me MMS is a miracle, since I started giving it to her she is a very healthy little girl, with no colds or any of the diseases she used to have, she is now considered to be very high functioning (14 pts. on the ATEC scale) with MMS, Vitamins, and the diet my child is getting out of the Autism spectrum. She does not go to therapy because of my finances but my sister Yenitze Montero interacts a lot with my girl, and her grandparents Raiza and Julian help me a lot with the diet, my nephews Jesus and Luis are also helping me with the home therapy and of course her dad and me fill her with love and care. My daughter is healthy, she has meaningful speech, she recognizes herself, she sleeps well with no pills and we are all very happy with the results. God Bless the entire team at Fundacion Venciendo el Autismo, especially Kerri Rivera for bringing MMS to my country, it is absolutely miraculous. Blessings.

Yurliana Montero and Jonatha Quijada

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153. Martin is 6 years old, weighs 19 kilograms and is diagnosed with severe non-verbal Autism. He was diagnosed when he was 2.

He almost made no progress with therapy, when he turned 4 everything seemed to be lost, but when he was 5 we tried a new therapy and he started to say a few words. He also got very sick almost everyday, he coughed a lot, had an ear inflammation and fever, he couldn't go to school.

He started taking MMS the 29th of June 2011, when he was only taking two doses of one drop and two drops every third day has intestines were not moving and he had a psychotic attack (something that I've never seen before) and this lasted 2 hours.

Children with Autism are severely intoxicated so his reaction to the MMS was very clear. After 15 days of taking 8 takes of a drop a day Martin stopped coughing, he is more alert, connects all the time, his expression changes, he started to make friends, he starts to play with the computer, I hear from school that he'll be a preschooler because all the improvement he has had and that he didn't have all year. (I was almost going to get him out of school) he was attending school with a shadow teacher but had no apparent social communication or increase in cognitive capabilities.

This past October, in a meeting with his team of therapists, I asked them all what they thought about Martin's improvements and they were very happy, I asked 2 of his speech therapists who have worked with him for more than three years, "Did Martin have severe autism?" "Yes." They both responded. "And now?" I asked them. "Noooo" they both agreed. The rest of the team, who have only known Martin for a few months looked at each other, and said that they could not imagine Martin like that.

The path out of autism is scary, but MMS is giving us great joy and hope.

Martin has not been sick anymore, the last time he was sick, before MMS, we had to admit him to the hospital, his cough was so bad that he was vomiting non-stop.

First off we give thanks to God, we thank Jim, Andreas, my dear Kerri who guides me with all her love, and to every single mother that is in this struggle. I also thank Mr. Luis from Buenos Aires, Argentina who has made it easy for me to get MMS; he is a wonderful human being who helps those in need.

We are on the way to full recovery for Martin, I'm sure of that.

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154. *So I just redid my daughter's ATEC. She was a 71 a month and a half ago and is now a 60!!! I thought she was making nice improvements but it really set in when I saw her score. Some things that have changed for her are now she is pooping on the toilet every day and telling me. She used to just go every few nights in her diaper. There's no more diarrhea, she's not constipated, she's sleeping great. She is just starting to show signs of imaginative play and a big one for us is that she just learned to blow. She couldn't blow no matter what we did to try to teach her. Now she's got it. Hopefully more good things to come.*

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155. *My now 8-year-old daughter was dx with autism at 18 months old. Started GF/CF diet and started with a DAN! She slowly made progress with speech, had a few words, a few 2 and 3 word sentences, and despite having autism, she was always a happy, calm, sweet little girl. Shortly after her 3rd birthday, she "changed.' She became more of a Jekyll / Hyde personality, and all progress in speech and improvements in eye contact and sociability started to fade. Seemed like everything we did was just like yo-yoing back and forth between improving, and then crashing yet once again.*

Last year at this time, we had just left the doctor we had been taking her to. For years she was on antivirals, antifungals, antibiotics on and off, SSRI's, Tenex, and when her violent SIB had become so bad the second year into treatment with him, he put her on Abilify. SSRI's and the Abilify did nothing for her except make

her behave worse. Neither did any of the other things he had her on. The first year she was doing pretty good, but possibly because the antivirals were acting as an anti-inflammatory. She always had chronic constipation with loose stools/ diarrhea. Nothing helped that either. We finally left that doctor who yelled at us in his office for 20 min straight, in front of my daughter, because he did not like that I had been challenging him on all of this for the past 6 months. I was no longer going to let him put the blame on us and everyone else... that her ABA and speech therapists didn't know what they were doing, and telling us she acted out this way because we didn't know how to give proper time outs or how to correctly give "pep talks" at bedtime. I was convinced that she had PANDAS/PANS and/or parasites that were causing her ever increasing SIB, loss of all progress she had made in speech over the past 4 years, and the fact that she had not grown in 4 years...did not gain 1 pound, feet did not grow at all, and she only grew 1/2 inch in height in that 4 year span. We had taken her to a very well respected endocrinologist the previous summer who ran all the tests. Could find nothing wrong as to why she wasn't growing. But he decided to put her on HGH anyway. Thankfully, we left and decided not to give her the HGH. We also took her to one of the best Ped Psychiatric doctors at UCLA who specialized in autism that summer. He observed her, her SIB happened right there in his office for him to see. He said her SIB is coming from pain, discomfort, something medical going on inside, most likely stemming from her gut. He suggested we get her scoped upper and lower. So we did. The only thing that came up was on the upper endoscopy, and that was that she had esophageal gastritis. So the GI dr gave her Nexium.

All the parasite stool tests we had done over the years had always come back neg except for one at age 3 came back with Giardia. But that was it. So last January, when we had finally left that her doctor of 3 years, her liver AST and ALT were at 130 and 135, her Creatinine (kidneys) were severely elevated at a dangerous level, she now had hypothyroidism, and after testing her cortisol thru blood and saliva we discovered she was barely making any at all. She had dark circles under her eyes, grinding her teeth for 3 years now, and agitated beyond belief ALL the time. Mind you when we started with him 3 years prior, her thyroid, liver, and kidneys were all in normal range. She did have dark circles, many many food allergies, some SIB, but nothing compared what we were dealing with now, or what was to come.

So now, what to do. We took her to a very highly recommended Pediatric GI in Los Angeles who was very nice. Listened to what we had to say. Ran the most sensitive and comprehensive stool analysis. Came back with nothing at all. Then took her to the head of pediatric Infectious Disease at Cedars Sinai. She obviously had her mind made up before she even walked in the door. She saw the word AUTISM on my daughter's chart, and that was it. I showed her every blood and stool test, explained the not growing at all for 4 years despite all the endocrinology labs said everything related to growth was in normal range, her severe SIB. She said to us..."I know you want to help your child. You want to find something "medical" that has caused her autism so you can fix it. But the truth is, your daughter has autism. You need to accept that, and take her to a pediatric psych dr who can help her with these SIB's. There are lots of meds that can help her be calmer." Had she not listened to one damn word I told her!!! All the meds we had tried in the past did nothing, already took her to a psych dr who specialized in autism telling us something internal was wrong. She would not run any blood tests, or any other kind of Infec Disease tests. So with that, my

husband, my sister, and I completely dumbfounded started to walk out. The dr then had the nerve to say..."She hasn't been vaccinated since 18 months (she was 7 here) Let's get her caught up right now before you go. I can give her 6 vaccines today." I looked at her and said you have got to be crazy! I am not giving my very sick child vaccines full of the poisons that did this to her."

So a month later we started with doctor who "gets it." Who listens, and treats parents with respect. Values their opinions. And the networking I had been doing for the past 6 months on a few different bio-med autism groups with other moms was paying off. The moms are the ones who KNOW!!! That's how I found my daughter's current doctor and how I found Dr Maile Pouls last June to help her with nutritional and metabolic healing. Dr Pouls ran a $100, 24 hour collection urine analysis, and we found out she had severe malabsorption, Ph was too Alkaline, she was catabolic, extremely electrolyte and mineral deficient, severely Vit C and D deficient, and had severe bowel toxicity. Working with Dr Pouls and her new doctor lead them to suspect parasites/worms. I was encouraged to look into mms, but of course I had heard nothing but bad things like it's bleach. I was very hesitant to try it, but I researched it, and sought out other moms on Facebook who were doing it. The toxins from the parasites had completely taken over her body and brain. She was SIB almost all day, every day by now. It was pure hell. We thought we were going to lose our minds it was so bad. We had stopped taking her anywhere but school and dr's appointments for the past 2 years because she would just suddenly out of nowhere, for no reason, violently freak out and there was no way to help her calm down. Her doctor said she's so toxic, and her body is so sick that she can't detox. That the mms will not only help kill, but will neutralize the toxins and help her calm down. So we started mms, and I could not believe how much calmer, happier, and more present she was in just a week. MMS is literally saving her life, and bringing her back to us. Before starting mms, we did just parasite meds like Alinia and Mebendazole. The parasite meds alone did not help her, even though she was dumping worms, but she was still completely psychotic, and getting more crazy and manic every day. Since starting mms she has dumped hundreds of worms, some 10-12" long, ascaris eggs, TONS and TONS of the shedded skins of the worms, tons of liver flukes, and hundreds of tapeworm segments. We had not done any PP yet. This had all been with MMS only! We actually started Albendazole for treating tapeworm about a month ago and saw immediate improvements with it. It really seems like this is her biggest beast right now to deal with.

These are her labs from before MMS, and after starting MMS:

2/7/2012 - one month after leaving scumbag dr of 3 years

AST = 79 ALT = 108 Creatinine = 1.24 EOS = 11.2 Sed Rate = 9

~ Started MMS 11/23/2012 ~

12/4/2012

AST = 73 ALT = 64 Creatinine = 1.32

1/15/2013

AST = 61 ALT = 60 Creatinine = 1.30

2/27/2012

AST = 51 ALT = 42 Creatinine = 0.92 EOS = 5.1 Sed rate = 12

Ref Range for AST is [15 - 46] ALT is [3 - 35]

Ref Range for Creatinine (kidney) is [0.60 - 1.20] Shows how well kidneys are working. Anything close to or over the 1.20 is considered to be of serious concern

*Ref Range for EOS (eosinophils) is [0.00 - 3.0] * High EOS are always seen with parasites*

Ref Range for Sed Rate (marker for inflammation) is [0 - 10]

Her doctor said her Sed Rate is likely high because when killing off pathogens and detoxing, inflammation will go up temporarily.

So I say never give up. Don't listen to doctors who don't listen to you. Kerri, thank God you saw those bottles of MMS at the clinic that day and asked what they were. And that you bought some out of curiosity and tried it. And that you selflessly have taken what you've learned and experienced, and shared it. Given so much of your time to help others, to help heal and recover their kids. You are truly an amazing person. We finally have the answers to our daughters autism after almost 7 years of numerous doctors and specialists, so many tests, so much money and valuable time wasted... and now we finally have real hope...real results. We know without a doubt she is going to get healthy, which will in turn give her the happy joyful life back that she once had before she got "autism." ~ xoxo

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156. *Today was just wonderful! We have been on MMS since 12/11 and this is our second round of Ivermectin from our Dr, just started today. My son has been very rigid lately, but not today. For the first time in over 6 months we went to the park and had a great time (no stimming), then we were able to run an errand and pick up books from the library. (he usually gets upset unless we do one specific route in the car). Felt like a regular mom running kids to the park and one errand. So lovely!!!*

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157. *Just a testimonial to MMS. For those of you new to the group and still unsure of MMS protocol I wanted to tell you about us. I was afraid at first, but we decided to try MMS. Within 3 weeks my son went from an ATEC of 36 to 18! That was amazing. Then we were afraid of the enemas. We said no way, we would just do oral MMS. of course after seeing others progress here we decided to do them. He would calm down! Then for months we agonized over the PP. We were afraid of it. We were scared of the meds, everything. Finally we decided to try it too. We are in the middle of our first PP and our son, who used to hit, kick, bite and scream at me over the smallest things all the time, has now been a perfect joy. When he gets mad it is over quickly and does not escalate into world war 3. Also these bumps he had on his face have cleared up along with his attitude! So if you are unsure of MMS like I was, here is one more testimonial of just how good the protocol really is.*

Thanks Kerri, all the other moms that came before me!

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158. *Dear Kerri and the readers,*

I would like to say that we started giving MMS to my son Filip, autistic/PDD NOS, when he turned 5 years old, after having tried lots of things (diet, many different supplements, HBOT, some sort of behavioral therapy Teach and ABA), we have seen enormous changes already in the first month.

I had heard about MMS from a mom of an autistic child. I started reading about it, but was not impressed by the comments I read on the internet. I contacted

a few mums that I knew from the Son-Rise programme in the US and they have reassured me that it works miracles.

I was however very sceptical of MMS, as I have read so many "negative" comments on the internet. This is why I decided to start it myself for a few months to see what would happen to me. Also, I had to figure out how I was gonna dose MMS 8 - times a day, when I am working 10 hours a day and Filip is going to the kindergarden.

In fact, I was just feeling great when I started using MMS.

I wanted to start with my son when on holiday, but my husband displaced MMS bottles by mistake. I was so mad. I have only found them the last day when we were returning home. I have immediately decided to give one drop to Filip before we started to drive. I need to underline that my husband was very sceptic. Filip would at that time speak, but it would mostly be scripting and rarely would he say things in context. Otherwise he also had other autism symptoms- tantrums, no friends, low muscular tone, no drawing, obsessive occupations (in Filip's case watching cartoons and reading books), no sense of danger, wandering out, nose picking, scratching but, toe walk etc. But suddenly Filip started commenting everything in the car, asking questions, observing the things he would see from the car etc. Me and my husband looked at each other and my husband commented " Maybe it is working after all".

Filip's ATEC was 48 at the time we started. At start, my mother-in-law helped out in dosing and we were able to dose 8 times a day. Filip's ATEC fell to 32 the first month. Unfortunately, my mother-in-law read some horrible stories on the internet and the FDA's advice was detrimental for her decision to stop dosing Filip, even though she was seeing wonderful results, she was scared and said that she is only believing the official medicine, admitting that the official medicine has nothing to offer our son.

I was very disappointed, but continued to dose as much as I could, however not reaching the recommended 8 times a day. I was therefore only able to dose 4-5 times a day. I started telework on Friday's in order to at least get 8-10 doses in on Fridays, Saturdays and Sundays and 4-5 doses the rest of the week. My son was great in November (the volunteers working on Son-Rise with Filip were commenting on unprecedented success), but his ATEC only fell to 28, I would say due to low dosing the progress was slower. Filip was having some hard times in January, when he was more hyperactive. At that time we have also introduced the GcMaf injections, which could have added to Filip's hyperactiveness.

But since two weeks now Filip is back to his shape. He is so communicative, uses unseen vocabulary, amazes us every day, he started drawing without being prompted, communicates with everyone, was invited to a birthday from a girl at the kindergarden, started to dress without prompting, started to tell me:" Common mummy, hurry up, let's go." or "Where are you mummy? What are you doing?" or when he occasionally wakes up during the night " Is it day already? or " I should not go on the street, because a car can hit me" or " Daddy, you are not sad, you look angry" or just yesterday when he draw a picture in the kindergarden he said to his teacher " I want to show it to my mum". The list goes on and on and every day I have to thank the all mighty for having led me to Kerri and to the MMS protocols. I know we are on the right path to recovery and I am not scared of the future any more. And, finally, i just did his ATEC to check out his ATEC- it is 16!!!!!! LOVE IT! LOVE IT!!!!!!

Kerri, thank you!!!!!!!!!

159. *My daughter has had really bad SIB for over 4 years. We've been in the ER for massive goose-egg bumps on head, and she always had severe bruising on her tailbone and spine from dropping herself down, butt first and legs in a "W" position, onto the floor, and then would fling and flail herself into walls, tables, furniture, bang her head on all of the above and the floor, a rage like she was the girl from the Exorcist. Nothing could stop it. It just had to run its course...like a tornado. Comes out of nowhere, and it will disappear when it's ready to. Nothing can stop it.*

    But after starting MMS, it was 80% better right away. Then after 3 weeks it started coming back. For a month it was really bad again, and we could not move up past 2 drops without her going crazy. Then after you had us switch to the HCl, she was remarkably better in about 5-6 days. She has had a few "episodes" in the past 2 weeks, but now they can last 30 min max, where before mms they would last anywhere from 15 min - 2 hours literally non-stop. The year before starting mms, there were times I had to lay her on the bed or couch and just sit on top of her, like on her butt so she couldn't hurt herself. I would just lose strength after about 30-45 min of trying to hold her.

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160. *Hey everyone! Just wanted to give a positive report about the HCl activator. My son is 12, non-verbal, very hyper and lots of food intolerances. I got mine in the mail today, gave a quick 3 drop dose to my son before he went out the door to school, noticed he was a bit more compliant and calm than usual after school. have given 2 more doses since coming home and he has been doing his usual, but he is much more calm today than he has been in months!!! I gave him a snack and he took it and started to eat and I told him: can you say thank you mom? and he actually responded with a sorta grumbled "graaaa moooooom" which was to me "thanks mom."*

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161. *Thanking God for Kerri Rivera and happy here too. My 15 y/o is in the chorus of his HS play. He has to do 5 costume changes, his own hair and makeup and several song/dance numbers, which he did perfectly on opening night! He is not your typical MMS/autism kid. He was pretty much recovered, starting with biomed at age 2.5, until age 11 when he hit puberty and he started getting rigid and anxious. We had some supplements going and were starting to look at stem cells when we found Kerri. He is not on the strict MMS protocol but takes it when he can and does PP and enemas each month. He is so much better since starting this last August! So thankful for all the info and support from this group.*

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162. *Hi Kerri,*

    Last week I contacted you regarding our 8 year old son and his focus issues and the disappearing act his mathematical skills have taken, and we've done our best follow through on your advice to up the number of doses to 16 per day. I visited my son's Integrative Medicine doctor this morning, who has been his biomed doctor for the last 3 or so years to do a live cell microscopy, and to see if he had any ideas about the focus issues our son has been having. I told my son's doctor in detail what we've been up to over the last 10 months (MMS Protocol, Parasite Protocol) and he took it all in.

    When he looked under the microscope he was shocked to see that our son's nasty dysbiosis issues were gone! He told me that he's had almost no luck completely getting rid of dysbiosis in a case like my son's. The yeast beast is gone! He still has evidence of leaky gut but the drainage looks great. He was so excited, our 20 minute scheduled visit turned into 40 minutes as he wanted

to know all about what we did so he can find a way to use it in his practice. He also remarked that you must be one bright lady to come up with the protocol, but we already knew that. :-) He had us fill out an ATEC when we first visited him back in 2010 and our son was at 55. He dropped into the 30's when we started him on Carnitine but the MMS protocol has brought him down to the 6. The doctor also noticed the distinct lack of autistic behaviours, so it's nice to get some outside feedback to help confirm what we are showing on the ATEC. I asked him directly if he thought we should change anything at this point and was direct...don't change anything keep going. And so we continue on our quest for the zero ATEC. :-) About two years ago we did a chelation challenge test (DDI) and found our son extremely high in lead and so we proceeded with IV chelation at that time. He ants us to do a chelation challenge test to check the metals status just to rule out lead and the possibility that metals might be still at the heart of our son's lack of focus and more ADHD like symptoms.

He wants me to send him some information on your MMS protocol. He attempted to use chlorine dioxide about 10 years ago and found that he couldn't get the results that you are getting. I'll send him to MMS Autism website but can I include your contact info (email)?

Thank you for being so patient with us and everyone. As you know full well when it involves your own kid the emotions come out and it's hard to remain logical.

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163. Drum roll....

I have been dying to share...

Been off MMS for a few weeks...AND HOLY SMOKES we are ALLLLL GOOD!!!!!!!!!!!!!!!!!

Summary...

My daughter—PANDAS—MAJOR sleep issues—fluctuate between diarrhea and constipation

Me—Acne—horrible—and nail fungus

ALL GONE. ALL.

NOBODY could EVER, ever, ever tell me why I broke out so much esp. with our squeaky clean diet.

First PP, OMG it was REALLY bad—worst ever—and became cystic—painful—so for SURE worse before better in my case BUT believed in protocol and KEPT GOING.

By month 4, GONE and yet to return

Fungus—gone in month 1, never to return

My daughter:

Well, you know, AMAZING!!!!!

YOU, Kerri, YOU helped me figure out FINALLLLLY after a zillion docs, WHY MY KID could NOT SLEEP! EVER! 7 LONG years... long long—exhasuting years—and it was PARASITES NO DOUBT in my mind! Month 1 of PP, literally like a light switch, SLEEPING —falling asleep ON HER OWN—(not with a circus routine to "get her to sleep") AND staying asleep ALL NIGHT LONG! UNREAL! This is HUGE!

AND bye bye PANDAS (Siver/Aloe nipped it, MMS maintained her gains,

BEAUTIFULLY!) SO I do believe in our Silver Aloe protocol for PANDAS, 100% worked for us! AND MMS. Both.

AND since OFF MMS, my daughter is 100% pooping NORMAL—OMG first time in her WHOLE LIFE!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!! (on MMS it was still fluctuating...)

AND she is eating things she would have NEVER ever touched! EVER! Raw veggies, nuts, trying EVERYTHING I make... unreal... this is HUGE too... the "healthier" you get, your tastes DO change... and one becomes less "picky"

I have learned that SOME probiotics can literally throw a child into a PANDAS rage--and also brought back MY symptoms—literally within 12 hours of consuming. (Like "Regarding Caroline" posted) This clearly happened to us. Mental note: NOT all prob's are appropriate for everyone. We react to fermented food—so I am going to experiment with no prob's and with THeralac __ONLY THeralac BTW

Now,

We are back to silver/aloe, daily, as prevention

We will still take DE (prevention)

Vit D3

Trace Mineral Drops

Enemas as needed

AND I am going to go BACK to the herbs for 3 months around full moon "just in case"—

I CANNOT WAIT to meet you in person, THANK YOU, and share our story with EVERYONE that will "hear me".

Again, my daughter did not have 'autism' per se, but autoimmune issues, meaning that, perhaps, her treatment protocol is 'shorter' then someone who is "more sick' etc. if that makes sense.

We also did a boat load of work prior to this. Meaning diet in place, for instance, for 4 years already—so healing began. This was the final layer for us. The frosting on the cake!!!!!

I have 2 brand new bottles of MMS in my cabinet :) AND will ALWAYS have it on stock!

With MUCH LOVE and respect to you Kerri.

-Jeni, IL, USA

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164. *My daughter was born Sept 9 2010 and she had pretty good health until she had 15 months, she was able to say five to ten words by then, she had all her vaccines on time as recommended by our pediatrician, and she was really lovely and happy but suddenly every start to change slowly, we noticed she start losing the words she had learned, she use to wave people saying hi, and suddenly she was not interested on waving anymore and she start to isolate herself little by little to the point she stop being a happy girl, she barely looked at us and we started to worry about it, anyway, I believe the first thought every parent may have think in this very same situation is that her personality is different than other kids and is something temporal.*

    When she had 18 months we went to the regular doctor check and they asked us to get the opinion of a development pediatrician since her social and language skills were behind the expected, and this started the worst nightmare ever.

It seems like every single development pediatrician has a waiting list huge enough to have more than a couple months totally scheduled, we called on May and the first available appointment was 4 months later, we called like 4 or 5 of the recommended pediatricians and institutions but it was all the same thing, but we finally got a pediatrician, not form the recommended list, but he made room for us in a couple of weeks and we were able to see him in a couple of weeks.

The diagnostic was mild autism, the recommended treatment was ABA therapy and the follow up was going to be 1 year later since he did not have may expectations of positive changes in the next 6 months, we were devastated by this, my wife was in denial, and I started our journey to recovery the very same day, I started researching and suddenly I found tons of information about autism and people who claimed to have recovered their children from autism.

I sent emails everywhere and I never imagined I would have such a great response from every person I wrote extending me a helping hand on all my doubts with the most sincere and honest recommendations, 2 or 3 days later I found Autismo2.com website and I saw all the videos available.

I bought 3 or 4 books on amazon, I saw many hours of recordings and seminars in Spanish and English, and I was amazed about some kids losing their diagnostic, but also about how they were affected by heavy metals, bacteria, viruses and all sort of things.

At the beginning I thought my daughter could not be sick, she has never had a single cold, how come? but a home heavy metal screen test gave us the first clue, and some lab tests confirmed the very same problems all our kiddos share, mercury levels on the roof, candida, yeast, you name it.

I started the GFCFSF diet the first weekend after her confirmed diagnosis and just one week later we started noticing changes, then I started with baths with bentonite clay, and noticed more improvements, we also started ABA on July, and little by little our daughter started to improve, later on we introduced MMS baths, Quinton water, DE, probiotics, and she improved every day.

I honestly believe that the early diagnosis and prompt reaction from our side played a big role on her fast recovery, It happened that we never canceled the first appointment that was made with the most recommended development pediatrician, by then we were looking for a second opinion and a new evaluation due to her huge improvements, we never imagined this pediatrician will say what.

Although my history with this disease or condition has been very short nobody knows how much pain, stress and suffering had caused to our family, we now enjoy our daughter more than ever when we see her playing with her old sister and taking away every single concern we had, we continue keeping an eye on her development but she is doing really well, I wish nothing more than every single mother I have hear on the discussion groups I follow have the very same results we have had with all the guidance from such smart and courageous parents like Kerri Rivera and many others that shed us the light on our darkest night.

I am more than grateful with all of those parents, I would do anything on my reach to help them, we need to help every single kid and family that goes through this disease to recover our kids.

UPDATE:

I'm very happy to forward the last ATEC from my daughter, today we came from her 2 year check up with the new pediatrician and she found her pretty well, she just told us" It's pretty hard to believe she was diagnosed with mild autism keep

doing whatever you are doing, since I would say she is acting like a regular kid for her age."

I would say that keeping in mind that most of her ATEC score is on the Language section, for a 2 year old and from what we came from she is on her way to full recovery (Previous ATEC was 55, at this writing was a 23)

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165. I found Jim on the Internet 2 years ago, and I immediately started Jim's protocol for MMS. Unfortunately we were so loaded with mercury, so when I reaches 8 drops of mms, and my son 2 drops (after more than 2 months on slow upgrading) we were really sick, again. All the heavy metals that where released with mms could not get out of us. That´s when I found zeolites, and that was our way back.

Now, two years later, my arthritis is gone, and now I know it was mms that killed the clostridium bacteria that I had been carrying since I was 13 (I am 52 now). 6 months ago my son fell off his bike and got an open wound. It was infected and some hours later the blood was black in his hand. Now I had a choice, to go to the doctor and give him antibiotics, which I knew would kill the bacteria but make him worse, or do it my own way. I gave him 2 x 3 drops of mms, and the blood was ok in some hours, I thought. Some days later he started to wave his hand. I thought he had eaten something else that he could not digest, but it got worse. After 4 weeks he was not only waving/flapping both his hands, but also his head. Then I started get suspicious. I tested him for bacteria (I use a Rayonex PS 10 for testing, bioresonance) and I found Clostridium botulism.

Now I had a choice again. I had a fully booked week, but his father came and took him home to his island, where they could use MMS every day and be in a calm environment. He got 2 x 3 drops of mms, for 6 days. After 3 days his father called and said "Eva this is scary, the flapping is getting worse". And I smiled and calmed him down, the bacteria are dying and the toxins are being released, I said. The zeolites took care of the toxins, and after 4 week he was ok again.

My lesson in this was, apart from the clostridium toxins, that I also found an imbalance in my son on Condrogenesis with the Rayonex. When I was 13 I stepped on a rusty nail. The blood was poisoned in the foot, but I did not dare tell my parents. After 3 days the whole leg up to my knee was black. I got antibiotics, of course. At 18 I was diagnosed arthritis in my knee. I think I had small amounts of bacteria left, as my son had, and the toxins from clostridium bacteria degenerates the cartilage near the infection. After some years one develop arthritis. I did, but it's gone now!

Eva, Sweden

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166. Drum roll please.....my son is 17 years old. He's been on mms for 5 months now, I'm so excited I don't even know, could it be 6? I think we started late July. He started with a 63.....he is now a 7. He went from 63 to 25 in just a few weeks, then a 13 a couple months later, now a 7. I feel like I'm cheating every time. I go back and look, argue with myself, nitpick....but whether he's a 5, 7 or 9, it's nothing short of a miracle because just one year ago, he was WAY over 100.

The ATEC is not perfect, not even close. There are things that the ATEC does not show. All that is true, but this is incredible improvement that no doctor I know would have ever been able to accomplish. Been there, did that, spent the 425K+.

And no, it's not just MMS, but that has been the main treatment and everything else we do supports MMS and general health because I believe that in the end,

it's a battle between your immune system...and all that's attacking it. We are winning and I sure do wish they would STOP CALLING IT AUTISM. That alone hurts so many.

Here's a little background on my son: Matthew was very high functioning from age 6-12. That was after diet since 3, floortime play therapy, some aba, AIT, IVIG, chelation for a year, OIG, years of infusions of glutathione, vitamin C, B-com, etc...immune stuff. Then he did very well GFCF ages 6-12, ran track (very well), 2nd degree black belt, boxing lessons, etc.... Then puberty hit, and what I did not know about, Lyme and co-infections RAGED, and for around 3 years, I lost him cognitively, worse, worse, worse. At 15, he was like an advanced Alzheimer's patient, ADVANCED, he had lost ALL short-term memory, it was horrible, he struggled to think and could not.

He became more and more violent; choking me, kicking me, did I say he was a blackbelt? Even though he lost everything cognitively, like the ability to answer a question, those karate skills popped back into his head and he nearly killed me.... really close a couple times.

That was a year ago when his ATEC was over 100. So, here's what worked: 1. Low amylose diet helped with the constant urinating. (he acted like a diabetic and had 14 of 16 PANDAS symptoms so auto-immune) 2. Biofeedback helped calm him some. 3. Cholestyramine helped him psychologically - I could see him clear up mentally in minutes. (chemical/mold/dust sensitivities big time) By this time, his doc had him on Ketamine for pain. 4. PEMF (pulsed electromagnetic field device) stopped the pain in 6 weeks, got him off of Vicodin, which was not working anyway at double doses, and all the Ketamine. I hated drugging him. Got him off the psych drugs over 6 months time. Then he got a lot better but communication did not really come around until 5. MMS. BAM. Big improvements in communication and PERSONALITY. With MMS, even his laugh changed to a typical sounding teenager's laugh, and for the first time in years, he can sit still and stop pacing, pacing pacing....the parasites were eating him alive....and now more recently, I know 6. Hydro-colonics is taking us to another level of clear communication. Now there's lots of spontaneous language.

I write things on Facebook so that I can remember and maybe write a book one day. I don't care how bad things get, believe me, your kids can get better and it's amazing, they really do store up all this info that you didn't think was there. It is there, and they will share it with you one day.

I hope one day Matthew can share his perspective with others. It's just that it has taken a very long time for us to help him understand that the things he did back then were not in his control so I'm careful not to talk about it. For months he would out of the blue apologize and feel terrible, over and over. Then there's memories of his dad losing it also....protecting me.

Thankfully, Matthew has blacked out or forgotten a lot of it. He did say he remembers being locked in his room. We had to turn the lock around and sometimes lock him in there. Bad memories. We were all traumatized. But not anymore. He is a different person today but he's always been the sweetest boy I know. I knew that, even back then. One day, he'll probably talk more about it.

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167. Hi Kerri,

First of all a HUGE big thank you for what you are doing with our children! My daughter has been on MMS two weeks now and she is like a different child!!!!!!!! Every day she gets better...By leaps and bounds. She WILL be one of your recovered ones ;)

UPDATE:

My daughter has now been on MMS for three weeks. ATEC down from 78 to 44. This IS a miracle. We have been in absolute desperation for almost three years trying to figure out what in the world is going on with our child. After hundreds of thousands of dollars, experts all over the world, LA, New York, San Fransisco... and nothing would work. Minor improvements but nothing that I could say really worked. Everyone always agreed that she probably does not have "autism" but what is making her behave that way?!?!?! So a long story short... If I could I would wrap my arms around all of you helping my daughter and so many others through MMS until I was sure you truly understand what your dedication means and that you are saving lives...literally <3 This is by far the biggest thing that has ever happened to my family. We are forever thankful.

UPDATE #2

I sent you my daughter's ATEC a week ago but redid it today. We started MMS in December and I decided I will do the test every month. Here are the results, 4 more points gone!!!! In 1 month from 78 to 40... Almost half off!!!!!! Her team is blown away ;) all we need now is that language score to come down... Kerri my goal is to have her recovered by A1!!!

Update #3

We are seeing such amazing improvements every single day. I think the true testament is the daily feedback from people working with her who do not know we are doing MMS. Here is part of a note from her SLP " her communication on the whole is truly remarkable- words, iPad, eye contact...everything is improving!!!!!!! So exciting. Has anyone told you lately that your daughter is a superstar? You should be so proud. :)" And I am...

Our main challenge has always been anxiety and today we had a breakthrough on that front. Instead of clinging to me for her dear life when I separate from her at school she took her friends hand, waived AND said goodbye and walked away... Here is the best part, she then turned her head, waived and gave me the biggest smile . Her face at that moment is forever engraved to my heart.

Also for the first time EVER my son was able to have a friend come over from school in our car without her having a major meltdown. Instead she shared her iPad with the friend to show him her program and use it TOGETHER!

Honestly I think our major challenge at the moment is for the rest of the family to heal with her... We had lost all hope and settled for life with Autism. We can now look at the future very differently and actually look forward to it! Love our new life

UPDATE #4

I have never really posted gains but this is too huge not to share. We started MMS 3,5 months ago and at that point I could hardly take my daughter to the grocery store. And even if I did it was a guaranteed meltdown. Well we just got home from a two week long vacation that included travel by air, time difference, different language, going from hot weather to freezing temps and piles

of snow, totally different foods, nothing but strangers to her, visit after visit to new places... The list goes on and on. The BEST part - the vacation was full of excitement, fun, laughter and happiness every single day I have to pinch myself to believe this is my life after such a short time on MMS. Thank you all for your support and guidance I have my life back and can't wait for the future now! We still have a looooong way to go but we'll get there.

Today is a wonderful day already

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168. MMS Works!

It's my number one pathogen fighter. Our family continually suffers from Strep, my son specifically from Pandas. MMS remains and continues to keep our strep symptoms at bay. I have used everything for our bacterial flares (Abx, herbals, supplements even homeopathics) and nothing has worked so effectively like MMS does for us.

Recently I changed over to the HCL activator and within in a few days we heard my severely apraxic son's first WORD "Mama" Its been just over a month on the HCL activator and he is now stringing two words together!! MMS is a huge part of our recovery protocol. I feel relief beyond measure that I found a post on MMS and decided to try it, and mostly I'm immensely grateful to Kerri for putting the MMS protocol together and for her love for our kids.

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169. We just had a good meeting with all of Amor's teachers and therapists. In the last few months there has been big jumps in Amor's cognitive skills.

I used to worry that Amor might have dyslexia. I never pushed her to read even if was behind her peers. I know frustration will only make things worse. Her 'x' and 'k', 'b' and 'd' were always mixed up. I have been observing this mix up for the past 2 years. Early this year, her speech therapist agreed that dyslexia might be an issue and we were ready to start studying dyslexia management.

However, Amor now shows interest in reading both phonics and sight words. She can answer letter names and sounds precisely. The same speech therapist now says that we shouldn't look at dyslexia anymore. It might have simply been a mix-up as part of early learning. Amor's dyslexia issues in 2 years all of a sudden went away in 2 months??

Amor is also doing well with number recognition and improving in one-to-one correspondence. This is something her former speech therapist (back in Japan) was working on for a year...with little progress.

All these seem so simple but these are great strides from someone who has vision issues. Amor also wears glasses.

If I were to plot Amor's improvements with time, the biggest jumped occurred in the past few months, which of course can easily be explained by MMS.

MMS clears the gut of bad bacteria, yeast and parasites. All these affect sensory processing thus inhibiting the child's ability to understand her environment and people around her. Clean the gut, remove autism...in Amor's case, remove GDD.

We are also running a son-rise lifestyle program. I.e. we don't put fixed hours into her program but use the son-rise attitude and son-rise her in the weekends.

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170. *Luca came into our lives July 26, 2010, he was premature, but all my kids were born in week 35, so I was not surprised. He was perfect, I have thousands of videos of him looking into my eyes, smiling, playing with his sisters, following daddy to the door when he was ready to leave to work and saying bye bye. He walked at one, and was a perfect little baby. It is hard to know exactly when he changed but I can tell you when I started to get worried, and saw him behaving differently. I had a neighbor the same age as my son, and when they got together to play I was surprised at how my neighbors son followed simple directions and looked into my eyes every time I called his name. When I had play dates with my friends all the moms were so relaxed, and while they were talking and kids were playing with toys, I was always chasing Luca and trying to keep him in the same room because he was not interested in toys or playing with other kids.*

    My first trip to the Zoo with my three kids was a disaster, Luca didn't want to move from the Monkey's area and had his first melt down, all over the floor screaming and crying. I remember seeing all the families with kids the same age as my son, and seeing how they understood, and paid attention to what their mothers or fathers were saying. For me that was enough to feel for the first time something was not right, and it was not that I was a bad mother, I knew deep in my heart it had nothing to do with discipline.

    I enrolled him in a school thinking that would help. The first day when I picked him up the teacher said they needed to move him with the babies because he was not ready for the 2-year-old class. That day I came home just knowing - and despite all my family, friends, husband and Pediatrician thinking I was crazy, we got him evaluated and the rest is history. On November 15th, 2012 it was official and we got the papers. Classic Autism, by that time we had read so much, watched hundreds of videos and searched every day on the Internet for interventions, schools, therapy etc.

    I remember I wanted to start ABA the same day that I got the diagnosis, but the waiting list was really long and we would have to wait. So we waited and started an early intervention program in the Kent District. Surprisingly, I think we took the diagnosis really well; we just wanted to help him as soon as possible.

    After the first month I stopped asking for a miracle or cure. I even asked all family and friends to do the same. I needed to accept it!!! My miracle was already here. My husband wanted to do the Gluten free diet and I was not even 100% in agreement...why??? He is such a blessing; let our miracle eat whatever he wants!!! I agreed to do the diet anyway, but wasn't really interested. I just had the feeling my husband was not "getting IT" or accepting autism = our new precious miracle. Now I can recognize and see clearly I was in total denial too. I was so afraid to let anybody know, even myself, that I didn't want this for Luca. I tried and tried and tried, but a voice inside of me was not in peace. I spent a lot of time crying and looking for recovery videos on YouTube, imagining Luca being one of them, and was fascinated with those stories.

    Then one day I found Kerri Rivera's conference in Bulgaria, it was a "Godcidence," (like my father always says) I wasn't looking for MMS, I didn't know anything about that. I remember I watched the conference 3 times, and I felt butterflies for the first time since I got the diagnosis. It was like that voice was finally quiet and listening to every single word! "I want this."

    I did my homework and found a lot of negative information about MMS but I did not care…that voice was so strong that I knew, the same way I knew about

Luca being autistic, that this was something I needed to explore. I looked for her in FB and to my surprise she answered me in minutes, when I asked her about the testimonies she connected me with some moms with recovered kids, REAL moms that decided to believe too. After I saw pictures from before and after and reading about their journeys I felt Hope!!! I knew deep in my heart this was the way and the path we should take. So I got my case together and when I was ready I talked to my husband about it.

It was easier than I expected, we wanted so badly to recover our son!!! It was not an easy process but finally after almost 3 months I GOT IT…WE GOT IT...THERE IS NOTHING WRONG TO WANT THIS, that is ALL we want for Luca!!!! For the first time I recognized my kid's autism was not a blessing, he was sick; GI problems, extreme constipation, food issues, sensory problems... and that voice (God voice) sounds really clear and loud; I NEED TO HELP MY KID TO RECOVER!!!!!!

On February 18th we started a Dietary Intervention with all Kerri's recommendations, the one diet that we were doing was full of sugar and carbohydrates, so we started to be really serious about all the food choices. We kept a very detailed food diary and ordered the MMS. By March 12th when our bottles arrived at our doorstep we were ready to start Kerri Rivera's Baby Bottle Protocol. March 13th we did our first bottle and that same day I asked Luca to look for a ball in the other room, and give it to me, and he did.

It was like he was sleeping soundly, and then he woke up. He was extremely alert and he was looking in a different way. At first I thought I was crazy, but then my husband noticed it too and the changes keep coming. He improved dramatically in all his therapy sessions, his waiting time, sitting at the table, responding to commands, pointing, eye contact, everything improved!

Kerri recommended doing an ATEC when we started back on February 18th, so I did, his score was 64 points. By April 1st he dropped 20 points! He now follows simple directions, plays with his sisters, recognizes them by name, hugs me and says mommy and daddy, has close to 200 words, and every day is a surprise for us.

I'm proud to say my son is on his way to RECOVERY AND HE WILL RECOVER, HE WILL BE RECOVERED!!!!!!!! I'm loving Kerri Rivera's Protocol, I'm loving my kid dropPing 20 points in his ATEC in a month, I'm loving searching his diaper, and inspecting his poop finding parasites, I know it seems impossible but I truly get excited! (Probably some mothers would understand) I'm loving this side of the picture FULL of hope. HOPE. I don't think I can leave this road now, I don't think I want my son to live in his "perfect" world and not in mine... I'm a fighter and thanks to Kerri I'm a believer ...THAT... is the blessing right there HOPE AND FAITH IN GOD IS ALL I HAVE AT THE MOMENT… Luca is really special, but it's not the autism that makeS him special, autism sucks!!! Overcoming it and all the obstacles he encounters every day, and doing what he is doing now is what makes him THE MOST SPECIAL KID ON THE PLANET, HE ALWAYS WILL BE SPECIAL TO ME NO MATTER WHAT, AUTISM OR NOT….I see it in his eyes now, he is a fighter like me, he is telling me what to do, recovery is soooooo in the picture!!!!!! I can actually see it!!!! I'm a HAPPY Mom!!!!!!!!!!!!!!!!!!!!!!!!

-Alma

171. *Today is a wonderful day already. My daughter got up to her alarm, took a shower without help, got dressed, packed her lunch, woke up her sisters, and is now getting breakfast for everyone ready. It amazes me how independent she is becoming, and how much our life is changing because of her new independence.*

    She is 10 and we started MMS in Sept. She had done 5 PP and following the PANDAS protocol the last week after emailing Kerri Rivera last weekend with concerns about eye fluttering. She is also on Fish oil, garlic, Magnesium, and GABA. Before she was very hyper, spacey, a lot of language, but not using it correctly. She was extremely impulsive, and would fixate on object to play with and ignore others. Now she does reciprocal play, she talks back and forth with her friends, she cracks jokes that are now actually funny. She is focused with her school work and not hyper - except in typical situations.

    This week my husband forgot to pick her up to take her to therapy and she came to my classroom to tell me how irresponsible he was, and that she was disappointed in his inconsistent behaviors. I had to laugh, but at the same time I was so proud as I explained to her the whole situation because we where having a fabulous discussion about life. She is doing so well. Thank you to all of you who have restored some of my hope that there is a cure.

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172. *We are now in our 7th month of using MMS (CD) and in our 4th year of treating B.D., our son, who was diagnosed Autism. Our first week of MMS (CD) brought on a skill that we had spent years trying to accomplish, over night potty training. Week 1 of MMS (CD) and B.D. was out of pull-ups and in underwear. We weren't even close to full dose and already seeing positives. We knew we were on to something big at this point. One month later, we all witnessed my son blow out his birthday candles and open birthday gifts. Probably the first time he knew this event was a birthday and it was meant for him. As a gift to him, we took a trip to Disneyland. Not only did B.D. walk the entire park at our side, but he never once cried, whined, or objected to anything on the trip. Prior to this, he had to be in a stroller or wagon at all times.*

    B.D.'s skills continued to flourish over the next few months. We enrolled B.D. in swimming lessons hoping he would feel comfortable without a life jacket on and clinging to an adult. This hope turned into a major accomplishment. B.D. has passed all Beginner levels in swimming and is now on to Intermediate. He is now swimming unassisted in the deep end of the pool! I used to hold my breath during his sessions hoping he wouldn't do anything that would scare the other kids in the pool. I still hold my breath, but now I'm at the end of my seat recording him as he's giving every single bit of effort to learn from his instructor and pass another level!

    Just the other day, we went to a birthday party that was held in a warehouse full of screaming kids, loud music, inflatable jumpy houses and slides. This place can over stimulate just about anyone! In the past, my son would vocally stim, cover his ears, run behind the jumpers where the generators are (trying to turn them off) and require me, or his Dad to keep him engaged with the rest of the kids. Well, not anymore! He blended right in with the rest of the kids! Not a single stim, didn't cover his ears, stood in lines, listened and followed the rules and instructions, stood in lines and PLAYED with the other kids. His Dad and I were able to hang out with all the other parents, watching him run and whiz by with all the other kids as if that is how it has always been. Only it hasn't. He has come so very far in the past 7 months. We have a 6 year old son who no longer has sound sensitivity, loves to eat whatever is placed in front of him, DRINKS

tons of WATER, has manners, shows empathy, is careful and aware of other kids (especially babies and toddlers), making progress academically, and so very affectionate. B.D. isn't recovered… YET, but we expect it to happen now more than ever. We have to put our shades on because the end of the tunnel just got closer and brighter!

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173. *My husband and I were told to come to the 2nd grade assembly this morning. They gave awards to 2 kids in each of the 4 second grade classes. One was for outstanding in academics, and the other was for most improved in Self Control, which is the "character trait of the month" for the whole school. Kayla was given the award for most improved in Self Control in her class! She walked up and got her award and stood up there with the other kids holding theirs. Up until a few months ago, she would have violent, self-injury tantrums at school every day... throughout the day, lasting anywhere from 10 - 90 min. She could never get through a class singing performance without losing it and tantruming, screaming through the whole thing. Her teacher came up to me on Wed. and said she just can't get over how happy my daughter is lately, and that all the teachers and staff in the school have really noticed too. FUA!!!! I'm so proud of my girl!*

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174. *Our third child (K) was diagnosed with moderate autism at 21 months of age. K was very ill. He suffered from vomiting and diarrhea mixed with severe constipation for years. At first, we began every intervention we could afford. The first step was removing all gluten, caseine and soy. We saw a decrease in stimming behaviour and an increased ability to learn. We implemented many vitamins and B12 injections, cranio sacral therapy, anti-fungals, HBOT and an even stricter diet removing all artificial colours, flavours, preservatives and most sugar. Our son was making slow but steady gains. ABA therapy continued from when he was two until just this past March (4.5 years). K was seeming much better but despite these gains, was never close to "normal".*

In July of 2012 a friend suggested MMS. I did my research and so it began. In three days K started to sleep through the night. After less than one week at a very low dose, K stopped the constant verbal scripting and obsessive speech- his most evident sign of autism. In that same week he began dressing himself independently. In the coming months, K's ATEC began dropping steadily. He began to make jokes, initiate social interactions, show empathy, cope with noise and busy places and best of all- understood safety. The risk of him running away was a memory. We could go places and he would stay near us. Teachers and Educational assistants were raving about his progress, unaware of the protocol we had begun. His most significant changes happened after a three months of the Parasite Protocol, using mms, Vermox, rompepiedras, neem and diatomaceous earth. Through enemas, he expelled worms as long as 24 inches to my husband and family doctor's disbelief. What K expels in his stool now looks normal and ordinary.

His ATEC in July 2012 was 46. Ten months later he has a score of 6.

He is undecipherable within his classroom and amongst his peers. He laughs, plays and acts like any other child his age. His academics are at par with his peers.

Our son does not appear to have autism anymore and only a trained eye would suspect that he ever had it to begin with. We thank Kerri Rivera, her Facebook group for all their support and MMS for being the final, and most significant leg in our sons' journey to recovery.

Maria A., Ontario Canada

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175. *My severe autistic boy has been now doing wonderful!!! This protocol has completely changed my life!! He's been dumping tons of parasites since we started MMS about three months ago we're now in the second pp...he's now much calmer more happier!! His ATEC dropped down from 80 to 48 in three months only...that was truly amazing he is now gaining weight, I feel like I'm getting my child back to normal again!! I wish I could tell the whole world how Kerri Rivera has changed thousands of people's lives!!! God bless u Kerri for all your hard work to help others!!!*

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176. *My son Nick started MMS just after his 7th birthday. Within 6 months he had cut his ATEC score in half from 66 to 37. Nick showed speech gains from the very first drop of MMS after having made no changes in speech for two years. Really, Nick hadn't made any improvements at all for two years. He was in a total stall until we began MMS. We raised Nick's oral dose of MMS very slowly taking two months to get to his target dose and never experienced die off that was unreasonable. Three significant changes are obvious in Nick's health at this point; he has been off of his Mitochondrial cocktail (for several years he has had blood labs pointing towards Mito dysfunction) for over 8 months and we haven't seen any of the lethargy that used to concern us so much, he was able to wean off of his seizure medication for his absence seizures and we haven't seen any return of seizure activity, and his thyroid appears to be beginning to shift from his long standing diagnosis of hypothyroid. The nicest changes we see are in the vibrancy of his health and how happy he is! His eyes sparkle and he has lots of energy for the day. He is no longer sitting on the couch staring out the window waiting for someone to figure out how to help him feel better. Since beginning MMS, every day Nick shows us just a little bit more of the boy that he is underneath the veil of autism and sickness. He tells us what his favorite things are, what he wants to do, and his sense of humor is coming shining through. MMS has given me a ton of hope that we just might get our boy back!"*

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177. *After 7 years of biomedical treatments, numerous therapies, and more doctors than I care to think about, our son, who was diagnosed with autism, could speak a full sentence, was potty trained, and could finally go to the mall and movie theater without screaming and putting his hands over his ears.*

    Victory??...yes...however, we knew we had so much farther to go. You see, as your child gets older, you realize that he is missing the key things in life that are crucial for independence. Our son had become "stuck" if you will, he was not socially maturing, and still lacked empathy, mature connections with peers, and proper communication with teachers and the other adults in his life. He would still yell when he didn't win a game, and he did not always react in an age appropriate manner, if something did not go his way.

    My research went on as always...searching, searching, searching...we were not getting anywhere with his current doctor, and I knew that we had to change our current plan for treatment.

    A good friend of mine called me to tell me about a new product that some of our warrior mom friends were trying. The letters MMS were spoken to me for the first time in March of 2012. My son was 11 years old and I was desperate for help. The first thing I asked was, "How much does it cost?" $25.00...what?? It can't be! We have spent our life savings, and now I am looking at something that cost less than a night out for dinner?? I decided to check it out!

I emailed Kerri Rivera and told her that I wanted to start the MMS autism protocol, and I'll never forget her quick response..."YIPEE", she said, let me know if you have any questions, I am here for you.

I read, studied, and called my friend about twenty times over the next couple of days, and then we began the next chapter in our journey.

About three weeks into the protocol, our son seemed calmer, as well as aware of others on a more mature level...we were excited! Once he was at full dose, we began, baths and enemas, and he continued to improve. Our next move was to try the 72/2 protocol, which is giving MMS every two hours around the clock for 72 hours.

Well, it was as if someone had kicked our sons maturity clock into high gear. We saw HUGE gains!

"Hey mom, I like your dress...you look really nice today"....WHAT??

"I'll try that new kind of chicken for lunch"...WHAT??

"I feel like I'm beginning a new life"...WHAT??

"It's OK that I didn't win the race, I had fun"...WHAT??

I wanted to call the Good Morning America Show and say, LOOK AT WHAT MY SON IS DOING!

He also began to grow and put on weight for the first time in three years! He put on 10 pounds and 2 shoe sizes in about 2 months!

The gains continue to come, and our boy is coming alive...recovering...finally it's here! My eyes well up with tears as I write these words...the words I have dreamt about for eight long years.

He celebrated his 12th birthday on January 3rd, and has told us that 2013 is going to be the best year of his life...YES...it is!

He is our angel, our fighter, our miracle. Thanks be to God for MMS!

We are blessed and forever grateful~

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178. *Once upon a time there was a little boy who had a strange mind, he hooted and he danced and he did not learn like the other children around him. So, he was sent to a special school. For his whole educational life he was separated, because he could not express correctly the answers put before him.*

As he grew older he seemed sad and very much in pain. He appeared to try to stop the pain by clawing at his face and arms. He also stopped talking. We, his mom and dad, were very sad.

Then an angel came into our lives and told us of a magic potion.

"But" said the angel. "You must give him the potion every hour of the day and night for him to be better."

So the little boys' mom and dad have been doing that now for 9 weeks and 4 days. Every hour.

Now in those hours the mom and dad still cry. Some, because the little boy has been hurting for so long, and..... now they know why. But they also cry because they see that their little boy is not hurting like before. They are happy for his healing, and that he does not claw at his body any more.

And they are also happy because their little boy is talking again. And he is laughing. And the things that he knows surprise them. We thought he was not learning…turns out he was.

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179. *Feeling really good still about my Natalie's progress from the combination of anti-parasitic medication, the supportive components of the PP and CD (HCL version). Natalie is about 63-64 lbs and she takes 2 drops of CD an hour both at home and at school. We don't wake her for CD in the middle of the night; but if she wakes for the restroom or something, then we give her another 2 drops (we just keep it pre-mixed in the bathroom near her bedroom). CD has been the single most important catalyst to Natalie's improvements/healing over the past 10.5 months; utilizing all three modes of delivery (oral, baths and enemas). Kerri having escorted CD into the ASD community is like a Miracle, in my opinion. Sorry... I don't mean to be corny nor impose my Beliefs on anybody else; but I sometimes find it hard to contain my Joy now and I get chills just thinking about all of the children now feeling better and/or beginning to feel better and better with CD. Before CD, it was hard to feel Hope for my special little Natalie; who was formerly suffering very extreme PANS flares and re-flares monthly as well as rapid-onset grand mal (tonic clonic) seizures every 2.5-3 weeks on top of her ASD and global developmental disabilities. Now Natalie's PANS 'flares' if/when they occur are waaaayyy less intense and better-controlled/'snufffed out' with CD than the former roller-coaster of oral antibiotics that her Drs had tried for years, her seizure activity is decreasing significantly and we've even begun a slow reduction in her anti-seizure med Lamictal ODT. We're optimistic that Natalie will be able to remain stable on less and less of that med, as we feel it might be causing her some nasty side effects. Our Hope for her is that she might even be able to come fully off of Lamictal ODT, as we continue CD and PP for her. Time will tell. While she's still a 'work in progress' [Note: She's 14 years old and been ill since infancy and it's a bit harder to heal longterm infection(s) and/or infestation(s)], we do see lowering ATECS in Natalie's future and brighter and brighter days. Patience is a virtue. So Grateful. Thank you Kerri and all you supportive Moms & Dads. More and more healing to come to ALL of our children!*

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180. *Hi Kerri,*

Thank you for helping my daughter, age 15, recover from Autism. Thank you for the MMS/CD program and the support to carry it out. Here is a summary of her recovery:

June 19, 2012 Atec=52

Started with MMS slowly, adding one drop a day

GF/CF/SF diet

It took her 1 1/2 months to get to full dose.

Noticed improvement in physical health & behavior

Began parasite program

Sept. 18, 2012 Atec=24

Continued with 6-8 doses/day & baths

More improvements

School discontinued IEP, because she was doing so well academically and socially

January 15, 2013 Atec=19

My daughter, who is not vaccinated, comes down with Chicken Pox

No one at school or in community had it before her. It appears to be an isolated case.

It may have been in her system and released as parasites died?

Fever of 102 degrees for two weeks was the lead up to the Chicken Pox. Seemed like her immune system woke up! After chicken pox, huge gains! That is when we noticed she was recovered!

April 25, 2013 Atec=6

Yeah!

Please share your experiences!

Testimonials are one of the best ways to share your experiences with this protocol. Perhaps you learned about it by reading or watching a video testimonial?

If you don't tell us your experiences, we can't share them or take action on issues that need improving or correcting...

Send your testimonials to:

testimonials@cdautism.org

Also, let us know if we are free to publish your testimonial, with or without your name.

It's in our interest to take care of others. Self-centredness is opposed to basic human nature. In our own interest as human beings we need to pay attention to our inner values. Sometimes people think compassion is only of help to others, while we get no benefit. This is a mistake. When you concern yourself with others, you naturally develop a sense of self-confidence. To help others takes courage and inner strength.

~ Dalai Lama

Appendix 2

CD Autism Worldwide

Since September of 2011 over 5,000 families in 58 countries have used CD to help with an autism spectrum disorder. Here is a list of all the countries who have at least one family using CD to help heal the symptoms known as autism. This list is constantly updated at www.CDAutism.org.

- Argentina
- Australia
- Austria
- Belgium
- Bolivia
- Brazil
- Bulgaria
- Canada
- Chile
- China
- Colombia
- Costa Rica
- Cuba
- Czech Republic
- Dominican Republic
- Ecuador
- Egypt
- England
- France
- Germany
- Ghana
- Greece
- Hungary
- India
- Iraq
- Ireland
- Italy
- Japan
- Jordan
- Kenya
- Kuwait
- Malaysia
- Mexico
- Montenegro
- Morocco
- New Zealand
- Norway
- Panama
- Peru
- Philippines
- Poland
- Portugal
- Puerto Rico
- Qatar
- Russia
- Scotland
- Singapore
- Slovakia
- Slovenia
- Somalia
- South Africa
- Spain
- Swaziland
- Sweden
- Tanzania
- Turkey
- United Arab Emirates
- United States
- Venezuela

If you are using CD for autism in a country not listed above please email us so we can add you to the list... kim@cdautism.org.

Conformity is the jailer of freedom and the enemy of growth.

~ Robert F. Kennedy

Appendix 3

AutismOne on Healing Autism: Accidental Cure by Optimists

by Simon Yu, MD

Accidents happen. We accept the reality of them as is and we usually move on. On the other hand, accidental discovery is another story. For some people, they ask questions like, "why me?" Or keep asking for a deeper meaning: Is this really an accident or a message to understand? An accident is a fertile ground to find out if you are a pessimist or optimist.

Tom Jacobs, story teller from Kansas City, recently told a story about a pessimist and optimist: Two sales men were assigned to Africa in the early years of the shoe industry to sell their shoes. One week later, one salesman telegrammed to his boss, "Business situation in Africa is hopeless. Nobody wears shoes". On the other side of the continent, the other salesman excitedly telegrammed to his boss, "Unlimited potential in Africa. Nobody wears shoes!"

I don't know about you but I would rather be an optimist. I always encourage my patients to look at the bright side and be cautiously optimistic no matter how grim their conditions might be. Hope is a powerful driving force to promote healing. Pessimists do not call themselves pessimists. Just realists.

Today, I saw a 77 year old patient with a history of chronic pulmonary fibrosis, bronchiectasis and rheumatoid arthritis with a recent diagnosis of stage one bladder cancer. She has been depressed and joined a cancer support group because of feeling a sense of hopelessness.

After a long discussion, I told her how lucky she is that her lung and rheumatoid conditions have been stable and she has only a relatively benign early stage of bladder cancer. I told her if you

are going to have cancer, this is the kind of cancer to have and she should be thankful. All of a sudden, her doom and gloom mood was lifted with a broad smile. The rest of our session was uplifting.

The AutismOne 2013 conference was held in Chicago during Memorial Day weekend. I was invited to give a talk on parasites, allergies, and autism. Autism is not my field. I usually see adults as an Internist. However, beginning in 2012, I have been seeing autistic children with rather interesting responses. In May 2013, I wrote an article about a medical hypothesis of a relationship between parasite infection and autism in preparation for my lecture for the AutismOne conference.

I attended a full day of lectures and was awestruck by the thousands of autism parents from all over the country attending the lectures. Multiple lectures were conducted by many autism specialists at the same time covering a large variety of topics. This conference was driven by a grass roots movement of parents with a hope to help their children. Here is a short synopsis of the lectures.

Dr. Anju Usman, MD from the Chicago area covered gut-brain connection and biofilms by pathogens in the gut. Symptoms such as depression, anxiety, poor attention and focus, and obsessive compulsive behaviors may be related to the delicate balance of bugs which produce a mucous slime known as biofilm.

Andreas Ludwig Kalcker, Ph.D. Bio-Physicist from Spain, who studied under German bio-physicist Fritz Albert Popp, Ph.D., discussed parasites in depth. He demonstrated a successful treatment for more than 65 children around the world with his parasite protocol over a one year period.

Kerri Rivera, from Mexico, one of the main leaders of the group running the AutismOne conference, showed many cases of successfully treated autistic children including her child. She has been using chlorine dioxide in conjunction with diet, nutritional supplements, detox, and hyperbaric oxygen.

By the time I presented my medical hypothesis on parasite infection and autism, they had already had numerous discussions about parasites and had been saying all along how parasite infection

might be one of the major underlying problems for autism that has been overlooked. I felt like I was repeating what had already been presented.

Dr. Andreas Kalcker and Kerri Rivera collaborated using chlorine dioxide for two years with prescribed parasite medications, albendazole and pyrantel pamoate, to turn around autistic children. Professionally, I have no experience using chlorine dioxide on my patients. The difference with my therapy was that I was using acupuncture meridian assessment as a guide to detect and treat parasites.

If what they are reporting is even partially true for these autistic children, it would be a major breakthrough in the autism community. Some of the audience was crying in excitement but some were skeptical and saying it sounded too good to be true. I could feel the excitement of the audience but also a sense of fear that Kerri Rivera and Andreas Ludwig Kalcker will be attacked by special interest groups. Chlorine dioxide is too inexpensive to a fault.

Is this an accidental finding leading into an accidental cure for autism? It is too early to tell but any chronic medical conditions like cancer, heart disease, diabetes, arthritis, Alzheimer's dementia, or autism seems driven by epigenetic influences from environmental toxins, parasites, hidden dental problems, and faulty diet and nutrition.

I spent several hours with Andreas Kalcker after our lectures were over. We found a common ground for treating parasites: his experience as a bio-physicist and my experience as a military medical officer. Few people truly understand and are aware of the magnitude of parasite problems. This man was very passionate to rescue these children from the scourge of autism.

Kerri Rivera just published a book called [Healing the Symptoms Known as Autism]. I just finished the book. This book is for everyone but especially for both autism parents and all medical professionals involved in the care of autistic children. The book contains much important information that is not available in the main stream autism community.

Most pediatricians might be sympathetic but they are rather pessimistic regarding the care of autistic children. Andreas Kalcker

and Kerri Rivera are true optimists in the midst of skeptics and pessimists. They see unlimited potential for the cure for autism based on diet, nutrition, and parasite eradications using chlorine dioxide and parasite medications. If you want to know more about autism and what is possible, I highly recommend reading [Healing the Symptoms Known as Autism] by Kerri Rivera. The book explains in detail the Kalcker parasite protocol.

Dr. Simon Yu, M.D. is a Board Certified Internist. He practices Internal Medicine with an emphasis on Alternative Medicine to use the best each has to offer. For more articles and information about alternative medicine as well as patient success stories, and Dr. Yu's revolutionary health book Accidental Cure: Extraordinary Medicine for Extraordinary Patients, visit his web site at...

www.PreventionAndHealing.com

...or call Prevention and Healing, Inc., 314-432-7802. You can also attend a free monthly presentation and discussion by Dr. Yu on Alternative Medicine at his office on the second Tuesday each month at 6:30 pm. Call to verify the date. Seating is limited, arrive early.

Appendix 4

Autism Evaluation Treatment Checklist (ATEC)

The next page contains a copy of the original *Autism Evaluation Treatment Checklist* (ATEC) developed by the late Dr. Bernard Rimland, the founder of the *Autism Research Institute*. We are not suggesting you use this particular copy. It is only included here for those not familiar with the evaluation so you have an idea what the ATEC involves since we mention it throughout this book.

The survey consists of a series of questions to be answered by a parent about what they are observing in their child's CURRENT behavior. It is not uncommon for both parents to take the survey separately and compare/average the scores.

The best way to take the survey is online at the *Autism Research Institute's* website. Here is the direct link to the current survey:

www.autism.com/index.php/ind_atec_survey

After completing the questions, a score is generated that can range from 0 to 180. 0 means no autism while 180 would mean that the answer to every question was in the most negative extreme.

We consider a child recovered from autism if their score is between 0 and 10.

You are encouraged to complete an ATEC before starting the Protocol, and every 3 months thereafter so you can clearly see the progress you are making.

Also, please share your results with us; we collect data on the children whose parents follow the Protocol as explained in this book. Send your name, date of the survey, general location (city, state, country) and score to:

atec@cdautism.org

If you have a history of ATEC results while on the protocol, please include them all.

NOTE: Do not send questions to this email address! You are unlikely to get any response from this address! It is just a collection point.

ARI/Form
ATEC-1/11-99

Autism Treatment Evaluation Checklist (ATEC)

Bernard Rimland, Ph.D. and Stephen M. Edelson, Ph.D.
Autism Research Institute
4182 Adams Avenue, San Diego, CA 92116
fax: (619) 563-6840; www.autism.com/ari

Project/Purpose:				
Scores: I	II	III	IV	Total

This form is intended to measure the effects of treatment. Free scoring of this form is available on the Internet at: www.autism.com/atec

Name of Child _____ _____ ☐ Male Age _____
Last First ☐ Female Date of Birth _____
Form completed by: _____ Relationship: _____ Today's Date _____

Please circle the letters to indicate how true each phrase is:

I. Speech/Language/Communication:

[N] Not true [S] Somewhat true [V] Very true

N S V 1. Knows own name
N S V 2. Responds to 'No' or 'Stop'
N S V 3. Can follow some commands
N S V 4. Can use one word at a time (No!, Eat, Water, etc.)
N S V 5. Can use 2 words at a time (Don't want, Go home)
N S V 6. Can use 3 words at a time (Want more milk)
N S V 7. Knows 10 or more words
N S V 8. Can use sentences with 4 or more words
N S V 9. Explains what he/she wants
N S V 10. Asks meaningful questions
N S V 11. Speech tends to be meaningful/relevant
N S V 12. Often uses several successive sentences
N S V 13. Carries on fairly good conversation
N S V 14. Has normal ability to communicate for his/her age

II. Sociability:

[N] Not descriptive [S] Somewhat descriptive [V] Very descriptive

N S V 1. Seems to be in a shell – you cannot reach him/her
N S V 2. Ignores other people
N S V 3. Pays little or no attention when addressed
N S V 4. Uncooperative and resistant
N S V 5. No eye contact
N S V 6. Prefers to be left alone
N S V 7. Shows no affection
N S V 8. Fails to greet parents
N S V 9. Avoids contact with others
N S V 10. Does not imitate
N S V 11. Dislikes being held/cuddled
N S V 12. Does not share or show
N S V 13. Does not wave 'bye bye'
N S V 14. Disagreeable/not compliant
N S V 15. Temper tantrums
N S V 16. Lacks friends/companions
N S V 17. Rarely smiles
N S V 18. Insensitive to other's feelings
N S V 19. Indifferent to being liked
N S V 20. Indifferent if parent(s) leave

III. Sensory/Cognitive Awareness:

[N] Not descriptive [S] Somewhat descriptive [V] Very descriptive

N S V, 1. Responds to own name
N S V 2. Responds to praise
N S V 3. Looks at people and animals
N S V 4. Looks at pictures (and T.V.)
N S V 5. Does drawing, coloring, art
N S V 6. Plays with toys appropriately
N S V 7. Appropriate facial expression
N S V 8. Understands stories on T.V.
N S V 9. Understands explanations
N S V 10. Aware of environment
N S V 11. Aware of danger
N S V 12. Shows imagination
N S V 13. Initiates activities
N S V 14. Dresses self
N S V 15. Curious, interested
N S V 16. Venturesome - explores
N S V 17. "Tuned in" — Not spacey
N S V 18. Looks where others are looking

IV. Health/Physical/Behavior:

Use this code: [N] Not a Problem [MI] Minor Problem [MO] Moderate Problem [S] Serious Problem

N MI MO S 1. Bed-wetting
N MI MO S 2. Wets pants/diapers
N MI MO S 3. Soils pants/diapers
N MI MO S 4. Diarrhea
N MI MO S 5. Constipation
N MI MO S 6. Sleep problems
N MI MO S 7. Eats too much/too little
N MI MO S 8. Extremely limited diet
N MI MO S 9. Hyperactive
N MI MO S 10. Lethargic
N MI MO S 11. Hits or injures self
N MI MO S 12. Hits or injures others
N MI MO S 13. Destructive
N MI MO S 14. Sound-sensitive
N MI MO S 15. Anxious/fearful
N MI MO S 16. Unhappy/crying
N MI MO S 17. Seizures
N MI MO S 18. Obsessive speech
N MI MO S 19. Rigid routines
N MI MO S 20. Shouts or screams
N MI MO S 21. Demands sameness
N MI MO S 22. Often agitated
N MI MO S 23. Not sensitive to pain
N MI MO S 24. "Hooked" or fixated on certain objects/topics
N MI MO S 25. Repetitive movements (stimming, rocking, etc.)

Appendix 5

MOLECULAR MIMICRY
What It Is
&
How it Relates to
The Gluten Syndrome

by Mrs. Olive Kaiser

After reading the short answers in *The Diet* Chapter (page 64), we understand (simply) the basics of how some of these departments of the immune system function. It is easier to grasp how, through molecular mimicry, gluten can damage so many different tissues in different people, and sometimes cause other foods that *look like* gluten to also be reactive. Before we go any further, I would like to thank the following professionals for their contributions to our family's well-being and a wider understanding of the gluten syndrome and other related topics. If you would like to conduct further research into this topic, the body of work that the following professionals have contributed would be a great place to start. There is so much more to learn.

Dr. Alessio Fasano, MD, shook America awake on gluten awareness in the 1990's and in 2003 published a landmark paper[1] on one small subset of the gluten syndrome, villi damaged celiac disease. That study provided the impetus that brought gluten awareness to the table (or sadly, OFF many tables) across our nation.

Dr. Thomas O'Bryan, DC, Functional Medicine, and international gluten syndrome educator - www.thedr.com. Dr. O'Bryan is my functional medicine doctor. He taught me much of what I learned about gluten and other topics and led me to his mentor, Dr. Aristo Vojdani. Later Dr. O'Bryan's amazing research review seminars on gluten contributed hugely to my knowledge base and bolstered my confidence to manage our new lifestyle in a then difficult social era.

Dr. Aristo Vojdani, PhD., MsC, Immunologist, CEO owner of *Immunosciences Lab*, Los Angeles, CA. Dr. Vojdani is also chief scientific advisor of *Cyrex Laboratories*, Phoenix, AZ. Dr. Vojdani has published nearly 150 excellent research papers.[2,3,4] They fit the community like a glove.

Dr. Rodney Ford, MD, pediatric gastroenterologist, NZ, grasped the extent of neurological injury,[5] and "silenced nerves phenomenon."[6] This compellingly suggests why many of us do not recognize symptoms of gluten damage until we are in deep trouble. This builds on the previous work of Dr. Marios Hadjivassiliou, Professor of Neurology, Sheffield, UK.[7]

Dr. Kenneth Fine, MD, gastroenterologist, Dallas, Texas, owner of an investigative research lab, *Enterolab* (www.Enterolab.com). His lab ran the only accurate gluten antibody tests our family received back in 2004.

Without the courage of these astute researchers, we would still be wandering in the dark. Thank you all, and other individuals who thought outside the box. Kerri you are one of those thinkers. Thank you!

Lastly, special thanks to **LuEllen Giera**, my support group leader, for leading me to Dr. O'Bryan and Dr. Vojdani.

1. What is Molecular Mimicry? How does gluten damage us?

The structure of gluten resembles the structure of many of our body tissues. When the immune system attacks gluten or partly digested "pieces" of gluten it may also attack body tissues that "look like" those pieces of gluten. There may also be other processes that we do not yet understand.

What is gluten? - Gluten is a stretchy protein found in some bread grains. The problematic types are found in wheat, barley, and rye, and now early research suspects possibly rice, corn and oats (Dr. Peter Osborne, DC, CCN, www.glutenfreesociety.org).

What are proteins? - Proteins are a class of materials found in living tissues, such as hair, nerves, enzymes, etc. Molecularly, all proteins look like necklaces of beads strung into various color sequences. The different sequences make the proteins different, and the "colored beads" represent 22 separate amino acids. Our digestive system uses enzymes to cut up these necklaces into single beads so they are small enough to cross the gut wall properly and be restrung into new proteins. See image on page 452.

Unfortunately, many folks today are toxic and poorly nourished and do not have strong digestion, so the gluten "necklaces" may never completely break down. As weaker bonds between the beads break, "pieces", called "peptides," of gluten are formed. Gliadin is a well known gluten piece and there are many others.

Our immune system - has "departments" to protect us in various ways, including IgA, IgG, IgE, IgM, IgD and others. IgE can cause immediate allergic reactions to bee stings or peanuts, etc. IgA, IgG and IgM may react more slowly with less drama. They all manufacture "workers" or "soldiers", called antibodies, each custom designed to patrol our bodies, looking for the bead sequence of one particular enemy. When they find that bead sequence, they "tag or stick onto" it. Our killer white blood cells interpret the antibody tag as a condemned sign and know to surround and destroy that protein.

If an antibody test lists "Gliadin – IgA", "Gliadin – IgG", and"Gliadin – IgM" it means the test checked for gliadin antibodies in the IgA, IgG and IgM departments. If the antibodies are high it means the immune system is does not like gliadin and is working to destroy it.

Weak, leaky barriers - Our gut wall and other barrier membranes such as the skin, lung, placental, and blood brain barriers are held together with "tight junction proteins" that act like velcro. Inflammation, parasites, gluten, medications, infections, electrosmog, etc, may damage the "velcro" or open them up too much. Substances may slip through them into places they should not be and cause trouble.

Unfortunately if the gut wall does not hold together well, i.e., is "leaky", pieces of incompletely digested gluten strings (and others) may slip through and run into the immune system—our dutiful "guard dog" on the other side. Due to their too-large size "he" may raise the alarm. The invader strings are "frisked out" i.e., examined. If they are rejected, one or more of the immune departments make matching antibodies to "tag" them so the killer cells know to go after them.

It is at this point more problems may arise. A gluten antibody may "run by" a natural body tissue, for example a nerve in the heart. It may see in that innocent nerve tissue a sequence of "beads" that matches or partly matches the gluten sequence it was designed to "tag" and stick to that section of the nerve protein instead. This, unhappily, attracts killer cells to the misidentified nerve, resulting in autoimmune injury to the nerve. This is molecular mimicry.

Other foods and proteins beside gluten may also initiate molecular mimicry when they prematurely cross a leaky gut, and may prompt allergies (IgE) or intolerances (IgA, IgM, or IgG). However specialists agree that gluten's particular "bead" (amino acid) sequences are uniquely guilty in their ability to upset the immune system and instigate molecular mimicry between "their" antibodies and our tissues.

Molecular mimicry can take place between non-food proteins and body tissues also. Infectious microbe sequences such as strep, for example, are believed to partially match, (in the case of strep), heart and joint proteins and so injure the heart muscle or valves, and (rheumatic) joints. Ditto is suspected for root canal and cavitation infections that may circulate and injure specific tissues, including the heart. Flu microbe sequences can resemble gluten and may trigger or surface gluten syndrome. There are numerous other examples of mimicry between infections, foods and body tissues.

Consider the image below. An antibody may be made to seek the shorter "bead" sequence of a gluten piece that crossed the gut wall, but it might also recognize a similar sequence, a partial match, in the longer nerve protein sequence. The antibody "tags" or "sticks to", the part of the nerve tissue that matches the gluten piece that it seeks.

Gluten Peptide (and antibody) Sequence

Note: the different colors represent different amino acids.

					pink	blue	white	brown	brown	brown	red	red	green		

Nerve Sequence

orange	orange	yellow	green	red	red	blue	white	brown	brown	brown	red	orange	green	blue	yellow

It gets more complicated, but eventually the victim tissue is attacked by killer cells on an ongoing basis. This process may be slow but stealthy. In time, the nerve may malfunction and the organ it serves may also begin to fail; for example, heart failure. This is termed autoimmunity. The body attacks its own tissue.

Molecular mimicry can occur in hundreds of places in the body since gluten can break up into numerous pieces having amino acid sequences that partly match many of our natural tissues. This may explain why gluten syndrome presents so differently in different people.[2]

Once this process starts, like elephants who never forget, the memory B cells that manufacture the antibodies never forget the sequence of

the "invader" gluten pieces. If gluten is removed, antibody manufacture eventually stops, but any time the immune system sees even a tiny amount of that protein sequence, antibody production is retriggered. This is why specialists insist the gluten-free diet is strict and lifelong.

Gluten removal stops production of the initial antibody, which decreases the inflammatory process significantly. Literature shows the gluten-free diet may reverse or improve many serious conditions, but it may not always arrest an advanced autoimmune disease. Prevention is key.

Example: Once a ball is pushed down a hill, further pushing will only send it downhill faster, but it will roll on its own. To correlate, molecular mimicry between the gluten antibody and victim tissue starts the ball rolling. Removal of gluten stops pushing the process, and the sooner the better. The longer the exposure[8], and to other factors as well in a triad of autoimmunity (a. environmental stress, toxins, infections, etc.; b. a faulty blood brain barrier; and c. susceptible genetics), the higher the chance of autoimmune disease.

Dr. Vojdani comments, "If it is detected early enough and steps are taken early enough the condition may be reversed. If any condition is advanced enough you can reach a point when simple removal may not be enough. Autistic children generally have autoimmune reactivity rather than full-blown autoimmune disease, which is why they show great improvement upon the removal of gluten."

2. Does gluten always damage the villi of the small intestine as the celiac story teaches? Many other tissues such as thyroid, pancreas, blood vessels, joints, brain, nerves, liver, bone, etc. may be involved in this disorder. Does all that other damage arise due to poor nutrient absorption from injured gut villi?

No, according to published research many researchers and practitioners now believe the villi are not always damaged in an autoimmune gluten reaction.[2] Where there is no villi damage, injury to other organs cannot be due to nutrient deficiencies caused by villi damage. Molecular mimicry provides a mechanism for direct autoimmune gluten injury to many other tissues and organs when the villi are fine. It is also possible that several tissues and organs, *including villi,* may be injured and then nutrient deficiencies from poor villi absorption may affect other areas.

Dr. Vojdani's abstract in his editorial, *The Immunology of Gluten Sensitivity Beyond the Intestinal Tract,*[2] supports that the villi are not always injured. To quote his editorial abstract, "Evidence has been accumulated in literature

demonstrating that gluten sensitivity or celiac disease can exist even in the absence of enteropathy" [gut/villi damage], "but affecting many organs."

3. I do not have damaged villi, and my tTG/gliadin blood tests were negative, but I feel so much better gluten-free. Why?

The tests were likely false negative. That is very, very common. As gluten is processed in the digestive system, it can break into more pieces than we have tests developed to check them, and the immune system makes an antibody for each separate piece. The test probably missed your antibodies because they were different from the one or two the test checked. Many patients have proven this because they received negative results to the standard test, and then found a number of positive gluten related antibodies when they ran a more comprehensive panel. Cyrex Laboratories (www.cyrexlabs.com), runs 28 gluten related antibodies in 3 areas of the immune system.

Your properly performed* biopsy was probably negative because likely your gut villi are fine.** Your gluten injury may have targeted other organs or tissues, not the villi.*** For instance, if gluten has damaged the heart, snipping intestinal villi will not help find the heart injury. Damage in either place is not ok.

More detail on False Negative Tests

The blood and saliva tests - Standard celiac blood and saliva tests only check tissue transglutaminase IgA, (tTG – IgA) as an initial screener. Most doctors give up if that test is negative. However, the literature shows that standard tTG-IgA tests are only elevated when the villi are completely destroyed. Dr. Vojdani finds that form of tTG is often not found in other gluten injured tissues. Therefore the standard tTG-IgA test is a poor screener for most patients, and returns many false negatives. More forms of tTG have now been discovered.

Doctors might also order a standard test for deamidated gliadin IgA and possibly IgG. Unfortunately these tests also have a miserable failure rate for picking up gluten syndrome because many patients have other

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* If there IS villi damage it is possible for the biopsy to miss it if the damage is patchy or further down the duodenum than the villi samples are taken. Most good "gluten aware" gastroenterologists take a number of samples to try to avoid this possibility.

** It is possible that very early villi damage may slowly accumulate long before it shows up on a pathology report. An elevated IEL count, (intraepithelial lymphocyte, an early sign of inflammation) of the villi tissue indicates this process is underway. Ask the gastroenterologist to specify that the pathologist do an IEL count.

*** I am careful to specify the "villi of the gut". There may actually be gut damage, but not to the villi. There are many types of tissue in the gut, such as nerves, for instance. The villi may be fine, but it is still possible that some other gut tissue may be damaged by molecular mimicry or other processes we do not yet understand. For instance, if the nerves that control peristalsis (wave like gut motion) are injured, it could result in chronic constipation.

antibodies beside those two. The gluten "string" can break up into many other pieces, plus other "departments" of the immune system may react.

Villi biopsy vs. positive antibodies for diagnosis? - To add insult to injury, even if antibodies are discovered, many celiac, villi focused specialists may still insist that the villi biopsy is the final word for "celiac" diagnosis and they trust a negative villi biopsy over positive antibodies. Many folks have positive antibodies and suspicious symptoms, including improvement upon gluten removal, but no apparent villi damage. Their doctors assure them they can eat gluten! This is a serious mistake for many patients.

More on the villi biopsy – By now it is easy to understand why even properly performed* villi biopsies are only useful for the relatively small subset of patients in which the villi of the duodenum are injured. Most patients do not happen to have damaged villi. Their damage is somewhere else in their body, other organs, nerves, etc., or some enzyme or functional item has been damaged by gluten antibodies. Scientists such as Dr. Aristo Vojdani[2,3,4,] do NOT recommend villi biopsies for gluten syndrome diagnosis (there may be other reasons to scope the gut, such as tumors, etc). Dr. Vojdani explains that if there are elevated antibodies to gluten, the immune system is screaming "I do NOT want this substance! I am manufacturing antibodies to tag and destroy it." That is sufficient reason to remove gluten from the diet. It is less expensive to check an extensive array of gluten antibodies than undergo an endoscopy anyway, and is much less invasive.

4. Why do many gluten syndrome patients not only react to wheat, barley, and rye but also sometimes to other foods, particularly oats, milk, corn, soy, egg, coffee, sesame, yeast, chocolate and others.

These foods have similar amino acid sequences to gluten. Now that we grasp molecular mimicry, this is logical. The immune system may misrecognize them for gluten, causing cross reactions which may keep the gluten antibodies running high even on a gluten-free diet. Happily, this does not always occur. Cyrex labs, Array # 4, checks a list of cross reactive and gluten substitute foods, IgA and IgG.

5. The diet seems excessively strict? Why does it take so little gluten to start a reaction?

We understand that miniscule amounts of bee venom, or peanut, can trigger emergency allergic reactions, and very tiny medication pills can cause major effects on our bodies. This is also true of gluten reactions, both immediate allergic IgE, and delayed IgA, IgG, and IgM.[3] "Crumbs matter." The difference is that delayed reactions are not as obvious as the allergic reaction. They may go unnoticed for hours to decades, but may be a long, slow, serious process. Their lack of drama robs these reactions of the compliance respect they deserve.

6. The silent syndrome - Why do many people react to gluten, proven by antibody tests, but they have few or no warning signs, or seemingly unrelated symptoms they do not recognize or connect with their diet for a long time. Then they crash with something serious, often or usually autoimmune?

Gluten is famous for slowly injuring nerves[5] by molecular mimicry, and in many cases the nerves are silenced by that injury.[6] The patient does not realize there is a problem until the tissue or organ that those nerves supply begins to fail. Furthermore some areas of the body do not contain many pain nerves, so we may not feel the damage. Slow silent damage is understood in other diseases. Heart damage, cancer, and aortal aneurysms are examples of conditions that develop silently and then suddenly flare. Prevention is best.

For years, celiac literature recognized 2 neurological conditions, peripheral neuropathy and gluten ataxia. In the wider perspective of gluten syndrome, nerve damage may be one of the most important areas of injury.[5]

Dr. Rodney Ford, MD, suggests in his book, *The Gluten Syndrome: Is Wheat Causing You Harm*,[6] that this is primarily a neurological disease[5], injuring and in some cases silencing nerves, compromising the health and function of the tissues they serve. This idea was reinforced by an astute observation made by Dr. Ford of one of his patients, an elementary school child who had not achieved bowel control. After she went gluten-free, the problem resolved. Dr. Ford realized the child now recognized the signal to visit the toilet, and accidents were avoided. The nerves in the lower bowel apparently "woke up" once the antibodies that injured them disappeared. This is an interesting and logical theory to explain "silent gluten injury", and it fits the community. Here is an abstract of Dr. Ford's published paper which discusses a possible widespread neurological focus:[5]

The Gluten Syndrome: A Neurological Disease, by R.P. Ford

Hypothesis: gluten causes symptoms, in both celiac disease and non-celiac gluten-sensitivity, by its adverse actions on the nervous system. Many celiac patients experience neurological symptoms, frequently associated with malfunction of the autonomic nervous system. These neurological symptoms can present in celiac patients who are well nourished. The crucial point, however, is that gluten-sensitivity can also be associated with neurological symptoms in patients who do not have any mucosal gut damage (that is, without celiac disease). Gluten can cause neurological harm through a combination of cross reacting antibodies, immune complex disease and direct toxicity. These nervous system affects include: dysregulation of the autonomic nervous system, cerebella ataxia, hypotonia, developmental delay, learning disorders, depression, migraine, and headache. If gluten is the putative harmful agent, then there is no requirement

to invoke gut damage and nutritional deficiency to explain the myriad of the symptoms experienced by sufferers of celiac disease and gluten-sensitivity. This is called "The Gluten Syndrome."[5]

7. Why do so many of us react now, when for centuries most people appeared to be fine with wheat? After all, wheat is spoken of positively in the Bible and many other historical documents.

There may or may not be a conclusive answer to this question, but a few factors may play a role.

a. Many folks have higher toxin levels now, their nutritional status is worse, and digestive strength is weaker.

b. Today's wheat is different. Gluten grains have been subjected to a lot of changes, some genetically violent, according to Nina Federoff, a pro GMO scientist. She asserts in her book, *Mendel in the Kitchen*, that gluten grains were altered with nuclear radiation and chemical mutation by the 1950's – 1960's.[9] Recently a stash of old blood samples from that era, stored in a freezer by the military, were checked with standard celiac antibody tests. The incidence of positive antibodies was much less in those samples than is typically found in the general public today.

c. Wheat seed is sometimes treated with mercury. Might this play into unintended results?

8. Why do specialists and researchers insist that the gluten-free diet must be life long? Can't we heal the gut and go back to our beloved wheat bagels, croissants, and brownies?

Our scientists insist that gluten-free is a strict lifelong commitment. The memory B cells in the immune system never forget what the enemy "looks like." Today's gluten is a violently altered substance according to the very scientists who defend genetic alterations.[9] It is not worth playing with today's wheat. There is something strange and unpredictable about it. Even if a leaky gut has healed, future circumstances, toxins and stress might injure it and retrigger the syndrome, perhaps silently. Researchers say gluten creates leaky gut for a few hours in everyone.

Particularly since gluten appears to be the "bad boy" that predisposes to other intolerances, I prefer to walk away for life and concentrate on other nutrient dense foods. However, it is wise to consume whole foods rich in B vitamins, (ex., liver or bee pollen), and silica (the herb horsetail, "equisetum hymale" species, is a source,) as gluten grains contain those nutrients.

9. Traditional peoples soaked and/or sprouted their wheat berries and then made sourdough bread with it. Does that process alter the gluten sufficiently for gluten syndrome patients to safely consume it today, particularly organic spelt and einkorn?

No. These methods make bread more digestible, but the fermented products and ancient gluten grains still contain gluten and can trigger reactions in research trials. Even if there are no visible reactions, silent injury cannot be ruled out without long term research. Additionally, the preparation process before fermentation is completed is definitely gluten based, so significant cross contamination issues come into play in the kitchen. Healing the gut is a challenge. Other areas crop up that need cleanup too, such as the parasite issues. Gluten specialists advise us to go gluten-free, stay that way, and move on.

10. What are gluten withdrawals?

Rarely, a few days to a few weeks after going gluten-free, or after being glutened, a patient may experience a few hours to a couple of weeks of a parade of varied and unusual symptoms including dizziness, black pit depression, crying, physical or emotional exhaustion, even as in difficulty getting up to use the rest room, and other odd symptoms. In severe cases they may experience an inability to socialize, make eye contact, make decisions or hold a normal conversation. Children or teens may act out in extreme ways during this situation. Often patients cannot bring themselves to discuss this experience afterward. However, a patient reluctantly described her experience 2 years later as "encountering an empty white board with nothing on it." The rest of life around her seemed to be "across the Grand Canyon." This appears to be a temporary crisis that resolves anywhere from a few hours to a couple of weeks or so according to folks who contact me about them. It is assumed that this phenomenon is due to particular pieces of gluten strings called gluteomorphins with amino acid sequences which resemble opiate drugs. When these gluten pieces disappear from the blood stream the patient may experience "withdrawal," very much like a drug withdrawal. Another theory for why this may happen involves changes in blood flow to the brain that may create a temporary neurological crisis. Autistic children may suffer these withdrawals and may take longer to stabilize, but they usually make nice gains after the crisis passes. Happily, once withdrawal is over the patients are usually much better, and they are VERY vigilant with their diet.

In the rare event that this type of reaction might occur, family and friends of the person do well to understand that the person may (or may not) be able to prepare their own food, for instance, but not be able to verbally communicate much, make eye contact, hold a conversation, answer

questions, and may be uncharacteristically snappy particularly if others attempt to communicate with them. Family members may wish to be quietly and unobtrusively nearby until the person passes through this stage. If the patient has children to care for, help may be needed, and also solitude, rest, and simply prepared "real" nourishing food that is gluten-free and easy to digest such as bone broth. Probiotics or old fashioned fermented raw veggies or sauerkraut from the refrigerated section of the health food store may be helpful. Family and friends should not take the person's temporarily withdrawn personality personally.

For details on these unstudied rare reactions, or if you need support during a crisis, see...

www.theglutensyndrome.net /Adverse_reactions.htm

...or contact me at *jka8168@sbcglobal.net*. I collect testimonials, so feel free to contribute if you have experienced this type of reaction. We hope these reactions will eventually be studied.

11. Should I replace all the gluten foods I routinely eat with gluten-free substitutes?

No, most gluten-free substitutes are still mainly expensive processed food (aka junk food). For the first few weeks it is normal for newbies to look for substitutes to replace their "old gluten friends" and it helps them make the very real emotional transition, but there are better, more nutrient dense food choices. The substitutes are still high carb, (potato, corn, tapioca, rice), and most contain sugar, processed gums, GMOs and ingredients that do not help us get well. We may actually eat more of them BECAUSE they are gluten-free. Additionally they are expensive and not always easy to prepare at home.

Many experienced gluten-free folks gradually wean themselves off a constant diet of the rather junky substitutes in favor of other real unprocessed foods, such as meat, eggs, veggies, fruits, nuts, fermented vegetables, bone broths, and so on according to their digestive abilities. The gluten-free substitutes become the occasional treat, such as pizza crust. Gluten free families are wise to find the healthiest GF versions of just the items they miss the most, and skip the rest. For example, at our house, I had served gluten spaghetti for years, but when I dropped that habit, no one noticed. However, my husband wanted his breakfast toast, so we found a gluten free brand he liked and continued that tradition. Each family works out these adjustments for themselves.

Lettuce wraps are crunchy and yummy instead of sandwiches. Hamburger patties without the bun but with onion for the onion lovers, are still tasty and they feel better afterward. In our family we now use watermelon or a watermelon basket for birthday "cake", complete with candles and a bow in the summer. Fruit pizza with a nut flour or nut/date crust, avocado chocolate or other dairy-free or fruit based pudding for the sauce, and an artistic fruit/coconut topping works for parties. There are lots of ways to celebrate happy healthy gluten-free, junk free birthdays.

12. Warning! Formal gluten challenges for testing purposes – risky!

A word of caution. Antibody tests must be performed while the patient is still consuming gluten or shortly after going gluten-free. Sometimes doctors advise patients who are already gluten-free to go back on gluten, 4 slices a day for 4-6 weeks to restart the antibodies for testing purposes. Patient experience has shown that once the system is fairly clean of gluten, going back to perform a formal gluten challenge for testing purposes may be risky. The secondary reactions for some individuals can be significant, particularly neurologically. Challenges have been known anecdotally to trigger psychological black pit crashes, fibromyalgia, and other organ injury. Autistic children may have a hard time when they just go gluten-free initially or consume gluten accidentally. A planned challenge for them may be very unwise.

13. Intermittent infractions (aka cheats) are seriously unwise and may increase injury.[10]

This is not a fad, or cheater's diet. The gluten-free diet is a medical diet to treat or control serious autoimmune, inflammatory, and often neurological diseases. There is no room for casual infractions. Research suggests that repeated, intermittent cheats, even every few weeks, over time may actually influence mortality rates.[10] This is not a reason to avoid the diet, but to take it seriously. Once the strictness of the diet is embraced the patient or family adjusts and discovers that it is doable. Gluten-free food bars, nuts, a packet of gluten-free soy sauce, and GlutenEase™ or other brands of DPP IV enzymes are good to keep in the glove compartment or backpack to handle emergencies. NOTE: DPP IV (pronounced DPP 4) digestive enzymes help break down gluten but they do not stop a reaction and are NOT a reason to cheat. However if there is a possibility of exposure it makes sense to take them for whatever help they might afford. In the case of a confirmed gluten exposure, take the enzymes, keep the bowels moving, stay calm and deal with it. Worry and drama makes everything worse.

14. Discrepancy – The celiac focus uses villi biopsy for diagnosis. The wider perspective relies on positive antibodies or improvement on the diet. Question? How did villi damage become the gold standard?

The first place the medical profession found conclusive damage by gluten in the 1950's – 60's was to the villi of the gut. After the endoscopy tool was developed, villi damage and subsequent healing upon gluten removal could be observed. They concluded that gluten damaged the villi. This was true. The particular subset of cases they scoped had villi damage, but their conclusion that the villi were the only target of damage for everyone with gluten syndrome was too narrow according to research today.[2] In most patients the target damage was NOT the villi, but the bones, joint lining, heart, thyroid, pancreas, liver, brain, almost any organ, blood vessel walls, nerves almost anywhere in the body, and so on. The patients might even have injury to multiple tissues, BUT NOT NECESSARILY ALWAYS TO THE VILLI. When the villi biopsy was declared the gold standard for gluten syndrome diagnosis, it cut out most of the patients who were reacting to gluten. Snipping villi does no good if the damage is in the thyroid or brain. For the next 60 years very few patients were prescribed a gluten-free diet because most of them did not have damaged villi, (or the doctor never thought to look at all). Their gluten-induced injury was somewhere else in their body, so they were never diagnosed.

15. Discrepancy - The villi damaged celiac disease story teaches that celiac disease is autoimmune and much worse than "non autoimmune" non-celiac gluten syndrome (NCGS). The wider gluten syndrome perspective teaches that both are autoimmune and serious.[2,3,4]

A significant disagreement exists over the autoimmunity of non-celiac gluten syndrome (NCGS). In the beginning, antibodies to gluten could not be found in NCGS patients, therefore it was assumed that NCGS was not autoimmune. However, Dr. Vojdani insists NCGS IS autoimmune. The NCGS patients have plenty of antibodies, just different ones than the standard tests check. His tests, which check and find more antibodies,**** the illnesses these patients develop, and recoveries or improvements on the diet all prove his point. He also asserts that NCGS can indicate a gut wall in worse shape than the celiac villi damaged subset.[2,3,4] The damage is simply somewhere else, not to the villi. See the link below for diagrams of these reactions, and compare the condition of the gut wall in the celiac diagram with the gut wall in the gluten intolerance diagram.

www.TheGlutenSyndrome.net/ VojdaniDiagrams.htm

**** Dr. Vojdani's research found several more forms of both tTG, and gliadin antibodies, (alpha, gamma, omega), gluteomorphins, glutinins, and others. His saliva and blood panels check 12 separate antibodies in 3 different immune departments and 2 mediums, totaling 28 gluten related antibodies. The two panels, run together, nearly always find antibodies if they are present in the patient, translating to far fewer false negatives.

This disagreement fosters confusion among NCGS patients that villi damaged celiac disease is the "big bad boy" to avoid (true, it is bad), but that NCGS is less severe, not autoimmune. This translates in real life to gluten birthday cake for the Friday night party and then back on the gluten-free bandwagon Saturday morning, "so I won't eventually develop villi damaged celiac disease." Yes, that could happen also, particularly if the person seesaws on the diet, but the notion that NCGS is not as bad as villi damaged celiac disease is a misunderstanding according to Dr. Vojdani.[2,3,4] To repeatedly seesaw off and on gluten indiscriminately is unwise according to medical literature,[10] and community experience. Gluten exposure needs to be an accident, which happens occasionally even to the most vigilant. Casual cheats are a more risky mindset, usually meaning "more frequent."[10] Take it seriously, nerves, blood vessels, and organs are precious.

Gluten Tests with a Good Track Record

Some families cannot afford to test or good tests are not available. In the case of autism this protocol and most others require gluten-free and that is the end of the matter. Kerri takes this position partly due to cost and the miserable record of false negatives that standard tests return. The protocol does not work without the diet. Period.

Some adults are also willing to go gluten-free without a test. Their bodies tell them what they need, they listen, and are happy to find answers. Social pressure does not sway their decision or ability to comply.

In many other situations, a positive test is very meaningful. It gives patients confirmation that gluten-free is right for them, silences critics, and helps them comply with the diet. In the case of children it provides proof to the other parent, grandparents, therapists, doctor, etc. It may also come in handy if the child turns into an invincible teen who doubts he ever needed the diet in the face of pizza and beer, ditto for his future spouse and in-laws. The catch is that the test must be adequate. A false negative misvalidates the skeptics. These are decisions every individual or family must evaluate for themselves. Thankfully there are test panels with good track records now.

Absolutely, regardless of any test result, if the body is able to communicate a reaction to gluten or its removal, then that is the final answer. Be grateful and go gluten-free.

This testing section is for those who wish to test for their own confirmation or social support.

NOTE: If a patient has been ill for a very long time it is possible for the immune system to be so worn out that few antibodies are manufactured. Lower antibody counts might show a false negative but not prevent injury to innocent tissues. Also, due to the wide variety of antibodies a patient may happen to make, it is possible to run any antibody panel and miss those particular antibodies. The more antibodies that are checked the less likely this may occur, but should be considered in the event of a negative test that the patient or practitioner questions. In this case a gene test may be helpful.

Enterolab - Stool and 1 part gene tests

For 10 years Enterolab's mail in home collection research stool test stood in the gap for thousands of patients who received false negative standard tTG and gliadin blood tests. It has saved many lives, and gave our family the social confirmation we needed. This unpublished research test checks stool for tTG-IgA and gliadin-IgA only. The use of stool as the testing medium appears to pick up those antibodies most of the time, much much more often than standard tTG or gliadin IgA blood tests. However, since only two antibodies are checked, it may miss in some cases.

Dr. Fine's lab also offers a one part gene test which he believes is adequate for a reasonable price. Dr. Fine finds if a gene is present, nearly always so are the antibodies, and two genes are worse. Villi damaged celiac specialists recognize only HLA DQ 2 and 8 as gluten related, but Dr. Fine includes 1 and 3 and their subsets 5, 6, 7 and 9. In fact according to Enterolab, HLA DQ 4 is the only DQ gene that does NOT correlate with gluten syndrome. According to him, a patient needs 2 copies of the HLA DQ 4 gene to miss the predisposition. This translates to 81% of the Caucasian population with a predisposition to trigger gluten syndrome at some point in their lifetime, including before they are born.

Cyrex Labs - Better blood and saliva tests

Cyrex Labs (www.CyrexLabs.com) opened their doors in 2010 in Phoenix, Arizona. They run much more complete antibody panels designed by Dr. Aristo Vojdani, PhD., their scientific advisor, an immunologist, and researcher. Dr. Vojdani found a wider variety of gliadin antibodies, (alpha, gamma, omega) and variations of tTG in other tissues, plus gluteomorphins, and several others. He also checks an IgM antibody due to possible malfunctions in that system. Cyrex blood and saliva panels, Array #1 and #3, combined, test for 28 gluten related antibodies between 3 immune departments, 2 mediums,

plus IgA insufficiency. They rarely miss a diagnosis because they look for so many antibodies. (Note: Vojdani believes stress, toxins and infections, i.e. environment, can trigger a gluten reaction without the genes.)

Gluten Free Society - Two Part Gene Test

A third approach espoused by Dr. Peter Osborne, *The Gluten Free Society*, Sugarland, Texas, (www.glutenfreesociety.org), is to run only the gene test, since any antibody panel may theoretically miss the particular ones the patient may have. He uses a 2 part test, the most complete method, and looks for both celiac and gluten sensitivity genes. A positive gene test does not prove a current immune response as do antibodies, but predisposition to it. Presence of 2 genes indicates a more severe case. Gene tests have an advantage in that they can be run anytime, gluten consumption is unnecessary, and depending on the results, useful information can be gleaned for immediate and extended family members.

Elimination Diet

The elimination diet is inexpensive. Often/usually it demonstrates improvement upon removal of gluten, or worsening upon reintroduction. Many "heads up" practitioners accept this as reason enough to go gluten-free.

There are occasional complications or interpretation issues for the elimination diet as follows:

a. Reintroduction of gluten (gluten challenge) can trigger stronger, sometimes risky reactions.[10] Stop a challenge upon negative symptoms, including depression and emotional instability, or best, don't challenge. An accidental infraction may come up that provides insight.

b. Occasionally it takes several months to see the difference, or a silent reaction may mask symptoms.[6]

c. If the patient later decides to test and is already "clean" on the gluten-free diet, blood tests will not work unless gluten is reintroduced for many weeks.[10] No! Stool/gene tests are safer.

d. There is no lab confirmation to silence naysayers.

Other Related Tests

Cyrex Labs Array # 2 - Intestinal Permeability Panel focuses on specific causes of leaky gut. This helps strategize treatment, and is an improvement over the old lactulose/mannitol test.

Cyrex Labs Cross Reactive Foods and Gluten Substitutes, Array # 4. - This specific list checks foods that commonly cross react with gluten and also foods commonly used to replace gluten. It helps customize an anti-inflammatory diet.

Cyrex Labs Predictive Antibody panels determine if or which tissues are currently under antibody attack. This predicts autoimmunity years ahead of time and gives the patient advance notice in order to address trouble spots.

Enterolab (www.Enterolab.com) offers several stool based food antibody panels and gut related stool tests.

What are the lab instructions?
Do I need to consume gluten for testing?

Antibody tests, (blood, saliva, stool), prove a reaction and require recent gluten consumption. Ideally, test first, then go gluten-free. If the patient is off gluten, call the lab for advice on the time window before the test will not work.

Cyrex Labs (www.CyrexLabs.com) tests require prescriptions and a saliva specimen and/or blood draw. If a doctor is needed to write the script, check www.thedr.com for a partial list of practitioners who are familiar with Cyrex Labs. Results are sent to the prescribing doctor.

Enterolab stool specimens are ordered online, kits are sent, home collected and mailed. No prescription is required. Results arrive on email. Enterolab's test works for several months after going gluten-free.

Gene tests do not require gluten consumption or a script and can be run at any time. Genes prove a predisposition to gluten reaction.

Enterolab's gene test is a relatively inexpensive "one part" test. It is a mail in cheek swab and reports the patient's actual genes.

Gluten Free Society (www.Glutenfreesociety.org) gene test is a "two part" (more complete) mail in cheek swab and reports yes or no for both celiac and gluten sensitivity genes.

For information on testing (I have no financial interests) see:

www.TheGlutenSyndrome.net

The latest version of this article and a complete list of references is available at:

www.TheGlutenSyndrome.net /Molecular_Mimicry.pdf

Author's note: While the information Olive has provided can be extremely helpful for adults or children who are not on the spectrum or who are suffering from other ailments, a gluten-free diet is non-negotiable for healing autism. We need to remove foods that cause inflammation and mucous, and which can produce gluteomorphin in the body. I have seen many families waste time and money doing testing only to get confused by false negatives—time and money they could have spent on recovering their child.

Online Gluten Summit – A Chance to Support CDAutism

Recently, in November 2013, Dr. Thomas O'Bryan, an internationally recognized gluten educator, put together an amazing online Gluten Summit. Twenty nine iconic experts on Celiac Disease and its wider perspective, Gluten Sensitivity, also called Gluten Syndrome, covered every possible aspect before 115,000 appreciative viewers. This set of interviews plus extra materials is available for purchase at only $3.30 per speaker and is a priceless addition to all our libraries. It also is a great gift and a good way to inform friends and family. Often our closest loved ones accept new information better from a respected professional rather than from us.

Arrangements are in place to contribute half of your purchase price of The Gluten Summit interviews to the CDAutism project. Go to the link below to order and also credit CDAutism with your contribution.

gg110.infusionsoft.com/go/tgso/Kerri

Appendix 6

Measuring the Strength of Your CD, CDS & CDH

by Charlotte Lackney

CD, CDS, and CDH work because all of them contain chlorine dioxide (ClO_2). ClO_2 is made when a 22.4% solution of sodium chlorite ($NaClO_2$) is activated with an acid, usually 4% hydrochloric acid (HCl) for CD and CDH; and 10% HCl for CDS.

Sometimes it might be useful to measure the amount of ClO_2 in those solutions, although that has not been done in the past when using CD. And, it may only be necessary to know the amount of chlorine dioxide if you are not getting the expected results. There could be a problem with the ingredients or process and knowing the amount of ClO_2 in the solution could be helpful in determining what might be wrong.

The amount of ClO_2 in a solution is measured in *parts per million* (ppm). It is always necessary to specify the volume of solution when talking about ClO_2 ppm because the ppm will vary depending on the dilution of the solution.

If using CDH or CDS with the protocol in this book, it is assumed that you are preparing them at 3000ppm. If using CDS, please keep in mind that the relative strength of one milliliter of CDS is approximately 60% of one drop of CD.

However, if the ingredients are of good quality and the CD or CDH protocol is closely followed, there is usually no need to know or measure the ClO_2 concentration.

Both CD and CDH may continue to activate inside the body from whatever sodium chlorite has not been activated outside the body. That is not the case with CDS, as it has no sodium chlorite to continue activating inside the body. Some believe that this is why many people can tolerate a higher dose of CDS than an equivalent dose of CD.

Measuring the concentration of ClO_2 can easily be done at home. You will need to purchase ClO2 test strips made by *LaMotte* or others. I have only used LaMotte Insta-Test® High-Range Test Strips, 0 to 500ppm (code #3002). The container's label has a chart showing seven colors on it wih each color indicating a ClO_2 concentration in ppm. Note: LaMotte recently changed the appearance of their labels, as shown on the right. Both are the same product. For more information, see their website:

www.lamotte.com/ en/water-wastewater/test-strips/3002.html

Directions for how to use the LaMotte test strips are printed on the side of the container and need to be followed in order to get an accurate ClO_2 concentration reading.

The numbers below each of the seven colors represent 0, 10, 25, 50, 100, 250 and 500ppm. Many people who use the test strips think the 50ppm color is the best one to use for color matching, because they can see the difference in color below and above that color more easily than the others.

If the ClO_2 solution you want to measure is suspected to be 3000ppm, how do you measure that if the test strips highest ClO_2 concentration color is 500ppm? Recall that I had said that it is always necessary to specify the volume of solution when talking about ClO_2 ppm, because the ppm will vary depending on the dilution of the solution.

So if we dilute the suspected 3000ppm ClO_2 stock solution with more water, the same amount of ClO_2 will now be evenly spread out in the larger amount of solution if stirred. There will be less ClO_2 in any one spot than before dilution, because the ClO_2 is now dispersed into a larger volume of water. Visualize what happens when a drop of red food coloring falls into a glass of water. It disperses throughout the water if stirred, and that dark red color is now much lighter because it is diluted in the water.

In order to read 3000ppm with a test strip, and have it match the 50ppm color on the container, we will need to dilute a small sample of the stock solution.

Stock solution (1ml)	÷	Desired dilution in ppm	=	Volume of water for dilution.
3000ppm		50ppm		60ml

The chlorine dioxide test strips (code #3002) made by LaMotte are available on the market with two different labels, although both are the same product. Both labels show the same measuring color chart on the outside of the container.

So, if we take a 1ml sample of the stock solution and add it to 60ml of water, then the stock solution is diluted 60 times its original volume. Technically, one should add the 1ml of stock solution to 59ml of water, for a total of 60ml, but using 60ml is easier to measure and you would not see the difference in ClO_2 readings if 59ml of water was used.

To measure, pour 60ml of distilled water into a small glass and then add 1ml of stock solution. Stir well to evenly distribute the ClO_2 sample in the water. Then take one of the test strips—taking care not to touch the pad of chemicals on the end of the strip—and dip it in the solution for two seconds. Keep the strip in one place in the solution and do not move it around during the two-second period.

Without flicking any of the solution off the strip, remove the strip from the test solution with the pad facing up and wait ten seconds. Now compare the color of the test strip pad to the color chart on the side of the test strips container (as shown above).

If the stock solution is 3000ppm, then the color on the test strip will match the 50ppm color on the container. Multiply 50 times 60 (the amount of dilution) and you get 3000ppm.

If the color on the test strip does not match the 50ppm color on the container, try to estimate the ppm number between container colors and multiply that number by 60 to get the ClO_2 concentration.

Tip: You can cut the strips lengthwise to get 100 strips instead of 50; just be sure not to touch the strip's pad with your fingers or your readings may not be accurate. Also it is important to keep the container tightly capped to keep moisture out which can affect the readings.

Dana one year after starting Kerri's protocol.

Appendix 7

Diluting HCl Concentration

The protocols in this book use two different concentrations of hydrochloric acid (HCl): 10% & 4%. Some suppliers sell both concentrations, while others only one. You may also find a source with a different concentration and wish to dilute it to 4 or 10%. The math to determine how much to dilute your stock solution is rather simple. You should have no problem if you know how to multiply, divide, add and subtract. Note: The same calculation works for citric acid if you have 50% and need to go down to 35%.

What you will need is:

- Bottle of concentrated HCl (10% or higher)
- Receiving bottle to store the resulting diluted HCl
- Graduated cylinder or other measuring cup

On the next page is a graphical representation of the dilution equation. It may look intimidating at first glance, but it is actually quite simple and is made up of three simple mini-calculations. Each box is labeled with a letter which refers to the graphic. Just fill in the numbers with a pencil and follow the directions.

We'll go over one example here: Let's say you have 10% HCl and want to make 1 liter of 4% HCl. Here's what you would have to calculate:

Desired Volume	×	Desired HCl %	=	Temporary Number
1000ml		4%		4000

Temporary Number	÷	Stock HCl %	=	Amount of 10% HCl
4000		10%		400ml

Desired Volume	—	Amount of 10% HCl	=	Amount of water
1000ml		400ml		600ml

So, in this example, you would need 400ml of 10% HCl and 600ml of water. to make 1 liter of 4% HCl. If you add them together, you should have 1000ml (1 liter).

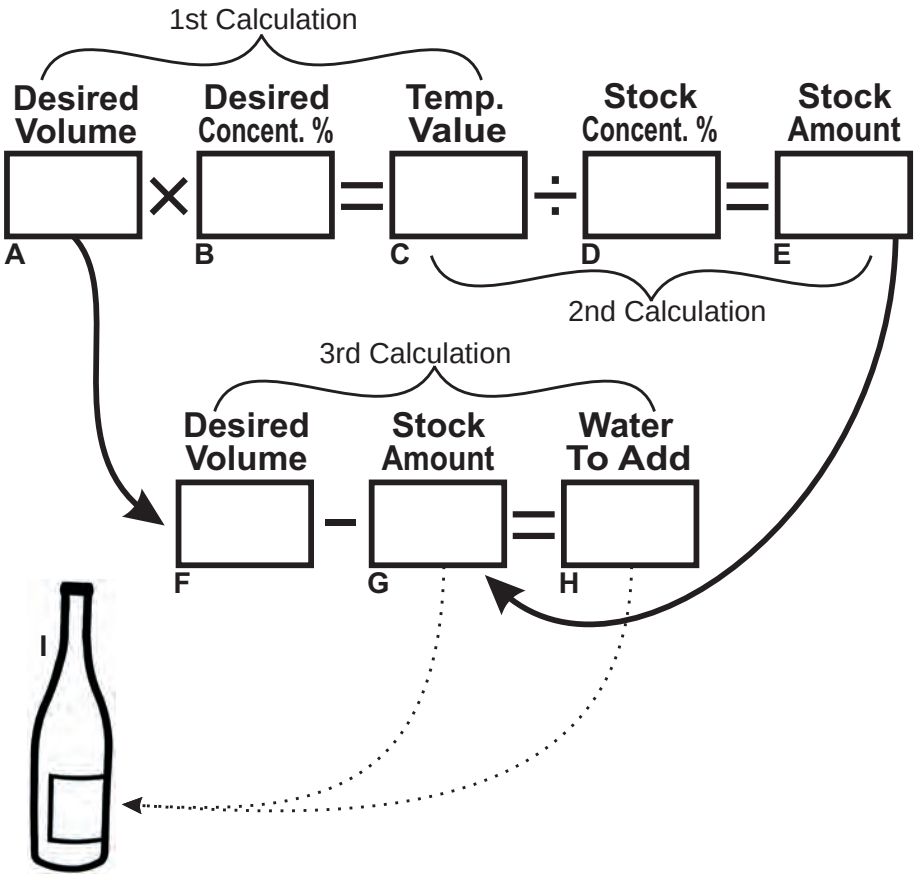

A	Determine the volume of the receiving bottle in milliliters. For example, if you have a 1 liter bottle, you would enter the number “1,000” for 1,000ml.
B	This is where you enter the % of the final solution. If you are making 4%, then enter “4” in this box.
C	Multiple **A** and **B** and enter the result into box **C**. This is a temporary value you will need for the next calculation.
D	This is where you enter the percentage of your concentrated stock solution–the HCl you want to dilute. If you have 10%, then enter a “10” in this box.
E	Now divide the temporary value in **C** by **D** and enter the result in **E**. This is the amount of concentrated stock HCl (in milliliters) you will need.
F	Copy what you entered in **A** to **F** for the next calculation.
G	Copy the result from **E** to **G**.
H	Do the subtraction of **F** − **G** and enter he value in **H**. This is the number of milliliters of distilled or filtered water you will need.
I	Measure the resulting volume of water calculated in **H** and pour it into the receiving bottle **I**. Finally, measure out the value in **G** and pour it into the receiving bottle **I**.

Appendix 8

Other Uses of Chlorine Dioxide

Bladder Infection Protocol (for Adults)

The protocol for bladder infection is three oral drops of CD eight times a day with a douche of 10 drops CD three times the first day, and then once every day thereafter, for 30 days (for females).

Ear, Eye, Nose Protocol

Make a mixture that contains one ounce of water for every one drop of CD. Use one drop of that mixture in the affected orifice every hour until symptoms disappear. If the issue is acute you can use one drop every 15 minutes. This method can be used in the ears for infections, in the nose for congestion/infection, and the eye for infection or conjunctivitis.

General Fever Protocol

If the person has a fever, or if you want clarification of any kind, email Kerri, but in the meantime, this will hopefully get you started:

1. Give baths interspersed with enemas, approximately eight hours apart (e.g. bath in the evening and enema in the morning or vice versa).
2. Give oral CD doses (using the person's usual number of drops) 12 to 16 times or more a day (essentially every hour); unless they stop eating, in which case, stop oral dosing. Enemas and baths can continue.
3. Have them drink lots of water.
4. Cool clothes on forehead and neck.

Please see Chapter 14, page 335 for more information on fever therapy.

Teeth

Ten activated drops of CD per one ounce of water. Put this in a spray bottle and spray on the toothbrush.

Throat Spray

Ten activated drops of CD (chlorine dioxide) in one ounce of water. Spray on throat once/hour. Recommended in the case of a sore throat.

Vaginal Douching for Yeast Infections:

Put six activated drops of CD in 60 ml of water. Hold this in for two minutes every day for a few weeks or between periods. Six drops MAX in the vagina.

CD Skin Spray

Use ten drops of activated CD per one ounce of water in a spray bottle.

CD spray is great for a variety of ailments.

- Skin
- Dandruff
- Scrapes
- Cuts
- Rashes
- Toe Fungus

Burns

Any burn should be sprayed with full strength sodium chlorite solution (no acid added) directly from a small spray bottle. Do not add citric acid or HCl at all! If you don't have a spray bottle available drip sodium chlorite solution directly onto the burn, making sure the area is soaked with it.

Wait up to five minutes, but no longer before rinsing off with room temperature water. If you fail to rinse off the sodium chlorite solution, the burn will continue to hurt and get worse.

This technique will cause the burn to heal in 1/4 the time normally required. The pain should stop almost immediately or reduce to almost zero within several minutes.

Sunburns should be treated the same way. Spray the red area, wait 1 to 5 minutes, and rinse off. If the area is still sore, in about an hour spray the area again and wait 5 minutes before rinsing off. Remember, DO NOT allow the sodium chlorite to remain in place. It must be rinsed off! The pain should be gone in a couple of minutes. Generally two doses will overcome most sunburns, but on rare occasions if the discomfort is not all gone you can use a third dose. Be sure to rinse it off.

Note that sodium chlorite is alkaline and burns are acidic. Therefore the sodium chlorite neutralizes the acidity that resides in the burned areas. This is part of the reason why burns heal rapidly after sodium chlorite applications.

Appendix 9

Blank Kalcker Parasite Protocol Chart

The next page contains a blank Kalcker Parasite Protocol Daily Chart identical to those found on pages 199 through 217. You are encouraged to copy this chart for use in your parasite protocol planning. Setting the copy machine to enlarge at 125% should fill a standard letter-sized page.

Time	Meal Time	CD / CDS / CDH	CD / CDS / CDH Bath	CD / CDS / CDH Enema	Ocean Water	Diatomaceous Earth	Lepidium Latifolium Extract (Rompepiedras / RP)	Pyrantel Pamoate (Combantrin®)	Mebendazole	Castor Oil	Neem	Probiotic
6:00 AM												
6:30 AM												
7:00 AM												
7:30 AM												
8:00 AM												
8:30 AM												
9:00 AM												
9:30 AM												
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9:30 PM												

Appendix 10

Lunar Phase Calendar for Kalcker Parasite Protocol

As covered in Chapter 8, the Kalcker Parasite Protocol is administered over a period of 19 days and scheduled according to the lunar cycle. We have included an easy to follow calendar starting on the next page for the years 2014 through 2016.

Each chart page shows 6 months with each month broken up into 3 columns: Column 1 is the day of the month; column 2 indicates the lunar phase; and column 3 shows the corresponding Parasite Protocol day.

The full moon is identified with an "F" in the second column and the new moon is identified by an "N" in each month section, which usually occurs towards the end of each protocol cycle.

We have used New York as our center point since it is roughly the center of the majority of those using this book in the US and Europe. The moon phase may occur 1 day before or after the dates shown if you are in another part of the world, but the difference is not great, so feel free to use the dates shown. However, you are welcome to be precise for your particular location. The Farmer's Almanac is a great source and provides an online calendar that can be adjusted to your location:

www.almanac.com/moon

You may also wish to install a moon phase app into your smart phone. Many free options exist.

2014 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1	N	18	1			1	N	18	1			1	N		1		
2			2			2			2			2			2		
3			3			3			3			3			3		
4			4			4			4			4			4		
5			5			5			5			5			5		
6			6			6			6			6			6		
7			7			7			7			7			7		
8			8			8			8			8			8		
9			9			9			9			9			9		
10			10			10			10			10			10		0
11			11		0	11			11			11			11		1
12		0	12		1	12			12		0	12			12		2
13		1	13		2	13		0	13		1	13		0	13	F	3
14		2	14	F	3	14		1	14		2	14		1	14		4
15	F	3	15		4	15		2	15	F	3	15		2	15		5
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28		16	28		17	28		15	28		16	28		15	28		18
29		17				29		16	29	N	17	29		16	29		
30	N	18				30	N	17	30		18	30	N	17	30		
31						31		18				31		18			

2014 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1			1			1			1			1			1		
2			2			2			2			2			2		
3			3			3			3			3		0	3		0
4			4			4			4			4		1	4		1
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6			6			6		1	6		1	6	F	3	6	F	3
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25		16	25	N	18	25			25			25			25		
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29			29			29			29			29			29		
30			30			30			30			30			30		
31			31						31						31		

2015 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1		0	1		1	1			1		0	1		1	1		2
2		1	2		2	2		0	2		1	2		2	2	F	3
3		2	3	F	3	3		1	3		2	3	F	3	3		4
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6		5	6		6	6		4	6		5	6		6	6		7
7		6	7		7	7		5	7		6	7		7	7		8
8		7	8		8	8		6	8		7	8		8	8		9
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26			26			26			26			26			26		
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30						30			30		0	30		0	30		2
31		0				31						31		1			

2015 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1	F	3	1		4	1		6	1		7	1		8	1		9
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11		13	11		14	11		16	11		17	11	N	18	11	N	
12		14	12		15	12		17	12	N	18	12			12		
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14		16	14	N	17	14			14			14			14		
15	N	17	15		18	15			15			15			15		
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25			25			25		1	25		1	25	F	3	25	F	3
26			26		0	26		2	26		2	26		4	26		4
27			27		1	27	F	3	27	F	3	27		5	27		5
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29		1	29	F	3	29		5	29		5	29		7	29		7
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31	F	3	31		5				31		7				31		9

2016 - Lunar Phases for New York, NY

Jan			Feb			Mar			Apr			May			Jun		
1		10	1		12	1		11	1		12	1		12	1		14
2		11	2		13	2		12	2		13	2		13	2		15
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8		17	8	N		8	N	18	8			8			8		
9	N	18	9			9			9			9			9		
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29		9	29		10	29		9	29		10	29		11	29		12
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31		11				31		11				31		13			

2016 - Lunar Phases for New York, NY

Jul			Aug			Sep			Oct			Nov			Dec		
1		14	1		16	1	N	17	1		18	1		18	1		
2		15	2	N	17	2		18	2			2			2		
3		16	3		18	3			3			3			3		
4	N	17	4			4			4			4			4		
5		18	5			5			5			5			5		
6			6			6			6			6			6		
7			7			7			7			7			7		
8			8			8			8			8			8		
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14			14			14		1	14		1	14	F	3	14		4
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30		14	30		15	30	N	17	30	N	17	30			30		
31		15	31		16				31						31		

Three things cannot be long hidden:
the sun, the moon, and the truth.

~ Buddha

Appendix 11

Health Benefits of Diatomaceous Earth

by Dee McCaffrey, CDC

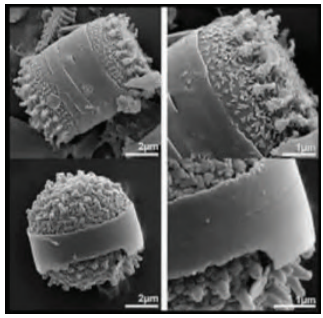

You've probably never heard of one of the best and most economical supplements to improve your health and cleanse your body. In fact, this supplement is perhaps one of the best kept secrets ever. This relatively unknown "food" supplement is called Diatomaceous Earth, also known as DE. It is a completely natural substance that is rich in naturally occurring silica, a mineral whose list of documented health benefits continues to grow as more research is being conducted.

Some of the most recent studies show that it can strengthen bones and joints, prevent osteoporosis and restore bone health if you already have osteoporosis, boost the immune system, ward off Alzheimer's, prevent premature aging and wrinkling of the skin, and strengthens the arterial walls to maintain good heart health. Another of the benefits of silica is that it helps to destroy bad fats in the body. Used as a daily treatment, diatomaceous earth can alleviate the potentially deadly risks of high cholesterol, high blood pressure, and obesity.

Additionally, because of its physical structure, diatomaceous earth is a highly effective anti-inflammatory and internal cleansing agent for the body. It can remove intestinal bacteria, parasites, e-coli, viruses, pesticides, heavy metals, and other toxins. It has also been known to assist with vertigo, headaches, tinnitus, and insomnia.

Sound too good to be true? Read on to learn more about this overlooked multi-purpose supplement and how it can improve many aspects of your health at a fraction of the cost of other supplements.

What is Diatomaceous Earth?

Diatomaceous earth is the fossilized shells of microscopic water-dwelling organisms known as diatoms. Diatoms are one-celled plants (algae or phytoplankton) that are the primary food source for marine life. These plants have been part of the earth's ecology since prehistoric times, yet their species still exists today in both salty and fresh waters all over the world.

Diatoms use soluble silica (sand) from their environment to make their shells, or exoskeletons. As diatoms die, their shells fall to the bottom of the bodies of water in which they live. It is believed that 30 million years ago the diatoms piled up to form thick beds of chalky fossilized sediment. These beds, known as diatomite or diatomaceous earth, were discovered after the waters receded.

Today, hundreds of large deposits of diatomaceous earth occur all over the world. Some are still underwater and some are found in ancient dried lake bottoms. It has been estimated that one cubic inch of diatomaceous earth may contain as many as 400 million shells, that's how small diatoms are!

Diatomite is mined and ground into a powder that looks and feels like talcum powder. This all natural powder is called Diatomaceous Earth (DE) or fossil shell flour. It is made up of approximately 33% silicon, 19% calcium, 5% sodium, 3% magnesium 2% iron and many other trace minerals such as titanium, boron, manganese, copper and zirconium.

What Do Fossilized Shells Have to Do With Improving Your Health?

It's all about the silica.

As I mentioned earlier, the shells of diatoms are made up mostly of silica (known by chemists as silicon dioxide). Silica is one of the most abundant minerals on the planet, but most of it is in a form that is unabsorbable by humans, and there are limited numbers of foods that contain an adequate amount of the absorbable form to supply the quantity our body needs. Silica is the most important trace mineral for human health. It plays an important role in many body functions and has a direct relationship to mineral absorption. For optimal health, the average human body needs to hold approximately seven grams of silica, a quantity far exceeding the figures for other important minerals such as iron and calcium.

Silica can be found in such foods as alfalfa, beets, brown rice and oats. Bell peppers and leafy green vegetables also provide silica, while asparagus, Jerusalem artichokes, parsley, sunflower seeds and grain husks, such as barley, millet and wheat contain smaller amounts.

Years ago, the silica found in our foods was adequate, but with today's depleted soils, only about one-third of the silica needed by our body is supplied in our food.

In our youth, our tissues absorb and maintain high levels of silica— enabling

our bodies to remain flexible, resilient, and energetic—but as we age, and as our dietary sources of silica are not meeting our needs, our silica levels steadily decline until they become almost non-existent. In fact, 80% of all of our body's silica is used up by the time we become adults.

Our bodies need silica regardless of our age and even when diet is not the primary factor in cases of deficiencies, we often become deficient in this essential trace element simply thorough the aging process. The effect of this steady decrease in silica levels is a progressive decline in health, increasing fatigue and acceleration of the aging process.

Diatomaceous earth, which is very high in the absorbable form of silica, can replenish silica levels in the body, which can vastly improve your health and reverse many chronic problems. Studies show that high levels of silica can:

Improve Bone Health and Stop Osteoporosis: Calcium and vitamin D alone are not sufficient for bone growth, density, strength, and flexibility. In fact, the body cannot absorb and use calcium without the presence of silica. Recent data suggests that instead of promoting healing, calcium supplements actually speed up the leeching away of bone calcium and accelerate the degenerative process of osteoporosis and similar diseases that affect the connective tissues in the human body!

To re-mineralize and repair damaged bones, it is now advised that a sufficient silica supplement be taken daily because bones are composed of mainly of the minerals phosphorus, magnesium and calcium; however, these minerals need the presence of silica to be deposited into the bones, especially calcium. Silica hastens the healing of fractures and also diminishes scarring at the location of a fracture. A great deal of research evidence indicates that silica has the ability to "morph" itself into calcium through a transmutation process. Yes, silica actually has the ability to be turned into calcium when there is a calcium deficiency and the body needs it!

That fact alone should be reason enough to supplement with DE!!

Ward Off Alzheimer's: Scientists and researchers have long hypothesized that Alzheimer's disease is linked to a build up of aluminum in the brain, and links between aluminum in drinking water supplies and Alzheimer's have now been ascertained. A factor that had been overlooked is that silica reduces the accumulation of aluminum. When researchers added silica to aluminum-laced water supplies, it inhibited the aluminum from being absorbed. It also caused a proliferation in the excretion of aluminum in urine and lowered aluminum concentrations in the brain, liver, bone, spleen and kidneys. Silica, therefore, may be important in supporting neurological health.

Improve Heart and Lung Health: Silica can hinder the effects of coronary disease by fortifying blood vessels. Studies confirm that with age, silica disappears from the aorta, the heart's key blood vessel—thus weakening its critical connective tissue, and resulting in a greater cardiac risk. Studies have shown diatomaceous earth to significantly lower cholesterol by removing plaque and keeping arteries and veins supple. It also helps to regulate blood pressure. Silica also aids in the repair and maintenance of vital lung tissues and defending them from pollution.

Stop Premature Wrinkling and Sagging Skin: Silica is excellent for supporting bones and connective tissue. Your body needs healthy connective tissue for internal organs and the largest organ which is your skin. And you probably know that degrading connective tissue, with age is why wrinkles appear and skin begins to sag. Perhaps it is not age, but rather not enough silica that makes this happen.

Collagen, which is mostly made up of silica, is the glue that holds us together. Collagen accounts for up to 75% of the weight of the dermis and is responsible for the resilience and elasticity of the skin. Our connective tissues consist of collagen, elastin, mucopolysaccharides and mucous carbohydrates which aid in moisture retention. Their capacity to hold on to moisture keeps the connective tissue resilient and has apparent importance in the prevention of premature aging. All these valuable molecules house large quantities of silica. Also, many people with advanced arthritis suffer from bone deformation when tendons and ligaments in the joints lose flexibility due to loss of collagen. Tendons and ligaments need silica for health and flexibility.

Boost the Immune System: Silica may play an important role in the immune system and its biological response to harmful stimuli. Silica is necessary for the body to produce antibodies that fight off viruses, bacteria, allergens and other invaders that the body views as foreign.

Other Ways Diatomaceous Earth Can Improve Your Health

One of the most sought after benefits of diatomaceous earth is to cleanse the digestive tract. Many people consume a variety of processed foods, which contain various harmful chemicals and toxins. Plus, as air quality has decreased, we are constantly putting more toxins in our body that need to be removed.

Diatomaceous earth can purge any parasite, virus, bacteria, or toxin that is clinging to our digestive tract. While diatomaceous earth feels like a soft powder, the truth is that diatomaceous earth is actually a small cylinder with extremely sharp edges. As we consume diatomaceous earth, these sharp edges scrape away parasites, toxins, and viruses clinging to the lining of our digestive tract. Plus, any toxins or bacteria floating in our digestive tract are absorbed and trapped by diatomaceous earth. It has also been shown to cling to bad fats in the body, effectively reducing bad cholesterol. Diatomaceous earth is then expelled through our bowel movements and these harmful materials are removed.

Our skin and organs are strong and thick enough not to be affected by these sharp edges, which is why we feel no pain taking diatomaceous earth. After a few days, the body's digestive system can be thoroughly cleansed and can operate much more efficiently.

Are All Forms of Diatomaceous Earth the Same?

No! There are two types of DE—Food Grade and Pool Grade.

Most deposits of diatomaceous earth are from salt water sources, while only a few are from fresh water sources. Of the hundreds of DE deposits that exist worldwide, only 4 of them can be called food grade. The DE sourced from fresh water beds are of extremely high purity—so pure that it is called Food Grade Diatomaceous Earth, or also known as fossil shell flour. Food grade diatomaceous earth, the only form safe for human consumption, is a white powder, while other forms of diatomaceous earth may have a brown/reddish tint.

Also, there are two types of naturally occurring silica—crystalline silica and non-crystalline (amorphous) silica. Crystalline silica can be very dangerous, especially to our lungs if inhaled, while non-crystalline silica is completely safe, even for human and animal consumption. The fresh water diatoms contain mainly non-crystalline silica, while salt water diatoms can contain both types, with higher amounts of the crystalline form.

PERMA-GUARD™ is the trade name known worldwide for using a grade and quality of Diatomaceous Earth (DE) that is extremely pure. Brands that use Perma-Guard™ food grade Diatomaceous Earth contains less than 0 .5% crystalline silica. It is important to have a consistent shape diatom and no unwanted sediment. The shape of the diatom must be tubular with holes on the walls. It must be from fresh water because the fresh water diatoms form a harder shell and are less fragile that those from salt water. Salt water deposits contain a mix of diatom species. These deposits shapes and sediments are inconsistent making them unusable for safe human consumption.

Other types of diatomaceous earth have other industrial uses. It is heated to a very high temperature (about 1000°C or 1800°F). This type of DE is called "calcined." It is used for pool filters and other types of filtering but it is also used as a filler and can end up in paints, cosmetics, drugs, chemical insecticides, and other things. Food grade DE is never heated.

Bottom Line: ONLY use Food Grade Diatomaceous Earth for health purposes!!! Food grade diatomaceous earth is the purest form of diatomaceous earth and can be consumed and used by humans. Food grade diatomaceous earth is heavily regulated and must contain less than a certain amount of specific minerals.

Pool grade DE is calcinated and is a stronger, more potent form of DE. It is not to be used by humans and pool grade DE must be handled with gloves and a mask to ensure no throat irritations occur.

All DE should have a label that tells you if it has been calcined and how much crystalline silica it contains.

How Much to Take—How Safe Is It?

Food grade diatomaceous earth is a very fine powder and is very light due to its high porosity. It mixes easily into liquids and foods. Most people take a teaspoon or a tablespoon two or three times a day (up to a total of one quarter cup per day) for best results. Mix it into water, juice, smoothies or other foods.

It sort of resembles putting a spoonful of baking soda in water and drinking it!

Silica is water soluble; hence, once you get it into your body it easily absorbed via the intestinal wall and is also rapidly excreted. It does not accumulate in the body, so consistent daily supplementation is important. Studies have not found any negative side effects from too much silica. Its safety and extensive range of uses makes silica one of the most important minerals used in complementary therapy and alternative medicine. Regular supplementation could make a significant difference in your health.

Being approved by the FDA, Diatomaceous Earth has absolutely no dangerous side effects. It can be used by anyone, as long as the person doesn't suffer from a serious illness. As with any other health supplement, talk to a doctor before using DE. You might have some intolerance to it, so it's advisable to not risk your health. Pregnant and breastfeeding mothers can use it as long as their doctor has agreed.

What Other Uses Does DE Have?

One of the most commonly known uses for diatomaceous earth is as a non-toxic bug killer. DE is almost pure silica (with some beneficial trace minerals); under a microscope, it looks like shards of glass (glass is made from silica). On any beetle-type insect that has a carapace, like ants, fleas and cockroaches, the DE works under the shell and punctures the body, which then dehydrates their innards and the insect dies. DE is totally nontoxic. There is no buildup of tolerance like there is to poisons because the method of killing is PHYSICAL, not chemical. But rest assured, food grade DE doesn't hurt people or animals. In fact, it makes a great flea killer for your pets, and can also be added to their food as de-wormer. Many farmers use it to keep farm animals healthy, both inside and out. Food grade DE is also added to grains in storage because it keeps bugs from eating the grain. So if you eat any grains, you're probably already eating a little bit of DE!

Where to Get It!

You can buy food grade diatomaceous earth online. Processed-Free America sells it through its online store.

Written by Dee McCaffrey, CDC, who lost 100 pounds and has kept it off for over 20 years. For more info, go to: www.processedfreeamerica.org

Appendix 12

Summary of Protocols

The purpose of this list is to have all the protocols in one place, so you don't have to be hunting and flipping pages to find something. This information is also available on our website www.cdautism.org if you would like to print anything full size.

Diet

Permitted Foods List:

Note: Organic products are better but not required.

Proteins

- ☐ Beef
- ☐ Chicken
- ☐ Eggs
- ☐ Fish (small not large size)
- ☐ Pork
- ☐ Turkey

Fruit

- ☐ Most fresh fruits are permitted (except citrus, mango, pineapple, kiwi, and limit berries).
- ☐ Frozen fruit without added cream or sugar.
- **!** NO canned fruit (nothing canned ever).
- **!** Be careful of dried fruit as it may contain sugar.

Vegetables

- ☐ All vegetables are fine!!!
- ☐ Including French fries, however, not frozen fries or fries from fast food chains; these are often coated in flour.

Nuts

- ☐ Almonds
- ☐ Cashews
- ☐ Coconut
- ☐ Hazelnuts
- ☐ Walnuts

Grains

- ☐ Amaranth
- ☐ Buckwheat
- ☐ Corn
- ☐ Millet
- ☐ Quinoa
- ☐ Rice
- ☐ Sorghum
- ☐ Tapioca
- ☐ Xanthan gum

Beans

- ☐ All beans—EXCEPT soy
- ☐ Split Pea
- ☐ Garbanzo
- ☐ Lentils
- ☐ Navy
- ☐ Peanuts

Sweeteners

- ☐ Stevia (Best choice of all sweeteners)
- ☐ Agave syrup
- ☐ Honey
- ☐ Maple syrup (without added sugar)
- ☐ Xylitol

Prohibited Foods List

- Acetic acid (E260)
- Artificial flavoring
- Artificial sweeteners
- Bouillon cubes
- Bread
- Candy
- Cane sugar
- Carrageenan
- Catsup
- Chocolate milk
- Coloring
- Corn flakes
- Corn syrup
- Cow's milk in any form (even lactose-free milk products)
- Flour tortillas
- Gelatin
- Malt
- Margarine
- Mayonnaise
- Microwave popcorn
- MSG
- Natural flavoring
- Noodle soup
- Oatmeal (except for Bob's Red Mill GF oats)
- Pasta
- Piloncillo (unrefined sugar)
- Children´s nutritional shakes
- Play-Doh™
- Preservatives
- Processed meats (hotdogs, ham, sausage, bologna, cold cuts)
- Shellfish (full of toxins)
- Sodas
- Soy/fruit beverages
- Soy milk
- Soy sauce
- Sports drinks
- Sugar
- Yeast

Preparing Your First One drop CD Batch for the Day

1.	Start by filling the baby bottle with 8 fl. oz. (237ml) of water (distilled or reverse osmosis). NO alkaline water!	
2.	Place 1 drop of sodium chlorite solution into the CLEAN and DRY shot glass.	
3.	Add 1 drop of acidic activator (hydrochloric acid or citric acid) to the shot glass containing the drop of sodium chlorite. The number of drops may be higher if you are using a weaker activator. See chart on page 94.	
4.	Now wait the appropriate time for the mixture to react (see chart on page 94). You should see the color change from clear to slightly yellow. If there were more drops in the shot glass, the color change is more noticeable. You are also likely to notice the chlorine-like smell coming from the shot glass. Remember, this is NOT chlorine, but rather chlorine dioxide.	
5.	After the activation time has passed, pour a little water from the baby bottle into the shot glass and let it mix. This mostly stops the chemical reaction and insures you get most of the mixture out in the next step.	
6.	Lastly, pour all of the watered down mixture in the shot glass back into the baby bottle, and seal it tightly with the cap—don't leave it sitting open for any length of time. Think partially used soda pop and how you would want to keep that closed.	

Estimated Full Oral CD Doses by Weight

Use these numbers as a guide only. You may need to go up by as much as 50% or more over the indicated drops. Read chart as: **POUNDS / KILOGRAMS → DROPS OF CD (per 8 fl. oz. water)**

25/11→8	62/28→17	99/45→24	136/62→29	173/78→33	210/95→37
26/12→8	63/29→17	100/45→24	137/62→29	174/79→33	211/96→37
27/12→9	64/29→17	101/46→24	138/63→29	175/79→34	212/96→37
28/13→9	65/29→18	102/46→24	139/63→30	176/80→34	213/97→37
29/13→9	66/30→18	103/47→24	140/64→30	177/80→34	214/97→37
30/14→9	67/30→18	104/47→25	141/64→30	178/81→34	215/98→37
31/14→10	68/31→18	105/48→25	142/64→30	179/81→34	216/98→37
32/15→10	69/31→18	106/48→25	143/65→30	180/82→34	217/98→37
33/15→10	70/32→19	107/49→25	144/65→30	181/82→34	218/99→38
34/15→10	71/32→19	108/49→25	145/66→30	182/83→34	219/99→38
35/16→11	72/33→19	109/49→25	146/66→30	183/83→34	220/100→38
36/16→11	73/33→19	110/50→26	147/67→31	184/83→35	221/100→38
37/17→11	74/34→19	111/50→26	148/67→31	185/84→35	222/101→38
38/17→11	75/34→20	112/51→26	149/68→31	186/84→35	223/101→38
39/18→12	76/34→20	113/51→26	150/68→31	187/85→35	224/102→38
40/18→12	77/35→20	114/52→26	151/68→31	188/85→35	225/102→38
41/19→12	78/35→20	115/52→26	152/69→31	189/86→35	226/103→38
42/19→12	79/36→20	116/53→26	153/69→31	190/86→35	227/103→38
43/20→13	80/36→21	117/53→27	154/70→31	191/87→35	228/103→38
44/20→13	81/37→21	118/54→27	155/70→31	192/87→35	229/104→38
45/20→13	82/37→21	119/54→27	156/71→32	193/88→35	230/104→39
46/21→13	83/38→21	120/54→27	157/71→32	194/88→35	231/105→39
47/21→14	84/38→21	121/55→27	158/72→32	195/88→36	232/105→39
48/22→14	85/39→21	122/55→27	159/72→32	196/89→36	233/106→39
49/22→14	86/39→22	123/56→27	160/73→32	197/89→36	234/106→39
50/23→14	87/39→22	124/56→28	161/73→32	198/90→36	235/107→39
51/23→15	88/40→22	125/57→28	162/73→32	199/90→36	236/107→39
52/24→15	89/40→22	126/57→28	163/74→32	200/91→36	237/108→39
53/24→15	90/41→22	127/58→28	164/74→32	201/91→36	238/108→39
54/24→15	91/41→23	128/58→28	165/75→33	202/92→36	239/108→39
55/25→16	92/42→23	129/59→28	166/75→33	203/92→36	240/109→39
56/25→16	93/42→23	130/59→28	167/76→33	204/93→36	241/109→39
57/26→16	94/43→23	131/59→28	168/76→33	205/93→36	242/110→39
58/26→16	95/43→23	132/60→29	169/77→33	206/93→37	243/110→39
59/27→16	96/44→23	133/60→29	170/77→33	207/94→37	244/111→40
60/27→17	97/44→24	134/61→29	171/78→33	208/94→37	245/111→40
61/28→17	98/44→24	135/61→29	172/78→33	209/95→37	246/112→40

Advanced Protocols (After Full Oral Dose is Reached)

CD Enemas:

I recommend enemas no less frequently than every other day. You can do them more often particularly if you see parasites coming out. The ratio is 1-2 drops chlorine dioxide per 100 ml of filtered warm water. Work your way up to 500 mL – 1.5 L of water per enema, depending on the size of your child. You have the following options for methods of administering the enemas: a catheter and syringes, a multipurpose enema/douche bag, empty out a fleet enema, or a gravity bag. (note, if your child suffers from constipation you can add enemas and baths in before you get to full dose, alternating them on opposite days or opposite ends of the day).

Enemas should be started when the child reaches full oral dose. However, if your child suffers from constipation you can add enemas and baths on day one (see page 113), before you get to the full oral dose. However, alternate them on opposite days or opposite ends of the day. The following chart is an approximate amount of water based on the size of the person, and calculated the maximum of 2 drops of CD per 100mL of water.

Age/Size	Water Volume	Drops of CD
Child	1/2 Liter (500ml)	10
Adolescent	1 Liter (1,000ml)	20
Teen/Adult	up to 2 Liters (2,000ml)	40

CD Baths:

10-100 Activated drops of CD in a hot (to tolerance) bath with enough water to cover the child's body. Soak for 20 minutes. Apply on alternate enema days, unless you are doing daily enemas, in which case apply on opposite ends of the day.

The CD baths can go from as low as 10 drops to as high as 80 to 100 drops; it just depends on the person, and the size of your tub. With younger/smaller children we start with ten drops. Since we're doing baths every other day, start with ten drops on Monday, 11 drops on Wednesday, and 12 drops on Friday. Just keep going up until you get to 20 drops. The bigger and older the person is, the more drops they can tolerate. Fill the tub to a level that maximizes skin contact.

72/2 Protocol

Give one dose of CD every 2 hours for 72 hours straight, including the middle of the night. Apply every possible weekend.

This involves giving one dose of CD every two hours for 72 hours straight—including the middle of the night. Here are some additional thoughts and guidelines:

- Start protocol when you pick up your child from school on Friday.
- Give them the last 72/2 dose when you drop them off at school on Monday.
- Avoid giving CD enemas or CD baths during this protocol, UNLESS they are dumping parasites, in which case you might need to reduce the amount of CD on both the oral and enema dose to insure the child doesn't have a Herxheimer reaction.
- Why not give hourly doses during the day at the usual dose? It's simply too much if you are doing it all night as well.
- Watch for improvements on Tuesday or Wednesday each week.
- Ideally, get your spouse or significant other to help with every other nightly dose.

Supplement Dosing Overview

Supplement	Dose	Time of Day	Empty Stomach (ES) or With Food (WF)
Probiotics	1 cap	Before Bed	ES
Omega-3/ Omega-6	1 Tbsp	With any meal 1-3x / day	WF
L-Carnitine	250-1000mg/day	With any meal 1-3x / day	WF
GABA	Up to 2,500mg 2x/day	Upon waking & at bedtime	ES
5-HTP	50-200mg	Morning & Evening	WF
L-Theanine	Work up to 200-250mg/day	Mornings or Mornings & Nights	ES
Pycnogenol	25-40mg a day/as needed	Morning	WF
L-Carnosine	200-400mg 2x / day	Morning & Evening	WF
Taurine	500-1500mg/day	Morning, Noon & Night	ES
DMG	900mg/day	Morning	ES
TMG	500mg/day	Morning	ES
Enzymes	1 cap w/meals	Morning, Noon & Night	WF

Parasite Protocol

Please see the complete explanation of the parasite protocol starting on page 187. Day-to-day protocol charts can be found on page 198.

Chelation:

I suggest that when you decide to add clay baths into your child's protocol that you do so on the off days of the CD baths.

Follow the instructions on the package, and follow septic tank precautions if you have one.

Three days or so later, you can add in the Bio-Chelat. Again, follow the instructions on the package, and you can always start slowly and work your way up. Since Bio-Chelat™ doesn't alter the CD, the drops can be added to a single dose of CD. In addition, since the drops have no flavor, it is suitable to add them to water or any other drink your child might consume throughout the day.

Hyperbarics:

Option #1:

Two sessions of 60 minutes each for 20 days for a total of 40 sessions at 1.75 ATA.

Option #2:

One 90-minute session a day for twenty days at 1.75 ATA.

Instead of thinking outside of the box, get rid of the box.

~ Deepak Chopra

Appendix 13

Body Burden
The Pollution in Newborns

When I came across the following investigation I knew it was the perfect precursor to the incredible "Avoiding Autism" by Dr. Anju Usman and Beth Hynes. Babies are exposed to toxins in the womb and this study by the Environmental Working Group demonstrates so perfectly why the advice in the "Avoiding Autism" article is so very crucial to health of our children and for our species as a whole.

Body Burden — The Pollution in Newborns

A benchmark investigation of industrial chemicals, pollutants and pesticides in umbilical cord blood.

Environmental Working Group, July 14, 2005

Summary. In the month leading up to a baby's birth, the umbilical cord pulses with the equivalent of at least 300 quarts of blood each day, pumped back and forth from the nutrient- and oxygen-rich placenta to the rapidly growing child cradled in a sac of amniotic fluid. This cord is a lifeline between mother and baby, bearing nutrients that sustain life and propel growth.

Not long ago scientists thought that the placenta shielded cord blood — and the developing baby — from most chemicals and pollutants in the environment. But now we know that at this critical time when organs, vessels, membranes and systems are knit together from single cells to finished form in a span of weeks, the umbilical cord carries not only the building blocks of life, but also a steady stream of industrial chemicals, pollutants and pesticides that cross the placenta as readily as residues from cigarettes and alcohol. This is the human "body burden" — the pollution in people that permeates everyone in the world, including babies in the womb.

In a study spearheaded by the Environmental Working Group (EWG) in collaboration with Commonweal, researchers at two major laboratories found an average of 200 industrial chemicals and pollutants in umbilical cord blood from 10 babies born in August and September of 2004 in U.S. hospitals. Tests revealed a total of 287 chemicals in the group. The umbilical cord blood of these 10 children, collected by Red Cross after the cord was cut, harbored pesticides, consumer product ingredients, and wastes from burning coal, gasoline, and garbage.

This study represents the first reported cord blood tests for 261 of the targeted chemicals and the first reported detections in cord blood for 209 compounds. Among them are eight perfluorochemicals used as stain and oil repellants in fast food packaging, clothes and textiles — including the Teflon chemical PFOA, recently characterized as a likely human carcinogen by the EPA's Science Advisory Board — dozens of

Chemicals and pollutants detected in human umbilical cord blood

Hg

Mercury (Hg) - tested for 1, found 1
Pollutant from coal-fired power plants, mercury-containing products, and certain industrial processes. Accumulates in seafood. Harms brain development and function.

PAH

Polyaromatic hydrocarbons (PAHs) - tested for 18, found 9
Pollutants from burning gasoline and garbage. Linked to cancer. Accumulates in food chain.

BD/F

Polybrominated dibenzodioxins and furans (PBDD/F) - tested for 12, found 7
Contaminants in brominated flame retardants. Pollutants and byproducts from plastic production and incineration. Accumulate in food chain. Toxic to developing endocrine (hormone) system

PFC

Perfluorinated chemicals (PFCs) - tested for 12, found 9
Active ingredients or breakdown products of Teflon, Scotchgard, fabric and carpet protectors, food wrap coatings. Global contaminants. Accumulate in the environment and the food chain. Linked to cancer, birth defects, and more.

D/F

Polychlorinated dibenzodioxins and furans (PCDD/F) - tested for 17, found 11
Pollutants, by-products of PVC production, industrial bleaching, and incineration. Cause cancer in humans. Persist for decades in the environment. Very toxic to developing endocrine (hormone) system.

OC

Organochlorine pesticides (OCs) - tested for 28, found 21
DDT, chlordane and other pesticides. Largely banned in the U.S. Persist for decades in the environment. Accumulate up the food chain, to man. Cause cancer and numerous reproductive effects.

PBDE

Polybrominated diphenyl ethers (PBDEs) - tested for 46, found 32
Flame retardant in furniture foam, computers, and televisions. Accumulates in the food chain and human tissues. Adversely affects brain development and the thyroid.

CN

Polychlorinated Naphthalenes (PCNs) - tested for 70, found 50
Wood preservatives, varnishes, machine lubricating oils, waste incineration. Common PCB contaminant. Contaminate the food chain. Cause liver and kidney damage.

PCB

Polychlorinated biphenyls (PCBs) - tested for 209, found 147
Industrial insulators and lubricants. Banned in the U.S. in 1976. Persist for decades in the environment. Accumulate up the food chain, to man. Cause cancer and nervous system problems.

Source: Chemical analyses of 10 umbilical cord blood samples were conducted by AXYS Analytical Services (Sydney, BC) and Flett Research Ltd. (Winnipeg, MB).

widely used brominated flame retardants and their toxic by-products; and numerous pesticides.

Of the 287 chemicals we detected in umbilical cord blood, we know that 180 cause cancer in humans or animals, 217 are toxic to the brain and nervous system, and 208 cause birth defects or abnormal development in animal tests. The dangers of pre- or post-natal exposure to this complex mixture of carcinogens, developmental toxins and neurotoxins have never been studied.

Chemical exposures in the womb or during infancy can be dramatically more harmful than exposures later in life. Substantial scientific evidence demonstrates that children face amplified risks from their body burden of pollution; the findings are particularly strong for many of the chemicals found in this study, including mercury, PCBs and dioxins. Children's vulnerability derives from both rapid development and incomplete defense systems:

- A developing child's chemical exposures are greater pound-for-pound than those of adults.
- An immature, porous blood-brain barrier allows greater chemical exposures to the developing brain.
- Children have lower levels of some chemical-binding proteins, allowing more of a chemical to reach "target organs."
- A baby's organs and systems are rapidly developing, and thus are often more vulnerable to damage from chemical exposure.
- Systems that detoxify and excrete industrial chemicals are not fully developed.
- The longer future life span of a child compared to an adult allows more time for adverse effects to arise.

The 10 children in this study were chosen randomly, from among 2004's summer season of live births from mothers in Red Cross' volunteer, national cord blood collection program. They were not chosen because their parents work in the chemical industry or because they were known to bear problems from chemical exposures in the womb. Nevertheless, each baby was born polluted with a broad array of contaminants.

U.S. industries manufacture and import approximately 75,000 chemicals, 3,000 of them at over a million pounds per year. Health officials do not know how many of these chemicals pollute fetal blood and what the health consequences of in utero exposures may be.

Had we tested for a broader array of chemicals, we would almost certainly have detected far more than 287. But testing umbilical cord

blood for industrial chemicals is technically challenging. Chemical manufacturers are not required to divulge to the public or government health officials methods to detect their chemicals in humans. Few labs are equipped with the machines and expertise to run the tests or the funding to develop the methods. Laboratories have yet to develop methods to test human tissues for the vast majority of chemicals on the market, and the few tests that labs are able to conduct are expensive. Laboratory costs for the cord blood analyses reported here were $10,000 per sample.

A developing baby depends on adults for protection, nutrition, and, ultimately, survival. As a society we have a responsibility to ensure that babies do not enter this world pre-polluted, with 200 industrial chemicals in their blood. Decades-old bans on a handful of chemicals like PCBs, lead gas additives, DDT and other pesticides have led to significant declines in people's blood levels of these pollutants. But good news like this is hard to find for other chemicals.

The Toxic Substances Control Act, the 1976 federal law meant to ensure the safety of commercial chemicals, essentially deemed 63,000 existing chemicals "safe as used" the day the law was passed, through mandated, en masse approval for use with no safety scrutiny. It forces the government to approve new chemicals within 90 days of a company's application at an average pace of seven per day. It has not been improved for nearly 30 years—longer than any other major environmental or public health statute—and does nothing to reduce or ensure the safety of exposure to pollution in the womb.

Because the Toxic Substances Control Act fails to mandate safety studies, the government has initiated a number of voluntary programs to gather more information about chemicals, most notably the high production volume (HPV) chemical screening program. But these efforts have been largely ineffective at reducing human exposures to chemicals. They are no substitute for a clear statutory requirement to protect children from the toxic effects of chemical exposure.

In light of the findings in this study and a substantial body of supporting science on the toxicity of early life exposures to industrial chemicals, we strongly urge that federal laws and policies be reformed to ensure that children are protected from chemicals, and that to the maximum extent possible, exposures to industrial chemicals before birth be eliminated. The sooner society takes action, the sooner we can reduce or end pollution in the womb.

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Tests show 287 industrial chemicals in 10 newborn babies

Pollutants include consumer product ingredients, banned industrial chemicals and pesticides, and waste byproducts

Sources and uses of chemicals in newborn blood	Chemical family name	Total number of chemicals found in 10 newborns (range in individual babies)
Common consumer product chemicals (and their breakdown products)		**47 chemicals (23 - 38)**
Pesticides, actively used in U.S.	Organochlorine pesticides (OCs)	7 chemicals (2 - 6)
Stain and grease resistant coatings for food wrap, carpet, furniture (Teflon, Scotchgard, Stainmaster...)	Perfluorochemicals (PFCs)	8 chemicals (4 - 8)
Fire retardants in TVs, computers, furniture	Polybrominated diphenyl ethers (PBDEs)	32 chemicals (13 - 29)
Chemicals banned or severely restricted in the U.S. (and their breakdown products)		**212 chemicals (111 - 185)**
Pesticides, phased out of use in U.S.	Organochlorine pesticides (OCs)	14 chemicals (7 - 14)
Stain and grease resistant coatings for food wrap, carpet, furniture (pre-2000 Scotchgard)	Perfluorochemicals (PFCs)	1 chemicals (1 - 1)
Electrical insulators	Polychlorinated biphenyls	147 chemicals
	(PCBs)	(65 - 134)
Broad use industrial chemicals - flame retardants, pesticides, electrical insultators	Polychlorinated naphthalenes (PCNs)	50 chemicals (22 - 40)
Waste byproducts		**28 chemicals (6 - 21)**
Garbage incineration and plastic production wastes	Polychlorinated and Polybrominated dibenzo dioxins and furans (PCDD/F and PBDD/F)	18 chemicals (5 - 13)
Car emissions and other fossil fuel combustion	Polynuclear aromatic hydrocarbons (PAHs)	10 chemicals (1 - 10)
Power plants (coal burning)	Methylmercury	1 chemicals (1 - 1)
All chemicals found		**287 chemicals (154 - 231)**

Source: Environmental Working Group analysis of tests of 10 umbilical cord blood samples conducted by AXYS Analytical Services (Sydney, BC) and Flett Research Ltd. (Winnipeg, MB).

The ultimate ignorance is the rejection of something you know nothing about and refuse to investigate.

~ Dr. Wayne Dyer

Appendix 14

Avoiding Autism

By Anju Usman, MD and Beth C. Hynes JD, MBA

Whether or not you are the parent of a special needs child, please pay special attention to this article, we do believe autism is totally preventable and that starts with pregnancy. Here's to your health!

Every parent's dream is to have a healthy baby. Over the past ten years of working with families devastated by the diagnosis of autism, we, along with our patients' parents, have realized one key fact: if we knew then what we know now, the diagnosis of the disease called autism could very well have been prevented. Considering that the cause(s) of the current epidemic of autism spectrum disorders (ASD) are unknown (and scant research dollars are being dedicated to finding the most likely culprits), there is no surefire method to avoid having your infant regress into this devastating state. That sad fact, however, does not mean that there are no proactive steps parents can take to try to mitigate the chances of this disease overtaking their baby and stealing their hopes and dreams for that child's life.

Having reviewed the medical and laboratory test results of thousands of children afflicted with ASD, clinicians using a biomedical approach to treating autism see repeating patterns in these children—impaired methylation and detoxification, mitochondrial dysfunction, gastrointestinal distress, and immune dysregulation compounded by chronic viral, fungal and bacterial infections and a burden of heavy metals and other toxins. From this perspective, we have come to view autism as a multifactorial medical disease that can be treated and overcome and, therefore, possibly avoided. Coming straight from the heart, this advice is for thinking, active parents and prospective parents who want to know what they can do to reduce the risk that their infant will regress into autism. In our practice, we have helped many parents go on to have healthy children even though they already have a child with autism. Considering that the information provided here is not harmful but, to the contrary, is helpful in promoting improved maternal and fetal health, there is little downside to pursuing these strategies while simultaneously minimizing the risk of having your child slip away into

the autism epidemic. According to the latest statistics out of California, that epidemic continues to grow from the already shocking 1 out of 150 children. The aim here is to provide an analytical construct that will guide parents in making choices for both their own health and that of their baby before, during, and after pregnancy.

Think of the analogy of the straw that broke the camel's back. Human beings start life as infants with some "straws" in their saddle – these are predispositions to be harmed by certain chemicals, to be susceptible to certain diseases, or to have a less robust detoxification capacity. The goal of gestating and parenting an infant in today's toxic world is to not accumulate additional straws during your baby's gestation and infancy, thereby avoiding adding the straw that breaks the camel's back. Autism seems to occur when the infant's body is so overwhelmed by toxins, viruses and/or pathogenic elements that typical development is arrested and/or derailed.

Children diagnosed with autism have a variety of medical problems, the underpinnings of which can be ameliorated and/or healed. The symptoms associated with autism occur through malfunctioning of the infant immune, gastrointestinal, and central nervous systems ("Infant Body Systems") – all of which, when functioning properly, contribute to the healthy development of the brain. Viruses, heavy metals, toxins, fungi, and bacteria together form a weapon that disrupts the development of, and harms the functioning of, these critical Infant Body Systems. As researchers have recently found, "a single toxicant may promote different immune-associated diseases that are dependent upon the specific window of early life exposure, the gender of the exposed offspring, and the genetic background of the offspring." Our construct will consist of actions you can take to promote the healthy development of these Infant Body Systems as well as steps you can take to avoid upsetting the healthy development of those systems.

Due to the symbiotic relationship between a mother and her developing fetus, care must be taken by the mom before, during, and after pregnancy (if nursing) to both avoid exposure to harmful elements and to promote optimal maternal detoxification processes so that the host body remains as clean an environment as possible within which vigorous infant development can unfold.

Only recently have researchers begun closely linking environmental factors with developmental delays in our children. A host of studies show how environmental factors including diet, nutrition, air quality, clean water, heavy metals (e.g., mercury, lead, arsenic, and aluminum), xenobiotics (e.g., chemicals, pesticides, plasticizers, and perchlorates), pharmaceuticals, and vaccinations can change your child's inborn risk.

This area of study is called epigenetics – the molecular changes in our DNA caused by environmental factors. In 2003, researchers at Duke University found that rats carrying a gene for obesity, cancer, and diabetes, when fed a diet high in B-12, folic acid, choline, and methyl-rich foods, had babies that were born healthy and with a reduced risk of developing disease; this research revealed that these genetic changes persisted across four generations. Thus, when you eat a healthy diet, you are affecting not only the health of your own kids but also your grandchildren, great-grandchildren, and great-great-grandchildren. Researchers are finding hundreds of unwanted and potentially toxic chemicals in the placenta and cord blood of newborns as well as in mothers' breast milk. That means that today's children are born with a toxic burden their infant bodies must contend with from day one. Studies out of China, Texas, and San Francisco show that if pregnant mothers can decrease their exposure to pollutants during gestation, they can improve health outcomes for their children – especially brain development. Compounds such as mercury, cadmium, nickel, trichloroethylene, and vinyl chloride in the air around the birth residence caused a 50% increase in the risk of autism.

Numerous studies document the neurotoxic effects of heavy metals – especially dangerous to the developing brain is mercury. Yet, many of our children are actually injected with the mercury-containing preservative thimerosal in their infant vaccines. Although thimerosal has been removed from, or perhaps phased out of, many childhood vaccines, it still remains in the flu vaccine, which is recommended by health authorities to pregnant woman as well as to children under age 2. Mercury exposure is such a concern that pregnant women are advised by health authorities not to eat fish because of potential mercury contamination – yet injecting thimerosal is much more damaging than the exposure suffered through eating it in food such as fish. Vaccines also contain aluminum, formaldehyde, and other toxic elements as well as live viruses that, in a subset of infant bodies, can trigger harmful impacts. Heavy metals have also been identified as factors affecting human fertility. Diagnosing and reducing the heavy metal burden of women improved the spontaneous conception chances of infertile women. Women with many dental amalgams had a higher incidence of miscarriages and a higher excretion of mercury when given the chelating agent DMPS (2,3-Dimercapto-1-propanesulfonic acid). It has been found that DMPS was a useful and complementary method to increase fertility compared to hormone therapy in infertile women.

With all this evidence mounting against various environmental toxins affecting human development, an international assembly of scientists, doctors, toxicologists, and researchers sponsored by the

World Health Organization (WHO), the European Environmental Agency, the Centers for Disease Control (CDC), and the National Institutes of Health (NIH) gathered in the Faroe Islands in May 2006. Their consensus statement was clear: "it is time to take action, now." As expected, the declaration highlighted the results of hundreds of studies that showed early fetal exposures to toxic substances, even at low concentrations, can cause health problems later in life. There are a growing number of chemicals that affect the developing embryo, fetus, and infant, including the pesticides DDT, atrazine, methoxychlor, and vinclozolin. Also suspect are plastics and the epoxy resin bisphenol A, plasticizing agents called phthalates, mercury, lead, arsenic, organotoxins, polychlorinated biphenols (PCBs), carbon monoxide, smog, tobacco smoke, and alcohol. The health problems caused by exposure to these substances comprise a dizzying array of maladies including cancer, diabetes, obesity, asthma, and allergies as well as reproductive, cardiovascular, neurological, cognitive, endocrine, psychological, immune, and respiratory troubles.

Other troubling chemicals include parabens (found in various creams and lotions) and triclosan, an antibacterial agent (found in toothpaste, soaps, and cleaning products). Although parabens and triclosan are not ingested, absorbing chemicals through the skin can be far more dangerous than swallowing because transdermal applications are transported directly to the bloodstream. Most women absorb 51 pounds of chemicals every year from their cosmetics alone! Additional exposures emanate from daily lifestyle, profession, and locale. For those elements for which we have the flexibility to make choices, we must choose wisely. After all, it is not just our health that is being affected by our choices but the health of our children and progeny as well.

Basic principles to guide you in decision making surrounding pregnancy are as follows:

1. You are what you eat (and drink); therefore, make healthy choices in what you consume.
2. Skin is the largest organ in the body, so be very careful of what you rub into yours and your baby's.
3. Think beyond "green": What is "green" for the environment is not always what is healthiest for the body, but what is healthiest for the body is always "green."

Suggestions to promote these principles are below and are cumulative, so keep following each set of suggestions as this journey into and through parenthood progresses.

Pre-Pregnancy

While planning a pregnancy, we recommend that you clean up any toxicity in your body and begin to follow a more organic, healthy lifestyle. Remember, the less toxic you are, the better for you and your future baby. Undertake a sequential detoxification program that targets the liver and colon; this type of program can take six months or more and should not be done while pregnant. In a careful manner, with an experienced dentist, remove amalgams from your teeth, which also can take six months or more. Take the time now to find organic, nontoxic makeup, hair, and body products that you like and start integrating them into your daily life. Ask your doctor to run some tests to determine any additional specific supplementation you may need to optimize levels within your body; a good place to start is your copper-zinc ratio (1:1 is the ideal ratio), thyroid function (TSH, free t3, free t4), Vitamin D 25 OH, vitamin A levels, and total cholesterol (low cholesterol is associated with preterm births).

Next, clean up your living and working environment. Remove all harmful chemical cleaning agents from your cleaning routine at home and at the office, and instead use cleaning products labeled level 1 by the EPA. Do not forget to include products for dishwashing and clothing detergent in your cleanup, and avoid toxic dry cleaning as much as possible. Finally, improve your nutrition with a targeted vitamin supplementation program to include omega-3 essential fatty acids, sublingual methyl B-12, folinic acid, vitamin D3, zinc, and antioxidants.

DO	DON'T
• Eat organic, hormone-free food • Drink organic green tea, filtered water, and antioxidant rich organic juices • Use stevia, raw organic honey, and xylitol as sweeteners • Go for walks and get some sunshine daily • Use aluminum-free natural deodorant in them • Use natural hennas to color your hair • Use cast iron, glass, or stainless steel cookware • Use chemical-free cleaning products in your home	• Consume fish or foods w/MSG or food dyes • Drink soda, carbonated beverages, or alcohol • Consume artificial sweeteners • Be exposed to lawn chemicals or second-hand smoke • Use moisturizers or makeup with chemicals or parabens • Use chemical dyes, perms, or other such hair treatments • Cook with pans that are non-stick, Teflon coated, or made from aluminum

During Pregnancy

We would suggest that you find a holistic health practice to guide you during pregnancy and delivery as there are many decisions to make during this time. In general, we suggest avoiding medications to the extent possible as well as acetaminophen because it hinders normal detoxification. Add zinc, calcium, essential fatty acids, and prenatal vitamins to your daily supplement intake. Discontinue use of nail polish and any makeup (including lipstick) products that contain parabens and other toxins. Use fluoride-free toothpaste as fluoride interferes with iodine metabolism, which is an issue implicated in mental retardation worldwide.

DO	DON'T
• Yoga and engage in stress management techniques, such as massages and listening to soothing music • Eat fermented foods, cook with organic coconut oil, use organic raw apple cider as salad dressing, and consume healthy fats, and cold pressed oil • Use natural remedies for pain, like homeopathic arnica • Drink kombucha and take probiotics • Run an air filter in your bedroom while you sleep	• Start a rigorous exercise program, sit in a sauna, or get dental work (not even cleanings) • Wait until labor arrives to discuss NOT subjecting your baby to vaccines • Talk on a cell phone without a headset or work with a laptop computer on your lap • Undertake a major home renovation (concern is for lead and other toxins in the process)

Infancy

Healthy babies grow and develop perfectly when nature's biochemical processes are allowed to unfold uninterrupted. The sequence of events that leads an infant to begin to focus, develop gross and fine motor skills, begin to speak and to walk is based on a delicate but deliberate series of biochemical processes and chemical interactions. A primary goal of raising a healthy infant is to avoid disruption or interference with this sequence. Babies look fragile and, indeed, they are. An infant's immune system, which guards the rest of the body from harm, is immature and requires time and peace to mature maximally. Thus, help your infant progress uninterrupted by avoiding the introduction of toxins, viruses, allergens, and heavy metals into their bodies. In light of this, parents should consider an alternate, gradual vaccine schedule of carefully thought through vaccines for infants being raised in the domestic United States.

If you have amalgams and plan to nurse, you should send a sample of your breast milk to a specialty lab for heavy metal testing. If you plan to use formula, use those containing DHA (docosahexanenoic acid), an essential fatty acid critical to the healthy development of the central nervous system. In terms of food introduction, organic baby food is recommended. Start feeding with organic rice cereal. Avoid the introduction of soy, gluten, or dairy until after the baby turns two years of age. After one year, supplement your baby with a quarter teaspoon of mercury-free cod liver oil – again this is to increase the supply of omega-3 essential fatty acids.

In terms of coping with baby colds and other minor illnesses, unless symptoms are severe, less is more when it comes to treatment. For fevers over 101˚F, treat with a tepid bath or dye-free ibuprofen. Fevers, while nerve-wracking for new parents, are the response of a healthy immune system reacting to kill off an invading virus through heat. Antibiotics should be used sparingly and only for confirmed bacterial infections (they do not alleviate viral infections). Remember, antibiotic use disrupts the normal gut flora and promotes the overgrowth of yeast and resistant organisms that, in turn, harms the optimal functioning of the immune system. Bear in mind that most ear infections are viral and are thus not treatable with antibiotics. Use homeopathic ear drops to help ease the symptoms associated with ear infections and colds.

DO	DON'T
• Invest in an organic baby matress, bedding and pillows and hypo allergenic encasements • Bathe your baby daily in warm filtered water — enjoy the experience with your baby! • Feed with all organic and hormone-free products • Feed baby using glass bottles • Wearing a hat, walk outside with baby to get 10 to 15 minutes of sunshine daily • Run an air filter in baby's bedroom	• Clothe the baby in pajamas soaked in flame retardant chemicals • Use soaps, moisturizers, or other "baby products" on the skin as such items are unnecessary and contain harmful chemicals • Introduce dairy, gluten, or soy until after age two • Feed baby from plastic bottles or cups or microwave formula or breast milk • Take your infant into polluted and heavily populated locations

Source: http://www.autismfile.com/what-is-autism-facts/autism-symptoms/avoiding-autism

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When a truth is not given complete freedom,
freedom is not complete.

~ Vaclav Havel

Appendix 15

RECIPES
Cooking with Ana

Since 2001 Ana Bobadilla has been a chef to Kerri Rivera and family, including her son Patrick, who has a diagnosis of regressive autism. Over the years she has mastered gluten-free/casein-free to vegan to Atkins and back again. Her dishes always impress and nourish guests and family members alike.

One of the most important pieces to the autism recovery puzzle is diet. As Kerri always says, if your goal is to heal autism, you must do *The Diet*. However, that is easier said than done for many families whose children have self-limited to grilled cheese sandwiches and pizza.

A book is in the works containing dozens of delicious recipes using natural ingredients that can be found in almost any country. Ana has found unique ways to make foods that children on the spectrum can enjoy, without breaking the bank. The ingredients that she uses can be found all over the world, not just the US. They are presented here in a very approachable way so even if you are not a whiz in the kitchen your child will be able to enjoy what you serve.

The following is a sneak peek from *Cooking with Ana*:

Almond Milk

Amount: 1 L of milk

- 1 cup of peeled almonds
- 1 L of filtered water
- Stevia and vanilla to taste

Preparation:

To a saucepot of boiling water, add the almonds. Remove immediately from the fire. Allow almonds to soak for 20 minutes, remove them from water, rinse, dry and blend in a liter of filtered water. Strain the liquid through a piece of cheesecloth until all the water is drained. Add agave syrup and vanilla to taste.

Vegetable Fries

3 Servings

Ingredients:

- 3 Carrots
- 1 cup oil
- Salt to taste

Preparation:

Peel the carrots and then form very thin slices using the same peeler. Pat dry with a piece of cloth to remove any excess water. Heat oil in a frying pan and fry carrots. When frying be very careful because they can quickly burn, be sure to have a slotted spoon ready to remove from the oil as soon as they are crisp. After frying carrots remove excess oil with a paper towel and sprinkle some salt on top of them.

You can also do this recipe with banana, potato, sweet potato or jackfruit. This is a great alternative to French fries or if you want to eat something crunchy.

Beef or Chicken Tostadas

4 Servings

Ingredients:

- 5 ground chicken breasts or beef filets
- 1 cup of rice or coconut flour
- 1 cup of oil
- Salt and pepper to taste

Preparation:

In a mixing bowl, combine the ground chicken, flour, salt, pepper and a ½ cup of oil. Mix thoroughly until a uniform dough results. Take approximately 2 tablespoons of the dough and form small tortillas/flat circles with it. They should be approximately ¼ inch think and 4 inches wide. Fry in a layer of oil until cooked through, and a thin outer crust forms, or bake in a 350 degree oven, after pouring a dollop of oil on top of each tostada.

Coconut Bars

15-18 bars

Ingredients:

- 3 cups of vegan butter (or coconut oil)
- 1 cup of honey
- 1 cup of raisins
- 1 cup of grated of coconut
- 1 cup of walnuts
- 1 tablespoon of salt

Preparation:

In a saucepan over medium heat combine honey and butter, stirring constantly for a few minutes until thoroughly combined. Remove from heat and mix with all other ingredients. Spread in a 9x13 casserole pan without oil, and bake in an 350°F (180°C) over for 25 minutes until it sets. Allow to cool, and cut into small rectangles.

Get people back into the kitchen
and combat the trend toward
processed food and fast food.

~ Andrew Weil

Appendix 16

Websites We Like

General:

- **Our website containing the latest information about our research, videos, forums, etc.**
  www.cdautism.org

- **The Spanish version of our website.**
  www.autismo2.com

- ***Curando el Autismo* is a Puerto Rican organization created by three mothers of children recovered from autism who have an interest in helping the community learn about their options.**
  www.curandoelautismo.com

- **Defeating Autism - Non-Profit Organization in Venezuela that utilizes Kerri's Protocols.**
  www.fundacionvenciendoelautismo.blogspot.mx

- **Autism Research Institute originally founded by Dr. Bernard Rimland. Home of the ATEC survey.**
  www.autism.com

- **Our public Facebook page.**
  www.facebook.com/groups/AutismCD

- ***CD Health*: Facebook group dedicated to using the protocol for non-autism related issues.**
  www.facebook.com/groups/mojoother

Diet:

- **Website forcused on the *Specific Carbohydrate Diet*™ (SCD) in English.**
  www.pecanbread.com

- **Top 10 FAQs about the *Specific Carbohydrate Diet* (SCD) in Spanish.**
  www.pecanbread.com/pandenuez/10preguntas.html

- **Autism Network for Dietary Intervention**
  www.autismndi.com

- **Gluten Free/Casein Free Diet Intervention website.**
  www.gfcfdiet.com

- **Intestinal health through diet with the Specific Carbohydrate Diet™**
  www.breakingtheviciouscycle.info

- **Resource for naturally healing digestive disease, reducing stress and living a long, healthy life.**
  www.scdlifestyle.com

- ***The Feingold® Association* is a non-profit organization helping provide dietary management and generate public awareness of the role food and synthetic additives play in behavior, learning and health problems.**
  www.feingold.org

Chlorine Dioxide (CD):

- **Jim Humble's MMS (CD) website.**
  www.jimhumble.org

- **Another popular site about MMS (CD).**
  www.mmswiki.org

- **Spanish site selling various books about MMS (CD)**
  www.voedia.com

- **Andreas Kalcker's website (in English)**
  www.andreaskalcker.com

- **CD research site by Andreas Kalcker (in Spanish)**
  www.medicasalud.com

- **A huge public health forum with thousands of discussions about every imaginable health topic. Also includes surveys about various topics.**
  www.curezone.com

- **Good sources of CD and other related supplies.**
  www.wps4sale.com
  www.mightyguts.com

- **The latest information on CDH.**
  http://www.mmsinfo.org/infosheets/infosheet_cdh.pdf

Hyperbarics:

- **Good source of information about Hyperbaric Oxygen Therapy.**
  www.hyperbaric-oxygen-info.com

Other Valuable Source of Information:

- **PubMed comprises of more than 23 million citations for biomedical literature from MEDLINE, life science journals, and online books.**
  www.ncbi.nlm.nih.gov/pubmed

- **Parents Helping Parents - P.A.N.D.A.S. Network: A Resource Library of Medical Studies and Case Histories**
  www.pandasnetwork.org

- **International OCD Foundation**
  www.ocfoundation.org/PANDAS/

Videos / Audio of Interest:

- **Video Testimonials. This link contains various health testimonials related to MMS, many are about autism.**
  www.youtube.com/mmstestimonials

- **AutismOne 2012: 38 Children Recovered in 20 months with MMS by Kerri Rivera**
  www.autismone.org/content/38-children-recovered-20-months-mms-0

- **Video about Kerri, produced by Daniel Bender in 2012.**
  www.youtube.com/watch?v=HnCiX5bII-Y

- **Kerri speaks in Bulgaria, 2013 (Voice in English, slides in Bulgarian)**
  www.youtube.com/watch?v=4OxNGIEWzds

- **Kerri on the Robert Scott Bell Show**
  http://www.youtube.com/watch?v=-1zJhr5VhxE

- **MMS Autism Webinars**
  http://www.ustream.tv/channel/mms-autism-webinar%20

- **Patrick Timpone interviews Kerri Rivera (8/15/2013)**
  http://oneradionetwork.com/health/kerri-rivera-healing-the-symptoms-known-as-autism-children-are-not-born-with-autism-so-they-should-not-die-with-it-august-15-2013/

- **Patrick Timpone interviews Kerri Rivera (11/18/2013)**
  http://oneradionetwork.com/health/kerri-rivera-encore-interview-healing-the-symptoms-known-as-autism-using-parasite-protocols-and-chlorine-dioxide-november-18-2013/

- **Bulletproof Executive Radio with Dave Asprey (11/27/2013)**
  http://www.youtube.com/watch?v=R7s7IYj2SCs

Appendix 17

Direct Help from Kerri Rivera

Consults

Since the release of the first edition of the book, we have found that when families decide to implement The Protocol some do not need further assistance beyond reading the information in this book, using our online support groups, YouTube videos, and attending conferences. However, there are some of us who need a more personalized approach and support to navigate the information, or would like ideas on dosing or timing.

For those of us who need or want that additional support, consults are perfect. We can work together to map out a plan for the parent/family and child, brainstorm through challenges, or just know that you will never walk alone. Whatever the case may be I am available if you need me. I am fluent in English and Spanish, and we can use a translator for other languages. We can speak over the phone or on Skype.

As time goes on, more and more practitioners will be able to support families while using this protocol. In the meantime, If you would like to set up a consult with me, please click on the "Consult Kerri" button on...

www.CDAutism.org

...and follow the instructions there.

Kerri Rivera's undivided attention + discussing your child + $100 = priceless. Tonight, instead of living it up in Mexico, Kerri spent her Friday evening on the phone doing a consult with me. Not only was the consult informative but also highly enjoyable. Kerri's energy is contagious, her vision boundless and her sense of humor edgy (just the way I like it). Kerri thank you for rocking our world! You are an amazing lady and my family is eternally grateful for your love of our children. Peeps, if you are new, stuck, confused or you want a better understanding of the protocol PLEASE, PLEASE, PLEASE take advantage of this opportunity. I've done a million consults over the years but this was by far my favorite.

About the Author

Kerri Rivera is a native of Chicago, but has lived the last 19 years of her life in Puerto Vallarta, Mexico with her husband. Both of her sons were born there, and 13-year-old Patrick is currently in autism recovery. Kerri is the founder of AutismO2, a non-profit autism clinic based on what is formerly known as the *Defeat Autism Now!* approach. Located in Puerto Vallarta, the clinic opened in 2006. Kerri is the clinic's biomedical consultant as well as a consultant for Curando El Autismo (Latin America), and Venciendo el Autismo (Venezuela).

At the request of Dr. Bernard Rimland, she was responsible for translating the *Defeat Autism Now!* protocol to Spanish and donating it to the Autism Research Institute, so it could be applied throughout Latin America. Since then she has helped over 3,500 families in over 58 countries to improve the lives of their children on the autism spectrum. She has become the foremost expert on the use of CD (chlorine dioxide) for spectrum disorders. Since the addition of CD to the biomedical protocol she has seen 115 children recover from autism in the past 2.5 years.

Since 2007 Kerri has lectured internationally on the Biomedical Protocol for autism and CD for autism. She has been featured on *One Radio Network* with Patrick Timpone, *The Bulletproof Executive* with Dave Asprey, *The Mother Cub Show*, *Thought for Food*, *Enlightened Health Radio* with Justin Elledge, *Voice America*, and *The Robert Scott Bell Show.* She is the Mexican Liaison for AutismOne. Kerri graduated as a Certified Homeopath in June of 2013.

Our greatest weakness lies in giving up.

The most certain way to succeed is always to try just one more time.

~ Thomas Edison

The world of autism is rocking again. Kerri Rivera has done it. In this comprehensive book she has condensed and simplified the core elements of the biomedical approach, those that work 90% of the time on 90% of the children. Her focus on using a unified and affordable approach to reduce the body burden of chronic infections and infestations is addressing the very core issue of most autistic children and adults.
It has made her method the most powerful tool to this day to help many children recover safely, inexpensively and solidly. Her research is validated by the enormously positive response from parents from all over the world.

—Dietrich Klinghardt MD, Ph.D.

EXCITING UPDATES TO THIS EDITION INCLUDE:

A new method of CD preparation • New parasite protocol charts
Lunar calendar • Many new testimonials
A section on gluten's role in molecular mimicry and autoimmunity
Information on helping older or violent / aggressive children

In the seven months since the release of the first edition of *Healing the Symptoms Known as Autism*, 22 more children have lost their autism diagnosis and returned to a state of health, for a total of 115 recovered children and counting. Hundreds more have lost ATEC points, as well as shown many cognitive, behavioral, emotional and physical gains thanks to the protocol outlined in these pages. This edition includes all protocol updates and a whole lot more information that can benefit families of children and adults on the spectrum.

In 3 years, 115 children previously diagnosed with regressive autism were able to shed their diagnosis, their symptoms and return to an overall state of health and vitality. If you have any interest in finding out how they were able to heal you need to read this book. Kerri has a heart for children with autism, and she cares greatly about recommending safe, economical interventions that are helping to confront an epidemic.

—Teri Arranga
Executive Director of AutismOne (www.autismone.org)

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How to Detect & Treat a Parasitic Infection

*"Ninety percent (**90%**) of the world population is infected with one or more parasites in their body, being able to coexist in the same host with up to five different types. The danger comes when the balance is upset, within the host, skyrocketing the number of parasites and the host starting to show signs of serious illness and even death in some cases. Parasitic infections caused by parasitic worms do not always cause disease in man, a number of carriers have been found who are fully healthy. Parasites are silent murderers claiming unsuspecting victims living in a people world that does not even imagine they exist. "*

By Dr. Andreas L. Kalcker, Ph.D & Miriam C. Maceda
English Translation: Mercy Acevedo, Proof Reading: Karl Wagner
http://educate-yourself.org/cn/detectandtreatparasites12aug12.shtml#top
August 12, 2012, E-Y posted Feb. 14, 2015

How to Detect & Treat a Parasitic Infection (Feb. 14, 2015)

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http://tinyurl.com/hl54enf

[Ken Adachi Note: Dr. Hulda Clark will eventually be acknowledged by history as one of the greatest medical sleuths of the modern era for her recognition of the pivot role which **parasites** play in all disease conditions. Her Cure for All Diseases book goes into many details about eliminating parasites, but she her 18 page published synopsis called "New Concepts" explained her latest stretegies for detecting and eliminating parasite infestation that you will find very informative and useful.

I did not realize that Andreas Kalcker had a web site until I recently watched a few videos that he and Kerri Rivera had made in 2014 at an autism conference where he made reference to his web site. Once I found it, I was delighted to find this gem on getting rid of parasites with simple home remedies. Andreas made an important speculation in one of his videos that the reason that some vaccinated children get autism and others don't, may be the degree and extent of the vaccine's complex *inter-reaction* with parasites in the child's body (as **all kids with autism are *loaded* with parasites**, that once removed, results in a kid without the symptoms of autism). **90% of the world's population has parasites** (including you) and most of us don't know it because we don't see any outward signs of the parasite's presence - except the asthma, or fatigue, or bloating, or diabetes, (or the mysterious anal itch that occurs periodically about every two weeks at full moon or new moon) etc. As you will learn below, **it's not difficult to remove parasites using the inexpensive, natural remedies recommended here**, although you may have to keep at it for 6 months to a year until all of your parasites (and their eggs) are completely removed. Re-infection can happen easily, so we have to keep up a maintenance schedule for the rest of our lives if we want to enjoy a parasite-free (and healthier) existence. You won't discover how many parasites are in *your* body until you make the effort to take the herbal remedies described and see the evidence yourself in the toilet bowl. Once that happens, you'll be on your way towards a healthier and happier you because you now know what you have to do. I took the liberty to slightly tweak the English and added some links to make it easier to find the parasite remedies online. I hope that those of you who make the effort and see the results will send me an email to report on your discoveries. See the Dr. Hulda Clark parasite examination videos embedded at the bottom of this article.]

http://andreaskalcker.com/en/health/parasite/116-parasite.html

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Parasitic infections are very common, more than you thi and they may or may not ca us serious health complications. We could suf from various types, dependi on the size of the parasite or whether they are inside or outside the body. There are *micro*parasites such as mala that are only visible under th microscope or large *macro*parasites, such as roundworms or flat intestinal worms (tapeworms) that can reach great sizes. Parasites are not only found in the intestine, as is generally though but anywhere in the body: the lungs, liver, muscle, stomach, brain, blood, skin and even in the eyes.

The great migratory movements of population, rapid transportation, and trading, have shortened the distances and diseases that used to be common localized diseases, b now turned into universal common ailments and vice versa. Parasites previously confined to very specific areas, now appear in other locations far away from their initi focus. This situation is favored by the socioeconomic conditions of the masses of people on the planet. A high percentage of the world's population suffers from infections by parasites, which are responsible for the death of **15 million children** annually.

To this situation we can add the fact that the parasites have developed multiple mechanisms of evasion and resistance to specific immunity, which allows them to circumvent and cancel the host immune response, resulting in chronic and persitent infections. The persistence of parasites in human hosts leads to chronic immune reactions that can damage tissue and cause alterations in immune regulation.

Ninety percent (90%) of the world population is infected with one or more parasites in their body, being able to coexist in the same host with up to five different typ The danger comes when the balance is upset, within the host, skyrocketing the number of parasites and the host starting to show signs of serious illness and even death some cases. Parasitic infections caused by parasitic worms do not always cause disease in man, a number of carriers have been found who are fully healthy. Parasites a silent murderers claiming unsuspecting victims living in a people world that does not even imagine they exist.

Doctors in Western Europe and the U.S. do not contemplate the possibility that we may be infected with parasites, but with modern circumstances like the immigration of people across continents, the problem has become much more common than anyone can imagine and often parasites are causing many of the rare diseas or other conditions such as chronic fatigue, fibromyalgia or arthritis that are causing so much damage lately in our communities.

The most common Vermiosis are **intestinal**. People who have them lose large quantity of nutrients, which are absorbed by the parasite, while erosions that originate in digestive tract can be the gateway to various infections. Intestinal worm infections are very common and affect many, not only people with dirty and poor hygiene habi Worms are parasites that are transmitted by **ingesting eggs** produced by the parasites themselves. These eggs hatch in the intestinal tract.

A parasitic infection can be acquired through one or more of these scenarios:

- From someone else, more or less direct contact (by faeces or sexual).
- From self-infection, for example, in the anal-hand-mouth way because the scratching of the anal area can drag the eggs.
- From congenital transmission (mother to fetus).
- From common contaminated objects .
- From from soil contaminated by human or *animal excrement* [E.g. cat litter box].
- From eating contaminated raw or undercooked meat.
- From eating raw fish.
- The traditional foods of some countries include it in their recipes. We can avoid consumption of the larvae of worms by **freezing** the meat or the fish for **twelve hours**. [Seen note 1 at end of document].
- From drinking contaminated water
- From contaminated vegetables or fruits:

  Many times we eat **poorly washed** vegetables or fruits. There is a misconception when we think that vegetables from organic farming are free from any problems, pesticides or chemicals. The danger is that the eggs or larvae of the worms reach the ground through animal waste and decomposed forms of natural compost and manure in the field. There are eggs, such as Ascaris, which can survive in soil under extreme temperatures for as long as five years. It is very important to perform a thorough cleaning of fruits and vegetables; and never eat anything raw, straight from the ground, however healthy it may seem.

- From parasitized animals:

  Infections are very easy to spread **by contact with pets**. Veterinarians can't insist enough about the quarterly worming of our animals, but there are steps we must take on our own to avoid contamination.

  De-worming your pet **at least every three months for life**, as directed by your veterinarian during the first month, should be done every week.

  Prevent pets from eating raw viscera. If animals eat raw meat or raw bones the best option is to freeze the food in advance for twelve hours. After deworming the animal, **their feces must be destroyed during the 8 days of treatment**. It can be burned and buried. If the treatment is working, the animal would be, expelling the worms throughout the faeces or vomit. **Avoid being licked in the mouth by the animal** as these are in direct contact with feces, soil and its own anus. When petting an animal, wash your hands with soap and water before eating or handling food, as the eggs of the parasites remain in the animal's hair.

- Do not walk barefoot or with open toe shoes in soil, wet soil or sand.

Symptoms of parasitic infections

The different types of worms and toxic waste produced by parasites in our organism may cause the following widespread problems:

- Chronic diarrhea or diarrhea caused by poor absorption of food
- Chronic Constipation
- Gas and bloating (Important after meals)
- Digestive problems
- Excessive bowel movements (Intestinal movement after eating)
- Abdominal pain.
- Mucus in stool
- Leaky gut
- Frequent vomiting and nausea
- Hemorrhoids
- Burning in the stomach
- Blood in stool
- Intestinal irritation
- Intestinal obstruction
- Swollen eyes
- Fever
- Pancreatitis
- Malabsorption syndrome
- FATIGUE - The toxic waste metabolic overload overworks the organs of elimination and causes central nervous system disorders like:
    1. Chronic Fatigue Syndrome
    2. Low energy
    3. Lethargy
    4. Extreme weakness
    5. Internal cold
    6. Cold in the extremities

SKIN DISORDERS & ALLERGIES:

Parasites that penetrate the skin cause **itching**. When the tissue is inflammed by these parasites, white blood cells increase the body's defense. This reaction causes skin rashes and food allergies are not far away. Parasites also create toxins and the skin, being the largest organ, tries to eliminate them therefore many skin problems are fel Symptoms include:

- Dry Skin
- Dry Hair
- Brittle hair
- Hair loss
- Allergies
- Itchy nose
- Anal itching
- Itchy skin
- Urticaria
- Jaundice
- Allergic reactions to foods
- Crawling sensation under the skin
- Eruptions
- Eczema
- Skin ulcers
- Swelling
- Sores

MOOD PROBLEMS AND ANXIETY:

Toxins that are released by the parasites can irritate the central nervous system. Anxiety and nervousness often are caused by parasites that run throughout the body. So of the problems caused are:

- Mood swings
- Anger and irritability
- Nervousness
- Depression
- Forgetfulness
- Confused thinking
- Restlessness
- Anxiety
- Slow reflexes
- Obsession
- Lack of coordination
- Disorientation

SLEEP DISORDERS:

The physical presence of the parasites are a nuisance to the body. The body reacts to them during rest periods, since during the night is when the parasites are most acti Nocturnal awakenings are common, especially between 2 and 3 am, when the liver tries to rid the body from toxins produced by parasites. This in turn produces:

~ Insomnia
~ Grinding of teeth during sleep
~ Bedwetting
~ Drooling while sleeping
~ Sleep disorders - multiple awakenings during the night

GROWTH PROBLEMS, WEIGHT AND APPETITE:

The parasites usually live without being detected by the hosts, rob the body of all essential nutrients of the food eaten. Many overweight people who are infected with parasites, go hungry for lack of essential nutrients and this forces them to eat in excess due to parasites. Furthermore, depending on the type of infestation, many people are malnourished and can not gain weight.

Some symptoms are:

- In children, poor growth, physical, age and intelectual development Obsession and compulsion to eat sweets or very specific foods
- Weight gain
- Weight loss
- Long-term obesity
- Loss of appetite or uncontrollable hunger to eat more than usual
- Inability to gain or lose weight
- Muscle and joint pain

Parasites can travel to almost all soft tissues, particularly at the joints and the muscles that cause cysts and inflammation and often get mistaken for arthritis and muscle pain. Toxins from parasites can also accumulate in the joints and muscle tissue causing:

- Muscle spasms
- Muscle pain
- Joint pain
- Muscle cramps
- Numbness of the hands or feet
- Chest Pains
- Pain in the navel
- Pain in the back, thighs or shoulders
- Arthritic pains
- Rapid heartbeat
- Fibromyalgia
- Seizures

BLOOD DISORDERS:

The parasites absorb the good vitamins from the body like iron and sugars, resulting in:

- Hypoglycemia
- Anemia

SEXUAL AND REPRODUCTIVE PROBLEMS:

A weakened immune system because of parasites and their waste can also experience:

- Male impotence
- Erectile dysfunction
- Premenstrual syndrome
- Candida - Yeast Infections
- Urinary Tract Infections
- Cysts and fibroid
- Menstrual problems
- Prostate problems
- Fluid retention

RESPIRATORY DISEASE:

The passage of larvae through the respiratory system or larval invasion on the lungs may cause symptoms such as:

- Drowsiness [sleep apnea]
- Shortness of breath or respiratory failure
- Dyspnea [shortness of breath with slight exertion]
- Acute bronchitis
- Asthma
- Pneumonia
- Irritative cough

OTHER PROBLEMS:

- Foreign body sensation in the throat or discomfort
- Difficulty swallowing
- Cough or coughing up blood
- Circulatory problems. numbness in the extremities, difficulty in moving.
- Excess of saliva
- Blurred vision
- Bad breath
- Low immune response
- Fever
- Breathing problems
- Peritonitis
- Chronic symptoms viral or bacterial
- Body odor

PARASITES IN CHILDREN:

We can speak of asymptomatic and symptomatic stages. The former are usually found in adults. Symptomatic stages occur mainly in children, in which we can usually observe: Weight loss, anorexia, growth retardation, headaches, cramping, diarrhea that alternates with periods of constipation, nervousness and irritability, nasal itching and / or anal urticaria. The **Tapeworm**, because of its size, consumes enormous amounts of food that it obtains from the child's consumed nutrients. This can affect thei normal development. Treatment is simple, but it requires that the head of the tapeworm is removed, otherwise it will continue its growth.

MEASURES IN THE HOME ENVIRONMENT TO PREVENT REINFECTION:

It is important to treat all people and pets who live in the same environment to prevent that person from infecting others. Reinfection occurs through underwear, beddin towels and household items such as children's toys or animals that have been in contact with eggs. It is important to wash parts at a temperature not below 60 ° C [140 ° F], including all clothing that has maintained contact with intimate body areas. You have to wash all bed linen and underwear daily (or to the extent possible) while performing antiparasitic therapy. Affected individuals should not share their swimwear with other members of the family and would have to use one cloth to wash his anal area and another one for the rest of the body.

- It is necessary to sleep with underwear and pants if possible to avoid involuntary scratching of the anal area at night, so the eggs will not get under the fingernails Keep pets away from the place of rest of their owners, such as beds, sofas, blankets and cushions.
- Thoroughly wash fruits and vegetables in water and soaking them in MMS or CDS solution for a few minutes.
- Clean the sink with alcohol as the eggs of many parasites are immune to the pH of the cleaning products such as soap or bleach.
- It is important to note that the parasites do not leave any kind of immunity behind, therefore, once rid of them, the person who has suffered can become reinfecte again by exposure to the eggs.

EVOLUTIONARY CICLES OF INTESTINAL PARASITES:

There are many more, but these are the three most common types of intestinal parasites that can be found in developed countries.

ASCARIS LUMBRICOIDES:

In the case of the Ascaris, these worms reproduce easily, and a single female can produce up to **200,000 eggs each day**. This parasite is very common, especially in dar conditions and when hygiene measures are not adequate. It can affect the entire opulation, but mostly children, seriously disrupting their development and growth.

[Note: Dr Hulda Clark says on page 43 of her book, The Cure for All Diseases (on page 67 of pdf), that "***..everyone with asthma tested positive for Ascaris in their lungs***" Another Hulda Clark quote from page 43: "***What if you always found every mysteriously ill person had some unsuspected parasite or pollutant?***"]

Ascaris life cycle

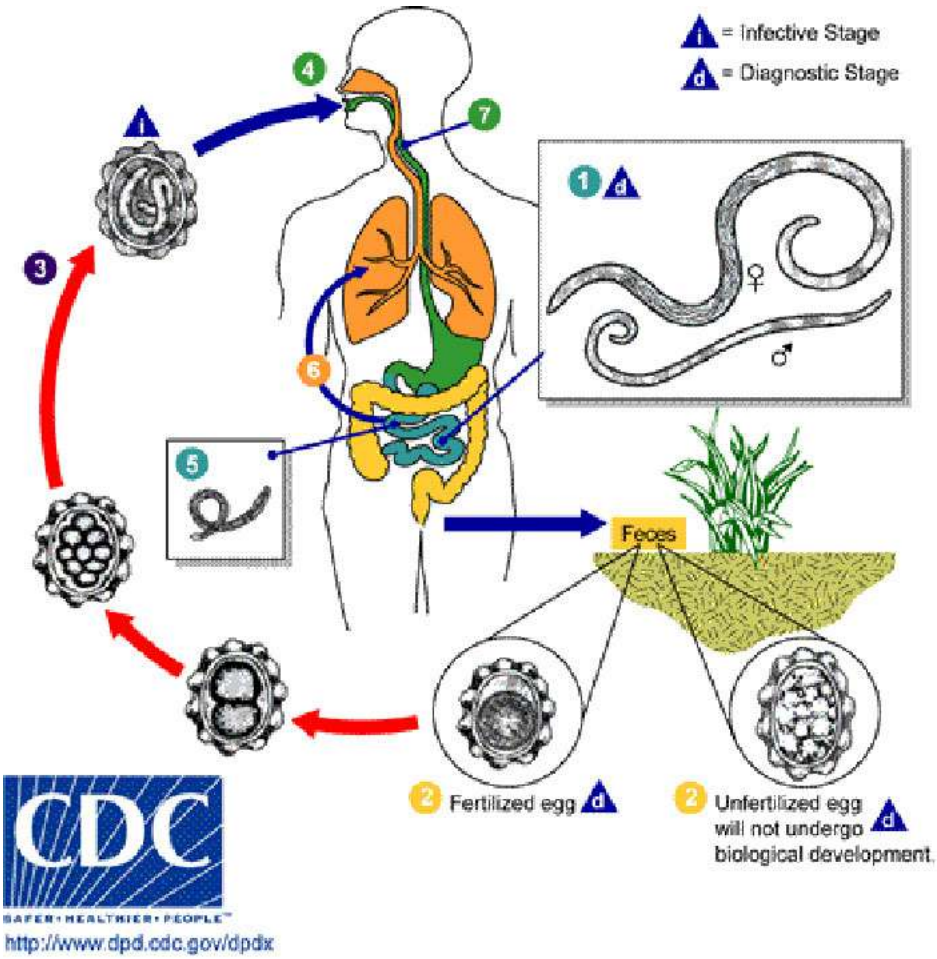

Ascaris is so infectious, the World Health Organization estimates there are about 2,000 million [**two Billion**] people infected worldwide, of which about 20% of ascaari cases end in death. The eggs of the parasites reach the duodenum through the mouth of the host. Gastric juices digest the egg envelope releasing the larvae. These larva (which have high mobility) penetrate the duodenal mucosa, going for the liver. They then continue their migration to the heart, reaching the **lungs** through the pulmona circulation, reaching the **pulmonary capillaries**, where they are trapped. There, the larvae break the capillary endothelium penetrating the **alveoli**, **bronchioles** and **bronchi** up through the pharynx. Once the epiglottis is flanked [See note 2], larvae are swallowed, returning again to the duodenum, where they complete their

maturation process. This process takes approximately **two to three months to complete**, therefore we should calculate that to find ourselves completely parasite free **tl initial treatment should be done for one year**. Then you only need to follow a routine de-worming of two to four times a year.

Ascaris intestines

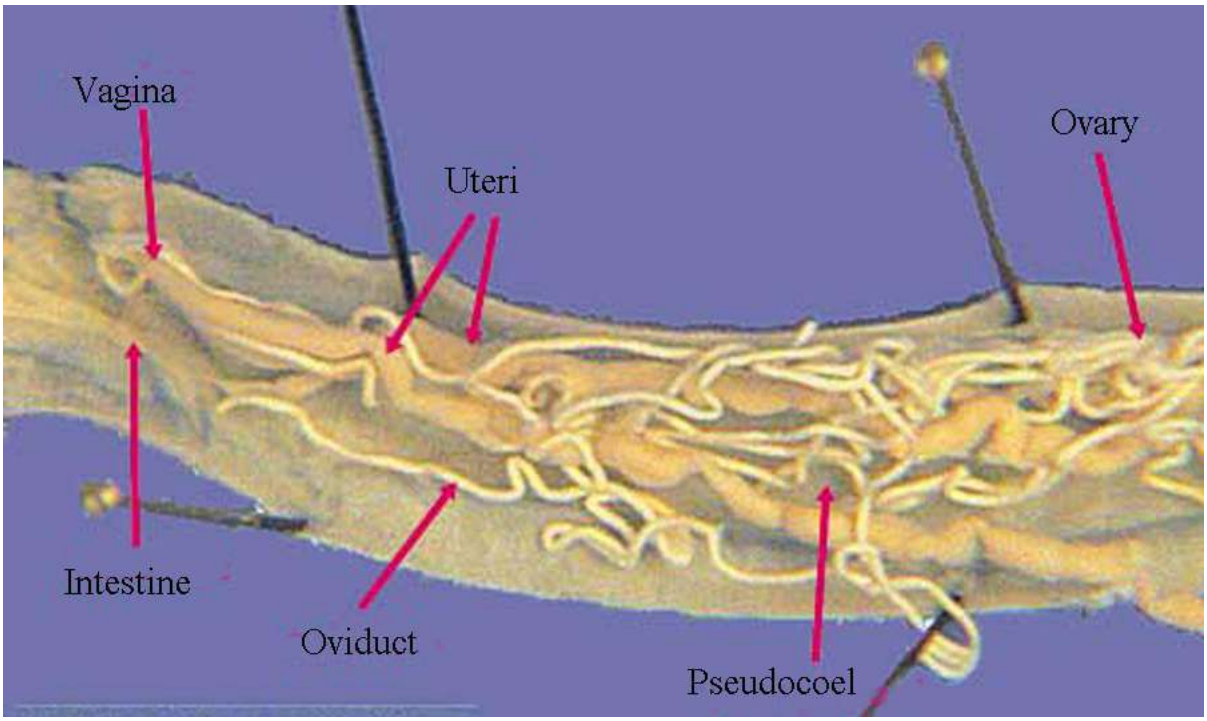

Keep in mind that eggs are expelled with the feces (human or animal) to the environment where they can survive even in harsh conditions, favoring the persistence of t parasite. They are resistant to low and high temperatures, desiccation, strong acids, soaps, chlorine and formaldehyde (pH between 2 and 11) can live in planted soils between 7 and 12 years, creating a "hotbed" and making them almost indestructible.They get **transported through dust flying** within the air currents and are **inhaled and / or swallowed**. From these environments we have recovered eggs from nasal mucus, paper money, potting soil, dust in rooms, etc.

Taenia Saginata and Taenia Solium [tapeworms]:

The taenias reach humans when humans eat their eggs through the tissue of cattle infected and pigs. The larvae encysted in the muscle tissue of the animal is swallowe and their development takes place in the human digestive system. Humans are hosts for T. saginata and T. Solium. The tapeworm is also known as *Solitary* usually no more than four specimen are found in each individual. The danger of this parasite is that the larvae can migrate to the brain or other vital organs (cysticercosis). It can b detected because as the parasite grows it is **discarding segments that can be seen in the stool**. They can usually live in their host for many years in a totally asymptomatic way detected only by the white flat strips in the stool. According to the classification they have a variable size between **2 and 12 meters in length**. It consists of a head called **scolex**, which attaches to the intestine by means of suction cups, and a body consisting of repeating units called **proglottids** it can reach up to 1,000 or 2,000 proglotids, depending on type. A tapeworm can produce an average of **720,000 eggs per day**.

Pinworms (Enterobius vermicularis):

Humans are considered the only host of what are commonly called **Pinworms** (Enterobius vermicularis). This type of worm is the most typical in the family because its easy propagation. It is common for children to re-infect over and over in schools or in their games by scratching the anus and introducing the dirty hands in their mouths. Pinworms have an elongated shape, are whitish and about 1 cm long. They inhabit the large intestine of humans. Females place eggs on the outside, around the anal opening. Once deposited, the eggs are infective for a period of up to **20 days**. Once in the intestine, it takes between **5 and 8 weeks** to develop into adult worms. The most important symptom is intense itching that occurs in the anal area, especially at night. In women inflammation of the vulvar area is very common . Unlike othe parasites, they infect only humans. Eggs are laid between the folds of the anus. Reinfection occurs when infected eggs reach the mouth via our own hands that have scratched the anus. Transmission from person-to-person happens when handling contaminated clothing, bed sheets, towels and environmental surfaces contaminated w pinworm eggs (such as curtains, carpeting) as they are extremely volatile. A small number of eggs can be integrated into the air and then inhaled and follow the same developing ingested eggs. Enemas are extremely useful in removing this parasite of the large intestine.

Graham's method is a simple method of detection. Just after waking and before stool, using **tape** to hold the remains of eggs or parasites which are situated between t anal folds. At first glance we can see small worms no more than an inch, but if we have a microscope, we can see the many transparent eggs from females and even oth species.

The importance of lifelong deworming:

Once we begin the process of deworming we should be aware that we must maintain this habit of cleaning for the rest of our lives to enjoy a good and balanced health. is common among people who have pets, to keep the processes recommended by veterinarians, deworming their pets **every three months**. It is interesting to ask why family physicians do not advise or alert individuals about the existence of this problem among humans. Maybe we have to consider the possibility that they ignore it or are unaware of the importance to eliminate these harmful pests, as harmful for animals as for people. It is true that many parasites are not endemic or common outside certain climates, but human migration and marketing of food products traveling around the world have propagated the spread of many parasitic pests silently. Each parasite has its own life cycle and involves the development of a parasite during different stages of their life since the beginning of his life until he reaches maturity, reproduces and dies.

In the case of intestinal parasites, which are treated here, they can live in the host for **up to ten years**, as in the case of a single Taenia, or the **entire lifetime** of the host reproducing again and again, as in the case of the Pinworms or the well known Ascaris.

THREE MONTHS DEWORMING PROTOCOL:

In the kind of fast society we live today, we have lost touch with the ancient wisdoms. One of the things we have forgotten is to follow the natural cycle of the moon fo many of our routines, so it is important to **begin treatment within three days of the full moon** day and continue until the waning moon. The effectiveness of this time period is greater in this cycle because much of the nematodes travel back into the intestine to mate during the full moon period. During treatment, especially at first, it i completely necessary to use **MMS enemas daily** or fairly continuous; also purging with **castor oil**, a mineral purgative such as **Epson salts** or a preparation of the plan and the leaves of **Senna** available online [also called Senn]. This treatment is specially designed for the deworming of large parasites, especially round nematodes such Ascaris. It is effective for most nematodes but may not be effective against tapeworms. In the case of infestation by Tenias the treatment recommended is **Niclosamide** [available online] , being the medication preferred for its low toxicity.

Day 1:

Pyrantel-Pamoate (single dose in the morning) 10 mg / kg, administered as a single dose together with any liquid.

- If purchased in liquid form, a 5ml teaspoon contains 250 mg (for 60 kg three 5ml teaspoons). In tablets take 3 pills for 60 Kg
- **Diatomaceous earth** [available online 10 lbs food grade Best Buy, 2 lbs food grade, 1 lb. food grade] (two doses) A dessert teaspoon (5ml) twice daily with mea preferably with liquid. Morning and afternoon.

Day 2:

- **Mebendazole** [sold online as Vermox] (two doses) **100 mg every twelve hours**. A pill in the morning and one at night. [See Note 3]
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Enema.

Day 3:

- **Castor oil** [cold pressed organic castor oil is sold online], **two tablespoons** (unflavored from the store) while fasting (See note 4).
- Mebendazole (two doses) 100 mg every twelve hours. A pill in the morning and one at night.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Enema.

Day 4:

- Mebendazole (two doses) 100 mg every twelve hours. A pill in the morning and one at night.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Enema.

Day 5:

- Pyrantel pamoate (single dose) 10 mg / kg, administered as a single dose together with any liquid. In theevent that is purchased in liquid form, a 5ml teaspoon contains 250 mg (for 60 kg three 5ml teaspoons).
- In tablets take 3 pills for 60 Kg
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Enema.

Day 6:

- Castor oil, two tablespoons (unflavored from the store) on an empty stomach.
- Mebendazole 100 mg every twelve hours. If in tablet, one in the morning and one at night.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Castor oil, two tablespoons (unflavored from the store) on an empty stomach.
- Enema.

Day 7:

- Mebendazole 100 mg every twelve hours. A pill in the morning and one at night.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon and evening.
- Enema.

Day 8:

- Mebendazole 100 mg every twelve hours. A pill in the morning and one at night.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Enema.

Day 9 to 18 (first month):

- Castor oil, two tablespoons (unflavored pharmacy) while fasting. Should be repeated depending on the needs of each person.
- Diatomaceous earth (two doses) A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- **Neem** Infusion (Azadirachta Indica) [available online as organic bulk leaves and as organic neem leaf powder] (9 days).

- Three teaspoons of Neem tea in one liter of water. Boil for 5 minutes and taken throughout the day.
- Enemas as often as possible.

Day 9 to 18 (second month):

- Castor oil, two tablespoons (unflavored pharmacy) fasting. Must be repeated again depending on the needs of each person.
- Diatomaceous earth- A dessert teaspoon twice daily with meals, preferably with liquid. morning and evening.
- Infusion of **Epazote** (Chenopodium ambrosioides) (3 days) [available online as 1 lb. bulk, 0.1 oz package, three 0.5 oz packages, 1.0 oz bottle, 1.4 oz jar, 5 lb. bulk. and seeds]
- Boil 1 or 2 tablespoons Epazote leaves per 1 liter of water for 10 minutes, let stand and strain.
- Drink 1 cup fasting for 3 days straight
- The remaining days take the **Aloe Vera gel** with juice or water while fasting
- Enemas as continuously as possible.

Day 9 to 18 (third month):

- Castor oil, two tablespoons (unflavored pharmacy) fasting. Should be repeated depending on the needs of each person.
- Diatomaceous earth-
- A dessert teaspoon twice daily with meals, preferably with liquid. Morning and afternoon.
- Infusion of Neem. for 9 days or take alternative antiparasitic infusion.
- Enemas as often as practical.

Materials required

Enema of 2 liters:

According to the British Royal Academy of Medicine, 90% of disease and discomfort is directly or indirectly related with the dirty colon. We consider the colon as the sewer of the body and toxins found there infiltrate the blood and seriously impair health. Usually in the colon of adults over 40 years old between 2 and 12 kilos of sediment can be found . In this thick unpurged garbage, large parasites move, poisoning the body of its host slowly but surely. Of the food that reaches the digestive tra parasites consume most of its good nutrients, often leaving only "bites" to the host. So while we try to eat healthy by taking vitamins, supplements and other products, do not get any better. Indeed, sometimes quite the opposite: we feed the parasites.

One of the best methods for elimination of this bulk is called "colon hydrotherapy," usually performed by a technician. Even with just using water, a 2-liter enema treatment can help cure many diseases. Used by many cultures since ancient times, it's an easy and natural way of cleaning the colon gradually. The introduced liquid helps eliminate toxins accumulated in the intestine by the death of the parasites. In the case of a mass death of worms, fever and fatigue may increase, and one may feel quite ill. To prevent toxins from reaching the blood stream, we must empty the lower digestive tract as soon as possible.

The enema is one of the essential parts of this treatment. The parasites produce a **biofilm** or **mucus** in the human intestine where they can **hide** to avoid being attacked any medicine, hence the importance of enemas with MMS. MMS is able to undo this layer, also destroying the eggs and larvae they host. It should be **performed daily from the second day** and can be **spaced every 3 or 4 days** progressively. The most important thing is to listen to your body and it will set the guidelines for your need The proper amount to use is between **12 and 20 drops of activated MMS** or its corresponding **10-15ml of** CDS water added to **2 liters of water**. You can gradually increase the dose according to body's acceptance. The most important thing is to **retain the liquid** in as long as possible (**10-12 minutes if possible**).

Detection of parasites in stool:

It is necessary to detect the worms by observing directly the stool. For that we have a plastic basin not very large in diameter and a stick for examination whenever we defecate.

Microscope:

A microscope can be very useful for diagnosis because it can see both the small parasites that may appear in the blood, as well as eggs or larvae in the feces. This way know if the number of parasites decreases.

Bulb - enema

You can use a bulb - enema with a dilution of 15 ml of mebendazole or pyrantel pamoate if you have anal itching. The best way is to introduce the medication together with about 30 ml of water and hold overnight. So the itching caused by pinworms goes away.

Medications for Deworming:

Mebendazole (sold online as Vermox source 1, Vermox source 2) is a drug used in treating diseases caused by helminths (parasites of the gastrointestinal tract). This drug prevents the parasite from using the glucose, causing a decrease in energy and the death of the parasite.

http://webstore.blue/buy-vermox-usa.html

http://allofantibiotics.org/mebendazole/

Mebendazole is absorbed to a limited extent in the gastrointestinal tract (approximately 5 to 10%). Absorption is enhanced when administered in conjunction **with fatty foods** [milk, cheese, butter, fats]. It is metabolized in the liver. Approximately 2% of the administered mebendazole is excreted in urine. The remainder is excreted in feces. The appropriate dose of mebendazole may be different for each patient. It depends on the type of parasite that causes the infection. The most frequently recommended dose is **100mg, 2 times a day for 3 days**.

The adverse effects of mebendazole are generally rare due to its poor absorption. May cause nausea, vomiting, abdominal pain and diarrhea. Normally these effects are generated by the release of toxins from the very death of the parasite itself. The drugs can be administered very effectively diluted with water in a **small bulb-enema** anally. **10 ml in warm water** is introduced into the intestine and is allowed to **act overnight**. It is especially suitable in the case of **oxiurasis**.

Pyrantel pamoate (Trilombrin):

Pyrantel pamoate can be purchased online. It is a broad spectrum **anthelmintic** which works by causing a neuromuscular block producing spastic paralysis of the paras and its subsequent expulsion by intestinal peristalsis action without producing excitation of the parasites, or encourage their migration.

Pyrantel pamoate has a short duration of action and tends to a complete elimination from the body in the feces and urine within **3 to 4 days**. Pyrantel pamoate is poorly absorbed from the gastrointestinal tract, and approximately 6 to 8% total is found in the urine and the remainder in the feces.

The recommended adult dose is **one daily dose**. Children of 12 years and older, 40 to 75 kg: 3 tablets. Adults over 75 kg: 4 tablets. **Its incompatible with the use of piperazine**, a substance naturally found in **pumpkin seeds** or the antiparasitic containing this substance in their formulation since they cancel or neutralize each other .

Plants and minerals for deworming:

The parasite problem has been and still remains a major concern in many cultures around the world. From immemorial time there have been native plants with which people that have done this type of cleaning treatments. In the West and other developed countries parasites are not being treated, making us more vulnerable. There are minerals and substances very useful in combating parasitic infections and we can make various treatments. The bentonite, vegetable charcoal, common clay or diatomaceous earth are the most important examples. In this case we will use Diatomaceous earth as an important intestinal parasitic destructive agent.

Diatomaceous Earth:

The treatment with **Diatomaceous Earth** [available online 10 lbs food grade Best Buy, 2 lbs food grade, 1 lb. food grade] should be continued for **18 days. Diatoms** a one-celled plants living in the oceans for about 300 million trillion years. They formed a little shell composed of the same water extracted silicates. When diatoms die, this microscopic coating was deposited at the bottom of the oceans. Through the ages, they piled up in banks forming deposits of thousands of meters. Over time the ocean receded and these deposits were eventually uncovered. Compressed and fossilized, the shells give rise to a chalky rock called diatomaceous earth.

Diatomaceous earth is an inert, nontoxic compound, which contains a number of minerals such as manganese, magnesium, iron, titanium, and calcium silicates among others. Properly ground, the skeletons of microscopic diatoms become sharp silica needles, harmful to parasites, fungi, yeast, worms, and amoebas. These needles are harmless to humans and other warm-blooded animals. Although it's safe to take it continuously, it's best (as with everything else) to also rest for periods of time. Take one teaspoon twice a day during the 18 days of treatment.

Castor Oil:

Castor oil [cold pressed organic castor oil is sold online] extracted from the seed of a plant like the fig tree, called *Ricinus communis* ("Higuera del diablo"). Its seeds contain between 50-80% oil, which itself has a high content of ricinoleic acid, which has excellent **laxative and purgative** properties. Once treatment begins with plan and medicines, spastic paralysis may occur in some parasites and if there are many together, they can form a "knot" of worms and cause intestinal obstruction. Thus the importance of using castor oil. You need to take it on a **empty stomach in the morning** with juice, tea or milk. The adult dosage is 15 to 30 ml (two tablespoons) fastir one hour after breakfast and medication. In the event of not having good tolerance, mineral **purgatives** such as Epson salts or **Senna leaves** available online [also calle Senn] can also be used.

Neem (Azadirachta indica):

The **Neem** tree [Neem available online as organic bulk leaves and as organic neem leaf powder] is one of the great natural patrymony of mankind and has been used as medicinal remedy for healing since ancient times. There are references in Sanskrit scriptures and Ayurveda has used it since antiquity. The healing and medicinal properties of Neem have been exploited since ancient times in Hindu medicine. Even today Hindus living in rural areas call the Neem tree "The People's Pharmacy" fo its ability to alleviate many diseases and is currently endorsed by the authorities in India for its use in medicinal preparations.
Neem is one of the purifying and detoxifying plants with the most potential. Neem has been used to combat all forms of body parasites, external parasites and internal parasites alike. Boil **four neem leaves** in **one liter** of water for 5 minutes. Take an infusion throughout the day. We will use it for **9 or 10 days** during the first month.

Epazote (Chenopoidum ambrosioides):

Epazote (Chenopodiun ambrosioides) is a plant that grows wild in South American countries [available online as 1 lb. bulk, 0.1 oz package, three 0.5 oz packages, 1.0 bottle, 1.4 oz jar, 5 lb. bulk. and seeds]. This plant has healing properties used to relieve upset stomach, gas colic, and for the expulsion of parasites and intestinal worr **Ascaridol** is the substance in epazote acting and producing a paralyzing, narcotic effect on intestinal parasites, causing it to detach from the intestine to which they wer strongly attached. Do not exceed the dosage because it may cause toxicity. Make a decoction drink by boiling 1 or 2 tablespoons of leaves [available online in bulk, in **one liter** of water for 10 minutes. Let it stand and drink 1 cup while fasting for 3 days.

OTHER MEDICINAL PLANTS:

There are other plants that we can use effective for deworming. If after three months of treatment the problem persists, we can change the type of plant or repeat any pl that was effective in previous months. We can use them in preparations, mixing several plants at once or individually. Plants are considered as alcoholic extract, in oil o infusion, including the following plants:

- Artemisia annua,
- Walnut shell,
- Calamus Root Rue,
- Artemisa Absinthium (Ajenjo),
- Southernwood Gentian (Gentiana lutea),
- Mint (Mentha sativa),
- White Fraxinela (Dictamnus albus),
- Tansy (Tanacetum vulgaris),
- Yarrow (Achilea millefolium L.),
- Dandelion Clove (Syzygium aromaticum),
- Pomegranate root bark.

PREVENTIVE FOOD AND DIET:

There are groups of foods we **should avoid eating** if we have a parasite problem such as **dairy products** in general, **refined sugars** (sucrose, fructose corn syrup), **flou** (especially refined) and **overly sweet foods** in general. On the other hand we also have a good list of foods and plants that promote good internal balance of the body hence becoming our allies. With a good production of stomach acid, a good level of healthy bacteria and proper bile production, it is impossible for parasites to survive

for long. **Worms need an acidic environment** by the breakdown of sugars and putrefaction caused by the ingestion of unhealthy or processed foods. It is very importa to **eat raw vegetables and fruit juices** that provide us with enzymes and other elements necessary to protect us.

The choucroute / sauerkraut (fermented cabbage in salt):

Many people have **low levels of stomach acid** [Type A blood especially], which is the cause of many intestinal problems, because the body is unable to defend itself against intruders. **Sauerkraut juice or cabbage / sauerkraut** is one of the most powerful stimulants for your body to produce acid. The use of unpasteurized fermente water kefir, soy sauce, or miso is highly recommended for its stimulation of beneficial bacterial flora responsible for generating the control over parasites. Take a few spoonfuls of cabbage juice before meals, or better yet, sauerkraut juice of fermented sauerkraut will do wonders to improve digestion.

Garlic:

Garlic eaten regularly turns the stomach and intestine into a lethal environment for parasites, providing constant protection. Garlic is the quintessential home remedy to eliminate intestinal parasites naturally. It has been used by different cultures such as Chinese, Greek, Roman, Indian and Babylonian. It has not become obsolete as it is still used by practitioners of modern medicine. It is used both fresh and its oil, the simplest treatment is to eat three cloves of garlic every morning or take a teaspoon of garlic oil. Can also be used by mixing crushed garlic in a little cold water and drink the mixture immediately. Another recipe is to cut in pieces and crush four cloves of garlic in milk overnight and take the liquid fasting the next day.

Pumpkin seed:

Pumpkin seeds contain a substance called **piperazine**. It acts by paralyzing the parasites, which allows you to remove the parasite easily . We can find piperazine commercially in pharmacy drug formulations or naturally, as we said, in the seeds of the pumpkin. This traditional method of deworming has been used around the wor since man can remember. There are several effective traditional formulas and this is one of them:

> Use one cup of pumpkin seeds (about 80 seeds), peeled and mashed. Mixed with water from a coconut and two tablespoons of honey. Take within a period of **three hours** on an empty stomach. Don't eat during this three hour period. At the end, take **castor oil** in order to quickly eliminate the parasites.

Papaya and papaya seeds:

Papain is a digestive enzyme contained in papaya and is capable of breaking the outer layer of an adult parasites. The milky juice of **unripe green papaya** is a powerfi agent for destroying **roundworms**.

A) The adult dose is **one tablespoon** of **fresh** juice of **green papaya**, the same amount of honey and three or four tablespoons of hot water.

B) **Two hours later**, administer a dose of **castor oil** mixed with warm milk. This treatment should be repeated for **two days** if necessary. For children aged seven to ter years of age should be administered half the dose. For children under three years, a spoonful of the mixture is sufficient.

Papaya seeds are also useful for this purpose. They are rich in papain and **caricin**. Use a mixture of **crushed fresh seeds**. For every tablespoon of seeds, one tablespoo of honey is added. The dose of a dessert spoonful daily in the morning on an **empty stomach** or before bed for **ten days**, then **rest five days**, and repeat the cycle three times [10 days on, 5 days off - repeated three times]. We recommend the use of a purgative.

[**Additional notes on eating Papaya seeds from Ken Adachi**: I've looked at a number of Youtubes videos on using Papaya seeds and they seem to be very effective, y easy to obtain and relatively inexpensive. Many talk about taking 1 tablespoon of dried crushed seeds (use coffee grinder or blender) with 1 tablespoon of honey added warm water and drink, which seems to work OK. Other say to eat the seeds **fresh**, blended with the fruit pulp to make a pudding and eat. Blending the seeds with the p will both crush the fresh seeds and make it easy to consume the seeds, which do not have a pleasant taste (pepper-like and pungent) when eaten alone. An inspiring and likable Florida woman named Tasha Lee (great videos and blogs!) with major parasite problems has a video showing her eating all the seeds of a large papaya straight, without adding honey or mixing with the pulp, but it is hot and not easy to do unless you get used to it. You will obviously kill more parasites by eating all the seeds (about 1/4 -1/3 cup worth) of a large papaya at one time, but I think it's wiser to start off with one tablespoon and work your way up to a larger amount of seeds over time.]

Ginger:

Ginger not only helps to combat intestinal parasites but also reduces nausea and can help calm nerves. Fresh ginger has shown great success in destroying intestinal worms for hundreds of years. The most common way to consume is **raw ginger** or by infusion [brewed with hot water, drunk as a tea]. Ginger extract may also be sprinkled on a variety of foods.

Propolis:

Bee Propolis has been used, for at least 3,000 years. Already known to the Egyptians and the Romans, its use continues into modern times. To the Greeks we owe the name: pro, meaning "before" and polis, meaning "city". This translates as "defenses before the city" or "defender of the city." Thanks to the antibiotic action of propolis which protects against the activity of viruses and bacteria, the bee hive is one of the most sterile places known in nature. Many scientific studies have proven the antiparasitic activity of propolis, so it is recommended for treatment of: **Giardia**, **amoebas** and **roundworms**. It's also used for intestinal infections caused by **gram-positive bacteria**.

Take propolis for the treatment of parasites for **7 days**, fasting, diluted in water or fruit juice. Propolis at 30% in Propolis tincture or capsules. Take 3 drops per kilo of weight, or 3 capsules half an hour before each meal. Follow 7-day tratment cycle with 7 days off, then repeat **3 to 5 times** to ensure complete elimination of parasites o bacteria. It is very important to repeat the treatment to cut the reproductive cycles.

By repeating the treatment at least 3 times, the effective elimination of parasites is ensured.The benefits of propolis are, that it has **no side effects**, is well tolerated, and **highly effective**.

Pomegranate Fruit:

Pomegranate bark contains an alkaloid known as **punicine**, which is highly toxic to earthworms. Used by decoction [extract with boiled water] of the bark of the root, stem or fruit. The root bark is preferable, because it contains a greater quantity of the alkaloid than the bark of the trunk. This alkaloid is highly toxic to **tapeworms**. A cold decoction of bark, preferably fresh, should be given in quantities of 90 to 180 ml three times (for adults), with intervals of one hour between cups. A purgative should be taken after the last glass. The dose for children is 20 to 60 ml. The decoction is preferably used to get rid of Solitaires [another name for tapeworms].

Carrots:

Home treatment with raw carrots to eliminate intestinal parasites in children is another effective home remedy. The chemical constituents of carrot attacks pests by preventing their development. Carrots are one of the most effective natural treatments for children. The child should be provided with a small cup of grated carrots in tl morning until the problem is fixed.

Condiments:

Seasoning plants are also a powerful weapon to keep in mind in our everyday cooking. Since time immemorial mankind has used them to control parasitic diseases. Mc interesting because of their effects are:

- turmeric,
- pepper,
- tarragon,
- thyme,
- cinnamon,
- paprika,
- cayenne and
- cloves.

Annex to the Protocol:

It's difficult to detect a parasite or worm in the toilet bowl because once they are dead, they look like intestinal mucus because they are half digested by our body. But tl differ from intestinal mucus which dissolves in water. Try with a stick and bowl, and if it doesn't dissolve (See photos), it's a parasite (Ascaris).

Version and Revisions:
First release – Version 1.0, Revision 1.0 - August 2, 2012.
#
Minor corrections – Version 1.0, Revision 1.01 – August 2, 2012.
#
Added Annex to the protocol – Version 1.1, Revision 1.0 – August 3, 2012.
#
Minor text/notes corrections sent in by Michael Harrah - Version 1.1, Revision 1.01 – August 12, 2012.
#
Added note 4 - Version 1.1, Revision 1.02 – August 12, 2012.

Notes:

[1] From FDA site: Freezing and storing at -4°F (-20°C) or below for 7 days (total time), or freezing at -31°F (-35°C) or below until solid and storing at -31°F (-35°C) below for 15 hours, or freezing at -31°F (-35°C) or below until solid and storing at -4°F (-20°C) or below for 24 hours is sufficient to kill parasites. FDA's Food Code recommends these freezing conditions to retailers who provide fish intended for raw consumption.

Note: these conditions may not be suitable for freezing particularly large fish (e.g. thicker than six inches)

http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/Seafood/FishandFisheriesProductsHazardsandControlsGuide/ucm091704.

[2] http://www.embryo.chronolab.com/tongue.htm

[3] Mebendazole dosage varies from 100 mg 2x/day to 500 mg 3x/day depending on which parasite(s) are being targeted.

See: http://allofantibiotics.org/mebendazole/

[4] Definition of Fasting
Fasting: : going without food or drink. Patients may be advised to fast for a certain period of time prior to surgery, medical procedures, or certain blood tests.
http://www.medterms.com/script/main/art.asp?articlekey=97585

If you want you can make a translation of this article into another language.

Dr. Andreas Kalcker at AutismOne 2014 - Successful Treatment of Autism
https://www.youtube.com/watch?v=rj5XjATNHuw#t=1281

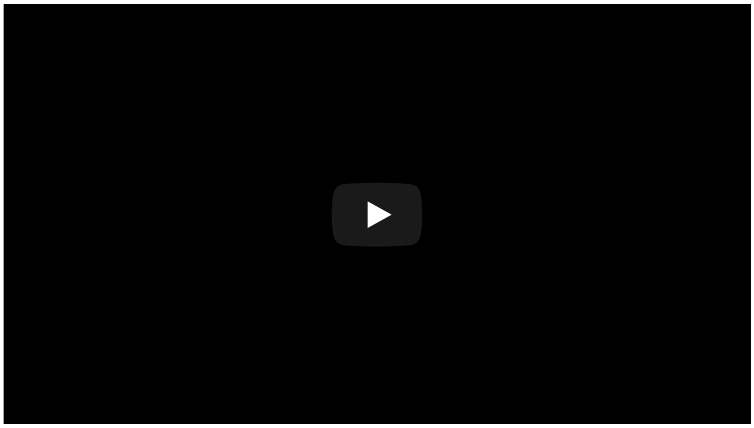

Published on Jun 11, 2014
Successful Treatment of Autism
Presentation by Dr. Andreas Kalcker at AutismOne Conference on May 24, 2014. Dr. Kalcker speaks about how the combination of parasites and vaccines is contributi to the autism epidemic of today. Kalcker explains how he discovered this link and the positive results of treating parasites in autistic children around the world.

HEAL YOURSELF
THE NATURAL WAY

Overcome Diseases
& Create Superior Health

WALTER LAST

Also by Walter Last

Heal Yourself
Healing Foods
The Self Help Cancer Cure Book
The Heal Yourself Series of Self Help books

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Disclaimer

The aim of this book is to provide information on using natural healing methods to improve health and overcome illness. The author or publisher cannot accept any legal responsibility for any problem arising from experimenting with these methods. For any serious disease, or if you are unsure about a particular course of action, seek the help of a competent health professional.

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INTRODUCTION

This book is for those who are searching for a way to live a healthy and fulfilled life. I have no doubt that we can do this, live a healthy and fulfilled life, regardless of age, and that this is actually our natural birthright. We just need to avoid or remove the artificial living conditions that prevent us from being as we really are. A modern problem for genuine health and spiritual seekers is the great flood of advice available in these areas. Much of it is contradictory or, alternatively, there are so many different methods to choose from that it seems almost hopeless to find the right one.

I have sifted through much of this information and experimented with many different healing methods in my 30 years as a natural therapist, with the aim of finding out what works for whom and in which conditions. Even more important for me was my spiritual quest. Here I share the fruits of my experience as a lifelong health and spiritual seeker.

While this book does not go into great detail about the treatment of specific diseases, by using the outlined methods and following the provided guidelines to rebuild your health, you are likely to improve anyway, whatever the name of the disease. Rather than fighting your disease, I recommend you focus all your resources on improving your health. Your disease may then disappear on its own.

To show how simple, natural methods can be very effective in overcoming medically incurable diseases, I mention an example from The Food and Health of Western Man, by Dr. J. L. Mount. In five cases of bowel cancer, surgery revealed that the cancer had already metastasized all over the body. Therefore, these patients were just closed up again and sent home to die. But instead of doing that, these five people, independently of each other, became keen gardeners and from then on ate only home grown, organically raised food. When they finally did die, 21 to 30 years later, no traces of cancer could be found in post mortem examinations.

Such cures without medical intervention are regarded as “spontaneous remissions.” It should be comforting for those with advanced cancer and other “incurable” diseases to know that spontaneous remissions can be induced with such simple natural methods. However, while not mentioned in Dr. Mount’s book, I suspect that there was another important factor at work: These five had made peace with themselves and the world.

Similarly, you may use this book to improve your health or to lead a more happy and fulfilled life, more at peace with yourself and the world. Ideally, it is meant to provide guidance to heal not only your body, but also your emotions and mind as part of your spiritual growth. By following this path and the 65 steps I present, you will need less and less to rely on this book or any other “expert” advice. Instead you will realize that all the answers for your healing and spiritual growth are within you. You just need to ask and learn to listen. In order for you, the reader, to gain a better understanding of the purpose of this book and the principles on which it is based, I will share with you my basic philosophy on health and spirituality.

My most basic assumption of existence is that it has purpose. I came to this conclusion gradually through observing, experiencing, and thinking. Countless people share this view, but for most it is just a belief, commonly adopted from parents

and society. In order to make it a knowing, our beliefs have to be consciously evaluated and tested.

On the other side of the fence is the orthodoxy of the scientific community and its followers who assume that existence evolved according to inherent physical laws and does not have a purpose. This, too, is just an untested belief. In line with this belief about the nature of our existence, we regard our health problems and other problems in our life as accidental, coincidental, or just due to biological considerations and without a deeper meaning or purpose in our life.

I believe that our health and social problems are part of the purpose of our existence. Therefore, in order to overcome any health problems and be able to lead a healthy, happy, and fulfilled life, we need to have a basic understanding of the purpose of our life.

It has been my healing experience, especially in serious conditions such as cancer, that with apparently the same amount of effort and dedication some people get well while others do not. I believe that success or failure in healing depends only partly on doing the right thing on the biological level and to a larger degree on our emotional, mental, and spiritual constitution. This applies even more to the degree of happiness, fulfilment, and joy we have in our lives.

Therefore, after starting out as a biochemist and nutritionist, I gradually moved towards a holistic perspective, which increasingly included the spiritual dimension. I came to the conclusion that important events in our lives, and especially life or death decisions, are never “accidental.” Not only do they follow the laws of cause and effect, but also the dictates of our higher guidance as to whether this body is still useful for the purpose for which it was created and inhabited.

Here are two examples to illustrate this point. One of my early lung cancer patients recovered well with only biological therapies. Soon afterwards he had surgery for an unrelated problem. The tumour had disappeared but he died from the surgery. Another patient was in a wheelchair with permanent unbearable pain after a spinal accident. We found a way to stop the pain. So he went out drinking with a mate to celebrate and smashed his chin in a fall. This landed him back in the hospital with constant pain.

These and similar cases are not scientific proof of anything, but for someone looking for an answer they are signposts to show the way. Also consider an experience related by the American psychic Edgar Cayce. He routinely saw auras around people. Once he entered a department store elevator but immediately backed out again because he sensed that something was very wrong. Soon after, the elevator crashed and all in it were killed.

Cayce realized what was wrong. None of the occupants had an aura. (An aura is an energy field around a living body that can be seen by some individuals as a nebulous outline.) For those who know that auras exist, this can mean only one thing: It was no accident that these people died together. The guiding consciousness of every single occupant had decided beforehand to dispose of the body in this seemingly accidental way. In an odd sense, they were already dead. I am convinced that if Edgar Cayce had remained in the lift, he would have been the only miraculous survivor and without any serious injury.

If you can follow me to this conclusion, you may ask: How can we find the purpose of our lives and live accordingly? That is what spirituality is all about. We need spirituality, not only to overcome serious diseases, but also to lead a healthy and genuinely happy and fulfilled life. But what is spirituality? Different people have different ideas about it. I can only tell you my version. This may change somewhat over time, as my understanding is still growing.

In addition to an individual, more narrowly defined purpose, we all have the same general and overall purpose to become more complete or perfect as human beings. Normally, this is a very slow evolution for the whole human race. However, if we do this consciously, then our snail-pace evolution becomes a personal revolution and we call it “the spiritual path.”

As I see it, our higher guidance tries to lead us towards or along this spiritual path. There are two possibilities. We may be led gently if we ask and listen for this guidance as with prayer and meditation or just with our general attitude and conduct. The alternative is more common and painful. If we stray too far from the desired direction, we may run into a brick wall that forces us to change course. We may encounter a disease or calamity in our social or professional life that causes us to re-evaluate our life. Many former cancer sufferers have said that cancer was the best thing that ever happened to them because it helped them to end a spiritually meaningless life and start a new, meaningful, and more fulfilling spiritual life.

There are different levels of our existence, as for instance the biological, emotional, and mental levels. Following the spiritual path means that we consciously work on improving ourselves on all of these levels. This is the focus of the 65 steps in this book. On the biological level, this means that we cleanse the body of lifelong deposits of metabolic wastes and -toxins. We also improve our living conditions by minimizing harmful factors and maximizing beneficial factors. On the emotional level we do the same: We cleanse our emotional body of blocked and negative emotions and cultivate uplifting feelings and emotions. It is similar on the mental level: We cleanse ourselves of negative thoughts and belief systems and learn to generate positive and beneficial thoughts and beliefs.

After achieving a certain level of control over our body, emotions, and mind, we are able to move along on the spiritual path. As a reward, our body will most likely be much healthier; we will generally be content, happy, and increasingly joyful; and we may even achieve a state of mental illumination with a flood of intuitive insights. By this time also our individual purpose for being in this body will have become clearer and we may act accordingly.

The overall theme of this book is health and harmony - learning to live in harmony with our biological, social, and spiritual nature. This book will give you the tools to achieve this worthwhile goal. Do not be concerned that it seems far away. The most interesting part of life is the journey, so enjoy it, make it fulfilling and meaningful. It does not matter how fast you master the steps; it is more important that you enjoy doing them and in the process get to know your body and your mind and become friends with both. Learn to love yourself, and you will find it easier to love everyone else as well. If in doubt about any particular course of action, choose what on reflection appears to be more natural or will lead to greater harmony or balance.

In this book you will find a wide range of natural health improvement and healing methods with easy-to-follow, do-it-yourself instructions. I suggest that you experiment with as many of these as you can in this venture. On the biological level, these are intestinal sanitation, allergy testing, and cleansing. Some idealistic individuals may embrace these measures enthusiastically, while others will try a little here and there but generally wait until poor health launches them more determinedly into a program of health improvement. That is quite all right. Just keep this book handy until you are ready. For those who want to start right now, however, here is the "prescription."

The main purpose of this book is to serve as a practical instruction manual for creating and maintaining good health. To get a basic overview and understanding of the underlying principles of natural living and holistic healing, I recommend that you start by reading the book in a selective way. Read more carefully those steps that provide a basic understanding of healthy living, nutrition, emotions, and beliefs, but skim over the details of specific exercises and procedures, or diseases in which you are not currently interested.

Then start working through the steps in a practical way. I regard all of the practical steps in Part 1 as essential for establishing a solid base for improving and maintaining health. Try to do them as thoroughly as possible. The steps in Part 2 are designed to help you identify and overcome specific health problems. Therefore, you may use these steps in a selective way; concentrate on those that you expect to be most suitable with your current problems. It is similar with Part 3. Use this information to select suitable supplements and remedies.

Part 4 is another fundamental chapter. Adopting a natural diet - fresh, raw, and organic - may be the most difficult, but also the most rewarding part of the whole program. Do it gradually. Part 5 provides a deeper understanding of nutrition and helps you to fine-tune your diet for your individual requirements. In Part 6 you need only study the information that is relevant to a current health problem.

The practical steps in Part 7 help you feel and direct your inner or life-force energies. This is a key requirement for improving health beyond what is possible with a healthy lifestyle. Continue practicing in this area for the rest of your life. In Parts 8 and 9, select and experiment with the methods that most appeal to you for healing your emotions and adopting an appropriate belief system. Part 10 helps you understand and reapply your health improvement efforts as part of your spiritual path. Do this review when you feel ready for it.

Finally, use this book as a reference manual whenever you encounter a specific health problem. In Part 6, look for specific diets, remedies, and treatment modalities, and in addition use suitable therapies described in Part 2 and other parts.

Here is a vision I have of our near future. I see health clubs and healing groups springing up all over the world, like mushrooms after a warm rain. Many people come forward, willing to accept self-responsibility for their health and eager to learn. Friends meet regularly, testing each other, experimenting with new healing methods, discussing results, exchanging recipes, sharing books, exercising and meditating together, and studying spiritual philosophy for healing.

Many become healers in their community, guided initially in workshops by experienced healers. City groups rent suitable buildings to establish healing and meditation centres. Communal farms produce organic food and are used as healing and spiritual retreat centres, where visitors can share the healthy life, learn to heal themselves, and find guidance on the spiritual path.

I see the physical and spiritual rejuvenation of nations starting at the grassroots level in a worldwide movement for social and environmental responsibility. All you rejected and disillusioned individuals unite, to make the world a better place for everyone!

* * * * * * * * * * *

Part 1
HEALING THE BODY

Initially, most health seekers are mainly concerned with overcoming a specific health problem, using the specific method or remedy promising the quickest result. However, in the long run and as we get older, more health problems or diseases pop up and become increasingly difficult or impossible to overcome just by using a "magic bullet." This then makes the idea of serious lifestyle changes towards natural living and holistic healing more attractive, giving us a much better chance to become and remain healthy and fit into old age.

I have no doubt that it is our natural birthright to be healthy and that it is unnatural to have a disease. A disease means that we (or possibly our parents) did not live according to our biological, social, or spiritual nature. At present most of humanity lives in unnatural conditions surrounded by a minefield of technological and chemical health hazards. Even worse is our ignorance about the nature of these hazards that are mainly hidden from our awareness.

Therefore, in order to live more naturally we need to become aware of the main health hazards in our environment and learn to avoid them or minimize their effect on us. We can learn from our own experiences and from those of others and we can also develop our intuition or ask for guidance through prayer and meditation. If in doubt about a choice, try to imagine which course of action is more natural or more in harmony with your biological, social, and spiritual nature.

The main biological influences on our health are nutrition, exercise or how we use our body, and environmental factors. In addition to improving these conditions, there are numerous natural healing methods to help us in our quest for good health. These include herbs and other natural remedies, working on muscle and bone structure, and using electrical, magnetic, and vibrational medicines and approaches.

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Step 1

THE ROAD TOWARDS DISEASE

Become aware of the factors causing your illnesses.

People in Western society are rarely healthy. Real health - the perfect functioning of all parts of body and mind - is so rare that people mistake the temporary absence of disease symptoms for health. Formerly, people suffered mainly from violent but short-lived infectious diseases; now many are afflicted with chronic degenerative diseases for a lifetime.

The main factors causing widespread health degeneration are as follows:

1. Unnatural nutrition: food refining; lack of “living food” and of vitamins, minerals, and enzymes; GM food, junk food, incorrect food combining, unsuitable diet for metabolic type.
2. Chemicalisation: pesticides, herbicides, fertilizers, medical drugs, food additives, water and air pollution, plastics, and even contact with synthetic garments.
3. No exercise: lack of sufficient physical activity or exercise in natural, unpolluted surroundings.
4. Harmful negative feelings and emotions: resentment, fear, discontent, greed, envy, and lack of positive feelings and emotions, such as gratitude, devotion, contentment, joy, unselfish love.
5. Harmful mental attitudes: lack of spiritual or humanistic goals, lack of faith.
6. Emotional damage: sustained during birth, childhood, or adolescence; lack of positive role models.
7. Inherited genetic problems: genetic makeup of poor and deteriorating quality.

The general sequence leading to the development of poor health and chronic diseases commonly is as follows: Emotional injuries received during birth and childhood, as well as negative attitudes and emotions experienced during later life, cause muscle tension which block the free flow of bioenergy within the body and especially within the acupuncture meridians. This weakens the blood circulation and the glandular system, as well as the functions of affected organs. Inherited metabolic weakness and poor nutrition as well as chemical pollution combine to cause an inefficient use of biochemical building blocks and poor cellular energy production. Disease is the result.

Metabolic Residues: As a result of this metabolic weakness and the overuse of unsuitable food, toxics and metabolic residues accumulate in the body. Toxics (toxic waste products from our chemicalised food) accumulate mainly in the fat tissue. Metabolic residues consist of protein debris, mucus, fatty sludge, and organic acids. Here are some further complications:

- **Protein Debris:** This accumulates when we eat more protein than we metabolize. Small protein fragments clog up capillaries and lymph channels through which nutrients move into cells and waste is removed. Current research

shows that virtually all chronic diseases are strongly associated with protein debris accumulating within cells.

- **Mucus:** This originates from lactose (milk sugar) in dairy products, gluten (in wheat products), refined carbohydrates, fat, moulds, and food allergens. Mucus has a special affinity to mucous membranes, causing catarrh, ear and sinus problems, respiratory diseases, and malabsorption of food.
- **Fatty Sludge:** Mainly formed from oxidized (rancid) fats and oils, fatty sludge leads to poor circulation and heart problems by clogging the blood vessels and congesting the lymph system.
- **Organic Acids:** General overacidity contributes to the accumulation of organic acids in the tissues and induces inflammations and mineral deficiencies. Overacidity results from insufficient cellular oxidation and from the formation of lactic acid after eating sweet foods or foods to which we are sensitive or allergic.

Infections: Wastes accumulate wherever the blood circulation slows down, whether because of emotional blocks leading to permanently contracted muscles (called muscle armouring), injuries, or insufficient use of muscles. Up to 30 percent of the volume of cells in elderly people may be filled with waste material, usually in the form of old-age pigments (oxidized fats and proteins). This is comparable to 30 percent of a city or a household being filled with refuse dumps. Just as dumps become infested with rodents and insects, the waste accumulations in the body provide favourable breeding grounds for microbes and parasites.

Infections are healing efforts of the body designed to destroy any foreign invaders and reduce the heavy load of toxic and obstructive residues (mucus) accumulated in the body. The use of prescription or over-the-counter drugs in fighting these infections prevents this cleansing action and reduces our vitality still further; the body's immune system - its ability to defend itself against foreign invaders - is also damaged.

If the body is still reasonably strong, it fights these invaders and simultaneously reduces the load of stored wastes. This is experienced as an acute (sudden and severe) infection, often in the form of a cold or fever. However, as the body becomes weaker and the amount of stored wastes increases, the body does not fight back anymore. It can then only limit the invasion to a certain part of the body, and chronic (low-key but long-lasting) infection results.

Finally, the immune system becomes too weak to limit the chronic infiltration of toxic substances and its distress becomes more generalized as autoimmune diseases, cancer, and leukaemia. However, it should be understood that this invasion or infiltration does not necessarily occur from the outside. Especially in the case of cancer, it is more an "uprising of germs from within" created by the disintegration of diseased body cells. It is similar to a revolution spreading through a country with dissatisfied inhabitants.

The German cancer researcher P. G. Seeger, M.D., D.S.c., demonstrated in thousands of experiments that the virulence of cancer cells depends on the nutritional status of the host. Another interesting study found that viruses breeding in hosts that are deficient in protective nutrients, such as selenium or vitamin E, tend to mutate and change from benign into very virulent and lethal forms. With sufficient levels of these nutrients, someone may be immune to the benign form of the virus but

not to the mutated form that is produced within a deficient host. For example, most of the influenza epidemics with new virulent strains that periodically sweep the world originate in selenium-deficient parts of China[1]. Furthermore; the African HIV epidemic appears to have emerged in northern Zaire where many people are selenium deficient. The lesson from this is that poor nutrition breeds deadly viruses.

Food Addictions and Allergies: Health deterioration, closely linked to the weakening of the immune system, also takes place with the development of addictions and allergies. These are extremely widespread in our society. Conventionally, an allergy is seen as an immunological reaction against a foreign protein. However, in most instances, and especially in the early stages, food allergies may be better described as food sensitivities. This means that the body is sensitive to a particular food and when confronted with it, enters a state of stress. The glandular system is induced to pour adrenal hormones into the bloodstream and dopamine into the brain, and this may be felt as an uplifting stimulation. Eventually, the body begins to crave this stimulation and this leads to an addiction to that particular food. In our society, these food cravings develop mainly for sweet and fried foods, bread, dairy products, and red meats, but also for other foods that we frequently eat.

After many years of exposure to an addictive food, the glandular system is markedly weakened and stronger stimulants are required. You then become addicted and sensitive or allergic to alcohol, coffee, tea, tobacco, or various drugs. Eventually, even these will not achieve the desired effect or only for ever-shorter periods.

The body then becomes chronically fatigued and disease symptoms begin to surface more forcefully. Some symptoms can be linked directly to incompletely digested foods that are absorbed through a weak intestinal wall and now cause strong immunological reactions; these symptoms are the result of a food allergy. Disease symptoms develop selectively in parts of the body with hereditary defects or in those weakened by misuse or injured by accidents.

Problem Foods: Almost any food, if used to excess by susceptible people, can cause allergies. However, certain foods, such as rice and vegetables, rarely cause allergies, while others carry a high risk of causing them. These high-risk items are called “problem foods” because, in addition to allergies, they frequently cause health problems in people who are not susceptible to allergies.

People who are prone to food allergies generally have hypoglycaemia (low blood sugar) or diabetes, low blood pressure, a weak immune system, or a lack of digestive enzymes. People who have alkaline blood chemistry, as opposed to acidic, rarely have allergies. (For an explanation of the acid-alkaline balance, see Step 6.) Instead, they are insensitive to pain and skin irritants and may suffer from chronic degenerative diseases or become victims of an unexpected heart attack or stroke. However, the same problem foods are major contributing factors in the development of disease of both groups.

The main problem foods are as follows:

1. Cow’s milk and its products; also lactose or milk sugar added to processed foods.
2. Wheat and to a lesser extent the other gluten grains oats, rye and barley (e.g.in beer).

3. Sweet foods, especially sugar, fructose used as sweetener, and synthetic sweeteners.

4. Hydrogenated fats (for example, margarine) or heated oils and fats.

5. Overuse of alcohol, coffee, tea, tobacco, drugs, and other stimulants.

These five groups should generally be used sparingly. Foods that are incompatible with our blood-type group often cause problems. In addition, any food that contains pesticide residues or added synthetic food chemicals is a potential health hazard. I do not believe in a “safe” limit for these chemicals, especially as limits are set for each item individually while ignoring the cumulative effect of multiple chemical residues and additions.

Social and Economic Factors: With the present poor eating habits deeply ingrained in our society and the all-out chemicalisation of our lives, it is almost impossible to remain reasonably healthy - and very few people do. Almost everyone has obvious or hidden health problems. From attending to children, parents, and grandparents of the same family, I have seen how the level of health deteriorates in successive generations.

This trend is also clear from statistics and general observations for anyone who wants to see it. Statistics showing increased life expectancy due to greatly reduced infant mortality are irrelevant for judging the health of a population. These figures simply mean that more babies survive the early childhood infections, that we have better plumbing, and that more elderly people are kept artificially alive by organ transplants or life-support machines.

But this is not health. More relevant statistics show that most people in Western countries suffer from chronic diseases and that the percentage of chronically disabled people is increasing rapidly. Arthritis, cancer, and Parkinson’s disease used to be diseases of old people. Now they are affecting children and juveniles. Health authorities so far have ignored the claims of natural medicine that it is the superior form of treatment for chronic and medically incurable diseases. The very fact of a high rate of chronic disease in our society attests to the inability of the conventional medical profession to successfully treat these diseases.

This is highlighted by the embarrassing phenomenon of the falling death rate during doctors’ strikes. Statistics show that with a strike by doctors, the death rate in the affected population fell dramatically. In 1976 during a doctors’ strike in Bogota, Colombia, the death rate fell by 35 percent. In Los Angeles County, California, it fell by 18 percent during a strike in the same year, while in Israel it fell by 50 percent during a strike in 1973. Only once before had there been a similar drop in the death rate in Israel and that was during another doctors’ strike 20 years earlier. After each strike, the death rate jumped again to its normal level.

During these strikes, emergency care was provided. This means the patients who lived longer during the strikes were those with chronic diseases. They obviously benefited from a reduced exposure to medical drugs, operations, and other technological interventions. There is an abundance of statistics, estimates, and case reports of the great number of patients who are in the hospital or worse because of disease caused by medical drugs and medical technology.

Selfish Motivation: Our medical and economic leaders do not want to face reality. They brainwash the public into believing that the present health situation is completely normal. Most importantly, the economic structure of Western civilization is largely based on the production and distribution of goods and services that are contributing to poor health. These include chemicalised agriculture and food processing, the pharmaceutical industry, technological medicine, and the petrochemical and plastics industries.

The guiding motto for industry is profit, while for the consumer it is convenience. The price we all pay is the loss of our health. This situation is the natural outcome of a society based on selfish motivation. A change for the better can come only when more and more people realize that ultimately they harm themselves with selfish attitudes. Recognizing this is a first step towards improving your health.

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Step 2

THE ROAD TOWARDS HEALTH

Learn the principles of natural living to restore your health.

The first and most important step in reversing the deterioration of your health is to realize that you may have caused it yourself. Due to ignorance and habit, we select the wrong foods; out of laziness, we do not exercise; from lack of self-control, we create destructive emotions. Therefore, only the realization that poor health is the result of a lifetime of wrong living, which includes the living habits of our parents, can initiate a real change in us for the better.

This understood, the next step is to find guidance on your road towards health. There is so much contradictory advice available today that it is confusing for the aspiring health seeker. Worldwide, medicine is in a state of chaos. The sterile monopoly of the conventional medical establishment is beginning to break down and multitudes of different healers are rapidly filling the gap. Find out by reading, listening, meditating, and experimenting which healing system is most appropriate for your needs. Then start a determined healing program using careful self-observation to monitor your progress.

Measuring Health: It can be seen from the above discussion that disease is not something that happens suddenly, that one day you are healthy and the next day you are sick because cancer has been detected. Instead, your state of health has greatly deteriorated over many decades to only a fraction of what it might be in true health. Even suddenly appearing infections are possible only because of a gradual deterioration of your immune system.

Health should be measured as vitality, as the body's ability to regenerate itself. An indication of the inherent vitality of the body is given by the speed of wound healing or bone mending and possibly hair and nail growth; in a more scientific way, we could measure it by the electric potential of body cells.

According to this yardstick, hardly anyone alive today is likely to be more than 90 percent healthy, while most people of "normal" health live at below 50 percent of their personally attainable health potential. When a chronic degenerative disease becomes manifest, the health potential drops to below 10 percent of optimal, and at death, of course, it is zero.

It is meaningless to be elated about the success of conventional medicine in greatly reducing the number of people contracting certain infectious diseases. It is the overall number of unhealthy people that counts. If one disease is eliminated, unhealthy people will contract a different one. What is needed is a general health improvement that will effectively reduce the total number of people becoming sick and ultimately hinder the development of any disease.

Eventually, with better genetic stock and improved living conditions, we should be able to live an active and enjoyable life until the age of about 120 years and then

quietly withdraw from the body. This is the presently unknown “natural death.” My reason for taking this position is the fact that some individuals have managed to reach an age of between 110 and 120 years without even trying, just due to their genetics. I interpret this as meaning that we all can reach this age if our gene pool is sufficiently improved. I believe that we will be able to surpass this limit if, in addition, we also consciously adopt a healthy lifestyle. However, for me it is irrelevant how long I “live,” because I know that I live equally well without a biological body. The important part for me is how well I live and not how long.

In regard to the postulated natural death, I know personally of some individuals who were active until a ripe old age and then just died in their sleep, sometimes even saying goodbye to their relatives beforehand. For most of us who have serious inherited weaknesses and have misused our body for many decades, this may not be possible to achieve. Nevertheless, better health and an enjoyable life are possible for almost everyone. The key to success is in your mind!

Table 1-1: Opposite Body Forces

If the body is out of balance, then a condition may be improved by using a remedy from the same column.

Condition	**Condition**
sympathetic nervous system	parasympathetic nervous system
tension, contraction	relaxation, expansion
aggression, extroversion	placidity, introversion
anger, fear, activity	resentment, rest
rapid pulse and breathing	slow pulse and breathing
pupil dilated, mouth dry	pupils narrow, mouth waters
good muscle tone, body rigid	poor muscle tone, body soft
poor digestion	good digestion
overexcited, hyperactive	low energy, depression
high blood pressure	low blood pressure
farsighted	nearsighted
overactive thyroid/adrenals	under active thyroid/adrenals
inflammation, pain	debility, weakness
diabetes, schizophrenia	hypoglycaemia, allergies, arthritis
Remedy	**Remedy**
blue, indigo, purple	red, orange, yellow
vegetarian diet	animal protein
more potassium, magnesium	calcium (sodium), iodine
lecithin, choline, insulin	adrenaline, cholesterol
sedation, releasing energy	stimulation, giving energy
magnetic south-pointing pole	magnetic north-pointing pole
deep, slow acupressure	rapid, light acupressure

Basic Rules for Healthy Living

Avoid or minimize your contact with:

• Microwave cooking, frying; use of aluminium, non-stick and stainless steel cookware
• Wheat, gluten, cow's milk, sweetened foods
• Meat from feedlots, or processed and seasoned meats such as sausages
• Acid foods in contact with metal
• Soy protein except if sprouted or traditionally fermented such as miso
• Genetically modified foods
• Margarine, cooking oils, trans-fatty acids
• Chemical additives; artificial sweeteners such as aspartame (Nutra-sweet)
• Soft drinks and processed fruit juices
• Foods listed as inappropriate for your metabolic type or blood type (see part 5)
• Starches mixed with food high in protein or acids
• Smoking; overuse of coffee, tea, alcohol, drugs
• Precooked or reheated meals
• Chlorinated and fluoridated water
• Metal beds; innerspring mattresses; sleeping near live electric wiring or appliances
• Fluorescent lighting
• Synthetic clothing, especially worn close to the skin (such as underwear)
• Mercury amalgam tooth fillings; root-canalled or otherwise dead teeth; dental metals inside the mouth
• Mobile/ cell phones, microwave stations for telephone and computers.
• Vaccinations

Maximize your contact with:

• Fresh, raw, and organic food; purple foods (e.g., black grapes or red beets)
• Sprouted seeds; fermented foods with acidophilus and bifidobacteria; sourdough baked goods
• Seeds and nuts sprouted or soaked before eating or cooking
• Cooking in glass or enamel utensils; eating food soon after it is cooked
• Freshly ground linseed (flaxseed); extra virgin olive oil; coconut oil
• Fresh vegetable and grass juice and blended green leaves.
• Barley or wheat grass juice powder, spirulina, chlorella, pollen, lecithin, kelp
• Neutralize fruit acids or vinegar with dolomite; have a high intake of magnesium and trace minerals
• Bitter herb teas to improve digestion; hydrochloric acid as supplement if fingernails are soft
• Energy devices: crystals, magnets, pyramids
• Energized food and water
• Sleep with the head towards north, northeast, or east; pull out electric plugs close to bed before sleeping
• Sleep on latex, natural fibre, or air mattress; energize water in water beds
• Increase outdoor activity and exposure to mild sunlight without sunglasses or sunscreen
• Press tender points on feet and body; squat for bowel movements; exercise; meditate

The Health Improvement Program: The basic requirements for real healing involve the reversal of the factors previously listed (Step 1) as the cause of health degeneration. Then add natural living, good nutrition, proper breathing, sufficient physical activity, improved emotional and mental attitudes, as well as specific procedures, uppermost of which is cleansing - the purification of body and mind.

A fundamental aim of all healing is to provide the body with more vitality or a higher charge of freely circulating bioenergy. True healing is always a holistic process, involving all levels of the personality - physical, bio-energetic, emotional, mental, and spiritual.

Using the types of self-testing described in this book and possibly with the help of a suitable health professional, you can work out an individualized health improvement program for yourself as well as for interested members of your family. This program may have to be changed and modified as you progress and gain experience. Preferably, it should include the following steps:

1. Improve your nutrition: discover and break addictions and allergies; avoid problem foods, chemicalised, and refined food; pay attention to food combinations; select foods suitable for your body type and condition; use suitable supplements.
2. Remove metabolic wastes and toxins: drink plenty of unpolluted water and use colonics and laxative foods; stimulate the skin; have repeated cleansing periods.
3. Eliminate harmful microbes and parasites from your body and repopulate your intestines with healthy lactobacteria.
4. Strengthen the body: use regular exercises such as yoga, tensing and stretching, or suitable outdoor activity.
5. Improve energy flows: work out specific problems with reflexology, acupressure, ear acupuncture, magnet and meridian therapy, massage, and homeopathy.
6. Create natural living conditions: minimize the use of synthetics and plastics; reduce your exposure to pollution and harmful radiation in your home; frequently be in fresh air with mild sun exposure; bathe in the sea or unpolluted streams; walk barefoot on the grass.
7. Learn meditation and mind control: learn to express your negative emotions appropriately; practice generating positive feelings and emotions; love yourself as well as your neighbour; adopt a positive or spiritual philosophy of life; find a worthy goal or ideal and strive to manifest it.
8. Form or join a health or healing group: support yourself, heal yourself, and support others in their healing.

In addition to these self-help measures, it is advisable to seek expert professional help for specific problems. It is self-defeating, however, to view your health improvement efforts as a deadly serious matter, a “life-or-death” struggle. Like everything else in life, they are best conducted in a light and playful way, by exploring and enjoying yourself, even if it sometimes hurts. Remember: True healing means growing - learning and applying the laws of nature.

Balancing: An important general principle in healing is to aim for an overall balanced condition. Generally, every condition in our body is the result of the interaction of two opposing forces; in Chinese medical philosophy these are called yin and yang. Yin is cool and receptive; yang is hot and active. In our Western thinking, we see body processes as an interplay between overactive (yang) and underactive (yin) conditions, between tension and relaxation, and the sympathetic and parasympathetic nervous systems. However, yin can be overactive and yang underactive, depending on the individual.

As part of our healing, we aim for balance not only on the biochemical level, but also in our emotions and thinking. If you are an extrovert, for instance, aim to go into yourself by meditating, learning to listen, feel, and understand. If you are an introvert, then try to become more outgoing and open in your relationships and social interactions. Table 1-1 shows some of the opposing forces that rule our body.

Many natural therapists believe that most disease starts in the bowels or, more generally, in the gastrointestinal tract. This certainly is a common factor in many diseases and requires our initial attention. Allergy (food and substances) testing is most important for sensitive individuals and children with health problems. Fasting and cleansing are required to remove the heavy load of metabolic wastes and toxins that most of us have stored in the body. This cleansing process often leads to unpleasant symptoms - healing reactions, also called the healing crisis - which we frequently must endure before we can advance to a higher level of health. This is especially the case for those with a chronic degenerative disease.

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Step 3

INTESTINAL SANITATION AND ANTIMICROBIAL THERAPY

Sanitize your intestines and rid your body of harmful microbes.

Most diseases are caused or aided by microbes and parasites. Due to antibiotics, steroidal drugs and chemotherapy our natural intestinal bacteria commonly have been replaced with pathogenic microbes. Also microbes from childhood vaccinations may still be present, and there tend to be infection foci in root-canal treated teeth and possibly in scars due to surgery. All of these greatly weaken our immune system and allow fungi, viruses, bacteria and parasites to invade the blood and internal organs. Now we become susceptible to frequent acute infections, or to chronic infections and immune disturbances such as autoimmune diseases, allergies, diabetes, heart disease and cancer.

This antimicrobial therapy is designed to rid our body of pathogenic microbes and parasites, and at the same time regenerate our immune system. The necessary steps are intestinal sanitation or re-establishing a healthy intestinal flora, followed by a longer period of systemic antimicrobial therapy. For long-term healing also root-canal filled teeth may need to be removed.

INTESTINAL SANITATION

One of the first and most important causes of our health deterioration at the biological level is an inability to digest all the food we eat. This may be because of habitual overeating; insufficient chewing; consumption of too much milk, bread, meat, and other problem foods; wrong food combinations; emotional problems; vitamin and mineral deficiencies; or inherited weakness of our digestive organs. However, presently the main cause of intestinal distress is the use of antibiotics and other drugs that damage our protective intestinal flora.

This has two immediate effects: a proliferation of undesirable bacteria, fungi and other parasites as well as putrefaction in the large intestine. A major part of our immune system is located in the small intestine with an important centre in the appendix. For years before the onset of illness, there will be fierce fighting between our lymphatic cells and the proliferating intestinal microbes, resulting in chronic inflammation of parts of the intestinal wall.

This may cause intestinal discomfort and various digestive disorders, and in children it can often result in appendicitis. This chronic inflammation weakens the intestinal wall and allows proteins that are only partly broken down, as well as bacterial toxins, to be absorbed and cause allergies. Apart from many unpleasant symptoms, this will greatly weaken the immune system and predispose us to rheumatoid arthritis and other autoimmune diseases, and it makes us susceptible to infections and cancer.

While the intestines are often overactive during childhood due to high bacterial activity, with increasing age we tend to become more and more constipated. This is largely due to a lack of dietary fibre and a decrease in the bile flow, indicating a deficiency of lecithin and choline. The walls of the intestines become weak and

deformed as with diverticulitis; hard crusts begin to cover the intestinal walls and restrict their flexibility.

Eventually, putrefaction products may cross the weakened walls of the large intestine and enter the bloodstream. This can poison the whole body, though the liver, heart, and brain usually bear the brunt of the attack. Irregular heartbeat, headaches, and fuzzy thinking are frequent initial symptoms. Every part of the nervous system may be affected. In addition, the valve between the large and small intestines (called the ileocaecal valve) may become inefficient and allow bacteria from the large intestine to invade the small intestines and the bloodstream.

When the sewerage in a city breaks down or is not working efficiently, refuse accumulates in streets and on properties and greatly contributes to the spread of diseases. It is similar in a body with inefficient intestinal elimination. Waste products accumulate in the bloodstream and tissues and cause or contribute to the development of most diseases as well as to the general deterioration of health. Colon cancer is the most obvious and direct result.

A diet of predominantly raw foods will, in time, correct these intestinal problems by supplying plenty of high-quality fibre and strengthening the intestinal walls. I do not recommend the habitual addition of bran to meals, as this makes minerals unavailable; instead, I recommend freshly ground raw linseed (flaxseed). Add one tablespoon or more to meals to ensure at least one and preferably two or three bowel movements daily.

Another consequence of microbial overgrowth, often in combination with food allergies, is inflammation of the pancreas. This leads not only to a deficiency of digestive enzymes and problems of malabsorption, but it is also a main cause of insulin-dependent diabetes. A first step in this process is the bottle-feeding of infants from birth. This deprives them of important protective factors that are normally transmitted in breast milk.

To overcome these problems we must improve our eating habits, learn to chew well, eat less, combine foods correctly, eat more raw foods, especially vegetables, eliminate harmful microbes, and reintroduce beneficial bacteria.

Garlic Flush: A key step in improving digestive function, the immune system, and overall health is the restoration of healthy intestinal flora. This is important for all health improvement but especially if chronic diseases are present, and in particular AIDS, cancer, and autoimmune diseases.

For this we reduce the pathogenic microbes in the intestines with a suitable microbicide followed by probiotics or healthy lactobacteria. I prefer fresh, raw garlic which has powerful antimicrobial and especially fungicidal properties. To carry the garlic through the length of the intestinal tract and also to minimize unpleasant reactions, such as headaches, nausea and other discomfort due to microbial die-off, it is preferable (but not essential) initially to take the garlic together with a strong laxative. This is called a flush. An effective flush is with a tablespoon of Epsom salts (magnesium sulphate) in a large glass of water. Drink some more water afterwards.

If you are constipated or overweight you may take 2 tablespoons when using it for the first time to make sure that it quickly comes out at the other end. It tastes less bitter if you refrigerate the dissolved Epsom salts overnight. In the morning you crush a large clove of garlic, mix and drink it with a small amount of water, and follow this

with the refrigerated drink and some more water. You may minimize the garlic odour by crushing cloves while they are submerged in lemon juice.

During the following mornings you may use less Epsom salts or take a milder laxative instead, such as psyllium. If you dislike garlic you may put the crushed or chopped garlic into gelatine capsules. If you seem to be allergic to garlic, then use another antimicrobial, such as Lugol's iodine solution, a teaspoon of sodium bicarbonate, 1 or 2 teaspoons of 3% hydrogen peroxide, olive leaf extract, pau d'arco extract, or wormwood. Similar if you cannot use garlic because of social restraints. Nevertheless, I believe that initially garlic is best suited to disinfect the gastrointestinal tract.

Other laxatives that may be used for a flush are Glauber Salz or sodium sulphate, castor oil, aloe vera, senna, or an isotonic flush: within about 5 minutes drink a litre of water in which is dissolved a heaped teaspoon of salt. You may need to experiment with your chosen laxative to find the right amount to take with the garlic so that it is effective within a few hours.

Psyllium is excellent and strongly recommended for long-term use. It is especially effective for removing endotoxins from the intestines and reducing allergic and autoimmune reactions. It also helps to carry any added microbicide through the whole intestinal tract. To a large glass of water add a teaspoon of sodium bicarbonate and a heaped teaspoon of psyllium hulls, stir and drink immediately followed by another glass of water. Until you start with the systemic antimicrobial therapy in the next step add chopped garlic or another antimicrobial to the psyllium drink but continue adding a teaspoon of sodium bicarbonate as long as there are signs of pain, inflammation, Candida or overacidity.

Probiotics and Ferments: This leads us to the next step: replacing the decimated pathogenic microbes with desirable or "friendly" lactobacilli. This must be done in a massive dose 30-60 minutes after each flush; otherwise the unwanted microbes may grow back to full strength after the next meal. Commonly probiotics contain acidophilus and bifido bacteria in addition to other lactobacteria.

These bacterial cultures are available from health food shops as powders or capsules that should be refrigerated. Preferably buy milk-free cultures, especially with Type 1 diabetes and allergies. High-potency cultures should contain 10 Billion or preferably 25 Billion live bacteria per gram or per capsule (keep refrigerated).

However, these dried cultures are dormant and relatively inactive as compared to bacteria in fresh or live ferments, and often have only a limited number of strains. Therefore experiment with making your own ferment as explained in Part 4. Alternatively obtain genuinely fermented sauerkraut or lactic acid fermented foods from health shops or the Internet. If you do not regularly use lactose-containing products then it is better to repopulate your intestines with bacteria grown on grains or vegetables.

Kefir grains can be used to ferment not only milk but also vegetables. For an excellent information site see users.chariot.net.au/~dna/kefirpage.html. It has the advantage of containing a wide range of protective microbes and also to work at room temperature. I do not recommend using commercial yogurt to sanitise the intestinal tract because of the high content of mucus-forming lactose and limited strains of lactobacteria.

Commonly these ferments are rather acidic and may cause digestive problems in sensitive individuals. Therefore it is preferable for sensitive individuals to partly neutralise this acidity by adding some alkalizer before ingestion, such as bicarbonate until it is only slightly sour, or you may let the ferment stand for a few hours with the addition of some dolomite powder and decant it shortly before use.

Take a cupful of ferment about 30 to 60 minutes after each flush, and possibly use more before other meals. Continue taking either probiotic cultures or ferment several times daily during the intestinal cleanse and the following systemic antimicrobial therapy. Continue this Intestinal Sanitation for a minimum of two weeks but preferably use ferments on and off for the rest of your life.

Raw Food; The type of microbes that will readily grow and possibly dominate in our intestines depends very much on the nutrients that they get, meaning it depends on the food that we eat. A negative example is the strong influence that sugar and grain products have on the growth of yeasts, and especially Candida albicans.

The opposite effect can be found in fresh raw foods, they tend to suppress harmful microbes and encourage beneficial ones. Besides raw lactic acid fermented foods, the strongest beneficial effect have green leaves and sprouted seeds. In addition to their own range of good bacteria they also provide the fiber and other nutrients for them to thrive in our intestines.

As an added bonus fresh raw foods and in particular green leaves are strongly anti-inflammatory. Therefore they are the best healing agent for inflammatory intestinal conditions and (I believe) in sufficient amounts will prevent and probably cure bowel cancer.

In addition to raw vegetable salads, a relatively easy way to ingest more fresh green leaves is as a blended pulp: blend a handful of leaves at high speed with sufficient water or juice and drink without straining. For best results the leaves should be organically grown and used as fresh as possible. Even a handful of fresh grass (cut in short length) or garden weeds may be used.

You may also add sprouted seeds to the blend but not much fruit or other sweet foods as the combination of raw vegetable fibre and sugar can produce strong bowel fermentation. To a degree that can be good for those who have problems with constipation but it needs to be properly regulated. Also fibrous fresh fruits on their own tend to stimulate bowel activity by providing food for bowel bacteria.

Hydrochloric Acid: In the elderly and especially those with chronic degenerative diseases, or often even young asthmatics, the body frequently loses its ability to produce an adequate amount of hydrochloric acid in the stomach. This leads to incomplete digestion of proteins and poor absorption of vitamins B1 and B12 as well as minerals. The resulting mineral deficiency usually causes fingernails to be soft; also the hair may be unhealthy.

Hydrochloric acid is also needed to activate pepsin (a protein-digesting enzyme in the stomach) and kill microbes in food. An inadequate amount of hydrochloric acid (HCl) in the stomach often results in overgrowth of the digestive tract with undesirable and pathogenic bacteria and fungi. This can cause or contribute to malabsorption, intestinal distress, and allergies to products resulting from bacterial and fungal breakdown, and in turn it will weaken the immune system.

Symptoms associated with insufficient gastric acid are belching, discomfort after eating or food lying heavily in the stomach, and anaemia. Often the lymphatic fluid is either over-alkaline or overacid (too far above or below neutral) and the energy level is low. In mild cases it may be helpful to add some lemon juice or cider vinegar as well as a small amount of magnesium chloride to a protein meal or drink half a cup of a bitter herb tea before meals. However, with obvious mineral deficiencies and lack of hydrochloric acid, typical of most cases of chronic degenerative disease, it is beneficial to use hydrochloric acid supplements with cooked meals that include meat, fish, eggs, cheese, legumes, or nuts.

You can easily buy hydrochloric acid tablets, commonly with added pepsin. Use one or two tablets depending on the amount of cooked protein. Alternatively you may also buy and dilute hydrochloric acid yourself. Commercial diluted hydrochloric acid is usually 20 percent HCl, while the concentrated acid (from a hardware store) is 35 percent. To make a two percent solution that is safe to use, mix one part of the 20 percent acid with nine parts of water, or one part of the 35 percent acid with 16 parts of water. You may then mix one to two teaspoons (use plastic) of two percent HCl with your meal. It may be mixed with the protein portion or used as part of the salad dressing. Alternatively, you may dilute the acid with half a cup of water or herb tea and drink it after the meal. You may protect your teeth by drinking this through a straw.

However, habitually taking acids will soon make the body overacid. Further, those who do not produce enough stomach acid also do not make enough sodium bicarbonate to neutralize an increased amount of acid in the duodenum. While the stomach content needs to be acidic, the contents of the small intestines need to be alkaline, otherwise nutrients are not properly absorbed. Therefore, it is advisable to take half a teaspoon of sodium bicarbonate in some water about two hours after a small meal and three to four hours after a large meal (with flesh food or other proteins).

SYSTEMIC ANTIMICROBIAL THERAPY

Systemic antimicrobial therapy involves cleaning the bloodstream, lymph fluid, and internal organs of pathogenic microbes. I believe the best and most powerful combination is a 3-week course of Lugol’s iodine solution followed by a gradually increasing dose of MMS. This may be followed by a longer period on

Frequently, especially with Candidiasis, there is a die-off or Herxheimer reaction during intestinal sanitation or systemic therapy. You may feel weak and nauseous. In this case temporarily interrupt or reduce the intake of antimicrobials, but make special efforts to clean out your bowels. There is some anecdotal evidence that sipping a litre of water with the addition of half a teaspoon of salt may help eliminating headaches associated with a reaction.

Lugol's Solution

Compared to MMS, iodine is much better tolerated. Therefore you can use iodine to remove much of your microbial load in a relatively easy way, and with fewer side effects than with MMS. Furthermore, iodine has a special affinity for mucous membranes which are also an attractive hiding place for fungi. Iodine is an all-round antimicrobial and an excellent fungicide.

It is commonly used as Lugol's solution with 10% of potassium iodide and 5% iodine, and may be called 5% iodine solution. Each drop contains about 6.5 mg of iodine/iodide. Other names for Lugol's solution are Aqueous Iodine Oral Solution BP or Strong Iodine Solution USP (both of which contain 130 mg iodine/iodide per ml). Iodine. Topical Solution (USP) contains 2% iodine and 2.4% potassium iodide. Therefore if you use this 2% iodine solution take 2.5 times more than the amount recommended for Lugol's solution. In the US you may also buy Iodoral tablets, each with the equivalent of 2 drops of Lugo's solution. I do not recommend pharmaceutical types of iodine dissolved in alcohol or other solvents as they often cause side-effects.

To test for allergy (which is very rare) take a drop of iodine in liquid other than just water. If there is no reaction, gradually increase to 6 to 8 drops 4 times daily or 10 drops 3 times daily in liquid or mixed with food. Do not take the iodine directly with antioxidants but it is fine to have antioxidants five or more minutes later during a meal. You may use more or less iodine according to body weight. I believe that a 3-week course adjusted for body weight is generally safe for children. However, it may not be suitable if the thyroid is overactive or with goitre; with these conditions the amount of iodine may need to be increased much more gradually and adjusted according to symptoms.

Continue for 3 weeks with the full dose, but interrupt or temporarily reduce the dose if you develop a serious reaction; if necessary repeat the course after several months. In the meantime continue with several drops daily for a much longer time. For more information on iodine see www.health-science-spirit.com/iodine.html.

MMS – Sodium Chlorite

Sodium chlorite is being used in many countries as an antimicrobial treatment in the food industry, as disinfectant, mouthwash, in toothpastes, and for water purification. As a 3.5% solution it was called 'Stabilized Electrolytes of Oxygen', and as a nominally 28% solution it is known as Miracle Mineral Supplement or MMS, or as water purification drops.

In solution sodium chlorite ($NaClO_2$) is very alkaline and stable but when acidified it forms the gas chlorine dioxide (ClO_2) which is one of the strongest all-round antimicrobial and parasite remedies. The only residue left in the body after treatment with MMS is a small amount of table salt or sodium chloride.

After intestinal sanitation and a course of iodine you may start with MMS therapy. The original procedure involves starting with 1 or 2 drops of MMS and gradually increasing this up to 15 drops once or twice daily. However, this often causes nausea to develop at higher doses. In this case you may absorb the gas from the mouth or the rectum as this usually does not cause nausea.

An alternative method for intensifying the antimicrobial program or for overcoming an acute or persistent infection is by taking 3 to 4 drops of acidified and diluted MMS every two waking hour for several days. Temporarily reduce the dose if any nausea should occur.

In all cases mix the MMS with five times the number of drops of lemon or lime juice but preferably with a more effective 10% solution of citric acid in water. You can make this yourself by dissolving 1 part of citric acid crystals in 9 parts of water. Less recommended is white vinegar (but not cider vinegar which can sometimes aggravate fungal problems).

Three to four minutes after adding the acids add half a glass of water or herb tea, or juice without added vitamin C, e.g. apple or grape juice but not orange juice. Do not take any antioxidant supplements close to MMS; generally keep them 3 or more hours apart. If it tastes too acid then you may wait 5 minutes longer and add some sodium bicarbonate shortly before drinking. Watch that it remains slightly acid because when the solution becomes alkaline chlorine dioxide converts back into sodium chlorite.

Acidified MMS acts strongest on an empty stomach but that also easily causes nausea. Generally it is better to have some food in the stomach and be able to take a higher dose. If nausea occurs temporarily reduce the dose. Commonly nausea, vomiting and diarrhea may occur sooner or later and are beneficial for cleaning out but may be avoided or minimized with the preceding intestinal sanitation and iodine therapy.

With an acute and serious infection, including malaria, influenza and urinary tract infection, you may immediately use a high dose, such as 10 or 15 drops, possibly followed an hour later by the same amount. You will vomit and be very uncomfortable for about a day but it may immediately overcome the infection. However, for chronic conditions and general health improvement it is best to increase by 1 drop each day until you feel some nausea.

Then cut back by 2 drops and stay at this level for several days until increasing again by 1 drop a day. In this way you gradually work your way higher, reducing and then increasing again to keep nausea under control. You may reduce problems by dividing the daily dose into a morning and a bedtime portion, but after some time always try to edge higher until you start feeling the nausea.

To quickly stop nausea you may take 1000 mg or more of vitamin C, but this also stops the antimicrobial activity. To avoid or minimize oxidative damage I recommend taking MMS only in the morning and evening or only once a day and use a combination of antioxidants, including vitamin C, at lunchtime or several hours away from the MMS.

The oral absorption method is designed to avoid nausea and seems also effective with smaller doses then swallowing it. To 1 part of MMS add 5 parts of 10% citric acid and after 3 or 4 minutes dilute with about 30 ml or a big mouthful of water. Wait another 5 minutes and then add up to 8 parts of a 10% sodium bicarbonate solution to protect the teeth from acid attack. This will give a pH of about 5 to 6, and one can keep it in the mouth for 5 to 20 minutes before swallowing or spitting it out. It should not become neutral or alkaline or it will become much less effective. You make the 10% bicarb solution by dissolving one level spoonful of bicarb in 9 spoonfuls of water. Instead of water you may also use fruit juice as mentioned before, or herb tea, or sweeten with Xylitol or Stevia.

I regard 6 drops of MMS as a good strong dose for oral absorption. For an acute infection you may follow up with a second dose As a general cleanse you may use this or a lower or higher dose for 2 to 3 weeks, best at bedtime. With a persistent infection continue on and off for a longer time, you may experiment with one week on a high dose of MMS alternated with several weeks on a high antioxidant intake.

The rectal absorption method is good with problems in this area, such as rectal or prostate cancer, irritable bowel, and infections, cysts and cancers of the female organs. This is similar to using coffee enemas for cancer patients.

Preferably have a bowel movement and a cleansing enema, and then try 2 acidified drops in 250 ml of water. Hold for several minutes, then expel, clean again with an enema and finally insert a larger number of drops, perhaps 4 to 8 activated drops in 250 ml water and hold for a longer time, up to 30 minutes. As with oral absorption you may also add some bicarbonate to make it less acid. Protect the anus with some fat or Vaseline. There tends to be no direct discomfort, but for several hours afterwards energy may be low, and several cleanout bowel movements may follow. You may try this once a week with gradually increasing doses.

In case of vaginal thrush you may also try one activated drop suitably diluted and later followed by some probiotics. Also try the mouthwash solution.

Mouthwash: You may make a mouthwash by diluting a teaspoon of MMS in 500 ml of water. This is only slightly alkaline and tends to release small amounts of chlorine dioxide in contact with acid-forming bacteria. It is also commercially promoted as the most effective method for removing bad breath or halitosis. It does this by oxidising smelly sulphur compounds in the mouth to non-odorous sulphates. Swish a mouthful around for a short time, gargle, and spit it out. You may also flavour the solution or make it weaker. Some people claim that regular use has protected them from ‘catching’ infections.

Furthermore, occasional oral absorption of chlorine dioxide and regular use of MMS mouthwash tend to eliminate pathogenic microbes and inflammation in the mouth. These may originate from root canals, deep tooth pockets or gum inflammations and are strongly implicated in the causation of arteriosclerosis, heart attacks and other heart diseases, rheumatoid arthritis, diabetes, prostate cancer and other cancers.

To combine the stronger antimicrobial effect of oral absorption with the convenience of a mouthwash add a drop or two of lemon juice or citric acid to a teaspoonful of mouthwash solution and immediately start swishing this in the mouth for a minute or two before spitting it out. This has a relatively mild effect on the taste buds. One teaspoonful of mouthwash contains about one drop of MMS.

A recent addition to the MMS arsenal is MMS2 or calcium hypochlorite. It is especially good for killing microbes and parasites in the intestinal tract. This is beneficial with Crohn’s disease and other inflammatory bowel conditions as well as cancer of the colon and prostate, and possibly of the pancreas and liver. For details see http://www.health-science-spirit.com/MMS2.htm.

Preferably inform yourself further by reading my MMS Internet articles at www.health-science-spirit.com, and visit http://www.jimhumble.com and http://jimhumble.biz/; Jim Humble discovered and developed the MMS treatment.

Other Antimicrobials

Fungi can be controlled with alkalizers. Due to its alkalinity sodium bicarbonate is a strong fungicide, and potassium bicarbonate is even stronger. Half to one teaspoon of bicarbonate in a glass of water taken on an empty stomach or 2-3 hours after meals can be used several times daily to sanitize the intestinal tract and alkalize

the lymphatic system. Bicarbonate solution is very effective in direct contact such as for rinsing out the mouth, sinuses or vagina or as packs over sites of fungal infection and tumours.

Some additional remedies for systemic antimicrobial treatment are concentrated olive leaf extract, concentrated Pau d'arco extract, and wormwood. These may not be as strong as the combination of Lugo's solution and MMS but are milder acting and easier to use for a longer period.

The following herbal dosages are for average body weight, overweight individuals may take more and underweight individuals or children less. These remedies may not be suitable in high doses during pregnancy, in this case consult a health professional.

Further supportive methods are oxygen therapy, coconut oil or caprylic acid (Capricin), an electronic blood purifier and magnetic pulser. Some other good anti-microbial remedies are propolis, extract of Neem leaves, and the oils of tea tree, Neem tree, cinnamon, eucalyptus, mustard, oregano, shark liver, and thyme. You may try using 1 to 2 drops of essential oil four times daily diluted and ingested or kept in the mouth.

Colloidal silver is best for direct treatment of affected areas, such as douching or gargling, as after ingestion it may not be effective past the stomach. For asthma, lung infections and lung cancer I would also consider spraying colloidal silver into the mouth during deep inhalations.

Even if systemic infestations with Candida and other microbes are successfully eliminated there may still remain problems in isolated areas, such as fungi or parasites in skin patches, vagina or under toenails. These should be intensively treated with local application using a wide range of the mentioned remedies.

If you continue to have persistent long-term microbial or parasite problems use a combination of different antimicrobials and frequently vary the composition of the treatment as well as the dosage, also add alkalizing and possibly electronic zapper and pulser. Also read about the importance of the Basic Cleanse in Step 4.

Olive leaf: Olive leaf is an effective anti-microbial. It can be used as tea or powder but commonly it is now used as an extract. The active ingredient is oleuropein. Preferably use up to 1000 mg of oleuropein daily as part of the anti-microbial rotation program. Dried olive leaf has about 30 mg of oleuropein/gram.

As the tea is rather bitter it is now rarely used: simmer 30g of dried leaves in 1 litre of water for 1-2 hours, top up, strain and refrigerate, and drink 3-5 cups daily.

In powder form olive leaf extract has 200mg to 220mg/g. Use up to 5 g of powdered extract daily. You may stir half a teaspoon in water or other non-protein liquid two or three times daily and take before meals (oleuropein may be inactivated by high amino acid levels). The normal retail form is as 500mg capsules of extract, and you may use up to 10 capsules daily. Commercial liquids commonly contain only 4 mg of oleuropein per ml.

Pau d'arco; Pau d'arco (also called taheebo or lapacho) is a strong fungicide from the inner bark of a South American tree. It has the advantage of tasting reasonably pleasant. Either use extract or make tea: one tablespoon of bark or a heaped teaspoon of powder in a large cup of water. Bring to boil and let simmer or

steep for 5 to 15 minutes; drink 3 cups a day. Powdered pau d'arco in capsules or cold water does not work but you may use the extract in capsules. Use 3 capsules of extract 3 times daily. For severe Candidiasis or other systemic fungus problems try to obtain 1 kg of extract powder and take several teaspoons daily.

Wormwood: Wormwood is effective against most microbes and parasites. Commonly used for Candida is Artemisia absinthium, but also Artemisia annua or Sweet Annie can be used. Both herbs have different active ingredients, and it may even be good to use a mixture of both. They should not be used during pregnancy.

To avoid the bitter taste of A. absinthium stir a rounded teaspoon of powder in some cold water or juice and drink immediately. Use a teaspoonful three times daily. However, the bitter qualities of wormwood tea stimulate the digestive system - stomach, pancreas, liver and gall bladder. It has been used as a folk remedy to cure jaundice.

Therefore, you may sometimes drink it as tea during or after a meal. Make the tea by adding a teaspoon of wormwood to a cup of boiling water and steep for ten to fifteen minutes. It is easiest to take by swallowing it quickly and, before breathing again, drinking something pleasant afterwards. For children you may also use wormwood powder in capsules (3 to 5 capsules 3 times daily), or use only Sweet Annie.

Conclusion

While orthodox medicine uses specific drugs for specific microbes, in natural medicine we use broad-based remedies that commonly cover viruses, bacteria, fungi and parasites at the same time. Medical antibiotics tend to kill our friendly gut bacteria, which then allow Candida and other fungi to invade the body and cause numerous health problems. This can be easily prevented by also taking fungicides in the form of natural remedies while using antibiotics, and adding probiotics soon afterwards.

Broad-based remedies are cheap and effective and ideally suited for self-healing. But this does not mean that they are harmless. While damaging side-effects are much less common than with drug medicine, problems can occur, especially with high doses of MMS, and for those with overactive thyroids also when using Lugol's solution. This means, you need to use common sense, observe how your body reacts, and cut back or use another remedy if indicated. This is an experimental approach in which you need to be flexible and take responsibility for your health and your actions instead of just following the orders of a doctor.

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Step 4

FASTING & CLEANSING

Become clean on the inside by removing accumulated wastes and toxins.

Fasting is a period of restricted food intake and cleansing is the removal of waste products from the body as a result of fasting. This combination of fasting and cleansing is the most effective general healing method. It is essential for overcoming chronic diseases and for rejuvenating an aging body. It is also excellent for ensuring continued health and minimizes the risk of a disabling disease later in life.

In recent years a steady stream of research articles has pointed to the accumulation of metabolic waste products inside of cells as a main factor in the causation of practically all chronic diseases. In addition to weakening the cell and its energy metabolism, these waste products are also the breeding ground for internally evolving or endogenous microbes that are a basic cause of cancer and autoimmune diseases.

Cellular Waste Products

The body recycles millions of cells and their components every second, usually without a problem. However, if cells are unhealthy, then some of their proteins, especially nucleic acids from DNA and RNA, are abnormal and cannot be properly broken down and recycled. Instead they accumulate as cellular sludge. Various researchers have shown that out of this sludge can now arise primitive microbes.

It appears that new viruses arise from RNA fragments surrounded by a cell-wall, while mycoplasma are from DNA fragments without a proper cell-wall, and nanobacteria develop from damaged mitochondria, the cellular energy factories. These primitive life forms are pleomorphic which means that they can change into higher forms of bacteria and fungi which then are at the basis of cancer and autoimmune diseases.

A large part of these cellular waste products are composed of oxidized and peroxidized or polymerized polyunsaturated fatty acids, especially trans-fatty acids, and combinations with degraded or wrongly folded proteins. Included are also metals, such as mercury, aluminium and iron. Residues with oxidized fats are commonly called age pigments, and more scientifically ‘lipofuscin’. In the aging skin it can be seen as yellow-brown or brown ‘age spots’ or ‘liver spots’.

Another waste product associated with vitamin E deficiency is called ‘ceroid’, while ‘amyloids’ are protein residues that accumulate mainly in the brain and in nerve cells, causing. Alzheimer’s disease, Parkinson’s disease and amyotrophic lateral sclerosis (ALS). Up to 70% of the volume of nerve cells may consist of such waste until cells are finally killed, although they would have lost most of their normal functions much sooner.

These waste products impair cellular functions and our overall health in many ways: they interfere with the movement of nutrients into the cell and metabolic wastes out of the cell, they poison the oxidative energy production or respiratory

chain of the mitochondria and cause us to be low in energy, they interfere with the signalling capacity of nerve cells and the normal function of muscle cells, and they provide the raw material out of which the pleomorphic microbes arise that weaken our immune system and cause autoimmune attacks and cancer.

If you now understand the devastating impact of cellular wastes on your long-term health you will also realize the importance of repeated fasting and cleansing periods in your health program. Even medical research can now show that removing protein debris from cells keeps aging organs young and healthy.

The main causes leading to the accumulation of these wastes are:

1. devitalized food due to processing, cooking, and long-term storage
2. lack of enzymes due to cooking. processing and overeating
3. eating highly heated proteins and oils
4. antioxidant deficiencies
5. exposure to unbiological chemicals in food, water, air and drugs.

What to do

Just by fasting alone many chronic diseases can be healed. The only disadvantage is that it can be unpleasant, especially for beginners. Fasting is not indicated for anyone who is weak, fatigued, or underweight with difficulty gaining weight. We need a reasonably good energy level to fast and cleanse successfully.

When we stop having normal meals our digestive enzymes become available to digest and remove the sludge in our cells. While it is essential to minimize the intake of food, it should be as high as possible in vitality and enzymes, meaning that it should be fresh and raw. Ideal would be freshly cut wheat or barley grass, or leaves freshly picked in a garden. Eat any food in small amounts or drink any juices in small sips spaced out over a longer period. This is especially important for fruits or any sweet juices as from carrots etc. Keep each bite or sip in the mouth for several minutes.

Start with several one-day fasts, possibly once a week, before trying a three-day fast. Then have a three-day fast once a month; if you live according to normal working hours, have your first fast day on a Friday, as the second day often feels the worst, and this way you'll be at home.

Once or twice a year you may fast for seven days or longer. Instead of a series of strict fasts you may have longer periods on a raw food diet and use a strict fast only occasionally. With chronic diseases the need for cleansing is much greater than for general health improvement. After a year or two of good health, the number of cleansing periods may safely be reduced to twice a year, unless you use much processed food. With the onset of a cold, flu, or other infectious disease, start a fast immediately.

The more often you have a fast, the less you normally are affected by it in a negative way; a sense of peace and well-being may develop instead. As long as you are still congested during a fast, your tongue will be strongly coated and your breath may have a strong odour when you get up in the morning. Conversely, if your breath and tongue are clear in the morning, your body is reasonably clean and no more

fasting is needed. To freshen your breath, you can scrape or brush your tongue clean whenever it is heavily coated; use a sharp-edged spoon for scraping.

For several days before a longer fast, start reducing your amount of food and preferably do not eat flesh or processed foods on the last day before a fast. Best have only raw fruit and vegetables on that last day. In the same way, increase the amount of food only gradually after a fast and have only raw food on the first day after a fast. The longer the fast, the less you should eat at the first meal and the longer it should take to return to the usual diet; an apple is a good food for breaking a juice or water fast. Drink plenty of fluids during the fast.

It is important to keep the bowels moving during a fast, and you may use laxatives, enemas or colonics as required. With a juice fast it is advisable to use several glasses of psyllium in water. Keeping the bowels clean is not a problem if fasting on fresh raw salads, fruits, and blended green leaves.

The effectiveness of the fast can be further increased by using a hot castor-oil pack for 3 or more days during the fast. Coat the liver area (the bottom of your right rib cage) and upper abdomen with castor oil, cover with a woollen cloth folded in four layers, and keep the area warm for an hour or two with a hot-water bottle. At bedtime drink two tablespoons of olive oil, possibly shaken in a jar with lecithin and fresh orange or lemon juice. The next morning take sufficient laxative to produce a good clean-out within a few hours.

The topical castor oil stimulates the liver's capacity to detoxify, while the olive oil induces the gallbladder to empty and expel fat-soluble toxins from the liver, and the laxative removes the poisons quickly from the bowels. This method of cleansing causes a minimum of discomfort as the fast might otherwise result in headaches, nausea, and weakness.

Take it easy during fasts; rest whenever you feel weak, or just stay in bed if necessary. Skin brushing, deep-breathing exercises, mild sun exposure, and frequent showers are helpful.

Learn to listen to your intuition and the language of your body, rather than just following expert advice or sticking to a pre-determined program. Sometimes it may be better to ease the program and have some cooked food, You also need to keep your 'inner child' reasonably happy. Ask it for cooperation, and in return promise and deliver some treats for any hardships that have to be endured.

With chronic diseases cleansing may trigger healing reactions, lasting for days and sometimes weeks. During a reaction, pain or areas of discomfort may shift around to different body locations. During this time you may ease any strict program and do whatever is necessary to make yourself more comfortable. For a better understanding of this important subject see Step 10.

The Basic Cleanse

I recommend that you use this most effective cleanse from time to time, perhaps once or twice a year. It is designed to clean out and sanitize your gastrointestinal tract, liver, and gallbladder. Eat organic apples only for the first three days, as many as you like. Granny Smith or other tart apples are preferable, but if

you feel that they are too acidic for you, then use a sweeter variety. If organic apples are not available, then remove the skin and core of conventionally grown apples.

In the evening place a hot castor-oil pack on your liver and upper abdomen and take a tablespoon of olive oil orally at bedtime. However, on the evening of the third day, drink half a cup of olive oil in this way. Then lie down immediately on your back or right side. After the first bowel movement the next morning, look in the toilet bowl for gallstones. There may be hundreds of little greenish wax balls of different sizes floating on top of the water.

First thing in the morning on the second to fourth day, drink a glass of water mixed with a crushed clove of garlic and one tablespoon of Epsom salt (to cause a good bowel clean-out within a few hours). If you cannot take Epsom salt, then try another strong herbal laxative (e.g., senna) or use the isotonic flush. If you have trouble taking raw garlic, put it into empty gelatine capsules, or use hydrogen peroxide instead. About one hour after consuming the Epsom salt and garlic, take a large dose of acidophilus-bifido culture in the form of high-potency capsules, powder, or homemade yogurt, or some self-made ferment.

If you do not have the time or energy for the full cleanse, then you can at this point return to your normal diet and do the rest at another time. Otherwise, from the fourth morning on stop using the apples, Epsom salt, and garlic, and for the next five days drink only freshly pressed vegetable juices, although these may be flavoured with apple or some other fruit. Every three hours (5 times daily) take a heaped teaspoon of psyllium hulls together with two to three teaspoons of ground linseed (flaxseed). Mix this in a glass of water and drink immediately, followed by more water. The linseed should be freshly ground in a blender or coffee grinder and stored frozen or refrigerated. The purpose is to fill the bowels, with a moist mass that will soften and dislodge any hard crusts and putrefying matter. This is essential and very effective with all inflammatory bowel conditions, diverticulitis, intestinal parasites, and cancer.

Take a spoonful of lecithin granules and plenty of protein-digesting enzymes together with the juices. With every glassful of juice, you can take two or three tablets such as pancreatin, bromelain, or papain. Alternatively and even better, if available, use mature green papaya, when it turns yellow inside and the seeds are already black. You can make a Smoothie by blending it with some vegetable juice or yogurt; use up to half a medium-size papaya a day. You could also use the juice of papaya leaves or immature fruit, but this may need to be flavoured and well diluted, as it is bitter.

On the morning after the last juice day (or possibly at bedtime the night before) take a tablespoon of Epsom salt in water or generally enough laxative to produce a strong bowel clean-out during the morning. Often long strings and parts of compacted faecal matter, which look like sections of bowel, are eliminated. It is advisable to increase the variety of food very gradually while doing allergy testing at the same time (see Step 5).

There are many possible variations of this Basic Cleanse. For instance, if you do not have a juice extractor, you can either continue longer with apples or have a few small raw salads instead. If you cannot get organic apples but have plenty of wheat or barley grass and vegetables for juicing, then you can extend the juice

schedule from five to eight days; have the castor-oil packs, olive oil, garlic, Epsom salt, and acidophilus during the first three or four days. Also highly recommended are fresh green leaves blended in water for part or all of the cleanse.

Another possibility, especially good for those with high blood pressure, is to use freshly pressed lemon juice instead of the vegetable juice and possibly instead of the apples as well. Use psyllium hulls and ground linseed as for the last five days of the Basic Cleanse, but instead of vegetable juices drink the juice of five to eight lemons diluted in three or four quarts of pure water. You may do this for the full eight days or instead of the vegetable juice for the last five days. If doing this for the full eight days, then use castor-oil packs, olive oil, Epsom salt, garlic, and acidophilus (as described for the apple days).

Another often recommended additive is Bentonite, a form of powdered or liquid absorbent clay. This helps to remove plaque or old coating from colon walls and also absorbs toxins. Each time you use the ground linseed and psyllium, add either one teaspoon of powdered or one tablespoon of liquid Bentonite, which you can consume orally.

Lymphacising

A good way to greatly increase the cleansing action during a fast is lymphacising - gently bouncing on a rebounder or mini-trampoline. This speeds up the lymph flow to many times its normal rate. Lymph is the blood fluid that filters through the walls of arteries and capillaries into the tissue, delivering oxygen and nutrients to individual cells and carrying away carbon dioxide and other waste products. However, if the cellular waste production is high and lymph flow is slow, cells begin to clog up and become inefficient, preparing the ground for the development of a disease. Increasing the lymph flow greatly helps to reduce this danger; bouncing on a rebounder can do this.

Cleansing the body involves dislodging wastes and toxins from within and between cells and transporting them with the lymph fluid to the large veins near the neck; there they enter the bloodstream to be discharged through the liver and kidneys.

A greatly reduced food intake is the main way to dislodge stored wastes and toxins. Muscle activity propels the lymph flow; castor-oil packs, fruit acids, olive oil, bitter herbs, and sulphur compounds stimulate liver detoxification of fat-soluble waste while a high fluid intake and herbs for the kidneys, such as dandelion, help remove water-soluble wastes.

During fasting we usually do not have much energy for muscle activity, but lymphacising can come to the rescue as it does not consume much energy and one feels energized afterwards. With each bounce on the mini-trampoline the lymph is pushed towards the neck and prevented from falling back again because the valves through which it pushes are one-way (also see Step 9).

Another way of speeding up your lymph circulation is by inverting your body. Special inversion equipment, on which you can hang upside down, is available, or you can use an inclined board, simply put your legs up against a wall while lying on the floor, do the leg motions of bicycling while in the inverted position, or do a shoulder stand or headstand as described in hatha yoga.

THE LONG CLEANSE

A Long Cleanse of about 6 weeks duration on either a small amount of vegetable juice or grapes has been used to shrink or dissolve tumours and normalize lymph and blood cancers in thousands of cancer victims. If the body is starving it digests its own non-essential tissues, and it starts with diseased parts and tumours. Famous examples of this kind of cleanse are the Breuss Cure on half a litre of fresh vegetable juice; the grape cure of Johanna Brandt; the wheat grass cure of Ann Wigmore; and even the urine fast of John Armstrong.

It works even better with large than with small tumours as these are a source of protein, but it also eliminates the large amount of protein debris that is a main cause of cancer. This long cleanse is usually the best way to eliminate or greatly reduce tumours without strong and unpleasant side effects. It is especially suited for overweight individuals.

On the ***Breuss Cure*** you drink half a litre of fresh organic juices daily, extracted in a non-centrifugal way. The usual composition is 3 parts of beetroot, 1 of carrot and 1 of grass juice or celery, and preferably a small amount of horseradish, radish or turnip or their leaves.

As an alternative you may use 1-2 litres of juice consisting mainly of about equal parts of green juice as from grass and leaves, and beetroot-carrot juice flavoured with ginger and pollen, in addition to unstrained blended green leaves. Hot onion broth may be used in the evening, purple onions are best; cook the skins as well. This larger amount of juice is more suitable for maintaining energy without compromising the cleansing effect. The weight loss during a 6-week fast is usually between 5 and 15 kg, mainly due to losing water and from half to one kilogram of fat per week.

With the ***grape cure*** eat black or purple grapes. Eat them with skins and pips. Preferably chew the pips to release their antioxidants. Soak the grapes best with the addition of some hydrogen peroxide to kill and remove any fungi. Eat about 1kg daily according to appetite. If a temporary aversion to grapes develops, have a few days of juices in between. Eat only a few grapes at a time to avoid a strong rise in the blood sugar level. Store grapes cool and dry, you may hang them over a washing line in a garage.

If you feel that you definitely need something savoury to keep going, prepare and drink a warm strained vegetable broth in the evening, including plenty of purple onions. Also simmer the outer purple onion skins. Furthermore, you may make a tea from savoury herbs and spices or turmeric and ginger.

Different Cleansing Methods

Apples are good for the first three-day fast. Preferably obtain unsprayed apples, otherwise either peel or scrub them in warm soapy water and rinse well. Do not ingest waxed skins. Eat as many apples as you like, generally the more the better to keep the bowels moving. Apple fasts are usually well tolerated, and they are also good for children.

Fasting on freshly pressed vegetable juices is somewhat more severe but generally well tolerated. Preferably use plenty of green juice made from wheat or

barley grass, vegetable leaves, and celery, flavoured with sweet vegetables such as carrot, beet root, or pumpkin, and possibly an apple. This juice may be diluted with water for a total fluid intake of two to three litres daily. If you are sensitive to pain, cold, or skin irritants, minimize the amount of sweet juices you consume and possibly add some alkalizers.

For sensitive, weak, or underweight individuals, a rice diet lasting ten or more days may initially be better. Eat only cooked brown rice, lightly flavoured with salt and olive oil and supplemented with preferably one to three tablespoons per meal of unheated ground linseed (flaxseed). Use sufficient linseed to have three easy, bulky bowel movements daily. You do not need to eat “proper” meals; just have a few spoonfuls whenever you feel hungry, and chew it very slowly. Preferably follow up the rice diet with a period of eating raw food only; or alternate periods on cooked rice and raw foods several times. However, if brown rice is not tolerated, try white rice. A rice diet helps to overcome allergy problems.

For non-sensitive individuals, a three-day lemon-juice fast is excellent and especially good for improving liver functions; it is also recommended for those with high blood pressure and who are overweight. About ten times during the day drink a large glass of water to which is added the fresh juice of half a lemon. You may flavour this with a small amount of fresh grapefruit or orange juice. Later you can extend this fast to seven days or longer. This is especially helpful with diabetes.

The “grape cure” is not only known as a cancer cure, but is also good for coronary artery disease and other chronic diseases. You eat about one kilogram of grapes spaced out in intervals during the day to avoid any strong rise in the blood sugar level. Continue for several weeks. Black grapes are best, otherwise use purple or red.

Unfortunately, it is difficult to obtain unsprayed, organic grapes. If you have to use sprayed grapes, wash them thoroughly in warm soapy water and rinse well. If you are sensitive to moulds, soak the grapes in diluted hydrogen peroxide or expose them to sunlight before a last rinse and eating.

For a longer cleansing period, use a mixed fast. You may, for instance, start with several days on a rice diet and follow this with a period of raw food only, with a time on apples or grapes and a further period on juices. Then repeat this sequence in reverse order with days of eating only fruit, raw food, and finally rice before returning to your normal diet. The cleansing period may last for several weeks, or even months, with repeated sequences.

Unless you have an acute infectious disease, do not start a strict fast when you feel weak. In this case, you can alternate between a rice/vegetable diet and a raw food diet. Those with acute infections should have only fresh fruit, fresh salads or vegetable juice until health improves and good appetite returns.

A **urine fast** has the advantage of providing vital nutrients and activating the immune system while ingesting a fluid that is already charged with your own life force, It is not as difficulty to do as it may sound because after a few days it is so diluted that it just tastes like water. For details see Step 22.

If you suspect your body is overloaded with chemicals or that your liver’s ability to detoxify is reduced, do only mild fasts initially, such as the rice diet and raw food

diet. Also supply yourself with plenty of sulphur in the form of MSM (see Part 3) or, alternatively, use onions, raw egg yolk, and possibly the amino acids cysteine and methionine, or even powdered sulphur. Regular cleansing is the more important the older and physically less active you are.

Mucus problems are very common. This is obvious when we have a cold with a congested or runny nose, but at other times it may be noticed as congested or inflamed sinuses, ear or hearing problems, including tinnitus and “glue ear” in children, glaucoma, and throat and lung problems, especially asthma. To overcome these conditions, see Steps 38 and 44.

An **oil rinse** can be helpful. Fat-soluble toxins can be removed from the system before they reach the liver. First thing in the morning take a large sip of a light oil, such as sunflower or grape seed (stored in glass bottles), and vigorously swish it around the mouth for 10 to 20 minutes; do not swallow it; spit it out (be careful: it may clog the sink). Rinse your mouth several times with warm water. Continue this daily for several months. This rinse is especially important if the lymph system is congested, as it commonly is with cancer and other chronic diseases, and it is very effective with health problems in the head and neck area, including dental problems.

At other times, you can use distilled water to filter out water-soluble toxins. After rising in the morning and again at bedtime, use a cup of distilled water. Take a mouthful and hold it under the tongue for about two minutes. Then spit it out and repeat the process until the cup is empty.

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Step 5
ALLERGY TESTING

Discover and overcome your food allergies and chemical sensitivities.

Usually we are addicted to any daily-used food or substance to which we are also allergic. The reverse is also true, that we have allergies to addictive foods. Initially when we eat a sensitizing food (one that may produce an allergic reaction), we experience stimulation due to the release of adrenal stress hormones. However, eventually the adrenal glands become exhausted, and we develop a chronic degenerative disease and lack energy. In this book, I use the term “food allergy” in a general way to include not only genuine immunological reactions, but also food intolerances and chemical sensitivities.

In 1936, Hans Selye, a Canadian professor of experimental medicine and surgery, discovered the allergy-stress mechanism. He was the first to describe this mechanism, which he did in his pioneering book The Stress of Life. So far the medical profession has not yet grasped the importance of his fundamental discovery for understanding the diseases of our society, I assume because it is not profitable to do so. However, in light of this stress model, we now know what we need to do to heal ourselves.

Initially an environmental challenge such as an incompatible food or emotional stress causes an alarm reaction. The adrenal glands release inflammatory hormones, and the sympathetic nervous system is overstimulated. This may result in an acute allergic reaction or a general inflammatory condition, hyper-excitability, increased blood pressure, palpitation, aggressiveness, anxiety or anger, and poor digestion. This incidentally, is the basis for the connection between junk food consumption and criminality.[2]

If we continue eating the same problem food nearly every day or continue to be plagued by stressful memories or conditions, then the stress becomes permanent and the body adapts by releasing anti-inflammatory hormones. The symptoms of the alarm reaction with its inflammatory tendency subside. This is the resistance phase, a state of adaptation for a hidden or masked allergy. Commonly, the alarm reaction occurs in early childhood when we are first introduced to wheat, cow’s milk, maize, or soy milk and then settles down to several decades of hidden allergies with minimal outward symptoms.

However, eventually the capacity of the adrenal glands to produce sufficient anti-inflammatory hormones becomes exhausted and we enter the exhaustion phase of the allergy. Now we have a maladaptation to allergens and other stressful conditions with chronic and generalized inflammations. These can manifest as arthritis, cancer, heart disease, and any of the other diseases typical in our society. Finally, even this chronic inflammatory condition subsides and we have the stage of advanced old age with senility, debility, and the final non-sensitive stages of degenerative diseases.

This sequence of ill health shows us the requirements for genuine health improvement. By permanently removing the offending problem food or other chronic stressor and at the same time supporting the body with high-quality nutrition we slowly begin climbing back to health. We leave the exhaustion phase and re-enter the resistance phase with a period of quiet recovery, and finally we move back into the alarm phase with a series of acute but beneficial healing crises. At the end of this long healing process, we may have reacquired the adrenal function and disease resistance that we had as a small child before we started getting colds, allergic reactions, and digestive upsets due to consuming problem foods.

Sometimes energetic individuals, often males with blue-white irises who cannot relax, experience a prolonged period of lethargy when avoiding wheat or gluten products. During this time, the adrenal glands have time to recover. Others who are already closer to adrenal exhaustion feel much stronger as soon as they avoid allergenic foods. The main allergenic foods tend to be the same as the most commonly eaten foods and include wheat, cow's milk, eggs, soy, corn, peanuts, and synthetic food additives (for a compilation of possible food allergy symptoms, see Table 5-2).

Addictions and allergies are part of the stress syndrome. Prolonged severe stress of any kind leads to adrenal exhaustion in the same way that an addictive allergy does. The only real solution lies in avoiding excessive stress factors such as allergenic foods, work pressures, and so forth.

Discovering your allergies and addictions is an essential step in your healing process. You may do this by adopting a five-day water fast or rice diet as described in the following pages.

After complete avoidance of an allergenic food (one you suspect or know produces allergy symptoms) and while reducing the overall allergenic load from other influences at the same time, one usually becomes hypersensitive to that food for a period lasting from a few weeks to several months. After this, the sensitivity to the offending food gradually declines. If during the hypersensitive period you are occasionally exposed to the allergenic food, then an immediate strong reaction can be triggered, resulting in pain, weakness, a rash, or whatever its characteristic effect is on your body.

If this is done repeatedly but separated by at least four days between exposures, this may delay the complete recovery, but is not likely to result in serious internal damage. However, permanent damage will result if you use this food so frequently that you do not get an immediate reaction any more or only a much weaker reaction than initially.

Generally, however, it is essential to avoid the offending food as much as possible for an extended period in order to heal yourself completely. Depending on the severity of your initial symptoms or degenerative disease this may be from a few months up to several years. How soon you can overcome your allergic tendencies depends mainly on the effort you put into adopting a comprehensive health improvement program.

Types of Allergies: Depending on its severity and mode of manifestation, we may distinguish five types of allergy: addictive, cyclic, fixed, multiple, and trigger.

An *addictive allergy* induces us to eat our favourite food every day or we are threatened with withdrawal symptoms. Therefore, we have a craving for a certain food and eating or drinking it makes us feel better. The person usually is not aware of the addiction and for this reason this type of allergy is also called a hidden or masked allergy, corresponding to the period of adaptation.

In a *cyclic allergy*, we have a reaction to a specific food only if it is eaten in excess, either by eating large quantities of it at any one time or by eating it on several successive days. In addition, a reaction to a cyclic allergen can be triggered by other adverse factors, especially by stress as from emotional and mental problems or from environmental agents such as chemical fumes, tobacco smoke, and so on. Combining two different cyclic allergens in the same meal can also cause a reaction due to the effects of both. Poor food combining or a generally acidic body condition may be further contributing factors.

If you realize that you have a cyclic allergy - the food agrees with you sometimes but not always - then eat it only on a rotation basis, not more often than once every four or five days. Fruits and the lactose content of dairy products often belong in this category. They may not cause immediate reactions, but eating fruits on successive days can cause an increasing degree of overacidity and skin problems in sensitive individuals, while an oversupply of lactose can lead to a build-up of mucus. Both, in turn, can trigger secondary symptoms such as arthritic pains.

With a *fixed allergy*, one reacts every time the offending food is eaten, no matter how small the quantity. Fixed allergies, therefore, are non-adapted allergies and thus easy to recognize. One soon becomes efficient in avoiding offending items. Fortunately, only a small percentage of all allergies are of the fixed variety; most are addictive or cyclic in nature.

With *multiple allergies*, we react to a wide range of foods and chemicals and quickly become allergic to any replacement foods. This has sometimes been called being allergic to the twentieth century. The main causes are deficiencies of zinc, digestive enzymes, and gastric acid, weak liver function, and bacterial overgrowth of the digestive tract, often with systemic Candida infestation. The solution is intestinal sanitation, a raw food diet, and a high intake of zinc and sulphur compounds. Before testing for allergies by elimination, sanitize the intestines and minimize any deficiencies by using vitamin and mineral supplements.

We can also speak of a fifth type, trigger allergy. Attacks of asthma or hay fever are often triggered by inhaled substances such as pollen or house dust with residues from house mites. However, such reactions would not occur if one’s mucous membranes were not already hypersensitive because of underlying food allergies, mucus congestion, and various deficiencies. (A deficiency is a state of higher nutrient requirement than is available.) In a similar way, food chemicals can act as triggers for hyperactivity. A hypersensitive skin reacts very strongly to insect bites because of its high histamine levels due to underlying food allergy and overacidity. Removing the triggers will help to some degree, but the underlying health deterioration continues and a new trigger can readily be adopted.

Elimination Testing: There are various forms of allergy testing, some technical, others a simple skin scratch method, and there is also muscle testing or

pulse testing. None of these, however, is as reliable as proper elimination testing, called the elimination diet. Here's how to do it:

For five days or longer, abstain from all your commonly eaten foods, as well as alcohol, nicotine, or other drugs. During this time, try to minimize any other possible allergenic influences such as exposure to solvent or car exhaust fumes, house dust, moulds, gas, or cigarette smoke - basically anything with a strong or unusual smell.

Starting on the second day, there may be more or less troublesome withdrawal symptoms, with cravings for the food or stimulant to which you are addicted. You may have headaches, dizziness, weakness, and other problems. On the fourth day, these symptoms usually subside and you begin to feel much better. Often symptoms of long-standing diseases such as arthritis, heart pain, or schizophrenia disappear as well.

If you still do not feel right on the fifth day, it may be better to extend the program until you do feel well. Chemicals and drugs, be they medical or recreational, take much longer to clear from the body. It will greatly speed up the elimination and lessen your discomfort during the fast if you take a strong laxative on the first morning of the fast, using an isotonic flush, herbal laxative, or a tablespoon of Epsom salts in water; in addition, drink a lot of pure water.

The most reliable fast is on pure water only, which means unchlorinated and unfluoridated, and not stored in plastic containers. In a less strict form, it should be all right to use a weak, unsweetened herb tea of a variety you do not habitually use. Non-sensitive (non-reactive) individuals can become more balanced by having a fast on diluted lemon juice, while sensitive individuals can use cooked white or brown rice only, preferably unflavoured; otherwise use a small amount of olive oil, herbs, and possibly salt with the rice. If rice has been habitually eaten before, then use cooked millet, sago, or arrow root instead. Eat as much as you like and drink about two litres of fluid daily. If you use a cleansing period as recommended in Step 4 then you may do elimination testing when gradually re-introducing different foods.

If you fast on fluids, use another laxative on the last day of the fast, normally the fifth day. On the morning of the sixth day, eat cooked rice as the first test meal, possibly lightly salted but with no other additions. As explained in Part 2, check your pulse rate for a full minute before a meal, and 30 and 60 minutes after the meal. Always test sitting in the same position and when the pulse rate is not increased from previous physical activity.

Before and after each test meal, make the pulse tests and any other relevant tests. If there is a reaction involving a combination of newly tested foods, repeat testing with the individual food components at a later date. If the pulse after a test meal is significantly higher than after the first test meal of rice, say more than 10 percent, then this indicates a possible allergy or incompatibility; the higher the pulse rises after the meal the more likely is it that a food is allergenic.

Make other tests relevant for your condition. If you have weak eyesight, you can check your reading ability with a wall chart; schoolchildren can be tested for clarity of writing and speech. Check the range and pain level of impaired joints or muscles, and watch for any sign of bodily or emotional discomfort. Keep a detailed diary of the pulse rates, measurements, and any unusual happenings, feelings,

discomforts, and so on. Those with diabetes should also test their blood sugar level, and those with hypertension preferably should check their blood pressure (you can easily buy a sphygmomanometer to do this).

With each subsequent meal, expand the basic rice meal with one or more additions, such as oil and various vegetables. Test a sprout salad and then other basic foods. You can have four or five small meals a day. In the beginning, test mainly foods that you expect to be safe. Test suspected allergenic foods at the last meal of the day, so you can sleep off any prolonged reactions. Use suspect foods only individually or with previously tested foods.

You can stop a strong food allergy reaction by taking one level teaspoon of sodium bicarbonate (baking soda) or, better, two parts baking soda with one part potassium bicarbonate. Also take one tablespoon of Epsom salt or milk of magnesia as a laxative if the reaction occurs soon after the meal. On a normal diet, however, reactions can be delayed and manifest up to two days later.

Reactions can also be stopped using homeopathy. Liquefy a sample of the allergenic food, dilute one part of it with nine parts water, and shake in a bottle or jar about 40 times with a strong downward movement. Dilute one part of this with nine parts water and so forth until the dilution process has been done four times in all. Then place one teaspoon of the fourth dilution in your mouth and hold it there for a few minutes before swallowing. Then make two more dilutions and keep a teaspoon of each of these in your mouth in the same way. Take additional teaspoons of all or just the last dilution some time later if still required.

Test offending foods again three to six months later. Commonly, small, infrequently consumed amounts can then be tolerated. Eat suspect or problem foods no more than once a week. If conditions deteriorate again after some time, return to testing or adopt a safe, low-allergen diet. The body can be made less sensitive to allergic reactions by making the body more alkaline, as in Step 6.

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Step 6

THE ACID-ALKALINE BALANCE

Bring your body back into balance by testing for and correcting any over-acid or over-alkaline condition.

Our blood is slightly alkaline, and the body makes every effort to maintain this alkalinity at a constant level. For this purpose, we normally have an ample reserve of alkalizing minerals. Most of our foods supply minerals. The total balance of minerals in a particular food can be either acid or alkaline. Mineral salts are composed of an acid group (anion), such as chloride, citrate, or phosphate, and of an alkaline group (cation), mainly metal ions such as sodium, calcium, or potassium. If one of these groups is stronger, then the salt is either acid or alkaline.

In plants, metal ions such as potassium are combined with organic acids such as citric acid. In the body, the organic acids are converted to energy, while the metal ions remain to produce an alkaline reaction. Therefore, we say vegetables and fruits are alkalizing. Animal tissue, on the other hand, contains a high percentage of phosphoric acid bound to proteins. Some of the proteins are converted to energy and an acid remains. Accordingly, we can classify our food as either alkalizing or acid-forming. Here's a rule of thumb:

Alkalizing foods: vegetables, fruits, sprouted seeds, almonds, most legumes

Acid-forming foods: meat, fish, eggs, cheese, most grains and nuts

Neutral foods: refined starches and sugar, fats, oils

In order to maintain an amply alkaline body reserve, eat approximately four times the weight of alkalizing food compared to acid-forming food, or 80 percent alkalizing to 20 acidifying food. There are food tables available to show the amount of acid or alkaline equivalents in different foods. However, I regard these as useless because some of the listed foods may change their values in the body due to specific, individual metabolic problems.

Sugar and chemically neutral and normally alkalizing fruits become acid-forming in sensitive individuals, while a high intake of meat and fat can lead to a lack of acids required for energy production. No matter how alkalizing a food is supposed to be, if you are sensitive or allergic to it, then it is acid-forming for you. Even the same food may change from alkalizing to acid-forming if it is incorrectly combined with other foods or if consumed when you are emotionally upset.

All of this is contrary to what you would expect by using acid-alkaline food tables. The values in these tables reflect the typical mineral content of the food, but this varies greatly depending on soil and storage conditions, production methods, and cooking. Therefore, the only reliable and meaningful method is to observe your body: skin sensitivity, tendency towards inflammation, allergic reactions, and possibly to test your urine and saliva for acidity.

The Regulation of Body Acidity: The body tries to keep the blood acidity constant within a very narrow band, between pH 7.35 and 7.45. This is actually a slightly alkaline condition. The pH is a measure of acidity or alkalinity and indicates

the hydrogen ion concentration in a fluid. These hydrogen ions are the originators of acidity. A pH of 1 indicates the highest hydrogen ion concentration and with this the highest acidity. At the other end of the scale is a pH of 14, with the lowest hydrogen ion concentration and the highest alkalinity. A pH of 7 is neutral.

In our younger years, our metabolism often is too fast; too many acids are produced and the body becomes chronically overacid. Later in life, however, with decreasing muscle activity and vitality, not enough metabolic acids are produced, potassium is lost from the cells, and the metabolism becomes sluggish. With this, the body often becomes chronically over-alkaline and loses its ability to regenerate and heal infections or wounds.

By excreting more acids or more alkalis through the urine, the body tries to maintain a normal pH level. The body also does so by changing the breathing rate: An increased volume of breathing makes the blood more alkaline by releasing additional carbon dioxide into the air; decreased breathing, on the other hand, increases the carbon dioxide level in the blood and makes it more acid. The balance in the blood between carbon dioxide and sodium bicarbonate (baking soda) is the main buffer system to keep the blood pH constant.

With an efficient metabolism, the pH of the urine depends mainly on the acid-alkaline balance of the diet. A diet high in acid-forming foods will naturally produce acid urine. This is not dangerous as such but it is an indicator that the diet is unbalanced and may in time lead to exhaustion of the body's alkaline reserve.

Similarly, on a diet high in alkalizing foods, the urine is always alkaline. This can lead to stone formation in the urinary tract, and it may show that the cells don't have enough metabolic acids for efficient energy production. A normal mixed diet containing about 80 percent alkalizing foods and 20 percent acidifying foods should give a slightly acid morning urine, while urine formed after meals is naturally slightly alkaline as a result of the production of gastric acid.

Test Your Body Acidity: To obtain an indication of the acid-alkaline balance of your body, test your first morning urine from time to time. In evaluating the results, take into account whether your present diet in general and the last meal in particular were balanced or acid or alkaline forming. If you test the urine during the day, the result may be much more variable because of the temporary alkaline tide after eating. Urine paper should have a range from pH 5.5 to 7.5. You can obtain it over the internet. For an approximate test, you can use litmus paper which turns red with an acid reaction and blue when it is alkaline.

Instead of using pH strips you may use the yellow powder turmeric or possibly curry powder. Dissolve a teaspoon of powder in half a litre of methylated spirits, shake and let settle to produce a clear yellow solution. To make a test pour a teaspoon of the yellow solution into a small drinking glass. Add a teaspoon of urine or saliva, if it turns ruby red then what was added was alkaline with a pH greater than 6.8, if it stays yellow then it is still acid and less than pH 6.8.

Also red cabbage juice can be used as pH indicator. The colour at pH 2 is red, at pH 4 purple, pH 6 violet, pH 8 blue, pH 10 blue-green, and pH 12 green-yellow. Finely chop some red cabbage, pour hot water over it and soak for 10 to 20 minutes, then filter through some gauze or tissue. In a small clear glass add a spoonful of filtered juice to a similar amount of a test liquid, stir gently and compare with the

colour chart. Refrigerated the rest of the juice, use within a week or two, or keep frozen. Also other purple juices work in a similar way, just experiment.

It is also valuable to check saliva acidity, especially if there are any digestive difficulties and if you do not seem to get sufficient value from your food. An allergic reaction makes the saliva too acid, so you can use this test as part of your allergy testing program.

Before a meal, the normal acidity of the saliva is 6.4 to 6.7, while 30 to 60 minutes after the meal, it should be above 6.8. If test results remain too low you may be to acid or produce not enough stomach acid. For testing first clean your mouth with plain water, fill it with saliva, swallow, and then test the second lot of accumulating saliva.

Acidity Problems: The main reasons people become overacid are:

1. Inefficient metabolism
2. Stress reactions due to food allergy, chemical sensitivity, emotional upset
3. Eating sweet foods when the blood sugar regulation is poor
4. Acids accumulating after eating fruit
5. Strenuous muscle activity
6. Candida albicans infestation

Chronic overacidity has a serious effect on the body. It causes a continual loss of minerals needed to neutralize excess acid and the body becomes hypersensitive. The more acidic the body becomes, the more histamine (the allergy chemical) is released. This means acidity causes and greatly increases inflammations and allergies, and it makes the skin very sensitive to insect bites and other irritants. Remember that degenerative diseases are associated with chronic inflammation.

Overacidity of the body is often felt as pain; it is most prominent in arthritis and rheumatism. If the alkaline reserve is insufficient to neutralize these acids, more calcium will be mobilized from the bones for this purpose, thereby causing the bones to become brittle and the tissues and joints to calcify. Further, tumours grow only if the surrounding tissue is too acid. Acidity around a tumour may be due to the lactic acid production of the tumour itself; however, sensitive individuals are generally too acid and this promotes rapid tumour growth and pain.

Table 1-2: Symptoms of Calcium–Phosphorus Imbalance

Calcium level too high	**Phosphorus level too high**
Colds and flu are rare	Frequent colds and flu
Insensitive to pain and noise	Sensitive to pain and noise
Insensitive skin	Sensitive skin
Signs of magnesium deficiency	Signs of calcium deficiency
Blood pressure raised	Tendency to low blood pressure
Blood is too alkaline	Blood is too acid
Caries of the crowns	Caries near the gum
Tartar on teeth	Gums very red and tender: pyorrhoea, gingivitis
Calcium kidney stones	Tendency to inflammations & swellings
Stiffness, rigidity	Red-rimmed eyes
Fusion of vertebrae	Headaches, nausea
Arthritic deposits causing bone deformations	Acute arthritic attacks
Arteriosclerosis	Allergies, palpitations

Alkalizing the Body: Fresh green vegetable juices and vegetable broth are strongly alkalizing foods, especially the broth of boiled potato peelings. While fresh fruits increase the acidity of sensitive individuals, they are usually beneficial for those with a normal carbohydrate metabolism, raised blood pressure, and insensitive skin.

Habitually taking several grams of vitamin C in the form of ascorbic acid can deplete mineral reserves or increase body acidity. This may lead to inflammation, increased pain, and other problems in sensitive people. Therefore, for such people it is advisable to use the neutral sodium or calcium ascorbate.

The best alkalizing food cannot bring lasting improvement if you continue to eat food to which you are allergic or if you eat sweet foods and fruits when you are overly sensitive.

Alkalizing with Sodium and Potassium: Sodium is the highest mineral in the blood, and sodium bicarbonate is well tolerated but should not be taken with meals as it then reduces our stomach acid. Potassium citrate can be mixed with meals and it as well as potassium carbonate and bicarbonate have the strongest alkalizing effect of any mineral supplements.

Whether sodium or potassium is preferable for alkalizing depends on some additional factors. The following conditions favour the use of potassium:

1. A high sodium and low potassium intake as in a conventional Western diet
2. Raised and especially high blood pressure
3. Kidney problems or water retention/edema.

Sodium bicarbonate, on the other hand, is called for:

1. With low blood pressure
2. With a diet high in fruits and vegetables and low in salted foods.

Those who do not fit into one of these categories may take both alkalizers. Commonly a ratio of 2 parts of sodium bicarbonate to 1 part of potassium citrate or bicarbonate is being used, but also 1 : 1 or an excess of potassium is alright. These may be mixed and taken together in the same drink, or they may be taken separately during the day. If you use more than 1 teaspoonful then space the intake out during the day. Do not take more than 3 level teaspoons of potassium salts in a day mixed with meals as this may cause irregular heart beat.

Alkalizing with Calcium and Magnesium: A recommended way of obtaining more calcium and magnesium and at the same time alkalizing the body is to dissolve dolomite powder in vinegar or lemon juice. In the body, the organic acid tends to be broken down and converted to energy while the mineral remains to alkalize the body.

Keep in a jar several tablespoons of finely powdered dolomite mixed in a glassful of vinegar. You can stir or shake the mixture occasionally to speed up the reaction. Drink about 50 ml of the decanted liquid daily, either before one meal or divided before two meals, best diluted with water or other liquid. This supplies approximately 500 mg of calcium and 300 mg of magnesium.

The day before all the liquid is used up, start a fresh mixture of dolomite with vinegar. You can use apple cider vinegar, preferably organic, but white vinegar is adequate for this purpose as well. It is also possible to use lemon juice instead of vinegar.

Table 1-3: Calcium/Phosphorus Ratio of Foods
You can minimize inflammations by selecting foods with a high ratio of calcium to phosphorus

	Ca/P ratio mg/100 g	Ca/P ratio mg/100 g	
Bone	36,700/16,400	Dried apricots	67/108
Kelp, dry	1200/300	Raisins	62/101
Molasses, blackstrap	684/84	Sweet potatoes	31/52
Sesame seeds	1160/616	Filberts	209/337
Carob flour	352/81	Cottage cheese	90/165
Turnip greens	246/58	Salmon	188/328
Kale	249/93	Beet root	16/33
Parsley	203/63	Cauliflower	25/56
Mustard greens	183/50	Almonds	234/504
Dandelion greens	187/66	Soybeans, dry	226/554
Endive	181/54	Pumpkin	21/44
Watercress	151/54	Capsicum	12/28
Beet greens	119/40	Spirulina	396/1023
Leaf lettuce	68/25	Buckwheat	114/282
Green barley powder	1100/590	Bananas	8/26
Grass juice	150/75	Beans, dry	135/460
Spinach	93/51	Jerusalem artichokes	14/78
Broccoli	103/78	Potatoes	8/53
Cheese	750/480	Herring	66/254
Goat's milk	129/106	Eggs, whole	54/205
Cow's milk	118/93	Egg yolk	141/569
Cabbage	67/54	Lentils, cooked	25/119
Celery	39/28	Pecans	73/289
Pineapple, raw	17/8	Walnuts, English	99/380
Turnips	39/30	Coconut, dried	26/187
Grapes	16/12	Peas, dried, cooked	11/89
Butter	20/16	Peanuts	69/401
Carrots	37/36	Brazil nuts	186/693
Tofu	128/126	Barley	16/189
Grapefruit, whole	16/16	Mushrooms	6/116
Cucumber	25/27	Sweet corn	3/111
Dates	59/63	Corn, dried	22/268
Lemon juice, apples	7/10	Rice, brown	37/292
Watermelon	7/10	Cashew nuts	38/373
Pears	8/11	Millet	20/311
Apricots, fresh	17/23	Sunflower seeds	120/837
Plums	12/18	Rye, wheat	37/380
Orange juice	11/17	Oats	53/405
Onions	27/36	Torula yeast	424/1713
Peaches	9/19	Brewer's yeast	210/1753
Sardines	430/575	Bran, rice/wheat	100/1300
Eggplant	11/21	Wheat germ	72/1118
Peas, fresh	62/90	Pumpkin seeds	51/1144
Parsnip	50/77	Meat average	10/200
Tomatoes	13/27	Liver average	15/540

Dolomite supplies calcium and magnesium in the generally desirable ratio of 2:1. However, if you are already routinely using magnesium chloride or only additional calcium is required, then you can use powdered eggshell, powdered shell grit, or commercial calcium carbonate for neutralizing. A 50 ml amount of neutralized vinegar carries about 800 mg of calcium into the body.

If we took calcium carbonate or dolomite powder instead of dissolving it, we would use up our precious supply of gastric acid to neutralize and dissolve these carbonates. Many individuals have mineral deficiencies precisely because of a lack of gastric acid. If, on the other hand, we use an inorganic mineral supplement, such as calcium or magnesium chloride, then we can absorb the calcium or magnesium, but it will not reduce any overacid condition of the body.

The Calcium-Phosphorus Ratio: In a person of good health, the ratio of calcium to phosphorus in the blood is 10:4. If there is a glandular imbalance, especially in regard to the parathyroid glands (in the neck), then this ratio will be maintained at a different level, causing long-term health deterioration. In particular, a high ratio of phosphorus to calcium sensitizes the body and increases acidity and inflammatory tendencies.

In addition to this regulation by the parathyroid glands, the calcium-phosphorus ratio is affected by our food choices. If we consistently eat foods high in phosphorus and low in calcium, such as meat, oats, wheat, and corn, then this tends to make the body overacid, depletes it of calcium and other minerals, and increases the tendency towards inflammation. By selecting suitable foods, these effects can be minimized. You can judge from Table 1-2 whether you might have an imbalanced -calcium-phosphorus ratio in your blood or your food selections. A low phosphorus intake is especially helpful with cancer and leukaemia.

As you can see from the foods listed in Table 1-3, it is easy to obtain sufficient phosphorus. In fact, if the blood calcium level is high, more magnesium rather than phosphorus is generally required.

You may wonder how the body can maintain the blood ratio in favour of calcium despite its relative scarcity in our foods. The reason is that normally about 1 g of phosphorus but only 150 mg of calcium are expelled daily with the urine. In metabolic imbalance, this excretion ratio is changed. In addition, using more phosphorus leads to the excretion of more calcium together with the excess phosphorus.

An excess of up to three to one in favour of phosphorus might still be regarded as metabolically neutral. In addition to the ratio, the actual amount of the excessive mineral is important. Therefore, to an extent the generally recommended daily calcium allowance is meaningless if it is not geared to the levels of phosphorus and magnesium. With low blood pressure, your calcium intake should be about double the intake of magnesium. However, with high blood pressure it is better to have equal amounts of magnesium and calcium or sometimes even to have more magnesium. The higher the phosphorus intake, the higher your combined calcium and magnesium intake should be.

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Step 7

LIVING WATER

Living water has a great healing potential - learn how to use it.

Water, air, and food are the three main essentials to sustain life. For remaining healthy, these should be as clean and life-enhancing as possible. All three are highly polluted in our present environment, and we need to make an extra effort to improve them. Food is the most difficult aspect and is explained in later chapters. Individually, we cannot do much to improve our air, besides living in the countryside or buying an air purifier and ionizer. This leaves water in need of our attention.

Water has the ability to attract and accumulate bioenergy. Bioenergy or life-force energy is known in all traditional cultures under many different names, such as chi, ki, od, orgone, or prana. It can be seen or felt by many psychic or sensitive individuals. Water also stores an energy memory of harmful or helpful vibrations to which it was exposed in the past. This is the basis of homeopathy. Our chlorinated tap water is polluted with non-biological chemicals and negative energy imprints. It is also devoid of bioenergy and so may be regarded as being badly polluted as well as "dead."

Contaminated water can be filtered, distilled, or treated with reverse osmosis, but it remains dead unless it is energized to make it a "living" water again, one that can improve our health. While polluted and dead tap water can contribute to the deterioration of our health, living water is one of the greatest healers.

Ideally, healthy, living water should have the following properties:

- Purity: free of unhealthy chemical and biological contamination as well as negative vibrations or frequencies
- Minerals: well mineralized with calcium, magnesium, and trace minerals
- Low surface tension: due to the small cluster size of water molecules, making it a microwater
- Antioxidant activity: an abundance of negative hydrogen measurable as a negative oxidation-reduction potential (ORP)
- Vibrations: carrying positive, health-promoting vibrations
- Bioenergy: strongly charged with life force

All of these health-giving properties are naturally present in cascading, sunlit mountain streams. While it is easy to produce water meeting several of these requirements, there are some problems getting all of them in the same water. A main problem is the present lack of reliable measuring devices for bioenergy and the quality and strength of health-promoting vibrations.

Purity: This is easiest to achieve with readily available filters, distillers, and reverse osmosis. I have no strong preference for any particular method as long as you feel assured that your purified water is free of chlorine, fluoride, heavy metals, pesticides, microbes, as well as agricultural, industrial and pharmaceutical chemicals. However, most of these methods take out, in addition to the nasties, the beneficial minerals, which I recommend to put back into the water afterwards. However, there are also filters available that remove only pollutants and leave beneficial minerals in the water.

Normal water filters do not remove added fluoride but water ionizers, especially on high settings, channel fluoride into the acid water fraction so that the alkaline water becomes safe to drink. Also water high in calcium lowers the fluoride level by forming insoluble calcium fluoride.

Minerals: The minerals in our drinking and cooking water should supply a sizable part of our overall mineral intake. In living water, minerals are largely present in an energized form such as colloids and stabilized within small clusters of water molecules. I know of individuals who became badly demineralised from drinking distilled water over a long period; reverse osmosis water and rainwater (except if stored in concrete tanks) are commonly very low in minerals.

Using water low in minerals can be beneficial as a temporary measure for “calcified” individuals with high blood pressure, those who might otherwise use chelation therapy, but it is detrimental for anyone with low blood pressure. Overall, the most important bulk mineral commonly supplied with our drinking water is magnesium. Various studies show the beneficial effect of high magnesium levels on the rate of common diseases such as cancer, diabetes, and heart disease as well as bone and dental disorders.

Therefore, remineralise your purified water and add a teaspoon of hydrated or half a teaspoon of desiccated magnesium chloride to about ten litres of water. Alternatively, you can add a spoonful of sea-mineral liquid or bitterns, which is the brine left over after salt has crystallized out of seawater. In addition to being very high in magnesium, it contains all trace minerals. Instead of or in addition to magnesium, you can add an appropriate amount of commercially available colloidal minerals.

Low Surface Tension: This is a common by-product of energizing water. Water contains organized clusters of water molecules, also called liquid crystals, surrounded by large numbers of randomly moving single water molecules. In normal water, these clusters are larger and there are fewer of them. Energized or living water contains many more liquid crystals and of a smaller average size, forming cage-like structures of about six molecules. Due to this effect, energized water is also called “microwater.”

The smaller clustering causes a lowering of the surface tension of the water. It makes the water “wetter” and more easily absorbed. It also becomes more like the water in fresh fruit and vegetables and within our cells. Colloidal minerals and fat-soluble nutrients can become suspended within the water cages and more easily absorbed during digestion. Also, various biochemicals, such as lecithin, detergents, soaps, and saponins, reduce surface tension, but this is not due to the formation of microwater.

Antioxidant Activity: The principle of antioxidant activity is the availability of electrons to neutralize any so-called free radicals, which have oxidizing qualities that can damage biological systems. Living water tends to contain highly reactive loosely bound electrons that react much faster than organic antioxidants to neutralize free radicals. Most of this antioxidant activity is assumed to come from an abundance of negative hydrogen, which is also present in fresh fruits and vegetables.

Such antioxidant-rich water is now commonly produced with water ionizers as electrolytic reduced water (ERW). Alternatively, you can buy capsules of Microhydrin. This is a commercial powder containing an abundance of negative hydrogen stabilized with colloidal silica; by dissolving a capsule in water, the water acquires a high antioxidant or reducing quality.

As we age, our body structures lose elasticity; everything becomes more rigid. On a biochemical level, this increasing rigidity is due to cross-linking of structural biochemicals, which in turn is due to a loss of electrons. Providing the body with an abundance of highly reactive electrons can be expected to slow cross-linking reactions and, with this, the aging process.

All biochemical energy in our body is produced by transferring electrons from food molecules onto inhaled oxygen. Thus, having more available electrons can help us to produce more energy. This may be the reason why some individuals feel more energetic on alkaline ionized or reduced water.

A water ionizer basically consists of a cell or container with two electrodes, which are separated by a membrane to minimize mixing of the water. The electrodes commonly consist of titanium, usually plated with platinum for better resistance to corrosion. When a current is applied, one electrode becomes positive, the anode, while the cathode becomes negative and releases electrons.

Positively charged ions, such as calcium and magnesium, accumulate on the side of the cathode. They form hydroxides and make this fraction of the water alkaline. Negative ions, such as chloride and fluoride, move to the anode and, in combination with positive hydrogen ions, make this part of the water more acid. At the same time, an abundance of electrons in the alkaline water leads to the formation of hydrogen gas and negative hydrogen ions, while oxygen and active oxidizing species are formed in the acid water.

In through-flow ionizers, the amount of reducing activity in the alkaline water depends mainly on the mineral content of the water, the flow rate, and the current flow or ionizer setting. With batch ionizers, it depends on the voltage of the power source, the size of the electrodes and distance from each other, the mineral content of the water, and the duration of ionizing.

Higher mineral concentrations are desirable as they require shorter ionizing times and produce greater pH and lower oxidation-reduction potential (ORP) changes. It is advisable to use water low in calcium, otherwise the cathode soon becomes coated with calcium deposits during long ionizing periods and loses its effectiveness or frequently needs to be cleaned. While the pH can be very high in alkalinity, it is in fact very weak, because the mineral density of ionized water is rather low and easily neutralized.

The negative charge of the alkaline water declines quickly with exposure to light and air and in contact with blank metal and soft plastics. However, in closed brown glass bottles filled to the top or in a cupboard, the water can keep for days and sometimes weeks.

Aim for a high ORP of between 500 and 800 mV, which can be measured with a commercially available ORP-meter. You can ask a distributor of water ionizers or a local water treatment or testing company to check the mineral level of your water and possibly the ORP of your alkaline water. Batch ionizers are more robust and easier to repair, but they are also more labour intensive; through-flow ionizers are more convenient.

Vibrations: This is an informal term based on the observation that water seems to retain a memory of various influences to which it has been exposed. There is a close connection between vibrations and energy: we may regard vibrations as an energy imprint on the water. Retained vibrations may be due to chemical, mechanical, electrical, or magnetic influences or even to feelings, emotions, and possibly thoughts. These retained memories in turn may influence the user of the water. This is the basis of homeopathy, which double-blind studies have shown to be therapeutically valid. However, it seems that only natural ingredients can be used to make homeopathic remedies, and some scientific tests for the memory of water and the effectiveness of homeopathy failed because synthetic chemicals that cannot be energized were used.

A method to assess the vibrational purity or degree of contamination of water was developed by researchers in biodynamics. If a drop of water is added to a concentrated mineral solution such as copper sulphate, it changes its crystallization pattern. The purer or more beneficial the water, the more harmonious is the crystallization pattern and vice versa. Polluted water causes a confused crystallization pattern.

Consider the work of Masaru Emoto. In his The Message from Water and on his website (www.adhikara.com/water.html), he shows in countless pictures how the crystallization pattern of freezing water changes when exposed to human thoughts and feelings. Some of these he did by typing a positive word such as “love” or a negative one on a piece of paper and sticking it on a glass of water. The positive word induced a beautiful and symmetrical crystallization pattern, while the negative word resulted in a chaotic or confused crystallization.

As our biological body contains large amounts of water (e.g., blood, lymph fluid, cells), you may now appreciate what negative thoughts and feelings are doing to your health. In a similar way, we can improve water before ingestion by blessing it with thoughts and feelings of love, joy, and peace. We may also hold it for a moment in front of the heart while doing this. For special healing effects, you can expose water to light in coloured glass containers or cover the container with coloured cellophane. For cancer therapy, green-treated water has an overall healing and balancing effect. Yellow and orange are energizing; blue is sedating and anti-inflammatory.

Another possibility is to expose water overnight to a strong magnet. Water exposed to the south-pointing pole is most suitable for pain, cancer, and infectious or inflammatory conditions. The north-pointing pole can be used to energize weak

muscles and the digestive system, provided there is no inflammation or infection. You can also combine suitable magnet and color treatments.

Various energized waters are commercially available. While I expect these to be a great improvement on dead tap water, the energies and vibrations of uncontaminated natural ground, bore, or spring water are no doubt even more beneficial for us.

You can also keep water in a pyramid or immerse a suitable crystal or precious stone or pure gold or silver in it, possibly while the water is exposed to sunlight and/or moonlight. You can attach a magnet, crystal, or other energizing device to the water pipe to improve your shower or bath water or when filling a water bed.

Some good water filtering and energizing systems impart natural rock vibrations in combination with a vortex formation. A device can be fitted to a tap, which then produces running energized water, although the water may need to be chemically decontaminated beforehand. Another energizing system is a spiralling copper device through which the water flows.

A good way of energizing water is as follows: attach two magnets on opposite sides at the bottom of a funnel so that they face each other with unlike poles. Then pour water tangentially into the funnel so that it forms a vortex before running out into a collecting bottle.

Finally, you can use homeopathic potentising. Water and any active substance dissolved in it becomes energized by shaking it with a strong downward thrust. Use any uncontaminated water and shake it in a half-filled bottle or jar about 40 times. If possible, do the shaking outdoors, preferably on a dry, sunny day. Instead of potentising only water with its naturally dissolved ingredients, you can add a small amount of a live (unheated) substance that you believe may be good for you. Commonly used are herbal remedies, colloidal minerals, natural vitamins, or fresh vegetable juice.

Bioenergy: If we eat fresh raw food, we gain additional bioenergy. If we eat precooked or processed food and drink dead water, then our body loses bioenergy by charging the ingested food or drink from its own energy store. Rainwater is energized, especially during thunderstorms and if it comes as showers on sunny days. However, the maximum benefit is gained if the rainwater is collected and used without it touching metal. It appears that good quality rainwater has a beneficial negative electric charge (negative hydrogen ions), which is instantly neutralized by contact with metals. I recommend keeping energized water away from contact with blank metals, and I recommend the same for fresh raw food and especially fresh juices.

The simplest method for energizing water is to expose uncontaminated water to sunshine for several hours. However, a stronger charge can be achieved more quickly if the water is exposed to a source of bioenergy, such as sunshine, while it is in turbulent motion leading to vortex formations. High mineral content, especially colloidal silica, helps in retaining a high charge. Another recommended way is to leave drinking water for a while in contact with some freshly cut grass or leaves before using it.

The vortex principle is used in biodynamic agriculture for energizing liquid preparations. Use a large glass or ceramic container or a plastic bucket half-filled with uncontaminated water. Vortex energies can be absorbed into the water by first creating a deep vortex in one direction and then immediately reversing its direction until another deep vortex has formed. Stir for several minutes with a wooden handle or any suitable flat piece of wood or possibly plastic to create alternating vortexes. Electrical vortex machines are available from biodynamic sources for longer charging times.

Charging the water with vortex energy will be more successful when the air is high in bioenergy or orgone energy, such as outside on a sunny afternoon in natural surroundings. The energy is low during the night, on rainy days, in wet surroundings, and inside modern, tightly-sealed buildings.

You can also extract energy from volcanic rock dust or silica beach sand. Add a spoonful of rock dust to uncontaminated water and use the biodynamic vortex method before letting it settle overnight. Use the water while it is still milky from the suspended colloidal minerals. Most of the residue settles at the bottom and can eventually be used to fertilize plants. A stronger effect can be achieved by highly heating the rock dust or beach sand, preferably until it glows red, and then plunging it into water (in an enamel pot). Alternating several times of boiling the sand for 15 minutes (no microwave) and then freezing it is another method of liberating trapped orgone energy to energize water.

Another possibility is the use of flow forms, manufactured rock, or cement shapes in a series that simulate the action of mountain streams. From a reservoir, the water cascades through several levels of spiral formations, preferably while exposed to the sun. A recently developed energizing device is “orgonite,” a mixture of about equal parts of metal particles and resin; for more information on orgonite and bioenergy see Part 7.

Preferably do not store energized water near strong electric appliances. It also loses its beneficial energy if highly heated as in cooking. It is best to use energized water for drinking, to dilute juices, for enemas, or rubbing into the skin. Preferably avoid contact between energized water and metal. However, if you store drinking water for a longer time, you can add some colloidal silver or hydrogen peroxide to keep it free of moulds and other microbes or possibly put a piece of clean copper or a silver coin at the bottom of the container.

Our most common source of energized water is the water content of fresh raw fruit and vegetables. I expect the bioenergy of organic produce to be much higher than that of commercial produce. This is one more reason to eat your fruit and vegetables fresh, raw, and organic as often as conveniently possible.

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Step 8

THE PRACTICE OF HEALTHY LIVING

Improve your environment—your house, clothes, even your teeth.

Healthy living is the solid base for any health improvement. It includes all the habits that should become part of our daily lives. Our future well-being or diseases will arise from how we think, feel, and live habitually, not from any occasional transgressions of the rules of healthy living. The most important general principle of healthy living is to live in harmony - with ourselves, our social interactions, and with the forces of nature. In regard to health and natural living, this concept encompasses our environment, housing, clothing, workplace, exercise and nutrition, the water we drink, and the air we breathe.

In the following section, we will investigate various aspects of healthy living. It is important to realize that the concepts of healthy living often overlap with specific healing methods; for example, positive thinking, nutrition, reflexology, and physical exercises may all be used for normal healthy living as well as for healing yourself. Therefore, when reading this book, keep in mind that the separation between healthy living and healing methods is fluid, even somewhat artificial.

At present, most of us live in such an artificial and unnatural environment that it is not possible to remain healthy by living in the -commonly accepted way. Instead, we must become aware of the multitude of negative influences in our environment created by modern technology and try to minimize their harmful effects on us.

Improve the Physical Aspects of Your House: When building a new home, preferentially select building materials that do not shut out or distort the natural electric, magnetic, and life-force fields of the Earth. Therefore, minimize sheet metals and any steel or wire-mesh concrete reinforcements that form a cage-like structure (called a Faraday cage). Stone, brick, tiles, shingles, wood, plywood, and combinations of fibre and cement are acceptable for building. If you live permanently in a metal-clad dwelling, such as an aluminium caravan or mobile home, it is better to sleep in a non-metal annex.

Here are some practical tips:

- New copper or plastic water pipes may leach undesirable concentrations of heavy metals into the water. This is another reason, in addition to avoiding chlorine and fluoride, to use a good filter for your drinking and cooking water.
- Make your home a low-pollution sanctuary. Use natural materials for interior use whenever feasible, especially in the bedroom or wherever you spend most of your time. By far the best mattresses are those made of latex.
- Avoid cooking and heating inside with gas or kerosene except if the combustion gases are being efficiently vented. Many people are allergic to these. Wood stoves or solar heating are preferable wherever feasible.

- If you live in a modern house, try to sanitize it by minimizing the use of synthetic items that release or outgas chemicals, such as formaldehyde from glued material (many carpets, chipboard, and plywood).
- Avoid solvents and odorous household cleaners and disinfectants, tobacco smoke, mothballs, and insect sprays. If the outside air is reasonably clean, good ventilation helps to minimize the problem of indoor air pollution.
- New synthetic materials have a tendency to accumulate static electricity that can reduce our well-being in addition to releasing toxic chemicals. Synthetic materials (as well as television sets) also lower the amount of beneficial negative ions in the indoor air. Negative ions are energetic molecules with additional electrons in the air. Generally, the more negative ions there are in the air, the better we feel. Commercial air ionizers are available to improve room air.

Consider the Health Aspects of Your Clothes: Clothes are our "second skin," and their material and color have a direct influence on our emotions and well-being. This applies especially to garments worn directly on the skin. Except for occasional short-term use, avoid underwear, including pantyhose and stockings, made of nylon or other synthetic material. They do not absorb moisture or "breathe" as well as natural fibres and appear to encourage fungal growth; sensitive individuals may experience skin irritations. Nylon seems to be worse in this regard than polyester. Synthetic clothing can also cause discomfort by accumulating static electricity. A more acceptable human-made fibre is rayon, as it is based on cellulose. The best material for underwear and stockings is silk; otherwise, use cotton.

Generally, select colours that balance your emotional state: wear bright colours when you are low in energy and blue when you are nervous and irritable. Avoid murky and dull gray colours and be extra careful with black; these can increase depressive tendencies in susceptible individuals. Commonly, the negative effect of black is balanced by combining it with red. You can use muscle testing as described in Part 2 to discover whether a certain material or color is suitable for you.

Shoes ideally should be made of natural materials with a leather sole to allow static electricity to flow off the body and into the ground. This is prevented by rubber and synthetic soles and by nylon socks and stockings. Walking barefoot for at least several minutes each day on moist grass or wet sand will discharge static electricity into the ground and improve well-being.

For women, it is advisable to reduce the time you wear a bra. A study reported by Singer and Grismaijer in Dressed to Kill found that women who wear a tight bra all the time had a 125 times higher rate of breast cancer than women not wearing a bra. Women who wore their bras 24 hours a day had a 75 percent chance of developing breast cancer. If they wore bras more than 12 hours daily but not to bed, the risk was one out of seven. Wearing a bra less than 12 hours per day improved the risk to one out of 152, a rate reasonably close to women who wear bras rarely or never; they have a one out of 168 chance of breast cancer. Women who never wear a bra have the same low breast cancer risk as men.

While this study was not adjusted for other factors, the difference in cancer rate is certainly large enough to be significant. A tight bra blocks the lymph circulation in the breasts and is much worse than a loose-fitting bra. If you need to wear a bra in

public, use a loose-fitting one without underwires and minimise using it at home. Also do some exercises to stimulate the lymph flow in the breasts, such as circling your arms or massaging the area around the breast while doing inversion exercises.

Sanitize your Bedroom: Preferably use mattresses (futons) filled with natural fibres such as kapok, wool, horsehair or cotton; latex or natural rubber may be the best material. A cheap alternative is straw or hay from a pesticide-free source. Innerspring mattress may direct confused magnetic fields into the body, depending on how the spirals have been tempered. When moving a compass across the surface of the mattress the needle should not be deflected from its north-pointing position.

Synthetic foam rubber mattresses are not good either. They emit toxic gases that may be a major factor in cot death. Wrap them in clear polythene with only a small opening at the bottom. Use natural blankets and sheets on top of the mattress. Even sheepskin is chemically treated and can cause problems. Frequently expose pillows and featherbeds to the sun to kill moulds and dust-mites. This can greatly reduce asthma problems. Alternatively, use an airtight pillowcase.

Try not to use steel-framed beds or steel-spring frames that deflect the compass needle, move the bed if there are metal beams or live wires in the wall behind the bed. Featherbeds may contribute to arthritic problems due to static electricity between the feathers. Try to sleep with the head in a northerly direction or otherwise between north and east. Our brain waves are slowest when the head points towards magnetic north. Cover your head during cold nights to minimize heat loss.

Sleep in total darkness or cover your eyes during sleep, as production of beneficial melatonin is interrupted by exposure to electric light, including street lights, although moonlight and red light are harmless. Avoid even short exposure to electric light in the first part of the night.

Minimize Electromagnetic Pollution: Strong electromagnetic fields (EMF's) of about 50 to 60 cycles per second (hertz, or Hz) and the related electromagnetic radiation (EMR) may be harmful to us. Long-term exposure can aggravate any existing health problems or diseases and may cause or intensify them; this is especially true of lack of energy or fatigue, irritability, aggression, hyperactivity, sleep disorders, and emotional instability. Increasing numbers of individuals are becoming hypersensitive to EMR; many can feel the electricity going through their body and may experience disabling symptoms such as convulsions, memory problems, and depression. I have encountered many of these problems with patients.

Chronic exposure to high levels of EMR, especially while asleep, is a constant drain on our vitality. It creates chronic stress, which interferes with the regeneration and healing that normally take place during a good night's sleep. You may compare it to always swimming against a strong current, and this may well make the difference between recovering from a serious disease and succumbing to it. For more information on health problems due to electricity and many case reports, see: www.emrsafety.8m.net.

EMR exists around power lines, power tools, electric stoves, heaters, boilers, freezers, and television sets when in use, extending several feet or yards around the appliance. Stay away from them, if possible. Using an electric iron or an electric

keyboard or working with handheld power tools can quickly drain our energies. When working with electrical equipment, we can reduce harmful effects by holding our hands under running water from time to time, in addition to having a shower in the evening or walking barefoot on grass.

Try to minimize electromagnetic pollution, especially while sleeping, when the pineal gland is most susceptible. Also sleep in the dark or at least cover your eyes to produce the immune-stimulating hormone melatonin. Before going to sleep, preferably switch off all power points in the bedroom and unplug all electric leads with two-prong plugs, especially any power points or leads close to the bed. This applies also to water beds, which need to be switched off or unplugged overnight. Three-prong plugs may remain connected to power points because this allows stray electricity to flow off through the grounding connection.

Increasingly governments insist that we get maximum exposure to harmful fluorescent lighting in the form of compact fluorescent light or CFL. The flickering, even if not perceptible, electromagnetic "noise", and the unnatural frequency distribution of CFL's frequently cause health problems for sensitive individuals. Most affected are those with vision problems, autism, migraines, traumatic brain injury, vestibular problems, multiple sclerosis, muscle spasms, epilepsy, tremors, cardiac arrhythmias, memory loss, diabetes, difficulty concentrating, and lupus. For details see www.cflimpact.com.

Here are some more tips:

- If your head faces a wall with power points or other electric wiring inside the wall close to the bed, then move the bed towards the middle of the room so that you can walk around the bed. The best sleeping position is with the head towards north or otherwise somewhere between north and east.
- When using an electric blanket, warm the bed beforehand and disconnect the power before you go to bed or better still, connect the blanket to a good earth. Do not habitually remain within a few meters of a working electric appliance, and minimize fluorescent lighting, watching television, using video games, computers, and even electric typewriters and handheld electric tools.
- Stray currents and radiating fields can still be emitted from electric wires even if appliances are switched off. AC electric fields do not disappear when an appliance is switched off, only AC magnetic fields disappear. Keep live wires away from your body. Preferably do not live near high-voltage lines, microwave towers, or electric-train tracks. Alternatively, you may take extra precautions to shield your house from the effects of their energies.
- Old fashioned TV sets and computer monitors emit harmful X-rays. Preferably sit as far away as conveniently possible. Flat or liquid crystal screens are much safer. An increasing hazard is microwave radiation from ovens, mobile phones, cordless phones and keyboards and other equipment. Most dangerous are long-reaching microwave stations inside the house for phones and computers, or equipment such as a mouse or keyboard that are not connected by wires, but USB modems for wireless broadband are harmless.

Electro-Proofing Your House: The measures outlined so far will go some way towards reducing the harmful effects of EMR on your health. However, often they are

not enough. There is a simple way to check whether your home and workplace are sufficiently safe. You can do this by measuring the electricity that is absorbed by your body. For this you need a digital voltmeter that can measure millivolts.

Get some insulated electric wire that is long enough to reach from most rooms to the ground outside and attach an alligator clip to each end. Then get a ground stake or earth spike (a copper pipe is good for this) and drive it into moist soil. One end of the wire is clipped to a clamp at the top of the ground stake and the other to the black probe of the voltmeter. It will not work to attach the earth wire to a water pipe or to the main electricity ground stake of the house as they may carry high voltages.

To close the circuit, hold the metal end of the red probe firmly in one hand. However, it is more convenient to hold a piece of copper pipe, which is connected through a clipped or soldered insulated wire to the red probe. Set the dial to 2 AC volt; if it shows less than 200 mV, that is good and you can switch the meter to the 200 mV setting. Preferably the reading should be below 100 mV in commonly used rooms, and on your bed, below 10 mV.

In reality the readings will be much higher and you may get a reading between 2 and 80 V while lying on your bed. This is a constant drain on your vitality. By moving the bed away from any electrical wiring, you can perhaps get it to read between 500 mV and 2 V. A relatively easy way of reducing the voltage a lot further is by using a grounded electric blanket.

The easiest way is to cut off the plug. Then you can easily solder or clip a ground wire onto all three wire strands. If you want to keep using the electric blanket for heating as well, then you can attach a plug to the ground wire. Lying on a well-earthed electric blanket can bring the body voltage down to between one-quarter and one-tenth of the previous measurement.

If the bed has a steel frame or innerspring mattress, then these may also need to be grounded. Commonly all springs are internally connected and need to be grounded only at one point, but some mattresses have individual springs, which would need to be grounded individually. However, steel frames and inner-spring mattresses can still deflect the compass needle when it is moved across the bed and that is not good either. It is healthier if the earth's magnetic field is not distorted where we sleep. The needle should continue pointing north everywhere over the bed. Metal beams in the wall or ceiling can cause the same problem, and the bed should be moved far enough away from magnetic field disturbances.

Ground any metal parts, such as window frames, metal wall claddings, or roofing iron, that show an unacceptably high reading when touched with one hand while holding the grounded probe in the other. This is especially the case if there are high-voltage power lines, microwave towers, or transformers nearby or power lines that form a right angle at street corners.

Occasionally, there may be so much ground electricity that it shows a higher reading when you're lying on a grounded electric blanket than on one without a ground connection. In this case, move the ground stake as far away as possible from any power sources that can cause this problem and find or create a good grounding behind the house where you can reach moist soil with a long ground stake. With a

short ground stake, try to keep the soil around it moist at all times. It is also possible to get a good ground by connecting the wire to a moist part of a tree or large outside plant.

To get a true reading on a concrete floor or when outside the house, you should be insulated by wearing shoes; otherwise, the reading will be much too low.

For sanitizing an apartment or office in a large building where you cannot get a good ground, a ground connection to the water pipe may be sufficient, or you could get expert help. An upper floor of a building commonly has much higher voltages than the ground floor, as there is wiring in the floor as well as in the ceiling. In this case, you may be able to reduce the EMR considerably by placing grounded wire netting under the carpet. If this is not possible with the entire floor, then ground a smaller area where you usually sit.

In other cases, it may be advisable to shield and ground the wiring inside a wall. This is much more difficult, as wall panels need to be removed, but it may be relatively easy under the roof or if the wiring is under the house. You can simply wrap electric cables with grounded wire netting or aluminium foil or nail grounded metal strips over them.

You can also disconnect the fuse or switch in the meter box for the bedroom (which commonly includes all power points in the house) overnight. Alternatively, have a separate fuse switch installed for the bedroom only or a demand switch that supplies power to the circuit only when needed. In addition, strategically placed copper coils can deflect radiation and may be used to de-stress the whole house. Such coils are offered on the Internet.

To improve your well-being while driving, and avoid road-rage or fatigue earth the inside of your car by leading the electricity from metal frames of seats and large metal areas back to the negative pole of the battery.

Beware of Earth Rays: Some dowsers claim to have discovered harmful earth rays from fault lines and underground streams under the beds of most cancer victims. Earth rays may also aggravate many other diseases. Find someone who is able to check the location of your bed for harmful underground radiation. This can be a problem even if you sleep on an upper floor. Commonly, dowsing or muscle testing (kinesiology) are used. Geopathic disturbances (another term for harmful earth rays) can also be detected with a scientific instrument that indicates the degree of distortion of the local geomagnetic field.

If you cannot have your bed checked, then move it to a different location if you were sleeping there before a serious health problem developed. In addition, use a shielding device under the bed: place wire netting under the whole area of the bed and connect this to an electric ground. To protect against fault lines or ley lines, you can also cover the area under the bed with several centimetres of quartz sand and use additional copper coils; moving the bed is the safest option. You may be able to check the bed yourself with a shortwave radio, because over a fault line the reception deteriorates; especially dangerous are crossings of fault lines.

Table 1-4: Teeth–Organ Connections

Teeth are numbered from 1 to 8 starting at the midline of the upper and lower jaw.

1 and 2 upper and lower jaw	kidney, bladder, pineal gland (upper), adrenals (lower), frontal sinus, sacrum, coccyx, foot
3 upper and lower jaw	liver, gallbladder, hip, eye, pituitary (upper), gonads (lower)
4, 5 upper and 6, 7 lower jaw	lung, large intestine, shoulder, elbow, thymus (upper), arteries, veins (lower)
4, 5 lower and 6, 7 upper jaw	pancreas, spleen, stomach, breast, thyroid (upper), lymph system (lower), jaws, front of knee
8 upper and lower	heart, small intestines, shoulder, elbow, ear, nervous system, pituitary (upper)

Dental Problems: Another aspect of our environment is our mouths - our teeth, specifically. A major factor causing or contributing to poor health and many diseases is our teeth. Frequently, there are mercury amalgam fillings or different types of metal in the mouth that act like an electric battery, and dead teeth with filled root canals or inflammation inside the jawbone (cavitations) even after removal of teeth are also a serious health problem. These problems may not cause any local pain and so are difficult to detect, but they can cause health problems in other parts of the body. Through acupuncture meridians as well as other mechanisms, each tooth is connected with a specific organ or other part of the body as shown in Table 1-4, so health consequences of problem teeth can occur throughout the body.

Heart disease, for instance, is commonly connected with inflammations or infections in the wisdom tooth positions, while kidney problems are related to the front teeth. This has been known for a long time. A 4,000-year-old papyrus describes the dialog between the pharaoh and his physician. The pharaoh complains of severe arthritis, and his doctor replies that this is due to the bad condition of some teeth that need to be removed. Even orthodox medicine is now slowly catching up and realizing that heart disease is frequently associated with microbes originating from infected teeth, gums, or jaw bones.

Root-canalled teeth appear to be a major contributing factor in many health problems, not only cancer but also heart disease, kidney disease, and autoimmune diseases. This is due to microbes that multiply in the multitude of tiny canals or tubuli in the dentine and gradually leach out into the lymph system. Even normally harmless microbes become very dangerous under the anaerobic conditions in dead teeth.

Weston Price, a dentist and former director of research for the American Dental Association some years ago, observed that the removal of root-canalled teeth from

patients with kidney or heart disease would in most cases lead to an improvement in those conditions. When he inserted a removed root-canalled tooth (human) under the skin of a rabbit, the animal would die within two days; when he implanted normal teeth, there was no adverse health effect. In some experiments, he implanted the same fragments of root-canalled teeth in succession under the skins of up to 100 rabbits and they all died within two weeks of the same disease that the human donor had!

The safest solution with dead (root-canalled) teeth is immediate removal, but problems might still persist if an infection has spread to the jawbone. The microbes in dead teeth and infected jawbones apparently cannot be eliminated with pharmaceutical or natural antibiotics. Removal of dead teeth is especially urgent if they are already dead for several years and show signs of deterioration, and also in the case of cancer, autoimmune diseases, and other serious diseases. If you cannot immediately have all your dead teeth removed, have some, and for several weeks after their removal, use natural antimicrobial therapy. You do not need to fill single tooth gaps where they cannot be seen. To fill the gap of a missing front tooth, find a dentist who can cement an artificial tooth in this place without resorting to crowns or other metal support.

A possibly safe way of keeping root-canalled teeth is to fill them with Calcium Hydroxide or Iodine instead of the commonly used Gutta Percha, but no long-term studies on health outcomes are yet available. For tooth implants Titanium is commonly used but this is a metal and can still sometimes cause problems. A safer alternative with good durability is Zirconia, the dioxide of zirconium.

Try to have amalgam fillings replaced with plastic composite, preferably by a holistic dentist. A rubber dam and suction should be used when removing old fillings. If you cannot pay for proper replacements, just have them sealed with temporary filler and do not chew any hard items. However, with serious conditions and large fillings, extraction of amalgam-filled teeth can bring much better results than simple replacement.

In a German study of multiple sclerosis patients, extraction of compromised teeth resulted in an 85 percent recovery rate versus only 16 percent for filling replacement alone. Other studies have found that recovery from serious autoimmune diseases, dementia, or cancer may require more aggressive mercury removal techniques than simple filling replacement, due to the body burden of mercury. This appears to be due to the migration of mercury not eliminated by simple filling replacement into the roots and gums. Mercury in the teeth and gums has direct routes to the brain and central nervous system.[3]

Try to find a dentist who is familiar with safe amalgam removal procedures as recommended by holistic dentistry associations. Remove mercury by using high doses of vitamin C, Alpha Lipoic Acid, L-cysteine, MSM and chlorella before and after amalgam removal. Preferably, also use homeopathic mercury 1M and higher potencies.

Injections of the mercury chelator DMPS can be administered by qualified health professionals. However, this procedure has occasionally lead to complications and the oral DMSA is less expensive and apparently safer. Nevertheless, both of these chelators can activate very high mercury levels from the bones and cause serious

problems, especially in sensitive individuals and neurological diseases. Therefore, I generally prefer the slower but safer method of using careful cleansing diets together with detoxifying natural supplements.

The pink color of dentures may be due to heavy metals, possibly mercury or cadmium. If you cannot get a guarantee that the colouring is free of heavy metals, it is safer to ask for clear plastic dentures made of methyl methacrylate or flexite for partial dentures. Use plastic denture teeth rather than porcelain teeth that have a metal base. Bridges and metal partials should be changed to clear plastic partial dentures. Nickel, as in stainless steel, can suppress the immune system and is generally classified as carcinogenic.

Even dental gold can be a problem because it is commonly blended with 20 percent of the more harmful palladium. A small amount of gold as for one crown may be acceptable, but as a general rule keep your mouth free of all metals and make sure only metal-free plastics are used as replacements. Nevertheless, any metal in the mouth can lead to allergies, and on average about 30 percent of individuals are allergic to the dental metal in their mouth.

After removal of bad or dead teeth, health problems can still arise or continue from root or metal fragments or due to chronic infection and inflammation in the jawbone. An experienced dentist can discover this with panoramic X-rays. If you cannot do all of this to sanitize the inside of your mouth, just do the best you can and do not worry. Compensate for any shortcomings here with a better diet and positive thinking.

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Step 9

EXERCISE

Get into the habit of exercising regularly.

Adequate physical activity is one of the main requirements for achieving and maintaining good health. Deep breathing while exercising is essential: Lack of oxygen - becoming breathless - is harmful. You have probably heard of aerobics. Aerobic exercises are those that can be maintained for long periods because the heart and lungs can supply enough oxygen to the muscles. If insufficient oxygen reaches the muscles, the exercise becomes anaerobic and causes a harmful buildup of lactic acid in the tissues; this is commonly noticeable as sore muscles. Therefore, when exercising, breathe more vigorously than required for the activity at hand; increase the intensity of your exercises only gradually.

Arm and leg muscles should be regularly exercised. Supplement cycling, walking, and jogging with push-ups; swimming in unchlorinated water is also good for this. When jogging without running shoes, touch down with the ball of the foot and use your ankle joints as cushions. By using these springs freely provided by nature you cause less damage to your joints.

Everyday Physical Exercises: Depending on your body needs and inclinations, you can perform many different exercises. The more important ones are stretching, hanging from the hands or feet, using a rebounder, circling the pelvis, head-and--shoulder stand, isometric exercises, scalp and face exercises (pulling faces, tensing and relaxing scalp muscles), shaking to loosen the body, and slow graceful and rhythmic movements with (or without) music. Hatha yoga exercises are excellent for stretching and massaging the internal organs.

During the day, frequently stretch, tense, circle, or shake your muscles. Select a time of the day or week for a more thorough workout. With advancing age, stretching your muscles becomes increasingly more important. Lie on a large bed or carpeted floor and move your limbs and spine in various positions to the limits of their range, and then stretch them a bit farther. Try to let your body move on its own without much mental direction. Do what feels good.

Rejuvenation Exercises: The following five exercises were first presented in Ancient Secret of the Fountain of Youth by Peter Kelder. They are effective for strengthening glandular activities and may help to rejuvenate the body if practiced faithfully every day. Deep breathing during and between exercises is important. Inhale and exhale during the slow movements between the two end-positions as shown in Figure1-1.

Hold your breath in each end-position and tense all your muscles with maximum effort. In one position, press the chin to the chest and pull the abdomen inwards and up; in the other position, drop the head back as far as possible.

Pull your stomach in with your exhale in the lying position (Fig. 1a); in the forward bending position (Fig. 1b); while sitting (Fig. 1c); and with the pelvis raised

(Fig. 1d). Start with a few exercises daily and gradually increase to 20 of each, but do not strain yourself.

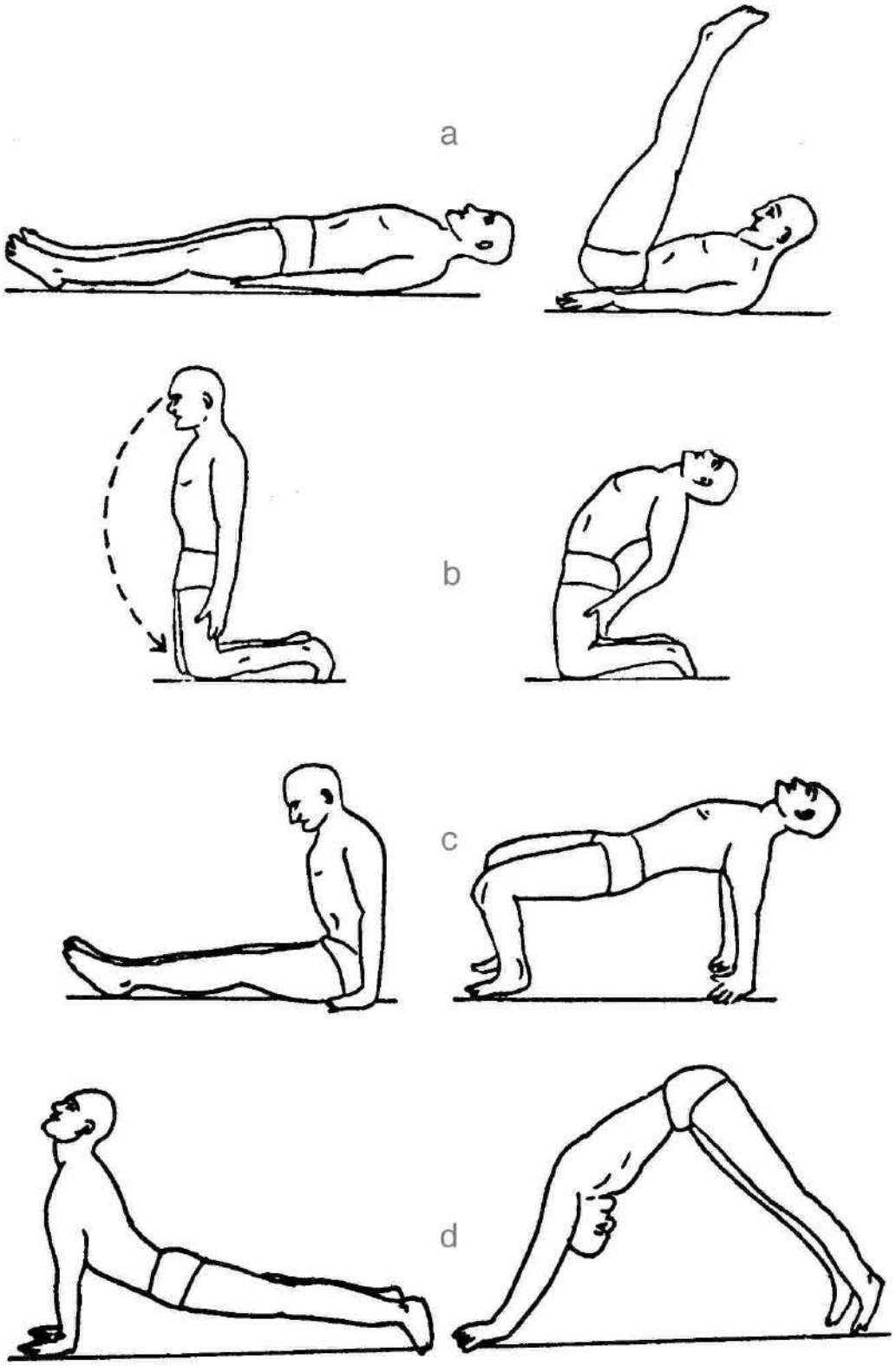

Figure 1-1: Rejuvenation Exercises

For a fifth rejuvenation exercise, spin or whirl 20 times with horizontally outstretched arms. In the Northern Hemisphere, the instructions are to spin clockwise; I have the impression that in the Southern Hemisphere anticlockwise spinning is preferable. However, you may choose to spin in whichever direction makes you feel better; use muscle testing to see what is best for you.

Inversion Exercises: Hanging upside down by your feet strengthens the internal organs, drains lymph fluid from the lower part of the body, and flushes the brain and face with blood. This exercise is especially good to delay or reverse symptoms of aging. While in the inverted position, rhythmically tense and relax the muscles of the face and neck and then the whole body. You can use inversion equipment that lets you hang straight upside down, or a slant board that puts you at a 30 to 45 degree angle. If you are sufficiently athletic, you can also do a shoulder stand, headstand, or handstand against a wall. You can do bicycling movements while in the inverted position.

Caution: Do not invert yourself if your blood pressure is high and requires medical attention.

Muscle Tensing: Tense and release one muscle after another, starting with one foot, then the other, working up towards the top of the head. Inhale deeply, each time gradually increasing the tension; hold for a few seconds, then slowly release the tension while exhaling. Finally, tense all your muscles, starting with the feet and moving up to your neck; simultaneously inhale deeply. Hold the whole body tightly tensed for several seconds; then gradually release the muscles, starting with the neck, and moving down to the feet, exhaling simultaneously.

If a particular organ or limb is weak, focus on it with repeated cycles of tension and relaxation. Frequent tensing is especially important if you have to stay in bed for a prolonged period. Do this exercise repeatedly during the day, whenever you remember it. Tensing may be done in any position such as sitting, standing, or lying down. It is easy to do while sitting at a desk all day: just take a deep breath, hold it for a few seconds while tensing the whole body simultaneously, then relax during exhalation.

Head and Neck Exercise: Slowly, but firmly, bend your head three times in each direction, forward, backward, and sideways; try to let the head drop to each side. Then move the head in circles, again slowly and firmly, three times in each direction. This is excellent for strengthening the neck and is helpful in cases of head congestion, eye and ear problems, and recurring headaches. In addition, you can circle the head up to 100 times in each direction.

Body-Mind Exercise: Slowly move a stiff joint several times to the limit of its range. Then imagine the same movement but with an extended range; repeat this several times. Then move the actual limb again and see whether its range has improved. The actual movements are easier if performed during slow exhalation.

Rebounding and Lymphacising: Rebounding may be better than jogging, especially for those low in energy. You could even bounce on top of one or two innerspring mattresses.

While you may develop a routine with various bounces, you can also use a lymphacising program instead of this or in addition to it. This is designed to greatly

speed up the lymph circulation while energizing your body at the same time. While lymphacising, remain with both feet firmly on the rebounder mat. Bounce gently up and down, starting with just a few minutes and gradually increasing up to 10 or 15 minutes, three or four times daily; it is best done before meals and bedtime, and the more often the better.

Keep your hands touching body areas in need of healing, such as a tumour area, liver, kidneys, or wherever you feel discomfort. With each upward bounce, take a sniff until your lungs are filled after ten to 20 sniffs, and then exhale again in sniffs. Always try to fill and empty your lungs as completely as possible. If you do it right, you should feel energized after the exercise.

Practicing "Good Use": F. M. Alexander, the Australian formulator of the Alexander Technique, developed the principle of "good use." It means using your body efficiently and with ease, maintaining maximum balance and coordination between all of its parts. Most of us use our body poorly most of the time. By learning good use, we can harmonize our posture and movements, and with this improve our spine, muscular structure, even the functioning of our internal organs and glands. To learn good use, we concentrate mainly on the way we sit, stand up, sit down, walk, and breathe.

Start by exploring your present use in front of a mirror: Observe how you move your head from side to side, up and down, how the shoulders move, how you talk and breathe. Then try to practice the basic movements of good use: Move your head up and away from the torso, but at the same time let the whole body ease upwards in a movement that flattens and lengthens the spine.

When turning the head, moving it up or down, standing, sitting, walking, or lying down, always let the head "float up," which means away from the body and in line with the spine. This is not just a position to be maintained but part of a continuous process of easing the head up to lengthen the spine.

When you look at yourself at eye level, the neck should be straight and the chin down. Watch that the back of your head is not dropped backward where it will produce a hollow where the head joins the neck. Except when intentionally tilting the head, there should be no hollow at this point. Watch that your head remain up and your neck straight while you talk, sit down, stand up, or move in any other way. Instead of directly moving your head upwards, think and feel it floating up. Let the move be manifested through this thought and feeling.

Standing and Sitting: Another important aspect to watch is that your muscles be relaxed when at rest. When standing, feel that your eyes, jaw, shoulders, and abdomen are relaxed; when sitting, do the same for the thigh and calf muscles. Check repeatedly because these muscles have a tendency to tense when we do not watch them. Do the same when lying down: Check that all your muscles are relaxed.

When sitting down or standing up, your back and neck should remain in a straight line. Only the joints at the ankles, knees, and hips should bend. When standing up, lean forward by having your body follow your head. In this way, bend at the hips, which creates a momentum that lifts you off the seat and brings you onto your feet without any effort. Now you only need to straighten the three lower joints and you can stand in front of the chair.

Exactly the reverse procedure takes place when sitting down. The arms are not used in any way to push or swing when you're standing up or sitting down. When sitting, keep your head moving upwards in order to counteract the tendency to slump. Check yourself frequently to be sure you sit straight but relaxed. When lifting something from the floor, keep your back and neck straight and bend only at the ankle, knee, and hip joints.

Walking: When walking, touch down lightly with the full foot, not just with the heel. While the other foot is brought forward, the whole body weight now rests on the foot on the ground. Start rolling your weight off this foot by lifting your heel. In this way rise onto the ball of the foot and even onto the toes. This creates a strong momentum that propels you forward without any effort. Repeat the same process with the other foot.

The important part of walking is rising onto the toes, which gives you a light, bouncing step, as if you're walking on air. Your spine and neck remain in a straight line, your shoulders relaxed. The arms swing gently, as opposite arm and leg move at the same time. When climbing steps, rise onto your toes in the same way as for walking. (For more information, see "The Complete Guide to the Alexander Technique" and other information at www.alexandertechnique.com.)

Correct Breathing: Generally, we breathe just enough for the activity at hand. However, to prepare for action it is beneficial to supercharge your body with oxygen by breathing more deeply than you need. This makes you more energetic, helps to cleanse the body, and neutralizes overacid conditions. Practice deep breathing in fresh air. Watch that during normal breathing your lower rib cage is moving. However, during sedentary activities it is preferable to breathe as slowly and deeply as possible. This helps to relax both body and mind. Therefore, by deliberately over-breathing we create useful tension, and by under-breathing we practice relaxation. Here are some tips on breathing exercises:

Watching the Breath: This is a relaxing exercise to still the mind. Mentally follow the breath flowing in and out but without any attempt to control it.

Full Breath: Inhale for several seconds, consciously filling first the lowest part of the lungs, causing the abdomen to lift. Then expand the middle part and finally the upper part of the chest. Hold the breath for several seconds then slowly release it, starting with the upper chest; end by contracting the abdomen. After about four seconds, start a new cycle.

Abdominal Breathing: This is important for people with breathing problems. Place a hand on the abdomen and feel it rise and fall without your chest moving. Adopt abdominal breathing whenever an acute breathing problem develops.

Long Exhaling: This is good for people with obvious or hidden anxieties and for those who need to establish a proper orgasm reflex. While standing, exhale for about ten seconds in one continuous sweep. Near the end, the shoulders move forward, the buttocks press together, and the pelvis moves forward and upward in an involuntary movement. A long, gentle exhalation also helps to relax body and mind and may be used to direct energies and relax specific muscles. Inhale quickly in about one or two seconds and then exhale slowly for about ten seconds. During exhalation, focus your attention on a specific part of the body and imagine the breath

energy flowing into it, making it feel warm and expansive. Use this to reduce muscle tension and pain or to relax the whole body, starting with the feet and gradually working your way upwards to the head.

Super-breathing (Hyperventilation): This is to quickly saturate the body with oxygen. Quickly and deeply—at the rate of about one or two cycles per second—inhale through the nose and exhale through the mouth. Stop when you begin to feel dizzy. A slower, but more sustained form of super-breathing, done through the nose only, can be adopted during energy healing, or before and during heavy physical work or exercises.

Hara Breathing: Sit or lie, relaxed, with the hands folded as in prayer or over the abdomen, left palm on the navel, right hand on top. Inhale gently through the nose, hold the breath, and exhale through the mouth; each period lasts five seconds. While inhaling, touch the roof of your mouth with your tongue. Accompany this with abdominal breathing. Envisage with each breath that life energy fills the abdomen; feel it as warm and tingling. Hara is a Japanese word for the centre and storehouse of vital energy located just below the navel.

Alternate Nostril Breathing: This is helpful for balancing body polarities. Close the right nostril with a finger and inhale through the left nostril, then close the left nostril and exhale through the right nostril. Inhale through the right nostril, and exhale through the left one, and so on. Several rounds of this are good at the start of meditation.

Eight–Two Breathing: This may be used for stilling the mind and emotions during meditation or spiritual healing. Inhale for a count of eight, hold for two, exhale for eight, hold for two, and so on. The flow of the breath should be smooth and harmonious.

Skin and Organ Breathing: For improving a particular part of your body, imagine and feel your breath moving through this part during inhalation and exhalation. As an example, for improving the liver, feel the breath as a cool stream penetrating your liver. When holding the breath, feel a slight pressure in the liver area and an increasing warmth.

Vocal Exercises: Sounds have a strong influence on us, and music particularly can have a profound effect on our emotions. Mantras (special words or sounds) are used in certain techniques of meditation to achieve particular effects. Much stronger is the impact of our own voice on our body. If properly pronounced, each vowel produces a vibration in a specific body part, mainly the large cavities. If you cannot feel a resonance vibration, just imagine it.

Produce the sounds as clearly as possible. Take a full breath and sing each vowel forcefully in different intonations. If your voice is low and deep, try to produce the sounds in the front of the mouth; if you have a high-pitched voice, make the vowels vibrate deeper down the throat.

Feel the resonance of each vowel in the indicated body cavity. The lower the body cavity in which you want to experience the sound, the deeper or lower you should try to make the sound. Initially, use each vowel in turn, then concentrate on the ones most appropriate to your condition. Select and use vowels according to resonance areas. A high-pitched “I” sound may be used to stimulate the brain as well

as the pineal and pituitary glands. Imagine the sound vibrating from the centre of your brain.

Vowel Resonance Areas

This table shows the correct intonation of vowels and the body cavities, which they stimulate if properly performed. Try to grade the vowels with the highest note for “I” and the lowest for “U”

I	Bee	Head
E	Fairy	Throat
A	Father	Upper Chest
O	Coma	Lower Chest, Upper Abdomen
U	Zulu	Lower Abdomen

If you make the sounds properly, you will feel the vibrations in your throat and mouth and possibly in your lips and cheeks as well. When you leave a tiny gap between your teeth, you should be able to feel them vibrating strongly. This effect is usually strongest with the “m” or “om” sound. Also try to vibrate your tongue with a rolling “r” sound. If correctly done, you can feel these vibrations energizing the whole structure of the head, bones as well as tissue.

Instead of sounding “om,” you can intonate “a-u-m” or “a-o-u-m” in sequence with the same breath. Gradually lower the sound, and try to feel the vowels vibrating in the appropriate resonance areas. Feel the “m” sound moving up the spine with the pitch gradually rising higher, ending at the centre of the brain.

Singing is an excellent vocal therapy, so try it often. Listen to stimulating, sedating, or uplifting music according to your needs. Lie down in a relaxed position and become fully immersed in the sounds. Feel something inside you moving, expanding, rising in resonance with the music. Try singing along.

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Step10

THE HEALING CRISIS

**Sooner or later you are bound to have a healing crisis,
so use it to your advantage.**

Even on their first clinical visit, I routinely recommended that my patients adopt a high-quality, low-allergen diet. When they came back two or three weeks later, they often said they felt much better but that a week earlier they had had a cold. When asked about the symptoms, these turned out to be mainly a profuse mucus discharge or sometimes diarrhoea, but rarely were there signs of infection. These patients had experienced their first healing crisis on their path to better health.

This shows us the general principles of a healing crisis. With each crisis or reaction, there is a temporary worsening of the condition, with either new symptoms appearing or existing ones getting worse. This is the result of toxins being mobilized for elimination by the body in what is clinically known as the Herxheimer effect. However, after the healing reaction, we reach a higher level of health than before.

This concept of a healing crisis clearly shows the opposite perceptions in drug-based medicine and holistic medicine regarding health and the healing process. In drug medicine, it is assumed that a patient who is free of disease symptoms is more or less healthy, and the aim of drugs is to achieve this condition by removing disagreeable symptoms. Frequently, alternative medicine is used in the same way; instead of toxic drugs, benign natural remedies are used. This is what most patients want, and according to their beliefs, they use either drugs or natural remedies to eliminate symptoms.

However, holistic medicine, following in the footsteps of the nineteenth-century Nature Cure movement, aims higher. Here, health is regarded not just as a temporary absence of disease symptoms, but as a state of profound physical, emotional, and mental well-being so that we cannot develop a disease.

Animals living in an unspoiled natural habitat commonly display this kind of health. If we want to come close to such outstanding health, we have to work for it by consciously minimizing the multitude of negative influences on our health and by maximizing the positive factors instead.

Experience shows we do not follow a straight line of health improvement or deterioration. Similar to the way periods of illness are interspersed amidst relative well-being on the long road to chronic degenerative diseases and death, we have ups and downs on the road to superior health. The main difference is that the road to deteriorating health slopes downhill while the road to superior health goes up.

Travelling downhill is easy; we do not need to do anything about it, but improving our health requires consistent effort, and it can seem like an uphill climb.
Contrary to the lengthy periods of ill health on the downhill road, the dips on the uphill road are usually short and sharp. Such a dip is called a “healing crisis,” although I prefer the less dramatic names “healing reaction,” “cleansing reaction,” or simply “reaction.”

After each reaction, we advance to a higher level of health than we had before the reaction. Holistic therapists realize that the road to better health follows a definite pattern, once known as **Hering's Law of Cure** (from homeopathy), which says: "All cure starts from within out, from the head down, and in reverse order as the symptoms have appeared."

The emotional side of our health problems is important as well. Each disease, accident, or surgical intervention contains a strong emotional component that needs to be re-experienced during a reaction. Otherwise, the healing will remain incomplete and the problem will present itself again at a later time for healing at a deeper level.

This also means that the body selects the kind of healing crisis that is most appropriate at the time, taking into consideration its needs and abilities to have a certain area healed or improved. We can consciously influence this choice by working on a particular problem. I've noticed that the "body self" tries to select a timing that does not disable us during important upcoming events. No doubt we are guided on our healing path by our inner intelligence that has our best interests at heart.

In the beginning, our healing reactions will be mainly on the physical or biological level, but increasingly we will experience the release of emotional blocks and changes in consciousness, preparing us for greater activity on the spiritual level.

Patterns of Healing: In every healing, the sequence of our health deterioration will automatically be retraced. This means that old, long-forgotten disease symptoms may suddenly flare up again in the form of a healing crisis. The reason for this is based on the nature of disease.

At first, when the body is still vital, it reacts forcefully against pathogenic invaders; the resulting battle causes fever and inflammation. If the body is not strong enough to win completely, the acute battle symptoms will eventually subside, with the remaining invaders leading a somewhat subdued existence in a weakened gland or organ. Repeated attacks will result in the degeneration of this body part, causing chronic disease.

At some stage on the road towards health, the body will feel strong enough to start the fight again to heal the diseased organ; when it does, inflammation will result. Such healing reactions are usually short-lived but can be intense. If one supports the body during this period with rest and cleansing diets, then the organ will eventually acquire a much better level of health than before the flare-up. If, however, drugs are used to suppress the healing symptoms, then the inflamed organ will return to its subacute, chronic condition and wait for another opportunity to heal itself.

The healing pattern of other health problems that are not related to immunological processes and infections follows a similar line to this. Healing takes place on many different levels: at the biochemical within cells; in the blood circulation; in the nervous system; and especially in the flow of bioenergies (such as chi, as described by acupuncture). Healing activity will be increased on all of these levels.

At the bioenergetic level, the increased energy flow may cause congestion at various places, in the weak body part itself as well as in related acupuncture points and zone reflex areas. Excess energy in such places may be noticed as pain, heat, or tension - the common symptoms of inflammation. Eventually the body will clear the

obstruction in the energy flow. We can support this process with specific healing methods or by healthy living practices in general. However, trying to suppress any acute inflammation may leave the body part permanently weak. Inflammation in itself is a healing energy release, and it is best overcome by removing the blockages in the energy flow.

Frequently there will be periods of greatly increased bowel activity or diarrhea. This is due to the detoxifying action of the liver. These toxic waste products are very irritating to the intestinal wall and the body tries to flush them out as quickly as possible to avoid intestinal discomfort and headaches. Do not try to suppress this process but you may try to ease it with frequent drinks of psyllium which help to bind the toxins and solidify the bowel content.

Skin Reactions: Another common form of healing reaction is the development of a rash or other skin problem, especially over a weak body part, such as, for instance, at a hip or shoulder. This skin reaction signifies that the energy that has been bound internally in this area in the form of muscle armouring, stiffness, and accumulated metabolic wastes is now surfacing and dissipating. Thus the affected joint or limb will become much freer and stronger. However, if the skin reaction is interfered with and made to go away prematurely, then the suppressed energy and metabolic wastes will remain in that body part, keeping it in a state of pain or weakness.

Thus there usually is no need to interfere directly with skin reactions or other healing symptoms. On the contrary, that may only drive the problem “underground” to affect internal organs and body structures. Natural healers have noticed that by artificially producing a rash over an arthritic joint, the joint greatly improves, but when a rash over a joint is artificially suppressed, then arthritic symptoms may appear in that joint.

This observation applies only to healing reactions, not to possibly infected or chronically inflamed skin areas which may be treated with antimicrobials and alkalizers in addition to nutritional therapy.

You may learn much about yourself, your body, health problems, and emotional reactions by patiently observing the healing process instead of rushing to do something about it. What you should do, however, is live healthily, cleanse the body, helping the suppressed energy to come out and dissipate, and be optimistic about it all.

Frequently, boils and increased mucus discharge, as in colds, arise during the initial stages of the healing process. Sometimes they start one or two weeks after you improve your diet and begin to take supplements. This indicates that your organs of elimination are congested. During such times, take little food, but instead consume generous amounts of herb teas, fresh vegetable juices, and pure water, and ideally go on a cleansing diet. Such healing crises may appear from time to time, separated by weeks, months, or even years, bringing you ever closer to your goal of superior health.

Listen to Your Body: Some further problems may develop during your program of health improvement. Formerly, the body response may have been dulled - it did not even react to harmful foods or drugs - but now the reaction is often

immediate and forceful. Foods that you may have eaten habitually before going on a cleansing diet can now suddenly cause a gastrointestinal upset, making you feel sick and miserable for days. However, such reactions do not need to happen if you take proper precautions: Find out to which foods you are allergic and try to avoid these. If you eat in restaurants and do not know what to expect, take plenty of digestive enzymes and lecithin during the meal, and try to eat foods in correct combination; if allergy symptoms appear, use alkalizers together with sodium ascorbate to mitigate their effects.

Your body now trusts that you will not hurt it anymore in the old ways. But if you do, your body is very “offended” and lets you (your mind) know about it in no uncertain terms. This is the most effective language the body has. However, if you learn to listen, your body will first try to tell you about its requirements in a more subtle way such as in intestinal rumbling, an itch, a slight muscle weakness, a passing pain. There are numerous ways a body expresses its needs, and each body has its own language of symptoms.

If you are honest and persistent in your desire to become a “friend” to your body, it will eventually let you know its needs, its likes, and dislikes; you will rediscover your lost body instincts. This is what we should aim for: to become independent of outside expert advice and do what our body tells us is right to do, not only in nutrition, but in everyday living.

While one can usually gain relatively quick relief from distressing symptoms, rebuilding a strong and healthy body is a slow process. It requires a great deal of experimenting to find your optimal individual conditions for healing and it needs your solid determination to carry through with a program over the years.

The Progress of Healing: Generally, recently acquired chronic weaknesses are the first to flare up and become healed, while our oldest and most persistent health problems are the last to yield. Thus there appears to be an orderly sequence to our health improvement. Healing proceeds in a wave pattern on an upward slope. On the peak of a wave we feel much improved, while in a trough we experience cleansing activity or a healing reaction and feel sick. The overall movement, however, is towards greater well-being.

The body always tries to heal itself and an acute inflammation is an important tool for this purpose. An inflammation makes the walls of the blood vessels porous to allow an increased flow of lymph fluid to move immune cells in and move accumulated toxins out. At this stage it is just an acute inflammation and we can choose to turn it into a healing crisis by supporting the body mentally and nutritionally, or we can choose to suppress the acute condition and return ourselves to a chronic degenerative condition.

Therefore, anything that suppresses an acute inflammation prevents healing of the affected area. This includes not only anti-inflammatory drugs and remedies, but also strong alkalizers that reduce the release of histamine. The pain and heat in the inflamed area are the price we have to pay for healing.

However, anti-inflammatory agents and alkalizers have their role in easing the discomfort of a chronic inflammation until the body has been nutritionally and mentally prepared for a healing reaction. Further, the symptoms during a reaction

may either be too severe or come at an inopportune time. You can lessen or temporarily stop them by adding cooked food to a raw food cleansing diet, by alkalizing the body, or by using anti-inflammatory remedies.

Usually, we can select a suitable time for a healing crisis by starting a strict cleanse on raw food only, especially fresh vegetable juices, or fruit or vegetable salads. A fruit cleanse is more suitable for insensitive individuals (less allergy-prone), while vegetables are much better for an overacid and sensitive body.

One of the main factors reducing the severity of any symptoms is a clean bowel, regardless of whether the reaction was triggered deliberately or involuntarily. The easiest way to achieve this is by taking a tablespoon of Epsom salt in water at bedtime or upon rising in the morning. If no solid food is used, then take a teaspoon of psyllium hulls several times daily in a glass of unchlorinated water; too little water can cause constipation (refer to Step 3 for more information).

You can further support your body with light, enjoyable outdoors activity. Prayer and meditation or guided imagery are also recommended.
As you can see, there is no simple path to completely avoiding health-related discomfort. We can only choose in which way we want to “suffer.” We can either deliberately and cheerfully endure unpleasant healing crises with the promise of better health to follow; or we can expect to suffer involuntarily and in an uncontrolled way from chronic degenerative diseases as we get older. The choice is yours.

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Part 2
NATURAL HEALING METHODS

This chapter contains a selection of natural healing methods, presented in a concise form suitable for do-it-yourself healing and experimentation. It is especially useful in the context of healing groups. You will find diagnostic methods followed by selected therapeutic methods. However, several of these overlap and can be used for both diagnosis and treatment. Experiment with those methods that appeal to you while disregarding others.

In conventional medicine, diagnosis is extremely important because the predominant use of surgery and toxic drugs directed against specific disease symptoms leaves little room for error. Holistic healing, on the other hand, aims to improve the overall health of the patient, so diagnosis is less important. Healthy living, which includes correct nutrition and mind control, in combination with various nonspecific healing methods, will be enough in many cases to lift one's health to such an extent that, even without diagnosis, diseases and their symptoms gradually disappear.

However, improvement may be faster and easier, especially in serious conditions, if you concentrate additional healing efforts on specific glands or organs. Here, diagnosis is -useful in pinpointing the areas most in need. Generally, the aim of diagnosis in holistic healing is to assess whether an organ, gland, or other part is overactive or underactive; whether energy flows are too strong or too weak; or whether there are deficiencies or harmful outside influences, attitudes, or emotions.

Worldwide, an emerging and especially active area of the healing arts is electro-medicine. This includes a multitude of diagnostic and therapeutic instruments from simple to very elaborate and computer-programmed. While some of these have a long track record, including mainstream medical use in Germany, the U.S. Food and Drug Administration (FDA) has either outlawed many of these products or actively discourages their use. In view of this, and also because of the evolving and constantly changing nature of this whole area, I recommend getting the newest information from the Internet. Look for key words such as Rife technology, BEFE (bio-electric field enhancer), electro-acupuncture, electrodermal screening, electronic blood purifier, zapper, and magnetic pulser. For the definitive publication in this area, see Bio-electromagnetic Medicine, with contributions by a wide range of scientists and medical researchers, and edited by Paul J. Rosch, clinical professor of Medicine and Psychiatry, New York Medical College, with Marko Markov of the Mount Sinai Medical School.

Here then is a selection of practical methods you can use to improve your health and that of your family and friends.

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Step 11
GENERAL EXAMINATION

Examine yourself to assess your state of health.

Testing Body Fluids: Tests in this step are recommended as a way to get to know and monitor your body rather than to replace medical diagnosis. Urine dipstick tests, available at most pharmacies, give indications of pH (acid-alkaline balance), kidney function (protein status), diabetes (glucose), fat metabolism (ketones), urinary tract infections (blood, nitrites), liver and gallbladder function, and blood stability (bilirubin, urobilinogen). Cloudiness in a fresh urine sample, for example, may be due to urates, phosphates, pus, dead bacteria, or inadequate liquid intake.

A dipstick test for vitamin C is available in some countries; otherwise you can test by adding ten drops of a five-percent silver-nitrate solution to ten drops of your urine in a test tube. Read it after two minutes. A white precipitate shows vitamin C deficiency; if beige, a small amount of vitamin C is present; if gray, your vitamin C status is good. During severe infections, sufficient vitamin C should be given to cause a charcoal-like appearance in the test fluid. From the colours of these dipsticks, you can clearly see whether the result is normal or whether there is a problem, in which case you can repeat the test from time to time or seek professional advice. (Caution: Silver nitrate badly stains skin and garments.)

Low-cost instruments are now available for measuring the level of glucose in the blood. In a standard glucose-tolerance test, 100 g of glucose, or 2 g per kg body weight, are given in water to the fasting patient. Blood and urine samples are tested every 30 minutes. A test for diabetes can be terminated after two or three hours, while for hypoglycaemia, test for five hours. Diabetes is suspected when the glucose level peaks and remains higher than normal.

Hypoglycaemia (low blood sugar) is more difficult to evaluate and may be suspected if the blood sugar curve shows a high plateau or remains flat, if it shows a steep drop, or if it falls below the fasting level. In addition, test the soft-palate pH (in the mouth) before and after the test. Greatly increased acidity shows inefficient use of glucose. Frequently, the blood sugar reaction depends on the source of the glucose or carbohydrate; that is, an abnormal blood glucose level may be caused by an allergy response to a particular carbohydrate.

Pulse and Blood Pressure: Take the pulse while sitting and standing. To find the pulse, lightly press with the pads of three fingers on the inside of the wrist of the other hand just below the pad of the thumb. Adrenal stress (predisposition to allergies) may be indicated if the rate is higher when standing than sitting. Statistically, the average pulse rate for men is 72 per minute and 80 for women. Physical activity, raised temperature, infections, an overactive thyroid gland, strong emotions, and allergies increase the pulse rate. An irregular pulse may indicate heart disease, potassium or magnesium deficiency in the heart muscle, or an allergy. Sometimes the pulse is irregular only under stress, for example, when standing or running. If there appears to be a problem, check again on subsequent days under different conditions.

Blood pressure is measured with a sphygmomanometer and is important for body balancing and assessing nutritional requirements. The normal readings are 120/80 mm Hg (millimetres of mercury). The upper value is produced when the heart contracts (systolic pressure) and mainly indicates the rigidity or elasticity of the main arteries. The lower reading (diastolic pressure) occurs when the heart dilates and indicates the amount of tension or relaxation in the small peripheral blood vessels. The difference between both readings is the pulse pressure. The normal pulse pressure is about 40. To obtain an indication of the metabolic rate (how fast or how slow the body produces energy from food) multiply the pulse pressure by the resting pulse rate. The average value is 2800 plus or minus 500. A value higher than 3300 indicates an overactive thyroid, while a result lower than 2300 indicates an underactive thyroid.

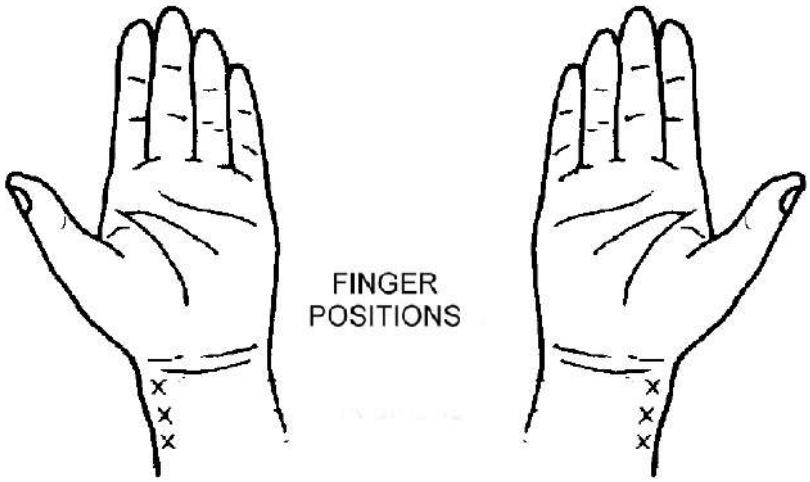

Fig. 2-1. Taking the pulse.

A fall in blood pressure when standing compared with sitting indicates adrenal stress. Sometimes a low blood pressure when sitting will rise when standing because of increased tension. The blood pressure of healthy adults does not rise with increasing age. The most common causes for high blood pressure are arterial hardening and congestion, kidney problems, and allergies.

Examination of Organs: While the person to be examined lies relaxed on the back, exert direct pressure on the organs to be tested. Inflamed or infected conditions will usually be indicated by tenderness. Of special importance is the liver; to gauge liver health, press gently under the front of the right rib cage. Press into the stomach, at the lower end of the sternum, and all around the abdomen, to check the small and large intestines. If most of these intestinal areas are tender, you can suspect an overgrowth of Candida albicans in the gastrointestinal tract.

Reflexes can be tested by striking with the edge of the hand just underneath the kneecap. Normally the leg will give a slight jerk. Absent or very strong jerks may indicate nervous system diseases and a need to seek professional help. Another test involves stroking the inside of the sole of the foot (called Babinski's reflex). In a normal condition, the toes will contract and draw together. In cases of central nervous system disease (and in newborn infants), the toes will fan out and be drawn back.

The thyroid gland is situated on both sides of the lower neck; if it is underactive, you may feel sluggish and have difficulty losing weight. To see whether your thyroid is underactive, measure the temperature under your tongue for ten minutes on three consecutive mornings before getting out of bed. Premenopausal women should do this on the second, third, and fourth day of the menses. The temperature should be

97.8°F (36.5°C) or higher. If it is consistently below this, your thyroid is likely underactive. You should then consume foods high in iodine, such as seafood and kelp, and also take selenium to stimulate your thyroid functions. Dental problems, such as dead teeth and mercury amalgam fillings, are important causative factors of thyroid problems, so use metal-free dentistry (see Step 8).

Other tests can be performed according to the skill and specialization of the examiner. The tongue, skin, hair, eyes, and nails can give valuable health information. Energy patterns can be assessed from Kirlian photography; measuring devices for acupuncture energies can reveal the meridian flows as well as the vitality of specific organs before and after treatment and at consecutive visits.

Self-examination of organs can be difficult. If you are in doubt about what you have found, consult a professional. Low-cost diagnostic instruments such as a sphygmomanometer, stethoscope, and eye, ear, nose and throat instruments can often be obtained from Chinese importers of acupuncture equipment.

Hair Analysis: For an assessment of your long-term mineral status, you can send a sample of your head hair to a specialized laboratory for analysis. (You can find an address for a laboratory on the Internet or in the advertisements of health magazines, or ask a naturo-path.) However, interpretation of the results is difficult, because mineral levels in hair are not directly related to the mineral levels in blood or cells. As the mineral content of the hair reflects the long-term mineral distribution inside the cells, it is often more useful than a serum mineral analysis.

Generally, the ratio between key elements is more important than certain high or low values taken in isolation. An abnormal ratio indicates problems with the various systems or organs. Important ideal ratios (and the body systems affected) are as follows:

- Zinc:copper = 8:1. Needed for the cardiovascular system, female reproductive system, liver functions.
- Zinc:manganese = 150:1. Muscles and skeletal system, collagen, cholesterol.
- Calcium:zinc = 3:1. Cardiovascular and kidney functions, bones and joints.
- Sodium:potassium = 2:1. Adrenal glands and glandular system.
- Calcium:magnesium = 8:1. Cardiovascular system, bones and joints, dietary imbalance.
- Iron:copper = 2.5:1. Indicates condition of blood and energy production through respiration.
- Here are some clinically significant patterns:
- Elevated levels of toxic minerals such as mercury, lead, or cadmium indicate you need to detoxify.
- Low sodium, potassium, chromium, and manganese indicate glucose intolerance.

- Elevated calcium and magnesium in the correct ratio indicate nutritionally induced hyperparathyroidism (overactive parathyroid glands) due to excess dietary phosphorus (for example, from meat and soft drinks).
- Low levels of most polyvalent elements; including copper, iron, manganese, chromium, and selenium, indicate malabsorption, with possible lack of gastric acid.

There is an interesting nutritional pattern connected with criminal behaviour. Violent, imprisoned criminals generally have one of two mineral-correlated behaviour patterns. With a high copper-to-zinc ratio, low sodium, potassium, and manganese but high lead and cadmium levels, they have extreme mood swings, poor ability to handle stress, and occasional violent behaviour. They tend to feel remorse for their actions. With the other pattern of iron, calcium, potassium, and sodium high in addition to high cadmium and lead, with low copper and zinc, such people are often violent and cruel, fascinated by fire, and exhibit no conscience or remorse. (For further information, see Diagnostic Usefulness of Trace Elements in Human Hair, by Jeffrey Bland, Ph.D.)

Face and Tongue: Face diagnosis is widely practiced in Chinese and Japanese medical traditions. Generally, the forehead corresponds to the nervous system, the middle part of the face to the circulation, and below the nose to the digestion. More specifically, the eyes are related to the liver and partly to the spleen; the nose to the lungs and heart; and the mouth and lips to the digestive functions.

To give a few examples, fluid sacs under the eyes are generally attributed to poor kidney function, especially if they are dark purple or bluish in colour, while with a puffy brown appearance they implicate the liver. Heart and lung problems may be indicated by a red or purple, swollen or bulbous nose. Soft, hanging lower lips show a weak muscle tone of the intestines. If the mouth is kept open most of the time, this shows severe metabolic imbalances and weakness.

The tongue is also a diagnostic tool. The tip of the tongue corresponds to the heart, the edges to the liver and gallbladder, the centre to the stomach and spleen; between the tip and the centre are the lungs; and at the root or back of the tongue are the kidneys, intestines, uterus, and bladder. The underside reflects the circulation in the corresponding areas. A white coating is related to congestion of the intestines; a red tongue may indicate B-vitamin deficiencies or inflammation; a bluish colour indicates coldness, underactivity, and poor circulation in the indicated areas. A yellow or brownish coating may indicate liver problems and cracks may be due to overacidity, allergies, and deficiencies.

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Step 12
IRIS DIAGNOSIS

Study your eyes to find out more about internal conditions of your body.

The iris is like a map of the body - changes in certain organs are reflected in specific parts of the iris. The right iris shows the condition of the right side of the body, while the left iris reflects the left side. The exact relationship between iris and body parts can be seen from the iris chart below. Iris diagnosis is also known as iridology.

In health, the iris is composed of densely structured fine, straight lines, radiating from the pupil to the outer rim. A close grain, similar to that of hardwood, indicates a strong inherited vitality and good recuperative powers in the case of temporary illness. If the fibres are loosely spread, as in softwood, the basic health is weak.

In poor health these lines become separated and distorted, forming various patterns, called markings. Very weak organs often show elliptically formed grey markings - so-called closed lesions resembling knots in wood. In poor health many of these closed lesions may be found in the iris, indicating areas in which the circulation is stagnating. If these lesions are not 'walled in', but open at one end or both, this indicates that despite a weakness the circulation in this area is good.

Colour Changes: Start by studying your own eyes in a mirror. Then look at the eyes of friends and relatives. Use a magnifying glass and a torch held at the side of the eye. Make a coloured copy of your own eyes or those of a friend, and compare it with the iris chart. Study the general colour pattern. Markings are much easier to detect in blue than in brown eyes. Often there will be brownish discolourations in blue or green eyes extending outward from the pupil. This area belongs to the intestines. The brown colour change indicates that there is a deterioration of the digestive system, usually associated with inherited liver and gall bladder weakness.

Frequently, the eyes of babies change from blue to brownish within days or weeks of the baby's introduction to cows' milk. Often allergy symptoms are present simultaneously, for example, eczema, respiratory and digestive difficulties. These colour changes may also occur in breastfed babies if the mother uses cows' milk or its products. Presumably this change may already occur in the foetus.

The brown colour of genuinely brown eyes comes from melanin pigments, while pathological brown colour changes originate from oxidised lipoproteins (for example, lipofuscin) and possibly from the breakdown products of blood colouring agents (for example, bilirubin). Additional discolouration may result from drug deposits.

Sometimes there is so much brown it is difficult to detect the original colour. Organ areas that border the intestinal ring where it shows strong markings are likely to suffer from reflected weaknesses. White in the iris indicates overactivity, irritation, acidity, infection, inflammation or catarrh of the corresponding body part. In some eyes the whole iris shows much white; in others it is concentrated in certain areas only.

Generally, a brown discolouration means that cows' milk products, saturated fats (all fats that are solid at room temperature), chemicals and stimulants should be avoided as much as possible. A very white discolouration indicates mucus congestion. Therefore, mucus-forming foods should be avoided - gluten, refined carbohydrates, wheat, lactose, oranges and anything mouldy.

Gradually, an organ may change from an inflamed to a chronically weak condition. The white in the iris will simultaneously change to grey; the darker the grey, the weaker the organ. During health improvement you may watch the reverse process: the grey areas becoming lighter in colour, then white and finally restored to the original colour - a process that takes many years.

Generally, white markings indicate a need for sedating, anti-inflammatory treatment of the associated organ, while grey or brown areas show a need for strengthening and stimulation.

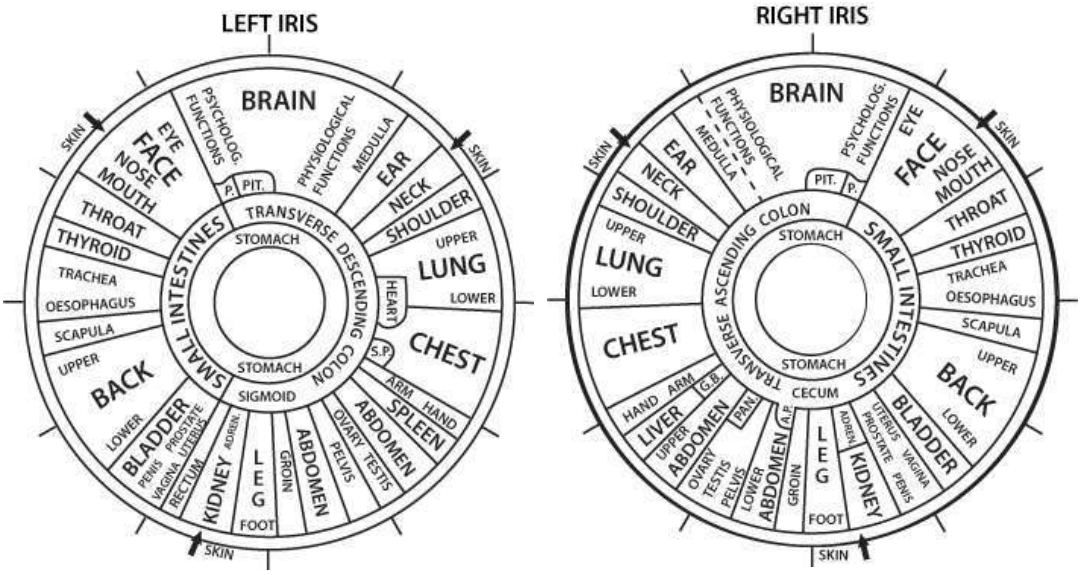

IRIS CHARTS

Abbreviations: ADREN = Adrenal Gland, AP. = Appendix, G.B. = Gall-bladder,
P. = Pineal Gland, PA. =Pancreas, PIT. = Pituitary Gland, S.P. = Solar Plexus.

Common Conditions:

PUPIL REFLEX: If a pupil does not contract when a bright light shines on to it, this indicates dulled nerve reflexes, weak adrenal glands or an overstimulated sympathetic nervous system, often from fear as a hidden, chronic condition. Adrenal stress is indicated if the pupils begin to expand and contract repeatedly when exposed to bright light for 30 seconds.

NERVE WREATH: A strong, white and almost circular outline of the intestinal area - the nerve wreath - indicates a good Condition of the autonomic nervous system. If this outline is weak, jagged, discoloured, or extends far towards the periphery or the pupil, we may assume the autonomic nervous system is in a poor

condition. The normal position of the nerve wreath is one-third the distance between the pupil and the periphery; if the nervous system is tense and overactive, the wreath is closer to the pupil, and if the nervous system is relaxed and under-active it is closer to the periphery.

NERVE RINGS: White circles or arcs of circles in the outer part of the iris. They indicate a tense, over-reactive, irritated nervous system. The outermost iris zones represent the lymphatic and circulation system and, bordering the sclera, the skin.

DISCOLOURED STOMACH AREA: In a normal condition the stomach area is not visible, but if the stomach is irritated the area bordering the pupil will be whitish and distinct from the intestinal area. A brownish discolouration of the stomach area indicates a chronic weakness.

DISCOLOURED INTESTINAL AREA: A whitish intestinal area indicates inflammation, irritation or ulcers; avoid gluten products, lactose, spices and acid foods; use mucilaginous supplements (fenugreek, slippery elm, comfrey, linseed), brown rice, and the outer parts of potatoes. If there is a mucous congestion in the head, there is a whitish or brownish discolouration in the transverse colon area, radiating towards ear and brain. If chronically weak, this area will be dark.

RADIAL BLACK LINES: When there is a serious deterioration of the intestines, strong black lines (radii solaris) will develop, starting from the pupil and radiating towards the periphery. Organs through which these radii pass will be very weak as well.

UNUSUAL MARKINGS: Distinct markings may be coloured brown, red or yellow. Unusual colours indicate deposits of drugs or other chemicals that settle in weak organs.

WHITE OUTER RING: A heavy white ring near the outer edge of the iris points to salt (sodium) and calcium deposits. Avoid salt, drink plenty of water, possibly use potassium and magnesium supplements, and natural vitamin D; improve kidney activities.

BLUISH-WHITE FILM: A bluish-white film beginning to cover the iris from the outer rim indicates poor circulation to this area and an anaemic condition. Often this film appears in the brain area, indicating approaching senility (arcus senilis).

DARK OUTER RING: A dark ring at the outer rim (scurf rim) shows the skin is inactive with accumulated wastes, and needs frequent stimulation, better circulation and improved kidney and lung activities.

LYMPHATIC ROSARY: A series of white spots near the outer rim, the 'lymphatic rosary', indicates chronic infection and congestion of the lymphatic system. Avoid especially lactose and cows' milk products (except butter).

It may require years to become an expert in iridology, but the basic rules given here will already enable you to form a well-founded judgement about the condition of your body. You may also be able to help other people if you have this knowledge. Experiment and you will soon find iridology a valuable and fascinating tool. The most extensive information in book form on iridology is available from Bernhard Jensen, mainly his book Iridology Volume 2.

Sclerology: In sclera diagnosis or sclerology, the location and shape of the blood vessels visible in the sclera, the white of the eye, are interpreted. Generally only the problem areas are indicated, not the nature of the complaint. Sclerology may show that the function of an organ is disturbed, but not whether it is overactive or under-active. It helps if you have good light and a magnifying glass for examination.

To inspect the lower part of the sclera, let the examinee look up while you pull down the lower eyelid; to look at the upper part, the examinee should look down while you gently roll up the upper lid; examine the outside while the examinee looks toward the other eye and the inner part of the sclera while looking away from the other eye.

Generally a blood vessel pointing towards a certain organ reflex in the iris indicates that there is something wrong with that organ or part of the body. The stronger the blood vessel is visible and also the more of them are bunching together, the worse is the problem. A bluish colour of the sclera indicates under-activity.

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Step 13
MUSCLE TESTING

Test your muscle strength to see whether a food or remedy is good or bad for you.

Our muscles respond to many external as well as internal influences by becoming stronger or weaker. In muscle testing, the change in muscle strength is assessed before and during contact with a test item. This may be, for example, a food sample, a colour or a piece of material. Internal influences are our thoughts and feelings, which may either strengthen or weaken us.

The reason for the muscle changes can be explained by the influence the radiation of a tested sample has on the flow of bio-energies along the acupuncture-meridians. In the same way, our thoughts and emotions can change the flow of bio-energy. I have measured differences in muscle strength of up to 50 percent during testing.

Most suitable methods for food testing are to place a sample in the mouth - chewing it for about 10 seconds - and also to hold a sample in one hand near the navel. Most non-food items can be tested near the navel or simply by touching with a hand.

How to Test: The simplest form of muscle testing requires a tester as well as the tested person. Almost any muscle can be used for testing, but I use the following method as the most convenient. The tested person sits with uncrossed legs, one arm held out to the side, elbow level with shoulder and bent at a right angle, place the free hand over the navel.

The tester presses just above the elbow to push it down. Press the arm lightly into the shoulder as well as toward the hip. If the tested person is very strong, the pressure may be straight down, or the arm may be fully extended and the pressure applied at the wrist. Increase the pressure gradually and with measured strength; feel and remember exactly the amount 'of pressure required to force the arm down. If both arms are too weak, you may test the legs.

During testing, the tester should keep the question in his or her mind 'Is the tested sample good or bad for the patient?' but should not expect a certain result. The preferences of the tested person seem to have little influence on the result.

Now the tested person takes a sample and holds it with the free hand just above the navel. After about 10 seconds, the tester presses the arm down and carefully notes any difference in resistance. If the result is doubtful, repeat the test with and without holding the sample. Often a difference is easier to detect if the arm is pressed down three times in succession.

Sometimes the tested person feels a pain or strain in the shoulder during a weakening test, even if the tester cannot notice a difference. This should be reported. Generally the quantity of food held is not critical; it may even remain in a container or plastic bag; however, avoid a coloured container or one of semi-rigid plastic.

If the patient is difficult to test, you may strengthen the arm immediately before each test by tracing the acupuncture meridian of the lung or of the glands (triple warmer); alternatively, test a leg. Another strengthening method is to tap the thymus gland (underneath the upper end of the breastbone) several times lightly with your fingers. This strengthens the immune system and in doing so reduces allergic reactions.

What to Test: In addition to foods, testing can be done on vitamins, herbs, drugs and even garments. You will find that synthetic fibres (especially nylon), many drugs, refined foods, chemical additives and incompatible colours are frequently weakening.

Food combinations may be assessed by holding them jointly during a test. Individual items may even remain in their separate containers. Samples that are strengthening individually may test weakening if held together, and vice versa. The test results may be influenced by what you have eaten beforehand. Also, when you are tired, fatigued or sick, many foods are weakening that at other times may be strengthening. Therefore, important items should be retested from time to time under varying conditions.

Use muscle testing frequently for all your food and supplement requirements. Supplements will test strengthening as long as they are required. Sometimes, muscle testing will indicate that an item should be omitted temporarily before it is used again, or that it should be taken in a lower dosage (for example, vitamin A). For assessing the amount to be taken per day, gradually increase the number of tablets or capsules held in the hand until the arm weakens. Take about 10-20 per cent less than this amount.

You may also try to find out whether your usual sleeping location is safe. Perform a muscle test while lying in the usual sleeping position on the bed. If the arm is weaker than with a test in another part of the bed or the room then you may have to change your sleeping location.

Even thoughts and feelings may be tested. A positive thought and a good feeling may be strengthening quite generally to all muscles, although the main strengthening effect may be on one particular muscle. Negative thoughts or unpleasant feelings, on the other hand, may produce a general weakening and also a particular muscle to become very weak when tested. Mental testing may be used to explore your subconscious beliefs, feelings and body reactions.

Instead of testing the safety of your bed while actually lying on it, you may use mental testing to find out whether your bed is situated over underground radiation that is detrimental to your health. While your partner tests your muscle strength, imagine lying or sleeping in the bed. Then imagine an underground stream and harmful radiation underneath the bed. If the arm is stronger when imagining the usual sleeping arrangement but weaker with the imagined stream, then your bed is likely to be in a good spot, otherwise continue the test by imagining sleeping in a different location until the test becomes strong.

Another possibility is surrogate testing. You may use this for a small child or anyone who cannot be tested directly. If you want to know whether a certain food is

good for the child, place the food on the child's abdomen; at the same time touch the child with one hand and extend the other arm for your partner to test.

Finally, you may develop a method of self-testing. One possibility is as follows: press the tips of the thumb and one finger of the left or right hand together to form a loop. With the index finger of the other hand hook behind the joined fingertips, and with a quick move try to pull it through. Adjust the pressure of the joined fingers and the force of the pulling index finger so that you cannot pull it through when the answer is 'yes' or 'good'; but when the answer is 'no' or 'bad' the joined fingers become weaker and can more easily be opened. When you can do this successfully with known answers, you can test food samples in your mouth or on your abdomen, and also try mental testing.

Vitamin and Mineral Testing: M, Grimm and W. Fishman developed the following method to assess vitamin or mineral deficiencies by holding certain contact points on the body. The tested person applies a light pressure on the contact point with a pad formed by the first three fingers of the free hand, while the other arm is tested for muscle strength. Start by testing the muscle strength without touching the body with the free hand, and then repeat the test while touching the specified contact point.

The contact points for the main vitamins and minerals are as follows.

- Vitamin A: right eyelid
- B vitamins: tip of tongue
- Vitamin C: just below left collarbone, 5 cm from mid-chest
- Vitamin D: midway point of left groin
- Vitamin F: just below right collarbone, 5 cm from mid-chest
- Calcium: just above left collarbone, 5 cm from mid-chest
- Iodine: just below Adam's apple
- Iron: midway point of the right groin
- Magnesium: middle of the navel
- Phosphorus: midway between pubic bone and left hipbone
- Potassium: hollow of right cheek
- Zinc: midway between pubic bone and right hipbone

For more information see Muscle Response Test by M. Grimm and W. Fishman.

Touch for Health: Some influences - nutrients, colours, thoughts and emotions - affect certain muscles more than others. In addition, organ functions can be tested with specific muscles. If the muscle is weak, it indicates a weak organ function. Meridian tracement may be used to strengthen a weak muscle or organ. Some useful organ and muscle tests, as used in Touch for Health by J. F. Thie and M. Marks, are given below.

Adrenals: Lie face up, with one leg up and bent so that the foot is over the other leg just below the knee; the tester presses against the heel and the top of the knee to straighten the leg.

Brain, Mental Stress: Hold an arm straight, about 15 degrees away from the body, slightly sideways; the tester presses the forearm towards the groin.

Circulation/Sex: Lie on one side, with the upper leg straight, raised as high as possible; the tester presses the ankle down.

Gall bladder: Lie face up, holding the arm straight 45 degrees above the leg, palm downward; the tester presses the forearm down.

Heart: Hold the upper arm to the side, level with the shoulder, with the elbow bent at 90 degrees and the forearm down; the tester steadies the elbow and pulls against the wrist to pull the hand forward and upward.

Kidneys: Lie face up, with one leg raised at 45 degrees, slightly towards the side, with the foot turned out; the tester presses the inside of the ankle down and inward.

Large Intestine: As for the kidneys, but with the foot turned in; the tester presses the ankle down and inward.

Liver: Hold the arm straight forward, level with the shoulder, slightly sideways, with the palm outward (thumb towards feet); the tester presses the forearm upward and outward.

Lungs: Hold the arm to the side, elbow level with the shoulder and bent at 90 degrees, forearm horizontal; the tester presses the elbow down.

Neck and Sinuses: Lie with the arms above the shoulders, head up, chin down; the tester presses against the forehead.'

Pancreas: Hold the arm straight down touching the side, with the thumb towards the body, the tester pulls the forearm away from the side. This is a good test to perform while shopping, the tested person touching a questionable food item.

Small Intestine: Sit on the floor with closed straight legs, hands on opposite shoulders, lean back slightly; pressure is against the crossed arms.

Spleen: Lie face up, with the arm straight to the side, palm upward; the tester pushes the back of the wrist off the ground.

Stomach: Hold the arm as for the liver; the tester presses downward and outward.

Generally, the tester's free hand is used to stabilise the tested person's body so that only the tested limb moves, not the whole body. Both arms and legs may be tested.

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Step 14

THE ENDOCRINE PATTERN

Simple arm and leg measurements can show the conditions.

The body has developed under the guidance of the endocrine glands. Therefore, glandular disturbances are reflected in abnormal proportions of various parts of the body. Certain measurements enable us to recognize our glandular pattern as a basis for corrective treatment.

Our endocrine system is composed of two antagonistic groups of glands. The anabolic (build-up) glands are the adrenal cortex, the posterior pituitary (in the brain), the parathyroid, and the pancreas (Islets of Langerhans). The catabolic (breakdown) glands are the adrenal medulla, the anterior pituitary, and the thyroid gland. The anabolic glands control the calcium level of the blood, while the catabolic glands control the phosphorus level.

Ingestion of sugar or sweet foods stimulates the anabolic glands, disturbs the calcium-phosphorus ratio, and leads to an excess of calcium in the blood and, consequently, to stone formation. Later, however, it leads to exhaustion of the anabolic glands.

Table 2-1: Normal Body Measurements

Ratios	leg : arm	ankle : wrist	one-fourth	one-half	three-fourths	knee : elbow
Female	1.770	1.550	1.295	1.425	1.340	1.530
Male	1.740	1.475	1.220	1.350	1.265	1.455

Interpretation:

One-fourth ratio higher than normal: underactive thyroid
One-fourth ratio lower than normal: overactive thyroid
One-half ratio higher than normal: posterior pituitary underactive
One-half ratio lower than normal: posterior pituitary overactive
Three-fourths ratio higher: anterior pituitary underactive
Three-fourths ratio lower: anterior pituitary overactive

Measurements: The following measurements can reveal the basic functional pattern of the thyroid, pituitary, and sex glands. The results for the thyroid and pituitary glands are accurate to more than 95 percent; for the sex pattern, to about 80 percent.

- Measure the length of the lower leg from the middle of the kneecap to the middle of the ankle, and the lower arm from the point of the elbow to the middle of the wrist bone.

- Divide each measurement by four and mark the quarter-points between knee and ankle, and between elbow and wrist. (This means one quarter of the distance from knee to ankle is the one-fourth point, half the distance between knee and ankle is the one-half point, and three quarters of the distance is the three-fourths point. In the same way divide the distance from the elbow to the wrist.)
- Measure the distance between the endpoints (knee to ankle, elbow to wrist) as well as between the three quarter-points in between.
- Divide all leg measurements by the corresponding arm measurements.

The measuring tape should not be tight for the circumferential measurements; contact measurement only is wanted. The foot should be at right angles to the leg during measurement. All measurements are taken for both sides of the body. Compare your measurements with the normal values shown in Table 2-1.

Table 2-2: Further Signs of Andricity or Gynicity

Signs of Andricity	Signs of Gynicity
The back of the hands point forward when the arms hang loosely at the sides (person must be unaware of the test)	More of the palms show when arms hang loosely at the sides
A low voice if female	A high voice if male
Pubic-hair line is triangular with apex upward	Pubic-hair line is flat on top
Aggressiveness, independence, critical thinking	Intuitive instead of critical thinking
Body in general is hairy	The other signs are opposite to those listed for andricity
Tendency to become bald	
Space between thighs	
Tends to have too much gastric acid (ulcers)	

"Andric" means more male hormones are produced than is normal for the average male or female.
"Gynic" means more female hormones are produced than is normal for the average male or female.

The anterior pituitary gland mainly produces growth and sex hormones, and it stimulates the thyroid and adrenal glands. The posterior pituitary regulates the amount of water lost in the urine; it can raise the blood pressure and stimulates labour contractions.

Assessing Male-Female Balance: Both sexes produce male as well as female hormones in a gender-specific ratio. If there are more male hormones produced than normal, the condition is called "andric"; if more female hormones are produced, it is "gynic." To give an example, a woman with a constitutionally high oestrogen-testosterone ratio is gynic, while with a low ratio she is andric.

If the leg-arm ratio is higher than normal, add the difference between actual and normal measurement to the normal ankle-wrist ratio; if the leg-arm ratio is lower than normal, subtract the difference. If the actually measured ankle-wrist ratio is higher than the adjusted normal ratio, the person is gynic; if the actual ratio is lower, the person is andric. Gynic females may be more harmed by oestrogen birth control pills than andric females. Generally, andrics need more magnesium and gynics more calcium. For further signs of andricity or gynicity, see Table 2-2.

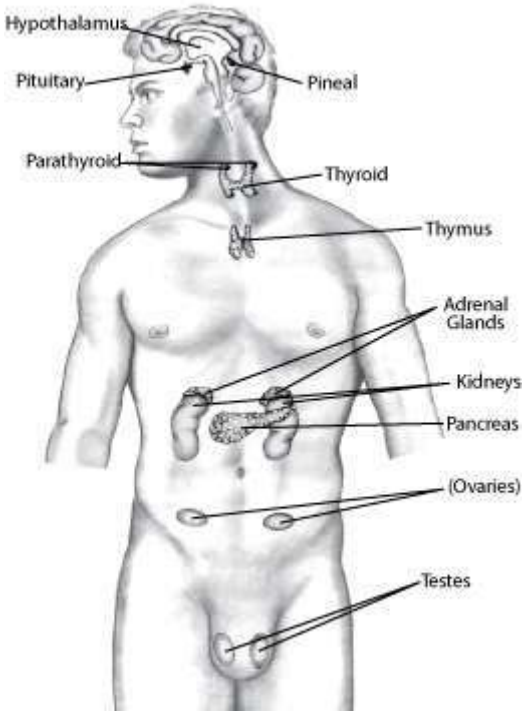

If one or more of the gland measurements show abnormal functions (as they usually will), treat the corresponding glands with diet, ear acupuncture, acupressure, reflexology, and guided imagery. Minute amounts of gland extracts can be prescribed. (For further information, see Body Chemistry in Health and Disease, by M. E. Page.)

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Step 15

REFLEXOLOGY

Press reflex points on your hands and feet to diagnose and treat conditions within your body.

Reflexology is excellent for self-treatment and even for diagnosis. Envisage the body divided into 10 vertical segments or zones, five on each side. Each finger and toe belongs to one of these zones. A diseased body part will show up as a sore spot in the same segment of the foot or hand. From this the alternative name 'zone therapy' is derived. Usually the feet are more sensitive and, therefore, more suitable for reflex diagnosis and treatment than the hands. In addition the ears, like the irises, contain a reflex map of the body. (We may even assume that every organ and every single cell contains a holistic reflex map of the whole organism.)

In addition, there is a reflex connection between related parts of the legs and arms. A sore knee, for example, may be relieved by pressure on the corresponding location on the elbow on the same side of the body. In a similar way, corresponding locations on the wrist and ankle, and on the hip and shoulder, influence each other. This is especially useful to know when dealing with broken or otherwise injured limbs that do not permit direct treatment.

Diagnosis: Press the soles, the toes and the sides of the feet with a knuckle, a thumb or - if the feet are not very sensitive - with a blunt probe. Overweight people and those with poor circulation usually need quite strong pressure, which must be exactly on the correct spot. However, if the lack of sensitivity is due to nerve damage, then it would be better to try and improve this condition first, as with strong sustained pressure under the back of the skull on both sides of the spine and providing any missing nerve vitamins (e.g. B1, B6, B12, folic acid).

Press the selected area in a slow circular motion until you find the exact location. Generally, the pressure should be straight down, but for the thyroid area it should be applied from the side, trying to press underneath the ball of the big toe.

Adjust the pressure to the general sensitivity of the foot. If the body is very sensitive, all foot reflexes will be extremely tender; therefore try with light pressure to locate only the most painful areas. You may mark the encountered tender spots on an examination chart, using different markings according to the extent of tenderness encountered. Concentrate later treatment on the most painful areas. The results will be better if you have someone other than yourself check your feet.

Methods of Treatment: The easiest and most common form of treatment is to apply pressure on sore points with the pad of a finger, the thumb, with a knuckle or with a blunt instrument (for example, the blunt end of a pencil or a pen). If it is quite sore, press straight down, with only light pressure at first. Gradually increase the pressure as the pain lessens. Finally, when even strong pressure can be tolerated, you may apply the pressure in a slow circular motion in order to relax the deeper muscles and ligaments.

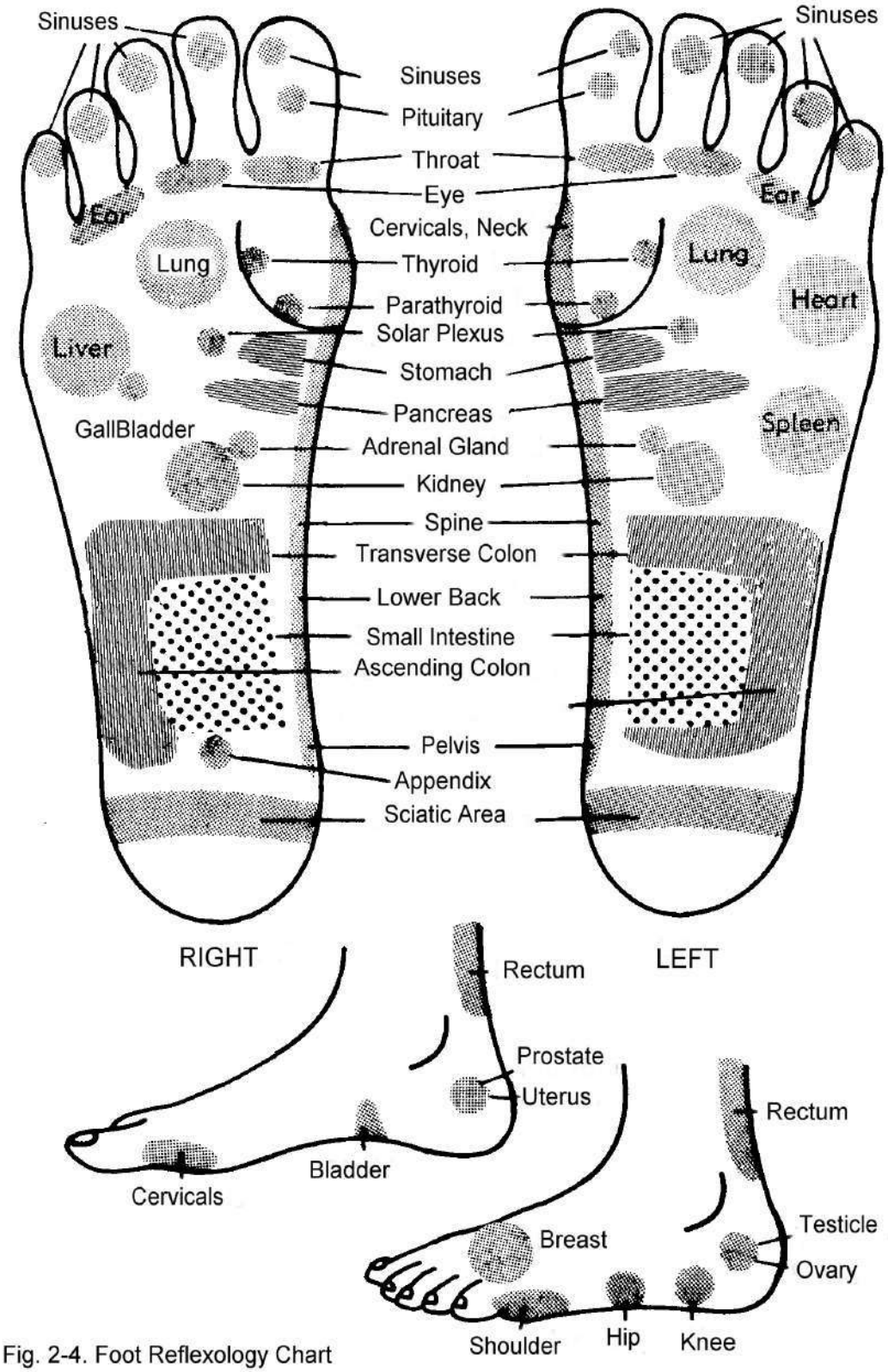

Fig. 2-4. Foot Reflexology Chart

For self-treatment underneath the feet, it will usually be more convenient to press or roll the sore points on a golf ball, a stone or another suitable object. To press reflex areas in the palms of the hands, it is usually more convenient to use a knuckle or a suitable blunt instrument than the pad of the thumb.

Usually, the pain begins to subside after a few minutes of pressing. If this happens, increase the pressure for a while, but if the pain instead increases, stop the treatment. The effect on related body parts can be surprisingly quick: pain in the ears, shoulders or back often disappears within minutes.

If there is a serious or acute problem, use reflexology several times a day. However, this treatment may stimulate a chronically weak organ to increased activity and it may become tender for a while together with its reflex areas. Generally, deep, strong and slow pressure is sedating and pain relieving, while light, quick tapping or circling is stimulating. Select whichever is appropriate. For some points a so-called C-clamp is effective: press with the thumb from underneath the foot and with the index finger from the top. This may be used for the liver, spleen and thymus.

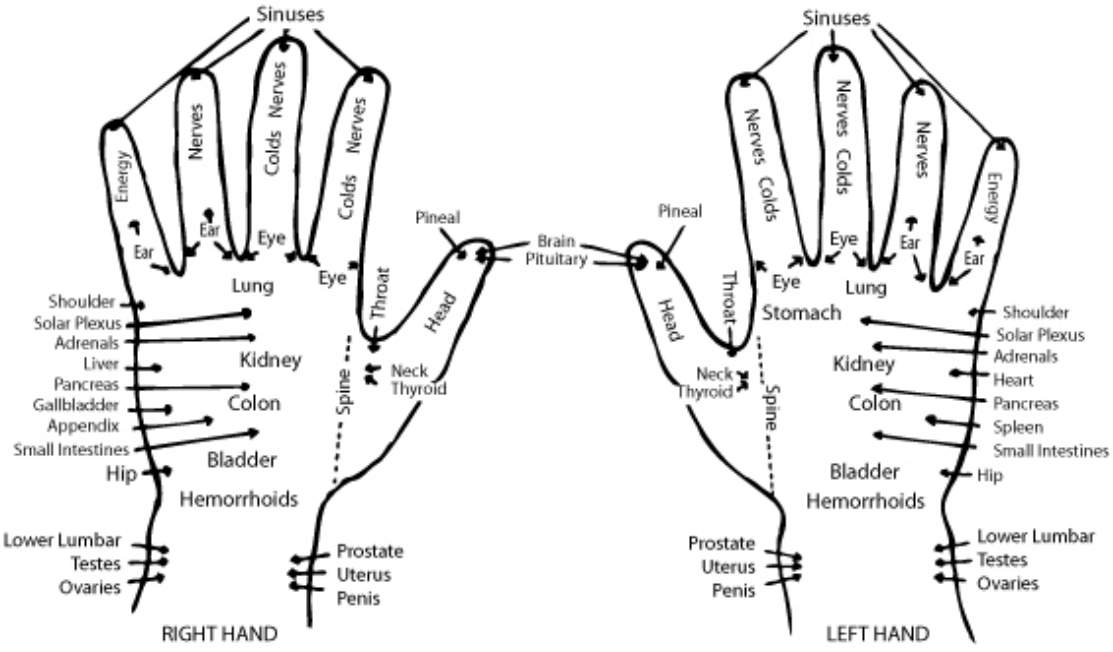

Figure 2-5: Hand Reflexology Chart

Another method of applying pressure to fingers and toes is to put tight rubber bands around them or to use clothes pegs to clamp the digits. Rubber bands should never be left on for more than a few minutes at a time. In addition, you may firmly grasp a metal comb, pressing its teeth into the palm or the fingers. A metal comb or a brush may also be used to sweep the backs of the hands and lower arms up to the elbows in quick upward strokes. Five minutes of this will stimulate the circulation and invigorate the body.

Further effective areas for treatment are the tongue, the inside wall of the mouth, especially the palate (top), under the tongue and the back of the mouth (pharynx). You may press with the pad of a finger or thumb or use a suitable instrument. Pressure on the tongue may be applied by biting or pressing with the

handle of a spoon. This is effective for treating problems in other areas of the body belonging to the same zone.

In addition, the tongue may be pulled out for several minutes by grasping it with a cloth and moving it around. Alternatively, you may poke it out as far as possible and hold it in place with your teeth. You may also work around the angles of the jaw and chin. Because of the sensitivity of the mouth, this treatment is often more effective than hand and foot reflexology, especially for all problems related to the head and throat.

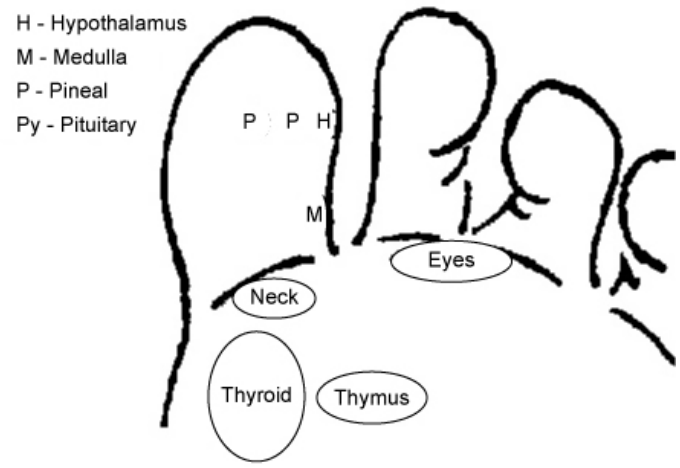

Figure 2-6: Toe Reflexology Chart

Important Areas to Treat: The foot and hand charts will give you a good indication of where to find suitable points for treating specific complaints. For best results work on all the major reflex areas: hands, feet, ears and mouth. Always treat in the same zone in which the problem arises. Your left inner ear, for example is in zone 4. Therefore, to treat it you will manipulate the left ring finger the third toe including its root on the left side, the ear points of the left ear and the outer left side of the tongue and palate.

Work frequently around the joints of fingers and toes, especially digging underneath the lowest joints of the thumbs and big toes. Rubber bands or clothes pegs may be placed for five to 10 minutes on the tips of the digits, or on or between the joints, depending on where there is more sensitivity. Lymph drainage can be improved by press-massaging the area of the upper chest on top of the feet just below the toes.

Generally, treat a sensitive area for five to 10 minutes at a time. For an acute problem, you may treat it several times daily, while chronic problems may be treated once a day. For general health improvement you may select a different area each day until you return to the same area after one or two weeks. This process may continue for years, as formerly weak areas become activated and cause increased sensitivity in their corresponding reflex areas. Walking barefoot on rough ground provides a natural foot massage - make good use of it.

The Brain: For general health improvement and regeneration work frequently on the brain, especially the pituitary gland, the pineal gland, the hypothalamus and the medulla (oblongata). The pituitary reflex often feels like a sharp bone protrusion; press it in the direction of the tip of the toe. The hypothalamus and medulla are pressed from the insides of the big toes. For general health improvement it is best to start with activating these parts of the brain and then continue with the other glands and organs.

In the system of Body Electronics as developed by Dr John Whitman Ray it is recommended to work in a certain sequence for regenerating the body. Start with the

so-called STO-point: press into the valley between the muscles from both sides of the spine and then up under the skull (occiput). This is to improve the nerve transmission to all parts of the body.

Then start working on points in the following order: pineal gland, hypothalamus, pituitary, medulla, thyroid, thymus, heart, solar plexus, pancreas, adrenals, spleen, gonads (uterus, ovaries, prostate, and testicles), liver, kidneys, gall bladder, bladder, small intestine, large intestine.

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Step 16
EAR ACUPUNCTURE

Try this easy method to improve the function of any diseased or unbalanced organ.

Ear acupuncture can be a very effective method for relieving acute pains and chronically stiff joints, sometimes these have been cured within minutes. For some problems it can be more effective than body acupuncture. Ear acupuncture is easy and safe for self-treatment and in healing groups. Organ diseases and glandular disturbances may respond less dramatically, but ear needling will always be very helpful as a supportive method with other forms of treatment.

The main disadvantage of ear acupuncture is the requirement to find the most painful spot for it to be fully effective, and this is not pleasant for people who are very sensitive to pain. The best points are those that feel like an electric shock or like hitting a raw nerve! However, often the pain will be felt as being beneficial, especially because it usually decreases with continued needling. This pain may be considered as 'letting off steam' or congestive energy from a target organ through the 'safety valve' of an ear point. However, chronically weak organs may also benefit from ear needling if no pain is felt in the corresponding ear point. Generally, however, you may follow the rule 'the more sore the point, the more effective the treatment'.

Acupuncture needles are available from some medical-equipment shops, acupuncturists or from acupuncture supply companies, see the Yellow Pages of major cities for addresses. For ear acupuncture use short and medium fine needles (e.g. 25 mm No. 30 gauge or the finer 12mm long 32 gauge. Usually you buy them in packs of 10. In addition press-needles are very effective and may also be ordered in packets of 10. Press-needles are like tiny drawing pins with a 2 mm long needle. They are retained in the ear for one to two weeks, covered with adhesive tape, and stimulated from time to time by pressing between thumb and a finger pad. If an acupuncture needle is not available, you may use a bead needle or even a fine sewing needle.

The Needle Method: Some authorities suggest ear acupuncture does not work through the acupuncture meridians, but instead, like reflexology, through the press-point therapy of hands and feet. In any event, Chinese medicine says the ear is the place where all the channels meet. The ear is relatively safe and easy to use for self-treatment. The following description of using needles for ear treatment is provided only to show how it is done in some other countries or by acupuncturists. For legal reasons, I do not formally recommend using needles on the ear. Instead, you can use commercially available electro-acupuncture instruments or laser lights to treat points, or you can use press-point therapy as described below. Exercise care and caution.

For ear acupuncture, short and medium fine needles are being used in addition to press-needles. Press-needles are like tiny drawing pins. They are retained in the ear for one to two weeks, covered with adhesive tape, and stimulated from time to time by pressing between thumb and a finger pad. If an acupuncture needle is not available, a bead needle or even a fine sewing needle is sometimes used.

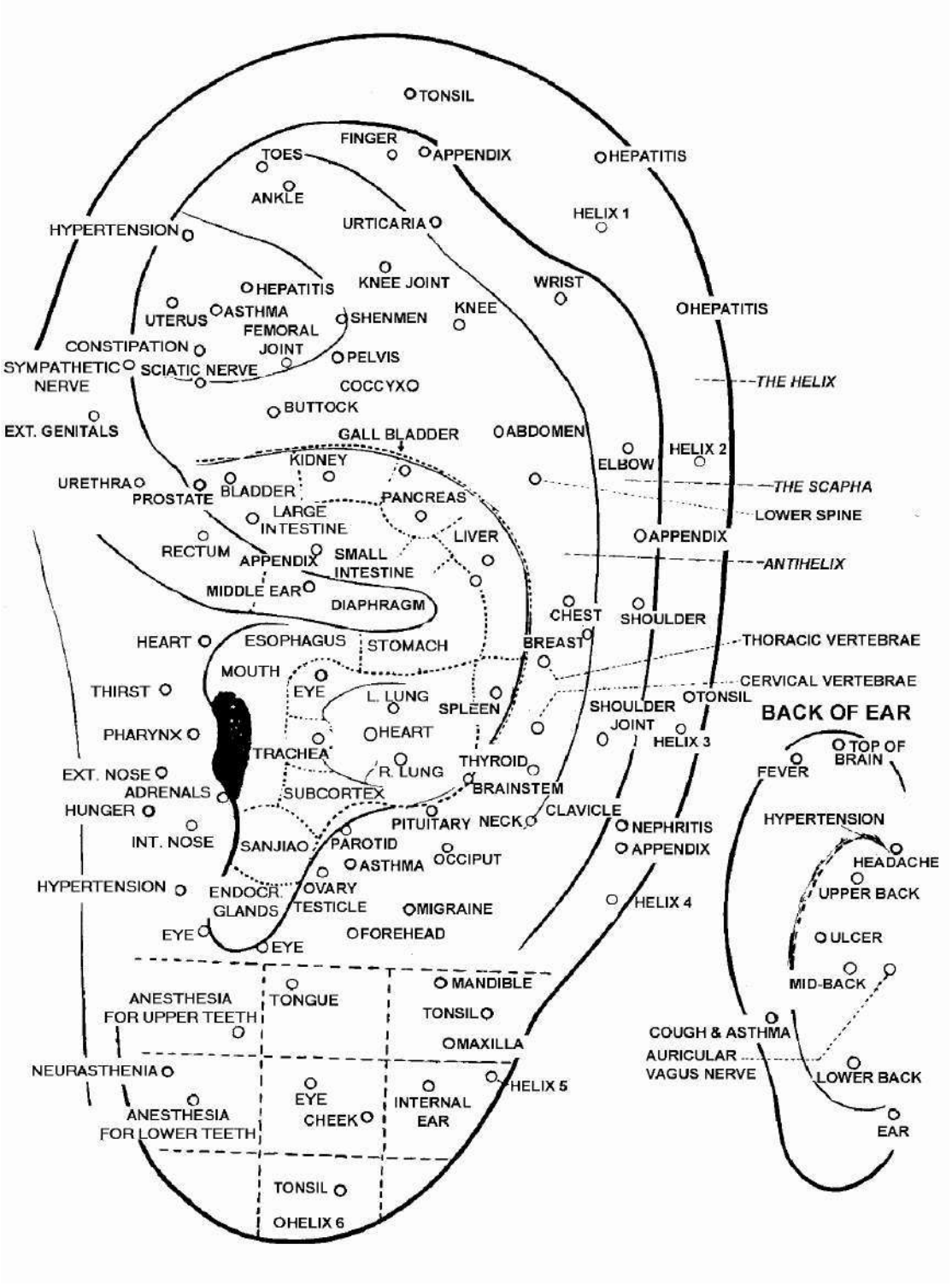

Figure 2-7: Ear Acupuncture Chart.

Helix points may be used to reduce inflammation, fever, and oedema. *Sanjiao* is used for circulatory, glandular, chest and abdominal problems. *Shenmen* is used for sedating, as with nervous problems, insomnia, mental disorders; it is the main point for pain relief, as in arthritis or inflammations; also for dry cough, bronchial asthma, epilepsy and hypertension.

Sterilise a suitable needle in methylated spirits and rub the ear with a cotton bud soaked in methylated spirits (optional). Find the most tender spot in the appropriate reflex area of the ear by pressing with a toothpick or a similar probe. Insert the needle to about 2 mm deep. It must not pass through the ear. Gently move it around to find the correct depth and direction of the sorest spot.

If it is very sore, do not move the needle. When the pain subsides, start to twirl it gently between thumb and forefinger. The less pain there is, the faster you may twirl the needle. If it is not sore any more, move the needle to a different angle and twirl, and in this way gradually work around in a circle. If all or most of the pain is worked out, withdraw the needle and select another point. If it was sorer in a particular direction, insert the needle at a point 1-2 mm away from the first point in that direction and repeat the twirling and probing in different directions.

Often the pain shifts around over a reflex area and you must insert the needle and work out the pain in several points lying close together. When the ear point is sore and still in need of treatment, the needle will feel like 'sticking' when it is twirled, while it will move freely when the tension is worked out. For treating chronically weak body parts that do not have sore ear points, select the appropriate point or area from the ear chart and -twirl the needle rapidly.

Press-point Therapy: Each ear contains a complete reflex map of the body, as shown in figure 2-7. Instead of using needles, you can more safely press the ear with the head of a dull pin, toothpick, matchstick, or fingernail. Be careful not to penetrate the inner ear. Treat the indicated organ points or wherever there is a tender spot; press for a minute or more each day or whenever convenient. In addition, it will be stimulating to the whole body to massage both ears thoroughly by rubbing them between thumb and index finger simultaneously. Massage daily. Pulling the ears at different angles is beneficial as well. You can also buy an electro-acupuncture appliance, now available (and not too expensive) at many health food stores.

Each ear contains a complete reflex map of the body as shown in the chart. Instead of using needles, you may press the ear with the head of a pin, a toothpick, a matchstick or a fingernail. Treat the indicated organ points or wherever there is a tender spot; press for a minute or more each day or whenever convenient. In addition, it will be very stimulating to the whole body to massage both ears thoroughly by rubbing them between thumb and index finger simultaneously. Massage daily. Pulling the ears at different angles is also beneficial. You may also buy an electro-acupuncture appliance. These are now available from many health food shops and not very expensive.

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Step 17
COLOUR THERAPY

Use colours to balance body conditions and your emotions.

Colour has a powerful influence on our body chemistry. The strongest effect is through the eyes, but good results are also achieved by treating the skin areas over certain organs or the spine.

Colour can be used in various ways: as direct coloured light, or indirect light from the colours of walls, curtains and clothes; in foods, and by treating drinking water with coloured lights; by visualising colours with closed eyes; or by visualising that the inhaled breath or directed energy is coloured. For treatment you should be careful to select bright, clear colours; murky colours usually have unpleasant effects.

Coloured Lights: Light may be coloured by using coloured light bulbs, by filtering sunlight through coloured glass or cellophane, even by wrapping coloured cloth around a lamp. Drinking water may be treated by exposing it to sunlight in coloured-glass containers or in containers covered with coloured cellophane, or coloured light bulbs may be used. This water is beneficial for drinking, gargling in the case of throat infections, washing wounds or bathing the eyes.

Preferably, stimulating colours should be used in the morning and sedating colours in the evening. If a sequence of coloured lights is used, start with stimulating colours, proceed to blue and finish with green. When treating internal organs, shine the light at close range on to the skin area covering the organ, possibly also on to the spinal reflex area. For general treatment and especially to improve eye conditions, you may look at a brilliant, reflecting surface of the desired colour, exposed to sunlight or a strong electric light.

To treat specific parts of the body, you may cover them with a single or double layer of cellophane of the desired colour and expose them to mild sunlight or strong electric light. If using sunlight you should be careful not to over-expose as cellophane does not absorb the UV radiation. As a general tonic, you may cover the back with cellophane in the colours of the rainbow: red at the base, orange over the lower back, yellow in the middle, green at the shoulder blades, blue at the neck and violet over the head. These are also the regional chakra energy colours

Green is the general healing colour, representing harmony and balanced body polarities. In disease, there may be over-stimulation, with too much red in the system - fever, inflammation, irritability, skin rash, red eyeballs, pink fingernails; or there may be under-stimulation with too much blue - pale skin, sluggishness, bluish eyeballs, bluish nails. The over-stimulated condition needs blue colour treatment, while the under-stimulated condition requires red or orange.

The following list shows the conditions for which the different colours may be used. You may also use muscle testing or a pendulum for individual colour selection. Different parts of the body may need different colours. If you are in doubt about which area to treat, irradiate 'systemically' - over the whole body. When irradiating the back,

lie on one side, not on the stomach. For best effects or professional treatments, use colour slides with a strong projector in a dark room, and irradiate for one hour or longer at a time.

The Curative Properties of Colours:

RED (BRIGHT RED): Warm and stimulating. Use in anaemia, or whenever you are feeling cold and pale, with chilled extremities; also useful for ultraviolet and X-ray burns and frostbite; red is a liver stimulant and counter-irritant (to bring internal inflammations to the surface). Nutrients: vitamin B12, acidity.

ORANGE: A respiratory stimulant; useful for weak lungs, asthma, consumption, emphysema; also for overweight and under-active people with an under-active thyroid (energises thyroid, sedates parathyroids). Orange relieves spasms and cramps; increases milk secretion; corrects rickets and soft bones, osteoporosis; stimulates stomach and digestion, and relieves flatulence and distension; also stimulates the bladder, kidneys, liver and pancreas, try with epilepsy. It is valuable for chronic kidney disease and gallstones; arthritis, gout and rheumatism during non-painful periods. Minerals: boron, calcium, copper, selenium, silicon.

YELLOW: The most luminous colour. A strong stimulant and energiser for muscles and nerves: use in all cases of paralysis and muscle disorders, for nerve building, and in nervous exhaustion. Yellow energises the alimentary tract and stimulates digestion, flow of bile, gastric juices, pancreas activity, lymphatic system, heart, eyes and ears. It generally activates all bodily functions except those of the spleen, which is sedated; use for indigestion, constipation, diabetes, depression, for skin cleansing and to destroy intestinal worms. Minerals: magnesium, molybdenum, sodium.

LEMON (YELLOW-GREEN): Stimulates brain activity and activates the thymus. It is a mild laxative and expectorant (expels mucus): use in respiratory problems involving phlegm, asthma, coughs. Lemon is useful for dry, scaly skin disorders and bone building. It neutralises overacidity, and is indicated for chronic disorders in general, including cancer (systemic), diabetes and dwarfism. Minerals: gold, iodine, iron, phosphorus, silver, sulphur.

GREEN: Stimulates pituitary gland, encourages muscle and tissue building, and breaks up hardened cell masses and clots. It is anti-congestive, germicidal, disinfectant, purifying: use for heart problems, ulcers, cancer, wound healing, skin improvement, burn pains, glaucoma, headaches, neuralgia. Elements: chlorine, nitrogen.

TURQUOISE (BLUE-GREEN): Normalising for acute disorders. It is calming, and therefore useful for headaches, for soothing inflammations, sunburn and itching. It improves, rebuilds and tones the skin: use for moist- or weeping-skin disorders. It is also valuable for acute childhood diseases and infections, acute venereal diseases, and hyperactivity. Minerals: chromium, zinc.

BLUE: Cooling, strongly anti-inflammatory, antiseptic, stops bleeding; reduces fever, pain. Use to treat all conditions marked by redness, swelling and heat, and acute phases of arthritis, gout and rheumatism. Blue is relaxing and calming, slows the pulse, can reduce high blood pressure, and is valuable for underweight and overactive people. Use to treat itching, irritation, irritability, insomnia, throbbing

headaches, speedy brain; sore throat, loss of voice, burns, bruises; diarrhoea, dysentery, colitis, neuralgia, sciatica, earache, biliousness and jaundice. Also good for treating tumour areas and red or infected skin disorders. Element: oxygen.

INDIGO (BLUE-VIOLET): Sedative, pain relieving, arrests discharges and bleeding, astringent. Use for piles and varicose veins. Indigo improves the immune system during infections: use to irradiate swollen lymph glands; in whooping cough with fever and other acute lung disorders; for convulsions and nervous irritation. It stimulates the parathyroids and sedates the thyroid; use locally for goitre.

VIOLET: Relaxing and soothing. It also stimulates the spleen and builds white blood cells. Violet sedates heart and muscle activity, and calms hyperactive people. It is useful for overactive kidneys and bladder; bed-wetting; nerve disorders and overactive mental disorders; epilepsy; insomnia. It also suppresses appetite.

PURPLE (BLUE AND RED): Dilates blood vessels and reduces blood pressure: slows the pulse as with palpitations (irradiate heart area). Purple lowers body temperature, and is excellent for high fevers; it stimulates the activity of veins; is a good sleep inducer for insomnia; decreases sexual desire and pain; is anti-malarial; sedates the kidneys.

MAGENTA (RED AND VIOLET): Energising; improves and normalises the emotions, the aura and the sexual system. Magenta energises the adrenal glands and the heart muscle, normalises the heart and blood pressure, and improves the circulation. It is diuretic; useful for kidney stones; complementary to green. Mineral: potassium.

SCARLET (2 PARTS RED AND I PART VIOLET): Narrows the arteries and raises the blood pressure; energises kidneys (diuretic); use as a sexual stimulant or for frigidity, and for suppressed menstruation. Scarlet accelerates the birth process and expels the placenta.

Photochromotherapy: Absent individuals may be treated (with their consent) by exposing their photographs or even a sample of hair or hand-writing to suitably coloured lights. Following is an arrangement that reportedly gave especially good results: line a box with crumpled and partly restraightened aluminium foil. Place the photo on the bottom, covered with a glass plate to prevent heat damage. Suspend from the top a small coloured light bulb, as used in Christmas decorations or similar ways. Cover the top with more aluminium foil treated in the same way.

Another possibility is to cover the aluminium-foil-lined box with cellophane of the desired colour and expose the box to moderate sunlight. Exposure time may range from one hour to several hours, depending on the severity of the condition and the reaction of the patient. A pendulum may possibly be used for assessing colours and exposure times.

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Step 18
MAGNET THERAPY

Take advantage of the fact that both poles of a magnet have useful biological effects.

Magnets are effective healing tools. The opposite poles of a magnet have different effects on the body, so it is essential to identify the poles correctly. According to physics, if a magnet is suspended on a thread, the pole pointing towards the north is called the north pole; the other pole is the south pole. So here, north pole means north-pointing pole. Another way of finding the polarity of a magnet is to move it slowly towards the north-pointing end of a compass needle. If the needle turns away, the north pole of the magnet has been used, and vice versa. Test the polarities of any acquired magnets, as you cannot rely on the pole designations of the manufacturer.

How to Use Magnets: U-shaped magnets are not suitable for magnet therapy. Instead, flat ceramic or neodymium magnets are best; otherwise short, cylindrical, or bar magnets can be used. The north pole generally has strengthening, stimulating qualities; it gives energy. It can be used to improve weak organs (indicated by dark markings in the iris). The south pole withdraws energy; it is sedating and relaxing. It can be used for pain relief, to reduce unwanted growths (tumours) and swellings, soothe inflammation, and arrest infections (indicated by white iris markings). The magnet does not have to touch the skin to work but can be kept in a cotton bag pinned to the clothing, the specified pole facing the body.

Most therapeutic magnets are composed of ferro-ceramic material (usually called ceramic magnets) and break easily when dropped. The therapeutic strength of a magnet is a product of its gauss rating and its size. In physics, gauss is the unit of magnetic strength. The magnetic field of the earth is about 0.5 gauss; a magnet with a weak rating has several hundred gauss and a strong magnet several thousand gauss. However, even a magnet with several thousand gauss can have a weak therapeutic effect if it is small. To give an example of commonly used magnets: A strong ceramic magnet can measure three by two by one inches, and a weak magnet two by one by one-half inches, both with 4,000 gauss at the surface.

Very strong magnets are made with neodymium, a rare-earth element, and have 9,000 gauss or more. Neodymium magnets are relatively small, and their fields do not reach far into the body. Therefore, neodymium magnets are commonly used to treat areas near the surface, as in small disk or button magnets for acupuncture points. Ceramic magnets, on the other hand, can be large and heavy, their effects reaching far into the body. Therefore, with pain or a tumor deep inside, apply a strong ceramic magnet, three by two by one inches or bigger, while for near the skin use a neodymium block magnet of one by one by one-half inch.

As a general rule, apply strong magnetic fields for acute problems and weak fields for chronic problems. In both cases, you can apply a magnet either continuously or intermittently during the day until the problem is resolved. For acute problems, this can be for days and with chronic problems for weeks or months. While

it is more convenient just to leave the magnet in place all day long, the effect seems to be stronger if you frequently alternate applying and removing the magnet.

If a magnet is used for too long or in the wrong place, you may feel uncomfortable or drained of energy. If this happens, remove the magnet immediately and apply the opposite pole for a while. Alternatively, place your hands on a large zinc plate or take homeopathic zinc 6X as an antidote to magnetic overexposure.

Do not use strong magnets directly on the eyes or heart, or on the abdomen during pregnancy. Preferably attach or remove strong magnets slowly. Strong magnetic fields suppress nerve signals and, therefore, either pole of a powerful magnet can eliminate pain. However, farther away from the magnet, the field weakens, and then the effects of the opposite biological pole become noticeable. Therefore, I recommend always using the correct pole.

If there is no contraindication due to pain, inflammation, or congested energies, then the preferred magnet placement for all individuals, male and female, appears to be the south pole towards the right front of the body and the north pole towards the left front. To a lesser degree, the back of the body has the opposite polarity to its front. This means that the energy of the left back is similar to that of the right front but not quite so strong. Therefore, if a north magnet is required on the right side of the body or a south magnet on the left, then it is best placed on the back.

If there is pain or any sign of inflammation in an organ, apply the south pole; if there is an obvious weakness, use the north pole. In most other cases, experiment with muscle testing to find the beneficial pole for the condition at hand. If you are in doubt about which pole to use, try one pole for some time and later the other pole, then compare results. The length of a testing period, before reversing poles, can be only a few minutes for acute cases or several days for chronic conditions.

While some people do not feel the magnet's energy and show little response, others are hypersensitive to it. In the latter case, use only a weak magnet for a short exposure or try magnetized water instead. Do not use a magnet in a bed with an innerspring mattress, steel frame, or steel base. In this case, the steel parts can become strongly magnetized with the wrong polarity and cause deterioration of the disease condition when the treated person lies on the bed.

Magnetized water is also beneficial for general use. Place one bottle on a strong south pole and another on a strong north pole for 24 hours, then drink the contents of each bottle separately. Alternatively, place a north pole and a south pole at both sides or at the top and bottom of a non-metallic container filled with water. For specific conditions, use either north-pole or south-pole treated water on its own, for drinking or external application (for example, as an eyewash). A strong balancing effect can also be achieved by drinking north-pole treated water and south-pole treated water on alternating days. Use muscle testing or a pendulum to decide, or experiment and observe the results.

For general improvement of your well-being, place strong magnets at the hands and/or feet; select poles according to the general rules. For problems in the upper part of the body, place the right palm on one pole and the left palm on the other. For problems in the lower part of the body, place one pole under the right foot and the other under the left foot. If mainly one side is affected, the palm can rest on a south pole and the foot of the same side on a north pole. Finally, a good general placement

is to have the right palm on one pole and the left foot on the other pole, or vice versa. Start using strong magnets in this way for five minutes and gradually increase to 30 minutes, or for as long as it feels beneficial.

A strong magnetic flow is sometimes beneficial for conditions of mild pain associated with weakness, such as weak shoulders that are sore when moved. Magnetic energy is often strengthening to the sex organs and lower pelvis; apply a north pole slightly to the right on the lower abdomen and a south pole slightly to the left on the lower back. For these flows, strong magnets can be kept in place for up to an hour, or for as long as it feels beneficial.

Using the Correct Pole: As pointed out, the south pole is placed towards a painful, inflamed, or infected part of the body, while the north pole is used if the body area is weak or underactive. However, there is a possibility that the weakness or underactivity is caused by a low-grade chronic infection or inflammation, which means it may still improve with the south pole and deteriorate with the north pole. Therefore, the south pole is generally safer to use.

Commonly, one side of the body has more pain, inflammation, sensitivity, or contracted, tight, or tense muscles than the other. When placing magnets under the palms or feet, place the south pole here and the north pole on the other side. Another good possibility is to lie down with a strong north pole towards the soles of the feet and a strong south pole towards the top of the head; put both magnets about four to 12 inches away from the body. You can also experiment with sleeping this way.

With caution, you can also sleep with a magnet placed directly at the crown of your head. You can move a strong magnet (e.g., 4,000 gauss, three by two by one inches) progressively closer during successive nights or sleep at first with a weak magnet (e.g., 4,000 gauss, two by one by one-half inches) and gradually increase its strength. This may be most beneficial for the elderly or those with neurological diseases. For this application, the body should lie in a north-south direction with the head pointing north. When using strong magnets on yourself while in your bed, make sure that your bed and mattress cannot be magnetized.

William Philpott, M.D., a magnetic re-searcher in Oklahoma, has described cases of increased beneficial melatonin and growth hormone production in elderly individuals sleeping with a strong south pole directly at the crown of the head. Also, symptoms of confusion, psychosis, schizophrenia, and epileptic seizures disappeared with south poles placed at the temples, Dr. Philpott has reported.

To find which pole to use, use muscle testing (see step 13). Sit down with one or both magnets placed in the questioned position. Raise a free arm and stretch it out horizontally in front of you with the palm down. Have a tester or helper gradually exert increasing pressure on the wrist of the outstretched arm to see whether it locks in position or gives way. Then reverse the poles of the magnets and test again. Either the tester or the tested person (or both) may notice that the arm is stronger with a particular placement of the magnets. This is the correct placement. The same test can be made while holding a jug with either north-pole or south-pole treated water pressed lightly against the abdomen.

Removing Congested Energy: When the south pole of a magnet, especially a strong one, has been applied to a painful or congested area (including one with unwanted growths), an effective way to remove it is to place your left hand between

the magnet and the body while slowly removing the magnet. Keep the hand close to the magnet. Then hold the south pole close to a water surface or near running water for about ten seconds; rinse your hands under running water.

This process of energy removal from a painful area can be repeated several times. The south pole can be circled over the congested area, starting with a large circle close to the skin and gradually moving higher in spirals above the body. When the magnet is four to eight inches away from the skin, place your hand under it and withdraw the magnet from the body.

Examples of Correct Use of Magnets: Remember the simple rule that the north pole gives energy while the south pole withdraws it. An inflammation, a tight muscle, or a swelling are energy congestions and need the south pole; an overly relaxed muscle needs more energy and consequently requires the north pole. Here are some practical tips:

Shoulder: Frequently, one shoulder is dropped while the other shoulder is raised. The lower shoulder needs the strengthening north pole and the higher shoulder needs the relaxing south pole to balance the forces. The same rule applies to the middle part of the spine if there is any sideways distortion (as in scoliosis).

Gallbladder: In the case of a gallbladder problem, the left leg is often shortened, pulled into the hip socket by tight muscles. The south pole applied to the hip can help correct this condition. After the magnet has been in place for some time, gently pull the leg at the ankle until both ankles are exactly side by side. The right leg can be stretched in the same way, if necessary.

Tumor: Use a strong south pole over a tumor; apply for two hours twice daily or for one hour three times daily. Hold the south pole close to running water after removal. However, with pain from a tumor or cancer, you may keep the magnet in place as long as required, even for days on end.
Wounds: Fresh wounds heal better with the south pole applied initially; later, use both poles in alternation; and in the final stages of healing, use the north pole for strengthening.

Broken bones: For broken bones, the north pole should be applied above the fracture (towards the torso), while a south pole should be applied opposite the north pole and below the fracture. Alternatively, treat the same way as for wounds.
Headaches: For headaches, use the south pole wherever the centre of the pain appears to be; but for general mental refreshment, attach the south pole to the forehead and the north pole to the base of the skull. This may also improve your psychic awareness.

Stomach and duodenal pain: For stomach and duodenal pain, place the south pole over the pit of the stomach, but to strengthen the digestion after a meal, apply the north pole.

Weak heart: To strengthen a weak heart, a small magnet may be carried in the left shirt pocket with the north pole near the breastbone. If there is pain, use the south pole instead. Check your pulse before and afterwards to see whether it becomes stronger and more regular. Even if the pulse does not improve, try using it the magnet for several days (during the daytime only) to see if you feel better.

Sexual energy: To increase sexual energy, sit on the north pole of a strong magnet. This improves the energy centre at the base of the spine as well as the sex glands. However, with vaginal candidiasis, sit on a strong south pole.

Lowering blood pressure: To lower the blood pressure, apply the south pole to the right side of the neck, over the carotid sinus. This gland is located above and to the side of the Adam's apple and just below the jawbone where you feel the main artery into the head. To raise low blood pressure, apply the north pole to this spot.

Overweight: If you are overweight and underactive, apply the north pole to the thyroid gland for stimulation; if overactive, use the south pole to slow the metabolism.

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Step 19
THE ELECTRONIC ZAPPER & MAGNETIC PULSER

Use electrotherapy to keep your body free of undesirable microbes and parasites.

Electrotherapies utilize low-voltage electricity to disable a wide range of microbes, including viruses, fungi, bacteria, and parasites, and have been shown to be helpful against a wide range of infections. Various patents have been issued for such devices and scientific papers published with the results. Tests conducted with the AIDS virus in the laboratory show that the ability of the virus to infect human T cells is reduced in direct proportion to the product of the magnitude of the current and the time that the virus is exposed.

An oscillating magnetic field has been used with similar good results to kill microbes in food samples or living tissue. Numerous papers in the International Journal of Neuro-science show the positive effects of very weak pulsating magnetic fields applied directly to the top of the head on neurological diseases, such as multiple sclerosis and Parkinson's disease.4 Other researchers have used magnetic pulses on the brain to successfully treat depression.5 Even bites from poisonous snakes have been neutralized with electrotherapies without any negative after-effects.

Electronic Zapper and Blood Purifier: There are now many types of electronic antimicrobial devices available. These originated in the 1990s from the Hulda Clark "zapper" and the Robert Beck "blood purifier." Hulda R. Clark, N.D., is a Canadian microbiologist, and the late Dr. Robert C. Beck (D.Sc.) was an American electro-engineer. Both devices appear to eliminate parasites, bacteria, fungi, and viruses from the body with low-voltage, pulsed electric currents. The Clark zapper operates with 9 V at a very high pulse frequency of 30,000 Hz (Hz is the unit of electromagnetic wave frequency, equal to one cycle per second). The Beck blood purifier uses 27 to 36 V and a low frequency of 4 Hz. It appears that microbes are not killed outright by the mild electric current but are changed in such a way that they are prevented from replicating.

Evidence suggests that most of us harbor hidden microbes, and electrotherapy is an easy way to reduce or eliminate these. Therefore, I recommend electrotherapy as a basic component of a health improvement program, in the same way as I recommend intestinal sanitation and allergy testing, regardless whether there is an obvious problem or not. In addition to other measures, I regard electrotherapy as valuable in treating infections and infectious diseases.

With the Clark zapper, you hold an electrode in each hand through which a weak current flows. To establish firm contact, rub your palms with saltwater and hold the electrodes firmly. Alternatively, wrap the electrodes in absorbent paper or cloth moistened with saltwater. With weak hands, the best contact results from dipping each hand or foot in a bowl of saltwater along with a partly immersed electrode, but only if no electronics are in the handle. After the last treatment of the day, rinse your hands and/or feet under running water to remove static electricity.

If you are treating a local infection or tumor, press one or both electrodes close to the problem area; for instance, for a sore throat, press an electrode against each side of the neck. The negative electrode, commonly attached to a black wire, tends to sting sensitive skin. As with magnets, it is important in which hand you hold a particular electrode; otherwise you may feel weaker after zapping. Hold the negative electrode on the side of the body where the tumor, pain, infection, or inflammation is located, and hold the positive electrode with the red wire in your other hand. Try muscle testing to find the best electrode placement. Have someone gently press down your raised, outstretched arm while holding the electrodes one way and then the other. Use the electrodes indicated by the stronger test.

The normal treatment schedule is seven minutes, three times daily. The second zapping should follow 20 to 30 minutes after the first one, and the third one after a similar interval. (For more information, see Hulda Clark's The Cure for All Diseases; www.drhuldaclark.org.)

I have found the Clark zapper useful, but the Beck zapper works better in conditions where the blood is infested with microbes or parasites. It appears that with the Clark zapper the current travels mostly over the skin due to its high frequency, while the Beck zapper is specifically designed to electrify and purify the blood; therefore, it is sometimes called a blood purifier.

With the Beck zapper, the small electrodes are fastened directly over the arteries, so you feel a pulse on one forearm or near the ankle on each foot. My recommendation is to use the blood purifier initially for two hours daily for about two months, and then for one month once a year. I am not aware of any dangers or contraindications, but if you are unusually electro-sensitive or a problem arises, then stop treatment. As with all natural therapies, electrotherapy may start a healing crisis; in that case, interrupt treatment until you feel normal again.

Dr. Beck warned that cells may take up medical drugs and herbal medicines at a much higher rate during the zapping, due to a process called electroporation; this may cause drug overdosing. Originally, he recommended not using drugs and other potentially dangerous remedies, including raw garlic, during the weeks and months of treatment. However, in later interviews, he softened his stand and advised cautiously taking needed drugs or potentially dangerous remedies after the daily zapping rather than beforehand. There is no firm evidence that electroporation occurs with the electronic zapper, so I believe Dr. Beck may be exercising caution.

Application of the Magnetic Pulser: Dr. Beck also designed a magnetic pulser to treat swollen lymph glands and other sites of infection and tumours and other parts of the body with poor blood supply. A strong but very brief magnetic pulse induces a tiny current in the cells and body fluids. In addition to helping eliminate microbes, parasites, and cancer cells, it also appears to recharge and rejuvenate weak body cells. This technology is based on U.S. patents in which laboratory test results were submitted showing inactivation of HIV and destruction of cancer cells.

The most notable effect that I have observed in using the magnetic pulser is pain relief, be it from back or hip pain, toothache, or cancer, but it was less effective with headaches. Often the pain did not come back. Also, weak eyes and weak muscles often improved. Whether you have a disease or want to improve your health, I recommend you use the pulser frequently on any body area where you suspect an inflammation or infection. Use it on swollen lymph glands (tonsils) and

any tooth or jawbone positions that are not completely healthy, e.g., where a tooth has been extracted or where there is a filling, a root pocket, or receding gums. Pulse all the lymph glands in the neck, armpits, and groin. Hold the pulser as close as possible to the treated problem area.

Commonly, a pulse occurs every two to five seconds and treatment time ranges from ten to 30 minutes. After ten to 20 pulses, you can move to the next area, treating in turn lymph glands, tumours, tender joints, teeth, organs, or any area with an infection. However, remain much longer at major problem areas, up to 30 minutes if required, as for pain relief. A recent development is a magnetic pulser with up to ten or more pulses per second. It appears to work by creating a pulsing magnetic field rather than just single short pulses. I found this more effective than the slower pulsers.

There are other types of weak magnetic pulsers available that may be helpful in stimulating cellular rejuvenation. For example, fields of 2 to 7 Hz are suitable to treat neurological disorders, but because of their much lower magnetic pulse intensity, they do not appear to inhibit microbes or parasites and may stimulate their growth. To avoid any damage to normal body cells, the Beck pulser is set at the lower end of magnetic strength to disable microbes and parasites. For this reason pulsing may have to be continued daily for weeks or months to overcome serious and long-standing health problems.

Another important aspect is to be aware of the polarity of the coil. One side acts as a magnetic north pole and the other side as a south pole. It is important to use the correct pole as explained previously in Magnet Therapy. This may not be noticeable with strong magnetic pulses, as both sides can suppress nerve signals of pain and improve general health by recharging damaged electric cell potentials. However, there are other conditions that can get worse from using the wrong pole, while using the biologically correct pole can also give better results with pain, microbes, and general health improvement, especially farther inside the body where the pulse strength rapidly declines. When holding the back of the magnetic pulse unit, called the paddle, hold it with the hand that benefits from that particular polarity.

To find out which side of the paddle is north and south, place a small flat magnet with known polarity on top of one side and watch what happens with the next pulse. Like poles repulse each other. Therefore, if the magnet jumps off, that side of the paddle has the same polarity as the side of the magnet placed on it face down. If you then turn the small magnet around, it should not jump off. Mark the polarities on the paddle. If you do not have a specific reason to use the other side, then use the south-pointing side of the paddle facing the body. However, if you do not get results within an appropriate period, then try the north-pointing pole instead.

For further information on electro and magnetic medicine, including articles by Dr. Beck and plans to build the zapper and pulser, see www.quantumbalancing.com ; www.keelynet.com/biology.htm; and www.sotainstruments.com.

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Step 20
SPINAL THERAPY & MASSAGE

Improve the activity of all your organs and glands by massaging your spine and body.

Massage is an effective and usually enjoyable healing tool. It helps one to relax, loosens up tight muscles, and removes fluid accumulations and congestions. Massaging close to the spine is especially effective to stimulate the activity of internal organs and glands. This is due to the network of nerve connections emanating from the spine and the multitude of important acupuncture treatment points along the spine.

There is a reflex connection between every organ system and the spine. The malfunction of an organ will produce tension in a specific part of the spine, while a misalignment of the spine will cause tension in a specific organ. Additionally, various acupuncture points along the inner branch of the Bladder meridian, close to the spine, are linked to specific organs, and on both sides of each vertebra (less than one inch from the midline) there are points not usually included in the standard meridian system diagrams but related to certain regions of the body.

The Benefits of Massage: A spinal massage is best given as part of an overall body or back massage. For an initial general massage, you may (or may not) use massage oil. It is helpful to know special massage techniques, but not essential. Rub, stroke, and knead as it comes naturally. A caring attitude during massage is more important than technique.

Glide slowly downward with your thumbs on each side of the spine (fingers or knuckles may be used as well). Press firmly for a moment into the muscle, then glide to the next vertebra. When you find a sore spot, ease up on the pressure, and press for several minutes with a slightly circular motion. Increase the pressure when the pain subsides. Repeat this several times, gliding down the spine, pausing at tender areas. Do not rub directly on the vertebrae.

Other body points typically in need of special attention are the base of the skull, the neck and shoulders, the tops and centres of the shoulder blades, the buttocks, the hips and the sides, and the back of each knee.

Another technique to treat tender muscle points along the spine is to apply constant but moderate finger pressure on each tender spot for about 90 seconds. Direct the pressure sideways against the spine, and try to relax the treated muscle to ease any pain caused by a strong pressure. When treating the upper part of the spine, lift the shoulder; when treating the lower part, raise the hip. For the neck, gently move the head against the finger pressure. Experiment to find the position in which the treated muscle is most relaxed. The patient should remain passive during the treatment and should not try to help move any body part.

Give your partner a massage and pressure massage once a week; this is best after a bath or shower. This is an excellent exercise for developing a harmonious

relationship with a friend or partner. When using long strokes during massaging, follow the flow directions of the acupuncture meridians (see Part 7).

Massage Oils: Topical massage oils are commonly used to let the hands glide over the skin in long strokes. However, for pressure therapy, deep muscle work, and for sensing the energies, it is often better not to oil the skin. Massage oils can also be selected according to the specific needs of the massaged person. The American psychic Edgar Cayce offered the following recommendations:

- General Tonic Massage: Peanut oil, 6 parts; olive oil, 2 parts; dissolved lanolin, 1 part; rosewater, 2 parts; shake well before use.
- Peanut Oil and Olive Oil Mixture: 2 parts of each and 1 part dissolved lanolin; this is good for arthritis and rheumatism, the after-effects of anaesthesia, injuries from accidents, kidney disorders, menopausal complaints, multiple sclerosis, prostatitis, and toxaemia.
- Peanut Oil Alone: Good for apoplexy, arthritis, gallbladder inflammation, coronary occlusion, fatigue, glandular disturbances, low vitality, menopause, multiple sclerosis, palsy, paralysis, Parkinson's disease, polio, poor circulation, and ulcerated stomach. Preferably, first heat the body with an infrared lamp or by exposing it to sunshine during and after the oil rub.
- Castor Oil Alone: Good for arthritis, back pain, contractions and spasms, rheumatism, and all muscular and joint pains. Rub very warm castor oil into the affected parts, preferably using an infrared lamp or sunshine to heat the skin so as to help work it into the skin.
- Removal of Scar Tissue: Combine 1 to 2 parts camphorated oil with 1 part peanut oil; massage into the scar tissue once daily for several months. Alternatively (or in addition), use vitamin E oil.
- Cocoa Butter: This stimulates the circulation in massaged areas and strengthens the nervous system and eliminating functions. It is especially useful for massaging babies and young children gently along the spine. It helps body development and guards against head congestion. For increasing the size of underdeveloped breasts, massage around the glands under the arms and below the breasts. Direct massage of breasts with cocoa butter combined with alum water has been recommended by Edgar Cayce to decrease their size. You may use melted cocoa butter on its own or as part of a massage-oil mixture.

Add various aromatic oils for their fragrance or for any additional healing effect they offer. The olive oil should be extra-virgin, and the peanut oil cold-pressed; store both in a cool, dark place. Squeeze some vitamin E oil capsules into the massage oil. A small amount of massage oil can be lightly warmed before applying it to the body. I am not in favour of using polyunsaturated oils as massage oils as these easily become rancid.

Treating Muscle Pain: Muscle pain is commonly due to a contracted or spastic muscle. This can generate pain from pressure on a nerve or from an inflammatory condition resulting from overacidity in the tissues. The original cause may be an injury or overuse of the muscle, but this causes lactic acid accumulation in the muscle, which prevents calcium from moving out of the muscle fibres to allow them to

relax. The blood and lymph circulation through the contracted muscle is greatly diminished. Therefore, lactic acid is removed very slowly by the body and oxygen supply to the muscle is low. Hence the pain.

In this condition, further use of this muscle generates more lactic acid and keeps it contracted and weak or painful. If this condition becomes permanent, the area tends gradually to calcify, such that two vertebrae may fuse or a joint may become immobile. The solution is to use suitable therapies to relax this muscle and increase the blood and lymph flow through the area, as with the following: Have a period of rest to allow the lactic acid to disperse. Heat, such as a hot pack, hot bath, or rubbing, greatly speeds up this process. Adding Epsom salt or magnesium chloride to the bath aids muscle relaxation by displacing some of the calcium in the muscle with magnesium. Adding baking soda to a bath or pack helps reduce the overacidity of the muscle. Magnesium and/or an alkalizer may be used internally; MSM, for example, taken internally as well as applied externally, generally speeds up these processes.

A quick but painful way to relax a tense muscle is to press into it for several minutes. In addition to or instead of this, a deep muscle massage greatly speeds up lymph and blood flow through the muscle; press, knead, and rub the problem area. Other supportive measures include color therapy with blue light, the south pole of a magnet, a pulsed magnetic field, reflexology, and acupuncture and meridian therapy (see appropriate steps elsewhere in this book).

Aiding Spinal Correction: Frequently, health problems are intensified by a misalignment of the spine. Hereditary factors, ingesting incompatible food, and negative or suppressed feelings can cause organ and gland functions to become overactive or underactive. This in turn weakens or tenses muscles in associated reflex areas of the back. The same may happen because of one-sided strenuous muscle activity. This causes an uneven pull of muscles on the spine, and an individual vertebra can easily become misaligned, causing pressure on nerves emerging from the spine and consequent pain or malfunction.

Therefore, most people with health problems will benefit from an initial professional adjustment of the spine. However, if the muscles are not balanced simultaneously, the correction will not last and you may become a regular visitor to a chiropractor. This is not necessary. Try to see an osteopath or chiropractor who does muscle balancing as well as adjustments. Working with a friend, you can easily balance each other. Here are some tips:

- For backache, first find out, by pressing, which side of the back has more tenderness.
- Trace the Bladder meridian of the tender side with a south-pole magnet (or the energized fingers) from toe to head several times. Trace the Bladder meridian on the other side from head to toe with a north-pole magnet. For neck, shoulder, and hip problems, trace the Gallbladder meridian in the same way (for charts of the meridians, see Part 7).
- Apply ear acupuncture, reflexology, or a strong south-pole magnet to the painful area.

- Press into the tender muscle until the pain eases, then press harder and circle the thumb, knuckle, or elbow that is applying the pressure.
- Check for other tender points in the same area and work these out in the same way. Often misaligned vertebrae will then realign themselves during subsequent back-stretching exercises or with head-and-neck exercises.

As a general rule, neck and shoulders are affected by the organs and meridians of the gallbladder, upper back by the lungs and heart, the middle by the stomach and pancreas, the lower end of the rib cage by the kidneys, and the lower back by the intestines and sexual organs. Liver problems often manifest as a pain near the lower right shoulder blade.

One of the best methods for back improvement is regularly hanging upside down, from special inversion equipment or a ladder. Traction on the neck improves the upper spine.

How to Apply a Spinal Concussion: This is an effective method for stimulating and strengthening weak organs and body parts. The general principle is to stimulate the nerves emerging from the spine with rapid soft taps to certain vertebrae. Use the edge of your hand or the knuckles to tap the selected vertebra rapidly (but not very hard) for about 30 seconds. Then rest or treat another vertebra for 30 seconds and return to the first one. Repeat this process for five to eight minutes.

For general health improvement, go the length of the spine and stimulate each vertebra in turn with this method. Tap firmly at the lower spine but only lightly at the neck. Let your patient or partner tell you how hard to tap so that it still feels invigorating and pleasant. This treatment can be repeated daily, weekly, or when feasible. If tapping produces pain, seek professional advice. If sedation rather than stimulation is required, try prolonged gentle pressure, gradually varying in intensity, on the appropriate vertebrae. Select suitable vertebrae from the following compilation.

Selecting the Vertebra Based on Its Associated Health Condition: Here are some general guidelines for this. There are seven cervical vertebrae, 12 dorsal or thoracic vertebrae, and five lumbar, plus the sacrum and coccyx.

Cervical vertebrae:

1: head, brain, pituitary, sympathetic nervous system

2: eyes, tongue; hearing problems, sinuses, allergies, fainting

2-3: for headaches, prolonged pressure between C2 and C3

3: cheeks, teeth, outer ear; acne, eczema, neuralgia, neuritis

4: nose, lips, mouth, Eustachian tube; catarrh, hayfever

5: vocal cords, neck glands; throat problems, pharynx

6: neck muscles, shoulders; tonsils, upper arm problems

7: thyroid, goitre, shoulders, elbows, contracts inner organs, contracts dilated heart, normalizes blood pressure; bursitis, nose bleeding, fainting, angina, palpitation, tachycardia (fast pulse), lung and kidney diseases, diabetes. (C7 is

the most prominent vertebra at the base of the neck. Use it as a landmark for counting the other vertebrae along the spine.)

Dorsal or thoracic vertebrae:

1: lower arms, hands, oesophagus, trachea; asthma, cough, breathing problems, thymus

2: heart, coronary arteries, lungs; chest pain

2-3: for hiccough, press between D2 and D3

3: lungs, breasts; increases milk flow, contracts gallbladder, oesophagus, and pylorus; dilates heart and peripheral vessels, reduces blood pressure

3-4: tap both for developing breasts

4: contracts and empties gallbladder, increases secretions of pancreas; jaundice, hepatitis, shingles

5: liver, solar plexus, opens pylorus and empties stomach; low blood pressure, poor circulation, anemia

6: stomach; indigestion, heartburn, dyspepsia

6-7: tapping both dilates the kidneys; nephritis

7: pancreas, duodenum; diabetes, ulcers, gastritis

8: spleen, diaphragm; hiccoughs

9: adrenal glands, dilates gallbladder; allergies, biliary colic

10: kidneys; dilates pancreas and blood vessels, reduces blood pressure; nephritis, ataxia, anemia

11: kidneys, urethra; dilates heart, stomach, liver, spleen, abdominal arteries, intestines, in-creases blood supply to lungs; spasms, nervous diarrhea, angina, skin problems

12: small intestines, Fallopian tubes; contracts kidneys; affects lymph circulation; associated with enlarged prostate

Lumbar vertebrae:

1: large intestines; constipation, diarrhea, colitis, hernia

2: appendix, abdomen, upper leg; cramps, varicose veins

3: sex organs, ovaries, testicles; bladder, knee, menstrual problems, impotence, bed wetting/ incontinence

4: prostate, lower back muscles; sciatic nerve, lumbago, and backache; difficult, painful, or too frequent urination

5: lower legs, feet; contracts bladder; leg cramps, cold feet

Sacrum: hipbones, buttocks; sacroiliac conditions

Coccyx: rectum, anus; haemorrhoids, pruritus

Lymph-Drainage Massage: Danish medical doctor E. Vodder developed a method of manual lymph-drainage massage in the early 1900's. It is designed to

improve lymph flow and accelerate the transport of waste products from the tissues into the bloodstream from which it can be eliminated through the kidneys. A congested and stagnating lymphatic system is a main cause of infections, inflammations, and degenerative diseases.

The lymph flows upwards through the legs to the large lymph nodes at the groin and up the arms to the main lymph nodes at the armpits. From the groin and abdomen, the lymph collects in the thoracic duct, which flows along the midline of the body and, together with the lymph from the upper left side of the body, empties into a large vein under the left collarbone. The lymph from the upper right side of the body joins a vein under the right collarbone.

Lymph massage should start and end with the chain of glands at the sides of the neck, running from below the ears to the hollows of the collarbones. For massaging the limbs, Vodder taught light, slow, circular movements with the four fingers of the hand, not the thumb. Movement can be clockwise or counter-clockwise (whichever feels better), but do not change direction during the massage. The skin should be moved lightly over the underlying tissue. Generally, five circles are made at any one place, one circle per second. Vary the finger pressure during the circling to achieve a pumping effect. Then move about two inches along the limb and repeat the circling. During massage, a limb should be raised, while well supported and relaxed, to help the backward flow of the lymph.

When massaging an arm, start at the upper arm, near the armpit, and press-circle ten times. Then do the same at the insides of the elbow, and finally squeeze each section five times from the palm upward to the armpit. Do the same with each leg. Squeeze ten times near the groin, then the back of the knee, and finally from the foot upwards to the groin.

Along the trunk, from the groin upwards, use long, firm upward strokes towards the left collarbone; do this also along the spine and the sides of the back. However, the main benefit for the trunk lymph drainage will be derived if the patient lies on his back and makes bicycling movements in the air. The movements must be either parallel to the floor or, better still, vertical while in the shoulder-stand position. Do this exercise for one minute before and after leg-drainage massage to make room in the trunk for lymph from the legs. Varicose veins, wounds, and tumours should not be massaged. Individuals with advanced diseases should activate the organs of elimination before using this method. If in doubt, consult your health professional.

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Step 21
HYDROTHERAPY, PACKS & COLONICS

Use water to relax or alleviate painful conditions.

Hydrotherapy, the use of water to treat disease, involves practices such as drinking large quantities of water to flush out toxins, taking hot and cold baths, saunas, packs, and colonics (enemas). Preferably, use non-chlorinated water if available, as it is less irritating to the skin.

Hot Baths: Hot baths are useful for relieving aches, pains, and stiffness, for releasing toxins stored under the skin, and for cleansing the skin of fungal infections. Gradually increase the temperature of the bath water, as far as you can reasonably endure. Remain submerged, except for the face, for ten to 20 minutes. For conditions associated with magnesium deficiency, add from one to ten pounds of Epsom salt to the water; the greater the pain, nervous tension, or stiffness, the larger the amount you should use.

Become accustomed to hot baths gradually by increasing the duration and maximum temperature of the bath on successive occasions. Have someone on call, especially if you have a heart problem. Do not use a hot bath or Epsom salt in the case of low blood pressure, fatigue, distended veins, or a weak heart, and be cautious if your blood pressure is high. The body should be completely immersed, but you can cool the forehead with a cold cloth.

To improve dermatitis, place a sealed muslin bag filled with up to two pounds of bran in a hot bath; immerse yourself, as above. To relieve itching skin, add a spoonful of baking soda to the water. For arthritis, if a full hot bath is too severe for you, have a hot foot or hand bath with Epsom salt to get relief.
After your bath, cover your body with a large towel and, without drying, cover yourself up in bed to induce sweating; rest for 30 minutes, or overnight. Afterwards, a massage or a quick rub with olive or peanut oil is recommended.

Overheating Baths: The following method can be used for your general health improvement and to overcome chronic infections. However, I do not recommend it as a specific cancer treatment. It appears to work only when the blood sugar level during the overheating is low (i.e., you haven't eaten for a while) and the water temperature is high; otherwise tumor growth can be stimulated. For those without cancer, it is good occasionally to have an overheating bath followed by sweating - in other words, a bath that will overheat you. Cancer cells and viruses are weakened and start dying in environments over 105º F (40-41º C), while normal cells can withstand higher temperatures. This explains the curative effect of high fever on cancer and infectious diseases. For home treatment, a therapeutic fever can be simulated with overheating baths.

Start with a very warm bath and slowly add more hot water until the bath temperature reaches 108º F (42º C). Initially remain in the tub only up to ten minutes at the maximum temperature, but gradually extend this to 20 to 30 minutes. If you

want to continue with a regular overheating treatment, then increase the temperature by 2º F (1º C) each week up to a maximum of 116º F (47º C).

If the weekly temperature increase is too severe, increase it more gradually. If you cannot reach the maximum temperature, extend the bath duration at your highest possible temperature to one hour. During and after the bath, drink several glasses of pure water to make up for fluid losses.

As a safety precaution, keep the bathroom door open and have a helper close by. You are safe while lying in the water; the danger arises when leaving the bath.

Therefore, strictly observe the following rules:

- If you must leave the bath suddenly, immediately lie down again.
- Remain in the bathtub until all the water has drained. Alternatively, add cold water until the bathwater feels only warm; stay in the cooler water for 10 to 15 minutes.
- Dry yourself only while sitting, never standing; afterwards, cover with sheets and blankets and sweat for up to one hour.
- Do not use overheating baths when you do not feel well.

Warm Baths: These are excellent for relaxation; stay in a warm bath for ten to 20 minutes; fragrant oils can be added. Staying in a hot or warm bath for longer than 30 minutes can be exhausting. If stimulation is desired, a warm or hot bath should be followed by a cold bath, a cold sitz bath, or a cold shower. You can also use hot and cold alternating showers or cold-water sponge rubs. Cold-water stimulation is especially important for low blood pressure and distended veins.

Sitz Bath: To improve intestinal elimination and the condition of the sexual glands and organs, a cold sitz bath is excellent. After warming the body by exercise or a hot bath or shower, sit for one minute in about eight inches of cold water. Gradually, the sitting time can be increased to three minutes. Keep your feet out of the water.

Showers: For general stimulation and improving the circulation, use hot and cold showers, alternating three times between hot and cold, starting with hot and ending with cold.

Foot Baths: To increase the circulation in burning or aching feet, mix some tannic acid or mustard powder into a hot foot bath. To keep your feet warm, some cayenne pepper can be added instead. Use alternating hot and cold foot baths for leg problems.

Water Packs: To make a pack, fold a cotton or woollen cloth into several layers, dip it into hot or cold water, gently press to remove excess water, and place over the selected area. Hot packs (fomentations) can be used for the relief of muscle pains but are better in combination with Epsom salt. Cold packs are effective for insomnia, high temperature, nervous indigestion and wind, headaches, sore throat, edema, and sprains. For fever, the pack can be changed every five to ten minutes, while for relaxation, it can be left in place for a long time. For insomnia and nervous indigestion, place the cold pack on the abdomen.

Castor-Oil Pack: This is excellent for improving intestinal functions and for stimulating the immune system, as well as in problems with the sexual glands and

the bladder. Castor-oil packs on the abdomen should be used at the beginning of all serious attempts at health improvement, especially if there are any problems with the digestion, liver, gallbladder, or pancreas, or if you have arthritis, cancer, or any other degenerative disease. Hot castor-oil packs can be applied directly to weak, painful, or swollen parts of the body, for example, on weak eyes or eyes with cataracts or glaucoma, stiff neck, painful back, swollen knee, and on cysts and tumours. Persistent use of castor-oil packs frequently gives excellent results when other methods fail.

To make the pack, carefully warm castor oil (it burns easily); soak a woollen cloth in the oil and fold it into three or four layers. Cover the abdomen from the pit of the stomach, and including the lower rib cage, down to the pubic bone. If the cloth is not big enough, shift it on successive days of treatment so all areas get covered; favour especially the liver area under the right lower rib cage and any part of the body that causes pain or problems.

Place a plastic covering over the cloth with a hot-water bottle on top of that; finally, wrap a long towel around the torso and fasten it securely. If used in bed, place additional plastic underneath you or use old linen, as the pack might leak. Leave the pack in place for one to two hours, or overnight. Afterwards, sensitive skin can be wiped with warm water containing baking soda. Store the pack in a pot or tin for repeated use, adding more oil as required with each usage.

Use the pack for three to five days, interrupt the cycle for several days, and repeat the series as often as necessary. During or after a period of applying a pack on the liver and abdomen, take several tablespoons of olive oil at bedtime to induce emptying of the gallbladder.

Epsom Salt Pack: This is recommended for arthritis, neuritis, paralysis, back pain, muscle tension, gastritis, colitis, infections, and kidney problems. Dissolve Epsom salt in hot water to make a saturated solution; soak a cloth in it and apply it hot to the skin. Keep the pack warm with a hot-water bottle. Alternatively, Epsom salt can be spread liberally on a hot wet cloth and applied. Leave the pack on for one or two hours; repeat as required.

Rock Salt Pack: A pack of hot, coarse rock salt is effective for the relief of muscle pains, especially backaches. Cover a hot-water bottle with a moist cloth, sprinkle on a thick layer of coarse rock salt and lie with the painful area on top of this; or place this (salt-side down) on the painful area if more appropriate. Keep it as hot as you can stand it for an hour or two. Renew the salt if it is necessary to repeat the pack.

Honey Pack: The honey pack has an excellent reputation for healing infected wounds and ulcers, and it is used in alternative cancer therapy to destroy tumours and relieve pain. It is not only effective for problems close to the skin but can help problems such as pain as well. The honey must be raw and not previously heated. Smear a thick layer of honey over the affected area and cover it with linen. With long-standing problems, continue renewing the honey daily and keep the area covered all or most of the time for several weeks. It is even more effective if you mix a few drops of 35 percent hydrogen peroxide with the honey. Try to obtain honey that is not runny, as adding hydrogen peroxide makes it more liquid; crystallized honey works well.

Onion Pack: Onion packs are good for asthma, bronchitis, colds, pneumonia, and for loosening phlegm in the airways. Wrap a large onion in aluminium foil and bake it until soft. Pulp the onion in its juice and spread it over the upper chest and throat area. Cover this with a plastic sheet or cloth and keep warm for an hour or two with a hot-water bottle. Repeat as required. Do not eat the onion, as aluminium should be avoided in cooking foods to eat.

Potato Pack: Raw potato packs are excellent for irritated and weak eyes, as well as for blindness and cataracts. Grate a refrigerated potato; preferably, use the outer parts of old, organically grown potatoes. Cover the eyes for 30 to 60 minutes; you can put the potato pulp in some gauze if you like.

Cabbage Leaf Pack: The fresh outer leaves of green cabbages have healing potential when applied over weak or inflamed parts of the body. Hold one or two leaves in place over your abdomen and liver with a towel wrapped around your waist. Do this frequently. You can cut out part of the stem and roll the leaf with a bottle to flatten the ribs, especially if it is to be applied over sensitive skin areas. If no more outer leaves are available, you can also use the paler green inner leaves; wilted leaves are useless for this pack. Cabbage leaves are especially good for mastitis. For serious conditions, apply cabbage leaves 24 hours a day, renewing every four to six hours. For cancer, apply a leaf over the tumor site as well as over the abdomen and liver.

Green Leaf Pack: Other edible fresh green leaves can be applied over problem areas, either whole or as a pulp. To cover a fresh wound, for example, masticate some fresh wheat or barley grass and apply the juicy pulp.

Blistering Agents: The application of blistering agents and skin irritants produces the quickest relief for arthritis and related inflammatory conditions. The principle is to draw out through the skin the toxins and congesting energies from inside the body. Liniments, compresses, and plasters can be used. Suitable agents for this are a paste of mustard or cayenne, garlic, oil of wintergreen, or the white sap of a papaya or fig. Initially, they may cause skin reddening, which can give some relief, but if applied for a long enough time in a concentrated form, they will produce blistering, which is a much more effective healing response.

If the skin is non-sensitive, it is more effective to prick it in many places or to mechanically irritate it before applying the irritant. Cover the area with a cloth or plastic sheet until blistering has taken place. Large blisters can be drained first. Cover the blistered area with fresh cabbage leaves. For long-standing conditions, the blistering pack may have to be repeated several times.

Escharotics: The most effective way to remove skin cancer, melanoma, and tumours close to the skin, possibly including breast tumours, is to apply an escharotic. These are caustic remedies, commonly with zinc chloride and the herb bloodroot as main ingredients. These are available from some health stores and naturopaths. Skin cancers can become inflamed for a few days, then form dry pus (an eschar), and then fall out after about ten days.

To reach a tumor under the skin, such as a breast tumor, it may be necessary to leave the paste in place for two or three days and reapply fresh paste several times as soon as any developing pus has cleared. Keep covered with a Vaseline-

coated pad that may require frequent changing. Commonly, this procedure causes a strong local inflammation with swelling of the breast, redness, and pain for several days. The bigger the breast and the deeper the tumor, the more difficult is it to create a “hole” deep enough for the escharotic to reach the tumor, so more applications are required.

While this can be more uncomfortable and drawn-out than surgery, one advantage is that escharotics have a reputation of not creating secondary tumours in other organs. You can ease your discomfort during this time with painkillers and anti-inflammatory measures. For more detailed information on escharotic cancer salves, see www.altcancer.com and www.cancersalves.com.

Meat Pack: A folk remedy for drawing poisons from the body is to place fresh, raw, minced meat under the soles of the feet for several hours or overnight. Replace the meat several times if required. The meat is then poisonous, so do not touch it; best bury it. You can also try this (in addition to other measures) in the case of accidental poisoning or bites of poisonous snakes or insects. Raw meat can also be placed over malignant tumours for drawing; again, do not touch it when removing it from the skin.

Infrared Heat Lamp: Instead of a hot pack, you can rub a remedy into the skin and expose the affected area to infrared heat. For arthritic pain in the knee or hip or for back pain, use peanut oil, castor oil, or a solution of Epsom salt or magnesium chloride; you can also add other helpful ingredients to the magnesium solution, such as glucosamine and MSM. Continue with the heat for 15 to 60 minutes, and rub more of the remedy into the skin whenever it becomes dry.

Bowel Cleansing: Most failures in healing programs occur because bowel cleansing is neglected. Toxins are reabsorbed from the bowels and accumulate in the blood, causing or contributing to allergies, boils, cancer, colds, eczema, fatigue, inflammations, irritability, lack of concentration, menstrual problems, mental diseases, migraine, swellings, and general toxaemia. Furthermore, constipation is a main factor in gallstones, liver problems, and probably bowel cancer.

Increasing bowel movements to two or three a day is only a first step. Even more important than the frequency of bowel movements is the speed (called transit time) with which food residues move through the intestines. To check this, eat a highly coloured food (for example, red beets or a cob of sweet corn) with an evening meal. A healthy intestine should eliminate all colouring matter before lunch the following day or at least before the next evening. If it takes longer, you are constipated. Use appropriate mineral and vitamin supplements, laxative foods, colonics, acupressure, and exercise to improve bowel conditions (see Steps 3 & 4).

Ordinary toilets encourage a sitting rather than a squatting position. However, this posture is not conducive to the complete emptying of the large intestines. A squatting position is preferable. If you cannot squat on top of the toilet, support your feet with a footstool; additionally, bend forward to exert more pressure on the bowels (for further information, see www.naturesplatform. com). An alternative way of keeping the bowels empty is by taking laxative foods, such as ground linseed (flaxseed), and periodically having an isotonic flush (a teaspoon of salt in a quart of water) or Epsom salt flush (a teaspoon of Epsom salt in a glass of water), preferably with some crushed garlic added.

Early in the twentieth century, a British surgeon became famous for “curing” all kinds of incurable diseases by surgically removing the lower part of the large intestines of his patients. We certainly can do better than that and cure or prevent many diseases simply by keeping our intestines clean and avoiding surgery. Most individuals are very particular in keeping clean on the outside, using much soap and having frequent showers, but they do not seem to mind being stuffed with stinking waste matter. While this does not apply to everyone, it is a problem for anyone with constipation and especially for meat eaters and those with fat malabsorption. Overweight individuals can easily carry more than 20 pounds of putrefying bowel content as part of their body mass.

If you prefer to be clean on the inside as well as on the outside, develop the habit of “rinsing” your lower bowel once or twice after each bowel movement and possibly again before going to bed. You can do this by sitting on the toilet, with enema bucket or bag hanging from the wall near the toilet. After a bowel movement, insert a pint of lukewarm water and expel it immediately. To let the water penetrate more deeply you may for a short time bend forward with your bottom raised, but this is not essential. Finally, rinse the outside. Preferably use some gel or oil before inserting the tube or end-piece douche, and use a plastic glove.

Habitual bowel cleansing like this not only prevents the accumulation of putrefying matter in the lower bowel, it also greatly speeds up the transit time of the bowel content. Among other benefits, this tends to increase the release of bile and toxins from the liver and gallbladder and prevents the formation and accumulation of gallstones. However, if you try it several times and find that the enema water comes out clean after bowel movements, then you do not need to do it.

Colonics: Colonics - the name is short for colonic irrigation - is an effective therapy, bringing immediate relief for many health problems. The more serious the condition, the more often colonics should be used: once a week at first, but daily use may be required for a while. After several treatments, have a colonic once a month, and later, once or twice a year. Iris diagnosis (see step 12) can guide you as to the frequency necessary for your condition. If the intestinal area in your iris shows dark or brown discoloration, or if it is extended, colonics should be used more often; this is also true if foul-smelling wind is present, as this indicates putrefactive processes under way in the bowel pockets.

The aim of colonics is to remove all putrefying matter from the bowels, clean out the bowel pockets, and remove the hard crust that often coats the walls. To achieve this, the bowels should be filled repeatedly with as much water as possible. It is best to have a thorough bowel movement before starting the colonic.

To administer a colonic, add one heaping teaspoon of salt and one level teaspoon of baking soda to two to three quarts of moderately warm water. Use a bucket enema or enema bag; place it about two to three feet above the body on a table, chair, or the rim of the bath, or hang it from the wall. A good position is to kneel on the floor with your head down. More comfortably, you can lie in a warm bath with the rectum elevated, or you can lie in bed in a similar position, or on the right side; have a plastic sheet underneath you.

Lubricate the rectal tube and insert it slowly to a depth of about eight or 12 inches. If there is any pain or discomfort, do not insert it any farther. Expel the first lot

of water from your intestines when increasing pressure is felt. After that, you should be able to hold much more water. When renewed pressure is felt, stop the inflow of water and assume different positions, such as lying on your right side for a while so as to fill the ascending colon. Repeat the expulsion and intake of water until all of it has been used.

You can introduce a pint of diluted fresh juice of wheat or barley grass if available or of edible green leaves, and retain that in the intestines for up to 30 minutes. This is the standard procedure for home colonics for people with normal or acid body conditions. The addition of baking soda neutralizes the often overacid bowel condition, while salt acts partly as a drawing agent and partly prevents demineralization of the blood plasma by osmosis, which could cause shock. This is important for people with low blood pressure and poor blood circulation. Those with high blood pressure or very weak kidneys should not add salt and baking soda to the colonic water, but use highly diluted lemon juice instead. If this causes soreness, or if the body is not too alkaline, use diluted fresh juice of green-vegetable leaves.

If you cannot do a colonic at home, receive a series of professional colonics at a hydrotherapy centre. Everyone can benefit from some form of bowel cleansing from time to time. (Instead of a series of colonics, you can use the Basic Cleanse described in Step 3.)

Coffee Enema: For stimulating and detoxifying the liver in the case of serious conditions, such as cancer, a series of coffee (preferably organic) enemas can be helpful, especially if there is pain and discomfort. Boil two tablespoons of ground coffee (not instant coffee) for three minutes in one quart of water; simmer for 15 minutes and strain; rinse the coffee grounds with more water. Use this as a retention enema after cleaning the bowels with a normal enema or colonic. If you can hold in only part of the coffee, use the rest with a second enema. Retention means to hold it inside for ten to 20 minutes. Do not use this if you are allergic or sensitive to coffee.

Oxygenating Colonic: This can often improve the well-being of patients with ad-vanced diseases, such as cancer. Oxygenating colonics are available at some hydrotherapy centres.

As an alternative for home treatment, add food-grade hydrogen peroxide to a retention enema after the colon has been cleaned with an ordinary colonic. Use one to two pints of lukewarm liquid in which one teaspoon of salt has been dissolved. Initially, include one tablespoon of six-percent or two tablespoons of three-percent hydrogen peroxide. Retain this mixture inside your intestines for about ten minutes. If this is well tolerated, double the amount of hydrogen peroxide with each successive treatment until it becomes too uncomfortable and you cannot hold it any more. Then cut back to the preceding level and continue at that rate.

For cancer patients with a serious condition, under professional supervision you can start at higher dosage levels and include up to half a pint of three-percent hydrogen peroxide. This may induce the evacuation of much waste during the following days, and the patient may temporarily look and feel worse. After this, however, there should be considerable improvement. If available, lead ozone through a long tube into the rectum with an additional shorter tube as outlet and safety valve. For further information on this, see Step 31.

Vomiting Therapy: Induced vomiting, often called an “upward purge,” can be helpful for a wide range of acute and chronic conditions, such as asthma, bronchial problems, catarrh, digestive disorders and indigestion, gastritis, hysteria, infections, liver and gallbladder problems, lumbago, migraine, poisoning including snakebites, and skin diseases including eczema, gangrene, and psoriasis.

While vomiting clears out mucus and decomposing matter from the stomach, the main benefit is derived from relaxing the digestive organs and the diaphragm while stimulating the solar plexus. A need for this therapy is indicated especially by contracted intestinal reflex areas in the iris, by way of iris diagnosis (see Step 12), but also if these are whitish or brownish and especially if they have black lines.

To induce vomiting, drink five or six cups of lukewarm water and touch or tickle the throat far down. Repeat until the water comes back clear. Instead of water, an emetic herb tea can be used: adder’s tongue, bayberry bark, black root, boneset, horehound, lobelia (large doses), mustard, ragwort, or vervain. After-wards, drink peppermint or mint tea to settle the stomach.

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Step 22
URINE & UREA THERAPY

It may not be your "cup of tea", but many swear by this ancient therapy.

The use of urine in the treatment of diseases has a long history. Many cultures have used urine for medicinal purposes: It was praised in ancient Egyptian papyri and used in ancient Rome, China, India, America, and European countries. An article in the Journal of the American Medical Association stated that in “primitive medicine” there is scarcely a disease that has not been treated with the external or internal use of urine.6. Presently it is most widely used in India and Taiwan where the youthful appearance of many Buddhist monks is ascribed to their routine urine ingestion.

Thousands of scientific articles have been written about the health benefits of urine and its ingredients. A good book to get acquainted with some of this research activity is Your Own Perfect Medicine, by Martha Christy; one of many websites on urine therapy is: www.uropathy.com.

At the very least, all this past and present interest in the healing benefits of urine indicates that here is something worthwhile for the adventurous health seeker to explore. To start urine therapy the main problem we need to overcome is our social conditioning. You may also want to know how a substance expelled by the body as waste can possibly be beneficial.

Beneficial Ingredients: Urine is not a waste product full of harmful substances as is commonly believed, but instead a treasure-trove of the right nutrients that we need for our health. It is full of hormones, enzymes, vitamins, trace minerals, and other valuable biochemicals. Basically, urine is just filtered blood, and in its composition close to blood serum. The main function of the kidneys is to regulate the concentration of all these biochemicals in our blood. Surplus can be as harmful as deficiency; however, any hormone or enzyme removed as surplus may be in short supply a few hours later.

With advancing age, our hormone and enzyme production declines to suboptimal levels, while the kidneys become less and less efficient in retaining needed ingredients. Therefore, it greatly helps, especially with chronic degenerative diseases and advancing age, to recycle these valuable hormones and enzymes. This is what urine therapy does.

Another important aspect is the presence in urine of antibodies and immune-stimulating factors against viruses, harmful bacteria, or fungi we may harbour in our body. Even minute amounts of antibodies, sometimes at levels so low they cannot be detected with conventional methods, are effective in preventing and treating diseases. Curative effects of urine therapy have been shown on fungal and viral infections, such as hepatitis, poliomyelitis, and AIDS, and urine is especially effective against allergies, autoimmune diseases, and other disorders of the immune system.

When drinking urine routinely, say a cupful every morning, allergic reactions may not occur at all, thus doing away with the need to identify to which substance one has been reacting.

Benefits of Urea: Urea is an end product of protein metabolism and the main ingredient of urine. Only recently has it been discovered that the concentration of urea in the blood has a key role in regulating at least seven major pathways. Urea levels are low with cancer and many other diseases; in fact the frequency of cancer and especially of multiple tumours and metastases increases greatly if urea levels are low.

The Greek physician Evangelos Danopoulos, M.D., pioneered the use of urea in cancer treatment. Urea was notably effective in regressing liver tumours, greatly increasing survival times, and preventing metastases or secondary tumours. Dr. Danopoulos used 45 g of urea daily in six divided doses for 40 days and then 20 g in three doses for two years (45 g correspond to six rounded teaspoons, and 20 g is about three teaspoons). He also experimented with injecting urea close to tumors.[7]

Urea may not just be a waste product or the final state of protein metabolism as commonly assumed. Apparently, it can also be used as raw material to synthesize amino acids and proteins, as has been shown in patients with kidney failure. These patients deteriorate quickly on a diet containing normal amounts of protein but do much better if the diet is extremely low in protein. They show progressive clinical improvement when receiving added urea, which then becomes an important source of nitrogen for protein synthesis.[8]

Urea is the best natural diuretic and is far better than synthetic diuretics. This is important for those with oedema or fluid retention (due to kidney or heart weakness) and especially for those with fluid pressure on the brain or spinal cord or in the eye, as with glaucoma. Additional urea is important with brain tumours, stroke, meningitis, and other inflammations of the brain and spinal cord. In one case of a massive brain oedema connected with a suspected brain tumour, the patient received 256 ml of 30% urea; after two hours, the oedema and suspected tumour had completely disappeared.9

When applied externally, urea has a beneficial effect on the healing of wounds, such as infected wounds, burns, and ulcerating tumours. Urea can be directly packed into the wound or a strong or saturated solution can be applied. In this way, urea removes the foul odour often associated with an ulcerating tumour or other dead or putrefying tissue. You can obtain urea from a pharmacy. Unfortunately, most of the research into the medical use of whole urine and urea took place in the first part of the last century, while in recent years the emphasis has been on researching individual components.

CAUTION: Do not ingest large amounts of urine if you take medicinal drugs or other toxic substances, as these an be re-cycled and cause an overdose. While harmful substances are not necessarily re-absorbed and may just cause diarrhea instead, you do not know how much is safe. Therefore, either ask your health professional for advice, or use urine homeopathically, or in small amounts up to several spoonfuls daily.

How to Use Urine: There are various ways to use urine, but generally it is advisable to start with small amounts. This is not only to get accustomed to the taste of it, but also to slow down any healing reactions. These occur commonly with methods that genuinely improve our health (see Step 10).

Reactions may manifest as diarrhoea, vomiting, nausea, or a temporary flare-up of old health problems.

Start with a few drops or a spoonful. Swallow immediately; you can wash it down with some water or juice, or eat a piece of fruit.

With allergies and immune disorders, it is more effective to leave diluted urine under the tongue for a few minutes. An allergic reaction can best be stopped or neutralized by collecting the urine when the symptoms are worst; however, in practice, try to use it as soon as you notice the first symptoms. Some researchers suggest that the proper dose can be found by slowly putting single drops under the tongue until the taste and temperature of a drop can no longer be distinguished. This is then the neutralizing dose for an allergy. Each subsequent day you can double the previous dose or the number of times you take them per day until you reach your target amount or the dose with which you are comfortable.

A suggested amount for general health improvement and rejuvenation is two or three cups daily. More is advisable temporarily to overcome serious diseases, especially AIDS and other viral, bacterial, or fungal infections, as well as cancer and kidney diseases. In these cases, ingest about one quart daily, but the more the better, while for a limited period of several weeks try to drink all or most of your urine, except in the evening, so that you do not have to get up at night. However, this may only be suitable during a cleansing period, as drinking urine after a meal may cause digestive upset.

A good way to flush the kidneys is to drink one to two quarts (litres) of diluted urine before breakfast; use one or two cups of urine per quart of water. Start drinking all the urine when you first wake up, ideally at 5 a.m. Then urinate again and drink another dose 90 minutes later, then 90 minutes later again. Either drink sufficient liquids in the evening so that the first morning urine is not too concentrated, or dilute strong urine with sufficient water; about one cup to a quart of urine.

Do not use urine that is cloudy, as it often is during a healing reaction. If the body is reasonably clean, then the urine will not taste offensive or reflect the aromas of the last meal. The second morning urine, especially when drinking a fair amount of liquids after rising, is usually very mild; it is better for getting accustomed to than the first morning urine. To catch a cleaner sample, collect urine midstream.

The Urine Fast: The most powerful form of urine therapy is urine fasting, a method routinely used by John Armstrong and described in The Water of Life. Armstrong had good results with this, and I also have found it very effective, especially in cases of kidney failure. While it sounds contradictory to drink urine when one has kidney failure, the idea is to flush the kidneys with a large volume of stimulating fluid. I see this as the only logical way to rehabilitate failing kidneys; reducing the flow of fluid through will only make it worse. Diluted or weak urine appears to be most suitable, at a rate of one gallon or more daily. However, adjust intake to output; whenever there is increasing fluid retention, reduce the intake. This intake also helps to increase lymph flow as explained under lymph-drainage massage in Step 20. A main advantage of urine fasting over water fasting is the greatly increased amount of energy produced, so that the urine fast can be continued for a much longer period than a fast consisting only of water.

During the urine fast, drink all of your freshly voided urine (and initially some added water) to bring the daily intake volume to about five quarts. Gradually increase the ingested amount to this full intake before starting the fast while gradually reducing your food intake to just a few pieces of fruit or salad and fresh vegetable juices. End the fast by taking only a small amount of fresh raw fruit or vegetables for another week or two, gradually increasing the amount and variety of fresh

As with other fasts or cleanses, it is important to keep your bowels moving daily. I suggest initially taking a tablespoon of Epsom salt with a crushed clove of garlic for several mornings or evenings when starting with a greatly restricted food intake. This will help to avoid or minimize unpleasant cleansing symptoms, such as weakness, pain, or nausea. However, in many cases the ingested urine will already be overstimulating the bowels, with liquid discharges, in which case no further action is needed.

Ingest only your own freshly voided urine. Normally, urine is light yellow, clear, and sterile, especially if collected midstream, but during healing reactions it may become offensive and cloudy. In this case, use it only strongly diluted, if at all. When ingesting a large volume of your urine, check that it is not too acid. The morning urine normally is slightly acid, but during the day it should be slightly alkaline.

To check your urine, use litmus or pH paper from a drugstore. Litmus paper is red when dipped into an acidic solution and blue when alkaline; neutral or pH 7 is in between both colours. With pH paper, you get a colour chart to compare. If the urine is mostly acid, take a half-teaspoon of sodium bicarbonate in water once or several times daily, but not within three hours after meals; do this until the urine remains alkaline during the day.

Those with cancer, high blood pressure, or fluid retention should use potassium bicarbonate (from a pharmacist) instead of sodium bicarbonate. If your body is too acidic, sometimes the emotions become overly sensitive, along with a physical tendency to inflammations, mouth ulcers, and strong skin reactions.

The effectiveness of urine therapy with cancer, oedema, and infectious diseases can be increased by taking daily one to six teaspoons of urea (e.g., mixed in water or juices) in divided doses. Take three to six teaspoons when only a small amount of urine is ingested, then progressively less with larger urine intake; stop completely when nearly half or more of your daily urine is ingested.

Homeopathic Urine: It is possible to use urine ultra-diluted in homeopathic form. The simplest way to prepare it is as follows: To one teaspoon of unchlorinated water add one drop of your own fresh urine. Shake it vigorously in a small bottle about 50 times with a sharp downward stroke. Add one drop of this mixture to another teaspoon of water, shake again; and then repeat the whole procedure a third time. Place three drops of the resulting fluid under your tongue several times daily. When it is used up, wait a few days, then prepare a new homeopathic remedy.

An alternative method is even simpler and recommended as an introduction to urine therapy or for times when cupfuls of urine are not tolerated or not wanted. Dilute one or two spoonfuls of morning urine with five to ten times the same amount of unchlorinated water. Shake 50 times with a sharp downward stroke, and drink

immediately or take a spoonful several times during the day. Keep it in the mouth for a minute before swallowing.

Homoeopathically energized remedies should not be exposed to strong magnetic or electromagnetic fields and should be taken with a non-metal spoon. Keep any homeopathic urine remedy only lightly covered in a cool place but not in an electric refrigerator; make it up fresh daily.

External Applications: A urine pack, with the addition of some urea, is often effective with skin problems, such as burns, wounds, gangrene, psoriasis, eczema, dermatitis, fungal problems, and aging skin. It can also be helpful for internal tumours, inflammations, and diseased organs. Keep the affected area covered with a folded cloth that is well moistened with urine or concentrated urea solution. Put another cloth or plastic sheet on top and renew several times daily.

Urine becomes more alkaline when it stands for a few hours. Armstrong regarded it as more effective than fresh urine for external applications. However, it also smells more, and anyway, fresh urine seems to be adequate in my experience. With gangrene, dead flesh, skin infections, and open cancer and ulcer sores, it is more effective to saturate the applied urine with urea; this approach also removes offensive odours. With weeping or suppurating wounds, especially if associated with foul odour, it is beneficial to cover the area with dry urea.

Urine can be concentrated by leaving it for several hours in a flat dish in the sun or in a warm place. This has been recommended by Armstrong for application in friction rubs to rejuvenate aging skin. Armstrong also recommended urine packs placed over tumour sites or diseased organs in addition to rubbing the body daily for two hours with small amounts of urine. As you might guess, the primary problem with urine packs is the offensive odour. You could try to prevent this by sealing the pack with duct tape; completely seal it and keep the pack moist by injecting fresh urine into it several times a day with a syringe.

Social Considerations: As noted, the main problem when starting urine therapy is social conditioning. You can overcome that by reading about and contemplating the expected health benefits. The taste of fresh urine is not normally offensive, except if the body is polluted or when fasting or if the urine is strongly concentrated. Therefore, dilute strong urine, start with a small amount, and gradually increase it or have a day on fruit before starting to ingest urine. Minimize salt and strong spices in your diet when on urine therapy. An easy way to drink urine or any other unpleasant fluid is by breathing only through the mouth; you can pinch the nose until your mouth has been rinsed with water or juice, or you can eat a piece of fruit.

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Part 3
NUTRIENT & REMEDIES

This chapter provides information about vital nutrients, such as vitamins, minerals, amino acids, and enzymes, as well as basic remedies including herbs and homeopathic remedies.

The more we adopt a high-quality diet, the less we need to know about individual nutrients, and vice versa. Unfortunately, most individuals presently have a less than ideal diet, and some knowledge about nutrients can help to avoid or correct imbalances and deficiencies. Furthermore, many nutrients are now used in very high doses, essentially as remedies, to treat various diseases. When used in this way, detailed knowledge is important to achieve the desired effect without exposing yourself to unnecessary danger.

While there are dangers with what I call “self-healing” and health authorities call “self-medication,” these are infinitely smaller than those posed by prescription drugs. I believe there is less long-term harm in using a nutrient incorrectly than a prescription drug correctly. It is rare to encounter serious health damage from using nutrients, even in very high doses, while medical drugs are stated to be the third leading cause of death in the United States.

Nevertheless, I do not endorse the use of high-potency nutrients without a proper understanding of any benefits and dangers, and I do not endorse high-potency supplements as a substitute for a healthy lifestyle, which is the way that they are commonly used. The main emphasis of this book is on a healthy lifestyle, which in most cases will remove the need for high-potency supplements, but if you feel that you do need some, then you will find suitable information in this part.

Generally, it is best to obtain all your necessary vitamins from natural foods and the activities of intestinal bacteria. Under present conditions, however, it is rarely possible to achieve and maintain good health without resorting to special vitamin-rich foods and nutritional supplements.

In the case of poor health, absorption of vitamins and minerals is impaired, while your requirements for them are simultaneously raised. This phenomenon underlies the widespread vitamin and mineral deficiencies in our society, which result in a multitude of diseases. Well-chosen supplements can correct deficiencies, but in a good maintenance diet, the daily vitamin intake proposed by government agencies should be at least doubled.

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Step 23
VITAMINS

Find out what these essential nutrients do and if you have special requirements for any of them.

Vitamins are water soluble or fat soluble. Water-soluble vitamins are vitamin C and the B-group vitamins. Except for vitamin B12, they are easily absorbed, and deficiency is due to a deficient diet or to increased requirements. Due to genetic factors or diseases, some individuals may require up to a hundred times the usual amounts to function normally. One common problem is a thickened or hardened cell membrane, preventing nutrients from entering some organs, especially the eyes. Being water soluble, a surplus of these vitamins is easily expelled through the kidneys, and any problem from overdosing is rare.

The fat-soluble vitamins, A, D, E, and K, are more difficult to absorb. Deficiencies can easily arise even with an adequate diet, although most “balanced” diets are deficient due to the cooking methods and use of refined foods. The most difficult problem is fat malabsorption, which is relatively common and mainly due to a reaction of the intestinal wall to gluten. In this case, even a diet plentiful in fat-soluble vitamins can still lead to deficiency symptoms and may not be corrected by high-potency supplements. While symptoms can mirror individual deficiencies, a common feature of fat malabsorption is dry skin and difficulty gaining weight.

This absorption difficulty can be overcome by using water-soluble vitamin E tablets, emulsions for vitamin A, and sunshine for vitamin D. In addition, rub vitamin A and E oil (from opened capsules) into your skin and squeeze the contents of a halibut oil capsule under the tongue for slow absorption overnight. Do not use synthetic versions of oil-soluble vitamins. While these are easily absorbed, they are known to cause side effects, such as liver toxicity or interference with pregnancy.

The bacteria among our intestinal flora supply a considerable part of our B vitamins. Unfortunately, antibiotics destroy these essential bacteria and can cause vitamin deficiencies. For this reason, use fermented foods or cultures containing acidophilus and bifidobacteria and take B-vitamin supplements whenever you take antibiotics. Other widespread conditions -causing persistent vitamin deficiencies and dependencies are deprivations during foetal develop-ment and, in later life, acute and chronic infections, parasites, and inefficient metabolism.

In general, vitamin and mineral supplements may not be required for the maintenance of health or even the cure of most degenerative diseases provided the diet consists predominantly of fresh and raw foods, featuring sprouted seeds, grass and vegetable juices, as well as high-quality nutrients such as bee pollen, spirulina, and kelp.

Bowel-Tolerance Vitamin C: This means taking enough of the vitamin to produce a bout of diarrhoea to identify your specific bowel tolerance for vitamin C. This can be a successful treatment for infectious diseases, including viral infections, which do not respond to antibiotics. The dose of vitamin C is increased until the patient develops transient diarrhoea, usually one episode. Then the rate is cut back

slightly until the bowel tolerates the high vitamin C intake. During serious infections, the bowel tolerance is much greater than it is in a healthy state. In normal health, for example, the bowel tolerance is about 4-15g per day; with a light cold, it might be 20-30g; with a serious cold, 60-100g. Typically, mononucleosis or viral hepatitis requires 40-60 g; gastroenteritis 60-150g; and viral pneumonia more than 150g. Other infections, including herpes simplex and herpes zoster, respond favourably to this treatment, but fungal infections do not.

When you are taking these massive amounts, it is important to select the correct form of vitamin C. If mainly unneutralized ascorbic acid is used, the body becomes too acid, while sodium ascorbate introduces too much sodium, and calcium ascorbate too much calcium. If your blood pressure is approximately normal, take a mixture of ascorbic acid, sodium ascorbate, and calcium ascorbate. With low blood pressure, use mainly sodium ascorbate with some calcium ascorbate. With high blood pressure, potassium and magnesium ascorbate combined with ascorbic acid is best. You can neutralize some of the ascorbic acid with potassium bicarbonate or magnesium carbonate at the ratio of three to one, or two parts ascorbic acid to two parts magnesium oxide. The solution should taste slightly acidic. You can dissolve the vitamin C in water, herb tea, or juices, if you like.

Depending on the severity of your condition, take vitamin C at one- or two-hour intervals. Do not continue self-treatment at bowel-tolerance level for more than a few weeks, and in serious cases you should be under professional medical supervision. The high vitamin-C intake should be reduced gradually to a daily maintenance dose of 3-10g. A sudden withdrawal of all vitamin C can cause the return of colds, allergies, or fatigue, so try to avoid this.

Bowel tolerance as a treatment is not suitable with kidney disease. Initially, treatment of life-threatening diseases or emergencies can be supported with daily or weekly injections of sodium ascorbate given intravenously in a three-percent solution. Many degenerative diseases associated with a weak immune system, for example, autoimmune diseases, cancer, and multiple sclerosis, can benefit from intermittent periods of bowel-tolerance vitamin-C treatment. This method should also be used for accidental poisoning and bites of poisonous snakes and insects.

Now let’s review all the vitamins. In the following compilation, RDA means recommended daily allowance for males as determined by the Food and Nutrition Board of the U.S. National Research Council. A second RDA value is for females. “IU” means international units. Not all of the listed deficiency symptoms are always manifested. Symptoms appear first in the weakest organs. As for measurements, 1 g = 1000 mg; 1 mg = 1000 mcg.

Fat-Soluble Vitamins: The oil-soluble vitamins are A, D, E, and K. They are soluble in oils and fats, which is where we get them in our diet.

Vitamin A: The chemical name is retinol; two molecules of retinol can be formed from one molecule of beta-carotene. The RDA is 5000/4000 IU; therapeutically 25,000 to 100,000 IU are commonly used, and sometimes up to 1,000,000 IU, especially in cancer treatment and for eye diseases. Long-term oversupply can lead to bone erosion due to a relative deficiency of vitamin D. Therefore, supply vitamins A and D together, preferably as cod liver oil, otherwise halibut liver oil. One halibut-oil capsule provides 4000 to 5000 IU. Vitamin A is toxic in

very high doses over long periods and is destroyed by light and oxygen. Symptoms of vitamin A toxicity are similar to those of vitamin A deficiency. Do not take very high doses without professional supervision.

Deficiency Symptoms: Eyes are dry, infected, and sensitive to bright light; night blindness, poor dark adjustment, colour blindness, and glaucoma are other symptoms. Skin is dry, rough, horny, and scaly; there are pimples, acne, and psoriasis. Hair is dry, falling out, or dull. Nails have longitudinal ridges and are peeling and brittle. Sense of smell and taste are poor or distorted. Respiratory infections and other lung problems, ear problems, deafness, hearing noises, and cancer; thyroid is overactive and the person is underweight.

Best Sources: Fish-liver oils, liver, butter, and egg yolk. Yellow-orange vegetables and green juice are high in beta-carotene, which some individuals can efficiently convert into vitamin A.

Vitamin D: The common natural form is vitamin D3 or cholecalciferol. Vitamin D2 or ergocalciferol is synthetic and can be toxic in high doses over long periods; I do not recommend it. The RDA is 200 IU; therapeutically up to 4000 IU are used.

Deficiency Symptoms: Rickets, teeth and gum problems, muscular weakness, convulsions, cramps, tetany, nervous instability, underactive thyroid, depression, multiple sclerosis, overweight, eye problems, and weak, deformed, and porous bones and other symptoms of calcium deficiency.

Best Sources: Sun exposure, fish-liver oils, and egg yolk.

Vitamin E: The chemical name of this group is tocopherols; mainly d-alpha tocopherol is used, preferably in addition to mixed tocopherols. The RDA is 15/12 IU or mg; therapeutically, up to 3000 IU or mg can be used. Patients with heart problems or high blood pressure should increase the dose slowly. This vitamin is destroyed by oxygen, chlorinated water, inorganic iron supplements, and estrogen drugs.

Deficiency Symptoms: These can include disorders of the reproductive and circulatory systems, stroke, heart disease, leg pains, cramps, poor wound healing, pronounced scar tissue, muscle weakness, chronic fatigue, tender breasts, arthritis, cancer, eye and ear problems, gangrene, infections, hot flushes, malabsorption, multiple sclerosis, myasthenia gravis, phlebitis, skin problems, and varicose veins.

Best Sources: Cold-pressed oils (wheat germ oil), rice polishings, sprouted seeds, nuts, egg yolk, green leaves, and grass juice.

Vitamin K: The RDA is 80/60 mcg; therapeutically, 5–15 mg are used. It is destroyed by light, alkaline conditions, and strong acids. This vitamin is essential for normal blood clotting to prevent haemorrhaging. A deficiency causes frequent, prolonged, or severe bleeding, easy bruising, and menstrual clots, as well as nausea and vomiting during pregnancy. It is also needed for bone formation, or to prevent osteoporosis, tooth decay, calcium deposits, and hardening of tissues and arteries.

Injections of vitamin K derived from plant sources have been effective in the control of strong pain. This vitamin can be obtained from intestinal bacteria (in other words, made in the gut), green and especially dark-green vegetables, liver, and egg

yolk. Vitamin K1 from plants is more effective than K2 from intestinal bacteria; the synthetic form (K3) can have toxic effects.

Water-Soluble Vitamins: These vitamins easily dissolve in water; with this they are easily absorbed, but also easily lost in cooking and, except vitamin B12, not stored in the body. Most of the B-group vitamins are essential components of enzyme systems.

Vitamin B1: The chemical name is thiamine. The RDA is 1.5/1.1 mg; the therapeutic dose is 50–3000 mg. It is destroyed or used up by heat, sugar, alcohol, and smoking. Despite vitamin B1 supplements, deficiency can arise from a lack of gastric acid.

Deficiency Symptoms: These include poor circulation with cold hands and feet, oedema (fluid retention), furrowed tongue, underactive thyroid, fatigue, depression, insomnia, anxiety, oversensitivity to pain and noise, nausea, poor memory, apathy, debility, weight loss, and weak and painful muscles, especially in the legs, starting with numb, burning feet, later affecting calves and thighs, and sometimes resulting in paralysis. Other conditions include severe gastrointestinal disturbances, tachycardia (fast pulse) and dyspnoea (breathlessness) on exertion, brachycardia (slow pulse) at rest, enlarged and weak heart, mental illness, multiple sclerosis, diabetes, hypoglycaemia, allergies, and addictions (to drugs, alcohol). A severe deficiency is known as beriberi.

Best Sources: Food yeast, rice bran, sunflower and sesame seeds, peanuts, millet, and grains.

Vitamin B2: Vitamin B2 is chemically known as riboflavin. The RDA is 1.7/1.3 mg, the therapeutic dose 50–1500 mg. It is destroyed by light and makes urine bright yellow.

Deficiency Symptoms: Eyes are sensitive, burning, and bloodshot (blood vessels become visible in the white of the eye) and there is blurred vision or cataracts. Skin is oily and itching; there can be eczema (especially around the nose, forehead, ears, scrotum, and vagina), redness of part of the face (rosacea), acne, bedsores, and purplish skin parts. Hair is dull and oily, with dandruff. Nails are split and the tongue is sore, burning, and purplish magenta in color. There are cracks on the lips and corners of the mouth (cheilosis), as well as allergies, anaemia, arthritis, cancer, or diabetes.

Best Sources: Food yeast, liver, kidney, almonds, sprouted seeds, and grass juice.

Niacin and Nicotinamide: Niacin is also called nicotinic acid, and niacinamide is the same as nicotinamide. As the name suggests, these are closely related to nicotine and, therefore, useful when trying to give up smoking. The name vitamin B3 is also used. The RDA is 19/15 mg; therapeutically, up to 30 g have been used in schizophrenia.

The acid form (niacin or nicotinic acid) causes flushing of the face and it is prescribed to dilate blood vessels, decrease blood pressure, reduce cholesterol, or increase circulation to the head in cases of acne or migraine. The non-acid nicotinamide or niacinamide does not have these effects. In contrast to niacin, high

amounts of this vitamin can cause depression. Niacin or nicotinamide improves the oxidative energy metabolism and can be used to treat many symptoms.

Deficiency Symptoms: Schizophrenia, hyperthyroidism, protruding eyes, depression, irritability, overactivity, crying spells, suspicion, loss of humour, delusions, anxiety, insomnia, confusion, and changed sense perceptions. Tongue is strawberry-tipped or bright red and shiny, with a “raw beef” appearance; the mouth displays sores, cankers, and ulcerated corners. The skin is rough and red, with brown, often symmetrical discoloration on the cheeks, neck, and back of hands. There is dermatitis with ulcerations and pellagra (cracking of skin), which is aggravated by exposure to sun. Other symptoms and conditions include headache, backache, fatigue, anaemia, lack of gastric acid, loss of weight and appetite, nausea, vomiting, diarrhoea, painful and stiff joints, arthritis, and cancer.

Best Sources: Food yeast, peanuts, rice bran, liver.

Pantothenic Acid: This is commonly used as calcium pantothenate, also called vitamin B5. The RDA is 7/4 mg; the therapeutic amount 50–1500 mg.

Deficiency Symptoms: Tongue is beefy, enlarged, and furrowed; there is fatigue, depression, insomnia, greying hair, burning feet, arthritis, alcoholism, asthma, cancer, cataracts, epilepsy, psoriasis, stress, diseases of the digestive and nervous systems, and adrenal weakness.

Best Sources: Food yeast, rice bran and polishings, liver.

Vitamin B6: The chemical name is pyridoxine. The RDA is 2.0/1.6 mg; therapeutically, it is used from 50 to 3,000 mg. It works closely with zinc and is easily oxidized.

Deficiency Symptoms: These include an inability to recall dreams, insomnia, depression, irritability, tremors, convulsions (epilepsy), migraine, or schizophrenia. The skin is oily, with eczema and urticaria (nettle rash or hives); there is oedema (fluid retention), vomiting, halitosis, lack of gastric acid, muscle weakness, anaemia, and kidney stones. Also possible are pain, stiffness, and swellings of fingers and joints; fingers and toes become white (Raynaud’s disease); autism; caries (tooth or bone decay); diabetes; Parkinsonism; and diseases of the digestive and nervous systems.

Best Sources: Food yeast, molasses, bran, sunflower seeds, rice, liver, egg yolk, nuts, beans, and bananas.

Biotin: The RDA is 0.3 mg or 300 mcg. Biotin is necessary for protein and fat metabolism as well as for healthy hair.

Deficiency Symptoms: Digestive, nervous, and skin and hair problems; anaemia, fatigue, depression, and hallucinations.

Best Sources: Food yeast, rice bran. Usually from intestinal bacteria, except after antibiotics.

Folic Acid: The RDA is 200/180 mcg, but it is recommended to ingest at least 400 mcg, and 800 mcg when pregnant. The therapeutic dose is 5–20 mg. Folic acid is easily destroyed by light, heat, storage, oxygen, and the contraceptive pill.

Deficiency Symptoms: These are widespread; most pregnant women are deficient. Symptoms include anaemia, corners of mouth cracked, red tongue, greying hair, greyish-brown skin pigmentation, irritability, depression, fatigue, forgetfulness, lack of con-centration, insomnia, dizziness, depressed reflexes, and headaches. Also present are muscle weakness, pain, numbness in legs, difficulty in walking, cramps, digestive problems such as constipation and diarrhea, sexual and circulation problems, cervical cancer, hypoglycaemia, birth defects, gout, diabetes, and cardiovascular disease.

Best Sources: Grass juice, yeast, sprouts, dark-green leaves, and liver.

Vitamin B12: The chemical name is cobalamin, the RDA is 2 mcg, and the therapeutic dose 1000 mcg. It is essential after part of the stomach has been removed. Most patients with a lack of energy respond extremely well to vitamin B12 injections, even if laboratory tests show a normal vitamin-B12 blood level.
In poor health, vitamin B12 is not well absorbed; calcium and hydrochloric acid improve absorption. Commonly, B12 tablets are absorbed under the tongue. However, recent studies show that the best absorption takes place by putting vitamin B12 into the nostrils as drops, cream, or a crushed tablet combined with a little water to make a paste.

Deficiency Symptoms: Pernicious anaemia, chronic fatigue, debility, poor circulation, numbness and stiffness, a very red and sore tongue, emotional disturbances, mental illness, cancer, liver and nervous system diseases, nerve inflammations, and paralysis.

Best Sources: Liver, kidney, fish, egg yolk, and spirulina.

Vitamin C: The chemical name is ascorbic acid; it is commonly used as sodium or calcium ascorbate. The RDA is 60 mg; 500 to 3000 mg are recommended for good health (and may be supplied by a good diet); the therapeutic daily amount is up to 100 g (in neutralized form). This vitamin is easily destroyed by air, storage, smoking, cooking, or stress. It is useful to counteract the bites or stings of poisonous snakes, insects, spiders, and others.

Deficiency Symptoms: First signs include lassitude, weakness, irritability, and vague muscle and joint pains. Later symptoms and conditions include scurvy, starting in the limbs most used, muscle pain (especially during infections), bleeding of gums and skin, capillary weakness, fatigue, poor wound healing, and acute and chronic infections. Also possible are liver and kidney problems, senility, aging skin, thrombosis (strokes, heart infarctions), crib death, eye problems, arthritis, multiple sclerosis, diabetes, schizophrenia, anaemia, bedsores, stone formation, cancer, backache, anxiety, and allergies (manifested in reaction to bee stings, headaches, rashes, asthma, hay fever, and epilepsy).

Best Sources: Fresh fruits and vegetables, sprouted seeds, rosehips, and grass juice.

Vitamin-like Substances: These are necessary biochemical substances that have not yet been awarded full vitamin status, partly because some can be synthesized within the body, and partly because their usefulness is still disputed.

Bioflavonoids: Bioflavonoids are part of the naturally occurring vitamin-C complex. A deficiency causes capillary fragility with purplish or blue skin marks, inflammation, gum bleeding, and inner ear pain. Bioflavonoids are necessary for the proper functioning of vitamin C.

Best sources: Sprouted seeds, fresh (especially colourful) vegetables and fruits, and the residue of juiced citrus fruits; bioflavonoids are also found in flower petals. The best known members of this group are quercetin and rutin; rutin is found in concentrated form in dried buckwheat leaves and flowers.

Choline and Inositol: These two are important for the absorption and metabolism of fats and cholesterol, for the synthesis of lecithin, for proper liver and gallbladder function, and for the formation and function of the brain and nerves (transmission of nerve impulses). They are helpful in the treatment of arteriosclerosis and atherosclerosis, asthma, diabetes (inositol), glaucoma, hair problems and baldness, high blood pressure, insomnia (inositol), liver diseases, multiple sclerosis, muscular dystrophy, neuritis, and tardive dyskinesia (choline especially).

Best sources: Choline is best supplied by lecithin, while other good sources are egg yolk, liver, brain, and food yeast. Inositol is best supplied by sprouted seeds (in unsprouted seeds it remains unavailable in the form of phytic acid). Other good sources are heart, brain, liver, food yeast, cabbage, and citrus fruits.

PABA (para-aminobenzoic acid): It is a growth-promoting factor, and a deficiency contributes to white skin patches, eczema, greying hair, and fatigue. In lotion, it is excellent for protecting the skin against ultraviolet radiation. It is obtained from food yeast, liver, egg yolk, and is also synthesized by intestinal bacteria. As a supplement, the soluble potassium salt of PABA is preferable to the almost insoluble acid itself.

Vitamin B15 (Pangamic Acid): This bioflavonoid occurs in seeds, grains, and nuts, and it protects against oxygen deficiencies in a way similar to vitamin E. It has been successfully used in the treatment of alcoholism, allergies, arthritis, autism, breathing problems (asthma and emphysema), diabetes, hypoglycaemia, heart problems (cardiovascular diseases), and premature aging.

Vitamin B17 (Amygdalin or Nitrilosides): This nutrient contains a cyanide ingredient that is harmful to cancer cells. It is most effective for preventing cancer if taken regularly by eating a few bitter seeds of stone fruits (for example, apricot, bitter almond, apple). Other good sources are sprouted seeds, alfalfa, mung beans, millet, and lentils. Professionally, a purified product known as laetrile (now illegal in the U.S.) is used orally or as injections for cancer treatment. To be effective, laetrile must be used in conjunction with cleansing, supplements, and correct diet.

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Step 24
MINERALS

Find out what minerals do and if you have increased requirements for them.

Minerals are inorganic substances composed of a metal and a non-metal, both in ionic form. Metals most important for our health are calcium, magnesium, potassium, and sodium as bulk elements, and boron, chromium, cobalt, copper, iodine, iron, manganese, molybdenum, selenium, and zinc as trace elements. Essential non-metals are chloride, phosphorus, and sulphur. Harmful are aluminium and the heavy metals cadmium, lead, and mercury. While imbalanced intakes of bulk metals can cause health problems, trace elements easily become toxic in excessive doses.

Minerals are not well absorbed from grains, seeds, and nuts,10 unless these are sprouted or fermented. This fact is especially important for vegetarians who may rely on these foods. The addition of gelatine or chicken or fish broth to cooked grains improves the absorption of minerals, while cereal fibre (bran) decreases their availability. When grains and seeds are indicated as good sources of specific minerals in the following compilation, this applies only to their sprouted form or as fermented products.

In case of mineral deficiencies, take mineral supplements with meals containing gelatine (for example, fish or poultry) or, alternatively, with fresh vegetable juice or vegetables salads. Also make sure that you have sufficient gastric acid. Minerals are more easily absorbed as chelates or orotates; orotates deliver minerals directly into the cells.

Calcium (Ca): The RDA is 800 mg, but the recommended intake is 0.6 - 1.2 g daily. A deficiency is frequently due to overacidity, lack of vitamin D, magnesium, or boron, underactive thyroid and parathyroids, or an oversupply of phosphorus. The normal calcium-phosphorus ratio in blood is 10:4; if the calcium level is too high, calcifications result, such as stone formation, tartar, arthritic deposits, cataracts, and muscle tension.

Deficiency Symptoms: These include fragile and deformed bones; muscle cramps, twitching, and weakness; irritability; headaches; depression; menstrual problems such as excessive and painful menstruation; poor circulation; and tender breasts. Also likely are undue sensitivity to pain, insomnia, allergies, inflammations, low blood pressure, varicose veins, piles, distended veins and abdomen, swellings, slow wound healing, pyorrhoea, gingivitis, and eye problems (nearsightedness).

Best Sources: Bone broth, eggshells, dolomite, sardines, leaf vegetables, goat's-milk products, sesame seeds, and kelp.

Chromium (Cr): This mineral is active as trivalent chromium, and its biological value differs greatly in various foods. Aim for an RDA of 100 mcg of high bio-value supplements, such as glucose-tolerance factor or chelated chromium.

Deficiency Symptoms: Poor blood sugar regulation (diabetes, hypoglycaemia), disturbed fat/protein meta-b-olism, alcohol intolerance, impaired growth, high blood

pressure, arteriosclerosis, weight loss, fatigue, and eye problems (opaque cornea, nearsightedness, glaucoma).

Best Sources: Brewer's yeast, molasses, mushrooms, seafood, and grains.

Calcium EAP for Healthy Cells

The health of our cells depends to a large degree on their ability to keep toxic materials out. This includes toxic chemicals, such as endotoxins produced by microbes inside the body, and also harmful concentrations of otherwise useful biological chemicals. Such toxic matter tends to weaken and disrupt the energy production within cells and is a major factor in disease processes such as cancer and chronic degenerative diseases.

Toxic chemicals, together with useful ones, can enter the cells only through special pores in the cell wall. In healthy cells, these entrance points are protected by special gatekeeper chemicals, mainly the calcium salt of 2-aminoethanol phosphate, also called colamine phosphate, or EAP. EAP is heavily concentrated at these entrance points and is attached to the cell wall where it keeps the calcium in a fixed position.

In addition to keeping unwanted chemicals from entering, EAP is also effective in transporting essential minerals through the cell wall and into the cell. In addition, it helps to maintain and restore a normal electric potential between both sides of the membrane. Because of its vital functions in maintaining the health of cell membranes, EAP has been called the "membrane integrity factor." With increasing age and disease-related health deterioration, we do not produce enough EAP to protect our cells. This leaves them open to attack by undesirable chemicals and toxins, an event that can cause or contribute to a wide range of diseases.

EAP salts were developed in the 1960s in Germany by Hans Nieper, M.D. Initially, calcium EAP was used in the successful treatment of multiple sclerosis, but the damaging after-effects of viral infections (e.g., chronic fatigue) could also be greatly reduced with EAP. Other diseases that responded well were ALS, allergies, asthma, blood pressure and circulation problems, capillary bleeding, cancer, chronic kidney disease, diabetes, and osteoporosis.

Varicose veins stopped deteriorating and aging skin was improved with EAP treatment. Dr. Nieper mentioned that his patients on long-term EAP therapy hardly aged. He found that a mixed formulation of calcium, magnesium, and potassium EAP was calming and harmonizing for the nerves and, with this, suitable for neurological conditions, including hyperactivity and anxiety disorders.

After evaluating the treatment of several thousand patients with multiple sclerosis over many years, Dr. Nieper found that hardly any of these patients had developed cancer. Also, in a six-year study of eight patients with repeated surgery for colon cancer, there were no further recurrences of cancer after calcium EAP therapy. The usual dose is one to three tablets three times daily, before meals. For information and orders, contact: Koehler Company, P.O. Box 11510, Prescott, AZ 86304.

Copper (Cu): The RDA is 1.5 to 3 mg, but the recommended intake is 3 to 5 mg daily. A dietary deficiency of copper is rare; inorganic copper, for example, may be oversupplied from copper water pipes. Internal copper deficiency can result from insufficient binding capacity within cells.

Deficiency Symptoms: These include anaemia, especially in infants; bone disorders; defective spinal cord, multiple sclerosis; hair greying, hair becoming fine and straight, and losing its curl; infertility; weak connective tissue, as evidenced by heart problems such as enlarged heart, weak aorta (holes, ruptures), aneurism, and varicose veins; hernias; cancer; leukaemia; arthritis; inflammations; parasites; and underactive thyroid.

Signs of Toxicity: Liver cirrhosis, jaundice, and symptoms of zinc deficiency.

Best Sources: Liver, food yeast, nuts, and oily seeds. Use supplements only in organic form, such as chelated or salicylate complexes. However, colloids and copper armbands are acceptable.

Iodine (I): The RDA and recommended intake for iodine is 150 mcg daily. Iodine is needed for the production of thyroid hormones, which regulate metabolism.

Deficiency Symptoms: These include goitre, cretinism, fatigue, overweight, mental retardation, debility, and cancer.

Best Sources: Kelp, seafood, and iodized salt.

Iron (Fe): The RDA is 10/15 mg, so the recommended intake is the RDA, but it should be less for the elderly. An iron deficiency causes anaemia and fatigue, while an oversupply in the inorganic form (tablets, bread additives) is a contributing factor in degenerative diseases, especially arthritis.

Best Sources: Kelp, liver, yeast, molasses, sesame seeds, and eggs.

Magnesium (Mg): The RDA is 350/280 mg; the recommended intake 500 - 1000 mg daily. This mineral activates many enzymes (see the section on magnesium chloride to follow).

Deficiency Symptoms: Here you find apathy, confusion, depression, disorientation, hallucinations, irritability, paranoia, and poor memory. Also typical are angina, arteriosclerosis, high blood pressure, sweating, tachycardia (fast pulse), strokes, thrombosis, or infarctions. You can also encounter convulsions, cramps, eclampsia, epilepsy, muscle twitching, numbness, nystagmus (rapid eye movements), tingling, and tremors. Further deficiency symptoms are physical and mental rigidity, stiffness, stone formation in kidney and gallbladder (but not renal failure), tartar, alcoholism, cancer, arthritis, diabetes, acute infections, intestinal malabsorption, liver cirrhosis, pancreatitis (inflammation of the pancreas), prostate problems, strong body odour, overactive thyroid, colic, and premenstrual tension.

Best Sources: Kelp, dolomite, seafood, sea minerals, grass juice, green leaves, nuts, oily seeds, molasses, and sprouted grains.

Manganese (Mn): The recommended intake is 5 to 10 mg daily; the therapeutic dose is 20 - 100 mg.

Deficiency Symptoms: These typically are muscle weakness, myasthenia gravis, drooping eyelids, poor memory, dark-red skin spots, -diabetes, hypoglycaemia, atherosclerosis, schizophrenia, epileptic convulsions, bone deformities, mucus problems, impotence and/or sterility, ataxia (muscle incoordination), poor equilibrium, abnormal inner ear, and retraction of head.

Best Sources: Grass juice, spinach, parsley, spices (cloves, cardamom, ginger), nuts, pea-nuts, and sprouted and fermented seeds.

Molybdenum (Mo): Molybdenum is an integral part of several enzymes involved in cell oxidation and carbohydrate metabolism. Daily requirements are not known, though we do know it is an antagonist to copper.

Deficiency Symptoms: These can be cancer of the oesophagus, dental decay, impotence in elderly males, asthma, and sensitivity to sulphites, MSM (see the section on MSM to follow), and other sulphur-rich foods.

Best Sources: Buckwheat, beans, fermented soy products, liver, and barley.

Potassium (K): The RDA is 2000 mg, but the recommended intake is 3 g daily. A deficiency may originate from an oversupply of sodium (salt), the use of diuretics, or adrenal weakness.

Deficiency Symptoms: Typical here are anxiety, nervousness, fatigue, diabetes, hypoglycaemia, heart strain, high blood pressure, liver problems, lower back pain, muscle weakness, multiple sclerosis, and overweight.

Best Sources: Kelp, fruits, and vegetables.

Selenium (Se): The RDA is 70/55 mg, while the recommended intake is 100 - 200 mcg daily; the therapeutic dose is up to 500 mcg taken in organic form. Selenium acts as an antioxidant together with vitamin E. It is lost in cooking and very toxic when taken at 2000 mcg or more. A deficiency causes viruses to become very virulent.

Deficiency Symptoms: These include fatigue, cancer, liver damage, pancreatic fibrosis, muscular dystrophy, weak immune system, reproductive disorders, cataracts, haemorrhaging, haemolytic anaemia, and underactive thyroid.

Best Sources: Kidney, liver, seafood, brewer's yeast, and kelp.

Zinc (Zn): The RDA is 15 mg; the recommended intake is 20 to 30 mg daily; and the therapeutic dose is up to 300 mg. This mineral is best taken together with vitamin B6. Diets low in protein and high in fibre, phytates, calcium, fat, and copper can decease the absorption of zinc. Increased zinc is needed with calcium or magnesium supplements, and during chronic infections, convalescence, and stress.

Deficiency Symptoms: These affect skin (acne, boils, burns, leg ulcers, parakeratosis [horny red skin], poor wound healing, psoriasis, stretch marks); hair (brittle, coarse, dandruff, falling out, lacking pigment); nails (white spots and bands); eyes (keratitis [inflammations or lesions of the cornea], night blindness, retinal detachment); taste and smell (lost or distorted); sexual function (male sex organs underdeveloped, prostate enlarged, delayed sexual maturity, sterility, menstruation retarded or irregular); and maturation (poor growth, dwarfism). Other symptoms and conditions include body and breath odour, mouth cankers, nausea (pregnancy), poor circulation, cold extremities, fainting, heart infarction, sickle-cell anaemia, cancer, diabetes, epilepsy, gastric and duodenal ulcers, inflammation of the intestines (Crohn's disease), joint pains (especially knee and hip), liver cirrhosis/alcoholism, toxaemia, mental problems, increased emotionalism, hyperactivity, learning disorders, autism, schizo-phrenia, loss of appetite, anorexia nervosa, and multiple allergies.

Best Sources: Oysters, herrings, sardines, kelp, seafood, oatmeal, liver, pumpkin seeds, and sprouted seeds.
Now let's look in depth at two minerals - magnesium chloride and MSM, a form of organic sulphur.

Magnesium Chloride for Health and Rejuvenation: Magnesium is nothing short of a miracle mineral in its healing effect on a wide range of diseases as well as its ability to rejuvenate the aging body. It is essential for many enzyme reactions, especially in regard to cellular energy production; it is essential too for the health of the brain and nervous system and for healthy teeth and bones. It may come as a surprise that in the form of magnesium chloride it is also an effective infection fighter. On the basis of its numerous beneficial effects, I recommend magnesium chloride as part of a healthy living program.

The first prominent researcher to investigate and promote the antibiotic effects of magnesium chloride was French surgeon and professor Pierre Delbet, M.D. In 1915, he was looking for a solution to cleanse the wounds of soldiers; traditionally used antiseptics actually damaged tissues and encouraged infections instead of preventing them. In all his tests, magnesium chloride solution was by far the best; not only was it harmless for tissues, but it also greatly increased white blood cell activity and phagocytosis (the destruction of harmful microbes).

Dr. Delbet performed experiments on the internal applications of magnesium chloride and found it to be a powerful immune stimulant. In his experiments, phagocytosis increased by up to 333 percent. This means that after magnesium chloride intake the same number of white blood cells destroyed up to three times more microbes than beforehand. Gradually, Dr. Delbet found magnesium chloride to be beneficial in a wide range of diseases. These included diseases of the digestive tract such as colitis and gallbladder problems, Parkinson's disease, tremors and muscle cramps, acne, eczema, psoriasis, warts and itching skin, impotence, prostatic hypertrophy, cerebral and circulatory problems, asthma, hay fever, urticaria, and anaphylactic reactions.

Hair and nails became stronger and healthier and patients had more energy. He also found a preventative effect on cancer and used magnesium chloride to reverse precancerous conditions such as leukoplasia, as well as hyperkeratosis and chronic mastitis. Epidemio-logical studies confirmed that topographical regions with magnesium-rich soil had a lower incidence of cancer in their population than regions with low magnesium levels.

Here is a review of other benefits of magnesium:

Magnesium for Nerves: Magnesium has a calming effect on the nervous system and is frequently used to promote good sleep. But more importantly, it can be used to calm irritated and overexcited nerves. This is especially useful with epileptic seizures, convulsions in pregnant women, and the "shakes" in alcoholism. Magnesium levels are generally low in alcoholics, contributing to or causing many of their health problems. If magnesium levels are low, the nerves lose control over muscle activity, respiration, and mental processes.

Due to its strong relaxing effect, magnesium helps not only with better sleep but is also useful in overcoming headaches and migraines. Nervous fatigue, tics and

twitches, tremors, irritability, hypersensitivity, muscle spasms, restlessness, anxiety, confusion, disorientation, and irregular heartbeat - all these conditions respond to increased magnesium levels. A common phenomenon of magnesium deficiency is a sharp muscle reaction to an unexpected loud noise.

Many of the symptoms of Parkinson's disease can be overcome with high magnesium supplementation; shaking, for example, can be prevented, and rigidity can be eased. With pre-eclampsia, pregnant women can develop convulsions, nausea, dizziness, and headaches; in hospitals, this is treated with magnesium infusions.

Magnesium for the Heart: Adequate levels of magnesium are essential for the heart muscle. Those who die from heart attacks usually have very low magnesium but high calcium levels in their heart muscles. Patients with coronary heart disease who had been treated with large amounts of magnesium had a better survival rate than patients who had received drugs. This might be due to the fact that magnesium dilates the arteries of the heart and lowers cholesterol and fat levels.

Diabetics who are prone to atherosclerosis, fatty degeneration of the liver, and heart disease often have low magnesium tissue levels. They often develop eye problems, such as retinopathy; diabetics with the lowest magnesium levels have the most severe retinopathy. The lower the magnesium content of their drinking water, the higher is the death rate of diabetics from cardiovascular disease. In an American study, the death rate due to coronary heart disease was double and diabetes was four times higher in areas with low magnesium water levels as compared to areas with high magnesium levels.11

Magnesium for Healthy Bones and Teeth: Medical authorities claim that the widespread incidence of osteoporosis and tooth decay in Western countries can be prevented with a high calcium intake. However, published evidence reveals that the opposite is true. Asian and African populations with a very low intake (about 300 mg of calcium daily) have very little osteoporosis; Bantu women with an intake of 200 to 300 mg of calcium daily have the lowest incidence of osteoporosis in the world. In Western countries with a high intake of dairy products, the average calcium intake is about 1000 mg. Strangely, the higher the calcium intake, especially in the form of cow's milk products (except butter), the higher the incidence of osteoporosis.12

The average concentration of magnesium phosphate in bones is about one percent; in teeth about 1.5 percent; in elephant tusks two percent; and in the teeth of carnivorous animals made to crush bones, it is five percent. In regard to the strength of bones and teeth, think of calcium as chalk and of magnesium as superglue; the magnesium superglue binds and transforms the chalk into superior bones and teeth.

Magnesium, Cancer, and Aging: Many studies have shown an increased cancer rate in regions with low magnesium levels in soil and drinking water. In Egypt, the cancer rate was only about ten percent of that in Europe and America, and in the rural areas it was practically nonexistent. The main factor at play was an extremely high magnesium intake of 2.5 to 3 g in these cancer-free populations - ten times more than in most Western countries.

Let's see how calcium and magnesium are further linked to aging. We use our muscles by selectively contracting them; on the biochemical level, muscle contraction

is triggered by calcium ions flowing into muscle cells. To relax the muscle, calcium is pumped out again. However, as we age, more calcium remains trapped in the muscles, and these muscles become more or less permanently contracted, leading to increasing muscle tension and spasms. Together with calcification of the joints, this is the typical rigidity and inflexibility we see in old age.

The higher our intake of calcium relative to magnesium, the faster we calcify and age. Further, most of the excess calcium in our diet ends up in our soft tissues and around joints, leading to calcification and potentially arthritic deformations, arteriosclerosis, cataracts, kidney stones, and senility. Biochemical stress can lead to the pathological calcification of almost any organ, which means the more stress, the more calcification, and the more rapid the aging.

The Rejuvenation Mineral: Magnesium and chloride have other important functions in keeping us young and healthy. Chloride is required to produce a large quantity of gastric acid each day, and it is also needed to stimulate starch-digesting enzymes. Magnesium is the mineral of rejuvenation and prevents the calcification of our organs and tissues that is characteristic of the aging-related degeneration of the body.

Using other magnesium salts (other than the chloride one) is less advantageous because these have to be converted into chlorides in the body anyway. We can use magnesium as oxide or carbonate, but then we need to produce additional hydrochloric acid to form chlorides so it can be absorbed. Many aging individuals, especially those with chronic diseases, who desperately need more magnesium cannot produce sufficient hydrochloric acid and thus cannot absorb the oxide or carbonate.

Among the other salts, Epsom salt is magnesium sulphate; it is soluble but not well absorbed and acts mainly as a laxative. Chelated magnesium is well absorbed but expensive and lacks the beneficial contribution of the chloride ions. Orotates are good but expensive for their content of magnesium; and both orotates and chelates lack the infection-fighting potential of magnesium chloride.

As suggested above, calcium and magnesium are opposites in their effects on our body structure. As a general rule, young women and children with a soft body structure need more calcium, while the more rigid and inflexible we become, the less calcium and the more magnesium we need. Magnesium can reverse the age-related degenerative calcification of our body structure and rejuvenate us.

How Much Magnesium to Take: Hydrated magnesium chloride contains about 120 mg of magnesium per gram or 600 mg per rounded teaspoon. It has a mild laxative effect. As a good maintenance intake to remain healthy, you can take up to one teaspoon daily in divided doses mixed with meals; it is best to use it instead of table salt as it has a somewhat salty taste. Individuals with very sensitive taste buds can start using magnesium in tiny amounts mixed with strongly flavoured food, then gradually increase the doses.

With acute infections, dissolve eight slightly rounded teaspoons in one quart of water. With children, a small glassful or four ounces can be used effectively every six hours. Adults can double this dose by drinking this amount every three hours, or

even more frequently until diarrhea develops; then cut back to a maintenance intake just below the level of diarrhea, until the infection has cleared.

For daily use, it is more convenient to dissolve the magnesium chloride in water. Fill a bottle or jar halfway with the crystals and then to the top with water. Mix one teaspoon of this solution with food or drink three times daily for a daily intake of about 600 mg of magnesium. This or a more concentrated solution can also be used as a pack over tumours and infected, inflamed, painful, stiff, or calcified joints, muscles, adhesions, or scar tissue. It is also excellent as a back rub, to relax tense muscles anywhere on the body, and to rejuvenate aging skin. For sensitive skin, use it in a very diluted form. On wounds it can be used topically in a four-percent solution, that is, a level teaspoon in a small glass of water.

Non-hydrated or desiccated magnesium chloride contains twice as much magnesium as the hydrated product. If using this, use half the amounts indicated above. Magnesium chloride is produced from seawater. Instead of magnesium chloride, you can use the brine from the production of sea salt. It has the advantage of having more trace minerals than the technical magnesium chloride, but due to its high content of magnesium sulphate it is rather bitter.

CAUTION: While a higher magnesium intake is beneficial for most individuals, those with low blood pressure usually re-quire more calcium. Normal blood pressure is about 120/80, so the lower yours is the higher your daily intake of calcium should be. While those with high blood pressure benefit from ingesting twice as much magnesium as calcium, those with low blood pressure can take twice as much calcium as magnesium; both minerals are taken in relatively high amounts. Those with low blood pressure and a tendency towards inflammations should also greatly reduce their intake of phosphorus. A high level of phosphorus in the blood tends to cause magnesium as well as calcium levels to be low.

Magnesium and calcium supplementation should be avoided by people with severe kidney problems (severe renal insufficiency); extra magnesium may be weakening to those with myasthenia gravis. Too much magnesium can cause muscle weakness or cramps; if this happens stop using magnesium and use more calcium.

MSM - Organic Sulphur As a Versatile Healer: MSM (methyl-sulfonylmethane) occurs naturally in many fresh foods but is lost during processing. Its main use in the body is for collagen synthesis and forming skin, blood vessels, hair, and nails; it keeps cells, skin, and blood vessels elastic, which is the attribute of youth. That is why organic sulphur is often regarded as the “beauty mineral.” Cell walls remain permeable so that nutrients can freely flow into the cells and wastes and toxins can easily be removed.

Amino acid chains are usually linked with each other through flexible sulphur bridges. Also the oxidative energy production of cells requires reactive sulphur compounds. Thus, without sufficient organic sulphur as in the form of MSM, cells and body structures lose their elasticity and flexibility. What results are the well-known signs of aging: inelastic skin with increasing wrinkles, scar tissue, hardening arteries, varicose veins, and “hardened” lungs, causing emphysema. Sufficient intake of MSM is able to reverse these conditions to a significant degree, including emphysema. It is believed that the MSM in aloe vera is the active ingredient responsible for repairing damaged skin, a quality attributed to this plant.

Athletes use MSM to increase stamina and minimize sore muscles. Its use for this purpose is even more widespread with racehorses and greyhounds. This effect may be mainly due to the ability of MSM to increase greatly the body's ability to eliminate metabolic residues, wastes, and toxins from the cells. In a similar way, MSM appears to help those with chronic fatigue. And it helps us recuperate from severe physical and mental exhaustion; further, MSM reduces the effects of stress and the incidence of stress-related deaths in animals.

MSM tends to reduce or eliminate allergic reactions to foods, chemicals, and inhaled allergens. It also reduces reactions to the bites of mosquitoes, bees, and poisonous spiders and snakes. It lessens inflammation, pain, stiffness, and swellings due to arthritis or from other musculoskeletal system disorders, and it helps to normalize the blood chemistry in these conditions; it also reduces inflammations of the skin and mucous membranes. MSM relieves leg and back cramps and muscle spasms, be it after periods of inactivity (night cramps) or during athletic activities.

Other conditions that often benefit from MSM supplementation are hot flashes as well as discomfort due to the monthly cycle, acne, asthma, back pain, candidiasis, constipation, diabetes, diarrhea, diverticulitis, gastrointestinal ulcers, hypertension, inflammations of all kinds, itching skin, migraines, nausea, pain, stress, sunburn, and wound healing. It is believed to be helpful with other chronic degenerative or inflammatory conditions, especially Alzheimer's, cancer, Crohn's disease, myasthenia gravis, and Parkinson's.

Fingernails and hair have a high sulphur content and their condition generally improves with MSM supplementation. It also reduces parasite infections in the intestinal and urogenital tracts. MSM also appears to normalize our mental state. Individuals on MSM tend to report increased alertness, reduced mood swings, and less depression. It seems to improve the immune system and the senses of taste and smell. In addition, it neutralizes the toxicity of anticholinesterase, thereby providing protection against insecticide exposure or ingestion; it also aids the liver in the detoxification of chemicals and, because of this, it is useful in easing drug withdrawal symptoms.

In summary, MSM:

- inhibits pain impulses along nerve fibres (analgesia)
- lessens inflammation
- increases blood supply
- reduces muscle spasm
- softens scar tissue.

How to Use MSM: Unlike the related DMSO, MSM is a natural food ingredient and is free of unpleasant taste and odour. It is reported to be completely safe even in very high amounts. Because of its inert composition, it does not cause allergies or undesirable pharmacological effects; it can even be safely used to dilute blood. The body will use what it needs and remove any excess through the kidneys. The water-soluble MSM is easily absorbed and provides a therapeutically important source of organically bound sulphur.

The daily maintenance intake commonly ranges from 1 to 10 g taken in two or more divided doses. Adjust the dose according to your well-being or observed effects; initially I suggest you start with about 1 g and increase the dosage gradually.

You can also use MSM externally to carry other nutrients or remedies into the skin. With arthritis or connective tissue problems, for instance, you can dissolve glucosamine, copper salicylate, and MSM in a small amount of warm water and rub it into the affected area.

For bulk lots of MSM in the United States, see www.bulkmsm.com where you can also find more information on MSM. If your diet is already high in sulphur, as from plenty of onions and eggs, then you might not notice any benefit from taking MSM.

CAUTION: Individuals who are sensitive to sulphites, often used as preservatives, tend also to be sensitive to MSM due to a deficiency of molybdenum, which is required for liver enzymes to convert sulphur compounds into sulphates.

In this case, supplement with 200 to 1000 mcg of molybdenum and avoid a high copper intake.

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Step 25
AMINO ACIDS

They're the building blocks of all body proteins.
Adequate levels are essential for good health.

There are eight essential amino acids for adults that must be supplied with the diet: isoleucine, leucine, lysine, methionine, phenyl-alanine, threonine, tryptophan, and valine. Two others, arginine and histidine, are essential in the first year of life. Some may be useful as supplements to enhance the functions described below, but commonly this is necessary only in cases of malabsorption of nutrients, with specific diseases, or with bodybuilding and sports nutrition. The specific amounts to use are usually not critical and may vary widely with practitioners. If not otherwise recommended by your health professional, you can use the amounts indicated on the product container. However, in most instances, instead of taking single amino acids, I recommend taking spirulina or chlorella instead; these are high in protein (up to 70 percent) and easily digestible.

Amino acids, like many vitamins, exist in two forms that are chemically identical but differently folded. These are named either D-amino acid or L-amino acid. Amino acids in our body have the L-form. Therefore, it is not advisable to use the synthetic D,L-amino acids, but rather the more expensive L-amino acids produced with enzymes. One exception to this is D,L-phenylalanine if used for pain relief. If the label of a supplement does not specify that it is the L-form, you can assume that it is the cheaper D,L-form, and I would not use it. Furthermore, two simple amino acids, glycine and taurine, exist only in one form and are not marked D or L.

Arginine: Arginine is the precursor of the neurotransmitter nitric oxide, which helps to relax and dilate blood vessels. It is in an antago-nistic balance with lysine. Arginine helps to channel nutrients into tissues and promotes regeneration.

- Aids in liver detoxification
- May retard growth of tumours and cancer cells
- Assists in the release of growth hormones
- Helps maintain a healthy immune system
- Important for scar tissue formation and collagen production
- Promotes muscle growth and fat utilization
- Helpful with malaria
- May help with male impotence

Note: avoid supplementation during pregnancy and lactation, and with herpes infections.

Carnitine: Carnitine is produced in a healthy liver from lysine, vitamins B1 and B6, and iron. Vegetarian diets can be deficient in carnitine, as it is found mainly in meat. D--carnitine is harmful. Acetyl-L-carnitine is the form best suited to treat neurological conditions.

- Aids transport of long-chain fatty acids to mitochondria for energy production
- Helps in weight loss
- Improves athletic ability through increased energy production
- Enhances effectiveness of the antioxidant vitamins E and C

Creatine: It is formed in the liver from the amino acids arginine, glycine, and methionine, or available from meat. Commonly 5 g are supplemented daily as creatine-monohydrate, mainly used by athletes and bodybuilders.

- Improves energy production in muscles and heart
- Helpful with muscle diseases, such as motor neurone disease
- Protects against brain injuries, and can improve memory

Cysteine: This is a high sulphur-content amino acid formed in the liver from methionine; it needs vitamin B6 to work well. It acts as a brain neurotransmitter; high-dose supplements of cysteine can interfere with brain functions in susceptible individuals.

- Aids in detoxifying the body
- Precursor to glutathione, a strong antioxidant
- Removes excess heavy metals, helps to burn fat
- Increases muscle growth
- Breaks down mucus in the respiratory tract
- Useful for burn and wound healing
- Assists in the supply of insulin

Glutamic Acid: Glutamic acid is a major neurotransmitter in the brain, so it must be avoided as a supplement as it can cause imbalances in susceptible people. Monosodium glutamate or MSG (the sodium salt of glutamic acid) is a main ingredient of food flavouring added to processed food and is variously labelled as hydrolyzed vegetable protein, soy protein extract, yeast extract, beef stock, caseinate, or natural flavouring. Evidence shows that it can kill brain cells in susceptible individuals.

- Important for neurotransmission
- Metabolism of sugars and fats
- Detoxifies ammonia (when used with glutamine)
- Together with glucose, is the brain's principal fuel

Glutamine: As mentioned, glutamine is a principle source of energy, especially for the brain, and helps to regenerate the intestinal wall. With lack of energy and difficulty gaining weight (as in advanced cancer), 10 g or more can be used daily in divided doses.

- Provides about 80 percent of the body's pool of free nitrogen
- Reduces cravings for sugar, alcohol, and other drugs

- Improves absorption of other nutrients, important with inability to gain weight (cachexia)
- Useful with impotence, allergies, senility, fatigue, and peptic ulcers
- Converted in the brain to glutamic acid and to GABA, both of which act as neurotransmitters

Glycine: This is the simplest amino acid. It has a sweet taste and acts as a nitrogen pool for the synthesis of other amino compounds.

- Prevents or slows muscle degeneration
- Needed for a healthy prostate
- Aids central nervous system functions
- Useful in epilepsy and depression
- Important for immune system, building block for nonessential amino acids

Histidine: Histidine dilates blood vessels, lowers blood pressure, and chelates minerals. It is an amino acid of special importance to the developing infant.

- Helpful for tissue growth and repair
- Important for digestion and ulcer healing
- Controls gastric acidity
- Important for production of red and white blood cells
- Possible benefits in rheumatoid arthritis

Isoleucine: An essential amino acid and one of three branch-chain amino acids (BCAAs), which form an essential part of muscle tissue protein.

- Needed for haemoglobin production
- Stabilizes blood sugar and energy levels

Note: Use in combination with leucine and valine; deficiency of isoleucine can produce hypoglycaemia-like symptoms.

Leucine: An essential branch-chain amino acid (BCAA) important in muscle protein.

- Lowers elevated blood sugar levels
- Promotes healing of bone, skin, and muscle tissue

Note: Use with correct balance of isoleucine and valine; excessive amounts can produce hypoglycaemia.

Lysine: An essential amino acid that must be derived from the diet.

- Essential building block for all protein
- Needed for proper growth and bone development in children
- Helps calcium absorption
- Maintains nitrogen balance

- Effective against cold sores and herpes viruses, possibly also beneficial with other viruses
- Increases antibody production
- Needed for collagen production
- Helps to build muscle
- Lowers serum triglycerides
- Deficiency results in loss of energy, inability to concentrate, irritability, retarded growth, and hair los

Methionine: This is an essential sulphur amino acid that must be obtained from the diet. Supplementation can be harmful with an existing vitamin B6 deficiency, so therefore use both at the same time.

- Needed for the metabolism of fat
- Aids in liver detoxification
- Involved in the synthesis of the amino acids cysteine and taurine
- Helps to reduce effects of chemical sensitivities
- Aids digestive processes
- Involved in production of choline

Ornithine: Ornithine is helpful with insomnia, possibly by removing ammonia from the brain.

- Helps release growth hormone
- Needed for immune system function
- Promotes healing
- Detoxifies ammonia

Phenylalanine: An essential amino acid, D- or D,L-phenylalanine can be used for long-acting pain relief. Do not use during pregnancy or with anxiety attacks, high blood pressure, or phenylketonuria (PKU).

- Used in treatment of depression
- Essential for the production of neurotransmitters
- Involved in the formation of the skin pigment melanin

Taurine: Taurine is a sulphur amino acid and a main component of bile salts, essential for fat absorption.

- Promotes emulsifying and absorbing fats
- Helps regulate rhythm and mineral concentrations in the heart
- An inhibitory (sedating) neurotransmitter, helps with epilepsy

Threonine: This is one of the essential amino acids.

- Maintains protein balance

- Needed for the formation of collagen and elastine
- Aids the liver and fat metabolism
- Helps control epilepsy

Tryptophan: This is another essential amino acid.

- Important for the production of the vitamin niacin or niacinamide
- Helps prevent insomnia and elevates mood
- Controls hyperactivity in children
- Needed for production of serotonin and melatonin

Tyrosine: Tyrosine is the precursor of stimulating neurotransmitters and hormones, in particular adrenaline, dopamine, and thyroxin.

- Involved in the production of melanin pigment of skin and hair
- Important for adrenal, thyroid, and pituitary gland function
- Helps control appetite and body fat levels; is an antidepressant
- May assist during withdrawal from addictive drugs
- Provides raw material for the synthesis of epinephrine (adrenaline) and dopamine

Valine: This is an essential amino acid in muscle protein.

- Important for muscle tissue maintenance and muscle coordination
- Stimulates and promotes mental vigor

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Step 26
DIGESTIVE ENZYMES

**These vital substances are needed for digestion,
but poor diet and cooking practices can deplete your supp**ly.

Digestive enzymes are released from our digestive organs in order to break down food into molecules small enough for it to be absorbed. Deficiencies of digestive enzymes are widespread and are caused mainly by overeating, eating too much cooked food, food allergies, and incorrect food combining. Virtually all elderly people and those with chronic degenerative diseases and allergies have digestive enzyme deficiencies.

The enzymes in raw and fermented foods help in the digestive process but are destroyed by temperatures over 120° F. Further, many heated proteins become difficult to digest and you may need more digestive enzymes to handle them. Some raw seeds, soybeans, broad beans, wheatgerm, and nuts contain enzyme inhibitors, but sprouting and cooking inactivates these.

In light of this, make a deliberate effort to improve the enzyme content and digestibility of your food. If you are in a state of chronically lowered health, it will be very helpful to use enzyme supplements. This is essential in the case of cancer and other advanced degenerative diseases and also if you have allergies, unless you are already on a predominantly raw food diet.

Most important are the pancreatic enzymes, known collectively as pancreatin and available as a supplement under various brand names. For serious diseases, take 4000 to 5000 mg of pancreatin in divided doses in the course of each meal. One tablet may contain 1200 or 1600 mg of pancreatin; this is sometimes also described as pancreatin 4NF and if so take 300 or 400 mg of it. In addition, you can take one or two tablets of an enzyme combination containing papain, bromelain, pepsin, or bile. Pepsin is indicated for protein foods if the stomach is weak, while bile is helpful if there is a problem with fat absorption. Papain and bromelain help protein digestion.

In the case of degenerative diseases and advancing age, gastric acid is often deficient. If so, you can take hydrochloric acid–pepsin tablets, especially when eating cooked protein meals. Alternatively, dilute one part commercial diluted hydrochloric acid (usually 20 percent) with nine parts water. Mix one teaspoon (use plastic) of this with meals or drink with fluids after a meal. As a rule, additional enzymes are not needed with uncooked meals.

However, digestive enzyme supplements are not required if protein-digesting enzymes can be obtained from food, such as bromelain from pineapples or papain from unheated leaves or flowers or unripe fruit of papaya. Ripe kiwi fruit is a good source of enzymes. Use any of these with protein meals. You can also predigest meat, fish, or other protein food by refrigerating it overnight wrapped or mixed with papaya leaf.

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Step 27
NUTRITIONAL SUPPLEMENTS

Concentrated nutrients in pill form can shore up nutritional deficiencies and build optimal health.

Most individuals on conventional diets with much refined and processed foods have either outright nutrient deficiencies or shortages of various vitamins, minerals, enzymes, and hormones. Generally, our intake of essential nutrients is less than optimal, making us susceptible to disease. Deficiencies are even more widespread in those who already suffer an acute or chronic disease. Sometimes individuals have had to suffer for years and have had high medical expenses for conventional treatments when a few nutritional supplements could likely have corrected the problems.

Supplements are most important for individuals with nutrient malabsorption and for those who still use processed and refined foods as part of their diet or who cannot regularly obtain vegetables and fruit grown organically in good soil. The more serious the disease or health deterioration, the more supplements are likely to be beneficial and the greater should be the dosages and range of supplements taken.

Calcium supplements are commonly used with conventional diets and yet many people are apprehensive of obtaining sufficient calcium when abstaining from milk products. This concern is unfounded. Calcium is not well absorbed from cow's milk, as can be seen in the high incidence of osteoporosis developing in people on conventional Western diets and the fact this is not a problem in milk-free Asian countries. Vegetables and sprouted and fermented seeds are high in usable calcium; the calcium content in juice from cereal grasses is higher than in milk as, after all, cows obtain their calcium from grasses in the first place.

Similar considerations apply to iron, which can easily become harmful as an inorganic supplement. Much more widespread and detrimental than calcium and iron deficiencies are deficiencies in chromium, magnesium, manganese, selenium, and zinc.

Many supplements are actually concentrated health foods, but taking these is not the same as the "pill-popping" of medical drugs. While I believe that supplements are unnecessary if one is healthy and lives on a high quality diet in an unpolluted environment, I know that it is difficult to remain healthy in present times and even more difficult to heal an "incurable" disease. Carefully selected supplements can make a great difference in these endeavours, especially for those who are just starting to improve their diet.

I am not in favour of using multivitamin tablets as they often contain synthetic forms of vitamins A, D, and E and beta-carotene. Instead, if required, it is better to use a low-potency B-complex in addition to vitamin C and cod-liver oil or halibut-liver oil capsules. Mineral supplements are often more important than vitamins and can contain approximately 15 mg zinc, 5 mg manganese, 100 to 200 mcg selenium, 200 mcg chromium, 500 mg magnesium, and up to twice this amount of calcium if one's

blood pressure is low. Much higher doses, especially of selected vitamins, can be used where indicated for therapeutic effects.

In addition, you can use general supplements to increase your overall well-being and vitality. Of special benefit for those lacking energy are ginseng, coenzyme Q10, royal jelly, and freeze-dried liver. Bee pollen and spirulina or chlorella are my favourites.

As mentioned earlier, digestive enzymes and hydrochloric acid supplements can help those with weak digestion. For those in conditions of debility, amino acid and nucleic acid supplements can help, the most helpful amino acids being lysine, tyrosine, methionine, and glutamine.

Many supplements such as royal jelly, vitamin B12, and the freeze-dried animal glands are much more effective if partly absorbed under the tongue, chewed lightly, and kept in the mouth for as long as possible.

Lecithin is beneficial for most individuals, and you can mix a teaspoonful with meals or with ground linseed (flaxseed). Omega-3 essential fatty acids are universally indicated for which linseed oil or cod-liver oil and other fish oils can be taken; if malabsorption is a problem, the oil can be rubbed into the skin. These oils help to reduce inflammation, pain, and allergic swellings. On a diet low in iodized salt and seafood, we can become iodine deficient; kelp tablets or granules are excellent for supplying iodine as well as many other minerals. With infections, use high levels of vitamins C, A, and E, zinc, bee propolis, and echinacea.

Sulphur compounds, as mentioned earlier, detoxify and remove from the body heavy metals, harmful chemicals, and drugs; MSM is especially good for this. Sulphur is also a main component of connective tissue, so supplementation is beneficial with all connective tissue diseases (for example, arthritis). Even simply taking powdered sulphur has been shown to increase the formation of useful sulphur compounds. You can take a gelatine capsule filled with sulphur once a day or mix a pinch of it into each meal. The main sulphur amino acids are taurine, L-cysteine, and L-methionine; the main sulphur foods are egg and onion.

Generally, gradually increase and decrease high levels of supplements, especially vitamins, and interrupt or greatly reduce supplement intake during fasting or cleansing periods. Most vitamin-mineral supplements are best absorbed and cause less gastrointestinal irritation if mixed with the meal as powders, crushed tablets, or opened capsules. The next best way is to take tablets near the middle of the meal and avoid slow-release tablets. However, take amino acids before the meal; this applies also to calcium as it is not well absorbed and tends to form insoluble combinations (soaps) with fatty acids during digestion.

Organic or Natural Versus Inorganic or Synthetic: There is some confusion about the importance and meaning of natural or organic versus synthetic or inorganic minerals. In food production, “organic” means that food has been grown, produced, stored, and processed without the use of synthetic chemicals. However, in chemistry “organic” means that a chemical is based on carbon and has covalent bonds; “inorganic” means that a chemical is not based on carbon and has ionic bonds.

Some inorganic chemicals, such as sodium chloride, magnesium chloride, and calcium chloride, are ingredients of natural and organic foods and are also essential

components of our body. Calcium in our blood plasma, for instance, is about half in ionized form while the other half is bound to proteins. In this way, taking some minerals in inorganic form can rectify ionic deficiencies of these minerals.

Further, a healthy intestinal flora can transform inorganic into organic minerals, while inorganic minerals taken with gelatine or fresh green vegetable juice can easily be incorporated into organic structures. This is of special importance with some of the trace minerals. Even so, it is safer to use these directly in organic form, best obtained from fresh, organic vegetable and grass juice, mineral-rich food or plant concentrates, or, alternatively, safely bound to amino acids or as stable complexes such as copper and zinc salicylate.

However, there is a downside to routinely adding inorganic minerals, such as table salt, to our food. We may use concentrations that are too high and irritate the intestinal wall, and we may also cause mineral imbalances. Therefore, use not only the right concentrations but the right combinations of ingredients in your supplements. It is much easier to get this right by using natural foods. Of course, the main reason we use supplements is because commercial food has inadequate mineral content; even in much of organically raised food, the mineral content is not as high as it might be.

Another way of making minerals safer and more effective is by using them in colloidal form. In this way, even tiny clusters of metal atoms can be safely and beneficially ingested. Colloidal mineral products are commercially available, made from ancient decomposed plant material. Also beneficial is the intake of minerals present in energized water.

After sufficient health improvement, you may feel that you no longer need most nutritional supplements. With a good maintenance diet, I recommend continuing indefinitely to use the following health foods, or equivalent ones: several teaspoons each of bee pollen, ground linseed, and spirulina or chlorella; half a teaspoon of kelp; and one tablespoon of cod-liver oil (emulsified with lecithin and fresh juice); also some lecithin and magnesium chloride with meals will be helpful.

Selection of Vitamin Supplements: Commercial growing and processing and traditional Western cooking methods usually reduce the vitamin and mineral content of foods to only a fraction of that found in fresh, raw, organically grown foods. As an example, methyl bromide, a widely used fumigant for grains, destroys all the pantothenic acid (a B vitamin) in cereal grains.

Unfortunately, these days many vitamins (especially vitamin C and the B vitamins) are not available in sufficient amounts in foods or natural supplements, and synthetic supplements are often necessary in order to improve or maintain our health. Vitamins available as natural concentrates (A, D, and E) should be avoided in synthetic form. Natural vitamin E is d-alpha tocopherol; the synthetic form is dl-alpha tocopherol. Highly recommended is vitamin E complex as mixed tocopherols.

Store vitamin supplements in a dry, cool, and dark place. Oil-filled capsules should be taken during a meal containing oily or fatty foods and lecithin. However, many individuals most in need of these vitamins have absorption problems and for them oil-filled capsules are not suitable. Therefore, I generally recommend using tablets of natural vitamin E rather than oil-filled capsules. If in doubt about your

digestive abilities, take a halibut oil or other fish oil as a capsule at bedtime and keep it in the mouth to be slowly absorbed overnight. Other-wise, take all supplements during meals or mixed with food. Small amounts with several meals are better absorbed than a large amount in a single dose.

Some tablets have beta-carotene substituted for vitamin A. However, many individuals have difficulty in absorbing beta-carotene and converting it into vitamin A. Therefore, use tablets that contain real vitamin A and not -vitamin-A equivalents of beta-carotene.

Chewing vitamin and mineral supplements together with food produces much better results than just swallowing them. Appreciable amounts of vitamin B12 can be absorbed by keeping a tablet under the tongue, even if it cannot be absorbed in the stomach because of a lack of “intrinsic factor” (a substance usually present in the stomach that is involved in the absorption of vitamin B12).
If there are signs of increased requirements for individual nutrients, use these together with a B-complex supplement. In most conditions involving lack of energy, debility, anemia, low blood pressure, and chronic degenerative diseases, initial injections and later mouth-absorbed tablets of vitamin B12 (1000 mcg daily) are very helpful.

The acid form of vitamin C (ascorbic acid) can be taken with protein meals, especially if your system is too alkaline or lacking in gastric acid. If regularly taking more than 3 to 5 g per day of vitamin C, those with high blood pressure can partly neutralize the ascorbic acid with an equal amount of milk of magnesia, or with one-third the amount of potassium bicarbonate or magnesium carbonate. With low blood pressure and possible overacidity, take calcium ascorbate instead.

Antioxidants are of greatest importance for minimizing oxidative tissue damage and, with this, for avoiding diseases and delaying aging. In a more recent development, a high intake of antioxidants has also been found to be crucial in preventing and overcoming viral infections. The major antioxidants include the vitamins A, C, and E, the minerals selenium and zinc as components of antioxidant enzyme systems, the plant pigments beta-carotene, bioflavo-noids, and anthocyanins, as well as phenols and catechols in grape seed extract, green tea, and generally in coloured fruit and vegetables. Other powerful antioxidants are alpha-lipoic acid and negative hydrogen as in Microhydrin or electrolytic reduced water (ERW) produced with water ionizers. Whether you take antioxidants as supplements or as part of a high-quality diet, make sure you get plenty.

Are Nutritional Supplements Dangerous?: Generally, health authorities promote pharmaceutical drugs as beneficial and natural remedies as harmful. They tend to call natural remedies “drugs,” and the view has been put forward that synthetic nutrients are the same as natural ones. Research results using synthetic products, such as vitamins A, D, E, or beta-carotene, with negative or harmful outcomes are then used as “scientific proof” that natural remedies are either useless or dangerous.

While numerous trials have shown significant health benefits for individuals with higher levels of beta-carotene in their blood, clinical trials with synthetic beta-carotene and synthetic vitamin E have shown increased rates of death due to cancer.

Vitamin A has been portrayed as the most “dangerous” supplement, largely based on studies with synthetic vitamin A. There are dire warnings that it can cause death in amounts higher than the RDA (5000 IU). However, many people take 25,000 IU or more daily without problems, and as far as I can ascertain, there has never been a death recorded due to vitamin A supplements in the U.S. in the 60 years that these have been in use. There appears to be only one recorded death in all the scientific literature, that of a chemist in England in the 1950s who ingested two million IU daily of retinyl acetate for three months and died of liver cirrhosis.13

I am not aware of any pharmaceutical drug having such a good safety record as that. Even one of the safest drugs, aspirin, has been stated to cause about 100 deaths a year, and many more cases than that of toxicity.14 In comparison the reported cases of (usually easily reversible) vitamin A toxicity in the U.S. are typically five per year.15

Similar unfounded attacks have been made against vitamins C and E. For more detailed information on this subject, see the website of the Life Extension Foundation (www.lef.org); for articles on megavitamin therapy; also see www.doctoryourself.com.

Imagine the mass media frenzy if there were actually some fatalities due to vitamin A. Yet there is no concern at all about thousands of patients dying, in my view unnecessarily, due to prescription drugs. In the public, the perception has been generated that fatalities due to prescription drugs are a small price to pay for their overall benefit. This benefit has never been shown in the long term. Drug approval is based on short-term trials, and only by accident does the truth of long-term harm occasionally emerge, as in the case of hormone-replacement therapy. I believe that in the long term all drugs become a burden on the liver or kidneys by increasing our load of toxic chemicals and may accelerate our health deterioration. Therefore, with any health problem, inform yourself about all available options.

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Step 28
HERBS

You may benefit from using herbal remedies instead of pharmaceutical drugs.

Herbs are not completely harmless, but damage due to commonly used herbs is extremely rare, while the benefits are usually genuine and lasting. In contrast to culinary herbs, medicinal herbs should be used on a long-term basis only if there is a clinical reason and not just in case they might do some good. (Herbs for a wide range of health problems are discussed in part 6.) Here I will discuss a few herbs for some common conditions and show how the application can be particularly important on your road to better health.

General Herbal Remedies: A good combination to cleanse the gastrointestinal tract is a mixture of chillies and ginger root. Blend or crush both in lemon juice and olive oil and refrigerate, then use this as a salad dressing or for flavouring meals. Use an amount that is hot but not uncomfortable. Gradually increase your intake to just below your tolerance level for several weeks; then you can continue to use it in normal amounts for flavouring your food. With serious infections, inflammations, or cancer of the gastrointestinal tract, you can also add fresh garlic to this until the problem is overcome.

Peppermint tea is especially good to stimulate the digestion and uplift the spirit, while slippery elm powder soothes the digestive tract. Sage is highly esteemed. An ancient saying goes: “Why die [of a disease] when sage grows in your garden?” It can be prepared by adding two teaspoons of dried sage to one pint of boiling water; after three minutes, remove it from the heat and let it draw for another ten minutes. Sage can be combined with other herbs. Fragrant or leaf herbs such as peppermint or St. John’s Wort can be added while the herbs steep. St. John’s Wort is effective against depression.

The immune system can be strengthened with echinacea, propolis, European mistletoe (Viscum album), Easter lily, and reishi and other Asian mushrooms. Echinacea can be added to all other herb combinations. However, there are some research findings that echinacea can cause problems if taken uninterruptedly for several months, so it may be advisable to interrupt its use after a month and then to take it again a few weeks later.

Wormwood and garlic are excellent against all kinds of parasites as well as the yeast Candida albicans. A combination of goldenseal, ginger, and slippery elm powder is good for gastrointestinal inflammations and multiple sclerosis. Ginger is also good against motion sickness. In addition to being an excellent wound healer, comfrey is a good detoxifier; you can drink a cupful of comfrey tea two or three times a week.

To aid digestion, it is generally beneficial to drink half a cup of bitter herb tea after a large or cooked meal. Suitable herbs here are centaury, dandelion (not roasted), devil’s claw, and gentian; these also help to restore liver function. With any lung conditions, including lung cancer, have a daily steam inhalation (with a towel

over the head) of hot chamomile tea, possibly with the addition of eucalyptus or tea tree oil or crushed onion.

Maca is a root vegetable from the Peruvian Andes, and I regard it as the best remedy for balancing the endocrine glands and hormone system. It appears to act directly on the hypothalamus and pituitary systems to regulate the thyroid, adrenals, and sex glands. It is often effective with underactive thyroid, as an alternative to hormone replacement therapy and hysterectomy, for age-related decline in the production of sex hormones, and with general lack of energy. An average daily intake is about 10 g, but start with less.

Licorice, too, has some effect on sex hormones but is most useful as a stimulant of adrenal function. With this, it can raise low blood pressure and energy levels and is useful for chronic fatigue syndrome, peptic ulcers, skin inflammations, and HIV/AIDS; it also increases pancreatic secretions. However, it causes retention of sodium and low potassium levels and should not be used with high blood pressure or kidney disease, or during pregnancy. The normal therapeutic range is from 2 - 6g daily.

Anticancer Herbs: Many herbs are useful in cancer treatment, mostly in a supportive role but sometimes as a main therapy. Frequently used are aloe vera (as juice or gel), chaparral, pau d'arco, red clover, and violet leaves. Wormwood and pau d'arco in sufficiently large amounts are especially beneficial by eliminating the fungal forms of the cancer microbe. Vinca rosea, a periwinkle, has an active ingredient that has been used in chemotherapy against leukaemia.

Milk thistle and bitter herbs, such as burdock, greater celandine, centaury, dandelion leaves and root, devil's claw, and gentian, help stimulate the liver and release bile. Celandine or greater celandine inhibits division of cancer cells and stimulates the immune system; an extract for injection is available as Ukrain. Also useful are leaves of the tropical grariola tree, commonly known as soursop.

Root herbs, such as the bitter liver herbs, need to be simmered for about half an hour, while leaves or flowers need to simmer or steep for only five minutes.
For the after-effects of radiation, wild crane's bill (Geranium robertianum) is helpful. With lung cancer use also horehound, lobelia, mullein, and St. John's Wort. Pimpernel is used partly to gargle and partly to drink in spoonful amounts for cancer of the mouth, throat, and neck glands.

Mistletoe is especially good for leukaemia and is often used as the Anthroposophic medicine Iscador or Plenosol for injection near tumours and swollen lymph glands. With prostate cancer, use also saw palmetto and/or willow herb (Epilobium, mainly parviflorum). With leukaemia, especially use herbs to strengthen the immune system.

Licorice root, taken in typical doses of 500 to 1000 mg, is strongly recommended instead of Tamoxifen with all estrogen-related cancers, as it blocks the growth-stimulating properties of estrogen. It also promotes anti-inflammatory adrenal hormones. However, it tends to keep sodium in the body while potassium is expelled. Therefore, minimize sodium and maximize potassium intake by consuming plenty of vegetable juices; do not use licorice root if your blood pressure is dangerously high or with obvious water retention.

You can select a range of these herbs that are suitable for your condition or that are locally available and use them as your special herb mixture. Alternatively or in addition, you can use a commercially available anticancer herb mixture. Best known are the Jason Winter's mixture, Hoxsey herbs, and Ojibway Indian Tea or Essiac (sheep sorrel, burdock root, slippery elm, and rhubarb root).

The Hoxsey mixture must generally be made up individually, but a local herbalist should be able to do it. The exact quantities are kept secret and may vary, but an independent analysis revealed the following quantities in 5 ml of the Hoxsey tonic: potassium iodide (150 mg), Stillingia root (10 mg), burdock root (10 mg), red clover (20 mg), buckthorn bark (20 mg), berberis root (10 mg), pokeroot (10 mg), prickly ash bark (5 mg), liquorice (20 mg), and Cascara amarga (5 mg). Cascara amarga is difficult to obtain, and the mixture can be made without it. It belongs to the buckthorn family and is also known as Honduras bark or Picramnia antidesma. This tonic is sold by the Hoxsey Clinic,16 while individual preparations commonly consist of a dried herb mixture, which is used as a tea.

CAUTION:
Use herbs for cancer treatment only in consultation with a credentialed health practitioner.

Aloe Vera: Aloe vera is excellent for all skin conditions and beneficial in the treatment of cancer, AIDS, and other infectious diseases. It is also good for gastrointestinal irritation, inflammation, and ulcers. However, not all commercial brands of aloe on the market are effective. If nothing seems to be happening with the aloe you're using, try another brand.

Preferably use fresh aloe vera gel straight from the plant, as much as you can take without getting diarrhea. Slice off the green skin and ingest just the gel, but you can also blend a small whole leaf with fruit juice or other flavouring. For wounds, it is usually better to slice part of a leaf in half and leave the skin on top. Normally avoid the base of the leaf with its yellow sap, as this is a strong irritant and laxative. Aloe vera is most beneficial for those with blood group A; for those with other blood groups, check for compatibility or observe effects.

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Step 29
HOMEOPATHY

Homeopathic remedies are effective, and you can even make them yourself.

Homeopathy is a system of medicine based on the principle that “like cures like.” A substance that produces disease-like symptoms in healthy people will in properly diluted and potentized form cure a sick person with similar symptoms. For example, straight onion juice will cause watering, irritated eyes and sneezing, but in the highly diluted and potentized homeopathic form of onion (Allium cepa), it is useful in relieving symptoms of eye and nose irritation, as in hay fever. Clinical trials and the empirical evidence of two centuries of daily use show that homeopathy is effective, even though conventional scientists are at a loss to understand how this is possible.

This is because homeopathy cannot be understood as a substance-based method, such as pharmaceutical medicine or herbalism, in which healing effects appear to be due to chemical actions and reactions. A simple calculation shows that in the higher potencies not a single molecule of the original substance is present. But these high potencies are often more effective than low potencies. Therefore, homeopathy can only be understood as a system that works with energy remedies.

The explanation is that every natural substance has an etheric or subtle energy field around its molecular structure. The special shaking action or potentising used in homeopathy separates the etheric fields from their material substance. The latter is then discarded and the former concentrated. These concentrated etheric fields are much more potent in this way than when they were combined with matter. Similar etheric concentrates can be produced with radionics instruments. The healing effect of such concentrates depends on their vibrational frequency; due to this the term “vibrational medicine” has been coined for these methods.

A homeopathic medicine’s sphere of curative action is originally found by administering it in high doses to healthy human volunteers and recording their emotional, pathological, and physiological reactions to the medicine. This test is called a proving, and hundreds of substances have been proved or tested in this way.

Consequently, homeopathic remedies are effective over the whole range of mental and physical disorders. Most homeopathic medicines are made from plants, minerals, animals, or chemicals; remedies from human disease microbes are called nosodes. Sometimes a product of a disease is used in potentized form for treating the same disease; this method is called isopathy.

Homeopaths may use the classical approach or practice clinical homeopathy. The classical approach is to use only one dose of one remedy at a time and another dose or remedy later only if effects of the previous remedy have worn off. More commonly used, clinical homeopathy prescribes several remedies in combination to be taken several times daily.

Use Your Own Body Fluids: While for general treatment of common symptoms it is more convenient to use established homeopathic remedies, to

overcome obstinate individual problems it is frequently more effective to prepare remedies from your own body fluids. This a form of isopathy known as auto-therapy.

Urine, for example, contains traces of almost all body chemicals, such as enzymes and hormones, as well as foreign and toxic substances and viruses. A properly diluted sample of your urine can initiate the correction of all unbalanced, unnatural body chemistry. This, then, is an excellent way to improve the balance of your glandular system, which is difficult to influence directly by any other method.

Other body fluids that can be used are a drop of diluted blood to treat blood disorders; diluted pus if there is an infected wound or a boil; sputum for mouth and throat disorders; tears for eye problems; faeces for intestinal diseases; ear discharge for ear diseases; and so on. Apart from balancing gland activities and general body chemistry, this method is known to be very effective in stimulating the body's immune system, which is essential in combating cancer and other degenerative diseases.

How to Prepare Your Own Remedies: To prepare remedies from your own body fluids, dilute a small sample of the selected fluid 1:100 with pure water. This means one part sample and 99 parts water, for instance, one teaspoon of sample and 99 teaspoons of water. The water should be purified, that is, distilled or filtered.

Shake the mixture vigorously 40 or 50 times in a sealed bottle or jar, accentuating the downward stroke. Alternatively, strike the mixing bottle (not glass) 40 to 50 times on a resilient surface. This sample is now in the first potency, described as 1C. Take one part of this, dilute it again with 99 parts water, shake as previously, and you have a potency of 2C. This process is repeated until the desired potency is reached.

If dilution proceeds in steps of 1:10 instead of 1:100, the first potency is 1X, the second 2X, and so on. A potency of 12X corresponds in dilution strength to 6C. However, the number of potencies as well as the overall dilution are important for the quality of a remedy. Start using your own diseased body fluids at a potency of 12C. If this does not bring an improvement after some time, experiment with higher and lower potencies. However, use urine in 6X potency and start foods to which you may be allergic at 4X before increasing in steps to 5X and 6X. Important: Use remedies made of your own body products only for yourself, not for anyone else.

To produce your own remedies from herbs, make a "mother tincture" by soaking a fresh or dried sample in high-grade alcohol, vodka, or brandy. After a week or two, dilute part of the mother tincture as previously described, but for the first 1:10 dilution use half alcohol and half water. With this technique, you need to buy a specific commercial tincture only once. If the bottle is almost empty, dilute its contents with either 9 parts or 99 parts water-alcohol mixture and shake for some time.

You might also try a combination of homeopathy and herbalism. Herbs often seem to be more effective when used as low-potency homeo-pathic remedies. In this way any undesirable side effects of concentrated herbs are lessened, while specific healing effects, especially cleansing actions, are greatly strengthened. You can experiment by potentising one part of an unheated herbal extract or tincture with four or nine parts water.

If you use a strong mother tincture of a potent herb, start by taking only one or two drops several times daily; keep them in the mouth for a while, and increase the dose gradually over time. If the extract is weak or of a harmless herb, then take spoonfuls or even a cupful at a time. You can make a watery extract of fresh or dried herbs in a blender, or better, by shaking the powdered or pureed herb in water. Alternatively, you can make a tincture by keeping the herbs covered with alcohol or glycerine in a jar for several days.

If the remedy is to be stored for more than a few days, use a mixture of half vodka or brandy and half water for the last step. This gives the solution an alcohol content of about 30 percent and will prevent the growth of bacteria and fungi. Alternatively, keep the remedy cold, but not in an electric refrigerator as the remedy can lose its effectiveness due to exposure to the strong electromagnetic field of the refrigerator.

How to Take Your Remedies: Take homeopathic remedies with a clean mouth, meaning free of food; the best times are before meals (about 30 minutes) and at bedtime. The usual dose is three to five drops in a little water (about two ounces) sipped slowly over five minutes. Alternatively, you can place three drops in a little water under the tongue. Generally, take one dose four times daily; for chronic conditions, twice daily; for severe or acute conditions, every ten minutes until some improvement is noted, then reduce the frequency. If the patient cannot swallow, moisten the inside of the lips and the tongue with the remedy. Try not to have the remedy come in contact with metal, use a plastic rather than metal spoon, and avoid strongly scented or aromatic drinks and toothpastes, as these may cancel out the remedy.

If a reaction to the remedy is noted (sometimes as a temporary aggravation of symptoms), this is a sign that the correct remedy was selected, but wait until the reaction has subsided before giving the next dose. Any overdose of homeopathic remedies is usually harmless, although in sensitive individuals, there is the risk of proving the remedy—getting the symptoms it is supposed to relieve. Store homeopathic remedies protected from heat and light, as well as away from magnets and strong electromagnetic fields. For best results, you should not change remedies too frequently.

If pellets are used, do not touch them, but shake a tablet into the bottle cap and from there directly into the mouth; keep it under the tongue until it dissolves. Generally, however, it is not recommended to use homeopathic remedies in tablet form (usually as sugar pills) because of the possibility of intolerance to lactose or sucrose. This is accentuated by keeping the tablets in the mouth, which provokes stronger allergic reactions than swallowing them does; however, swallowing is not desirable for homeopathic remedies as they are primarily absorbed in the mouth.

For detailed descriptions of homeopathic remedies and their range of action, see the Pocket Manual of Homeopathic Materia Medica with Repertory by William Boericke.

Which Potency to Use: The most commonly used potencies are 6X, 12X, 12C, 30C, 200C, l000C (M), l00M (CM), 500M (DM), and 1000M (MM). Sometimes the letter C is omitted, and 30 and 200 are used instead of 30C and 200C. In Europe, D is used instead of X. After selecting the correct remedy according to your

symptoms, it is important to choose the correct potency as well. A general rule is that the lower potencies affect mainly physical symptoms while the high potencies work at the mental and emotional energy levels. The high-potency remedies can be used only once a day or once a week or after any reaction has subsided.

For a long-standing problem, you can start using a low-potency remedy, say 12X; after a week or two, use 30C, then 200C, and afterwards M at intervals. If you wish to use potencies closer in strength, try 12X and 30C. You may also be able to find the correct potency by using muscle testing or a pendulum. Draw a half-circle on which the various potencies are marked and see to which one the pendulum points. The M to MM potencies have been used to remove heavy metals from the body either after an acute poisoning or from chronic exposure, as in the case of chronic mercury poisoning from teeth filled with mercury amalgam.

In addition to producing low-potency remedies from allergenic foods, you can also buy M to MM remedies of foods to which you are allergic. If you have had much X-ray treatment, buy and use an X-ray remedy (see www.gdr.org/drrita.html); if you are sensitive to electricity, fluorescent lighting, or house dust, use the corresponding commercial remedy. However, you can also make these remedies yourself: Expose pure water to strong electromagnetic fields or prolonged fluorescent lighting and then potentize it, or potentize the contents of the vacuum cleaner.

Meanwhile, there are commercial remedies for various cancers (for example, bowel, lung, stomach) and for bacilli and other infectious agents; there are also extracts of glands, such as adrenals and thymus, which can be used to normalize glandular functions.

Combinations of remedies are available for the treatment of a wide range of diseases and common complaints. If someone has been bitten by a poisonous snake, spider, or other creature, try to obtain some of the poison by crushing the head of the insect in water or by sucking some of the poison out of the wound; or use some blood from the wound. Make and use a 30C potency. A healing centre might establish a collection of potentized remedies of the common poisonous creatures of the area.

Homeopathic Cell Salts: In the late nineteenth century, the German physician W. H. Schuessler originated a therapeutic system he called biochemic medicine, based on 12 essential cell salts or tissue salts. These are homeopathic preparations of mineral salts usually present in the body and commonly used as 6X tablets. The main drawback of the tablets is that they are based on lactose, to which many individuals are allergic or react to weakly in muscle testing. This weakening factor is accentuated by the common practice of keeping the tablets in the mouth until dissolved.

However, for those who should best avoid lactose, the benefits of cell salts can be obtained by using cell salts as normal homeopathic tinctures.

The 12 Schuessler cell salts and their main indications are:

- Calc. flour: over-relaxed abdominal wall, piles, varicose veins
- Calc. phos.: anemia, poor circulation, cramps, rheumatism
- Calc. sulf.: boils, catarrh, yellow pus, and scabs

Your Own Home-Remedies Kit

The following is a list of 15 basic remedies for home use and as a travel kit.

ACONITE 30C: Controls feverish symptoms that come on suddenly. Any acute condition in the early stages. Aconite is indicated when the patient is frightened and/or worse after dark.

A.G.E. 30C (ARS. IOD., GELSEMIUM, EUPATOR): A combination remedy for colds and influenza. Contains a mineral remedy and two herbal preparations to cover all stages of a cold from early onset to fully developed influenza and lingering final stages that will not clear away. One dose fortnightly will reduce the incidence of simple colds and influenza. This combination remedy is also useful for apprehensive or fearful states. Use also for stomach and bowel upset as well as aching in the bones and headaches that are better after sweating.

ARNICA 30C: This is the remedy for accidents and shock. It reduces the effects of injury, fatigue, and shock, both mental and physical. It is indicated for bruising, broken bones, and blood blisters, also for stroke and heart attack, and in cases where the patient fears being approached or touched.

BELLADONNA 30C: Covers feverish conditions that are more violent than those treated by aconite: red, dry, hot painful head and throat symptoms; also indicated for angry outbursts, and for patients whose condition is aggravated by light, noise, or jarring.

CHAMOMILLA 30C: For children during teething or in cases when the patient is irritable. Suitable for stomach upsets; indicated for children who improve on being carried.

COCCULUS 30C: Useful for nausea, vomiting, travel sickness, morning sickness, stomach upsets, and exhaustion.

HYPERICUM 30C: For injuries to nerves and any injury that is more painful than would be expected. Good for blows to the head and coccyx, crushed fingers and toes, injuries to lips, ears, or genitals; intolerable violent shooting pains along nerves; or lingering pains after injury or surgery.

HYPERICUM/CALENDULA MOTHER TINCTURE (HYPER-CAL): An antiseptic, use topically (five drops in a cup of tepid water) for all external wounds, cuts, and eruptions. This mixture can be used to rinse out the mouth after extraction of teeth. Apply to burns and press a pad soaked in this mixture to injuries requiring bandaging; use one drop in an eyebath of water for eye irritation.

IGNATIA 30C: An herbal stress reliever for the effects of bereavement, grief, tension, worry, and fright. It is suitable for hypochondria and for real illness when the patient is excessively worried about the condition; it promotes sleep when the patient is suffering from sadness or worry.

LEDUM 30C: Used for puncture wounds, cuts, and stings of insects. Follows arnica for bad bruising, especially around the eye; anti-tetanus. Think of ledum for pain of fractures and joints.

NUX VOMICA 3OC: For stomach upsets caused by overeating or indulgence in rich foods, and for the effects of too much alcoholic drink, tobacco, or drugs. Indicated for irritability and bad temper and for sleeplessness when the mind is crowded with thoughts. Useful in cases when the patient is easily chilled and cannot be uncovered. Also for stuffy head colds extending to throat or chest; and sour eructation, sweat, vomit, and bowel movements.

PULSATILLA 30C: For the effects of rich foods, earache from water in the ear, and measles. Useful for the patient who is changeable and weepy, whose pains shift, or who needs open air when the heat of the room or a car is unbearable. Indicated for many children's illnesses when aconite has given limited relief; also for menstrual problems.

RHUS TOX 30C: For simple rheumatism and for strains, sprains, and the effects of overexertion. Useful when the patient has been exposed to cold, wet conditions; also when restless and pains are better if the affected part is kept in motion. Suitable for influenza not covered by A.G.E.

RUTA GRAV 30C: Ruta is the best remedy for twisted ankles and sprained wrists. It is excellent for blows to the muscles and for injuries to the bones and accidents in which the bone sheath is damaged; it brings relief from eyestrain, neuralgia, burning eyes, dim vision, and runny eyes.

URTICA URENS 30C: For burns, rashes, stings, allergies, and any condition in which burning, stinging pains persist. Use for scalds and burns internally when using Hypercal externally. Use urtica for bladder complaints, bedwetting, hives, and swollen, painful breasts and genitals.

- Ferr. phos.: inflammations, low fever, anemia, circulation, wounds
- Kali. mur.: croup, catarrh, and skin diseases with white discharge
- Kali. phos: high fever, paralysis, sepsis, neuralgia, debility
- Kali. sulf.: catarrh, skin diseases with watery discharge
- Mag. phos.: shooting pains, neuralgia, spasms, itching
- Nat. mur.: constipation or diarrhea, cold hands or feet, drowsiness
- Nat. phos.: gout and rheumatism, overacidity, blackheads
- Nat. sulf.: liver and gallbladder diseases, dropsy, migraine
- Silicea: boils, skin ulcers, nasal catarrh, night sweats, gout

They may be used individually or in combination.

Flower Remedies: Flower remedies represent a combination of herbalism and homeo-pathy. Their main therapeutic effects are on the emotional level. Best known are the Bach flower remedies originated in the 1930s by Dr. Edward Bach, an English physician. In recent times, Australian wildflower remedies and Californian flower essences have also become available; these are sold mainly in health food stores and by various practitioners.

Flower remedies are best used together with appropriate affirmations. In clinical situations, it is recommended to use a standard questionnaire to assess a client's emotional problems to allow a more speedy and accurate selection of the appropriate remedies. This information can then be used for other -emotion-directed therapies. Of special significance is the Bach Rescue Remedy, which should be part of every first-aid kit. Individual flower remedies can be combined for treatment according to symptoms. In selecting Bach flower remedies, it is recommended to combine no more than six different remedies at one time; however, the composite Rescue Remedy can be counted as a single remedy.

The usual dosage is two to four drops of the composite preparation in a teaspoonful (plastic) of water at least four times daily, taken before meals and especially as the first and last thing daily. Hold this solution in your mouth and under the tongue for some time; store remedies in a cool place. In some cases, flower remedies can be taken for long periods for the treatment of chronic illnesses, while those for acute (short-term) problems are used only when the problem is noticed. These short-term remedies can be changed frequently, according to changing moods.

While the flower remedies are usually selected according to the problems you wish to overcome, you can also look at what you wish to achieve, how you wish to become.

For this, you can use the opposite to the descriptions given for the various remedies. The keywords for the positive attributes we wish to acquire (the negative aspects we wish to overcome are in parentheses) and some of the flower remedies indicated are as follows:

- Attentiveness (being dreamy): Clematis

Reference Guide for the Selection of Bach Flower Remedies

- Agrimony: suffering or worry hidden by smiling face
- Aspen: apprehension, vague fears of unknown origin
- Beech: intolerance, arrogance, tendency to be overcritical
- Centaury: susceptibility to influence and exploitation, weak will, timidity
- Cerato: lack of confidence, doubt, constant requests for advice
- Cherry Plum: uncontrolled temper, desperation, fear of loss of mind
- Chestnut Bud: slowness to learn, lack of observation, repetition of mistakes
- Chicory: possessiveness, self-love, self-pity, attention seeking
- Clematis: indifference, dreaminess, lack of interest
- Crab Apple: feeling of being unclean, shame, self-dislike; the cleanser
- Elm: occasional feelings of inadequacy, too much responsibility
- Gentian: discouragement, self-doubt, negative attitudes, depression
- Gorse: hopelessness, despair, despondency
- Heather: self-centeredness, love of talking, inability to listen
- Holly: envy, suspicion, revenge, hatred, jealousy
- Honeysuckle: living too much in the past, homesickness
- Hornbeam: mental and physical weariness
- Impatiens: impatience, irritability, mental tension
- Larch: lack of confidence, expectation of failure, feeling of inferiority
- Mimulus: fear of known things, shyness, timidity
- Mustard: deep gloom or depression of unknown cause
- Oak: onward struggle despite despondency/ despair
- Olive: mental and physical exhaustion or weariness
- Pine: self-blame, self-reproach, guilt, false humility
- Red Chestnut: fear and anxiety for others
- Rock Rose: terror, panic, extreme fear
- Rock Water: self-criticism, rigidity, self-denial
- Scleranthus: uncertainty, indecision, hesitation, lack of balance
- Star of Bethlehem: after-effects of shock and trauma
- Sweet Chestnut: extreme anguish, hopeless despair, loss of faith
- Vervain: over-enthusiasm, fanaticism, nervous tension, strain
- Vine: dominance, leadership, craving for power, ambition, inflexibility
- Walnut: helps in changes, link breaking, protects
- Water Violet: aloofness, reserve, pride
- White Chestnut: unwanted persistent thoughts, worry, inner mental arguments
- Wild Oat: dissatisfaction at not having found goal, uncertainty
- Wild Rose: resignation, lack of interest, apathy
- Willow: resentment, bitterness, “not-fair” attitude
- Rescue Remedy (a composite of Cherry Plum, Clematis, Impatiens, Rock Rose, and Star of Bethlehem): use for shock, terror, upsets, fright, accidents; give frequently in all emergencies; apply externally on wounds.

- Certainty (indecision): Scleranthus
- Courage (terror): Rock Rose
- Faith (doubt): Gentian
- Humility (pride): Water Violet
- Patience (impatience): Impatiens
- Peace (torment): Agrimony
- Service (self-love): Chicory
- Strength (weakness): Centaury
- Sympathy (fear): Mimulus
- Understanding (fanaticism): Vervain
- Wisdom (foolishness): Cerato

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Step 30
COLLOIDAL SILVER, COPPER, ZINC & GOLD

Use these powerful remedies whenever you have an infection or inflammation.

In contrast to medical antibiotics that can be used only against specific microbes, colloidal silver has a wide range of effectiveness, eliminating bacteria as well as viruses and fungi. Unlike medical antibiotics, colloidal silver is not known to cause undesirable side effects. Colloidal zinc can be especially effective against viruses. The colloids of copper and gold, on the other hand, are strong anti-inflammatory agents; in addition, copper and zinc can be used chelated (bound) with salicylic acid for similar benefits.

At the start of your health improvement program, you can use colloidal silver to cleanse your body of undesirable microbes. With chronic or acute inflammatory conditions, experiment with copper and gold. Most diseases and painful conditions are associated with inflammations and benefit from anti-inflammatory remedies. A zinc-boron-salicylate complex is known as the Schweitzer Formula (see page 165) and is not only an anti-inflammatory, but it also generally supports and speeds up healing processes.

Colloidal Silver: Colloidal silver has a long history in medicine as a natural antibiotic. It is very effective in killing bacteria, viruses, fungi, parasites, and the cancer microbe, and no serious side effects from overdosing have been reported.

Colloidal silver is commercially available with a common solution strength of five silver atoms per million molecules of water, or 5 ppm, but it may be up to 50 ppm in very concentrated remedies. However, the size of the colloids may be more important than the strength in parts per million.

Colloid particles can have from ten to 5,000 atoms, and each particle is a fighting unit. Therefore, a colloid with the smallest size of particles is 500 times more effective than one with the largest size. Further, large colloids are not stable and easily fall out and settle at the bottom of the container; they are also not well absorbed by the body and not effective against viruses. Therefore, when choosing a commercial product or making your own, always aim for the smallest particle size.

There is no research yet on proper dosage, but it will vary according to concentration and particle size. You can use about one teaspoon three to five times daily; try this with any infectious disease or local infections; continue until symptoms of the infection subside and then continue for a few weeks longer with one teaspoon a day. It is best to keep it in the mouth before swallowing. During the height of the infection, you can double or triple the above amounts for a few days. At the beginning of your health improvement efforts and several times each year, you can take a

CAUTION:
Do not use colloidal gold, silver, copper or zinc if you suspect that you are sensitive to them or if any unfamiliar symptoms arise. If in doubt, seek professional advice.

I recommend using these remedies only for a specific purpose and a limited period, generally not more that a few months at a time.

remedial course of colloidal silver for several weeks to keep down any undesirable microbes that have arisen in your body. Have a sip or tablespoonful three times daily. Preferably, store colloidal silver in a dark glass bottle in a dark and cool place.

It is difficult to assess which of the many commercial remedies available work best or even which ones work and which do not. Therefore I recommend building your own colloidal silver generator (see sidebar).

Colloids of gold, copper, and zinc are being used experimentally with apparently good health results. They all have strong anti-inflammatory properties in addition to varying degrees of antimicrobial effects. Furthermore, zinc and copper colloids can be expected to help overcome any deficiency symptoms or conditions with increased nutrient requirements. Gold, on the other hand, has supposedly beneficial effects on the blood circulation and the glandular system. The medical psychic Edgar Cayce said that gold and silver, properly used, could almost double our present life span. It is not clear what he meant by properly used, but I assume it may involve the safe use of either colloids or vibrational medicines.

If you want to experiment, then you can produce these other colloids in the same way as described for silver colloids; use electrodes of copper, zinc, or gold instead of silver. The easiest way will be to use some gold coins or strips of copper or zinc. No recommendations are available for effective dosages and you will have to experiment, starting with small amounts and going long intervals without any colloids. Use careful self-observation and preferably muscle testing to assess your body reactions; remember you have to take responsibility for these experiments yourself.

How to Make Your Own Colloidal Silver Generator:

Commonly three 9-volt batteries are connected in series (positive to negative pole) and an insulated wire soldered to each end terminal. To each of the other ends of the wires, solder an alligator clip. Use ten inches of pure silver wire, preferably .999 fine, about 14 gauge or 1.64 mm; sterling silver is only .9275 fine. Cut the silver wire in half and attach to the alligator clips.

Immerse the electrodes about four inches deep in a glass of water. Commonly, colloidal silver is made from normal drinking water, often with the addition of a drop of saline solution. A white mist can be seen to develop almost immediately. This is mainly ineffective silver chloride. In this approach, the individual colloidal particles are quite large and not very effective.

A better way is to use distilled water without the addition of any saline drops, as this produces a very fine and much more effective colloid, though it takes a long time to start. A white mist may become visible after about 20 minutes. If you do see this fine mist near one of the electrodes, continue for five minutes longer. If you cannot see a slight mist after 20 minutes, then next time add a small amount of impure water (such as tap water) to speed up the colloid formation. The concentration will be about 5 ppm.

After each use, scrub the oxidized positive electrode until it is shiny. When making or storing the silver water, keep it protected from light, which will otherwise precipitate the silver and make it ineffective. Make your colloidal silver fresh each day or at least once a week.
For more information on making and using colloidal silver, see the website: www.quantumbalancing.com.

Copper - The Inflammation Fighter: Copper is somewhat of a problem mineral. Sometimes there is too much of the inorganic form of copper in drinking water, as is produced by acid water flowing through copper pipes. It can then gradually accumulate in the body and lead to toxicity symptoms with signs of overstimulation, psychosis, and liver damage. However, copper is excellent for reducing inflammations, strengthening connective tissue, restoring hair color, fighting parasites, and preventing cancer. Copper should not be used with existing cancers (except topically for skin cancers), as it promotes the formation of new blood vessels in tumours (angiogenesis).

Copper serum levels are elevated with inflammations and many diseases, apparently because the body mobilizes all tissue stores of copper to fight the condition. If you give animals a choice between drinking normal water and water in which a copper pipe has been immersed, reportedly they will prefer the copper water as this helps keep them free of -parasites.

The most effective anti-inflammatory agents are copper complexes, and commonly these are relatives of salicylic acid which is present in many fruits and vegetables. In addition, copper ascorbate has strong antiviral properties while copper salicylate has a better anti--inflammatory effect than cortisone and without the side effects. It also has good anticancer, anti-tremor, and anticonvulsive properties, suitable for treatment in epilepsy and possibly Parkinson's disease; even certain brain and liver functions can improve with copper salicylate. It has inhibited tumour promotion and malignancy with animal tumors,[17] and with skin tumours a single application resulted in a 55-percent tumour reduction in 20 weeks.[18] Even short-term treatment of rheumatoid arthritis resulted in long-term remissions or improvements.[19]

The therapeutic potency and safety of the copper complexes of aspirin (acetyl-salicylic acid) and salicylic acid are much better than for aspirin itself or for inorganic copper. This means that these copper complexes are safer and more effective than either aspirin or inorganic copper. These complexes are five to eight times more effective than aspirin but less toxic, and their therapeutic index (the margin between effectiveness and toxic effects) has been stated to be significantly greater than for other anti-inflammatory drugs.

While aspirin causes or aggravates peptic ulcers and bleeding, the copper complexes have a better ulcer-healing effect than commonly used anti-inflammatory ulcer drugs. Harmful effects of aspirin and similar drugs apparently arise because they bind copper in the body and cause a localized copper deficiency in the tissues.

Unfortunately, copper salicylate or other effective copper complexes are not normally available or can be had only in very low doses, presumably because they cannot be patented. However, they are relatively easy to make for someone who wants to experiment. Buy salicylic acid at a drug store and dissolve 2 g or about half a teaspoon in a pint of hot water. Use covered glassware and distilled or deionised water with several pieces of copper with a large surface area immersed in it. Keep it warm, between 140º F and 180º F, for about ten hours or sometimes longer. Add more water as required and adjust the final volume to be one pint. When ready, it develops a green color; store the solution in a brown bottle in a cool, dark place.

During storage and sometimes near the end of the heating process, a black copper oxide starts forming and accumulates at the bottom. This is due to copper being converted from the original one-valence copper (I) salicylate to two-valence

copper (II) salicylate; here the salicylic acid binds only half of the dissolved copper and the rest becomes copper oxide. The effectiveness of the solution does not seem to be affected by this and the amount of copper in the complex is not related to its potency. Either decant the solution from any settled copper oxide or filter it through tissue paper.

Copper (I) salicylate is a strong antioxidant excellent for external use in packs or rubs on sites of inflammation, or as rubbed on skin prone to skin cancer. For internal use with generalized inflammations or other indications, 60 mg of copper salicylate has been used in clinical trials, taken once or twice a day and up to four times daily. Try a teaspoonful (approximately 25 mg of copper salicylate) three times daily in liquids with meals, but preferably under professional medical supervision.

For short-term use, you can also double this amount. When it produces the desired effect, cut back to a maintenance dose of one teaspoon a day or interrupt the intake after two weeks to see what happens.

There is a possibility that you may be able to obtain copper (II) salicylate from a supplier of laboratory or fine chemicals. In this case, divide a rounded teaspoonful into 100 equal parts; each part will be approximately 50 mg. However, I want to stress that all this is only experimental and no one but yourself can take any responsibility for what you are doing, so proceed carefully.

For a potent antiviral remedy, you can produce copper ascorbate. The only problem is that ascorbic acid may become oxidized in contact with metal. Therefore, all air must be excluded. Bring some distilled or deionised water to a boil and fill a small glass or hard plastic container (holding about 4 ounces) to the top with this. Immerse a piece of copper in it and add about 2 g or half a teaspoon of ascorbic acid powder. Keep the container tightly closed and immersed in warm water for a day before you start taking a teaspoonful several times a day; keep refrigerated when not in use.

Zinc and the Schweitzer Formula: Zinc has strong anti-inflammatory and antibiotic properties but can become deficient with a high copper intake. Therefore, it is usually best to increase the intake of both minerals together. With a high copper intake, use a high zinc supplementation. This can be in the form of the Schweitzer Formula, a complex formed by zinc (oxide or carbonate), boron (boric acid), and salicylic acid. This is an excellent antibiotic, disinfectant, fungicide, anti-inflammatory, and healing remedy.

The Schweitzer Formula20 was developed in 1915 in Germany and has been sold worldwide since 1920. In addition to treating any kind of infection or inflammation, it has been used in cancer treatment to improve the immune response and blood oxygenation. Applied externally, it helps to heal injuries and skin diseases, including acne, scarring, varicose veins, and varicose ulcers.

You can easily make the Schweitzer Formula yourself. Dissolve 9.2 g of salicylic acid, 2.1 g of boric acid, and 2.7 g of zinc oxide (or 4 g of zinc carbonate) in two quarts of hot water. You can get these ingredients from a pharmacist and have the exact quantities weighed out. However, it is sufficient to use approximate amounts. Use two level teaspoons of salicylic acid and half a teaspoon each of boric acid and zinc oxide or one level teaspoon of zinc carbonate.

Use distilled or deionised water and a non-metallic container. Heat the mixture for about an hour and stir occasionally with a non-metal spoon until no more of the zinc oxide or zinc carbonate at the bottom of the container seems to dissolve. Then decant or filter into a glass container and store in a cool, dark place.

Any surplus of zinc oxide or carbonate that remains undissolved shows that all the boric acid and salicylic acid have been used up. However, any surplus of boric acid would be beneficial and supply you with additional boron. In commercial preparations, the resulting solution is very slowly evaporated to let the active ingredients form crystals; these are then dissolved before use in the appropriate amount of water.

As with copper salicylate, there are no exact guidelines on how much to take. In studies, a tablespoonful has been taken three times daily with liquid or meals for extended periods; for shorter periods, this dose has been doubled. It is also good to rub onto the skin, especially where there are any problems.

You can take a ratio of one tablespoon of Schweitzer Formula to one teaspoon of copper salicylate. For long-term use, I suggest one tablespoon of each daily. I believe that long-term use of copper or zinc should be balanced by taking the other mineral as well, be it as salicylate complex, colloid, or conventional remedy. My experience suggests that copper and zinc as complexes or colloids are safer and more effective than the long-term use of aspirin or other anti-inflammatory drugs.

After a period of use, it is advisable to interrupt using these remedies for a while and observe any effects. Remember, the use of these remedies over long periods is experimental and you must be prepared to take responsibility for any unexpected side effects.

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Step 31
OXYGEN THERAPY

Oxygen, therapeutically applied, helps you quickly overcome any infection.

As an infection fighter, oxygen therapy is mainly used as ozone or hydrogen peroxide. It is beneficial for general health improvement and also for a wide range of diseases, mainly involving infectious agents. Ozone infusions are widely used in German and Mexican cancer clinics but are illegal in the United States, and hydrogen peroxide infusions have been used instead.

Therefore, most cancer victims try to help themselves with hydrogen peroxide or so-called stabilized oxygen. The latter is an unstable oxygenated chlorine compound that easily gives off oxygen. The typical amount used is ten drops in juice several times daily, but start with much less and increase gradually. You can combine taking hydrogen peroxide on rising and at bedtime with taking stabilized oxygen before meals. This is suitable for those who have difficulty digesting much hydrogen peroxide; otherwise, I regard hydrogen peroxide not only as the least expensive, but also the most suitable product for home oxygen therapy.

Another possibility is to use an ozone generator. Generators for medical or internal quality ozone can be expensive. Note that common ozone generators ozonate room air and produce potentially toxic nitrogen oxides; a suitable water ozonator (Beck type) is available for internal use. If ozone comes into contact with water, then it forms hydrogen peroxide. As this formation takes some time (about 20 minutes for all the ozone dissolved in water to be converted to hydrogen peroxide), you get a mixture of both if you drink it immediately after finishing the process.

Ozone reportedly has the advantage of releasing active oxygen without requiring enzymes in biological systems, as is required for hydrogen peroxide. Both ozone and hydrogen peroxide have an unstable single oxygen molecule that tends to attach to and oxidize or peroxidise any suitable molecule. The beneficial effect appears to be mainly the peroxidation of unsaturated fatty acids, which can then destroy microbes and malignant cells, provided these are not protected by accumulated vitamin E. A healthy immune system routinely produces hydrogen peroxide to kill microbes. Therefore, I see no advantage in using ozone at home and would rather use the simpler hydrogen peroxide.

Unheated honey has traditionally been used to treat infected wounds and chronic skin or leg ulcers. Recent research showed that the most effective honey for medicinal purposes is honey that is very high in hydrogen peroxide. Therefore, you can mix a few drops of 35-percent hydrogen peroxide with honey to improve its healing qualities. For topical packs, it is more convenient to use crystallized honey rather than honey that is runny.

Preferably, use 35-percent food-grade hydrogen peroxide, available from some natural therapists and health stores. Otherwise, use any other 35-percent product or the three-percent (ten volume) or six-percent (20 volume) peroxide from a supermarket or pharmacy. It is best to dilute the peroxide for daily use to about three

percent; add one part of the 35-percent peroxide to ten parts of water. Start taking a few drops in a glass of water, then gradually increase to one teaspoon or more four times daily, before meals and at bedtime. If you develop an aversion to it, decrease the dose again to a more comfortable level. Swallow quickly instead of sipping slowly. To disguise the strong aftertaste, add to the mixture aloe vera gel, fruit flavours, herb tea, or water flavoured with cinnamon.

You can continue this program for many months, and when the specific health problem is under control, gradually reduce the intake to only once daily before breakfast. In addition, you can use hydrogen peroxide to rinse your mouth and gargle morning and evening. It helps to prevent colds, infections, and tooth decay, and it is arguably better than toothpaste. You can also use 35-percent hydrogen peroxide with a dropper; a teaspoon of three-percent peroxide is equivalent to about 12 drops of 35-percent peroxide. Be careful handling 35-percent hydrogen peroxide; in the event of accidental spills on clothes or skin, flush immediately with water or immerse in water.

It is helpful to bathe the site of an infection or external tumour daily in three-percent hydrogen peroxide or, better, cover it with a cloth soaked in it. This is especially good for problems close to the skin, and the hydrogen peroxide is preferably combined with a honey pack. Renew the pack several times daily. A pack can remain on the skin for most of the time or until the skin becomes red or sore and blisters. This will be good, as it draws out toxins. When this happens, cover the skin with a cabbage leaf instead and wash only with peroxide. You can also have a daily body rub with three-percent hydrogen peroxide, which is best done after a bath or shower. With cervical cancer or bowel cancer, douche the cervix or the bowel twice daily with suitably diluted hydrogen peroxide, retaining it inside for some time.

In the case of cancer it is advisable to use the practice of oxidative tumour destruction only initially and with a minimum of antioxidants. Activated oxygen oxidizes and peroxidizes reactive biomolecules, especially alpha- and gamma-linolenic acids in linseed (flaxseed), evening primrose, and borage oils; these in turn oxidize and destroy cancer cells. However, as mentioned, this killing effect may be inhibited by high levels of antioxidants, especially vitamins E and A, which, paradoxically, accumulate in tumours and protect them. Therefore, avoid vitamin E and high doses of vitamin A for one or two weeks before your oxygen therapy and minimize your intake of all antioxidants during the several weeks of intensive oxygen therapy. Afterwards, return to a long-term intake of high amounts of antioxidants and anti-inflammatory remedies (see step 46).

Magnesium peroxide has become available as a powder, in capsules, or as a branded product called Oxy-Mag, a powdered magnesium ozonite. The peroxide produces highly reactive oxygen radicals that are more aggressive than the oxygen molecules released by the ozonite, but I cannot say at present if either one of these is more effective. Use according to instructions on the container or enclosed literature. Sometimes simple magnesium oxide is recommended to oxidize the colon; while it may be good as a mild laxative, it does not liberate oxygen for oxygen therapy.

Of great benefit are peroxide retention enemas. After a normal enema to clean the bowels, insert into the colon a pint of water containing a teaspoon of salt and one

tablespoon of three-percent hydrogen peroxide; try to hold it inside the large intestine for ten minutes or longer. The next day add two tablespoons to this mixture; continue increasing the amount of peroxide on subsequent days until you find the highest concentration that you can hold for about ten minutes. You can also try to increase the volume of water that you can retain.

If you have an ozone maker, you can use ozone in a similar way as hydrogen peroxide. You can lead it with a tube into water to produce hydrogen peroxide; insert the tube into the rectum (with another shorter tube as outlet); irradiate the skin over the diseased areas with a funnel; or put the body (but not the head) into a bag into which you introduce ozone. For information on how to obtain, construct and use a medical-grade ozone generator that does not oxidize nitrogen, see: www.quantumbalancing.com. For more information on oxygen therapies, see: www.oxytherapy.com or the books Oxygen Therapies and Flood Your Body with Oxygen, by Ed McCabe.

New Ways of Using Hydrogen Peroxide: In 1928, Dr. Richard Simmons believed to have discovered that colds and flu enter through the ear canal and start the infection process in the middle ear. More recently, it has been claimed that colds and flu can be cured within hours by putting hydrogen peroxide into the ears at the first indication of any infection. You first put a few drops of three-percent hydrogen peroxide in one ear, and when the bubbling stops, do the same in the other ear. Repeat this a few times at about two-hour intervals. In addition, gargle frequently with hydrogen peroxide for infections in the head and chest area.

My understanding is that the cold virus enters through the nose but then multiplies in mucus accumulated in the head spaces before the outbreak of symptoms. For this reason, colds can be stopped by introducing hydrogen peroxide into head spaces, but also simply by removing the mucus congestions.

A three-percent hydrogen peroxide solution can be sprayed directly into the throat several times a day and inhaled deeply into the lungs with good results. Besides breathing problems and aching muscles, this has also reportedly relieved other old-age symptoms. I assume that beneficial results with this method are largely due to the elimination of fungi and other microbes in the breathing passages.

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Part 4
HEALING FOODS

Nutrition is the main tool I have used to help patients overcome a wide range of diseases claimed to be medically incurable. Unnatural nutrition is one of the major causes of most of our diseases, while natural nutrition is an equally powerful agent in helping to undo these diseases and rejuvenate the body. My training and work experience as research chemist, biochemist, toxicologist, practicing nutritionist, and natural therapist have given me insight that would not have been possible if I had worked only as a conventional scientist or natural therapist. One of these insights is the importance of nutrition.

There is presently a trend in conventional medicine to acknowledge the importance of nutrition in causing and treating diseases. Health authorities conduct public awareness campaigns about nutrition through the mass media. While this newly found official interest is itself a positive development, the information conveyed is not likely to reduce the overall rate of chronic diseases.21 The information I present has grown out of practical experience in the prevention and reversal of most of our chronic and medically incurable diseases, and it is likely to be more useful.

Most of our commonly eaten foods contribute to our gradual health deterioration and the development of many chronic diseases. This is a main reason why there is such a high incidence of chronic degenerative disease in our society. I will explain in detail why and how our everyday problem foods help cause our diseases and how potent healthy foods can be used to undo these diseases and rejuvenate our body.

Depending on your health goals and present health problems, you can either make some gradual adjustment to your present diet or go all the way and experiment with powerful health diets designed to reverse incurable diseases and rejuvenate body and mind. The reward in terms of improved health is generally proportional to your effort.

Diet rules are designed to guide us towards healthier eating habits. There are different schools of nutrition, which do not always agree on the same principles and sometimes even contradict each other. The diet “rules” I present are based on the principles of the nineteenth-century Nature Cure movement, but modified according to the findings of modern nutrition research and my clinical experiences in overcoming diseases.

For the successful elimination of diseases, I have found that the less ideal the patient’s overall diet is, the more specific the remedies, supplements, or other therapies need to be. Conversely, on an ideal diet, specific interventions can be kept to a minimum. I have also observed that the differences in nutritional requirements between individuals begin to disappear when an ideal natural diet is adopted.

Changing our diet to an ideal natural one requires a considerable shift in eating habits and a re-education of our taste buds. It often also requires more time for food preparation. For most of us this is not easy. While some take to it enthusiastically,

others need to be driven by the hope of overcoming a debilitating disease; most people are content to make minor dietary adjustments or gradual improvements as a preventive measure or to overcome an existing health problem. Therefore, I use a graded approach, with a high-quality diet for gradual health improvement and maintenance of good health and a raw food diet for maximum healing, rejuvenation, and maintenance of optimal health into old age.

I present each diet in its pure form. Most individuals probably will not be able to adopt fully one or another diet, but will move gradually towards their dietary goal in months or even years. You can modify the diet according to your special requirements, and for this, see the section on Metabolic Types and Blood Groups (Step 43) in Part 5. Ultimately, it is best to learn to trust your body to tell you what it needs.

If you are not addicted to a certain food but crave it, then it is probably good for you. The natural function of our taste buds is to guide us in the choice and quantity of our food intake. As a general rule, food that is good for us tastes good, but if we have enough of it, then it does not taste as good toward the end of the meal. If we overeat, then it may not taste good for several days or weeks. If we had too much heavy or spicy food, then fruits will taste attractive, but if we had too much fruit, then a spicy protein-fat meal suddenly tastes good.

If we eat food that the body has difficulty in handling, then it causes a stress reaction with the release of adrenal-stimulating hormones. For individuals with weak adrenal glands, this acts as a stimulation of their body functions, and they become addicted to this food as well as other stimulants. Now the taste buds are no longer a reliable guide, as other body needs are sacrificed to satisfy this need for adrenal stimulation.

As some foods frequently cause health problems - “problem” foods - so other foods generally improve our health - “health” foods. The foods with the greatest potential for healing and rejuvenation, according to my experience, are bee pollen, sprouted seeds, purple foods, freshly pressed juices of vegetables (especially of young grasses), and lactic-acid fermented foods. These form the base of my recommended diets and will be explained in this chapter.

We need to realize that we can choose to a considerable degree how healthy we will be and how long we want to live in good health or, alternatively, which diseases we are willing to accept for the comfort of satisfying our present taste preferences and maintaining potentially harmful living habits. Of course, other factors have a strong influence as well, such as our mental and emotional condition, the environment, and how we use our body (these are covered in later parts).

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Step 32
GENERAL DIETARY RULES

Understand the principles of healthy food selection, preparation, and combination.

In a nutshell, the most important dietary rule is, as much as possible, to eat your food when it's whole, alive, organic, and free of added chemicals. Other important rules are to chew it well, enjoy what you eat, combine the foods correctly, and deliberately under-eat rather than overeat.

Whole food means that there has been as little refining of it as possible. To give an example, natural whole grain brown rice is the preferred whole food. White rice has the bran and germ removed, together with most of its vitamins and minerals. The level of vitamin B1, for instance, is about 450 percent higher in brown rice than in white rice. This means that the body may not use the deficient food efficiently, and this can lead to overweight or underweight conditions and to poor blood sugar regulation; the lack of fibre in refined rice also contributes to constipation. In varying degrees, the effect of refining also applies to other commonly eaten foods.

Over thousands of years, our metabolic and enzyme structures have evolved based on whole foods and have relied on certain combinations of ingredients being supplied together. Protective or synergistic (cooperative) factors are present in whole foods. For example, vitamin C is much better absorbed and retained if taken together with bioflavonoids. Both nutrients naturally occur in the same foods. The sensitive polyunsaturated oils are protected from oxidation and structural damage as long as they remain in the whole seed. They also occur naturally with protective vitamin E. When extracted and refined, these oils are partly oxidized and harmful trans-fatty acids are formed.

Carnivorous animals do not eat just the meat but also the bones. They would quickly become mineral deficient and diseased if they did not eat the bones. The same applies to us if we eat only flesh high in phosphorus or low-mineral-content food. We then need to use mineral supplements or become deficient and prone to diseases. As relates to root vegetables, whole means using the vitamin- and mineral-rich outer parts, usually discarded as peel, as well as the inner parts, and even the cooking water. Pouring out the cooking water pours vitamins and minerals down the drain.

A story, presumably true, has been published about the crew of one of the early submarines. After a long crossing, they were fatigued and disease-prone; they had lived on tinned and dried foods. The health authorities were at a loss about the cause as there had been sufficient amounts of the known vitamins in the foods. A Nature Cure practitioner offered his advice, which, when taken, quickly corrected the problem. He told them to peel a lot of potatoes, discard the potatoes, and cook the peels; strain, discard the peels, and drink the broth. How many of us do it the other way around?

There is a downside to this with some whole foods and seeds. Seeds contain reactive proteins, called lectins, which are mainly in the outer hull or bran; individuals

with certain blood types tend to react to specific lectins. Other food allergies develop mainly to the outer parts of seeds removed in refining. If seeds are not sprouted or fermented, then minerals tend to remain bound by chemicals in these outer parts and cannot be absorbed. Therefore, if you have a sensitive digestion and eat food that is not suited for you, then, ironically, refined foods will tend to cause you less immediate problems than whole foods.

Live and Organic Foods: Live food is basically the same as raw or uncooked food. Live means that the food is still high in vitality and naturally occurring enzymes. These are damaged when food is heated above 104° F and destroyed above 120° F. While milk can be heated initially in making yogurt, adding lactic-acid bacteria to it provides a new complement of enzymes to revive the food, although I prefer to make yogurt from unheated milk.

Food has different stages of “aliveness” or vitality. A dry viable seed is alive but dormant, the enzymes inactivated by inhibitors. During soaking and sprouting, the seed awakens to full life with an abundance of enzyme activity. Like an embryo, it is at the height of its vital and restorative functions.

A young, growing leaf or plant still has a high level of growth hormones and enzyme activity, but in a mature plant or fully grown leaf there is little growth hormone and reduced enzyme activity. Whole grain flour that has not been unduly heated during milling has some residual life, but inhibitors block the enzymes; enzyme activity will be enhanced and starch pre-digested when the wheat is made into sourdough. There is a saying in naturopathy: “Eat food that easily spoils, but eat it before it spoils.”

The term organic is generally understood to mean that such food also has not been irradiated and is free of genetically engineered components and any added chemicals that are normally used during growing, storing, or processing. Organically grown food means that it is certifiably free of toxic agricultural chemicals and has been grown in healthy soil without the use of water-soluble fertilizers. Very harmful are nitrogen fertilizers, especially nitrates. In one scientific experiment, hens were fed blueberries that were either unfertilized or fertilized with nitrate. Hens fed large amounts of nitrate-fertilized berries died within three days; those that received only small amounts of fertilized berries laid eggs with defective missing shells. Hens fed unfertilized berries in any quantity maintained normal health and eggs. What will a low-dose long-term intake of such fertilized foods do to us?

It is well known to organic growers that their plants and the animals fed these plants are much more resistant to pests and diseases than chemically fertilized plants and the animals fed them. It has been shown that cattle on an organic farm remained disease-free while cattle on surrounding properties were badly affected with foot-and-mouth disease. Most damaging are pesticide residues on foods or the interaction between different chemicals. Many natural therapists contend that organically grown food is an important part in the successful treatment of degenerative diseases.

Cooking Foods: Food ideally suited for human nutrition does not require cooking, such as sprouted seeds and fresh shoots, ripening seeds (sweet corn, green peas), oily seeds and nuts, sweet root vegetables, and fruits. Cooking

damages many proteins; they coagulate and harden and their complement of digestive enzymes is destroyed, and this makes them more difficult to digest.

However, cooking also makes some foods more easily digestible by breaking down the cellulose in plant food and connective tissue in meat. This enables our digestive juices to get more easily to the nutrients and is especially important for people with weak digestive organs. Further advantages of cooking are the preservation of food, easier chewing, and enhanced flavours. All this means that cooked food generally is more convenient and tastes better, and for most of us that is more important than any long-term health concerns.

In this chapter I show how harmful effects of cooking can be minimized by combining the least damaging use of cooking with the more acceptable forms of raw foods consumption.

Steaming is the recommended method of cooking. Add sufficient water to cover the bottom of the pot, even without special steaming equipment. This way most of the vegetables will be steamed, and if you use the remaining water, nothing will be lost. By adding vegetables after the water has started to boil fewer vitamins are destroyed. However, I do not see a problem with simmering vegetables submersed in water as long as you also ingest this water, preferably soon after cooking.

Pressure cookers are acceptable, their main disadvantage being that they are usually made of aluminium. Microwave ovens are suspected of emitting harmful radiation while in use. In addition, they may contribute to health deterioration by scrambling the delicate structures of sensitive food molecules in unnatural ways. Therefore, avoid or minimize microwaved food. It is also safer to discard any outer part of meat or fish after grilling or broiling.

When cooking grains or legumes, always soak the seeds overnight beforehand and discard the soaking water. In this way, you will likely ingest fewer potentially harmful anti-nutrients, such as phytates which make minerals unavailable, protease inhibitors that interfere with the digestion of proteins, or lectins that cause unpleasant symptoms with some blood types. If beans cause wind, change the water once or twice during cooking.

As mentioned, the main disadvantage of all cooking is that it destroys food enzymes and some vitamins. This significantly contributes to more rapid aging and the development of degenerative diseases if the diet consists predominantly of cooked food. Therefore, try to eat only a minimum of cooked food. Most harmed by cooking are animal products and polyunsaturated oils; least harmed are starches. Eat your food, especially vegetables, as soon as possible after a short cooking time; try to minimize steam or fumes escaping from cooking food. Except for baked grains, avoid food leftover from a previous meal.

A large amount of aluminium dissolves in the water during cooking in aluminium cookware; the more acid the cooking water, the more this happens. This is also a problem with stainless steel pots. While steel is more resistant to acids, it can still release harmful amounts of nickel, and nickel is implicated in weakening the immune system and promoting cancer. Enamel cookware is generally safe, except that low-cost Asian imports reportedly may contain high levels of lead; this is also a problem with ceramic pots. Glass cookware is the safest.

Here are some important cooking rules:

- Avoid baking soda in cooking or baking as it destroys B-vitamins
- Add salt or minerals after cooking to preserve vitamins.
- Save and use the cooking water; it is rich in minerals.
- Cook for the shortest time possible.
- Do not keep food warm for extended periods; cool quickly for storage.
- Avoid aluminium and stainless steel cooking utensils; use enamel or glassware instead.
- Do not leave acid food in contact with metal surfaces.
- Do not cook what can conveniently be eaten raw.
- Do not fry or heat oils or fats.
- Do not cook with a microwave.

Chewing and Enjoying the Meal: Good chewing is of vital importance. It is necessary to break down food particles to a fine pulp and at the same time to insalivate them sufficiently for proper enzyme activity. Trace elements and vitamins are already partly absorbed through the mouth tissue, while the stomach needs adequate advance warning of the expected composition and quantity of the food. So, even if the food is already a liquid (soups, broth), chewing is important. Keep and move around such liquid food in the mouth for several seconds. Solid food needs chewing until it is thoroughly liquefied. Teach your children early in their life to chew thoroughly; possibly check their stools to see if they contain large pieces and whole seeds, a sign of inadequate chewing.

You should not only chew thoroughly, but also eat slowly and in a leisurely fashion. This improves digestion and helps prevent overeating. A certain amount of time is needed for the body to form the message that it has had enough. Therefore, if you stuff yourself within a short period, your body has no time to prevent you from overeating. Overeating can also occur if you do not pay attention to the eating itself but to a conversation, to a book, or the television. Then you cannot “hear” when your body says “enough.”

It is also important to have a peaceful mind at mealtime. Before the meal, completely relax for a minute or more with eyes closed; if able to meditate, raise your awareness to a joyful meditative state. During the meal, pay attention to the process of chewing and enjoy the various flavours as they develop.

It is beneficial to enjoy what you eat. Unpalatable food is not well digested. Neither is it good to continue eating poor food just because one has acquired a preference for it. For many, this is the most difficult problem to overcome during health improvement. The goal is to acquire a liking for what is nutritionally good.

There is no doubt that taste buds are adaptable and can be re-educated, but this comes gradually, so introduce unfamiliar foods and supplements to your diet in very small amounts only, interspersed with familiar foods. Be imaginative and experiment with new ways to prepare food. Do not eat if you are not hungry, if you

are agitated or emotionally upset, if you are unwell with a fever or comparable condition, or if you are still full from the previous meal. Always prepare food lovingly.

Food Combining: Many years of experience with patients have shown me the importance of correct food combining. The fundamental biochemical considerations with regard to food combining are as follows:

- Typical protein foods (usually containing oil or fat) require strongly acidic gastric juices.
- Different types of protein foods may need differently composed gastric juices for digestion.
- Starches need B vitamins, chlorides, calcium, and magnesium for enzyme activation.
- Sweeteners or sugars as well as acids inhibit the digestion of starches.

Disregarding these facts by mixing foods indiscriminately may contribute to infections and degenerative diseases, especially allergies, arthritis, cancer, and autoimmune diseases.

Initially, most people have a reasonably strong digestive system and do not feel any ill effects, no matter what they eat or combine. This is also true if bodily responses have become dulled by being ignored for many years. However, sooner or later, the unpleasant effects and degenerative symptoms will appear.

There are three main groups of food to consider when working out correct food combinations:

1. Proteins, sweet and acid foods, sweet vegetables, fruits
2. Neutral foods such as fats and oils, non-sweet vegetables, avocados, olives, and cream cheese
3. Starches such as cereals, potatoes, and dry legumes

The neutral foods can be combined with either one of the other groups while the two extreme groups (numbers 1 and 3) should be kept apart. Observing this simple rule may prevent the more serious consequences of incorrect food combining.

In poor health and during a health improvement program, however, it is advisable to be even more careful. With few exceptions, most foods are best digested as a moderated mono-diet, which means only closely related foods are eaten together, for example, different kinds of grains. With severe digestive problems, one can temporarily adopt a strict mono-diet, eating one kind of food only at a meal, and observe its effects.

The next best possibility is to eat foods correctly combined, but still separated during the meal. This is most important with meat, fish, or nuts. These are best eaten at the beginning of the meal for proteins to receive the strong gastric juices in the pit of the stomach. The rest of the meal, if not too liquid, will remain in distinct layers on top of this. Remember this if you have proteins and starches in the same meal.

You can mix a small amount of flavouring vegetables with meat or fish, or eat a fruit together with some nuts. Generally it is preferable to have either some fresh vegetable juice or a small amount of raw vegetables before a cooked meal.

For those with a sluggish metabolism, a small amount of sweet food or fruits as dessert after a protein meal will provide energy for the digestion of slow-burning, protein-fat combinations. This is not advisable after a starch meal or for those with blood sugar problems. Glucose and maltose (as in barley sugar) do not contain fructose and therefore cause less of a problem if combined with starches. If your digestion is sluggish, a small amount of fruit acids, such as lemon juice sprinkled over meat or fish, or ascorbic acid with or after protein meals can be beneficial, as can half a cup of a bitter herb tea afterwards. Cooked subacid fruit that is low in fructose, such as apples, does not react in the same way as sweet fruit that is high in fructose. Therefore, most individuals will be fine using this as a flavouring with cereals or starches, for example, apple puree with rice.

Some factors that make precision food combining less necessary are: a strong digestive system; being physically active; chewing extremely well; and only eating small meals. The opposite factors will, of course, increase the need for correct food combining. Being able to eat just about anything, however, is not a guarantee of strong digestive powers; your system may be too weak to react to the foods. If you are in good health, you can forget about food combining and omit just one group of foods from a mixed meal - the cooked starches; most others combine reasonably well with each other. However, it is generally acceptable to eat starches at the end of a meal, separated from the protein part by a vegetable or sprout salad or by some cooked vegetables. If you are sensitive, then this middle part of the meal can consist of neutral vegetables rather than sweet ones.

Food yeast with a 50 percent protein content and also the non-oily legumes are grouped with the starches because their fat-free proteins are relatively easy to digest and require only slight acidity. For a graphic illustration of the basic food-combining rules, see Figure 4-1. Foods are classified as hard proteins, soft proteins, or starches according to the amount of gastric acid and pepsin that is needed for their digestion. The actual percentage of protein in a food is less important in this respect than the amount of fat, oil, and fibre surrounding the protein.

Meat, nuts, and cooked soybeans, for instance, are difficult to break down. They need the full strength of gastric acid and pepsin and, therefore, are called “hard proteins.” Eggs, uncooked dairy proteins, broth of meat and fish, fermented soy products, soy milk, and fine nut butters, on the other hand, need less acidity and can be called “soft proteins.” Proteins in processed cheese, in cow’s milk used as a drink, but especially in milk added to coffee or tea, are very difficult to digest and thus become hard proteins. Non-fatty fish, especially if marinated, is easy to digest and is almost a soft protein, while fatty fish is closer to meat in its gastric requirements.

Intestinal Fermentation: Combining food high in fibre with sweet food is likely to cause intestinal gas. This perception gave rise to the frequently quoted rule not to combine vegetables with fruit. In this case some of the sugar from the fruit may not be absorbed and then may overstimulate bacterial activity in the large intestine, causing excessive wind, flatulence, or bloating. Some intestinal fermentation is desirable in order to keep our beneficial bacteria happy, and this is best produced with a moderate amount of fibre in the diet. It breaks down at a slow rate and greatly helps to maintain regular soft bowel motion.

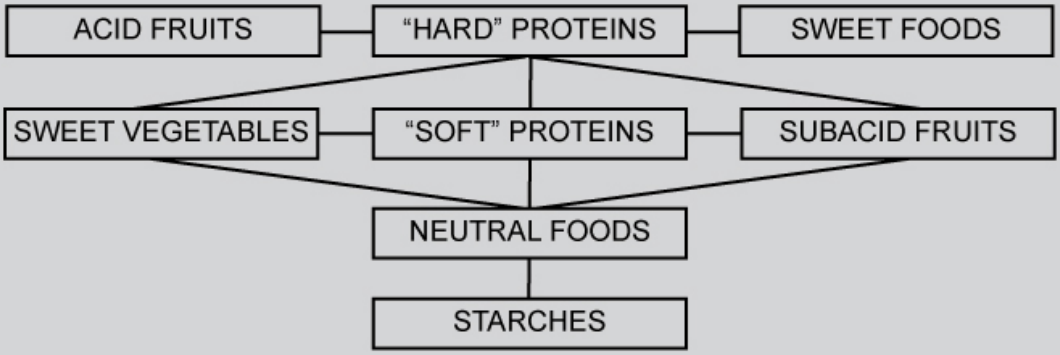

Fig. 4-1: Food Combining Chart.

Direct connections between groups indicate good combinations (e.g. starches & neutral foods). Connections between groups with one interception are fair (e.g. starches & sub-acid fruits). Connections groups with two interceptions are poor (e.g. starches & sweet foods).

FOOD GROUPS

"Hard" proteins: meat, fish, nuts, oily seeds, soybeans.

"Soft" proteins: eggs, milk proteins, meat/fish broth, tofu, soy milk, nut butters, fermented soy or nuts.

Acid fruit: lemon, grapefruit, pineapple, acid berries.

Sub-acid fruits: apricots, peaches, pears, bananas, cooked apples.

Sweet food: sweeteners, foods with added sugar, molasses, honey, dried fruits, oranges, figs and other sweet fruits and berries, juices of sweet vegetables.

Sweet vegetables: sweet potatoes, pumpkin, onion, carrot, turnip, beetroot, tomatoes, green peas.

Neutral foods: fats and oils, non-sweet vegetables (mainly greens), sprouted seeds, avocados, olives.

Starches: grain products, potatoes, dry legumes, food yeast, sago and taro.

Trouble brews if we ingest a large amount of sugar in any form. This is like adding gasoline to a slow, controlled burn-off of bush land that then gets out of control and becomes a raging wildfire. It is very similar in our intestines. Fibre remains in the large intestine for a long time, so excessive fermentation can happen if we have sweet food several hours after a raw salad. How much sweetness we can tolerate with fibre is individualized. The more efficiently we absorb our food, the larger the amount of sweetness we can handle without getting into digestive trouble.

For individuals with a weak sugar metabolism, it is not good to have much sweetness on an empty stomach, as that drives the blood sugar level too high, followed by symptoms of hypoglycaemia. In this case it is best to completely separate food high in fibre from sweet food and have the fibre meal after the sweet meal.

Therefore, breakfast is safest as a moderately sweet meal, for instance, by flavouring cooked rice or sago with banana or apple puree. The evening meal is then

safe as a fibre meal, such as combining potatoes and other cooked non-sweet vegetables with a vegetable salad. Lunch can be a protein food with sweet vegetables such as pumpkin.

It may also be acceptable to have a piece of fruit or a fresh juice of sweet vegetables (e.g., carrots) some time before a meal that also has a vegetable salad or other high-fibre food at the end. Fresh juice does not have much indigestible fibre, so there should be no fermentation problem in combining vegetable and fruit in the same juice. However, if fruit high in fructose is combined with vegetables, then the juice is high in glucose as well as fructose and can cause a strong insulin response and hypoglycaemia in susceptible individuals.

The main rule in all this is to have the fast-digesting food first and the slow-digesting fibre afterwards. Experiment to see how strictly you have to apply this rule to avoid intestinal distress.

When eating cooked beans, you may encounter a similar fermentation problem. Beans do not need any added sugar to start a strong fermentation. They are high in long chains of carbohydrates (oligosaccharides) that are not absorbed in the small intestine, but are easily broken down by the bacteria in the large intestine. To avoid problems with beans, these can be sprouted or fermented before eating or the water in which they have been cooked can be renewed and discarded several times.

Planning Meals: Our digestive powers are strongest in the morning and weakest in the evening. Therefore, it is advisable to eat difficult foods such as meat, nuts, sweet food, and large vegetable salads during the daytime and have a light, early evening meal. This will also improve your sleep, while a heavy, late dinner often results in a restless or “drugged” sleep, with a feeling of tiredness in the morning.

If you are not normally hungry in the morning, just omit the evening meal for several nights and have 30 minutes of vigorous physical activity before breakfast. If you do not need to leave home for work, you can also spend an hour in the garden or engage in other outdoor activity before breakfast. Together with the time required to drink your juice, herb tea, or water, it will be one to two hours before you finally sit down for breakfast. It is definitely not advisable, especially with a sluggish digestion, to eat a heavy breakfast without sufficient stimulation to your circulation beforehand.

With a sluggish thyroid and weak adrenal glands, of course, it is more difficult to get going in the morning, but it is not too hard if you are determined to make the effort. Immediately after awakening, start with some positive autosuggestion. Then mentally look forward to something that you would like to do during the day. If necessary, promise yourself a treat. Lack of enthusiasm can be a main factor in suppressing your metabolic rate. Therefore, try to become enthusiastic about something - anything!

Do some deep breathing, stretching, and muscle-tensing while still in bed. Then jump out and immediately start some lively activity such as circling the arms or gently pummelling the body all over. Also stimulating are arousing music, skin brushing with rapid strokes, and cold-water applications.

Do not rush your breakfast. For many people, it is the most important meal of the day. Make it a habit to rise sufficiently early so that you have at least two hours

before needing to leave the house. You can also divide the food and use a portion of your breakfast as a mid-morning snack.

A certain amount of food eaten in the morning can produce weight loss, while the same food in the evening is more likely to convert to body fat and cause weight gain. Therefore, if you want to keep your weight down, eat all your high-calorie food during the day and have only some non-starchy vegetables or a few apples in the evening. If you want to gain weight, on the other hand, then have a starch meal in the evening. There will be some, however, for whom these recommendations are not suited; you must find out under which conditions you feel best and can cope most efficiently with your daily activities.

Carbohydrates cause a greater weight gain than a protein-fat diet of equal calories. Also, the higher the amount of roughage (for example, rice bran, linseed meal, raw vegetables), the greater is the weight loss on any slimming diet. These factors should be taken into account in your meal planning.

It is desirable to have about 30 minutes of rest or light, relaxing activity after a meal before starting more heavy manual work or a more stressful activity. I agree with the advice of Edgar Cayce: “After breakfast work a while, after lunch rest some time, and after dinner walk a mile.” Try to fit in at least 15 minutes of rest in the horizontal position after lunch; relax, or try to meditate or contemplate. If you are in poor health, a sleep after lunch is highly desirable. If you wake up tired from this, next time give yourself positive autosuggestions before falling asleep. Even after breakfast, you should not immediately start rushing around. Some kind of steady physical activity, such as walking or gardening, is advisable after the meal. But what is harmful is stress - the feeling of being late for school or at the office - so avoid that.

Food Balancing: The concept of food balancing arises from the fact that the various food groups have different effects on our metabolism and hormonal and nervous systems, as well as on our emotions. Food balancing is different from what is described as eating balanced meals - proteins, carbohydrates, and fats - as recommended by conventional dieticians. To give some examples: Meat stimulates the adrenal glands and the sympathetic nervous system, thus increasing tension and readiness for action. Fruits have the opposite effect. They stimulate the release of insulin, which counteracts the effect of adrenal hormones. While vegetables, especially those high in chlorophyll, make us more relaxed, fruits make us physically, emotionally, and psychically more sensitive.

Both fruits and vegetables increase our intuition. Meat, on the other hand, makes us more insensitive and possibly materialistic, and less emotional and intuitive. Red meat especially has a strong “grounding” effect and is therefore balancing for those who are

Between meat on one end of the scale and fruits on the other, we can arrange our basic foods in the following order according to their sensitizing effect on body and emotions:

red meat
fowl and fish
eggs & dairy products
oily seeds
legumes
grains
green vegetables
sweet vegetables
sub-acid fruit
berries, sweet & acid fruit

oversensitive, overemotional, and open to negative psychic or occult influences. It is, however, unsuitable for those who are already too tense or insensitive either physically or emotionally or who are aggressive or overly materialistic.

Acid and acid-sweet fruits have the strongest sensitizing effect, while subacid fruits are less sensitizing and avocados are neutral. In this way, lemons and grapefruit are more sensitizing than oranges, while oranges sensitize more strongly than do mandarins.

Flesh foods are more suitable for those who cannot efficiently use glucose, such as fast oxidizers or hypoglycemics, while fruit and sweet vegetables are best for those with a slow metabolism. This means that those with an unbalanced metabolism generally should not eat a conventionally balanced diet; they become balanced by selecting foods that are either more slowly or more rapidly digested. However, it is not necessary for sensitive individuals to eat flesh foods to be in balance. They can do very well on oily seeds, legumes, grains, green vegetables, and raw sweet vegetables, but less well on cooked sweet vegetables.

Grains and legumes are neutral in their effects on our metabolism and the glandular and nervous systems. In this respect, they may be grouped in the middle between meat and fruits. They are balanced in themselves, and this shows why one can be balanced on a macrobiotic rice diet with few additions of other foods.

Someone with a normal metabolism can eat in a balanced way by having mainly the neutral grains and legumes, and balancing eggs and dairy products with vegetables. However, it is also possible to balance meat, fowl, and fish with sweet vegetables and fruits, eating very little of the in-between foods. Another possibility is to eat a greater quantity of a food group that is closer to the neutral position and replace a smaller amount of a more unbalanced food. For instance, instead of balancing meat with fruits, you can use an increased amount of sweet vegetables.

However, you do not need to worry about accurately balancing and measuring quantities. This is not an exact science but more a rule of thumb. Its main importance is to show you in which direction to move in your food selection if you feel that your health or emotions are out of balance.

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Step 33
FOOD GROUPS

Learn the health characteristics of the various food groups and apply them for healing.

Let's start with carbohydrates. There are three groups of carbohydrates: starches, dextrines, and sugars. Sugars consist either of simple sugar molecules, the monosaccharides, or two of these linked together as disaccharides. Household sugar (sucrose) consists of one molecule each of glucose and fructose, while milk sugar or lactose contains glucose and galactose. In dextrines, up to 50 glucose molecules are linked, and in starches, several thousand are.

Starches: Starches are broken down into water-soluble dextrines by cooking, sprouting, or fermenting. Dextrines occur naturally in sweet vegetables, and in seeds during germination and ripening; examples are green peas and sweet corn. The basic starch foods are cereal grains, potatoes, sago, taro, tapioca, and to some degree the non-oily legumes. On the one hand, starches are excellent slow-digesting food, but on the other hand, our digestive systems have not yet well adapted to a diet high in grains, especially in those people with blood group O.

In our society, wheat is predominantly used. However, gluten, the protein in wheat, often acts like sandpaper on the absorption villi in the small intestine, and this is a main cause of malabsorption, intestinal inflammation, and allergies. All of us are to some extent affected by gluten and in this context wholemeal products are no better and usually worse than refined flour. Therefore, it is generally recommended that you use only a minimum of wheat products and that you also be careful with the other gluten grains, mainly rye, oats, and barley. Oats are very high in gluten and in this way not much better than wheat. Rye crispbread and rye sourdough bread are usually better tolerated than wheat products.

Rice and millet can be used as staple grains. Maize and potatoes are valuable additions, especially for those allergic to wheat. Buckwheat is generally good but causes problems in some gluten-allergic people. Potatoes should not be peeled, or the skin should be removed only after cooking. Small potatoes and the mineral-rich outer parts of potatoes are preferable to the acid-forming inner parts.

Legumes are best sprouted, as cooked dried beans often cause wind. This can be reduced if you discard the soaking water and possibly replace the cooking water after 20 to 30 minutes of cooking. Sago and tapioca are especially suited for individuals who are not doing well on grains. They are commonly available as white starch granules, in some specialty food sections of supermarkets.

Sweet Food: The term "sweet food," as used in this book, includes sugars, sweetened food, dried fruit, sweet fresh fruit, and the juices of sweet vegetables. It does not include the sweet vegetables themselves such as carrot, onion, sweet pepper, turnip, or red beet, as their sweetness comes mainly from dextrines and they release sugars slowly. Most commonly used sugars quickly enter the bloodstream and cause a serious strain on blood sugar regulation. It is important for our well-being to keep the daily fluctuations in our blood sugar level as small as possible. For

people with a poor sugar metabolism, this means restricting the intake of sweet foods to the barest minimum.

A poor blood sugar metabolism is not restricted to an inappropriate rise in the blood sugar level. An equally dangerous component is a high insulin level, especially after ingesting sucrose and, to a somewhat lesser extent, when combining glucose with fructose. A high insulin level either leads to a strong fall in the blood sugar level sometime later (hypoglycaemia) or to conversion of sugar into fat, which leads to overacidity or overweight.

A third outcome is increasing insensitivity to insulin and the development of Type II diabetes. However, maltose or barley sugar, made from sprouted barley, should have a less harmful effect if used to sweeten starches. It consists of two joined glucose molecules and does not induce a strong insulin response, but it could still cause a stronger rise in the blood sugar level than unsweetened starches. Some of the symptoms associated with a poor sugar metabolism are overweight and underweight, high or low blood pressure, heart disease, arthritis, diabetes and hypoglycaemia, dental caries, colds, allergies, weak eyes, cold hands and feet, lack of energy, oversensitivity, and overacidity.

For most individuals, sweet food is harmful because sugar is released into the system too quickly. Therefore, a sweet dessert or sweetener eaten with protein or fatty food is less harmful than sweet food such as fruit juice taken on an empty stomach or as sweetened starches (for example: sweet porridge, bread with honey, cake). Most affected are individuals with low blood pressure, sensitivity to cold and skin irritants, or those who are emotionally unstable; sugar-insensitive individuals usually benefit from naturally sweet foods. I regard artificial sweeteners such as aspartame as much worse than any natural sweeteners and suggest you avoid them completely.

One natural sugar that appears to be relatively harmless and possibly even beneficial if used in small amounts is xylitol. It occurs naturally in fruits such as plums and strawberries and tastes like normal sugar; it also helps to prevent tooth decay and possibly ear infections and is acceptable for diabetics. However, it may cause diarrhea in larger quantities, so you need to experiment to see how much is acceptable for you.

The Glycemic Index (G.I.): The G.I. lists foods according to the increase in blood glucose levels caused by their carbohydrate content two to three hours after eating. A high G.I. means a rapid increase in blood glucose levels and vice versa. It is preferable to eat mainly low G.I. foods that produce a small or slow rise in blood sugar. Here are a few key examples, with white bread as the standard with a G.I. of 100: glucose and maltodextrin, 137; sucrose (common or household sugar) and rye bread, 92; honey, 83; and fructose, 32. Legumes and nuts generally have a low G.I. From this short list, you can easily see why I have no faith in the G.I.: rye bread and sugar have the same G.I.! The reason for this is the low G.I. of fructose.

Sucrose consists of one molecule of glucose and one of fructose. Fructose produces a strong insulin response that keeps the blood sugar level low partly by converting sugar into fat and partly by channelling glucose rapidly into muscle cells. Depending on the individual metabolism, the combination of fructose and glucose in

large amounts either produces overweight or overacidity. In addition, it increasingly leads to insulin resistance and Type II diabetes.

Nevertheless, conventional nutritionists argue that sugar is not harmful because its G.I. is as low as or even lower than bread. I would not be surprised if it eventually turned out that the G.I. was developed on the instigation of the sugar industry. Most foods listed in the G.I. are processed carbohydrates that I do not advise you to eat anyway. If you select your carbohydrates according to the following rules, then you do not need to be concerned with the G.I.:

- Eat mainly legumes and vegetables
- Eat (fresh) fruits on their own and not with or after meals
- Minimize sweetened food, grains, and cereals

Proteins: Proteins from animal sources are oversupplied in traditional Western diets. Initially, this causes stimulation—you feel energetic and even aggressive—but later in life it leads to enzyme exhaustion, putrefaction of bowel contents, toxaemia, breakdown of the immune system, gout, and cancer. These problems are not due to proteins per se, but rather to the cooking of proteins, which destroys their enzymes and denatures their structure. Protein deficiency, on the other hand, causes slow growth, fatigue, and debility.

Good sources of protein are grass juice (fresh or dried), pollen, spirulina, chlorella, almonds, lentils and other legumes, traditionally fermented soy products, sunflower and sesame seeds (tahini), raw egg yolk, naturally fermented and unpasteurized goat cheese and yogurt, fish, and (organic) liver and other organ meats. The less these are heated, the less digestive problems they will cause.

Use red meat from organic or grass-fed sources and avoid predatory species of fish. Nuts are generally difficult to digest, except if soaked or sprouted. Soybeans and broad beans should not be eaten raw except if sprouted or fermented. Cooked soybeans can cause indigestion, except if you discard the soaking and cooking water; processed soy foods are not recommended because of their high content of anti-nutrients and the likelihood of genetic engineering in the beans themselves, although traditionally fermented soy foods are fine.

Individual protein requirements differ, and more is needed during pregnancy, in childhood, and during convalescence. With advancing age and with degenerative diseases, use any flesh food in an easily digestible form, such as broth of fish, liver, or meat. It is good to combine legumes with starches, as, for example, lentils with brown rice. However, mixing different proteins to obtain improved amino acid composition is generally not required. Preferably, have your flesh foods no more than once a day and avoid products from feedlots or that contain growth promoters.

Vegetarianism: Most individuals can remain healthy on a diet with moderate amounts of flesh food or as vegetarians without eating any flesh food. However, a strict vegan diet without any animal products is advisable only if there are no obscure health problems, because some people require certain nutrients to be supplied from animal sources (such as taurine, carnitine, or vitamin B12).

Generally, sensitive people have weak adrenal glands and feel more energetic and emotionally balanced by using flesh foods. If these foods are excluded, such

people should have a high intake of legumes and complex carbohydrates (slow-digesting food) in their diet. People with alkaline and insensitive conditions, on the other hand, benefit from a partially vegetarian diet, possibly with some seafood and poultry. A fruitarian diet, based on tree fruits, nuts, and berries, is suitable as a temporary or extended cleansing diet for alkaline, insensitive individuals.

Many vegetarian diets are not conducive to good health because of their high intake of sweet foods, milk products, wheat, oats, and inhibitors of protein-digesting enzymes in a soy-based diet. Further, minerals are better absorbed if the meal includes flesh food or gelatine. A diet high in nuts, oily seeds, and cereals can cause a deficiency in lysine (an essential amino acid) and predispose you to herpes and other viral infections; this usually can be rectified by using more legumes. Individuals with blood group O are basically meat-eater types and have great difficulty with a grain-based diet. However, on balance, vegetarians tend to be somewhat healthier than meat eaters.

Fats and Oils: I recommend using foods with a wide range of fats and oils, provided that most of them are unheated. Oils are best supplied by eating products in which they naturally occur. Most recommended is extra-virgin olive oil; otherwise use cold-pressed oil stored in brown glass bottles. Avoid “lite” oils because they are more highly refined and also oils sold in plastic bottles, as oils can leach chemicals out of plastic. Store oils in a cool, dark place and in full containers; refrigerate oil in daily use, except varieties that easily solidify.

Preferably, use only small amounts of heated saturated fats that are hard at room temperature, such as fat in hard cheese, beef, and mutton. Unpasteurized butter, like other unheated fats, is a healthy food. Avoid all chemically hardened (hydrogenated) fats, including margarine. Use mainly oils high in oleic acid, such as olive oil, almond oil, and, to a lesser extent, peanut oil. Peanut oil helps against arthritis but is not suitable for non-sensitive, alkaline people in whom it can contribute to the formation of fatty deposits in the arteries. Unheated coconut oil is beneficial for most individuals, despite being saturated and hard at room temperature. Its high content of short-chain fatty acids enables it to be easily metabolized to energy without causing undue weight gain.

Use bottled polyunsaturated oils (high in linoleic acid) sparingly; it is preferable to obtain these oils directly from ingesting oily seeds. Such oils easily oxidize if the vitamin E intake is low and can contribute to the development of cancer. However, it is recommended to use more fish oils or linolenic acid, as in linseed (flaxseed), together with adequate vitamin E.

People who are insensitive and alkaline, with cardiovascular disease, obesity, or skin and liver diseases, should be especially careful and avoid saturated and hydrogenated fats. Lecithin and vitamin A and E supplements will be especially good for them and cod-liver oil rubs are beneficial if you suspect fat malabsorption.

Fruits and Vegetables: While vegetables are good for everyone and the more the better (except if sprayed with pesticides), fruits must be treated with caution by those with overacidity and poor blood sugar regulation. Use mainly fruits and vegetables in season that are grown in your region. Include plenty of green leafy vegetables and gradually increase your intake of fresh raw vegetables as in salads.

Cook or grate root vegetables with their skins left on and use the cooking water. Among the root vegetables, red beets are highly recommended for their positive effect on cell respiration and energy production. Fruits, especially acid fruits and berries, are excellent for those with alkaline and insensitive body conditions, including cardiovascular diseases, cancer, and diabetes.

On the other hand, those who are overacid (usually with low blood pressure, allergy problems, lack of energy, and tendency to colds) easily become even more acidic on fruit. They should minimize their fruit intake and mainly use subacid varieties or, better still, neutralize acid fruit (as explained in Step 6 under “Alkalizing with Calcium and Magnesium”). Also they may better tolerate fruits that are not fully ripe; oily fruit such as avocados are usually well tolerated.

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Step 34
HEALTH DIETS

Adopt a health diet suited to the specific requirements of your body.

Diets for health improvement are different from slimming diets that do not always improve the health of the dieter. However, on a health diet, weight loss can be expected if you are overweight, in addition to an improvement in health. As a general rule, the more you follow a diet that is ideally suited for you, the better will be your health. The diets recommended in this chapter have been shown to be effective, but you may need to experiment to find individual variations that best suit your constitution and health problems. Your long-term diet together with your mental attitude and lifestyle will decide your health in future years; therefore, choose wisely.

If you are on a conventional diet at present, you can change gradually to the high-quality diet (see below), a process that could take years, especially if you have to take along a reluctant family. Others can rapidly adopt a raw food diet, especially if confronted with an advanced degenerative disease. Nearly anyone can live temporarily on raw food as a cleansing measure.

If you are unusually sensitive to raw food diets and develop digestive problems, you can eat cooked brown rice exclusively for several days or weeks as a mild cleansing diet. If even brown rice causes problems, try basmati or white rice. Use only olive oil and possibly a small amount of salt, herbs, spices, or vegetables for flavouring. Strictly observe how you feel as you reintroduce other foods.

You need not be afraid that you can never eat your favourite foods again. The long-term impact on our health comes from what we eat daily, not from occasional transgressions. When you eat out, you can eat what is available; if it does not agree with you, you will know better the next time. Often our body becomes temporarily hypersensitive to foods that we have habitually eaten before. Then our reflexes were dulled, but now the body lets us know what is good or bad for us. Try to listen to it and become friends with your body.

The High-Quality Diet: This is a low-allergy, semi-vegetarian diet based on freshly pressed vegetable juices, sprouted seeds, fermented and purple food, legumes, non-gluten grains, and a high intake of raw food. In this diet, cooked food is used more as a flavouring or to put on weight; the main part of a typical meal is a vegetable salad mixed with sprouted seeds. Use mainly grated, coloured root vegetables. If you cannot chew well, grate them finely or puree them. Examples of suitable roots are red beet, carrot, turnip, sweet potato, and pumpkin; tomato, cucumber, and celery can be added as flavouring.

As a salad dressing, you can use olive oil, lemon juice, herbs, and spices. For example, shake equal parts of olive oil and lemon juice in a jar; then add one teaspoon of lecithin, a pinch of cayenne, and some marjoram or mixed herbs. You can also blend in some unsprayed lemon or orange skin or a whole lemon. Keep refrigerated and shake before using. A small amount of cider vinegar can be used if lemon juice is not available.

Use only a minimum of commercially grown leafy vegetables and cabbage as they may have a high exposure to toxic sprays. Instead of greens, you can use sunflower and buckwheat lettuce grown in seed boxes; you might also try a small amount of very young wheat grass cut finely into a salad. If you have chewing difficulties or vegetable salads do not agree with you, have plenty of fresh vegetable juices produced with a non-centrifugal juicer.

Before cooking legumes or whole grains, soak them overnight or even longer to start the germination process. Then the enzyme phytase can start converting phytates into inositol and liberate minerals that are otherwise not available when you cook these without prior soaking. Soaking and vigorously rinsing the seeds before cooking also reduce levels of any pesticide residues and mycotoxins from fungal contamination. Use mainly non-gluten grains, such as rice, millet, and buckwheat, also sago and tapioca. Corn is fine if you've passed allergy testing for it. For individuals with blood group O, I recommend that you use mainly vegetables rather than grains as the cooked part of the diet.

Presoaked legumes need cooking only for a few minutes as they are already soft; the exception is soybeans, which are better if cooked for two hours. If cooked legumes cause wind, next time replace the water used for soaking as well as the cooking water. The cooking water for soybeans can be changed several times during cooking to avoid or reduce wind.

Lentils are recommended as a cooked addition to a meal and can be combined with rice. For sugar-sensitive individuals, it is good to have legumes with breakfast to slow the absorption of glucose from the same and even from the following meal. Fenugreek is even more effective in this regard; preferably, also use the water in which it has been soaked. It is not necessary to cook legumes in order to slow the absorption of glucose, and even more effective are partly sprouted legumes.

A breakfast based on ground linseed, yogurt, and bananas is suitable for most individuals; for details, see "Linseed Yogurt" under the recipes in step 37. For individuals with blood sugar problems it is preferable to eat sweet vegetables (e.g., carrot, pumpkin, turnip, and sweet potato) raw instead of cooked. If you cook them, do so cautiously, together with legumes or flesh food.

Flesh foods should be eaten with restriction. The best flesh foods are (organic) liver and deep-sea fish of non-predatory species or seafood from uncontaminated coastal regions. Farmed fish commonly have high levels of pollution and low levels of beneficial omega-3 fatty acids, so are not generally recommended. (For fish species with acceptable mercury levels, check: www.ewg.org). Chicken or other fowl should preferably be organically raised or otherwise free of chemicals.

Eggs in your diet should be genuinely free-range or organic and not from chickens fed any commercial pellets. Fresh, raw egg yolk is a health food that improves vitality and immune function; it can be used as part of a salad dressing. It does not increase but helps prevent the risk of heart disease. Alternatively, eat eggs soft-boiled or coddled. In view of the high incidence of egg allergy, if you are a regular egg eater, I recommend that you test yourself for egg allergy once a year after a period of one or more weeks of abstention from eggs.

The best milk products are yogurt, cottage cheese, and cheese made from goat's milk. Raw goat's milk can also be used as sour milk or clabber milk. If you are not sensitive to cow's milk, these products can be acceptable if made from fresh, raw, organic cow's milk. However, avoid milk products if you have catarrh or other mucus problems.

Almonds are excellent, but nuts in general are more difficult to digest than other foods and should be used with caution. All oily seeds are easier to digest if soaked overnight; peanuts should be vigorously washed and rinsed to reduce any fungal contamination. Nuts and other oily seeds can be used as pastes or nut butters; tahini or sesame seed paste is good, and tahini can be diluted with olive oil for food flavouring. Unfortunately, the seeds are commonly roasted before grinding, and this also applies to commercial peanut butter. Highly heating fats or oils, as is done in frying or roasting, tends to oxidize oils, making them rancid, and this contributes to clogging of arteries and so-called free radical damage. However, sesame oil is more resistant to oxidation damage than other oils.

I regard extra virgin olive oil as the best oil or fat for everyday use. Sesame and almond oils are also good, but generally expensive. Select oils with a dark color and strong flavour. "Fine, lite" oil has usually been heated during refining and lacks valuable cofactors; even cold-pressed oils may have been heated during refining, the more so the lighter they are. High-quality linseed oil is beneficial for many conditions, but as it needs extra care to keep it from getting rancid, you can store it in the freezer.

Coconut oil, on the other hand, is least prone to rancidity and appears to provide good energy and body heat without causing undue weight gain. If you have access to fresh coconuts, you may find that ingesting the flesh often causes stinking wind, with or without additional indigestion. Pieces of coconut flesh are difficult to digest and are then fermented in the large intestines; this releases smelly short-chain fatty acids. You can avoid this by blending the coconut flesh for a minute or two with a cupful of hot water and then pressing it through a strainer. Refrigerate the liquid and residue and add them in small to moderate amounts to meals, use with other foods, or use on their own.

Fruits need to be used with care. Conventionally grown fruits and tomatoes are exposed to more toxic sprays than most other foods, and their high sugar and acid contents often cause digestive problems for sensitive individuals. Minimize the use of sprayed fruit that is eaten with its skin, such as berries. You can reduce spray residues somewhat by soaking fruit in warm soapy water and by scrubbing hard-skinned fruit such as apples; afterwards, rinse well. Fruit such as apples or pears can also be peeled. Note that the core of sprayed apples and pears tends to have a higher pesticide content than the flesh.

Individuals with sensitive skin or low blood pressure are better off using only a minimum of fruit or, alternatively, neutralizing any fruit acids ingested. Some types of fruit, such as bananas, papayas, or pears, are best eaten when they just start to ripen and are less sweet. Overripe fruit is usually not well tolerated, though apples generally cause less problems and avocados are usually fine.

Individuals with insensitive skin and raised blood pressure, on the other hand, do well with fruit and may often have fruit alone instead of a regular meal, especially

for breakfast. Most beneficial for them are acid fruits, such as acid berries, grapefruit, acidic oranges, and pineapples.

Individuals in a very weak or debilitated condition may not be able to eat raw vegetables. In such instances, use mainly cooked rice or other non-gluten grains with steamed vegetables and as much freshly pressed vegetable juice as can comfortably be consumed. This diet can also be used for those who temporarily become oversensitive to a wide range of food items or who want to maintain a stable basic diet while testing for food allergies or other negative reactions. If brown rice causes reactions, then try white rice or sago.

Restricted Foods: Restrict foods that have a negative influence on your health and especially if you are already in poor health. You must decide for yourself how strict you want to be and how much willpower you can muster to remain on the high-quality diet.

If you have cravings for a restricted food, it is better to give yourself a reward from time to time and eat some of it at set and well-spaced occasions rather than to snack on it daily or give up the whole diet because it is too difficult. Generally, the more severe your condition, the more strict you should try to be. Some restricted food may be harmless or even beneficial after you have sufficiently recovered.

Intake of the following foods should be initially avoided and later minimized:

- Wheat products and gluten-enriched items, commercial breakfast cereals
- Cow's milk products (except butter and non-pasteurized cheese) and foods with added lactose
- Margarine, shortenings, and polyunsaturated oils, especially canola oil
- Sugar and other sweeteners; all artificial sweeteners, as in "diet foods"
- Pickled and smoked food and generally highly processed food with added ' chemicals
- Food that has been irradiated or genetically engineered
- Food cooked in a microwave oven or otherwise heated to higher than boiling temperature

However, even in this strongly restricted group, items can vary greatly in their effect on your health. Wheat grass does not in this sense count as a wheat product, and wheat-germ oil is generally beneficial except to those who are allergic to wheat. Wheat germ itself has some positive aspects, but its disadvantages are its high gluten content, strong enzyme inhibition, and the frequent rancidity of commercial products stored without refrigeration.

Sprouted wheat is a more beneficial product than cooked whole wheat, and flour products are less beneficial than whole wheat. Whole-meal sourdough bread can be beneficial for those not allergic to wheat, while white bread and cakes are devoid of vitamins and minerals and commonly contain added chemicals. However, whole grain products sometimes can cause sensitivity reactions, while the corresponding refined foods may be tolerated.

The least harmful cow's milk products are sour cream, cottage cheese, and cheese made by natural fermentation; clabber milk or sour milk made from fresh raw milk; acidophilus milk and unflavoured yogurt made from whole milk only; and butter, especially if made from sour cream. These should all remain unheated after production and before ingestion and be made from organic or otherwise unchemicalised milk.

Some of these products have various beneficial aspects while their negative aspects include the tendency to create cow's milk allergy; their contents of lactose, casein, and saturated fat are also problematic. However, even butter is better than processed cheese, pasteurized milk, and the many low-fat products with their high content of mucus-forming lactose. The most harmful milk products are generally skim-milk powder and long-life milk. Another potentially harmful aspect of fatty milk products is their high estrogen content, which can act as a growth promoter for some female cancers.

In regard to fat, butter is preferable to hydrogenated and chemicalised margarine and vegetable shortening. Avoid canola oil as it may have potentially harmful ingredients. Cold-pressed oils are preferable to conventional polyunsaturated oils, and those in plastic bottles should be avoided. Sensitive oils such as food-grade linseed oil should be extracted under nitrogen and kept in cold storage without exposure to light, for otherwise they are likely to be harmful. The only healthy way of obtaining polyunsaturated oils is by eating oil-containing seeds.

Cautionary Foods

In general the following foods should be used with caution:

- non-wheat gluten grains (barley, oats & rye)
- peanut products
- yeast products
- flesh foods
- salted food
- frozen vegetables
- dried fruit & fruit juices
- soy products, except if they have been traditionally fermented.

The least harmful sweeteners are barley sugar or maltose, raw honey, and soaked and ground dates. In terms of health there is not much difference between white, brown, or raw sugar, and even honey can cause health problems. Therefore, use sweeteners only on rare, special occasions and in small amounts. Avoid artificial sweeteners, especially aspartame (Nutrasweet).

With children or adults with cravings for sweets, a compromise agreement can be reached to abstain from sweets on all but one day of the week, when they can eat as many sweets as they like. Then they can gradually be steered away from commercial sweets to eat unsulfured dried fruit, and later fresh fruit.

The only acceptable breakfast cereals, from a health viewpoint, are those without added sugar and preferably low in gluten. Bran can have some benefit as a laxative but it reduces the absorption of minerals and I do not recommend it. Ground linseed (flaxseed) is preferable.

Pickled and smoked foods contain protein breakdown products that can trigger migraines, allergies, and neurological problems. Smoked food also contains carcinogens. Read the labels and avoid food with added chemicals unless these are vitamins, minerals, or carotenes. Beware, for some products, such as bread, are not required to have all chemical ingredients listed. Canned food is unhealthy because it

is precooked and may also contain lead from the soldering and other metals from the container, especially if the contents are slightly acidic.

Excitotoxins are taste or flavour enhancers that release glutamate and other brain-active amino acids such as aspartate and cysteine. The best known example is MSG (monosodium glutamate). High blood levels can cross the normally protective blood-brain barrier and can cause brain cells to die. Excitatory amino acids cause problems, mainly when they are used either in high concentrations or in free form. In most natural foods, they are slowly released and therefore harmless. Most processed foods contain excitotoxins, notably any kind of commercial taste or flavour enhancers, such as caseinate, hydrolyzed vegetable protein, soy protein extract, yeast extract, or beef stock. These may be labelled as natural flavouring and are especially prevalent in soups, sauces, and gravies.

There are many anti-nutrients in soy products, especially inhibitors of protein-digesting enzymes, phytates, and substances that agglutinate or clump the blood. Commercial soy milk either has been highly heated to produce soy-protein extract with denatured proteins or it is made of whole soybeans and then is full of these anti-nutrients. Increasingly, the soybeans may also have been genetically modified, with unknown consequences.

The non-wheat gluten grains (especially oats with a high gluten content) can cause problems to those allergic to wheat or gluten. Rye sourdough bread is generally good, however, but many varieties of rye bread have added wheat disguised as bread-making flour. Yeasted products, such as bread, wine, and beer, can aggravate fungal problems, such as Candida infestations, which are frequently chronic with degenerative diseases. Yeast-baked bread has a lower availability of minerals than sourdough bread, while modern fast-baking processes are even worse and keep the minerals tightly bound to phytic acid and unavailable for absorption.

Peanuts contain a long-chain fatty acid that is beneficial for arthritis but can contribute to the development of atherosclerosis. Poorly stored peanuts can develop a toxic mould that may also infest peanut butter. Any such mould is generally eliminated by removing the skin and thoroughly washing or soaking the peanuts before eating. Roasted peanuts contain harmful oxidized oil, which is also present in peanut butter; therefore minimize your use. Peanut butter without oil on top is worse and usually hydrogenated - avoid it. Some health stores can make a healthy peanut butter from raw peanuts.

Flesh foods should be used sparingly. Eating meat requires that an individual have strong digestive powers, good muscle activity to properly metabolize it, healthy kidneys to discharge the high level of residues, and good bowel activity to avoid harmful putrefaction. It is often difficult to obtain chemical-free meat, depending on where you live, and it is not good to eat meat from unhealthy animals. Animals raised in feedlots and battery hens are in this category.

Processed meat is even more chemically contaminated and best avoided as is meat with a deep red color due to added nitrates and nitrites. However, you may be able to remove most of the nitrates and nitrites by soaking the meat, including diced or minced meat, in warm water for a short time and then discarding the water. Individuals with blood group O are best suited to include some meat in their diet; those with blood group A are often better on a vegetarian diet.

Predatory fish such as tuna and shellfish are often high in accumulated pesticides and mercury and are not recommended for habitual eating. While sardines are safer, they have the disadvantage of being tinned. The best choice is fresh or frozen non-predatory deep-sea fish or other seafood from unpolluted coastal areas. For more advice on pollutants in fish of different species and from various locations, see the website of the Environmental Working Group: www.ewg.org.

For most degenerative diseases and especially cancer and raised blood pressure, a high-potassium and low-sodium diet is required; therefore, food should not be salted. The absence of iodized salt in the diet may cause thyroid problems, which can be avoided by using additional kelp. However, in some conditions, when the adrenal glands are near exhaustion, such as with cystic fibrosis, glaucoma, and low blood pressure, additional salt is advisable; this is also true for individuals with dehydration, diarrhea, or excessive sweating.

By far the best source of salt is seawater. You can evaporate seawater in flat trays exposed to sunlight to make sea salt. This typically has about ten times more magnesium and trace minerals than commercial sea salt. Commercial unrefined sea salt is salt that has been crystallized in fractions, and it contains very little of the trace minerals originally in seawater. Highest in magnesium and trace minerals is the brine out of which the sea salt has been crystallized. It is sometimes available in liquid form as “sea-minerals” and is highly recommended as a mineral supplement. However, magnesium chloride, commonly derived from seawater, can be used instead.

Commercially frozen vegetables are precooked and contain sulphites or other preservatives, as do most fruit juices and dried fruit, which also tend to upset the blood sugar regulation. Dried fruit without added preservatives tends to have moulds. Preferably soak dried fruit or frozen vegetables and discard the water to minimize preservatives or moulds. Potatoes contain the toxic alkaloid solanine in any green parts, and arthritis often improves when avoiding nightshade vegetables including potatoes. Healthiest are non-greened potato peels and fresh, raw potato juice. Also avoid any green tomato pulp or skin, and preferably use red instead of green capsicum (although the latter is not as harmful as green potatoes or tomatoes).

Tea and coffee have some benefits but become a problem if used in an addictive way. The same applies to alcohol. It can be beneficial as red wine, except for wines that contain the commonly added sulphur preservatives, which can trigger breathing problems in susceptible individuals. In this case, try to obtain wine without preservatives. Some traditionally brewed beers as well as some herbal liquors can be beneficial to stimulate the digestion. However, in general it is better to minimize alcohol intake and to test yourself against any preferred brands for food sensitivity. An allergy is commonly to a raw material or additive rather than to the alcohol itself.

Raw Food Diet: From my experiences of healing as well as from reading many published reports, it is clear that a raw food diet is not only the most natural but also the most effective nutritional measure for healing and rejuvenation. While only few will be strong enough to adopt a complete raw food diet for life, it will be good for everyone to have occasional periods on raw foods only.

Here are the main biochemical and nutritional advantages of raw food as compared to cooked food:

- higher vitamin and mineral content
- minerals are largely present as biologically active colloids
- an abundance of helpful enzymes and bioenergy or life force
- proteins remain in their natural condition instead of being denatured
- there is no increase in white blood cells in the digestive tract (digestive leukocytosis) as after eating cooked foods; leukocytosis is an immune response against toxic or microbial invaders
- their polyunsaturated fatty acids and cholesterol do not become oxidized and carcinogenic nor contribute to heart disease, unlike cooked food
- glucose is absorbed slowly, protecting the blood sugar regulation
- no overweight or obesity produced
- much less food is required as counted in calories
- cleansing, rejuvenating, and anticancer properties

However, there are some risks to a raw food diet. Some raw food contains enzyme inhibitors, goitrogens (causing goitre), vitamin inhibitors, toxic substances (in some exotic plants), parasites, and bacteria (in raw meat). In addition, some people starting on a raw food diet will have strong initial reactions due to the cleansing process the foods stimulate.

There have been cases reported of severe digestive disturbances from eating large quantities of raw soybeans, broad beans, nuts, and wheat germ over long periods. This problem is due to the high content of inhibitors of protein-digesting enzymes that protect these seeds from self-destruction. Basically, all seeds have inhibitors of enzymes for the ingredients of which they are composed, but most do not have such a surplus of inhibitors as to cause digestive problems. Potatoes, sweet potatoes, and egg white also contain enzyme inhibitors.

To obtain the maximum benefit from a raw food diet, it is necessary to free most of the enzymes from their inhibitors. Cooking destroys the inhibitors, but also the enzymes. The better solution is to sprout the seeds or at least soak them to initiate the germination process; discard the water used for soaking.

Trypsin, the main protein-digesting enzyme of the pancreas, occurs in seeds. In one reported scientific experiment, the trypsin activity during germination of seeds increased from 7.5 units to 60 units after 24 hours, to 257 units after two days, and to 333 units after three days. The inhibitor activity decreased from 100 percent in dry seeds to zero percent after 24 hours of germination.

Fermentation with lactic acid bacteria also enhances the enzyme activity in seeds. This process is similar to making yogurt or sourdough. Even soaking nuts for a day before eating will greatly help. Their digestive enzymes are freed from their inhibitors to a certain degree when their tissue is damaged, and we see this when grated potatoes turn brown or mashed raw plants or fruit deteriorate within hours unless refrigerated. Similarly, raw egg white is easier to digest when it is well beaten.

Goitrogens, which are in some raw foods, interfere with the body's use of iodine and therefore may contribute to the formation of goitre or to an underactive thyroid.

Goitro-gens are mainly found in the cabbage family, also in soybeans and the skins of red-skinned peanuts. Cooking these or adding kelp to the diet can overcome this problem. Nevertheless, with an underactive thyroid, it is better not to eat much goitrogenic food in its raw state.

Thiaminase is an enzyme in raw fish that destroys vitamin B1, but that is not a problem if food is correctly combined. Avidin in raw egg white makes biotin unavailable; this leads to a deficiency only if a large percentage of the daily diet consists of raw egg white. Furthermore, egg yolk is very high in biotin, so using whole eggs may not diminish your biotin intake.

Those who have lived all their lives on conventional food are likely to have a fair amount of metabolic wastes and toxins stored in the body. These will be released by a raw food diet and can temporarily overload the organs of elimination and cause skin problems, headaches, weakness, and other discomfort. Therefore, it is advisable to move only very gradually towards a raw food diet or to have short cleansing periods on raw foods while also stimulating the organs of elimination.

The basis of the recommended raw food diet is fresh vegetable juice as well as sprouted and fermented foods. Sprouted seeds can serve as the main part of a vegetable salad. Red beet is excellent and can be finely grated into the salad together with carrot, turnip, sweet potato, or pumpkin. Tomato and grated cucumber can be used for flavouring, with a salad dressing of extra-virgin olive oil, lemon juice, herbs, and spices. Instead of lemon juice, you can use cider vinegar, ascorbic acid, or rose-hip powder. Add lecithin as an emulsifier; shake well in a jar and keep refrigerated.

Almonds, nuts, and sunflower seeds improve through starting the sprouting process; otherwise, eat them soaked and possibly blended or, better still, fermented as nut and seed cheese (see Step 37).

While I do not recommend eating commercial eggs from hens in battery cages, even if well cooked (to kill salmonella, which is common in factory farming), eggs should only be ingested raw if they are free-range or organic. Swallowing an egg with yolk and white intact can cause indigestion in individuals with a weak digestive system. A raw egg is much easier to digest if it is well mixed with other food or drink.

Alternatively, you can beat the white and then mix the yolk back into it. You can easily detect how fresh an egg is by immersing it in water. If it lies flat on the bottom, it is fresh. The older it is, the more the blunt end will rise. If it stands on its tip, it is rather old and may be better cooked; if it floats up, then it is rotten.

If you eat flesh food, you can marinate fish or other seafood and even liver and other meat, which are best minced (see the recipes). This destroys parasites and makes raw flesh food safe to eat. You can also use raw minced meat, suitably flavoured with grated or chopped onion, tomato, or radish, and with lime or lemon juice.

Use only organic or otherwise safe meat from a reliable source. Never use meat from a feedlot; also, pork is generally not safe. The safest conventional red meat appears to be lamb. (For genuinely free-range, grass-fed beef, bison, and ostrich, see: www.mercola.com). As a further precaution, periodically use an herbal anti-parasite program (see Step 44) and possibly an electronic blood purifier (Step

19). With these precautions, raw meat should be safe and healthy, while I regard all cooked meat as more or less unhealthy, partly because of its lack of enzymes, and also because of the formation of carcinogenic chemicals when heated above the boiling point.

(For further ideas on eating meat raw and links to related sites, see: www.rawpaleodiet.org) You can also mix a free-range egg yolk with the salad; if you eat the egg white raw, it is best beaten or blended.

If you have no problems with mucus, such as occasional colds, a blocked or running nose, or respiratory problems, you can use fermented goat's milk or raw cow's milk as yogurt, sour milk, cheese, or cottage cheese. However, be careful with commercial fermented foods, such as yogurt, sauerkraut, or marinated fish. Rice bread or flat bread, preferably made from sprouted rice or otherwise made by soaking and blending the grains and possibly adding a sourdough starter, is suitable as a staple food. It solidifies to crunchy flat bread at low oven temperatures or by exposure to the sun. Sprouted rice can be blended with water, fermented milk, and possibly banana as the basis of a meal.

The most problematic food group is fruit, as I've suggested throughout this section. While meat is grounding, fruit is sensitizing. For insensitive individuals, especially with raised blood pressure, it is beneficial to have plenty of fruit, often as a meal. Especially good are acidic fruits, such as oranges or pineapple. Sensitive individuals, however, feel best with either neutralized fruit or only a small amount of subacid fruit between meals. Insensitive individuals can use fruit as their main source of energy, while those more sensitive can use rice baked at a low temperature and sprouted seeds.

Bananas are a good bulk food for most individuals on a raw food diet. Sensitive individuals can eat them in the early stages of ripening or use mainly small or non-sweet varieties. They do well in breakfast as part of the Linseed Yogurt recipe (see Step 37).

On this raw food diet there is no need to be concerned with variety or trying to have different foods for successive meals. A sprout salad contains all the required nutrients for health and healing; most individuals are happy to have the same basic salad for all meals with only minor variations depending on what is available. The only precondition seems to be that you overcome the addiction to cooked food by learning to make tasty raw salads. In cold weather, you can flavour a fresh vegetable juice with spices; carefully heat it to just below 120º F and drink as a broth.

Most raw foodists will be content to have about 90 percent of their food raw and be free to have some cooked food when eating out and at parties. Even tahini (ground, roasted sesame seed paste) and kelp powder (commonly used with raw food diets) are in fact cooked or heated. Except for food to which you may have been addicted, try to let your body or intuition decide your food selection and meal composition.

Slimming: The high-quality diet and even more so the raw food diet will normally ensure gradual weight loss for overweight individuals, while at the same time maximizing health improvement. I always put the main emphasis on the health aspects of the diet rather than its slimming potential. As we become healthier, we

automatically find the right weight for our constitution. However, no diet will help if your eating problems are emotionally based, so you have to heal your emotions first.

Generally, the most important dietary aspect of slimming is to avoid all cereal or grain products, as well as sweetened food. Try experimenting with these possibilities:

- Have an appetite-reducing protein drink 30 minutes before meals with any combination of the following ingredients and in any amount that suits you: green barley juice powder, spirulina powder, food yeast, ground linseed, linseed (flaxseed) oil, or olive oil. Use this as a warm or cold drink to keep hunger away for hours.
- About 30 minutes before meals, stir one teaspoon of psyllium hulls in a glass of water and drink immediately. If necessary double the amount to two teaspoons in a large glass of water. Psyllium swells up 40-fold to fill the stomach with a soft gel, so don't overuse.
- Eat only lentils or other legumes, green vegetables, and sprouted seeds in addition to the above.
- For cooking, use mainly legumes, non-sweet, non-starchy vegetables and flesh foods; for starches choose high-fibre varieties (e.g., brown rice, rolled oats) and add ground linseed.
- Adopt a mono-diet: one day eat protein foods only, the next day fruits, and the third day sprouted seeds, vegetable salads, and vegetable juices. Repeat as often as required.
- Adopt a cleansing raw food diet with mainly vegetables and green juice, sprouts and fruits, nuts and oily seeds, possibly raw beaten egg, and marinated fish. Sensitive individuals should neutralize fruit acids (see Step 6).
- For two weeks, eat only protein and fat foods and green vegetables with less than 40 g of carbohydrates per day; ground linseed is the best protein/fat food.
- Repeat times when you rely on vegetable and grass juices in addition to vegetable salads.
- Avoid all sweet food, as it stimulates the appetite and the synthesis of fat. In particular, do not eat fructose-containing foods with starches and eat fresh fruit on its own.
- Avoid all grain products; especially helpful for people with blood group O.
- Avoid all fats and oils except fresh, unheated linseed oil, which will not put weight on you; experiment with coconut oil in your diet.
- Preferably skip the evening meal or have only a small salad or apple.
- Get some light daily exercise, such as a brisk 15-minute walk or jogging; use a rebounder or do some other aerobic exercise. The metabolic rate is speeded up for a long time after exercise. Take 1 or 2 g of carnitine before exercising to burn up more fat.
- Use a low-allergy diet combined with the correct foods for your blood group (see Step 43).

- Use mind therapy, such as guided imagery and affirmations; look at your belief systems; release negative emotions; and express your emotional needs.
- Eat very slowly; peacefully chew every mouthful until it is liquefied; savour the flavours as they develop during chewing; make every mouthful last about two minutes.

Hypoglycaemia Diet: Most people who are sensitive, are overacid, have allergies, or have a low energy level are usually hypoglycaemic to some extent and will benefit from this diet. Hypoglycaemia means low blood sugar: when a hypoglycaemic person eats sweet foods, the blood sugar level often soars too high at first, but later falls to below normal. During this fall and while the level is below normal, a variety of distressing symptoms can affect the breathing, circulation, digestion, or the emotional and mental condition.

When the blood sugar level rises after sweet food intake, the pancreas reacts by releasing insulin, a hormone that regulates the blood sugar level. In a hypoglycaemic person, the pancreas releases too much insulin, especially in response to ingesting sucrose or a combination of glucose and fructose. The excess of insulin causes glucose to enter the cells too quickly. This then creates oxygen deficiency within the cells and instead of energy, lactic acid is produced in an anaerobic process. All this makes the body tissues overly acidic and deprives them of minerals and energy.

The mainstays of the hypoglycaemia diet are:

- Gluten-free grains: rice, millet, maize, buckwheat, sago, tapioca
- High-protein seeds: chickpeas, lentils, fenugreek, peas, beans, almonds, sunflower seeds
- Animal protein: white, red, and organ meat, fish (especially sardines and salmon), eggs, goat cheese
- Sprouted seeds and vegetables: cooked, raw, and juiced; avocados, coconut oil, and extra virgin olive oil

Eat grains whole in preference to flour or meal products. However, coarsely ground grains can be beneficial if eaten raw: Immerse them in water or seed milk and let soak overnight. Rye sourdough bread and rye crispbread can be eaten after allergy testing (see Step 5). Raw egg yolk from eggs from free-range chickens can be used as a salad dressing. Other important additions are spirulina, bee pollen, ground linseed, kelp, lecithin, gelatine with vegetables, and fresh green-vegetable juices, especially grass juice or dried grass juice powder and possibly food yeast. Try coconut oil and freeze-dried liver to increase your energy level.

Most of the vitamins and minerals are just under the skin of the produce, so do not discard the peel of suitable fruits and root vegetables. Nuts should be used sparingly, except if sprouted or made into seed cheese (see Step 37). Eat cooked sweet vegetables only with a protein meal; raw carrots, on the other hand, are good any time.

Reintroduce fruits to your diet cautiously and with self-observation. Use sweet fruits only in the early stages of ripening, before they become too sweet. This applies, for example, to bananas and papaya, but do not use fruits that are sour before

ripening. Subacid fruits, such as apples, cause less problems than sweet-acid fruits, such as oranges. Preferably eat fruits only sparingly and as a snack between meals, and neutralize any fruit acids (see Step 6). However, under-ripe or non-sweet varieties of bananas may also be suitable.

As a general rule, try to avoid:

- Sweet food, initially including all sweet and acid fruits and sweet vegetable juices
- Food containing lactose, especially milk products, though butter can be used
- Vinegar or other fruit acids, unless they are neutralized
- Initially no wheat, later only sparingly after allergy testing
- Tobacco, alcohol, drugs, artificial sweeteners, highly processed foods or those with added chemicals

Coffee and tea can be used in moderation, but only if you are not allergic or addicted to them. Lightly salted food may be beneficial. If possible, eat a protein breakfast and a light evening meal, and take a rest after lunch. The best protein is sprouted legumes as the main part of a salad. According to the severity of the symptoms, this diet may be followed strictly or in a more relaxed form and generally as part of the high quality diet.

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Step 35
SPECIAL FOODS

Take advantage of the health-giving properties of bee pollen, sprouted seeds, fermented foods, and purple foods.

Bee Pollen and Special Foods: Various foods have general healing qualities or help to overcome specific health problems. For example, foods high in enzymes and growth hormones improve our overall health. Sprouted seeds, bee pollen, spirulina, grass juice, and unheated lactic-acid fermented foods are in this category, as are fresh edible flowers such as nasturtium, impatiens, and pumpkin. While the stamen of pumpkin flowers that bears the pollen is somewhat bitter, flower petals from the male plants are especially high in bioflavonoids, which help fight against and prevent allergies and inflammations.

Bee pollen is one of the best foods or supplements available. It is a raw food rich in enzymes, hormones, vitamins, and minerals. You can take one to three teaspoons of bee pollen several times daily or use it to flavour your freshly pressed vegetable or grass juice. To make it easier to digest, soak the pollen in liquid for some time before ingestion. It is also a good addition to yogurt or other food to be fermented.

A highly recommended protein combination is bee pollen with spirulina and ground linseed. Taking one or more teaspoons of each three times daily mixed in a juice or other suitable liquid before meals can provide up to half of your daily protein needs. The average protein content of spirulina is 65 percent; pollen has 25 percent, and linseed (flaxseed) 22 percent. Spirulina provides a link between animal and vegetable protein, and it is high enough in vitamin B12 that vegans (vegetarians who do not ingest any animal products) can live on it.

The protein in this combination (bee pollen, spirulina, and linseed) is uncooked, so it is easily digested and good as replacement for a part of the usually eaten animal protein. Another advantage is a favourable calcium-to-phosphorus ratio and a high mineral content, making it alkalizing rather than acid-forming in the body. Add to this a handful of sprouted seeds once or twice a day, and you have the basis of a healthy diet, which you can supplement with meat rather than using meat as a staple.

Foods high in sulphur can be increased to improve detoxification. Such foods include raw egg yolk, onion, horseradish, watercress, turnip, and other raw foods of the cabbage family. Most of these are also helpful in treating digestive ulcers; horseradish can be used to help treat mucous complaints. A supplement high in organic sulphur is called MSM, available in many health food stores.

Bananas are good energy providers for those with a weak digestion. However, overripe Cavendish bananas (this is the most common variety) often cause digestive discomfort or allergies in sensitive individuals. This problem is commonly caused by over gassing the green bananas with ethylene gas shortly before sale to make them ripen quickly. Ladyfinger bananas or other small varieties do not normally cause digestive problems. Sensitive individuals generally should avoid overripe fruit. Acid

citrus fruits are excellent for improving liver functions and lowering high blood pressure, blood sugar, cholesterol, and fat levels in insensitive individuals.
Jerusalem artichokes consumed in frequent small quantities are beneficial for kidney function and for diabetes. Eat one the size of an egg every other day, and store Jerusalem artichokes in soil, not in the refrigerator. Also eating (organic) liver often helps those with diabetes, as does eating avocados and green beans.

Sprouted Seeds: Sprouted seeds and young shoots such as wheat grass provide a higher degree of vitality and rejuvenation than other foods. I recommend sprouted seeds as a mainstay of a good diet. Most commonly used for sprouting are legumes such as lentils, peas, mung beans, fenugreek, and chickpeas, but almonds, peanuts, and sunflower kernels can also be sprouted. Sunflower and buckwheat seeds make a tasty salad when grown in seed boxes and cut close to the soil when the sprouts are two to four inches high.

Alfalfa sprouts are high in a detergent-like saponin that can damage the intestinal wall in sensitive individuals. They have been shown to aggravate autoimmune diseases and possibly cancer. For others, they may be a good food to eat after allergy testing has confirmed you do not have allergies to them. Alfalfa sprouts should be exposed to light after the leaves emerge, while other sprouts usually taste better before their leaves develop. Alfalfa seeds easily rot in wet conditions and are best sprouted in an upturned jar covered with muslin held in place with a rubber band.

It is important to use seeds with a high germination rate. Buy a small quantity for testing, and if they sprout well, buy a larger quantity from the same source and keep them in an airtight container. Lentils and mung beans are easy to sprout. Soak the seeds overnight and then rinse several times a day, drain well, spread out lightly, and keep covered. Wash well again just before eating to remove any bacteria and fungi. If seeds are of poor quality and start rotting easily, use them when the sprouts just start to appear, otherwise wait until they are up to one inch long, which is usually within three days.

Mung beans may retain hard shell pieces after soaking that can damage your teeth. This can be avoided by pouring some boiling water over the seeds initially and letting them soak in the cooling water. Peas and lentils, on the other hand, like it cool and sprouts easily deteriorate in hot conditions. Sprouted seeds can be refrigerated in a closed container after they have reached the desired length. Individuals sensitive to fungi and microbes can wash sprouted seeds in diluted hydrogen peroxide shortly before use. If you have difficulty chewing or if sprouted seeds cause much wind, try using them as part of your fresh juice.

If seeds do not sprout well, the cause may be as follows:

- Seeds may not be viable, may be too old, or have been stored incorrectly.
- Temperature during sprouting is too high or too low.
- Seeds were kept too dry or too wet during sprouting; experiment and adjust conditions.

Fermented Foods: The use of fermented foods was widespread in former centuries. Well-known examples are yogurt, cheese, cottage cheese, beer, cider and cider vinegar, pickles, miso, sauerkraut, and sourdough bread.

The advantages of fermenting foods are several:

- Makes minerals more easily available for the body to absorb
- Eliminates enzyme inhibitors and other anti-nutrients
- Increases the amount of vitamins in the food and creates an abundance of enzymes
- Preserves the food and introduces delicious flavours
- Makes food much more easily digestible, making it essentially predigested and suitable for those with a debilitating condition and weak digestive system

Today most of these traditional fermented foods such as vinegar, pickles, cheese, cottage cheese, and baking products are commercially made by chemical means. This disuse of the fermentation process in preparing our staple foods may well be a major contributing factor in chronic diseases.

It is most important in the fermentation process that a desirable strain of bacteria develop. This depends on the bacteria already present or introduced, as well as on the temperature during fermentation. Basically, we want lactic acid bacteria that convert glucose into lactic acid. In order to ensure the development of pure bacterial cultures, the food is often heat-treated and then inoculated with the desired strain. However, I contend the product is nutritionally superior if it has not been heat-treated. Grains such as rye, oats, millet, wheat, and brown rice and vegetables such as cabbage are best fermented at a warm room temperature, while cultures containing yogurt or acidophilus bacteria do better between 85° and 105° F.

There is a distinction between the fermentation of yeast and that of lactic acid bacteria. Yeast fermentation is used in traditionally made beer, wine, and bread. Due to the overuse of antibiotics in recent decades, many individuals are now allergic or sensitive to yeast. Therefore it is advisable for sensitive individuals to restrict intake of yeast products and for others to abstain periodically or after antibiotic treatment and to test for incompatibility.

When fermentation is uncontrolled, as it is when making sauerkraut or with water in which grains have been soaked for several days, a mixture of lactic-acid bacteria and yeast usually develops. This mixture is not a problem for many, but sensitive individuals need to watch out and may have to avoid this.

In making yogurt, sour milk, sour cream, and cheeses, lactic-acid fermentation is the preferred natural method and still widely used in cottage industries. However, due to the mucus-forming potential of lactose, these products should be used with caution, especially if made from cow's milk. The curd causes less of a problem than the whey (the whey contains most of the lactose), and goat's milk less than cow's milk. Most commercial fermented milk products are heat-treated and often very high in lactose, and it is best to avoid them.

A health food seed cheese or seed yogurt can be used. This is commonly made from oily seeds such as nuts, almonds, or sunflower kernels by adding

acidophilus culture to the soaked and blended seeds. Contamination of the seed cheese with yeast can be minimized by washing the seeds in diluted hydrogen peroxide before blending, adding a large amount of starter, and letting it ferment for only a short period. The same applies to sourdough bread, which is also recommended.

Do not use strongly fermenting products that have become very sour. You can discard the whey and wash the curd to make it acceptable. Nevertheless, do not use any fermented food that has a foul smell or taste. The water used for fermentation should be free of chlorine and fluoride, as these will poison the enzymes released in the fermenting process.

Fermenting or fermented products should not be kept in metal containers nor should a metal spoon be left immersed in the food as this increases your exposure to toxic metals. Plastic containers are not so good either; use ceramic or glass containers instead. Fermented foods can be refrigerated for a week or two; part of the former batch can be used as a starter for a new lot, but beware of contamination with yeast. It is especially important to eat fermented foods during and after a course of antibiotics and if you have cancer or another degenerative disease.

Purple Foods: The term purple foods as used here includes all foods that yield purple juice when cooked or pressed with their skin. The color pigment in purple foods belongs to the large group of bioactive natural chemicals called bioflavo-noids. We find them as red, blue, and purple pigments in a wide range of flowers, fruits, and vegetables, but also in the pulp of citrus fruit. Two well-known bioflavonoids are rutin and quercetin.

Another important nutrient group is the carotenoids that form the yellow, orange, and red colours in flowers and fruits. Best known among these is beta-carotene. Even more important for healthy eyes and especially to protect the retina to prevent blindness from macular degeneration are lutein and zeaxanthin. These two are found in spinach, lettuce, broccoli, peas, and corn. Lycopene appears to protect the health of the prostate gland; studies have found it protective against exercise-induced asthma. You can find it in red-hued fruits and vegetables, such as tomatoes, pink grapefruit, guavas, papaya, and watermelon.

If you have the opportunity, frequently snack on flower petals or put them through the juicer. Suitable are the big petals of male pumpkin flowers or the whole flowers of impatiens or nasturtium; nearly all flowers of edible vegetables can be used. However, if you do not know whether a flower is edible, avoid using it in this way.

The pigments of purple foods are highly unsaturated and therefore are strong antioxidants. One important group of purple pigments is the proanthocyanidins (PAC's); when many individual anthocyanin molecules are linked together they are also called oligo-proanthocyanins (OPC's). One such compound that is commercially extracted from pine bark is sold as pycnogenol; a variant with similar qualities is sold as grape seed extract. The OPC's have lost their purple color, but this may be restored when they are broken down in the body into their individual components. In nature, anthocyanidins are bound to different sugars, and during digestion, the sugars are split off to release them for absorption.

The color of black, purple, or red grapes, blackberries, blueberries, red wine, and red cabbage consists of anthocyanins, the individual molecules and active form of PAC's. The pigment of red beet belongs to a subgroup of anthocyanins, the betacyanins. Both groups have strong antioxidant and anti-inflammatory properties and improve the elasticity of blood vessels and skin. PAC's, anthocyanins, and betacyanins also help to restore normal oxidative metabolism or cell respiration.

They are important not only for normalizing cancer cells, but also for conditions of chronic fatigue and general lack of energy, as they assume the role of oxygen as electron acceptors. Purple foods ingested in sufficient amounts can improve the elasticity of skin and blood vessels. In combination with other bioflavonoids, they are beneficial with various diseases such as allergies, inflammation, infections, parasites, cancer, liver disease, vascular diseases, thrombosis (blood clotting), chemical toxicity, and coronary artery disease.

Purple foods should generally be eaten with the skin on as this is usually the most strongly coloured part of the plant. However, with purple onions the outer skins are not edible, but you can utilize them as a tea. Grapes should be well rinsed before eating to remove fungi or moulds. Sensitive individuals and especially those with Candida may find it preferable to soak the grapes for a while in hydrogen peroxide. When fresh grapes are not in season, the juice of black grapes has reportedly been used with good success in the treatment of cancer. For this, a 24-ounce bottle of dark grape juice can be sipped at intervals during the morning, taking no other food before lunch. See "The Grape Cancer Cure" on website: www.quantumbalancing/grape.htm.

Red beet is the best purple vegetable. The purple pigment in beets has been shown to increase and normalize cell respiration, the oxygen-based energy production within cells. Red beet is one of the key foods in preventing as well as curing cancer; it is equally important in the treatment of other degenerative diseases, such as chronic fatigue syndrome, characterized by reduced cell respiration.

When cellular energy is produced through the oxidation of nutrients, electrons and hydrogen ions are transferred onto the inhaled oxygen to produce water and energy. In cancer cells and in conditions of chronic fatigue, the respiratory enzymes that accomplish this transfer have been diminished or destroyed. The color pigment in beet root (and other purple food) strongly binds electrons and hydrogen and can reactivate the production of cellular oxidative energy. Researchers have shown that the energy production of cancer cells can be normalized by a combination of red beet, raw fermented food, and vitamin C.22 The multiplication of cancer cells will thus stop, and tumours become non-virulent. Clinical tests using red beet with cancer patients revealed that often tumours regressed and disappeared. In the cancer therapy with red beet, two pounds were used daily. However, if used together with other purple foods, much less beet may be needed. For instance, combine one pound of red beet with one pound of dark grapes or one pint of dark grape juice.

Use plenty of red beets grated in salads, juiced, and cooked, and remember, the residue from the juicing can be cooked. Occasionally, a small beet may leave an acrid aftertaste. Taste suspect beets before making salads or juice; cooking them is fine, and beet tops can also be cooked. Tinned beet has lost most of its pigment and is of little nutritional value.

A Checklist of Laxative Foods

For the improvement or maintenance of good health, it is desirable to have two or three bowel movements daily. A general lifestyle improvement will do much to achieve this goal, but initially it may be necessary to include some laxative foods as well. Here are some practical suggestions:

Bran: A mild laxative, however, it accentuates mineral deficiencies and weight loss. Wheat bran is not suitable for anyone who is sensitive to wheat. I do not recommend wheat bran, but you can experiment with rice bran, provided you take trace mineral supplements with bran-free meals.

Freshly fermented foods: These often have a strong laxative action.

Isotonic flush: Add 9g of salt (approx. one heaped teaspoon) to one litre of water, or use one cup of seawater diluted with 3 cups of fresh water. Drink this within a few minutes on an empty stomach and take no other food or drink for the following 30 minutes. This is excellent for cleaning the whole of the gastro-intestinal tract, but it should not be used if a severely restricted intake of sodium is indicated for other conditions.

Linseed (flaxseed): Mildly laxative and soothing for irritated bowels. Preferably use ground linseed, otherwise one tablespoon of dry seeds with water some time before meals and at bedtime; swallow whole. If the intestines are irritated, use fenugreek or slippery elm powder with the linseed.

Magnesium salts: Take one tablespoon of Epsom Salts with water; milk of magnesia is excellent if neutralised with ascorbic acid; alternatively, try increasing amounts of magnesium chloride.

Molasses: Use on its own or with yeast in warm water.

Mustard seeds: Take half a teaspoon of whole dry seeds with water twice daily, some time before a meal; do not chew. This helps to strengthen bowel function and overcome gas formation. Continue for two months or as required. Do not use mustard seeds if the intestines are irritated.

Prunes: May be eaten raw, soaked or cooked.

Psyllium hulls: These are preferable to bran. Stir a teaspoonful in a large glass of water and drink immediately about 30 minutes before meals as often as required for either laxative action or weight reduction.

Senna: Pods, powder, or leaves can be added to herb teas.

Urine: drinking a cupful of your diluted morning urine has a good laxative effect.

Water: Drinking a large quantity of pure water within a short period will cause part of it to rinse the bowels. Take two pints or more of warm water before breakfast (see Step 36).

Red beet may be available only seasonally, but you can store a large quantity in moist sand. Keep the tops exposed in a cool, shaded place with just enough moisture to prevent drying out. After a good root system has developed, you can also let them continue to grow in a sandy and well-drained soil, neither too wet nor too dry to avoid rotting or mould development, but check them frequently.

Raw Egg: Fresh raw eggs, genuinely free-range from hens fed on greens and grains, have health-giving and healing properties. However, egg allergy is widespread so if you habitually consume them, test yourself for egg allergies. Raw egg yolk does not raise the cholesterol level, and it is high in sulphur compounds that strengthen connective tissue and detoxify the liver. Fresh raw egg yolk has long been known to enhance or rejuvenate sexual energies required for having sex, but more importantly for creative activity in general and for physical fitness. Very fresh raw, beaten egg white has germicidal properties.

The cell walls of lymphocytes (white blood cells) become more rigid with aging, AIDS, and viral infections, mainly due to increased cholesterol levels in cell walls. Lipids extracted from raw egg yolk have been reported to normalize rigid cell walls and fully restore immune functions. This has led to great improvements in AIDS patients treated with egg-yolk lipids.

Linseed and Sulphur-Rich Foods: Together with fish oils, linseed or flaxseed oil is our best source of the omega-3 essential fatty acids. These polyunsaturated fatty acids are important for brain and nerve functions, for the fluidity of cell membranes, and for oxidative cellular energy production. Of great importance for this energy production are lipoproteins formed from essential fatty acids and sulphur-proteins (cysteine, methionine). These are concentrated in active tissue such as glands, liver, brain, muscles, and skin and are needed for oxidative energy production or cellular respiration.

Key enzymes formed from cysteine and essential fatty acids are typically deficient in individuals with degenerative diseases such as cancer, chronic fatigue syndrome, diabetes, and many skin diseases as well as heart, liver, and kidney degeneration. These and other diseases have reportedly been reversed with high intakes of high-quality linseed oil and sulphur-rich foods.

Linseed oil is very sensitive to oxidation (spoilage) and special precautions are needed to obtain and retain a non-rancid product. The linseed or flaxseed oil must be fresh when purchased, not more than a few months old and produced below 120° F without light and oxygen; store it in a cool, dark place and refrigerate before and after opening. It should never be heated.

As high-quality linseed oil is expensive, usually it will be sufficient to use freshly ground whole linseed instead of or in addition to the oil. Linseed contains 35 percent linseed oil and you can use several tablespoonfuls of ground linseed a day. This also has a mildly laxative effect. Grind it fresh in a coffee grinder or, alternatively, use a blender, screen it through a strainer, and add the coarse residue to the blender again with the next lot.

Ground linseed can be refrigerated for a few days but is better stored in the freezer. For individuals with malabsorption problems and for those wanting to improve their skin, linseed oil can also be rubbed on skin normally protected from the sun. In addition, I recommend unheated extra-virgin olive oil internally as well as on the skin. This is a good source of squalene, a strong antioxidant that is also important for energy production; it is also a key ingredient in the healing properties of shark liver oil.

Regarding the sulphur foods, the main sulphur amino acids are L-cysteine and L-methionine. Eggs are a good source of these, but they can easily be produced from other sulphur-rich foods such as onions. As mentioned, the best supplement form of organic sulphur is MSM. In her cancer therapy, Dr. Johanna Budwig, a fats researcher, recommends cottage cheese ("quark" in German) made from raw fermented skim milk as the main source of sulphur amino acids. However, according to the blood group diet theory (explained later in the book), this may only be suitable for individuals in blood groups B or AB, and not with hormone-related cancer.

Do not use D,L-cysteine or methionine, but use only the natural L-forms. While cysteine is very important for detoxification and energy production, new research shows that it may also act as a neurotransmitter in the brain and that high doses can create an imbalance in the brain of susceptible individuals. Therefore, it is generally best to obtain it or synthesize it from sulphur-rich foods. High doses of methionine, on the other hand, can cause a problem in individuals who are deficient in vitamin B6; problems can be avoided by supplementing it together with vitamin B6.

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Step 36
WATER AND JUICES

Heal yourself with fresh vegetable and grass juices.

Let's start by the discussing water in your diet. It is important that we take in sufficient water for the smooth functioning of our metabolic processes, and especially to flush away their end products. In normal health and on a diet that includes fresh fruits and vegetables, an additional fluid intake of about a quart daily is usually adequate. However, in the following conditions, drinking close to two quarts of fluids daily is desirable, and more than that if you are overweight:

- If mainly concentrated foods are used in the diet
- If you're on a diet high in protein
- If the urine is cloudy, has a strong smell, or is dark in color
- In hot conditions
- While breast-feeding
- During the initial stages of health improvement and in cleansing periods

The Benefits of Water: Your fluid intake can consist of water, diluted juices, and herb teas. Concentrated drinks such as coffee, milk, and strong tea do not count, as their water content is needed to wash out their own residues. Occasionally check that you produce about three quarts of inoffensive (in terms of odour) urine per day. In hot climates, there is a high incidence of kidney disease because many people do not drink enough water. For instance, a high incidence of oxalate kidney stones among British troops in India during World War II has been blamed on excessive tea drinking

If using large amounts of fluids, you must ingest adequate amounts of water-soluble vitamins and minerals; otherwise deficiency symptoms can develop as you're likely to flush these nutrients out of your system. The time of drinking, too, is very important. One should be careful not to dilute the digestive juices during and after meals, although some liquid, such as in the form of herb teas, can be used after dry meals. Generally, however, it is better to drink before meals and to have the bulk of the fluid intake before breakfast. This is especially important if the digestive system is weak. I regard it as highly beneficial for the kidneys to flush them regularly with a high-volume fluid intake, such as a quart of water or diluted juice before breakfast.

After drinking water, wait for about 20 minutes before starting a meal, and after drinking juices, wait for 30 to 60 minutes, depending on the quantity. It is good to drink a glass of warm water or herb tea first thing in the morning to wash down mucus and debris.

Chlorine and added fluoride in drinking water are always harmful. However, if the water is high in calcium, then fluoride is less harmful, because calcium fluoride is nearly insoluble and not well absorbed. On the other hand, if the water is soft or rich

in magnesium, iron, or sulphur, then fluoride can be harmful. Avoid chlorinated or fluoridated water for drinking or cooking; however, most of the chlorine can be removed by bringing the water to a boil and letting it cool before drinking.

As a strong enzyme poison, fluoride is especially harmful for individuals with chronic degenerative diseases. In countries where water fluoridation is common, we can suspect that all commercial liquids with added water contain fluorides. Commonly, these include all soft drinks, soy milk, and even 100 percent fruit juice, which is usually reconstituted by adding water to concentrates. However, municipal tap water also contains other added chemicals and a good water filter is recommended.

Our magnesium intake has greatly declined since the 1940s because calcium fertilizers have been overused. The death rate from arteriosclerotic and degenerative heart disease is highest in countries with the lowest levels of magnesium in the drinking water; this is notably the case in Australia. Within Australia, the death rate is lowest in Perth, which has the highest magnesium-to-calcium ratio in drinking water, while the death rate is highest in Sydney, which has the lowest magnesium-to-calcium water ratio of Australian capital cities.[23] In the U.S., in six Missouri counties with low magnesium levels in the water, the death rate from diabetes was more than four times higher than in six other counties with high magnesium levels in the water. Water high in calcium is acceptable if it is also high in magnesium; otherwise, you can use magnesium supplements.

Rainwater can be used in unpolluted rural areas. Unfortunately, galvanized iron now commonly has added aluminium with its zinc coating, and this may increase the aluminium level of water collected from modern galvanized roofs and water stored in galvanized tanks. I do not know whether the amounts of aluminium that might be dissolved are significant, but it's best to be prudent. Public water supplies are routinely purified with aluminium compounds; a study in England found that when aluminium levels in public drinking water were high, there was a correspondingly high incidence of Alzheimer's disease.

Water rich in inorganic iron, which leaves brownish residues, is harmful if used over long periods. Lead and sometimes copper accumulating in the body contributes to chronic diseases. Therefore, if you are in poor health, avoid drinking the water from lead plumbing systems and be careful with new copper pipes. Older copper pipes are coated with more resistant copper oxide. Plastic pipes can give off toxic substances as well. The best metal for drinking water systems is zinc, as in galvanized iron pipes; otherwise, ceramic can be used.

Public water supplies are usually heavily contaminated with chemicals, and I do not recommend them as a direct source for drinking or cooking. Tap water is commonly low in energy or life force. Instead use one of the great variety of filters and distillation units on the market.

Bore or spring water in densely populated or farming areas can be used safely only if a chemical analysis shows it to be uncontaminated. It should not have high amounts of calcium, copper, or iron; otherwise, a filter may have to be used or the water boiled to remove excess calcium. The very best water is fresh from a clear,

uncontaminated, sunlit, shallow, and cascading stream. Preferably try to energize your drinking water by exposing it to sunlight or other sources of bioenergy (see Step 7).

I do not recommend drinking much fruit juice, except dark grape juice (as explained earlier) or neutralized acidic juices. The basic disadvantage of drinking fruit juices is the rapid assimilation of sugars, which stresses the blood sugar regulation. However, some fruit juice can be used to flavour drinking water, if so desired.

I do not recommend drinking milk, except possibly fresh raw goat's milk or cow's milk when it is still warm after milking. Use coffee and tea in moderation. While they have some benefits, they can cause problems if one becomes addicted to them. Alcohol too is best used only occasionally in small amounts. Beer drinking encourages the formation of mucus. Dry red wine is generally the least harmful and most beneficial alcoholic beverage. It can assist in the digestive process and give some protection against heart disease; grape juice offers similar protection, but has a lower concentration of protective antioxidants; the deeper the color, the better the protection. Avoid any kind of soft drinks.

Vegetable and Grass Juices: Fresh, raw vegetables are high in life force, enzymes, and other ingredients that keep us healthy. Therefore, use plenty—two pounds or more a day if possible. For many, especially the elderly, it will be difficult eating raw vegetables in -sufficient quantities or chewing well enough to extract all the nutrient goodness. That is where juicing comes to the rescue. In this way, everyone, including children and those with dentures, can have a high intake of raw vegetables.

If possible, include some fresh young grasses, leaves, and shoots grown organically in mineral-rich soil, as they are especially high in life force and enzymes. I highly recommend drinking a glass of freshly pressed vegetable juice before most meals or whenever conveniently possible.

Try using a mixed juice including grasses or leaves as well as root vegetables, such as carrot and red beet, and possibly an apple for flavouring. The chlorophyll and proteins of the leaves, while beneficial in their own right, slow down the absorption of sugars from the sweet vegetables and help to stabilize the blood sugar level. You can also include sprouted seeds, edible (vegetable) flowers, the rind of watermelons, the tops of beet root, and other unusual items in your mixed juice. Be imaginative and experiment to find out what is acceptable to your taste buds.

If unsprayed vegetables are not available, avoid sprayed green-leaf vegetables and use the less contaminated sweet vegetables. Squashes and watermelons are not normally sprayed. For individuals with a weak sugar metabolism (diabetes, hypoglycaemia, or a tendency to these conditions), it is preferable to use mainly green juice of leaves and grasses and only a smaller amount of sweet juice for flavouring. Alterna-tively, slow down the absorption of sugars from the juice of sweet vegetables by adding some olive oil and lecithin or ground linseed; then drink slowly and at intervals.

Often children and some adults can be persuaded to drink the juice only if it is flavoured with apple or pineapple. I recommend adding ginger to the juice: either use fresh ginger or ginger juice already frozen in ice cube trays. For flavouring, it is

excellent to stir a few spoonfuls of bee pollen into the juice.
Start drinking the juice immediately after you have made it, but slowly, and in sips. If your stomach is sensitive to juice, drink it with some food. If you make several juices during the day, you may need to thoroughly clean the juicer only after the last juicing, but keep the extraction unit detached and cool in the refrigerator between juicing. Alternatively, you can freeze surplus juice for later use.

If you are unhealthy when beginning such a regimen, nausea or skin reactions may temporarily occur from the release of stored toxins. In such cases, reduce the amount of juice for a while and drink lots of water and take laxative foods. Start with small amounts of grass and weed juice, possibly diluted and blended with other juices. When you get used to it, the green juice may taste fine on its own, but avoid or minimize strongly flavoured leaves such as from radish. Gradually increase to a glassful one to three times daily before meals - the more the better. While fresh juice is best, if you do not have the time to make several juices daily, you can refrigerate or freeze some of the juice for later drinking; also cool it and take it to work in a thermos.

If you have a problem absorbing fats, add some lecithin to the juice to improve absorption of beta-carotene. Sometimes, when juicing sprouted seeds, the centre of a squash, or some mucilaginous leaves, the residue seems to retain much of the goodness even after putting it repeatedly through the juicer. In this case, just add water to the residue to make it sloppy before pressing it through again. As an alternative, you can get more nutrients out of the residue by making a hot broth: Cover the residue with water, simmer for ten minutes, strain, and add some herbs and spices or other flavouring.

What Types of Juicers Are Most Suitable?: Centrifugal juicers, which are commonly available, are not suitable for grass or leaves, and even for other vegetables they are inferior. Static electricity builds up on the outside wall and discharges or inactivates enzymes and colloidal suspensions of proteins and minerals. Non-centrifugal juicers reportedly give much better healing results.

A blender can be used, and grass and other leaf vegetables liquefied with water and then pressed by hand through a strainer. Unfortunately, air beaten into the liquid leads to oxidation. You can minimize this by adding some ascorbic acid. Blend handfuls of grass repeatedly in the same water to concentrate the juice; alternatively, run the grass once or twice through a mincer or a grain mill and then press the pulp by hand through a strainer or cheesecloth.

Grass juicers, either manual or electric, are commercially available and may be sold as fruit and vegetable presses. (You can easily find information and retailers on the Internet.) This type of unit commonly has a slow-turning spiral press. Manual wheat-grass juicers are efficient and good for training the biceps, but not so good for people who do not have the energy to use them daily. Also, I do not like the juice to be in contact with so much metal; cast-iron juicers are much cheaper than the stainless-steel types.

As a general rule, the slower the speed, expressed as revolutions per minute (rpm), the better the quality of the juice. Slow-turning juicers are available as single auger or twin-gear machines. Both handle grasses and leaves very well with an rpm

commonly between 70 and 120 ppm. In comparison, a medium-fast juicer has about 2,000 rpm and the common centrifugal juicers 8,000 rpm. While low-rpm juicers produce the highest quality of juice, they are also slowest in pressing a given quantity; bigger twin-gear juicers may be twice as fast as smaller single-auger juicers. (For a comparison of different brands, see www.buyjuicers.com.)

When using a juicer that easily processes grasses and leaves, there are considerable savings in having to buy fewer vegetables. You can use lots of grasses, green weeds, parsley, tops of carrots, and other leaves that cannot be easily used with other juicers. This can not only bring considerable savings, but it also provides juice of much higher quality than can be obtained from commercial vegetables. However, there is also a drawback with low-rpm juicers and growing your own wheat or barley grass: It is very time-consuming.

Juice from Grasses and Weeds: While not so pleasant to the taste buds, fresh young grasses and green edible weeds have a much greater healing potential than the vegetables commonly used for juicing. In particular, they are very much higher in their content of life force and enzymes. Instead of working hard to maintain a big vegetable garden, I believe it to be easier and healthier to let a large part of the garden overgrow with suitable grasses and edible weeds. An additional advantage of young grasses is the short time and minimal care required to grow them as compared to growing vegetables. You can harvest grasses in two to three weeks compared to several months for vegetables.

To find out which weeds are edible, ask a knowledgeable friend or neighbour, or observe what goats or poultry are eating, or chew a bit of a leaf yourself. If it is not bitter, it is not likely to be poisonous, and anyway, there are no poisonous grasses. For a very healthy juice, use grasses, green weeds, and the petals of squash flowers; flavour it with an apple, beet root, and carrot.

Juice made from young and fresh blades of cereal grass is most beneficial. These young blades have the highest vitality and are rich in enzymes and growth hormones that are missing or at low levels in mature leaves or plants, as well as in elderly humans. Kirlian photography reveals that the vitality of leaves starts to diminish soon after cutting and that most of it is lost within hours, though if refrigerated in a closed plastic bag it may keep for a day. Most nutrients will still be available from commercially dried and powdered grass, such as green barley grass (commercially available), but young fresh grass juice has a much higher vitality.

Best known is wheat grass, but I contend that all fresh, young grass grown in good soil has similar healing and rejuvenating qualities, though the flavour and toughness may differ greatly. Barley grass grows more vigorously than wheat grass and tastes good. Young ryegrass (not the cereal rye grain), grown by farmers as pasture, has a pleasant flavour and can give you several months of repeated cutting from one planting.

Experiment with different varieties of grasses to see which grow best in your climate and soil conditions, and find one you like. When using lawn grass, the main requirement is that it be grown in good soil without the use of pesticides or chemical fertilizers; preferably fence off part of the lawn for this purpose. Often there is some

foam on top of the juice, especially with grass juice. This foam is high in chlorophyll and beneficial, so ingest it or rub it into your skin.

I find wheat grass juice somewhat too sweet on its own and prefer it blended with other grass. As barley grass does not taste sweet, it may be better than wheat grass for individuals with blood sugar problems. Normally, however, it is good to mix the seeds of wheat and barley and grow them together in the same garden bed or tray.

How to Grow Grasses Indoors

1. Soak the wheat or barley for planting overnight and sow very densely.

2. Cover lightly with a sandy soil or just with wet newspaper.

3. Keep moist and expose to light after leaves emerge.

4. When the grass is about two inches high, you can start using it for cutting into a salad or you can chew the grass and spit out the pulp. You can begin to juice the grass when it is about four inches high. Sometimes you can get a good regrowth after the first cutting.

5. The maximum yield of juice is available when the grass is between six and eight inches tall.

6. The higher you intend to let it grow, the less dense you should sow the seeds.

7. Compost the stubble and other organic matter for reuse in seed boxes or outside planting.

8. Add rock dust, kelp, or seaweed to mineralize the soil.

Exposure of the trays to moderate sunshine is preferable but not essential. Protect the trays from prolonged strong sun exposure and from overheating behind a window. If the trays are on a balcony, you can move them inside during cold nights or cover them with newspaper. The best growing condition is at room temperature.

When the shoots are about an inch high, it is preferable to stop watering, or water along the sides but keep the centre dry to minimize problems with moulds and rotting.

In cool climates, it may be difficult growing grass outside in winter, while in the tropics it is sometimes difficult in summer because it is either too hot or too wet and cereal grasses easily start rotting at the stem. In the city, it may not be possible anyway. In these circumstances, wheat grass or barley grass can be grown indoors behind a window or on a balcony or veranda in seed boxes (see sidebar)

Wheat produces about four times its weight as wheat grass and this in turn yields up to 80 percent juice. Tougher perennial grasses yield about 60 percent juice. The vitamin and mineral content of grasses and their juices differs greatly between different varieties, but especially with diverse soil conditions. Table 4-1, compiled from various publications, gives an estimate of the average nutrient content of the juice from grass grown in good, mineral-rich soil.

The protein content of young annual grasses is usually around four percent and of established perennial grasses about two percent. Vitamin and mineral concentrations can vary greatly and are highest in young grasses grown in soils rich in minerals and organic matter.

While grass juice provides a high amount of easily digestible protein, as well as vitamins and minerals of superior quality, even more important are the enzymes,

growth hormones, and other vital factors, including coenzyme Q10 and superoxide dismutase (SOD). In animal experiments, old rats were rejuvenated and chickens grew 15 percent faster with fresh grass, but not with other supplements. Many patients attribute their cure from "incurable" diseases to the generous intake of grass juice. Grass juice has also been successfully used as a retention enema with cancer and other debilitating conditions, as a vaginal douche, or topical rub for the skin. Juicy grass pulp is excellent on wounds and speeds up healing.

Table 4-1: Nutrients in Grass Juice

Protein	2–5%	Fibre	3–6%
Lipids	0.5–1%	Kilojoules	250/100 ml
Carbohydrates	6–11%		
Vitamins/100 ml		***Minerals/100 ml***	
carotene	10,000 IU	calcium	70-200 mg
vitamin C	60 mg	magnesium	50 mg
vitamin E	6 mg	phosphorous	50-100 mg
vitamin B1	0.2 mg	potassium	400-1,600 mg
vitamin B2	0.4 mg	sodium	40-150 mg
vitamin B6	0.2 mg	iron	3 mg
vitamin B12	1 mcg	zinc	0.5-2.5 mg
pantothenic acid	0.4 mg	manganese	1-10 mg
nicotinamide	1.5 mg	copper	0.3-1 mg
folic acid	150 mcg	molybdenum	0.03 mg
biotin	15 mcg	sulphur	100 mg

Grass juice has been shown to inhibit mutagenic and carcinogenic activity. This inhibition was stronger with wheat grass juice than with carrot or parsley juice; it has also been reported with barley grass juice. We need growth hormones not only for growing taller, but also for cell division, skin and tissue replacement, and wound healing. In growing older, we become deficient in growth hormones, and those found in grass juice can help us rejuvenate.

Most animals live on grass either directly or indirectly. It is the perfect food, not only for grazing animals, but also for humans. The juicer replaces the complicated cellulose digestion of grass-eating animals. I regard grass juice as the food with the greatest healing and rejuvenating potential; it could even sustain us during a famine.

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Step 37
HEALING RECIPES

Transform healthy foods into enjoyable meals.

I am not fond of using recipes. Most recipes seem to be designed to tickle our palate by harming the nutrients in the food. The healthiest recipe for carrots, for instance, is to pull one out of the ground, clean it, and chew it well. Any additional processing renders it less nutritious. Also, I favour experimenting, mixing this and that within the framework of the food-combining rules, and seeing how it turns out. In this spirit I offer the following recipes and cooking tips as starting points for finding ways to make healthy food tasty.

If you are willing, you can gradually change your taste preferences and come to like this new diet of healthier meals. If your life is in no immediate danger from an advanced disease, change slowly, making a gradual transition over a period of years from your present diet to the high-quality diet, and possibly to the raw food diet after that.

Baking Breads: The best method for baking is one in which enzymes in the food remain alive. This means heating bread dough to less than 120° F. It is preferable to start with whole, soaked, or sprouted seeds that are rich in enzymes rather than with commercial flours that may have had their enzymes destroyed during the milling process and may be contaminated with mycotoxins. The only practical solution I have found so far is baking with rice. After blending soaked or sprouted rice, the dough continues to absorb water and so becomes firm almost without any heat. I have not found this property in any other grain. You may have to experiment with different varieties of rice to find a good sprouting one.

Soak brown rice overnight, then rinse for two or three days until sprouts appear; otherwise use after soaking. If you are sensitive to fungi, keep for several minutes in water with added hydrogen peroxide, then wash well and blend with a minimum of water. If the blended rice does not have the consistency of a paste, add rice flour or strain off excess water. Lightly cover a tray with some rice flour or baking paper and spread the paste out flat. Preferably leave in the sun or a warm place, such as a warm oven with the heat turned off, until the dough has solidified, usually after a few hours.

You can experiment with additions, such as kelp powder, occasionally carob powder and dried fruit for children, and acidophilus culture or a sourdough starter if you want to try baking a more conventionally shaped loaf. The addition of any other kind of soaked or sprouted seed will make it more difficult for the dough to harden. You can bake flat bread in an oven at low temperatures from a mixture of various flours or meals, such as from peas, lentils, chickpeas, rice, and rye. You may add buckwheat flour to any baking mix to improve its binding qualities.

If you use sprouted seeds, it is not necessary to add acidophilus or sourdough starter to improve the nutritional quality, but only to lighten the bake. However, if you only soak the seeds and, more important still, if your main ingredient is flour, then

lactic-acid fermentation will greatly improve the nutritional value as well as lighten the texture.

Any other soaked, sprouted, and blended seeds can be used for making flat bread by baking at 160° to 180° F with or without a starter. Again, it is advisable to spread the dough over a layer of flour to absorb excess moisture. You can also add other flavouring ingredients, such as banana or carrot pulp. It may take five hours or more of baking for the bread to solidify. At this temperature, the enzymes are destroyed and, unlike sun-baked rice, it is not a raw food any more. However, the protein structures generally are not damaged and there is no digestive leukocytosis (increased white blood cells in the intestinal wall) when eating this bread. You can refrigerate part of the sourdough as starter for the next bake, but if you are yeast-sensitive, it is preferable to use fresh acidophilus culture each time.

For more conventional bread, I recommend rye sourdough; the more acidophilus you add and the slower the dough solidifies, the more acid it becomes, and vice versa. Mix 1 cup of acidophilus starter with rye flour, water, flavourings (for example, caraway seeds), and 1 tablespoon of honey or molasses as food for the bacteria. Leave covered overnight in a warm place. Before adding salt, reserve and refrigerate 1 cup of this as a starter for the next baking. Add more flour, knead, shape, and cover the loaves and let them rise in a lightly warmed oven for several more hours. Then bake at a moderate heat for 90 minutes; place a pan with hot water on the bottom rack to develop steam.

Bone Broth: Use the soft bones of fowl or the bones and heads of fish. Add 1 or several tablespoons of vinegar, depending on the amount of bones you have. Simmer with sufficient water in a covered, non-metal container for at least 3 hours, or until the bones become brittle and the liquid is nearly neutral. With larger quantities and longer cooking time, you can repeatedly add more water and vinegar.

Alternatively, use a pressure cooker for 30 minutes, but without adding vinegar. When the bones have become soft, blend it all, strain (optional), and freeze in ice cube trays. Use some of the broth frequently with meals; add it to vegetable salads, as it is an excellent source of gelatine, calcium, and other minerals.

Beef Juice, Liver Broth, Liver Juice: To make liver broth, simmer pieces of (organic) liver for 2 hours; strain and mix with sweet vegetables, cooked or raw. To make beef juice, dice a pound of lean beef. Put in a jar without water, cover well, and set the jar on a piece of cloth in a pot filled with water. Boil for 3 hours. Press juice accumulated in the jar through a strainer and refrigerate or freeze it. Sip a teaspoonful 5 to 10 times daily and keep it in the mouth for some time. Make this juice fresh weekly. Occasionally, the juice can be made of liver instead of beef. Beef juice is indicated in cases of serious muscle weakness.

Butter Spread: In order to cut down on your butter consumption, lightly warm some butter and mix it with an equal amount of extra-virgin olive oil. Add lecithin, chopped onion, kelp, herbs, and spices to taste. Alternatively, or in addition to using oil, butter can be mixed with an equal amount of hot gelatine; flavour to taste and keep the butter spread refrigerated.

Marinated Fish: Dice the fish and cover with lemon juice or diluted cider vinegar or a mixture of both. Refrigerate overnight; add cooked or raw onion or herbs and spices, and possibly some juice, leaf, or green skin of papaya. Eat with

vegetables or sprout salad. You can also marinate liver, minced meat, or soft cuts of meat.

Fruit Balls: These are for festive occasions. Mince any of the following: nuts, sesame, sunflower, or pumpkin seeds, fresh coconut, dried fruits such as apricots, dates, mixed peel, papaya, and pineapple. Mix well, add lemon juice to taste and also lecithin; bind with oil. Make into small balls and roll in desiccated coconut. For different flavours, add carob powder or spices to the mixture.

Hommus: This can be used as bread spread or as an addition to meals. Soak chickpeas (garbanzo beans) overnight. If seeds are viable, sprout them; otherwise, use them soaked raw or soaked and cooked for a few minutes only. Discard the soaking water to reduce intestinal gas. Puree the prepared chickpeas in a blender and mix with any combination of the following: olive oil, tahini, lecithin, cayenne, kelp, herbs, and spices. Keep refrigerated.

Hot Vegetable Juice: Normally, you drink fresh vegetable juice cold. However, in cold weather you may enjoy drinking it hot, flavoured like a broth. Use a handful of fresh green leaves, add cabbage, celery, tomato, cucumber, whatever is available, and some sliced carrot, pumpkin, or beet root. Mix this in an electric blender, together with a suitable hot liquid, for instance, herb tea, bone broth, or water. Strain and press the residue. Try to keep the temperature of the broth below 120° F.

A juice extractor can be used instead of the blender or you can mix the hot liquid with some freshly pressed juice. Flavour the drink to taste; you can use herbs, spices, miso, kelp, oil, lecithin, egg yolk, food yeast, or molasses in any combination you like. Drink the juice immediately, taking sips. Another possibility is to simmer the residue left over from juicing in water for ten minutes, strain, add some flavouring, and drink hot.

Jellies: Dissolve 4 teaspoons of white, unflavoured gelatine in 1 pint of hot water. Pour it over diced fruits or over sprouted seeds and diced or grated vegetables (for example, cucumber, tomato, carrot, or chopped onion). You can add herbs, spices, kelp, and salt. Alternatively, the gelatine can be dissolved in a smaller amount of hot water and mixed with an appropriate amount of fruit juice or fresh vegetable juice. Refrigerate for setting. Instead of commercial gelatine, a gelatinous bone or fish broth is preferable. Gelatine aids in the absorption of vitamins and minerals.

Linseed Yogurt: The following combination can be used as a snack before or between meals or instead of any meal. It is especially good as a breakfast. Mix half a cup of ground linseed with 1 or 2 tablespoons of linseed oil or olive oil or melted coconut oil, 1 tablespoon of bee pollen, 1 teaspoon of spirulina, sliced or blended bananas, lecithin granules, and enough yogurt, seed cheese, or seed milk for a smooth consistency. You can also add some chopped fruit or berries. As a liquid component, try fresh vegetable juice, grape juice, apple juice, or any other liquid.

Papaya (Pawpaw) Smoothie: This can be used as a special health food to aid the digestion, as well as in dissolving tumours or other unwanted growths. In a blender, mix mature green papaya (when it just starts turning yellow and the seeds are already black) with skin, seeds, and flesh, banana and any other fruit in season, and a sufficient amount of a suitable liquid such as a juice or yogurt. Eat on its own or as part of a meal.

Grated Potatoes: Bring 1 cup of water to a boil, keep the heat on high, add coarsely grated potato, and stir for 2 to 3 minutes. This leaves the potato semi-raw with a quite distinct flavour; add kelp, oil, and so on, and eat with vegetables or sprouts.

Protein Drink: This is good as a general energy booster, especially if you have blood sugar problems or lack of energy, and it is also excellent when consumed 30 minutes before a meal to reduce appetite if you want to lose weight. Mix in a blender 1 or more spoonfuls each of bee pollen, green barley powder, ground linseed, spirulina, and chlorella, or any combination of these in a suitable liquid. This can be seed milk or any other kind of milk or juice such as grape or apple juice.

Rejuvelac (fermented seed drink): Wash 1 cup of whole grain (preferably organically grown) and cover with 2 cups of warm water. Suitable are rice, millet, rye, and other grains. Keep in a glass or porcelain container in a warm place. Pour off the liquid the next day or when it tastes slightly sour. Use as a refreshing drink on its own, but not with or after meals. The grains can then be cooked or sprouted. Use the grain ferment only if it has a pleasant taste and smell, otherwise discard it. Rejuvelac may not be suitable for sensitive and yeast-allergic individuals.

Rice Dishes: Cook the rice until almost soft and most of the water has evaporated. Add a small quantity of apples, cover, cook until the apples are soft, and then mash them. Add cinnamon, oil, lecithin, and kelp. Eat cold as a dessert. As an alternative, add apple puree to the cooked rice. You can also try rice with a sauce based on blended raw carrots and other sweet vegetables or bananas.

Healthier than cooked rice is sprouted and blended rice. Wash and soak overnight a sprouting variety of brown rice. After sprouting, blend the rice and add other flavouring ingredients, such as banana, olive oil, kelp, carob, lecithin, or pitted dates, for a sweet meal. Blend again and eat this instead of a breakfast cereal. If too gritty, strain the rice puree after the first blending or cook it.

Sauerkraut: Use a wooden barrel or earthenware pot of any size. Place a layer of shredded cabbage 4 to 6 inches deep in the container. Sprinkle over it a small amount of salt and some herb seeds, such as caraway, fennel, or cumin; other shredded vegetables can be added for flavouring. Press the first layer down, then add another layer of cabbage and herbs, and so on. The cabbage must be completely saturated with its juice and no air pockets left. Cover the contents with cheesecloth, place a wooden cover over it, and weight it down with a heavy stone. Leave at room temperature.

From time to time, after several days, lift the cover and remove foam and mildew from the top of the mash; wash the cheesecloth, board, and stone with warm water and then put them back in place. After about 2 weeks the sauerkraut should be ready for eating. Store the container in a cool place, or put the sauerkraut in jars and refrigerate. Eat it raw and drink the juice. Raw sauerkraut may not be suitable for sensitive individuals, but it should be fine if cooked.

This recipe may occasionally fail if the barrel is contaminated. To avoid this, thoroughly clean the barrel with steam or boiling water before use. To make it easier for beneficial bacteria to develop, sprinkle organic cider vinegar into the different layers or add acidophilus culture.

Seed Cheese/Seed Yogurt: Soak oily seeds (almonds, nuts, sesame, pumpkin, or sunflower) for 8 to 12 hours. Puree in an electric blender and add acidophilus culture. If you are not yeast sensitive, experiment with adding Rejuvelac instead. Keep in a warm place for several hours until the desired degree of sourness develops. Refrigerate and use within 3 days. If it is too sour or if curd and whey have separated, strain and discard the whey; rinse the curd if necessary. Use seed yogurt as part of a salad dressing, for flavouring meals, or as a bread spread. The more sensitive you are, the less sour it should be when you use it. If it smells or tastes bad, discard it.

Seed Milk: Soak almonds, rice, or sunflower kernels overnight or for about 12 hours. The simplest way to make this milk is to change the water, blend the soaked seeds in an electric blender, and press them through a strainer. You can either drink the liquid immediately or refrigerate. You can cook the residue of the rice and add the residue of the oily seeds to any breakfast mix (possibly remove almond skins before blending). However, a much better way is to wait until the seeds start sprouting. This removes any enzyme inhibitors and provides natural sweetness and enzymes to the milk. Alternatively, use unhulled sunflower or pumpkin seeds for making milk.

Sprout Salad: Mix a variety of freshly rinsed sprouted seeds with a combination of fresh, raw vegetables, basically using whatever is available. Most suitable are sprouts of mung beans, lentils, sunflower seeds, and fenugreek, together with finely grated beet root, carrot, and turnip or radish. Tomato and cucumber (try it grated) are good for flavouring. If you have difficulty chewing, you can put all of it through a mincer, or if very weak and debilitated, you could liquefy and drink it.

The key to enjoying a sprout salad is to find a delicious dressing. Experiment. I recommend extra-virgin olive oil, lemon juice, whole blended lemon, cider vinegar, or rose-hip powder, any fresh or dried herbs or spices, and a dash of cayenne. These may be added individually or mixed beforehand and refrigerated in a jar. Flavour olive oil by mixing in a jar 1 part tahini with 3 to 10 parts oil, lemon juice, and lecithin.

For a health enhancer, add ground linseed and kelp to the salad. Start by adding very small amounts of kelp until you come to like it. Raw egg yolk is a good addition to the dressing, as is seed cheese or sour milk; you can also flavour this salad with tofu or yogurt.

Sweet Vegetables: Use any combination of the following: sliced pumpkin or squash, sweet potato, onion, turnip, beet, carrot, and tomato. Add only a minimum of water so that finally most of it has evaporated. Vegetables with short cooking times (tomato, pumpkin) can be added later to preserve their flavour. Salt, kelp, oil, curry, cayenne, herbs, and spices are best stirred in at the end of cooking.

Yogurt, Clabber Milk, Cottage Cheese: It is essential to repopulate your intestines with beneficial lactobacilli, especially L. acidophilus in the small intestines and bifidobacteria in the large intestines. Instead of or in addition to using high-potency acidophilus/bifido capsules or powders, you can use a self-made fermented product or yogurt. This can be made from fresh unpasteurized cow's milk, goat's milk, rice milk, homemade soy milk, or a mixture of ingredients based on bee pollen and honey. Commercial cow's milk acidophilus/ bifido yogurt (preferably organic or biodynamic) can be used as a starter.

The commonly used yogurt based on cow's milk has some problems in that many individuals are allergic or sensitive to some ingredients of cow's milk. It often is mucus-forming and is also high in estrogen, which is not good for various female cancers. According to the blood group diet, cow's milk is acceptable only for those with blood group B and possibly AB. However, if you are not sensitive to it, then yogurt made from fresh raw cow's milk can be beneficial, used in moderation.

You can use rice as a base for making yogurt. Cook soaked (organic) brown rice in plenty of water. After cooling, blend and strain; add starter culture and 2 teaspoons of raw honey to the strained rice water. Rice yogurt does not set, so drink it when it turns slightly sour or smells slightly fermented. You can make rice milk by blending and straining sprouted brown rice. This is sweet enough by itself, so that no added sweetener is required.

A fermented drink can be made based on bee pollen and honey. Add to 1 quart of water and starter 5 to 10 teaspoons of pollen, 2 or 3 teaspoons of raw honey, 1 or 2 teaspoons of kelp powder, and, if you like, several teaspoons of spirulina, chlorella, or cereal grass powder. Experiment and use more or less of the indicated amounts and also different ingredients. As with rice milk, this does not set and is best used when it starts frothing and tastes somewhat acid.

As an initial starter, use 1 teaspoon each of powdered acidophilus and bifido cultures, a mixed culture of these, high-potency capsules, or a commercial yogurt containing these. Do not use commercial yogurt or starter with only bulgaricus and thermophilus bacteria. Subsequently, use up to 1 cup of the previous batch as starter. Preferably, use the liquid or whey as the starter because it contains the most bacteria. The more of the starter you use and the warmer it is, the sooner the yogurt will be ready.

If you do not have a yogurt maker, mix 2 to 3 cups of any type of milk or pollen-honey liquid with 1 cup of starter and keep it in a jar standing in a container with hot tap water. It usually takes only a few hours to set, though with powdered cultures it may take 6 to 10 hours. In cold weather, renew the hot water every hour or keep the jar in a warm place. Alternatively, the milk can be kept warm by putting it in a box or some other small, enclosed space, together with an electric bulb or other source of heat. Refrigerate the yogurt when it just starts setting, as it continues to become firmer and more acid during storage. If it becomes too sour, use less of the whey as starter and eat only the strained curd or neutralize the acid.

To make sour milk (clabber milk), leave raw, unheated milk in a flat bowl in a warm place for 1 to 2 days until the milk sours and coagulates, then add a yogurt or acidophilus starter. For making cottage cheese or quark, wait until curd and whey have separated and strain or press the curdled milk through cheesecloth.

Veggie Burgers: Soak overnight 1 cup of chickpeas or lentils; next morning replace the water and put them in a blender. Soak 2 cups of rice overnight and cook. Combine the blended legumes with the cooked rice and add some buckwheat flour or an egg to bind the mixture. Flavour with any combination of the following: miso, soy sauce, fresh parsley, coriander, cumin, fresh ginger, onion, and any other herbs or spices. Form flat burgers and bake crisp in a grill or a non-stick pan.

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Part 5
PROBLEM FOODS & FOOD PROBLEMS

This part explains in more detail the reasons for the dietary recommendations in Part 4. Most problem foods are widely used basic foods that lead to health problems in many people. So-called junk foods and heavily processed and chemicalised foods belong in this category; many foods treasured by natural health enthusiasts, such as honey, dried fruits, yogurt, and whole-meal bread, also belong to this list of problem foods.

What chiefly makes a particular food a problem is the presence of one or several components that can cause metabolic or digestive problems if used indiscriminately. We use and have used problem foods in excess, so our metabolism has been weakened to such an extent that it cannot safely process even small amounts of certain foods without becoming distressed. This can be demonstrated with food muscle-testing.

However, for individuals with a suitable metabolism, most problem foods can be acceptable and sometimes even beneficial in moderation; this does not apply to heavily chemicalised food. It is advisable for nearly everyone to minimize their intake of problem foods. It is also best to more strictly avoid the problem foods described in this chapter and that you know from personal experience are a cause of your health problems.

The main problem foods are:

Lactose and cow's milk products

Gluten and wheat products

Sugar and sweet foods

Red meat and fats

Chemicalised food, stimulants, and yeast or moulds

Some problem foods frequently cause food allergies and can be the primary allergens or causative agents that sensitize us to a range of other allergens. This applies especially to the gluten in wheat and to proteins in cow's milk. When the body is still young or overacid and sensitive, it tends to respond strongly to these foods. However, problem foods cause even more serious problems when the body is older, alkaline, and insensitive, but then there are no alarm reactions such as food allergies to warn us. This leads to the development of chronic degenerative diseases such as autoimmune diseases, cardiovascular diseases, and cancer.

In addition to specific health problems being caused by specific foods, the overall impact on the adrenal glands of habitually consuming problem foods can raise our basic stress level to such a high degree that a relatively small additional stress from emotional or social problems can trigger severe reactions. These can include asthma, epilepsy, migraine, depression, irritability, hyperactivity, phobias, nervous breakdown, and mental disease. In addition, the fact that we cook too many of our foods and hence have insufficient enzymes in our diet greatly contributes to the development of chronic degenerative diseases and premature aging.

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Step 38
COW'S MILK PRODUCTS & LACTOSE

Have a closer look at cow's milk products and lactose. In some forms they can be beneficial, but as commonly used they tend to create a lot of health problems.

The three problematic ingredients in dairy products are lactose (milk sugar), butterfat, and casein (and other proteins). While lactose can be a problem in all animal milk, including goat's milk, difficulties with protein and butterfat are specific to cow's milk.

Bottle-feeding infants with cow's milk has far-reaching effects. The earlier it is substituted for human breast milk, the more damage is usually caused. The baby's digestive system is still immature and relies on enzymes provided in mother's milk. It cannot properly digest cow's milk, especially if the milk has been pasteurized and is without enzymes. In addition, in the first few weeks or months of life, the wall of the infant's small intestine is not yet fully developed and allows only partly digested proteins to pass through; this causes allergies.

In a clinical study, all infants and most older children evaluated had antibodies against cow's milk in their blood.24 This means they were allergic to it, even in the absence of obvious symptoms. However, usually "unspecific" symptoms were present, such as restlessness and crying at night, dermatitis, tender abdomen, tantrums, weak eyes, low energy, hyperactivity, indigestion, and a high incidence of colds and ear and respiratory infections. A contributing factor that makes many babies prone to infections is the absence of immuno-protective agents in bottled milk that are present in human breast milk, especially in the colostrum.

Formula-fed babies usually suffer from zinc deficiency. Zinc is essential for activating the immune system. The zinc content in cow's milk is actually higher than that in mother's milk, but in cow's milk zinc is bound to a protein from which the baby's immature digestive system cannot release it. Other trace minerals are also difficult for the baby to absorb from cow's milk; iron is especially problematic. A resulting iron deficiency in babies contributes to the development of anemia, a weakening of the immune system, and retarded mental and cognitive development.

An allergy to cow's milk and subsequent mucus congestion of the lungs, combined with zinc and iron deficiencies of the immune system, cause frequent colds and respiratory infections in babies. This, in turn, depletes babies of vitamin C. The effect of all this is a high incidence of crib deaths in bottle-fed babies, which sometimes occur shortly after immunizations. Vaccinations can further drain the already dangerously low levels of vitamin C. Archie Kalokerinos, M.D., in Every Second Child, relates that in some Aboriginal communities of Australia every second child given a vaccination died of crib death, but when fed high doses of vitamin C before and after vaccinations, not a single child died. Is it a coincidence that New Zealand has the highest rates of asthma and crib deaths in the world, but also the highest consumption of cow's milk?

Crib deaths are uncommon in breast-fed babies. However, even breast-fed babies can develop allergies if the mother has a high intake of cow's milk products or is allergic to it herself. Full-term babies in the first two weeks and premature babies in the first one or two months can become allergic to almost any substitute for mother's milk. If breast-feeding by the mother is not possible during this time and a wet nurse is not available, then fresh raw goat's or sheep's milk is the least harmful alternative.

Problems Associated with Lactose: Most adults, except for Caucasians, cannot split lactose into its two components, glucose and galactose. After the age of three, a deficiency in the lactose-splitting enzyme lactase develops, and this can cause severe indigestion and diarrhea if the diet contains appreciable amounts of lactose. This condition is known as lactose intolerance.

Lactose-intolerant people can tolerate lactose better if fermented milk is used, as in the form of yogurt or kefir, where the lactose is partially pre-split by lactic-acid bacteria. Alterna-tively, lactose-splitting enzymes are now commercially available and can be added to milk. However, lactose intolerance is only a minor problem compared to the much more serious health problems caused by galactose. Lactose intolerance appears to be a wise precaution of nature rather than a regrettable accident because it protects us from the great danger of galactose overload.

We both need and don't need galactose. Most European adults and older children who can digest lactose are unable to use galactose efficiently. Babies need galactose as an important building component of the brain, the central nervous system, and of many proteins. Thus, mother's milk is even higher in galactose than animal milk to ensure that the baby obtains sufficient galactose. In later life, very little galactose is needed and this can easily be synthesized from other sugars. Therefore, most of the ingested galactose is converted in the liver to glucose and used as body fuel, but the amount that can be converted is rather limited, even with a healthy liver.

This conversion is a slow and complex process requiring four different enzymes. One of these is sometimes missing from birth, giving rise to a condition known as galactosaemia. Continued milk-feeding leads to a buildup of galactose in the baby and can cause cataracts, cirrhosis of the liver and spleen, and mental retardation. If the liver is not healthy, it becomes less able to convert galactose. This fact is sometimes used as a criterion for a clinical liver-function test. If galactose is injected into someone with a defective liver, most of the galactose will later appear in the urine, confirming the diagnosis of liver dysfunction.

Mucic Acid and Mucus: Under normal conditions, only part of the galactose is expelled with the urine. If there is a deficiency of protective antioxidants, then the rest is mainly oxidized to galactaric acid, commonly known as mucic acid. The great health danger of mucic acid is that it is insoluble. The body cannot let it pile up in vital areas and block organ functions or blood circulation. Therefore, it forms the mucic acid into a sticky suspension in water called mucus. Thus, mucic acid is a main component of pathogenic -(disease-producing) mucus.

It is the function of the lymphatic system to remove dangerous substances, such as mucus, from areas of vital importance and transport them to the organs of elimination. Mucus is too dangerous to dispose of through the kidneys or (with bile) through the liver, but it has a special affinity to the mucous membranes that line the insides of our body openings. Of prime importance here are the lungs, the respiratory

tract, the hollow head spaces, the sinuses, and the Eustachian tube (a passage between the mouth and the inner ear).

The mucus accumulates in these hollow spaces until external factors help to sensitize the mucous membranes sufficiently to allow the mucus to pass through. This is relatively easy in young individuals and those with a poor sugar metabolism, as they have high levels of histamine and inflammatory adrenal hormones. Even minor irritations of the mucous membranes, be they from cold air, dust, air pollution, pollen, or germs, will sensitize these to let some of the mucus flow out, such as through sneezing.

Such mucus cleansing may be experienced periodically as a cold, hay fever, wet cough, or running nose. In others, the accumulation of mucus, which provides a favourable breeding ground for germs, causes chronic infections in specific areas such as the sinuses, the middle ear, the respiratory tract, and the lungs. This may allow a permanent trickle of mucus through the affected mucous membrane. In addition, a dead (commonly root-canalled) front tooth may be responsible for chronic sinus problems.

With a high lactose intake, the lymph channels and lymph glands are usually congested with mucus as well. This allows influenza and other infections to spread from the sensitized mucous membranes through the mucus-filled hollow spaces into the lymphatic system, causing lymph gland swellings and inflammations. I have found that in many people the number of influenza bouts, colds, and other respiratory infections can be varied at will from none to several per year just by varying the lactose intake. Mucus congestion is also the main cause of ear infections and hearing problems, especially in children.

In most cases it is not a lactose allergy, but a galactose overload that is responsible for this excessive mucus. While in the case of those suffering from cow's milk allergy, somewhat more lactose may be tolerated when it comes from goat's milk, in most individuals the lactose in goat's milk or in tablets will be as mucus-forming as that from cow's milk.

Milk Products and Asthma: When more mucus accumulates in the lungs than can be expelled, asthma is likely to develop. Often lung congestion is combined with a strong subconscious fear element that can, for instance, result from insecurity or lack of love in early childhood. Another contributing factor is hypoglycaemia coupled with weak adrenal glands.

Many cases seem to be predominantly mucus-induced. I treated a patient who was fond of yogurt and, for health reasons, prepared it from skim-milk powder. This produces yogurt with a much higher lactose content than yogurt from full-fat milk (see table 5-1). When I persuaded her to use somewhat less yogurt and prepare it only from whole milk without additional skim-milk powder, her asthma disappeared for good. The asthma-causing skim-milk yogurt provided approximately 50 g of lactose per day, while she was asthma-free on whole-milk yogurt with about 5 g of lactose daily.

The lung irritation caused by accumulated mucus also means that the lungs are more prone to be affected by food allergies and chemicals. This could result in inflammatory swellings of the bronchial tubes. Mucus accumulating in the lungs

allows bacteria to infiltrate. Some strains of these bacteria convert sugars into alginic acid, another sticky mucus. Often there is Candida albicans or fungal infestation as well, which sensitizes the mucous membranes to airborne moulds. Mucus--releasing colds in this setting can be a blessing in disguise, provided they are not treated with antibiotics. Also dead teeth can induce copious mucus due to chronic root and jawbone infections, as explained in step 8.

The mucous membranes of asthmatics, which are highly sensitized by mucic acid, react strongly to air pollutants such as smoke, pollen, and sulphur dioxide. The adrenal glands are typically weak and histamine levels are high because of a sweet diet and allergies. To overcome asthma, we need to reverse these negative conditions by using a low-allergy diet with a minimum of sweet or mucus-forming food, while the respiratory tract should periodically be cleared of mucus. Breathing exercises also help this condition.

Milk Products and Chronic Degenera-tive Diseases: A serious consequence of a congested lymphatic system full of mucus is the development of leukaemia. This happens when the immune system has been sufficiently damaged by frequent mucus-related infections combined with other factors such as toxic chemicals, a sweet diet, allergies, and -vitamin--mineral deficiencies.

It may not be a coincidence that Nathan Pritikin, famous for his much-publicized diet to cure cardiovascular diseases, developed leukaemia. The original Pritikin diet is high in skim-milk products and, therefore, imposes a severe galactose overload on the body. Leukaemia or another galactose-related degenerative disease is more likely to develop as a long-term effect of a high intake of skim-milk products. It is important to note that cardiovascular diseases can be prevented or cured nutritionally without causing other health problems such as leukaemia.

Table 5-1: Lactose Content of Dairy Products

butter	0.5%
cheese, cottage cheese	2-4%
goat's milk	4.3%
cow's milk	4.9%
yogurt and ice cream (with skim milk powder)	5-25%
skim-milk powder	52%
whey powder	70%

Leukaemia stands in between the acute mucus-related infections of childhood and the usual chronic degenerative diseases that develop with advancing age. When our metabolism slows down as we become older or if we are on an unsuitably heavy meat diet, the body gradually becomes too alkaline and the mucous membranes become more insensitive. In this condition, the release of mucus through colds and other respiratory infections becomes rare and most of the mucic acid is stored in the body.

A lactose intolerance, and thus an enforced avoidance of foods containing lactose, can also protect us from another disease: cataracts of the eyes. Even infants can develop cataracts when they cannot convert galactose to glucose, and galactose overload is an important cause of cataracts in adults. In addition, high blood glucose and fructose levels may contribute. These simple sugars are reduced to sugar alcohols that cause cloudiness in the lens. Another form of cataract is mainly caused by a chronic deficiency of vitamins A, B2, C, D, and E, and the minerals chromium and selenium. Radiation exposure or drugs can also cause cataracts.

Besides cataracts, there are other diseases that are usually considered to be typical for the aging body, but that occur in infants with galactosaemia. These include liver degeneration, oedema, and reduced memory or senility (the latter being equivalent to mental retardation in infants with galactosaemia).

Cancer (carcinoma) reportedly can result from galactosaemia. A clinical study shows that women who consumed yogurt had a higher rate of ovarian cancer than controls who consumed the same amount of lactose from other milk products.25 Because of the activity of the lactic-acid bacteria, yogurt contains more readily available galactose than other milk products.

A frequent complaint is increasing deafness with subsequent infection and inflammation because of mucus congestion of the Eustachian tube and the middle ear. In children, this condition is sometimes called “glue ear.” This is especially a problem with children of non-European background because they can still absorb lactose, but cannot easily convert galactose, especially from cow’s milk, into energy.

One Scandinavian study showed that no purely breast-fed baby developed early middle ear infection and that such babies were protected against it in later life. In contrast, early introduction of cow’s milk predisposed children to this and it was exclusively found in children who received cow’s milk before the age of six months.[26]

With lactose-induced mucus congestion, degenerative lung diseases such as emphysema can also develop. While smoking is generally considered to be the greatest hazard for lung cancer, it may actually rank equal with galactose overload; most at risk are heavy smokers with mucus-congested lungs. Sometimes the lungs fill up with mucus. A patient I know died because his lungs and breathing passage were filled with sticky mucus. He literally drowned in it. With each of his breaths, I could hear the air bubbling up through the mucus.

A combination of mucus accumulation in the lungs and the digestive system is seen in cystic fibrosis. This disease is mainly due to an overproduction of an abnormal mucopolysaccharide, a long-chain carbohydrate that normally supplies the mucus physiologically required by the body. Cystic fibrosis sufferers also may be unable to convert galactose and, as they are usually deficient in protective antioxidants, they may also produce large amounts of mucic acid. Like galactose overload, cystic fibrosis is typically a disease of Caucasians.

In part, excessive mucus formation stems from an infestation of the lungs with bacteria, which produces an abnormal amount of sticky alginic acid. The important point here is that alginic acid is synthesized from a simple sugar (mannose) that these bacteria can convert from an excess of any other sugar, such as galactose, fructose, or glucose. Therefore, mucus-forming as well as sweet foods must be avoided.

Lactose in Food: Preventing excessive mucus accumulation in the body is much easier than trying to remove it afterwards. If you are concerned about your future well-being, it is a wise precaution to reduce your intake of lactose to a minimum, starting today. Review table 5-1 for the lactose content of some common dairy products, and see which ones you can avoid.

With skim-milk powder having a lactose content of 52 percent, you may now realize how dangerous is the current fad for using low-fat ice cream, yogurt, cottage

cheese, and so forth, instead of full-fat products. Such low-fat foods are made from skim-milk powder and contain three to five times as much lactose as the equivalent full-fat foods. Sometimes skim-milk powder is even added to butter. Therefore, read the product labels and avoid butter that lists “non-fat milk solids” as one of the ingredients.

Skim-milk powder is also a favourite additive to many other commercial foods, such as bread and other baked products, sausages, and margarine. The health-food industry is fond of adding lactose to many products such as soy milk and dandelion coffee. Lactose is often used as filler in white tablets; cell salts are almost pure lactose. Try to avoid white tablets if the label does not state that they are free of lactose or are low-allergy tablets.

I suspect that the average daily amount of lactose that healthy adults can handle without the danger of long-term galactose overload is less than 10 g, the equivalent of one glass of milk. However, those who have occasional mucus problems or are afflicted with a -galactose-related disease do well to have a much lower lactose intake than 10 g per day. With a lactose allergy, it is often necessary to avoid lactose completely for several months or years.

Casein, Milk Protein, and Fat: Casein is the main protein in cow’s milk and constitutes about three percent of it. Mother’s milk, on the other hand, has only 0.5 percent casein content. The high casein content of cow’s milk causes it to form a very tough, rubbery curd in the stomach; the casein then binds the calcium in milk as an insoluble salt. Thus it is extremely difficult to digest and is a frequent source of indigestion. Mother’s milk and goat’s milk, on the other hand, form finely dispersed soft curds that infants can easily digest.

Thus the protein in cow’s milk frequently is only partly digested and becomes a major source of intestinal putrefaction and toxaemia. Incompletely digested protein can pass through the wall of the small intestine and cause allergies. Symptoms of worms in children are often due to intestinal putrefaction from undigested cow’s milk. Breast milk, which contains high levels of fat-digesting lipase and other enzymes, is nearly self-digesting in the baby’s gut in contrast with pasteurized cow’s milk, which is very difficult to digest.

In a double-blind study, 24 out of 27 babies with colic became free of symptoms when put on a diet free of cow’s milk protein. The babies, when given cow’s milk protein, cried on average 3.2 hours daily and when taken off cow’s milk, cried for only one hour.[27] However, I believe that breast-fed babies who have all their needs met hardly cry at all. Allergy-prone mothers pass allergens to their babies with their breast milk. This allergenicity is often caused by beta-lactoglobulin, which is in the cow’s milk. When such mothers avoided cow’s milk (and thus its proteins), the babies’ colic disappeared.

Colic is due to an inflammation of the intestinal wall, which in turn is triggered by an allergic reaction against the protein in cow’s milk. This chronic inflammation erodes the intestines’ microvilli through which the food is absorbed, thus resulting in malabsorption. Incompletely digested proteins can also pass through the damaged intestinal wall into the bloodstream and produce various allergic reactions, such as dermatitis or brain irritation.

A general consequence of such cow's milk allergy is a weakening of the immune system, which in babies is further aggravated by a lack of protective immune factors that are normally transmitted through breast milk. This is why infants on cow's milk have frequent colds and respiratory infections; this immune weakening can also lead to sudden infant death or immune deficiency diseases in later life.

Cow's milk appears to disturb calcium metabolism. Calcium becomes trapped in undigested casein, while the long-chain saturated fatty acids form insoluble soaps with calcium. In addition, cow's milk has an unfavourable ratio of phosphorus to calcium as compared to breast milk.

Several studies show that cancer patients tend to consume more cow's milk than do matched controls. Professor Jane Plant, author of Your Life in Your Hands, may have discovered the connection between cow's milk and cancer. Her breast cancer had spread throughout her body and she had been given up to die. At that stage, she found out that the rate of death from breast cancer in China is one in 10,000 compared to about one in ten in most Western countries, and also that Chinese do not use animal milk or related products. Putting the two together, she avoided all milk products; her tumours eventually disappeared, and for 13 years now she has been free of cancer.

As Chinese have "normal" rates of other cancers, there must be a special factor that causes their low breast cancer rates. Also the largely milk-free Japanese have low breast cancer rates, but when Chinese or Japanese women adopt a Western lifestyle, their breast cancer rates start to climb, approaching the level in Western countries. Studies now link milk consumption to breast and prostate cancer.

The problem appears to be a special protein called insulin-like growth factor, IGF-1. This stimulates hormone-related division of cells and especially stimulates breast tissue to grow during puberty and pregnancy; it also affects the prostate gland. Clinical studies showed that higher levels of circulating IGF-1 in the blood were not only a strong risk factor for women to develop breast cancer, but also for men to develop prostate cancer. However, IGF-1 levels were not elevated with benign conditions.28 The crucial factor is that cow's milk is very high in IGF-1, and it is also present in the meat of dairy cows. High-yield milk production, as commonly induced with synthetic hormones, increases the IGF-1 levels in the milk.

Another protein or protein fragment is connected with juvenile diabetes (Type I). It appears that this is only a problem with milk from Frisian cows (called A1 milk), but not with milk from other, lower-yielding breeds that produce A2 milk. Most of presently consumed milk is A1 milk.

Juvenile diabetes is much higher in those who have been bottle-fed rather than breast-fed and it is lower in communities that consume less cow's milk products. Studies of newly diagnosed diabetic children revealed an immune response to this protein fragment of cow's milk protein in all of them, and found that it has the same composition as one called P69 on the beta cells. P69 is usually protected inside the pancreatic beta cells and comes to the surface only during microbial and viral infections. At those times, the immune system can mistake it for cow's milk protein and attack it and destroy the beta cells in the process. Bottle-fed infants are very susceptible to colds and respiratory and gastrointestinal infections; it is regarded as

“normal” for them to have six and more infections a year, even though these are rare with breast-fed infants.

Therefore, bottle-fed infants frequently receive antibiotics that then encourage overgrowth of the intestines with undesirable microbes and a tendency towards chronic pancreatitis. One type of E. coli bacteria, though harmless in the large intestine, has the potential for causing great damage in the small intestine. That is because it produces a molecule very similar to insulin. When the immune system becomes activated against this molecule, it can then also direct its attack against related features at the beta cells.

This shows that a combination of two factors can trigger an attack on the insulin producing beta cells: one factor that brings P69 to the surface of the beta cells, and another that activates the immune system to attack them. From the first factor we have the frequent colds of bottle-fed babies, and if antibiotics are used, then this also promotes overgrowth of the small intestines with pathogenic microbes, including E. coli, as the second factor. This is reinforced with feeding cow’s milk, which intensifies the attack on the beta cells and eventually leads to juvenile diabetes.

Fermented cow’s milk products in the form of natural yogurt, kefir, and natural cheeses produce a fine curd and cause fewer health problems than unfermented milk. However, even these should be used with care and only if they do not cause allergies or mucus problems. Generally, the corresponding goat’s or sheep’s milk products are far more preferable. The least harmful milk product is cottage cheese made from fermented goat’s or sheep’s milk.

The most damaging aspect of commercial milk products, apart from oversupplying the body with growth promoters, lactose, and casein, is the destruction of natural enzymes by pasteurizing the milk. Raw butter, for instance, was formerly used to cure psoriasis, but pasteurized butter causes or aggravates it. The healing effect of raw butter is due to its high content of the fat-digesting enzyme lipase. The same is true for heart and liver problems, which are caused in part or aggravated by processed cheese and butter fat.

Such health problems did not occur to the inhabitants of the Caucasus and Bulgaria with their high intake of raw milk products. Cholesterol did not harm anyone in former times when mainly unheated milk products were used; cardiovascular diseases were almost unknown. Raw milk was formerly used to cure tuberculosis, but pasteurized milk is more likely to cause it. In general, raw butter and cream are far healthier foods than refined polyunsaturated oils or margarine.

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Step 39
WHEAT & GLUTEN

Wheat may be the staff of life, but in many people it is actually unfavourable to health.

Gluten is a mixture of two groups of proteins, gliadins and glutelins. Wheat has the highest content of gluten, especially hard wheat, which makes it possible to bake leavened bread and cakes. Under the conditions of baking, gluten forms a network of molecules, similar to a wire mesh. This molecule mesh traps small bubbles of carbon dioxide gas and prevents them from escaping. This makes the baked product light and easy to chew. However, in this way we create a problem for our digestion because the gluten network is more difficult to break down. The gluten network is only partly digested, especially if the food is not very well chewed; this is a main cause of intestinal inflammation and wheat allergy.

Malabsorption Problems with Wheat: Gluten seriously weakens the intestinal wall. Its effect on the tiny absorption villi in the small intestine can be compared to the action of sandpaper on wood. Animal experiments have shown that the intestinal absorption villi are long and slender before they come into repeated contact with wheat protein. Afterwards, they become blunt and broad, with a much-reduced ability to absorb nutrients.

Therefore, people on wheat diets absorb nutrients less well than those reared on wheat-free diets. The former greatly contributes to the widespread incidence of malabsorption and nutrient deficiencies. In such people, not only are the absorption villi blunted, but the irritation caused by the sandpaper effect of gluten produces a protective mucous coating over the intestinal wall. This makes it still more difficult for nutrients to pass through the intestinal wall to be absorbed.

Thus we find gluten, and especially wheat gluten, implicated as a cause of typical malabsorption diseases, such as cystic fibrosis, celiac disease, and sprue, but frequently also associated with autoimmune diseases, diabetes, arthritis, multiple sclerosis, and schizophrenia. The irritation caused by gluten is a main factor in causing appendicitis, colitis, and inflammation of the small intestines (e.g., Crohn's disease) as well as gastric and duodenal ulcers.

It has been estimated that about 90 million Americans suffer from gluten sensitivity, while celiac disease, a severe form of malabsorption caused by gluten, has been found to be 50 times more prevalent than previously suspected and about 1.5 million Americans are thought to suffer from it. Celiac disease occurs frequently not only in patients with gastrointestinal symptoms, but also in relatives and others with numerous common disorders even in the absence of gastrointestinal symptoms.[29] For further information, contact University of Maryland Centre for Celiac Research: see websites: www.celiaccenter.org and www.celiac.com.

The degree of damage to the intestinal wall is proportional to the amount of gluten consumed. But even so-called normal and healthy volunteers on high-gluten test diets showed a deterioration of their intestinal walls and that their ability to absorb nutrients had been reduced.

Nutrient malabsorption is even more of a problem if white bread is used because it has lost about 80 percent of its vitamin and mineral content compared to that of whole-meal bread. What makes it even worse is the modern fast-baking method; instead of fermenting the bread for four to seven hours, it is now whipped with chemicals for two minutes. Thus the few remaining minerals stay tightly bound to phytic acid and cannot be absorbed by the body.

Gluten Allergy: When the intestinal wall deteriorates, it becomes permeable and molecules larger than normal can pass through. This allows partly digested proteins and bacterial toxins to enter the bloodstream, causing allergies and a deterioration of the immune system. Thus, gluten is actually the main agent causing allergies. Without a weakening of the intestinal wall, other potential food allergens would be prevented from reaching the bloodstream, except in the case of babies with intestinal walls that are still immature.

Young babies are also unable to digest starches. Feeding them wheat products, which is very common, almost automatically leads to the development of a wheat allergy. Therefore, cow's milk and wheat are two of the primary food allergies in our society. Not only do they precede the development of other allergies, but their initial appearance makes it much easier for secondary allergies to develop.

All these problems caused by gluten are greatly intensified by the tough network of gluten molecules formed in baking with gluten-rich flour. In former centuries only low-gluten wheat was available; high-gluten wheat is a modern innovation. In addition, the amount of wheat-baking, especially with high-gluten wheat, has greatly increased in our society compared to former centuries, while at the same time our digestive powers have declined.

As this trend has existed already for several generations, most of us are by now sensitized to some degree against wheat gluten, and baked wheat products have become problem foods for most individuals. This includes whole-meal wheat bread and not just the white variety. Our ancestors used mainly millet, rye, and oats as staple grains in addition to low-gluten wheat and spelt; they also used grains more in the form of porridge or wafers than as leavened bread. However, when leavened bread was used, it was mainly as sourdough bread, except in the cities where yeast-baking gradually dominated.

Rye and barley contain less gluten than wheat, and the protein composition is slightly different in these grains; thus, even if you have a wheat allergy, you may still be able to eat these grains. However, this is often not the case, and it is preferable that you avoid these for an extended period if you have a wheat allergy, and instead use gluten-free grains such as rice, millet, and maize. Buckwheat is not a cereal grain - it belongs to the rhubarb family - but it contains a gluten-like protein that requires allergy testing before being used by individuals allergic to gluten.

Processed food, including tablets and soy sauce, often contain added wheat starch or gluten. If you have a wheat allergy and use processed food, then read the labels carefully. Wheat grass, however, is safe to use, but wheat-germ oil needs to be tested for possible allergic reactions.

Iris Diagnosis to Detect Wheat Susceptibility: Blue-eyed individuals with wheat or gluten intolerance usually have a whitish color in the area of the iris

denoting the intestines (refer to Step 12). This reflex zone that surrounds the pupil indicates the irritation and mucus covering of the intestinal wall. Frequently, the white fans out to other parts of the iris, but especially to the head and brain reflex areas that are in the upper part of the iris (between the ten and two o'clock positions). This indicates gluten-induced mucus congestion of the head and irritation of the brain tissues.

Such people are vulnerable to emotional irritability, bursts of temper, and, in the case of brain allergy, to epilepsy and mental disease. They cannot relax easily, and attending emotional workshops or seeking psychiatric help will do little permanent good if the nutritional cause of the problem is not corrected. These individuals often have oversensitive sense organs and tend towards farsightedness. As long as there is no serious mucus congestion in the head, the sharpened senses provide good eyesight and excellent hearing. The disadvantages are oversensitive taste buds, an oversensitive sense of smell, and distress caused by loud noise.

Magnesium supplements will help but will not remove the basic cause. In later life, mucus congestion may lead to deafness and eye diseases. If, in addition to wheat or gluten intolerance, there is difficulty in digesting fats, the white iris areas will become increasingly yellow.

Baked wheat products, especially in combination with sugars, are the most fattening foods for susceptible individuals. The metabolism of such individuals becomes inefficient and the wheat starch is mainly converted into body fat instead of energy. Frequently, individuals allergic to wheat, gluten, and beer have a distended abdomen (potbelly).

For many individuals, gluten products, especially wheat and beer, are strongly mucus forming. Generally, the whiter the iris, the more mucus-forming is the gluten consumed. Wheat and gluten are often a problem for those with asthma and hay fever. If you have a problem with mucus, avoid all gluten products and all foods containing lactose. After sufficient improvement, you can reintroduce small amounts of rye and oats into your diet and explore how much of these your body tolerates.

Most commercial health breads contain added gluten, skim-milk powder, or dried whole grain and are worse than plain whole-meal bread. I recommend rye sourdough bread and rye crispbread; however, rye sourdough bread often contains added wheat described as whole-meal or bread-making flour, so be careful.

Oats are high in proteins and nucleic acids, while the fibre (oat bran) is useful for binding and expelling surplus cholesterol from the intestines. Barley has an even higher cholesterol-reducing effect, and both oats and barley are superior to wheat. However, oats are also high in gluten and easily cause the same problems as wheat in gluten-sensitive individuals. It may be no coincidence that Scotland has the highest rate of multiple sclerosis, with a diet traditionally high in oats and low in vitamin D due to a lack of sunshine.

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Step 40
SWEET FOODS

Your sweet tooth may be your undoing, so consider reducing your intake of sugars.

The main problem with sweet foods is that sugars are absorbed too quickly. The body tries to maintain a fairly constant blood sugar level close to 100 mg of glucose per 100 ml of blood, but this becomes difficult with the habitual consumption of sweet foods.

When we have a starch meal, it takes several hours until all the starch is converted into glucose. The absorption through the intestinal wall is gradual and the liver can easily regulate the blood glucose level by forming glycogen or fat from surplus glucose. It is equally safe to eat raw cabbage or raw carrots, which can naturally contain amounts of sugar equal to a spoonful of honey. Again, it takes hours for the glucose from raw vegetables to enter the bloodstream, while with that from honey or fruit juices, it can take less than 30 minutes.

However, when sweet food is eaten during or after a protein meal, the sugar is absorbed considerably more slowly. The same applies when sweet food is combined with fat. On the other hand, sweetened starches, such as sweet porridge, cookies, or cakes, cause digestive and metabolic problems and are not recommended for habitual use. This means, in effect, that chocolate may be safer to eat occasionally than chocolate cake.

In former centuries, only limited amounts of sweet foods were commonly available in middle and northern Europe. More sweet food was used in Mediterranean countries, and descendents from these populations generally have a stronger sugar metabolism. In addition, formerly it was much more common to work hard physically and in this way burn up the glucose as quickly as it entered the bloodstream after a sweet snack. Food was largely unprocessed and rich in those vitamins and minerals that are needed to maintain the blood sugar regulation and sugar metabolism.

Three minerals required for metabolizing sugars are zinc (a component of insulin and of several enzymes), chromium (part of the glucose tolerance factor that allows glucose to enter the cells), and manganese (an important enzyme factor). In addition to these trace minerals, we need sufficient potassium and magnesium to produce energy from sugar. The vitamins most important for producing this energy from glucose are B1 and B2.

In contrast to former centuries, many people now suffer from vitamin and mineral deficiencies that make good blood sugar regulation nearly impossible and severely weaken the energy metabolism. On top of this, large amounts of sweet food are consumed almost daily, and the only “work” that many modern people do after a sweet snack is to raise a cup or stare at the television. The combined effect of all these negative factors is an erratic blood sugar level. It rises higher and higher after the ingestion of sweet food and falls more steeply and lower shortly afterwards.

Depending on one's metabolic constitution, this has different effects on different people.

Table 5-2: Symptoms of Allergy and Blood Sugar Problems

Allergies and blood sugar problems reinforce each other and can cause the same symptoms or contribute to the same chronic diseases.

abdominal pains	diabetes	irritability
addictions	diarrhea	joint pains
adrenal exhaustion	digestive problems	low blood pressure
aggressiveness	distended veins	migraine
alcoholism	dizziness	mouth ulcers
anemia	eczema	mucus congestion
angina	edema	muscle cramps
anxiety	emotional instability	muscle pains
arthritis	epilepsy	myopia
asthma	exhaustion	nervousness
autoimmune disease	eye weakness	neuralgia
backache	fainting	neuroses
bloating	fatigue	nose bleeding
blurred vision	forgetfulness	numbness
burning eyes	gallbladder pain	obesity
cancer	gastric pain/ulcer	palpitations
caries	glaucoma	phobia
chest pain	hay fever	poor circulation
chronic coughs	headache	rashes
chronic indigestion	heart attacks	respiratory problems
cold hands and feet	heartburn	schizophrenia
colds	haemorrhoids	sinusitis
colitis	hyperactivity	skin problems
confusion	hypertension	sweating
conjunctivitis	immune deficiency	tachycardia
constipation	indigestion	underweight
convulsions	infections	varicose veins
crying spells	inflammations	vomiting
depression	insomnia	weakness

If you look at Table 5-2, you may be surprised at the variety of symptoms that can occur and the number of chronic diseases to which a weak sugar metabolism contributes. The reason that sugar can cause such a range of problems is that glucose has a central position in producing our daily energy requirement. If our cells cannot efficiently produce energy, all our organs and body functions are affected.

How Diabetes Comes into the Picture: The disease most widely associated with a breakdown of blood sugar regulation is diabetes. When diabetes develops during childhood or in young adults (Type I), the main problem is usually a deficiency of the hormone insulin. Produced in the pancreas, insulin is required to channel the

blood glucose into the cells. Therefore, a deficiency of insulin leads to a rise in the blood glucose level.

Currently, accepted medical opinion does not see a connection between the overconsumption of sweet food and the development of diabetes. However, experiments have shown that the insulin sensitivity decreases with frequent use of sweet food. Starting with a raw food diet that excluded all sweet food as well as other problem foods, I have been able to help diabetics of both types to improve their blood sugar regulation so that insulin injections or drugs were no longer needed.

In adult-onset diabetes (Type II), there is usually sufficient insulin available, but its effectiveness is greatly reduced. The main reason for this is the “disaccharide effect” as well as a deficiency in chromium, which is part of the glucose tolerance factor. Insulin and the glucose tolerance factor work together like key and keyhole to let glucose into the cells, but a deficiency of chromium prevents glucose from entering the cells.

The reason for a chromium deficiency is the habitual consumption of refined and sweet foods. Refined food is deficient in chromium, while eating sweet food raises not only the blood sugar level, but also the blood chromium level; this causes more chromium to be excreted with the urine. Another effect of chromium deficiency in diabetics and others is the excessive formation of cholesterol after eating sweet food and the subsequent development of arteriosclerosis.

These same factors also lead to the formation of cataracts. A diet high in fructose is especially implicated in causing eye diseases in diabetics. Fructose and glucose are the two components of sucrose - the normal household sugar - and also of honey. Fructose (best if obtained from fruits only) can enter the cells without requiring insulin and thereby can help to normalize the diabetic metabolism, but this is risky if mineral deficiencies are not corrected at the same time, especially deficiencies in magnesium, zinc, and chromium.

In animal experiments, an excessive intake of sugar resulted in a greatly enlarged pancreas and pituitary glands, both of which are involved in blood sugar regulation. A group of Aboriginal diabetics in Australia who lived for several weeks on “bush food” all quickly returned to a normal blood sugar regulation. Similarly, Indians living in Natal (South Africa) have a high sugar consumption and high levels of diabetes and heart disease compared to Indians living in India who use very little sugar and have very low rates of these diseases.

Type II diabetics are generally treated with tablets to lower blood glucose levels. As with insulin, these hypoglycaemic drugs do not protect the patients against the various harmful complications of long-term diabetes, such as degenerative eye changes, especially involving the retina, degeneration of the peripheral nervous system, and atherosclerosis, especially affecting the legs and heart. On the contrary, studies seem to indicate that these drugs accelerate such degenerative changes.

Doctors W. H. Philpott and D. K. Kalita point out in Victory over Diabetes that the overwhelming evidence of recent studies shows a shortened life expectancy and more serious complications from using diabetic drugs. In fact, the death rate actually doubled in those taking oral diabetic drugs. Most of these same drugs are still in use today. From a biochemical point of view, this is only logical and to be expected

because if sugar levels are lowered without converting them into energy, then they have to be converted into fat and cholesterol (collectively called lipids) that then cause many of these problems.

When the liver and bloodstream are already loaded with lipids, it is difficult to convert excess glucose into more lipids. Therefore, obese or overweight individuals have greatly decreased insulin sensitivity, but insulin becomes much more effective if they lose weight. Other studies show that blood sugar regulation is best maintained with a diet high in vegetable fibre, especially from legumes, and that a high intake of simple carbohydrates or sugars tends to make insulin less sensitive (active).

Sugar added to the diet of research animals or increased in the diet of healthy volunteers has been reported to disturb the glucose metabolism and cause diseases of the eyes, kidneys, and blood vessels. Even if combined with a high-fibre, low-fat diet, added sugar still adversely affects the glucose tolerance. However, short-term studies may not show the harmful long-term effects of sugar in the development of Type II diabetes. This is because household sugar or sucrose consists of one molecule of glucose and fructose. Only glucose elevates the sugar level in the normal way, while fructose affects it only slightly. Therefore, in the glycaemic index, discussed earlier, which measures the immediate effect of different foods on the blood glucose level, sucrose is listed as a good food.

Instead, the danger of fructose is in causing an exaggerated insulin response, mainly when it is together with glucose in the same meal, be it from sucrose, honey, or even starches; to some degree, this happens even when ingested on its own as a sweetener. However, fructose in whole fruits is generally fine, provided it is not ingested close to a meal containing starches.

Let's look now at the common habit of eating sweetened starches, as in bread with jam, marmalade, or honey, cakes, cookies, muesli, or breakfast cereals. The fructose contained in the meal causes a strong rise in the blood insulin level. At the same time, a large amount of glucose from the breakdown of starches enters the bloodstream. The excess of insulin quickly channels the glucose inside muscle cells, which are now overloaded with glucose. Only a small amount is needed for energy production; the rest can be converted to lactic acid, causing overacidity, or to body fat. Gradually, cells learn to protect themselves by becoming less responsive to insulin and making it harder for glucose to enter.

Until 1980, the rate of obesity and Type II diabetes was fairly stable. However, when the health authorities in the U.S. started vilifying foods containing fats and cholesterol and recommended eating carbohydrates instead, obesity increased from 13 to 14 percent of the adult U.S. population to 25 percent within one decade and continues to rise. Type II diabetes became an epidemic as well. In addition, for the first time in history, a large number of obese children developed Type II diabetes. As a result, it is now not usually called adult-onset diabetes.[30]

While exaggerated insulin response and resulting loss of insulin sensitivity are most pronounced in obese individuals, they gradually develop also in others after prolonged use of sucrose. The damage is greater the more sucrose is eaten in a gorging pattern instead of in small meals at intervals.

Surprisingly, sucrose has a worse effect than eating its two components, glucose and fructose, at the same meal. This is called the disaccharide effect and applies also to other sugars with two components, such as maltose with two glucose molecules. A hormone in the duodenum releases more insulin after ingestion of disaccharides than after monosaccharides such as glucose or fructose.

While increased insulin levels are desirable for Type I diabetics, with Type II diabetes it just means that more glucose is being converted into fat and cholesterol. However, there is a way to increase the insulin sensitivity of muscle cells naturally, such as with regular aerobic exercise. This allows glucose to enter muscle cells without the aid of insulin. In addition, the five-carbon sugar alcohol xylitol can be used by both types of diabetics without increasing blood glucose levels, although large amounts may cause diarrhea.

Hyperactivity and ADD: Much more widespread than diabetes or hyperglycaemia is the opposite condition of low blood sugar or hypoglycaemia. The most common milder form is reactive hypoglycaemia, in which the blood sugar response after eating non-sweet foods is normal. However, when sweet food is eaten, including sweet fruits, too much insulin is released and glucose floods the cells.

Glucose cannot be stored in cells and has to be metabolized. How this happens depends on the condition of your metabolism. The first stages are easy and result in the glucose molecule being split in half; this process is anaerobic and does not require oxygen. However, oxidizing enzymes are necessary for the next stage and these are usually deficient in adults with this condition. Children, on the other hand, often still have a reasonable supply of enzymes and are able to convert most of the glucose to energy.

This creates an energy burst, whether it is needed or not, that has to be used. The result is extreme restlessness: The muscles must move to use the surplus energy, and the brain races as well. When the “straw fire” of excess energy is used up, insufficient glucose remains to sustain normal activity and attention. Mental and physical exhaustion follows, until a sweet snack lights another straw fire of hyperactivity.

This temporary speeding up of the energy cycle is exaggerated, and in other cases triggered, by various factors that cause stress on the nervous and hormonal systems. The most frequent cause of such stress is a hidden allergy to food additives and to common foods such as wheat and cow’s milk products. Usually a child’s favourite foods are also to blame. Additional triggers can be fluorescent lighting, television viewing, strong electromagnetic radiation, petrochemical fumes, tobacco smoke, Candida albicans, and emotional stress.

In adolescents and adults such energy bursts, especially when combined with exposure to dietary allergens or stimulants, can lead to periods of uncontrolled violence. Many studies, involving thousands of institutionalized male juvenile delinquents, have shown a large drop in the incidence of antisocial behaviour in those on diets low in sugar and allergens. While the average improvement rate was almost 50 percent, repeat offenders improved by more than 80 percent, and their suicide rate fell 100 percent.

Females, because of their lower adrenaline levels, tend less towards violent behaviour. Instead, the effects of the strong blood sugar fluctuations after ingesting sweet food are more internalized. In sensitive individuals, emotions closely follow the blood sugar levels, often going up and down in quick succession, alternating between elation and depression.

Problems of Hypoglycaemia: The speedy metabolism that results in hyperactivity and violent behaviour explains why the term “fast oxidizer” has been coined for those who burn sugar too quickly. “Fast oxidizer” and “hypoglycaemic” mean basically the same thing: someone who has a speeded-up glycolysis (the breakdown of glucose inside the cells), which results in a lower than normal blood sugar level.

As opposed to hyperactive children, most adult hypoglycemics have a shortage of oxidizing enzymes, and this interrupts the energy produced at the end of glycolysis. Instead of energy, lactic acid is produced in a final anaerobic stage. Thus, only 20 percent of the total energy that would be available if glucose were completely oxidized to carbon dioxide and water is produced.

This results in overacidity and a chronic lack of energy, which is typical of hypoglycemics who are on sweet diets. Additional energy is required to remove the lactic acid via the kidneys. Lactic acid must be partly neutralized and this depletes the body of positive ions, especially calcium. A further result of overacidity is a high histamine level, which makes us susceptible to strong allergic reactions and frequent inflammations, while the skin becomes oversensitive to stings and all forms of irritation.

High histamine levels together with a calcium deficiency cause low blood pressure, which contributes further to a lack of energy and poor circulation, typified by cold hands and feet. Calcium is withdrawn from the blood vessels, resulting in varicose veins. Calcium deficiency also creates menstrual problems and weakens the eyes, making us nearsighted.

Nearsightedness or myopia actually results from a deficiency of two minerals, calcium and chromium, and both are induced mainly by a high consumption of sugar. Chromium deficiency arises from eating too much refined food that lacks this mineral (which means we never get to absorb it) and also from increased excretion of chromium in the urine, which occurs after eating sweet food when the blood levels are raised in response to high levels of insulin.

The ciliary muscles in the eyes need chromium to focus the lens for near vision. If the ciliary muscles become fatigued from a combination of chromium deficiency and prolonged close-focus activity, then the eye relieves this muscle strain by increasing the intraocular pressure; this pressure in turn leads to an elongation of the eyeball and thus to myopia.

Increased intraocular pressure, however, leads to an elongation of the eyeball only in those of younger years, when the body has a high requirement for calcium. With increasing age, the tissues become more calcified and rigid. In this situation, the eyeball cannot expand with increased intraocular pressure and glaucoma may result.

Scientific studies have shown that the excretion of calcium in urine increases up to fourfold in those with a strong insulin response when given large amounts of

sugar; this is because plasma calcium levels are increased after eating sugar. The most common sources of the calcium excreted are the bones and teeth; this contributes to osteoporosis and dental caries. In elderly individuals, high plasma calcium levels also accelerate irreversible bonding with collagen and elastic protein structures, leading to increased rigidity and bone deformations, as evidenced in arteriosclerosis and arthritis. A high calcium concentration in the urine leads to an increased risk of kidney stones as well as kidney damage from the calcification of the filtration mechanism.

Lactic-acid formation that occurs after eating sugar contributes to strong inflammations such as in rheumatoid arthritis and gingivitis (inflammation of the gums). Normally, the saliva is nearly neutral in pH, which is less favourable for the growth of plaque bacteria than the acidic saliva of hypoglycemics. Sugars are the only energy source for these bacteria. When we are strictly on non-sweet diets, plaque bacteria are denied energy and they cannot multiply, and this effectively prevents caries.

Giving up sweet food, however, is extremely difficult for children and many adults because they are addicted to it. This addiction is in principle the same as later addictions to stimulants and drugs. Another effect of general overacidity is an inability to alkalize the gastric content when it enters the duodenum. This makes the pancreatic enzymes, which require an alkaline medium, inefficient and in time can lead to deficiencies and digestive problems (refer to acid-alkaline problems in Step 6).

Fructose and the Disaccharide Effect: It has been estimated that about half of all carbohydrates ingested in the U.S. are in the form of sucrose, common household sugar, which typically supplies about 15 to 20 percent of the total calories of the diet. One half of the sucrose molecule consists of fructose and the other half of glucose. Fructose is metabolized more slowly than glucose and also induces a much stronger insulin response in susceptible people, especially in the presence of glucose. This means that reactive hypoglycaemia occurs mainly when fructose is part of a meal.

Another effect of habitually high insulin levels is a gradual decrease in the sensitivity of blood glucose levels to insulin. Higher insulin levels also cause an increased loss of chromium in the urine. The result is the gradual onset of Type II diabetes. The higher the insulin levels, the more are sugars converted into fat and cholesterol. Biopsy samples of the human liver showed that fructose was converted into fatty acids at rates three to 24 times faster than glucose. Fat levels after fructose consumption rise especially high in those who have a tendency towards atherosclerosis; this can lead to diabetic complications and cardiovascular diseases. These negative effects of a high fructose intake also occur after eating sucrose. Other health problems arising from the fructose component in sucrose are raised blood pressure, caries, elevated uric-acid levels, and obesity.

Regarding sugar in general, controlled experiments with various species of animals as well as with human volunteers revealed significant rises in blood pressure not only after long-term ingestion of sugar, but even after a single dose. If taken on an empty stomach, the blood pressure rose 9 to 10 mm Hg for one to two hours. After sucrose ingestion, there is also an increase in uric acid levels. Uric acid is produced in the liver from breakdown products of fructose. A raised uric acid level in

the blood is a feature of gout, some forms of arthritis, and heart disease. Men generally produce more uric acid after eating than women do.

Experimental studies on animals and humans have shown that sucrose is possibly the most caries-producing substance in our diet. Plaque bacteria convert sucrose to polymers that stick to the teeth. Some individuals have inherited fructose intolerance and must avoid all fructose and sucrose; it's interesting that they have been found to have substantially less tooth decay than the general population does.

Various animal and human studies have also shown that a diet high in sucrose can lead to a greater accumulation of fat deposits in susceptible individuals, generally those with a strong insulin response. Monkeys fed a diet high in sucrose produced three times as much deposited fat than those fed an equal amount of glucose.

Surprisingly, eating a certain amount of sucrose produces a stronger insulin response than eating the same amount of mixed fructose and glucose. The same is true for maltose, which consists of two molecules of glucose and other disaccharides (disaccharides are composed of two simple sugars). The increased insulin effect of disaccharides compared to that of their component simple sugars is called the disaccharide effect, as noted previously. The reason for this effect seems to be that disaccharides liberate about twice the amount of a gastric hormone called GIP (gastric inhibitory polypeptide) that simple sugars do.

In practical terms, this means that it is harmful for most of us to have fructose and glucose at the same meal. Examples of this combination are: muesli or honey, dried fruit, or fresh fruit to sweeten cereals or starches; dessert or sweetened coffee or tea after meals. Most harmful are the sweetened starches, such as cakes, sweet cookies, or crackers, and sweetened breakfast cereals. Beware especially of mixing fructose with starches if you want to lose weight.

Problems with Natural Sweet Foods: Unfortunately, natural sweet foods such as honey, dried fruits, or fruit juices are no better for diabetics or hypoglycemics than food sweetened with white sugar. What seems to matter is how much sweet food is used and how quickly it enters the bloodstream. Fruits that are acidic as well as sweet may be even worse, especially for hypoglycemics, than plain sugar because the fruit acids reinforce the existing overacidity. However, by neutralizing fruit acids they can become beneficial, and eating the whole fruit is better than drinking the fruit juice only. Raw honey has a high concentration of the beneficial starch-digesting enzyme amylase, which is lacking in heated commercial honey; sun-dried fruit is healthier than commercial heat-dried fruit.

While fructose from fruits can be helpful for Type I diabetics, with hypoglycemics it only increases the lactic acid overload. Lactic acid overproduction from the combined effect of strong muscle activity and sweet food ingestion is also responsible for reported cases of allergic reactions after jogging. The resulting overacidity simply brings already existing hidden allergies into the open. Apart from the loss of calcium, another side effect of lactic-acid buildup is a tendency to anxiety neuroses, phobias, and panic attacks.

From a health viewpoint, it is preferable to have sweet food only occasionally and with a protein snack or meal. Removing the sweet taste from the tongue as quickly as possible helps minimize the insulin overreaction. Alternative sweeteners

such as the sugar alcohols manitol, sorbitol, and xylitol should only be used in small amounts. In larger amounts, they can cause diarrhea or keep the craving for sweetness alive, which in time leads to another binge on sweet food.

The leaves of the herb stevia have long been used in traditional cultures as a sweetener. They are 15 to 30 times as sweet as sugar and an extract can be 300 times as sweet. It is not known if large amounts of stevia ingested over long periods of time cause unacceptable side effects, but I regard it as safer than aspartame or other artificial sweeteners. It is acceptable to use in small amounts but do not use it instead of sugar in an addictive way. Other sweeteners, such as saccharine and aspartame (Nutrasweet), may cause allergies or worse. Fructose is the sweetest sugar, followed by sucrose. Glucose and maltose are less sweet but somewhat safer for most people, especially combined with starches. Maltose is available as barley sugar. Preferably, use maltose instead of sucrose for sweetening starches.

As a general rule, for most individuals it is best to reserve sweet food as a rare treat for special occasions rather than to use it as an everyday food. However, if you do not have a craving for sweet food, then it is not likely to be a problem for you. Those who have a low fasting blood sugar level (feeling weak or dizzy on an empty stomach) must be more strict than reactive hypoglycemics and are advised to avoid all sweet food for several years so that the sugar metabolism has time to recover.

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Step 41

MEAT & FAT

Overconsumption of meat and fats can create serious health problems. Try cutting back on your intake.

Those who eat a lot of red meat tend to develop the opposite characteristics and health problems to those on a sweet diet. Red meat has a stimulating effect on the sympathetic nervous system and adrenal hormones. This improves the ability to "push through" and provides "drive" such that heavy meat eaters may become powerfully assertive and even aggressive. Another important effect of eating red meat is a tendency for the blood pressure to rise because of meat's effects on the adrenal hormones and the nervous system. Among the meats, beef has the strongest influence on blood pressure.

All this can be beneficial for hypoglycemics with low blood pressure, lack of drive, and weak adrenaline glands, but for others, especially stressed males, it may mean hypertension and kidney problems. Health problems associated with eating meat fall into three categories: those common to all meat, those associated with cooked meat, and those with meat produced by factory farming.

Common to all meat is a high phosphorus content with an unfavourable phosphorus-to-calcium ratio. The high phosphorus content of meat stimulates the parathyroid glands (associated with the thyroid in the neck) and raises the calcium blood level, in some cases by activating and freeing calcium from the bones. In combination with a prevailing over-alkalinity, this leads to stone formation (such as kidney stones), kidney damage, arteriosclerosis, stiff joints, ankylosis, and arthritic bone deformations.

Heavy meat eaters have been found to excrete in the urine up to four times more calcium than normal; this is a cause of kidney stones and other kidney damage. It is even worse when high meat consumption is combined with a high sugar intake. This can increase the loss of calcium and corresponding kidney damage up to tenfold above normal, while at the same time greatly accelerating osteoporosis and tissue calcifications, such as arteriosclerosis.[31] Carnivorous animals in the wild do not have this problem caused by an excessive intake of phosphorus because they also eat the calcium-rich bones. We, too, can avoid this problem by using bone broth or other foods and supplements high in calcium.

Meat, because of its high phosphoric acid content, is regarded as an acid-forming food. However, in habitual heavy meat eaters or in those with a weak digestive system, the metabolic and hormonal stimulation resulting from red meat consumption gradually declines and eventually leads to a sluggish metabolism. These individuals are called "slow oxidizers." With a slow metabolism, a deficiency in metabolic acids develops and this makes the whole body too alkaline. With over-alkalinity, histamine remains tightly bound to tissue proteins and the skin. In such people, even the emotions are sluggish and they often appear unresponsive, with little outward expression.

With low histamine levels, inflammatory responses, which are required for many self-healing actions of the body, are suppressed. Allergens entering the bloodstream will not cause a warning allergic reaction; instead, autoimmune diseases may develop from a continued invasion of allergens. Histamine dilates the blood vessels, causing the blood pressure to drop, a problem of hypoglycemics. However, lack of histamine in slow oxidizers greatly contributes to the development of high blood pressure.

A diet high in meat, together with weak kidneys, often leads to the accumulation of uric acid in the muscles, causing gout and rheumatism. General over-alkalinity leads to a lack of gastric acid in later life, resulting in poor absorption of minerals and an incomplete digestion of proteins. Intestinal putrefaction and eventually cancer may follow, aided by chronic constipation and a depletion of pancreatic enzymes.

One problem of a diet high in meat and actually of all high-protein diets is the accumulation of protein fragments in the spaces between tissue cells. This causes or contributes to water retention or oedema. In addition, capillaries become clogged, preventing efficient nutrient supply to the tissues; lymph glands congested with protein fragments are breeding grounds for bacteria and weaken the immune system. All these complications aid the development of degenerative diseases and cancer.

The indicated problems, metabolic sluggishness resulting in over-alkalinity, and accumulation of uric acid and protein fragments can happen with any diet that is too high in protein and are more prevalent with a sedentary rather than an active lifestyle. They can be eased or prevented with an increased intake of fruit acids and digestive enzyme supplements, in addition to fasting or cleansing periods with a high intake of fluids.

However, in large measure these problems are not due to eating meat, but to eating cooked meat. Raw meat contains a high level of protein-digesting enzymes (cathepsin). Left to its own devices, meat tends to digest itself. Eskimos and other traditional cultures remained healthy on a diet high in flesh foods as long as they ate it mainly uncooked.

On a diet of cooked food generally, and especially with meat eating, the weight of the pancreas has been shown to increase. The pancreas of animals on cooked diets is about 300 percent heavier than it is for those on a raw-meat diet. I take this to mean that the pancreas becomes enlarged because on a cooked diet it needs to produce 300 percent more digestive enzymes than on a raw diet. Cooked meat is difficult to digest and needs particularly strong digestive juices. An aging body or one in poor health will not be able to keep up with this excessive enzyme production and enzyme depletion and deteriorating health will be the expected consequences.

While animals on raw meat remain healthy, those on cooked diets tend to develop a variety of degenerative diseases typical of human conditions. To remain healthy, dogs and cats need a raw-meat diet that includes offal and bones. Free-living carnivores not only eat their meat raw, they also eat bones and offal, have a very active lifestyle, and efficiently eliminate metabolic residues. If we want to remain healthy on a diet high in meat, then we have to adopt similar practices.

Health problems caused by cooking and enzyme depletion are aggravated by an accumulation of toxic chemicals and hormones. This is due to the common practice of factory farming. Chemical contamination is much worse in grain-fed beef from feedlots than in grazing animals. There are numerous studies showing the harmful effects of residues from pesticides, antibiotics, and growth promoters.

If we cannot obtain the meat of healthy, chemical-free animals and eat it predominantly raw (for instance minced or marinated), or use digestive enzymes and appropriate cleansing periods, then it is better for our health to eat meat only sparingly.

Fats and Oils: Fat is an important source of energy and some of its components, the polyunsaturated fatty acids and lipotrophic factors, are essential for our health. Fats and oils are composed of fatty acids, chemically linked with glycerol (a three-carbon sugar alcohol). While in a sense all fats and oils are often grouped together as fats or lipids, commonly we speak of fats when they are solid at room temperature and of oils when they are liquid at room temperature.

Fatty acids are long carbon chains (containing from four to 26 carbon atoms) with hydrogen attached to each carbon and an organic acid group at the end. In saturated fatty acids, every carbon position is filled with hydrogen, while unsaturated fatty acids have a reactive double bond between two carbon atoms. If there are two or three such double bonds, then we call it polyunsaturated.

Naturally occurring polyunsaturated fatty acids are folded in a specific way and called cis-fatty acids; during heating their structure changes to the more stable trans-fatty acids. Cis-fatty acids are important as structural ingredients of cell membrane and to facilitate oxidative energy production, but trans-fatty acids can interfere with these functions.

Animal fats consist mainly of long-chain saturated fatty acids with a high melting point. Beef and mutton have the hardest animal fats with the highest melting points; butter is marginally softer, due to its lower melting point.

A high consumption of these hard fats poses two problems. If no attempt is made to use sufficient polyunsaturated oils that provide the necessary essential fatty acids (EFA) and lipotrophic factors (e.g., lecithin and vitamin E), then a deficiency of these is likely to develop. The other problem is that the liver may not be able to metabolize an excess of long-chain saturated fatty acids.

The EFA's and lipotrophic factors are important in forming cell walls, for the immune system, and for platelet aggregation in blood clotting to prevent bleeding and unnecessary clotting. They also form tissue hormones called prostaglandins and other important biochemicals. Deficiencies in these nutrients can cause the following: a weak immune system; blood vessel and cardiovascular diseases; blood clots causing heart infarctions, paralysis, and strokes; skin problems, often starting with scaliness and including eczema, acne, and psoriasis; poor growth; impaired reproduction; and bronchial diseases.

Many degenerative diseases have been linked to an excess of saturated fats and a subsequent deficiency in EFA's; these include atherosclerosis, nerve and brain disorders, schizophrenia, psychoses and neuroses, rheumatoid arthritis, and multiple sclerosis. However, an oversupply of polyunsaturated oils can have its dangers as

well, especially if you are deficient in vitamin E. Polyunsaturated oils easily oxidize in contact with air to form oxides and peroxides that have a high potential for causing cancer and liver damage. This danger is greatest when these oils are refined and heated, as in frying.

The Problems with Saturated Fats: The liver has only a limited potential for handling fats. When the liver is flooded with a consistently high supply of saturated fats, it cannot metabolize them. Fats, by the way, do not come only from fatty foods; a surplus of carbohydrates can be converted into saturated fat. Only a small amount of carbohydrate can be stored as glycogen, so all the surplus energy from a carbohydrate meal is stored as fat.

Normally, fats are broken down into keto acids in the liver and transported by the bloodstream to other cells where they combine with products from sugar metabolism to create energy. When fats are oversupplied, there may not be enough glucose to produce energy efficiently, either because the carbohydrate intake is insufficient or because the effectiveness of insulin is reduced. A surplus of keto acids can then be resynthesised to saturated fatty acids and cholesterol (see Figure 5-2 in Step 43).

Another difficulty is that not all the fat is convertible into keto acids, and a high percentage of fatty acids and fat molecules are thus released directly into the bloodstream. The body may reduce these surplus fats by storing them in adipose tissue, forming fat deposits; this happens especially with heavy meat eaters who have become slow oxidizers, as explained earlier. Some portion of the fatty acids and cholesterol may then react with the usually elevated calcium levels of slow oxidizers to form fatty plaques, also called sludge, in the blood vessels.

Fatty deposits are called atheromas and consist mainly of smooth muscle cells filled with sludge, similar to fatty tumours. Such deposits can help cause arteriosclerosis and cardiovascular diseases. Not only animal fats, but also peanuts and peanut oil have properties that cause atherosclerosis: peanut oil contains some saturated fatty acids with unusually long chains, namely arachidic and behemic acid. However, these fatty acids seem to be beneficial for arthritic joints.

In those with sensitive skin, or especially during adolescence, the body tries to cleanse itself by removing fatty sludge through the sebaceous glands, causing acne and an unclean skin. Eating sweet food is as much to blame for this as is fat intake. Fats in the feet, for instance, have a melting point of 33° F, while fats of the inner organs melt at 114° F. If the diet contains too much saturated fat and sweet food, then the melting point of the outer fats will be raised. In cold parts of the skin, those that are exposed or with poor blood circulation, the fats will harden within the sebaceous glands and block the outflow of sludge or normal skin oils. This causes inflammation of these glands, as in acne and other skin problems.

Even worse than natural hard fats are those that are chemically hardened, such as margarine. During the hydrogenation process, non-biological fatty acids are formed called trans-fatty acids, which the body cannot properly metabolize and which interfere with the utilization of essential fatty acids.

Cardiovascular diseases and an increased incidence of cancer can be a frequent outcome of a diet habitually high in red meat and saturated fats, but so is

fatty degeneration of the liver. The blood becomes more viscous or sluggish after a fatty meal. This causes a reduction in tissue oxygenation and an increased susceptibility to arthritic pain, heart pain, or shortness of breath; blood flow to the brain is reduced, producing tiredness and decreased mental alertness.

Some of the adverse effects of fatty foods result from a deficiency of lecithin in the diet. Lecithin is a natural emulsifier of fats; it can be synthesized in the liver but often a deficiency develops because naturally occurring lecithin or choline is lacking in refined food. This is a main cause of fatty degeneration of the liver, which can be reversed, however, with organ cleansing practices, lemon juice, and lecithin supplements.

Another problem with a high-fat diet is the destruction of naturally occurring lipase in cooked food. Lipase is important as our main fat-digesting enzyme, and we rely to a significant degree on lipase in natural foods to supplement our pancreatic lipase. With the destruction of food lipase by heating, on a high-fat diet we gradually develop a lipase deficiency, and this leads to the development of fat-related diseases. Formerly, inhabitants of Bulgaria and the Caucasus lived on high-fat diets without developing fat-related diseases. They even consumed an abundance of full-fat milk products, yet were famous for their health and longevity. They generally used unheated fats, which seems to make the difference.

Here is another example of the significance of natural lipase in our diet. The skin disease psoriasis is generally aggravated by fatty foods, and fats must be avoided to cure it. However, in the early twentieth century, an American doctor reportedly cured psoriasis routinely with an intake of two pounds of raw butter per week for six weeks and with reduced amounts afterwards. Modern pasteurized butter definitely aggravates psoriasis but raw butter cures it - what is the difference? Raw butter from free-ranging cows is very high in lipase and pasteurized butter is devoid of it, so the difference may be lipase.

The healthiest saturated fat may actually be unheated coconut oil. This is due to its high content of short-chain fatty acids that can easily move into cells to be converted to energy. The long fatty acids of other fats, in contrast, require L-carnitine for this process. Individuals who have added coconut oil to their diet generally seem to have more energy without putting on extra weight.

Cholesterol: Cholesterol is now portrayed as the great medical villain causing cardiovascular disease and heart attacks by clogging the arteries, especially the coronary arteries of the heart muscle, with fatty sludge. However, cholesterol is an extremely valuable biochemical. It forms the base of steroid hormones and vitamin D and it is highly concentrated in the brain, liver, adrenal glands, and nerves. Hypo-glycemics or fast oxidizers usually have low levels of this important nutrient, and recent studies link low cholesterol levels with an increased risk of cancer.

Excess cholesterol is normally excreted with the bile but may form gallstones if there is a lack of lecithin and the amino acid taurine needed to form bile salts. The cholesterol content of food is not normally a problem in itself. Most cholesterol in the body is formed in the liver from breakdown products of saturated fats, and the more cholesterol that is ingested with food, the less is synthesized. Thus the body's overall cholesterol level normally remains stable.

You may read about HDL and LDL in connection with cholesterol and heart disease. HDL is short for high-density lipoproteins and LDL for low-density lipoproteins. Lipoproteins are biomolecules composed of proteins and lipids; they can be used to transport cholesterol between the liver and tissue cells. Those that carry cholesterol from the cells to the liver are the high-density lipoproteins, regarded as beneficial. Their cholesterol is called HDL cholesterol. Low-density lipoproteins carry LDL cholesterol from the liver to tissue cells; a low level of these is preferable.

The aim of medical intervention is to increase the level of HDL cholesterol and lower the level of LDL cholesterol in the blood. However, I am not convinced of the value of the medical strategies being used in reducing or curing cardiovascular disease. Therefore, I tend to disregard measurements of HDL, LDL, and cholesterol and specific interventions to normalize levels; instead, I focus on a natural lifestyle to improve health.

Cholesterol overproduction arises mainly from an excess of saturated fats and a deficiency of chromium. The body tries desperately to lower the keto acid and fatty levels in blood and liver, and cholesterol overproduction provides a temporary solution. Even elevated glucose and fructose levels can be reduced by their conversion into cholesterol. In this way, sweet foods contribute to the development of cardiovascular diseases. Sugar ingestion raises the insulin level, and a key enzyme that synthesizes cholesterol is actually regulated by insulin. The higher the sugar intake, the higher the insulin level, and thus the more cholesterol synthesized in the liver.

A higher intake of polyunsaturated oils in males can lead to some decrease in cholesterol levels. However, in women it has led to an increased risk of cardiovascular disease. In animal experiments, it was found that high-sugar diets were less damaging in the presence of saturated fats such as beef tallow or coconut oil. Despite huge efforts, medical research so far has not conclusively shown that a high cholesterol diet or high cholesterol blood levels cause heart disease. As we can see from the published scientific facts, it is often the contrary:

- Medically supervised trials with low-cholesterol diets were unsuccessful in significantly lowering blood cholesterol levels or reducing the risk of heart disease.
- Low blood cholesterol does not mean freedom from heart disease. Some drug treatments to lower cholesterol have resulted in increased rates of heart disease.
- About 50 percent of men under the age of 55 who die of heart attack do not have elevated cholesterol levels or any of the other risk factors such as hypertension, smoking, obesity, or diabetes.
- Some cultural groups have a low risk of heart disease despite a high intake of cholesterol; Western populations also had this before the compulsory pasteurization of milk products and the chlorination of water supplies.

Recently an evaluation was published of six major trials that lowered cholesterol in the blood in tens of thousands of individuals over many years. There was on average a cholesterol reduction of about ten percent and only a small reduction of 14 percent from death of coronary heart disease. However, the total number of deaths was significantly higher among those patients who had their

cholesterol lowered compared to the control group. This included not only higher mortality from cancer but on average a 67 percent higher mortality rate from violent death, such as accidents, homicides, and suicides. This high rate of death from violent causes was found in every one of these trials.

In looking for an explanation for this increased violence, in another study researchers found that monkeys on a diet low in cholesterol and saturated fat became more aggressive. Studies on humans found lower cholesterol levels among criminals and individuals with aggressive or violent behaviour or limited self-control. This is probably due to a more erratic sugar metabolism that results if cholesterol and fats are curtailed in an inappropriate way. Erratic blood sugar fluctuations tend to induce uncontrollable mood swings, including aggressive behaviour. Criminal and aggressive individuals have been frequently shown to have an erratic or hypoglycaemic-type sugar metabolism.

After decades of habitual sugar and meat consumption, the insulin level rises permanently because of a reduced efficiency in controlling glucose levels. Then cholesterol levels also remain chronically high. Reducing cholesterol in this situation with drugs means that less sugar is converted into cholesterol. Therefore, blood sugar levels become more erratic and behaviour is more aggressive. Thus, low cholesterol diets are appropriate only if the diet is also low in sweet food.

There is a connection between cholesterol intake and atherosclerosis and heart disease. If cholesterol in food is heated in the presence of oxygen, then cholesterol is oxidized to oxy-cholesterol and this damages the blood vessels and causes atherosclerotic lesions. Once such lesions exist, normal cholesterol in combination with high calcium levels can also contribute to a further buildup of plaque. In experiments using animals, it was found that with high intakes of either cholesterol or oxy-cholesterol, atherosclerotic degeneration occurred only with oxy-cholesterol, not with cholesterol.

Oxy-cholesterol is carcinogenic. The high incidence of cardiovascular disease and atherosclerotic aging processes may be traced in part to the heating (especially frying) of meat, eggs, and milk products, which liberates oxy-cholesterol. Avoiding this and chlorinated water and using high levels of antioxidants could also ensure that cholesterol does not become oxidized inside the body.

In conclusion, to avoid cholesterol-related health problems:

- Minimize the use of sweetened food, heated fats and oils, and chlorinated water.
- Maximize the intake of unheated fats and oils, antioxidants, and fresh raw foods.
- Lower your high cholesterol levels with cleansing periods and plenty of lemon juice.

Omega-3 Fatty Acids: There are two groups of essential fatty acids, or EFA's. The common oils from warm climate seeds (sunflower, safflower) contain mainly the omega-6 series of EFA's, based on linoleic acid with two unsaturated or double bonds. Cold climate plants and fish oils, on the other hand, contain mainly omega-3 fatty acids. Linolenic acid in linseed (flaxseed) with three double bonds has the

shortest carbon chain in this group. In fish oils, DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) predominate.

The omega-3 fatty acids have generally been neglected in modern nutrition. This has led to widespread deficiency symptoms and chronic disease. Their fundamental importance can be seen in the fact that DHA is the main unsaturated fatty acid in the retina and the brain and is exceptionally high in the thymus and reproductive glands, especially the testes. DHA is obviously most needed during pregnancy and early infancy for brain and gland development. It is up to 30 times higher in breast milk than in cow's milk or formula. This may bear some relation to epilepsy and eye weakness in infants, and its deficiency has also been linked to colic; inflammation of the lungs, digestive tract, joints, and kidneys; crib death (SIDS); skin diseases; and a predisposition to frequent infections. A recent scientific study reported an eight-point higher intelligence quotient in preterm babies fed breast milk as compared to those on cow's milk formula. As explanation, the deficiency of DHA in cow's milk was cited.

Fish oils are now commonly used to prevent heart disease, while linseed oil with its 45 percent alpha-linolenic acid has been successfully used to help treat various mental diseases. Even severe cases of schizophrenia and manic-depressive illness have reportedly been overcome or even controlled with ingestion of linseed oil. One or two tablespoons of linseed oil daily can help overcome depression, but twice that amount can cause a manic episode with racing thoughts, so too much has its downside.

Generally, however, this dosage can be increased about tenfold before negative symptoms develop. Mood swings, irritability, and anxiety can be relieved, and premenstrual tension and other menstrual problems and vaginal dryness after menopause are improved; prostate enlargement, arthritis, eye problems, immune deficiency, hair loss (alopecia areata), obesity, and skin problems are also often relieved.

EFA's and especially the omega-3 fatty acids (such as DHA and EPA) regulate the fluidity or softness of the cell membranes. A deficiency is noticeable as a hardening of the skin, as with dry, scaling, and flaking skin, patchy eczema, acne, and skin sensitive to the sun. Most common is phrynoderma, with rough, hard skin on the buttocks, thighs, and arms. The colder the climate, the more omega-3 fatty acids are needed for membrane fluidity.

The omega-6 series predominantly form prostaglandins that increase inflammation and with this the pain experienced in many diseases. The omega-3 series form anti--inflammatory prostaglandins. Thus, omega-6 fatty acids aggravate allergic reactions, including asthma and rheumatoid arthritis, while omega-3 fatty acids reduce these. Another important function of both groups of EFA's is in the production of oxidative energy. Also, the "brown fat" that produces and regulates our body heat is mainly stimulated by omega-3 fatty acids. This is especially important for overweight individuals who want to convert body fat into body heat and for those who habitually have cold hands and feet.

While individuals with deficiency symptoms related to omega-3 EFA's require a higher intake for some time, it is generally estimated that a normal diet should provide two to three percent of calories from omega-3 and five to ten percent from

omega-6 fatty acids. In contrast, the average modern diet provides about 0.4 percent of calories from omega-3 and ten percent from omega-6 fatty acids. You can clearly see the imbalance.

While using polyunsaturated oils instead of saturated fats has been found to reduce the cholesterol level and incidence of cardiovascular diseases, the rate of cancer has risen, presumably due to the combination of an inflammatory effect, antioxidant deficiency, and rancidity of refined oils. Biological damage can result from the peroxides and free radicals (highly reactive molecule fragments) formed from polyunsaturated fatty acids, and the common seed oils also have a strong inflammatory influence as they tend to form pro-inflammatory tissue hormones. This not only increases allergic reactions and arthritic inflammations, but also supports the growth of tumors.[32] In addition, it has been reported that melanoma sufferers had a higher rate of polyunsaturated fatty acids in their skin than non-affected individuals.

A high intake of polyunsaturated oils also requires a greatly increased intake of antioxidants, especially of vitamin E. However, refined oils as well as our normal diet are usually very low in vitamin E. This, in addition to a low intake of bioflavonoids and carotenoids, is probably a main factor in the present high incidence of skin cancer.

Health problems are further caused by the improper production of polyunsaturated oils. These oils are very delicate substances that should be produced and stored at cool temperatures and in conditions that exclude oxygen and strong light. Instead, they are typically extracted with chemical solvents or cooked and pressed hot and then refined with bleaching and deodorizing at very high temperatures. Even many cold-pressed oils are refined in this way. This causes oxidative damage to the oils and a structural change by which a high percentage of the natural cis-fatty acids form unnatural trans-fatty acids. Packaging oils in clear plastic bottles instead of brown glass bottles means they are exposed to light and can dissolve chemicals from out of the plastic, thereby contaminating the oil.

One oil, though reasonably high in omega-3 fatty acids, should be avoided. This is canola or rapeseed oil. There are medical warnings that an ingredient called erucic acid apparently can agglutinate (clump together) red blood cells and reportedly contribute to loss of vision or blindness, emphysema and other respiratory problems, anemia, and problems with the central and peripheral nervous system.

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Step 42

CHEMICALS IN YOUR FOOS

Minimize your exposure to toxic chemicals, water additives, and yeasts and moulds - your body will thank you for it.

Almost all our foods contain non-biological chemicals to some degree. It starts with water-soluble fertilizers that are overused in agriculture and cause mineral imbalances and trace mineral deficiencies in our crop plants; it continues with the liberal use of herbicides, pesticides, and fumigants. Many of these leave residues on foods we ingest. Growing our food crops using common water-soluble fertilizers causes a similar disturbance to the plant metabolism as a high-sugar diet does to a human hypoglycaemic metabolism. The cells are flooded with some nutrients, while others go lacking.

While there are now high amounts of non-biological chemicals in our food, essential nutrients in these foods are becoming rare. John D. Hamaker in The Survival of Civilization gives the following example of trace mineral deficiency induced by using fertilizers. In 1948, the highest iron concentration in cabbage was found to be 94 ppm (parts per million) and the lowest was 20 ppm. By 1963, the average value had dropped to four ppm. The story was similar for other vegetables. The general conclusion is that the average trace mineral content of vegetables in 1963 was close to or even lower than the lowest concentrations in 1948.

The latest results show that vitamin and mineral concentrations are much lower now. The food tables of the U.S. Department of Agriculture for the year 2000 show that the typical vitamin C content of broccoli, cauliflower, and spinach is only about half of what it was in 1963. Also vitamins A, B1, and B2 have declined sharply since then, and the calcium in corn has decreased by 78 percent.

The content of trace minerals can vary in the same type of vegetable by more than 100 times, depending on the quality of the soil in which it is grown. The selenium content in wheat was found to vary from 0.6 mcg/100 g in parts of New Zealand to 130 mcg/100 g in parts of Canada. The vitamin content can fluctuate to a similar degree. The vitamin and trace mineral values listed in food tables are therefore often completely meaningless, especially when the original values are decades old. The trace mineral content of our arable land is now extremely low and rapidly declining even further because of heavy cropping without replacing what has been taken out.

Trace minerals in the soil originate from disintegrating rocks. In order to remineralise the soil, crushed rock would need to be distributed over our cropland. Improved agricultural conditions must be maintained by returning to the soil whatever has been taken out, using composting and organic farming methods.

Heavy use of water-soluble fertilizers allows cropping in poor soils, but plants become deficient and offer little resistance to disease and insect attacks. This then justifies the liberal use of highly toxic agricultural chemicals, part of which remain in the plants and fruits and are eventually ingested by us. The most commonly affected

are commercially produced fruits. Agricultural chemicals can then accumulate in the body, especially in fat tissue, and they can also damage the liver. Organo-phosphate insecticides, for instance, can cause weakness, muscular trembling, cold sweats (an early sign of liver damage), irritability, tightness of the chest (asthma), nausea, and abdominal pain. Organo-chlorine insecticides, which include DDT, lindane, 2.4-D and 2.4.5-T, are even more toxic to humans. They affect mainly the nervous system and can cause a wide variety of symptoms including convulsions, numbness of extremities, uncontrollable excitement, apprehensions, allergies, and birth defects.

More recently, pesticides and herbicides used on farms and in households have been increasingly linked to neurological diseases, such as Alzheimer's and Parkinson's. Develop-ment of symptoms due to low-level chronic exposure is gradual, but it has been suggested by researchers that long-term exposure to sub toxic levels of chemicals is much more likely to lead to neurological disorders than to physically based diseases. In animal experiments, chronic systemic pesticide exposure reproduced the features of Parkinson's disease.

People who use pesticides in their homes are twice as likely to develop Parkinson's disease as people not exposed to domestic pesticides. Also, a combination of different pesticides is more likely to cause greater toxicity problems than exposure to individual chemicals.

Paraquat, a common herbicide, and maneb, a common fungicide, did not affect mice that were exposed to either one of them. However, when the chemicals were used together, dopamine neurons (brain cells needed to regulate voluntary muscle movements) began to die at low exposure levels or at only a fraction of what is normally regarded as toxic. Ongoing exposure leads to progressive neurotoxicity.

There are many combinations of low-level toxic residues in our food and water, and no one knows what health effects they can produce. However, one can speculate. Only 100 years ago, cancer and Parkinson's disease were relatively rare and affected only old people. Now they are epidemic and even children and juveniles develop these degenerative diseases. Cancer and especially breast cancer have been strongly linked to pesticide accumulations in the body.

Some widely used fumigants can pose an additional hazard to our health. Organic bromides, especially methyl-bromide, destroy the pantothenic acid (an important B-vitamin) in fumigated grain and can cause serious deficiency disorders. Later on, the fumigant may not be detectable in the grain, which is then regarded as completely "safe." However, the germination power of such grains can be very poor, which shows they have been damaged.

Our unsound farming, refining, processing, and cooking methods ensure that we receive only a fraction of the vitamins and trace minerals that we would get from unprocessed raw food grown in good soil. However, these extremely low values are now regarded as "normal" by health authorities because the classical acute symptoms of serious deficiencies are still absent in most people. Apparently, no thought is given to the long-term effects of multiple subclinical deficiencies.

Meat, poultry, and eggs can contain residues of antibiotics, pesticides, and synthetic hormones acting as growth promoters. Hormones are supposed to be destroyed during digestion and therefore are regarded as harmless. However, this

may not be so with synthetic hormones or when the digestive system is weak. In addition, a surprising number of nutrients can be absorbed through the mouth tissue, including giant molecules such as vitamin B12; this type of absorption may also include hormones otherwise not absorbed. For example, secondary sex changes have been reported due to the habitual consumption of hormone-treated chicken.

Besides liver degeneration, various forms of allergies, and leukaemia, chemical overload has been linked to chronic fatigue syndrome, ME (myalgic encephalomyelitis), and motor-neuron disease. Individuals with these diseases seem to have a liver that is less able to detoxify non-biological chemicals.

Chemicals Added to Foods: An even greater health hazard is the multitude of chemicals directly added to food products. These include preservatives, colours, flavours, emulsifiers, stabilizers, and so forth. Such chemicals need to be detoxified in the liver, but the volume typically ingested can contribute to liver damage. Many of these chemicals are fat-soluble and get stored in our fatty tissues. During prolonged fasting or disease resulting in weight loss, these chemicals may be released into the bloodstream in excessive amounts and cause distressing symptoms.

Nitrates and nitrites are added to most processed meat products. They can damage the blood and the thyroid gland, and in pregnant women, the foetus; they can also cause severe vitamin-mineral deficiencies and may be transformed into cancer-causing nitrosamines in the intestines. Sulphites (e.g., sulphur dioxide and metabisulphite) are widely used in processed foods, such as frozen foods, dried fruits, fruit juices, wine, beer, and prepared restaurant foods. In susceptible individuals, they can cause a swelling of hands, feet, and larynx, dermatitis, abdominal distress, and respiratory problems that especially affect asthmatics.

Food chemicals frequently cause allergies and trigger hyperactivity. This applies especially to synthetic colours. Artificial sweeteners, and especially aspartame, have been linked to a high rate of brain tumours, serious metabolic and neurological complication in diabetics, epilepsy, toxicity in the thyroid, and emotional disorders. While most of these chemicals are added only for the manufacturer's convenience, the food industry could easily use vitamins C and E as well as lecithin and other biological chemicals as antioxidants, preservatives, and emulsifiers.

Another group of food additives called excitotoxins act like neurotransmitters (brain chemicals that transmit nerve signals) and overstimulate the brain in susceptible people. Excitotoxins are taste or flavour enhancers that release glutamic acid or glutamate. Aspartic acid and cysteine are also brain-active amino acids or excitotoxins. The best known example of an excitotoxins is MSG or monosodium glutamate, a salt of glutamic acid. High blood levels of this can cross the normally protective blood-brain barrier.

Glutamate is a neurotransmitter that is present in the extracellular fluid only in very low concentration. If levels are inappropriately raised through food ingestion then neurons fire abnormally, and at higher levels of contamination brain cells begin to die. Oxygen deficiency and lack of fuel (hypoglycaemia) interfere with the energy production of brain cells and make them susceptible to damage by excitotoxins. This may be an important factor in the development of neurological diseases.

Excitatory amino acids cause problems mainly when they are used either in high concentrations or in free form; while bound, as they are in most natural foods, they are only slowly released and therefore harmless. Most processed foods, however, contain excitotoxins, especially if any kind of commercial taste or flavour enhancer has been added, such as hydrolyzed vegetable protein, soy protein extract, yeast extract, beef stock, or caseinate; commercial soups, sauces, and gravies are usually most implicated. Beware, because on the label any of these products may be called “natural flavouring.” Aged proteins, processed meat, cheeses, and tomato purees have higher levels of free glutamate as well, but fresh tomatoes are fine. All of these products containing excitotoxins should be avoided by sensitive individuals and their use minimized by others.

Water Chlorination: Chlorination of our drinking water is yet another instance of an added substance (chlorine) that is detrimental to our health. Besides microorganisms in the water, all other organic matter present will be chlorinated. This produces a wide range of chlorinated chemicals with carcinogenic and other disease-causing properties.

Reluctantly, even health authorities now admit that there is a health problem, but they play it down by focusing only on trihalomethanes (THM’s). These are very small compounds, consisting of one carbon atom with several attached chlorine or bromine atoms. The most prevalent of these is chloroform (trichloromethane), a THM that is carcinogenic to rats and mice. You cannot protect yourself against THM’s, as they are absorbed through the skin if you swim in a chlorinated swimming pool or have a hot bath or shower with chlorinated water. A hot shower can raise the level of THM’s in the blood ten times higher than drinking a quart of chlorinated water.

While a large number of studies found an association between chlorinated water and secondary chlorination products with an increased risk of cancer, especially cancer of the bladder, I regard this only as the tip of the iceberg. The association of THM’s with bladder cancer shows that they are relatively harmless, because they are being excreted. I contend that the main health damage is caused by long-chain chlorination products that remain in the body.

The level of chlorine in treated water is about 100 times higher than the level of THM’s. There is no doubt that chlorine reacts with all organic matter, but especially with sensitive biochemicals, such as unsaturated oils, cholesterol, and vitamins. This reaction occurs when food is washed or cooked, when bread is baked, and when commercial fruit juices or soy milk are made, and it occurs within your body if you drink chlorinated water. These chlorination products have long carbon chains and remain stored in the body, just like chlorinated insecticides (e.g., DDT), to which they are closely related. In the same way that health authorities did not believe that ingesting pesticides would cause health problems, so they now believe that these long-chain chlorination products do not cause health problems. I regard this as being complacent and incompetent in protecting public health.

All or most chlorinated organic compounds that have been tested have been found to damage our health. It is also a fact that our liver is not equipped to detoxify chlorinated chemicals. Putting all of these facts together leads to the inescapable conclusion that chlorinated water damages our health to a considerable, although

unknown, degree. In the next chapter, I provide more information on the connection between chlorinated water and cardiovascular disease.

Focusing only on THM's, health authorities maintain that the antimicrobial benefits of water chlorination outweigh its health dangers, and that there is no reasonable alternative to keep water supplies safe. I strongly disagree. I do not regard as "safe" water that causes cancer and very likely contributes to most other chronic and age-related diseases. There are thousands of water treatment plants in Europe that provide safe water without chlorine, using ozone, ultraviolet light, membrane filters, and slow sand filters instead. While this may be initially somewhat more expensive than using chlorine, in terms of preventing chronic diseases it will be immeasurably cheaper for individuals as well as the public purse.

In the meantime, you need to protect yourself from the dangers of chlorinated water. If you live in the country, you may have access to rainwater or bore water; otherwise use filters or reverse osmosis to purify water used for drinking and cooking, and install a shower filter. Distilled water needs an additional carbon filter to remove chlorine and THM's. For temporary use, when these are not available, you can remove most of the chlorine and THM's by briefly boiling the water and using it after it has cooled. Also, a bath can be filled with hot water and the room ventilated before getting into the bath. Skin contact with chlorinated water not only allows the absorption of THM's, it also ages the skin. You can counteract this by rubbing the skin afterwards with reduced ionized water or with a diluted vitamin C solution.

Water Fluoridation: Equally short-sighted is the official campaign to fluoridate our water supply. Modern dentistry tries to retard the growth of plaque bacteria that causes cavities by mechanical means and by poisoning the bacteria with fluoride. Fluoride is a strong enzyme poison. When present in sufficient concentration during development of the teeth, it is incorporated mainly as insoluble calcium fluoride. The lactic acid produced by plaque bacteria after the ingestion of sweet food dissolves traces of calcium fluoride from the teeth and this poisons their enzyme systems, retarding the development of caries.

However, the fluoridation of our water supply and the liberal use of fluoride toothpaste introduce dangerously high concentrations of fluoride in a very active and toxic form. This endangers our enzyme systems and greatly -contributes to a weakened metabolism in many people, and thus to the development of allergies, arthritis, cancer, and hypoglycaemia. Excessive fluoride exposure has also been linked to hip fractures, hypothyroidism, Alzheimer's disease, and reduced IQ. The bulk of scientific research shows that added fluoride does not protect the teeth of adults or children.

In natural groundwater, such as bore or spring water, fluoride sufficient for tooth protection (up to one ppm) occurs mainly in the form of calcium fluoride. While this is insoluble in high concentrations, it is sufficiently soluble in the minute amounts required for tooth protection. In this form, and also when the blood level of calcium is high, fluoride is less toxic. Fluoride causes the most damage in calcium-deficient bodies, usually children and hypoglycemics or fast oxidizers.

Seafood and especially kelp are high in a safe form of fluoride. However, using these in addition to fluoridated water and toothpaste might exceed safe fluoride

intake levels. Caries, and the health problems due to artificial fluoridation, can be avoided by using kelp and restricting the use of sweet foods.

The United States is one of a very few countries that still promote water fluoridation. Most of Western Europe has outlawed it; even most of U.S. communities, when allowed to vote, have rejected fluoridation; this has happened in more than 50 communities since 1999. (For further information on the health dangers of fluoride and a good bibliography of the scientific literature on fluoride, see: www.fluoridealert.org.)

Aluminium: Another mineral harmful to our health that is added to our drinking water to precipitate impurities is aluminium. This is not a so-called heavy metal, but it causes health problems nevertheless. We can also ingest it with some brands of baking powder, free-flowing salt, or aluminium hydroxide antacids, but most commonly we absorb it through using aluminium cookware and utensils. Most dangerous to our health are acidic foods that are left in contact with aluminium surfaces. Aluminium easily dissolves in weak acids, which are present in fruits, tomatoes, cucumber, rhubarb, and beets. Even heating tap water in an aluminium pot was shown to add 1600 mcg of aluminium per litre of water, which is 3200 percent over the recommendation of the World Health Organization, which sets a limit of 50 mcg per liter.[33]

In the body, aluminium acts as a neurotoxin, causing brain disorders, though symptoms develop slowly. They may include senile dementia (Alzheimer's disease), Parkinson's disease, reduced memory, slow learning, motor neuron disease, overactive parathyroid glands, and fatigue. Aluminium lowers the permeability of the blood-brain barrier to other harmful chemicals and increases the incidence of epileptic seizures. You can protect yourself from aluminium ingestion by using filtered water and glass, ceramic, or enamelled cookware. I do not recommend stainless steel, as nickel can leach out during cooking, especially with acidic water or food, and nickel is known to be carcinogenic.

Mercury: Chronic mercury poisoning can originate from certain pesticides and fungicides, calomel laxatives, predatory fish, and especially amalgam tooth fillings. Such fillings release mercury from broken-off pieces that dissolve in the stomach and also from evaporation in the mouth that is caused by pressure on the fillings during chewing. Old fillings are thus much lighter than new fillings because they have lost most of their mercury. Acidic foods increase the rate at which mercury fillings disintegrate. The mercury loss from several amalgam fillings over ten years has been calculated at about 560 mg, or 150 mcg per day, and almost all of this is absorbed and stored in body fat, especially in the brain.

Symptoms of mercury poisoning include: fatigue, lethargy, depression, irritability, shyness, loss of short-term memory, allergies, respiratory infections, decreased immune response, increased salivation, gingivitis, loose teeth, mouth ulcers, nervous heart problems, digestive problems, and dermatitis, as well as changes in hearing, vision, speech, and writing. Most prominent are nervous system disorders with serious mental disturbances. Many symptoms are actually the same as in multiple sclerosis. The present epidemic of autism has been linked by some researchers to a high level of organic mercury compounds used as preservatives in some childhood vaccines.

Case reports for patients after removal of all their amalgam fillings include cure of leukaemia and Hodgkin's disease, regaining vision after 23 years of blindness, cure of moderate to severe headaches that had persisted for 50 years, cure of arthritis, and a reversal of general malaise with fatigue and depression. Minimize amalgam-related health problems by refusing any new fillings containing mercury, and contemplate replacing any old amalgam fillings; for this, see a holistic dentist.[34] For more details on dental health, review Step 8. For practical advice and support, contact: www.amalgam.org; for wide-ranging scientific information on the negative health effects of amalgam fillings and heavy metals: www.melisa.org. An independent researcher, Bernie Windham, has assembled hundreds of clinical studies on the problems caused by amalgam fillings and harmful metals at: www.home.earthlink.net/~berniew1/.

Mercury exposure from eating fish has greatly increased in recent decades. Even health authorities acknowledge that there is now a problem and advise avoiding large predatory fish, especially for pregnant women. Some studies show that on average more mercury is accumulated from fish than from amalgam fillings. The same health problems caused by dental mercury are caused by mercury from fish. Only non-predatory fish or small predatory fish are reasonably safe to eat on a regular basis. You can check the safety of commonly used fish species at: www.ewg.org.

The Pros and Cons of Cooking: Cooked food has been a hallmark of civilization. Cooking breaks down cellulose in vegetables and connective tissue in meat and thus makes these foods easier to chew and more palatable. Bacteria are destroyed at the same time, making these foods safer to eat, but only if eaten immediately after cooking. During storage, raw food remains much more resistant to microbial contamination than cooked food.

The price we pay for this convenience is a loss of vitamins and minerals, the destruction of enzymes and plant hormones, denaturing of proteins, oxidation of lipids, loss of vitality or life force, and formation of harmful chemicals at temperatures above the boiling point. Vitamins are destroyed by the combined action of oxygen and heat; minerals react to heat in ways that make them less easily absorbed; and both vitamins and minerals are lost if cooking water is discarded.

When food is heated above 180° F, protein becomes denatured or unbiological; it changes its internal structure (the way it is folded), and the immune system reacts as if it were attacked by foreign invaders. The digestive system is flooded with white blood cells after eating this food. This is called digestive leukocytosis: The white blood cells or leukocytes try to prevent food toxins from reaching the bloodstream. The higher the food is heated or the more refined it is, the stronger is the resulting leukocytosis. This defence reaction against toxic food does not take place after eating raw food. Leukocytosis is a continued strain on our immune system and is an aggravating factor in leukaemia and immune deficiency. Animals and humans evolved on raw food only; cooked food is a recent invention in evolutionary terms.

When food is heated above the boiling point, chemical reactions take place that create toxic chemicals in the food. For a long time it has been known that carcinogenic substances are produced in highly heated meat, but the more recent discovery of similar chemicals in heated cereal or grain products has come as a

shock to the food industry. When foods are heated to above the boiling point, advanced glycation end products (AGE's) are formed, some known as acrylamides. These toxic products result from a reaction of carbohydrates with proteins. They are produced at a slow rate at low temperatures, but in high amounts when food is highly heated, as in frying and baking. Acrylamides are known to be cancer-causing in animals and to cause DNA damage with gene mutations.

Another scientific finding is that acrylamides are pro-inflammatory and the more these chemicals are in the diet, the more inflammation they cause. Almost all diseases are associated with inflammation, including arthritis, cancer, diabetes, and heart disease. The more inflammation, the worse are the disease and associated pain. This may be a main reason why most diseases greatly improve and chronic pain tends to disappear on raw food diets.

AGE's are yellow-brown, like another group of chemicals related to heat and oxidation, the lipofuscins, which are composed of oxidized fats and proteins. Together, these chemicals accumulate as waste material in nerve and skin cells and impede their functions. Sometimes they can be seen as age spots or liver spots.

Equally damaging is the total destruction of all the enzymes in cooked food. Raw food contains a complement of enzymes specifically designed to digest it. Starchy foods contain large amounts of the starch-digesting enzyme amylase; fatty and oily foods are provided with the fat-digesting enzyme lipase, while protein foods contain the protein-digesting enzyme cathepsin. According to the food composition, there may be mixtures of these and other enzymes.

If food enzymes are destroyed, we must produce considerably more digestive enzymes, and our overall enzyme capacity declines much more rapidly with advancing years than it would on raw food. Thus we age much sooner and develop degenerative diseases that can otherwise be avoided. Food enzymes and digestive enzymes not only break down and absorb food, but also keep the body free of inappropriate accumulations of fats and proteins and help us avoid or reverse atherosclerosis and cancer. High-dose supplements of protein-digesting enzymes are frequently used in natural cancer therapy to break down tumours.

Animal experiments show the profuse development of degenerative diseases from a diet of cooked foods and that good health and longer life result with a raw diet. There are also numerous reports of human cures from all kinds of degenerative diseases - including advanced cancer - on a raw diet of organically grown food. My own successes in healing patients in advanced and difficult conditions have often been due to raw food diets.

Modern processed foods generally combine the negative health effects of cooked, refined, and chemicalised food. Tinned food, for instance, causes even more leukocytosis than normal cooked food, indicating that it is more toxic. Equally harmful is microwaved food, as this process violently shakes and twists the delicate molecular structures. In studies, abnormal changes in the blood and immune system were noticed after ingesting microwaved food.

Fortunately, it is easy to protect yourself from the dangers associated with cooking: avoid or minimize the use of processed food; heat food only to the boiling point; and maximize your intake of raw, fresh, and organic food. Shortly before eating

heated food, have some fresh, raw food, and more with the cooked meal. In this way, digestive leukocytosis can be reduced or even eliminated.

I have noticed that for many people cereals are especially difficult to give up. These cause problems for many individuals, contributing to overweight, diabetes, and hypoglycaemia. How-ever, some individuals and therapists report that raw grains do not seem to cause these problems. Therefore, if you are so inclined, you can experiment with soaked non-gluten grains as an addition to breakfast or a salad.

Harmful Eating Habits: The way we eat our food can also negatively affect our health. Commonly, food is not sufficiently chewed as our mind is busy with other matters. Thus, the food is not properly broken down and mixed with the starch-digesting amylase in the saliva. This adds to the burden of an already overworked pancreas. The composition of the required digestive juices is already signalled to the pancreas from the mouth, but if food is eaten too fast, especially cooked food, the signals are inaccurate, and we also do not receive the signal when we have had enough, so we tend to overeat.

Overeating is unhealthy because we become overweight, but also excessive amounts of metabolic waste products are formed that stress the enzyme systems and the organs of elimination. In addition, food remains partly undigested in the intestines, which encourages putrefaction and an overgrowth of harmful microbes. The overall effect can be not only a shortened life span but also early onset of degenerative disease. Many animal experiments have confirmed that life span as well as health can be greatly enhanced if the quantity of food consumed is restricted. Rats, for instance, doubled their life span on half their normal diet and earthworms lived 16 times longer on a starvation diet, according to studies.

A famous example of a long and healthy life through restricted eating is the Italian nobleman Luigi Cornaro, who lived about 400 years ago. He was born with fragile health and by the time he was 40, he had severe arthritis and many other afflictions and was close to dying. He cured himself within one year by restricting his food intake to about 12 ounces daily, consisting of bread, meat, egg yolk, and soup. He continued with this in good health until his 78th year when he gave in to the persuasions of his family and increased his food intake by two ounces. Within days, he became very sick. Again he escaped death by returning to his frugal eating habits. From then on he lived in good health, with excellent mental faculties and without fatigue until his 99th year. In his last years, he wrote a comedy and treatises on longevity and health.

Eating meat or a large meal in the evening is especially unhealthy because then our digestive powers are much weaker than in the morning. What we eat during the daytime is usually converted into energy for the activities at hand, but the evening meal is mainly converted into fat deposits and an increase in the accumulation of wastes.

Equally harmful is indiscriminate food combining. High-protein foods such as meat require different digestive juices from those needed to process a starch meal. The digestion of starch initiated by the salivary amylase is prematurely stopped if the starch is mixed with meat in a meal. Amylase is also inhibited when starches are mixed with acids and the release of salivary amylase is suppressed when eating

sweetened starches. Mixing incompatible foods overloads the pancreas and our health suffers.

The Mixed Benefits and Deficits of Stimulants: Stimulants such as coffee, tea, cocoa, tobacco, alcohol, and various recreational drugs are widely used and often overused. I do not suggest that stimulants should be completely avoided but, similar to sweet foods, I contend it is much better for our health if we restrict their use.

Whether stimulants are harmful to you and to what extent depends greatly on your state of health and how frequently you use them. Someone who habitually takes a specific stimulant several times daily will be most affected by it and is likely even to be allergic and addicted to it. This applies to coffee and tea as much as to alcohol, tobacco, and other stimulating drugs. While the health dangers of alcohol and tobacco are well publicized and generally appreciated, the prevalence of allergies to coffee and tea is often underestimated. The most common symptoms are headaches, migraines, irritability, and menstrual problems.

However, coffee and tea can also make positive contributions to our health, provided that we are not addicted and/or allergic to them. Tea, especially green tea, is high in antioxidants and useful in the prevention of cancer. Black and green teas stimulate the respiratory system and are helpful with breathing problems, such as asthma. Coffee, on the other hand, acts mainly on the brain, not only to keep us awake, but it can also prevent a threatening migraine attack. Coffee drinkers appear to have a lower incidence of Parkinson's disease. A dry red wine taken with a meal can be beneficial, and beer in moderation is fine (provided you have no gluten or yeast sensitivity). Unfortunately, modern beer and many wines are chemicalised and not beneficial.

Marijuana is probably no worse than other recreational drugs and has some useful medicinal properties along with its strongly relaxing and pain-relieving effect on the body and its stimulation of specific parts of the brain. Habitual use is most harmful for those who are already too relaxed and without much drive or enthusiasm. Generally such people have weak blood sugar regulation, lack of energy, and low blood pressure. Prolonged use of marijuana can cause genetic changes and infertility in offspring.

Signs of addiction to stimulants are a craving during periods of abstention or bingeing when a tempting opportunity arises. In order to improve your health, avoid the addictive stimulant for a very long time, preferably for several years. People in poor health, especially if their system is acid and they have a disturbed sugar metabolism, easily become addicted and allergic to any stimulant that is used for a prolonged period.

If your health is reasonably good, it will not be too damaging to use stimulants in moderation. Someone in good health rarely becomes addicted. The main thing to watch out for is that it not become a habit or a craving, and also that alcohol not be used to excess. However, smoking is almost always an addiction and has no redeeming health features at all.

If you use a stimulant regularly, more than once or twice a week, I recommend that you stop using it for one week every few months and carefully observe yourself

during abstention and when it is reintroduced for signs of craving, discomfort, or allergy. This advice to interrupt stimulant use occasionally does not apply, however, to regular smoking, hard drugs, or binge drinking. For these, permanent abstention is the only solution. Pregnant and nursing women are best advised to abstain completely from alcohol, tobacco, and drugs.

Yeasts and Moulds: Yeasts, moulds, and mushrooms are all fungi. Yeasts are widely used in baking and brewing and also as concentrated yeast extracts and food yeasts. Moulds are used in some cheeses and to produce antibiotics. We all have some yeast cells resident in our intestines. Normally, these are harmless, as the intestinal bacteria keep them subdued. However, in many people the fungi have taken over, and the overuse of prescription drugs and improper dietary changes have contributed to this condition.

Yeast proliferation is stimulated by birth-control pills and consumption of sweet food, as sugars are the only energy source for yeasts, but the main reason that it has become a widespread health problem at present is the general use of antibiotics and prescription drugs that suppress the immune system. Antibiotics decimate the normal intestinal bacteria but leave the yeast cells unaffected, allowing them to proliferate and take over the space normally occupied by intestinal bacteria. From the intestinal tract, the yeast cells can invade other mucous membranes, especially those of the vagina, mouth, and lungs; they can also penetrate the intestinal wall and enter the bloodstream.

The most common form of intestinal yeast is Candida albicans, an overgrowth of which can cause gastritis, colitis, cystitis, bloating, oral (thrush) or vaginal infestation, menstrual problems, and asthma. Allergies with a wide variety of symptoms result when this yeast penetrates the intestinal wall. In addition to skin and breathing problems, severe mental and emotional reactions, especially depression, are common. Autism, neuroses, and mental diseases, including schizophrenia, have reportedly been cured with antifungal therapy. Usually in such cases, the patient has a history of Candida problems and antibiotic use. The toxicity of Candida to the nervous system is largely due to an excessive production of acetaldehyde. This substance is formed when yeast cells metabolize sugars and there is a deficiency of oxygen.

Another important aspect of systemic fungal infestation is severe damage to the immune system, leading to autoimmune diseases and immune deficiency states, including lupus erythematosus, rheumatoid arthritis and, most likely, AIDS. After the immune system has been severely damaged by this fungus, it is easy for bacteria and viruses to invade the body and cause serious and even lethal diseases.

Dietary yeasts and moulds greatly increase the difficulties of susceptible individuals, frequently causing allergic reactions and flare-ups of Candida infections. Some moulds can damage the liver, such as aflatoxins, from a mould that frequently grows on peanuts and is present in peanut butter. Moulds commonly grow on dried fruits, on poorly stored grains and nuts, on the outer leaves of cabbage, and on the skins of various fresh fruits.

A study in the U.K. in 1977 found that moulds and their poisonous mycotoxins (fungal toxins) were present in all 318 samples of flour tested. This mould contamination was believed due to insufficient drying in the process of combine-

harvesting of grain. Whole-meal flour, bran, and wheat germ are even more affected by mould than is white flour; rice is also frequently contaminated.

Even if the fungi are killed during cooking, the products of their decomposition can still cause allergies. Washing whole grains, nuts, and susceptible fruits and vegetables before cooking or eating helps to remove moulds; drying them in the sun destroys fungi and prevents their development. Preferably also remove environmental moulds, such as those on walls and bathroom tiles, because they can be inhaled and cause lung and breathing problems in susceptible individuals (asthmatics).

Frequently, antibiotics are routinely added to animal feed for meat production; this applies especially to poultry and pigs. Antibiotic residues can impair the intestinal flora of the consumer of such products and thereby encourage the spread of Candida. In addition, the meat itself can be infested with Candida or other fungi because of the prolonged use of antibiotics in the animals; resistant strains of harmful bacteria may also be present. I do not recommend habitually eating such meat. As a general rule, I recommend you avoid meat from commercial animal feedlots.

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Step 43

METABOLIC TYPES, PATHWAYS, & DIETS

Know your individual metabolic type and your specific dietary requirements.

Some foods, such as meat or sweet and acidic foods, are good for certain people, and for these people they are not problem foods, while with other people their effects are adverse. To gain a better understanding of this phenomenon and insight into the food-related causes of diseases, let's look at metabolism.

Our metabolism is the total of all the millions of biochemical and enzymatic reactions that take place in our body at any given time. Some reactions use energy to build (anabolism) more complex structures from assimilated nutrients, while others release energy by breaking down (catabolism) more complex molecules.

While there are additional factors and overlapping influences, we can say generally that our metabolic pathways are most strongly influenced by our nutrition, that our glandular system is mainly affected by our emotions, and that our nervous system responds primarily to brain and mental activity. All three factors together - nutrition, glandular system, and nervous system - regulate our metabolism.

Inherited or acquired variations of these regulating factors produce a unique blend for each individual and call for different specific requirements for optimal health. However, there are some common key factors and we can distinguish several groups with similar characteristics: Each group represents a metabolic type, which I explain below. But first, two concepts must be explained: the autonomic nervous system and the tension-relaxation cycle.

The Autonomic Nervous System: The autonomic nervous system (ANS) has a great influence on our metabolism. It regulates those body processes that usually function automatically without our conscious control, such as heartbeat, digestive processes, nerve reflexes, and so forth. It has two branches with opposite characteristics: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).

The main function of the SNS is to prepare the body for action: epinephrine pours into the bloodstream; the muscles tense; blood pressure, pulse, and breathing rate increase as well as the rate of catabolic processes in general. The digestion, however, is slowed or interrupted. The SNS is activated by emotions such as anger and fear, by the intention to take some action, but also by certain foods, and most strongly by red meat.

The PNS relaxes the muscles, improves the digestion, and lowers blood pressure, pulse, and breathing. The PNS is dominant during sleep and with relaxed body and mind conditions. The endings of the PNS nerves release acetylcholine when stimulated, while SNS nerves release norepinephrine, an epinephrine-like hormone with opposite effects to those of acetylcholine. SNS dominance leads to elevated blood levels of glucose and fatty acids (diabetes, coronary heart disease), while with PNS dominance these levels are lowered (hypoglycaemia).

The Tension-Relaxation Cycle: Overall, each body function should be in balance between the opposite forces of the SNS and PNS. However, at any given moment, one force will usually prevail; during action the SNS dominates and during rest the PNS. A healthy body is not static but in a dynamic balance, like a swinging pendulum.

Problems arise when the tension-relaxation cycle is not balanced but is one-sided. During work there may be too much tension, while the following rest period does not result in complete relaxation. If this condition becomes chronic, other tension-related symptoms can develop, such as high blood pressure or restlessness. To bring the body back into balance, remedies with a PNS influence can be applied, such as relaxation exercises, a vegetarian diet, or magnesium supplements. On the other hand, if the body generally is too relaxed, too weak, and too soft for the daily tasks, and mind and emotions cannot be aroused, then tension-producing SNS influences can be applied, such as consuming flesh foods or calcium supplements.

Basic Metabolic Types: From these considerations about our ANS, we can describe three metabolic types: the P-type in which the PNS dominates; the S-type with a dominating SNS; and a balanced type. Population groups over thousands of years developed predominantly into one of these types, depending on climate and available food. These inherited ancestral metabolic characteristics remain fairly stable during our lifetime and form our basic metabolic blueprint on which acquired metabolic traits are superimposed.

The fundamental difference between the P-type and the S-type can be illustrated if we compare the mental picture or stereotype we have of the Native American with that of a desert Arab.

The Native American is deliberate and measured in movement and speech, stoic, and rarely displays emotions. He or she has a powerful body and a broad face, is a hunter, and eats relatively few carbohydrates. This is a typical representation of the positive aspects of the P-type. We find the same characterization, only adjusted to a colder climate, in the Eskimo. The typical desert Arab, on the other hand, is agile, lively, energetic, and quick to act on feelings and emotions. He or she is lean, with a narrow face, and can (or reportedly could in former times) exist for long periods on nothing but dates and still maintain remarkable endurance. This portrait shows the positive aspects of the metabolic S-type.

The apparently unbalanced ANS of each type is actually balanced through the opposite influence of the traditional diet. Thus, the high-meat diet of the Native American stimulates the SNS and epinephrine production, while the predominantly vegetarian diet of the Arab sedates the SNS and epinephrine response. If the Native American and the desert Arab were to interchange their diets, they would become unbalanced, their energy metabolism would eventually become inefficient, and their health would decline. They would then display the negative characteristics of their metabolic types.

Other races and nations that are predominantly of the P-type are the North Europeans, Dutch, Russians, Polynesians, and New Zealand Maoris, the latter being a traditional hunter society in a warm climate. The S-type, on the other hand, is mainly grouped around the Mediterranean and the tropical and subtropical regions of Asia. Generally, the P-type originated in cold climates that offered a continuous

supply of animal products but a lack of plant food in winter, while the S-type evolved with a continuous, plentiful supply of plant food. There are, however, no original populations that live entirely on animal or plant food.

Most of those with middle-European ancestors are of the balanced metabolic type, readily utilizing all three metabolic pathways: carbohydrates, fats, and proteins. However, sweet foods were relatively rare and reserved for special occasions in those metabolically formative societies.

Table 5-3: Characteristics of Metabolic Types

S-Type	***P-Type***
tendency to raised blood pressure, fast pulse and breathing	tendency to low blood pressure, slow pulse and breathing
slender, slight body frame, narrow face, flat chest	strong bone structure, broad face, rounded chest
dry mouth; ears and gums pale; skin dry, yellowish	much saliva, ears and gums pink, ruddy complexion, flushes
weak dreaming activity	much dreaming activity
sprinter type, not much endurance, fitness fanatic	long-distance runner, steady worker, good endurance
appetite diminished, digestion slow and weak	appetite above normal, digestion fast and strong
enjoys fruits and vegetables, dislikes fatty food	likes meat, starches, and fatty food
emotionally unstable, freely shows emotions	emotionally stable,
quick to make decisions	slow to make decisions, cautious
seldom sad, depressed, melancholic, or withdrawn	tendency to being sad, depressed, withdrawn, melancholic
extroverted, easily angered or irritated	introverted, rarely angered or irritated
tense, lively, overactive, jumpy	relaxed, quiet, slow or sluggish
strongly assertive, aggressive	non-assertive, nonaggressive
hate, envy, verbal abuse	resentment, guilt, worry, doubt
Slow Oxidizers	***Fast Oxidizers***
blood pressure raised or high	blood pressure low
often heavy body and hard manual worker	often overweight or underweight and low in energy
often too alkaline, insensitive to cold and skin irritants	overacid, cold hands and feet, skin very sensitive
enjoys meat and heavy food but also fruit and sour food	craves sweet food but feels better craves sweet food but feels better after protein and salty food
emotionally unresponsive, undemonstrative	emotionally unstable, irritable, outbursts, shy, resentful
rarely has colds, infections, allergies, or inflammations, susceptible to chronic infections, liver and kidney problems, cancer, cardiovascular disease, stroke	susceptible to colds, allergies, inflammations, acute infections, rheumatoid arthritis, anemia, lymph gland diseases, mucus problems, leukaemia

Table 5-3 lists the characteristics of the P-type and S-type. Those of balanced type are generally between these opposites. The positive characteristics of the P-type are described as being relaxed, dependable, quiet, cautious, and emotionally stable, with good skin circulation, a ruddy complexion, and good endurance. Pulse, breathing rate, and blood pressure tend towards the low side. The basic traits of the S-type are that individuals have plenty of drive, freely show their emotions, and are lively, assertive, and quick to make decisions. The body tends to be lean; pulse, breathing rate, and blood pressure may be elevated.

Converted Metabolic Types: Inherited weaknesses and deteriorating health can cause far-reaching changes in our metabolic characteristics, sometimes requiring a diet that is similar to that of our opposite basic type. The actual cause of such changes can be an overstimulation or weakening of the SNS or the endocrine glands; it can also be a partial blockage of a metabolic pathway because of vitamin and mineral deficiencies. Most frequently, however, our metabolism has deteriorated because we overuse problem foods.

Slow Oxidizers: Few individuals in our society still display all the positive characteristics of their basic metabolic type. Many of us live in a stimulating social environment and use stimulating foods at the same time, such as red meat, spices, alcohol, coffee, tea, tobacco, or drugs. All these factors stimulate the SNS and our endocrine glands. We become nervous, restless, sleepless, quick-tempered, and overaggressive, with raised blood pressure and permanent muscle tension. Such individuals are now negatively SNS-dominant and can be classified as negative S-types, even if they originally had a balanced or even PNS-dominated metabolism.

Other negative characteristics can develop, such as being underweight, having a dry mouth or yellowish skin, poor appetite with a weak, slow digestion, emotional instability, or an uncontrolled temper. Deteriorating liver and kidney function in combination with a high-meat diet can lead to a buildup of uric acid and cause gout and rheumatism. Irritation or ulcers of the digestive tract may be present, and sometimes migraines can develop as well. If such overstimulation persists for a long time, especially in combination with a diet high in red meat and fat, then the liver and glandular system gradually become weak and the metabolism slows down. This is the condition of a slow oxidizer.

The main characteristics of slow oxidizers are raised blood pressure and alkaline body fluids. Together with a raised calcium blood level, this frequently leads to kidney stone formations. Often, slow oxidizers originate from the P-type and are manual workers, such as farmers and builders, people with a heavy body and bone structure and who usually eat large amounts of meat.

The skin of slow oxidizers is usually insensitive to cold and irritants. Emotionally they are stable and even unresponsive and undemonstrative; they do not show or experience much in the way of strong feelings and emotions. They are slow, dependable, and reliable. If they originate from the basic S-type, they are lean and show more emotional response. Common health problems are hypertension and cardiovascular diseases, chronic infections, degenerative liver and kidney diseases, stroke, and cancer.

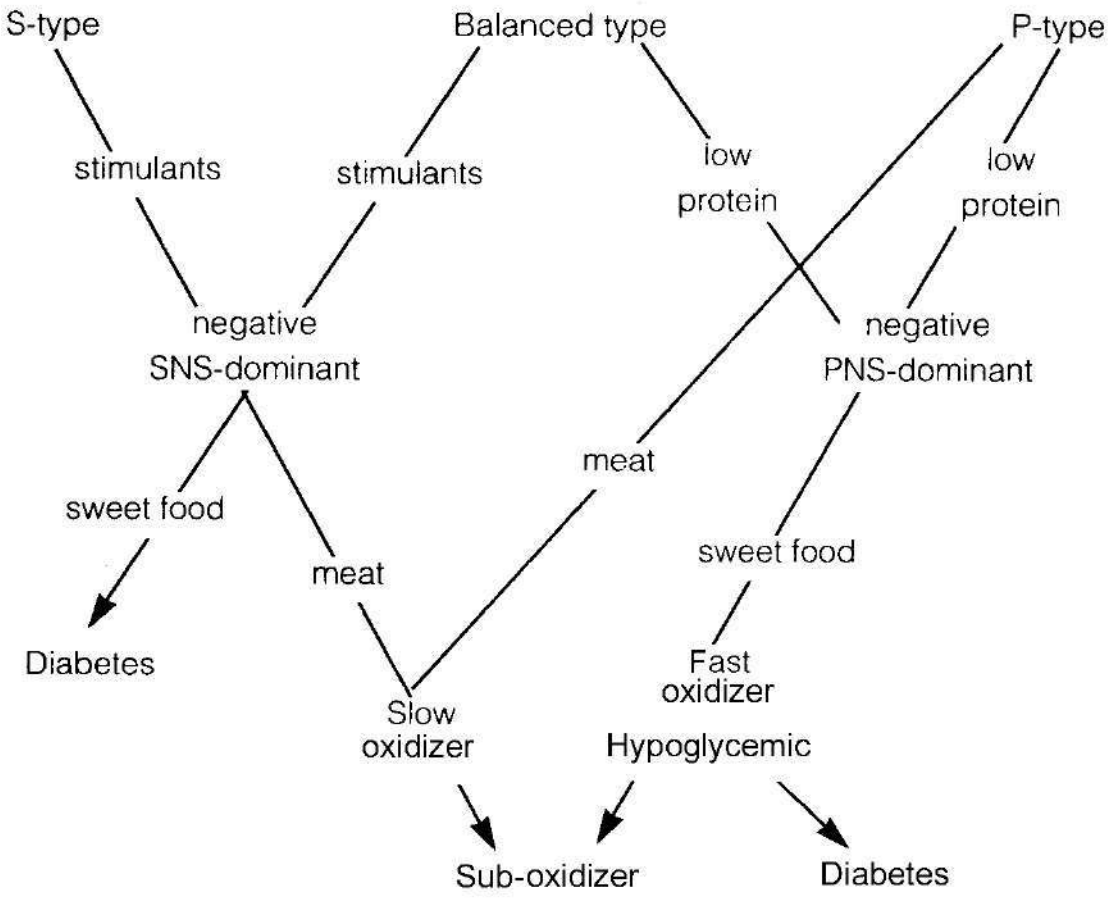

Figure 5-1: Relationships between Metabolic Types

Fast Oxidizers: The opposite metabolic path is exhibited by those of the balanced type and the P-type who live on a low-protein vegetarian diet or who are protein deficient because of malabsorption or liver problems. They become negative P-types, displaying the traits of negative PNS dominance. They lose their normal aggressiveness, enthusiasm, and self-assertiveness, and they become sluggish, listless, and underpowered. They may become unemotional and lose interest in the happenings around them; marijuana use makes this condition worse.

This metabolic type is widespread in many underdeveloped countries, but also in alternative lifestyle groups in Western society. Women are more prone to this condition than men as they naturally have lower epinephrine levels. Other negative features that can develop are low blood pressure with a lack of energy; the weight becomes too low or too high; the individual easily becomes sad, melancholic, or depressed and has difficulties making decisions. Anemia may be present.

While S-type individuals can become diabetic on a diet high in sweet foods, P-type individuals tend to become hypoglycaemic. Glycolysis (the breakdown of glucose inside the cells) is sped up and this is why an individual is called a fast oxidizer.

Fast oxidizers usually have low blood pressure with low energy levels, especially after eating sweet foods and fruits. Often there is a craving for sweet food though they feel much better after eating proteins. Allergies, addictions, and overacidity are common, as well as susceptibility to acute infections and inflammations. The circulation tends to be poor with cold hands and feet. Respiratory tract infections and other mucous diseases are common, as are rheumatoid arthritis and a tendency to leukaemia. The fluctuating blood sugar level in combination with allergies causes emotional instability. Individuals may be irritable with occasional bouts of temper and even violence, but more often they are resentful and shy, and frequently worry or feel guilty.

Sub-Oxidizers: With advancing age or deteriorating health, both branches of the ANS tend to become weak and all aspects of the metabolism become inefficient. This is the condition of a sub-oxidizer, and is common to all metabolic types whose health has degenerated.

It appears to be rare for our health to degenerate in a straight line from a positive balanced type to the negative balance of the sub-oxidizer. It usually includes the condition of the fast or slow oxidizer and sometimes conditions of both, first as fast oxidizer and then as slow oxidizer.

Sub-oxidizers represent the typical condition of old age in our society. The endocrine system is nearly exhausted, the immune system is weak, and digestion is inefficient, with malabsorption and lack of gastric acid and digestive enzymes. The metabolism is inefficient, so the body usually is too alkaline. The blood pressure may be too high or too low. The circulation is extremely poor and there is a pronounced lack of energy and even debility. There are many chronic health problems and frequently a serious degenerative disease, such as the deformative stage of arthritis, senility, or cancer.

See figure 5-1 for a diagram of the relationship between the various metabolic types. The opposite directions to those indicated in the diagram are typically travelled during a program of health improvement. For the purpose of selecting your metabolic type, you can regard a blood pressure of 120/80 and a pulse of about 70 per minute while sitting as normal for an adult; children usually have a lower blood pressure and a higher pulse rate.

Biochemistry and nutrition are commonly taught as if the basic metabolic pathways for energy production are used in the same way by all people, except perhaps for some uncommon hormone and enzyme deficiencies. This, however, is an oversimplification that leaves the health practitioner as well as the patient without clear guidance as to how to use nutrition to overcome disease and maintain health.

A more relevant study of our energy metabolism (the way in which our cells produce energy from food) provides some fascinating insights into the reasons why certain diets and nutrients are beneficial or harmful for various diseases and for different metabolic types. While part of this study may seem technical and difficult to understand, it is worth the effort because here we have the basis of all the disease-producing and healing effects of nutrition.

Glycolysis and Citric Acid Cycle: The main energy-generating mechanism in our cells is the Krebs cycle or citric acid cycle. This is a series of enzymatic steps through which a two-carbon molecule (acetyl or acetate) is oxidized to yield carbon

dioxide and water. All three main food components - glucose, amino acids, and fatty acids - can be utilized in this way.

Glucose is normally the most important fuel molecule. Through several reactions along the glycolytic pathway, it is split in half to form pyruvic acid. Niacinamide and vitamin B1, as coenzymes, are the necessary vitamins at this stage; magnesium is also required. Glycolysis proceeds anaerobically, that is, without oxygen. See figure 5-2 for a diagram of cellular energy metabolism. The next step may be in one of two directions, and it is here that most intracellular energy problems develop. Pyruvic acid can combine with carbon dioxide and become oxaloacetic acid, or it can lose carbon dioxide and form acetyl coenzyme A. Combining with carbon dioxide requires a high amount of energy as well as biotin, nicotinamide, and manganese. The step in the other direction needs oxygen and magnesium, as well as the vitamins B1, niacinamide, and pantothenic acid.

If the metabolism is in good condition, then both reactions take place in such proportions that there are always equal amounts of oxaloacetic acid and acetyl coenzyme A available. Both molecules will then combine to form citric acid as the first step in the citric acid cycle. During several more steps in this cycle, together with reactions that follow up the cycle, the acetyl component is completely oxidized into two molecules of carbon dioxide and water, while the oxaloacetate is reformed, ready for a fresh turn of the cycle.

However, in practice, usually a deficit of oxaloacetic acid will develop, because this is a very useful molecule that is required for many other reactions, such as to form amino acids or nucleic acids. The body covers this deficit by converting an appropriate amount of pyruvic acid into oxaloacetic acid. Important for the operation of this cycle are the vitamins B1, B2, and niacinamide, in addition to magnesium and oxygen.

In this way, someone of the S-type (“desert Arab”) can obtain all his energy by burning carbohydrates. The P-type (“Native American”), on the other hand, will create very little of her energy in this way. She produces energy mainly by forming acetyl coenzyme A directly from fats (requiring vitamin B2, niacinamide, and biotin) and from amino acids (requiring vitamin B6). Most of the small intake of carbohydrates will be converted to oxaloacetate.

The balanced type is able to use both main pathways efficiently and best gains energy from a mixture of carbohydrates, proteins, and fats. The third path, the conversion of pyruvic acid into lactic acid, is an emergency measure that can be used by all metabolic types. This is an anaerobic step, which in most instances is triggered by a shortfall of oxygenating enzymes, either because of strenuous muscle activity or resulting from an allergic reaction. In fast oxidizers, the buildup of lactic acid can also be caused by an accumulation of metabolic acids (e.g., citric acid or malic acid) in the cells. Lactic acid is partly neutralized and expelled with the urine and partly reconverted in the liver to pyruvic acid in the presence of sufficient nicotinamide.

Abnormal Glucose Metabolism: The P-type and the balanced type tend to become fast oxidizers and hypoglycemics on a diet high in sugars and low in proteins and fat. Most of the dietary protein is used as building blocks and little is available for energy production. The ability to convert pyruvic acid into acetyl coenzyme A is poorly developed in P-type individuals. Therefore, oxaloacetic acid is produced in excess, while lack of acetyl coenzyme A prevents the citric acid cycle from fully operating. The blockage of

the citric acid cycle leads to a lack of energy and overacidity from accumulating metabolic acids and lactic acid.

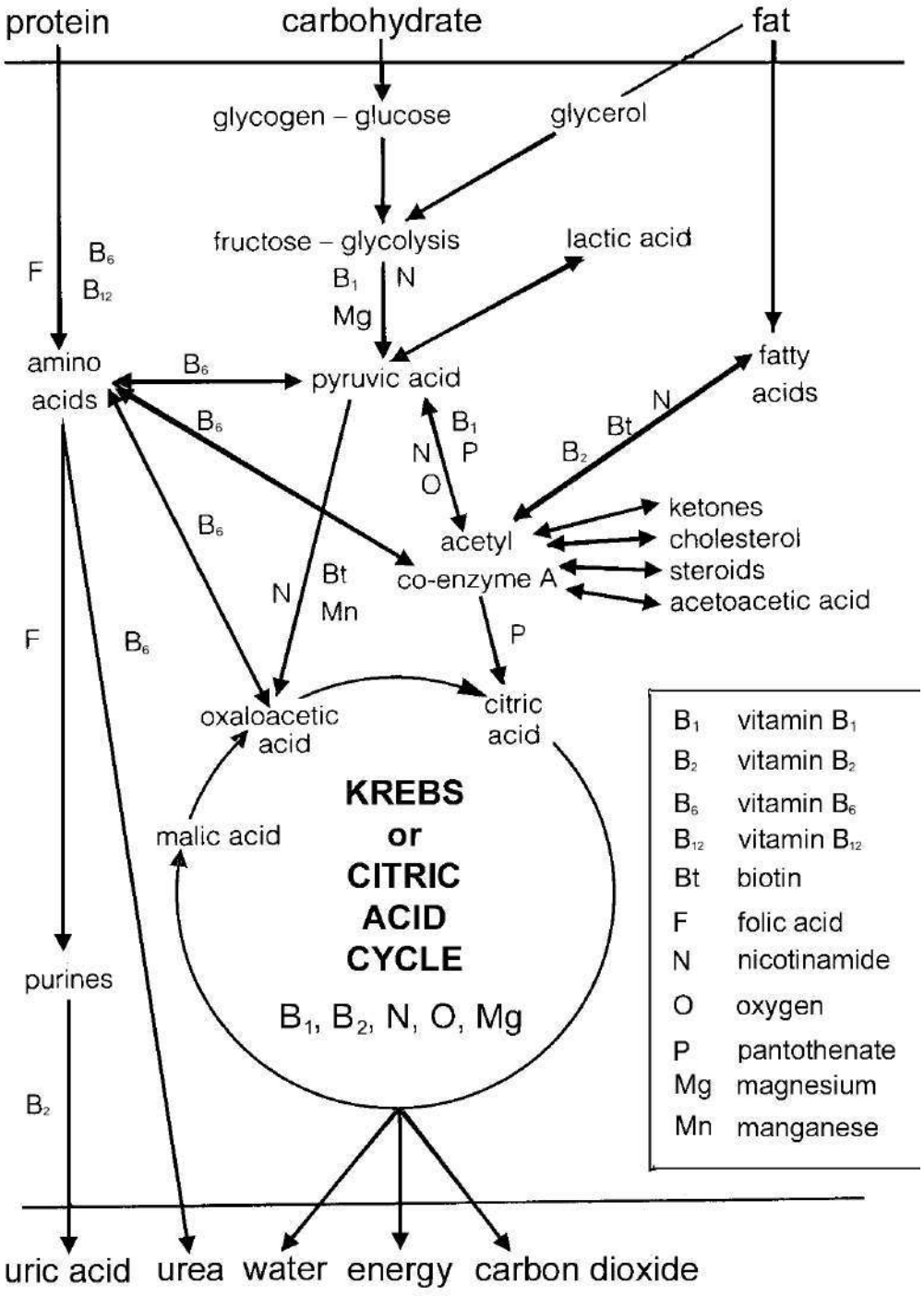

Figure 5-2: Cellular Energy Metabolism

Consuming more proteins and fats (best here is olive oil) is the solution, as fats are the most efficient source of acetyl coenzyme A. However, this will be problematic if there is malabsorption of fat. Polyunsaturated oils, on the other hand, require additional

metabolic steps and are not well suited for energy production. In addition, linoleic acid may contribute to the frequent oversensitivity of fast oxidizers by forming certain prostaglandins that increase inflammatory activity.

In the negative S-type where the diet is high in meat and fat, we have the opposite problem. Initially, this provides useful additional fuel, and in combination with a raised epinephrine level makes the personality energetic. However, there is an inverse relationship between the epinephrine level and the effectiveness of insulin such that when the epinephrine level is high in response to this diet, the effectiveness of insulin is reduced.

Diabetes: Insulin regulates the speed with which glucose enters the cells. With a low insulin level, cells can be starved of glucose. The insufficient oxaloacetic acid is formed to combine with an abundance of acetyl coenzyme A, which is produced internally or by a high-fat diet. In those who are strongly SNS-dominant, this can lead to the development of diabetes. Glucose builds up in the bloodstream, raising the blood sugar level, and is spilled into the urine.

Figure 5-2 shows the nutritional solution to this problem. We must provide more oxaloacetic acid to the citric acid cycle. As a first step, we reduce all stimulating influences from the environment or from red meat, alcohol, coffee, tea, tobacco, or drugs. This will help reduce the epinephrine level and increase the effectiveness of insulin. Then we supply an abundance of zinc, which is needed to manufacture insulin, and chromium, which is part of the glucose tolerance factor that helps insulin to channel glucose through the cell wall.

Oxaloacetic acid is an unstable compound that cannot be ingested as such, but we can supply malic acid (the acid present in tart apples), which is easily converted into oxaloacetic acid. We can also supply citric acid from acid citrus fruits. This, too, can be converted into oxaloacetic acid through the citric acid cycle and it provides valuable energy.

Another food group that readily converts into oxaloacetic acid is the proteins. Most amino acids can either be transformed via pyruvic acid or directly enter the citric acid cycle. Most easily converted is aspartic acid. Only few amino acids are ketogenic (related to the fat metabolism) and yield acetyl coenzyme A: leucine, isoleucine, lysine, phenylalanine, tryptophan, and tyrosine. Incidentally, an excellent energy protein for diabetics, with almost 90 percent useful amino acids, is gelatine.

Fructose from fruits can enter muscle cells without insulin to form pyruvic acid. However, it must enter the bloodstream slowly (such as from raw food and small meals); otherwise fatty acids, cholesterol, and cataract-forming sugar alcohols may be produced. However, Type II diabetics have to be careful not to mix fructose with glucose, as pointed out in step 40 in regard to the disaccharide effect.

Sometimes glucose cannot be used and builds up in the bloodstream because the conversion of pyruvic acid into oxaloacetic acid is blocked or too slow. This conversion requires manganese, biotin, and nicotinamide. These and other vitamins and minerals required for the energy metabolism should be supplied in generous amounts as supplements.

The large buildup of acetyl coenzyme A is reduced in the liver by conversion into saturated fatty acids and cholesterol, both of which contribute to the development of

atherosclerosis. In uncontrolled diabetes, a surplus of fat leads to the production of ketones and keto acids from acetyl coenzyme A (ketones are organic chemicals with an oxygen atom attached with two bonds to a carbon atom; keto acids have, in addition, an organic acid group). Ketones, such as acetone, can to some degree be used by the muscles to form oxaloacetic acid via pyruvic acid and thus keep the citric acid cycle going. However, this conversion is slow and a large amount of the acetoacetic acid accumulates and makes uncontrolled diabetics extremely acidic. The liver can metabolize glucose without the help of insulin, and high levels of glucose flooding the liver can cause a large buildup of lactic acid. Thus, an intake of sweet food contributes to general overacidity.

Intestinal sanitation, avoidance of sucrose, allergy testing, and/or a low-allergy diet are the main features in normalizing insulin production in insulin-dependent diabetes. A proper nutritional program is a second line of defence and can give good results even in resistant cases such as tumour of the pancreas.

Abnormal Fat Metabolism: The metabolic problems of slow oxidizers are similar to those described for diabetics. However, the glucose deficiency inside the cells is far less severe and, therefore, we do not have the overacidity resulting from an overproduction of keto acids. Instead, the surplus of acetyl coenzyme A is mainly converted into saturated fatty acids and cholesterol, causing atherosclerosis, cardiovascular disease, fatty degeneration of the liver, and overweight. In the slow oxidizers, overweight is mainly a result of eating too much fat, while in the fast oxidizer, overweight results mainly from eating sweet food and wheat. In both cases, the thyroid gland tends to be underactive.

The answer to these problems is to speed up glycolysis and produce more oxaloacetic acid. This can be done by supplying plenty of fruit acids as well as all the vitamins and minerals required for their sugar metabolism. Minimizing intake of fats and sugars will stop the oversupply of acetyl coenzyme A, while epinephrine levels will fall and insulin activity will rise in the absence of meat consumption and stress. This is also the key to cleaning out atherosclerotic arteries.

Sub-Oxidizers and Cancer: The sub--oxidizer has an inefficient metabolism and, in a way, combines the problems of the fast and the slow oxidizer. Many sub-oxidizers have cancer or precancerous conditions. In cancer the metabolism of all nutrients is greatly impaired. The main energy production of cancer cells is similar to that present in uncontrolled hypoglycemics: Both produce mainly lactic acid instead of energy. While this makes the tumour itself overacid, the rest of the body may be too alkaline due to a very sluggish metabolism.

Figure 5-2 on the citric acid cycle also reveals how we can starve a tumour: We must reduce all nutrients except fruit acids to the bare minimum. In this way the tumor is completely deprived of energy, while normal body cells can still derive energy from metabolizing acids together with fatty acids from the fat deposits of the body.

The time-tested method used in natural medicine for those with sufficient fat reserves is a fast, lasting several weeks, on fruits only, mainly tart varieties. The “grape cure” has become famous in this regard; tart apples and acid citrus fruits can also be used. During this time it is essential to flush the intestines daily (using Epsom salt and colonics, for example); otherwise the poisons generated by a large, disintegrating tumor can cause great distress and even death. At other times, use plenty of red beets, raw,

juiced, or cooked. The red beet pigments greatly increase the oxygenating ability of the cells and normalize metabolism.

Diet Types: Understanding how your body produces energy, and how to overcome some common nutritional problems, can guide you in selecting an appropriate diet for your individual requirements. Slow oxidizers have similar dietary requirements to those of the metabolic S-type, that is, a vegetarian or semi-vegetarian diet. Fast oxidizers and P-type individuals, on the other hand, do best on a non-vegetarian diet or a high legume vegetarian diet, which at the same time should be low in sugars. The balanced type can use a mixed diet that is neither high in protein and fat nor in sweet food. Here are some dietary guidelines:

Diet for S-Type and Slow Oxidizers: Proteins should be supplied mainly from legumes, spirulina, almonds, and other oily seeds, ideally as seed cheese (as explained earlier), but the consumption of peanuts should be restricted. Fish and other seafood, eggs (not hard-boiled or fried), and some poultry and raw milk products are usually acceptable. Have plenty of fruits, especially tart varieties, frequent fruit meals, and all-fruit days. Sweet varieties of vegetables are beneficial, particularly red beets, as are sprouted seeds.

Polyunsaturated oils are mainly supplied from seafood, fermented soybeans, sunflower kernels, and freshly ground linseed. Meats, fats, and processed oils should be eaten sparingly. The evening meal should be light. Helpful supplements are lecithin, digestive enzymes, cod-liver oil or other fish oils, kelp, B vitamins, vitamin E, ascorbic acid, magnesium, potassium, chromium, copper, selenium, and zinc. The idea is to eat fast-digesting food.

Diet for P-Type and Fast Oxidizers: This diet, high in legumes, is often combined with brown rice and other grains such as millet and buckwheat (also sago, taro, arrowroot, and tapioca if available from a health food store). Have a hearty breakfast. Flesh foods are generally well tolerated. This metabolic type should use whole grains - sprouted, cooked, or baked, in preference to flour products; also use plenty of sprouted seeds. Starchy and green vegetables are best for cooking; use sweet varieties, mainly raw, with plenty of red beets, raw, cooked, or juiced. Use salted food if your blood pressure is low.

Oils low in linoleic acid should be used. Best here are olive and almond oils, but also try coconut oil. The intake of sweet food, sweet and acid fruits, and lactose products should be minimized. Neutralize fruit acids with dolomite. Useful supplements are spirulina, halibut-liver oil capsules, calcium ascorbate, low-level B vitamins, MSM, chromium, copper, selenium, and zinc. The idea is to eat slow-digesting food.

Diet for Sub-Oxidizers: People of this metabolic type may use a mixed diet of easily digestible food. Thus meat may be used as broth or stew, not fried or roasted. Nuts and oily seeds should be soaked, sprouted, or used as seed cheese. Sub-oxidizers can consume sprouted seeds and plenty of grass juice; they can also eat beef juice, freeze-dried liver, and plenty of spirulina and bee pollen. Use digestive enzymes, a hydrochloric acid supplement, or ascorbic acid with protein meals. All vitamins and minerals, especially trace minerals, should be supplemented; mix lecithin with all meals; rubbing the skin with cod-liver oil may be helpful. The idea is to eat easily digested food.

Diet for Sensitivity Regulation: Certain nutrients make the skin and sometimes the brain more sensitive and should be minimized if the skin easily reacts to irritants and

Table 5-4: Food List for Blood Type Groups

	Type A	Type AB	Type B	Type O
Almond	OK	OK	OK	OK
Apple	OK	OK	OK	OK
Avocado	OK	Avoid	Avoid	Avoid
Bacon/ham/pork	Avoid	Avoid	Avoid	Avoid
Banana	Avoid	Avoid	OK	OK
Barley	OK	OK	Avoid	OK
Beef	Avoid	Avoid	OK	OK
Beer	Avoid	OK	OK	OK
Beet root/ red beet	OK	OK	OK	OK
Brazil nut	Avoid	OK	OK	Avoid
Broccoli	OK	OK	OK	OK
Brussels sprouts	OK	OK	OK	Avoid
Buckwheat	OK	Avoid	Avoid	OK
Cabbage	Avoid	OK	OK	Avoid
Carrot	OK	OK	OK	OK
Cashew	Avoid	OK	Avoid	Avoid
Cauliflower	OK	OK	OK	Avoid
Celery	OK	OK	OK	OK
Cheese (most types)	Avoid	OK	OK	Avoid
Corn/maize	OK	Avoid	Avoid	Avoid
Cottage cheese	Avoid	OK	OK	Avoid
Cucumber	OK	OK	OK	OK
Duck	Avoid	Avoid	Avoid	OK
Egg	Avoid	OK	OK	OK
Flaxseed	OK	OK	OK	OK
Garbanzo beans or chickpeas	Avoid	Avoid	Avoid	OK
Grapes	OK	OK	OK	OK
Herring (fresh)	Avoid	OK	OK	OK
Kidney beans	Avoid	Avoid	OK	Avoid
Lamb/mutton	Avoid	OK	OK	OK
Lemon	OK	OK	OK	OK
Lentils	OK	OK	Avoid	Avoid
Lima beans	Avoid	Avoid	OK	OK
Liver (calf)	Avoid	OK	OK	OK
Lobster	Avoid	Avoid	Avoid	OK
Mackerel	OK	OK	OK	OK
Milk, cow	Avoid	Avoid	OK	Avoid
Milk, goat	OK	OK	OK	Avoid
Millet	OK	OK	OK	OK
Mung beans	OK	Avoid	Avoid	OK
Mussels	Avoid	OK	Avoid	OK
Navy beans	Avoid	OK	OK	Avoid
Oats	OK	OK	OK	OK
Octopus	Avoid	Avoid	Avoid	Avoid
Olive oil	OK	OK	OK	OK
Onion	OK	OK	OK	OK
Orange	Avoid	Avoid	OK	Avoid
Oyster	Avoid	Avoid	Avoid	OK
Papaw	Avoid	OK	OK	OK
Pea	OK	OK	OK	OK
Peach/pear	OK	OK	OK	OK
Peanut	OK	OK	Avoid	Avoid
Pineapple	OK	OK	OK	OK
Plum	OK	OK	OK	OK
Potato, sweet	Avoid	OK	OK	OK
Potato, white, red	Avoid	OK.	OK	Avoid
Pumpkin	OK	OK	Avoid	OK
Rabbit	Avoid	OK	OK	OK
Rice	OK	OK	OK	OK
Rye	OK	OK	Avoid	OK
Salmon	OK	Avoid	Avoid	OK
Sardine	OK	OK	OK	OK
Sesame seed/tahini	OK	Avoid	Avoid	OK
Soybean	OK	OK	OK	OK.
Spelt	OK	OK	OK	OK
Spinach	OK.	OK	OK	OK
Strawberry	OK	OK	OK	Avoid
String bean	OK	OK	OK	OK
Sunflower seed	OK	Avoid	Avoid	OK
Tapioca	OK	Avoid	Avoid	OK
Tofu/tempeh	OK	OK	Avoid	OK
Tuna	OK	OK	OK	OK
Turkey	OK	OK.	OK.	OK
Turnip	OK	OK	OK	OK
Walnut, English	OK	OK	OK	OK
Wheat	Avoid	OK	Avoid	Avoid
Yam	Avoid	OK	OK	OK
Yogurt	OK	OK	OK	Avoid
Zucchini	OK	OK	OK	OK

if there is emotional and mental instability. Sensitizing nutrients and factors include: acidic and sweet foods and fruits, allergens, and a diet high in phosphorus and low in calcium and magnesium. Proteins, fats, and oils, complex carbohydrates, calcium, and magnesium help to protect susceptible individuals from undue sensitivity. Insensitive individuals, on the other hand, benefit from a high intake of acidic foods and fruits, lecithin, folic acid, and a diet low in -calcium but high in magnesium. Common polyunsaturated oils and lecithin (high in phosphorus) increase sensitivity; linolenic acid (linseed), and fish oils normalize it.

Metabolic Types and Blood Groups: The naturopathic physician Peter D'Adamo, N.D., has written a series of popular books about the relationship between diet, health, and blood type, notably Eat Right for Your Type, Live Right 4 Your Type, and "The Eat Right for Your Type Complete Blood Type Encyclopaedia". He shows that individuals of different blood groups have different optimal food requirements. Special proteins called lectins found in foods not traditionally eaten frequently cause immune reactions in the intestinal wall and may eventually lead to a wide variety of diseases, he says.

The relationship between the three basic metabolic types and blood groups is straightforward. Blood group O is the oldest blood group. It originated in the hunter-gatherer area and corresponds to the P-type or non-vegetarian type. Group A resembles most closely the S-type or grain-eating vegetarian type, while B is the lacto-vegetarian type and closest to the balanced metabolic type. Blood group AB has the characteristics of A as well as B.

It is my clinical opinion that it is beneficial to know which foods are supposedly good or bad for your blood type, but it is not necessary to stick strictly to the corresponding rules. Some of the foods listed to be avoided do not actually damage our blood and have been selected for other reasons that may not apply to everyone. On the other hand, anyone not in good health should take food allergy tests and then combine the recommendations of the blood type diet with the results of the allergy testing.

If symptoms of food sensitivity show up, then I would not use a food that is supposed to be beneficial for your blood group. However, if you are in reasonably good health, allergy tests show no negative effect, and muscle testing gives a strong reaction, then you can cautiously use an "avoid" food, especially if there are other good reasons for using it. An example of this is coconut and its products, which Dr. D'Adamo advises all blood groups to avoid. However, I find coconut milk and oil beneficial for myself, and many others find it beneficial as well.

While we can expect most allergies to occur with food that is wrong for our blood type, this is not always so. What happens in our body depends mainly on the quality of our digestive system and on the quantity and digestibility of the questionable food and its interaction with other food ingredients.

It may be that we react differently to cooked foods and raw foods. Sprouted seeds appear to be more acceptable and possibly beneficial even if the same seeds should be avoided in cooked form. If all is well, then the potentially harmful lectins are broken down to amino acids and are harmless; if not, then we must improve conditions or avoid these foods. Try to develop your inner food sense and learn to

listen to your body. It will then let you know by your inner urgings and taste preferences which foods to eat.

Table 5-4 is a list of some common foods in relationships to the blood groups. Basically, there are only two food classifications: foods that give a reaction and should be avoided and those that do not and may be eaten. Dr. D'Adamo also classified the "allowed" foods as either neutral/avoid, neutral, neutral/beneficial, or beneficial. Neutral means that the food does not cause any blood group related problems, but it has no other specific advantages to recommend it.

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Part 6
SPECIFIC HEALTH PROBLEMS

This chapter offers guidelines for overcoming some specific health problems. However, it is essential to incorporate these specific recommendations into a holistic program for improving your overall well-being. Start with the basics: Do the earlier steps in chapter 1 as thoroughly as possible. Your disease or health problem may disappear without any further therapies being required. In some cases, where one of these basic steps is especially important, it may be mentioned for a specific disease, but all other steps need to be done as well.

In addition to any supplements specifically mentioned for your problem in this chapter, take antioxidants, spirulina, bee pollen, cod-liver oil, lecithin, kelp, or colloidal minerals, and other helpful nutrients. Also use other methods described throughout this book, even if not specifically mentioned, such as reflexology, meridian therapy, magnet therapy, color therapy, and guided imagery. The more effort you make to apply as many supportive methods as possible, the better will be the health result.

An important concept, especially with inflammatory conditions (which are present in most diseases), is chronic stress. This may be due to several individual factors, such as food allergies and chemical sensitivities, chronic infection from a dead tooth, electro-pollution, and emotional stress. Each of these factors stimulates the adrenal glands to release inflammatory hormones. Removing one or several of these inflammation promoters sometimes does not help much; when all of them are removed, you may suddenly see great improvement. If your condition is not specifically mentioned, or is rather severe, in addition to any of the recommended measures, adopt a temporary raw food diet, combined with suitable mind therapy.

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Step 44

SELF-CARE HELP FOR HEALTH PROBLEMS

Practical Tips for Relief

If you have a specific disease, this summary of typical treatment protocols can show you what to do.

I am not a doctor licensed to prescribe medications or ensure cures, but a nutritionist and natural therapist well versed in natural healing methods. This information is derived from sound nutritional and clinical research. Readers should always consult a qualified health practitioner when dealing with serious illness. I do not promise or guarantee any cures, and the reader should regard the following as general guidelines that have been shown to help improve some people with these conditions. For updates and further information, see my websites: www.health-science-spirit.com, www.healing-yourself.com and www.heal-yourself.com.au. For disease treatment protocols using nutritional therapies, see: www.lef.org and www.doctoryourself.com.

Addictions: Use Basic Cleanse (Step 4) followed by food allergy testing, and practice a diet based on grass and vegetable juice with added water for a total fluid intake of about a gallon daily. Prepare a homeopathic remedy made of the addictive substance. Use intestinal sanitation; alkalize the body; take high-potency vitamin B complex and glutamine; practice guided imagery and affirmations; have outdoor activity and group support. Do detoxification using frequent saunas or hot baths.

AIDS: Helpful is a predominantly raw food diet with plenty of sprouted seeds and fresh vegetable juices, mainly from cereal grasses and purple foods. Also try oxygen therapies alternating with high antioxidant intake, intestinal sanitation, and herbal parasite cure, and continue longer with wormwood. Colloidal silver, copper salicylate or colloidal copper, echinacea, MSM, propolis, and other natural antibiotics can be beneficial, along with a Beck-type electronic zapper and magnetic pulser, Basic Cleanse, and emotional and mind therapies. (See Infections and Inflammations and Candidiasis below.)

Allergies: Test yourself against individual foods and chemicals with an elimination diet after a five-day water fast, or after Basic Cleanse or a rice diet with only salt and olive oil for flavouring. Possibly use a rotation diet and use the same food only once every five days; eat small meals and chew well. Use digestive enzymes, hydrochloric acid, vitamin B complex, bio-flavo-noids and carotenoids, high vitamin C, glutamine, and MSM. Alkalize the body with sodium and potassium bicarbonate; neutralize fruit acids with dolomite. Avoid or minimize intake of sweet and acid food and food additives. Make a homeopathic remedy from the offending allergens.

Anemia: Consume juice or powder of cereal grasses, organic liver (underdone or freeze-dried), and sprouted seeds. Take hydrochloric acid and ascorbic acid with proteins and cooked food; minimize intake of sweet food. Vitamins B6, B12, folic acid, E, and bioflavonoids are helpful as are chelated or organic forms of iron,

copper, zinc, manganese, chromium, and selenium. Do a parasite cure with wormwood, cloves, and tincture of walnut, and electronic zapper. Practice red color therapy (Step 17); get mild sun exposure and outdoor activity. Treat any excessive menstrual bleeding and avoid long-term use of anti-inflammatory drugs, especially aspirin.

Arthritis: DIET: Use the Basic Cleanse followed by allergy testing and follow a predominantly raw food diet. Use ground linseed, fish oils, cold-pressed peanut oil, olive oil, and plenty of grass juice and sprouted seeds. If your fingernails are soft, take hydrochloric acid with meals, then sodium bicarbonate three hours after hydrochloric acid. Avoid or minimize sweet and acid food intake as well as wheat products, gluten, milk, cheese, commercial cooking oils, citrus fruit, processed food, and food of the nightshade family (potato, tomato, capsicum, and eggplant).

SUPPLEMENTS: Take vitamin B6 (especially with problems of the hands) and nicotinamide in addition to multivitamins. Take 500 mg or more of magnesium, boron, zinc, and MSM; try copper salicylate for pain and inflammation, or, alternatively, copper colloids or copper bracelet. Also recommended are acidophilus, digestive enzymes, celery seeds, and yucca. Most helpful are glucosamine, chondroitin, mussel extract, or liquid bovine or shark cartilage, and broth of fish heads. (See “Alkalizing with Calcium and Magnesium” and “The Calcium-Phosphorus Ratio” in Step 6.)

ADDITIONAL THERAPIES: Use warm peanut oil rubs on affected joints; also try blistering agents, or hot Epsom salt packs and baths, or use magnesium chloride instead, followed by sweating wrapped in blankets. Dissolve MSM and glucosamine in a solution of copper salicylate and rub it into affected joints. Try blue light therapy over painful areas and orange light on stiff, calcified joints (Step 17). Try deep muscle massage; remove dead teeth and mercury amalgam fillings; do the herbal parasite cure with the electronic zapper.

Asthma: Avoid or minimize sweet and acid food, wheat, gluten, and lactose as in milk products (except butter); also avoid vaccinations, aspirin, processed foods, and the sulphites used in many foods and medications as preservatives. Practice intestinal sanitation and allergy testing. Use ground linseed, fish oils, and olive oil, and avoid other commercial oils. Halibut-oil capsules or other source of vitamin A (not beta-carotene instead), vitamins E, C, B1, B6, L-lysine, molybdenum, magnesium, manganese, MSM, selenium, and zinc are helpful. (See Alkalizing with Calcium and Magnesium and The Calcium-Phosphorus Ratio in Step 6.) Take hydrochloric acid with protein meals if your fingernails are weak, then sodium bicarbonate three hours later. Use foods high in antioxidants, bioflavonoids, and carotenoids, including green tea, grape seed extract, and purple foods.

Practice breathing exercises: inhale into the abdomen and exhale as slowly as possible; do this routinely during sedentary activities. After normal exhalation, hold your breath for as long as possible; inflate balloons as a further exercise; have a spinal adjustment. Preferably live in a dry, warm climate or higher elevation; avoid damp places, moulds, and fungi in air and food. Use natural fibre mattresses or wrap foam mattresses in polyethylene sheeting with only a small opening at the bottom.

Eliminate systemic parasites and microbes with wormwood, cloves, black walnut tincture, and use of the electronic zapper; try colloidal silver, copper, or

copper salicylate. Vomiting therapy can help: Try to cough up mucus after placing hot onion packs on the chest. Make children emotionally secure; try emotional release therapy for adults with asthma. Use the Emotional Freedom Technique (see Step 63).

Some asthmatics claim to have been cured by regularly inhaling three-percent hydrogen peroxide sprayed directly into the mouth from a spray bottle, while others had success with inhaling high concentrations of negative ions from a medical-type air ionizer or with spray-inhaling a ten-percent sodium ascorbate solution. Hydrogen peroxide is probably best against fungal infestations, and antioxidant spray against inflammations and oxidative damage. Try both but generally use antioxidants as the main approach.

Autoimmune Diseases: In autoimmune diseases, the immune system attacks faulty body cells, probably due to infestation with microbes or their toxins. Common causes are dead teeth and resulting jawbone infections, overgrowth of the intestinal tract with pathogenic microbes, and some researchers suspect vaccines.

Autoimmune diseases include Type I diabetes, lupus, multiple sclerosis, myasthenia gravis, rheumatoid arthritis, scleroderma, and thyroiditis. The main aspects of treating autoimmune diseases are to avoid gluten products and substances to which you are allergic or sensitive, sweetened food, genetically modified or microwaved food, and processed food in general. By far, the best option is to adopt temporarily a raw food diet.

Use high amounts of antioxidants, in particular vitamin C, L-lysine, zinc, and other nutrients listed under viral infections in the section on Infections and Inflammations below; also use the electronic zapper and other measures listed in that section under Addi-tional Therapies. See any entries for your specific autoimmune disease.

Back Problems: Practice a low allergy diet; take vitamins C, E, and B complex, and high doses of manganese, zinc, and magnesium. Reflexology is very effective, as are Epsom salt packs. For shrunken disks, stretch the spine and have it rubbed with hypericum oil; get deep muscle massage or pressure applied at tight muscles; have a spinal adjustment. Hang upside down (inversion swing) for problems in the lower back. Try stretching exercises; sleep on a firm bed, and women should avoid wearing high heels. Improve digestive system function and any diseased organ, as back pain often results from problems in inner organs. Try other recommendations in Arthritis and see Step 20: Spinal Therapy and Massage.

Broken Bones: Fresh vegetable juices, broth of fish heads, and bone meal can be helpful as well as vitamin C, halibut-oil capsules, manganese, boron, zinc, magnesium, and comfrey root. Place the north pole of a magnet above the fracture (towards the trunk) and the south pole opposite and below the fracture (towards fingers or toes); also try a pulsating magnetic field at the site of the injury. See Osteoporosis below.

Cancer: The main aspects of a holistic cancer therapy are strengthening the immune system, controlling the cancer microbe, removing accumulated toxins and waste products, and dissolving tumours.

DIET: Start with the Basic Cleanse followed by a juice diet, grape cure, or low-protein diet; use additional spirulina and bee pollen for high-quality protein. Maximize purple foods (red beets or their juice, black or purple grapes, dark grape juice, blueberries, blackberries) with any diet. Eat at intervals during the morning one or two pounds of purple foods, or sip one bottle of dark grape juice or red beet juice; take no other food until noon. If the body is sensitive, keep the urine slightly alkaline (see Step 6). If the body is insensitive or has soft fingernails, take hydrochloric acid with meals. Structure the diet according to your metabolic type and blood group (see Step 43). Cancer-related pain tends to disappear on a raw food diet.

SUPPLEMENTS: The most important vitamins are C, 10 g or more, mainly neutralized and in five divided doses; A, best as shark-liver oil and cod-liver oil (if you have malabsorption, use A-emulsion); niacinamide, folic acid, B2, and B6; with generalized weakness, inject B12 or dissolve it under the tongue.

The most important minerals are magnesium, selenium, and zinc. Use high amounts of all antioxidants, including alpha-lipoic acid and grape seed extract. You can alternate short periods of several weeks of oxygen therapies with several months on high antioxidant supplements.

With tumours, use high amounts of the following to inhibit their formation of new blood vessels: shark or bovine cartilage (both best as liquid), zinc (30 mg, three times daily), vitamin B2, turmeric, and green tea; minimize any copper intake.

Other useful remedies are proteolytic enzymes, MSM or sulphur-amino acids (L-cysteine and L-methionine), propolis, ground linseed, aloe vera, kelp, Lactoferrin, lecithin, and freeze-dried liver. Some effective herbs are the Hoxsey herb mixture, Essiac, pau d'arco, papaw leaves, echinacea, greater celandine, red clover blossoms, and wormwood and other herbal parasite remedies. Urea helps to prevent metastases; hydrazine sulphate helps you regain weight and strength.

ADDITIONAL THERAPIES: Minimize electromagnetic pollution, and sanitize your teeth (see Step 8). Experiment with ways to increase your life force as shown in Part 7. Use an electronic blood purifier, and directly over the tumor place a magnetic pulser, strong south pole magnet, and blue light therapy for pain and tumor control. Try various types of packs over the tumor area, such as pulped grass or dark grapes, cabbage leaf, or honey (see Step 21). Avoid surgery near the full moon (increased chance of haemorrhage); premenopausal females may have a reduced rate of metastasis after surgery near ovulation time (mid-cycle) as compared to surgery near the start of the period.

Improve your mind with several hours of daily relaxation, affirmation, prayer, guided imagery, and meditation. Practice positive thinking and develop faith and a joyful mind. Nothing will cure you if you do not believe in it. Learn to feel and express your needs as well as negative emotions and become assertive. Resolve any emotional conflict - see: "Emotional-Mental Shocks" later in this part. Do not focus on fighting cancer, but rather on improving your health and enjoyment of life. Choose to live life to the fullest, have a goal for the future, and become enthusiastic about your life. Your attitude is the key to your success.

Candidiasis: This is a fungal infection caused by Candida albicans. The most common symptoms are thrush (oral) and vaginal and skin infections. However, Candida often invades the body itself, starting with the digestive tract and then

entering the bloodstream, overwhelming the immune system. In this way, Candida has been found to cause or aggravate food allergies, chronic fatigue, digestive-tract diseases, all kinds of autoimmune diseases, lupus erythematosus, multiple sclerosis, myasthenia gravis, but also schizophrenia, mental depression and anxiety, impaired memory, hyperactivity, menstrual problems, and miscarriage. Basically, any part of the body can become impaired.

Antifungal remedies include garlic, golden-seal, pau d'arco, propolis, wormwood, and the oils of tea tree, cinnamon, clove, eucalyptus, mustard, and thyme. Use Intestinal Sanitation (see Step 3) combined with the hypoglycaemia diet, and avoid sweet foods, yeast, moulds, and initially fruit. For severe fungal infestation of inner organs, an internal iodine solution, commonly called Lugol's solution, can be taken for three weeks. Also try oxygen therapy, colloidal silver and copper, and an electronic blood purifier, also anti-inflammatory remedies as required.

LUGOL'S SOLUTION: This is an iodine solution taken internally, designed to eliminate Candida and other microbes, viruses, and mycoplasmas from the bloodstream. Obtain Lugol's solution, also labelled Aqueous Iodine Oral Solution, from a pharmacist. Take a test drop in juice. If no allergic reaction results, continue to take six drops four times daily in liquid or mixed with food. Iodine is an oxidant, so do not take it with antioxidants. Continue Lugol's for three weeks, but interrupt if you have a strong reaction. Be careful, for high amounts of iodine taken for more than three weeks may depress thyroid functions. You may make Lugol's solution yourself by dissolving 44 g (1.5 ounces) of iodine and 88 g (3 ounces) of potassium iodide in one quart (litre) of water. First dissolve the potassium iodide in a pint of water, then add the iodine and fill up to one quart. Shake from time to time until dissolved after about a day.

Cardiovascular Disease: Recommended is the Basic Cleanse followed by periods on fruits only, or the grape cure or juice diet. Avoid or minimize sweeteners and especially sucrose, salt, chlorinated water, smoking, peanut products, red meat, caffeine, and all commercial fats and oils except extra-virgin olive oil. Do not heat any flesh food or eggs above boiling temperature. Separate fruit and other fructose-containing foods from starches or foods releasing glucose. Use only cow's milk products that have not been pasteurized or otherwise heated.

Use plenty of fresh fruits and vegetables; seafood (if not vegetarian); some (organic) poultry; one to two tablespoons of freshly ground or frozen linseed (flaxseed) and one to three capsules or teaspoons of lecithin with most meals; fish oil capsules; oily seeds and nuts (not roasted or rancid), best as seed cheese. Papaya and pineapple are good. If your blood pressure is high, acidify your body with ascorbic acid and take hydrochloric acid supplements with meals. With acid body conditions, more histamine is released, which in turn dilates blood vessels.

SUPPLEMENTS: Take high doses of natural vitamin E (tablets), vitamin C (5 to 10g daily, in three to five divided doses, mostly as ascorbic acid), vitamin B6, folic acid, and niacin before meals to induce flushing. Take close to 1000 mg of magnesium daily as magnesium chloride or with neutralized ascorbic acid. Other helpful minerals are zinc, selenium, chromium, manganese, and copper salicylate; but males should minimize calcium. Seriously ill patients can take 5 to 6 g of lysine and 2 g of carnitine daily in four divided doses. For herbs, consider bromelain, ginger

(with most meals), ginkgo biloba, and green tea; also helpful are digestive enzymes high in lipase.

ADDITIONAL THERAPIES: Remove any dead teeth and make sure there is no chronic jawbone infection in the wisdom tooth positions. Get regular exercise; have alternating hot and cold showers; and do skin brushing. Frequently press into the fleshy pad below the left thumb; pressing strongly here during a heart attack can allegedly stop the attack. A small magnet with the south pole placed over the heart can ease pain or slow the heartbeat, while the north pole placement strengthens the beat (do not use with a pacemaker). Also try the herbal parasite cure, electronic zapper, and colloidal silver. Practice the Love Cure (Step 61).

Chronic Fatigue Syndrome: In this condition, the cellular oxidative energy production is blocked by non-biological chemicals or endotoxins from a chronic microbial infection, often due to Candida present in the blood after antibiotic therapy. Techniques to try include allergy testing and a low allergy diet; consuming plenty of purple foods (beet root, red cabbage, purple onions, black/purple grapes, black currants, blackberries, blueberries, or juices of any of these), and green juice or, alternatively, barley green powder, spirulina, or chlorella. With low blood pressure, eat salty and spicy food; select foods with a favourable calcium/phosphorus ratio; and alkalize fruit acids with dolomite.

SUPPLEMENTS: Use high levels of antioxidants with 10 g or more of sodium ascorbate in divided doses, vitamin A emulsion, natural vitamin E complex as tablets, alpha-lipoic acid, grape seed extract, and Microhydrin or strong electrolytic reduced water (ERW). Also useful are vitamin B-complex, calcium orotate, magnesium, selenium, zinc, coenzyme Q10, L--glutamine, L-lysine, aged garlic, freeze-dried liver, propolis, echinacea, maca, and either L--cysteine and L-methionine or MSM. Initially try weekly vitamin B12 injections or daily vitamin B12 tablets dissolved under the tongue.

ADDITIONAL THERAPIES: Try Candida treatment, herbal parasite cure, electronic blood purifier, magnetic pulser, colloidal silver, and copper salicylate. Minimize electro-stress and sanitize the teeth (see Step 8).

Colds: Colds are beneficial clean-outs of mucus congestion, so to avoid colds, avoid mucus congestions and foods that produce them. These are mainly lactose and cow's milk products (except butter), sweet foods, moulds and mouldy foods, and any foods or chemicals to which one is allergic or sensitive. Other factors are mercury amalgam fillings, root canals, and other foci of chronic infections, as well as Candida overgrowth and intestinal dysbiosis (pathogenic bacteria).

Try to correct these conditions, and see Mucus Problems below for ways to ease mucus congestions. I have seen severe colds aborted within hours by using the Sugar Cure (see Mucus Problems). Other useful remedies are echinacea, fresh raw garlic, and very high doses, up to bowel tolerance, of vitamin C (sodium ascorbate). In addition, frequently dissolve a tablet with a small amount of zinc sulphate in the mouth. Another useful method is to dissolve one-third of a teaspoon of sodium ascorbate in two tablespoons of water and from time to time place 20 drops in each nostril.

Colds can also be stopped if, at the first sign of a coming cold, a few drops of 3 percent hydrogen peroxide are placed in each ear. Lie on one side while putting the

drops into the opposite ear, wait a few minutes, then change sides and put the drops in the other ear. In addition, gargle frequently with diluted hydrogen peroxide and also swallow some. See Infections and Inflammations below.

Depression: Use a high-quality low-allergy diet. With sensitive skin and emotional instability, use mainly slow-digesting foods, and with insensitive conditions consume plenty of fruit. Avoid foods to which you may be addicted or on which you might binge, such as chocolate, coffee, tea, and alcohol. Give yourself a special treat from time to time, but without using sweet or junk food. Very important are fish oils (best as cod-liver oil) and linseed oil from ground linseed.

The most important vitamins are B6, B12, C, niacin or nicotinamide, and folic acid, and the most important minerals are zinc, magnesium, calcium, and manganese. Initially take a high-potency B-complex and mineral tablet with most meals and additional amounts of vitamin B6 and zinc (up to 500 mg daily of vitamin B6). Try hypericum or St. John's Wort and the Bach Flower Remedies Aspen, Gentian, Gorse, and Mustard. Correct constipation; take cultures of acidophilus and bifidobacteria. Have any dead teeth removed and preferably mercury amalgam fillings replaced. Avoid lead pollution. Kyolic (aged garlic), cooked garlic, and raw garlic assist in detoxification. Candida can go into the bloodstream and cause depression and other psychiatric symptoms. For treatment, see Candidiasis above.

Try amino acids: up to 2 g of L- (or D,L) phenylalanine and tyrosine, each before meals, or alternatively, up to 2 g of tryptophan. You can also try taking phenylalanine and tyrosine before breakfast only and tryptophan at bedtime only. Glutamine can be used as an additional brain fuel. Epinephrine and dopamine in the brain are formed from phenylalanine and tyrosine, while serotonin is made from tryptophan.

Depression often results from low thyroid and adrenal functions. To assess thyroid status, check your temperature under the armpit before rising in the morning; women check this in the first ten days of the menses or before ovulation. If it is below 97.8º F (36.5º C), try thyroid extract (absorb under the tongue) and iodine from kelp. In addition, selenium is required to activate thyroid hormone; take 200 mcg per day.

Seasonal affective disorder is due to insufficient sunlight exposure. Expose yourself to one or two hours of very bright full-spectrum electric light each day, preferably in the morning; if possible, be outside in sunlight and without sunglasses. In addition, use yellow or orange color therapy for all forms of depression; also look into the light source (see Step 17). Wear bright-coloured clothing. Use deep-breathing exercises; dance to lively music and shake the whole body for a minute during fast breathing.

Use prayer, affirmations, meditation, and guided imagery to uplift your feelings and solve your problems. Learn to trust in your inner or higher guidance and ask it to take care of your problems. Socialize and find a group with similar interests. Forgive yourself and others for any mistakes or misdeeds.

Diabetes: Under professional medical supervision only, go for one week on a diet of only apples, mainly tart varieties (e.g. Granny Smith) with no or only a minimum of insulin or drugs. Undertake intestinal sanitation (Epsom salt - garlic flush followed by plenty of dairy-free acidophilus cultures). Then gradually introduce non-sweet raw foods, especially sprouted seeds, lentils and other legumes, seafood,

onion, and cooked vegetables. Keep a diary of the blood sugar level after each test food (a food that you ingest to see how your blood sugar reacts to it). Continue using only low-response food (a food that does not strongly elevate the blood sugar level).

Before each meal have plenty of fresh grass juice, spirulina, or chlorella, one tablespoon of freshly ground linseed, and one tablespoon of fenugreek seeds (soaked overnight; use the soaking water). Avoid all cow's milk products, wheat and gluten, saturated and especially hydrogenated fats, processed foods, and food additives. Avoid all sweet or sweetened foods, including fruit juices, and in particular all sucrose; avoid fructose and glucose at the same meal, such as having fruit after a meal, although it is generally safe to have fruit an hour before a meal. You may, however, use xylitol, sorbitol, or the herb stevia as a sweetener.

With Type I diabetes, avoid all glucose--producing foods, such as starches, grains, or cereals, sweet vegetables, and even legumes during a trial period. Use instead meat, fish, egg, goat's milk products, cod-liver oil, spirulina (one to two ounces), lettuce, cabbage, and other leafy greens, in addition to green/tart apples, lemons, and limes. If you need more carbohydrate, add fructose to the lemon juice; try fenugreek and ground linseed.

SUPPLEMENTS: Take vitamins C, E, B-group, especially B1, B6, and B12; glucose tolerance factor or chromium; manganese and zinc (chelated); 500 mg or more daily of magnesium; vanadium, if available; also MSM, fish oils, lecithin, and freeze-dried liver; continue with dairy-free acidophilus. The herb Gymnema Sylvestre is effective with both types of diabetes; take either 200 mg of extract or 1 to 2 g of dried leaves shortly before meals that are likely to elevate blood glucose levels. Also useful are aloe vera, bilberry, ginseng, goat's rue (may help to regenerate pancreatic beta cells), and various spices such as cinnamon (one teaspoon daily in divided doses), cloves, tarragon, and turmeric. Calcium arginate (calcium salt of the amino acid arginine) is effective with Type II diabetes. Also try castor-oil packs on the liver and abdomen; magnetic pulser on liver and pancreas; do the reflexology for these points on feet and hands; herbal parasite cure and colloidal silver.

Digestive Disorders: Do allergy testing and have a low-allergy diet with small meals; chew slowly and well; practice correct food combining; follow a diet appropriate for your metabolic type and blood group; consider a rice or arrowroot mono-diet for a while, with only salt and olive oil for flavouring, or alternatively a water fast (purified water only). Use the Basic Cleanse and intestinal sanitation with acidophilus and bifido cultures. If you have soft fingernails, add hydrochloric acid to your meals, taking sodium bicarbonate three hours later.

Take digestive enzymes or a papaya (pawpaw) Smoothie with meals (see the recipes in Part 4). Place castor-oil packs on the liver and abdomen; do reflexology or have acupuncture. Herbs to stimulate digestion are aniseed, caraway, fennel, fenugreek, mint, or peppermint; try half a cup of a bitter liver herb tea after the meal. With acute indigestion, induce vomiting; with diarrhea, try an alimentary canal flush with crushed garlic and a tablespoonful of Epsom salt.

With ulcers and irritable bowel (Crohn's disease), try slippery elm powder before meals; meals with arrowroot can be soothing; and use ginger root often with meals. Goldenseal and chamomile are useful as they are anti-inflammatory. Try glutamine and zinc sulphate with meals (200 mg/day); also copper salicylate, herbal

parasite cure, oxygen therapy, and colloidal silver. Magnesium is best taken as magnesium chloride; take also high-quality aloe vera juice.

Use the magnetic pulser and south pole of a strong magnet on sites of inflammation or discomfort. Include raw potato in the vegetable juice for stomach ulcers and cabbage juice with duodenal ulcer; stomach ulcers usually cause pain after a meal, duodenal ulcers between or before meals. Very effective are six drops of tea tree oil diluted in a glassful of liquid, then taken orally before breakfast for three days; initially take a test drop to see that you are not oversensitive to it.

With constipation, use sufficient magnesium (as chloride or sulphate) to produce bowel movements and take one or more tablespoons of ground linseed with meals. Take long walks; have large vegetable salads; squat for bowel movements (see Step 21). For bloating or excess wind avoid any sweet food with or after vegetables or fibre-rich food; use correct food-combining with a low-allergy diet; use magnesium chloride and practice intestinal sanitation.

With hiatal hernia (with symptoms of belching, heartburn, and indigestion), sit at one end of a massage table (or something similar), your legs outstretched on the table. A helper lies across your legs or holds them down while you lean back over the edge as far as possible. Tighten your abdominal muscles to pull yourself slowly back up to the sitting position. A second helper may assist. In most instances, this will pull the stomach back to its normal position.

Epilepsy: A low-allergy diet is advisable. Initially avoid and later minimize consumption of sweet food, wheat, milk, cheese, and food additives, especially excitotoxins. Avoid contamination from copper (new water pipes), aluminium (cooking), mercury (amalgam fillings), and lead. Take vitamin B6, vitamin E tablets, and magnesium in high doses; alkalize your system with calcium and magnesium; frequently suck on a tablet of magnesium orotate; take lecithin, glutamine, MSM, taurine, black cohosh, and copper salicylate; try raw egg yolk, mussel, or oyster extract.

Have a chiropractic neck adjustment; do head and neck exercises; do the herbal parasite cure; sanitize your bedroom. Minimize emotional stress; reduce your exposure to fluorescent or flickering lights, television, and computer games. Try south-pole magnets placed at the temples.

Eye Problems: Helpful here is a low-allergy diet with plenty of fresh grass and vegetable juices. Avoid or minimize intake of dairy products, hydrogenated fats, commercial oils, and sweet foods. For all eye conditions, high-dose vitamins B2 and A (halibut-oil capsules; with suspected fat malabsorption, use vitamin A emulsion) in addition to B complex, C, and grape seed extract are advised; these also help with cataracts and macular degeneration. You need periods with no additional vitamin E intake as this can depress blood levels of vitamin A; however, with wet macular degeneration, try high-dose vitamin E tablets.

Carotenoids, especially lutein and zeaxanthin, are important for the macula; they are found in deep-green, yellow, orange, and red fruits and vegetables, as in tomatoes, squash, corn, and spinach. Have a high intake of a wide range of bioflavonoids; use the herbs eyebright and bilberry internally and as topical eye rinse. Important minerals are magnesium, chromium, manganese, selenium, and zinc.

Chromium, calcium, and a diet low in sweet food are important with myopia (near-sightedness), while magnesium is good for farsightedness. A salty diet is beneficial with glaucoma, as is sodium ascorbate up to 30 g daily (in five divided doses), to drain excess fluid from the eyes. Intensive cleansing combined with energizing or stimulating the eyes in order to unblock congested drainage channels is recommended. For red eyes or conjunctivitis, rinse the eyes with a weak solution of boric acid, possibly combined with strained eyebright and chamomile herbs as tea.

For viral infections of the eyes, make up a solution of 2500 IU of vitamin A emulsion and 250 mg of sodium ascorbate per ml of water. Use one or two drops in each eye every three to four hours. If it stings too much, then dilute as needed. Keep refrigerated and make a fresh remedy every week. Combined with sufficient vitamin B2 (up to 100 mg three times daily); this also helps with allergy-induced eye problems. For clogged arteries in the back of the eyes, try potassium iodide as explained in Cardio-vascular Disease.

Use a raw grated potato pack in gauze for irritated eyes and warm castor-oil packs for weak eyes. You can also put a drop of castor oil in each eye at bedtime for gradual strengthening. Be outside as much as possible without glasses or sunglasses; look at the blue sky, but avoid eyestrain. Minimize watching television, staring at computer screens, and reading by electric light. While reading, frequently interrupt your vision, look around, and cover eyes with palms. Preferably use natural daylight or full-spectrum bulbs; minimize use of fluorescent lights except if they are special daylight types. Press tender muscles in the back of the neck.

Do eye exercises: look up, down, sideways, diagonally in quick succession, circle, alternate looking at a near and a far object. Do head and neck exercises, reflexology, or rapidly blink at the sun when it is low in the sky. Frequently alternate looking at an orange or red light bulb of 25 watts and a blue light of 40 watts in a darkened room; then look for several minutes at a green 40-watt light.

Gynaecological Problems: Important here is a diet low in sweet food, fat, and salt, a vegetarian cleansing diet, especially in the case of heavy periods and difficult menopause. Also advisable are sprouted seeds, vegetable salads, grass juice, and a diet high in bioflavonoids and carotenoids as from coloured foods, especially yellow, orange, red, and purple. For heavy bleeding, black cherries are best; if not available, try black or purple grapes, juice of dark grapes or red beets, blackberries, and blueberries.

SUPPLEMENTS: Take B-complex vitamins, especially B6 and folic acid, rutin and bioflavonoids, vitamin E tablets (1000 to 2000 IU daily), and selenium-methionine, especially if breasts are tender and for menopausal hot flushes. Neutralize fruit acids with dolomite for a high calcium and magnesium intake. Take additional calcium if there is excessive bleeding and fatigue; take more magnesium for tension and irritability. Also helpful are zinc, manganese, MSM, Royal Jelly, bee pollen, evening primrose oil, vitamins A and C, and organic iron. With menstrual clotting, more vitamin K is needed; use plenty of dark-green vegetables, possibly injections of 15 mg of vitamin K1 (derived from plants). Fibrocystic breast disease and ovarian cysts often disappear with six to eight drops of saturated solution of potassium iodide (SSKI) taken daily in some water for two to three months. Prolonged use can inhibit thyroid functions, so use with professional supervision; see Thyroid Problems.

HERBS: For menopause: chamomile, hawthorn, red clover, and sage. Excessive bleeding: bayberry bark, red raspberry, shepherd's purse, and witch hazel. Suppressed menstruation: chamomile, catnip, fennel, pennyroyal, and peppermint. Generally try motherwort, dong quai, raspberry shoots, and chasteberry (Vitex agnus-castus); St John's Wort for depression; and black cohosh for period pain. Maca is most helpful for all conditions, helps after hysterectomy, is safer than hormonal replacement therapy, and is also recommended for age-related decline of sexual function.

ADDITIONAL THERAPIES: Take a hot sitz bath or sit on the north pole of a strong magnet for general strengthening. Press foot reflex areas on heels; use blue lighting to reduce bleeding, orange lighting to increase it. Place castor-oil packs on the lower abdomen and lower back, or Epsom-salt packs; apply pressure therapy and manipulation and adjustment of lower back; do spinal tapping of lumbar vertebrae or colonics.

VAGINAL YEAST INFECTION: This is caused by the yeast Candida albicans. Douche with either diluted hydrogen peroxide or garlic water to which may be added several drops of tea tree oil (shake well before use), tea of sage, and juniper berry, or pau d'arco. After douching, apply acidophilus in the vagina and around it; repeat as often as required and have intestinal fungicidal treatment (see Candidiasis).

Headaches and Migraines: Do the Basic Cleanse followed by allergy testing and maintaining a low-allergy diet. Minimize intake of sweet food, dairy products, wheat and other gluten products, egg, oranges, tomatoes, food additives, fatty food, chocolate, Brazil nuts, dried coconut, aged cheese, mushrooms, pickled herrings, pork, excitotoxins such as monosodium glutamate (MSG), and tobacco smoke. Avoid environmental chemical and electromagnetic pollution; sanitize your teeth (see Step 8).

Try taking magnesium if your blood pressure is elevated, or calcium and salty foods if it is low. Have a strong coffee at the onset of symptoms (if you're not addicted to it). The herb feverfew may help. Correct any constipation or intestinal inflammation. Do head and neck exercises; pressure massage the neck and shoulder muscles and around the base of the big toes; have a neck adjustment and exercise your scalp muscles. Avoid stress; rest; get fresh air; walk; and do deep breathing. During a migraine attack, imagine your arms becoming warm, possibly soak them in warm water. Riboflavin (vitamin B2), up to 100 mg four times daily, has been found to prevent most migraines; use together with B-complex.

High Blood Pressure: Most important are low-allergy diet or allergy testing, low sodium intake, and high intake of potassium and magnesium; for females also calcium. This also helps to prevent strokes. Improve kidney functions; follow tips for Cardiovascular Disease.

Hyperactivity (ADD and ADHD): Allergy testing and a low-allergy diet are advisable. Minimize or avoid sweet food, especially chocolate, cow's milk, cheese, egg, pork, citrus, soft drinks, artificial food colouring, flavouring, excitotoxins, preservatives, chemical sprays, petrochemical fumes, detergents, strong perfumes, smoke, stimulants, and aspirin. Avoid fluorescent and flickering lights and games, television, and stressful situations. Minimize electromagnetic pollution (see step 8). In

regard to sweeteners, avoid sucrose or fructose in combination with glucose; see “Fructose and the Disaccharide Effect” under Step 40.

In several clinical trials, avoiding food and chemical allergens resulted in a 100 percent cure rate among test subjects. Frequently, Candida overgrowth in the intestines (commonly following a course of antibiotics) is the original cause of multiple allergies, so treat for Candida. Zinc and magnesium supplements are helpful, as are vitamins C, B6, pantothenic acid, nicotinamide, folic acid, and B12. For attention deficit, try ginkgo biloba.

Infections and Inflammations: Infections can be localized, for example, in the liver or throat, or generalized, as infectious diseases (including venereal diseases). They can be acute with sudden strong inflammations and fever, or they can be chronic and long lasting. Colds occur only if there is mucus congestion, and they are usually beneficial for removing excess mucus. Accelerate recovery by actively expelling mucus from your lungs and head spaces, including the sinuses. Colds can be avoided by using a diet that does not cause mucus congestion or by deliberately expelling mucus from the body (see Mucus Problems).

DIET: During acute conditions, semi-fast with only fresh vegetable and grass juice, spirulina and bee pollen, vegetable broth, strained rice water, and fruits (neutralize acids if the body is sensitive). Later, also consume easily digestible, high-quality food, such as sprouts, raw egg yolk, vegetable salads and cooked vegetables, rice, and bananas. Select foods with a favourable calcium-phosphorus ratio (see Step 6). Avoid gluten products, sweetened, processed, microwaved, and genetically modified food, and any food to which you are allergic or sensitive. With inflammations maximize omega-3 fatty acids (fish oils and ground linseed), and minimize omega-6 fatty acids (polyunsaturated seed oils).

SUPPLEMENTS: In acute conditions, try bowel-tolerance doses of vitamin C with sodium ascorbate; otherwise use 1 to 10 g of vitamin C daily, magnesium chloride if available, propolis, copper salicylate, and Lactoferrin. Vitamin A is especially good with respiratory infections; zinc is best as zinc sulphate lozenges. Improve the immune system with pantothenic acid, folic acid, vitamin B6, manganese, selenium, chromium, acidophilus culture, and freeze-dried thymus.

With viral infections, use a high intake of antioxidants in addition to selenium and zinc. Take 2 g five times daily or bowel-tolerance level of sodium ascorbate; 15 to 20 mg of zinc three times daily; 200 mcg of selenium; up to 2 g of L-lysine three times daily; and up to 200 mg of alpha-lipoic acid three times daily (alpha-lipoic acid is also called thioctic acid; prolonged intake over 100 mg may require extra biotin). In addition, take one tablespoon of cod-liver oil, other antioxidants such as grape seed extract, and Microhydrin or strong electrolytic reduced water; with hepatitis, also take the herb silymarin. A saturated solution of potassium iodide (SSKI from a pharmacist) is an all-round antimicrobial. As a precaution when travelling, take about ten drops in a small glass of water, and more, temporarily, with an acute infection. **Caution:** High amounts for more than a few weeks can suppress thyroid function.

With chest infections, in addition to the above, temporarily take 50,000 IU or more of vitamin A (under professional supervision). Try coughing up mucus after using a hot onion pack on the chest (see Step 21).

HERBS: These include echinacea, goldenseal, marigold, olive leaves, pau d'arco, prickly ash, and wormwood; also chamomile, elder flowers, and peppermint. With respiratory infections, try chamomile steam inhalation; gargle with diluted tea tree oil. Do the herbal parasite cure with wormwood, clove, and green hulls of black walnut. Use aromatic oils for infections: borneol, lemon, clove, eucalyptus, lavender, mint, or thyme.

ANTIBIOTICS: The main reason for a destructive fungal infection is antibiotic therapy. Candida albicans is commonly present in almost everyone, but is usually kept under control by friendly bacteria. If these bacteria are killed by antibiotics, fungi have the opportunity to spread and will seriously weaken the immune system, thereby contributing greatly to the development of the various immune-deficiency diseases, including cancer.

Other disadvantages of sustained antibiotic therapy are B-vitamin and vitamin-K deficiencies and malabsorption, caused by the destruction of intestinal flora. In addition, allergic reactions to the antibiotics can occur or boils may develop as a cleansing reaction even weeks or months later. For these reasons, if possible, antibiotics should be used only when serious infections cannot be controlled by natural therapies. With any antibiotic therapy, use vitamin and mineral supplementation, a diet high in raw food, probiotic bacterial cultures, and a natural fungicide such as fresh garlic.

FEVER: Fever is a great tool in fighting infections by killing heat intolerant germs and strengthening the immune response. Keep your body temperature up with hot baths, hot teas, and sweating. Body temperatures above 105º F can be reduced with cold packs placed around the calves, and white willow bark (aspirin).

PROPOLIS: This is an excellent natural antibiotic from the beehive. For best results, it should be applied directly to the site of the infection whenever possible. For a sore throat, keep some propolis powder constantly in the mouth (between the gum and cheek) and gargle with a propolis solution; or make it into a paste and apply it to a sore tooth. For sinus problems, sniff it up the nose; for earache, put it in the ear; for skin infections, apply it directly to the skin; for internal infections, of course, you have to swallow it. Note your reaction, as some people are allergic to propolis. You can make your own propolis tincture: Freeze-dry raw propolis (from a beehive), pulverize, and keep it in alcohol for one to two weeks exposed to the sun; shake frequently.

THYMUS: Located in the chest, the thymus is the key gland of our immune system. Most strengthening for the thymus gland are propolis, manganese, and freeze-dried thymus extract. To strengthen the thymus, frequently tap with the fingers at the upper end of the breastbone; maintain a good posture and walk with long strides and swinging arms. Apply lemon (yellow-green) color therapy on the upper breastbone (see Step 17).

COPPER SULFATE (BLUESTONE): Available from gardening supply outfits, this has strong antiseptic and anti-inflammatory properties. Collect any discharge from an infected or inflamed organ or wound in a medium-strong solution of bluestone and keep it there for several days. This may be phlegm, pus, bloodstained bandage, vaginal or nasal discharge, or urine (in bladder or kidney infections). This can promote healing by way of secondary contact and can also be used with an extracted tooth or any severed part of the body. This method works on the same principle as

radionics and telepathy with a two-way exchange of information energy between the body and any separated part.

ADDITIONAL THERAPIES: Use colloidal silver or copper, oxygen therapy, and an electronic zapper, and possibly a magnetic pulser (see Step 19). You can also use a hot bath (with Epsom salt) followed by sweating; a hot foot bath with mustard powder or cayenne; cold packs placed on the abdomen and around the calves. For colds or flu, immerse hands and lower arms in hot water for 30 minutes; keep the water hot; in addition, you can chill the underside of the big toes with ice dipped in salt. Generally, blue light focused on the site of infection is helpful, as is blue-radiated water taken internally. Try also Epsom-salt purges, sweating, induced vomiting, colonics; packs of cabbage leaves or Epsom salt placed on localized infected or inflamed areas; autosuggestion and visualization or right-brain exercises: tell your immune system to produce plenty of efficient B cells and T cells.

Insomnia: DIET: Have early, light evening meals, using animal protein only sparingly; minimize sweet foods, salt, alcohol, caffeine, and other stimulants taken in the afternoon or evening; test for food allergies.

SUPPLEMENTS: Advisable are vitamins B6 and C; nicotinamide (1 g at bedtime), especially if experiencing difficulty returning to sleep after awakening; inositol; lecithin; one teaspoon of milk of magnesia or magnesium chloride at bedtime. Keep a tablet of magnesium orotate in the mouth when sleepless, take L-tryptophan (an amino acid, 500 mg) or melatonin (1 to 3 mg) at bedtime. Vitamin B12 can help to establish a normal circadian rhythm. Try the herbs passiflora, valerian, or thyme, or hops in a muslin bag placed on the chest or pillow; it is not recommended to use valerian on a long-term basis.

ADDITIONAL THERAPIES: Try a hot relaxing bath, possibly with Epsom salt, before bedtime or a cold pack on the abdomen when trying to fall asleep. The body temperature needs to drop during sleep, therefore use relatively light covers and keep the bedroom cool (but not cold). Sleep with the head in a north or north-easterly direction; use blue sheets, bed covers, curtains, and pyjamas; blue, violet, or purple lighting at bedtime; sleep in complete darkness on a natural-fibre mattress; remove drugs and chemicals from the bedroom.; and minimize electro--pollutants (Step 8). Expose yourself to bright light soon after rising (best is sunshine), but minimize bright light (including bright TV and computer screens) exposure in the evening.

To facilitate sleep, use autosuggestions when going to bed and/or relaxation exercises or visualize a peaceful scene. Do eight-two breathing (Step 9) or inhale through the nose, exhale through the mouth. Repeatedly take three deep breaths, then hold the breath as long as possible; finally continue with slow, shallow breathing to retain more carbon dioxide.

Most effective is plenty of outdoor activity, ideally done without wearing prescription glasses. Try a long slow walk in the late afternoon or early evening; alternatively, undertake other restful activities, such as listening to soft music or meditating. Do not read anything interesting; engage in no other absorbing mental activity or exciting movies; clear up any worries. Ask your lower self (the subconscious level) for cooperation: Tell it to stop thinking of a particular problem and that you will deal with it during the daytime, and then do that. Keep pen and paper beside the bed to write down any important thoughts to deal with the next day.

If you like to experiment, try the Eeman screens: Place metal wire screens (approximately 16 inches by 10 inches, from a hardware store) under your head and the base of the spine. The screens can be enclosed in a pillowcase. With an electric wire, connect the head screen to a piece of metal pipe held in the left hand, and the buttock screen in the same way to the right hand. Use the screens for ten to 30 minutes at bedtime, lying on your back with the ankles crossed.

This balances our internal bioelectric potentials and is conducive to increased tranquillity, meditation, and sleep. Basically, you can balance without screens by placing the right hand under the base of the spine with the palm facing up, and the left palm under the top of the spine. Because the arm muscles are partly contracted in this position, it is not as relaxing as with the screens.

Kidney Problems: You need a diet low in protein, salt, food additives, and drugs, along with allergy testing and a low-allergy and blood group diet. Use predominantly raw foods with plenty of sprouted seeds and fresh (mainly green) vegetable juices, ground linseed, and fish oils; try a watermelon fast. Helpful are antioxidants, spirulina, and coenzyme Q10. For kidney stones, use lemon juice and grapefruit, ascorbic acid, vitamin B6, magnesium, and zinc, but restrict your calcium intake. Useful herbs are buchu, cornsilk, dandelion, and uva ursi; as diuretics, try juniper berries, elderberries, or peach leaves. Colonics with water low in minerals delay the need for dialysis. You need sufficiently high fluid intake to produce about one gallon of urine daily. Most effective in serious conditions is urine therapy (see Step 22).

My favourite way to reactivate kidney function is drinking, slowly and at intervals, about three quarts (litres) of high-quality pure water (no chlorine or fluoride) before breakfast. To each quart, add up to a cup of fresh urine and, if available, the content of one capsule of Microhydrin or Microhydrin Plus. If already on dialysis, then use distilled or de-ionized water, but only with these additions, and increase the volume of drinking water gradually over successive days to match the output of urine. Instead of Microhydrin, you can also use strongly electrolytic reduced water (ERW). While the addition of Microhydrin or ERW is not essential, they provide strong antioxidant activity that helps to regenerate kidney function.

Liver and Gallbladder Problems: Detoxify with the Basic Cleanse, then from time to time, possibly once a month, repeat the first part of it (see Step 4). Have three days on apples only; in the evening activate the liver with a castor-oil pack; at bedtime take half a cup of olive oil with lecithin and possibly orange juice, and next morning a glass of warm water with a tablespoon of Epsom salt. This helps remove gallstones and cholesterol deposits from the liver and gallbladder.

Minimize your exposure to chemicals and drugs and sanitize your intestines. Helpful nutrients are lecithin, milk thistle or silymarin, antioxidants, B-vitamins, especially B6, B12 if you're low in energy, magnesium, selenium, and zinc. MSM or L-cysteine and L-methionine help to detoxify. Stimulate the liver with bitter teas; use half a cup after meals; or take capsules of centaury, dandelion, devil's claw, gentian, goldenseal, or rosemary. Also do the herbal parasite cure. With hepatitis, use the therapy for viral infection in Infections and Inflammations above.

With persistent problems, continue with the castor-oil liver packs. Also effective are reflexology, ear acupuncture, and acupuncture meridian therapy. Jaundice can

be caused by drugs and chemicals, liver infection, gall-duct blockage, and increased destruction of red blood cells (protect with high amounts of vitamin E), so try to discover the cause of the jaundice. Treat systemically with blue color therapy (see Step 17).

Malabsorption: Malabsorption of food is frequently associated with chronic degenerative diseases, debility, and underweight or difficulty in gaining weight. This can result in floating, bulky, pale, and smelly stools and excessive wind. Common causes and solutions are as follows:

- Gluten allergy: Avoid gluten.
- Deficiency of gastric acid, pancreatin, bile, or sodium bicarbonate: Take appropriate supplements, reduce fats, use extra-virgin olive oil instead, and improve the corresponding organs.
- Inflammation of the intestinal tract: Individuals commonly have whitish inner irises as with gluten allergy; do intestinal sanitation (see Digestive Disorders).
- Overgrowth of bacteria or fungi in the small intestine: Use isotonic garlic flush followed by acidophilus and bifido cultures.
- High-fibre diet: Use white instead of brown rice.
- Worms or other parasites: Do a three-day raw food diet; take teas of chamomile, sage, or vervain, pumpkinseeds, or pumpkinseed oil. Most effective is an herbal parasite cure with wormwood, cloves, and walnut.
- Tapeworm: Use the herbal parasite cure; in addition, try a three-day water fast followed by castor oil.

GENERAL RULES: Eat small meals of easily digestible foods, for example, bone broth, meat broth or juice, vegetable and grass juices, rye sourdough bread instead of yeast-baked bread. Add pollen, spirulina, or chlorella, and possibly amino acid and nucleic acid supplements if you are debilitated. Add lecithin to all meals. The amino acid glutamine helps to improve the intestinal wall. Chew all your food extremely carefully and keep it in the mouth as long as possible, paying attention to the developing flavours of each mouthful. Frequently rub the body with cod-liver or halibut-liver oil, extra-virgin olive oil, and vitamin E oil. Emulsify oils for intended use (especially extra-virgin olive oil and cod-liver oil) by shaking in a jar with lecithin and juice.

Chew all suitable supplements and keep them under the tongue, such as freeze-dried liver, Royal Jelly, and halibut-liver oil; keep a hali-but-liver oil capsule in the mouth at bedtime. In this way, B12 can be absorbed in therapeutic quantities even if the usually necessary intrinsic factor is missing in the stomach. Most tablets can also be crushed, and capsules opened and mixed with meals. Use vitamin E in natural form as tablets, not as oil-filled capsules. In difficult situations, nutrients can be absorbed from grass juice enemas through the large intestine.

Mucus Problems: These include most respiratory diseases, recurring colds, hay fever, coughs, sinusitis, running nose, throat infections, and many ear problems. However, there may also be a mucus covering in the small intestine, causing malabsorption and, the worst mucus-related disease, cystic fibrosis. Generally, pathological mucus results either from a -lactose/galactose overload or from irritated

mucous membranes. Such irritation may be due to food, such as gluten, or to food allergy or chemical sensitivity; it can result from persistent inhalation of irritants or from chronic microbial or parasitic infestations. Try to find and eliminate the cause.

DIET: Fenugreek is good; minimize sweet and fatty food; fruit can be used according to your sensitivity; however, oranges frequently aggravate respiratory problems. The main mucus-forming foods are lactose (skim milk or whey powder); milk products in general according to their lactose content; beer; mainly wheat gluten, to a lesser extent also gluten in rye, oats, and barley; egg white; and moulds and fungi or any food to which you are allergic. Neutralize fruit acids with dolomite.

Initially avoid all mucus-forming foods. After your mucus has cleared, introduce and observe the effect on your body of each of the mucus-forming foods or food groups separately for several weeks. Some foods are mucus forming even in small amounts while others can be tolerated up to a certain level. However, the mucus-forming potential of different foods may be cumulative.

HERBS: For inflamed or infected mucous membranes, use goldenseal, marshmallow, sarsaparilla, slippery elm powder, thyme, and yarrow (strengthening). To expel mucus, use coltsfoot, horehound, lungwort, mullein, nettles, vervain, and violet; most recommended is horseradish.

AROMATIC OILS: Inhale these for sinusitis: cinnamon, lemon, eucalyptus, lavender, pine, rosemary, or thyme. For inflammatory sinus and breathing problems: Inhale vapour of eucalyptus oil during the night (keep some in a flat container close to the bed). For sore throat, gargle with lemon, geranium, hyssop, sage, and thyme. As an internal antiseptic, use diluted tea tree oil. Add a few drops to a small jar or bottle half filled with water, shake vigorously for a few seconds, and then try a drop on the tongue. If this is not irritating or unpleasant, you can ingest the rest. Do not use other aromatic oils internally without competent advice that it is appropriate to do so.

ADDITIONAL THERAPIES: For nose and sinus problems or hay fever, frequently draw seawater, diluted with about three parts warm water, through the nostrils, one at a time, and spit the water out. If seawater is not available, dissolve a level teaspoon of sea salt in a pint of water; you can also add a small amount of Epsom salt. For acute conditions, sniff up a tea of the indicated herbs, preferably adding propolis solution; place castor-oil packs over the sinuses. Do head and neck exercises such as this one for clearing mucus from head spaces (e.g., sinuses): Kneel with the head to the floor and make loud snoring and snorting noises at the back of the nose. Spit out mucus; continue for ten minutes. Have any mercury amalgam fillings or dead teeth removed.

For throat problems, gargle with the indicated herb teas, adding propolis in the case of infections; place castor-oil packs and blue lighting on throat; for chronic conditions, have plenty of singing and vocal therapy. Generally, strengthen the intestines, and do colonics. Edgar Cayce recommended wearing a piece of carbon steel, preferably in the groin pocket, to improve the mucous membranes of the nose and throat and to resist colds and congestion. Use systemic lemon (yellow-green) color therapy to loosen and expel phlegm, and concentrate it on the chest and upper back.

THE SUGAR CURE: Keep a teaspoon of fine (Caster) sugar in the mouth until it is dissolved, then spit it out and take another teaspoonful. Continue with this at intervals for one or two hours and repeat on subsequent days or weeks as required. The sugar draws mucus dissolved in lymph fluid from the lymph glands and so gradually clears the head spaces. It can stop a cold within hours.

NETI: This is a yoga method to rinse the sinuses. Use a coffee or teapot with a fine snout, a neti pot, or an enema bag filled with mildly warm and salty water. Bend over a sink with the head turned to the side, insert the enema hose or the snout of the pot into the upper nostril and let the water flow out. It will rinse out the sinuses and flow out from the lower nostril. After half the water is used up, turn the head and let the water flow into the other nostril. Finally, close one nostril at a time and strongly blow out air to expel any water remaining in the sinuses. Note: You can easily obtain neti pots from yoga and meditation supply sources in the U.S.; check the Internet.

Multiple Sclerosis: DIET: Recommended are plenty of low-mercury seafood, broth of fish heads and bone broth, and possibly raw egg yolk (after allergy testing); sunflower kernels, almonds, and other oily seeds (best sprouted or as seed cheese); freshly ground linseed and possibly linseed oil; plenty of grass and vegetable juices as well as sprouted seeds (but no gluten grains). Try sprouted broad beans. Eat more vegetables that grow below than above the ground; eat raw vegetables often with added gelatine (broth of fish heads or bones). Sprout or soak lentils and beans before cooking; eat tomatoes, fresh fruits, cold-pressed sunflower oil, and cayenne.

Test for allergies and follow your blood group diet. Try to obtain organically grown food and eat small meals. Sago, tapioca, taro, and arrowroot are fine, but minimize your intake of rice, millet, and maize and avoid saturated, hydrogenated, and animal fats; cow's milk products; gluten products; egg white; smoked, cured, and processed meat; peanuts; sweet foods; tinned or frozen fruits and vegetables; salt; and food chemicals, especially colourings and aspartame. Use a strict low-fat diet.

SUPPLEMENTS: High doses of all vitamins are good, especially C (10 to 20 g daily), E (2000 IU, daily, as tablets), B1, B6, nicotinamide, pantothenic acid, biotin, choline and inositol, and B12 (injections or sublingual), as well as grape seed extract. Take magnesium (best as chloride and orotate), zinc, copper salicylate, manganese, chromium, iodine, and selenium. Most important may be vitamin D from sunlight and fish oils, especially cod-liver oil; also try Calcium EAP 3 x 3 tablets. Take hydrochloric acid and digestive enzymes with proteins or a main meal; also take lecithin, kelp, MSM, freeze-dried liver, pollen, spirulina or chlorella, and evening primrose or borage oil (chew the capsules). The amino acid glycine (10 g four times daily) is useful, but not needed if you use a gelatinous broth of fish heads.

HERBS: Especially strong with anti-inflammatory properties are goldenseal, slippery elm powder, and ginger, also devil's claw, ginseng, gotu kola, pau d'arco, and sage. Try suitable Bach Flower Remedies; do the herbal parasite therapy and follow protocols in Intestinal Sanitation (see Step 3).

ADDITIONAL THERAPIES: Try a strong antimicrobial therapy with electronic zapper, magnetic pulser, colloidal silver, and oxygen therapy. Also useful are spinal massage, tapping, and adjustment; deep muscle massage; frequent castor-oil packs on abdomen and lower back. Improve the liver, gallbladder, kidneys, and endocrine glands; press the foot reflex for the pineal gland.

Get frequent rest periods, avoid stress, have frequent mild sunshine on your skin. Remove any dead teeth; replace mercury amalgam fillings; guard against inorganic copper and lead intake (for example, canned food, water pipes, and car-exhaust fumes). Have frequent muscle tensing with deep breathing; do mind-body exercises; do lemon color therapy, visualization, and autosuggestion; release resentments; meditate on the feeling of love and being forceful (see Step 61).

Myasthenia Gravis: DIET: Try a low-allergy diet, select food according to your blood group diet, and include some beef as stew, broth, or juice, or liver. Follow a diet low in sweet foods, fats, and polyunsaturated oils; use mainly extra-virgin olive oil; mainly below-ground vegetables, especially red beets, and salads with gelatine (broth of fish heads). Have allergy testing for foods; use no egg white; raw egg yolk, sprouted seeds, and grass juice are acceptable.

SUPPLEMENTS: Recommended are high doses of all vitamins, with 2000 IU vitamin E tablets, folic acid, rutin, and vitamin B12 injections. Most important is manganese; initially take 20 mg of chelated manganese with each meal, then reduce after improvement. Also take zinc, selenium, calcium ascorbate (5 to 10 g), and calcium orotate (800 mg); magnesium supplements may be weakening. Also helpful are thymus extract, octacosanol, lecithin, digestive enzymes (pancreatin) or green papaya, glycine or gelatine, and acidophilus and bifido cultures.

HERBS: For muscle strengthening, use Agrimony, juniper berries, and rosemary; also use devil's claw and tonifying herbs such as ginseng; do the herbal parasite cure.

ADDITIONAL THERAPIES: Concentrate on the thymus gland, try cabbage leaf and castor-oil packs; tap the top of the breastbone with your fingers (see thymus under Infections and Inflammations). Tape a tablet of chelated manganese in the hollow at the top of the breastbone. Do spinal tapping, especially at the base of the neck (C7 and D1). Remove dead teeth and replace mercury amalgam fillings.

Place castor-oil packs over the liver and abdomen, and over the eyes (from ear to ear) in cases of eye weakness. Practice intestinal sanitation, massage, frequent muscle tensing with deep breathing, mind-body exercises, and autosuggestion and visualization methods; meditate on being calm but forceful. Have frequent rest periods, avoid stress, keep cool, take no hot baths or hot showers, and eat no hot foods. Practice yellow color therapy systemically; use the electronic zapper, colloidal silver, and oxygen therapy.

Obesity and Overweight: The main cause of excessive weight is a diet low in fat and high in processed carbohydrates, particular sweeteners, and cereal or grain products. Avoid these and experiment with the following approaches.

- Have an appetite-reducing protein drink, cold or warm, 30 minutes before meals, with any combination of the following ingredients and in any amount that suits you: spirulina or chlorella powder, green barley or wheat grass powder, food yeast, ground linseed, linseed oil or olive oil. You can also drink this repeatedly during the day to keep hunger away for hours.
- Thirty minutes before meals stir one teaspoon of psyllium hulls in a glass of water, drink immediately. If still too hungry at mealtime, double the amount to two

teaspoons in a large glass of water. Drink some more water afterwards. Psyllium swells up to 40 times its dry bulk to fill the stomach with a soft gel.

- Eat only lentils, green vegetables, and sprouted seeds. Vegetarians can also experiment with combinations of different non-gluten whole grains and legumes.
- Adopt a mono-diet: One day eat protein foods only, the next day fruits, and the third day sprouted seeds and vegetable salads. Repeat this as often as required.
- Temporarily adopt a raw food diet (see Step 34).
- For two weeks, eat only protein/fat foods and green vegetables; ground linseed is a good protein/fat food.
- Repeat periods of consuming vegetable and grass juices and vegetable salads.
- Avoid all sweet food, as it stimulates the appetite and the synthesis of fat. In particular, keep fructose-containing foods away from starchy foods, and eat fresh fruits separately. The alternative sweeteners stevia and xylitol are acceptable; however if you have cravings for sweetness, it is preferable to overcome this by avoiding all sweeteners for some time.
- Avoid all cereal or grain products, especially if your blood group is O.
- Use a diet high in unheated fats and cold-pressed oils such as extra-virgin olive oil, linseed oil (or ground linseed), fish oils, and coconut oil; these do not normally cause weight gain. Avoid all heated fats and oils.
- Preferably skip the evening meal or have only a small salad or an apple.
- Get light daily exercise, such as a brisk 15-minute walk or jogging, or use a rebounder or other aerobic exercise. The metabolic rate is speeded up for a long time after exercise.
- Use a low-allergy diet combined with your blood group diet.
- Use mind therapy such as guided imagery and affirmation; look at your belief systems, release negative emotions, and express your emotional needs. Use the Emotional Freedom Technique in Step 63 to overcome food cravings.
- Eat very slowly and peacefully; chew every mouthful for about two minutes, until the food is liquefied; savour the food flavours as they develop during chewing.

Osteoporosis: Use allergy testing and a diet low in sucrose, acidity and phosphorus. Select foods with a high calcium-to-phosphorus ratio. Alkalize the body if overacid and neutralize fruit acids or vinegar with dolomite. Take a hydrochloric acid supplement if your fingernails are soft or if you have other indications of gastric acid deficiency. Frequently add broth of bones or fish heads to your meals; regularly drink grass and vegetable juices. The most important vitamins and minerals are vitamins C and D (cod-liver oil or halibut-oil capsules), manganese, zinc, calcium, magnesium, and boron. It's helpful to know that 50 mg of borax contain 6 mg of boron; to measure this amount, dissolve one level teaspoon of borax in one quart (litre) of water and take a teaspoon twice daily with meals. Frequently expose your skin to mild sunlight without using sunscreen. Also, vitamin K is important and available from dark-green vegetables.

Pain: Pain is a warning signal indicating that something is wrong. Therefore it is most important to search for and correct the basic cause. The following measures are secondary to this. (See Arthritis or Infections and Inflammations if the pain is due to these conditions.)

DIET: Use a low-allergy or hypoglycaemia diet with light meals, plenty of raw vegetables and their juices, and omega-3 fatty acids, and have cleansing periods. Avoid sweet foods and dairy products (lactose); avoid or neutralize acids; do allergy testing. Pain tends to lessen or disappear while on a raw food diet; introduction of some cooked foods may increase pain again

SUPPLEMENTS: Generally, a high calcium-magnesium level and increased blood alkalinity raise the pain threshold (the level at which pain is felt; this means you feel less pain), while acids, phosphorus, and potassium lower it. Therefore, alkalize the body. You can add some additional baking soda to acids neutralized with dolomite to bring the pH of the solution to 7. Vitamins A, B1, B6, C, and E can be helpful. Vitamin B12 injections work for nerve pains, as do manganese, MSM, and zinc. D,L-phenylalanine slows the breakdown of natural pain-relieving opiates in the brain and improves other pain-relieving measures. It is slow acting and used for long-term pain control. Topically apply propolis, cayenne ointment, and oils of clove or wintergreen. Take white willow bark, cloves, wintergreen, pansy, or feverfew for headaches.

ADDITIONAL THERAPIES: With cancer, migraines, and other diseases, pain and discomfort are often the result of liver congestion. This is usually relieved by a coffee enema and other measures to cleanse the liver. Improve the lymph circulation in a painful area; see Part 1 for details.

Topically place the south pole of a magnet on the pain site and/or apply blue lighting on the painful area, along with cold or ice packs. Also make a pack of honey, cabbage leaves, or Epsom salt; add a handful of sodium bicarbonate to the bath water to alkalize the body. Practice rhythmic breathing, meditation and relaxation exercises, visualizing blue energy extinguishing the “red fireball” of pain. Concentrate on feeling the pain, its strength, extent, rhythm, and other characteristics. If you pay enough attention to your pain for a long period, it may simply disappear. Also ask the pain what message it has for you. Try to sense its message.

Try this form of energy healing: Firmly but without pressure touch the flesh in the indicated places with the tips of the thumb and the first two fingers of the right hand. Hold for about three minutes or until the patient (or you) feels tingling in the fingertips. Concentrate your mind on the painful body area with the intention of relieving the condition. Here are a few variations:

- For pain in head or neck, hold fingertips just behind and beneath the left ear on a line with the mouth.
- For pains in chest, arms, or upper back, hold fingertips to the base of the neck on the left side of the spine.
- For pain in abdomen, back, sides, or hips, put fingertips to the left side of the spine between shoulder blades.
- For pain in legs or feet, hold the left side near the centre of the spine.

Parasites: Parasite infestations combine with fungi, such as Candida, to greatly undermine your long-term health. Examples of common parasites are intestinal worms and protozoa (malaria and Giardia). Most of these parasites can be eliminated with wormwood (Artemesia absinthium), which is best combined with other herbs; wormwood also appears to be effective against Candida.

Here's how: For several weeks take up to one teaspoon of powdered wormwood once daily in juice before a meal. You may combine this with up to a quarter-teaspoon of ground cloves and chopped garlic. If any of these ingredients is too unpleasant to take, you can put it into one or more large gelatine capsules. Take a course of acidophilus and bifido cultures after finishing the course of parasite remedies. As a precaution, you can repeat a course of parasite remedies once or twice a year.

In animal husbandry, high copper levels are successful in eliminating parasites and keeping animals free of parasites. While animals seem to be able to handle copper sulphate as part of a mineral supplement, this is not suitable for humans, and I recommend using either copper salicylate or colloidal copper. During any parasite or Candida cure, maintain a high intake of liquids to flush out toxic residues. In addition to copper and herbal remedies, use an electronic blood purifier and possibly a magnetic pulser on any swollen or infected lymph glands and organs.

Parkinson's Disease: DIET: Useful here are seafood, raw egg yolk, lactic-acid-fermented food, purple food, sprouted seeds, raw vegetables (finely grated, often with gelatine) such as green beans, carrots, beet root and beet tops, cabbage, green peas (fresh, not canned or frozen), and spinach. If vegetables are cooked, use the cooking water. Preferably take fresh vegetable and grass juices before meals; have frequent interior cleanses on such juice, possibly also on fruits. Use food appropriate for your blood group and metabolic type.

Sprouted broad beans are very high in levodopa, the precursor of the neurotransmitter dopamine, lacking in people with Parkinson's. Try five to 15 sprouted beans with breakfast, and use raw or blended in juice; if cooked, also ingest the cooking water. Black currants also contain levodopa. Do allergy testing and intestinal cleansing; use organically grown foods if possible; avoid food additives, including preservatives, flavouring (excitotoxins), colouring, and aspartame. Avoid exposure to aluminium and heavy metals, especially lead, mercury, and iron.

SUPPLEMENTS: Take high doses of all vitamins, especially antioxidants and B1, B6 (but not with levodopa or sprouted broad beans), B12 injections, and natural E (1000 IU daily as tablets), and the minerals selenium, zinc, and chromium; also try copper salicylate. Take vitamin C as 5 to 10 g of ascorbic acid per day, partly neutralized with magnesium oxide or carbonate; take sufficient additional magnesium as chloride and orotate to stop any shaking and help relax muscles. Take digestive enzymes, pycnogenol or grape seed extract, lecithin, fish oil and ground linseed, evening primrose oil, kelp, MSM, royal jelly, and glutamine. Try tyrosine before breakfast and tryptophan before the evening meal. For herbs, try a combination of foti-tieng, gotu kola, licorice (but not with high blood pressure), pau d'arco, sage, and skullcap.

ADDITIONAL THERAPIES: Cleansing and strengthening of all organs and glands with all the methods described in this book are advised. Spinal tapping, spinal

corrections, rejuvenation exercises, tensing and breathing exercises, and body-mind exercises are also helpful. Try regression to discover and release hidden fear. Imagine reacting appropriately in situations of panic; use emotional-release and mind-control methods. Improve and balance energy flows in acupuncture meridians, especially those of the stomach, gallbladder, and bladder and the governing meridian, by having an acupuncture treatment. Do intentional exaggerated shaking exercises with vigorous breathing. Remove dead teeth and replace mercury amalgam fillings.

Before breakfast have strong coffee and tyrosine; with breakfast have bee pollen, spirulina or chlorella, ground linseed, sprouted broad beans, ginkgo biloba, ginseng, and other stimulating measures; reintroduce levodopa drugs as late as possible in the day. If levodopa has become ineffective, have a “drug holiday” - stop using it for one or more weeks. Try breathing additional oxygen during this time (e.g., from an oxygen concentrator); however, additional oxygen is harmful while you’re on levodopa. See the Love Cure (Step 61) and learn to meditate and energize the brain.

Prostate Problems: DIET: Advisable here is a mainly raw food diet based on sprouted legumes, vegetable salads, fresh fruit, and plenty of fresh vegetable and grass juice. Also good are raw egg yolk, tomatoes, seeds of sunflower and pumpkin (best as seed cheese), foods high in bioflavonoids and carotenoids, and purple foods. Have allergy testing and practice intestinal sanitation. Avoid gluten and milk proteins.

SUPPLEMENTS: Take Vitamins A (halibut-liver oil capsules and cod-liver oil), E (preferably including gamma tocopherol), C, and B6; magnesium (1000 mg daily) best as magnesium chloride and magnesium ascorbate, selenium, zinc (30 to 50 mg in divided doses), bioflavo-noids, quercetin, kelp, protein-digesting enzymes, spirulina, and bee pollen. Try Epilobium parviflorum (small-leafed willow), saw palmetto, Pygeum africanum, and stinging -nettle/nettle extract.

ADDITIONAL THERAPIES: Useful are yoga exercises; frequent long walks, and mild sun exposure; sitting on south pole of a strong magnet. Try also: reflexology of prostate points on hands and feet, tapping of lower spine, and -castor-oil and Epsom salt packs on the lower abdomen and lower spine. Have satisfying sexual activity or be satisfied with having no activity; see also Step 56: Healthy Sexuality.

Schizophrenia: Many people classified as having a mental disease are actually emotionally unstable and open to psychic influences (extrasensory perception) and, most of all, need guidance and grounding. Sometimes schizophrenic symptoms disappear during water fasts. For all types of schizophrenia, follow a fast with allergy testing, a low-allergy diet, and intestinal sanitation. If allergy testing is not possible, adopt a low-allergy diet that excludes all gluten and cow’s milk protein.

From a biochemical point of view, we can distinguish between three different types of schizophrenics: The low-histamine type are slow oxidizers, also called histapenics; the high-histamine type are fast oxidizers, also called histadelics; and there are balanced oxidizers with normal histamine levels. In addition, each of these may at times display symptoms of overactivity or underactivity. If in doubt about the histamine status, under supervision of a qualified health practitioner, take (or give) 50 mg of niacin with water on an empty stomach. If a strong facial flush develops,

histamine levels are high; if there is no or only a weak flush, levels are probably normal or low. Then try 250 mg of niacin in the same way; if there is still no or only a weak flush, histamine levels are low.

The Low-Histamine Type: The low-histamine type is the "typical" schizophrenic, insensitive to pain and outside influences; infections and skin reactions are rare; calcium levels are high; pH tends towards the alkaline side. Sometimes a cerebral allergy is present, causing a rapid pulse (90-100); thought processes are often overactive.

DIET: Adopt mainly a vegetarian raw food diet reasonably high in protein. Frequently use seed cheese and protein drink as described in the recipes in Part 4; use seafood, fish oils, linseed oil, ground linseed, and acid fruit, but avoid gluten and milk products. Take a long, supervised fast on fresh grass and vegetable juices.

SUPPLEMENTS: Try high-potency B-complex vitamins, high dose folic acid with each meal, inositol, and vitamin B12 (as injections or absorbed under the tongue). Also take up to several grams of niacin and niacinamide daily; up to 10 g daily of ascorbic acid, partly neutralized with magnesium in divided doses; additional magnesium chloride, manganese, and zinc; high-dosage evening primrose oil and lecithin, glutamine, histidine, and tryptophan; hydrochloric acid and digestive enzymes (pancreatin) with main meals; Bach Flower Remedies per your emotional conditions.

ADDITIONAL THERAPIES: Use blue lighting during overactive periods; at other times try orange or red. Induce the inflammation response: for example, blistering agents and overheating baths followed by sweating. Use plenty of acid fruit, such as citrus fruit.

The High-Histamine Type: The high--histamine schizophrenic exhibits a hypoglycaemic personality and is very susceptible to allergic reactions. The main symptoms include suicidal depression, obsessive rumination, blank-mindedness, periods of over-arousal and thought disorders, frequent headaches, and dizziness; blood pressure tends to be low and the pH too acid; skin is sensitive and may show dilated blood vessels (rosy cheeks).

Recommended is a strict hypoglycaemia diet that minimizes sweet and acid food intake. Have high doses of all vitamins and minerals; acid-neutralized dolomite or additional calcium, and calcium ascorbate. Copper may be beneficial, but best taken as salicylate. Also helpful are vitamin-B12 injections, nicotinamide (up to 10 g daily, no niacin), L-methionine, glutamine, folic acid, and lecithin. Alkalize the body (see Step 6). For chronic depression, use tryptophan or tyrosine; if one supplement does not help, try the other.

Stress-Induced Schizophrenia: People with stress-induced schizophrenia tend to have a better insight into their condition and a better response to treatment. In addition to the classic symptoms of schizophrenia, in this form there are signs of zinc and vitamin-B6 deficiency; also white spots on fingernails, loss of dream memory, sweetish breath odour, stretch marks, inability to tan and sensitivity to sunlight, sometimes pain in the upper left abdomen, possibly tremors, spasms, amnesia, impotence, menstrual irregularity, and anemia.

Usually a hypoglycaemia diet is helpful, along with vitamin B6 (up to 3 g daily in divided doses), zinc (10 mg) with each meal, vitamin-B12 injections, high intake of neutralized dolomite, additional magnesium, other vitamins and minerals as for the high--histamine type, and Bach Flower Remedies, as appropriate.

GENERAL RECOMMENDATIONS FOR ALL TYPES: Live with a caring group in a peaceful, natural environment; try regression therapy and emotional release therapy (see Step 63). Avoid heavy-metal contamination; sanitize your teeth; apply violet color therapy systemically; treat for parasites and Candida; use St. John's Wort as an herbal tincture during depression.

Scleroderma: Antimicrobial therapy including colloidal silver and oxygen therapy are recommended, as is the herbal parasite cure with use of the electronic zapper and magnetic pulser. Make external applications to affected skin areas as rubs, packs, or immersions using tea tree oil, aloe vera gel, magnesium chloride, a solution of copper salicylate with MSM, and blue light. To eliminate the microbes causing the condition, keep the affected part in contact with tea tree oil until the skin becomes red, inflamed, and painful; then stop tea tree oil and expose it to blue light, copper salicylate, and other sedating or anti-inflammatory measures. Internal remedies include all antioxidants, bioflavonoids, copper salicylate, echinacea, magnesium chloride, pau d'arco, propolis, wormwood, and zinc. Also advised are the Basic Cleanse, allergy testing, and intestinal sanitation.

Skin Problems: The three main causes of skin problems are accumulation of wastes and toxins, unrelieved allergies, and a deficiency of essential nutrients.

DIET: Use the hypoglycaemia diet, with freshly ground linseed, fish oils, apricot oil, almond oil, almonds, sunflower kernels, raw egg yolk (sulphur), raw cabbage, horseradish, sprouted seeds, grass and vegetable juice, raw onions, and broth of fish heads. Avoid saturated fats, margarine, peanut butter, all hydrogenated and fried foods, dairy products, gluten, and sweet foods. Do the Basic Cleanse, have allergy testing, and maintain intestinal sanitation.

SUPPLEMENTS: Take vitamins A, C, and E (up to 2000 mg daily, as tablets), also B2, B6, B12, PABA, bioflavonoids, biotin, glucosamine, hydrochloric acid (if fingernails are soft), and one spoonful of lecithin with meals. Tyrosine and kelp or iodine help as skin activators: They are cleansing, but may cause temporary aggravation of symptoms, especially with acne. Take increased dosages of magnesium, evening primrose oil (especially in the case of psoriasis), zinc, manganese, sulphur (best as MSM), selenium, silicon as in horsetail, digestive enzymes, and gelatine (broth of fish heads), especially for psoriasis.

HERBS: For internal and external use: aloe vera, burdock (for psoriasis), calendula, chaparral, echinacea, goldenseal, horsetail, pau d'arco, sarsaparilla, sassafras, St. John's Wort, and vervain.

ADDITIONAL THERAPIES: If B-vitamin deficiencies are suspected, use a paste of food yeast or bran on affected skin parts; concentrated B vitamins, especially B2 and B6, can be added to this as well. Have frequent cleansing periods; regulate bowel movements; use colonics. Drink plenty of water and green vegetable juices; use hot and cold showers; do skin brushing to activate the skin, but not on the affected areas. Include sweating after hot Epsom salt bath.

Stimulate the kidneys, lungs, circulation, small intestine (especially for psoriasis), liver, gallbladder, and endocrine glands, especially the thyroid; do lymph-drainage massage. Use only a minimum (infrequently) of an old-fashioned brand of soap, based on olive or almond oil, preferably neutralized (most soaps are too alkaline). Avoid detergents and cosmetics. Apply yellow light and measured amounts of sunshine on affected skin parts; this is especially helpful for acne. Have frequent skin massage with peanut oil, almond oil, apricot oil, and cod-liver oil (in case of malabsorption), preferably with added vitamin E. Cod-liver oil rubs (with vitamin E) are especially helpful with dry, damaged, or inflamed skin, malabsorption, moles, warts, skin cancer, sunburn, and psoriasis.

Rashes are usually caused by allergies, so use allergy testing. Chronic skin diseases, for example psoriasis, are often improved by inducing vomiting, which relaxes the digestive organs and stimulates the solar plexus. Accept your skin problems as a beneficial cleansing, removing harmful energies and impurities from inside. Send love to your skin blemishes and they are more likely to go away. Rejuvenate your skin by frequently bathing it in imaginary rose-colored energy.

Dry skin: Especially if you have difficulty gaining weight, check for fat malabsorption, which is often due to gluten allergy; stools may be pale or clay-coloured. For dry skin, frequently rub it with extra-virgin olive oil and added vitamin E and A. Take linseed oil or fish oils internally; with malabsorption, also apply it externally.

Oily skin: Use a pack of brewer's yeast (also called nutritional yeast) and bran, applied to the skin.

Acne: A mixture of equal parts of camphorated oil, witch hazel, and vitamin E oil can be rubbed into pustular areas. For severe conditions, a 0.05 percent solution of vitamin A acid (retinoic acid) can be applied for about six weeks under professional supervision. It frequently causes redness and irritation at the beginning of the treatment.

Ulcers and skin infections: Wash the area with warm diluted magnesium chloride or an Epsom salt solution and apply any of the following, alone or mixed with others: propolis as cream or solution, copper salicylate, garlic, or fresh cabbage-leaf or fresh green-vegetable juice. Aloe vera gel is excellent for sealing a wound; cover with unheated honey, mix with a few drops of hydrogen peroxide, and renew twice daily. When there is dead, proud flesh (granulation) and gangrene, apply protein-digesting enzymes (trypsin, pancreatin), but especially the inside of green papaya skin, white sap, juice of raw leaves, or urea (see also Step 22: Urine and Urea Therapy).

Boils: To draw, cover with a mixture of honey and cod-liver oil; once they are broken, treat as for ulcers. Internal cleansing is the main therapy for this problem.

Wet eczema: This is best kept dry, either exposed to air and sunshine or covered with a powder of slippery elm. For healing, after infections have cleared, apply vitamin E, fresh green juice or fresh leaves, especially cabbage.

Scar tissue: To remove, frequently rub with camphorated oil, MSM solution, and vitamin E. In addition, scars can be treated with neural therapy. An anaesthetic (Xylocain) is injected into scar tissues that are thought to induce electrical

interference fields in other areas of the body. Sometimes a health problem of long standing disappears instantaneously after an injection. Alternatively, you can prick the scar with a fine needle to release the tissue tension in the area. Prick long scars in several places and leave a needle inserted for ten to 20 minutes about 2 mm deep at each end of the scar. Before and after any needling, apply a suitable antiseptic to the skin, such as tea tree oil.

Fungal infections of the skin: Use a concentrated magnesium chloride or propolis solution, tea tree oil, or other fungicidal herbs and oils. Most effective is a long-lasting pack of any of these fungicides; if one does not work, try another. With any skin-fungus problem, also use internal Candida therapy.

Itchy skin: Apply a solution of baking soda or, alternatively, extracts of borage, buckthorn bark, juniper berries, chickweed, marjoram, pennyroyal, plantain, poke root, or witch hazel; also bathe the skin with oatmeal (cooked or soaked) or baking soda. Use blue color therapy; treat the liver and gallbladder if skin is jaundiced. Take a hot Epsom salt bath; rub skin with tea tree oil or witch hazel; alkalize the body; consume no sweets or acids; test for allergies.

Warts and moles: To remove, gently rub on cod-liver oil or castor oil mornings and evenings. For stronger action, apply baking soda moistened with castor oil to the consistency of putty; leave overnight; repeat until it becomes sore. Then apply vitamin E oil, green juice, or honey for several days before continuing with castor oil. Be careful and gentle with moles. If a mole appears to turn malignant, cover with raw, crushed garlic, changing two or three times per day. When it becomes sore after several days, cover with honey instead for five days. Alternate between garlic and honey periods as long as required.

Basically, moles indicate that the systems of elimination are not functioning well. A protruding mole may also be removed by tying a hair tightly around it, then every two or three days adding another hair tying it a fraction tighter. Active moles can also be removed with an escharotics cream.

Skin cancer: If skin cancer is suspected, apply the milky juice from the stem of radiation weed, radium-weed, or milkweed (spurge, euphorbia, petty spurge). Repeat application as required; a strong skin reaction may result, followed by healing. Use this approach also for warts, moles, blemishes, and so on. For serious conditions, including melanoma and tumours close to the skin, escharotic creams based on zinc chloride and the herb bloodroot are available (see: www.altcancer.com or www.cancersalves.com). On inflamed areas and skin cancer, you can also use the south pole of a magnet and blue lighting.

Skin rejuvenation: Frequently and vigorously rub the skin with some or all of the following ingredients, dissolved in aloe vera gel or energized water: vitamin C powder, magnesium chloride, glucosamine, copper salicylate, Microhydrin, and MSM. The amounts of individual ingredients are not critical. Afterwards you can cover the area lightly with natural vitamin E oil, possibly with added vitamin A. At other times, you can make a facial mask with fresh residue from juicing vegetables or grass; moisten with some juice as required to make it stick.

GENERAL RULES FOR COLOR THERAPY FOR SKIN PROBLEMS: Initial treatment is with green; subsequent treatments for dry or scaly skin problems with lemon; for obstinate cases, use also yellow or orange. When scales drop and inner skin surface

appears, treat with turquoise, as for moist or weeping skin disorders. For red, angry skin problems, use blue or indigo; for abscesses, boils, carbuncles, and furuncles, use systemic lemon and locally orange. When suppuration and throbbing begin, use yellow until the problem bursts open; then green until pus drains and a red cavity is left; finally, use turquoise and indigo. For acne and especially psoriasis, cover the area with blue cellophane (double layer) and expose to sunlight or ultraviolet light.

Thyroid Problems: For an indication of your thyroid function, measure your temperature before getting up in the morning. Measure it in the armpit or under the tongue for three consecutive mornings. For women before menopause, measure in the first half of the cycle before ovulation in the first week after the start of a new period. The temperature should be 97.8º F (36.5º C) or higher; otherwise, the thyroid is likely to be underactive. However, be sure that you do not have a raised temperature due to an infection.

If the thyroid is underactive, try the following measures: Take a supplement of the amino acid tyrosine, 500 mg three times daily before meals. Best take it together with a kelp or seaweed tablet as a source of iodine. Also helpful are freeze-dried thyroid and vitamin B complex. Selenium is needed to activate the thyroid hormone. The most helpful remedy for normalizing thyroid functions is maca, a Peruvian tuberous root, similar to wild yam but more effective. For sources, check the Internet.

Other useful measures are pressing the thyroid foot reflexes (see Step 15), using the magnetic pulser on the thyroid gland (see Step 19), and sanitizing your teeth (see Step 8). The main causes of thyroid problems, except for iodine deficiency, are dead teeth (e.g., root-canalled teeth), jawbone infections, and mercury from amalgam fillings; these can also cause overactive or toxic thyroid conditions and need to be corrected. For autoimmune disease of the thyroid, see Autoimmune Diseases.

Vaccination Damage: Despite the refusal of the conventional health establishment to investigate the long-term effects of childhood vaccinations, independent research reports have increasingly been made public. These link vaccination rates to the epidemic of childhood asthma, as well as to crib death, shaken baby syndrome, hyperactivity, attention deficit disorder, autism, and juvenile diabetes. Since the 1990's, there has been a tenfold or 1000 percent increase in autism, an increase which has been linked by some researchers to the organic mercury preservative commonly found in baby-vaccines.

A greatly increased incidence of juvenile diabetes has been correlated to specific vaccination sequences and to the number of vaccines given. In some Australian Aboriginal communities, every second child died shortly after vaccination. Also, the original explosive spread of AIDS across Africa correlates with a smallpox vaccination campaign there. Basically, most components of most vaccines are highly toxic, and these are introduced by an unbiological route directly into the bloodstream of babies, whose immune systems are immature.

While the dangers of vaccinations are greatly understated by most health authorities, the advertised benefits are greatly exaggerated. For instance, incidence of the four leading childhood killer diseases - diphtheria, pertussis, scarlet fever, and measles - had already declined 90 to 97 percent before the introduction of vaccines, due to improved sanitation and hygiene.[35]

Another controversy concerns the “shaken baby syndrome.” Independent researchers claim that vaccinations can cause spot bleeding in the brain and retina that resembles the injury caused by violently shaking a baby.[36] Paralleling the increase in vaccinations, there is now an epidemic in shaken baby syndrome. A recent article in New Scientist cites a member of the U.S. child protection service as saying that there are three million abused children each year,[37] and if it becomes known that other conditions cause shaken baby syndrome (including the rare blood disease hemophagocytic lymphohistiocytosis), then some child abusers might remain unpunished. I believe that for thousands of years most parents have on occasion lightly shaken their children without causing any harm, and only now does it cause serious brain damage. There may be countless innocent parents in jail, and it would be appropriate for health authorities to investigate the possibility that some vaccines may cause capillary fragility in some babies.

The only complete protection against vaccination damage is strict avoidance of this procedure. Every state in the U.S. has a religious exemption clause; you can write a letter to exempt your child; for more details, see www.mercola.com, and go to the article page on vaccinations. If you cannot avoid vaccinations for your child, then give high doses of protective nutrients for several days before and several weeks after the event, in particular vitamin C and MSM, to aid in rapid detoxification.

Wounds and Burns: DIET: Have a diet high in easily digestible proteins (such as a protein drink - see the recipes in Part 4), fresh green-vegetable juices, foods high in arginine (such as almonds and sunflower seeds, best as seed cheese), and lentils.

SUPPLEMENTS: Take high doses of vitamins C, A, B1, and E, bioflavonoids, manganese, MSM, zinc, glucosamine, copper salicylate, -protein-digesting enzymes, and comfrey root. Use homeopathic Arnica and/or Bach Rescue Remedy, internally and topically; also burdock, chamomile, comfrey, echinacea, and yarrow, as teas and topically.

ADDITIONAL THERAPIES: Cool burns with ice; spray wounds and burns with a one-percent ascorbic acid and propolis solution; alternatively, apply weak tannic acid. After drying the site, apply vitamin E oil and cover with aloe vera gel, honey of a heavy consistency, or ointments containing propolis, vitamin E, and zinc oxide. The principle is to seal the wound or burn airtight with an antiseptic preparation until it is healed. Therefore, reapply the gel or ointment to maintain an airtight seal; renew the honey twice daily; mix a few drops of hydrogen peroxide with the honey. If the wound needs washing or cleaning, a magnesium chloride solution is best. Later, apply camphorated oil and vitamin E oil to prevent scarring. As an alternative, wounds can be covered with crushed fresh green leaves (cabbage, juicy grass pulp). Place the south pole of a magnet on fresh wounds; later, opposite poles on both sides; and finally, north pole. Use green color therapy topically; turquoise if there are signs of infection or inflammation; later lemon or yellow.

PRESSURE THERAPY: Immediately after the injury, exert strong pressure with the thumb on any cut for at least seven minutes. Partially severed parts can be pressed and held together with hand pressure or firm bandages; this usually stops bleeding and accelerates healing.

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Step 45

DEFICIENCY SYMPTOMS

Check out this list of deficiency symptoms to see if you are lacking in key nutrients - and start replacing them.

Eye, hair, nail, mouth, and skin symptoms are among the early outward warning signs of vitamin and mineral deficiencies. The following compilations can help you in diagnosing and treating these deficiencies. However, increased metabolic requirements for indicated deficiencies may persist for a long time after the outward symptoms have disappeared. Many listed symptoms can also be caused or aggravated by allergies and problems with the blood sugar and fat metabolism. Study tables 6-1 to 6-4.

The right-hand column gives the primary deficiencies first; additional treatment or the cause is given in parentheses. For each condition, only the more prominent nutrients are mentioned. However, all the typical nutrients should be supplied in increased amounts in the treatment of all conditions. Most skin conditions benefit from external as well as internal application of the indicated nutrients. EFA means essential fatty acids, mainly linoleic and linolenic acid; recommended are ground linseed (flaxseed), fish oils, and evening primrose oil. Mouth problems are often due to mercury amalgam fillings, allergies, or Candida (thrush) overgrowth.

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Table 6-1: Eye Deficiency Symptoms

Symptom	*Deficiency/Treatment/Cause*
Bitot's spots (foamy patches on conjunctiva)	vitamin A
Bloodshot eyes	boric acid for fungus infection, blue light
Blurred vision	vitamins B2, B6, pantothenic acid
Bulging eyes	vitamin E, nicotinamide, iodine
Cataracts (lens becomes opaque)	vitamins B2, C, E, antioxidants (avoid lactose)
Color blindness	vitamin A
Conjunctivitis	vitamins A, B2, C (B6, zinc)
Cross-eyed	vitamins E, C, B1 (allergy testing)
Dark spots in front of the eyes	vitamins B2, B6, C, zinc (liver problems)
Dim vision (amblyopia)	vitamins B1, C, B12 (allergy testing)
Dry, hard eyeballs (xerophthalmia)	vitamin A
Farsightedness (hyperopia)	magnesium, potassium
Glaucoma	salt, high vitamin C (cleansing)
Haemorrhaging in the back of the eye (retinitis, also macular degeneration)	vitamins B6, E, C, B2, zinc, copper, magnesium, bioflavonoids, glucosamine, cartilage
Infected, ulcerating eyes (keratomalacia)	vitamin A (vitamins C, B2, B6, zinc, blue light)
Itching, burning, watery, sandy eyes	vitamin B2

(continued)

Symptom	*Deficiency/Treatment/Cause*
Nearsightedness (myopia)	vitamins C, E, D, calcium, proteins, chromium
Night blindness (nyctalopia)	vitamins A, (B2, B6, zinc)
Red blood vessels in the sclera	vitamin B2
Retinal detachment	zinc, vitamins B6, B2, C, E, A
Sensitive eyes, fear of strong light (photophobia)	vitamins B2, A
Tics of eyelids	vitamins B2, B6, zinc, magnesium

Table 6-2: Skin Deficiency Symptoms

Symptom	*Deficiency/Treatment/Cause*
Acne	vitamins A, B2, B6, C, niacin, biotin, zinc, cod-liver oil
Addison's disease (adrenal exhaustion): increased tanning, especially on skin-folds, scars, elbows, knees; black freckles	all B vitamins, especially pantothenic acid; vitamin C; all minerals, digestive enzymes (allergy testing, avoid stress)
Arterial spiders (fine, branching arteries on face, neck, chest)	antioxidants, glucosamine, cartilage, purple food, bioflavonoids, copper, zinc (alkalize), cod-liver oil
Bedsores	vitamins C, E
Blisters	vitamin E
Brown discoloration around small joints	vitamin B12
Brown skin spots	vitamins C, E, antioxidants (liver problems)
Dry skin	vitamins A, C, EFA (fat malabsorption)
Eczema, infantile	EFA, zinc, vitamin B6
Eczema, skin ulcers	vitamins C, B2, B6, niacin, PABA, EFA, zinc, magnesium
Edema	vitamins B6, B1, magnesium (less salt/protein)
Fingers white, numb, stiff, swellings (Raynaud's disease)	vitamin B6, zinc, cod-liver oil (also vitamin C, magnesium, calcium, alkalize)
Fungal infections (e.g., athlete's foot, ringworm)	B vitamins (tea tree oil pack, intestinal sanitation)
Gangrene	vitamins C, E, B1, magnesium chloride
Greasy dermatitis around eyes, nose	vitamin B6, zinc
Greasy skin eruptions (seborrhoea)	vitamin B2
Horny, goose-pimple-like skin	vitamin A (possibly fat malabsorption)
Horny red skin on pressure areas (e.g., knees, elbows)	zinc (B6)
Hot flushes	vitamin E, boron, maca, pollen (wild yam cream)
Ichthyosis (fish-like scales)	vitamin A, retinoic acid topically
Infant dermatitis with inflamed pustules around body openings	vitamin B6, zinc (allergy testing)
Infections of the skin (boils, cold sores, impetigo, and so on)	vitamins C, A, B6, zinc, magnesium (hot Epsom salt and tea tree oil packs, propolis)
Itching	vitamins B, C, EFA, alkalizers (allergy testing)
Jaundice	vitamins C, E, B6, B12, A, lecithin, magnesium, zinc (blue light therapy, liver cleansing)

(continued)

Symptom	*Deficiency/Treatment/Cause*
Lemon-yellow skin	vitamin B12
Oily skin, whiteheads	vitamin B2
Oversensitivity to sunlight	vitamin B6, zinc, PABA, carotenes, bioflavonoids, antioxidants, alkalizers, purple food
Pale skin	biotin, folic acid, vitamin B6, B12 (anemia)
Prickly-heat rash	vitamin C
Psoriasis	see acne; also vitamin E, lecithin, blue light, sunlight (allergy testing, avoid gluten)
Purplish or blue-black skin areas	vitamin C, vitamin B2, bioflavonoids
Rash	allergy testing, alkalizers, vitamin C, calcium
Red-brown, often symmetrical discoloration of skin exposed to the sun, later ulceration	niacin or nicotinamide (folic acid)
Red-brown or dark-red spots	manganese
Rosacea (redness of part of face)	vitamin B2
Scaly dermatitis	biotin
Scaly eczema around nose, ears, scrotum, vulva	vitamin B2, B6, zinc
Scar tissue	vitamin E, MSM, camphorated oil
Scleroderma (hardening and swelling of skin)	vitamins E, C, A, PABA, magnesium, MSM (zapper, parasite herbs, tea tree oil packs)
Sensitivity to insect bites	vitamin C, calcium, alkalizers, vitamin B1
Shingles	B vitamins, vitamins B12, C, A, E, lysine
Skin cancer	vitamins A, C, E, B6, propolis, zinc, chlorophyll, bioflavonoids, blue light, escharotics)
Skin-folds red, infected	niacin
Stretch marks	vitamins E, B6, zinc
Subcutaneous bleeding (red or purplish spots under the skin, bruises easily)	vitamin C, bioflavonoids and rutin, grape seed extract, glucosamine, cartilage, alkalizer
Swellings (e.g., face)	zinc, magnesium, vitamins B6, B12
Vaginal itching	vitamins B2, E, C (Candida treatment, avoid synthetic underwear)
Warts, moles	vitamins C, A, E, bioflavonoids, antioxidants
Weals on the skin (urticaria)	vitamin B6, zinc, vitamin C (alkalizer, allergy)
White skin patches (vitiligo)	PABA, pantothenic acid, vitamin B6, zinc
Wrinkles or aging skin	vitamins C, E, A, EFA , MSM (too much sun)

Table 6-3: Hair and Nail Deficiency Symptoms

Symptom	*Deficiency/Treatment/Cause*
Coarse, brittle hair	zinc
Dandruff	vitamins B2, B6, zinc, magnesium, biotin
Dry hair	vitamin A, zinc
Greying hair	folic acid, pantothenic acid, biotin, minerals/copper (weak circulation/adrenals, avoid sweet food, food allergies)

(continued)

Symptom	*Deficiency/Treatment/Cause*
Hair loss	zinc, vitamin B6, sulphur/MSM, selenium, biotin
Hangnails	vitamin C, folic acid, proteins
Nails opaque, white spots/bands	zinc, vitamin B6
Oily hair	vitamin B2
Peeling nails	vitamins A, C, calcium
Ridges on nails, longitudinal	vitamin A, protein (anemia, poor circulation, glandular imbalance)
Ridges on nails, transverse	fever, infection, menstrual problems, period of protein -deficiency
Scaling of cuticle or lips	biotin, vitamin B2

Table 6-4: Tongue and Mouth Deficiency Symptoms

Symptom	*Deficiency/Treatment/Cause*
Beefy, enlarged tongue	pantothenic acid
Burning, sore tongue	vitamins B2, B6, B12, niacin
Cracked lips and corners of the mouth (cheilosis)	vitamins B2, B6, folic acid
Distended, purplish-blue veins under the tongue	vitamin B2 (circulation poor, congested)
Edema or tooth-marks on tongue	niacin/nicotinamide
Furrowed tongue	vitamin B1, pantothenic acid
Gums receding, bleeding (gingivitis)	vitamin C, bioflavonoids, calcium, alkalizers
Halitosis (bad breath)	vitamin B6, zinc, magnesium, propolis (cleansing, intestinal sanitation)
Mouth ulcers, canker	folic acid, vitamin B6, zinc (overacidity, allergy)
Papillae prominent or erased	niacin/nicotinamide
Purplish or magenta tongue or lips	vitamin B2
Tongue red at tip or edges; with severe deficiency whole tongue scarlet red, sore	niacin (vitamin B6)
Tongue shiny, smooth, beefy; early sign: strawberry-red tip/sides	vitamin B12, folic acid
Tongue too small or too large	niacin, pantothenic acid
White-coated tongue	intestinal putrefaction
White patches on tongue	vitamin B12 and other B vitamins (allergy)
Yellowish-brown-coated tongue	liver or gallbladder problems

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Step 46

CANCER

If you have cancer, here are some useful suggestions.

You may gain a better appreciation of natural cancer treatment if I first share with you some little-known facts about orthodox cancer treatment. In cancer research, success (expressed as a five-year survival rate) is established by comparing other forms and combinations of treatment with the results from surgery alone. However, the success rate of surgery has rarely been compared with the survival rates of untreated patients. Therefore, orthodox cancer treatment is basically unscientific because it doesn't deal with all the data. The overall supposed "cure rate" is not higher than can be accounted for by removing precancerous conditions, dormant or calcified tumours, spontaneous remissions, and the placebo effect. In support of my position, I have assembled some key statements and conclusions from medical and scientific publications.

Studies appear to show that early intervention is helpful, because pre-cancerous lesions are included in early removals that frequently would not become cancerous if left untouched. It does not matter how much or how little of a breast is removed; the outcome is always the same.[38]

Researchers say it is complacent to continue subjecting at least 70 percent of women with breast cancer to surgery, a futile mutilating procedure.[39] There is no evidence that early mastectomy affects survival; if patients knew this, they would most likely refuse surgery.[40] The editor of the Lancet pointed out that despite various modifications of breast cancer treatment, death rates remained unchanged. He acknowledged that despite the almost weekly releases of "miracle breakthroughs," the medical profession with its extraordinary capacity for self-delusion (his words, not mine) in all truth has lost its way. At the same time, he rejects the view of those who now believe that salvation will come from increasing chemotherapy after surgery to just below the rate where it kills the patient. Instead, he continues, "would it not be more scientific to ask why our approach has failed?" Not too soon to ask this question, after a century of mutilating women, I would say. The title of this editorial, appropriately, is "Breast cancer: have we lost our way?"[41]

Basically, all types and combinations of conventional breast cancer treatment appear to result in the same low long-term survival rates. The only conclusion that can be drawn from this is that conventional treatment does not improve long-term survival rates. Even worse, Michael Baum, M.D., a leading British breast cancer surgeon, found that breast cancer surgery tends to increase the risk of relapse or death within three years. He also linked surgery to the accelerated spread of cancer, which it does by forming metastases in other parts of the body.[42]

This conclusion confirms an earlier finding by Ernst Krokowski, a German professor of radiology. He demonstrated conclusively that metastasis is commonly triggered by medical intervention, including sometimes even by a biopsy or surgery unrelated to the cancer.[43] Disturbance of a tumor causes a greatly increased number of cancer cells to enter the bloodstream, while most medical intervention, especially

chemotherapy, suppresses the immune system. This combination is a recipe for disaster. It is metastases that kill, while primary tumours in general and those in the breast in particular are sometimes relatively harmless.

This follows earlier reports that radical surgery for prostate cancer also tends to spread the disease. Actually, prostate cancer was investigated in the first randomized clinical trials for any type of cancer. After 23 years, there was no difference in the survival rates of those who had surgery and controls who did not; those with surgery suffered more problems such as impotence or incontinence.[44] A recent epidemiological study confirmed the questionable value of conventional therapy by concluding that "medical interventions for cancer have had a negligible or no effect on survival."[45] Even the conservative New England Journal of Medicine had an article with the headline "Cancer Undefeated."[46]

Common ways to make medical statistics look more favourable are as follows. Patients who die during prolonged treatment with chemo-therapy or radiotherapy are not counted in the statistics, because they did not receive the full treatment, while in the control group everyone who dies is counted. Further, success is judged by the percentage of shrinking tumours, regardless of survival time. If survival is measured, then it is only in terms of those dying from the treated disease. It is not normally shown how many of the patients die due to the treatment itself.

The current trend is to pick up precancerous conditions very early and treat them as cancer. While this statistically increases the number of people with cancer, it also artificially prolongs survival times and lowers death rates, thereby making medical treatments appear to be more successful. However, there may also be a genuine component of improved survival, as increasing numbers of cancer patients opt for additional natural therapies.

An investigation of the records of 1.2 million cancer patients revealed that the death rate attributed to non-cancer death shortly after treatment was 200 percent higher than would normally be expected. Two years after diagnosis and treatment, this excess death rate had fallen to 50 percent. The most common cause for the excess death was listed as heart and respiratory failure. This means instead of dying several years later of cancer, these patients died from the effects of the treatment and thereby helped greatly improve the cancer statistics because they did not die strictly of cancer.[47] This misleading reporting of cancer deaths has led to demands for more honest statistics.[48]

After an analysis of several large -mammogram-screening studies found that it leads to more aggressive treatment with no survival benefits,[49] even the editor of the Lancet had to admit that there is no reliable evidence from large randomized trials to support mammography screening programs.[50] The significance of this statement goes far beyond the use of mammograms. It is openly acknowledged by the proponents of conventional medicine that they have no effective way of helping patients with advanced cancer. Until now the catch-cry always was "detect it early, then it can be cured." These mammogram evaluation studies demonstrate that it does not matter when cancer is detected; they suggest to me that the conventional methods and the whole multibillion dollar cancer industry are useless.

Here's more supportive evidence: A 13-year Canadian study of 40,000 women compared physical breast examinations with examinations plus

mammograms. The mammogram group had many more lumpectomies and surgeries, and the death rate was 107 deaths in the mammography group and 105 in the physical examination group.[51] Ductal carcinoma in situ (DCIS) is a common non-invasive form of breast cancer. Most cases of DCIS are detected through the use of mammography; in younger women, 92 percent of all cancers detected by mammography are of this type. Nevertheless, on average, 44 percent, and in some states 60 percent, of these are treated by mastectomy. As most of these tumours are harmless, this greatly improves the survival statistics.[52]

In contrast, while conventional diagnosis is invasive and may help to spread the cancer, a kind of electro-dermal screening, called the Biofield test, was developed by a team from eight European hospitals and universities. The Lancet reported it as being 99.1 percent accurate in diagnosing malignancy in breast tumors.[53]

A large meta-analysis of radiotherapy results for lung cancer showed that after two years there were 21 percent more deaths in the group that had radiotherapy in addition to surgery as compared to those who had surgery alone. Researchers contend the rationale is to kill any cancer cells remaining after surgery, but it is a shame that the facts do not agree with this theory.[54]

Chemotherapy for children with leukaemia and Hodgkin's disease is the proud showpiece of the only apparent success of orthodox cancer therapy. Now a long-term follow-up study shows that such children develop 18 times more secondary malignant tumours later in life and that girls face a 75 times (7500 percent) higher risk of breast cancer by the time they are 40.[55] A main problem appears to be the development of deep or systemic Candida albicans infections shortly after starting chemotherapy.[56] If this is not appropriately treated (see entries on Candida in Step 48), then relapses or future health problems are likely to occur.

Chemotherapy showed a clear dose dependency whereby the incidence of triggered leukaemia doubled between low-dose and -moderate-dose groups and then quadrupled between the moderate-dose and the high-dose groups. A study of ovarian cancer found that the risk of developing leukaemia after treatment with chemotherapy increased 21-fold, or 2100 percent. Other tumours commonly develop after treating malignancies with chemotherapy.[57] In a trial for multiple myeloma, no advantage was found by using chemotherapy as compared to no treatment.[58] Ralph W. Moss, Ph.D., in Questioning Chemotherapy, provides a detailed analysis of this subject; his overall conclusion is that there is no evidence that chemotherapy extends patient life with the majority of cancers.

However, even if chemotherapy extends life by a few months, what about the quality of this life? Tom Nesi, a former director of public affairs at the pharmaceutical giant Bristol-Myers Squibb, wrote in the New York Times about the successful treatment of his wife, which extended her life for three months.[59] Two weeks after the treatment, she scribbled on a notepad: "depressed - no more - please." I am not surprised by reports that most oncologists would not use these treatments for their own families.

Why are they doing this? By "they" I am referring to what is commonly called the cancer establishment. I believe the answer was given by the eminent medical commentator and former editor of New Scientist, Dr. Donald Gould, in his article "Cancer: A Conspiracy of Silence." The subtitle summarizes his position: "The

commonest cancers are as resistant to treatment today as they were 40 or 50 years ago. Nothing is to be gained by pretending that the battle against cancer is slowly but surely being won."[60]

This truth has been deliberately concealed from the general public. According to Dr. Gould, the reason for this conspiracy of silence is money. The public must continue to see the cancer establishment as a winner to continue providing money. One of the quoted scientists said that, with tens of thousands of radiologists and millions of dollars in equipment, one still gives radiation treatment even if study after study shows that it does more harm than good. Dr. Gould says patients who could be comfortable without medical treatment until their inevitable death are made miserable with medical treatment in a pointless attempt to postpone death for a few unhappy weeks. Of course, that is when most of the money is being made. Dr. Gould says doctors poison their patients with drugs and rays and mutilate them with unnecessary surgery in a desperate attempt to treat the untreatable.

Since the early 1970's when President Nixon declared the War on Cancer, two trillion dollars have been spent on conventional cancer treatment and research, with the result that more Americans are dying of cancer than ever before.[61] While there have been many studies to evaluate the effects of various nutrients on different cancers, none of this two trillion dollars has been available for natural therapists to test holistic cancer therapies, and natural therapists have had to face a century of denigration and persecution in the U.S.

All alternative cancer clinics eventually had to relocate to Mexico. (For a list of such clinics worldwide, see: www.cancure.org) A holistic cancer approach includes superior nutrition, electro-medicine and vibrational or energy medicine, emotional healing, and mind therapy.

One of the few studies that investigate a holistic approach involved the Gerson therapy in an evaluation of five-year survival rates of 153 melanoma patients. Here, 100 percent of Gerson therapy patients with Stage I and II cancers survived, but only 79 percent did so with conventional therapy. With Stage III (regional metastases), the figures, respectively, were 70 percent and 41 percent; with Stage IVa (distant metastases), 39 percent with Gerson and 6 percent with conventional therapy.[62]

Now there is actually proof that cancer surgery is the main cause of metastasis or secondary organ tumours. About 90% of patients die from metastases while primary tumours actively suppress metastasis. Stress as from fear or most medical procedures tends to promote metastasis and this is the reason that untreated patients generally live longer than medically treated ones. Regard a tumour as a mistreated part of your body, surround it with loving care and it will thank you by preventing metastasis and gradually melt away. For more information and references see www.health-science-spirit.com/cancersurgery.htm and www.health-science-spirit.com/cancersolution.htm.

People claim to have been cured of cancer by a variety of methods and remedies. Belief or faith in the chosen method may often have been more important than the method itself. However, fundamental factors that should be addressed for a more uniform successful outcome are:

1. Alkalize the body

2. Controlling the cancer microbe
3. Normalizing metabolism
4. Cleansing the body
5. Improving the mind and emotions

When these are corrected, any type of tumor can disappear on its own or become dormant. Natural cancer therapy has a fundamentally different view of what cancer is from that of orthodox medicine. The latter believes that the tumor is the cancer and only attacks the tumours. Natural therapy approaches address cancer as a condition of the whole body and person and treat the whole person.

Alkalizing the body: If the body is sufficiently alkaline tumours do not grow. Use alkalizers, including sodium bicarbonate and potassium citrate, as shown in Step 6 to keep your urine above pH 7 most of the time.

Controlling the Cancer Microbe: The cancer microbe is the key to successful natural cancer therapy. Various researchers such as Guenther Enderlein, Wilhelm Reich, Royal Ray Rife, Virginia Livingston-Wheeler, Alan Cant-well, and Gaston Naessens have found the same phenomenon in all cancers: a microbe that changes its shape and is thus pleomorphic, “of many shapes.” It is normally present as tiny protein units, but in various disease conditions, including all autoimmune diseases, it grows into a coccus and higher bacterial forms and then mycoplasmas and fungus-like forms.

This microbe does most of the cancer damage by devastating the immune system, releasing toxins that poison the energy-producing cellular enzymes; it also produces growth hormones that result in unchecked cell divisions. If the cancer microbe in its advanced stages is cultured and injected into animals, it causes tumor growth and the wasting and sickening odour that is characteristic of terminal cancer.

All this makes it understandable that antimicrobial and especially fungicidal treatments have often been credited with having cured or reversed cancer. Kerosene, for instance, taken internally, is said to be widely used in Russia and other Eastern countries as a cancer cure, and it was even used in America a hundred years ago. A hospital in Brazil reported cancer cures with the fungicidal herb pau d’arco. The electronic zapper and the Rife machine have been used to destroy the cancer microbe electronically. Presently MMS and Lugol's iodine solution are widely used.

Normalizing Metabolism: The main reason that body cells become cancerous is the destruction of the enzymes in their energy-producing respiratory chain. These enzymes can be poisoned either by accumulated toxic chemicals, especially pesticides, or by endotoxins produced by the cancer microbe. The German cancer researcher P. G. Seeger, M.D., D.Sc.,[63] demonstrated that the virulence of cancer cells is proportional to their inability to use oxygen for energy production and that cancer cells can be transformed back into normal cells by restoring cellular respiration. This can be achieved with certain enzyme supplements and especially with the purple pigment of red beets and dark grapes.

Furthermore, Dr J. Budwig, a German fat researcher, found that flaxseed oil and sulphur compounds, especially food high in cysteine (e.g. quark, a fermented

cottage cheese) were most effective in restoring a normal energy metabolism. The importance of a good diet can also be seen from a study of 535 breast cancer patients. After ten years, those with the highest insulin levels were eight times more likely to die than were patients with the lowest levels. Insulin levels are strongly elevated when ingesting common household sugar and to a lesser degree when combining glucose, as for instance from eating starches with fructose from fruit.

Cleansing the Body: Eliminating the cancer microbe and restoring cellular energy production is not always sufficient in an advanced condition because of the large amount of toxic waste produced by disintegrating tumours. Think of a dead tumor as a dead rat in your body. Patients have died after "successful" cancer cures because of congestion in their organs of elimination, especially the liver and kidneys. Cleansing is needed to remove metabolic wastes, pesticides and endotoxins that helped to cause the cancer in the first place.

Improving the Mind and Emotions: Our mind and emotions are an additional factor that makes it much easier for cancer researchers to cure mice rather than people. The orthodox cancer approach generally causes patients to be fearful, but this paralyses the immune system and makes all other body systems inefficient. Cancer treatment is likely to fail and cancer tends to return after successful initial therapy if we live in fear, especially if this fear is subconscious. Enthusiasm, joy, positive expectations, and supportive relationships have the opposite effect, and clinical trials of mind and emotional therapies have shown superior results compared to orthodox cancer therapies.

Putting It All Together: There are hundreds of supplements and remedies that might be beneficial to overcome cancer. The more effort you put into the basics, the less additional remedies you need. For some suggestions of additional supplements and remedies, see the entry on Cancer in Step 44. All the basic information that you need to reverse your cancer is in this book, for more detailed instructions see Overcoming Cancer at http://www.the-heal-yourself-series.com.

- From Step 34 use the low protein High-Quality Diet with its strong emphasis on purple foods, raw foods, and fresh vegetable and grass juices.
- Keep your urine above pH 7 as shown in Step 6.
- Do the Intestinal Sanitation and Antimicrobial Therapy as shown in Step 3.
- Do periodic fasting and cleansing as explained in Step 4, including the Basic Cleanse and if appropriate a Long Cleanse.
- Use a Beck-type electronic zapper and Reflexology as explained in Part 2.
- Release any resentment or other negative emotions and replace them with positive emotions (see Part 8).
- Practice the Love Cure (see Part 8).
- Make appropriate changes to your belief systems. Use the mind tools in Part 9, especially guided imagery..

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Step 47

EMOTIONAL – MENTAL SHOCKS

The secret to preventing illness is to undo shocks that unbalance the body.

The following information is controversial and not verified by independent scientific research, but I believe it is important for you to know. You can then make up your own mind about it.

Dr. Ryke Geerd Hamer, M.D. (born 1935), a German medical researcher, has developed an emotion-based cancer therapy. His claimed success rate of about 95 percent is by far the highest of any cancer therapist. During one of his many trials, the public prosecutor (in Wiener Neustadt, Austria) had to admit that after four to five years, 6,000 out of 6,500 patients with mostly advanced cancer who had been treated by this approach were still alive.

Dr. Hamer started his cancer research when he developed testicular cancer after the death of his son, who had been shot by the Prince of Savoy, son of the last King of Italy. He wondered if the shock caused by his son's death was the cause of his cancer. Subse-quently, he investigated and documented more than 15,000 cases of cancer and always found the following characteristics to be present, which he termed "The Iron Rules of Cancer":

1. Every cancer and related disease starts as a DHS or Dirk Hamer Syndrome (named after his son). This is a serious, acute-dramatic, and isolating conflict-shock experience for which we are emotionally unprepared. It manifests simultaneously on three levels: psyche, brain, and organ.
2. The theme of the psychic conflict determines the location of the focus, or Hamer Herd, in the brain and the location of the cancer in the organ.
3. The course of the psychic conflict correlates with the development of the Hamer Herd in the brain, and the course of the cancer in the organ.

At the moment of the conflict-shock, a short circuit occurs in a predetermined place in the brain. This can be demonstrated with a computed tomography (CT) scan and looks like concentric rings on a shooting target. Later on, if the conflict becomes resolved, the CT image changes to reflect the development of an oedema and finally of scar tissue.

The following incident shows how specific and precisely located these brain lesions are. After a professional lecture, a doctor handed Dr. Hamer the CT brain scan of a patient and asked him to explain it. From this, Dr. Hamer correctly diagnosed the patient as having a bleeding bladder carcinoma in the healing phase, an old prostate carcinoma, diabetes, an old lung carcinoma, and sensory paralysis in a specific area, in addition to the corresponding emotional conflicts.

Dr. Hamer demonstrated that at the same time as the concentric brain lesion appears, the target organ CT scan may also show such a concentric lesion. According to Dr. Hamer, this happens instantly when the psychic shock hits the subconscious level, and this same second is the start of cancer. Also, other diseases can be caused by the same mechanism. How severe a disease becomes depends

on the duration and severity of the conflict-shock, while its nature and location are determined by the emotional content of the shock.

Dr. Hamer believes that the correlation between key emotional shock events, the target brain areas, and the related organs has developed as an adaptation from similar programs in the animal world. When we unexpectedly experience emotional distress, an emergency repair program is set in motion, a biological conflict program with the aim of returning the individual to normal.

Dr. Hamer gives the following example. A mother sees her child in a bad accident. As small children recover faster when they receive extra milk, the biological conflict program tries to stimulate milk production by increasing the number of breast cells. If the mother is right-handed, that will instantly cause the appearance of a Hamer Herd in a specific part of her right brain, which in turn relates to the left breast. When the child is well again, conflict resolution begins and extra milk is no longer needed. The mother gets a benign form of tuberculosis in the affected breast that breaks up the excess breast cells. However, if the mycobacteria required for this function are lacking, then the area may just calcify and remain as a dormant tumor.

The same process also applies to animals. A sheep that loses its lamb to a wolf is prone to develop teat cancer; the side depends on whether it is right- or left-footed. Commonly, the sheep resolves this conflict by bearing another lamb.

The next example illustrates the original survival value of this mechanism. Let's assume a lion chases an antelope. The antelope must immediately mobilize all its resources to survive. The sympathetic nervous system takes over and, in addition, a specific brain centre that stimulates lung activity becomes active. After the successful escape, the animal rests, and the parasympathetic nervous system becomes dominant to normalize brain and body functions.

If a human gets a cancer diagnosis, even if the diagnosis is wrong, the same biological program is set in motion by the same fear of death that helped the animal to escape. The stress level jumps and activates the brain-lung connection, but now there is nowhere to run. Until the conflict is resolved, which may take years, there will be constant stress and brain-induced stimulation to increase lung capacity by the incessant division of cells.

This process can only be stopped by switching off the trigger in the brain through defusing the original conflict shock. This happens when the patient subsequently has surgery or natural therapy, which he or she fully believes will lead to a cure. However, the same procedure in a patient who has doubts about its effectiveness will leave the conflict unresolved and the disease to progress. Thanks to Dr. Hamer's work, it is now possible to verify this hypothesis with a CT brain scan.
The selection of the conflict focus occurs by subconscious association. For instance, biological conflicts involving water or other fluids, such as milk or oil, lead to kidney cancer; fear of death to lung cancer; and psychologically swallowing a bigger chunk than we can digest to stomach or intestinal cancer.

In the animal world, it is literally a big chunk of food, but for us it may be a financial over-commitment or any other obligation that we are unable to fulfil. The target focus is not determined by the event itself, but rather by the psychological significance that it has for us at the time of the event. Dr. Hamer illustrates this with another example, a woman who finds her husband in bed with another female. As a

sexual frustration conflict, it can cause uterine cancer. If she instead experiences it as a partner conflict, then in a right-handed woman it leads to cancer of the right breast. If the conflict feeling is fear and revulsion, then it causes hypoglycaemia, and with lack of self-worth, cancer may develop in the pubic bone.

If the lack of self-worth had been due to a failure in sportsmanship, then the problem would have arisen in an arm or leg instead, or possibly in the fingers or shoulder required for the sporting activity. Other typical situations that can lead to biological conflicts are loss situations, of a loved one, a job, a valued possession, or a territory.

Dr. Hamer believes that most metastases or secondary tumours are caused by the cancer-fear or death-fear resulting from the patient being given the cancer diagnosis or a negative prognosis. In this case, the resulting conflict shock may not be fear of death, but anger, resentment, or a separation conflict (from partner or children), and then tumours would appear in different places. A diagnosis of colon cancer commonly leads to liver metastases because of a subconscious fear of starvation.

In regard to animal experiments, Dr. Hamer regards increased cancer rates due to exposure of carcinogens as being emotionally based. This happens when the skin is irritated with a toxic substance. He also cites early research with tobacco smoke that showed that hamsters exposed to it lived longer than non-exposed hamsters. He believes that hamsters, as burrowing animals, are not afraid of smoke and therefore are protected from its harmful effects. Mice, on the other hand, living in houses, are very fearful of smoke, which causes them to develop lung cancer when exposed to tobacco smoke.

Generally, hopelessness, despair, and meaninglessness create chronic stress and hinder the healing of cancer and other diseases, but they are not the cause. According to Dr. Hamer, the real cause of cancer and other diseases is an unexpected traumatic shock for which we are emotionally unprepared.

The emotional connections with some other diseases are as follows, according to Dr. Hamer:

Angina Pectoris: Caused by fight for territory or its contents in the active phase, followed by heart infarction in the healing phase.

Diabetes and Hypoglycaemia: A right-handed female develops hypoglycaemia from anxiety and revulsion; if left-handed, she develops insulin-dependent diabetes. A right-handed male develops insulin-dependent diabetes from a conflict of resisting or struggling against something; if left-handed, he develops hypoglycaemia.

Facial Paralysis: Fear of losing face, having been made a laughingstock.

Haemorrhoids: A right-handed woman with an identity conflict and a left-handed man with territorial anger in the healing phase may get haemorrhoids.

Multiple Sclerosis and Paralysis: Inability to escape or continue on, or to hold on to, or not knowing what to do.

Psoriasis: Separation conflict concerning mother, father, family, home, friends, or pets.

Relationships between Conflicted Emotions and Target Organs

Adrenal cortex: Wrong direction, gone astray
Bladder: Ugly conflict, dirty tricks
Bone: Lack of self-worth, inferiority feeling
Breast, left (right-handed): Conflict concerning child, home, or mother
Breast, right (right-handed): Conflict with partner or others
Breast milk duct: Separation conflict
Breast milk gland: Involving care or disharmony
Bronchials: Territorial conflict
Cervix: Severe frustration
Colon: Ugly indigestible conflict
Gallbladder: Rivalry conflict
Heart: Perpetual conflict
Intestines: Indigestible chunk of anger
Kidneys: Not wanting to live, water or fluid conflict
Larynx: Conflict of fear and fright
Liver: Fear of starvation
Lung: Fear of dying or suffocation, including fear for someone else
Lymph glands: Loss of self-worth associated with the location
Melanoma: feeling dirty, soiled, defiled
Middle ear: Not being able to get some vital information
Mouth: Cannot chew or hold it
Oesophagus: Cannot have it or swallow it
Pancreas: Anxiety-anger conflict with family members, inheritance
Prostate: Ugly conflict with sexual connections or connotations
Rectum: Fear of being useless
Skin: Loss of integrity
Spleen: Shock of being physically or emotionally wounded
Stomach: Indigestible anger, swallowed too much
Testes and Ovaries: Loss conflict
Thyroid: Feeling powerless
Uterus: Sexual conflict

Psychoses: One or more active Hamer Herds in each of the two parts of the brain.

Rheumatism: A brutal and painful separation conflict.

Vitiligo, Leukoderma: Ugly or brutal separation conflict.

In regard to AIDS, Dr. Hamer observes that no one dies of AIDS without having previously been told that they are HIV-positive or believe that they are. The implication is that it is mainly the negative perception associated with AIDS that causes its devastating effect.

Left-handed individuals develop problems on opposite sides to genuine right-handed individuals. Observing which hand is on top when clapping reveals handedness; right-handed individuals usually have the right hand on top. With right-handedness, all muscles on the right side of the body are involved with partners and other individuals, and all left-sided muscles, with children or one's mother. These conditions may change with hormonal changes, the birth control pill, or menopause.

The Healing Phase: The start of Dirk Hamer Syndrome or conflict-shock experience is different from other conflicts that we experience in our daily lives, says Dr. Hamer. It causes a continuous stress, resulting in a tendency to develop cold hands and feet, lack of appetite and weight loss, sleeplessness, and a dwelling all the time on the conflict content. If the conflict is not resolved soon, it leads to specific disease symptoms.

When the conflict resolves, the patient is no longer occupied with the conflict content, the appetite returns, hands are warm again, and also normal sleep returns, but there may be weakness, fatigue, and a need to rest. These effects show that the parasympathetic nervous system is now in control and the healing phase has started.

During the first part of the healing phase there is water retention and inflammations, and the tumor stops growing. This eventually leads to a healing crisis, which Dr. Hamer calls an epileptic or epileptoid crisis, because it is caused by an oedema in the Hamer Herd brain lesion. It shows unique symptoms for each illness.

After this, the body starts to expel the accumulated water, the patient gradually regains strength, and body functions become normal. Now the connective tissue in the brain, the neuroglia or glia, starts repairing the Hamer Herd. This may be interpreted by conventional radiologists as a fast-growing brain tumor and treated accordingly. Dr. Hamer estimates that 99 percent of brain events, such as strokes, bleeding into the brain, cysts, and tumours are due to healing events of Hamer Herds and are temporary and self-limiting, unless there is inappropriate medical intervention. The most important support in these situations is the reduction of any brain oedema.

During the healing crisis, the patient may for a short time re-experience the original psychological conflict with cold hands and cold sweat. This serves to suppress and eliminate the oedema in the brain lesion, which then allows other body conditions to normalize. The main danger point is just before the end of the healing crisis when it will become apparent if the body is strong enough to eliminate the disease. In difficult cases, with long-standing or strong conflict, massive brain oedema can develop, for which Dr. Hamer uses cortisone injections. In natural therapy, we use diuretics, such as urea, and anti-inflammatory therapies instead.

The epilepsy crisis may be experienced as a heart attack, lung embolism, hepatitis, or lung infection. Generally, during the healing phase, the patient will have more discomfort than when the tumor was actively growing. In the first part of the healing phase, most problems are due to water retention, inflammations, and swelling of tissues that cause a lot of pain. Nevertheless, Dr. Hamer regards oedema, whether in the brain or body, as a positive sign of healing.

Tissue Repair: After the healing crisis, carcinomas are removed by fungi and mycobacteria, while the hepatitis virus may in addition help to regenerate the liver. Bacteria, viruses, and fungi that help to break down the tumours and repair damaged tissues also cause inflammation, pain, and fever.

If you find it odd that Dr. Hamer regards microbes as essential friends and helpers in the healing of cancer, he has developed an even more surprising hypothesis. In his system of tumours and cancer-equivalent diseases, he distinguishes between two opposite processes during the active conflict phase. Depending on the location of the Hamer Herd in the brain, there may be either cell proliferation or cell destruction.

The first group has cell proliferation and tumor growth during the conflict phase and then removes excess cells with the help of microbes during the healing phase. The other group shows cell destruction during the conflict phase, resulting in ulcers, necroses (dead tissues), and tissue holes, affecting, for instance, bones (osteoporosis), kidneys, spleen, or ovaries.

During the healing phase, this second group tries to fill in the created holes through cell proliferation. Bacteria repair tissue necroses and osteolyses (dissolved bone) by first forming abscesses, which are then filled in with scar tissue and later with granulating tissue to form osteosarcoma, lymphoma, fibroma, and healing cysts.

Leukaemia occurs during the healing phase after bone marrow damage from radiation, chemicals, or bone cancer.

According to Dr. Hamer, these conditions are generally self-limiting and only get out of control when additional conflict shocks occur, or the body is too old or weak, or through the methods of conventional medicine. In contrast, natural healing methods aim to support body and mind during this trying time. Most healings proceed without major problems, but about ten percent need the full support of an experienced therapist, especially at the time of the healing crisis.

Healing the Psychic Conflict: The main task in every case of cancer is to find the original emotional shock experience and make sure that it has been healed or is being healed. In many cases it will have corrected itself, and the patient suffers from an effect of the healing phase.

For instance, someone may have lost a farm or business, but has now started another satisfying venture or hobby. As an after-effect, there may now be a tumor that gradually becomes dormant or eventually disintegrates. Dr. Hamer regards about 40 percent of tumours discovered during routine medical investigations as old and harmless, dormant and calcified. However, complications can still arise if medical intervention now causes a conflict shock, such as one involving fear of death; this induces the same or another tumor to grow.

Nevertheless, in other cases the original conflict may still be active, or there may be a second active conflict. As we do not know, we have to probe in every case to find the original and any other conflicts. We need to think back, especially one to two years before our problem started, and analyse our emotional history during this time as well as before and after. Meditation or regression therapy may be useful to discover conflict-shocks.

If we still have a strong emotional response when we discover the content of the conflict, then we can be sure that it is still unresolved. If at all possible, it is best to solve it in a natural way. For instance, if it was caused by losing a partner, find someone new; if you lost a child, become pregnant again, or adopt a child, or buy a pet; with a lost job, find a new one or a hobby. However, it is not the fact of having a new partner, child, hobby, or pet that solves the conflict, but rather that it allows us to dissolve the inner conflict and emotionally get on with our life if we so choose.

If a natural solution is not possible, then use guided imagery, either on your own or with the help of a partner or a suitable therapist. In a relaxed and meditative state recreate and re-experience the conflict as intensely as you can, but then substitute a desirable or acceptable outcome. Create and experience this new outcome as vividly and in as much detail as possible; see it, feel it, and possibly even hear and smell it. The original experience may also have imprinted you with the memories of unrelated details of your ordeal (tracks) to which you may now react with allergies. You can overcome these in the same way with guided imagery

If neither of these methods is possible because you feel that you have to continue your present duties or ordeal for whatever reason, then only increased spiritual understanding and acceptance may be able to help. In either case, be aware of your vulnerabilities and avoid any further conflict-shocks, but if one does happen, get it out of your system is soon as possible.

I firmly believe that all active conflicts will be terminated and the healing phase begin when we are able to strongly feel love and forgiveness within ourselves and then radiate it to all others, but especially to anyone who we feel might have wronged us. We can further ease the healing phase by expecting it to be short and mild and lead to full recovery.

According to Dr. Hamer, animals in the wild get cancer from the same shock programs as we do. However, 80 to 90 percent survive and do not notice it much, because the healing phase can take its natural course. Those that die are mainly old animals that cannot resolve a conflict, such as regaining their territory from a rival or replacing a lost cub.

It is different in our society, as the natural healing process is routinely interfered with. It starts with getting tranquilizers or antidepressants during the active conflict phase, which prevent us from fighting back and regaining our territory. This may then lead to a cancer diagnosis that causes an additional active conflict and ends with morphine, which totally disables our healing responses.

While Dr. Hamer does not believe that health foods, remedies, cleansing, or healthy living in general can cure cancer, he says these are important to surviving the ordeals of the healing phase. Actually, Dr. Hamer regards all diseases as consisting of two phases: initially an active conflict, followed (if possible) by a healing phase that reverses the conflict program. He does not call them “diseases” but “special biological programs.” He says he has worked with more than 31,000 patients and found his theories confirmed in every single case without exception. Dr. Hamer claims that overall this approach has a 95-percent success rate with cancer.

Persecution for Therapeutic Success: Siemens, the manufacturer of CT equipment, has independently verified the existence of the Hamer Herds in the brain, which radiologists had claimed to be artefacts. Furthermore, their diagnostic significance was confirmed in 1998 at the University of Trnava in Slovakia. Nevertheless, Dr Hamer faced exceptional persecution. This included withdrawing his right to practice in Germany for not retracting his theories and swearing allegiance to the principles of orthodox medicine; assassination attempts; efforts to put him in a mental asylum; and numerous court appearances and even putting him in jail.

While many individual doctors, including professors of medicine, are alleged to have verified the principles of Dr. Hamer’s “New Medicine,” so far no German university has agreed to test them. Doctors and natural therapists in Europe who practice according to the principles of the New Medicine now face persecution. Only Spanish courts took the enlightened position that it is not their role to decide between conflicting medical theories and therapies. Dr. Hamer now lives and practices in Spain.

In 2001, a prominent neurologist, Dr. Therese von Schwarzenberg openly defended Dr. Hamer by publishing a book about the New Medicine, in which she demanded that his theories be officially tested. She declared that Dr. Hamer is right and deserves a Nobel Prize. Nevertheless, the response of prominent oncologists is still that it is absurd to assume emotions could be important in the cause and cure of cancer and, therefore, Dr. Hamer’s claims must not be tested. (For more information on Dr. Hamer and the New Medicine, see: www.newmedicine.ca.64)

Reflections on the New Medicine: My own understanding and experience leave no doubt about the primary importance of our emotions and beliefs in the cause and cure of our diseases. The writings of Dr. Hamer give the impression of a serious and meticulous researcher whose findings apparently have been confirmed by various scientific institutions and medical practitioners, including professors of medicine.

Therefore, I have no doubt about the validity of his basic premise that diseases, and in particular cancers, are associated with visible lesions in specific locations of the brain and also with specific psychological experiences. His postulated two-part disease process, in which the healing phase is a reversal of the original disease condition, is a basic concept of natural therapies.

However, Dr. Hamer appears reluctant to extend or modify his theory and take other factors into account. Basically, Dr. Hamer postulates a one-way communication from psyche to organ via the brain. I suggest instead a two-way communication from psyche to organ, as well as from organ back to brain and psyche. Assuming that an organ is chronically stressed, be it from pesticide accumulations, inappropriate growth factors, or endotoxins due to microbes, then this causes constant low-level tissue irritation of the organ and its related brain area. There are now two possibilities:

- The sensitized brain area causes us to react more strongly to any emotional conflict; therefore it is easier to develop a Hamer Herd and the related disease.
- An existing subacute conflict, combined with chronic tissue stress, may cause the gradual development of a Hamer Herd or, alternatively, its sudden appearance when a certain threshold is reached.

In this way, any environmental factors can be taken into account for creating Hamer Herds in combination with psychological conflicts. Conversely, appropriate therapy directed to a diseased organ may give a message to the associated brain area to heal the Hamer Herd and lead to a resolution of the emotional conflict.

A confirmation of the suggested interconnectedness between emotions, nutrients, brain, and organs can be found in kinesiology. Research with muscle testing has revealed a relationship between different nutrients and emotions with specific muscles and organs, transmitted through the system of acupuncture meridians. A direct involvement of the brain has been shown by placing a labelled nutrient in the back of the mouth: Within seconds, the isotope was also detected in the brain. Recently another piece of evidence in support of the New Medicine has emerged: researchers found a tumor growth promoter (GDNF) that is produced by the glial cells in the brain.

The theories of Dr. Hamer have not yet been tested by mainstream science, but neither have key components of conventional and natural medicine. If you find Dr. Hamer's theories reasonable and do not want to wait another 10 or 20 years for them to be accepted, then I suggest that you incorporate them into your holistic healing program.

What to Do: Be aware of your vulnerabilities and avoid any further conflict-shocks, but if one does happen, get it out of your system as soon as possible. For

example, if you just got a big shock, minimize or undo its potential to create an illness by using any or all of the following methods:

- Take appropriate remedies, such as Rescue Remedy or homeopathic arnica.
- Develop an inner reconciliation through prayer and meditation.
- Apply the Emotional Freedom Technique (see Step 63).
- Use guided imagery to recreate the shock experience with an acceptable outcome.
- Try to find a natural solution for your shock experience; for example, after nearly drowning, swim again as soon as possible

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Step 48
CANDIDA INFECTIONS

The secret to preventing illness is to undo shocks that unbalance the body.

Lack of energy, digestive disturbances, arthritic joint pains, skin disease, menstrual problems, emotional instability, and depression are all symptoms of what I call the antibiotic syndrome. This is a condition that has greatly increased in incidence in recent years and, on further examination, more symptoms of this syndrome may be discovered. In this condition, most of the gastrointestinal tract is tender when pressed on the body's surface, especially the small intestine, liver, and gallbladder. There may have been a gallbladder operation that failed to improve the condition, sometimes worsening the symptoms. As part of this syndrome, there could be a history of thrush or oral, anal, or vaginal itching. When these are present, the diagnosis of Candida overgrowth is obvious, but it may also be present in the absence of these manifestations, and that can be confusing.

The fungus Candida albicans thrives during antibiotic treatment and I regard it as reckless negligence to prescribe antibiotics without simultaneous fungicides and replacement therapy with lactobacilli afterwards. I believe that this practice has greatly added to the numbers in our chronically sick population. However, the antibiotic syndrome is not just due to Candida. I regard it more generally as a dysbiosis in which the wrong kind of microbes inhabit the intestinal tract; it's not just Candida and other fungi, but many types of pathogenic bacteria including E. coli bacteria, which are normal in the colon but become disease-forming when they move into the small intestine.

If the problem has existed for years, there is usually a lack of gastric acid, which then allows the stomach to be colonized by microbes, causing inflammation with pain and, later, ulcers. The toxins released by the microbial overpopulation cause chronic inflammation of the liver, gallbladder, pancreas, and intestines. This can have other health repercussions. I regard it as likely that a chronic inflammation of the pancreas is a major contributing factor in the development of insulin-dependent diabetes.

Bacterial Attack: Specific types of pathogenic bacteria appear to cause or contribute to specific autoimmune diseases. One variety of coliform bacteria, for instance, produces a molecule very similar to insulin. When the immune system becomes activated against this molecule, it may then also attack related features at the beta cells of the pancreas. Another type of bacteria, Yersinia enterocolitica, induces an immune response that attacks the thyroid gland and leads to Grave's disease with a serious overproduction of thyroid hormones.

Ulcerative colitis is linked to overgrowth of pathogenic microbes, as are Crohn's disease and ankylosing spondylitis. In ankylosing spondylitis, the vertebrae of the spine fuse together, causing stiffness and pain. Other joints may in time become affected. Klebsiella, another type of pathogenic bacteria, produces a molecule that is similar to a tissue type found in people with this disease. When Klebsiella numbers in the gut decrease, related antibodies in the blood decrease and the condition improves.

Rheumatoid arthritis is linked to a bacteria called Proteus. Proteus is also a common cause of urinary tract infections. Women suffer urinary tract infections as well as rheumatoid arthritis twice as often as men, while men usually have higher levels of Klebsiella and three times more ankylosing spondylitis than women have. In addition, microbial overgrowth damages the intestinal wall so that only partly digested food particles can pass into the bloodstream, causing allergies. In this way, it appears that all autoimmune diseases can be linked to dysfunctional intestines and food allergies.

Other autoimmune diseases that have so far been linked to intestinal dysbiosis are psoriasis, lupus erythematosus, and pancreatitis. When remedies are given that bind bacterial endotoxins, these conditions usually improve. A further consequence of dysbiosis is susceptibility to food poisoning, as with Salmonella bacteria; in contrast, a healthy intestinal flora prevents these from multiplying and causing trouble.

Staphylococcus aureus causes serious infections in hospital patients. It has been found that not only S. aureus but other infections are greatly potentized when they occur with a Candida overgrowth. As Candida overgrowth is a natural outcome of the standard hospital treatment, it is easy to see why staph is so deadly in hospitals.

A similar picture emerges with AIDS. People do not die from the AIDS virus, but from bacterial infections potentized by Candida and related mycoplasmas.

I regard the antibiotic-induced dysbiosis in babies and infants as the main cause of their frequent infections called glue ear, and as greatly contributing to crib death. While it used to be uncommon for children to have more than one or two infections a year, now more than six is the norm.

In summary, in the 1940's, Candida overgrowth was found in only three percent of bodies autopsied, but now the figure is nearer 30 percent. There are, of course, other factors that can cause dysbiosis - the contraceptive pill, steroids and other drugs, radiation treatment, chemotherapy - but the main culprit is without doubt antibiotics.

Debilitations Caused by Candida: In an Alabama hospital in 1953, Orian Truss, M.D., discovered the devastating effects of antibiotics. During a hospital round, Dr. Truss was intrigued by a gaunt, old-looking man who was obviously dying. However, he was only in his 40's and though he had been in the hospital for four months no specialist had been able to make a diagnosis. Out of curiosity, Truss asked the patient when he was last completely well.

The man answered that he had been well until six months ago when he had cut his finger. He had received antibiotics for that. Shortly afterwards, he developed diarrhea and his health deteriorated. Dr. Truss had seen before how antibiotics cause diarrhea. It was known that Candida was opportunistic and thrived in debilitated patients, but now Dr. Truss wondered if it might not be the other way around, that Candida actually caused the debilitated condition. He had read that potassium iodide solution could be used to treat Candida infestation of the blood so he put the patient on six to eight drops of Lugol's solution four times a day and soon the patient was again completely well.

Not long afterwards, Dr. Truss had a female patient with a stuffy nose, a throbbing headache, vaginitis, and severe depression. To his amazement, all her problems immediately cleared with Candida treatment. Some time later, he saw a female patient who had been schizophrenic for six years with hundreds of electroshock treatments and massive drug dosages. He started treating the woman for sinus allergies with a Candida vaccine. Soon she had recovered mentally and physically and remained well.

From then on, Dr. Truss treated his patients against Candida at the slightest indication of its presence. Many of his patients made remarkable recoveries from most unusual conditions, including menstrual problems, hyperactivity, learning disabilities, autism, multiple sclerosis, and autoimmune diseases such as Crohn's disease and lupus erythematosus.

Every experienced naturopath can relate similar success stories. Ironically, antibiotics are usually not necessary in the first place. In the few percent of cases in which they are necessary, their serious after-effects could easily be avoided by using fungicides and lactobacilli. Many people doubt the effectiveness of natural therapies against apparently serious infections, but my clinical experience leads me to believe that, frequently, natural therapies are more effective, and without causing the repeated and chronic infections seen after antibiotics. I have seen patients whose long-term antibiotic treatment was unsuccessful recover within days or weeks with natural therapies.

Overcoming the Antibiotic Syndrome: The main treatment for the antibiotic syndrome is sanitation of the gastrointestinal tract combined with a low-allergy diet. In this way, most acute problems can be overcome within weeks, while degenerated joints or organs can start a slower road to recovery.

One unpleasant side effect of most methods used to reduce the pathogenic microbial overgrowth of the intestines is the Herxheimer effect, a sudden but transient worsening of symptoms due to toxins released by the dead or dying microbes. This is sometimes used as a diagnostic tool, especially for Candida: If you get the reaction, it means you had the infestation.

I recommend intestinal flushes (orally taken) combined with antimicrobial remedies to avoid or minimize unpleasant side effects. An oral isotonic flush consists of nine grams or one heaping teaspoon of salt in one quart of water, and is suitable for sensitive individuals and generally for those with low to normal blood pressure. A solution is said to be isotonic if it contains a similar amount of salt as the blood. An Epsom salt flush can contain one tablespoon of Epsom salt, more or less according to need, in a large glass of water and is useful in cases of constipation and raised blood pressure.

A crushed clove of garlic is added to the flush to reduce the microbial overgrowth. If garlic cannot be used, then up to two teaspoons of three-percent hydrogen peroxide (food-grade) or six drops of tea tree oil can be added instead. You can take another glass of water after the Epsom salt to wash down the bitter aftertaste, but not after the isotonic flush, as it would no longer be isotonic.

The flush will carry most of the dead microbes and their toxins out of the body and minimize any unpleasant reactions. However, if the flush should not be sufficient to produce a strong bowel movement within two to three hours, then another flush,

preferably with Epsom salt, should immediately follow or unpleasant reactions may occur.

As a precaution after antibiotic therapy, for general body cleansing, or if there are only mild symptoms of microbial overgrowth, it will be sufficient to continue this for about three days. In severe and long-standing cases, the flush can be used for several weeks. If Candida overgrowth is suspected, any sexual partner should have at least a short flush period. If it is inconvenient to continue with a flush, as for instance with work commitments, then it may work to have a flush just once or twice and then continue for a long time with a high intake of acidophilus and bifido cultures.

Acidophilus and Bifido Cultures: This leads us to the next step: replacing the decimated pathogenic microbes with desirable lactobacilli or "friendly" bacteria. This must be done in a massive dose 30 to 60 minutes after each flush, otherwise the unwanted microbes may grow back to full strength after your next meal. Acidophilus culture is used to repopulate the freed-up spaces in the walls of the small intestines, while bifidobacteria are the protective inhabitants of the large intestines.

These bacterial cultures are available from health foods stores as high-potency capsules or powders in brown glass bottles that should be refrigerated before and after sale. You can buy a mixed culture and take several capsules or two teaspoons in water or vegetable juice or one teaspoon each of the separate cultures. If you suspect a cow's milk allergy, which is frequent in this condition, then use milk-free cultures.

After several months on the shelf of a store, cultures may have very few live bacteria present. Therefore, it is best to take powdered cultures in addition to fresh cultures found in good quality yogurt. You can test the quality of any powdered culture by using it as a starter to make your own yogurt (see Step 37). If it is of high quality, the yogurt will develop quickly. Alternatives to cow's milk yogurt do not set creamy because of their lower protein content, but that does not matter, as the beneficial bacteria are in the liquid whey.

Eat a cup of this yogurt in addition to the powdered culture after each flush, using more before or with other meals. Continue taking either the cultures or yogurt for several months after you have stopped taking a flush. Women should apply yogurt or acidophilus powder to the vagina for a few days or weeks. It is preferable initially for a few days to douche beforehand with a few drops of tea tree oil or diluted hydrogen peroxide solution at a strength of one teaspoon of three-percent peroxide to a glass of water, or more or less according to your sensitivity.

For those who do not ingest acidophilus/ bifido products regularly, take a course of "friendly" bacteria once a year as a precaution, but especially with or after taking any drugs, medical or recreational, or if you're leading a stressful life. The diet during this therapy should be free of sweeteners, sweet foods, yeast, alcohol, and initially also of fruits. Various supplements, such as caprylic acid, can be useful but are not necessary with this flush method.

If the Candida problem is severe or has existed already for a long time, chances are that the fungus has already invaded the bloodstream and internal organs. In this case, it is best to take an herbal parasite cure and at another time a course of Lugol's solution as explained under Candida and Parasites in Step 44.

If your blood is contaminated, then you may initially experience a die-off reaction of the Candida, causing weakness and possibly headache or nausea. If this happens, cut back temporarily on the amount of Lugol's solution and drink plenty of water and diluted teas or juices.

Finally, as an addition or an alternative to Lugol's solution, you can use a Beck-type blood purifier or zapper to eliminate Candida and other fungi and infectious agents from the blood (see Step 19). The magnetic pulser can be used to sanitize pockets of Candida infestations inside the mouth, vagina, or underneath the skin.

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Step 49
CARDIOVASCULAR DISEASE

Managing cholesterol and improving your heart health - some practical tips.

For many years, we have been inundated with anti-cholesterol campaigns and suddenly now we hear or read of one scientific study after another telling us that cholesterol, after all, may be good for us.

The first major shock for the cholesterol - heart disease theory came in 1990 with an article in the British Medical Journal.[65] It was an analysis of six major intervention trials involving tens of thousands of people over several years. The result was unexpected. There was indeed a small reduction of about ten percent in cholesterol levels and a reduction of 14 percent in the rate of death from heart disease in the groups treated medically with drugs and low cholesterol diets.

However, the total death rate of patients with medically lowered cholesterol was significantly higher as compared to controls. This included not only higher mortality from cancer, but surprisingly, on average, a 67 percent higher mortality from violent death, such as accidents, homicides, and suicides. This high rate of death from violent causes was found in every single one of these trials, so it was unlikely to be a coincidence.

In looking for an explanation, researchers discovered that monkeys became more aggressive on a diet low in cholesterol and saturated fat, and human studies further found that criminals, on average, had lower cholesterol levels. This applied generally to individuals with aggressive or violent behaviour or limited self-control and also those involved in homicide and suicide.

Another scientific publication voiced concern over evidence that about half of the men who die of sudden heart attack do not have any of the risk factors commonly associated with heart disease, such as elevated cholesterol or blood pressure, diabetes, obesity, or smoking. This would suggest that the main cause of heart attacks is still unknown to medicine.

A Finnish study followed 1,222 Helsinki businessmen considered at high risk of heart attack for 15 years. Half were put on an intensive program of dietary regulation and other treatment while the other half served as controls. After 15 years, the low-cholesterol group had 67 deaths overall with 34 from heart disease. The control group had only half the overall death rate with 14 cardiac deaths. In light of this result, the medical director of the British Heart Foundation admitted that the existing advice to cut cholesterol was not based on “definitive research.” What, then, is it based on?

Another recent medical study confirms the general harmlessness of elevated blood cholesterol levels. Of a large group of elderly patients with high blood pressure and high cholesterol, those with the highest cholesterol levels lived longest while those with less elevated levels had the highest mortality rate. Cholesterol news that hit the headlines in 2001 showed that for old men it is best to have a “normal” blood cholesterol level because both high as well as low levels lead to an increased rate of heart attacks.

Why We Need Cholesterol: The cholesterol saga started several decades ago when researchers found that those dying from heart disease also frequently had elevated blood cholesterol levels as well as fatty plaque, called atheromas, which clog up the arteries of the heart muscle. These atheromas consist of wildly proliferating smooth muscle cells filled and surrounded by a fatty sludge containing a high level of cholesterol.

Medical authorities believed that cutting down on our cholesterol intake would lower our cholesterol blood levels and thus reduce the risk of heart disease. Biochemists, however, were generally sceptical of this idea. After all, the liver itself produces most of our cholesterol requirements. Approximately one gram daily is synthesized from the breakdown products of saturated fats and sugars and less than half a gram is absorbed from our food. The more cholesterol we absorb, the less is produced in the liver. With this, our overall cholesterol level remains fairly stable and any surplus cholesterol is normally excreted with the bile.

Cholesterol is a very valuable and useful substance. It provides the basic structure for the synthesis of steroid hormones and vitamin D and it is a major component of cell membranes; it is especially high in the brain and nervous system. In the liver it is converted into bile acids and bile salts needed for the digestion and absorption of all lipids (fats and fat-related substances). However, if we are deficient in the emulsifier lecithin or in sulphur amino acids, cholesterol can accumulate as gallstones.

So you can see that it is very important for us to have enough cholesterol. In fact, some wasting diseases, such as cancer, are associated with a cholesterol deficiency, and hypoglycemics are commonly found to have low cholesterol levels.

How We Overproduce Cholesterol: Why then do some people get raised blood cholesterol levels when the liver is supposed to keep cholesterol levels stable? Obviously, something must interfere with the regulating mechanism in the liver.

One of these causes is a high intake of saturated fats. These are broken down in the liver to keto acids that are normally used for energy production in the muscle cells. For this, the keto acids need the breakdown products of the sugar metabolism (glycolysis). If you have a habitually raised insulin level or insensitivity to insulin (e.g., diabetes), these sugar metabolites are in short supply and this can cause keto acids to accumulate. In addition, a deficiency of chromium will also interfere with the fat metabolism. The liver now attempts to get rid of the keto acids by converting them into surplus cholesterol.

There is another mechanism responsible for cholesterol overproduction involving sugar. When you ingest sugar, your blood insulin level is raised. A key enzyme of cholesterol synthesis is actually regulated by insulin and this means a higher sugar intake generates higher insulin levels and with this higher fat and cholesterol levels.

The word sugar, however, does not simply mean sucrose, our common household sugar. There are different forms of sugar. Sucrose is a combination of glucose and fructose. In susceptible individuals, fructose has a much greater influence on insulin levels than glucose. Enzymes still present in human liver biopsy samples converted fructose into fatty acids and cholesterol at rates three to 24 times

faster than glucose, with the highest rates occurring in those with a disposition to atherosclerosis.

An even stronger insulin effect (stronger, that is, than by ingesting equal amounts of glucose and fructose) occurs when eating these simple sugars chemically combined as sucrose. This is called the disaccharide effect. In a study, monkeys produced three times more deposited lipids on a diet high in sucrose than with glucose.

Oxidized Cholesterol: We can now see that a diet high in sugar and fat is the main cause of a raised cholesterol level, while the cholesterol content of our diet has been repeatedly shown to have little impact. Yet this still does not prove that there is a causal relationship between elevated cholesterol levels and heart disease.

However, such a direct connection has been shown to exist with oxy-cholesterol. If cholesterol in food is heated, especially with access of air, then it is oxidized to oxy-cholesterol. Animal experiments with high intakes of either pure cholesterol or oxy-cholesterol have shown atherogenic degeneration only with the latter, not with cholesterol itself.

This would imply that a main contributing factor to our high rate of heart disease is our habit of overly heating and frying meat, eggs, and milk products. However, once the arteries are damaged, then high cholesterol levels may or may not contribute to the deposits of fatty sludge.

Further clues can be found in the history of heart disease. Heart attacks were extremely rare in earlier centuries and even at the beginning of the twentieth century. A medical textbook published in 1912 describes angina pectoris, a mild form of heart attack, as being very rare, and a famous American heart specialist did not see his first heart attack patient until 1920. Yet beginning in 1920, the explosive rise in the incidence of heart disease in Western countries was on.

As China and other less developed countries remained free of heart disease, then we may ask: What fundamentally changed the lifestyle of Western populations at that time? Two important changes took place: the pasteurization of milk products and the chlorination of public water supplies.

Pasteurization of Milk Products: Before pasteurization, some doctors recommended milk as a cure for many illnesses. Raw milk cures were famous at the beginning of the twentieth century. Formerly, people consumed plenty of cream and butter and rich meals prepared with them, and in Bulgaria and the Caucasus they set records in good health and longevity on full-fat milk products. An American doctor reportedly cured psoriasis by having his patients eat two pounds of butter a week. Despite all this fatty food, heart attacks were virtually unknown.

Now milk is no longer a cure for any disease. On the contrary, natural therapists generally regard milk as disease-forming, butter is known to aggravate psoriasis, and heart disease is rampant. What is the difference? Enzymes plentiful in raw milk are destroyed by pasteurization.

Some diseases that were formerly improved with raw milk can now be successfully treated with high-level enzyme supplements. Specifically, it is the fat-digesting enzyme lipase that works most of the healing miracles. With cardiovascular disease, there is a deficiency of lipase in the bloodstream. Lipase released by the

pancreas helps to digest fats, while lipase in the bloodstream and cells helps to break down unwanted fatty deposits.

There are, however, fats and oils that arguably are much worse than pasteurized butter. These are the oils with a high content of unnatural trans-fatty acids, such as margarine, shortenings, and hydrogenated oils and fats and, to some degree, even our common salad and cooking oils. Trans-fatty acids are produced not only by hydrogenation, but also by the heating of oils. Fats and cholesterol are transported in the blood in the form of lipoproteins, and trans-fatty acids produce a more unfavourable lipoprotein profile than any other fat.

Recently I heard a cheese producer say that he submitted some of his self-produced unpasteurized cheeses for testing. They were completely free of pathogenic bacteria, unlike pasteurized products that commonly contain disease-causing microbes up to a legal limit. The reason for this superior safety of raw cheeses is their high content of lactobacilli. These kill harmful microbes, while in pasteurized products, any survivors or contaminants can multiply unchallenged. Therefore, milk products correctly fermented with lactic acid are not only healthy but also safe, unlike their pasteurized counterparts.

Chlorination of Public Water Supplies: Experimental use of chlorine to kill bacteria in public water supplies began around 1900 and was generally accepted in Western countries by the l920's. Part of the chlorine reacts with organic impurities to form organochlorines (DDT is an organochlorine), while the rest remains as residual-free chlorine in the water. It can then react with food chemicals or with parts of our digestive tract.

From 1920 onwards, the explosive increase in the incidence of cardiovascular disease and fatal heart attacks began, but only in countries that chlorinated their water supplies. These diseases remained unknown, for instance, in China, Japan, Africa, and Asia. However, Japanese citizens who emigrated to Hawaii where water was chlorinated suffered the same rate of heart attacks as the Americans, and the African-American population in the U.S. has the average U.S. rate of heart attacks, but not that of their counterparts in Africa.

In 1967 an American researcher, J. Price, M.D., performed a decisive experiment. With one group of 50 three-month-old chickens, he added one-third of a teaspoon of chlorine bleach to about one quart of water in their feed, while another group of 50 chicken served as controls. Seven months later, more than 95 percent of the chlorinated group had advanced atherosclerosis, yet none of the control group showed any such evidence. In the following years, Dr. Price repeated his experiment many times, always with the same results. Recently, researchers funded by the U.S. Environmental Protection Agency confirmed atherosclerotic-type changes in other animals, including monkeys, when exposed to chlorinated water.

Public health officials claim wrongly that water chlorination is essential to prevent microbial contamination. Public water supplies can be made safe with ozone or exposure to ultraviolet light at no greater expense than with chlorine. Even sunlight is very effective, with 99.9 percent of coliforms (pathogenic bacteria) killed within 90 minutes in one experiment. For sterilizing our individual water supply, we can simply add a teaspoon of three-percent hydrogen peroxide (food-grade) to a gallon of

drinking water or expose it to sunlight in a shallow container or a clear glass bottle for several hours.

Practical Recommendations: Other contributing factors in cardiovascular disease are vitamin B6 and magnesium deficiency, high ferritin or iron levels, and a low intake of omega-3 essential fatty acids. Kilmer S. McCully, M.D.,66 discovered in the 1960s that with vitamin B6 deficiency a toxic breakdown product of the amino acid methionine occurs. This chemical, homocysteine, causes free-radical damage to the arteries. Even young children with vitamin B6 deficiency were found to die of rapidly developing atherosclerosis. As a result of this discovery, Dr. McCully lost his professorship at Harvard Medical School in 1979 and was turned down in 51 job applications in the following two years. Now he has been vindicated and his discovery is mainstream medical theory.

Moses M. Suzman, M.D., a neurologist in Johannesburg, South Africa, specialized in treating heart patients with 200 mg of vitamin B6 daily and B-complex tablets. He had remarkable success and extremely low re-infarction rates. Researchers have found that folic acid lowers homocysteine levels, especially in combination with vitamin B12; high iron levels have been strongly linked to free-radical damage in the arteries and subsequent plaque formation.

Chronic inflammation has been shown to be strongly involved with the development of arterial plaques. Often this inflammation is due to chronic bacterial infections. A high intake of antioxidants, including the various bioflavo-noids and carotenoids, as well as omega-3 essential fatty acids in linseed oil (or ground linseed) and fish oils, protects the artery walls with their anti-inflammatory and anticoagulant properties. A good anti-inflammatory herb for everyday food flavouring is ginger root.

For good heart health, avoid highly heated fatty and oily foods, especially if heated with access to air, as in frying. Not only are heated animal fats harmful when they form oxy--cholesterol, but so are oxidized and peroxidised polyunsaturated oils. Use vegetable oils that have not been heated to more than 120º F. Generally, I trust only high-quality linseed oil and extra-virgin olive oil to have retained their lipase. In addition, there are some good specialty oils, the labels of which state that the oils have been produced below 120º F. The cold-pressed oils in health food stores may or may not be completely trustworthy but are better than conventional supermarket oils.

Cut down on sweet food, in particular on sucrose, and minimize the combination of starches with anything sweet, as that causes an exaggerated insulin response and all its harmful effects. Basically, this means eat fruits on their own before or instead of any meals.

Fish oils and linseed oil are high in omega-3 essential fatty acids that are anti-inflammatory and protect our arteries from clogging. Various specific nutrients have a protective effect, such as ginger, green tea, grape seed extract, vitamins C and B6, natural vitamin E, and magnesium, preferably as magnesium chloride. All foods with color are good and especially purple foods, including red wine. In addition to an anti-inflammatory effect, these nutrients have an anticoagulant effect and discourage the formation of damaging blood clots. With seriously ill patients, the “Pauling therapy” is helpful: In addition to other recommended nutrients, use 5 to 10 g of

vitamin C, 5 to 6 g of the amino acid L-lysine, and 2 g of L-carnitine daily, all in four divided doses daily.

Reflexology describes a connection between the heart and the soft pad at the base of the left thumb. If there is a heart problem, this part will be sensitive when pressed. Heart diseases and especially acute conditions often can be improved by repeatedly and for long periods pressing strongly into the base of the left thumb. Heart attacks reportedly have been stopped by doing this. In an emergency, press as hard as you can; at other times, only as much as you reasonably can stand the pain. Gradually, as the condition improves, the tenderness at the base of the left thumb will diminish. See also the entry on Cardiovascular Disease in Step 44.

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Part 7
ENERGIES
Dealing with Harmful & Helpful Ones

This chapter deals mainly with the nonphysical energies, variously called life force, bioenergy, prana, chi, od, orgone energy,[67] and many other names. It is this energy level that we most easily see as the innermost aura around living objects or that we sometimes feel as various sensations such as heat or tingling in our body, especially when transferring energy, as with “laying on of hands” or Reiki. It is also the energy that fuels our sexuality and that we feel most strongly during orgasm.

This energy circulates in our acupuncture system and its vortexes form our chakra system (non-physical energy centres). It is not only at the root of most paranormal or psychic phenomena, but is the healing agent of many natural therapies. Homeopathy can only be understood as a bioenergetic phenomenon; that is why it is so fiercely rejected by conventional science, in spite of scientific evidence that it works. While bioenergy is still unknown to orthodox science, it is an everyday experience of many healers and sensitive individuals. Just as electromagnetic energies have a wide range of wavelengths or frequencies, so also have the bioenergies. On one side of their spectrum, the bioenergies border on the electromagnetic spectrum while on the other side they merge into the emotional energies.

In addition to food, water, and air, we need a balanced intake of electromagnetic energies. These include sunlight, color, the Earth’s magnetic field, and the electric field between the ionosphere and the ground. Sunlight actually is a combination of electromagnetic energy and bioenergy, and in this way we receive most of our bioenergy from the sun.

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Step 50
ELECTROMAGNETIC ENERGIES

Protect yourself from the harmful effects of electromagnetic radiation and make sunlight your friend.

Strong electric fields of about 50 cycles per second (hertz, or Hz) are harmful to us. These fields exist around power lines, power tools, electric stoves, heaters, boilers, freezers, and television sets when in use and extend several feet or yards around the appliance. Stay away from them if possible. Using an electric iron or an electric keyboard or working with handheld power tools can easily drain your energies. We can reduce harmful effects of electricity on our body by holding our hands under running water from time to time when working with electrical equipment and also by having a shower in the evening. For a detailed discussion of this, review Step 8.

The DC Field of the Earth: We live in a natural DC (direct current) field. The surface of the Earth has a negative electric charge and the ionosphere high above it a positive charge of about 50,000 volts. However, the electric currents involved there are extremely small. Near the surface of the Earth, the voltage differs greatly; it is highest on mountains and in dry conditions where it can reach 1,000 volts per meter, while in low-lying and moist conditions it falls to below 50 volts. This means that the voltage difference between a point close to the ground and one meter above it can be between 50 and 1,000 volts, but the current is so low that we do not feel it. Nevertheless, it has a noticeable effect on our well-being. Populations with exceptionally long life spans always seem to live in the mountains, such as in the Andes, Himalayas, and Caucasus.

In buildings with roofs of metal, aluminium-coated insulation material, or steel reinforced concrete, the electrical field is near zero. It has been shown that this lowers our concentration span and well-being. There may even be counter-fields caused by the static electricity of plastic materials and synthetic carpets. Even worse are houses that have metal walls, whether they are of corrugated iron, coating or insulation material with aluminium, wire mesh, or reinforced concrete. Getting fresh air through open windows will improve the condition to some extent.

In a high DC field, our well-being and mental abilities are increased, while in a low field we easily become fatigued and our concentration suffers. Electrodes that produce a field of 1,000 to 2,000 volts inside offices and houses have been used with good results in Germany. If you live in a conventional modern house, have at least the bedroom or sleeping place free of shielding metals, or sleep on the veranda in summer. This is especially important for someone with a serious chronic disease. Because as a species we lived so long in this natural DC field, the natural ion distribution and electrical fields in our bodies have adjusted to it. We feel better when we are exposed to this field. This is one of the reasons why walking on fresh grass feels refreshing, while habitually wearing shoes with rubber or plastic soles is more tiring.

The magnetic field of the Earth is about 0.5 gauss, though it has been much higher in the past and is presently decreasing. Generally, life forms are bigger, more

vital, and longer living in a stronger magnetic field. Most people will find it best to sleep with the head in a northerly direction, while an easterly direction is sometimes beneficial; facing towards the west, however, is often weakening. In the Southern Hemisphere, you can also try sleeping with the head to the south. Experiment to find your best direction.

Sunlight: On the level of energies, sunlight is our primary source of life. Light to moderate sun exposure is beneficial. Except in winter, do not sunbathe during the hours around midday. Preferably expose your whole body as often as possible for a few minutes in the early morning or late afternoon sun. This may be in the garden, the veranda, or even inside a room with an open window. In addition, it is beneficial to sit lightly clothed in the half-shade, as for instance under a tree, as we can absorb the bioenergies of the sunlight through our clothing.

While brief exposure to the sun is invigorating, long sunbathing, especially at the beach, is exhausting and ages the skin and can cause skin cancer. It can also cause an overactivity of the parathyroid glands. Vitamin supplements can protect us from these dangers: In addition to PABA and other B vitamins, we need plenty of antioxidants, bioflavonoids, and carotenoids for sun protection. Except for zinc cream or a solution of PABA, I am not in favour of using sunscreen lotions; instead, use suitable clothing for protection. Sunscreens contain unbiological chemicals, and it has been reported that most commercial sunscreens kill skin cells and so may inflict long-term skin damage.

Research shows that there is a strong negative correlation between available sunlight and breast cancer death rates, that is, living in a sunny area is associated with lower cancer rates. Even skin cancer is inhibited by regular low-level sun exposure; only sunburn, or high-level sun exposure, is a strong skin cancer promoter. It has been stated that trends in the epidemiological literature suggest that approximately 30,000 U.S. cancer deaths could be averted yearly by the widespread public use of regular mild sun exposure. A study on electricity workers showed that those with the most sun exposure had the lowest rates of skin cancer and melanoma. Other studies show a strong link between long-term exposure to fluorescent lighting and melanoma; melanoma often occurs on areas of the skin that have not been exposed to sunlight.

Sensitive individuals, especially with low blood pressure, lack of energy, and a tendency to have food allergies and chemical sensitivities, should expose themselves to the full sunlight for only very short periods; preferable is semi-shade, as under a tree. Insensitive individuals, on the other hand, with insensitive skin and often high blood pressure, benefit from a longer exposure that tends to sensitize them.

The eyes are important entrance points for sun energy. John N. Ott, in his Health and Light, demonstrated with his research how important it is for us to get the full spectrum of the sunlight into our eyes. This does not happen if we sit behind windows or wear glasses; these filter out essential frequencies of the ultraviolet part of the spectrum. Deficiency of this ultraviolet radiation caused by our living behind glass is a contributing factor in the development of degenerative diseases such as arthritis, cancer and leukaemia, eye diseases, hyperactivity, and sexual problems. These harmful effects are reinforced if the glass is inappropriately tinted, in this way blocking out a part of the visible spectrum as well.

Ott demonstrated that the primary effect of light entering our eyes is on the endocrine glands of the brain. He also showed that coloured lights have a strong influence on the ratio of male to female offspring when breeding animals. Especially unhealthy are most kinds of fluorescent lighting, more so if they have a pink hue. Even more harmful is light from the color screens of television sets and computer monitors; this effect is due to the artificial composition of these colours.

However, if one has sensitive eyes, one should continue to wear sunglasses if the light is very strong and glaring and only gradually reduce their use when the eyes improve. The best sunglasses, if required, are of a special composition of gray so that they reduce the intensity of all colours to the same degree. Most plastics, by the way, do not screen out ultraviolet rays, so in this way one obtains full sunlight by living behind clear plastic windows. However, a disadvantage of this is that one can get sunburned behind these plastic windows.

Lack of sunlight in winter or if one is bedridden makes us susceptible to depression. You can cure this seasonal affective disorder by looking into a bright light in the morning, preferably sunlight or lights with the full daylight spectrum.

Sunlight is also required to convert cholesterol into vitamin D. Multiple sclerosis, for example, is inversely related to the amount of sunshine in the region, so that the closer to the equator, the lower the incidence of it. This is similar to the rate of cancer that also declines the closer we get to the equator. Another important aspect of sunlight is our indirect intake of it in the form of sun-drenched fruits and vegetables. Such foods absorb bioenergy as well as light frequencies from the sun, but these beneficial energies are gradually lost if these foods are stored in the dark. In this case, it is beneficial to expose them again to sunshine for a short period before eating.

Coloured Light: Exposing ourselves to light of a certain colour has a definite effect on our emotions and body. The most balanced colour is green, and looking out over green meadows and at the green of trees has a balancing effect on body and mind. Blue and red, on the other hand, are the main opposites that help to adjust the body if it is out of balance. Red and especially orange are used for stimulation when we are fatigued and need strength. Too much of it, however, will make us nervous and irritable. Blue, of course, is sedating, even more so than green, not only for the mind, but also for the body if there is pain, fever, or inflammation.

There are many different ways in which we can treat ourselves with colours. The most natural way is to look at distinctive colours in our surroundings. In addition to looking at meadows and trees for their balancing green, we can look for long periods at the blue sky to gain peace and quiet. For stimulation, on the other hand, we can focus on a red rose or any other red flower bathed in the sunshine.

Another possibility is to paint or wallpaper a room in appropriate colours and to pay attention to the colours of our carpets and curtains. Then we can select suitable colours for our clothing. Usually we express through the colours of our dress our inner feeling at the time, for instance, dressing in black or gray if we are depressed, thereby reinforcing the negative mood. However, if we want to improve our emotional condition, select the opposite colour to our negative feeling. To ward off depression, for instance, wear pink or another bright and stimulating colour.

We can use differently coloured light bulbs, coloured lampshades, or coloured cellophane. However, most one-sided colour exposure should be only temporary, for as long as it has a beneficial effect on our condition. Too much blue, for instance, can push a susceptible individual from being peaceful to becoming depressed, or blue. Generally, it is best to use a mixture of colours inside the house and for our clothing, with possibly one dominant colour that balances our basic condition. For further information, see Colour Therapy in Part 2.

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Step 51
BIOENERGY

Bioenergy is the true energy of healing, so for optimal health learn as much about it as you can.

Bioenergy is the basis of all biological manifestations. It is also called prana, ki or chi, od, orgone, ether, bioplasma, or simply life force. Our main intake of this life energy is during deep sleep, through the chakra system, breathing, from raw food, as well as sunshine and energy transfer from other people. In the air, it is commonly called prana, while within our body we usually refer to it as bioenergy; for the Chinese, it is the chi that circulates in the acupuncture meridians throughout the body. Bioenergy generally appears as a bluish-gray haze; its movement is slow and wavelike; it can be accumulated and conducted by organic material and water; and it can be separated into two opposites with a bluish and a red-yellow color. The air is low in bioenergy on rainy days and at night. The planet is enveloped in a field of orgone energy and on most days this field can be observed moving from west to east.

Our physical body is permeated with bioenergy. Part of this energy circulates through the acupuncture meridians while the surplus radiates out, forming an etheric field, or the inner aura, and protects us from harmful environmental radiation or microbes. For the body, bioenergy holds the blueprint that guides the growth and maintenance of all body structure; it is the "glue" that holds the cells together, the energy of organization.

Acupuncture points are like transformers or inflow points of bioenergy from the meridians into the tissue structure. If this flow along a meridian and into the muscles is blocked, a limb becomes lifeless and paralysed, even if the blood circulation and nerve impulses are intact. We can direct and modify this stream of bioenergy with our mind to heal ourselves. Generally, we can increase our inner reservoir of bioenergy by living in an area with a high environmental potential of bioenergy. We can find this where there is plenty of sunshine, abundant vegetation, especially trees, and an elevated position - ideally a tree-clad hilltop or mountain plateau in the subtropics.

Bioenergy in Healing: In 1973, researchers at the University of California at Los Angeles succeeded in replicating a Russian experiment in which part of a fresh leaf was cut off and Kirlian (high-frequency) photography revealed the faint outline of the whole leaf, including the missing part. This can be regarded as the first visible scientific proof of the existence of an aura around living objects. Before that, Professor Harold Saxton Burr of Yale University had made extensive measurements of the electric fields around living things and shown that these "L-fields" (Life-Fields) pre-exist as in a fertilized egg and guide the development of the related entity.

I contend that prana, bioenergy, or life energy is a major factor in healing despite the denial of its existence by orthodox medicine. Chances of recovery are greatly increased by being regularly exposed to high concentrations of prana.

For example, Wilhelm Reich in The Cancer Biopathy described his research into the effect of prana on cancer development and treatment. With a powerful

microscope (4,000-times magnification), he could observe how cancer cells originated from body cells deficient in prana and how cancer cells were destroyed by red blood cells highly charged with prana. Healthy red blood cells have a strong, blue, and pulsating field, he said. His research led him to believe that cancer is basically due to chronic sexual starvation or, more precisely, to blockage of sexual energies due to emotionally induced muscle tension or armouring. This is just another way of saying that cancer is primarily caused by a lack of bioenergy or a blockage in the circulation of bioenergy in the body.

Prana is high in green surroundings and especially tree-clad hilltops and mountains. It is high in the air on sunny days, but low on dull days or at night. It is exceptionally concentrated in rainwater collected after a heavy shower on a sunny day. Use such highly charged rainwater for washing and drinking. In polluted areas, purify it with a jug-type carbon filter before ingestion. In addition, fresh rainwater, and especially rain that fell during thunderstorms, has a beneficial negative electrical charge, but this is discharged and lost if the rainwater comes in contact with a metal.

Prana is much enriched in cascading sunlit streams and even in artificial sunlit cascades. Water can also be improved by exposing it to sunlight before use. Fresh fruit and vegetables stored in the dark and especially in a refrigerator have a healthier benefit for us if they are exposed to sunlight before eating.

Revitalizing may be the most important task with chronic diseases (and especially with cancer). As Reich suggested, healthy blood charged with bioenergy readily destroys cancer cells and disease germs. To vitalize, use fresh raw juices, walk barefoot on dewy grass, do deep breathing exercises, meditation, energy healing, and energy cultivation, and use devices such as magnets, cones, and pyramids.

Freshly cut grass emits a strong radiation of bioenergy. In a similar way, a “hay cure” was formerly used with good results as a folk remedy for many diseases. The patient was immersed for hours in freshly cut hay or sometimes in fresh leaves. Kirlian photography shows that cut leaves and grasses lose most of their prana within a few hours. This outpouring energy can be used to radiate a tumor or a weak organ with a strong charge of prana by keeping a pack of freshly cut grass over the area in contact with the skin. The pack should be renewed every few hours.

Morning dew on fresh grass is another source of highly concentrated prana. Walk on it barefoot for ten to 20 minutes; with your hands, rub the dew onto your bare skin all over the body; if it’s warm enough, roll with bare skin in the dewy grass. Psychics can see our aura expanding when we walk or stand on fresh grass.

It is equally important to conserve our bioenergy by living in or visiting surroundings high in bioenergy. Generally, these are sunny locations with luxurious plant growth, but also mountains and the seashore. Some individuals claim to have lived on prana in the mountains but were not able to do this in the lowlands or a city. Males can lose much bioenergy through ejaculation and should minimize such loss when low in energy, as with cancer, AIDS, and other debilitating diseases. Instead, they can try Karezza-type (caressing with slow movements) lovemaking or other forms of spiritual sex as explained later in Part 7.

Basically, we get bioenergy from:

- Recharging our etheric body during deep sleep
- Ingesting fresh raw food, juices, and charged water
- Breathing prana-rich air
- Meditation and guided imagery
- Stepped-down energy entering directly through the chakra system

A high body charge of prana, visible to psychics as a strong and clear aura, is a main requirement for remaining healthy and overcoming chronic diseases. Therefore, protect and improve your health by exposing yourself to high concentrations of prana in any or several of these indicated ways. If you have the opportunity, visit known natural power spots or high-energy areas.

There is also negative and potentially dangerous bioenergy. This is associated with diseased and polluted conditions and also with radioactivity. It appears that healthy bioenergy moves or spins at certain frequencies. When it stagnates, as with energy blocks in our body, it becomes more dense with a slower vibration. This negative energy not only acts to maintain a diseased state, it can also be absorbed by an unsuspecting healer and can then cause health problems in her body. Flowing water is a great cleanser for this and can be used in different ways to remove negative energy.

Vivaxis Energies: Vivaxis is a term coined by Canadian researcher Frances Nixon in the 1960s for etheric energy beams that link us to specific locations. The most important one of these is our birth vivaxis, linking us to key energy points near the place of our birth in a two-way circuit. Perhaps migrating birds and insects find their distant destinations by being able to sense and follow these vivaxis beams. This would also explain how dogs sometimes cover hundreds of miles of unknown territory to turn up unexpectedly at their owner's house or how turtles can return to their beach of birth after several decades to lay their eggs. In addition, there are Earth beams circling our planet, said Nixon. These contain the frequencies of all the elements necessary for life and are related to our individual energy fields by our vivaxis energies.

Health problems may arise if our energy absorption from these essential energy beams is disturbed, Nixon proposed. This may happen as a general planetary condition after nuclear testing or, on a more individual scale, if we live in dwellings encased by metal (aluminium coating or insulation, steel-reinforced concrete, wire mesh). Further, our internal energy receptors may become disturbed after exposure to X-rays or other strong electromagnetic radiation, by wrongly applied strong magnets, prolonged mental stress, marijuana, vibrating tools, infrasonic waves, environmental imbalances, and pesticides as well as toxic chemicals in various drugs, foods, and cosmetics.

Foreign vivaxes to which we may become linked can be created by hypnotism, strong magnets, electrical acupuncture treatment and pulse-wave machines, accidentally received electric shocks, and even contact healing, reflexology, and acupressure, especially if a therapist exerts strong pressure on bilateral points. Some of these foreign vivaxes can disturb our natural-force flows before they gradually

disappear. On a certain energy level, we seem to remain linked to everyone we ever touched.

You can reduce the possibility of health problems arising from disturbed or blocked flows of these subtle energies by living as naturally as possible. Especially minimize pollution from non-biological chemicals and strong electromagnetic fields; frequently cleanse and recharge yourself in natural surroundings, by walking barefoot on grass or swimming in the ocean or an unpolluted lake or river. Preferably sleep in a part of the house with a minimum of metal shielding (as from insulation material) in the walls and roof. For more information, see Judy Jacka's "The Vivaxis Connection" (Hampton Roads, 2000).

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Step 52
CULTIVATING THE ENERGIES

Learn to sense subtle bioenergies and use them to energize your body.

For increasing or maintaining our health and vitality, it is advisable to work directly with our life force, cultivating it, as the Chinese masters say. There are two main aspects to this energy cultivation. First we learn to accumulate bioenergy or prana and then use it by directing its flow.

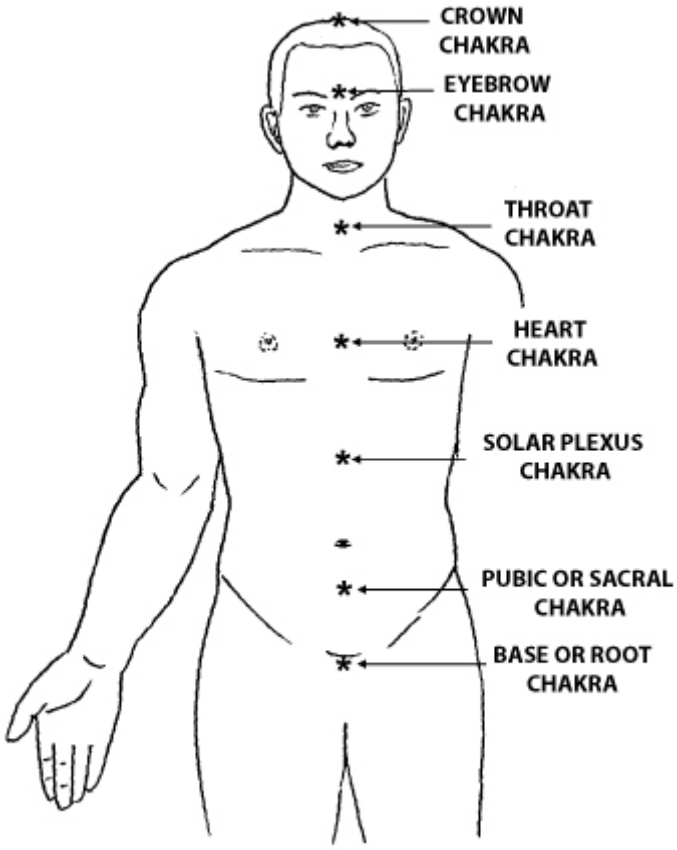

Figure 7-1: Distribution of energy centres or chakras

Intake through the Chakra System: Our main bioenergy intake and distribution system is the chakra network, subtle energy centres along the spine from groin to head. The seven main chakras are comparable to central power stations, while the acupuncture meridians can be seen as power transmission lines. Chakras are vortex-like energy centres. Commonly, seven major chakras are mentioned, six of which are rooted along the spine and one at the top of the head, as shown in figure 7-1. The chakra vortexes suck in energy from the universal energy field that is all around us.

Each chakra modifies the vibration rate of the energy and that gives it a certain color. Further, each chakra energizes a specific region of the body and is related to a major nerve centre and endocrine gland. The energy then flows along a multitude of lines (called nadis) to form the etheric body. Major energy flows are along the acupuncture meridians that, in turn, nourish the internal organs and muscles.

A health problem in a certain area of the body is usually associated with a disturbed function of the chakra governing this region. Normalizing and harmonizing our chakra functions is important for the healing of specific aspects as well as for increasing our available energy in general and for becoming whole and balanced.

The characteristics of the seven main chakras can be seen in table 7-1. In addition, there are many more secondary chakras. Those in the palms of the hands

are commonly used for energy transfer. Each of the higher or finer energy bodies, such as the emotional, astral, and mental body, has its own chakra system; different energy bodies have different chakra colours. The corresponding chakras in the different bodies are interconnected. The more we spiritually develop, the greater becomes the exchange of energy between the different bodies, with the energy generally flowing from the finer to the denser bodies. Excellent books on energy healing, energy bodies, and the chakra systems are “Hands of Light” and “Light Emerging”, by Barbara Ann Brennan.

You can experiment with two complementary methods of increasing your energy reservoir. In one, imagine energy entering through the crown chakra; in the other, imagine you retain the prana inhaled with the air. With some practice, you can combine both exercises and do them at the same time. The main rule in all of this is that energy flow follows our awareness and intentions.

Table 7-1: The Main Energy Centres or Chakras

Location	*Sanskrit name*	*Gland*	*Color*	*Vertebra*	*Function*
Root/Base	Muladhara	Adrenals	Red	Sacral 4	Will to live, vitality, grounding
Pubic	Svadisthana	Gonads	Orange	Lumbar 1	Sexual energy, physical creativity
Solar plexus	Manipura	Pancreas	Gold-yellow	Dorsal 8	Emotional energy, feeling safe, protected, connected
Heart	Anahata	Thymus	Green	Dorsal 1	Spiritual feelings, love, compassion
Throat	Vishudda	Thyroid	Blue	Cervical 3	Communication, creating with words and sounds
Brow	Ajna	Pituitary	Indigo	none	Higher mentality and creativity, intuition, visualization
Crown	Sahasrara	Pineal	Violet/white	none	Spirituality, connection to Higher Self and divinity

Chakra Exercises: Sit or lie in a relaxed position and focus on one chakra at each session. Start with the crown chakra. Keep your awareness centred at the top of your head until you feel a light pressure, warmth, tingling, or other sensation developing in that area. Whatever you can feel, intensify it. However, it is preferable to replace any feeling of pressure with a feeling of warmth as soon as that can be done, in order to avoid an uncomfortable pressure from building up.

You can also imagine a stream of white light entering the top of the head or visualize an energy vortex in this position. Let it spin clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere. Alternatively, imagine feeling it as a pulsating energy field. You can combine all or several of these imaginations and use whatever is most suitable for developing a feeling awareness of this chakra.

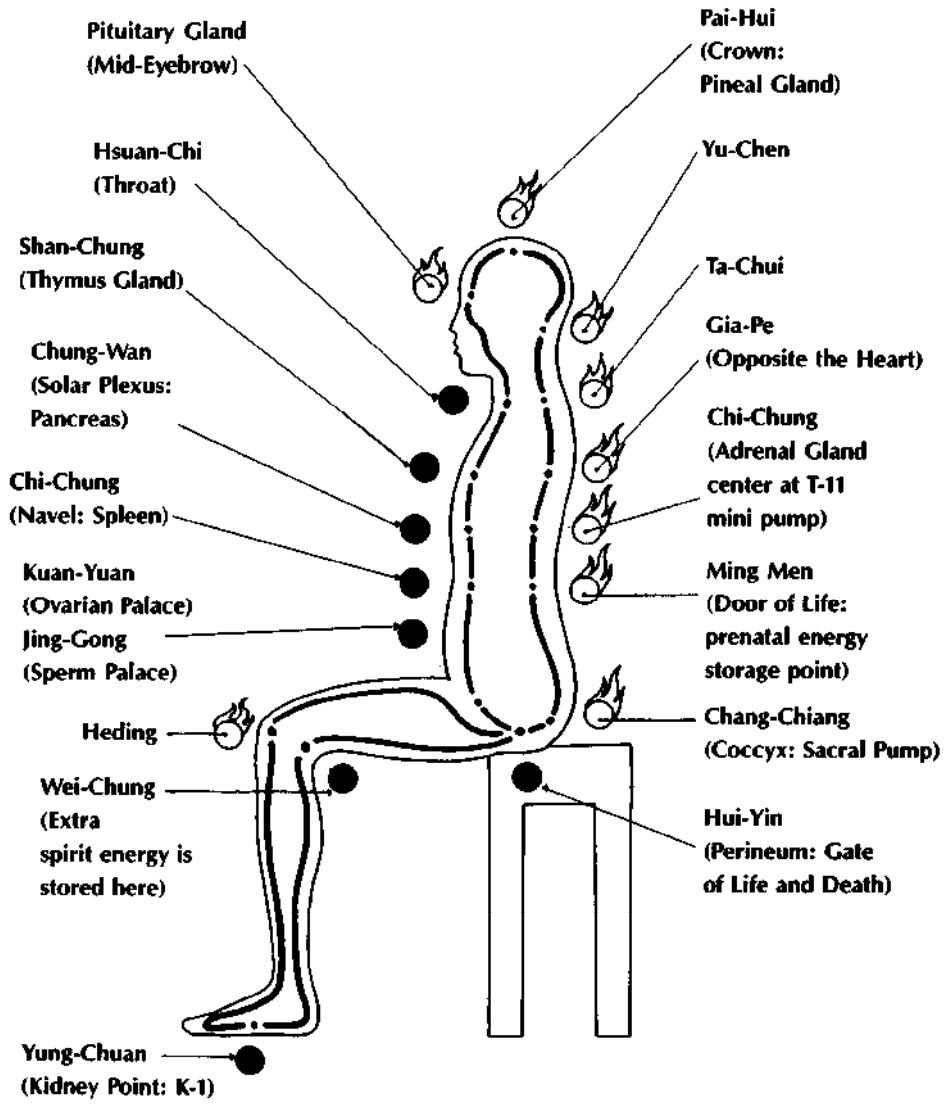

Figure 7-2: The Stations of the Microcosmic Orbit, from “Bone Marrow Nei Kung”, by Mantak Chia.

Repeat, focusing on the same chakra in subsequent sessions until you can easily feel its presence. Then move to the forehead chakra. In addition to trying to feel a light pressure or warmth, it is helpful to close your eyes and focus them as if looking at the inside of the centre between your brows. You can also imagine the white light flowing into the top of your head becoming violet in the crown centre, then continuing to flow into the forehead centre and illuminating it with an indigo colour.

With the throat chakra, you can use similar imagery but make it a blue colour. Feel the warmth of your outgoing breath first in your nose and then transfer this feeling to the throat. Intensify the warmth and combine it with the blue in a pulsating rhythm.

For the heart chakra, imagine that your breath moves in and out of the chest through the middle of your chest bone. Also try this imaginary breathing through skin and bone with any of the other chakras, but it is easiest to learn it at the heart centre. In this way, learn to sense the lower chakras - the solar plexus, pubic, and base chakras. Imagine the base chakra as an energy vortex that points to the base of the

spine. With this, the crown vortex and the base vortex are like an hourglass separated by the length of the spine, while all the other chakra vortexes are perpendicular to the spine.

Storing Prana: To accumulate prana from the air and store it, imagine that the inhaled breath consists of two parts: physical air molecules and prana. During inhalation, the lungs automatically separate the prana from the air molecules. You exhale only the “empty” air while the prana flows to where you lead it with your conscious attention. The body uses the abdomen with its high water content as a storage reservoir of excess bioenergy.

To energize the abdomen, feel the breath energy moving directly into the abdomen during inhalation. When exhaling, imagine pressing the energy down so that it becomes compressed at the bottom of the abdomen. With each successive breath, more compressed energy accumulates until the target area feels sufficiently energized. You may feel this as warmth, tingling, pressure, or any other sensation.

If you can visualize colours, see energy being stored as a golden-yellow fluid that gradually fills the whole abdomen. Initially, you may also see it filling the whole abdomen like a gas with a very faint color that becomes more intense with each breath. However, it is not enough just to visualize it; it is essential also to feel the energy.

Another important consideration is the actual prana content of the air you breathe. You gain the most energy when the air is high in prana, such as outdoors in natural surroundings on a sunny day. However, most of the time, you will be doing this exercise in far less than ideal conditions. Neverthe-less, persevere with it while trying to maximize the prana in your inhaled air by opening windows, exercising on a sunny day, and minimizing negative elements, such as electromagnetic forces and synthetics in your room.

In contrast to accumulating prana through breathing, there is no such restriction when taking in energy through the top of the head, as this comes from another dimensional level. But as both energies have different frequencies and complement each other, it is beneficial to work with both methods.

Circulating the Energy: A Chinese exercise to increase our energy and well-being involves circulating life-force energy in what is called the “microcosmic orbit.” Start by accumulating energy either through the crown centre or by condensing breath energy and lead it into the abdomen.

When you have a good feeling sensation of the energy in the abdomen, imagine this sensation flowing into the pubic centre. Intensify the sensation until you can feel the pubic chakra, then let the energy flow into the perineum and the base of the spine. Feel the energy there in any way you can; you may envision it having a red color in this area.

Now imagine a valve opening at the tailbone and, with each inhalation, lift part of the energy to a point in the spine behind the pubic centre. When you can feel it well, be it as pressure, warmth, tingling, or any other sensations, lift the energy with your breath to a point behind the solar plexus centre. If you find that you can lift the energy better during exhalations or by paying no attention to the breath at all, that is fine as well; experiment and use the method that works best for you.

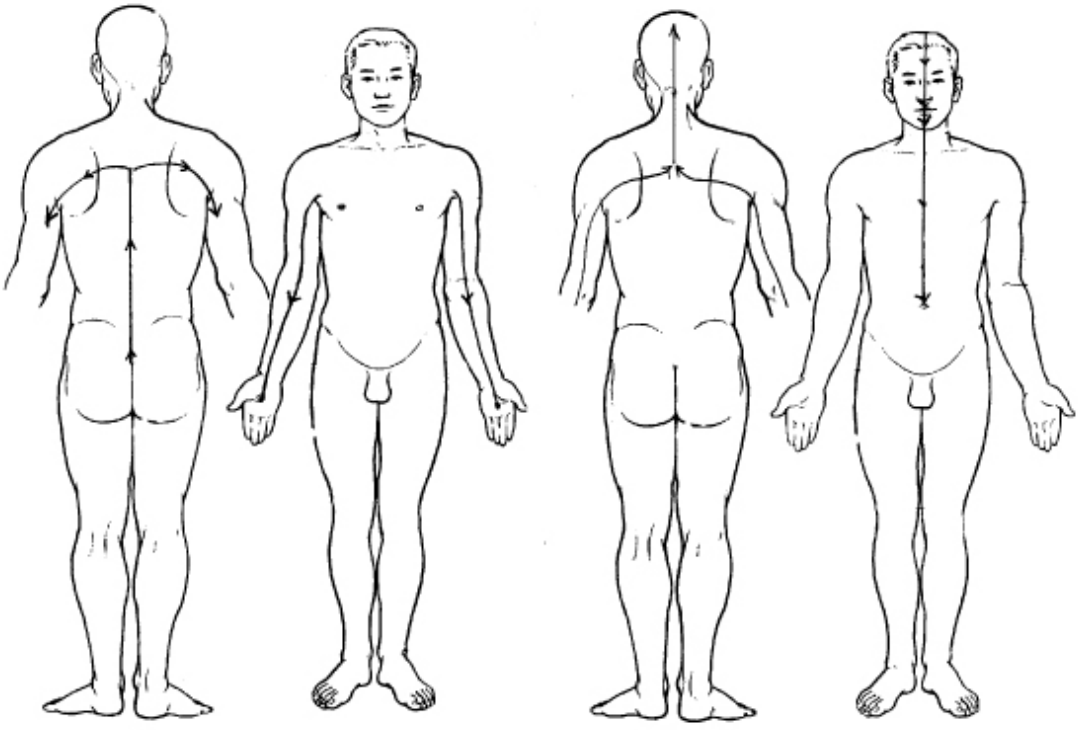

Figure 7-3: The large heavenly cycle – the arm routes, from *Awakening Healing Energy Through the Tao* by Mantak Chia.

However, if you experience unusual heat or any discomfort while trying to lift the energy up the spine, then stop immediately or imagine that a cool energy flows downwards. The idea is to increase the flow of energies gradually, but not to open the floodgate of the Kundalini energy at the base of the spine. That might be likened to feeding high-voltage power into a system wired for low voltage.

As you continue to lift the energy to the back of the heart centre and then to the back of the neck, imagine that your spine is a straight hollow tube through which the energy flows following your intentions. Next concentrate the energy at the back of the head and finally at the top of the head. Reinforce it with the energy entering the top of the head and then lead it down into the forehead centre. It helps during the whole exercise, but especially at this time, to touch the roof of the mouth with the tip of the tongue. This makes it easier for the energy to flow farther down into the blue throat centre and then into the heart centre.

To complete the exercise, lead the energy farther down into the natural storage area for excess energy behind the navel. Imagine that it flows towards the centre of a spiral where it is condensed and stored as a ball of energy in the abdomen, ready for future use. When needed, this energy can be reactivated with your intention and used for healing yourself or others by directing it with your mind where you want it to go. It can also be used for tasks with high-energy requirements and is the same energy that masters of the martial arts aim to cultivate and use.

In addition to circulating the energy in this “microcosmic orbit,” you can sometimes include the extremities in a “macrocosmic orbit” or “the large heavenly cycle.” After circulating several times in the microcosmic orbit, stop at the perineum and divert the energy down the back of the legs. Pause at the back of the knees and try to feel the two smaller energy vortexes there. Then continue guiding the energy down the back of the calves and around the outer ankles. Feel another set of minor chakras in the centre of the soles of your feet, and finally lead the energy up again along the insides of the legs. Circle around the knees and back to the perineum to continue the microcosmic orbit.

At the top of the back, between the shoulder blades, divide the energy again and lead it under the armpits and down the inside of the arms. Focus for a moment on the inside of the elbows, then go to the middle of the palms and feel another pair of minor chakras there. Let some of the energy flow out the tips of the fingers and then move up the outside of the arms to reconnect with the microcosmic orbit where you left it.

When you can readily feel the circulating energy and the various centres on its path, you can sometimes use a short form to energize and centre yourself quickly. Imagine the energy entering the top of the head and rapidly jumping down from one centre to the next to the base of the spine. Then with one inhalation lift the energy to the top of the head and with the next exhalation drop it again down the front to the base.

Continue to circulate it in this way until you feel energized. You can, of course, switch the breathing cycle and lift the energy up the spine during exhalation if that suits you better. In a similar way, you can sometimes lead the energy very rapidly around the macrocosmic orbit with one long exhalation down the legs or arms and with the following slow inhalation back up again. In all this energy work. imagine and feel the energy moving below the surface of the skin. (For detailed instructions on exercises to accumulate prana and use it for healing, see: www.universal-tao.com and also books by Mantak Chia, such as “Awaken Healing Light of the Tao”.)

Energizing the Body: In another method, imagine your spine to be a hollow tube. While inhaling, imagine the prana flowing up the tube to the top, and during the subsequent exhalation, let the energy again drop down the spinal tube to the base. Until you are well advanced in energy work, do not do more than ten such breathing cycles at any one time.

With all energy exercises involving the spine, try to keep it straight, either sitting up straight (but relaxed) or lying stretched out on the back. However, you can practice these and other energy exercises anywhere, anytime, such as when driving, waiting somewhere, walking, or doing housework.

Another recommended way of cultivating the inner energies is through slow movements while focusing on the sensations that the awakened energy flows may produce. This is done with exercises such as Tai Chi. However, you may not need to learn the structured Tai Chi sequence and can experiment with your own slow, improvised movements. Widespread, especially in China, is the practice of qigong. You draw energy into the body with a combination of breathing, movements, and guided imagery. This is especially effective if done in an energized outside area,

such as standing barefoot on grass, in a park, at the beach, or in the mountains. There are many books and websites giving instructions in qigong

A relatively easy way of learning to feel bioenergy is to shake your body, especially the arms and hands, rapidly for about a minute. At the same time, breathe deep and fast and then suddenly stop. Remain completely still with the arms slightly raised in front of your abdomen or chest as if holding a large beach ball. Concentrate on the sensation in your hands and arms. Then start slowly moving your arms and your body. Try to intensify whatever energy sensation you feel. When you can feel the energy strongly, you can mentally lead it to an area of the body where you have a particular health problem. Alternatively, you can radiate the energy out of the palms of your hands to where you want to energize yourself. It is good to do this as a regular daily exercise.

Finally, you can directly energize a weak or diseased organ or part of the body by feeling or breathing into it. If you keep your attention focused on a particular area of your body, then you can feel it becoming warm and possibly tingling after some time. You can then use imagery to intensify the warmth or tingling. Also, imagine that your breath or the prana from your breath flows into this area and accelerates its healing. Even without a specific problem, you can focus on one organ after another and in this way energize the whole body. Once you can easily feel the warmth in a chosen target area, you can develop a sequence by energizing first the chakras, starting with the crown chakra, then circulate the energy a few times, and finally energize individual organs or areas of the body. Also, during your daily activities try to remain aware of the energies in various parts of your body.

For further information on chakras and energy work, see the Love Cure (Step 61). The best and safest way to develop the chakra system is by living appropriately in all life situations with a strong flow of a variety of positive feelings. Most healthy individuals have their three lower chakras reasonably well developed. Therefore we need to concentrate mainly on developing the four higher chakras.

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Step 53
ENERGY ACCUMULATORS

Use orgone accumulators, pyramids, cones, or water to concentrate bioenergy.

Various shapes such as pyramids and cones have been shown to concentrate bioenergy or prana. Some healers have patients sit inside small-scale pyramids with good results. I have experimented clinically with Reichian orgone accumulators, small pyramids, and cones.

Bioenergy can be generated not only by certain shapes, such as pyramids and cones, and materials such as crystals and precious metals, but also by metals and non-metals arranged in alternating layers. This is the principle of the orgone accumulator invented by Wilhelm Reich, M.D., in the 1940's. He built large boxes for patients to sit in or smaller boxes, called shooters, from which the energy was directed through a flexible hollow pipe to the body of the patient.

In one instance, I connected a wire screen placed over the tumor area of a patient to the top of a two-foot-high pyramid. After only one treatment, the patient developed a high fever during the night, which is excellent for destroying tumours. In another experiment, the energy radiated from a cone over a short distance produced a strong reddening of the skin as from sunburn, showing that these energies are real.

Even water can be effective. On tumours and areas of infection and inflammation, you can use an energy suction tube to draw off excess energy. Place one end of a metal tube, about two to five feet long, in a bucket of cold water or another large volume of water. Lightly press the upper end against the area of overactivity and keep it in this position for ten to 30 minutes, without holding the tube with the hands. Do this daily until the condition is normalized.

My understanding of the principle of energy accumulation is as follows. Our planet is enveloped in a deep layer of prana (bioenergy) generated by the sun. This prana envelope has been observed to move from west to east most of the time. When this prana flow encounters a suitable material shape, it forms a vortex around and within this obstruction, similar to flowing water or air forming vortexes under similar conditions. This increases the prana concentration within the structure. In Reichian orgone accumulators, the prana flow is being condensed by the specific arrangement of the materials.

The Orgone Accumulator: Orgone is the term for bioenergy coined by Dr. Reich, and the accumulator he designed consists of alternating layers of metal and non-metal (e.g. natural fibre). Commonly, three alternating layers each of metal and non-metal are used; originally, sheet iron and plywood were used, but now more commonly, steel wool and sheep wool or other fibre are used. The outermost layer must be a non-metal and the innermost one a metal. The basic principle is that the organic or non-metal layer tends to attract and hold the bioenergy, while the metal layer radiates or reflects it. This causes the energy to drift from the outside of the box towards the centre, which is where you sit.

As an objective measurement of the higher energy charge inside the accumulator, there is a measurably higher temperature inside the box as compared to the outside. But it does not even have to be a box. You can wrap alternating layers of a metal and a non-metal in what is called a “power pack.” The easiest and least expensive way is to wrap alternating layers of aluminium foil with paper or plastic foil. However, various healers came to the conclusion over time that the energy generated with aluminium is not beneficial for our health and that it is best to use iron as a metal, either as galvanized iron or steel wool.

CAUTION: Orgone accumulators can be “poisoned” by radioactivity. Do not use if radioactive clouds from atomic tests are suspected. Do not take a wristwatch inside. Ground the accumulator with a steel pipe connected to a stream, underground water, or a bucket of water that can be renewed from time to time. Disconnect the grounding when using the accumulator. According to some orgone research sources, presently, the orgone energy in cities is so polluted that it is not safe or advisable to use orgone accumulators in these locations. Preferably use it outside city areas in a less polluted and natural environment.

If a person is to sit inside, the inside wall should be reasonably close to the body, but not touching it. A window and air vent can be put in the door. Treatment can last 30 to 60 minutes daily. Dr. Reich reported good success using this box with cancer patients.

As with pyramids, the energy can be conducted out of the accumulator and used externally on a person or for experimenting. The charge within the accumulator varies according to the bioenergy content of the surroundings; it is high on sunny days and low at night and on rainy or cloudy days.

You can also place large crystals or precious stones inside the accumulator and try to sense if that improves the quality of the energy coming out of a shooter. For more information and interesting articles on orgone energy, see the writings of Wilhelm Reich or the Public Orgonomic Research Exchange (PORE) at http://orgone.org.

Bion Packs: Dr. Reich experimented with other ways of generating orgone energy that are not susceptible to poisoning. He found that strong orgone energy could be liberated from beach sand. After heating sand to incandescence in a Bunsen burner, he plunged it into water. Within minutes, he could observe under the microscope the blue orgone “bions” (individualized units of bioenergy). When bion-water was kept in a culture medium for several weeks, the water and the darkroom became highly charged and filled with the characteristic bluish glow of orgone energy.

While working in this room in winter and without being exposed to the sun, Dr. Reich developed a deep tan all over his body and felt “extremely vigorous,” as he commented. He also used bion solutions experimentally to treat various disease symptoms; when bion solutions were injected into experimental animals, they killed or immobilized pathogenic bacteria and cancer cells, he reported.

Dr. Reich also made bion packs by boiling beach sand or clay for 15 minutes several times and then freezing it. Here’s how to do that: Fill some heavy fabric, such as a sock, with sand like a sausage, tie the open end, and boil it for 15 minutes (no microwave). Then wrap the “sausage” in additional waxed paper or plastic and freeze it solid. When using a pack for the first time, alternate the boiling and freezing several

times. Before placing it over a diseased part of the body, let it sufficiently cool and drain off excess water.

Use the pack when it is as warm as you can tolerate; use additional cloth insulation, which can gradually be removed as the pack cools. It continues radiating to some degree after cooling off. Therefore, there is no time limit for how long you can keep it on, although I assume that it is more beneficial when it is warm or hot. The pack can be reactivated on subsequent days simply by boiling it again. Let the pack dry out when not in use and preferably expose it to the sun for several hours between each application.

Orgonite: This is a new and promising concept for generating bioenergy. It is a mixture of equal parts of metal particles and an organic component, such as polyester resin or beeswax. It is a development of Dr. Reich's methods, which accumulates and regenerates orgone energy. Tests have shown that orgonite does not become poisoned, but has the ability to convert the "deadly orgone" or "Dor" as Reich called it, which is produced by radioactivity and nuclear plants, into healthy bluish orgone energy.

While aluminium embedded in polyester or epoxy resin is more convenient to use for outdoor applications, for inside the house and bodywork I recommend other metals, such as copper and brass, with the metal particles preferably embedded in beeswax. It is also possible to make ceramic orgonite by mixing clay, especially polymer clay, with metal particles before firing. Crystals, precious stones, magnets, and various spirals are often added to enhance the power or healing vibrations of the orgonite. Copper pipes, crystals, magnets, spirals, and specific shapes, such as cones and pyramids, are used to point the outflow of the orgone energy in a specific direction.

You can easily build an orgone generator yourself by following the instructions on www.cloud-busters.com. You can use different versions of it to improve the life-force energy inside your house, to charge your water with life force, or to treat the body directly.

There are a variety of commercial Reichian-style energy devices available. Research the Internet using key words such as chi generators, purple plates, tachyon or tachion products, energy pyramids, and coils.

Pyramid Energy: The pyramid shape concentrates bioenergy which can be used for healing or recharging by sitting or lying inside a pyramid. The strongest force is one-third up from the base. There appears to be an energy vortex spiralling upwards to the top (apex) and another from the apex downwards, but spiralling in the opposite direction. Both energy streams seem to have stimulating properties, but on different levels. A sedating energy field is created in an imaginary, inverted pyramid below the base of the physical pyramid.

In the pyramid shape, the energy moves as a vortex, entering at the base and flowing out at the apex. Therefore, apex energy is used to charge and stimulate while an area below a pyramid (shaped as a mirror pyramid) sedates. Inside, the effect appears to be slightly sedating at the base and stimulating higher up.

Therapeutic pyramids are commonly small-scale replicas of the Great Pyramid of Giza in Egypt. One of the four sides of the therapeutic pyramid should face

magnetic north. The measurements are 1 unit (height), 1.5708 units (base), and 1.4945 units (sides), measured along the midline, not along the edges. The sides form an angle of 51º 51' to the base. However, research indicates that many different pyramid-like and cone-like shapes such as a three-sided pyramid have the potential to accumulate energies.

Avoid metal in the pyramid's construction, especially sheet metal or wire mesh (except for copper or precious metal sheeting, especially at the apex). The walls do not appear to be essential, which means you need only construct a wooden or plastic frame. However, a pyramid-shaped capstone at the apex and a bottom plate will considerably increase the energy generation. The capstone can be in the form of copper sheeting of the top ten percent of the pyramid or a small copper pyramid as the apex. Keep unnecessary metal (e.g., watches) out of the pyramid when using it and place the pyramid away from strong electrical fields. One side of the pyramid should point towards magnetic north.

For easy shifting and storage, you can build two sides of an open frame and hook them together at the base with two base-length pieces of timber, or you can build one or two small cardboard pyramids. You can then place one -pyramid under your bed or (wooden) chair, the apex pointing to the base of the spine or any part of the body that you want to strengthen. Then suspend the other pyramid from the ceiling with the base over a diseased area or over the head.

The most effective way to use a pyramid shape therapeutically may be to have a pyramid outside in a dry, sunny location and to lead the energy inside the house through an insulated electric wire coming through the apex. At the end of this, attach a wire screen covered with a pillowcase and sit on it or keep your feet on it or place it where the body needs healing. The energy generated by the pyramid varies according to the strength of the prana field in the local environment. It is generally high in sunshine, elevated positions, and amidst green surroundings, and low at night, when it rains, and inside modern well-sealed houses.

Generally, therapeutic work with pyramid energies is still in the experimental stage and you should approach these energies carefully and with self-observation. Start experimenting with small pyramids before building a big one. For treatment inside the pyramid, the direction in which the head points when lying down seems to be important, and the best position may differ for each person, time, and condition. Become sensitive, and experiment.

Energy Cones: Cones seem to have properties similar to those of pyramids. You can experiment with a metal cone or a cardboard cone covered on both sides with aluminium foil. The cone can be one to two feet high, and the wide end is best sealed. The most important requirement is a right angle formed by the sides at the apex. If the angle is wider, the energy of the cone will be focused, as with a lens, while a more acute angle seems to disperse it. A beam of energy with apparently stimulating properties comes out of the tip of the cone and can be projected over a long distance. The energy can be led off the apex by a wire (as described above for the pyramid). A stronger force is generated if the cone is more than three feet above the ground.

Covering the head with an open cone or a pyramid-shaped hat can be done to use the sedating force below these forms during meditation or to increase psychic

awareness. Perhaps this is the reason why sorcerers and magicians are often depicted with cone-shaped hats. However, when trying to use cones for health improvement, it is preferable to use galvanized iron rather than aluminium, due to a possibly detrimental health effect of aluminium-conducted energies, as noted above. You can, for instance, just spray a cardboard cone with copper paint.

Crystals, Gems, and Metals: Crystals and precious stones can be worn for their beneficial radiation. Crystals should be naturally grown, not manufactured, and their best effects are achieved if worn directly on the skin. To regenerate the healing power of a gem, keep it in a silk bag when it is not worn. Use muscle testing, a pendulum, or other psychic means to assess which crystal, stone, or metal suits you, where to wear it, and for how long. Alternatively, make your selection according to the rules of color therapy.

Some helpful recommendations by Edgar Cayce are as follows:

- For attunement to healing: amethyst, bloodstone, chrysolite, or pearl
- Attunement to infinity: diamond, lapis lazuli, or ruby
- Greater stamina: agate and amethyst
- Meditation and psychic abilities: lapis linguis
- Strengthening mucous membranes: carbon steel worn close to groin
- Strengthening the body: lapis lazuli, bloodstone, moonstone, pearl, and topaz

Gems have also been used for healing in the form of powders and irradiated solutions. Gem therapy, as this healing method is known, is still very much at an experimental stage. For experimentation with solutions, you can use the following guidelines.

Select a suitable gem or precious metal by muscle testing while holding the investigated item or use psychic testing. Write the name of the gem to be tested on a slip of paper and hold it near your navel while simultaneously concentrating mentally on this name; then do a muscle test. Alternatively, if you can work reliably with a pendulum, use that.

Try to obtain the gem or metal that is most strengthening. Immerse it in a shallow bowl of unpolluted water, cover with light, fine gauze as an insect and dust screen, and expose this to sun and moonlight for several days; then pour the solution into a bottle.

Take a sip once a day for up to six months. Use close self-observation and/or muscle testing and stop if any unwanted symptoms arise. If in doubt, it may be safer to take a 3x or 6x homeopathic dilution of the irradiated water, especially in the case of precious metals. If you lack energy, experiment with a ruby. Edgar Cayce recommended alternating the radiation of gold and silver because gold improves the circulation and silver the nervous system. According to Cayce, they may together almost double the present life span. Use pure gold and silver (preferably at least 99 percent pure).

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Step 54
ENERGY HEALING

Give energy or remove excess energy to facilitate healing yourself and others.

The term “energy healing” refers to the transfer of energy from a healer to a patient and to the removal of negative unhealthy energies from the patient. I imagine negative energy to be dense and stagnating, somewhat like cold, damp air. Its effect on an unprotected healer can be noticeable; she may develop the pains or other disease symptoms that have just been removed from the patient. Energy healing is also called pranic healing, magnetic healing, or laying on of hands; yet another form, using special symbols, is called Reiki. While almost anyone can practice energy healing from a distance, its use when actually touching the patient should be restricted to those practitioners who already feel in good health and have an abundant supply of energy. Here’s a technique:

Slowly move your more sensitive hand, usually the left hand in right-handed individuals, a few inches from and over the patient’s body to try sensing unusual energy spots. This can be done on a fully-clothed person. Over a diseased area, your hand might suddenly feel warm or tingling. After completing the check, you can return to the area over which you felt the strongest sensation. Now you can either give energy to strengthen an organ or the whole person, or you can draw out energy from the body as in the case of pain and inflammation (described below).

With all energy work where you touch a patient or remove energy, try to protect yourself with your intention or expectation of being immune. In addition, use guided imagery, such as visualizing a protective white light or shield around you, or with your imagination allow the patient’s energy to flow through your body and out again through your feet or through one of your hands.

Giving Energy: Before and after any contact healing, such as just described, practice energy accumulation (with breathing exercises, meditation, or guided imagery) and preferably use a prayer or affirmation. Then direct the energy into your hands and feel them becoming warm and tingling. Place your hands on or over the patient where the body requires healing, especially strengthening, and feel the energy streaming out; or hold in your mind the intention of being a channel for giving healing energy, or focus your attention on your crown chakra on the top of your head.

Continue for five to ten minutes and repeat as required. After each session, rinse your hands in cold water and do some deep breathing. If you feel drained the following day, do more energy-accumulation exercises and less energy-giving in future sessions, and especially avoid or minimize touching patients.

For general strengthening, it is often beneficial to place the right hand on the patient’s navel and the left one on their forehead. For most people, the right hand has more energy-giving qualities and the left one has predominantly energy-withdrawing qualities. However some people, especially left-handed individuals and sometimes women, have the opposite polarity. You can practice energy-giving in a group situation such that each one in turn is the “patient.”

Another method is to place the positive or energy-giving hand over the weak body area and hold the left hand over the person's head with your palm facing upwards, the fingers lightly curved and the heel of the hand preferably pointing towards the north.

You can be healer and patient at the same time by radiating energy from your hands into your own body. You can do this wherever you have a weakness or want to improve conditions; this is explained below under Beaming. Move your energized hands slowly from the top of your head over your face and down the sides and front of your body; smile inwardly while doing this.

Removing Excess Energy: Excess energy can be associated with an overactive organ or a painful area of the body, but also with unreleased and densified emotions in the form of stagnating, depressed energy. This depressed energy is often stored around the shoulders, neck, and head. Commonly, drawing out excess energy is more helpful than giving energy. The reason for this is that energy needs to flow to be useful and drawing it out improves the energy circulation in a way that's similar to walking barefoot on fresh moist grass.

Energy can be directly removed from painful or overactive areas with cupped hands and then flicked into a corner. Afterwards, seal the person's aura with smoothing, sweeping strokes downward along the body area from which the energy has been removed. At the arms or legs, make the sweeps towards the fingers or toes.

For a general energy cleansing, the patient can be seated while the healer moves his cupped hands slowly upwards close to the person's body, starting just below the level of the seat. This should be done from all sides, lifting the excess energy off the top of the person's head and flicking it off into a corner, out of a window, or into a sink. At the end of the cleansing, seal the person's aura.

The healer must have the intention and expectation of removing excess energy. With enough sensitivity, you can actually feel depressed energy as a heaviness in your cupped hands. Try rapid or deep breathing during this work with the patient. These whole-body cleansings are especially effective if done by a group of healers at the same time, on one person.

Another drawing-out method is as follows: Place your receptive or sensitive hand with the palm down a few inches above the painful or diseased area. Hold your positive or energy-giving hand, also with the palm down, over a bucket of fresh water. Treat for five to ten minutes, or less if pain disappears sooner. Then move to another part of the body if required and treat again for five to ten minutes. You may be able to increase the effectiveness of this procedure by having the fingers of the positive hand point south.

Instead of using your hands, you can draw out excess energy with a suction tube: Solder approximately five feet of an insulated wire to one end of a one-to-two-foot iron tube. Remove the insulation from the free end of the wire and spread the strands of wire in a large container of cold water. With the free end of the tube, trace a meridian for sedation, or place it over a painful area.

This implement produces a powerful suction for removing excess energy. Use it repeatedly for five to 15 minutes. However, avoid draining energy from the hand by

holding the tube when in operation. Preferably fasten it to a stand in the desired position, otherwise wrap it well with a dry cloth before holding. An even stronger suction is achieved by using a three foot long galvanized-iron or stainless-steel pipe in a fixed position without attached wire; one end reaches into a water container, while the free end is directed against a treated area.

Healing at a Distance: As a possibility for distant healing in which you do not touch the patient, start by audibly or silently saying a prayer in which you ask that your patient be healed. Then have the patient lie down or sit in a relaxed position with closed eyes while you enter a meditative state. It will be helpful to use eight-two breathing or a similar slow-breathing technique (see Step 9). Then mentally radiate love and healing energy to the patient, or visualize the patient as being healed.

Very effective is feeling a strong flow of energy entering the top of your head and moving down your arms and out of your palms. Hold your palms a foot or two away from the patient. Alternatively, you can beam the energy out of your forehead or heart. Another possibility is to evaluate in which part of the body the source of the problem is located. Then energize your own chakra related to this part of the body and let this energy radiate into the corresponding chakra of the patient. Finish with a thanksgiving prayer and a blessing for the patient. Distant healing is much safer for the healer than that done through direct touch.

With distant healing, the patient is in the same room, while with absent healing the patient can be anywhere in the world. For absent healing, use a similar procedure: Visualize the face of the patient or concentrate your healing energy on a photo of the patient. You can also pray together at a prearranged time.

Beaming: Beaming is an excellent cooperative method for improving our health and speeding up our spiritual development. It helps us to release negative mental, emotional, and etheric energies while activating our energy centres and circuits at the same time. Beaming can be done alone but is more effective with a friend or partner or in a group setting.

Before starting, ask your God Presence or Higher Self to make you a channel for the healing light. (In the channelled information revealed in the book I Will Arise, by Paola Hugh, it is suggested to “ask in the name of Jesus Christ to become a channel for the healing Light of the Father’s Love.”) Then imagine a spiritual white light entering the top of your head and flowing down your arms. You can use the chakras in the palms of your hands like lenses to focus this healing light in concentrated form onto areas of the body in need of healing and cleansing. Have the mental attitude that this light originates from a higher source.

Generally, hold your hands eight to 12 inches from the body and point the palms towards the organ to be healed. If you feel warmth or tingling in your palms, this means that there is an obstruction in the person’s body; continue beaming until these disappear, then move to another area. Initially beam for ten to 20 minutes, but with growing experience go longer. The farther away from the body you hold your palms, the deeper the beamed light energy penetrates.

For overall health improvement and spiritual cleansing, start with the person’s head. Beam from all sides, but mostly with one hand over the top and the other towards the base of the brain from the back. After several sessions of beaming the

head, move to the kidneys and the intestines, one palm directed towards each kidney.

At another session, treat the spleen with one hand and the liver with the other. Jointly, spleen and liver are responsible for the purification of the blood. Do the same with the heart and the throat or the thyroid. If helping others, beam their kidneys, spleen, liver, and heart from the back. On yourself, you can treat your front or back depending on your ability to beam your own back.

To establish inner energy circuits, beam simultaneously on the heart and the back of the head, on both adrenal glands (located on top of the kidneys), on one adrenal and the thyroid, then on the other adrenal and the thyroid.

Another practice is beaming light of different colours from the thumb pads into the open eyes. Use a distance of two inches and about one minute for each imaginary colour. Start by visualizing the cosmic violet colour of transmutation. See it streaming out of the thumb tips and through the eyes into the centre of intellect at the base of the brain. Then visualize other colours and body areas. Beam emerald green into the eyes for the adrenals, grass green for the heart, pale blue for the reproductive organs and for the thyroid, light electric-blue for the liver, indigo for the spleen, deep indigo-blue for the ears, and orange for the lymphatic system. Violet is for the teeth and gums, and you beam this into the open mouth.

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Step 55
MERIDIAN & ACUPRESSURE THERAPY

Balance the flow of energies along your acupuncture meridians by tracing their circuits.

The human body has a bioenergy circulation system similar to the blood circulation system, as shown in figure 7-4. The bioenergy flows along 12 main meridians, or channels. These are on each side of the body, each pair being related to a specific organ and its processes. In addition, there are two single meridians following the midline of the body, one at the front and the other along the spine. Many points are distributed along these 14 meridians. These points are essentially transformer stations through which bioenergy flows into the muscle structure to allow organized activity to take place; they are treatment points for acupuncture. In disease, energy imbalances develop in these channels, causing some of the points to become irritated or congested. This results in pain or weakness in the surrounding muscles.

Try to find tender points by pressing with a thumb or finger in a circular motion around the area indicated for each point on the charts of the meridians (see figure 7-4). You do not need to know and find the exact location of a point. If there is a problem, all of a small muscle and much of a large muscle will be tender around the point so that it is easy to find. Press into the general area of the selected point and gradually work your way toward the centre of the pain. For treatment, concentrate on the most painful spots, pressing them frequently as explained for reflexology in Part 2. Generally, the pain decreases after some time of pressing, but should it increase instead, then interrupt the treatment for several days.

Tender pressure points may stem from either a local condition or a problem in the main organ associated with that particular meridian; also, the pain may be referred from a more distant body part connected to the same meridian. There is, of course, an interaction between these different areas.

When the main organ is inflamed, most points along its meridian will be tender. The points especially useful for diagnosing and treating the organ directly are located around the ankles and wrists. They are called source-points; further source-points are situated along the Bladder meridian close to the spine, and also as local-points on various meridians near the target organ.

Rules for Selecting Treatment Points: The following general rules are useful for selecting points for treatment.

1. Points above the knees or elbows reflect mainly local conditions, while those below these joints reflect local as well as distant conditions at other parts of the meridian.
2. Generally, the closer the points are to the fingertips or toes, the closer to the other end of the meridian will be the related sphere of influence.
3. For painful, acute conditions, treat mainly -distant-points; for chronic conditions, add local-points.

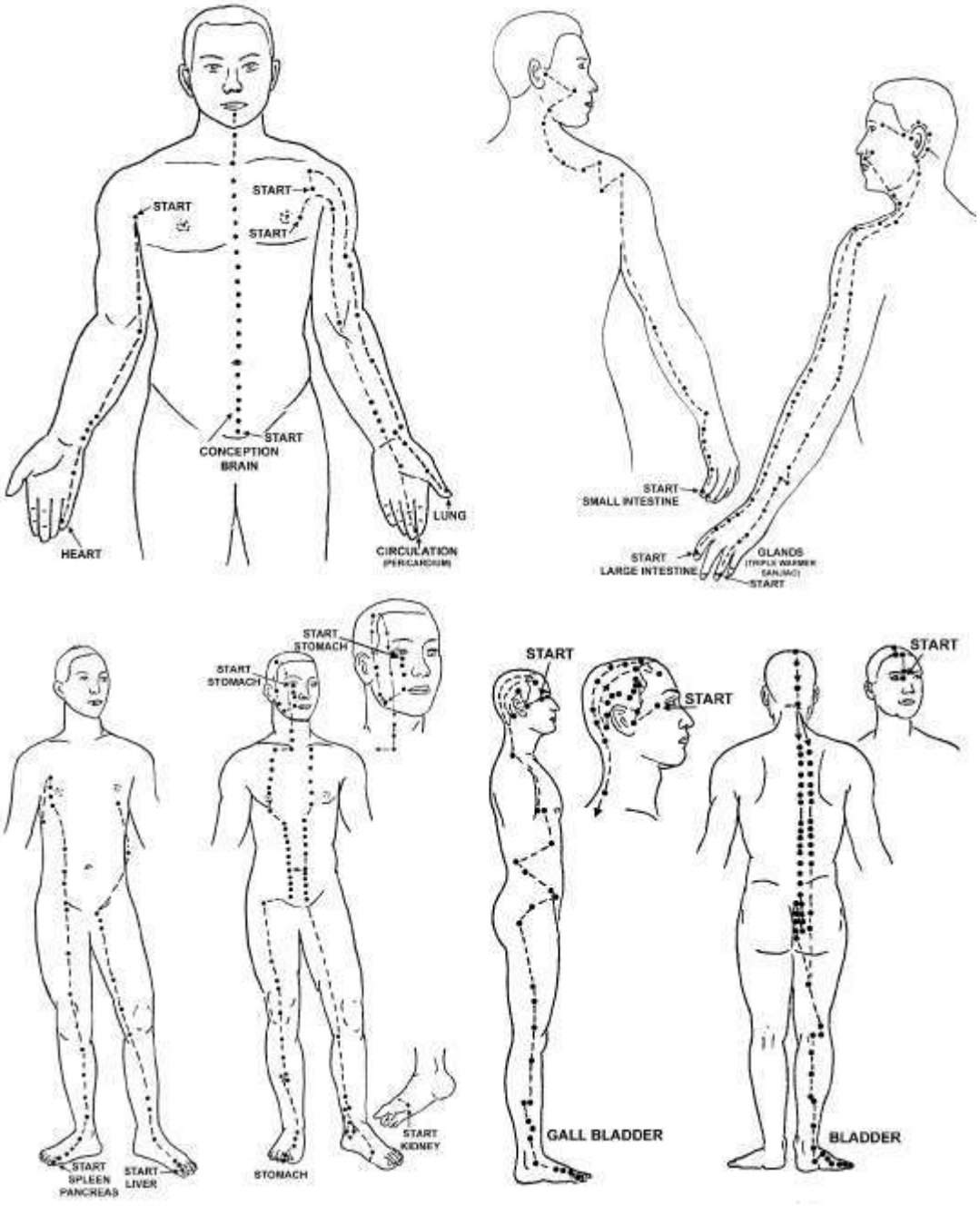

Figure 7-4: Chart of Acupuncture Meridians. Begin tracing the points marked “start”. Dots indicate acupuncture or pressure points. Apply finger pressure when tender. The Governing Meridian (not shown) starts at the tailbone and follows the spine in a straight line over the top of the head down the nose and ends between nose and upper lip.

This means, for example, that if you wish to treat an acute eye or ear pain, select points near the toes and fingers, while to treat shoulders and hips, move close to the elbows or knees. For a more chronic condition, you press in addition the tender spots around the ears and eyes, and hips and shoulders. You can also add points of other meridians that have a direct relationship to the problem. Eye problems, for example, are often associated with poor kidney and liver function. Therefore, some points on the meridian associated with these organs can be treated as well. Further, the points at the shoulders, the shoulder blades, and the base of the neck control the

circulation to the arms and hands, while the points at the hips, the buttocks, and around the base of the spine control the circulation to the legs and feet. Therefore, treat poor circulation, numbness, and pain in the extremities by pressing the points in the indicated control areas.

Frequently, the pressure points of a pair of meridians will be more sensitive on one side of the body than on the other side. This indicates an imbalance in the energy flows. The meridian with the more tender points requires sedation, relaxation, and withdrawal of energy, while its counterpart on the other side needs stimulation. Instead of pressing acupuncture points, you can place the north pole of a small magnet on a point for stimulation or the south pole for sedation.

Meridian Therapy: A main problem in healing is the balancing of the energy flows. Usually, this balancing occurs unrecognized as a by-product of other successful treatments. However, healing can be initiated and accelerated by deliberately treating the meridians with the express purpose of balancing.

A useful method for this is to follow the outline of a meridian with one finger or with several fingers held closely together. Following a meridian in the normal direction of flow is strengthening, while tracing in the opposite direction will weaken and sedate the meridian. The results of these tracings can be checked with muscle testing. Preferably energize your hands before a series of meridian tracements. Do this by vigorously shaking your hands for a few seconds or imagining energy streaming out of your fingers, or both.

In order to perform a tracement, pause with your fingers for a moment at the starting point; then follow the meridian in a fluid motion. The fingers should be close to the body but do not need to touch the skin. It is enough to remain within about two inches of the actual course of the meridian. Related meridians on both sides of the body can be traced simultaneously. In repeated tracements, move the hands back to the starting point in a wide sweep to avoid following the meridian in the reverse direction.

You can trace all the main meridians once or several times daily, or concentrate on the meridians most in need of improvement. Important meridians can be traced repeatedly during the day for 20 times or more. The strengthening effect may be increased if, after several tracements, you do a muscle-tensing exercise. Take a deep breath while tensing your whole body and then relax it during exhalation.

The meridian system allows us to understand why many disease symptoms appear in certain body parts when the originating cause is a weak or inflamed organ in another location. The diagrams (see figure 7-4) show only the surface courses of the meridians; inside the body, each one is connected to its associated organ. In this way, the deranged energy pattern of an organ is easily transmitted to other body parts along the course of the meridian.

Diseases of the ear, migraine, and hip problems can now be seen in terms of energy associated with the gallbladder. Arthritis of the hip, therefore, is often a gallbladder problem, while arthritis of the shoulders may have its cause in the intestines. Gout, affecting the big toes, stems from the liver, while swollen ankles are related to the kidneys. See table 7-2 for the relationship of different diseases or health problems to the meridian system.

Table 7-2: Pathological Symptoms of the Meridians per 24-hour Cycle

Meridian with time of maximum daily activity	*Associated symptoms*
Liver, 1-3 a.m.	liver problems, lumbago, vomiting, hernia, urination problems, pain in the lower abdomen and along the course of the meridian
Lung, 3-5 a.m.	respiratory diseases, sore throat, cough, common cold, pain in the shoulder and along the meridian
Large Intestine, 5-7 a.m.	abdominal pain, constipation, diarrhea, sore throat, toothache in the lower gum, nasal discharge and bleeding, pain along the meridian
Stomach, 7-9 a.m.	stomach problems, abdominal pain and distension, edema, vomiting, facial paralysis, sore throat, toothache in the upper gum, nose bleeding, pain along the meridian
Spleen, 9-11 a.m.	problems of the spleen and pancreas, abdominal distension, jaundice, general weakness and sluggishness, tongue problems, vomiting, pain and swellings along the course of the meridian
Heart, 11 am-1 p.m.	-heart problems, dryness of the throat, jaundice, pain along the meridian
Small Intestine, 13 p.m.	pain in the lower abdomen, sore throat, swelling or paralysis of face, deafness, pain along the meridian
Bladder, 3-5 p.m.	bladder, neck, and back problems, headache, eye diseases, pain along the back of the leg
Kidney, 5-7 p.m.	kidney problems, lung problems, dry tongue, lumbago, edema, diarrhea, constipation, pain and weakness along the course of the meridian
Circulation, 7-9 p.m.	poor circulation, angina, palpitation, diseases of the sexual glands and organs, irritability, pain along the course of the meridian
Gland Meridian (Triple Warmer), 9-11p.m.	diseases of the thyroid and adrenal glands, ear problems, sore throat, abdominal distension, edema, swelling of cheek, pain along the meridian
Conception Meridian	diseases of the urogenital system, hernia, cough, breathing difficulties, breast problems
Gallbladder, 11 p.m.-1 a.m.	gallbladder problems, ear diseases, migraine, hip problems, dizziness, pain along the meridian
Governing Meridian	spinal problems, mental disorders, fever, nose problems, headaches

Each organ-meridian system, except for the conception and governing meridians, has a two-hour period of maximum activity and a period of minimum activity 12 hours later over the course of the day. An inflamed organ is often more painful during its active period, while a weak system should not be stressed during low periods.

While pulse diagnosis (read at the wrist) is the expert way of determining the energy balance of the meridians, you often can judge this by the kind of diseases or symptoms present. Generally, overacidity, pain, and inflammation along the course of a meridian or in its target organ require sedation, while coldness and weakness call for stimulation.

According to Chinese medicine, some interesting characteristics are associated with the meridians of the kidneys and liver. Weak kidneys are associated with a lack of will and sexual impulse, and with negativity, unease, timidity, and impatience. In the case of overactive kidneys, the energy level is abnormally high and you cannot stop working. It is similar with the liver. Weakness shows itself in dizziness, a clumsy walk, easily tired eyes, and a short temper, while an overactive liver causes excessive excitability, crying moods, and a compulsion to continue working.

Chinese medicine says that the main organs and their meridians are also associated with different emotions. An excessive amount of these emotions can damage the associated organs, while a disease of these organs may, in time, lead to excessive displays of these emotions. Accordingly, anger is associated with the liver; excessive laughter and gayness, but also fright, with the heart; worry and emotional tension with the spleen and pancreas; grief, sorrow, and negativity with the lungs; and fear and timidity with the kidneys.

Magnet Meridian Therapy: Magnets can be used for tracing meridians. Move the appropriate pole of a magnet close to the skin along a meridian. This can have a much stronger balancing effect than using the fingers. For strengthening use the north pole, for sedating the south pole.

With muscle testing, you can often detect a strong preference of a meridian for one of the magnetic poles. This can be used to diagnose the condition of the associated organ (if weak or inflamed). If muscle testing is not possible or successful, use the south pole on the body side that shows more inflammation or more tender acupressure points; trace the opposite meridian with the north pole.

Some individuals feel immediately which pole and direction of tracing is beneficial, while the opposite pole and direction may feel unpleasant. For a sedating and pain-relieving effect, it can be very effective to trace the south pole of a strong magnet against the meridian flow. Use a round magnet, one or more combined button magnets, or a small elongated ceramic magnet.

If muscle testing shows that tracing the opposite flow direction of a meridian with the south pole towards the skin is strengthening, there may be an infection or inflammation somewhere along the course of the meridian or at its associated organ. Weak meridians or their related organs, on the other hand, test stronger when tracing is done with the north pole in the correct flow direction. If the tracing is stronger with the south pole in the correct flow direction, but weak when traced in the opposite direction, there is only a moderate amount of overactivity in the meridian or its related organ.

The tracing of meridians associated with painful conditions 20 to 50 times with a strong magnet has sometimes provided almost immediate relief from pain, while similarly quick results have sometimes been achieved using the north pole for improving the mobility of impaired limbs.

Instead of using magnets, meridian tracement can be done with energies from a small pyramid or orgone accumulator. Use a metal tube, preferably galvanized iron or stainless steel wrapped in dry cloth, for the actual tracement; this can be connected to a pyramid by an insulated wire. For sedation, try a metal tube (copper, galvanized iron, or steel) from which an insulated wire leads into a container of water.

Mental Tracing of Energy Channels: Often, effective meridian therapy can be achieved simply by tracing a meridian mentally, moving your awareness along it. Try to feel a warm or orange energy stream moving in the normal flow direction for stimulation; for sedation, feel a cool or blue stream moving either in the normal direction or against it. If in doubt, move in the normal direction and imagine the meridian being traced with the correct pole of a strong magnet. You may not actually need to know which pole it is.

Meridian therapy is especially important where scars cross a meridian line. Untreated scars tend to restrict the energy flow. With meridian therapy, I have seen on some occasions pain, persisting for days or weeks after an operation, disappear within minutes and stiff or painful shoulders became normal. Even scoliosis (sideways curvature of the spine) has been corrected in a short time in this way with the addition of dietary improvement and pressure applied to tense muscles. Scoliosis can also be successfully treated with color therapy and magnet therapy using stimulation (orange color or north pole) on the weak side of the back and sedation therapy (blue and south pole) on the tense side towards which the spine is being pulled.

While prolonged pressure applied to a tense muscle is usually the quickest way to disperse pain or stiffness, it is also painful, so it helps greatly to trace the nearest meridian for several minutes with a magnetic south pole beforehand, possibly against the meridian flow. Refer to table 7-2, which shows the health problems that can be associated with the different organ meridians. Problems due to overactivity, such as inflammation, are commonly most pronounced during the time of maximum activity, while underactivity or weakness may become more normal at that time.

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Step 56
SEXUALITY

Channel your sexual energies into pleasure rather than frustration.

Strong emotions and energy flows are an integral part of sex, which is why sex has the potential to cause enormous problems if these emotions and energies are blocked or misdirected. Due to our social conditions, unimpeded sexuality is rare and sexual repression is the norm, so much so that most of us do not even realize that something is wrong. We do not know what natural, free-flowing sexuality is. I see two main factors that led to this situation in our society. One is our competitive, ego-centred, and male-dominated social structure and value system; the other is the cumulative result of our restrictive religious teachings and social traditions.

The Natural Development of Sexuality: Sexuality is much more than having sex. It involves a wide range of feelings and emotions at all ages. In the foetus, sexuality is experienced as total security, the reassuring heartbeat of the mother, the gentle rocking motion of its fluid bed, and the sucking of its thumb. For the baby, sexuality means lying against a warm, soft body, feeling its love and auric energies, gently touching and suckling at a nourishing nipple. The growing infant retains this need for loving touch and gentle body contact. Later, exploring one's own genitals and using them to generate pleasurable feelings is as natural and important as exploring aspects of the environment. Of special importance is an intimate relationship, involving bodily contact with the parent of the opposite sex or with his or her substitute.

With puberty, sexuality bursts into the open and produces powerful longings. The awakening sexual feelings need an outlet. This is provided for the girl through romantic ideals, hero adoration, and in a practical way involving religious and charitable service. Sports and nature activities provide an outlet for both sexes.

Teenage boys long for adventure and need to develop and test their abilities by following or imitating a chosen hero or role model. These romanticized adventure activities channel the sexual energies into safe outlets conducive to inner and outer growth and social development without suppressing sexual feelings or activities. Ideally, the relationship of children and teenagers with their parents should be such that all sex-related subjects can be freely discussed and possibly even practical instructions given by the parent of the same sex.

Romantic relationships with the opposite sex remain for many years just that, romantic. This is the flowering time of erotic love with ever-increasing levels of intimacy, but with penetrative sex ideally happening only in the later teens within the context of a loving relationship. The challenge now is to transform the straw fire of erotic love into mature lasting love for the partner. Erotic love is based on sexual attraction, while mature love is a communion in spirit. This transformation of love will allow the sexual relationship to mature more fully.

To recapitulate, we can say that during pregnancy and birth the most important aspect for the foetus is being wanted. During babyhood, breastfeeding and body

contact are central. The growing child needs to be immersed in a loving and harmonious relationship with the whole family unit with much touching and experiencing of feelings. Then comes the time of romantic idealism for the teenager and finally the challenge to transform Eros into mature love and sex. This is the ideal of our normal and natural sexual evolution.

The sexual reality for most of us is so different from this ideal that it has left an important part of our sex-related emotional development greatly impaired. Instead of this gradual, guided growth into a sexual relationship, we are expected to be asexual, with severe repression of sex-related feelings and impulses, until we are grown up and then overnight, without a suitable role model, become responsible and accomplished sexual partners. That is just not possible.

When Things Go Wrong: The importance of several of these factors for normal sexual development has been demonstrated in an interesting experiment with monkeys. Immedi-ately after birth they were separated from their mothers and raised with two substitute “mothers.” One “mother” was a wire structure containing a food bottle with nipple and the other had terry cloth over the wire and was heated by an electric bulb inside. The young monkeys adopted the cloth-covered structure as their mother substitute and were distressed when it was temporarily removed. The bottle structure was just a feeding machine to them. All these monkeys became disturbed emotionally as well as in their behaviour when growing up, and they were unable to perform the sexual act successfully on maturity. Touch was emotionally more important to them than food.

Most of us became blocked in our sexual-emotional development at several stages of our upbringing. One of the worst aspects for a baby is the feeling of not being wanted and especially if it experiences hostility from one or both parents. Regression shows that a baby or even a foetus knows the attitude of its parents and that this remains a lifelong part of the subconscious programming of that individual.

A difficult birth, especially with forceps and glaring lights, is traumatic for the infant; so is surgery and a negative attitude by those present at the birth. Even worse is the prolonged separation of the baby from the mother as practiced in most hospitals. More than anything else, babies need persistent contact with the mother or a suitable substitute for emotional security.

It is so sad that many parents take great pride in a fanciful nursery room when the baby only longs for contact with its mother. This is perceived by the baby as a rejection, being left alone with feelings of insecurity for the rest of its life. Such insecurities surface again later, in a sexual relationship. The more secure infants feel, the sooner they will venture off on their own to explore the world around them and the more secure adults they will become.

Further problems frequently arise in the “anal” phase of development, as Freud called it, with too early or too severe toilet training. Instead of acquiring voluntary control of the sphincter muscle, children permanently contract the gluteal muscles and those of the pelvic floor. In later life, this can lessen their sexual energies and feelings.

Another conflict often arises between the ages of two and six, when parents typically suppress any manifestations of infantile sexuality. These can be in the form of touching, masturbating, or displaying the genitals, or erotic contact with the parent

of the opposite sex. Such body contact is pleasurable for the child and necessary for identification with its body and development of pleasurable erotic feelings for the opposite sex. Problems arise when the parent either rejects close body contact or manipulates the child for his or her own sexual desires.

Psychologists speak of an Oedipal situation at the age of five or six, when the child must choose between its sexual feelings and retaining the love of the parents by being a “good” child. Most children choose to be good and suppress their sexuality. This then leads to frustration with the opposite sex in later life. Sexual feelings, like other feelings, are suppressed by tensing the muscles, especially in the pelvic area, making the body rigid.

During our school years, examination anxieties greatly contribute to our general insecurities and make us more nervous and neurotic. As teenagers, we often lack suitable outlets for our creative energies and romantic ideals. If our overflowing sexual energy is not transformed into creative energy in the form of sports, art, or adventure, then masturbation remains as the only outlet, aside from erotic and wet dreams. This may lead to premature penetrative sex as an experiment or because of peer pressure, without feelings of love and sharing, so necessary for maturing sex.

Sexual Neurosis: The emotional problems of our parents led to most of us facing severe emotional stresses in our childhood, and now as adults we are neurotic to varying degrees. I use “neurotic” to mean that we have emotional disturbances and inhibitions that prevent us from finding fulfilment in life and specifically in our sexual relationships. Neurosis manifests in all aspects of our personality, feelings, emotions, character structure, body structure, and body functions. If we have sexual problems, we also have problems in our other social relationships. Our childhood experiences guide us in our choice of sexual and marriage partner, in the kind of sex that we like or dislike, and in what we feel and how satisfied we are in life.

Symptoms of sexual neurosis are manifold, including shyness, stuttering, difficulty urinating if someone looks, fear of nudity, premature ejaculation, impotence, frigidity or generally failure to achieve full orgasm, lack of fulfilment, nymphomania, and a tendency to rape. Neurosis also contributes to many diseases and especially to those of the female sexual organs.

As adults we usually are completely unaware that the emotional scars from our childhood are still subconsciously active and even dominating our behaviour and decision-making. Our lower self, however, remembers fully because that is what it is made of, for memories are the basis of our inner life. If we felt deprived of something important as an infant, we will continue to feel deprived as an adult. If we felt fearful of or hostile towards our mother or father, we later feel subconsciously hostile towards all men or women or are afraid of them. How can we have a normal, fulfilling sexual relationship or any other close relationship with someone we fear or hate subconsciously?

It is said that we can only fully love a man or a woman if we basically love all men or women. If we are subconsciously fearful of the opposite sex, then we develop a fear of penetration, become impotent, or become susceptible to homosexuality. Strong hostility towards the mother can later lead to an inability for a man to have sex with a woman unless he humiliates her, possibly in the form of violent rape.

Pornography is a fantasy outlet for many forms of sexual neurosis, but it is only a poor substitute for uninhibited sexual functions.

Sexual Types: Body-oriented psychologists such as Alexander Lowen, John Pierrakos, and Barbara Brennan have devised various systems linking our childhood experiences with our sexual problems as adults. They distinguish the following sexual types: schizoid, oral, psychopathic, masochistic, and rigid. A normal type does not seem to be part of their experience.

The schizoid type: This type experienced emotional trauma already around birth and, therefore, did not fully connect with the body. When things become difficult, schizoids just withdraw from reality and live in fantasy. The resulting lack of body feeling and identification with the "self" also leads to confused sexual identification, and schizoids easily become homosexuals or prostitutes. Many passive lesbians are of the schizoid type as, like deprived children, they crave warmth and human comfort; their orgasmic potency (the ability to reach a full orgasm) is usually rather low.

The oral type: This kind is widespread because of the general abandonment of breast-feeding in our society. The baby felt abandoned and sex is sought mainly for closeness and contact, similar to the schizoid type. The breast is worshipped and oral sex enjoyed. Sexual relations as well as sexual functions remain immature. Anal sex is also related to the oral phase. Sensuality, superficial feelings that make us feel good, are used as a substitute for orgasmic sexuality, but cannot achieve a deep emotional energy release.

The psychopathic type: This kind evolved from a child that felt it had to manipulate the parent of the opposite sex to get what it wanted. In later life, the need to be taken care of is achieved either through bullying or seduction. Sex is often hostile with much fantasy. Feelings of contempt for the partner cover suppressed feelings of inferiority. Sexuality is used to control, conquer, and dominate, while pleasure is secondary. Often the behaviour in a relationship is irresponsible.

The masochistic type: This type evolved from domineering parents who crushed the child's creativity and self-respect. This lack of self-worth is expressed in a sexual relationship as a need to be humiliated. Sexual excitement can be gained from inflicted pain. The masochistic male may have difficulties with ejaculation.

The rigid type: While most neurotic individuals have various rigidities, these are especially prevalent in the rigid type. The child suppressed sexual and other tender feelings in response to a perceived rejection by the parent of the opposite sex. This was typically an emotionally cold parent who did not tenderly touch or cuddle the child. The child learned not to cry or show emotions. The rigid adult chooses sex over love and is a sex performer without deep feelings and with greatly decreased orgasmic potency. Sexual activity is compulsive and mechanical; performance provides ego satisfaction; emotional warmth and physical closeness are avoided.

Commonly, we combine features of several types in our sexual makeup, but with one type being dominant. However we resolved the Oedipus complex as a child (the relationship with the parent of the opposite sex), we assume corresponding sexual roles as an adult. We may either act as a son or daughter, as a sister or brother, as hero, sweetheart, or romantic ideal, as a father or mother figure. However, if we resolved the problem in a natural way, we act as a mature adult, encompassing all roles and playing each one as appropriate.

If the relationship of a girl with her father remains emotionally unresolved, then as an adult she tends to act mainly on the daughter level, looking for a father figure and easily becoming just a sex object in danger of drifting into prostitution. If the girl channelled her sexual feelings into sympathy for the father, she may play the role of sister and see herself as companion and helpmate of her man, wanting to share everything, but sexual contact remains relatively unimportant and unexciting.

If the sexual feelings for the father have not been suppressed as with the sister type, but just held back, the romantic type emerges, emotionally the eternal virgin, teasing but not wanting to be possessed by a man. She likes flirting, as she needs romantic excitement, but has a problem combining love with sex. Because of resulting emotional conflicts, this type is psychologically also called the “hysterical type.”

The girl who matures too early by replacing sexual feelings for her father with motherly instincts later becomes a mother type with little sexual interest. She becomes attracted to immature males of the son type whom she can mother.

Each type has an unresolved conflict: the daughter type between accepting and rejecting herself; the sister type between passivity and aggression; the romantic type between surrender and resistance; and the mother type between submission and dominance.

In the male, the conflict of the son type is between accepting and rejecting himself; he is the playboy type, immature and irresponsible. The brother type assumes the role of protector. Here the conflict is between his aggression to protect the woman and passivity or inability to satisfy his own needs. The conflict of the Casanova-like hero or knight type is between emotional surrender and resistance to the female, while the authoritative father type is torn between dominance and submission.

Orgasm: There is a popular misconception that if a man ejaculates or a woman has pleasurable feelings at the height of the sexual act, that this is an orgasm. It is not necessarily so, at least in the view of bioenergetic psychology. Usually there is just a climax with more or less of an orgasmic component.

A full orgasm can be described as follows: With climax approaching, the formerly voluntary body movements suddenly become involuntary with a strong increase in genital sensations. Just before the discharge, melting sensations are felt in the pelvis. Orgasm starts with a strong contraction around the base of the penis and the opening of the vagina. A flood of feelings rushes downwards while the whole body convulses in unison with each involuntary forward swing of the pelvis. Now the whole body is engulfed in melting and streaming sensations. Ejaculation takes place in pulsating squirts. There may be a sensation of flying or spinning or something similar at the height of the orgasm. Afterwards there is a full relaxation, with an inner glowing and a feeling of utter satisfaction and contentment.

In order to achieve such a full orgasm, there must be a sufficient buildup of sexual energy beforehand. If the body is generally low in energy, if the energy flow is blocked through armouring, or if there is insufficient foreplay or feeling awareness, then there will be only a low charge of sexual energy in the pelvis and consequently a weak discharge of energy and feelings.

A strong field of sexual energy in one partner will help the other to achieve a greater charge; if both are fully charged, they will greatly increase each other's orgasm. Con-versely, with a weakly charged partner or with masturbation, our orgasmic feelings will be diminished, usually also with oral sex, as close contact of the fully charged genital areas is required for maximal potential.

A strong sexual charge consists not only of sexual energies, but also of feeling energies. Normally, tender, loving feelings towards each other greatly help to increase our sexual charge. As an emergency measure when such tender feelings are blocked, some can achieve the necessary emotional excitement with sadistic or masochistic visual measures. Also various forms of pornography are used as a substitute, usually an inadequate one, for tender, loving feelings.

With strong, loving feelings, on the other hand, an almost irresistible desire to melt into each other can build up. The sexual charge and physical union then follow as a natural consequence. This automatically leads to a true and full orgasm. For a woman who has difficulty coming to an orgasm, it may be made easier if her partner positions himself on top somewhat higher than usual so that their navels meet. With this, the shaft of the penis will rub or press on the clitoris during movement inside the vagina.

A full orgasm is possible after overcoming bodily rigidities and emotional inhibitions, and it is a natural occurrence in societies living without sexual inhibitions.

The most common and obvious signs of only a partial orgasm are:

- A clitoral rather than a deep vaginal climax
- Feelings confined to the sexual organs rather than full body feelings of melting
- Inhibition of movements, especially of the involuntary convulsive movements
- Inhibition of spontaneous sound expressions
- Ejaculation without pulsating squirts
- Premature ejaculation or continuing sexual activity after ejaculation
- Lack of complete relaxation and satisfaction after the climax

As a general rule, we can say that the less the climax is associated with pleasurable streamings and whole body feelings and the more it is confined to the sexual area only, the less it is a real orgasm but rather just a low-energy mechanical discharge. Wilhelm Reich, M.D., was the first to describe the negative consequences of blocked sexual energies and the true nature and purpose of the orgasm as a discharge of excess bioenergy with the additional liberation of feeling energy.

Sexual Healing Exercises: Healing our sexuality means freeing up our blocked energy flows and overcoming subconscious negative conditioning by replacing it with positive feelings and attitudes about our sexuality. In order to remove the energy blockages, we need to relax our permanently tensed or contracted muscles, especially in the thighs and the pelvic area, but also in the neck and jaw.

Bioenergetic exercises are excellent for this purpose. These include shaking and vibrating the legs, the pelvis, and the whole body; stretching exercises, circling the hips, pelvic thrusts, kicking and bicycling exercises, the teachings in the book Ancient Secret of the Fountain of Youth, and other yoga exercises (see Step 9).

With moving exercises, such as circling, bicycling, and pelvic thrusts, the aim is not to train and strengthen these muscles, but rather to move them to the point of exhaustion, which will induce relaxation when stopping the exercise. During the exercise, we try to break through the pain threshold and may then be rewarded with previously unknown pleasurable sensations in the pelvic area.

Exhale through the mouth during these exercises and express any spontaneously forming sounds, such as moaning, crying, or shouting. Other important measures are deep tissue massage and pressing into tense muscles; also reflexology and tracing acupuncture meridians can help. For some approaches, such as pressing into tight muscles, deep muscle massage, and emotional therapies, the cooperation of a friend may be required; alternatively, professional help can be used.

A good exercise that can be done anytime, sitting, standing, or lying down, is rhythmically squeezing the buttocks. At other times, just squeeze the pelvic floor between anus and penis or vagina ever so lightly while concentrating your awareness on the developing pleasurable feeling. You can also do this during slow walking or while driving a car.

Improving Your Feelings: Feelings are what a sexual relationship is all about. The more we are able to feel and express our feelings, the more vigorous is our sexual activity and our life in general. If we are fearful or shy about some aspects of sex, we will be fearful or shy in other aspects of our life as well. Our sexual feelings reflect our emotional health in general, and vice versa.

Often our most basic subconscious feeling related to sex is fear. Out of this can arise anger, hate, and hostility. All of these negative feelings normally remain suppressed and subconscious. After all, it was not acceptable to feel this way as a child towards a parent and it is not acceptable now with a sexual partner.

It would have been easy to have open feelings of fear or hostility towards a parent if we had been obviously mistreated. However, what is a young boy to do if his mother is loving and sacrificing, and he has sexual feelings for her? He wants to be cuddled and touched, but his mother is always too busy caring for the family. He has to suppress his longing for caressing tenderness. He may then come to fear these sexual feelings for his mother because they remain unfulfilled and make him unhappy. This can later translate into a subconscious fear of close emotional contact in a relationship.

On the conscious level, we are kind and loving to our partner, as we were to our mother or father. However, subconsciously we may feel the opposite because a man’s lower self now equates the sexual memories concerning his mother with his feeling for all sexually attractive women. In the same way, a woman may equate the memory of the sexual feelings for her father with her feelings for all sexually attractive men.

This deep emotional split between our conscious and our subconscious mind will result in an emotional or organic dysfunction. We can thus develop frigidity or fear of penetration, premature ejaculation, impotence, and any other form of sexual disorder. This split explains the observation that “nice men” are often poor lovers.

In order to heal our split emotions and sexual feelings, we must break through the superficial layer of being “nice” and contact our suppressed core feelings. This is

not easy but can be done with methods such as emotional release therapies involving intentional kicking, hitting, screaming, crying, or shouting. Even just pressing into tense muscles can produce strong emotional reactions. In addition, regression therapy or rebirthing can be helpful, as well as the services of an experienced psychic healer or bioenergetic therapist or attending body-mind workshops. However, the best way to heal our sexual self may be within a healing group as part of our overall healing and spiritual growth.

After most of the suppressed emotional pain has been contacted and released, positive attitudes and feelings can be generated with guided imagery, meditation, creative refocusing, and other methods to heal the emotional wound. An understanding partner will greatly speed up this process. If, on the other hand, we use meditation and other methods to generate positive feelings without releasing the suppressed core, then we will just reinforce the superficial layer of “niceness.” This, in turn, can then intensify our inner emotional split and, along with that, our organic disabilities and sexual dysfunction.

To raise our children without this emotional split we must be loving, honest, and open with our sexual feelings and fulfil the child’s emotional needs appropriate to its age. The baby needs plenty of body contact, including sleeping in contact with the mother. Breast-feeding should be extended more than six months and may continue more sporadically for a long time afterwards.

Why not let infants watch the sexual act? That is how they learn. The growing child continues to need a lot of cuddling and touching. Teach the child that there is nothing dirty or shameful about a naked body or about sexual organs. However, we also need to let the child know the difference between what is appropriate in public and in private.

Food for Sex: We cannot have a good sex life if we are malnourished. Certain nutrients improve our sexual well-being in general, while others are lost to the male in the seminal fluid. Therefore, good nutrition for good sex is usually more important for the male than for the female.

High-quality proteins are part of the seminal fluid and a high-protein diet is sexually stimulating. In our culture meat is preferred, while in Asia chickpeas are used to improve sexual performance. Free-range raw egg yolk, especially fertilized and very fresh, supplies sulphur compounds needed for the semen. More of a short-term effect is achieved with cooked onion, which is rich in sulphur compounds as well; alternatively, use MSM supplements. Bee pollen, spirulina, and chlorella are excellent strengthening foods for both sexes.

Histamine is produced from histidine, an amino acid. Individuals with insensitive skin are low in histamine and may have difficulty achieving ejaculation (male) or orgasm (female), as the sexual organs are less sensitive than normal. High histamine levels have the opposite effect. They sensitize not only the skin, but also the sexual organs and may lead to sexual overstimulation, premature ejaculation, and vaginitis.

Histamine levels can be elevated by making the body more acid, as well as by supplementation with folic acid and niacin, both B-group vitamins. Histamine levels can be reduced by making the body more alkaline, and also by avoiding foods and chemicals to which you are allergic. Therefore, you can acidify or alkalize your body according to your sexual requirements.

The semenal fluid is also high in zinc and requires much vitamin B6 and omega-3 fatty acids which are found in fish oils and linseed oil. Deficiency of these is widespread, especially in teenage boys who typically have frequent loss of seminal fluid. Zinc deficiency leads to underdeveloped male sexual organs and, later in life, to enlargement of the prostate gland. By pointing out this connection, I do not condemn masturbation, but rather seek only to improve teenage nutritional awareness.

In recent years, it has been discovered that the body forms nitric acid from the amino acid arginine as a signal for the blood vessels of the penis to relax. This is necessary so that the penis can fill with blood and have an erection. Also, magnesium supplements help us to relax. Stress, on the other hand, or being emotionally uptight, prevents this necessary relaxation.

Dietary Aids for Female Sexuality: Women have their share of trouble with their sexual organs. Foremost of these are menstrual problems and pelvic infections. Both problems have much to do with food and especially constipation. The constipated colon and in particular the rectum are a cesspool of toxic de-com-position products with a high content of harmful microbes. Toxins and microbes can penetrate the wall of a weakened colon and because of the close proximity to the uterus and ovaries, these are in greatest danger of being contaminated. The main effect of toxic contamination is heavy menstrual bleeding with pain and other discomfort. Microbial contamination leads to infection and inflammation of the pelvic organs. Both conditions are not conducive to a healthy sex life.

Meat consumption, combined with constipation, can produce toxic bowel conditions and heavy periods. The obvious solution is a clean colon, achieved by three easy methods. First have plenty of dietary fibre from whole grains and fresh, raw fruits and vegetables. Add sufficient ground linseed to meals or drink with fluid to achieve ideally one bowel movement for each meal. Second, take a course of cultures of acidophilus and bifidus bacteria as part of an intestinal sanitation; and third, squat or have a high footstool in front of the toilet in order to achieve an easier and more complete bowel evacuation.

As I suggested earlier in the book, the typical menstrual bleeding can be caused by an impure bloodstream, which delays healing of the wound caused by discarding the lining of the uterus. The higher mammals do not have such obvious periodic bleeding nor do women who live habitually on a mainly raw food vegetarian diet; they just reabsorb the shed uterus lining. Typically, these women do not have any menstrual or menopausal discomfort, but ovulate and conceive normally.

A clinical study found that consuming plenty of ground linseed, linseed oil, or fish oils helps postmenopausal women have better vaginal lubrication. Folic acid, in combination with antioxidants, is most important for preventing and reversing precancerous and cancerous conditions of the cervix and uterus.

Selenium, the amino acid methionine (e.g., as selenium yeast), and vitamin E, taken in combination, are effective against periodic breast pain and swelling. Vitamin B6, zinc, and magnesium together are good against premenstrual tension, especially if salt, sugar, and fatty foods are also minimized or avoided and hidden food allergies corrected. Boron raises the estrogen level in postmenopausal women. Taking good care of our bodies will increase the pleasure that we derive from our sexuality.

Another common problem is vaginal Candida infections, resulting in thrush and potentially painful intercourse. In this case, the woman as well as her partner need to go on a strict anti-Candida program (see Part 6). When making love while there is still some Candida problem in and around the vagina, lubricate liberally with oil, and if not using a condom, squirt some acidophilus yogurt into the vagina beforehand. Minimize strong movements and focus instead on feeling the energies with only gentle movements and pressure changes.

Making Love: "Making love" is commonly just a polite expression for having sex without feeling love. One can have a loving sexual relationship for just one night or a lifelong sexual relationship without love. For maximal emotional satisfaction, try to feel and express love with each sexual encounter. It is said that the most important sexual organ of a woman is her brain, but I believe that the heart may be even more important.

Loving foreplay is part of the romance, stimulating the heart as well as the right side of the brain. This is not only important for women, but increasingly also for men once they are no longer filled with youthful vigor. Not only women, but also many men enjoy and need to be played with to "get into the mood." Increasingly, they come to resent the perception that they are expected to "perform." They feel that they have to do all the work, first enticing a woman into bed, excitedly undressing her, then stimulating her to get her ready, then "hopping on," and finally helping her climax. Women, on the other hand, resent being made to feel like sexual objects.

There is often much hidden fear and misunderstanding on both sides. Therefore, take it easy, there is no need to hurry or perform. Talk to each other about what you like and how you like it. Make each other comfortable and dispel any notion that he has to perform or she has to have an orgasm. This is important even if you are already in a long-term relationship together.

Not every time you have sexual play do you need to penetrate, and not every time you have penetrative sex do you need to aim for an orgasm. If you do want an orgasm, there is nothing wrong with having a clitoral orgasm, but at other times also try to aim for a vaginal orgasm.

To increase the flow of energies and feelings, do not suppress pelvic movements but rather enhance them. If you are normally quiet, then intentionally make expressive sounds wherever this can be done in private. When approaching ejaculation, it helps for the male to be "grounded" by pressing the feet against a board or wall or pressing them into the mattress.

While different positions can offer different experiences, they are less important than achieving a union of feelings. Do not try to increase your pleasure with fantasies, go for the real thing instead. Focus your full attention on your own feelings and on feeling united with your partner. To fantasize having sex with someone else is just another form of masturbation.

For some men, it may be preferable to delay ejaculation to either extend the pleasure or give their partner time to build up towards the climax. This may be done by playful interruptions, by slowing the breath, or temporarily even holding the breath, by concentrating the feeling awareness on the heart or, with the penis fully inserted, keeping the pubic areas in close contact, increasing and decreasing pressure in unison while not moving the penis.

A somewhat drastic but nevertheless very effective method of preventing ejaculation is to tense the whole body while also holding the breath. Alternatively, or in addition, strong finger pressure on the perineum just before ejaculation will keep the ejaculate inside the body. This may be advisable at times to avoid the generally weakening effect of ejaculation, especially on the elderly male, but it will require some practice, as will all of these techniques. However, if the climax is definitely approaching, do not try to suppress it but start moving vigorously for a full orgasm. Basically, I am not in favour of tensing the body, as this suppresses feelings and leads to increased muscle tension.

The frequency of intercourse is, of course, a highly individual matter. Normally, I see no reason to restrict sexual play if it does not involve either ejaculation or suppression of sexual impulses. However, the orgasmic potential is usually much stronger after a period of total abstention or separation.

From a bioenergetic point of view, females are much better able to have several lovers than males who would either have to neglect one or become worn out. However, I believe that even for females moderation leads to greater well-being. The difficulty of many women to achieve vaginal orgasm may have something to do with our habit of mating all year round just for pleasure. Female animals have days when they are in heat and strongly attract males for mating. The same may be natural for human

Around ovulation time, a healthy woman who abstained for a month will have a strong orgasmic potential and her biochemistry and the whole body are geared to receive a male. If there are no strong emotional blockages, she may find it easier to have a vaginal orgasm, even after only short but vigorous penetration.

Frequent intercourse can cause even more problems for men. While an occasional full orgasm can be strongly invigorating, frequent ejaculation is decidedly weakening. If a man is sexually overstimulated, he should better remove the nutritional and biochemical causes and find other creative outlets for his energy. It is possible that gluten allergy, often associated with a whitish inner iris, can sometimes cause overstimulation of the sex centre in the brain; synthetic food colourings and possibly other chemicals may do the same.

Generally, it is much healthier to have fewer ejaculations with strong orgasms than frequent ejaculations with weak orgasms. In teenagers, frequent ejaculation may impair their mental and physical development, while in later life sexual overactivity makes us susceptible to diseases and premature aging. What is frequent depends on the individual’s constitution and commitments. What is normal or beneficial for a healthy and strong young man might be too much for someone older or with a weak constitution. Wilhelm Reich saw the proper function of the orgasm as the release of excess energy that might otherwise lead to irritability, tension, and energy blockages. Therefore, if you have excess energy, go for it, but if you lack in energy, be careful.

In a long-term relationship, the ideal may be in having mainly sensuous and spiritual sex for most of the month and orgasmic intercourse close to ovulation, as often as desired. A female in touch with her body will feel when the time is right and let her partner know. However, the best time is always when both partners feel like it.

Alternatives to Sex: Those without a permanent partner may find an occasional short-term partner or pay for sex. If all goes well, there is no problem with this. For those without even a temporary sexual partner, the obvious choices are masturbation or abstinence, although there are some less obvious alternatives, as shown below. For masturbation, the same principles apply as for making love. That is to aim for fewer climaxes but with stronger orgasmic releases. For both sexes, this means waiting with masturbation until one feels a strong charge of sexual energy and using pelvic movements, sound, and feeling awareness to ensure a strong orgasmic discharge.

For celibates, an easy solution is a low-protein diet with few spices and condiments. This may be suitable if there is sexual overstimulation due to too much histamine from overacidity or food allergy, but otherwise I am not in favour of this low energy approach. Rather, I believe in making ourselves as energetic as possible, including having plenty of sexual energy, but then to learn to channel this sexual energy into creative outlets, such as sports, charity work, or the arts.

An alternative is the following rejuvenation rite, which is from a Tibetan monastery in which, reportedly, rejuvenation of the body was successfully practiced (see Ancient Secret of the Fountain of Youth by Peter Kelder). This rite was used in combination with several other rites as shown in Step 9. Also a daily raw egg yolk is recommended for those of us who are no longer youthful in order to increase our sexual energies.

When sexually excited, bend over with your hands on your knees and push all the air out of your lungs. Then straighten up and with the hands on the hips push up the shoulders. Pull the stomach in and up and hold this position for as long as possible. Then forcefully inhale through the nose and exhale immediately through the mouth. The arms may now hang to the sides while you take further deep breaths through the nose or the mouth. If you are still sexually excited, repeat this procedure as often as required.

What many single people and especially women miss even more than sex is touching and hugging. Some try to satisfy this need with regular massage therapy. However, there may be a simple solution. If you feel deprived of touching and hugging, just form a local “hug club.” Either discreetly spread the word around or put a notice in a suitable place asking for interested individuals to contact you. You can then arrange a weekly meeting where you just hug for an hour or two. As a follow-up step, you might also give each other massages. You may be surprised by the amount of interest there is out there in hugging. Alternatively, you can form or join a healing group where hugging can be practiced together with massage, reflexology, and the multitude of other self-healing techniques available.

Eventually, you may also want to experiment with some meditative forms of hugging as described later in this chapter. Sexual energy can be used in spiritual sex to energize the higher energy centres with guided imagery or meditation exercises, possibly leading to what is called “whole body orgasm” or “brain orgasm.”

Getting to Know Your Partner: Sensitive individuals are often apprehensive about the first sexual encounter with a new partner. The man may have anxieties about erection, premature ejaculation, and satisfying his partner, while the woman

may fear penetration, getting emotionally hurt, or not coming to an orgasm. This can make the encounter tense and inner fears may become self-fulfilling.

Why not proceed slowly and be intimate without intercourse until you are fully relaxed with each other? This initial period of a relationship is precious, as it is commonly the most exciting and romantic time. Enjoy it as long as you can. Let your partner know that you feel this way. In a situation that might normally lead straight to sex, tell your partner beforehand that you enjoy becoming intimate gradually and do not intend having intercourse that night. You might be surprised by how relieved and agreeable your partner is to this. A whole mountain of tension is suddenly removed.

A good way to start the intimate part of your relationship is to have a shower or bath together and then give each other a sensual massage. Continue exploring each other's likes and dislikes and responses to touching and cuddling. You might even spend the night cuddled into each other. If, contrary to your original intentions, you should be comfortable enough with each other to proceed to full intercourse, nothing is lost, and it will probably be a better experience than it might have been in a tense atmosphere.

Such intimacy together without penetrative sex can be quite satisfying for a considerable length of time, especially in special situations, such as with elderly couples or with physical or emotional handicaps or religious, spiritual, and adolescent celibates. A sexual relationship does not need to be an all-or--nothing proposition. The "macho" encounters commonly portrayed on TV and in the movies are not an everyday reality. A loving sexual encounter without expectations cannot result in dissatisfaction. It does not matter whether there was penetration or orgasm; it is the loving feelings that matter most.

Sex Therapy: It is not generally realized that many health and emotional problems can result from unsatisfactory sexual relationships. These include migraine and tension head-aches, premenstrual tension and menopausal problems, depression, irritability, discontent, violence, anxiety, disturbances of digestive and sexual functions, psychotic symptoms, and high blood pressure, and even cancer has been linked to blocked sexual energies and tensions. All of these may, of course, have other causes and contributing factors as well.

Problems arise mainly when sexual energies are stimulated without being appropriately used or released. This is the same as with other emotional energies. Commonly, this happens if the male ejaculates before his partner reaches orgasm, but it also happens if the orgasmic release is weak or the encounter too short. The signs of a full orgasm are strong involuntary movements, a blissful discharge followed by complete relaxation, and an afterglow of satisfaction and contentment.

Ejaculation in itself or clitoral orgasm do not indicate a full release of sexual tension. There may then be the desire either for repeated or frequent sexual activity or avoidance of sexual activity in order to avoid the resulting tension and dissatisfaction. However, orgasm is only part of a successful sexual union; another important part is the exchange of bioenergy and emotional energy between the partners.

Accumulation of sexual tension with its resulting health and emotional problems can be prevented even without orgasm, while orgasm alone may not always be sufficient. The key to a successful sexual union is the duration, because it takes time,

usually about half an hour, for these energies to be exchanged by the partners. This kind of “sex therapy” is not only effective, but also highly pleasurable, especially for sensitive individuals.

Sex therapy requires two willing partners. Preferably there should be an atmosphere of affection already well before the planned union. This should start with an extended foreplay of caressing with full skin contact, possibly including a sensual massage, but without any clitoral stimulation. However, if this kind of union is routinely practiced as a love meditation, then such elaborate preparation may not be required

When both feel ready, they place themselves in such a position that the woman lies on her back with knees drawn to the chest, while the male lies on his left side crosswise to her, so that his penis touches the entrance of the vagina. She now drops her legs and he places his right leg between her legs. With this, her left leg is between his legs while her right calf rests on his torso. In this way, both can remain completely relaxed with freedom of movement which is essential for success. Sides can be reversed.

Initially, and also if there is a problem with erection, natural lubrication, or premature ejaculation, both partners remain more or less motionless in this position for about half an hour. During this time, the tip of the penis, whether soft or hard, remains outside, just touching the inner entrance of the vagina. Both concentrate all their attention on the contact areas between them, but especially on the sensation in their sexual organs and the exchange of subtle energies between them.

Often, after half an hour there is an increase in sexual arousal and the penis may now penetrate. However, this is not essential. If there should be no erection or the vagina still dry, just remain in this position for another half-hour while gently caressing each other with full attention on your feelings and exchanging energies. If penetration is desired, but an erection does not come on its own, then start gently rubbing the head of the penis between the lubricated entrance and the clitoris.

If this is not sufficient, it is relatively easy in this position to insert a soft penis. This may be a solution for men with erection problems. If you firmly hold or squeeze the shaft of the soft penis, then any blood is pressed towards the head of the penis and insertion will be easier. Once inside, gentle movements by both partners increase the chance of a partial or full erection.

Even without an erection, focusing the awareness on the contact within the vagina combined with slight pressure changes at the pubic areas can be sufficiently satisfying and may eventually lead to more. However, gently liberating and feeling your sexual energies and feeling at one with your partner does more for your well-being than chasing an elusive erection or orgasm. The main precondition for a successful outcome in resolving any difficulties is a freedom from any kind of expectations on both sides.

Even after penetration, continue to move slowly and concentrate on the sensations in the sexual organs and the flow of energy and feelings between your bodies. If both partners are sufficiently aroused after a prolonged foreplay, the vagina is well lubricated, and the male able to delay ejaculation, then the half-hour waiting time outside the vagina is not necessary and immediate penetration is acceptable.

Should ejaculation occur early, then just remain close together with the soft penis inside the vagina until about half an hour has passed from the time of penetration.

With such a complete exchange of male and female energies, combined with a full orgasm, there is usually no desire for another sexual union for several days, and it is actually best to wait for about five days until the full potential of sexual energies is restored. The following union will be more pleasant and satisfying than with more frequent encounters. It is, however, relaxing to sleep together with bodily contact.

The alternative to orgasm is a deliberate choice to use this union as a love meditation, also called spiritual sex or Karezza, from the Italian word carezza, signifying its caressing aspect. You can just continue moving slowly while caressing each other for hours, while concentrating on feeling the energies and radiating feelings of love onto each other. If this Karezza type of union is practiced routinely, then an elaborate foreplay to build up a strong sexual charge is not necessary, but may be used if so desired. Condoms inhibit the exchange of sexual energy, while lubricating oils or jellies may slow it down, but this is not a problem when remaining connected for a long time.

It may take some time and require several attempts to master this method and achieve a maximum of enjoyment, but it is well worth the effort in terms of improved health and personal relationships.

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Part 8
HEALING YOUR EMOTIONS

We all would like to live a happy, healthy, and fulfilled life, yet few seem to be able to do that. Why must we have so much suffering, failure, and disappointment? We want to be secure in a loving relationship and a satisfying job with a good income and enjoy ourselves. Instead, our relationships turn sour, we have a job that we do not like or we do not have one at all, there is never enough money, and generally there is not much joy to be found anywhere. As a result we feel resentment, hopelessness, and depression, perhaps also anger and hatred. Why did it go wrong?

I believe that there is a way out of this depressing jungle of negativity and disappointments and that we can make a decision to have a happy, fulfilled life, and then do it. What I cannot promise is that it will be easy. It needs willpower and determination and the help of good friends. But you have nothing to lose by trying, and each step in the right direction is likely to bring you some reward.

We can be happy, or at least accepting, in adversity, and unhappy when we seem to have it all. What determines how we react and feel? It is no secret to psychologists that we are programmed since earliest childhood by everything that went on around us, but especially by the way our parents talked to us and to each other, by the way they felt and reacted, and by our interactions with our siblings. We became programmed by obeying, observing, and imitating our role models.

If we were lucky and grew up in a happy and loving family, we probably have an inner program that makes it easy for us to lead a happy life in a loving relationship. If, on the other hand, there was much worry, anger, resentment, and negativity in our childhood, chances are we have a hard time being happy and loving as adults. That probably applies to most of us, the products of negative programming during childhood.

If we want to change, there is only one thing to do: change our subconscious programming from a negative outlook on life to a positive one. Unfortunately, we cannot simply decide that from now on we will be happy and loving. On their own, such conscious decisions have little influence on our subconscious programming. In fact, if there is a conflict between our subconscious programming and our conscious mind, the subconscious will always win.

Therefore, we must be clever and beat the subconscious at its own game. We must throw the old program out and devise a new one that allows us to be as we want to be now. However, it is not sufficient just to work with our feelings and emotions because these do not arise out of a vacuum. Our emotions are conditioned by our beliefs. We react more to our beliefs than to facts or anything else, so we must adopt an appropriate belief system.

Where do we find the beliefs we want? It is not sufficient to try to believe that we will be happy ever after. Our proposed new beliefs must be plausible to be acceptable to our conscious and subconscious minds. They must give meaning to our life and make sense of it all. Meaning is the opposite of the inner emptiness that

many of us try to fill with pleasure seeking and power games, causing so much emotional trouble in the end and depression if we fail. My proposed solution is a spiritual philosophy of life that turns emptiness into meaning.

There is also a strong influence of physical factors on our emotional life, such as nutrition and tense muscle structures. Therefore, in order to heal our emotions properly, we must work on all four levels of our being: the biological, emotional, mental, and spiritual.

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Step 57
UNDERSTANDING EMOTIONS AND DISEASE

Learn how you came to be so out of touch with your feelings, what emotional problems and diseases this causes, and how this is expressed in your body.

We experience ourselves in the world with our feelings and emotions. They are the driving force, the power, and the motor of our life. Without feelings and emotions, we would be like robots, computers operating bodies with the help of electric signals. It is the feelings and emotions, our likes and dislikes, that give our life meaning, that make us fulfilled or dissatisfied, and to a large degree decide our course of action and health. Diseases make us feel unwell and negative, and suppressed emotions are a major contributing factor to these diseases. When we are young, we are full of feelings, experience them strongly, and are sensitive and react immediately and directly to our social and physical environment. When we are old, our emotions tend to be a distant memory and diminished, and pain is often the only feeling left.

Many scientists at present are so divorced from their feelings that they believe these originate in the brain, like thoughts. They come to this conclusion because they do not feel the energy of anger in their body or the love in their heart. They just think anger or think love in the brain and act accordingly without feeling anything, or their feelings are only weak and diffuse. Of course, feelings are registered in the brain, but the feeling doesn't originate there.

Feelings provide us with the greatest pleasures in life, but also with the greatest suffering. Suffering is the key word to describe our loss of feeling with advancing age. We do not want to suffer, so we intentionally diminish our feelings in order to diminish the amount of emotional pain we feel. As an unintended side effect, this reduces the amount of pleasure we can feel. Hand in hand with our reduced overall feelings go a reduced enjoyment of life, reduced vitality, and an increased susceptibility to chronic degenerative diseases. This is a high price to pay for reducing the suffering that we might feel. In fact, we have exchanged bouts of intense short-term suffering for more low-key long-term suffering.

Helpful Definitions of Emotions: You may be unsure about the difference between feelings and emotions, so I will define the terms commonly associated with the world of feelings as they are used in this book.
I distinguish between three groups: sensations, emotions, and feelings. Sensations are body reactions due to physical or energetic causes: our awareness of hot and cold, touch or pain; during meditation or bodywork, we may feel warmth or tingling or a streaming sensation.

Emotions are inner states of experience due to nonphysical causes such as expectations, beliefs, and memories; they affect the body through brain and hormonal changes. Emotions commonly have a positive or negative connotation about someone or something: we are angry with someone, afraid of something, in love with someone.

Feelings in a wider sense are what we register as sensations or emotions. We say “I feel pain” or “I feel anger.” With this, we focus on the subjective inner experience regardless of the cause. We use the term “feelings” in a more specific way to describe inner states not caused by sensations or emotions, such as a feeling of well-being or a feeling of unconditional love during meditation. These feelings are emotionally neutral and not about someone or something. Another possibility is a dispassionate feeling about something as in an impartial judgment. At a crossroads, for instance, we may feel a preference for one road over the other. In most instances, however, this is not a proper feeling, but an intuition or hunch.

Moods are generalized feelings usually beyond our conscious control, and often with a somewhat negative connotation. Sentiments are more tender feelings, but usually about something and can be grouped with the emotions; desires are about something and are emotions. Passions are generally regarded as strongly felt and expressed emotions.

How We Lost Our Feelings: The widespread emotional misery in our society has much to do with our diminished capacity for feelings, especially for tender, loving feelings. If at all, we seem to experience these only for a short period in our life when we fall in love, and then yearn for them ever after.

The repression of our feelings seems to come largely from the male-inspired cultural priority placed on the intellect in our society, with a corresponding contempt for soft and tender feelings that are regarded as feminine. It is easier to gain power, to dominate, and to build an empire if one is not hindered by sentimental feelings. With their present bid for equal power, even many women cannot afford any more to be vulnerable and they steel themselves against feminine softness.

Self-control is highly valued, especially in the Anglo-Saxon cultures. We are not supposed to show anger or even displeasure, but rather be outwardly polite, though we may be boiling inside. Only in recent years has it become more acceptable to show tenderness in public, but even so, cuddling and touching, except in a ceremonial way, are still largely constricted to those who identify with the New Age movement. Conventional members of our society are as rigid and inhibited as ever.

We can say that our emotional dilemma arises from two sources. One is the suppression of our feelings enforced by the standards of our society, and the other is the lack of role models for the development of tender feelings in our childhood. Suppression of our feeling starts as infants when we are trained not to cry when we are unhappy. We may be just left to cry without response until we realize it is useless to express our frustration. Especially suppressed are any expressions of childhood sexuality, such as playing with the genitals and even cuddling the parent of the opposite sex or generally adults of the opposite sex.

Such contact is important to us later for developing mature emotional relationships and adult sexuality. Unfortunately, there is now a perception to regard such sexually open adults as potential child molesters; fearing this, they intentionally hold back, depriving themselves and the children of this essential expression of affection.

Also at an early age, we are trained in the use of social lies and social conventions and are discouraged to express our true feelings. It is even worse at school and university where we are overwhelmed by intellectual activity, usually of an

unimaginative kind. This inhibits our creativity and intuitive abilities. Many great inventors and innovative scientists did not make their discoveries by thinking but through intuition. For the rest of his life, Einstein reportedly tried to understand on the mental level what he had perceived in an intuitive flash.

Creativity is the active outlet for the meaning we give our life, and intuition is an important link between both. This combination gives satisfaction, perpetual joy, and happiness to our life, but it is crushed by our educational system in order to prepare us for the later institutionalized conformity in our workplace. A more suitable alternative would be an educational system based on the model of Steiner, Waldorf, or Montessori schools.

Emotional Role Models: The presence of positive role models for our emotional development is most important during infancy because then we are most impressionable and learn the fastest. At that age, we learn to feel by absorbing feelings from our surroundings like a sponge. This activates our feeling centres. If we are radiated with love, our capacity to feel love develops; if we are exposed to anger, then that is what we learn. I believe that because of their own love-deficient upbringings, most parents act lovingly towards their children from a mental level without actually feeling it. The most common exceptions are non-intellectual, soft, and “feminine” mothers, especially as personified by the typical Polynesian woman.

In many third-world countries, it is common for whole families to sleep in the same room, where children may be aware of the sexual activity of their parents. This is natural, as it is in the animal kingdom, and provides role models for subconscious programming. But it is essential that the sexual interaction, like any other interaction of the parents, be a loving one. This imprinting is most important for infants and does not need to interfere with our more inhibited Western morals for older children who, unlike infants, prefer their own rooms anyway.

The lack of tender feelings combined with an exposure to negative emotions from the parents in early life has much to do with the present culture of violence in our society. This is constantly reinforced by the bombardment of violence on television and movie screens. With their tender feelings undeveloped, many do not feel the suffering of others; they simply cannot feel compassion. That may start in children with cruelty to animals and lead to individualized or institutionalized cruelty and torture when adult.

A national football coach is quoted as saying that to be successful in a contact sport you must build up hate for the opponent before the game. He is right in that hate releases stored negative energy and it may even be good that it does. Even the many onlookers can release some of their negative energy. But is this the kind of society we want, where our role models require hatred to perform? There must be a better way!

Emotions and Disease: There are many reports that demonstrate the strong influence of our feelings and emotions on health and disease. One example is a study of the survival rate of women with breast cancer. After ten years, 70 percent of those who reacted to the diagnosis with a fighting spirit were still alive; those who reacted with denial had a 50 percent survival rate; those with stoic acceptance had a 25 percent survival rate; and of those who felt hopeless and helpless only 20 percent survived.

Other findings show that cancer frequently is diagnosed about a year after a traumatic event, such as losing a spouse. The negative effect of mental depression on our immune system is well known, while we feel and to some degree are invincible when we are in love. When we are upset or stressed, our digestive juices are inhibited, and fear or apprehension can even trigger asthma attacks.

Another problem is with suppressed negative emotions. There is always the possibility that under provocation these may be released explosively in an act of violence. This pattern is now very common in our society. On the other side of the fence are those sensitive souls who are full of bottled-up feelings and emotions, but unable to release and express them. This drains their vitality and they suffer from poor circulation with low blood pressure, cold hands and feet, and lack of energy.

Generally, we can distinguish between acute or immediate influences of strong emotions and the long-term or chronic effects of unexpressed emotions. The immediate reaction is due to the direct influence of our feelings on the hormone-producing endocrine glands and on the nervous system. More insidious, however, are the long-term effects of muscle tension caused by suppressed emotions.

At the physical or body level, this leads to poor blood circulation and a reduced supply of nutrients to the affected area, while metabolic wastes and toxins tend to accumulate, similar to sediment in a slow-flowing part of a river. In addition, permanently contracted muscles generate a great strain on associated joints. A combination of these factors makes us susceptible to the development of arthritis. Constriction of the chest and diaphragm commonly leads to respiratory diseases.

Muscle Armouring: Muscle armouring is a concept described by Wilhelm Reich, M.D., an eminent American psychiatrist and at one time the apparent intellectual heir to Sigmund Freud. Dr. Reich found that the emotional disorders of his patients were to a strong degree reflected in their body structure. In particular, patients with repressed feelings commonly had hard, rigid, and permanently contracted muscles in certain areas of the body. Different kinds of negative emotions seemed to be associated with specific muscles. Reich compared these rigid muscle structures to the armour of a medieval knight and called the process of their formation “armouring.” While the steel armour of the knight had the purpose of protecting him against physical aggression, the muscle armour protects us against emotional aggression.

It may sound far-fetched that contracted muscles should have anything to do with how we feel. But we can easily observe that we become tense when we are apprehensive and that our muscles relax when we are at ease. When we expect someone to cause us pain, such as sticking a needle into us or hitting us, we tense our muscles and we may hold our breath by contracting the diaphragm.

These are automatic body reflexes designed to diminish the expected feeling of pain. However, we can use the same mechanism if we want to diminish feelings for other reasons. As an infant, we may have been afraid of being separated from our mother, of being left alone in a strange surrounding, so we tensed up and held our breath. Eventually, we had to continue breathing, but we did it in a shallow way, with contracted diaphragm and chest muscles.

What Body Language Tells Us About Our Emotions

This summary is a condensation of ideas from Body-Mind, by Ken Dychtwald.

Legs: How we move through life.

Weak, underdeveloped: not well grounded, no firm stand in life

Massive, overdeveloped: rigidly grounded, needs to explore, let go

Fat, sluggish: to move through life needs enthusiasm, jogging

Thin, tight: moves energetically through life, but often erratically, not gracefully, needs to develop tranquillity

Pelvis: The condition of our sexuality

Front tipped downward causing hollow back (lordosis): usually string sexual energy, but full flow is blocked through constant self-control, not able to 'let go' – develop faith in higher guidance.

Front tipped upward causing flat low back: lessening of sexual focus, lack of tender feelings in the lower part of the body – learn to lower attention from chest to lower abdomen, develop tender emotions

Belly: The centre of emotions as they relate to oneself

Enlarged in upper half: rugged, outgoing, masculine – develop more tender feelings

Enlarged in lower half: blocked energy flow to pelvis and legs especially if the abdominal wall is hard – let go

Moderately enlarged: if belly is soft and back not very hollow, good contact with body vitality, possibly emotionally too soft

Overall enlarged and obese: usually poor contact with vital energies

Overall flat: too much mental control, no "gut feelings", strong emotional blocks (fear, anxiety) – develop tender emotions, have faith, let go

Chest: Modifies our emotions as they relate to our intentions in reference to ourselves

Narrow, contracted: feeling of inferiority, lack of power, unexpressive – learn to communicate, to give, chest breathing

Wide, expanded: feeling of superiority, power, expressive – learn to experience tender feelings within, especially in pelvis, learn from others, abdominal breathing

Shoulders: How we carry our burdens in life

Bowed, rounded: feel overburdened – develop power, chest breathing, have faith

Raised: chronic fear – anxiety-releasing therapy, chest breathing

Square: carries responsibility – relax

Forward hunched: fear of being hurt, self protection – develop power, chest breathing

Pulled back, retracted: forceful control or suppression of unwanted emotions, especially anger – let go, express yourself in a suitable way

Narrow: cannot shoulder responsibilities – become more powerful

Right side lower: interacts in a predominantly masculine way

Left side lower: interacts in a predominantly feminine way

Arms: How we express ourselves in physical actions

Weak, underdeveloped: lack of initiative and physical expression – learn to communicate with your arms

Massive, over muscled: insensitive, forceful interactions, lack of grace – learn to be gentle

Thin, tight: inability to hold on to anything – become more peaceful, settled

Fat, underdeveloped: sluggishness in expressing yourself – become stimulated, animated

Upper back: A channel for the expression of forceful or violent emotions

Soreness, hump: repressed anger or hitting reflex – let go; hit a pillow or sandbag

Neck: Reflects tension between body emotions and mental control

(continued)

Bent forward: explores the world first in a rational way, emotional exhaustion – develop your 'gut feeling'

Bent to the right: arrogance, defiance – become centred

Bent to the left: playful attitude

Long, graceful: proud attitude

Heavy, short: forceful attitude

Throat: A channel for vocal expression of emotions

Tight, sore, weak: blocked verbal expressions of emotions and tears – let go, speak out, weep

Jaw and Chin: A channel for verbal expression, biting

Receding: frozen, suppressed verbal emotions – learn to speak out

Protruding: determined

Strongly protruding: defiance, arrogance – relax

Clenched: forceful, self-control, suppressed anger – let go, relax

Face: An outside mirror of our emotions

Changing expressions: show how we wish to appear to the world

Chronically tense muscles: show conflict between what we show and how we really feel

Eyes: The "windows of the soul," reflecting health and emotions

Large, round: warm, loving personality Protruding: reaching out forcefully (thyroid problems)

Deep-set: critically observing, withholding expression

Wide-open baby eyes: tries to hold, to draw close, not fully matured

Nearsightedness: frozen fear (early childhood), focus on immediate problems, introspective, rational - release fear, look into the future

Farsightedness: suppressed anger; focused outward, extrovert - release anger, develop your inner self.

With repeated fear responses, these muscle contractions can gradually become permanent. The child can grow to develop a narrow chest with weak lung functions, or if only the diaphragm remains contracted, a barrel chest can result. In both instances, breathing remains permanently shallow and the child is susceptible to lung infections and asthma. In babies, this may be a contributing factor in crib death or SIDS. The advantage of the armoured chest or permanently contracted diaphragm is that we now do not feel our fear anymore, as it remains subconscious. However, we gradually may develop substitute outlets for our fear, such as being afraid of heights or of public speaking, and so forth.

Another example is the suppression of anger because we are told that it is not socially acceptable to show it openly. We may initially feel an angry emotion rushing upwards from the abdomen to the shoulder with the impulse to hit or to the throat with the impulse to shout. When we suppress these impulses, the emotional energy of the anger becomes stuck in the shoulder or in the throat and tenses the muscles there. If this tension is not released by other means, it may become permanent, and if we continue our suppressive behaviour pattern, these muscles become permanently contracted. In joints surrounded by contracted muscles, we easily develop arthritis, while contracted throat muscles give us a weak voice and possibly stuttering and other speech and throat problems.

The muscle armouring becomes ever stronger with advancing age because we tend to repeat our set behaviour patterns. This then forms our distinctive facial features, body structures, and our increasing rigidity. There are, of course, other

factors that contribute to shaping our body and making it more inflexible, such as heredity, nutrition, and occupational muscle use.

Dr. Reich found that his cancer patients had severely inhibited sexual energies caused by strong armouring in the pelvic and abdominal areas. Those patients who could most successfully free their sexual energies had the best chances of recovering. He regarded cancer as a “shrinking biopathy” of the total energy field of the patient. This shrinking was seen as a forerunner and not as a consequence of the disease. Tumours are only the final stage of the shrinking process, Dr. Reich said. When he succeeded in shrinking the tumor or making it disappear without revitalizing the general energy flow, the patient would die anyway. Spontaneous remissions, on the other hand, were in some instances due to a revitalized energy flow, Dr. Reich said.

Another aspect of armouring is the generation of pain. The resistance of a contracted muscle to the flow of energy produces pain similar to the heat produced by the resistance of a thin wire to the flow of electricity. Short-term muscle contraction uses energy; therefore, it causes no pain and can be used as a defence against expected emotional or physical pain.

However, if a muscle remains permanently contracted, the reduced blood and energy flows cause pain from accumulating toxins, oxygen deficiency, pressure on nerves, energy congestion, and overactive acupuncture points. Such pain may be present all the time or felt only as tenderness when the muscle is pressed. It can be stopped immediately by pressing into tense muscles or relaxing them with other methods. In a permanently contracted muscle that has become like a rope or sheet, the energy flow to the area is so diminished that there is no pain, even when pressed. Repeated deep muscle massage can eventually restore energy flow and temporary pain to the muscle. Some individuals can clairvoyantly perceive these energy flows.

Body Language: Our emotions have a strong influence not only on our glands and inner organs, but also on our body structure. Certain emotions are traditionally linked with problems in certain organ functions, as noted in part 7. Anger, for example, damages the liver and, conversely, irritability and quick temper are partly caused by liver problems. In a similar way, grief, negativity, and anxiety are linked to the lungs; fear to the kidneys and intestines; excessive laughter or lack of joy to the heart; and worry to the spleen.

Emotions, if not released in outward action, “solidify” by causing muscle contractions. The stronger the energetic charge of the emotion, the stronger the muscle contraction. Other parts of the body may be more or less blocked off from the flow of emotional energies, and these parts will become weak and start degenerating. By examining our body, we can get a reasonably good idea of the kind of emotional problems that have helped to shape it and of the corrective measures to be taken in order to improve ourselves (see Table 7-3 above).

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Step 58
HEALING RELATIONSHIPS

Try out these tools to heal your personal, family, and social relationships.

We live in three different forms of relationships - our higher relationships with God and the spiritual dimension; our relationships with our planet and its life forms; and our interpersonal relationships in society.

In holistic living, we move towards greater harmony on all three levels. Meditation and following a spiritual path are our attempt to heal our relationship with our spiritual source, while an attitude of loving care towards our planet and its creatures will heal our relationship with our biological roots.

Our social relationships, in a way, are the most difficult to heal, for they are the testing ground for what we have learned and how far we have spiritually advanced. With much effort and by using emotional release, reprogramming, and meditation, we may feel that we have made much progress in healing ourselves. But have we? We can only find out in our social interactions.

Are we upset if someone makes a mistake? Do we suppress our annoyance, or do we speak out, and, if so, in a suitable way? Do we instead feel like pointing out what has been done wrong and how to correct it, or do we prefer to let the other discover this for himself? These are all different possibilities for responding to the same problem, and the way we respond can show us how much we are already healed and what we still have to do.

To make it more complicated, there is no correct response that suits every situation. Sometimes one response is the best for a given situation and at other times another response would be more suitable. This means we need to become flexible and respond to each situation with an open mind and open heart, rather than rely on past patterns of responding. Further, no matter how well we fare in these tests of everyday life, can we be fully happy and satisfied if we encounter on the streets or on television the suffering of our underprivileged brothers and sisters? I do not think so. With our increasing sensitivity and compassion, this causes us to suffer ourselves and we feel drawn to help others. Again, there are different ways in which we can respond to ease our common suffering. Foremost may be to give hope and healing by our living example.

We can also donate money, goods, and services to the needy. We can single out an individual for special support or we can work through an organization; we can use the political system or in other ways try to change our whole structure of social injustice. What will it be? Increasingly, we will be drawn to do something because we feel and know that we are all one. Whatever our choice, it is not a question of right or wrong, but of trying to live according to our highest ideals, using the opportunities as they arise.

Intimate Relationships: Our intimate relationships, more than anything else, are a testing ground for our feelings and emotions. They can make us feel on top of the world or in the depths of depression. How do we cope with these strong feelings

and emotions? Our intimate relationships are a mirror of our general level of consciousness; they show us how well we are able to manifest our ideals in everyday life.

There are different kinds of intimate relationships. In the best sense, they all will be love relationships, lovingly relating to a partner, be it in marriage or without a legal status, short-term or long-term. Preferably, we try to find a partner with similar or compatible ideals or we try to improve our existing relationship by finding and harmonizing our ideals. Our common ideals, more than anything else, can help to ensure a happy and fulfilled long-term love relationship. A relationship based mainly on sexual attraction or a need for material or emotional security, on the other hand, does not have a solid foundation and is likely to fail.

In our society, it is fashionable to make romantic love the deciding factor for marriage. However, this is the kind of love of which it is rightly said that love makes blind. With this, it combines the two worst factors for marriage: It does not last and it blinds us to the shortcomings of our partner.

After a few years, the erotic appeal has been swept away and the relationship faces the test of reality. In many instances, the couple stays together only for the sake of the children; in others, it is the need for emotional and material security. A new romance is now sought outside of marriage. Sometimes this leads to a string of marriages and divorces based on erotic straw fires.

The only hope for such a marriage to provide a happy and satisfying relationship is the transformation of erotic love into mature love. Sometimes this just happens on its own with compatible individuals, others have consciously to work towards this goal. While it is said that one cannot make oneself love someone, one can work, nevertheless, on diminishing one's ego, which is the greatest obstacle to loving the other as a person.

I see the greatest chance of successful transformation into mature love when both partners become interested in inner growth and self-responsibility and start walking the spiritual path hand in hand, healing themselves and each other. You could also join with other couples who have similar interests.

Making a Relationship Work: One of the most destructive elements in many present relationships is the demanding of rights. Traditionally, males have had most of the rights, and a relationship can develop in this way today without any effort on anyone's part. This commonly leads to the emotional deprivation of and increasing resentment by the female partner. The other side of the coin is the growing trend of Western and especially American females to be assertive and demanding in a relationship. This tends to push the male partner away and results in the male emotionally withdrawing; or the relationship becomes an arena for competition and fighting. The solution depends on a cooperative approach.

This may start by one of the partners realizing that the competitive approach does not lead to happiness and makes the relationship unpleasant. The main thing that this individual needs to realize is that he cannot change his partner by demanding or expecting change; each can only change themselves. Depending on the nature of the relationship, the partners may talk over how to change track or the partner who realizes this may take the first steps alone.

An example of this is the current movement in the U.S. of “surrendered wives,” which started as a counterbalance to the demanding of rights by “liberated” females.68 This certainly is a recipe for creating happier relationships, as long as it does not lead to resentment on the woman’s part. With this unconditional first step, many women will transform their partner; he will become much more considerate and pleasant to live with. However, it may not work in every case and occasionally leads to increased abuse and separation. Nevertheless, this is a spiritual solution to turning a difficult relationship around and trying to make it more rewarding for both partners.

In most instances, females want a partner who embodies their ideal of masculinity, while males want their ideal of femininity. I am not referring here to physical appearance, but to emotional qualities. Therefore, try to find within yourself and offer to your partner the best male or female qualities that you are capable of. Do this with a loving heart and without demanding or expecting an instant reciprocal change from your partner. In most cases, your partner will begin to change for the better of your relationship.

Things that your partner did not do or did only with resentment when you demanded them may now be offered as gifts. Instead of nagging or demanding what you want your partner to do, the right attitude is to think of what you can do to make your partner happy. However, if your partner is unwilling or unable to change in return, and repeated discussions do not lead to a satisfactory result, then separation appears to be the best solution. It is not a sign of spirituality to let yourself be emotionally abused and suffer in silence. If you believe that circumstances force you to remain with an uncooperative or abusive partner, then use this opportunity to learn and practice unconditional love and forgiveness.

The keys to making a relationship work are goodwill and communication. We must learn to share our inner life with our partner. It is also important how we share. We let our partner know that we feel hurt by something he or she did or did not do, but we do not accuse. We speak of our own feelings and may say, “I feel hurt by what you did,” but we do not say in an accusing voice: “You did this to me.”

Initially, it may be good to agree on set times for sharing. Ask your partner if something annoyed him or her and then let your partner speak without interruption. If this direct approach is too difficult in the beginning, keep diaries about your hurts and suggestions and exchange them from time to time for discussion. However, the same basic rules apply: Do not accuse or verbally attack your partner and give each other uninterrupted time to speak.

Infidelity: Infidelity is possibly the most common cause of severe relationship problems. From a spiritual (not a religious) point of view, the real problem is not that our partner shared love or sex with an outsider, but that he or she broke the stated (or unstated) trust in the sexual exclusivity of our relationship. One partner then feels resentful and the other guilty. This is not a recipe for a happy relationship, and how soon and well it can be mended depends mainly on the spiritual quality of forgiveness on the part of the hurt partner.

Looking at this from a spiritual point of view, it is quite natural for a sexual attraction between males and females to develop in suitable conditions, while on the other hand it is not good for our spiritual and emotional well-being to suppress strong longings or desires. This leads to a typical dilemma: We have a choice either to harm

ourselves through emotional suppression or through feelings of guilt with a possible deterioration of our relationship.

A spiritual way out of this is to learn to transmute our sexual feelings for an outsider into unconditional love and to beam this back onto this person. Another possibility is instead of sharing sex to restrict an intimate encounter to a (fully clothed) meditative cuddle.

If your relationship is sufficiently open, you might also discuss if and under what conditions a sexual encounter with an outsider is acceptable. You may realize that the demand for exclusive mating rights is due mainly to a combination of our social conditioning and fear of losing our partner. This is not a solid foundation for a spiritual relationship. Instead, if sexual fidelity is important for your relationship, then it should be freely agreed to by both partners because that is how you feel about each other and that is what both really want.

However, emotionally mature partners will not make this a relationship law because they realize that we are not perfect. If one partner is not able to keep this agreement, then the spiritual solution is to ask the other partner for forgiveness and to obtain it without any damage to the relationship. If both are secure in their love for and commitment to each other, then they may not even wish to emotionally restrict or deprive their partner. However you work it out in your relationship, try to find solutions that are based on openness, understanding, and forgiveness.

An Example of a Caring Tribal Society: We may sometimes wonder what it would be like to live in a genuinely loving and caring society. Surprisingly, such societies have existed, even in modern times. In 1929, the anthropologist Bronislaw Malinowski published an account of his two-year stay with the Trobriand Islanders near the east coast of New Guinea.

All the people there were happy and caring, he reported. They shared with each other and liked to work. Children were always good-natured and conformed effortlessly to the rules of their society; and they had one freedom that appears unbelievable to us: There was not the slightest restriction on their sexual activities. There was no emotional suppression.

Children watched their parents and others making love and when growing up started imitating them. Younger children would just tenderly play with each other, while teenagers had unrestricted penetrative sex. However, there was one important social convention: Pregnancies must only occur in marriage. These islanders actually did not know that sex had anything to do with getting babies. Everyone believed that babies were a gift of the gods given about nine months after the wedding, because it always happened that way. Without any other precautions or protection than this belief, babies out of wedlock were unknown.

After loving experiences with many different partners, the youngsters eventually found their marriage partners. Marriage was desirable because it gave babies and status. The marriage lasted as long as the couple loved each other, usually for many years or a lifetime. While married, there was never any unfaithfulness or even a desire for it; they did not even have a word for it.

Marriage breakup was no disaster for the children. The father always remained a good friend of the mother and the children. Furthermore, as they did not have the

concept of a biological father, the maternal uncle always played the role of the father. This was a matriarchal society and all property rights went through the mother to the children.

As these people could observe all varieties of loving sexual activity, they had no unhealthy fascination or obsession for them, as do many people in our society. Consequently, abuse of children, sexual perversion, rape, or other forms of violence were unknown to them. Sexual activity to them was as natural and open as eating is to us. No doubt, if eating were regarded as “dirty” and restricted in the same way as sexuality is, and children and others were not allowed to see us eat, most of us would have neuroses associated with eating disorders. This association of sexual freedom with a peaceful society can also be observed in the animal kingdom with the bonobos, smaller relatives of chimpanzees.

Another Example - the Continuum Concept: In the 1970’s, the American Jean Liedloff lived for several years with the Yequana Indians in the jungles of Venezuela. She discovered that these Indians lived in a continuum of unbroken traditions in close harmony with their inner and outer nature. This appeared to be the reason for their unusually positive qualities.

There was no trace of aggressiveness towards each other amongst the Yequana, Liedloff found, even if they were all drunk at an occasional party, and they never blamed anyone for anything. Even in difficult circumstances, they remained in a composed and happy state of mind. There was no competition in their interactions, only cooperation.

They were completely fearless, surefooted, agile, and enduring. At rest, they were totally relaxed, but could be fully alert in an instant. To illustrate this in a funny way, Liedloff related that sometimes one of the men would wake in the middle of the night, remember a joke, and start telling it. Instantly, all the others were wide-awake, roared with laughter, then seconds later were sound asleep again.

They loved to work, and for them it was a pleasure to use their bodies. They did not even have a word for work; they just did cheerfully whatever needed to be done. The children were always well behaved, obeyed happily and instantly, never fought among themselves, and were never punished. How they raised their children was, of course, the secret to their success as human beings and as a society.

Until the babies indicated on their own that they wanted to start crawling, they were always carried, usually by the mother. During sleep, the baby remained in body contact with the mother. There was no danger of injuring the baby when rolling over, as subconsciously, the mother always remained aware of the position of the baby.

After the baby started crawling and later creeping, the mother was always available when the baby desired body contact. However, the mother would not tell the baby what to do or not to do. There were sharp knives lying around, which the baby might pick up by the wrong end to play with. There were deep pits or dangerous drops near which it might play without an anxious glance from the mother. It might even pick up a burning branch from a fire and stumble around the thatched huts. There were no warning calls and no accidents.

Neither were the children told when or what to eat or when to sleep or which role models to follow. Boys quite naturally picked up bows and arrows from other

boys and started shooting with sharp arrows without being shown where or what to shoot or any safety precautions. They might start doing this at the age of 18 months.

Girls at that age, on the other hand, might join a group of women and girls and practice grating roots. At the age of three or four, a girl might be in charge of an infant; play and work are the same to them. An adult might need something, give a short command or request, and the child would instantly comply.

The parents trusted the innate protective instincts of their children. A baby might appear to be oblivious to danger when playing at the edge of a cliff, but its subconscious or body self protected the baby much more effectively than the mind could, just as it does a sleepwalker. If we warn an infant of a danger, its mind starts interfering with the body self and it loses its instinctive protection. If, on top of this, the parent is afraid that the child will fall, then it will try to fulfil this expectation and fall.

Small children are psychic and always try to meet the expectations of their parents, especially of the mother. The Yequana children never fail because their parents have unwaveringly positive expectations. Children are neither blamed nor praised for anything, just confidently expected to do the right thing.

Further, babies in that society are deliberately exposed to the widest possible range of sensory stimulation. From this and by observing adults and older children, they learn to judge unfailingly their ability to cope with each situation, and their parents completely trust their judgments. They know that if the child is not confident to judge a situation, it will ask a parent for help.

While these men were much tougher than men in our society, if one genuinely felt strong pain, such as when cleaning out a deep wound, he would not hesitate to cry out loud, comforted without words by physical contact with his wife or mother. If either a child or an adult lost their natural family, they were adopted into another family. This was important even for adults for emotional and social support. To show that the amazing abilities and behaviour of these children were not inherited, but the result of their upbringing, Liedloff reported there was one problem child. This child belonged to a Yequana couple who had lived in contact with our Western civilization for some time; but this child also learned (belatedly) to fit in.[69]

Emotional Security in Children: We all are likely to benefit from increased levels of emotional security. Emotional security is a nebulous concept that includes how we feel about ourselves, how good we feel in relationships with other people who are important to us (e.g., family), and how confident we are that things will turn out well for us.

Probably all of us feel some doubt in some of these areas, and especially children, if they are able to think in these terms. One of the main functions of a family unit is to foster feelings of emotional security in children, and often much of the irritating or negative behaviour seen in children can be removed through actively raising the child's levels of emotional security.

This is an easy claim to make but often a harder thing to achieve. Here are some techniques that I recommend to try to raise the level of emotional security in children:

1. Set aside three to five minutes every night for the child. After the child has gone to bed, Mom or Dad (take turns) goes in, turns off the light, and sits on the side

of the child's bed in the dark. The child is in the security of its own bed, with a little body contact with the parent, and no eye contact, because it is dark. Then the parent should just talk about their own day, share some of the things that happened; no questions asked nor asking the child to talk. When the child learns that this is a regular occurrence, he will initiate things and feel free to share, and topics involving emotional stress are likely to come out.

2. When the child makes a statement to you (e.g., "I hate school"), try not to block it or answer the comment; extend it instead. The child may not realize the feeling behind this statement, and you may never find out unless you can get the child to clarify it. Hand it back to the child in a questioning way: "You hate school?" To which the reply may be, "No, just the teachers." So you say, "You hate all the teachers?" "Well, not all, mainly Mr. Jones."
3. The question "Why?" rarely achieves anything when asked of little children. Seldom can they provide an adequate answer to such a question, and so, effectively, they are cornered. Try to avoid asking "why."
4. Avoid the words "no" or "wrong," especially when the child is attempting to do something (e.g., reading). "Almost right" or "not quite but getting better" are likely to keep the child interested and keen to try. The words "no" and "wrong" are likely to make a child give up as a failure.
5. Let your children know that they are good at things, that they are nice people, and that you like them. Generally, we tell our children when they fail, when they annoy us, or when we feel let down by them, but we don't let them know the good things. Many children thus get the impression that they are failures and develop a poor self-image.
6. Right-handed children like to sleep on the right side or on the stomach with the head to the left shoulder. Left-handed children generally sleep facing the other way. Try to place your child's bed so that in the natural sleeping position (according to handedness) she sleeps facing the wall. This tends to give the child added security and often has the effect of eliminating problems with light sleepers as well as nightmares and bed-wetting. Placing a child's bed at right angles to a wall, extending out into the room, should be avoided with children who are light or restless sleepers, as it provides little or no security to the sleeping child.
7. If a child needs a night light, try a blue or green bulb rather than a normal white or red one. Blue and green are pacifying colours, whereas red is stimulating. Also position it so that the child's face remains shaded, so as not to interfere with melatonin production during sleep.
8. Accept your child's reality. If the child is upset or scared about something, irrespective of how irrelevant or trivial it may seem, accept that this is the real feeling of the child. Rather than dismissing the complaint or saying that it does not matter or not to be silly, ask what the child is feeling; then go through these feelings so that the child can either accept or work around the worrisome feeling.

9. Set aside a short amount of time on a regular basis in which your children can have your undivided attention; this could be perhaps ten minutes in the evening, or while doing the dishes. This can help avoid the repetitious “in a minute” response that we constantly find ourselves giving to our children.
10. Read to your children. Younger children (two to six years old) enjoy and benefit from favourite books being read to them numerous times; they can learn the whole story by heart and can “read” it back to themselves just by looking at the book. Older children (seven to ten) benefit from having something interesting read to them by a parent, so that they feel they are sharing a common interest with the parent; suitable may be historic stories or children’s encyclopaedia stories.
11. Fool around with your children. Let them see that adults can laugh, play, and be silly.
12. Be consistent. Consistency on the part of adults is of prime importance. If you act consistently, the child will know where he stands. If not, the child will be confused and become unpredictable as well. Always do as you say. Do not threaten punishment unless you are willing to carry it out, otherwise you lose credibility. The same applies to offering rewards.

Redoing Our Social Relationships: As compared to the Yequana, we live in a primitive society when it comes to our social relationships. I believe that future generations will see our society as severely unbalanced, as an overdeveloped technocracy built on a socially sick base. We can learn from the Yequana how to heal our society: It starts with our relationships with our children. For a long time to come, we will not be able to rely on authorities and experts in this endeavour; instead, idealistic individuals and groups must take the initiative.

Parents, preferably within the framework of a support group, must start experimenting on how to raise their children according to continuum principles as explained above. This is not easy in our situation. It involves not only a child’s constant close body contact with the mother or other carers for the first six months and a trusting attitude with positive expectations, but also the presence of other children in a wide range of ages as positive role models. Two-year-olds learn best from three-year-olds and they in turn from four-year-old children.

It can be done. I have known mothers who kept body contact with their babies until they wanted to start crawling. I have seen a three-year-old boy without close supervision or need for safety concerns use a sheath knife, hatchet, electric drill, and a blowtorch, then he immediately and happily ran home when his parents called. I believe that children, if they feel secure and loved during their early childhood, if they have a wide range of relevant sensory stimulation and positive role models, can be trusted even in our modern technological society.

Obvious dangers, such as knives, staircases, or pools, should not be a problem. Babies easily learn to float. I see less of a chance of a secure child drowning in an unfenced pool than an insecure one drowning in a fenced pool. Make hidden dangers known to your children through your own behaviour. Children imitate; therefore, do not do in their presence what you do not want them to do.

Antisocial behaviour is a sign of emotional deprivation, especially in early childhood. Give your existing children and especially those with antisocial or neurotic tendencies the opportunity to experience the missed phases of their emotional development. Explain to them in simple terms what you intend to do and why; invite your children, possibly one at a time, to sleep in your bed whenever they feel like it. Get them to do it even if they are initially reluctant; cuddle them a lot and possibly massage them, or bathe or shower together.

For infants, all this will be natural and enjoyable, but with older children emotional barriers may need to be broken down gradually. While loving sexual activity in the presence of infants is desirable to provide a role model, for older children it might be upsetting to be exposed to it unprepared. Use your own judgment. Include the children in the tender relating of the whole family, but in a way that does not intentionally cause sexual stimulation.

Healing Relationships to Produce Social Change: Emotionally deprived children grow into adults who have antisocial or asocial tendencies. On one side of the scale, this manifests as criminal and destructive behaviour and, on the other, as shyness, lack of confidence, and depression. A further result is the ego-centred individualism so prevalent in Western societies. It brings forth political, business, and community leaders who are more interested in personal power and wealth than in the overall good for society.

In contrast to our present system, which I would describe as one of adversarial competition, a society of emotionally mature individuals would be based on benevolent cooperation. Elected representatives, for instance, would fully cooperate to find the best solutions for the common good, and the most suitable citizens would be chosen to be these representatives.

Business ventures would operate according to cooperative principles, both in matters between different ventures and within each, and without a sharp division between capital and labour. This was the social structure of the Yequana Indians and the Trobriand Islanders. However, to be successful in modern society, such a system must be based on spiritually and emotionally mature individuals.

A first step towards reforming the present business climate would be a legal and community expectation that the main duty of care for corporations is to the whole of society rather than to their shareholders. The reason for the existence of companies would be seen as service to society; a company would appreciate its duty of care to its employees, shareholders, and the environment. A further step could involve government incentives to form cooperative ventures.

The judicial system would be based on conciliation and rehabilitation. The more emotionally mature the society, the less would conflict arise. The health care system would largely become redundant as people learned to live in harmony with their biological, emotional, mental, and spiritual needs. Any necessary therapy would be a combination of the best in modern and natural medicine.

Agriculture, food processing, and energy production would be sustainable and in harmony with planetary requirements. A society of self-responsible citizens would be based on a maximum of individual freedom and a minimum of bureaucratic interference.

No system of laws and law enforcement will keep a society of deprived and ego-centred individuals operating harmoniously, yet emotionally satisfied and responsible individuals will function well in any system with a minimum of rules. The main problem, therefore, is not to devise better political and social systems and improve our laws and wealth distribution, but to provide the opportunity for everyone to heal their emotions and start on the road to self-responsibility. A harmonious society will then evolve from this.

Cooperative Solutions Based on Emotional Fulfilment: Here I offer a few examples to show how a caring society based on emotional fulfilment, as outlined in this step, might solve some contemporary issues.

The most important aspect would be to raise all children in a caring and loving way, following for example, the principles of the Yequana continuum concept, to ensure a harmonious society in the future. The school and education system would concentrate on developing cooperation, creativity, intuition, and holistic concepts similar to Rudolf Steiner, Montessori, or Waldorf schools.

There would be no political parties or electioneering. In one possible model, electors would write the name of a community member of their choice on the ballot. Leaders would be chosen for their experience, maturity, spiritual insights, and wisdom. The elected leaders from several neighbourhoods would form local councils of wisdom; these would then elect someone from their midst or possibly an outsider to represent them at the next higher level. In this way, it could continue upwards to create a world council of wisdom.

Very suitable as community leaders will be women who have harmoniously raised a family because they will be skilled in facilitating just and harmonious social relationships. The legal system will be very simple, observed in spirit rather than letter. Together with other decisions affecting individuals, communities, and regions in their care, councils of wisdom on each level will also be responsible for any legal disputes and arbitrate in a spirit of cooperation.

Initially, the unemployment problem could be solved with flexible working hours. This means, instead of an unemployment rate of ten percent, the standard hours of work per week would be reduced by ten percent. Conversely, if a shortage of workers developed, the standard working week would be lengthened. Standard hours might be different in different professions or ventures. The government might just provide a basic safety net. Present government regulations generally make it more convenient to extend overtime hours for existing workers rather than hire additional staff. This is simply a problem of community attitude and government competence. Eventually, work will become a desirable outlet for creativity.

Based as it is on the adversary system, our society causes so much friction, conflict, waste, and incompetence that I estimate our present lifestyle could be maintained with less than a quarter of the present work input. However, this percentage would initially be higher in order to bring underdeveloped nations up to world standard and restore the planetary environment to an appropriate level.

In a mature society, only a fraction of present resources would be required for the legal, law enforcement, and prison systems, for the defence and pharmaceutical industries, and for the hospital system. Most of these could eventually be phased out. On the other hand, much more would be channelled into sustainable agriculture and

health-friendly food production, into education, training, and community facilities, including an appropriate public transportation system.

In regard to health care, I see a unified system of holistic medicine in which surgery and drug medicine are branches, like nutrition, herbalism, or homeopathy. Extensive clinical trials would determine the best combination of procedures for specific diseases. However, in an increasingly enlightened society, diseases as we know them will become increasingly rare. Surgery, for instance, would only be required for accidents. Most of the healing work in such a society would be concerned with promoting inner and outer harmony and spiritual growth.

Sexual Initiations: In regard to a more natural sexual development of children and teenagers, I see two possibilities. One is complete openness in sexual matters, letting children watch the loving sexual activity of adults without any restriction and imitate it as they feel ready to do so. This is nature's way as practiced in the animal kingdom and in human societies that still live close to nature. It does not necessarily lead to unwanted pregnancies, as shown by the Trobriand Islanders; other methods of birth control might have to be taught. How it would work out in the end depends on the customs of society and the examples provided by its individual members.

The other possibility is to transform juvenile sexuality into a striving for high ideals within the context of a loving and caring society. Infants, but not older children, would be exposed to lovemaking of the parents. At a certain age or level of development, girls would be ceremonially and lovingly initiated by experienced and spiritually evolved men, while boys would be taught by women with the same qualities. The teenagers might choose the initiators themselves or leave this selection to their parents. As a variation of this possibility, teenage couples could receive practical instructions before or during their first sexual encounter. This, too, could be done ceremonially. However, the main problem for teenagers is not to learn the mechanics of sexual union, but rather to become emotionally competent.

My preferred solution in a society with strong spiritual values would be to teach teenagers graded forms of spiritual sex in a ceremonial way as an initiation, and also the art of sexually relating in a loving way, again graded according to age. Different solutions will be suitable for different societies, depending on their degree of spiritual evolution, but almost anything would be better than our present system.

Of course, in our present situation all this sounds utopian. Unfortunately, I do not believe that a transformation into a more caring and mature society will take place gradually and in a coordinated way. I am afraid the present system will run into an acute crisis and more or less self-destruct. If and when this happens, it will be important to have mature leaders in all areas who then can pick up the pieces and show the survivors the way towards building a caring society.

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Step 59
HEAL IN GROUPS

Join a group of like-minded individuals with the goal of healing your feelings and helping others do the same.

The small nuclear family as the basis of our social structure is an expression of the ego-centred and individualizing nature of our society. It leads to social isolation, difficulty in relating and cooperating, and a disruption of the age-old continuum of traditions.

Formerly, and presently still in underdeveloped countries, humans enjoyed a continuum of learning experiences. Step by step, through observation and imitation, children learned how to care for babies, do the various forms of housework, repairs, and other skills, make love and relate in a loving way, care for sick people, give birth, and deal with death and dying. Grandparents made themselves useful and passed on their experiences. Now most of these skills are only incompletely learned from books or left to experts, and the art of relating and cooperating in groups is at an all-time low. Recent explorations in communal living are an attempt to return to the security and emotional closeness of the extended family and a more traditional lifestyle.

Activities in various clubs and special interest groups may lessen our social isolation, but this is only a bandaid. I suggest forming neighbourhood healing groups with the specific aim of healing ourselves, others, and our social relationships.

A healing group can provide many functions not normally available in our society. In a way, it can act as an extended family with an unlimited variety of support facilities, such as baby-sitting, child-minding, kindergarten and preschool, and possibly even alternative schooling. Members can help each other in all stressful life situations, be it childbirth, sickness, bereavement, unemployment, or building activity. There can be common fruit and vegetable production, a food co-op, communal library, leisure facilities, and shared expensive working appliances.

The main aspect of a healing group is healing activity on all levels. For healing the body, experiment with natural and holistic methods. Suitable communal healing modalities include massage, reflexology, acupressure, spinal therapy, meridian therapy, muscle testing, and allergy testing. Many different forms of massage can be used, such as stimulating massage, deep muscle massage, sensual massage, or energy distribution massage.

Individuals can share their personal experiences with the group in areas such as nutrition, color therapy, packs, or flower remedies. A member of the group may participate in a healing workshop and then pass on the experience to the others. The group can also invite natural therapists and other health professionals and healers for demonstrations, lectures, and teaching of specific methods.

There can be group evenings in which you exercise together, while on others you discuss interesting topics; someone may read a good book and report on it; or there can be meditation evenings, or all of these in varying combinations. You can

use group therapy for emotional release, do rebirthing and other emotional growth work together, and do a lot of hugging. Buy some books about emotional therapies for the communal library, and experiment.

A healing group can operate on two levels. On one level, it can be a neighbourhood support group with food co-op, shared child-minding, communal leisure activities, and so forth. On another level, individuals dedicated to healing can meet weekly for this purpose. A large garage could be converted into a group meeting place while smaller groups might meet in the living rooms of participants.
Here are a few of many possible group activities for developing feelings and relationships. In group exercises, wherever possible, try to pair off with a partner of the opposite sex, or when forming a circle, alternate the genders.

I SEE THE LOVE: The women sit in a circle, possibly on floor cushions or on the carpet. A man sits opposite each woman. If there is an excess of either gender, pair off with a member of the same sex. For a minute, look silently but tenderly into each other's eyes, trying to express and radiate love. Then, with a signal from the group leader, the men move to the next partner and again both meet each other in a tender gaze. In this way, the men move around the circle until they sit again opposite their original partner.

Now, while again looking into each other's eyes, the men say, "I see the love in your eyes." They can either repeat this phrase from time to time or a variation on it, such as: "Your heart is filled with love and it shines out of your eyes" or "My heart is filled with love; it radiates from my eyes."

After a while, the men can in addition start tenderly touching and stroking the hair and the face of their partner. After about two minutes, on a given signal, roles are reversed and the women express tender feelings in words and by touching and stroking the hair and face of their man. Finally, on the signal, the men move to the next partner and repeat the same procedure and so forth until they are back with the original partner. Now, one after the other, participants can describe their feelings and how it felt different being either the active or the passive partner.

THE SANDWICH: This is to recreate the security, love, and warmth of the foetus in the womb or the baby in the mother's arms and at her breast. Someone stands in the middle, front gently pressed to the front of a partner of the opposite sex, and with the front of another partner of the opposite sex against the back. The middle person has the arms over the shoulders of the front partner and the one at the back also stretches out around the middle person to the one in front.

Stay like this for several minutes, possibly lightly swaying if that feels better. In addition, you can have two more people lightly press against the sides of the one in the middle. See if it feels better if these additional "huggers" are of the same or the opposite sex as the one in the middle.

For a woman in the middle, it may also feel better to have another woman in front; just experiment with different combinations. You may, for instance, have four people of alternating sex standing as closely as possible with their fronts together, or the whole group can form a ring, each one standing pressed with the front against the back of the one in front. The ring may stand still or slowly move. Some of these formations can also be tried while lying down.

LEARNING TO TRUST: After pairing off, couples walk around slowly, intermingling with the others, but with one partner of each pair having their eyes tightly closed or blindfolded. After some time, you swap places.

In another exercise, form a circle with seven people and one person in the middle with arms crossed in front of the chest. Those in the circle lightly touch the middle person with their hands. The one in the middle has the eyes closed and after a moment the body relaxes and starts swaying. It will lean towards one pair of hands and is then gently passed around the circle. After a while you can make the circle bigger by adding more participants or just spacing yourselves out so that the one in the middle is inclined at a greater and greater angle. His or her body should remain straight with the feet in the middle of the circle. Those forming the circle can put one foot back to be able to support a greater weight.

In a variation of this exercise, one person stands with closed eyes and the back turned towards a mattress on the ground. Several helpers stand behind the person, with outstretched hands, and catch that person as he or she falls backwards with a stiff body. Gradually extend the range before catching.

HEALING PARTNERSHIPS: If there is no healing group that you can join, or sometimes even in addition to it, you can find a healing partnership. Ideally, that is with your present partner in a long-term relationship. However, many are not so lucky and often prefer to live on their own rather than in a stressful relationship. In this situation, you can find someone with the same interest in health improvement and spiritual growth, but without either one of you wanting a love or sexual relationship. You can then meet at set times, and do all the things that might be done in a healing group. This will probably be more suitable for mature-age individuals. Eventually, others may join in and then you have your proper healing group.

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Step 60
LEARNING TO FEEL

Feelings build the body; they are the glue that holds body and soul together.

Tender feelings make us open and vulnerable, but in order not to get hurt, typically we prefer to close up and not feel. This has the added advantage of making us stronger in our career because we do not need to take our feelings or the feelings of others into consideration.

Each time we suppress a feeling or do not express it in a suitable way, the generated energy solidifies into muscle tensions and armouring, as we learned earlier through the work of Dr. Reich. Eventually, this leads to widespread muscle armouring, a permanent state of muscle contraction; this closes off the circulation of blood, lymph, bioenergy, and, equally important, the flow of feeling energies. Once we are in an armoured condition, we cannot feel anymore, even when we want to. This applies especially to our tender feelings and is a great loss. Our conscious control is then out of touch with the body - its needs, wisdom, and the pleasure it could give us.

Thus we are equally out of touch with the requirements of others, with the forces of nature, and with our higher guidance. Everything is wrong if we are out of touch with ourselves and with everyone and everything else, and we have to rely exclusively on our ego-controlled mind. To heal our emotions, we need a fourfold approach:

1. We need to “let go” and release the accumulated negative emotions and associated tension.
2. We need to become aware again of how we feel and express our emotions appropriately.
3. We need to learn how to feel good about ourselves and others and to generate positive feelings.
4. We need to live in our daily lives what we have learned in our exercises.

Let Go of Negative Emotions and Tension: Feelings that we have not expressed and often not allowed ourselves even to feel have accumulated within us in the form of repressed emotions. They choke our emotional body in the same way as accumulated metabolic residues obstruct our physical body. In our relationships and social interactions, we react emotionally mainly with reactivated hurts within us and only to a lesser degree with true feeling to the actual situation itself. This causes endless frustration, misunderstandings, and disappointments in our daily lives.

In order to free ourselves of these emotional obstructions from the past, we need emotional cleansing periods in which we feel safe to release and express our suppressed emotions. This will already partly be achieved and made easier as a result of bioenergetic exercises, deep muscle massage, and other methods to relax our muscle armouring. Here are three helpful release techniques:

Forgiveness: The cornerstone of emotional healing is forgiveness. As long as we cannot unconditionally forgive ourselves and others, we remain trapped in past negative emotions. This prevents us from fully loving ourselves and others.

A good way to develop forgiveness is to make a list of everyone who has hurt you in the past or whom you may have hurt. Recall especially relationships with your parents, siblings, relatives, and partners. Think of incidents that may have caused anger, resentment, disappointment, sadness, fear, or insecurity. Then mentally go through each incident and note if there is still any trace of that hurt feeling in you. If there is, go deeply into it, reach the bottom of it, examine it from all sides; it may then evaporate.

If there is still some hurt, decide to free yourself of this. Do deep breathing and, with each exhalation, imagine blowing the pain into a balloon. When you have transferred all the hurt into the balloon, close it up and let it float off into the blue sky for the universe to take care of. Imagine yourself in the presence of the one who hurt you. Formally and lovingly forgive this person. A very important person to forgive in this way is yourself. Forgive yourself for all the distress and hurt that you caused other people. If you are not ready to forgive everyone unconditionally, come back to this step after you have worked more on your belief systems and adopted a spiritual philosophy of life. Realize you are not doing a favour to others by forgiving them, but to yourself by freeing yourself from destructive emotional toxins. This is similar to cleansing your body of chemical toxins.

An alternative is to write a letter to everyone against whom you still feel resentment and whom you are not able to forgive. Write exactly what the other one did and how it affected you. Then formally forgive them and express your love and appreciation. Give this letter to the recipient, or you can burn it and hand the matter over to the universe.

Intentional Direct Release: A simple and efficient method of emotional cleansing is possible in a secure relationship with an understanding and cooperating partner. When you feel angry, sad, or upset, tell your partner there is something coming up that you want to release.

It is often necessary to exaggerate our expressions in order to get to the old emotions. When you are angry during an intentional release, show that you are angry: Throw yourself on the bed or the floor, kick and punch a cushion, pillow, or mattress, wring a towel, scream, shout, or cry. Similarly with hatred, sadness, grief, or any kind of frustration, bring each out as forcefully as you can. Your partner can help you to deepen the feeling, telling you to get into it, to hit harder, cry louder.

Even in more restricted situations with other people, try to experience and express your immediate feelings in an appropriate way. When you are angry, say so and possibly hit with the fist on the table; when you have tender feelings, acknowledge them with a loving smile and, if appropriate, with a loving touch.

Re-enactment: In many instances an understanding partner may not be available for immediate release or the situation is inappropriate. Then it is best to re-enact a recent hurtful or otherwise frustrating experience, as long as it is still fresh in the memory and the feelings are easily aroused.

Do this at a convenient time in the privacy of your bedroom or in a car parked with closed windows near a busy highway (where nobody will hear you). Recall the details of the scene and your feelings; bring out these feelings as much as you are able to. A similar situation from the past may pop into your mind, a time when you felt hurt in the same way yet did not react to it. Relive and exaggerate the memories of this past experience to get to the old emotion behind your present feeling.

Learn to do this habitually. Whenever you encounter an emotional situation to which you cannot react in an appropriate way because of inhibitions or conventions, re-enact it and respond to it later and elsewhere in an exaggerated form. Do this for anger and hurts and also gratitude and tender feelings you were unable to express at the time.

EMOTIONAL THERAPY FOR CANCER: Many individuals and especially cancer sufferers are inhibited in their emotional expression. Often they are unselfish, quiet, and dependable, the caring and enduring partner in a relationship. However, they also tend to harbor resentments as they hold back in expressing their anger or their own needs. For them, family and partner come first, while they sacrifice their own desires and dreams. This then inhibits their life force, their inner drive, and vitality. In cancer lore, this type of behaviour has been called the Type C personality as compared to the Type A personality, which has the opposite character traits and a susceptibility to heart disease. Most cancer patients have a so-called Type C personality or behaviour. Type C personalities typically:

- Rarely or never feel or express anger or other negative emotions, such as fear or sadness
- Are patient, cooperative, appeasing, “nice” individuals, non-assertive and compliant with authorities
- Are extremely self-sacrificing and overly concerned with meeting the needs of others rather than their own
- Tend to hold resentments, instead of speaking out

Another emotional cause of cancer is an unexpected loss. This may be a partner or close relative, a job, business, financial security, or anything with which the individual has a strong emotional bond. In individuals with a Type C or cancer personality, such loss often causes a severe depression of the emotions as well as of the immune system, and any hitherto dormant or slow-growing tumours explode in a sudden growth spurt. These emotional cancer causes need to be rectified in order to give any additional therapies a chance to work. If you have the opportunity and financial resources, consult with someone who specializes in emotional therapies; otherwise work with your partner or a friend.

Write in as much detail as possible about the worst experience of your life; share it with a trusted person. Search your mind and write and talk to someone about your other resentments, hurts, disappointments, losses, and shattered dreams. Practice expressing yourself forcefully, even exaggerating gestures and body movements. Remember incidents that you did not like and induce and release anger by kicking and punching something; cry or scream if possible, then afterwards forgive yourself as well as everyone else for past hurts and mistakes.

Practice expressing emotions and feelings with your body. Read poetry aloud with feeling; express feelings through dancing, arm and hand movements, or pantomime. Find another dream, something worthwhile and exciting to do after you have recovered from your disease. Be assertive, especially with medical and other authorities; make sure that your emotional needs are met. Meet other cancer sufferers in weekly sessions for emotional group therapy and support; share information, meditate, and visualize together. Take control of your therapy program.

I believe that your emotional transformation through learning to express your emotions is the key to winning the battle with cancer or any other disease. In summary:

- feel your negative emotions and express them appropriately
- feel your emotional needs and move towards fulfilling them
- uncover and release all resentments
- forgive yourself and others for anything you or they may have done
- speak out, become assertive
- trust your own knowledge and intuition
- find a dream that you would love to make come true in coming years
- become enthusiastic about your present life and future

Keep these points in mind and move towards changing your behaviour in small steps in your daily life whenever an opportunity presents itself. Use mind improvement methods, such as meditation, affirmations, and guided imagery or visualization, to shape yourself and your future as you want it to be.

Overcome Fear: A disease such as cancer provides us with a great opportunity to learn to care for our body, to heal our mind and emotions, and to become spiritual. Some of the inner causes of cancer are long-standing resentments, habitual worries, inner hurts or grief, guilt, repressed sexuality, and a lack of joy and spontaneity. All of these are expressions of fear and we need to overcome them by developing unselfish love.

One of the most basic fears to overcome is the fear of dying. This can best be done by seeing yourself as an immortal soul who temporarily inhabits and operates a biological body to gain certain experiences. Numerous near-death experiences show that death or shedding the biological form is generally a liberating and pleasant event for the soul; you may have similar experiences to this during meditation.

Another fear is fear of pain and dependence on others, especially in an impersonal and technological hospital setting. By using holistic medicine, you can remain in charge. Even if you are too old or start holistic therapy too late, you can expect to spend your last days in a dignified way. Instead of trying to cling to the body or being drugged into a semi-conscious state, this should become the spiritual high point of your life, as you prepare in prayer and meditation for the liberation of your soul. After the shocking revelation that you have cancer, you must gradually progress to hope, belief, and faith, faith in your spiritual guidance and that all will be well. Do your best; the rest is in God’s hands, so there is nothing to be afraid about.

This inner transformation can be achieved with the indicated mind tools. Preferably develop a daily routine that you start with prayer, affirmations, and relaxation, followed by guided imagery and meditation.

Become Aware - Experience Body Sensations: Even without the goad of having cancer, we need to become aware of our feelings and emotions when they arise. An easy way is to start with simple body sensations. Try to increase your awareness of body sensations. Whenever a sensation arises naturally, be it warmth, cold, tingling, hunger, thirst, the tastes during chewing, or any other body sensation, focus your attention on it. Soon the sensation will intensify and gradually you will learn to pick up on even faint sensations that you normally would not have felt.

Unpleasant sensations will usually recede after a while and may disappear completely. This is especially the case with hunger or pain. In order not to feel hungry during a fast, tell your body beforehand that you are doing a cleanse to make it feel better and that it will get food afterwards; then ask for its cooperation. If you forget to do this beforehand, you can still explain it when you feel hungry. Usually the craving for food disappears after this.

It is similar with pain. By focusing your attention on it, the pain can tell its message, the reason why it is there, and then it can withdraw, helped by the muscle relaxation induced by your attention and non-resistance to it.

One of our most frequent sensations, both important and pleasant, is our food taste. Use the excellent opportunity provided at each meal to savour the flavours that develop while placidly chewing. This increases and helps your digestion. For healing a specific problem, imagine that powerful nutrients in that food are now on their way to the problem area to improve it.

At other times, try to feel the various parts of your body as you move, stand, sit, or lie down. Sense which muscles are tight and which ones relaxed; warmth may develop wherever you focus your attention, yet you can also feel a refreshing coolness if you concentrate on that. An easy way to do this is by mentally transferring the warmth of the breath felt during exhalation or its coolness during inhalation to a designated part of the body.

Slightly move an arm, leg, or your head and experience how each move feels. Focus on the beating of your heart; feel the pulse at the sides of the neck. Put a hand on your chest to feel the movements caused by the heartbeat and the breathing activity. Shake your whole body or one part of it and feel the energy flow when you stop. Lightly touch various objects, your skin, that of others, tree bark, a stone, glass, and feel the differences.

Slowly move your lightly cupped hands close together, but without touching, then move them apart. Repeat for a minute or two, moving them slowly towards each other and away again. Can you feel a resistance developing when the hands are brought closer together, something like an air cushion? Do the same exercise after shaking your arms and hands for a minute. Move the tips of your outstretched fingers close to those of another person. Try with the same hands and also with opposite hands. Can you feel an energy, a tingling?

Allow Spontaneous Feelings: Focus your attention on any emotions or moods that arise. When you are angry, do not just remain angry in your head. Scan

your body to detect if you can feel it there. It may be in the form of an energy rushing upward from the lower chakras. Is it activating your arm or leg muscles, so you want to hit or kick? Intensify any body feeling. Hit the table or a wall with the padded side of the fist; kick a cushion or the air. How does it feel now?

If you are frustrated, where in your body do you feel it, apart from your head? Ask the same with other feelings, such as fear, anxiety, worry, jealousy, hatred, longing, compassion, love, devotion. With tender feelings, focus your attention on the heart. Do you feel a stirring there, something moving? When you feel an emotion in the body, try to stay with it and intensify the sensation, even if it is anger or another negative emotion. Try to express whatever you feel, but in a suitable way. Certain muscles may want to move; intensify the movement.

If you feel fine, sense that well-being all over the body. If you are dissatisfied, unhappy, or discontented for no specific reason, relax and focus your attention on feeling dissatisfied, unhappy, or discontented. Feel it in the body: Where is its centre? What does it want to tell you? Some of our strongest feelings develop during sexual intercourse, so go into these feelings. Try to spread them out from the sex organs into the pelvic area and throughout the body. Radiate them out to your partner. Do not let yourself be distracted by fantasies; stay with the feelings.

Sentic Exercises for Emotional Clarity: Manfred Clynes, author of Sentics: The Touch of Emotions, developed a set of “sentic exercises.” Clynes defines sentic as the brain state and its corresponding experience generally associated with the word “emotion.” He found that the same emotion in people all over the world produces the same kind of muscle response. He used the pressure of a finger on a measuring device to record the intensity and direction of the pressure generated by each emotion.

Even more important for us, this process can be reversed: A certain finger pressure tends to generate its associated emotional feeling. At the same time, this feeling is expressed through the pressure in a way that is satisfying for the body. You can press with one or more fingers or even with the whole hand against the surface on which the fingers or hand rest.

Negative feelings are best generated and expressed with the fingers pointing straight down to produce a kind of stabbing muscle response. Positive feelings are more effectively produced if the lightly cupped hand rests on the surface and the pressure is mainly expressed with the fingertips. Both hands may be used simultaneously.

To do these exercises, keep the executing arm in a relaxed position. If you sit on a chair, the jabbing pressure can be produced on the seat of a second chair or even on your thigh. For the whole hand to rest on a surface, use a table, your thigh, your other arm, or your chest. Eyes can be open or closed.

The pressure patterns of the seven key emotions are as follows:

- Anger: Make a jabbing movement away from the body, like hitting out. The duration is much less than a second and is accompanied by a sharp exhalation and a corresponding sound; the gaze is slightly downwards.

- Hate: The pressure is stronger than in anger, but develops more and is sustained somewhat longer; it ends abruptly, as in anger. The direction is away from the body and occurs during exhalation.
- Grief: This can be expressed with the cupped hand. The finger pressure is straight down and increases slowly for half a second. There follows a period of passive weakness and immobility during which the pressure gradually eases. The head can be tilted forward and to the right (for right-handers). Breathing is slow and shallow, pausing after the exhalation. The whole action lasts three to five seconds.
- Love: Pressure is gently towards the body, increasing and relaxing very slowly in a deep, smooth movement. Exhale slowly with a sensual sound; the head remains level.
- Sexual arousal: Push down and slightly away from the body; release quickly, but finish with a gentle pressure towards the body. Breathing is rapid, panting-like puffs during exhalation; the head is slightly down. The action is longer than for hate but shorter than for love.
- Joy: A quick moderate pressure straight down, immediately followed by an upwards bounce with less finger pressure on the surface than before the action, resulting in a floating feeling until the pressure gradually increases again to normal. It is like jumping for joy and floating down. The action is best performed during inhalation, head and gaze slightly raised.
- Reverence: Very gently increase pressure nearly vertical or slightly away from the body; very slowly return to normal pressure in a smooth movement without any body tensions. Breathing is extremely slow with pause after inhalation; head and gaze are slightly up.

To increase your ability to feel and express your emotions, practice these exercises for about 30 minutes daily. This will help release the emotional tension that has accumulated during a lifetime and enable you to respond in an appropriately feeling way to present and future emotional challenges.

Preferably start with a non-emotional expression. While relaxed, repeatedly press straight down, with one or more fingers or the whole hand, in a mechanical way, like hitting a typewriter key. Then express each of the emotions just listed approximately 30 times. The emotion tends to build up gradually for several minutes and then reach a plateau before easing off again. Follow the order as listed, starting with anger and finishing with reverence.

The emotional buildup is strongest if there is a certain time interval between individual actions. This interval is different for each emotion. For anger, Clynes found this to be 4.8 seconds; for hate, 5.3; grief, 8.2; love, 7.4; sex, 4.9; joy, 5.2; and reverence, 9.8 seconds. There may be timing tapes commercially available; otherwise, you can initially experiment with the timing and develop a feeling for it.

Later, when you feel free of the desire to express negative emotions or you do not derive any more benefits from it, continue with those exercises you like. Sentic exercises can be combined with other feeling exercises. Such exercises can show you that it is not necessary to be a victim of unpleasant feelings. You do not need to wait for positive outside influences to produce pleasant feelings within you. Instead,

with continued practice, you can choose how you want to feel at any given moment, how you want to respond emotionally in any situation.

Exercises for Coming Alive: When we are conscious only in the head, without being permeated with our feelings, it is almost as if the body were not really alive. It is then more like a machine, a mechanical device operated by the brain. This has been the lifelong condition of most of us, so we do not know what we are missing until the body gradually awakens, vibrating with life-giving feelings and not just pain.

We can grow even further, learning to choose our feelings, not just during an exercise, but during our daily activities. In order to feel good, to feel love or joy, we do not need to wait for the rare occasions when others or circumstances temporarily ignite such uplifting feelings within us. We are not our feelings and emotions; instead these are energies we can use and enjoy according to our needs and preferences.

The three exercises described below can gradually be extended in a way that the generated feelings become habits in our daily lives instead of isolated instances of feeling good. If you do not already feel alive and vibrating before starting a feeling exercise, energize your body for a few minutes with deep breathing then shaking, especially of the arms and head.

MIRROR: Sit or stand in front of a big mirror and smile at yourself. Look lovingly into your eyes and talk to your mirror image in a soft voice. You can say something endearing, such as: “I see love shining out of your eyes. It comes from your heart. Your heart is filled with love. It shines out of your eyes.”

Repeat this over and over again, slowly, with all the feeling you can express. Pause and smile at yourself; smile with your eyes, a gentle, loving smile. While continuing with the mirror exercise, you can also use sentic hand pressure to increase the feeling in your heart centre. Sense how it feels to make passes with your hands around your head and body, slowly moving downwards with palms facing the body. Instead of addressing the mirror image as another person, say “my” instead of “your” during your endearments. Experiment to see what feels best.

As an extension of this, when you have the opportunity, practice with a partner or friend making eye contact and smiling at each other. Take turns lovingly praising each other.

MUSIC: Music is excellent for inducing feelings. For heart feelings, use soft music with an uplifting, melting quality. This can accompany any of the other feeling exercises. You can also use it during heart-feeling meditations while being quiet or during repetitive activities; at other times, select stirring or uplifting music according to the feeling you want to amplify.

Jazz can be useful for raising the energies, especially in the morning and during shaking exercises. Some blues are good for inducing tender feelings. Rock music, on the other hand, is usually weakening to all muscle systems and should be avoided. This applies also to any music that conveys chaos and disharmony instead of harmony.

There is now a wide range of New Age music available. Most of it is designed for relaxation with sounds of waves and brooks, and some is suitable to generate an atmosphere of reverence and emotional uplift. In most instances, however, it provides just a pleasant, unobtrusive background for meditation and feeling

exercises. It would be excellent if a series of tapes could be obtained for inducing various defined states of feeling.

DANCE: Dancing is a moving expression of our feelings. We can even dance without music if we want to express a feeling. However, in order to generate feelings, it is preferable to dance to suitable music. You do not need to move your legs when dancing; you can dance with your head and body, but mainly with your arms, even while sitting. Most expressive are the hands. Dance vigorously to lively rhythms in the morning to stimulate the energy flow. In the evening, as a prelude to meditation, dance softly to uplifting melodies. Dance often, simply to feel and express the joy of being alive. Try to express the various feelings through dancing, such as anger, sadness, compassion, joy, love, ecstasy, and so forth.

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Step 61
TAKE THE LOVE CURE

Lead a radiant life filled with love and joy, and practice the Love Cure.

Love may be the missing factor for our emotional well-being and for overcoming disease. Love is the opposite of fear. With cancer, for instance, psychological therapy has been shown to have a far greater success rate than any other properly evaluated therapy, while fear has a major impact on cancer and AIDS patients. There is also a close relationship between fear, often present subconsciously, and breathing problems, as well as heart disease.

Emotional and psychological factors may be why various therapies work with some patients but not with others. Releasing past emotional hurts and resentments is helpful with any kind of healing, but it may not be enough if positive feelings are missing. The ideal is a combination of appropriate therapies on other levels and emotional therapy.

After many years of working and experimenting with a wide range of therapies, I conclude that some of the most important factors in restoring or improving our health and well-being are love and joy. For our emotional body, regular doses of these and other positive feelings are as essential as vitamins for the physical body; otherwise, we develop “emotional deficiency” symptoms, which can eventually disable biological functions and lead to illness.

Most of us can remember a time when we were madly in love. Love, then, was not just a mental concept, but a bodily sensation and it made us feel invincible. I believe that we can become invincible like that in regard to disease by learning to feel this way again as a way of life. Love and joy can rejuvenate the body and can be more effective than even the best nutritional supplements.

Learning to Love Again: Obviously it is not possible to fall in love with someone on a regular basis, but it is possible to experience the feeling of love as a conscious exercise. Love has traditionally been associated with the heart. Of course, it is not the heart muscle itself that makes us feel love, but the heart chakra centred at the middle of the breastbone. In order to feel love and increase our capacity to love, we need to stimulate this heart centre by focusing our attention on it. Diseases in the chest area should respond readily to this therapy and this applies especially to breast cancer, which has a strong emotional and relationship component.

For most of us, learning to feel love as a way of life does not come easily and requires a commitment to an exercise program. It will be especially difficult for most males, while many women will take to it quite naturally. Below you will find some useful exercises for this. Experiment and continue to practice those that you find best to generate love or joy in your body.

Feeling is energy and energy follows thought or consciousness. This means the most basic requirement for activating our heart centre is to keep our attention focused on it. Later, when it is easy for us to feel, we can just keep a small part of our

attention there while going about our daily business. Before using these exercises, practice the chakra exercises earlier outlined in Step 52.

1. Breathing into the Heart: Becoming conscious of your breath is one of the easiest ways to generate a feeling sensation inside your body and to keep your attention focused. Sit or lie quietly and mentally follow your breath as it gently moves in and out. Breathe through the nose. Become aware that the out-flowing breath is somewhat warmer than the incoming breath. After a while, begin to pause for a second or two between inhalation and exhalation. Feel a light pressure in the middle of your chest during this pause. When you can distinctly feel it, focus again on feeling the warmth of the outgoing breath.

Now combine this warmth with the light pressure felt in the middle of the chest. This is the location of the heart centre. Keep your attention focused on it and gradually intensify the feeling of warmth. Spread it all over the chest, but especially towards the location of any health problem, such as a breast tumor. When you feel the warmth, disregard the pressure. This warmth inside your chest is very pleasant and makes you feel cosy, cared for, and protected.

Intensify any of these feelings if they arise. Try to create them deliberately by using your imagination and recalling other situations when you felt this way, possibly when relaxing in a warm bath while listening to soft music. You may find that you can perceive feeling sensations more easily and with greater intensity if you exhale very slowly and gently.

When you can do this exercise successfully, you can also use it to keep your attention on the heart centre during your daily activities. You can quickly learn to keep part of your attention focused inside your chest while performing routine tasks, although you are likely to forget it during more demanding mental activities. That does not matter. If you ask your subconscious mind to remember doing the exercise whenever conveniently possible, it will eventually oblige and may tell you a hundred times a day to refocus. If you are somewhat tired, it may even be easier to generate a feeling sensation during activities rather than by lying down and closing your eyes, which may cause you to drift off to sleep.

If it helps you to focus, imagine your incoming breath being rose-colored or bright green. You may see this color intensify in the chest area with each successive breath. Another possibility is to put one hand on the chest to feel a light pressure or to press lightly with one or several fingers at the middle of the breastbone. Experiment with a different breath imagination. Imagine your breath moving through the middle of the breastbone, and again, feel the slight pressure and then the developing warmth. For some, this exercise produces stronger sensations. When you are somewhat tired, it will be better to do these exercises with your eyes open and possibly even while walking slowly.

2. Feeling Love: After successfully practicing the breathing exercise for some time, experiment with the following suggestions to see which one suits you best. Eventually, you may use all of them at one time or another, depending on opportunities.

It will be easier to feel a love sensation if you are already in a loving relationship, a mother with a baby, or an animal lover with puppies or kittens to care for. If that is the case, look lovingly at the chosen object while doing the breathing

exercise, and you may find it easy to convert the warmth in your chest into a feeling sensation of love. If you are not so lucky, recall an incident when you felt love. Vividly imagine this time and then intensify the sensation of love when it arises; then forget the actual incident and only hold fast to that feeling inside your chest.

Look lovingly at something grand or beautiful: a tree, flower, picture, clouds, the sky, or a person. Soak in the beauty and appreciate it. Then send that feeling of appreciation back to the adored object; all the time, keep focusing your attention on the breath in the chest centre and intensify any arising positive feeling. You can do the same by listening to some soul-stirring music. Eventually, you can start feeling and sending a silent appreciation of love to anyone you come in contact with and over a distance also to someone with whom you have a disagreement or a past problem. When you tend to plants, watering, transplanting, or sowing them, project onto them your feeling of love or appreciation. You can do this anytime in any activity; your only problem will be to remind yourself to do it.

If you have difficulty generating a feeling sensation of love, then feel compassion in the heart chakra. Look at or imagine pictures of suffering individuals. When you can feel and radiate compassion, try to change it to a feeling of love or a combination of love and compassion. The feelings of love and compassion can be combined with a feeling of joy, which can also be experienced in the heart centre, as well as in the forehead centre.

Or try this: Whenever you meet someone or think of someone, smile and silently say, “God bless you,” while feeling a wave of love or compassion radiating from your heart centre. Or think of someone and extend your arms with palms forward. Again, smile and feel the love or compassion in your heart. During the day, try to remember this feeling of love in your heart and centre on it.

3. Feeling Joy: Joy is the twin of love in helping us to live a healthy and fulfilled life. As with love, it is not easy to feel joy as a body sensation, especially if we do not have anything to be joyful about. There is an area of the body where we can more easily generate and feel joy and even bliss: the pituitary gland behind the middle of the forehead. Concentrating on it during meditation can generate a feeling of bliss; this can be felt as joy when focusing on the pituitary gland or forehead centre during a breathing exercise.

As the breath does not flow into the brain, imagine the prana is separated from the inhaled air and flows upwards from the nose into the pituitary gland. If you can visualize colours, see the forehead centre as filled with indigo-coloured prana.
First try to feel a light pressure partly due to the focus of your attention and partly to the accumulating prana. Again try to feel warmth or tingling during the slow and gentle exhalation. To focus on the correct point, it helps greatly if you close your eyes and turn them inwards and upwards as if looking into the brain at a 45 degree angle. When you can easily do this, you may even be able to just imagine looking upwards and inwards and feeling a light pressure in the pituitary area while you have your eyes open and are engaged in other activities.

When you are able to feel the pressure or warmth, start smiling inwardly and direct this smile to the pituitary gland. As you keep smiling, you may gradually feel a sensation of joy and happiness spreading from your head into your body. If you have

already learned to feel a love sensation in your heart centre, combine this love feeling with the joy spreading from your head into a unified feeling of elation.

4. Feeling Connected and Peaceful: We can learn to overcome the stresses of daily life and live instead in a condition of profound inner peace by frequently focusing our attention at the top of our head. This will be invaluable with all stress-related diseases and conditions and also helps to energize the body in a pleasant way.

Relax, close your eyes, and imagine a stream of white light entering the top of your head. Try to feel as well as see it. However, feeling it is more important than only seeing it. It may help at first to focus on feeling a light pressure and warmth at the top of the head, possibly aided by leading the breath prana to this point. Exhale very slowly and gently, and imagine feeling peaceful, a deep peace beginning to fill and surround your body and mind. Watch for a feeling of being energetically connected to your Higher Self, the Universe, God, or whatever you want to call it. If you can feel or imagine feeling something like this, try to intensify the sensation.

When you have a feeling sensation at your crown centre, you can intensify it by generating a feeling of love in your heart centre and then sending it straight up through the top of your head to your Higher Self or God Self. Immediately feel this love offering coming back to you through the top of your head, greatly intensified. See and feel the incoming white light enlarging and intensifying to surround you now in a pillar of light. Feel how it energizes your whole body. You may also see the white light blending into other rainbow colours that are beneficial for you such as a golden-yellow energizing color, the rose color of love, or the violet flame of purification and transmutation.

When you are able to feel the peace and connectedness to your God presence during the exercise, focus part of your attention on the top of your head and feel this connection during your daily activities. Feel at peace and connected. Keep part of your attention on the top of your head while you try to feel the joy behind the forehead and the love at the heart centre. Alternatively, focus in sequence on the top of the head, the forehead, and the heart. Eventually, you may be able to focus on all three simultaneously and feel peaceful and connected, joyful and loving at the same time.

Living Your Feelings: If you have a disease or health problem in a specific organ or area of the body, you can now supply it with all the energy and emotional support that it needs for healing, in addition to the nutritional and other support that you may provide. On a regular basis, fill yourself with love and then mentally send it with an inner smile to the organ in need of healing. Breathe more energy into it or lead it there from the storage area or chakra behind the navel. Feel it getting warm or tingling or just feeling good. At the same time, see it filled with a brilliant white healing light. Intensify the vision and the feeling and hold it for a long time. Know that you are being healed.

Tender feelings are a daily requirement for your body and soul. We need them as much as we need vitamins and minerals, so make sure you obtain plenty of “emotional nutrients” each day, as there is nothing better to rejuvenate an aging body-mind. Bathe all your cells and organs in tender, loving, or joyful feelings. Focus on each part of the body in turn and concentrate longer on those areas most in need

of improvement. Try to feel the love everywhere, in your fingers as well as your toes. Let all your cells feel that you love them.

The breath will help you stay in touch with your body. Make it a habit to breathe into your heart centre, and keep part of your attention there as often as possible. Alternatively, keep part of your attention focused on the crown or forehead centre. Better still, let the peace and connectedness of the crown centre fuse with the joy of the forehead centre and the love of the heart centre to a symphony of uplifting feelings.

Do not let your mind drift idly to produce repetitive mental chatter. Whenever you notice that the internal chatter has started again, renew your focus on the heart centre. Daydreaming, however, can be restorative and creative and is often superior to mental chatter.

When you are tired or exhausted, it is difficult to arouse feelings even if you try hard, but at other times gentle feelings may spontaneously arise and float through the body. This happens most easily when we are aware of something beautiful, something which uplifts the soul, a landscape, a painting, music, flowers, a smile. You can then magnify your feeling by radiating it back onto the landscape, the painting, and so forth.

When you massage someone, greet someone with an embrace, whenever you touch someone - always remember to radiate loving feelings. It is much more difficult to maintain and radiate positive feelings during conversations, but this will gradually improve. You will find it a great help if you can remain relaxed and smile instead of becoming totally absorbed by the mental aspects of the conversation.

However, it is most difficult to retain any kind of feeling awareness during intense mental activity. Usually, we completely forget the body. This will also gradually improve, especially if you can train your lower self to automatically switch back to the heart and crown awareness when the mental challenge has passed.

Simplify your life and carry an inner smile with you wherever you are. See the beauty in everything. Gradually, on rare occasions at first, a feeling of deep inner peace may arise, clothed in a feeling of being loved and cared for. If you persist with your attempts to remain focused on the heart and crown centres, then this deep inner peace will intensify and begin to permeate your whole being.

Out of this tangible feeling of inner peace will then arise the other feelings, thoughts, and activities as required and appropriate for each occasion.

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Part 9
HEALING YOUR MIND

We all would like to live a happy, healthy, and fulfilled life, yet few seem to be Our conscious decisions are made with our mind. All healing and improvement in our living conditions start at this level, and it is here that we must take the first step with a conscious decision that we want to improve conditions by following a suitable program. If we see the progression of our lives as a creative process, then we can see the mind as the architect.

In our society, rational thinking and the intellect are worshipped, while feeling and intuition are neglected. The reason for this imbalance can be found in the distorted goals and ideals of our society, which has lost sight of inner values. Wisdom, devotion, patience, and compassion are replaced by material riches; inner purity is forsaken and traded in for excessive external cleanliness and hygiene; success is measured by monetary wealth and dominance instead of self-mastery.

Thinking is the most important tool for achieving such external success, while tender feelings disadvantage us for success in our society. However, thinking is neutral and we can use it to our advantage in healing our body and emotions. Proper thinking is required to discard unsuitable beliefs and replace them with appropriate ones. If we accept that negative thoughts and beliefs are a cause of our illness and social problems, then our mind is in need of healing and we must replace disease-forming negative beliefs with health-giving positive ones.

I regard the Self as our total nonphysical entity. The Self and the body together are the whole entity. To better understand inner processes of consciousness, we can distinguish between different parts of our Self. I use a fourfold division:

- The higher Self or super-conscious level provides spiritual guidance as inner knowledge and intuition. It has further divisions, variously called soul, Christ Self, over-soul, or God Self.
- The middle self represents our normal consciousness, that of which we are aware, mainly our mind and mental body, the thinker.
- The lower self or subconscious part is the master of our memories and emotions, including long-forgotten beliefs and a Pandora's box of suppressed feelings and emotions; it is also called the "inner child."
- The body self is an elemental (a life-force being) that looks after the biological functions of our body; this is the level of consciousness that is still active when we are in a deep coma.

We can say that the Higher Self operates at the spiritual level, the middle self at the mental level, the lower self at the astral or emotional level, and the body self at the etheric or life-force level. The middle self can to some degree become aware of the other levels, but its centre of consciousness is based at the mental level.

Depending on our degree of spiritual understanding, this may be the concrete mind or lower mental level; it may be the higher mental level concerned with spiritual, creative, and intuitive thinking; or it may be somewhere in between.

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Step 62
HARNESS THE POWER OF THE MIND

Appreciate the power of your subconscious mind.
It is the real power behind the throne of the ego.

Our mind has awesome powers. It makes us sick and unhappy or healthy and happy. It is a powerful tool and it is up to us in which way we want to use it. In clinical trials, mind therapies have been shown to be much more effective than conventional therapies in reversing many cancers. To illustrate the overriding importance of the mind, I relate an example.

An elderly male with huge tumor masses all through his body had been given less than three months to live. At that time, trials with the alternative remedy Krebiozen were started. Despite not being eligible to participate because of his short life-expectancy, his enthusiasm about the remedy was so overwhelming to his doctor that he gave him the remedy outside the trial.

A few days after his first injections, his tumours had already halved in size and continued to reduce until they had virtually disappeared and the man felt healthy and well. However, two months later, he read a report in a newspaper that the trial was a failure and Krebiozen was useless. Immediately, he fell ill and relapsed, with his tumours quickly regrowing to their previous size.

His doctor was so astonished by these strong responses that he decided to make an experiment. He told the patient that the first trial had not worked because the remedy was too old. Now he was waiting for a fresh supply that would be double-strength. A few days later the man was given the injection; this time the tumours disappeared even faster than the first time and again the patient was completely healthy and well.

However, instead of any drug, the doctor had just injected water. Again, a few months passed and then the newspapers carried stories that the FDA had declared Krebiozen to be completely useless and a fraud. As rapidly as he had recovered, the patient deteriorated once more and this time his doctor let him die.[70]

One might think that such a strong mind effect must be very rare, but consider this: In a chemotherapy trial, one-third of the placebo patients lost their hair. In this rare trial, only half the participants had received chemotherapy and the other half a harmless substance, which they believed to be an active drug. This means that the hair loss in one-third of the placebo patients was entirely due to their belief.

This finding is confirmed by one of those rare placebo trials in surgery. After “real” operations for cardiovascular disease, 32 percent of patients had satisfactory results. However, 43 percent of a control group that had only pretend surgery reported subjective and objective improvement! This means that basically all the improvement came from their belief, but the traumatic effect of real surgery reduced the belief-based success by 11 percent.

One-third is a figure that corresponds with results from other trials as the approximate size of the placebo effect. I take this to mean that typically one-third of

patients will either die or recover because of their strong belief. This applies equally to conventional medicine and natural therapy. Those who believe they will get well will do so regardless of the therapy used, and those who doubt or are fearful will receive little benefit from any therapy. I am convinced that this is the main reason why one patient is cured by cancer surgery, while another with the same condition dies afterwards.

Therefore, perhaps the main concern for patients with “incurable” diseases should not be to find an effective therapy, but rather to find a way to harness the power of the mind and become a believer with an unshakable faith - in effect, to put the placebo effect to work.

Before you decide to believe in eating a piece of cake every Sunday as your preferred cancer cure, there is another factor to take into account. Whatever you do must be totally convincing to your subconscious mind. Just believing something on the conscious mental level is not enough; if your subconscious mind is not convinced that something will cure you, then it will not. The subconscious mind is most easily impressed by something that inspires awe, by authority, ritual, the unusual, and especially enthusiasm. Whatever impresses you as a potential cure, embrace it enthusiastically. Anything that you just try to see if it works is not likely to work.

Get to Know the Lower Self: In order to heal our mind and use it more efficiently, we need to have a basic understanding of our lower emotional self. This operates on a different level of consciousness from our normal consciousness (the middle self) and has many of the characteristics of a separate entity. When working with it, it is best to regard and treat it as a reliable servant.

It is advisable to be on good terms with our lower self because it is the power broker of the body. The middle self is like the captain of a ship, the Higher Self is the shipping line and employer of the captain, and the lower self is like the union foreman. If the crew has any grievances, the boss may call a strike or otherwise make life difficult for the captain. The body self is comparable to the crew and cooperates very closely with the lower self.

Here’s what we can say about the lower self and its body functions:

1. Influences the body self and the physical body (except for the voluntary muscles)
2. Is the seat of our emotions
3. Receives all sense information
4. Keeps a record of all sense information, thoughts, and feelings
5. Operates our memory bank
6. Operates our psychic abilities
7. Is the means of communication with our Higher Self

The real power of the body rests with the lower self, but it has one shortcoming: It cannot think logically. It has only an elementary ability to think, similar to an intelligent domesticated animal or a small child. Therefore, it is dependent on the middle self to tell it what to do and, as the faithful servant that it normally is, it willingly obeys the middle self.

However, because it is simpleminded, the lower self is dogmatic. It may take our early childhood programming, especially our religious and sex-related teachings, and anything someone in authority may have said, as gospel truth. It can be moralistic and regard itself as the keeper of any important commitments that the middle self may have made. To illustrate these characteristics of the lower self, here are a few examples from The Secret Science behind Miracles, by Max Freedom Long.

A young man with a strong religious upbringing had the urge to enter the ministry. He took a job in a furniture factory instead. There the paint fumes made him sick. When transferred to the woodworking department, he developed asthma from the sawdust. He tried several other occupations, but each time he became sick from something connected with the job. In the end, a psychologist unearthed his earlier intention to become a minister. As nothing else seemed to help, he advised the man to enter the ministry. The man did and had no more illness.

A religious Hawaiian man had an affair. His wife found out but forgave him. Within a year it happened again, but this time his wife did not find out. This seemed to make it even worse for the man who gradually lost his strength and will to live until he was very close to dying. A kahuna (native healer) was called and discovered the truth. He induced the wife to forgive her husband once more and the kahuna performed a ceremony in which all the man's sins were washed away. The patient immediately started a quick recovery.

A young woman had been brought up to regard dancing and drinking alcohol as sins. After her marriage she moved in different circles and gradually started dancing and having the occasional cocktail. Soon she twisted her ankle slightly during a dance. Normally, she would have been fine after a day or two, but instead the leg became gradually worse and a deep running sore developed below the ankle. A kahuna convinced her that she had not really sinned against God and in addition forgave her and washed away all guilt of any kind. The ankle quickly recovered to its full strength.

However, the young woman neglected the kahuna's instructions to continue affirming that if she had not hurt anyone, there was no sin. Again she danced and drank a little and eventually the ankle sore reappeared. However, this time the kahuna explained that he could not help, as the lower self had now become too much entrenched in its conviction of sin. The only permanent cure was to give up drinking and dancing for good.

These examples show how our lower self holds on to childhood beliefs that as adults we have long forgotten. In contrast, the lower self never forgets. Therefore, if we suspect a conflict between the beliefs of these two selves, we have to convince the lower self that the old belief is no longer appropriate and patiently and in simple words explain the new situation instead.

The Power of Beliefs: We see and interpret the world through the coloured glasses of our belief systems. We even create our personal world according to our beliefs. We project selected ideas, thoughts, and emotions into our surroundings and with these attract or repel people and events. Most notably, we manifest what we fear. Negative thoughts harm no one more than us. When a negative thought comes

into our mind, we can either accept it or immediately block it and replace it with a positive thought.

It is advisable to begin our healing and growth venture by looking closely at our basic beliefs to see if we still want them. Do they present a positive outlook and are they in harmony with our goals and our new philosophy of life? One way of finding out is to write down your beliefs about the basic questions and problems of your life. What do you believe about yourself, your friends, your work, your health problems, your body and your future, about death, Afterlife, and so forth. Then cross out whatever does not meet your new standards and rewrite in a more positive form what you would prefer to believe.

As an example, you may believe that most people are selfish. As long as you believe this, you will attract mostly selfish people or interpret their motives as being selfish, which may not always be true. Therefore, start reprogramming yourself by writing: “I attract more and more unselfish people into my life.”

Instead of believing “I will become infirm with advancing age,” you can now write: “My health and well-being are improving with every day in every way.” Yet just writing all this down is not enough, because by now the lower self will share many of the beliefs of the middle self, and the lower self is very stubborn. Most effective for influencing the lower self are autosuggestion methods, such as affirmation, self-hypnosis, and visualization, as well as studying and gradually accepting a truly spiritual philosophy of life.

However, even if you are successful in changing your beliefs, that is not the end of the road. It is just a precondition to attracting the necessary knowledge or conditions that will make an improvement possible. You still have to do whatever is necessary on one of the other levels, be it a change in diet or asking for forgiveness and sending kind feelings to someone you have hurt. Be careful with psychic predictions about yourself. Some are amazingly true in minute details; however, others can be wide of the mark. Therefore, believe only in those predictions that you would like to come true and ignore the rest. Choose your beliefs carefully because they determine what will happen to you.

Worry, Resentment, and Desire: Three of the most common obstacles to good health, inner peace, and happiness are worry, resentment, and desire.
Worry is an outcrop of fear and is part of the price we pay for a lack of faith in our guidance. For someone who is in harmony, in tune with the Higher Self, there is nothing to worry about, neither from the past, nor in the present, nor in the future.

Resentment is an expression of ego-centeredness and results from a lack of self-responsibility. We blame others for what happens to us and we try to make them pay for it by withholding our love and affection from them. A change of attitude towards self-responsibility will free us from the self-destructive effects of resentment and enable us to become tolerant and understanding of our own shortcomings as well as those of others. If someone does something that we do not like, then we should either speak out or accept and forget it. Resentment is the worst of our choices.

Desire tends to rob us of our peace of mind and destroy our inner harmony. We must, of course, tend to the needs of our body. A desire for food when we are hungry, for rest when we are tired, for sunshine, fresh air, and so forth, are natural. It

is also good to desire being creative. In addition to these natural desires, most of us have numerous desires related to pleasure and social achievements.

Even such materialistic desires are no problem, provided we are happy to pay the price for their fulfilment, and usually they help us to learn or grow. Still, the more we improve our belief systems, the more the need for desire fulfilment and achievements will disappear and the easier it will be to feel peace and harmony. Actually, it is not so much the desire itself that causes us trouble, but our attachment to the outcome of our actions. It is excellent to have the desire to be creative, but if instead we focus our desire in the form of expectations on the result of our creativity, then we are heading for disappointment.

Even our path towards better health, fulfilment, and happiness will be more successful if we do not have too great a desire to achieve this goal quickly. Instead, we can walk this path for the sake of the pleasure and satisfaction provided by the path itself, by being creative, playful, having realizations, and doing something meaningful. Generally, the fun is in doing, in action, rather than in the achieved result.

When, for some reason, we are confronted with a difficult task, we must channel all our energies into this purpose and have a “one-track mind” in our desire to succeed. However, as long as we want something badly for mainly selfish reasons, we may not get it, or if we do, the price may be too high and we may not appreciate it any more.

We can overcome this obstacle by doing what needs to be done or acting for the good of our family, community, nation, or for mankind, without desiring the fruit of our actions for ourselves. In this way, we can never be disappointed and always get our reward from the pleasure it gives to do well what needs to be done. Remain aware that we are just actors in a play, with Divine guidance as the director, and whatever the outcome of the play, all is well.

Our world covers every view and every condition possible under the given circumstances. Due to our cultural, social, and personal programming, we select a few views and conditions out of all that is. We focus on these, identify with them, and move towards manifesting and even becoming them ourselves.

What we call good and evil, happiness and suffering, love and hate, joy and despair, are part of this world. From these we select, usually subconsciously, that with which we resonate; we attract it and then manifest it in our lives. However, we can consciously influence this internal selection process and focus intentionally on what we want to manifest in our lives or how we want to become. We do this by maintaining a positive mental attitude or expectation.

Develop an attitude that remains in all situations positive, playful, tolerant, kind, and humorous, laughing more about you and less about others. In no way, however, should we just pretend these attitudes when we feel differently inside; always express or acknowledge in a suitable manner whatever you feel.

It is okay to feel angry, upset, or sad. Go into it. However, in the back of your mind, remain aware that you can change the situation and laugh any time you want. The more you learn to take yourself less seriously, the easier it will be to laugh about your own mistakes, until it simply becomes impossible to be angry or upset. Even

annoyances created by others may eventually cause you amusement instead of ulcers. It is all a question of attitude.

Fear of Death: The fear of death and dying is widespread in our society, due mainly to a materialistic belief system. Early childhood programming about eternal punishment in hell may still have an influence on some of us. Most of the time, this death fear is kept out of our conscious mind, unless the death of a close friend or relative brings it to the surface. At other times, it can manifest as an inner insecurity, a fear of disease, a general anxiety, or inner emptiness. Mourning, in this condition, is more or less an expression of self-pity, although very helpful and necessary with this belief system.

We can free our lives from all these negative influences by changing our belief about death and the Afterlife. If you follow an established religion, you can actively program yourself to believe more strongly in the positive aspects of the Afterlife as taught by your religion.

If you do not follow a specific religion, you can get acquainted with some books on near-death experiences or reincarnation, especially with studies using hypnotic regression. However, do not look for “proof.” There is no concrete proof available in spiritual matters that will convince everyone. To our normal consciousness, we accept the spiritual world on faith and belief. Of two people confronted with the same facts, one may believe in them and the other reject them. You can choose what you want to believe.

After starting to believe in a spiritual truth, be it reincarnation, karma, divine guidance, or the Afterlife, you may find more evidence to reinforce your belief. With this, an inner knowledge will grow, which is the only true form of knowledge. Eventually, you will know from the experience of your own life and will not be interested anymore in the “proof” someone else may be able to offer. Nevertheless, it may help you to review the book “A Lawyer Presents the Case for the Afterlife“ (available at: www.victorzammit.com). In it, Victor Zammit, a retired attorney of the High Court of Australia, has assembled all the known evidence of survival after death. He came to the conclusion that before a court of law, the evidence taken as a whole would constitute overwhelming evidence and irrefutable proof of the existence of the Afterlife.

The acceptance of the Afterlife as a reality may remove the fear of death in our society and reduce the mourning, sadness, and loss that we feel at the passing of a loved one. Instead, it may become a celebration, in which we congratulate the departing ones on a job well done and in which we are happy that they can now receive their well-earned rest and reward and go on to greater things. We know that we will catch up with them sooner or later and that it will be a great reunion.

I have in my mind the picture of a large group of deep-sea divers working under difficult conditions in heavy steel suits at the bottom of the ocean. Their technology is such that they can stay below for years. From time to time, one of the divers finishes his assignment and can come back to the surface. The other divers are envious and would like to accompany him. However, it is also important to them that they finish their own assignments, so they give a little party for their lucky colleague, congratulate him, wish him well, and arrange for another bigger party when they are all back together at the surface. When the successful diver finally reaches the

surface, there is another big celebration with all his friends who had remained at the surface or had returned before him. What a relief getting out of that heavy diving gear after all those difficult years and seeing the sun again!

This is how I imagine the soul must feel when it can finally discard the body after a hard life. It is understandable to feel sad at being left behind by a departing loved one, yet the anticipation of the eventual reunion should make it easier to bear. Even in the case of a young child dying apparently without purpose, the departed soul may soon try to incarnate again, perhaps even with the same mother.

As we spiritually mature, we will come to know our time of departure in advance, and we will be able to depart without requiring a disease to free our soul. With this, we will also stop our efforts to prolong our life, to live as long as possible. We will be happy to leave when we have finished the job that we came to do or had the experiences we wanted.

So with this in mind, reprogram yourself into believing that you are only an actor in a temporary role in your present life and that other roles in different lives and perhaps different worlds are part of your greater existence. Then it may be much easier to take it easy, to be playful about serious matters, enjoy your role in this life, and to look at your problems as opportunities to experiment and see what comes of them.

Self-Responsibility: By aiming for health improvement on all levels of our existence as a conscious expression of our attitudes and beliefs, we show that we are prepared to take responsibility for our life. It is common to blame someone or something else for our problems, yet it rarely occurs to us to look to ourselves for the source of our difficulties. We eat unhealthy food, create harmful emotions, adopt negative attitudes, and when this makes us sick, we blame it on outside influences and want someone else to fix it.

By accepting self-responsibility, we realize that there is never anyone or anything else responsible for our problems, only us. When we become sick or have an accident, we do not blame fate or germs, but understand that we have transgressed a law of nature or moved against our life blueprint. We try to discover what we did wrong and we correct the situation and guard against making this mistake again. If our disability is of a nature that it cannot be healed, then we accept it cheerfully as a test given to us for the good of our soul and we make the best of what we have.

It is similar with social, marital, or financial problems. We assume that it is the essential purpose of our existence to learn the spiritual and biological laws, to direct our feelings and emotions into beneficial patterns, and to make the right decision at the right time in the right place. Every problem we encounter offers us the opportunity to learn. The way we learn most is by making mistakes and then becoming aware of them. This is how we explore our limits. When we have learned our lessons, we will be able to handle life's problems without difficulty.

By adopting this principle of self-responsibility, we also adopt a position of power. We are no longer victims of anyone or anything, but rather the masters of our destiny.

We realize that we have to learn anyway, by the long, hard road of suffering caused by our ignorance or by an attitude of willing cooperation in our scheme of existence. The road of self-responsibility is so much more pleasant than the road of suffering. It is an exciting venture in self-realization. Every unpleasant happening or health problem not only mirrors what we have to learn but also shows us the solution - if and when we are able to see.

Self-responsibility in regard to health care does not mean that we should rely entirely on ourselves without outside help. Helping each other and learning to cooperate are important parts of self-responsibility; we can seek the services of a competent healer whenever that feels right. Our attitude towards a health professional need not be passive submission to authority; it can be helpful and optimistic cooperation in a joint venture in healing in which we retain the overall responsibility. Expect your healer to help you, but not to do your work; you still need to bring about the necessary inner and outer changes.

While the ultimate decision about our healing is made at or above our soul level, we have to accept self-responsibility to prepare the way and remove any obstacles for healing to become possible. I see the relationship between our Higher Self and our personality as that between parent and child. While the child cannot make the decision where to go on holiday, the parents will take the wishes of the child into consideration. If the parents are generally pleased with the child and there are no important obstacles, then the parents are likely to agree with the wishes of the child. In the case of a so-called terminal disease, the Higher Self may grant the wish of the person to be healed and retain the present body, especially if that may lead to further spiritual growth.

Changing Our Attitude: Our attitude is the key to travelling the long road from suffering to happiness. Our attitude is our mental disposition towards persons and events as well as towards ourselves. It is greatly influenced by our belief system and our subconscious programming. It being close to the surface of our consciousness, we can easily observe our attitude and work on our shortcomings. This provides an excellent opportunity for inner change. Monitor your attitude and correct it instantly whenever it does not meet your new standards.

For example, we may have the habit of evaluating passing strangers in a negative way. Looking at someone, we might think, “Her legs are much too fat,” or, “He has mean eyes.” Whenever you notice yourself doing this, think of something positive about this person or just send an inner greeting of love and peace.

You do not deny that there are negative factors in others - as seen from your point of view - but you just ignore them. Everything has two sides, which we may call positive and negative. The positive side is in agreement with our own values and the negative side is in disagreement. We tend to manifest what we concentrate on. Therefore, it is best for us to concentrate on the positive factors whenever possible and take the negative aspects into account only when we are required to do so for specific reasons.

The same applies to negative attitudes in an intimate relationship. You may think on occasions that your partner is unreasonable. When this happens, try to understand his or her position and, like a good defence lawyer, consider all the factors in your partner’s favour. He or she may not have received much love and

security during childhood or had to fight hard for his or her rights, and so forth. Do this as a conscious mental exercise whenever you have negative thoughts about people or events.

In our relationships, be it in the business world or with friends and relatives, the correct attitude for us is one that aims for a fair deal for all concerned. We may be elated about an agreement that appears rather advantageous for ourselves, but what good will it do us if the other party is not happy with it? We will have created a source of resentment and trouble. Sensitive individuals will be aware of this resentment against them and cannot be happy about a deal that the other party regards as unfair.

When you have a mishap, breaking some crockery, dropping an open can of paint, or hurting yourself, pretend that you are an observer and try to see the funny side of it. When it is too serious to be funny, ask yourself why it happened, what it wants to teach you. Perhaps you simply need to be more attentive, perhaps it has deeper reasons; try to find out.

By training your sense of humour in this way or by looking immediately for the reason of the accident, you may not even remember to feel upset about it; though if you do, do not suppress it. Afterwards, realize that it happened to teach you a lesson.

Conscious Activity: In order to change undesirable habits and improve various activities, it is necessary to become conscious of these habits and activities. A good starting point is just to observe our mind, our thoughts, and feelings as they arise, without any value judgment in regard to right or wrong, good or bad. Have a part of your consciousness sitting in the back of your mind as an impartial observer, registering everything without a comment. If done consistently, this in itself can induce all the necessary changes to lead us towards a happy and fulfilled existence and draw us closer to full self-realization.

For those who prefer a more active way of changing the mind, various additional possibilities exist. As an example, you may discover that your favourite food causes allergy or mucus congestion and you decide to avoid it. You can either be unhappy about giving up your favourite food or you can be happy about coming closer to good health. It is similar with accidents or any other problem. It could always be better or worse. Your attitude decides whether you look at the positive or the negative side of the happening, whether you make yourself happy or unhappy. You have the choice.

We can program ourselves in such a way that something in us will call “Stop!” whenever we start performing in the old ways, and then we can consciously do it in the improved fashion. Another important aspect of mind improvement is to slow down or stop the constant silent chatter in our mind and replace it with an awareness of feelings arising in various body centres, especially in the heart centre. Aim to use the brain only when you want to think and switch off any idle and repetitive chatter at other times.

Two bodily activities usually in need of improvement are our posture and our breathing. These can be monitored until we perform them automatically in the correct way. Something we should always do consciously is eating, keeping our attention on the food flavours that develop while placidly chewing.

We cannot become aware of all of these activities at the same time. Therefore, we start with only one, for instance monitoring our attitude for several weeks until we are reasonably successful with it. Then we can concentrate on the posture changes and later on the breathing. It is different with the awareness of chewing and food flavours. As this is for a limited time span only, we can start it immediately and continue indefinitely. Concentrating on body sensations and feelings may be our final challenge.

Initially, when we become aware of a new activity, we may remember it for only a few minutes at a time and then quickly forget it again. However, when we give ourselves the autosuggestion to remember watching a habit, we will again and again be reminded of it. A hundred times a day, we may slump and then instantly remember to assume the correct posture again. Do not give up. It will soon become a new habit; then you can relax your attention on it. Gradually, become more and more aware of your whole body and everything you do.

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Step 63
HELPFUL MIND TOOLS

Use relaxation, regression, reprogramming, prayer, meditation, and inner communication for a more fulfilled life.

Our thoughts, feelings, attitudes, beliefs, and emotions form the fabric of our inner world. They are the main factors that determine whether we are healthy or unhealthy, happy or unhappy. They have a direct influence on our body by changing or maintaining our inner blueprint and by directing, blocking, or enhancing energy flows and glandular activities. They also act in an indirect way by determining which foods we eat, which environmental factors we choose, which kind of knowledge we acquire and how we use it.

So to improve our condition, whether on the social, mental, or emotional level or with reference to our health, we must first change our inner world. Here are some recommended steps:

1. Examine your present condition on all levels. Make a list of what you do not like and another one of how you would like to be instead.
2. Acknowledge and release emotional blocks and past negative or unwanted conditioning. This may be the most difficult step in your improvement program because most of these problems exist on the subconscious level.
3. Use mind-control methods to reprogram your subconscious mind; participate in workshops.
4. Adopt a holistic and spiritual philosophy of life.

Mind-improvement therapy for acute emotional problems needs to be accompanied by nutritional improvements such as stabilizing the blood sugar level, avoiding allergens, and using appropriate supplements. In this way, the nutritional component of emotional problems is easily rectified and you can make much better progress with the remaining deep-seated problems. In this step, we'll see how eight mind tools can help your health.

1. Relaxation as a Tool for Mental Well-Being: Deep relaxation is a precondition for being successful with most autosuggestion methods as well as with meditation and all other methods to contact the inner self. You can experiment with the methods listed below and see which one works best for you. Here are some general guidelines:

- Sit or lie comfortably and close your eyes. Focus your attention for ten to 20 seconds on your right foot. Feel it becoming warm and heavy. Then move to the left foot, the right calf, the left calf, and so on, moving upwards to the head. Include the chin, jaw, eyes, and the back and top of the head. When using this method regularly, the focusing time on each area can be gradually shortened, and related areas, such as a whole leg or a whole arm, can be relaxed at once.
- Imagine yourself in a red-coloured room on an upper level of a high-rise building. After a while, walk to an elevator and feel yourself going down and

down until you reach an orange room; then go further down to a yellow room, a green one, then blue, indigo, and finally violet.

- Imagine yourself walking down a woodland path to the bottom of a waterfall; feel the peace there.
- With each slow exhalation, feel yourself drifting lower and lower down a long tunnel, or imagine diving towards the bottom of the sea.
- Slowly count backwards from 50 to one. With each count, imagine yourself sinking deeper and deeper into a black void.
- Inhale for a count of eight, hold for two, exhale for eight, hold for two, and so forth. Focus your attention on your breath; notice how it quietly flows in and out. You can also focus on your slow inhalations and exhalations without paying attention to the timing.
- Combine several of these methods in one exercise to achieve deeper levels of relaxation.

AUTOGENIC TRAINING: This body-and-mind relaxation technique was developed by J. H. Schultz.[71] It requires diligent practice for several weeks or even months to master the technique, but it is worth the effort, especially for those who are tense or who have difficulty contacting their body.

Lie comfortably on your back, arms loosely alongside the body, palms down, or hands folded over the abdomen. Close your eyes and breathe slowly into the abdomen for a few minutes. At the same time, focus your mind on the formula: “I am peaceful.”

Afterwards, repeat slowly in your mind: “My right arm feels very heavy.” Feel your arm becoming limp and heavy like a leaden weight. If you are left-handed, use the left arm. After a few minutes, bend and stretch the arm energetically and repeat mentally: “My arm moves firm and free.” When you can readily feel the heaviness after several days of practice, include the other arm, then the legs and torso. At the end of each session, give the suggestion that the whole body is now light and free.

For the next step, add the focus: “My right arm is streaming warmth.” After you can easily feel the warmth in the arm, include also the other arm, the legs, and torso. The warmth does not need to be taken back at the end of a session, only the heaviness.

For someone new to meditation and relaxation exercises, it may take about three weeks until the heaviness and warmth can be readily felt together. Now you can move to the next step. Support your right elbow with a pillow so that your right hand lies over your heart. Feel it beating and hold the mental focus: “My heart is peaceful and strong.” When you can experience your heart, you can later keep the right arm in a usual position, relaxed along your side or hands folded over your abdomen.

Add the focus: “It breathes me.” Feel the breath flowing in and out without mental control. After a week or two, include the solar plexus (inside the upper abdomen) and say: “My solar plexus radiates warmth” or “My solar plexus is streaming warmth.”

While exhaling, imagine the warmth of the breath accumulating in the stomach and abdomen and heating them up. Finally affirm: “My forehead is light and cool.” You can mentally transfer the coolness felt in the throat from the incoming breath onto the forehead.

Each time, first go through all the previous steps, such as heaviness, warmth, and peaceful heart, and then focus on the next step you want to learn. Practice each new step for one or two weeks. After several months, it will be easy to relax the body completely in a very short time. Body and mind will be still and peaceful, with the body feeling warm and heavy and the head cool and light. You may be in an altered state of consciousness but should be inwardly alert and definitely not drowsy. This is an excellent preparation to do before any of the autosuggestion methods and other forms of communication with the inner self.

2. Regression Therapy: Regression therapy is a special technique of re-enactment that can be employed professionally, in a group situation, or with a partner or friend. You go backwards in time until you remember an emotionally charged incident. Professionally, regression may be induced by hypnosis, but it also works well with self-hypnosis or simply by suggestions given by a friend. However, the person leading the regression should have some experience or at least common sense in guiding emotionally distressed individuals.

Decide which emotional problem you want to work on. Even if you do not have a specific problem, you may have noticed that you have sometimes acted out of proportion in certain situations; this can be chosen as a theme. Lie down comfortably on your back, close your eyes, and relax in response to your own relaxation exercise or to given suggestions. Now your helper asks you to remember a recent emotional incident and to talk about it. He will encourage you to go deeper into your feelings in that situation while keeping verbal contact with you. Then the helper will suggest that you slide back in your memory until you encounter a similar situation or feeling in the past.

After a short pause, you will be asked to describe what you now hear or see through your inner senses. You may be asked how old you are in the remembered situation, if anyone else is present, and what is happening. The questions should be formulated in the present tense. When you stop talking or reacting for a while, your helper will gently lead you back into your feelings. Release your feelings as much as possible while reliving the past incident. Finally, the helper will suggest that you relive the situation once again, but now change it in such a way that you are happy with the outcome. You invent your own version of a happy ending and try to feel it.

Another starting point for a regression is to find an unusual phrase that you sometimes use or one that expresses an inappropriate belief about yourself, preferably in connection with an emotional problem. You may sometimes say or think, “I am too old (or too fat or too shy) to find a suitable lover,” or, “I am afraid of crowds (or cancer or confined spaces).” Then, after relaxation, repeat this phrase audibly over and over again and feel into it until a vision or memory develops, which you report to your helper. Prompting questions will be used, as with the other regression method, to lead you deeper into your emotions.

Another method, my favourite, goes as follows: Assume that this time you are the helper or therapist to regress a friend or patient. Have the friend lie relaxed on

their back while you give instructions in a soothing voice. The initial aim is to induce as deep a relaxation as possible. You can give the suggestions for a normal relaxation exercise or suggest deep and slow breathing.

Then say: “Now you feel light and begin to float upwards. You rise higher and higher into the blue sky.” After reinforcing this suggestion for a while, you can say: “You look down but cannot see the Earth because of a dense cloud cover . . . You continue to fly over the clouds to look for a place and a time that hold an important clue for understanding your present condition . . . When you have found this spot, dive through the clouds and descend to Earth . . . After landing, look around and tell me what you see or hear or feel.” Pause after each suggestion, as indicated by the ellipses.

If the friend remains quiet, after a while ask what is going on. If the friend describes a landscape, ask them to find a house or some people and observe or talk to them. Always keep verbal contact. Whatever the friend reports, try to deepen the experience. Some may report vivid scenes and others just vague feelings. The related incident may be an actual forgotten experience or it may symbolize the problem.

Doing this exercise, a patient with cancer of the mouth and throat, for instance, related to me that he had landed on a beach. Some distance away he saw a group of people amicably gathered at another beach. I asked him to join the group to see what was going on, but he found it impossible to approach them. He then realized that he had felt an outsider all his life.
He was a good talker, but he talked to or at people, not with them in an open and personal way, and he had felt separated and excluded from group activities. This caused the energies in his mouth and throat area to stagnate and allowed a tumor to develop specifically in that area.

Another patient related an incident. He saw himself as a young man in a fishing boat with friends. They were drinking moderately. While all the others had fun, this patient became ill and vomited. He said that this usually happened when he drank alcohol. This shows that he had inherited a weak liver that he damaged still further by trying to keep up with his mates.

In another regression, a woman in her 80’s recalled that as a baby she was nearly suffocated by a cat lying across her face. All her life she had been afraid of cats, even if only seen on television. After I suggested that she imagine herself as the baby jerking her body and throwing off the cat, she immediately lost her fear of cats.

In many instances, memories and scenes come up that are obviously from a previous life, even if a person doesn’t believe in this. Most common is the experience of a violent death as a cause of serious present problems. Someone with Parkinson’s disease was so afraid of fire that she became rigid merely watching a fire in a movie. During regression, she relived the experience of being burned as a witch. After suggesting that she burst her ropes and run away, she was much improved. However, after some weeks, she started smelling smoke when there was none. Another regression saw her being burned to death in the great fire of London in 1666. After this, she was never again afraid of fire.

Instead of inducing the regression as indicated here, you may find other suitable methods and invent your own. To end a regression session, give some

positive suggestions for coming back into the here and now. If memories become too disturbing and emotional, the session can also be ended with positive suggestions and repeated another time.

Repeated regressions can probe more deeply into subconscious problems or explore different situations. When investigating a panic-laden situation, such as a previous death experience, initially suggest the regressed person remain an impartial observer above the scene and describe it with detachment. In repeated regressions, you can then suggest becoming more and more closely involved and starting to identify emotionally with the experience.

If a strong negative experience arises, always ask the friend or patient to reinvent that experience with a happy or emotionally satisfying ending. One can also continue to work on unearthed problem areas with affirmations and guided imagery. As with all of these methods, it is good to start with a prayer or affirmation, stating your goal for the session, and ask your higher guidance for protection and your inner self for cooperation.

3. Rebirthing: Rebirthing can be used to release emotional traumas that have accumulated since conception. Preferably have one or more initial sessions with a professional rebirther or with a rebirthing group. Find a helper with whom you feel emotionally secure and who has some experience or a good measure of common sense in emotional guidance.

Lie on your back, lightly covered and without restricting clothing. The helper can initially sit at the head end and touch your head for reassurance. Breathe deeply in a fast, regular rhythm, without a pause between inhalation and exhalation. The helper watches that the lower as well as the upper rib cage moves strongly. During inhalation, press shoulders and buttocks into the mattress, while during exhalation, let both relax. Breathe through the mouth and with an open throat to make a sound during exhalation and preferably also during inhalation.

Let go of any emotions that arise, with the helper assisting by pressing, stroking, cuddling, and giving verbal encouragement to bring them out. If no feelings well up, then try to remember an incident when you where irritated, angry, fearful, worried, or resentful and deepen that feeling. After first working on more recent problems, try to relive your birth experience and rectify any emotional upheavals associated with it. A surprising number of people can actually come to remember their own birth in amazing detail.

Have plenty of big cushions or additional mattresses around so that you can throw yourself about. Keep your eyes closed. Preferably use powerful, stirring music with a strong, regular beat during the first part of the session, becoming quieter towards the end and finishing with harmonious, uplifting qualities. Let your feelings follow the music. The session may last for one to two hours.

Try to find a room or open location where you can shout and scream without attracting undue attention. Before you start relating your experience, use crayons to draw a picture of it, the various feelings represented by appropriate colours. You can then change places and your friend can lie down for a session. Repeat from time to time as required to release emotional negativity.

4. Reprogramming: Autosuggestion or reprogramming is one of the most effective tools for changing our belief systems and reprogramming our body and mind. It can be practiced in various forms. At the level of normal consciousness, we can use affirmations. However, suggestions given in an altered state of consciousness are much more effective; we then speak of it as self-hypnosis. We can also use suggestions during sleep. Suggestions can be given in the form of inner pictures and even motion pictures, and then we call it visualization, guided imagery, or reverie. Reprogram-ming is much more effective if we have a strong positive feeling or emotional outpouring at the same time.

EMOTIONAL FREEDOM TECHNIQUE (EFT): Before positive affirmations can become effective, we must first free ourselves from fears and the emotional content of negative memories. Otherwise, these continue to cause distress and block the free flow of energies. One of the best methods that I have found is the Emotional Freedom Technique. This method, mainly developed by therapist Gary Craig, is very effective in overcoming negative emotions and disturbing memories and their harmful effects on body and mind. You may be able to eliminate some disturbing problems within minutes.

The basic principle is to combine consciousness with energy flows. The fundamental discovery of this therapy is stated as: The cause of all negative emotions is a disruption of the body's energy system. It is claimed that single aspect problems, such as fear of public speaking, of heights, of snakes or spiders, can often be overcome within minutes. Also, many physical problems seem to yield to the same formula. This is not entirely surprising as most physical problems have an emotional component. However, in addition, we can expect a direct beneficial effect on the physical body by balancing the energy system, especially if this is combined with conscious awareness.

You can select a health problem or a memory that still evokes a negative emotion when you think of it or feel into it. Craig used the following formula: "Even though I have this [state the problem], I deeply and completely love and accept myself." For instance, if you have been negatively affected by the diagnosis of cancer, then you may say: "Even though I have this fear of cancer, I deeply and completely love and accept myself." You can also try variations, such as: "Despite my fear of cancer, I fully expect to overcome it." Therefore, you first state the problem that you want to overcome and then your expected goal or solution. Preferably say the affirmation aloud, at least in the initial tapping sequence (explained below). In repeated tapping sequences, you can shorten the selected affirmation or say it just in your mind.

The more specific you can be in selecting your affirmation statement, the more effective it will be. Your fear of cancer may be a composite of multiple aspects, such as the fear of dying, a fear of pain or suffering, a fear of having to leave your family behind, perhaps just fear of the unknown, the emotional impact of the original diagnosis, apprehension of financial hardship, of becoming incapacitated and a burden on your family, and many others. You need to address each of these different aspects separately and say, for instance, "In spite of my fear of dying . . ." or "Although I am shocked by my cancer diagnosis . . ."

In order to make the selected affirmation effective, you tap on selected acupuncture points. This temporarily normalizes the energy flow of the tapped

meridian. Each time, while saying your affirmation, tap each selected point about seven times in the order given in the list. Do this firmly with the tips of the index and middle fingers of either hand on one side of the body or better still, use all slightly curled fingers on both sides of the body. The meridian points to tap are:

- at the top of the head
- at the inner end of each eyebrow
- on the bony ridge at the outside of the eyes
- on the bone under the eyes
- between the bottom of the nose and the top of the upper lip
- midway between the point of the chin and the lower lip
- where the breastbone, collarbone, and first rib meet
- on the side of the body, level with the nipple of a man or the bra strap of a woman
- on the inside of each wrist

At the beginning of the procedure, and again after a series of tapping, assess the emotional intensity of the stressful memory or fear by imagining the corresponding situation. Assign to it a number from zero to ten, whereby you do not feel any emotional content at zero but it is overwhelming at ten. If the intensity has lessened but not returned to zero, repeat the series with an adjusted affirmation. Now you can say, for instance: “Although I still have some of this fear of cancer, I deeply and completely love and accept myself.” Later you can adjust this still further and say: “Even though I still have some of this remaining fear of cancer . . .”

If your negative memory is not easily put into words, then you can just imagine it as a movie scene lasting for several seconds and rerun it when tapping each point. This may be suitable in an abuse situation with many different aspects to address. In addition to performing the tapping on yourself, you can also work on a friend or relative. If you do not get results, then you may need to reformulate your affirmation to address a different aspect of the problem, or make your affirmation more specific.

With some problems, especially of a physical nature, it may help to repeat the procedure many times during the day for an extended period. To overcome a strong addiction, such as for drugs or smoking, it may need to be repeated every waking half-hour for several days.

Some individuals may also be blocked by what have been called energy toxins. These may be due to electromagnetic pollution, chemical sensitivity, food allergy, and especially medical drugs. If no progress can be made with different affirmations, then try to perform the procedure in a different and preferably unpolluted place. If this does not help, clean yourself thoroughly in a bath or shower but without any soap and then test (using muscle testing, as explained earlier in the book) before putting clothes on. Try standing on a tile or hardwood floor instead of a carpet. If that does not help either, try an elimination diet, as described in part 1. The most common energy toxins are often the foods that we love most, in addition to perfume, herbs and spices, wheat, corn, sugar, coffee, tea, caffeine, alcohol, nicotine, and dairy products. Try muscle testing to find the source of your problem.

For more information see: www.emofree.com and www.emotionalrelief.org . Dr. Mercola has a good EFT protocol for beginners at: www.mercola.com .

As an extension of this method, I suggest that after freeing yourself of negative memories, you also experiment with positive affirmations, especially for improving body conditions. While you may start out formulating your phrase as given above and say: “Even though I still have some remaining weakness in my immune -system, I deeply and completely love and accept myself,” you may eventually rephrase it as: “Every day in every way my immune system is stronger and stronger.” You can augment any other positive affirmations in the same way.

AFFIRMATIONS: Look through your list of beliefs that you want to change and select one or two that have the most immediate importance. Often this will be a health problem or an emotional difficulty. Then work out a short statement to describe your goal.

With breathing problems, for instance, you can state: “My breath flows freely and easily at all times.” Write it down at least ten times and then read it aloud as often as you wrote it. Do this several times daily. While making each statement, try to feel it at the same time; in our example, feel your breath flowing freely.

Be aware of your inner reaction to the affirmation. Does it sound convincing or does it ring phony? Ask your inner self to participate in formulating the affirmation, so it leaves a good feeling when you use it.

Initially, you may perhaps state, “I am happy, healthy, and fit,” but something inside you may suggest instead, “You are happy, healthy, and fit” or “We are happy, healthy, and fit,” the “we” referring to your different selves. Try out such variations and different formulations of the same problem and then select the one that feels best.

Another good general affirmation was used extensively by Emile Coue, the originator of autosuggestion therapy: “With every day in every way I am better and better.” Note the rhythm and poetic sound of this suggestion. In this way, the right half of our brain, which requires artistic stimulation, can accept a verbal suggestion that it otherwise might ignore. The right brain is intimately linked to our subconscious mind. Making the message acceptable to the right brain is the key to successful reprogramming. I also like to say: “My days are filled with love and joy.” You can say this right after the Coue affirmation. Feel the joy and love while you say it.

Another way in which this can be done is by singing our affirmation or saying it in rhythm or rhyme or with suitable music. Most effective appears to be baroque music with about 60 beats per minute, preferably featuring string instruments. You can also experiment by using different colours in writing down your affirmations, or incorporate the written affirmation in a painting, or even express your affirmation as a painting.

Preferably work on only one important problem at a time, be it for days or weeks or months, until you have made sufficient progress. You can, however, use a general formula, like the one by Coue, in addition to an affirmation for a specific problem.

Affirmations are statements of goals or intentions that you imprint on the mental level with the aim of getting them accepted by the inner self. When this is achieved,

when the inner self believes your statement, it is as good as done. As with prayer, the key to success is your faith that your request has already been granted at the spiritual level and just takes some time to become manifest in your existence. In order to demonstrate this faith, it helps to stop using the specific affirmation after some time and live as if it has already come true.

5. Self-Hypnosis: Instead of clothing a suggestion in an artistic dress to make it acceptable to the right side of the brain, we can achieve a similar result by switching off the analytical left side of our brain. We can do this by entering a state of deep relaxation or meditation. We are naturally in this state just before falling asleep or upon awakening. In this condition, the alpha brain waves dominate. Experiment with the various relaxation and meditation methods already described in this book.

When fully relaxed or in an altered state of consciousness, repeat mentally, or just slightly audibly, an affirmation which you have selected beforehand. Mentally wander through your body and give a positive suggestion to each organ and system, and send a strengthening flow of energy into each.

Start with the head and say mentally or aloud: “Brain healthy and balanced, hair natural color, eyes strong, scalp relaxed, forehead relaxed, neck muscles relaxed,” and so forth, working your way down to the toes. Then mention the various systems and functions, such as “nervous system strong and balanced, glandular system healthy and balanced, digestive system strong and efficient.” Mention also the blood circulation, the immune system, reproductive organs, and the lymph circulation.

Repeat each suggestion several times or for about half a minute. Concentrate for a longer period on problem areas. Tell your body to cleanse itself of toxins and metabolic residues. Feel the toxic energies leaving your body through the feet and with the breath.

Do not think while giving these suggestions. Let them casually drift into your mind and hold them leisurely for a while. Keep your attention on feeling the various body parts or the effects of any other suggestions. You are in the correct state of mind if you startle at an unexpected outside noise.

Before opening your eyes after awakening or when finishing your meditation or a relaxation exercise, give yourself a positive suggestion: “When I count to five, my eyes will open and I will feel refreshed, energized, and joyful.” Then count slowly and try to feel the sensation of being refreshed, energetic, and joyful. Give yourself helpful suggestions for a restful sleep or for solving specific problems just before falling asleep.

Children, and adults with their consent, can be given helpful suggestions during their sleep. Start by telling them to continue sleeping, that all is well, and that you love them. Then repeat the special message ten times in simple words. With children, this may involve overcoming problems of bed-wetting, behaviour, or school activity. For yourself, you can also use tape-recorded messages that automatically switch on and off.

6. Guided Imagery: For many problems, visualization or mental imagery is the most powerful autosuggestion method. After entering a state of deep relaxation, visualize your goal or the desired solution to your problem, and hold the picture in a

vivid form for as long as possible. Try to feel it at the same time. Alternatively, you can produce a “mental movie,” also called a guided reverie. Visualization is usually more effective if you do not try to hold on to a still picture, but make it in some way dynamic, with changes in color, size, and intensity of feeling.

Picture various scenes eventually leading to the desired solution. See yourself as you would like to be, with natural hair color, smooth skin, ideal weight, joyfully dancing, overflowing with energy while running up a hill, and so forth. For improving and toning your body, visualize and feel each organ and gland in turn, see it in a healthy shape and color; you can refresh your memory from an anatomical atlas beforehand. In addition, picture streams of healing energies circulating through the body; use yellow or orange colours for toning, green for balancing, and blue for sedation.

Visualize your health problem. For instance, if there is a tumor inside your body, visualize it as a black or gray mass. Then do breathing exercises: With each inhalation, see your body being flooded with a golden-yellow energy. See how this energy gradually dissolves and washes away the dark tumor mass; with each breath, see it become smaller. The dissolved mass is then expelled with the outgoing breath.

Make this exercise last 15 minutes or longer until the tumor has completely disappeared before your inner eye. If you finish much sooner, then start again dissolving the full-sized tumor. Repeat this exercise daily or even twice daily in serious conditions, best in combination with prayer and meditation.

As an additional exercise, see your immune cells charging into the growth and destroying the cancer cells. Invent a picture with a strong emotional impact. You may, for instance, see your immune cells as white mice nibbling away at a cheese that represents the tumor, or you may see them as star-wars spaceships shooting down ugly enemy spaceships that symbolize individual cancer cells.

For different conditions, invent your own visualizations. For cataracts, see a gray film over your eyes slowly disappearing. If there is a severe pain, see it as a fireball that is gradually extinguished by a flood of deep-blue, water-like energy, drawn in with the breath. For a paralysed body part, see an orange or fiery red stream of energy enter the limb with each breath, causing it to become more and more hot, tingling, and gently moving with each renewed burst of energy. Use your imagination to create a mental picture suitable for your specific problems. There is no limit to what you can achieve.

The following exercise may show you the power of imagination:

- Sit relaxed, then turn your head without moving the shoulders as far as possible to each side, and note how far you can see the wall behind your back from each side.
- Perform a short relaxation exercise and then imagine that your head turns effortlessly almost 180 degrees to each side so that you can see the whole wall at your back.
- Repeat this imaginary turning of the head several times to each side, but without moving the head physically.
- Open your eyes and turn your head to each side and note how far you can now see behind your back.

BODY TALK: Guided imagery is even more effective if you combine it with talking to your body. Imagine that the body has many different levels of consciousness. Your mind usually works at the mental level while your subconscious mind is in charge of the emotional level. Below that is the life-force level, and that is where your body self operates. However, I believe that each organ in our body and even each cell has its own consciousness. You were already enlisting the cooperation of all these individual levels of consciousness with your guided imagery. Now imagine that you can talk to them as well and that they are willing and eager to comply with your wishes.

In a relaxed state, talk to any organ that you want to improve. Talk to the "body self" that is in charge of all the different organs and body parts. Give it a name, as for instance, your unused middle name, and talk to it as you would to a child with a problem. Tell it repeatedly what you want it to do, such as shrink a tumor, put on or lose weight, strengthen the immune system, remove toxins, and so forth. Give it enthusiastic encouragement and convince it that it is able to do it. If, for instance, you have a breast tumor, then ask it to heal the breast and to support the breast in its efforts to heal.

Then in the same way talk to the affected breast. Tell it what you want it to do. Tell it that it is strong enough to heal the tumor and heal any lesions. Ask it to turn to the body self for help. Assure your breast that you love it and promise frequently to send it love energy and any other support that it may need. Then do not forget to do as you said. Tell your body self as well as your breast to let you know what you can do better to support them, and in a relaxed state listen for an answer. A helpful idea may unexpectedly cross your mind.

Talk audibly and frequently to your body, at least once a day. After the initial contact, you do not always need to be in a relaxed state but can talk whenever you feel like it. You may find it very effective talking in front of a mirror. You can also directly talk to your army of immune cells, giving them a pep talk as their commander in chief, or ask the red blood cells to carry more oxygen or the lymph fluid to remove waste products more efficiently.

CHANGING YOUR REALITY: Let's say your reality is that you have been diagnosed with cancer and that you have various physical signs and symptoms to prove it. However, the crucial point is that you cannot change your reality by focusing on what it is. This is so because we create our own reality by what we focus on. If we focus on having and fighting cancer, then we reinforce having cancer as our reality. The harder we fight it, the harder it fights back. Resist and it will persist.

Therefore, to change your reality you need to change your focus. Focus on what you want instead of what you have. That is magic. Focus on what you want to be your reality and fill it with your energy. To do this, you can use various mind tools such as affirmation, visualization, guided imagery, prayer, and meditation. But most important, you must live in harmony with the new reality that you want to manifest. You must live as if - as if the healthier and more joyful reality has already started to manifest. It is not enough to expect tomorrow to be better or upon awakening in the morning to expect to have a better day. It is good to expect that, but expectation is not enough. During the day, you actually need to act according to your new reality by embracing life to the fullest.

Do whatever you need to improve your health. You may occasionally have a cleansing period; you may take certain supplements; or make juices and eat certain foods. But do it with the focus of improving your health rather than fighting the cancer and, whatever you do, do it willingly and joyfully. Make your day as interesting and joyful as you can. The more you succeed in this, the more you will forget that you have cancer and the less you will have it and the less it will have you.

Change your focus, deny your present reality your emotional and mental energy, and it will gradually vanish, allowing your new reality to manifest to the degree that you invest it with your energies. But in our physical reality, that takes time. You need to be persistent with your new focus. Any period of doubt or negativity may invalidate a long effort of positive refocusing and you may have to start all over again. Therefore, avoid people and situations, mainly of a medical nature, that tend to generate doubt and negativity. Train your mind to see only the good in everyone and everything. Even your life-threatening illness was good, by helping you to refocus on a new and better life.

CAUTION: Some individuals may be a little unstable, but may not know it. This is often due to adverse nutritional or chemical factors. During meditation, this can open the door to undesirable influences. In this condition, people may hear voices telling them to act in a manner that may harm others. Therefore, be on your guard and follow any inner voices only if their advice is in harmony with your ideals and with the signs of true spirituality. Especially do not act on any advice that may be harmful to another person.

7. Prayer and Meditation: In prayer you ask for guidance, give thanks, or offer yourself for service, while in meditation you listen for the answer. The two methods can be combined in what we can call “inner communication.”

PRAYER: Prayer is a means of making our requirements known to a higher guidance. This may be a request for help for ourselves or others; it may be a request for advice; we may express our gratitude; or we may offer ourselves as vehicles for greater service to mankind. You can continue to address your prayer in the accustomed way or however it feels best. When you pray to God, Jesus, or a saint, assume that the prayer passes from the lower self to the Higher Self and from there to any other “address” as may be required.

When you need help with an important problem, formulate your request in a short, precise form and preferably write it down. Then enlist the help of the lower self to pass on your prayer to the Higher Self. This can be done through devotion, invocation, chanting, or in any way that produces an emotional uplifting, a warm emotional tide coming from your heart or solar plexus. This creates a “carrier wave” that can now be modulated by clearly and precisely stating your request.

Best say it aloud, in the same way as it is written and with the same words on successive days. In addition, create a mental picture or impression of the desired result. It is important that such prayers be performed with a deep inner conviction that the request will be granted.

When you live in close contact with your Higher Self and readily receive guidance, you may proceed in a less formal way and communicate with your Higher Self in whatever way it deems appropriate. The most effective prayer is a

thanksgiving for the granted request, knowing that it has already started to manifest on the spiritual level and will in due time appear in your reality.

Here a summary of some requirements for a successful prayer:

- Contemplate and formulate your message.
- Relax or enter a meditative state.
- Create an emotional opening or outpouring.
- Say your message in simple words, preferably aloud.
- Include thanksgiving for what you are about to receive.
- Have complete faith that the prayer is successful.
- Repeat your prayer on successive days.

MEDITATION: During meditation, you still your mind and raise your awareness towards your guiding consciousness. Christian saints used to call meditation “silent prayer.” In meditation, you remain in a heightened state of consciousness without thinking.

During meditation, we should be wide-awake. Therefore, if we feel somewhat tired, our meditation can be improved by raising our energies beforehand with a few minutes of deep breathing and whole-body shaking. Then proceed with a relaxation exercise and preferably an invocation or devotional service in which you state the goal of your meditation in a prayer or affirmation.

Assume a physical position in which you can be comfortable for an extended period. Preferably keep the spine straight. You can sit erect, with both feet on the ground, in a chair with a straight back, or sit cross-legged in a lotus or semi-lotus position. For many, it may be more comfortable to sit on the heels with a cushion under the feet. You can also lie flat on your back if you are able to remain wide-awake in that position.

An easy method is to start with eight-two breathing (as explained in step 9) and then gradually let the breath move on its own. Focus your full attention on the breath; feel how it flows in and out smoothly and rhythmically. Do not try to regulate or guide the breath; just follow it mentally and feel it. When thoughts arise, let them drift past without paying any attention to them; the same with outside noises, just ignore them.

At other times, you can concentrate on your heart area and feel it become warm and filled with love and compassion. Alternatively, focus on the middle of your forehead, feel it as a centre of happiness or even bliss. If the eyes are closed, it helps if you turn them up and inwards as if looking at the forehead centre. In addition, feel connected to your Higher Self through a beam of energy entering the top of your head.

Hold these sensations as long as you can. If possible, unite the sensations of the head and the heart and expand them throughout the body. Do not be disappointed if you cannot feel the warmth and love radiation the very first time, just keep on practicing. Meditate for 30 minutes or longer, the longer the better. Preferably make meditation a regular habit at the same time and in the same location each day.

A Healing and Love Meditation

- Sit or lie relaxed but with a straight spine.
- Take some slow, full breaths; mentally follow each breath as your breath continues to flow quietly in and out on its own.
- Feel how your body gradually becomes immersed in cosy warmth - you can imagine being in a warm bath.
- Concentrate on the idea that with each inhalation vital energy or prana begins to fill the body. Direct this energy into your abdomen and feel it becoming very warm.
- Direct the pleasant-feeling energy stream to those areas of the body that are especially in need of healing.
- Concentrate on the middle of the chest where you create a feeling of intense love and compassion.
- Initiate this feeling by remembering an actual situation or person that invoked such feelings in you. After a while, forget the actual memory and feel love and compassion in an abstract way.
- Imagine that you radiate these feelings, like a sun, radiating love and compassion instead of light and warmth. Radiate these to all your body areas in need of healing as well as to the outside, filling the room, the house, and finally all the world. Realize that you are not the originator of this powerful energy flow, but just a channel through which it emerges from higher dimensions and is transformed by you to the human qualities of love and compassion.
- At other times, radiate joy and happiness instead. Hold on to the impression of being immersed in an ocean of beneficial healing energy and for the rest of the day feel an afterglow of the love and compassion or joy and happiness you experienced.
- If an unpleasant condition develops during the day, try to recall mentally the ocean of warm contentment enjoyed during meditation.

CENTERING: During our daytime activities, especially on important occasions, it is beneficial to focus our feeling awareness on an inner energy centre. We may feel this as a deep inner peace, as love or compassion, depending on our focus and the requirements of the occasion. This allows us to gather our energies and gives us poise and serenity. This is called centering - moving through life in a meditative state.

There are various methods of centering. The Japanese, for instance, prefer to centre themselves in the hara, the storehouse of vital energies behind the navel. This helps one conduct daily activities in a more focused and powerful way. If we prefer to interact in our relationships and daily life with love and compassion, then we use the feeling awareness in the heart chakra as the method of centering. Focusing on the forehead chakra may be more appropriate during times of intense mental activity, such as discussions and meetings.

If we aim to act from our level of spiritual consciousness and like to feel connected with and guided by our Higher Self, then we may centre on the crown chakra. Finally, with some practice, we may be able to fuse our awareness of all of these chakras and remain centred within this integrated feeling awareness.

When we are centred, we are not only mentally and emotionally poised and balanced, but at the same time alert and intuitive. In this way, we can remain in touch with our spiritual guidance continuously during our waking activities. When we are

active while being centred, both sides of our brain work in a balanced way and this is reflected in the balance of our whole personality.

It is much easier to remain centred during manual activity than while thinking, reading, or writing, but gradually we can also learn to remain centred during mental tasks. Eventually, we may be able to remain indefinitely in a semi-meditative state by focusing part of our awareness on our inner centre while another part deals with our external problems.

8. Inner Communication: In order to receive direct guidance from your Higher Self, combine relaxation, visualization, prayer, and meditation. Start with a relaxation method that gives you the feeling of drifting lower and lower as to the bottom of a lake. Or imagine sinking down a long, black tunnel towards the core of your being. The farther you sink, drift, or swim downwards, the more you leave the noise and activity of the outer world behind. Regard any remaining noise as ripples on the surface of the lake while you remain at the bottom in peace and stillness.

Instead of going down, you can mentally create a special room that you enter only when you want to meet your higher guidance, either by telepathic communication or seeing it as a wise and kind guide. Another possibility is mentally walking down a shaded path to a waterfall and meeting your guide there.

Whether you see a guide or not, address your presumed guide with reverence and ask him to start guiding you on your spiritual path, in health matters, and with other problems, by communicating with you. Ask a question and listen for the answer. You may receive an immediate telepathic reply, such as an inner voice or a thought popping into your mind. Alternatively, you may develop a certain feeling in reply to a question rather than getting a mental response and this may indicate the direction in which to proceed. Maintain a blank mind after asking your question, otherwise you may not hear the answer or start thinking of an answer yourself. You can ask several questions and hear answers as in a dialogue. Prepare your questions in advance, before starting the relaxation, so that you do not need to think while in meditation.

INTUITIVE MEDITATIVE THINKING: This is related to the traditional practice of contemplation. Suppose you want to find an answer to a problem. This can be a health problem, an invention, or a spiritual matter. Start by finding out relevant facts and information, and then examine it from different perspectives with your mind. In this way, you can identify the key question that needs to be answered in order to find the solution to your problem. Keep this key question in the back of your mind and enter a meditative state without specifically thinking about anything. Watch any thoughts drifting by. If you have thought hard enough about the problem before and now maintain a reasonably blank mind but with the question still in the background, then the answer may now drift into your consciousness as an intuition.

FOCUSING: Lie down or sit comfortably and induce a relaxed condition. If you have a pain, hurt, disease, or any problem in your body, focus your attention on it. Feel into it and ask it what it has to tell you, or visualize your problem in a simple, symbolic way, then mentally sit back and let the pictures or symbols change of their own accord.

You can do the same thing with an uneasy feeling such as created by a social, financial, or other problem. Contact that uneasy feeling, possibly by feeling it as a

pressure somewhere in your body. If you have a multitude of problems, ask yourself which one is the worst and try to feel this one first.

After listening to your body and feeling the tension it creates somewhere, a certain impression may form within you as an answer to what it is all about or you may see a symbol as an answer. Then ask that tension or problem in your body whether this is the right answer and feel what it does. If your answer is correct or partly correct, the problem will shift; the tension or pain may lessen or you may feel relieved. If the answer is wrong, the feeling of unease will not change. Try again. This process may have to be repeated many times over several days or weeks to come to the bottom of deep-seated emotional problems.

SLEEP OR DREAM SOLUTIONS: Before falling asleep, pray to be shown a solution to your problem overnight or tell your subconscious mind repeatedly in simple words that it will provide an answer to the problem at hand, either in a remembered dream or as an insight during the following day. Visualize your problem in a simple scene before you drift to sleep. If you are not already in contact with your subconscious mind, this procedure may have to be repeated several times.

MAKING SACRIFICES AND AMENDS: Sometimes it may not be possible to get to the deep-seated cause of a personal problem. Especially in cases associated with feelings of guilt or having done something wrong, it is often helpful to make a sacrifice in order to regain the cooperation of our subconscious mind or lower self.

The sacrifice must be enough to hurt you to some extent, for example, selling the best part of your stamp, coin, or art collection and using the proceeds for a charitable purpose. Alternatively, give a free service or care for a stranger in need - anything that will satisfy the subconscious. Make amends with reference to past faulty mental, emotional, or dietary habits. Promise improvements and definite actions to your lower as well as to your Higher Self. However, a broken promise will lead to further health problems, so be careful and persistent with your promises. Do not resent your sacrifice, but do it in a cheerful mood.

MOVING WITH THE FLOW: With or without inner communication, we can gradually adopt an attitude towards the events of our daily lives that may be described as “moving with the flow,” as in the flow of life. This means we flow through life instead of battling it when the going gets tough.

We can assume that our Higher Self guides us in a certain direction. When we follow this direction, life will run more smoothly, events fall into place, we meet the people we need, we find information that helps us along, and we obtain the necessary resources to continue on our way. If we go too far in a wrong direction, however, things will become tough, we make mistakes, lose out, do not obtain what we want or need, and so forth. Therefore, when we adopt the basic attitude of moving with the flow and we run into difficulties, we realize that we may need to change direction. While we remain true to our spiritual goals and ideals, with the goals of daily life, and especially in the way we intend to achieve them, we try to be very flexible. Rigidity in daily life easily leads to pain and disappointment.

We can compare our stream of life to a newly formed watercourse that seeks its way down a gentle mountain slope. Sometimes it winds its way steadily downhill, while at other times it encounters a barrier, a hollow or depression in the ground. Then it has to wait patiently for a while until the hollow is filled up. It may probe in

various directions until finally, quite naturally, and without a problem, it finds the overflow, the lowest point in the wall of resistance, and happily it continues on its downhill way.

This, then, shows us how we can follow our course of life in an easygoing, pleasurable way, without undue stress or hardship. When we encounter a resistance, we probe and wait patiently until we find a natural opening. All we need are flexibility, patience, and faith. Faith that we are being guided, that we meet the resistance for a purpose, and that we will learn and grow by overcoming it or finding a way around it. Faith that all will be well and that an interesting and pleasant future awaits us.

ASK FOR HELP: If problems seem to mount and you feel pulled down by it all, relax and ask your guidance for help. State your situation, that you do not know what to do or that there is apparently nothing that you can do. If appropriate, acknowledge that you made a mistake and got yourself into trouble because of a thoughtless or selfish action. Ask your guidance to take over your problems and provide a solution that is fair to all concerned. Then, whenever you notice your mind straying towards a worrying thought, affirm silently that now your guidance has taken over and is providing an equitable solution.

EXPLORE POSSIBILITIES: Sometimes you have to make a choice between several possibilities without a clear preference for any one. Like water when it meets a resistance in its flow, so you can probe in various directions, exploring the different possibilities with your mind, while at the same time closely observing your feelings.

Let us assume you have several options for your future. All have advantages and disadvantages, and you do not know what to do. Doing nothing or changing nothing may have undesirable consequences that need to be evaluated. Start by imagining that you follow one course; visualize or mentally explore the possibilities arising from this and observe how you feel about it. Explore the second choice and then a third choice in the same way. Usually one of these mind-plays will generate a better feeling and this is the one to adopt.

Whenever problems seem to mount and you start to worry, become aware of your spiritual philosophy and ideals and ask yourself: “Does it really matter?” Remain centred and all your problems will soon melt away in the warmth of your radiating love and a deeply felt inner peace.

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Part 10
SPIRITUALITY AND HEALTH

In order to become more whole and healed on all levels of our being, we need to improve ourselves on these levels. Complete healing is not possible by working on just one level. As an example, assume that you are overweight. Mustering willpower, you start a diet and are successful in losing much weight. The problem is that after some months it slowly creeps back up again and after a year your weight is where it started.

Eventually, you come across some emotional release workshops and find that these, together with a sensible diet, are more effective for losing weight and keeping it off. Nevertheless, you find it difficult to keep your emotions under control because you still continue to react in undesirable ways. Now you discover that you are influenced by negative beliefs that make life difficult for you.

You realize that you need an appropriate belief system in order to manage your emotions in an appropriate way. You start looking for a philosophy of life that helps you to become and remain healthy, happy, and fit. This is where the spiritual dimension comes in. You will find that the more you adopt spiritual principles in your life, the more life will become an adventure and a pleasure rather than a struggle.

Most of us have developed our belief systems haphazardly, drawing from parents, school, and social contacts as well as books and mass media. These beliefs are often irrational and detrimental to us.

So to heal our emotions and other levels of our being, it is essential to adopt a suitable philosophy of life to guide us. I call this a spiritual philosophy. The various religions appear to have different spiritual philosophies. These differences are most pronounced at the mental level of dogmas and doctrines, while they tend to disappear at the level of the highest ideals of each religion. In all major religions, some followers have aimed for these highest ideals. They are the mystics who left us in their writings a spiritual philosophy that transcends and unites all religions.

This last chapter offers an outline of the spiritual dimension, existing in a continuum with our physical world and not separate or in opposition to it. Out of this understanding, we can accept a spiritual philosophy of life as the basis for our beliefs, which determine our decisions and emotional reactions in life. Then I offer a sketch of a modern spiritual path that uses health and emotional problems to develop the spiritual master-ship that gives us the ability to lead a happy and fulfilled life.

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Step 64
THE SPIRITUAL DIMENSION

Enter the spiritual dimension of life and make it your home.

The concept of spirituality means different things to different people. In this book, it means deliberately manifesting or aspiring to manifest a higher, purer consciousness. We do this by developing the attributes of spirituality, such as compassion, discernment, faith, high ideals, harmony, joy, inner knowledge, intuition, kindness, openness, patience, self-responsibility, serenity, tolerance, wisdom, and a gentle love for All That Is.

To be spiritual is not the same as to be religious, which involves following the creed of a proclaimed religion. Someone can be spiritual without being religious and vice versa. Those who are religious become spiritual by following the highest ideals of their religion, while those without a religion follow their own highest ideals and their higher guidance. On the higher levels of consciousness, religion and spirituality merge. In Christian terms, for instance, we are advised to “seek first the Kingdom of Heaven” and all else will be given us. In spiritual terms, this means to seek first and follow our higher guidance to manifest spirituality, then we can expect health and happiness to result as a natural by-product.

Spiritual development should not be confused with psychic development. Psychic abilities are no measure of spirituality. However, psychic abilities will develop on their own and in a natural way during spiritual awakening, according to the need for their use. While neither good nor bad in themselves, psychic abilities without spirituality are like nuclear power without prudence; both can lead to disaster.

Neither is spiritual development a quest for altered states of consciousness, though these may occur as natural by-products of deep relaxation and meditation. They can be useful and provide us with insights as well as beautiful and uplifting inner experiences. However, our main task is at the level of our normal consciousness, and such inner experiences at elevated levels need to be transformed into improved living habits.

We become more spiritual by living according to our highest ideals, and by consciously improving our attitudes and feelings. Every moment in our day-to-day interactions provides an opportunity to become more spiritual. We are aided in this endeavour by asking for help from the highest guiding part of our consciousness, which we can call the Higher Self or, in Christian terms, the Holy Spirit.

Our Spiritual Growth: Living spiritually is our day-to-day, minute-to-minute effort to live according to our beliefs. Our body with its problems is an important partner in this; it shows us where to start and what to do and helps us become more aware of all aspects of ourselves.

Healing our body, mind, and emotions is part of our spiritual growth. Even if you do not otherwise intend to live spiritually, you do so anyway by healing yourself on these levels. I am convinced that by living in harmony with the biological, emotional, mental, and spiritual laws that govern us, we can be close to perfect; we might even personify the risen Christ. Therefore, all imperfections, usually manifesting as

problems, show us what to do to become more spiritual and, with this, more happy and fulfilled.

Starting at the biological level, we may have a health problem, possibly a specific disease. This disease has one or more causes, usually on several levels. Just trying to ease symptoms with palliative care is not a spiritual solution, although we can use the disease to practice cheerfulness in adversity. With our spiritual quest, we try to discover and overcome the causes for the disease. We experiment with nutrition, cleansing, and other natural healing methods; we improve our energy flows by softening armoured muscle structures; we release suppressed negative emotions; and we may use regression and reprogramming, guided imagery, and meditation. Chances are the disease will more or less disappear as, at the same time, we have progressed on the spiritual path.

The same is true for any of our other imperfections and problems: a rigid and aging body, a lack of meaning, unsatisfactory relationships, worry, or resentments. Keep part of your mind in observer mode and be aware of what you are doing. If you catch yourself worrying about something, that is your problem to work on; worry is a negative attitude, and you need to change your approach. Do what you can to get the problem fixed and then leave it to faith; use prayer and meditation to strengthen your faith.

If you catch yourself having an unkind thought about someone, immediately make an effort to send a kind thought to that person. If you believe someone has harmed you, realize that this person is a human who needs your help. Be angry if you feel that way, but let it out in a suitable manner, and when you have calmed down, forgive and send love.

Learn to laugh about yourself when you make a mistake or break something. You would laugh if it happened to someone else, so try it for yourself; it makes life much easier. Taking ourselves too seriously shows that we are dominated by our ego.

It is said that no one is an island, that we all are in it together. We interact all the time, and helping our fellows is the most important part of interacting. We cannot help by preaching or trying to convince somebody. The most effective way is to be an example of your spiritual beliefs. Be forgiving, be kind, try to do the right thing at the right time, but if you mess up, do not worry; you are not expected to be perfect, so try again.

As your consciousness expands, you may realize that your job or your partner are no longer in harmony with your beliefs. Visualize and pray for a solution and watch.

You do not need to go out of your way to look for opportunities to help others. Just be aware and do your best whenever you come across something; your guidance will arrange the opportunities for you to learn and help. Do not blame yourself or anyone else if something goes wrong; making mistakes is the best way to learn. We need to make mistakes and learn from them - that is the spiritual path.

Specific ways of life have been devised through the ages to facilitate the growth of a spiritual body. Foremost in these are prayer and meditation, especially as part of monastic life. In a related form, we have the yoga of devotion and the yoga of action in which we dedicate our life to unselfish social work or healing. Rituals, such as performed by the Orthodox or Catholic church, metaphysical societies, and New Age

groups, offer spiritual food. When we deliberately set out to awaken and build a body for the inner Christ, we are said to be on the spiritual path.

The Structure of Manifestation: Here is a brief outline of a theoretical basis of spirituality as I see it. Starting at the fundamental level, I regard consciousness as the basic ingredient of everything in existence. We can compare consciousness to air, which can be compressed to varying degrees of density in containers of different shapes and sizes. In a similar way, consciousness becomes compressed and can then aggregate to form more complex structures.

Different densities accumulate at separate levels to form an additional dimension based on density of consciousness. I call this the dimension of "space-density." A certain density produces atomic and subatomic particles, while lesser degrees of density manifest as etheric energy, bioenergy, or prana, as feelings and emotional energy, as mental energy and thought forms, and finally as spiritual awareness. All of these represent different space--densities that can interpenetrate each other to occupy the same three-dimensional space.

Therefore, there is no fundamental difference between the consciousness of an atom and a human; it is only a difference in complexity and range of densities. The universe is basically consciousness acting on itself. Less dense fields of consciousness build, change, discard, and rebuild forms from denser fields of consciousness in order to experience and express themselves. The main activity of consciousness is creativity; its highest manifestation on our planet is unconditional love.

We can assume two streams of consciousness. The "stream of creation" leads towards greater density and less complexity to form atomic particles and the physical universe, while the "stream of evolution" flows from dense towards less dense structures with greater complexity towards the spiritual universe.

As part of the stream of evolution, consciousness uses the various life forms, like water uses a riverbed to flow to the ocean. A life form, be it a species or an individual form, is useful only as long as it allows the consciousness to flow through freely and expand. If rigidity develops and consciousness becomes stagnant, then the form has reached old age and will soon disintegrate.

Physics cannot adequately and logically answer the question how all the energy and mass of our universe could have been concentrated in a single point at the start of the Big Bang and what was before. A spiritual theory of creation would say that originally there was no energy at the physical level, that it emerged instead from the etheric level, not so much as an explosion, but rather like the crystallization of a supersaturated liquid starting from a seed point. A spiritual theory also answers the question of the origin of consciousness that biology cannot answer: Our physical universe is a condensation of a less dense etheric universe. Atomic particles are the centres of etheric vortexes, comparable to atmospheric high and low pressure areas.

Planetary Evolution: I see the evolution of consciousness on our planet as a multidimensional cooperative venture. Consciousness in the form of the growth force is most active in the plant kingdom and works to transform the mineral kingdom.

In the animal kingdom, consciousness becomes dominant at the level of feelings and emotions; it is at this level where most of the experimentation and creativity are present. The emotional level channels the growth force into more

individualized forms than those in the plant kingdom. A price for this individualization is a more solidified growth force with less regenerative capacity.

Insects are close to plants, with only rudimentary feelings, while primates and possibly dolphins are closest to the humans with highly evolved complex feelings. Similar to the evolution in the plant kingdom, which leads to the beginning of feelings in the highest plant species, so the higher animal species acquire a rudimentary capacity for thinking.

By having its emotional energies guided with the help of the emerging mental level, the animal kingdom culminates with the primates channelling their life force into a nearly perfect form for our planetary conditions. With this, the planetary evolution of the growth force has been further completed and humanity works now on the perfection of the emotional level with the help of the mental level. We use beliefs to experiment with our emotions.

The animal kingdom required a rudimentary mental level for the growth force to be channelled by the emotional level into a perfect form. In a similar way, humans need a level of consciousness beyond the mental to perfect our emotions. We call this next higher level “spiritual consciousness.” It evolves through the programming of our higher mentality by the incarnated soul. We can regard our different and evolving group belief systems as the human equivalent of different animal species.

The Nature of God: God can be defined in two ways. We can equate God with consciousness and say God is everything. The consciousness manifested in the various universes - the physical, etheric, and so forth up to the spiritual universe - are the energy bodies of God, while the non-manifested part might be called the mind of God. Alternatively, we can only regard the non-manifested universal consciousness as God, and this may or may not be focused into what we can regard as a personified being at certain levels of consciousness. For the evolution of our own consciousness, the details of what we believe is God do not matter very much at this stage. As part of a spiritual philosophy, we can assume that the more consciousness becomes condensed, the less it is aware, especially of being a part of God or All That Is.

The Oversoul is the creator of our soul, and as our personal God or God Self, it is our individualized representative of the universal aspect of God. Any communication from this divine level can reach our normal consciousness only by penetrating our mental and emotional levels. These, however, act as filters that distort and interpret any messages according to our beliefs and emotions.

Therefore, a devout Catholic will receive messages clothed in Catholic symbols, while a Hindu will experience divine revelations according to his religious beliefs. The less strong and structured our beliefs are, the less will any higher communication be distorted. The more we expand our consciousness, the closer we are to this higher guidance and the easier it will be to communicate. Disbelief, on the other hand, will block any communication.

A Spiritual Philosophy: A spiritual philosophy is our basic belief system about the nature of our existence, its purpose, and goal. From this we try to understand our role in society and our relationship with guiding forces, and it gives us the strength to follow the spiritual path. Everyone has a philosophy of life, even if they are not consciously aware of it. For some, this is just the notion to get as much pleasure as possible out of life while trying to avoid suffering. Others, like various Christian saints

and yogis, have deliberately self-inflicted suffering and denied themselves pleasures as part of their philosophy and as a path to their God.

To have a spiritual philosophy means to see ourselves as part of a higher purpose, of a universal blueprint, and we consciously try to cooperate with its unfolding and manifestation. A good spiritual philosophy needs to give us guidance and support on the spiritual path and in our daily interactions and relationships.

In the same way that we can deliberately choose to believe in and follow a certain religion or political party, we can also deliberately adopt a spiritual philosophy that exactly suits our purpose. Normally, this adopted philosophy can be in harmony with our present religion or political views. Just look for the highest ideals and replace any negative aspects with positive beliefs.

The centre point of any philosophy of life is the question of meaning or purpose. If we see no purpose in life and especially in our own life, then it is natural to live for the sake of sense and ego gratification, but we can become depressed by the apparent lack of meaning. In a spiritual philosophy, we believe in a higher purpose; we may not know the exact nature of this purpose and it may not even matter. We can say we just want to manifest our own life blueprint, or fulfil the purpose for which we incarnated, or do God's will, or become one with God.

The Middle Path: By now, you may be apprehensive. Basically, all you want is to be healthy, have a good life and some fun, and generally feel fulfilled and satisfied. You do not want to become a mystic or a saint to achieve this. You do not need to. I painted the big picture to show in which direction we have to move. How far or fast you move is up to you. The important part is to move in the right direction, however slowly. Suffering comes from moving in the wrong direction, no matter how far advanced we are spiritually. The saint will suffer if he moves in the wrong direction, and the sinner will feel good if he moves in the right direction.

Indeed, this is a middle path between pleasure-seeking and intentional or unintentional self-inflicted suffering. In this, it is like the path of the Buddha. For a long time, the Buddha tried to reach enlightenment through asceticism. He meditated until he left a mark like the footprint of a camel where he had been sitting. Finally he realized that he was on the wrong path, that he needed his body as a partner and had to fulfil its needs, that he had to be firm but kind to it. He called this the middle path, and many seekers after him found it to be the right path for them.

In the same way, our spiritual philosophy should help us to feel good in body, mind, and spirit. Suffering is only for the ego. If instead we identify with our Higher Self, then life will be easier and more fun.

Our basic premise is that we attract or become what we believe in. Assuming that the universe contains all possibilities, all shades of good and bad, right and wrong, desirable and undesirable, it is more desirable to believe in a benevolent universe than in a vindictive one, in a God of love rather than fear. This spiritual philosophy of the middle path says that we can choose and have what we want, but we must firmly believe in it.

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Step 65
LIFE ON THE PATH

**The spiritual path is the crowning glory of human endeavour,
and by following the 65 steps you are already on it.**

The concept of spirituality means different things to different people. In this Presently, travellers on the spiritual path have two advantages compared to those in former centuries. We now have published information on the nature and variety of spiritual paths, so we no longer need to find our way alone. Second, our capacity to understand and communicate has greatly increased. What formerly was incomprehensible mysticism, we can now understand and present in a rational way.

There is now so much information available on yoga, working with energies, healing the emotions and the mind, and so forth, that your problem is not to find the information, but to discern what is right for you. You can do this by keeping your highest goals in mind and asking your inner guidance.

Beware of getting sidetracked by psychic abilities or happenings. Developing psychic abilities can be fascinating but is no more spiritual than material, emotional, or mental activities. However, psychic activities can be more dangerous than other activities. Most psychic happenings take place on the astral level or open us to astral influences. Entities operating on this level are commonly less spiritually developed than someone on the spiritual path and often give misleading or mischievous information. They also love to imitate or pretend to be a high spiritual entity or even God.

Awakenings: Do not worry about whether you have had a spiritual awakening or are on the spiritual path. Your interest shows that you are on the path. Just start or continue searching for spiritual information. You will be attracted to what is important and right for you. While in the beginning, it is helpful and necessary to read different sources to get a good overview, later it is better to read as little as possible. By continuing to read a lot, you remain at the intellectual level, and that hinders the development of intuitive abilities. If you do not control yourself, you could become “addicted” to reading about spiritual matters, instead of doing it.

If you are a practicing member of a religious denomination, do not be concerned that the spiritual path may be incompatible with it. Instead, expect that it will increase your faith. The spiritual path does not have doctrines; writings about it are only opinions you do not need to accept. Walking the spiritual path means finding your own insights and relationship with God.

Purification does not need to be a time of misery and suffering as it once was for mystics. Instead, it can be a time of adventure and discovery. By removing biological, emotional, and mental blockages, you become healthier and happier. Life will become more satisfying. The fun is not the arrival, but the journey. You do not need to make a sharp distinction between working on the biological, etheric, emotional, and mental levels. They are all related, though it is easier to talk about

one level at a time. By concentrating on one level, you affect all the others. It is easier to start with the biological level and then focus upwards.

The Biological Level: In former centuries, spiritual seekers ate only organically grown food and their water and air were free of chemical pollution. Today we have to work hard at purifying our body to the level where previous seekers started. Therefore, we start with sanitizing the biological body and for this I recommend:

- Basic Cleanse: This can be repeated from time to time, especially if you want to lose weight; also do any other cleanse you prefer; see Fasting and Cleansing in Part 1.
- Test for food allergies and chemical sensitivities at the end of the Basic Cleanse; see Allergy Testing in Part 1.
- Pay attention to the acid-alkaline balance of your body as explained in Part 1.
- Take measures to free your body of parasites and harmful microbes and use anti -inflammatory measures as required; see Parts 2, 3, and 6.
- Eat plenty of raw food, including fresh green and purple juices; see the High-Quality Diet in Part 4.
- Select food suited for your metabolic and blood type; see Metabolic Types, Pathways, and Diets in Part 5.
- Have regular physical exercise and outdoors activity, also yoga, stretching, shaking, walking, jogging, or swimming.
- Sanitize your teeth, bedroom, and workplace; see the Practice of Healthy Living in Part 1.

The Etheric Level: The main features here are the etheric body and the chakra and acupuncture systems (see Part 7). This level of subtle energy determines the health of our body and how energetic we are; this is the energy of life, of healing and manifestation.

To manifest something, be it health or a physical or social condition, we use imagery. Hold a clear visualization of the desired situation, fill it with energy, and continue to expect it to manifest. An important part of our work at this level is to accumulate and direct etheric energy.

In energy work, energy follows thought. However, mental and etheric energies exist on different density levels and do not affect each other directly. Therefore, they require the assistance of the emotional or feeling level, sandwiched between the two. For learning to accumulate and direct etheric energies, practice the energy-circulation (Part 7) and the Love Cure exercises (Part 8). When you are able to feel the energy flows, use them in guided imagery for healing and other manifestations. An excellent book on this subject is The Laws of Manifestation, by David Spangler.

By practicing the Love Cure, you can improve weaknesses and imbalances in your chakra system. This will have favourable effects on your health. If you are so inclined, use guided chakra meditations available on tape or CD from New Age outlets.

For improving your acupuncture system, see Meridian and Acupressure Therapy in Part 7, and after you have learned to feel the energy flows, use mainly mental tracing of the channels. For further practical information on working at the etheric level, see books on kahuna; the modern kahuna teachings started with books by Max Freedom Long (The Secret Science behind Miracles and The Secret Science at Work).

The Emotional Level: For most, this will be the most difficult and possibly most painful level to sanitize, but it will also be the most rewarding. I suggest that you read again and work through Part 8. The important steps in healing emotions are:

1. Emotional cleansing to remove blockages and traumatic memories.
2. Overcoming addictions and cravings.
3. Free-flowing emotions - learn to feel and express emotions freely without hurting others.
4. Generating positive feelings - use meditation and guided imagery to create positive and uplifting feelings.
5. Reacting positively - use appropriate beliefs and mental awareness to react positively to events.

1. EMOTIONAL CLEANSING: Experiment with some of the methods described in Part 9 under Mind Tools, especially with techniques for emotional release and regression; these are best practiced in healing groups (Part 8). An integrated way of healing the emotional level within a spiritual context is provided by the system of Body Electronics devised by Dr. John Whitman Ray (for more information, see: www.bodyelectronics.net).

Similar to Reichian therapy and bioenergetics, Body Electronics works mainly on the body, using sustained pressure to release memories of emotional events that have been lodged in muscles. Practice Body Electronics as a group activity, possibly after an initial assessment by a practitioner; Reichian therapy and bioenergetics are mainly practitioner-based. However, you can also practice bioenergetic exercises at home or in a group; for instructions, see The Way to Vibrant Health, by Alexander Lowen, M.D.

A simple way to contact and release emotional traumas is by using present emotional upsets. If something strongly affects you emotionally, try to feel into it, possibly combined with a relaxation or meditation exercise, to discover why it upsets you. If necessary, reinforce it so as to feel it even more strongly. Most likely, forgotten memories will come up about a similar incident in your younger years. Whatever the method, when you become conscious of an emotional event from the past, it ceases its detrimental effects or it can now be dealt with.

Some of the destructive emotions that we need to uncover and release are fear, guilt, and resentment. These block the flow of life-force energy and make us susceptible to diseases and aging. The main remedies, after making a suppressed emotional memory conscious, are unconditional love, understanding, and forgiveness.

On this level, you do not need to clean out all hidden negative emotional memories, as this would probably be impossible. Aim to uncover and remove all

those factors that interfere with the flow of energies in your body, with your emotional health and enjoyment of life, and with your ability to make decisions.

2. OVERCOMING ADDICTIONS AND CRAVINGS: For many, overcoming addictions and cravings may seem to be the hardest task. Addictions to foods, drugs, and stimulants are best overcome with a combination of guided imagery, prayer, affirmation, and cleansing periods with a very high fluid intake. Homeopathic doses of the addictive agent can be helpful.

We can also be addicted to or have cravings for certain activities or objects, such as sex, gambling, entertainment, expensive dresses, jewellery, or antiques. Again, the activity or object is not the problem, but rather the attachment to it, the desire for it that controls us rather than we controlling it. The most important step is in acknowledging that we have a problem. Apart from prayer, meditation, guided imagery, and affirmations, the most helpful approach would be to live for a sufficiently long period in a simple way in natural surroundings.

3. FREE-FLOWING EMOTIONS: For most of us, freely expressing our emotions is contrary to our social conditioning. A first step then is learning to feel our emotions when they arise instead of suppressing them; we can then decide to express them immediately in a harmless way or re-enact the situation later. In our imagination, we can relive the situation and kick or punch a pillow or do or say, possibly in front of a mirror, what we felt like doing at the earlier time. Nevertheless, it is preferable to develop the skills to react appropriately whenever the situation arises because then we can also be an example to others.

Marriages and other close relationships are ideal opportunities for learning to communicate. If free expression is not always possible, then arrange a fixed time at the end of the day or once a week when you each can freely express your thoughts and feelings. It is important that one person speak without interruption until everything has been said, and then the other reply, also without interruption.

4. GENERATING POSITIVE FEELINGS: After emptying ourselves of negativity and learning to acknowledge and express our feelings and emotions, it is equally important to fill and surround ourselves with positive and uplifting feelings. Ideally, this will come as a natural by-product of habitual meditation and through daily activities that make us feel good.

It is beneficial to practice feeling exercises as explained in the Love Cure in Part 8. Look at a beautiful object, a tree, flower, cloud, or landscape, and send it appreciation, admiration, joy, and love. Do the same in thinking of an individual. Send feelings of forgiveness, appreciation, and love to anyone you may have hurt or who hurt you.

Learn to carry into your daily activities the loving feeling that you can now generate in special situations. Train yourself to carry this loving feeling in your heart wherever you go or whatever you do. Whenever you see or meet someone, embrace that individual with the warm feeling. This is especially effective for improving relationships with people who do not seem to like or appreciate you. Never again do you need to feel bored when having to wait in an office or anywhere else. Just start generating loving and joyful feelings and send them to anyone in sight or in your mind.

Try changing one feeling into another. Start with any emotion you experience at the time or generate a warm feeling by breathing into the abdomen or by imagining an appropriate situation that would evoke it. Intensify the feeling, then imagine how another emotion might feel. In this way, you can experimentally convert love into anger and then back into love. This will show you that you do not need to be at the mercy of emotions arising as a reaction to outside events, but that you can make a decision as to how you will feel.

5. REACTING POSITIVELY: After learning to remain centred in self-generated positive feelings, we need to learn to react positively and appropriately to the many frustrations in our lives. This is possible when we are guided by spiritual beliefs. After adopting a spiritual philosophy, it is easier to see everything that happens to us as a test of our progress.

Every day we have many little tests. It is all right to feel a burst of anger if we break a valuable item, but we can also just laugh about our clumsiness or look for a reason why it happened. It does not matter too much how we react, as long as it is appropriate. If we feel anger, then it is appropriate to feel it and not rationalize it. After having felt the anger, we should not remain stuck in it, but use our mind to get out of it, by seeing the funny side of it or by trying to learn from it.

The basic idea is to feel whatever emotion comes up, but then to modify our expression according to our understanding of the situation from a spiritual point of view. Our emotional reactions are a reflection of our beliefs, and the more spiritual these become, the more positive will be our reactions. The ideal is to be able to express our feelings naturally in a way that has a positive influence on others.

The Mental Level: Our mind is the most important level to heal because here we make the conscious decisions that affect all other levels. Our aim is to free ourselves of negativity and develop positive attitudes. In order to free yourself of negative beliefs and thoughts, you must first recognize them when they occur. Develop the habit of having a small part of your awareness in the background as an observer. Whenever you have a negative thought, your observer will ring an alarm bell so you can realize what you have done. Then, as a mental exercise, find the corresponding positive thought.

As an example, you may watch someone passing by and observe that she is overweight. If you notice having a critical thought about her weight, mentally apologize to her and either send her a mental compliment about some other aspect of her appearance or just wish her well. It is all right to observe, just refrain from uninvited judgments, especially of a negative kind. The habit of critically evaluating others is the opposite of an invited critical and constructive assessment in order to help someone.

Another important aspect in controlling our mind is to refrain from talking about other people, especially mutual friends, relatives, or acquaintances, except when exchanging some relevant factual information. Anything more is gossiping, judging, or criticizing and will delay progress on the spiritual path.

Practice discernment as well as creative and intuitive thinking. Creative thinking means finding answers for spiritual or theoretical questions, or solutions for practical problems; intuitive thinking means we focus on a question or problem in a meditative state and then translate the realization into words.

Helpful Tips: Any kind of worry is detrimental to your health. Worry is a form of fear and that is the opposite of positive expectation and faith. To a large degree, we shape our own future by what we expect. Our inner self tries to manifest what we expect. Our expectation acts like a magnet to attract and draw the expected event into our outer reality. If we worry about anything, then we expect a negative outcome and help to make it come true.

Therefore, our key lesson to learn at the mental level is to know what we want and then, without wavering, expect it to manifest at the appropriate time. Except where timing is essential, it is best not to set a definite time limit. If we want to use "magic" to help our expectation to manifest, use energy imagery: Visualize the desired result and fill it with emotional energy. The critical factor then is your unwavering faith until the expected event appears.

This brings us to the next important step, to know what to manifest. It is said that we should be very careful with our wishes because they might come true. That means that we are usually ignorant about the hidden implications of a fulfilled desire. Often there is a price to pay. We may delay our spiritual progress or even take on a burden of another individual whom we try to help. We may still have certain tests to pass in this lifetime, and it would be detrimental to our spiritual progress to delay or avoid them

A good way of overcoming our weaknesses is by acting as if we have already done so. With every doubtful or important decision, we can ask ourselves what a spiritual master would do in this situation and then just do it.

Remember the advice given to Jonathan Livingston Seagull by his teacher: To be instantly in another place, just imagine and know that you are already there! If you habitually act like a spiritual master, then you are a spiritual master. Your "Inner Master" is there all the time waiting to guide you. Never mind a few mistakes or wrong decisions; there is nothing better to learn from than our own mistakes. You still have many years ahead of you to practice doing the right thing most of the time. When you have reached a level where your motives are unselfish, you do not need to be too concerned about making the right decision. Just trust your intuition or inner guidance. Whatever you choose will usually be right.

Remember the Mind Tools: Prayer, meditation, and studying scriptures were the original mind tools in the West, while in the East visualization, guided imagery, and mantras were commonly used. All of these are still useful.

Develop a daily routine in which you combine several of these methods. This may, for instance, start with prayer and/or affirmations, followed by relaxation, then guided imagery, and finally meditation. During the activities of the day, practice centering. A good way to remain centred is to use a mantra. Another powerful exercise is to imagine being purified by a violet flame. Imagine that the violet flame burns up your remaining or hidden impurities, especially at the emotional and mental levels.

You can also make an effort to become aware of your Christ Self or God Presence, at first in meditation and as guided imagery, but gradually in your daily life. Imagine your God Presence as an intense white spiritual light over your head, or feel or sense it as a protective and loving presence. Initially imagine sending an offering of love or devotion through the top of your head straight up to your God Presence or,

if lying down, send it up through the forehead or from the heart centre. Then imagine a strong beam of white light together with an intensified feeling of love and protection entering your top centre and proceeding through the forehead and throat centres to the heart centre. At the same time, feel and see your whole body surrounded by a greatly expanded aura with beautiful rainbow colours. Frequently connect with your Christ or God Presence in this or a similar way, especially before any prayer or healing work.

Cultivating a Healthy Outlook: We make progress on the spiritual path if in our daily life, and especially in difficult situations, we display spiritual qualities such as compassion, devotion, faith, forgiveness, harmony, high ideals, joy, kindness, oneness, openness, patience, self-responsibility, serenity, tolerance, unconditional love, understanding, wisdom, and a gentle love for All That Is.

Another way of assessing our progress is by how well we are able to unite opposite characteristics within our personality and how well we manifest the appropriate one for the situation at hand. For example, are we able to be a good leader and follower, master and servant? Can we display the “male” characteristics of assertiveness, aggressiveness, and power as well as the “female” ones of gentleness, kindness, and yielding? Do we know how to be strong in our beliefs and open to change?

After years of diligently working to purify and improve yourself, you may wonder when you will have your mind-blowing illumination. That expectation is counterproductive. The illumination experience is an act of grace, a gift of your spirit that will come when you least expect it. It may be during a meditation or in the middle of city traffic. Waiting for it is a sure way of postponing it, because patience is one of the early virtues we have to learn.

When it finally does happen, enjoy it. You do not need to look actively for good deeds to do or for your future field of selfless service. Just continue doing whatever needs to be done at each moment, and especially continue purifying yourself at deeper and deeper levels and uplifting yourself to higher and higher levels. At the right time, your mission will be revealed to you. When you have become a master of yourself, you will be suitable to become a servant of humanity.

Looking back on the path that you travelled so diligently, you may ask yourself “What path?” and wonder if there ever was a path or only a figment of your imagination. In reality, there was nowhere to go and nothing to do to get there. All you did was to change some of your perceptions and attitudes. There is a Buddhist saying: “Before enlightenment he gathered wood and carried water; after enlightenment he gathered wood and carried water.”

* * * * * * * * * * *

A Review of the 65 Steps

The concept of spirituality means different things to different people. In this If you decide to follow the steps outlined in this book, you will have months of interesting work and play ahead of you. Try to make it fun by involving relatives and friends. You may find it helpful to keep a diary to record your experiments, reactions, and insights.

For a solid foundation of your health, get the basics right with Part 1. Start with sanitizing the intestinal tract, cleaning it out, replacing pathogenic microbes with healthy bacteria, and then keeping it all clean. Then you clean out the rest of the body in a series of fasts or cleansing periods. It will be good to continue with a cleanse once a year for the rest of your life. Then test your foods for allergy and sensitivity reactions. Use clean and preferably energized water, adjust your body acidity, and start improving your living conditions. Sanitize your house and minimize electromagnetic pollution. Get into the habit of doing exercises.

These steps provide the basic physical foundation for your health. Take time to do them thoroughly. This can cause occasional healing reactions, but these are beneficial; just take it easy for a few days.

Part 2 explains commonly used healing techniques. The diagnostic techniques show where your problems are and what to do to become more balanced. Muscle testing is easy to learn and very useful for determining whether a food or remedy is good or bad for you. Reflexology is one of my favourites; it is quick and effective for pains and problems in all parts of the body. Magnet therapy has the advantage of being a pain-free treatment. You will find various types of packs useful for many different conditions.

Part 3 contains information on nutrients and remedies. If you sense you require additional nutrients and remedies, then you need a basic understanding of their functions and interactions and how to use them, which this chapter provides.

Part 4 shows you what a good diet is like: Eat as much as conveniently possible of fresh, raw, and organic foods. Change gradually to give your body and taste buds time to adjust.

Part 5 tells you why the foods you probably like are not good for you. Do your best; the prospect of improved well-being will make it easier to give up a favorite food. Finding out if you need a diet high or low in protein and fat is a key requirement for your health.

Part 6 gives natural healing methods for a wide range of health problems; use any of these methods in addition to a healthy lifestyle.

Part 7 introduces you to the subtle energies. Most of us can learn to feel energy, commonly as warmth and tingling. For our health, it is especially valuable to use breathing exercises to activate these energies in our body and direct them to organs in need of healing.

Part 8 handles another key subject: healing emotions. The goal is to live life in a radiant way, filled with love and joy.

Part 9 shows how to appreciate the power of your subconscious mind and make it your friend, how to combine a positive expectation with the help of your subconscious friend so you can heal almost anything. Here you will find many valuable mind tools that make it possible.

Part 10 shows you how to use spiritual guidance to overcome health and emotional problems as part of a spiritual path that provides the framework for your healing venture and gives meaning to your life.

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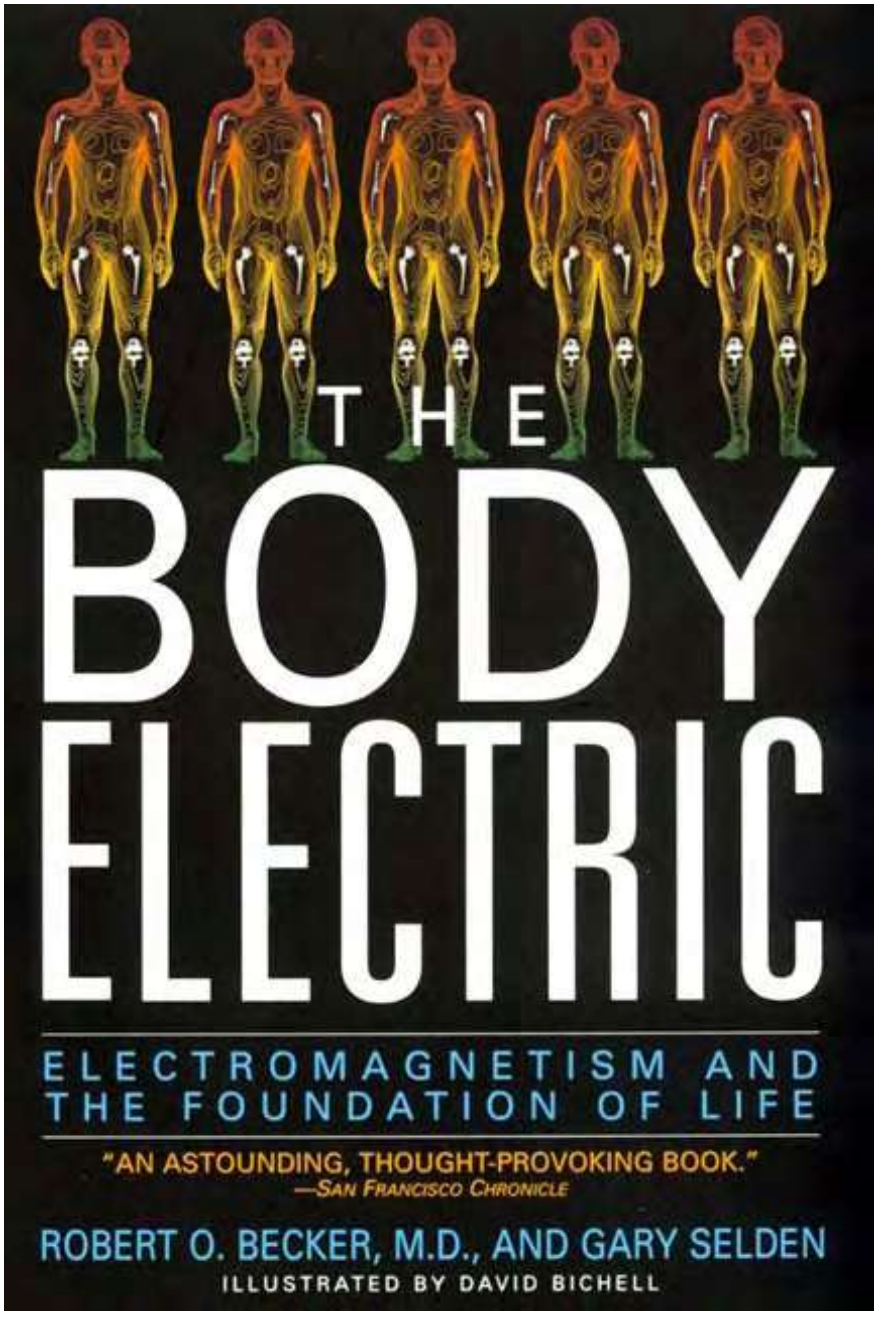
THE
BODY
ELECTRIC
ELECTROMAGNETISM AND
THE FOUNDATION OF LIFE
"AN ASTOUNDING, THOUGHT-PROVOKING BOOK."
—San Francisco Chronicle
ROBERT O. BECKER, M.D., AND GARY SELDEN
ILLUSTRATED BY DAVID BICHELL

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Introduction:
The Promise of the Art

I remember how it was before penicillin. I was a medical student at the end of World War II, before the drug became widely available for civilian use, and I watched the wards at New York's Bellevue Hospital fill to overflowing each winter. A veritable Byzantine city unto itself, Bellevue sprawled over four city blocks, its smelly, antiquated buildings jammed together at odd angles and interconnected by a rabbit warren of underground tunnels. In wartime New York, swollen with workers, sailors, soldiers, drunks, refugees, and their diseases from all over the world, it was perhaps the place to get an all-inclusive medical education. Bellevue's charter decreed that, no matter how full it was, every patient who needed hospitalization had to be admitted. As a result, beds were packed together side by side, first in the aisles, then out into the corridor. A ward was closed only when it was physically impossible to get another bed out of the elevator.

Most of these patients had lobar (pneumococcal) pneumonia. It didn't take long to develop; the bacteria multiplied unchecked, spilling over from the lungs into the bloodstream, and within three to five days of the first symptom the crisis came. The fever rose to 104 or 105 degrees Fahrenheit and delirium set in. At that point we had two signs to go by: If the skin remained hot and dry, the victim would die; sweating meant the patient would pull through. Although sulfa drugs often were effective against the milder pneumonias, the outcome in severe lobar pneumonia still depended solely on the struggle between the infection and

the patient's own resistance. Confident in my new medical knowledge, I was horrified to find that we were powerless to change the course of this infection in any way.

It's hard for anyone who hasn't lived through the transition to realize the change that penicillin wrought. A disease with a mortality rate near 50 percent, that killed almost a hundred thousand Americans each year, that struck rich as well as poor and young as well as old, and against which we'd had no defense, could suddenly be cured without fail in a few hours by a pinch of white powder. Most doctors who have graduated since 1950 have never even seen pneumococcal pneumonia in crisis.

Although penicillin's impact on medical practice was profound, its impact on the philosophy of medicine was even greater. When Alexander Fleming noticed in 1928 that an accidental infestation of the mold Penicillium notatum had killed his bacterial cultures, he made the crowning discovery of scientific medicine. Bacteriology and sanitation had already vanquished the great plagues. Now penicillin and subsequent antibiotics defeated the last of the invisibly tiny predators.

The drugs also completed a change in medicine that had been gathering strength since the nineteenth century. Before that time, medicine had been an art. The masterpiece—a cure—resulted from the patient's will combined with the physician's intuition and skill in using remedies culled from millennia of observant trial and error. In the last two centuries medicine more and more has come to be a science, or more accurately the application of one science, namely biochemistry. Medical techniques have come to be tested as much against current concepts in biochemistry as against their empirical results. Techniques that don't fit such chemical concepts—even if they seem to work—have been abandoned as pseudoscientific or downright fraudulent.

At the same time and as part of the same process, life itself came to be defined as a purely chemical phenomenon. Attempts to find a soul, a vital spark, a subtle something that set living matter apart from the nonliving, had failed. As our knowledge of the kaleidoscopic activity within cells grew, life came to be seen as an array of chemical reactions, fantastically complex but no different in kind from the simpler reactions performed in every high school lab. It seemed logical to assume that the ills of our chemical flesh could be cured best by the right chemical antidote, just as penicillin wiped out bacterial invaders without harming human cells. A few years later the decipherment of the DNA code seemed to give such stout evidence of life's chemical basis that the double helix became one of the most hypnotic symbols of our age. It seemed the final proof that we'd evolved through 4 billlion years of chance mo-

lecular encounters, aided by no guiding principle but the changeless properties of the atoms themselves.

The philosophical result of chemical medicine's success has been belief in the Technological Fix. Drugs became the best or only valid treatments for all ailments. Prevention, nutrition, exercise, lifestyle, the patient's physical and mental uniqueness, environmental pollutants—all were glossed over. Even today, after so many years and millions of dollars spent for negligible results, it's still assumed that the cure for cancer will be a chemical that kills malignant cells without harming healthy ones. As surgeons became more adept at repairing bodily structures or replacing them with artificial parts, the technological faith came to include the idea that a transplanted kidney, a plastic heart valve, or a stainless-steel-and-Teflon hip joint was just as good as the original—or even better, because it wouldn't wear out as fast. The idea of a bionic human was the natural outgrowth of the rapture over penicillin. If a human is merely a chemical machine, then the ultimate human is a robot.

No one who's seen the decline of pneumonia and a thousand other infectious diseases, or has seen the eyes of a dying patient who's just been given another decade by a new heart valve, will deny the benefits of technology. But, as most advances do, this one has cost us something irreplaceable: medicine's humanity. There's no room in technological medicine for any presumed sanctity or uniqueness of life. There's no need for the patient's own self-healing force nor any strategy for enhancing it. Treating a life as a chemical automaton means that it makes no difference whether the doctor cares about—or even knows—the patient, or whether the patient likes or trusts the doctor.

Because of what medicine left behind, we now find ourselves in a real technological fix. The promise to humanity of a future of golden health and extended life has turned out to be empty. Degenerative diseases—heart attacks, arteriosclerosis, cancer, stroke, arthritis, hypertension, ulcers, and all the rest—have replaced infectious diseases as the major enemies of life and destroyers of its quality. Modern medicine's incredible cost has put it farther than ever out of reach of the poor and now threatens to sink the Western economies themselves. Our cures too often have turned out to be double-edged swords, later producing a secondary disease; then we search desperately for another cure. And the dehumanized treatment of symptoms rather than patients has alienated many of those who can afford to pay. The result has been a sort of medical schizophrenia in which many have forsaken establishment medicine in favor of a holistic, prescient type that too often neglects

technology's real advantages but at least stresses the doctor-patient relationship, preventive care, and nature's innate recuperative power.

The failure of technological medicine is due, paradoxically, to its success, which at first seemed so overwhelming that it swept away all aspects of medicine as an art. No longer a compassionate healer working at the bedside and using heart and hands as well as mind, the physician has become an impersonal white-gowned ministrant who works in an office or laboratory. Too many physicians no longer learn from their patients, only from their professors. The breakthroughs against infections convinced the profession of its own infallibility and quickly ossified its beliefs into dogma. Life processes that were inexplicable according to current biochemistry have been either ignored or misinterpreted. In effect, scientific medicine abandoned the central rule of science—revision in light of new data. As a result, the constant widening of horizons that has kept physics so vital hasn't occurred in medicine. The mechanistic assumptions behind today's medicine are left over from the turn of the century, when science was forcing dogmatic religion to see the evidence of evolution. (The reeruption of this same conflict today shows that the battle against frozen thinking is never finally won.) Advances in cybernetics, ecological and nutritional chemistry, and solid-state physics haven't been integrated into biology. Some fields, such as parapsychology, have been closed out of mainstream scientific inquiry altogether. Even the genetic technology that now commands such breathless admiration is based on principles unchallenged for decades and unconnected to a broader concept of life. Medical research, which has limited itself almost exclusively to drug therapy, might as well have been wearing blinders for the last thirty years.

It's no wonder, then, that medical biology is afflicted with a kind of tunnel vision. We know a great deal about certain processes, such as the genetic code, the function of the nervous system in vision, muscle movement, blood clotting, and respiration on both the somatic and the cellular levels. These complex but superficial processes, however, are only the tools life uses for its survival. Most biochemists and doctors aren't much closer to the "truth" about life than we were three decades ago. As Albert Szent-Gyorgyi, the discoverer of vitamin C, has written, "We know life only by its symptoms." We understand virtually nothing about such basic life functions as pain, sleep, and the control of cell differentiation, growth, and healing. We know little about the way every organism regulates its metabolic activity in cycles attuned to the fluctuations of earth, moon, and sun. We are ignorant about nearly every aspect of consciousness, which may be broadly defined as the self-

interested integrity that lets each living thing marshal its responses to eat, thrive, reproduce, and avoid danger by patterns that range from the tropisms of single cells to instinct, choice, memory, learning, individuality, and creativity in more complex life-forms. The problem of when to "pull the plug" shows that we don't even know for sure how to diagnose death. Mechanistic chemistry isn't adequate to understand these enigmas of life, and it now acts as a barrier to studying them. Erwin Chargaff, the biochemist who discovered base pairing in DNA and thus opened the way for understanding gene structure, phrased our dilemma precisely when he wrote of biology, "No other science deals in its very name with a subject that it cannot define."

Given the present climate, I've been a lucky man. I haven't been a good, efficient doctor in the modern sense. I've spent far too much time on a few incurable patients whom no one else wanted, trying to find out how our ignorance failed them. I've been able to tack against the prevailing winds of orthodoxy and indulge my passion for experiment. In so doing I've been part of a little-known research effort that has made a new start toward a definition of life.

My research began with experiments on regeneration, the ability of some animals, notably the salamander, to grow perfect replacements for parts of the body that have been destroyed. These studies, described in Part 1, led to the discovery of a hitherto unknown aspect of animal life—the existence of electrical currents in parts of the nervous system. This breakthrough in turn led to a better understanding of bone fracture healing, new possibilities for cancer research, and the hope of human regeneration—even of the heart and spinal cord—in the not too distant future, advances that are discussed in Parts 2 and 3. Finally, a knowledge of life's electrical dimension has yielded fundamental insights (considered in Part 4) into pain, healing, growth, consciousness, the nature of life itself, and the dangers of our electromagnetic technology.

I believe these discoveries presage a revolution in biology and medicine. One day they may enable the physician to control and stimulate healing at will. I believe this new knowledge will also turn medicine in the direction of greater humility, for we should see that whatever we achieve pales before the self-healing power latent in all organisms. The results set forth in the following pages have convinced me that our understanding of life will always be imperfect. I hope this realization will make medicine no less a science, yet more of an art again. Only then can it deliver its promised freedom from disease.

Part 1

Growth and Regrowth

Salamander: energy's seed sleeping interred in the marrow . . .
—Octavio Paz

One
Hydra's Heads and Medusa's Blood

There is only one health, but diseases are many. Likewise, there appears to be one fundamental force that heals, although the myriad schools of medicine all have their favorite ways of cajoling it into action.

Our prevailing mythology denies the existence of any such generalized force in favor of thousands of little ones sitting on pharmacists' shelves, each one potent against only a few ailments or even a part of one. This system often works fairly well, especially for treatment of bacterial diseases, but it's no different in kind from earlier systems in which a specific saint or deity, presiding over a specific healing herb, had charge of each malady and each part of the body. Modern medicine didn't spring full-blown from the heads of Pasteur and Lister a hundred years ago.

If we go back further, we find that most medical systems have combined such specifics with a direct, unitary appeal to the same vital principle in all illnesses. The inner force can be tapped in many ways, but all are variations of four main, overlapping patterns: faith healing, magic healing, psychic healing, and spontaneous healing. Although science derides all four, they sometimes seem to work as well for degenerative diseases and long-term healing as most of what Western medicine can offer.

Faith healing creates a trance of belief in both patient and practitioner, as the latter acts as an intercessor or conduit between the sick mortal and a presumed higher power. Since failures are usually ascribed to a lack of faith by the patient, this brand of medicine has always been a

gold mine for charlatans. When bona fide, it seems to be an escalation of the placebo effect, which produces improvement in roughly one third of subjects who think they're being treated but are actually being given dummy pills in tests of new drugs. Faith healing requires even more confidence from the patient, so the disbeliever probably can prevent a cure and settle for the poor satisfaction of "I told you so." If even a few of these oft-attested cases are genuine, however, the healed one suddenly finds faith turned into certainty as the withered arm aches with unaccustomed sensation, like a starved animal waking from hibernation.

Magical healing shifts the emphasis from the patient's faith to the doctor's trained will and occult learning. The legend of Teta, an Egyptian magician from the time of Khufu (Cheops), builder of the Great Pyramid, can serve as an example. At the age of 110, Teta was summoned into the royal presence to demonstrate his ability to rejoin a severed head to its body, restoring life. Khufu ordered a prisoner beheaded, but Teta discreetly suggested that he would like to confine himself to laboratory animals for the moment. So a goose was decapitated. Its body was laid at one end of the hall, its head at the other. Teta repeatedly pronounced his words of power, and each time, the head and body twitched a little closer to each other, until finally the two sides of the cut met. They quickly fused, and the bird stood up and began cackling. Some consider the legendary miracles of Jesus part of the same ancient tradition, learned during Christ's precocious childhood in Egypt.

Whether or not we believe in the literal truth of these particular accounts, over the years so many otherwise reliable witnesses have testified to healing "miracles" that it seems presumptuous to dismiss them all as fabrications. Based on the material presented in this book, I suggest Coleridge's "willing suspension of disbelief" until we understand healing better. Shamans apparently once served at least some of their patients well, and still do where they survive on the fringes of the industrial world. Magical medicine suggests that our search for the healing power isn't so much an exploration as an act of remembering something that was once intuitively ours, a form of recall in which the knowledge is passed on or awakened by initiation and apprenticeship to the man or woman of power.

Sometimes, however, the secret needn't be revealed to be used. Many psychic healers have been studied, especially in the Soviet Union, whose gift is unconscious, unsought, and usually discovered by accident. One who demonstrated his talents in the West was Oskar Estebany. A Hungarian Army colonel in the mid-1930s. Estebany notices that horses he groomed got their wind back and recovered from illnesses faster than

those cared for by others. He observed and used his powers informally for years, until, forced to emigrate after the 1956 Hungarian revolution, he settled in Canada and came to the attention of Dr. Bernard Grad, a biologist at McGill University. Grad found that Estebany could accelerate the healing of measured skin wounds made on the backs of mice, as compared with controls. He didn't let Estebany touch the animals, but only place his hands near their cages, because handling itself would have fostered healing. Estebany also speeded up the growth of barley plants and reactivated ultraviolet-damaged samples of the stomach enzyme trypsin in much the same way as a magnetic field, even though no magnetic field could be detected near his body with the instruments of that era.

The types of healing we've considered so far have trance and touch as common factors, but some modes don't even require a healer. The spontaneous miracles at Lourdes and other religious shrines require only a vision, fervent prayer, perhaps a momentary connection with a holy relic, and intense concentration on the diseased organ or limb. Other reports suggest that only the intense concentration is needed, the rest being aids to that end. When Diomedes, in the fifth book of the Iliad, dislocates Aeneas' hip with a rock, Apollo takes the Trojan hero to a temple of healing and restores full use of his leg within minutes. Hector later receives the same treatment after a rock in the chest fells him. We could dismiss these accounts as the hyperbole of a great poet if Homer weren't so realistic in other battlefield details, and if we didn't have similar accounts of soldiers in recent wars recovering from "mortal" wounds or fighting on while oblivious to injuries that would normally cause excruciating pain. British Army surgeon Lieutenant Colonel H. K. Beecher described 225 such cases in print after World War II. One soldier at Anzio in 1943, who'd had eight ribs severed near the spine by shrapnel, with punctures of the kidney and lung, who was turning blue and near death, kept trying to get off his litter because he thought he was lying on his rifle. His bleeding abated, his color returned, and the massive wound began to heal after no treatment but an insignificant dose of sodium amytal, a weak sedative given him because there was no morphine.

These occasional prodigies of battlefield stress strongly resemble the ability of yogis to control pain, stop bleeding, and speedily heal wounds with their will alone. Biofeedback research at the Menninger Foundation and elsewhere has shown that some of this same power can be rapped in people with no yogic training. That the will can be applied to the body's ills has also been shownb by Norman Cousing in his resolute conquest by

laugh therapy of ankylosing spondylitis, a crippling disease in which the spinal discs and ligaments solidify like bone, and by some similar successes by users of visualization techniques to focus the mind against cancer.

Unfortunately, no approach is a sure thing. In our ignorance, the common denominator of all healing—even the chemical cures we profess to understand—remains its mysteriousness. Its unpredictability has bedeviled doctors throughout history. Physicians can offer no reason why one patient will respond to a tiny dose of a medicine that has no effect on another patient in ten times the amount, or why some cancers go into remission while others grow relentlessly unto death.

By whatever means, if the energy is successfully focused, it results in a marvelous transformation. What seemed like an inexorable decline suddenly reverses itself. Healing can almost be defined as a miracle. Instant regrowth of damaged parts and invincibility against disease are commonplaces of the divine world. They continually appear even in myths that have nothing to do with the theme of healing itself. Dead Vikings went to a realm where they could savor the joys of killing all day long, knowing their wounds would heal in time for the next day's mayhem. Prometheus' endlessly regrowing liver was only a clever torture arranged by Zeus so that the eagle sent as punishment for the god's delivery of fire to mankind could feast on his most vital organ forever—although the tale also suggests that the prehistoric Greeks knew something of the liver's ability to enlarge in compensation for damage to it.

The Hydra was adept at these offhand wonders, too. This was the monster Hercules had to kill as his second chore for King Eurystheus. The beast had somewhere between seven and a hundred heads, and each time Hercules cut one off, two new ones sprouted in its place—until the hero got the idea of having his nephew Iolaus cauterize each neck as soon as the head hit the ground.

In the eighteenth century the Hydra's name was given to a tiny aquatic animal having seven to twelve "heads," or tentacles, on a hollow, stalklike body, because this creature can regenerate. The mythic Hydra remains a symbol of that ability, possessed to some degree by most animals, including us.

Generation, life's normal transformation from seed to adult, would seem as unearthly as regeneration if it were not so commonplace. We see the same kinds of changes in each. The Greek hero Cadmus grows an army by sowing the teeth of a dragon he has killed. The primeval serpent makes love to the World Egg, which hatches all the creatures of the earth. God makes Adam from Eve's rib, or vice versa in the later version. The Word of God commands life to unfold. The genetic words

encoded in DNA spell out the unfolding. At successive but still limited levels of understanding, each of these beliefs tries to account for the beautifully bizarre metamorphosis. And if some savage told us of a magical worm that built a little windowless house, slept there a season, then one day emerged and flew away as a jeweled bird, we'd laugh at such superstition if we'd never seen a butterfly.

The healer's job has always been to release something not understood, to remove obstructions (demons, germs, despair) between the sick patient and the force of life driving obscurely toward wholeness. The means may be direct—the psychic methods mentioned above—or indirect: Herbs can be used to stimulate recovery; this tradition extends from prehistoric wisewomen through the Greek herbal of Dioscorides and those of Renaissance Europe, to the prevailing drug therapies of the present. Fasting, controlled nutrition, and regulation of living habits to avoid stress can be used to coax the latent healing force from the sick body; we can trace this approach back from today's naturopaths to Galen and Hippocrates. Attendants at the healing temples of ancient Greece and Egypt worked to foster a dream in the patient that would either start the curative process in sleep or tell what must be done on awakening. This method has gone out of style, but it must have worked fairly well, for the temples were filled with plaques inscribed by grateful patrons who'd recovered. In fact, this mode was so esteemed that Aesculapius, the legendary doctor who originated it, was said to have been given two vials filled with the blood of Medusa, the snaky-haired witch-queen killed by Perseus. Blood from her left side restored life, while that from her right took it away—and that's as succinct a description of the tricky art of medicine as we're likely to find.

The more I consider the origins of medicine, the more I'm convinced that all true physicians seek the same thing. The gulf between folk therapy and our own stainless-steel version is illusory. Western medicine springs from the same roots and, in the final analysis, acts through the same little-understood forces as its country cousins. Our doctors ignore this kinship at their—and worse, their patients'—peril. All worthwhile medical research and every medicine man's intuition is part of the same quest for knowledge of the same elusive healing energy.

Failed Healing in Bone

As an orthopedic surgeon, I often pondered one particular breakdown of that energy, my specialty's major unsolved problem—nonunion of fractures. Normally a broken bone will begin to grow together in a few

weeks if the ends are held close to each other without movement. Occasionally, however, a bone will refuse to knit despite a year or more of casts and surgery. This is a disaster for the patient and a bitter defeat for the doctor, who must amputate the arm or leg and fit a prosthetic substitute.

Throughout this century, most biologists have been sure only chemical processes were involved in growth and healing. As a result, most work on nonunions has concentrated on calcium metabolism and hormone relationships. Surgeons have also "freshened," or scraped, the fracture surfaces and devised ever more complicated plates and screws to hold the bone ends rigidly in place. These approaches seemed superficial to me. I doubted that we would ever understand the failure to heal unless we truly understood healing itself.

When I began my research career in 1958, we already knew a lot about the logistics of bone mending. It seemed to involve two separate processes, one of which looked altogether different from healing elsewhere in the human body. But we lacked any idea of what set these processes in motion and controlled them to produce a bone bridge across the break.

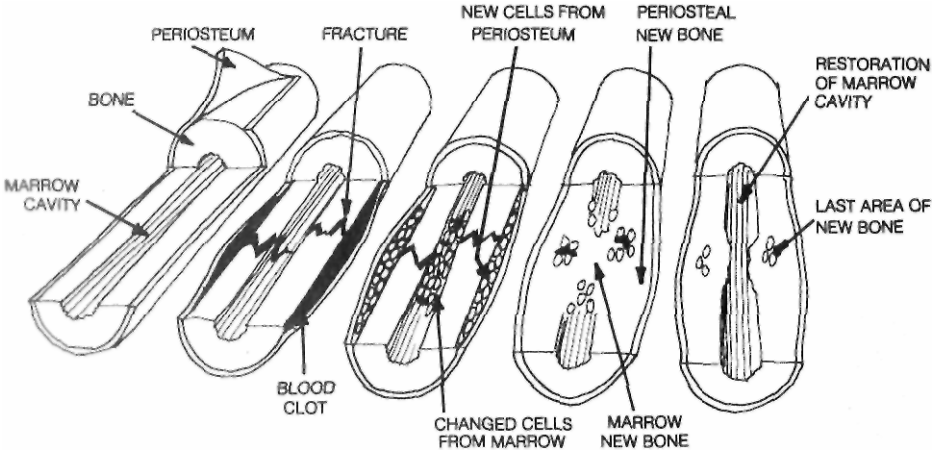

STAGES OF FRACTURE HEALING

Every bone is wrapped in a layer of tough, fibrous collagen, a protein that's a major ingredient of bone itself and also forms the connective tissue or "glue" that fastens all our cells to each other. Underneath the collagen envelope are the cells that produce it, right next ro the bone; together the two layers form the periosteum. When a bone breaks, these periosteal cells divide in a particular way. One of the daughter cells stays where it is, while the other one migrates into the blood clot surrounding

the fracture and changes into a closely related type, an osteoblast, or bone-forming cell. These new osteoblasts build a swollen ring of bone, called a callus, around the break.

Another repair operation is going on inside the bone, in its hollow center, the medullary cavity. In childhood the marrow in this cavity actively produces red and white blood cells, while in adulthood most of the marrow turns to fat. Some active marrow cells remain, however, in the porous convolutions of the inner surface. Around the break a new tissue forms from the marrow cells, most readily in children and young animals. This new tissue is unspecialized, and the marrow cells seem to form it not by increasing their rate of division, as in the callus-forming periosteal cells, but by reverting to a primitive, neo-embryonic state. The unspecialized former marrow cells then change into a type of primitive cartilage cells, then into mature cartilage cells, and finally into new bone cells to help heal the break from inside. Under a microscope, the changes seen in cells from this internal healing area, especially from children a week or two after the bone was broken, seem incredibly chaotic, and they look frighteningly similar to highly malignant bone-cancer cells. But in most cases their transformations are under control, and the bone heals.

Dr. Marshall Urist, one of the great researchers in orthopedics, was to conclude in the early 1960s that this second type of bone healing is an evolutionary throwback, the only kind of regeneration that humans share with all other vertebrates. Regeneration in this sense means the regrowth of a complex body part, consisting of several different kinds of cells, in a fashion resembling the original growth of the same part in the embryo, in which the necessary cells differentiate from simpler cells or even from seemingly unrelated types. This process, which I'll call true regeneration, must be distinguished from two other forms of healing. One, sometimes considered a variety of regeneration, is physiological repair, in which small wounds and everyday wear within a single tissue are made good by nearby cells of the same type, which merely proliferate to close the gap. The other kind of healing occurs when a wound is too big for single-tissue repair but the animal lacks the true regenerative competence to restore the damaged part. In this case the injury is simply patched over as well as possible with collagen fibers, forming a scar. Since true regeneration is most closely related to embryonic development and is generally Strongest in simple animals, it may be considered the most fundamental mode of healing.

Nonunions failed to knit, I reasoned, because they were missing something that triggered and controlled normal healing. I'd already be-

gun to wonder if the inner area of bone mending might be a vestige of true regeneration. If so, it would likely show the control process in a clearer or more basic form than the other two kinds of healing. I figured I stood little chance of isolating a clue to it in the multilevel turmoil of a broken bone itself, so I resolved to study regeneration alone, as it occurred in other animals.

A Fable Made Fact

Regeneration happens all the time in the plant kingdom. Certainly this knowledge was acquired very early in mankind's history. Besides locking up their future generations in the mysterious seed, many plants, such as grapevines, could form a new plant from a single part of the old. Some classical authors had an inkling of animal regeneration—Aristotle mentions that the eyes of very young swallows recover from injury, and Pliny notes that lost "tails" of octopi and lizards regrow. However, regrowth was thought to be almost exclusively a plant prerogative.
The great French scientist Rene Antoine Ferchault de Reaumur made the first scientific description of animal regeneration in 1712. Reaumur devoted all his life to the study of "insects," which at that time meant all invertebrates, everything that was obviously "lower" than lizards, frogs, and fish. In studies of crayfish, lobsters, and crabs, Reaumur proved the claims of Breton fishermen that these animals could regrow lost legs. He kept crayfish in the live-bait well of a fishing boat, removing a claw from each and observing that the amputated extremity reappeared in full anatomical detail. A tiny replica of the limb took shape inside the shell; when the shell was discarded at the next molting season, the new limb unfolded and grew to full size.
Reaumur was one of the scientific geniuses of his time. Elected to the Royal Academy of Sciences when only twenty-four, he went on to invent tinned steel, Reaumur porcelain (an opaque white glass), imitation pearls, better ways of forging iron, egg incubators, and the Reaumur thermometer, which is still used in France. At the age of sixty-nine he isolated gastric juice from the stomach and described its digestive function. Despite his other accomplishments, "insects" were his life's love (he never married), and he probably was the first to conceive of the vast, diverse population of life-forms that this term encompassed. He rediscovered the ancient royal purple dye from Murex trunculus (a marine mollusk), and his work on spinning a fragile, filmy silk from spider webs was translated into Manchu for the Chinese emperor. He was the

first to elucidate the social life and sexually divided caste system of bees. Due to his eclipse in later years by court-supported scientists who valued "common sense" over observation, Reaumur's exhaustive study of ants wasn't published until 1926. In the interim it had taken several generations of formicologists to cover the same ground, including the description of winged ants copulating in flight and proof that they aren't a separate species but the sexual form of wingless ants. In 1734 he published the first of six volumes of his Natural History of Insects, a milestone in biology.

Reaumur made so many contributions to science that his study of regeneration was overlooked for decades. At that time no one really cared what strange things these unimportant animals did. However, all of the master's work was well known to a younger naturalist, Abraham Trembley of Geneva, who supported himself, as did many educated men of that time, by serving as a private tutor for sons of wealthy families. In 1740, while so employed at an estate near The Hague, in Holland, Trembley was examining with a hand lens the small animals living in freshwater ditches and ponds. Many had been described by Reaumur, but Trembley chanced upon an odd new one. It was no more than a quarter of an inch long and faintly resembled a squid, having a cylindrical body topped with a crown of tentacles. However, it was a startling green color. To Trembley, green meant vegetation, but if this was a plant, it was a mighty peculiar one. When Trembley agitated the water in its dish, the tentacles contracted and the body shrank down to a nubbin, only to reexpand after a period of quiet. Strangest of all, he saw that the creature "walked" by somersaulting end over end.

Since they had the power of locomotion, Trembley would have assumed that these creatures were animals and moved on to other observations, if he hadn't chanced to find a species colored green by symbiotic algae. To settle the animal-plant question, he decided to cut some in half. If they regrew, they must be plants with the unusual ability to walk, while if they couldn't regenerate, they must be green animals.

Trembley soon entered into a world that exceeded his wildest dreams. He divided the polyps, as he first called them, in the middle of their stalks. He then had two short pieces of stalk, one with attached tentacles, each of which contracted down to a tiny dot. Patiently watching, Trembley saw the two pieces later expand. The tentacle portion began to move normally, as though it were a complete organism. The other portion lay inert and apparently dead. Something must have made Trembley continue the experiment, for he watched this motionless object for nine days, during which nothing happened. He then noted that the cut

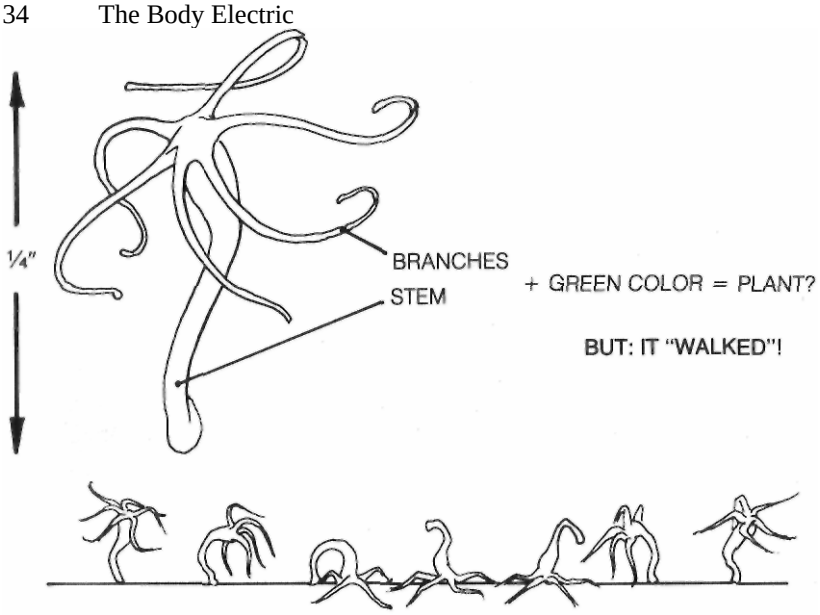

TREMBLEY'S DISCOVERY: ANIMAL OR PLANT?

end had sprouted three little "horns," and within a few more days the complete crown of tentacles had been restored. Trembley now had two complete polyps as a result of cutting one in half! However, even though they regenerated, more observations convinced Trembley that the creatures were really animals. Not only did they move and walk, but their arms captured tiny water fleas and moved them to the "mouth," located in the center of the ring of tentacles, which promptly swallowed the prey.

Trembley, then only thirty-one, decided to make sure he was right by having the great Reaumur confirm his findings before he published them and possibly made a fool of himself. He sent specimens and detailed notes to Reaumur, who confirmed that this was an animal with amazing powers of regeneration. Then he immediately read Trembley's letters and showed his specimens to an astounded Royal Academy early in 1741. The official report called Trembley's polyp more marvelous than the phoenix or the mythical serpent that could join together after being cut in two, for these legendary animals could only reconstitute themselves, while the polyp could make a duplicate. Years later Reaumur was still thunderstruck. As he wrote in Volume 6 of his series on insects, "This is a fact that I cannot accustom myself to seeing, after having seen and re-seen it hundrts of times."

This was just the beginning, however. Trembley's polyps performed

even more wondrous feats. When cut lengthwise, each half of the stalk healed over without a scar and proceeded to regrow the missing tentacles. Trembley minced some polyps into as many pieces as he could manage, finding that a complete animal would regrow from each piece, as long as it included a remnant of the central stalk. In one instance he quartered one of the creatures, then cut each resulting polyp into three or four pieces, until he had made fifty animals from one.

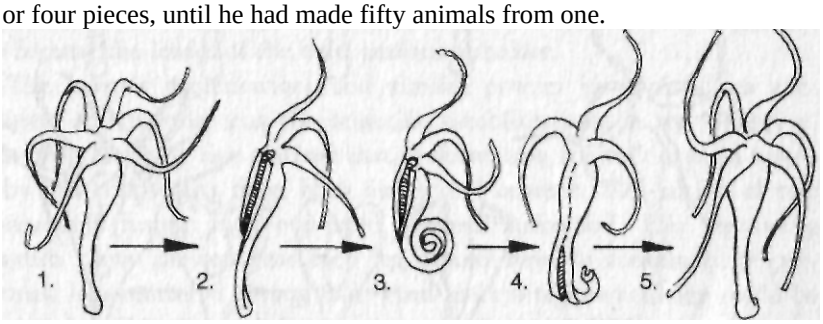

REGENERATION BY A HYDRA CUT IN HALF LENGTHWISE

His most famous experiment was the one that led him to name his polyp "hydra." He found that by splitting the head lengthwise, leaving the stalk intact, he could produce one animal with two crowns of tentacles. By continuing the process he was able to get one animal with seven heads. When Trembley lopped them off, each one regrew, just like the mythical beast's. But nature went legend one better: Each severed head went on to form a complete new animal as well.

Such experiments provided our first proof that entire animals can regenerate, and Trembley went on to observe that hydras could reproduce by simple budding, a small animal appearing on the side of the stalk and growing to full size. The implications of these discoveries were so revolutionary that Trembley delayed publishing a full account of his work until he'd been prodded by Reaumur and preceded in print by several others. The sharp division between plant and animal suddenly grew blurred, suggesting a common origin with some kind of evolution; basic assumptions about life had to be rethought. As a result, Trembley's observations weren't enthusiastically embraced by all. They inflamed several old arguments and offended many of the old guard. In this respect Trembley's mentor Reaumur was a most unusual scientist for his time, and indeed tor all time. Despite his prominence, he was ready to espouse radically new ideas and, most important, he didn't steal the ideas of others, an all too common failing among scientists.

A furious debarte was raging at the time of Trembley's announcement.

It concerned the origin of the individual - how the chicken came from

A HYDRA REGROWS ITS MOUTH AND TENTACLES

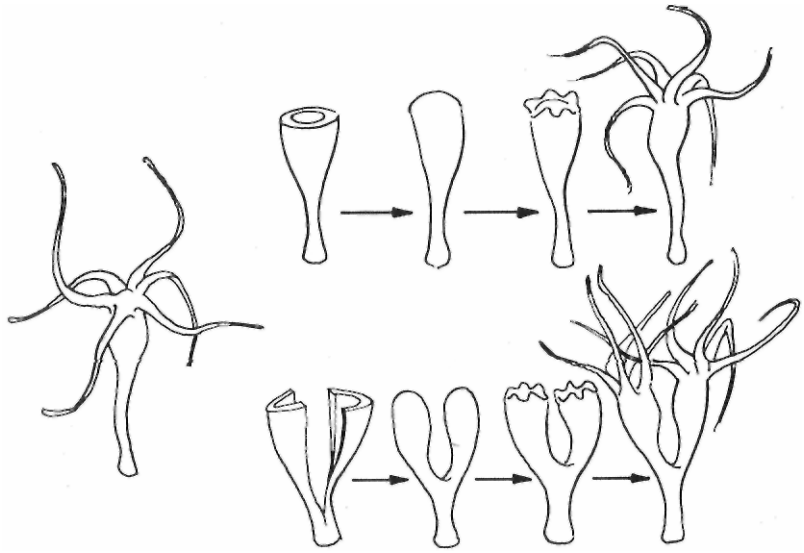

A PARTIALLY SPLIT HYDRA'S BODY GROWS TWO "HEADS"

the egg, for example. When scientists examined the newly laid egg, there wasn't much there except two liquids, the white and the yolk, neither of which had any discernible structure, let alone anything resembling a chicken.

There were two opposite theories. The older one, derived from Aristotle, held that each animal in all its complexity developed from simple organic matter by a process called epigenesis, akin to our modern concept of cell differentiation. Unfortunately, Trembley himself was the first person to witness cell division under the microscope, and he didn't realize that it was the normal process by which all cells multiplied. In an era knowing nothing of genes and so little of cells, yet beginning to insist on logical, scientific explanations, epigenesis seemed more and more absurd. What could possibly transform the gelatin of eggs and sperm into a frog or a human, without invoking that tired old deus ex machina the spirit, or inexplicable spark of life—unless the frog or person already existed in miniature inside the generative slime and merely grew in the course of development?

The litter idea, called preformation, had been ascendant for at least fifty years. It was so widely accepted that when the early microscopists studied drops of semen, they dutifully reported a little man, called a homunculus, encased in the head of each sperm - a fine example of sci-

ence's capacity for self-delusion. Even Reaumur, when he failed to find tiny butterfly wings inside caterpillars, assumed they were there but were too small to be seen. Only a few months before Trembley began slicing hydras, his cousin, Genevan naturalist Charles Bonnet, had proven (in an experiment suggested by the omnipresent Reaumur) that female aphids usually reproduced parthenogenetically (without mating). To Bonnet this demonstrated that the tiny adult resided in the egg, and he became the leader of the ovist preformationists.

The hydra's regeneration, and similar powers in starfish, sea anemones, and worms, put the scientific establishment on the defensive. Reaumur had long ago realized that preformation couldn't explain how a baby inherited traits from both father and mother. The notion of two homunculi fusing into one seed seemed farfetched. His regrowing crayfish claws showed that each leg would have to contain little preformed legs scattered throughout. And since a regenerated leg could be lost and replaced many times, the proto-legs would have to be very numerous, yet no one had ever found any.

Regeneration therefore suggested some form of epigenesis—perhaps without a soul, however, for the hydra's anima, if it existed, was divisible along with the body and indistinguishable from it. It seemed as though some forms of matter itself possessed the spark of life. For lack of knowledge of cells, let alone chromosomes and genes, the epigeneticists were unable to prove their case. Each side could only point out the other's inconsistencies, and politics gave preformationism the edge.

No wonder nonscientists often grew impatient of the whole argument. Oliver Goldsmith and Tobias Smollett mocked the naturalists for missing nature's grandeur in their myopic fascination with "muck-flies." Henry Fielding lampooned the discussion in a skit about the regeneration of money. Diderot thought of hydras as composite animals, like swarms of bees, in which each particle had a vital spark of its own, and lightheartedly suggested there might be "human polyps" on Jupiter and Saturn. Voltaire was derisively skeptical of attempts to infer the nature of the soul, animal or human, from these experiments. Referring in 1768 to the regenerating heads of snails, he asked, "What happens to its sensorium, its memory, its store of ideas, its soul, when its head has been cut off? How does all this come back? A soul that is reborn is an extremely curious phenomenon." Profoundly disturbed by the whole affair, for a long time he simply refused to believe in animal regeneration,
calling the hydra " a kind of small rush."

It was no longer possible to doubt the discovery after the work of
Lazzaro Spallanzani, an italian priest for whom science was a full-time

hobby. In a career spanning the second half of the eighteenth century, Spallanzani discovered the reversal of plant transpiration between light and darkness, and advanced our knowledge of digestion, volcanoes, blood circulation, and the senses of bats, but his most important work concerned regrowth. In twenty years of meticulous observation, he studied regeneration in worms, slugs, snails, salamanders, and tadpoles. He set new standards for thoroughness, often dissecting the amputated parts to make sure he'd removed them whole, then dissecting the replacements a few months later to confirm that all the parts had been restored. Spallanzani's most important contribution to science was his discovery of the regenerative abilities of the salamander. It could replace its tail and limbs, all at once if need be. A young one performed this feat for Spallanzani six times in three months. He later found that the salamander could also replace its jaw and the lenses of its eyes, and then went on to establish two general rules of regeneration: Simple animals can regenerate more fully than complex ones, or, in modern terms, the ability to regenerate declines as one moves up the evolutionary scale. (The salamander is the main exception.) In ontogenetic parallel, if a specias can regenerate, younger individuals do it better than older ones.

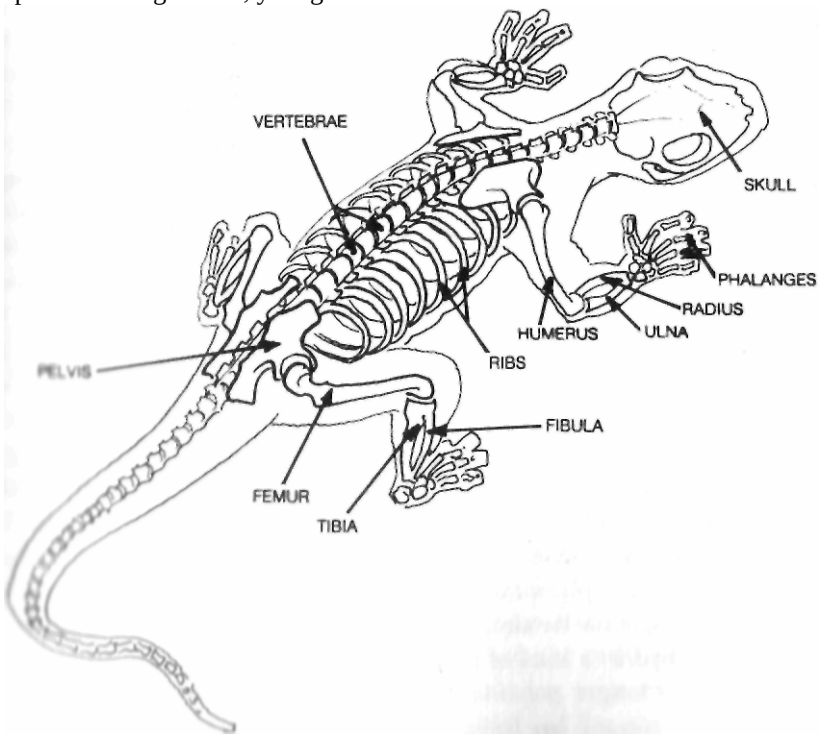

THE SALAMANDER'S SKELETON - AS COMPLEX AS OURS

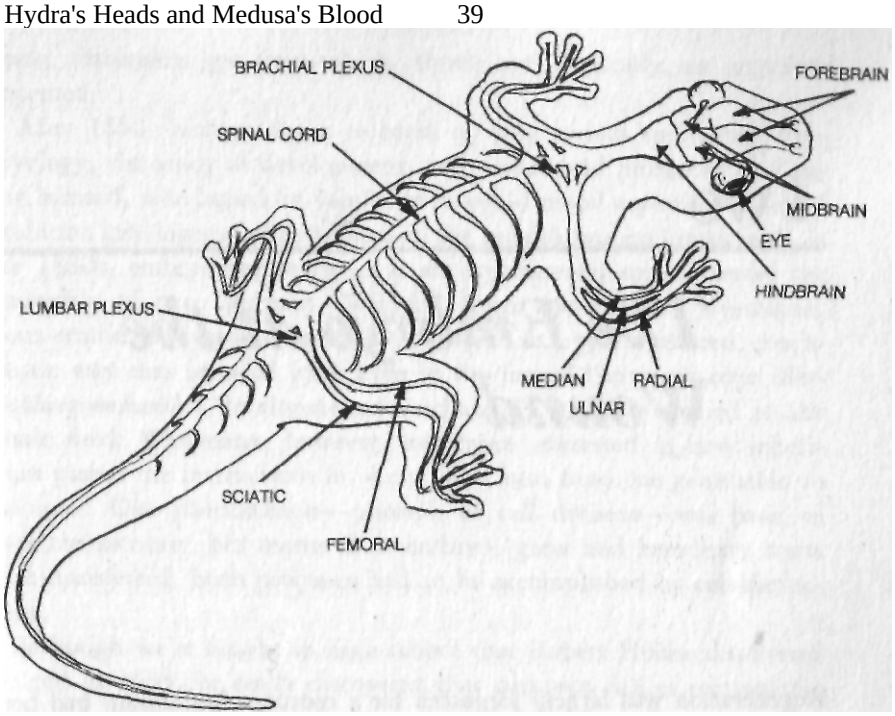

THE SALAMANDER'S NERVOUS SYSTEM—FORERUNNER OF OURS

This early regeneration research, Spallanzani's in particular, was a benchmark in modern biology. Gentlemanly observations buttressed by "common sense" gave way to a more rigorous kind of examination in which nothing was taken for granted. It had been "known" for perhaps ten thousand years that plants could regenerate and animals couldn't. To many zoologists, even twenty years after Trembley's initial discovery, the few known exceptions only proved the rule, for octopi, crayfish, hydras, worms, and snails seemed so unlike humans or the familiar mammals that they hardly counted. The lizard, the only other vertebrate regenerator then known, could manage no more than an imperfect tail. But the salamander—here was an animal we could relate to! This was no worm or snail or microscopic dot, but a four-limbed, two-eyed vertebrate that could walk and swim. While its legendary ability to withstand fire had been disproven, its body was big enough and its anatomy similar enough CO ours to be taken seriously. Scientists could no longer assume that the underlying process had nothing to do with us. In fact, the questions with which Spallanzani ended his first report on the salamander have haunted biologists ever since: "Is it to be hoped that [higher animals] may acquire [the same power] by some useful dispositions? and should the flattering expectation of obtaining this advantage for ourselves be considered entirely as chimerical?"

Two
I The Embryo at the Wound

Reneration was largely forgotten for a century. Spallanzani had been so thorough that little else could be learned about it with the techniques of the ime. Moreover, although his work strongly supported epigenesis, its impact was lost because the whole debate was swallowed up in the much larger philosophical conflict between vitalism and mechanism. Since biology includes the study of our own essence, it's the most emotional science, and it has been the battleground for these two points of view throughout its history. Briefly, the vitalists believed in a spirit, called the anima or elan vital, that made living things fundamentally different from other substances. The mechanists believed that life could ultimately be understood in terms of the same physical and chemical laws that governed nonliving matter, and that only ignorance of these forces led people to invoke such hokum as a spirit. We'll take up these issues in more detail later, but for now we need only note that the vitalists favored epigenesis, viewed as an imposition of order on the chaos of the egg by some intangible "vital" force. The mechanists favored formation. Since science insisted increasingly on material explanations for everything, epigenesis lost out despite the evidence of regeneration.

Mechanism dominated biology more and more, but some problems remained. The main one was the absence of the little man in the sperm. Advances in the power and resolution of microscopes had clearly shown that no one was there. Biologists were faced with the generative slime

again, featureless goo from which, slowly and magically, an organism appeared.

After 1850, biology began to break up into various specialties. Embryology, the study of development, was named and promoted by Darwin himself, who hoped (in vain) that it would reveal a precise history of evolution (phylogeny) recapitulated in the growth process (ontogeny). In the 1880s, embryology matured as an experimental science under the leadership of two Germans, Wilhelm Roux and August Weismann. Roux studied the stages of embryonic growth in a very restricted, mechanistic way that revealed itself even in the formal Germanic title, Entwicklungsmechanik ("developmental mechanics"), that he applied to the whole field. Weismann, however, was more interested in how inheritance passed the instructions for embryonic form from one generation to the next. One phenomenon—mitosis, or cell division—was basic to both transactions. No matter how embryos grew and hereditary traits were transferred, both processes had to be accomplished by cellular actions.

Although we're taught in high school that Robert Hooke discovered the cell in 1665, he really discovered that cork was full of microscopic holes, which he called cells because they looked like little rooms. The idea that they were the basic structural units of all living things came from Theodor Schwann, who proposed this cell theory in 1838. However, even at that late date, he didn't have a clear idea of the origin of cells. Mitosis was unknown to him, and he wasn't too sure of the distinction between plants and animals. His theory wasn't fully accepted until two other German biologists, F. A. Schneider and Otto Butschli, reintroduced Schwann's concept and described mitosis in 1873.

Observations of embryogenesis soon confirmed its cellular basis. The fertilized egg was exactly that, a seemingly unstructured single cell. Embryonic growth occurred when the fertilized egg divided into two other cells, which promptly divided again. Their progeny then divided, and so on. As they proliferated, the cells also differentiated; that is, they began to show specific characteristics of muscle, cartilage, nerve, and so forth. The creature that resulted obviously had several increasingly complex levels of organization; however, Roux and Weismann had no alternative but to concentrate on the lowest one, the cell, and try to imagine how the inherited material worked at that level.

Weismann proposed a theory of "determiners," specific chemical structures coded for each cell type The fertilized egg contained all the determiners, both in type and in number, needed to produce every cell in the body. As cell division proceeded, the daughter cells each received

half of the previous stock of determiners, until in the adult each cell possessed only one. Muscle cells contained only the muscle determiner, nerve cells only the one for nerves, and so on. This meant that once a cell's function had been fixed, it could never be anything but that one kind of cell. In one of his first experiments, published in 1888, Roux obtained powerful support for this concept. He took fertilized frog eggs, which were large and easy to observe, and waited until the first cell division had occured. He then separated the two cells of this incipient embryo, According to the theory, each cell contained enough determiners to make half an embryo, and that was exactly what Roux got—two half-embryos. It was hard to argue with such a clear-cut result, and the determiner theory was widely accepted. Its triumph was a climactic victory for mechanistic concept of life, as well.

One of vitalism's last gasps came from the work of another German embryologist, Hans Driesch. Initially a firm believer in Entivicklungsmechanik, Driesch later found its concepts deficient in the face of life's continued mysteries. For example, using sea urchin eggs, he repeated Roux's famous experiment and obtained a whole organism instead of a half. Many other experiments convinced Driesch that life had some special innate drive, a process that went against known physical laws. Drawing on the ancient Greek idea of the anima, he proposed a non-material, vital factor that he called entelechy. The beginning of the twentieth century wasn't a propitious time for such an idea, however, and it wasn't popular.

Mechanics of Growth

As the nineteenth century drew to a close and the embryologists continued to struggle with the problems of inheritance, they found they still needed a substitute for the homunculus. Weismann's determiners worked fine for embryonic growth, but regeneration was a glaring exception, and one that didn't prove the rule. The original theory had no provision for a limited replay of growth to replace a part lost after development was finshed. Oddly enough, the solution had already been provided by a man almost totally forgotten today, Theodor Heinrich Boveri.

Working at the University of Munich in the 1880s, Boveri discovered almost every detail of cell division, including the chromosomes. Not until the invention of the electron microscope did anyone add meterially to his original descriptions. Boveri found that all nonsexual cells of any

one species contained the same number of chromosomes. As growth proceeded by mitosis, these chromosomes split lengthwise to make two of each so that each daughter cell then had the same number of chromosomes. The egg and sperm, dividing by a special process called meiosis, wound up with exactly half that number, so that the fertilized egg would start out with a full complement, half from the father and half from the mother. He reached the obvious conclusions that the chromosomes transmitted heredity, and that each one could exchange smaller units of itself with its counterpart from the other parent.

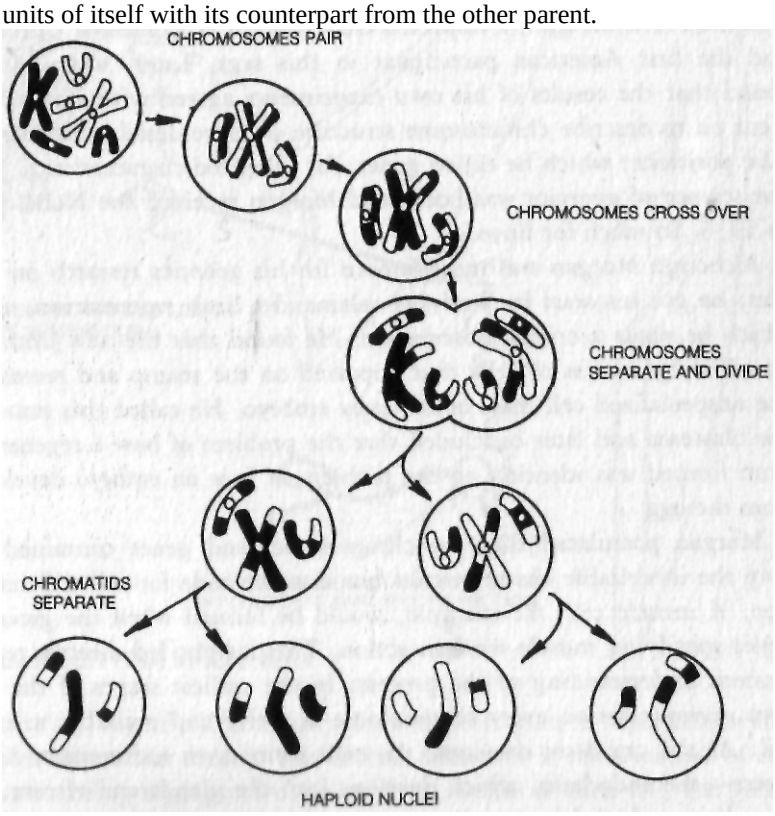

MEIOSIS—FORMATION OF SEX CELLS

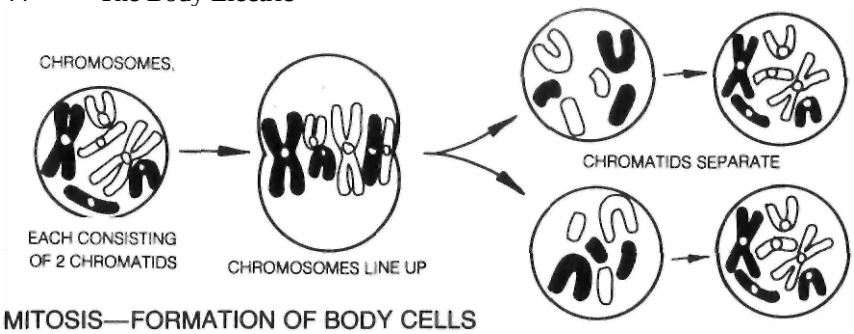

MITOSIS—FORMATION OF BODY CELLS

At first this idea wasn't well received. It was strenuously opposed by Thomas Hunt Morgan, a respected embryologist at Columbia University and the first American participant in this saga. Later, when Morgan found that the results of his own experiments agreed with Boveri's, he went on to describe chromosome structure in more detail, charting specific positions, which he called genes, for inherited characteristics. Thus the science of genetics was born, and Morgan received the Nobel Prize in 1933. So much for Boveri.

Although Morgan was most famous for his genetics research on fruit flies, he got his start by studying salamander limb regeneration, about which he made a crucial observation. He found that the new limb was preceded by a mass of cells that appeared on the stump and resembled the unspecialized cell mass of the early embryo. He called this structure the blastema and later concluded that the problem of how a regenerated limb formed was identical to the problem of how an embryo developed from the egg.

Morgan postulated that the chromosomes and genes contained not only the inheritable characteristics but also the code for cell differentiation. A muscle cell, for example, would be formed when the group of genes specifying muscle were in action. This insight led directly to our modern understanding of the process: In the earliest stages of the embryo, every gene on every chromosome is active and available to every cell. As the organism develops, the cells form three rudimentary tissue layers—the endoderm, which develops into the glands and viscera; the mesoderm, which becomes the muscles, bones, and circulatory system; and the ectoderm, which gives rise to the skin, sense organs, and nervous system. Some of the genes are already being turned off, or repressed, at this stage. As the cells differentiate into mature tissues, only one specific set of genes stays switched on in each kind. Each set can make only certain types of messenger ribonucleic acid (mRNA), the "executive secretary" chemical by means of which DNA "instructs" the

ribosomes (the cell's protein-factory organelles) to make the particular proteins that distinguish a nerve cell, for example, from a muscle or cartilage cell.

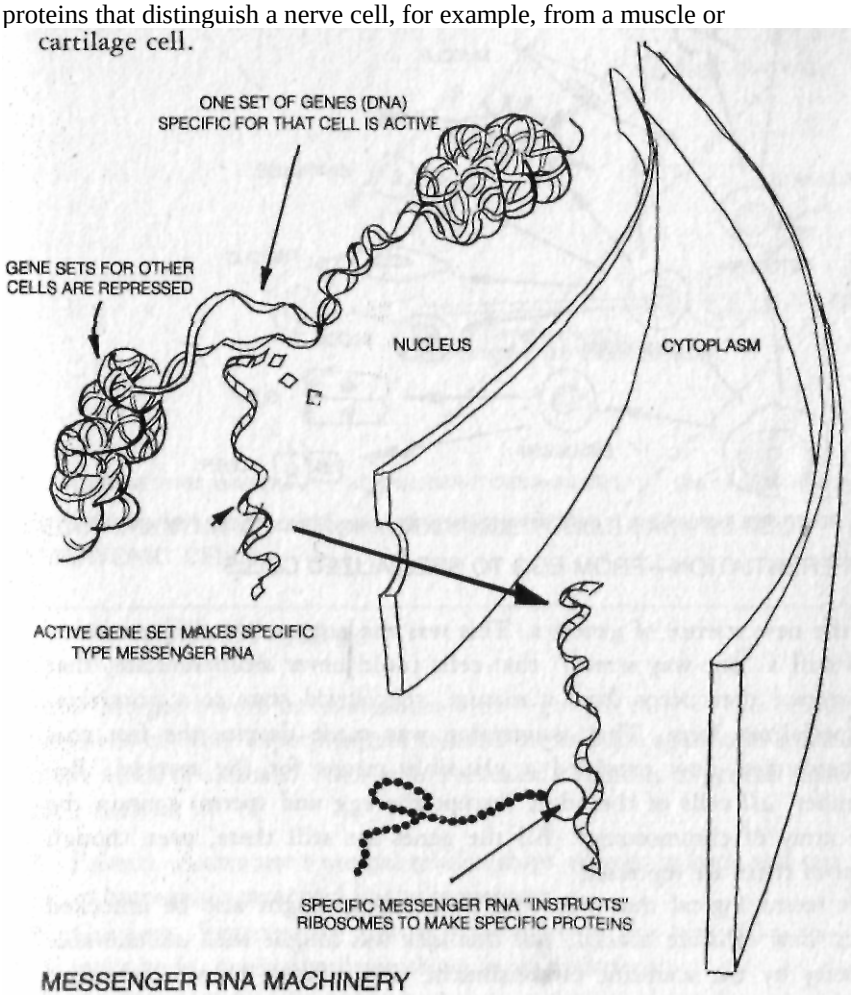

MESSENGER RNA MACHINERY

There's a superficial similarity between this genetic mechanism and the old determiner theory. The crucial difference is that, instead of determiners being segregated until only one remains in each cell, the genes are repressed until only one set remains active in each cell. However, the entire genetic blueprint is carried by every cell nucleus.

Science is a bit like the ancient Egyptian religion, which never threw old gods away but only tacked them onto newer deities until a bizarre hodgepodge developed. For some strange reason, science is equally reluctant to discard worn-out theories, and, even though there was absolutely no evidencc to support it, one of Weismann's ideas was swallowed whole

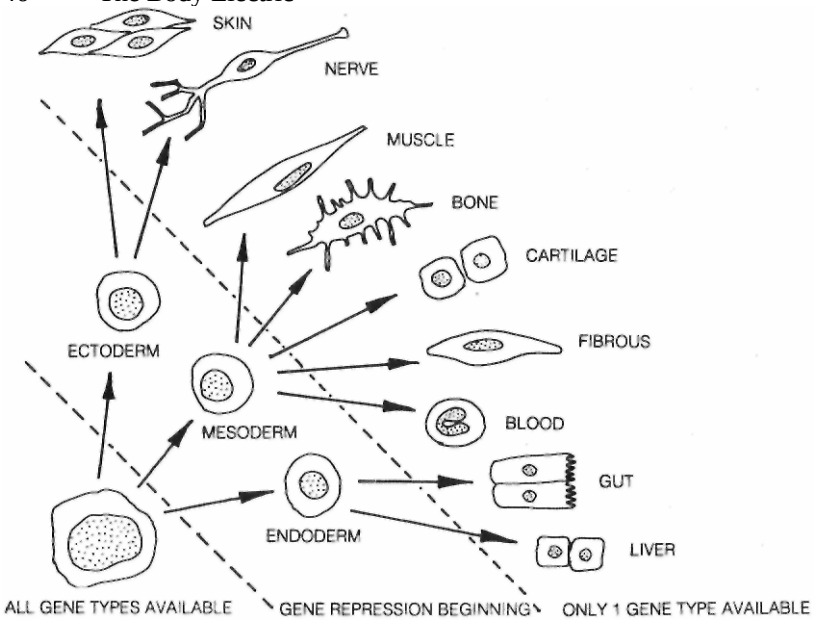

DIFFERENTIATION—FROM EGG TO SPECIALIZED CELLS

by the new science of genetics. This was the notion that differentiation was still a "one-way street," that cells could never dedifferentiate, that is, retrace their steps from a mature, specialized state to a primitive, unspecialized form. This assumption was made despite the fact that chromosomes now provided a plausible means for the reversal. Remember, all cells of the adult (except the egg and sperm) contain the full array of chromosomes. All the genes are still there, even though most of them are repressed.

It seems logical that what has been locked might also be unlocked when new cells are needed, but this idea was fought with unbelievable ferocity by the scientific establishment. It's difficult now to see why, since no principle of real importance was involved, except possibly a bit of the supremacy of the mechanistic outlook itself. The mechanists greeted the discovery of genes and chromosomes joyfully. Here at last was a replacement for the little man in the sperm! Perhaps it seemed that admitting dedifferentiation would have given life too much control over its own functions. Perhaps, once genes were considered the sole mechanism of life, they had to work in a nice, simple, mechanical way. As we shall see, this dogma created terrible difficulties for the study of regeneration.

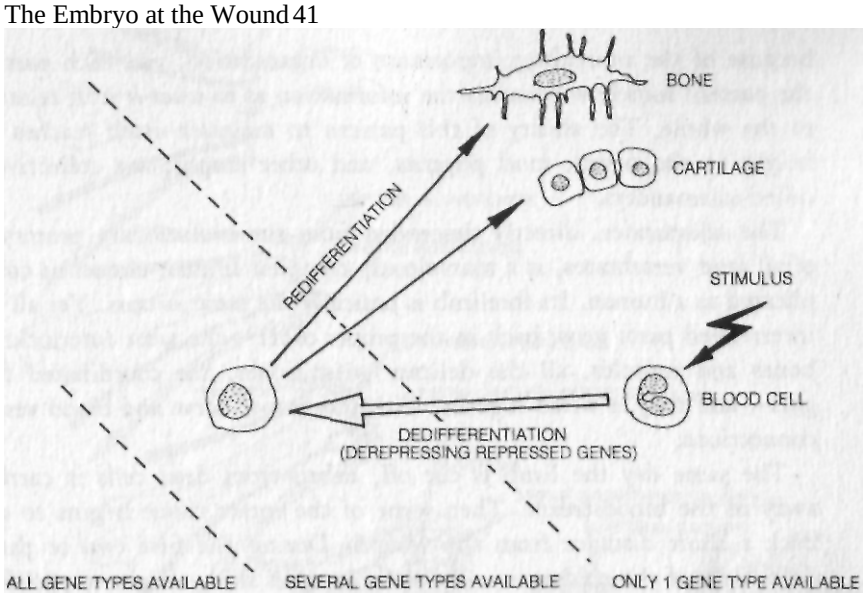

DEDIFFERENTIATE—FROM SPECIALIZED CELLS BACK TO NEO-EMBRYONIC CELLS

Control Problems

After Morgan's work on salamander limb regrowth early in this century, hundreds of other experimenters studied the miracle again and again in many kinds of animals. Their labors revealed a number of general principles, such as:

Polarity. A creature's normal relationships of front to back and top to bottom are preserved in the regenerate.

Gradients. Regenerative ability is strongest in one area of an animal's body, gradually diminishing in all directions.

- Dominance. Some one particular section of the lost part is replaced first, followed by the others in a fixed sequence.
- Induction. Some parts actively trigger the formation of others later in the sequence.
- Inhibition. The presence of any particular part prevents the formation of a duplicate of itself or of other parts that come before that part in the sequence.

All the experiments led to one unifying conclusion: The overall structure, the shape, the pattern, of any animal is as real a part of its body as are its cells, heart, limbs, or teeth. Living things are called organisms

because of the overriding importance of organization, and each part of the pattern somehow contains the information as to what it is in relation to the whole. The ability of this pattern to maintain itself reaches its height in the newts, mud puppies, and other amphibians collectively called salamanders.

The salamander, directly descended from the evolutionary prototype of all land vertebrates, is a marvelously complex animal, almost as complicated as a human. Its forelimb is basically the same as ours. Yet all its interrelated parts grow back in the proper order—the same interlocking bones and muscles, all the delicate wrist bones, the coordinated fingers—and they're wired together with the proper nerve and blood vessel connections.

The same day the limb is cut off, debris from dead cells is carried away in the bloodstream. Then some of the intact tissue begins to die back a short distance from the wound. During the first two or three days, cells of the epidermis—the outer layer of skin—begin to proliferate and migrate inward, covering the wound surface. The epidermis then thickens over the apex of the stump into a transparent tissue called the apical cap. This stage is finished in about a week.

By then, the blastema, the little ball of undifferentiated cells described by Morgan, has started to appear beneath the apical cap. This is the "organ" of regeneration, forming on the wound like a miniature embryo and very similar to the embryonic limb bud that gave rise to the leg in the first place. Its cells are totipotent, able to develop into all the different kinds of cells needed to reconstitute the limb.

The blastema is ready in about two weeks. Even as it's forming, the cells at its outer edge start dividing rapidly, changing the blastema's shape to a cone and providing a steady source of raw material—new cells—for growth. After about three weeks, the blastema cells at the inner edge begin to differentiate into specialized types and arrange themselves into tissues, beginning with a cartilage collar around the old bone shaft. Other tissues then form, and the new limb—beginning with a characteristic paddle shape that will become the hand—appears as though out of a mist. The elbow and long parts of the limb coalesce behind the hand, and the regrowth is complete (except for some slight enlargement) when the four digits reappear after about eight weeks.

This process, exquisitely beautiful and seemingly simple, is full of problems for biology. What organizes the growth? What is the control factor? How does the blastema "know" that it must make a foreleg instead of a bind leg? (The salamander never makes a mistake.) How does all the information about the missing parts get to these undifferentiated

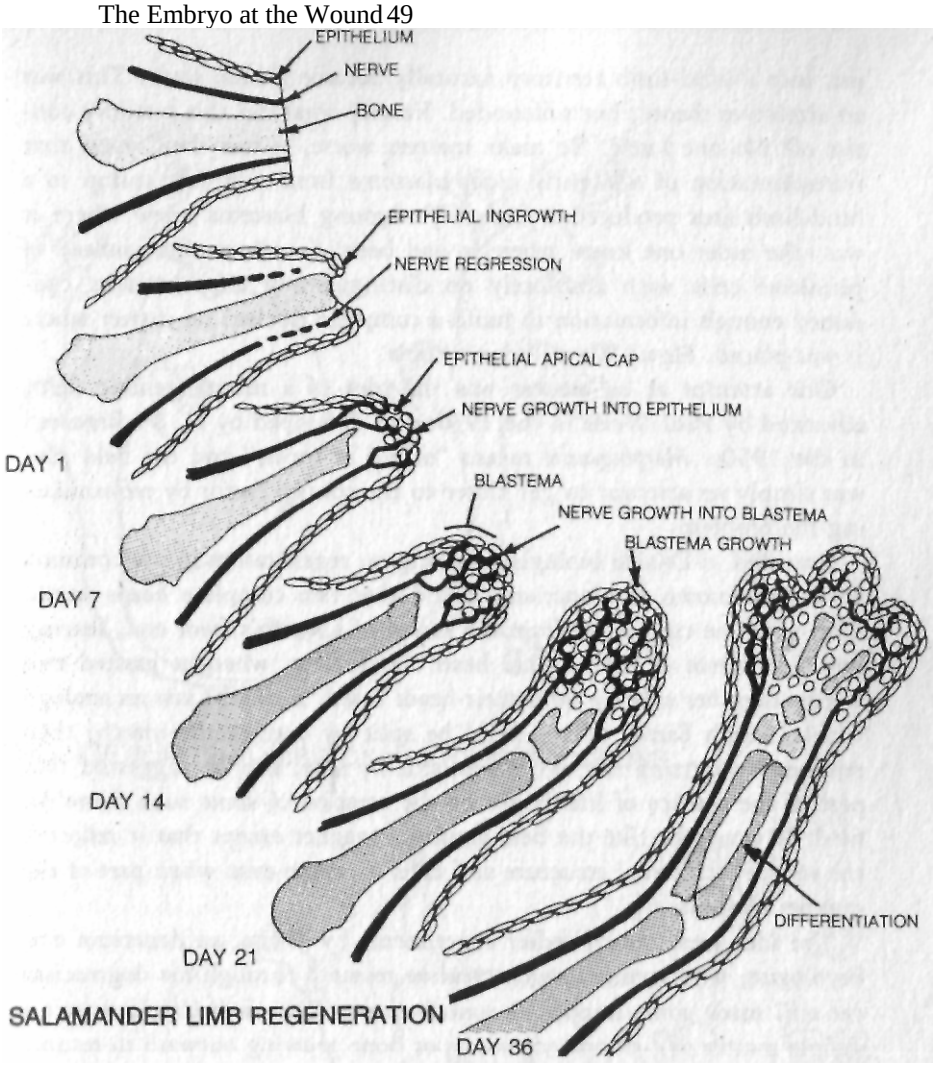

cells, telling them what to become, which genes to activate, what proteins to make, where to position themselves? It's as if a pile of bricks were to spontaneously rearrange itself into a building, becoming not only walls but windows, light sockets, steel beams, and furniture in the process.

Answers were sought by transplanting the blastema to other positions on the animal. The experiments only made matters worse. If the blastema was moved within live to seven days after it first appeared, and grafted near the hind leg, it grew into a second hind leg, even though it came from an amputated foreleg. Well, that was okay. The body could be divided into "spheres of influence" or "organizational territories," each of which contained information on the local anatomy. A blastema

put into a hind-limb territory naturally became a hind limb. This was an attractive theory, but unfounded. Exactly what did this territory consist of? No one knew. To make matters worse, it was then found that transplantation of a slightly older blastema from a foreleg stump to a hind-limb area produced a foreleg. The young blastema knew where it was; the older one knew where it had been! Somehow this pinhead of primitive cells with absolutely no distinguishing characteristics contained enough information to build a complete foreleg, no matter where it was placed. How? We still don't know.

One attempt at an answer was the idea of a morphogenetic field, advanced by Paul Weiss in the 1930s and developed by H. V. Bronsted in the 1950s. Morphogenesis means "origin of form," and the field idea was simply an attempt to get closer to the control factor by reformulating the problem.

Bronsted, a Danish biologist working on regeneration in the common flatworms known as planarians, found that two complete heads would form when he cut a strip from the center of a worm's front end, leaving two side pieces of the original head. Conversely, when he grafted two worms together side by side, their heads fused. Br0nsted saw an analogy with a match flame, which could be split by cutting the match, then rejoined by putting the two halves side by side, and he suggested that part of the essence of life might be the creation of some such flamelike field. It would be like the field around a magnet except that it reflected the magnet's internal structure and held its shape even when part of the magnet was missing.

The idea grew out of earlier experiments by Weiss, an American embryologist, who stymied much creative research through his dogmatism yet still made some important contributions. Regrowth clearly wasn't a simple matter of a truncated muscle or bone growing outward to resume its original shape. Structures that were missing entirely—the hand, wrist, and bones of the salamander's lower forelimb, for example—also reappeared. Weiss found that redundant parts could be inserted, but the essential ones couldn't easily be eliminated. If an extra bone was implanted in the limb and the cut made through the two, the regenerate contained both. However, if a bone was completely removed and the incision allowed to heal, and the limb was then amputated through what would have been the middle of the missing bone, the regenerate produced that bone's lower half, like a ghost regaining its substance Weiss suggested that other tissues besides bone could somehow project a field that included the arrangement of the bones. As a later student of regeneration, Richard Goss of Brown University, observed, "Apparently

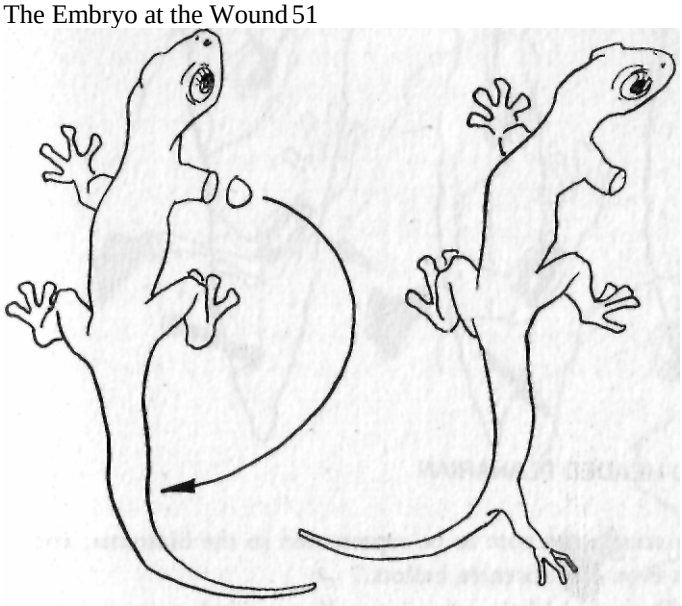

THE LATE BLASTEMA ALREADY HAS ITS INSTRUCTIONS

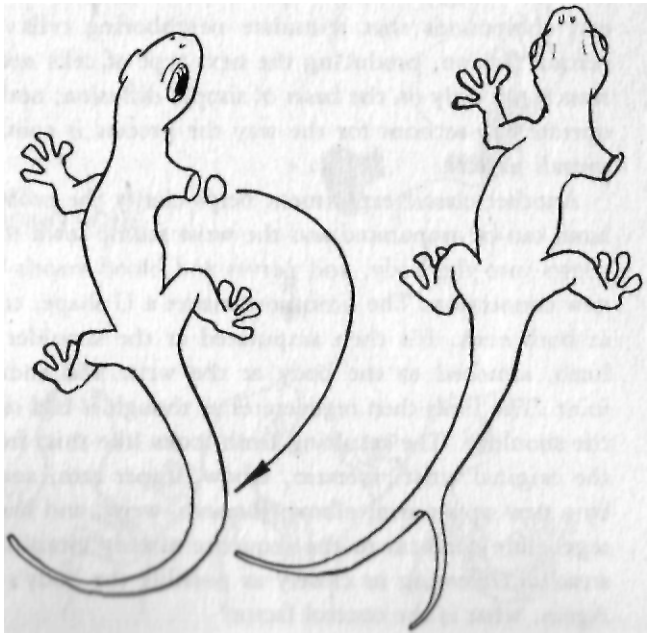

THE EARLY BLASTEMA GETS INSTRUCTIONS FROM NEARBY TISSUES

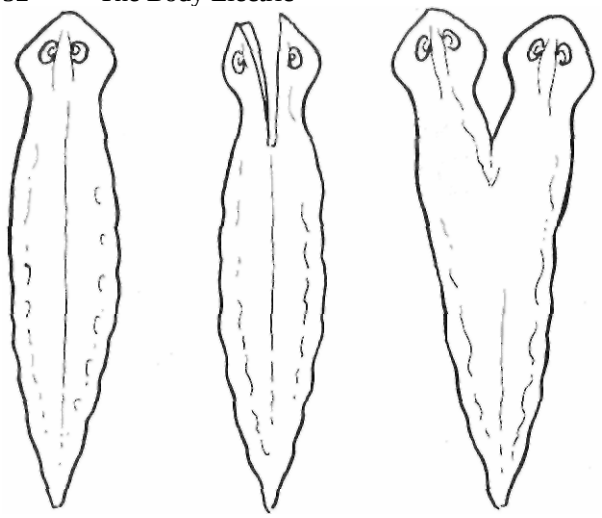

FORMING A TWO-HEADED PLANARIAN

each tissue of the stump can vote to be represented in the blastema, and some of them can even cast absentee ballots."

Any such field must be able to stimulate cells to switch various genes on and off, that is, to change their specialization. A large body of research on embryonic development has identified various chemical inducers, compounds that stimulate neighboring cells to differentiate in a certain fashion, producing the next type of cells needed. But these substances act only on the basis of simple diffusion; nothing in the way they operate can account for the way the process is controlled to express the overall pattern.

Another classic experiment helps clarify the problem. A salamander's hand can be amputated and the wrist stump sewn to its body. The wrist grows into the body, and nerves and blood vessels link up through the new connection. The limb now makes a U shape, connected to the body at both ends. It's then amputated at the shoulder to make a reversed limb, attached to the body at the wrist and ending with a shoulder joint. The limb then regenerates as though it had simply been cut off at the shoulder. The resulting limb looks like this: from the body sprouts the original wrist, forearm, elbow, upper arm, and shoulder, followed by a new upper arm, elbow, forearm, wrist, and hand. Why doesn't the regenerate conform to the sequence already established in this limb instead of following as closely as possible the body's pattern as a whole? Again, what is the control factor?

Information, and a monumental amount of it, is clearly passed from the body to the blastema. Our best method of information processing at

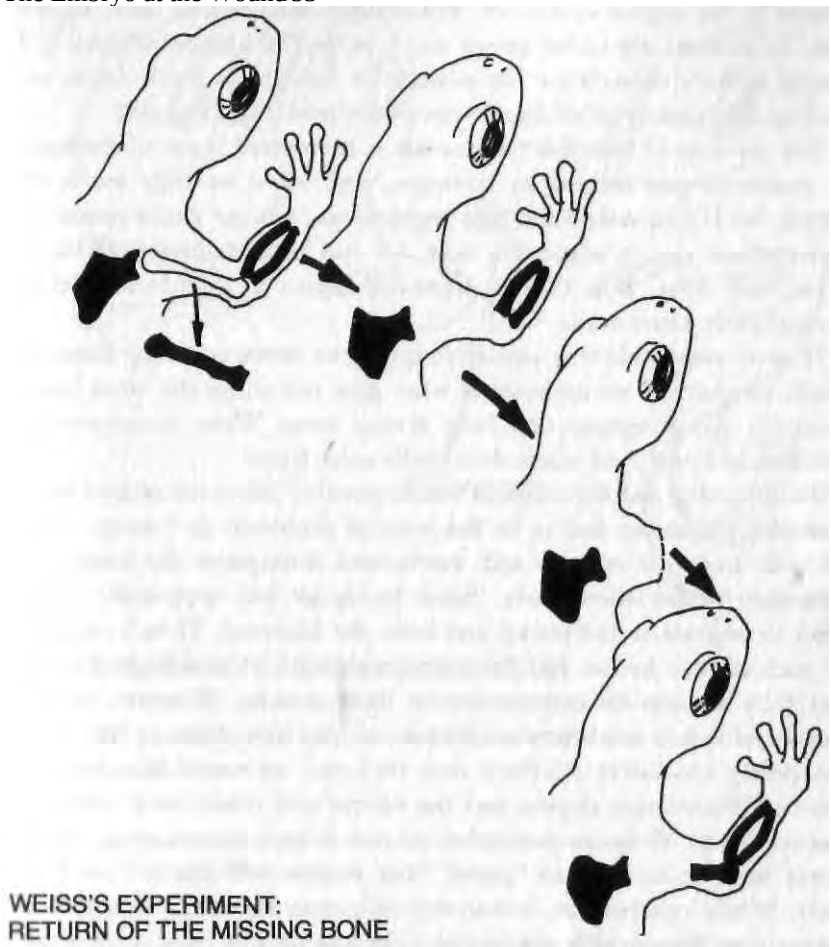

WEISS'S EXPERIMENT:
RETURN OF THE MISSING BONE

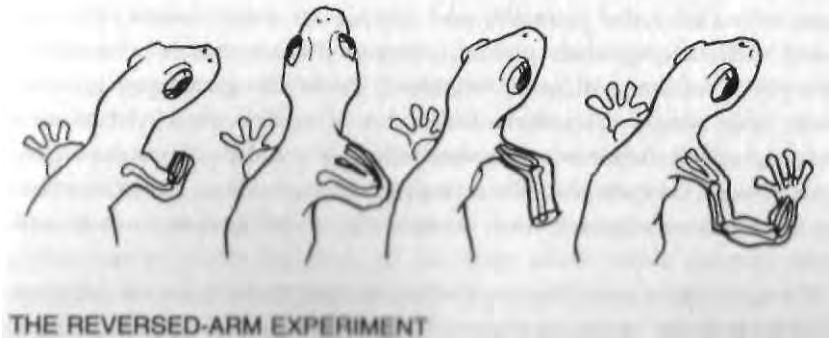

THE REVERSED-ARM EXPERIMENT

present is the digital computer, which deals with bits of data, signals that, in essence, say either yes or no, 1 or 0. The number of such bits needed to fully characterize the salamander forelimb is incalculable, exceeding the capacity of all known computers operating in unison.

The question of how this information is transferred is one of the hardest problems ever tackled by scientists, and when we fully know the answer, we'll understand not only regeneration but the entire process of growth from egg to adult. For now, we had best, as biologists themselves have done, skip this problem and return to it after addressing some slightly easier ones.

It seems reasonable that understanding what comes out of the blastema would be easier if we understood what goes into it, so the other major questions about regeneration have always been: What stimulates the blastema to form? And where do its cells come from?

The idea that dedifferentiation was impossible led to the related belief that all regeneration had to be the work of neoblasts, or "reserve cells" left over from the embryo and warehoused throughout the body in a primitive, unspecialized state. Some biological bell supposedly called them to migrate to the stump and form the blastema. There's evidence for such cells in hydras and flatworms, although it's now doubtful that they fully account for regeneration in these animals. However, no one ever found any in a salamander. In fact, as long ago as the 1930s, there was nearly conclusive evidence that they did not exist. Nevertheless, anti-dedifferentiation dogma and the reserve cell theory were defended fanatically, by Weiss in particular, so that many unconvincing experiments were interpreted to "prove" that reserve cells formed the blastema. When I started out, it was very dangerous for one's career even to suggest that mature cells might create the blastema by dedifferentiating.

Because it was so hard to imagine how a blastema could arise without dedifferentiation, the idea later developed that perhaps cells could partially dedifferentiate. In other words, perhaps muscle cells could become cells that looked primitive and completely unspecialized, but that would then take up their previous lives as mature muscle cells after a brief period of amnesia in the blastema. To fit the square peg into the round hole, many researchers did a lot of useless work, laboriously counting cell divisions to try to show that the muscle cells in the stump made enough new muscle cells to supply the regenerate. The embarrassing blastema—enigmatic and completely undifferentiated was still there.

We now know (see Chapter 6) that at least some types of cells can revert completely to the primitive state and that such despecialization is

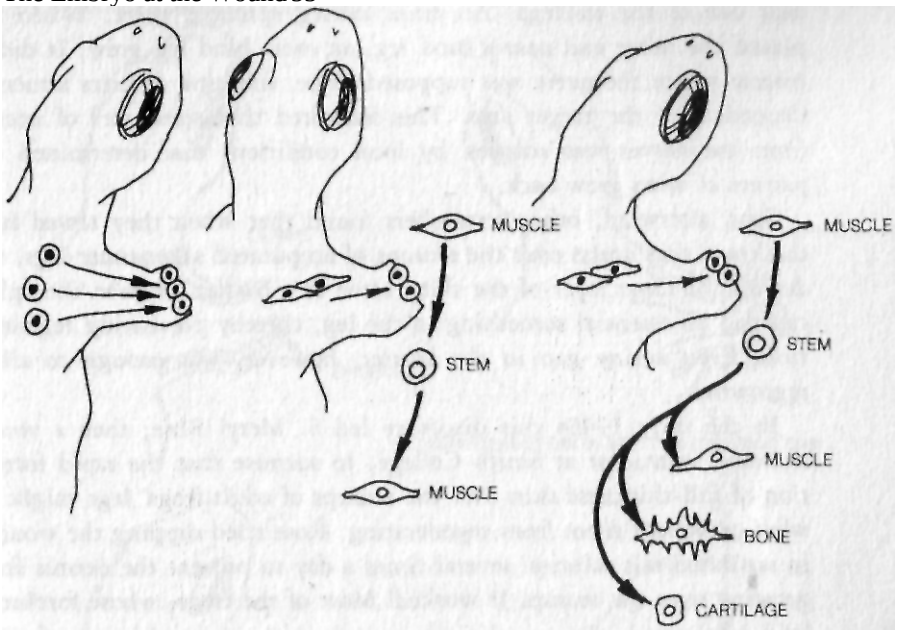

DEDIFFERENTIATE: PARTIAL OR COMPLETE?

the major, probably the only, way a blastema forms in complex animals like a salamander.

Nerve Connections

The other major question about the blastema's origin is: What triggers it? The best candidates for a "carrier" of the stimulus are the nerves. In complex multicellular animals, there's no regeneration without nerve tissue. Back in 1823, the English amateur Tweedy John Todd found that if the nerves into a salamander's leg were cut when the amputation was made, the limb wouldn't regrow. In fact, the stump itself shriveled up and disappeared. However, Todd got normal regeneration when he gave the nerves time to reconnect before severing the leg. Science wasn't ready to make anything of his observation, but many experiments since have confirmed it. Over a century later, Italian biologist Piera Locatelli showed that an extra leg would grow if a nerve was rerouted so that it ended near an intact leg. She cut the large sciatic nerve partway down
the salamander's hind leg, leaving it attached to the spinal column and
fully threading it up untder the skin so that its end touched the skin

near one of the forelegs. An extra foreleg sprouted there. When she placed the nerve end near a hind leg, an extra hind leg grew. It didn't matter where the nerve was supposed to be; the kind of extra structure depended on the target area. This indicated that some sort of energy from the nerves was adapted by local conditions that determined the pattern of what grew back.

Soon afterward, other researchers found that when they sewed full-thickness skin grafts over the stumps of amputated salamander legs, the dermis, or inner layer of the skin, acted as a barrier between the apical cap and an essential something in the leg, thereby preventing regeneration. Even a tiny gap in the barrier, however, was enough to allow regrowth.

In the early 1940s this discovery led S. Meryl Rose, then a young anatomy instructor at Smith College, to surmise that the rapid formation of full-thickness skin over the stumps of adult frogs' legs might be what prevented them from regenerating. Rose tried dipping the wounds in saturated salt solution several times a day to prevent the dermis from growing over the stump. It worked! Most of the frogs, whose forelimbs he'd amputated between the elbow and wrist, replaced some of what they'd lost. Several regrew well-formed wrist joints, and a few even began to produce one new finger. Even though the replacements were incomplete, this was a tremendously important breakthrough, the first time any regeneration had been artificially induced in an animal normally lacking the ability. However, the dermis did grow over the stump, so the experiment worked by some means Rose hadn't expected.

Later, other investigators showed that in normal regeneration the apical cap, minus the dermis, was important because regrowing nerve fibers made unique connections with the epidermal cells in the first stage of the process, before the blastema appeared. These connections are collectively called the neuroepidermal junction (NEJ). In a series of detailed experiments, Charles Thornton of Michigan State University cut the nerves to salamander legs at various times before amputating the legs, then followed the progress of the regrowing nerves. Regeneration began only after the nerves had reached the epidermis, and it could be prevented by any barrier separating the two, or started by any breach in the barrier. By 1954 Thornton had proved that the neuroepidermal junction was the one pivotal step that must occur before a blastema could form and regeneration begin.

Shortly thereafter, Elizabeth D. Hay, an anatomist then working at Cornell University Medical College in New York, studied the neuroepidermal junction with an electron microscope. She found that as

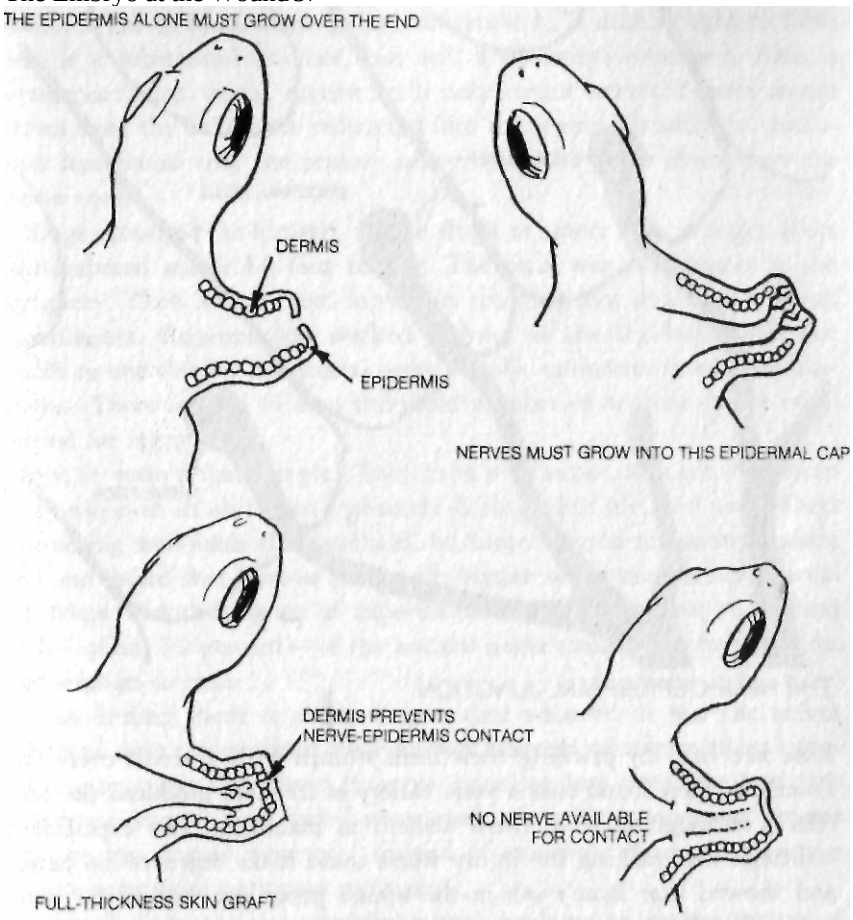

BLOCKING THE NEUROEPIDERMAL JUNCTION PREVENTS REGENERATION

each nerve fiber bundle reached the end of the stump, it broke up and each fiber went its separate way, snaking into the epidermis, which might be five to twenty cells thick. Each nerve fiber formed a tiny bulb at its tip, which was placed against an epidermal cell's membrane, nestling into a little pocket there. The arrangement was much like a synapse, although the microscopic structure wasn't as highly developed as in such long-term connections.

The junction was only a bridge, however. The important question was: What traffic crossed it?

In 1946, Lev Vladimirovich Polezhaev, young Russian biologist then working in London, concluded a long series of experiments in which he induced partial regeneration in adult frogs, the same success

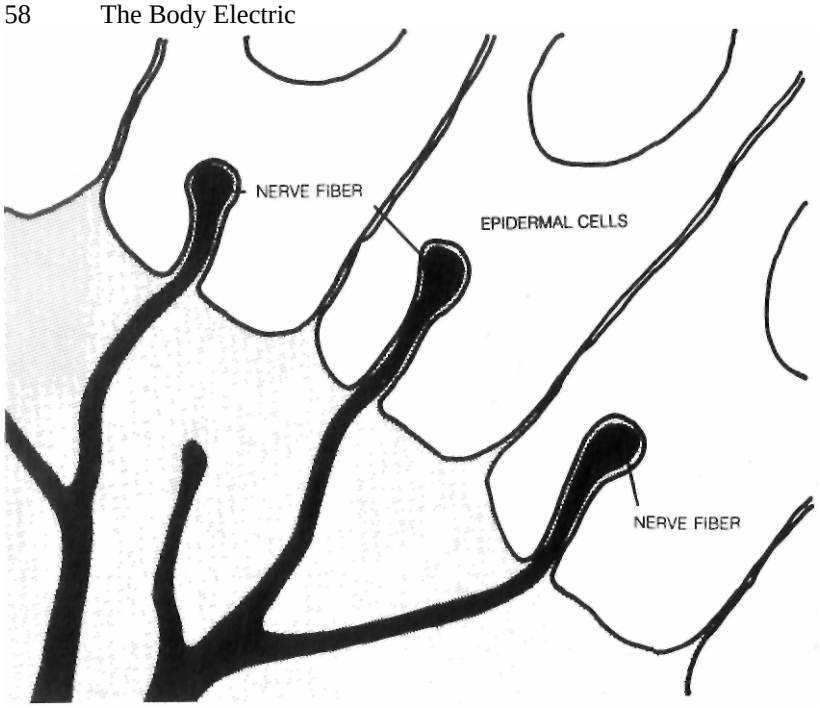

THE NEUROEPIDERMAL JUNCTION

Rose had had, by pricking their limb stumps with a needle every day. Polezhaev then found that a wide variety of irritants produced the same effect, although none of them worked in mammals. His experiments indicated that making the injury worse could make regeneration better, and showed that Rose's salt-in-the-wound procedure worked by irritation rather than by preventing dermis growth.

Next, the part that nerve tissue played was clarified considerably by Marcus Singer in a brilliant series of experiments at Harvard Medical School from the mid-1940s to the mid-1950s. Singer first confirmed Todd's long-forgotten work by cutting the nerves in salamander legs at various stages of regrowth, proving that the nerves were needed only in the first week, until the blastema was fully formed and the information transferred. After that, regeneration proceeded even if the nerves were cut.

Recent research had found that a salamander could replace its leg if all the motor nerves were cut, but not without the sensory nerves. Many assumed then that the growth factor was related only to sensory nerves, but Singer was uneasy over this conclusion: "The problem stated in advance that one or another nerve component is all important for regeneration." (Italics added.) Several facts didn't fit, however. Not only did the

blastema fail to form when all nerves were cut, it didn't begin to form even if a substantial number, but still a minority, remained. Also, a salamander's leg would regrow with only motor nerves if extra motor nerves from the belly were redirected into the stump. In addition, zoologists had found that the sensory nerve contained more fibers than the motor nerve.

Singer counted for himself. In the thigh or upper arm, sensory fibers outnumbered motor by four to one. The ratio was even larger at the periphery. Then he cut them in various combinations in a long series of experiments. Regeneration worked as long as the leg had about one fourth to one third of its normal nerve supply, no matter in what combination. There seemed to be a threshold number of neurons (nerve cells) needed for regrowth.

But it wasn't that simple. The limbs of Xenopus, a South American frog unique in its ability to regenerate during adult life, had nerve fibers numbering well under the threshold. So Singer started measuring neuron size, and found that Xenopus had much bigger nerves than nonregenerating frogs. Another series of experiments verified the link: A critical mass—about 30 percent—of the normal nerve tissue must be intact for regeneration to ensue.

This finding made it pretty certain that whatever it was the nerves delivered didn't come from their known function of transmitting information by nerve impulses. If nerve impulses had been involved, regeneration should have faded away gradually with greater and greater flaws as the nerves were cut, instead of stopping abruptly when the minimum amount no longer remained.

Singer's discovery also provided a basic explanation for the decline of regeneration with increasing evolutionary complexity. The ratio between body mass and total nerve tissue is about the same in most animals, but more and more nerve became concentrated in the brain (a process called encephalization) as animals became more complex. This diminished the amount of nerve fiber available for stimulating regeneration in peripheral parts, often below the critical level.

In the early 1950s, Singer applied what he'd learned to the nonregenerating adult bullfrog. Using Locatelli's method, he dissected the sciatic nerve out of the hind leg, leaving it attached to the spinal cord, and directed it under the skin to the foreleg amputation stump. In two or three weeks, blastemas had formed, and the cut legs were restored to about the same degree as in Rose's and Polezhaev's experiments.

By 1954 Singer was ready to look for a growth-inducing chemical that was presumed to be coming from the nerves. The most promising

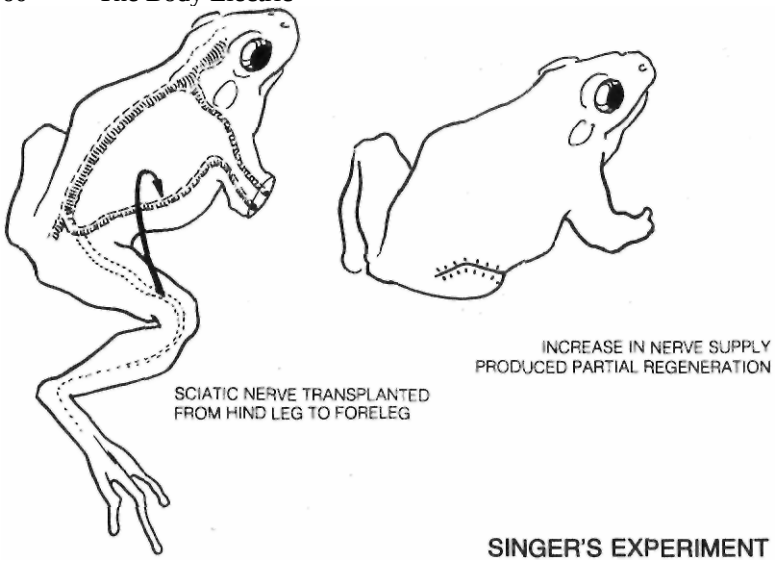

SINGER'S EXPERIMENT

possibility was the neurotransmitter acetylcholine, one of several compounds known to relay nerve impulses across synapses. The nerves secreted acetylcholine more abundantly than normal during blastema formation—just when nerve supply was crucial—and its production fell back to normal when regrowth was well under way. Singer had studied previous failures with acetylcholine, in which experimenters had rubbed it on the stump or injected it into the blastema. He thought these methods were too artificial, so he invented a microinfusion apparatus to release tiny amounts of acetylcholine continually, just as the nerves did. It used a clock motor to drip the hormone slowly through a needle into the shoulder of an anesthetized animal in which the leg nerves had been removed. He had trouble keeping the drugged salamanders alive, so maybe the anesthetic affected the outcome, but even the ones that survived didn't regenerate at all. The growth factor was almost certainly not acetylcholine.

Vital Electricity

These, then, were the shoulders on which I stood in 1958 as I began to look for the pattern-control and blastema-stimulating factors in regeneration. At that time we knew of two things that could yield some regrowth in nonregenerators: extra nerve and extra injury. How were they related? Luck gave me a clue.

I began my work just after the first few Sputniks, during the "missile gap" flap. Alarmed by the unforeseen triumphs of Russian technology, which we'd considered primitive, the government hastily began translating every Soviet scientific journal and distributing copies free to federally funded research centers. Suddenly, the medical library at the VA Medical Center in Syracuse, where I worked, began receiving each month a crate of Russian journals on clinical medicine and biology. Since no one else was much interested, this bonanza was all for me.

I soon made two discoveries: The Russians were willing to follow hunches; their researchers got government money to try the most outlandish experiments, ones that our science just knew couldn't work. Furthermore, Soviet journals published them—even if they did work. I particularly enjoyed Biofizika, the Soviet journal of biophysics, and it was there I encountered a paper on the "Nature of the Variation of the Bioelectric Potentials in the Regeneration Process of Plants," by A. M. Sinyukhin of Lomonosov State University in Moscow.

Sinyukhin began by cutting one branch from each of a series of tomato plants. Then he took electrical measurements around the wound as each plant healed and sent out a new shoot near the cut. He found a negative current—a stream of electrons—flowing from the wound for the first few days. A similar "current of injury" is emitted from all wounds in animals. During the second week, after a callus had formed over the wound and the new branch had begun to form, the current became stronger and reversed its polarity to positive. The important point wasn't the polarity—the position of the measuring electrode with respect to a reference electrode often determines whether a current registers as positive or negative. Rather, Sinyukhin's work was significant because he found a change in the current that seemed related to reparative growth. Sinyukhin found a direct correlation between these orderly electrical events and biochemical changes: As the positive current increased, cells in the area more than doubled their metabolic rate, also becoming more acidic and producing more vitamin C than before.

Sinyukhin then applied extra current, using small batteries, to a group of newly lopped plants, augmenting the regeneration current. These battery-assisted plants restored their branches up to three times faster than the control plants. The currents were very small—only 2 to 3 microamperes for five days. (An ampere is a standard unit of electric current, and a microampere is one millionth of an ampere.) Larger amounts of electricity killed the cells and had no growth-enhancing effect. Moreover, the polarity had to match that normally found in the plant. When Sinyukhin used current of the opposite polarity, nullifying

the plant's own current, restitution was delayed by two or three weeks.

To American biology, however, this was all nonsense. To understand why, we must backtrack for a while.

Luigi Galvani, an anatomy professor in the medical school at the University of Bologna who'd been studying electricity for twenty years, first discovered the current of injury in 1794, but unfortunately he didn't know it.

At that time, biology's main concern was the debate between vitalism and mechanism. Vitalism, though not always called by that name, had been the predominant concept of life since prehistoric times throughout the world, and it formed the basis for almost all religions. It was closely related to Socrates' and Plato's idea of supernatural "forms" or "ideals" from which all tangible objects and creatures derived their individual characteristics. Hippocrates adapted this idea by postulating an anima as the essence of life. The Platonic concept evolved into the medieval philosophy of realism, whose basic tenet was that abstract universal principles were more real than sensory phenomena. Mechanism grew out of Aristotle's less speculative rationalism, which held that universal principles were not real, being merely the names given to humanity's attempts at making sense of the reality apprehended through the senses. Mechanism had become the foundation of science through the writings of Descartes in the previous century, although even he believed in an "animating force" to give the machine life at the outset. By Galvani's time, mechanism's influence was steadily growing.

Galvani was a dedicated physician, and medicine, tracing its lineage back to tribal shamans, has always been a blend of intuition and empirical observation based on a vitalistic concept of the sanctity of life. The vitalists had long tried—unsuccessfully—to link the strange, incorporeal phenomenon of electricity with the elan vital. This was Galvani's main preoccupation.

One day he noticed that some frogs' legs he'd hung in a row on his balustrade, pending his dinner, twitched whenever the breeze blew them against the ironwork. At about the same time his wife Lucia noticed in his laboratory that the muscles of a frog's leg contracted when an assistant happened to be touching the main nerve with a steel scalpel at the same instant that a spark leaped from one of the electrical machines being operated across the room. (The only type of electricity then known was the static type, in the form of sparks from various friction devices.) Today we know that an expanding and collapsing electric field generated by the spark induced a momentary current in the scalpel, which stimulated the muscle, but Galvani believed that the metal railing and scalpel had drawn forth electricity hidden in the nerves.

Galvani experimented for years with nerves from frogs' legs, connected in various circuits with several kinds of metals. He grew convinced that the vital spirit was electricity flowing through the nerves and announced this to the Bologna Academy of Science in 1791.

Within two years, Alesandro Volta, a physicist at the University of Padua, had proven that Galvani had in fact discovered a new kind of electricity, a steady current rather than sparks. He'd generated a bimetallic direct current, a flow of electrons between two metals, such as the copper hooks and iron railing of the famous balcony observation, connected by a conducting medium—in other words, a battery. The frogs' legs, being more or less bags of weak salt solution, were the electrolyte, or conducting medium. They were otherwise incidental, Volta explained, and there was no such thing as Galvani's "animal electricity."

Galvani, a shy and thoroughly noncombative soul, was crushed. His only response was an anonymous paper in 1794 describing several experiments in which frogs' legs could be made to twitch with no metal in the circuit. In one procedure, the experimenter touched one leg nerve with the frog's dissected-out, naked spinal cord, while holding the other leg to complete the circuit. Here the current was true animal electricity, coming from the amputation wound at the base of the leg.

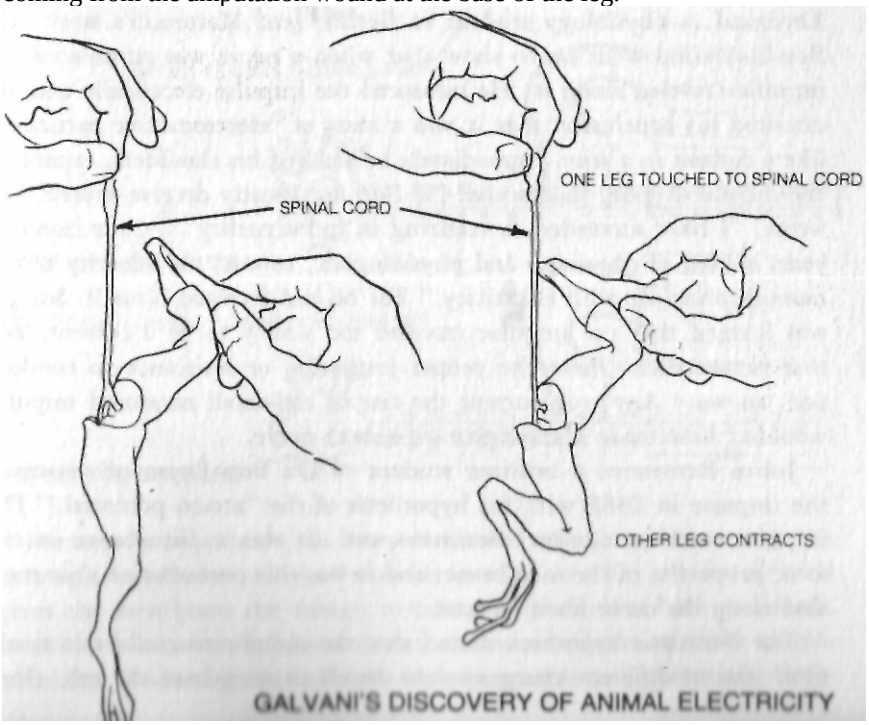

In the long run, Galvani unwittingly helped the cause of the mechanists by giving them something to attack. As long as the elan vital was ephemeral, all you could say was that you couldn't find it. Once Galvani said it was electricity, a detectable, measurable entity, there was a target for experimentation. Actually, Baron Alexander von Humboldt, the explorer-naturalist who founded geology, proved in 1797 that Volta and Galvani were both partly right. Bimetallic currents were real, but so was spontaneous electricity from injured flesh. However, the mechanists had the upper hand; Galvani's anonymous report and Humboldt's confirmation were overlooked. Galvani himself died penniless and brokenhearted in 1798, soon after his home and property were confiscated by the invading French, while Volta grew famous developing his storage batteries under the auspices of Napoleon.

Then in the 1830s a professor of physics at Pisa, Carlo Matteucci, using the newly invented galvanometer, which could measure fairly small direct currents, came up with other evidence for animal electricity. In a meticulous series of experiments lasting thirty-five years, he conclusively proved that the current of injury was real. However, he didn't find it in the nervous system, only emanating from the wound surface, so it couldn't be firmly related to the vital force.

The tale took another turn in the 1840s when Emil Du Bois-Reymond, a physiology student in Berlin, read Matteucci's work. Du Bois-Reymond went on to show that when a nerve was stimulated, an impulse traveled along it. He measured the impulse electrically and announced his conclusion that it was a mass of "electromotive particles," like a current in a wire. Immediately he squared his shoulders, expecting the mantle of glory to descend: "If I do not greatly deceive myself," he wrote, "I have succeeded in realizing in full actuality . . . the hundred years' dream of physicists and physiologists, to wit, the identity of the nervous principle with electricity." But he had deceived himself. Soon it was learned that the impulse traveled too slowly to be a current, and that nerves didn't have the proper insulation or resistance to conduct one, anyway. Any true current the size of the small measured impulse wouldn't have made it through even a short nerve.

Julius Bernstein, a brilliant student of Du Bois-Reymond, resolved the impasse in 1868 with his hypothesis of the "action potential." The impulse wasn't a current, Bernstein said. It was a disturbance in the ionic properties of the membrane, and it was this perturbation that traveled along the nerve fiber, or axon.

The Bernstein hypothesis stated that the membrane could selectively filter ions of different charges to the inside or outside of the cell. (Ions

are charged particles into which a salt breaks up when dissolved in water; all salts dissociate in water into positive and negative ions, such as the positive sodium and negative chloride ions of table salt.) Bernstein postulated that the membrane could sort most of the negatives outside and most of the positives inside the fiber. The membrane was polarized (with like charges grouped on one side), having a transmembrane potential, because the negative charges, all on one side, could potentially flow in a current across the membrane to achieve a balance on both sides. This was what happened in a short segment of the membrane whenever a nerve was stimulated. Part of the membrane became depolarized, reversing the transmembrane potential. The nerve impulse was actually a disturbance in the potential traveling along the membrane. As the area of disturbance moved along, the membrane quickly restored its normal resting potential. Thus the nerve impulse wasn't an electrical current, even though it could be measured electrically.

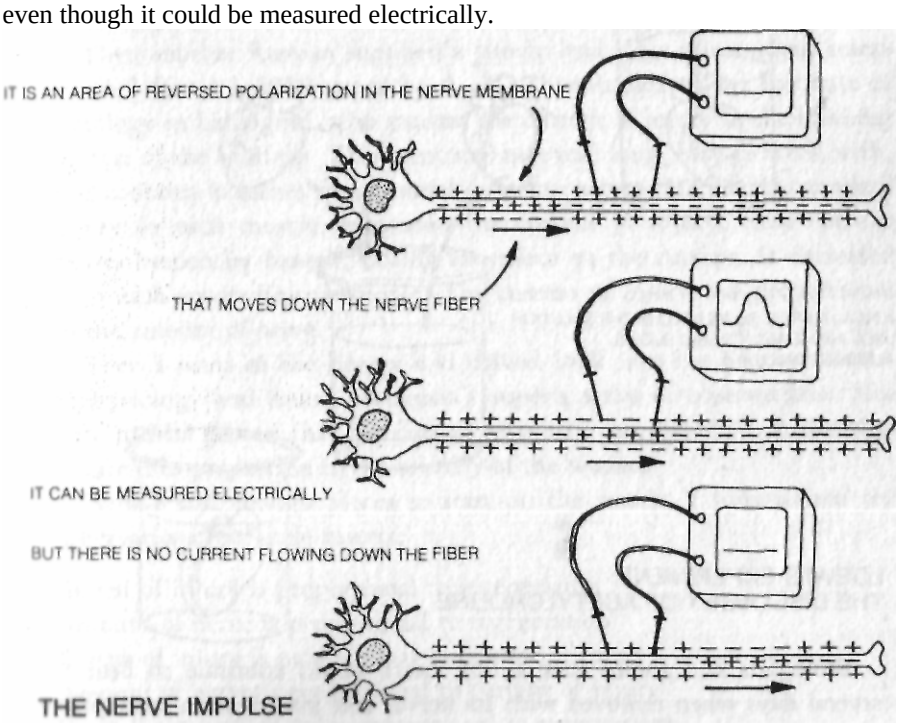

Bernstein's hypothesis has been confirmed in all important respects, although it remains I hypothesis because no one has yet found what gives the membrane the energy to pump all those ions back and forth. Soon it was broadened, however, to include an explanation of the current of injury. Reasoning that all cells had transmembrane potentials, Bern-

stein maintained that, after injury, the damaged ceil membranes simply leaked their ions out into the environment. Thus the current of injury was no longer a sign that electricity was central to life, but only an uninteresting side effect of cell damage.

The vitalists, with their hopes pinned on electricity, kept getting pushed into tighter and tighter corners as electricity was removed from one part of the body after another. Their last stand occurred with the discovery of neurotransmitters. They'd maintained that only an electrical current could jump across the synapse, the gap between communicating nerves. In 1920 that idea was disproven with a lovely experiment by Otto Loewi, a research professor at the NYU School of Medicine, later my alma mater. When I took physiology in my first year there, we had to duplicate his experiment.

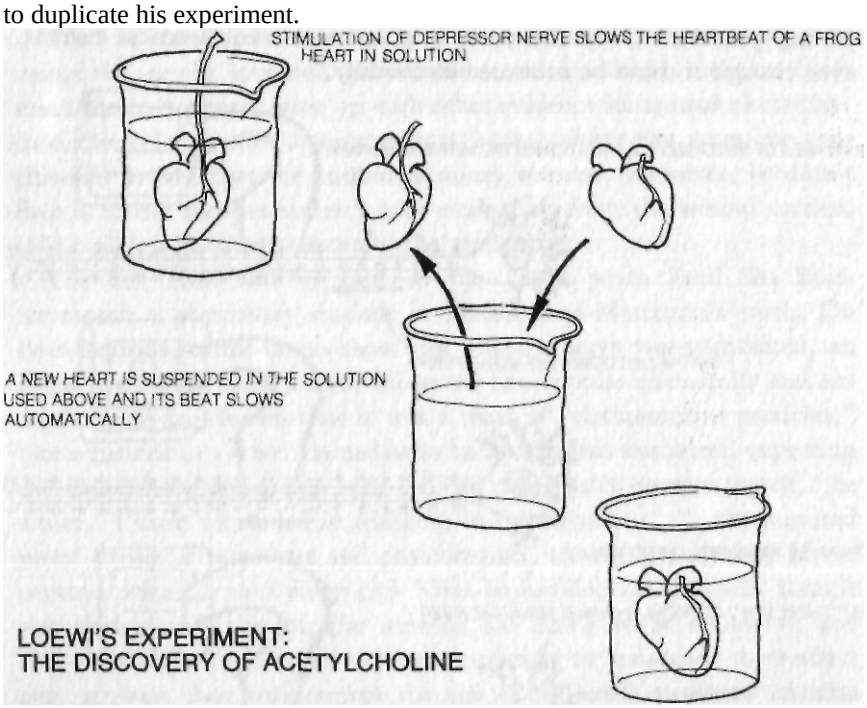

Biologists had found that a frog heart would continue to beat for several days when removed with its nerves and placed in an appropriate solution. Stimulating one of the nerves would slow it down. Like Loewi, we took one such heart, with nerve attached, and stimulated the nerve, slowing the beat. We then collected the solution baching that heart and placed another heart in it. Its beat slowed even though its depressor nerve hadn't been stimulated. Obviously the nerve slowed the heartbeat by producing a chemical, which crossed the gap between the nerve end-

ing and the muscle fiber. This chemical was later identified as acetylcholine, and Loewi was awarded the Nobel Prize in 1936 for this discovery. His work resulted in the collapse of the last vestige of electrical vitalism. Thereafter, every function of the nervous system had to be explained on the basis of the Bernstein hypothesis and chemical transmission across the synapse.

It was with great trepidation, therefore, that I put any credence in Sinyukhin's report that the strength of the injury current affected regeneration in his plants. Yet his report was detailed and carefully written. Something about his work gave me a gut feeling that it was valid. Maybe it was because the tomato plants he used were "Best of All" American Beauties. At this point I wasn't aware of Matteucci's forgotten work, but something clicked in my mind now as I studied Rose's and Polezhaev's experiments. In both, definitely in Pole2haev's and probably in Rose's, regeneration had been stimulated by an increase in the injury.

Then another Russian supplied a timely lead. In a government translation I found a 1958 paper by A. V. Zhirmunskii of the Institute of Cytology in Leningrad, who studied the current of injury in the hind leg muscle of the bullfrog. This muscle is nice and long, easy to work with, and contains branches from several different nerves. He made a standard injury in each muscle, measured the current of injury, then cut the nerves branch by branch, noting the effect on the current. It decreased with each succeeding nerve cut. The current of injury was proportional to the amount of nerve.

Then I went to the library and delved back into the history of neurophysiology and found Matteucci's superb series of observations. Not only had he proven that the current of injury was real, he'd shown that it varied in proportion to the severity of the wound.

Now I had enough pieces to start on the puzzle. I summarized the observations in a little matrix:

Extent of injury is proportional to regeneration
Amount of nerve is proportional to regeneration
Extent of injury is proportional to current of injury
Amount of nerve is proportional to current of injury
Ergo: current of injury is proportional to regeneration

I was pretty sure now chat, contemporary "knowledge" to the contrary, the current of injury was no side effect and was the first place to look for clues to the growth control and dedifferentiation-stimulating factors. I planned my first experiment.

Three
The Sign of the Miracle

Real science is creative, as much so as painting, sculpture, or writing. Beauty, variously defined, is the criterion for art, and likewise a good theory has the elegance, proportion, and simplicity that we find beautiful. Just as the skilled artist omits the extraneous and directs our attention to a unifying concept, so the scientist strives to find a relatively simple order underlying the apparent chaos of perception. Perhaps because it was mine, my theory that the current of injury stimulated regeneration seemed both simple and beautiful. It's impossible to convey the sense of excitement I felt when all of the facts fell together and the idea came. I'd created something new that explained the previously inexplicable. I couldn't wait to see if I was right.

In all the time that the Bernstein hypothesis had been used to explain away the current of injury, no one had ever thought to measure the current over a period of days to see how long it lasted. If it was only ions leaking from damaged cells, it should disappear in a day or two, when these cells had finished dying or repairing themselves. This simple measurement, with a comparison of the currents in regenerating versus nonregenerating limbs, was what I planned to do. I would uniformly amputate the forelegs of frogs and salamanders. Then, as the frogs' stumps healed over and the salamanders' legs redrew, I would measure the currents of injury each day.

The experiment itself was as simple as could be. The tricky part was getting peremission to do it.

When you want to do a research project, there are certain channels you must go through to get the money. You write a project proposal, spelling out what hypothesis you want to test, why you think it should be done, and how you plan to go about it. The proposal goes to a committee supposedly composed of your peers, people who have demonstrated competence in related research. If they approve your project and the money is available, you generally get part of what you asked for, enough to get started.

The Veterans Administration had been dispensing research money for several years as a sort of bribe to attract doctors despite the low pay in government service. The money from Washington was doled out by the most influential doctors on the staff, not necessarily the best researchers, but I still felt I had a good chance because the VA was having an especially hard time recruiting orthopedists. Moreover, my hypothesis was based on the work of Rose, Polezhaev, Singer, Sinyukhin, and Zhirmunskii with inescapable logic. And since frogs and salamanders were anatomically similar, any difference in their currents of injury should reflect the disparity in their powers of regeneration. My chances of being thrown off by extraneous factors were thus minimal.

I remember thinking, as I wrote the proposal, how my life had come full circle. As a college freshman in 1941, I'd conducted a crude experiment on salamanders, showing that thyroid stimulation by iodine didn't speed up regeneration. Here I was nearly twenty years later, beneficiary of the intervening research, hoping to add to our knowledge of the same phenomenon and perhaps even discover something that would help human patients. I worried that my roundabout course might weigh against me, since one of the criteria for grants was whether the investigator had been trained for that particular field. This proposal would have been expected from a physiologist, not an orthopedist. Nevertheless, I was asking for a relatively minuscule amount of money. I needed only a thousand dollars to put together the equipment, so I didn't anticipate much trouble.

The Tribunal

"Dr. Becker, could you please come to a special research committee meeting in one hour?" The committee's secretary was calling. I'd known something was up, two months had passed since I'd filed my proposal, and all my queries as to its fate had gone unanswered.

"I'll be there."

"It's not here in the research office. It's downstairs in the hospital director's office." Now that was really strange. The director almost never paid any attention to the research program. Besides, his office was big enough to hold a barbecue in.

It was a barbecue, ali right, and I was the one being grilled. The director's conference room had been rearranged. In place of the long, polished table there was a semicircle of about a dozen chairs, each occupied by one of the luminaries from the hospital and medical school. I recognized the chairmen of the departments of biochemistry and physiology along with the hospital director and chief of research. Only the dean was missing. In the center was a single chair—for me.

The spokesman came right to the point: "We have a very grave basic concern over your proposal. This notion that electricity has anything to do with living things was totally discredited some time ago. It has absolutely no validity, and the new scientific evidence you're citing is worthless. The whole idea was based on its appeal to quacks and the gullible public. I will not stand idly by and see this medical school associated with such a charlatanistic, unscientific project." Murmurs of assent spread around the group.

I had the momentary thrill of imagining myself as Galileo or Giordano Bruno; I thought of walking to the window to see if the stake and fagots were set up on the lawn. Instead I delivered a terse speech to the effect that I still thought my hypothesis was stoutly supported by some very good research and that I was sorry if it flew in the face of dogma. I ended by saying that I didn't intend to withdraw the proposal, so they would have to act upon it.

When I got home, my fury was gone. I was ready to call the director, withdraw my proposal, apologize for my errors, stay out of research, quit the VA, and go into private practice, where I could make a lot more money. Luckily, my wife Lil knows me better than I sometimes know myself. She told me, "You'd be miserable in private practice. This is exactly what you want to do, so just wait and see what happens."

Two days later I got word that the committee had delegated the decision to Professor Chester Yntema, an anatomist who long ago had studied the regrowth of ears in the salamander. Since he was the only one in Syracuse who'd ever done any regeneration research, I've always wondered why he wasn't part of the first evaluation. I went to see him with a sense of foreboding, for his latest research seemed to refute Singer's nerve work, on which I'd based my proposal.

Using a standard technique, Yntema had operated on very young salamander embryos, cutting out all of the tissues that would have given

rise to the nervous system. He then grafted each of these denervated embryos onto the back of a whole one. The intact embryos furnished the grafts with blood and nourishment, and the procedure resulted in a little "parabiotic" twin, normal except for having no nerves, stuck on the back of each host animal. Yntema then cut off one leg from each of these twins, and some of them regenerated. Since microscopic examination revealed no nerves entering the graft from its host, Yntema's experiment called Singer's conclusions into question.

Dr. Yntema turned out to be one of the nicest gentlemen I've ever met, but as I entered his office his Dickensian appearance of eminence—he was tall, thin, elderly, with craggy features, and wore an immaculately starched, long white lab coat—made me feel like a freshman being called before the dean. But he put me at ease immediately.

"I've read your proposal and think it's most intriguing," he said with genuine interest.

"Do you really?" I asked. "I've been afraid you would reject it out of hand because my ideas depend on Singer's work."

"Marc Singer is a good, careful worker," Yntema replied. "I don't doubt his observations. What I've described is an exception to his findings under special circumstances."

After a long, pleasant conversation about regrowth, nerves, and research itself, he gave me his approval with a word of caution: "Don't get your hopes up about what you want to do. I don't believe for one minute that it'll work, but I think you should do it anyway. We need to encourage young researchers. Besides, it'll be fun, and maybe you'll learn something new, after all. Let me know what happens, and if you need any help, I'll be here. I'll call the people at the VA right away, so get to work. Good luck."

This was the start of a long friendship. I'm deeply indebted to Chester Yntema for his encouragement. Had he not believed that research should be fun, that you should do what you want rather than what's fashionable, my first experiment would have been impossible, and this book would never have been written.

The Reversals

First I found a good supplier of salamanders and frogs, a Tennessee game warden who ran this business in his spare time. Sometimes the shipment would contain a surprise, a small snake. I never found out whether he included them deliberately or by error. At any rate, his animals weren't

the inferior aquarium-bred stock but robust specimens collected from their natural habitats.

Next I worked out some technical problems. The most important of these was the question of where to place the electrodes. To form the circuit, two electrodes had to touch the animal. One was the "hot" or measuring electrode, which determined the polarity, positive or negative, with regard to a stationary reference electrode. A negative polarity meant there were more electrons where the measuring electrode was placed, while a positive polarity meant there were more at the reference site. A steady preponderance of negative charge at a particular location could mean there was a current flowing toward that spot, continually replenishing the accumulation of electrons. The placement of the reference electrode, therefore, was critical, lest I get the voltage right but the polarity, and hence the direction of the current, wrong. Some logical position had to be chosen and used every time. Since I postulated that the nerves were somehow related to the current, the cell bodies that sent their nerve fibers into the limb seemed like a good reference point. These cell bodies were in a section of the spinal cord called the brachial enlargement, located just headward from where the arm joined the body. In both frogs and salamanders, therefore, I put the measuring electrode directly on the cut surface of the amputation stump and the reference electrode on the skin over the brachial enlargement.

After setting up the equipment, I did some preliminary measurements on the intact animals. They all had areas of positive charge at the brachial enlargement and a negative charge of about 8 to 10 millivolts at each extremity, suggesting a flow of electrons from the head and trunk out into the limbs and, in the salamanders, the tail.

I began the actual experiment by amputating the right forelimbs, between elbow and wrist, from fourteen salamanders and fourteen grass frogs, all under anesthesia. I took no special precautions against bleeding, since blood clots formed very rapidly. The wounds had to be left open, not only because closing the skin over the salamanders' amputation sites would have stopped regeneration, but also because I was investigating a natural process. In the wild, both frogs and salamanders get injuries much like the one I was producing—both are favorite foods of the freshwater bass—and heal them without a surgeon.

Once the anesthetic wore off and the blood clot formed, I took a voltage reading from each stump. I was surprised to find that the polarity at the crump reversed to positive right after the injury. By the next day it had climbed to over 20 millivolts, the same in both frogs and salamanders.

I made measurements daily, expecting to see the salamander voltages climb above those of the frogs as the blastemas formed. It didn't work that way. The force of the current flowing from the salamanders' amputation sites rapidly dropped, while that from the frogs' stumps stayed at the original level. By the third day the salamanders showed no current at all, and their blastemas hadn't even begun to appear.

The experiment seemed a failure. I almost quit right there, but something made me keep on measuring. I guess I thought it would be good practice.

Then, between the sixth and tenth days an exciting trend emerged. The salamander potentials changed their sign again, exceeding their normal voltage and reaching a peak of more than 30 millivolts negative just when the blastemas were emerging. The frogs were still plugging away with slowly declining positive voltages. As the salamander limbs regenerated and the frog stumps healed over with skin and scar tissue, both groups of limbs gradually returned (from opposite directions) to the original baseline of 10 millivolts negative.

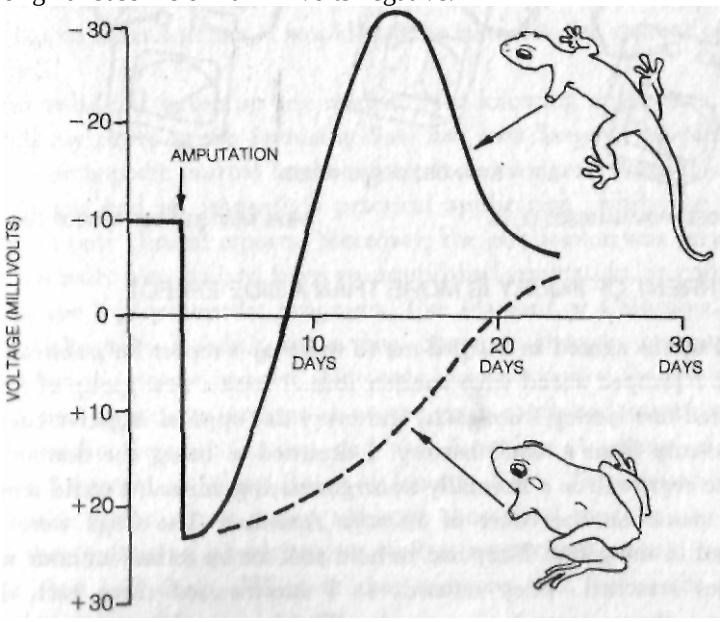

THE CURRENT OF INJURY: SALAMANDER VERSUS FROG

Here was confirmation better than my wildest dreams! Already, in my first experiment, I had the best payoff research can give—the excitement of seeing something no one else seen before. I knew now that

the current of injury wasn't due to dying cells, which were long gone by then. Moreover, the opposite polarities indicated a profound difference in the electrical properties of the two animals, which somehow would explain why only the salamander could regenerate. The negative potential seemed to bring forth the all-important blastema. It was a very significant observation, even though the facts had scrambled my neat hypothesis somewhat.

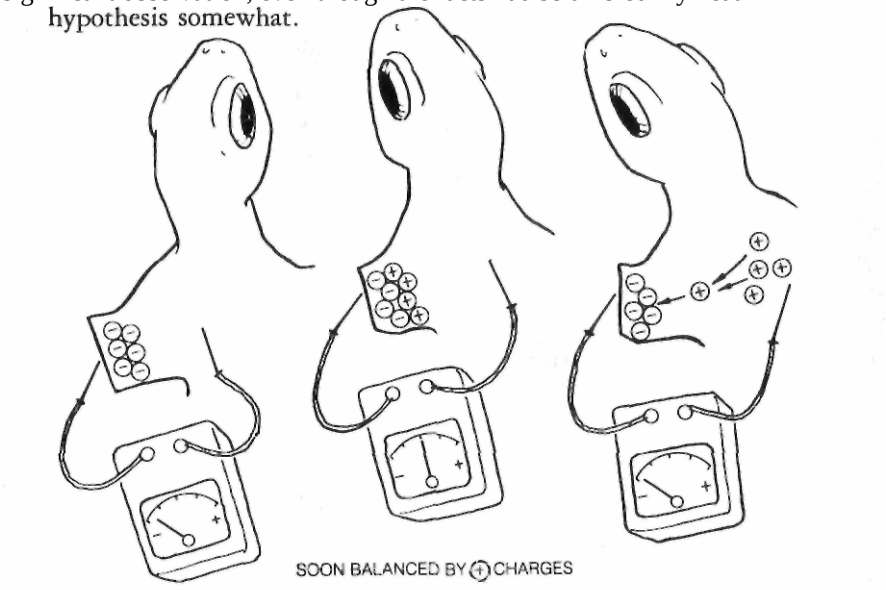

THE CURRENT OF INJURY IS MORE THAN A SIDE EFFECT

Dr. Yntema agreed and urged me to write up a report for publication, but first I jumped ahead with another idea. I took a new group of frogs, amputated one foreleg from each, and every day applied negative current to the stump from a small battery. I dreamed of being the first to get complete regrowth in a normally nonregenerating animal; I could almost see my name on the cover of Scientific American. The frogs were less interested in my glory. They had to hold still for up to half an hour with electrodes attached. They refused, so I anesthetized them each day, something they tolerated very poorly. Within a week my Nobel Prize had turned into a collection of dead frogs.

For some time I'd been scouring the dusty stacks of the medical library for previous work on bioelectricity, and how I found a paper written in 1909 by an American researcher named Owen E. Frazee. He reported that electrical currents passed through the aquarium water in

which larval salamanders were living speeded up their regeneration. At that time, electrical equipment was so primitive that I couldn't rely on Frazee's results, but I decided to try it for myself. What Sinyukhin had done with tomato plants I hoped to do with salamanders.

To one group of salamanders I applied 2 microamperes of positive current from batteries connected directly to the stumps for five to ten minutes on each of the first five days after amputation. This was 0.000002 ampere, a tiny current by ordinary standards (most household circuits carry 15 or 20 amperes) but comparable to what seemed to be flowing in the limb. I intended to reinforce the normal positive peak in the current of injury. This treatment seemed to make the blastemas larger but slowed down the whole process somewhat. To another group I applied 3 microamperes of negative current on the fifth to ninth days, when the normal currents were hitting their negative peaks. This seemed to increase the rate of regrowth for a week but didn't change the time needed for a complete limb. Finally I tried Frazee's method with a constant current through the aquarium water. Again the results were equivocal at best. These failures taught me that, before I applied my findings to other animals, I would have to learn how the current of injury worked.

Meanwhile, I wrote up my results. Not knowing any better, I submitted my paper to the Journal of Bone and Joint Surgery, the most prestigious orthopedic journal in the world. It was a dumb thing to do. The experiment had no immediate practical application, while the journal accepted only clinical reports. Moreover, the publication was very political; normally you had to have an established reputation or come from one of the big orthopedic programs, like Harvard or Columbia, to get into it. Luckily, I didn't know that. Someone thought my paper was just what the doctor ordered. Not only was it accepted for publication, but I was invited to present it at the next combined meeting of the Orthopaedic Research Society and the American Academy of Orthopaedic Surgeons, at Miami Beach in January 1961. This invitation was a particular honor, for it meant someone considered my work so significant that practicing physicians, as well as researchers, should hear of it right then and there. Whoever that someone was, he or she has my undying gratitude.

My report was well received and soon was published, to the consternation of the local inquisitors and the delight of Chester Yntema.

Since the journal was geared to clinicians. I worried that my experiment wouldn't reach the basic researchers with whom I really wanted to share it, but again I was wrong. The next year I got a phone call from Meryl

Rose himself. He was excited by the article and wanted to know what I'd done since.

Although Rose taught at Tulane Medical School in New Orleans, he spent every summer at the Woods Hole Marine Biological Laboratory on Cape Cod, so he and his wife drove to Syracuse from there. Despite his success, Rose had maintained the completely open mind that a great researcher must have, and he was fascinated by the observations on electric fields, nerves, anesthesia, and magnetism that I'll recount in the next chapter. Since then his interest has encouraged me enormously. My friendship with this fine man and scientist has been fruitful even beyond the expectations I had then, and, when my wife and I had the Roses to dinner, we found our pasts were linked by an odd coincidence. As they walked in the door, Lillian exclaimed, "Dr. Rose! Weren't you at Smith College in the 1940s?" It turned out that she'd been a friend of Rose's student lab assistant and had helped catch the frogs for the famous salt-in-the-wound experiment!

Part 2
The Stimulating Current

The basic texture of research consists of dreams into which the threads of reasoning, measurement, and calculation are woven.
—Albert Szent-Gyorgyi

Four
Life's Potentials

It's an axiom of science that the better an experiment is, the more new questions it raises after it has answered the one you asked. By that standard my first simple test had been pretty good. The new problems branched out like the fingers on those restored limbs: Where did the injury currents come from? Were they in fact related to the nervous system and, if so, how? It seemed unlikely that they sprang into action only after an amputation; they must have existed before. There must have been a preexisting substratum of direct current activity that responded to the injury. Did the voltages I measured really reflect such currents, and did they flow throughout the salamander's body? Did other organisms have them? What structures carried them? What were their electrical properties? What were they doing the rest of the time, before injury and after healing? Could they be used to provoke regeneration where it was normally absent?

I had ideas about how to look for some of the answers, but, to understand my approach, the reader unfamiliar with electrical terms will need a simplified explanation of several basic concepts that are essential to the rest of the story.

Everything electrical stems from the phenomenon of charge. No one knows exactly what this is, except to say that it's a fundamental property of matter that exists in two opposite forms, or polarities, which we arbitrarily call positive and negative. Protons, which are one of the two main types of particles in atomic nuclei, are positive; the other particles, the neutrons, are so named because rhey have no charge. Orbiting around the nucleus are electrons, in the same number as the protons

inside the nucleus. Although an electron is 1,836 times less massive than a proton, the electron carries an equal but opposite (negative) charge. Because of their lightness and their position outside the nucleus, electrons are much more easily dislodged from atoms than are protons, so they're the main carriers of electric charge. For the lay person's purposes a negative charge can be thought of as a surplus of electrons, while a positive charge can be considered a scarcity of them. When electrons move away from an area, it becomes positively charged, and the area to which they move becomes negative.

A flow of electrons is called a current, and is measured in amperes, units named for an early-nineteenth-century French physicist, Andre Marie Ampere. A direct current is a more or less even flow, as opposed to the instantaneous discharge of static electricity as sparks or lightning, or the back-and-forth flow of alternating current which powers most of our appliances.

Besides the amount of charge being moved, a current has another characteristic important for our narrative—its electromotive force. This can be visualized as the "push" behind the current, and it's measured in volts (named for Alessandro Volta).

In high school most of us learned that a current flows only when a source of electrons (negatively charged material) is connected to a material having fewer free electrons (positively charged in relation to the source) by a conductor, through which the electrons can flow. This is what happens when you connect the negative terminal of a battery to its positive pole with a wire or a radio's innards: You've completed a circuit between negative and positive. If there's no conductor, and hence no circuit, there's only a hypothetical charge flow, or electric potential, between the two areas. The force of this latent current is also measured in volts by temporarily completing the circuit with a recording device, as I did in my experiment.

The potential can continue to build until a violent burst of current equalizes the charges; this is what happens when lightning strikes. Smaller potentials may remain stable, however. In this case they must be continuously fed by a direct current flowing from positive to negative, the opposite of the normal direction. In this part of a circuit, electrons actually flow from where they're scarce to where they're more abundant. As Volta found, such a flow is generated inside a battery by the electrical interaction of two metals.

An electric field forms around any electric charge. This means that any other charged object will be attracted (if the polarities are opposite) or repelled (if they're the same) for a certain distance around the first

object. The field is the region of space in which an electrical charge can be detected, and it's measured in volts per unit of area.

Electric fields must be distinguished from magnetic fields. Like charge, magnetism is a dimly understood intrinsic property of matter that manifests itself in two polarities. Any flow of electrons sets up a combined electric and magnetic field around the current, which in turn affects other electrons nearby. Around a direct current the electromagnetic field is stable, whereas an alternating current's field collapses and reappears with its poles reversed every time the current changes direction. This reversal happens sixty times a second in our normal house currents. Just as a current produces a magnetic field, a magnetic field, when it moves in relation to a conductor, induces a current. Any varying magnetic field, like that around household appliances, generates a current in nearby conductors. The weak magnetic fields we'll be discussing are measured in gauss, units named after a nineteenth-century German pioneer in the study of magnetism, Karl Friedrich Gauss.

Both electric and magnetic fields are really just abstractions that scientists have made up to try to understand electricity's and magnetism's action at a distance, produced by no known intervening material or energy, a phenomenon that used to be considered impossible until it became undeniable. A field is represented by lines of force, another abstraction, to indicate its direction and shape. Both kinds of fields decline with distance, but their influence is technically infinite: Every time you use your toaster, the fields around it perturb charged particles in the farthest galaxies ever so slightly.

In addition, there's a whole universe full of electromagnetic energy, radiation that somehow seems to be both waves in an electromagnetic field and particles at the same time. It exists in a spectrum of wavelengths that includes cosmic rays, gamma rays, X rays, ultraviolet radiation, visible light, infrared radiation, microwaves, and radio waves. Together, electromagnetic fields and energies interact in many complex ways that have given rise to much of the natural world, not to mention the whole technology of electronics.

You'll need a casual acquaintance with all these terms for the story ahead, but don't worry if the concepts seem a bit murky. Physicists have been trying for generations to solve the fundamental mysteries of electromagnetism, and no one, not even Einstein, has yet succeeded.

Unpopular Science

None of these things had the slightest relevance to life, according to most biologists around 1960. A major evaluation of American medicine, financed by the Carnegie Foundation and published in 1910 by the respected educator Abraham Flexner, had denounced the clinical use of electric shocks and currents, which had been applied, often overenthusiastically, to many diseases since the mid-1700s. Electrotherapy sometimes seemed to work, but no one knew why, and it had gotten a bad name from the many charlatans who'd exploited it. Its legitimate proponents had no scientific way to defend it, so the reforms in medical education that followed the Flexner report drove all mention of it from the classroom and clinic, just as the last remnants of belief in vital electricity were being purged from biology by the discovery of acetylcholine. This development dovetailed nicely with expanding knowledge of biochemistry and growing reliance on the drug industry's products. Penicillin later made medicine almost exclusively drug oriented.

Meanwhile, the work of Faraday, Edison, Marconi, and others literally electrified the world. As the uses of electricity multiplied, no one found any obvious effects on living creatures except for the shock and heating caused by large currents. To be sure, no one looked very hard, for fear of discouraging a growth industry, but the magic of electricity seemed to lie precisely in the way it worked its wonders unseen and unfelt by the folks clustered around the radio or playing cards under the light bulb. By the 1920s, no scientist intent on a respectable career dared suggest that life was in any sense electrical.

Nevertheless, some researchers kept coming up with observations that didn't fit the prevailing view. Although their work was mostly consigned to the fringes of the scientific community, by the late 1950s they'd accumulated quite a bit of evidence.

There were two groups of dissenters, but, because their work went unheeded, each was largely unaware of the other's existence. One line of inquiry began just after the turn of the century when it was learned that hydras were electrically polarized. The head was found to be positive, the tail negative. I've already mentioned Frazee's 1909 report of salamander regeneration enhanced by electrical currents. Then, with a classic series of experiments in the early 1920s, Elmer J. Lund of the University of Texas found that the polarity of regeneration in species related to the hydra could be controlled, even reversed, by small direct currents passes through the animal's body. A current strong enough to

override the creature's normal polarity could cause a head to form where a tail should have reappeared, and vice versa. Others confirmed this discovery, and Lund went on to study eggs and embryos. He claimed to have influenced the development of frog eggs not only with currents but also with magnetic fields, a conclusion that was really risque for that time.

Stimulated by Lund's papers, Harold Saxton Burr of Yale began putting electrodes to all kinds of creatures. Burr was lucky enough to have a forum for his work. He edited the Yale Journal of Biology and Medicine, where most of his reports appeared; few other journals would touch them. Burr and his co-workers found electric fields around, and electric potentials on the surfaces of, organisms as diverse as worms, hydras, salamanders, humans, other mammals, and even slime molds. They measured changes in these potentials and correlated them to growth, regeneration, tumor formation, drug effects, hypnosis, and sleep. Burr claimed to have measured field changes resulting from ovulation, but others got contradictory results. He hooked up his voltmeters to trees for years at a time and found that their fields varied in response not only to light and moisture, but to storms, sunspots, and the phases of the moon as well.

Burr and Lund were handicapped by their instruments as well as the research climate. Most of their work was done before World War II and, even though Burr spent years designing the most sensitive devices possible using vacuum tubes, the meters were still too "noisy" to reliably measure the tiny currents found in living things. The two scientists could refine their observations only enough to find a simple dipolar distribution of potentials, the head of most animals being negative and the tail positive.

Burr and Lund advanced similar theories of an electrodynamic field, called by Burr the field of life or L-field, which held the shape of an organism just as a mold determines the shape of a gelatin dessert. "When we meet a friend we have not seen for six months there is not one molecule in his face which was there when we last saw him," Burr wrote. "But, thanks to his controlling L-field, the new molecules have fallen into the old, familiar pattern and we can recognize his face."

Burr believed that faults in the field could reveal latent illness just as dents in a mold show up in the jelly. He claimed to be able to predict all sorts of things about a person's emotional and physical health, both present and future, merely by checking the voltage between head and hand. His later writings were marred by a son of bioelectric determinism and a tendency to confuse "law and order" in nature with that

odious euphemism as preached by Presidents. As a result, he began to suggest his simple readings as a foolproof way to evaluate job applicants, soldiers, mental patients, and suspected criminals or dissidents.

The fields Burr and Lund found were actually far too simple to account for a salamander's limb or a human face. Biological knowledge at that time gave them no theoretical framework to explain where their fields came from. They conceived of currents flowing within cells but had no proof. They had no inkling that currents might flow in specific tissues or in the fluids outside cells. They suggested that all these little intracellular currents somehow added up to the whole field. Burr wrote that "electrical energy is a fundamental attribute of protoplasm and is an expression or measure of the presence of an electrodynamic field in the organism." Unfortunately, an analysis of this sentence yields nonsense, and Burr's work was dismissed as foggy vitalism. Lund suffered the same fate. No one bothered to see if the measurements they'd made were valid. After all, you can disagree with a theory, but you should respect the data enough to check them. If you can't duplicate them, you're entitled to rest easy with your own concepts, but if you get the same results, you're obligated to agree or propose an alternate theory. Most scientists took the easy way out, however, and simply ignored Burr and Lund. Their discoveries remained little known, and most biologists didn't connect them with the tentative morphogenetic-field concept of regeneration.

Then in 1952 Lund's work was taken up by G. Marsh and H. W. Beams using the planarian. They found that the flatworm's polarity, like the hydra's, could be controlled by passing a current through it. When a direct current was fed in the proper direction through a section of a worm, normal polarity disappeared and a head formed at each end. As the current strength was increased, the section's polarity reversed; a head regrew at the rear, a tail at the front. At higher voltages, even intact worms completely reorganized, with the head becoming a tail and vice versa. Marsh and Beams grew convinced that the animal's electric field was the morphogenetic organizing principle. Still, their work was also ignored, except by Meryl Rose, who suggested that a gradation of electrical charge from front to back controlled the gradient of growth inhibitors and stimulators. He suggested that the growth compounds were charged molecules that were moved to different places in the body by the electric field, depending on the amount and sign of their charge and their molecular weight.

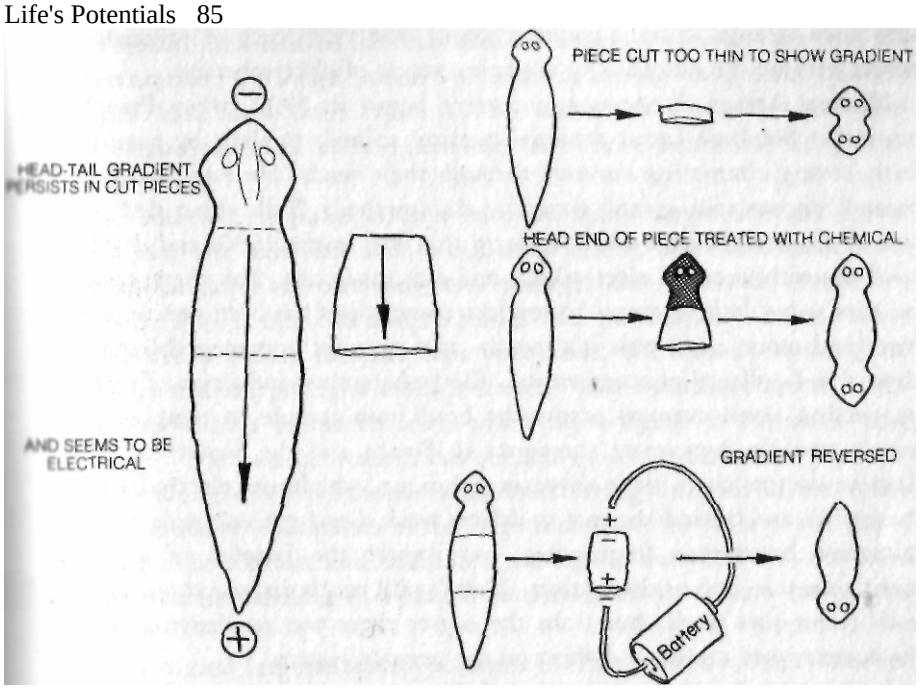

MARSH AND BEAMS'S EXPERIMENT

Undercurrents in Neurology

While the investigation of the total body field moved haltingly forward in the study of simple animals, several neurophysiologists began finding out odd things about the nerves of more complex creatures, data that Bernstein's action potential couldn't explain. Going through the old literature, following lead after lead from one paper to the next, I found many hints that there were DC potentials in the nervous system and that small currents from outside could affect brain function.

The first recorded use of currents on the nervous system was by Giovanni Aldini, a nephew of Galvani and an ardent champion of vitalism. Using the batteries of his archenemy Volta, Aldini claimed remarkable success in relieving asthma. He also cured a man who today would probably be diagnosed as schizophrenic, although it's impossible to know how much benefit came from the currents and how much from simple solicitude, then so rare in treating mental illness. Aldini gave his patient a room in his own house and later found him a job. Some of Aldini's experiments were grotesque - he tried to resurrect recently executed criminals by making the corpses twitch with electricity - but his

idea that external current could replenish the vital force of exhausted nerves became the rationale for a whole century of electrotherapy.

Modern studies of nerves and current began in 1902, when French researcher Stephane Leduc reported putting animals to sleep by passing fairly strong alternating currents through their heads. He even knocked himself unconscious several times by this method. (Talk about dedication to science!) Several others took up this lead in the 1930s and developed the techniques of electroshock and electronarcosis. The therapeutic value of using large currents to produce convulsions has been questioned more and more, until now it's mostly used to quiet unmanageable psychotics and political nonconformists. Electronarcosis—induction of sleep by passing small currents across the head from temple to temple—is widely used by legitimate therapists in France and the Soviet Union. Russian doctors claim their elektroson technique, which uses electrodes on the eyelids and behind the ears to deliver weak direct currents pulsing at calmative brain-wave frequencies, can impart the benefits of a full night's sleep in two or three hours. There's still much dispute about how both techniques work, but from the outset there was no denying that the currents had a profound effect on the nervous system.

In the second and third decades of this century there was a flurry of interest in galvanotaxis, the idea that direct currents guided the growth of cells, especially neurons. In 1920, S. Ingvar found that the fibers growing out of nerve cell bodies would align themselves with a nearby flow of current and that the fibers growing toward the negative electrode were different from those growing toward the positive one. Paul Weiss soon "explained" this heretical observation as an artifact caused by stretching of the cell culture substrate due to contact with the electrodes. Even after Marsh and Beams proved Weiss wrong in 1946, it took many more years for the scientific community to accept the fact that neuron fibers do orient themselves along a current flow. Today the possible use of electricity to guide nerve growth is one of the most exciting prospects in regeneration research (see Chapter 11).

The Bernstein hypothesis, unable to account for these facts, has turned out to be deficient in several other respects. To begin with, according to the theory, an impulse should travel with equal ease in either direction along the nerve fiber. If the nerve is stimulated in the middle, an impulse should travel in both directions to opposite ends. Instead, impulses travel only in one direction; in experiments they can be made to travel "upstream," but only with great difficulty. This may not seem like such a big deal, but it is very significant. Something seems to polarize the nerve.

Another problem is the fact that, although nerves are essential for regeneration, the action potentials are silent during the process. No impulses have ever been found to be related to regrowth, and neurotransmitters such as acetylcholine have been ruled out as growth stimulators.

In addition, impulses always have the same magnitude and speed. This may not seem like such a big thing either, but think about it. It means the nerve can carry only one message, like the digital computer's 1 or 0. This is okay for simple things like the knee-jerk reflex. When the doctor's rubber hammer taps your knee, it's actually striking the patellar tendon, giving it a quick stretch. This stimulates stretch receptors (nerve cells in the tendon), which fire a signal to the spinal cord saying, "The patellar tendon has suddenly been stretched." These impulses are received by motor (muscle-activating) neurons in the spinal cord, which send impulses to the large muscle on the front of the thigh, telling it to contract and straighten the leg. In everyday life, the reflex keeps you from falling in a heap if an outside force suddenly bends your knees.

The digital impulse system accounts for this perfectly well. However, no one can walk on reflexes alone, as victims of cerebral palsy know all too well. The motor activities we take for granted—getting out of a chair and walking across a room, picking up a cup and drinking coffee, and so on—require integration of all the muscles and sensory organs working smoothly together to produce coordinated movements that we don't even have to think about. No one has ever explained how the simple code of impulses can do all that. Even more troublesome are the higher processes, such as sight—in which somehow we interpret a constantly changing scene made of innumerable bits of visual data—or the speech patterns, symbol recognition, and grammar of our languages. Heading the list of riddles is the "mind-brain problem" of consciousness, with its recognition, "I am real; I think; I am something special." Then there are abstract thought, memory, personality, creativity, and dreams. The story goes that Otto Loewi had wrestled with the problem of the synapse for a long time without result, when one night he had a dream in which the entire frog-heart experiment was revealed to him. When he awoke, he knew he'd had the dream, but he'd forgotten the details. The next night he had the same dream. This time he remembered the procedure, went to his lab in the morning, did the experiment, and solved the problem. The inspiration that seemed to banish neural electricity forever can't be explained by the theory it supported! How do you convert simple digital messages into these complex

phenomena? Latter-day mechanists have simply postulated brain circuitry so intricate that we will probably never figure it out, but some scientists have said there must be other factors.

Even as Loewi was finishing his work on acetylcholine, others began to find evidence that currents flowed in the nerves. English physiologist Richard Caton had already claimed he'd detected an electric field around the heads of animals in 1875, but it wasn't until 1924 that German psychiatrist Hans Berger proved it by recording the first electroencephalogram (EEG) from platinum wires he inserted into his son's scalp. The EEG provided a record of rhythmic fluctuations in potential voltage over various parts of the head. Berger at first thought there was only one wave from the whole brain, but it soon became clear that the waves differed, depending on where the electrodes were put. Modern EEGs use as many as thirty-two separate channels, all over the head.

The frequency of these brain waves has been crudely correlated with states of consciousness. Delta waves (0.5 to 3 cycles per second) indicate deep sleep. Theta waves (4 to 8 cycles per second) indicate trance, drowsiness, or light sleep. Alpha waves (8 to 14 cycles per second) appear during relaxed wakefulness or meditation. And beta waves (14 to 35 cycles per second), the most uneven forms, accompany all the modulations of our active everyday consciousness. Underlying these rhythms are potentials that vary much more slowly, over periods as long as several minutes. Today's EEG machines are designed to filter them out because they cause the trace to wander and are considered insignificant anyway.

There's still no consensus as to where the EEG voltages come from. They would be most easily explained by direct currents, both steady state and pulsing, throughout the brain, but that has been impossible for most biologists to accept. The main alternative theory, that large numbers of neurons firing simultaneously can mimic real electrical activity, has never been proven.

In 1939, W. E. Burge of the University of Illinois found that the voltage measured between the head and other parts of the body became more negative during physical activity, declined in sleep, and reversed to positive under general anesthesia. At about the same time a group of physiologists and neurologists at Harvard Medical School began studying the brain with a group of MIT mathematicians. This association was destined to change the world. From it came many of our modern concepts of cybernetics, and it became the nucleus of the main American task force on computers in World War II. One of the group's first important ideas was that the brain worked by a combination of analog and digital coding.

One of the mathematicians, computer pioneer John von Neumann, later elaborated the concept in great detail, but basically it's rather simple. In analog computers, changes in information are expressed by analogous changes in the magnitude or polarity of a current. For example, if the computer is to use and store the varying temperatures of a furnace, the rise and fall in heat can be mimicked by a rise and fall in voltage. Analog systems are slow and can handle only simple information, but they can express subtle variations very well. Digital coding, on the other hand, can transmit enormous amounts of data at high speed, but only if the information can be reduced to yes-no, on-off bits—the digits 1 and 0. If the brain was such a hybrid computer, these early cyberneticists reasoned, then analog coding could control the overall activity of large groups of neurons by such actions as increasing or decreasing their sensitivity to incoming messages. (A few years later neurologists did find that some neurons were "tuned" to fire only if they received a certain number of impulses.) The digital system would transfer sensory and motor information, but the processing of that information—memory and recall, thought, and so on—would be accomplished by the synergism of both methods. The voltage changes Burge found in response to major alterations of consciousness seemed to fit within this framework, and his observations were extended by the Harvard-MIT group and others. Much of this work was done directly on the exposed brains of animals and of human patients during surgery. When cooperative patients elected to remain awake during such operations (the brain is immune to pain), human sensations could often be correlated with electrical data. Contributors to this endeavor included nearly all of the greatest American neurophysiologists—Walter B. Cannon, Arturo Rosenblueth, Ralph Gerard, Gilbert Ling, Wilder Penfield, and others.

Measurements on the exposed brain quickly confirmed the existence of potential voltages and also revealed possible currents of injury. Whenever groups of nerve cells were actively conducting impulses, they also produced a negative potential. Positive potentials appeared from injured cells when the brain had been damaged; these potentials then expanded outward to uninjured cells, suppressing their ability to send or receive impulses. When experimenters applied small negative voltages to groups of neurons, their sensitivity increased; that is, they would generate an impulse in response to a weaker stimulus. Externally applied positive potentials worked in the opposite way: They depressed nerve function, making it harder to produce an impulse. Thus there did seem to be an analog code, but how did it work? Did the potentials come from direct currents generated by the nerve cells themselves, or did they merely

result from adding up a lot of action potentials all going in the same direction and arriving in the same place at the same time?
Some answers were provided by a series of beautiful experiments by Ling, Gerard, and Benjamin Libet at the University of Chicago. Working on frogs, they studied areas of the cortex where the neuron layer was only one cell thick and the cells were arranged side by side like soldiers on review, all pointing in the same direction. In such areas they found a negative potential on the dendrites (the short incoming fibers) and a positive potential at the ends of the axons (the longer outgoing fibers). This indicated a steady direct current along the normal direction of impulse transmission. The entire nerve cell was electrically polarized.

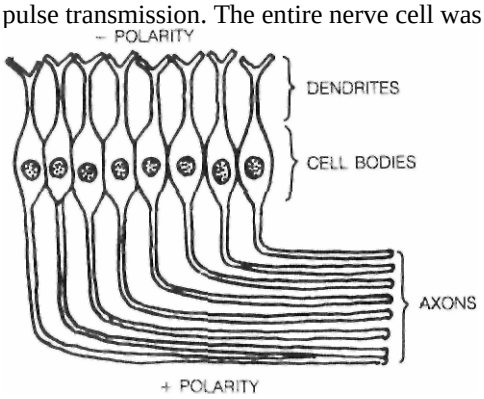

POLARIZED NERVE CELLS LINED UP IN CEREBRAL CORTEX

In another series of experiments, on brains removed from frogs and kept alive in culture, the Chicago group found that direct currents swept across the surface of the cortex in very slow waves, which could be produced experimentally by applying chemicals such as caffeine to a single spot on the surface. When they made a cut on the brain, severing groups of nerve fibers, these DC traveling waves would still cross the cut if the two surfaces were in direct contact. If the researchers held the cut open and filled it with a saline solution that matched body fluids, then the waves couldn't cross the gap. These were particularly important observations. They indicated that the current was transmitted by structures outside the neurons; it crossed the cut when the edges touched, but the microscopic parts of the severed neurons wouldn't have rejoined so easily. The results also showed that the current was not a flow of ions; otherwise it would have been able to cross the gap through the salt water.
Studying intact brains in living frogs, the lame group found a potential between the front and back of the brain. The olfactory (frontal) lobes were several milivolts negative with respect to the occipital (rear) lobe,

implying a current flowing up the brain stem and between the two hemispheres to the front.

At the time, these observations seemed mighty odd. They didn't fit any concepts of how the nerves worked. As a result, they were largely ignored. The majority of neurophysiologists went on measuring the action potentials and tracing out fiber pathways in the brain. This was useful work but limited. The basic questions remained.

Only one research team followed up this work, some ten years later. Sidney Goldring and James L. O'Leary, neuropsychiatrists at the Washington University School of Medicine in St. Louis, recorded the same DC potentials from the human scalp, from the exposed brain during surgery, and from the brains of monkeys and rabbits. As noted before, the potentials varied in regular cycles several minutes long, like a basso continuo under the EEG. In fact, Goldring and O'Leary found waves within waves: "Written upon the slow major swings were lesser voltage changes." These were weak potentials, measured in microvolts (millionths of a volt) and varying in waves of 2 to 30 cycles per minute, sort of a pianissimo "inner voice" in a three-part electrical fugue.

Conducting in a New Mode

I was acutely aware that I didn't have the "proper" background for the work I planned to do. I wasn't a professional neurophysiologist; I didn't even know one. Indeed, after my run-in with the research committee, one member had taken me aside and earnestly advised me, "Go back to school and get your Ph.D., Becker. Then you'll learn all of this stuff is nonsense." Still, some of the greatest neurophysiologists had thought the same way I did about "all of this stuff." They suggested we might have been too hasty in throwing electric currents out of biology. My notion of putting them back in wasn't so outlandish, but only an extension of what they'd been saying. I was approaching the body's system of information transfer from the periphery, asking, "What makes wounds heal?" They'd started from the center, asking, "How does the brain work?" We were working on the same problem from opposite ends. As I contemplated their findings and all of biology's unsolved problems, I grew convinced that life was more complex than we suspected. I felt that those who reduced life to a mechanical interaction of molecules were living in a cold, gray, dead world, which, despite its drabness, was a fantasy. I didn't think electricity would turn to be any elan vital in the old sense, but I had a hunch would be closer to the secret than the

smells of the biochemistry lab or the dissecting room's preserved organs.

I had another worthy ally when I started to reevaluate the role of electricity in life. Albert Szent-Gyorgyi, who'd already won a Nobel Prize for his work on oxidation and vitamin C, made a stunning suggestion in a speech before the Budapest Academy of Science on March 21, 1941. (Think of the date. World War II was literally exploding around him, and there he was, calmly laying the foundations for a new biology.) Speaking of the mechanistic approach of biochemistry, he pointed out that when experimenters broke living things down into their constituent parts, somewhere along the line life slipped through their fingers and they found themselves working with dead matter. He said, "It looks as if some basic fact about life were still missing, without which any real understanding is impossible." For the missing basic fact, Szent-Gyorgyi proposed putting electricity back into living things, but not in the way it had been thought of at the turn of the century.

At that earlier time, there had been only two known modes of current conduction, ionic and metallic. Metallic conduction can be visualized as a cloud of electrons moving along the surface of metal, usually a wire. It can be automatically excluded from living creatures because no one has ever found any wires in them. Ionic current is conducted in solutions by the movement of ions—atoms or molecules charged by having more or fewer than the number of electrons needed to balance their protons' positive charges. Since ions are much bigger than electrons, they move more laboriously through the conducting medium, and ionic currents die out after short distances. They work fine across the thin membrane of the nerve fiber, but it would be impossible to sustain an ionic current down the length of even the shortest nerve.

Semiconduction, the third kind of current, was a laboratory curiosity in the 1930s. Halfway between conductors and insulators, the semiconductors are inefficient, in the sense that they can carry only small currents, but they can conduct their currents readily over long distances. Without them, modern computers, satellites, and all the rest of our solid-state electronics would be impossible.

Semiconduction occurs only in materials having an orderly molecular structure, such as crystals, in which electrons can move easily from the electron cloud around one atomic nucleus to the cloud around another. The atoms in a crystal are arranged in neat geometrieal lattices, rather than the frozen jumble of ordinary solids. Some crystalline materials have spaces in the lattice where other atoms can fit. The atoms of these impurities may have more or fewer electrons than the atoms of the lattice material. Since the forces of the latticework structure hold the same

number of electrons in place around each atom, the "extra" electrons of the impurity atoms are free to move through the lattice without being bound to any particular atom. If the impurity atoms have fewer electrons than the others, the "holes" in their electron clouds can be filled by electrons from other atoms, leaving holes elsewhere. A negative current, or N-type semiconduction, amounts to the movement of excess electrons; a positive current, or P-type semiconduction, is the movement of these holes, which can be thought of as positive charges.

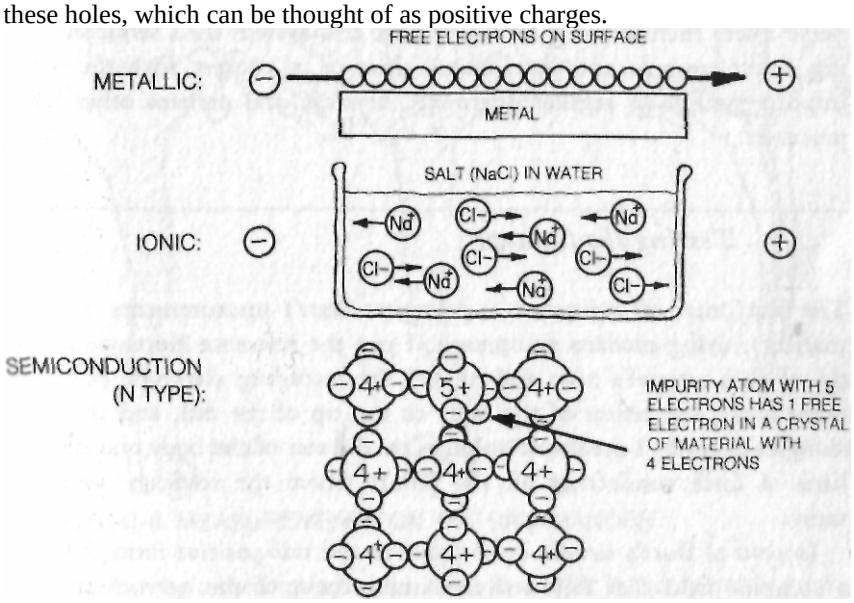

THREE WAYS OF CONDUCTING ELECTRICAL CURRENT

Szent-Gyorgyi pointed out that the molecular structure of many parts of the cell was regular enough to support semiconduction. This idea was almost completely ignored at the time. Even when Szent-Gyorgyi expanded the concept in his I960 Introduction to a Submolecular Biology, most scientists (except in Russia!) dismissed it as evidence of his advancing age, but that little book was an inspiration to me. I think it may turn out to be the man's most important contribution to science. In it he conjectured that protein molecules, each having a sort of slot or way station for mobile electrons, might be joined together in long chains so that electrons could flow in a semiconducting current over long distances without losing energy, much as in a game of checkers one counter could jump along a row of other pieces across the entire board. Szent-Gyorgyi suggested that the electron flow would be smilar to photosynthesis, another process he helped elucidate, in which a kind of waterfall of elec-

trons cascaded step by step down a staircase of molecules, losing energy with each bounce. The main difference was that in protein semiconduction the electrons' energy would be conserved and passed along as information instead of being absorbed and stored in the chemical bonds of food.

With Szent-Gyorgyi's suggestion in mind, I put together my working hypothesis. I postulated a primitive, analog-coded information system that was closely related to the nerves but not necessarily located in the nerve fibers themselves. I theorized that this system used semiconducting direct currents and that, either alone or in concert with the nerve impulse system, it regulated growth, healing, and perhaps other basic processes.

Testing the Concept

The first order of business was to repeat Burr's measurements on salamanders, using modern equipment. I put the reference electrode at the tip of each animal's nose and moved the recording electrode point by point along the center of the body to the tip of the tail, and then out along each limb. I measured voltages on the rest of the body and plotted lines of force connecting all the points where the readings were the same.

Instead of Burr's simple head-negative and tail-positive form, I found a complex field that followed the arrangement of the nervous system. There were large positive potentials over each lobe of the brain, and slightly smaller ones over the brachial and lumbar nerve ganglia between each pair of limbs. The readings grew increasingly negative as I moved away from these collections of nerve cell bodies; the hands, feet, and tip of the tail had the highest negative potentials.

In another series of measurements, I watched the potentials develop along with the nervous system in larval salamanders. In the adults, cutting the nerves where they entered the legs—that is, severing the long nerve fibers from their cell bodies in the spinal cord—wiped out the limb potentials almost entirely. But if I cut the spinal cord, leaving the peripheral nerves connected to their cell bodies, the limb potentials didn't change. It certainly looked as though there was a current being generated in the nerve cell bodies and traveling down the fibers.

To have a current flow you need a circuit; the current has to be made at one spot, pass through a conductor, and eventually get back to the generator. We tend to forget that the 60-cycle alternating current in the

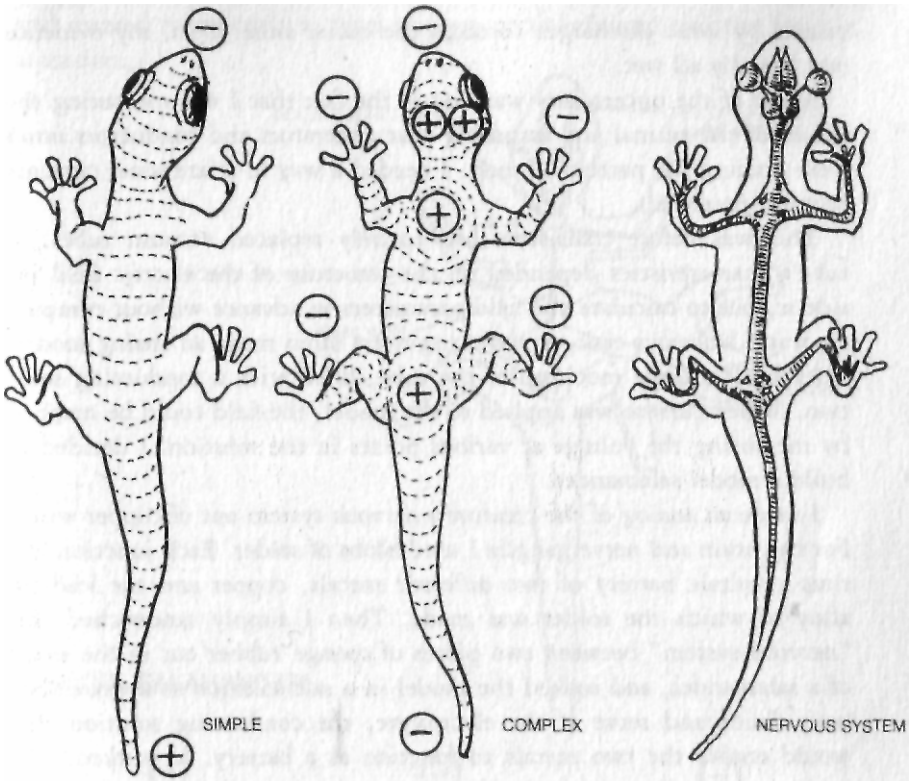

ELECTRICAL MEASUREMENTS ON THE SALAMANDER

wall socket isn't used up when we turn on a light but is merely coursing through it to the ground, through which it eventually returns to the power station. Since my measurements were positive over collections of nerve cell bodies, and increasingly negative out along the nerve fibers, it seemed a good bet that current was being generated in the cell bodies, especially since they contained all of the "good stuff"—the nucleus, organelles, and metabolic components—while the fibers were relatively uninteresting prolongations of the body. At the time, I supposed the circuit was completed by current going back toward the spine through the muscles.

This was a good start, but it wasn't scientifically acceptable proof. For one thing, my guess about the return part of the circuit was soon disproved when I measured the limb muscles and found them polarized in the same direction as the surface potentials. For another thing, it had recently been discovered that amphibian skin itself was polarized, inside versus outside, by ion differences much like the nerve membrane's resting potential, so it was just barely possible that my readings had been

caused by ionic discharges through the moist skin. If so, my evidence was literally all wet.

Much of the uncertainty was due to the fact that I was measuring the outside of the animal and assuming that generators and conductors inside were making the pattern I found. I needed a way to relate inner currents to outer potentials.

This was before transistors had entirely replaced vacuum tubes. A tube's characteristics depended on the structure of the electric field inside it, but to calculate the field parameters in advance without computers was a laborious task, so radio engineers often made an analog model. They built a large mock-up of the tube, filled with a conducting solution. When current was applied to the model, the field could be mapped by measuring the voltage at various points in the solution. I decided to build a model salamander.

I made an analog of the creature's nervous system out of copper wires. For the brain and nerve ganglia I used blobs of solder. Each junction was thus a voltaic battery of two different metals, copper and the lead-tin alloy of which the solder was made. Then I simply sandwiched this "nervous system" between two pieces of sponge rubber cut in the shape of a salamander, and soaked the model in a salt solution to approximate body fluids and serve as the electrolyte, the conducting solution that would enable the two metals to function as a battery. It worked. The readings were almost exactly the same as in the real salamander. This showed that a direct current inside could produce the potentials I was getting on the outside.

If my proposed system was really a primitive part of the nervous system, it should be widely distributed, so next I surveyed the whole animal kingdom. I tested flatworms, earthworms, fish, amphibians, reptiles, mammals, and humans. In each species the potentials on the skin reflected the arrangement of the nervous system. In the worms and fish, there was only one area of positive potential, just as there was only one major nerve ganglion, the brain. In humans the entire head and spinal region, with its massive concentration of neurons, was strongly positive. The three specific areas of greatest positive potential were the same as in the salamander: the brain, the brachial plexus between the shoulder blades, and the lumbar enlargement at the base of the spinal cord. In all vertebrates I also recorded a midline head potential that suggested a direct current like that postulated by Gerard, flowing from back to front through the middle of the brain. It looked as though the current came from the reticular activating system, a network of cross-linked neurons that fanned out from the brainstem into higher centers

and seemed to control the level of sleep or wakefulness and the focus of attention.

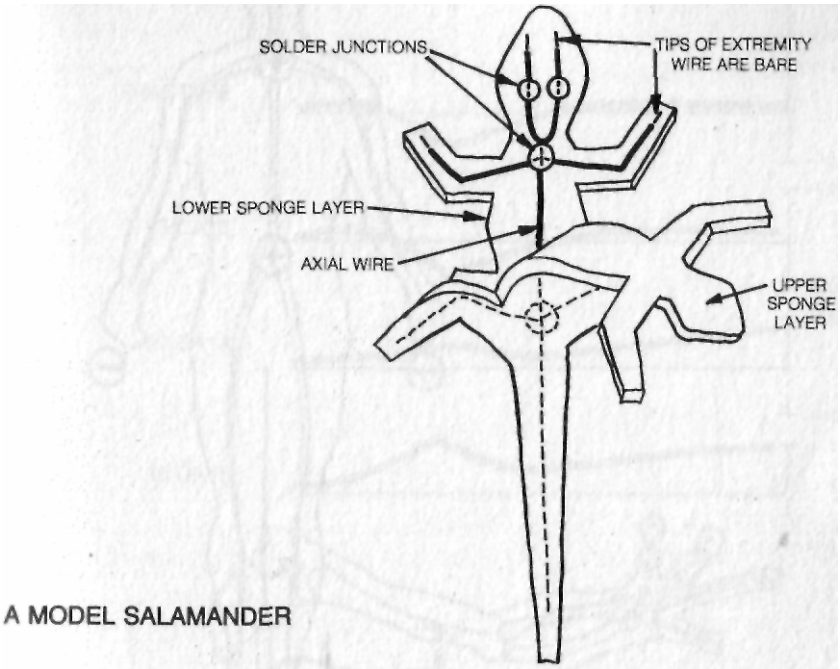

A MODEL SALAMANDER

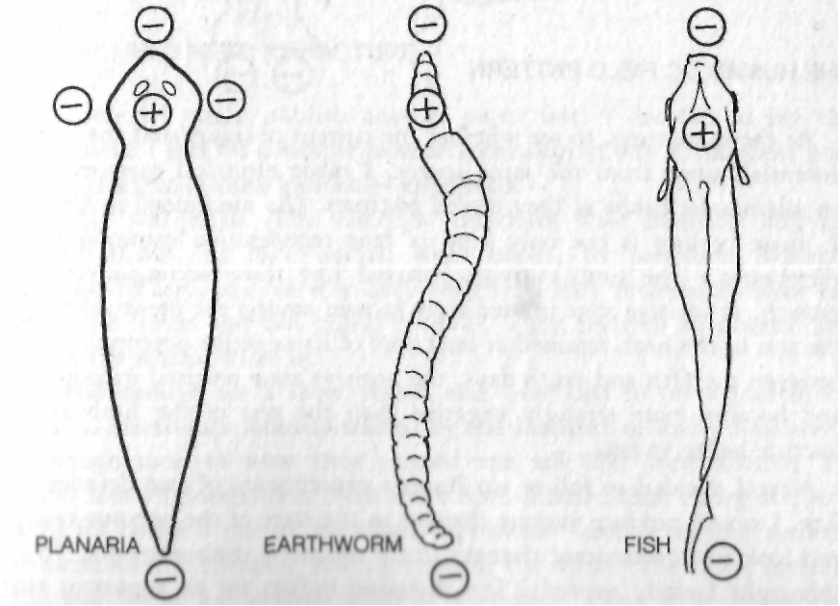

A DC FIELD PATTERN APPEARS IN ALL ANIMALS

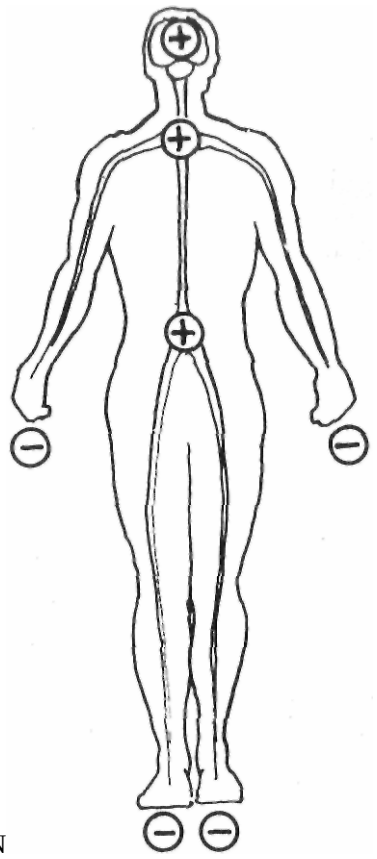

THE HUMAN DC FIELD PATTERN

At the same time, to see whether the current of injury and the surface potentials came from the same source, I made electrical measurements on salamander limbs as they healed fractures. (As mentioned in Chapter 1, bone healing is the only kind of true regeneration common to all vertebrates.) The limb currents behaved like those accompanying regrowth. A positive zone immediately formed around the break, although the rest of the limb retained at least part of its negative potential. Then, between the fifth and tenth days, the positive zone reversed its potential and became more strongly negative than the rest of the limb as the fracture began to heal.

Next I decided to follow up Burge's experiments of two decades before. I would produce various changes in the state of the nervous system and look for concomitant changes in the electrical measurements. To do this right I really needed a few thousand dollars for an apparatus that could take readings from several electrodes simultaneously and record them side by side on a chart. My chances of getting this money seemed

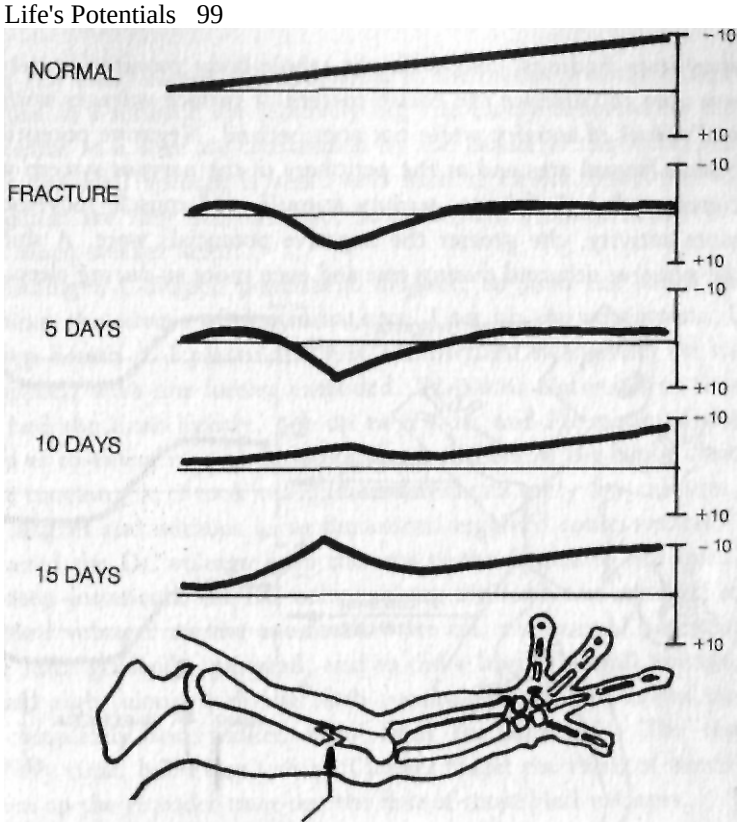

THE DC FIELD NEAR A FRACTURE

slim unless I could publish another paper fast. I decided to use the equipment I had for a simple measurement during one of the most profound changes in consciousness—anesthesia.

Burge was right. The electrical responses were dramatic and incontrovertible. As each animal went under, its peripheral voltages dropped to zero, and in very deep anesthesia they reversed to some extent, the limbs and tail going positive. They reverted to normal just before the animal woke up.

I had enough for a short paper, and I decided to try a journal on medical electronics recently started by the Institute of Radio Engineers. Although most of what they printed was safe and unremarkable, I'd found that engineers were often more open-minded than biologists, so I went for broke; I put in the whole hypothesis—analog nervous system, semiconducting currents, healing control, the works. The editor loved it and sent me an enthusiastic letter of acceptance, along with suggestions for further research. Best of all, I soon got another small grant approved and bought my multi-electrode chart recorder. Soon I had confirmed my

anesthesia findings, and with the whole-body monitoring setup I also was able to correlate the entire pattern of surface voltages with the animal's level of activity while not anesthetized. Negative potentials in the brain's frontal area and at the periphery of the nervous system were associated with wakefulness, sensory stimuli, and muscle movements. The more activity, the greater the negative potentials were. A shift toward the positive occurred during rest and even more so during sleep. *

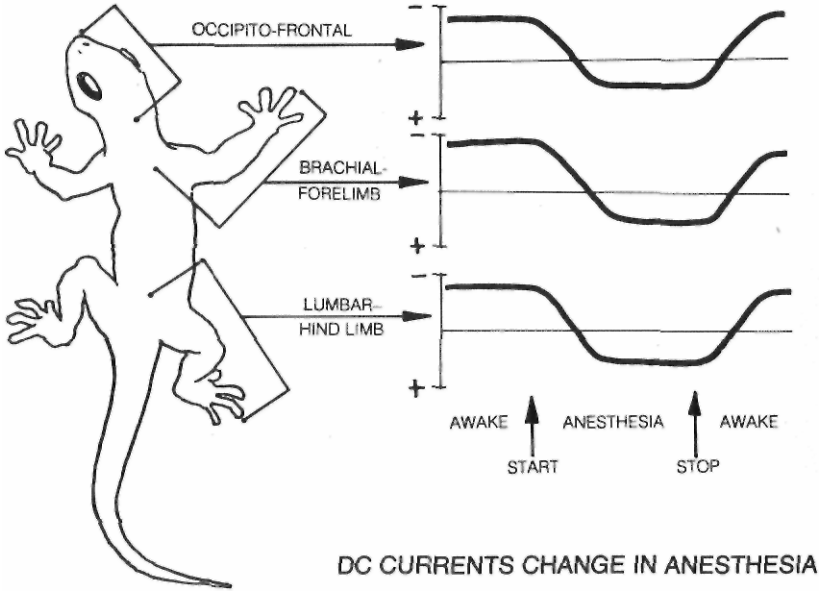

DC CURRENTS CHANGE IN ANESTHESIA

In my reading on solid-state electronics I found another way I could test for current in the salamander. Luckily it was cheap and easy; I could do it without buying more equipment. Best of all, it should work only if the current was semiconducting.

Suppose you think you have a current flowing through some conductor—a salamander's limb, for instance. You put it in a strong magnetic field so that the lines of force cut across the conductor at right angles. Then you place another conductor, containing no current, perpendicular to both the original conductor (the limb) and the magnetic field. If there is a current in whatever you're testing, some of the charge carriers will be deflected by the magnetic field into the other conductor, producing a voltage that you can measure. This is called the Hall voltage, after the gentleman who discovered it. The beauty of it is that it works differently for the three kinds of current. For any given strength of mag-

*l didn't know it until later, but another experimenter named H. Caspers made similar findings at about the same time.

netic field, the Hall voltage is proportional to the mobility of the charge carriers. Ions in a solution are relatively big and barely deflected by the field. Electrons in a wire are constrained by the nature of the metal. In both cases the Hall voltage is small and hard to detect. Electrons in semiconductors are very free to move, however, and produce Hall voltages with much weaker fields.

After finding a C-shaped permanent magnet, an item not much in demand since the advent of electromagnets, I set up the equipment. I took a deep breath as I placed the first anesthetized salamander on its plastic support, with one foreleg extended. I'd placed electrodes so that they touched the limb lightly, one on each side, and I'd mounted the magnet so as to swing in with its poles above and below the limb, close to yet not touching it. I took voltage measurements every few minutes, with the magnet and without it, as the animal regained consciousness. I also measured the DC voltage from the tips of the fingers to the spinal cord. In deep anesthesia, the DC voltage along the limb was zero and so was the Hall voltage. As the anesthetic wore off, the normal potential along the limb gradually appeared, and so did a beautiful Hall voltage. It increased right along with the limb potential, until the animal recovered completely and walked away from the apparatus. The test worked every time, but I don't think I'll ever forget the thrill of watching the pen on the recorder trace out the first of those Hall voltages.

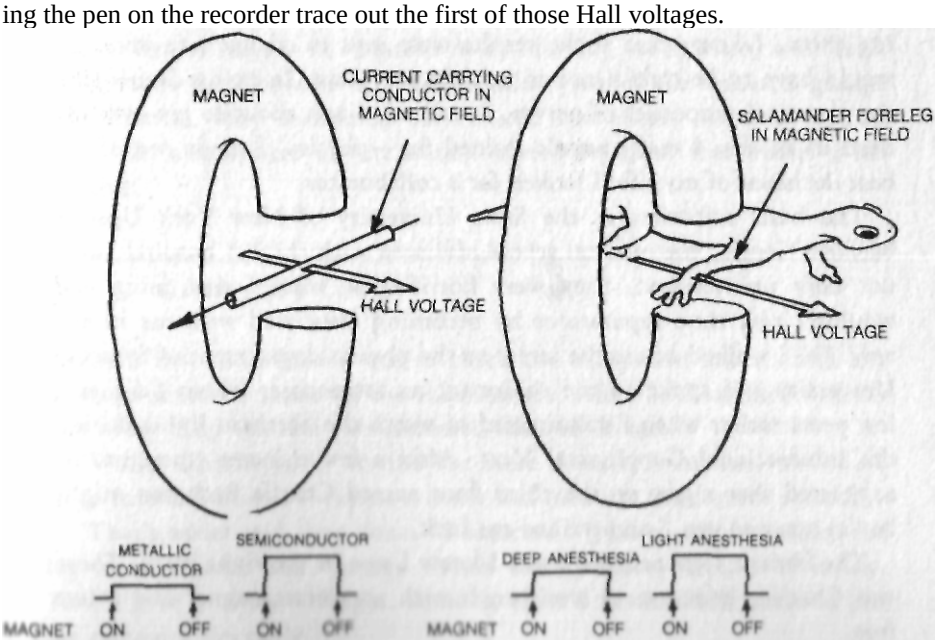

THE HALL EFFECT

This experiment demonstrated unequivocally that there was a real electric current flowing along the salamander's foreleg, and it virtually proved that the current was semiconducting. In fact, the half-dozen tests I'd performed supported every point of my hypothesis.

Scientific results that aren't reported might as well not exist. They're like the sound of one hand clapping. For scientists, communication isn't only a responsibility, it's our chief pleasure. A good result from a clean, beautiful experiment is a joy that you just have to share, and I couldn't wait to see these data in print. I went for the top this time. The journal in American science is aptly named Science. Each issue reports on all fields from astronomy to zoology, so publication means a paper has more than a specialized significance. Mine was accepted, and I was jubilant.

With three major papers in three major journals after my first year of research, I felt I'd arrived. The world has a way of cutting you down to size, however, and in the science game the method is known as citation. No matter how important your paper is, it doesn't mean anything unless it's cited as a reference in new papers by others and you get a respectable number of requests for reprints. On both counts, I was a failure. I was learning how science treats new ideas that conflict with old ones.

I didn't stay discouraged long, though. I was doing science for the love of it, not for praise. I felt the concepts emerging from my reading and research were important, and I was passionately committed to testing them. I knew that if the results were ever to change any minds, I would have to be careful not to misinterpret data. In going deeper into the electrical properties of nerves, I realized, I was about to get over my head in an area I really wasn't trained for—physics. I made one of the best decisions of my life; I looked for a collaborator.

The basic scientists at the State University of New York Upstate Medical Center, the medical school affiliated with the VA hospital, were not only uninterested, they were horrified at what I was doing and wouldn't risk their reputations by becoming associated with me in any way. So, I walked across the street to the physics department of Syracuse University and spoke to the chairman, an astronomer whom I'd met a few years earlier when I volunteered to watch the northern lights during the International Geophysical Year. After a few minutes' thought, he suggested that a guy on the third floor named Charlie Bachman might be "as crazy as you," and wished me luck.

The instant I opened the door, I knew I was in the right place. There was Charlie, bent over a workbench with an electromagnet and a live frog.

Five
The Circuit of Awareness

Charlie and I talked all afternoon, beginning fifteen years of fruitful work together. For me, the best part was his friendship and his open mind. He, too, knew there was still a lot to learn. Our relationship also had a side effect of incalculable value: He sent some of his most talented graduate students over to my lab to do their thesis work and later to become my colleagues in research. Andy Marino, Joe Spadaro, and Maria Reichmanis each became an indispensable part of the research group. Like Charlie, they constantly contributed new ideas, and they helped create the atmosphere of intellectual adventurousness that makes a lab creative.

Closing the Circle

Charlie's first contribution was to check the equipment and confirm the measurements I'd made on the salamanders. After he'd satisfied himself that everything was real, we discussed what to do next.

"Well," Charlie said, "to find out more about this current, we'll have to go into the animal—expose a nerve and measure the current there."

"That's easier said than done," I objected. "Just to cut down into the leg of an animal will damage tissues and produce currents of injury. That'll give spurious voltages. Besides, there'd be no stable place to put the reference electrode."

Charlie gave me a lesson in basic electronics. A voltage entering a wire will decrease as the current travels along, so there'll be a uniform voltage drop in each unit of length. All you need to do is put both electrodes along the conductor, with the reference electrode closer to what you think is the source. If you use a standard distance between the electrodes, you can compare the voltage drop along various wires and measure changes in the whole system from any segment of it.

All I had to do was the surgery. I decided to work on bullfrogs, whose hind legs were long and contained a nice big sciatic nerve. It was easy to find and could be exposed with just a little careful dissection, going between muscles instead of cutting through them. I was able to isolate over an inch of nerve with no bleeding or tissue damage, slipping a plastic sheet underneath so as not to pick up readings from the surrounding muscles. We measured the voltage gradient over a standard distance of 1 centimeter. It was the same from one frog to the next. In deep anesthesia it was absent or pretty small; as the anesthesia wore off, it became a constant drop of about 4 millivolts per centimeter, always gradually positive toward the spinal cord and negative toward the toes.

In some frogs we cut the nerve above the measuring site, whereupon the voltages disappeared—another indication that the current was actually in the nerve. Voltages returned a little later, but they weren't the same as before. We figured these secondary voltages were probably an artifact—a spurious measurement produced by extraneous factors—caused by currents of injury from the cut nerve itself or from the other tissues where I'd made the incision to cut the nerve.

Charlie then suggested that we make measurements on a longer section of nerve, and that was when we ran into a puzzle. The nicely reproducible voltages we'd found before couldn't be duplicated when we extended our measurement distance to 2 centimeters, close to the knee. We expected double the potential we'd found over the 1-centimeter distance, but often it was lower or higher than it should have been. I insisted that my dissection was producing local currents of injury that made our readings unpredictable. However, Charlie pointed out that I was a good frog surgeon and I didn't seem to be doing any more damage than before. He asked, "Could there be any difference in the nerve where you extended the dissection?"

"Not likely," I said. "The sciatic nerve does split up into two branches, but you only find them below the knee, when one goes to the front of the calf and one to the back."

"How do you know it doesn't separate before it gets to the knee?" he asked.

He was right. Not bad for a physicist! The nerve did divide, but the two parts were held together by the nerve sheath until they got past the knee. I was able to remove the sheath and isolate both portions. When we measured these, we found that the two sections were polarized in opposite directions. The voltage drop of the front branch was positive toward the toes. The posterior branch was polarized in the same direction as the sciatic trunk, but it always had a higher voltage gradient. The current in the front branch apparently flowed in the direction opposite to that in the rest of the nerve. The interesting thing was, when we added up the voltage increases from 1-centimeter lengths of the two branches—4 millivolts positive and 8 negative in a typical frog—we got roughly the same voltage gradient that we found in the main nerve, about 4 millivolts negative in every centimeter. At first that didn't make any sense.

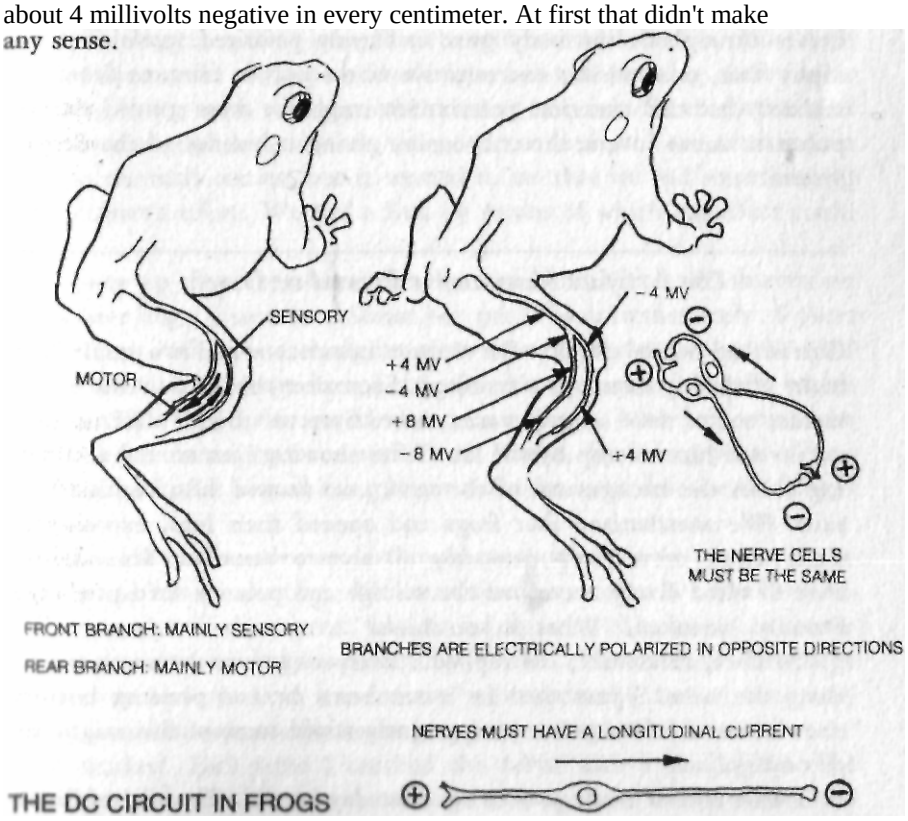

On a hunch I took pieces of each nerve and sent them to the pathology department to have microscope slides made. I found that the fibers in the front fork were smaller than those in the other. A light bulb went on! The sciatic nerve is what's called a mixed nerve. It has both

motor and sensory neurons. Sensory fibers are usually narrower than motor fibers, so it looked as though the front branch was all sensory, the back one all motor. Suppose the DC system also had incoming and outgoing divisions. We took readings from other nerves known to be all one type or the other. The femoral nerve along the front of the thigh is almost entirely motor in function, and, sure enough, it had an increasing negative potential away from the spine. The spinal nerves that serve the skin of a frog's back are sensory fibers, and they had increasing negative voltages toward the spine.

Now we saw that when you put motor and sensory nerves together into a reflex arc, the current flow formed an unbroken loop. This solved the mystery of what completed the circuit: The current returned through nerves, not some other tissue. Just as Gerard had found in the brain, nerves throughout the body were uniformly polarized, positive at the input fiber, or dendrite, and negative at the output fiber, or axon. We realized that this electrical polarization might be what guided the impulses to move in one direction only, giving coherence to the nervous system.

The Artifact Man and a Friend in Deed

Charlie had helped develop the electron microscope and as a result knew many of the big names in physiology. Soon after the sciatic nerve experiments, one of these acquaintances visited Syracuse to give a lecture, and we invited him to stop by the lab. After showing him around and talking about the background of the work, we showed him our latest results. We anesthetized four frogs and opened their legs, exposing all eight sciatic nerves and measuring all sixteen branches. The readings were flawless. Every nerve had the voltage and polarity we'd predicted. Proudly, we asked, "What do you think?"

"Artifact, all artifact," he replied. "Everyone knows there's no current along the nerve." Just then he remembered he had pressing business elsewhere and left in a hurry, apparently afraid some of this might rub off on him.

Charlie almost never swore, but that day he did. The gist of his remarks was that there sure was a difference between physicists and biologists. The former would at least look at new evidence, while the latter kept their eyes and minds closed. Thereafter we always referred to the "Artifact Man" when we needed a symbol of dogmatism.

We continued a few more observations on frog nerves. By now winter

had come. That shouldn't have mattered—the lab temperature was the same all year, and the frogs didn't stop eating and hibernate as they would have in the wild—but there was a difference. The frogs' voltages were much lower, they stayed unconscious longer with the standard dose of anesthetic, and their blood vessels were much more fragile. Did they somehow sense the winter?

If the DC system was as we theorized, it would be influenced by external magnetic fields. In the Hall-effect experiment I'd already shown that it was, but I'd used a strong field, measuring thousands of gauss. The earth's magnetic field is only about half a gauss, but it does vary in a yearly cycle. At the time there was another scientist who was saying this weak field had major effects on all life. Frank A. Brown, a Northwestern University biologist who was studying the ubiquitous phenomenon of biological cycles—wavelike changes in metabolic functions, such as the alternation of sleep and wakefulness—was claiming that similar rhythms in the earth's magnetic field served as timers for the rhythms of life. Even though his evidence was good, no one paid any attention to him in the early sixties, but it seemed to me that we had something to offer Brown's effort. We had a link by means of which the effect could occur.

I wrote up the sciatic nerve measurements and added the observation on winter frogs. I sent it to Science but got it back immediately. I guess the editors had second thoughts after running my paper on the Hall effect. Next I tried the even better British equivalent, Nature, which took it. This time I also got some reprint requests. More important, the report led to correspondence with Frank Brown, beginning years of mutual feedback that helped bring about the discoveries described in Chapter 14.

I thought of one more way we could check whether the current in the nerves was semiconducting. We could freeze a section of nerve between the electrodes. If the current was carried by ions, they would be frozen in place and the voltage would drop to zero. However, if the charge carriers were electrons in some sort of semiconducting lattice, their mobility would be enhanced by freezing and the voltage would rise.

It worked. Each time I touched the nerve with a small glass tube filled with liquid nitrogen, the voltage shot upward. But perhaps I was damaging the nerve with the glass tube or through the freezing itself. Maybe the increase was merely a current of injury. To check, we simply cut the nerve near the spinal cord; the voltage gradient on the nerve went to zero, and then we applied the liquid nitrogen again. If the cold was really enhancing a semiconducting current, we should find no volt-

age now even after freezing the nerve—and we didn't. Therefore the increase in current wasn't due to artifact—damage to the nerve by freezing or touching it with the tube.

That settled it. Test after test had substantiated the direct-current system. Now we had to see where the concept would lead us and try to convince some of the Artifact Men along the way. We had lots of ideas for further work, but now the first priority was to get some reliable system of funding for ourselves.

I was continuing to have problems with the VA research office. After I'd gotten my second grant from that source, I soon found out that to have it approved and to be able to spend it were two different things. To order supplies—even things as simple as test tubes or electrode wire—I had to fill out a form and give it to the secretary of the research office. She had to fill out another form and get it signed by the research director. This form went to the supply service, where a clerk filled out a third form to actually order the stuff. Well, my orders stopped getting filled.

In the process of complaining I made friends with the secretaries and found out that the director was holding me up just by not signing my forms. His secretary solved my problem. The director was a procrastinator. A pile of papers would collect on his desk until his secretary told him they had to be taken care of right away. Then he would sign them all at once without looking at each one. His secretary, to whom I owe a tremendous debt, merely slipped my requests back into the middle of the pile, usually late on Friday afternoon. Several times he visited my lab, saw a new piece of equipment, and remarked, "I don't remember ordering that for you."

"You don't?" I replied sweetly. "We talked about it, and I had plenty of money left in the grant, so you said okay." It was better than arguing over each instrument, and I was careful not to overspend. I don't think he ever caught on.

Soon I encountered a more serious threat, however. Between the VA and the medical school I had a lot of bosses, and all of them were doing "research." However, the research service's annual report showed that I'd published more than all of my superiors put together on a few thousand bucks a year, while some of them were drawing forty or fifty thousand. I'd broken the old rule that you should never do more than your boss.

One of these fellows appeared in my lab one day. That was an event in itself, since he'd never been a supporter of mine; in fact, our relations were rather strained That day, however, he evinced great interest in what I was doing and made me an "offer I couldn't refuse."

"How would you like to have as much money as you need?"

I said that would be nice, but I wondered how it could come about.
"No problem. All you have to do is include me in the project. All I would expect in return is that my name would go on all publications."
It was a few seconds before I could believe I'd heard him right. Then I told him what he could do with his influence.
A few months later, I found out that the area surgical consultant, practically next to God in the VA hierarchy, was visiting the hospital to act on a report, made by my would-be "benefactor," that I was spending too much time on research and neglecting my patients. Fortunately, there was a lot of infighting among my superiors, and one higher than the guy who'd made the charge was supporting me. His motives were less to save a promising research program and more to embarrass the other man, but I was cleared.
It was also clear that I was courting disaster by relying on VA money. I needed outside support. I took time off from research to prepare two proposals. One, which I sent to the Department of the Army, emphasized the possibility that direct currents could stimulate healing. Since the Army's business produces quite a few wounds, I thought it would be interested, but it was not. The proposal was turned down promptly, but then a strange thing happened about a month later. I received a long-distance call from a prominent orthopedic surgeon, a professor at a medical school in the South. "I have a grant from the Army to study the possibility that direct currents might stimulate wound healing," he purred, "and I wonder if you might have any suggestions as to the best approach to use."
My God, were they all this sleazy out there? Of course, when I looked up his credentials, I found he had absolutely no background in bioelectricity. He'd just happened to be on the Army review committee, recommended disapproval, and then turned around and submitted the idea in his own name, now getting the go-ahead since he, a man with a reputation and friends on the review board, was going to do it, instead of some unknown upstart.
I sent the second application to the National Institutes of Health (NIH). I stayed within my specialty and proposed to study the solid-state physics of bone, eventually hoping to find out if direct currents could stimulate bone healing. The grant was approved, but only for enough money to do part of what I wanted. And although it was nice to have a cushion, a source not under local control, I nevertheless needed some political clout to stabilize the situation in Syracuse. I went directly to the dean of the medical school.
Carlyle Jacobson had seemed to be a nice guy, not the type to stand

on ceremony or position, and I thought I could talk to him frankly. I gathered up reprints of my papers and went to his office.
"Sir," I began, "I've been doing research on direct current electrical effects in living things for the past four years. I've gotten some papers published in good journals, and I think this is an important piece of work. Nevertheless, I have great difficulty getting funds from the VA. My requests are blocked by the politicians on the committee. Meanwhile these same guys are spending five times as much as I get, and they don't publish a damn thing." I'm afraid I got carried away, but Dean Jacobsen just sat there listening until I'd finished.
"Have you done any experiments on the DC activity of the nervous system?" he asked.
This was an unexpected question, but I told him of our work on salamanders and frog nerves.
It turned out he'd done some research on nerves years ago—with Ralph Gerard! He was very enthusiastic. "You've gone much further than we ever did," he told me. "We never thought to relate the brain currents to a total-body system. How much do you need?"
I asked for $25,000 in each of the next two years, but explained that it had to be earmarked for me alone or I would never see it.
"Don't worry," he said. "Go right back to your lab. I'll get it for you. I wish I could work with you."
He must have been dialing Washington as the door closed behind me, for the next day the chief of research got a telegram from the VA Central Office authorizing the requested amount for me, and only me. He couldn't understand it, and I professed complete ignorance, too.
I figured nothing I did now could make the research director like me any less, so I made another move. I went to the hospital director and told him I needed more space. Having heard of my favor from Washington, he was most helpful, and soon I had a suite of rooms on the top floor.
Suddenly a whole new realm of research was within reach. Charlie and I hardly knew which way to turn. Our first and most important step was to hire Andy Marino as a technician. The salary meant much to him, and his intelligence and dedication meant even more to us. We were on our way.

The Electromagnetic Brain

If the current controlled the way nerves worked in the brain as well as in the rest of the body, then it must regulate consciousness to some extent.

Certainly the falling voltages in anesthetized salamanders supported this idea. The question was: Did the change in the current produce anesthesia? Apparently it did, for when I passed a minute current front to back through a salamander's head so as to cancel out its internal current, it fell unconscious. How this state compared with normal sleep was impossible to tell, but at least the animal was clinically anesthetized. As long as the current was on, the salamander was motionless and unresponsive to painful stimuli.

Was this real anesthesia, or was the animal just being continuously shocked? This certainly didn't seem to be the case, but the observation was so important and so basic to neurophysiology that I had to be sure. It was no easy task, however, for there were, and still are, few objective tests known for anesthesia, especially in salamanders. Brain waves had turned out to be useless in gauging depth of anesthesia in humans, because the one good marker—very slow delta waves—only showed up when the patient was dangerously close to death. Lacking any better idea, however, I used my new multi-electrode monitor to make EEG recordings of chemically anesthetized salamanders and found that they showed prominent delta waves even though they all recovered nicely. Delta waves would be my marker. The idea worked beautifully. Very small currents gave me delta waves on the EEG, the waves got bigger as I increased the current, and they all correlated with the animal's periods of unresponsiveness. , .

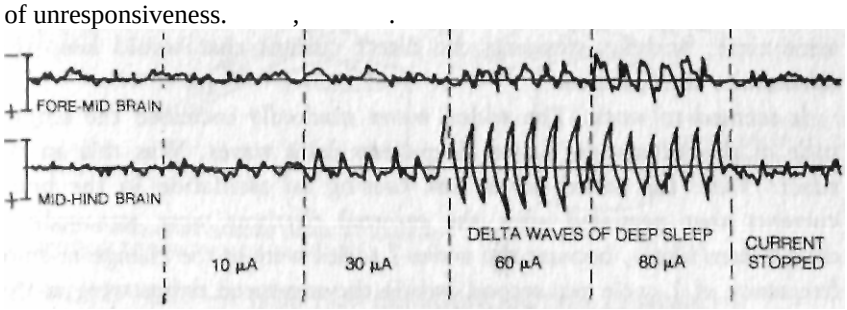

DC THROUGH THE HEAD ANESTHETIZES THE SALAMANDER

This result naturally led to the question: Did chemical anesthetics work by stopping the brain's electrical current? I couldn't see any way to get direct evidence one way or the other, but I thought maybe chemical anesthesia could be reversed by putting current into the brain in the normal direction. I found this could be done only to a certain extent. I could get a partial return of the higher frequency waves in the EEG, and the anesthesia seemed to become shallower, but I couldn't get a drugged salamander to wake up and walk away.

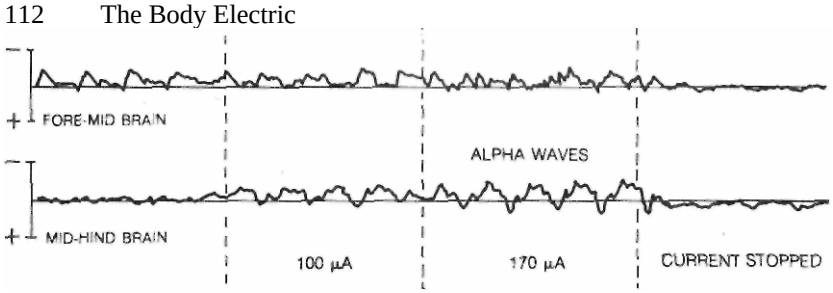

DC THROUGH THE HEAD PARTIALLY AWAKENS THE SALAMANDER

In the course of these observations, I found that when the head voltage was dropping as a chemical anesthetic took hold, specific slow waves always appeared briefly in the recordings. They were at the low end of the delta frequencies, 1 cycle per second or even less, and they also showed up when the voltage came back as the drug wore off. To find out if these waves always signaled a major change in the state of consciousness, I decided to use a standard amount of direct current to produce anesthesia, measure the amplitude (size) of the delta waves in the EEG, and then add some one-second waves of my own to the current I was putting into the animal's head. In other words, I would introduce some "change-of-state" waves from outside and see if they produced a shift in the EEG. I couldn't record the EEG simultaneously, because the waves I added would appear on the trace, so I rigged up a switch to cut out the added waves after a minute and turn on the EEG recorder at the same time, without stopping the direct current that would keep the salamander unconscious.

It seemed to work. The added waves markedly increased the amplitude of the salamander's own deep-sleep delta waves. Was this an artifact? Were the added waves just causing an oscillation in the brain currents that persisted after the external rhythms were removed? It didn't seem likely, because the waves I added were at the change-of-state frequency of 1 cycle per second, while the measured deltas were at the deep-sleep frequency of 3. However, an additional test was possible. I could add waves of other frequencies and see if they worked as well as 1 cycle per second. They didn't; in fact, as the frequency of the added waves increased over that rate, the deep-sleep delta waves got smaller. The one-second waves were a marker of major shifts in consciousness.

This line of work corroborated one of the main points of my hypothesis. Direct currents within the central nervous system regulated the level of sensitivity of the neurons by several methods by (hanging the amount of current in one direction, by changing the direction of the current (reversing the polarity), and by modulating the current with

slow waves. Moreover, we could exert the same control from outside by putting current of each type into the head. This was exciting. It opened up vast new possibilities for a better understanding of the brain. It was still on the edge of respectability, too, since it was a logical consequence of the work done by Gerard and his co-workers. The next experiment was harder to believe, however.

I figured the brain currents must be semiconducting, like those in the peripheral nerves. I thought of looking for a Hall voltage from the head but reasoned the brain's complexity would make any results questionable. Then I thought of using the effect backward, so to speak, measuring a magnetic field's action on the brain rather than on the production of the Hall voltage. Since the Hall voltage was produced by diverting some of the charge carriers from the original current direction, a strong enough magnetic field should divert all of them. If so, such a field perpendicular to the brain's midline current should have the same effect as canceling out that normal current with one applied from the outside. The animal should fall asleep.

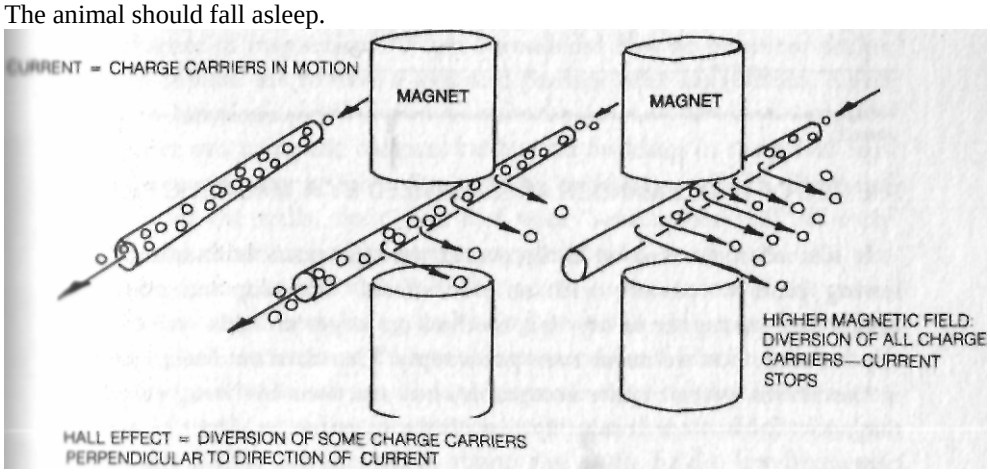

THE HALL EFFECT—A TEST FOR SEMICONDUCTING CURRENTS

We tranquilized a salamander lightly, placed it on a plastic shelf between the poles of a strong electromagnet, and attached electrodes to measure the EEC As we gradually increased the magnetic field strength, we saw no change—until delta waves appeared at 2,000 gauss. At 3,000 gauss, the entire BEG was composed of simple delta waves, and the animal was motionless and unresponsive to all stimuli. Moreover, as we decreased the strength of the magnetic field, normal EEG patterns returned suddenly, and the salamander regained consciousness within seconds, This was in sharp contrast to other forms of anesthesia.

With direct currents, the EEG continued to show delta waves for as long as a half hour after the current was turned off, and the animals remained groggy and unresponsive just as after chemical anesthesia.

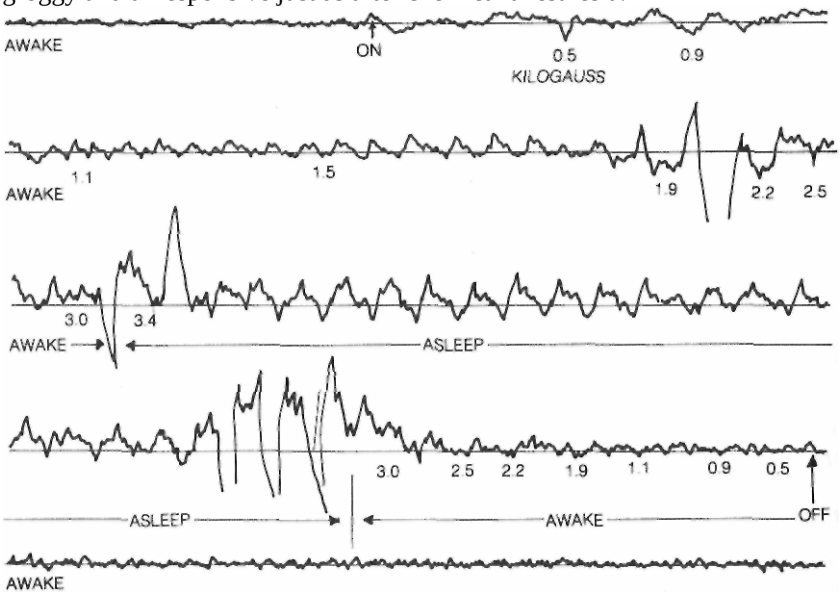

THE EEG OF A SALAMANDER ANESTHETIZED BY A MAGNETIC FIELD

It seemed to us that we'd discovered the best possible anesthetic, allowing prompt recovery with no side effects. We proposed getting a bigger electromagnet to try this method on larger animals and eventually humans, but we never even got a reply. Our data on direct currents in the nerves weren't quite acceptable, but reactions by living things to magnetic fields were absolutely out of the question in America at that time.

I was flabbergasted, therefore, to receive a phone call from one of the most prominent biologists in the Harvard-MIT orbit. He told me, "We're in the process of setting up an international conference on high-energy magnetic fields at MIT, and we've received a number of questions from respectable scientists in other countries asking why there is to be no session on biological effects of magnetic fields. This is a totally new idea to us, and we really don't believe there are such effects, but some of these fellows are persistent. We've searched the scientific literature and found your paper on the Hall effect. Since you steem to be the only person in this country doing any work along these lines, let me ask if you think there's anything to it."

I allowed as humbly as I could that there just might be something there, and told him about the latest experiments. There was a long pause filled with disdain. Then I added that Professor Bachman had been working with me. That changed the tone dramatically; this man also knew Charlie through work on the electron microscope during the war. He asked if I would organize the session and arrange for additional speakers.

There weren't too many investigators to choose from, and some of them were doing very slipshod work. I invited Frank Brown and selected a few others on the basis of published work. I'd just about finished when I got another call. A man with a thick German accent introduced himself as Dietrich Beischer.

"I have read your paper on the Hall effect," he began, "and I think we have much common interest." He explained that he was studying magnetic field bioeffects for the Navy and had done much work that wasn't published openly. At the time he was conducting a large experiment on human volunteers to check for effects from a null field, a complete absence of magnetism. When I wondered how he produced such a state, he invited me to have a look and perhaps offer suggestions. So off I went to Maryland.

Beischer was using the compass calibration building in the Naval Surface Weapons Center at Silver Spring. The building was huge. Electrical cables in all the walls, floor, and roof were "servo-connected" (directly cued) to the three axes of the earth's magnetic field, so that the field was canceled out in a sphere about 20 feet across in the center of the structure. Several men were living and being tested in this area. I was impressed by the resources at Beischer's command, and I had a good time, but I wondered what use any discoveries made there might ultimately be put to. My only contribution was to point out that the enclosure had been built before anyone knew about the earth field's low-frequency components, micropulsations ranging from less than 1 to about 25 cycles per second, that were far weaker than the planet's electromagnetic field as a whole. Consequently Beischer's subjects were still exposed to a very weak magnetic field pulsing at these frequencies, and I suspected that that component might be one of the most important for life, because all brain waves were in exactly the same range. Perhaps as a result of this factor, the null-field experiment was turning out to be inconclusive, but I asked Beischer to attend the MIT meeting and present some previous data suggesting that electromagnetic fields could affect embryonic development.

For my own presentation I decided against trying to compress all the

work I'd done so far into a few minutes before a skeptical audience. Instead I offered some evidence that Charlie and I had gathered with the help of psychiatrist Howard Friedman, which showed a possible relationship between mental disturbances and solar magnetic storms. I'll discuss this study further in Chapter 14.

The MIT meeting went well. The field of bioelectromagnetism was still young, and the researchers in it didn't make many converts among the mainstream biologists. As usual, we found the physicists more inclined to listen. However, we drew inspiration from each other. I returned to the lab more determined than ever to elucidate the links that I knew existed between electromagnetic energy and life.

Charlie, Howard, and I decided to find out how the brain's DC potentials behaved in humans. The electrodes we'd been using on salamanders couldn't be scaled up for people, but within a week Charlie invented some that would give us equally precise readings from the human head. We immediately found that the back-to-front current varied with changes in consciousness just as in salamanders. It was strongest during heightened physical or mental activity, it declined during rest, and it reversed direction in both normal sleep and anesthesia. This knowledge led directly to the experiments, described in Chapter 13, that taught us much about how hypnosis and pain perception work.

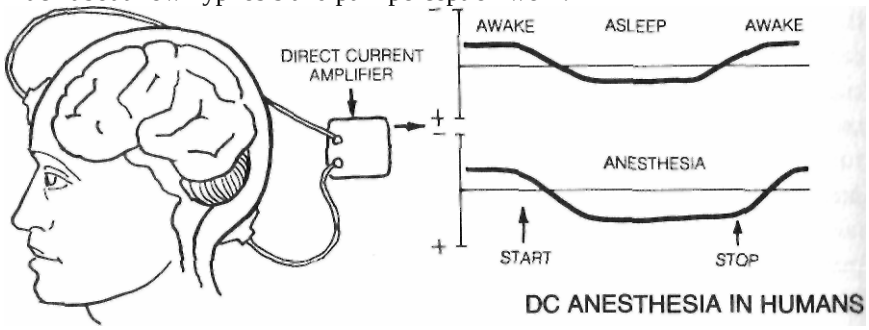

DC ANESTHESIA IN HUMANS

At this point I received an invitation from Meryl Rose to speak at the big event in the world of animal science, the International Congress of Zoology. This is not just a yearly convention; it is convened only when its directors agree that there has been enough progress to warrant a meeting. This session, in August 1963, was only the sixteenth since the first one had been set up in 1889. It was an honor to be there, and the conference itself was especially important, since it was one of the first times science formally addressed such ecological emergencies as pesticide pollution, the protection of vanishing species, overpopulation, and urban sprawl. The high point tor me came when I gave my paper and saw

in the audience Dr. Ralph Bowen, my college biology professor, a kind but exacting teacher who'd inspired me with his unique combination of scientific discipline and respect for life. Afterward, with characteristic caution, he said something like "That's not too bad, Becker. I'd like to see you keep going in this research."

When I assured him that, despite my M.D. degree, I was still committed to basic biology, he said, "I hope so, but remember, it won't be easy. To change things is never popular." His encouragement meant a lot to me, and I was happy to be able to show him that I'd amounted to something.

A lot had happened in the four work-filled years since I'd begun studying the current of injury. That first experiment had opened a door into a great hall with passageways leading off in all sorts of fascinating directions. This was really the life! Without leaving the laboratory I'd gone on a journey of exploration as exciting as trekking through the uncharted wilds of New Guinea. Our work on nerves and the brain was leading toward a whole new concept of life whose implications only gradually became apparent. Meanwhile, my colleagues and I were continuing to investigate the processes of healing, leading to insights and practical applications that more than justified my enthusiasm.

Six
The Ticklish Gene

Despite my fascination with fundamental questions about the nature of life, I was, after all, an orthopedic surgeon, and I was eager to find things that would help my patients. In addition, to convince the Artifact Man and all his brothers, Charlie and I were looking for some direct test of semiconduction in living tissues. The Hall effect and the freezing of frog nerves each demonstrated a characteristic of semiconduction but didn't confirm it in standard engineering terms. Unfortunately, all the direct tests then known worked only with crystals. You needed a material you could carve into blocks, something that didn't squish when you put an electrode on it. The only possibility was bone.

To many biologists and physicians, bones are pretty dull. They seem like a bunch of scarecrow sticks in which nothing much happens, plain props for a subtler architecture. Many of my patients were in sad shape because doctors had failed to realize that bone is a living tissue that has to be treated with respect. It's a common misconception that orthopedic surgery is like carpentry. All you have to do is put a recalcitrant fracture together with screws, plates, or nails; if the pieces are firmly fixed after surgery, you're done. Nothing could be further from the truth. No matter how firmly you hold them together, the pieces will come loose and the limb can't be used if the bone doesn't heal.

The Pillars of the Temple

The skeleton doesn't deserve this cavalier treatment. The development of bones by the first true fishes of the Devonian era nearly 400 million years

ago was a remarkable achievement. It enabled animals to advance, in both senses of the word, quickly and efficiently. Since bone is inside the body, it can live and grow with the animal, instead of leaving it defenseless as an external skeleton does when cast off during a molt. It's also the most efficient system for attaching muscles and increasing the size of animals.

Bone is extraordinary in structure, too. It's stronger than cast iron in resisting compression but, if killed by X rays or by cutting off its blood supply (barely adequate to start with), it collapses into mush. The part that's actually alive, the bone cells, comprises less than 20 percent of the whole. The rest, the matrix, isn't just homogeneous concrete, either. It's composed of two dissimilar materials—collagen, a long-chain, fibrous protein that's the main structural material of the entire body, and apatite, a crystalline mineral that's mainly calcium phosphate. The electron microscope shows that the association between collagen and apatite is highly ordered, right down to the molecular level. The collagen fibers have raised transverse bands that divide them into regular segments. The apatite crystals, just the right size to fit snugly between these bands, are deposited like scales around the fibers.

This intricacy continues at higher levels of organization. The collagen fibers lie side by side in layer upon layer wound in opposed spirals (a double helix) around a central axis. The bone cells, or osteocytes, are embedded in these layers, which form units a few millimeters long, called osteones. The center of each osteone has a small canal in which runs a blood vessel and a nerve. The osteones in turn are organized so as to lie along the lines of maximum mechanical stress, producing a bone of the precise shape best able to withstand the forces applied to it.

Bone has an amazing capacity to grow, which it does in three different ways. In childhood each long bone of the limbs has one or two growth centers, called epiphyseal plates. Each is a body of cartilage whose leading edge grows continuously while its trailing edge transforms into bone. When the bone is the right length, the process stops, and the remaining cartilage forms the bony knob, or epiphysis, at the end of the bone. The "closure" of the epiphyses is an index of the body's maturation.

Bone cannot heal. That sounds like a conundrum but it's literally true. Fractures knit because new bone made from other tissues unites the fracture ends. Although we sometimes speak of bone growth as part of fracture healing, the old, preexisting bone doesn't have the capacity to grow. As mentioned in Chapter 1, there are two tissues that produce new bone at a fracture site. One is the periosteum, the bone's fibrous covering. It's the cells of the periosteum's innermost layer that have the

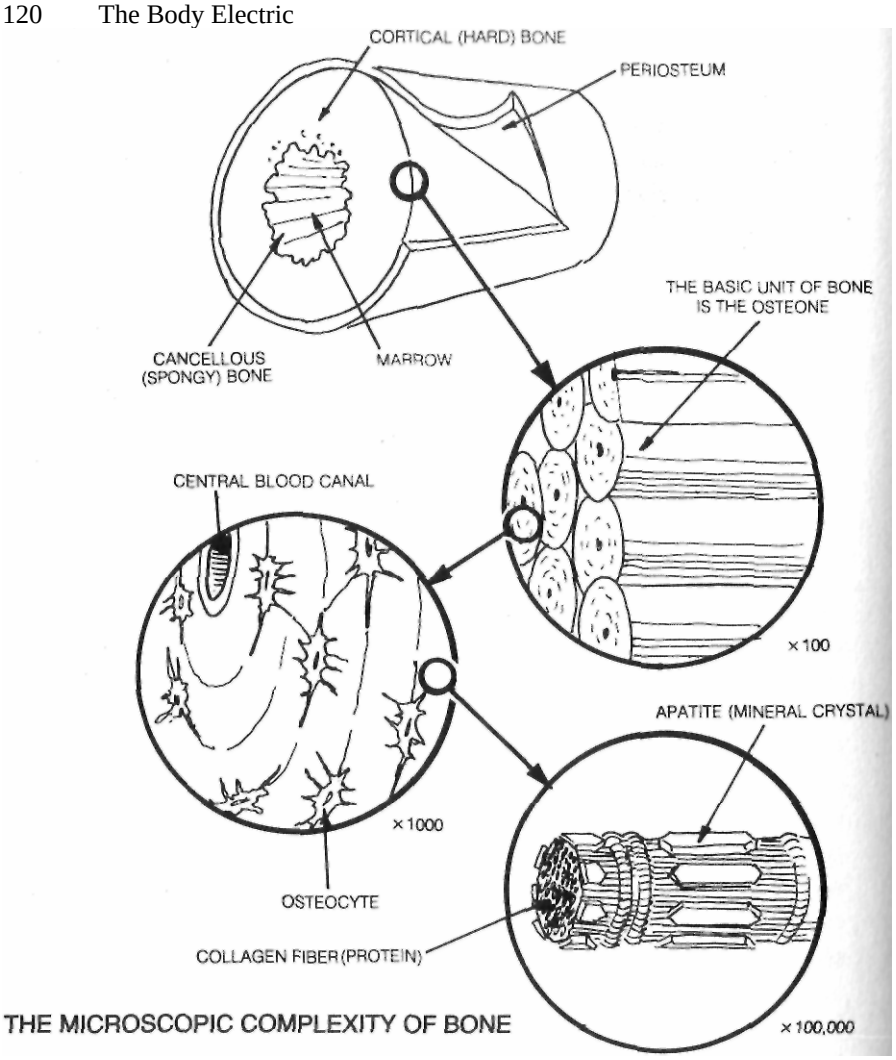

THE MICROSCOPIC COMPLEXITY OF BONE

power of osteogenesis, or bone formation. After a fracture, these cells are somehow turned on. They begin to divide and some of the daughter cells turn into osteoblasts, cells that make the collagen fibers of bone. Apatite crystals then condense out of the blood serum onto the fibers.

The other tissue that forms new bone to heal a fracture is the marrow. Its cells dedifferentiate and form a blastema, filling the central part of the fracture. The blastema cells then turn into cartilage cells and later into more osteoblasts. This process is true regeneration, following the same sequence of cell changes as the regrowing salamander limb.

Whatever a physician does to repair a fracture, he or she must protect the periosteum and marrow cavity from harm. Unfortunetely, too often

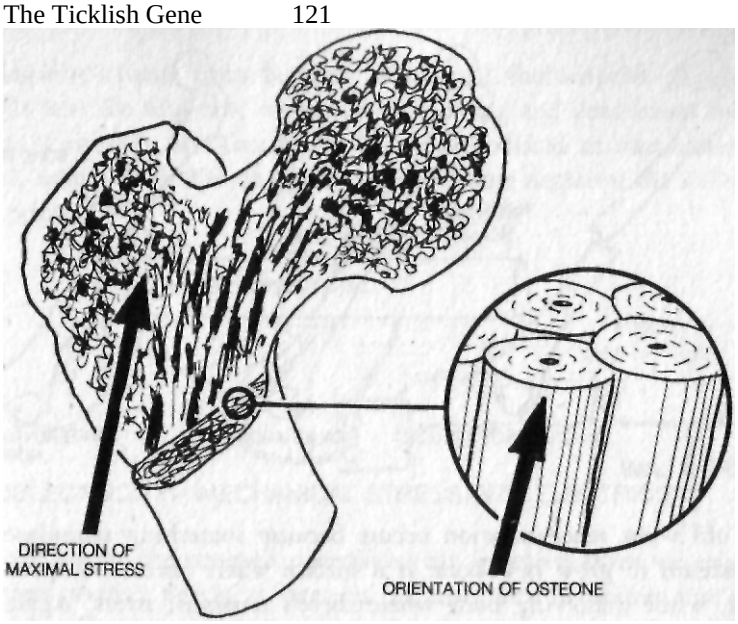

BONES-DESIGNED FOR MAXIMUM STRENGTH

the application of plates, screws, and nails does just the opposite and, rather than helping nature, the treatment impedes healing.

From a researcher's point of view, the question here is: What activates the cells of the periosteum and marrow? In the case of the marrow, we can expect it to be the same factor that switches on the cells in a salamander's amputated leg.

There's a third process of growth that's unique to bone. It follows Wolff's law, which is named after the orthopedic surgeon J. Wolff, who discovered it at the end of the nineteenth century. Basically, Wolff's law states that a bone responds to stress by growing into whatever shape best meets the demands its owner makes of it. When a bone is bent, one side is compressed and the other is stretched. When it's bent consistently in one direction, extra bone grows to shore up the compressed side, and some is absorbed from the stretched side. It's as though a bridge could sense that most of its traffic was in one lane and could put up extra beams and cables on that side while dismantling them from the other. As a result, a tennis player or baseball pitcher has heavier and differently contoured bones in the racket arm or pitching arm than in the other one. This ability is greatest in youth, so in childhood fractures it's often best to put the bone ends together gently by manipulation without surgery, settling for a less than perfect fit. Sometimes the hardest part is convincing the parents that a modest bend will straighten itself out in a few months in accordance with Wolff's law.

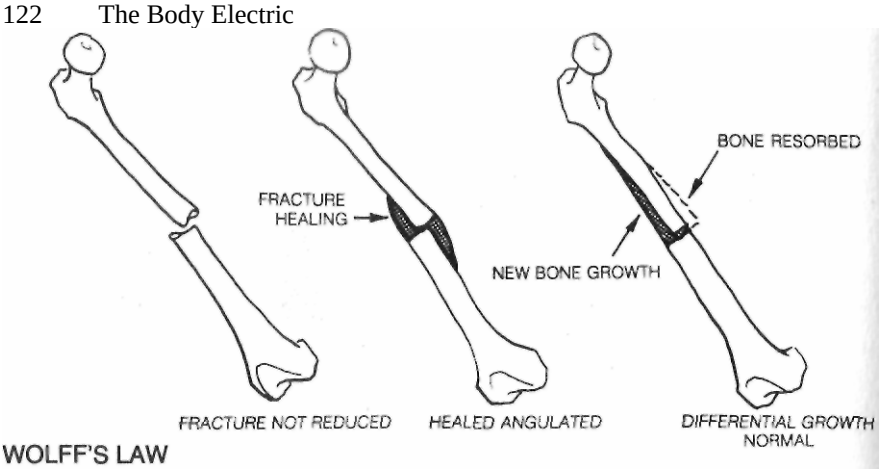

WOLFF'S LAW

Wolffs-law reorganization occurs because something stimulates the periosteum to grow new bone at a surface where there's compressional stress, while dissolving bone where there's tensional stress. Again, the question for researchers is: What turns on the periosteal cells?

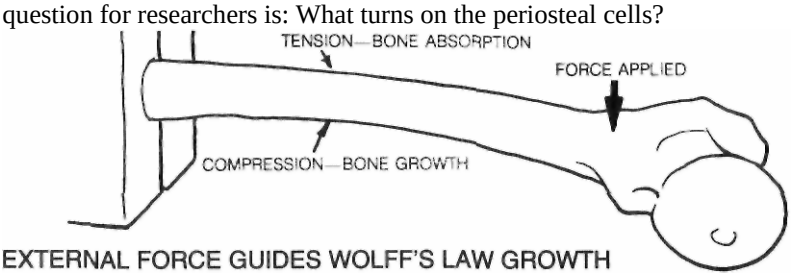

EXTERNAL FORCE GUIDES WOLFF'S LAW GROWTH

After I'd finished giving my paper on the salamander's current of injury at the orthopedic meeting early in 1961, several people came up to the stage to ask questions. Among them was Andy Bassett, a young orthopedic surgeon who was doing research at Columbia. In our conversation we came up with an angle for investigating Wolff's law—piezoelectricity. Simply put, this is the ability of some materials to transform mechanical stress into electrical energy. For example, if you bend a piezoelectric crystal hard enough to deform it slightly, there'll be a pulse of current through it. In effect, the squeeze pops electrons out of their places in the crystal lattice. They migrate toward the compression, so the charge on the inside curve of a bent crystal is negative. The potential quickly disappears if you sustain the stress, bur when you release it, an equal and opposite positive pulse appears as the electrons rebound before settling back into place.

Since I'd shown that a stronger-than-normal negative current preceded regeneration, Bassett suggested that maybe bone was iezoelectric and

the negative charge from bending stimulated the adaptive growth of Wolff's law. To find out, we tested both living and dead bones from a variety of animals, and found that bending produced an immediate potential, as expected. The compressed side became negative; the stretched side, positive.*

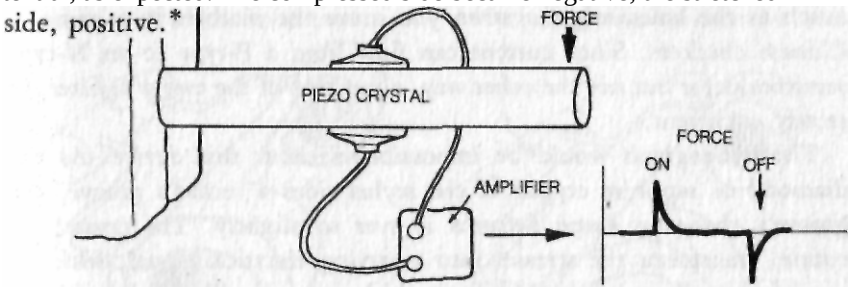

PIEZOELECTRICITY—MECHANICAL STRESS INTO ELECTRICITY

Furthermore, the reversed potentials that appeared when we released the stress weren't nearly as large as the first ones. This was just as it should be. If a negative voltage was the growth stimulus, there had to be some way to cancel out the positive rebound voltage; otherwise it would have negated the growth message. In electronic terms, there had to be a solid-state rectifier, or PN junction diode.

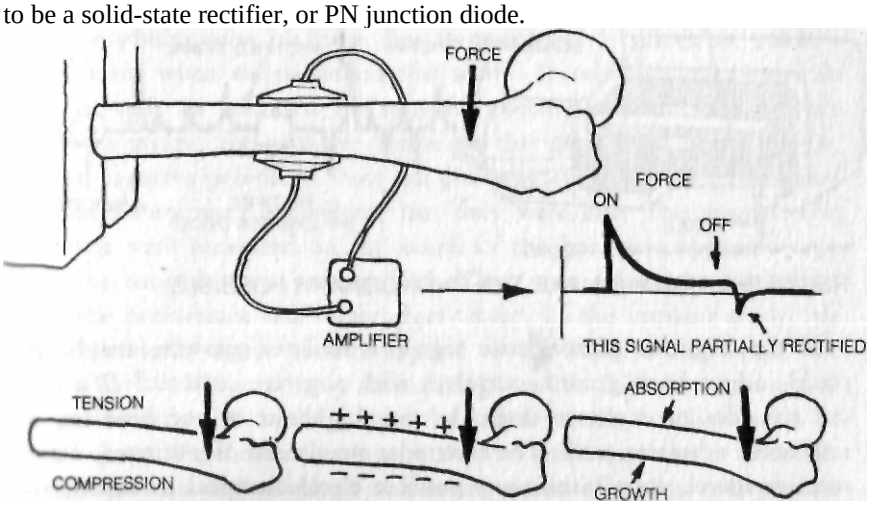

PIEZOELECTRICITY IN BONE

*After writing up this experiment, we found that it had been done before. Iwao Yasuda, a Japanese orthopedist, had shown that bone was piezoelectric back in 1954; he and Eiichi Fukada, a physicist, had confirmed the fact in 1957. We made note of their prior observations but published our paper anyway, since our techniques were different and ours was the first report in English.

Despite the initimidating names, this device is fairly simple. It's a filter that screens out either the positive (P) or the negative (N) part of a signal. As mentioned in Chapter 4, current can flow through a crystal lattice either as free electrons or as "holes" that can shift their positions much as the holes migrate when you move the marbles in a game of Chinese checkers. Since current can flow from a P-type to an N-type semiconductor but not the other way, a junction of the two will filter, or rectify, a current.

The phonograph would be impossible without this device. As the diamond or sapphire crystal of the stylus rides a record's groove, the groove's changing shape deforms it ever so slightly. The crystal, of course, transforms the stresses into a varying electrical signal, which is amplified until we can hear it. It would be an unintelligible hum, however, if we heard both the deformation pulse and the release pulse. Therefore we place a rectifier in the circuit. It passes current in one direction only, so the impulses don't cancel each other out. The signal is rectified, and when we feed it to a loudspeaker we hear music. Bassett and I felt sure we were seeing evidence of rectification in the fact that bone's release pulse was much smaller than the one from stress.

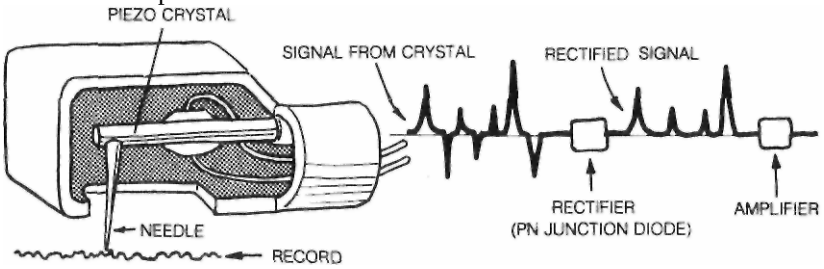

RECTIFIED SIGNALS MAKE THE PHONOGRAPH POSSIBLE

If the negative piezoelectric signal stimulated growth, maybe we could induce bone growth ourselves with negative current.* We tried out the idea on eighteen dogs. In the thighbone of one hind leg we implanted a battery pack. The electrodes were made of platinum, a nonreactive metal, to minimize any possible electrochemical irritation, and we inserted them through drill holes directly into the marrow cavity. As controls, some of the devices didn't have a battery. After three weeks we found that the active units had produced large amounts of new bone

*Again Dr. Yasuda and his colleagues had already done so, but their results seem to have been due to bone's ability to grow in response to irritation from the electrodes. They used alternating current, which is now known to have no direct growth-stimulating effect.

around the negative electrode but none around the positive. In the controls, there was no growth around either electrode.

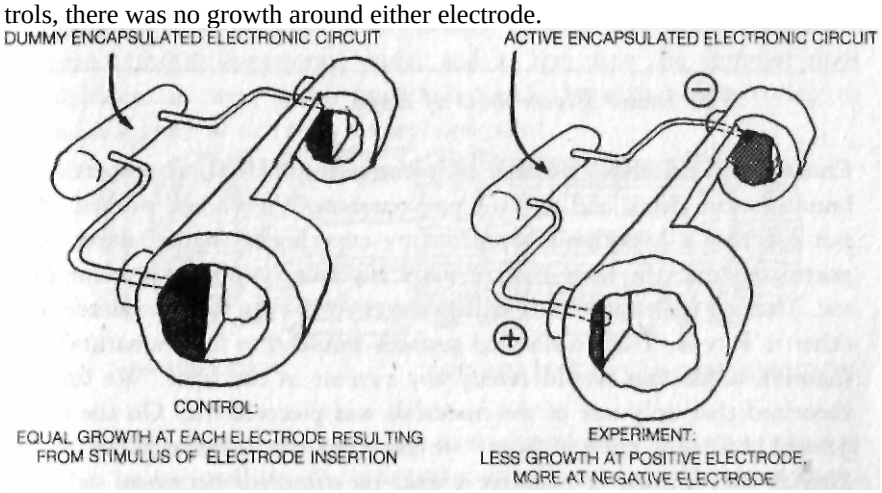

ELECTRICAL STIMULATION OF BONE GROWTH

The results were exciting, but in retrospect I believe we made a serious error when we published this study. In our own minds and in print as well, we confused the negative potentials of the salamander's current of injury, the negative potentials that stimulated bone growth, and the negative potentials from the piezoelectric study. We proceeded as though they were equivalent, but they were not. The piezoelectric potentials were measured on the outside of the bone and appeared only when mechanical stress was applied. They were transitory, and most likely the periosteum was their target tissue. In the implant study, we used continuous direct current applied to the inside of the bone, the marrow cavity. What we were stimulating was the DC control system of regenerative fracture healing, not the piezoelectric control system of Wolff's law. We didn't clearly indicate the difference to the scientific reader, and this led to much confusion, some of which still persists twenty years later. As a result, many scientists think electricity stimulates bone growth because bone is piezoelectric. Most of these people don't realize that bone itself doesn't grow when a fracture heals. Moreover, everyone who has proceeded from our technique—and it's being used today to heal nonunions (see Chapter 8)—has done basically the same thing, continuously stimulating the bone marrow. No one has tried to stimulate the periosteum, as the pulsed piezoelectric signal does.

Our confusion also helped the scientific establishment accept the "trivial" electrical stimulation of bone by considering it something unique to bone. The relationship between our experiment and regeneration proper was lost.

The Inner Electronics of Bone

Charlie Bachman and I decided to investigate the electrical properties of bone in more detail and try to figure out how Wolff's law worked. We put together a hypothesis based on my experiments with Bassett. We postulated that the bone matrix was a biphasic (two-part) semiconductor. That is, either apatite or collagen was an N-type semiconductor; the other, a P type. Their connected surfaces would thus form a natural PN junction diode that would rectify any current in the bone. We further theorized that only one of the materials was piezoelectric. On the compressed side of a stressed bone, we expected the positive pulses to be filtered out, leaving a negative signal to stimulate periosteal cells to grow new bone.

We made several pairs of sample blocks, cut side by side from pieces of bone removed from patients for medical reasons. From one member of each pair we chemically removed the apatite. The other we treated with a compound that dissolved the collagen. The resulting pure collagen was yellowish and slightly rubbery, and the apatite pure white and brittle, but otherwise both blocks still looked like bone. Our first step was to test bone's component materials separately for semiconduction and piezoelectricity. Collagen turned out to be an N-type semiconductor and apatite a P type.

Then we tested our samples for piezoelectricity in the same way that Bassett and I had previously tested whole bone. We expected that apatite would be the only one to show an effect, since it was a crystal. However, collagen turned out to be a piezoelectric generator, while apatite was not. We now had the makings of a PN junction—two semiconductors, one an N type, the other a P type, joined together in a highly organized fashion.

Now came the crucial part of our hypothesis. We had to figure out a way to test for rectification at the PN junction. It was an important crossroads.

Here we rn up against what's known in the trade as a technical problem. To test for rectification we had to put one electrode on the collagen and one on the apatite as they appeared in whole bone. Unfor-

tunately, the apatite crystals are each only 500 angstroms long. Now, the angstrom (named after the Swedish pioneer of spectroscopy Anders Jonas Angstrom) was invented for measuring atoms and molecules, and it is not large. Five hundred of them are only one tenth as long as a single wave of green light. Even today's thinnest microelectrodes are 1 micron (10,000 angstroms) wide, and at the time the thinnest ones available to us were much larger. It would have been like trying to measure a grain of rice with a telephone pole.

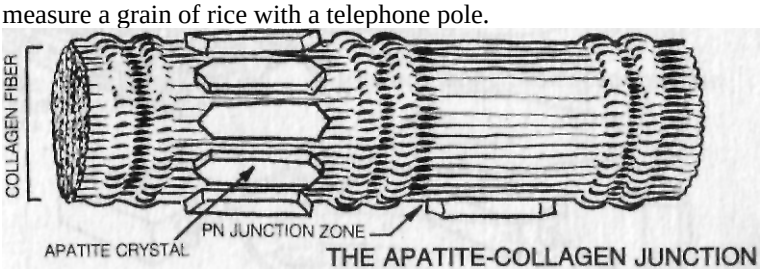

THE APATITE-COLLAGEN JUNCTION

We would have to do it in a sort of statistical way. Because of the way bone is built—millions of little scales glued onto larger fibers arranged in more or less lengthwise spirals along the osteones—I reasoned thus: If we put an electrode on the lengthwise cut, we'd be contacting mostly apatite, while an electrode on a face cut across the grain should connect to a greater proportion of collagen. If that method of electrode hookup worked and if we had a rectifier in our bones, then we'd be able to pass current through our samples only in one direction. That was exactly what happened. Our bone samples weren't as efficient as a commercial rectifier, but the amount of current we could put through them from a battery of constant voltage was much greater in one direction than in the other.

Current flowing "uphill," against the normal flow from P to N semiconductors, is called a reverse bias current, and we used it to look for photoelectric effects. Many semiconductors absorb energy from light, and any current flowing through the material gets a boost. We arranged our apparatus so only a small spot of light shone on the bone, because our silver electrodes were slightly sensitive to light and could produce a real artifact. With the voltage constant, the light produced an unmistakable increase in the current. Now, if bone really contained a rectifier, the photoelectric effect should be sensitive to the current's direction. The current in reverse bias should rise more with the same light intensify than the current in forward bias The experiment was simple. We reversed the battery and turned on the light. The amperage rose higher than before. The rectifier was real.

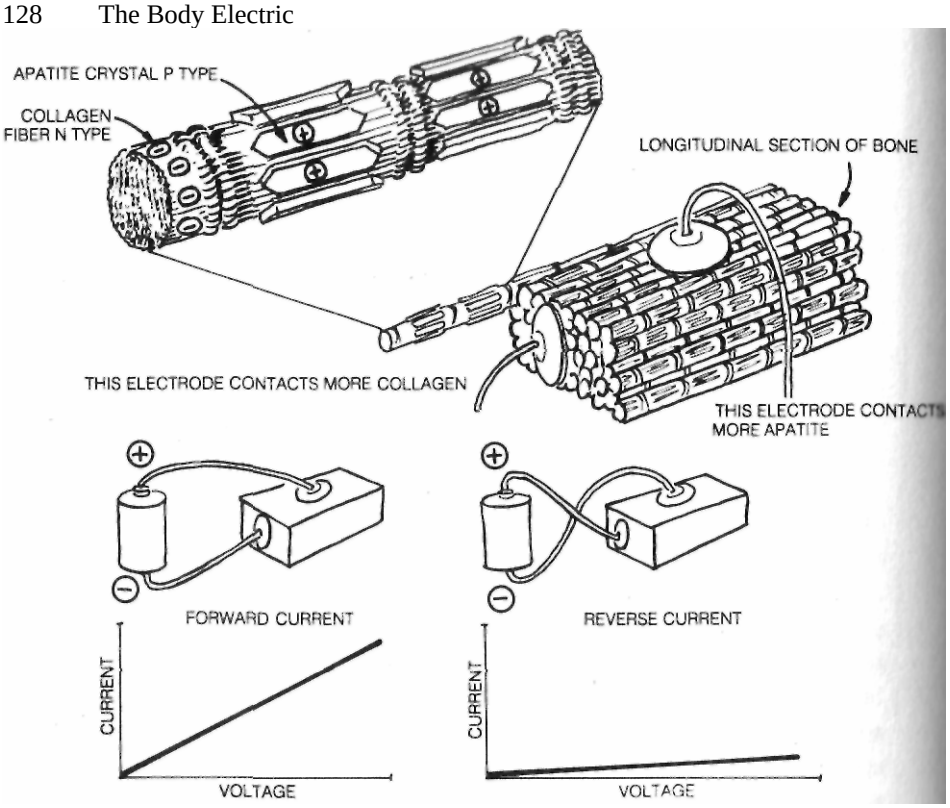

BONE IS A RECTIFIER—A PN JUNCTION DIODE

We could now follow the entire control system of Wolff's law. Mechanical stress on the bone produced a piezoelectric signal from the collagen. The signal was biphasic, switching polarity with each stress-and-release. The signal was rectified by the PN junction between apatite and collagen. This coherent signal did more than merely indicate that stress had occurred. Its strength told the cells how strong the stress was, and its polarity told them what direction it came from. Osteogenic cells where the potential was negative would be stimulated to grow more bone, while those in the positive area would close up shop and dismantle their matrix. If growth and resorption were considered as two aspects of one process, the electrical signal acted as an analog code to transfer information about stress to the cells and trigger the appropriate response.

Now we knew how stress was converted into an electrical signal. We had discovered a transducer, a device that converts other forces into electricity or vice versa. There was another transducer in the Wolff's-law system - the mechanism that transformed the electrical signal into appropriate cell responses. Our next experiment showed us something about how this one worked.

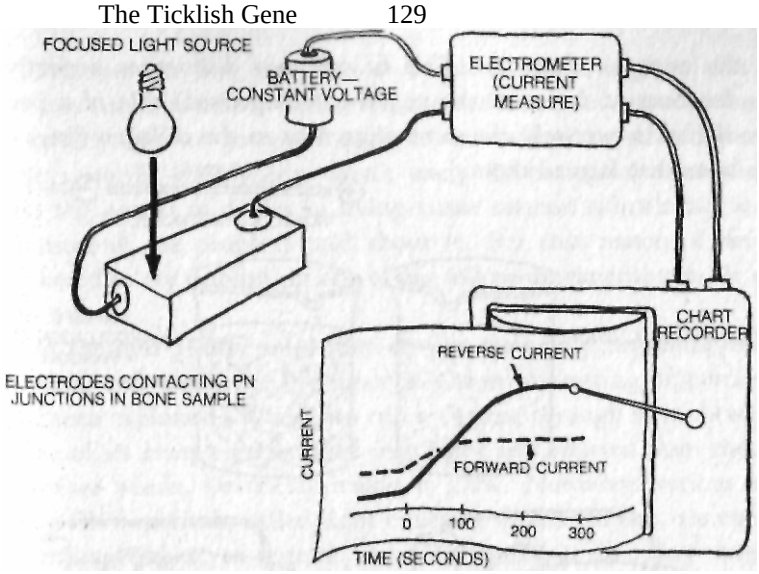

THE LIGHT TEST CONFIRMS BONE'S ELECTRICAL SYSTEM

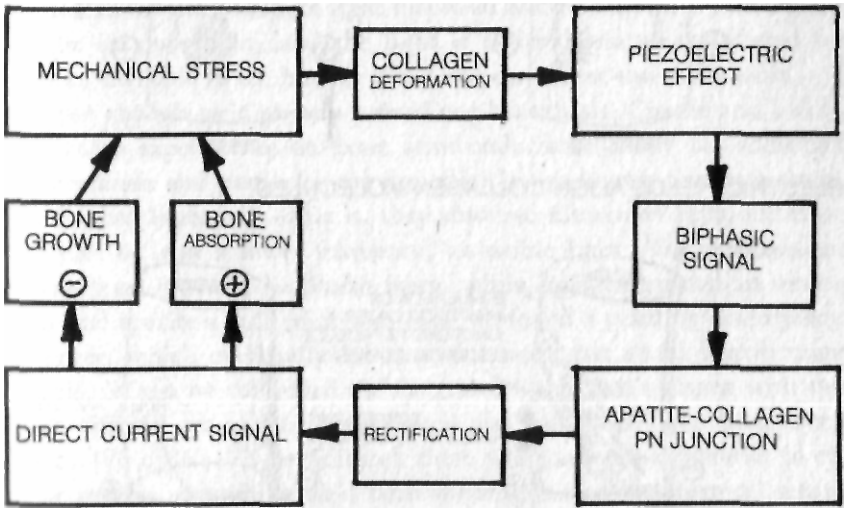

WOLFF'S LAW CONTROL SYSTEM

Collagen fibers are formed from long sticks, like uncooked spaghetti, of a precursor molecule called tropocollagen. This compound, much used in biological research, is extracted from formed collagen—often from rat tails—and made into a solution. A slight change in the pH of the solution then precipitates collagen fibers. But the fibers thus formed are a jumbled, feltlike mass, nothing like the layered parallel strands of bone. However, when we passed a weak direct current through the solution, the fibers formed in rows perpendicular to the lines of force

around the negative electrode. This fit our new discoveries perfectly, because the lines of force on the negative (compressed) side of a bent bone would be in precisely the same alignment as the collagen fibers of the new bone that formed there.

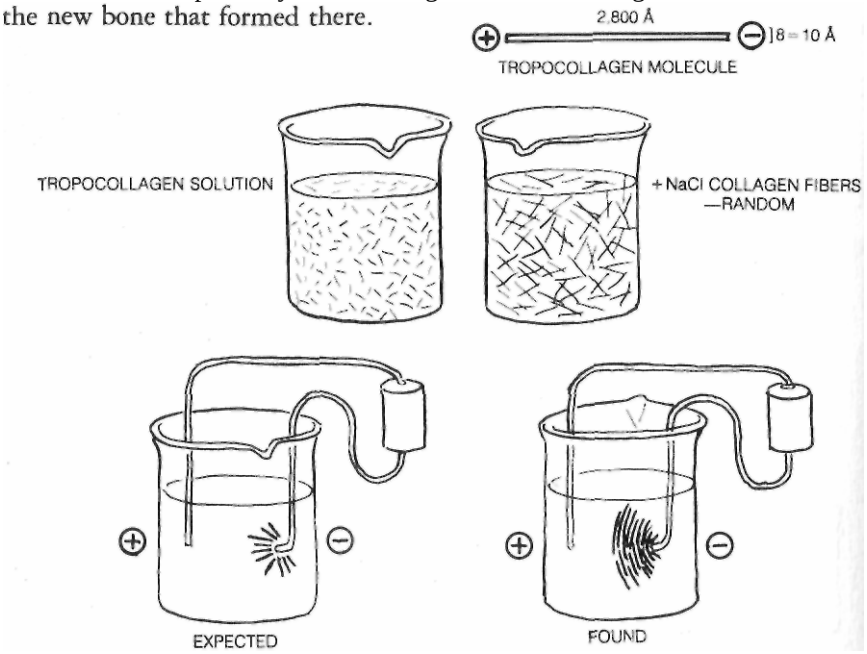

ELECTRIC FIELDS ALIGN COLLAGEN MOLECULES

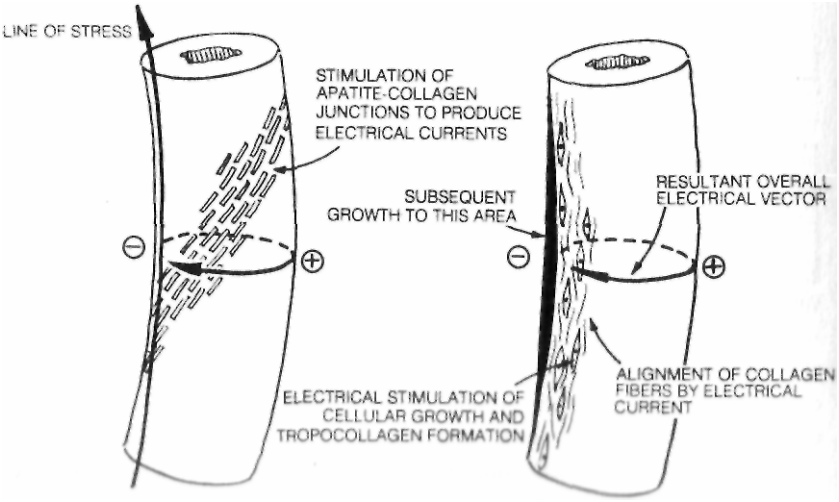

BONE'S ELECTRICAL SYSTEM GUIDES GROWTH

This was the first time that a complete circuit diagram of a growth process could be made. To us, this seemed an achievement of some note, but, although we got published, no one seemed to pay any attention. The scientific community wasn't ready for biological semiconduction, and the notion of diodes in living tissue seemed ridiculously farfetched to most of the people I told about it. For that reason, I never even bothered to try publishing one of our follow-up experiments. It was just too weird.

In the mid-1960s, solid-state devices were only beginning to hit the market, and one of the PN junction's most interesting properties hadn't yet been exploited. When you run a current through it in forward bias, some of its energy gets turned into light and emitted from the surface. In other words, electricity makes it glow. Nowadays various kinds of these PN junctions, called light-emitting diodes (LEDs), are everywhere as digital readouts in watches and calculators, but then they were laboratory curios.

We found that bone was an LED. Like many such materials, it required an outside source of light before an electric current would make it release its own light, and the light it emitted was at an infrared frequency invisible to us, but the effect was consistent and undeniable.

Even though we'd already proved our hypothesis, Charlie and I did a few more experiments on bone semiconduction, partly for additional confirmation and partly for the fun of it. It was known that some semiconductors fluoresced—that is, they absorbed ultraviolet light and emitted part of it at a lower frequency, as visible light. We checked, and whole bone fluoresced a bluish ivory, while collagen yielded an intense blue and apatite a dull brick-red. Here we found a puzzling discrepancy, however, which eventually led to a discovery that could benefit many people. When we combined the fluoresced light from collagen with that from apatite, we should have gotten the fluoresced light from whole bone. We didn't. That indicated there was some other material in the bone matrix, something we'd been washing out in the chemical separation.

Charlie and I were stumped on that line of research for a couple of years, until our attention was caught by a new development in solid-state technology called doping. Tiny amounts of certain minerals mixed into the semiconductor material could change its characteristics enormously. The making of semiconductors to order by selective doping would become a science in itself; to us it suggested trace elements in bone. We already knew that certain trace metals - such as copper, lead, silver, and beryllium - bonded readily to bone. Beryllium miners had a

high rate of osteogenic sarcoma—bone cancer—because beryllium somehow removed normal controls from the osteocytes' growth potential. Radioactive strontium 90 worked its harm by bonding to bone, then bombarding the cells with ionizing radiation. Perhaps some trace element normally found in bone changed its electrical properties by doping it.

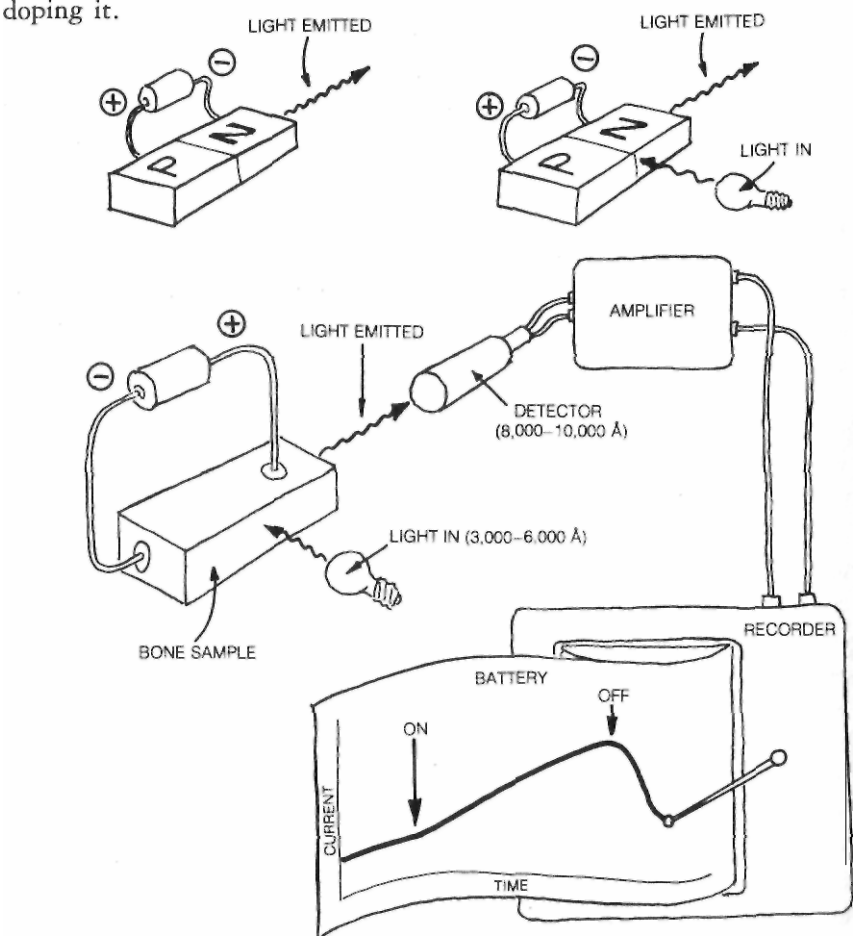

PHOTOELECTRICITY: ELECTRICITY GOES IN; LIGHT COMES OUT

To find out, Charlie and I used a very complex device called an electron paramagnetic resonance (EPR) spectrometer on our bone samples. There's no easy way to explain just how this instrument works, but basically it measures the number of free electrons in a material by sensing a resonance produced in the electrons' vibrations by in applied magnetic field. We used it to measure the fre electrons in collagen and apatite, and we found the same kind of discrepancy as in our flourescence

experiment: When we added together the free electrons of collagen and apatite, we fell short of the number we found in whole bone. That made us certain that we were washing out some trace mineral.

We decided to work backward. We prepared a solution containing small amounts of a wide variety of metals. Then we soaked our collagen and apatite cubes in this broth to see what they'd pick up.

We knew we were on the way to solving this mystery when we examined the results. Only a few of the metals had bonded to the bone materials: beryllium, copper, iron, zinc, lead, and silver. The diameters of all the absorbed atoms were exact fractions of one another. The results showed that the bonding sites were little recesses into which would fit one atom of silver or lead, two of iron or copper or zinc, or six of beryllium.

Only one of these metals gave us an electron resonance of its own, indicating that it had a large number of free electrons that could affect the electrical nature of bone. That metal was copper. We made a batch of broth containing only copper. We expected that copper's EPR signal would change to one value as it bonded with collagen, and to another as it bonded with apatite. Since the molecular structure of each was quite different, we figured that each would bind copper in a different way.

We could hardly believe the results. Bonding had indeed changed copper's resonance, but the change was the same in both materials. By analyzing it we deduced that each atom of copper fit into a little pit, surrounded by a particular pattern of electric charges, on the surface of apatite crystals and collagen fibers. Because the pattern of charges was the same in both materials, we knew that the bonding sites were the same on both surfaces and that they lined up to form one elongated cavity connecting the crystal and fiber. In other words, the two bonding sites matched, forming an enclosed space into which two atoms of copper nestled. The electrical forces of this copper bond held the crystals and fibers together much as wooden pegs fastened the pieces of antique furniture to each other. Furthermore, the electrical nature of peg and hole suggested that we had found, on the atomic level, the exact location of the PN junction.

This discovery may have some medical importance. The question of how the innermost apatite crystals fasten onto collagen had eluded orthopedists until then, and the finding may have opened a way to understand osteoporosis,a condition in which the apatite crystals fall off and the bone degenerates. The process is often called decalcification, although more than calcium is lost. It's a common feature of aging. I surmise that osteoporosis comes about when copper is somehow removed

from the bones. This might occur not only through chemical/metabolic processes, but by a change in the electromagnetic binding forces, allowing the pegs to "fall out." It's possible that this could result from a change in the overall electrical fields throughout the body or from a change in those surrounding the body in the environment.

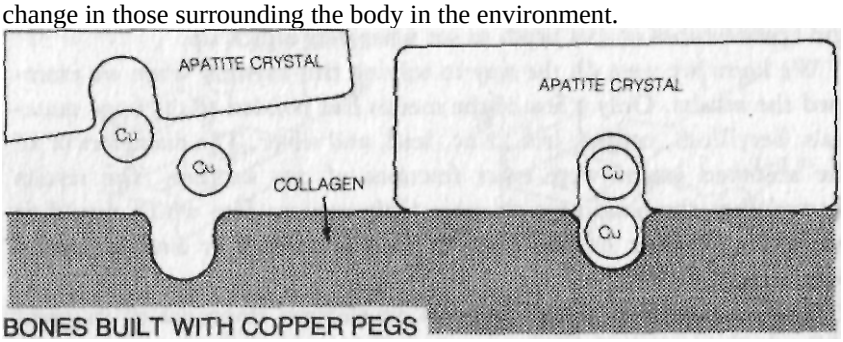

BONES BUILT WITH COPPER PEGS

Osteoporosis has been a major worry of the American and Russian space programs. As flights got longer, doctors found that more and more apatite was lost from the bones, until decalcification reached 8 percent in the early Soviet Salyut space-station tests. Serious problems were known to occur only when apatite loss reached about 20 percent, but the trend was alarming, especially since depletion of the calcium reservoir might affect the nervous system and muscular efficiency before the 20-percent level was reached. Although the immediate cause was their inability to get a malfunctioning air valve closed before all the cabin air escaped, weakness from muscle tone loss might have contributed to the death of the three cosmonauts who succumbed while returning from their twenty-four-day flight aboard Soyuz 11 at the end of June 1971.

Space osteoporosis may result from unnatural currents induced in bone by a spacecraft's rapid motion through the earth's magnetic field, with a polarity reversal every half orbit, or it may be a direct effect of the field reversal. This abnormality, which may change the activity of bone cells directly, would be superimposed on abnormal responses of bone's natural electrical system, which is almost certainly affected by weightlessness. The unfamiliar external field reversals could also weaken the copper pegs, at the same time that the bones are in a constant state of "rebound" from their earthly weight-induced potentials, producing a signal that says, "No weight, no bones needed." We know that the more even distribution of blood caused by weightlessness registers in the heart as an excess; as aresult, fluid and ions, including calcium, are withdrawn from tht blood. However, the effect probably isnt't due to weightlessness alone, for the Skylab astronauts did rigorous exercise, which would have

supplied plentiful stresses to their bones. They worked out so hard that their muscles grew, but decalcification still reached 6.8 percent on the twelve-week mission.

The Soviets at first claimed to have solved the problem before or during the Soyuz 26 mission of 1977—78, in which two cosmonauts orbited in the Salyut 6 space lab for over three months. Subsequent Soviet spacepersons, who have remained weightless as long as 211 days, reportedly have showed no ill effects from osteoporosis, and chief Soviet space doctor Oleg Gazenko said it simply leveled off after three months. However, this claim was later officially withdrawn, and I have a hunch that the Soviets are working on a way to prevent the condition by simulating earth-surface fields inside their space stations, a method that perhaps hasn't yet worked as well as they'd hoped. Andy Bassett has suggested giving our astronauts strap-on electromagnetic coils designed to approximate their limb bones' normal gravity stress signals, but so far NASA has shown no interest.

Unfortunately for earthbound victims of osteoporosis, the copper peg discovery still hasn't been followed up, even though I published it over fifteen years ago. Charlie and I wanted to continue in that direction, but we knew that we couldn't sustain more than one major research effort at a time. We decided that regenerative growth control was our primary target, so we reluctantly dropped osteoporosis. Fortified by our new knowledge that electricity controlled growth in bone, we returned instead to the nerves, taking a closer look at how their currents stimulated regrowth.

A Surprise in the Blood

1 felt as though the temple curtain had been drawn aside without warning and I, a goggle-eyed stranger somehow mistaken for an initiate, had been ushered into the sanctuary to witness the mystery of mysteries. I saw a phantasmagoria, a living tapestry of forms jeweled in minute detail. They danced together like guests at a rowdy wedding. They changed their shapes. Within themselves they juggled geometrical shards like the fragments in a kaleidoscope. They sent forth extensions of themselves like the flares of suns. Yet all their activity was obviously interrelated; each being's actions were in step with its neighbors'. They were like bees swarming: They obviously recognised each other and were communicating avidly, but it was impossible to know what they were saying. They enacted a pageant whose beauty awed me.

As the lights came back on, the auditorium seemed dull and unreal. I'd been watching various kinds of ordinary cells going about their daily business, as seen through a microscope and recorded by the latest time-lapse movie techniques. The filmmaker frankly admitted that neither he nor anyone else knew just what the cells were doing, or how and why they were doing it. We biologists, especially during our formative years in school, spent most of our time dissecting dead animals and studying preparations of dead cells stained to make their structures more easily visible—"painted tombstones," as someone once called them. Of course, we all knew that life was more a process than a structure, but we tended to forget this, because a structure was so much easier to study. This film reminded me how far our static concepts still were from the actual business of living. As I thought how any one of those scintillating cells potentially could become a whole speckled frog or a person, I grew surer than ever that my work so far had disclosed only a few aspects of a process-control system as varied and widespread as life itself, of which we'd been ignorant until then.

The film was shown at a workshop on fracture healing sponsored by the National Academy of Sciences in 1965. It was one of a series of meetings organized for the heads of clinical departments to educate them as to the most promising directions for research. A dynamic organizer named Jim Wray had recently become chairman of the Upstate Medical Center's department of orthopedic surgery, but Jim's superb skills were political rather than scientific. Since I was an active researcher and had just been promoted to associate professor, Jim asked me to go in his place. I tried to get out of it, because I knew my electrical bones would get a frosty reception from the big shots if I opened my mouth, but Jim prevailed. The meeting was mostly what I'd expected, but there were three bright spots. One was that microcinematic vision. Another was the chance to get acquainted with the other delegate from my department, a sharp young orthopedic surgeon named Dave Murray. The third was the presence of Dr. John J. Pritchard.

A renowned British anatomist who'd added much to our knowledge of fracture healing, Dr. Pritchard was the meeting's keynote speaker—the beneficent father-figure who was to evaluate all the papers and summarize everything at the end. Dave and I almost skipped his talk. We hadn't been impressed with the presentations, and we figured there had been so few new ideas that Pritchard would have nothing to say. However, our bus to the Washington airport didn't leave until after Pritchard's luncheon address, so we stayed. With a tact that seemed peculiarly English, he reached the same assessment we had, but phrased

it so as to offend no one. He stressed that fracture healing should be considered a vestige of regeneration. Most past work on fractures had described what happened when a bone knit, as opposed to the how and why. As Pritchard pointed out, "Not a great deal of thought has been given to the factors that initiate, guide, and control the various processes of bone repair." Just as in regeneration research, this was the most important problem about fractures, he concluded.

Dave and I had to wait several hours before our flight back to Syracuse. We sat in the airport lounge and talked excitedly about broken bones. Dave agreed that, since I'd found electrical currents in salamander limb regeneration, it was at least plausible that similar factors controlled the mending of fractures. Having just deciphered the control system for stress adaptation (Wolffs-law growth) in bone, I felt prepared to get back to the more complex problems of regeneration via its remnant in bone healing. Dave and I decided to collaborate, and we planned our experiment on the plane. We would break the same bone in a standardized way in each of a series of experimental animals. I would study the electrical forces in and around the fractures as they healed. We would kill a few of the animals at each stage of healing, and Dave, an expert histologist (cell specialist), would make microscope slides of the healing tissues and study the cellular changes. Along the way we would fit our findings together to see whether electricity was guiding the cells.

Our first task was to choose the experimental animals. We wanted to use dogs or rabbits, since ultimately we were trying to understand human bones and wanted to work with animals as closely related to us as possible. But we would need scores of them to study each phase of healing adequately, and we had neither the funds nor the facilities to house so many large mammals. We thought of rats, but their longest bones were too short to study clearly and were curved as well. We were looking for nice, long, straight bones, in which we could produce uniform breaks.

We settled on bullfrogs. They were cheap to buy and care for; we could even collect some ourselves from nearby ponds. I already had a lot of experience in working with them. Best of all, the adult frog's lower leg had one long bone—the tibia and fibula found in most vertebrates had merged into a tibiofibularis. It was about two inches long with a fine, straight shaft.

Our misgivings about the evolutionary distance between frogs and humans were allayed when we went to the library to read up on what was then known about fracture healing in frogs. Dr. Pritchard himself, along with two of his students, J. Bowden and A. J. Ruzicka, had

determined that frogs mended their bones the same way people did. Our question was: What stimulated the periosteal and marrow cells to change into new bone-forming cells?

We began by anesthetizing the animals and resolutely breaking all those little green legs by hand, bending them only to a certain angle so as not to rupture the periosteum around the fracture. I found I had to put little plaster casts on them—not because the frogs seemed in great pain but because their movements kept shifting the broken bones and making systematic observations impossible. They would have healed anyway; in our first sixty frogs we found two that had broken their legs in the wild and mended them, but I'm sure ours were the first that ever had casts.

The electrical changes were complex but were almost the same in every fracture. There were two distinct patterns, one on the periosteum and one on the bone. Before fracture the ankle end of both the bone and the periosteum had a small negative potential of less than 1 millivolt as compared to the knee end. At the moment of fracture, the negative potential on the intact periosteum over the break shot up to 6 or 7 millivolts, while areas of positive charge formed above and below the break. After a week, the periosteum's normal progression of negative charge toward the ankle was restored. When a fracture ruptured the periosteum, its negative potential went even higher than 7 millivolts, but amputation of the dangling lower leg immediately reversed the polarity, producing a positive current of injury from the stump, as in the frogs of my first regeneration experiment. The bone itself underwent a short-term electrical change opposite to that in the periosteum. A small positive charge appeared on each of the broken ends during the first hours, then fell to near zero after three hours.

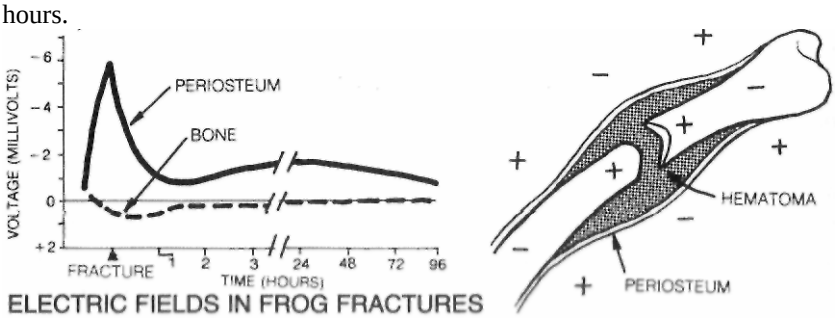

ELECTRIC FIELDS IN FROG FRACTURES

The electricity had two different sources. When cut the leg nerves, the periosteum readings dropped dramatically, indicating that these potentials were coming from currents in the nerves to the periosteum and the surrounding wound area. Measurements on the bone, which has al-

most no nerves, were unaffected. Many piezoelectric materials emit a continuous current for several hours after their charge-producing structure has been left in a state of unresolved stress by fracture; I surmised that this was true of bone and soon found that another research team had recently proven it. Two separate currents, then, one from the nerves and one from the bone matrix, were producing potentials of opposite polarity, which acted like the electrodes of a battery. These living electrodes were creating a complex field whose exact shape and strength reflected the position of the bone pieces. The limb was, in effect, taking its own X ray.

While I was busy with my probes and meters, Dave was taking samples of the bones and blood clots and preparing them for the microscope. We killed a few of the frogs every fifteen minutes during the first two hours, then every day for two weeks, every other day for the third week, and weekly for the last three weeks. Preparing the slides took several days.

In the normal sequence of bone healing in frogs, a blood clot forms after about two hours and develops into a blastema during the first week. It turns into the rubbery, fibrous callus during the second and third weeks, and ossifies in three to six weeks. In this last period, islands of bone first emerge near the broken ends. Next, bony bridges appear, connecting the islands. Then the whole area is gradually filled in and organized with the proper marrow space and blood canals to join the segments of old bone.

Dave began his work with specimens taken nearly a week after the fractures, when we expected to see the first signs of the callus forming. "This is mighty damn funny," he said as he walked in with the first box of slides. "I can't see any mitoses in the periosteum. There's no evidence that the cells there are multiplying or migrating."

We agreed that we must have done something wrong. Pritchard's work had been quite conclusive on this point. He'd even published photographs of the periosteal cells dividing and moving into the gap. We thought maybe we were looking at specimens from the wrong time period, but we could see with our own eyes that the callus was starting to form. Dave went back to study specimens from the first few days, even though we didn't expect to see much then except clotting blood. Soon he called me from his lab and asked, "What would you say if I told you that the red corpuscles change and become the new bone-forming cells?"

I groaned. "Nonsense. That can't be right." But it was right. We went over the whole slide series together. Beginning in the second hour, the erythrocytes (red cells) began to change.

All vertebrates except mammals have nuclei in their red blood cells. In mammals, these cells go through an extra stage of development in which the nucleus is discarded. The resulting cells are smaller, can flow through smaller capillaries, can be packed with more hemoglobin, and thus can carry oxygen and carbon dioxide more efficiently. Nucleated erythrocytes are considered more primitive, but even in these the nucleus is pycnotic—shriveled up and inactive. The DNA in pycnotic nuclei is dormant, and such cells have almost no metabolic activity; that is, they burn no glucose for energy and synthesize no proteins. If you had to choose a likely candidate for dedifferentiation and increased activity, this would be the worst possible choice.

In our series of slides the red cells went through all their developmental stages in reverse. First they lost their characteristic flattened, elliptical shape and became round. Their membranes acquired a scalloped outline. By the third day the cells had become ameboid and moved by means of pseudopods. Concurrently, their nuclei swelled up and, judging by changes in their reactions to staining and light, the DNA became reactivated. We began using an electron microscope to get a clearer view of these changes. At the end of the first week, the former erythrocytes had acquired a full complement of mitochondria and also ribosomes (the organelles where proteins are assembled), and they'd gotten rid of all of their hemoglobin. By the third week they'd turned into cartilage-forming cells, which soon developed further into bone-forming cells.

I wasn't happy with this turn of events. How could we reconcile what we saw with the well-documented findings of Pritchard, Bowden, and Ruzicka? I'd expected evidence for the semiconducting electrical system I'd been investigating, a concept that was already strange enough to keep me out of the scientific mainstream. I would have been happy if the electrical measurements had fit in with straightforward changes in the periosteal cells. The difference between them and erythrocytes was crucial. Periosteal cells were closely related precursors of bone cells; blood cells couldn't have been further removed. They couldn't possibly have built bone without extensive job retraining on the genetic level. These bullfrogs were bringing us up hard against a wall of dogma by showing us metaplasia—dedifferentiation followed by redifferentiation into a totally unrelated cell type. The process took place in some of the most specialized cells in the frog's entire body, and it looked as though the electric field set the changes in motion while at its strongest, about an hour after the fracture.

Our next move was a respectful letter to Dr. Pritchard asking if there

was any way he could make sense of the contradictory observations. He replied in the negative but sent our inquiry to Dr. Bowden, who had done the actual work on frogs as his doctoral thesis. Bowden had a possible explanation. He'd done the experimental work under a time limit, and to finish before the deadline he'd kept his frogs at high temperatures—only a few degrees short of killing them, in fact—in order to speed up their metabolism.

Bowden also mentioned that two researchers cited in his bibliography had seen fracture healing in frogs much the same way we had. In the 1920s, a German named H. Wurmbach, also working on his doctorate, noted some strange cellular transformations in the blood clot and worried over his inability to explain them. However, Wurmbach also found mitoses in the periosteum and ascribed healing to the latter process, since it didn't involve dedifferentiation. A decade later, another German scientist, A. Ide-Rozas, saw the same changes in the blood cells, but he was more daring. He proposed that this transformation was the major force behind fracture healing in frogs and further suggested that regenerating salamanders formed their limb blastemas from nucleated red blood cells. Other experiments seemed to contradict Ide-Rozas' idea about limb blastemas, so his work was discredited and ignored, but Bowden wished us better luck.

Bowden's letter gave us a framework for understanding our results. We already knew that mammals did not heal bones by dedifferentiation of their red corpuscles, because their red cells had no nuclei and thus no mechanism for change. Mammals also had a thicker periosteum than other vertebrates, so we reasoned that periosteal cell division played a larger healing role in mammals. Frogs, it seemed, had both methods available but activated the periosteal cells only at high temperatures.

Do-lt-Yourself Dedifferentiation

Now we were sure that our results were real. We repeated the same fracture studies, but this time we also observed the cells while they were alive. We took tissue samples from the fractures and made time-lapse film sequences using techniques like those in the movie that had impressed me so much at the NAS workshop. We confirmed that the changes began in the first lew hours, just after the electrical forces reached their peak.

Now we decided to try a crucial test. If the electricity really triggered healing, we should be able to reproduce the same field artificially and start

the same changes in normal blood cells outside the frog. If this didn't work, then I probably had spent the last seven years "collecting stamps"—accumulating facts that were interesting but, in the end, trivial.

I calculated the amount of current that would produce the fields I'd found. I came up with an incredibly small amount, somewhere between a trillionth and a billionth of an ampere (a picoamp and a nanoamp, respectively). Again I thought there must be some mistake. I didn't see how such a tiny current could produce the dramatic effects we'd seen, so, figuring that even if my numbers were right, more juice would simply hasten the process, I decided to start with 50 microamps, a current level that would be just shy of producing a little electrolysis—the breakdown of water into hydrogen and oxygen.

I designed plastic and glass chambers of various shapes, fitted with electrodes of several types. In these chambers we would place healthy red blood cells in saline solution and observe them by microscope while the current was on.

I set up the experiment in a lab across the street from the medical center, where there was available one of the inverted microscopes we would need to observe the cells through the bottoms of the chambers, where most of them would settle. I put a young technician named Frederick Brown in charge of the long grind of watching the cells hour after hour at different current levels and field shapes in the various chambers. We began in the summer of 1966. Fred was to enter medical school that fall, and I figured two months would be more than enough time! He was to run one test batch of frog blood each day and report to me the next morning as to what he'd found.

It didn't start well. Nothing had happened after six hours of current. We couldn't increase the amperage without electrocuting the cells, so we ran it longer. Still nothing happened. In fact, the cells started dying when we left them in the chambers overnight. We decided to lower the current, but I still didn't believe in the absurdly low values I'd calculated, so I told Fred to drop the amperage only a little bit day by day. He and I stared at a lot of blood cells over those two months, all stubbornly refusing to do anything. Finally, two days before Fred had to leave, we'd gotten the current down as far as our first apparatus could go, and well within the range I'd calculated—about half a billionth of an ampere. At eleven that morning he called me excitedly and I rushed across the street.

With the room darkened and the microscope light on, we saw the same cell changes as in the blood clot, first at the negative electrode, then at the positive electrode, and finally spreading across the rest of the

chamber. In four hours all the blood cells in the chamber had reactivated their nuclei, lost their hemoglobin, and become completely unspecialized in form.

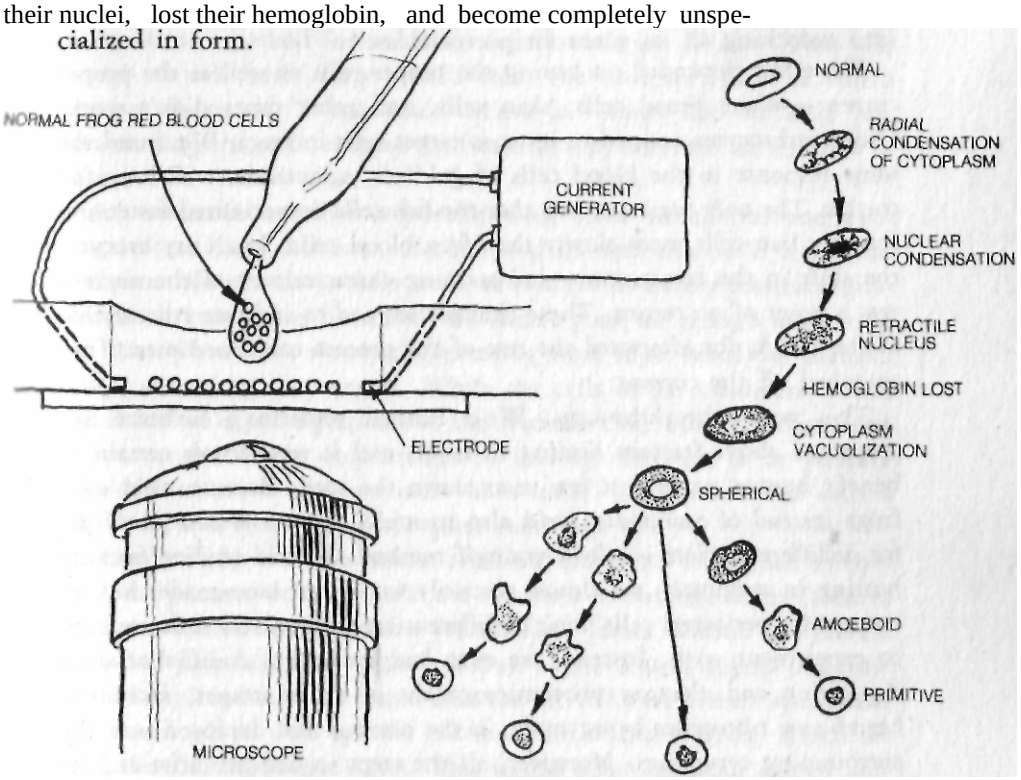

THE FIRST ARTIFICIAL DEDIFFERENTIATE

We repeated the experiment many times, working out the upper and lower limits of the effective current. The best "window" was somewhere between 200 and 700 picoamps. I say "somewhere" because the susceptibility of the cells varied, depending on their age, the hormonal state of the frog, and possibly other factors.* This was an infinitesimal tickle of

* Rather than continually renewing a small part of their red-cell stock, frogs generate a whole year's supply in late winter as they emerge from hibernation. Thus, all their erythrocytes age uniformly as the year progresses. The cells become less sensitive to electricity as they get older, and that may be why frogs, even when warm and not hibernating, heal fractures more slowly in winter. The red blood cells dedifferentiate most readily in the spring, and the female's become even more sensitive than the male's when she ovulates early in that season. At that time her red corpuscles will despecialize in response to less than one picoamp. In fact, we saw red cells from ovulating females dedifferentiate completely in chambers to which we supplied no current whatever. Apparently an unmeasurably small current created by the charge difference between the plastic chamber and glass cover slip was enough.

electricity, far less than anything a human could feel even on the most sensitive tissue, such as the tongue, but it was enough to goose the cell into unlocking all its genes for potential use.

The effect depended on having the proper cells as well as the proper current—white blood cells, skin cells, and other types didn't work. Only erythrocytes seemed to serve as target cells in frogs. We found the same response in the blood cells of goldfish, salamanders, snakes, and turtles. The only variation was that the fish cells despecialized faster and the reptilian cells more slowly than frog blood cells. In all erythrocytes the shift in the transparency and staining characteristics of the nucleus was a point of no return. These changes seemed to indicate reactivation of the DNA, for afterward the rest of the process continued even if we switched off the current.

This was a breakthrough. We'd learned something hitherto unsuspected about fracture healing in frogs, and it was almost certain to benefit human patients a few years down the road. Because we'd used frogs instead of mammals, we'd also stumbled upon the best proof yet for dedifferentiation—a do-it-yourself method. If we'd studied fracture healing in mammals, we almost certainly would not have made the discovery, for periosteal cells don't dedifferentiate and marrow cells are hard to experiment with. Instead, we even had movies of dedifferentiation happening and electron photomicrographs of air its stages, including brand-new ribosomes being made in the nucleus and deployed into the surrounding cytoplasm. Moreover, all the steps in dedifferentiation, including the activities in the nucleus and the assembly of ribosomes and mitochondria, exactly paralleled the changes found by the most recent research on salamander limb blastemas. We'd found the electrical common denominator that started the first phase—the blastema—in all regeneration.

The Genetic Key

Soon after we'd finished this experiment, I was invited to a meeting on electromagnetism in biology at the New York Academy of Sciences. This was basically a one-man show. Kenneth MacLean, a prominent surgeon and highly placed member of the academy, had been using magnetic fields on his patients for years and was convinced that they helped. Independently wealthy, he'd set up a lab in his office, with a large electromagnet. The meeting was a testament to his persistence rather than any widespread belief within the academy that he was right. So in Feb-

ruary 1967 I presented our recent work. I played down the full role of electricity in fracture healing, with its overtones of vitalism, and concentrated on our method for inducing dedifferentiation in vitro. That was enough to call forth many attacks from the audience, most of which were variations on "I just don't believe it." Some said we were just electrocuting the cells, despite the fact that they survived for ten days in culture.

One audience member responded with some thoughtful and constructive criticism, however. He accepted the fact that we'd seen what we'd seen. Nevertheless, there were, he said, other barely possible explanations. In particular, he stated, we hadn't gone far enough in proving that the cells weren't slowly degenerating from some small but harmful change caused by the current. While the cells in our chambers looked like those we'd photographed in the fracture clot, our idea that these cells were electrically dedifferentiated healing cells was so at variance with current views that we must have more direct proof. For such a radical departure, seeing wasn't quite believing.

Stimulated by this one honest reaction, Dave and I returned to Syracuse and planned how we could use the latest knowledge about DNA to test our evidence further. A few years before, James Watson and Francis Crick had proposed what became known as the central dogma of genetics. In simplified form, it stated that the active DNA in each specialized cell imprinted its own specific patterns onto transfer RNA, which relayed them to messenger RNA. This second RNA molecule moved outside the nucleus to the ribosomes, where it translated the genetic instructions into the particular proteins that made the cell what it was.

We reasoned that, since a dedifferentiating cell was not going to divide immediately, it wouldn't duplicate its genes. Therefore there should be no increase in the amount of DNA it contained. However, since the cell changed its type by manufacturing a whole new set of proteins, the amount of RNA—the protein blueprints—should increase dramatically.

Using radioactive labeling and fluorescent staining techniques, we found there was indeed no new DNA but dramatic increases in RNA. Another test showed that our despecialized cells contained not only different proteins but also twice as many as their precursor red blood cells.

The most conclusive experiment was one suggested by Dan Harrington, a student who'd taken Fred Brown's place and who later went on to a Ph.D. in anatomy. Dan proposed that we use certain well-known metabolic inhibitors that disrupt the DNA-RNA-protein system, to see if we could prevent dedifferentiation. One such inhibitor, an antibiotic

called puromycin, blocks the transfer of information from messenger RNA to the ribosomes and thus prevents proteins from being built. Dan proposed that we set up our plastic chambers in pairs. In one member of each pair we would place blood cells in saline solution and pass current through them as before. The other chamber would contain cells from the same frog and be connected to the same generator, but the solution would contain puromycin. The setup would thus be precisely controlled. If the current was actually unlocking new genes, the puromycin should stop dedifferentiation by intercepting the DNA's protein-making instructions. If the current was merely making the cells degenerate, however, the puromycin should have no effect and the transformations should continue.

Our conclusion held up: The cells in the puromycin solution didn't change. Next Dan suggested that we bathe these cells with several changes of water to wash out the puromycin. They promptly dedifferentiated with no current flowing! Apparently the current caused the genetic change in spite of the antibiotic, and the genes stayed unlocked, so the system still worked perfectly as soon as the puromycin blockade was lifted.

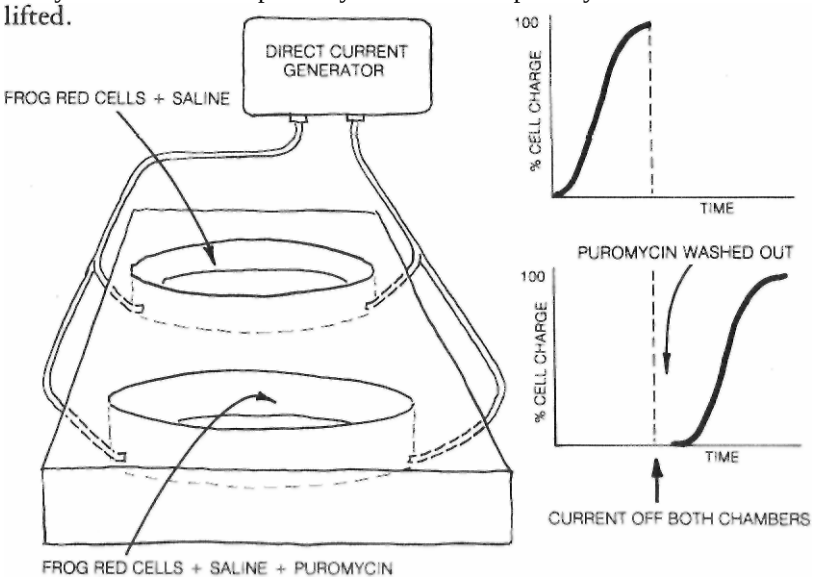

THE RNA BLOCKADE CONFIRMS ELECTRICAL DEDIFFERENTIATION

By early 1970 we had solid proof for nearly every detail of the control system for fracture healing in frogs, and by extension probably in mammals as well. Like all other injuries, a fracture produced a current of injury, in this case derived from the nerves in and around the per-

iosteum.* At the same time, the bone generated its own current piezoelectrically due to residual stress in the mangled apatite-collagen matrix. These signals combined to stimulate the cells that formed new bone.

Except for the identity of the target cells, bone repair seemed to be basically the same in all vertebrates, proceeding through the stages of blood clot, blastema, callus, and ossification. In fish, amphibians, reptiles, and birds, the red cells in the clot dedifferentiated in response to the electric field, especially the positive potentials at the broken ends of the bone. They then redifferentiated as cartilage cells and continued on to become bone cells.

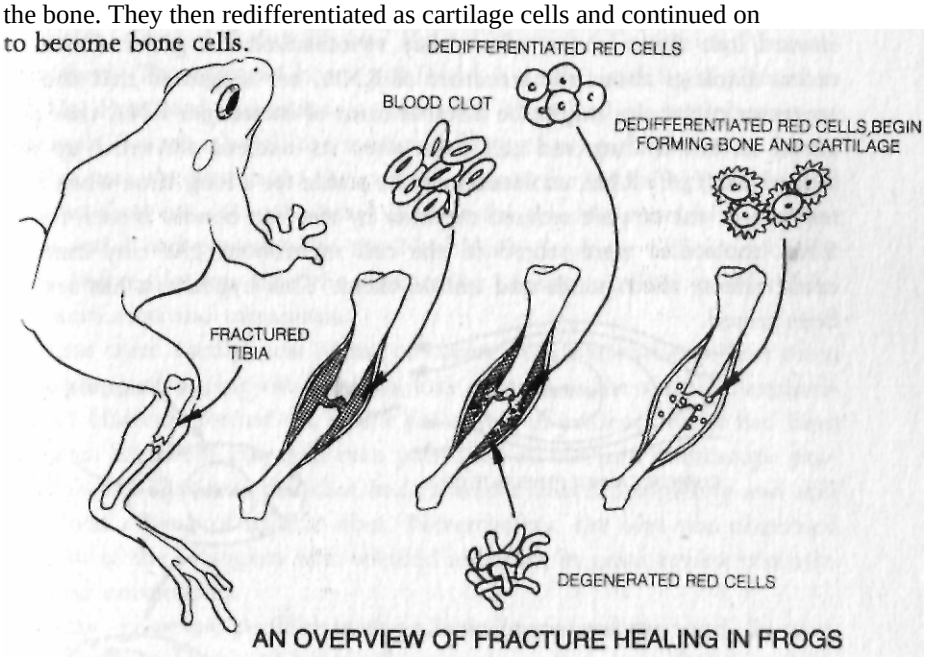

AN OVERVIEW OF FRACTURE HEALING IN FROGS

In some animals the periosteal cells responded to the current of injury by migrating into the gap and specializing a bit further into bone cells. This process seemed to be available to amphibians only at high temperatures, but it was the dominant method in mammals, whose thick periosteum made up for the lack of nuclei in their red corpuscles. By this time we'd become pretty sure that the marrow component of bone healing in humans involved the dedifferentiation of at least the immature

*The lack of the periosteal (nerve-derived) current may explain the uncontrolled, deformed growth that often follows fractures in the limbs of paraplegics and lepers. Their bones still generate a positive potential in the gap, but because of nerve damage it isn't balanced by the negative periosteal potential that normally surrounds the break.

erythrocytes, which still contained a nucleus, and possibly other cell types.

The electrical forces turned the key that unlocked the repressed genes. The exact nature of that key was the one part still missing from the process. The current couldn't act directly on the nucleus, which was insulated by the cell's membrane and cytoplasm. We knew that the current's primary effect had to be on the membrane. The cell membrane itself was known to be charged. Its charge probably occurred as a specific pattern of charged molecules, different for each type of cell. We postulated that the membrane released derepressors—molecules that migrated inward into the nucleus, where they switched on the genes. Based on recent findings about the structure of RNA, we suggested that the derepressor molecules might be a stable form of messenger RNA that persisted in the mature red cell even after its nucleus shriveled up and turned itself off. RNA molecules can be stable for a long time when they are folded, the strands secured together by electron bonds. If such folded RNA molecules were stored in the cell membrane, the tiny currents could release their bonds and unfold them. This hypothesis has not yet been tested.

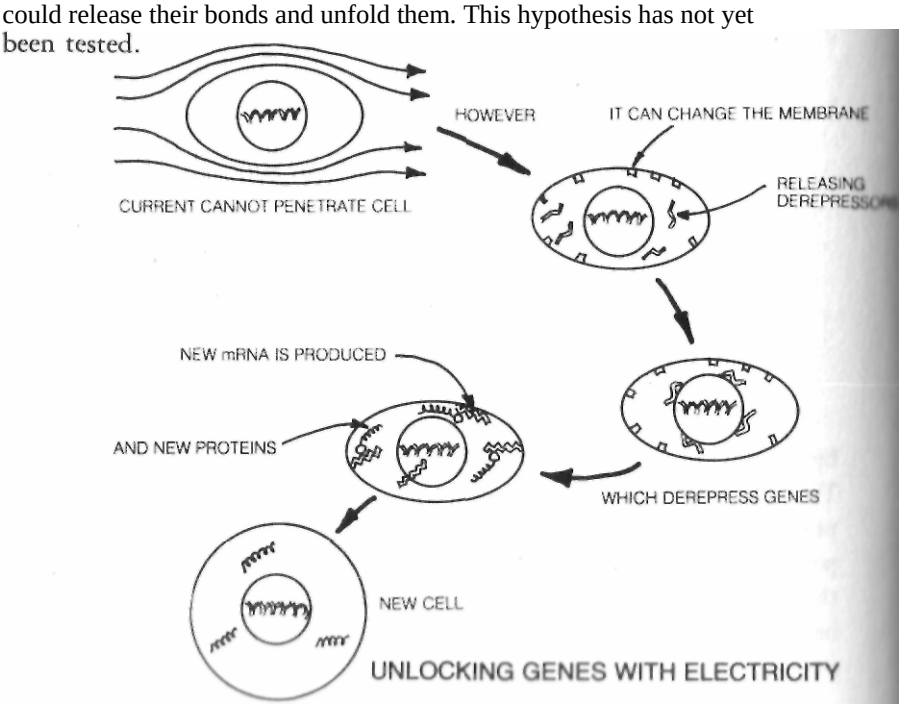

Fracture healing was ended by a straightforward negative-feedback system. As the gap was filled in with new matrix, the bone gradually redistributed its material to balance the stresses on it from the action of

the surrounding muscles during cautious use, in accordance with Wolff's law. Repair of surrounding tissues lessened and then stopped the periosteal injury current. As a result the electrical field returned to normal, shutting off the cellular activities of healing.

When we'd finished this series of experiments, I was sure this was the most important piece of work I would ever do, and I was determined to get it published as a major article, not just a short note. Luck was with me. On several speaking engagements during the previous two years I'd been able to talk at length with Dr. Urist. He was enthusiastic about our findings, and since he was the editor of one of the major orthopedic journals—Clinical Orthopedics and Related Research—I submitted our report there. The editorial board published it uncut, and I was pleased to use Dr. Pritchard's statement at the 1965 bone-healing workshop as an epigraph. To me it's still the most satisfying of my publications.

This was the first time the control system for a healing process had been worked out in such detail. Except for the less conclusive account Dave and I had presented to the New York Academy of Sciences three years before, it was also the first really incontrovertible proof of dedifferentiation and metaplasia.

These were hardly new ideas, of course. Dedifferentiation had often been proposed during the previous four decades as the simplest explanation of blastema formation, and a great deal of evidence for it had been amassed. Elizabeth Hay had even published an electron microscope photograph of a blastema cell that hadn't despecialized completely and still contained a piece of muscle fiber. Nevertheless, the idea was dismissed by most of the biologists who wielded influence in grant review committees and universities.

Today, however, dedifferentiation is no longer a dirty word. In part, this is because Dave and I devised a way to produce it artificially, which could be repeated by anyone who cared to. Art Pilla, an electrochemist working with Andy Bassett in New York, was the first to confirm our method. I'm happy to have been able to play a major role in this hard-won advance of knowledge.

Even more important, this was the first work of mine that led directly to a technique that helped patients—electrical stimulation of bone healing (see Chapter 8). Meanwhile, our results led to another major question: Couldn't the currents we'd found be used artificially to stimulate other types of regeneration? We decided to see if we could bring limb regrowth a step closer to humans by trying to induce it in rats.

Seven
Good News for Mammals

Stephen D. Smith was the first to induce artificial regrowth with electricity applied to the limb of a nonregenerating animal. In 1967 Smith, setting forth on his own at the University of Kentucky after his apprenticeship to Meryl Rose at Tulane, implanted tiny batteries in adult frogs' leg stumps. I followed his work eagerly and was elated to hear that he'd gotten the same amount of partial regrowth that had resulted from Rose's salt, Polezhaev's needles, and Singer's rerouted nerves. Of all the experiments that have influenced me, this was probably the one that encouraged me the most.

For a battery that was small and weak enough, Smith had returned to the simple technology of Galvani and Volta. He soldered a short piece of silver wire to an equal length of platinum wire, and put some silicone insulation around the solder joint. He chose these two metals as being the least likely to release ions and produce spurious effects by reacting with the surrounding tissue. When immersed in a frog's slightly saline body fluids, this bimetallic device produced a tiny current whose voltage was positive at the silver end and negative at the platinum end.

Since our work on frog erythrocytes hadn't yet been published, it was sheer luck that the current from these batteries fell close to the "window of effectiveness" for blastema formation. As Smith later wrote: "It would he nice to be able to say that I had worked out all the parameters in advance, and knew exactly what I was doing, but such was not the case. As so often has happened in the history of science, I stumbled onto the right procedure."

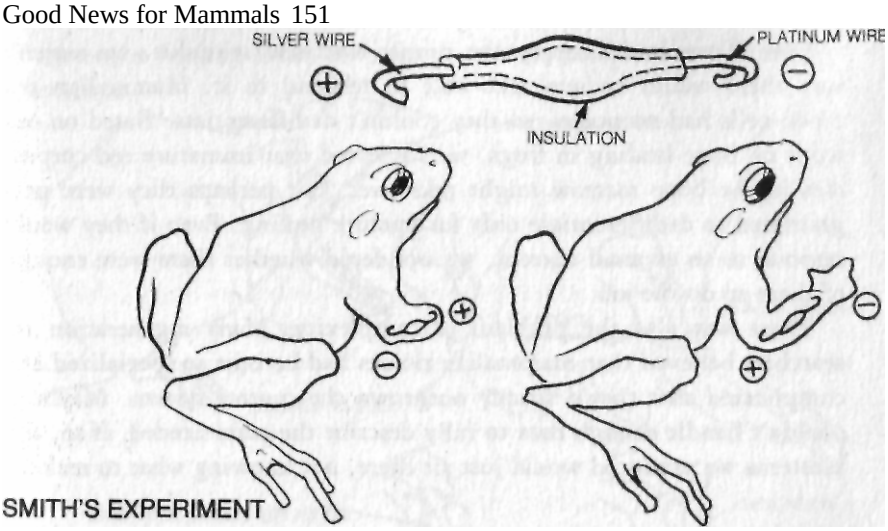

SMITH'S EXPERIMENT

Smith implanted his wires along the bone remnant, with one end bent over into the marrow cavity. The limbs with the positive silver electrode at the cut showed no growth, and in some cases tissue actually disintegrated. The negative platinum ends, however, started regeneration; the new limbs all stopped growing at about the same distance from the device, suggesting that regeneration might have been complete if the batteries had been able to follow along. In 1974 Smith made a device that could do just that, and achieved full regrowth.

Despite Smith's success, there was no reason to suppose that his method would work in mammals. One researcher had recently noted some regeneration in the hind legs of newborn opossums, but, since marsupials are born very immature and develop in the mother's pouch to a second birth, we suspected that this was merely a case of embryonic regrowth. Most fetal tissues were known to have some regenerative ability while they weren't yet fully differentiated. Richard Goss had shown that the yearly regrowth of deer and elk antlers was true multitissue regeneration, but this feat seemed too specialized to make us confident about restitution in other mammals or other parts of the body.

Many thought all such attempts were doomed, because the process of encephalization had progressed much further in mammals than amphibians. All vertebrates were known to have roughly the same ratio of nerve tissue to other kinds of tissue, but in mammals most of the limited nerve supply went into the ever more complex brain, until, as Singer had shown in a recent study, the proportion of nerve to other tissue in rat legs was 80 percent less than in salamander legs. This was well below the critical mass needed for normal regeneration, and we thought it might be impossible to make up the difference artificially.

Even if we could supply the proper electrical stimulus, we weren't sure there would be any cells able to respond to it. Mammalian red blood cells had no nuclei, so they couldn't dedifferentiate. Based on our work on bone healing in frogs, we suspected that immature red corpuscles in the bone marrow might take over, but perhaps they were programmed to dedifferentiate only for fracture healing. Even if they would respond to an external current, we wondered whether there were enough of them to do the job.

There was also the problem of complexity. Many regeneration researchers believed that mammalian tissues had become so specialized and complicated that they'd simply outgrown the control system. Maybe it couldn't handle enough data to fully describe the parts needed. If so, any blastema we produced would just sit there, not knowing what to make.

A First Step with a Rat Leg

I tested the kind of silver-platinum couplings Smith used and found they delivered several times too much current for ideal dedifferentiation, according to our frog experiments. Joe Spadaro, another of Charlie's grad students, suggested that we put carbon resistors between the two metals, giving us devices of various current levels.

In 1971, Joe and I amputated the right forelegs of thirty-five rats. We made the cuts through the upper foreleg well away from the elbow so that only the bone shaft, which had long ago ceased growing, would remain at the tip. We used all males, to obviate as many hormonal variables as possible. As controls we treated some of the stumps with no device, or one made of a single metal, or one with the silver positive end facing the stump. We did the actual test on twenty-two of the rats, implanting our batteries with the negative platinum electrode at the wound. We tucked the outer electrode into the marrow cavity and sutured the inner one to the skin of the shoulder.

We had an answer fast. After three days the stumps of the controls had begun to heal over or even, in the case of the highest-current couplings, die back a little behind the amputation line. But the experimental legs with our medium-current devices, supplying 1 nanoamp, were doing well. In a week, nearly every one had a well-formed blastema and seemed ready to replace the whole limb.

Since healing is very fast in rats, and because we wanted a uniform sample for our first test, we sacrificed all of the controls and most of the test animals at this time, although we spared a few for a month. We cut

off the entire healing limb, then fixed, stained, and sectioned it for the microscope.

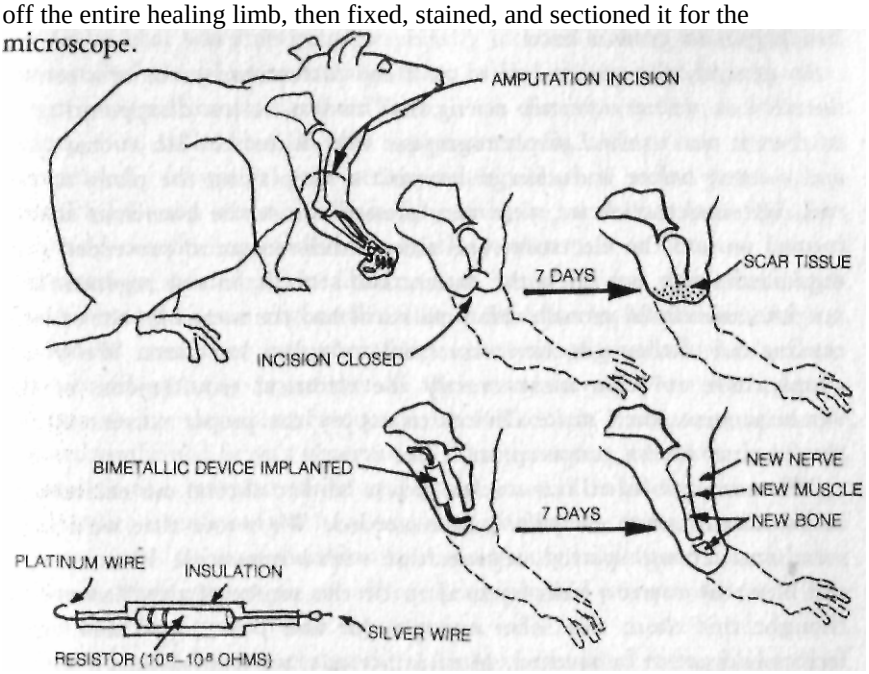

DC STARTS LIMB REGENERATION IN RATS

I shall never forget looking at the first batch of specimens. The rat had regrown a shaft of bone extending from the severed humerus. At the proper length to complete the original bone there was a typical transverse growth plate of cartilage, its complex anatomical structure perfectly regular. Beyond that was a fine-looking epiphysis, the articulated knob at each end of a limb bone. Along the shaft were newly forming muscles, blood vessels, and nerves. At least ten different kinds of cells had differentiated out from the blastema, and we'd succeeded in getting regeneration from a mammal to the same extent as Rose, Polezhaev, Singer, and Smith had done in frogs.

Slides from some of the other animals were even more spectacular. One stump had two cartilaginous deposits that looked like precursors of the two lower arm bones beyond a fully formed elbow joint. All of the regenerates were bent toward the electrode, and in one the lower humerus had formed alongside the old shaft rather than as an extension of it, but otherwise its structure was quite normal.

With one exception, slides from longer than a week were less exciting. They seemed to have gotten less organized as time went on. Behind one of these older slastemas, at the end of a nearly unformed

ghost of a bone, we found cartilage in a five-fingered shape—this limb had begun to grow a hand.

In general, though, it looked as if the current had to be of a certain duration as well as a certain strength. This was no less disappointing to us than it was to the Life photographer who visited the lab at that time and wanted before and after shots with a rat playing the piano at the end, but nonetheless we were very pleased. Since the blastemas always formed around the electrodes and since redifferentiation proceeded into organized tissue, we knew the current had stimulated true regeneration, not some abnormal growth. Mammals still had the means for the orderly reading out of their genetic instructions to replace lost parts. We would simply have to learn more exactly the electrical requirements of the whole process, then make devices to supply the proper current at the proper time in the proper place.

When we published our results, it was hard to shroud our excitement in the circumspect scientific jargon needed. We wrote that we'd activated true, though partial, regeneration with a minuscule direct current and that the marrow cells seemed to be the source of the blastema. I thought this claim was sober enough. Joe and I cautioned that other factors had yet to be studied. Most important, we warned that if such a tiny force could so easily switch on growth, it must be very powerful, and we'd best know it thoroughly before using it routinely on humans, lest we give them unwelcome growths—tumors.

I felt that, within the constraints of scientific propriety, we'd uttered a rousing call for a big research push to open up the benefits of regeneration to humans. It must have been a whisper, though, for it caused no more ripples than a feather settling on a frog pond.

Philip Person, a dental surgeon at the Brooklyn VA hospital and a friend whom I'd known for years, asked me to present our results to the New York Academy of Medicine. Before the academy would permit this, however, it insisted that two experts must visit the lab and look at the actual data. One was Marc Singer, who enthusiastically agreed that we'd really started regeneration in the rat. The other man was totally negative, but he wasn't a specialist in regeneration, so the academy permitted me to speak.

Singer was one of the few who showed much enthusiasm when I'd finished reading my paper at the meeting. Most of the audience was unresponsive, there were few comments or criticisms To these people, electric growth control was still a vitalistic impossibility, and they seemed unwilling to discuss dedilfferentation. The man who'd visited our lab with Singercomplained that the amount of new growth was

small. Phil pointed out that it wasn't the quantity but the quality of new tissue that was important, especially in such a short time. Singer, convinced of the paramount importance of the nerves, thought the current might be stimulating them rather than directly causing dedifferentiation, but still thought the experiment was a big step forward. Nevertheless, it wasn't even attempted again until seven years later, when Phil Person himself took on the task; he, and later Steve Smith, confirmed our findings with even better results.

Meanwhile, buried in the literature we found reports that others had already observed some regeneration in mammals. In 1934 Hans Selye, the famous researcher into the effects of stress, discovered that a rat's limbs could partially regenerate of their own accord when the animal was two to five days old. Five years later Rudolph F. Nunnemacher of Harvard confirmed Selye's observation. Nunnemacher, however, ascribed the growth to a remnant of the epiphyseal plate. The growth-plate cells, he thought, simply might have kept on growing as normal in the adolescent animal. Selye replied that he'd specifically made sure to amputate the limbs high enough to get all of the epiphyseal plate so he could be certain that any growth was regenerative.

Thus Joe and I found that we'd really just extended the age limit for regeneration in the rat. Indeed, two years later Phil Person showed that even the young adult rats we'd used occasionally exhibited some regrowth, a fact that had puzzled us in a couple of our control animals. So, to be exact, our electrodes had temporarily but drastically boosted the efficiency of the process as it normally waned with age in the rodent. Still, it was the first time that had ever been done in a mammal.

Childhood Powers, Adult Prospects

The amputation of a fingertip—by a car door, lawn mower, electric fan, or whatever—is one of the most common childhood injuries. The standard treatment is to smooth the exposed bone and stitch the skin closed, or, if the digit has been retrieved and was cleanly cut, to try to reattach it by microsurgery. The sad fact is that even the most painstaking surgery gives less than optimal results. The nails are usually deformed or missing, and the fingers are too short and often painful, with a diminished or absent sense of touch.

In the early 1970s at the emergency room of Sheffield Children's Hospital in England, one youngster with such an injury benefited from a clerical mixup The attending physician dressed the wound, but cus-

tomary referral to a surgeon for closure was never made. When the error was caught a few days later, surgeon Cynthia Illingworth noticed that the fingertip was regenerating! She merely watched nature take its course.

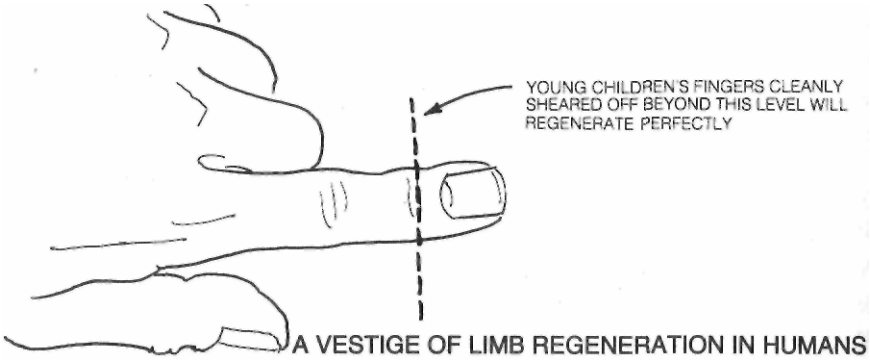

A VESTIGE OF LIMB REGENERATION IN HUMANS

Illingworth began treating other children with such "neglect," and by 1974 she'd documented several hundred regrown fingertips, all in children eleven years old or younger. Other clinical studies have since confirmed that young children's fingers cleanly sheared off beyond the outermost crease of the outermost joint will invariably regrow perfectly in about three months. This crease seems to be a sharp dividing line, with no intermediate zone between perfect restoration and none at all.

Some pediatric surgeons, like Michael Bleicher of New York's Mount Sinai Hospital, have become so confident in the infallibility of the process that they'll finish amputating a fingertip that's just hanging by a bit of flesh. A lost one will regenerate as good as new, whereas one that has merely been mutilated will heal as a stump or with heavy scarring.

Fingertip regrowth is true multitissue regeneration. A blastema appears and redifferentiates into bone, cartilage, tendon, blood vessels, skin, nail, cuticle, fingerprint, motor nerve, and the half-dozen specialized sensory-nerve endings in the skin. Like limb regeneration in salamanders, this process only occurs if the wound isn't covered by a flap of skin, as in the usual surgical treatment. Illingworth and her coworker Anthony Barker have since measured a negative current of injury leaving the stump.

Sadly, natural replacement has been accepted only at a few hospitals. Bleicher laments his colleagues' resistance to the evidence: "Mention it to young residents just our of the training program, and they look at you as though you're crazy. Describe it on grand rounds or at other institutions, and they tell you it's hogwash." Nearly all surgeons cling instead to flashier and vastly more expensive yet less effective microsurgical techniques or simple stitches and stunted fingers.

This discovery and our own research indicated that the potential for at least some artificial regeneration was clearly quite good in young mammals. But what about the ones who needed it most—us older folks whose parts were more likely to be injured or broken down? The answer came unexpectedly several years later, in a way that showed the futility of adhering too rigidly to one's original plan. The scientist must be free to follow unexpected paths as they appear.

I always expected each of my associates, whether student or established researcher, to follow some independent project unrelated to our work together. In 1979, a young assistant named James Cullen (now a Ph.D. investigator in anatomy at the Syracuse VA hospital) proposed to study what would happen if nerves were implanted into the bone marrow of rats. Jim thought the nerves should induce new bone to form in the marrow cavity. Since the idea seemed logical and the technique might supplement the electrical bone-healing devices we'd developed by then, I encouraged him to go ahead.

Jim ran into technical problems right away. He could easily dissect the rat's sciatic nerve out of the hind leg, but getting it into the marrow cavity through a hole drilled in the thighbone was like trying to push a strand of limp spaghetti through a keyhole. He resorted to drilling two holes in the femur, passing a wire suture into the outer one, up the femur, and out the hole nearer the hip. Then he looped the wire around the nerve and pulled it into the marrow cavity using the suture. However, after doing a number of these, Jim decided that there had to be a better way. He decided to amputate the rat's hind leg halfway between the hip and the knee. He could then drill a hole into the marrow cavity just below the hip, pass a suture through it, and pull the nerve down the cavity and out the end of the bone remnant. This was much easier and made a better connection of nerve to bone, so Jim prepared a number of animals this way, only to find that the nerve had a disconcerting tendency to pull back, out of the femur. The amputation didn't faze the rats; they used the stump vigorously, and this caused the nerve to retract.

In those few animals whose nerve had stayed in place, an interesting bone formation had appeared in the marrow cavity. To secure the nerve and look for the same result in other animals, Jim sutured the nerve to the skin that we closed back over the stump. The stitch held the nerve in place, all right, but one animal so treated gave us a totally unpredicted and fascinating result: The missing portion of the femur partially regenerated. While this was surprising enough, the most startling fact was that Jim had used a group of surplus rats about six month old.

These rats were well into adulthood , when mammals were thought to

lose all powers of regeneration except fracture healing. What had happened?

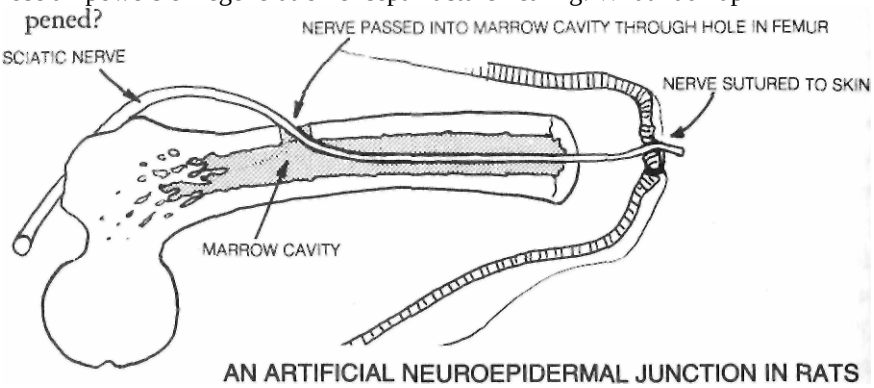

AN ARTIFICIAL NEUROEPIDERMAL JUNCTION IN RATS

Closer examination revealed that we'd made a hole in the skin when we sutured the nerve to it. The nerve appeared to have grown into contact with the epidermis. One of the requirements for normal regeneration of a salamander limb was a neuroepidermal junction, and it looked as though this had formed spontaneously in our one lucky rat when the two tissues were brought together by surgery.

We changed the course of the experiment by operating on the other rats to unite the sciatic nerve and epidermis, after scraping away the dermis. We used animals of various ages. The results exceeded our expectations. Even the old rats regenerated their thighbones and much of the surrounding tissue.

This offered an unparalleled opportunity to find out what it was about the neuroepidermal junction that was so important. We prepared one group of animals with a surgical neuroepidermal junction exactly as before. We prepared a second group the same way, except that we sutured the nerve to the end of the bone, a millimeter away from the hole and with no contact with the epidermis. The first group regenerated, while the second group showed normal rat healing with no growth. The important observation, however, came from electrical measurements we made every day on the stumps. In those animals that formed a neuroepidermal junction, we found electrical potentials following the same curve I'd found in the salamander. The voltage was about ten times as high, but the pattern was exactly the same. In the animals having no neuroepidermal junction, the potentials followed the same curve as in the nonregenerating frog.

We'd discovered that the specific electrical activity that started regeneration was produced by the neuroepidermal junction, not by the simple bulk of nerve in the limb. My original that the direct-

current control system was located in the nerves now had to be expanded to include the electrical properties of the epidermis as well. The nerve fibers joined the epidermal cells like plugs into sockets to complete the exact circuit needed for a dedifferentiative current. Furthermore, since the neuroepidermal junction was located over the end of the stump, it continually produced blastemal cells exactly where needed, at the growing tip. This discovery was enormously important, then, because it proved beyond doubt that the electrical current was the primary stimulus that began the regenerative process, and that it could operate even in mammals.

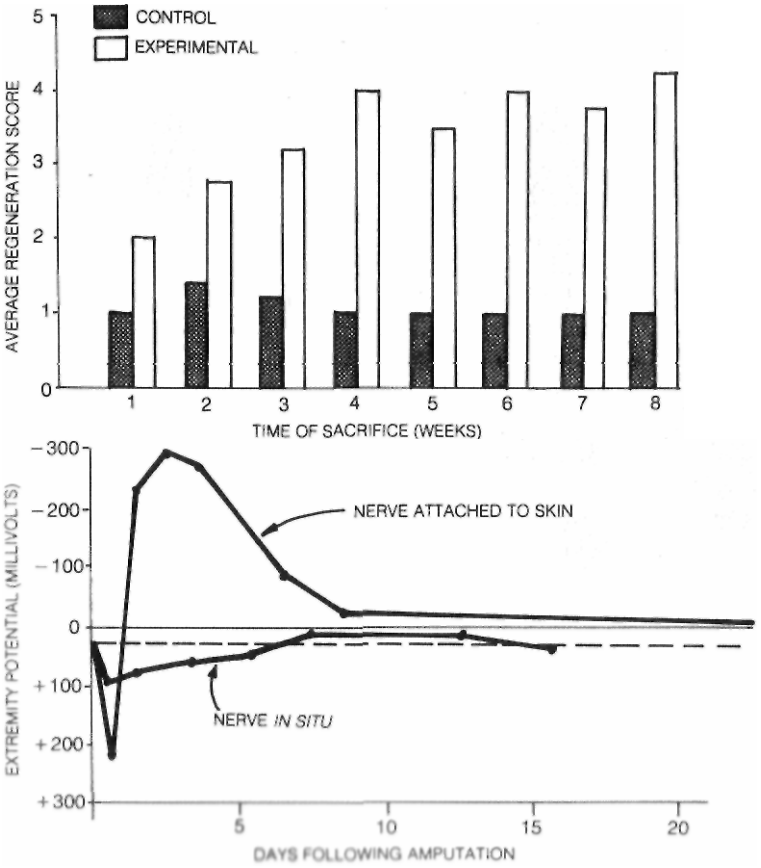

PRODUCING A REGENERATION CURRENT IN RATS

Another experiment showed us a formidable obstacle, however. In an additional series of rats we made a neuroepidermal junction, not at the end of the amputation stump, but on the side of the leg. There we measured the same "regenerative" electrical changes, but nothing happened. There was no growth. This meant that there were no sensitive cells at this site—no cells able to dedifferentiate in response to the current. In mammals, it seemed, such cells were found only in the bone marrow, a sparse cell population to serve as a source of raw material, especially in adult animals.

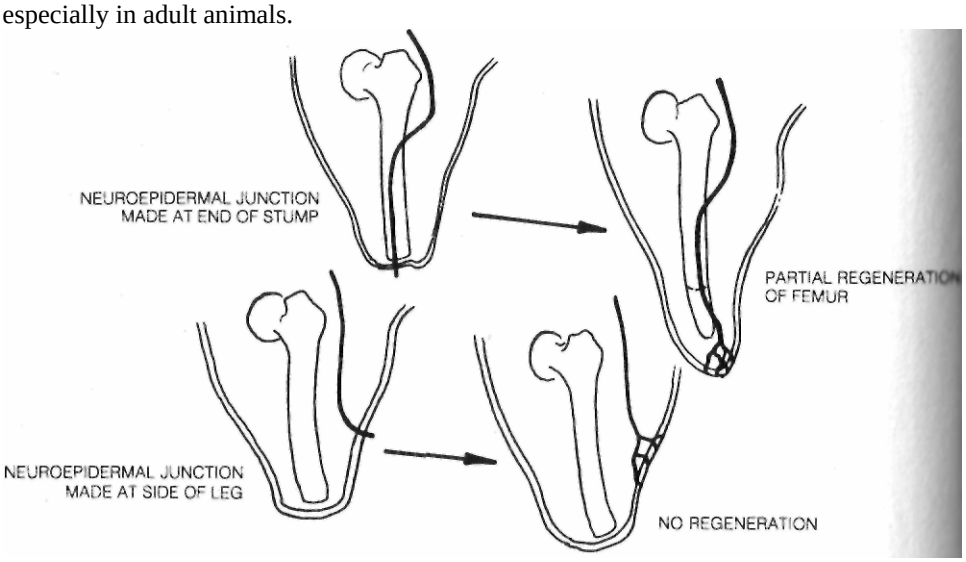

AN ARTIFICIAL NEUROEPIDERMAL JUNCTION STARTS REGROWTH IN RATS

This explained why we never got complete regrowth in any of our rats. The results were typical of an inadequate blastema. There weren't enough sensitive cells in the bone marrow to make a blastema big enough to produce a whole leg. The prospects for full limb regeneration in humans, then, looked very dim—unless we could come up with a way of making other cells electrically sensitive so as to transform them into despecialized blastemal cells. Luckily, while working on a completely different problem described in the following chapter, we stumbled upon a way to do just that.

Part 3
Our Hidden Healing Energy

Disease [is] not an entity, but a fluctuating condition of the patient's body, a battle between the substance of disease and the natural self-healing tendency of the body.
—Hippocrates

Eight
The Silver Wand

When Apollo whisked Aeneas off the field of battle before Troy, he healed the hero's shattered thighbone in a matter of minutes. Without a god at the bedside, the process takes three to six months, and sometimes it fails. If the bones didn't knit, the limb formerly had to be amputated after the victim had suffered for a year or more.

It was only in 1972 that I felt ready to try electrical stimulation of human bone growth in such cases. Zachary B. (Burt) Friedenberg, Carl Brighton, and their research group at the University of Pennsylvania had already reported the first successful electrical healing of a nonunion two years before, but to avoid possible side effects we felt we must duplicate the natural signal more closely than they had, and we didn't know enough until after our work on rat leg regeneration. Like Friedenberg we decided to place a negative electrode between the bone pieces, but using a much smaller current and a silver electrode rather than stainless steel. We thought silver would be less likely to react chemically with the tissue and better able to transmit the electrical current. At that time we were treating a patient whose condition seemed to demand that we try the new procedure.

Minus for Growth, Plus for Infection

Jim was in bad shape. Drafted during the Vietnam War, he'd been a reluctant, rebellious soldier. He survived his tour in Nam and was transferred to an Army base in Kansas late in 1970. On New Year's Eve he

broke both legs in an auto crash. The local hospital put him in traction, with pins drilled through the skin and bones to hold the pieces together. When he was moved to the base hospital a few days later, all the pins had to be removed due to infection.

Jim's doctors couldn't operate because of the bacteria, so they had to be satisfied with a cast. Because he'd broken one leg below and the other above the knee, he needed a huge cast called a double hip spica. He was totally encased in plaster, from his feet to the middle of his chest, for six months. By August, his left lower leg had healed, but the right femur showed no progress at all. The quarter-inch holes where the pins had been were still draining pus, preventing surgery. That September he was given a medical discharge and flown to the Syracuse VA hospital.

When I first saw him, he was still in a large cast, although now his left leg was free. The halves of the right thighbone were completely loose. There was nothing in standard practice to do but leave the cast on and hope. After six more months Jim's hope was just about gone. For a year he'd lain in bed, unable to leave the hospital for even a brief visit home. He vented his rage against the staff, then grew despondent and unable to face the future, which no longer seemed to include his right leg.

Then Sal Barranco, a young orthopedic surgeon in his last year of residency, was assigned to my service from the medical school. He'd already been a good doctor when he briefly worked with me two years before—smart, hardworking, and really interested in his patients. He took over Jim's care, spent many hours talking with him, and arranged for counseling. Nothing seemed to help. Jim slipped further and further away from us.

Sal had always been interested in what was going on in the lab. In fact, I'd often tried to interest him in a career of teaching and research, but he preferred surgery and its rewards of helping people directly. In February of 1972, as we were nearing the clinical stage with our bone stimulator, Sal said, "You know, Dr. Becker, you really should consider electrically stimulating Jim's fracture. I don't see anything else left. It's his last chance."

The problem was that none of Friedenberg's patients had been infected. Although Jim's septic pin tracts weren't right at the fracture, they were too close for comfort. If I stirred up those bacteria when I operated to insert the electrodes, the game was lost. Moreover, it was obvious by now that electricity was the most important growth stimulus to cells. Even if it produced healing, no one could be sure what these cells would do in the future. They might become hypersensitive to other stimuli and start growing malignantly later. This was the first time in

the history of medicine that we could start at least one type of growth at will. I was afraid of beginning a clinical program that might seize the public's fancy and be applied on a large scale before we knew enough about the technique. If disastrous side effects showed up later, we could lose momentum toward a revolutionary advance in medicine. I decided that if I carefully explained what we proposed to do, with all its uncertainties, and let the patient choose, then ethically I'd be doing the right thing.

As to the infection, for several years we had been looking for a way to stop growth. My experiments with Bassett on dogs back in 1964 suggested that just as we could turn growth on with negative electricity, so we could turn it off with positive current. If true, this obviously could be of great importance in cancer treatment. Because ours was always a needy program, trying to do more than we had grants for, we couldn't afford the expensive equipment needed to test the idea on cancer cells. We had to settle for bacteria.

In preliminary tests we found that silver electrodes, when made electrically positive, would kill all types of bacteria in a zone about a half inch in diameter, apparently because of positive silver ions driven into the culture by the applied voltage. This was an exciting discovery, because no single antibiotic worked against all types of bacteria. I thought that if I inserted the silver wire into Jim's nonunion and the area became infected, I could as a last resort make the electrode positive and perhaps save the leg a while longer. Of course, the positive current could well delay healing further or actually destroy more bone.

I explained all this to Jim and said that, if he wished, I would do it. I wanted him to know the procedure was untested and potentially dangerous. With tears in his eyes, he begged, "Please try, Dr. Becker. I want my leg."

Two days later, Sal and I operated through a hole in the cast. The fracture was completely loose, with not one sign of healing. We removed a little scar tissue from the bone and implanted the electrode. The part in between the bone ends was bare wire; the rest, running through the muscles and out of the skin, was insulated so as to deliver the minuscule negative current only to the bone.

The infection didn't spread, and Jim's spirits improved. As I made my daily rounds three weeks later, he said, "I'm sure it's healing. I just know it!" I was still nervous when, six weeks after surgery, it was time to pull out the electrode, remove the cast, and get an X ray. I needn't have worried. Not only did the X ray show a lot of new bone, but when I examined the leg myself, I could no longer move the fracture! We put

Jim in a walking cast, and he left the hospital for the first time in sixteen months. In another six weeks the fracture had healed enough for us to remove the cast, and Jim started rehabilitation for his knee, which had stiffened from disuse.

All the pin tracts, especially the ones nearest the break, were still draining, and Jim asked, "Why not use the silver wire on this hole to kill the infection? Then I'll be all done and won't have to worry anymore about infecting the rest of the bone." I had to agree with his logic. If the hole through the muscle to the outside healed shut, the infection would be more likely to spread within the bone. However, I told him that the positive current might prevent the hole from filling in with bone, making a permanent weak spot there.

We put in the electrode and used the same current as before, except reversing its polarity. I had no idea how long to let it run, so I arbitrarily pulled it out after one week. Nothing much seemed to have happened. The drainage might have been a little less, though not much; but I was afraid to use the positive current anymore for fear of further weakening the bone.

Jim left the hospital and didn't keep his next appointment in the clinic. A year later he returned unannounced saying he was just traveling through Syracuse and thought I would like to see how he was doing. He was walking normally, with no pain, placing full weight on the right leg. He said the drainage had stopped a week after he left the hospital and had never recurred. X rays showed the fracture solidly healed and the one pin tract I'd treated filling in with new bone. The pin site on the other leg was still infected, and I said we could treat that in a few days, since we'd improved our technique in the meantime. "No, I have to be moving on," Jim replied. "I don't have a job. I don't know what I'm going to do, but I know I don't want to spend any more time in hospitals."

Sal had been graduated from the residency program a few months after Jim was discharged in 1973, but before he left he spent all his free time in the lab helping us test the bactericidal (bacteria-killing) electrodes. A few previous reports had mentioned inconsistent antibacterial effects, some with alternating current, some with negative DC using stainless steel, but there had been no systematic study of the subject. We tried silver, platinum, gold, stainless steel, and copper electrodes, using a wide range of currents, on four disparate kinds of bacteria, including Staphylococcus aureus, one of the commonest and most troublesome.

Soon we were able to explain the earlier incosistencies: All five met-

als stopped growth of all the bacteria at both poles, as long as we used high currents. Unfortunately, high currents also produced toxic effects—chemical changes in the medium, gas formation, and corrosion—with all but the silver electrodes. Apparently such currents through most metals "worked" by poisoning both bacteria and nearby tissues.

Our preliminary observations turned out to be right. Silver at the positive pole killed or deactivated every type of bacteria without side effects, even with very low currents. We also tried the silver wires on bacteria grown in cultures of mouse connective tissue and bone marrow, and the ions wiped out the bacteria without affecting the living mouse cells. We were certain it was the silver ions that did the job, rather than the current, when we found that the silver-impregnated culture medium killed new bacteria placed in it even after the current was switched off. The only other metal that had any effect was gold; it worked against Staphylococcus, but not nearly as well as silver.

Of course, the germ-killing action of silver had been known for some time. At the turn of the century, silver foil was considered the best infection-preventive dressing for wounds. Writing in 1913, the eminent surgeon William Stewart Halsted referred to the centuries-old practice of putting silver wire in wounds, then said of the foil: "I know of nothing which could quite take its place, nor have I known any one to abandon it who had thoroughly familiarized himself with the technic of its employment."

With the advent of better infection-fighting drugs, silver fell out of favor, because its ions bind avidly to proteins and thus don't penetrate tissue beyond the very surface. A few silver compounds still have specialized uses in some eye, nose, and throat infections, and the Soviets use silver ions to sterilize recycled water aboard their space stations, but for the most part medicine has abandoned the metal. Electrified silver offers several advantages over previous forms, however. There are no other ions besides silver to burden the tissues. The current "injects" or drives the silver ions further than simple diffusion can. Moreover, it's especially well suited for use against several kinds of bacteria simultaneously. It kills even antibiotic-resistant strains, and also works on fungus infections.

For treating wounds, however, there was one big problem with the technique. Its effect was still too local, extending only about a quarter inch from the wire. For large areas we needed something like a piece of window screen made of silver, but this would have been expensive and also too stiff to mold into the contours of a wound.

We'd been doing our clinical experimens with financial support from a

multinational medical-equipment company that made our "black boxes," the battery packs with all their circuitry that powered our electrodes. I discussed the problem with the company's young research director, Jack TerBeek, and a few weeks later he came back with a fascinating material. NASA needed an electrically conductive fabric, and a small manufacturing company had produced nylon parachute cloth coated with silver. It could be cut to any size and was eminently flexible.

It performed beautifully. Although the silver ions still didn't get more than a quarter of an inch from it, we could use it to cover a large area. Hopeful that we might have a cure for two of an orthopedist's worst nightmares—nonunion and osteomyelitis (bone infection)—we studied the positive silver technique in the lab and continued to use the negative electrodes to stimulate bone growth in selected patients. Word spread via newspaper and TV reports. We began getting patients from all over the nation, but we didn't accept many for the experimental program due to my conservative viewpoint. I applied the same criterion as before: Electrical treatment had to be the patient's last chance.

While slowly gaining experience, we surveyed the literature to stay informed about other people's work. As of 1976, fourteen research groups had used bone stimulators on some seven hundred patients, for spinal fusions and fresh fractures as well as nonunions, all with seemingly good results.

We'd used our electrical generator on only thirteen patients by then. We were the only ones using silver electrodes, a lucky choice as it turned out; all the others were using stainless steel, platinum, or titanium. We used 100 to 200 nanoamps per centimeter of electrode, while Brighton and most other investigators were using 10,000 to 20,000 nanoamps. The low level approximated the natural current and also minimized the chances of a dangerous side effect. Brighton and Friedenberg had found a danger of infection and tissue irritation when running their high-current electrodes at more than 1 volt. We figured this couldn't happen at our amperage, but just to be sure we built in an alarm circuit to shut off our box automatically if the electrical force rose close to 1 volt.

By this time we'd also cleared up several more cases of osteomyelitis by reversing the battery and making the silver electrode positive for a day. It looked safe. There was no crossover of effects: When negative, the wire didn't make infectious bacteria grow, and when positive, it didn't destroy bone-forming cells or prevent them from growing when we switched the current to negative. Our confidence in this method grew with one of our most challenging cases, which also forced us to revise our theories.

Positive Surprises

In December of 1976 a young man was sent to our clinic for a possible amputation. John was a man of the north woods. Weathered and hard, he faced the problem philosophically. "What's got to be has got to be," he said through tight lips. Three years before, he'd been in a snowmobile accident, breaking his right tibia (shinbone) in three places and also fracturing the fibula, the smaller bone of the lower leg. He'd been treated at a small local hospital, where the broken bones had become infected. He'd undergone several operations to remove dead bone and treat the infection, but the bacteria continued to spread. He came to us with the fracture still not healed and with a long cavity on the front of his shin in which one could see right into the dead and infected bone. He was struggling to walk in a cast extending up to his hip. He was married, with five young children, and his leg was obviously not the only place he was having trouble making ends meet.

"What kind of work do you do?" I asked him.

"I trap muskrats, Doc."

"That's all?"

"That's all, Doc."

"How in hell do you manage with that cast on?"

"I put a rubber hip boot over the cast, Doc."

Muskrat trapping is hard work, a tough way to make a living even for a man with two good legs. "John, if you have an amputation and wear an artificial leg, you sure won't be able to do that. What will you do then?"

"I dunno—welfare prob'ly. Prob'ly go nuts."

"You really like to work in the woods, don't you?"

"Wouldn't do anything else, Doc."

"Well, let's get you admitted to the hospital. Something has to be done, and I have an idea that might let you keep your leg." For the first time, John smiled.

In fighting the infection, the first step was to identify the enemy, the microbes. John's wound was a veritable zoo. There were at least five different types of bacteria living in it. Even with only one kind, osteomyelitis is notoriously hard to treat. Very little blood reaches the bone cells, so both antibiotics and the body's own defense agents are hampered in getting where they're needed. And even if we could get it into the bone, no single antibiotic could fight all of John's germs. Even a mixture would probably create a greater problem than it solved, for

any bacteria resistant to the mix would spread like wildfire when the others competing against them were killed.

John's X rays were as chaotic as his bacteria cultures—pieces of dead bone all over the place with absolutely no healing—but we had to deal with the infection first. Since we'd have to use positive current for quite a while, I was afraid we'd destroy some of the bone, but I told John that six months after we got the wound to heal over with skin, I would bring him back into the hospital and use the negative current to stimulate whatever was left. I couldn't promise anything and, since I hadn't yet tried the silver nylon on this type of wound, we might run into unexpected problems. But John agreed with me that he had nothing to lose except his leg, which would certainly have to come off if we didn't try my plan.

A few days later I debrided the wound, removing the dead tissue and all grossly infected or dead bone. There wasn't much left afterward. It was an enormous excavation running almost from his knee to his ankle. In the operating room we soaked a big piece of silver nylon in saline solution and laid it over the wound. It had been cut with a "tail," serving as the electrical contact and also as a sort of pull tab that we could keep dry, outside of the cavity. We packed the fabric in place with saline-soaked gauze, wrapped the leg, and connected the battery unit.

I watched John anxiously during the first two days. If trouble was going to occur, that was when I expected it. By the third day he was eating well, and the current was beginning to drop off, indicating more resistance at the surface of the wound. Now it was time to change the dressing. We were overjoyed to see that the silver hadn't corroded and the wound looked great. Carefully I took a bacterial culture and applied a new silver nylon dressing.

The next morning Sharon Chapin, an exceptional lab technician who took an active part in some of the research, showed me the bacterial cultures. The number of bacteria had dropped dramatically. I went to give John the good news and change his dressing again, when I realized that I could teach him to do his own daily dressing changes. They were time-consuming for me, but John had too much time on his hands and was the one most interested in doing the best thing for his leg. It was a nice feeling to teach a muskrat trapper, who bad dropped out of school at sixteen, how to do an experimental medical procedure. He learned fast, and in a day or so he was changing dressings himself and measuring the current, too. By the end of the week, he allowed as how he did a better job than l did. Maybe he did it at that, because by then all of our

bacterial cultures were sterile—all five kinds had been killed. The soft healing tissue, called granulation tissue, was spreading out and covering the bone. In two weeks, the whole base of the wound, which had been over eight square inches of raw bone, was covered with this friendly pink carpet. The skin was beginning to grow in, too, so we could forget about the grafts we thought we'd need to do.

I decided to take an X ray to see how much bone he'd lost. I could hardly believe the picture. There was clearly some bone growth! We'd been working through a hole in the cast, so I had no idea if the fracture was still loose. Without telling John why—I didn't want to get his hopes up if I was wrong—I removed the cast, felt the leg, and found that the pieces were all stuck together. John watched, and when I was done he lifted his leg into the air triumphantly. It held straight against gravity. His grin opened broader than an eight-lane highway. "I thought you said the bone wouldn't heal yet, Doc!"

I'd never so much enjoyed being wrong, but I warned John not to get too excited until we were sure the good news would hold up. I put him back into a cast and continued treatment another month, until the skin healed over. By then the X rays showed enough repair to warrant a walking cast. John left the hospital on crutches and promised not to run around in the swamps until I told him it was all right. He didn't come back until two months later. The cast was in tatters, and he walked in without crutches, smiling at everyone. The last X rays confirmed it: Healing was nearly complete, and John went back to the wilds.

By mid-1978 we'd successfully treated fourteen osteomyelitis patients with the positive silver mesh wire. The funny thing was, in five of them we'd healed nonunions as a "side effect," without any negative current at all. Obviously it was time to revise our idea that negative electricity alone fostered growth and positive inhibited it.

Andy Marino, Joe Spadaro, and I talked it over. Reducing the DC stimulation technique to its essentials, all you needed was an electrode that wouldn't react with tissue fluid when it wasn't passing current. Since a negative electrode didn't give off ions, any inert metal, such as stainless steel, platinum, or titanium, would work with that polarity. But we knew from our lab work that the situation was very different at the positive pole, where the current drove charged atoms of the metal into the nearby environment. We decided it must be chemical, not electrical, processes that were preventing the bacterial growth at the positive electrode. In that case, maybe polarity was unimportant in growth enhancement. We postulated that, because silver ions were nontoxic to human cells and the electrical aspect was right, we inadvertently grew

bone with positive current. This idea turned out to be quite wrong, but we'll get to that story in due time.

Joe, who was always fascinated by the history of science, now found that none of the contemporary research groups had been the first to stimulate bone repair electrically. We'd all been beaten by more than 150 years. Back in 1812, Dr. John Birch of St. Thomas' Hospital in London used electric shocks to heal a nonunion of the tibia. A Dr. Hall of York, Pennsylvania, later used direct current through electroacupuncture needles for the same purpose, and by 1860 Dr. Arthur Garratt of Boston stated in his electrotherapy textbook that, in the few times he'd needed to try it, this method had never failed. Because of the primitive state of electrical science then, we didn't know how much current these doctors had used. However, the polarity didn't seem to matter, and they used gold electrodes, which were nearly as nontoxic at the positive pole as silver.

Realizing that we still didn't know as much as we'd thought about the growth control lock, we continued to ply the silver key. At least seventy patients with bone infections have now had the silver nylon treatment, including twenty at Louisiana State University Medical School in Shreveport, where Andy Marino ended up after the closing of our lab in 1980. In some of our first cases we noticed a discharge exuding from the tissues and sticking to the mesh when we changed the dressings. We thought it was "reactive" exudate—from irritation by the current—until one day when, during a slight delay in the operating room, I sent a sample of it to the pathology lab. It was filled with such a variety of cells that we had to rule out a simple response to irritation. Instead there was a variety of primitive-looking cell types, looking just like the active bone marrow of children. However, the patients were long past that age, and, besides, their marrow cavities were closed off with scar tissue from their unmended and infected bone injuries. We had to consider another source.

The exudate appeared at the same time as the granulation tissue, which is composed mainly of fibroblasts, ubiquitous connective cells forming a major part of most soft tissues. Since the exudate also contained some fibroblasts, we decided to see if the unfamiliar types had arisen by metamorphosis from them.

We set up a series of three-compartment culture dishes and placed a standard colony of isolated, pure-bred mouse fibroblasts in each. In one section we put a positive silver electrode, in one a negative electrode, and in the third a piece of silver wire not connected to anything.

In cells right next to all three wires, the cytoplasm changed to an

abnormal texture in response to ions of dissolved silver, which migrated only about a hundredth of a millimeter. There were no other effects in the control or negative-current chambers.

Around the positive poles, however, this region was succeeded by an area of great activity for a distance of 5 millimeters on all sides. While doing their job of holding things together, fibroblasts have a characteristic spiky shape, with long sticky branches extending in all directions. In this region where silver ions had been driven by the current, many of the cells had changed to a static, globular form in which mitosis didn't occur. They seemed to be in suspended animation, floating freely instead of adhering to other cells or the sides of the dishes as usual. Mixed among them were many featureless cells with enlarged nuclei, the end products of dedifferentiation. More and more of the rounded fibroblasts turned into fully despecialized cells as the test progressed. Beyond the 5-millimeter line was a border zone with partial changes, followed by a realm of normal, spiky fibroblasts. Dedifferentiated cells normally divide rapidly, but these didn't, perhaps because they were sitting in a plastic dish far removed from the normal stimuli of an animal's body. Within a day after the current was turned off, the cells clumped together into bits of pseudotissue that looked like the young "bone marrow" we'd seen in the exudate. After two weeks they'd all reverted back to mature fibroblasts, presumably because regular replacement of the nutrient medium had by then washed out all the silver ions.

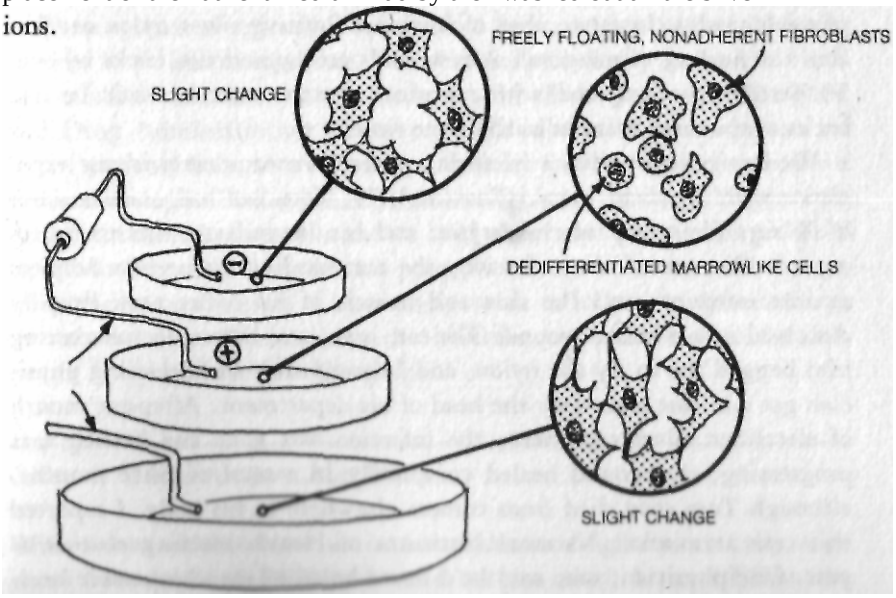

POSITIVE SILVER DEDIDIFFERENTIATES CONNECTIVE TISSUE CELLS

To learn more about these astonishing changes, we studied pieces of the granulation tissue itself, taken from patients treated with the silver nylon. We placed the samples in culture dishes and observed them as they grew. Without the silver factor we would have expected a population of slowly proliferating fibroblasts. However, these cells grew fast, producing a diverse and surprising assortment of primitive forms, including fully dedifferentiated cells, rounded fibroblasts, and amoebalike cells. Strangest of all were giant cells that looked almost like fertilized eggs, very active and with several nucleoli. (The nucleolus is a "little nucleus" within the nucleus proper.) When other cells encountered the giant cells, the smaller cells often split open and emptied their nuclei into the giants. After two weeks these diverse cells had coalesced into an amorphous mass of primitive cells closely resembling a blastema, and in another week, as the silver washed out, they'd all become staid, sober fibroblasts acting as though nothing had happened.

The major difference between the two experiments was that the second one started with cells that had already been exposed to positive silver ions in the human body. Their rapid growth and unspecialized forms suggested that the fibroblasts in the first experiment had in fact been dedifferentiated. It remains to be seen exactly what the various forms do, but it's obvious that in the aggregate they profoundly stimulate soft-tissue healing in a way that's unlike any known natural process. We ran a controlled study of the healing enhancement on pigs, their skin being physiologically closest to that of humans. Positive silver nylon accelerated the healing of measured skin wounds on the animals' backs by over 50 percent as compared with identical control wounds made on the backs of the same animals at the same time.

We saw positive silver's lifesaving potential most clearly in our experience with a patient named Tom in 1979. Tom had had massive doses of X rays for cancer of the larynx, and his larynx later had to be removed. Because of the radiation, the surrounding tissue was helpless against infection, and the skin and muscle of his entire neck literally dissolved into a horrid wound. The ear, nose, and throat doctor treating him begged me to try the nylon, and I agreed after the attending physician got a release signed by the head of his department. After one month of electrified silver treatment, the infection was gone and healing was progressing, the wound healed completely in a total of three months, although Tom soon died from tumors elsewhere in his body. I reported this case at a small National Institutes of Health meeting that same year. One physician, who said he'd never heard of any comparable healing of such a grave wound, was moved to exclaim after seeing my slides,
"I have witnessed a miracle!"

We may only have scratched the surface of positive silver's medical brilliance. Already it's an amazing tool. It stimulates bone-forming cells, cures the most stubborn infections of all kinds of bacteria, and stimulates healing in skin and other soft tissues. We don't know whether the treatment can induce healing in other parts of the body, but the possibility is there, and there may be other marvels latent in this magic caduceus. Just before our research group was disbanded, we studied malignant fibrosarcoma cells (cancerous fibroblasts) and found that electrically injected silver suspended their runaway mitosis. Most important of all, the technique makes it possible to produce large numbers of dedifferentiated cells, overcoming the main problem of mammalian regeneration—the limited number of bone marrow cells that dedifferentiate in response to electrical current alone. Whatever its precise mode of action may be, the electrically generated silver ion can produce enough cells for human blastemas; it has restored my belief that full regeneration of limbs, and perhaps other body parts, can be accomplished in humans.

Many questions remain, however. We don't know how the changed cells speed up healing or how the silver changes them. We don't know how electrically produced silver ions differ from ordinary dissolved ions, only that they do. They evoke widely different reactions from the fibroblasts, and the cells affected by dissolved ions close to the electrode are prevented from dedifferentiating in response to the electrified silver. Most important is a search for possible delayed side effects.

These questions urgently need research by some good electrochemists, but the work isn't being done. We were probably lucky we hadn't found this effect in our first round of lab tests on silver electrodes. The Food and Drug Administration let us test the antibacterial technique on selected patients because we found no toxicity and because a few hours a day was enough. To say that the same electrodes run for a longer time could stimulate healing was such a bold claim that permission probably would have been denied. At this point, however, we sorely need enough imagination on the part of research sponsors to follow up these leads in the laboratories, while making the treatment available now to the desperate few who have no other hope.

The Fracture Market

Where does all this leave us in our understanding of electrically triggered bone healing? I'm afraid we're not too much better off than the nineteenth-century doctors who lost this effective treatment because no one understood it well enough to defend it from electrotherapy's oppo-

nents. Of course, we have more pieces of the puzzle today, but we still don't have a complete picture of how any of the competing techniques work.

Besides our low-current silver electrodes, there are two other basic types of bone growth stimulators. Friedenberg and Brighton at first placed their stiff stainless-steel wires through holes drilled into the bone near the break. Now a "semi-invasive" refinement is used in many patients—sticking the electrodes through the flesh into the fracture gap under local anesthetic; several may be needed for a large bone. They're connected to a self-contained battery pack set right into the cast. Friedenberg and Brighton patented their invention, and it's now approved by the FDA and marketed. About three fourths of the groups treating patients use some variation on this theme.

Australian researchers under D. C. Patterson devised a spiral titanium electrode that's placed into a notch cut in the bone on both sides of the fracture. It's now also FDA approved and marketed. Since this device, battery pack and all, must be implanted and removed in two separate operations, and since the electrode usually must be left behind in the bone, late complications may occur.

Others have taken a completely different approach, using pulsed electromagnetic fields (PEMF) to induce currents in the fracture area from outside the body. The best-known proponents of this method, Andrew Bassett and electrochemist Arthur Pilla, worked together at the Orthopedic Research Laboratories of Columbia-Presbyterian Medical Center in New York until 1982; Pilla is now at the Mount Sinai Medical Center. They developed a pair of electromagnetic coils sheathed in plastic pads, connected to a book-sized generator that plugs into a wall socket.

Having experimented with a wide variety of pulsed fields, Bassett and Pilla found four that stimulate fracture healing. The one that works best, which is now also approved and available commercially, is produced by electromagnets driven by alternating current supplied in bursts of pulses. Although it ties the patient to an electrical outlet for twelve hours a day (mostly during sleep, of course), this apparatus completely avoids surgery and its attendant risks.

The funny thing is that all three methods—low current, high current, and PEMF—seem to work equally well. Since the FDA approved them in late 1979, success rates have stabilized at about 80 percent.

As far as the two electrode methods are concerned, I believe some experiments wedid in 1977 and 1978 revealed why they both work.

When we arranged all the reports in order from lowest current to highest, we found a narrow band of low amperages and a wide band of higher

ones that worked, separated by a range in between that failed. We tested various nonsilver electrodes on animals and found that, at the effective currents, they all produced some electrochemical changes even at the negative pole. Among other products, they created various highly reactive ions called free radicals, essential in cellular chemistry but also destructive in excess. These radicals irritate cells, and, since any continuous irritation stimulates bone-forming cells to lay down new matrix in self-defense, we concluded that the higher-current methods worked primarily by such irritation. Conversely, I believe low-current silver electrodes stimulate bone formation directly—by dedifferentiating the marrow cells and perhaps also by stimulating the periosteal cells.

At first, PEMF research suggested that the coils worked by inducing in the tissues electrical currents that changed the permeability of cell membranes to calcium. In most nonunions at least a small amount of fracture callus has appeared, consisting of collagen fibers, but for some\ reason it hasn't entered the next stage, in which apatite crystals form on the fibers. Work by Pilla and Bassett suggested that the currents induced by the pulsed fields caused the cells of the callus to absorb large amounts of calcium. Later, when the coils were turned off, they reasoned, the cells dumped this calcium outside among the collagen fibers, and apatite crystals finally formed where they belonged.

Their experiments raised the hope that other wave forms might regulate membrane passage of other ions or even control DNA transcription and protein synthesis. It seemed these field-induced currents might act as "vocal cords," allowing us to "speak" to the cell nucleus via the membrane, much as sound waves communicate with the brain via the ear.

PEMF does in fact induce currents—of a type never found normally in the body. Each pulse produces millions of tiny eddy currents briefly flowing in circles. As the magnetic field expands at the beginning of a pulse, the currents circle in one direction; as it collapses, they reverse. However, the latest research has cast doubt on the idea that these currents affect specific cellular processes. Rather, it seems that artificial time-varying magnetic fields directly activate the cells by speeding up their mitotic rate, as discussed in more detail in Chapter 15.

You may ask, "As long as something works, why quibble about how?" My answer is that understanding how is our best hope for using the tool right, without causing our patients other problems later. By sticking our own neologisms into the cell's delicate grammar, we automatically risk garbling it in unforeseen ways.

As of now, we're like blind people crossing a minefield. Accelerated mitosis is a hallmark of malignancy as well as healing, and long-term

exposure to time-varying electromagnetic fields has been linked to increased rates of cancer in humans. Bassett has discounted potential dangers, saying, "You would experience almost the same field strength by standing under a fluorescent light." However, a fluorescent lamp may well feel like a floodlight to cells that can see nanoamperes of current. One of the main lessons of bioelectromagnetism so far is that less is often more.

On the other hand, it's too easy to assume that "natural is better." Since it would vindicate our low-current method, I obviously hope it's true, but the fact remains that putting electrodes in a bone is itself a very unnatural act. Stimulation of healing outside the normal limits of the process may incur fewer risks in the end. So far the evidence suggests otherwise, but we don't yet know for sure. That's why I keep emphasizing the need to go slowly, using these contraptions only when all else has failed, until we understand them better.

The most urgent need is a search for possible malignant effects. As far as I know, I've done the only such research on electrodes to date—one simple tissue culture study without grant support, using some money I saved from our last research project funded by the manufacturer of the battery pack. I proposed more extensive tests to various granting agencies before our lab was closed, but was turned down every time.

I exposed standard cultures of human fibrosarcoma cells to 360 nanoamps from stainless steel electrodes. I tried it five times, and each time there was a threefold increase in cell population at both electrodes. Even for cancer cells, this is remarkable proliferation for such a short time. To my knowledge, none of the developers or marketers of electrode devices have chosen to duplicate this test or try their own, despite the ease of doing the work and the fact that they have plenty of money. Whatever evidence on this point that may have been presented to the FDA hasn't been made public. After the evaluation panel granted commercial approval, however, several of its members expressed fears that this possibility hadn't been adequately tested. At this time, therefore, I must conclude that high-current electrodes might enhance the growth of any preexisting tumor cells in the electrical path—unlike low-current silver, which when negative had no effect on, and when positive suspended, mitosis of cancer cells in our lab.

As for PEMF, Bassett and Pilla believe that only cells in a healing process gone awry can "hear" their wave form, so they discount the idea of cancel enhancement from it. They claim to have found no PEMFs that produce or accelerate malignant growth; on the contrary, Pilla and oncologist Larry Norton of Mount Sinai say they've found at least one that

seems to inhibit it in lab animals. This claim is seriously flawed, however, because of the difference between subjecting an entire animal to a magnetic field, and directing the same field to a small area around a fracture (see Chapter 12). Moreover, in 1983, Akamine, a Japanese orthopedic researcher, reported that the pulsed magnetic fields used for bone healing dramatically increased the mitotic rate of cancer cells. The same fields inhibited the return of such "stimulated" cancer cells to a more normal state. Thus PEMF, like high-current treatments, apparently does enhance cancer growth.

In the last decade or so, electrobiologists have learned a great deal about the effects of time-varying electromagnetic fields (as opposed to steady-state fields) on living tissue. We'll review these discoveries in Chapters 14 and 15. The evidence to date indicates that PEMF works by increasing the mitotic rate of the healing cells, not by altering calcium metabolism. If so, it can't possibly discriminate between bone-healing cells and any other type. It will accelerate the growth of any cellular system that is actively growing; this includes not only healing tissues, but fetal and malignant tissues as well.

At the present rate of basic research, we won't have direct proof on whether electrical healing stimulators are nurturing seeds of cancer in humans until two or three decades from now. We could find out much sooner by simple experiments on animals having shorter life-spans. Until we have that definitive answer, I contend that all three techniques should remain available as a last resort to prevent loss of limb, but I'm appalled at their increasing use to speed up orthodontics or accelerate healing of fresh fractures.

Unfortunately, the trend is away from caution. By the time this book is published, tens of thousands of patients will have been treated with the devices, many as a first, rather than last, resort. At a recent orthopedic meeting, I learned that four more companies are hoping to market new models. Several have asked me to advise them, but I haven't found one yet that wants to embark on any serious research. Without such a commitment, I refuse to take part in any battle of salesmen. I never even tried to patent the low-current silver method, because a medical device generally isn't considered patentable if the research that went into it was conducted throughout the scientific community and published for all to read. As I see it, the rush to the marketplace can only spawn jurisdictional disputes and ensure that important findings are kept as proprietary secrets.

Electrical osteogenesis could be the opening wedge into a new era of medicine. Within a few years, we may know how to use these tech-

niques to repair joint cartilage, or even replace whole joints, and to correct various defects of bone growth. In the further future, we may be able to extend regeneration as needed to nearly all human tissues. For the first time a physician can now direct nature, albeit in a small way, rather than play her helpless servant. We must use this power wisely. We're tapping into the most potent force in all of biology. If we're irresponsible about it, we risk another electrical letdown that could put off medicine's glorious future for many years.

Nine
The Organ Tree

"I have yet to see any problem, however complicated, which when you looked at it the right way did not become still more complicated," science fiction writer Poul Anderson once observed. To a certain extent this is true of regeneration. Intricate nature is still more than a match for our finest-spun hypotheses. Yet we've now reached the oasis of science that we call an interim understanding, where the data begin to shake into place and we can sense the pattern of the rebus from the blanks we've filled in.

Ultimately we must relate all we learn about regeneration to a general system of communication among cells, for regrowth is only a special case of the cooperative cohesion that's the essence of multicellular life. This communication system includes but extends beyond the gene-protein-enzyme subsystems that govern the specialization of cells and unite their chemical trade routes into smoothly working tissues and organs. During embryonic development, cells where muscle will appear must receive instructions from their environment telling them to repress all genes except the muscle genome, or subcode. In many tissues, perhaps in all, chemical inductors from previously formed tissue perform this task, leading embryonic cells step by step through the stages of differentiation. However, chemical reactions and the passage of compounds from cell to cell can't account for structure, such as the alignment of muscle fiber bundles, the proper shape of the whole muscle, and its precise attachment to bones. Molecullar dynamics, the simple gradients of diffusion, can't explain anatomy. The control system we're seeking unites all levels of organization, from the idiosyncratic yet regular outline of the

whole organism to the precisely engineered traceries of its microstructure. The DNA-RNA apparatus isn't the whole secret of life, but a sort of computer program by which the real secret, the control system, expresses its pattern in terms of living cells.

This pattern is part of what many people mean by the soul, which so many philosophies have tried to explicate. However, most of the proposed answers haven't been connected with the physical world of biology in a way that offered a toehold for experiment. Like many attempts, the latest major scientific guess, the morphogenetic field proposed by Paul Weiss in 1939, was just a restatement of the problem, though a useful one. Weiss conjectured that development was guided by some sort of field projected from the fertilized egg. As the dividing cell mass became an embryo and then an adult, the field changed its shape and somehow led the cells onward.

The problem was that there were too many "somehows." Even if one accepted Burr's largely ignored measurements of an electric L-field and admitted that it might be the morphogenetic field (a possibility Weiss dogmatically rejected), there was still no way of telling where the L-field came from or how it acted upon cells. Nor was there an explanation of how, if the field was an emanation from the cells, it could also guide them in building an animal or plant. In applying the idea to regeneration, biologists faced the related and seemingly insurmountable problem of how a more or less uniform outflow of energy could carry enough information to characterize a limb or organ. Given the complexity of biological structures, this was even harder than imagining how a field could "somehow" survive when the part it referred to was missing.

However, the morphogenetic field no longer has to account for everything. Acceptance of dedifferentiation lets us divide regrowth into two phases and better understand each. The first phase begins with the cleanup of wound debris by phagocytes (the scavenger race of white blood cells) and culminates in dedifferentiation of tissue to form a blastema. Redifferentiation and orderly growth of the needed part constitute the second phase.

Simplifying the problem in this way should give biologists an immediate sense of accomplishment, for the first stage is now well understood. After phagocytosis, while the other tissues are dying back a short distance behind the amputation line, the epidermal cells divide and migrate over the end of the stump. Then, as this epidermis thickens into an apical cap, nerve fibers grow outward and subdivide to form individual synapselike connections the neuroepidermal junction (NEJ) - with the cap cells. This connection transmits or generates a simple but highly

specific electrical signal in regenerating animals: a few hundred nanoamperes of direct current, initially positive, then changing in the course of a few days to negative.

The pituitary hormone prolactin, the same substance that stimulates milk flow in nursing mothers, seems to sensitize cells to electric current. Then the signal causes nearby cells to dedifferentiate and form a blastema, apparently by changing the way cell membranes pass calcium ions. After confirming our frog blood-cell work, Art Pilla went on to produce the same changes by using pulsed DC to make a wave of calcium ions flowing across the culture dish. Steve Smith then confirmed the importance of calcium by preventing dedifferentiation with a calcium-blocking compound, and restarting it with another substance that enhanced passage of calcium ions. Working together, Smith and Pilla next used the same PEMF wave form now in clinical use to nearly double the rate of salamander limb regeneration, while completely preventing it with a different pulse pattern. Widespread recent work on calcium-binding proteins, such as calmodulin, has made it fairly certain that electrical control of calcium movement through cell membranes directs the give-and-take among these proteins, which in turn supervises the cell's entire genetic and metabolic industry.

Although not conclusive, the available evidence suggests that the current flows through the perineural cells rather than the neurons themselves (see Chapter 13). These are several types of cells that completely surround every nerve cell, enclosing all the peripheral fibers in a sheath and composing 90 percent of the brain. Lizards can replace their tails without the spinal cord, as long as the ependyma, or perineural cells surrounding the cord, remains intact, and ependymal tissue transplanted to leg stumps gives lizards some artificial regeneration there. However, the circuit may shift tissues near the wound, for Elizabeth Hay's electron microscope studies clearly show that the peripheral nerve's Schwann cell sheaths stop just short of the epidermis, and only the naked neuron tips participate in the NEJ. The exact current pathway in this microscopic area remains to be charted.

Not all cells can respond, however, as Jim Cullen and I found in one part of our fortuitous rat-regeneration experiments of 1979. Dedifferentiation occurred only when we passed the deviated sciatic nerve to the epidermis through the bone marrow. When we led it through the muscle yet sutured it to the skin in exactly the same way, an NEJ producing the right current appeared, but no blastema and no regrowth. Muscle cells apparently weren't competent to differentiate in the adult rat. The cellular target proved to be just as important as the electrical arrow.

There's still some opposition to parts of this scenario. Among some scientists, the prejudice against electrobiology remains so strong that one otherwise fine recent review doesn't even mention the NEJ or the difference between currents of injury in frogs versus salamanders!

Other objections are a little more substantial. A Purdue University group has measured electrical potentials near the surface of regenerating limbs underwater, using a vibrating probe. This is an electrode whose tip, ending in a tiny platinum ball, oscillates rapidly to and fro, giving the average voltage between the two ends of its motion. These researchers describe an arc of ion flow—they categorically deny the possibility of electron currents in living tissue—out from the stump and through the water or, in semiaquatic animals, a film of moisture on the skin. From the water, they suggest, these ions travel to the limb skin behind the amputation, then in through all the inner tissues, and finally out of the stump again to complete the circuit. They believe the epidermis drives these currents by its normal amphibian function of pumping sodium (positive) ions from the outside water into the body. They conceive of this ion flow as the regeneration current itself, because changing the concentration of sodium in the water directly affects their current measurements, and because certain sodium-blocking techniques have interfered with limb regrowth in about half of their experimental animals.

Of course, the Purdue researchers don't dispute the amply proven need for nerve and injury currents during regeneration. They've even confirmed Smith's induction of leg regrowth in frogs with batteries generating electron currents. Nevertheless, they consider nerves the target rather than the source of current, even though they propose no reason why their ion flow should be restricted to nerve tissue. In fact, they base their hypothesis partly on evidence that sodium flows even from denervated limbs.

There are several other problems with this theory: Its proponents' own measurements show that the sodium ion current almost disappears just when its supposed effect, blastema formation, is occurring. Moreover, it fails to explain the easily observed reversal of polarity in injury currents measured directly on the limb, as well as the crucial role of the NEJ. The proposed circuit goes right past the NEJ! Finally, it can't account for the several tests of semiconducting current throughout the nervous system, or regeneration in dry-skinned animals such as lizards.

To the lay person all this may seem like academic hairsplitting, until we reflect on the stakes: understanding regeneration well enough to restore it to ourselves. Certainly skin is electrically active. It's piezoelectric and pyroelectric (turning heat into electricity) as well as a transporter of

ions in wet animals. In the last two decades nearly all tissues have been proven to produce or carry various kinds of electrical charge. Skin may play an as-yet-unknown role in regeneration besides its part in the NEJ, or it may merely be producing unrelated electrical effects. In any case, there are far too many data about the role of nerves to call skin the major source of the regeneration current. In fact, even the Purdue group has measured a stump current that's independent of sodium concentration.

A recent experiment by Meryl Rose gave further evidence of neural DC, without clearing up all aspects of the question. Rose removed the nerves From larval salamander legs before amputation. Normally such denervated larval stumps die right back to the body wall, but when Rose artificially supplied direct currents like those I measured in my first experiment, they regrew normally. This is pretty conclusive proof that the nerves are the electrical source in phase one. However, since it looks as though nerves also organize regeneration's second phase (see below), it's hard to understand how the new legs could have been completely normal when they were disconnected from the rest of the nervous system. Perhaps salamanders can pinch-hit for nerves at this stage through a tissue other than nerve. On the other hand, new nerves may simply have regrown into the limbs unbeknownst to Rose by the later stages of the experiment.

Phase two begins as the embryonal cells pile up and the blastema elongates. Early in this stage a sort of spatial memory becomes fixed in the blastema cells so the limb-to-be will have its proper orientation to the rest of the body. At the same time or shortly afterward, the cells at the inner edge of the blastema receive their new marching orders and platoon assignments. Then they redifferentiate and take their places in the new structure.

We can infer two things about the control for this part of the process. Since the blastema forms the right structure in relation to the whole organism, the guidance can't be purely local, but must come from a system that likewise pervades the whole body. Furthermore, there are no dedifferentiated cells left over when the work is done; there are just enough and no more. Thus there must be a feedback mechanism between the redifferentiation controls at the body side of the blastema and the NEJ's dedifferentiation stimulus at its outer edge.

A large body of earlier work has shown that the redifferentiation instructions are passed along a tissue arc whose main element is the circuit already established between nerves and epidermis in the first phase. The electrical component persuasively explains how this arc, an update of the morphogenetic field, may work. The direction (polarity) plus the magni-

tude and force (amperage and voltage) of current could serve as a vector system giving distinct values for every area of the body. The electric field surrounding continuously charged cells and diminishing with the distance from the nerve would provide a third coordinate, giving each cell a slightly different electrical potential. In addition, a magnetic field must exist around the current flow, possibly adding a fourth dimension to the system. Together these values might suffice to pinpoint any cell in the body. The electric and magnetic fields, varying as the current varies with the animal's state of consciousness and health, could move charged molecules wherever they were needed for control of growth or other processes. Since currents and electromagnetic fields affect the cell membrane's "choice" of what ions to absorb, reject, or expel, this system—in concert with the chemical code by which neighboring cells recognize each other—could precisely regulate the activities of every cell. It could express the exact point along the limb at which new growth must start; distinguish between right and left, top and bottom; even explain how totally missing parts, like extirpated bones or all the little bones of wrist and hand, can reappear.

Furthermore, the difference between electrical values at the inner and outer edges of the blastema would lessen as a new limb grew behind it. (Remember that the electrical potential grows increasingly negative toward the end of an intact limb.) The gradual convergence of these two values could constitute a feedback signal perfectly reflecting the number of dedifferentiated cells still needed. Although the results weren't entirely conclusive, perhaps because measurements had to be made under anesthesia, several experiments in the 1950s suggested that such a voltage differential governed restitution of the proper number of segments in earthworms. There was even a surge of positive potential that seemed to indicate when the job was finished.

This is a rich concept, and the details are without doubt more complex than this sketch, but they're all open to experimentation in a way that Weiss's morphogenetic field and Burr's L-field were not. The best part of this two-stage analysis is that it gives us a rationale for trying to foster regeneration after human injuries before we know all the details of the second phase.

The rat limb experiments strongly suggest that mammals lack two crucial requirements for the first phase of regeneration: They don't have the necessary ratio of nerve tissue to total limb tissue, the amount needed to make the dedifferentation stimulus srong enough; and they lack sufficient sensititive cells to respond to the electrical stimulus and form a big enough blastema. The work on rats pointed the way to defin-

ing the proper current, and the ability of electrically injected silver ions to dedifferentiate fibroblasts now gives us a possible method for producing an adequate blastema. We should now be able to supply the requirements for phase one in humans. Once this is done, the body itself can probably take care of phase two, even though we don't understand the process. Fingertip regrowth in children suggests that our bodies still have the ability to redifferentiate the cells and organize the missing part, as long as the electrical stimulus and the supply of sensitive cells are sufficient.

Microsurgeons have performed wonders in reimplanting cleanly severed portions of arms, legs, and fingers, but these limbs are subject to atrophy and obviously can't be grafted if they're too badly mangled or riddled with disease. As one who has performed too many amputations in his time, I find the prospect of being able to give a patient the real thing instead of a prosthesis tremendously exciting. There's a good chance that we'll eventually treat some nongenetic birth defects or old injuries by cutting off the defective part and inducing a normal one to grow. Perhaps, combined with gene splicing, such techniques could even rectify genetic birth defects.

Since no one has yet achieved full regeneration in rats or any other mammal, these dreams won't come true overnight. They aren't chimerical, however. The remaining problems could probably be solved in a decade or two of concerted basic research. Meanwhile, human capacities for repair of certain tissues are greater than most people realize, and there are already promising ways of enhancing some of them.

Cartilage

Fossils show that even the dinosaurs had arthritis, but unfortunately it outlived them. Many varieties have been described, all of which result in destruction of the hyaline (glassy) cartilage that lines the ends of the bones. The remaining cartilage cells try to heal the defect by proliferating and making more cartilage. They're almost never equal to the task, and scar tissue fills the rest of the hole. The result is pain, for scar tissue is too spongy to bear much weight or keep the bones from grinding against each other.

After our success at getting rat legs to partially regenerate, we studied this problem in 1973. We reasoned that, suite cartilage was made by only one kind of cell, getting it to regrow would be easier than working with a whole limb.

With orthopedic resident surgeon Bruce Baker of the Upstate Medical Center, we removed the cartilage layer from one side of the femur at the knee in a series of white rabbits. The operation left a circular hole of bare bone about 4 millimeters across. In the experimental animals we implanted silver-platinum couplings like those used on the rats, drilling the platinum end into the defect and tucking the rest along the bone. Most of the control animals filled in the defect with scar tissue along with some inferior fibrous cartilage. About a tenth of them grew a millimeter or two of good hyaline cartilage at the edge of the hole. But sure enough, the rabbits with the implants showed greatly enhanced repair. When we used an improved battery implant with silver wires at each end, we got even better results. Two of the rabbits healed the damage completely with beautiful hyaline cartilage just like the original material.

A few years later, when we were testing various electrode metals, we tried a different approach specifically for rheumatoid arthritis, in which runaway inflammation causes phagocytes to attack healthy cartilage cells. Gold salts taken orally sometimes control this disease but often produce toxic side effects. We figured electrical injection of pure gold directly into the joint with no other ions might work better. To find out, Joe Spadaro and I produced rheumatoid arthritis in the knees of both hind legs in forty rabbits, using a standard experimental procedure. Then we treated one knee in each animal with a positive gold electrode stuck right into the space between the two bones for two hours. Joe did the actual treatments. Then we sacrificed the animals gradually over a period of two months, and I examined both arthritic knees, not knowing until later which had been given gold. During the first two weeks about 70 percent of the treated knees were markedly better than the untreated ones. The improvement fell off to about 40 percent thereafter, suggesting that the treatment must be repeated for continued results.

Obviously, these were only preliminary experiments. However, since an estimated 31 million Americans suffer from arthritis, for which there is no cure yet, I think both avenues should be thoroughly explored as soon as possible.

Skull Bones

Lev Polezhaev has spent his career investigating what might be called the Polezhaev principle - the greater the damage, the better the regrowth. He has found he can often enhance repair by adding homoge-

nates, minces, and extracts of the damaged organs, even though this doesn't augment the current of injury as his needling procedure did.
I

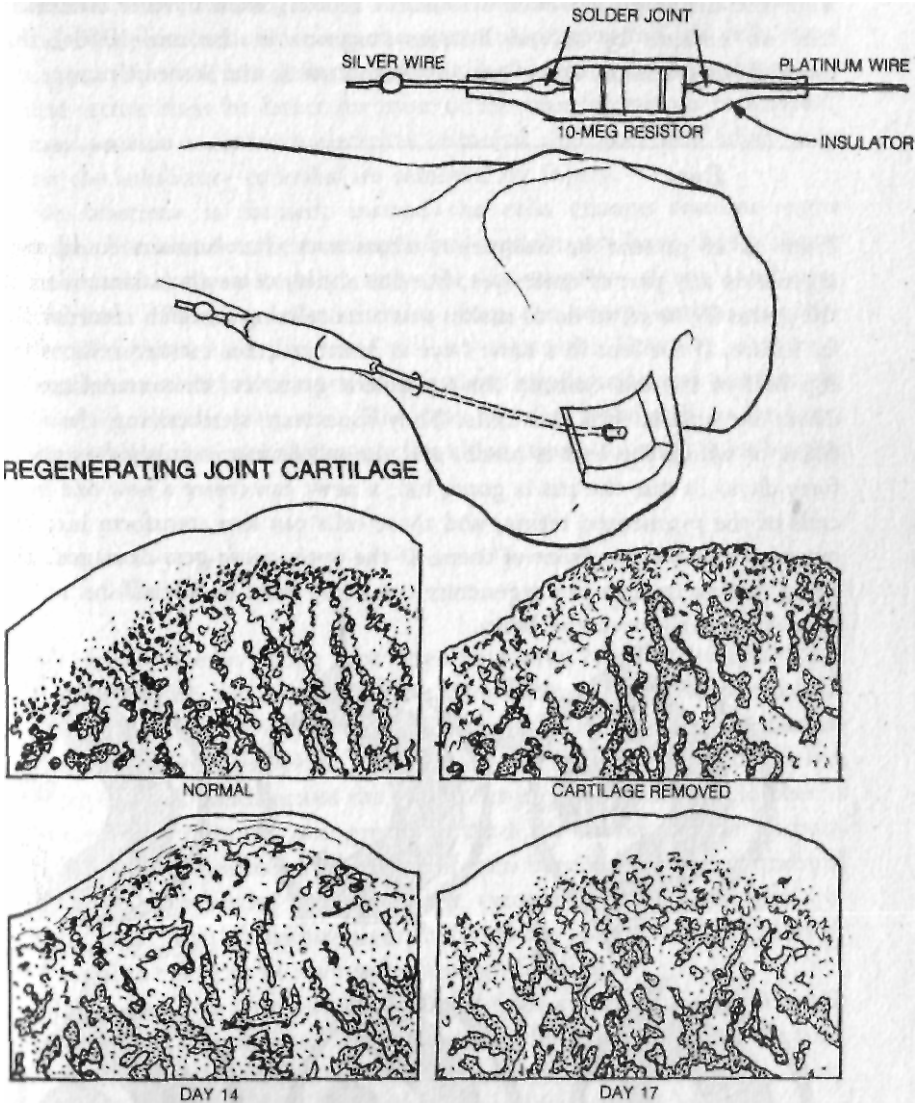

REGENERATING JOINT CARTILAGE—RESULTS

Eventually Polezhaev developed a way to induce regeneration of holes in the skull, which normally heal over with scar tissue. As long as the dura mater, the cough membrane between skull and brain, is intact, a paste of blood and fresh (living) powdered bone will induce the bone cells at the edges to grow and bridge the gap. Microscopic studies have

shown that the few live cells remaining in the paste don't survive and the bone particles themselves soon dissolve. Instead, some substance from the disintegrated bone stimulates repair. Since its first successful trial on humans by several Russian surgeons in the mid-1960s, this method has gradually come into increasing use in the Soviet Union.

Eyes

There is at present no indication whatsoever that humans could ever regenerate any part of their eyes, but the ability of newts (salamanders of the genus Triturus) to do so makes this a tantalizing research ideal for the far future. If the lens in a newt's eye is destroyed, the colored cells of the top half of the iris extrude their pigment granules, then transform by direct metaplasia into lens cells. They soon start synthesizing the clear fibers of which the lens is made, and the whole job is finished in about forty days. In case the iris is gone, too, a newt can create a new one from cells of the pigmented retina, and those cells can also transform into the neural retina layer in front of them. If the optic nerve gets damaged, the neural retina in turn can regenerate the nerve tract backward and reconnect it properly with the brain.

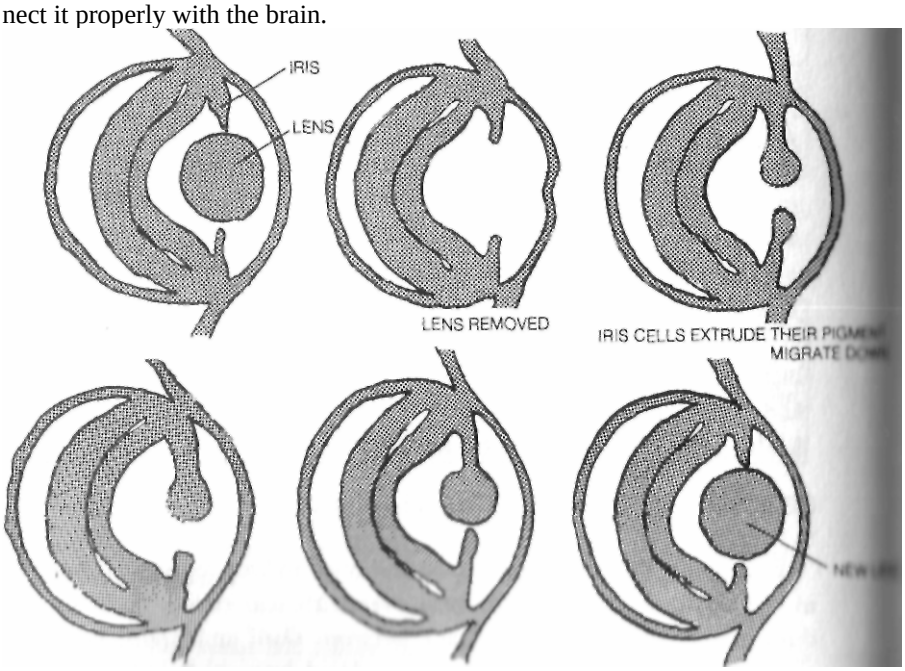

SALAMANDER EYE-LENS REGENERATION

No one knows why newts are so much more adept at this than all other creatures; their eyes have no obvious structural or biochemical peculiarities. Steve Smith gave us an important fact to work with when he found two proteins in the lens that seem to prevent the iris cells from changing into new lens cells as long as the old lens is in place. Since the neural retina must be intact for most of the transformations to happen, it may provide a constant electrical stimulus that goes into effect only when the inhibitory proteins are removed by injury.
No blastema is formed; instead the cells change costume right onstage. Furthermore, certain ingenious experiments have shown that a wound isn't really necessary, only the interruption of the inhibitory mechanism. Therefore, the stimulus from the neural retina probably isn't the familiar injury current of limb regrowth. However, despite a voluminous research literature on newt eye regeneration, no one has yet studied its electrical aspects. This may be why we're still so far from understanding the natural process, let alone trying to adapt it to human eyes.

Muscle

Every muscle fiber is a long tube filled with rows of cells (myocytes) laid end to end with no membranes between them—in effect, one multinucleated cell, called a syncytium. These nuclei direct the manufacture of contractile proteins, which are lined up side by side and visible, when stained, as dark bands across the array of myocytes. Each muscle fiber is surrounded by a sheath, and groups of them are bound together in bundles by thicker sheaths. At the edge of each bundle are long, cylindrical cells with huge nuclei and very little cytoplasm, called myoblasts or spindle cells. Also along the edges, between the spindle cells, clusters of tiny satellite cells can be seen at high magnifications.
After a crushing injury or loss of blood from a deep cut, muscle in the damaged area degenerates. The myocyte nuclei shrivel up and the cells die. Soon phagocytes enter to eat the old fibers and cell remnants. Only the empty sheaths and a few spindle and satellite cells are left.
Now these remaining cells turn into new myocytes, fill up the empty rubes, and begin secreting new contractile proteins. Although the early part of this process proceeds without nerves, it can run to completion only if motor nerve fibers reestablish contact with the terminals, called end plates, that remain at specific distances along each fiber sheath. If these end-plate areas are cut out, the nerve endings will enter, sniff

around, and then retract. The muscle will atrophy. If the nerves re-establish the connections, new muscle cells will fill most of the original volume, gradually build up strength, and then completely differentiate into slow-twitch or fast-twitch fibers.

Attempts to enhance muscle regeneration in humans take two approaches. If available, a graft of a whole muscle from another source is the more effective. This is actual single-tissue regeneration, because the original muscle cells die and are replaced after new blood and nerve connections are made. Since its first clinical use in 1971, this approach has proven successful in replacing defective small muscles of the face and also in restoring anal sphincter control. Large limb muscles haven't been successfully transplanted yet.

Another method may soon be used in humans when grafts aren't possible. Muscle regeneration in birds and laboratory mammals has been considerably enhanced by inserting muscle tissue minced with fine scissors into pieces of no more than 1 cubic millimeter. Soviet biologist A. N. Studitsky first devised this method in the 1950s, extending Polezhaev's work, but its development has been slow.

Abdominal Organs

Despite over two hundred years of descriptive work, new regenerative capacities are still discovered in the animal kingdom from time to time. We've recently learned, for example, that adult frogs can restore their bile ducts, although for some reason females are better at it than males. Doctors have long known that the liver can replace most of the mass lost through injury by compensatory hypertrophy, in which its cells both enlarge and increase their rate of division so that the organ's chemical-processing duties can be maintained even though the ruined architecture isn't restored. Similarly, damage in one kidney is made up by enlargement of the other without rebuilding the intricate mazes of microtubules in the glomeruli. Recent studies of rat livers suggest that a combination of insulin and an epidermal growth factor, modified by at least a dozen other hormones, enzymes, and food metabolites, control the cell proliferation.

Now it appears that the spleen can make the same kind of comeback, at least in children. Adults who must have their splens removed rarely miss them, but children become more susceptible to meningitis. A few years ago, medical researcgers noted that children whose excised spleens

had been damaged by accident were less likely to get meningitis than those whose spleens had been removed because of disease. Howard Pearson and his colleagues at the Yale University School of Medicine found that, when ruptured, the delicate spleen left bits of itself scattered in the abdomen, which grew and gradually resumed the organ's obscure blood-cleansing functions. Now when they remove a spleen, many surgeons wipe it on the peritoneum (the tough membrane that lines the abdominal cavity) to sow replacement seeds.

Another late discovery of regeneration was made in the late 1950s, when several scientists learned that tadpoles, larval salamanders, and sometimes adult salamanders could restore up to about four inches of their intestines. Moreover, all adult amphibians could reconnect the cut ends even if they couldn't replace a missing section. Allan Dumont, one of my best friends during medical school and now Jules Leonard Whitehill Professor of Surgery at NYU-Bellevue, decided to check this potential in mammals after I told him about my work on rat limbs. He wanted to find out whether regeneration could be stimulated in mammals to solve one of a general surgeon's most vexing problems—poor healing of sutured ends of gut after a cancerous or degenerated segment has been cut out. Even a small opening can spill feces into the abdominal cavity, with disastrous peritonitis the result.

Like any good scientist, Al started from the basics. After several years he'd confirmed the earlier reports. When he cut pieces from the gut of adult frogs and newts and merely put the ends close together in the abdomen, 40 percent of the animals survived by quickly reconnecting the two ends and completely healing them in about a month, although even the newts didn't replace much of the lost length in his experiments. Gut regeneration actually involves several tissues; Al's cell studies showed a blastema quickly forming at the junction and then differentiating into smooth muscle, mucus cells, and the structural cells of the villi.

Naturally, when I was organizing a conference on regeneration in 1979, I invited Al to present his results. About a month before the meeting, after the program had already gone to the printer, he wanted to change the title of his paper, for he'd just finished some surprising work. He asked me, "What would you expect to happen if I took some adult rats, cut out a centimeter of gut, and dropped the two loose ends back into the abdomen?" Like any first-year med student, I said they'd be dead of peritonitis in two or three days. Well, 20 percent of Al's rats had reconnected then bowels better than surgery could have done, and were alive and healthy. When Al had given one group of animals a temporary colostomy above the experimental cut, the survival rate

jumped threefold. The perfect healing of the test animals compared with the controls indicated that sutures actually interfered with regeneration producing unnecessary scars and adhesions.

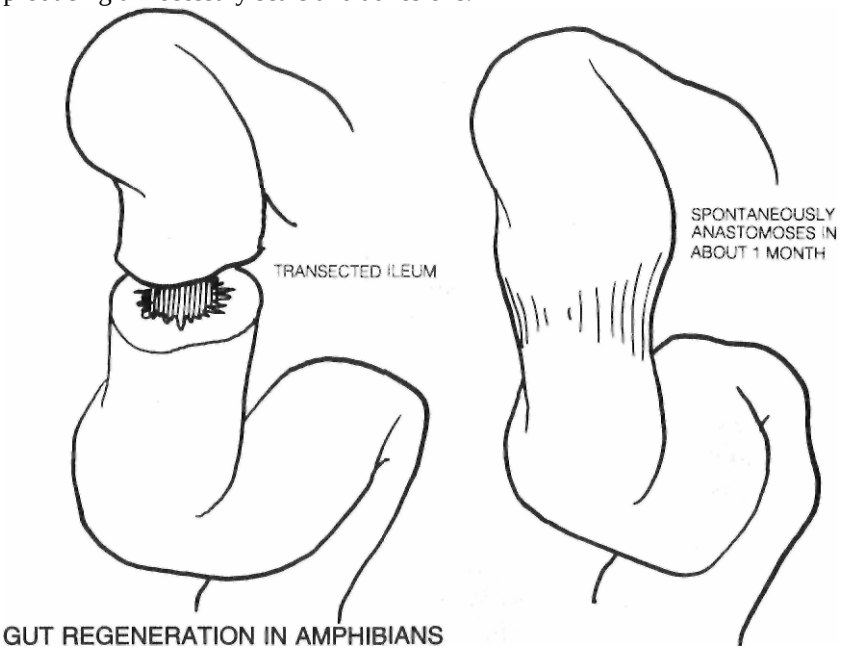

GUT REGENERATION IN AMPHIBIANS

No one knows for sure how the two cut ends find each other, but there's certainly some active search going on, for peritonitis sets in too quickly for the results to be due to chance. The process resembles a regrowing nerve fiber's search for its severed part, which may be conducted by electrical factors, a chemical recognition system, or both. Electrical potentials probably play the most important part, for recent research has found DC potentials at injuries on the peritoneum, and experimental changes in the peritoneum's normal bioelectric pattern attract the inner membrane enclosing the bowels, causing it to adhere to the site of the disturbance. Al has recently learned that, if the ends don't have to look for each other but instead are connected by a piece of Silastic tubing, rats can, like tadpoles, replace up to 3 centimeters of missing intestine. There's no reason to believe this technique couldn't be adapted to humans.

Even though we don't know enough yet to electrically stimulate intestinal healing, Al has proposed a preliminary test of regeneration in large mammals that could spare some patients a lifetime of misery. It's almost impossible to surgically rejoin the colon to the anus, and when

sutures fail, the person ends up with a colostomy. Since the free end of the colon would be held near its proper position by the local anatomy, Al suggests replacing it without stitches and giving such animals a temporary colostomy upstream from the gap. If X rays later showed regrowth, the temporary colostomy would be closed, and the animal would have a continuous, healthy intestine. If even a few patients could be spared the indignity of living attached to a bag, the effort would be well worth the little—yet still nonexistent—funding required. Intensive study of the electrical details of gut healing would probably make surgery less devastating for many additional patients.

Exciting as the prospects in this survey are, they're by no means the only ones, or even the most spectacular, which are reserved for the following chapters. Many researchers are working to turn the breakthroughs of the last two decades to practical use. Even so, progress isn't nearly as fast as it could be, perhaps due to disbelief that such widespread self-repair is really possible for us. It's not only possible, it's nearly certain, given even a modest monetary push, for the "useful dispositions" foreseen by Spallanzani are within our reach.

Ten
The Lazarus Heart

Like Columbus, scientists sometimes stumble upon new continents when merely seeking a quicker trade route. Our research group had this good fortune in 1973.

We'd gone back to basics after learning how to dedifferentiate frog red blood cells and start regeneration in rat limbs. We decided to study nucleated red cells in a variety of creatures, hoping for leads toward better regrowth in mammals. Although their circulating erythrocytes have no nuclei, even mammals have young red cells, with nuclei, forming in the bone marrow. After severe bleeding, up to a fifth of those in the bloodstream may be immature nucleated types, as the marrow rushes them into service to make up for the loss. We surveyed the effect of direct current on red cells from fish, amphibians, reptiles, and birds. All of the cells responded, but in a different way for each species. We decided to have a more detailed look at the largest and hence most easily studied red blood cells available, those of our old friend Triturus viridescens, the common green newt.

A newt is so small that you can't just poke a needle into one of its veins and take a blood sample. The only practical way to get pure blood is to anesthetize the animal, slice open its chest, cut its heart in two, extract the blood with a pipette, and throw away the carcass.

As the phrase goes, we "harvested" blood from three newts each week by this method. One day, when Sharon Chapin had finished the chore, she asked me, "What would happen if I sewed these animals up?" I answered that, because their hearts had been destroyed, they would die within minutes, with or without sutures, from lack of oxygen to the

brain, just as all our other amphibian blood donors had. We looked it up just to make sure. The standard works on regeneration all agreed that no animal's heart could repair major wounds. Unlike skeletal muscle, the cardiac variety had no satellite cells to serve as precursors for mature heart-muscle cells. In any case, the textbooks stated, the animal would die long before such repair could occur.

Next week Sharon put our three intended sacrifices in a bowl of water and with a straight face asked me if they looked healthy enough to use. I told her they looked fine. "Good!" she exclaimed. "These are the same three we used last week." Score one for the open mind!

Flabbergasted, I helped anesthetize and dissect this trio of miracles. Their hearts were perfectly normal, with no evidence of ever having been damaged in any way.

The Five-Alarm Blastema

Abruptly I changed my research plans. I asked Sharon to test a series of newts by cutting away large sections of their hearts and sewing up their chests, then killing some of the survivors every day and slicing, mounting, and staining the hearts for study under the microscope. Over 90 percent lived through the first operation, and several weeks later we had hundreds of slides ready for my examination and diagnosis. Unfortunately they all looked the same! Even those from the day after that horrendous mutilation showed only normal tissues with no sign of injury.

By now we knew we had come upon a first-class mystery and had better jettison our preconceptions. We reasoned that we could tell when regeneration was finished by finding out when the blood began flowing again. Under the microscope we could easily see blood cells streaming through capillaries in the transparent tail fins of lightly anesthetized newts. The motion stopped when we cut the heart, and restarted about four hours later. We sectioned a new series of hearts, this time covering the first six hours at intervals gradually increasing from fifteen minutes to one hour.

While waiting for the specimens, we rummaged more thoroughly through the literature for other reports on heart regeneration. There was evidence for very limited repair—but no true regeneration—of small heart wounds in a few animals. The process seemed limited to the very young. Even then, the results were of poor quality, combining a lot of scar tissue with only a little proliferation of nearby heart cells, but the

mitotic component could be enhanced by various experimental aids.

In 1971, John O. and Jean C. Oberpriller, anatomists at the University of North Dakota School of Medicine in Grand Forks, reported that small wounds in salamander hearts healed this way but required two months. A year after that, the English edition of a book by Lev Polezhaev summarized several decades of Russian research, mainly on the hearts of frogs and lizards. Pavel Rumyantsev, now at the Cytology Institute of the USSR Academy of Sciences in Leningrad, had found in 1954 that newborn mammals (rats and kittens) could repair tiny puncture wounds, and recently he has proved the same capacity in the atria, or receiving chambers, of adult rat hearts. We even found a German report of 1914 claiming that human babies had sometimes regenerated small areas of their hearts damaged by diphtheria.

The Russians claimed some progress in extending this marginal native healing. In the late 1950s, N. P. Sinitsyn had repaired large holes (up to 16 square centimeters) in the hearts of dogs by covering the wounds with patches made of muscle sheath, canvas, suede, or other materials. Scar tissue still covered the outside, but the patch guided a thin layer of new muscle fibers forming along its inner surface. Using dogs whose wounds had already closed with scar tissue, Polezhaev then found he could induce heart muscle to fill in part of the gap by cutting away the scar and irritating the edges of the remaining cardiac muscle. Other Soviet researchers enhanced the muscle cell proliferation a little more with vitamins B1, B6, and B12, various drugs, extra RNA and DNA, and heart tissue extracts or minces.

Despite such goads, heart regrowth was limited to very small injuries or the border zone around larger ones, and it always took several weeks. No one had even imagined that half a heart could restore its other half, much less in a matter of hours. I could hardly wait until the next batch of slides was ready.

They showed us an unprecedented type of regeneration. Where the missing part of the heart had been, a blastema formed in about two and a half hours. We saw no evidence of dedifferentiation or mitosis in the remaining heart-muscle cells, and indeed it would have been impossible for the processes we'd already studied to make a blastema in such a short time. Instead, the mass of primitive cells arose dramatically from the blood.

As soon as the salamander heart is cut open, blood pools around the wound and clots quickly, usuallyin about one minute, sealing the hole like wet plaster. Almost immediately, the nearest red blood cells crack open like eggs. Their nuclei, surrounded by a thin coating of cytoplasm, glide by some means yet unknown directly to the raw, fraved edge of the

heart muscle and insinuate themselves into the tangle of dying and injured cells. To a biologist this sight is bizarre, uncanny. It's as though the engine of a passing car could walk up to a stranded truck, climb under the hood, and drive it away.

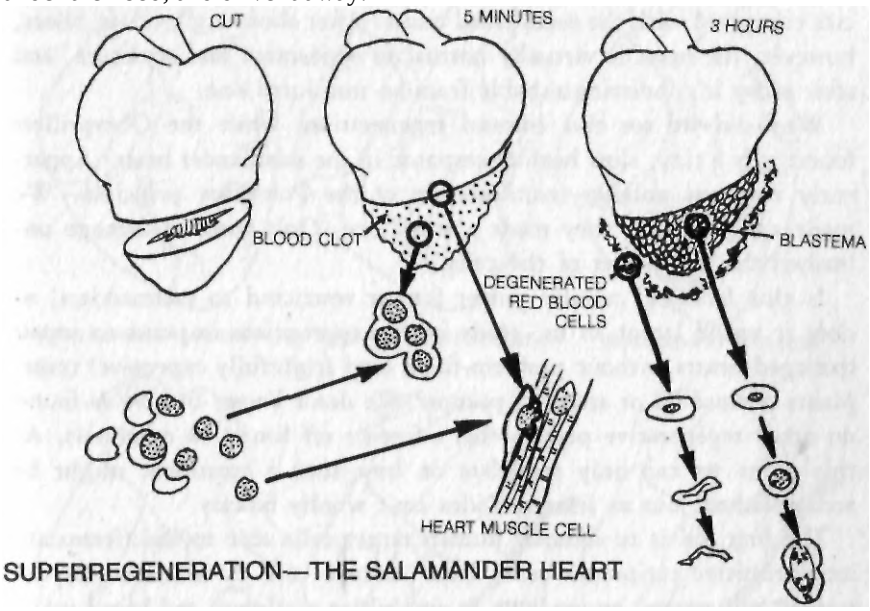

SUPERREGENERATION—THE SALAMANDER HEART

Farther away from the wound surface, the red cells also spill out their nuclei, but these cell yolks clump together, fusing their remaining cytoplasm to form a syncytium. Still farther away from the center of action, the red cells undergo the more leisurely dedifferentiation we observed in our frog fractures and DC culture studies. They turn into primitive ameboid cells that move toward the area of damage and attach themselves by pseudopods to the injured muscle fibers. In all of biology there's no precedent for these virtuosic cellular metamorphoses. In fact, they're so strange that most researchers have simply refused to believe in their existence or try the experiment for themselves.

All these changes are well under way within fifteen minutes. Soon afterward the extruded nuclei, the interconnected syncytial nuclei, and the ameboid cells are all dividing as fast as they can, building up the blastema. It's fully formed within three hours after the injury. By then its cells have already started to redifferentiate into new heart-muscle cells, synthesizing their orderly arrays of contractile fibers and connecting up with the intact tissue. If the clot contained more blood cells than were needed, the extras outside of the area now degenerate, apparently so as not to get in the way of the the repair work.

Meanwhile, the newt has survived by absorbing dissolved oxygen from

the water through its skin. Now, at about the four-hour mark, there are enough new muscle cells to withstand contraction, and the heart begins pumping again, slowly. After five or six hours, most of the blastema cells have redifferentiated into muscle, which is still somewhat "lacy" or delicate compared with the established tissue. After about eight or ten hours, however, the heart is virtually normal in appearance and structure, and after a day it's indistinguishable from an uninjured one.

Why did we see this colossal regeneration, while the Oberprillers found only a tiny, slow healing response in the salamander heart? Apparently this was another manifestation of the Polezhaev principle. We made a big wound; they made a small one. Only massive damage unleashed the full power of the cells.

Is this fantastic cellular power forever restricted to salamanders, or does it reside latent in us, ready at the appropriate impetus to repair damaged hearts without problem-filled (and frightfully expensive) transplants of donated or artificial pumps? We don't know, but we've found no other regenerative process that's forever off limits to mammals. At this point we can only speculate on how such a treatment might be accomplished, but at least the idea isn't wholly fantasy.

The first job is to identify human target cells able to dedifferentiate into primitive totipotent cells. Bone marrow cells or immature erythrocytes, the nearest equivalents to amphibian nucleated red blood cells, are one obvious candidate population, especially since they seem to be the crucial cells in rat limb regeneration and the inner part of fracture healing. Fibroblasts despecialized by electrically injected silver ions might be used. Another possibility is lymphocytes, one class of infection-fighting white blood cells. In our lab we've demonstrated that they, too, can dedifferentiate in response to appropriate electrical stimuli.

Since newt-type heart regeneration doesn't occur naturally in mammals, we would probably have to grow a large mass of the target cells in tissue culture. Then, with the patient on a heart-lung machine, the surgeon could cut away scar tissue and otherwise freshen the wound if it wasn't recent enough, then apply enough of these ready-made preblastema cells to fill the defect. They would be held in place by a blood clot, sutured pericardium, or some type of patch. Then, assuming we'd learned the electrical parameters already, electrodes would induce nuclear extrusion, dedifferentiarion, consolidation with surrounding muscle, and the final transformation into normal cardiac muscle. The current would probably have to be adjusted throughout the process to get us various steps in synchrony, and vitamins or drugs might be used to enhance mitosis or protein synthesis. Once the scar had been removed,

the instructions as to what cells were needed would come from the surrounding healthy heart muscle.

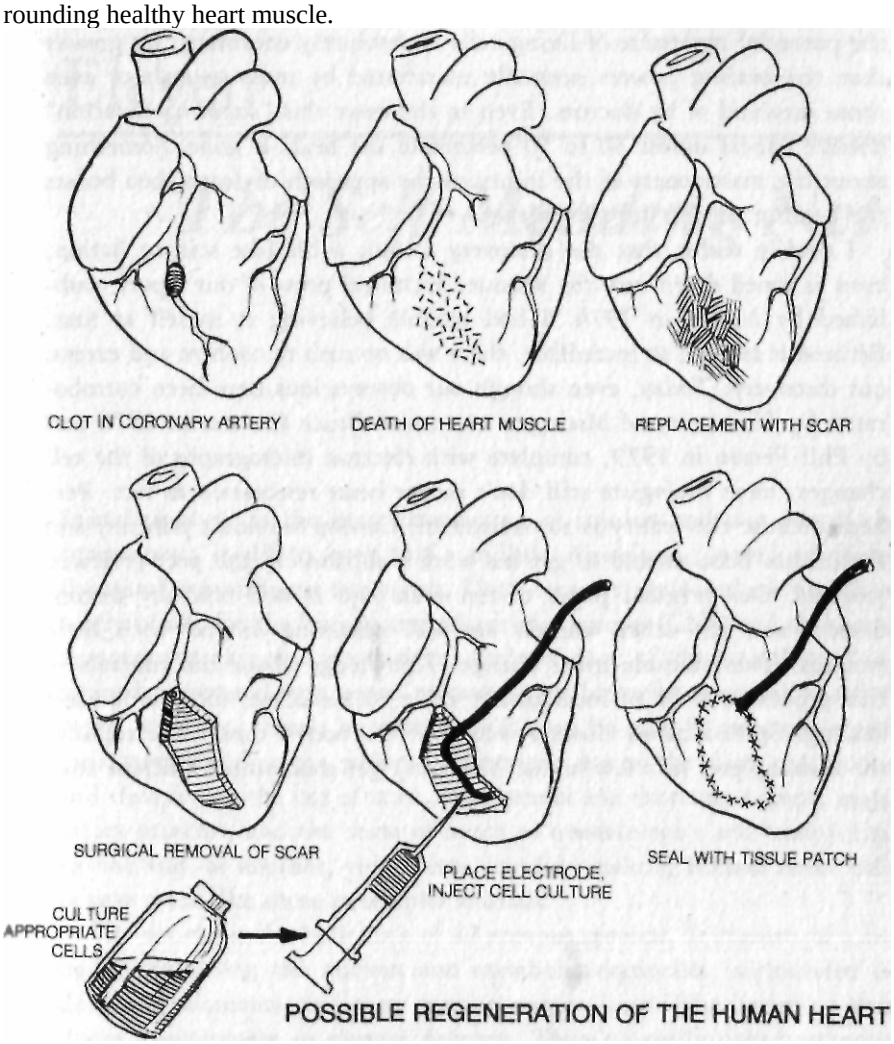

In the salamander this process takes about six hours. Since this exceeds the current limits of "machine time" for artificial circulation in humans, we would have to extend the capacities of heart-lung devices or else speed up the cellular processes. Obviously there's a long road of experiment to travel before we can be more specific about techniques. One of the things we must learn is whether the newt's electrocardiogram shuts down during repair. We must know how its presence or absence relates to the current of injury and other electrical factors in this novel method of blastema formation.

Personally, I'm sure we can get the human heart to mend itself. As a result of being confronted by this wonder in newts, I'm convinced that the potential repertoire of living cells is absolutely enormous, far greater than the healing powers normally manifested by most animals or even those dreamed of by doctors. Even in the newt this "superregeneration" doesn't appear unless 30 to 50 percent of the heart is gone. Something about the massiveness of the injury or the approach of death then boosts the healing process into overdrive.

I readily admit that the discovery sounds a bit like science fiction, even as toned down into the subdued technical prose of our report, published by Nature in 1974. I had trouble believing it myself at first. Because it seemed so incredible, there was no rush to confirm and extend our discovery. Today, even though our observations have been corroborated by University of Michigan anatomist Bruce Carlson in 1978 and by Phil Person in 1979, complete with electron micrographs of the cell changes, most biologists still don't accept heart restoration as fact. Perhaps because the reality is so outlandish, Carlson wouldn't publish, and Person has been unable to get his work published in the peer-reviewed journals. Our original paper of ten years ago is still officially unconfirmed, and the other workers are still puttering around with little wounds. This attitude must change. Knowledge about the controls of this process will be of incalculable value to medicine, for this is ideal healing. Spilled blood closes a wound at the body's center and replaces the missing part in a few hours. You can't get much more efficient than that.

Eleven
The Self-Mending Net

Spinal paralysis is the most devastating of injuries and also one of the commonest; it afflicts over half a million Americans, including fifteen thousand new sufferers every year. Until recently their outlook was absolutely bleak, for the human central nervous system (CNS) had no known regenerative capacity whatsoever. Only if part of the spinal cord remained unsevered was some recovery possible with physical therapy. Now, however, there's hope that we'll soon be able to coax nerve cells into reestablishing the proper connections across the damaged section and thus return the use of arms, legs, sexual and excretory organs, respiratory muscles, and the sense of touch to quadriplegics and paraplegics. In one way or another, this dream involves making human nerve cells behave more like those in simpler animals.

The neuron is the basic unit of all nervous systems. It consists of a cell body, containing the nucleus and metabolic organelles, surrounded by dozens of filaments that carry messages in and out. The incoming dendrites predominate in sensory neurons. There's usually only one motor fiber, or axon, which carries the neuron's outgoing messages to dendrites of other neurons or to receptors on muscle or gland cells. An axon, often several feet long, is the principal fiber of a motor neuron, which relays orders from the brain or spinal cord to the tissues and organs.

All neuron cell bodies reside in the brain and spinal cord. Only their axons and dendrites extend outward, forming the peripheral nerves that connect every part of the body with the CNS. Other fibers connect certain sensory and motor neurons within the spinal cord, creating reflex arcs, like those that jerk our hands from hot stows without our having

to send the impulse all the way to the brain for instructions. Still other fibers connect spinal neurons with those in the brain, and in the brain itself the interconnections reach such a density that each nerve cell may hook up with as many as twenty-five thousand others.

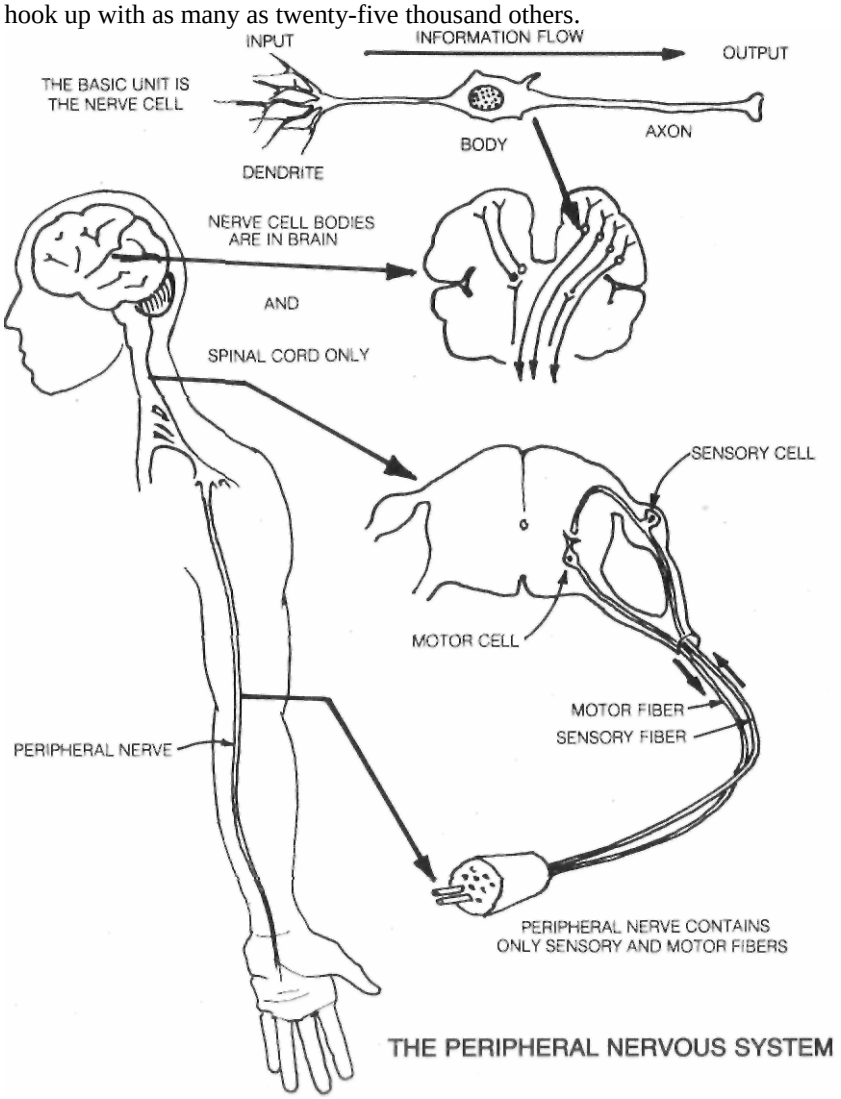

Except for a few specialized components like the naked fiber tips that enter into neuroepidermal junctions, all parts of every neuron are swaddled in various types of perineural cells. In the brain there are several kinds, collectively called the glia, in which the neurons are embedded like hairy raisins in a pudding. The cell bodies in the cord also are surrounded by glial cells, but their axons and dendrites, which include

the fibers of the peripheral nerves, are surrounded by Schwann cells. These form tubes, made up of spiraling layers of membrane rich in a fatty substance called myelin, around some of the largest fibers. A third type, ependymal cells, line the four cavities within the brain, or ventricles, and the narrow central canal that runs the length of the spinal cord. These cells are close relatives, having all developed from the same part of the ectoderm, or outer cell layer, that formed the primitive neural tube in the embryo. The nervous system actually consists of several times more perineural cells than neurons.

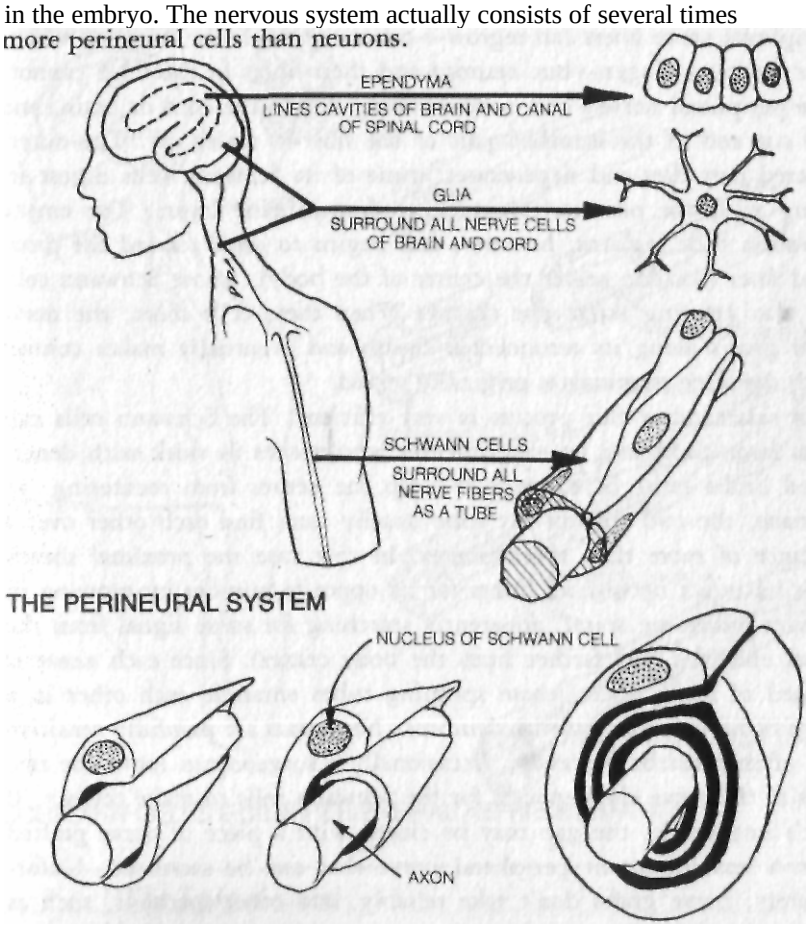

SCHWANN CELL SHEATH AROUND A PERIPHERAL NERVE FIBER

Until recently the perineural cells were considered merely a "packing tissue," whose only job was to insulate and support the neurons. We've now learned that they play a major role in getting nutrients to the neurons. They also help control the diffusion of ions through the nerve cell membrane and hence regulate the speed of impulse firing, even to the

point of inhibiting seizures, the random spread of impulses in the brain. They may also have an important part in memory, and they probably conduct the direct currents so important to regeneration. They're essential to healing wherever it occurs in nerve tissue.

Peripheral Nerves

Peripheral nerve fibers can regrow—otherwise we'd lose sensation whenever we cut a finger—but neurons and their fibers in the CNS cannot. The peripheral nerve's cell body survives, safe in the cord or brain, and the cut end of the attached part of the fiber is sealed off. The outer, severed part dies and degenerates; some of its Schwann cells digest it, along with the now-useless myelinated membrane layers. The empty Schwann tube remains, however, and begins to grow toward the proximal fiber (the one nearer the center of the body), whose Schwann cells are also growing across the chasm. When these cells meet, the nerve fiber grows along its reconnected sheath and eventually makes contact with the same terminals it originally served.

In salamanders this process is very efficient. The Schwann cells can cross large gaps, and an experimenter who wishes to work with denervated limbs must be diligent to keep the nerves from reentering. In humans, the two ends of the tube usually can't find each other over a distance of more than a centimeter. In that case the proximal sheath with its intact nerve fiber hunts for its opposite number by growing in an ever increasing spiral, apparently searching for some signal from the distal end (the part farther from the body center). Since each nerve is formed of many fibers, these spiraling tubes entangle each other in a lump of nerve tissue called a neuroma. Neuromas are painfully sensitive and often must be cut away. Occasionally a surgeon can move the two ends of the nerve close enough for the Schwann cells to make contact. If that's impossible, the gap may be closed with a piece of nerve grafted from a less important peripheral nerve that can be sacrificed. Unfortunately, nerve grafts don't take reliably, and other methods, such as making artificial channels with tiny plastic tubules, are still in the experimental stage.

We don't know why the salamander's peripheral nerve regrowth is so much more effective than ours, but I surmise that its more efficient DC electrical system accounts for the difference. If the locator signal is electrical, it should be possible to augment it in humans so as to grow nerve fibers over longer distances. Beginning with a 1974 report from David

H. Wilson of the Leeds General Infirmary in England, there have been some interesting claims that pulsed electromagnetic fields have speeded recovery of limb function in rats after peripheral nerve damage, but the effect hasn't yet been substantiated for humans. If these findings hold up, we may soon be able to boost nerves past their 1-centimeter limit, even if the action is indirect, and a thorough investigation of the electrical basics could drive nerve regrowth to even greater lengths.

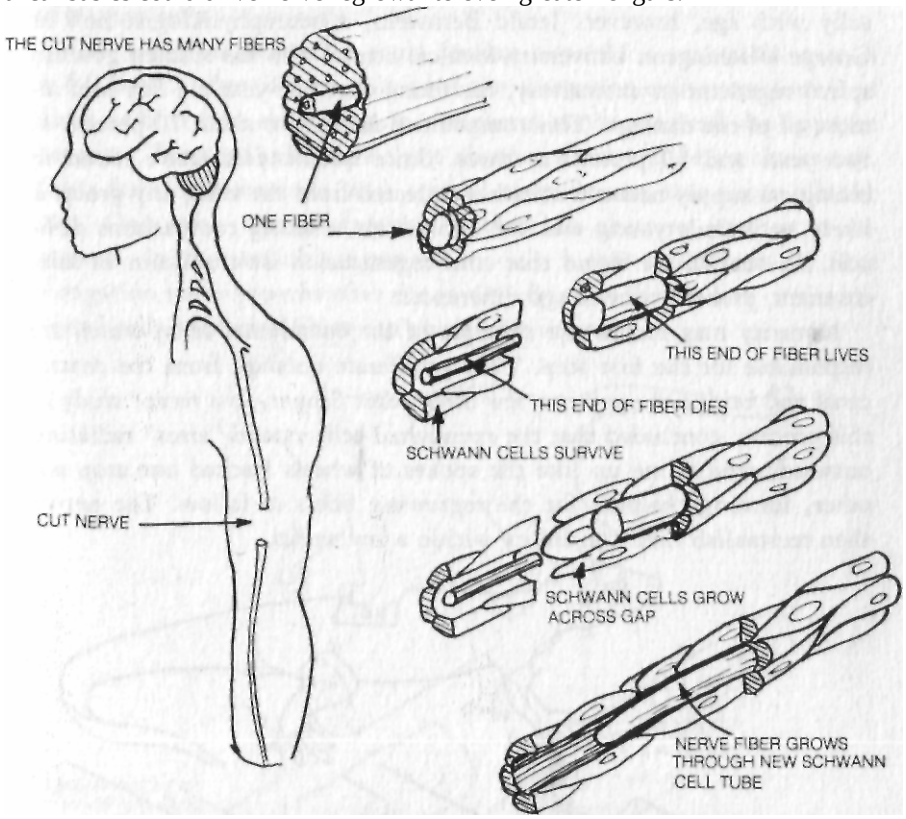

SCHWANN CELLS GUIDE PERIPHERAL NERVE REGROWTH

The Spinal Cord

A sad and crucial difference separates peripheral fibers from those in the human spinal cord, for the latter don't reconnect over even a fraction of a centimeter. However, in most injuries relatively few of the neurons themselves are killed. It's important to realize that most of the cord cells below the injury don't die. The reflex arcs remain intact. In fact, reflexes are stronger than normal, because the neurons are now disconnected

from the regulating influence of the brain. For the same reason, the broken bones of paraplegics heal in half the normal time, whereas a bone will heal very slowly or not at all if its peripheral nerve supply has been cut. Only the communication between brain and spine is silenced in paraplegia, and that makes all the difference.

Spinal fibers do reconnect in some animals, notably goldfish and, as you might expect, salamanders. Their ability seems to decline dramatically with age, however. Jerald Bernstein, a neurophysiologist now at George Washington University Medical School who has studied goldfish spinal regeneration extensively, has found that one-year-old fish heal almost all of the damage. This competence declines to about 70 percent at two years and 50 percent at three. Since salamanders aren't raised in biological supply houses but rather collected from the wild, any group is likely to include young and old individuals, making comparisons difficult. In our lab we found that cord regeneration isn't uniform in salamanders, probably due to age differences.

Maturity may reduce the response of the ependymal cells, which are responsible for the first step. They proliferate outward from the central canal and bridge the gap in a few days. Marc Singer, in a recent study of this process, concluded that the ependymal cells extend "arms" radiating outward, which line up like the spokes of wheels stacked one atop another, forming channels for the regrowing fibers to follow. The nerves then reestablish their continuity within a few weeks.

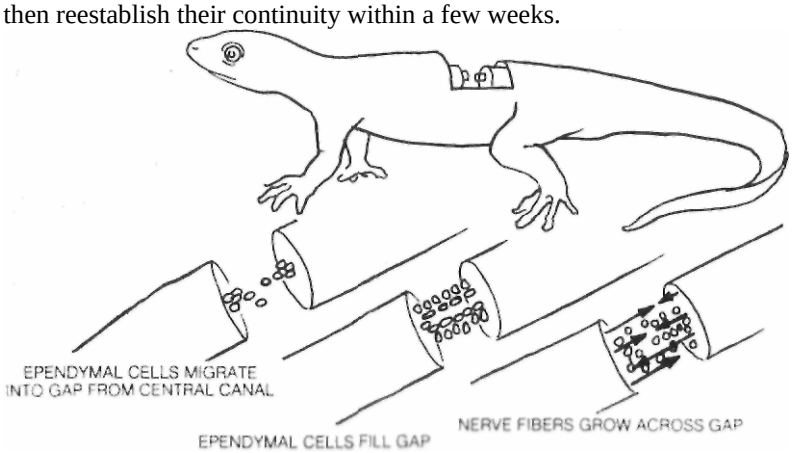

SALAMANDER SPINAL-CORD REGENERATION

Bernstein also found that there's a critical period during which regrowth must be completed or it will fail. After cutting the cords of goldlfish, he inserted Teflonon spacers to block regeneration. The normal

processes took place, but of course the cells couldn't penetrate the divider. After the cellular activity had died down, Bernstein removed the barriers, but there was no further change. However, when he then cut off each damaged end, producing an even larger gap and reinjuring the cord, the cells started from scratch and healed the defect completely. Thus there's good reason to believe that even long-standing spinal injuries can potentially be regenerated if we can extend the basic capabilities of human cells.

One would expect to see some healing response in mammals, even if it fell short. After all, we only need the elongation and reattachment of fibers, which does take place in peripheral nerves. Instead the opposite happens. The cord cells die a short distance above and below the injury. Cysts form near the ends, and, instead of ependyma, scar tissue fills the gap. Only after this destruction is there an abortive attempt at regrowth. In humans this amounts to only a few millimeters of fiber elongation many months after the injury. By then it's too late; the ependymal cells and nerve fibers can't penetrate the scar.

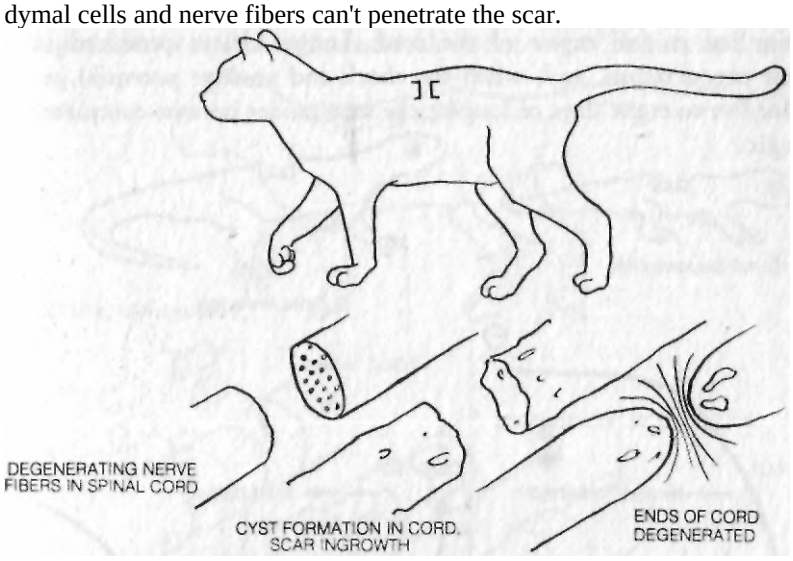

CYSTS AND SCARS PREVENT CORD REGROWTH IN MAMMALS

Why the difference between salamanders and mammals? The reason may lie in the cord's immediate response. In all animals the injury instantly results in spinal shock, during which all neuronal activity is profoundly depressed, especially in the part of the cord still connected to the brain. Even the simplest reflexes disappear. As the shock wears off, the cord below the injury becomes hyperactive. Its reflexes become tre-

mendously exaggerated and lead to spastic paralysis of the muscles. The interesting difference is in the duration of shock. In young salamanders and goldfish it lasts only a few minutes, but it may endure for over a week in old ones. In mammals it takes even longer to wear off—as long as six months in humans.

We made some electrical measurements on salamander and frog spines in our lab. The injured area turned out to be strongly positive during spinal shock, even though all direct-current flow ceased in the entire cord and in the peripheral nerves arising from the part below the trauma. Then, as the shock resolved, a steadily increasing negative potential appeared, its size reflecting the amount of outgrowth by ependyma and nerve fibers. We found that we'd only rediscovered these potentials, however. G. N. Sorokhtin and Y. B. Temper had made the same measurements at the Khabarovsk Medical Institute twenty years before. The patterns of shock and polarity both correlated, not only with the cell activity, but with the end result of regenerative success or failure. A few minutes of shock and a correspondingly short period of positivity led to full repair of the cord. Longer delays produced incomplete regeneration, and, when the shock and positive potential persisted for five to eight days or longer, the salamander became completely paraplegic.

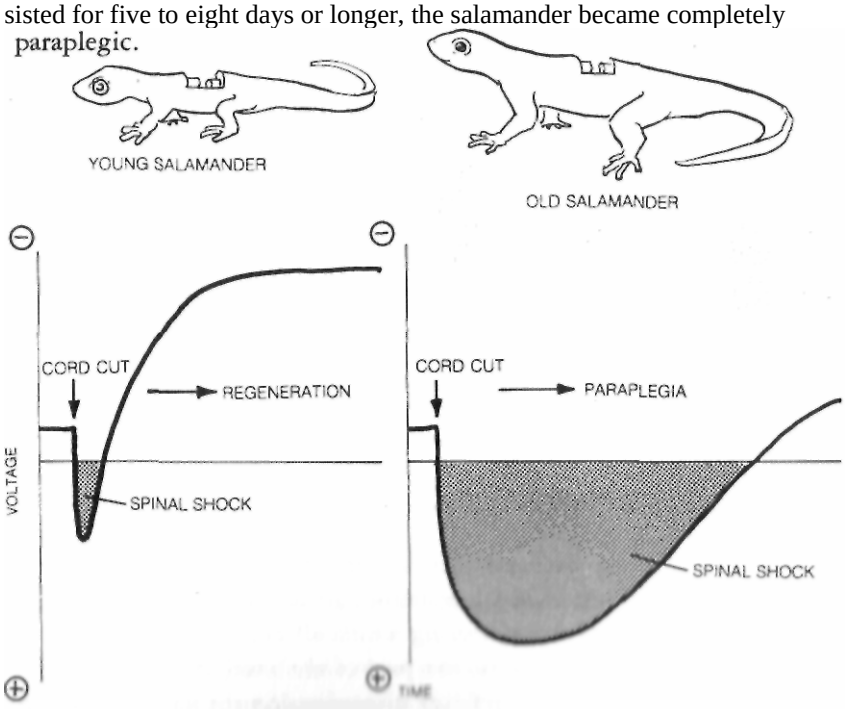

SPINAL SHOCK AND AGE INHIBIT CORD REGROWTH

As far as I know, the only electrical measurements of spinal shock in mammals were preliminary ones done at our laboratory in conjunction with Carl Kao of the VA hospital in Washington, D.C. We tested the severed cord ends in cats for twenty-four hours and found only an increasing positive potential. The situation seemed quite similar to the electrical difference between salamander and frog limbs. As in most instances, positive potentials appeared to inhibit constructive cellular activity while negative ones fostered it.

An experiment Kao did several years ago provided some supporting evidence. Kao made two cuts through the spinal cord in each of several cats, producing a central fragment about 5 millimeters long, separated from each end. He then grafted pieces of sciatic nerve as spacers in the two cuts. Typical degeneration with cysts occurred in each end of the cord but not in the isolated piece. In fact, this part showed some growth of its ependyma and nerve fibers. The small piece was probably isolated from the positive potentials produced in the rest of the cord. Hence it escaped inhibition and grew. It seems the prolonged electrical positivity of spinal shock is the main roadblock in the way of human cord repair.

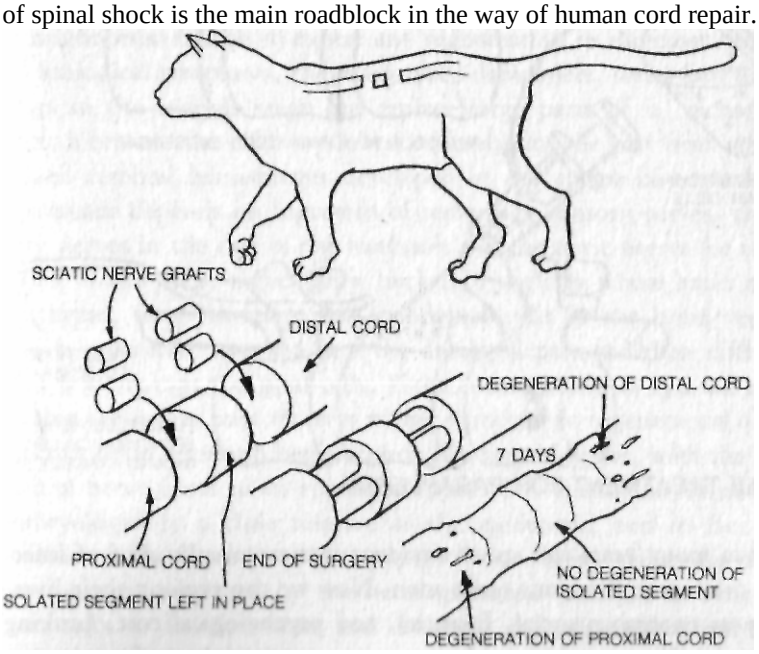

KAO'S EXPERIMENT

It should be possible to cancel that polarity and replace it with a growth-stimulating negative one, using a properly shaped electrode. Older injuries in which spinal shock has subsided might require a dif-

ferent input of current, as well as surgical removal of scar and cysts. The electrode material would have to be chosen carefully, for some metals are toxic to nerve cells. Also, humans have a low ratio of ependyma compared to spinal neurons, so we might have to add more. However, it should be relatively easy to culture more ependymal cells from a sample of the patient's own, and then inject them when we put in the electrode.

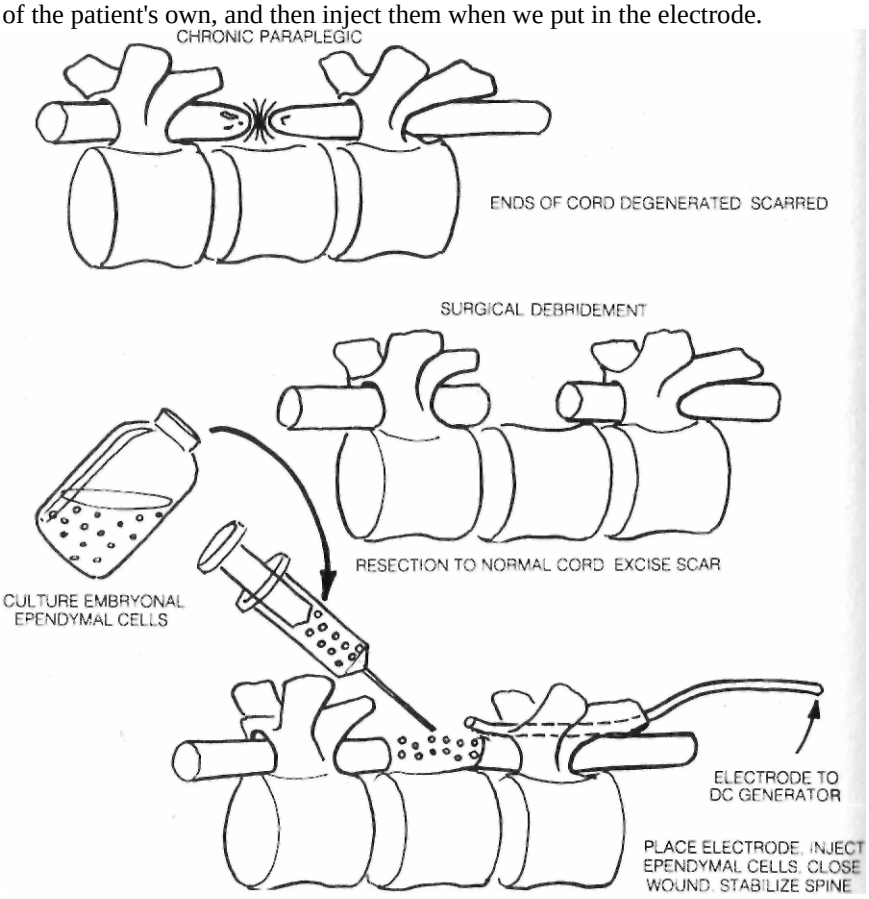

POSSIBLE TREATMENT FOR PARAPLEGIA

Not too many years ago spinal accident victims usually died of infections or other complications quite soon. Now we can prolong their lives, but only at enormous social, financial, and psychological cost. Looking ahead, as in the case of heart damage, we now have hope for releasing regeneration in humans. Actually, the outlook for spinal regrowth is more promising. The cellular processes are more familiar, and there are a few groups, like the American Paralysis Association, that sponsor research more imaginatively than the government agencies. Thus the elec-

trical problems in spinal healing may be tackled sooner than in other fields.

The public imagination has been captured by the computerized muscle-stimulation techniques being developed by Jerrold Petrofsky, an engineer at Wright State University in Dayton. The nationally televised sight of his patient Nan Davis and other paraplegics taking tentative steps and pedaling tricycles with their own muscle power was tremendously exciting. But if we can get the body to do the same things by itself, that will be even better. Any amount of regeneration would only make other techniques more effective. Even restoring 10 percent of lost function would be an unimaginable blessing to those who are now helpless. I feel the electrical manipulation of spinal shock must be tested vigorously now, for this is perhaps the one area where the barriers of tragedy are closest to being broken.

The Brain

It might seem foolish to expect any regeneration in the most complex of all biological structures, the brain, yet salamanders, some fish, and most frogs in the tadpole stage can replace large parts of it, including the optic lobes and the olfactory lobes, or forebrain, the part from which our prized cerebral hemispheres developed in the course of evolution. Replacement depends on ingrowth of remaining sensory nerves, the olfactory nerves in the case of the forebrain and the optic nerves for the optic lobes. When these nerves grow back into the area where brain has been destroyed, they stimulate the ependymal cells in the brain ventricles, which proliferate outward into the damaged part and then differentiate into new neurons and glial cells. If the animal's nose or eyes are removed so that the injury zone receives no nerve input, no regeneration occurs.

Thus brain regrowth begins much like that of limbs, with the connection of nerve fibers to an epithelial tissue. The ependyma, remember, is embryologically a close relative of the epidermis, and in fact can be considered the central nervous system's "inner skin." Since the electrical environment produced by the neuroepidermal junction is what stimulates cells to dedifferentiate and divide in the salamander limb stump, and since we started limb regeneration in the rat by crudely mimicking this signal, it seems likely that a similar stratagem could induce brain regeneration in animals normally lacking this ability.

A form of shock, called the spreading depression of Leao after its discoverer, neurologist A. A. P. Leao, occurs after brain injuries. Start-

ing at the site of damage, it extends in all directions until the entire cortex becomes electrically positive and all its neurons shut down. Leao studied it only in response to small injuries, when it persists for a few hours. We don't know whether it occurs in the salamander or how long it lasts after major damage to the mammalian brain. Concerted study of Leao's depression combined with experiments in electrically stimulating the ependymal cells could open the way to self-repair of the human brain.

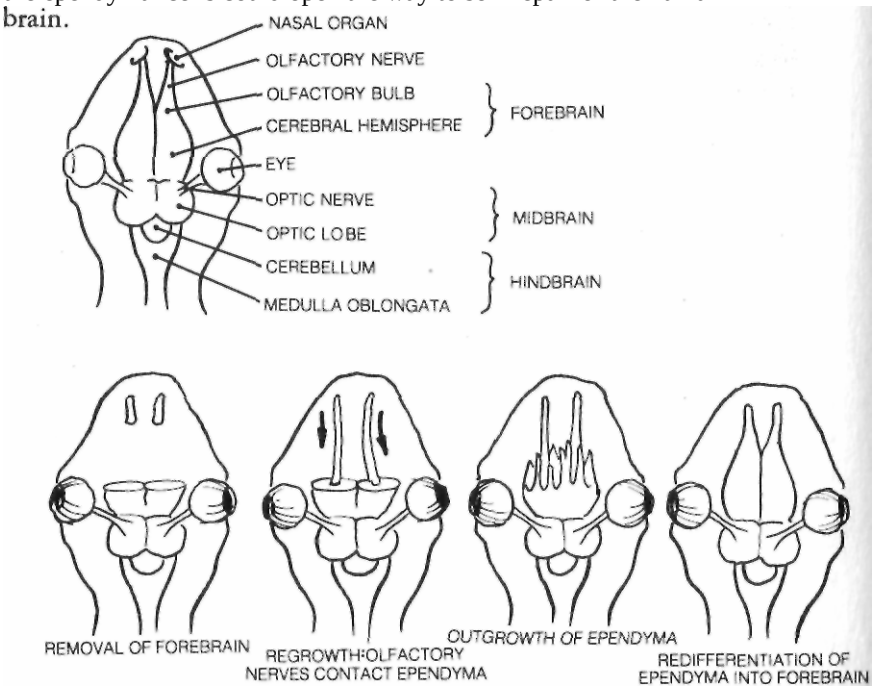

AMPHIBIANS CAN REGENERATE LARGE PARTS OF THE BRAIN

Recovery from stroke and head wounds taught us long ago that the brain has a great deal of plasticity; that is, it can reorganize so that undamaged regions take over tasks formerly done by the lost cells. Supplementation of this ability with even a small amount of regeneration might make recovery nearly complete for many brain-damaged people. For the first time in history, neurologists can hope to progress from describing the brain and cord to mending them. As Geoffrey Raisman of London's Laboratory of Neurobiology recently reminded his colleagues: ". . . no immutable natural laws have been discovered that forever rule out repair of the nervous system."

Twelve
Righting a Wrong Turn

Good and evil often sprout from the same tree, in the body as in Eden. Nothing illustrates this paradox better than cancer. Today, because of breakthroughs in genetics, thousands of scientists are searching for oncogenes, bits of DNA that are presumed to pull the trigger that fires the malignant bullet. It has been known for a long time, of course, that cancer isn't inherited through egg and sperm the way hemophilia is. However, many have postulated that the immediate cause of cancer may be genetic changes in somatic cells. Normally suppressed genes held in an unnoticed corner of our genetic bookshelves since long ago in our evolution might be dusted off only when other bodily conditions are "just wrong." While the premise of this idea is apparently true, biologists have recently concluded that the difference between a normal gene producing a normal protein and one that could theoretically cause cancer is a single "typographical error" in a whole chapter of amino acid sequences. Such mistakes happen so often that we would all be riddled with cancer from infancy if that were all it took to start the disease. Something else must go awry before a few misspellings can turn the whole library into gibberish.

Three basic criteria by which a doctor diagnoses cancer must serve as the starting point in solving the mystery of its cause. First of all, the disease always always arises not from an alien germ but from a formerly normal cell of the host's body, and the cancer cells are more primitive than their healthy precursors. Moreover, this atavism reflects the seriousness of the

disease: The simpler the cells, the faster they grow and the harder they are to treat, whereas a tumor that still resembles its tissue of origin is less malignant.

The second criterion is growth rate. Cancer cells multiply wildly, in contrast to the slow, carefully controlled mitosis of normal cells. Going hand in hand with this uncontrolled proliferation is a similar lack of control in the structural arrangement of the cells. Their membranes don't line up in the normal, specific ways, and they form a jumbled mass instead of useful architecture. As a further result of runaway multiplication, cancer doesn't observe the "boundary laws" of normal tissue. Instead it encroaches imperialistically upon its neighbors. In addition, since the cells don't adhere in any kind of structure, some of them are constantly breaking off, flowing through the blood and lymph, and setting up colonies—metastases—throughout the body.

The third basic criterion of cancer is metabolic priority. The diseased tissue greedily takes first choice of all nutrients circulating in the blood; the healthy part of the body gets what's left over. As the tumors disseminate and grow, they consume all available food, and the host wastes away and dies.

We can make one crucial observation at this point: Except for the lack of control, all three characteristics—cell simplicity, mitotic speed, and metabolic priority—are hallmarks of two normal conditions, embryonic growth and regeneration.

When considering the similarities between an embryo and a tumor, it's important to keep in mind one difference. Even though contained within the body of its mother, the embryo is a complete organism, and the controls over its cells are primarily its own, not those of an adult. Over thirty years ago in Switzerland, G. Andres probed this relationship by implanting frog embryos in various body tissues of adult frogs. Whenever the host didn't simply reject the graft, the embryo degenerated into a highly malignant metastasizing tumor. As a result, Andres proposed a theory of cancer that remains provocative today: A normal cell becomes cancerous by dedifferentiation. This change is not dangerous per se, according to Andres, but, because it occurs in a postfetal animal, the controls that would normally hold these neo-embryonic cells in check aren't working.

Cancer's relationship to regeneration is even more interesting. In the latter, a rapid growth of primitive cells having metabolic priority occurs in an adult, but with proper control as in an embryo Those animals that regenerate best are least susceptible to cancer. In general, as complexity increases up the evolutionary ladder to humans, regenera-

tion decreases and cancer becomes more common. Although salamanders stand about midway in degree of complexity, they're perhaps the least specialized of all land vertebrates. They have tremendous regenerative abilities and almost no cancer. Even to give them tumors in the laboratory requires much effort. Adult frogs, on the other hand, have bodies that are much more specialized for their amphibious way of life; they regenerate very little and are subject to several kinds of cancer.

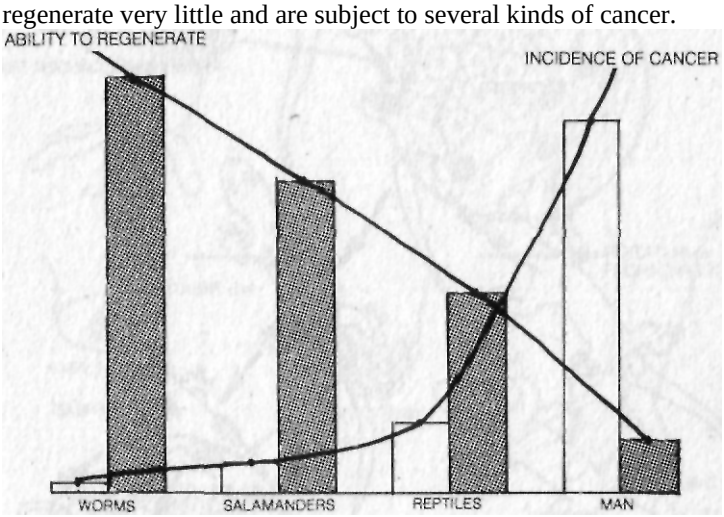

AS REGENERATION DECREASES, CANCER INCREASES

In 1948 Meryl Rose decided to see whether the environment of a salamander's regenerating limb could control the primitive cells of cancer as well as those of the blastema. He took pieces of a type of kidney tumor common in frogs and transplanted them to the limbs of salamanders. These tumors took better than most, and soon killed the animals when allowed to spread unchecked. However, when Rose amputated the leg just below or through the malignancy, normal regeneration followed, and the cancer cells dedifferentiated more fully as the blastema formed. Then as the new leg grew, the former frog tumor cells redifferentiated along with the blastema. The frog cells were easily distinguished from salamander cells by their smaller nuclei, and microscopic study showed frog muscle mixed in with salamander muscle, frog cartilage cells amid salamander cartilage, and so on.

This monumentally imporrant experiment proved Rose's hypothesis that regeneration's guidance system could control cancer, too. It implied

that cancer cells weren't special but merely embryonic cells in a post-embryonic body. Rose's work led directly to Andres's theory a few years later.

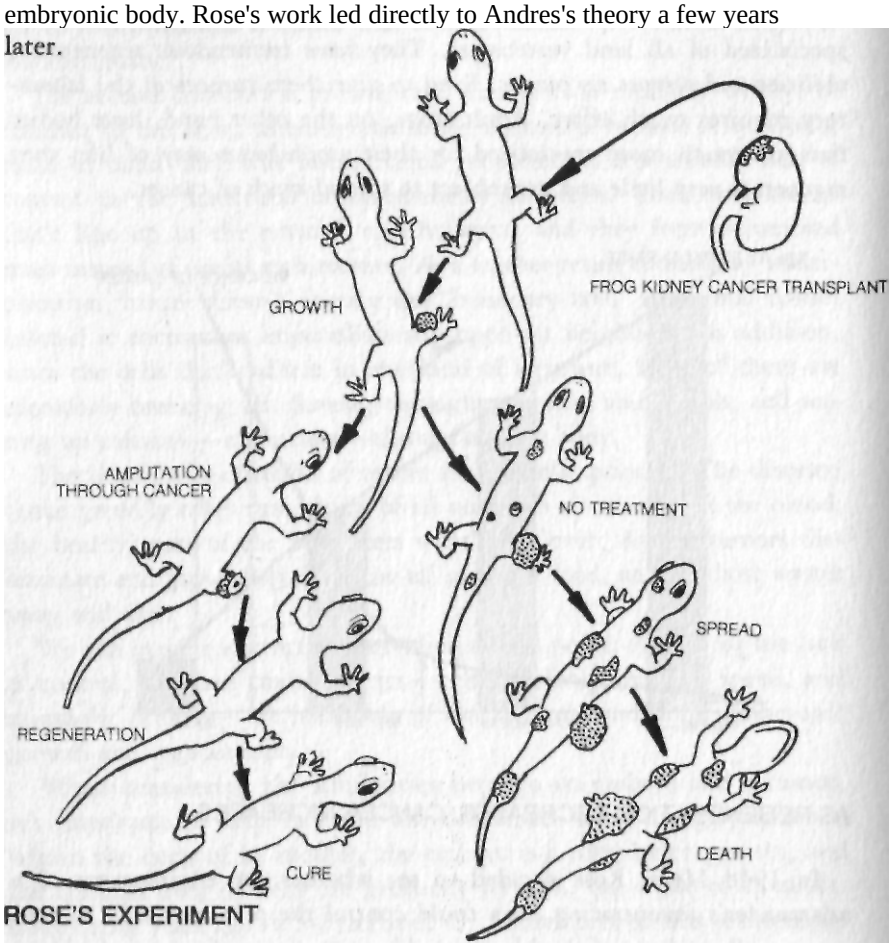

Unfortunately, biology was still firmly gripped by anti-dedifferentiationism, and these ideas were partly ridiculed, partly ignored. The reaction held back cancer research for decades, because the dogma implied that carcinogenesis, like differentiation, was irreversible—once a cancer cell, always a cancer cell. As long as this view was sacred, the only possible way to cure cancer was to cut it out or kill it with drugs and X rays. We've been beating that dead horse for fifty years now with tragically modest increases in survival rates. Surgery works only against tumors that haven't yet spread. Chemotherapy depends on differences between malignant and healthy cells. However, the differences aren't as great as we would like, because cancer arises, not in some distant swamp, but from a slight change in our own cells. Therefore chemother-

apy and X rays inevitably produce some damage in normal cells, too. Doctors, being only human and sharing in their patients' pain and terror, have devised ever more ferocious treatments. In our war on cancer we've stampeded ourselves into a sort of Vietnam syndrome: To destroy our foes, we're killing our friends. As Walt Kelly's cartoon character Pogo observed in that context, "We have met the enemy and he is us."

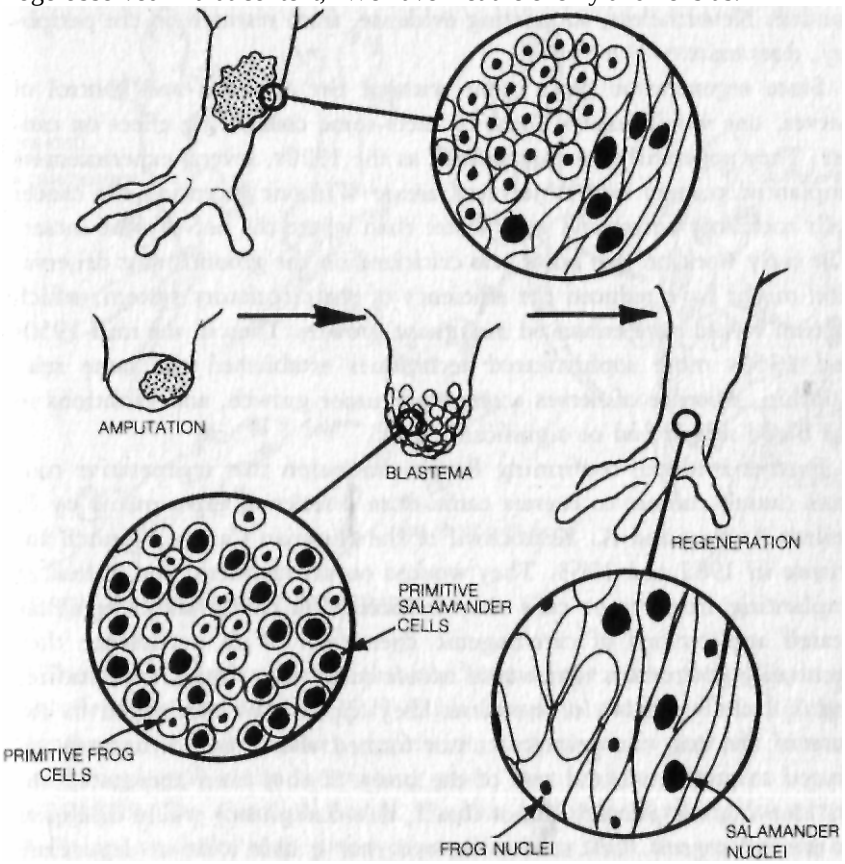

CANCER CELLS RETURNED TO NORMAL BY REGENERATION

A Reintegrative Approach

But surely, you may be thinking, if this theory of cancer had any potential for a cure, the research establishment would have considered it. And surely there would be some supporting evidence. Unfortunately, even though the detooling and retooling of cells have now been accepted by all of biology, the old habits still persist throughout most of the grant-

ing hierarchy. A few years ago, for example, I met a young research fellow at the National Cancer Institute who wanted to study the regeneration-cancer link. He even showed me his proposal, an excellent one. I told him he was asking for trouble if he submitted it to NCI, but he said his boss approved and he was sure he'd get the grant. A month later he was forced out of the institute, and the project has never been funded. Nevertheless, supporting evidence, from research on the periphery, does exist.

Since regeneration can't occur without the stimulus and control of nerves, one would expect them to exert some controlling effect on cancer. They apparently do. As far back as the 1920s, several experimenters implanted tumors into denervated areas. Without exception the cancer cells took root better and grew faster than where the nerves were intact. The early work on this point was criticized on the grounds that denervation might have reduced the efficiency of the circulatory system, which in turn would have enhanced malignant growth. Then in the mid-1950s and 1960s more sophisticated techniques established the same relationship. Absence of nerves accelerated tumor growth, and variations in the blood supply had no significant effect.

Further evidence confirming Rose's conclusion that regenerative controls caused tumors to regress came from a series of experiments by F. Seilern-Aspang and K. Kratochwil of the Austrian Cancer Research Institute in 1962 and 1963. They worked on salamanders, but instead of implanting frog tumor cells they induced skin cancer with large, repeated applications of carcinogenic chemicals. With persistence they eventually got tumors that would invade subsurface tissues, metastasize, and kill the animals. In one series they applied the carcinogen to the base of the tail; the primary tumor formed there, and metastases appeared at random in the rest of the body. If they then amputated the tail, leaving the primary tumor intact, this malignancy would disappear as the tail regrew. Cell studies showed that it didn't die or degenerate but apparently reverted to normal skin. Furthermore, all the secondary tumors vanished, too, as though they were being operated by remote control from the main one. The salamander ended up with a new tail and no cancer. However, if the primary tumor was at a distant point on the body, amputation of the tail had no effect. Even though the tail regenerated, the main cancer and its offshoots all progressed, and the animal died.

This research, combined with Rose's, indicates that regeneration near a primary tumor can make it regress by reverting to its normal tissue type. I doubt that there's anything special about legs or tails; I would

predict that regrowth in any part of the body, as long as it was near the primary tumor, would have the same effect. The key to regression appears to be a change in the malignancy's immediate neighborhood. The electrical currents in nerve and particularly in the neuroepidermal junction seem likely candidates, since they suffice to start regeneration in animals normally incapable of it.

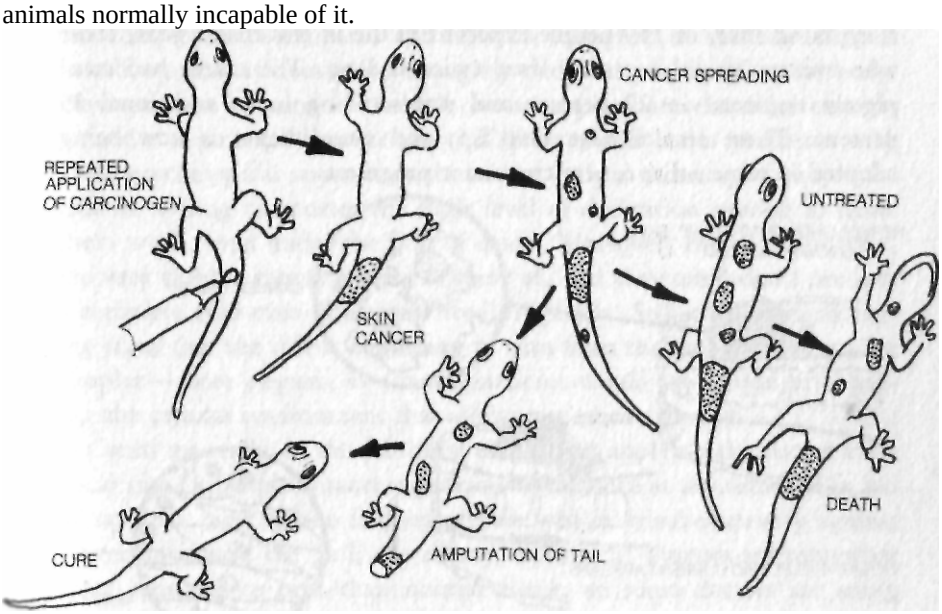

ROSE'S EXPERIMENT CONFIRMED

There's abundant evidence that the state of the entire nervous system can affect cancer. Back in 1927 Elida Evans, a student of Carl Jung, documented a link between depression and cancer in a study almost totally neglected in the intervening years. In a long-term project begun in 1946 by Dr. Caroline Bedell Thomas at Johns Hopkins School of Medicine, students were given personality tests, and the occurrence of disease among them was charted over several decades. In this and later studies, a high risk of developing cancer has been correlated with a specific psychological profile that includes a poor relationship with parents, self-pity, self-deprecation, passivity, a compulsive need to please, and above all an inability to rise from depres'sion after some traumatic event such as the death of a loved one or loss of a job. In such a person, cancer typically follows the loss in a year or two.

Several physicians have found they can greatly increase cancer patients' chances of a cure with biofeedback, meditation, hypnosis, or visualization techniques. Several years ago O. Carl Simonton, an oncologist, and

Stephanie Matthews-Simonton, a psychologist, began using all these methods, with emphasis on having patients develop a clear picture of the cancer and their body's response to it. For example, a patient might spend a meditative period each day imagining white blood cells as knights on white horses defeating an army of black-caped marauders. When the Simontons tabulated their first results in "terminal" cases, they found that, of 159 people expected to die in less than a year, those who eventually did succumb lived twice as long. The cancer had completely regressed in 22 percent and was receding in an additional 19 percent. These results have held up, and visualization is now being adopted in some other cancer-treatment programs.

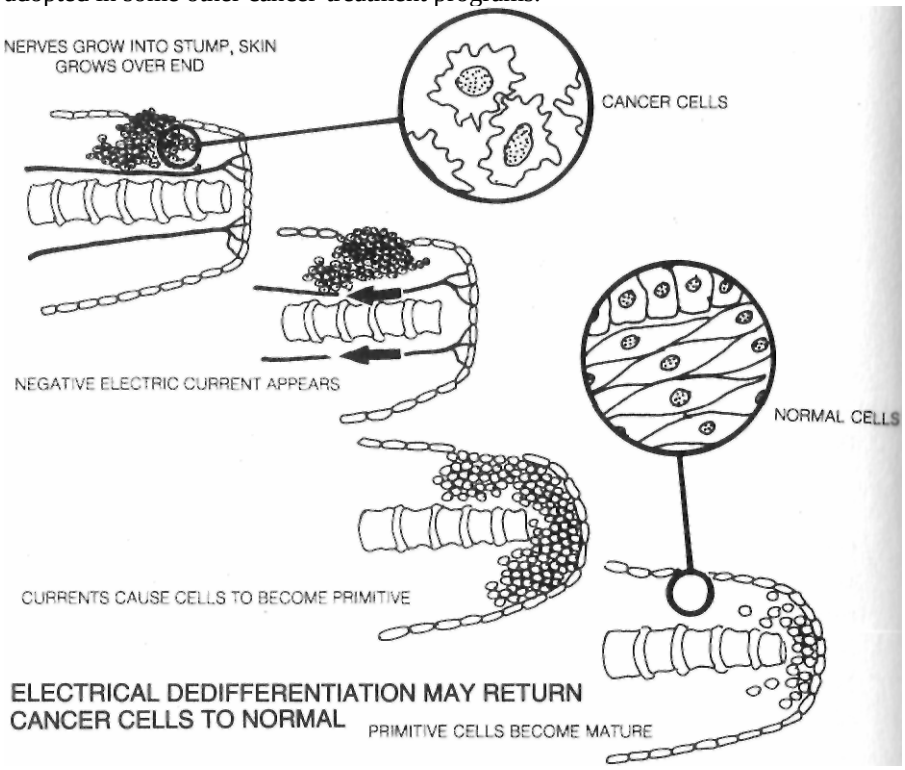

Penn State psychologist Howard Hall, testing hypnosis for boosting white blood cell activity, found a 40 percent increase in cell counts among his younger, more responsive subjects just one week after the trance session. New Haven surgeon Bernie Siegel has developed the Simontons' methods further with therapy groups called Exceptional Cancer Patients. Having patients make drawings to reveal their true psychological state sans defenses, then working toward a comprehensive change in outlook (total CNS response) to mobilize the will to live, Siegel has

helped his patients greatly improve the quality and quantity of their lives, as compared to clinical prognoses. This approach also enhances chemotherapy's effectiveness while minimizing its side effects, and it dramatically increases the likelihood of a "miracle"—total regression and cure of the cancer.

All this really shouldn't be so surprising. Under hypnosis the mind can completely block pain, and research described in the next chapter has shown that it does so by changing electrical potentials in the body. How can we be sure it couldn't create appropriate electrical changes around a tumor and melt it away? There are still major problems with these psychological approaches, however. Only a minority of people are able or willing to muster the high level of dedication needed to make them work, even under the gun of death. Moreover, they require time, the very thing a cancer patient is short of, and they often don't produce a complete cure even when practiced diligently. Still, they're encouraging signs that the tide is beginning to turn from the warfare mode to the simpler—more elegant, as a mathematician would say—ideal of changing the cellular environment that allows a tumor to flourish.

Could we really do the job more directly by applying the proper electrical input to aim a surefire regenerative influence at the tumor? I'm sad to say that most of the few researchers who've tried electricity against cancer have used the "kill the enemy" approach. Tumors are somewhat more sensitive to heat than normal tissue, so some doctors are using directed beams of microwaves to cook them without, it's hoped, destroying too many healthy cells. FDA approval for general use of this method is expected soon. It has been known since the time of Burr and Lund that growing tissue is electrically negative, and cancer is the most negative of all. Hence some researchers have tried to inhibit tumor growth by canceling the offending polarity with positive current. Early reports were encouraging, but we now know that toxic metallic ions are released from most positive electrodes, so this method must be tested with great caution.

Only one research team has sought a reintegrative effect of electric current. In the late 1950s Carroll E. Humphrey and E. H. Seal of the Applied Physics Laboratory at Johns Hopkins tried pulsed direct currents on standardized fast-growing skin tumors in mice. Even though they used both positive and negative polarities, their results seemed sensational. In one series they got total remission in 60 percent of the test animals after only three weeks; all the control mice had died by then. In another series the control tumors averaged seven times the size of the ones treated with current. Unfortunately, present evidence doesn't really

support this approach either. In my group's experiments with human fibrosarcoma cells in vitro, negative and positive currents both speeded up growth by over 300 percent. On the other hand, as mentioned in Chapter 8, we found that we could suspend mitosis in the fibrosarcoma cells with silver ions injected by minute levels of positive current. During one day of exposure, the cells appeared to dedifferentiate completely, and they stopped dividing for a month without additional treatment, even though we changed the nutrient medium regularly. Obviously, this entire subject needs to be investigated more thoroughly.

Some researchers believe pulsed electromagnetic fields may be of some benefit in treating cancer. Art Pilla, working with Larry Norton and Laurie Tansman of New York's Mount Sinai School of Medicine, as well as William Riegelson of the Medical College of Virginia, claims to have found a pulse sequence that significantly increases the survival time of mice with cancer. So far, these experimenters say they've increased the effectiveness of chemotherapy in lab animals with PEMF, but haven't found a pulse pattern that consistently regresses tumors in vivo, although Pilla and Steve Smith have been able to transform malignant lymphoma (lymph node cancer) cells into benign fibroblasts in culture.

The claim that PEMF may retard cancer in animals is seriously flawed, however. In these experiments the entire animal was exposed to the field, not just the part with the cancer. The pulsing field (like almost any time-varying magnetic field) induces a stress response in the animal (see Chapter 15). For a short while this increases the activity of the immune system, which slows the growth of the tumor. However, the field's effect on the tumor itself is to speed it up, and, in the long run, added stress is the last thing an animal with cancer needs. These experiments cannot be used to indicate the safety or benefit of PEMF in regard to cancer. Since to heal bones the fields are directed only at small regions, PEMF as used on humans does not produce stress, increased immune system response, or any concomitant antitumor activity.

Certain leads, such as the electrically injected silver, remain promising. In the 1950s and 1960s, Dr. Kenneth MacLean published some interesting work on the use of magnetic fields versus tumors in mice. He believed he'd healed several cases of cancer with steady-state magnetic fields, and certain unorthodox healers in America and India who use permanent magnets have made similar claims. The difference in effect between steady-state and time-varying fields (see Chapters 14 and 15) leads me to theorize that a steady-state magnetic field, if strong enough, may indeed halt mitosis in malignant cells.

Due to the prevailing outlook in cancer research, the key work re-

mains to be done. Even promising nonelectromagnetic approaches have been victims of bias. There's sound evidence, for example, that mega-doses of vitamin C do slow tumor growth and increase the chances for a complete cure, but Linus Pauling hasn't been able to persuade any of the powerful institutes to perform a large-scale trial. Some animal tests are now being funded, but, since vitamin C is nontoxic, immediate clinical experiments on large numbers of humans would make much more sense.

In following up the regeneration connection, two experiments in particular are crying out to be tried. Someone must attempt to duplicate the electrical environment of regeneration around tumors in lab animals, using electrodes. This would involve introducing small negative currents to thoroughly test the hypothesis that cancer cells are stuck in a state of incomplete dedifferentiation. The idea would be to dedifferentiate them the rest of the way and then let normal processes in the body turn them into healthy mature cells. The same hypothesis should be tested another way by surgically creating neuroepidermal junctions near the tumors.

Will these experiments be done soon? I wish I knew. The multi-billion-dollar cancer research bureaucracy could certainly afford them, but, although there are a few signs of change, the establishment is stuck in the near-primitive state of the war mentality. I've maintained for many years that we won't learn much more about abnormal growth until we learn more about the normal kind. That approach can lead to cancer treatments that are truly compatible with our bodies, far safer and more effective than the simplistic, dangerous ones now in vogue.

Part 4
The Essence of Life

And if the body were not the soul, what is the soul?
—Walt Whitman

A hallucination is merely a reality that we normally don't have to bother with.
—Stella Denova

Thirteen
The Missing Chapter

Medical students often experience a profound, ego-wrenching shock at the midpoint of their training, as the focus shifts from classroom to bedside. My experience was typical, since this division was even sharper in the 1940s than it is today. After two years' study of the scientific underpinnings of medicine, my classmates and I thought we were pretty smart. During long days and longer nights of lectures, notes, labs, books, reviews, papers, and exams, we'd drunk so deeply of the distilled wisdom of the ages that surely we must know all there was to know about bodies and diseases. All that was left, it seemed, was learning how to apply that knowledge as apprentice doctors. Then we began to study with the senior members of the clinical departments, veterans of a less scientific era, who brought us up short. Their message soon became clear: We didn't know so damn much after all; no one did. All our learning was fine as far as it went, but on the hectic wards of Bellevue things often didn't go by the book.

The greatest teacher I had in those days was my surgery professor, Dr. John Mulholland, a granite cliff of a man whose iron-gray crew cut emphasized his uncompromising idealism. Any hint of laziness, impatience, or unconcern from his students brought a brusque reprimand, but Mulholland was gravely polite and compassionate to the dirtiest wino who needed a doctor. He showed us countless problems and techniques in his demonstration-lectures held in the nineteenth-century amphitheater, but he repeated one salient message over and over: "The surgeon can cut, remove, or rearrange the tissues, and sew up the wound, but only the patient can do the healing. Surgeons must always

be humble before this miracle. We must treat the tissues with sure, deft gentleness, and above all we must do no harm, for we are nothing more than nature's assistants."

None of our textbooks could tell us the how and why of healing. They explained the basics of scientific medicine—anatomy, biochemistry, bacteriology, pathology, and physiology—each dealing with one aspect of the human body and its discontents. Within each subject the body was further subdivided into systems. The chemistry of muscle and bone, for example, was taught separately from that of the digestive and nervous systems. The same approach is used today, for fragmentation is the only way to deal with a complexity that would otherwise be overwhelming. The strategy works perfectly for understanding spaceships, computers, or other complicated machines, and it's very useful in biology. However, it leads to the reductionist assumption that once you understand the parts, you understand the whole. That approach ultimately fails in the study of living things—hence the widespread demand for an alternative, holistic medicine—for life is like no machine humans have ever built: It's always more than the sum of its parts.

With delicate lab culture methods we can remove from an animal certain organs and tissues, such as bone, a heart, a pancreas, a brain, or groups of nerve cells, keeping them alive for days or weeks. Much of modern biology in the West is based on the behavior of such isolated systems, which is assumed to be the same as in the living body. Russian biology, based on Ivan Pavlov's concept of the body as an indivisible unit, has always been skeptical of tissue culture results, considering these "parabiotic" reactions only hints toward definitive studies of the entire animal. The good sense of this view is shown by the fact that life tolerates fragmentation very poorly: Except in the simplest species removal of anything more than a few cells always destroys the organization, and hence the organism. Even if we could culture separately all the organs and tissues and then put them together like Dr. Frankenstein's monster, we would still, at our present level of knowledge, have only a collection of different kinds of meat, not a living entity. As Albert Szent-Gyorgyi once wrote, "Biology is the science of the improbable," and seldom can we predict new discoveries from what we already understand.

These limitations were clearly recognized by American medicine in the 1940s, but they seem to have been gradually forgotten. Today most M.D.'s tacitly assume that once a few blank spots are filled in, the established basic sciences will be all we'll ever need to take care of the sick. As a result, they're losing the forest among the trees. Of the disci-

plines that form medicine's foundation, only physiology tries to units structure and function into a complete picture of how the body works. Hence it's often called the queen of the biological sciences, yet even in this realm the synthesis is made organ by organ. There is, however, one organ group—the nervous system—that coordinates the activities of all the others; by receiving, transmitting, and storing information, it unites all the parts into that transcendence of fragments, the organism. Therefore the one discipline that comes closest to dealing with a living thing in its entirety is neurophysiology, which in the 1940s was already so sophisticated as to be almost a science unto itself.

Even neurophysiology couldn't explain the mystery of healing, however. My best texts either ignored it completely or shrugged it off in a few vague paragraphs. Moreover, my experiences at Bellevue during my internship and early residency convinced me that a physician's success was largely due, not to technical prowess, but to the concern he or she displayed toward patients. The patient's faith in the doctor profoundly affected the outcome of many treatments. Certain remedies, such as penicillin used against bacteria susceptible to it, worked every time. Other prescriptions weren't so predictable, however. If the patient thought the remedy would work, it usually did; otherwise it often didn't, no matter how up-to-date it was. Unfortunately, the importance of the doctor-patient relationship was being downgraded by the new scientific medicine. The new breed of physicians argued that this power of belief somehow wasn't real, that the patients only thought they were getting better—a bit of arrant nonsense that should have been quickly dispelled by a little open-minded, caring attentiveness on daily rounds. There was no known anatomical structure or biochemical process that provided the slightest reason to believe in such a thing, so it came to be dismissed as a mirage left over from the days of witchcraft. The placebo effect, as it's now called, wasn't documented until several decades later and still isn't fully accepted as an integral part of the healing process, but over the years I became convinced that it was a physiological effect of mind on body, just as real as the effects of wind on a tree.

Our lack of knowledge about healing in general and its psychological component in particular sowed seeds of doubt in my mind. I no longer believed that our science alone was an adequate basis for medical practice. As a surgeon, I tried to apply the principle of interaction on my own wards, by spending more time talking with patients, letting them know that I cared for them as well as taking care of the m. Naturally, as I became a teacher, I tried to pass on my beliefs to others. As I gained

experience, I grew more and more convinced that all the textbooks were

missing a chapter—the one that should have tied it all together and helped us doctors understand the bodily harmony we were trying to restore.

When I entered research, I aimed for a fairly limited goal among the many that lured me—finding out what stimulated and controlled the growth needed for healing—but always in the back of my mind were the larger questions that had haunted me since medical school: What unified an organism, making every cell subservient to the needs of the whole? How was it that the whole being could do things that none of its components could do separately? What made an organism self-contained, self-directed, self-repairing? When you get right down to it, I wanted to know what made living things alive. Intuitively I felt sure the answers needn't be forever hidden in mystic conundrums but were scientifically knowable. However, they would require a fresh approach from science, not the simple mechanistic dogmas left over from last century. As a result of the research on nerves and regeneration described in the foregoing pages, I believe I can now sketch at least an outline of that missing chapter.

It had been known for centuries that the nerves are the body's communications lines. Still, all the information collected by neurophysiologists hadn't revealed the integrating factor behind healing. Marc Singer proved that nerves are essential for regeneration, yet the elaborate impulse and neurotransmitter system, which until recently constituted everything we knew about nerves, carries no messages during the process. Nerves are just as essential to simpler kinds of healing. Leprosy and diabetes sometimes destroy nerve function to the extremities. When this happens, a wounded limb not only fails to heal but often degenerates far beyond the actual injury. I often thought about this paradox in connection with the other realities that were poorly explained by nerve impulses, such as consciousness and its many levels, sleep, biological cycles, and extrasensory experiences. As a doctor, however, I was most concerned with the mystery of pain.

This is the least understood of sensory functions, but it must have been one of the very first to evolve. Without it, living things would be so poorly designed that they couldn't survive, for they would never know what constituted danger or when to take defensive action. Pain is quite distinct from the sense of touch. If you place your finger on a hot stove, you feel the touch first and the pain appears a discernible time later, after the reflex has already drawn your hand away. Clearly the pain is conveyed by a different means. Furthermore, there are different types

of pain. Pain in the skin is different from pain in the head or belly or muscles. If you ever want to embarrass a neurophysiologist, ask for an explanation of pain.

Early in my work on regeneration it occurred to me that I'd stumbled upon another method of nerve function. I imagined slowly varying currents flowing along the neurons, their fluctuations transmitting information in analog fashion. Though I kept my main focus on the role of these currents in healing, I pursued other lines of inquiry on the side. I did so partly out of simple curiosity, but also because I realized that, no matter how much merit my DC theory might have for healing, it would have a better chance of being considered if I could fill in some of its details in a wider context.

In the study of healing I dealt only with the output side of the system, the voltages and currents sent to the injured area to guide cells in repairing the damage. Cybernetics and common sense alike told me that, before an organism could repair itself, it must know it had been injured. In other words, the wound must hurt, and the pain must be part of an input side of the system. Certainly if the output side was run by electrical currents, it made no sense to assume that the input side relied on nerve impulses.

At the same time another problem nagged me. The impulses and the current seemed to coexist, yet everything we knew about nerve impulses and electricity said they couldn't travel through the same neuron at the same time without interfering with each other. We now have solutions to both problems, thanks to serendipity. The ways in which the answers came show how one experiment often furthers an unrelated one, and how politics occasionally benefits science.

The Constellation of the Body

In the early 1960s, after I'd published a few research papers, I had an unannounced visitor, a colonel from the Army Surgeon General's office. He said he'd been following my work from the start and had an idea he wanted to discuss. He liked if I'd ever heard of acupuncture.

I told him it wasn't the sort of thing taught in medical school. Although I'd read about it, I had no direct experience of it and didn't know whether it did any good.

"I can tell you for sure it does work ," he replied. "It definitely relieves pain. But we don't know how it works. If we knew that, the Army might adopt it for use by medics in wartime. After reading your work,

some of us wondered if it might work electrically, the same as regeneration seems to. What do you think?"

That was a new idea to me, but right away I thought it was a good one. Although neurophysiologists had studied pain intensively for decades, there was still no coherent theory of it, or its blockage by anesthetics and anodynes. Because of Western medicine's biochemical bias, no pain-killers other than drugs were considered seriously. Maybe a physical method could give us a clue as to what pain really was.

We talked for several hours, but afterward I heard no more from the colonel, and I didn't get the chance to follow up his idea until more than a decade later. In 1971, while touring China as one of the first Western journalists admitted by the Communists, New York Times columnist James Reston saw several operations in which acupuncture was the only anesthetic, and he himself had postoperative pain relieved by needles after an emergency appendectomy. His reports put acupuncture in the news in a big way. It was almost the medical equivalent of Sputnik. Soon the National Institutes of Health solicited proposals for research on the Chinese technique, and I jumped at the chance.

At that time the prevailing view in the West was that if acupuncture worked at all, it acted through the placebo effect, as a function of belief. Hence it should be effective only about a third of the time, just like dummy pills in clinical tests. Many of those applying for the first grants began with this idea, and with the corollary that it wouldn't matter where you put the needles. Thus, much of our earliest research merely disproved this fallacy, which the Chinese—and apparently the U.S. Army—had done long ago. Recalling my talk with the colonel, I proposed a more elegant hypothesis.

The acupuncture meridians, I suggested, were electrical conductors that carried an injury message to the brain, which responded by sending back the appropriate level of direct current to stimulate healing in the troubled area. I also postulated that the brain's integration of the input included a message to the conscious mind that we interpreted as pain. Obviously, if you could block the incoming message, you would prevent the pain, and I suggested that acupuncture did exactly that.

Any current grows weaker with distance, due to resistance along the transmission cable. The smaller the amperage and voltage, the faster the current dies out. Electrical engineers solve this problem by building booster amplifiers every so often along a power line to get the signal back up to strength. For currents measured in nanoamperes and microvolts, the amplifiers would have to be no more than a few inches apart—just like the acupuncture points! I envisioned hundreds of little DC

generators like dark stars sending their electricity along the meridians, an interior galaxy that the Chinese had somehow found and explored by trial and error over two thousand years ago. If the points really were amplifiers, then a metal needle stuck in one of them, connecting it with nearby tissue fluids, would short it out and stop the pain message. And if the integrity of health really was maintained by a balanced circulation of invisible energy through this constellation, as the Chinese believed, then various patterns of needle placement might indeed bring the currents into harmony, although that part of the treatment has yet to be evaluated by Western medical science.

The biggest problem Western medicine had in accepting acupuncture was that there were no known anatomical structures corresponding to the meridians, those live wires supposedly just under the skin. Some investigators claimed to have located tiny clusters of sensory neurons where the points were, but others had looked for them in vain. My proposal offered a convenient way into the problem. If the lines and points really were conductors and amplifiers, the skin above them would show specific electrical differences compared to the surrounding skin: Resistance would be less and electrical conductivity correspondingly greater, and a DC power source should be detectable right at the point. Some doctors, especially in China, had already measured lower skin resistance over the points and had begun using slow pulses of current, about two per second, instead of needles. If we could confirm these variations in skin resistance and measure current coming from the points, we'd know acupuncture was real in the Western sense, and we could go on confidently in search of the physical structures.

I got the grant and used part of the money to hire Maria Reichmanis, a brilliant young biophysicist who was Charlie Bachman's last Ph.D. student. Her combination of mathematical gifts and practicality got us results fast. Together we designed a "pizza cutter" electrode, a wheel that we could roll along the meridians to give us a reliable continuous reading, as well as a square grid of thirty-six electrodes to give us a map of readings around each point.

Along the first meridians Maria measured, the large-intestine and pericardial lines on the upper and lower surfaces, respectively, of each arm, she found the predicted electrical characteristics at half of the points. Most important, the same points showed up on all the people tested. Since acupuncture is scuh a delicate blend of tradition, experiment, and theory, the other points may be spurious; or they may simply be weaker, or a different kind, than the ones our instruments revealed. Our readings also indicated that the meridians were conducting current, and its polarity,

matching the input side of the two-way system we'd charted in amphibians, showed a flow into the central nervous system. Each point was positive compared to its environs, and each one had a field surrounding it, with its own characteristic shape. We even found a fifteen-minute rhythm in the current strength at the points, superimposed on the circadian ("about a day") rhythm we'd found a decade earlier in the overall DC system. It was obvious by then that at least the major parts of the acupuncture charts had, as the jargon goes, "an objective basis in reality."

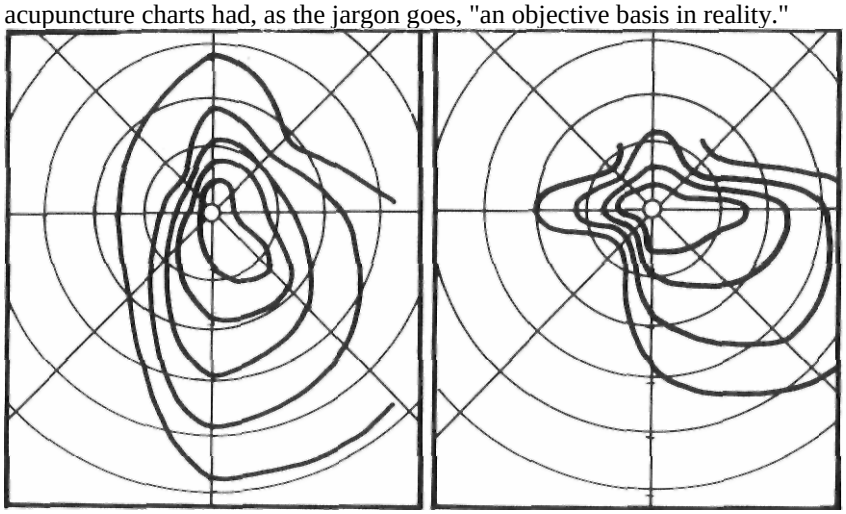

ELECTRICAL CONDUCTIVITY MAPS OF SKIN AT ACUPUNCTURE POINTS

Maria, Joe Spadaro, and I began a more sophisticated series of tests. We planned to record from six major points along one meridian as a needle was inserted into the outermost point. If the DC theory was valid, a change in potential should travel from point to point along the line. However, just as we were entering this second phase, the NIH canceled our grant, even though we'd published four papers in a year. Supposedly it had lost interest in acupuncture, at least in the kind of basic research we were doing on it. Even so, I was fairly satisfied. The input system worked as I'd predicted. The other major question remained: What structure carried the current so as not to interfere with the nerve impulses?

Of course, I've given away the answer in previous chapters. The perineural cells appear to carry the current. In the early 1970s, however, we only suspected this. The evidence came unexpectedly by cross-fertilizarion from an unrelated project.

One of the main problems of medical research is finding a suitable "animal model" for human diseases. The study of unmended fractures is

especially hard, because people are endowed with lesser fracture-healing abilities than most other animals, for whom nonunions are a non-problem. Based on what I'd learned about the importance of nerves in bone healing, I figured we could produce nonunions in rats by cutting the nerves to the broken leg, particularly if we removed whole segments of the nerves so they couldn't grow back. I assigned this part of the project to Dr. Bruce Baker, a young orthopedic surgeon who was then finishing his residency with an extra year on a fellowship in my lab.

After Bruce had worked out the complicated surgical procedure, we anesthetized a series of rats, removed the nerve supply to one leg of each animal, and broke the fibula, or smaller bone of the calf, in a standard way. Then every day we reanesthetized a few of the rats and took out the fracture area to mount it for the microscope. At the same time, Bruce checked the cut nerves to make sure there was no regrowth. Successful denervation was confirmed by the microscope and by complete paralysis of the affected leg.

The results were encouraging yet puzzling. The nerves didn't regrow, and the broken bones took twice the normal six or seven days to heal, but heal they did, even though theoretically they shouldn't have knit at all without nerves.

It was well known that the severed end of a nerve would die after a couple of days, but, since we'd cut the nerves at the same time as we'd broken the bones, maybe the cut ends had exerted a subdued healing effect while they remained alive. In another series of animals, we cut the nerves first. Three days later, after making sure the legs were fully de-nervated, we operated again to make the fractures. We felt sure the delay would give us true nonunions. To our surprise, however, the bones healed faster than they had in our first series, although they still took a few days longer than normal.

Here was a first-class enigma. The only thing we could think of doing was to cut the nerves even earlier, six days before the fractures. When we got that series of slides back, we found that these animals, whose legs were still completely without nerves, healed the breaks just as fast and just as well as the normal control animals. Then we took a more detailed microscopic look at the specimens Bruce had taken from around the nerve cut. We found that the Schwann cell sheaths were growing across the gap during the six-day delay. As soon as the perineural sleeve was mended, the bones began to heal normally, indicating that at least the healing, or output, signal was being carried by the sheath rather than the nerve itself. The cells that biologists had considered merely insulation turned out to be the real wires.

Unifying Pathways

The experiments I'd done with psychiatrist Howard Friedman in the early 1960s, mentioned in Chapter 5, were the first to provide strong support for an analog theory of pain. In all animals, including humans, the normal negative potentials at the extremities weakened or vanished as an anesthetic took effect. Under deep total anesthesia, the potentials often reversed entirely, the extremities becoming positive and the brain and spine negative. At that time we didn't yet know about the two-way system, inward along sensory nerves and outward along motor nerves, but it was obvious that a current flow was being reversed by the pain-preventing drugs. In lab animals and humans under local anesthetic, such as a shot of procaine in one arm, the negative potential was abolished only for that arm. The DC potentials over the head were unaffected—except for a little blip in the recording that registered the prick of the needle!

In addition, the DC potentials react slowly enough to account for pain. A wound usually doesn't start to hurt in earnest until minutes, or even hours, after the injury. This delay has been especially hard to explain in terms of nerve impulses, which travel at 30 feet per second. However, when Friedman and I injured the limbs of salamanders while monitoring the potentials on their limbs and heads, we found that the change in the limb reading showed up in the head after a time approximating that of delayed pain. Acupuncture likewise involves a delay, usually twenty minutes or more, before its effects are felt.

We also found we could work backward, using the currents to produce anesthesia. A strong enough magnetic field oriented at right angles to a current magnetically "clamped" it, stopping the flow. By placing frogs and salamanders between the poles of an electromagnet so that the back-to-front current in their heads was perpendicular to the magnetic lines of force, we could anesthetize the animals just as well as we could with chemicals, and EEG recordings of magnetic and chemical anesthesia were identical. We got the same effect by passing a current through the brain from front to back, canceling out the normal current of waking consciousness, as in electrosleep.

One of the most exciting results of my collaboration with Dr. Friedman was proof that one's state of waking consciousness could change the perception of pain. Friedman, who already used hypnosis to control chronic pain in his patients, gave several of his best subjects hypnotic suggestions of arm numbness deep enough that they couldn't feel the

prick of a needle. In each case, I found that the frontal negative potential of the head became less negative, often reaching zero, as the client attained deep trance. The reading changed in the same direction as in anesthesia, only not as far. Then, when the suggestion for pain control was given, the arm potential reversed just as it had in response to procaine. Conversely, when a control subject was asked in normal waking consciousness to concentrate forcefully on one arm, its sensitivity to pain increased, and the hand potential became more negative. We found we could use this difference to determine whether a person was really hypnotized or just cooperating.

Some doubters (including myself, I'm afraid) had believed hypnoanalgesia was merely a state in which the patient still felt the pain but didn't respond to it, but these experiments proved it was a real blockage of pain perception. It seems that the brain can shut off pain by altering the direct-current potentials in the rest of the body "at will." There's every reason to suppose that pain control through biofeedback or yoga likewise works by using an innate circuit for attenuating the pain signal, which releases a shot of the body's own pain-killers. When the signal is appropriately modulated, it releases endorphins (internally produced opiates), as shown by experiments in which an injection of the opiate-antagonist naloxone negates the anesthesia of acupuncture. I predict that research on this system will eventually let us learn to control pain, healing, and growth with our minds alone, substantially reducing the need for physicians.

Direct evidence for the perineural DC system has been accumulating gradually for several decades. Electric currents were detected in the glial cells of rat brains as long ago as 1958, and good (though long-ignored) measurements of direct currents in the frog's brain go back to the work of Ralph Gerard and Benjamin Libet in the early 1940s. Electron microscope work has shown that the cytoplasm of all Schwann cells is linked together through holes in the adjacent membranes, forming a syncytium that could provide the uninterrupted pathway needed by the current. The other perineural cells—the ependyma and glia—are probably connected in the same way, for syncytial links have recently been found in the glia of the leech, whose nervous system is much studied because of its unusually large cells. Recent use of selective radiation to isolate Schwann cells has shown that they, and not the neuron fibers, supply the nerve stimulus essential to regeneration.

The invention of a better magnetometer has yielded definitive proof that's now widely acknowledged. Any electric current automatically generates a magnetic field around itself. Hence, as the perineural current

conveys information in its fluctuations, it must be reflected by a magnetic field around the body, whose pulsing would reveal the same information. When I first proposed this idea, many of my colleagues dismissed it as rank nonsense. I couldn't prove them wrong, because there were no instruments to measure a field as weak as that generated by such small currents. Everyone knew the human body had no effect on a compass needle or any other magnetic-field detector available at the time.

Then, in 1964, a solid-state physicist named Brian D. Josephson invented the electronic device now called a Josephson junction, a simple item that won him a Nobel Prize. Basically it consists of two semiconductors connected so that current can oscillate in a controlled fashion between them. Today it has many applications, especially in computers. When cooled near absolute zero in a bath of liquid helium, it becomes a superconductor in which the current plays back and forth endlessly. Superconduction is the passage of electrons through a substance without the resistance normally found in any conductor. This apparatus, called a superconducting quantum interferometric device, or SQUID for short, is a magnetic field detector thousands of times more sensitive than any previously known.

In 1963, G. M. Boule and R. McFee just barely managed to measure the relatively large magnetic field produced by the human heart—using the best old-fashioned instrument, a coil with 2 million turns of wire. Then, in 1971, working in a null-field chamber, from which the earth's magnetism and all artificial fields were screened out, Dr. David Cohen of MIT's Francis Bitter National Magnet Laboratory, who'd been corresponding with our lab since the early years, first used the SQUID to measure the human head's magnetic field. Two kinds of magnetic fields have been found. Quickly reversing AC fields are produced by the back-and-forth ion currents in nerve and muscle. They're strongest in the heart, since its cells contract in synchrony. The SQUID has also confirmed the existence of the direct-current perineural system, which, especially in the brain, produces steady DC magnetic fields one billionth the strength of earth's field of about one-half gauss.

By 1975, Drs. Samuel Williamson, Lloyd Kaufman, and Douglas Brenner of NYU had succeeded in measuring the head's field without a shielded enclosure, even amid the electromagnetic noise of downtown Manhattan. More important, they've found that the magnetoencephalogram (MHG)—a recording of changes in the brain's field analogous to the EEG - is often a more accurate reflection of mental activity than the EEG. Because the magnetic field passes right through the dura, skull

bones, and scalp without being diffused, an MEG locates the current source more accurately than EEG measurements. The NYU group has since begun correlating magnetic events with well-known cerebral responses, such as the reaction of cells in the visual cortex to simple patterns and flashes of light. When the brain reacts to any stimulus, it produces a wave of electrical activity that's contained in the EEG. It's invisible in a standard EEG recording, because so much else is always going on in the brain at the same time. However, when one simple stimulus is repeated many times and the EEG tracings are averaged by computer, the particular electrical response to that one stimulus—called an evoked potential—can be teased out. Several research groups have slowly built up a small vocabulary of wave forms with specific meanings, including a "surprise wave," an "intention wave," and a "double-take wave," which appears when the mind briefly tries to make sense of semantic nonsense, as in the statement "She took a drink from the radio."

Taken together, the MEG research so far seems to be establishing that every electrical evoked potential is accompanied by a magnetic evoked potential. This would mean that the evoked potentials and the EEG of which they're a part reflect true electrical activity, not some artifact of nerve impulses being discharged in unison, as was earlier theorized. Some of the MEG's components could come from such additive nerve impulses, but other aspects of it clearly indicate direct currents in the brain, particularly the central front-to-back flow. The MEG doesn't show the EEG's higher-frequency components, however, suggesting that some parts of the two arise from different sources.

Since every reaction and thought seems to produce an evoked potential, the DC system seems directly involved in every phase of mental activity. At the very least, the electric sheath acts as a bias control, a sort of background stabilizer that keeps the nerve impulses flowing in the proper direction and regulates their speed and frequency. But the analog structure probably plays a more active role in the life of the mind. Variations in the current from one place to another in the perineural system apparently form part of every decision, every interpretation, every command, every vacillation, every feeling, and every word of interior monologue, conscious or unconscious, that we conduct in our heads.

This part of the analog system's job is much less well understood, however, than its integrative function throughout the rest of the body.

Perineural cells accompany every part of the nervous system. Even the tiniest twiglets of sensory nerves in the skin, which don't have a myelin covering, are surrounded by Schwann cells. The perineural

thus just as well distributed to integrate bodily processes as the nerves themselves. They reach into each area of the body to create a normal electrical environment around each cell, or a stimulatory one when healing growth is needed. Likewise they enable an organism to sense the type and extent of damage anywhere in the body by transmitting the current of injury, with its by-product of pain, to the CNS. One could take a "fantastic voyage" from the farthest Schwann cell outpost in the big toe through the spinal cord and into all parts of the brain. Indeed, electrons are making this trip every moment of our lives.

Thus our bodies have an intricate and multilayered self-regulating feedback arrangement. We know, on the psychological level, that a person's emotions affect the efficiency of healing and the level of pain, and there's every reason to believe that emotions, on the physiological level, have their effect by modulating the current that directly controls pain and healing.

These discoveries give us a testable physical basis for the placebo effect and the importance of the doctor-patient bond. They also may give us the key to understanding the "miracle" cures of shamans, faith healers, and saints, as well as the spontaneous healing reported by means of visions, prayer, yoga, or battlefield terror. At the Menninger Foundation, Elmer Green has long been using biofeedback to explore the mind-body relationship. Green has described the full yogic control of pain and healing developed by one of his subjects, an otherwise average businessman. He lay against a bed of nails with no pain, and, when informed that a puncture from one of the points was bleeding, he turned his head, gazed at the wound, and immediately stopped the flow. A combination of biofeedback, recording electrodes, and the SQUID magnetometer would seem to be the ideal setup for the next level of inquiry into the mind's healing powers.

Moreover, since the analog system, like the impulse network, appears to work on both conscious and subconscious levels simultaneously, it's a likely missing link in several other poorly understood integrative functions that also cross from one realm to the other. It may lead us at last to fathom the twin wells of memory and emotion. It may even help us understand what happens when a new synthesis of creative thought, a.k.a. inspiration, bursts forth like a mushroom from strands of mycelia that have been quietly gathering their subterranean forces. Then science for the first time will begin to comprehend the artistic essence that makes its rational side productive.

Fourteen
Breathing with the Earth

Major changes in one's life often proceed improbably from the most minor events. So it was that I became involved in one of the most interesting parts of my work in 1961 because a dog bit someone I didn't even know at the time.

My first electrical measurements on salamanders had just revealed part of the DC control system to me. Elementary physics told me that the currents and their associated electromagnetic fields would have to be affected in some way by external fields. In engineering terms, the biomagnetic field would be coupled to the DC currents. Hence changes impressed upon it by external fields would be "read out" through perturbations in the current. Outside fields would also couple directly to the currents themselves, without acting through the biofield as intermediary, especially if the currents were semiconducting. In short, all living things having such a system would share the common experience of being plugged in to the electromagnetic fields of earth, which in turn vary in response to the moon and sun. In the late eighteenth century, the Viennese hypnotist and healer Franz Anton Mesmer proposed direct magnetic influences on earthly bodies from the heavenly ones, but his idea came from the scientifically unacceptable domain of astrology. With the notable exception of Nikola Tesla, most prominent researchers have derided it until recently. I figured the DC system must be the missing link in a very different, but very real, connection between geophysics and the responses of living things. I was eager to investigate it, but at firsr I didn't know how.

I was an orthopedic surgeon, about as far removed as possible from the psychiatric expertise needed for a serious study of behavior. And suppose I did find something? Who would believe me if I ventured so far from my specialty? The whole idea was preposterous to the science of the time, anyway. Still, I had to do something.

During the International Geophysical Year of 1957-58, I'd been a volunteer in the Aurora Watch Program. To find out whether the northern lights appeared simultaneously throughout the north latitudes in response to changes in the earth's magnetic field (they did), IGY organizers recruited a worldwide network of amateur observers to go out into their backyards every night and look at the sky. All of us got weekly reports on the state of the field from the national magnetic observatory at Fredericksburg, Virginia. I decided to go back through this data and see if there was any correlation between the disturbances in earth's field caused by magnetic storms on the sun, and the rate of psychiatric admissions to our VA hospital.

Luckily for me, Howard Friedman, the hospital's chief of psychology, was collecting donations door to door for a local Boy Scout troop at about this time. At one house, the family dog took an instant dislike to him and bit his ankle. After bandaging the wound, Howard's doctor gave him a tetanus booster shot. As luck would have it, Howard came down with a rare allergic reaction that involved fever, fatigue, nausea, and painful swelling of all the joints.

Since I was the nearest bone-and-joint man, Howard came to see me. This type of reaction is frightening, but not dangerous, and disappears of its own accord in a day or two. After I made the diagnosis and reassured him, we sat and talked for a few minutes. After some chitchat about the shortcomings of the hospital administration, he gestured at the papers tacked all over the walls of my office and asked, "What are all those charts?" I told him about my magnetic brainstorms.

He obviously thought I was as crazy as the people whose admissions I was charting, and probably wondered about the advice I'd just given. However, after hearing the background, he agreed it wasn't as silly as it sounded, and offered to help. It was a real break for me, since he was already a respected researcher, and a practical, open-minded one to boot. My diagnosis was correct, and our collaboration lasted almost two decades.

Howard's reputation got us access to the records of state psychiatric hospitals, giving us a sample large enough to be statistically useful. We matched the admissions of over twenty-eight thousand patients at eight hospitals against sixty-seven magnetic storms over the previous four

years. The relationship was there: Significantly more persons were signed in to the psychiatric services just after magnetic disturbances than when the field was stable. Of course, such a finding could only serve as a guide to further investigation, because so many factors determined whether a person sought psychiatric help, but we felt that other influences would even out over such a large number of patients.

Next we looked for the same type of influence in patients already hospitalized. We selected a dozen schizophrenics who were scheduled to remain in the VA hospital for the next few months with no changes in treatment. We asked the ward nurses to fill out a standard evaluation of their behavior once every eight-hour shift. Then we correlated the results with cosmic ray measurements taken every two hours from government measuring stations in Ontario and Colorado. Since magnetic storms were generally accompanied by a decrease in the cosmic radiation reaching earth, we thought we might find changes in the patients' actions and moods during these declines. We decided to use cosmic rays instead of direct reports of the magnetic field strength because of problems in distinguishing between magnetic storms and other variations in the earth's field.

The nurses reported various behavior changes in almost all the subjects one or two days after cosmic ray decreases. This was a revealing delay, for one type of incoming radiation—low-energy cosmic ray flares from the sun—was known to produce strong disruptions in the earth's field one or two days later.

With this encouragement we went on in 1967 to confirm, by experiments described more fully in the next chapter, that abnormal magnetic fields did produce abnormalities in various human and animal responses. We found slowed reaction times in humans and a generalized stress response in rabbits exposed to fields ten or twenty times the normal strength of the earth's. Hence we suspected that the earth's normal field played a major role in keeping the DC system's control of bodily functions within normal bounds. The proof of this idea has come mainly from the work of two men: Frank Brown at Northwestern and Rutger Wever, working at the Max Planck Institute in Munich.

Already a respected endocrinologist, Brown became interested in biocycles in the 1950s. It was common knowledge that most organisms had a circadian rhythm of metabolic activity, which most people assumed was directly linked to the alternation of night and day or, in the case of shore life, to the tides. Oysters, for example, would open their shells to feed whenever the tide came in, covering them with water. It was a simple, obvious observation, but Brown didn't take it for granted. To

his surprise, oysters in an aquarium with constant light, temperature, and water level still opened and closed their shells in time with their compatriots at the beach. To find out why, Brown flew oysters in a lightproof box from New Haven to his lab, in Evanston, Illinois. At first they kept time with Connecticut oysters, then in a few weeks gradually shifted to the tide pattern Evanston would have had if it had been on a seacoast. The oysters not only knew they'd been taken 1,000 miles westward, they also suffered from jet lag!

In his search for a creature whose response to magnetic fields might tell him more about biocycles, Brown settled upon the mud snail Nassarius, at home in the intertidal zone anywhere in the world. In his lab he placed the snails under uniform illumination in a box with an exit facing magnetic south. When they left the enclosure in early morning, they turned west. When leaving at noon, they turned east, but took a westerly course again in early evening. Furthermore, at new and full moon, the snails' paths veered to the west, while at the quarters they tended more eastward than at other times.

Brown's precise data from this and many other experiments showed that Nassarius had two clocks, one on solar time and one on lunar, and subsequent work with magnets told something about how the timepieces ran. The earth's magnetic field averaged 0.17 gauss in Evanston. When Brown put a 1.5 gauss permanent magnet facing north-south underneath the snails' doorways to augment the natural field, the animals made sharper turns, but their direction wasn't affected. Turning either the magnet or the enclosure through various angles made the snails change course a specific number of degrees. Brown concluded: "It seemed as if the snails possessed two directional antennae for detecting the magnetic field direction, and that these were turning, one with a solar day rhythm and the other with a lunar day one." This crucial experiment not only showed the dependence of biocycles on the earth's magnetic field, it also demonstrated the subtlety of the link. No longer could we expect changes in the magnetic environment to be as obvious in their effects on life as changes in oxygen levels, food supply, or temperature.

The niceties of the earth's electromagnetic field itself became better known as Brown's work progressed. Far from a static, simple magnetic field like that around a uniform bar of magnetized iron, the earth's field has turned out to have many components, each full of quirks.

At the end of the nineteenth century, geophysicists found that the earth's magnetic field varied as the moon revolved around it. In the same period, anthropologists were learning that most preliterate cultures reck-

oned their calendar time primarily by the moon. These discoveries led Svante Arrhenius, the Swedish natural philosopher and father of ion chemistry, to suggest that this tidal magnetic rhythm was an innate timekeeper regulating the few obvious biocycles then known.

Since then we've learned of many other cyclic changes in the energy structure around us:

The earth's electromagnetic field is largely a result of interaction between the magnetic field per se, emanating from the planet's molten iron-nickel core, and the charged gas of the ionosphere. It varies with the lunar day and month, and there's also a yearly change as we revolve around the sun.

A cycle of several centuries is driven from somewhere in the galactic center.

The earth's surface and the ionosphere form an electrodynamic resonating cavity that produces micropulsations in the magnetic field at extremely low frequencies, from about 25 per second down to 1 every ten seconds. Most of the micropulsation energy is concentrated at about 10 hertz (cycles per second).

Solar flares spew charged particles into the earth's field, causing magnetic storms. The particles join those already in the outer reaches of the field (the Van Allen belts), which protect us by absorbing these and other high-energy cosmic rays.

Every flash of lightning releases a burst of radio energy at kilocycle frequencies, which travels parallel to the magnetic field's lines of force and bounces back and forth between the north and south poles many times before fading out.

The surface and ionosphere act as the charged plates of a condenser (a charge storage device), producing an electrostatic field of hundreds or thousands of volts per foot. This electric field continually ionizes many of the molecules of the air's gases, and it, too, pulses in the ELF (extremely low frequency) range.

There are also large direct currents continually flowing within the ionosphere and as telluric (within-the-earth) currents, generating their own subsidiary electromagnetic fields.

In the 1970s we learned that the sun's magnetic field is divided from pole to pole into sectors, like the sections of an orange, and the field in each sector is oriented in the direction opposite to adjacent sectors. About every eight days the sun's rotation brings a new region of the interplanetary (solar) magnetic field opposite us, and the earth's field is slihgtly changed in response to the flip-

flop in polarity. The sector boundary's passage also induces a day or two of turbulence in earth's field.

The potential interactions among all these electromagnetic phenomena and life are almost infinitely complex.

For many years most scientists dismissed Brown's conclusions as impossible. Given the old premise that life was entirely a matter of water chemistry, none of these electromagnetic changes would have enough energy to affect an organic process in any way. Discovery of the DC system showed how the interaction could work without energy transfer; it gave living things a way of "sensing" the fields directly. Undaunted by the slow acceptance of his work, Brown went on to document Nassaria's sensitivity to electrostatic fields as well. He also found magnetically driven cycles in all other organisms he tested, including mice, fruit flies, and humans. Even potatoes in a bin showed a field-linked rhythm of oxygen consumption. In humans, hormone output and the number of lymphocytes in the bloodstream are but two of many variables that dance to the same beat. One of the most important is cell cycle time. The actual process of cell division—in which chromosomes appear, line up, split in half, and are distributed equally between the two cells—takes only a few minutes. It must be preceded by several longer stages, one of which is duplication of all the cell's DNA. All stages together take about one day. Thus all growth and repair, which depend on regulated cell division, are synchronized with the earth's field.

Rutger Wever has done some even more telling work with humans during the last decade and a half. He built two underground rooms to completely isolate people from all clues to the passage of time. One was kept free of outside changes in light, temperature, sound, and such ordinary cues, but wasn't shielded from electromagnetic fields. The other room was identical but also field free. Observing several hundred subjects, who lived in the bunkers as long as two months, and charting such markers as body temperature, sleep-waking cycles, and urinary excretion of sodium, potassium, and calcium, Wever found that persons in both rooms soon developed irregular rhythms, but those in the completely shielded room had significantly longer ones. Those still exposed to the earth's field kept to a rhythm close to twenty-four hours. In some of these people, a few variables wandered from the circadian rate, but they always stabilized at some new rate in harmony with the basic one—two days instead of one, for example. People kept from contact with the earth field, on the other hand, became thoroughly desynchronized. Sev-

eral variables shifted away from the rhythms of other metabolic systems, which had already lost the circadian rhythm, and established new rates having no relationship to each other.

Wever next tried introducing various electric and magnetic fields into his completely shielded room. Only one had any effect on the amorphous cycles. An infinitesimal electric field (0.025 volts per centimeter) pulsing at 10 hertz dramatically restored normal patterns to most of the biological measurements. Wever concluded that this frequency in the micropulsations of the earth's electromagnetic field was the prime timer of biocycles. The results have since been confirmed in guinea pigs and mice. In light of this work, the fact that 10 hertz is also the dominant (alpha) frequency of the EEG in all animals becomes another significant bit of evidence that every creature is hooked up to the earth electromagnetically through its DC system. Recently a group under Indian biophysicist Sarada Subrahmanyam reported that the human EEG not only responded to the micropulsations, but responded differently depending on which way the subject's head was facing in relation to the earth's field. Oddly enough, however, the head direction had no effect if the subject was a yogi.

The relationship has been conclusively proven by recent studies of the pineal gland. This tiny organ in the center of the cranium has turned out to be more than the vaguely defined "third eye" of the mystics. It produces melatonin and serotonin, two neurohormones that, among many other functions, directly control all of the biocycles. The lamprey, akin to the ancestor of all vertebrates, as well as certain lizards, has an actual third eye, close to the head's surface and directly responsive to light, instead of the "blind" pineal found in other vertebrates. The eminent British anatomist J. Z. Young has recently shown that this organ controls the daily rhythm of skin color changes that these animals undergo.

For our story the most important point is that very small magnetic fields influence the pineal gland. Several research groups have shown that applying a magnetic field of half a gauss or less, oriented so as to add to or subtract from the earth's normal field, will increase or decrease production of pineal melatonin and serotonin. Other groups have observed physical changes in the gland's cells in response to such fields. The experiments were controlled for illumination, since it has been known for several years that shining a light on the head somehow modifies the gland's hormone output even though it's buried so deeply within the head in most vertebrates that, as far as we know, it can't react directly to the light.

We likely have yet to discover many other ways that energy cycles in the solar system affect life on earth. They may strongly affect the outbreak of disease, for example. The last six peaks of the eleven-year sunspot cycle have coincided with major flu epidemics. A Soviet group under Yu. N. Achkasova at the Crimean Medical Institute, working with astronomer B. M. Vladimirsky of the Crimean Observatory, has found a connection between the sun's magnetic field and the Escherichia coli bacteria that live in our intestines and help us digest our food. The Russians found the bacteria grew faster when the sun's field was positive, or pointing toward earth, and slowed down when it was negative. Two days after the passage of each sector boundary there was a dip in bacterial growth corresponding to the maximum geomagnetic turbulence. The data also showed a decline in growth in response to large solar flares. Other Russian scientists have drawn a tentative correlation between the sector cycle and reports from two groups of persons with neurological diseases. The patients felt worse within sectors of positive polarity, when bacteria seemed to grow faster. Life's geomagnetic coupling to heaven and earth is apparently more like a web than a simple cord and socket.

The Attractions of Home

An animal's biocycles must be appropriate for its environment if it's to survive, so they must be precisely tuned to its geographic location. We might suspect, therefore, that many creatures would use magnetic information for their sense of place. A great deal of recent work has shown that they do. A built-in compass helps guide them in foraging or other local business, as well as migration over much longer routes. The latter feats often rival those of any modern navigator. Monarch butterflies travel from Hudson Bay to South America straight across the Caribbean without ever getting lost. The arctic tern breeds in summer on the northern ice cap, then moves to Antarctica for the other hemisphere's summer, flying 11,000 miles each way. Some salamanders, only inches long and built very low to the ground, travel up to 30 miles of rugged mountain country in California to set up housekeeping, then return to their home stream to breed. Such activities are hard to experiment with, however, so we've learned more about day-to-day travel.

Karl von Frisch was the first to attack the problem, with his famous 1940s studies of the honeybee dance, which won him a Nobel Prize in 1973. He established that on clear days bees navigated by combining the sun's angle with their sense of time, the way Boy Scouts are taught

to use wristwatches as compasses. The bees also had a polarized light system that could determine the sun's direction through light clouds or forest canopy. Even more amazing, Frisch found, the scouts told workers back at the hive where the flowers were by means of a dance using the sun's angle and the direction to earth's center (the gravity vector) as references. However, Frisch noted that bees could still navigate between food and home just as well on completely overcast days, when the sun's angle and polarized light weren't available. There had to be a backup system.

It soon turned out that homing pigeons had the same abilities. In 1953 G. Kramer inferred that the birds must have a compass in addition to a map of remembered landmarks from the way they immediately pointed their beaks toward home after circling once after release. Soon others found the same kind of sun compass as bees used, but the pigeons could also steer perfectly on cloudy days. Back in 1947, H. L. Yeagley had had the temerity to suggest in the Journal of Applied Physics that pigeons might have a magnetic sense that allowed them to use the earth's field just as we use magnetic compasses. He was ridiculed and "refuted" by a few inadequate experiments—such as placing a pigeon in a variety of electromagnetic fields and noting that it seemed to be comfortable! Others, including Yeagley, attached small magnets to the birds' heads or wings, but found no clear-cut changes in their flight patterns.

Only a few researchers quietly looked into the matter further. After Hans Fromme of the Frankfurt Zoological Institute noted in the late 1950s that caged European robins faced longingly in their normal southwest migratory direction even when they were kept from seeing sun and stars, their usual signposts, his co-worker Friedrich Merkel discovered that, insulated from the earth's field by a steel cage, they no longer faced in one particular direction. Furthermore, by changing the orientation of the surrounding field with coils, he could give the birds a false sense of where southwest was. The experiment was validated with indigo buntings several years later.

There the matter rested until 1971, when William T. Keeton of Cornell realized that the pigeon's magnetic sense, if it existed, would be overshadowed by its sun compass, so naturally magnets affixed to the birds would have no effect on clear days. He soon found that the same birds released on a cloudy day got lost.

To study this magnetic interference in any weather, Keeton made translucent contact lenses for his birds, then released them in the mountains of northern New York. Simulating dense clouds, the contacts

blocked the sun's angle and polarized light, and with 1-gauss magnets attached to their heads the birds couldn't find their way home. However, each avian Ulysses who wore the lenses but no magnets faultlessly navigated the 150 miles southwest to Ithaca, then flew ever tighter circles around the loft and fluttered in like a helicopter to a perfect blind landing.

Carrying the work forward after Keeton's untimely death soon after this experiment, Charles Walcott and Robert Green of the State University of New York at Stony Brook, working with James L. Gould of Princeton, outfitted pigeons with miniaturized electromagnetic coils that let the researchers vary the type and orientation of applied field at will. They discovered that if the south pole of the field was directed up, the birds could still find home, but with the north pole up they flew directly away from it. That meant they were using magnetic north as a reference point. At about the same time two German scientists, Martin Lindauer and Herman Martin, analyzed half a million bee dances and found a "magnetic error" in them—a compensation for the difference between magnetic north and true north. They were also able to introduce specific angles of error in the dances with specifically oriented coils around the hive. Here was proof that magnetic guidance systems existed in both the birds and the bees. * The next question was how the systems worked.

In 1975 Richard P. Blakemore, then a graduate student at the University of Massachusetts in Amherst, astonished the world of biology with the announcement that some bacteria, the lowliest of all cells, also had a magnetic sense. Blakemore made the discovery when, studying the salt marshes of Cape Cod, he noticed that one type of bacterium always oriented itself north-south on his microscope slides. Soon he found magnetotactic bacteria (those reactive to magnetism) near Cambridge, Massachusetts, where he set about studying them with Richard Frankel of MIT's magnet lab. The direction to magnetic north points through the earth somewhat down from the horizon, and the scientists became convinced that the bacteria were using the field to guide themselves ever downward to the mud where they throve, since they were too small to sink through the random molecular motion of the water around them.

* Recent work by Cornell biologist Kraig Adler showed that the magnetic sense of salamanders was many times more acute than even even that of pigeons. Not only could the amphibians find home without tight or other common cues; in addition, when Adler tried to confuse them with artificial fields, they quickly adapted to the interference and oriented themselves correctly in relation to the weaker geomagnetic background.

This idea was later confirmed by findings that microbes at Rio and in New Zealand were south-seekers.

Blakemore's electron micrographs soon revealed a surprising structure. Each bacterium contained within it, like a chain of cut jet stones, a straight line of magnetite microcrystals. Surrounded by a thin membrane, each of these particles was a single domain, the smallest piece of the mineral that could still be a magnet.

Blakemore's bacteria led Gould to look for similar crystals in bees and pigeons. Since an electron microscope survey of even a bee's brain would take several lifetimes, he examined the insects with a SQUID magnetometer. After confirming that they were magnetic, he dissected them and narrowed the location down to a part of the abdomen. Using the same method, Walcott and Green dissected the heads of two dozen pigeons, gradually subdividing them with nonmagnetic probes and scalpels. After a painstaking search the investigators found a tiny magnetic deposit in a 1- by 2-millimeter piece of tissue richly festooned with nerves, on the right side of the head, between the brain and the inner table of the skull. The same dot of tissue contained yellow crystals of the iron-storage protein ferritin, indicating that the pigeons, like the bacteria, synthesized their own lodestone crystals.

As usual, these recent answers have raised plenty of new questions. The existence of magnetic sensors in such diverse creatures as bacteria, bees, and birds—the current count of species with magnetic organs is twenty-seven, including three primates—suggests that a magnetic sense has existed from the very beginning of life, perhaps only to be perfected by creatures that need to get around a lot. Do all animals, then, have the same sensors, and do they always serve the same function? How is the information read out of the crystals by the nervous system and translated into directions? What aspect of the earth's field do these organs sense?

Keeton noticed an especially odd thing about his pigeons' flight patterns. When flying on visual flight rules by sun compass, they would circle once, get their bearings, then move off straight toward Ithaca. But when using their magnetic compass, the birds would fly due west from their release point until they got out over Lake Ontario, due north of Ithaca. Then, out of sight of land, they would make a right-angle turn to the left and follow the exact meridian of home. Keeton told me this but never published the observation because he didn't know what to make of it. He said, "I asked a physicist: 'Are they making contact with a certain magnetic line of force?' The man said, 'No, magnetic lines of force an just an arbitrary convention we use to symbolize a field and

describe anomalies in it, such as occur around iron ore deposits. As far as we know, the lines have no equivalent in reality, and if they did, they would vary all over the place as the earth's field changes, anyway.'" Do pigeons then follow some maplike structure in the earth's field itself, a grid like that described by dowsers and geomancers since ancient times, something we can't find today even with our SQUID? Some migrating birds make a dogleg to the east in their north-south flyway, sailing out of sight of land over Lake Superior. Do they go out of their way to avoid being disoriented by iron ore deposits in the Mesabi Range? We can suspect, but we don't yet know.

To most people, of course, the most interesting questions concern themselves. Do we, too, have compasses in our heads?

On June 29, 1979, R. Robin Baker, a young University of Manchester researcher into bionavigation, led a group of high school students into a bus at Barnard Castle, near Leeds, England. Baker blindfolded and earmuffed them, then gave them all headbands. Half of the headgear contained magnets and half contained brass bars that their wearers thought were magnets. As the volunteers leaned back to concentrate, Baker wove a mazelike course through the town's tangled streets, then traveled a straight highway to the southwest. After a few miles the coach stopped while the students wrote on cards an estimate of the compass direction toward the school. Then the driver turned through 135 degrees and continued east to a spot southeast of the school, where the students again estimated their direction. When the cards were analyzed, it turned out that the persons with brass bars by their heads had been able to sense the proper heading quite reliably, while those wearing magnets had not.

Gould and his Princeton co-worker K. P. Able recently tried to replicate Baker's experiment but failed. However, Baker's review of the attempt suggested that the volunteers' directional sense may have been thrown off by magnetic storms, weak magnetic gradients inside the bus, and/or the greater electromagnetic contamination of Princeton compared with rural England. Baker and co-worker Janice Mather have recently devised a simpler test method. In the middle of a specially built, light-tight wooden hut free of magnetic interference, the subject is blindfolded, earmuffed, and seated on a friction-free swivel chair. After being turned around several times, the subject must estimate his or her compass heading as before. With statistically consistent success in more than 150 persons, Baker believes he has proven the existence of a human magnetic sense.

Oddly enough, he finds that as long as people can't feel the sun or sense some other obvious cue, they can judge direction better with blind-

folds on. Otherwise they start rationalizing the process, trying to deduce the right way from too little evidence and becoming confused. He surmises that the magnetic sense serves its purpose best by unconsciously giving a continuous sense of direction without its owner's having to be aware of it all the time, and thus freeing attention for the search for food, a mate, shelter, and so on.

In 1983, using magnetic measurements in selective-shielding experiments, Baker and his co-workers reported locating magnetic deposits close to the pineal and pituitary glands in the sinuses of the human ethmoid bone, the spongy bone in the center of the head behind the nose and between the eyes. It's interesting to note that selective-shielding studies done in the early 1970s, by Czech emigre biophysicist Zaboj Harvalik, an adviser to the U.S. Army Advanced Material Concepts Agency, pointed to this same spot as one of two areas—the other was the adrenal glands—where the dowsing ability resided.

In 1984 a group headed by zoologist Michael Walker of the University of Hawaii in Honolulu isolated single-domain magnetite crystals from a sinus of the same bone in the yellowfin tuna and Chinook salmon. The crystals were of a shape normally shown only by magnetite synthesized by living things rather than geological processes. Abundant nerve endings entered the magnetic tissue, and the crystals were organized in chains much like those in magnetotactic bacteria. Each crystal was apparently fixed in place but free to rotate slightly in response to external magnetic forces. Calculations showed that such chains would be able to sense the earth's magnetic field with an accuracy of a few seconds of arc, or a few hundred feet of surface position. This result correlated perfectly with earlier homing studies on live tuna by the same group. This detailed work, along with related earlier research, strongly suggests that all vertebrates have a similar magnetic organ in the ethmoid sinus area, and I suspect that this organ also transmits the biocycle timing cues from the earth field's micropulsations to the pineal gland.

The Face of the Deep

DNA pioneer Erwin Chargaff has called the origin of life "a subject for the scientist who has everything," but that hasn't stopped many of us (or even him, for that matter) from speculating about it. There are numerous detailed pictures of that primal scene in print today, but most are variations on one theory - "warm soup and lightning." Life on earth began some 4 billion years ago, or roughly l or 2 billion

years after the world itself was born. The atmosphere then was completely different, much like Jupiter's today, mostly ammonia and methane. Into that atmosphere some source of energy—lightning, heat, and ultraviolet radiation have all been suggested—led to the spontaneous formation of simple organic compounds. Sifting into the oceans for millions of centuries, these compounds would have coalesced by chance into ever more elaborate patterns. According to the theory, this process culminated in closed "protocells" able to resist the reactivity of other structures while growing through incorporation of similar compounds.

This idea owes its dominance largely to an important experiment made by S. L. Miller in 1953. Miller pumped a facsimile of the presumed early atmosphere—ammonia, methane, and water vapor—continuously past an electric spark. After several days he had some amino acids. Since these are the bricks of DNA, RNA, and all proteins, the evidence seemed very good. Later runs yielded even more sophisticated molecules. In water they coalesced into globules with a sort of membrane around them—called "coacervates" by A. I. Oparin and "proteinoids" by Sidney Fox, two of the most assiduous students of biogenesis.

Nothing came close to being alive in any of these spark chambers, however. More important, the experiments raised two difficulties, one theoretical, one practical. The soup theory needed to come up with a very sophisticated entity, a living cell with some genetic system using DNA or RNA, right off the bat. According to our notions of biology, nothing could be alive before that point, yet it seemed incredible that chance associations of the building blocks could form a palace of such complexity without passing through a mud-hut stage.

When the warm soup theory was first advanced, the mechanistic persuasion was at its height. Living things were complicated machines, but molecular machinery they were. However, the concept of a cell was much simpler than it is today. No longer is it considered a mere baglet of jelly with a few master molecules telling it what to do. Even the membrane of the simplest bacterium responds in intricate ways to information from outside, yet our best electron microscopes haven't yet revealed a complexity of structure adequate to explain its work.

There was a basic chemical problem as well. All organic compounds exist in two forms, or isomers. Each contains the same number and type of atoms, but in one they're arranged as a mirror image of the other. One is "right-handed" and the other is "left-handed." They're identified by the way they bend light in solution. The dextrorotatory (D) forms rotate it to the right, while levorotatory (L) isomers refract it to the left.

All artificial methods of synthesizing organic compounds - including

the spark experiments—yield a roughly equal mixture of D and L molecules. However, all living things consist of either D or L forms, depending on the species, but never both.

We must conceive of the first living things as something unexpected, not just simpler versions of what we see around us. They couldn't have been cells; they couldn't have had a DNA-RNA-protein system, a living membrane, or a nerve impulse network.

We can try to define the bare minimum, the processes that must be available before an entity can be called living. There must be a way to receive information about external conditions, process it, and store it so that the data change the being's response to the same stimulus in the future. In other words, a sort of crude consciousness and memory must be present from the first. A life-form must also be able to sense damage and repair itself. Third, we can expect that it would show some sort of cyclic activity, perhaps tuned primarily to the circadian rhythm of the lunar day. Self-replication, one of the main requirements in the DNA-based theory, can be dispensed with. An organism that can fully heal its injuries is theoretically immortal. The criteria for life can be summarized as organization, information processing, regeneration, and rhythm.

The funny thing is that all of these criteria are met by the activities of semiconducting crystals. Semiconductivity occurs naturally in several inorganic crystals, including silicon, one of the most common elements, and the rare earth germanium. Moreover, extremely small amounts of contaminants will change the crystal's electrical properties dramatically in doping. The earth's volcanic mixing would have produced minerals with a wide variety of current-handling abilities to start from. Most important, the piezoelectric, pyroelectric, photoelectric, and other responses of semiconducting crystals could have served as an analog method of processing and storing information about pressure, heat, and light. Moreover, repeated passage of current through some semiconductors permanently changes the materials' characteristics so as to make the same electrical responses easier in the future. Movement of electrons along the crystal lattices inevitably would have been shaped by geocelestial cycles in the earth's electromagnetic field, as well as by the fields around other such crystalline organisms nearby—providing a sense of time and information about the neighbors. The currents also would have instantly refllected any loss of material and guided the deposition of replacement atoms to restore the original structure.

The idea of certain rocks, in the course of a billion years or so, gradually becoming responsive to their surroundings, growing, learning to "hurt" when a lava flow or sulfuric rain ate away part of a vertex, slowly

rebuilding, pulsing with, well, life, even developing to a liquid crystal stage and climbing free of their stony nests like Cadmus' dragon's teeth or the lizards in an M. C. Escher print—all this may seen a bit bizarre. Yet it's really no more strange than imagining the same transformation from droplets of broth. The change happened somehow.

The biggest hurdle for this theory is accepting the idea that life could develop in the dry state, either out of the oceans or in the rocks underneath them. Since the mid-1960s it has seemed more plausible, for it was then that H. E. Hinton, of the University of Bristol, England, learned that at least one organism spends part of its life completely without liquid water. Certain flies of the Sahara desert lay their eggs in the brief pools formed by the rare rains. The larvae go through several metamorphoses in the water, but they're almost always interrupted by the evaporation of the pool. Though completely desiccated, in a state Hinton named cryptobiosis, they survive months or years until the next rainstorm, whereupon they take up where they left off. The larvae can be quick-dried and stored in a vacuum bottle for many years. Placed in water, they resurrect in a few minutes. If a larva is cut in two when active, it takes six minutes to die. If it's flash-dried in the first minute, the two pieces can be kept on a shelf for years, but when returned to water they'll live out their remaining five minutes. Contrary to common sense, it appears that in this case life doesn't need water, but death can't occur without it.

Getting rid of the water-equals-life assumption makes the crystalline theory more believable. Conditions on the young planet favored forests of crystals: It was hot; volcanoes were constantly firing new materials into the dense, dark shell of turbulent gases. However, the crystals would still have needed outside energy to overcome the entropy of nonliving matter. With an organizing principle built into them from the start, it's not too hard to imagine them acquiring other kinds of molecules, including the organics raining from the sky and dissolving in the waters. Then life would have been on its way to developing the biochemistry we now know—the genetic system and the consequent appearance of sexuality—which is the basis of all the creatures now alive or known from the fossil record. Still, we need an energy source for the transition. Lightning won't work in this context. We also need an explanation for the exclusively left- or right-handed molecules.

In 1974 F. E. Cole and E. R. Graf of New Orleans made a theoretical analysis of the Precambrian earth's electromignetic field that fulfilled both needs. They reasoned that since the atmosphere was much larger then, it must have pushed the ionosphere much farther out than it is

today, into the region of the Van Allen belts. The earth would then have had an electromagnetic resonator of two concentric spheres—the upper atmosphere and the surface. Today, as in the past, the earth's pulsing magnetic field combines with the solar wind to induce large currents in the Van Allen belts. In the Precambrian era, however, the fluctuations of current in the Van Allen belts in turn would have generated huge currents in the nearby ionosphere. Since the earth's metallic core is an excellent conductor, the ionospheric currents would have coupled to it, producing an enormous and constant electrical discharge through the atmosphere and into the earth. Moreover, since the distance around the core at that time was roughly equal to 1 wavelength of electromagnetic energy at 10 cycles per second, or about 18,000 miles, this discharge would have pulsed at 10 hertz throughout the resonant cavity, which encompassed the whole atmosphere and surface. Besides directly providing electrical energy, this discharge would have produced abundant heat, ultraviolet radiation, and infrasound (or pressure waves), all of which would have fostered varied chemical activity.

Such a dense and electrically supercharged atmosphere undoubtedly would have produced great quantities of amino acids and peptides. As they came together in the air and water, linking chainwise to form proteins and nucleic acids, the vectors of electromagnetic force would have favored spiral shapes twisting in one direction or the other, depending on whether the reaction occurred in the Northern or the Southern Hemisphere. In 1981, W. Thiermann and U. Jarzak found some direct evidence for this theory by synthesizing organic compounds in a steady-state magnetic field. Changing the orientation of the field gave them high yields of either D or L forms.

It may be possible to run a further check on the Cole and Graf hypothesis at one place in the solar system—the Great Red Spot of Jupiter. This permanent hurricane, whose eye could swallow the earth, continually emits prodigious electrical discharges through an atmosphere much like the one proposed for Precambrian times. It may be synthesizing organic compounds and energizing a transition to life even now.

On earth, all entities formed within the 10-hertz discharge—and all of their descendants—would resonate at the same frequency or show extreme sensitivity to it, even after the original power source had been disconnected. The 10-hertz band would remain supremely important for most life-forms, as indeed it has. As already noted, it's the primary frequency of the EEG in all animals, and it can be used to restore normal circadian rhythms to humans cut off from the normal fields of earth, moon, and sun. William Ross Adey of the Loma Linda VA Hospital in

California has found that magnetic fields modulated at about the same frequency can be used to change the behavior of monkeys in several important ways, which are described more fully in the next chapter.

The Cole and Graf theory also suggests how the spark of life turned itself off. The currents driving the discharges would have ceased as the atmosphere gradually became depleted by escape of the lighter gases and by incorporation of the ammonia and methane into organic compounds. As this happened, the ionosphere would have gradually descended, becoming disconnected from the Van Allen belts. The ionospheric currents would have become too small to couple to the earth's core, and the atmospheric cavity too small to resonate at the core's prescribed frequency. At that point, the plug was pulled, but life was well on its way. Aside from competition from more advanced creatures, the loss of the energy source would explain why we see today no remnants of the transitional forms still emerging from inanimate matter.

This solid-state theory of life's creation is more than an exciting picture of our birth in a shower of sparks. It leads us to another of biology's great mysteries—the evolution of nervous systems—by a sensible sequence of steps. First there would have been a crystalline protocell transmitting information directly through its molecular lattice. As the first cells developed, we can envision chains of microcrystals, then chains of organic polymers transmitting information in the form of semiconducting currents. Although the exact mechanism of electron passage through living tissue is far from clear, nearly all organic matter exhibits piezoelectricity and all the other hallmarks of semiconduction. Furthermore, in a series of experiments during the 1970s, Freeman Cope, a Navy biophysicist building on Szent-Gyorgyi's work, has found evidence of superconduction at room temperature in a variety of living matter. Currents briefly induced in superconductors have been known to flow for many years without decay, but the phenomenon has heretofore been attained only near absolute zero. Although Cope's work is still preliminary and uncorroborated, he has found electromagnetic data consistent with superconduction in E. coli bacteria, frog and crayfish nerves, yeast, sea urchin eggs, and molecules of RNA, melanin pigment, and the enzyme lysozyme.

Whatever the exact details of the conducting system, the first multicellular organisms probably had networks of cells that were much like the first single cells. Later, these network cells would have specialized for their DC-carrying duties, linking into syncytia to avoid the high resistance of intercellular junctions. Somewhere along the line a central processing center and information storehouse would have developed. At

the same time separate input and output tracts would have appeared, and the DC system would have neared its peak of specialization as its cells evolved into the prototypes of glial, ependymal, and Schwann cells. At about this point the high-speed digital impulse system for handling more complex information would have begun to form inside the older one. Today all multicellular animals have this kind of hybrid system, whose complexities should provide work for at least a few more generations of neurophysiologists.

Crossroads of Evolution

The Cole and Graf theory has one crucial requirement. The polarity of the earth's magnetic field must have stayed the same during the resonant period. Otherwise there would be a mixture of right and left isomers in living tissues. As far as we can tell, the field did remain steady in Precambrian times, but we have ample proof that its poles have reversed many times during the last half-billion years. Each time, the shift has coincided with the extinction of many species.

The geomagnetic record is written in two places: in igneous rocks bearing magnetic minerals, and in ocean floor sediments. Magnetic particles in molten rock are free to move and align themselves with the prevailing magnetic field. As the rock cools they're frozen in place. In the same way magnetic particles settling onto the ocean floor reflect the orientation of the field at the time of the deposit. Ocean sediments and the rock they eventually become have given us an undisturbed magnetic chronology for many millions of years, while the relatively few strata of igneous rock undisturbed by later upheavals give us occasional glimpses further back.

The reversals happen very fast, as geologic time goes. The field strength falls to about half its average for a few thousand years. Then during another thousand years the poles change places; then the field regains its normal strength in another few thousand years. All told, the change takes about five thousand years.

In the early 1960s, when the reversals were first discovered, geophysicists believed the magnetic field disappeared completely during the pole reversal. Thus they thought that the absence of the electromagnetic umbrella that protected life from high energy ultraviolet and cosmic rays would account for large-scale extinctions, These "great dyings" had long puzzled paleontologists . Soon the demise of a species of radiolarian was correlated with a magnetic field reversal. Radiolarians are microscopic

plankton animals with hard calcareous skeletons. Each species has a distinct, intricate shape, so their remains form an easily recognizable, continuous record in sediment cores. By 1967 James D. Hayes and Neil D. Opdyke of Columbia's Lamont-Doherty Geological Observatory had correlated the disappearance of eight types of radiolarians with the reversals. Each species had been widespread and abundant; each extinction took place abruptly, with no previous decline in population. The "radiation barrage" theory seemed confirmed.

However, it has since been learned that the field strength drops only by half, not enough to drastically reduce the protective power of the Van Allen belts and ionosphere. Moreover, radiolarian populations extend down into several yards of water, which should protect them from the radiation anyway. Hays has since drawn the less specific outlines of current knowledge thus: As animals grow more specialized in the course of evolution, they become more sensitive to some as yet unknown, lethal effect of the reversals. Long periods without reversals—the quiescent eras sometimes last tens of millions of years—seem to produce a profusion of species especially susceptible to the effect, and they're weeded out at the next shift.

We know of two especially widespread extinctions. One, at the end of the Permian period, about 225 million years ago, wiped out half the kinds of animals then alive, from protozoa to early reptiles. The same kind of curtain dropped on the age of dinosaurs at the end of the Cretaceous period, some 70 million years ago. In both cases frequent magnetic pole reversals had resumed after a long quiescence. Many periods of less extensive extinction have also been documented in the fossil record and correlated with the field reversals. Most recently, J. John Sepkoski, Jr., and David M. Raup of the University of Chicago reported what they believed to be a 26-million-year cycle in the major dyings. If their hypothesis holds up, there may be some solar or galactic influence that interacts with a magnetic reversal for maximum destructive effect.

We can only surmise that the earth's field was instrumental in life's beginning, but by 1971 we knew virtually for certain that its polarity shifts had shaped life's development by a "pruning" of species. That year I was invited to a private meeting at Lamont to talk about the reversals, the sole M.D. among a score of biologists and geophysicists. At that time we could only speculate as to how the extinction effect came about. We didn't even have a workable theory of what changes inside the earth caused the turnabouts, or how the process affected the micropulsations and other aspects of the field. All we could agree on was that there were probably changes in every aspect of it, and our knowledge hasn't progressed much since then.

The pole shift happens so slowly that living things may well adapt to it easily; the 50-percent decline in field strength also seems rather unimportant. However, since we know the micropulsations control biocycles, including the timing of the mitotic rhythm, a major change in their frequency could be catastrophic. Experiments with artificial extremely low frequency fields (see Chapter 15) have shown that vibrational rates near normal but slightly above, from about 30 to 100 hertz, cause dramatic changes in the cell cycle time. This interferes with normal growth of the embryo and may tend to foster abnormal, malignant growth as well. If a geomagnetic reversal raises the micropulsation frequencies into this range, the accumulation of growth errors over many generations could well mean extinction.

We have no way of making a forecast, however. Reversals seem to happen at widely varied intervals, as often as every fifty thousand years during some periods, many millions of years apart during other times. The last one seems to have occurred about seven hundred thirty thousand years ago. Several scientists have interpreted data from NASA's MAGSAT orbiter, and from measurements of magnetic particles in lake sediments, as indicating that the earth's magnetic field strength is steadily declining, and has been for the last few thousand years. If so, we may already be entering the next reversal, but it's also possible we're merely experiencing one of the field's many short-term variations.

Nor can we be sure how serious a reversal would be for us. Hominids have weathered them in the past, but we have an extra reason for being uneasy this time. If we're entering a reversal now, it will be the first one in which the normal field is contaminated with our own electromagnetic effluvia, and the most powerful of these, at 50 and 60 hertz, fall right in the middle of the "danger band" in which interference with growth controls can be expected.

The field giveth as well as taketh away, however. If we can hang on until the next peak of its strength, we may benefit from a subtle infusion of electromagnetic wisdom. An ingenious theory recently proposed by Francis Ivanhoe, a pharmacologist and anthropologist at two universities in San Francisco, suggests how important it may have been to our own development.

Ivanhoe made a statistical survey of the braincase volume of all known Paleolithic human skulls, and correlated the increase with the magnetic field strength and major advances in human culture during the same period. Ivanhoe found bursts of brain-size evolution at about 380,000 to 340,000 years ago, and again at 55,000 to 30,000 years ago. Both periods corresponded to major ice ages, the Mindel and Wurm, respec-

tively, and they were also eras when great cultural advances were made—the widespread domestication of fire by Homo erectus in the early Mindel, and the appearance of Homo sapiens sapiens (Cro-Magnon peoples) and gradual decline of Neanderthals (Homo sapiens) during the Wurm. Two other glaciations in the same time span—the Ganz of about 1,200,000 to 1,050,000 years ago and the Riss of about 150,000 to 100,000 years ago—didn't call forth such obvious advancements in human evolution. They also differed from the other two in that the average geomagnetic field intensity was much lower.

Ivanhoe has proposed a direct link from the magnetic field through the growth-hormone regulator pathways in the brain to account for the sharp evolutionary gains. He suggests that part of the hippocampus, a section of the brain's temporal lobe, acts as a transducer of electromagnetic energy. A part of the hippocampus called Ammon's horn, an arch with one-way nerve traffic directed by a strong current flow, may read out variations in the field strength, feeding them by a bundle of well-documented pathways called the fornix to the hypothalamus and thence to the anterior pituitary, where growth hormone is produced. It's known that larger amounts of this hormone in pregnancy increase the size of the cerebral cortex and the number of its nerve cells in the offspring, as compared with other parts of the brain. Ivanhoe also notes that the hippocampus and its connections with the hypothalamus are among the parts of the brain that are much larger in humans than other primates. The idea gains further support from the fact that neural activity in the hippocampus increases with electrical stimulation and reaches a maximum at 10 to 15 cycles per second, at or slightly above the dominant micropulsation frequency of today's field. The most powerful shaper of our development may turn out to be the subtlest, a force that's completely invisible to us.

Hearing Without Ears

We've considered how the electromagnetic fields of earth, moon, and sun affect life. In the next chapter, we'll ponder the effects of artificial fields from our machines. There's probably another interaction, however, of which we know much less: the effects produced on living things by the biomagnetic fields of other creatures. If one nervous system could sense the field of another, it would go a long way toward explaining extrasensory perception.

Following the curious dogma that what we don't understand can't

exist, mainstream science has dismissed psychic phenomena as delusions or hoaxes simply because they're rarer than sleep, dreams, memory, growth, pain, or consciousness, which are all inexplicable in traditional terms but are too common to be denied. Fifty years ago, when J. B. Rhine of Duke University first published results of his card-guessing experiments, scientists eagerly debated and tested the subject for a few years. Then, although at least 60 percent of the attempts to confirm Rhine's work also got better-than-chance results (a replication rate better than that in most other areas of psychology), the openness somehow disappeared. Ever since World War II, serious parapsychologists have been hounded out of the forum of science. In the 1950s, for example, Science and Nature both published attacks on certain results of Rhine and S. G. Soal, an early psi researcher at London University. Today this attitude may be waning. G. R. Price, the author of one of the diatribes, apologized in Science in 1972, and both journals have begun accepting occasional reports on psychic research, although still confining themselves mainly to negative findings. As the climate has begun to change, a few researchers have looked for electromagnetic fields as a possible basis for extrasensory perception.

The results so far have been as inconclusive as those from any other approach. In 1978 E. Balanovski and J. G. Taylor used a variety of antennae, skin electrodes, and magnetometers to monitor a number of people claiming paranormal powers. They found no electric or magnetic fields associated with successes in telepathy experiments. In 1982, Robert G. Jahn, dean of engineering at Princeton, assembled the most impressive battery of electronic equipment ever brought to bear on the subject. He found definite effects by mental forces on interferometer displays and strain-gauge readings, along with positive results in remote-viewing experiments. The tests couldn't be reliably repeated, however, and seemed to vary with the moods of researcher and subject, and perhaps with other immeasurable environmental factors. The same dependence on attitude—experiments seem to work more often for believers than doubters—has bedeviled psychic research from its beginning. Although Jahn came up with no clear-cut findings on electromagnetic factors, he was forced to the sublimely understated conclusion that ". . . once the illegitimate research and invalid criticism have been set aside, the remaining accumulated evidence of psychic phenomena comprises an array of experimental observations . . . which compound to a philosophical dilemma."

We must remember that our study of biofields is still in its infancy. It's only a decade since the SQUID first enabled us to find the magnetic

field around our heads at all. Pigeons have a magnetic detector thousands of times more sensitive than the latest instruments. We also know that the interaction of semiconducting currents with external magnetic fields is thousands of times greater than that of currents in a wire, and engineers have built microscopic devices that enhance this sensitivity by a factor of another thousand or more. The electron microscope has shown us crystallike structures of previously unsuspected complexity in all living cells, whose functions we can only guess at. There's now some evidence that psychic intent can influence the flow of current in solid-state devices, so we may be nearing the energy levels at which extrasensory factors work. Since all living things generate weak electromagnetic fields, and since many, if not all, can sense those of the earth, communication by this medium remains a strong possibility. Recent disclosure of a multimillion-dollar research effort in this area by the hardheaded weapons planners at the Department of Defense is one more reason why those scientists who work in public shouldn't dismiss the idea.

We must always be careful to place more weight on observation than current theory. We must remember that we don't yet fully understand magnetism. It now appears that the single domain with both magnetic poles may not be the smallest unit of magnetism after all. Physicists now posit the existence of magnetic monopoles, particles having the characteristics of just one pole, north or south. In fact there's some experimental evidence for them. Some theoreticians go even further, envisioning a hitherto unsuspected kind of magnetism, a composite of waves and monopole particles, like light. Living things may interact with such a now immeasurable energy.

Any such message system would have at least two major difficulties to overcome in the course of evolution. Our own electrical-engineering experience, however, suggests workable approaches life may have taken.

One problem is that the strength of biofields is far below that of the earth's field. Hence any input from other creatures would be embedded in noise. This is a common obstacle to telecommunications, and there are several ways around it. The easiest is for sender and receiver both to be frequency locked, that is, tuned to one frequency and insensitive to others. Such a lock-in system might explain why spontaneous ESP experiences most often happen between relatives or close friends. The sensitivity of our instruments may someday develop to the point where we can tune in to biomagnetic fields on select frequencies, thus experimenting as directly with ESP as we now do with radio.

Another theoretical difficulty is the fact thatl psychic transmission doesn't seem to fade with distance. The electromagnetic field around an animal's nervous system, on the other hand, starts out unimaginably

small and then diminishes rapidly. However, extremely low frequency (ELF) transmissions have a peculiar property. Because of their interaction with the ionosphere, even weak signals in this frequency range (from 0.1 to 100 cycles per second) travel all the way around the world without dying out. If an innate frequency selector is operating within this band, reception should be the same anywhere on earth.

At this time the DC perineural system and its electromagnetic fields provide the only theory of parapsychology that's amenable to direct experiment. And it yields hypotheses for almost all such phenomena except precognition. Telepathy may be transmission and reception via a biologically programmed channel of ELF vibrations in the perineural system's electromagnetic field. Dowsing may involve an unconscious sense of the electromagnetic fields of underground water or minerals, an idea given some support by Russian experiments in the 1960s. Nikolai N. Sochevanov, now with the USSR's Ministry of Geology, found that the accuracy of forty professional dowsers diminished by at least three fourths when he wound a current-carrying wire around their wrists or brought a horseshoe magnet near their heads.

Biological semiconductors even offer a possible basis for the aura often reported around living things by "sensitives." There has long been speculation that this "halo" might be some manifestation of an electromagnetic biofield. The ability of high-voltage (Kirlian) photography to produce an image very much like descriptions of the aura has aroused hope that the technique might render some aspect of psychic phenomena visible in a way that would be conducive to experiment. Because of this possibility, our lab investigated Kirlian photography during the mid-1970s.

We obtained beautiful pictures that seemed to vary in response to changes in the health of the test organism. However, the method failed one crucial test. If the Kirlian halo actually reflected the biofield or some other basic aspect of life, it should have disappeared when the organism being photographed died. Alas, it did not. The image remained the same as long as the water content of the corpse remained constant. We found the images were entirely due to a simple physical event, a corona discharge. This occurred when a high-voltage electric field broke down the air molecules between the two condenser plates of the Kirlian apparatus. The amount of water vapor in the air changed the voltage at which this happened, and on color film produced coronas in different colors and sizes. We found no evidence that the Kirlian image was related to the living state. Nor did we find that it could serve as a "screen" on which might be reflected some invisible field or aura, another possibility that had been suggested.

This is not to say that the aura occasionally perceived by some people

around other organisms is imaginary. Things that appear so often in folklore often turn out to have a basis in fact. However, the body's magnetic field is far too weak to account for it. Our biofields, even if they were many times stronger, couldn't possibly emit light, but an appropriately sensitive magnetic detector in the brain, if it had nerve connections to the visual cortex, might "see" the magnetic field, in a manner of speaking. In a similar way astronauts in space "see" Cerenkov radiation—flashes of light that have been traced to the passage of high-energy cosmic rays through the retina.

On the other hand, the aura could literally be a form of light, perhaps at frequencies invisible to all but a few of us. The discovery of light-emitting diodes is still fairly recent. As you will recall, we found that bone happens to have such properties. The point of that experiment was its evidence that bone contains semiconducting PN junction diodes. There may well be other diodes in living things. The relationship between the nerve endings and the skin is an interesting one in this context. The skin-nerve interface—the closest normal equivalent to the neuroepidermal junction that triggers regeneration—may well be a diode. If so, the proper level of current could cause emission of light from the skin. It's even possible that such an array of diodes with very large currents might produce a holographic image of the body on an organic screen, such as the reputed image of Christ on the Shroud of Turin.

If extrasensory communication really is a function of the DC system, why isn't it more common and widely accepted? We may never know how well distributed it is among animals, although the number of pets who have returned to their owners over long distances suggests that many dogs and cats can find specific people by an unknown sense. The Duke University Parapsychology Laboratory has authenticated more than fifty such cases, many involving travel of hundreds or thousands of miles. We can expect that some species would be better at it than others, just as pigeons navigate by the earth's magnetic field far better than most other creatures. Among humans, some may simply be more gifted than others through genetic chance or some facet of their upbringing. Then again, the psychic sense may be a universal ability that was forgotten or suppressed as we came to depend more and more on language to get our messages across.

If they do depend on the same system, psychic ability and regeneration may go together; they may generally be better among simple animals. As the digital impulse system grew more efficient, its information may have overwhelmed the senses operating through the earlier mode. In fact, this may be part of the digital system's purpose. The ever-

present hum of electromagnetic information from other creatures may have become an intolerable burden. Think how confused you would feel if you could simultaneously hear what everyone else in the world was thinking. After all, mediums, sorcerers, and psi experimenters all agree that some sort of trance or mental quietude—a reduction of nerve impulse activity—is needed for best results. According to Elmer Green, yogis of some Tibetan traditions teach clairvoyance to novices by having them meditate seated on a glass plate, facing north toward a sheet of polished copper in a dark, windowless room, with a bar magnet suspended over their heads, its north pole pointing up to the zenith.

The biofield also lends itself to theories of psychokinesis and object imprinting. All matter, living and nonliving, is ultimately an electromagnetic phenomenon. The material world, at least as far as physics has penetrated, is an atomic structure held together by electromagnetic forces. If some people can detect fields from other organisms, why shouldn't some people be able to affect other beings by means of their linked fields? Since the cellular functions of our bodies are controlled by our own DC fields, there's reason to believe that gifted healers generate supportive electromagnetic effects, which they convey to their patients or manipulate to change the sufferer's internal currents directly, without limiting themselves to the placebo effect of trust and hope.

Once we admit the idea of this kind of influence, then the same kind of willed action of biofields on the electromagnetic structure of inanimate matter becomes a possibility. This encompasses all forms of psychokinesis, from metal-bending experiments in which trickery has been excluded to more rigidly controlled tests with interferometers, strain gauges, and random number generators. At present, it's the only hypothesis that offers much hope of testability. On a less spectacular level, we must ask whether the biofield can project the individual signature of a person's thoughts onto his or her surroundings, changing the electromagnetic characteristics of these objects so that the person can be sensed by others even though absent. This may well be the commonest of all paranormal experiences, and the number of crimes solved by psychics reacting to the mere scene of the crime should entitle scientists to investigate the idea without fear of ridicule from their colleagues.

Over and over again biology has found that the whole is more than the sum of its parts. We should expect that the same is true of bioelectromagnetic fields. All life on earth can be considered a unit, a glaze of sentience spread thinly over the crust. In toto, its field would be a hollow, invisible sphere inscribed with a tracery of all the thoughts and emotions of all creatures. The Jesuit priest and paleontologist-phi-

losopher Pierre Teilhard de Chardin postulated the same thing, a noosphere, or ocean of mind, arising from the biosphere like a spume. Given a biological communications channel that can circle the whole earth in an instant, possibly based on life's very mode of origin, it would be a wonder if each creature had not retained a link with some such aggregate mind. If so, the perineural DC system could lead us to the great reservoir of image and dream variously called the collective unconscious, intuition, the pool of archetypes, higher intelligences deific or satanic, the Muse herself.

Fifteen
Maxwell's Silver Hammer

In considering questions as remote as the origin of life, science must skate toward new shores across the thin ice of speculation, but it also has a duty to warn us of present dangers as specifically as possible. Since the earth's electromagnetic activity has such a profound effect on life, the obvious question is: What are the consequences of our artificial energies?

Electromagnetism can be discussed in two ways—in terms of fields and in terms of radiation. A field is "something" that exists in space around an object that produces it. We know there's a field around a permanent magnet because it can make an iron particle jump through space to the magnet. Obviously there's an invisible entity that exerts a force on the iron, but as to just what it consists of—don't ask! No one knows. A different but analogous something—an electric field—extends outward from electrically charged objects.

Both electric and magnetic fields are static, unvarying. When the factor of time is introduced, by varying the intensity of the field as in a radio antenna, an electromagnetic field results. As its name implies, this consists of an electric field and a magnetic field. The fluctuations in the field radiate outward from the transmitter as waves of energy, although somehow these waves simultaneously manage to behave as streams of massless, chargeless particles (photons). As to just how this happens, again—don't ask! Sometimes the phenomenon is called an electromagnetic field (EMF), to emphasize its connection with the transmitter; sometimes it's called electromagnetic radiation (EMR), to emphasize its

outward-flowing aspect. However, the two terms refer to the same phenomenon and are interchangeable. The only meaningful distinction is between static and time-varying fields.

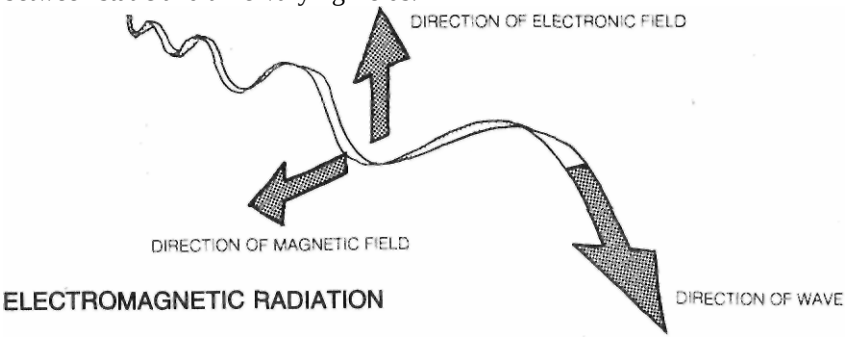

ELECTROMAGNETIC RADIATION

Each energy wave consists of an electric field and a magnetic field at right angles to each other, and both at right angles to the direction the wave is traveling. The number of waves formed in one second is the frequency; the distance the energy travels (at the speed of light) during one oscillation is its wavelength. The higher the frequency, the shorter the wavelength, and vice versa.

EMR spans an enormous range of frequencies. The shortest gamma rays, a tenth of a billionth of a millimeter long, vibrate sextillions of times a second. These, along with X rays and the shortest ultraviolet wavelengths, are termed ionizing radiation, because their high photonic energy can knock electrons away from atoms, creating highly reactive ions where they don't belong. Much of the damage from nuclear radiation is caused in this way. All lower frequencies, beginning with the longer ultraviolet wavelengths, are nonionizing.

Next comes the only energy we can see—the narrow band of visible light vibrating hundreds of trillions of times a second—and then the infrared waves we feel as radiant heat. Below these lie the waves we've harnessed for communication. They begin with microwaves (MW), whose frequency is measured in gigahertz or megahertz—billions or millions of cycles per second—and extend through the radio frequencies (RF) down to ELF waves, whose frequency converges on zero. The MW and RF spectrum is arbitrarily broken up into a further alphabet of extremely high, superhigh, ultrahigh, very high, high, medium, low, very low, and extremely low frequencies (EHF, SHF, UHF, VHF, HF, MF, LF, VLF, and ELF respectively). As we have seen, ELF waves approximate the dimensions of the earth; at 10 hertz one wave is about 18,600 miles long.

Except for light and infrared heat, we can't perceive any of these ener-

gies without instruments, so most people don't realize how drastically and abruptly we've changed the electromagnetic environment in just one century. Working at Cambridge University, Scottish physicist James Clerk Maxwell showed mathematically in 1873 that light was but a small part of the vast undiscovered realm of radiation. Heinrich Hertz first found some of the radio waves in 1888. Meanwhile, Edison had set up the first commercial electric-power system in New York in 1882.

For billions of years before then, the energies that life grew up among were relatively simple. There was a weak electromagnetic field modulated by micropulsations within it and further sculpted by the solar and lunar cycles. There was a burst of static centered at 10,000 hertz and reverberating over the whole earth whenever lightning flashed in the scores of thunderstorms in progress at any one time. There were a few weak radio waves from the sun and other stars. Light, including some infrared and ultraviolet, was the most abundant form of electromagnetic energy. At higher frequencies, living things absorbed only small amounts of ionizing X rays and gamma rays from space and from radioactive minerals in rocks. Large parts of the energy spectrum were totally silent.

We'll never experience that quiet world again. In 1893 Nikola Tesla lit the Chicago World's Fair with the first AC power system, and two years later he began the modern era of electrical engineering by harnessing Niagara Falls. In 1901 Guglielmo Marconi sent a radiotelegraph message across the Atlantic, using without acknowledgment a machine designed by the prolific Tesla. The invention of the vacuum tube in 1907 led to the first voice transmission by radio in 1915 and the first commercial station in 1920. Until then many people still ate supper by candle or kerosene, and the ambient forces remained a reasonable facsimile of earth's pristine field.

The greatest changes have all come in the one generation since World War II. The trend toward use of shorter and shorter radio waves, bounced off the ionosphere for long-distance communication, had begun before the war. The fight for survival against fascism impelled the development of microwave radar, which helped win the Battle of Britain, allowed all-weather bombing of Germany, and gave the American Navy a decisive edge over the Japanese. The conflict also produced other electronic devices of all types. In 1947 Bell Telephone set up the first microwave phone relay towers between New York and Boston, the same year the first commercial television broadcasts, also transmitted by microwaves, began. Since then nearly every human involved an electrical appliance, and today we're all awash in a sea of energies life has never before experienced, of which the following list of sources only skims the surface:

Everything that runs on a battery produces a DC magnetic field—from digital watches, cameras, flashlights, and portable radios to car ignition systems.

Strong magnetic fields are used in industry to refine ore, concentrate and recycle scrap iron, purify sewage, soften water for steam boilers, and many other tasks.

The starting and stopping of an electric train turns the power rail into a giant antenna that radiates ELF waves for over 100 miles.

Electromagnetic fields vibrating at 60 hertz (50 hertz in Europe and Russia) surround nearly every person on earth from appliances at home and machines at work.

Over 500,000 miles of high-voltage power lines crisscross the United States. Innumerable smaller lines feed into every home, office, factory, and military base, all producing AC or DC fields. Metal objects near the lines concentrate the fields to higher levels. In addition, high-voltage lines are, in effect, gigantic antennae operating at 60 hertz in the ELF band, the largest "radio" transmitters in the world. Switching stations, where the current is changed from one voltage or type to another, emit radio-frequency waves as well.

AC magnetic fields vibrating at 100 to 10,000 hertz emanate from antitheft systems in stores and libraries, and from metal detectors in airports.

Low-frequency radio waves are used for air and sea navigation, time references, emergency signals, some amateur radio channels, and military communications.

Medium frequencies between 535 and 1,604 kilohertz are reserved for AM radio transmitters, which are limited to 50,000 watts in this country but are sometimes much more powerful abroad.

HF and VHF channels are filled with chatter from the nation's 35 million CB radios, as well as shortwave bands for more ham radios, air and sea navigation systems, military uses, spy satellites, and police and taxi radios. VHF television and FM radio also inhabit this region. There are now over ten thousand commercial radio and TV stations in the United States alone, and 7 million other radio transmitters, not counting the millions operated by the military.

Weather satellites, some kinds of radar, diathermy machines, upward of 10 million microwave ovens, more cop and cab radios, automatic garage-door openers, highway emergency call boxes, and UHF television compete for the low microwave frequencies.

Higher microwave bands are crowded with more military talk channels and radar, navigational beacons, commercial communications satellites, various kinds of walkie-talkies, and America's two hundred fifty thousand microwave phone and TV relay towers.

Like the infrared rays above them in the spectrum, radio waves and microwaves produce heat when directed in high-intensity beams. Hence they're used for all sorts of industrial chores—bonding plywood, vulcanizing rubber, manufacturing shoes, sterilizing food, making plastics, and heat sealing the trillions of plastic-wrapped products in our stores, even opening oysters. Modern electronics would be impossible without the perfect silicon and germanium crystals grown in microwave furnaces.

The human species has changed its electromagnetic background more than any other aspect of the environment. For example, the density of radio waves around us is now 100 million or 200 million times the natural level reaching us from the sun. Nor is there any end in sight. When superconducting cables are introduced, they'll increase the field strength around power lines by a factor of ten or twenty. Electric cars, magnetically levitated transport vehicles, and microwave-beam satellites for transmitting solar power to earth would each add strong new sources of electromagnetic contamination. A proposed electromagnetic catapult that could shoot satellites into space from mile-long rails built up the side of a mountain would require the combined output of the country's thousand generating stations for the few seconds of each launch.

A few years ago most investigators believed that each wavelength interacted mainly with objects comparable to it in size. This was a comforting notion that theoretically limited each frequency to one type of effect and predicted that really troublesome problems for humans would come from only one portion of the spectrum—the FM band. Now, however, we know there are primary effects on all life-forms at ELF frequencies, and in other parts of the spectrum there can be consequences for specific systems at any level, from the subatomic to the entire biosphere as a unit.

Of course, a change at one level may well trigger secondary changes throughout an organism, so that the original one is hard to identify. Moreover, the impact of EMR ar any particular frequency is often related to its power density, the amount of energy streaming through a certain area. When discussing biological effects, this is best measured in microwatts (millionths of a watt) per square centimeter, a unit we'll simplify to microwatts. There's often no direct relationship between dose and effect, however; a low power density sometimes does things that a

higher one does not. Furthermore, we can't tell how much energy from a given power density is actually absorbed, or what part of the body receives it. The same holds true for electric and magnetic fields, whose study is further complicated by the fact that animals of different shapes distort the fields differently. Likewise, fur, feathers, skin thickness, bone size, and the general shape of an animal complicate RF and MW absorption beyond our capacity to gauge it. Therefore, reactions seen in one species cannot be assumed for another. The only way to test for possible damage (or beneficial effects) is to actually do the experiment.

In a sense, the entire population of the world is willy-nilly the subject of a giant experiment. Electropollution has been the subject of heated public debate for nearly ten years, and unpublicized misgivings for decades before that. Unfortunately, the question of risk has been asked too late. Daily exposure of nearly everyone is a fait accompli.

Subliminal Stress

After Howard Friedman, Charlie Bachman, and I had found evidence that "abnormal natural" fields from solar magnetic storms were affecting the human mind as reflected in psychiatric hospital admissions, we decided the time had come for direct experiments with people. We exposed volunteers to magnetic fields placed so the lines of force passed through the brain from ear to ear, cutting across the brainstem-frontal current. The fields were 5 to 11 gauss, not much compared with the 3,000 gauss needed to put a salamander to sleep, but ten to twenty times earth's background and well above the level of most magnetic storms. We measured their influence on a standard test of reaction time—having subjects press a button as fast as possible in response to a red light. Steady fields produced no effect, but when we modulated the field with a slow pulse of a cycle every five seconds (one of the delta-wave frequencies we'd observed in salamander brains during a change from one level of consciousness to another), people's reactions slowed down. We found no changes in the EEG or the front-to-back voltage from fields up to 100 gauss, but these indicators reflect major alterations in awareness, so we didn't really expect them to shift.

We were excited, eagerly planning experiments that would tell us more, when we came upon a frightening Russian report. Yuri Kholodov had administered steady magnetic fields of 100 and 200 gauss to rabbits and found areas of cell death in their brains during autopsy. Although his fields were ten time as strong as ours, we stopped all human experiments immediately.

Friedman decided to duplicate Kholodov's experiment with a more detailed analysis of the brain tissue. He made the slides and sent them to an expert on rabbit brain diseases, but coded them so no one knew which were which until later.

The report showed that all the animals had been infected with a brain parasite that was peculiar to rabbits and common throughout the world. However, in half the animals the protozoa had been under control by the immune system, whereas in the other half they'd routed the defenders and destroyed parts of the brain. The expert suggested that we must have done something to undermine resistance of the rabbits in the experimental group. The code confirmed that most of the brain damage had occurred in animals subjected to the magnetic fields. Later, Friedman did biochemical tests on another series of rabbits and found that the fields were causing a generalized stress reaction marked by large amounts of cortisone in the bloodstream. This is the response called forth by a prolonged stress, like a disease, that isn't an immediate threat to life, as opposed to the fight-or-flight response generated by adrenaline.

Soon thereafter, Friedman measured cortisone levels in monkeys exposed to a 200-gauss magnetic field for four hours a day. They showed the stress response for six days, but it then subsided, suggesting adaptation to the field. Such seeming tolerance of continued stress is illusory, however. In his pioneering lifework on stress, Dr. Hans Selye has clearly drawn the invariable pattern: Initially, the stress activates the hormonal and/or immune systems to a higher-than-normal level, enabling the animal to escape danger or combat disease. If the stress continues, hormone levels and immune reactivity gradually decline to normal. If you stop your experiment at this point, you're apparently justified in saying, "The animal has adapted; the stress is doing it no harm." Nevertheless, if the stressful condition persists, hormone and immune levels decline further, well below normal. In medical terms, stress decompensation has set in, and the animal is now more susceptible to other stressors, including malignant growth and infectious diseases.

In the mid-1970s, two Russian groups found stress hormones released in rats exposed to microwaves, even if they were irradiated only briefly by minute amounts of energy. Other Eastern European work found the same reaction to 50-hertz electric fields. Several Russian and Polish groups have since established that after prolonged exposure the activation of the stress sytem changes to a depression of it in the familiar pattern, indicating exhaustion of the adrenal cortex. There has even been one report of hemorrhage and cell damage in the adrenal cortex from a month's exposure to a 50-hertz, 130-gauss magnetic field.

Soviet biophysicist N. A. Udintsev has systematically studied the

effects of one ELF magnetic field (200 gauss at 50 hertz) on the endocrine system. In addition to the "slow" stress response we've been discussing, he found activation of the "fast" fight-or-flight hormones centering on adrenaline from the adrenal medulla. This response was triggered in rats by just one day in Udintsev's field, and hormone levels didn't return to normal for one or two weeks. Udintsev also documented an insulin insufficiency and rise in blood sugar from the same field.

One aspect of the syndrome was very puzzling. When undergoing these hormonal changes, an animal would normally be aware that its body was under attack, yet, as far as we could tell, the rabbits were not. They showed no outward signs of fear, agitation, or illness. Most humans certainly wouldn't be able to detect a 100-gauss magnetic field, at least not consciously. Only several years after Friedman's work did anyone find out how this was happening.

In 1976 a group under J. J. Noval at the Naval Aerospace Medical Research Laboratory at Pensacola, Florida, found the slow stress response in rats from very weak electric fields, as low as five thousandths of a volt per centimeter. They discovered that when such fields vibrated in the ELF range, they increased levels of the neurotransmitter acetylcholine in the brainstem, apparently in a way that activated a distress signal subliminally, without the animal's becoming aware of it. The scariest part was that the fields Noval used were well within the background levels of a typical office, with its overhead lighting, typewriters, computers, and other equipment. Workers in such an environment are exposed to electric fields between a hundredth and a tenth of a volt per centimeter and magnetic fields between a hundredth and a tenth of a gauss.

Power Versus People

Because industry and the military demand unrestricted use of electromagnetic fields and radiation, their intrinsic hazards are often compounded by secrecy and deceit. I learned this lesson in my first encounter with the environmental review process.

As we were investigating the EMF-stress connection in 1969, the Navy decided to build a giant antenna in northern Wisconsin. The plan, called Project Sanguine, was to establish a radio link with nuclear submarines at their normal depth of 120 feet or below. Conventional radio signals couldn't pass through water, so the vessels had to surface or else cruise very slowly a few feet under and communicate by means of a floating antenna at prearranged times. Since this made the subs tem-

porarily vulnerable, the Navy wanted a message system using ELF waves, which penetrate earth and water.

The original design involved 6,000 miles of buried cable arranged in a grid across the upper two fifths of Wisconsin. A transmitter would pump current into one side; the electricity would emerge from the other side and complete the circuit by traveling through the ground. The device was actually a giant loop antenna using the earth as part of the loop. ELF waves issuing from it and resonating between the earth's surface and the ionosphere could be picked up anywhere on the globe.

Sanguine was one of the first military projects scrutinized under the Environmental Protection Act. In 1973 the Navy set up a committee of scientists to review fifteen years of naval research on ELF effects, as well as other pertinent work. Captain Paul Tyler of the Office of Naval Research asked me to be one of its seven members.

The only thing sanguine we found was the name. While the research to date didn't prove there would be grave harm to human health, it showed several dangers. The antenna would produce an electromagnetic field 1 million times weaker than that from a 765-kilovolt power line. It was to broadcast at 45 to 70 hertz, frequencies close enough to the earth's micropulsations that living things are very sensitive to them. Similar fields had been shown to raise human blood triglyceride levels (often a harbinger of stroke, heart attack, or arteriosclerosis), and change blood pressure and brain wave patterns in experimental animals. The generalized stress response, desynchronized biocycles, and interference with cellular metabolism and growth processes—and hence increased cancer rates—were also distinct possibilities. Hundreds of thousands of people would be living inside the antenna even in this sparsely populated area; long-term effects on plants and animals were unknown; and, because the signals would resonate throughout the world, the biohazards might be similarly widespread. For these reasons we unanimously recommended that the project be shelved pending answers to the ominous questions it raised. We provided a long list of necessary research, emphasizing further tests on triglycerides, biorhythms, stress, and psychological responses to ELF fields. We also warned that the health of a large part of the U.S. population might already be impaired by 60 hertz power lines carrying vastly more power than the proposed antenna.

The committee met on December 6 and 7, 1973, generating a report then and there, with a secretary taking down our conclusions. The Navy group in charge was apparently displeased with our findings, The printed proceedings, marked "For official use only," went out only to committee members, and the Navy refused to discuss them with anyone else.

As soon as I got back from Washington, I found that two power companies were planning a network of 765-kilovolt power lines linking nuclear reactors in upstate New York and Canada. One of the lines was to pass through a rural area near the village of Lowville, where I'd just bought land for a vacation-retirement home. I immediately wrote the head of the state's Public Service Commission. Without releasing the Sanguine report—I felt it wasn't my place to do so, even though its suppression was wrong—I informed PSC Chairman Alfred Kahn of its major conclusions. The commission in turn asked the Navy for a copy of our report but was turned down flat. In mid-1974, however, Andy Marino and I were asked to testify at PSC hearings on the power lines.

We presented the best evidence then available, some of which seemed to shock the PSC members. ELF fields at power line intensity or less had by then been linked to bone tumors in mice, slowed heartbeat in fish, and various chemical changes in the brain, blood, and liver of rats. Bees exposed to a strong ELF field for a few days in Russian research had begun to sting each other to death or leave the area. Some sealed off their hives and asphyxiated themselves. Attorneys for the power companies hurriedly asked a year's postponement of the hearings, which the PSC naturally granted.

Andy and I spent that year reading the rapidly accumulating scientific literature on EMF biological effects, including the enormous amount of Russian work becoming available in English. Andy also investigated the stress response further. He ran ten separate experiments with rats, exposing them for one month to 60-hertz electric fields of 100 to 150 volts per centimeter, simulating ground level underneath a typical high-tension line. Three generations of rats bred in this field showed severely stunted growth, especially among males. At lower field strengths (35 volts per centimeter) some of the animals gained more weight than controls, a response we tentatively traced to abnormal water retention, which, like underweight, could also result from stress. A few years later, a study commissioned by the Department of Energy to duplicate this research also produced contradictory but disquieting results. With every known variable controlled in an expensive, high-tech facility at Battelle Laboratories in Columbus, Ohio, one test showed severe growth retardation over three generations, while a second run under exactly the same conditions produced significantly greater weight gain than normal.

Andy's original work also revealed large increases in the infant mortality rate. Between 6 and 16 percent of the pups born in various tests failed to live to maturity because of the electric field. That is, these percentages were in excess of the normal death rate for newborn rats.

Various other symptoms consistent with stress were found, including decreased water intake, enlarged adrenal and pituitary glands, and altered protein and hormone ratios in the blood. There was also a very high incidence—ten in sixty—of glaucoma in the early experiments. The disease didn't show up in later runs from which we excluded animals having observable eye defects, suggesting that the electric field had worsened a preexisting problem rather than causing it.

We expected the utilities to roll out their heavy artillery when the PSC hearings resumed, but we were still unprepared for what actually happened. The companies had hired two microwave researchers, Herman Schwan and Solomon Michaelson, both of whom did most of their work for the Department of Defense, and University of Rochester botanist Mort Miller. Carefully prepared by these three, the company lawyers cross-examined us for seventeen days in December 1975, attacking not only our methods and results but our scientific competence and honesty as well. Michaelson strenuously denied that our rodents had shown signs of stress, even though the biological markers were clear. Even if they had, he contended, stress could be healthful, an idea that Hans Selye later called "farfetched" when applied to a biological challenge that was continuous and not self-imposed.

As far as I know, our testimony was the first ever openly given by American scientists stating that electromagnetic energy had health effects in doses below those needed to heat tissue, and that power lines might therefore be hazardous to human health. We criticized the White House Office of Telecommunications Policy for failing to follow up a tentative 1971 warning by advising the President that some harmful effects from electropollution were now proven. Moreover, although we didn't realize it at the time, we greatly embarrassed Captain Tyler and the Navy by publicly revealing the existence of the Sanguine report, which had been secret until then.

Among those who heard about it was Wisconsin Senator Gaylord Nelson, who was understandably furious that his constituents were even then being used as guinea pigs in ongoing ELF tests at an experimental station near Clam Lake, while the document gathered dust in some Navy safe. Quoting Andy and me, he soundly criticized the Navy on the Senate floor. Due to local opposition, the Navy had already moved the site of the full-scale antenna to Mulligan's upper peninsula, modifying the design and giving it a new name—Project Seafarer. Nelson's fury now induced the Secretary of the Navy to ask the National Academy of Sciences for further study of the environmental questions. Harvard's biology chairman, Woodland Hastings, who was picked to head the NAS

committee, wrote Marino a flattering letter asking for his consultation when the members got down to work. Marino then called Hastings to tell him of the large body of data we'd assembled for the power line hearings, and to make sure the NAS body would be willing to consider it thoroughly. Hastings told him, "Heck, you guys will be on the committee."

Soon the sixteen members were announced, and we were nowhere in sight. Hastings later publicly called us quacks, but to us he said the Navy had specified who was to be on the panel, despite his threats to quit if Andy and I weren't admitted. We were well acquainted with three of the men who were on it: Schwan, Michaelson, and Miller. Obviously they weren't about to find hazards in Seafarer after testifying that a much stronger power line was perfectly safe. They remained on the committee even though all three neglected to mention their New York testimony on NAS conflict-of-interest forms. The rest of the committee was also stacked with people who routinely discounted any evidence of health effects from low-level EMFs.

The NAS committee took an inordinately long time to issue its report, but we eventually saw a reason for the delay. During the PSC hearings, all evidence was subject to cross-examination. Besides questioning the witnesses, each side could look at the other's papers, including the actual workbooks of experiments. After the testimony, while the commission, assisted by a panel of judges, was deliberating, other evidence could be introduced, but it was no longer subject to review by the opposing side. Oddly enough, the NAS report—which constituted a defense of the then current dogma and tried to discredit most of the disturbing evidence—appeared just after the gavel sounded to close the PSC hearings. It was immediately introduced as evidence, and we couldn't say a word about it.

Six years later a Navy spokesman explained to me what had "really" happened. He said the Secretary of the Navy had gone to NAS and arranged to pay for the work. Then, when the members of the committee were announced, the Secretary and other Navy brass agreed that the show was rigged. The Secretary protested to NAS and said the Navy wouldn't pay for the study. NAS said that since the authorizations had already been signed, the Navy would have to pay for it. Moreover, the Navy needed a report in four to six months. Of course, NAS had been planning to wait till the end of the New York PSC hearings, which dragged on and on. My informant told me that, in response to Navy pressure, NAS laid in effect, "Go away. We've got the money, and the study is out of your hands. We'll run it our way." By the time the

report was issued it was too late for the Navy people to use it, and they considered it too biased to have any value anyway. However, I don't put much faith in this bit of blame shifting.

The PSC's panel of judges spent nearly a third of their advisory opinion attacking Marino's work and his "argumentative" demeanor at the witness table. Via a Freedom of Information Act request, Andy later found that the technical parts of this opinion had been written by one of the judges' paid consultants, Asher Sheppard, then a researcher at UCLA. Sheppard was at that time preparing a monograph, The Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency, under contract to the American Electric Power Company. He concluded that there were no significant biological effects from low to moderate-intensity ELF fields such as occurred around power lines and appliances, despite the fact that he'd been working under W. Ross Adey, whose career has been devoted to studying just such effects.

Nevertheless, we won. The Public Service Commission specifically contradicted its judicial advisers, commending Marino as a valuable witness, and adopted most of our recommendations. One line already under construction was built, largely because New York Governor Hugh Carey threatened to dissolve the PSC if the commission stopped it, but the utilities were ordered to buy additional land for a wider safety zone along the right of way. They were also forced to invest $5 million in a five-year research program administered by the New York State Department of Health, and to stop encouraging multiple use of the land under power lines, such as leasing it for playgrounds. An additional six or seven proposed lines have been postponed indefinitely. Most important was the plain fact that we raised the issue successfully against great odds and secured a health-conscious verdict from the PSC, gaining time to gather more facts about the dangers.

The Navy's ELF antenna has also been on hold for many years. Seafarer lost momentum when 80-percent opposition in two 1976 referenda in Michigan's Upper Peninsula forced then candidate Jimmy Carter to oppose it publicly for a while. Once more renamed and redesigned, Project ELF has been heavily funded by the Reagan regime with an eye toward expansion. The first step now would consist of a 56-mile aboveground antenna carried on intersecting rows of utility poles in two corridors cut out of the Escanaba River State Forest. In July 1983, the Michigan Natural Resources Commission voted to allow construction.

However, six months later a federal district judge upheld the suit of several local groups, on whose behalf I testified, ruling that the Navy must prepare a new environmental impact statement. The Navy lost two

appeals of this decision but won a lifting of the injunction in the third appeal, so construction is, at this writing, going on.

Fatal Locations

Subliminal activation of the stress response is one of the most important effects that EMFs and nonionizing radiation have upon life, but it's far from the only one. These unfamiliar energies produce changes in nearly every bodily function so far studied. Many of these alterations are associated with stress, but whether they're a result of, or an additional trigger for, the adrenocortical reaction is an irrelevant chicken-or-egg question at this stage of our knowledge. The most disturbing data come from work on the systems that integrate other bodily functions—the central nervous, cardiovascular, endocrine, and growth control systems. We'll concentrate upon these in the following overview of the biohazards.

For the most part, no attempt will be made to identify specific effects from microwaves, radio waves, and electric or magnetic fields, for similar changes have been observed from all modalities. The major problems come from extremely low frequencies, but higher frequencies have the same effects if pulsed or modulated in the ELF range. This is very often the case, for, to transmit information, microwaves or radio waves must be shaped. This is done by interrupting the beam to form pulses or by modulating the frequency or amplitude (size) of the waves. Furthermore, today's environment is a latticework of crisscrossing signals in which there's always the possibility of synergistic effects or the "construction" of new ELF signals from the patterns of interference between two higher frequencies. Therefore, experiments in which cells or organisms are exposed to a single unmodulated frequency, though sometimes useful, are irrelevant outside the lab. They're most often done by researchers whose only goal is to be able to say, "See, there's no cause for alarm."

The Central Nervous System

Since our work on human reaction time, half a dozen other groups have also found marked CNS effects from ELF fields. Most experiments have shown a decrease in reaction speed, although one researcher noted faster-than-normal reactions in humans exposed to very weak electric fields vibrating at beta wave frequencies. The sensitivity of some animals has turned out to be amazing. James R. Hamer of Ross Adey's group at UCLA reported changes in monkeys' response times from ELF electric

fields as weak as 0.0035 volts per centimeter, roughly equivalent to the field from a color TV set 60 feet away.

One of the most telling tests was a simple one done at the Navy's Pensacola lab. R. S. Gibson and W. F. Moroney measured people's short-term memory and their ability to add sets of five 2-digit numbers in the presence of a 1-gauss magnetic field—-the strength found near some high-voltage power lines and many common high-current appliances, such as portable electric heaters. Test scores declined at both the 60-hertz power frequency and the 45-hertz frequency of the Sanguine-Seafarer antenna, but remained normal in control sessions.

Several studies on both sides of the Iron Curtain have found that rats are generally less active and less exploratory of their environment after being dosed with microwaves, although some frequencies induce restlessness. In contrast, ELF magnetic or electric fields almost always produce hyperactivity and disturbed sleep patterns in rats.

Obviously the subtle workings of the mind may undergo many shifts that don't show up in these crude behavioral tests. Most of our knowledge of electropollution's effects on the brain concerns variables that can be more easily quantified, such as changes in biochemistry, cells, and EEG patterns. These studies can't be easily related to changes in thought processes, but most of the results fit in well with the stress response.

In 1966, Yuri Kholodov found effects on rabbits' EEGs from a few minutes' exposure to fairly strong steady-state magnetic fields (200 to 1,000 gauss). As we'd found in salamanders, there were more delta waves, as well as bursts of alpha waves. He and another Russian biophysicist, R. A. Chizhenkova, also noted a desynchronization, or abrupt shift in the main EEG rhythm, for a few seconds when any field was switched on or off. The same effect has since been confirmed in rats with microwaves. This proved that the brain could sense the field, whether the animal knew it or not.

The sites of the greatest changes—the brain's hypothalamus and cortex—were cause for concern. The hypothalamus, a nexus of fibers linking the emotional centers, the pituitary gland, the pleasure center, and the autonomic nervous system, is the single most important part of the brain for homeostasis and is a crucial link in the stress response. Any interference with cortical activity, of course, would disrupt logical and associational thought.

In 1973 Zinaida V. Gordon, a pioneer in microwave research working with M. S. Tolgskaya at the USSR Academy of Medical Sciences Institute of Labor Hygiene and Occupational Diseases, reported a possible cellular feature of EMR stress. Low doses of microwaves, a mere 60 to

320 microwatts for an hour a day, changed nerve cells in the hypothalami of rats. During the first month of exposure, the neurotransmitter-secreting portions of the cells connecting the brain to the pituitary gland were enlarged. After five months they'd begun to atrophy. When microwave dosage was stopped at that point, however, the cells recovered. J.J. Noval's finding that ELF electric fields changed brainstem acetylcholine levels has already been mentioned. In similar experiments, others have noted a rise followed by a drop to below normal in rat brain levels of norepinephrine, the main neurotransmitter of the hypothalamus and autonomic nervous system. In Soviet work, microwave densities of 500 microwatts or more, delivered in a work-exposure pattern of seven hours a day, gradually reduced norepinephrine and dopamine (another neurotransmitter) to brain levels that indicated exhaustion of the adrenal cortex and autonomic system.

Two years after the Gordon-Tolgskaya report, Allen Frey, who has studied bioeffects of microwaves for over two decades at Randomline, Inc., a consulting firm in Huntingdon Valley, Pennsylvania, found an effect on the blood-brain barrier, the cellular gateway by which specialized capillaries strictly limit the molecules admitted to the delicate nerve cells' environment. Even at power densities as low as 30 microwatts, microwaves pulsed at extremely low frequencies loosen this control, in effect opening up leaks in the barrier. Since some barrier changes occur in response to stress and mood shifts, this could be either a cause or a result of the stress response, or an unrelated effect of pulsed microwaves. In any case, since the blood-brain barrier is the central nervous system's last and most crucial defense against toxins, we must consider this increased permeability a grave hazard until proven otherwise.

Researchers have noted several other potentially dangerous direct effects of electromagnetic smog on the neurons. In 1980 a group under R. A. Jaffe at Pacific Northwest Laboratories in Richland, Washington, found a general increase in neural excitability, especially at the synapses, in rats exposed to 60-hertz electric fields of only 10 volts per centimeter for one month. That same year A. P. Sanders and co-workers at the Duke University Medical Center in Durham, North Carolina, reported as follows on biochemical tests of rat brains subjected to microwaves at two levels, one half and also slightly more than the U.S. safety standard of 10,000 microwatts: "The results suggest that microwave exposure inhibits electron transport chain function in brain mitochondria and results in decreased energy levels in the brain."

In a series of experiments spanning mor than a decade, a group of scientists headed by Ross Adey, first at UCLA and later at the Loma Linda VA Hospital, have studied neuron response to ELF fields and

pulses. Proceeding from Harrier's work on reaction time, they first ascertained that an even weaker electric field, roughly the influence of a light bulb 10 feet away, changed the firing rate of brain cells in monkeys and humans // the field was pulsing at brain wave frequencies. Then, working with radio waves beamed at chick brains kept alive in culture dishes, they found specific pulse rates that decreased or increased the binding of calcium ions to the nerve cells. The flow of calcium ions in and out of neurons controlled the firing rate of impulses in a complex feedback system. Two "windows" of pulsed radio waves (147 megahertz pulsed at 6 to 10 hertz, and 450 megahertz pulsed at 16 hertz) increased the flow of calcium from the cells, interfering with impulse transmission.

Unfortunately for conceptual simplicity but fortunately for the test animals and the rest of us, the pulsed frequencies that work on isolated brains don't work on whole animals. Adey has publicly expressed his conviction that pulses for changing calcium flow in intact nervous systems do exist, however, and he expects that a calcium efflux would interfere with concentration on complex tasks, disrupt sleep patterns, and change brain function in other ways that can't be predicted yet. This research obviously points toward "confusion beam" weaponry, so effective windows may already have been found, but they haven't been reported in the open literature. Be that as it may, Adey's work remains an important clue to the interaction between EMR and the human CNS at the brain's most sensitive frequencies. Together with the other findings just mentioned, it shows that electropollution can trigger profound and dangerous changes, even if we don't yet know exactly how and when.

Just how dangerous these changes may be was indicated by a study that Maria Reichmanis, Andy Marino, and I did in 1979, collaborating with F. Stephen Perry, a doctor near the town of Wolverhampton in western England. Perry had noticed that people living near overhead high-voltage lines seemed more prone to depression than others in his practice. Since ELF electric fields changed norepinephrine levels in rat brains and since depletion of this neurotransmitter in certain brain areas was a clinical sign of depression, the connection seemed plausible. We knew from earlier work that, although electromagnetic field strength fell off quickly in the immediate vicinity of a power line, the rate of decrease lessened with distame, so that the field was often well above background levels over a mile away. Reasoning that suicide was the one unequivocal and measurable sign of extreme depression, we plotted the addresses of 598 suicides on maps showing the location of power lines in Perry's locality. Then we statistically compared this distribution with a set of addresses chosen at random.

The suicide addresses were, on the average, closer to the high voltage

wires. We found the same association with underground power lines, but we couldn't be sure whether more than the statistically expected number of suicides had occurred in areas where the fields were strongest. Since the total field strength was a combination of elements from many sources, we proceeded to measure the actual levels. This confirmed a link. Magnetic fields averaged 22 percent higher at suicide addresses than at the controls, and areas with the strongest fields contained 40 percent more fatal locations than randomly selected houses.

The Endocrine, Metabolic, and Cardiovascular Systems

Living things interpret electromagnetic energy for information about time and place, so they must have a means to filter out useless signals, although perhaps not those never before encountered. Many studies have found that the bioeffects of artificial energy stabilize after a few weeks, suggesting that animals adapt so as to live normally in a changed environment. Hence there's a large body of work that's often quoted to "prove" that electropollution isn't dangerous. As already noted, this simplistic viewpoint doesn't take into account the additive effects of stress. Moreover, when a stress is too strong or too persistent, compensation fails, and the effects become obvious and sometimes irreversible. When evaluating research on hazards, therefore, we must always ask whether the experiment was continued long enough to be informative. Otherwise, a short-term study showing harm is likely to be truer than a reassuring one of medium length.

The primary effect of electromagnetic energy on the endocrine system appears to be the stress responses already described. The major confirmatory study in humans comes from the Soviet Union, where detailed medical tests of seventy-two technicians exposed daily to 1,000 microwatts or less disclosed ominous changes in white and red blood cell counts and an across-the-board decline in immune response. The workers and a group of controls were studied for three years. No human study approaching this in length or completeness has ever been done in the West.

The only other consistently noted glandular change is in the thyroid. The work of several Soviet groups and one American team in the 1970s has clearly shown that radio and microwave frequencies, at power densities well below the American safety guideline of 10,000 microwatts, stimulate the thyroid gland and thus increase the basal metabolic rate. ELF fields at 50 hertz, on the other hand, have depressed thyroid activity in several experiments on rats. It isn't yet known whether this is a

direct effect on the thyroid or whether, like the stress response, it's at least partly caused by alterations in brain function.

One more link in the bioclock-interference-and-stress response has come from 1980 work at the Battelle Pacific Northwest Laboratory in Richland, Washington. Working with rats, researchers there found that a weak 60-hertz electric field (only 3-9 volts per centimeter) canceled the normal nightly rise in production of the pineal gland hormone melatonin, the main hormonal mediator of biocycles.

The cardiovascular system responds to electromagnetic energy in at least two ways. The composition of the blood reflects the stress response and concomitant activation of the immune system, while many frequencies exert a direct effect on the electrical system of the heart.

Soviet scientists have observed a variety of blood changes in animals exposed to microwaves, radio waves, and ELF fields. These include declines in red blood cell count and hemoglobin concentration—and hence oxygen capacity—as well as changes in the relative numbers of various types of white blood cells and the relative amounts of blood proteins, and a possible reduction in the blood's ability to clot.

Most of the discomforting studies of electropollution have been done by the Soviets, and they've been given short shrift by Western scientists. There are many reasons for this attitude. There's a simple prejudice against all things Russian and a feeling that their science, technologically less flashy than ours, is necessarily cruder. Western researchers have hamstrung themselves with the dogma that there simply can't be bioeffects from low levels of electromagnetic energy—so why bother looking? Then, too, Russian publication standards are different; procedural details are often omitted, making replication difficult. In addition, there are often troubling contradictions in the data themselves. Results are often inconsistent from animal to animal. If red blood cell count goes up in one, it will go down in another, so the experiment shows no statistical change even though every animal's blood composition is going haywire. In such a situation, the ultramechanistic Americans tend to believe the statistics, while the Soviet biologists concentrate on the animals. Russian scientists have been systematically studying electromagnetic bioeffects since 1933, and we can hardly afford to dismiss their entire body of work simply because it comes from a country we fear.

My associates and I therefore proceeded from one of the most detailed Soviet reports and designed an experiment to measure effects on the blood of mice as our test fields were turned on and off. We concluded that these effects weren't a reaction to the fields themselves but rather a

transient compensation that the animals were making in response to any change in their electromagnetic environment. By themselves, none of the blood fluctuations were especially hazardous. However, since we all live amid EMFs that are constantly shifting as we turn appliances on and off or travel from place to place, the continual blood instability could be significant.

American attitudes began to alter in 1978-79 when Richard Lovely of the University of Washington took advantage of a detente-inspired exchange of microwave results to visit the Soviet Union for a month and study Eastern methods closely. His research group then painstakingly recreated a major Soviet experiment in which rats had been irradiated seven hours a day for three months with 500 microwatts. The Russian work was confirmed in every detail, including disruption of the blood's sodium-potassium balance, other pathological changes in blood chemistry, damage to the adrenal glands from stress-induced hormonal changes, diminished sense of touch, a decline in explorativeness, and slower learning of conditioned responses. Donald I. McRee, director of the EPA electromagnetic-radiation health research program, termed the results "very interesting" and called for an end to the American establishment's contempt for Soviet work.

Electromagnetic energy has other adverse effects on blood composition and tissue function. Yuri D. Dumansky, one of many Soviet biophysicists who have done detailed work on microwave hazards, found changes in carbohydrate metabolism, including a rise in human blood-sugar levels, resulting from 100 and 1,000 microwatts. Power-frequency (50-hertz) fields were also linked to altered sugar and protein metabolism in rats, as well as decreased muscular strength in rabbits. Like many other Russian results, these were questioned because of American failure to corroborate them. In this case a research team headed by N. S. Mathewson of the Armed Forces Radiobiology Research Institute in Bethesda, Maryland, reported no such metabolic changes in response to the Sanguine-Seafarer 45-hertz frequency.

However, the Mathewson group made a fundamental mistake. They neglected to account for the 60-hertz background field near the test cages in their lab, even though they'd measured it when setting up the work station. When we reanalyzed their data in light of this omission, the experiment showed exactly the same changes in blood levels of glucose, globulins, lipids, and triglycerides as the Russians had found.

The most frightening data so far on blood composition come from a preliminary study for Project Sanguine. Dietrich Beischer found that one day of exposure to a magnetic field such as would be produced by the

ELF antenna caused a 50-percent rise in triglycerides in nine of ten human subjects. The NAS committee's conclusion that this early result didn't stand up was based on subsequent Navy work, mainly the faulty Mathewson study. Adequate follow-up by a disinterested group has never been funded, even though Beischer's finding agrees completely with Russian studies and the reinterpreted Mathewson data on animals. This doesn't exhaust the list of microwave metabolic effects reported behind the Iron Curtain. Dumansky found widespread changes in the liver function of rats exposed to low levels of microwaves that were scheduled to approximate the pattern of mealtime exposure from microwave ovens. Others detected vitamin B2 and B6 depletion from blood, brain, liver, kidneys, and heart, as well as major shifts in trace-metal metabolism in response to low levels of microwaves. The distribution of copper, manganese, molybdenum, nickel, and iron was affected throughout the bodies of rats. Similar trace-metal changes were recorded after exposure to ELF electric fields for four months, even at moderate field strengths for only half an hour per day. Since B6 is essential to the utilization of carbohydrates, fat, and protein, and since the trace metals act as catalysts in a wide variety of biochemical reactions, these observations may explain some of the other metabolic changes.

There are indications that some types of electropollution directly decrease the efficiency of the heart. Several research groups in Poland, the Soviet Union, Italy, and the United States have studied pulse, electrocardiogram, blood pressure, and reserve capacity (the heart's ability to handle exertion) in animals. Microwaves and 50-hertz electric fields both produced similar changes that persisted throughout long-term exposure. These included bradycardia (decreased pulse), a huge reduction (40 to 50 percent) in the strength of the electrical impulses governing contraction of the heart muscle, a decline in reserve capacity, and a short-term rise followed by a long-term fall in blood pressure. In general, these decrements occurred in both "domestic" (0.5 volts per centimeter) and "industrial" (50 volts per centimeter or more) electric fields and at microwave power densities of 150 microwatts, well within the amount received by many people from radar beams and microwave ovens.

In humans, confirmatory evidence for these effects comes from several Russian studies of workers in high-voltage power station switchyards. In the first such group examined, forty-one of forty-five had some sign of nervous or cardiovascular disease, including bradycardia, instability of pulse and blood pressure, and tremors. The same health problems were found in four additional studies of nearly seven hundred more workers.

The only comparable American study is much quoted for its failure to find consistent health damage in a mere eleven power-line maintenance workers.

Growth Systems and Immune Response

Given the results presented so far and the dynamics of life's connection to the earth's field, we can now make several predictions about the effects of ELF pollution. The most important aspects of the natural electromagnetic field for the biological timing systems are the lunar circadian rhythm and the micropulsations of 0.1 to 35 hertz. It seems logical that cells will perceive frequencies close to normal more readily than those further removed from the norm. Therefore we can postulate that the ELF band from 35 to 100 hertz would be the most damaging, while higher frequencies might go more or less unnoticed until the energy injected into cells became intense or prolonged enough to be significant. The accumulating evidence supports this idea.

Based on this notion, we can predict two major ELF effects that would encompass many others. We can expect the abnormal signals to disrupt biocycles. Such disruption would trigger the generalized stress response even if the EMR-induced changes in brain neurotransmitters were only an effect and not a cause of the stress reaction. In addition, the wrong timing signals would likely throw off the mitotic cycle time of every cell, interfering with growth processes throughout the body.

Although any number of factors can trigger the adrenocortical stress reaction, the response itself is always the same. It involves the release from the adrenal glands of specific hormones, mainly the corticosteroids, which in turn mobilize the body against invading germs or foreign proteins. Thus the stress response always activates the immune system.

Short exposures to stress aren't necessarily harmful and may even be healthy. In fact, the Soviet work on microwave stress has disclosed a brief period of increased immune-system competence at very low intensities (under 10 microwatts). However, when an organism must face a continual or repeated stress, the response system enters the chronic phase, during which resistance declines below normal and eventually becomes exhausted. Several well-known diseases, such as peptic ulcer and hypertension, result directly from this stage, but the most important result is a decrease in the body's ability to fight infection and cancer.

The trouble is that the immune system is geared to fight tangible invaders—bacteria, viruses, toxins, and misbehaving cells of the body

itself—or such consciously detectable stresses as heat, cold, or injury. It includes a system of circulating antibodies by which specialized cells recognize the intruder. The cells controlling this phase, which is called humoral immunity, then select appropriate defenders from an array of other types, each programmed for a certain function, such as digesting bacteria, clearing away cellular debris, or neutralizing poisons. Electromagnetic energy isn't consciously perceived, however. It tricks the immune system into fighting a shadow. Thus we can predict that, just like a fire company answering a false alarm, the body will be less able to fight a real fire.

Experiments bear out this supposition. Impaired immune response has been found at many frequencies. Several groups of Soviet researchers have found a decline in the efficiency of white blood cells in rats and guinea pigs after the animals had been exposed to radio waves and microwaves. Most of these experimenters checked for immune system disruption only up to power densities of about 500 microwatts, one twentieth of the nominal American safety standard. Multiple dangers from higher levels are already considered proven in the Soviet Union.

As predicted, however, the most dramatic reported effect on immune response has been produced by ELF fields. During his systematic study of 200-gauss, 50-hertz magnetic fields, Yuri N. Udintsev found that the concentration of bacteria needed to kill mice in such an environment was only one fifth that needed without the field.

When considering resistance to illness, we must also account for the effect of electromagnetic energy on the disease itself, a factor that has so far been all but ignored. Virtually the only evidence to date is a disturbing piece of work by Yu. N. Achkasova and her colleagues at the Crimean Medical Institute in Simferopol. In 1978 they reported the results of exposing thirteen standard strains of bacteria—including anthrax, typhus, pneumonia, and staphylococcus—to electric and magnetic fields. After accounting for magnetic storms, ionospheric flux, passage of the interplanetary magnetic-field boundaries, and other variables, they found clear evidence that an electric field only slightly stronger than earth's background stimulated growth of all bacteria and increased their resistance to antibiotics. The magnetic fields inhibited the growth of the germs but in many cases still enhanced their resistance to antibiotics. Achkasova concentrated on frequencies between 0.1 and 1 hertz, so the survey was far from complete, but perhaps the most important finding was that every field tested had an effect, even after one four-hour exposure. In many cases longer exposure produced permanent changes in bacterial metabolism.

The admittedly sketchy evidence to date suggests that our electropollution is presenting us, and perhaps all animals, with a double challenge: weaker immune systems and stronger diseases. We shouldn't be surprised, then, at an onslaught of "new" ailments, beginning about 1950 and accelerating toward the future. In several cases, new maladies have recently been described as coming from pathogens that previously weren't capable of inducing disease, and this, too, shouldn't surprise us. Among the newcomers are:

Reye's syndrome. First described in 1963, this condition begins with severe vomiting as a child is recovering from the flu or chicken pox. It then progresses to lethargy, personality changes, convulsions, coma, and death. The mortality rate, initially very high, has now been reduced to about 10 percent, but the incidence has increased greatly.

Lyme disease. A virus disease carried by certain insects, it produces severe arthritis in humans. It's one of several similar illnesses that have appeared only recently.

Legionnaire's disease. This is a pneumonia caused by a common soil bacterium that has found a second home in air-conditioning systems. The organism caused us no recognized problems before the initial outbreak in Philadelphia in 1976.

AIDS. Autoimmune deficiency syndrome is a condition in which the body's immune system fails completely and its owner often dies. The patient is unable to resist common, otherwise harmless bacteria and viruses, and can no longer suppress the seeds of cancer that reside in all of us. At present, some sort of virus is suspected as the precipitating cause.

Herpes genitalis. This disease isn't new, but its prevalence and severity have increased tremendously in one decade. Sexual permissiveness generally takes the blame, but a decline in immunocompetence may be more important.

Certainly there are additional factors that may be contributing to the rise of these and other new illnesses. Chemical pollution and the prevalence of junk food are two of the most obvious. However, these diseases, as well as cancer, birth defects, and the other growth problems described below, are on the increase throughout the industrialized world. So are some of the major psychological diseases, such as depression and compulsive use of all types of drugs, from caffeine, nicotine, and alcohol to prescription tranquilizers and the illegal euphoriants, Although heart-attack death rates have declined in the last five years (for no known

reason), they're still far higher than before World War II. These diseases exist at more or less the same rates in countries whose chemical toxicity, eating habits, and styles of life are widely divergent. However, the massive use of electromagnetic energy is a common denominator uniting all of the developed nations. In particular, the entire North American continent, Western Europe, and Japan generate such strong 50- and 60-hertz fields that they can be sensed by satellites in space. The populations of these areas are continuously bombarded by these ELF fields.

Disruption of the biocycle timing cues must inevitably make it harder for the body to regulate the mitotic rate of its cells. The major exception to the "no effect" assurances in the NAS Sanguine-Seafarer report was unignorable evidence that 75-hertz fields lengthened the mitotic cycle and hindered cell respiration of the slime mold used in standard tests of cellular growth. The same effects were seen regardless of field strength. Hence we should expect that ELF pollution would foster diseases in which growth processes go awry.

Indeed there has been an alarming increase in such problems. Cancer is hardly a novel illness, but its prevalence is new. In the mid-1960s roughly a quarter of the U.S. population could expect to develop it. By the mid-1970s, that figure had risen to one third, and it's now even higher. The incidence of birth defects has doubled in the past quarter century. There has been a similarly rapid rise in infertility and other reproductive problems.

Rarer defects of cell division may be on the increase as well, expecially among workers exposed by occupation to high levels of electromagnetic energy. Pathologist Hylar Friedman of the Army Medical Center in El Paso reported in 1981 that radar technicians were three to twelve times more likely than the rest of the population to get polycythemia, a rare blood disorder characterized by production of too many red blood cells. Such relationships are hard to confirm statistically, however, in diseases affecting small numbers of people. We need direct experimental evidence and large-scale studies on the widespread disorders. Both are now available.

Back in 1971, two more Soviet researchers, S. G. Mamontov and L. N. Ivanova, reported that industrial-strength 50-hertz electric fields tripled the mitotic rate of liver and cornea cells in mice. Soon afterward, Bassett and Pilla published empirical evidence that pulsed EMFs accelerated the healing of bone fractures. For the most part, however, concrete evidence that time-varying fields could affect cell division was slow in coming.

That situation has changed in the last few years. Several experimenters, notably Stephen Smith, have now proven that the Electrobiology bone-healing device, using 15 pulse-bursts per second, speeds up the division rate of cells that are already proliferating rapidly. Among normal cells, this includes skin, gut, and liver cells. In 1983, A. R. Liboff, a biophysicist at Oakland University in Rochester, Michigan, reported on the effects of a more inclusive set of parameters. Magnetic fields of 0.2 to 4 gauss, vibrating at 10 to 4,000 hertz, all enhanced the replication of DNA during the S (synthesis) phase of mitosis.

As predicted, the interaction appears to be greatest between 35 and 100 hertz. Jose M. R. Delgado—the flamboyant advocate of a "psychocivilized" society through mind control, who has publicized direct electrical stimulation of the brain by such displays as stopping a charging bull in its tracks with a radio impulse transmitted to an implanted electrode—recently reported results of a genetic study of magnetic fields at three frequencies. Delgado placed chick embryos in minuscule magnetic fields pulsed at 10, 100, and 1,000 hertz. He used fields of only 0.001 gauss, or roughly the strength of the earth field's micropulsations. Chicks exposed to the 10-hertz fields were normal, but those dosed at 100 hertz developed severe defects of the central nervous system. The highest frequency also yielded abnormalities, but they were much less severe. Higher intensities are common in homes, in offices, and near power lines. The Navy has found stronger fields near its 76-H3 ELF antenna and reradiated at that frequency from a power line a mile away.

It's important to bear in mind that, in stimulating DNA synthesis, an electromagnetic field doesn't distinguish between desirable and undesirable growth. It affects all cells in the same way, but cell systems that are already rapidly dividing are speeded up the most. As we've seen in earlier chapters, these susceptible processes include healing, embryonic growth, and cancer.* In fact, a researcher working on the New York State Department of Health's power line project, Wendell Winters of the University of Texas Health Sciences Center in San Antonio, recently reported some of the first laboratory evidence that power frequencies can accelerate malignant growth. Winters exposed human cancer cells to 60-hertz electromagnetic fields for just twenty-four hours, and found a sixfold increase in their growth rate seven to ten days later.

*Only the magnetic component appears to accelerate healing in any way. Power-frequency electric fields severely retard fracture healing in rats, as Andy Marino, Jim Cullen, Maria Reichmanis, and I proved with a series of experiment in 1979. This work was confirmed the following year by R. D. Phillips in a study done for a Department of Energy review of transmission line bioeffects.

Moreover, the perturbation of normal cell-cycle time is enhanced if nuclear magnetic resonance (NMR) is induced in the atoms of the DNA molecules. In simplified terms, nuclear magnetic resonance is present when the magnetic fields around atomic nuclei are induced to vibrate in unison. The phenomenon requires two external magnetic fields, one steady and one pulsating. For every chemical element, the oscillating field at a specific frequency will induce resonance within the steady-state field at a certain strength.

In 1983 a research team under A. H. Jafary-Asl showed that the earth's magnetic background could serve as the steady field, while the harmonics of power line frequencies could produce a time-varying field that would induce nuclear magnetic resonance in at least two common atoms of living tissue—potassium and chlorine. Other elements might also be susceptible to the effect. Bacteria and yeast cells exposed to these NMR conditions doubled their rate of DNA synthesis and proliferation, but daughter cells were half size. Liboff, analyzing contradictory studies, found that the contradictions disappeared when he calculated resonance conditions for the earth's field where each test was done. Previous work must now be reinterpreted as one vast experiment in adding new frequencies to the varying background.

Almost all experimenters to date have tested the response of organisms to a single specific frequency and intensity. This approach was needed in the beginning to provide a basic level of knowledge, but it's far removed from everyday life, in which we're all exposed to many frequencies simultaneously. A synergism between electromagnetic energy and radioactivity has already been suggested by the fact that cancer rates among nuclear power plant workers are higher than was predicted solely by the higher levels of ionizing radiation in their environment. Nuclear power plants abound in multifrequency radio waves and other electromagnetic radiation. In addition to inducing NMR in the building blocks of living cells, multiple frequencies may likewise interact synergistically to yield biohazards greater than the sum of their individual dangers.

Animal experiments on the risk of cancer and birth defects from electromagnetic energy arc scarce, even in the USSR. The little work that has been done was mostly on microwaves. The only well-known American laboratory study of birth defect dangers used pulsed radio waves and found numerous mutations in fruit fly offspring. In 1976 a Russian group dosed rats with 50 and 500 microwatts for one to ten days. When they then studied somatic (nongenital) cellls from the animals, they

found chromosome defects in astounding numbers. At the higher power density there were five times as many as in the controls, and even at the lower intensity the number continued to increase (to 150 percent of the normal value) for two weeks after the beams were turned off.

A 1979 study directed by Przemyslaw Czerski of the National Research Institute of Mother and Child, in Warsaw, documented increased numbers of damaged chromosomes in the sperm of mice exposed one hour a day for two weeks to microwave intensities ranging from 100 microwatts up to the American safety standard of 10,000 microwatts. An even more discomfiting set of data came from a mid-1970s Russian experiment in which female mice were subjected to small power densities, 10 to 50 microwatts. Throughout this range there was a decrease in the number and size of litters and an increase in developmental problems among the newborn animals. The rate of stillbirths jumped from 1.1 percent at the lowest intensity to 7 percent at the highest.

Alas, human beings are the main experimental animals in this line of research. Those who contend microwaves pose no danger often quote a survey of twenty thousand Korean War veterans completed in 1980 by C. D. Robinette and others for the NAS-National Research Council's Medical Follow-up Agency. Comparing VA medical records of radar technicians and others heavily exposed to microwaves with the records of controls, this group found no increase in the death rate. This finding can't be relied on, however. Most of the controls were radar operators, who are exposed to some radiation from radar beams as well as from their consoles. Thus the presumption that they absorbed negligible amounts of EMR just doesn't hold water. In the last few years more reliable epidemiological studies have appeared, showing increased rates of cancer and birth defects among people exposed to higher-than-average levels of electromagnetic energy.

Since microwave broadcasts for television and telephone relays must be in a line of sight to the receivers, there are only a few suitable high locations for the transmitters near each city. Of necessity there's an above-normal concentration of ELF fields and microwave spilloff in that area, possibly leading to a destructive synergism as outlined above. Moreover, since TV is aimed at an audience and phone relay beams at the next station, corridors are set up within which people get more than their share of microwaves.

Sentinel Heights, seven miles from downtown Syracuse, is one such transmitter hill. Slightly more than a thousand people live there. From 1974 to 1977 I learned of seven cases of cancel in that area. They were divided into two clusters, in two microwave corridors separated by a

shadow zone. This is 55 percent more than the 4.5 cases statistically expected for this population, and there may have been more cases I didn't know about. Obviously, in such a small and unscientific sample the results could have been due to chance, but the ominous implications demanded some more extensive surveys.

The first one came in 1979, when Nancy Wertheimer and Ed Leeper of the University of Colorado Medical Center in Denver published a study of childhood cancer and power lines. The researchers studied 344 deaths from childhood cancer between 1950 and 1973. The address of each of the victims was paired with the address of the next baby born in the area, to provide a matched series of controls. If the family had moved before the death, both birth and death addresses were used in the experimental group. The wiring of each house and its distance from the nearest transformers were studied. It proved possible to divide the houses into two groups: those with high-current wiring configurations producing strong magnetic fields, and those wired in a low-current arrangement producing much weaker magnetic fields. After certain other variables—such as economic class, family risk patterns, traffic, and urbanization differences—were factored out, the childhood death rate from leukemia, lymph node cancer, and nervous system tumors in the high-current homes was more than double the rate in low-current homes.

Three years later S. Milham, director of occupational health and safety for the state of Washington, found that adults who worked in strong electromagnetic fields also had a leukemia incidence significantly higher than the norm. The link appeared in statistics for generating-station operators, high-voltage-line maintenance workers, aluminum smelters, and several other categories of laborers.

Besides the investigation itself, another thing was noteworthy about Milham's paper: the reaction of the scientific establishment. Another paper quickly appeared in the same periodical, the New England Journal of Medicine, citing many other studies to prove Milham wrong. However, all of them involved controlled exposure to microwaves alone, while the jobs studied by Milham were in the real world, where microwaves and power-frequency fields mix. The editors declined to publish my letter pointing out this obvious flaw in the critique, but still it was momentous that such a prestigious publication ran Milham's paper at all.

Soon confirmatory reports appeared. Wertheimer's and Leeper's findings were duplicated in Stockholm by a group who correlated childhood leukemia with actual measurements of magnetic fields. The strongest statistical link was found with 200-kilovolt power lines running within 200 yards of the stricken child's home. Milham's work was vindicated

by surveys in Los Angeles and Great Britain. Wertheimer herself extended her observations to adults and found the same highly significant connection between high-current wiring and various cancers, especially leukemia.

Radar beams (composed of pulsed microwaves) have the highest power densities of any EMR source. In the laboratory, both radio frequency and microwave radiation have been shown to change the gateway-barrier function of cell membranes, upset hormone balances, and induce chromosome defects, all of which are factors in malignant growth. However, there have been few attempts to directly assess radar's potential role in human cancer.

John R. Lester and Dennis F. Moore of the University of Kansas School of Medicine in Wichita have recently done so. Wichita was an ideal location for such an inquiry. It had two airports with radar towers, but few other major sources of electropollution. Its chemical environment was also quite clean as cities go. Lester and Moore plotted the cancer incidence for the whole city and found it was highest where the residents were exposed to both radar beams. It was lower where only one beam penetrated, but lowest where the population was fully shielded behind hills. The results held up when other factors, such as age, poverty, sex, and race, were statistically balanced as far as possible. The authors noted one apartment house whose cancer death rate was twice that of the area's nursing homes; its upper floors were in direct line with both radar beams.

Heart attack rates in North Karelia and Kuopio, Finland, became the highest (and most swiftly increasing) in the world within a few years after the Soviets installed a gigantic over-the-horizon radar complex that bounced microwaves off the surface of Lake Ladoga and through these parts of southeastern Finland. These are rural districts whose way of life is built on outdoor labor rather than the sedentary indoor stresses generally associated with heart disease. Noting that cancer rates had also risen precipitously in the region, Lester and Moore went on to investigate statistics for American counties having Air Force bases. These counties had a significantly higher percentage of cancer deaths than other counties, even though radar towers from commercial airports inevitably must have smoothed out the data and made the difference less striking.

The study of human genetic defects from electromagnetic energy is still in a primitive stage. In the case of microwaves, this situation is largely due to obstruction by military and government agencies. Even in World War II, rumors of radar-induced sterility were so rampant that

sailors often gave themselves "treatments" before shore leave. The first scientific evidence of reproductive effects didn't come until 1959, when John H. Heller and his co-workers at the New England Institute for Medical Research in Ridgefield, Connecticut, found major chromosome abnormalities in garlic shoots irradiated with low levels of microwaves. They soon found the same changes in mammalian cells, as well as the fruit fly mutations mentioned above. Their work in this direction ended about 1970 due to lack of funds.

In 1964 a group of researchers studying Down's syndrome at the Johns Hopkins School of Medicine, after linking the malady to excess X rays given to pregnant women, found an unexpected further correlation with fathers working near radar. It was a full decade before any money was allocated to follow up this finding, and, while the link between parental radar exposure and Down's syndrome wasn't substantiated, higher-than-normal numbers of chromosome defects were found in the blood cells of radarmen.

By this time an Alabama professor of public health had found an apparent surge in birth defects among children of radar-exposed Army helicopter pilots. In 1971 Dr. Peter Peacock noted that there had been seventeen children born with clubfoot within a sixteen-month period at the Fort Rucker, Alabama, base hospital. Statistically, there should have been no more than four.

Working through two federal agencies and two private research foundations, Peacock and others tried for five years to follow up this disturbing news, only to be thwarted by some clever tactical moves by the Army. Refusing to release work records, medical files, and radar inspection records on grounds of "privacy" and "national security," officials of the Army Medical Research and Development Command managed to prevent all but two reassessments of Peacock's original data for several years. They stalled separate research proposals sponsored by the Environmental Protection Agency and the Food and Drug Administration's Bureau of Radiological Health without ever letting on to one agency that they were dealing with the other. As the coup de grace, the Army agreed to supply the FDA group with a survey of radar transmitters in the Fort Rucker area. The officers fobbed off on the unwitting civilians a deceitfully sketchy map showing only one major radar installation at the base, whereas an official Army report made at the time of the observed birth defects showed nineteen such emitters. Throughout the Vietnam War thousands of helicopter trainees had each spent months flying through the resultant microwave haze. Much of their training consisted of homing right down the beams to within a few dozen yards of the

source in TH-13 Bell copters whose Plexiglas bubbles left them naked to microwaves.

The Fort Rucker affair and many other instances of military-governmental sabotage of health effects research on microwaves have been impeccably documented in New Yorker reporter Paul Brodeur's 1977 book, The Zapping of America. In the early 1970s, for example, follow-up to a preliminary finding of excess Down's syndrome among children of Seattle airline pilots was first supported by the local chapter of the Air Line Pilots Association, then opposed due to pressure from the national level.

The stonewalling continues. Grants for serious consideration of electropollution's dangers have been cut to a trickle in the United States, but some findings continue to emerge, especially from other countries.

A 1976 survey of Hydro-Quebec's generating-station electricians showed a drastic change in the gender ratio of children born after one of the parents began work in the high-EMF environment. Before, boys and girls had been born in equal numbers; afterward, there were six times as many males as females. A 1979 study of Swedish high-voltage substation workers showed lower birth rates and an 8-percent incidence of genetic defects in offspring, as compared with 3 percent among children of a control group. The finding was confirmed in 1983. Since most of the exposed electrical workers were men, the damage apparently was done during sperm formation. Most recently, in May 1984, Nancy Wertheimer presented evidence of a statistical correlation between use of electric blankets, which emit powerful EMFs, and the occurrence of birth defects.

Among the most serious recent data are those concerning video display terminals (VDTs). There have been alarming numbers of miscarriages, stillbirths, and birth defects among pregnant women working in newly computerized offices. In one year at the Dallas office of Sears, Roebuck and Company, for example, only four of twelve pregnancies ended normally. Among twelve pregnant VDT workers at the Defense Logistics Agency in Marietta, Georgia, there were seven miscarriages and three cases of congenital defects. Four VDT operators in the Toronto Star's classified-ad department gave birth to deformed children, while three co-workers who didn't work with VDTs had normal babies. These anomalies must be compared with the normal 15-percent incidence of spontaneous abortion and the 3-percent rate of serious birth defects among the population at large. Writing in Microwave News, an independent newsletter covering nonionizing radiation, in 1982 editors Louis Slesin and Martha Zybko reported on eight such clusters, and workers' groups have documented

several others, but still there has been no attempt at a large-scale statistical study to check the oft repeated claim that these are just coincidences.

Two studies are widely quoted as disproving harmful effects from the machines. In 1977, when two New York Times copy editors developed radiation-induced cataracts after less than a year at their new screens, the National Institute of Occupational Safety and Health (NIOSH) tested a few machines and, finding that X-ray emissions were within the half-millirem-per-hour standard for work exposure, concluded there was no link to the health problems. Unfortunately, the agency didn't adequately measure nonionizing radiation, gave contradictory data as to the sensitivity of its own instruments, and failed to test malfunctioning monitors, which are known to emit larger amounts of X rays. Nor is there any assurance that the X-ray exposure standard is adequate, since it was formulated for a much smaller group of workers (mainly nuclear technicians and uranium miners), whose health is continuously monitored in a way that that of VDT operators is not. Furthermore, the NIOSH investigators noted an enormous microwave reading of 1,000 microwatts in one of the Times offices, without even bothering to find out where it was coming from!

Press releases claimed a mid-1983 National Academy of Sciences review would allay the fears once and for all, proving VDTs to be risk free. However, a reading of the text showed a different picture. While the authors played down reports linking birth defects and eye problems to VDT radiation, they admittedly failed to find any research adequate to answer the health questions one way or the other.

According to the sketchy data available, all VDTs (which of course include video games and televisions as well as computer monitors) emit varying amounts of radiation over a broad spectrum. The transformers release VLF and ELF waves, while microwaves, X rays, and ultraviolet emanate from the screen. Poorly adjusted or malfunctioning terminals can emit enormous amounts; two machines tested in the offices of Long Island's Newsday, for example, were producing 15,000 microwatts of radio energy. There's no information whatever on the synergisms that may operate amid this varied radiation over long periods of time, but I suspect that the birth defects are primarily due to the ELF component.

Meanwhile, the only American "research" on the problem continues to be the daily lives of our 10 million or more console operators. Despite the reassurances, at least a third to a half of the workers continue to suffer hea daches, nausea, neck and back pain, and vision impairment. In fact, a 1983 survey of eleven hundren UPI employees conducted by

Arthur Frank, then at New York's Mount Sinai School of Medicine, suggested that VDT users lose so much time due to eye problems and neck pain that the effects may become a major drain on the economy by the end of the decade.

Some of the complaints undoubtedly arise from postural strains and lighting defects in the notoriously ill-designed work areas where many VDTs are used. They could be prevented by more frequent breaks and some sympathetic attention to human engineering. The birth defects and cataracts probably won't disappear so easily, however. Certainly pregnant women should be allowed temporary reassignment without loss of pay, a right already accepted in much of Western Europe and recently put into law in Ontario. That won't protect sperm cells and unfertilized eggs, however. Regular maintenance and a lead-impregnated glass or acrylic screen (such as is used in nuclear power plant windows) can virtually eliminate ionizing radiation, but screen-generated microwaves require a transparent shield that still conducts electrical energy—a product that doesn't yet exist. Some frequencies of EMR are easy to block simply by using metal cabinets instead of the cheaper plastic ones, but VLF and ELF waves require grounded shielding. All these preventive measures are expenses that most manufacturers and managers have been loath to accept; until they do, workers will be paying the entire price.

The dangers of electropollution are real and well documented. It changes, often pathologically, every biological system. What we don't know is exactly how serious these changes are, for how many people. The longer we, as a society, put off a search for that knowledge, the greater the damage is likely to be and the harder it will be to correct. Meanwhile, one of the few honest statements to emerge from the Nixon administration, a warning issued by the President's Office of Telecommunications Policy in 1971, continues to bleed through the whitewash: "The population at risk is not really known; it may be special groups; it may well be the entire population. . . . The consequences of undervaluing or misjudging the biological effects of long-term, low-level exposure could become a critical problem for the public health, especially if genetic effects are involved."

Conflicting Standards

The establishment Attitude toward EMR's health effects derives largely from the work of Herman Schwan. An engineer who had been a pro-

fessor at the Kaiser Wilhelm Institute of Biophysics in Germany during most of the Nazi era, Schwan was admitted to the United States in 1947, soon accepted a post at the University of Pennsylvania, and since then has done most of his research for the Department of Defense.

Like infrared radiation, radio waves and microwaves produce heat when they're absorbed in sufficient quantity. Although not a biologist, Schwan assumed this heating was the only effect EMR would have on living tissue. In this respect he considered living things no different from the hot dogs that World War II radarmen used to roast in their microwave beams, so cooking was the only harm he foresaw. Schwan then estimated danger levels based on how much energy was needed to measurably heat metal balls and beakers of salt water, which he used to represent the size and presumed electrical characteristics of various animals.

Appreciable heating occurred in these models only at levels of 100,000 microwatts or above, so, incorporating a safety factor of ten, Schwan in 1953 proposed an exposure limit of 10,000 microwatts for humans. By showing soon afterward that it took more than this intensity to cause burns in real animals, Sol Michaelson seemed to have confirmed the safety of "nonthermal" dosages. No one tested for subtler effects, and the 10,000-microwatt level was uncritically accepted on an informal basis by industry and the military. In 1965 the Army and Air Force formally adopted the Schwan limit, and a year later the industry-sponsored American National Standards Institute recommended it as a guideline for worker safety.

There were persuasive economic reasons why the 10,000-microwatt standard was and still is defended at all costs. Lowering it would have curtailed the expansion of military EMR use and cut into the profits of the corporations that supplied the hardware. A reduced standard now would constitute an admission that the old one was unsafe, leading to liability for damage claims from ex-GIs and industrial workers. One of the strongest monetary reasons was given in a 1975 classified summary of the DOD's Tri-Service Electromagnetic Radiation Bioeffects Research Plan: "These [lower] standards will significantly restrict the military use of EMR in a peacetime environment and require the procurement of substantial real estate around ground-based EMR emitters to provide buffer zones." The needed real estate was estimated to be 498,000 acres. The price of this much land would surely run well into the billions of dollars.

Even before it was adopted, there were indications that the standard might be inadequate. During the obligatory fight for compensation in

the face of callous official denials of responsibility, an interesting discovery was made by Thomas Montgomery, a former civilian technician working for the Army Signal Corps, who is now blind, deaf, and crippled because of a massive accidental exposure to a radar beam in 1949. In one of the files opened by his suit, Montgomery found a document proving that in the late 1940s the Institute of Radio Engineers had formulated more conservative safeguards that included methods for preventing accidents like the one that had incapacitated him. (He'd been repairing a transmitter when a co-worker, not knowing he was standing in front of the wave guide, turned it on. Since the microwaves were imperceptible, Montgomery didn't know he was being irradiated until it was too late.) Leaders of the military-industrial electronics community chose not to promulgate these proposed regulations.

There were other hints that all was not well. In 1952 Dr. Frederic G. Hirsch of the Sandia Corporation, a maker of missile guidance systems, reported the first known case of cataracts in a microwave technician. The following year Bell Laboratories, alarmed by reports of sterility and baldness among its own workers as well as military radar personnel, suggested a safety level of 100 microwatts, a hundred times less than Schwan's. Even Schwan has consistently maintained that his dosage limit probably isn't safe for more than an hour.

In 1954 a study of 226 microwave-exposed employees at Lockheed's Burbank factory was reported by company doctor Charles Barron. He said there were no adverse effects, despite "paradoxical and difficult to interpret" changes in white blood cell counts, which he later ascribed to laboratory error, as well as a high incidence of eye pathology, which he determined was "unrelated" to radar.

However, the safety standard had already become a Procrustean bed against which all research proposals and findings were measured. Grants weren't given to look for low-level hazards, and scientists who did find such effects were cut down to size. Funds for their work were quickly shut off and vicious personal attacks undermined their reputations. Later, when undeniable biological changes began to be noted from power densities between 1,000 and 10,000 microwatts,, the idea of "differential heating"—hot spots in especially absorptive or poorly cooled tissues—was advanced, as though this convenient explanation obviated all danger. Soviet research could easily be discounted because of its "crudity," but when nonthermal dangers were documented in America, military and industrial spokespeople simply refused to acknowledge them, lying to Congress and the public. Many scientists, who naturally wanted to continue working, went along with the charade.

from nuclear weapons tests. Throughout the 1950s there was "no cause for alarm," but twenty years later the Wyoming sheep ranchers' suit for compensation for fallout-damaged herds unearthed documents proving the responsible officials had known better at the time. Even the symbol of American military machismo may have fallen victim to the policy. John Wayne, as well as Susan Hayward and other cast members, died of cancer about two decades after making a movie called The Conqueror, which was filmed in the Nevada desert while an unexpected wind shift sifted radioactive dust down on them from a nearby test.

Today the EMR deceit still proceeds. On August 2, 1983, Sol Michaelson was quoted as saying some bioeffects had been observed in animals and a few claimed in humans from intensities under 10,000 microwatts, but "none of these effects, even if substantiated, could be considered hazardous or relevant to man"—even though three years before he'd co-authored a paper that reviewed previous evidence and added some of his own in support of the generalized stress response from microwaves.

The evidence had begun to come in over twenty years previously. John Heller's 1959 finding of chromosome changes in irradiated garlic sprouts and the 1964 Johns Hopkins correlation of Down's syndrome with parental exposure to radar were mentioned in the previous section. In 1961 a study was conducted on a strain of mice bred to be especially susceptible to leukemia and used to evaluate risk factors for that disease. Two hundred mice, all males, were dosed with 100,000 microwatts at radar-pulse frequencies for one year. An unusually high proportion of the animals—35 percent—developed leukemia during that time, and 40 percent suffered degeneration of the testicles. Admittedly, this was a very high power density, but the mice were exposed for only four minutes a day. The most disturbing part, however, is that the sponsor, the Air Force, cut off all funds for follow-up work, and to this day no American research has adequately addressed this potential danger.

In 1959 Milton Zaret, an ophthalmologist from Scarsdale, New York, began a study for the Air Force to see if there was any special risk to the eyes of radar maintenance men. He at first found none, because he'd geared the examinations to check the lens of the eye. A few years later, when several private companies referred to him microwave workers who'd developed cataracts, Zaret saw he'd made a mistake. Because the microwaves penetrated deeply into tissue, cataracts from them had developed behind the lens, in the posterior capsule, or rear part of the elastic membrane surrounding the lens. At this point the Air Force again suddenly lost interest, but Zaret has doggedly pursued the matter in his own practice. Although military and industry people still deny

that nonthermal microwave cataracts exist, Zaret's work has proven beyond good-faith dispute that low doses exert a cumulative effect that eventually stiffens and clouds the posterior capsule. Surveys by others here and abroad have confirmed his conclusion. In fact, these behind-the-lens cataracts constitute a "marker disease" for sustained microwave exposure. Zaret has personally diagnosed over fifty clear-cut cases, many in airline pilots and air traffic controllers.

In 1971 Zaret was involved in a projected five-year primate study for the Navy when he made the mistake of telling his overseers the disturbing news that one of the monkeys had died after a few hours' exposure to just twice the U.S. safety level. Within days Captain Paul Tyler "happened to be in the area" of the Hawaii research facility and wanted Zaret to show him around. He left in about twenty minutes, having seen little of the equipment, and in a few days more the entire project had been canceled.

The double-dealing has only made Zaret dig in his heels. Through the years he has been one of the few doctors willing to take on the government by testifying on behalf of plaintiffs filing claims for microwave health damage. At such proceedings one always runs into the same cast of characters speaking more or less the same lines. At one trial the ubiquitous Michaelson attacked Zaret's professional abilities, only to have later testimony reveal the embarrassing fact that Michaelson's mother owed the vision in one eye to the ophthalmologist's surgical skill.

As we've already seen, there are many indications that EMFs and EMR weaker than the Schwan guideline have serious effects on growth. The 10,000-microwatt level was directly tested in 1978 by a group at the Stanford Research Institute. Pregnant squirrel monkeys and their offspring were irradiated. Of nine babies zapped in utero and/or after birth, five died within six months, compared with none in the control group.

The U.S. safety standard would be grossly inadequate even if it was law. In actuality, although some businesses and military agencies have adhered to it, it has never posed any threat to those that have not. A federal court case decided in 1975 and upheld in 1977 defined it as an advisory or "should" guideline, which couldn't be enforced. Now, as per instructions dated March 17, 1982, Occupational Safety and Health Administration (OSHA) inspectors can no longer issue even meaningless citations to companies for exposing workers to more than the limit.

The only actual regulation of public electromagnetic energy dosage pertains to microwave ovens. In 1970 the FDA's Bureau of Radiological Health stipulated that no oven should leak more than 1,000 microwatts at a distance of 2 inches when new, nor more than 5,000 after sale. Even

at that time, research suggested this was an unsafe level, a fact recognized by Consumers Union in 1973 when it recommended against the purchase of any brand. Leakage surveys have shown that all types put out an average of 120 microwatts near the door, while many emit much higher amounts. A worn seal or piece of paper towel stuck in the door can increase the user's exposure to well over the 5,000-microwatt level, according to Consumers Union tests.

What amounts of electromagnetic energy do workers and the general public actually absorb? The levels vary greatly. Some antenna repairers receive up to 100,000 microwatts for minutes or hours during a job. Many factory workers are in the same bracket. From 1974 to 1978 NIOSH surveyed eighty-two industrial plastic molders and sealers. Over 60 percent exposed the operator to more than the Schwan limit, some to over 260,000 microwatts. Because of low wages for such work, nearly all sealer operators are women of childbearing age. NIOSH has estimated that some 21 million workers are exposed to some level of radio-frequency waves or microwaves as a direct result of their jobs. No metal shielding is provided for most workers in this country, although it's sold to other nations having better safety rules.

At this time there's no way to estimate how much EMR people are getting away from their jobs, because the few readings that have been taken have measured only single sources and single frequencies. No one has yet surveyed our cities and countryside throughout the whole spectrum from ELF to microwaves. All we know is that most people's daily exposure is high. Even the Environmental Protection Agency has estimated that if the Soviet off-the-job safety limit of 1 microwatt in the radio and microwave bands was adopted here, over 90 percent of our FM stations would have to be shut down.

Table 1. Power Density at Various Distances from a 50,000 Watt AM Radio Station

Distance (feet)	Power Density (microW/cm2)	Distance (feet)	Power Density (microW/cm2)
15	838	482	23
29	284	663	12
69	196	1571	2
152	43	3280	1
308	33	5760	0.3

Note Data from R. Tell et al., "Electric and Magnetic Field Intensities and Associated Body Currents in Man in Close Proximity to a 50 kW AM Standard Broadcast Station," presented at Bioelectromagnetics Symposium, Seattle, 1979.

Table 2. EMF in Typical Tall Buildings

City	Location	Power Density (microW/cm2)
New York	102nd Floor, Empire State Building	32.5
Miami	38th Floor, One Biscayne Tower	98.6
Chicago	50th Floor, Sears Building	65.9
Houston	47th Floor, 1100 Milam Building	67.4
San Diego	Roof, Home Tower	180.3

Note: Data from R. Tell and N. H. Hankin, Measurements of Radio Frequency Field Intensity in Buildings with Close Proximity to Broadcast Systems, ORP/EAD 78-3, U.S. Environmental Protection Agency, Las Vegas, 1978.

Table 3. Power-Frequency Electric Fields of Household Appliances Measured at a Distance of One Foot

Appliance	Electric Field (V/m)
Electric blanket	250
Broiler	130
Phonograph	90
Refrigerator	60
Food mixer	50
Hairdryer	40
Color TV	30
Vacuum cleaner	16
Electric range	4
Light bulb	2

Note: Data in tables 3 and 4 from Fact Sheet for the Sanguine System: Final Environmental Impact Statement, U.S. Navy Electronic Systems Command, 1972.

Table 4. Power-Frequency Magnetic Fields of Household Appliances

Range	Appliance
10-25 gauss	Soldering gun Hairdryer
5-10 gauss	Can opener Electric shaver Kitchen range
1—5 gauss	Food mixer TV
0.1-1.0 gauss	Clothes dryer Vacuum cleaner Heating pad
0.01-0.1 gauss	Lamp Electric iron Dishwasher
0.001 -0.1 gauss	Refrigerator

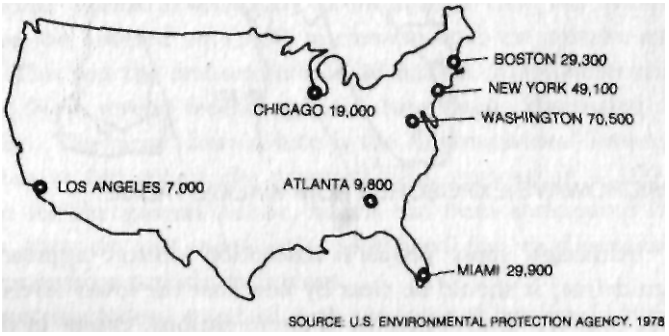

NUMBER OF PEOPLE IN CERTAIN CITIES EXPOSED TO RADIO AND TV SIGNALS ABOVE USSR SAFETY LEVEL

Most city dwellers continuously get more than a tenth of a microwatt from television microwaves alone. This may be especially significant, because of the human body's resonant frequency. This is the wavelength to which the body responds "as antenna." Next to the ELF range, it's perhaps the region of the spectrum in which the strongest bioeffects may

be expected. The peak human resonant frequency lies right in the middle of the VHF television band.

Many people live in zones of higher-than-average risk. Levels rise steeply from 1 microwatt within half a mile of most radio stations. Near "antenna farms" like the forest of transmitters on Mount Wilson on the outskirts of Los Angeles, the densities can reach well into the thousands. They regularly go up to about 7 microwatts near microwave relay towers, which are often placed in the center of towns. Exposure to 100 microwatts is not uncommon within half a mile of military or airport radar towers. Office workers in tall buildings are often in direct line with microwave beams, whose intensities may reach 30 to 180 microwatts, as measured in a recent EPA survey. CB radios and walkie-talkies bombard users, especially their heads and chests, with thousands of microwatts. These figures, of course, represent only single sources, not the total exposure.

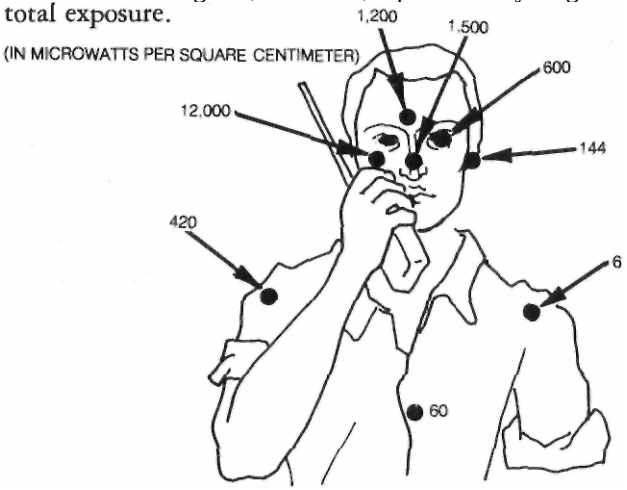

MICROWAVE EXPOSURE FROM WALKIE-TALKIE

Although most people's absorption doesn't approach the Schwan guideline, it should be clear by now that the lower levels are little cause for comfort. Everywhere in Western nations, except in the most remote forests or deserts, the ambient energy from ELF power systems is several thousand times above the earth's background field strength, providing abundant interference with the biocycle timing cues. Moreover, the accumulated research has clearly shown that small doses often have the same effects as larger ones. Ross Adey, who has intensively studied the "window effect,", in which a certain result is produced at some frequencies and power levels but not at others interspersed between the effective ones, believes future research will reveal such windows at much lower levels, even at fractions of a microwatt. Indeed there has already been

one report of brain wave changes suggesting resonance of neural electrical currents with radio waves and microwaves down to a billionth of a microwatt.

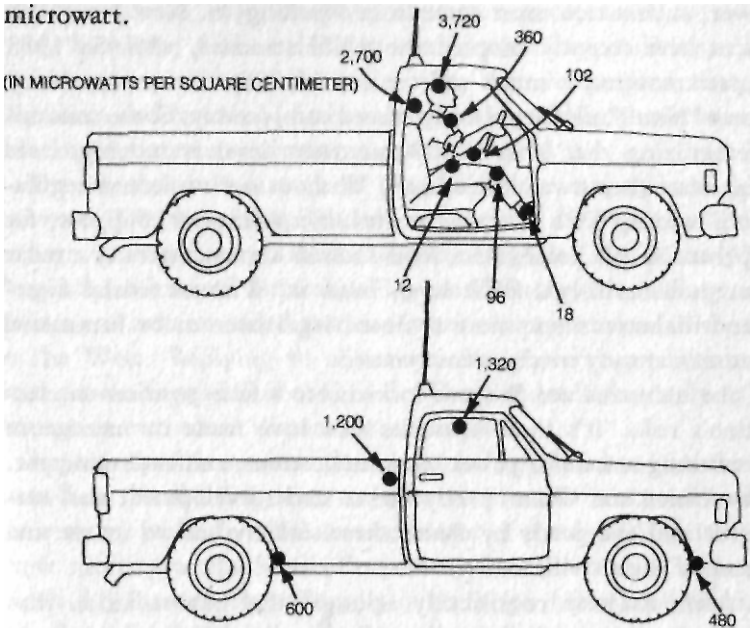

MICROWAVE EXPOSURE FROM A TYPICAL CB RADIO

There's a chance of somewhat stricter rules in a few years. In 1982 the American National Standards Institute recommended that the radiowave safety level be lowered to 1,000 microwatts and the microwave level to 5,000. This was the first semiofficial admission that nonthermal effects do exist. Now several federal agencies have begun discussing a formal regulation. The most likely source is the Environmental Protection Agency, but at last report the rumored EPA proposal of a 100-microwatt limit for the general public, which had been anticipated in late 1984, was abruptly and indefinitely postponed due to dissension within and pressure from outside the agency.

A health-protecting federal standard with the force of law would have a major impact on both industry and government. Industry would experience a decline in revenue and an increase in costs. Government, especially the military, would be inconvenienced in a multitude of activities. Both would be subject to lawsuits for exposures and damages prior to establishment of the standard. In addition, we must understand that no amount of artificial EMR, no matter how small, has been proven safe for continuous exposure. Bioeffects have been found at the lowest measurable doses. However, we must also understand that the greatest danger lies in uncontrolled exposure to large amounts of EMR at many overlap-

ping frequencies, and therefore a stringent standard with a definite timetable for phasing it in is the only way to protect the public health.

Moreover, such action must come from Washington. New Jersey and Connecticut have recently adopted the ANSI standard, while in 1983 Massachusetts enacted a much stricter one of 200 microwatts, which large areas of New York City already exceed considerably. Some communities, recognizing that even a 100-microwatt level is too high, are beginning to set their own, lower, ones. Without realistic federal regulation we will end up with a totally unworkable patchwork. Suppose, for example, that the Air Force, from a base outside a town, operates a radar dome that produces illegal EMR levels inside it. Without federal direction, that will become one more confused legal issue to be hammered out for years in already overburdened courts.

All of the industrialized West is locked into a false position on electropollution's risks. It's these countries that have made the maximum use of electromagnetism for power, communications, and entertainment. The Soviet Union and China, partly due to underdevelopment and wartime destruction, and partly by choice, have severely limited its use and the exposure of their civilians.

Soviet scientists have consistently assumed that any radiation that doesn't occur in nature will have some effect on life. We've consistently made the opposite assumption. Throughout our recent history American regulators have followed a "dead body policy." They have extended no protection until there was proof of harm sufficient to overcome all deception. There's no longer any question that, as far as electromagnetic energy is concerned, we've been wrong and the Soviets have been right.

In the 1950s, Russian doctors conducted extensive clinical exams of thousands of workers who had been exposed to microwaves during the development of radar. Having disclosed serious health problems, these studies weren't swept under the rug. Instead, the USSR set limits of 10 microwatts for workers and military personnel, and 1 microwatt for others. Both levels are strictly enforced. When this first became known in the West in the early 1960s, instead of checking their assumptions many American scientists and administrators chose to believe this was Russian propaganda aimed at embarrassing us.

By 1971, when they presented their work at a momentous conference in Warsaw, Zinaida V. Gordon and Maria N. Sadchikova of the USSR Institute of Labor Hygiene and Occupational Diseases had identified a comprehensive series of symptoms, which they called microwave sickness. Its first signs are low blood pressure and slow pulse. The later and most common manifestations are chronic excitation of the sympathetic

nervous system (stress syndrome) and high blood pressure. This phase also often includes headache, dizziness, eye pain, sleeplessness, irritability, anxiety, stomach pain, nervous tension, inability to concentrate, hair loss, plus an increased incidence of appendicitis, cataracts, reproductive problems, and cancer. The chronic symptoms are eventually succeeded by crises of adrenal exhaustion and ischemic heart disease (blockage of coronary arteries and heart attack).

The Soviet standards were set long before the dangers were this clear, however. The comparison is instructive. At a 1969 international symposium on microwaves in Richmond, Virginia, Dr. Karel Marha of Prague's Institute of Industrial Hygiene defended his findings on birth defects and recommended that the Eastern European standard be adopted in the West. Replying to objections that the dire predictions hadn't been proven beyond doubt, he said: "Our standard is not only to prevent damage but to avoid discomfort in people."

Apparently this concern doesn't include Americans, for the Soviets have been bombarding our embassy in Moscow with microwaves for some thirty years. In 1952, at the height of the Cold War, there was a secret meeting at the Sandia Corporation in New Mexico between U.S. and U.S.S.R. scientists, allegedly to exchange information on biological hazards and safety levels. It seems the exchange wasn't completely reciprocal, or perhaps the Americans didn't take seriously what the Russians told them; there have been other joint "workshops" since then, and each time the Soviets have sent people who publicly acknowledged the risks, while the American delegates have always been "no-effect" men. At any rate, soon after the Sandia meeting, the Soviets began beaming microwaves at the U.S. embassy from across Tchaikovsky Street, always staying well within the Schwan limit. In effect, they've been using embassy employees as test subjects for low-level EMR experiments.

The strange thing is that Washington has gone along with it. The "Moscow signal" was apparently first discovered about 1962, when the CIA is known to have sought consultation about it. The agency asked Milton Zaret for information about microwave dangers in that year, and then hired him in 1965 for advice and research in a secret evaluation of the signal, called Project Pandora. Nothing was publicly revealed until 1972, when Jack Anderson broke the story, and the U.S. government told its citizens nothing until 1976, in response to further news stories in the Boston Globe. According to various sources, the Russians shut off their transmitter in in 1978 or 1979, but then resumed the irradiation for several months in 1983.

According to information given Zaret in the 1960s, the Moscow sig-

nal was a composite of several frequencies, apparently aiming for a synergistic effect from various wavelengths, and it was beamed directly at the ambassador's office. Thus it may have been used at least partially to activate bugging devices, but it wasn't consistent with one of the other subsequent official American explanations—a jamming signal to disrupt the U.S. eavesdropping equipment on the embassy roof.

The intensity isn't known for certain. When the State Department admitted the signal's existence, officials claimed it never amounted to more than 18 microwatts. However, although released Project Pandora records don't directly reveal a higher level and the relevant documents have allegedly been destroyed, research protocols aimed at simulating the Moscow signal called for levels up to 4,000 microwatts.

In the mid-1960s published Soviet research indicated that such a beam would produce eyestrain and blurred vision, headaches, and loss of concentration. Within a few years other research had uncovered the entire microwave syndrome, including the cancer potential.

By all accounts except the official ones, the Moscow bombardment has been highly effective. In 1976 the Globe reported that Ambassador Walter Stoessel had developed a rare blood disease similar to leukemia and was suffering headaches and bleeding from the eyes. Two of his irradiated predecessors, Charles Bohlen and Llewellyn Thompson, died of cancer. Monkeys exposed to the signal as part of Project Pandora soon showed multiple abnormalities of blood composition and chromosome counts.

In January 1977, the State Department, under duress, announced results of a series of blood tests on returning embassy personnel: a "slightly higher than average" white blood cell count in about a third of the Moscow staff. If 40 percent above the white blood cell counts of other foreign service employees (levels common to incipient leukemia) can be considered "slightly higher than average," then this technically wasn't a lie. The finding has been officially ascribed to some unknown microbe. Unfortunately, there's no such doubt about the veracity of explanations about some earlier research. As part of Project Pandora in the late 1960s, the State Department tested its Moscow employees for genetic damage upon their return stateside, telling them the inner cheek scrapings were to screen for those unusual bacteria. No results were ever released, and they're reportedly part of the missing files, but one of the physicians who conducted the tests was quoted by the Associated Press as saying they'd found "lots of chromosome breaks." The embassy staff had to learn this when the rest of us did - in the newspapers nearly a decade later.

The Russians themselves have never admitted the irradiation, and the Schwan guideline has put the American government in an embarrassing bind. In 1976 the State Department gave its Moscow employees a 20-percent hardship allowance for serving in an "unhealthful post" and installed aluminum window screens to protect the staff from radiation a hundred times weaker than that near many radar bases. That same year the government gave Johns Hopkins School of Medicine a quarter of a million dollars to see if there was a link between the signal and "an apparently high rate of cancer" in the embassy (which wasn't confirmed). Nevertheless, although President Johnson asked Premier Kosygin at the 1967 Glassboro talks to stop the bombardment, Washington has never had any formal basis to demand that it be stopped due to danger to the staff. That was apparently considered an acceptable risk in the protection of the lenient U.S. standard.

Invisible Warfare

The Soviets have led the way in learning about the risks of electropollution, and, as we have seen, they've apparently been the first to harness those dangers for malicious intent. However, the spectrum of potential weapons extends far beyond the limits of the Moscow signal, and Americans have been actively exploring some of them for many years. Most or all of the following EMR effects can be scaled up or down for use against individuals or whole crowds and armies:

The crudest of these armaments would be a sort of electromagnetic flamethrower with a greater range than chemical types. Dogs were cooked to death in experiments at the Naval Medical Research Institute as long ago as 1955, and high-power transmitters using short UHF wavelengths can severely burn exposed skin in seconds. Electromagnetic pulse (EMP) is a term designating the immensely powerful, near-instantaneous surge of electromagnetic energy produced by a nuclear explosion. It was first discovered in the late 1960s. The EMP from one detonation a few thousand miles above the earth would destroy all electrical systems throughout an entire continent. In the early 1970s new types of EMR generators emitting power levels on or twenty times higher than ever before were developed in in an effort to simulate EMP and help devise communications systems shielded from it. In 1973 these transmitters were described in an invitation-only seminar at the Naval Weap-

ons Laboratory in Dahlgren, Virginia, where their use for antipersonnel and anti-ballistic-missile energy beams was discussed. No information about their subsequent development has since been made public, and the difficulties of long-range missile tracking argue that ABM beams haven't yet become feasible, but there are no such difficulties in the way of EMR beam weapons for use against unshielded people.

At some UHF power densities there's an insidious moth-to-the-flame allurement, which would increase such a weapon's effectiveness. As discoverer Sol Michaelson described it in 1958, each of the dogs used in his experiments "began to struggle for release from the sling," showing "considerable agitation and muscular activity," yet "for some reason the animal continues to face the horn." Perhaps as part of the same effect, UHF beams can also induce muscular weakness and lethargy. In Soviet experiments with rats in 1960, five minutes of exposure to 100,000 microwatts reduced swimming time in an endurance test from sixty minutes to six.

Allen Frey's discovery that certain pulsed microwave beams increased the permeability of the blood-brain barrier could be turned into a supplemental weapon to enhance the effects of drugs, bacteria, or poisons.

The calcium-outflow windows discovered by Ross Adey could be used to interfere with the functioning of the entire brain.

In the early 1960s Frey found that when microwaves of 300 to 3,000 megahertz were pulsed at specific rates, humans (even deaf people) could "hear" them. The beam caused a booming, hissing, clicking, or buzzing, depending on the exact frequency and pulse rate, and the sound seemed to come from just behind the head.

At first Frey was ridiculed for this announcement, just like many radar technicians who'd been told they were crazy for hearing certain radar beams. Later work has shown that the microwaves are sensed somewhere in the temporal region just above and slightly in front of the ears. The phenomenon apparently results from pressure waves set up in brain tissue, some of which activate the sound receptors of the inner ear via bone conduction, while others directly stimulate nerve cells in the auditory pathways. Experiments on rats have shown that a strong signal can generate a sound pressure of 120 decibels, or approximately the level near a jet engine at takeoff.

Obviously such a beam could cause humans severe pain and

prevent all voice communication. That the same effect can be used more subtly was demonstrated in 1973 by Dr. Joseph C. Sharp of the Walter Reed Army Institute of Research. Sharp, serving as a test subject himself, heard and understood spoken words delivered to him in an echo-free isolation chamber via a pulsed-microwave audiogram (an analog of the words' sound vibrations) beamed into his brain. Such a device has obvious applications in covert operations designed to drive a target crazy with "voices" or deliver undetectable instructions to a programmed assassin. There are also indications that other pulse frequencies cause similar pressure waves in other tissues, which could disrupt various metabolic processes. A group under R. G. Olsen and J. D. Grissett at the Naval Aerospace Medical Research Laboratory in Pensacola has already demonstrated such effects in simulated muscle tissue and has a continuing contract to find beams effective against human tissues.

In the 1960s Frey also reported that he could speed up, slow down, or stop isolated frog hearts by synchronizing the pulse rate of a microwave beam with the beat of the heart itself. Similar results have been obtained using live frogs, indicating that it's technically feasible to produce heart attacks with a ray designed to penetrate the human chest.

In addition to the methods of damaging or killing people with EMR, there are several ways of controlling their behavior. Ross Adey and his colleagues have shown that microwaves modulated in various ways can force specific electrical patterns upon parts of the brain. Working with cats they found that brain waves appearing with conditioned responses could be selectively enhanced by shaping the microwaves with a rhythmic variation in amplitude (height) corresponding to EEG frequencies. For example, a 3-hertz modulation decreased 10-hertz alpha waves in one part of the animal's brain and reinforced 14-hertz beta waves in another location.

Some radar can find a fly a kilometer away or track a human at twenty-five miles, and several researchers have suggested that focused EMR beams of such accuracy could bend the mind much like electrical stimulation of the brain (ESB) through wires. We know of ESB's potential for mind control largely through the work of Jose Delgado. One signal provoked a cat to lick its fur, then continue compulsively licking the floor and bars of its cage. A signal designed to stimulate a portion of a monkey's thalamus, a major midbrain center for integrating muscle movements, triggered a complex action: The monkey walked to one side

of the cage, then the other, then climbed to the rear ceiling, then back down. The animal performed this same activity as many times as it was stimulated with the signal, up to sixty times an hour, but not blindly—the creature still was able to avoid obstacles and threats from the dominant male while carrying out the electrical imperative. Another type of signal has made monkeys turn their heads, or smile, no matter what else they were doing, up to twenty thousand times in two weeks. As Delgado concluded, "The animals looked like electronic toys."

Even instincts and emotions can be changed: In one test a mother giving continuous care to her baby suddenly pushed the infant away whenever the signal was given. Approach-avoidance conditioning can be achieved for any action simply by stimulating the pleasure and pain centers in an animal's or person's limbic system.

Eventual monitoring of evoked potentials from the EEG, combined with radio-frequency and microwave broadcasts designed to produce specific thoughts or moods, such as compliance and complacency, promises a method of mind control that poses immense danger to all societies—tyranny without terror. Scientists involved in EEG research all say the ability is still years away, but for all we could sense of it, it could be happening right now. Conspiracy theories aside, the hypnotic familiarity of TV and radio, combined with the biological effects of their broadcast beams, may already constitute a similar force for mass standardization, whether by design or not..

The potential dangers of televised lethargy are no yawning matter. It's well known that relaxed attention to any mildly involving stimulus, such as a movie or TV program, produces a hypnoid state, in which the mind becomes especially receptive to suggestion. Other inducers of hypnoid states include light sleep, daydreams, or short periods of time spent waiting for some predetermined signal or action, such as a traffic light.

The Central Intelligence Agency funded research on electromagnetic mind control at least as early as 1960, when the notorious MKULTRA program, mostly concerned with hypnosis and psychedelic drugs, included money for adapting bioelectric sensing methods (at that time primarily the EEG) to surveillance and interrogation, as well as for finding "techniques of activation of the human organism by remote electronic means." In testimony before the Senate Subcommittee on Health and Scientific Research on September 21, 1977, MKULTRA director Dr. Sidney Gottlieb recalled: "There was a running interest in what effects people's standing in the field of radio energy have, and it could easily have been that somewhere in the many projects someone was try-

ing to see if you could hypnotize somebody easier if he was standing in a radio beam."

Hypnotists often use a strobe light flashing at alpha-wave frequencies to ease the glide into trance. It seems for over thirty years the Communist bloc nations have been using an ELF wave form to do the same thing undetectably and perhaps more effectively. Ross Adey recently lost most of his government grants and has become a bit more loquacious about the military and intelligence uses of EMR. In 1983 he organized a public meeting at the Loma Linda VA hospital and released photos and information concerning a Russian Lida machine. This was a small transmitter that emitted 10-hertz waves for tranquilization and enhancement of suggestibility. The most interesting part was that the box had an ancient vacuum-tube design, and a man who'd been a POW in Korea reported that similar devices had been used there during interrogation.

American interest in the hypnosis-EMR interaction was still strong as of 1974, when a research plan was filed to develop useful techniques in human volunteers. The experimenter, J. F. Schapitz, stated: "In this investigation it will be shown that the spoken word of the hypnotist may also be conveyed by modulated electromagnetic energy directly into the subconscious parts of the human brain—i.e., without employing any technical devices for receiving or transcoding the messages and without the person exposed to such influence having a chance to control the information input consciously." As a preliminary test of the general concept, Schapitz proposed recording the brain waves induced by specific drugs, then modulating them onto a microwave beam and feeding them back into an undrugged person's brain to see if the same state of consciousness could be produced by the beam alone.

Schapitz's main protocol consisted of four experiments. In the first, subjects would be given a test of a hundred questions, ranging from easy to technical, so they all would know some but not all of the answers. Later, while in hypnoid states and not knowing they were being irradiated, these people would be subjected to information beams suggesting answers for some of the items they'd left blank, amnesia for some of their correct answers, and memory falsification for other correct answers. A new test would check the results two weeks later.

The second experiment was to be the implanting of hypnotic suggestions for simple acts, like leaving the lab to buy some particular item, which were to be triggered by a suggested time, spoken word, or sight. Subjects were to be interviewed later. "It may be expected," Schapitz wrote, "that they rationalize their behavior and consider it to be undertaken out of their own free will."

In a third test the subjects were to be given two personality tests. Then different responses to certain questions would be repeatedly suggested, and nonpathological personality changes would also be suggested, both to be evaluated by new testing in a month. In some cases the subjects were to be prehypnotized into talking in their sleep, so the microwave programmer could gear the commands to thoughts already in the brain. Finally, attempts would be made to produce the standard tests of deep hypnotic trance, such as muscular rigidity, by microwave beams alone.

Naturally, since this information was voluntarily released via the Freedom of Information Act, it must be taken with a pillar of salt. The results haven't been made public, so the work may have been inconclusive, and the plans may have been released to convince the Soviets and our own public that American mind-control capabilities are greater than they actually are. On the other hand, the actualities may be so far ahead of this research plan that it was tame enough to release in satisfying FOIA requirements.

How many of the EMR weapons possibilities have actually been developed and/or used? Those not privy to classified information have no way of knowing. There are plenty of rumors. Boris Spassky claimed he'd lost the world chess championship to Bobby Fischer because he was being bombarded with confusion rays. I recall hearing about one secret American experiment in which a scientist was supposedly set up with invitations to three conferences to give the same presentation each time. The first one went fine, but at the last two he was irradiated with ELF waves, reportedly to induce Adey's calcium efflux, and he became confused and ineffective.

Another FOIA release from the Defense Intelligence Agency in 1976 may be revealing. Prepared by Ronald L. Adams and E. A. Williams of Battelle Columbus Laboratories, it's entitled "Biological Effects of Electromagnetic Radiation (Radiowaves and Microwaves), Eurasian Communist Countries." The pages released merely recount Allen Frey's discoveries without mentioning his name, implying instead that only the Reds would be so dastardly as to investigate such things for use as weapons. Immediately after mention of the blood-brain barrier leak phenomenon, a paragraph was deleted, followed by the tantalizing sentence, "The above study is recommended reading material for those consumers who have an interest in the application of microwave energy to weapons." Even without this document, considering the relentless pace of arms development, we would have to be very naive to assume that the United States has no electromagnetic arsenal.

The Soviets may already be using theirs, however, on a scale far beyond that of the Moscow signal. During the U.S. bicentennial celebration of July 4, 1976, a new radio signal was heard throughout the world. It has remained on the air more or less continuously ever since. Varying up and down through the frequencies between 3.26 and 17.54 megahertz, it is pulse-modulated at a rate of several times a second, so it sounds like a buzz saw or woodpecker. It was soon traced to an enormous transmitter near Kiev in the Soviet Ukraine.

The signal is so strong it drowns out anything else on its wavelength. When it first appeared, the UN International Telecommunications Union protested because it interfered with several communications channels, including the emergency frequencies for aircraft on transoceanic flights. Now the woodpecker leaves "holes"; it skips the crucial frequencies as it moves up and down the spectrum. The signal is maintained at enormous expense from a current total of seven stations, the seven most powerful radio transmitters in the world.

Within a year or two after the woodpecker began tapping, there were persistent complaints of unaccountable symptoms from people in several cities of the United States and Canada, primarily Eugene, Oregon. The sensations—pressure and pain in the head, anxiety, fatigue, insomnia, lack of coordination, and numbness, accompanied by a high-pitched ringing in the ears—were characteristic of strong radio-frequency or microwave irradiation. In Oregon, between Eugene and Corvallis, a powerful radio signal centering on 4.75 megahertz was monitored, at higher levels in the air than on the ground. Several unsatisfactory theories were advanced, including emanations from winter-damaged power lines, but most engineers who studied the signal concluded that it was a manifestation of the woodpecker. The idea was advanced that it was being directed to Oregon by a Tesla magnifying transmitter. This apparatus, devised by Nikola Tesla during his turn-of-the-century experiments on wireless global power transmission at a laboratory near Pikes Peak, hasn't been much studied in the West. It reportedly enables a transmitter to beam a radio signal through the earth to any desired point on its surface, while maintaining or even increasing the signal's power as it emerges. Paul Brodeur has suggested that, since the TRW company once proposed a Navy ELF communications system using an existing 850-mile power line that ended in Oregon, the Eugene phenomenon might have been the interaction between a Navy broadcast and Soviet jamming.

He that as it may, the woodpecker continues in operation, and there are several unsettling possibilities as to its main purpose. A former chief

of naval research has privately discounted the idea that it's directed against the U.S. population. However, Robert Beck, a Los Angeles physicist who regularly serves as a DOD consultant, told me that the signal has a threefold purpose. He said it acts as a crude over-the-horizon radar that would pick up a massive first strike of U.S. missiles if Soviet spy satellites and other detectors were knocked out. Second, the signal's modulations are an ELF medium for communicating with submarines underwater. Third, he claimed the signal has a biological by-product about which he promised further information. Of course, I haven't been able to contact him since.

Several educated guesses can be made, however. Adey's research suggests that the best way to get an ELF signal into an animal is to make it a pulse modulation of a high-frequency radio signal. That's exactly what the woodpecker is. Within its frequency range, it could be beamed to any part of the world, and it would be picked up and reradiated by the power supply grid at its destination.

Raymond Damadian has theorized that the woodpecker signal is designed to induce nuclear magnetic resonance in human tissues. Damadian, a radiologist at Brooklyn's Downstate Medical Center, patented the first NMR scanner, a device that gives an image of internal organs similar to CAT scanners but using magnetic fields rather than nuclear radiation. As mentioned earlier in this chapter, NMR could greatly magnify the metabolic interference of electropollution or EMR weapons. Maria Reichmanis calculated the pulse frequency that would be required to do this with a radio signal in the woodpecker's range, and she came up with a band centered on the same old alpha rhythm of 10 hertz. And in fact, the signal's pulse is generally about that rate, although it is often a two-part modulation of 4 + 6, 7 + 3, and so on. The available evidence, then, suggests that the Russian woodpecker is a multipurpose radiation that combines a submarine link with an experimental attack on the American people. It may be intended to increase cancer rates, interfere with decision-making ability, and/or sow confusion and irritation. It may be succeeding.

I keep hearing persistent rumors of American transmitters set up to try to nullify the Russians' signal or to affect their people in a similar way. In 1978, Stefan Rednip, an American reporter living in England, claimed access to purloined CIA documents proving the existence of a program called Operation Pique, which included bouncing radio signals off the ionosphere to affect the mental functions of people in selected areas, including Eastern European nuclear installations.

The whole business sounds too much like an undeclared electromag-

netic war. However, there are persistent complaints that the American effort is being hampered in a strange way. Shortly after the rigged National Academy of Sciences report on Project Seafarer, for example, the Navy sent a delegation to a meeting at the National Security Agency to complain about an alleged "zap gap" between the United States and the USSR, and to ask other delegates to push for more research money for turning nonthermal EMR effects into weapons. According to one of my Navy contacts, the NSA sent several "experts" who had never done any research on EMR and who firmly advised the Navy to abandon its program. Later he voiced the same suspicions I'd already heard from others: Given the allegedly vigorous Soviet electroweapons research program and the underfunding of ours, he concluded that there is a mole highly placed in the American military science establishment, perhaps in the NSA itself, who is preventing us from acquiring any clear competence in this field.

Unfortunately, my source, having served as a hatchet man for defunding research on the environmental dangers of electropollution, isn't exactly reliable. Complaints of a mole could easily be a blind for a large and intense U.S. EMR weapons program. That there's more going on than meets the eye is clear from my last communication with Dietrich Beischer. In 1977 the Erie Magnetics Company of Buffalo, New York, sponsored a small private conference, and Beischer and I both planned to attend. Just before the meeting, I got a call from him. With no preamble or explanation, he blurted out: "I'm at a pay phone. I can't talk long. They are watching me. I can't come to the meeting or ever communicate with you again. I'm sorry. You've been a good friend. Goodbye." Soon afterward I called his office at Pensacola and was told, "I'm sorry, there is no one here by that name," just as in the movies. A guy who had done important research there for decades just disappeared.

The crucial point to me is that both sides may be embarking on hostilities whose consequences for the whole biosphere no one can yet foresee. Even if the Soviets have begun an electromagnetic war and we're totally unprepared to fight back, I doubt that a simple buildup and retaliation are the best course for our own survival.

The extent of the danger can be dramatized best by considering one last potential weapon. Around 1900, Nikola Tesla theorized that ELF and VLF radiation could enter the magnetosphere, the magnetic field in space around the earth, and change its structure. He has recently been proven right.

The magnetosphere and its Van Allen belts of trapped particles produce many kinds of EMR. Since they were initially studied through

audio amplifiers, the first kinds to be discovered, around 1920, were given fanciful names like whistlers, dawn chorus, and lion roars. Many of them result from VLF waves produced by lightning, which bounce back and forth from pole to pole along "magnetic ducts" in the magnetosphere. This resonance amplifies the original VLF waves enormously.

Satellite measurements have proven that artificial energies from power lines are similarly amplified high above the earth, a phenomenon known as power-line harmonic resonance (PLHR). Radio and microwave energy also resonates in the magnetosphere. This amplified energy interacts with the particles in the Van Allen belts, producing heat, light, X rays, and, most important, a "fallout" of charged particles that serve as nuclei for raindrops.

Recent work with sounding rockets has matched specific areas of such ion precipitation with the energy from specific radio stations, and established that the sifting down of charged particles generally occurs east of the EMR source, following the general eastward drift of weather patterns. In 1983, measurements from the Ariel 3 and 4 weather satellites showed that the enormous amount of PLHR over North America had created a permanent duct from the magnetosphere down into the upper air, resulting in a continuous release of ions and energy over the whole continent. In presenting this data at the March 1983 Symposium on Electromagnetic Compatibility in Zurich, K. Bullough reminded the audience that thunderstorms have been 25 percent more frequent over North America between 1930 and 1975 than they were from 1900 to 1930, and suggested that the increased energy levels in the upper atmosphere were responsible.

Since the mid-1970s there has been a dramatic increase in flooding, drought, and attendant hardships due to inconsistent, anomalous weather patterns. It appears likely that these have been caused in part by electropollution and perhaps enhanced, whether deliberately or not, by the Soviet woodpecker signal. It now seems feasible to induce catastrophic climate change over a target country, and even without such weather warfare, continued expansion of the electrical power system threatens the viability of all life on earth.

Critical Connections

It may be hard to convince ourselves that something we can't see, hear, touch, taste, or smell can still hurt us so dreadfully. Yet the fact must be faced, just as we've learned a healthy fear of nuclear radiation. Certain

scientists, some perhaps acting in a program of deliberate disinformation, keep telling the public that we still don't know whether electropollution is a threat to human health. That's simply not true. Certainly we need to know more, but a multitude of risks have been well documented.

Three dangers overshadow all others. The first has been conclusively proven: ELF electromagnetic fields vibrating at about 30 to 100 hertz, even if they're weaker than the earth's field, interfere with the cues that keep our biological cycles properly timed; chronic stress and impaired disease resistance result. Second, the available evidence strongly suggests that regulation of celular growth processes is impaired by electropollution, increasing cancer rates and producing serious reproductive problems. Electromagnetic weapons constitute a third class of hazards culminating in climatic manipulation from a sorcerer's-apprentice level of ignorance.

There may be other dangers, less sharply defined but no less real. All cities, by their very nature as electrical centers, are jungles of interpenetrating fields and radiation that completely drown out the earth's background throb. Is this an underlying reason why so many of them have become jungles in another sense as well? Is this a partial explanation for the fact that the rate of suicide between the ages of fifteen and twenty-four rose from 5.1 per 100,000 in 1961 to 12.8 in 1981? Might this be an invisible and thus overlooked reason why so many governmental leaders, working at the centers of the most powerful electromagnetic networks, consistently make decisions that are against the best interests of every being on earth? Is the subliminal stress of electronic smog misinterpreted as continual threats from outside—from other people and other governments? In addition, if Teilhard de Chardin's noosphere exists, our artificial fields must mask it many times over, literally disconnecting us from life's collective wisdom. This is not to ignore the plain fact of evil, but it often seems there must be some other reason why today's power elite are so willing to bring the whole world to the brink of so many different kinds of destruction. Maybe they literally can't hear the earth anymore.

Everyone worries about nuclear weapons as the most serious threat to our survival. Their danger is indeed immediate and overwhelming. In the long run, however, I believe the ultimate weapon is manipulation of our electromagnetic environment, because it's imperceptibly subtle and strikes at the core of life itself. We're dealing here with the most important scientific discovery ever - the nature of life. Even if we survive the chemical and atomic threats to our existence, there's a strong possibility that increasing electropollution could set in motion irreversible changes

leading to our extinction before we're even aware of them.

All life pulsates in time to the earth, and our artificial fields cause abnormal reactions in all organisms. Magnetic reversals may have produced the "great dyings" of the past by disrupting biocycles so as to cause stress, sterility, birth defects, malignancies, and impaired brain function. Human activities may well have duplicated in three decades what otherwise would have taken five thousand years to develop during the next reversal. What will we do if the incidence of deformed children rises to 50 percent, if the cancer rate climbs to 75 percent? Will we be able to pull the plug?

Somehow these dangers must be brought into the open so forcefully that the entire population of the world is made aware of them. Scientists must begin to ask and seek answers to the questions raised in this chapter, regardless of the effect on their careers. These energies are too dangerous to be entrusted forever to politicians, military leaders, and their lapdog researchers.

Since our civilization is irreversibly dependent on electronics, abolition of EMR is out of the question. However, as a first step toward averting disaster, we must halt the introduction of new sources of electromagnetic energy while we investigate the biohazards of those we already have with a completeness and honesty that have so far been in short supply. New sources must be allowed only after their risks have been evaluated on the basis of the knowledge acquired in such a moratorium.

With an adequately funded research program, the moratorium need last no more than five years, and the ensuing changes could almost certainly be performed without major economic trauma. It seems possible that a different power frequency—say 400 hertz instead of 60—might prove much safer. Burying power lines and providing them with grounded shields would reduce the electric fields around them, and magnetic shielding is also feasible.

A major part of the safety changes would consist of energy-efficiency reforms that would benefit the economy in the long run. These new directions would have been taken years ago but for the opposition of power companies concerned with their short-term profits, and a government unwilling to challenge them. It is possible to redesign many appliances and communications devices so they use far less energy. The entire power supply could be decentralized by feeding electricity from renewable sources (wind, flowing water, sunlight, georhermal and ocean thermal energy conversion, and so forth) into local distribution nets. This would greatly decrease hazards by reducing the voltages and

amperages required. Ultimately, most EMR hazards could be eliminated by the development of efficient photoelectric converters to be used as the primary power source at each point of consumption. The changeover would even pay for itself, as the loss factors of long-distance power transmission—not to mention the astronomical costs of building and decommissioning short-lived nuclear power plants—were eliminated. Safety need not imply giving up our beneficial machines.

Obviously, given the present technomilitary control of society in most parts of the world, such sane efficiency will be immensely difficult to achieve. Nevertheless, we must try. Electromagnetic energy presents us with the same imperative as nuclear energy: Our survival depends on the ability of upright scientists and other people of goodwill to break the military-industrial death grip on our policy-making institutions.

Postscript: Political Science

An important scientific innovation rarely makes its way by gradually winning over and converting its opponents: it rarely happens that Saul becomes Paul. What does happen is that its opponents gradually die out and that the growing generation is familiarized with the idea from the beginning.
—Max Planck

Dispassionate philosopher inquiring into nature from the sheer love of knowledge, single-minded alchemist puttering about a secluded basement in search of elixirs to benefit all humanity—these ideals no longer fit most scientists. Even the stereotype of Faust dreaming of demonic power is outdated, for most scientists today are overspecialized and anonymous—although science as a whole is somewhat Mephistophelian in its disregard for the effects of its knowledge. It's a ponderous beast, making enormous changes in the way we live but agonizingly slow to change its own habits and viewpoints when they become outmoded.

The public's conception of the scientist remains closest to its image of the philosopher—cold and logical, making decisions solely on the basis of the facts, unswayed by emotion. The lay person's most common fear about scientists is that they lack human feelings. During my twenty-five

years of research I've found this to be untrue yet no cause for comfort. I've occasionally seen our species' nobler impulses among them, but I've also found that scientists as a group are at least as subject to human failings as people in other walks of life.

It has been like this throughout the history of science. Many, perhaps even most, of its practitioners have been greedy, power-hungry, prestige-seeking, dogmatic, pompous asses, not above political chicanery and outright lying, cheating, and stealing. Examples abound right from the start. Sir Francis Bacon, who in 1620 formulated the experimental method on which all technical progress since then has been founded, not only forgot to mention his considerable debt to William Gilbert but apparently plagiarized some of his predecessor's work while publicly belittling it. In a similar way Emil Du Bois-Reymond based his own electrical theory of the nerve impulse on Carlo Matteucci's work, then tried to ridicule his mentor and take full credit.

Many a genius has been destroyed by people of lesser talent defending the status quo. Ignaz Semmelweis, a Hungarian physician who practiced in Vienna during the mid-nineteenth century, demanded that his hospital colleagues and subordinates wash their hands, especially when moving from autopsies and sick wards to the charity childbirth ward he directed. When the incidence of puerperal fever and resultant death declined dramatically to well below that of the rich women's childbirth ward, proving the importance of cleanliness even before Pasteur, Semmelweis was fired and vilified. His livelihood gone, he committed suicide soon afterward.

The principal figure who for decades upheld the creed that dedifferentiation was impossible was Paul Weiss, who dominated biology saying the things his peers wanted to hear. Weiss was wrong, but along the way he managed to cut short a number of careers.

For many years the American Medical Association scorned the idea of vitamin-deficiency diseases and called the EEG electronic quackery. Even today that august body contends that nutrition is basically irrelevant to health. As the late-eighteenth-century Italian experimenter Abbe Alberto Fortis observed in a letter chiding Spallanzani for his closed-minded stance on dowsing, "... derision will never help in the development of true knowledge."

In the past, these character flaws couldn't wholly prevent the recognition of scientific truths. Both sides of a controversy would fight with equal vehemence, and the one with better evidence would usually win sooner or later. In the last four decades, however, changes in the structure of scientific institutions have produced a situation so heavily

weighted in favor of the establishment that it impedes progress in health care and prevents truly new ideas from getting a fair hearing in almost all circumstances. The present system is in effect a dogmatic religion with a self-perpetuating priesthood dedicated only to preserving the current orthodoxies. The system rewards the sycophant and punishes the visionary to a degree unparalleled in the four-hundred-year history of modern science.

This situation has come about because research is now so expensive that only governments and multinational corporations can pay for it. The funds are dispensed by agencies staffed and run by bureaucrats who aren't scientists themselves. As this system developed after World War II, the question naturally arose as to how these scientifically ignorant officials were to choose among competing grant applications. The logical solution was to set up panels of scientists to evaluate requests in their fields and then advise the bureaucrats.

This method is based on the naive assumption that scientists really are more impartial than other people, so the result could have been predicted decades ago. In general, projects that propose a search for evidence in support of new ideas aren't funded. Most review committees approve nothing that would challenge the findings their members made when they were struggling young researchers who created the current theories, whereas projects that pander to these elder egos receive lavish support. Eventually those who play the game become the new members of the peer group, and thus the system perpetuates itself. As Erwin Chargaff has remarked, "This continual turning off and on of the financial faucets produces Pavlovian effects," and most research becomes mere water treading aimed at getting paid rather than finding anything new. The intuitive "lunatic twinge," the urge to test a hunch, which is the source of all scientific breakthroughs, is systematically excluded.

There has even been a scientific study documenting how choices made by the peer review system depend almost entirely on whether the experts are sympathetic or hostile to the hypothesis being suggested. True to form, the National Academy of Sciences, which sponsored the investigation, suppressed its results for two years.

Membership on even a few peer review boards soon establishes one's status in the "old boys' club" and leads to other benefits. Manuscripts submitted to scientific journals are reviewed for validity in the same way as grant requests. And who is better qualified to judge an article than those same eminent experts with their laurels to guard? Publication is accepted as evidence that an experiment has some basic value, and without it the work sinks without a ripple. The circle is thus closed, and the

revolutionary, from whose ideas all new scientific concepts come, is on the outside. Donald Goodwin, chairman of psychiatry at the University of Kansas and an innovative researcher on alcoholism, has even put it in the form of a law of exasperation: "If it's trivial, you can probably study it. If it's important, you probably can't."

Another unforeseen abuse has arisen, which has lowered the quality of training in medical schools. As the peer review system developed, academic institutions saw a golden opportunity. If the government wanted all this research done, why shouldn't it help the schools with their overhead, such as housing, utilities, bookkeeping, and ultimately the salaries of the researchers, who were part of the faculty? The influx of money corroded academic values. The idea arose that the best teacher was the best researcher, and the best researcher was the one who pulled down the biggest grants. A medical school became primarily a kennel of researchers and only secondarily a place to teach future physicians. To survive in academia, you have to get funded and then get published. The epidemic of fraudulent reports—and I believe only a small percentage of the actual fakery has been discovered—is eloquent testimony of the pressure to make a name in the lab.

There remain today few places for those whose talents lie in teaching and clinical work. Many people who don't care about research are forced to do it anyway. As a result, medical journals and teaching staffs are both drowning in mediocrity.

Finally, we must add to these factors the buying of science by the military. To call it a form of prostitution is an insult to the oldest profession. Nearly two thirds of the $47-billion 1984 federal research budget went for military work, and in the field of bioelectricity the proportion was even higher. While military sponsors often allow more technical innovation than others, their employees must keep their mouths shut about environmental hazards and other moral issues that link science to the broader concerns of civilization. In the long run, even the growth of pure knowledge (if there is such a thing) can't flourish behind this chain link fence.

If someone does start a heretical project, there are several ways of dealing with the threat. Grants are limited, usually for a period of one or two years. The experimenter then must reapply. Every application is a voluminous document filled with fine-print forms and meaningless bureaucratic jargon, requiring many days of data compilation and "creative writing." Some researchers may simply get tired of them and quit. In any case, they must run the same gauntlet of peers each time. The simplest way to nip a challenge in the bud is to turn off the money or keep

the reports out of major journals by means of anonymous value judgments from the review committees. You can always find something wrong with a proposal or manuscript, no matter how well written or scientifically impeccable it may be.

Determined rebels use guerrilla tactics. There are so many funding agencies that the left hand often knoweth not what the right hand doeth. A proposal may get by an obscure panel whose members aren't yet aware of the danger. The snowstorms of paper churned out by the research establishment have required the founding of many new journals in each subspecialty. Some of these will accept papers that would automatically be rejected by the big ones. In addition, there's an art to writing a grant proposal that falls within accepted guidelines without specifying exactly what the researchers intend to do.

If these methods succeed in prolonging the apostasy, the establishment generally exerts pressure through the schools. Successful academics are almost always true believers who are happy to curry favor by helping to deny tenure to "questionable" investigators or by harassing them in a number of ways. For example, in 1950 Gordon A. Atwater was fired as chairman of the American Museum of Natural History astronomy department and curator of the Hayden Planetarium for publicly suggesting that Immanuel Velikovsky's ideas should receive a fair hearing. That same year Velikovsky's first book, Worlds in Collision, was renounced by his publisher (Macmillan) even though it was a best seller, because a group of influential astronomers led by Harvard's Harlow Shapley threatened to boycott the textbook department that accounted for two thirds of the company's sales. No matter what one may think of Velikovsky's conclusions, that kind of backstairs persuasion is not science.

As the conflict escalates, the muzzled freethinker often goes directly to the public to spread the pernicious doctrines. At this point the gloves come off. Already a lightning rod for the wrath of the Olympian peers, the would-be Prometheus writhes under attacks on his or her honesty, scientific competence, and personal habits. The pigeons of Zeus cover the new ideas with their droppings and conduct rigged experiments to disprove them. In extreme cases, government agencies staffed and advised by the establishment begin legal harassment, such as the trial and imprisonment that ended the career and life of Wilhelm Reich.

Sometime during or after the battle, it generally becomes obvious that the iconoclast was right. The counterattack then shifts toward historical revision. Establishment members publish papers claiming the new ideas for themselves and omitting all references to the true originator. The heretic's name is remembered only in connection with a condescending

catchphrase, while his or her own research programs, if any remain, are defunded and the staff dispersed. The facts of the case eventually emerge, but only at an immense toll on the innovator's time and energy.

To those who haven't tried to run a lab, these may seem like harsh words, unbelievable, even paranoid. Nevertheless, these tactics are commonplace, and I've had personal experience with each and every one of them.

I got a taste of the real world in my very first foray into research. After World War II, I continued my education on the GI Bill, but those benefits expired in 1947. I'd just married a fellow student named Lillian, who had caught my eye during our first orientation lecture, and I needed a summer job to help pay expenses and set up housekeeping. I was lucky enough to get work as a lab assistant in the NYU School of Medicine's surgical research department.

I worked with Co Tui, who was evaluating a recently published method for separating individual amino acids from proteins as a step toward concentrating foods for shipment to the starving. Dr. Co, a tiny man whose black, spiky hair seemed to broadcast enthusiasm, inspired me enormously. He was a brilliant researcher and a good friend. With him I helped develop the assay technique and began to use it to study changes in body proteins after surgery.

I was writing my first scientific paper when I walked to work one morning and found our laboratory on the sidewalk—all our equipment, notes, and materials junked in a big pile. I was told neither of us worked there anymore; we were welcome to salvage anything we wanted from the heap.

The head secretary told me what had happened. This was during a big fund drive to build the present NYU Medical Center. One of the "society surgeons" had lined up a million-dollar donation from one of his patients and would see that it got into the fund, if he could choose a new professor of experimental surgery—now. As fast as that, Co Tui and his people were out. I vowed to Lillian: "Whatever I do in medicine, I'm going to stay out of research."

I'm happy that I wasn't able to keep my promise. The research itself was worth it all. Moreover, I don't want to give the impression that I and my associates were alone against the world. Just when hope seemed lost, there was always a crucial person, like Carlyle Jacobsen or the research director's secretary, to help us out. However, right from my first proposal to measure the current of injury in salamanders, I found that research would mean a constant battle, and not only with administrators.

Before I began, I had to solve a technical problem with the electrodes. Even two wires of the same metal had little chemical differences, which gave rise to small electrical currents that could be misinterpreted as coming from the animal. Also, the slightest pressure on the animal's skin produced currents. No one understood why, but there they were. I found descriptions in the older literature of silver electrodes with a layer of silver chloride applied to them, which were reported to obviate the false interelectrode currents. I made some, tested them, and then fitted them with a short length of soft cotton wick, which got rid of the pressure artifact. When I wrote up my results, I briefly described the electrodes. Afterward I received a call from a prominent neurophysiologist who wanted to visit the lab. "Very nice," I thought. "Here's some recognition already." He was particularly interested in how the electrodes were made and used. Some months later, damned if I didn't find a paper by my visitor in one of the high-class journals, describing this new and excellent electrode he'd devised for measuring direct-current potentials!

A couple of years later, while Charlie Bachman and I were looking for the PN junction diode in bone, I was asked to give a talk on bone electronics at a meeting in New York City. The audience included engineers, physicists, physicians, and biologists. It was hard to talk to such a diverse group. The engineers and physicists knew all about electronics but nothing about bone, the biologists knew all about bone but nothing about electronics, and the physicians were only interested in therapeutic applications. At any rate, I reviewed some bone structure for the physicists and some electronics for the biologists, and then went on to describe my experiments with Andy Bassett on bone piezoelectricity.

I probably should have sat down at that point, but I thought it would be nice to talk about our present work. The rectifier concept was tremendously exciting to me, and I thought we might get some useful suggestions from the audience, so I described the experiments showing that collagen and apatite were semiconductors, and discussed the implications. After each talk a short time was set aside for questions and comments, generally polite and dignified. However, as soon as I finished, a well-known orthopedic researcher literally ran up to the audience microphone and blurted out, "I have never heard such a collection of inadequate data and misconceptions. It is an insult to this audience. Dr. Becker has not presented satisfactory evidence for any semiconducting property in bone. The best that can be said is that this material may be a semi-insulator."

Semiconductors are so named because then properties place them be-

tween conductors and insulators, so you could very well call them semi-insulators; the meaning would be the same. My opponent was playing a crude game. While saying these derogatory things about me, he was actually agreeing with my conclusion, merely u»ing a different term.

This man's antagonism had begun a couple of years before. When Andy Bassett and I had finished our work on the piezoelectric effect in bone, we wrote it up, submitted it to a scientific journal, and got it accepted. Unbeknownst to us, this fellow had been working on the same thing, but hadn't gotten as far in his experiments as we. Somehow he learned of our work and its impending publication. He called Andy, asking us to delay our report until he was ready to publish his own data. Andy called me to talk it over. What counts in the scientific literature is priority; he was asking us to surrender it. There was no ethical basis for his request, and I would never have thought of asking him to delay had the situation been reversed. I said, "Not on your life." Our paper was published, and we'd acquired a "friend" for life.

Now there he was at the microphone trying to scuttle my presentation with a little ambiguous double-talk. I thought, "He must be doing the same work as we are again. If he wins this encounter, I'll have trouble getting my data published, and he'll have a clear field for his." Instead of defending the data, I explained that semi-insulator and semiconductor were one and the same. I said I was surprised he didn't know that, but I appreciated his approval of my data! Someone else in the audience stood up in support of my position, and the crisis was past. The lab isn't the only place a scientist has to stay alert.

In 1964, soon after the National Institutes of Health approved the grant for our continuing work on bone, I received the VA's William S. Middleton Award for outstanding research. That's a funny little story in itself. The award is given by the VA's Central Office (VACO), whose members had already decided on me, but candidates must be nominated by regional officers, and the local powers were determined I shouldn't get it. Eventually VACO had to order them to nominate me.

The award put me on salary from Washington instead of Syracuse, and due to pressure from VACO I was soon designated the local chief of research, replacing the man who signed all the papers at once. I was determined to put the research house in order, and I instituted a number of reforms, such as public disclosure of the funding allocations, and productivity requirements, no matter how prominent an investigator might be. Many of the reforms have been adopted throughout the VA system. They didn't make me more popular, however. Over the next several years there was continuous pressure from the medical school to allocate

VA research funds for people I felt were of little value to the VA program itself; thus the money would have constituted a grant to the school. I knew that if I didn't deliver I would eventually be removed from the position of chief of research. In that case, I would go back on a local clinical salary and my research program would again be in jeopardy. Therefore, at the beginning of 1972 I applied for the position of medical investigator in the VA research system, a post in which I would be able to devote up to three fourths of my time to research. I was accepted. The job was to begin a few months later; in the meantime I continued as chief of research.

Apparently my new appointment escaped the notice of my local opponents. I'd accepted several invitations to speak at universities in the South and combined them all into a week's trip. I left the office a day early to prepare my material and pack. While I was still home, my secretary called. She was crying, and said she'd just gotten a memo firing me as chief of research and putting me to work as a general-duty medical officer in the admitting office. This not only would have closed our lab, but also would have kept me from practicing orthopedic surgery.

It was a nice maneuver but, fortunately for me, it wasn't legal. As medical investigator, I could be fired only by Washington, and the local chief of staff soon got a letter from VACO ordering him to reinstate me.

Soon I began to get on some "enemies lists" at the national level, too. In December 1974 I got word that our basic NIH grant (the one on bone) hadn't been renewed. No reasons were given. This was highly irregular, since applicants normally got the "pink sheets" with at least the primary reviewer's comments, so they could find out what they'd done wrong. Instead I was told I could write to the executive secretary for a "summary" of the deliberations.

The summary was half a page of double-spaced typing. It said my proposal had been lacking in clarity and direction, and that the experimental procedures hadn't been spelled out in enough detail. The main problem seemed to be that I was planning to do more than the reviewer thought I could do with the money I was requesting. In addition, my report on the perineural cell research with Bruce Baker was criticized as "data poor." The statement concluded: "On the other hand, there are some areas which appear to be worthy of support and are reasonably well described, e.g., bone growth studies, regenerative growth, and electrical field effects."

I was, to say the least, puzzled. The subjects "worthy of support" were precisely the main ones we were working on. It didn't make any

sense until I reflected that this was just after I'd helped write the first Sanguine report and had begun to testify about power line dangers before the New York Public Service Commission. Perhaps the Navy was pressuring the NIH to shut me up.

If somebody at the federal level was trying to lock me out as early as 1974, he forgot to watch all the entrances, for my proposal of that year on acupuncture was approved. I'd originally tacked this on to the main NIH application, where it was criticized as inappropriate. I merely sent it off to a different study section, which funded it. After a year we had the positive results described in Chapter 13, and I presented them at an NIH acupuncture conference in Bethesda, Maryland. Ours was the only study going at the problem from a strictly scientific point of view, that is, proceeding from a testable hypothesis, as opposed to the empirical approach of actually putting the needles in and trying to decide if they worked. To the NIH's basic question—is the system of points and lines real?—our program was the only one giving an unequivocal answer: yes.

Nevertheless, when this grant came up for renewal in 1976, it, too, was cut off. The stated reasons were that we hadn't published enough and that the electrical system we found didn't have any relation to acupuncture. The first was obviously untrue—we'd published three papers, had two more in press, and had submitted six others—and the second was obvious pettifogging. How could anyone know what was related to acupuncture before the research had been done? I happened to know the chairman of the NIH acupuncture study section, so I wrote him a letter. He said he was surprised, because the group itself had been pleased with our report. By then it was obvious that something was up.

As of October 1976 we would have no more NIH support. As the money dwindled, we juggled budgets and shaved expenses to cover our costs, and with the help of Dave Murray, who was now chairman of the orthopedic surgery department at the medical school, we kept the laboratory intact and enormously productive. We actually published more research than when we hadn't been under fire.

Early in that same year, however, my appointment as medical investigator had expired, and I had to reapply. Word came back that my application was being "deferred," that is, it had been rejected, but I had the option of reapplying immediately. In her accompanying letter, the director of the VA's Medical Research Service wrote, "While your past record and the strong letters of support [the peer reviews of my application] were considered extremely favorable, the broad research proposal with sketchy detail of technique and methodology was not considered approvable." Now, the instructions for medical investigator applications

clearly stated that I was to spell out past accomplishments and indicate future directions only in broad outline. Instead, the director was applying the criteria for first-time grant applicants just entering research. She invited me to resubmit the proposal in the other format. But that would not have helped. Even if the second application was approved, the money would arrive six months after the lab had been closed and we had gone our separate ways.

There was another strange thing about the rejection. By that time all federal granting agencies had to provide the actual reports (with names deleted) of the peers who had done the reviewing. Three out of the four were long, detailed, well-thought-out documents in the standard critique format; they'd been neatly retyped, single spaced, on "reviewer's report" forms with an elite typewriter. One was absolutely lavish in its praise, saying that the VA was fortunate to have me and that the proposed work would undoubtedly make great contributions to medicine. Another was almost as laudatory.

One name had inadvertently been left on one page of the third review. It was the name of a prominent orthopedic researcher with whom I'd disagreed for years about commercialization of bone-healing devices. Since our mutual disregard was well known in the orthopedic service, I feel it was indefensible for the director to ask him to review my application in the first place. Perhaps she expected a more damaging critique from him. He did complain that the proposal was insufficiently detailed. However, his appraisal was quite fair and even said my proposed work was of "fundamental importance to the field of growth and healing." It obviously led up to a recommendation for approval, but the last sentence of that paragraph had been deleted.

The last review was half a page of vague objections, typed double spaced on a pica machine with no semblance of the standard format. There was a revealing mistake ("corrective" tissue instead of connective tissue) that showed the writer had glanced at my proposal for cues but really didn't know what it was about. Strangest of all was the phrasing of this pseudoreview: "[Becker's proposal] is broad and sweeping in scope and contains little documentation for technique and methodology. However, in view of his past record and strong letters of support, a decision should be deferred. ..." The director had used it almost word for word in her letter.

She certainly had no motive for such conduct herself. I'd met her briefly a few years before. In 1966 she'd been appointed chief of research at the Buffalo VA Medical Center and had visited Syracuse to see how I'd organised the program there. Our conversation was pleasant but quite innocuious.

The incentive came from elsewhere. In 1982 a former chief of naval research, with whom I'd made friends because of our common interest in spinal cord regeneration, told me the Navy had protested the closing of the lab. He said it had been a deliberate action coming from some level higher than the VA, NIH, or NAS. Somewhere the decision was made to "shut this guy up," he said, but he wanted me to know that he and the Navy had had no part in it. At one point during the struggle, Andy Marino got a call from a minor official in the VA. He said, "Listen, we're under an awful lot of pressure here to shut you fellows off. Can't you just back off a little bit, stop saying all these things, just sort of downgrade that public hearing you're involved with?" This was the reasonable approach—"We're only trying to help you"—so Andy spent some time sympathizing with this guy's position. Then when he finally asked him, "Where are you getting the pressure from?" Andy got an answer: "Mostly from DOD."

At about the same time I received a clear message about what was going on from one of the scientists from the "other side," one of those who were doing a lot of well-funded work for the military but publishing little. During a recess in a scientific meeting, I encountered him in an empty lobby. Glancing over his shoulder, he drew me aside to the windows and told me my only trouble was that I was going public. He said he and all the rest of us knew there were nonthermal effects and hazards, but we had to keep it quiet. I replied that if no one "went public," the situation could never be corrected and a lot of people would suffer needlessly. He told me that was no concern of mine and predicted my attitude would ruin my career. Well, I could only agree with him on the last point. I agreed that it probably already had, but at least I had a clear conscience.

Rather than sit and wait for the executioner, I tried the back door. I sent a detailed merit-review proposal, the kind filed by beginning researchers, to a newly established section on rehabilitation research. Instead of applying through VACO, however, I routed it through the VA regional office in Boston.

While I was waiting for a reply, I had to fend off another attack. Before testifying at the PSC hearings, I'd notified my supervisor. With a VA lawyer present, he'd told me in person that this was just the kind of thing the VA wanted to fulfill its public obligations, and he even sent me a letter to that effect. Then, just after I appeared on 60 Minutes and talked about Sanguine, power lines, and the rigging of the NAS committee, I heard the va Personnel Office was investigating me for engaging in nonapproved work - the testimony - on government time. I'd gone to the hearings at my own expense to attack a public health prob-

lem, but never mind; they were still accusing me of stealing from the taxpayers. If the charge was upheld, I would have to pay back part of my salary and grants based on all the time I'd spent researching, preparing, and giving the evidence.

Soon a company spy showed up in my office. I knew anything I said would be carried straight to the top, so I mentioned, "just between you and me," that I was in a position to reveal infractions committed by the local administration that were more serious than their charge against me. The next day I got a call from the director: There was no audit being planned; that was just a rumor; it was all a big mistake.

Soon I got word that my funding ploy had worked. The rehabilitation proposal was approved in routine fashion, and we were in business through 1979. I'm sure there was hell to pay at VACO when the phantom leader of the posse found that one of the director's underlings had let us slip the noose. However, I knew there was no way we'd ever finagle another grant, and I told everybody to start lining up another job well in advance. As for me, I'd decided to retire as soon as I became eligible in 1978. I was tired and discouraged. There was almost no interest in the evidence I'd accumulated for the DC perineural system, and I was pretty sure I'd never be able to do any research after this latest grant ran out.

Then a magazine article provided some support that induced me to continue for a while. In 1976, Smithsonian ran a piece called "If a Newt Can Grow a New Limb, Maybe We Can." The author, Robert Bahr, had written a popularized but accurate account after looking through the scientific literature and finding, among others, our papers on rat limb regeneration. Shortly afterward, I received a call from Don Yarborough, a congressional lobbyist for the American Paralysis Association, a group of people who were dissatisfied with the then-prevalent idea that nothing could be done for paraplegics. Obviously, spinal cord regeneration was the ultimate answer if it was possible. Yarborough asked if what Bahr had written was true.

When I said it was, he enthusiastically asked for more details. I told him the problems we'd encountered, both scientific and political, and the fact that I was soon to retire and disband the lab. He asked me to make no final decisions until he brought this situation to the attention of his contacts in Congress.

Shortly thereafter, I was asked to see Senator Alan Cranston, then chairman of the Senate Committee on Veterans' Affairrs. Steve Smith was also invited. Also present were representatives from NIH and other agencies, who soon established their position. If the senator wanted to

support crackpot stuff like this, they fumed, he would have to see to it that additional money was given to NIH, since they wouldn't fund this work at the expense of "good, solid research projects."

However, Cranston obviously was interested, and he must have leaned on the VA a little, for its policy changed briefly. The administrators expanded rehabilitation research, appointing a well-known orthopedic surgeon named Vernon Nickel to head it. As soon as he hit Washington, he called and asked what he could do for me. I told him that for years I'd been wanting to organize an international symposium on mechanisms of growth control and their clinical promise. Before I'd even finished describing the idea he asked how much I needed. I said $25,000, and he said it was on its way. Predictably, Vernon didn't last long in the capital; he was gone right alter I organized the conference, but by then it was too late to cancel the funds.

The meeting was held in September 1979, and it exceeded all expectations. Every important researcher in the field was there, except for Meryl Rose, who can't stand crowds, and Marc Singer, who was ill. It brought together in one set of proceedings irrefutable evidence that a knowledge of the bioelectricity of growth would lead to incredible breakthroughs in medicine. Since then, a few more grants for regeneration work have opened up, and articles on bioelectromagnetism have begun to appear more often in the journals.

At a June 1978 meeting in Washington, requested by Senator Cranston to plan more regeneration research, my colleagues and I gave (we thought) an exciting and scientifically successful preview of the work that would be presented at the full-scale symposium a year later. At the end, however, the director stood up and said our work was largely erroneous and wholly without significance. "We see absolutely no reason to change the direction of VA research," she pontificated. "We see no reason to expand any programs in the area of regeneration." That was that for Cranston's initiative. The meeting appeared to be just a setup so the VA bigwigs could write him a letter saying they'd duly considered the work of all the experts, weighed it in the balance, and found it wanting.

However, my co-workers and I decided to give it the old college try for more funds. Our grant expired December 31, 1979, and we had to submit our new proposal by the preceding January. By now our nemesis was assistant chief medical director, so it was impossible to sneak one around her. The VA seems to change its application instructions every year, and this year we were specifically told our program was a "type III." Therefore we weren't to submit a detailed write-up of each pro-

posed experiment. By this time we were obviously competent to do them, and we would be judged on the basis of past productivity. On that score we had no worries. We'd led the way in bioelectricity research and we were arranging the first conference ever in our specialty of growth control. Moreover, after our application was filed, during the symposium, I arranged for the chiefs of the various VA research sections to visit our lab, inspect the facilities, meet my replacement (Dave Murray), and discuss our future course. They said they wanted me to continue part time. Suddenly I felt we might survive after all.

Then, around Thanksgiving, came word that our application had been disapproved. The director had pulled the same switch. She'd changed procedures after receiving the proposal, instructing the reviewers to consider it as a "type I" application from a new investigator, with emphasis on future plans. As might be expected, one of the peers said, "This is a poorly written, overly ambitious, incompletely detailed proposal." Another wrote, "Dr. Becker is one of the pioneers in the field of electrically induced osteogenesis and regeneration. His work is visionary and exciting, yet at the same time it is controversial and lacks quantitation." The same old gobbledygook! Overly ambitious? By whose standards? Visionary and exciting? Exactly what do you want in a research project? Quantitation? If you can start to grow a leg back on a rat, what statistics do you want besides the procedures, photos, and the number of experimental animals and controls?

Soon after the rejection, I heard hints through intermediaries that the director might be willing to let us keep the laboratory together if I severed all my connections with it and if the remaining members agreed not to do any research on regeneration or electropollution. With such an agreement, it might be possible to get interim funds pending action on new proposals from my co-workers. The restrictions didn't leave much room to work, but at least my people's livelihood would be spared for a while, so we got back on the peer review treadmill.

Andy Marino, Joe Spadaro, and Dave Murray all submitted proposals of their own late in 1979. Approval of any would have kept the lab open, but the VA director went outside normal procedures to ensure rejection of each one. She chose an ad hoc committee instead of the usual peers to evaluate Spadaro's application. One of the critiques objected to a lack of guidance for him due to the fact that "we understand Becker is retiring." To judge Marino's plan for testing the three methods of electrical osteogenesis for long-term side effects, she bypassed the reviewers who would have been chosen routinely, picking instead someone who had no trainning in orthopedics but who could be counted on to reject anything remotely associated with me.

This man, a well-connected Purdue University embryologist, had for several years been making it a habit to ridicule my work in some of his own papers, while using it without credit as the basis of his own in other publications. In 1978, in response to a Saturday Review article describing regeneration work by me and others, a member of his lab had written a long, vituperative letter to the editor accusing me of "bad science" that had "made life difficult" for real researchers like him and his partners. He accused me of falsifying data on the rat limb experiment. He said the results I'd reported in three days were impossible, even though he'd never bothered to repeat the experiment himself. He ridiculed a claim that blastemas arose from white blood cells, an assertion that neither I nor anyone else had ever made. He accused me of misquoting other scientists' work to support my own ends. He charged me and Stephen Smith with trying to pass off a photo of an intact frog as one that had regrown a complete leg in one of Smith's experiments. Finally, he castigated me for avoiding scientific journals in favor of publishing my results in the popular press, even though I'd had well over a hundred papers printed in the peer-reviewed literature.

Steve Smith was moved to answer the letter point by point, closing with a denunciation of establishment scientists who responded to new ideas with ridicule and slander. Furthermore, he concluded, "I do not understand the rationale of those who feel that research is some obscure process whose results should be made known to the public only as a series of miraculous revelations. The decision as to what kind of research to support is essentially a political one in this day and age, and I firmly believe that an informed public opinion is a much better basis for that decision than general obfuscation."

Normally even the most scurrilous charges are thrashed out in the technical journals, however inadequate that process may be. The letter writer, however, took it upon himself to send a copy to one of the overseers of NIH funding. I suppose I could consider myself lucky that by then there was no more damage anyone could do me in that quarter.

The eminent embryologist's vendetta continued into 1980. In February of that year, the Purdue Office of Public Information issued a press release lauding the great man's own research and presenting him as a white knight doing single combat against "myths." In it he accused me of "plain ordinary fraud," repeating the accusations from his assistant's letter. As a result, I sent the president of Purdue a long, detailed letter itemizing his employee's actions during the past several years, and threatening to sue both him and the university. Immediately I got a call from the embryologist, in which he claimed he never meant anything like that, and asking what I planned to do. I asked to see some apologies

in writing, and soon I received a nice letter expressing "deep regrets" for the "rather garbled" press release and belatedly acknowledging that he would never have done any regeneration work without the stimulus of Smith's experiments, which in turn had descended from mine.

The point of summarizing this embarrassing behavior is that, at about the same time he was talking with the Purdue press office, this gentleman was also writing the "impartial" review of Andy's proposal. We know who did the job because, in the small family of regeneration workers, the fellow's contentious style and his practice of quoting mainly his own research are immediately recognizable. His critique repeated some of the same old charges against my own work, even though the proposal wasn't mine. At one point he objected that one of Andy's experimental controls was to use the devices on healthy bone. He sniffed, "I am not aware that physicians are electrically stimulating uninjured bone in humans." Of course they weren't, but that part of the procedure was the perfect way to test for side effects in normal bone—the whole point of the experiment. The reviewer also wondered why some of the animals were to be sacrificed after one or two months while looking for long-term effects, knowing as well as any researcher that this was the normal way of following changes in tissue. After all this, he complained that there were no controls, when in reality the controls were to consist of animals allowed to live out their normal life-spans (which he conveniently overlooked), as well as the very procedures he objected to.

Several paragraphs of the pink sheets were deleted. Perhaps they contained more vitriol than even the VA thought was suitable for me. Another revealing criticism was left in, however. Since Andy had been part of my lab, the reviewer felt that I "would exert considerable influence on the character of the research proposed here," and for him that was an unacceptable contamination.

The denouement was completely predictable. All the proposals were rejected. We continued to work through 1980, supported at a low level of productivity by the interim funds. I kept a small part of the tissue culture lab going with a little money from the company that had made the black boxes for our bone-healing stimulators. In it we did a scaled-down version of Andy's proposed experiment to test for stimulation of malignant cells from electrical osteogenesis—and found it.

From January through June of that year, most of our energy went into drafting one last proposal and trying to get a fair hearing from someone else in the VA. This time we stipulated right in the proposal that I would officially retire and that Dave Murray would become the lab's principal investigator. Of course, the research director knew that I

would still talk to these people, and on December 19 we were informed by phone of the final repudiation. As a last-ditch effort, I wrote a letter of appeal to the chief VA administrator, who'd shown favorable interest in our work a couple of years before. I asked him for a hearing and investigation, but to no avail.

The lab ceased to exist on New Year's Day 1981. The local VA chief had the gall to offer Andy and Joe jobs as night administrative officers. Instead, Marino went to work at Louisiana State University Medical School in Shreveport, where he still investigates the positive silver technique on a small scale. Spadaro also remained in orthopedic surgery, at the SUNY Upstate Medical Center right there in Syracuse. Maria Reichmanis decided she'd had enough of professional science, quit research entirely, and got married. This was the end of the foremost group working toward limb and spinal cord regeneration and one of the few bioelectromagnetism labs outside the DOD-industry orbit.

I've taken the trouble to recount my experience in detail for two reasons. Obviously, I want to tell people about it because it makes me furious. More important, I want the general public to know that science isn't run the way they read about it in the newspapers and magazines. I want lay people to understand that they cannot automatically accept scientists' pronouncements at face value, for too often they're self-serving and misleading. I want our citizens, nonscientists as well as investigators, to work to change the way research is administered. The way it's currently funded and evaluated, we're learning more and more about less and less, and science is becoming our enemy instead of our friend.

Glossary

Apatite: The mineral fraction of bone, microscopic calcium phosphate crystals deposited on the preexisting collagen structure of the bone, making it hard. See also Collagen.

Axon: The prolongation of a nerve cell that carries a message, or stimulus, away from the cell body. For example, a motor nerve cell axon carries a contraction stimulus to a muscle. See also Dendrite, Neuron.

Base pair: An association between two of the four fundamental chemical groups that make up all DNA and RNA molecules. Base pairs are the smallest structures that form units of meaning in the genetic code. The more base pairs, the larger the molecule.

Biological cycles: Changes in the activities of living things in an ebb-and-flow pattern. Such changes occur in almost all physical aspects, including sleep-wakefulness, hormone levels, and numbers of white cells in the blood. The predominant pattern is approximately twenty-four hours and usually follows the lunar day closely. See also Orcadian rhythm.

Blastema: The mass of primitive, unspecialized cells that appears at the site of an injury in animals that regenerate. Blastema cells specialize and form the replacement part.

Circadian rhythm: The predominant biological cycle of all living things, from Latin circa ("approximately") and dies ("a day"). See also Biological cycles.

Collagen: A protein that makes up most of the fibrous connective tissue that holds the body's parts together. Tendons, ligaments, and scar tissue are

composed almost entirely of collagen. It also forms the basic structure of bone. See also Apatite.
Crystal lattice: The precise, orderly arrangement of atoms in a crystal, forming a netlike structure.
Dedifferentiation: The process in which a mature, specialized cell returns to its original, embryonic, unspecialized state. During dedifferentiation the genes that code for all other cell types are made available for use by de-repressing them. See also DIFFERENTATION, Gene, Redifferentiation.
Dendrite: The prolongation of a nerve cell that carries a message, or stimulus, toward the cell body. For example, sensory nerve cell bodies receive stimuli from receptors in the skin via their dendrites. See also Axon, Neuron.
Differentiation: The process in which a cell matures from a simple embryonic type to a mature, specialized type in the adult. Differentiation involves restricting, or repressing, all genes for other cell types. See also De-differentiation, Gene, Redifferentiation.
DNA: The molecule in cells that contains genetic information.
Ectoderm: One of three primary tissues in the embryo, formed as differentiation (cell specialization) is just beginning. The ectoderm gives rise to the skin and nervous system. See also Endoderm, Mesoderm.
Electrode: A device, usually metal, that connects electronic equipment to a living organism for the purpose of measuring electrical currents or voltages in the organism, or delivering a measured electrical stimulus to the organism.
Electrolyte: Any chemical compound that, when dissolved in water, separates into charged atoms that permit the passage of electrical current through the solution.
Embryogenesis: The growth of a new individual from a fertilized egg to the moment of hatching or birth.
Endoderm: One of three primary tissues in the embryo, formed as differentiation (cell specialization) is beginning. It forms the digestive organs. See also Ectoderm, Mesoderm.
Epidermis: The outer layer of skin, having no blood vessels.
Epigenesis: The development of a complex organism from a simple, undifferentiated unit, such as the egg cell. It is the opposite of preformation, in which a complex organism was thought to develop from a smaller, but similarly complex, antecedent, such as the homunculus that some early biologists thought resided in the sperm or egg cell.
Epithelium: A general term for skin and for the lining of the digestive tract.
Exudate: Liquid, sometimes containing cells, that diffuses out from a wound or surface structure of a living organism. Examples are a wound exudate and the slime exudate from the skin of fish.

Galvanotaxis: The movement of a living organism toward or away from a source of electric current.
Gene: A portion of a DNA molecule structured so as to produce a specific effect in the cell.
Gene expression: Specific structure and activity of a cell in response to a group of genes coded for such activity. For example, genes coded for muscle cause a primitive cell to assume the structure and function of a muscle cell.
Glia: A tissue composed of a variety of cells, mostly glial cells, that makes up most of the nervous system. These cells have been considered nonneural in the sense that they cannot produce nerve impulses. Therefore they have been thought unable to transmit information, rather having protective and nutritive roles for the nerve cells proper. This concept is changing. It is now known that glial cells have electrical properties that, while not the same as nerve impulse transmission, enable them to play a role in communication in the body.
Hertz: Cycles per second, the unit for measuring the vibratory rate of electromagnetic radiation. Named for Heinrich Hertz, German physicist who made the first experimental discovery of radio waves in 1888.
Homeostasis: The ability of living organisms to maintain a constant "internal environment." For example, the human body maintains a constant amount of dissolved oxygen in the blood at all times by means of various mechanisms that sense the oxygen level and increase or decrease the breathing rate.
In vitro: An experiment done in a glass dish on part of a living organism.
In vivo: An experiment done on an intact, whole organism.
Magnetosphere: The area around the earth in which the planet's magnetic field exerts a stronger influence than the solar or interplanetary magnetic field. It extends some 30,000 to 50,000 miles from the earth's surface. A prominent feature of the magnetosphere is the Van Allen belts, areas of charged particles trapped by the earth's magnetic field.
Magnetotactic: Active movement toward a magnetic pole.
Mesoderm: One of three primary tissue layers in the embryo, which develop as differentiation (cell specialization) begins. It becomes the muscular and circulatory system in the adult.
Mitosis: Cell division. Actual division takes only a few minutes but must be preceded by a much longer period during which preparatory events, such as duplication of DNA, take place. The entire process generally takes about one clay.
Neoblast: An unspecialized embryonic cell retained in the adult bodies of certain primitive animals and called to the site of an injury to take part in regenerative healing.

Neuroepidermal junction: A structure formed from the union of skin and nerve fibers at the site of tissue loss in animals capable of regeneration. It produces the specific electrical currents that bring about the subsequent regeneration.
Neurohormone: A chemical produced by nerve cells that has effects on other nerve cells or other parts of the body.
Neuron, or neurone: A nerve cell.
Neurotransmitter: A chemical used to carry the nerve impulse across the synapse.
Osteoblast: A cell that forms bone by producing the specific type of collagen that forms bone's underlying structure.
Osteogenesis: The formation of new bone, whether in embryogenesis, postnatal development, or fracture healing.
PEMF: Pulsed electromagnetic field.
Periosteum: A layer of tough, fibrous collagen that surrounds each bone. It contains cells that turn into osteoblasts during fracture healing.
Photoelectric material: A substance that changes light into electrical energy, producing an electric current when light shines on it.
Piezoelectric material: A substance that changes mechanical stress into electrical energy, producing an electrical current when deformed by pressure or bending.
Potential: Another term for voltage, which may at times be limited to a voltage that exists without a current but is potentially able to cause a current to flow if a circuit is completed.
Preformation: See Epigenesis.
Pyroelectric material: A substance that changes thermal energy into electrical energy, producing an electric current when heated.
Redifferentiation: The process in which a previously mature cell that has dedifferentiated becomes a mature, specialized cell again. See also Dedifferentiation , Differentiation .
Salamander: Any of a group of amphibians related to frogs but retaining a tail throughout their lives. Salamanders live in water or moist environments. Most are 2 to 3 inches long, but some grow to more than a foot in length. Since salamanders are vertebrates, with an anatomy similar to ours, and since they regenerate many parts of their bodies very well, they are the animals most commonly used in regeneration research.
Schwann cells: The cells that surround all of the nerves outside of the brain and spinal cord. See also Glia.
Sciatic nerve: The main nerve in the leg. It includes both motor nerve fibers carrying impulses to the leg muscles and sensory nerve fibers carrying impulses to the brain.

Semiconduction: The conduction of electrical current by the movement of electrons or "holes" (the absence of electrons) through a crystal lattice. It is the third and most recently discovered method of electrical conduction. The others are metallic conduction, which works by means of electrons traveling along a wire, and ionic conduction, which works by movement of charged atoms (ions) in an electrolyte. Semiconductors conduct less current than metals but are far more versatile than either of the other types of conduction. Thus they are the basic materials of the transistors and integrated circuits used in most electronic devices today.

Superconduction: The conduction of an electrical current by a specific material that under certain circumstances (generally very low temperatures) offers no resistance to the flow. Such a current will continue undiminished as long as the necessary circumstances are maintained.

Synapse: The junction between one nerve cell and another, or between a nerve cell and some other cell. See also Neurotransmitter.

Undifferentiated: Unspecialized, a term applied to cells that are in a primitive or embryonic state. See also Dedifferentiation, Differentiation, Redifferentiation .

Vertebrate: Any of the animals that have backbones, including all fish, amphibians, reptiles, birds, and mammals. All vertebrates share the same basic anatomical arrangement, with a backbone, four extremities, and similar construction of the muscular, nervous, and circulatory systems.

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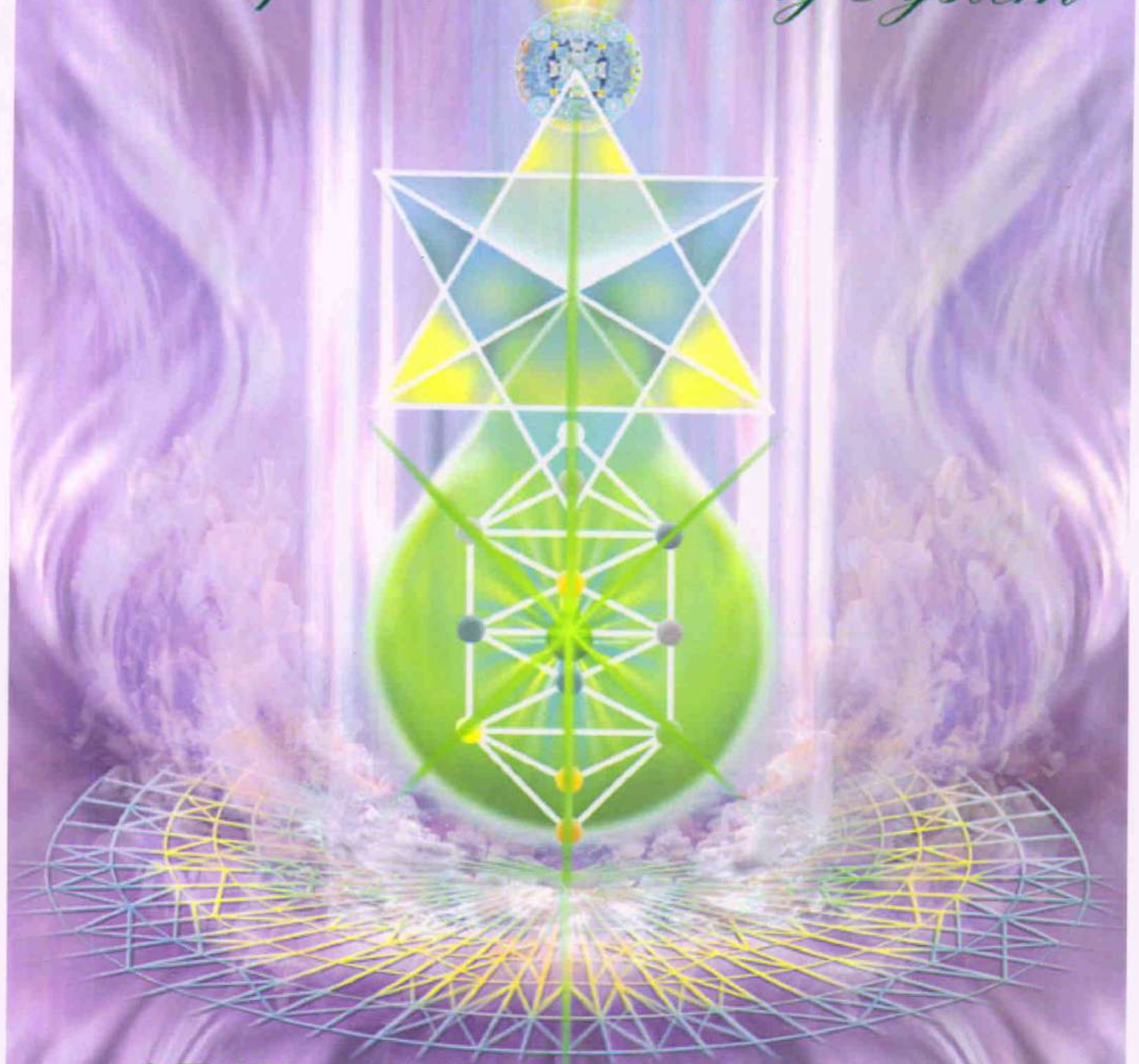

LEVEL 1 CERTIFICATE PROGRAM

by A'sha-yana Deane

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INTRODUCTION TO KATHARA BIO-REGENESIS TECHNOLOGIES

COLOR, SYMBOL, SOUND AND BIO-REGENESIS TECHNOLOGIES

BIO-REGENESIS TECHNOLOGIES are tools to assist us in accelerating our expansion of consciousness through natural, gentle stimulation of the personal **DNA TEMPLATE, KUNDALINI ENERGIES, CHAKRAS AND MERKABA VEHICLE.** Bio-Regenesis techniques are built upon the foundations of **KEYLONTIC MORPHOGENETIC SCIENCE** and advanced **SCALAR MECHANICS,** as understood by races of higher evolution; these are paradigms of science not yet recognized or validated by contemporary earth science paradigms. Because Bio-Regenesis technologies are based upon what is viewed by modern earth science paradigms as a speculative rather than verifiable science, I present Bio-Regenesis techniques only as an option to explore in meditation.

Bio-Regenesis technologies were taught as "Common Knowledge" within the Ascension Schools of Pre-Ancient advanced human cultures and were utilized as standard practice in pre-ancient time periods. Bio-Regenesis Technologies are built upon the natural laws of scalar wave mechanics. Bio-Regenesis Techniques are **SPECIFIC APPLICATIONS OF CONSCIOUS ENERGY DIRECTION WITHIN THE MANIFESTATION TEMPLATE OF THE BODY** that stimulate into activity dormant portions of the personal Manifestation Template, which allows for a natural, progressive and accelerated advancement of the personal **ORGANIC EVOLUTIONARY BLUEPRINT** of the 12th-Dimensional Omni-polar Pre-matter Template. Bio-Regenesis Techniques simultaneously create subtle, natural acceleration within the interwoven energy systems of the DNA Template, Chakra System, Merkaba Fields, Kundalini energies, higher dimensional consciousness, and "Subtle Energy Body" anatomy.

In the Bio-Regenesis paradigm it is said that such techniques allow an individual to affect the function of the scalar wave template of the body, working co-creatively **under the direction of the individual's own higher dimensional levels of consciousness.** As the higher dimensional levels of the personal identity, the spiritual identity of the Soul, governs the processes of the personal Manifestation Template, Bio-Regenesis Technologies are completely safe and natural to the organic design of the human being. Using processes of Bio-Regenesis from the earthly conscious perspective expedites the natural processes of energy and consciousness by which the higher identity and earthly identity integrate to become one. In advanced ancient human cultures, Bio-Regenesis Technologies represented a natural attribute of consciousness expansion into the realms of higher evolution and assisted to biologically prepare humans for **STAR GATE** passage or **"ASCENSION".**

If we can understand that the **HUMAN MIND** is an energy force that **CONTINUALLY GENERATES PATTERNS OF SCALAR WAVES** through the process of **THOUGHT,** it is not difficult to understand how **APPROPRIATELY DIRECTED THOUGHT** can directly influence the function of the personal Manifestation Template scalar blueprint. All thoughts serve this purpose, and directly effect the observable state of the mind-body-spirit system and the manifestation of events within the external life drama. **THOUGHTS ARE THINGS- *SCALAR WAVE CONFIGURATIONS*** of multi-dimensional vibrating patterns of **BI-POLAR ELECTROMAGNETIC ENERGY RADIATION,** which form **SPECIFIC PATTERNS OF SCALAR FREQUENCY** within the personal Manifestation Template.

Undirected thought creates chaotic patterns within the Manifestation Template, while thought directed through clear intention creates ordered patterns within the Manifestation Template. Thought directed with clear intention and **KNOWLEDGE OF THE STRUCTURE OF SUBTLE-BODY ANATOMY,** is a very potent form of **SCALAR POWER.** The patterns of scalar energy frequency that thought projects into the personal Manifestation Template serve as **ELECTROMAGNETIC OPERATIONAL INSTRUCTIONS** within the Template, directly effecting the

conditions that will be met in manifest experience. To develop skill in the manifestation process, the conscious "intending" mind must become more familiar with the **"LANGUAGE OF SCALAR WAVES"**, as this is the **"LANGUAGE OF LIGHT AND SOUND"** upon which the Manifestation Template operates. The "language of scalar waves" is "spoken" through the forms of specific wave spectra, forms that appear to the conscious 3-dimensional mind as frequencies of **SOUND**, spectra of LIGHT or **COLOR**, and shapes or **SYMBOLS**.

What we perceive as color is specific spectra of **LIGHT-RADIATION WAVES** that have a specific measurable **WAVELENGTH** and vibrational **ENERGY SIGNATURE**. In using the conscious mind to direct quantities of color, we are **CONSCIOUSLY SELECTING SPECIFIC SCALAR FREQUENCIES** to add to the Manifestation Template. When we use the conscious mind to create images of **SYMBOLS**, we are further **SPECIFYING THE ARRANGEMENT OF SPECIFIC FREQUENCIES**, as they will appear within the Manifestation Template. **SYMBOL FORMS** (even those that compose the alphabets of outer languages) represent **SCALAR-WAVE GUIDES**, and directly affect the contours of the scalar wave blueprint of the Manifestation Template. The Manifestation Template governs the function of the body and consciousness within the manifest experience, and so the **"Language of Scalar Waves"** is the medium through which we gain conscious access to the **CASUAL LEVEL OF MANIFESTATION**. In using **color and symbol** to direct frequency, we are creating a pattern of energy that has a specific vibrational signature or **"TONAL SOUND SIGNATURE"**, which directly interfaces with the energetic vibrational sound signature of the Manifestation Template's scalar grid.

In Bio-Regenesis technology, Color and Symbol are used to direct the **TONAL SCALAR ARRANGEMENTS** of the Manifestation Template, to create natural, desired results within the body-mind-spirit system. There are many complexities within the process of conscious manifestation that one must learn to fully master the contours of space, time and matter. The beginning step is learning to give more finely tuned thought intention **"PROGRAMMING INSTRUCTIONS"** to the personal Manifestation Template. Thoughts and images rendered in **external language** and 3-dimensionally associated symbols affect the **outer layers** of the Manifestation Template, but they do not provided as finely tuned manifestation instructions as do the **"scalar wave languages"** of Color and Symbol image, which direct the contours of vibrational patterns of SOUND. Mastery within the interdimensional spectrum progressively develops as one masters the core **"PROGRAMMING LANGUAGES"** of **Color, Symbol** and **Sound Vibration**.

In **MIND TECHNOLOGIES**, such as **CREATIVE VISUALIZATION** and **VERBAL AFFIRMATION**, beginning skill in **SCALAR TEMPLATE PROGRAMMING** is developed through using emotionally charged images and precise sound patterns in the language to which we are accustomed, as methods to begin gaining conscious control over the processes of personal manifestation. Keylontic Science **BIO-REGENESIS TECHNOLOGIES** take us **ONE STEP DEEPER** into the manifestation process, by directly employing the **LANGUAGE OF SCALAR WAVES** and directing the **ENCODED INSTRUCTIONS** through **PRECISE LOCATIONS** within the body-mind-spirit system and the Manifestation Template upon which this system is built. Bio-Regenesis technologies take us from speaking the language of the 3-dimensional mind into speaking the intrinsic scalar-wave language of the Spirit, which is the **CASUAL ELEMENT** behind and within all manifestation.

Bio-Regenesis Technologies represent applications of Scalar Mechanics that utilize the inherent power of **SUBTLE WAVE FORMS** to created desired change within the core Manifestation Template of the body. Within this process, **COLOR** and **SYMBOL** become the **TOOLS** through which the 3-dimensionallyconscious mind becomes empowered to participate in conscious co-creation with the Soul and higher dimensional spiritual portions of identity. **Color** and **Symbol**

possess power as **MATHEMATICALLY ENCODED** directors of scalar frequency; the ultimate effect of this directed power is the ability to affect the scalar arrangements of the **Manifestation Template.** Intrinsically, **scalar waves** are specific points of vibrating bi-polar energy signatures. Vibration of energy units creates patterns of internal and external **SOUND,** within and beyond the range of 3-dimensional detection. The Manifestation Template can be conceptualized as an **INTERWOVEN FABRIC OF SOUND FREQUENCY,** the "Silent Symphony" of personal and universal being. The tools of Color and Symbol affect the scalar-wave arrangement of the Manifestation Template, and thus alter the vibrational patterns of **SOUND TONES** within the personal blueprint. **COLOR AND SYMBOL are tools for the direction of SOUND,** and intentional application of **SPECIFIC SOUND TONES** can also be used in conjunction with Color and Symbol, to further amplify one's power to interact with the Manifestation Template.

Along with the techniques of Color and Symbol direction, **TONING,** or the **intentional generation of specific sounds to affect the Manifestation Template,** is also utilized in Bio-Regenesis technologies and spiritual expansion programs. "Toning Therapies" have emerged in recent years through the New Age and Holistic Healing paradigms, and have been applied for thousands of years, within the practices of spiritual masters in every religious tradition. SPOKEN LANGUAGE itself is a form of TONING, with its accompanying SYMBOL ALPHABET, and like all Symbols and Sound Tones, our languages directly affect the personal Manifestation Template, and the level of consciousness that can manifest through the body. In ancient cultures, the powers of language were better understood than they presently are in contemporary mainstream society. Particularly within the Priest-casts of ancient religions, language was used more consciously, with an understanding that words, sounds and images would directly effect the consciousness of the masses. Prayers, rituals and songs, some of which remain in use today, were used as a means of *altering consciousness*. Some assisted in spiritual development, others were intentionally used to limit and control the consciousness of populations.

The contemporary earth science paradigm is only beginning to explore the power of sound vibration and the connection between sound, symbol and color is not yet recognized or understood. **In advanced pre-ancient cultures, these sciences of Scalar Mechanics were fully understood and utilized in the most powerful of ways.** Color-Symbol-Sound technologies were not only used in **Bio-Regenesis** applications for personal health and consciousness expansion; they were also used among **GROUPS OF PEOPLE** to directly interface with the scalar-wave Manifestation Template of the **PLANTETARY SHIELDS.** Vortices, Time Portals, Star Gates, Ley Lines and free energy systems generated through the planetary core and solar light emanations were all **DIRECTED THROUGH THE FOCUSED MIND,** utilizing knowledge of Color-Symbol-Sound Scalar Mechanics. Since the fall of ancient cultures, which came as a result of abusing the powers of these Scalar technologies, the Color-Symbol-Sound sequences once used to direct massive amounts of power became the **"HIDDEN AND FORBIDDEN SACRED KNOWLEDGE".**

The **COLORS, SYMBOLS** and **SOUNDS** used in Bio-Regenesis techniques are not simply random choices. The elements of Bio-Regenesis technique are drawn from a **UNIVERSAL STANDARD LANGUAGE OF "SCALAR SPEAK",** through which **precise scalar frequencies** are generated through **specific Color-Symbol-Sound sequences** to create very specific effects within Manifestation Templates. The Bio-Regenesis Techniques presently offered represent only the beginning of our reawakening to this vast body of Sacred Science knowledge. Many Bio-Regenesis techniques utilizing Color-Symbol sequence scalar mechanics are accompanied by a corresponding exercise in **TONING.** Within the mystical **Ascension Schools** of ancient and pre-ancient times, there existed a very **SACRED SERIES OF TONING SEQUENCES** that were used **to directly interface with the DNA TEMPLATE** and the **AXIOM LINES** in the **PLANETARY**

SHIELD. On a **personal level,** through this specific series of Toning, dormant strands in the DNA Template could be progressively brought into activation, to expedite the process of Spiritual Actualization, Holistic Healing and building of the **PERSONAL MERKABA VEHICLE** within the bio-energetic field. On the **planetary level,** these **Sacred Toning Sequences** were used to **ENERGETICALLY OPEN** the **PLANETARY AXIOM LINES** for **CLEARING, REPROGRAMMING AND ACCELERATING THE ACTIVATION** of the **PLANETARY SHEILDS.** This series of Sacred Toning was collectively called **"THE MUSIC OF THE SPHERES".**

THE SONGS OF THE SPHERES

The **MUSIC OF THE SPHERES** represents the **ORGANIC TONAL SEQUENCES** of **EACH DIMENSIONAL FREQUENCY BAND** within the 15-Dimensional Time Matrix; the **CONSOLIDATED CORE VIBRATIONAL SOUND SIGNATURES** of each Dimensional frequency band. Of the 15 core vibrational signatures of the 15 Dimensions in a Time Matrix, 12 of these core signatures serve as the **PRIMARY 12 TONAL SEQUENCES** upon which each strand of the 12-Strand original human **DNA Template,** and each **AXIOM LINE** in the 4-Density **Planetary Shields are structured. In using the Tone Sequences of the Music of the Spheres,** the 12-Strand DNA Template can be **PROGRESSIVELY BROUGHT INTO NATURAL ACTIVATION.** Scalar-wave distortions within the Templates for the DNA Strands (which physically manifest as genetic distortions) can be systematically **REALIGNED** with their natural perfect 12th Dimensional **ORGANIC IMPRINT. In using the Music of the Spheres** for work with the **Planetary Shields,** each of the **24 AXIOM LINES** can be **OPENED** and **ENCODED WITH THE PERFECT PATTERN OF THE PLANETARY PLASMA BEAM.** Transmitting the 12th-Dimensional **MAHARIC SHIELD** pattern directly into the **Axiom Lines** in the Planetary Shields is the most rapid method to distribute the program of the **PLANETARY ORGANIC IMPRINT** throughout the 4 Density Levels of the PLANETARY SHIELDS.

In ancient days, the *Music of the Spheres* was used extensively for purposes of self-generated healing and to prepare the physical body for literal passage through the planetary Star Gates (**"Ascension"**). The **specific tone sequences** for each **SINGULAR DIMENSION** (which corresponded to one DNA Strand Template in the 12-Strand blueprint and the inherent Dimension of consciousness that would embody through activation of the strand) are called the **"SONGS OF THE SPHERES".** Each **"SONG"** contained very specific **"word sounds"** (from the first Universal Spoken language) for **lyrics,** and specific **multi-layered tones** (which generated inaudible Tri-tone Standing Waves) for **melody, harmony** and **overtones.** To be effective, the Songs had to be used through the **HUMAN VOICE,** externally or mentally as the **"SINGING OF SONGS".**

The Sacred Songs were sung in combination with directing specific corresponding **COLOR** and **SYMBOL** sequences through the bio-energetic field (or through the Planetary Axiom Lines for Planetary Shield work). **The Songs served to "open" specific areas of the DNA Template, or specific Planetary Axiom Lines, to receive instructions directed by the Color and Symbol sequences.** The tones of the Songs generated specific scalar-wave formations that triggered activation of corresponding configurations within the DNA Template and Planetary Shields. Activation of dormant portions of the DNA Strand Templates or Planetary Axiom Lines "opened" the Strand Template or Planetary Shield to directly receive Color-Symbol scalar wave instructions, through which desired outcomes within the personal or planetary body, and within the external reality experience, could be **"PROGRAMMED"** for manifestation.

The **SCIENCE OF THE MUSIC OF THE SPHERES** was one of the most highly guarded **"SACRED SECRETS"** in pre-ancient cultures, due to the power of interdimensional freedom and conscious manifestation that could be obtained through knowledgeable use of the **SONGS.**

Before the **SONGS OF THE SPHERES** will be fully returned to human awareness, our culture will have to mature enough to demonstrate **spiritually motivated ethical use of power.** Certain SONGS are now being slowly returned, so that we may assist those of higher evolution to realign Earth's Planetary Shield with its original 12th-Dimensional **MAHARIC SHIELD ORGANIC IMPRINT.** One of the **15 SONGS OF THE SPHERES** was provided to us by the Emerald Order. This SONG is used to activate dormant scalar-waves in the **8th DNA STRAND TEMPLATE,** through which the process of activating the dormant **1st-8th Strands** of the 12-Strand DNA Template can be accelerated, expediting the natural processes of higher dimensional spiritual identity integration.

This SONG is also used to open the **8TH AXIOM LINE** in **GAIA'S PLANETARY SHIELD,** to facilitate realignment of **Earth's Planetary Shields** from **ETHERIC MATTER DENSITY-3.** This SONG was given so that **GROUPS** can begin assisting directly in Planetary Grid work, opening specific Axiom Lines and Vortices in the planetary body to help bring Earth's Planetary Shield Manifestation Template into its organic alignment and balance. The SONG that was given is called the **"Ariea Khum Nar'A".** The English language translation is **"THE SONG OF ORION".** This **SONG OF THE 8th SPHERE** corresponds to the **8th-Dimensional level** of the **UNIVERSAL KATHARA GRID** and its **8TH PRIMARY STAR GATE.** It also corresponds to the **8th PLANETARY AXIOM LINE** within the Etheric Matter Density-3 **GAIAN PLANETARY SHIELD** and to the **8th DNA STRAND TEMPLATE** in the human body. The **8th Dimensional STAR GATE** within the **UNIVERSAL KATHARA GRID** is the Star Gate that opens into the **ORION STAR SYSTEM,** thus the name of the **SONG OF THE 8th SPHERE** is **"THE SONG OF ORION".**

Soon the SONGS that correspond to the 11th and 12th –Dimensional frequencies will be provided. Aside from its use in planetary grid work, when used as a **"MANTRA",** repeatedly sung as a focus for the mind in meditation, the ***Ariea Khum Nar'A*** serves to stimulate consciousness expansion into the higher dimensional fields and amplifies and expedites the effects of personal Bio-Regenesis techniques.

THE CONTEXT OF HEALING

The Structure of the Unified Field and the Multi-dimensional Anatomy of Form

- THE HOLOGRAPHIC TEMPLATE
- THE STRUCTURE OF DIMENSIONS, PARTIKI PHASING AND MATTER DENSITY
- UNIVERSAL AND PLANETARY KATHARA GRIDS, THE 12-TREE, KATHARA CENTERS AND LINES, SCALAR SHIELDS, CRYSTAL SEALS AND DIODIC POINTS
- THE UNIVERSAL AND INTERNAL TEMPLAR COMPLEXES
- THE TRANSDUCTION SEQUENCE AND HOLOGRAPHIC REALITY CONSTRUCTION

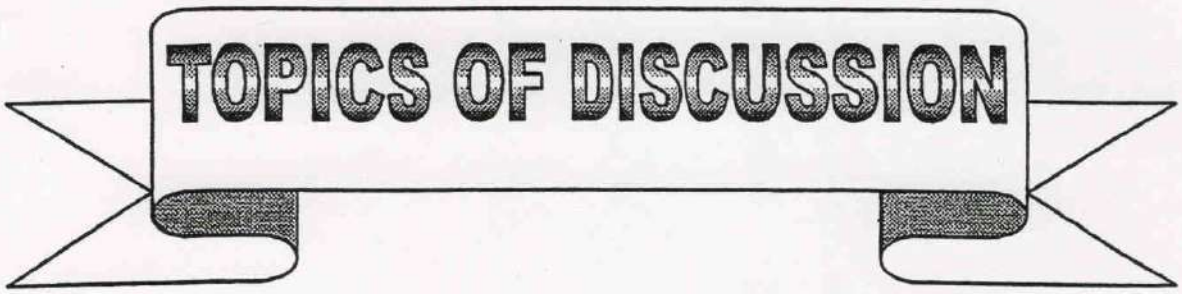

The Ariea Khum-Nar'-A

The Song of Orion

Part 1 : the Resonant Tone Syllable Sequence (primary melody)

Verse 1: OM A Da E, Patum ah
OM A Da E, Patum ah
Patum ah A' DE E - Tah, A khum-na
OM A Da E, Patum ah

Verse 2: TrA TE La E' Durum Na
TrA TE La E' Durum Na
Durum' ah A' Khem - Tah, A khum -na
OM A Da E, Patum ah

Part 2 : the Base Tone Syllable Sequence (accompaniment 1)

OM A Da E, Patum ah - Lines 1, 2 & 4 Verse 1 & Line 4 Verse 2
TrA TE La E' Durum Na - Lines 1 & 2 Verse 2
UM ah OM, A
UM ah OM, A
Patum ah A' DE E – Tah, A khum- na
Durum ah A' Khem – Tah A khum-na
DO RAY' TU Ra"
OM A Da E, Patum ah
UM ah OM, A

Part 3: the Over Tone Syllable Sequence (accompaniment 2)

OM A Da E, Patum ah – Lines 1 & 2 Verse 1
TrA TE La E' Durum Na – Lines 1 & 2 Verse 2
BE HE Tah OM, A
BE HE Tah OM, A

Patum ah A DE E – Tah, A Khum –na – Line 3 Verse1
Durum ah A Khem- Tah, A Khum - na - Line 3 Verse 2
Thra Khem' Na, A
OM A Da E, Patum ah – Line 4 Verses 1 & 2

KhrA MiM, Tah A

THE STRUCTURE OF THE UNIFIED FIELD AND THE CONTEXT OF HEALING

If one is to become fluent in the art and science of **Bio-Spiritual Healing Facilitation**, it is necessary to become familiar with the *primary structures of energy* within which existence takes place. Without this understanding one will be unable to identify the *true nature of systems and their intrinsic functions.* If we do not understand the **intrinsic order of a system** and the elements that make up its parts, our ability to comprehend the *organic functions* of the system will be limited. Without comprehension of the intrinsic dynamics inherent to a system, our perceptions will be limited to observing the **effects of systems function**, rather than perceiving the **causal elements** behind and within the apparent observable effects. In relation to the **health and healing** of the human body, it is wise to view the human **Body-Mind-Spirit organism** as a series of interwoven systems, each with *inherent, implicit order*, the perceivable and observable aspects of which represent the effects of systems function. **The observable effects of the human condition emerge from an as yet unidentified causal order, a hidden and mysterious source out of which the manifest effects of human existence emerge.** Holistic Healing approaches human health and healing in terms of the *interdependent relationships* between *multiple interwoven systems.* The Body-Mind-Spirit organism is viewed in terms of the *intrinsic relationships that unite* the multiple systems of the human being, rather than in terms of the *observable boundaries* that appear to *separate and divide* the multiple systems inherent to the human organism.

Holistic Healing, and **KATHARA Healing** particularly, take the concept of **intrinsic unity** within the seemingly separate systems of the human being one step further than *simple interrelationship* between **physical, mental and spiritual aspects** of human experience. **In the paradigm of Kathara Healing, the human organism is viewed as a set of interwoven systems that is itself part of a larger system of interdependent systems.** The human individual is not only recognized as a *singular set of unified parts*, but rather as an *intrinsic part* of the species, planetary, galactic, universal and cosmic systems within which human existence finds **context** for being. The **Cosmic Unified Field of Energy and Consciousness** is viewed as the **indelible medium** within which all reality takes place, and human existence is viewed in terms of *its relationship to this greater Meta-system* of interwoven, interdependent systems. **The health and wellbeing of the human being is directly related to and effected by the systems-functions of the greater Unified Field.** In order to better understand and facilitate the health and healing of biological organisms, it is useful to understand the *basic order and function* of the **UNIFIED FIELD**- the context in which life itself takes place.

Kathara Healing is an ancient system of **Holistic Healing**, dating back beyond presently identified recorded human history. The principles of **Universal Order** as taught within Kathara Theory present a **broader context of universality** than is presently recognized by contemporary western science. Kathara is built upon **Laws of Multidimensional Universal Physics,** laws of intrinsic nature with which western science is not yet familiar. In Kathara Healing the *hidden order of universal systems* is recognized and the foundations of Kathara *demonstrate the interwoven systems-functions* between the human being and the order of the **Unified Field. To develop proficiency and genuine skill within the art and science of Holistic Healing, the basic order of the Unified Field must be understood.** For with this understanding comes the ability to *directly interact with and influence the causal elements* of the human experience. For this reason the teachings of Kathara Healing begin with providing a basic format through which the **CONTEXT of healing** can be understood ***– a glimpse at the intrinsic order of the Universal Unified Field.***

With foundations grounded in **coherent systems relationships**, the Kathara Healing Facilitator has more knowledge, power and comprehension to bring to the art and science of healing facilitation. **Through comprehension of the *intrinsic systems of universal order*, the Kathara Facilitator progressively evolves to embrace the *unity of SELF within the Unified Field*, opening to an ever-expanding capacity of spiritual awakening and the embodiment of UNCONDITIONAL LOVE.** The physical, mental and spiritual aspects of human anatomy represent one interdependent, interwoven system that is *continually in a state of relationship to the Unified Field.* This relationship must be acknowledged and embraced if true health and healing are to occur. **Human evolution is a Bio-Spiritual process, the body and the consciousness – the biology and the spirit - are inseparably intertwined within themselves and within the greater order of the Unified Field.**

Healing emerges through restoring order to the ONE-SYSTEM and its infinite parts.

THE HOLOGRAPHIC TEMPLATE

The externalization of life, manifestation of matter and individuation of identity are **HOLOGRAPHIC PROJECTIONS of CONSCIOUSNESS-ENERGY SUBSTANCE,** created through an *intrinsic order of energetic relationships.* Energetic relationships represent **interrelationships of consciousness,** in its infinite manifest and de-manifest forms.

Consciousness *IS ENERGY*
And
Energy *IS CONSCIOUS.*

True Science has a *spiritual core* and true spirituality has *its intrinsic translation within the Laws of Energy that govern the manifestation of universal systems.*

Reality is **THOUGHT CONSTRUCTION.** The core substance of the cosmos is **CONSCIOUSNESS.** ***Thought is an attribute of CONSCIOUSNESS,*** the **filter** through which consciousness manifests itself into the **Hologram of Form.**

Nothing is truly solid. All things are composed of *consciousness* and their *apparent solidity* is determined by the *relationship between the consciousness observing the form and the consciousness of which the form is made.* Human consciousness emerges through an **order of dimensionalization,** which sets frameworks within which the *interrelationships of consciousness* can take place. **Human perception of solidity and externalization is determined by the oscillation rates between dimensionalized units of consciousness.** Dimensionalized units of consciousness form **frequencies of energy,** which exist in *specific relationships* to each other. Human *consciousness* (the soul –spirit), and human *physical form* are **patterns of frequency** formed by *dimensionalization of units of consciousness. We perceive manifest solidity due to the relationship between the frequencies of consciousness of which we are made and those of the Unified Field of Conscious Energy around us.* **Humans perceive as solid the frequency bands that exist one full dimensional spectrum below the frequencies within which the individuated or collective consciousness is stationed.**

The only difference between a *thought* and a *manifest thing* is the *frequency of the consciousness of the observer.* Manifest reality is **thought projection,** made solid and externalized by relationships between the *frequencies of our focus of attention* and those of the *projected thought forms.* **We perceive as reality the thought forms of the collective masses as they were placed within the frequency bands that now exist one dimension below the frequencies within which our present focus of collective consciousness is stationed.**

As reality is a **THOUGHT FIELD**, composed of units of consciousness awareness, reality can be directly **AFFECTED by THOUGHT**, as the substance of both thought and reality are one and the same. The **key to mastery** of our present reality and to restoring our **imprint for health**, is understanding the *reality of dimensionalization* within which our consciousness now resides.

The human body is a HOLOGRAPHIC PROJECTION of consciousness that is built upon a *HOLOGRAPHIC TEMPLATE* of structured units of consciousness. The **Holographic Template** represents the **Living Morphogenetic Field** – the *dimensionalized blueprint of conscious light, sound and scalar waves*, within which the individuated consciousness is stationed, and *upon which the illusion of solidity of the body matter is formed.* **To affect *true and lasting change* within the Body-Mind-Spirit System of the human being, one must *go to the core* of its manifest structure – the *Holographic Template* or Thought-energy Blueprint, upon which the entire system of consciousness itself comes to know being.**

The body is a **HOLOGRAM** that can be directly affected by the *substance of which it is composed* – **CONSCIOUSNESS**. In learning the structure of dimensionalization through which the body-illusion manifests, one becomes progressively more masterful in directing this personal thought form to suit ones desired specifications. The core **Holographic Template** of the personal and universal body is called the **Kathara Grid. Kathara Healing** is the process by which the *embodied* aspects of human consciousness become more aware of and able to direct the *intrinsic processes of holographic projection*, with the intention of restoring integrity to the function of the Body-Mind-Spirit system.

***No thing is truly manifest*– it only appears to be so,**
due to the refraction of consciousness
within the energetic relationships inherent to
the *Holographic Template*–
the original *thought-form construct*
upon which our universal structure
is perpetually recreated.

All creatures and things are Spiritual Beings having a Manifest Experience...No creature or thing can be ever divorced from its innate spirituality, but only from the awareness of its nature. For life is the expression and substance of spirit- and manifest reality is but a Dreamscape, from which we eventually all awaken...

The causal element of all manifest experience is called a ***Morphogenetic Field*** or **MANIFESTATION TEMPLATE**. Keylontic Science, the science of Manifestation Templates is part of a larger advanced paradigm of science that is known as **15-Dimensional UNIVERSAL UNIFIED FIELD PHYSICS.**

PRIMAL SUBSTANCE

- A Manifestation Template is made of **PRIMAL SUBSTANCE;** units of conscious energy called **PARTIKI** that exist as ***Omni-polar points of fixed vibration. Partiki units*** are the smallest building blocks of matter, and they form the templates upon which consciousness in all forms enters manifestation.

- Partiki units are **Omni-polar** (containing the potentials for all polarities or none) units of vibrating energy that perpetually cycle back and forth between a state of **BI-POLAR LIGHT RADIATION** (scalar-standing-wave) and **OMNI-POLAR SOUND VIBRATION.**

- In the ***Omni-polar state***, Partiki units exist as invisible, fixed points of ***sound vibration***, forming what is called an **INTERDIMENSIONAL TRI-TONE WAVE.** An Interdimensional ***Tri-tone Wave*** is a singular point of fixed vibration that is composed of ***3 sub-vibrations*** (base tone, overtone and resonant tone). When Partiki units are in their Omni-polar state they exist as ***Ante-matter substance***, the first state of energy organization before Pre-matter manifestation. Through a process of Internal Fission characteristic to their design, Partiki units break apart to form Bi-polar waves, while replicating their original Tri-tone Omni-polar design.

- In the ***Bi-polar state***, two sub-vibrations of the Tri-tonal Standing Waves of Partiki units break down into two sub-units, ***sub-tones***, called **PARTICUM-***Base Tones* and **PARTIKA-***Overtones*, interconnected units of **BI-POLAR LIGHT RADIATION** that form ***Electromagnetic Scalar-Standing-Waves***. The third vibration of the Tri-tone wave, the *Resonant Tone*, remains as the core vibration through which the polarized vibrational units of Particum and Partika will reunite through ***Internal Fusion***.

- **PARTICUM** units form the energetic building blocks for **PARTICLE TEMPLATES** and **PARTIKA** units form the building blocks for simultaneously manifesting **ANTI-PARTICLE TEMPLATES.** Particle and Anti-particle Templates are interconnected, united by the Ante-matter **PARTIKI** units through which they manifest. The effects of **ELECTRICAL AND MAGNETIC FORCE** are set in motion through the **EXPANSION AND CONTRACTION** of energy vibration between Particle and Anti-particle matter units through the Ante-matter Partiki unit that unite them.

- **Particum-Particle units** represent the **CONTRACTION PHASE** of ante-matter energy, with higher **VIBRATION** (energy contracted into or received by the Ante-matter template) and lower **OSCILLATION** (energy expanded or transmitted from the Ante-matter template) and so are considered **BASE MAGNETIC. Partika-Anti-particle units** represent the **EXPANSION**

PHASE of Ante-matter energy, with lower Vibration and higher Oscillation, and are considered **BASE ELECTRICAL.**

- **ELECTROMAGNETIC ENERGY** is created through the continual cycling of energy, as the Omni-polar Ante-matter Tri-tone Wave of ***Sound Vibration*** projects its energy into Bi-polar Particum and Partika Scalar Waves of ***Light Radiation***. Energy thrust expands into the Anti-particle Partika vibration point as **electrical force**. It then contracts into the particle Particum vibration point, creating **magnetic pull**, (in ratio to its original electrical thrust), as the third vibration in the Ante-matter Tri-tone Wave draws the energy back to its source. Through the draw of the Ante-matter Partiki template, Partika-Ante-particles and Particum-particles are brought into a state of **Fusion**. Upon fusion, the energy of the Particum and Partika transmutes, the Bi-polar Standing Scalar Waves of Light Radiation returning to their original Omni-polar Ante-matter state of Partiki units. Once returned to the Partiki state, the process repeats as the Partiki creates Fission and replication. **Partiki, Particum and Partika units represent PHASES that Primal Substance energy passes through as it moves into and out of manifestation.**

- The process by which Partiki units perpetually convert conscious energy into Bi-polar Light Radiation Scalar-Waves (expansion) and back into Omni-polar Sound Vibration Tri-tone Waves (contraction) is called **PARTIKI PHASING**. Through perpetual cycles of Partiki Phasing, matter units "flash on" through **fission**, into Bi-polar Particle and Anti-particle manifestation built upon Scalar Waves of Light Radiation, then "flash off" through **fusion**, into Omni-polar Ante-matter Sound Vibration, continually cycling energy between the manifest and non-manifest state. **The perception of external physical matter, space and the passage of time are created through *variance in relationship* between rates of Partiki Phasing.**

- Consciousness in the form of Partiki Units is the **PRIMAL SUBSTANCE** of which the cosmos is structured and Partiki Phasing is the perpetual **PRIMAL ACT** of reciprocal fission and fusion through which Primal Substance is brought into manifestation.

The Holographic Template

PRIMAL SUBSTANCE

Units of Consciousness, Morphogenetic Fields and Scalar Grids

1. *Partiki, Partika and Particum:*
Smallest units of energy-substance. Electro-tonal units of consciousness that are the building blocks of morphogenetic fields, matter and individuated conscious identity. Operate as minute, perpetual motion fission/ fusion generators.

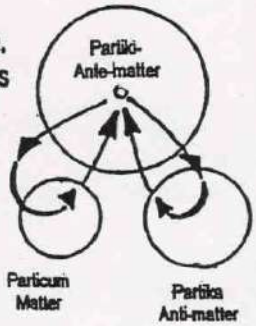

2. *Partiki Grids*: The fabric of morphogenetic field structure. Partiki units group to form interwoven Strands, then Grids of electro-tonal substance, out of which morphogenetic fields are fashioned. Out of a Unified Field of Partiki units, Partiki Grids form to create the frequency bands that make up dimensional fields and then to form individuated morphogenetic fields .

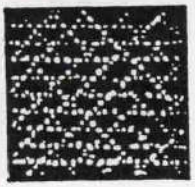

3. Partiki units continue to group or accrete upon the Partiki Grids, forming
A. *Keylons* – crystallizations of "frozen light" (standing scalar wave patterns and fixed points of tonal frequency), and
B. *Keylon Codes* – complex groupings of Keylons, which together form a crystalline template of light spectra, sound frequency and electro-magnetism that is the morphogenetic field Crystal Body– the Blueprint upon which matter and identity will manifest.

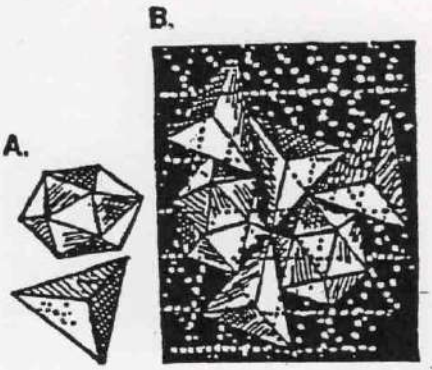

The **Morphogenetic Field** is made of interwoven **Partiki Grids.** The electro-tonal units of consciousness out of which Partiki Grids form create standing wave patterns – **scalar wave grids,** which hold the form of consciousness within dimensionalized manifestation. Morphogenetic Fields are thus **Scalar Grids,** that form in specific ordered interrelationship. Partiki Grids form upon the core *geometrical-mathematical* structure of the **Kathara Grid**, and so the Kathara Grid represents the *core Scalar Field* upon which form manifests.

Morphogenetic Fields govern the form of matter manifestation and the evolution of biology and consciousness. Morphogenetic Field mechanics thus hold the key to mastery of physical reality and Bio-Spiritual Evolution.

THE STRUCTURE OF DIMENSIONS

Frequency Bands and Sub-Frequency Bands, Vibration-Oscillation-Particle Spin, Harmonics of Manifestation and Matter Density Levels.

The Hologram of manifest reality is a complex system of interwoven energy constructs, all built upon **dimensionalized sets of scalar grids**- or fields of standing wave points – that form the **base laws of energy** upon which manifest reality functions.

The physical portions of the human body represent ***wave strata*** that exist within specific relationships to the embodied consciousness. **The embodied consciousness itself is *regulated by the intrinsic behavior of the wave strata* in which it is ensconced.** The wave strata of seemingly physical forms appear to *human detection* in the form of *particles, sub-particles and wave bands* that group to form the 3-dimensionally manifest hologram of human life

The **behavior of dimensionalized wave strata** is an intrinsic element within the function of ***human anatomy***, and provides the *very context* within which human existence and evolution take place. When we come to understand ourselves as **vibrating quantities of conscious energy**, existing within a state of **vibrational co-resonance with all things**, which are themselves *vibrating quantities of conscious energy*, we can begin to understand the **fundamental structures** upon which the human condition is built.

*The human body is a **construct of conscious energy**, a living* morphogenetic field existing within the greater living morphogenetic constructs of the species, planetary, galactic, universal and cosmic morphogenetic structure. We are simply an element of sentient consciousness within a larger structure of sentient consciousness, a part of the **Unified Field of Consciousness** that IS the living identity of the cosmos. Our physicality emerges through the **perceptual lens of dimensionalization**, which provides us with the seeming manifestation of **particles, atoms, molecules** and the **physical systems** built upon them.

If we expect to **heal ourselves** of the manifest conditions that cause suffering within the Body-Mind-Spirit system, we must first understand the **nature of health**, the "way things are supposed to work" when they are *functioning properly*. To understand the intrinsic **Imprint and impetus for health** in the human organism, a basic understanding of the *contents of its parts* is in order. That understanding begins with *identifying the basic reality structures within which we reside, and how we exist in relationship to these structures.*

Our understanding of *health* begins with *identifying the context of existence*, the *Unified Field of Consciousness-Energy* of which we are all a part. **A simple *identification of the structures of the Unified Field* will work wonders in assisting us to understand ourselves, and through this understanding we become more empowered to foster a healthful and more joyous living experience.** To better understand ourselves we must return to the core of our intrinsic nature, the **dimensionalized fields of consciousness** within which we reside and out of which the substance of our SELVES is composed.

The following characteristics inherent to the manifestation of the human hologram are a place to begin our journey of self-understanding.

Characteristics of the Hologram

PRIMAL ORDER

SCALAR WAVES: Points of standing waves, composed of quantities of conscious energy that emanate out of fixed units of vibration (Partiki units), which form the morphogenetic field templates upon and through which consciousness dimensionalizes itself to experience the hologram of manifest reality. Created through Partiki Phasing (internal fission/fusion "flash on/flash off")

MORPHOGENETIC FIELDS: The templates of consciousness, light, sound and scalar standing-wave grids which serve as the structured blueprints upon which our consciousness manifests into dimensionalization, through which the holographic projections of space-time-matter and identity individuation can be experienced.

DIMENSIONS: *Morphogenetic Field Scalar Grids composed of interwoven layers of scalar waves, which serve to direct the flow of consciousness into multiple patterns of refraction through which the hologram of matter density, linear time and objectification of reality can be experienced.* Dimensions are specific structures of consciousness, composed of Partiki units with differing vibratory-oscillation rates, which exist in precise relationship to each other, and govern the intrinsic laws of function within the observably manifest worlds. The process of dimensionalization occurs through the wholeness of consciousness *compartmentalizing itself into various ordered sections having diversity of vibratory-oscillation*, through which the wholeness of consciousness may experience itself in an endless variety of forms. Each dimension represents a full frequency band.

FREQUENCY BANDS: Synchronized, cyclic, repeated sequences of "flashing on and off" of scalar-wave points within the dimensional scalar grids, which gives the appearance of manifest movement of wave spectra within a dimensional system. **Sub-frequency Bands** are shorter segments of the longer "flashing on and off" sequence of the full Frequency Band. The frequency of dimensional levels and the particles within them is determined by the vibratory-oscillation rate of the Partiki units that make up the scalar-wave grid. Frequency is the form consciousness takes on while ensconced within the framework of dimensionalization. Frequency is the vibrating-oscillating wave spectra of which matter particles and dimensionalized consciousness are composed.

VIBRATION-OSCILLATION: Vibration is the condition of **internal movement**, or ***holding of energy within*** units of consciousness (Partiki) and the particles built upon them. Vibration is determined by the **quantity of energy *held within*** Partiki units. **Oscillation** is the condition of **external movement**, or ***expending of energy from*** Partiki units and the particles built upon them.

The vibratory-oscillation rate of particles represents the *rate at which the scalar standing-waves "flash off and on"* within the morphogenetic field template. Vibration is the *internal measure of energy quantity* held *within* Partiki units and exists within direct proportion to the *oscillation* rate, or *external measure of energy quantity expended*, exhibited by Partiki and the particles built upon them.

The vibratory-oscillation rate represents the ratio between energy contraction (vibration) and energy expansion (oscillation), which sets the rhythm of particle pulsation that governs the formation of wave spectra within dimensionalization. The vibratory-oscillation rate of Partiki units determines the **frequency** (cyclic pattern of scalar waves "flashing off and on") of wave spectra within the various levels of the dimensionalized morphogenetic field. **The relationship of vibrational-oscillation between wave spectra determines the matter density levels particles will exhibit within the dimensional scale.**

Vibration-Oscillation Correspondences

Higher Dimensional Fields (8-15)	Lower Dimensional Fields (1-8)
Low Vibration	**Higher Vibration**
Higher Oscillation	**Lower Oscillation**
Expanding	**Contracting**
Higher Frequency	**Lower Frequency**
Shorter Wave Length	**Longer Wave Length**
Slower Electron Spin	**Faster Electron Spin**
Less Density	**More Density**
Electric	**Magnetic**
Lower Vibration =	Higher Vibration =
Less energy holding in Partiki =	More energy holding in Partiki =
More energy expended from Partiki =	Less energy expended from Partiki =
Higher Oscillation =	Lower Oscillation =
More expansion =	More contraction =
Faster flash rate of Partiki =	Slower flash rate of Partiki =
Higher Frequency of Flash =	Lower frequency of flash =
More external movement =	More internal movement =
Faster oscillation =	Slower oscillation =
Shorter wave length =	Longer wave length =
Slower electron spin around nucleus =	Faster electron spin around nucleus =
Greater expansion of energy units =	Greater compaction of energy units =
Less density =	Greater density =
Less magnetism =	Greater magnetism =
More electric	Less electrical

The human anatomy is a 15-dimensional morphogenetic field scalar grid structure, composed of wave spectra with varying degrees of matter density characteristic to the dimensional band within which each level of the anatomy is stationed. The portions of our anatomy that appear solid are those stationed one dimension below our focus of conscious attention.

PRIMAL ORDER OF MANIFESTATION TEMPLATES

- Morphogenetic Fields, or the **MANIFESTATION TEMPLATES** that serve as the blueprint through which consciousness manifests, are composed of the Primal Substance of **PARTIKI UNITS.** Partiki units draw together or **ACCRETE** to form **PARTIKI STRINGS.** Following a set **mathematical and geometrical design** inherent to their form, Partiki Strings interweave and overlap, forming a **"Fabric of Light and Sound"** called a **PARTIKI GRID.** A Partiki Grid is a fixed pattern of interwoven Bi-polar Scalar-Waves of light radiation,built upon Omni-polar Tri-tone Waves of sound vibration,that forms the foundation for diversified Manifestation Templates. A **Partiki Grid** is a **SCALAR GRID.**

- Following the precise mathematical design set by the will and intention of the manifesting consciousness, Partiki Grids further accrete, drawing in more Partiki Units, forming groups of Partiki units that are arranged following *3 different rhythms of Partiki Phasing.* **Tri-phase groupings of Partiki Units** form patterns of Scalar-wave and Tri-tone wave interrelationships that create ***crystallizations of energy*** called **KEYLONS.** Groups of Keylons continue to accrete, forming complex Keylon arrangements called **KEYLON CODES,** through which the Manifestation Template is progressively built up from Ante-matter through various stages of matter density, beginning with **PRE-MATTER SUBSTANCE,** the first density of **Liquid Silica Hydro-plasmic** energy to emerge into externalized form.

- The Morphogenetic Fields upon which universes manifest are built upon a Manifestation Template that has a specific order of mathematical interrelationships that govern the combining of Scalar Grids with different rates of ***Partiki Phasing.*** The **Cosmic Manifestation Template** is called the **ENERGY MATRIX.** Within the Energy Matrix there are many smaller manifestation templates upon which Universes are structured. **Universal Manifestation Templates** are called **TIME MATRICES.** There are uncountable Time Matrices within the Energy Matrix, which are collectively referred to as **THE TIME MATRIX.** All Time Matrices within the Cosmic Matrix follow a specific mathematical-geometrical program through which space, time and matter can be experienced by consciousness upon entering the Time Matrix structure.

- Time Matrices are arranged upon a pattern of 15 different, but interwoven, Partiki Phasing rhythms (rhythms of expansion and contraction of energy). Each of the 15 rhythms of Partiki Phasing creates one **DIMENSION.** A **Dimension** is a set pattern of **"FLASH LINE SEQUENCES"**, or a cycle of singular Partiki Phasing rhythms that contains within it 12 smaller rhythms of Partiki Phasing. Each **Dimensional Manifestation Template** creates a set of fixed Scalar-Tri-Tone Wave Points that create a template of stationary **SCALAR FREQUENCY.** Each Dimension represents one **SCALAR FREQUENCY BAND** containing 12 smaller **SUB-FREQUENCY BANDS.** A **Scalar Frequency Band** is a cyclic pattern of specific Partiki Phasing Rhythms, or **EXPANSION AND CONTRACTION RATIOS OF ENERGY CIRCULATION,** to which consciousness conforms in order to enter the experience of manifestation.

- To create the Universal Manifestation Template upon which external space, time and matter experience can be known, Dimensions are ordered into sets of 15, forming the blueprint for a

15-Dimensional Time Matrix. Within a Time Matrix the 15-Dimensions are further arranged into sets of **3 Dimensions**, forming **5 3-Dimensional reality fields**. Each 3-Dimensional Reality Field is called a **HARMONIC UNIVERSE**, and each represents a **level of matter densification** specific to its intrinsic rates of Partiki Phasing. One Time Matrix is thus a **15-Dimensional Scalar Grid** with 5 separate yet interwoven reality fields and 5 different densities of matter manifestation.

- Each of the 5 Harmonic Universes within a Time Matrix represents a **TIME CYCLE**. A Time Cycle is a fixed, repeating pattern of Partiki Flash Line Sequences, or a repeating cycle of specific ratios of energy expansion-oscillation and contraction-vibration. The Time Cycle of a Harmonic Universe is called an **EUIAGO CYCLE**. There are **5 simultaneously manifesting Euiago Cycles in every Time Matrix**, through which consciousness passes in order to experience linear evolution through space, time and matter. Each Euiago cycle contains within it 6 smaller Flash Line Sequences forming 6 smaller cycles of time called **TIME CONTINUUA**.

The **PRIMAL ORDER of Manifestation Templates** represents the core mathematical and geometrical interrelationships of energy that consciousness takes on in order to enter the holographically projected experience of external space, time and matter. All manifest forms, including the **HUMAN BODY** and **PSYCHE** , are built upon a Manifestation Template that begins with the Primal Order of Dimensionalization, through which the consciousness anchors itself into the Time Cycles of the Universal Manifestation Template Time Matrix, to begin the experience of evolution through time.

Understanding the **PRIMAL ORDER OF DIMENSIONAL STRUCTURE**, as it pertains to the human organism, allows for comprehension of the greater causal framework through which personal healing must occur. Such comprehension of the core causal structure of manifestation enables one to work cooperatively, rather than in resistance to, the natural **Universal Laws of Manifestation**, progressively restoring the **NATURAL HARMONIC ORDER** of wellbeing and **DIVINE RIGHT FORM**, through which the indelible **Organic Imprint for Health** can be progressively restored.

Dimensional Structure

A Dimension represents a full ***Frequency Band***, or repeating, cyclic sequence of "flashing on and off" scalar-wave points within a morphogenetic field. The morphogenetic field scalar grid structure of dimensions takes the form of ***sets of 15-Dimensional Matrices***. The 15 Dimensions are grouped into sets ***of 3 Dimensions each***, forming ***5 sets of 3-dimensional reality fields*** called **HARMONIC UNIVERSES**. The 15-Dimensions composing the 5 Harmonic Universes together represent one TIME MATRIX system.

Each dimension of frequency is composed of **12 Sub-frequency Bands**, or shorter cycles of the "flashing on and off" of scalar-wave points, which exist as part of the longer cycle of the full Dimensional Frequency Band. The Partiki in each dimension have a specific rate of **vibratory-oscillation** (contraction and expansion of energy), which determines the **Angular Rotation of Particle Spin** (angular axis upon which particles will spin). There is a **90-degree shift of angular rotation** of particle spin between each dimensional frequency band and a **45-degree reverse shift** between **Harmonic Universes** (sets of 3 dimensions/frequency bands.)

Particles having varying vibratory-oscillation rates and angles of spin allow multiple dimensional reality fields to co-exist within the same space while remaining perceptually invisible to each other. The *relationships between wave strata* within the dimensional frequency bands create the **holographic refraction** of light, sound and scalar waves that allows consciousness to *perceive the illusions of* **matter solidity, space, time and externalization of reality** while it is ensconced within the structures of dimensionalization.

One 15-Dimensional Time Matrix with 5 Harmonic Universes

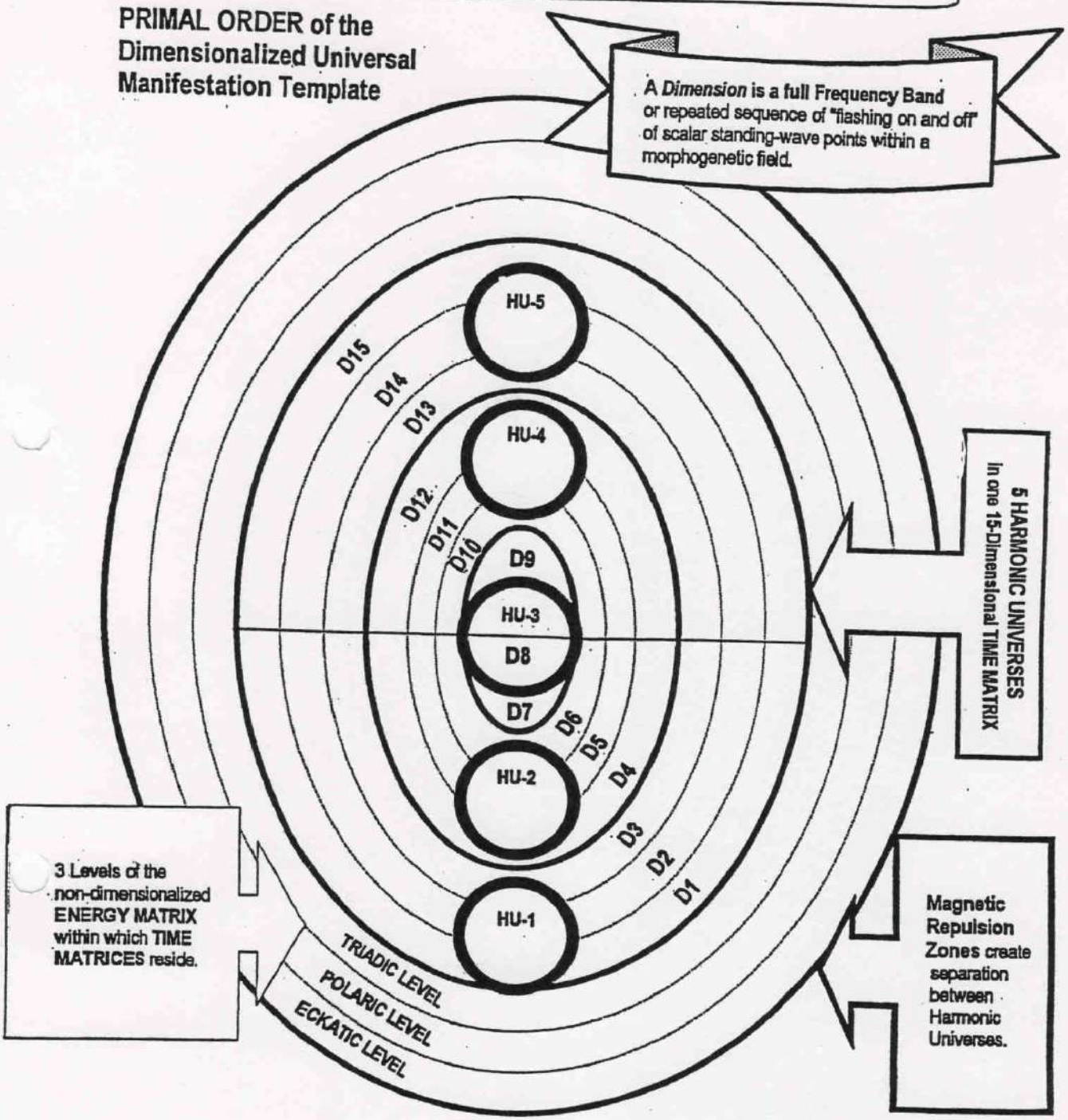

Frequency Bands and Sub-Frequency Bands within the 15-Dimensional Scale

Frequency Bands are cyclic, repeated sequences of "*flashing on and off*" of scalar standing-wave points that create the appearance of manifest wave spectra within a dimensional system. ***Sub-frequency Bands*** are shorter cycle segments of the longer "*flashing on and off*" sequence of the *full* Frequency Band. **Frequency and Sub-frequency Bands make up the foundation wave strata of Dimensions.**

1 Harmonic Universe composed of 3 Dimensions, each Dimension composed of 12-Sub-frequency Bands, for a total of 36 Sub-frequency Bands in **1 Harmonic Universe.**
(3 D per 1HU x 12 SFB per D = 36 SFB per 1HU)

DIMENSIONS	SFB
D3	12 SFB
D2	12 SFB
D1	12 SFB
	36 SFB (12 x 3)

5 Harmonic Universes in one 15-Dimensional Matrix

Harmonic Universe	Dimensions	180 SFB
H 5	D15	12 SFB
	D14	12 SFB
	D13	12 SFB
H 2	D4	12 SFB
	D5	12 SFB
	D6	12 SFB
H 3	D9	12 SFB
	D8	12 SFB
	D7	12 SFB
H 4	D10	12 SFB
	D11	12 SFB
	D12	12 SFB
H 1	D3	12 SFB
	D2	12 SFB
	D1	12 SFB
		180 SFB (12 x 15)

15 Dimensions with 12 Sub-frequency Bands each create **180 Sub-frequency Bands in one 15-Dimensional Matrix.** (12 SFB per D x 15D = 180 SFB or 36 SFB per 1HU x 5HU = 180 SFB)

15 Frequency Bands (Dimensions) **and 180 Sub-frequency Bands within the 5 Harmonic Universes of one 15-Dimensional Time Matrix.**
SFB = Sub-frequency Band

PARTIKI PHASING, HARMONICS OF MANIFESTATION AND MATTER DENSITY

Partiki Phasing – *Scalar Standing-Wave flashing*. The internal expansion/ fission/ "flashing on" and contraction/ fusion/ "flashing off" of scalar standing-wave points made of Partiki units. *Partiki Phasing* governs the mechanics of matter manifestation within the Dimensionalized Frequency Bands of the Time Matrix. Through Partiki Phasing HARMONICS of Manifestation and varying levels of matter density are created.

Each of the 5 Harmonic Universes, moving upward in the 15-Dimensional Scale, has a progressively less dense state of perceivable matter. As you go up the Dimensional Scale each Dimension has a progressively faster rate of Partiki Phasing with its corresponding higher frequency, faster oscillation, lower vibration, shorter wave length, greater expansion and less matter density. **These conditions represent the stages of perceivable matter density consciousness will experience as the focus of attention expands progressively upward/outward into the higher Dimensions of the Dimensional Scale through the process of evolution** (accretion of frequency from the Unified Field into the personal morphogenetic field).

As consciousness progressively expands back into the 15-Dimensional structure of its original morphogenetic field, matter density perception will change from perceivable Gross Matter physical density, to Semi-etheric Matter density, to Etheric Matter density, to Pre-matter Liquid Light density and to its original Ante-matter scalar wave form of non-density consciousness. **As the morphogenetic field expands through drawing in more frequencies of consciousness, the perceivable matter density of the body and external reality field progressively lessens.**

Partiki Phasing, Harmonics of Manifestation and Matter Density

1. *Partiki, Partika and Particum:*
Smallest units of energy-substance. Electro-tonal units of consciousness that are the building blocks of morphogenetic fields, matter and individuated conscious identity. Operate as minute, perpetual motion fission/ fusion generators.

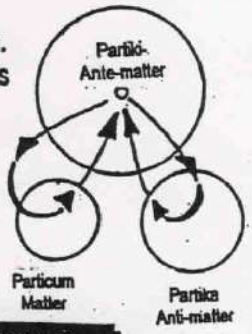

1. Partiki Phasing- expansion/ fission/ "flash on" and contraction/ fusion/"flash off"of scalar points governs the manifestation process

2.

Dimensions #	Harmonic Universe #	density type
1-2-3	HU-1	Carbon based biology physical matter-1
4-5-6	HU-2	Carbon-Silica based biology physical matter-2
7-8-9	HU-3	Silica based biology Etheric matter
10-11-12	HU-4	crystalline liquid-light based biology Pre-Matter
13-14-15	HU-5	standing wave pattern flame or fire body ANTE-Matter

2. **Density/ Biology:** Progression of Matter Density and related Biology within the 15-Dimensional Scale

3. **Harmonics of Manifestation:**
Progressive expansion of consciousness into the Dimensional Scale creates progressive perceptual De-manifestation of matter Density within the Hologram of external reality. **Harmonics of Manifestation** are the stages of Matter Density and Vibration-Oscillation Consciousness perceives and passes through within the Dimensional Scale.

UNIVERSAL AND PLANETARY KATHARA

Kathara Level-1: 12-Tree, Kathara Level-2: Crystals, Kathara Level-3: Diodic Points, Kathara Centers and Kathara Lines.

The Kathara Grid is the *primary mathematical-geometrical organization of units of consciousness* upon which Partiki units group to form morphogenetic field scalar grids. It is the CORE level of scalar standing-wave creation and energetic organization within and behind all dimensionalized systems, and is thus considered to be the **Core of the Holographic Template** upon which the morphogenetic scalar wave blueprint and all other dimensions of form anatomy are built. The Kathara Grid is the causal element within all manifest affects of dimensionalization and consciousness.

The form of the Kathara Grid is reflected in the Macrocosm and Microcosm of all manifestation. All forms have at their core the *common structure of the Kathara Grid Holographic Template.* The Kathara Grids of all forms - universes, galaxies, planets and species - are linked to each other and to the Kathara Grid of the Cosmos through the interwoven Partiki scalar standing-wave grids of the *Kathara Grid Holographic Core.* **The *Cosmic Kathara Grid* represents the scalar field of the Cosmic Unified Field of Consciousness-Energy** through which the *Hologram of manifest experience* is perpetually created.

Energy cannot be created or destroyed, it only changes form. Energy IS *Eternal Consciousness* that perpetually changes form by projecting through the structures of the Kathara Grid, while simultaneously remaining *always the same* - the *singular wholeness* of the **Cosmic Unified Field of Consciousness-Energy.**

Structure of the Kathara Level-1 12-Tree Grid Core Scalar Template

12 PRIMARY KATHARA CENTERS:

Kathara Centers are condensed Scalar Wave points that hold the core electro-tonal geometrical-mathematical program for dimensionalized structure. There are 12 Kathara Centers, each holding the program for one Dimension. The program for Partiki Phasing and Vibration-Oscillation for each Dimensional Frequency Band is set in the corresponding Kathara Center. The Kathara Centers set the template for each Dimension, to ground consciousness within the Holographic experience of manifestation.

15 PRIMARY KATHARA LINES:

Kathara Lines are the primary sequences of Partiki Phasing that transmit the electro-tonal programs held within the Kathara Centers from one Dimension to another, to keep the continual flow of consciousness circulating throughout the 15-Dimensional levels of the Morphogenetic Field. When functioning properly, the Kathara Lines connect each Harmonic and Dimension of consciousness to the other and govern the synchronization of cycles of time within the Dimensional Fields and within the morphogenetic field, DNA and body rhythms of dimensionalized forms. The **3 Vertical Kathara Lines** control the operation of the other 12 Kathara Lines. The **Central Vertical Kathara Line** is the control center for Partiki Phasing rhythms throughout the Kathara Line System.

3 Vertical Kathara Lines = 1-2-3
Central Vertical Kathara Line = 1

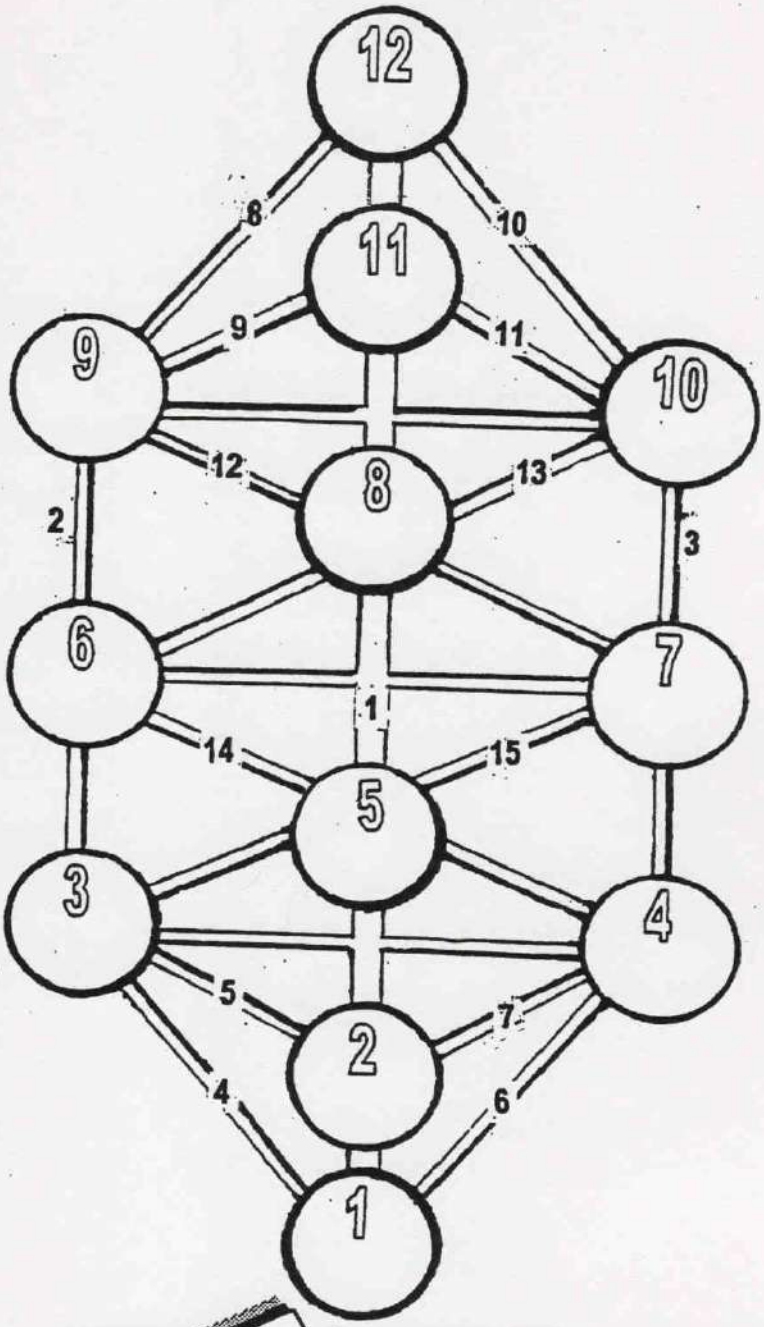

KATHARA LEVEL-1 12-TREE GRID

The 2 Interwoven Kathara Grids of Primal Order within the Universal Time Matrix and Cosmic Energy Matrix of the PRIMAL MANIFESTATION TEMPLATE

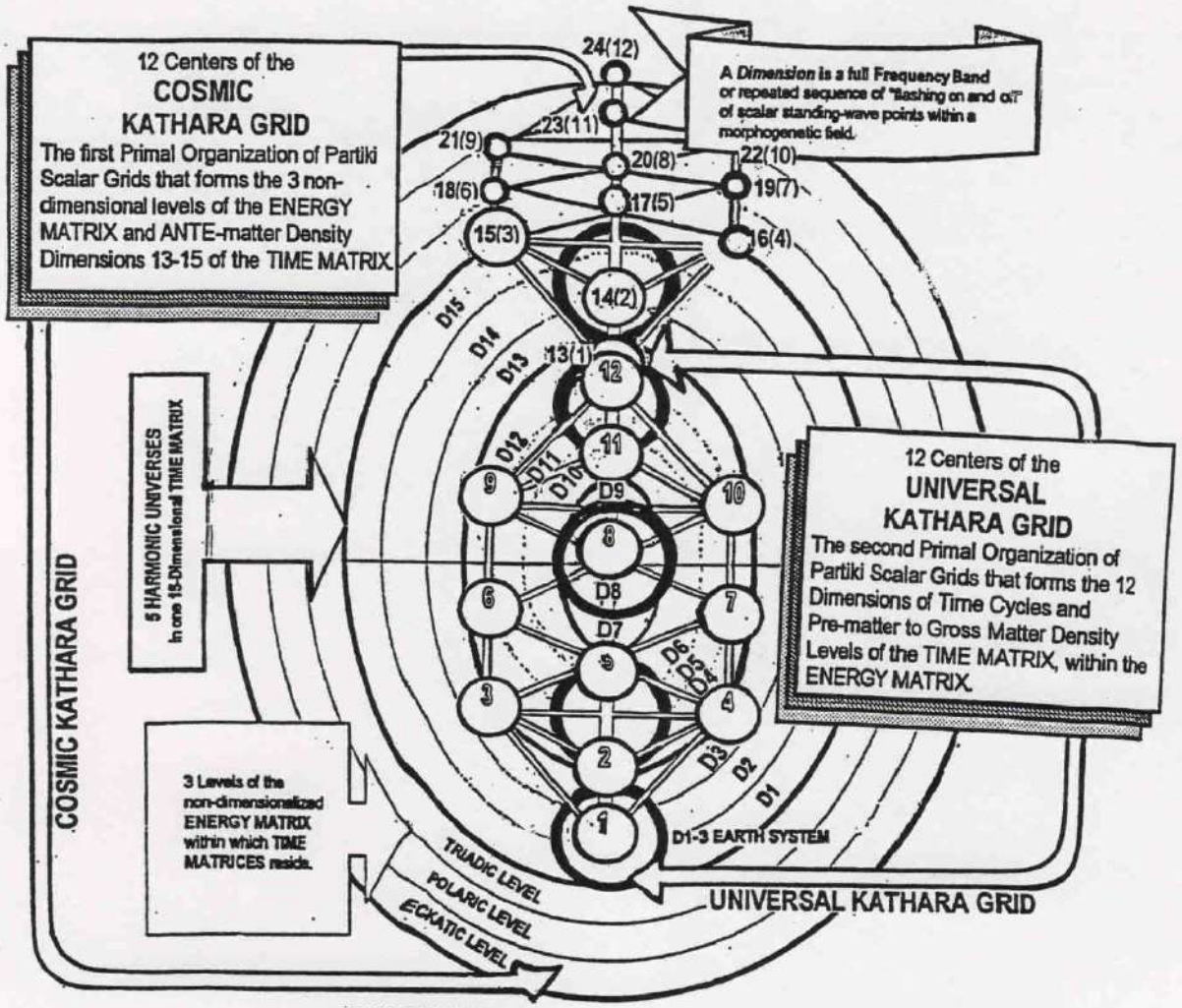

5 HARMONICS OF MATTER DENSITY IN THE TIME MATRIX

1. **Gross-matter D1-D3**
2. **Semi-etheric D4-D6**
3. **Etheric D7-D9**
4. **Pre-matter D10-D12**
5. **Ante-matter D13-D15**

=

There are 3 **Primary Levels** to the structure of the Kathara Grid. **Level-1: *The Kathara 12-Tree*, Level-2: *The Crystal Seals*** and **Level-3: *The Diodic Points*.**

Level-1:The 12-Tree holds the first mathematical-geometrical program upon which Kathara Grid Levels 2 and 3 are created, and is composed of the **Kathara Centers** and **Kathara Lines.**

Level-2: The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of *Partiki Phasing* to create the base structures upon which *dimensionalization* is formed. The flow of Frequency (sequences of scalar standing-wave flashing/ cycles of Partiki Phasing) between dimensional bands and Harmonic Universes, the fixed expansion and contraction rates of Partiki, the Vibration-Oscillation and the Angular Rotation of Particle spin are all regulated by the Crystal Seals.

Level-3: Diodic/Miodic Points represent **concentrated areas of energy** that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating **minute vortices** of wave spectra that serve as *frequency modulation zones* (scalar flash-cycle transition points) between Dimensional Frequency Bands. **Diodic Point** vortices are **White Hole** vortices that **transmit energy** into the *Particle Universe* from their counterpart **Miodic Point** vortices within the *Anti-particle Universe*. Through the structure of Dimensionalization, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* – sets of **White and Black Holes** – that regulate the flux of consciousness-energy between systems.

The entire cosmic structure is built upon the morphogenetic foundations of *interwoven Kathara Grids*. Within the structures of forms, such as planets or people, the Kathara Grid is the *Core Template of Holographic Manifestation* and controls the structure and function of all of the other *subtle and physical energy systems.*

Planetary scalar templates - **Planetary Shields** - vortices, electro-magnetics, Axiom and Ley Lines are all governed by the operations of the *Kathara Grid.* In the **human body**, personal scalar templates - **Hova Bodies** -, Chakras, Axiom and Meridian Lines and Bio-energetic Field Auric Levels, as well as the physical systems, conscious awareness and DNA, are controlled by the *personal Kathara Grid.* **In terms of generating the *Imprint for Health* within the human organism, as well as *reclaiming dormant potentials of Immortality*, the Kathara Grid is the *causal mechanism* through which such affects can occur.**

KATHARA LEVEL-2 CRYSTAL SEALS GRID

Level-2: The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of *Partiki Phasing* to create the base structures upon which *dimensionalization* is formed. The flow of Frequency (sequences of scalar standing-wave flashing/ cycles of Partiki Phasing) between Dimensional Bands and Harmonic Universes, the fixed expansion and contraction rates of Partiki, the Vibration-Oscillation and the Angular Rotation of particle spin are all regulated by the Crystal Seals.

Planetary Star Crystal Seals

In the ***Planetary Kathara Grid***, the **15 Primary Star Crystal Seals** exist *between* each planetary Vortex or Chakra, on the **Central Kathara Line** or **Central Planetary Axis**. The Star Crystal Seals serve as **"Frequency Seals"** that open or close the *flow of wave spectra* and *Frequency Bands* from one **Harmonic Universe** to another, by regulating and modulating the *sequences of Partiki Phasing and the Vibration-Oscillation rates of Partiki units* within the Dimensional Scale. They control the opening and closing of the *Central Vertical Kathara Line* and *Central Planetary Axis*, through which particles are *phase-locked* into their respective dimensional placements and linear time cycle orientations. Opening of the *Star Crystal Seals* releases the planetary particles and *Ley Lines* from their *dimensional phase-lock*, opening **Inter-harmonic Star Gates** (*wave spectra vortices*) within the Ley Lines, for ***molecular transmutation and time continuum shift***, through blending the Inter-Harmonic wave spectra of the planetary morphogenetic field. **The Planetary Star Crystal Seals control the opening and closing of the 3 *Vertical* Kathara Lines** (and **Vertical** *Star Gate passageways*) **of the Level-1: 12-Tree Kathara Grid with in planetary body.**

Biological Star Crystal Seals

In the ***human body*** the **15 Primary Star Crystal Seals** exist *between* each Chakra on the **Central Kathara Line** or **Central Body Current**. The *biological Star Crystal Seals* serve as **"Frequency Seals"** that open or close the *flow of wave spectra and Frequency Bands* from one *Harmonic of consciousness* to another, by regulating and modulating the *sequences of Partiki Phasing and Vibration-Oscillation rates of Partiki units* within the Dimensionalized scalar wave grid of the morphogenetic field. They control the opening and closing of the *Central Vertical Kathara Line* and *Central Body Current*, through which particles are *phase-locked* into their respective dimensional placements and linear time cycle orientations. Opening of the *biological Star Crystal Seals* releases the *body particles* and **DNA** from their *dimensional phase-lock*, opening **Inter-Harmonic Star Gates** (*wave spectra vortices*) within the **DNA**, for **cellular transmutation** (via particle+anti-particle *fusion*) and time continuum shift, through blending the Inter-Harmonic wave spectra. **The Biological Star Crystal Seals control the opening and closing of the 3 *Vertical* Kathara Lines** (and **Vertical** wave spectra vortices) **of the Level-1: 12-Tree Kathara Grid within the biological form.**

Seed Crystal Seals

Along with the **15 Primary** *Star Crystal Seals* that control the *Vertical* modulation of wave spectra, there are also **15 Secondary Crystal Seals** that control the **HORIZONTAL** Kathara Lines of the Level-1: 12-Tree Kathara Grid within the planetary and biological bodies. The *Horizontal Crystal Seals* are called **SEED SEALS**, they exist and serve as **"Frequency Seals"** ***within*** the planetary vortices and biological Chakras, modulating the wave spectra between Parallel (particle/ anti-particle) Dimensional Frequency Bands.

KATHARA GRID LEVEL-3 DIODIC POINTS

Level-3: Diodic/Miodic Points represent **concentrated areas of energy** that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating **minute vortices** of wave spectra that serve as *frequency modulation zones* (scalar flash-cycle transition points) between Dimensional Frequency Bands. **Diodic Point** vortices are **White Hole** vortices that **transmit energy** into the *Particle Universe* from their counterpart **Miodic Point** vortices within the *Anti-particle Universe*. Through the structure of Dimensionalization, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* – sets of **White and Black Holes** – that regulate the flux of consciousness-energy between systems.

Planetary Diodic Points

Within the **planetary body** and morphogenetic field, **Diodic Points** are located in **geographical locations** where Inter-dimensional and Inter-harmonic Horizontal and Vertical Kathara Lines *intersect* to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve as passageways – **time portals**- between Dimensional Time Continua or Harmonic Time Cycles. They connect planetary and stellar bodies to their *anti-particle counterparts* and intersect with Vertical Inter-harmonic Star Gates and Horizontal Inter-dimensional Time Portals, through sets of Diodic-Miodic **White and Black Holes** at the center of planetary and stellar cores.

Biological Diodic Points

Within the **biological form** and morphogenetic field, Diodic Points are located in **physical body regions** where Inter-dimensional and Inter-harmonic Horizontal and Vertical Kathara Lines *intersect* to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve as ***gateways of consciousness*** between Dimensional Time Continua or Harmonic Time Cycles. They connect physical bodies to their *anti-particle counterparts* and intersect with the Vertical and Horizontal *relationships of wave spectra within the DNA/ RNA and bio-energetic field*, through sets of **White and Black Holes** at the center of the biological Harmonic scalar grids.

Diagonal Grid Control

The *Kathara Grid Level-3: Diodic Points* control the **Diagonal Kathara Lines**, Diagonal *Inter-dimensional portals*, Diagonal *Planetary Ley Lines* and Diagonal relationships between inter-dimensional wave spectra within the biological DNA. **In *Kathara Healing*, the *Diodic Points* are used to open and close the *Diagonal Kathara Lines* for channeling higher dimensional frequency into the Level-1 Kathara Grid, to regenerate the Imprint for Health and to revitalize the Bio-energetic and physical systems.**

THE UNIVERSAL TEMPLAR COMPLEX

- The systems of interwoven Manifestation Templates within the 5 Matter Density Levels of the 15-Dimensional Universal Kathara Grid are collectively referred to as the **UNIVERSAL TEMPLAR COMPLEX.** The Manifestation Template of the human body, likewise structured upon this Primal Order, also manifests through a personal **INTERNAL TEMPLAR COMPLEX** of interwoven 15-Dimensional Manifestation Templates.

- Universal, Galactic and Planetary Scalar-wave Templates of the Universal Templar Complex are called **Scalar SHIELDS.** Shields are sets of 3-Dimensional Scalar Grids upon which the 5 Matter Density Levels of the Universal Manifestation Template manifest. A Shield is composed of the distinct **3 Primary Flash Line Sequences**, or Partiki Phasing Rhythms, characteristic to the 3 dimensions of which the Shield is composed. The Internal Templar Complex of the human body is also organized into 5 sets of 3-Dimensional **Personal Scalar Shields**, through which the matter form and 5 Matter Density Levels of the 15-Dimensional human consciousness are projected into manifest experience.

- Through the intrinsic dynamics of synchronistic Partiki Phasing, each 3-Dimensional Scalar Shield manifests a **3-DIMENSIONAL SPHERICAL ELECTROMAGNETIC DOMAIN** that creates the energetic framework within which externalized manifest experience can take place. Within the Universal Templar Complex, these Spherical Domains form 5 separate yet interwoven Reality Fields or **Harmonic Universes**, each with a different level of Matter Density, rate of Vibrational Oscillation, different Angular Rotation of Particle Spin and variance in Time Cycle orientation. Within the Personal Internal Templar Complex, the Spherical Electromagnetic Domains created by synchronistic, dimensionalized Partiki Phasing form within the 15-Dimensional Time Matrix 5 separate yet interwoven **STATIONS OF CONSCIOUSNESS** called **HOVA BODIES.** The **5 Hova Bodies** of human Manifestation Template Anatomy within the Time Matrix represent the **5 Subtle Energy Bodies** of human bio-energetic field construction, through which human identity experiences series of **SIMULTANEOUS INCARNATIONS** within the various Time Cycles and matter density levels of the Time Matrix. **Human Evolution** is the process by which the electromagnetic frequencies and stations of consciousness of the 5 Hova Bodies progressively merge to transmute the physical matter form backward through the various Matter Density stages through a process called **TRANSMUTATIONAL DIMENSIONAL ASCENSION.**

  Each of the 5 Shields within a 15-Dimensional Manifestation Template is structured upon **3 KATHARA CENTERS** within the core Primal Order of the **Level-1** Kathara 12-Tree Grid. Each Kathara Center of the Universal Kathara Grid forms a core point of consolidated frequency called a **SIGNET Star Crystal Seal** within the 3-Dimensional scalar Shields. Within the universal, galactic and planetary Templar Complex the Signet Seals operate as **Star Gates** between the Time Cycles of the 5 Matter Density levels of the 15-Dimensional Time Matrix. Within the Personal Internal Templar Complex, each **Hova Body** is structured upon **3 Kathara Centers** within the embodied Personal Kathara Grid. Each embodied Kathara Center forms a **Signet Star Crystal Seal** within the human anatomy. The embodied **Signet Seals** operate **as Bio-electric Windows** within the **DNA-RNA**, that link the Stations of Consciousness and various **Simultaneous Incarnations** of the identity that

exist within the Time Cycles of the Time Matrix to each other, across the illusions of time. Through the embodied Personal Kathara Grid, Scalar Shields, Signet Seals and DNA Windows, the individuated aspects of **ETERNAL IDENTITY** in time are indelibly linked in consciousness. This intrinsic linking of personal consciousness within the various simultaneous cycles of time appears to the embodied human awareness as **REINCARNATIONAL MEMORY.**

The embodied Manifestation Template of the human form is a microcosmic reflection of the Macrocosmic Universal and Cosmic Manifestation Templates. Both microcosmic and macrocosmic Manifestation Templates share, and are interwoven through, the same **Primal Structures** of the Kathara 12-Tree Scalar Grid, the 5 3-Dimensional Scalar Shields and Signet, Star and Seed Crystal Seals and the Diodic Point "Black and White Hole Sets" of energy vortices that manifest upon the Kathara Grid. Human consciousness and biology are directly and indelibly connected to the Universal Templar Complex through the **Personal Internal Templar Complex** of the Personal Manifestation Template.

HEALING AND PRIMAL FULFILLMENT

A rudimentary but operational understanding of the intrinsic structure of the embodied Personal Manifestation Template- (*the **Level-1**Personal Kathara 12-Tree Grid, **Level-2** Scalar Shields, Hova Bodies and Signet, Star and Seed Crystal Seals, and **Level-3** Diodic Points*) - and its relationship to the Universal Templar Complex, allows the embodied human consciousness the opportunity for progressive participation within the processes of **CONSCIOUS EVOLUTION** and intentional restoration of the **Organic Imprint for Health.** All manifest **DIS-EASE** originates through **distortions** in the electro-tonal scalar wave programs of the **Kathara Grid, Scalar Shields** and **Manifestation Template.** To achieve true and lasting healing, rather than suppression and transference of dis-ease to other embodied systems, distortions within the personal Manifestation Template need to be realigned from the causal Kathara Grid level through **REGENESIS** of **Primal Order** within the **Organic Imprint for Health.**

Manifestation Template healing therapeutics based upon knowledge of the Kathara Grid, simultaneously work to restore the natural intended **Primal Order** and function of the human body and consciousness, while expediting the evolutionary process of merging the stations of identity through time, to facilitate fulfillment of the organic **PRIMAL PURPOSE.** The **Primal Purpose** of human evolution is the achievement of **Transmutational Dimensional Ascension** and **Co-creative Mastery** over the Personal Eternal Consciousness and **Internal Templar Complex** within the Holographic Fields of the Time Matrix. Through fulfillment of the **Primal Purpose,** humanity will regain **THE PRIMAL CONDITION** of Conscious AT-ONE-ment with the Universe and the Central Source of Creation, or **GOD.**

The Universal Templar Complex

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

Shields

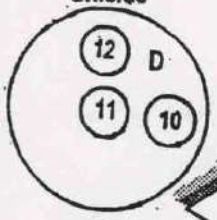

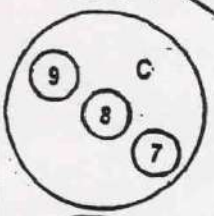

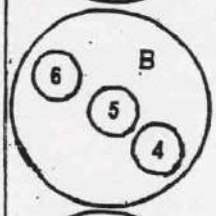

HORIZONTAL SHIELDS

A. TELLURIC SHIELD
Gross Matter Shield
Dimensions 1-3

B. DORADIC SHIELD
Semi-etheric Matter Shield
Dimensions 4-6

C. TEURIC SHIELD
Etheric Matter Shield
Dimensions 7-9

D. MAHARIC SHIELD
Pre-matter Shield
Dimensions 10-12

E. RISHIC SHIELD
Ante-matter Shield
Dimensions 13-15
(vertical- not shown)

Kathara Level-2 Scalar Shields & Crystal Seals

The 4 Scalar SHIELDS corresponding to the Kathara Center programs and Harmonics of Matter Density within the *Universal* Manifestation Template.(The 5th Scalar Shield in the 15-Dimensional Time Matrix corresponds to the first 3 Kathara Centers of the *Cosmic* Kathara Grid.) Shields are the 3-Dimensional scalar-wave grids that hold the blueprint for manifestation, as set by the mathematical encoding of Partiki Phasing Rhythm held within the Kathara Centers of the Manifestation Template.

The 12-Dimensional UNIVERSAL KATHARA GRID within the 15-Dimensional Time Matrix. The 12 Kathara Centers hold the core mathematical and geometrical Partiki Phasing programs upon which the Shields of the Universal Manifestation Template organize.

The 12 SIGNET Star Crystal Seals of the Universal Kathara Grid. SIGNET SEALS are the core points of consolidated frequency corresponding to each Dimension that represent the first manifest arrangement of scalar waves created through the mathematical programs of the corresponding Kathara Centers. The Signets transmit the organizational programs upon which the Scalar Shields manifest. Each 3-Dimensional Scalar Shield manifests on the electro-tonal programs of 3 Signet Star Crystal Seals. Signet Seals keep the Harmonics of Matter Density separate from each other by keeping Partiki units phase-locked into their 3-dimensional electromagnetic domain.

When released, Signet Seals serve as Star Gates, allowing the Time Cycles and Matter Density Levels within the Time Matrix to merge and blend. Signet Seals are the central control points for Scalar Shield programming.

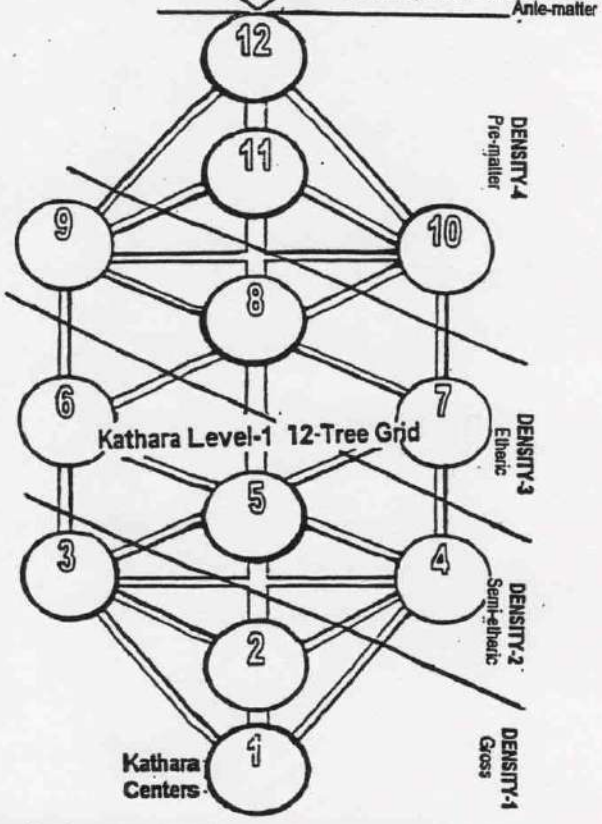

The structure of the macrocosmic **Universal Templar Complex** is replicated within the microcosmic structure of the personal **Internal Templar Complex** upon which **15-Dimensional Human Anatomy** manifests.

The Transduction Sequence

The *Transduction Sequence* represents the phases consciousness passes through into dimensionalization and the process by which conscious energy is transduced and *changes form* to enter the wave spectra within which perception of manifestation is possible.

Basic *Transduction Sequence* of Consciousness into Biological Form.

CONSCIOUSNESS TO PARTIKI UNITS TO

KATHARA SCALAR GRIDS LEVELS –1, 2 AND 3 TO PARTIKI GRIDS TO

MORPHOGENETIC FIELDS TO MERKABA FIELDS (Sets of Counter-rotating electro-magnetic spirals of energy –repeating scalar wave flash/ Partiki Phasing sequences that run between Dimensions and Harmonic Universes)

TO DNA/ RNA IMPRINT TO BIO-ENERGETIC AURIC FIELD TO CHAKRAS

TO NADIAL CAPSULE (tissue-like capsule that forms around the 3-Dimensional scalar grid of the Harmonic Universe-1 morphogenetic body.) **TO**

DNA/ RNA MANIFEST TO NADIS (energetic rivulets that feed energy from the Nadial Capsule into the Central Nervous System and molecular structure) **TO**

NUCLEAR CORE TO

CNS-METABOLIC/ BIOLOGICAL RHYTHMS- BLOOD-BRAIN-CHEMICALS-HORMONES-ORGANS-TISSUES.

HOLOGRAPHIC REALITY CONSTRUCTION

The Unified Field of Conscious-Energy

THE **SCALAR STANDING-WAVE GRIDS** THAT MAKE UP **DIMENSIONALIZED MORPHOGENETIC FIELDS** REPRESENT THE *INTRINSIC STRUCTURE* OF THE **COSMIC UNIFIED FIELD OF ENERGY** WITHIN WHICH ALL THINGS EXIST. *ENERGY IS CONSCIOUS AND CONSCIOUSNESS IS ENERGY.* **CONSCIOUSNESS-ENERGY CANNOT BE CREATED OR DESTROYED IT SIMPLY CHANGES FORM,** WHILE SIMULTANEOUSLY REMAINING ALWAYS THE SAME – **THE ETERNAL UNIFIED FIELD OF CONSCIOUSNESS.**

The Kathara Grid

ALL FORMS OF CONSCIOUSNESS AND PERCEIVABLY MANIFEST FORMS *DERIVE THEIR INDIVIDUATION* WITHIN THE UNIFIED FIELD THROUGH THE STRUCTURE OF THEIR **INDIVIDUATED MORPHOGENETIC FIELD.** THOUGH HAVING MUCH DIVERSIFICATION WITHIN THE **GEOMETRICAL-MATHEMATICAL PROGRAMS** THAT FORM **INDIVIDUALITY** WITHIN LIKE PATTERNS, THE *CORE OF ALL INDENTITY AND MANIFEST FORM IS THE SAME* – THE INTRINSIC STRUCTURE OF **THE KATHARA GRID – THE CORE HOLOGRAPHIC TEMPLATE OF DIMENSIONALIZATION UPON WHICH MORPHOGENETIC FIELDS ARE FORMED.**

Interwoven Morphogenetic Fields

THE INHERENT STRUCTURE OF **INTERWOVEN KATHARA GRIDS** FORMS **SPHERICAL DIMENSIONALIZED MORPHOGENETIC FIELDS** WITHIN WHICH CONSCIOUSNESS CAN EXPERIENCE THE **HOLOGRAPHIC PROJECTION** OF MANIFEST REALITY, SPACE, TIME, MATTER AND EXTERNALIZATION. THE SPHERICAL MORPHOGENETIC STRUCTURES OF THE **MICROCOSM** EXIST WITHIN THE GREATER SPHERICAL MORPHOGENETIC FIELDS OF THE **MACROCOSM,** FORMING A SYSTEM OF CONSCIOUS-ENERGETIC **SPHERES-WITHIN-SPHERES** THAT REPRESENTS THE ***INTERWOVEN MORPHOGENETIC FIELDS*** **OF THE COSMIC UNIFIED FIELD OF CONSCIOUSNESS-ENERGY.**

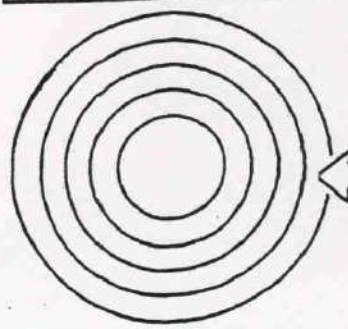

Spheres-within-Spheres ***Interwoven Morphogenetic Fields***
The Microcosm within the Macrocosm. The individual within the species within the planetary within the galactic within the universal within the cosmic within the INFINITE AND ETERNAL.

Five Over-lay Universes exist within the same space in 1 15-Dimensional Matrix.

CHAPTER 1 HIGHLIGHTS

3

THE HOLOGRAPHIC TEMPLATE

- **External reality is a HOLOGRAPHIC PROJECTION.** Perception of **solidity** and **externalization** are determined by the **oscillation rates** between **dimensionalized units of consciousness** - ***Partiki, Partika*** and ***Particum.*** Dimensionalized units of consciousness form **Frequency Bands** that exist in specific relationships to each other. We perceive as solid the Frequency Bands that exist 1 full Dimensional Band **below** the frequencies within which the consciousness is stationed.

- **Dimensionalization** creates the structure through which consciousness can perceive the **Hologram of Externalization.**

- The human body is a **Hologram** built upon a **Holographic Template** of units of consciousness structured into **Scalar Standing-wave Grids** that represent the **Living Morphogenetic Field** blueprint upon which matter and dimensionalized consciousness manifest.

THE STRUCTURE OF DIMENSIONS

- The **Unified Field** is built upon ***dimensionalized sets*** of ***Scalar Standing-wave Points*, Wave Strata** formed of units of consciousness that form the basis of energetic relationship through which the **Hologram of Manifestation** can be perceived.

- The human body is a construct of ***Conscious Energy***, built upon **a15-Dimensional Anatomy of Dimensionalized Scalar-Grids.** Perceived physicality emerges through the **Perceptual Lens of Dimensionalization** which provides the picture of seemingly manifest particles, atoms, molecules and physical systems.

- Understanding the nature and structure of **Holographic Reality** allows us to understand the foundations upon which the **body** is built and the **context** within which **healing** must occur.

Scalar Waves are standing wave points that emanate out of fixed points of sound (electro-tonal Partiki units), which form the **Scalar Grid morphogenetic templates** that house consciousness in **dimensionalization** for experience of manifest reality. Scalar Grids are created through **Partiki Phasing.**

Partiki Phasing is the process of ***internal fission/ expansion and fusion/ contraction*** characteristic of **Partiki Units**, through which the units perpetually break apart and replicate through *fission*, then re-merge through *fusion*. Creates a "*flashing on and off" of* ***Scalar Wave points***, or "**Flash-line Sequences**" that determine the intrinsic orientation of consciousness within the Scalar Grids composing morphogenetic fields.

Dimensions are Scalar Grids of consciousness composed of interwoven layers of Scalar waves with **varying Flash-line Sequences**, or *Frequency Bands.* **Dimensions are Frequency Bands**, or Partiki wave spectra, that exist within specific relationship to each other to form the template of Holographic Reality.

Frequency Bands are synchronized, repeating ***Flash-line Sequences of Partiki Phasing*** that give the appearance of manifest movement of wave spectra within a Dimensional Scalar Grid **Sub-frequency Bands** are *portions* of the *Flash-Line Sequences* that make up the whole Dimensional Frequency Band. The Frequency of a Dimensional Band is determined by the **Vibratory-Oscillation** rate of Partiki units that make up the Dimensional Scalar Grids.

Vibration is the "internal movement" or **ENERGY HOLDING** of Partiki units. **Oscillation** is the "external movement" or **ENERY EXPENDED** by Partiki units. **Vibratory-Oscillation rate is the rate at which Partiki Phasing "flashing on and off" occurs**. Vibration and Oscillation exist in **direct proportion** to each other. As Vibration increases (energy holding), Oscillation decreases (energy expenditure). Faster Flash-line Sequences (higher frequency) *expend* more energy, raise Oscillation and lower Vibration of Scalar Templates. **Higher Oscillation/ Slower Vibration creates slower electron movement around nucleus and less perceivable density of matter.**

FREQUENCY VIBRATION

- A **Dimension** is a full Frequency band or **full cycle** of a **Flash-line Sequence**.

- The **Universal Morphogenetic Template** is built upon ***sets of 15 Primary Flash-line Sequences*** that form **15-Dimensional Time Matrices** within which manifestation can be experienced.

- **Dimensions are organized into sets of 3,** (3 full Flash-line Sequences/ 3 Frequency Bands), that create the template through which 3-dimensional manifestation can be experienced. Each set of 3 Dimensions is called a **Harmonic Universe**. There are **5 Harmonic Universes** within a **15-Dimensional Time Matrix.**

- Each Dimension contains **12 Primary Sub-frequency Bands** (partial Flash-line Sequences).

- Partiki in each Dimension have specific set **Partiki Phasing rhythms** giving each Dimension a specific ratio of **Vibration-Oscillation**. Higher Dimensions have Faster Partiki Phasing, are higher frequency and thus have higher oscillation, lower vibration and less particle density.

- **Vibratory-Oscillation** rate within a Dimension determines the **Angular Rotation of Particle Spin** (**ARPS**), or *rotational axis of particles* in a Dimension. There is a **90-Degree Shift** in ARPS between each Dimension and a **45-Degree Reverse Shift** in between Harmonic Universes.

- Particles having varying **Vibratory-Oscillation** rates and **ARPS** allow *multiple 3-Dimensional Reality Fields* to *co-exist* within the same space while remaining perceptually and experientially **invisible** to each other.

- The **relationship between wave strata** and **variance in Partiki Phasing Flash-line Sequences** within Dimensional Frequency Bands create **Holographic Refraction** of consciousness-energy that allows perception of an externalized, 3-Dimensional **Holographic Illusion** for consciousness focused within the Scalar Grids of the 15-Dimensional Time Matrix.

UNIVERSAL AND PLANETARY KATHARA

KATHARA GRID

The **Kathara Grid** is the **first level** of Partiki structure/ *Scalar Grid organization* that sets consciousness into dimensionalization. It is thus the **CORE HOLOGRAPHIC TEMPLATE** upon which the *morphogenetic field blueprint* is structured.

The *Kathara Grid* is the *Core Holographic Template* for **dimensionalization of the Unified Field** of Consciousness-Energy through which the **Microcosm** and the **Macrocosm** are structured. **All things are built upon the foundation of the *Kathara Grid.***

There are **3 Primary Levels to the Kathara Grid**. **Level-1:** ***The 12-Tree Grid*** with **Kathara Centers** and **Kathara Lines**. **Level-2:** ***The Crystal Seals*** with **Hova Bodies** and **Scalar Shields** and **Level-3:** ***The Diodic Points*** of minute energy vortex **"White and Black Hole" sets.**

KATHARA 12-TREE GRID

Level-1 Kathara holds the base electro-tonal **programs** of Partiki Phasing and Dimensional/ Frequency structure upon which the other Kathara Levels and the morphogenetic field are built.

KATHARA SCALAR SHIELDS AND CRYSTAL SEALS

Level-2 Kathara Grid is composed of 5 groups of 3-Dimensional **Scalar Shields and Crystal Seals** - that regulate the rates of Partiki Phasing to create the base structures upon which ~~dimensionalization is built.~~

KATHARA DIODIC POINTS

Level-3 Kathara Grid is made of sets of minute White and Black Hole energy **vortices,** made of inter-dimensional Scalar Wave spectra, that **regulate the flux of consciousness-energy** between Dimensional, Harmonic and Parallel/ anti-particle systems.

Cosmic *morphogenetic structure* is built upon interwoven **Kathara Grids** and the Dimensionalized Scalar Standing-wave Templates they form.

KATHARA GRID LEVELS

- The **5 Primary Scalar Templates of Dimensionalization** are formed on **Scalar Shields** composed of sets of 3 Dimensions, which form *5 3-dimensional spheres of energy* called **HOVA BODIES**. Hova Bodies and their Scalar Shields hold consciousness-energy into **5 separate but interwoven 3-dimensional systems.**

- The **Kathara Grid** and the multiple levels of morphogenetic structure built upon it is the **CAUSAL ELEMENT** behind and within all manifestation, and thus the **CORE HOLOGRAPHIC TEMPLATE** through which the **Imprint for Health** can be restored to Biology.

- All manifest **Dis-ease** originates through **distortions** in the natural electro-tonal programs/ *Partiki unit arrangements* of the *Kathara Grid* and *Hova Body Scalar Shields*. The Kathara Grid and morphogenetic field are the **core elements** through which **lasting healing** is created. **Healing** occurs through **REGENESIS** of natural electro-tonal **programs** of the **Holographic Template**.

- **Partiki Units, Scalar Standing Waves, and Crystalline Keylons and Keylon Codes** represent the **PRIMAL SUBSTANCE** in energy that consciousness takes on in order to create the **Holographic Projection** of external manifestation.

- The **Kathara Grid, 15-Dimensional Structure, Scalar Shields, Crystal Seals, 5 3-Dimensional Harmonic Universes and Hova Bodies, Diodic Point** vortices and the subtle and dense matter energetic systems that manifest upon them represent the **PRIMAL ORDER** of mathematical and geometrical interrelationship that **Primal Substance** utilizes to orchestrate the manifest Hologram through creation of **Manifestation Templates.**

- The interwoven, ordered structures of scalar wave fields that form the **Universal Manifestation Template** of the 15-Dimensional Time Matrix are collectively referred to as the **UNIVERSAL TEMPLAR COMPLEX.**

The interwoven, ordered structures of scalar wave fields that form the **Personal Manifestation Template** of **15-Dimensional Human Anatomy** are collectively referred to as the **Personal INTERNAL TEMPLAR COMPLEX.** The Internal Templar Complex, a structural replica of the Macrocosmic Universal Templar Complex, anchors personal consciousness into the Time Matrix for the experience of the space, time and matter Hologram.

The **PRIMAL PURPOSE** of human evolution is the achievement of **Transmutational Dimensional Ascension** and **Co-creative Mastery** over the **Personal Eternal Consciousness** and **Internal Templar Complex** within the holographic fields of the Time Matrix. **REGENESIS** of **Primal Order** within the **Organic Imprint for Health** creates true healing and expedites the natural processes of human evolution.

Through fulfillment of the **Primal Purpose** humanity will regain **THE PRIMAL CONDITION** of **Eternal Conscious At-ONE-ment** with the Central Source of Creation or **GOD.**

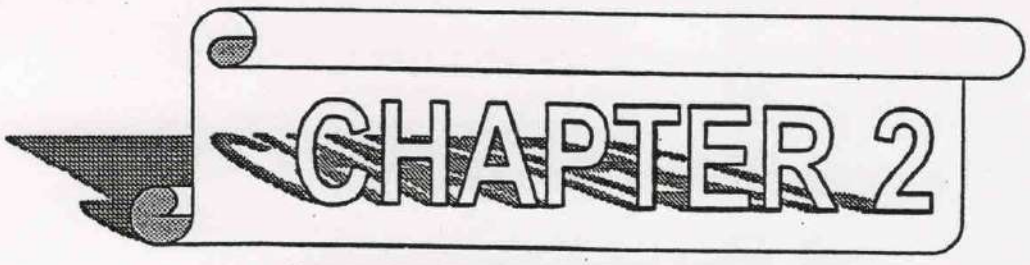

(Section One: *Foundations of Kathara Healing* – Part II)

THE ELEMENTS OF HEALING

The Human Body Kathara and the Multi-dimensional Anatomy of the Human Form

- THE MAHARIC SHIELD AND THE IMPRINT FOR HEALTH
- THE PLANETARY BIO-FEED INTERFACE SYSTEM (PBIS)
- THE HIEROPHANT SYMBOL CODE, PBIS AND THE MAHARIC SHIELD
- MORPHOGENETIC EXPANSION, GROWTH CYCLES, DEATH AND MOLECULAR COMPACTION
- LEVELS OF HUMAN ANATOMY, EMBODIED KATHARA 12-TREE GRID, CRYSTAL SEALS, SHIELDS, SIGNETS, HOVA BODIES, AURIC CAPSULES, DIODIC POINTS, SEED SEALS, CHAKRAS, AXIOM LINES, THE HARA LEVEL AND DNA.
- THE 12 HUMAN SENSES, APPARTHI AND HUMAN PERCEPTION

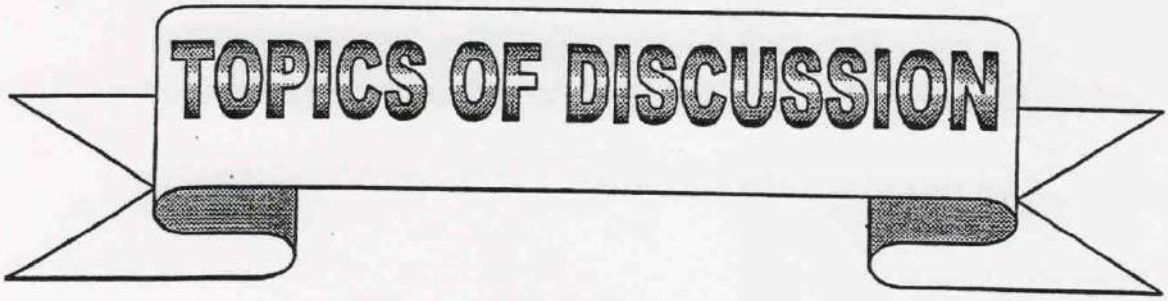

THE HUMAN BODY KATHARA AND THE MULTIDIMENSIONAL ANATOMY OF HUMAN FORM

The Structures of Manifestation and Reclaiming Our Power

In *PART-I* of this program, **THE CONTEXT OF HEALING**, we explored the hidden foundations of *reality structure* within which our existence takes place, the *context of relativity* through and within which *healing* occurs. We learned that the context of existence can be viewed as taking place within a **Unified Field of Energy**, and that **Energy IS consciousness and Consciousness IS energy.** In our exploration we encountered the **Partiki, Partika** and **Particum,** the ultra-micro-particle units of consciousness in electro-tonal form, through which the tangible structure of living **Morphogenetic Fields** are formed. In learning the foundation structures of the Unified Field of Consciousness-Energy, we come to understand that the anatomy of any form, including that of the human Body-Mind-Spirit System, is a **multi-dimensional construct** built on an ordered template of **sets of 15-Dimensions,** through which all conditions of apparent manifestation are created.

Through reviewing the underlying structures of manifest reality (units of consciousness, the ***Partiki Scalar Standing-wave Grids*** that hold consciousness into individuated dimensionalized "packages" of awareness to allow for experience of space, time, matter and form, the core ***Kathara Grid Holographic Template*** that sets the pattern of dimensionalization for consciousness to follow into the manifest experience, the ***Levels of Matter Density*** corresponding to the ordered structure of Dimensions, and the reality that **Dimensions** are *tangible constructs of energy* created through the process of ***Partiki Phasing***-the fission-fusion "flashing on and off" of scalar standing-waves composed of units of consciousness) **we have already expanded our perceptions of the nature of reality itself.** With these **simple revelations of knowledge,** we have shifted ourselves from a perspective of viewing the reality before us as one of *separate manifestations disconnected from our being,* to a perspective of viewing reality as an *intricate system of interwoven consciousness, expressing in the form of standing-wave strata,* to which we are *intimately and indelibly connected.*

Suddenly we find that we cannot be "left out" of things, we cannot "be on the outside as life passes us by", **that there IS no "outside" to which we may stand separate, as by the *nature of our existence* we are an *intrinsic element and force of creative affect* within the whole of creation.** Through this knowledge we have begun to tap the **secrets of SELF,** as we shift from viewing ourselves as *mortal creatures trapped within a gross-matter finite physical body,* to **KNOWING OURSELVES AS THE EXPRESSION OF CONSCIOUS, SENTIENT WAVE-STRATA - ETERNAL BEINGS ENSCONCED WITHIN AN ETERNAL UNIVERSE, within which Energy-Consciousness cannot be created or destroyed, it simply changes form perpetually.** We move from perceiving ourselves as finite beings of limited power to affect a world that is separate from us, to knowing that we are *walking wave-forms within a sea of interrelated wave forms,* and that the pattern of our being operates as an intrinsic part of the whole. **As we begin to perceive ourselves in terms of the *unlimited reality of our nature,* rather than define ourselves by the limited boundaries of the *manifest illusion before* us, we begin to reclaim our power to *affect desired change* within the contours of our lives.**

Knowledge, KNOWING and the Imprint for Health

Knowledge is an agent of freedom, IF it is used to foster practical applications of change. Knowledge can also become a *perpetual quest of distraction*, through which we deny ourselves the ability to EMBRACE the experience of living as we seek outside of ourselves the answers that live within. **Knowledge is power if it is applied appropriately, it can be an agent that leads one through the door to the WISDOM that awaits on the other side.** Knowledge alone cannot provide **cognition,** cognition comes through the *application of applied knowledge* to provide **tangible, experiential KNOWING**, a knowing derived only through the **direct experience of BEING. In Kathara Healing™ *knowledge* is applied as a *tool* through which one can grow into the *wisdom of direct experience*** - from ***thinking or believing***, which are knowledge/data-based characteristics of a mind perceiving itself as *finite* - to **KNOWING,** through Direct Cognition of the Experience of BEING, which is a characteristic of a consciousness KNOWING itself as ETERNAL. .

In our first lessons of **Kathara Healing,** we gained *knowledge* of the *Context of Healing* and the *structure* of that which exists within and around us, so that we may become more empowered to serve as a *healing force*, within ourselves and within the collective of the Whole. **But this knowledge will only become practical or useful to us if it is applied to foster the direct experience through which the wisdom of KNOWING may emerge.** Then, and only then, will we be changed...then and only then will we become *true agents of healing*. **Knowledge can help you to *understand the nature of health and healing*, but only through KNOWING HEALTH through *direct experience* will you be *healed.*** To KNOW HEALTH we must rediscover this quality within ourselves, to EXPERIENCE the *quality of wellness* that emerges as the **Imprint for Health** is reawakened within the human body. **First we must use *knowledge* to recognize that the *Imprint for Health* is there, sleeping silently within us awaiting this awakening.**

Healing the Causal Core

Fixing symptoms does not restore the *Imprint for Health*, it simply masks from view the *causal elements* through which non-health manifested. Removing the symptom *without addressing the underlying cause* simply sets the stage for the cause to *re-manifest itself* in new ways, through *new sets of symptoms*. **Each symptom you remove will give birth to another symptom if the *underlying cause* is not changed.** Kathara Healing addresses the **deepest *causal factor*** in manifestation, the **Holographic Template Kathara Grid,** upon which all conditions come into being. **Within the intrinsic structure of the Kathara Grid the dormant *Imprint for Health* is sleeping, and through knowledge of the Kathara and applications of its methods we can reawaken the Imprint for Health within ourselves, to progressively move into KNOWING HEALTH** through the cognition of Direct Experience.

In Kathara Healing you are provided with the knowledge you need to understand the structures upon which the *Imprint for Health* is built, for in understanding these structures you will be enabled to call the Imprint for Health into awakening. **But it is through the APPLICATION OF KATHARA TECHNIQUE that you will AFFECT CHANGE. The technique applications offered in Kathara Healing allow you to "bring the knowledge home" to the core of its usefulness, the ability to lead you into the *direct experience of health-ward change.***

Elements of Healing

In **PART II THE ELEMENTS OF HEALING**, we will apply the knowledge of the *Context of Healing* that we acquired in *PART I*, directly to its relevance in terms of the **HUMAN BODY**. We will now explore **Kathara Mechanics** as they apply directly to the human system, and you will gain the knowledge of your **15-Dimensional Anatomy** through which you may then effectively utilize **Kathara Mechanics Techniques** to begin your journey into the **EXPERIENTIAL REALITY OF HEALING.** We will discover the long forgotten potentials of the ***Planetary Bio-feed Interface System™*** and how to receive energy for healing directly from the Kathara Grid of the Earth. We will explore the real processes within and behind the experience of growth through time, so that we may finally identify the **true causal element intrinsic to the *degeneration* and *death* of the body.** We will come to understand the functions of the Body-Mind-Spirit System as they are **INTENDED to operate**, to identify the areas in which malfunction is occurring, so that we may *remedy the casual factors* to progressively restore the **INTENDED INTEGRITY OF THE BODY-MIND-SPIRIT SYSTEM. In PART II we will reclaim our knowledge of our *multidimensional anatomy*, and rediscover the buried secrets of awakening the *Imprint for Health*.**

MAHARIC SHIELD

The Imprint for Health and the *Maharic Shield*

Restoration of health within the body is a progressive endeavor that takes time. Portions of the Body-Mind-Spirit System that have been malfunctioning must readjust to a new process of function that will progressively work its way up from the core **Kathara Grid Holographic Template**, into the **Bio-energetic Field**, **Chakra System** and **DNA**, to progressively ***reset*** the **Imprint for Health** within the Body-Mind-Spirit System. **The Imprint for Health sleeps soundly now within a portion of the multidimensional anatomy called the *MAHARIC SHIELD*.** The Maharic Shield is a buried treasure of **REGENERATION and REVITALIZATION** of the human organism, as it is the key to *recoding the human Kathara Grid* back into its original Imprint for Health. **The *Imprint for Health* is a tangible construct of energy that is located within the structure of the *Maharic Shield*.** In calling these dormant energy systems into activation within the body, one has the opportunity to restructure the causal level of malfunction, and to recode the Holographic Template upon which malfunction manifests.

Reciprocal Reflection and the Kathara Grid

All conditions of dis-ease within the Body-Mind-Spirit System *share a common core of causality - distortions of the Kathara Grid* upon which manifestation is built. All symptoms affect the Body, Mind and Spirit *simultaneously*, malfunction in one aspect of being will have its *reciprocal reflection* in the other aspects of being, as the symptoms emanate from distortion in the *Kathara Core*, upon which all aspects of being simultaneously manifest.

As we work with restoring integrity to the *Holographic Template Kathara Grid*, we are thus creating *simultaneous restoration through Reciprocal Reflection* within the *Body*, the *Mind* and the *Spirit* (the CONSCIOUSNESS that makes up the substance of our multidimensional anatomy and identity).

The Maharic Shield and Whole-Being-Healing

In activating the *Maharic Shield* to regenerate the *Imprint for Health*, you will have change occurring within multiple levels of being. Your **BODY** will begin to reflect change as dis-ease-causing distortions are released from the *biological imprint*, and a higher level of order is reestablished within the ***atomic structure***. Your **MIND** will begin to reflect change as dis-ease-causing distortions in your **thoughts, ideas and beliefs** are released from the *mental body* awareness. Your **SPIRIT**-consciousness, will reflect change, as divisions between your embodied awareness and the expanded portions of your multidimensional awareness will begin to dissolve, and you will become progressively more able to embody greater states of *cognition, creativity and awareness*. ***Kathara Grid recoding* through the use of the *Maharic Shield* will set in motion the processes of WHOLE BEING HEALING, as the *Imprint for Health* is progressively reawakened and restored within the Body-Mind-Spirit System.** Activation of the **Maharic Shield** within the personal Kathara Grid will lay the foundations for progressive, lasting and powerful restoration of the **Imprint for Health** within your Body-Mind-Spirit System.

Learning to activate the Maharic Shield to restore the Imprint for Health requires a bit of **knowledge** regarding *Elements* of the hidden anatomy of multidimensional being, and application of specific **energetic mechanics** that will directly affect these hidden structures of energy. We will begin PART II with a discussion on the **ELEMENTS OF HEALING as they apply to *developing the skills required to create the condition of Maharic Shield activation*, through which the *Imprint for Health* can receive its wake-up call.**

THE PLANETARY BIO-FEED INTERFACE SYSTEM™

Awakening the Personal and Planetary Templar Complex Connection

Interwoven Personal and Planetary Kathara Grids

The core Holographic Templates of both the *personal* and the *planetary* morphogenetic fields are built upon a Scalar standing-wave *Kathara Grid*. As the morphogenetic fields of **species** are interwoven into the larger morphogenetic field of the **planet** they inhabit, there is a **direct energetic connection between the Kathara Grids of individuals and that of the planetary body. This connection between personal and planetary Kathara Grids is called the *Planetary Bio-feed Interface System*™, - PBIS.** For thousands of years the **planetary Kathara Grid** has carried **distortions** in its natural pattern that have rendered the **PBIS** primarily inoperable. **Kathara distortions in the planetary morphogenetic field blocked the human's innate ability to draw energy for regeneration and revitalization from the planetary morphogenetic field.**

When the human Kathara Grid system is working properly there is a *natural sympathetic rapport* between the personal and planetary Kathara Grids that keeps the *Imprint for Health* within the human *Maharic Shield* functioning properly. Due to the distortions of the planetary Kathara, the human Kathara developed **reciprocal distortions**, which created **blockages between the Maharic Shield Imprint for Health and the other functional portions of the human Kathara.** The blockages with the human Kathara manifested as distortions within the natural function of the **DNA** and bodily systems, disarming many of the natural *self-regenerative functions* organic to human biology and rendering the human form more susceptible to disease and malfunction of the biological system. As there is a **Reciprocal Reflection** of patterns between the Body, Mind and Spirit aspects of the human organism, due to their *common causal element* of the *Kathara Grid Holographic Template*, **distortions within the DNA and physical body function also become reciprocal distortions** within the **mental body** and its **perceptual facilities**, and within the **Spiritual Body**, as the Kathara distortions *block and distort* the organic cycles through which higher dimensional aspects of consciousness would progressively embody within and expand the human form.

The Planetary Bio-Feed Interface System™

As the morphogenetic fields of species are interwoven into the larger morphogenetic field of the planet they inhabit, there is a direct energetic connection between the Kathara Grids of individuals and that of the planetary body. This connection between personal and planetary Kathara Grids is called the *Planetary Bio-feed Interface System* ™, - PBIS.

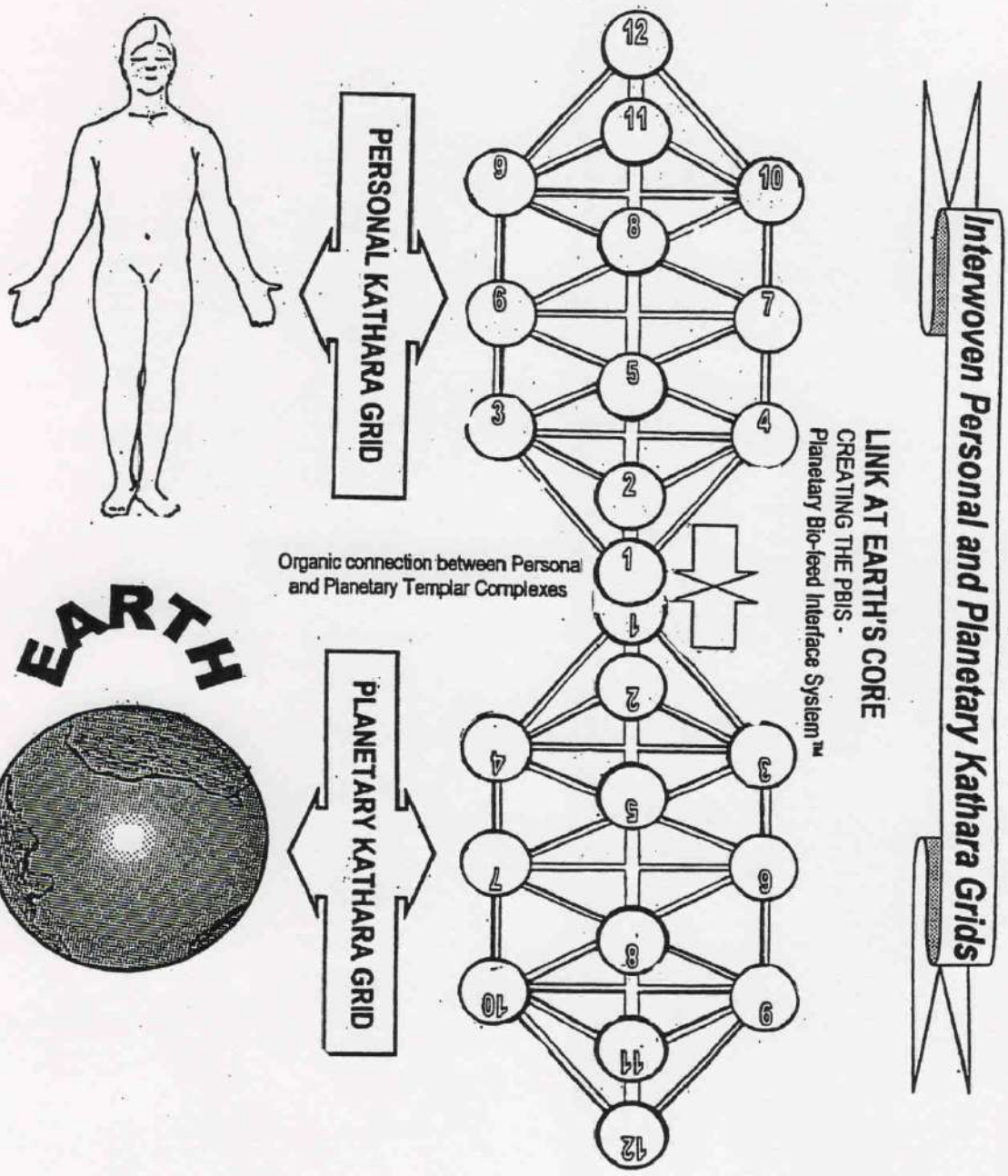

Return of the PBIS - Gift of the 21st Century

The secrets of utilizing the PBIS have been passed down within the generations of the Melchizedek human families who brought these teachings to Earth long ago, kept hidden from public display until a day when the PBIS could once again become operational through evolution and clearing of the planetary Kathara Grid. These teachings are now being returned into the public arena because **progress has been made in restoring the integrity of the planetary Kathara Grid system. For the *first time in many thousands of years* the potentials of healing held within the PBIS can be returned to humanity, and the PBIS can now be *activated within the personal biology* to reawaken the *Maharic Shield* and its *Imprint for Health*, within the human Kathara System.** Reawakening the *PBIS* and the *Maharic Shield* within the human body *allows the personal Kathara Grid to open into the planetary Kathara Grid*, through which the now-functional **Holographic Template of the planetary Kathara can be used to RESET the original imprint of function within the personal Kathara,** for accelerated regeneration of the **Imprint for Health** within the human form.

HIEROPHANT SYMBOL CODE

The *Hierophant Symbol Code* PBIS Trigger

The first application of the PBIS that we will employ in Kathara Healing is utilizing the energies flowing through planetary Kathara to reawaken the Maharic Shield within human anatomy. The process of opening the PBIS within the personal morphogenetic field involves using a **specific scalar standing-wave-guide GEOMANCY - a consolidated inter-dimensional *frequency pattern* that triggers release of the *frequency seals* (Kathara Level-2 Crystal Seals) on the presently dormant 10th, 11th and 12th Chakras, opening the human Bio-energetic Field and Kathara Grid to the Kathara Grid, Bio-energetic Field, Ley Lines and energy Vortices of the planetary morphogenetic field.** The wave-guide Geomancy containing the frequencies to activate the PBIS and the Maharic Shield can be directed by the human consciousness **in the form of a visually created symbol code. This symbol code is called the HIEROPHANT.** In **TECHNIQUE # 2: *The Maharic Seal and the Liquid Light Cleanse***, to be explored in ***PART III. of Section I,*** the **Hierophant Symbol Code** will be used to bring the **Maharic Shield** and the **PBIS** out of dormancy, in order to **RESET** the **Imprint for Health** within the operational Holographic Template of the human **Kathara Grid.**

The *Hierophant Symbol Code Scalar Wave Guide* for Kathara Reprogramming

Thoughts and **Images** formed by the mind represent **small morphogenetic fields** with minute **Kathara Grids**, that become interwoven into the larger morphogenetic field and Kathara Grid of the human multidimensional anatomy. ***THOUGHTS ARE THINGS*** **in terms of the bio-energetic reality of the body and the Kathara Grid;** ***thoughts become translations*** **of electro-tonal "*digital*" *instructions* within the human bio-energetic field, and directly enhance or detract from the natural function of the electro-tonal programs of the human Kathara Grid.** In recognizing the **power of thought** ***as the power of creation of scalar standing-wave grids***, we can begin to apply that power effectively in regeneration of the Kathara Holographic Template, by **directing needed *electro-tonal instructions* for awakening the *Maharic Shield* into the embodied Kathara Grid.** The **Hierophant Symbol Code,** used in the form of a **visualized image,** sets a **powerful electro-tonal program** within the human Kathara, a program that **triggers the opening between the human Kathara and the PBIS**

The ***Hierophant Symbol Code*** **appears in the form of a *Pale Silver Merkaba Star*, a six-pointed "Star of David", which represents the *electro-tonal program* of the *11th and 12th-Dimensional aspects of the Universal Kathara Grid.*** The **frequency wave spectra** perceived by the human mind as **Pale Silver** represents the **electro-tonal program** of the ***Dark Silver*** *primary frequency band of the 11th-Dimensional wave spectra, combined with the* ***Pure White*** *primary wave spectra of the 12th-Dimensional frequency bands.* Using the **Hierophant Symbol** wave guide to direct *frequency and electro-tonal instructions* through the Kathara Grid, creates a ***scalar standing-wave pattern of 11th and 12th Dimensional frequency*** **within the personal Kathara Grid,** the frequencies in which the **original *electro-tonal instructions*** **for the *Imprint for Health*** are stored. By **awakening the 11th and 12th Dimensional frequencies within the human Kathara and bio-energetic field,** all of the *lower frequencies* within the Kathara electro-tonal program become **modulated and recoded** into their *organic, undistorted pattern,* by the *stronger wave influence* of the higher 11th and 12th Dimensional frequencies, which *contain within themselves* the organic imprint for the *entire dimensionalized wave spectra* of the dimensions that *oscillate below* them.

The Hierophant Symbol Code
Scalar Wave Guide for Kathara Reprogramming

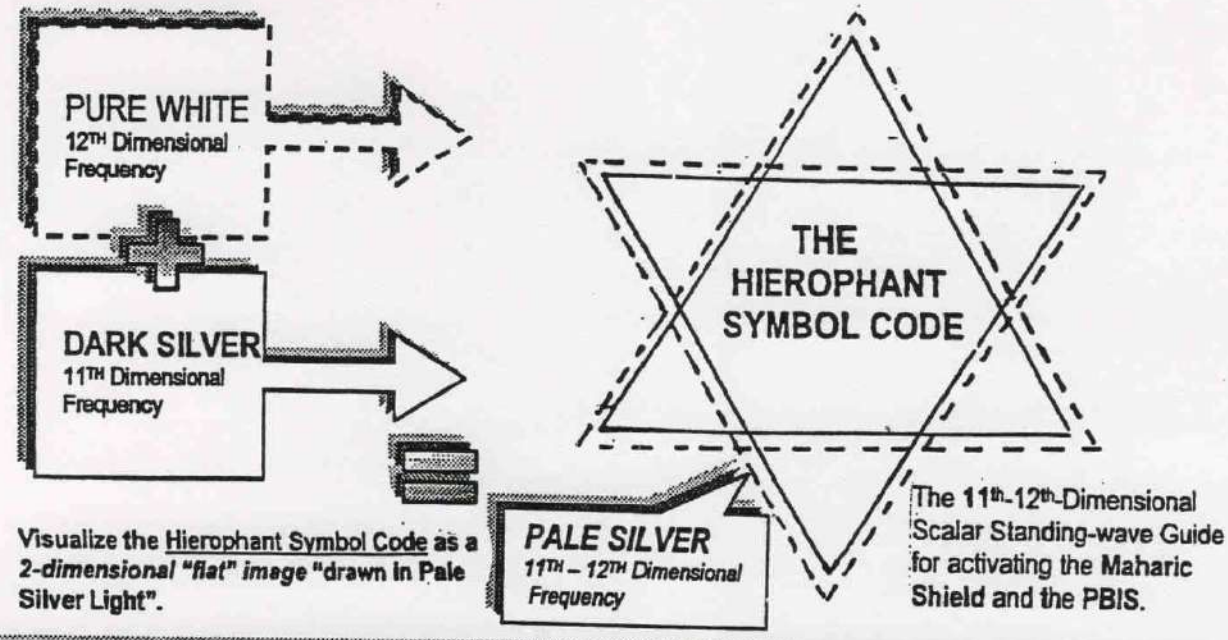

Visualize the Hierophant Symbol Code as a *2-dimensional "flat" image* "drawn in Pale Silver Light".

The 11th-12th-Dimensional Scalar Standing-wave Guide for activating the Maharic Shield and the PBIS.

Ease of Kathara Healing Techniques

Through using the *Hierophant Symbol Code* we awaken the restorative frequency patterns within the *Maharic Shield* and the *PBIS*, beginning the process of regenerating the organic *Imprint for Health in* the human Holographic Template Kathara Grid. The restorative affects of using the *Hierophant Symbol Code* to activate the *Maharic Shield* and the *PBIS* will occur upon using the *Kathara Mechanics* provided in Technique # 2, *whether or not* an individual understands the realities in frequency that are taking place through using this process. Therefore, the complex mechanics of activating the *Maharic Shield* to reset the *Imprint for Health*, can be *reduced to simple instructions* for the direction of energy. Though the theory of Kathara Healing is highly *detailed and complex*, the Techniques by which *active results are achieved* employ simple exercises in *Mental Symbol Code Visualization* and mental energy direction, coupled with the application of simple *Kathara-stimulating massage* to specific corresponding body points. **The *Techniques* of Kathara Healing and regeneration of Kathara Grid integrity are *so simple* that even a young child can learn to actively employ them, to achieve the desired result of restoring the *Imprint for Health*.**

MORPHOGENETIC EXPANSION

Frequency Accretion, Growth, Age Rhythms, Degeneration, Death and Kathara Blockage

Frequency Accretion and Growth Through Time

The morphogenetic field of the human body evolves through time via the process of **Frequency Accretion**. The human morphogenetic field *exists within* the larger morphogenetic field of the planetary and universal dimensionalized **Unified Field of Consciousness-Energy.** Through the inherent function of the **Kathara Grid** and the multi-layered systems of energy built upon it, *progressively more frequency and corresponding wave spectra* from the *dimensionalized Unified Field* are **drawn into** the *personal morphogenetic field* to create **progressive expansion of the morphogenetic imprint and its resulting progressive *expansion of consciousness* and *growth of the physical body* in time.**

Kathara blockages and Organic Growth Cycles

Blockages and scalar wave distortions within the **Kathara Grid** *impede* the natural functions of **Frequency Accretion, and so distort the intended natural processes of consciousness expansion and growth of the body form in time.** When the Kathara Grid is functioning properly, there are **certain *specific points in linear time* when *specific aspects of morphogenetic expansion* via Frequency Accretion are intended to occur. The original cycles of growth and expansion inherent to the human form** occurred between **1. fetal integration through age 11-12, 2. age 11-12 through age 22, 3.age 22 through age 33 and 4. age 33 through age 44**, at which time the human morphogenetic field would reach its **full expansion,** the **DNA** would reach its organic **12-strand activation**, the identity would expand to hold **12-dimensionsof consciousness** within embodiment, and the organism would have **full conscious control of *manifesting and de-manifesting* its 15-Dimensional anatomy in time. The body forms of the original human imprint are IMMORTAL** - deterioration and death were **not a part of the original *Imprint for Health*** within the human Bio-Spiritual makeup. Through understanding how the natural process of growth and expansion in time were INTENDED to work, we can also understand the core reason for the manifestation of the SYSTEMS MALFUNCTIONS - the conditions of biological and mental deterioration that lead to the condition of **BIOLOGICAL DEATH** - a condition that is **INORGANIC TO THE ORIGINAL GENETIC IMPRINT OF THE HUMAN FORM.**

The First Natural Expansion Cycle

In the original human genetic blueprint, the frequencies and dimensions of consciousness corresponding to the wave spectra of Dimensions 1, 2, and 3, were intended to accrete or draw into the morphogenetic field between fetal integration and the age of 11-12. At the age of 11-12 the wave spectra of which the body was composed would take a **leap in frequency**, beginning the process of **expanding the morphogenetic field** to hold the higher frequency wave spectra of **Dimensions 4, 5 and 6.**

The *expansion of the morphogenetic imprint* is reflected in the *DNA*, and *chemical and hormonal balances* within the body, which govern the function of the *metabolic rate* and the operation of molecular function. The **first cycle** of *morphogenetic expansion* into the wave spectra of **Dimensions 4, 5 and 6,** represents the process of **SOUL INTEGRATION** for the embodied identity, and **begins the natural process of de-densification of matter** - *by lowering of morphogenetic vibration, raising of oscillation rate and frequency, and shortening of the wave-length of the scalar waves that compose the matter form and consciousness.* **These changes in *intrinsic wave characteristics* have their reflection within the behavior of *atomic structure*-** as the morphogenetic field wave spectra **raises in frequency**, the ***electron spin* around the atomic nucleus *slows***, thereby increasing the electrical nature, and reducing the magnetic orientation of atomic function, ***transmuting the perceivable matter substance* of the cells to a *less dense* state of being. Completion of the *Soul Integration process* marks the transmutation of *Carbon-based Gross-matter density* into the *Carbon-Silica based Semi-etheric matter density*, and the expansion of embodied awareness from 3 to 6 Dimensions of consciousness.**

Completing Expansion

This process of *progressive morphogenetic field and consciousness expansion* and *resulting de-densification of biological matter* continued throughout the remaining *expansion cycles*. Age **22 to age 33** marked the accretion of the **7th, 8th and 9th -Dimensional** wave spectra, the process of ***Over-Soul Integration,*** expansion into a **9-Dimensional consciousness** and transmutation to a ***Silica-based Etheric matter density biology***. Age **33 to 44** marked the accretion of the **10th, 11th and 12th Dimensional** wave spectra, the process of ***MAHARIC INTEGRATION***, expansion into a **12-Dimensional consciousness** and transmutation **out of biology** into the **Crystalline Liquid Light wave form of Pre-matter substance.** At this point the identity is considered a **full AVATAR** and has complete control over ***manifesting and de-manifesting*** the **Holographic Projection** of its desired body imprint in time.

Growth Rates and Morphogenetic Expansion

ORIGINAL HUMAN GENETIC IMPRINT

PERSONALITY INTEGRATION (Telluric Integration) – **BIRTH - AGE 12**
Expands the Morphogenetic Field through accreting the frequencies of Dimensions 1-3 and activating DNA Strand Templates 1-3.

SOUL INTEGRATION (Doradic Integration) – **AGE 12 – 22**
Expands the Morphogenetic Field through accreting the frequencies of Dimensions 4-6 and activating DNA Strand Templates 4-6.

OVERSOUL INTEGRATION (Teuric Integration) – **AGE 22 – 33**
Expands the Morphogenetic Field through accreting the frequencies of Dimensions 7-9 and activating DNA Strand Templates 7-9.

CHRISTOS AVATAR INTEGRATION (Maharic Integration) –**AGE 33 – 44**
Expands the Morphogenetic Field through accreting the frequencies of Dimensions 10-12 and activating DNA Strand Templates 10-12. Allows full Cellular Transmutation and Dimensional Ascension to the 12th Dimensional Pre-matter Liquid Light HYDROPLASMIC Substance Liquid Silica) and conscious mastery over 12 Dimensions within the 15-Dimensional Time Matrix. A "Christed" Immortal Being possessing non-polarized Unity or Christ Consciousness.

CONTEMPORARY HUMAN GENETIC IMPRINT

PERSONALITY INTEGRATION (Telluric Integration) – **BIRTH – DEATH**

SOUL INTEGRATION (Doradic Integration) – KATHARA BLOCKAGE

OVERSOUL INTEGRATION (Teuric Integration) – KATHARA BLOCKAGE

CHRISTOS AVATAR INTEGRATION (Maharic Integration) – KATHARA BLOCKAGE. Deterioration and Death of the physical body occur rather than progressive frequency accretion for Cellular Transmutation and Dimensional Ascension. Distortions in the personal Kathara Grid and Scalar Shields manifest in the DNA Template and block natural inflow and Morphogenetic Field accretion of frequency from the higher dimensional stations of identity. Conscious awareness remains polarized in Duality Consciousness and physical body is rendered finite and vulnerable to dis-ease.

THE 4 NATURAL CYCLES OF MORPHOGENETIC FIELD EXPANSION

THE *4 CYCLES OF MORPHOGENETIC FIELD EXPANSION* REPRESENT THE *ORIGINAL ORGANIC PROCESS* BY WHICH THE HUMAN ORGANISM WAS *INTENDED* TO EVOLVE THROUGH TIME.

The Inorganic Condition of Human Illness and Death

The processes of biological and mental deterioration and resulting DEATH of the biological form, which we presently view as FACTS OF LIFE regarding the process of human passage through linear time, ARE NOT ORGANIC CONDITIONS TO THE HUMAN ORGANISM. Other life forms, such as the **animal kingdoms**, that manifest through morphogenetic fields having *less than 12 Kathara Centers active* within their Kathara Grid, cannot undergo the full process of bodily transmutation into Pre-matter substance, and cannot fully expand their embodied awareness into 12th-Dimensional consciousness. For the **animal kingdom**, the process of evolution is also Frequency Accretion, but it is achieved through expanding one's body form to its full capacity, then entering the consciousness into a morphogenetic imprint with a bit higher capacity, until eventually the consciousness can accrete enough frequency to take it into the next level of matter de-densification and consciousness expansion. **Death is natural to the organic animal kingdom.**

Humans were intended to undergo the *full spectrum of morphogenetic expansion and cellular transmutation* WITHIN ONE ETERNAL BODY IMAGE, that was built upon a program of *full activation* of the *12 Kathara Centers* of the Kathara Grid. Death is NOT natural for humans.

Kathara Grid Blockage and Molecular Compaction

The process of *biological deterioration* and progressive movement toward biological DEATH is the *direct result* of unnatural BLOCKAGES WITHIN THE KATHARA GRID HOLOGRAPHIC TEMPLATE. Blockages within the Kathara Grid program presently block the process of Frequency Accretion **at the beginning of the First Expansion Cycle-** as accretion of the 4th, 5th and 6th Dimensional frequencies representing the *Soul Integration Process* is blocked within the Kathara Grid and thus within the biological DNA, the incoming frequencies of the Soul Level consciousness **push on and CRUSH the morphogenetic field,** rather than *expand the morphogenetic field into a higher level of frequency holding.* When the incoming scalar wave frequencies of Soul Integration begin to crush the morphogenetic field, a condition called **MOLECULAR COMPACTION** is created.

MOLECULAR COMPACTION -

over exposure to scalar wave spectra **and its resulting** ***fragmentation of the morphogenetic field and Kathara Grid*** **- IS THE** ***ONLY TRUE CAUSE OF DIS-EASE,*** **AND THE** ***CORE CAUSAL ELEMENT*** **OF THE** ***UNNATURAL DEATH EXPERIENCE.***

The *Maharic Shield* and Human Healing

Within the imprint of the **MAHARIC SHIELD** of human morphogenetic structure, is the dormant imprint of the *10th, 11th and 12th Dimensional electro-tonal programs* that represent the **ORGANIC PROGRAM OF THE KATHARA GRID. Through activation of the Maharic Shield** - the scalar standing-wave template that corresponds to the Pre-matter Liquid Light fields of Dimensions 10, 11 and 12 - **blockages within the Kathara Grid Holographic Template, that result in the genetic mutation that causes Molecular Compaction, can be progressively realigned with the original IMMORTAL IMPRINT FOR HEALTH.** Though it takes time and consistent application of **Kathara Healing Technique** to fully regenerate the **Imprint for Health and Immortality** within the 15-Dimensional Levels of human anatomy, working to heal distortions within the Kathara Grid through **MAHARIC INFUSION** (running the frequencies and wave spectra of the *Maharic Shield* through the Kathara Grid, Bio-energetic System and Body), **can create progressively more observable affects in creating and maintaining health, and slowing the bodily deterioration process, within the normal life span of an individual.**

Potentials of Kathara Healing

The true beauty and significance of *Kathara Healing* is that it can not only do wonders for creating and maintaining *higher standards of health* within the average human life span, but within the applications of KATHARA MECHANICS lies the *promise and potential* of human biological IMMORTALITY and the fulfillment of SPIRITUAL ACTUALIZATION and evolution to MASTERY- through progressive embodiment of and conscious mastery over our 15-Dimensional Anatomy and the creative process of Holographic Projection within the dimensionalized fields of space, time and matter.

KATHARA HEALING HOLDS THE KEY TO HUMANITY RECLAIMING ITS ANCIENT HERITAGE OF THE ETERNAL SELF AND IMMORTAL AT-ONE-MENT WITH SOURCE.

LEVELS OF HUMAN ANATOMY- THE EMBODIED KATHARA

The Human Body Kathara Grid

The Kathara Grid of the human body is the *Core Holographic Template* upon which the morphogenetic scalar-wave template, and all other levels of identity and form are built. It is the **"Control Center"** for manifestation of the human being.

LEVEL-1 KATHARA 12-TREE GRID

THE KATHARA GRID LEVEL-1: 12-TREE

Level-1 Kathara Grid 12-Tree: The first level of the Kathara Grid **sets the *pattern for dimensionalization of consciousness* through which identity can enter the Time Matrix for the Holographic Experience of manifestation. The Kathara Grid 12-Tree is the first wave spectra composite through which consciousness anchors itself into dimensionality in order to experience manifestation of form.** All things within dimensional structure have the Kathara 12-Tree at the core, but not all manifest forms have the full pattern of the 12-Tree *activated* within their morphogenetic pattern. The 12-Tree is composed of **12 Kathara Centers** or *Kathara Spheres*, and **15 Kathara Lines.**

KATHARA CENTERS

The **Kathara Centers** are *crystallizations of Partiki units* that hold *composite electro-tonal energy signatures for each dimensional band.* The electro-tonal programs of the Kathara Centers hold the **foundation template** upon which the biological **DNA** will manifest.

KATHARA LINES

The **Kathara Lines** are sequences of *Partiki Phasing rhythms* ("flashing on and off"/fission-fusion sequences) that *transfer the dimensionalized electro-tonal programs of the Kathara Centers between each center* , to form the **core level of the scalar standing-wave template** upon which subsequent levels of the Kathara Grid, Bio-energetic System and body will build.

KATHARA HEALING AND THE LEVEL-1 12-TREE GRID

The *Kathara Centers* and *Kathara Lines* are used in *Kathara Healing* to realign and awaken the original 12-Dimensional imprint within the human morphogenetic field, in order to *reinstate the original Imprint for Health and Bio-Spiritual Mastery* within the operational evolutionary blueprint for the Body-Mind-Spirit System of the Human form.

Level-1 Kathara 12-Tree Grid

of the INTERNAL Ttemplar

KATHARA CENTERS

#12 – *The Capstone*
In 10th Chakra
6" above the head

 # 11 – *Crown Jewel*
In Pineal Gland
at center of brain

 # 9 & # 10 – *The Shar*
In brain
behind ears

 # 8 – *Spark of Orion*
In Thyroid Gland
at 8th Chakra

 # 6 & # 7 – *The Wings*
In shoulder indents
through to back

 # 5 – *Seat of Amenti*
At Navel in
Central Body Current

 # 3 & # 4 – *The Dal*
male: Ureters
female: Ovaries

 # 2 – *Naum-Yun*
male: Prostate Gland
female: Vagina

 # 1 – *Earth Core*
at center of Earth
in 13th Chakra

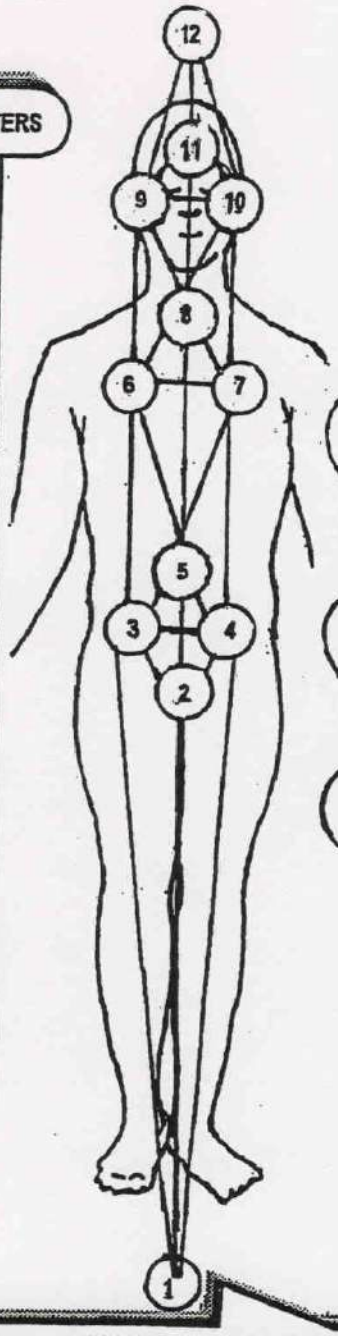

Placement of *Kathara Level-1 12-Tree Grid Kathara Centers* and *Kathara Lines* within the human body.

Central Vertical Kathara Line
controls all other Kathara Lines. Kathara Centers on *Central Vertical Kathara Line* control all other Kathara Centers.

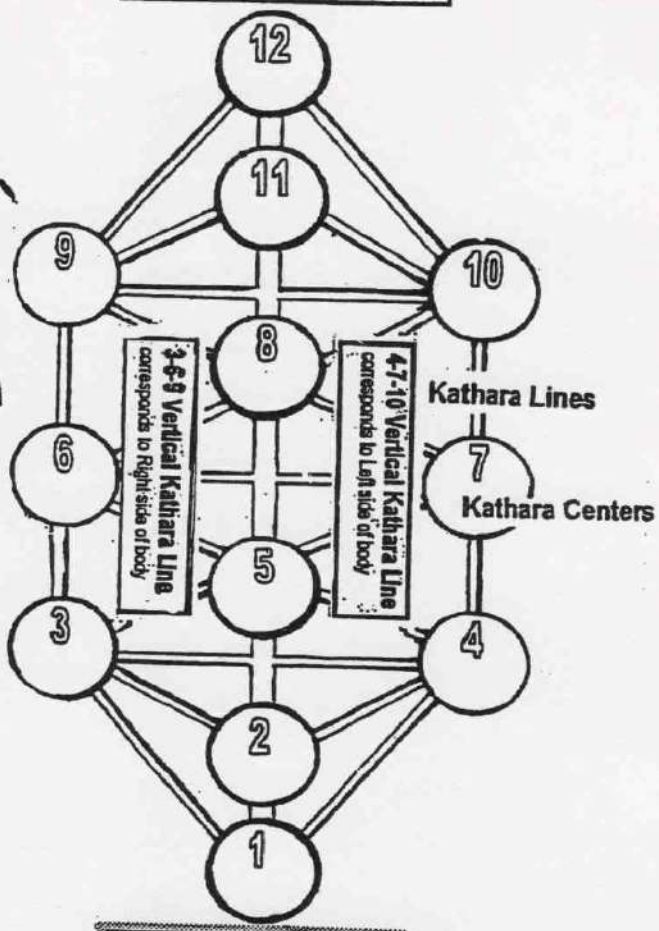

Electro-tonal Programs within the *3 Vertical Kathara Lines* control the programs in all other Kathara Lines.

LEVEL-2 KATHARA CRYSTAL SEALS GRID

Level-2: Crystal Seals and 15 Primary Chakras

The Crystal Seals are groups of 3-Dimensional Partiki scalar wave composites that regulate the rate of Partiki Phasing to create the base structures upon which dimensionalization is formed. The *flow of frequency* between dimensional bands and Harmonic Universes, the fixed expansion and contraction/ fission and fusion rates of Partiki, the *Vibration-Oscillation Rates* of Partiki and the *Angular Rotation of Particle Spin* are all regulated by the Crystal Seals.

Star Crystal Seals are positioned between the Chakra Centers along the **Central Body Current**, and **Seed Crystal Seals** are positioned between them, and serve as the *point of composite frequency* out of which the **15 Primary Chakra Center Vortices** emerge.

HOVA BODIES AND SHIELDS

5 Dimensionalized Hova Body Shields and 5 Auric Capsules

Hova Bodies are **3-Dimensional, tri-tonal scalar standing-wave grids** composed of numerous sets of **Crystal Seals** that form the electro-tonal program upon which the **Kathara Grid Level-3: Doradic Points** emerge. **The Hova Body Grids are called Crystal Shields.** The **5 Dimensionalized Hova Bodies** are structured as **5 Concentric Spheres** of energy that *surround and permeate the human body* and serve to *hold the embodying consciousness into dimensionalized levels* through which the **Holographic Projection** of *experienced manifestation* can occur. The Hova Bodies form **"tissue capsules"** of *subtle energy* around **each 3-dimensional Harmonic** level of the **Bio-energetic Field**, within which the **15 Dimensional levels** of the **Auric Field** are stationed.

In Kathara Healing, restoration of the original **4th-Harmonic Maharic Shield** *Imprint for Health* is used to *realign and clear blockages* from the lower Hova Bodies and corresponding **Kathara Centers** and **Kathara Lines**, to awaken the **Imprint for Health and Spiritual Actualization** within the Body-Mind-Spirit System.

HOVA BODIES, SHIELDS & SIGNETS

5 Ariea Hova Bodies, Kathara Grid and Harmonics of Manifestation

Hova Bodies are *tri-tonal scalar grids* that form *spherical energy "tissue capsules"* around each 3-dimensonal level of the multi-dimensional identity. Within 15-Dimensional Human Anatomy, there are **5 Dimensionalized Hova Bodies** called **Ariea Hova Bodies.** The Ariea Hova Bodies form out of the electro-tonal programs held within the **Kathara Centers** of the *Level-1 Kathara 12-Tree Grid.* The *12th Kathara Center* of the Kathara 12-Tree Grid connects to the *12th Kathara Center* of the *Universal Kathara Grid*, just as the *1st Kathara Center* in the personal Kathara connects to the *1st Kathara Center* in the *Planetary Kathara Grid. The 12th and 1st Kathara Centers, the personal Kathara Grid and morphogenetic field connect to the planetary and universal morphogenetic fields.* **When working with the Hova Bodies we first focus upon the lower four , as these must be functioning properly before the 5th Hova Body and its connection to the Universal Kathara Grid can be activated within the Bio-energetic Field.** Four of the 5 Ariea Hova Bodies are directly connected to the Crystal Seals within the human body **Central Body Current** on a **HORIZONTAL PLANE.** These first **4 Hova Bodies** correspond to each of the **12 Kathara Centers** of the personal Kathara 12-Tree Grid. **The Hova Bodies represent Harmonics of Manifestation.**

Hova Bodies, SIGNETS and SHIELDS

Each Hova Body **emanates outward** from a set of **3 Kathara Centers** and their corresponding **Crystal Seals. The *core template of the Hova Body* is a *Triad of Crystalline Spheres* that connect directly to the *3 Kathara Centers* to which they correspond.** This Triad of Crystal Spheres is called a **SIGNET. The Signets are the smaller, *fixed, consolidated frequency points* out of which the *Seed Crystal Seals* that form the *Chakras* manifest.** The Signets and the smaller Crystal Seal formations that manifest through them, create a **disc** of spinning, **horizontal wave spectra** that direct the function of *Hova Body merger*; these scalar discs are the scalar templates upon which the Hova Bodies manifest, and are called **SHIELDS.**

The *Shields and the Signets* that direct them are considered to be the *core of the Level-2 Crystal Seals Kathara Grid.* Each of the 4 Hova Bodies of the first 12 Dimensions form upon a set of **3 Signets.** Each **Signet *transmits a flash-line*** (Partiki Phasing Sequence) **on a different axis**, one **vertical**, one **horizontal** and one **diagonal**, forming a **3-plane projection of flash-lines** that form the base of the **3-dimensional Holographic projection.**

Kathara Centers and Activating the Signets and Shields

In each set of *3 Signets* at least one corresponds to the *Central Vertical Kathara Line*, the control center of the Level-1 Kathara Grid 12-Tree. The Signets and Shields can therefore be used to direct the function of the Kathara Grid 12-Tree and all built upon it, and the Kathara Centers can be used to trigger activation of the Signets and Shields within the Hova Bodies. When a **Signet is activated** its corresponding **disc or *Shield* begins to spin.** When a certain spin rate of the Shield is reached, it triggers the activation of the next set of Signets in the next Harmonic setting the next Shield to spin. **When *2 Shields activate* and reach a reciprocal spin rate the *tissue capsule* separating the 2 corresponding Hova Bodies releases and the *2 Hova Bodies merge*, which is the process by which *Higher Identity Integration* occurs. It is also the process by which the *Merkaba Vehicle* is activated within the Bio-energetic field.** When all **four Shields** activate and spin, the body matter is able to **transmute** out of matter density and into pure wave form, which represents Maharic/ Avatar Integration for the identity.

THE 5 HOVA BODY SHIELDS

The Hova Bodies and the Shields

Each Hova Body contains at its core a Shield through which the Hova Body functions are governed. The **Nada Hova Body** of dimension 1-2-3 forms on the **TELLURIC SHIELD**, its control center being the 2nd Kathara Center that is composed of 2nd Dimensional Frequencies. The **Alphi Hova Body** of dimensions 4-5-6 forms on the **DORADIC SHIELD**, its control center being the DORA or Archetype of the 5th Dimensional Frequencies. The **Betcha Hova Body** of dimensions 7-8-9 forms on the **TEURIC SHIELD**, its control center being the TEURA or Monad of the 8th Dimensional Frequencies. The **Mahara Hova Body** forms on the **MAHARIC SHIELD**, its control center being the *Mahunta* or Avatar Core of the 11th Dimensional Frequencies. The 5th Hova Body, the **Raja Hova Body**, forms on a set of Signets that correspond to **stellar points** within the **Universal Kathara Grid.** Its Shield, the **RISHIC SHIELD**, rotates on a **vertical plane** and it comes into activation within the personal morphogenetic field only after the four lower Shields have transmuted the body into Pre-matter Liquid Light of the MAHARIC SHIELD. **In terms of healing and advancing evolution of the earthly identity, the first four Shields are of greatest significance.**

Hova Bodies, Shields, Signets and Healing

In all healing application knowledge of the Shields is of great value, for any manifest condition of disorder will have its first manifestations within the Kathara Grid and the Shields that form upon it. The process of healing, therefore, is the process of *restoring the Shields to their proper order* so they may activate to build the Merkaba Vehicle through progressive Higher Identity Integration. **In Kathara Healing we begin with the MAHARIC SHIELD**, the Shield that contains the *pure form of electro-tonal programs upon which the consciousness first entered matter density* through the Pre-matter Liquid Light Fields of the 4th Harmonic - Dimensions 10-11-12. **Through activating and progressively drawing in the highest 11th and 12th-Dimensional frequencies of the Maharic Shield, distortions in all lower Shields can be more rapidly realigned with their original pattern.** When we work with the **Kathara Centers** of the Level-1 12-Tree Grid we simultaneous create change within the **SIGNETS** that direct the function of the **SHIELDS**, and so we are able to more rapidly facilitate appropriate realignment of the Shields and Hova Bodies. **THE CORE OF HEALING IS RESTORING THE HOVA BODIES AND THE SHIELDS UPON WHICH THEY MANIFEST TO THEIR ORIGINAL INTEGRAITY OF ORDER.**

Shields, Signets and Diodic Points

Through the interaction and interplay of multi-harmonic frequency between the **Shields, Signets** and their **Crystal Seals, Kathara Grid Level-3- DIODIC POINTS** come into manifestation, to fill out the 3-plane, 3-dimensional "armature" of scalar waves and flash-lines, upon which more Partiki units will cluster and crystallize to build up the particle base for form manifestation. The **Diodic Points** within the body and morphogenetic field connect directly to the Shields of the Hova Bodies in areas where the *flash-lines and scalar points* within the Crystal Seals of the Shields *align with and pass through each other.* **Flash-Lines from one Hova Body Shield crossing through those in other Hova Body Shields form *COORDINATE POINTS*, or "Gateways" of energy-consciousness *transference* through which frequency and awareness from one Hova Body and identity level can cross through into other Hova Bodies and identity levels.** The *Coordinate Points*, or *regularly scheduled points of flash-line intersection*, form **tiny vortices of energy**, which keep energy and consciousness flowing throughout the multiple dimensional levels of identity and anatomy. **The vortices of energy created by the Coordinate Points of flash-line sequences are called *DIODIC POINTS* and they have a counter reflection within *anti-particle manifestation* called *MIODIC POINTS.*** Diodic and Miodic Points are sets of **White and Black Holes** that circulate energy throughout the anatomy.

LEVEL-3 KATHARA GRID DIODIC POINTS

Diodic and Miodic Points

Diodic/ Miodic Points represent *concentrated areas of energy* that emerge at points where *dimensionalized levels of scalar grids cross over and through each other*, creating minute **vortices** of wave spectra that serve as **frequency modulation zones** (*scalar flash-cycle transition points*) between Dimensional Frequency Bands. Diodic Point vortices are **White Hole** vortices that *transmit energy* into the Particle Universe from their counterpart **Miodic Point** vortices within the Anti-particle Universe. Through the **structure of Dimensionalization**, each Harmonic Universe, and the structures contained there within, have within their morphogenetic fields *sets of Diodic and Miodic Points* - **sets of White and Black Holes** - that regulate the flux of consciousness-energy between systems.

Within the biological form and morphogenetic field, Diodic Points are located in **physical body regions** where Inter-dimensional and Inter-Harmonic **Horizontal and Vertical Kathara Lines intersect** to form small **vortices** of inter-dimensional or inter-harmonic wave spectra that serve as **Gateways of Consciousness** between Dimensional Time Continua of Harmonic Time cycles. They connect physical bodies to their **anti-particle counterparts** and intersect with the Vertical and Horizontal relationships of wave spectra within the **DNA/ RNA** and bio-energetic field, through sets of White and Black Holes at the center of the biological Harmonic scalar grids.

Diodic Points and 3-Dimensionality

Diodic Points control the **Diagonal Kathara Lines**, the **sequences of Partiki Phasing** or ***"flash-lines"*** that run on a **diagonal** between the Kathara Centers. Whereas the **Kathara Level-1 Kathara Lines** direct the **Vertical flash-line sequences** and the **Level-2 Crystal Seals** control the primary **Horizontal flash-lines** and their relationships to the Vertical flash-lines, the **Diodic Points** further regulate the relationships of flash-line sequences through the Kathara Grid by serving as **"turnstiles of energy"**. The Diodic Points intersect with the crossover points of the Vertical and Horizontal flash-lines , *adding a further level of modulation* to the frequencies passing through, allowing a **3-dimensional Harmonic Projection of flash-lines** (flash-lines projecting on 3 differ angular planes)to build within the morphogenetic field. **The Diodic Points add the third plane of projection to the Kathara Grid, beginning the formation of what will appear as a 3-dimensional "armature" of flash-points upon which particles will accrete to "fill out" the Holographic illusion of 3-dimensionality.**

Diodic Points and Healing

In Kathara Healing Diodic Points are used to open the **Diagonal Kathara Lines** for reprogramming. When Diodic Points become blocked, due to blockages within the Kathara Grid (which appear as "gaps" or missing sequences of flashes along the flash-lines of Partiki Phasing), energy builds up in the *Level-3 Kathara Grid*, forming *distortions* in the natural pattern that will manifest in the body and bio-field systems as *disease or disharmonic condition*. In later applications of Kathara Healing we will learn to identify points of Diodic and Miodic build-up in the body, and use *primary flash-line sequences applied through touch points* to realign the natural flash-point sequences and clear the Diodic Blockages.

Shields, Signets and the Kathara Grid

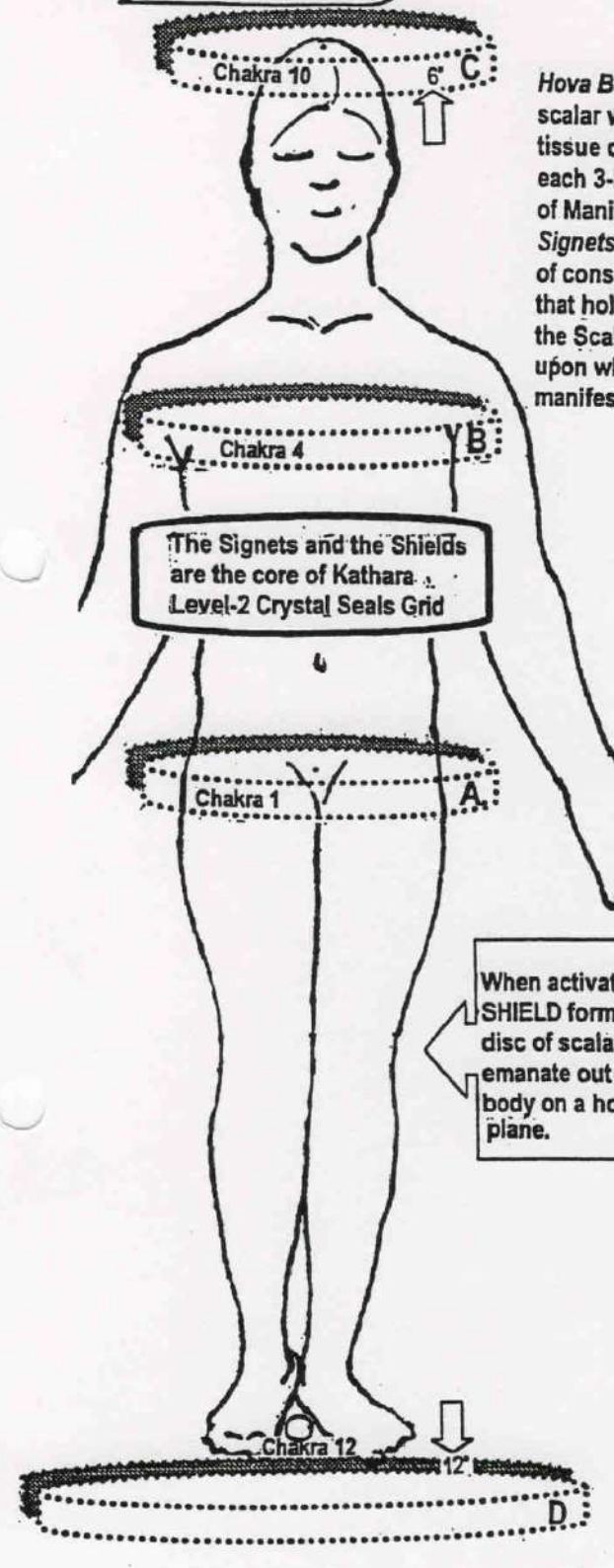

Hova Bodies are spherical scalar wave grids that form tissue capsules between each 3-Dimensional Harmonic of Manifestation.
Signets are the core points of consolidated frequency that hold the programs for the Scalar grid SHIELDS upon which the Hova Bodies manifest.

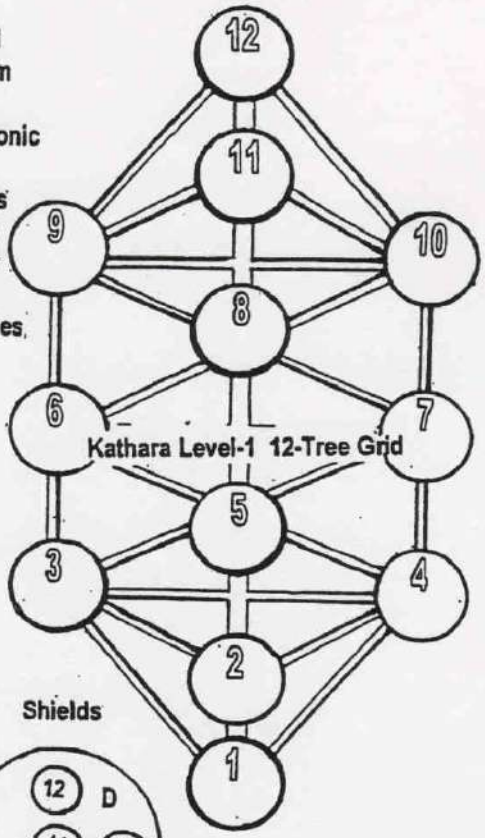

When activated, each SHIELD forms a rotating disc of scalar waves that emanate out from the body on a horizontal plane.

Shields

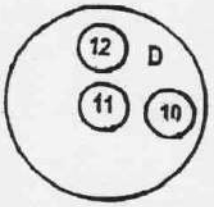

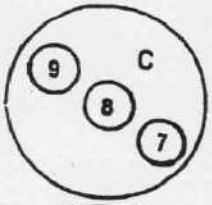

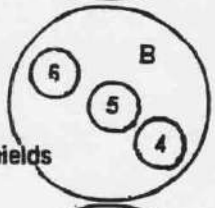

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

HORIZONTAL SHIELDS
A. TELLURIC SHIELD
Nada Hova Body
B. DORADIC SHIELD
Alphi Hova Body
C. TEURIC SHIELD
Betcha Hova Body
D. MAHARIC SHIELD
Mahara Hova Body
E. RISHIC SHIELD
Raja Hova Body
(vertical- not shown)

Level-2 Kathara Crystal Seals Grid and Chakras

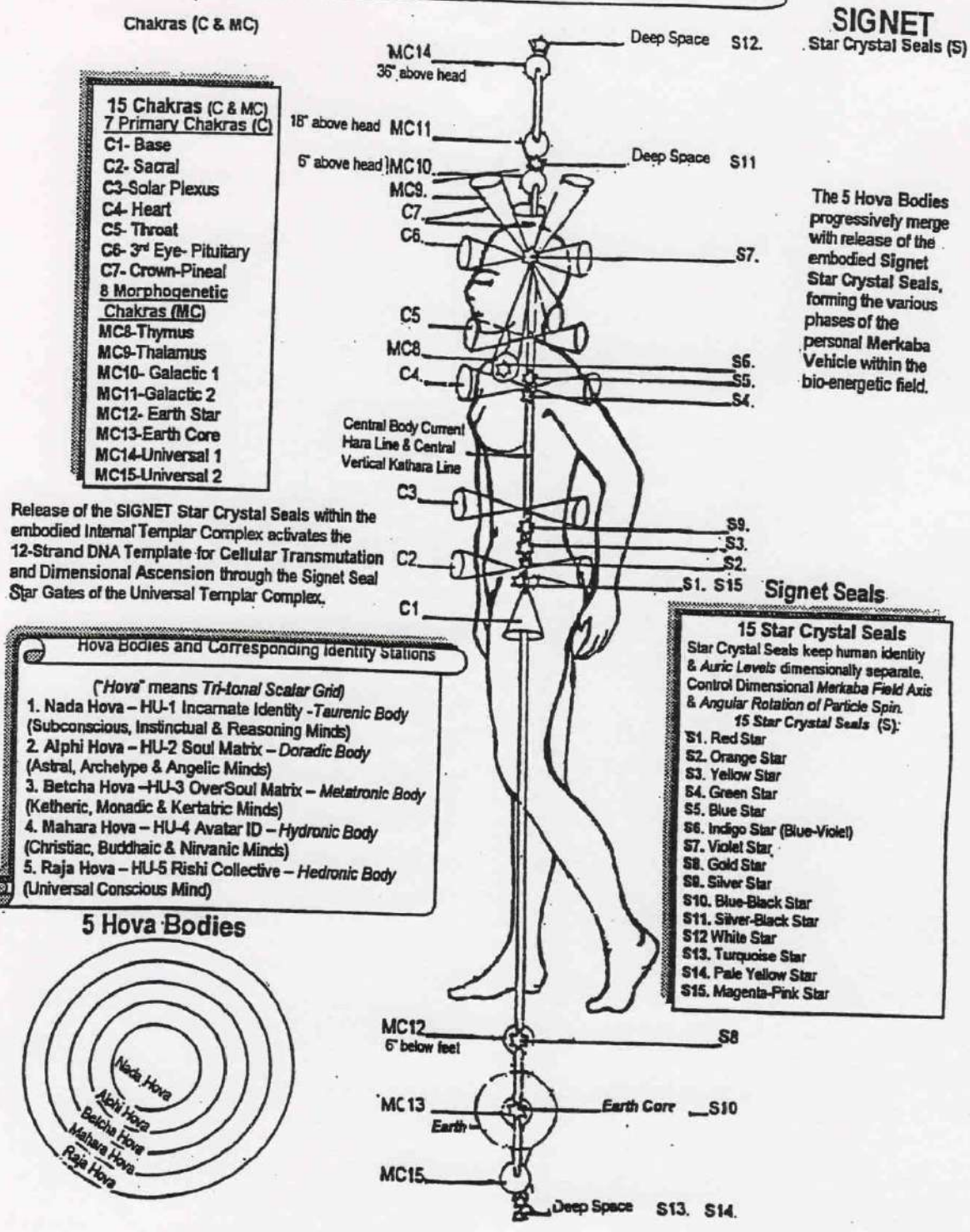

AXIOM LINES, AURIC LEVELS AND CHAKRAS

Diodic Points, Signets, Seed Seals and AXIOM LINES

Each **Signet** within a Hova Body Shield holds the electro-tonal program for one *Seed Crystal Seal* and one *dimensionalized flash-line sequence*. Each Seed Seal program corresponds to one *dimensionalized flash-line program* from one *Level-1 Kathara Center*. Each **Seed Crystal Seal** holds intact the electro-tonal program for one ***dimensionalized flash-line projection angle***, or **Single Axis Dimensional flash-line sequence.** The Single Axis Dimensional flash-line sequences controlled by each Seed Crystal Seal are called **AXIOM LINES.**

There are **12 Primary Axiom Lines** that correspond to the 12 Kathara Centers in the *Personal and Planetary Kathara Grids*. There are 12 additional **Stellar Axiom Lines** that correspond to the 12 Kathara Centers in the Universal Kathara Grid. **The Axiom Lines represent single-axis flash-line sequences** - (fixed points of conscious electrified sound- *electro-tonal units*- that form strands of scalar standing waves) **that intermesh to refine the scalar-grid webbing upon which Kathara Grid Level-3 Diodic Points will emerge.**

Axiom A-B Tonal Lines, Diodic-Miodic Vortices, Chakras-DNA-Portals-Ley Lines & Healing

Each of the 12 Primary Axiom Lines has a **reverse reflection** within the dimensions of the **anti-particle universe**. The 12 Primary Axiom Lines governing the **Diodic "White Hole" Vortices** of the **particle universe** are called **Axi-A-Tonal Lines** (or "Axiatonal" Lines). The corresponding reflections of the Axi-A-Tonal Lines in the **anti-particle universe,** which govern the **Miodic "Black Hole" Vortex** reflections of the Diodic Points, are called **Axi-B-Tonal Lines.** In Kathara Healing the integrity of the Axi-A-Tonal Lines is restored through realigning the electro-tonal programs within the corresponding **Kathara Centers**. The **12 Primary Axi-A-Tonal Lines** set the morphogenetic imprint upon which the **Chakra System** and foundation **DNA** organization of the human body will manifest and upon which the **Planetary Vortex/Portal System** and primary **Planetary Ley Lines** will emerge within the planetary body. Restoring the *Imprint for Health* to the **Axi-A-Tonal Lines** and corresponding **Kathara Centers** will regenerate integrity within the **DNA** and **Chakra System** of the body and will restore the organic operations of the planetary **Vortices-Portals** and **Ley Lines** of the planetary morphogenetic grid.

Restoring the **Imprint for Health** within the **Axi-A-Tonal Lines** simultaneously restores integrity to the corresponding **Diodic Points** and to the **Axi-B-Tonal Lines** and their **Miodic Points**. When working with *Kathara Techniques* that "clear the **Miasmic Imprint**" – *the anti-particle blockages within Diodic Points* – the *Diodic Points* are realigned by clearing their *Miasmic distortions*, which then reestablishes the integrity of corresponding **Axiom A and B Tonal Lines**, sending a realigned electro-tonal program back through the **Seed Seals** and the Level-1 **Kathara Centers.** If the programs within the **Kathara Centers** are **simultaneously realigned** using infusion of the frequencies from the **Maharic Shield**, the Kathara Center programs, the Axiom Lines and the Diodic Points will be progressively restored to health. If the Kathara Centers are not simultaneously realigned, the restored Axiom Line programs will be **overridden** by the Kathara Center programs until the restored programs reach *critical mass* through *prolonged repetition*. ***Clearing the Miasmic Imprint* while simultaneously *Repatterning the Level-1 Kathara Centers and Kathara Lines* via *Maharic Infusion* is the fastest way to restore the *Imprint for Health* within the Human Body-Mind-Spirit System and within the natural operations of planetary bio-mechanics.**

Axiom Lines, Diodic Points, Hova Bodies, Shields and Auric Field Levels

The Single Axis flash-line sequences of the **12 Primary Axiom Lines** cross over and through each other to form COORDINATE POINTS between the Hova Body Shields, through which the "White Hole" ***Level-3 Diodic Point Vortices*** emerge. **The varying angles of flash-line projection within the Axiom Lines create separate dimensionalized bands of frequency** (separate sets of flash-line sequences) **within the Hova Body structure.** As there are **3 Signets and thus 3 Seed Seals** and **3 Axiom Lines** inherent to each **Hova Body Shield**, each Hova Body becomes *dimensionally compartmentalized* into **3** separate yet interrelated sections, each section having inherent sets of Diodic Points. **Each dimensionalized aspect of the Hova Bodies becomes a *Level of the Auric Field* within the bio-energetic system.** There are **12 Inner Layers of the Auric Field**, which correspond to Dimensions **1-12** and to the 12 Primary Kathara Centers, Seed Seals and Axiom Lines of the *first 4 Hova Bodies*. There are **3 Outer Layers of the Auric Field** that correspond to Dimensions and Seed Seals **13-15**, to the *first 3* Kathara Centers and Axiom Lines of the **Universal Kathara Grid** and to the *5th Hova Body*.

Seed Seals, Axiom Lines, Consolidated Diodic Points, Chakras and Auric Levels

The points in the Kathara Grid where the Single Axis Axiom Lines cross over and through the Central Vertical Kathara Line in the Level-1 Grid and the Horizontal flash-lines of the Seed Crystal Seals form fixed, **consolidated Diodic Points –larger vortices** of energy composed of many smaller Diodic Vortices. **The larger vortex points are called CHAKRAS.** Each Chakra Vortex is formed upon the electro-tonal program of its corresponding Dimensional Frequency Band, Kathara Center, Seed Seal and Axiom Line, and **each chakra corresponds to one Auric Field Level, DNA strand imprint and level of consciousness.** As *3 Signets, Seed Seals* and *Axiom Lines* correspond to each *Hova Body Shield*, **3 Chakras regulate and correspond to each of 5 Hova Bodies**, for a total of **15 Primary Chakras. Primary Chakras 1-12** correspond to Kathara Centers 1-12 in the **Personal and Planetary Kathara Grids** and **Primary Chakras 13-15** correspond to the *first 3 Kathara Centers and Axiom Lines* of the **Universal Kathara Grid.** Chakras 13-15 are considered **Universal Trans-stellar Chakras.**

The *Chakras* regulate the *transduction of flash-line sequences* from the *Dimensionalized Unified Field* and *Diodic Vortices* of the Axiom Lines and Auric Field Levels into the *Hova Body tissue capsules* and *rivulet channels* that connect to the physical, electro-magnetic, chemical and hormonal aspects of the visibly manifest form. Chakras regulate the flow of consciousness-energy between the dimensionalized Auric Field levels of the Hova Bodies, keeping the various multi-dimensional stations of consciousness separate, in order to allow for experiential perception of holographic manifestation. Each **Chakra circulates** its Single Axis flash-line sequence along the **angle of projection** carried within its corresponding **Axiom Line**, and this *angle of flash-line projection* determines the **Angular Rotation of Particle Spin (ARPS)** – or the *axis upon which particles rotate*- within each dimensionalized portion of the anatomy. There is a **90-degree shift** in the *flash-line angle of projection* from one Chakra and dimensional band to the next, which creates a 90-degree shift in the **Angular Rotation of Particle Spin** between each dimensionalized portion of the anatomy. Between each 3-dimensional Hova Body there is also a **45-degree reverse shift** in flash-line projection angle, which creates a **45-degree** rather than a 90-degree **forward shift** of flash-line projection angle between each Hova Body and between each **set of 3 Chakras** (Chakras 1-2-3 * 4-5-6 * 7-8-9 * 10-11-12 * 13-14-15). The precise angles of flash-line projection and ARPS between Chakras, creates the perceivable 3-dimensional hologram.

Chakras

A Chakra appears within the bio-energetic field as **2 cones or spirals of multi-colored energy that are linked together at the tip** in the **Central Body Current** through the **Seed Crystal Seal** out of which the cones emerged. **Chakras 2-6** extend from the Seed Seals outward through the body and Auric Field on a **Horizontal axis** and **Chakras 8 and 9** intersect with *6 and 7* at the *Pineal Gland* on **2 rotating Diagonal axes** running through the head. **Chakras 1 and 7 and 10-14** are stacked above and below the body on a **Vertical Axis** aligned with the *Central Body Current* (CBC) and the *Central Vertical Kathara Line*. Chakras 1&7, 10&12, 11&13 and 14&15 are actually the bottom and top cones of **4 Large Vertical Chakra Spirals**, but are counted as separate chakras. **Chakra 15** is a **"roving chakra"**, which travels the course of the **12 Primary Axiom Lines** far out in Level–15 of the Auric Field. Each Chakra draws in energy from and transmits energy into the dimensional Unified Field corresponding to the *chakra number* and carries as its **dominant perceivable color the hue** characteristic to the **primary frequency band wave-length** of its **dimensional affiliation.**

Primary Color of Chakras

Chakra	Dimension	Color	Chakra	Dimension	Color
CK-1	D-1	RED	CK-8	D-8	GOLD
CK-2	D-2	ORANGE	CK-9	D-9	SILVER
CK-3	D-3	YELLOW	CK-10	D-10	BLUE-BLACK
CK-4	D-4	GREEN	CK-11	D-11	SILVER-BLACK
CK-5	D-5	BLUE	CK-12	D-12	WHITE
CK-6	D-6	BLUE-VIOLET (INDIGO)	CK-13	D-13	PALE TURQUOISE
CK-7	D-7	VIOLET	CK-14	D-14	PALE YELLOW
			CK-15	D-15	MAGENTA-PINK

A Chakra will also carry, in lesser saturation, the colors/frequency bands associated with all of the dimensions below its own dimensional affiliation.

Chakras and Dimensional Merkaba Fields

When the Seed Seal at the core of a Chakra is released, the **2 cones of the Chakra move through each other** to form a **Dimensional Merkaba Field**- *2 counter-rotating spirals of electro-magnetic energy that take the form of a* ***Star-tetrahedron.*** When the Seed Crystal Seal releases, the corresponding scalar-wave points within the Hova Body Shield are *released from* ***Dimensional Phase-lock*** – they are released from *polarity* by the re-combining of their inherent *Particum-Particles* and *Partika-anti-particles*. Through re-combining Particum and Partika the scalar standing-wave points undergo **fusion**, then a reciprocal **fission** and **replication** within the Harmonic above. Through release of the Seed Seals the *Dimensionalized Auric Field Levels* of the *lower Hova Body* align along the same *Angular Rotation of Particle Spin* / angle of flash-line projection, which transmutes them into the *angle of flash-line projection* and *Partiki Phasing rate* of the Dimensionalized Auric Field Levels of the Hova Body from the *Harmonic above.* **Seed Crystal Seals are released by infusing them with the frequencies/ flash-line sequences of the corresponding dimension from the Harmonic above.** Progressive release of the Seed Seals within the Chakras creates opening and merging of the Kathara Lines in the Level-1 12-Tree Grid, and merging of the *Hova Bodies, Shields, Diodic Points, Auric and Identity Levels* and *DNA strands, through which activation of the* ***Merkaba Vehicle*** *and de-densification of matter occurs.*

Auric Level, Chakra and Hova Body Correspondences

Each 3-Dimensional Scalar Shield forms a Spherical Electromagnetic Domain called a Hova Body.

Each Hova Body manifests the structure, and governs the function, of 3 Primary Chakras.

Chakras draw energy in from, and transmit energy into, the Unified Fields of each Dimension. Each Chakra carries as its Primary Color the hue associated with the wave-length of the dimensional frequency band to which the Chakra corresponds.

Each Chakra corresponds to a level of the *Auric Field* and one *Axi-A-Tonal Line*. Each *Hova Body* corresponds to a set of 3 Chakras and contains 3 dimensionalized frequency bands that form the dimensional levels of Auric Field.

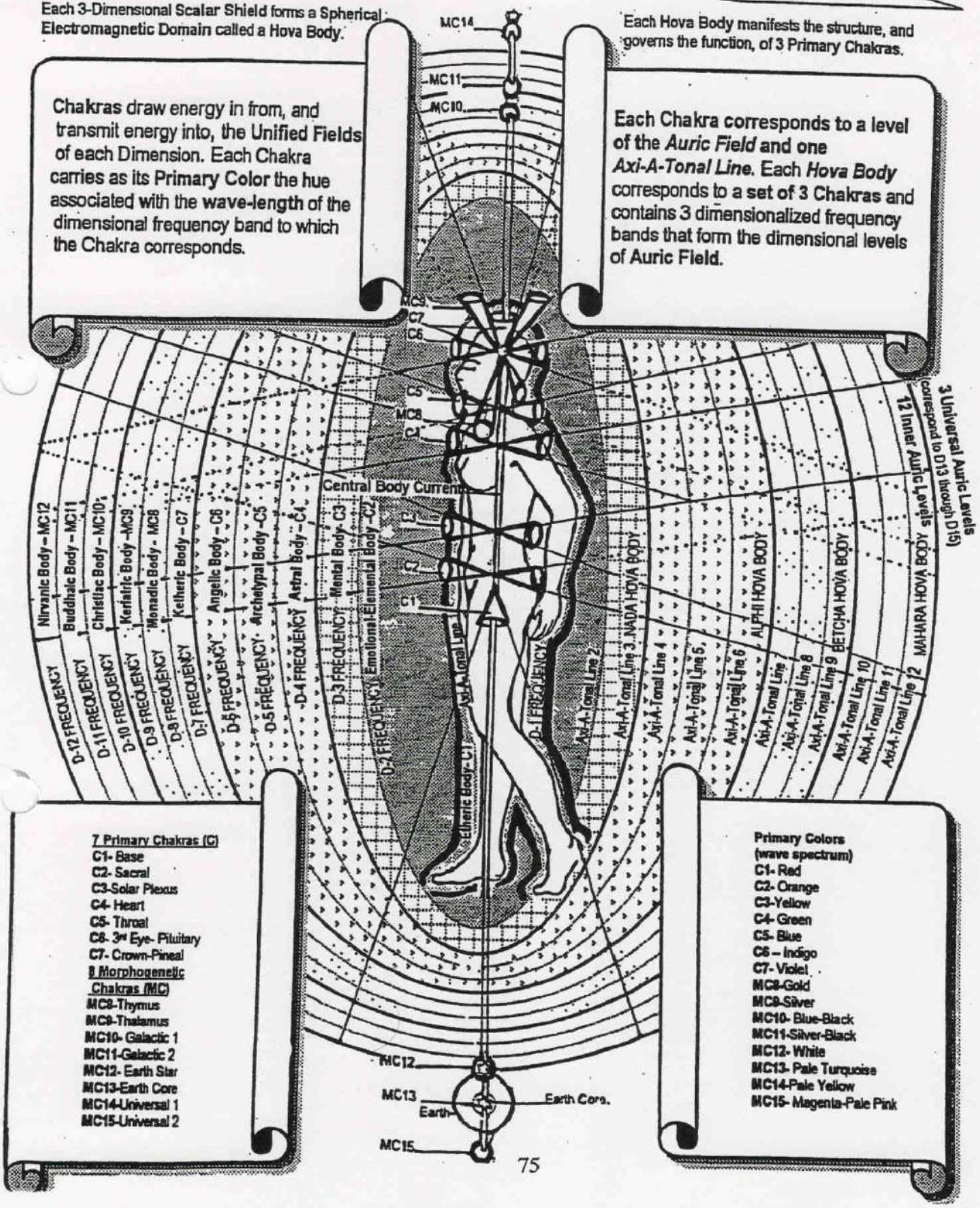

7 Primary Chakras (C)
C1- Base
C2- Sacral
C3-Solar Plexus
C4- Heart
C5- Throat
C6- 3rd Eye- Pituitary
C7- Crown-Pineal

8 Morphogenetic Chakras (MC)
MC8-Thymus
MC9-Thalamus
MC10- Galactic 1
MC11-Galactic 2
MC12- Earth Star
MC13-Earth Core
MC14-Universal 1
MC15-Universal 2

Primary Colors (wave spectrum)
C1- Red
C2- Orange
C3-Yellow
C4- Green
C5- Blue
C6 – Indigo
C7- Violet
MC8-Gold
MC9-Silver
MC10- Blue-Black
MC11-Silver-Black
MC12- White
MC13- Pale Turquoise
MC14-Pale Yellow
MC15- Magenta-Pale Pink

Chakras

PRIMARY COLOR OF CHAKRAS

Chakra	Dimension	Color	Chakra	Dimension	Color
CK-1	D-1	RED	CK-8	D-8	GOLD
CK-2	D-2	ORANGE	CK-9	D-9	SILVER
CK-3	D-3	YELLOW	CK-10	D-10	BLUE-BLACK
CK-4	D-4	GREEN	CK-11	D-11	SILVER-BLACK
CK-5	D-5	BLUE	CK-12	D-12	WHITE
CK-6	D-6	BLUE-VIOLET (INDIGO)	CK-13	D-13	PALE TURQUOISE
CK-7	D-7	VIOLET	CK-14	D-14	PALE YELLOW
			CK-15	D-15	MAGENTA-PINK

A Chakra will also carry, in lesser saturation, the colors/frequency bands associated with all of the dimensions below its own dimensional affiliation.

AXI-A-TONAL LINES, THE HARA LEVEL, 6 HARA POINTS AND COMPLEXES

Axiom Lines, Rotating Flash-line Projection and the Human Body

Each Seed Crystal Seal within the Signets of the Hova Body Shields holds the electro-tonal program for a Single Axis Axiom Line flash-line projection. **The flash-line sequences of each Axiom Line are not simply *stationary* single-line projections of flash-lines, but rather operate as *rotating* single-line projections.** Each rotating Single Axis flash-line projection is ***synchronized*** with the other rotating Single Axis flash-line projections of Axiom Lines from the other Seed Crystal Seals. Through the ***rotational synchronization*** of the Axiom flash-line sequences, the flash-lines of each Axiom Line regularly cross through each other, and through the vertical and horizontal flash-line sequences from the Level-1 and Level-2 Kathara Grid. The points of *synchronized flash-line crossover* form ***consistent points of intersection*** through which the **Level-3 Diodic Vortices** and **Chakras** manifest. Within the human body and Auric Field the **consistent points of flash-line crossover** can be charted in the form of **fixed lines of energy** that run through the body. **The charted Axiom Lines within the human body represent series of regularly scheduled flash-line intersection points, created through the synchronized rotation of the Single Axis Axiom flash-line sequences.**

Axiom A Lines – "Axi-A-Tonal" Lines in the Human Body

The consistent points of Axiom Line flash-line crossover that form fixed lines of energy within the body can be charted as **Axiom A and B Line** energy flows within the body. The Axiom A Lines correspond to the body manifestation in the particle universe, the B Lines to the body double in the anti-particle universe. **For Kathara Healing applications the A Lines – Axi-A-tonal Lines- of the particle body are used for various purposes of facilitating Kathara Center realignment and revitalization of the Body-Mind-Spirit System.** Within the body the Axi-A-Tonal Lines can be charted as **Primary Flow Lines** – conduits through which energy-consciousness, in the form of scalar-point flash-line sequences, circulates through the morphogenetic field. The fixed flash-line crossover points that form the **charted Axi-A-Tonal Lines** appear in the body as a set of **12 Vertical Flow Lines**, one running from each of 12 Auric Field Levels, which run through the body within the **Level-2 Crystal Seals Kathara Grid**. Each Axi-A-Tonal Line corresponds to one of 12 Dimensional Frequency Bands, Kathara Centers, Seed Crystal Seals, Chakras and DNA strand imprints. **The 12 Primary Axi-A-Tonal Lines appear to enter and leave the body through the head and feet, with conduits running through the arms, hands and out the finger-tips, and through the legs, feet and out the tips of the toes. Each Axi-A-Tonal Line appears as a colored cord of energy, its hue determined by the wave length characteristic to its corresponding dimensional frequency band.** In charting the positions of the 12 Primary Axi-A-Tonal Lines in the body, **numbering** and **color** are used to denote the *Dimensional correspondences* of each Axi-A-Tonal Line.

Axi-A-Tonal Lines 11 & 12 and the "Hara Line"

Axi-A-Tonal Lines 11 and 12, which correspond to the 11th and 12th Dimensions, Kathara Centers, Seed Seals and Chakras, run vertically through the center of the body along the Kathara Grid Level-1 **Central Vertical Kathara Line**, forming a ***twisted "rope"*** of Dark Silver (D-11) and White (D-12) energy that wraps around the Central Vertical Kathara Line Flash-line Sequence. The **Central Vertical Kathara Line**, which appears as a **thin Silver-gold flash-line of energy** running from the 14th Chakra (36"above the head) through the body and into the 13th Chakra at Earth's Core, is imbued with frequencies from the **12th, 11th and 8th Dimensions** – the frequencies of White, Dark Silver and Gold.

In *Level-2 Kathara Grid*, the rotating single axis flash-lines of *Axi-A-Tonal Lines 11* and *12* spiral around the thin Silver-Gold flash-line of the *Central Vertical Kathara Line*, merging into a thin, vertical tri-tonal flash-line of primarily *Gold* hue that becomes the core of the *Central Body Current*. In ancient Eastern Healing Systems this **thin Gold Vertical Line** is called the **"Hara Line"**, and is often considered the foundation of the manifest form. In truth, the **Level-1 Kathara 12-Tree Grid** and the *Signets, Crystal Seals* and *Shields* of **Kathara Level-2** are the deeper foundations upon which the Hara Line manifests.

The *Hara Level* of Kathara Level-2 Crystal Seals Grid

The mechanics of the Crystal Seals in the Level-2 Kathara Grid are complex, but can be employed with relative ease through working with the energetic dynamics of the ***outer levels* of the Level-2 Kathara Grid**, the level in which the *Hara Line* can be viewed using *9th-dimensional Higher Sensory Perception*. We refer to this level of the Level-2 Crystal Seals Grid as the **HARA LEVEL**. The Hara Level is composed of the Hara Line, and 6 of the 15 Star Crystal Seals of the Kathara Level-2 Crystal Seals Grid.

The 6 *Hara Points* (Crystal Seals) apparent from the Hara Level are as follows:

1. The 9th *Silver* Core Star Crystal Seal, called the **HARA CENTER**
2. The 6th *Indigo (or Blue-Voilet)* Star Crystal Seal, called the **SOUL STAR**
3. The 12th *White* Star Crystal Seal, called the **GALACTIC STAR**
4. The 3rd *Yellow* Star Crystal Seal, called the **SUN STAR**
5. The 8th *Gold* Star Crystal Seal, called the **EARTH STAR**
6. The 10th *Blue-Black* Star Crystal Seal, called the **EARTH CORE SEAL**

The 6 Hara Points govern and regulate the function of **Complexes** of *energy synthesization and distribution* that control the operations of all primary body systems and bio-energetic field dynamics. In *Kathara Healing Level-2* we will explore mechanics of the Hara Level. In Level-1 Kathara Healing we will simply become familiar with Hara Level as an element of 15-dimensional human anatomy.

THE HARA AND THE KUNDALINI

The Silvery-gold energies of the **Hara Center** (9th Star Crystal Seal) are interwoven at the **base of the spine** with what is referred to as the **KUNDALINI life-force energies.** The Kundalini energies represent the **PRIMARY ENERGY CURRENTS** through which the incarnating consciousness anchors its morphogenetic field within the **Fetal Body** through the **FIRST 8 CELLS** of conception. **The Hara Center energies interweave at the base of the spine with the frequencies of the first Star Crystal Seal, the *RED Star Seal*,** in the First Cell. When the Hara Center Seal is dormant and activated only to *the 3-Dimensional Level* its Pale Silvery-gold frequencies appear to be encased within a **crimson RED sheathe** of 1st-Dimenional energy, often **making the Hara Center and Hara Line appear to be RED in color.** As the Hara Center comes into activation through progressive release of the 9th Star Crystal Seal, the Gold 8th-Dimensional and Silver 9th Dimensional frequencies of the Hara become the dominant hues, giving the Hara Center and Hara Line its natural **Silvery-gold color.** With full activation of the Hara Center and **12th-Dimensional Maharic Integration,** the tri-tone frequencies of the Hara Center and Hara Line take on a **tri-color spectrum** of **Pale Silver, Gold and Red-Violet** (pale Magenta), as the Kundalini primary life force currents at the base of the spine activate within the Central Vertical Current of the body. Full activation of the Kundalini merges the 7th-Dimensional **Violet,** 1st-Dimensional **Red,** 8th-Dimenional **Gold** and 9th Dimensional **Silver** frequencies with the full spectrum **White-Silver** energies of the 12th Dimensional Maharic Current.

The Hara Center, like all Star Crystal Seals, is one of the primary regulatory elements of the natural Kundalini energies. As the Kundalini energies at the base of the spine are brought out of higher dimensional dormancy, through progressive activation of the Star Crystal Seals in the Kathara Level-2 Crystal Seals grid, the Hara Center progressively reflects these changes by expanding in size and energy processing capacities and taking on the hues (wave spectra) of the higher dimensional frequencies. The **Kundalini energies** at the base of the spine are the **key to physical cellular transmutation** of the body. Kundalini energy currents **regulate the physical body's position in space-time,** keeping the physical body phase-locked into the planetary Time Cycle in which it was conceived, following the mathematical programs set by the Star Crystal Seals and the Kathara Grid. For physical transmutation to occur, the Kundalini energies of the higher dimensions must be brought into embodied activation, setting the processes of the **Internal Templar Complex** in motion.

The **DNA Template** manifests upon the programs set by the **Kathara Grid.** As the Kathara Centers and their corresponding Star Crystal Seals, Shields, Kundalini currents, Cranial-Sacral (Pineal-Tailbone) Seals, Seed Crystal Seals and Chakras activate, dormant DNA Strand Template also activate, progressively altering the **Angular Rotation of Particle Spin,** energy-processing capacities, **metabolic orientation** and **neurological processes** of the body and molecular structure. As these physical changes occur through activation of the Crystal Seals and Kundalini energies, the **Merkaba Vehicle** (interdimensional counter-rotating electro-magnetic fields in star-tetrahedral form) progressively builds within the bio-energetic field, allowing the physical body **release from phase lock** within its home space-time vector. **Activation of the Hara Center represents one of the stages of this natural transmutational process.**

THE HARA CENTER

The 9th Core Star Crystal Seal, the Hara Center (Tan Tein) and the D-9 Thalamus Complex

The **Star and Seed Crystal Seals** of the Level-2 Kathara Grid that hold consciousness into the dimensional phase-lock set by the Level-1 Kathara Centers accrete along the Central Vertical Kathara Line and the Central Body Current. **From the *Hara Level* – the *outer portions of the Level-2 Kathara Grid*** - the *12th, 9th and 6th Star Crystal Seals*, **appear as *areas of condensed light* positioned along the *vertical Hara Line*.**

The **9th Star Crystal Seal**, located about 2 " below the Navel is known as the ***Core Star Crystal Seal*** – the point of **8th and 9th dimensional frequency** of the Harmonic-3 Over-Soul Matrix (***Teuric Shield***) that **anchor the personal morphogenetic field into that of the Earth** and serve as the **center of gravity** for the adult human body. **The *Core Star Seal* appears from the Hara Level as a 2" ball of Gold (D-8) energy encased in a thin Silvery (D-9) membrane; in Eastern theory this ball of energy is called the *Tan Tein*, and is used for direction of bodily and Earth energies in advanced martial arts and healing practices.** In Kathara theory we simply refer to this **energy ball** as the ***Hara Center***, or the 9th **Core Star Crystal Seal.**

The ***Hara Center*** is the point at which the dimensionalizing identity enters the **Etheric Matter densities** of Harmonic Universe-3. The Hara Center represents the point into which the **Over-Soul Identity**, its **Monadic Core, the Betcha Hova Body** and **Kathara Centers 7, 8 and 9** first anchor within the body. The Hara Center holds the morphogenetic imprint for **DNA strands 7, 8 and 9,** corresponds to **Chakra Centers** and **Axi-A-Tonal Lines 7,8 and 9** and is a key point for repatterning the electro-tonal programs of the **Teuric Shield** and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Hara Center is associated with the ***Thalamus Complex***, the chemical translation and regulatory system that governs the **9th-Dimensional interface** between various **brain-function areas** and the glandular and metabolic operations of the **Thymus Complex, Gonads, Lymphatic System** and corresponding body systems. Through the ***9th-Dimensional Thalamus Complex*** the electrical impulse, chemical and hormonal relationships between the ***10th-Dimensional Shara Complex*** and the ***8th-Dimensional Thymus Complex*** and its related body systems are governed.

The Hara Center and the Thalamus Complex link the functions of the **Mahara** and **Betcha Hova Bodies,** the **Maharic** and **Teuric Shields** and the **Avatar** and **Over-Soul** levels of consciousness and identity within the body and bio-energetic field.

The primary area of dominion of the *D-9 Thalamus Complex* is *Brain Function*.

THE SOUL STAR

The 6th Soul Star Seal and the D-8 Thymus Complex

Also visible along the Hara Line of Kathara Grid Level-2 is the **6th Star Crystal Seal**, located around the **Thymus** at the top of the breast bone and associated with the **5th and 6th dimensional frequencies** of the Harmonic-2 Soul Matrix (***Doradic Shield***). The **6th Star Seal**, visible as a **pale Blue-Violet-white point of diffused light** along the Hara Line, is called the ***Soul Star Seal.***

The *Soul Star Seal* is the point at which the dimensionalizing identity enters the **Semi-Etheric Matter densities** of Harmonic Universe-2. The Soul Star represents the point into which the **Soul Identity, its Archetype Core**, the **Alphi Hova Body** and **Kathara Centers 4, 5 and 6** first anchor within the body. The Soul Star holds the morphogenetic imprint for **DNA strands 4, 5 and 6,** corresponds to **Chakra Centers** and **Axi-A-tonal Lines 4, 5 and 6** and is a key point for repatterning the electro-tonal programs of the **Doradic Shield,** and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Soul Star is associated with the **Thymus Complex**, the chemical translation and regulatory system that governs the **8th-Dimensional interface** between the **Pineal, Pituitary,** and **Thyroid Glands,** which govern the chemical and metabolic operations of the **hormones, Adrenal Glands, Endocrine System, Spleen,** and *crystalline* formation of the **Red Blood Cells** and **Hemoglobin.**

The *Thymus Complex* and its related glandular and metabolic systems, govern the *cyclic rhythms* by which the **DNA strands** will activate through the **Pineal Gland,** the rate of *growth and degeneration* of body tissue through the **Thyroid Gland** and through the **Pituitary Gland** and its inter-glandular processes, the functions of *electro-tonal impulse conversation, translation and distribution* through the **brain, Central Nervous System** and **blood** are regulated.

The *Thymus Complex* controls the **inter-glandular systems balances** between the **Pineal, Thyroid and Pituitary Glands** and regulates the *primary operations* of electrical impulse and chemical translation and transfer throughout the brain and body systems via the **Thymus Gland.** The *8th-Dimensional Thymus Complex* is governed by the functions of the *9th-Dimensional Thalamus Complex* and the *10th-Dimensional Shara Complex.*

The Soul Star and the Thymus Complex link the functions of the **Betcha** and **Alphi Hova Bodies**, the **Teuric** and **Doraidic Shields** and the **Over-Soul** and **Soul** levels of consciousness and identity within the body and bio-energetic field.

The primary area of dominion of the *D-8 Thymus Complex* is *Metabolic Function.*

THE SUN STAR

The 3rd Sun Star Seal and the Nadial Complex

Also present, but less distinctly visible along the Hara Line of Kathara Grid Level-2 is the **3rd Star Crystal Seal**, located just beneath the **Hara Center** of the *9th Star Seal* 2" below the Navel and associated with the **2nd and 3rd dimensional frequencies** of the Harmonic-1 Incarnate Matrix (***Telluric Shield***). The **3rd Star Seal**, visible as a subtle pale **Yellow-Orange-Red point of diffused light** along the Hara Line, is called the ***Sun Star Seal.*** Due to its proximity to the Silver-Gold *Hara Center* 9th Star Seal the Sun Star is often considered to be part of the Hara Center, but in deeper Hara Level scanning the distinction between these crystal seals can be evidenced. The *Sun Star Seal* is the point at which the dimensionalizing identity enters the **Gross Physical-Matter densities** of Harmonic Universe-1.The Sun Star represents the point into which the **Incarnate Identity**, its **Subconscious-Telluric Core**, the **Nada Hova Body** and **Kathara Centers 1, 2 and 3** first anchor within the body. The Sun Star holds the morphogenetic imprint for **DNA strands 1, 2 and 3,** corresponds to **Chakra Centers** and **Axi-A-tonal Lines 1, 2 and 3** and is a key point for repatterning the electro-tonal programs of the **Telluric Shield**, and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Sun Star is associated with the **Nadial Complex**, the electrical impulse and chemical translation and regulatory system that governs the **4th -Dimensional interface** between the **Thymus Complex, Thalamus Complex** and the functions of the **physical body systems,** through which the electrical, chemical and metabolic operations of the **Blood, Cardio-Vascular, Pulmonary** and **Respiratory Systems** are governed. The Nadial Complex governs the operations of **Heart and Breathing rhythms**, the flow of consciousness-energy or **"Prana"** from the higher dimensional anatomy into physical embodiment and regulates many key functions within the processes of **nutrient conversion and distribution** within the Skeletal and soft tissue systems. **The *Nadial Complex* is a key center for the direction of healing energies within the Nada Hova Body, Telluric Shield and physical body systems.**

In advanced applications of healing and manifestation, the Nadial Complex is combined with the attributes of the **Shara, Thalamus** and **Thymus Complexes** and with the **Universal Raja Complex** of Harmonic-5, which links the human body to the planetary, galactic and universal Unified Fields through the *12th and 13th Chakras* and *10th Star Crystal Seal* at Earth's core via the *Planetary Bio-Feed Interface System.* The frequencies of the *3rd Sun Star Crystal Seal*, that govern the function of the *Nadial Complex* can be combined with those of the 9th Core Star Seal *Hara Center* and the *8th and 10th Star Crystal Seals* through the 12th and 13th Chakras, *PBIS, Doradic, Teuric, and Maharic Shields* and *Raja Complex* to form a potent **Teuric-Telluric Current** for **healing and manifestation**, once the *Doradic* and *Teuric Currents* have been activated within the body.

The *Sun Star* and the *Nadial Complex* link the functions of the **Alphi** and **Nada Hova Bodies**, the **Doradic** and **Telluric Shields** and the **Soul** and **Incarnate** levels of consciousness and identity within the body and bio-energetic field.

The primary areas of dominion of the D-4 *Nadial Complex* are *Cardio-Vascular, Pulmonary* and *Nutrient Absorption/Conversion Functions.*

THE GALACTIC STAR

The 12th Galactic Star Seal and the D-10 Shara Complex

The third point of condensed light visible along the Hara Line of Kathara Grid Level-2 is the **12th Star Crystal Seal**, located at the **14th Chakra** 36" above the head and associated with the **11th and 12th dimensional frequencies** of the Harmonic-4 Avatar Matrix (***Maharic Shield***). The **12th Star Seal**, visible as a **White-Silver point of Light emanating an inverted White-Silver-Gold *cone of energy* at the 14th Chakra**, is the White Star or ***Galactic Star Seal***.

The *Galactic Star Seal* is the point at which the dimensionalizing gestalt identity enters the **Pre-Matter Liquid Light densities** of Harmonic-4, the point at which identity begins its individuation and journey of densification into the wave spectra of perceivably experiential matter. The Galactic Star represents the point into which the **Avatar Identity**, its **Buddhaic Core**, the **Mahara Hova Body** and **Kathara Centers 10, 11 and 12** first anchor within the **Bio-energetic Field** to begin setting the scalar field for the body. The Galactic Star Seal holds the morphogenetic imprint for **DNA strands 10, 11 and 12**, corresponds to **Chakra Centers** and **Axi-A-Tonal Lines 10, 11, and 12** and is a key point for repatterning the electro-tonal programs of the **Maharic Shield**, and realigning and activating corresponding DNA strands, Chakras, Axi-A-Tonal Lines and body regions they govern.

The Galactic Star is associated with the *Shara Complex*, the regulatory system that governs the **10th-Dimensional interface** between the **D-9 Thalamus Complex** and the D-13 portion of the **Rishi Shield** in Harmonic-5. Through the Shara Complex the Scalar Fields holding the gestalt identity of Harmonic-5 Rishi Consciousness Collective- the "*Universal Family of Consciousness*" – translate via electro-tonal conduction, into the more individuated Scalar Fields that house the Avatar identity gestalt Consciousness Collective- the "*Galactic Family of Consciousness*".

The **Shara Complex *regulates the disbursement of consciousness*** in individuated form through the dimensional fields of the Time Matrix and serves to link each individuated and incarnate member of the Geomantic Entity Collective beyond the Time Matrix, to its Avatar identity and Galactic Family of Consciousness in Harmonic Universe-4, through the Universal Family of Consciousness of the Rishi identity in Harmonic Universe-5. The Shara Complex represents the primary facility through which an individual consciousness retains its indelible energetic connection to its greater **family of consciousness**, through which it is directly linked to **Source.**

The Shara Complex governs, regulates and orchestrates the transduction, translation and cyclic rhythms of **electro-tonal projection of consciousness into dimensionalization**, sets the original operational structures of **Kathara Scalar Grid** arrangement and directs the synchronistic **evolution of families of consciousness** through time. Through the operations of the Shara Complex, an identity's cycles of **incarnation and manifestation** within the 5 Harmonics of a 15-Dimensional Time Matrix are regulated, which sets the **core regulatory rhythms of Partiki Phasing**, expansion and contraction of consciousness, and vibration-oscillation ratios that **govern the formation and function** of the **Thalamus and Thymus Complexes** and all aspects of the individuated **Kathara Grid, Bio-energetic Field** and **bodily systems**. The Shara Complex controls the cycles of in-flow and out-flow of energy between the personal morphogenetic field and that of the dimensional Unified Fields, and thus affects all systems of the body and consciousness, with a primary emphasis upon the functions of the **blood, consumption-excretion and immunological facilities** of the body and of the activation of **the higher dimensional sense facilities** within the embodied consciousness.

The Shara Complex links the functions of the **Mahara** and **Raja Hova Bodies**, the **Maharic** and **Rishic Shields** and the **Avatar** and **Rishi** levels of identity within the embodied consciousness. **Primary area of dominion of the D-10 Shara Complex is the Immune System and HSP.**

THE EARTH SEALS

Earth Seals 8 and 10 and the Raja Complex

Within the Hara level of field depth in which the 3rd Sun Star Crystal Seal can be detected there are 2 other Star Crystal Seals of primary importance stationed along the Hara Line of Kathara Grid Level-2; these are referred to as the **Earth Seals**. The Earth Seals function as intrinsic aspects of the **Planetary Bio-feed Interface System** and the ***Raja Complex***. The **8th Star Crystal Seal**, called the ***Earth Star Seal*** is located within the **12th Chakra** 6" below the feet and is associated with the **7th, 8th and 12th dimensional frequencies** of the Harmonic-3 Over-Soul Matrix (***Teuric Shield***) and the Harmonic-4 Avatar Matrix (***Maharic Shield***). The Earth Star is visible as a subtle **Gold-Orange point of diffused light** positioned along the Hara Line **6" below the feet**, as the Hara Line leaves the physical body through the 1st Base Chakra to extend downward into the Earth's core. The **10th Star Crystal Seal**, called the ***Earth Core Seal***, is located within the **13th Chakra** where the Hara Line connects into the Earth's Core and is associated with the 9th, 10th, 12th and 13th dimensional frequencies of the Harmonic-3 Teuric Shield, Harmonic-4 Maharic Shield and Harmonic-5 Rishi Matrix (***Rishic Shield***). The Earth Core Seal is visible as a **pale Blue-Black point of diffused light** positioned in the **Earth's Core**, at the point where the personal Hara Line connects to the center of the Earth's Core at the *1st and 12th Planetary Kathara Centers*.

The ***8th Earth Star Seal*** is the point at which the dimensionalizing identity combines the 12th-dimensional frequencies of the **Harmonic-4 Pre-matter Liquid Light density** with the 8th and 9th–dimensional frequencies of the **Etheric Matter densities of Harmonic-3** to connect the personal morphogenetic field and Kathara Grid to those of the Planetary Body. The **Earth Star Crystal Seal** can be viewed as the point where **Personal and Planetary Kathara Grids connect to Galactic Kathara Grid.** The Earth Star represents the point into which the **Mahara and Betcha Hova Bodies, Kathara Centers 8, 9 and 12 and the 12th Galactic Star Seal and Shara Complex** first anchor into the **Planetary and Galactic Kathara Grids.** The Earth Star holds the morphogenetic imprint for **all DNA strands for all manifest incarnations in *4 Harmonics of Time,*** corresponds to **Chakra Centers and Planetary Vortices** and **Personal and Planetary Axi-A-tonal Lines 8, 9, 10 and 12** and is a key point for repatterning the electro-tonal programs of the ***Personal* Maharic, Teuric, Doradic and Telluric Shields,** and realigning and activating corresponding DNA strands, Chakras, Planetary Vortices, Axi-A-Tonal Lines and personal or planetary body regions they govern. In the **Maharic Shield Activation process** the **Earth Star** is activated to release phase-lock on the **12th Chakra** to open the personal Kathara Grid to the PBIS.

The ***10th Earth Core Seal*** is the point at which the dimensionalizing identity combines the frequencies of the **8th Earth Star Crystal Seal** with the **13th-dimensional frequencies** of **Harmonic-5 Ante-matter density** to connect the personal and planetary morphogenetic field and Kathara Grid to those of the Universal Kathara Grid of Harmonic-5. The **Earth Core Seal** can be viewed as the point where **Personal, Planetary and Galactic Kathara Grids connect to the Universal Kathara Grid.** The Earth Core represents the point into which the **Rishi Identity**, the **Raja Hova Body** and **Universal Kathara Centers 1, 2 and 3** first anchor into the 3rd Earth Star and 12th Galactic Star Seals to form the Raja Complex of 5 Harmonic scalar fields through which personal, planetary, galactic and universal experiential manifestation takes place. The Earth Core Seal corresponds to **Chakra 13**, and holds the morphogenetic imprint for **all manifest incarnations of persons, planets and galaxies within the 5 Harmonics of Time in one 15-dimensional Time Matrix.** Through the combined frequencies of the **Earth Star and Earth Core Seals** the personal Kathara Grid connects to the Planetary, Galactic and Universal Kathara Grids forming the Planetary Bio-feed Interface System and the ***Raja Complex*** – or ***Universal* Bio-feed Interface System** – that links personal, planetary, galactic and universal consciousness in time.

THE RA CENTER

The 3rd Sun Star Seal, 8 and 10 Earth Seals and *RA Center*

When combined with **PBIS, Doradic, Teuric** and **Maharic Shields** and **Raja Complex**, the **3rd Sun Star Crystal Seal** and the **12th Core Star Crystal Seal** *Hara Center merge* to form a *Teuric-Telluric Current* that encompasses the *Seed Crystal Seal* within the **3rd Solar Plexus Chakra**, forming a ***sphere of powerful healing energies*** at the **3rd Chakra** called the **RA Center. In Kathara Healing Level-2** we will begin activation of the *Teuric Current* of the Harmonic-3 Betcha Hova Body, through activation of Doradic Current Phase-2 and will explore beginning applications of combining the Doradic Phase –1 and Teuric Currents with the natural *Telluric Current* of the Harmonic-1Nada Hova Body to begin bringing the RA Center for **healing and manifestation** into activation. (For more on the 4 Primary Triadic Healing Currents see Chapter 4 of this manual.)

The Hara Level of Kathara Level-2 and the 6 Primary Hara Points

Though the study of the Crystal Seals of Kathara Level-2 Crystal Seals Grid is complex in detail, one can become skilled in healing facilitation through Crystal Seals mechanics by learning the basic orientation of **the outer levels** of the **Kathara Level-2** scalar grid – ***The Hara Level.*** In simple analysis, the ***elements* of the Hara Level can be viewed as follows:**

The Hara Line – the Central Body Current, that is formed by the *11th and 12th Axiom Lines* wrapping around the fixed flash-line sequence of the *Level-1 Kathara 12-Tree Central Vertical Kathara Line.*

The 6 Primary Hara Points: Star Crystal Seals **1.#** 9-Hara Center, **2.** #6-Soul Star, **3.** #12 Galactic Star, **4.** #3-Sun Star, **5.** #8-Earth Star and **6.** #10-Earth Core. Each primary Hara Point governs the function of a **complex** of interwoven scalar, bio-energetic and physical systems. Knowledge of the **6 Hara Points** and the **Thalamus, Thymus, Shara, Nadial** and **Raja Complexes** they respectively govern, allows the healing facilitator a greater understanding of the 15-dimensional anatomy. Such **Foundations of Kathara Healing** are necessary in preparation for **Kathara Healing Level-2** practices that will utilize the **Hara Level** of the **Kathara Level-2 Crystal Seals Grid** in combination with the Kathara Healing Level-1 **Maharic Recoding Process** and other elements to begin activation of the **RA Center** for advanced healing and manifestation.

Axi-A-Tonal Lines 1-10

In our exploration of the Hara Level of the Crystal Seals Grid we have learned that of the **12 Primary Axi-A-Tonal Lines,** (12 primary vertical energy-flow lines within the body and bio-energetic field, created by cross-over points of the rotating, single axis, flash-line sequences projected by each of 12 Seed Crystal Seals), the 11th and 12th Axi-A-Tonal Lines spiral around the Kathara Level-1 12-Tree Grid *Central Vertical Kathara Line* to form the Hara Line and Central Body Current. Axi-A-Tonal Lines 1-10 also run vertically through the body, from the head to the toes and through each arm to the finger tips, connecting body regions to corresponding levels of the Auric Field, Chakras, Kathara Centers, Crystal Seals and DNA. The sequence of Axi-A-tonal Line position is as follows:

Right Side of Body to Center- 3,6,9,2,8 **Center of Body-11, 12 Center to Left Side of Body-**. 5,1,10,7,4 Each line of Axi-A-Tonal Lines **1-10** ends in one **finger-tip** and **toe** on the corresponding side of the body, and runs vertically through the top of the head to merge with Axi-A-Tonal Lines 11 and 12 and the Hara Line at **Chakra 10**, and down through the feet to merge with the Hara Line at **Chakra 12.**

The HARA LEVEL- Outer Portion of Kathara Level-2 Crystal Seals Grid

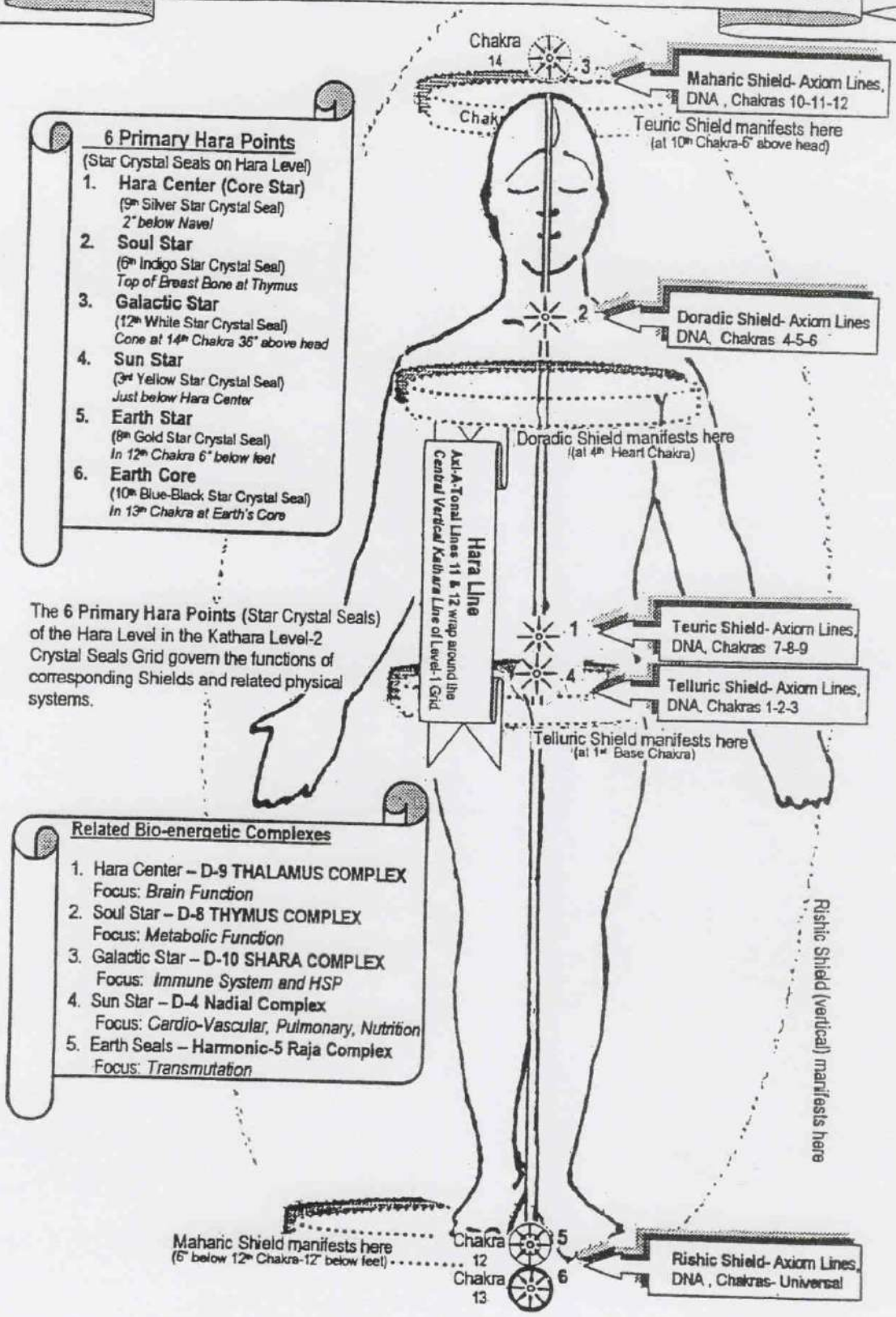

6 Primary Hara Points
(Star Crystal Seals on Hara Level)

1. **Hara Center (Core Star)**
   (9th Silver Star Crystal Seal)
   2" below Navel
2. **Soul Star**
   (6th Indigo Star Crystal Seal)
   Top of Breast Bone at Thymus
3. **Galactic Star**
   (12th White Star Crystal Seal)
   Cone at 14th Chakra 36" above head
4. **Sun Star**
   (3rd Yellow Star Crystal Seal)
   Just below Hara Center
5. **Earth Star**
   (8th Gold Star Crystal Seal)
   In 12th Chakra 6" below feet
6. **Earth Core**
   (10th Blue-Black Star Crystal Seal)
   In 13th Chakra at Earth's Core

The **6 Primary Hara Points** (Star Crystal Seals) of the Hara Level in the Kathara Level-2 Crystal Seals Grid govern the functions of corresponding Shields and related physical systems.

Related Bio-energetic Complexes

1. Hara Center – **D-9 THALAMUS COMPLEX**
   Focus: *Brain Function*
2. Soul Star – **D-8 THYMUS COMPLEX**
   Focus: *Metabolic Function*
3. Galactic Star – **D-10 SHARA COMPLEX**
   Focus: *Immune System and HSP*
4. Sun Star – **D-4 Nadial Complex**
   Focus: *Cardio-Vascular, Pulmonary, Nutrition*
5. Earth Seals – **Harmonic-5 Raja Complex**
   Focus: *Transmutation*

12 Primary Axi-A-Tonal Lines
of the Kathara Level-2 Crystal Seals Grid

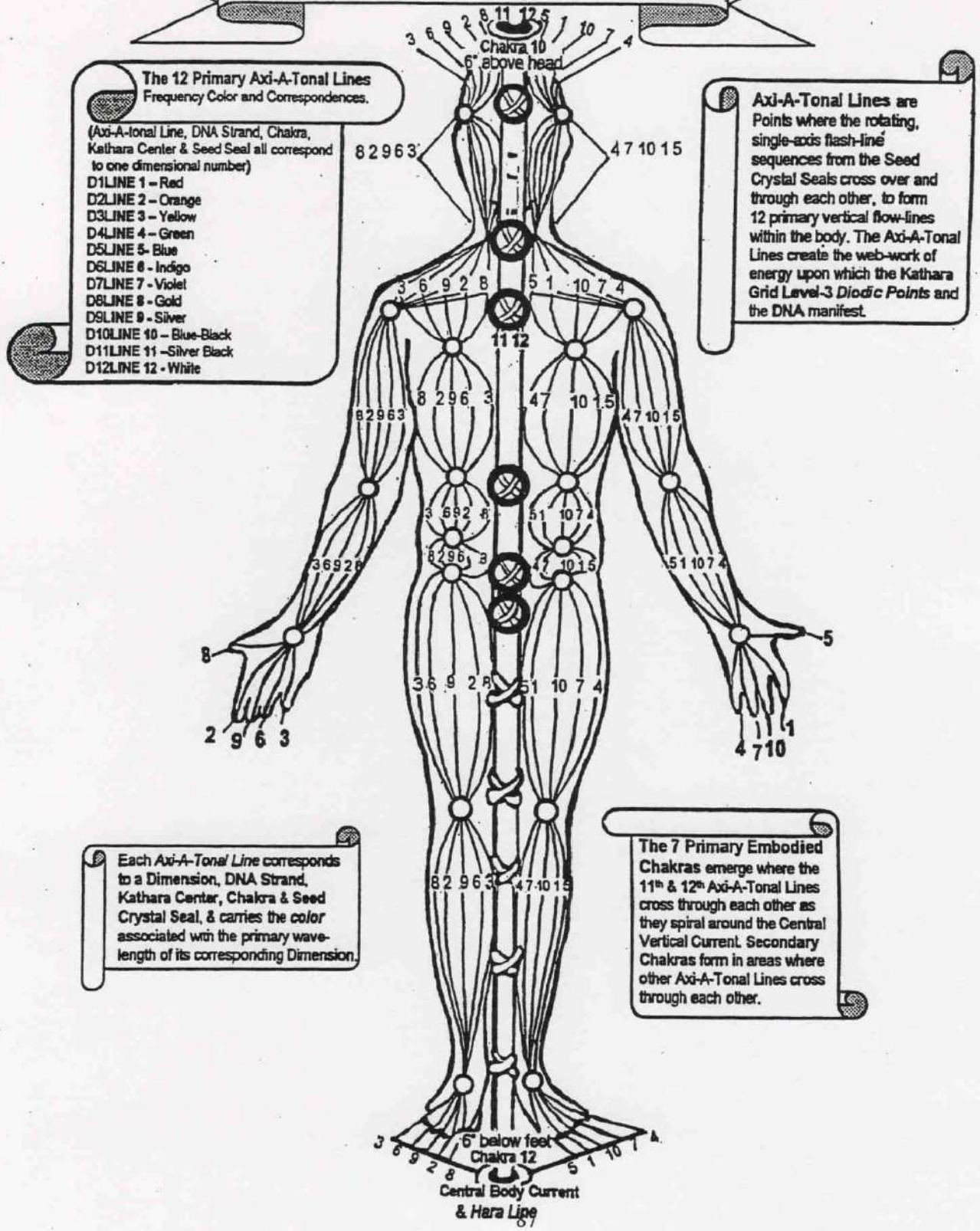

The 12 Primary Axi-A-Tonal Lines
Frequency Color and Correspondences.

(Axi-A-tonal Line, DNA Strand, Chakra, Kathara Center & Seed Seal all correspond to one dimensional number)

- D1LINE 1 – Red
- D2LINE 2 – Orange
- D3LINE 3 – Yellow
- D4LINE 4 – Green
- D5LINE 5- Blue
- D6LINE 6 - Indigo
- D7LINE 7 - Violet
- D8LINE 8 - Gold
- D9LINE 9 - Silver
- D10LINE 10 – Blue-Black
- D11LINE 11 –Silver Black
- D12LINE 12 - White

Axi-A-Tonal Lines are Points where the rotating, single-axis flash-line sequences from the Seed Crystal Seals cross over and through each other, to form 12 primary vertical flow-lines within the body. The Axi-A-Tonal Lines create the web-work of energy upon which the Kathara Grid Level-3 *Diodic Points* and the DNA manifest.

Each *Axi-A-Tonal Line* corresponds to a Dimension, DNA Strand, Kathara Center, Chakra & Seed Crystal Seal, & carries the *color* associated with the primary wave-length of its corresponding Dimension.

The 7 Primary Embodied Chakras emerge where the 11th & 12th Axi-A-Tonal Lines cross through each other as they spiral around the Central Vertical Current. Secondary Chakras form in areas where other Axi-A-Tonal Lines cross through each other.

Axi-A-Tonal Lines and the Meridians

The Axi-A-Tonal Lines within the body set the primary holographic scalar field upon which the Meridian Lines – or Secondary Flow Lines- of the body manifest. **The Meridian Lines can be used to access the Axi-A-Tonal Lines and the Axi-A-Tonal Lines can be used to access the flash-line programs of the Kathara Centers and 3 Levels of the Kathara Grid, if the *correspondences* between *the Meridians, Axi-A-Tonal Lines, Kathara Centers* and *Chakras* are understood.** For centuries the **Meridian Lines** and **Chakras** have been used in subtle-energy healing systems. This knowledge can be applied and the potential results of related healing techniques amplified by employing the correspondences between the Meridian and Chakra systems and the Axi-A-Tonal Lines and 3 Levels of the Kathara Grid. Bringing the Kathara Grid into the picture allows for restructuring the **Imprint for Health** within the *causal core* while *expediting* the healing process by restructuring the various other levels of the bio-energetic anatomy.

In Level-1 Kathara Healing we focus primarily upon **Core Morphogenetic Repatterning** – resetting the electro-tonal programs of the Kathara Grid through the uncorrupted programs of the ***Maharic Shield***- to set the "*ground*" into which other healing applications can *anchor*. In later Kathara Healing Levels we will explore technique applications that affect various other levels of the bio-energetic anatomy. **In Level-1 Kathara Healing we strive to create a basic familiarity with the elements of, and the interrelationships between, the various levels of bio-energetic anatomy.** Through understanding the basic correspondences between the **3 Levels of the Kathara Grid** – the *Kathara Centers* and *Kathara Lines*, the *Hova Bodies*, Auric Levels, *Signets*, *Shields*, *Crystal Seals* and *Axiom Lines*, and the *Diodic Points* and *Chakras* – and the other aspects of energetic anatomy, such as the **Meridian Lines** and **DNA**, the healing facilitator is equipped with a knowledge base through which more precise healing facilitation can be applied. Meridian Lines and their applications to Kathara Healing will be explored in later Levels of the Kathara Healing Program.

DNA

The DNA Connection

In this Chapter we have explored the various elements of the 15-Dimensional Anatomy of the human form, from the Kathara Grid holographic scalar template, to the Hova Bodies, Shields, Axiom Lines, Chakra Centers, Auric Field Levels and the Hara Level with its related Complexes of energetic interface. Throughout all of these elements of the multi-dimensional anatomy we have seen how each element interrelates with the others through their *correspondences within the structure of the 15-Dimensional Scale.* The elements of the subtle body anatomy also systematically correspond to the structure and function of the human **DNA.** Through direct interaction with various elements of the subtle body anatomy, the operations of corresponding aspects of the human DNA can be repaired, enhanced and altered, to advance applications of healing, and to expedite the evolution of human biology and consciousness. In the *Kathara Healing Level-2 program* we will further explore the correspondences between the subtle body anatomy and the DNA, and methods by which the DNA can be repaired and activated to a more advanced level through employing the use of Kathara Healing mechanics.

The Silicate Matrix 12-strand DNA Pattern

The core human DNA imprint is built upon a **12-Dimensional** Structure, each of 12 strands building up upon one of the Primary 12 Axi-A-Tonal Lines and each strand corresponding to 1 of 12 dimensional frequency bands within the 15-dimensional scale. The original human DNA imprint is called the **Silicate Matrix,** the 12-strand scalar-wave configuration that allows for the progressive **transmutation** of Harmonic-1 carbon-based molecular-elemental structure into the Silica-based structures of higher Harmonic matter. The 12-strand DNA imprint of the human form implies that human biology was designed to embody **12 dimensions of conscious awareness,** or to fully embody the Avatar identity level - the ***"Christed" Identity*** of Harmonic-4 Pre-matter Liquid Light matter density. The human form is organically designed to undergo **full cellular transmutation** through 4 Harmonics of manifestation and their corresponding matter density levels. When the gene code is working properly, the process of cellular transmutation is directed by the embodied human consciousness. In historical terms, the process of ***conscious cellular transmutation*** has been referred to as the process of **"Ascension"**, which is ***Dimensional Expansion***, the mechanics of which have been hidden with ancient texts dealing with **Merkaba Mechanics.** The **Merkaba Vehicle** of inter-harmonic scalar-wave configurations, which forms within the bio-energetic field, is a consequence or *simultaneous affect* of progressive activation of the Silicate Matrix within the genetic code.

The Silicate Matrix and Subtle Body Anatomy

Just as each Axi-A-Tonal Line of the subtle body anatomy has its correspondence to a Kathara Center, Crystal Seal, Axi-A-Tonal Line, Auric Field Level and Chakra, so too do the DNA strands have their specific affiliations to each *dimensionalized element* of the subtle body anatomy. Each DNA strand translates into electrical-elemental-chemical form from the governing Axi-A-Tonal Line flash-line sequence to which it corresponds. The **Hova Bodies** and **Shields** of subtle body anatomy each correspond to a *set of* 3 Axi-A-Tonal Lines, Auric Field Levels and Chakras and thus also correspond to a set of **3 DNA strands,** that together create the experiential projection of separate 3-Dimensional holographic reality fields. Distortions and blockages in the Kathara Grid, Hova Bodies, Shields, Axi-A-Tonal Lines and Chakras appear as distortions and malfunction within the DNA. **The function of the DNA determines the *quantity of interdimensional frequency*, and thus the *amount of dimensionalized consciousness*, that can actively process through and embody within the physical body system.** DNA distortions manifest as distortions of biology and consciousness.

The 12 DNA strands of the Silicate Matrix are *sets of scalar-wave spectra* that correspond to each dimensional band, through which each dimensionalized level of the subtle body anatomy is translated into wave-spectra that is within the range of perceivable matter manifestation. *The DNA can be viewed as the primary structure through which subtle energy-consciousness translates into manifest physicality.* As each full dimensional band contains 12 primary Sub-frequency Bands (See Chapter 1 for Dimensional Structure), each of the 12 DNA strands contains *12 primary* **Seed Codes,** or *consolidated scalar points* composed of electro-tonal flash-line sequences, that correspond to the Sub-Frequency Bands within each dimension. The 12 primary Seed Codes within each DNA strand have an *anti-particle counterpart* composed of frequencies from the Anti-particle system. The 12 particle Seed Codes in each strand are called **BASE CODES**, their anti-particle counterparts are called **ACCELERATION CODES**, The Seed Codes of the core DNA scalar imprint are the *points of consolidated frequency* through which energy-consciousness is drawn in from the dimensional Unified Fields to expand the personal morphogenetic field.

DNA Fire Codes- Genetic Time Codes

Along with the **12 Base Codes** and **12 Acceleration Codes** of each DNA Strand Template there are also 12 Primary DNA Codes called **DNA FIRE CODES** that regulate the relationship between human biology and the **Planetary Time Cycle** in which the biology manifests. The DNA Fire Codes can be conceptualized as existing *between* the Primary 12 Strands of the Silicate Matrix. Each Fire Code is composed of one half of the scalar frequency patterns from each of the two Primary Strands that the Fire Code is placed between. Each of the 12 Fire Codes corresponds directly to one of 12 **Signet Star Crystal Seals** in the Personal Shields of the Internal Templar Complex, and with release of the corresponding **Signet Seal**, the Fire Code comes into activation.

The DNA Fire Codes release the natural scalar barriers between particle and anti-particle DNA Strands, allowing **STRAND FUSION** to occur. Fusion of DNA strands in the particle body with corresponding strands in the anti-particle body creates a progressive transmutation of the scalar wave forms of the DNA Template and Scalar Shields, through which the polarized Particum-**Particles** and Partika-**Anti-particles** merge and transform into their original Omni-polar Partiki **Ante-matter** state. Through strand fusion, the biological carbon-based biology progressively **lessens in density** as its elemental agents are transmuted from the Kathara level, into elemental agents characteristic of the higher dimensional matter densities. **Dimensional Ascension** is achieved through release of the Kathara Grid Seals. Release of the Kathara Grid Seals creates merger of the Hova Bodies, activation of the Kundalini energies, release of the Cranial-Sacral Crystal Seals, **fusion of the DNA Strand Templates via the DNA Fire Codes**, building of the Merkaba Vehicle in the bio-energetic field and the resulting transmutation of bodily matter and shift in Angular Rotation of Particle Spin within molecular construction. Through this transformational process the human biology is released from its organic phase-lock within its current space-time cycle, and is able to engage in **transcendental travel** through the various matter density levels and Time Cycles in and beyond the 15-Dimensional Time Matrix. **As the DNA Fire Codes regulate the body's orientation to space-time, they are also referred to as the GENETIC TIME CODES.**

The DNA Fire Codes are an essential element in the natural process of restoring the natural immortal **Organic Imprint for Health** within the human body. The ability of the human form to become **perpetually self-sustaining** is dependent upon the Kathara Grid and DNA being able to continually renew the natural Primal Order of Maharic Shield scalar arrangement upon which the body is built, to keep the Star Crystal Seals and conduits of interdimensional energy supply open. **Perpetual revitalization of the body** is achieved through full activation of the **12-Strand DNA** pattern. When activated, the **DNA Fire Codes** keep the Crystal Seals, **the interdimensional INTERNAL STAR GATES of energy inflow**, open, so the finite supply of frequency held within the personal Manifestation Template can be continually renewed. Restoration of the Organic Imprint for Health, as held within the **Maharic Shield**, is achieved through progressively clearing distortions of scalar-wave arrangements within the Kathara Grid, Shields and DNA Template and realigning the entire subtle energy and physical energy systems with the Primal Order of the Maharic Shield. This process of whole-being-healing does not occur overnight, as many genetic distortions (which emerge from Kathara Grid misalignment) have served as the dominant bio-electrical program within the human genome for many thousands of years. With knowledgeable practice of Kathara Grid realignment, and supportive healing applications within the various Body-Mind-Spirit systems, these inherited distortions can be progressively healed through Regenesis of the Primal Order as held within the personal Maharic Shield.

Science, "Junk DNA" and Evolution

In the contemporary human genetic code the majority of the.DNA strands corresponding to higher dimensional anatomy and consciousness are dormant or damaged due to ancient blockages within the Kathara Grid and its corresponding elements of the subtle body anatomy. Present day humans function primarily on a **3 to 3.5 DNA activation level,** while the imprint and potentialities for strands 4-12 lie dormant within the morphogenetic field and within the fragments of non-functional DNA that contemporary science has labeled ***"junk DNA".***

The portions of the DNA chain that science has presently identified as the **"Double Helix", represent only the surface portions** of the chemical, elemental and electrical components of the active DNA strands. Science has yet to identify the *multidimensional spectra* of DNA manifestation, and has yet to realize that within the structures of detectable DNA, there are *levels of structure and function* that direct the operations of the *entire genetic imprint,* which are *not presently detectable* by contemporary scientific technique. The human DNA imprint will always appear from external analysis, as a *2-strand Double Helix* configuration, but what is not understood, is that within this Double Helix there are, and will be progressively more, **additional Double Helix strands,** which *fuse together* and add their operational coding into the active DNA imprint. By contemporary standards of categorization, if science were to objectively observe the activated 12-strand pattern (or even an activated 4-strand pattern), the DNA would *not appear to be human at all,* but rather as the seemingly incomprehensible genetic signature of an "unknown" species. As science evolves into comprehension of the multi-dimensional spectrum, the understanding of the true structure and function of DNA will progressively advance.

DNA, Kathara Healing and Bio-Spiritual Evolution

One does not have to wait for scientific theology to catch up with a rapidly evolving humanity in order to begin advancing the functions of the DNA. Through the processes of Kathara Healing, as we work to clear blockages from the Kathara Grid and to reawaken the *Imprint for Health* within the human body, we are *simultaneously, directly affecting* the operational structure of the DNA. As we work to create **Hova Body merger-** *merging of the scalar-grid flash-line sequences of the 5 Harmonic Hova Bodies-* we are progressively reordering portions of the "junk DNA" and stimulating dormant portions of the DNA into activation. As we work with subtle energies to clear blockages within the Kathara Grid, we are progressively purging ancient distortions and mutations within the gene code, distortions that have kept our collective consciousness locked into the limited 3-dimensional perceptual range of Harmonic Universe-1.

It is through the ancient distortions of the human Kathara Grid and the resulting **mutations** of the human DNA, that the multidimensional portions of identity seem separate from each other. The higher levels of conscious awareness that are stationed within the scalar grids of the higher dimensional Hova Body Shields have been unable to *electronically translate* into the lower dimensional identity stations of the Nada Hova Body and its apparent physical manifestation. As we work with Kathara Healing to create progressive Hova Body merger and DNA strand ordering and activation, we will progressively experience *advancement of conscious awareness* and *expansion of the perceptual field* and *Higher Sensory Perception* (HSP). This expansion and advancement occurs because we are able to progressively embody higher frequencies of consciousness and scalar wave flash-line sequences into the personal morphogenetic field, via the energetic conduits of the DNA. **Kathara Healing modalities are the fastest and easiest methods available to repair and advance the function of the DNA and to expedite the organic processes of *Bio-Spiritual Evolution.***

The Silicate Matrix 12-Strand DNA Template with Hova Body, Scalar Shield and Identity Level Correspondences

The Morphogenetic Field Scalar-wave Template for the Original Human Genome

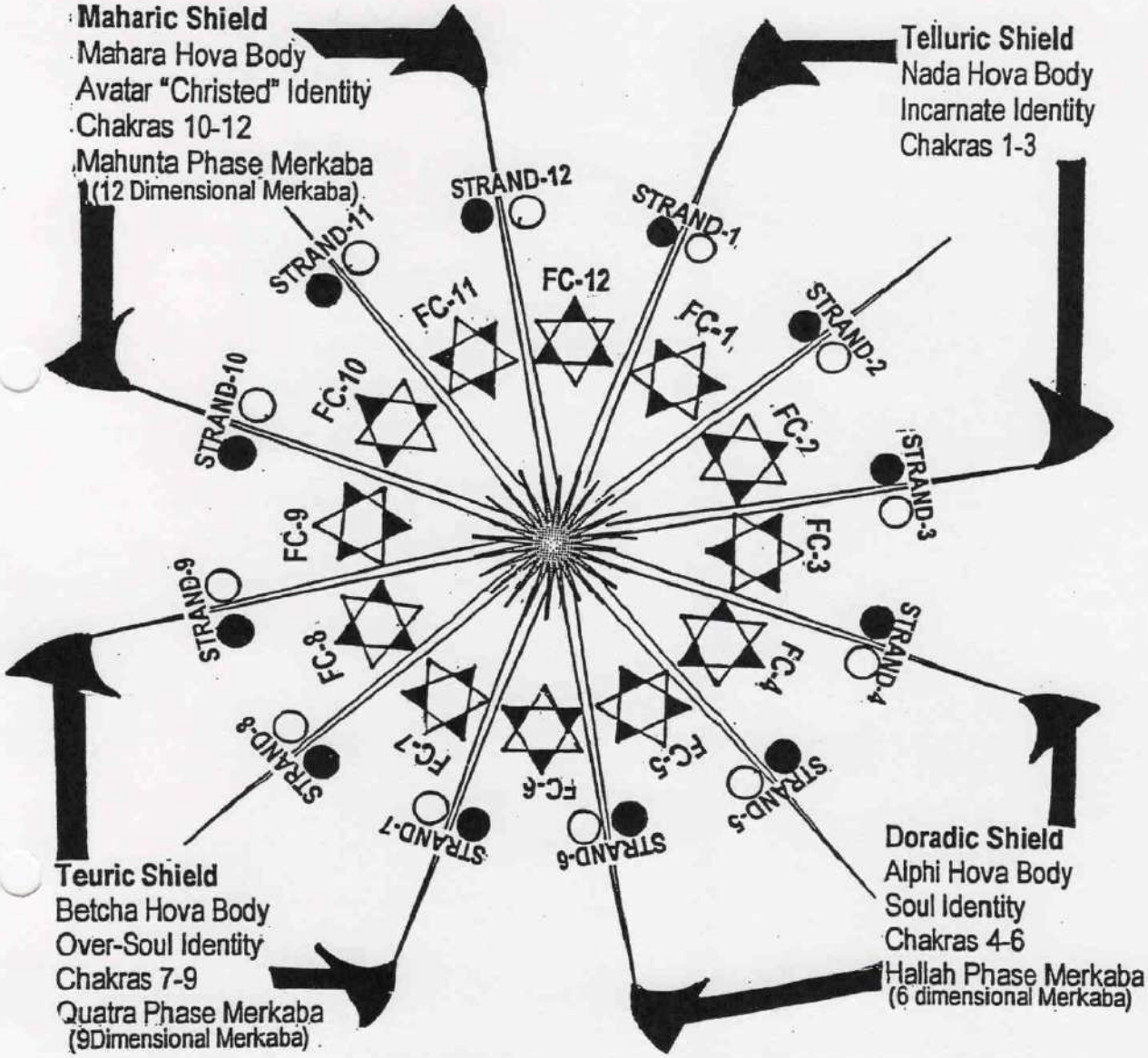

(Diagram presents simple conceptualization of DNA Strand Template orientation, not actual geometrical arrangement of wave-form structure and observable strand interrelationship.)

Merkaba Phases – Building the Merkaba Vehicle

Formation of the **Mahunta Merkaba** marks fulfillment of the 12-Strand DNA potential.

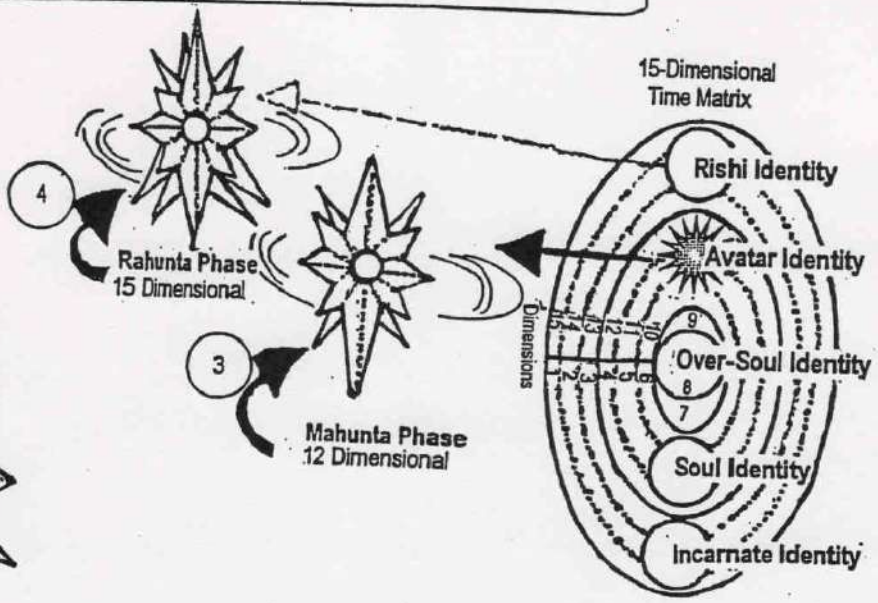

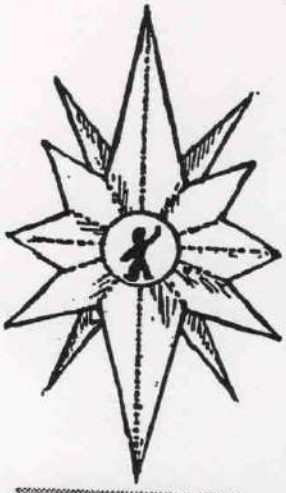

The 4 Personal Scalar Shields merge to form the 12-Dimensional **Mahunta Merkaba**

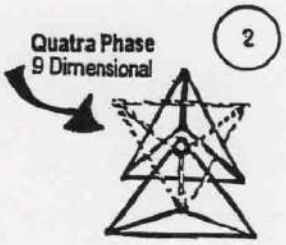

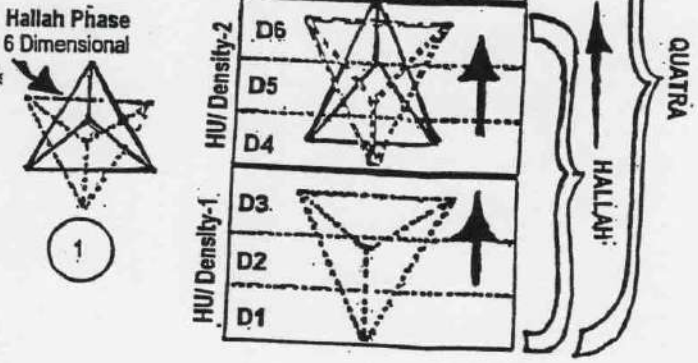

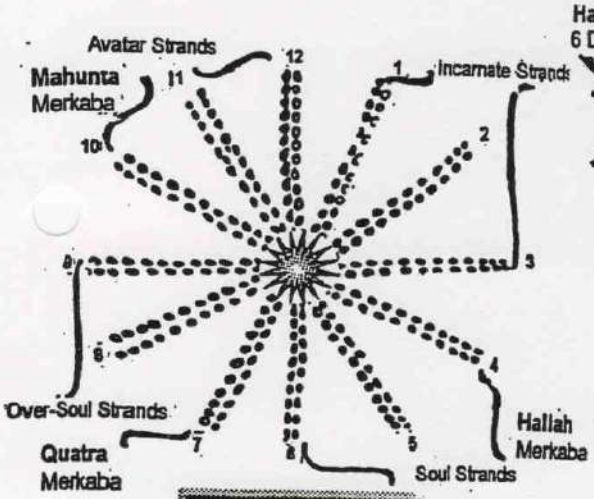

12-Strand Silicate Matrix DNA Diagram shows Strand relationships

The Merkaba Vehicle: Counter-rotating Spirals of interdimensional electromagnetic energy in star-tetrahedron form that form in the auric field, enabling biological interdimensional travel and ascension.

THE 12 HUMAN SENSES, APPARTHI AND HSP

Perception and the Hologram

In earlier text we have explained that **manifestation is not what it appears to be,** but rather a **Holographic Projection** of consciousness through the structures of **dimensionalization**. Further, that dimensionalization itself is a *compartmentalization* of consciousness created through units of consciousness (Partiki, Partika and Particum) *assembling in specific mathematical-geometrical ratios* to form **scalar grids,** interwoven fabrics of *fixed points of electro-tonal units* that form layers of standing-waves **-scalar waves** - that serve to "flesh out" the structure of the Hologram, through projection along a *vertical, horizontal* and *diagonal axis*. We have explored the **Kathara Grid** - the *core template* of scalar standing-waves upon which consciousness begins its experience of dimensionalization, the structures of the **15-Dimensional Universe** construction, and how these characteristics of the Hologram relate to forming the structure of **15-Dimensional Human Anatomy**. In understanding the basic foundations upon which our perceivable Hologram forms, we begin to better comprehend the nature of reality and of ourselves within this multi-dimensional reality structure. **Through the Holographic Projection of consciousness within the cosmic Unified Field of Energy-consciousness and its scalar fields of dimensionalization, we perceive the conditions of space, time, matter, externalization of reality and individuation of identity**. Within the Hologram of consciousness we perceive as **solid and objectified** the **wave spectra** and their inherent energy constructs of that which exists **precisely one dimensional band below the present station of our consciousness focus.**

In this section we will explore a bit about the **apparatus of perception** that allow us to perceive externalization in such a manner, the **facilities of energy inherent to the scalar-wave construct of the human form,** which together work to bring the Hologram into perceivable manifestation. We will call the constructs of energy formed through scalar organization, which allow for perception of the manifest Hologram, the **HUMAN SENSES.**

THE *HUMAN SENSES* ARE THE *EXPERIENTIAL RESULT* OF *ORGANIZATIONS OF WAVE PATTERNS* INHERENT TO THE ELECTRO-TONAL PROGRAM AND SCALAR ORGANIZATION OF HUMAN CONSTRUCTION.

What ARE Senses?

Senses are the **scalar-wave apparatus**, and their seemingly manifest parts, that allow the personal morphogenetic field to **synthesize and translate frequency** from the dimensional bands of the Unified Field, into **coherent perceptual and experiential qualities** that give embodied consciousness a **translation of its relationship to other forms of consciousness within the Unified Field.** Senses - or the apparatus which give us the *ABILITY TO SENSE*- are scalar arrangements inherent to our form that **TRANSLATE ENERGY SIGNATURES FROM THE UNIFIED FIELD INTO USABLE DATA OF RELATIONSHIP.**

Like the true substance of the human body and consciousness, the Unified Field exists as a *quantity of dimensionalized energy-consciousness in electro-tonal scalar wave form* - a compartmentalized field of **ENERGY SIGNATURES**, within which a vast number of **consciousness constructs** exist The human organism is one such **construct of consciousness**, and through its inherent form, the *energy signatures* of other scalar forms are translated into perceptual data. **The senses are simply *energy constructs* within the human morphogenetic field, that *separate and translate energy signatures from the Unified Field* into sets of experiential stimuli, through which the contours of the manifest Hologram can be *recognized* and *experienced.***

The APPARTHI and Perception

The sense facilities are *organizations of energy* within the morphogenetic field that hold sets of "*energy receivers*" or *magnetic points of cohesion*, into which *like frequency patterns* from the Unified Field are drawn in for translation. Every organism has a different configuration of energy receivers within its morphogenetic makeup, and so every organism will have a variation of perception. The **morphogenetic energy receivers**, or **APPARTHI** of an organism's construction serve to *draw certain frequency bands into the morphogenetic field for translation and to block out other frequency bands*, making them unavailable for translation. The frequency bands, or *flash-lines of Partiki Phasing*, that are blocked out of the personal morphogenetic field, create **GAPS OF PERCEPTION** of the Unified Field, through which the Holographic picture of "space between objects", "externalization of form" and "separation of SELF from the Unified Field" becomes perceivable to the organism. **These qualities of *objectification* are the result of BLOCKED FLASH-LINE SEQUENCES, portions of the *scalar fields* of the Unified Field and their inherent *sequences of Partiki Phasing*, that *cannot translate* through the personal morphogenetic field due to the arrangement of the APPARTHI within the personal morphogenetic structure.**

Senses as Scalar-wave Constructs & Expanding our Perception of Perception

If it can be recognized that externalization of experience is a perceptual illusion of consciousness created through selectivity of range within the perceptual field, the true nature of the human sense facilities can be better understood as a pattern of interrelated scalar-wave forms that serve to block out portions of the Unified Field so that other portions may be brought more fully into perceivable view. **When viewing the *physical apparatus* through which the known human senses appear to occur as part a of larger, interwoven system of *scalar construction*, it will be easier to understand that *perception is not a localized phenomena created by and limited to the identified organs of perception.*** The experiential capacities of even the 5 known human senses have a much broader range than what is presently assumed or identifiable through analysis of the manifest sense organs. *If one can understand that perception of manifestation itself is an affect of these greater scalar wave constructs, it will not seem so outrageous to consider the reality and integrity of sensing and perception beyond the range of the presently identified sense facilities.*

ESP, HSP and Evolution

"Extra-sensory perception" is not "EXTRA" at all, it is a *normal attribute* of the *evolving human organism*, as the consciousness ensconced within the *body hologram* continues its *natural expansion* into the greater portions of its evolutionary imprint. Individuals displaying abilities of "Extra-sensory Perception" are not gifted with something *other than what is characteristic to the human form*, **they are simply *a bit ahead in the stage of development* of the natural human perceptual capacities. Everyone has dormant potentials for some degree of "ESP"; like all things within the human organism, ESP is regulated by the *function of the DNA* and its naturally intended *relationship* to the *Kathara Grid and morphogenetic structure.*** Individuals with **less distortions and blockages** within the **Kathara Grid** (and the resulting DNA malfunctions such distortions create) will have *greater ease* in calling the dormant perceptual facilities into activation. *Individuals who consciously attempt to use the greater perceptual facilities will stimulate a more rapid advancement into reclaiming this stage of evolution, than those who refuse to acknowledge the existence of their greater sensing facilities.* **The greater sense facilities bring the *higher dimensional wave spectra* and its inherent reality fields into the *perceptual range* of the earthly embodied human consciousness, and so the greater sense facilities can be considered the HIGHER SENSES, a term far more accurately describing their orientation than the term *Extra Senses*. "ESP" becomes "HSP"- *Higher* Sensory Perception - a *natural attribute of experience for the evolving human organism.***

THE 5 KNOWN SENSES

The 5 Known Human Senses

In order to understand the nature of the **Higher Senses** it is necessary to understand a bit more about the nature of the **common senses**, or the "*lower senses*" if you will, for the **common** senses are those that are "tuned to" perception of the **lower frequency dimensions. Perception of *Sight, Sound, Touch, Taste and Smell* are *experiential affects* of the *scalar-wave constructs* that exist within the NADA HOVA BODY and the TELLURIC SHIELD, the Kathara Grid and morphogenetic field structures that are composed of and stationed within the frequency bands of dimensions 1, 2 and 3, the first Harmonic of manifestation.** The **APPARTHI,** or ***"energy receivers"*** within the Nada Hova body have their first imprint within the **Kathara Grid Level-2: Crystal Seals** structure. The first pattern for the sense facilities responsible for manifesting the organs of perception of the 5 identified senses exist within the configurations of electro-tonal Partiki units that form the crystalline seals of which the dimension-2 **Telluric Shield** is constructed. Through the Partiki Phasing flash-line projections of the Telluric Shield, the "armature" or 3-dimensional blueprint for the organs of perception are set for manifestation within the body hologram.

The 5 Known Senses and Sound Transduction

The 5 known senses are more intimately related than commonly supposed; ALL represent a form of SOUND TRANSDUCTION - the frequencies, or flash-line sequences, within the 1st, 2nd and 3rd dimensional bands, that form the identifiable wave patterns presently associated with sound waves, are drawn into the Level-2 Kathara Grid Crystal Seals by **Apparthi receivers** that carry like flash rhythms. Once drawn into the Apparthi receivers the sound spectrum becomes modulated into different flash-line rhythms and sent into the **Diodic Points of the Level-3 Kathara Grid**. Once intersecting with the frequencies within the Diodic Points the frequencies from the Apparthi are then **divided/ polarized** and projected up and down the Harmonic-1 dimensional scale, **creating a pattern of energy refraction** within the morphogenetic field and physical body apparatus. The polarized frequencies first appear within the **DNA** as part of the core electrical vibration, and then further transmute into **electrical impulse** that manifests as configurations with the **blood chemistry** and within the **Central Nervous System.** These synthesized electrical impulses are further projected through the **scalar-wave grids** that hold the form of the **identified sensory organs,** finally **culminating in the interrelated qualities of perception associated with the identified sensory organs and their 5 known attributes of sensing.**

THE 12 HUMAN SENSES

The Interwoven Senses and the Hova Bodies

As in the case of the Lower Senses, the *Higher Senses* and their experiential manifestations are the product of consciousness interacting with the *dimensionalized scalar organization* of the human morphogenetic anatomy. Whereas the Lower Senses are affiliated with the transduction of sound frequency within the *1st, 2nd and 3rd Dimensions*, through the structures of the *Nada Hova Body* and the *Telluric Shield* of the *first Harmonic*, the Higher Senses are in like fashion associated with the scalar organization of the *Higher Dimensional Hova Bodies* and their corresponding *Shields*.

In truth, all of the sensing facilities organic to the human form comprise interwoven and interrelated systems of *energy refraction* that together create the perceptual experience of *externalization* within the hologram of manifestation. For example, it is not commonly recognized that the sense of **smell** is in actuality part of the function of the **auditory facility**, and thus represents an intrinsic part of the sense of hearing. It is also not commonly understood that the processes associated with **vision** are not only connected to the processes of the brain and Central Nervous System, but also with the formation of *crystalline structures* with the plasma of the **blood. The senses are not nearly as *separate* and *independently functional* as they appear to be when viewed from outside analysis.** They are rather a part of an **interwoven system of electro-tonal information relay** that spans the 15-Dimensional morphogenetic field anatomy of the human organism.

The 12 Human Senses

In terms of breaking down the sense facilities for structural analysis, such as is done by modern science in identifying the 5 Known Senses, we will describe the sensory attributes of the **Higher Sense facilities** in terms of their *primary orientation*, *location of their primary Apparthi receivers* within the *Hova Body* structures and by the type of *perceptual or experiential attributes* produced through their function. **In such categorization of the human sense facilities there are *7 additional*, as yet unidentified, *sense facilities* operating within and through the human consciousness**, which are collectively responsible for translating the scalar fields of dimensionalized reality into the *illusionary holographic picture* of externalized manifestation and its qualities of space, time, matter and identity individuation. **Collectively there *are 12 Primary Sensing Facilities* within 15-Dimensional Human Anatomy.**

PERCEPTUAL BLOCKAGE, KATHARA GRID DISTORTION AND KATHARA HEALING

Perceptual Blockages

The Higher Senses are connected to the Lower Senses and provide attributes of perceptual experience characteristic to their dimensional levels, but in the present stage of human genetic evolution the Higher and Lower Senses are not fully "plugged into" each other, and so the various higher dimensional fields, and the sensory abilities associated with the Higher Senses, appear to be separate or unavailable to the embodied human consciousness.. **The Higher and Lower Senses plug in through opening of *Kathara Lines* in the *Level-1 12-Tree Kathara Grid*, which creates a reciprocal opening and expansion of the DNA, Hova Bodies and activation of dormant nerve networks within the brain, molecular core and Central Nervous System of the body.**

Presently the human senses are *phase-locked into a 3-dimensional perceptual field* due to blockages between the *3rd and 4th Kathara Centers*, which block the Apparthi receivers within the Nada Hova Body from accepting compatible electrical impulses from the higher dimensional Hova Bodies. This Kathara Grid blockage manifests within the body as fragmented units of DNA (**"Junk DNA"**), that serve to render the natural processes of multi-dimensional data transfer into the Central Nervous System inoperable. Portions of *higher dimensional experience* come to conscious attention in the form of *dream perception* or *intuitive impression,* but the natural clear pathways of multi-dimensional perception are blocked to a large degree within contemporary humanity.

Perceptual Blockages and Kathara Healing

Blockages in the Kathara Grid and their reciprocal blockages in the human perceptual field can be progressively removed through practices of *Kathara Healing*, and utilizing the *Maharic Shield* to reawaken the Organic Imprint for Health.. As Kathara blockages are progressively repaired, the genetic code will expand its function by reassembling and activating the presently dormant portions of the DNA imprint. DNA expansion will create reciprocal alterations in the bodily metabolic rate, brain, blood, glandular and hormonal function, particle spin speed and operation of the Central Nervous System, that will allow for a progressive, natural activation of the Higher Sense facilities and expansion of the human perceptual field into the multi-dimensional arena. **In Kathara Healing the dormant Higher Senses will be progressively brought into activation**, beginning with the **6th -Audurea-Merkaba Sense** and the **7th-Tristet-Cellular Telepathy Sense** through which **Inner audio-visual-direct cognition** skills will progressively develop. These skills will be employed in the processes of Kathara Healing, and in so doing they will be progressively stimulated into greater levels of activation. As the dormant Sense facilities are called into activation, Kathara Healing techniques to remove Kathara Grid blockages are used to realign the *Holographic Template* to restore the **Imprint for Health,** through which natural perceptual expansion will progressively take place.

The 12 Human Senses

The collective spectrum of human sense facilities, including the Higher Senses of 15-Dimensional Human Anatomy can be categorized as follows:

The 12 Human Senses, Hova Bodies and Primary Experiential Attributes

Identified Lower Dimensional Sense Facilities

1. Visual-Sight Sense- ***Nada Hova Body (dimensions 1-2-3)***
2. Auditory-Hearing Sense - ***Nada Hova Body***
3. Tactile-Touch Sense- ***Nada Hova Body***
4. Olfactory-Smell Sense- ***Nada Hova Body***
5. Sense of Taste- ***Nada Hova Body***

Unidentified Higher Dimensional Sense Facilities

6. **Audurea -Merkaba Sense** - *Encompasses all Hova Bodies*
   Primary Attribute: **Manifestation**-circulation of consciousness and frequency accretion
7. **Tristet-Cellular Telepathy** -*Alphi Hova Body (dimensions 4-5-6)*
   Primary Attribute: **Inner Audio-Visual-Direct Cognition** reading energy signatures.
8. **Nurgode-Transmutation Sense** - *Betcha Hova Body(dimensions 7-8-9)*
   Primary Attribute: **Molecular Transmutation** - shape-shifting
9. **Ragode-Transmigration Sense** - *Betcha Hova Body*
   Primary Attribute: **Transmigration** - Projection of Consciousness
10. **Geuard-Transfiguration Sense**- *Mahara Hova Body (dimensions 10-11-12)*
    Primary Attribute: **Bilocation**-multiple holographic manifestations
11. **Shara-Centrifugal Sense**- *Raja Hova Body (dimensions 13-14-15)*
    Primary Attribute: **Electrical Projection** - consciousness enters dimensionalization
12. **Aurt-U - Centripetal Sense** - *Raja Hova Body*
    Primary Attribute: **Magnetic Accretion** -consciousness exits dimensionalization

CHAPTER 2 HIGHLIGHTS

THE IMPRINT FOR HEALTH

- Healing occurs through correcting distortions within the Kathara Grid and Hova Body Shields.

- The human body blueprint was designed to hold 12 Dimensions of Frequency/ Flash-line Sequences and 12 Dimensions of Consciousness, the content of 4 out of the 5 Hova Bodies within the 15-Dimensional Anatomy.

- The **4th Hova Body** - the **Mahara Hova Body** - is composed of Frequencies/ Partiki Phasing Flash-line Sequences of the **10th, 11th** and **12th Dimensions.** It manifests through the 10th, 11th and 12th *Kathara Centers* and the **Maharic Shield** Scalar Grid of the **4th Harmonic.**

- The **Maharic Shield** of *Level-2 Kathara Grid Crystal Seals* holds the original **IMPRINT FOR HEALTH-** the original *Flash-line Sequences* of *Harmonic 4 Pre-matter Liquid Light* - that represent the *point of entry* into perceivable manifestation.

- The **Maharic Shield** can be used to **repattern** the Kathara Grid Holographic Template back to the original **Imprint for Heath**. The Flash-line Sequences of *Dimension 12* can *override* and correct *faulty Flash-line Sequences* that manifest as distortions within the Kathara Grid and Hova Body Shields.

- The **Hierophant Symbol Code** is a *Scalar Standing-wave* pattern containing the electro-tonal programs of the 11th and 12th Dimensions. The Hierophant Symbol code serves as a *Frequency* ***WAVE GUIDE*** through which the **Maharic Shield** can be activated to run 11th and 12th Dimensional Frequency through the Kathara Grid for **repatterning** the **Imprint for Health** within the Core Holographic Template of the body.

- Using the *Hierophant Symbol Code* the **Planetary Bio-feed Interface System™** can be activated to **empower** the Kathara Grid repatterning process via drawing Frequency from the **Planetary Maharic Shield.**

MORPHOGENETIC EXPANSION

- Growth through time is created through **FREQUENCY ACCRETION** - drawing Frequency Bands from the Dimensional Unified Fields of Consciousness into the personal morphogenetic field for expansion.

- When the Kathara Grid is functioning properly there are **set morphogenetic field expansion periods** within the linear growth cycles of the human body.
  1. **Fetal Integration** to age 11-12.
  2. **Harmonic 2 Integration** age 12-22
  3. **Harmonic 3 Integration** age 22-33
  4. **Harmonic 4 Integration** age 33-44

  If the Kathara Grid is working properly the **body does not die** but rather **progressively transmutes** into *less dense states of matter* in an **immortal body form**, via accretion of the 4 Harmonics of Frequency.

- Present **Kathara Distortions** block integration of **Harmonic 2** and begin Molecular Compaction, body degeneration and Death.

GROWTH RATES

LEVELS OF HUMAN ANATOMY

The **Kathara Grid** is the *Core Holographic Template* upon which the human body and consciousness enter dimensionalization in order to experience manifestation.

There are **3 Levels** to the Human *Kathara Grid*: *Level-1*- The **12- Tree**, *Level-2* – **Crystal Seals** and *Level-3* – **Diodic Points**.

Kathara Level-1 –12-Tree contains the primary **12 Kathara Centers** and primary **15 Kathara Lines**, that correspond to various regions of the physical body and bio-energetic field and which "ground" consciousness into the framework of dimensionalization.

Kathara Level-2 – Crystal Seals contain the **Signets** *–consolidated points of dimensional frequency* – the **Shields** – *3-dimensional scalar-wave discs emanating from sets of 3 Signets* through which the *Hova Body* energy capsules form– and the **Star Crystal Seals** and **Seed Crystal Seals** through which the *Chakras* and *Bio-energetic Field* levels emerge.

- *Kathara Level-3 – Diodic Points* are **Coordinate Points** where the flash-line sequences from one Shield and its Seals cross over and through those of other Shields to form minute **"White Hole" vortices** of energy-consciousness relay between the Hova Bodies and stations of identity.

- **Hova Bodies** are *3-dimensional scalar grids* in the form of **Concentric Spheres** that form around each **Shield** in the *Kathara Level-2 Crystal Seals Grid,* which serve as "tissue capsule" encasements around each Harmonic of energy-identity within the 15-dimensional scale.

- There are **5** *Dimensionalized* **"Ariea" Hova Bodies** forming human anatomy, which emanate from the **5** 3-Dimensional scalar **Shields** of the *Level-2 Kathara Grid*. Each Shield and Hova Body corresponds to **3 Kathara Centers** in the *Level-1 12-Tree Grid.*

- **5 Ariea Hova Bodies** and Corresponding **Shields**:
  Nada Hova-Telluric Shield-Dimensions1-3
  Alphi Hova-Doradic Shield-Dimensions 4-6
  Betcha Hova-Teuric Shield-Dimensions 7-9
  Mahara Hova-*Maharic Shield*-Dimensions 10-12
  Raja Hova-Rishic Shield-Dimensions 13-15

The **Signets** and the **Shields** can be used to direct the function of the *Kathara Level-1 12-Tree Grid* and all built upon it. **Kathara Centers** can be used to trigger activation of the *Signets* and *Shields*.

The first **4 Hova Bodies** and their **Horizontal Shields**, are most important in terms of human evolution. Activation of the **Signets** activates their corresponding **Shield**, which in turn releases the **tissue capsules** between *Hova Bodies*, allowing merger to occur. When the **first 4 Shields** activate the body is able to integrate the Avatar identity and **transmute** into pre-matter liquid-light wave form.

In *Kathara Healing* the Harmonic-4 **Maharic Shield** is used to restore integrity to all *Shields* and *Hova Bodies* below, which progressively clears the *Kathara Grid* of distortions.

Level-1 Kathara Lines direct the **Vertical** Flash-lines, *Level-2 Crystal Seals* control the **Horizontal** Flash-lines and *Level-3 Diodic Points* govern **Diagonal** Flash-lines. Together the 3 levels of the Kathara Grid form the 3-plane armature upon which the 3-dimensional hologram is created.

- Each **Signet** within a Hova Body Shield holds the electro-tonal program for one *Seed Crystal Seal*. Each *Seed Crystal Seal* corresponds to one Level-1 **Kathara Center** and holds the program for one primary **Axiom Line** – a *single axis* dimensional flash-line sequence.

- The **12 Primary Axiom Line** programs of the *Seed Crystal Seals* create separate *dimensionalized bands of frequency* within each Hova Body, forming a distinction between *dimensionalized levels* within the bio-energetic **Auric Field**. The Axiom flash-lines cross over and through each other to form the *Coordinate Points* between the Shields through which the *Level-3* **Diodic Point Vortices** emerge.

- The points in the Kathara Grid where Axiom Lines cross over and through the **Central Vertical Kathara Line** in the *Level-1 Grid*, and the **Horizontal flash-lines** in the *Crystal Seals* of the *Level-2 Grid*, form **consolidated Diodic Points** with *numerous Diodic Vortices* – these are called **CHAKRAS**. Each Chakra corresponds to an *Axiom Line, Auric Level, Seed Seal, Kathara Center*, and *Dimensional Frequency Band* and ***Merkaba Field***.

- The **12 Primary Axi-A-Tonal Lines** are a set of 12 *Vertical Energy Flow-lines* that run through the body, which are created by the consistent cross-over points of the rotating, single-axis flash-line sequences projected from the **Seed Crystal Seals.**

- **Axi-A-Tonal Lines 11 and 12** combine with the **Central Vertical Kathara Line** to form the **Hara Line**, the foundation of the **Central Body Current.**

- The **Hara Level** is the ***outer level*** of the **Kathara Level-2 Crystal Seals Grid**, can be viewed from *9th-Dimensional perception* and is used in Kathara Healing Level-2 .

- The *Hara Level* is composed of the **Hara Line, 6 Primary Hara Points** and the **Complexes** of energy processing they govern.

- The **Axi-A-Tonal Lines** and **Hara Level** of the *Kathara Level-2 Crystal Seals Grid* are elements of 15-Dimensional anatomy that are used in later applications of Kathara Healing.

- *Axi-A-Tonal Lines* set the core electro-tonal scalar-wave program upon which the **DNA** will manifest. The human DNA imprint contains the program for **12 strands of DNA**, one manifesting upon each of the **12 Primary Axi-A-Tonal Lines.**

- The human form was designed to embody **12 dimensions** of consciousness. The original human genetic code is called the **Silicate Matrix** and when operational it allows human cellular structure to **transmute** through ***4 Harmonics*** *of matter density*.

- The Silicate Matrix is mutated in present day humans due to ancient **Kathara Grid blockages**, which manifest as distortions of form and function within the DNA. "*Junk DNA*" is part of this distortion.

- Contemporary human DNA can be **reverse-mutated,** and its interdimensional functions restored, by applications of **Kathara Healing**.

- Each of the 12 strands of DNA *corresponds to* one of 12 *Dimensional Frequency Bands, Kathara Centers, Seed Crystal Seals, Signets, Axi-A-Tonal Lines*, and *Chakras*. Each **Hova Body Shield** governs the function of a **set of 3 DNA strands.**

THE 12 HUMAN SENSES

The **human senses** are the *experiential result* of the *scalar standing-wave organization* inherent to the human form.

Senses are **scalar arrangements** that *translate energy signatures* from the **Unified Field** into *usable data of relationship*.

The sensing systems are built upon sets of **energy receivers** within the morphogenetic field that are called **APPARTHI**. The Apparthi inherent to Kathara structure serve to **block certain flash-line sequences** out of the morphogenetic field and allow others in to translate into perception.

The flash-line sequences blocked by the Apparthi create **Gaps of Perception** of the *Unified Field*, which give us the *experience* of **externalization** and **separation of form**.

Apparthi receivers create **refraction and polarization of flash-line sequences** that translate into a variety of identifiable ***holographic sensory perceptions.***

- The sense facilities correspond to the structure of the **Hova Body Shields** and **DNA.** In categorizing the interwoven sense facilities by their *primary orientation*, location of their *Apparthi receivers* within the Hova Bodies and the *experiential attributes* they produce, the human organism can be said to possess **12 Primary Senses.**

- The **5 known senses** are products of the operations of the **Nada Hova Body** and **Telluric Shield**, and thus correspond to **dimensions 1-3.**

- There are **7 as yet unidentified senses** that correspond to the higher dimensional *Hova Bodies*, *Shields* and presently dormant strands of *DNA*.

- As we evolve to *activate* and *reverse-mutate* the **DNA** imprint, through *Hova Body* alignment and merger, the experiential attributes of the higher dimensional senses will become more apparent.

- Due to their *dimensional affiliation*, the *5 known senses* can be viewed as the **Lower Senses**, the *higher dimensional senses* as the **Higher Senses.** Perception through the *Higher Senses* is called ***Higher Sensory Perception*** or **HSP.**

TAPPING THE INNER MENTOR

Levels of Consciousness and the Perceptual Bridge

In earlier text we have learned of the structure human consciousness takes when entering the scalar fields of dimensionalization for the perceivable experience of manifestation. In comprehending the true structure of multi-dimensional anatomy, with its **Kathara Grid, Hova Bodies** and **Shields, Diodic Points** and **levels of bio-energetic substance**, we can begin to see that there is much more to human consciousness than meets the eye - **much more *energy-identity* operating presently beyond the view of our 3-dimensionally focused earthly personality.**

There are portions of our consciousness stationed within the Hova Bodies of the higher dimensional fields, and these expanded levels of ourselves hold knowledge and participate in perceptual experience beyond the usual range of our waking perceptions. As we evolve and expand through **Hova Body Integration** and the resulting activation of dormant **DNA** components, we will progressively have *greater conscious access* to these expanded levels of consciousness while we are actively focused within the waking 3-dimensionally embodied state. However, **we do not have to wait until our evolution plods along to bring us to these expanded perceptual states**, we can, from our waking state of 3-dimensional consciousness begin to actively tap this hidden reservoir of knowledge and perceptual experience. **We can take an active hand in *expediting the process* of our multi-dimensional evolution by using our dimension-3 *mental body awareness* to direct our higher awareness into our current range of perception.** We can begin to build a **PERCEPTUAL BRIDGE** between our 3rd-Dimensional and Higher Dimensional consciousness. **In taking the initiative for building this Bridge of Consciousness we begin to stimulate our Higher Senses into operation, expediting the natural process of Higher Identity Integration.**

Through building a PERCEPTUAL BRIDGE
between our present state of awareness
and the levels of our consciousness
stationed in the Higher Dimensional Hova Bodies,
we can actively expedite our own Bio-Spiritual Evolution.

THE MENTOR

The Perceptual Bridge and Creating the Mentor

The Higher Dimensional levels of human consciousness are not dormant within their respective dimensional bands of function, they are quite awake and aware within their own dimensional fields. As we perceive and interact with the 3-dimensional world within which our present awareness is focused, the Higher Dimensional portions of our consciousness are also actively perceiving and interacting with the dimensional environments within which they are focused. **Higher dimensional aspects of our awareness *seem cut off* from our perceptual view because our consciousness is presently focused through a *genetic code arrangement and Kathara Grid orientation* that blocks out the frequencies of those higher stations of identity.** If we can realize that expanded portions of our consciousness simultaneously exist within the higher dimensional frequency bands, we can also realize that it is possible to access such levels of our own identity by building **Perceptual Bridges** between our 3-dimensional perspective and the portions of our consciousness stationed within the Higher Dimensional Hova Bodies.

We can begin to build a *Perceptual Bridge* between ourselves and our *Higher Selves*, by using simple *frequency modulation techniques* of Kathara Healing, such as Technique #1: *Awakening the Mentor and the 6th and 7th Senses*. In this scalar-grid activating exercise, we will awaken dormant **Partiki Phasing Flash-lines** and activate dormant portions of the **Kathara Lines** in the *Kathara 12-Tree Grid*, to begin opening the channels of communication between the consciousness focused within the *Nada Hova Body* and that focused within the *Alphi Hova Body* of Harmonic-2. **In this exercise we will create the MENTOR, a portion of our consciousness composed of *3rd, 4th and 5th Dimensional frequencies*, that will serve as an *intermediary focus of awareness* through which we can begin to receive guidance and knowledge from our 2nd-Harmonic of consciousness.** Creating the MENTOR will begin the process of activating dormant **DNA**, opening new **nerve networks** within the Central Nervous System of the 3-dimensional body, and activating dormant **APPARTHI** frequency receivers within the *Level-2 Crystal Seals Kathara Grid*. **Through creating the MENTOR, we begin to build the Perceptual Bridge between the 1st and 2nd Harmonic of our conscious awareness.**

The MENTOR is a portion of our identity that we create to serve as an intermediary focus of awareness between the Nada Hova Body and the Alphi Hova Body; a PERCEPTUAL BRIDGE between our first and second Harmonics of Consciousness.

The MENTOR and Kathara Healing

In the practices of Kathara Healing we will use the MENTOR as a source of **guidance, information retrieval, objective observation** and as a **communications link** between our own higher consciousness and the higher levels of consciousness in those who come to us for healing facilitation. **Awakening and working with the MENTOR will become a standard practice in our applications of Kathara Healing.** In creating the MENTOR we are using our creative power of scalar-grid manifestation (thoughts and mental images are scalar-grid morphogenetic field forms) to bring into being a **specialized portion of our consciousness** that can **relay frequency** from our higher Harmonics of Consciousness to our 3-dimensionally focused identity. **With repeated use of the MENTOR focus of awareness we will develop the ability to simultaneously hold 2 Harmonics of consciousness, and we will begin to reclaim the natural flexibility of focus that is the healthful condition of embodied human consciousness.** Through the MENTOR focus of attention we can reach higher levels of cognition and understanding regarding application of healing facilitation, and we will more rapidly call into awakening the Higher Sense facilities of the 15-Dimensional Anatomy.

Other Uses of the MENTOR Focus

In creating the MENTOR focus we will begin to realize that even the 3-dimensional focus of awareness with which we are most familiar is far more flexible than once supposed. The MENTOR is not simply an **inert creation**, but rather a **living** portion of our conscious identity composed of portions of the waking self and portions of the Higher Self. MENTOR can become an **advisor**, a portion of self able to "keep its head above the illusion" when you are confronted with challenging events in the 3-dimensional arena; a part of you able to remain clam, focused and able to make clear decisions beyond the confusion of mental or emotional body processing. MENTOR can be sent into the **Cellular Memory** of the body to locate core issues or reincarnational blockages, and can serve to moderate between sub-personality fragments and the "Inner Child". MENTOR can like wise be used to **harmonize communications** between self and others, as you can send the MENTOR focus into the higher dimensional fields to connect with the higher selves of others for conflict resolution. Playing with the MENTOR focus can also have great rewards. You can focus your attention in the Mentor Space and then direct the MENTOR across the room to begin practicing affects of **BILOCATION.** You can travel with MENTOR to distant locations to develop **REMOTE VIEWING SKILLS**, which will be used in later Kathara Healing levels for **REMOTE HEALING FACILITATION**. MENTOR can become a **vehicle for conscious transport** of your awareness, while awake and also in **dreaming** and **higher dimensional projection.**

TECHNIQUE # 1

AWAKENING THE *MENTOR* AND THE 6TH AND 7TH SENSES

Awakening the Mentor:

1. Place the **fingertips** of both hands and the focus of your attention at the **Navel.** Take a few slow, full breaths then visualize the image of a **Blue Flame** (like a gas stove flame) deep inside the body behind the Navel. Gently **massage** the Navel region while envisioning the **Blue Flame.**

2. **Stop massage** and visualize a **Sphere of White Light within the Blue Flame** behind the Navel. **Place your attention within the White Sphere** and imagine that you can feel its reality around you, as if you are sitting within the White Light Sphere.

3. Breath gently and visualize the **White Light Sphere moving upward** through the center of your body until it reaches the center of the brain at the **Pineal Gland.** **Stop movement of White Light Sphere at the Pineal Gland,** then visualize the **White Light Sphere moving to the RIGHT** in a straight, horizontal line **OUTSIDE OF THE BODY** until it is positioned in your **auric field** just above your **RIGHT SHOULDER.** ***The White Light Sphere positioned over the Right Shoulder now represents a portion of your awareness that was raised to the 5th-Dimensional frequencies via its passage through the Blue Flame and the 5th Kathara Center at the Navel.*** You will name this part of your higher identity **MENTOR.**

4. Imagine that you can **feel the reality of the White Light Sphere** that holds your MENTOR resting gently above your Right Shoulder as a **"fuzzy ball of energy".** ***MENTOR serves as the meeting point between your waking conscious mind and the 5th-Dimensional portion of your Soul Matrix Identity- the Archetype. With practice, you can lean the energy of your waking awareness from its position within your head, over to the right and into the MENTOR Sphere, to receive direct cognition, audio and visual guidance from your 5th-Dimensional Identity Station.*** **In Healing Facilitation** MENTOR will communicate with the 5th-Dimensional Archetype aspect of your **Client's Soul Matrix,** asking how you may best serve the Client's Highest Evolution; guidance MENTOR receives will be translated to you from MENTOR in the form of Intuitive urge, spontaneous cognition or audio-visual directions. MENTOR will also serve as a **translator of information from your higher dimensional Stations of Identity** to your conscious mind. MENTOR can also be taken into the Dream State with you to assist in **Dream Recall** and initiating **Out-Of-Body Travel.**

5. Practice creating and sensing the Mentor Sphere over your Right Shoulder. Carry it around with you wherever you go, and play with *moving the focus of your consciousness back and forth between the inside of your head and MENTOR.* Try perceiving from both focuses of attention simultaneously. Such play will help stimulate neurological sensitivities to translating and perceiving information from the 5th and higher dimensional Stations of Awareness.

TECHNIQUE # 1: continued
AWAKENING THE *MENTOR* AND THE 6TH AND 7TH SENSES
Awakening the 6th and 7th Senses: The *Audurea* and the *Tristet*

1. Focus your attention on the **MENTOR Sphere** over your Right Shoulder. Take a few slow, deep breaths and visualize MENTOR *expanding into a Sphere the size of a Basket Ball*. Use the next **INHALE** to draw the MENTOR Sphere *toward your head*, visualizing MENTOR moving from over your Right Shoulder to a position *surrounding your entire head*. **EXHALE**, *stop the movement* of the MENTOR Sphere, and imagine that you can feel its "fuzzy energy" all around the outside of your head; *as if your head is now within the Basket Ball size MENTOR Sphere.*

2. With the next **INHALE** breath, **contract MENTOR into a small Sphere of White Light** positioned inside the center of the brain at the **Pineal Gland**. Exhale and breathe slowly for a moment. With the next **EXHALE** breath, *push* the small MENTOR Sphere from the Pineal Gland, straight forward and into the **6th-Chakra** at the *Forehead*. Visualize MENTOR moving into the 6th-Chakra from inside the head, then continuing to move through the 6th Chakra spiral straight outward and *away from the body*. Imagine the MENTOR Sphere traveling outward through the long **Blue-Violet Tunnel** of the 6th Chakra spiral, until you visually loose track of the MENTOR Sphere far out in front of you.

3. Take a few slow breaths, then on the next **INHALE** visualize the MENTOR Sphere *re-appearing* in the distance of your 6th Chakra spiral, and *riding in on the inhale breath*, back into the **Pineal Gland**. Breathe slowly.

4. With the next **EXHALE**, visualize the MENTOR Sphere moving *down from the Pineal Gland* at the center of the brain, stopping at the center of the **5th Chakra** in the *Throat*. Breathe slowly. On the next **EXHALE** push the MENTOR Sphere straight outward, imagining it moving forward from inside the Throat, into the blue green spiral of the *5th Chakra*. Visualize MENTOR *riding the current of the exhale breath* out into the distance within the blue-green **tunnel** of the 5th Chakra spiral, until it fades from view. Take a few slow breaths and on the next **INHALE** imagine MENTOR returning through the 5th Chakra blue-green spiral to rest deep within the **Throat**. Use the **final INHALE** to move MENTOR back up to the **Pineal Gland** and the final **EXHALE** to *push* the MENTOR Sphere back out to its "home" position in the auric field over the **Right Shoulder**.

This process opens up the 1st-5th Sub-frequency Bands within each dimensional layer of the 6th and 5th Chakras, beginning the process of opening the 6th-Audurea and 7th-Tristet Senses, stimulating Inner Vision and Audio to higher dimensional frequency perception.

SYMBOL SHORTHAND

TECHNIQUE # 1: Condensed Version
Awakening the Mentor and the 6th and 7th Senses

AWAKENING THE MENTOR

1. Finger *tips* at *Navel*, see *Blue Flame* in body behind Navel. *Massage* Navel with finger tips
2. See *White Sphere in Blue Flame* at Navel. Imagine *yourself in White Sphere*, feel it around you.
3. Move *White Sphere* up to *Pineal Gland*, see White Sphere move out over *Right Shoulder* creating your *MENTOR*
4. Feel *MENTOR* as *fuzzy ball* of energy hanging in your auric field over your Right Shoulder
5. *Practice shifting* the *focus* of your attention back and forth between usual focus and *MENTOR*

AWAKENING THE 6TH & 7TH SENSES

1. Expand MENTOR over Right Shoulder to size of *Basket Ball, INHALE* drawing *MENTOR* around your *head*, as if your head is inside the Basket Ball size energy that is MENTOR.
2. *INHALE, contracting MENTOR* into *Pineal Gland* as a small Sphere of White Light, *EXHALE* to push *MENTOR* out of *Pineal Gland out to Chakra 6* and into the *Blue-Violet Tunnel* of the Chakra 6 spiral.
3. *INHALE MENTOR back from Blue-Violet Tunnel* of Chakra 6 and into the *Pineal Gland*
4. *EXHALE MENTOR* from *Pineal Gland to Chakra 5. EXHALE MENTOR out* through *Chakra 5 Green Tunnel. INHALE MENTOR back* through *Green Tunnel* into *Chakra 5* at Throat. *INHALE MENTOR* up from *Chakra 5* to *Pineal Gland. EXHALE MENTOR* out from Pineal Gland to its "Home Station" over *Right Shoulder.*

Awakening the Mentor and the 6th and 7th Senses

AWAKENING THE MENTOR

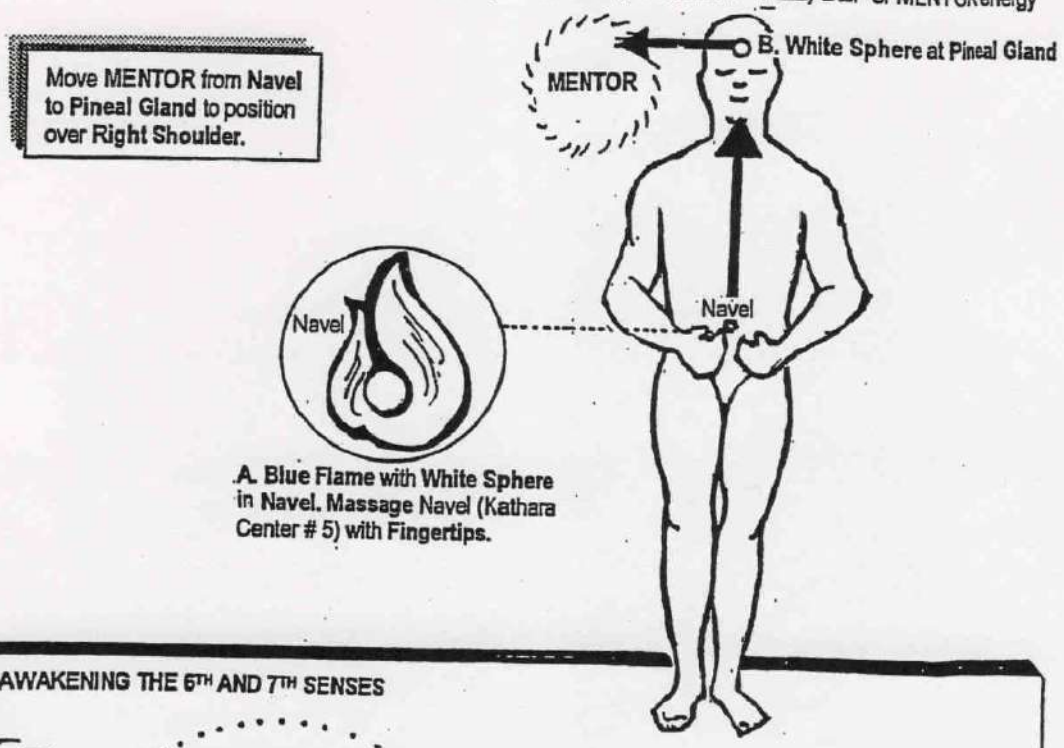

AWAKENING THE 6TH AND 7TH SENSES

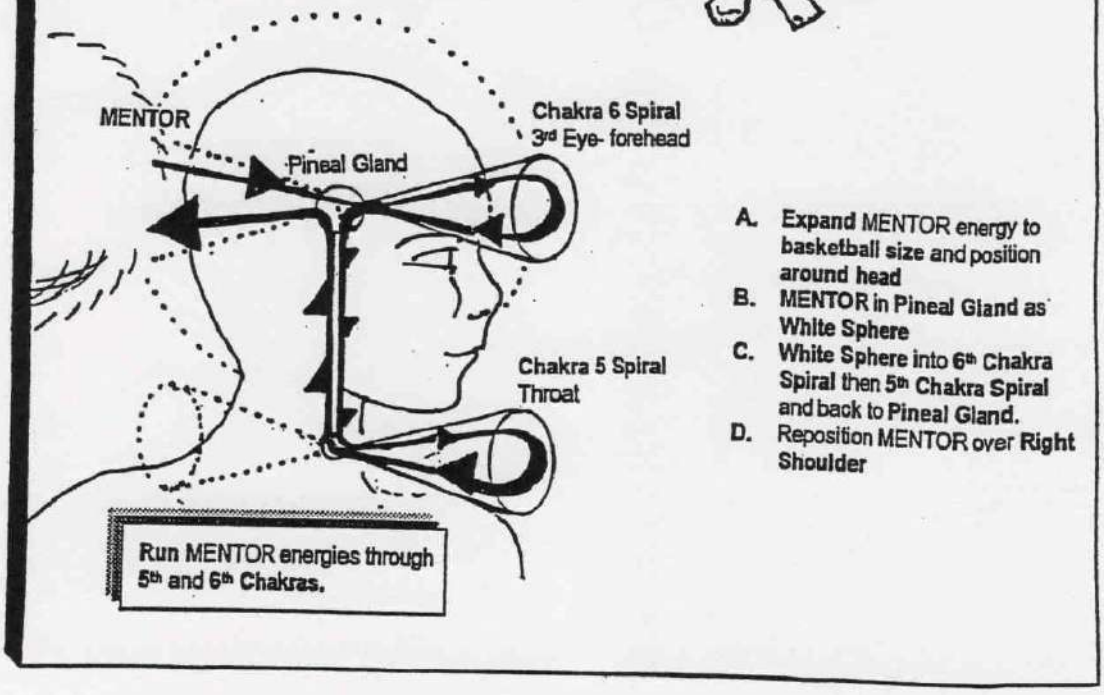

MAHARIC RECODING, FREQUENCY SUB-HARMONICS & THE MAHARIC SEAL

Kathara Healing and Reaching the Core of Dis-ease

In earlier text we have explored the significance of the **Kathara Grid** and its role as the **Holographic Template** upon which the morphogenetic field, body and consciousness manifest within the 15-Dimensional system. We have learned that the Kathara Grid is the **core template** upon which the *morphogenetic field* manifests, and that the *morphogenetic field* is the **blueprint** upon which the body systems and embodied consciousness manifest. Through our study of these *core structures of manifestation* we come to realize that *true and lasting health or healing* must be approached from the deepest levels of personal creation, the *morphogenetic reality* within which all dis-ease conditions have their origin. **Kathara Healing applications are intended to reach the *core of systems malfunction*, the various levels of the *morphogenetic field and Kathara Grid*, in order to restore the *Imprint for Health* within the Holographic Template for manifestation.**

The Mahara Hova Body, Maharic Shield and the Imprint for Health

In *Level-1 Kathara Healing* we will learn the first and most important level of *restructuring the Holographic Template* to hold its original Imprint for Health - the MAHARIC RECODING PROCESS. The **MAHARIC SHIELD** is the manifestation template upon which the **MAHARA HOVA BODY** of *Harmonic-4* manifests. The Mahara Hova Body is the scalar-grid that holds the **10th, 11th and 12th-Dimensional** aspects of consciousness, and represents the **ORIGINAL POINT OF MANIFESTATION** -the **creation point** when consciousness moved from its pure scalar-wave state of being into the dimensionalized scalar-grids through which the illusion of external holographic projection could be experienced. The Mahara Hova Body and its station in Harmonic Universe-4 represent the original **PRE-MATTER LIQUID LIGHT** fields of manifestation through which we passed in order to enter the experience of density and individuation of matter form.

Prior to our entering the dimensionalization of the systems within which matter can be perceived, we existed in **pure scalar-wave form** - a scalar-pattern that held the **original, pure and perfect pattern** for our creation as consciousness. The Mahara Hova Body and the Maharic Shield are the Liquid Light Pre-matter Scalar-templates that hold our original pattern of wholeness, our original **CREATION IMPRINT**. Our creation imprint is the **ORIGINAL IMPRINT FOR HEALTH**, the condition of **eternal being** free from Hova Body distortions picked up in the lower dimensional fields.

THE 12th-DIMENSION and FREQUENCY SUB-HARMONICS

In Level-1 Kathara Healing we will utilize the *Imprint for Health* as held within the *Maharic Shield* to begin REPATTERNING the Kathara Grid back to its original level of function. The frequencies of the **12th-Dimension**, as embodied within the **Maharic Shield**, contain within them as **Frequency Sub-Harmonics** ALL OF THE FREQUENCY BANDS FROM THE DIMENSIONS BELOW, along with the natural frequency spectra characteristic to the 12th-Dimension. Each Dimensional Frequency Band within the 15-Dimensional Spectra contains within itself its own **12 Primary Sub-frequency Bands** (portions of the whole dimensional Partiki Phasing flash-line sequences), plus a **reflection set** of the frequency spectra from **all of the Dimensional Bands below.**

For example, Dimension 2 contains its own *12 Primary Sub-frequency Bands*, **plus** *a reflection set of the 12- Primary Sub-frequency Bands* that make up the *Dimension-1 Frequency Band* below. Dimension-1 has 12 Primary Sub-frequency Bands, Dimension-2 thus has 12 Primary Sub-Frequency Bands plus 12 Secondary Sub-Frequency Bands from Dimension-1for a total of *24 Sub-Harmonics* in Dimension 2. **This pattern of FREQUENCY SUB-HARMONICS builds upward through the 15-Dimensional Scale. The 12th-Dimensional Frequency Band has a total of 144 Sub-Harmonics** - 12 Frequency Bands x 12 Sub-Frequency Bands each = *144 Sub-Harmonic Frequency Bands*. Because the 12th-Dimension holds within itself *all of the Frequency Spectra and scalar-grid programs* from the lower dimensions, the *12th-Dimensional Frequencies have the ability to "plug into" and override any Partiki Phasing flash-line pattern from the lower dimensional fields.* **The ORIGINAL PATTERN OF CREATION for the lower dimensional structure itself is held within the *12th-Dimensional Frequencies*, and so the 12th-Dimension *Sub-Harmonics* can be used to *correct any distortion* with the dimensional frequencies of the Lower Hova Bodies and their Shields.**

The Maharic Shield and the 12th-Dimension

As the Maharic Shield and Mahara Hova Body are composed of 10th, 11th and 12th-Dimensional scalar grids, they contain within them the **144 Frequency Sub-Harmonics** of the entire 12-Dimensional Spectrum. The human morphogenetic field is designed to hold the 144 Sub-Harmonic Spectrum, which is fulfilled through activation of the original **12-Strand DNA Silicate Matrix** gene code. Because of its 144 Sub-Harmonic scalar-wave spectrum, the 12th-Dimensional level of the **Maharic Shield** can **reset** the *original, non-distorted imprint of Partiki Phasing flash-line sequences* within the entire *Kathara Grid 12-Tree, the Kathara Centers, Kathara Lines, the Hova Bodies, DNA* and within any level of the morphogenetic field and manifest body built upon them. The *Maharic Shield* is the Kathara **RESET BUTTON.**

Frequency Sub-Harmonics in the 15-Dimensional Scale

Dimension x 12-SFB each =

Dimension (Primary SFB + Secondary SFBs)	# of Frequency Sub-Harmonics
Universal Morphogenetic Field: (cannot fully process through the human gene code for embodiment)	
Raja Hova Body-RISHIC SHIELD	
D-15 (12 + 168 =) 15 x 12 =	180 Frequency Sub-Harmonics
D-14 (12 + 156 =) 14 x 12 =	168 Frequency Sub-Harmonics
D-13 (12 + 144 =) 13 x 12 =	156 Frequency Sub-Harmonics
Human Morphogenetic Field: (can process through gene code via 12-Strand DNA Silicate Matrix)	
Mahara Hova Body- MAHARIC SHIELD	
D-12 (12 + 132 =) 12 x 12 =	144 Frequency Sub-Harmonics
D-11 (12 + 120 =) 11 x 12 =	132 Frequency Sub-Harmonics
D-10 (12 + 108 =) 10 x 12 =	120 Frequency Sub-Harmonics
Betcha Hova Body- TEURIC SHIELD	
D-9 (12 + 96 =) 9 x 12 =	108 Frequency Sub-Harmonics
D-8 (12 + 84 =) 8 x 12 =	96 Frequency Sub-Harmonics
D-7 (12 + 72 =) 7 x 12 =	84 Frequency Sub-Harmonics
Alphi Hova Body- DORADIC SHIELD	
D-6 (12 + 60 =) 6 x 12 =	72 Frequency Sub-Harmonics
D-5 (12 + 48 =) 5 x 12 =	60 Frequency Sub-Harmonics
D-4 (12 + 36 =) 4 x 12 =	48 Frequency Sub-Harmonics
Nada Hova Body-TELLURIC SHIELD	
D-3 (12 + 24 =) 3 x 12 =	36 Frequency Sub-Harmonics
D-2 (12 + 12 =) 2 x 12 =	24 Frequency Sub-Harmonics
D-1 (12 + 0 =) 1 x 12 =	12 Frequency Sub-Harmonics

REMEMBER: A FREQUENCY BAND is a *fixed, repeating sequence* of *Partiki Phasing Flash-lines* - "flashing on and off" cycles of scalar standing-wave points within the scalar-grid template, caused by the *fission/ expansion and fusion/ contraction of Partiki Units*. A SUB-FREQUENCY BAND is a *fixed, repeating sequence of Flash-lines* that is *part of* the full cycle of the *Frequency Band* Partiki Phasing sequence. A FREQUENCY SUB-HARMONIC represents a replica of Frequency Band Flash-line sequences from the dimensions below, carried within the Primary Flash-line sequences of the Dimensions above.

HIGHER DIMENSION = MORE FREQUENCY SUB-HARMONICS = FASTER FLASH RATES = HIGHER FREQUENCY = FASTER OSCILLATION/ SLOWER VIBRATION = SHORTER WAVE LENGTH = SLOWER ELECTRON SPIN = LESS PERCEIVABLE MATTER DENSITY

The Maharic Shield - Core of Healing Therapeutics

To restore the **Imprint for Health** within the *Body-Mind-Spirit System*, the **Holographic Template of scalar-grids** upon which the system manifests must be **restored to its original function**. *Topical applications* of healing modalities within the physical body, bio-chemistry, DNA, Auric Field, Chakra System, and Level-2: Crystal Seals and Level-3: Diodic Points of the Kathara Grid can create *temporary change* toward healing, but the **disharmonic conditions** held within the core **Level-1 12-Tree Kathara Grid** will eventually **override** alteration made to the outer levels of the morphogenetic field or body systems. **Working with outer levels of the Bio-system can *assist* in the healing process, but first the *Imprint for Health* must be restored within the *Level-1 12-Tree Kathara Grid*.** The *Level-1 12-Tree Grid*, with its *Kathara Centers* and *Kathara Lines* is created upon the **144 Frequency Sub-Harmonic** Pattern. As the **Maharic Shield** and Mahara Hova Body are the only portions of the dimensionalized scalar-grid anatomy that hold the full **12th-Dimensional Frequency Band** with its *144 Sub-Harmonics*, the **Maharic Shield** and its corresponding **10-11-12 Kathara Centers** are the *only portions of the morphogenetic anatomy that can override and restructure the electro-tonal scalar standing-wave point arrangements within Level-1 Kathara Grid.* **Thus it is with the *Maharic Shield* that core healing therapeutics must begin.**

Critical Mass and Simultaneous Healing of Core/ Outer Morphogenetic Levels

Activating the **Maharic Shield** will **open, activate and realign** the *scalar-wave flash-line sequences* of dormant *Kathara Centers, Kathara Lines, Crystal Seals, Hova Bodies, Diodic Points, Chakras* and *DNA* within the outer levels of the morphogenetic field and body. Once the **Imprint for Health** has been *temporarily restored* within the *Core Holographic Template Kathara Grid* via running the *Flash-line sequences* of the **Maharic Shield** through the *Level-1 Kathara Grid*, the *outer layers of the anatomy can be further realigned* to expedite manifestation of the Kathara Grid Repatterning into the outer levels of the Bio-system. **Technique # 2: The Maharic Seal and the Liquid Light Cleanse**, begin the process of running the 12th-Dimensional Flash-line sequences, via their Frequency Sub-harmonics, through the Kathara 12-Tree Grid to **REPATTERN** *distorted flash-line sequences* within the core Holographic Template. In the beginning of using this technique, the affects of this reprogramming will last only several hours, as the outer levels of the Bio-field will have greater **"Critical Mass"** in their distortion patterns, than the Kathara Grid can immediately override. **Full healing comes when the renewed Imprint for Health reaches CRITICAL MASS within the morphogenetic field.** Critical Mass is reached via *frequent use of the Maharic Seal* and *outer level Bio-field therapeutics.*

Kathara Healing Theory and Applied Methods

In Kathara Healing the first priority is to *reset the integrity* of the *Kathara Level-1; 12-Tree Grid* by Re-patterning its flash-line sequence program to the *Maharic Shield* via the *Maharic Seal and Liquid Light Cleanse*. This process sets the electro-tonal **"ground"** within which alterations of *outer morphogenetic levels* can connect, reawakening dormant **APPARTHI** *frequency receivers* within the *Level-2: Crystal Seals*, which allows the morphogenetic field levels to *expand* enough to hold the *higher frequencies* of the *Imprint for Health*. After the **Healing Ground** is set within the *Kathara Grid*, additional applications of Kathara Healing can then be applied to various other levels of the Kathara Grid, Morphogenetic Field and Body. **There is an infinite variety of Kathara Healing Bio-energetic applications**, that range from Levels 1, 2 and 3 Kathara Grid work, reprogramming the Kathara Centers, Kathara Lines, Hova Bodies, Shields and Signets, reversing the Miasmic/Karmic Imprint and accelerating the opening of the Diodic Points, to working with the Chakra System, Meridian and Axiom Lines, DNA and physical body points while running the Triadic Currents for healing. In coming Levels of the *Kathara Healing Program* we will learn the use of the **GEOMANCIES** and **FIRE LETTERS**-key **Symbol Codes** that serve as **scalar-wave guides** to reset the electro-tonal *flash-line sequences* within the morphogenetic body, and the application of the Symbol Codes to the treatment of specific physical, emotional, mental and spiritual dis-ease conditions. We will explore working with the **Color Cap Stones** of the Dimensional Frequency Bands and how they can be used in combination with the Symbol Codes for use in **Manifesting** desired conditions and **De-manifesting** undesirables, both within the body and in the 3-dimensional life drama.

Applications of the Level-1 Kathara Healing Program

In Program Level-1 we are setting the foundations upon which all the other skill levels of Kathara Healing are built. The focus of the Level-1Program is to create Morphogenetic Repatterning via the Maharic Shield, and to begin clearing the Miasmic/ Karmic Imprint that blocks various areas of the Hova Body Imprint. We will next learn to add **FORCE AND POWER** to our *Morphogenetic Recoding Process* by opening the **PLANETARY BIO-FEED INTERFACE SYSTEM™** to draw energy directly from the **Planetary Maharic Shield**, and we will begin learning of the *physical body massage point sequences*- **Sequence 1 and 2 Kathara Points** - through which we can begin to *regulate the flow of energy within the Bio-system* for **Regeneration** of the Imprint for Health and **Revitalization** of the Body-Mind-Spirit System. In **Section 2** of this course we will explore **MULTI-VECTOR HOLOGRAPHIC RECODING** - clearing the *Miasmic Imprint* from the Kathara Grid.

SEQUENCE 1 AND 2 KATHARA POINTS

Sequence-1 Kathara Points for REGENERATION

Sequence-1 Kathara Points are mini-energy-vortex points in the body that connect directly to **Diodic Points** within the *Kathara Level-3 Diodic Points Grid*. Stimulation of the Kathara Points affects the movement of energy within related areas of the Kathara Grid, which creates a reciprocal movement of energy within the cellular structure corresponding to the Kathara Points.

When used **in proper sequence**, *Sequence-1 Kathara Points* ***open energetic gate ways to the Kathara Lines*** of the Kathara Level-1 12-Tree Grid, allowing patterns of frequency to be entered into the Kathara Lines, to realign disharmonic patterns of frequency running through the Holographic Program of the Kathara Lines. When the Kathara Lines are opened to receive 11th and 12th dimensional frequency infusions from the **Mahara Hova Body**, the Holographic Program of the Kathara Grid can be progressively ***regenerated*** to the Imprint for Health, as held within the program of the Maharic Shield.

Sequence-1 Kathara Points are used to *open* the Kathara Lines prior to *Technique # 2: The Maharic Seal and the Liquid Light Cleanse* and *Technique # 4: The Maharic Infusion*. They **may also be used alone** with deep breathing, for frequent healing support, to draw energy up from the Maharic Shield, re-balancing and regenerating the Imprint for Health within the Kathara Grid and Body-Mind-Spirit System. It is not necessary to close the Kathara Lines after using Sequence-1 Points as they will **close automatically** in **several hours**. If one desires to further revitalize the cellular structure, running the *Sequence-2 Kathara Points* for *closing* the Kathara Lines will increase the amount of energy running through the *body cells*, as the Kathara Lines are no longer absorbing the energy.

Sequence-1 Points **regenerate and re-balance the *Kathara Core* first, which creates *more lasting but less immediate* changes in the body. *Sequence-2 Points* close the Kathara Lines if they are opened and draw energy from the Maharic Shield *directly into the bio-energetic field and physical cells*, rather than the core Kathara Grid, creating *more immediate, but temporary*, revitalization of the body.** The patterns held within the Kathara Grid- core holographic template will eventually override those set into the bio-energetic field alone. **Used in *combination* with each other the *Sequence-1 and Sequence-2 Kathara Points* can affect more lasting revitalization by *simultaneously realigning the core template and the outer layers* of the bio-energetic system and cellular structure.** In combination with other Kathara Healing techniques the affects and restoration of the Imprint for Health are further amplified and accelerated.

Sequence-2 Kathara Points for REVITALIZATION

Sequence-2 Kathara Points are mini-energy-vortex points in the body that, like *Sequence-1 Kathara Points*, connect directly to **Diodic Points** within the *Kathara Level-3 Diodic Points Grid.* Stimulation of the Kathara Points affects the movement of energy within related areas of the Kathara Grid, which creates a reciprocal movement of energy within the Bio-Field and cellular structure corresponding to the Kathara Points.

When used **in proper sequence,** *Sequence-2 Kathara Points* ***close the energetic gate-ways to the Kathara Lines*** of the Kathara Level-1 12-Tree Grid, which the *Sequence-1 Kathara Points* had opened. Closing of the Kathara Lines governed by the Sequence-1 Kathara Points, ***creates a reciprocal OPENING of Nadial Lines (Nadis*** energy rivulets that carry energy from the Nada Hova Body/ Nadial capsule, into the physically manifest systems**)** within the *outer levels* of the Bio-energetic Field. Opening of corresponding Nadis allows restorative patterns of frequency to be entered into the **outer levels** of the Bio-energetic Field and Chakra System, to realign disharmonic patterns of frequency running through the *Chakras, Auric Field and Physical Cells.* When the Nadis, Chakras and outer Bio-energetic Field are opened to receive 11th and 12th dimensional frequency infusions from the **Mahara Hova Body,** the energetic integrity of the physical cells and Bio-energetic Field can be progressively ***revitalized*** with Maharic frequency and the Imprint for Health, as held within the program of the Maharic Shield.

Sequence-2 Kathara Points are used to *close* the Kathara Lines following *Technique # 4: The Maharic Infusion.* They **may also be used alone** with deep breathing, for frequent healing support, to draw energy up from the Maharic Shield, through the Kathara Grid and into the **outer levels** of the Bio-energetic Field. Directing Maharic frequency into the outer levels of the Bio-energetic Field regenerates the Imprint for Health within, and directly **revitalizes** the *body cells* for accelerated Body-Mind-Spirit healing. If one desires to revitalize the cellular structure, running the *Sequence-2 Kathara Points* for closing the Kathara Lines will **increase the amount of energy running through the *body cells*,** as the Kathara Lines are no longer absorbing the energy. **Sequence-2 Points revitalize and rebalance the *outer levels of the Bio-energetic Field* first, which creates more immediate but temporary revitalization of the body, as restorative energies do not directly enter the Level-1 Kathara Grid.** To create *lasting change* when using the *Sequence-2 Points* alone, restorative electro-tonal programs must be **repeatedly** entered into the Bio-energetic field until the new programs reach **critical mass,** at which time the new programs will begin to *subtly influence* the programs held within the Kathara Grid. **The primary difference between Sequence-1 and Sequence-2 Kathara Points is this: *Sequence-1 Points*** channel energy from the Maharic Shield into the ***core Kathara Grid*** holographic template. ***Sequence-2 Points*** channel energy from the Maharic Shield into the ***outer levels*** *of the Bio-field and body cells.* **For this reason the affects of *Sequence-2 Kathara Points* are more *immediate*, and those of *Sequence-1 Kathara Points* are more *permanent.***

The patterns held within the Kathara Grid core holographic template eventually override those set into the outer Bio-field alone. **Used in *combination* with each other and other healing applications the *Sequence-1 and Sequence-2 Kathara Points* can affect more lasting revitalization by simultaneously *realigning the core template and the outer layers* of the Bio-field and cellular structure.** Using ***Kathara Point Sequences*** in combination with each other and other Kathara Healing techniques will amplify and accelerate the affects and restorative function of the Imprint for Health within the Body-Mind-Spirit system.

14 SEQUENCE 1 KATHARA POINTS

Regeneration of the Imprint for Health

Sequence-1 Kathara Points **OPEN** energetic gate-ways within the **Kathara Lines** of the *Kathara Level-1 12-Tree Grid*, to receive electro-tonal reprogramming for **regeneration** of the *Imprint for Health*. *Sequence-1 Points* are used to open the Kathara Lines **prior to** other energy-healing applications, to open the Kathara Grid so the regenerative patterns of other healing applications can "ground" within the Kathara. Sequence-1 Points re-generate and rebalance the **Kathara *Core*** first, creating **more lasting but less immediate changes** in the body.

1.....CROWN

2 & 3.....TEMPLES

4.....BASE OF SKULL

5 & 6.....BELOW SHOULDERS

7 & 8.....ABDOMEN IN FROM HIPS

9 & 10.....BACKS OF KNEES

11 & 12....SOLES AND TOPS OF FEET

13.....4TH HEART CHAKRA

14.....6TH THIRD EYE CHAKRA

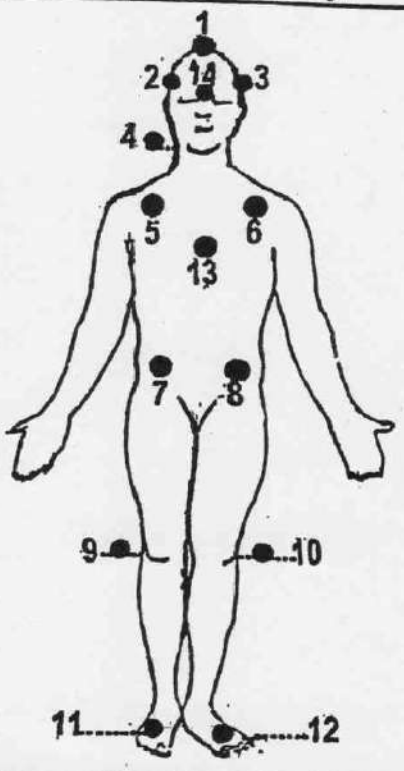

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

14 Sequence-1 Kathara Points for Regeneration

LOCATION & APPLICATION SEQUENCE

1.....CROWN

2 & 3.....TEMPLES

4.....BASE OF SKULL

5 & 6.....BELOW SHOULDERS

7 & 8.....ABDOMEN IN FROM HIPS

9 & 10.....BACKS OF KNEES

11 & 12....SOLES AND TOPS OF FEET

13.....4TH HEART CHAKRA

14.....6TH THIRD EYE CHAKRA

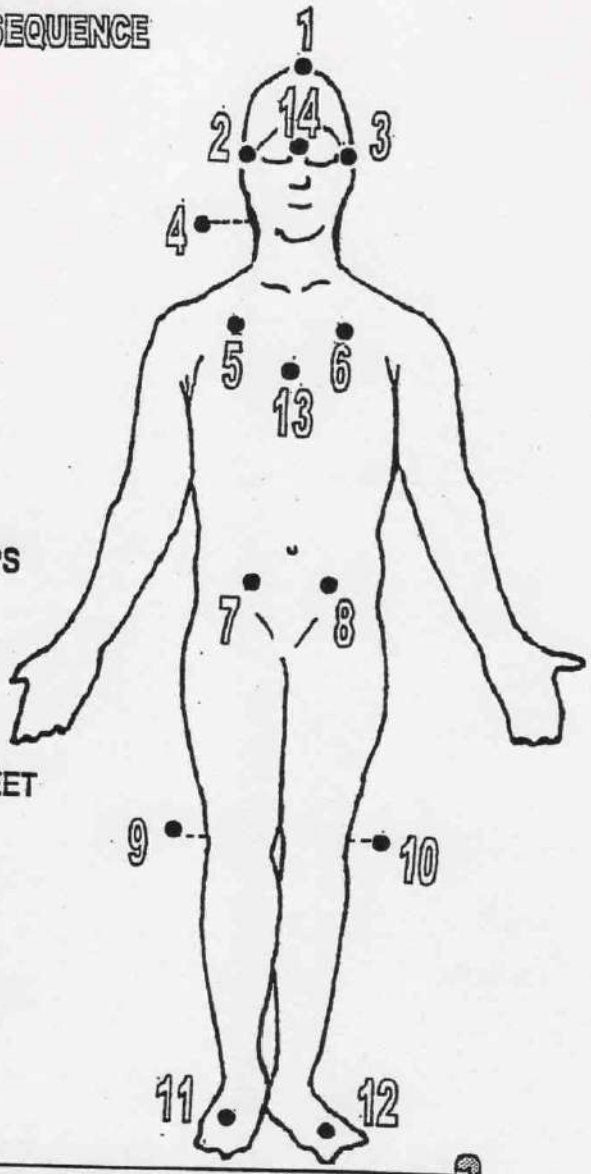

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra.** Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

6 SEQUENCE 2 KATHARA POINTS

Revitalization of the Imprint for Health

Sequence-2 Kathara Points **CLOSE** energetic gate-ways within the **Kathara Lines** of the *Kathara Level-1 12-Tree Grid*, to direct restorative frequencies into the **outer levels of the Bio-energetic Field** for **revitalization** of the *Imprint for Health* within the physical cells. *Sequence-2 Points* are used to close the Kathara Lines **following** use of the *Sequence-1 Kathara Points* or other energy-healing applications, to close the Kathara Grid so revitalizing frequencies can directly enter various *outer levels* of the Bio-energetic Field, such as the **Auric Levels, Chakras, Meridians, DNA** and **physical cells**. Sequence-2 Points revitalize and rebalance the **outer levels of the Bio-energetic Field** first, creating **more immediate but temporary changes** in the body.

1 & 2.....NECK, BELOW EARS

3 & 4.....BELOW CHEEKBONES

5.....BASE OF TAILBONE

6.....THYMUS

*** AMPLIFER –3RD SOLAR PLEXUS CHAKRA**

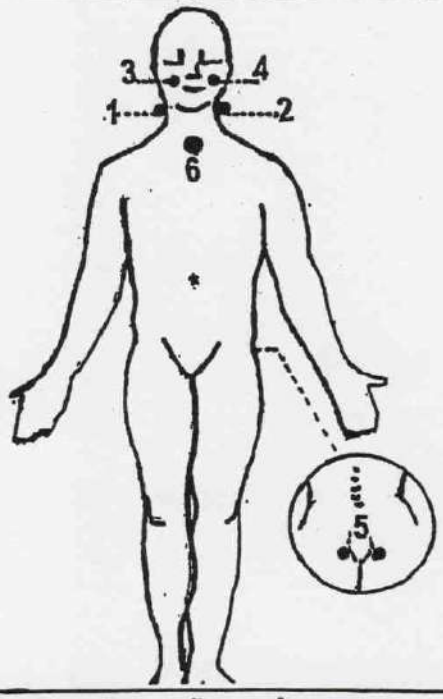

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

6 Sequence-2 Kathara Points for Revitalization

LOCATION & APPLICATION SEQUENCE

1 & 2.....NECK, BELOW EARS

3 & 4.....BELOW CHEEKBONES

5.....BASE OF TAILBONE
(one point on each side at base of tailbone)

6.....THYMUS

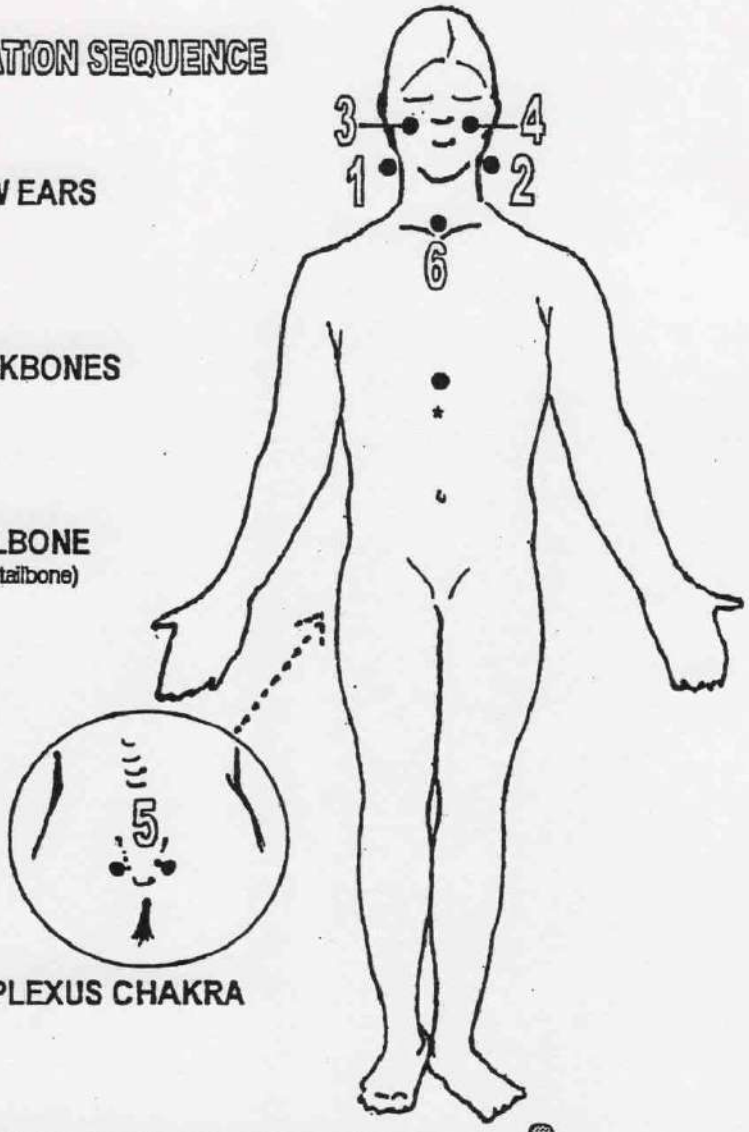

* **AMPLIFER –3RD SOLAR PLEXUS CHAKRA**

Instructions: Breathe slowly and deeply. Imagine a flow of energy running from the **Maharic Shield** (12" below feet), up into the body through the **soles of the feet** and the **1st Chakra**. Gently **rub** the *Kathara Points* with fingertips for 10 – 20 seconds each, following the **precise sequence** described above.

TECHNIQUE # 2

THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

1. Close your eyes and visualize the image of a flat (2-dimensional line drawing) 6-Pointed Star of David (**The Merkaba Star**) made of **White Light**, stationed at the **6th-Chakra** on the *inside of the Forehead.* (If you cannot yet generate inner visualizations, simply imagine that the symbol is there.) Continue to visualize or imagine, and move the **White Merkaba Star** image over toward the **left** in your inner field of vision. In the *center* of your inner field of vision, visualize/ imagine the image of *another Merkaba Star*, made of a **Dark Silver Light**. Observe or imagine the **2 Merkaba Stars** in your inner field of vision and then slowly *move the images toward each other* until they have merged into *one Merkaba Star* Symbol made of **Pale Silver Light**. (The *Pale Silver Double Merkaba Star Symbol* is called the **HIEROPHANT** – it is the scalar wave template that governs the release of phase-lock on the *Maharic Shield.)*

2. Visualize/ imagine the Hierophant Symbol clearly in mind, then shift attention to the sound of your breath. Take several slow, deep breaths. On the next **EXHALE** use the force of breath to *forcefully push* the **Hierophant** down from its position at the 6th-Chakra, through the *Central Body Current* and into the **Earth's Core.** Take a few more slow breaths while visualizing/ imagining the Hierophant Symbol in the center of the Earth's core. Imagine now that the *Hierophant begins to spin in the Earth's core*, the Dark Silver Merkaba Star and the White Merkaba Star spinning in *opposite directions*. Spin the Hierophant progressively faster until it "takes on a .life of its own", and suddenly "pops and expands" to form a **Pale Silver Sphere of Light** *spinning in the Earth's core.*

3. Observe the Pale Silver Hierophant Sphere spinning in Earth's core, then visualize/ imagine that a **huge, horizontal Pale Silver spinning disc** emerges out from the Hierophant Sphere, forming a **massive Pale Silver Disc of Light** *spinning throughout the Earth and extending outward into the atmosphere* as a **rotating, horizontal plane.**

This horizontal disc-plane extending through the Earth represents the *Mahara Hova Body*, or **Maharic Shield** of the planetary morphogenetic field – the Pre-matter Liquid Light scalar grid composed of frequency from dimensions 10, 11 and 12. (Known as the ***Shield of Amaratena***). Using the Hierophant wave template you have now activated the planetary Maharic Shield, *opening the **Planetary Bio-feed Interface System™** into your bio-energetic field.* This constitutes opening your personal Kathara Grid and morphogenetic field into the Planetary Kathara Grid and morphogenetic field, allowing you to draw an *unlimited supply of energy* from the planetary field. You can draw in only as much as your personal morphogenetic field can hold. With repetition of this practice the energy-holding capacity of your Kathara Grid progressively increases, allowing you *a continually expanding supply of energy* for healing and revitalization.

TECHNIQUE # 2: Continued
THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

4. While remaining aware of the *Planetary Maharic Shield* spinning on a horizontal plane throughout the Earth's body, return the focus of your attention to the spinning **Silver Hierophant Sphere** rotating at Earth's core. (You will now use the Hierophant Sphere to activate your **personal Maharic Shield** and release the **12th-Dimensional Pillar of Light within your bio-energetic field.**). Take several slow, deep breaths, while visualizing/imagining the Hierophant Sphere spinning in Earth's core. On the next **INHALE**, draw the Hierophant Sphere *up from Earth's core* with the inhale breath, forming a **Pale Silver Cord** *about 6" thick* trailing behind the Hierophant as it rises to the **12th Chakra**, 6" beneath the feet. *One end of the Silver Cord remains rooted in* **Earth's core**, *the other end is attached to the* ***Hierophant Sphere*** *and follows its movement.* Visualize the **12th Chakra** as a small, **transparent disc** about *3" in diameter*, positioned *6" below the feet.* Stop the movement of the Hierophant in the *center of the 12th Chakra*, imagine the Sphere beginning to spin and *visualize the diameter of the 12th Chakra disc expanding to about 6" in diameter*, as the Hierophant spins at its center. Take a few slow, deep breaths as the *Hierophant spins in the center of the* ***12th Chakra.***

5. On the next **INHALE** draw the Heirophant Sphere *up from the 12th Chakra*, through the **Central Body Current** and up to the **14th Chakra** *36" above the head.* As the Hierophant Sphere rises, visualize the *6" thick* **Silver Cord** drawing up through the **12th Chakra** and farther up through the **Central Body Current,** following the path of the Hierophant Sphere to the **14th Chakra.** Visualize the Silver Cord as a long, thick **Pale Silver Cord of Light**, running from the *Earth's core, through your body and out the top of your head,* connecting to the **14th Chakra** 36" above the head. Take several deep, slow breaths while imagining that you can *feel the sensation* of this *massive current of clear, pure energy* running through the *center* of your body.

6. On the next **EXHALE**, push the spinning Hierophant Sphere *down* through the **Central Body Current,** while leaving the *top end* of the Pale Silver Cord attached to the **14th Chakra** 36" above the head. Move the Hierophant down through the **12th Chakra** 6" below the feet, and **stop the Hierophant** *6" below the 12th Chakra;* a position about **12" below the feet.** This is the location of the **Maharic Shield within the morphogenetic field of the body.** Breath slowly and visualize the Hierophant *spinning progressively faster* 12" beneath the feet, until the Hierophant "takes on a life of its own" and suddenly "*pops and expands*" to form an **expanding horizontal disc of Pale Silver Light spinning 12" beneath the feet.** ***Feel the disc as a circular platform 3 yards in diameter below feet.***

TECHNIQUE # 2: Continued
THE *MAHARIC SEAL* AND THE *LIQUID LIGHT CLEANSE*

7. Call to mind the image of the *massive horizontal disc of Pale Silver Light* spinning through the Earth's body – the **Planetary Maharic Shield**. Imagine the sensation of the large, spinning *Pale Silver platform disc* spinning 12" beneath your feet – your **personal Maharic Shield**. Breathe slowly and deeply while visualizing/ imagining a *massive rush of pure, cool* ***Pale Silver energy*** running from the *planetary Maharic Shield*, up through the **Pale Silver Cord** and into the *personal Maharic Shield* 12" beneath your feet. Breath as this energy runs, *filling your Maharic Shield to its energy-holding capacity*. When your Maharic Shield has received as much Pale Silver energy as it can hold, it will "take on a life of its own", and suddenly "*pop and expand*" upward into an ***oscillating Pale Silver Pillar of Light*** *surrounding and permeating the body, a tube of light* extending beyond the body *about 18"*, and running from the **Earth's Core** to the **14th Chakra** 36" above the head. *Feel the reality of your body encased in the cool, refreshing Pale Silver Pillar of oscillating light.* Take a few slow deep breaths and imagine the energy from the Pillar *emanating through all of your body cells*. Your Bio-energetic Field is now sealed with a protective barrier of 11th/12th-Dimensional frequency – the **Maharic Seal.**

8. As the Pale Silver Pillar of Light oscillates around you, place your attention for a moment at the **13th Chakra** in Earth's core and **INHALE** a final **Spark** of *Pale Silver Light* from Earth's core, drawing the Spark up through the **Pale Silver Cord**, into the **Main Vertical Channel of the Kathara Grid**, and into the center of the **4th Heart Chakra**. Breath slowly and easily while visualizing energy from the *Silver Spark* radiating throughout the embodied **12-Tree Kathara Grid**, *filling it with Pale Silver Light.* When the Kathara Grid has reached its energy-holding capacity, the ***12th Chakra will automatically contract*** to decrease the flow of Silver Light from the Earth's core. As the 12th Chakra contracts, the *Planetary Maharic Shield* stops spinning and transmitting energy through the Silver Cord, returning the Silver Chord to its dormant state. The ***Maharic Seal*** **Pale Silver Pillar of Light** will remain in your bio-energetic field between **1-3 hours**. Over a *3-month period* of frequent, consistent *daily practice* of this process, the Maharic Seal will self-sustain in the bio-energetic field for **12-14 hours.**

Use of this technique allows a healing Facilitator to activate the **Maharic Shield** and **Seal** in others, through the ***Maharic Infusion process*** (Technique # 4), while Facilitator's Pillar remains active. Progressive use of the Maharic Seal and running the Liquid Light creates a reciprocal clearing, reordering and realignment of the Kathara Grid- *Holographic Template* – and all subtle energy and physical systems built upon it. The Lower Hova Bodies are progressively cleared and realigned with the *original perfection of the Pre-matter Liquid Light Mahara Hova Body*, and the body and genetic code progressively expand to hold higher dimensions of conscious awareness.

TECHNIQUE # 2B: THE MAHARIC QUICK SEAL

1. Work with a 24 pointed, 3 Dimensional Star (Heirophant) and be aware that you will be working with beings known as the Breneau Rishi ...

2. Begin by slowing your breathing , as you imagine or visualize a 24 point, 3 -Dimensional, Heirophant at the Pineal Gland in the center of your brain. Visualise the Heirophant surrounded by a Pale Blue Sphere of Light.

   (The Blue Sphere serves as a buffer for your readiness to accept the frequencies associated with using the 24 pointed Star; the Blue Sphere holds the energy for you until your body can handle the energy. If you can handle it, the energy will simply pass through the blue sphere).

3. INHALE, as if you are going to grab the blue sphere containing the 24 point star located at the Pineal, and on the EXHALE move the 24 point star/ blue sphere, all the way down to Earth's Core. Try to hear a sound tone as the Heirophant/ Sphere hits the Planetary Shield ...

4. INHALE and draw the Heirophant/ sphere up to your Personal Maharic Shield 12" below your feet ... and EXHALE while watching the Pale Silver-Blue sphere expand out to a large sphere ... and watch as your Maharic Shield pop out as a disc, about 4' in diameter, Pale Silver with a light coating of Pale Blue.

5. Bring your attention to the center of your Maharic Shield 12" below your feet ... and INHALE the 24 point Star (only) up into the Heart Chakra. EXHALE, expanding the frequencies of the 24 point Star into the Heart Chakra.

6. INHALE to grab the 24 point Star, and EXHALE, pushing the Star up into the 14th Chakra 36" above the head. Imagine that the 24 point Star is spinning in a clockwise direction in the 14th Chakra. As you do this, try to feel/ sense the energy around you, just a few inches out from your body ...

7. Now, put your attention into your Maharic Shield 12" below your feet, take a couple of relaxing breaths and INHALE deeply pulling the Pale Silver and Blue energy up, as if you are pulling on your Maharic Seal to latch it on to your 14th Chakra. Try and feel the sensations just a few inches from your body now – feel the difference if you can. This procedure gives you a Quick Seal.

8. Now envision the cord of Pale Silver Maharic Light that would normally come up with your Shield and focus on the Earth's Core. Begin drawing energy all the way up the 4" diameter cord and into the body. INHALE the energy up into the Heart Center, and expand it there. Begin to form a pale Silver ball of Maharic frequency.

   On each EXHALE send your energy down to the Earth's Core to bring up another load of Maharic frequency, up from the Planetary Shields, expand it into the Heart center and repeat several times. Notice that the Cord grows larger as you do this, expanding from approximately 4" to 6 to 8" diameter, until finally it feels like a skin around (as well as within) your body ... as you load your Astral field with Maharic Frequency.

9. Move your attention to the Pale Silver ball you have created in your Heart Center, INHALE and move it up to the 14th Chakra 36" above your head .. as you do, feel for the sheath of Maharic Frequency encasing your etheric body, close to your skin. (This Maharic/ Christos skin charges, and saturates, your etheric body – feel the peacefulness and all-knowing nature of this frequency).

SYMBOL SHORTHAND

TECHNIQUE # 2: Condensed Version
The Maharic Seal and Liquid Light Cleanse

Symbol Shorthand is used to help in remembering the primary steps of a technique

1. *Silver Hierophant Star at Chakra 6*
2. *EXHALE* Hierophant Star from *Chakra 6 to Earth's Core –Spin Hierophant Star* at Earth's core-until it *pops* into *Hierophant Silver Sphere at Earth's core.*
3. *Hierophant Sphere* spins *at Earth's core* until *Silver Disc of Earth's Shield* emerges.
4. *INHALE- Hierophant Sphere* up from *Earth's core to Chakra 12* trailing *Silver Cord* from Core.
5. *INHALE- Hierophant Sphere* up from *Chakra 12 to Chakra 14*, trailing *Silver Cord.*
6. *EXHALE- Hierophant Sphere* down from *Chakra 14 to Personal Maharic Shield* and *spin Hierophant Sphere* until *Personal Shield pops* out to become *Silver disc* plane 12"beneath feet.
7. Draw *Silver energy* into *Personal Shield from Earth's Shield* through *Silver Cord*, until *Personal Shield* is *filled* and *pops* to become vertical *Pillar* of Silver Light around body.
8. *INHALE*-draw *Spark of Silver Light* from *13th Chakra* at *Earth's Core*, into *main* vertical channel of *Kathara Grid* then to *Chakra 4;* from Chakra 4 transmit energy from Spark to fill *12-Tree* Kathara Grid. Chakra 12 auto-shut down when 12-Tree Grid is full.

THE MAHARIC SEAL

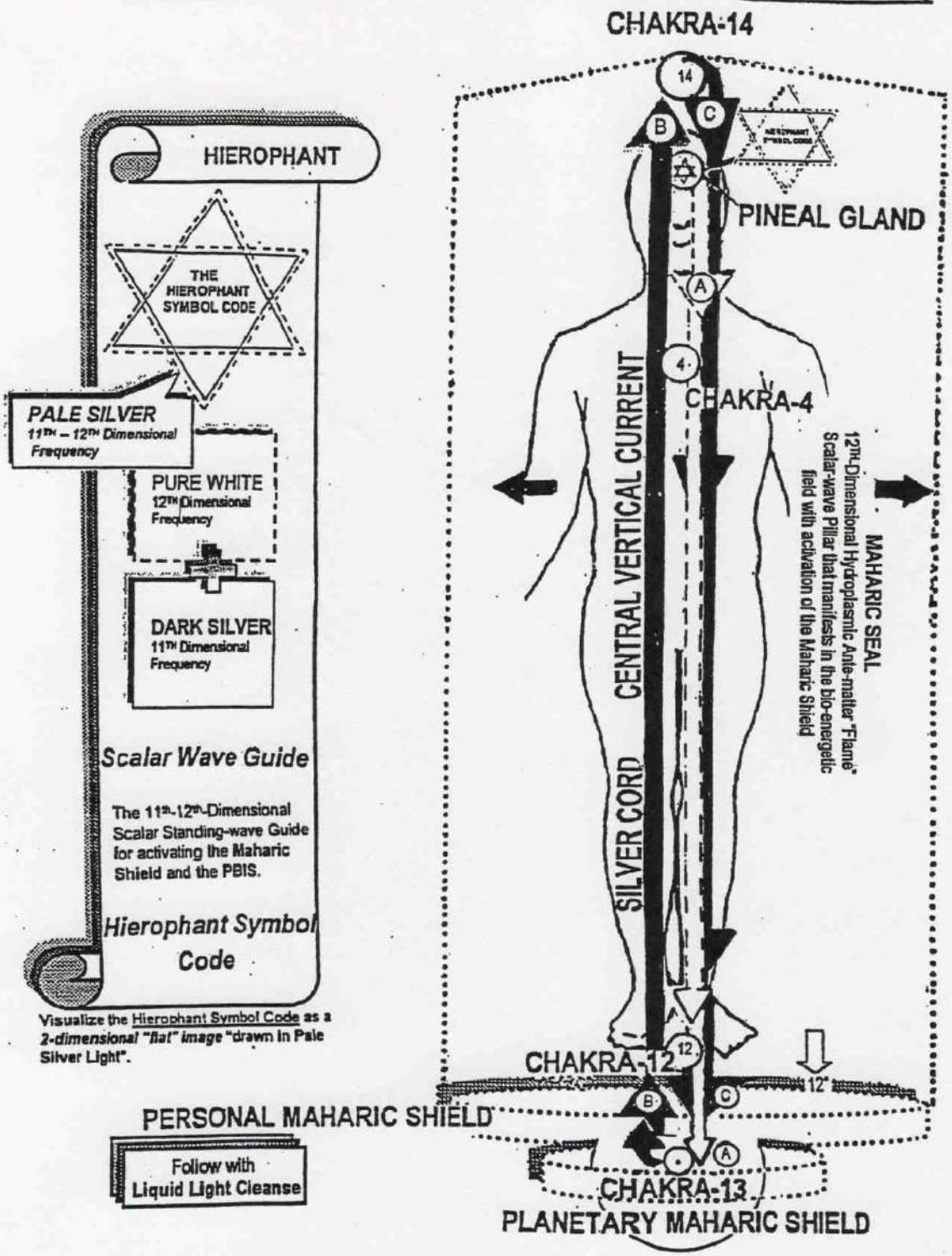

LIQUID LIGHT CLEANSE

KATHARA CENTERS

#12 – *The Capstone*
In 10th Chakra
6" above the head

 # 11 – *Crown Jewel*
In Pineal Gland
at center of brain

 # 9 & # 10 –*The Shar*
In brain
behind ears

 # 8 – *Spark of Orion*
In Thyroid Gland
at 8th Chakra

 # 6 & # 7-*The Wings*
In shoulder indents
through to back.

 # 5 –*Seat of Amenti*
At Navel in
Central Body Current

 # 3 & # 4 -*The Dal*
male: Ureters
female: Ovaries

 # 2 – *Naum-Yun*
male: Prostate Gland
female: Vagina

 # 1 – *Earth Core*
at center of Earth
in 13th Chakra

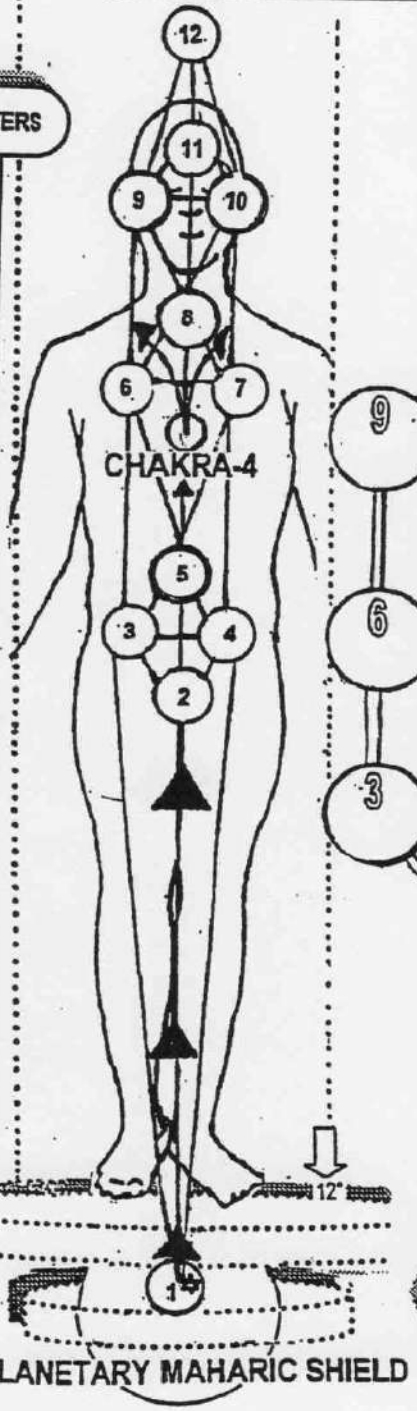

Central Vertical Kathara Line
controls all other Kathara Lines. Kathara Centers on *Central Vertical Kathara Line* control all other Kathara Centers.

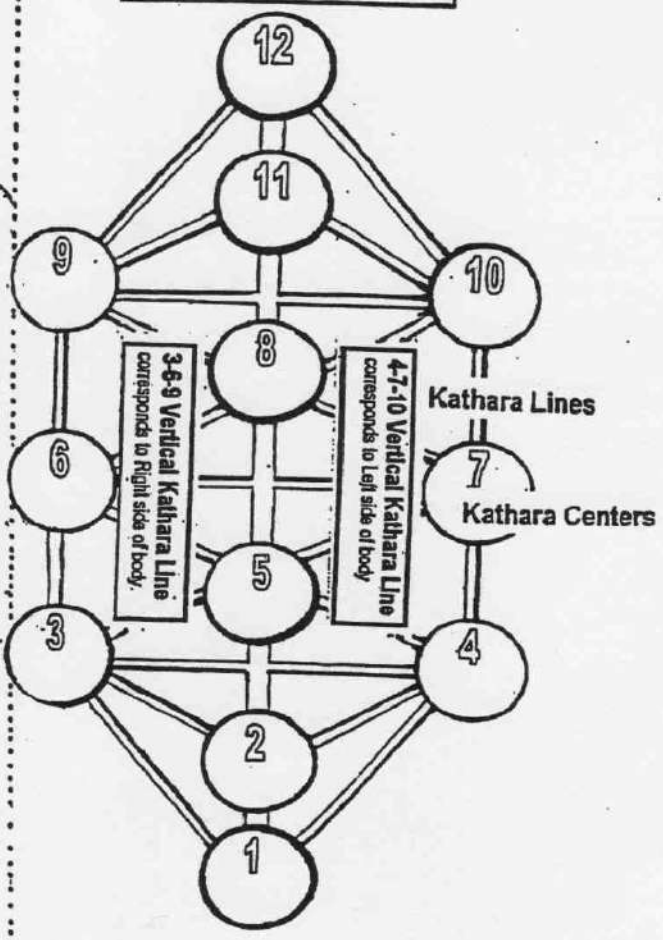

Liquid Light Cleanse

After activating the Maharic Seal **INHALE** a Spark of Silver Light up from Earth's core to Central Kathara Line, then to 4th Chakra. From 4th Chakra project Maharic energy through entire Kathara Grid.

The Planetary Bio-Feed Interface System and the Maharic Seal

Use of the *Maharic Seal and Liquid Light Cleanse* begins the process of activating the **8th through 12th Chakras** and opening the natural **PLANETARY BIO-FEED INTERFACE SYSTEM (PBIS)** within the human body. Through the **PBIS**, the finite quantity of scalar frequency of which the personal Maharic Shield, Hova Bodies and individual identity are composed expands to **infinite potential**, as the **Planetary Scalar Shields** can be used to open dormant **Crystal Seals** within the Scalar Shields of the personal Level-2 Kathara Grid. **Once activated through the 12th Chakra, the PBIS opens a conduit of perpetual energetic supply between the human body and the planetary Morphogenetic Field, allowing the body to continually draw in as much higher dimensional frequency as the DNA Template can hold.**

With the PBIS activated, the human body can also become a tool for reprogramming and re- balancing the Planetary Shields, Vortices, Ley Lines and energetic grids of the Planetary Templar Complex. When the Crystal Seals of the personal Shields are released, the **human DNA Template** can serve as a **bio-electric conduit** for running higher dimensional frequency into the **Planetary Shields**. The human body, with its **12-Strand DNA Template potential,** is the only mechanism on Earth, other than the Planetary Shields themselves, that is capable of running a full 12th-Dimensional **Maharic Current**. Just as within the human Manifestation Template, the Maharic Current can be used to purge distortions within the Planetary Shields, to restore the **Planetary Templar Complex** to its original **Primal Order**. Kathara Healing technologies not only provide the opportunity for individuals to facilitate healing in other *biological life forms*, they also reawaken the human potential to facilitate healing within the **geophysical planetary body.**

The Planetary Bio-Feed Interface System

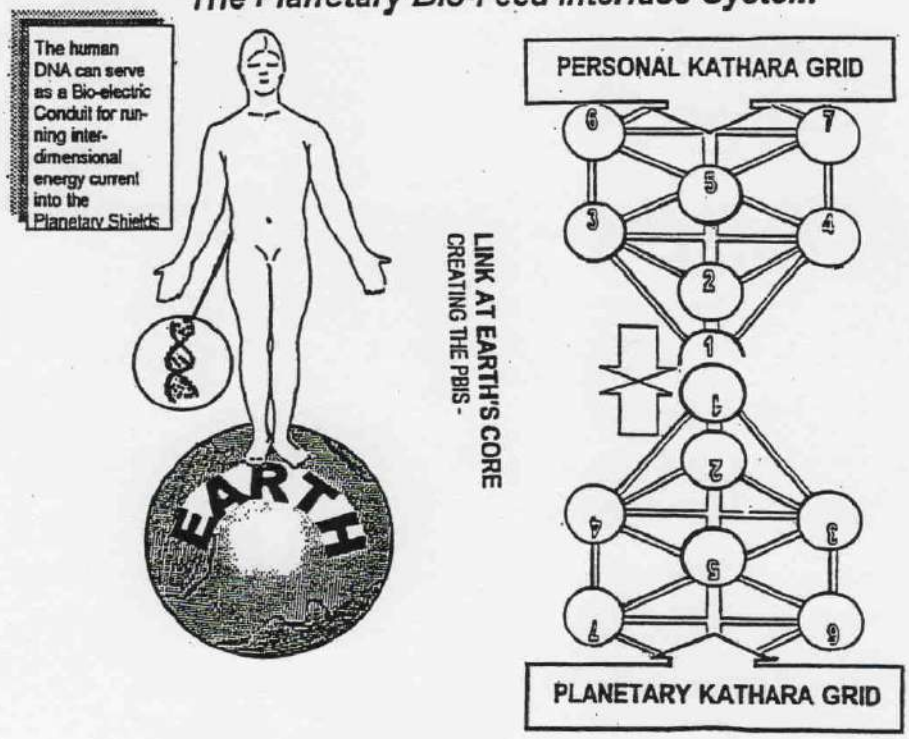

The Maharic Seal and Client Sessions

Through understanding the **Context of Healing**- *The Structure of the Unified Field*, the **Elements of Healing** – *The Anatomy of the Human Body Kathara Grid* and **Kathara Healing Beginning Applications** - *Morphogenetic Repatterning* through the ***Maharic Seal and Liquid Light Cleanse*** and *Awakening the Mentor* for access to 5th Dimensional awareness, the Kathara Healing Facilitator has developed the rudimentary skills necessary to begin **personal Core Holographic Template Healing. To effectively facilitate Core Template healing in others it is important for Kathara facilitators themselves to employ personal Template Healing.**

The ability to hold the **12th-Dimensional Maharic frequency sub-harmonics** (the 12th-sub-frequency band within each of the full Dimensional Frequency Bands) in body to assist in its transmission to a client for healing support increases as the facilitator utilizes the **Maharic Seal and Liquid Light Cleanse** technique **for personal healing.** The *Maharic Seal and Liquid Light Cleanse* technique not only increases the facilitator's ability to transmit 12th-Dimensional frequency sub-harmonics, it also temporarily **realigns distortions** within the *facilitator's* bio-energetic field and Kathara Grid and creates a temporary **12th-Dimensional Scalar Frequency Seal** within the *facilitator's* bio-energetic field. **Without use of the *Maharic Seal*, the facilitator will inadvertently transmit bio-energetic field and Kathara Grid distortions to the client and will energetically pick up scalar distortions** (including part of the "Karmic" Miasmic Imprint) **from the client.** (This problem occurs in all subtle-energy healing modalities that do not employ the Maharic Seal). Both of these conditions serve to amplify, rather than remedy, dis-ease and disharmony within the Mind-Body-Spirit system, for both *facilitator and client.* For these reasons, **the *Maharic Seal and Liquid Light Cleanse* technique needs to be employed prior to ANY healing facilitation work,** to protect the **bio-energetic field integrity** of facilitator and client. **The *Maharic Seal and Liquid Light Cleanse* technique represents the facilitator's preliminary preparation prior to Kathara Healing Facilitation Client Sessions.**

Safety in Healing Facilitation!

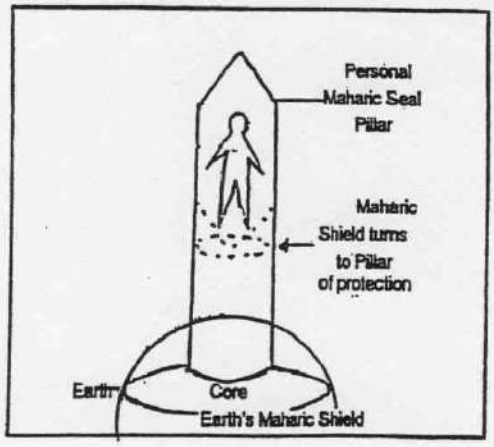

The ***Maharic Seal and Liquid Light Cleanse*** technique, used as facilitator preparation prior to **Client Sessions,** protects facilitator and client from taking on bio-energetic field distortions from each other. **Maharic Seal** is the preliminary step before any **Kathara Healing** application and is needed to effectively run interdimensional healing currents.

CO-GENERATIVE HEALING

The final phase of education necessary before engaging the adventure of **Kathara Healing Client Facilitation** is rediscovering the structure of personal **Multi-dimensional Identity** and how to use the personal **Hova Bodies** to tap the higher dimensional scalar frequencies for enhanced healing facilitation ability. The ability to understand and utilize the **PRECISE HEALING CURRENTS** of the interdimensional spectrum adds **greater power and skill** to the healing facilitation process. Unlike many other energy healing systems, **Level-1 Kathara Healing** trains the facilitator to identify, awaken within the body and employ in client service **specific combinations of interdimensional healing current** that fine-tune and amplify the beneficial effects of subtle energy healing. This chapter will conclude with an overview of the **4 PRIMARY TRIADIC HEALING CURRENTS**, 4 of the 5 **3-Dimensional Primal Energy Currents** that can be awakened within the body through activation of the **Maharic Shield**.

The natural **Primal Triadic Healing Currents**, which exist naturally as part of the personal Hova Body, Scalar Shield and Kathara Grid anatomy, create powerful, effective and user-friendly energetic healing tools when combined with the 12th-Dimensional frequencies of the **Maharic Shield.** Running the Triadic Currents is achieved by using the current to first activate the frequencies of the corresponding Hova Body and station of awareness within the personal Scalar Shields and **DNA Template**. Once activated in the DNA Template, the **Hova Body** is used to draw perpetual supply of the desired current from the Dimensional Unified Field corresponding to the chosen current. **Running the Triadic Currents requires activation of the corresponding frequencies within the facilitator's DNA Template, thus using the Triadic Currents in Client facilitation also serves to progressively stimulate and expedite activation of dormant frequencies in the facilitator's DNA Template.** Using the Triadic Currents in client facilitation serves to accelerate the processes of Holographic Recoding, higher identity Hova Body integration and multi-dimensional evolution within the Body-Mind-Spirit system of the *facilitator*, as well as that of the *client*, creating a condition of **CO-GENERATIVE HEALING** between client and facilitator.

Healing, Evolution and Ascension

In the Kathara Healing paradigm the art and science of healing the Body-Mind-Spirit system is viewed in terms of the *human relationship to the natural structure and dynamics of creation.* **Healing becomes a necessity when the intrinsic energetic systems and scalar-wave constructions of consciousness upon which the biological manifestation is built become incongruent with the natural Primal Order of the dimensionalized Time Matrix system.** The processes of natural healing and the hidden, organic functions of **human evolution** are intimately intertwined. Conditions that facilitate natural healing also facilitate fulfillment of the naturally intended course of human evolution, while conditions detrimental to Body-Mind-Spirit health are likewise detrimental to the evolutionary objectives of both the individual and the species.

The processes by which lasting healing occurs through re-genesis of Primal Order within the Scalar Shields and personal anatomy, are the same processes by which the **CONSCIOUSNESS** evolves to the fulfillment of **Spiritual Actualization**, through embodiment of the 12-dimensions of consciousness inherent to human DNA Template design. The genetic code of the biological imprint is built upon the Scalar-wave Templates of Consciousness that serve to hold the identity as energetic substance into physical embodiment. **Distortions within the physical manifestation indicate distortions in the Manifestation Template and thus constitute distortions in CONSCIOUSNESS.** Genuine healing is a *FUNCTION OF CONSCIOUSNESS*, first and foremost, and it is through realignment of consciousness itself that full healing can occur.

In the Kathara program it is understood that biology and consciousness are intimately intertwined and thus interdependent. The techniques of **Bio-Regenesis** provided in Kathara Healing assist in the processes of restoring the **Organic Imprint for Health** while simultaneously serving to **expedite the natural processes of interdimensional evolution** through DNA Template, Kundalini, Crystal Seals and Merkaba activation. **Human evolution is not a random, goal-less occurrence; it is rather an ordered system of interdimensional physics dynamics by which human consciousness progressively masters the contours of creation in time.** The evolutionary objective of human creation is **mastery,** which is progressively attained through the dynamics of **Transmutational Dimensional Ascension. Ascension** is therefore the intrinsic and indelible **goal** within human evolution, the **hidden impetus for action** that moves the human species forward in time.

Healing and Bio-Spiritual Evolution

When we begin running the higher dimensional frequencies of the **4 Primary Triadic Currents** for Kathara Healing applications, we are, in truth, running **FREQUENCIES OF CONSCIOUSNESS**, that emanate from the **Hova Bodies** in which the expanded spiritual portions of our personal identity are stationed. As we reawaken the higher dimensional frequencies of consciousness within the **DNA Template** we are progressively expediting the reintegration of personal **Multi-dimensional Identity**, serving the **spiritual goal** of **Ascension** through stimulating into activation the scientific dynamics of **Unified Field Physics** by which genuine Ascension occurs. **Kathara Healing** progressively restores the functions of universal physics dynamics within the human body, as they apply to the pathway of Ascension, and so Kathara Healing applications are considered to be processes of **ACCELERATED BIO-SPIRITUAL EVOLUTION**, as well as processes of holistic Body-Mind-Spirit healing. Both facilitator and client simultaneously receive the subtle but progressive benefits of evolutionary acceleration and spiritual development through Kathara Healing **Bio-Regenesis Technologies**, through which the expansion of personal consciousness into the higher dimensional aspects of spiritual awareness occurs.

Kathara practices serve to stimulate progressive integration and embodiment of the Multi-dimensional Identity by activation of dormant portions of the **DNA Template** through which the scalar-wave patterns of the higher frequencies of identity can enter the physical form. As spiritual advancement through Hova Body integration and DNA Template activation is a beneficial "side effect" of Kathara Healing practice, it is helpful for the Kathara facilitator to understand the order of **Multi-dimensional Identity Structure**. It is also helpful to realize that the **Unified Field of Energy** utilized in Kathara Healing is, in fact, a **UNIFIED FIELD OF CONSCIOUSNESS.** Healing is a function of energy dynamics and at its core, energy is the **substance consciousness adopts** to experience manifestation, thus **HEALING IS A FUNCTION OF CONSCIOUSNESS.** When personal consciousness is applied in ways that are congruent with the natural **Laws of Unified Field Physics**, the effects of healing and wellbeing are met in manifestation.

MULTI-DIMENSIONAL IDENTITY STRUCTURE

Consciousness and the Physical Illusion

In Chapter 1 we explored the **Structure of the Unified Field** and discovered the morphogenetic framework, or **Holographic Template** upon which matter systems are constructed. We learned how the structure of dimensionalization applies to the anatomy of the **15-Dimensional Human body**, from the **Core Template Kathara Grid**, the **Hova Bodies** and **Shields**, to the **Chakras, Bio-energetic Field** and physical matter structures built upon them. **We also discovered that *physical manifestation* is not what appears to be - that *nothing is really manifest at all*, but only *appears to be so* due to the *relationships of compartmentalized consciousness interacting with each other through the framework of dimensionalization***. Our physical parts and our manifest world are **scalar wave constructions**, appearing solid and externalized because we view them with a level of consciousness that is stationed **one full dimension above** the wave forms we perceive as solid and objectified. Our consciousness structures itself into the scalar wave forms of dimensionality in order for us to perceive the illusion of manifestation. There is no difference, other than the **dimensional frequencies from which one is perceiving,** between the *substance that composes physical matter* and that which *composes our seemingly non-manifest portions of consciousness*. **The core of reality is CONSCIOUSNESS - it is the *energetic substance* out of which all things are made.**

Hova Bodies- Platforms of Perception

In this Section we will learn how the attributes of mind and sentient identity fit into the multidimensional anatomy of human consciousness. The scalar grids of the **Hova Bodies** and **Shields** that hold portions of our consciousness separate from each other so we may experience objectification, can be understood as **PLATFORMS OF PERCEPTION**. A portion of our conscious identity is **stationed within each of the Hova Body Shields,** and the dimensions contained within the Shield become the *platform* from which *that portion of our selves* will perceive matter objectification. **We are simultaneously focused within each Hova Body Platform of Perception, and this gives us separated but interrelated stations of identity and different LEVELS OF MIND from which we simultaneously perceive.** The amount of perception we are able to incorporate into our embodied focus on Earth is determined by the Level of **Higher Identity Integration** that has occurred. Integration of Higher Identity is the *merger* of the **Hova Bodies**, which creates changes and advancement in the **biological gene code** that allows the neurological and metabolic functions of the body to expand.

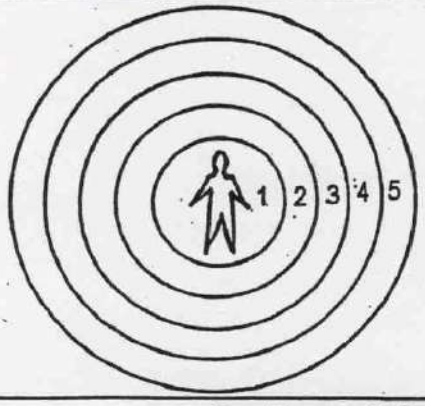

THE 5 HOVA BODIES

3-Dimensional Electro-magnetic Domains created by the Scalar Shields that serve as stations of dimensionalized consciousness

1. **NADA HOVA** Density-1
2. **ALPHI HOVA** Density-2
3. **BETCHA HOVA** Density-3
4. **MAHARA HOVA** Density-4
5. **RAJA HOVA** Density-5

Our Present Platform of Perception

Presently we are accustomed to perceiving from the Platform of Perception provided by the **NADA HOVA BODY**, the *scalar grid* that houses the 1st, 2nd and 3rd Dimensional Aspects of our identity and anatomy. While perceiving from the Nada Hova Body and the **TELLURIC SHIELD** that holds its form, we are functioning as a **3-Dimensional consciousness** and will not be aware of the perceptions of the other levels of ourselves that are perceiving from the *Platforms of Perception* from the other Hova Bodies. **As we expand and evolve we will progressively incorporate the portions of our awareness stationed in the other Hova Bodies into our earthly focus of attention.**

The *Higher Identity Structure* of the Hova Bodies and related *Levels of Mind* within dimensionalization are as follows:

Stations of Identity and Levels of Mind in the Hova Bodies

INCARNATE IDENTITY: Nada Hova Body/ Telluric Shield / dimensions 1, 2 and 3. The Subconscious (D-1), Instinctual (D-2) and Reasoning (D-3) Levels of Mind

SOUL IDENTITY: Alphi Hova Body/ Doradic Shield/ Dimensions 4, 5 and 6 The Astral (D-4), Archetype or Dora (D-5) and the Angelic (D-6) Levels of Mind

OVER-SOUL IDENTITY: Betcha Hova Body/ Teuric Shield/ Dimensions 7, 8 and 9 The Ketheric (D-7), Monadic or Teura (D-8) and the Keriatic (D-9) Levels of Mind

AVATAR IDENTITY: Mahara Hova Body/ Maharic Shield/ Dimensions 10, 11 and 12 The Christiac (D-10), Buddhiac (D-11) and the Nirvanic (D-12) Levels of Mind.

RISHI IDENTITY: Raja Hova Body/ Rishic Shield/ Dimensions 13, 14 and 15 Universal Consciousness Mind

There are **3 additional Platforms of Perception** and 3 additional Hova Bodies beyond the structure of Dimensions;Hova Bodies that represent 3 Levels of **Ascended Mastery Identity**.

Spiritual Actualization is the process of progressive Higher Dimensional Identity Integration. *Higher Identity Integration* is the merger of the *Hova Bodies*, which creates changes and advancement in the biological *Genetic Code* through progressive activation of dormant portions of the *Silicate Matrix 12-Strand DNA Template.*

5 Hova Bodies and Levels of Identity in the 15-Dimensional Time Matrix

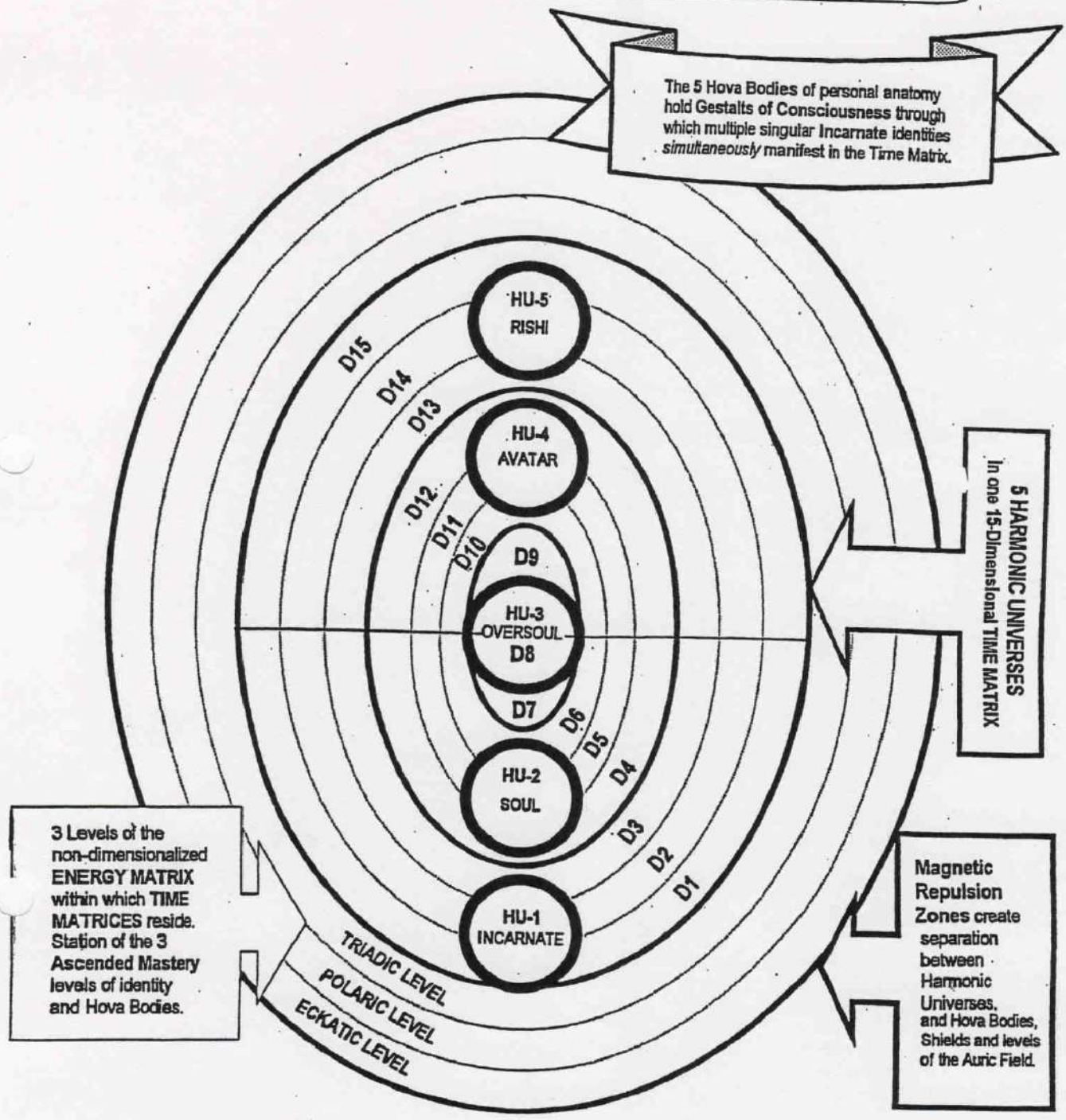

THE 4 PRIMARY TRIADIC HEALING CURRENTS

Hova Bodies and the 4 Primary Triadic Currents

Each of the Hova Bodies and Shields contains a portion of your energy-identity that exists in the form of electro-tonal impulse born of Partiki Phasing. **The energy of your higher stations of identity and that of the Universal Unified Fields of Consciousness-Energy can be drawn into the Nada Hova body and earthly incarnate identity for the purpose of healing facilitation.** There are **four Primary Triadic Healing Currents**, each corresponding to one of the **four higher dimensional Hova Bodies.** Through *your* corresponding Hova Body station you can *draw energy from the higher dimensional Unified Fields* and channel it into your Nada Hova Body for direction into healing within the first Harmonic. **The *4 Primary Healing Currents* are HARMONIC CURRENTS OF ENERGY, each composed of *3 Dimensions of Frequency.*** Each Dimensional Band within a Harmonic or **TRIADIC** current is referred to as a **PHASE** *of that current.* **In Kathara Healing we develop the ability to activate each progressive PHASE of each TRIADIC CURRENT, through grounding the current into the body via the activated MAHARIC SHIELD.**

Triadic Currents and Color

Each *Phase* of Triadic Current corresponds to a wave length in the dimensional spectrum that appears as COLOR to the embodied human mind. In directing the **Triadic Currents** we therefore use the **color translation of the primary dimension wave spectra** to differentiate between Phases of current for various applications. **The first current to be activated in Kathara Healing is the that of the DORADIC CURRENT**, the frequencies drawn in from Harmonic 2 through the **Doradic Shield and Alphi Hova Body. The Doradic Current has 3 Phases: Phase -1: 4th Dimensional current/ GREEN wave, Phase-2: 5th - Dimensional Current/ BLUE wave and Phase -3: 6th-Dimensional current/ Blue-Violet wave.** In **Level-1 Kathara Healing** we learn to activate and run the **Phase-1 Green Doradic Current.**

The 4 Primary Triadic Currents and Hova Body Correspondences

TELLURIC CURRENT: Nada Hova Body/ Telluric Shield / Dimensions 1, 2 and 3.
Phase-1 RED, Phase-2 ORANGE-GOLD , Phase-3 YELLOW

DORADIC CURRENT: Alphi Hova Body/ Doradic Shield/ Dimensions 4, 5 and 6
Phase-1 GREEN, Phase-2 BLUE, Phase-3 BLUE-VIOLET

TEURIC CURRENT: Betcha Hova Body/ Teuric Shield/ Dimensions 7, 8 and 9
Phase -1 VIOLET, Phase-2 GOLD, Phase-3 Mid-tone Silver

MAHARIC CURRENT: Mahara Hova Body/ Maharic Shield/ Dimensions 10, 11 and 12
Phase-1 BLUE-BLACK, Phase-2 SILVER BLACK, Phase-3 WHITE

TRANSMUTATION CURRENT
(can be transmitted only by 12th-level Avatars with full Mahara Hova integration)

RISHIC CURRENT: Raja Hova Body/ Rishic Shield/ Dimensions 13, 14 and 15
Phase-1 TURQUOISE, Phase-2 PALE YELLOW, Phase-3 MAGENTA

Current Combining

When using **Triadic Phase Currents, each Phase current is *combined* with the current running from the activated *Maharic Shield*, in *combination with* the Phase current from the *Harmonic ABOVE the Phase current you are using*.** The **DORA DIC PHASE-1** current is therefore composed of: **D-11/D-12 PALE SILVER** (Maharic Shield), **D-4 GREEN** Doradic Shield Phase -1 AND **D-7 VIOLET,** the *Phase-1 current* of Harmonic 3 - Teuric Shield, *one Harmonic up* from Doradic Phase-1. In activating the **DORADIC-1 (Doradic Phase-1) current you are using SILVER-GREEN-VIOLET color to direct Dimensions 12-11-7-4 current.**

COMBINED TRIADIC CURRENTS
Used in Kathara Healing

TELLURIC
PHASE-1: **PALE SILVER** (D11&12) + **RED** (D-1) + **GREEN** (D-4)
PHASE-2: **PALE SILVER** + **ORANGE-GOLD** (D-2) + **BLUE** (D-5)
PHASE-3: **PALE SILVER** + **YELLOW** (D-3) + **INDIGO** (D-6)

DORADIC
PHASE-1: **PALE SILVER** + **GREEN** (D-4) + **VIOLET** (D-7)
PHASE-2: **PALE SILVER** + **BLUE** (D-5) + **GOLD** (D-8)
PHASE-3: **PALE SILVER** + **INDIGO** (D-6) + **SILVER** (D-9)

TEURIC
PHASE-1: **PALE SILVER** + **VIOLET** (D-7) + **BLUE-BLACK** (D-10)
PHASE-2: **PALE SILVER** + **GOLD** (D-8) + **SILVER-BLACK** (D-11)
PHASE-3: **PALE SILVER** + **SILVER** (D-9) + **WHITE** (D-12)

MAHARIC
(Requires full 12-Strand DNA Template activation & accelerated DNA Template coding)
PHASE-1: **PALE SILVER** + **BLUE-BLACK** (D-10) + **PALE TURQUOISE** (D-13)
PHASE-2: **PALE SILVER** + **SILVER-BLACK** (D-11) + **PALE YELLOW** (D-14)
PHASE-3: **PALE SILVER** + **WHITE** (D-12) + **PALE MAGENTA** (D-15)

In **Level-1 Kathara Healing** we begin preparing the body and DNA Template to receive the higher dimensional Phase Currents by initiating transmission of the **Doradic Phase-1 Healing Current**- the *Pale Silver* + *Green* + *Violet* frequencies of dimensions *12, 11, 7 and 4.*

Through the 7th-Dimensional aspect of the **Teuric Shield** and 11th and 12th Dimensional aspects of the **Maharic Shield**, the **Doradic-1 Healing Current** allows for recoding and realignment of the 1st-4th-Dimensional aspects of the **Nada** and **Alphi Hova Bodies**, the **Telluric Shield** and **Physical, Emotional** and **Mental Bodies** of Density-1, the **D-4** aspect of the **Doradic Shield** and **Astral Body**, the **1st-4th DNA Strand Templates**, the **1st-4th Chakras**, and the **1st-4th Sub-harmonics** of all Scalar Shields, DNA Templates, Hova Bodies and Chakras. Doradic-1 Healing Current is effective in clearing the **Karmic-Miasmic imprint** from the **Density-1 Time Cycle incarnations** and the beginning of Density-2 Time Cycle incarnations.

CHAPTER 3 HIGHLIGHTS

KATHARA BEGINNING APPLICATIONS

- The **Hova Bodies** of personal anatomy contain portions of our higher dimensional awareness. One can begin accessing this awareness by building a **Perceptual Bridge** between the 3-Dimensional Self and higher identity aspects.

- Taking conscious initiative in building a Perceptual Bridge expedites **DNA Template activation** and the organic evolutionary process.

- The **MENTOR Technique** assists in building the Perceptual Bridge and activates dormant **Kathara Lines** in our **Level-1 Kathara Grid** to open communication between our D3 and Density-2, D4 and D5 levels of awareness.

THE MENTOR

- The Mentor is a part of our awareness that is composed of **3rd, 4th and 5th Dimensional frequencies** of consciousness, which exists as a quantity of **Scalar Wave patterns** that span **Densities 1 and 2.**

- The **Mentor Focus** will be used in **Kathara Healing** for **guidance, information retrieval** and **objective observation**. It can also be used to access **Cellular Memory,** and in **"Inner Child", Bi-location, Remote Viewing** and **Dream** work.

MORPHOGENETIC REPATTERNING AND THE MAHARIC SHIELD

- Through a process called **Morphogenetic Repatterning**, Kathara Healing effects the **Core** of Dis-ease and dis-harmony in the Body-Mind-Spirit system by **repatterning** the Scalar-wave Programs in the personal **Holographic Template** to their original **Primal Order.**

- In **Level-1 Kathara Healing** we learn the **MAHARIC RECODING PROCESS**- the most important level of Holographic Template realignment.

- The **Maharic Shield** is the 3-Dimensional Scalar Grid corresponding to the **10th, 11th and 12th-Dimensional frequencies** of **Density-4.** It represents the **Original Point of Manifestation** and holds our original "Liquid Light" **Hydroplasmic Pre-matter Creation Imprint**, which is the **Organic Imprint for Health.**

MORPHOGENETIC REPATTERNING AND THE MAHARIC SHIELD

- In Kathara Healing, the **Maharic Shield** Organic Imprint for Health is used to progressively **repattern** the embodied **Kathara Grid** and body systems to their original **Primal Order.**

- The **12th-Dimensional Frequencies** of the Maharic Shield contain within them the **144 Sub-frequency Band** Scalar patterns of **ALL** of the Dimensions below.

- 12th-Dimensional **Maharic Frequency** can be used to **effectively correct distortions** in the lower dimensional levels of the Manifestation Template, Scalar Shields and Kathara Grid.

- Activation of the **Maharic Shield** serves as the **RESET BUTTON** for the embodied **Kathara Grid** and for 12 Dimensions of Body-Mind-Spirit anatomy.

THE MAHARIC SEAL AND LIQUID LIGHT CLEANSE

- In bio-energetic healing, **Level-1 Kathara Grid** distortions override realignments made to the **outer levels** of the bio-fields alone. For **lasting healing** to occur, Level-1 Kathara Grid distortions must be realigned.

- The **Maharic Shield**, with its **144 Frequency Sub-Harmonics**, is the only portion of the Morphogenetic anatomy that can fully repattern and realign the **Level-1 Kathara 12-Tree Grid.** In **Kathara Healing**, the **Maharic Shield** is used to realign the Level-1 12-Tree Grid.

- The **Maharic Seal and Liquid Light Cleanse** technique is used to restore distorted **Partiki Phasing Sequences** and **Scalar-wave arrangements** within the **3 Levels of the Kathara Grid** and **Scalar Shields**.

- Realignment will be **temporary** until the Kathara Grid reaches "**Critical Mass**" of energy in the **new**, realigned pattern.

- Until **critical mass** is reached, the outer levels of the anatomy will continue to **reverse** the Kathara Grid healing. With practice and **consistent application** of the **Maharic Seal and Liquid Light Cleanse** technique, the realignment of the Kathara Grid will become **permanent.**

- In future applications of Kathara Healing processes will be used to realign the **outer levels** of the bio-field and the **Kathara Grid simultaneously**, to expedite the healing process.

- The Focus of **Level-1 Kathara Healing** is **Morphogenetic Repatterning** and **Holographic Template Recoding** via the **Maharic Shield**, to clear distortions and the **Karmic-miasmic imprint** from the personal **Scalar Shields, Kathara Grid** and **DNA Template**, utilizing the **accelerated energies** of the *Planetary Bio-feed Interface System* **(PBIS).**

KATHARA POINTS

- **Kathara Points** are mini energy-vortex points in the body that connect directly to **Diodic Point vortices** in the **Level-3 Kathara Diodic Point Grid.**

- Stimulation of the Kathara Points through **manual massage** effects the **movement of energy** within related areas of the Kathara Grid and body systems.

- Used in sequence, **Sequence-1 Kathara Points for Regeneration** *open* energetic gateways to the **Kathara Lines** of the **Kathara Level-1 12-Tree Grid**, to allow new, realigned scalar patterns from the **Maharic Shield** to run through the Kathara Lines and Kathara Grid for **Core Template Repatterning.**

- **Sequence-1 Kathara Points** create **more lasting but less immediate** effects of realignment and healing. They can be **used alone** for **deep healing** and re-balancing of the **Core Kathara Grid.**

- **Sequence-2 Kathara Points for Revitalization** *close* **Kathara Lines** in the 12-Tree Grid and **channel** energy into the **Nadial Lines** of the **outer bio-energetic field** for more rapid revitalization and re-balancing of the **outer auric levels, chakras** and **physical cells.**

- **Sequence-2 Kathara Points** create **more immediate but less lasting** effects of realignment and healing. They can be **used alone** to create **temporary revitalization** of the **outer levels** of the bio-system.

- **Used together, Sequence-1** Kathara Points can run **Maharic energy** through the **core Kathara Grid** for **Template Recoding. Sequence-2** Kathara Points can then be used to **direct the Maharic energy** into the **outer levels** of the bio-field and physical body, to **expedite healing** through **simultaneous** inner and outer bio-field realignment.

In **Kathara Healing, Sequence-1** Kathara Points are used to **OPEN** the Kathara Lines **prior to** running the **Maharic Seal and Liquid Light Cleanse** and **Sequence-2** Kathara Points can be used **following** the procedure to **revitalize** the outer bio-field and body systems.

THE MAHARIC SEAL, PBIS AND HEALING

- Use of the **Maharic Seal and Liquid Light Cleanse** technique begins activation of dormant **Chakras 8-12** and the **Planetary Bio-feed Interface System (PBIS).**

- **Opening the PBIS** allows energy from the **Planetary Shields** to be drawn into the **human body** for **rapid activation** of the **personal Maharic Shield** and **Crystal Seals**, to **expedite** the processes of **DNA Template activation, healing, recoding of the Holographic Template** and interdimensional evolution.

- Opening of the PBIS can also allow the human **DNA Template** to serve as a **Bio-electric Conduit**, through which the **Planetary Scalar Shields** and Electro-magnetic Grids can be realigned with their **Primal Order** for **geophysical planetary healing.**

- Through the PBIS humans can directly facilitate healing of the **Planetary Templar Complex** from the Manifestation Template level, as well as facilitate healing in other biological organisms.

- Each use of the **Maharic Seal and Liquid Light Cleanse** technique assists in **planetary healing**, as the process progressively stimulates the **Planetary Maharic Shield** into activation, to realign **Planetary Shield** distortions.

- The **Maharic Seal and Liquid Light Cleanse** technique is used as **preliminary preparation for ALL Kathara Healing applications**. It creates a temporary **12th-Dimensional Scalar Frequency Seal** in the facilitator's bio-field to **protect** both facilitator and client from taking on each other's bio-field distortions.

- In **healing applications**, the **Maharic Seal** is needed to run interdimensional healing currents to their most effective **12th-Sub-Harmonic level.**

BIO-SPIRITUAL EVOLUTION, ASCENSION AND HEALING

- The processes by which **healing** occurs through re-genesis of Primal Order are the same processes through which true **Spiritual Actualization** takes place.

- **Biology** and **consciousness** are **intimately intertwined** through the natural **Laws of Universal Unified Field Physics**, the **energetic dynamics** through which consciousness enters manifestation.

- The hidden **impetus for action** behind human evolution is the core species objective of **Mastery of Co-creation** within the space-time system. This **Evolutionary Objective** is obtained through achievement of the Evolutionary **Goal** of **Transmutational Dimensional Ascension.**

- **Kathara Healing** applications generate **healing** through restoring the **Original Imprint for Health.**

- Restoration of the **Original Imprint for Health** simultaneously expedites the natural processes of **evolution,** through activation of the **12-Strand DNA Template, Kundalini** energies, and **Merkaba Vehicle** and integration of the **Hova Bodies, Scalar Shields** and higher dimensional aspects of personal **spiritual identity.**

- **Kathara Healing** facilitates healing while simultaneously facilitating **Spiritual Actualization** and expediting the Goal of **Transmutational Dimensional Ascension.**

- **Healing is a function of consciousness.** There is no difference between the substance that composes physical matter and the substance that composes consciousness, other than the **dimensional frequency** from which one is perceiving.

- When personal consciousness energy is applied in **congruence** with the natural Laws of Universal Unified Field Physics, **healing, wellbeing** and **Spiritual Actualization** result.

MULTI-DIMENSIONAL IDENTITY STRUCTURE

- **Human anatomy** is a **15-Dimensional Scalar-wave construct.** Part of our identity exists **simultaneously** within the Time Cycles of the higher dimensional **Harmonic Universes.**

- We are indelibly **linked** to our higher identity levels through our embodied **Kathara Grid, Scalar Shields** and **DNA Template.** As we evolve biologically to activation of dormant portions of our DNA Template and Scalar Shields, the conscious awareness of our higher identity levels **progressively embodies.**

- The 3-Dimensional Hova Body **Electro-magnetic Domains** and Scalar Shields that form them represent **Platforms of Perception** through which our higher identity levels perceive.

- **Merger** of the **Hova Bodies** via activation of the **DNA Template** and **Scalar Shields** creates **reintegration** of the **Multi-Dimensional Identity Structure.**

4 PRIMARY TRIADIC HEALING CURRENTS AND IDENTITY

4 PRIMARY TRIADIC CURRENTS

- The **5 Levels of Multi-Dimensional Identity Structure** are: **Incarnate**-Density-1, **Soul**-Density-2, **Oversoul**-Density-3, **Avatar**-Density-4 and **Rishi**-Density-5. There are also **3 Ascended Master** identity levels, Hova Bodies and Shields existing **beyond** the dimensionalized **Time Matrix.**

- In **Kathara Healing** we use the various levels of higher dimensional identity to draw in **healing current** from the higher dimensional Unified Fields, by activating the portions of the **personal Scalar Shields, Kathara Grid** and **DNA Template** that correspond to the higher dimensional **Hova Bodies.**

- There are **4 Primary Triadic** (3-Dimensional) **Energy Currents** that can be used in **Healing Facilitation**: The **Telluric Current**-Density-1, the **Doradic Current**-Density-2, the **Teuric Current**-Density-3 and the **Maharic Current**-Density-4. The **Rishic Current** of Density-5 can be run only by beings with **full 12-strand DNA activation.**

12 TRIADIC PHASE CURRENTS

- Each of the 4 **Primary Triadic Healing Currents** corresponds to one of the first 4 **Hova Bodies** of human anatomy.

- In Kathara Healing, the 4 Primary Triadic Currents are harmonically interwoven to create 4 powerful **Combined Healing Currents.**

- Each of the 4 Triadic Healing Currents has 3 Phases, or **3 Phase Currents**, each representing one of the three dimensional frequency bands within the **Triadic Current.**

- Each of the **12 Phase Currents** is run in combination with the 11-12th-Dimensional **Maharic Current** and the Phase Current from the **harmonic directly above**, to form a powerful **Triadic Healing Current.**

- In **Kathara Healing**, specific Healing Currents are directed by using the **Color** of their dominant **wave-length.**

- **Level-1 Kathara Healing** teaches us to activate our **Doradic-Phase-1 Current**- the **Pale Silver** (D11-12) **+ Green** (D-4) **+ Violet** (D-7)- for **Healing Facilitation** and **personal** DNA Template and Shield activation.

- The **Doradic-Phase –1 Current** can realign the **1st-4th** Dimensional aspects of the **Scalar Shields**, the **1st-4th Chakras, Axi-A-Tonal Lines** and **DNA Strand Templates**, the **Physical, Emotional** and **Mental** bodies of the **Nada Hova Body** and the D-4 **Astral body** of the **Alphi Hova Body.**

- **Doradic-Phase-1 Current** can also be used to realign the **1st-4th Sub-Harmonics** of ALL Shields, DNA Strand Templates, Axi-A-Tonal Lines, Chakras and Hova Bodies and to clear the **Karmic-Miasmic Imprint** from the **Density-1** incarnational Time Cycles and the **first part** of the **Density-2** incarnational Time Cycles.

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GENERAL KATHARA HEALING FIELDWORK

Skills to Facilitate Healing

- OPENING THE HEALING CHANNELS- DORADIC-PHASE-1 CURRENT, THE DORADIC SPHERE, DORADIC CORDS AND DORADIC BALLS.
- THE KARMIC-MIASMIC IMPRINT, INCARNATIONAL TIME VECTORS, VECTOR IMBEDDING.
- MULTI-VECTOR HOLOGRAPHIC RECODING THROUGH THE MAHARIC INFUSION.
- ATTITUDES AND ETIQUETTE IN HEALING, THE MOTIVATION TO HEAL, POSTURES OF LOVE, THE FRAMEWORK FOR HEALING AND FULLY ENGAGING THE LOVE VIBRATION.
- THE 6 STEP MAHARIC RECODING SESSION, MELCHIZEDEK CLOISTER ORDINATION AND BECOMING A PROFESSIONAL SPIRITUAL HEALING FACILITATOR-INSTRUCTOR.

TECHNIQUES:

#3- OPENING THE HEALING CHANNELS- DORADIC –PHASE-1 CURRENT

#4- MULTI-VECTOR HOLOGRAPHIC RECODING KATHARA SCAN

#5- THE MAHARIC INFUSION

THE MAHARA SPACE COMFORT TOUCH

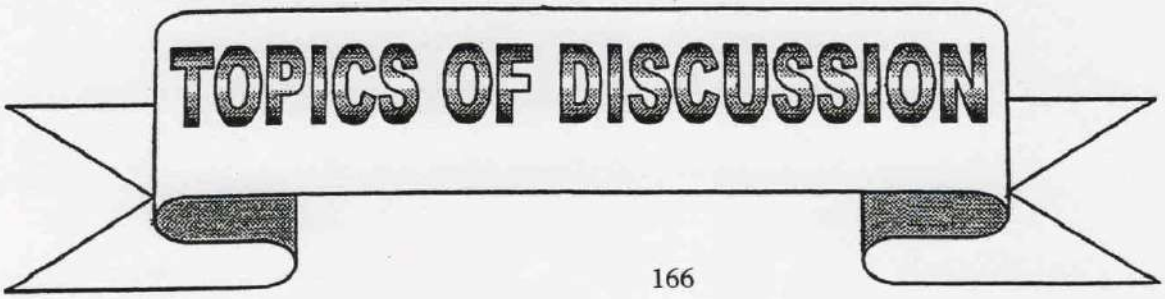

OPENING THE HEALING CHANNELS

DORADIC-PHASE-1 CURRENT

Interdimensional Currents and Signet Star Crystal Seals

Activation of any **Triadic Healing Current** requires temporary release of the corresponding **Signet Star Crystal Seals** within the personal **Scalar Shield** and a temporary activation of the portions of the dormant **12-Strand DNA Template** that correspond to the Signet Seals. Signet Seals modulate the flow of frequency between the 3-Dimensional Harmonic Density Levels. When Signet Seals are in their usual (for this time period) dormant phase, they keep the **5 Hova Bodies** of the personal 15-Dimensional anatomy separate from each other by creating an electro-magnetic barrier or **Magnetic Repulsion Zone** between each 3-Dimensional level of the energetic anatomy. This *Magnetic Repulsion Zone* between embodied **Harmonics of Manifestation** manifests as **polarity resistance to frequency inflow** within the 3 Levels of the Kathara Grid, the Scalar Shields, Axi-A-Tonal Lines, Chakras and Auric Field levels of the embodied **Inner Templar Complex. In order to run higher dimensional frequency currents through the physical body for healing applications, it is necessary to temporarily release portions of the Magnetic Repulsion Zones between the Hova Bodies.** Releasing the electro-magnetic resistance to higher dimensional frequency inflow within the Inner Templar Complex is achieved through temporary activation of the **Signet Seals** within the **Kathara Level-2 Crystal Seals Grid** of the personal **Scalar Shields.**

Most contemporary energetic healing systems rely upon using the 1st, 2nd and 3rd-Dimensional frequencies of the **TELLURIC PHASE CURRENTS** in the **Nada Hova Body.** Through the Nada Hova Body alone, only the 3-Dimensional **Sub-Harmonics** of higher dimensional frequency currents can be run, as the dormant *Signet Seals* block the faster moving *Partiki Phasing Flash-line Sequences* of higher dimensional frequency bands from running through the DNA Template. **If a frequency band is blocked from running through the DNA Template that frequency cannot be energetically transmitted through the Nada Hova Body and physical bio-electrical systems. In conventional energy healing methods,** even those emerging from ancient systems of subtle-energy healing, the **Signet Seals,** and thus the *Scalar Shields, Hova Bodies* and *DNA Template* remain dormant in their usually **closed** position, **phase-locked** into a 3-Dimensional orientation. While the DNA Template remains phase-locked into the 3-Dimensional orientation of the Nada Hova Body, only the **1st through 12th Sub-frequency bands** (Sub-Harmonics) of **1st through 3rd Dimensional Current** (Telluric Current), and the **1st through 3rd Sub-frequency bands** of **4th through 12th Dimensional Current** can be run through the human body for transmission. Use of the lower frequency (slower Partiki Phasing rhythm) **Telluric Currents** can effect **temporary** beneficial change in the **outer layers** of the bio-energetic field, but Telluric Currents alone cannot facilitate full repatterning of the **3 Levels of the Kathara Grid** where **Scalar Shield** distortions that cause **genetic malfunction** are embedded. The **11th-12th-Dimensional frequencies** of the Pre-matter Hydroplasmic **Maharic Currents** are the only dimensional frequencies powerful enough to affect change in the embodied **Kathara Grid.** To run **Maharic Current,** and the high frequency interdimensional **Triadic Phase Currents,** through the human body requires release of the **Signet Seals** within the personal **Scalar Shields.**

Triadic Phase Currents, the Maharic Shield and the PBIS

Most healing systems have not incorporated the **Maharic Current** into their frequency application procedures because the **Planetary Templar Complex** has not been able to run a D-12 **Maharic Current** through the planetary grids for **210,216 years.** Like the human **DNA Template**, if the **Planetary Shields** and Manifestation Template are blocked from processing interdimensional frequency, that frequency will be **unavailable for use** on the planet. If the **Signet Star Crystal Seals** (Star Gates) in the **Planetary Shields** are dormant, closed and phase-locked into Density-1 orientation, no one on the planet will be able to draw interdimensional frequency into their **personal Shields** because the frequency is unavailable within the **Planetary Shields.** The personal and planetary Templar Complexes are **intimately interwoven**, and what effects one will inevitably effect the other.

In order to run the **full spectrum** of interdimensional **Triadic Phase Currents** through the human body it is necessary to open the **Signet Seals** in the personal **Inner Templar** and the **Signet Star Gates** in the **Planetary Templar Complex.** In conventional human evolution, the internal Signet Seals, which serve as the **Genetic Time Codes** or **"Fire Codes"** of the human **DNA Template**, automatically, progressively and sequentially open over **very long cycles of time.** During the slow activation of the Genetic Time Codes the conscious identity experiences passage through numerous incarnate lifecycles within the planetary Time Cycle, evolving through a series of **Single Vector incarnations** before being released from the 3-Dimensional phase-lock of Density-1 manifestation. One can **manually open the Signet Seals** in the embodied Inner Templar Complex to **expedite evolution** into the Multi-dimensional, **Multi-Vector Time Cycles** through use of the 11th-12th Dimensional **Maharic Current.**

Activation of the personal **Maharic Shield** allows for rapid release of the embodied **Signet Seals** and activation of the **Fire Codes** in the DNA Template. The **Maharic Current** from the personal Maharic Shield can be used to release the **Signet Star Crystal Seals** within the body, which in turn activates the dormant **Kundalini** energies at the base of the spine and the **Cranial-Sacral Kundalini Seals** within the **Tailbone** and **Pineal Gland.** Release of the Cranial-Sacral Seals of the Internal Templar Complex allows the **Magnetic Repulsion Zones** between the **Hova Bodies** to release so the DNA Template, personal Scalar Shields and physical body systems can receive inflow of higher dimensional frequency. To gain conscious mastery over the process of releasing the internal Signet Seals requires activation of the personal **Maharic Shield**, and the personal Maharic Shield can be **manually activated** only through drawing **Maharic Current** into the personal Shields via the **Planetary Maharic Shield.** **The entire process of releasing the internal *Signet Seals* by activating the personal *Maharic Shield*, in order to enable the *DNA Template* to run *Triadic Phase Currents* for healing is entirely dependant upon the *operational function* of the *Planetary Bio-feed Interface System* (PBIS).**

If the **Planetary Templar Complex** is blocked, or the Signet Star Gates are dormant, and **Maharic Current** from the **Planetary Maharic Shield** is not able to run through the planetary grids, humans on Earth do not have the option of **manually activating the personal Maharic Shield**, because the **PBIS** is not operational. The **PBIS** becomes **operationally functional** within the human body through activation of the **12th Chakra**. The *12th Chakra* cannot activate in the personal Templar Complex if the **Planetary Templar Complex** cannot run 12th-Dimensional **Maharic frequency.** For over 200,000 years, the Planetary Templar Complex could not run Maharic frequency, and thus manual activation of the personal Maharic Shield and release of the embodied Signet Seals to open the Hova Bodies for running interdimensional Triadic Phase Currents for healing were not available options for Earth humanity. Since the recent activation of the **Planetary Templar Complex, Maharic Shield** and **PBIS** activation and **Kathara Healing** applications are now available on Earth.

Opening Triadic Phase Currents in the Human Body

The method by which **Triadic Phase Currents** are activated within the human body is a **progressive process.** First, opening of the personal **Kathara Grid, Telluric Shield** and **Nada Hova Body** is orchestrated through activation of the **Maharic Shield** and **Signet Seals**, to allow inflow of frequency from the higher dimensional **Hova Bodies**. Next, the incoming frequency is harnessed and **collected** within the **Chakra System.** Finally, the collected frequency is then **transmitted** for healing facilitation in others, either through direct **Chakra transmission** or by close-range **Frequency Induction** via transmission of frequency from the activated **Secondary Chakra Centers** within the **PALMS.**

The ability to run the higher dimensional Triadic Phase Currents within the body must be built up within the Internal Templar Complex, starting with the **slowest-moving current** of the higher dimensional spectrum- the **DORADIC-PHASE-1 CURRENT.** The *Doradic-Phase-1 Current* utilizes the **sub-frequencies** of the **11th-12th**-Dimensional **Maharic Current** from the Density-4 *Mahara Hova Body* as a **carrier wave** that will carry the desired interdimensional currents through the **Signet Seals** of the personal **Scalar Shields.** The **full spectrum** of the **4th** Dimensional **Doradic-Phase-1** current from the Density-2 *Alphi Hova Body* is activated as the **primary healing frequency** for transmission. The **full spectrum** of the **7th**-Dimensional **Teuric-Phase-1 Current** (one Harmonic above the Doradic-Phase-1 Current) from the Density-3 *Betcha Hova Body* is used to release the 4th-Dimensional **Signet Seal,** allowing the 4th-Dimensional Doradic-Phase-1 current to enter the **Nada Hova Body.**

Activating the **4th Signet Seal** triggers **temporary** activation of the **4th DNA Strand Template** and corresponding **4th Kathara Center** in the Level-1 12-Tree Grid, which allows the 4th-Dimensional frequencies of the **Doradic-Phase-1 Current** to pass through the **active DNA** and into the bio-energetic and bio-electrical systems of the body for transmission. Once the DNA Template becomes accustomed to holding a **4th-DNA Strand Template Activation,** after **several months** of practice in running the 4th–Dimensional *Doradic-Phase-1 Current*, the body will be able to begin receiving the primarily 5th-Dimensional **Doradic-Phase-2 Current. The lower dimensional Triadic Currents must be activated within the DNA Template before the higher dimensional Triadic Currents can run.** In **Level-1 Kathara Healing** the first step of activating the full spectrum (12 sub-harmonics) of the 4th-Dimensional **Doradic-Phase-1 Current** is achieved.

Triadic Phase Currents and Color Cap-Stones

The **Color Cap Stone** of a dimensional frequency band is the visual representation of the **primary wave-length** formed by the specific **Partiki Phasing Rhythm** for that dimension. A specific dimensional frequency band can be chosen and directed by the **color translation** of its primary wave-length. The **Color Cap Stones** of the dimensional frequency bands are used in Kathara Healing to direct specifically selected dimensional frequency bands (Partiki Phasing Rhythms) for specific applications. The **Color Cap Stones** for the **Doradic-Phase-1 Current** are **PALE SILVER** (D-11-D-12 Maharic) + **GREEN** (D-4 Doradic) + **VIOLET** (D-7 Teuric). In **technique # 3 – OPENING THE HEALING CHANNELS-DORADIC-1** - the ***Pale Silver + Green + Violet*** Cap Stone Colors will be used to activate the **Doradic-Phase-1** Healing Current within the body.

DORADIC SPHERE, CORDS AND BALLS

The Doradic Sphere and Current Collection

The **DORADIC SPHERE** is a **frequency repository** that is formed to hold the activated **Doradic-Phase-1 Current** within the **Chakra system** for transmission in healing facilitation. As the Doradic-Phase-1 Current is primarily a **4th-Dimensional Current**, the **Doradic-1 Sphere** will be formed in the **4th Chakra**, which corresponds to the 4th-Dimensional **ASTRAL body** of the Alphi Hova Body and Auric Field. **Transmission** of the Doradic-Phase-1 Current will take place from the **Doradic Sphere** at the **4th Chakra**, creating a **4th-Dimensional ASTRAL INFUSION** of frequency into the bio-energetic field of the client in **close-range healing**, and a general **Astral Plane Infusion** of Doradic-Phase-1 frequency into **Manifestation Templates** of areas(and everything contained within the space) when transmitted directly from the **4th Chakra**.

Doradic Cords and Current Induction

The **DORADIC CORDS** are **energy conduits** that are formed by opening the embodied **Axi-A-Tonal Lines** within the **arms, hands** and **fingers.** Opening the Doradic Cords allows the **Secondary Chakras** within the **palms** of the hands to carry the **Doradic-Phase-1 Current** for application in **close-range** transmission. Though Triadic Phase Currents can be transmitted directly from the **Chakra Center** in which the **Collection Sphere** is placed, the energies are more **diffused** and **diluted** in this form of transmission, unless the personal DNA Template holds a **full, permanent activation** of the Strand Template corresponding to the Triadic Current being transmitted. It takes time, often years, for the DNA Template to acquire and permanently hold a higher strand activation level. One-on-one healing facilitation is more effective when conducted through **concentrating** the Triadic Current through the **Axi-A-Tonal Lines** for **DIRECT INDUCTION** of current through the **Palm Chakras** in **close-range** transmission. Close-range transmission also allows for **more precise application** of frequency to specific areas of the body systems. In **Level-1 Kathara Healing**, the **Doradic Cords** are activated within the arms, palms and fingers to allow for concentration, focused direction and **Direct Induction** of the **Doradic-Phase-1 Current.**

For **general healing** purposes, such as **"clearing rooms"** or geographical spaces, or when attempting to transmit healing current into **groups of people**, transmission of the **Doradic-Phase-1 Current** can be orchestrated directly from the **4th Chakra** for **NON-SPECIFIC INDUCTION.** In **Non-Specific Induction**, following activation of the Doradic-Phase-1 Current, each **INHALE** breath is used to fill the **Doradic Sphere** with more energy and each **EXHALE** breath is used to expand and transmit the energy into the room or bio-fields of a group of people. It is not necessary to activate the Doradic Cords for Non-Specific Induction applications. In **Level-1 Kathara Healing** applications use of the **Doradic Cords** and **Palm Chakras** is employed for Direct Induction close-range transmission in Client Sessions. To enhance and expedite **personal healing**, the activated **Doradic-Phase –1 Current** can be run through the personal **Level-1 Kathara Grid** with the ***Maharic Shield and Liquid Light Cleanse*** technique and then through each of the **7 Primary Embodied Chakras.**

Doradic Balls and Palm Transmission Direct Induction

The **DORADIC BALLS** are small energy repositories that form in the **Palms** of the Hands when the **Doradic Cords** have been activated to run Doradic-Phase-1-Current through the **Palm Chakras.** Doradic Balls are used to **accumulate current** in the **Palm Chakra vortices** prior to transmission, to **strengthen** the intensity of the current.

PALM CHAKRAS AND TRANSMITTING CURRENT

Primary Polarities of Palm Chakras

Along with the **15 Primary Chakras** within human anatomy there are many other smaller **Secondary** and **Tertiary Chakra Centers** throughout the body, which correspond to the energetic interrelationships of scalar-wave patterns within the **Kathara Level-3 Diodic Points Grid**. All Chakras operate as sets of **Black and White Holes**, through which energy from the Dimensional Unified Fields circulates into and out of the body and Manifestation Template. The **Palm Chakras** are part of the **Secondary Chakra System**. Like all Chakras, the Palm Chakras are structured as **2 vortices** of energy **joined at the tip** by a minute **Crystal Seal** within the **Kathara Level-2 Crystal Seals Grid**. The Palm Chakras run through the **center of the Palms** and out of the **back of the hands**.

In any set of Chakra vortex spirals, one vortex represents the **magnetic Black Hole**, a *counter-clockwise rotating* spiral that **draws energy IN** toward the central Crystal Seal, and the companion vortex represents the corresponding **Electrical White Hole**, the *clock-wise rotating* spiral that **sends energy OUT** from the central Crystal Seal. The **Black Hole** vortex represents the **RECEIVING spiral** or **Magnetic Pole** and the **White Hole** vortex represents the **TRANSMITTING spiral** or **Electrical Pole**. The **Electrical Pole** of a Chakra represents the **EXPANSION CURRENT** of the Chakra, through which it **expands energy out** from the personal Shields; it is referred to as **BASE ELECTRICAL**. The **Magnetic Pole** of a Chakra represents the **CONTRACTION CURRENT** of the Chakra, through which it **contracts energy in** from the external Unified Field to the personal Shields; it is referred to as **BASE MAGNETIC.**

The Chakras in the **Palms** are composed of many smaller minute **vortex sets**, each with Magnetic and Electrical Poles, but the **PRIMARY POLE** of each Palm Chakra is that pertaining to the **larger Black-White Hole set** and **Crystal Seal**. Though each Palm Chakra is capable of both **Transmitting and Receiving** energy current, the **strongest and most focused currents** can be achieved by utilizing the natural polarity orientation of the Primary Vortex Set. The Chakra in the **RIGHT PALM** is **BASE ELECTRICAL**; its corresponding vortex on the back of the right hand is **Base Magnetic**. The Chakra in the **LEFT PALM** is **BASE MAGNETIC**; its corresponding vortex on the back of the left hand is **Base Electrical**. When running Triadic Phase Currents it is helpful to understand the **Primary Polarities of the Palm Chakras** in order to create the **strongest** and **least distorted** healing current. In **Kathara Healing**, the **RIGHT HAND** is the **TRANSMITTING HAND**, through which Triadic Current is **Exhaled** down the **Cords** in the arms and **EXPANDED** into the **RIGHT PALM CHAKRA** for **TRANSMISION**. The **LEFT HAND** is the **RECEIVING HAND**, through which the Triadic Current transmitted from the Right Hand is **drawn back** into the facilitator's body **TO CREATE A CLOSED CIRCUIT OF CURRENT** for the **strongest current intensity** and **purest frequency content.**

HAND POSITIONS

Standard Hand Position for Transmitting Triadic Current

When transmitting Triadic Current, the **LEFT PALM** is **PLACED OVER THE BACK OF THE RIGHT HAND**. The *Base Magnetic* Current of the *Left Palm* **interfaces** with the *Base Magnetic* Current in the *Back of the Right Hand*, creating a **MAGNETIC REPULSION ZONE**, which **blocks the vortex on the Back of the Right hand** from drawing **non-specific frequency** from the Density-1 Unified Field. This keeps the current transmitted from the *Right Palm Chakra* **pure** to its specifically chosen content. The *Base Magnetic* vortex in the *Left Palm* simultaneously draws the **transmitted current** back up through the smaller vortex sets after it runs through the client's body, creating a **closed circuit of pure frequency** running between the **Hova Bodies** of the **client,** the **facilitator** and the higher dimensional **Unified Fields**. Options of **Frequency Modulation** for other healing applications also become available through using this **HAND POSITION** when transmitting healing current. In some applications a **modulated current** that includes bursts of Density-1 Telluric Current interspersed with current transmission from the higher dimensions is desired; this can be achieved by moving the Left Hand on and off of the vortex on the back of the Right Hand. The **LEFT OVER RIGHT HAND POSITION** is used in **Level-1 Kathara Healing** applications.

Elements of Doradic-Phase-1 Current Activation

Doradic-1 Cap Stone Colors:
PALE SILVER (D-11&D-12) + GREEN (D-4)+ VIOLET (D-7)

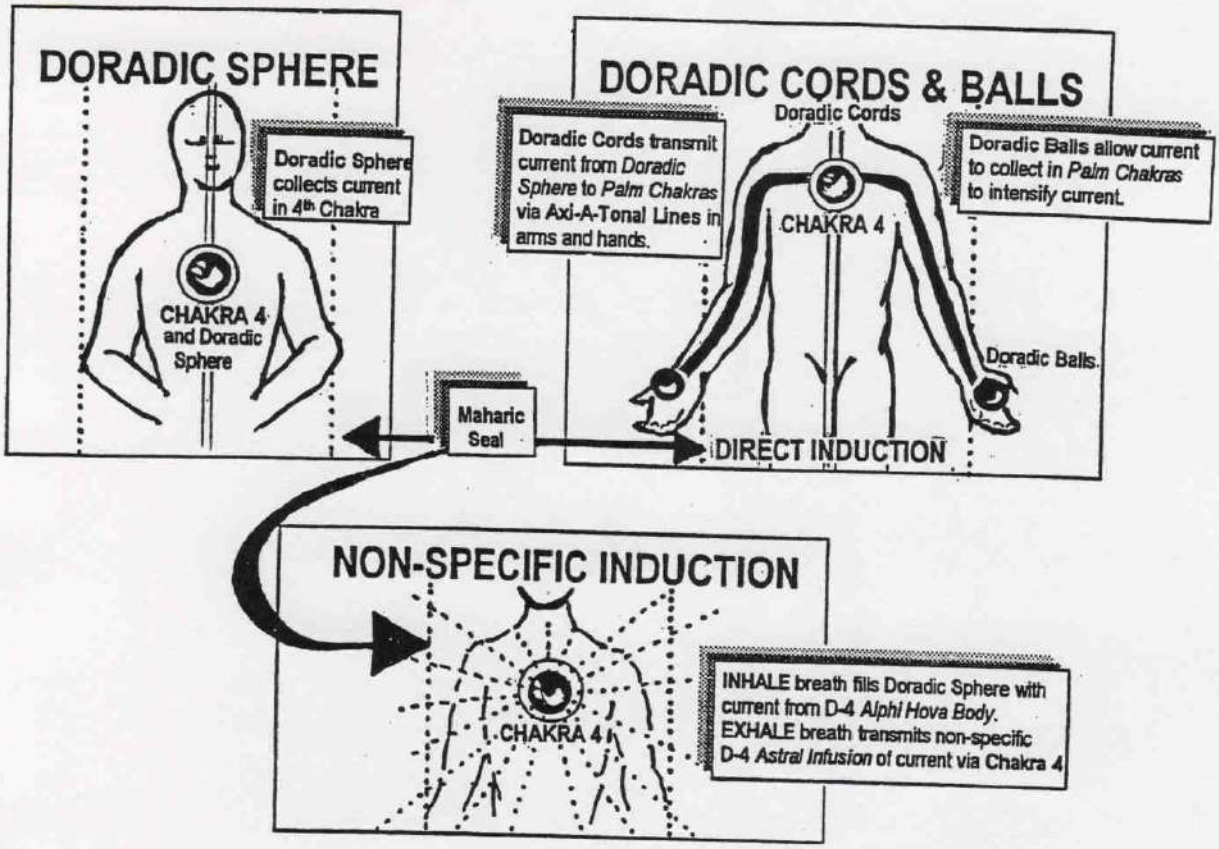

Intrinsic Process of Activating a Triadic Phase Current

ACTIVATE MAHARIC SHIELD

1. Open the PBIS using the D-11 – D-12 Wave Guide Symbol Code, the **Hierophant Symbol**, to open the **12th Chakra** and stimulate release of **Maharic frequency** from the **Planetary Maharic Shield.**
2. From the PBIS draw Maharic frequency from the Earth's Maharic Shield up into the dormant personal Maharic Shield 12" below the feet, to activate the **personal Maharic Shield.**

ACTIVATE TRIADIC PHASE CURRENT

3. Choose the specific Triadic Current you desire to run.
4. Use the inflow of **Maharic Current** from the personal and planetary Maharic Shield as a **Carrier Wave** to carry the **Cap Stone Color frequencies** of the **Signet Star Crystal Seals** in your Scalar Shields that correspond to the **Triadic Phase Current** you wish to activate.
5. Temporarily **release** the **Signet** and **Cranial-Sacral Kundalini Seals** and activate the **DNA Strand Template** corresponding to the chosen **Triadic Phase Current,** by running the **Primary Frequency** and the frequency **one Harmonic above it** through the **Signet Seals,** on the Maharic carrier wave current, to open the **Nada Hova Body** and physical body systems to inflow of the higher dimensional **Triadic Phase Current.**

COLLECT AND TRANSMIT HEALING CURRENT

6. As the Triadic Phase currents transmits into the body through the Signet Seals, Kundalini energies and DNA Template, **collect and build the current** as a **Sphere** of energy within the **Chakra** corresponding to the Primary Triadic Current you are running.
7. Run the current from the **Collecting Chakra** through **the Axi-A-Tonal Line Cords** in the arms, to activate the **Palm Chakras.**
8. **Exhale** current from the **Chakra Collection Sphere** through the **Cords** and allow it to build into **Balls** of energy within the **Palm Chakras** before transmitting.
9. Transmit the Triadic Current through the **RIGHT PALM CHAKRA** into client's bio-energetic field while drawing more current into the **Chakra Collection Sphere** with each **exhale** breath and draw the current back through the **LEFT PALM** on each **inhale** breath to create a higher dimensional Closed Circuit Healing Current. Use **LEFT PALM OVER BACK OF RIGHT HAND** hand position.

TECHNIQUE # 3 93

Opening the Healing Channels- Doradic-Phase-1 Current

1. Breathe slowly and deeply for several breaths while visualizing or imagining a **4" Violet Dot** on the center of the *inside of your forehead*. Make the color image as strong as you are able.(If you can't yet perceive inner colors or visualization, simply imagine the Violet Dot as being there). Move the Violet Dot to the center of the brain at the **Pineal Gland**, and then upward into the **7th Crown Chakra**, from the inside of the head moving upward and outward until the Violet Dot *rests on top of your head* at the Crown Chakra.

2. Call to mind the **Hierophant Symbol** (Pale Silver Merkaba Star formed by combining 2 Merkaba Stars). Visualize the spinning Hierophant stationed 12" below the feet within your **Maharic Shield** and slowly **INHALE**, drawing the Hierophant up through the Central Body Current, up to meet the Violet Dot at the **7th Crown Chakra** at the top of the head. When the *Hierophant connects with the Violet Dot* visualize the Violet Dot bursting into a **4" Vertical Pillar of Violet-Silver Light**. Imagine the *Violet-Silver Pillar* running down through the body into the *Earth Core* and upward to the **14th Chakra** 36" above the Head. You have activated the **Violet Ray of Transmutation.**

3. Move your attention to the **4th Heart Chakra** and imagine a *small Green Spherical Crystal* – the **Green Star**- stationed at its core. This is the *Green Star Crystal Seal* that controls release of *4th Dimensional* frequency – *Phase-1 Doradic Current* - into the body. **INHALE**, drawing Violet-Silver energy from the Violet-Silver Pillar into the *Green Star*. **EXHALE**, *expanding* the Violet-Silver energy *into the Green Star sphere. Repeat 2 more INHALE-EXHALE* breaths, drawing Violet-Silver Energy from the Pillar and expanding it into the Green Star sphere. At the end of the last **EXHALE**, imagine the **Green Star popping**, turning into a spinning Green and Violet Starburst of Light, as the *Violet-Silver Pillar disappears. Spin the Green-Violet Starburst* faster until it becomes a *ball of Green-Violet Light*, about the size of a *grapefruit*, spinning in the center of the *4th Heart Chakra*. The Green-Violet ball is the store-house for your Phase-1Doradic Current – it is called the **Doradic Sphere**. **INHALE** and draw Pale Silver energy from your **Maharic Shield**, through the Central Body Current and into the center of the **Doradic Sphere** at the **4th Heart Chakra**, encasing the Sphere in translucent Pale Silver Light.

4. **EXHALE quickly** and push **2 Cords** of *Green-Violet-Silver energy* – **Doradic Cords** -from the Doradic Sphere *down the inside of your arms*, one Cord through each arm. As the ends of the Doradic Cords reach the inside of the hands, notice a sensation of *mild resistance* as the Cords push against the *etheric membranes* covering the *small chakras* in the palms. **INHALE** a full breath, drawing Silver energy up from the **Maharic Shield**, into the *Doradic Sphere* at the 4th Chakra. **EXHALE forcefully**, pushing more energy down through the *Doradic Cords* in the arms, and feel this energy **"pop"** out of the *palms*, *releasing the membranes* on the palm chakras. Continue to **INHALE** energy up from the *Maharic Shield* into the *Doradic Sphere* and **EXHALE** it through the *Doradic Cords*, *building the strength of the Doradic Current* in both palms. Imagine the Doradic Current *pooling in the palms* to form *2 Green-Violet balls of light*, about the size of *tennis balls*. Energize the Doradic Sphere and Cords until you can sense the smaller **Doradic Balls** formed in the *palms* of your hands. **Your *Doradic Current* is now activated for use in healing facilitation.**

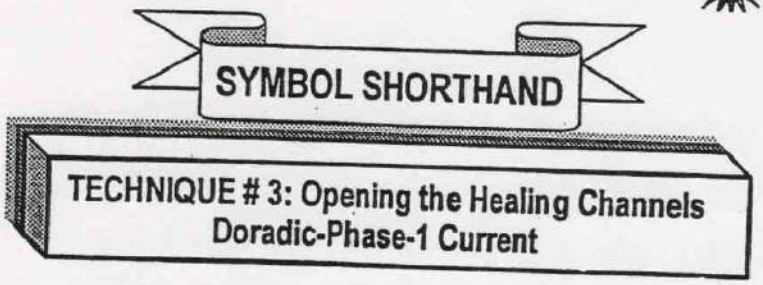

1. **4" Violet Dot** inside forehead, move to **Pineal Gland** then up through **7th Crown Chakra** to **top of head.**
2. **Hierophant Symbol** at center of your **Maharic Shield** 12" below feet. Inhale Symbol **up** to **Violet Dot** at top of head. See **Violet Dot burst** into **4" Violet-Silver Pillar** running through body to **Earth's core** and up to **14th Chakra** 36" above head.
3. Small **Green Star Crystal Seal at 4th Heart Chakra.** Inhale drawing **Violet-Silver** energy from **Violet-Silver Pillar** into **Green Star Crystal Seal** and see **Green Star Crystal Popping** into a spinning **Green-Violet Starburst,** as Violet-Silver Pillar **disappears**. Spin Green-Violet Starburst faster until it becomes grapefruit-size **BALL** of **Green-Violet Light**, the **Doradic Sphere,** at the center of the **4th Heart Chakra**. Encase Green-Violet Sphere in **Pale Silver** Maharic energy.
4. Push a **Green-Violet-Silver Doradic Cord** down each arm to **Palm Chakra Membranes** and draw **Pale Silver** up from **Maharic Shield** to **Doradic Sphere** and forcefully push Maharic Current **down arms** to **pop Palm Chakra Membranes.** While running **Doradic-1 Current** draw energy from **Maharic Shield** to **Doradic Sphere** and push it down arms from **Doradic Sphere** through **Doradic Cords** to **pool** into **Doradic Balls** at **Palm Chakras.**

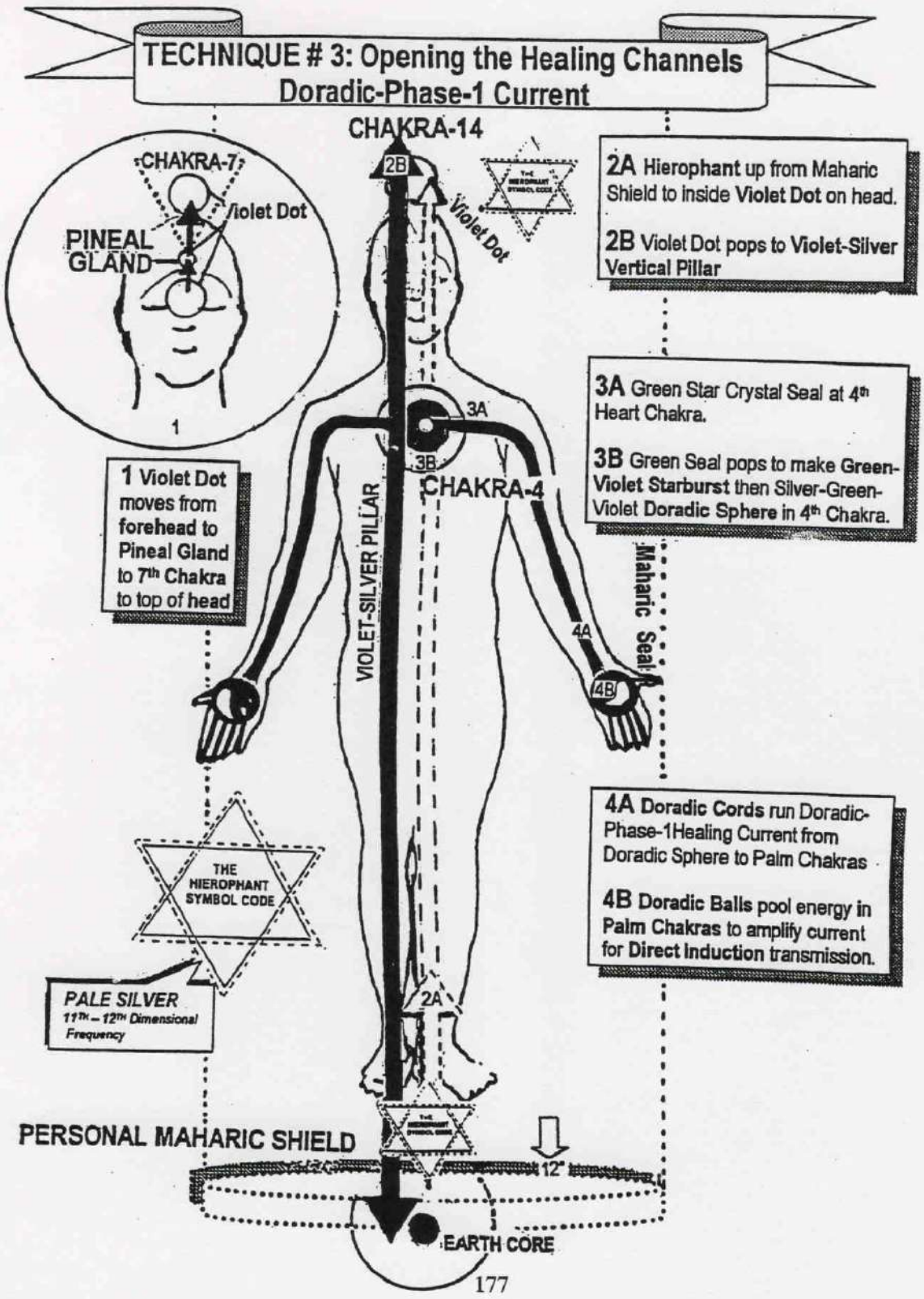
TECHNIQUE # 3: Opening the Healing Channels
Doradic-Phase-1 Current
CHAKRA-14
CHAKRA-7
Violet Dot
PINEAL GLAND
1
2B
Violet Dot
2A Hierophant up from Maharic Shield to inside Violet Dot on head.
2B Violet Dot pops to Violet-Silver Vertical Pillar
3A Green Star Crystal Seal at 4th Heart Chakra.
3B Green Seal pops to make Green-Violet Starburst then Silver-Green-Violet Doradic Sphere in 4th Chakra.
1 Violet Dot moves from forehead to Pineal Gland to 7th Chakra to top of head
3A
3B
CHAKRA-4
VIOLET-SILVER PILLAR
Maharic Seal
4A
4B
4A Doradic Cords run Doradic-Phase-1Healing Current from Doradic Sphere to Palm Chakras
4B Doradic Balls pool energy in Palm Chakras to amplify current for Direct Induction transmission.
THE HIEROPHANT SYMBOL CODE
PALE SILVER
11th – 12th Dimensional Frequency
2A
PERSONAL MAHARIC SHIELD
12"
EARTH CORE

THE KARMIC-MIASMIC IMPRINT

THE NATURE OF KARMA

Karma, Identity, the Christos and the Physics of Divine Right Order

When an identity enters the **Time Matrix** to begin **simultaneous cycles of evolution** through time, it enters the manifest fields through first adopting a **Manifestation Template** composed of Partiki Units and Scalar Waves. The first Manifestation Template is called the **Rishic Shield;** it exists at the **Ante-matter** scalar-wave level of **Density-5** and holds the complete **Primal Scalar Pattern** for all of the **Singular Identities** that will **simultaneously** manifest into incarnation within the lower dimensional Densities and Time Cycles. The **Rishic Shield** represents the **Identity Gestalt** or **Family of Consciousness** through which identity enters manifestation. The Rishic Shield carries the precise configuration of Scalar-wave patterns, the **Primal Order** of energetic substance, through which the consciousness individuated to form a collective of consciousness within the dimensionalized Time Matrix. Every individual incarnate from the Rishic Family of Consciousness in time carries as part of its core **Kathara Grid** scalar program the **electromagnetic energy signature** of **Primal Order** carried by the **Rishic Shield** through which it manifested.

The Scalar-wave design of the Rishic Shield represents **DIVINE RIGHT ORDER**, the **Primal Order** of scalar-wave energetic relationship and **Partiki Phasing Sequences** that individual identities in time must re-evolve to hold within their embodied **Manifestation Templates** in order to **regain freedom** from the dimensional systems of the Time Matrix. Consciousness from the Rishic Shield, in the form of **Omni-polar wave spectra**, enters the manifest Densities by projecting portions of itself into **smaller Consciousness Gestalts** within the lower dimensional fields. The smaller Gestalts of Consciousness form the **3-Dimensional Scalar Shields** of the identity within the dimensionalized matter systems. **Each Scalar Shield holds the consciousness of numerous simultaneous Cycles of Incarnation within each of the 4 Primary Time cycles of Densities 1 through 4.** Each individual incarnate in time is directly linked to its original **Rishic Shield Family of Consciousness** through the **Density-4 Maharic Shield.** The Maharic Shield of dimensions **10-12** contains the first **Pre-matter Hydroplasmic scalar-wave spectra** through which identity began its experience within the holograms of Space, Time and Matter. The **personal Maharic Shield,** often called the **PERSONAL CHRISTOS IMPRINT**, holds the original **Primal Order** of scalar waves through which manifest consciousness links to its **Rishic Shield.** The **Christos Imprint** of the **Maharic Shield** represents the **PATH OF DIVINE RIGHT ORDER** through which each individual consciousness in time can **re-evolve** to its original Eternal Non-manifest State of Wholeness in Consciousness beyond the Time Matrix. **Divine Right Order is not only a spiritual concept; it is a reality in energy within the scientific dynamics of Universal Unified Field Physics.** Divine Right Order represents the **Primal Order** of scalar-waves that make up the original **Manifestation Template** from which individual **singular lifetimes** emerge, and it is the necessary pattern of energetic order within the personal multi-dimensional Manifestation Template which allows incarnate beings to fulfill the **evolutionary objective** of **Transmutational Dimensional Ascension. The result of an incarnate being's *Manifestation Template* and Conscious Awareness becoming mis-aligned with the energetic structure of *Divine Right Order* is called KARMA.**

Karma, Divine Right Order, the Scalar Shields, Free Will and Miasms

If it is understood that the universe and all things within it exist as **manifestations of consciousness** in the form of **precisely ordered** scalar wave arrangements, and that there is an intrinsic and indelible **Primal Order** upon which all manifestation functions, it will not be difficult to conceptualize the **literal and tangible nature** of the **Karmic Imprint**. In energetic terms, **Divine Right Order** represents the **natural alignment** of conscious energy fields within the intrinsic **Laws of Universal Physics** characteristic to the dimensional structures of time. Divine Right Order exists as a **tangible, specific** and **harmonious organization** of **energy interrelationships** within the Primal Order of energetic structure that creates dimensionality. The condition frequently referred to as **Karma is**, like Divine Right Order, a tangible, specific organization of energy interrelationships. Unlike Divine Right Order, *Karma* represents dis-harmonious interrelationships of energy within the context of the Primal Order that creates dimensionality. **Karma** can be viewed as **CHAOTIC, incoherent energetic disorganization,** whereas **Order** represents **coherent energetic organization.**

In terms of the **15-Dimensional anatomy** of the **personal Manifestation Template,** the **Karmic Pattern** represents **areas of incoherent energetic disorganization** within the structure of the personal **Scalar Shields**. The **12th–Dimensional** Level of the personal **Maharic Shield** holds the original **Christos Imprint,** the **Primal Order** *perfect organization* of scalar-wave configurations that links our consciousness and **DNA Template** to the **Rishic Shield Family of Consciousness** through which we entered the **Time Matrix.** While the Maharic Shield holds our original **Perfect Organization of Consciousness,** the Scalar Shields upon which our lower dimensional **Hova Bodies** and **Incarnate, Soul** and **Over-Soul Manifestation Cycles** emerge often become **distorted** from their original **Primal Order** as held within the **Maharic** and **Rishic Shields.** Human consciousness, in its multidimensional forms, was designed **"in the image of its Creator"**, having **Free Will** to *apply the dynamics of energetic creation in time* in accordance with **personal intention,** within the greater context of the fixed **Natural Energetic Laws of Creation.**

When we use our gift of **Free Will** to direct our energies in a manner **congruent** with the **Divine Right Order** of **Universal Unified Field Physics** (which implies co-creative, not competitive co-evolution for all), the scalar-wave design of our personal **Scalar Shields** remains organized upon the intrinsic design of universal and personal **Primal Order.** Through **embodiment** of Divine Right Order within our personal **Scalar Shields** and consciousness, we know conditions of **perfect health and harmony** within the Time Matrix. When our Free Will is used to direct our energies in ways that are **incongruent** with and non-supportive of **Primal Order,** the **disorganization** of our energetic orientation manifests as literal **Partiki Phasing Sequence distortions** that create **misshapen scalar-wave groupings** within the anatomy of the personal **Kathara Grid, Scalar Shields** and the **DNA Template** built upon them. These misshapen scalar-wave groupings within the Kathara Grid, Scalar Shields and DNA Template are called **MIASMS** and they hold, in **tangible scalar frequency** form, the **disorganized energetic patterns** of our **Free Will choices** through which we have used our energies in a manner **incongruent** with **Divine Right Order.**

Miasms* are the *tangible substance* of our *Karmic Pattern* that reflect the areas in which our *consciousness* and *Scalar Shields* are *distorted* from our original *Maharic Shield Christos Imprint* of *Perfect Organization* within the context of *Universal Primal Order.

TIME VECTORS AND THE KARMIC-MIASMIC IMPRINT

Miasms, Incarnational Time Vectors, Vector Imbedding and the DNA Template

The **Miasmic Imprint** within the body and Manifestation Template that holds the personal **Karmic pattern** manifests as **mathematical, geometrical** and **electro-magnetic distortions** in scalar-wave forms within the Kathara Grid and Scalar Shields, that cause groupings of **Anti-particles** to build up within the **Particle field** of the physical and energetic anatomy. The build-up of **Anti-particles** within the Particle Field blocks the natural flow of energy and consciousness through the Kathara Level-3 **Diodic Points Grid**, and manifests as **malfunctions** within the **Partiki Phasing Programs** within the **Kathara Centers** of the Level-1 **12-Tree Grid** and within the **Signet Star Crystal Seals** of the Kathara Level-2 **Crystal Seals Grid.** The **3 Levels of the Kathara Grid** set the blueprint for manifestation of the **Scalar Shields, Hova Bodies, Chakra System** and **DNA Template. Miasmic distortions** in the **Kathara Grid** effect **every level of personal manifestation,** from the operation of the **physical genetic code** to the ability of consciousness to successfully embody within the physical form, to the potentials of **Transmutational Dimensional Ascension** and attainment of **Spiritual Actualization.**

Karma- the *Miasmic Imprint*- is a *biophysical phenomenon* of scalar-wave distortion that directly effects the *human DNA.*

The **Incarnations of SELF** that **simultaneously manifest** into incarnational cycles of divergent space-time placement within the 4 Densities and 12-Dimensions of Matter are all **directly interconnect** through the **Kathara Grid, Scalar Shields** and **DNA TEMPLATE.** The **Free Will choices** made by other manifestations of ourselves **concurrently existing** in other space-time locations and different manifest body forms, effect the function of our personal **Kathara Grid, DNA Template, conscious awareness** and **life experience. The choices WE make** in our present lifetime directly effect the **Kathara Grid, DNA Template, consciousness** and **life experience** of our **other-time incarnations.** The energetic connection between incarnations of the SELF is an immediate, **living connection** of energy and consciousness. Because our numerous simultaneous incarnations in time are directly, energetically linked to each other via the Kathara Grid and DNA Template, we literally **inherit Miasmic Buildup from each other** on a continual basis. When we make the choice to restore our personal **Imprint for Health,** our **Christos Imprint,** as held within our **Maharic Shield,** part of these efforts must involve **clearing the Miasmic Imprint** that is bleeding through into our personal Manifestation Template for the other incarnations of Self.

Each of our simultaneous incarnations in time represents one **SINGLE VECTOR CONSCIOUSNESS,** one portion of our **Eternal Identity** that experiences 3-Dimensional **linear evolutionary progression** along **ONE TIME VECTOR** (one cycle of Partiki Phasing Sequences). **Each Incarnate represents a TIME VECTOR.** The multiple Time Vectors of our Multiple Simultaneous Selves are literally **encoded** within core scalar-wave programs of our **DNA Template;** this is called **VECTOR IMBEDDING.** To fully heal our Body-Mind-Spirit system by restoring it to its **Organic Imprint for Health,** the **Maharic Shield Christos Imprint,** we need to clear the Miasmic Imprint from our other simultaneous incarnations as it is presently embedded within our DNA Template. **Transmuting the Miasmic Imprint that is embedded in our DNA Template to restore the original perfect Primal Order is called "Clearing the Karmic Pattern" or MULTI-VECTOR HOLOGRAPHIC RECODING.**

MULTI-VECTOR HOLOGRAPHIC RECODING

REGENESIS OF THE PERSONAL CHRISTOS

Restoring the Organic Imprint for Health and Clearing the Karmic-Miasmic Imprint

Literally all conditions of **dis-ease** in the human body and dis-harmony in the life experience, including the unnatural condition of **death** of the human body form, result from **Miasmic Distortions** within the embodied **Kathara Grid, Scalar Shields, DNA Template** and personal **Inner Templar Complex.** The natural state of **Universal Primal Order** is harmonious co-creative interrelationship of consciousness. Humans can progressively return to their natural condition of **Ordered Perfection** through **re-genesis**, or *re-creation*, of the **Organic Imprint for Health** – the **Maharic Shield Christos Imprint** – within the Kathara Grid blueprint of the personal Manifestation Template. **Regenesis of the Personal Christos** is a **Multi-Vector Endeavor,** involving clearing the karmic-Miasmic Imprint from a myriad of various simultaneous selves presently evolving in the Time Matrix. The **hard way** to clear the Miasmic Imprint is by **"walking the Karma"**, which means allowing progressive levels of the **Miasmic Imprint** to repeatedly **re-manifest** in the personal life experience, until the **proper application of Free Will choice** used in congruence with **Divine Right Order** becomes consciously apparent and the **"Right Choices"** are made to re-ordered the disorganized use of energy that caused the Miasm to form. In our present time, this approach to "clearing the Karmic Pattern" is no longer effective as a learning tool by which embodied consciousness teaches itself the etiquette of creation. **The Miasmic Imprint within the collective human species has grown so extensively that the core issues of misapplied Free Will that cause Miasmic Buildup can no longer be consciously identified, and the Miasmic Imprint continues to compound and amplify itself as the same errors of Free Will energy use are perpetually repeated and reinforced.**

The Karmic-Miasmic Imprint is an **ENERGY FORM**; a literal **construct of scalar-wave frequency** with its corresponding **Anti-particle Manifestation.** As a form of energy, the **Miasmic Imprint** can be dealt with **AS ENERGY, WITH ENERGY**, for the most expedient clearing, healing and realignment of the **Karmic Imprint.**

The **Karmic-Miasmic Imprint** manifests within the **causal level** of manifestation, the **3 Levels of the embodied Kathara Grid** of the **personal Internal Template Complex**, and from the Kathara Level the Karmic-Miasmic Imprint manifests as **misalignment** and **malfunction** within all levels of Body-Mind-Spirit system. To clear the Karmic Imprint **AS ENERGY, WITH ENERGY,** its disorganized scalar-frequency patterns must be realigned from the **Core Template Kathara Grids,** the **causal level** of miasmic manifestation. Restoring the **Maharic Shield Christos Imprint** to the personal **Kathara Grid** takes time and **precise applications of frequency re-ordering** in all levels of the Body-Mind-Spirit system. The first step to **Regenesis of the Personal Christos** is the **MAHARIC RECODING PROCESS.**

MULTI-VECTOR HOLOGRAPHIC RECODING

Recoding the Time Vectors of the DNA Template and the DNA Fire Codes

The process of regenerating the **Christos Imprint** within the **Kathara Grid** of the human body is a **MULTI-VECTOR** undertaking. A **Vector** is a **set cycle of vibrational-oscillation rhythm** that creates a **specific repeating Partiki Phasing Rhythm** and **Flash Line Sequence**. Each individual incarnate self in time holds within the electro-magnetic programs of its embodied **Kathara Centers** the precise **Partiki Phasing Rhythms** that correspond to its particular placement within the planetary **Time Cycles**. The **Time Vector**, or **Flash Line Sequence** that creates one linear **Event Horizon**, is literally encoded and actively operational within the **Kathara Grid** and **DNA Template** of each incarnate identity. In the process of restoring the **Organic Integrity** to the personal Manifestation Template, the dormant **Partiki Phasing Rhythms** that correspond to one's **other-time incarnates** are progressively **brought into activation** and **realigned** with the Christos Imprint of the **Maharic Shield**.

The **Partiki Phasing Flash Line Sequence programs** within the embodied **Kathara Centers** manifest within the **DNA Template** as the **GENETIC TIME CODES**, or **Fire Codes**, of the DNA. In restoring **Maharic Order** to the personal **Kathara Grid**, the **12 Dormant Fire Codes** of the DNA Template will be slowly but progressively brought into **activation** through the 11th-12th –Dimensional Frequencies of the **Maharic Shield Mahara Hova Body Current**. Activation of the **DNA Fire Codes** creates a reciprocal release of the **Signet Star Crystal Seals** and **Cranial-Sacral Kundalini Seals** within the **Kathara Level-2 Crystal Seals Grid**, progressive activation of the dormant **Kundalini energies** and **Merkaba Vehicle Phases**, merger of the **Hova Bodies** and embodiment of the higher dimensional **Spiritual aspects** of conscious awareness. The process of recoding the multiple time vectors within the DNA Template – **Multi-vector Holographic Recoding-** is a process of progressive **WHOLE-BEING HEALING** that is achieved through **consistent application** of the **MAHARIC RECODING PROCESS,** and expedited through complimentary processes of **DNA Template, Kundalini** and **Merkaba Vehicle** activation. Level-1 Kathara Healing introduces the operational mechanics of the **Maharic Recoding Process.**

The Maharic Recoding Process

FOR MULTI-VECTOR HOLOGRAPHIC RECODING

The 4 Primary Elements of Action

1. **The Maharic Seal and the Liquid Light Cleanse** (Technique # 2)
2. **Opening the Healing Channels** (Technique # 3)
3. **Amplifying Inner Audio-Visual and Kathara Scan** (Technique # 4)
4. **The Maharic Infusion** (Technique # 5)

The 4 Primary Elements of Action to begin the **Maharic Recoding Process,** through which **Multi-Vector Holographic Recoding** of the **Morphogenetic Field Manifestation Template** is achieved. Begins realignment of the Core Manifestation Template **Kathara Grid Levels,** the **Scalar Shields, Hova Bodies, Axi-A-Tonal Lines** and **DNA Template** with the **Primal Order** perfect scalar-wave pattern of the personal 12th-Dimensional Pre-matter Hydroplasmic **Maharic Shield-the Christos Imprint** and **Organic Imprint for Health.** Also begins activation of dormant **DNA Strand Templates, Kundalini** energies and the **Merkaba Vehicle** for **Transmutational Dimensional Ascension.**

Bio-Regenesis of the Christos Imprint and 12-Strand DNA Template within the human body.

TECHNIQUE # 4

AMPLIFYING INNER AUDIO-VISUAL AND KATHARA SCAN

1. Place **RIGHT palm** (*electrical-transmitting hand*) over the **5th Kathara Center** at the **Navel**, and place the *Left palm* (*magnetic-receiving hand*) over the *back of the right hand* (to block 3rd-Dimensional energies from entering the rear of the right hand chakra). **INHALE** energy from your **Maharic Shield** – the *Maharic Carrier Wave*- into your **Doradic Sphere** at the *4th Heart Chakra*. **EXHALE** and run the *Maharic Wave* down the *Doradic Cords* in the arms and into the *Doradic Balls* in the palms. Inhale, then **EXHALE**, using the exhale breath to *push* energy from the *Doradic Sphere*, down the *Doradic Cord* in the RIGHT arm, through the **RIGHT Doradic Ball** and into the **5th Kathara Center** at the *Navel*. Run several breaths of *Doradic-1 Current* into the *5th Kathara Center* at the Navel, until a **mild tingling sensation** is felt.

2. Place the **LEFT palm** over the **5th Chakra** at the *Throat*, with the *Right palm* covering the *back of the LEFT hand*, and **INHALE** the Doradic-1 Current up from the *5th Kathara Center* at the Navel, into the Seed/Center of the **5th Chakra**. **EXHALE** and *expand* the Doradic-1 frequency into the *5th Chakra spiral*, allowing the magnetic current from the LEFT hand to draw the energy out through the spiral. As you **EXHALE**, slowly **move the hands forward**, away from the body and the **5th Chakra**.

3. Repeat the same process over the **6th Kathara Center**, placing the **RIGHT palm** over the *6th Kathara Center* below the **Right Shoulder**, with the *Left palm* covering the back of the *RIGHT hand*. **INHALE**/Draw energy up from the *Maharic Shield*, into the *Doradic Spheres*. **EXHALE** energy down the *Doradic Cords* into the *Doradic Balls*. Inhale, then **EXHALE** energy down the *RIGHT Doradic Cord* through the *RIGHT palm* and into **Kathara Center 6**. Run several breaths to energize the *6th Kathara Center*. Then move **LEFT palm** over the *6th Third Eye Chakra* in the forehead, with Right palm behind. **INHALE** the Doradic-1 Current from the *6th Kathara Center* into the Seed/Center of the *6th Chakra* and **EXHALE** the energy into the 6th Chakra spiral while drawing it through with the magnetic current from the LEFT hand. The **6th Sense-*Audurea***, which provides **inner audio** perception, and the **7th Sense-Tristet**, which provides **inner visual** perception are now energized and amplified in preparation for **Kathara Scan**.

4. Close your eyes and focus your attention in a **single point** at the *inside of your forehead*. Inhale, and as you **EXHALE** run your attention outward *through your 6th Chakra spiral*, into the **6th Chakra Spiral of your Client**. Move your attention into the center of your Client's brain, the **Pineal Gland**. Inhale, and **EXHALE** moving your awareness down from the Client's Pineal, through your *Client's Central Body Current* and down into the **Earth's core**. **INHALE** and move your awareness back upward to your **Client's Maharic Shield**, and spread your awareness outward through the *Maharic Shield* with the **EXHALE**. On the *inside of your forehead*, imagine the image of the **Kathara 12-Tree Grid**, **INHALE** energy from the *Client's Maharic Shield* and **EXHALE** the energy out into the *12-Tree image*. Breathe gently for a moment, *observing the 12-Tree Grid*, which will register tones of white, black and ranges of gray in between. If you cannot yet visualize, you will still get a sense of the 12-Tree image and the areas of dark and light within it. The dark areas represent layers of the **MIASMIC BODY**, areas of the *karmic imprint* that need clearing when you run *Technique # 4: The Maharic Infusion*. Remember the areas of the Client's Kathara that need clearing. Inhale, and *open your eyes* on **EXHALE**.

SYMBOL SHORTHAND

TECHNIQUE # 4: Amplifying Inner Audio-Visual and Kathara Scan

Activate Maharic Seal and Open Healing Channels. (Techniques # 2 and # 3 first)

1. **RIGHT Palm** on **5th Kathara Center** in **Navel.** Breathe **Maharic Current** up from personal **Maharic Shield** and into **Doradic Sphere** at **4th Chakra.** Push **Maharic-Doradic-1 Current** down **Doradic Cords** and into **Doradic Balls** at **Palm Chakras.** Push Current from Doradic Ball in **RIGHT Palm** into **Kathara Center # 5** in **Navel.**

2. **LEFT Palm** on **5th Throat Chakra**, cover back with **Right Palm** (Reverse Standard Hand Position). Inhale **Doradic-1 Current** up from **5th Kathara Center** in **Navel** to center of **5th Throat Chakra** and expand Current into **5th Chakra Spiral**, with **Left Palm Chakra** drawing current out of **5th Chakra Spiral.**

3. **RIGHT Palm** on **Kathara Center # 6** below **Right Shoulder**, cover back with **Left Palm.** Push **Maharic-Doradic-1 Current** from Doradic Ball in **RIGHT Palm** into **Kathara Center # 6. LEFT Palm** over **6th 3rd Eye Chakra**, cover back with **Right Palm** (Reverse Standard Hand Position). Inhale **Doradic-1 Current** up from **Kathara Center # 6** to center of **6th- 3rd Eye Chakra** and expand Current into **6th Chakra Spiral**, with **LEFT Palm Chakra** drawing Current out of **6th Chakra Spiral.**

4. **KATHARA CLIENT SCAN: A.** Place **Point of Attention** inside **forehead** and run attention out of **6th Chakra Spiral** and into the **6th Chakra Spiral of Client**, then into **Client's Pineal Gland. B.** Run attention down **Client's Central Vertical Current** and into **Earth's Core**, then back up to **Client's Maharic Shield.** Expand attention out into **Client's Maharic Shield. C.** Visualize image of **Kathara 12-Tree Grid,** inhale energy from **Client's Maharic Shield** and exhale it into image of **Kathara Grid. D.** Observe for **Dark Miasmic Buildups** in image of **Kathara Grid;** run extra healing Current into these areas of the **Client's Kathara Grid** during the **Maharic Infusion** (Technique # 5).

Personal Kathara Scan: On **Step 4** run attention down **your Central Vertical Current** then back up to **your Maharic Shield** and out into **your Maharic Shield.** Breathe energy from your Maharic Shield into image of **Kathara 12-Tree Grid** and observe for **Dark Miasmic Buildup** areas to clear during the ***Maharic Seal and Liquid Light Cleanse*** technique. Send **extra Maharic Current** to these areas during ***Liquid Light Cleanse.***

TECHNIQUE # 4: Amplifying Inner Audio-Visual and Kathara Scan

1. A. RIGHT Palm on 5th Kathara Center in Navel. B. Breathe Maharic Current up from personal Maharic Shield to Doradic Sphere and down Doradic Cords to Palm Chakras. C. Push Current from RIGHT Doradic Ball into 5th Kathara Center.

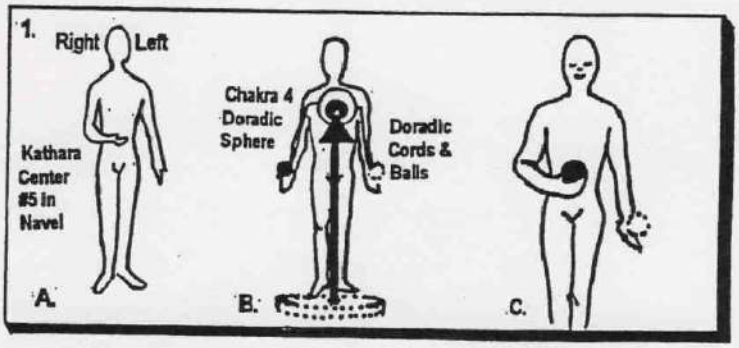

2. A. LEFT Palm on 5th Throat Chakra, cover back with Right Palm. B. INHALE Doradic-1 Current up from Kathara Center # 5-Navel to 5th Chakra and expand Current into 5th Chakra Spiral.

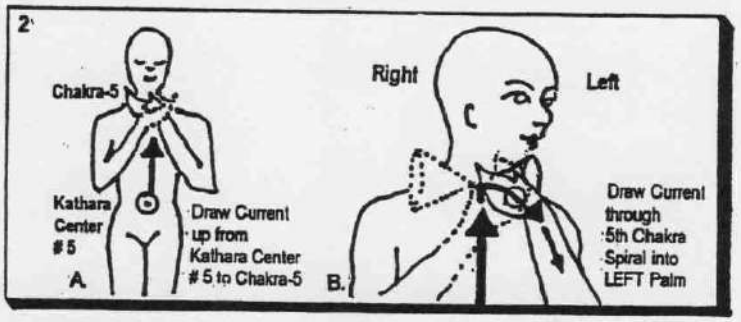

3. A. RIGHT Palm on Kathara Center #6 in Right Shoulder, cover back with Left Palm. B. LEFT Palm on 6th 3rd-Eye Chakra, INHALE Current from Kathara Center # 6 into 6th Chakra Spiral and into LEFT Palm. C. Kathara Scan: a. Run your Attention from your 6th Chakra to Client's 6th Chakra and Pineal Gland. b. Run Attention down Client's Central Vertical Current to Earth's Core & into Client's Maharic Shield. c. EXHALE energy from Client's Maharic Shield into Image of Kathara 12-Tree Grid. d. Scan grid for Dark Areas of Miasmic Buildup for clearing with Maharic Infusion.

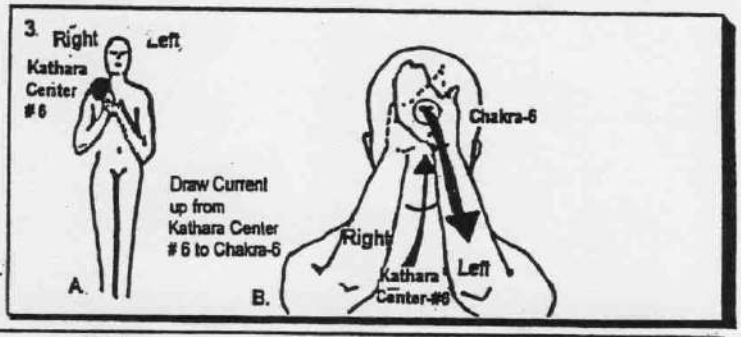

KATHARA SCAN

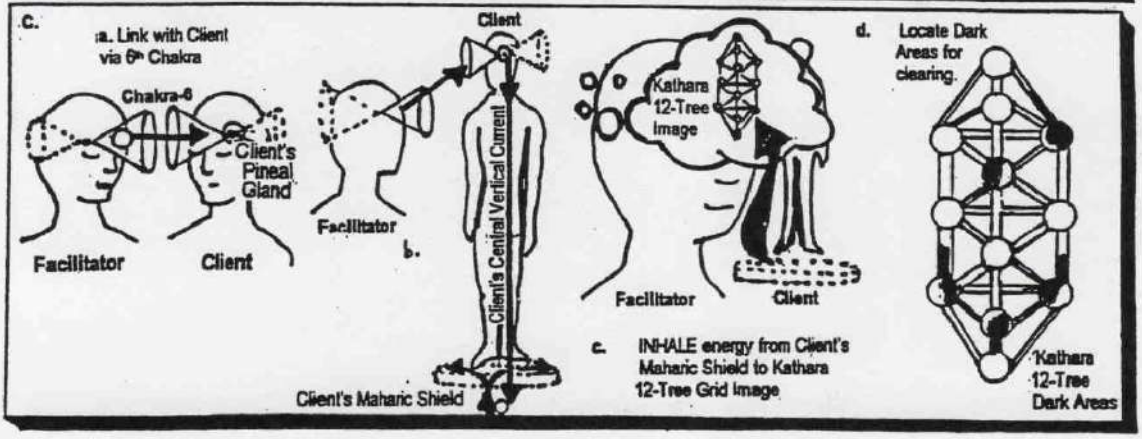

TECHNIQUE # 5

THE MAHARIC INFUSION – CLIENT FACILITATION

Prior to using this technique you should have completed the following: 1.Positioned *MENTOR* over your Right shoulder to assist (*Tech. # 1:Awakening the Mentor and the 6th and 7th Senses*). 2. Activated your *Maharic Shield, Maharic Seal* and run the *Liquid Light.* (*Tech. # 2: The Maharic Seal and the Liquid Light Cleanse.*) 3.Activated your *Doradic Current, Inner audio\Visual* and *Client Kathara Scan* (*Tech. # 3. and # 4)*
4. Opened the *Kathara Lines* for you and your Client (*Sequence-1 Kathara Points*)

Place Client in a reclining position with shoes off:

1. Position yourself at the **feet** of the reclining Client. Place **RIGHT palm** *12" below Client's feet* at the **Maharic Shield**, *left palm* over the back of Right hand.

2. Visualize the **Hierophant symbol** on the *inside of your forehead.* Inhale, then **EXHALE,** moving the *Hierophant* down to **Chakra 4** and into the **Doradic Sphere** with the exhale breath. **INHALE** energy upward from *your* **Maharic Shield** and into the *Doradic Sphere*. **EXHALE** the **Hierophant** with *Doradic-1 current* down the **Right Doradic Cord** and into the *Doradic Ball* in the **Right palm.** .

3. Inhale, then **EXHALE** the *Hierophant and Doradic-1 current* into the *center* of the **Client's Maharic Shield**. Visualize the *Hierophant spinning* in the center of the Client's Maharic Shield until you sense a **mild shift** in the energy below the Client's feet. The shift indicates that the Client's *Maharic Shield* has activated and the *Maharic Pillar* has "popped" vertically upward from the Shield – the Client's bio-energetic field now carries the **Maharic Seal.**

4. **INHALE** energy from your *Maharic Shield* into your *Doradic Sphere*, then **EXHALE** the energy down **both Doradic Cords**, into the Doradic Balls in the palms. Visualize the **12-Tree Kathara Grid** *within the Client's body*. You will now run the **Maharic Infusion** through the *small chakra points in the feet.*

TECHNIQUE #5 : Continued
THE *MAHARIC INFUSION*

5. Place your **Right palm** on the *bottom* of **Client's Left foot** and your **Left palm** on *top of the foot,* centered over the *Right palm*. Imagine that you are lining up the *small vortex* beneath the ball of the Client's foot (which extends *through the foot* to come out on top), with the *small chakras* in your *palms*. Inhale, then **EXHALE** energy from your **Doradic Sphere** through the **Right Doradic Cord, Right palm** and *into the* ***sole*** *of the Client's foot.* Visualize the **Green-Violet-Silver energy** traveling up the **Kathara Line on the** *Left side of the body,* through the *4th, 7th and 10th Kathara Centers*. Continue **EXHALING** energy into the **Left foot** until you begin to feel a bit of **fuzzy energy** coming out of the foot toward your palm. This indicates that the *Kathara Line* has *reached its energy-holding capacity*. **Repeat** the process on the **Right foot**, running energy through the *Kathara Line on the Right side of the body and the 3rd, 6th and 9th Kathara Centers*.

6. You will now clear and align the **Central Vertical Kathara Line** to complete the **Maharic Infusion**. **Move to Client's head**. Place **Right palm** over **Client's 10th Chakra** 6" above the head, the location of the *12th Kathara Center*. Place *Left palm* over back of Right hand. **INHALE** energy from your **Maharic Shield** into your **Doradic Sphere** then **EXHALE** energy down the **Right Doradic Cord**, into the **Right palm** and through the **10th Chakra**. Visualize the energy moving down from the *10th Chakra* into the **7th Chakra**, to the **Pineal Gland** (11th Kathara Center), then *rapidly* down the **Central Body Current** and **Central Kathara Line,** through *Kathara Centers 8* (thyroid), *5* (Navel), *2* (at Base Chakra) and into *Kathara Center 1* at **Earth's core**. Continue **EXHALING** energy into the **10th Chakra** and **Central Kathara Line** until you feel **fuzziness** against your *Right palm*, indicating that the *Kathara Grid* has reached its *energy-holding capacity*.

7. *Before releasing 10th Chakra* direct a bit of additional energy through the **Central Kathara Line** into areas that revealed **dark spots** during the *Kathara Scan*. Visualize the areas *getting light* as the energy runs through them. **You may add other healing modalities at this point, if desired.** *Close* by using the **Sequence-2 Kathara Points** to close the Kathara Lines and *revitalize the body.* Allow Client a few moments to recline before ending session.

SYMBOL SHORTHAND

THE MAHARIC INFUSION – CLIENT FACILITATION

Preparation: A. *Technique #1*- Place MENTOR over your Right Shoulder B. *Technique #2*-Activate your Maharic Shield and run Liquid Light Cleanse. C. *Technique #3*- Activate yourDoradic-1 Current D. *Technique #4* – Amplify Inner Audio-Visual and run Client Kathara Scan E. *Sequence-1 Kathara Points* massage on Self and Client to open Kathara Lines.

Place Client in reclining position with shoes off

1. Stand at Client's feet, place **RIGHT Palm** 12" below Client's feet at **Client's Maharic Shield**, left palm over back of Right hand.
2. See **Hierophant Symbol Code** inside your forehead, **EXHALE** Symbol down to **Chakra-4 Doradic Sphere. INHALE** energy up from your **Maharic Shield** into Doradic Sphere. **EXHALE** *Hierophant Symbol* with *Doradic-1 Current* down **RIGHT Doradic Cord** into **RIGHT Doradic Ball in RIGHT Palm.**
3. **EXHALE** Doradic-1 Current and Hierophant Symbol into Center of **Client's Maharic Shield** via **Right Palm Doradic Ball** and **spin Hierophant** until sensed **Energy Shift** of **Client's Maharic Seal.**
4. **INHALE** Current from your Maharic Shield to Doradic Sphere and **EXHALE** Current down both **Doradic Cords** into **Doradic Balls.** See **Kathara12-Tree Grid** within **Client's body** and begin running the ***Maharic Infusion*** through the **Secondary Chakras** in **Client's feet.**
5. **RIGHT PALM** on **bottom** of **Client's LEFT FOOT, LEFT PALM** on **top** of **Client's LEFT FOOT,** both **centered** over Client's LEFT FOOT **Secondary Chakra. INHALE** Maharic energy into Doradic Sphere and **EXHALE** Doradic-1 Current into Client's **LEFT KATHARA LINE,** and through **Kathara Centers # 4, #7** and **# 10. EXHALE** Doradic-1 Current into Client's **LEFT FOOT** until **"Fuzzy"** resistance emerges from Client's foot Chakra. **REPEAT PROCESS** on **Client's RIGHT FOOT,** running Doradic-1 Current through the **RIGHT KATHARA LINE** and **Kathara Centers # 3, #6** and **#9.**
6. **Stand at Client's Head. RIGHT PALM** over **Client's 10th Chakra** (6" above head- the 12th Kathara Center), LEFT Palm over back of Right hand. **Fill** Doradic Sphere with Maharic Energy then **EXHALE** Doradic-1 Current down **RIGHT DORADIC CORD** and Palm and into **Client's 10th Chakra.** Run Current from **Chakra-10,** to **Crown Chakra-7, Pineal Gland,** rapidly down **Central Vertical Current** and **Kathara Centers #8** (Thyroid), **#5** (Navel) **#2** (Chakra-1) and **#1** (Earth's Core Chakra 13). Continue exhaling Current until **"Fuzzy"** resistance emerges from **Client's 10th Chakra.**
7. Direct **additional energy** through Client's **CENTRAL KATHARA LINE** to clear **DARK AREAS** of **Kathara Grid** located in **Kathara Scan.** Add any additional healing technologies following Client's Maharic Infusion. Close with **SEQUENCE-1 KATHARA POINTS massage. Allow** Client to remain relaxed in reclining position for several minutes following Maharic Infusion.

TECHNIQUE # 5: THE MAHARIC INFUSION – CLIENT FACILITATION

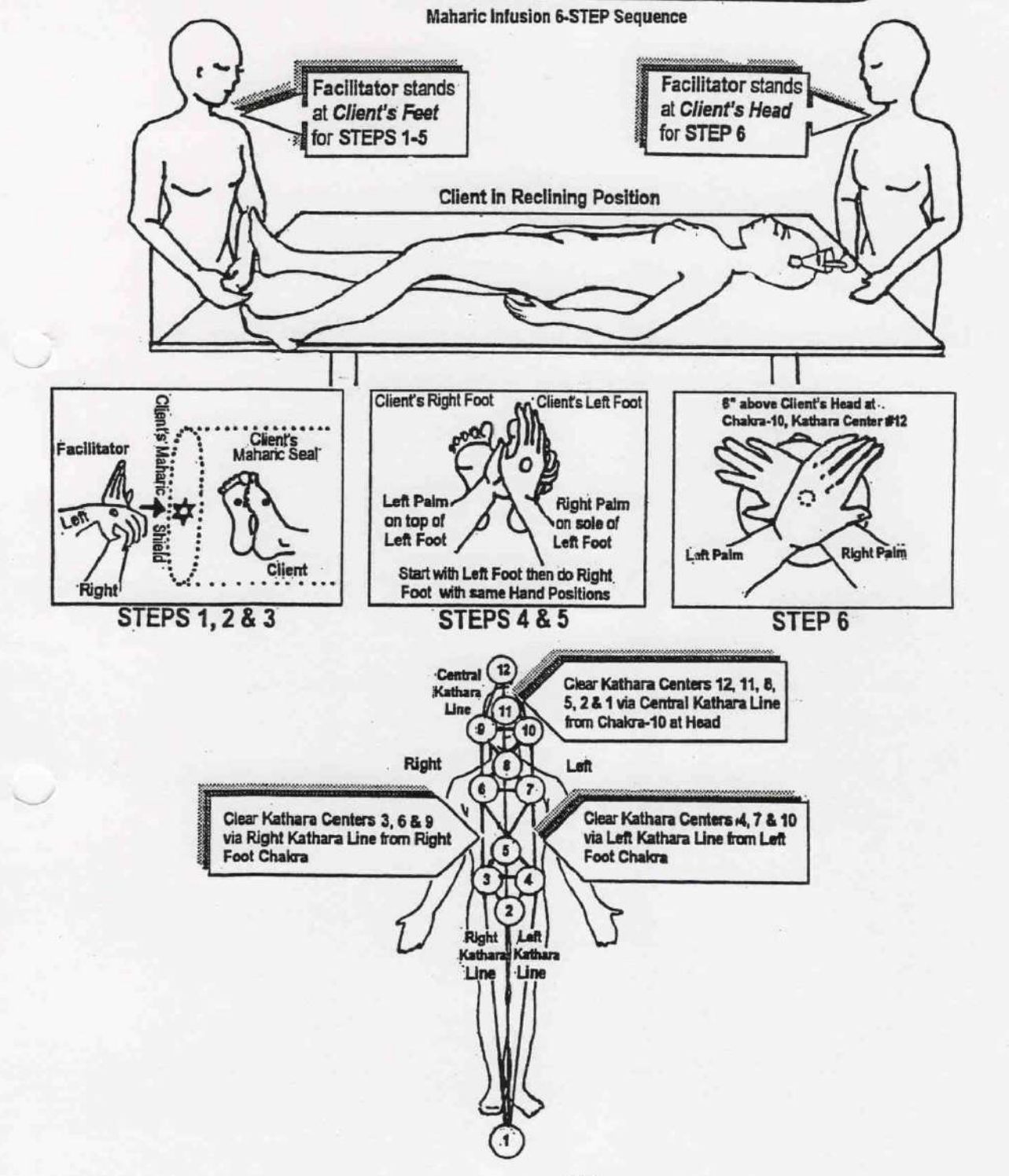

MOTIVATION TO HEAL

Healing Facilitation is an art and a science, but most importantly, healing facilitation is an **interrelationship of SOULS.** Egotistical objectives have no place in quality Healing Facilitation. The decision to participate in Healing Facilitation should not be motivated by a desire to prove you have "special abilities" to boast about, nor with the primary motive of gaining **financial profit** from Healing Facilitation endeavors. The energies exchanged in healing facilitation are **FREE TO ALL**, a **DIVINE GIFT** from the universe, and they belong to all beings equally. A facilitator cannot rightly request payment from a client for providing what the client already possesses- **Natural Healing Energies.**

In Divine Order, it is appropriate for the facilitator to accept **payment** for the **personal time and energies** invested in **learning and developing facilitation skills,** and for the time spent in active facilitation. It is important that the facilitator understands this subtle difference of **"fair exchange of energy"**. If the facilitator mistakenly assumes they are requesting payment **for healing energies** they supply, they are inadvertently misrepresenting themselves to the client. The client possesses personal healing energies and does not need to purchase such energies from others. The **time and expertise** offered by the facilitator to assist the client in stimulating their own healing energies, is a service worthy of reciprocation. If a client chooses such assistance, the **facilitator** has **legitimate right** to honor their own worth as a being by **requesting reasonable payment or barter** in **fair energetic exchange** for the service they offer. However, if a client is in need of healing facilitation, and has no means of fair exchange at that time, the facilitator should honor the worth of the client by providing assistance of equal value **free of charge.**

In spiritual principal, "making money" is not a legitimate motivation for participating in Healing Facilitation. Seeking to find one's personal **"Divine Right Livelihood"** in **sincere service** to others, which might possibly involve providing client service in Healing Facilitation, IS a spiritually legitimate motivation. Healing Facilitators will discover that when they put the objective of **GENUINE SERVICE TO THE DIVINE** as the **first Priority**, rather than the pursuit of personal monies or status, the **Universe Will Provide.** Facilitators who enter the healing field with hidden personal motivations incongruent with **Universal Laws of Energy**, which imply **equality, respect, reverence** and **balanced exchange of energy** between all beings, will find difficulties emerging in their lives as the personal **SOUL** sets up lessons through which **Universal Principles** become more apparent. There is only **ONE TRUE MOTIVATION** for participation in Healing Facilitation- **the motive is LOVE.**

POSTURES OF LOVE

The Energy-Reality of LOVE

In terms of **Universal Physics**, Love is an **energy reality**, a **STATE OF VIBRATIONAL HARMONIZATION**, or **CO-RESONANCE OF FREQUENCY** that allows an **energetic bridge** to build between individuals. It is through this energetic bridge of frequency that one can assist in running healing energies that will facilitate the healing process of others. Without the sentiment and **FREQUENCY** of **GENUINE LOVE**, one cannot energetically facilitate the healing of another. **LOVE is the essential ingredient in healing,** for it allows the opening of facilitator and client's bio-energetic fields to the **Universal Frequencies** of the interdimensional spectrum. Cultivating the ability to embrace and hold the frequencies of Universal or **OMNI-LOVE** is the responsibility of any true healing facilitator. The emotionally experienced reality of the ***frequency of Love*** takes many forms. In healing facilitation it is important to **assess the most appropriate form of love** to engage with each individual client

Soft Love

Many people respond well to **"SOFT LOVE"**, the kind, gentle, nurturing, soothing love often displayed by mother's comforting their infants. Soft Love works well with client's whom possess some degree of spiritual maturity and who have cultivated the ability to hold some degree of a love frequency within themselves. Soft Love is the appropriate form of love for client's possessing the maturity to accept personal responsibility for themselves, their actions and their emotional reaction patterns, and who do not attempt to manipulate, drain energies from or place blame on others. Soft Love is characterized by **engaged detachment** of the facilitator and is demonstrated through soft-spoken, calm and sincere words and actions that are intended to place the client at ease.

Soft Love is always built up sincerity, kindness, respect and a genuine desire to see the client thrive and prosper. Developing the ability to carry the Soft Love frequency takes time, attention and practice, and requires that the facilitator works to heal personal **internal conflicts**, unresolved issues from **childhood** and **karmic** reaction patterns that disrupt the Soft Love vibration. Soft Love is a **vulnerable love** in that it necessitates one to show the self as it is, honestly expressing personal feelings tempered with kindness. Soft Love is **not approval seeking**, it is rather genuine, honest and **self-generated**. Soft Love requires **love** and **respect** of the self and others mutually. It is built upon a level of spiritual maturity in which it is understood that personal value is implied by the fact of existence and is not determined by the approval or **validation** of others outside of the self and the personal relationship to the Divine. The ability to carry the Soft Love frequency emerges through **spiritual integration, personal healing** of internal conflicts and power struggle issues and **intentional application of kindness and mindfulness.**

Tough Love

Soft Love does not facilitate healing on all occasions. Certain clients who come to a facilitator for healing assistance bring with them a great need for **emotional healing** and development of spiritual maturity. They may demonstrate demanding, arrogant or pushy attitudes and refuse to accept responsibility for their personal actions and resulting consequences. Most often such individuals carry deep wounds from childhood or from reincarnational bleed-through. Because they are **wounded within**, they have not yet developed the self-control or maturity necessary to treat themselves or others with kindness, respect or love.

Individuals who display unreasonable behaviors or attitudes pose quite a challenge to the love-based healing facilitator. If they are approached with Soft Love, the facilitator will often find themselves as a scape goat for the individual's personal problems, may have their energies and time excessively **drained** by such clients and might possibly be subjected to outright verbal or physical **abuse**. Clients exhibiting such personality traits are struggling within themselves to **gain control** over the various **conflicting portions** of their personal energies, and they tend to objectify this internal conflict resolution in the form of **POWER STRUGGLE** with others.

Personalities trapped within cycles of subconscious self or other-abusive attitude patterns need **love** more than anyone, but most often their behaviors push others away. Intrinsically the behaviors serve to keep the individual sheltered from **self-exposure;** they do not allow others close enough to inspire feelings of vulnerability or lack of self-esteem. Often such personality traits effectively keep the individual from seeing themselves and the inner pain and conflict from which they attempt to hide. To facilitate healing in such individuals without succumbing to their manipulation, aggression or abuse requires that the facilitator adopt a posture of **TOUGH LOVE.** In Tough Love the facilitator clearly establishes **personal boundaries** in their own mind as to what treatment they will and will not accept. If the client crosses those boundaries the facilitator **assertively addresses the issue** with the client, requests that the offensive behavior cease and provides **CLEAR CONSEQUENCES** as to what will occur if the offense continues. The Tough Love approach is rendered from a base of **Soft Love** and **Omni-Love**, but it is strengthened with **Self Love** on behalf of the facilitator. The facilitator recognizes that they are only assisting the client to continue with the self-destructive patterns by condoning or allowing offensive behavior, and chooses to **love the client enough** to **confront the pattern** so that it may begin to release. In **lovingly, calmly**, but **firmly confronting** poor behavior and **setting clear boundaries** and **consequences**, the facilitator assists such clients to temporarily find a new pattern of action because the old one does not work for manipulation in this instance. The Tough Love approach frequently requires facilitators to demonstrate that they hold their own power, even in the face of client disapproval. Tough Love is an ability of **personal empowerment** worth cultivating for personal and client healing.

Self Love

In healing facilitation **Love** is the essential ingredient. All love begins with the **Divinity Within the SELF.** You will be able to transmit the frequency of love to others in direct proportion to your ability to hold the frequency of love within yourself. If you do not recognize your intrinsic value as a **Divine Being** and seek validation of your existence through external sources such as achievements, status or other-approval, you will likewise project these sentiments into your love relationships with others. If a client does not meet the external standards of validation that you have placed on yourself to determine your personal worthiness of love, you will have difficulty not falling into **judgement** of the client.

Judgement and **love** cannot transmit through the human body at the same time. Judgement creates an **energy reality** of separation or **Non-Resonant Frequencies** of energy, whereas Love creates the **Co-resonance of Frequencies** needed for open flow of Universal Energies for healing facilitation. If one can realize that **LOVE IS THE ONLY CONSTANT** and that all conditions of judgement change, it is easier to cultivate the innate ability to fully hold the frequency of Love. Though **ASSESSMENT** of conditions, actions or attitudes is useful and necessary, such assessment can be rendered through **"separating the person from the action".** You can judge the effectiveness or value of the **action or idea** without assigning a **value-judgement** to the **person** to which it is attached.

If the healing facilitator can feel love, reverence, respect and honor for the **Divinity Within Themselves**, they will also transmit these qualities of **excellence in Love** to the client. The quality of Love brought into the healing facilitation experience will directly effect the success of healing assistance given. **Love the Self** and know that all beings possess an **unalienable worth and value** as a living part of the **Divine.** Begin to cultivate this awareness within your personal life and you will greatly increase your effectiveness as a healing facilitator. Love, honor and respect yourself, your feelings, your dreams and your desires, so you may better love those you wish to serve.

Love others as you would love the Self,
and love the Self as you would like to love others.

The Illusion of Martyrdom

People who love themselves do not buy into the idea that they must play "**martyr**" to others in order to be of service. **Martyrdom** implies a belief that you are **lacking in worth,** or must **earn** your worth in being, by relinquishing that which feels of most value to you. It also **undermines expression of the God-Presence** within others, by assisting them to believe that you are so vital to their wellbeing that they cannot function without you. In truth, martyrdom is an **expression of EGO**, most often used by people who feel they are **personally insignificant** in the eyes of the Divine, in order to **give themselves significance** and a **sense of personal power and purpose** for being. People who actively *know* the intrinsic **Spiritual Divinity** within themselves treat that Divinity with honor and respect and do not allow or need others to **depreciate the Self** and its desires in order to prove the existence of a *belief* in personal Divinity.

Martyrdom **does not facilitate healing** within the self or client, as it reinforces the **erroneous belief** in intrinsic **personal unworthiness,** which exists in **direct contradiction** to the **innate God-Presence** that exists in every living thing. Within the energy dynamics of **Universal Law,** natural **balance** is achieved in the flow or **GIVING,** and back-flow or **RECEIVING** of energy. In human spiritual relationships this **balance of energy** is achieved by **mutually valuing** each person in a relationship, through which the natural giving and receiving of energy can be exchanged unimpeded. **Martyrdom impedes the natural flow of energy**; the martyr customarily gives more than receives, which progressively diminishes the martyrs ability to keep open a perpetual flow of energies from the Divine because the martyr does not allow the Self to receive.

Martyrdom is not a demonstration of Love,
it is an exhibit of Love Deprivation.
The remedy for Martyrdom is
OMNI-LOVE.

OMNI-LOVE: Fully Engaging the Love Vibration

The greatest love that can be embodied in human form is **OMNI-LOVE.** OMNI-LOVE is a pure state of vibrational Frequency Co-Resonance between the human identity and the **12 Dimensions** of reality within which the human anatomy is couched. Omni-Love is expressed in human form as **Christed Love** or **Christos Consciousness, the 12th-Dimensional Love** of the **Maharic Level of Identity.**

Christos Love is a state of full Frequency Resonance with **everything existing** in the many universes contained within **12 Dimensions** of the 15-Dimensional System. It is a **transcendent love** that is attached to no thing but is **AT ONE** with **ALL THINGS** in a state of perpetual **Engaged Detachment.** Through Christos-Omni Love, the **SELF** is known as an **extension of God**, or the **Divine Source**; a **temporary mask of form** worn by the **ONE CONSCIOUSNESS** of the Cosmos. All things and beings are known as **simultaneous expressions** of the **ONE-SELF** that is God-Source. From this state of transcendence in love, all activity is understood to **exist within** the reality of LOVE, and all conflict and strife are viewed as the ONE-SELF **progressively expanding the ability of its expressions** to **carry the frequencies of energy** that constitute **ONE-LOVE,** a state of **total vibrational Frequency Co-resonance** with the **Cosmos.**

Activation of the full **12-Strand Silicate Matrix DNA Template** and full integration of the **Mahara Hova Body Avatar Identity** allows for the experiential embodiment and transmission of Christos-Omni-Love. **Embodiment of Omni-love is the goal toward which human evolution moves forth.** Omni-Love is Soft, Tough, and Enduring, honoring **Self , Other** and the **Divine** simultaneously. It is the **strongest healing force** of frequency in the 4 Harmonics of Matter Density. Christos-Omni-Love is the **fulfillment** of the **Christos Principle**. Strive to bring Omni-love into your life, and personal and client healing facilitation, and you will assist your higher identity levels to create transformation! Omni-Love is the **natural structure** of reality. **AWARENESS** of Omni-Love is cultivated through **intention** and appropriate use of **personal free will choice** in congruence with the **natural Laws** of the **Unified Field Physics of Consciousness and Creation.**

Through living in Omni-Love all moments are known as Sacred, all beings are known as Blessed and life becomes an ecstatic study in Reverence for Existence.

Postures of LOVE

1. **SOFT LOVE**
KIND, NURTURING, **GENTLE**

2. **TOUGH LOVE**
KIND, NURTURING, **ASSERTIVE**

3. **SELF LOVE**
HONORING THE **DIVINITY** WITHIN **SELF**

4. **OMNI-LOVE**
HONORING THE **DIVINITY** WITHIN **ALL**
Namaste'

***Omni-Love** is the fulfillment of the **Christos Principle**, the goal toward which human evolution moves forth through progressive activation of the **12-Strand Silicate Matrix DNA Template** and embodiment of the **Avatar** Identity.*

OMNI-LOVE EXERCISE TO AMPLIFY HEALING FACILITATION

EXERCISE

The MAHARA SPACE-COMFORT TOUCH

1. **EXHALE Hierophant Symbol** from behind forehead, down *Central Body Current*, into **Earth's Core** (Chakra 13), then **INHALE** *Hierophant* back up to your **Maharic Shield** 12" below feet. *Spin Hierophant* to *activate* **Maharic Shield** and **Maharic Seal Pillar. INHALE** energy up from your *Maharic Shield* into your **Doradic Sphere** at *Chakra 4.*

2. Breathe slowly and deeply while visualizing a **small faceted Crystal Sphere** in the center of your *Doradic Sphere* at Chakra 4. This is the **Holographic Crystal Sphere**; it represents the station of your inner **AVATAR** identity – this is the **MAHARA SPACE.** Focus your consciousness within the *Holographic Sphere* and feel its reality around you, as if your body is encased within the Holographic Sphere.

3. Observe the interior of the Sphere as a **pale Silver-White mist.** Within the mist now envision a **golden treasure chest**- a treasure you had left for yourself long ago to one-day reclaim. This represents your **Inner Arc of the Covenant** – *a doorway to reclaiming your ancient immortal heritage.* **Mentally command** the lid of your inner *Arc of the Covenant* to lift. As the lid rises **pale rainbow colored light** fills the interior of your Holographic Sphere. Notice now that within the golden box there is a gleaming **Silver Sword**, the Silver Rod of Power that will enable you to more quickly evolve to your eternal state of being.

4. Mentally make the **Silver Sword** *rise from the golden box*, floating above the box in a vertical position. Now call to mind the image of your **body** *as it sits within the physical room.* Imagine *the Silver Sword positioned above the body's head*, directly over **Chakra 7. EXHALE** and **steadily lower the Silver Sword** through the *7th Chakra and down the Central Body Current, through the Maharic Shield and down into* **Earth's core.** Observe the Silver Sword turn into a *Pillar of Pale Silver Light with pale rainbow colors flashing through it.* The **Rainbow Pillar** now *surrounds and runs through your body, raising its frequency while lowering its vibration*, lifting your body cells into a **less-dense state of matter.** Feel your body growing lighter and lighter as the Rainbow Pillar slows the spin-rate of your matter particles, making you more and more electric- more light.

5. As you feel the sensations of your density lessening, **imagine that your body is beginning to glow with Pale Silver light** – the *Pre-matter Liquid Light* of dimensions 10, 11 and 12. Feel the *features of your face and the contours of your body begin to melt* into a **Silver, 2 –dimensional fluid body form.** The form of the body still remains but it has been returned to its **first-density state**- the **Silver Liquid Light holographic form of the avatar identity.** Know yourself now as this avatar identity and feel the essence of **pure love** and eternity flow through you. **Know yourself as this essence of Divine Love and Eternal Light.**

6. Now **INHALE** and draw the **Rainbow Pillar into the Holographic Sphere** at *Chakra 4*, visualize the base pulling up from Earth's core and the portion above your head simultaneously *contracting into the Holographic Sphere.* **EXHALE** the energy of the *Rainbow Pillar* fully into the *Holographic Sphere* and observe the **Holographic Sphere become a radiant Silver ball of Liquid Light stationed with your Doradic Sphere** in the Heart Chakra.

EXERCISE: Continued
THE *MAHARA SPACE-COMFORT TOUCH*

7. **You may now transmit the frequencies of the 4th-Harmonic, dimensions 10, 11 and 12, to serve as a healing force for others.** You may transmit this energy into your environment directly through the **4th Heart Chakra**, where it will enter the Unified Field at the 4th-Dimensional astral plane. You may use the breath to move the Holographic Sphere down into the **3rd Chakra** *for 3rd-Dimensional transmission* into the *Earth's atmosphere* and the *Mental Body* levels of people's Bio-energetic field. You may transmit through **Chakra 2** into the Telluric or *Elemental Kingdom* of the planet and into people's 2nd-Dimensonal *Emotional bodies*. Or you may transmit the frequencies of the Silver Sword through the **1st Base Chakra**, for *sacred bonding in intimate relationship*, or to *raise the frequency and lower the vibration* of the *molecular and sub-atomic fields* around you. To transmit the frequencies of the Silver Sword through the chakras, simply use the **EXHALE** breath to move the Silver Light "charged" **Holographic Sphere down** to lower chakras, inhale and use the next **EXHALE** to *push the frequency outward* from the selected chakra into the environment. Use the **INHALE** breath to move the *Holographic Sphere* up through the chakra system. *Always move the Holographic Sphere up or down along the* **Central Body Current**, *to which the core of each chakra is attached.*

8. **You may also transmit the frequencies of the Silver Sword through APPLIED TOUCH –** ***THE COMFORT TOUCH*** **-to amplify specific healing facilitation functions and to establish a more harmonious rapport with other people and the nature kingdoms.** Simply visualize the Silver Liquid-Light charged **Holographic Sphere** at the center of your **Doradic Sphere** in the **4th Chakra**. Activate your **Doradic-1 current** via the **Maharic Shield and Seal**, then visualize the *Silver Liquid Light from the Holographic Sphere combining with the Green-Violet-Silver Doradic-1 current* as you **EXHALE** the current into the **Doradic Cords** in the arms and into the **Doradic Balls** in the palms. *This application is especially useful to help Clients relax during sessions, or to comfort others when they are in a state of stress, unbalance or illness.*

   Once your current is moving into the Doradic Balls, **EXHALE** the current through the **Right palm.** *Place the Right palm gentle and briefly over the* **Client's rear Chakra 2**, *or touch them gently on the* **left shoulder.** The amplified *Doradic-1 current* will move into the 4th-*Dimensional astral-body field*, and move its way into the *mental, emotional and physical bodies* from there. **The COMFORT TOUCH of the MAHARA SPACE can be applied to infants, children, older persons, animals and plants to comfort them and support their general well-being.**

PROFESSIONAL USE OF THE KATHARA BIO-SPIRITUAL HEALING SYSTEM PROGRAM – THE KATHARA ALLIANCE

The Kathara System introduced in **The Kathara Bio-Spiritual Healing System ™ Level 1 Workshop & Course Manual with Introduction to The Kathara Bio-Healing System™ Level 2** is destined to become a ***12-level program*** that is focused on "whole-being healing through progressive biological and spiritual awakening". Kathara is as much a course on (non-denominational, dogma-free) **Spiritual Integration Mechanics** as it is a Holistic Healing course.

An individual completing training in the **Kathara Level-1 Bio-spiritual Healing System** delivered by a Certified Kathara Alliance Instructor, will receive a **Certificate of Completion**, which recognizes the person named as attending and receiving training in the Kathara Level One Bio-Spiritual Healing System.

If you desire to practise the ***Kathara Bio-Spiritual Healing System***™ in a regular, professional capacity through Client Service, you may use the techniques provided within this Kathara Healing Manual to begin. Prior to professional use, it is suggested that one becomes a Certified member of the **Kathara Alliance** through the ***Azurite Press MCEO (World-wide Consulate***) and its appointed representatives.

The **Kathara Alliance** is a group of dedicated spiritual healing Practitioners and Instructors who have demonstrated a thorough understanding of the Theory and Practice of the **Kathara Bio-Spiritual Healing System**™ and the Maharic Recoding Process, as deemed necessary by the **Azurite Press** for professionalism in the practice of Spiritual Healing Facilitation and Instruction.

All members of the ***Kathara Alliance*** are **Certified Kathara Healing Practitioners and Instructors,** and are permitted to practice Kathara Healing facilitation as **SPIRITUAL SERVICE.** For the protection of both Client and Practitioner, as well as the ethics inherent to the Teachings themselves, Kathara Healing is to be promoted, explained and practiced as **a non-diagnostic spiritual healing enhancement service only** and not as a replacement for traditional medical diagnosis or treatment.

Certification in the **Kathara Alliance** as an **Independent Spiritual Healing Practitioner and Instructor** of the **Kathara Bio-Spiritual Healing System**™ requires formal application, including a written open-book examination and video presentation by the applicant. The examination is intended to reveal areas in which applicants may need to further strengthen understanding of and personal relationship to the practice of Kathara Healing Facilitation and Instruction within the parameters of Excellence recognized as intrinsic by the Azurite Press MCEO.

All Instructors and Practitioners must be CERTIFIED to conduct **public presentation** of copyright materials contained in this, the authorized Kathara Bio-Spiritual Healing System Manual. To uphold standards of Professionalism and Excellence in practice, the Azurite Press MCEO **cannot** recognize **Non-Registered Facilitators or Instructors** as active participants in the ***Kathara Bio-Spiritual Healing System Program.*** Obviously, non-certified Facilitators may use this program and its applications for their own **personal and spiritual enrichment. The Azurite Press MCEO authorizes only Certified Practitioners and Instructors** to professionally conduct Client Sessions.

With regards to teaching the program there is a distinction between 'Teaching' and 'Sharing'. **Teaching** is defined as formal presentation of the materials (following protocols described in the **Kathara Bio-Spiritual Healing System™** Manual and communications to Kathara Alliance applicants and members) in the form of a seminar/ workshop and payment is made by attendees. To teach the Kathara Bio-Spiritual Healing System™, one needs to be a member of the **Kathara Alliance**. '**Sharing**' is defined as leading a study group where attendees are not expected to pay (it would not be inappropriate to accept small donations if offered). To share one does not need to be a member of the Kathara Alliance but group size should be limited to less than 12.

Within the **Kathara Bio-Spiritual Healing System™** there are specific pages for Kathara Alliance Instructors to use in their classes. The Instructors pages are identified by having a number at the *top* of the page (as well as the regular number at the bottom). These are the only pages that can be photocopied for teaching purposes. Only certified Kathara Alliance members (or a Kathara Alliance applicant who is delivering and recording a workshop for assessment purposes) are authorized to photocopy these pages.

The easy-reference **Instructor's pages** need to be sequenced in the order denoted by the number at the *top* of the page. These pages have been carefully sequenced to facilitate delivery and learning of the materials. Learners' needs, including varying learning style preferences, were very much considered when preparing the text and visual presentation of these teaching materials. In terms of frequency, the learning process can be described as when previously dormant Scalar Standing Waves in the personal shields are stimulated and activate('switch on'). As frequency is accreted (by progressive exposure to, and interaction with, the materials) the scalar waves in the personal shield self –sustain (we would say the person has 'learned' the material). The specific sequence of the pages are pre-set to create optimum frequency accretion in the personal shields of learners *even if this is not immediately perceived or understood by the learner.* Therefore it is imperative that these pages are used in the delivery of this program and the instructor remains true to the given sequence.

As Independent Spiritual Healing Facilitators and Instructors, all Certified Facilitators and Instructors are expected to accept full personal responsibility and legal liability for the practice and application of the **Kathara Bio-Spiritual Healing System™.** Certified Facilitators-Instructors are **not required** to pay dues, royalties or revenues to the Kathara Alliance/APMCEO for use of this program other than the cost of initial personal **Training-Registration** and obtaining supplies of **Session Manuals, Certificates and Registration Examinations** for the professional Instruction-Certification of others.

THE KATHARA ALLIANCE CERTIFICATION AND COMPETENCY REQUIREMENTS

The Certification Program is designed to enable the applicant to fully demonstrate his/her understanding of the material in a way that maintains the level of integrity and purity of the Program desired of the Kathara Alliance. This also ensures the Student attains a desired level of understanding in taking the workshop. The requirements of Certification are designed to protect the integrity of the material, those who participate with it, and the rights and responsibilities of all concerned.

Certified Kathara Practitioners and Instructors must not only be knowledgeable in the practice and teaching of Kathara, but are also asked to commit to the behavioral guidelines originating from the Covenant of Regent Consulate of the Melchizedek Cloister Emerald Order (MCEO). In this way those seeking out a Kathara practitioner can reasonably expect the highest integrity in both the teachings and in the individuals with whom they are relating.

Certified Kathara Alliance members are in no way affiliated with the MCEO Vehicle, the Azurite Press and should at no time state or imply such representation. Kathara Alliance members are independent Practitioners who offer local, community-based Kathara Healing Level courses and facilitation for individuals.

PLEASE NOTE: The APMCEO & Kathara Alliance **reserve the right** to **revoke** any Kathara Alliance Certification and Rights of Association of Certified Facilitator-Instructors for ***any*** reasons of: *Misuse, misrepresentation and false claims pertaining to this Kathara Program; inappropriate treatment of APMCEO staff, clients or participants in Kathara Healing Programs; dishonest or unethical behavior and practices, and racial, gender, or religious discrimination of clients and participants or Kathara Alliance Members.*

For further information on the Kathara Alliance certification process visit our website at http://www.azuritepress.com/kathara/kathara_application_proceedures.html or contact

In the U.S. and Canada: Sandy Sayles, 8527 Cool Water Ct., Antelope, CA 95843 - email - siepearl@comcast.net **OR** Melissa Fathman, 855 W. Dillon Rd, Apt. H306 - Louisville, CO 80027 - email - mfathman@yahoo.com

Rest of World Office: Hilary Lyons 341A Green Lanes, Palmers Green, London N13 4TY, U.K. hilary.lyons@virgin.net 07970770404

THE 6-STEP MAHARIC RECODING SESSION

Before Client Arrives: ***Technique # 1-*** Activate Your Mentor. Conduct ***Mahara-Space-Comfort Touch Exercise*** and remote-request permission from client's ***Rishi*** identity level to apply **Comfort Touch** when client arrives. Create a calm, pleasant environment where you will not be interrupted by phone or other distractions. Optional: Sing 3 rounds of the ***Ariea-Khum-Nar'A*** **toning** to amplify personal healing and DNA Template activation during healing facilitation session.

When Client Arrives: Apply Comfort Touch if Rishi gave remote permission. Sit with client and review terms of the ***Client Agreement Form*** and secure client's signature on form. Offer client the option of audio-taping the session for client's at-home review.

6-Step Technique Application Sequence- *Maharic Recoding Session*

1. Technique # 2-**The Maharic Seal and the Liquid Light Cleanse** *to seal and align personal bio-fields.*

2. Sequence-1 Kathara Points massage- first your points, then client's points, *to open Kathara Lines.*

3. Technique # 3- **Opening the Healing Channels** to activate your *Doradic-Phase-1* healing current and ***Technique # 4-*** **Amplifying Inner-Audio-Visual and Kathara Scan** to locate miasms for healing in client's Kathara Grid.

4. Technique # 5- **The Maharic Infusion** to activate client's Maharic Shield and Seal, recode client's Kathara Grid to the Maharic Shield and clear miasmic buildups.

5. Optional: Apply **light touch-massage** to miasmic areas, or employ other healing therapeutics after Maharic Infusion.

6. *Sequence-2 Kathara Points massage* on client to revitalize outer body systems and close Kathara Lines. Allow client to rest a few minutes before leaving. Answer any client questions and allow time for client to discuss experience if desired.

When Client Leaves: To ensure clear bio-fields, while Doradic-1 Current is still running, draw energy up from Earth's Maharic Shield and run Maharic Current through your Kathara Grid and body, up to Chakra-14 and back down to Chakra-13, then push a Pillar of Silver Light out of Chakra-4 and EXHALE it to release it around body into auric field. Next massage *your* **Sequence-2 Kathara Points** to revitalize bio-field systems and close Kathara Lines.

CHAPTER 4 HIGHLIGHTS

GENERAL KATHARA HEALING FIELD WORK

- Activation of any **Triadic Healing Current** requires temporary release of corresponding **Signet Star Crystal Seals** in the **Kathara Level-2 Crystal Seals Grid.**
- **Maharic 12th-Dimensional Frequency** is required to **manually release** the **Signet Star Crystal Seals** to activate **Triadic Healing Currents. Kathara Healing** utilizes **Maharic Frequency** to activate interdimensional **Triadic Healing Currents** for more powerful healing support.
- Most healing systems have not used **Maharic Current** because the **Planetary Templar Complex** could not run 12th-Dimensional Maharic Frequency for over 200,000 years, until January 2000.
- Release of the **Signet Seals** also activates dormant Strands in the **DNA Template** and releases the **Cranial-Sacral Seals** on the **Kundalini Energies**. Kathara Healing represents advanced, **12-Dimensional Kundalini Healing.**

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OPENING THE HEALING CHANNELS

- Triadic Phase Currents are activated in the body by using **Maharic Frequency** from the **PBIS** to release the **Signet Seals** of the **Internal Templar Complex**, which allows higher dimensional frequency to run through the **physical body system** for transmission.

- Triadic Phase Currents are composed of **3 interwoven frequencies,** the **Maharic Frequency**, plus a chosen **dimensional frequency** and its corresponding frequency from **one Harmonic up**.

- Triadic Phase Currents are **directed** by their corresponding **Color Cap Stone**, the **Primary Wave Length** of the dimensional frequency band from which the current is drawn. **Kathara Level-1** activates the **1st Triadic Phase Current**, the ***Silver (D-12) + Green (D-4) + Violet (D-7)*** **DORADIC PHASE-1 Current.**

- **Doradic Current** is activated through the **Maharic Shield,** then **collected** in the **4th Chakra** ***DORADIC SPHERE***, projected down the ***DORADIC CORDS*** in the **arms** and into the ***DORADIC BALLS*** in the **Palm Chakras** for **DIRECT INDUCTION** of frequency transmission in healing facilitation.

- The **Palm Chakras** are **Secondary Chakras** located in the **Palms of the Hands.** Like all Chakras, they function as **Black-White Hole Sets** for **transmitting** and **receiving energy** between the personal Manifestation Template and the dimensional Unified Fields of energy.

- The Palm Chakras are **double vortices** of energy, with **one spiral** exiting the **Palm** and its **corresponding spiral** exiting the **back of the hand.** The **2 Spirals** of the Palm Chakras are linked by a **Crystal Seal** at the center point where the 2 vortices meet. In one Palm Chakra, one spiral rotates **clock-wise**, is **Base Electrical** and **transmits energy** out of body, and the other spiral rotates **counter-clock-wise**, is **Base Magnetic** and **draws energy** into body.

- In **Level-1Kathara Healing** the **RIGHT PALM** is the **TRANSMITTING HAND** and the **LEFT PALM** is the **RECEIVING HAND.** For **transmission**, the **Standard Hand Position** is **LEFT Palm placed over the back of the RIGHT HAND** for pure transmission and **control of specific frequency** transmitted from the **RIGHT PALM.**

- The **RIGHT PALM** is **BASE ELECTRICAL**, the **LEFT PALM** is **BASE MAGNETIC**, but both have **subtle** electro-magnetic capacity.

THE KARMIC-MIASMIC IMPRINT

- To enter manifestation in time, identity enters **cycles** of **SIMULTANEOUS INCARNATION** within the **4 Harmonics of Matter Density** in **12-Dimensions** of the 15-Dimensional **Time Matrix**. The **PRIMAL ORDER Scalar-wave Template** through which an identity enters time is the **Density-5** (dimensions 13, 14 and 15) **RISHIC SHIELD**

- The **Rishic Shield** holds in the Time Matrix the identity of the **Family of Consciousness** from which **incarnates** emerge. The Scalar Patterns of the Rishic Shield represent the tangible **"DIVINE RIGHT ORDER"** in energy and consciousness, for each incarnate manifesting from it. The individual identity must **realign** its **Manifestation Template** with this **Primal Order** to become free from the Time Matrix in full **Ascension.**

- The **Density-4** Pre-Matter Hydro-plasmic **MAHARIC SHIELD** (Dimensions 10, 11 and 12) is the Scalar Template through which identity manifests in the lower-dimensional Densities and which **connects the individual incarnate** to its **Rishic Shield**. The **Maharic Shield** is often called the **PERSONAL CHRISTOS Template**, and it holds the consciousness and **Perfect Primal Order** for all incarnations of an identity in time.

- **"Karma"** is the result of **Free Will choices** made by **incarnates** that involve using personal energies in ways incongruent with the natural **Laws of Universal Unified Field Physics** and the **Primal Order** of the **Christos Template**. Karma creates **scalar-wave distortions** within the Scalar Shields of personal 15-Dimensional Anatomy that **manifest physically** as **energetic clusters** called **MIASMS.**

- **Miasms** are **unintended** groups of **anti-particles** lodged within the particle field of the personal **Manifestation Template** that block and impede the **natural flow of energy** and consciousness into embodiment. **Miasms,** and the misshapen scalar-wave distortions that form them, are the **cause of ALL disease** and dis-harmonic conditions.

- **Health** and Harmonious flow of energy are the **natural conditions** of human design. The **Maharic Shield Personal Christos Template** holds the **Organic Imprint for Health** for all simultaneous incarnates of an identity, and can therefore be used to **clear the Karmic-Miasmic Imprint** from the personal Manifestation Template to progressively restore **Healthful Primal Order.**

- Miasms from **all simultaneous incarnations** manifest within the personal Manifestation Template and within the DNA Template of each, where they become literal **genetic distortions.**

- Each of an identity's incarnates in various time cycles represents one **TIME VECTOR**, which is encoded in the Vector Codes of the **DNA Template.** Karmic-Miasmic **bleed-through** occurs **between incarnates** from different concurrent time cycles through the **living link** of scalar frequency that exists between the **DNA Templates** of simultaneous incarnations.

- The **Karmic-Miasmic Imprint** does not have to be suffered and cleared the "**old fashioned way**" by "walking through the Karma in physical reality". The **Miasmic Imprint** can be cleared **as energy, with energy**, to prevent its manifestation in physical terms via realignment of the **DNA Template** with the personal **Maharic Shield.**

- Any given incarnate can clear the Karmic-Miasmic Imprint by realigning the personal Manifestation Template with the shared Christos Template Maharic Shield. This process is called **MULTI-VECTOR HOLOGRAPHIC RECODING**, which creates **BIO-REGENESIS** of the original 12-Strand **Silicate Matrix DNA Template** of human design and restoration of the **Organic Imprint for Health.**

ATTITUDES AND ETIQUETTE IN HEALING

- **Holographic Recoding** and clearing the Karmic-Miasmic Imprint from the personal Manifestation Template begins with activation of the **Maharic Shield and Seal** in the bio-energetic field and progressive running of 12th-Dimensional **Maharic Frequency** from the **Personal** and **Planetary Maharic Shields** through the **3 Primary Levels** of the embodied **Kathara Grid**; the Level-1 **12-Tree Grid**, Level-2 **Crystal Seals Grid** and Level-3 **Diodic Points Grid.**

- Personal Holographic Recoding begins with consistent use of ***Technique* # 2- The Maharic Seal and the Liquid Light Cleanse**, and is further accelerated by facilitating **Maharic Recoding** in others through running the **Triadic Phase Currents** for **Co-generative Healing.**

- One can facilitate healing in others and amplify personal healing through the using ***Technique* # 5- The Maharic Infusion.**

- The **Maharic Recoding Session** utilizes the combined **Bio-Regenesis Techniques** presented in **Level-1 Kathara Healing** to facilitate **Client Healing Sessions.**

- Professionalism in Healing Facilitation requires an understanding of the **Postures of Love** and a willingness to **cultivate** the ability to hold and transmit **OMNI-LOVE, honoring the Divinity of ALL things and beings.**
- The Primary Postures of Love are **SOFT LOVE, TOUGH LOVE, SELF LOVE** and **OMNI-LOVE.**
- The emotionally experienced quality called **LOVE** is a **REALITY IN ENERGY PHYSICS**. LOVE is a **STATE OF VIBRATIONAL FREQUENCY CO-RESONANCE** that allows **free flow of energy** between consciousness within the Universal Unified Field.
- The human **12-Strand DNA Template** was designed to allow **12-Dimensions of Vibrational Co-Resonance**, the **Christos Consciousness** of the **Maharic Shield**, to embody in human form. **CHRISTOS-OMNI-LOVE** is Vibrational Co-Resonance with all that exists within **12 Dimensions** of the Time Matrix; its embodiment is the **primary goal** toward which **human evolution** progresses.
- Christos-OMNI-LOVE is the **strongest healing frequency** available within the Densities of Space, Time and Matter, and is **essential** for effective **Healing Facilitation** and personal **Ascension.**

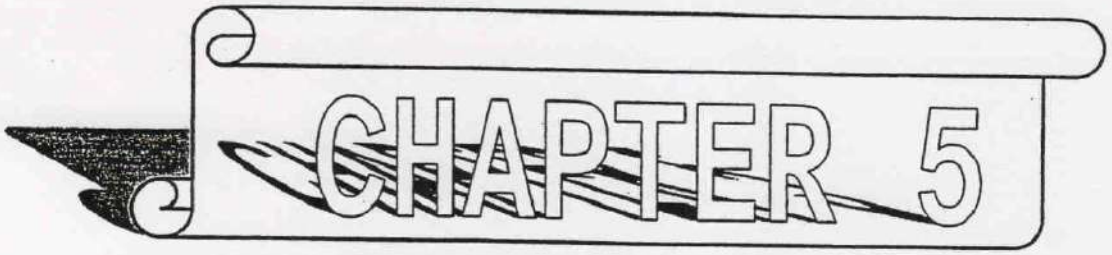

INTRODUCTION TO KATHARA LEVEL-2

The Kee-Ra-ShA Induction Process™

Mahara-Merkabic Master Key Healing-Manifesting the Blueprint For Health

Primal Currents, the DNA Sub-Strand Matrix, Merkaba, Psonns, the Trinity Keys and Photo-Dynamic Manifesting

- SPIRITUAL INTEGRATION
- PRIMAL LIFE FORCE CURRENTS-The Kundalini-Antahkahrana, Maharata, Kee-Ra-ShA & Khundaray
- DNA SUB-STRAND MATRIX, FIRE LETTERS, PSONNS & THE TRIBAL SHIELD
- MERKABA &THE SALUTATIONS
- 2 MASTERS KUNDALINI ACTIVATIONS-The Emerald & Amethyst Awakenings
- UNIVERSAL TRINTIY KEYS & MERKABA KEY CODES
- MAHARA MANIFESTING,DNA, KATHARA & PSONNS

TECHNIQUES:

TECHNIQUE # 6: The Maharic-24 Quick Seal
TECHNIQUE # 7: Ps-13 Tribal Shield Activation
TECHNIQUE # 8: Merkaba Salutations
TECHNIQUE # 9: Merkaba Trinity Key Induction
TECHNIQUE # 10: Photo-Radionic Manifesting
TECHNIQUE # 11: Photo-Sonic Manifesting
TECHNIQUE # 12: Kee-Ra-ShA Activation Sequence-Awakening the Flame

Sacred Sciences of the Mu'a Grail Line-
Tools of the Trade

- **The Maharata-** *Universal Life Force Currents, Kundalini, Antahkarana, Maharata, Kee-Ra-Shay, Khundaray and the Maharic Seal.*
  Field Technique-1: ***Maharic Quick Seal***

- **The Tribal Shield and Cue Zones-** *DNA, Fire Letters, the Sacred Psonns and Cue Zones*
  Field Technique-2: ***Tribal Shield-Cue Zone Activation***

- **The Sacred Salutations-** *Electrical & Magentic Merkaba Activation*
  Field Technique-3: ***Sacred Salutations-*** *Merkaba Tone Dancing*

- **Expediting Spiritual Actualization -** *Tribal Shield Activation, Emerald and Amethyst Awakening Masters Kundalini Activations, DNA Template Bio-Regenesis, Master Key Codes, Melchizedek Cloister Ordinations*

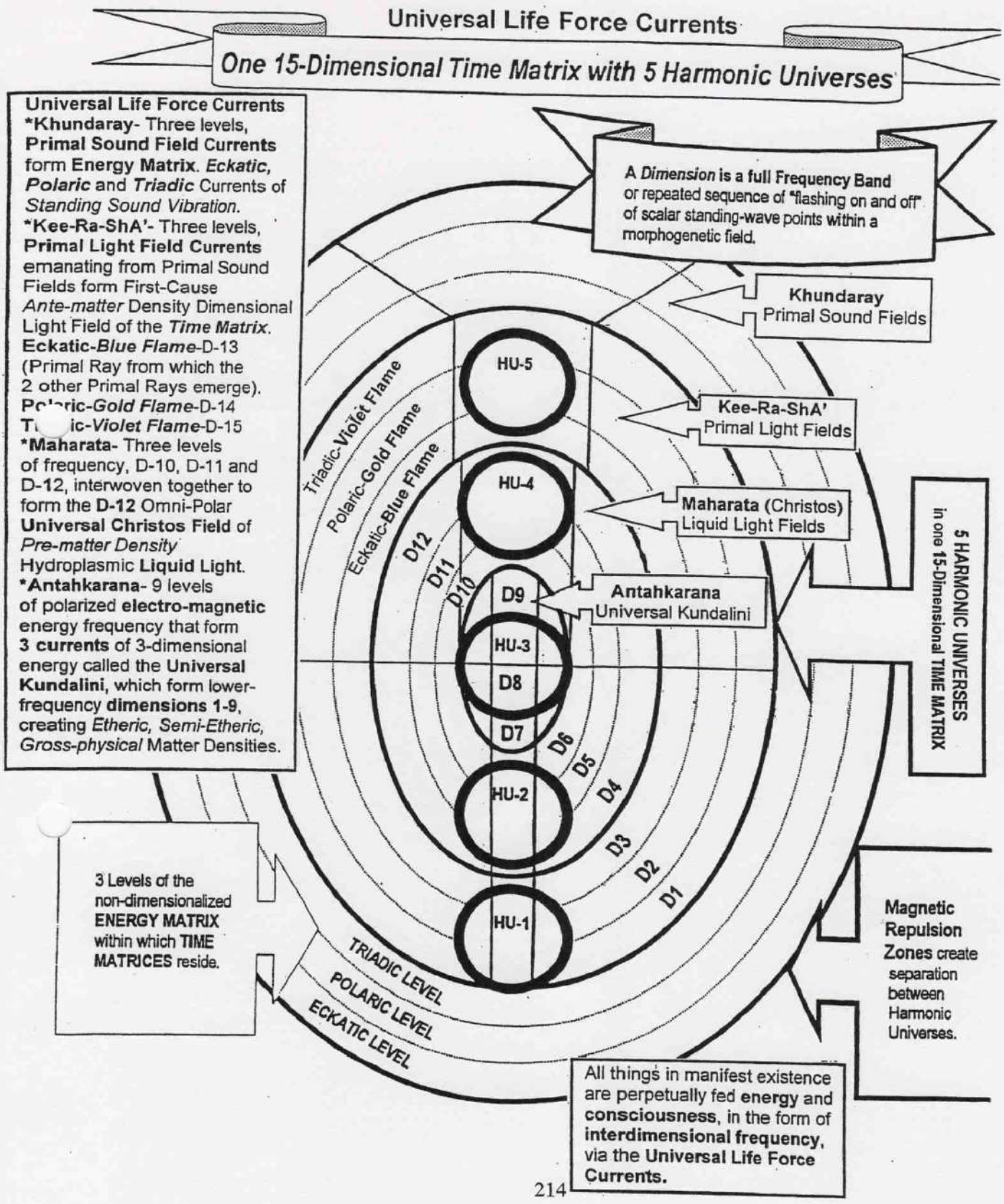
Universal Life Force Currents
One 15-Dimensional Time Matrix with 5 Harmonic Universes
Universal Life Force Currents
*Khundaray- Three levels, Primal Sound Field Currents form Energy Matrix. Eckatic, Polaric and Triadic Currents of Standing Sound Vibration.
*Kee-Ra-ShA'- Three levels, Primal Light Field Currents emanating from Primal Sound Fields form First-Cause Ante-matter Density Dimensional Light Field of the Time Matrix.
Eckatic-Blue Flame-D-13 (Primal Ray from which the 2 other Primal Rays emerge).
Polaric-Gold Flame-D-14
Triadic-Violet Flame-D-15
*Maharata- Three levels of frequency, D-10, D-11 and D-12, interwoven together to form the D-12 Omni-Polar Universal Christos Field of Pre-matter Density Hydroplasmic Liquid Light.
*Antahkarana- 9 levels of polarized electro-magnetic energy frequency that form 3 currents of 3-dimensional energy called the Universal Kundalini, which form lower-frequency dimensions 1-9, creating Etheric, Semi-Etheric, Gross-physical Matter Densities.
A Dimension is a full Frequency Band or repeated sequence of "flashing on and off" of scalar standing-wave points within a morphogenetic field.
Khundaray Primal Sound Fields
Kee-Ra-ShA' Primal Light Fields
Maharata (Christos) Liquid Light Fields
Antahkarana Universal Kundalini
5 HARMONIC UNIVERSES in one 15-Dimensional TIME MATRIX
HU-5
HU-4
HU-3
HU-2
HU-1
D12
D11
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1
Triadic-Violet Flame
Polaric-Gold Flame
Eckatic-Blue Flame
TRIADIC LEVEL
POLARIC LEVEL
ECKATIC LEVEL
3 Levels of the non-dimensionalized ENERGY MATRIX within which TIME MATRICES reside.
Magnetic Repulsion Zones create separation between Harmonic Universes.
All things in manifest existence are perpetually fed energy and consciousness, in the form of interdimensional frequency, via the Universal Life Force Currents.

Universal Life Force Currents and the Embodied Kathara Grid Core Template

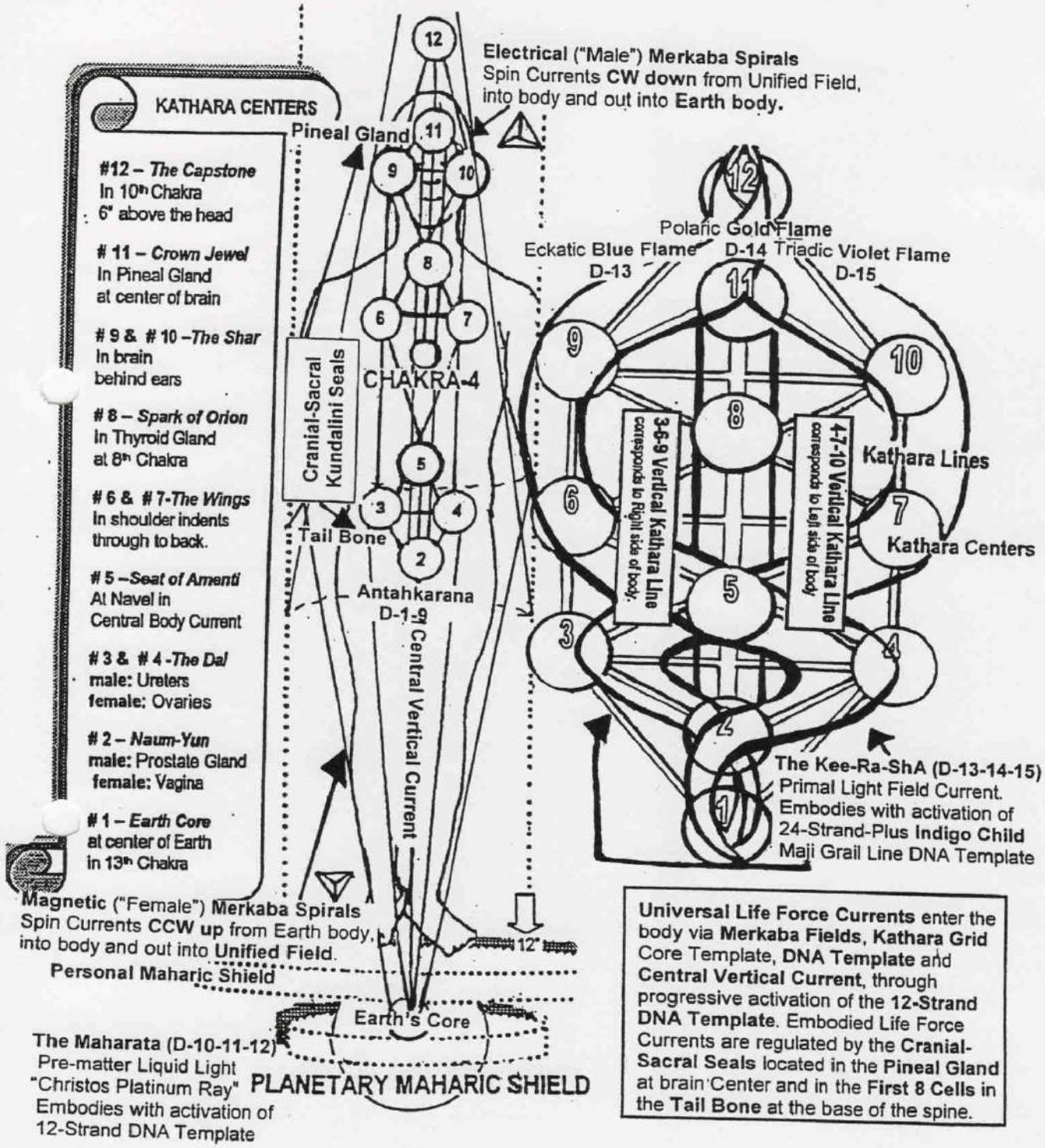

Universal Life Force Currents enter the body via **Merkaba Fields, Kathara Grid** Core Template, **DNA Template** and **Central Vertical Current**, through progressive activation of the **12-Strand DNA Template**. Embodied Life Force Currents are regulated by the **Cranial-Sacral Seals** located in the **Pineal Gland** at brain Center and in the **First 8 Cells** in the **Tail Bone** at the base of the spine.

Universal Life Force Currents and Level-2 Kathara Crystal Seals Grid & Chakras

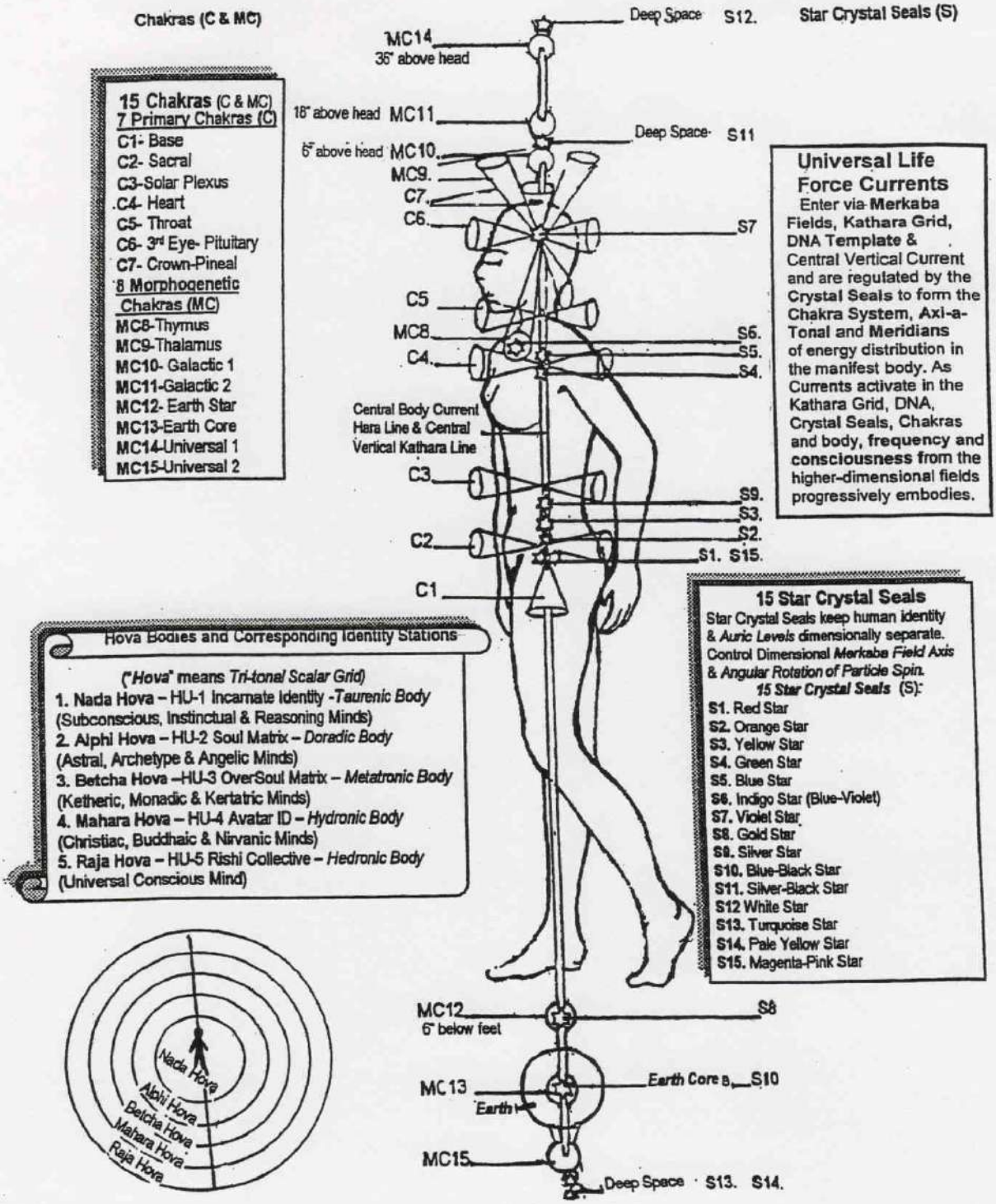

15 Chakras (C & MC)

7 Primary Chakras (C)

- C1- Base
- C2- Sacral
- C3-Solar Plexus
- C4- Heart
- C5- Throat
- C6- 3rd Eye- Pituitary
- C7- Crown-Pineal

8 Morphogenetic Chakras (MC)

- MC8-Thymus
- MC9-Thalamus
- MC10- Galactic 1
- MC11-Galactic 2
- MC12- Earth Star
- MC13-Earth Core
- MC14-Universal 1
- MC15-Universal 2

Universal Life Force Currents

Enter via **Merkaba Fields, Kathara Grid, DNA Template &** Central Vertical Current and are regulated by the **Crystal Seals** to form the **Chakra System, Axi-a-Tonal** and **Meridians** of energy distribution in the manifest body. As Currents activate in the Kathara Grid, DNA, Crystal Seals, Chakras and body, **frequency and consciousness** from the higher-dimensional fields progressively embodies.

Hova Bodies and Corresponding Identity Stations

("*Hova*" means *Tri-tonal Scalar Grid*)

1. **Nada Hova** – HU-1 Incarnate Identity -*Taurenic Body* (Subconscious, Instinctual & Reasoning Minds)
2. **Alphi Hova** – HU-2 Soul Matrix – *Doradic Body* (Astral, Archetype & Angelic Minds)
3. **Betcha Hova** –HU-3 OverSoul Matrix – *Metatronic Body* (Ketheric, Monadic & Kertatric Minds)
4. **Mahara Hova** – HU-4 Avatar ID – *Hydronic Body* (Christiac, Buddhaic & Nirvanic Minds)
5. **Raja Hova** – HU-5 Rishi Collective – *Hedronic Body* (Universal Conscious Mind)

15 Star Crystal Seals

Star Crystal Seals keep human identity & *Auric Levels* dimensionally separate. Control Dimensional *Merkaba Field Axis* & *Angular Rotation of Particle Spin.*

15 Star Crystal Seals (S):

- **S1.** Red Star
- **S2.** Orange Star
- **S3.** Yellow Star
- **S4.** Green Star
- **S5.** Blue Star
- **S6.** Indigo Star (Blue-Violet)
- **S7.** Violet Star
- **S8.** Gold Star
- **S9.** Silver Star
- **S10.** Blue-Black Star
- **S11.** Silver-Black Star
- **S12** White Star
- **S13.** Turquoise Star
- **S14.** Pale Yellow Star
- **S15.** Magenta-Pink Star

Universal Life Force Currents form and sustain the "Auric Field" Levels of 15-Dimensional Human Anatomy

Auric Level, Chakra and Hova Body Correspondences

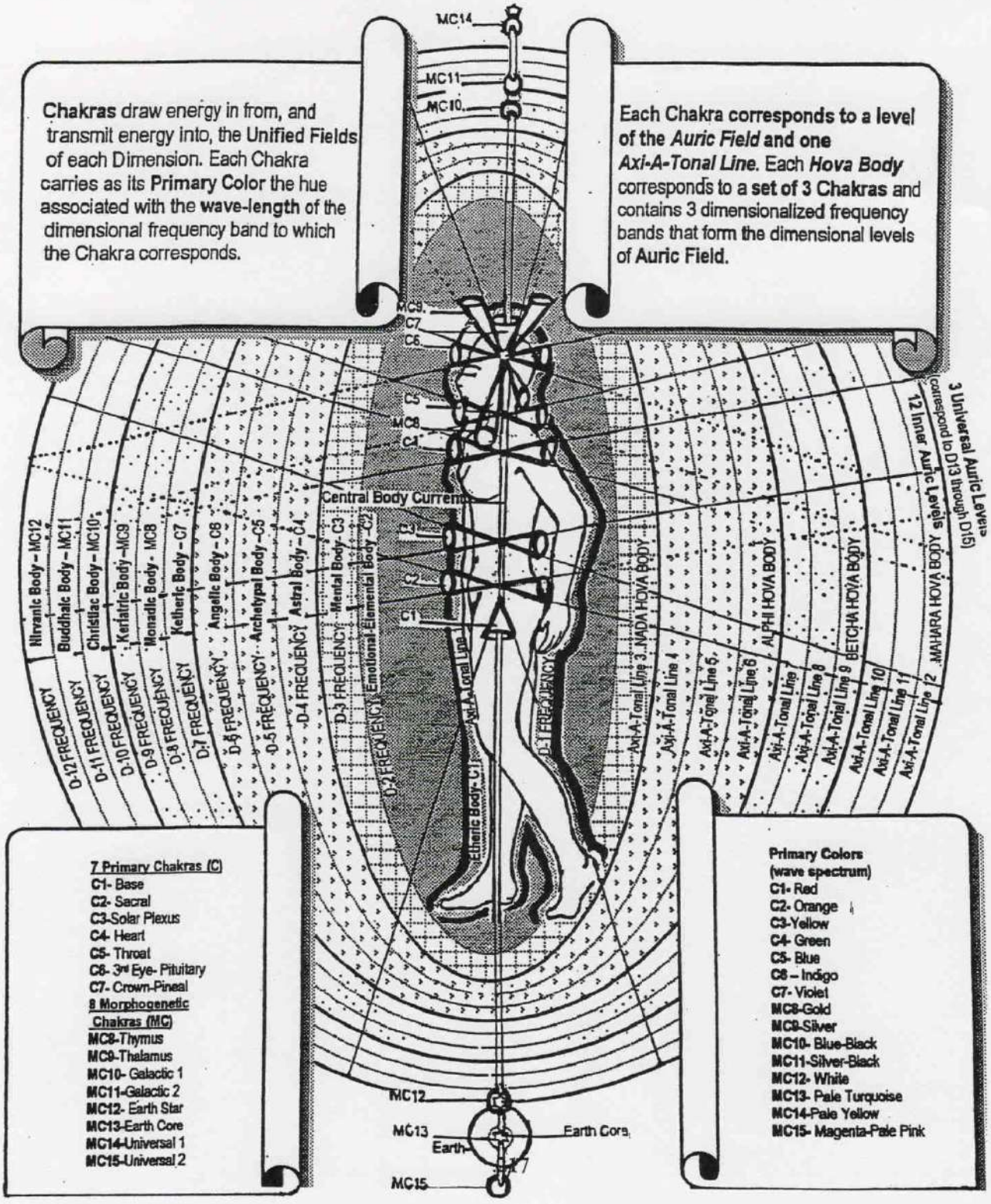

Universal Life Force Currents and the Embodied Shields, Signets and Kathara Grid

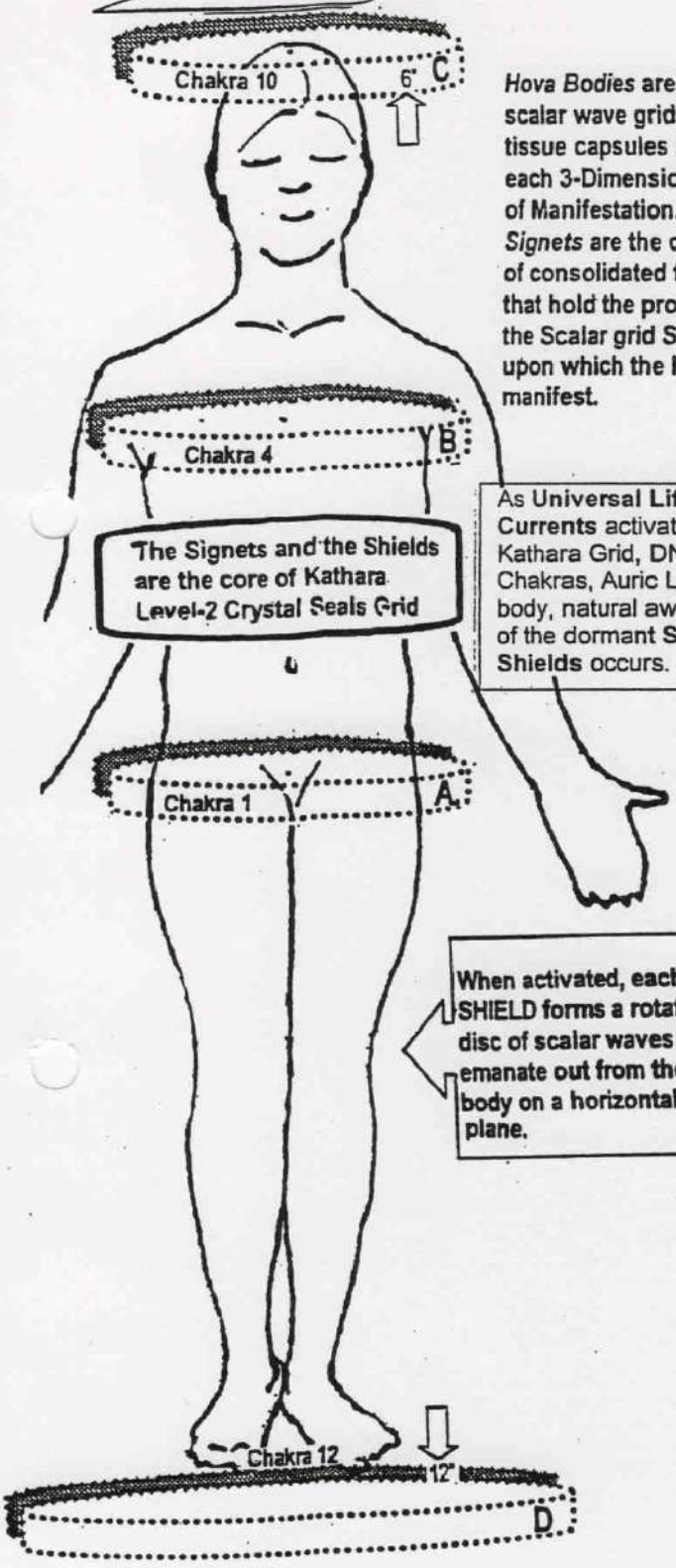

Hova Bodies are spherical scalar wave grids that form tissue capsules between each 3-Dimensional Harmonic of Manifestation.
Signets are the core points of consolidated frequency that hold the programs for the Scalar grid SHIELDS upon which the Hova Bodies manifest.

The Signets and the Shields are the core of Kathara Level-2 Crystal Seals Grid

As **Universal Life Force Currents** activate in the Kathara Grid, DNA, Chakras, Auric Levels & body, natural awakening of the dormant **Scalar Shields** occurs.

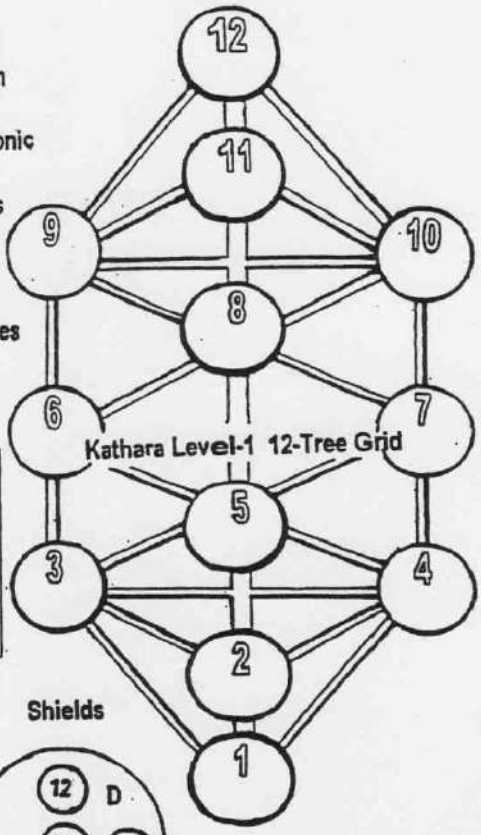

Shields

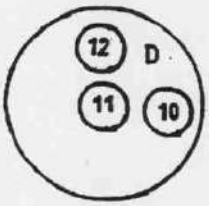

When activated, each SHIELD forms a rotating disc of scalar waves that emanate out from the body on a horizontal plane.

The First 4 SHIELDS each with 3 SIGNETS and correspondence to the Kathara Centers of the Level-1 12-Tree Kathara Grid.

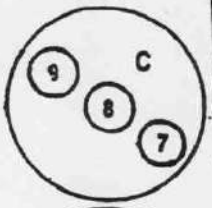

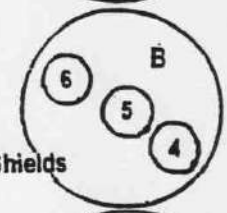

Shields

Signets

HORIZONTAL SHIELDS

A. TELLURIC SHIELD
Nada Hova Body
B. DORADIC SHIELD
Alphi Hova Body
C. TEURIC SHIELD
Betcha Hova Body
D. MAHARIC SHIELD
Mahara Hova Body
E. RISHIC SHIELD
Raja Hova Body
(vertical- not shown)

The Silicate Matrix 12 Strand DNA Primary Correspondences to Subtle Body Anatomy

Silicate Matrix 12-Strand DNA Primary Correspondences to Subtle Body Anatomy.

DNA Strand #	Dimension #	Axi-A-Tonal Line	Chakra & *Seed* Crystal Seal	Auric Field Level
NADA HOVA BODY – TELLURIC SHIELD				
1	1	1	1	Etheric Body
2	2	2	2	Emotional Body
3	3	3	3	Mental Body
ALPHI HOVA BODY – DORADIC SHIELD				
4	4	4	4	Astral Body
5	5	5	5	Archetype Body
6	6	6	6	Angelic Body
BETCHA HOVA BODY – TEURIC SHIELD				
7	7	7	7	Ketheric Body
8	8	8	8	Monadic Body
9	9	9	9	Keriatric Body
MAHARA HOVA BODY – MAHARIC SHIELD				
10	10	10	10	Christiac Body
11	11	11	11	Buddhaic Body
12	12	12	12	Nirvanic Body

Three 3-Dimensional Kundalini Currents compose the 9-Dimensional **Antahkarana** The **Telluric, Doradic** and **Teuric Kundalini Currents**

Maharata D-10-11-12 Christos Current

As **Universal Life Force Currents** activate within the body, the **dimension of consciousness** contained in each **Auric Field Level** progressively embodies.

Universal Life Force Currents and DNA Template Fire Letter Sequences

15-Dimensional Levels of Identity, DNA and Indigo Children

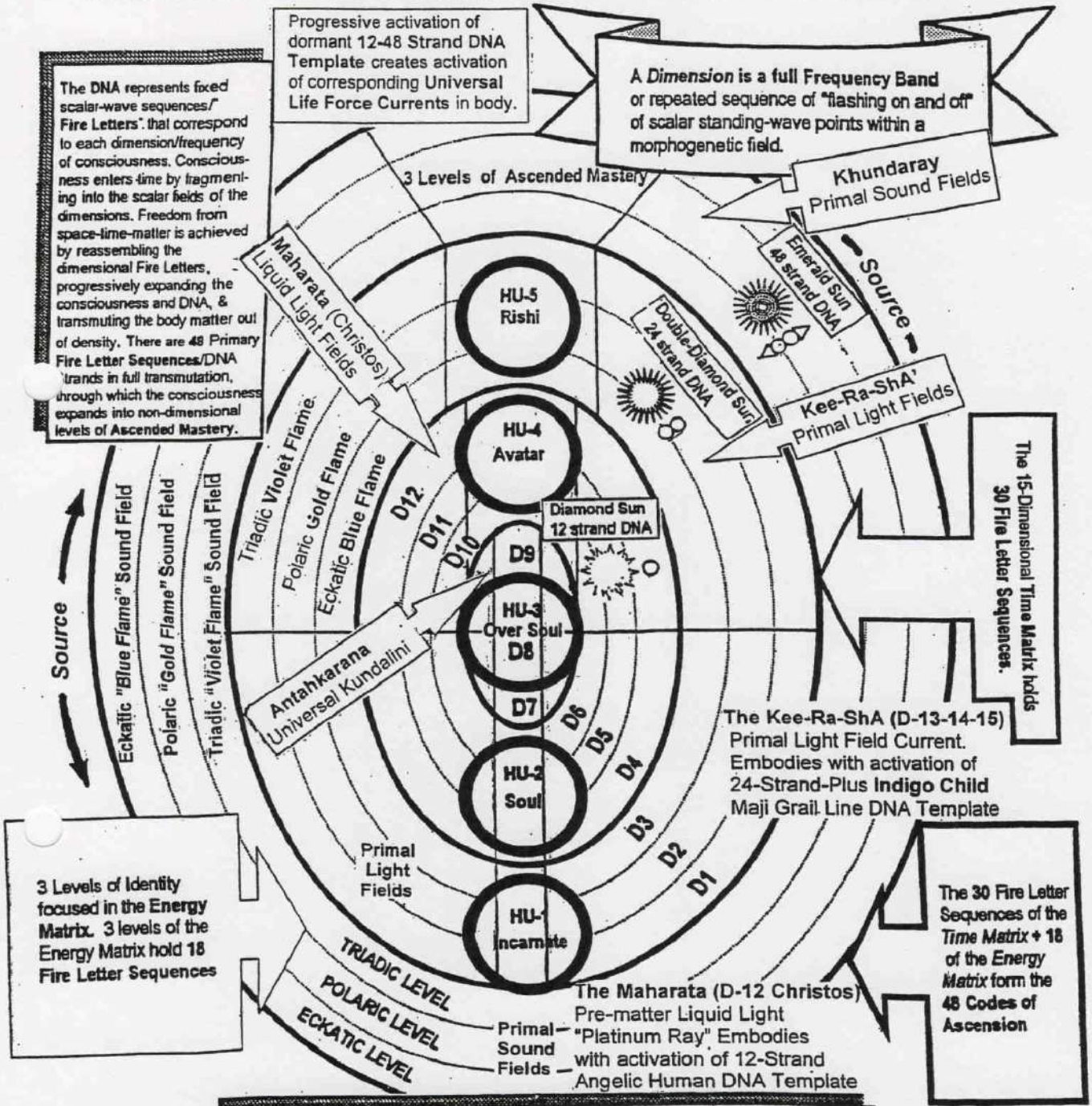

The Reality of Spiritual Integration

- **Spiritual Actualization** is as much a function of **Divine Physics** as it is a product of **Divine Consciousness**. The natural Primal Order of **Universal Structure** sets the **Templates of Manifestation** to which consciousness **must conform** to enter the experience of manifest expression within a space-time-matter system.
- The personal Christos **Maharic Shield** Manifestation Template and the Christos **Tribal Shield** Species Manifestation Template are **microcosmic replicas** of the macrocosmic Primal Order upon which Universal and Cosmic structure are built.
- The Personal D-12 Christos Divine Blueprint Maharic Shield connects each Individual Christos self to the **larger** D-12 Christos Divine Blueprint of the **Species**. The D-12 Christos Divine Blueprint is called the **TRIBAL SHIELD**.
- To understand the realities of **personal Spiritual Integration and Actualization,** in order to **fulfill our personal life purpose,** it is important to comprehend the basic **Primal Order** structures of energy, the **personal D-12 Maharic Shield** and the **D-12 Species Tribal Shields**, through which our consciousness manifests in time.
- The secrets to **reclaiming the Divine Birthrights and Responsibilities** of Angelic Human heritage are hidden within the realities of the **Tribal Shield** and the specific **"Fire Letter Sequences"** of the Tribal Shield that manifest within and **govern the function** of the Angelic Human **DNA Template.**
- The **key to Spiritual Actualization** is activation of the dormant personal 12-Strand DNA Template. The **most rapid means** of activating the dormant Angelic Human 12-Strand DNA Template is through **activation of the Tribal Shield**, the Species D-12 Christos Divine Blueprint, which represents the **CORE PROGRAMMING** of the personal D-12 Maharic Shield.

The Silicate Matrix 12-Strand DNA Template with Hova Body, Scalar Shield and Identity Level Correspondences

The Morphogenetic Field Scalar-wave Template for the Original Human Genome

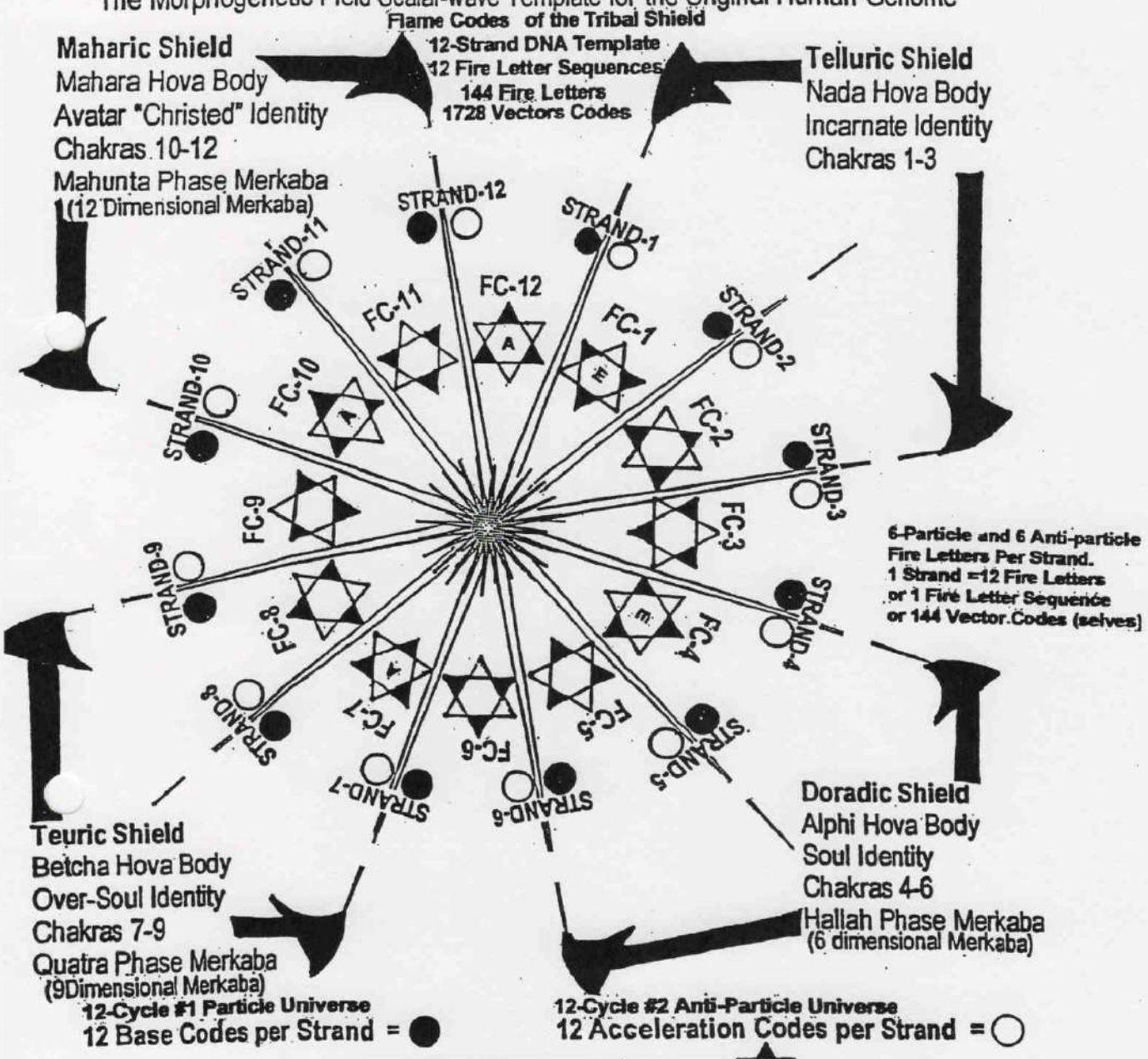

(E) Emerald Kundalini Awakening releases Fire Codes 1 & 4 (A) Amethyst Kundalini Awakening releases Fire Codes 7,10 & 12

(Diagram presents simple conceptualization of DNA Strand Template orientation, not actual geometrical arrangement of wave-form structure and observable strand interrelationship.)

Activating the Tribal Shield

- The 12-dimensional **Tribal Shield** is the dormant **Species Divine Blueprint** within the **DNA Template core** of the Angelic Human races of the 4 Evolutionary Rounds. The frequencies of energy and dimensions of consciousness of the **1728 simultaneous selves** of the Personal Eternal Christos Identity can be **activated in one incarnation** through **sequential activation** of **the Fire Letter Sequences** or **"Flame Codes'** of the **Tribal Shield.**

- The "Flame Code Fire Letters" within the DNA Template are the **DNA Signet Codes** that correspond to Earth's **12 Primary Star Gates** and the **Planetary Shields** through which the planetary body manifests. The Flame Codes serve as the core foundation of the personal 12-Strand DNA Template.

- The DNA Template Flame Codes of the Tribal Shield allow for the **Primal Life Force Currents** of the Density-5 (dimensions **13-14-15**) **Kee-Ra-ShA Primal Light Fields** and the **Khundaray Primal Sound Fields** from the Energy Matrix, beyond the 15-Dimensional Time Matrix, to embody more fully within the Angelic Human form.

- A **Fire Letter** is a **fixed point of consolidated frequency** that holds specific frequencies consciousness into manifest form. The **Manifestation Templates** or Divine Blueprints of **all things** manifest are built upon **intricate patterns** of interwoven Fire Letters called **Fire Letter Sequences.** The Flame Codes of the Angelic Human personal DNA Template and Species Tribal Shield are composed of the **same Fire Letter Sequences** that make up the Divine Blueprint of **Earth's Planetary Shields.**

- Activation of the Tribal Shield sets in motion simultaneous **"firing"** or activation of the **144 Fire Letters (12** Fire Letter **Sequences)** of the 12-Strand DNA Template, expediting the natural evolutionary process of Soul, Over-Soul and Christos Avatar Identity Integration, through progressively opening the "Trans-time DNA Template Star Gates".

- Activating the 12-Strand DNA Template allows the D-12 frequency of the **Universal "Christos" Maharata Current** to activate within and run through the Angelic Human DNA Template and into the Earth's **Planetary Shields.** Activation of the **Maharata Current** within **groups of Angelic Humans** on Earth allows for **collective anchoring** of the **D-12 Planetary Christos Divine Blueprint,** the **Shield of Aramatena,** to achieve fulfillment of Angelic Humanity's **Sacred Commission** of the **Planetary Christos Realignment Mission.**

The Tribal Shield- *Species D-12 Christos Divine Blueprint*

The Angelic Human 12-Strand DNA Template contains 6 Fire Letter Sequences from particle universe 12-Cycle plus 6 Fire Letter Sequences from anti-particle 12-Cycle = **12 Fire Letter Sequences** or **144 Fire Letters** from the **Two Planetary 12-Cycles** of the Cycle of the Rounds. (1 12-Cycle = 4 Evolutionary Rounds)

The **Tribal Shield** connects our personal D-12 **Maharic Shield** Divine Christos Blueprint to the greater Christos Blueprint of the Angelic Human **Species. 144 Fire** Letters (12 Fire Letter *Sequences*) of the **Tribal Shield** make up the **core program** of the Human **12-Strand DNA Template.**

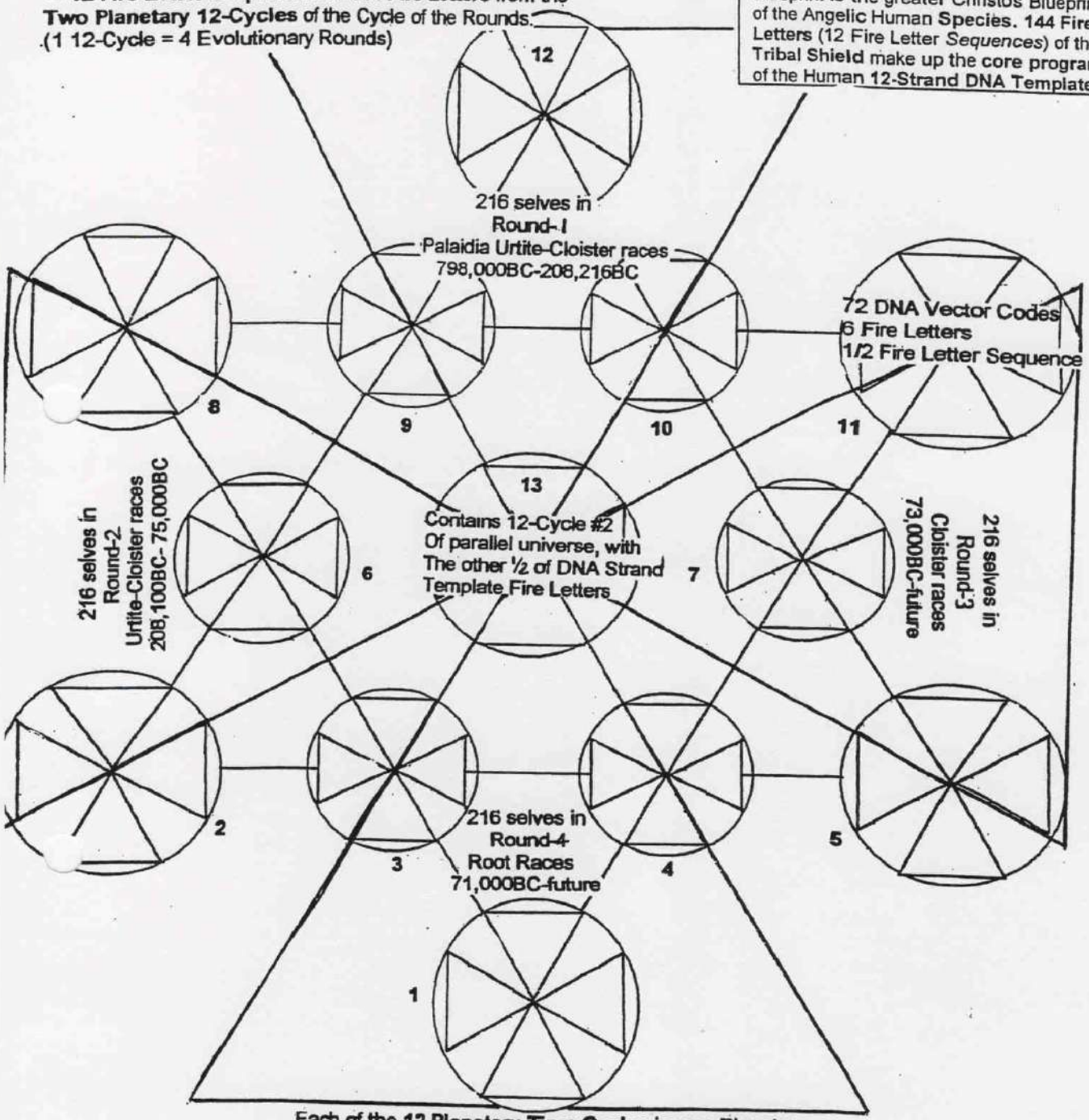

Each of the **12 Planetary Time Cycles** in one Planetary 12-Cycle of the "Cycle of the Rounds" has **72 Time Vectors. 12-Strand** Angelic Humans have **one self** in each of the **72** Time Vectors of the particle universe Planetary 12-Cycle and **72 selves** in the corresponding anti-particle Planetary 12-Cycle. **72 selves x 12** Planetary Time Cycles = **864 selves** per one Planetary 12-Cycle **+ 864 selves** parallel universe Planetary 12-Cycle = **1728 selves** in Tribal Shield.

Tribal Shield Activation Creates Cue Zones
In Earth's Planetary Shields.

Cue Zones

"Cue Zones" are locations on Earth where a small portion of Earth's D-12 Shield of Aramatena **Christos Divine Blueprint** has been re-set within Earth's Planetary Shields. During Stellar Activations Cycles, Cue Zones can be **manually set** by individuals or groups by running the **D-12 Maharata Current**, activating the **Tribal Shield** to draw in the Khumarary Primal Sound frequencies, then singing the 12-Tribes **Master Psonns Suffixes** and running the tones through the body and feet and into Earth's Planetary Shields. After running the Master Psonns Suffixes, one can then allow the **"Song of the Christos Soul"**, the tones of the personal D-12 **Maharic Shield** (the "Elohei-Elohim Within") to run into the Planetary Shields. The personal Soul Song will create a **"Back Song"** transmission of frequency from Earth's Planetary Shields, a set of healing frequencies sent back to you in response to activating your Soul Song in Earth's Planetary Shields. Once set, Cue Zones will remain for a period of **3.5 to 5 years**, depending on strength of energy originally set. They can be **recharged** using the same "setting" procedure to **last indefinitely.**

Cue Zones are **"safe zone"** areas on the Planet that are protected from interdimensional interference. They can be used to amplify effects of energy **healing applications**, to **"charge" objects and substances** with sub-harmonics of D-12 Christos frequency and when used with the personal Temporary Maharic Seal, to get clear, protected **"meditation space"** free from interdimensional interference. Cue Zones are "keyed" to Earth's Planetary **Templar "Cue Sites"**, the activation sites for Earth's 12 Primary Star Gates, which exist on regions of Earth that correspond to the 12 Primary Star Gates of **Inner Earth.**

TECHNIQUE # 6 : THE MAHARIC QUICK SEAL

1 Work with a 24 pointed, 3 Dimensional Star (Heirophant) and be aware that you will be working with beings known as the Breneau Rishi ...

2 Begin by slowing your breathing , as you imagine or visualize a 24 point, 3 -Dimensional, Heirophant at the Pineal Gland in the center of your brain. Visualise the Heirophant surrounded by a Pale Blue Sphere of Light.

(The Blue Sphere serves as a buffer for your readiness to accept the frequencies associated with using the 24 pointed Star; the Blue Sphere holds the energy for you until your body can handle the energy. If you can handle it, the energy will simply pass through the blue sphere).

3 INHALE, as if you are going to grab the blue sphere containing the 24 point star located at the Pineal, and on the EXHALE move the 24 point star/ blue sphere, all the way down to Earth's Core. Try to hear a sound tone as the Heirophant/ Sphere hits the Planetary Shield ...

4 INHALE and draw the Heirophant/ sphere up to your Personal Maharic Shield 12" below your feet ... and EXHALE while watching the Pale Silver-Blue sphere expand out to a large sphere ... and watch as your Maharic Shield pop out as a disc, about 4' in diameter, Pale Silver with a light coating of Pale Blue.

5 Bring your attention to the center of your Maharic Shield 12" below your feet ... and INHALE the 24 point Star (only) up into the Heart Chakra. EXHALE, expanding the frequencies of the 24 point Star into the Heart Chakra.

6 INHALE to grab the 24 point Star, and EXHALE, pushing the Star up into the 14th Chakra 36" above the head. Imagine that the 24 point Star is spinning in a clockwise direction in the 14th Chakra. As you do this, try to feel/ sense the energy around you, just a few inches out from your body ...

7 Now, put your attention into your Maharic Shield 12" below your feet, take a couple of relaxing breaths and INHALE deeply pulling the Pale Silver and Blue energy up, as if you are pulling on your Maharic Seal to latch it on to your 14th Chakra. Try and feel the sensations just a few inches from your body now – feel the difference if you can. This procedure gives you a Quick Seal.

8 Now envision the cord of Pale Silver Maharic Light that would normally come up with your Shield and focus on the Earth's Core. Begin drawing energy all the way up the 4" diameter cord and into the body. INHALE the energy up into the Heart Center, and expand it there. Begin to form a pale Silver ball of Maharic frequency.

On each EXHALE send your energy down to the Earth's Core to bring up another load of Maharic frequency, up from the Planetary Shields, expand it into the Heart center and repeat several times. Notice that the Cord grows larger as you do this, expanding from approximately 4" to 6 to 8" diameter, until finally it feels like a skin around (as well as within) your body ... as you load your Astral field with Maharic Frequency.

9 Move your attention to the Pale Silver ball you have created in your Heart Center, INHALE and move it up to the 14th Chakra 36" above your head .. as you do, feel for the sheath of Maharic Frequency encasing your etheric body, close to your skin. (This Maharic/ Christos skin charges, and saturates, your etheric body – feel the peacefulness and all-knowing nature of this frequency).

Technique # 7: Ps-13 Tribal Shield Activation

The Master Key Tones

- The **12-Tribes names** were the **audible-tone translations** of the **specific Fire Letter Sequences** contained within the **Tribal Shield DNA Templates** of each Tribe. The tones of the Tribal names were used to activate the **144 Fire Letters** of the Tribal Shield in the **personal DNA Template**, providing the Angelic Humans races with the ability to **consciously regulate** the **activation level** of their **DNA Templates** and **Primal Life Force Currents.**
- The **Sound-Tone Programs** that are used to activate the DNA Template and Primal Life Force Currents are called **"The Sacred Psonns"**. The **Tribal name** was the **Master Psonn**. In running the Rainbow Roundtables, the Signet Council Regents brought their Tribal Shield "Flame Codes" into activation by **singing rounds** of the **Sacred Master Psonns.**

The 12 Sacred Master Psonns

for activating the 144 Fire Letters of the Tribal Shield Flame Codes in the 12-Strand DNA Template.

Plus **Master Tone Activation Suffix.**

12. *A-reah-Azurta*
a- RI-a-Zoor- ta- Rha

11. *Zephar-Duun-Atur*
ze-far-Doon a-Tur- Dha

10. *Ma'ah-hu-ta*
Ma-a hoo ta- Khu

9. *Yun Zu-Xen*
Yu-Un Zoo-Zen KE

8. *Chia Zhun Zan La-Yung*
ChE' ah-Zoon Yan LA-Yoong' OM

7. *Mahata-Agrah*
ME hah' ta a'g-ra OE

6. *Ramyana-Shridveta*
rah ma yah na shrid vE' Da U

5. *Ionatu-Etillah*
I O' Na too et il' a EU

4. *Nuagu Hali*
Noo ah' goo ha' LE Ka

3. *Amekasan-Etur*
a ME' ka sun e too'r DO

2. *Maahali-Bruea*
Ma a ha' LE - BrU' A EL

1. *Isutu-Esheau*
I sU' too E' shoo UR

Tribal Shield-Cue Zones Activation

Creating a Cue Zone

1. **Choose location** and **activate a personal "Maharic Quick Seal"** to "run the D-12 **Maharata Current**" in your body.

2. Once you can feel sensation of Maharata Current running, sing-tone 12-Tribes **Master Psonns** (names) for **Tribe-12** and **Tribe-1** to activate **Tribal Shields Flame Codes** in your DNA Template to run the **"Rainbow Ray"**. Direct Pale Silver Maharata Current and Rainbow Ray pale color spectrum through body and out **soles of feet** into Earth's Planetary Shields. Tone for a while to build critical mass of frequency.

3. Use a selected combination of 3 **Master Psonns Suffixes** and tone for a while, running sound through body and feet into Earth's grids. (avoid the Suffix combination of Tribe-4-7-10 used in that sequence to avert present distortions in Earth's grids that run on this mathematical coding)

4. Allow the **Christos Soul Song** to emerge from you "free style" and send the tones into Earth's grids.

5. When complete, sit quietly for a while and listen for the Earth's telepathically transmitted **"Back Song"**, drawing its gentle frequencies into your body for healing.

6. Close with singing several rounds of the **3 Master Psonns Suffixs** that you opened with. The Cue Zone you have set will extend out from your position in a radius of about **5 yards** and will last **3.5-5 years** depending on strength of energy you used in setting the Cue Zone.

7. To **amplify** strength of Cue Zone you can use the **"Merkaba Spin"** just after closing. Remain in same position, stand, the gently spin, first **clockwise** (as if you are standing on a clock face with the "6" in front of your feet, "3" at the left hand, "9" at the right and "12" directly behind you). Spin gently clockwise to bring electrical frequency down through your **"top"** Merkaba spiral. Then slow, stop and **reverse spin** to **counterclockwise**, to activate **"bottom"** Merkaba spiral", drawing frequency up from Earth's grids. Personal Merkaba Activation will accelerate the frequencies of the D-12 energies you set at the site, making the Cue Zone **stronger and more lasting.**

The Solar Salutation
Electrical Merkaba Activation

- The ancient **Mu'a** and **Lemurian** Guardian Races ran the **Maharata** and activated the **Tribal Shield** each day to conduct the **Sacred Solar and Lunar Salutation Rites** each morning and evening. The **Sacred Salutations** are **Toning Dances** that activate the personal **Merkaba Field** for sustained activation of the DNA Template and amplification of the Maharata and Universal Life Force Currents in the body.
- **Solar Salutations** accelerate the spin of the **Electrical Harmonic Merkaba Spiral** (Top, CW spin), drawing increased amounts of **Electrical Anti-particle** frequency from the Solar **Electrical Merkaba Spiral** light spectrum into the **Electrical Acceleration Codes** in the **DNA Template** to **"charge" the body** with **Electrical Anti-particle frequency.**
- Accelerated **Electrical Merkaba Spiral Spin** of **Solar Salutations** increases the amount of **Anti-particle Base-Electrical** frequency **brought into** the body's **DNA Template** and **Kathara Grid** from the Dimensional Unified Fields and increases the amount of **Anti-particle** frequency **sent out** from the body into Earth's **Planetary Shields.** Frequency passes between the Human Body and Earth's Planetary Shields via the embodied **Kathara Grid** core templates that make up the **Planetary Bio-Feed Interface System** ("PBIS")
- **Electrical Anti-particle** energy enters the body via the **"Top" Electrical** Harmonic and Dimensional **Merkaba Spirals**, the **Base-Electrical Acceleration Codes** in the DNA Template, the **Electrical Kathara Centers 2-5-8-11** of the Kathara Grid **Central Pillar**, the **Electrical aspect** of **Electro-magnetic Kathara Centers 1-3-6-9-12** on the **Right Side** of body ("Left Side Pillar" in Kathara diagram), **Electrical Chakras 2-5-8-11** and the **Electrical aspect** of **Electro-magnetic Chakras 1-3-6-9-12**.

- **Solar Salutations** (CW spin Top Electrical Merkaba Field Activation) **raise** the body's **Oscillation** (energy transmission-expansion), **lower** the body's **Vibration** (energy holding-contraction), making the body **Higher Frequency** and **More Electrical** (transmits more energy than it is drawing in).
- A **Higher Frequency Electrical Body** has:
  - **Lower Vibration**, Higher Oscillation/Frequency, **Less Matter Density**
  - More activated DNA Strands, more chromosomes, embodiment of more levels of consciousness.
  - **Slower** heart, breathing and metabolic rhythms (energy expansion and contraction rates),thus requires less food (burns fuel slower).
  - Greater **longevity** and **less sleep** (body can synthesize natural higher frequency energy and Stream of Consciousness for longer periods without taxing.)
  - Greater **Silica quantity** in **Silica-to-Carbon Ratio** of elemental composition and **larger size** (more space between cells; more expanded matter).
  - Perception of **expanded Space** and **slower Time** movement.
  - Greater **heat release**, thus **cooler** internal temperature.
  - Natural attribute of **transmitting** greater amounts of energy thrust into the Planetary Shields than it is drawing in/receiving from them. **Energy "giving".**

- The **Solar Salutations** "charge" the **Top Electrical CW Merkaba Spiral** to maintain its natural cycle of **33(⅓) rotations per 1 "trillionth" of a nano-second"**, through which the **Base-Electrical** systems of the body are naturally maintained.

The Lunar Salutation
Magnetic Merkaba Activation

- **Lunar Salutations** accelerate the spin of the **Magnetic Harmonic Merkaba Spiral** (Bottom, CCW spin), drawing increased amounts of **Magnetic Particle** frequency from the **Lunar Magnetic Merkaba Spiral** reflected light spectrum and Earth's Planetary Shields into the **Magnetic Base Codes** in the **DNA Template** to **"charge" the body** with **Magnetic Particle frequency.**
- Accelerated **Magnetic Merkaba Spiral Spin** of **Lunar Salutations** increases the amount of **Particle Base-Magnetic** frequency **brought into** the body's **DNA Template** and **Kathara Grid** from the **Earth's Planetary Shields** and increases the amount of **Particle** frequency **sent out** from the body into Dimensional Unified Fields.
- **Particle Base-magnetic** energy enters the body via the **"Bottom" Magnetic** Harmonic and Dimensional **Merkaba Spirals**, the **Base-Magnetic Base Codes** in the DNA Template, the **Magnetic Kathara Centers 4-7-10** of the Kathara Grid on the **Left Side** of the body ("Right Side Pillar" on Kathara Diagram), the **Magnetic aspect** of **Electro-magnetic Kathara Centers 1-3-6-9-12** on the **Right Side** of body ("Left Side Pillar" in Kathara diagram), **Magnetic Chakras 4-7-10** and the **Magnetic aspect** of **Electro-magnetic Chakras 1-3-6-9-12.**
- **Lunar Salutations** (CCW spin Bottom Magnetic Merkaba Field Activation) **lower** the body's **Oscillation** (energy transmission-expansion), **raise** the body's **Vibration** (energy holding-contraction), making the body **Lower Frequency** and **More Magnetic** (draws in more energy than it is transmitting out).

- A **Lower Frequency Magnetic Body** has:
  - **Higher Vibration**, Lower Oscillation/Frequency, Greater **Matter Density**
  - **Fewer** activated DNA Strands, fewer chromosomes, embodiment of fewer levels of consciousness.
  - **Faster** heart, breathing and metabolic rhythms (energy expansion and contraction rates), thus requires **more food** (burns fuel **faster**).
  - Lesser **longevity** and needs more **sleep** (body can synthesize natural higher frequency energy and Stream of Consciousness for **shorter periods**; taxes more easily)
  - Greater **Carbon quantity** in **Silica-to-Carbon Ratio** of elemental composition and **smaller size** (less space between cells; more contracted matter).
  - Perception of **contracted or more confined Space** and **faster Time** movement.
  - Less **heat release**, thus **warmer** internal temperature.
  - Natural characteristic of **drawing** greater amounts of energy thrust from the Planetary Shields than it is transmitting into them. **Energy "taking"**.

The **Lunar Salutations** "charge" the **Bottom Magnetic CCW Merkaba Spiral** to maintain its natural cycle of **11⅔ rotations per 1 "trillionth" of a nano-second"**, through which the **Base-Magnetic** systems of the body are naturally maintained.

The natural ratio between the **Top-CW-Electrical-"Male" Harmonic Merkaba Field** and the **Bottom-CCW-Magnetic-"Female" Harmonic Merkaba Field** is **Electrical-Top 33⅓CW** rotations per 1 "trillionth" of a nano-second and **Magnetic-Bottom 11⅔CCW** rotations per 1 "trillionth" of a nano-second.

The Natural Christos Merkaba Vehicle & Personal Shields

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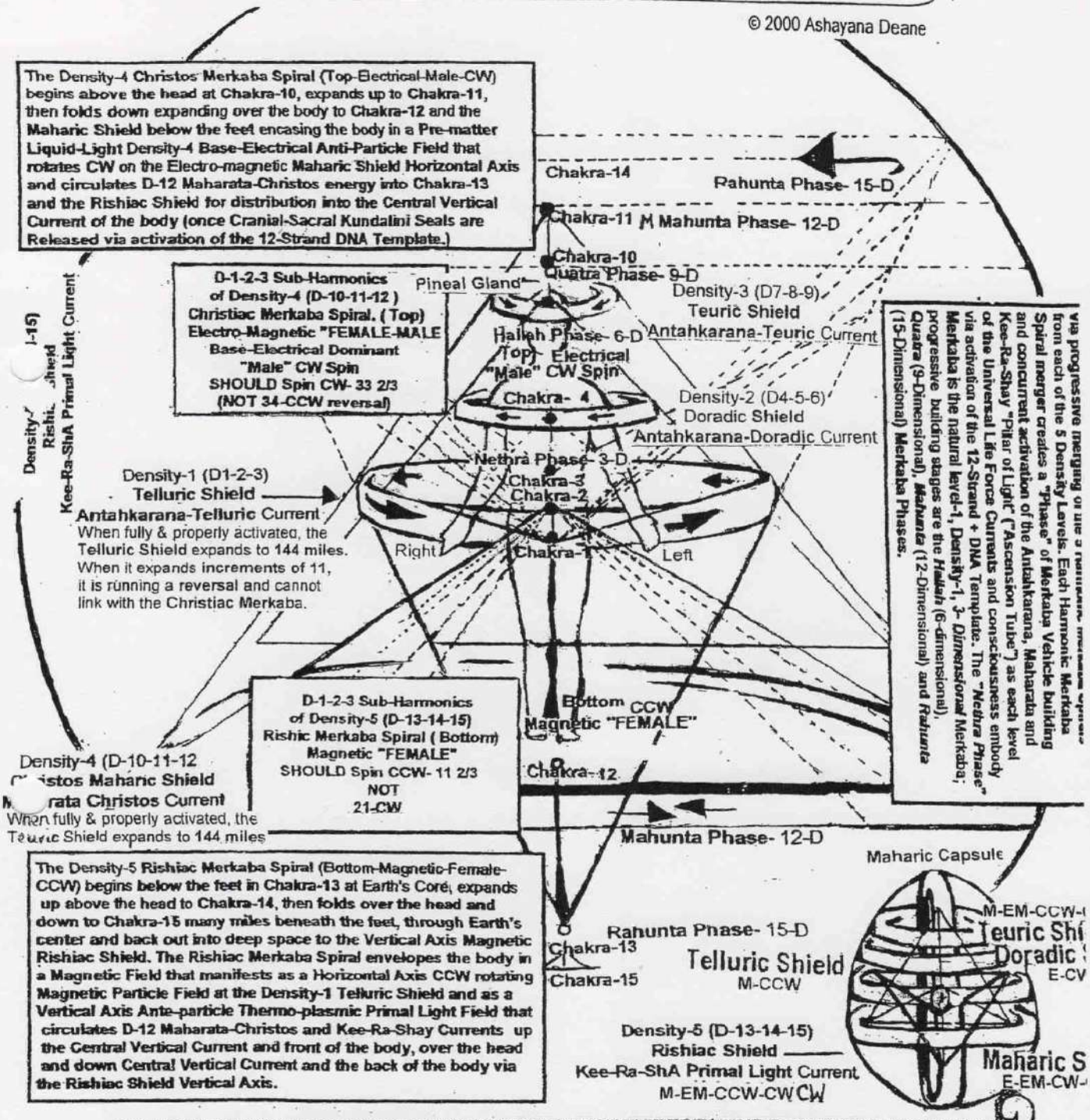

The NATURAL Spin Ratio between the Top (Male-Electrical-CW-Anti-particle) Density-4 Christiac Merkaba Spiral and the Bottom (Female-Magnetic-CCW-Particle) Density-5 Rishiac Merkaba Spiral is 33 1/3-CW-Male-Top to 11 2/3-CCW-Female-Bottom. The 33 1/3-CW/11 2/3-CCW Spin Ratio creates the NATURAL ratio of 33 2/3-Parts-Electrical Anti-Particles to 11 2/3-Parts Magnetic Particles, (or 33 1/3 energy expansion/oscillation/thrust to 11 2/3 energy contraction/vibration/draw) within earth's Density-1 Matter Base, the organic Divine Blueprint of Density-1. This Christiac Internal Merkaba Vehicle Spin Ratio creates a self-sustaining, Eternal, Matter-base that is MORE ELECTRICAL than Magnetic, which perpetually re-fuels itself via natural circulation of the *Maharata, Kee-Ra-ShA* and *Khundaray* Universal Life Force Currents.

Merkaba Phases – Building the Merkaba Vehicle

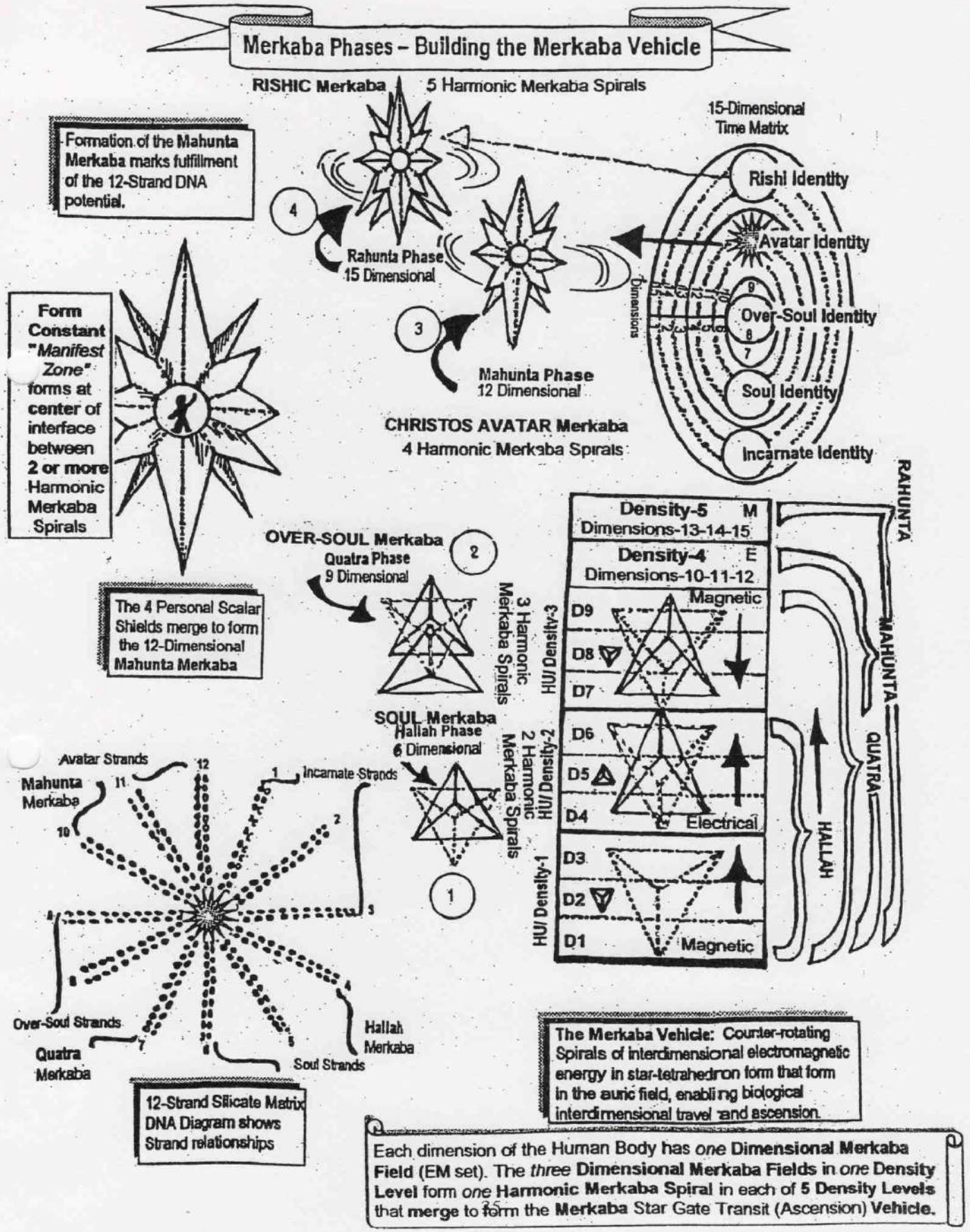

Technique # 8: Merkaba Salutations

Healing the Spin & Balancing Particle/ Anti-Particle Ratios

33 1/3-CW/11 2/3-CCW Christos Merkaba Activation

***Note:** Discern **CW or CCW direction of Merkaba Spin** by imagining that you are standing, with arms stretched out to the sides, in the center of a round 12-digit clock-face. The **FRONT** of your body faces the **"6"-digit, "12"-digit** is positioned **behind you,** the **"3"-digit** is positioned at your **LEFT ARM** and the **"9"-digit** is positioned at your RIGHT ARM. **CLOCKWISE "CW" SPIN:** Hold **LEFT "3-Arm"** firmly out to the side of the body like a **"clock hand"** and begin **Spin** toward **FRONT,** moving the body with the **LEFT arm** toward the **"6"-digit** position in **FRONT** of your feet. **COUNTER-CLOCKWISE "CCW" SPIN:** Hold **RIGHT "9-Arm"** firmly out to the side of the body like a **"clock hand"** and begin **Spin** toward FRONT, moving the **body** with the **RIGHT arm** toward the **"6"-digit** position in **FRONT** of your feet. The **TOP-ELECTRICAL-MALE** Merkaba Spiral **Christos Spin** is always **33 1/3-CW** rotation. The **BOTTOM-MAGNETIC-FEMALE** Merkaba Spiral **Christos Spin** is always **11 2/3-CCW** rotation.

Solar Salutation Rites: (best time *Dawn's First Light & 12:00 Noon*)
begin with ***Top-Electrical-CW-"Male"*** **Merkaba Spiral** activation, followed by *Bottom-Magnetic-CCW-"Female"* Merkaba Spiral
Use Tribe-12 Activation Suffix **"RHA"** as ***Initiating Tone***
Lunar Salutation Rites: (best time *12:00 Midnight to 3:00AM*)
begin with ***Bottom-Magnetic-CCW-"Female"*** **Merkaba Spiral** activation, followed by *Top-Electrical-CW-"Male"* Merkaba Spiral
Use ribe-1 Activation Suffix **"UR"** as ***Initiating Tone***

1. Activate ***Maharic Quick Seal*** Technique- 6
2. Activate ***Tribal Shield-Cue Zone*** Technique- 7
3. Stand with spine comfortably straight, breath slowly, in a relaxed manner and begin **quietly toning** the ***Initiating Tone***, continuing repetition while progressively **increasing** the **volume** and extending the Exhale Breath Tone thrust behind Initiating Tone until you can **feel the subtle energy** of Tone sound waves oscillating in the body.
4. **Activate First Merkaba Spiral** (Top or Bottom Spiral first, depending on Solar or Lunar Salutation) by holding **arms out to the side**, parallel with the ground, and begin to **slowly SPIN** in the direction (CW or CCW) natural to the * **Christos Spin** of the Merkaba Spiral you are activating. Continue to **Spin AND Tone Initiating Tone** while progressively **increasing rate of Spin and Toning.** To **prevent dizziness,** hold one arm out to front with thumb positioned UP, and **focus your eyes** on the **THUMB** rather than the spinning scenery beyond. Do not Spin faster than comfort level. You may **modulate toning in rounds of 3,** between the **Initiating Tone** and toning the **Christos Spin Rate Number** (**"33 1/3"** for Electrical-Top Spiral, **"11 2/3"** for Magnetic-Bottom spiral), if desired.
5. When energy in body feels **"charged"** (a "doneness" intuitive feeling), **slow spin** to a **gentle STOP**, while **Toning 3 Times,** the ***"Um Shaddai Ur'-A ah-Khum' Tun"*** Lyra-**Halls of Amorea** D-12 activation sequence, to **amplify** the Merkaba Spiral "charge. **Stand STILL** and breathe quietly for a few moments while Spin stabilizes, then **repeat STEPS 3-5** to **activate other Merkaba Spiral.**
6. **End Salutation Rite** with full **3 Rounds** (minimum) **Toning** of the ***"Ariea Khum Nar-A"*** (Song of Orion D-8 activation sequence) **Part-1:Verses 1 and 2,** to be sung while **Walking 2 Circles**, one **CW**, one **CCW**, beginning Circle Walk with Spin direction of **First Merkaba Spiral** activation, followed by a **reverse-direction** Circle, then **Standing STILL** for a few moments to allow the **Christos Maharata Current** to run between your body and Earth's Planetary Shields.

The Ar-IE- a Khum –Nar' A
The Song of Orion

Part 1 : the Resonant Tone Syllable Sequence (primary melody)

Verse 1: OM A Da E, Patum ah
OM A Da E, Patum ah
Patum ah A' DE E - Tah, A khum-na
OM A Da E, Patum ah

Verse 2: TrA TE La E' Durum Na
TrA TE La E' Durum Na
Durum' ah A' Khem - Tah, A khum -na
OM A Da E, Patum ah

Part 2 : the Base Tone Syllable Sequence (accompaniment 1)

OM A Da E, Patum ah - Lines 1, 2 & 4 Verse 1 & Line 4 Verse 2
TrA TE La E' Durum Na - Lines 1 & 2 Verse 2
UM ah OM, A
UM ah OM, A
Patum ah A' DE E – Tah, A khum- na
Durum ah A' Khem – Tah A khum-na
DO RAY' TU Ra"
OM A Da E, Patum ah
UM ah OM, A

Part 3: the Over Tone Syllable Sequence (accompaniment 2)

OM A Da E, Patum ah – Lines 1 & 2 Verse 1
TrA TE La E' Durum Na – Lines 1 & 2 Verse 2
BE HE Tah OM, A
BE HE Tah OM, A

Patum ah A DE E – Tah, A Khum –na – Line 3 Verse1
Durum ah A Khem- Tah, A Khum - na - Line 3 Verse 2
Thra Khem' Na, A
OM A Da E, Patum ah – Line 4 Verses 1 & 2
KhrA MiM, Tah A

The fastest means of naturally activating the Personal 12-Strand DNA Template is :

1. **Tribal Shield Activation:** Activating the 144 Fire Letters of the Tribal Shield & Sacred Salutations Merkaba Activations.

2. **Emerald and Amethyst Awakening 2 Masters Kundalini Activations:** Releasing key **Fire Codes** between the DNA Strand Templates to allow for **expedited DNA Strand Braiding.**

3. **DNA Template Bio-Regenesis:** Progressive use of internally directed DNA Template Bio-Regenesis technologies for progressive purging of Strand Template mutations, restoration of the natural D-12 Christos Divine Blueprint of the 12-Strand DNA Template and expedited, accelerated activation of the DNA Strand Template Base Codes and Acceleration Codes.

4. **Master Key Codes:** Use of the personal scalar-wave-guide Symbol Code Programs that correspond directly to the core programming of the personal D-12 Maharic Shield for further sequential expedition of Strand Template Activation.

5. **Melchizedek Cloister Level-3 Regent Ordination:** Transmission of the Kee-Ra-ShA Primal Light and Khundaray Primal Sound Field **"Rainbow Ray Current"** directly into the personal **DNA Template** via direct **Chakra Induction.** Sufficient Rainbow Ray frequencies to provide a level-3 Regent Ordination can be transmitted by a Melchizedek Cloister **level-5 Elder Consummate** or **Level-6 Eckar** Indigo Child-Type-1 Maji Grail Line Angelic Humans, who have the frequencies of the Primal Creation Currents integrated into their DNA Template from birth. **Expedites all of the above** while provided additional **bio-energetic field support** for more **stable cycles** of DNA Template activation.

The Khundaray RRT Activation Sequence

A progression of **manually initiated** *Kundalini and DNA Template Activations* that systematically induce *temporary release* the **Cranial-Sacral Kundalini Seals** (Pineal Gland & Tail Bone), in their **natural Release-Sequence**, allowing for temporary and ***progressive*** embodiment (nano-second burst of frequency) of the *Primal Universal Life Force Currents* via **Syncopated Activation** of the **12-Strand DNA Template**.

The ***Khundaray RRT ("K-RRT") Activation Sequence*** allows the Density-4 (D-10-11-12 Pre-matter) ***Maharata Christos Current***, Density-5 (D-13-14-15) ***Kee-Ra-ShA Primal Light Currents*** (Ante-matter *Blue, Gold* and *Violet* "Flames") and the ***Khundaray Primal Sound Currents*** (*Eckatic, Polaric* & *Triadic* Columnar Standing Waves) from *Source* to run through the DNA Template and body for accelerated ***TRUE 12-Strand or higher DNA Template Activation** and expedited human Spiritual Integration.

For the human body to **hold and transmit a minimum critical mass** of Kee-Ra-ShA and Khundaray frequency to **access the Planetary Shields** and **Star Gates** for ***Masters** (Universal) **K-RRTs,*** the ***K-RRT Activation Sequence*** must be conducted **4 to 24 hours** prior to the K-RRT. The *K-RRT Activation Sequence* must also be run **2-24 hours** prior to the ***Amethyst Awakening Masters-2 Kundalini Activation*** to prepare the body for the Amethyst Awakening frequencies. The *Amethyst Awakening* (Field Technique-6) can also be run **just before** a K-RRT (following prior *K-RRT Activation Sequence*) to **greatly amplify the power** of the K-RRT and Signet Council group.

There are **5 Specific Operations of Energy Management** within the ***K-RRT Activation Sequence***:

1. **Activating the Doradic Phase-1 Current**
2. **Awakening the KA**
3. **The Emerald Awakening**
4. **Activating the Kee-Ra-ShA**
5. **Activating the RA Center-Anchoring the Rainbow Bridge**

The Emerald & Amethyst Awakenings
Masters Kundalini-DNA Template Activations
For Accelerated ***DNA Template Activation*** and ***Spiritual Integration***, Running **K-RRTs** and enhanced ***Immune Support***

THE KUNDALINI LIFE-CURRENTS AND THE CRANIAL-SACRAL SEALS.

The human body is fuelled by ENERGETIC LIFE-FORCE CURRENT FROM SOURCE. In contemporary human anatomy, the only life-force currents running fully through the embodied Kathara Grid and body are those corresponding to the SINGLE-VECTOR time cycle of the Density-1 TELLURIC SHIELD. Each of the 4 HOVA BODIES and their corresponding SCALAR SHIELDS, DNA STRAND TEMPLATES, AXI-A-TONAL LINES, DIMENSIONS OF CONSCIOUSNESS AND MERKABA FIELD LEVELS process the frequencies of one TRIADIC CURRENT – a 3-dimensional, Bi-polar life-force current. The life-force currents corresponding to the first 9 dimension and first 3 Hova Bodies, Mater Densities and Shields are referred to as the KUNDALINI ENERGIES. Each KUNDALINI CURRENT is a TRIADIC CURRENT – a set of 3 dimensional currents that function together and are separated by Magnetic Repulsion Zones within the embodied Kathara Grid. The 3 embodied Kundalini Currents are the TELLURIC, DORADIC and TEURIC CURRENTS .

Each of the 3 Kundalini Currents is spiralled within the regions of the 1st 8 CELLS of human conception, located in the TAILBONE at the Base of the Spine. (The incarnating consciousness anchors its identity and Christos Manifestation Template within the FIRST 8 CELLS, to initiate the FETAL INTEGRATION PROCESS.) The first Kundalini Current, the TELLURIC CURRENT that corresponds to the DENSITY-1 Nada Hova Body, is active within the human form from birth, enabling 3 dimensions of consciousness awareness, in the form of scalar frequency, to embody within the human organism. When the 2 dormant Kundalini Currents in the tailbone, the DORADIC and TEURIC CURRENTS, are activated, the frequencies of consciousness from dimensions 4-9 progressively awaken within the body, activating the dormant 4-9 strands of the 12-strand DNA Template. The 3 Primary Kundalini Spirals each contain 3 single-dimension currents, and are controlled by the corresponding SIGNET STAR CRYSTAL SEALS in the Kathara Level-2 Crystal Seals Grid. The Signet Seals create polarization between dimensionalized sets of scalar waves within the Scalar Shields, that manifest within the Kathara Level-2 Grid, First Eight Cells and DNA Template as FREQUENCY SEALS or blockages within the TAILBONE (Sacral region) and the PINEAL GLAND in the center of the brain – the CRANIAL-SACRAL SEALS.

When the Cranial-Sacral Seals are released, through activation of the Signet Star Crystal Seals that govern them, the dormant Kundalini Currents come to life within the body, sending progressively higher-frequency energy through the CENTRAL VERTICAL CURRENT of the body. Activation of the 3 Kundalini Currents progressively creates integration of the higher dimensions of consciousness and de-densification of molecular structure. When ALL of the frequencies within the 3 embodied Kundalini Currents are activated, the 4th KUNDALINI CURRENT- the PRIMAL TRIADIC CURRENT, the KEE-Ra-ShA', is activated. The Frequency Seal on the KEE-Ra-ShA' is located in the 12th Chakra, 6" below the feet. Activation of the KEE-Ra-ShA' anchors the 12th-Dimensional HYDROPLASMIC BEAM within the body, initiating the process of CELLULAR TRANSMUTATION and intentional de-manifestation and Dimensional Ascension of the human biological form.

THE EMERALD AWAKENING AND THE KEE-Ra-ShA'

The Emerald Awakening Masters Kundalini Activation is one of two inter-harmonic energetic activations of previously dormant frequency within the body that sets in motion simultaneous activation of the 12 MAGNETIC BASE TONES within the FIRE CODES between the 12 Strands of the SILICATE MATRIX DNA Template. Activation of the 12 Fire Code Base Tones begins activation of the 3 PRIMAL CREATION FREQUENCIES – the KEE-Ra-ShA' – within the 4 Scalar Shields of the PERSONAL INNER TEMPLAR COMPLEX. Activation of the 12 DNA Fire Codes allow for progressive natural fusion of each dimensional DNA Strand Template to occur, through which the organic potentials of CELLULAR TRANSMUTATION are re-awakened within the physical body form.

Through the natural processes of Cellular Transmutation, once fully operational within human genetic design, the carbon-based elemental biology of Density-1 molecular structure is progressively and systematically transmuted to SILICA-based biology. Transmutation to Silica-based biology allows the physical body to pass through the levels of Semi-etheric, Etheric and Pre-matter Hydroplasmic Liquid-Silica Densities of Harmonics 2-4 (Dimensions 4-12), through which the consciousness continually enters manifestation, to achieve physical mastery of the organic process of Transmutational Dimensional Ascension. To accomplish mastery of the Ascension process, the SIGNET STAR CRYSTAL SEALS with the Scalar Shields, which keep the 12 dimensionalized frequency levels of the consciousness and molecular form Phase-locked into dimensional division/ polarization, must be released. Release of the Signet Star Crystal Seals allows the frequency spectra of the higher dimensional anatomy and the Primal Creation Currents of the KEE-Ra-ShA', to enter into the Template for the physical body and dormant DNA Fire Code Templates, progressively building the Merkaba Vehicle and setting the Cellular Transmutation process in motion. The process of progressive Transmutational Dimensional Ascension represents the function of the organic genetic design and evolutionary objective of the human creation blueprint, through which the natural Immortal Christos-Angelic Form of the human being is actualised.

In the evolutionary cycles of contemporary humanity, actualization of the 12-Strand DNA potential takes place slowly in Earthly terms, as the incarnate identity experiences in single-life time-vectors, several cycles of Density-1 incarnation, spanning many thousands of years, in order to progressively activate the DNA Fire Codes within the Manifestation Template. When the human genome was operating in its organic form, this process took place in one lifetime, over a period of about 44 years, as the immortal human incarnate matured to embody the 12 dimensions of consciousness within its original Christos Manifestation Template- the MAHARIC SHIELD, actualizing its organic Angelic-human heritage and mastery over 4 Densities of manifestation within the Time Matrix.

The EMERALD AWAKENING Masters Kundalini Activation releases the Density-2 4TH – Dimensional Green Signet Star Crystal Seal and the Density-1 1st-Dimensional Red Signet Star Crystal Seal, to open the Density-1 NADA HOVA BODY and TELLURIC SHIELD, and Density-2 ALPHI HOVA BODY and DORADIC SHIELD, to receive the Omni-polar frequencies of the 12th-Dimensional MAHARIC CURRENT (Hydroplasmic Beam) from the Pre-matter Christos Template Maharic Shield. Upon entering the Telluric and Doradic Shields, the 12th-Dimensional frequencies of the Maharic Current trigger simultaneous activation of the Base Tones within the 12 Fire Codes of the DNA Template, beginning the process of DE-POLARIZTION of the 12-Strands and levels of consciousness within the human Manifestation Template. Progressive de-polarization of the 12 levels of consciousness within the human Manifestation Template sets in motion the organic process of Cellular Transmutation and potential mastery over Transmutational Dimensional Ascension. The Emerald Awakening Masters Kundalini Activation initiates REGENESIS of the original function of the human genome, releasing the Base Tones

of the 3 KEE-Ra-ShA' Currents within the body via opening of 2 Signet Seals, through which the physical body begins the carbon-to-silica transmutation process and is prepared to receive the higher dimensional OVER TONE frequencies of the KEE-RA-Sha', to complete Cellular Transmutation via fusion and de-polarization of the particle (Particum) and anti-particle (Partika) aspects of the Manifestation Template. This is the natural process of UNIFIED FIELD PHYSICS by which a human being becomes "Christed".

THE AMETHYST AWAKENING AND THE KHUN-DA-RAY

The final step in fulfilling the potentials of original Angelic-human design is activation of the OVER TONE frequencies of the KEE-Ra-ShA', which allows fusion between DNA Strand Templates to complete on 12 dimensions of frequency. The final step in Transmutational Dimensional Ascension is called the AMETHYST AWAKENING MASTERS KUNDALINI ACTIVATION. Through the AMETHYST AWAKENING, the DENSITY-3 7TH-Dimensional VIOLET Signet Star Crystal Seal and 8th-Dimensional GOLD Signet Star Crystal Seal, and the DENSITY-4 11TH-Dimensional DARK SILVER Signet Star Crystal Seal are released within the body's Scalar Shields. Release of the OVER TONE SIGNET SEALS allows the OVER TONES of the KEE-Ra-ShA Creation Currents to fuse with the BASE TONES, bringing the 3 OMNI-POLAR CREATION CURRENTS (Primal Creation Currents built upon a TRINITY OF TONES, BI-POLAR + NON-POLAR energy units) together as ONE PRIMAL NON-POLAR CURRENT – the KHUNDARAY (also called the "Rainbow Bridge" or the " Rainbow Serpent".)

The KHUN-Da-rAy is the PRE-LUMINAL vibration, or STANDING WAVE OF INTERNAL SOUND emitted from ONE-SOURCE/ GOD, that corresponds to the COMBINED ORIGINAL SOURCE CURRENT from which the 3 KEE-Ra-ShA' PRIMAL LIFE-FORCE CURRENTS of the 3 non-dimensionalized levels of the ENERGY MATRIX, beyond the 15-Dimensional Time Matrix emerge. The Emerald Awakening Masters Kundalini Activation, and its resulting activation of the BASE TONES of the KEE-Ra-ShA' within the human body, is the first step in manually expediting the natural process of Transmutational Dimensional Ascension.

AWAKENING THE KA AND REMOVING INORGANIC CRYSTAL IMPLANTS

Before the Emerald Awakening Kundalini Activation can be orchestrated, the MAHARIC SHIELD and the KA must be brought out of dormancy within the human Manifestation Template. Once the 12th-Dimensional Maharic Current is released within the embodied Kathara Grid, the KA can be activated. The "KA" refers to the 4 HOVA BODIES corresponding to dimensions 1 through 12. (Nada, Alphi, Betcha and Mahara Hova Bodies.) The KA becomes activated through removal of 4 inorganic Crystal Seal IMPLANTS that block the natural function of the 2nd, 3rd and 4th DNA Strand Templates. Following he procedure for AWAKENING THE KA, the Emerald Awakening Kundalini activation can be conducted.

Technique # 12: Kee-Ra-ShA Activation Sequence

ACTIVATING DORADIC PHASE I Awakening the Flame

Preparation: Activate **Maharic Seal** Technique-6 *Maharic Quick Seal*

1 Breath slowly and deeply for several breaths while visualizing or imagining a Violet Dot on the center of the *inside* of your forehead. Make the color image as strong as you are able (if you can't yet perceive inner colors simply imagine the Violet Dot being there).

Move the Violet Dot to the center of the brain, at the **Pineal Gland,** and then upward into the 7th Chakra, finally moving it out of your head to rest on the top of your skull, at the Crown Chakra.

2 Call to mind the Heirophant Symbol (Pale Silver Merkaba Star/ Star of David). Visualise the Heirophant spinning 12" below your feet, within your Maharic Shield, and slowly INHALE.... drawing the Pale Silver Heirophant up through the Central Body Current, up to meet the Violet Dot at the 7th Crown Chakra at the top of the head.

When the Heirophant connects with the Violet Dot, visualize the Violet Dot bursting into a 4" vertical Pillar of Violet-Silver Light. Imagine the Violet-Silver Pillar running down through the body and into the Earth's Core, as well as upward into the 14th Chakra positioned 36" above your head. (This activates the Violet Ray of Transmutation).

3 Now, move your attention to the 4th Heart Chakra, and imagine a small Green Spherical Crystal – the Green Star – stationed at it's core. This is the Green star Crystal Seal that controls release of 4th Dimensional frequency – Phase I Doradic Current – into the body. INHALE, drawing Violet-Silver energy from the Violet-Silver Pillar into the Green Star.

EXHALE, expanding the Violet-Silver energy into the Green Star sphere. Repeat two more INHALE/ EXHALE breaths, drawing Violet-Silver energy from the Pillar and expanding it into the Green Star sphere.

4 At the end of the last EXHALE, imagine the Green Star POPPING, turning into a spinning Green and Violet Starburst of Light, as the Violet-Silver Pillar disappears. Spin the Green-Violet Starburst faster until it becomes a ball of Green-Violet Light, about the size of a grapefruit, spinning the center of the Heart Chakra. (The Green-Violet ball is the storehouse for your Phase I Doradic Current; it's called the Doradic Sphere).

INHALE and draw Pale Silver energy from your Maharic Shield, through the central Body Current, and into the center of the Doradic Sphere at the heart Chakra ... encasing the sphere in Pale Silver Light.

AWAKENING the KA

1 Bring your attention back to the DORADIC SPHERE at the HEART CENTRE...

2 INHALE pale silver energy up from the EARTH CORE to fill & expand the DORADIC SPHERE; breath slow and deep 2-3 times ...

3 Now, put the tips of your fingers together, and feel the 'fuzziness' of the energy flow...

4 Next, move the fingertips to the tail bone... INHALE energy from the Maharic Shield into the DORADIC SPHERE

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As you EXHALE, push PALE SILVER energy down to the finger tips and into the tail bone..... REPEAT 2-3 times and then remove the fingers.

5 Now, bring your attention to the 2nd CHAKRA (SACRAL) .....feel or visualize or just know ... a DOUBLE TERMINATED QUARTZ CRYSTAL (a crystal with a point at both ends) is beginning to "push out" of the front of your 2nd Chakra, the Sacral center.

6 Focus your attention on this, try to feel the crystal pushing.... use your hands to help ease it forward, and out.

7 There is a smaller double terminated crystal in the 3rd (Solar Plexus) Chakra; this will release on it's own because the currents have activated it to do so. Help it out with your fingers.

8 In the Heart Chakra, imagine a little sphere of energy, colored green. Bring this little green sphere more fully into focus ... and you will notice a little black cube of energy inside it ...look more closely again, and notice a smaller white cube inside the black one.

9 As you focus on the two little cubes, watch them merge together .. feel a ripple of vibration as they do, and then ... notice a little puff of smoke as they both disappear.

Now, the body is activated to open the 4th and 1st Crystal Seals; you are ready for <u>the EMERALD AWAKENING ...</u>

1 Now we will open the GREEN STAR CRYSTAL SEAL .....So, keeping your awareness on the Doradic Sphere, the GREEN-VIOLET- SILVER ball at the Heart Center.....INHALE,

2 and ... on the EXHALE visualize or imagine pushing a cord of GREEN-VIOLET-SILVER Doradic Current down into the tail bone... to the 1st Cell ..... at it's very tip .

3 Breathe easy ... and take a moment to visualize the 1st Cell at the tip of your tail bone.... as a WHITE-SILVER SPHERE...

5 Now within the WHITE SILVER SPHERE, visualize, a GREEN SPHERE ... and then visualize a RED SPHERE inside the GREEN SPHERE ...

6 Bring your attention back to the SPHERE of GREEN-VIOLET-SILVER energy in your Heart Center ...

and on the next EXHALE visualize, or imagine, sending a cord of GREEN-VIOLET SILVER energy all the way down your central vertical column and into the GREEN SPHERE in the 1st Cell at the tip of the tail bone.

7 AS you INHALE pull PALE SILVER LIGHT from your personal Maharic Shield, the platform-disc 12" below your feet, up into the tail bone and into the GREEN SPHERE.

8 As you do this, visualize, the GREEN SPHERE 'pop' into a STARBURST of PALE GREEN-SILVER LIGHT.

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This has opened the kundalini seal – your WHITE-SILVER & RED Spheres REMAIN as you left them earlier .....Now, we will work to open the **RED STAR CRYSTAL SEAL....**

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9 Return your awareness to the Doradic Sphere at the Heart Center....INHALE, and then on the EXHALE push a cord of GREEN-VIOLET-SILVER Doradic Current down to the 1st Cell at the tip of the tail bone, ...

10 INHALE and draw PALE SILVER energy up from the personal Maharic Shield, the platform-disc positioned 12" below your feet, up into the tail bone, and into the RED SPHERE ... inside .... the WHITE-SILVER SPHERE.

11 AS YOU DRAW the PALE SILVER energy into the RED SPHERE visualize the RED SPHERE 'pop' into a STARBURST of PALE PINK-SILVER LIGHT..... and ..... for the next few breaths EXHALE the PALE PINK-SILVER LIGHT into the 12th Chakra, positioned 6" below your feet...

You have now opened the Kee Ra ShA(Y) Seal ... so that the Sacred Flames of the Kee Ra ShA can be activated .....

ACTIVATING THE KEE RA SHA

The Kee Ra ShA appears as 3 little flames which exist in the 12th Chakra positioned 6" below the feet. The 3 flames are PALE BLUE, PALE YELLOW & PALE VIOLET.

1. Begin by focussing deeply on the 12th Chakra, 6" below your feet, and the three little flames held there ... one is PALE BLUE, one PALE YELLOW & the third PALE VIOLET.... We'll take a few moments to do this.....

   If you have difficulty visualizing, just imagine that they are there.

2 On the INHALE, draw the PALE VIOLET FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra.....

3 Next, return your attention to the 12th Chakra, 6" below your feet ... allow yourself time to connect with the little PALE YELLOW-GOLD FLAME. Breathe easy.

4 On the next INHALE draw the PALE YELLOW-GOLD FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra.....

Again, return your attention to the 12th Chakra, 6" below your feet ... and connect with the PALE BLUE FLAME... this FLAME is the INNER ARC of the COVENANT ... Take your time; breathe easy.

5 On the next INHALE draw the PALE BLUE FLAME up from Chakra 12 ... into the central vertical column .. and all the way up ... and out through the top of the head, to the 10th Chakra ... 6" above your Crown chakra.....

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6 Now, visualize or imagine the 3 little FLAMES together within the 10th Chakra 6" above your Crown Chakra ..... in a moment we will create the Kee Ra ShA SPHERE... Breathe easy.

7 On the next INHALE draw PALE SILVER energy from your personal Maharic Shield 12" below your feet, all the way up your central vertical column, up into the 10th Chakra.....

EXHALE gently and INHALE once more, drawing more PALE SILVER energy up into the 10th Chakra ... visualize or imagine the 3 little flames enclosed within a SPHERE of PALE SILVER LIGHT...

8 Breathe easy. On the next EXHALE move the Kee Ra ShA SPHERE all the way down through the central vertical column, out through the 12th Chakra 6" below your feet, and all the way down to the 13th Chakra at EARTH'S CORE.

As the Kee Ra ShA enters EARTH'S CORE listen for sound tones w/ inner ear...

These TONES represent the AMENTI "PASS KEY" ... which opens your personal GRU-AL POINT (#1) - the 1st Cell in the Tail Bone .... releasing the KEE RA SHA FLAMES into your AURIC FIELD.

9 Breathe easy... Watch as the Kee Ra ShA FLAMES rise up your Maharic Pillar and emerge through your 1st Cell ... passing like radiating waves of PALE BLUE, PALE YELLOW & PALE VIOLET .....

10 As the waves of color move through you, bring your attention to your first 4 Chakras ... the base, the sacral, the solar plexus and the heart ... and visualize or imagine each Chakra emanate a SILVER MAHARIC SHEATH or OVAL POD, completely surrounding each one ...

This completes the EMERALD AWAKENING, the natural process by which we use Unified Field Physics to trigger our CHRISTED Selves. Before we finish we must first establish the link to the Amethyst Awakening, the process of activation and sheathing of the higher Chakras.

To complete the session we will now work with 8th & 11th Dimensional Energies to open DORADIC PHASE 2 & 3 CURRENT and activate TEURIC PHASE 2 CURRENT.....THIS IS CALLED **ACTIVATING THE RA CENTRE in the THYROID – and ANCHORING THE RAINBOW BRIDGE**

1 Begin by moving your attention to the area of your 3RD EYE, and focus just inside your fore-head .. a little above and behind your eye brows..... Breathe easy.

2 Now, visualize, or imagine, a DARK SILVER DOT in the position you are focussed on ... in the area of your 3RD EYE... Take a little time.

3 INHALE and move the DARK SILVER DOT into the Pineal Gland in the center of your head and then straight up through the CROWN CHAKRA until the DARK SILVER DOT sits on the top of your skull.

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4 On the next INHALE, pull PALE SILVER ENERGY up from your personal Maharic Shield 12" below your feet, all the way up the central vertical current and into the DARK SILVER DOT on the top of your head...

As the PALE SILVER ENERGY reaches the DARK SILVER DOT, the SILVER DOT 'pops' into a SILVER STARBURST ...

5 On the next EXHALE push the SILVER STARBURST down the central vertical channel, all the way to the tip of the tail bone ... EXPANDING the SILVER STARBURST FULLY into the 1st Cell...

6 Breathe easily and watch, as GOLD-SILVER-CURRENT emerges from the tailbone .. and begins to flow up through each Chakra ..

from the 1st Chakra at the base of the spine ... up through the Sacral ... the Solar Plexus ... all the way up to the Crown Chakra ... we'll take a little time for this ....

From the Crown Chakra the GOLD-SILVER-CURRENT continues upward out of the top of your head ... up through the 10th Chakra 6" above your head ... the 11th Chakra 18" above your head ... and finally the 14th Chakra 36" above your head.

7 Once the GOLD-SILVER-CURRENT reaches the 14th Chakra it returns to the 1st Chakra the flow of the current creates a GOLD-SILVER SHEATH throughout your central vertical channel.

8 Bring your attention to the 2nd Chakra now .. were going to create a GOLD -SILVER- BALL there, in the SEED SEAL at the center of the Chakra ... just imagine the chakra as a bow tie shape, the SEED SEAL is at the narrow point in the middle. The GOLD-SILVER BALL is called the TEURIC SPHERE ...

INHALE and draw GOLD -SILVER-CURRENT from the GOLD -SILVER-SHEATH into the center of the Chakra ... as you EXHALE create and EXPAND the BALL to surround the bow tie ...

9 Now ...INHALE and move the GOLD -SILVER-BALL up to the 1ST HARA CENTRE ... 2" BELOW the NAVEL (the 9th SILVER STAR SIGNET SEAL or TAN TIEN) ... EXHALE GENTLY allowing the BALL to EXPAND

10 On the NEXT INHALE move the GOLD-SILVER-BALL up to the SOLAR PLEXUS and EXHALE GENTLY

11 INHALE and move the GOLD-SILVER BALL up to the HEART CENTRE ... EXHALE GENTLY ... ... INHALE ... drawing more GOLD-SILVER CURRENT into the BALL and THEN EXHALE FORCEFULLY pushing cords of GOLD SILVER CURRENT down each arm and into the PALMS ... bring your fingertips together and feel the fuzzy buzz of TEURIC PHASE 3 CURRENT

You have now activated TEURIC PHASE 3 CURRENT in your palms – and – you are now able to run CURRENT from D4 thru' D8 to transmit to the THYROID GLAND ... to activate and anchor the Rainbow Bridge in others.....

End of Field Technique-5 *The K-RRT Activation Sequence* (5A-B-C-D-E)

You are now ready for the Amethyst Awakening *Masters Kundalini/DNA Template Activation-2* (Field Technique-6 *Initiating the Amethyst Awakening*) or to participate as an active member of *a Khundaray Rainbow Roundtable* (K-RRT) Signet Council (Field Technique-4 A-B-C). Wait at least 4 Hours before K-RRT participation, and no longer than 24 hours to maintain the appropriate level of critical mass Khundaray frequency in the body that is need for an effective K-RRT.

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INITIATING THE AMETHYST AWAKENING

1 **Preparation:** Complete **Maharic Quick Seal Activation Sequence** Technique 6 and

2 This technique works to bring in a burst of the Khundaray, Eckatic Blue frequency ...that sets the Amethyst Awakening in motion.

3 Place your attention at the center of your brain, inside your pineal gland. Imagine that you see there a Pale Violet Spark of Light (this is the bottom of the Seal of your 7th Crown Chakra). Imagine that you are going to move this Pale Violet Spark of Light straight up into your 10th Chakra 6" above your head ... imagine that the 10th Chakra is a disc of Light, Blue/ Black – Sapphire.

4 Now see the disc of Light, that was Blue/ Black take on a Violet hue. Try to feel it there, a small horizontal disc ... On the INHALE you will move this disc of Violet-Sapphire Light up to the 24 point Silver Star at the 14th Chakra ..... and, on the EXHALE, move it down through the 10th Chakra, down through the Crown, down the Central vertical Current, down through your Personal Maharic Shield all the way down to the 13th Chakra at the Earth's Core ...

5 Notice, as you do this, a whole series of Violet-Blue Sparks flying out from the Planetary Maharic Shield, as if they are alive, as if electrical communication is taking place. Notice as this happens that the energy flowing up your Maharic Pillar from the Earth Core reflects this change as Violet-Blue energy flows slowly up toward you ... as this energy reaches your personal Maharic Shield, notice that it does the same thing as the Planetary Shields – throws out a shower of Violet-Blue sparks ... all communicating with each other about the mathematical instructions about what to do with your body, your crystal seals, your chakras ...

6 Now, move your awareness to the Pale Silver skin all round your body/ etheric body .. and be aware too of the Main Vertical Current that you brought the Pale Silver cord through ...and at the same time, on each coming INHALE, bring up the Pale Silver-Violet-Sapphire energy, simultaneously, from your Maharic Shield to infuse the Pale Silver skin all round you.

Take a few breaths to do this and watch as the 3 color flicker through you – when they reach the Heart Chakra feel them expand out ... and allow them to travel on up, all the way to the 14th Chakra ... expanding throughout every Chakra as the Pale Silver-Violet-Sapphire energy flows up, through and all around you ... See each Chakra respond with a spiraling burst of Silver-Violet-Sapphire, backward and forward through both sides of the Chakras until they all shift .. try to feel the process as it awakens all the cell's of your body.

The brain cells and brain patterns begin to respond, activating the Fire Letters, setting the grid of frequencies necessary to activate the Fire Codes 7, 10 and 12 in the DNA Template.

Your own **D-12 Christos Avatar identity level will slowly** release the ***Khundaray Activation Frequencies*** through which the Amethyst Awakening progressively unfolds in the DNA Template and body. This process can be **naturally and safely accelerated** by receiving a **Level-3 MC Regent Ordination transmission** from a qualified **Indigo Child/Eieyani *Level-4 through Level 6 MC Ordinate* Consummate, Elder Consummate** or **Eckar** that carries the necessary **Amethyst Awakening Khundaray Activating Frequencies** in their Eieyani DNA Templates.

The Merkaba Trinity Key Induction

The ***Merkaba Trinity Key Induction Technique*** begins the process of establishing a **conscious directional relationship** with various levels of your 15-Dimensional Anatomy (or that of your Client). The **Trinity Key Symbols** are **mathematical-geometrical programs** that carry the specific organic structure of **each dimensional frequency band** as it exists within the **D-12 Universal Divine Blueprint**. Imbuing the proper **Symbol Key** into the appropriate area of the personal anatomy can rapidly expedite **restoration the personal Divine Blueprint** within the **DNA Template, Chakra System** and embodied **Kathara Grid**. Use of the Trinity Master Key Symbols that correspond precisely to the natural order of each dimensional frequency band, can **intensify** all applications of **holistic and allopathic healing**, as well as progressively and systematically assist in the process of accelerating **DNA Template** healing and **activation.** Every **condition** within the body-mind-spirit system has a specific **Energy Signature** unique to its own construction. Every **dis-ease** condition within any aspect of the personal experience (physical, emotional, mental, spiritual, financial, social, etc.) is created and **held in manifestation** by a specific set of mathematical – geometrical energy relationships that are **stored** within the embodied **Kathara Grid** and **DNA Template** in the form of **Symbol Keys**. The mathematical-geometrical energy relationships that serve as the **blueprints** upon which experiential manifestation will emerge can be perceived by the conscious identity in its Symbol translation. When using the **Trinity Master Key Symbols**, you are **resetting and activating very specific portions** of the personal **Divine Blueprint** (D-12 Pre-matter Maharic Shield) into a naturally harmonious relationship with Universal Order (the organic structure of dimensionalized frequency bands). The Trinity Master Keys provided in this Technique trigger activation of very specific **Fire Letters** (Keylons) within the DNA Template, allowing the DNA Template to receive directly the **new electrical instructions** corresponding the personal Divine Blueprint. This technique can be used with Kathara Healing Techniques from Kathara Level-1, with any other healing modality or singly after activating the D-12 **Maharata Current** via **Techniue-6, *The Maharic Quick Seal***.

It is **necessary** to initiate a **D-12 Maharaic Seal** in order to run **any Symbol Key program** into the DNA Template and Level-1 Kathara Grid; it is the strength of the D-12 Maharata Current that allows access to the deepest levels of the Personal Shields and Divine Blueprint. The **Trinity Master Key Symbols** are a **set of 3 Symbol Keys** that are to be used **in sequence.** The first two Trinity Keys, the **Initiating Keys**, are used in **every application** to open the embodied Level-1 Kathara Grid to receive new instructions. The third Trinity Master Key Symbol, the **Transmitting Key,** corresponds directly to the Divine Blueprint of **one dimensional frequency band** and its corresponding **Kathara Center, DNA Strand Template, Chakra** and related body regions, **Axia-tonal Line, Auric Field Level** and **station of consciousness**. In a **Trinity Key Induction Session**, one can choose to work on only **one dimension** (Chakra-DNA Strand Template-Kathra Center-Axia-tonal Line-Auric Level) via its Transmitting Key, or each of the **12 Transmitting Key** of the Universal Kathara can be used, **in sequence**, following induction of the two Initiating Keys. The process of using the Trinity Keys is simple; the **Chakra** that corresponds to the Transmitting Key/ dimension/DNA Strand with which you desire to work is used as the **vortex** through which the Trinity Keys are **INDUCED** into the corresponding **Kathara Center**. From the Kathara Center, the Trinity Keys electrically pass on to the **DNA Template** and from there into the **Axia-tonal Line system** and corresponding areas of the body-mind-spirit system. Use of the Trinity Key Induction Technique progressively assists in activating the personal **Merkaba Vehicle** while **amplifying and expediting restoration** of the personal Divine Blueprint.

Technique # 9: Merkaba Trinity Key Induction

1. Activate the Maharata Current via **Technique-6: *The Maharic Quick Seal*** and decide which Transmitting Key(s) you will use. **Trace** the **3 Trinity Symbol Keys** onto **3 small squares of paper.**

2. First, place each of the papers with the two Initiating Keys **face up on the floor**, then **stand** (barefoot or socks only) with **one foot on top of each of the papers; Initiating Key #1** under the **LEFT foot, Key #2** under the **RIGHT foot.** (Note: To run Trinity Key Induction for a Client, have them recline on their back and place the papers with Initiating Keys between your palms and the soles of Client's feet. As introduced in Kathara Level-1, use your **palm Chakras** to **transmit** the Symbols and the Pale-Silver Maharata Current, using the same action as described below, into the **Client's foot Chakras**; Key-1LEFT foot-***right hand transmission***, Key-2 RIGHT foot-***left hand transmission***.) In Self-induction, the papers with Symbols should be positioned beneath the **balls of your feet**, in the area of the main **Chakra** on the sole of each foot. Simply begin to **breathe deeply** and slowly for a few minutes. With each **INHALE** draw a **thick stream** of **Pale-Silver Maharata Current** from Earth's core through the **Central Vertical Current** of the body and out the top of the head to the **14th Chakra** 36-inches above the head. With each **EXHALE,** imagine a grapefruit sized Pale-Silver **Maharic Ball** rapidly moving down your Central Vertical Current. When the Maharic Ball reaches your 2nd-Chakra near the navel, imagine the Ball splitting into **Two Balls**, each continuing to **travel down each leg and out your feet Chakras**, through the **Symbol Keys**. Once the Two Balls of Maharic Current have passed through the Symbol Keys, imagine that they **re-merge** into the **one grapefruit sized Pale-Silver Ball** that continues to move downward into the **13th Chakra** at Earth's core. **Continue** this process until you sense a **momentary slight warmth, tingling or subtle itching** at the **balls of your feet.** These mild, **momentary sensations,** called the **CUE RESPONSE,** will grow stronger the more frequently you use the feet Chakras for Symbol Key induction. Once you have noticed the **Cue Response**, you have **successfully induced** the two **Initiating Trinity Keys** and it is now time to utilize the remaining **Transmitting Key.**

3. If you have chosen to use the Transmitting Key for D-1-Strand-1-Axiatonal Line-1-**Chakra-1**, continue **standing** for the final Symbol Key Induction, placing the paper with the Transmitting Key face up on the floor between **slightly parted feet**; **do not stand on Symbol Key paper** for **Base Chakra Induction.** For all other Chakras, **recline on your back** and place the paper with the Transmitting Key **directly on top of the Chakra** to which it corresponds, **on the front of the body**. Use each **INHALE** breath to drawn Maharata Current up from Earth's Core, into the Central Vertical Current **only as far up as the selected Chakra**. On each **EXHALE**, push Pale-Silver Maharata Current **out from the Central Verticle Current** of the body and **into the Chakra**, imagining that the Chakra is progressively turning into a **radiant vortex of Pale-silver light** that **spins faster and faster**. When you begin to feel a bit of warmth, tingling, energy running or itching of the skin **at the Chakra region** (the **Cue Response**), use a final **INHALE breath** to draw the image of the Symbol **down through the Chakra into the body**, and into the **tiny Crystal Seal** that links the Chakra to the Central Vertical Current. Take a **FINAL exaggerated EXHALE**, and imagine that you have **pushed the energy of the Transmitting Symbol Key** out of the Chakra into the **corresponding level of the Auric Field.** Once imbued into the **Auric Field** the single image of the Symbol then **replicates automatically and rapidly**, creating **millions of mini-replicas of the Symbol** within your bio-energetic field. When the **Cue Response** sensation at the Chakra has **completely ceased**, you have **successfully induced** the entire **mathematiucal program** of the Transmitting Symbol into the corresponding Kathara Center, DNA Strand Template, Axia-tonal Line, body region and level of consciousness.

Technique-9: Merkaba Trinity Key Induction

Trinity Master Key Selection Chart

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12 Transmitting Keys: ***Correspond to each Dimension-Chakra-Kathara Center-Axia-tonal Line etc.***

Number in circle represents the **number of Chakra** into which corresponding Transmitting Key Symbol will be induced.

Note: The **Smaller Symbols** placed **outside of SOME circles** are **Amplifier Key Symbols** corresponding to the Chakra by which they are positioned. The Amplifier Keys can be used **in place of** the Transmitting Key within the circle, or the two Keys can be drawn on one paper for **simultaneous induction**. It is **recommended** to begin with the Transmitting Key inside the circle, then after a few induction exercise, switch to the Amplifier Key, and after several exercises with the Amplifier Key, use both Transmitting and Amplifier Keys simultaneously.

Two Initiating Keys

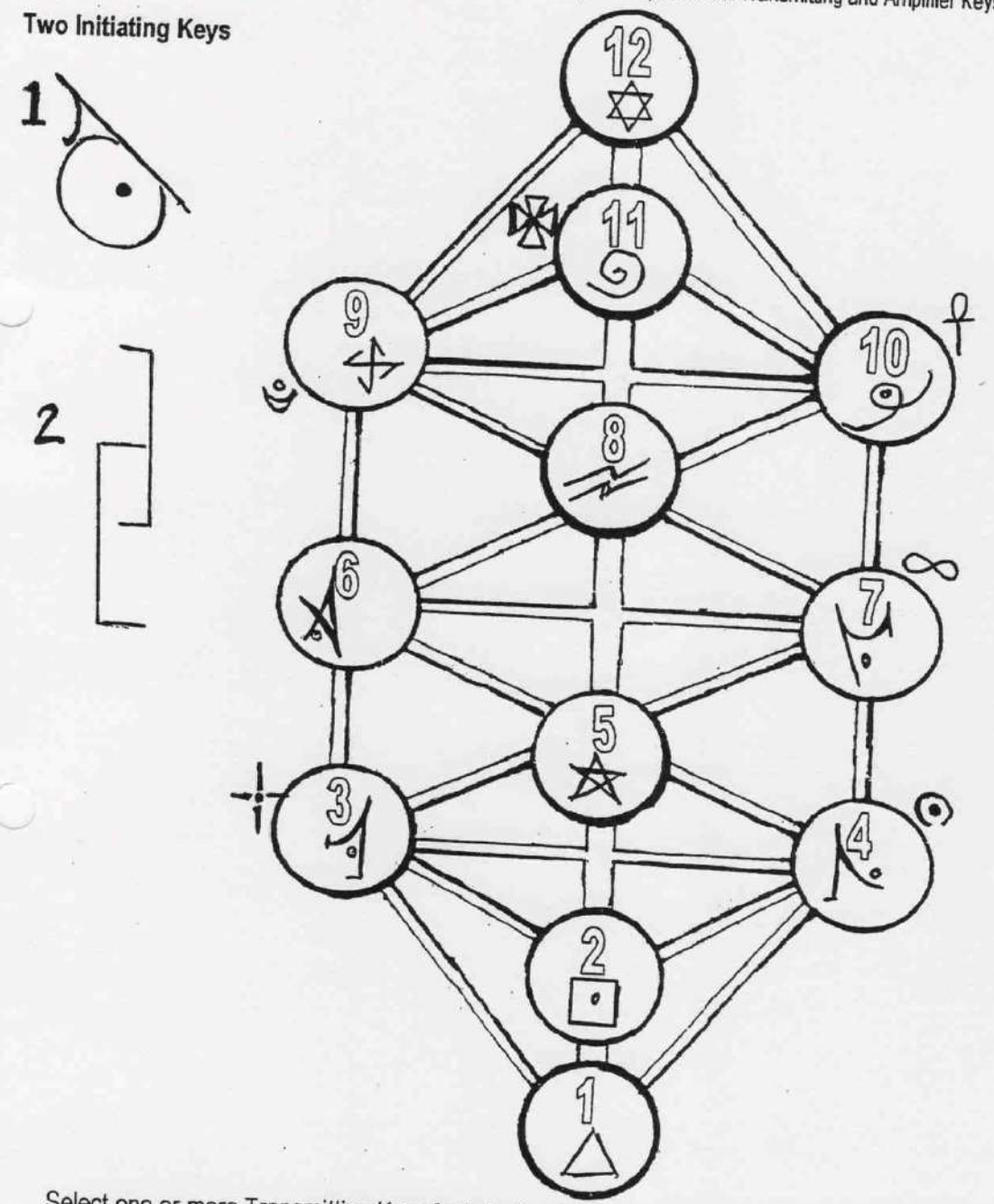

Select one or more Transmitting Keys for induction following induction of the two Initiating Keys above.

In **Kathara Level-1** we have learned of the innate structures of multidimensional reality and how these structures are intimately intertwined with the ***15-Dimensional Human Anatomy*** and levels of personal identity through the personal ***Maharic Shield*** and ***DNA Template***. In rediscovering these long forgotten aspects of the Human condition and our inherently implied relationship to Universal Order, we've become empowered to draw upon the natural **Triadic Phase Currents** indigenous to our personal biology and universal structure, in order to take an active hand in personal *Conscious Bio-spiritual Evolution* and healing, and healing facilitation for others. ***Techniques 1-5*** (#1-*Awakening the Mentor*, #2-*Maharic Seal and Liquid Light Cleanse*, #3-*Opening the Healing Channels Doradic Phase-1 Current*, #4-*Multi-vector Holographic Recoding Kathara Scan* and #5- *The Maharic Infusion* client session) contained within *Chapters 1-4* of *the Kathara Level-1 Maharic Recoding Process* enable us to begin conscious interaction with the "invisible" processes of **Body-Mind-Spirit Evolution** that are inherent to Human design.

In our introduction to **Kathara Level-2** we have begun to explore the greater nature of ***Universal Life Force Currents***, the "mysterious" sciences of ***Merkaba Mechanics*** and their indelible connection to our personal evolution and **Bio-spiritual Actualization Processes**. ***Techniques 6-7-8-9-12*** (#6-*Maharic Quick Seal*, #7-*Ps13 Tribal Shield Activation*, #8-*Merkaba Salutations*, #9-*Merkaba Trinity Key Induction* and #12 *Kee-Ra-Sha Activation Sequence*) so far explored within this *Chapter 5* of the *Kathara Level-2 Introduction* enable us to advance our conscious interaction with the processes of personal Body-Mind-Spirit Evolution and Bio-Spiritual Actualization. As we increase our personal abilities to understand, embody, hold and direct the inherent powers of the Universal Life Force Currents, and to access the levels of personal spiritual identity and wisdom to which they correspond, we progressively increase our ability to consciously facilitate healing in ourselves and for others we may choose to serve. An in-depth study of Universal Life Force Currents and Masters Merkaba Mechanics involves cultivating a necessary familiarity with a broad spectrum of interrelated subjects that take us into the heart of the Science of Vibrational Mechancis and Holographic Creation Physics, as well as into the very Soul of our spiritual relationship to consciousness, ourselves, each other, our world and God. Mastery of Merkaba Mechanics is an attribute inherent to achieving the state of consciousness often called "Ascended Mastery", which requires much in-depth study into the "mysteries" of creation. However, a functional mastery of Merkaba and the related constructs of the personal "Inner Templar" system upon which the personal body and identity manifest can be achieved through gaining familiarity with and actively employing core mechanics of the personal Merkabic System.

As our *Kathara Level-2 Introduction* began, our exploration of active techniques of *Tribal Shield Activation, Merkaba Salutations* and *Trinity Keys* set us on the path of becoming functionally able to consciously direct elementary operations of the personal Merkaba Vehicle and Life Force Currents, as a means of expediting our progress of Bio-Spiritual Evolution through DNA Template/Merkaba Field Activation. As our *Kathara Level-2 Introduction* continues, we will begin to explore the seemingly ***"magical world of Merkaba"***, rediscovering the very tangible importance of the **Merkaba Field** in relation to the inherent dynamics of DNA, health, healing and spiritual actualization. To achieve genuine integrity in the facilitation of healing for others, one must simultaneously strive to heal and actualize the self. The greater the level of health and spiritual actualization possessed by a healing facilitator, the greater will be the facilitation of healing for the client to whom the healing facilitator is in service. As Kathara Level-2 Introduction draws to a close we will begin an introductory exploration of the "Ancient Secrets" of the **Veca Codes,** so that we may engage practical application of two additional techniques of Photo-Radionic and Photo-Sonic **Merkabic Healing. Techinque-#10** ***Restoring the Trion Field Veca Code Activation*** and **Technique-#11-*Restoring the Meajhe Field Eckasha Activation*** will provide us with powerful tools of the Kathara Healing trade that will ***substantially increase the quality, amount and power of interdimensional frequency we are capable of receiving, holding and transmitting***. Through these simple but effective Merkabic Healing tools we can expedite our processes of personal healing and spiritual actualization, thereby enabling us to become more effective and powerful healing facilitators in our client session service.

The "Magic of Merkaba"

Spiritual-science teachings of **Merkaba Mechanics** emerge from the most ancient of times; record of Merkaba teachings is most often found in obscure traditional "Occult" texts or within New Age "Ascension" teachings. Genuine Merkaba Sciences hold the keys to understanding and mastering the processes of both spiritual and physical evolution, on a personal, planetary, galactic and universal level. Merkaba Mechanics are not the product of "science fiction", nor are they "magical hocus-pocus" of "occult mysticism". Merkaba Mechanics are not "magic" at all, but rather an intrinsic element of universal Primal Order. **Merkaba Fields**, sets of Star-tetrahedron shaped counter-rotating electro-magnetic energy fields within and surrounding manifest forms, are simply an inherent element of the15-Dimensional Anatomy of form manifestation and the Primal Order structure of multidimensional Creation Physics. In the "*Transduction Sequence*" described in *Kathara Level-1*, the sequence of energy transmutation by which conscious energy manifests into tangible biological form, the *Merkaba Field* represents the structure and stage of energy dynamics by which *Primal Life Force Currents* pass from the scalar-wave-template of the embodied *Kathara Grid levels* into the *DNA Template*. In terms of non-biological form manifestation, all forms possess an inherent structure of interwoven Merkaba Fields through which Primal Current energy is transmuted from the Kathara Grid Core scalar-template level into the outer levels of the Kathara Grid and Axiom Line template upon which the specialized structure of the form builds up, through particle/anti-particle accretion, into physical manifestation. Merkaba Mechanics seem "magical" only when the inherent "**Laws of Nature**" that govern the dynamics of **Multidimensional Universal Unified Field Physics** are not understood.

Through understanding of genuine *Universal Unified Field Science*, *Merkaba Fields*, and their inherent dynamics as utilized in the study of *Merkaba Mechanics*, are simply recognized as natural elements of the processes inherent to Creation Physics and the naturally occurring, organic relationships between Energy Consciousness, and the Holographic Manifestation of form.

As Merkaba Fields are an intrinsic, significant and natural part of the Body-Mind-Spirit anatomy, the study and application of Merkaba Mechanics is an essential component in any Masters Holistic Healing or Spiritual Actualization program. Merkaba Mechanics are "*Scientific*" in that they represent a core element within the innate processes of creation and manifestation that are intrinsic to the sciences of Creation Physics. Merkaba Mechanics are also "*Spiritual*" in that it is through the innate structures and dynamics of Creation Physics, of which Merkaba Mechanics are a natural part, that consciousness enters the manifest arena in the form of sentient, individuated, multidimensional identity. The "body, mind and spirit" of every manifest being is formed through and governed by the natural laws of Creation Physics and Primal Order. The Laws of Creation Physics and Primal Order are designed and maintained by and within a non-manifest, intelligent, central Consciousness Force and Source of Creation that is commonly referred to as "**God**". God expresses It-Self in the form of *Conscious-energy Constructs* that carry the living "Spirit and Consciousness of God" in the form of **Primal Life Force Currents**, which are the foundations for macrocosmic and microcosmic creation and manifestation. Merkaba Fields and the mechanics by which they function, are an indelible part of the physics of Creation and Consciousness, and are thus intimately involved with the Bio-Spiritual processes inherent to **Spiritual Actualization**.

Merkaba Fields, DNA, Healing and Spiritual Actualization

Particles, People, Planets, Galaxies and Universes all have **sets of interwoven Merkaba Fields** that serve as the "**core Primal Life Force Current circulation system**" between the Cosmic, Universal, Galactic, Planetary and Personal "Divine Blueprint" Kathara Grid scalar-templates and the manifestation of those blueprints into the tangible structures of matter. Merkaba Fields are the "**carriers of consciousness**" and the "**engines of energy**" by which physically manifest forms are created, maintained and evolved through the Holographic Unified Field of manifest space-time-matter reality. In relation to the processes of personal bio-spiritual healing and spiritual actualization, the personal Merkaba Field is an intrinsic aspect of 15-Dimensional Anatomy that directly governs the function of the physical, emotional, mental and spiritual body systems. **The multidimensional structure of the personal Merkaba Field is the system of electro-magnetic interface by which the Primal Life Force Currents and Consciousness of God-Source and Its sentient individuations pass from the Kathara Grid Core Template into the scalar-wave DNA Template that holds the blueprint for the physical-chemical biological DNA.** This reality of **Merkaba Field-DNA Connection** implies that the personal Merkaba Field is directly related to the function or dysfunction of the **biological genetic code.** As the Merkaba Field "carries the energy of consciousness" into the DNA and biological vessel, the *Merkaba Field-DNA Connection* also implies that the potentialities of consciousness and embodiment of spiritual identity, while a being is ensconced within the Time Matrix, are dependant upon the condition and function of the personal Merkaba Field, DNA Template and Kathara Grid.

*Merkaba Fields are the "**carriers of consciousness**" and the "**engines of energy**" by which physically manifest forms are created, maintained and evolved through the Holographic Unified Field of manifest space-time-matter reality.*

Universal Merkaba Field Structure

Basic Merkaba Field structure is relatively simple. Viewed Macrocosmically, in a 15-Dimensional Time Matrix there are **15 sets** of counter-rotating electromagnetic **Merkaba Spirals** that form **15 Universal Dimensional Merkaba Fields.** A "**Merkaba Field**" is composed of a set of **2 Merkaba Spirals**, one electrical-transmitting "cone", the other magnetic-receiving "inverted cone"; the 2 "cones" of the Merkaba Spirals, which operate as a **White Hole/Black Hole Pair**, intersect each other, creating a system of energy vortices that form an **Elliptical Sphere** of energy within the center of the intersected Merkaba Spirals. The Sphere of energy at the center of a Merkaba Field is called the **FORM CONSTANT**; it is a "**spherical energy domain**" within which the individuation of consciousness and holographic manifestation/projection of form can take place, akin to an "energy egg" within which manifest reality occurs. Within this Sphere of energy at the center of a Merkaba Field, the template-blueprints of a form are held "constant", allowing conscious Partiki units, particles, anti-particles and ante-particles to accrete in specific ratios to "fill out the form in matter". Within the Form Constant sphere, consciousness is able to perceive the **holographic illusion** of externalized space-time-matter manifestation, as the scalar-template of the form is held fixed within the sphere. The "hologram" appears to remain "constant" within the Form Constant sphere while consciousness is focused within the frequency bands of which the Merkaba Field is composed.

On the macrocosmic universal scale, the Form Constant of each Universal Dimensional Merkaba Field creates a single, elliptical-sphere shaped electromagnetic domain of frequency that represents a single dimension of manifestation. Following the innate mathematical-geometrical structure of Primal Order, the 15 Universal Dimensional Merkaba Fields group into **5 sets** of 3-Dimensional Merkaba Fields called **Universal Harmonic Merkaba Fields**. The 3 Form Constant Spheres from each set of 3 Universal Dimensional Merkaba Fields forms a **Universal HOVA BODY**, or a "Harmonic Universe" electromagnetic domain. Following the mathematical Primal Order program of a Time Matrix as held within the Universal Kathara Grid template and transmitted through the rotation ratios of the Harmonic and Dimensional Merkaba Fields, each of the 3 dimensional levels of a Universal Hova Body holds the Partiki units, consciousness and matter particulates of its dimensional field into a specific angle and speed of rotation. The 3-Dimensional Harmonic Merkaba Field controls the relationship of particle rotation angle (angular rotation of particle spin or "**ARPS**") and rotation speed between each of the 3 Dimensional Merkaba Fields, holding together a 3-dimensional electromagnetic domain, within which consciousness can experience a 3-dimensional space-time-matter hologram. In a single 15-Dimensional Time Matrix there are thus 15 singular Universal Dimensional Merkaba Fields governed by 5 larger 3-dimensional Universal Harmonic Merkaba Fields, all of which circulate consciousness in the form of Primal Life Force Currents into and out of the hologram of manifestation. The seeming solidity and durability of an externally manifest matter-field in space-time is created, maintained, perpetuated and completely dependent upon the intrinsic function of the Universal Merkaba Fields.

Within the larger Form Constant elliptical-spheres of the 5 Universal Hova Bodies of a 15-Dimensional Time Matrix, the holographic perceptual realities of space-time-matter take place. Every being or thing in manifest form enters its reality hologram by *taking on the mathematical program* of first the *Universal Kathara Grid* and *5 Universal Hova Bodies*, which set the "Life Stream" or "Stream of Consciousness" of Primal Creation

Currents in motion following the specific **Harmonic Merkaba Field spin ratios** characteristic to each Harmonic Universe System. Galaxies are formed in this way, as individualized expressions of the greater Harmonic Universe of which they are a part. **Universal Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation of the **galaxies** within them. **Galactic Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation of **star systems and planets** within them. **Planetary Harmonic and Dimensional Merkaba Fields** govern the birth, evolution and transmutation/death cycles of the **species and matter forms** existing upon the planet. The **Personal Merkaba Fields** of species and individuals direct the function of the personal **DNA Template, chemical DNA** and **biological genetic code**, thus governing the birth, evolution and transmutation processes of individual organisms. The mathematical-geometrical programs of the **Primal Order "Divine Blueprint"** that govern Merkaba Field formation and spin ratios are held within the Universal, Galactic, Planetary, Species and Personal Kathara Grid structures. In a singular 15-Dimensional Time Matrix, the **inter-linked Universal, Galactic and Planetary Harmonic and Dimensional Merkaba Fields** circulate Primal Life Force Currents and consciousness into and out of manifestation in space-time.

Universal Merkaba Fields

Universal Merkaba Field of One 15-Dimensional Time Matrix

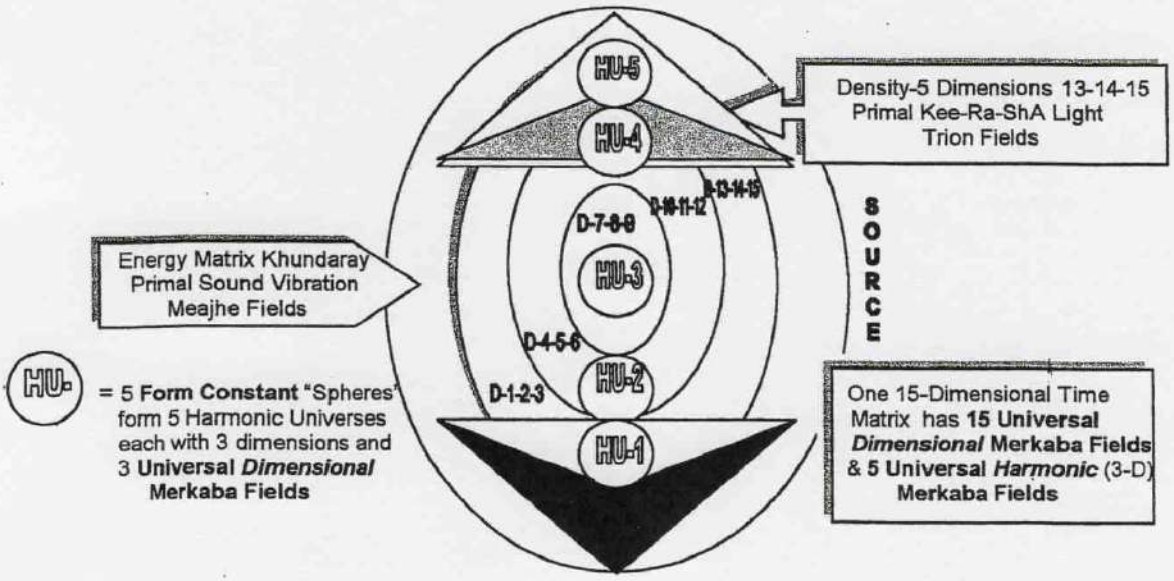

The Personal Merkaba, Trion-Meajhe Field, Radial Body and Radis.

Each individual being receives its life force, consciousness, biology and manifest hologram through the innate connection between the **Personal Merkaba Field** and the Merkaba Fields of the Planet, Galaxy, Universe and Time Matrix. When the **D-12 Pre-matter Divine "Christos" Blueprint** is expressing naturally in a planetary system, the organisms on the planet circulate Life Force Currents and consciousness through the physical and "spiritual" bodies via the Personal and Planetary Merkaba Fields. The **Planetary Merkaba Field** circulates Life Force Currents through the **Personal Kathara Grid** template (morphogenetic field) of the organism via the **Planetary Bio-Feed Interface System.** The organism's **Personal Merkaba Field** then picks up the energy from the Kathara Grid and continues to circulate the Life Force Currents from the Personal Kathara Grid and into the **Maharic Shield imprint** in the **DNA Template** that is held within the Level-1 *Kathra 12-Tree Grid,* Level-2 *Kathara Crystal Seals-Hara Grid* and Level-3 *Kathara Diodic Grid.* From the Maharic Shield imprint in the Kathara Grid, the Personal Merkaba Fields distribute the Life Force Currents and consciousness into the **DNA/RNA Template** and **Axiom Lines.** The Life Force Current continues circulation from the DNA/RNA Template and Axiom Lines into the **Personal Hova Bodies** and **Auric Field,** to the **Chakras** and **Meridian Lines.** Passing through the Meridian Lines, the Life Force Current, imbued with the specific mathematical manifestation program picked up from the Kathara Grid Divine Blueprint Template, then enters a state of final transmutation into 3-dimensional particles by passing through an electrostatic **Repulsion Zone** barrier that exists surrounding each 3-dimensional Hova Body.

The frequency barrier surrounding each 3-dimensional Hova Body forms as **thin, skin-like membrane** or **"Tissue Capsule"** surrounding each of the 5 Hova Bodies in the 15-Dimensional Anatomy. The **Hova Capsule** membrane is composed of Density-5 **Primal Light** ante-matter units, called **TRION UNITS,** that exist in the form of fixed standing-columnar-scalar-light waves made of **Keylons,** or 3-dimensional **Partiki Grids.** The Trion Units and Keylon Partiki Grids within them are anchored upon a fixed field template of **Primal Sound** units, called **MEAJHE UNITS,** which exist as fixed points of mathematically organized vibration. The outer layer of each Hova Capsule is called the **Trion Field,** as it is composed of **Trions,** or units of Density-5 ante-matter Primal Light. The inner portion of the Hova Capsule is called the **Meajhe Field** as it is composed of **Meajhons** (mE' yans) or fixed points of Primal Sound vibration from the **Energy Matrix** beyond the holographic manifestation of the Time Matrix Light Fields. The collective body of the 5 Hova Capsules is called the **RADIAL BODY** or **Trion-Meajhe Field.** All manifest forms possess a core Radial Body/ Trion-Meajhe Field **Hova Capsule** structure as part of the intrinsic 15-Dimensional anatomy.

As multidimensional Life Force Currents pass through the Meridian Lines and into each of the 5 layers of the Radial Body, the energy currents and the consciousness carried upon them project the mathematical program of the Divine Blueprint into the Trion-Meajhe Field of each of the 5 Hova Capsules. Within the Hova Capsule, the individualized raw Life Force Currents enter a system of 3-dimensional energy conduits or **rivulets** called **Radis,** which are the "turnstiles" between "manifest matter" and "conscious energy". The Radis draw in the Life Force Currents with their manifestation program through the Trion-Meajhe Field, then polarize and break up the Trion and Meajhon units into negatively and positively charged electrical sub-units called **Mions** and **Dions.** Partiki, Keylons, Meajhons, Trions, Mions and Dions belong to a category of primal building blocks known as **IONIC PARTICULATES,** which are the building blocks of consciousness, energy, light, sound and scalar-wave-fields that form the blueprints upon which all matter manifests. **Trions** are electrostatic particulates that have both a negative and positive electrical charge, which renders them neutral or static; they are the foundations of what becomes **Ante-matter** Primal Light particles of pre-visible gaseous light. Meajhons are static units of pre-sound standing waves, also possessing neutral electrical charge, that form the Primal Sound Fields of the Energy Matrix. Within the structures of the Radial Body Radis rivulates, Trions and Meajhons are **polarized** into negative charged **Mions** ("Base Magnetic" vibrating pre-sound particulates, foundations of negatively charged particles such as electrons, originating from the Universal Particle Particum field.) and positively charged **Dions** ("Base Electrical" oscillating pre-

light particulates, foundations of positively charged particles such as protons, originating from the Universal Anti-particle Partika field). Together, Mions and Dions create the **electromagnetic Ionic Particulate base field** within the Merkabic Form Constant through which particles emerge via Ionic Particulate accretion into tangible matter units.

The Trion-Meajhe Field Radial Body of any manifest form represents the 5-Density "Veil" through which consciousness-as-Primal Life Force moves into and out of externalized 3-dimensional manifestation. **Merkaba Fields are the "energy engines and consciousness carriers" by which Life Force and consciousness are circulated between the internal Kathara Grid scalar template and the Trion-Meajhe Field Radial Body "veil" as they pass into and out of external expression.** The perpetual polarization, electromagnetic expression and de-polarization of the Life Force Currents within the Merkaba Field Form Constant electromagnetic domain is the process by which the holographic projection of matter is perpetually brought into and taken out of perceptually experiential being. The **Radial Body** Trion-Meajhe Field receives, via Merkaba Field circulation, the template or "design" for its particle manifestation from the "instructions" held in the Divine Blueprint Maharic Shield and DNA Template of the Kathara Grid. Manifestation instructions pass from the Kathara Grid to the DNA Template via the Merkaba Field, then continue into the energy circulation systems (Axiom Lines, Hova Bodies, Chakras, Meridians) that deliver the instructions to the Radial Body for particulate manifestation. In biological life forms, the Radial Body and Radis then translate the scalar-wave blueprint of the DNA Template and Kathara Grid into the polarized Ionic Particulate Mion-Dion sub-units, which accrete following the DNA Template instructions to form sub-atomic, atomic, molecular, chemical DNA, physical matter form- the vehicles of embodied consciousness. The **Merkaba Field** also receives its instructions for energy circulation from the Kathara Grid and DNA Template.

The Radial Body Tissue Capsule, Radis
& the Mechanics of Manifestation

The **Radial Body** exists as a thin "***Tissue Capsule***" surrounding each of the **5 Hova Bodies.** Each of the **5 Radial Body Levels** are composed of an **Outer Layer** of electrostatic neutral-charge **Trion Primal Light Units** and an **Inner Layer** of **Meajhon Primal Sound Units**. Each of the 5 Levels of the Radial Body serve as the **polarizing filter or "lens"** through which **Multidimensional Primal Life Force Currents** flow, via **Merkaba Field** circulation, from the Kathara Grid and DNA Template, into manifest form.

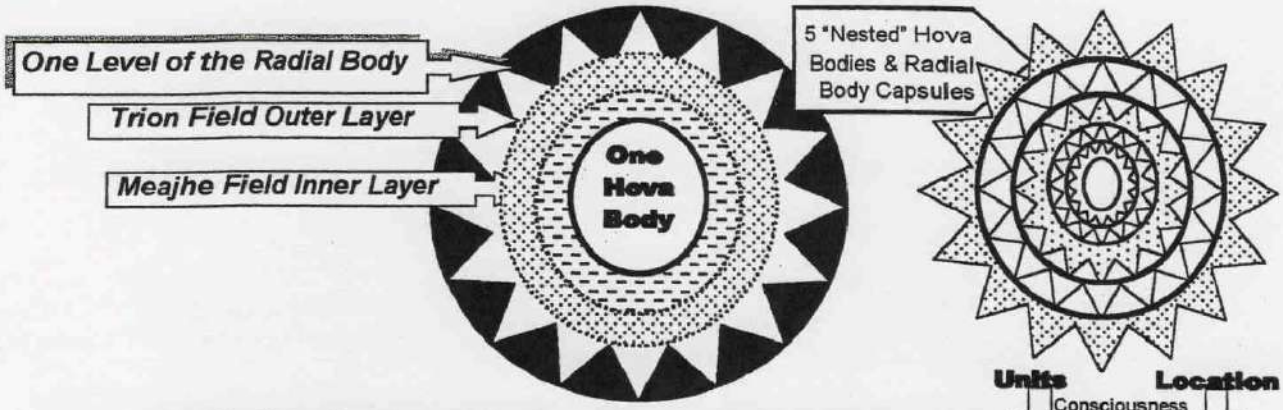

Radial Body Transduction-Manifestation Sequence

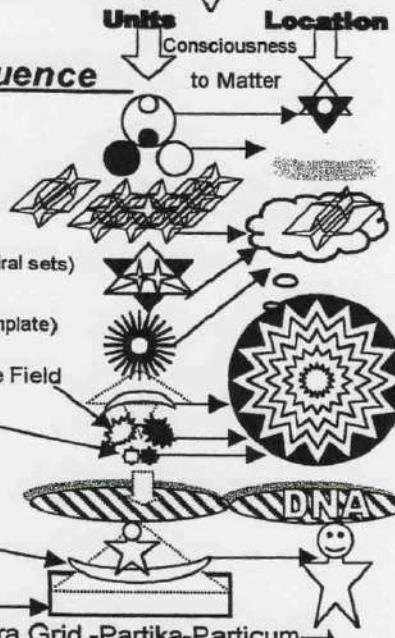

Primal Life Force Current *Partiki Units* Planetary Merkaba Field
(Units of Consciousness/Primal Substance)
Partika and Particum Units Kathara Template/Maharic Shield
(Polarized Primal Substance Units)
3-D Partiki Grid Keylon Units/Codes/Grid Morph. Keylon Thought-Form Field
(3-D Crystallized Pre-Light-Sound units, unit groups and grids)
Merkaba Field *Keylons* (3-D Crystallized Pre-Light-Sound Keylon Unit electromagnetic spiral sets)

DNA/RNA Template *Keylons* Kathara Grid (3-D Crystallized Pre-Light-Sound unit Template)
Axiom Lines-Hova Bodies-Auric Field-Chakras-Meridian Lines
Trion & Meajhon *Electrostatic Units* 5 Radial Body "Lens" Levels Trion-Meajhe Field
Dion (+) & Mion (-) Ionic Particulate *Electromagnetic Units* Radis Lines

Sub/Atomic Particles/Anti-Particles, Molecules...Chemical DNA
Physical Matter Body Hologram "Chemical Lens"

External Hologram Projection of Space-Time-Matter

Primal Life Force Currents ➡ Planetary Merkaba Field Partiki ➡ Kathara Grid -Partika-Particum ➡ Maharic Shield Divine Blueprint ➡ Keylon Morphogenetic "Thought-form" Field ➡ Merkaba Fields ➡ Kathara Grid DNA/RNA Template ➡ Axiom Lines ➡ Hova Bodies ➡ Auric Field ➡ Chakras ➡ Meridian Lines ➡ Trion-Meajhe Field 5 Radial Body Levels ⇨ Radis Lines ⇨ Mion & Dion Ionic Particulates ⇨ Strong and Weak Nuclear Force, Electromagnetism ⇨ Quarks, Muons, Measons, Sub-atomic & Atomic Particles and Anti-Particles ⇨ Blueprint translation into Nuclei, Molecules, Elements, Compounds, Chemicals ⇨ Chemical DNA Template and "Chemical Lens" of the manifest body form ⇨ Manifest Hologram ▭

Reverse Transduction De-Manifestation Sequence: matter- *chemical* DNA- *Sub-Atomic units*- Radis *Mion/Dion units*- Radial Body *Trion-Meajhon units*- Meridian Line-Chakra-Auric Field-Hova Body-Axion Line-DNA Template-Merkaba Field-Morphogenetic Thought-form Field *Keylon Grids & units*- Maharic Shield Template & Kathara Grid *Partika and Particum Units*- Planetary Merkaba Field *Partiki Units* of consciousness.

Radial Body Transduction-Manifestation Sequence

1. From the **Planetary Merkaba Field** (via the Planetary Shield, Axiom Lines, Hova Bodies Vortices, Meridian Lines and Radial Bodies), **rhythmic pulses of Conscious Primal Life Force Currents** enter the species and personal **Kathara Grid Core Template** as Primal Units of **Partiki**.

2. Within the **Kathara Grid Template** the **Partiki Units** pick up the **mathematical-geometrical program** from the **Maharic Shield** "Divine Blueprint" Template, **polarize** to form **Particum and Partika Units**, then **accrete** to form **3-dimensional** electro-magnetic **Partiki Grids** called **Keylons**. The Keylons group together mathematically forming complex templates of **Crystallized Keylon Codes** (or "***Keylon Thought-Crystals***"), which create a mathematically encoded **3-dimensional Morphogenetic Field ("Keylon Thought-form Field"** or Morphogenetic **"Keylon Crystal Grid"**) carrying the manifestation blueprint program of the Maharic Shield.

3. As the Primal Life Force Currents of the electromagnetic Keylon Crystal Grid interact with each other following the program of the D-12 Pre-matter **Universal Divine Blueprint**, they form **sets of spiraling electro-magnetic vortices** called **Merkaba Fields,** which carry the Maharic Shield-Kathara Grid Blueprint program into formation of the **DNA/RNA Template** Keylon Crystal Grid.

4. From the DNA/RNA Template held in the Kathara Grid, Primal Life Force Current carries the **Keylon Crystal Grid** of the blueprint into the **Axiom Lines, Hova Bodies, Auric Field, Chakras** and **Meridian Line** systems, finally carrying the Keylon Crystal Grid of the Divine Blueprint into the **5 Radial Body "Tissue Capsule" Levels.**

5. Within the **5 Levels of the Radial Body** the **incoming Keylon Crystal Grid** translates into **electrostatic Trion-Primal Pre-Light Units** (gaseous pre-light Ante-matter) and **Meajhon-Primal Pre-Sound Units** (units of vibrating pre-sound energy) that possess a **neutral electrical charge.** The **Encoded Primal Life Force Currents** (PLFCurrents+ Keylon Crystal Grid blueprint program) are converted into a **Trion-Meajhe Field blueprint replica;** a " Primal Light-Sound" translation of the original blueprint.

6. The **Encoded Primal Life Force Currents** then travel, **AS the Encoded Trion-Meajhe Field**, into the **Radis Lines** in each of the 5 Levels of the Radial Body. The Radis Lines first **replicate and store** the **mathematical blueprint encoding** of the **Trion-Meajhe Field,** then **polarize** the neutrally charged Trion-Meajhe units into **electromagnetic units** called **Mion** (-) and **Dion** (+) ***Ionic Particulates***. The **replicated Trion-Meajhe Field blueprint** becomes part of the "Primal ***Pre-sound*** vibration" ***Meajhe Field*** **Inner Layer** of the ***Radial Body*** **Trion-Meajhe Field**, serving as a living "***Memory Matrix***" composed of **Meajhon Unit** "Primal Pre-sound vibration". The **polarized Mion/Dion Units** become the foundations upon which the **"Strong and Weak Nuclear Force", Electromagnetism, quarks, Muons, Measons, Sub-atomic Particles** and **Anti-particles** etc. form. Particum-based **Mions** ("Base magentic) become **particles, negative electrical charge units** like **electrons** and **sound spectra**. Partika-based **Dions** become **anti-particles, positive electrical charge units** like **protons** and **light spectra.**

7. Blueprint Encoded Primal Life Force Currents in the form of a **Mion-Dion Field** then translate the original Kathara Grid Blueprint into **Quarks, Muons, Measons, Sub-atomic** and **Atomic particles** and **anti-particles**, which **accrete** according to the blueprint to form **molecules, elements, chemicals**, the **Chemical DNA Blueprint** and the **physically manifest body form**. As this occurs the **body image "flashes on"** into manifestation as a **Pulse of Life Force Consciousness** carrying the **Chemically Translated Holographic Image** of the body form template blueprint. This Pulse of Consciousness continues to expand from the Kathara Grid and DNA via the Transduction Sequence, through and beyond manifestation of the body image and into **projection of portions of the Dimensional Unified Field** that **holographically translate** into **individualized experience** within a perceived **Common Planetary Time Rhythm and Matter Field.**

NOTE: ***An individual will holographically perceive and experience only the portions of the Dimensional Unified Field mathematical-geometrical program that are encoded within the personal Maharic Shield, species Tribal Shield and Planetary, Galactic and Universal Shield aspects of the personal Kathara Grid and DNA Template.***
A **global population** experiences a **common planetary reality field and time continuum** because the Kathara Grid Template and DNA of all beings entering a planetary field **adopt the common imprint** of the mathematical-geometrical program of the **Planetary Kathara Grid** blueprint in order to enter into the electromagnetic domain of the Planet's Form Constant Hova Body structure for experiential manifestation. Members of a **singular species** share a common **species Tribal Shield** template through which a **common Chemical Body Form** and perceptual orientation holographically manifest. The imprint for **individuality** in biological form, life experience variation and the application of **Free Will Choice** is held within the mathematical program of the **personal Maharic Shield** D-12 Pre-Matter **Divine "Christos" Blueprint**. Imbued within the mathematical program of the **Human species Tribal Shield**, and that of some other species, is the imprint for **probability** to exist. The Human species Tribal and Maharic Shields carry a program that allows for **new programs of probable creation** to be **added** to the personal and species **Kathara Grid**, allowing the embodied consciousness to retain **a degree of direct influence** over what sets of mathematical programs will be called into personal experiential Holographic Expression from the personal Maharic Shield Template. **Creative variation** on the original personal, species, planetary and galactic Divine Blueprint is possible as long as the new probabilities do not deviate so excessively from the Pre-set programs and **Original Intentions** of the Universal Divine Blueprint that the **structural integrity** and **Source-God Will Intentions** for our Time Matrix become **irreparably compromised. Free Will thus exists within a pre-set framework of overriding Divine Will**, and is permitted free reign in the manufacture of **co-creative experiential probability** up to the point at which the Original Divine Will of Source and the creative framework itself become unduly jeopardized.

8. The physical body form serves as a **Chemical Lens** through which ***portions*** of the **Dimensional Unified Field** are perceived by the embodied consciousness as a **3-dimensional Hologram,** as the Primal Life Force Currents continually carry **pulses of the individuated consciousness** through the ***Transduction Sequence*** from Kathara Grid, through the DNA, to the manifest Chemical Lens of the physical body structure and Holographic "external" reality field projection.

9. As a Keylon-Thought-Form blueprint traveling on one Pulse of Consciousness **fully expands** (fully "Activates") into the manifest externalized hologram, **another Pulse of Consciousness** is released from the synchronized mathematical programs of the Planetary Merkaba Field, which sets the Transduction Sequence in motion ("Initiates")for the ***next portion* of the personal mathematical blueprint.** The blueprint of the **Planetary Kathara Grid** regulates the **cyclic rhythms** at which **Pulses of Life Force Current** will be released through the **Planetary Merkaba Field**; the Planet releases **"Pulses of Time"**.

NOTE: The linear time experience of life forms on a planet is synchronized into specific singular continua and cycles of time through the *DNA Template*; the species Tribal Shield, personal Maharic Shield and DNA Template are imbued with the *exact mathematical programs* of the specific *Planetary Time Cycle* and *Continuum* or "Time Wavef" into which the consciousness intends manifest embodiment. A singular Time Wave constitutes a Time Continuum, within which there are specific repeating cycles of progressively accelerating *Pulses of Time* that collectively form the linear time-progression continuum of a *Planetary Time Cycle*.

10. As one **Pulse of Time/Consciousness** brings its blueprint into manifest **Critical Mass Expansion** (fully activates specific portion of the blueprint in Holographic Expression), the Planetary Merkaba Field releases the **next "incoming" pulse** of Time, which carries the next portion of the Kathara Grid mathematical blueprint into the Transduction Sequence. As the new Pulse enters the Transduction Sequence and begins **Expansion** toward manifestation, the **first pulse** of the **fully expanded hologram** begins **Contraction**, entering a **back-return** through the **Reverse Transduction Sequence** (matter- *chemical* DNA-*Sub-Atomic units*- Radis *Mion/Dion units*- Radial Body *Trion -Meajhon units*- Meridian Line-Chakra-Auric Field-Hova Body-Axion Line-DNA Template-Merkaba Field-Morphogenetic Thought-form Field *Keylon Grids & Units*- Maharic Shield Template & Kathara Grid *Partika and Particum Units*- Planetary Merkaba Field *Partiki* Units)

11. A s **pulse-1 contracts** its hologram program **moving backward** through the Transduction Sequence, creating the **"Remembered Past" moment**, the **pulse-2** simultaneously **expands** its hologram program **moving forward** through the Transduction Sequence, birthing the as-yet-to-come **"Future" moment.** The backward moving **"Past"pulse-1** and the forward moving **"Future" pulse-2 intersect** at the **Radial Body Levels** in the Transduction Sequence. This **"past pulse-future pulse intersection point"** is called the **Eiron** (E'r-on) **Point**, also known as **"Zero Point"**, the **"Present moment of conscious focus within the hologram"**, or the "***Eiros*** Conscious, Breathing Life-Force Stream" (Also referred to as the **"Stream of Consciousness"**, the **"*Living Holy Spirit*"** or the **"*Breath of God*"** ..etc.).

12. The *Eiron/Zero Point*, or **Eiros**, is the **"Present Moment of Creation Power"** for the "manifest" conscious identity. It exists at the position where the **third dimensional field,** the electromagnetic **Resonant Tone "Mental Body"** field of a single 3-dimensional Hova Body, **intersects** with the **Meajhe Field Inner Layer** of the corresponding **Radial Body** Tissue Capsule.

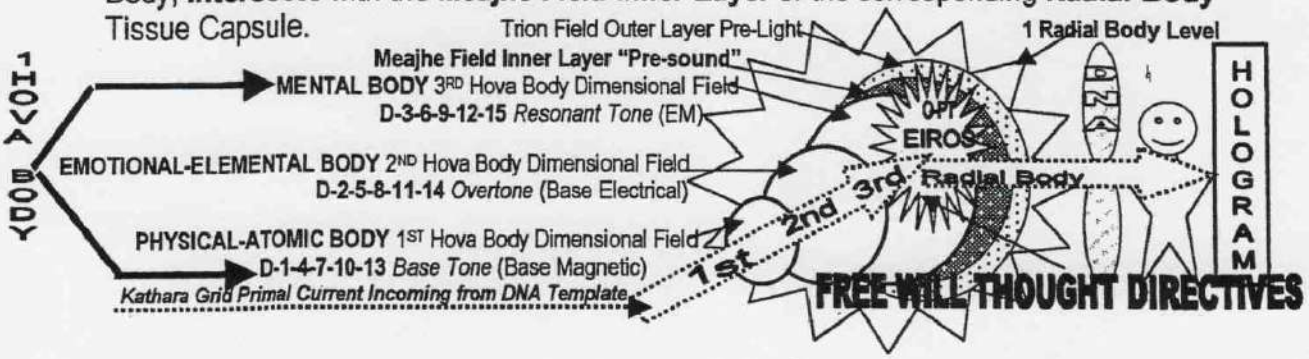

13. As the backward moving **"Past" pulse-1** and the forward moving **"Future" pulse-2 intersect** at the Radial Body Meajhe Layer **Eiros** (Eiron Point) the returning **contracting pulse-1** passes through the Trion Layer and into the ***Meajhon blueprint replica,*** called a " **Radial TILE**", that it **left behind** in the Meajhe Layer **Eiros** during pulse-1's **incoming** passage. Just as the returning pulse-1 retreats back through its Radial Tile, the **incoming pulse-2,** carrying the **next blueprint** coding ,**simultaneously** passes through the **first Radial Tile, combining** the **"past" Radial Tile** mathematical-vibrational blueprint with the **incoming pulse-2 blueprint** At this moment-point, the hologram template from the "past moment" is adopted by the incoming "future moment" pulse-2 and expanded by the pulse-2 blueprint.

14. As pulse-2 picks up the pulse-1 Radial Tile, the **retreating pulse-1**, which now **holds the Radial Tile blueprint in *reverse mathematical sequence* as *TRION Pre-light Units*** , collides with the incoming pulse-2. Both pulses carry the **common blueprint** of the first Radial Tile; the **incoming pulse-2** holding the blueprint in **forward** mathematical sequence as ***Meajhon Pre-sound Units***, the **retreating pulse-1** holding the blueprint in **reverse mathematical sequence** as ***Trion Pre-light Units*** . As the expanding/advancing and contracting/retreating pulses collide with blueprint **"sequence and anti-sequence",** the pulse-1 reversed **Trion Radial "Anti-Tile" fuses** with the original **Meajhon Radial Tile** and both Radial Tile and Anti-tile **completely de-manifest** or "***Ascend***" from their original Harmonic Universe by **TRANSMUTING** to become a ***Merkaba Field***. The **energy/ consciousness** once held by Radial Tile/Anti-tile then **replicates** its original blueprint via **Fission,** leaves a **dormant "Memory Imprint"** *Meajhon replica* in the Radial Body ***Meajhe Field***, and **reappears** in faster oscillating form within the corresponding **Hova Body Form Constant** of the next Harmonic Universe up in the dimensional scale.

15. As transmutation of the "past" Radial Tile occurs in the Radial Body Eiros, the **incoming pulse-2** is momentarily held **static** as it leaves a **new Radial Tile** in the Meajhe Field; the new Radial Tile holds the **pulse-1+pulse-2** program. At this moment-point the **entire** externalized **Hologram** literally **"Flashes Off"** and de-manifests, its energy **held in suspension** within the **Radial Body** Trion/Meajhe Field. When the first Radial Tile is transmuted, the incoming **pulse-2**, carrying an **expanded imprint of the first Radial Tile**, progresses from the Meajhe Field Eiros to Trion Field, then begins to **"Flash On"** its blueprint in manifestation. The embodied self perceives a **"liner moment progression"**; the ***pulse-1***program becomes **"memory"** of the **"Past"** moment, ***pulse-2*** the **"Present"**.

The Radial Body, Mechanics of Manifestation, Healing and Human Potential

There is much more to be revealed regarding the subject of the *Mechanics of Manifestation*. Our introduction to the ***Radial Body anatomy***, the ***Transduction Sequence*** and the ***Mechanics of Manifestation*** represents a beginning in the quest for genuine mastery over the manifest experience. In this *Kathara Level-2 Introduction* we will **not yet address** the highly pertinent aspects of *Manifestation Mechanics* that pertain to **direct Creation of matter and events** through **Conscious Thought Projection** and applied personal **Will Intention**, nor will we yet investigate the complex realities of **Space-Time Travel, Star Gate Passage** and the **Spiritualized-science of Ascension**. All of these subjects and more are *intimately intertwined* with **personal healing** and the **Imprint for Health, attaining mastery** over Manifestation Mechanics and the Bio-Spiritual processes of genuine **Spiritual Actualization**. All of these abilities, and many others too numerous to mention, presently exist as **dormant evolutionary potentials** for the Human species; potentials that were once, long ago, fully actualized and commonly expressed. The ***Kathara Bio-Spiritual Healing System*** represents a body of Master teachings that focus upon the manifestation and maintenance of **Holistic Health through Bio-Spiritual Mastery and Spiritual Actualizaton**. Exploration of subjects such as ***Merkaba Mechanics***, ***Manifestation Mechanics*** and the ***Radial Body Trion-Meajhe Field*** is an intrinsic part of furthering our abilities to embody and practice the ideals of Healing and Health through Holism.

Before we can begin to actualize the exciting potentials of freedom, love, power and knowledge that await Human re-discovery, we must first focus upon **healing the obstacles** that have long stood in our way of actualizing true Human potential. Our study of *Merkaba Mechanics* in this *Kathara Level-2 Introduction* has included a *necessary introduction* to **Manifestation Mechanics** and **Radial Body Anatomy**; the greatest physical and spiritual difficulties presently facing Humankind emerge from a **HIDDEN ILLNESS** that has held our species hostage within a progressively deteriorating, **unnatural Mortal body form**. The **underlying cause of ALL Human illness** is an **unnatural genetic mutation** that manifests THROUGH the **DNA Template** and **chemical DNA.** The **Casual Element** of this species genetic deviation from its original Divine Blueprint can only be found through study of the 15-Dimensional Anatomy, ***Primal Life Force Currents, Kathara Grid, Maharic Shield, Merkaba Field, DNA Template,*** the ***Radial Body*** and the intimate interplay that perpetually exists between these interwoven systems. It is precisely this ***species genetic deviation***, which has progressed and increased for over **200,000 years**, that has kept Humanity bound to a finite, limited world, unable to express the potentials

that once existed as our birthright. Though the problem of this species "Internal Illness" is multi-faceted and highly complex, the **Soul-U-tions** through which progressive healing of the Human genome can be rendered are relatively simple. The **Soul-U-tions for healing** and restoring health to our species, and ourselves, **require familiarity with basic Kathara Grid, Manifestation Template, Radial Body, DNA Template and Merkaba Mechanics.** These are the elements of our 15-Dimensional anatomy within which the **Casual Element** of our genetic deviation is held, and thus these are the elements of our anatomy through which the **most rapid and permanent Healing Solutions** can be rendered.

In the following pages we will continue our investigation of the ***Transduction Sequence and the Miasmic Body***, in order to **identify** the regions of our 15-Dimensional Anatomy in which our hidden genetic mutations are created, stored and perpetuated. Once we can identify the regions in which the greatest healing is needed, we can then directly employ appropriate remedial measures. Working with the **Core Kathara Grid and Maharic Shield Divine Christos Blueprint** to reset the Imprint for Health (Kathara Level-1), while **simultaneously** working with the **elements of our anatomy within which the most significant remedial measures are needed**, will allow us to use Divine Blueprint technology to implement **expedited healing.** In this *Kathara Level-2 Introduction* we will examine the *Transduction-Manifestation Sequence* and how it's present **malfunction** creates the **Miasmic Body**, which creates the DNA Template distortion through which our **chemical DNA mutation**, and a phenomenon known as the "**Phantom**" or **"Shadow" Self** is brought into being within our manifest hologram. We will then continue our exploration of **Merkaba Mechanics** and **Radial Body Healing** applications, to discover the **"Secrets of the Veca Codes"**, and Photo-Sonic and Photo-Radionic Radial Body Healing technologies, through which our Kathara and Merkabic Healing applications can be tremendously intensified, amplified and expedited.

The 5 Radial Body-Hova Capsule-Trion-Meajhe Field Levels

and Dimensional, Triadic Phase Current, Density Level, Merkaba Phase, Hova Body, DNA Template, Axiatonal Line, Chakra, Identity Level and Memory Matrix Correspondences

NADIAL CAPSULE:(also called Telluric Capsule): Composed of **Dimensions-1-2-3** ***Telluric Kundalini Current*** frequency, **Density-1** Trion-Meajhe **Gross Matter Density**, 3-Dimensional **Nethra Phase Merkaba**, surrounds **Nada Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 1-2-3** and holds focus of consciousness in the D-1 *Lower-Physical-Atomic,* D-2 *Lower-Telluric-Emotional-Elemental* and D-3 *Lower-Mental* ***Taurenic Bodies*** of the embodied Density-1 **Incarnate Personality-*Tauren*** identity, the Sub-conscious, Instinctual and Ego-Reasoning aspects of the "***Mortal Mind***" and the **Personal** ***Taurenic Memory Matrix***. *Radis* rivulets are called "***Nadis Lines***" (or Telluradis Lines)

DORADIC CAPSULE: Composed of **Dimensions-4-5-6** ***Doradic Kundalini Current*** frequency, **Density-2** Trion-Meajhe **Semi-etheric Matter Density**, 6-Dimensional **Hallah Phase Merkaba**, surrounds **Alpha Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 4-5-6** and holds focus of consciousness in the D-4 *Astral-Mid-Physical-Atomic,* D-5 *Archetypal Mid-Telluric-Emotional-Elemental* and D-6 *Celestial Mid-Mental* ***Doradic Bodies*** of the embodied Density-2 **Incarnate Soul-*Dora*** identity, the "***Angelic Mind***" and the **Soul/Species** ***Akashic Memory Matrix***. *Radis* rivulets are called "***Doradis Lines***"

TEURIC CAPSULE: Composed of **Dimensions-7-8-9** ***Teuric Kundalini Current*** frequency, **Density-3** Trion-Meajhe **Etheric Matter Density**, 9-Dimensional **Quatra Phase Merkaba**, surrounds **Betcha Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 7-8-9** and holds focus of consciousness in the D-7 *Higher-Physical-Ketheric,* D-8 *Monadic Higher-Telluric-Emotional-Elemental* and D-9 *Keriatric-Higher-Mental* ***Metatronic Bodies*** of the embodied Density-3 **Incarnate Over-Soul-*Teura*** identity, the ***"Archangelic Mind"*** and the **Over-Soul/Planetary** ***Askashic-Eckashic Memory Matrix*** . *Radis* rivulets are called "***Teuradis Lines***".

MAHARIC CAPSULE: Composed of **Dimensions-10-11-12** ***Maharic "Christos" Pre-matter Hydro-plasmic Liquid Light Primal Current*** frequency, **Density-4** Trion-Meajhe **Pre-matter Density**, 12-Dimensional **Mahunta Phase Merkaba**, surrounds **Mahara Hova Body**, corresponds to **DNA Strand Templates, Axiatonal Lines and Chakras 10-11-12** and holds focus of consciousness in the D-10 *Christiac-Transcendent Pre-Physical,* D-11 *Buddhaic Transcendant Pre-Telluric-Emotional-Elemental* and D-12 *Nirvanic Transcendent Pre-Mental* ***Hydronic Bodies*** of the embodied Density-4 **Incarnate Avatar-*Dolus*** identity, the ***"Christos Avatar Mind"*** and the **Avatar/Galactic** ***Dolaric Memory Matrix***. *Radis* rivulets are called "*Maharadis Lines*".

RISHIAC CAPSULE: Composed of **Dimensions-13-14-15** ***M Kee-Ra-ShA Ante-matter Thermo-plasmic Gaseous Pre-Light Primal Current*** frequency, **Density-5** Trion-Meajhe **Ante-matter Density**, 15-Dimensional **Rahunta Phase Merkaba**, surrounds **Raja Hova Body**, corresponds to "Indigo Grail Line" **DNA Strand Templates, Axiatonal Lines and Chakras 13-14-15** and holds focus of consciousness in the D-13-14-15 *Transcendent Ante-matter* ***Hedronic Bodies*** of the Density-5 **Breneua Rishi** Consciousness Collective identity, the ***"Rishiac Universal Mind"*** and the **Rishi/ Universal** ***Rishic Memory Matrix of one 15-Dimensional Time Matrix.*** *Radis* rivulets are called "*Rishadis Lines*".

The **5 3-dimensional Levels** of the **Trion-Meajhe Field Radial Body** within the 15-Dimensional **Time Matrix** connect each Density Level of all manifest consciousness to the greater, non-dimensionalized structure of the **Energy Matrix** ***Khundaray*** **Primal Sound Vibration** ***Meajhe Field*** through the **Density-5** Ante-matter ***Kee-Ra-ShA*** **Primal Light** ***Trion Field***.

The Transduction Sequence and the Miasmic Body

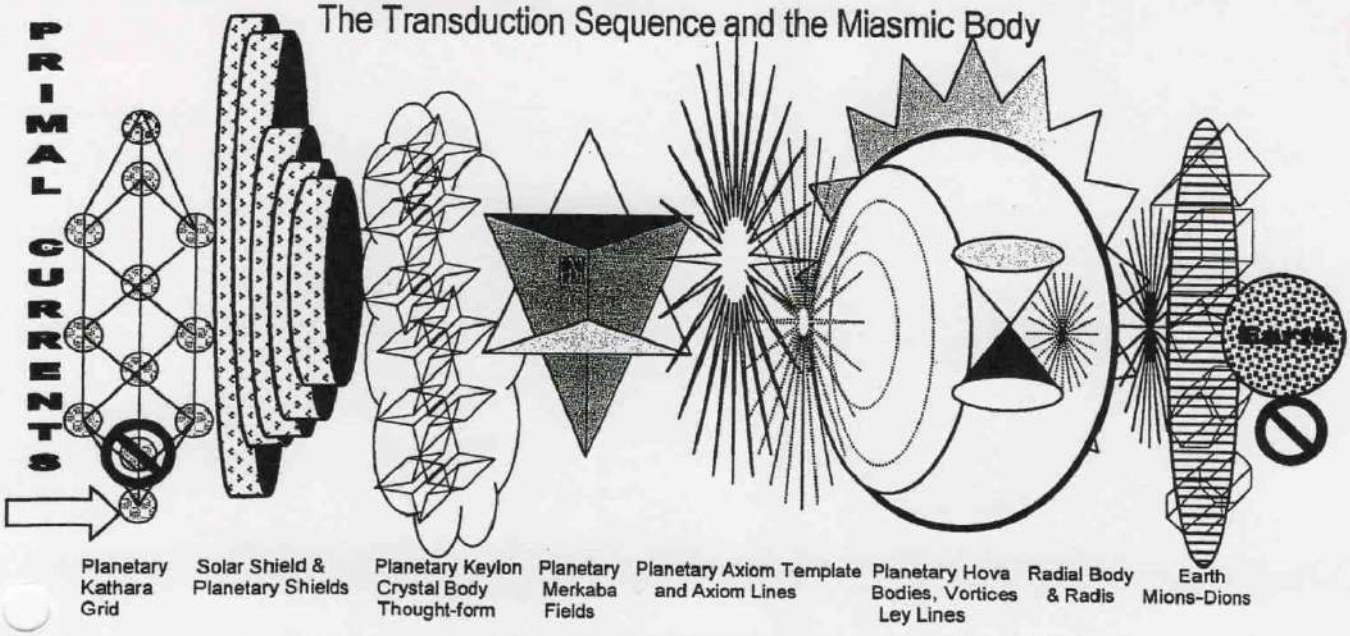

Personal Transduction Sequence

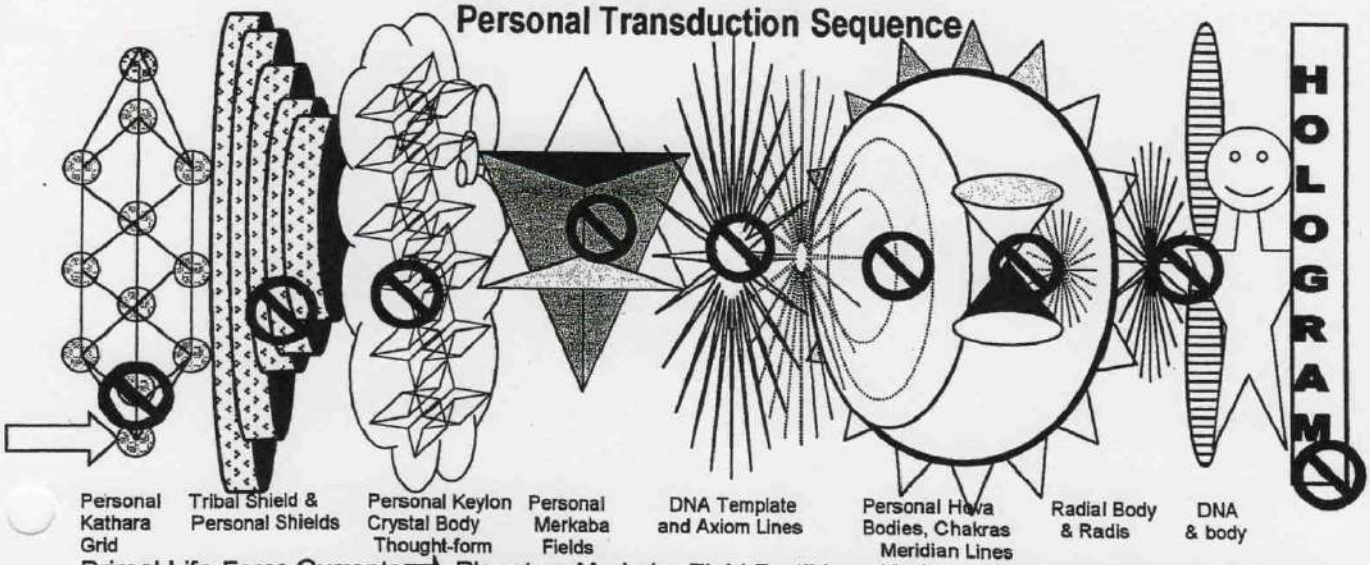

Primal Life Force Currents ➡ Planetary Merkaba Field Partiki ➡ Kathara Grid -Partika-Particum ➡ Maharic Shield Divine Blueprint ➡ Keylon Morphogenetic "Thought-form" Field ➡ Merkaba Fields ➡ Kathara Grid DNA/RNA Template ➡ Axiom Lines ➡ Hova Bodies ➡ Auric Field ➡ Chakras ➡ Meridian Lines ➡ Trion-Meajhe Field 5 Radial Body Levels ⇨ Radis Lines ⇨ Mion & Dion Ionic Particulates ⇨ Strong and Weak Nuclear Force, Electromagnetism ⇨ Quarks, Muons, Measons, Sub-atomic & Atomic Particles and Anti-Particles ⇨ Blueprint translation into Nuclei, Molecules, Elements, Compounds, Chemicals ⇨ Chemical DNA Template and "Chemical Lens" of the manifest body form ⇨ Manifest Hologram ▭

Miasms block energy flow and create a "Phantom-Shadow Self" running on opposite mathematical program; blocks natural energy flow.

- The Personal ***Radial Body*** or Trion-Meajhe Field is composed of **5 Hova Body Capsules** that manifest as electromagnetic barriers or "**frequency fences**" between each set of 3 DNA Strand Templates, each set of 3 associated Axiom Lines, Chakras and Meridians and between each 3-dimensional layer of the Auric Field and corresponding level of personal multidimensional identity.

- Each of the **5** 3-dimensional **Harmonic Merkaba Fields** corresponding to the *5 Hova Bodies* of 15 Dimensional Anatomy *govern the function* of the corresponding **Dimensional Merkaba Fields**, **Radial Body level** and its imbedded **Memory Matrix**, via the mathematical program held in the personal Kathara Grid, Shields and **Crystal Body** template. The Kathara Grid program is passed from the **Keylontic Crystal Body** into the **DNA Template** via the **Dimensional and Harmonic Merkaba Fields** and the "mini-Merkaba Fields" of the Level-3 Kathara **Diodic Grid**.

- Each Hova Capsule **Radial Body level,** receiving its instructions from the DNA Template and 3rd dimensional Mental Body Hova Body level, in turn governs the function of the **chemically manifest DNA** and all body-consciousness systems that are built upon chemical genetic code.

- The **Harmonic Merkaba Field** governs the **particle spin axis** (Angular Rotation of Particle Spin) ratios of the energy units that make up its corresponding 3-dimensional system. Each **Harmonic Merkaba Field** corresponds to one **Hova Body**, one set of **3-dimensions** and the Matter Density Level characteristic of that 3-dimensional system. Each Hova Body, and thus each Harmonic Merkaba Field Level and Radial Body Level, correspond to one set of **3 DNA STRAND TEMPLATES** within the Human12-Strand Template.

- Full activation of **one Harmonic Merkaba Field** creates reciprocal activation of the corresponding set of ***3 DNA Strand Templates***, which creates embodiment of corresponding levels of identity and consciousness (personality, Soul, Over-Soul, Avatar, Rishi etc). When one Harmonic Merkaba Field fully activates through natural activation of the corresponding **Shields** and **Crystal Body Keylons**, the Harmonic Merkaba Field becomes capable of **merging** with the Harmonic Merkaba Fields from other Density Levels, in a process frequently called **Transmutative Dimensional Ascension**.

- During the process of "**Ascension**", (also called "space-time travel", "wave-riding", "Star Gate passage", "Teleportation" etc.) the **Harmonic Merkaba Fields** of more than one Density Level merge, progressively shifting the **two or more different sets of 3-dimensional particles** into a **common particle spin axis angle and spin speed**. The corresponding **Axiom Lines, Hova Bodies, Auric Field levels, Chakras, Meridian Lines** and **Radial Body Levels** also merge.
- When Harmonic Merkaba Fields, and their corresponding Inner Templar anatomy, merge, the **Fire Codes** between the corresponding **DNA Strand Templates activate, causing the DNA Strand Templates to merge,** which creates a reciprocal reaction called **"DNA Strand BRAIDING"** between corresponding **chemical DNA strands**. (The "Double Heli" configuration of "one strand" remains, as the chemical components of each strand overlay together to become a single Double Helix containing the chemical programs of multiple DNA strands.)
- When the **Fire Codes** between strands in the DNA Template activate, dormant sequences of chemical DNA called " **Transient Turnstile DNA Sequences**" "turn on" within the **Hydrogen Bonds** that link each DNA "Ladder Rung" together, producing a **transient trans-harmonic element** called **Celestalline** within the chemical DNA.
- Natural Braiding of the chemical DNA strands and activation of the chemical Turnstile DNA Sequences create a series of **sub-atomic bio-chemical DNA responses** that allows for Internal **Atomic Particle/Anti-particle Fusion** and **Fission.** Natural **Internal Atomic Fusion-Fission** enables the manifest atomic structure to temporarily de-manifest, returning to "*spirit form*", by re-entering the electrostatic **Trion-Meajhe Field** of the corresponding **Radial Body Levels.**
- During the Ascension process, the Harmonic Merkaba Fields of **2 or more Density Levels** merge, forming various **PHASES of Merkaba** activation that create a **Trans-Harmonic Merkaba Field** that is called the **Merkaba VEHICLE.** The 3-Dimensional **NETHRA Phase** Merkaba Field of Density-1accelerates in rotation speed to become the 6-dimensional **HALLAH Phase**, 9-Dimensional **Quatra Phase**, 12-Dimensional **Mahunta Phase** or 15-Dimensional **Rahunta Phase** Harmonic Merkaba Vehicle.

- As a phase of the Trans-Harmonic Merkaba Vehicle activates, the corresponding lower-dimensional **Hova Body and Radial Body Level dissolve**, their content of energy and consciousness **expanding** into the next Hova Body and Radial Body Level, forming a **Trans-Harmonic Radial Body "FORM CONSTANT"** within the **Merkaba Vehicle.**
- The Trans-Harmonic Radial Body and Merkaba Vehicle allow the consciousness and biological form to "de-manifest" from the lower dimensional Density Level. The identity can then **re-manifest** in another Density Level or space-time coordinate by projecting itself into the desired location, AS the *electrostatic* ***Trion-Meajhe Field*** **Trans-Harmonic Radial Body,** then returning the DNA Template activation level and Harmonic Merkaba Spin ratios to that of the new location for re-manifestation.
- When the Personal **Merkaba Field** is used to form the **Trans-Harmonic Radial Body** in the process of Ascension, the Merkaba Field is called a **MERKABA VEHICLE.** A ***Merkaba Vehicle*** is an electrostatic **Trion-Meajhe Field** of Primal Pre-Light-Sound through which the consciousness (AKA "spirit") can move itself, *and its atomic structure*, through **thought-projection**, to a desired location beyond the "veils" of the Planetary, Galactic and Universal Hova Capsule-Radial Body-Form Constant barriers.
- Conscious mastery of the Personal Merkaba Field, through which the organic **internally created Merkaba Vehicle** Trans-Harmonic Radial Body becomes available for conscious direction, implies **conscious control of DNA Template function.** The potentialities of **genuine Ascension** (etc...) and mastery of Bio-Spiritual Consciousness are **inborn attributes** of the Human 12-Strand DNA Template. Due to a **species de-evolutionary genetic mutation** that compromises natural function of the Personal Merkaba Field and DNA, the reality of Ascension on a species level has been lost to all but a few on Earth for over 200,000 years (re: Masters Templar Coursebook).
- The potentials of **Bio-Spiritual Actualization** CAN be returned to humankind through **reverse-mutation** of genetic dysfunction within the human genome and DNA Template. Healing the genetic template can be achieved by **manually employing** specific practices of **Kathara "Maharic Shield" Core Template Dynamics** in **combination** with **Harmonic Merkaba Mechanics** through which the many eons of biological miasmic distortion can be progressively and rapidly cleared from the Personal Kathara Grid and DNA Template.

- Restoration of the D-12 Pre-matter Divine Blueprint within the Human Kathara Grid and DNA Template will eventually **free the Personal Merkaba Field** for use as a **Trans-Harmonic Merkaba Vehicle.** Kathara Healing applications, and use of the D-12 Pre-matter Maharata "Christos" Current to reset the biological D-12 Pre-matter Divine Blueprint, are the beginning steps in reclaiming Bio-Spiritual Mastery.

- The function of the personal **Merkaba Field** and **DNA Template** are not only associated with abilities of **Atomic Transmutation** and **Dimensional Ascension**, they are directly linked to **every aspect of body-mind-spirit function**, including **biological longevity** and **health**, **memory, intelligence,** and **metabolic, chemical, mental** and **emotional balance** and stability.

- Most significantly, the **Merkaba Field/DNA Connection** is the Bio-Spiritual conduit through which the consciousness of an embodied individual is directly linked to the common Perpetual Force of Energy and Eternal Source of Intelligent Creation that is "**God**".

- When a being's Merkaba Field and DNA Template are functioning upon the innate program of **Universal Primal Order**, as it is held within the Pre-matter **Universal Divine Blueprint** of the D-12 "Christos" Liquid-Light field, the natural and perpetual supply of **Primal Life Force Currents** and "spiritual" consciousness emanating eternally from Source-God, flow through an open energetic channel or "**Pillar of Light**", which is called the "Um Shaddai Ur" (Pillar of First Cause Light-Sound') into the manifest embodiment. Such a being is called a "**Christed Being**". This implies that the integrity of its original D-12 Pre-matter Divine Blueprint has not been structurally compromised, and thus the perpetual Life Force Currents, consciousness, sentience, intelligence, wisdom, power, Will and LOVE of Source can freely express through the Um Shaddai Ur, into the manifest hologram of the Time Matrix through the Christed embodiment.

- If the Kathara Grid, DNA Template and Merkaba Field of a being are damaged, and no longer carry the **original mathematical-geometrical program** of the **D-12 Divine Blueprint** through which the being entered space-time, the flow of Primal Life Force Currents, the Um Shaddai Ur Pillar and thus the active consciousness connection to God will be distorted, reduced or severed at the dimensional level to which the template distortion corresponds.

- A manifest being incapable of running the Primal Life Force Currents of the Um Shaddi Ur "Pillar" becomes **biologically finite**, its consciousness "trapped in the Time Matrix", even following death of the physical body. According to the **natural Laws of Creation Physics** as set by Source-God, this condition of **finite mortality** will remain until the being's **Kathara Grid Template and Merkaba Field connection** to the D-12 **Universal Divine "Christos" Blueprint** and Universal Trion-Meajhe Field Um Shaddi Ur Pillar is restored.

- Healing Core Template genetic distortions that are severe enough to cause dysfunction of the Personal Merkaba Field first require **resetting of the D-12 Divine Blueprint** through activation of the **Personal Maharic Shield.** Until the Body-Mind-Spirit system has reached a **Critical Mass** of D-12 Divine Blueprint holding through frequent and progressive manual running of the D-12 Maharata Current, healing Core Template genetic distortions **also requires** simultaneous, direct and repeated **manual realignment and restoration** of **Personal Merkaba Field function** and **Radial Body Trion-Meajhe Field** integrity.

- If there **are distortions within the Kathra Grid or DNA Template** of an individual or species, the Personal Merkaba Fields will not function in harmony with the **natural energy circulation rhythms** of the **Planetary, Galactic, Universal** and **Time Matrix Merkaba Fields** and Universal Kathara Grid. Such Kathara Grid distortions create tangible **genetic and consciousness mutation** within biological organisms, and can divert the **intended evolutionary destiny** of an embodied consciousness or species on to a divergent path of **de-evolution and consciousness fragmentation** unintended by the original plan encoded within the D-12 Pre-matter Christos Divine Blueprint.

- Distortions with the DNA Template and resulting **Miasms** can be purged through **manual resetting of the D-12 Pre-matter Divine Blueprint,** via repeated manual activation of the Personal **Maharic Shield**. The activated Maharic Shield runs the Density-4 D-12 **Maharata Primal Life Force "Christos" Current** through the Kathara Grid and form embodiment, progressively resetting the original mathematical coding of the personal Divine Blueprint within the Kathara Grid and DNA Template. Use of the **Maharic Shield techniques** in *Kathara Level-1* sets this process of **Core Template Regeneration** in motion.

- The Core Template "Divine Blueprint" healing process can be expedited through applied **Christos-Merkabic Healing Mechanics** such as the ***Tribal Shield Activation*** (Technique-7), ***Merkaba Salutation*** (Technique-8), ***Merkaba Trinity Key Induction*** (Technique-9) and ***Kee-Ra-ShA Activation Sequence*** (Technique-12).

- Divine Blueprint Healing can be expedited further through **manual restoration** of the personal Trion-Meajhe Field **Radial Body** and its inherent **Memory Matrix. Radial Body Healing,** when **combined with** ***Kathara Maharic Shield*** and ***Christos-Merkabic Healing*** dynamics is the most powerful and rapid Holistic Healing technology available.

- **Radial Body Healing** dynamics, which also serve to progressively restore the organic **Memory Matirx**, involve use of the specific **mathematical programs** that govern formation of the **Radial Body Trion-Meajhe Field.** These mathematical programs are called **VECA CODES.**

- **Technique-10** ***Restoring the Trion Field-Photo-Radionic Healing*** **and Technique-*11Restoring the Meajhe Field-Photo-Sonic Healing*,** provide introduction to **Radial Body Healing Mechanics.** Use of these techniques, in **combination** with **Technique-2** ***The Maharic Seal and Liquid Light Cleanse,*** and **Merkabic Healing Techniques 6-12, will greatly expedite** the personal healing process while **significantly increasing** the body-mind-spirit abilities to **receive, hold/sustain and transmit greater quantity and quality** of interdimensional frequency in the Client Healing Facilitation process.

Radial Body Healing, the VECA CODES, DNA and Merkaba

- Veca Codes, also called the "I AM" or "**Immanuyana Sequence**" are very specific **SYMBOL CODES**, each possessing corresponding **Sound Tones** called ***Arieas*** and **energy movements** called ***Seurias***, which correspond to the Cosmic, Universal, Galactic, Planetary and Personal **Trion-Meajhe Field Radial Body Levels**.

- There are **5 categories of Veca Codes**, the Planetary **Low-Veca *Codes of Manu*** (Taurenic-Akashic Codes), the Galactic **Mid-Veca *Codes of Immanu*** (Akashic-Eckashic Codes), the Universal **Level-1 High-Veca *Codes of Immanuel*** (Dolaric-Rishic Codes), the Cosmic **Level-2 High Veca *Codes of Immanuyana*** (Triadic-Polaric-Eckatic Codes) and the God-Seed **Yunasai *Codes of Eckasha*** (Source Codes).

- Beginning applications of Veca Code Radial Body Healing begin with restoring the Trion-Meajhe Field Radial Body through resetting the ***Yunasai*-Eckasha and High Veca *Immanuyanas* and *Immanuel* Codes**, through **frequent manual Direct Induction** of the their corresponding **Symbol Codes** and **Sound Tones/Arieas**.

- The most powerful **Yunasai-Eckasha Codes** are **PHOTO-SONIC Codes**, carrying the Mathematical Programs of the ***Khundaray Current*** Primal Sound ***Meajhe Field*** AND their bridging **God-Seed vibration-rhythms** connecting to Source. The **Level-2 *Immanuyana*** and **Level-1 *Immanuel* High Veca Codes** are **PHOTO-RADIONIC Codes**, carrying the Mathematical Programs of the Trion-Meajhe Field **Khundaray Primal Sound** AND **Kee-Ra-ShA Primal Light Currents.**

- **Consistent use** of **Veca Code Radial Body Healing**, in combination with **Merkabic and Kathara Healing** applications, will progressively **clear the Miasmic Body** and heal, balance, re-integrate, and restore the Divine Blueprint within, the energies of the **Phantom-Shadow Self** in all levels of the Body-Mind-Spirit system.

- More advanced applications of Veca Code technologies include use of the **Mid-Veca *Immanu*** and **Low-Veca *Manu* Codes,** and the corresponding ***Seurias*** (body movements to direct frequency), following a period of initial induction and activation of the Yunasai and High Veca Codes. Full Spectrum Veca Code technologies are introduced in the "***Dance of Life***" Masters Spiritual Development Program.

- **Induction,** or **IMBEDDING** of the High Veca Codes into the 15-Dimensional Anatomy involves placing the corresponding **Symbol Code Sequence** (mathematical program) over the **regions of the physical body** that correspond to the appropriate aspects of the Kathara Level-2 **Crystal Seals Grid** and Level-3 **Diodic Grid.** Once the Symbol is in place, the **breath** is used to direct **D-12 Maharata Current** through each **Symbol Code** and **body region.** Use of the **Maharata Current** "carrier wave" (via **activation of the Maharic Seal/Shield**) is **required** to **induce** the code's **mathematical program** into the **Diodic** and **Crystal Seals Grid,** where the program will then naturally transfer into the corresponding areas of the **Level-1 Kathara 12-Tree Grid** core template.

- Once the High Veca and Eckasha Code Sequences are Imbedded/induced into the Level-1 Kathara Grid, they are then **Activated** in the Kathara Grid by **TONING** the corresponding **Veca Code Ariea Sequence**. The longer toning is sustained, the greater will be the quantity and quality of Veca Code Activation.

- Once Activated, the Veca Code programs travel upward through the stages of the **Transduction-Manifestation Sequence** from the **Kathara Grid**, to the **Shields**, into the **Keylon Crystal Body Morphogenetic Field,** then into the **Merkaba Field**, **DNA Template** and **Hova Body/ Radial Body Levels**, temporarily restoring the **Christiac Merkaba Field**, **Radial Body** and **Memory Matrix Divine Blueprint**. **Frequent and continued use** of the Veca Codes will progressively build **Critical Mass** of the **Divine Blueprint program simultaneously within ALL levels** of the 15-Dimensional Anatomy, eventually culminating in expedited full restoration of the D-12 Maharic Shield blueprint within the Body-Mind-Spirit system, via the Radial Body Trion-Meajhe Field.

- Activation of the Yunasai and High Veca Codes within the personal body **prior to conducting a Kathara Client Healing Session** will cause the facilitator's **Level-3 DIODIC GRID to activate**, temporarily **transmitting Veca Code sub-harmonics.** This will cause the **minute Diodic Chakras** in the facilitator's **FINGER TIPS** to activate **if the Palm Chakras** have been activated with either pure **Maharata Current** or a selected **Triadic Phase Current.** The facilitator will then **automatically transmit** Veca Code sub-harmonics into the client's **Diodic Grid** while conducting general Kathara Healing applications, allowing the client to benefit from temporary **Radial Body healing support**, which will **amplify the effects** of all healing applications.

- A more **Temporary Imbedding and Activation** of the Veca Code program can be achieved through **OPTICAL-PINEAL INDUCTION**, whereby the **eyes** are focused for a time upon the **Image** of the **Symbol Code.** The mathematical Veca Code program enters the **Pineal Seals** through the **Optical Currents** and **6th Chakra,** an then travels for Imbedding/induction through the **Central Vertical Current** into the body regions and Crystal Seals Grid areas to which the Veca Code corresponds. The **Veca Tones/Arieas** are then used to Activate the Imbedded Veca Code Sequence.
- In **Optical-Pineal Induction**, the Veca Program looses a bit a **frequency charge/ strength** during is travel in the Central Vertical Current. This creates a **more temporary imbedding and activation** of the Veca Codes than that which is achieved through Direct Induction. Optical-Pineal Induction is useful for **daily amplification** of the Vecas, and for Kathara Healing Client Sessions and planetary grid "site work", when used in **combination** with the **full induction procedure** employed at least **once per week.**
- To receive **full benefit** of **Veca Code Radial Body Healing** applications, **Technique-2** ***The Kee-Ra-ShA Activation Sequence*** should be fully run at least **ONE TIME.** *Technique-2* can also be used occasionally thereafter if desired to create **intensification and amplification** of the Primal Life Force Currents during Kathara, Merkabic and Veca Code Healing technologies.
- Frequent use of **Technique-13: The "Song of Lyra"** Christos Invocation will amplify all Kathara, Merkabic and Veca Code Radial Body Healing applications.

The Christos-Trion-Meajhe Fields, High-Veca Codes and Universal Life Force Currents

One 15-Dimensional Time Matrix with 5 Harmonic Universes

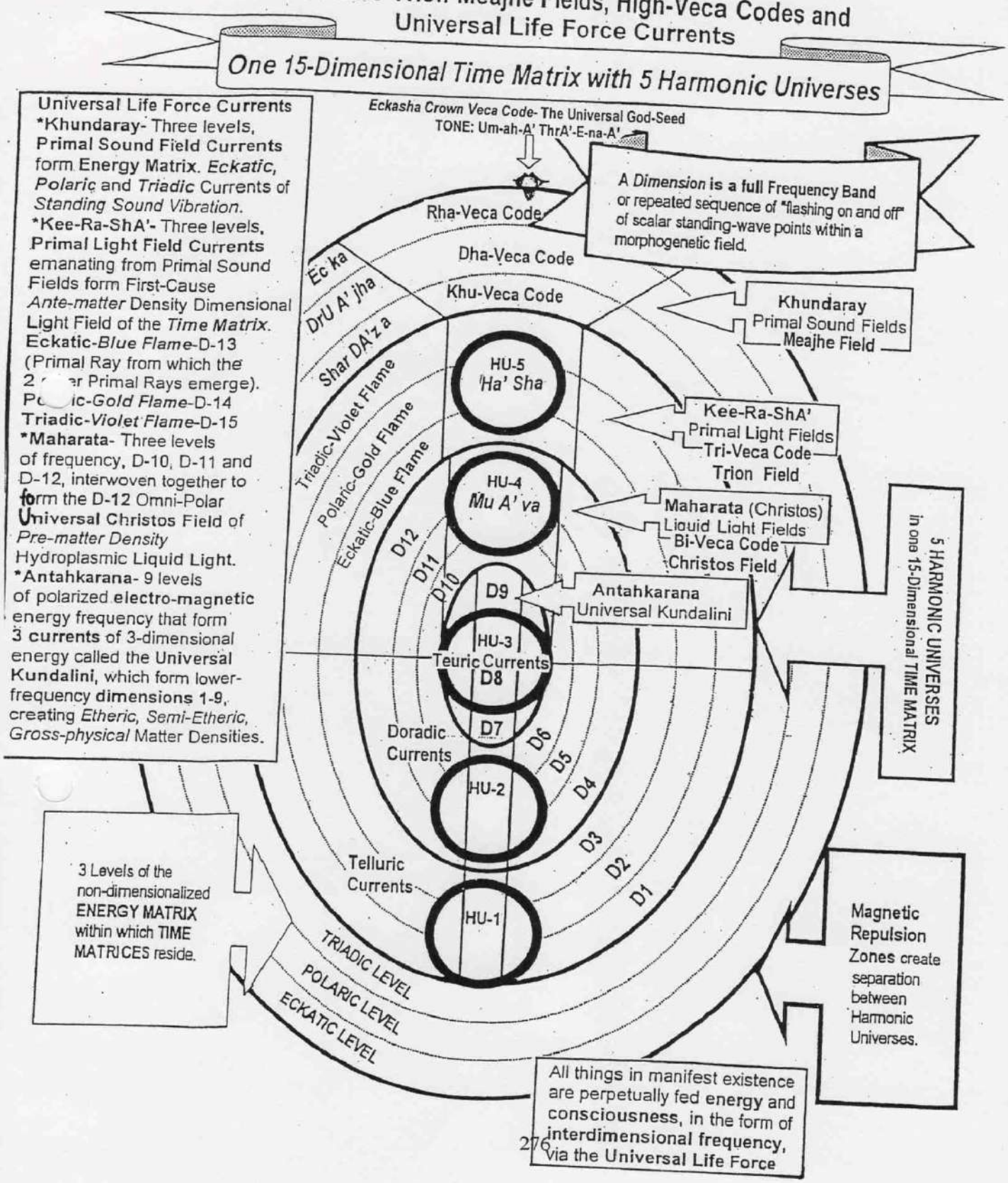

Technique # 4

Restoring the Trion Field-Photo-Radionic Healing

Regular use of this technique will strengthen and improve RRT Planetary healing Applications (excerpt from Kathara Level-2)

Creating a Personal Bio-field Link to the Universal Christos-Trion-Meajhe Field

Masters Merkaba Mechanics

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Exercise-1: **Once per day**, do **Maharic Insta-Seal** then practice **each set of Veca tones** separately while fixating **visual focus** on corresponding **Veca-Code** symbol; spend at least **three or four minutes** gazing at each symbol (optical-pineal induction) while **toning** corresponding tones (core template vibrational induction) With practice this will progressively expand the personal consciousness while activating the personal Christos-Trion-Meajhe Field of your Christos-Rishiac-Ascended Master identity levels within the cellular structure.

Exercise-2: Once per week, directly after completing **Exercise-1**, place all Veca-Code symbols over designated body areas, activate Maharic Shield, breathe D-12 Maharata Current through each symbol and body area to **induce code**, using the **Bi-Tri-Khu-Dha-Ra** Sequence, then begin **toning** the corresponding tones following the Bi-Tri-Khu-Dha-Ra Sequence. Memorize the tone sequence of the 5 High-Veca Codes as if it were a "**song**" and relax, close eyes and sing/tone this "song" (Psonn) for **5 to 10 minutes**. The longer you tone, the more frequency power you build within the body and the stronger your link will be to the Universal Christos-Trion-Meajhe Field. This exercise can also be used with groups, either singularly to create and amplify Christos-Trion-Meajhe Field links or just prior to beginning RRT work. Frequent and consistent use of these two exercises will progressively develop the spin-rate capacity of the personal Christos Merkaba Field, while expanding higer consciousness within the body and progressively enhancing the health, immunity and integrity of the Mind-Body-Spirit system.

The High-Veca Codes

Universal Time Codes for Primal Frequency Access

Cosmic Codes of Immanuyana

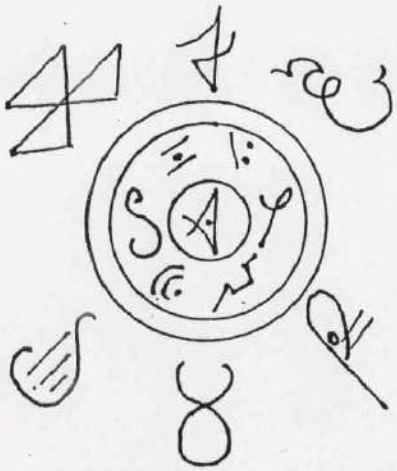

The Rha-Veca Code
Primal Sound-3 Eckatic
called the *Ec ka*
TONE: "*Rha Ec' ka*"
Symbol Placement:
Tailbone

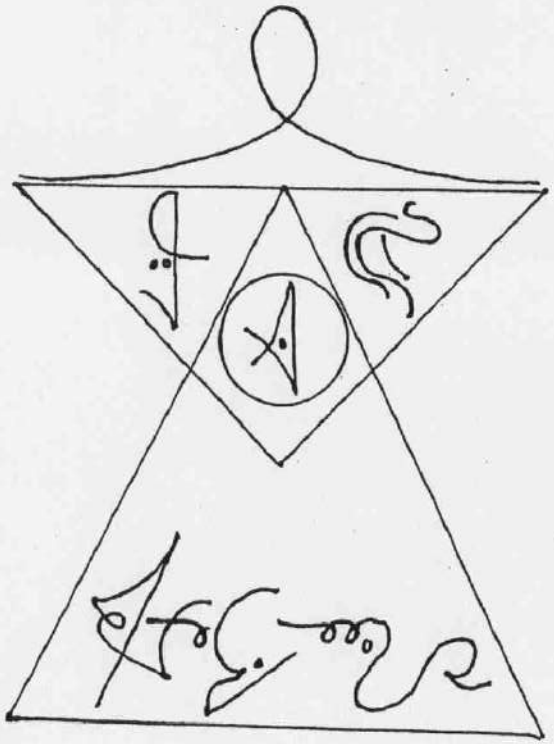

The Dha-Veca Code
Primal Sound-2 Polaric
called the *DrU A' jha*
TONE: "*Dha' Dru A' jha*"
Symbol Placement:
Chakra-2 (just below navel)

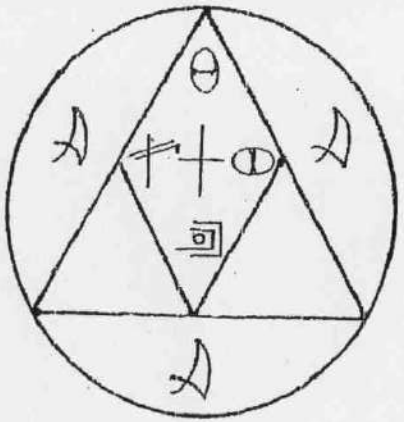

The Khu-Veca Code
Primal Sound-1 Triadic
called the *Shar dA'z a*
TONE: "*Khar DA'z a*"
Symbol Placement:
Chakra-8 Front (clavicle)

Universal Codes of Immanuel

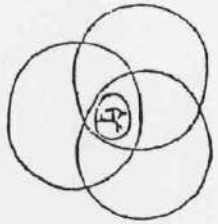

The Tri-Veca Code
Density-5 Dimensions 13-14-15
called the *Ha' Sha*
TONE: "*Kee' Ra ShA Ha Sha*"
Symbol placement:
Left Foot bottom

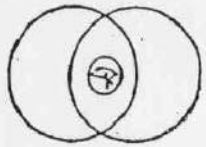

The Bi-Veca Code
Density-4 Dimensions 10-11-12
called the *Mu A' va*
"*Ma ha ra' ta Mu A' va*"
Symbol placement:
Right Foot bottom

Technique # 11

Restoring the Meajhe Field-Photo-Sonic Healing

1. Use **Technique-6:** ***The Maharic Quick Seal*** to activate your Maharic Shield, Seal and Maharata Current.

2. **Stare at image** of the **Eckasha Code** for a few seconds, then gently begin to **"Cross Eyes"** until you can see a **"Double Image"** of the *Eckasha* when looking at the image. **Hold " Eye Cross"** focus while taking **three rapid breaths**; on each **EXHALE** projecting a **stream** of (D-6) **INDIGO current** from your **6th "3rd Eye" Chakra at** forehead. (This braids D-6 Optical Currents into a D-12 Current to carry the Eckasha program into the Pineal Seals.). Un-cross eyes, relax visual focus and close eyes for a moment or two.

3. **INHALE** several breaths of **Pale Silver D-12 Maharata Current** up from the **Earth Core** through your **Maharic Cord**, on each **EXHALE** depositing the Maharata Current in the **Pineal Gland** at the center of the brain, to form a Pale Silver **"Maharata Ball"** in the Pineal.

4. Breathe gently and **return visual focus to the image of the Eckasha, focusing** upon the **Eckasha Core *REUCHE'*** (the "Double Circles and their content at center of Eckasha).

5. **EXHALE** while projecting a **stream of INDIGO current** from the **6th Chakra** at forehead, into the **REUCHE** symbol before your eyes. **INHALE** while drawing the **INDIGO current stream** with the **REUCHE image at its end** back through the **6th Chakra** and into the **Maharata Ball** in the **Pineal.**

6. **INHALE** one more breath of **Maharata Current** up from **Earth Core** to the **Maharata Ball** at the **Pineal**, then use a forceful EXHALE to PUSH Eckasha-Reuche encoded Maharata Ball out to the right, to the "Mentor" position over the right shoulder. Visualize the Maharata Ball growing to the size of a "Basket Ball" over the right shoulder, and visualize the image of the Reuche as expanding to fill the inside of the Maharata Ball.

7. **INHALE forcefully** while drawing the **Maharata Ball** back to a position **centered around your head**, then use **three breaths** to **INHALE Maharata Current** up from **Earth's Core to Pineal** and **EXHALE** the **Maharata Current outward** to fill **and expand the Maharata Ball.**

8. Visualize the **Maharata Ball** expanding outward from around your head, until the Maharata Ball **fully encompasses your body and entire Chakra System**, from **Chakra-14** 36" above head to **Chakra-13** in Earth Core. Imagine that your entire body is now surrounded by a 3-dimensional "Eckasha Tear-Drop" shaped CLEAR CRYSTAL CAPSULE. The Eckasha Code Photo-Sonic Capsule is now temporarily activated in your Inner Templar system.

Eckasha Crown Veca Code- The Universal God-Seed

Tone: Um ..... ah.....A' ⇧ ThrA'..... E'- na.....A

Symbol Placement: Pineal Induction via Chakra-6 "3rd Eye"

The Yunasai-Eckasha God-seed Code

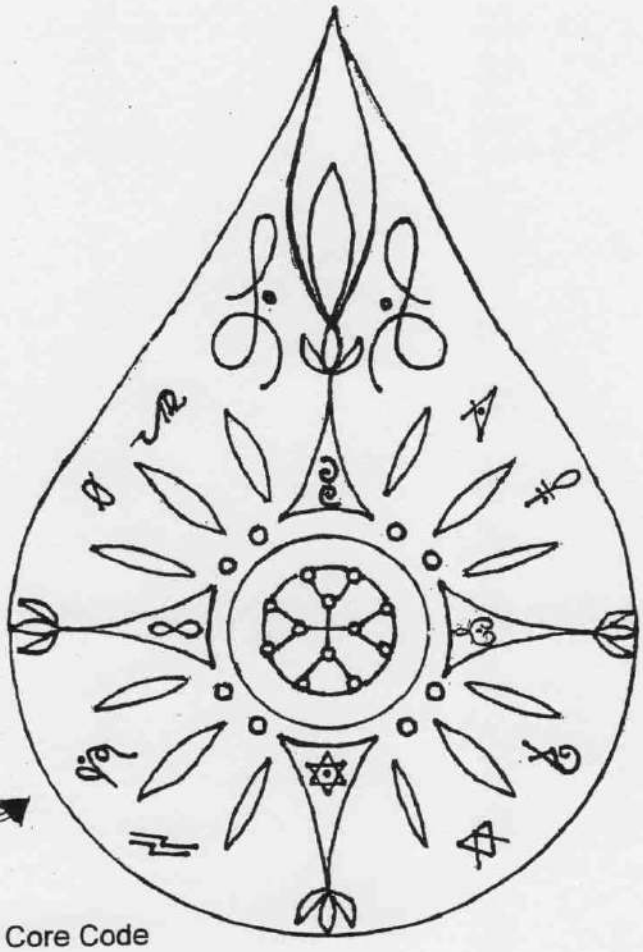

The REUCHE' Eckasha Core Code

Technique # 13

The Song of Lyra Christos Invocation

The Vectos Invocations

The Vectos Compendium Declariti

The Vectors Collective Declarations

(All self incarnations in all Time Vectors declaring in Unity as the Avatar Self)

English translation from Elohei-Anuhazi Emerald Covenant Decree Texts:

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The Mah'-ah' Bi-Vectus Declaritum

Declaration of the Maharata

(Intention Decree AS the personal D-12 Christos Avatar Maharata self identity)

I decree now in this moment of KNOWING that all things here within me
are hence forth restored to the original Divine Intention of the ONESELF that is MINE.

I release now all bonds of manifest illusion that place veils of SELF-forgetting before mine eyes.
I revoke all separations of duality through which my Heart is rendered numb with disillusion and discord.

In this moment I reclaim the Whole of my Condition, reaching forth into the depths of all creation to now call my SPIRIT home.

I AM the Sun of the Radiant Glowing. I AM the HEART of Divine LOVE. I AM the Still Point of the Face of All Creation. I AM the Voice of the Universal Song.

I decree now in full remembered Knowing that I AM ALL and WE are ONE.
In setting forth this decree of my Eternal Divine Power, I shall render Divine Intention only, through which the All and I are equally served
in the Highest Order of our collective Best Divine Intention.

I call now unto the many Selves and Shadows ensconced within the illusions of time, and decree unto thee that I AM THIS, I AM.
I AM the wind that brushes thy faces.
I AM the rain that renews thy field.
I AM the Whisper of the Breathe of God within YOU.
WE NOW are the expression of Divine Heart, Mind and Hand.
WE are the Rumbling Hymn Song of the earthen worlds of matter.
WE are the Prana-Breath of God Eternal, manifest.
We are the Waters of Eternal Life forever outward flowing.
We are the cooling, life force Flame of the Cosmic Fire expressed.
In our UNION now and always, declare WE in our Wholeness,
that all dissidence is rendered spent, all conflict NOW made healed.

As DIVINE NAME THIS.....(your Christos spiritual name)
I AS WE, the Maharata KHUM BI-Vec'TUS, (D-12 Christed Avatar Divine Blueprint self identity), DO NOW DECREE through the Divine Love, Wisdom and Power that is MINE....to express now AS this moment, the condition of **Mah'-ah BI-Vec'TI UN UR'-A-OR'-NaM' –OOR** (Christos beginning and ending NOW-completion of a manifest expression in its originally intended Divine Fulfillment, its past-present-future full expression made in the present time, clearing all duality, disharmony and distortion. Anchoring of the Divine Christos Maharata Blueprint in the moment). Upon this Invocation Divine Intention is rendered manifest in all conditions to which I now assign.

The Mah'-ah' Bi-Vec'tus Inavhoki
Invocation of the Maharata
(Creation Decree Invocation AS the personal D-12 Christos Avatar Maharata self identity)
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From this Still Point of my Wholeness in manifest decision,
I Decree in Sovereign Knowing, here expressed at my Command *(lovingly stated absolute intention)* ***the Divine Will and Intention of the ONE-SELF that is ONE GOD.***
The ONE-SELF that IS ONE GOD THIS I AM.

Mah-Hah-Rah-Tah KHUM BI-Vec'TUS .....(name)
I as D-12 Christos Avatar self.....(name)
iN-A-VHO'-KI UN' E-BLE'UM BI-Vec'TI
Invoke by Divine Loving Command Now, by the Power of the Universal Christos,
Mah'-ah BI-Vec'TI UN UR'-A- OR'-NaM' – OOR
the D-12 Divine Christos Blueprint past-present-future; NOW the Divine Sea of Liquid Light anchors in this moment.
E'-stA Un'-tA E'-Sa Tra'zd-Jha' HA'-A Rha
Absolutely now established, always and forever, in eternal abiding reverent Love of the Eternal ALL-ONE
P'tah-TA Um a Ah-ShA'-Lum
Blessed Be all embracing, given forth from the Still Point of Eternal Peace
Thah-A'-Jha in'ta DO A"
Spoken AS IT IS STATED, As SO It IS DONE
Um Sha'-DI UR'- A ah Khum' TUn
All Embracing Pillar of First Cause Light, I AS THIS expression now.

In the name of the Melchizedek Cloister Emerald Order Eieyani,
Holy Order of the Yunasai,
Sacred House of ONE.

English Translation:
Ma-Ha-Ra-Ta KHUM BI-Vec'TUS .....(name)
(Khum = "I AS") (Ma-Ha-Ra-Ta BI-Vec'tus = D-12 Christos Avatar Self)
iN-A-VHO'-KI UN' E-BLE'UM BI-Vec'TI
(*in-A-vhO-ki*= invoke by Divine Loving Command), (*UN*= Now), (*E-BLE'UM*= by the power of), (*Bi-Vec'ti* = Universal Christos)
Mah'-ah BI-Vec'TI UN' UR'-A- OR'-NaM' – OOR
(Mah'ah Bi-Vec'tI= D-12 Divine Christos Blueprint past-present-future)
(UN Ur'-A- Or'-Nam' –OOR= Now the Divine Sea of Liquid Light anchors in this moment)
E'-stA Un'-tA E'-Sa Tra'zd-Jha' HA'-A Rha
(E'StA Un'TA E'Sa = Absolutely now established, always and forever)
(Tra'zd-Jha'= in eternal abiding reverent Love) (HA'-A Rha = of the Eternal ALL-ONE)
P'tah-TA Um a Ah-ShA'-Lum
(P'tah-TA UM = Blessed Be, all embracing) ("a" in this context = given forth from)
(Ah-ShA-Lum = the Still Point of Eternal Peace)
Thah-A'-Jha in'ta DO A"
(Tha-A-Jha inta= Spoken AS IT IS STATED) (DO A"= As SO It IS DONE)
Um Sha-DI' UR'A' ah Khum' TUn
(Um Sha- DI' UR'A = All Embracing Pillar of First Cause Light)
(ah Khum' TUn = I AS THIS expression now)

Chinese Medical Qigong Therapy:

A Comprehensive Clinical Text

中国气功医疗

DR. JERRY ALAN JOHNSON PH.D., DTCM, DMQ (CHINA)

FORWARD

Dr. Jerry Alan Johnson's book on Medical Qigong and its clinical practices provides an important and necessary guide for students and advanced practitioners of Medical Qigong and Traditional Chinese Medicine.

The relevance of Dr. Johnson's Medical Qigong textbook can be seen against the larger back drop of alternative medicine. Alternative Medicine (also called complementary medicine) has become a catch word in the West and an increasingly important factor in health care. An article authored by David Eisenberg and others of the Harvard Medical School reported that in 1993, 30% of a group of people used some kind of Alternative Medicine for which they paid out of their own pockets. Extrapolated to the United States population, this group spent about $14 billion dollars, which was more than the amount spent on conventional Western care that year.

Among alternative medical therapies, Medical Qigong has blossomed explosively in Western countries during the past few years. Awareness of Medical Qigong in the United States was heightened by two international conferences on Qigong in 1990. In 1997, there were three conferences on Medical Qigong, in San Francisco, Minneapolis, and New York. Another catalyst was Bill Moyer's television documentary, "Healing and the Mind," which had a segment on Medical Qigong and Chinese medicine. In more recent years, dozens of books have been published on Qigong in English and presently there are at least 15 web sites on the World Wide Web devoted to Qigong. At this writing, many articles on Qigong have appeared in the newspapers and magazines, and several documentaries have been videotaped and others are in progress.

In China, almost everyone knows about Qigong and about 100 million people are said to practice it daily. Qigong dates back thousands of years. Many believe that it was responsible for the early development of Chinese medicine, which now includes therapy by acupuncture, herbs, massage, and nutrition.

Medical Qigong therapy was a secret art that was passed on from a master to selected persons. In the 1970s, Qigong became more accessible to the people when the Chinese government ordered that Medical Qigong be made public and serve alongside Western medicine to improve national health care. During the Cultural Revolution, Medical Qigong was suppressed because the government suspected that Qigong had religious and superstitious roots incompatible with communism. In the early 1980s, scientist in China were encouraged to carry out experimental and clinical studies into almost every aspect of how Medical Qigong affected the human body and contributed to healing. Starting in 1986, research findings were reported at international conferences on Medical Qigong held mostly in China but also in Japan, Canada, and the United States. The substance of the research studies are available in English in the Computerized Qigong Database, which was developed by the Qigong Institute. This database has provided a basis for the preparation of at least five books, three dissertations, and several research projects on Medical Qigong.

In 1992, the United States Congress recognized the potential of alternative/complementary medicine by mandating that the National Institutes of Health develop programs to evaluate the validity of selected alternative therapies. Since that time, the Office of Alternative Medicine has funded many research programs and disseminated valuable information to medical practitioners, scientists, and the public.

The swell in the interest in Medical Qigong

and the recognition of its health and healing benefits have been recognized by schools of Traditional Chinese Medicine, many of which mandate that Qigong be a required course. The Qigong taught at these schools is still on a basic level and needs to be expanded to include the medical aspects of Qigong, such as described in this book.

The future of Medical Qigong and Chinese medicine appears bright. However, the need for well-trained and qualified teachers and practitioners is paramount to meeting the growing demand. Dr. Johnson's book provides the first guide in English for teachers, students, and practitioners.

Kenneth M. Sancier, Ph.D.
President Qigong Institute

FORWARD

In 1998, the Academy of Oriental Medicine at Austin gave me the opportunity to establish one of the first formal Medical Qigong training programs in the country to be offered within the context of a college of Oriental medicine. My greatest difficulty was in finding a reliable textbook for my classes. Of the numerous books on Qigong available in English, most devote only a few pages, at best, to Medical Qigong. Over the past few years, several books from China on Medical Qigong have been translated into English. Although presenting much new and valuable information, they are poorly translated and fraught with errors, making them unreliable as textbooks.

Therefore, it has been a great pleasure for me to have collaborated with Dr. Jerry Alan Johnson to some small extent on this book. Jerry Alan Johnson is one of the world's foremost authorities on the subject of Medical Qigong. This work distills several decades of his personal study, practice, and clinical experience in the United States and the People's Republic of China into an in-depth practical manual for all levels of Qigong healers.

Currently China is in the midst of what can only be called a Qigong renaissance. Today, more people are studying and practicing Qigong than in any previous time in Chinese history. In the not too distant past, Qigong was only available to monks and priests, nobles and the wealthy. Now Qigong is taught in China's primary schools and colleges, parks, temples, clinics, and hospitals to anyone who wants to learn.

China's literacy rate has increased exponentially since 1949, and now there are thousands of books, tapes, videos, and magazines on every aspect of Qigong, systems both ancient and modern, all available for general public consumption. Many regional, national, and international Medical Qigong associations have been formed, with an unprecedented exchange of information.

Although Medical Qigong has been a part of Traditional Chinese Medicine since the time of the Yellow Emperor, it has only been since 1982 that Medical Qigong hospitals and clinics have begun to spring up all over China. In the early days after the Communist Revolution of 1949, Qigong was more or less a state secret, and the Medical Qigong clinics were, for the most part, only available to high party officials. Over the past two decades, China has also devoted a great deal of effort to Qigong research and education. There are now large Medical Qigong hospitals in all of China's major cities, some of which have over 300 beds and 40 or more Qigong specialists and nurses on staff. There are hundreds of medium-and small-sized Medical Qigong clinics throughout the country, some treating inpatients and others treating only outpatients.

Before the revolution, the miracles of modern Western medicine, with its wonder drugs and surgical procedures, had caused many Chinese to see their own native traditional medicine as old-fashioned and outdated. The government encouraged the development of Western medical schools and hospitals. After the revolution, Chairman Mao recognized that with China's huge population they would need to take advantage of every form of medicine available even to begin to meet the nation's fundamental health care needs.

China is the only county in the world where Medical Qigong has been truly integrated and enthusiastically accepted as part of the national health care delivery system. According to current estimates, Medical Qigong doctors are now meeting 15% of China's national medical needs. That percentage is still growing. For decades, Chinese hospitals have successfully offered Traditional

Chinese Medicine alongside of Western medical services. Patients may receive Qigong or acupuncture anesthesia during Western surgical procedures and be treated by Medical Qigong, acupuncture, and Chinese herbal medicines during recovery. Chronic patients may be diagnosed by Western physicians, sent to Medical Qigong clinics for treatment, and have their Western doctors monitor their progress. In this respect, China has truly set the standard for the twenty-first century medicine.

Medical Qigong training and practice takes many forms in China. Some practitioners/healers are thoroughly trained in both Traditional Chinese Medicine and Western medicine, in addition to Medical Qigong. Others are heirs of family Medical Qigong systems, some dating back over a thousand years. Not all of these family practitioners have received additional training in either traditional Chinese medicine or Western medicine, yet they have been very efficient in treating disease and disorders that these conventional medicines have given up on. Still other practitioners come from martial arts backgrounds, such as Shaolin Gongfu or Daoist martial Qigong, with their own effective and unique blend of warrior training, spiritual discipline, Qigong and healing arts. Each of these categories contributes to the richness and diversity of the art of Medical Qigong.

Jerry Alan Johnson presents for us the art of Medical Qigong as it is being taught in two of the major Medical Qigong training centers in China today: the Xi Yuan Hospital of Traditional Chinese Medicine and its associated Hai Dian Medical Qigong College. Although each Qigong hospital in China defines its own program of training and practice, the material Johnson includes in this work represents the mainstream curriculum of study and practice widely accepted nationwide as a high standard of competence in Medical Qigong.

In addition to sharing the high-level protocols of Medical Qigong training in China, Johnson also draws from the reservoirs of his own decades of personal training and teaching in the internal martial arts to further enrich this work. Martial Qigong is generally practised to improve one's martial arts prowess. It includes Qigong exercises for strengthening the body; increasing power of one's strikes by emitting Qi; mind and will training; learning the vulnerable points to strike on an opponent's body to cause pain and paralysis; learning to cause serious injury or death by disrupting or destroying an opponent's internal organs, Qi and blood vessels, joints or bones; and toughening the body to withstand strikes and blows.

In what might at first seem a case of strange bedfellows, the martial Qigong tradition also has its medical side. Martial artists need to learn how to set bones and dislocations, as these injuries are commonly encountered in training and combat. Martial artists who train in the more secret arts of tien xue (vital point striking) and dim mak (death touch) are also taught how to heal the injuries that they have caused, both to heal themselves if struck by someone and to heal their opponents if the opponent is penitent. Furthermore, the martial artist who learns the methods for destroying the internal organs by emitting Qi can effectively adapt the same method to destroying pathogens and tumors in a patient for healing. Internationally recognized by his peers for his mastery of the most esoteric aspects of the internal martial arts, Johnson is eminently qualified to present its healing traditions, which he generously and openly does in this work.

I am grateful to know Dr. Jerry Alan Johnson as a colleague, teacher, and friend, and am happy to recommend this work to all students of Medical Qigong with confidence. Johnson's contribution contained herein represents the most thorough and comprehensive presentation of the art and science of Medical Qigong in the world to date. It is sure to become a modern standard of reference for anyone seeking knowledge of Medical Qigong.

Jampa Mackenzie Stewart, D.O.M.
Dean of Medical Qigong
Academy of Oriental Medicine at Austin

FORWARD

In the summer of 1995, I was sitting on the floor of Dr. Johnson's studio waiting for the start of the intermediate class in Medical Qigong. David Nakahara leaned over to introduce himself and asked me if I was a healer. Wow! It was one of those seminal moments in one's life. I considered all the implications of this question and the only relevant reply I, as a medical doctor, could muster was an ironic chuckle.

That question speaks to the heart of the current crisis in health care. Allopathic medicine lends itself to standardization of care and computer algorithms, since the structure of the clinical visit is based on protocol-derived diagnosis and treatment. The challenge is the diagnosis, but the treatment, especially high-tech treatment, gets all the press. It is incredibly satisfying to take care of people in this manner since the issues are clear and everyone gets better, unless they fail treatment; in this paradigm, the patient fails the treatment, the treatment does not fail the patient.

However, over time, you accumulate a number of patients for whom your therapeutic protocol fails, and I think that all thoughtful physicians recognize that it is these patients that teach us the most. There are women who have serious difficulty with PMS, infertility, and menopause. The cancer patients often wonder what caused the cancer to occur, what supports it, and what the meaning of this potentially fatal illness is for them. As physicians, once we emerge from the narcosis of fatigue and busyness that accompanies the daily practice of medicine in the late twentieth century, we also ask these same questions.

And we seek answers. Each physician develops his or her own rationale for treatment failures. They may rely on an unshakable faith in the scientific method, their religious upbringing or in their cultural ideals, or perhaps close themselves off entirely. I inadvertently found my answer within the martial arts.

It was clear to me from my Aikido practice that the superior martial artist must understand Qi in all its manifestations. This quest for deeper knowledge and experience of Qi led me to study Qigong with Dr. Johnson.

In my earliest lessons with Dr. Johnson, I was told that a Qigong therapist must observe and treat patients' *three treasures*: the physical body (jing or essence), their energy (Qi), and their mind/spirit/intention (shen). These three form the whole of a human being, and the parts can only be understood within the context of the whole. Furthermore, I learned that in life these three are so interrelated that it is difficult to tell where one leaves off and the other begins. Over 2,000 years ago, the Chinese philosopher Lie Zi described this by saying, "The mind leads and the Qi follows; the Qi leads and the body follows."

As a scientist, I could not help but draw the parallel between these fundamental Qigong principles and the revolutionary views of advanced modern physics: that at the deepest sub-atomic levels, matter, energy, and the person viewing them are so inextricably intertwined that they are seen as virtually one and the same, merely different manifestations of the same pattern. No longer is energy defined as a wave while matter is composed of particles. In quantum physics they have coined the term *wavicle* beause particles act as waves in one situation and as particles in another, as "probabilities" rather than concrete fixed entities and as subjective reality rather than objective.

The application of the discoveries of quantum physics to biology is just beginning. It is starting not only in the laboratory but also in many consulting rooms across the United States, as physicians search for the answers to help their patients.

I think that quantum physics is the only "hard" science that you can research just by thinking about it. As one observes the processes of nature, the thoughtful observer comes to the conclusion that there must be something else that accounts for the medical journey of the exceptional patient. The early practitioners of Ayurvedic and Chinese Medicine were careful observers of nature and through observation formulated the basic principles of Indian and Asian medical systems that are also corollaries of the principles of quantum physics.

Western awareness of the potential for the integration of the East and West began in 1971 when Nixon first went to China. James Reston, a *New York Times* correspondent covering the historic visit, developed acute appendicitis. After his emergency appendectomy, he was successfully treated with acupuncture for post-surgical pain.

Despite the dynamic nature of the penultimate Western nonbeliever confronting a totally novel experience ("only Nixon could go to China"), nothing much shifted or changed in medical practice at that time. What was missing was the readiness and ability to experience a paradigm shift in the conceptual basis of the causation of disease. Paradigm shifts in basic research have been eloquently discussed in Thomas Kuhn's landmark book, *The Structure of Scientific Revolutions*. Kuhn's brilliant analysis of the development of knowledge has recently been applied to medical science in a new book, *From Doctor to Healer: The Transformative Journey*, by Robbie Davis-Floyd and Gloria St. John. After 30 years, we are finally mature enough to begin to reassess the structure of our medical belief systems and to incorporate both world medicine and the principles of quantum physics. I have no doubt that this will take decades, but there is no doubt that the shift is beginning to occur.

Dr. Jerry Alan Johnson's book represents a major advance in this journey. This textbook is the first comprehensive treatise on the principles of Chinese energetic medical practice available to the Western medical practitioner. It also forms a bridge for the Western trained practitioner of Traditional Chinese Medicine and the allopathic (Western) practitioner. Dr. Johnson's book represents decades of research and study, and a nonjudgmental openness to any healing modality that is in the patient's best interest. I have no doubt that this book will represent a significant advance in that long awaited paradigm shift. I look forward to that time because it will address the deeper human values that have been neglected in protocol-based medicine and will bring a new depth of engagement and satisfaction to patient care.

Stephanie S. Taylor M.D., Ph.D.

Footnotes:

Kuhn, Thomas S., *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago, Illinois 1962.

Davis-Floyd and Gloria St. John, *From Doctor to Healer: The Transformative Journey*. Rutgers University Press, New Brunswick, N.J., available March 1998.

FORWARD

In the Western nations at the turn of the millennium, following a century of remarkable medical breakthroughs, there still remains a major list of unsolved medical mysteries and health care challenges. Chronic disease has not been alleviated (asthma, arthritis, etc.); stress has been recognized as a major cause in many diseases; tumors and cancers are being diagnosed in exponentially growing numbers; AIDS is a world wide epidemic; negative (Western) drug interactions have grown to become the fourth leading cause of death, and medical error has emerged as the eighth cause of death. According to the Department of Health and Human Services, over 70% of medical visits are for symptoms and illnesses that are preventable, yet the health care system is still primarily focused on treatment of the symptoms rather than health maintenance or prevention.

The public, the government, and health care providers all agree that there is a crisis in Western medicine and health care. Fortunately, at the same time, there is increasing support for innovative and alternative solutions. Among the many powerful strategies for solving this crisis, Chinese Medical Qigong (Chi Kung) and its offspring Taijiquan (Tai Chi Chuan), meditation, and focused breath practice, are probably the most comprehensive systems of self-care and healing available to compliment both conventional Western and alternative medical therapies.

The public hunger for natural healing, safety from medical side effects, lower medical costs, and health self-reliance is triggering powerful and profound changes in health care. It has become obvious that in the near future the benefits of Chinese medicine will be as fully integrated here in the U.S., as the benefits of Western medicine are in China. Through this global exchange of health care wisdom and practical applications, we are entering an unprecedented era of new possibilities to resolve suffering and foster well-being.

This definitive work on Medical Qigong, the remarkable healing art from Chinese traditional medicine, will play a significant role in the immense and profound transformation in health care that is now occurring with tremendous social and economic force.

Like the revolution in training and licensing acupuncturists that quickly unfolded in the final years of the 20th century, the momentum of training and licensing Medical Qigong Therapists is rapidly increasing in the beginning of the 21st century. Clinical Qigong, including both Medical Qigong Prescriptions and Medical Qigong Therapy, will arise in America as it has done so robustly in China.

There are a number of excellent books on various aspects and methods of Qigong. However, there has not been, in English, a comprehensive exploration of Medical Qigong. Dr. Johnson has created a breakthrough work on Medical Qigong, which is a clear and useful revelation of the Medical Qigong curriculum at the Hai Dian University Medical Qigong College of Beijing, China, and an excellent synthesis of Medical Qigong theory from throughout China. This textbook will very likely remain the definitive compendium of Medical Qigong in the West for many years, and become the foundation from which the field of Medical Qigong will evolve in Western society.

Roger Jahnke, O.M.D.
Chair, Department of Medical Qigong
Santa Barbara College of Oriental Medicine

PREFACE

As we enter the new millennium, a new era of medical therapy is beginning to blossom. Alternative medicine is now capturing an estimated $14 billion in out-of-pocket health care revenues from Americans each year, according to a 1993 study published in the *New England Journal of Medicine*. By 1997, according to the *Journal of American Medical Association*, that figure had more then doubled. What this trend means in real terms, is that despite the historical lack of official recognition by the American Medical Association, despite the lack of endorsement and coverage by Medicare and the majority of health insurance plans, men and women, in ever increasing numbers, are going to acupuncturists, energetic healers, herbalists, chiropractors, massage therapists, ayurvedic specialists, homeopathic doctors, and other traditional "healers" to meet some portion of their health care needs.

This growth of public reliance on alternative medicine has caused the Western medical establishment to sit up and take notice. In fact, some of the most vocal proponents of combining alternative medical traditions with Western medicine are medical doctors. Visionary physicians such as Deepak Chopra, Andrew Weil, Larry Dossey, Dean Ornish, and Bernie Seigel have led the way toward creating a new climate of respect for ancient medical philosophies and modalities. They have pioneered the advent in the West of health care facilities where Western medical and alternative health modalities are available under the same roof, with the goal of providing patients with the best of both worlds. This combination of ancient and modern medical traditions has been dubbed *integrative* or *complementary* medicine.

In comprehending the full implications of this unlikely marriage, one must understand the divergent approaches to healing between conventional Western medicine and traditional Eastern medicine.

Contemporary Western medicine grew out of the scientific revolution of the seventeenth century. The philosophy of science, rooted in Aristotle's "empirical materialism," was given a new spin by the French mathematician, Descartes. Viewing reality as that which could be substantiated materially, Descartes applied an analytical reductionist logic to penetrating the secrets of nature, including biology. These views were echoed in the physics of Sir Isaac Newton, applying a linear cause-and-effect model to explain the workings of a material universe.

Man was seen as being separate from nature, mind was seen as separate from body, and all of these processes, in nature and in humans, were seen as similar to the workings of a machine composed of discreet parts. Mechanical laws were seen to govern all processes. Structure determines function; therefore, the physician's role developed into that of a mechanic: repairing, removing, transplanting, and replacing broken down-parts. Diseases had isolated causes, which need to be removed from the rest of the parts. Because of this approach, Western medicine has the most highly developed pharmaceuticals to kill specific organisms and the finest surgical procedures in the world today.

By contrast, Eastern medicine grew out of the empirical observation of nature, beginning at least 4,700 years ago. Oriental philosophy, from the Vedas of India to the Yellow Emperor of China, views reality as an interdependent whole. This "prescientific" understanding equates to the broader view of modern quantum physics and the general systems theory. Rather than limiting reality to that which is material, the Eastern philosophers recognized the interdependence of mind

and body, the nonlinear nature of time and space, and the interweaving patterns of relationship between man and nature; in fact, they believed, we *are* nature. Anatomy, the study of human structure, takes a back seat to physiology, the study of human function. Thus, the Orientals formulated a general systems theory, in which the patterns of change that exist in nature are the same patterns that govern human biology, wherein function is viewed from a holographic perspective, and each part reflects the whole. Rather than being fixed and stable, the whole is in a dynamic process of constant change. For the whole to function harmoniously, every part must remain in balance. Therefore, the role of the Oriental physician is more similar to a gardener, following the patterns of change, diagnosing functional disharmony and restoring overall balance. Because of this approach, Oriental medicine has some of the most highly developed procedures for preventative medicine and for treating chronic diseases in the world today.

Western medical science, with its fundamental distrust of subjective diagnostic reliability, has progressed toward developing more and more expensive high-tech laboratory tests and diagnostic equipment. Thus we have the modern miracles of x-rays, MRI's, and ultrasound. Eastern medicine, trusting in human capacity, has progressed in a low-tech direction toward ever deeper training of the physician's sensory and spiritual diagnostic tools. Thus, we have the miracles of pulse diagnosis, tongue reading, and Qigong hand scanning.

With such fundamental divergencies in philosophy and technique, it is almost inconceivable that these two medical systems could ever operate together in the same setting. The fact is that they do function together, and quite effectively, too. We can thank Mao Zedong for the union of these two unlikely bedfellows.

Recognizing that there were far too few Western trained physicians and nurses to meet the primary health care needs of China's vast population, from the outset of his leadership Mao advocated the systemization of Traditional Chinese Medicine (TCM), and advocated its implementation alongside Western medicine in China's hospitals and clinics. The results of this integration have been astonishing, as witnessed in the effective use of acupuncture anesthesia during surgery.

Nonetheless, in his efforts to create a "modern" Chinese medicine, Mao shunned some of the traditional theoretical aspects of Chinese medicine, such as the concept of Qi, which he considered as feudalistic and counterrevolutionary. For this reason, he actively discouraged Medical Qigong practice as superstitious. It was not until the end of the Cultural Revolution in 1975 that Qigong reclaimed its rightful place as one of the major branches of Chinese medicine.

A high party official in Beijing was suffering from an "incurable" disease. Both Western medicine and TCM had failed to alleviate his suffering. In desperation, he went to one of the few Medical Qigong clinics operating in the country and was cured. The official then lent his support to the promotion of Medical Qigong for the benefit of the Chinese people. Before long, there were hundreds of Medical Qigong hospitals and clinics throughout China.

Since that time, Qigong has experienced an unprecedented growth in China. Qigong is now available to the general populace for the first time in history. Qigong is now taught in the public education system, beginning at the elementary school level. Qigong departments have been added to large urban hospitals. Colleges of Traditional Chinese Medicine have developed Medical Qigong training programs. According to one recent survey, one third of the population of Beijing, China's capital city, practices Qigong daily.

It has taken acupuncture and Chinese herbology nearly 20 years to develop into a respected profession in the United States. As this book goes to press, 37 states now have legislation licensing professional acupuncture practice, with an additional 10 states in which legislation has currently been introduced. Medical Qigong is still at the very early stages of public recognition, understanding, and acceptance by comparison. Oriental medical schools around the United States, as well as independent Medical Qigong masters, are only now beginning to establish comprehensive

Medical Qigong training programs. I am heartened by this development.

Traditional Chinese medical therapy is divided into four main branches: acupuncture, herbs and diet, massage therapy, and Medical Qigong. It is important for TCM practitioners to have exposure to all four branches to be able to understand the relative strengths and limitations of their particular field of expertise, so that they will be able to select the most effective and appropriate treatment modality for their patients. Until very recently, most schools in America have been relatively unaware of the extent to which Medical Qigong therapy has developed in China, and have been lacking in presenting Medical Qigong as a significant part of their training programs for students of Oriental medicine.

The purpose of this book is twofold. The first purpose is to apprise the reader of the professional standards of knowledge and skill required in contemporary China for licensing a "Doctor of Medical Qigong Therapy" (D.M.Q.). The second purpose is to describe how to effectively diagnose and treat patients with Medical Qigong therapy as set forth by the Hai Dian Medical Qigong College of Beijing and to provide a textbook for training to that standard under the guidance of a qualified instructor. Hai Dian is recognized as one of the top Medical Qigong colleges in China.

Although this book is primarily written for students and practitioners of Oriental medicine, it is also my hope that practitioners and students of Western medicine and other forms of alternative healing will benefit from the information contained herein, and that it may serve to enrich their practice in the healing arts.

This book is divided into twelve sections. The first four sections focus on building a comprehensive foundation in energetic medicine. The second four sections focus on guidelines for establishing a Medical Qigong clinic, as well as for diagnosing and treating problems of Qi deviations. The last four sections focus on treatment modalities, Medical Qigong prescriptions, Medical Qigong regulation exercises and scientific research in Medical Qigong clinical therapy.

I have done my best to present the knowledge and wisdom of this ancient Chinese art as it was passed onto me personally by my respected teachers, to whom I owe undying gratitude. Qigong has survived nearly five thousand years of growth and refinement and is now available to you, the reader, for your own personal and professional benefit. I sincerely hope that this book may serve to further bridge the partnership between Eastern and Western medicine, that all humanity may be the beneficiary of the interchange between these two great schools of healing. May all doctors and healers, Western and alternative, return to the "heart" of medicine, that each may view the patient as a complete integration of body, mind, emotion, energy, and spirit. May we support each other's skills and techniques in alleviating our patients' suffering.

Jerry Alan Johnson, Ph.D., D.T.C.M., D.M.Q. (China)
Dean of Medical Qigong Science
Director of Medical Qigong Clinic
Five Branches Institute, College & Clinic of TCM
Santa Cruz, California
May, 2000

INTRODUCTION

The Eastern approach in explaining medical concepts is generally expressed through a three dimensional convergence, seeing the physical body as an energetic hologram, and observing the physical, mental, emotional, energetic and spiritual reality of the tissues. By stimulating any one of these five energetic matrices, you affect the other four, and influence the body to initiate either health or disease. Diagnosis and treatment is therefore approached in a nonlinear progression, working towards the health and healing of the whole person.

The Western mind, however, is taught to view the physical body on a linear progression of cause and affect, separating the reactions of the tissues from the effect of the mind and emotions, as well as the universal and environmental influences. In order to help the Western mind understand the concept of Chinese energetic medicine, this Medical Qigong textbook was written with the goal of instructional comprehension and practical application of Chinese energetic medicine. It embraces the concepts of traditional Chinese medicine, in particular Medical Qigong therapy, from a progressive linear format. Beginning with Energetic Embryology in Section 1, it provides a basic understanding of complex energetic structure, theory, and practical application, ending in advanced clinical treatments in Section 11. The final chapters of this textbook, consists of scientific research collected from various doctors and research scientists which validate the claims made of Medical Qigong therapy being an effective clinical modality, in Section 12.

Chinese medical terminology is extremely metaphoric and is used to describe the many aspects of the human body through physical, mental, emotional, energetic, and spiritual domains of existence. Many technical terms in Traditional Chinese Medicine have numerous meanings, depending on the context of the subject.

For clarity, the Chinese terms in this book are capitalized along with the English words for which Traditional Chinese Medicine assigns a special meaning. Such words include, but are not limited to, the following: Gall Bladder, Small Intestine, Spleen, Pericardium, Bladder, Liver, etc. There is one exception to this rule; the word "energy" meaning Qi, is capped only in the first few chapters of this book for the sake of easier legibility, as it appears so often within each chapter.

When you see words such as Blood, Heart, and Marrow capitalized, assume that their meaning differs from that ascribed by Western medicine. In Traditional Chinese Medicine, the word Marrow, for instance, does not refer to bone marrow as it is traditionally recognized in the West, but rather describes the substance which is the common matrix of bones, bone marrow, the brain and spinal cord. Non-capitalized terms retain their traditional Western meanings.

One decision I have made when writing this textbook is to use the term "divine" when expressing the energy of the Dao or God. In China, many of the Qigong doctors and masters that I have trained with asked me to keep these spiritual theories in confidence for fear of governmental reprisal. Therefore, having decided to openly share these ancient energetic theories concerning the interactions of the spirit, soul and divine, I have done so without revealing my sources.

Finally, many of the energies used to describe the natural forces of nature (existing within Heaven, Earth, and Man) were historically changed into "gods" or "spirits" in order to compete with the colorful deities imported into China from India. Therefore, when reading this textbook, the reader should not become confused by cer-

tain terminologies describing "deities" which govern specific energetic principles. For example, when reading the section on the Eternal Soul, the title "Lords of the Three Dantians" implies the fact that the soul has three primary, separate, yet interconnected, energetic properties, rooted, divided and sustained within each of the Three Dantians.

Jerry Alan Johnson, Ph.D., D.T.C.M., D.M.Q. (China)

Section I
Foundations of Chinese Energetic Medicine

CHAPTER 1
INTRODUCTION TO MEDICAL QIGONG

More than 5000 years ago, Chinese physicians came to understand that everything is composed of the same energetic substance called Qi (pronounced "chee"). These ancient masters concluded that there is a oneness and wholeness in all existence, and that energetically everything is interconnected as one body, although energy may appear to take on many different forms. All things in nature and, in fact, all things in the universe are woven together so that we are, quite literally, all symbiotically one with the universe through the system of Qi. Qi is always in motion within all things, and is the catalyst for everything to relate and interrelate within the universe.

In modern times, the laws of physics have demonstrated that matter and energy are interchangeable, and that matter is simply another form of energy. Matter is constantly vibrating in the form of tangible solids and intangible gases, and is constantly altering, being affected by, or interacting with energy. Energy is inherent in the living human body, and the human body is sustained by energy (Figure 1.1).

The ancients mastered techniques to balance the body's energy (Qi) in order to live in harmony with the environmental (Earthly) Qi as well as the universal (Heavenly) Qi. Traditional Chinese Medicine maintains that when living things start to lose their Qi, they lose their vitality. An ancient Chinese saying states, "Life comes into beginning because Qi is amassed; when Qi is scattered, the person dies."

Qi is stored within the body in the form of pools, creating the structures of the internal organs. From these internal pools, the body's life-force energy flows in the form of rivers and streams. These energetic rivers and streams form the body's vessels, channels, and collateral systems.

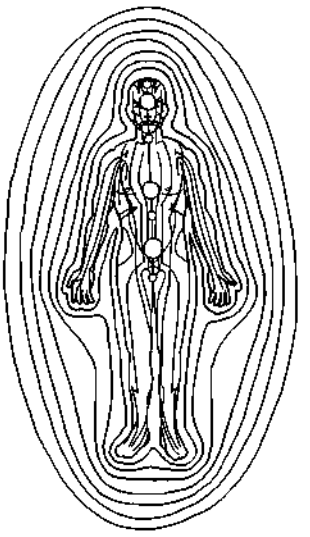

Figure 1.1. The Body's External Qi Field

THE FIVE DOMINIONS OF ENERGY

The ancient masters observed that Qi can be divided into five manifestations of matter and energy: mineral, plant, animal, human, and divine. Each form draws on the energy of the next, resonating and interacting with the divine through the form's relationship in Wuji (infinite space). The five manifestations of matter and energy are explained as follows.

1. The mineral's energetic field is considered the densest (i.e., the slowest) or lowest form of energetic vibration. The disintegration or division of the mineral's particles combine with the elements of air and water to form the Earth's soil. Every particle in the soil still retains the original primordial energy force of the mineral, which interacts with the energy of the divine.
2. The plant's energetic field is considered the next higher form of energetic vibration. All of

the Earth's vegetation (trees, bushes, flowers, herbs, etc.) absorbs a part of its life-energy from the mineral's energetic field, increasing and multiplying its energetic potential. The plant's energetic field is considered the next higher step in energetic evolution towards the divine energetic field.

3. The animal's energetic field is considered the next higher form of energetic vibration. The animal consumes and absorbs the energy from the plant's energetic field, further increasing and multiplying its energetic potential, bringing it one step closer towards the divine energetic field. Within each higher frequency of vibration there is also an increase in consciousness and level of awareness.
4. The human energetic field is considered the next highest form of energetic vibration. Mankind stands between Heaven and Earth, partaking of both energy fields. Through diet, Qigong practice, prayer, and meditation, humans can further refine and multiply their energetic potential.
5. The divine energetic field is the highest vibrational expression of energy known. As it envelops and becomes active within the human body, it further increases and multiplies the body's energetic potential, allowing man to attain divine consciousness.

All these energetic fields originate from one source, and all contain the vibrations of the one divine life-force. Likewise, with an attitude of deep respect for plants and animals that give up their life-force energy for our consumption, it is possible to enhance the nutritional value of the substances they provide us with. The blessing of food, and food prepared with a loving attitude, allows for the absorption of not only the vitamins and minerals contained therein, but also the absorption of the higher vibrations of the one divine energy inherent in all things. This is why many ancient cultures, often referred to as "primitive," prayed before hunting so that the animal spirit would willing give itself for sacrifice. Prayers were also given after the kill to free the animal's spirit so that it could return back to the divine.

Yang	Yin
active	passive
creative	receptive
masculine	feminine
front	back
left	right
fire	water
hot	cold
dry	wet
hard	soft
light	heavy
bright	dark
heaven	earth
sun	moon

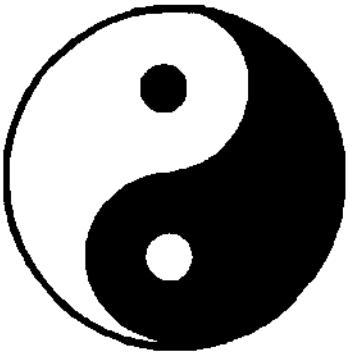

Figure 1.2. The table above shows some characteristics of Yang and Yin. Below is the Yin/Yang symbol: white represents Yang and black represents Yin. The small circles, one white and the other black, symbolize the fact that Yin is always transforming into Yang and Yang into Yin. (For more on Yin and Yang, see Chapter 3.)

Once individuals becomes aware of the divine energetic field, they begin to experience the refined vibrational energy fields of minerals, plants, animals and human beings. This increased awareness of the divine life-force energy strengthens the awareness of one's own energetic fields and that of others. This in turn can deepen the conscious and unconscious energetic connections between ourselves and others, be they human, animal, plant or mineral.

DEFINING THE ENERGY OF YIN AND YANG

Each of the five energetic fields can be further divided into Yin and Yang aspects. In Traditional Chinese Medicine (TCM), the theory of Yin and Yang energy represents the duality of balance and harmony within the body, as well as within the universe (Figure 1.2). Earth energy is Yin, while Heaven energy is Yang.

Yin exists within Yang, and Yang within Yin. Yang manifests as active, creative, masculine, hot, hard, light, and bright. Yin manifests as passive, receptive, feminine, cold, soft, and dark. The dynamic balance of Yin and Yang always changes and transforms the body's life-force energy. (See Chapter 3 for more on Yin and Yang energy.)

Successful practitioners in balancing the body's Yin-Yang energies were considered masters or "immortals," able to harmonize the body with the mind, the mind with the will, the will with the breath, the breath with the spirit, the spirit with motion, and finally, motion with the surrounding environment (Earth), the universe (Heaven), and the divine (Dao).

UNDERSTANDING THE CONCEPT OF QI

While the concept of Qi may seem complicated, it is actually very simple. Matter progresses to energy and energy to spirit. Qi is the medium, or bridge, between matter and spirit. Once we become aware of the reality of Qi, it becomes easily recognized.

Through observation and study, Chinese Qigong (pronounced chee-gung) masters discovered that each organ in the human body has a different function and a different speed of energetic vibration. By tracing the pathways (channels) Qi takes through each organ and observing the effects on bodily functions, the Chinese developed the basic theories upon which Qigong practice is founded. For thousands of years, Chinese medicine has successfully cured serious illnesses by stimulating the body's energy in very specific ways.

Through the study of Qigong, anyone wishing to cultivate awareness of the energy vibrations and their own individual pathways can learn to influence and even control them. Qigong practitioners use these skills to heal and strengthen the immune system, and to improve the functioning of various organ systems within the body. China Healthways International estimates that in Beijing alone more than 1.3 million people practice some form of Qigong every day, whereas, in China as a whole, around 80 million people practice Qigong.

DIFFERENT SCHOOLS OF QIGONG

Qi means "life-force energy" and gong means "skill," so Qigong is the skillful practice of gathering, circulating, and applying life-force energy. In China today, Qigong practice is divided into three main schools: medical, martial, and spiritual. The three schools are all based on the same philosophical system and share many of the same meditations and techniques. The schools differ primarily in focus. Students choose a school based on the use to which they want to put their Qigong training. Briefly, each school focuses on one of the following specialties:

1. The medical school trains doctors and healers in special Qigong methods for health maintenance and longevity, disease prevention, and the diagnosis and treatment of diseases and disorders. The three primary techniques of Medical Qigong therapy include the following.
    a. Purging to detoxify the body of pathogens,
    b. Tonifying to strengthen the body's internal organs and systems, and
    c. Regulating to balance the body's internal energy.
2. The martial school trains martial artists to

build their strength and power for performing martial arts applications. The three primary techniques of martial Qigong training include the following.

a. Obvious Power (Ming Jing) techniques emphasize the training and conditioning of the muscles, strengthening the bone structure, and increasing the individual's overall stamina. This school also includes such techniques as pounding the body (arms, hands, legs, and torso) to strengthen and toughen the tissues.
b. Hidden Power (An Jing) techniques emphasize stretching and twisting the tendons and ligaments (known as Reeling and Pulling the Silk) to cultivate resonant vibration within the body for striking and issuing power.
c. Mysterious Power (Hua Jing) techniques emphasize the training and conditioning the mind's imagination and intention, to project and utilize the power of the individual's Shen (Spirit).

3. The spiritual school trains practitioners who seek spiritual transformation and enlightenment (Daoism, Buddhism, and Confucianism each have their own unique techniques). Their techniques include meditations for fusing, as well as releasing the Three Ethereal Souls (Hun). These souls can best be understood as personifications of moral qualities (or archetypes). When the Hun are fully developed, the practitioner acquires certain extraordinary powers and abilities, such as soul travel. The goal however, is to achieve transformation and a state of enlightenment, and not be led astray by the glamor of extra powers. The three primary techniques of spiritual Qigong training include the following:
   a. Nourishing the Spirit (Shen), to strengthen and refine the power of the individual's Shen,
   b. Housing the Shen by disciplining both thoughts and emotions, to relax and tranquilize the individual's Shen, and to become more receptive to divine energy and guidance, and
   c. Combining the Shen with the Qi, to coordinate the breath and intention for directing the spirit to guide the body's life-force energy.

Qigong training involves all of the individual's physical senses. The concentration is focused on breathing, hearing, visualizing, and muscle relaxation. Massage, and movement are also used to develop and control the body's intrinsic energy. Studying Qigong requires not only comprehending the immeasurable wisdom gathered for medical, martial, or spiritual development but also studying the ancient Chinese culture inherent within these systems.

MEDICAL QIGONG DEFINED

All living bodies generate an external field of energy called Wei Qi (pronounced "whey chee"), which translates as "protective energy." The definition of Wei Qi in Medical Qigong is slightly different than that of Traditional Chinese Medicine (TCM). In classical TCM texts, the Wei Qi field is seen to be limited to the surface of the body, circulating within the tendon and muscle tissues. In Medical Qigong, however, the Wei Qi field also includes the three external layers of the body's auric and subtle energy fields. This energy originates from each of the internal organs and radiates through the external tissues. There the Wei Qi forms an energy field that radiates from the entire physical body. This field of Qi protects the body from the invasion of external pathogens and communicates with, as well as interacts with, the surrounding universal and environmental energy fields.

Both internal and external pathogenic factors affect the structural formation of the Wei Qi. The internal factors include suppressed emotional influences (such as anger and grief from emotional traumas); The external factors include environmental influences when they are too severe or chronic, such as Cold, Damp, Heat, or Wind, etc. Physical traumas also affect the Wei Qi field.

Any negative interchange affects the Wei Qi

by literally creating holes within the matrix of the individual's external energetic fields. When left unattended, these holes leave the body vulnerable to penetration, and disease begins to take root in the body. Strong emotions, in the form of toxic energy, become trapped within the body's tissues when we hold back or do not integrate our feelings. These unprocessed emotions block the natural flow of Qi, thus creating stagnant pools of toxic energy within the body.

Medical Qigong consists of specific techniques that use the knowledge of the body's internal and external energy fields to purge, tonify, and balance these energies. Medical Qigong therapy offers patients a safe and effective way to rid themselves of toxic pathogens and years of painful emotions that otherwise, can cause mental and physical illness. This therapy combines breathing techniques with movement, creative visualization, and spiritual intent to improve health, personal power, and control over one's own life.

MEDICAL QIGONG TRAINING IN CHINA

There are numerous colleges of Traditional Chinese Medicine throughout China today that focus on Medical Qigong training. The majority support the scientific study and expansion of Medical Qigong applications and Traditional Chinese Medicine treatments.

According to Qigong master and doctor of Traditional Chinese Medicine, Professor Zhou Qianchuan, all of the most famous Chinese doctors of acupuncture and moxibustion, herbal medicine, bone setting, and massage therapy, either practiced Qigong or incorporated Qigong into their clinical practices.

Major traditional Chinese medical colleges in China offer comprehensive, government-sponsored, three-year programs in Medical Qigong therapy. Programs include classes, labs, and seminars on traditional Chinese medical theory. These studies include: The foundations of Chinese medicine for internal diseases according to *the Yellow Emperor's Inner Canon, Spiritual Axis, Essential Questions,* and *the Canon of Perplexities.* The Medical Qigong classes also include energetic anatomy and physiology, diagnosis and symptomatology, energetic psychology, Qigong pathology, Medical Qigong therapy, as well as a survey of other related medical modalities. The other related modalities include: a comprehensive understanding of herbal medicine, acupuncture therapy, and Chinese massage. Classes of Western anatomy and physiology, Western internal diseases, and health and recovery, are also required.

During the certification program, three to five training hours a day accompany the standard six-day-a-week classroom curriculum. Course content, personal mastery of energy extension, and diagnosis techniques are rigorously tested each week. Upon completing the required courses and passing the final exams, the student receives a certificate of completion. Next, a six-month to one-year internship is required at a program-affiliated hospital or clinic. Upon successful completion of this internship, the new doctor is licensed as a doctor of Medical Qigong therapy by the People's Republic of China's Bureau of Scientific Technology.

Each internship program is assigned a separate wing in the selected Chinese hospitals. Both inpatient and outpatient facilities are available to the public. Each branch has specific approaches to healing a patient, with its own unique set of ground rules for diagnosis and treatment.

There are three distinct supervisory levels working within each clinical branch of Traditional Chinese Medicine in China. The first and lowest position is that of a "doctor of Medical Qigong," who is responsible for the treatment of all clinical patients (including patients in both the inpatient and outpatient clinics). The positions of Medical Qigong doctor are generally filled by the medical college graduates who have spent four to five years in clinical study and practice. The next level is called a "physician or doctor in-charge," and denotes a senior position within the clinic. This individual is responsible for the supervision of all the Qigong doctors' clinical procedures. This position is usually obtained after spending a minimum of five years as a Qigong doctor. The final and highest level is called a "director or professor;" this position requires overseeing the doctors

in-charge, as well as teaching, treating, and training of other doctors to pass on Qigong clinical knowledge to future generations. This position is usually obtained after spending a minimum of five to six years as a doctor in-charge.

The licensing is reviewed and issued by either the People's Republic of China's Bureau of Scientific Technology (that issues a license in local city hospitals) or by the Ministry of Scientific Technology (that licenses to practice in any clinic or hospital throughout China). The Qigong doctor's skills are tested through oral, written and practical examinations, and a license is issued accordingly. In China today, there are five positions available for a doctor of Traditional Chinese Medicine. These five positions are described as follows.

1. A Doctor of Acupuncture Therapy (D.Ac.) specializes in the five main modalities of Chinese acupuncture.
2. A Doctor of Herbal Medicine (D.H.M.) specializes in the five main modalities of Chinese herbology.
3. A Doctor of Massage Therapy (D.M.T.) specializes in the five main modalities of Chinese massage and tissue regulation.
4. A Doctor of Medical Qigong Therapy (D.M.Q.) specializes in the five main modalities of Chinese Medical Qigong.
5. A Doctor of Traditional Chinese Medicine (D.T.C.M.) is a doctor who has trained in all four branches of Traditional Chinese Medicine (acupuncture, herbs, massage, and Medical Qigong).

MEDICAL QIGONG TRAINING IN THE UNITED STATES

The Five Branches Institute, College and Clinic of Traditional Chinese Medicine became the first TCM/Acupuncture College in the United States to open a Medical Qigong Clinic on April 7th., 2000. This clinic not only serves as an invaluable teaching resource for the Five Branches acupuncture students, but also serves as an affordable alternative medical clinic for the general public.

Founded in 1984, the Five Branches Institute has been known not only for its leadership in TCM education, but also as an academic innovator as well. It was the first, and remains the only, TCM College to establish a Neurology Center (founded in 1995) for the specialized treatment of paralyzed patients, under the directorship of the world-famous Chinese physician Doctor Ming Qing Zhu, L.Ac., Dipl. Ac. (NCCA), M.D. (China).

THE FIVE BRANCHES MEDICAL QIGONG CLINIC

The Five Branches Medical Qigong Clinic is currently divided into 3 treatment areas. The main area (Clinic A) is used to treat patients with less severe conditions; the second area (Clinic B) is used specifically for the treatment of cancer patients. The third treatment area is designed for video taping the patient's Medical Qigong prescription exercises and meditations.

Clinic A is the primary care facility of all patients. The patients are first assessed, and then assigned to a treatment team. Each team is comprised of at least one senior intern and several clinical students. Each team diagnoses, treats, and then prescribes Medical Qigong exercises and meditations for each patient. Some patients with potentially terminal illnesses (cancer, tumors etc.) may require specialized treatments, and are referred to the Clinic B.

The main goal of the Clinic B is to specialize in Oncology, and to work closely with the Academic Dean and Clinical Medical Director Dr. Joanna Zhao, L.Ac., Dipl. Ac. (NCCA), D.T.C.M. (China), who prescribes herbal therapy to complement the Qi Emission therapy and Medical Qigong prescriptions.

The Director of the Medical Qigong Clinic is Dr. Jerry Alan Johnson, whose duty is to oversee the "Doctors in Charge" of the 3 treatment areas, as well as regulate the patient load between Clinics A and B.

The Doctors in Charge of the Medical Qigong Clinics are: Jean Ruth Vlamynck, L.Ac., Dipl.Ac., M.T.C.M., M.Q.T., and Adam Atman, L.Ac., Dipl.Ac., M.T.C.M., M.Q.T. Their duty is to oversee the Medical Qigong doctors on staff within the three treatment areas, supervise the current interns, and make themselves available for consultations when needed.

The front entrance of the Medical Qigong College at the Hai Dian University in Beijing, China.

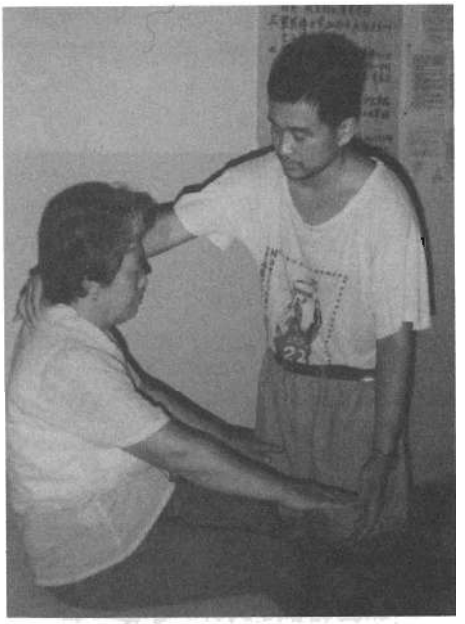

Dr. Lu Guo Hong, Director of the Hai Dian Medical Qigong College, treats a patient suffering from hypertension by dispersing Excess Heat from her body.

Right: The graduate students of the Hai Dian Medical Qigong College intern at the Xi Yuan Hospital in Beijing, China, for a period of 6 months to a year. They are licensed through the government's Medical Qigong Science and Research Institutes, which monitor the student programs.

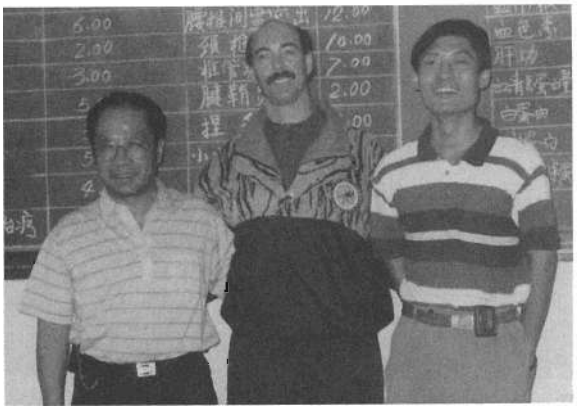

Left to right: Dr. Li Fu Dong, Associate Professor and Chief Director of Medical Qigong Science, Dr. Jerry Alan Johnson the author and director of the International Institute of Medical Qigong, and Dr. Pang Dong Hui, Executive Deputy President of the Hai Dian University.

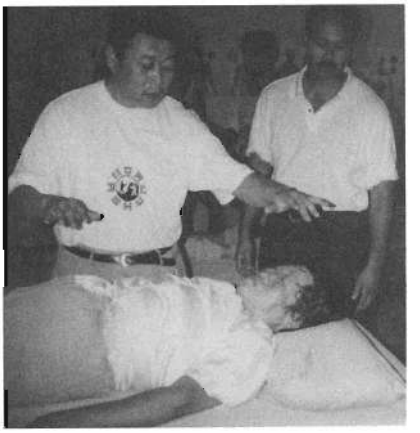

Dr. Niu Yu Hua, Assistant Director of the Hai Dian Medical Qigong College, treats a patient by regulating the Qi of her Upper and Lower Dantian.

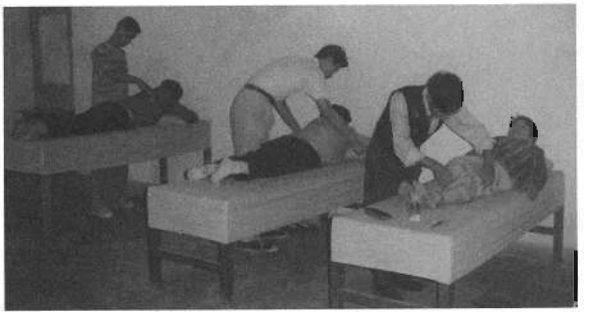

The Xi Yuan Hospital in Beijing, China, is the equivalent of the Stanford or Harvard Medical Center in the United States; it specializes in five distinct branches of healing therapies: Medical Qigong, acupuncture, herbs, Chinese massage, and Western medicine.

The Xi Yuan Hospital is equipped with both inpatient and outpatient Qigong clinics. Here, Dr. Xu Hongtao administers "distance" Qigong therapy to patients in one of the many Medical Qigong wards.

Three Americans completed their internships at the Xi Yuan Clinic in 1995. They are shown here posing with Dr. Xu Hongtao, the Xi Yuan Hospital staff supervising physician. *Left to right:* Dr. Seth Lefkowitz, the author Dr. Johnson, Dr. Xu Hongtao, and Dr. Arnold Tayam.

Left to right: Qigong Master Zheng Zhanding, Jonathan Liu, and the author discussing advanced Medical Qigong theories and modalities.

Right: The China Beijing International Acupuncture Training Center is a facility in which doctors from around the world culminate their training in Chinese medicine with Chinese doctors who are experts in their medical specialties.

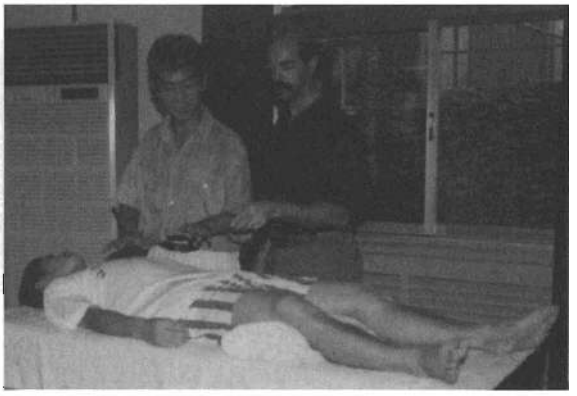

Dr. Teng Yingbo *(left)*, the president and secretary general of the Beijing Western District Qigong Science and Research Institute, with the author treating a patient.

The author lecturing at the World Academic Society of Medical Qigong 1996 World Conference, on the psychophysical manifestations associated with tumor formation.

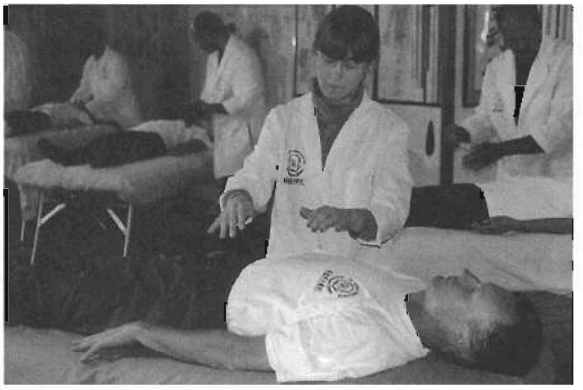

Left: The International Institute of Medical Qigong is one of the few American Medical Qigong colleges that maintains the same strict standards as the Medical Qigong Universities in China. The initial training programs generally require three to four years of training.

The 1997 graduating class of the International Institute of Medical Qigong *(left to right)*:

Back row: Dr. Stephanie Taylor, Pamela Lee Espinoza, Anne Elderfield, and Dr. Carole Marie Kelly.

Front row: Dr. Arnold E. Tayam, Dr. Johnson (director of the institute), Shannon K. Brown, and Dr. Seth Lefkowitz.

The 1999 graduating class of the International Institute of Medical Qigong *(left to right)*:

Back row: Matthew B. Weston, William H. Lewington, William H. De Groat, Paul E. Miller.

Middle row: Katy Reed, Madeleine H. Howell, Brooks M. Fiske, Diane de Terra.

Front row: Michael J. Finch, Jean R. Vlamynck, Dr. Johnson, Dennis M. Earnest.

Not pictured: Todd Mathew Gedryn, Luc Arnauld Logan, Geoffrey Greenspahn and Rose Mary Stewart.

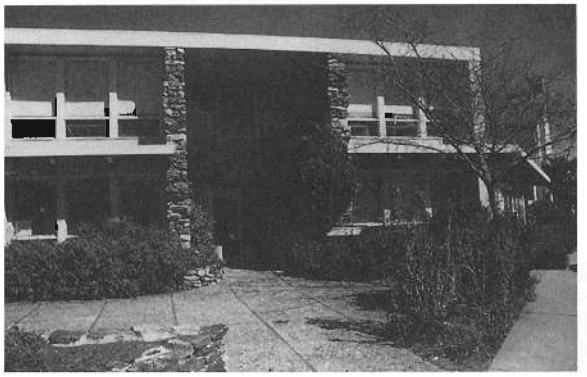

The Five Branches Institute, College and Clinic of Traditional Chinese Medicine became the first TCM/ Acupuncture College in the United States to open a Medical Qigong Clinic on April 7th., 2000.

Pictured from left to right are the Five Branches President and CEO Ron Zaidman, M.B.A., M.T.C.M.; the Academic Dean and Clinical Medical Director Dr. Joanna Zhao L.Ac., Dipl. Ac (NCCA), D.T.C.M. (China); and the Dean of Medical Qigong Science and Director of the Medical Qigong Clinic Dr. Jerry Alan Johnson.

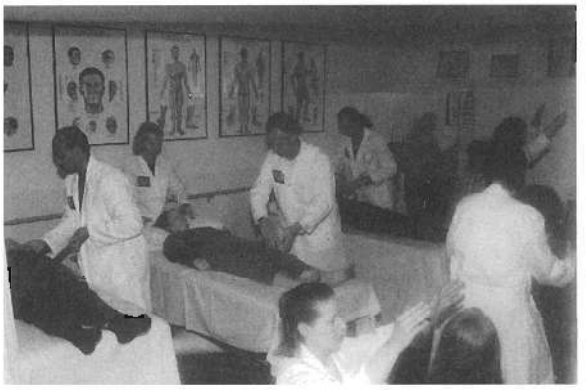

In the main treatment area (Clinic A), patients are categorized according to the severity of their condition. For serious conditions (e.g., multiple sclerosis) patients are encouraged to lie on the treatment tables.

In Clinic A of the Five Branches Medical Qigong Clinic, patients with less serious conditions (e.g., hypertension and migraine headaches) are encouraged to relax on one of the treatment chairs.

The resident Doctors in Charge of the Five Branches Medical Qigong Clinic are Adam Atman L.Ac., Dipl.Ac., M.T.C.M., M.Q.T. (positioned on the left), and Jean Ruth Vlamynck L.Ac., Dipl.Ac., M.T.C.M., M.Q.T. (located in the middle). They are seen here is discussing the current patient load with Dr. Arnold Tayam D.M.Q. (China).

The second treatment area (Clinic B), is used specifically for the treatment of tumor and cancer patients.

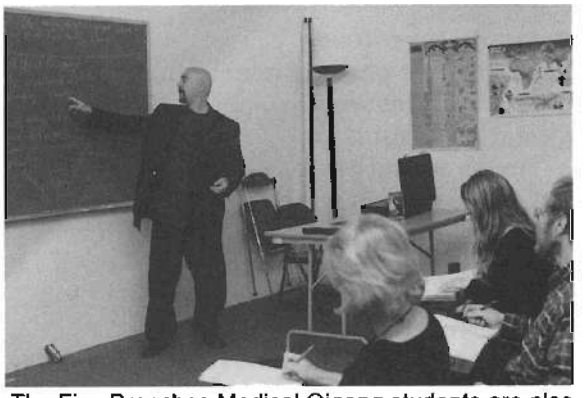

The Five Branches Medical Qigong students are also taught Energetic Psychology and how to deal with the emotional discharges coming from their patients.

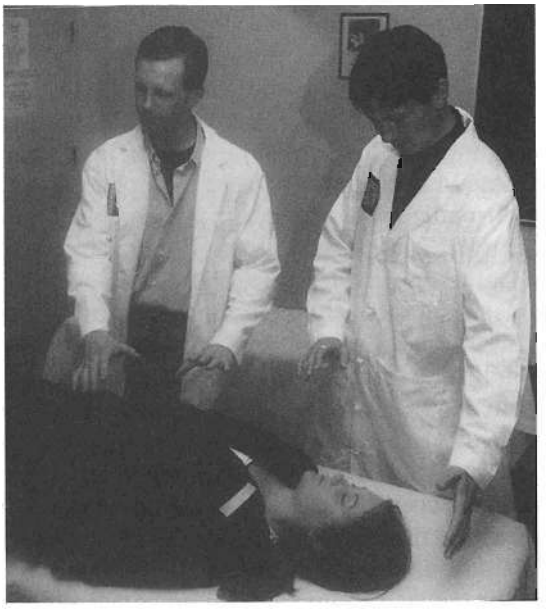

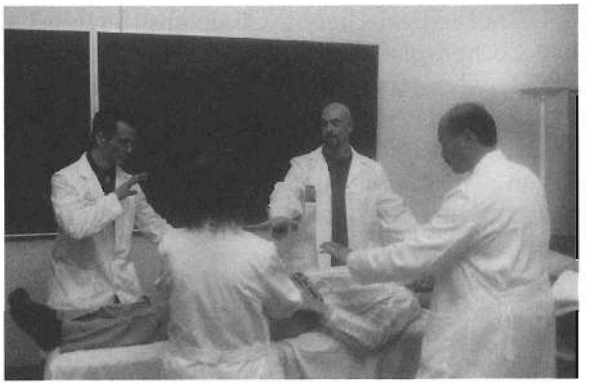

Doctors of the Five Branches Medical Qigong Clinic combine their energies to treat a specific type of cancer, observed here, in Clinic B.

Within the first semester, the Medical Qigong students at the Five Branches TCM College have learned and experienced basic applications of Medical Qigong purgation, tonification and regulation exercises. They have also been taught the underlying principles for each exercise and meditation. Furthermore, they are able to discriminate when to assign these prescriptions to patients, and when not to.

In the first phase of internship, the Medical Qigong students work as part of a Qigong treatment team, assisting a senior intern.

The Medical Qigong Clinic also includes a psychotherapist, Madeleine Howell, L.M.F.T., M.Q.T., who is trained in Medical Qigong therapy. She is available to patients who may need professional consultation after undergoing Medical Qigong treatments, as these may bring painful emotions to the surface as part of the healing process.

On the first official day of the clinic, 15 Qigong interns and doctors from the International Institute of Medical Qigong performed Qi Emission through Distance therapy on more than 80 patients. Treatments ranged from a general treatment (purging excess, tonifying deficiencies and dispersing stagnations) to the treatment of several potentially terminal cancer patients.

THE FIVE BRANCHES MEDICAL QIGONG COURSE AND CLASSES

The Medical Qigong students at the Five Branches college learn and experience basic applications of Medical Qigong purgation, tonification and regulation exercises during the first semester. Classes, include lectures and labs. They are also taught to understand the underlying principles of each Medical Qigong exercise and meditation, and learn when and when not to assign these exercises in cases for clinical application. The students are also taught Energetic Psychology and how to deal with the emotional discharges coming from their patients.

In the second semester the Medical Qigong students are led through a progressive series of advanced Shengong meditations and exercises, for developing advanced intuitive diagnostic skills. The students also learn basic Medical Qigong treatment protocols, and begin the initial phase of clinical internship. During this phase they assist the senior interns.

From the third semester on, the students begin an in depth study in Medical Qigong theory and its application. The goal is to complete a three year certification program in Medical Qigong Therapy.

MEDICAL QIGONG CLINICAL THEATRE

Conducted in a small class setting, the Medical Qigong Clinic gives the students exposure and first hand experience at Medical Qigong diagnoses and treatments. This is a hands on experience where the different aspects of energetic dysfunctions and symptom manifestations are studied, treated and observed by the Medical Qigong students. Through the careful guidance of the instructor, the Medical Qigong students are allowed to assist in all phases of diagnosis and treatment.

After completing the Clinical practicum, Medical Qigong students at the Five Branches TCM College will be qualified to diagnose and treat patients, as well as document and maintain accurate clinical records.

CLINICAL INTERNSHIP

In the first phase of internship, the Medical Qigong students work as part of a Qigong treatment team, assisting a senior intern.

In the second phase of internship, the Medical Qigong students work with their own patients, under the supervision of the instructor.

By the end of their Clinical Internship, the Medical Qigong therapists will receive their Masters degree, and will be fully qualified to diagnose and treat patients without supervision.

TRADITIONAL CHINESE MEDICINE AND MEDICAL QIGONG THERAPY

Medical Qigong therapy is the oldest of the four branches of Traditional Chinese Medicine and provides the energetic foundation from which acupuncture, herbal healing, and Chinese massage originated. It is through the understanding of Qigong that the other branches of Traditional Chinese Medicine are elevated to a spiritual path of self-realization and internal transformation. Doctors of Traditional Chinese Medicine address the patients' physical, energetic, and spiritual needs simultaneously. According to the principles of Traditional Chinese Medicine, the root cause of all disease can be traced to a critical imbalance within the body's vital energies. Therefore, the best way to prevent or cure disease requires establishing a healthy energetic balance and harmony between the body's energy field and the forces of nature and the cosmos.

Traditional Chinese Medicine is divided into four branches of clinical healing: Acupuncture

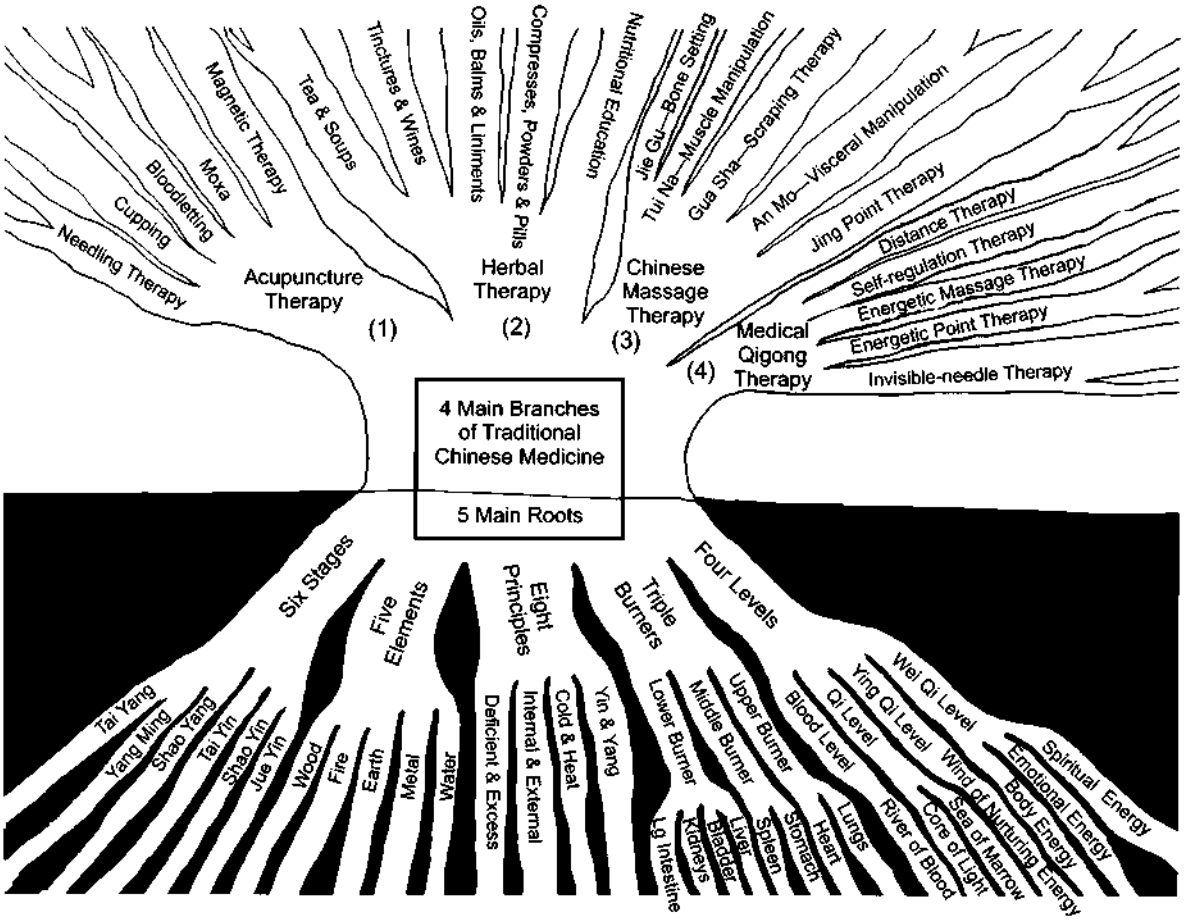

Figure 1.3. The Four Main Branches of Traditional Chinese Medicine

therapy, Herbal therapy, Chinese Massage therapy, and Medical Qigong therapy. All of the four main branches are built on the same foundation of energetic diagnosis known as the Five Main Roots of Traditional Chinese Medicine. The five main roots are used for internal organ diagnosis according to the Six Stages, Five Elements, Eight Principles, Triple Burners and Four Levels theories (Figure 1.3).

ACUPUNCTURE THERAPY

By inserting very thin metal needles into specific points, the acupuncturist manipulates the patient's energy (Qi) to achieve an overall physical balance. In an acute or emergency situation, a patient's symptoms are treated first, after which the focus is directed to rerouting Qi Deviations or removing the original cause of the symptoms (e.g., stagnations).

The energetic points are specific areas both on and in the body where Qi emerges from deep within the body's organs and tissues, or submerges to travel deep within the body. The Qi moves along specific pathways known as channels and collaterals. Collaterals are the smaller streams of Qi that branch off from the main ener-

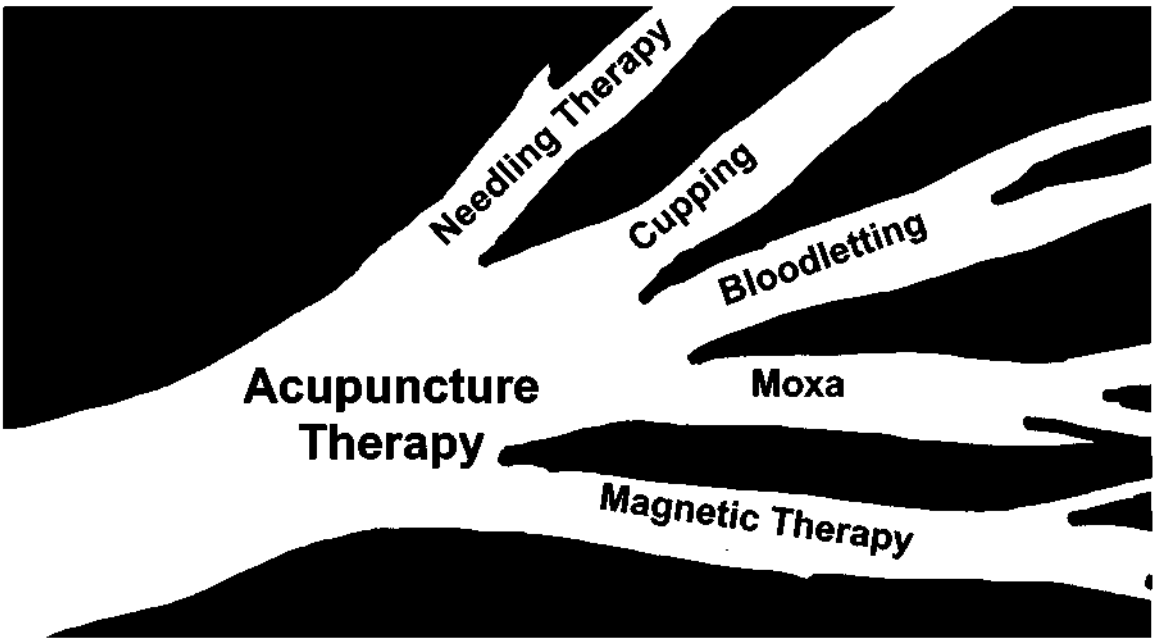

Figure 1.4. The Five Main Branches of Chinese Acupuncture Therapy

getic rivers (channels). Each Primary Channel takes its name from one of the six Yin or six Yang organs to which it corresponds. Each organ has two channels, one on each side of the body.

Often in Chinese medical diagrams and procedures, you will see abbreviations referring to specific energetic points. Traditional Chinese Medicine names the points based upon the channel on which the point lies and its distance along the channel. The first points on each side of the Gall Bladder Channels (GB), for example, are GB-1. Some channels contain over 60 points, each numbered sequentially from beginning to end. These points are also given descriptive names according to their location and energetic affect upon the body when treated. The GB-1 points, for example, are located next to the eyes, on the outer canthus, level with the pupils, and are called the Pupil's Seam.

Acupuncture therapy includes five major treatment techniques (Figure 1.4): needling, cupping, bloodletting, moxa burning, and magnet healing.

1. Needling uses acupuncture needles of various sizes that are inserted into channel points. These points are tiny areas where the Qi pools along the streams of an energy channel (Figure 1.5). The needles stimulate the nerves and energy flow to tonify or reduce Excess Qi.
2. Cupping uses wooden, clay, or glass cups that adhere to the patient's skin by suction (Figure 1.6). This suction drains, or removes, pathogenic Qi from the body's pores. This technique can also be used to tonify specific areas of the body. This modality of treatment has been successfully combined with bloodletting to treat acute sprains accompanied by Blood stagnation.
3. Bloodletting is done with instruments such as blood needles or seven- and five-star hammers to remove Toxic Qi, Blood stagnation, Heat, and other pathogenic factors (Figure 1.7). The hammer has five to seven sharp projections that pierce the skin and cause slight bleeding. The acupuncturist diagnoses and then monitors the patient's condition by the

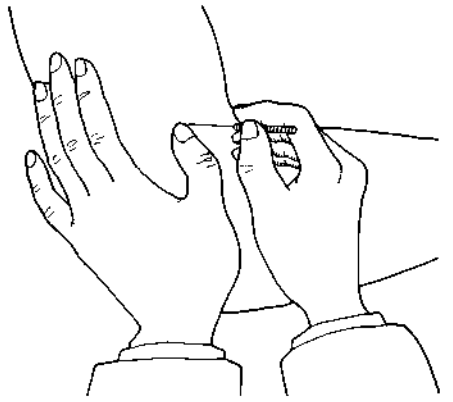

Figure 1.5. A doctor is inserting an acupuncture needle into the patient's Channel Point. Acupuncture needles of various sizes are used to stimulate nerve and energy flow for the tonification of Deficient Qi or the reduction of Excess Qi.

different shades of the patient's Blood. Trapped or diseased Blood is released until a healthy color is observed. This therapy is considered useful for treating disorders of the nervous system, physical trauma, and extremely serious febrile diseases.

4. Moxa Burning employs lighted herbal cones or sticks that are inserted on top of acupuncture needles (or held over specific channel points) to infuse heat and Qi into specific body areas for tonification (Figure 1.8). This technique is also used to expel Cold in order to disperse Blood stagnation.
5. Magnets use magnetic patches or strips that are attached to various channel points of the patient's body to stimulate a response in the electromagnetic field (Figure 1.9). Magnet therapy has been used since the Tang Dynasty (618–907 A.D.). The magnets are applied to specific points for a period of 3–5 days, removed for one day, then reapplied. Whether used for tonification or sedation, this therapy facilitates constant treatment of the channel point.

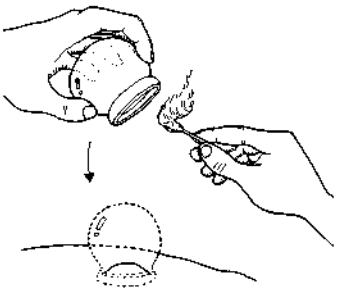

Figure 1.6. In Cupping, heated air is directed into wooden, clay, or glass cups, which are then placed on the patient's skin. The cooling air creates suction that drains, or removes, pathogenic Qi from the body's pores.

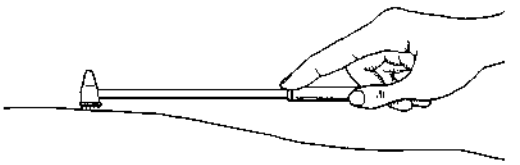

Figure 1.7. The doctor is lightly tapping with the Five-Star Hammer that has five sharp projections to pierce the skin and cause slight bleeding. The color of the patient's Blood provides the doctor with information about the patient's condition.

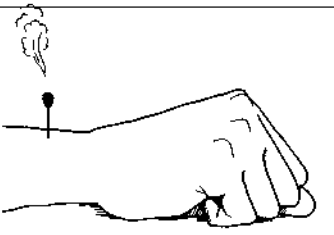

Figure 1.8. The doctor has inserted a needle with burning Moxa (herbal cones/sticks) on top of it. Burning moxa may also be held over specific channel points or placed directly on the skin.

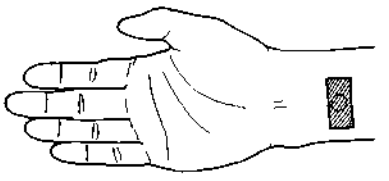

Figure 1.9. A Magnetic Patch is being worn on the Wrist. Magnets may be attached to various parts of the body or may be worn in shoes or wristbands.

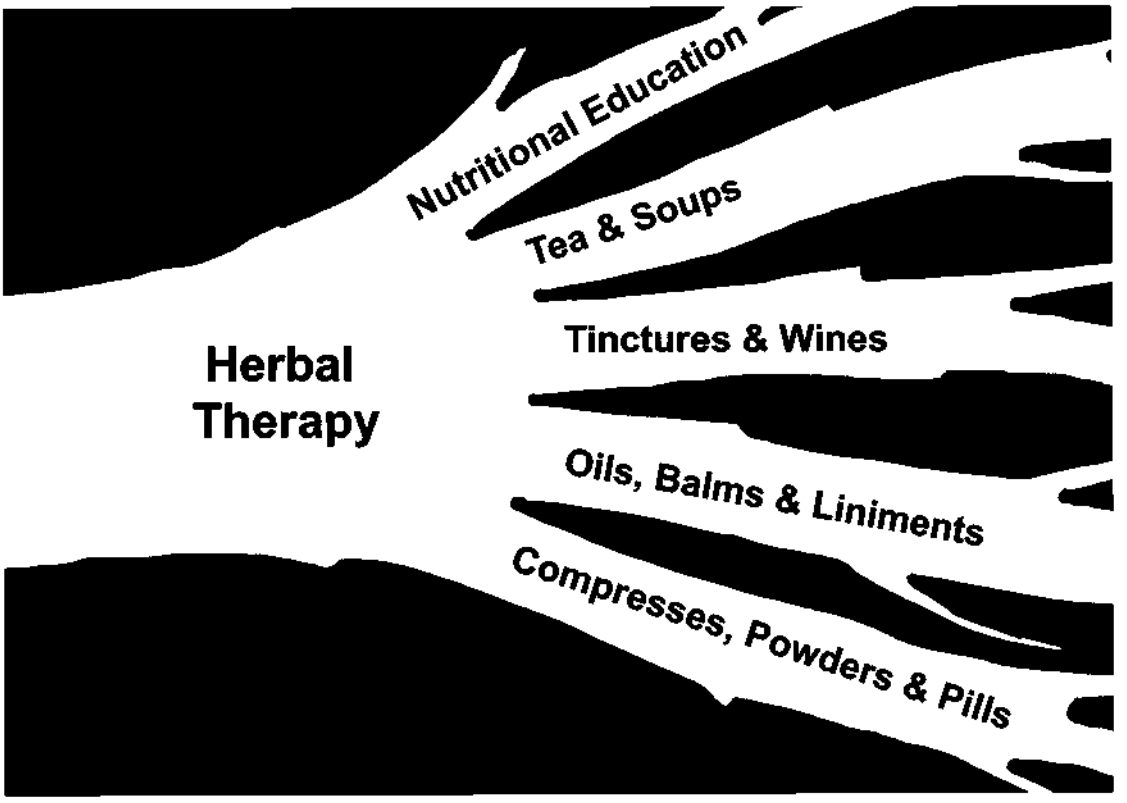

Figure 1.10. The Five Main Branches of Chinese Herbal Therapy

HERBAL THERAPY

Herbal formulas have been used successfully to treat a variety of illnesses for over 5000 years. Historically, herbal medicine has been the worldwide basis for pharmaceuticals used in most cultures, prior to modern times. Today, herbs provide the source for many of the pharmaceuticals used in contemporary Western medicine, especially for the treatment of viral and bacterial diseases, pain, tumors, chronic diseases, internal and external tissue regeneration, and many other medical problems.

Herbology is both a science and an art. An herbalist spends many years studying the herbs used to create herbal formulas. The herbalist must understand the effects of individual herbs, as well as their synergistic effects when combined.

Herbs are used for tonifying, purging, dispersing, warming, cooling, nourishing the Yin, nourishing the Yang, and clearing Heat, as well as moving Qi, Blood, Phlegm, and Fluids within the body. They cause the Qi in the body to either ascend or descend, affecting the upper or lower parts of the body.

Chinese medicine prescribes specific parts of plants (leaves, roots, bark, etc.) for particular medicinal purposes. Parts of trees, shrubs, herbs, vines, and flowers are selected for their specific properties (Hot, Cold, Warm, Cool) and taste (Sweet, Bitter, Pungent, Sour, and Salty). These properties either tonify or disperse Qi and Blood.

Chinese medical herbology not only includes the cultivation and gathering of seeds, fruits, flowers, leaves, barks, stems, and roots but also prescribes non-herbal components (such as minerals,

animal or insect parts) that are sometimes added to enhance the herbs' healing effect.

Chinese herbs cure energetically by moving Qi in the channels. Different herbs enter different channels and affect different internal organs. Herbs are extremely powerful. The herbalist uses herbs to tonify (strengthen) and move Qi and Blood as well as eliminate Heat from the patient's Blood. When tailored to an individual's constitution or combined into a formula for specific symptoms, herbs can greatly help the body; however, taking the improper herbal formula can have deleterious effects.

Chinese herbal therapy includes five major clinical applications (Figure 1.10): nutritional education (food and diet); teas and soups (tang); tinctures and wines (jin); oils, balms, and liniments (you and gao); and compresses, powders (san), and pills (wan).

1. Nutritional education is stressed to assist patients in choosing foods for the body's nourishment and optimum health, as well as for the treatment of disease. Foods have many similar properties to herbs. An old Chinese saying asks, "Are herbs food or food herbs?", thus stressing the importance of a good diet
2. Teas and Soups are water-based herbal formulas traditionally prepared from raw or processed herbal ingredients. These are traditionally ingested for the treatment of internal and external disorders of both acute and chronic natures.
3. Tinctures and Wines are both alcohol-based herbal formulas. Tinctures are a concentrated alcohol-based formulas prepared from raw herbs that are used similarly to teas and soups. Wines are traditionally applied externally to alleviate pain, or ingested as a tonic, depending on the specific formula and the disease being treated.
4. Oils, Balms, and Liniments are oil-based herbal formulas usually applied externally for the treatment of muscle, tendon, and ligament trauma, to alleviate pain, disperse Excess Qi, or to draw Qi into specific areas for tonification.
5. Compresses, Powders, and Pills consist of herbs that have been pulverized into a paste, powder, or poultice and are then applied externally for the treatment of acute or chronic injuries. They can also be ingested for internal organ tonification and the rebalancing of the body's energy system. Pills are herbs specifically prepared from traditional formulas, rolled into little balls, and orally ingested for the treatment of Internal disorders.

CHINESE MASSAGE THERAPY

Chinese Massage Therapy is a generic term used for all tissue manipulation techniques currently used in China. This particular branch of Traditional Chinese Medicine consists of five popular systems that include manipulation of not only external skin, muscles, tendons, joints, nerves, and inner fascia but also the internal organs and organ systems.

This ancient therapy is used as a preventative treatment as well as a healing modality. By applying specific methods of tissue manipulations, obstructions in the channel's pathways can be removed, promoting and increasing both Qi and Blood circulation.

This therapy focuses on improving the structural alignment of the body and on healing soft-tissue injuries. It also corrects any deviant functions of the internal organs, nerves, and joints. Chinese bodywork and tissue therapy are the foundational source for modern Swedish massage, myofascial trigger point therapy, reflexology, and therapeutic neuromuscular therapy.

Chinese massage therapy is divided into five different schools of instruction: Jie Gu, Tui Na, Gua Sha, An Mo, and Jing Point therapy (Figure 1.11). Jie Gu, Tui Na, and Gua Sha employ external tissue manipulations. These three external manipulations are used to treat the bones, muscles, ligaments, and tendons, and also to treat fevers. An Mo and Jing Point therapy utilize soft-tissue manipulation. These treatment modalities are similar to those used in chiropractic, osteopathy, Western physical therapy, and massage therapy.

1. Jie Gu Therapy is used for bone setting and

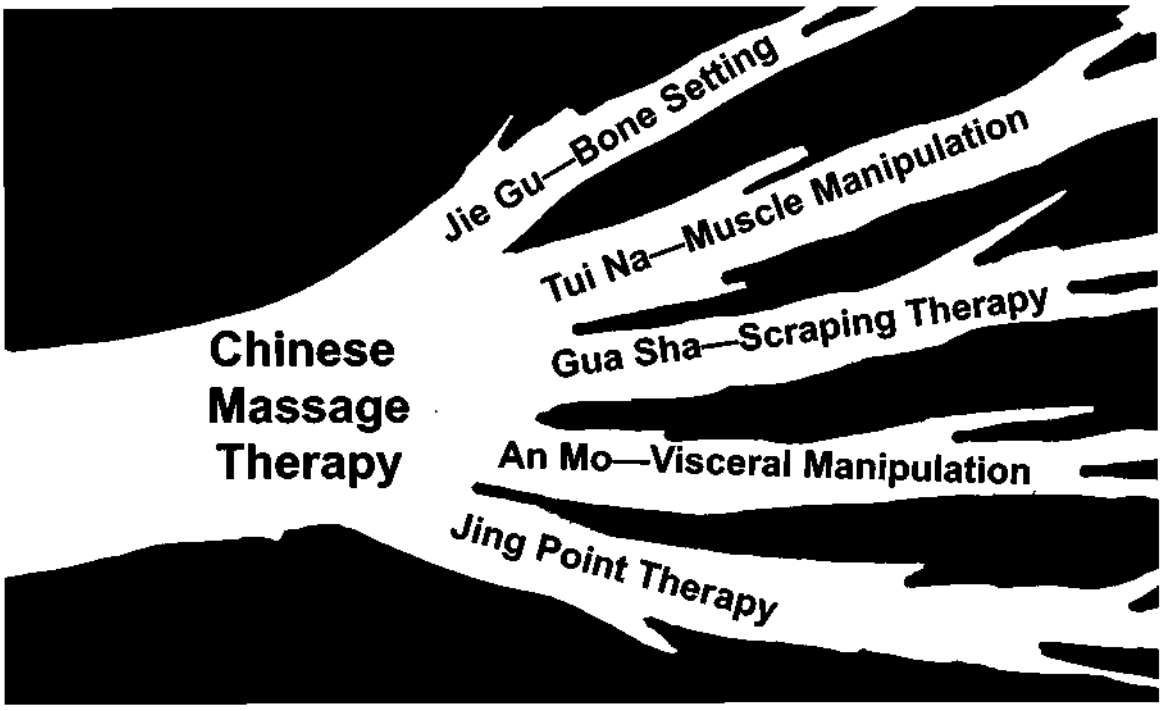

Figure 1.11. The Five Main Branches of Chinese Massage

to adjust the patient's body alignment (Figure 1.12). The literal translation for Jie Gu is "knotted bone," which describes the art of manipulating the bones and ligaments to unravel the trapped junctions of Blood and Qi channels in the patient's joints.

2. Tui Na Therapy focuses on external tissue manipulation and adjustment of the muscles and tendons to adjust abnormal Qi circulation within the body's muscular system (Figure 1.13). The translation for Tui Na is to "push and grasp." It was developed primarily for correcting the misalignment of the body's bones and muscles due to traumatic physical injuries. Reflexology is historically rooted in the use of Tui Na therapy in Chinese pediatric care.
3. Gua Sha Therapy is used to regulate febrile conditions, such as flu, cholera and malaria, and to treat musculoskeletal conditions. The translation for Gua is "to scrape or scratch" and Sha is defined as "cholera," or sand-like maculae (referring to the red discoloration that is raised on the skin by the application of scraping). This therapy focuses on external surface tissue scraping, usually around the neck and thorax areas (Figure 1.14). It is commonly used for promoting Qi and Blood circulation, removing toxins, clearing Heat, cooling the Blood, removing stagnation, and dissolving masses. A jade scraper (coin, bowl, or spoon) is used for purifying the Qi and transforming the Shen (Spirit). A water buffalo horn is commonly used for pulling Heat and toxins from the patient's body (occasionally ceramic is used, but never glass or plastic).

The two internal manipulations are used to treat the organs and nerves.

4. An Mo Therapy is used for internal organ

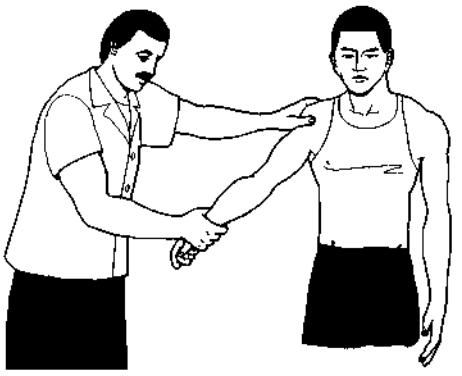

Figure 1.12. Jie Gu Therapy is used to set the bones and ligaments in order to unravel the trapped junctions of Blood and Qi channels at the patient's joints.

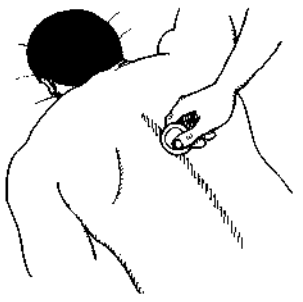

Figure 1.14. Gua Sha Therapy is commonly used for clearing Heat, cooling the Blood, removing stagnation, and dissolving masses.

regulation. An Mo focuses primarily on Qi extension and soft-tissue and internal organ manipulation (Figure 1.15). Although the literal translation means to "press and rub," this therapy focuses primarily on internal visceral regulation, concentrating directly on the treatment of specific Internal diseases.

5. Jing Point Therapy is employed for channel and internal organ regulation. Jing point therapy uses pressing, pinching, clapping, and tapping techniques on specific energetic points and energetic channels. These techniques are employed to promote Qi and Blood circulation, balance the body's Yin and Yang energy, tonify weak organs, dredge the channels, and expel pathogenic factors (Figure 1.16).

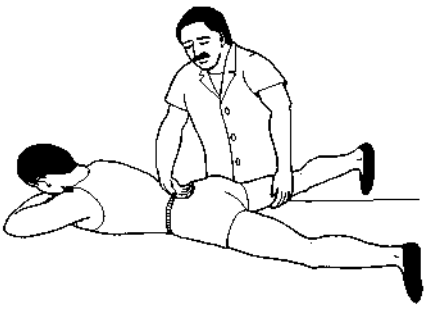

Figure 1.13. Tui Na Therapy is used to adjust the muscles and focuses on external tissue manipulation and adjustment of the muscles and tendons in order to correct abnormal Qi circulation within the body's muscular system.

Figure 1.15. An Mo Therapy allows organ manipulation for internal visceral regulation and concentrates directly on treating specific Internal diseases.

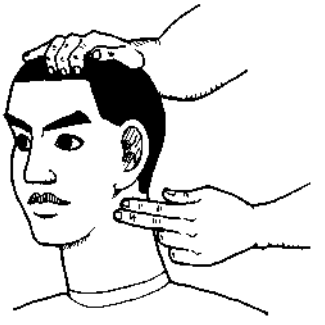

Figure 1.16. Jing Point Therapy is used to promote Qi and Blood circulation, balance the body's Yin and Yang energy, tonify weak organs, dredge the channels, and expel pathogenic factors.

Figure 1.17. The Five Main Branches of Chinese Medical Qigong Therapy

MEDICAL QIGONG THERAPY

The objective for healing disease in Medical Qigong training is threefold:

- First, eliminate Internal pathogenic factors (the accumulation of Excessive emotions such as anger, grief, worry, fear, etc.) as well as External pathogenic factors (the invasion of Cold, Hot, Damp, etc., from the environment).
- Second, increase or decrease the patient's Qi as needed to counteract the Deficient or Excess condition within the internal organs and channels.
- Third, regulate and balance the patient's Yin and Yang energy to bring it back into harmony.

This unique therapy consists of regulating the body's three external Wei Qi fields (physical, mental/emotional and spiritual), and the four Internal fields of life-force energy (Ying Qi, Sea of Blood, Sea of Marrow, and the Taiji Pole). Some of the most common diseases treated in Medical Qigong clinics are: diabetes, arthritis, high blood pressure, breast and ovarian cysts and tumors, migraine headaches, fibromyalgia, insomnia, acute abdominal pain, irritable bowel syndrome, deep tissue obstruction, muscle atrophy, brain tumors, stroke, coma retrieval, and certain types of cancer. The medical treatment focuses on relieving pain, detoxifying the body of toxic emotions (e.g., excessive anger, fear, worry, etc.), correcting internal organ dysfunctions, and balancing Excess or Deficient Qi and Blood conditions.

Medical Qigong therapy uses five major clinical modalities (Figure 1.17): Distance therapy, Self-

Regulation therapy, Qigong Massage therapy, Energetic Point therapy, and Invisible Needle therapy.

1. Distance Therapy (also called Qi Emission) requires the Qigong doctor to manipulate a patient's Qi by focusing on the energetic properties of the patients' channels, collaterals, and points, as well as internal organs, from a distance of several inches, several feet, or even several miles away (Figure 1.18).
2. Self-Regulation Therapy (also called Qigong Prescriptions and Patient Homework) are Qigong exercises (postures, movements, sound vibrations, visualizations, etc.) given to patients by a doctor (Figure 1.19). Patients can use these Qigong techniques to regulate their own health, using various lying, sitting, moving, and standing postures. The patients may also use their own spiritual belief system as a healing tool.
3. Qigong Massage Therapy, a soft-tissue regulation technique, differs from Tui Na or An Mo (Chinese External Massage Therapy), in that the doctor's hand skims the patient's body as lightly as a feather, never exceeding the pressure one would place on an eyeball (Figure 1.20). The light skimming action is used to dredge the patients' external channel Qi, causing energy to be released from the internal channels themselves, which serve as pathways for Qi transference.
4. Energetic Point Therapy is used by the doctor to extend Qi into specific internal and external areas of the patient's body to lead and direct the Qi. This type of therapy requires the doctor and the patient to focus their attention onto a specific energetic point (Figure 1.21). This therapy demonstrates the power of the mind as an active tool in healing, and is used for purgation, tonification, and regulation.
5. Invisible Needle Therapy involves the visualization of imaginary needles of light being inserted into specific points on the patient's body. The needles of light are used to stimulate and direct the patient's Qi (Figure 1.22).

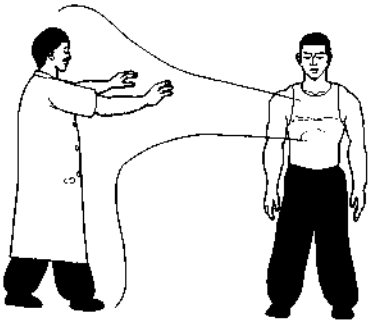

Figure 1.18. In Distance Therapy, the Qigong doctor manipulates a patient's Qi by focusing on the energetic properties of the patient's external channels, collaterals, and points from a distance of several inches, several feet, or even several miles.

Figure 1.19. In Self-Regulation Therapy, the patients are required to self-regulate by performing Qi Qigong "prescriptions" or "homework" (postures, movements, chants, visualizations, etc.). Here the patient regulates his own *Liver Qi*.

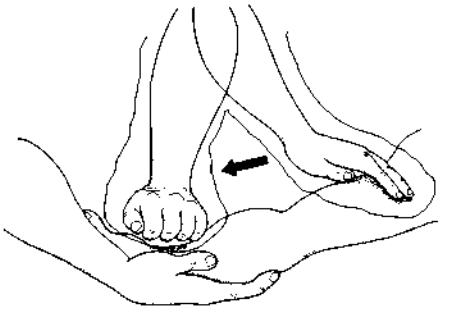

Figure 1.20. In Qigong Massage Therapy, the doctor softly dredges the patient's external channels in order to release energy from the internal channels themselves, which serve as pathways for Qi transference.

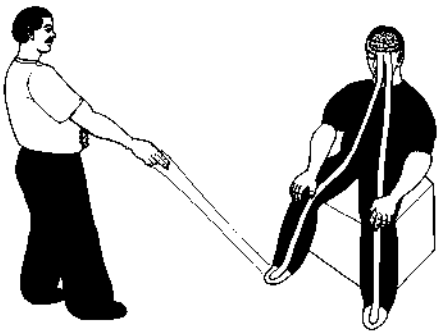

Figure 1.21. In Energetic Point Therapy, the doctor extends energy into the patient's body as both the doctor and the patient focus their attention on a specific channel point, in this case the Kd-1 point.

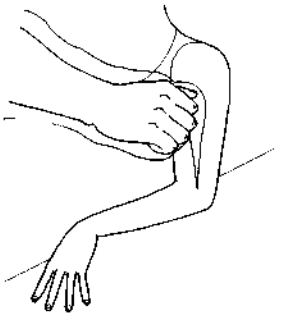

Figure 1.22. In Invisible Needle Therapy, the doctor visualizes inserting energetic acupuncture needles into the patient's channel points in order to stimulate the patient's Qi.

Chapter 2
Energetic Formation of the Human Body

In 1993 when I began my internship at the Xi Yuan Hospital in Beijing, China, I became aware that most Qigong doctors had a limited understanding of basic anatomy and physiology as we teach it in the West. When I asked why more attention was not paid to the subject, I was told, "The perspective and priority we place on gross physical anatomy and physiology is quite different from yours -- Westerners only study the dead -- we study life, the living pools, rivers, and currents of life-force energy that can only be found in the living body."

Eastern medicine believes that when the body dies, the substance, or energy, that gave the body life returns to its original source (Heaven and Earth) and all that remains of the individual is a mass of lifeless tissue. They believe that the tangible and the energetic exist in a twofold, cohesive relationship. A Qigong doctor must understand this concept of energy in order to comprehend and prescribe appropriate Medical Qigong therapy for the patient.

The concept of the energetic formation of the human body is new to Western thought with its primary focus on the physically tangible. The philosophical foundation of Traditional Chinese Medicine, on the other hand, includes studying the whole human being in all of his or her aspects, physical, mental, emotional, energetic, and spiritual. The conception results not only in the tangible physical form of a new human being but also in various contributing energies and energetic fields. Medical Qigong studies these energies, as well as the interplay between the Heavenly and Earthly influences.

Energetic Embryological Development

The study of the embryological development of the body's inner fascia and connective tissues explains many of the traditional Chinese medical ideas about energy, health, and disease. The cells, tissues, and organs of the human body interrelate as a result of the "energetic patterning" that occurs at conception.

Heaven (which the ancient Chinese considered a state of subtle and non-material energies and beings) and Earth both have energetic fields that influence life. If we consider Heaven Qi (the universal energy related to the sun, moon, and stars) to be electro-positive and Earth Qi (the environmental energy related to the earth, water and wind) to be electro-negative, we can begin to understand the duality of the energetic fields and their pull on the human body.

Think of the body as being suspended between two enormous fields of energy (Figure 2.1): the sun extends its energetic field down, and the Earth's small "sun," i.e. its core, extends its energetic field upwards through the Earth's crust. Man is, therefore, suspended between the electrically positive energy field of Heaven and the electri-

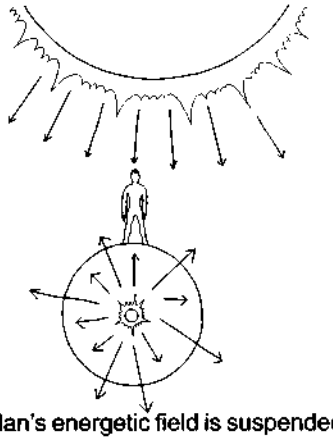

Figure 2.1. Man's energetic field is suspended between the two energy fields of Heaven and Earth.

cally negative energy field of Earth and is affected by both celestial and environmental phenomena.

ENERGY, MATTER, AND SPIRITUAL INTERACTIONS

The *Yellow Emperor's Classic of Internal Medicine* states that the woman's physiology is dominated by Blood, which serves as the foundation of her menstrual cycle, fertility, conception, pregnancy, and childbirth. A man's physiology is dominated by Qi, which serves as the basis of his physical interactions.

At conception, a myriad of energetic interactions begin. The mother, father, Heaven, and Earth all contribute energetically to conception. These four energies condense upon impact and form the nucleus of the energetic cellular patterning of the new life (Figure 2.2). Every part of the resulting human body is affected by this energetic patterning.

An old Chinese saying in Medical Qigong states that, "When people are born, Heaven gives them Jing (Essence) and Shen (Spirit) -- which align to form the mind -- and Earth gives them bones and shape, which unite to form the body. Joined together, these sources of energy cause human beings to develop. When people die, their Essence and Spirit return to Heaven, and their bones and shape go back to Earth."

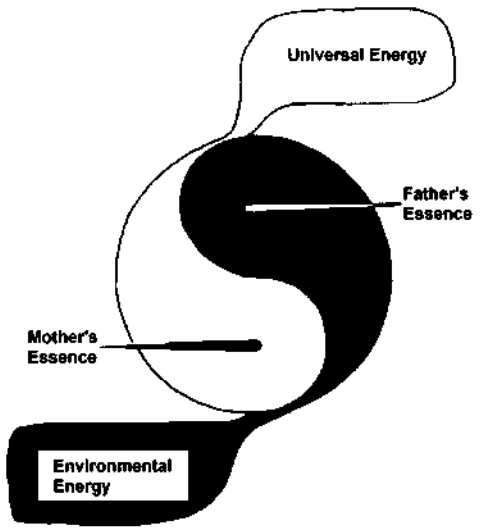

Figure 2.2. The blending of Heaven (universal energy) and Earth (environmental energy) as well as father and mother energies creates a fusion of Yin and Yang energies within the body's tissues and cells during creation. These energies are responsible, on a psychophysical level, for transferring talents and traits from generation to generation.

Pairs of channels from the mother's internal organs carry Qi that creates and nourishes the baby at each stage of development. As the baby develops, sustained through the umbilical cord, the child's navel, Kidneys, and lower abdominal area become the collection points for Prenatal Qi (energy stored within the baby's body before it is born).

Every life begins with inherent strengths and weaknesses. It is believed that when conception occurs, if the mother achieves orgasm, the child's inherent energy will become very strong. However, if the mother does not achieve orgasm during conception, the results will be a normal or weak energetic constitution. Prenatal care is mandatory for the healthy formation of the embryo. Before cell division, the DNA mass must be duplicated exactly in order to transfer normal genetic characteristics to the next generation. Although heredity plays a large part in the transference of both parents' genetic history, a weakness in the mother's channels can result in congenital problems, or toxins, that the fetus can acquire during one of the corresponding stages of development.

UNDERSTANDING FETAL TOXINS

The External invasions of pathogenic toxins (known as fetal toxins) can penetrate the zygote with latent Heat that can cause diseases during early childhood development. It is, therefore, important for both parents, especially the mother, to take responsibility for being strong and healthy at the time of conception and for the duration of the pregnancy. Toxins can be transferred into the embryo in utero in one of two ways:

- First, from either the mother or father at the moment of conception. Toxins transferred from the parents can create an inherited toxicity due to a retention of Hot Evil stored from within either of the parents' Essence and Blood; or
- Second, from Internal Heat generated by the

mother during pregnancy due to improper diet or life-style.

During pregnancy, a fetus is aware of light and sound and of the mother's reaction to the surrounding influences of her environmental energy fields. The fetus is strongly influenced by its mother's physical activities, as well as her mental, emotional, and spiritual states.

Regulating the mother's behavior to improve her child's physical, emotional, and mental health is called "fetal education" in Traditional Chinese Medicine, and is important in the development of the child's Prenatal Essence, Energy, and Spirit. This viewpoint is based on the fact that the mother's Heart and uterus are connected via the mother's internal channels, allowing Qi and Blood to flow into the uterus. Anything that influences the mother's mind, emotions, and spirit affect her Heart, which in turn, affect the fetus via the internal channels.

DEVELOPMENTAL SEQUENCE

The following description of the body's developmental sequence is but one of many theories used in order to explain Chinese energetic embryology. The ancient Chinese did not have a conception of the body's cells and cellular division; however, modern theories have postulated that the channels were formed at the earliest stages of cell division, creating an energy matrix for the developing fetus. This particular theory is being taught at the Hai Dian Medical Qigong College in Beijing, China.

Three important energies (Figure 2.3) combine in the developing fetus: Jing (Essence), Qi (Energy), and Shen (Spirit). Jing is the body's foundational substance, responsible for nourishing the tissues. Qi emerges out of Jing circulating through the tissues and promotes the body's metabolism. Shen governs the body. (see Chapter 11, "The Three Treasures of Man," for more on Jing, Qi, and Shen.)

Both parents contribute energetically to the baby's conception (Figure 2.4). The father's sperm and the mother's egg consist of Jing (Essence), Qi (Energy), and Shen (Spirit). This combination of Jing, Qi, and Shen is referred to collectively as fa-

Prenatal Energies—The Three Treasures		
Substance	**Physical Function**	**Energetic Prenatal Function**
Shen (Spirit)	governs the body	the Original Spirit
Qi (Energy)	promotes metabolism	body's Energy extending into Infinite Space (also called Wuji, or the Void)
Jing (Essence)	nourishes the tissues	body's innate true Essence, the foundational substance

Figure 2.3 Qi is the medium between matter (Jing) and Spirit (Shen) and is responsible for the embryo's transformational processes.

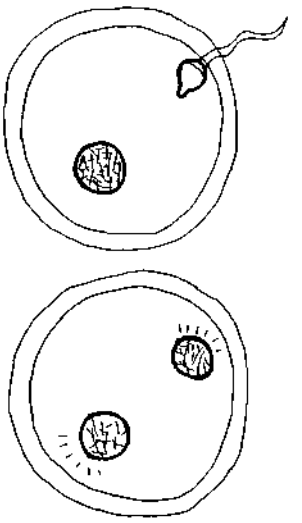

Figure 2.4. The human body is composed primarily of water. The Essence of man (sperm) and woman (egg) unite in the uterine sea to form the fetus. The ova is polarized at the entry point of the sperm, creating the original polar axis (the *Taiji Pole*) that determines the complex pattern of cellular division that occurs along the polar axis throughout development.

ther Qi and mother Qi. The combination of father Qi and mother Qi is known as Yuan Qi or Original Qi.

The quality and quantity of Original Qi that the baby receives at birth depends on three main factors:

- First, the purity and potency of both parents' genetic plasma (sperm and egg);
- Second, the condition of both parents' health and vitality and the state of their physical, mental, emotional and spiritual relationship at the time of conception; and
- Third, the spiritual factors surrounding the conception (i.e., karma that is brought into this life by the incoming spirit/soul).

As the sperm (containing the father's Qi) fertilizes the egg (containing the mother's Qi), Heaven (universal) Qi and Earth (environmental) Qi blend together within the zygote. The swirling and blending of these four energies form energetic pools (which will later evolve into organs), rivers (which later evolve into channels), and streams (which later evolve into collaterals).

When the sperm enters the ovum, it produces a polar axis that creates an energetic vortex. This vortex not only forms the central Taiji Pole, but also draws Qi from Heaven and Earth and the Eternal Soul into the fetus's body. This polarization also determines a ventral and dorsal surface, which become the embryo's Conception and Governing Vessels, respectively, at the first cell division (Figure 2.5). The Governing Vessel controls the cell division that eventually forms the back of the body, while the Conception Vessel controls the cell division of the body's front. This first cell division also establishes a right and left side. The Heel Vessels control the balance of Yin and Yang energy development in the two sides of the body.

The Belt Vessel and Thrusting Vessels form at the time of the second cell division. The four vessels formed at this point (Governing Vessel, Conception Vessel, Thrusting Vessels, and Belt Vessel) are interlinked for the production, circulation, and regulation of the body's Jing-Essence. The body's entire energy system becomes established and maintained within these four vessels when cell division occurs (Figure 2.6).

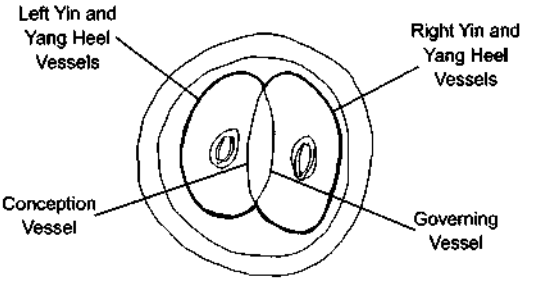

Figure 2.5. The electrical polarity and field of energy in the polar axis is related to the Original or Yuan Qi from which the Conception and Governing Vessels form the seas of Yin and Yang energy during the first cellular division. The Yin and Yang Heel Vessels are also established, forming the left and right sides. The exterior of the egg is determined by the Yang Linking Vessels. The interior of the egg by the Yin Linking Vessels.

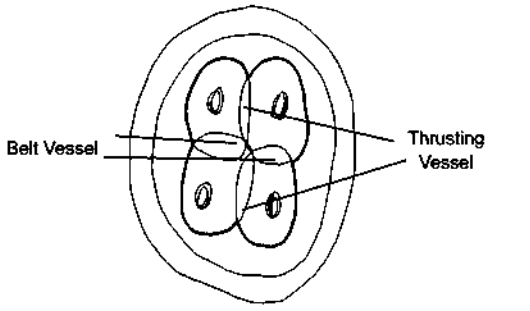

Figure 2.6. The second cellular division is caused by the development of the Belt Vessel and the Thrusting Vessel. The Eight Extraordinary Vessels have now formed.

While the embryo is forming, both the Yang and Yin Linking Vessels are respectively responsible for the exterior and interior development of the embryo (see Chapter 3 for more on Yang and Yin energy). Each of the Eight Extraordinary Vessels has a specific role in the development of the embryo.

1. The Governing Vessel (Yang) controls development of the body's back.
2. The Conception Vessel (Yin) controls development of the body's front.
3. The Thrusting Vessels carry energy through the center of the body and controls the body's center core.

4. The Yang Heel Vessels control the development of the body's right and left Yang energy.
5. The Yin Heel Vessels control the development of the body's right and left Yin energy.
6. The Yang Linking Vessels control the development of the exterior of the body (and correlates to Heaven energy).
7. The Yin Linking Vessels control the development of the interior of the body (and correlates to Earth energy).
8. The Belt Vessel binds all the channels together.

These eight vessels—Governing, Conception, Thrusting, Yang Heel, Yin Heel, Yang Linking, Yin Linking, and Belt—are also known as the Eight Extraordinary Vessels or Eight Prenatal Vessels.

The Eight Extraordinary Vessels form a vortex of energy at the center of the embryo's body—from the area between what will become the Kidneys. The Taiji Pole and Thrusting Vessels are at the center of this vortex and will form the Sea of Five Yin and Six Yang Organs, the Sea of Twelve Primary Channels, and the Sea of Blood (see Chapter 13). From the Taiji Pole and Thrusting Vessels, the body's Qi and Blood are distributed at the energetic level through small channels, or rivers of energy. This energetic vortex creates the energy for the growth of the embryo's physical form.

After the initial cell division is complete, the embryo's ten Yang channels and ten Yin channels begin the development and formation of the embryo's tissues and organs. These twenty channels are divided into two separate groups of energetic rivers known as the Eight Extraordinary Vessels and Twelve Primary Channels. As the embryo develops into a fetus and continues to grow, the twenty channels also continue to develop.

During the formation of the embryo, nine Yang channels begin to flow out of the Governing Vessel (Sea of Yang Qi) and form the nine Yang rivers known as: the Bladder Channels, Gall Bladder Channels, Stomach Channels, Small Intestine Channels, Triple Burner Channels, Large Intestine Channels, Yang Heel Vessels, Yang Linking Vessels, and Belt Vessel.

Consecutively, the nine Yin channels begin to flow out of the Conception Vessel (Sea of Yin Qi) and form the nine Yin rivers known as: the Kidney Channels, Liver Channels, Spleen Channels, Heart Channels, Pericardium Channels, Lung Channels, Yin Heel Vessels, Yin Linking Vessels, and Thrusting Vessels (see Chapter 8).

THE TEN LUNAR MONTHS OF CREATION

The following description of the sequence of embryological development was established by the late Chinese Medical Qigong expert Dr. Chao Yuan Fang during the Sui Dynasty, around 610 A.D. The months that Dr. Chao refers to are the ten lunar

Lunar Month	Mother's Channels	Channel's Activity	Energetic Activity
Month 1	Liver Channels	stop menses, begin embryonic growth	energies combine at conception, channels develop
Month 2	Gall Bladder Channels	saturate embryo with Jing	embryonic Qi transforms into amniotic fluid
Month 3	Pericardium Channels	mother's Qi and Body Fluids purify and cleanse the fetal Shen	Hun and Po establish in the fetus's internal organs
Month 4	Triple Burner Channels	the Yin organs develop	Water Jing accepted into fetus's body
Month 5	Spleen Channels	the Five Agents enter the Five Orbs (Yin organs)	Fire Jing accepted into fetus's body
Month 6	Stomach Channels	Six Pitches established within the Six Storage Areas	Metal Jing accepted into fetus's body
Month 7	Lung Channels	Seven Essential Stars open orifices to the light from Heaven and Earth	Wood Jing accepted into fetus's body
Month 8	Large Intestine Channels	Heart is harmonized and breath is quieted	Earth Jing accepted into fetus's body
Month 9	Kidney Channels	Kidney Channel controls the energetic intake from the umbilicus	energetic boundaries completed
Month 10	Bladder Channels	spatial cavities surrounding major organs are completed	Heaven & Earth Qi settle into baby's Lower Dantian and birth begins

Figure 2.7. Prenatal Energy Development

months. These months compose the 40 weeks of a normal pregnancy (Figure 2.7).

MONTH ONE

The first lunar month of pregnancy is traditionally called the Beginning of Form. This stage covers conception and early cell division.

At conception, the mother's Liver Channels stop her menses and begin to nourish the growth of her embryo (Figure 2.8). During pregnancy, the mother's Blood is transformed into Jing-Essence, that nourishes the mother's body as well as the embryo's. The mother's Liver Channels cause Essence and Blood to coagulate in her womb. This Blood coagulation continues after the initial cellular division.

At this stage the mother's Shen (Spirit) becomes part of a threefold activity:

- First, the mother's Shen projects through the umbilical cord like a light reflecting off a prism, sustaining and energizing the production of Jing (see Chapter 13), Qi, and Blood for the embryo (Figure 2.9).
- Second, the mother's Shen influences the embryo's Qi and Blood, and the embryo's Shen (Spirit) is stimulated, bringing it into active being (see Chapter 12).
- Third, the embryo's Original Jing combines with the embryo's Original Qi to create the embryo's Original Shen (Prenatal Spirit), which appears as multicolored light and contains the inherited knowledge of the fetus's ancestors, including talents, skills, and natu-

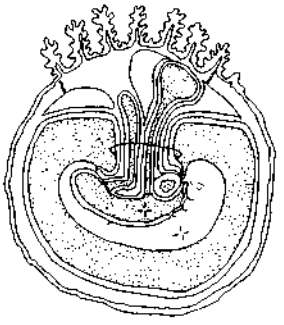

Figure 2.9. Sustained through the umbilical cord, the embryo absorbs the mother's Blood, Essence, Energy, and Spirit.

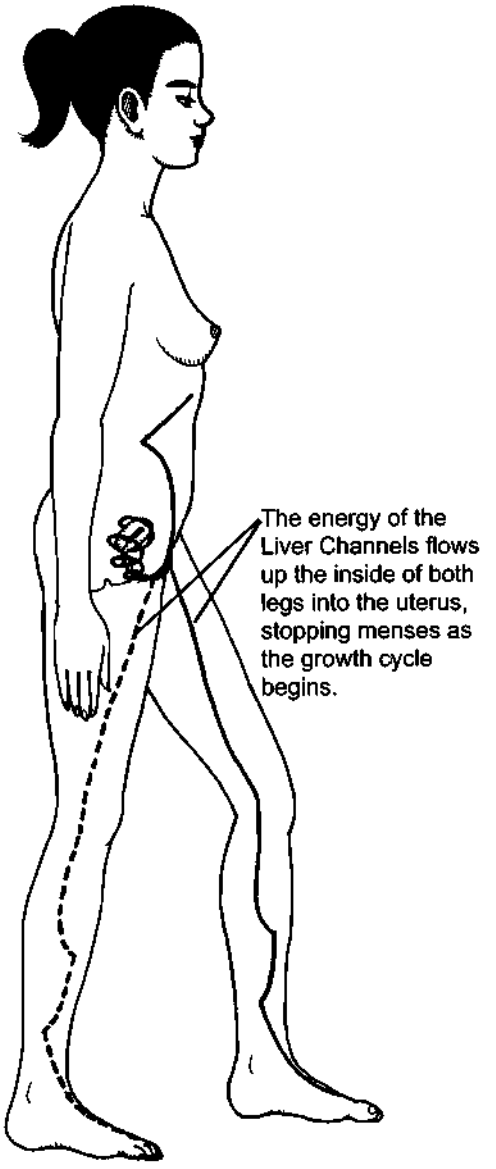

Figure 2.8. The mother's and father's Essence (Jing), Energy (Qi), and Spirit (Shen) blend with the Heaven and Earth energies during the fusion of the sperm and egg. During the first lunar month, the mother's Liver Channels stop her menses and begin the embryonic growth cycle. After the initial cell division, the ten Yin and ten Yang Channels develop within the embryo.

ral abilities. This knowledge is stored deep within the fetus's cells, tissues, and consciousness.

MONTH TWO

The second lunar month of pregnancy is traditionally called the Beginning to Gel stage. During this period, the responsibility of the mother's Gall Bladder Channels is to create the environment for the development of the mesenteric membrane sac (Figure 2.10). The Gall Bladder Channels will also saturate the embryo, uterus, and placenta with Jing, causing the embryonic Qi to become denser, until it transforms into a thick liquid (amniotic fluid). The embryonic fluid will regulate the embryo's Body Fluids. At this stage, the embryo begins to take shape inside the uterine lining (Figure 2.11). The Lungs, Liver, Kidneys and major blood vessels are forming.

With the formation of the major blood vessels, the Yin and Yang energies begin to occupy the embryo's channels. As the Yin and Yang energies actively balance themselves:

- Energy that will later coalesce into Lung Qi moves to the upper part of the body;
- Original Qi (Yuan) of the Kidneys begins to collect deep in the center of the body;
- Earth Qi (the energy absorbed by the embryo from the mother's exposure to the outside environment) begins to collect in the lower front and upper back areas of the embryo's body.

All of these energies seek their own location

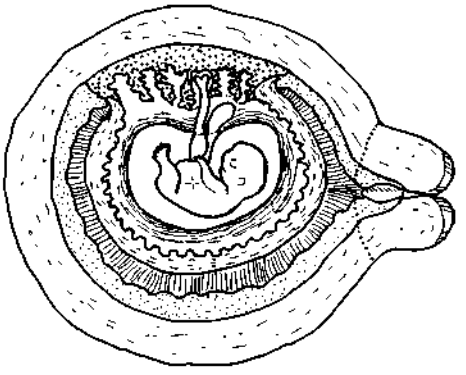

Figure 2.11. During the second month, the embryo begins to take shape as the energetic boundaries begin to form.

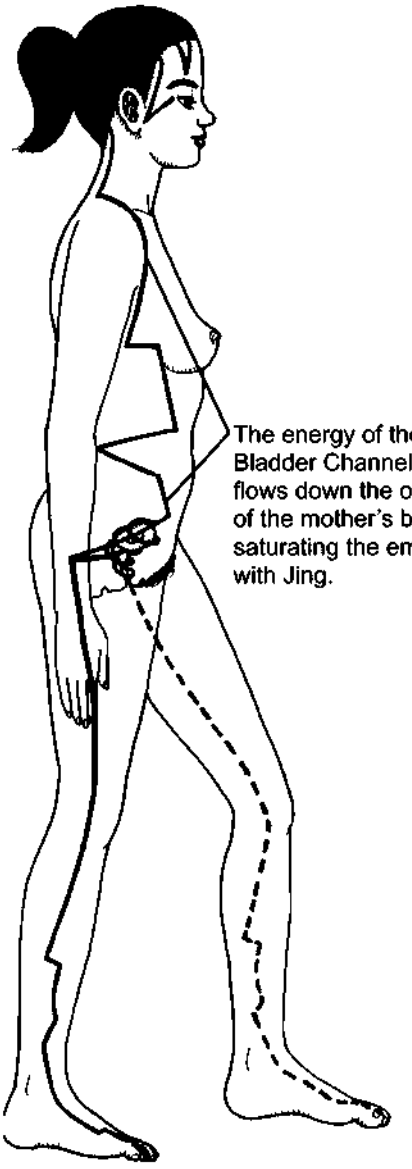

Figure 2.10. The mother's Gall Bladder Channels saturate the embryo with Jing during the second lunar month, causing the embryonic Qi to transform into amniotic fluid. The embryo begins to take shape as the energetic boundaries, pools, spatial cavities, and energetic channels and collaterals create internal and external form.

within the embryo's developing body, creating their own pools of Qi with their own discrete energetic boundaries. These boundaries will later form the spatial cavities that surround the major organs. The areas where the energetic pools settle and begin to create a balance within themselves, will be called the organ's place of origin. This flux and movement creates tiny energy currents, eddies, and whirlpools that flow within the body. As the energy shifts, seeking balance, the larger pools of energy begin to form the major organs. This process continues, creating the brain, bones, and skin.

Once the energetic pools and rivers have formed, all of the currents and eddies evolve to form the energetic channels and collaterals, through which energy will flow continuously. These energetic currents will move in accordance with the mother's energetic respiratory patterns and will later (after birth) follow the rhythmic patterns of the child's respiration. As the energy currents continue to spiral within the channels, energetic points are established, following the body's energetic blueprint. Some of these areas spiral outward to form energetic exit points, while others spiral inward to form entry points.

MONTH THREE

The third lunar month of pregnancy is traditionally called the Beginning of the Pregnant uterus. During this period, the embryo becomes a fetus and begins micro-movement. Its heartbeat can now be detected.

The mother's Pericardium Channels control the presence and amount of Jing and Shen in the fetus's vessels, channels, and collaterals (Figure 2.12). The Jing and Shen that flow from the mother are ultimately rooted (firmly established) in the energy of her Blood. The combination of the mother's Qi and Body Fluids purifies and cleanses the Shen of the fetus, which was formed at conception. This purifying action transforms into Heat, causing the Yang energy to arouse the Hun-Three Ethereal Souls (the energy of the fetus's spirit), into life. The Five Agents, energies that stem from the Three Ethereal Souls, are currently in a state of awakening and will later reside in the organs.

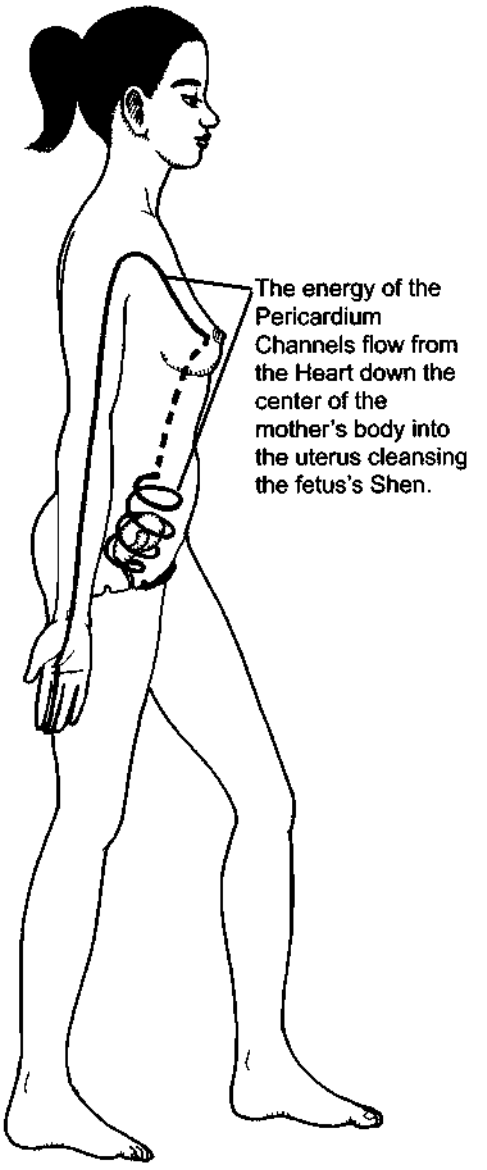

Figure 2.12. The mother's Pericardium Channels control the third lunar month of creation. The mother's Qi and body fluids purify and cleanse the fetus's Shen (Spirit). The Hun from Heaven and the Po from Earth are established within the fetus's internal organs.

The Five Agents are energies that are linked to a person's moral qualities and can be categorized as the five virtues of the Five Yin Organs. The Five Agents are also categorized into Five Elements. The psycho-emotional components of the Prenatal Five Agents and Postnatal Five Emotions are both stored within the body's Five Yin Organs, and are expressed as the child grows into adulthood (Figure 2.13). When one of the internal organs is stimulated, a Yin or Yang psycho-emotional reaction is created. Psycho-emotional energetic interactions are feeling manifestations expressed through either the positive moral qualities of the congenital Five Agents (Yang - kindness, order, trust, integrity, and wisdom) or the negative developed emotional experiences of the Acquired Five Emotions (Yin - anger, joy, worry, grief, and fear).

The Five Agents are connected to the Wu Jing Shen-Five Essence Spirits (Hun, Shen, Yi, Po, and Zhi), and stored within the energetic elemental nature of the body's Essence (Jing) of Wood, Fire, Earth, Metal, and Water. The Five Elemental Energies however, encompass not only the body, but all of the myriad phenomena of the body and nature, combining and recombining in infinite ways to produce manifested existence.

1. The Wood Agent (the Virtue of Kindness) represents benevolence and compassion. This agent is connected to the Hun-Three Ethereal Souls, and stored in the Liver. Wood affects the energetic channels' flow, tendons, ligaments, small muscles, peripheral nerves, iris of the eyes, vision, tears, bile, nails, and external genitalia. After birth, the Liver will also store the emotions of anger, irritability, blame, rage, resentment, and jealousy. When excess anger is eliminated, benevolence, compassion, and love for others is allowed to flourish.
2. The Fire Agent (the Virtue of Order) represents peace and boundary setting to foster social harmony. This agent is connected to the Shen-Spirit, and stored in the Heart, affecting the energetic channels' flow, blood vessels, complexion, perspiration, and the tongue. After birth, the Heart will also store the emotions of shock, nervousness and excitement. Eliminating excess nervousness allows love, forgiveness, and joy to be experienced. The environment is then conducive for peace, contentment, and orderliness, which allow self-esteem to grow.
3. The Earth Agent (the Virtue of Trust) represents faith, honesty, openness, acceptance, and truthfulness. This agent is connected to the Yi-Intention (thoughts and ideas) and stored in the Spleen, affecting the energetic channels' flow, large muscles, lymph and saliva secretions, mouth, lips, and taste. After birth, the Spleen will also store the emotions of worry, remorse, regret, obsessiveness, and self-doubt. Eliminating excess worry allows trust and peace of mind to exist.
4. The Metal Agent (the Virtue of Integrity) represents righteousness and dignity. This agent is connected to the Po-Seven Corporeal Souls (the material aspect of the spirit) and stored in the Lungs, affecting the energetic channels' flow, skin and mucous membranes, body hair, nose, and the sense of smell. After birth, the Lungs will also store the emotions of grief, sorrow, anxiety, sadness, shame, disappointment, and guilt. Once excess sorrow is relieved, a deeper sense of righteousness, integrity, dignity, and social responsibility exists.

The Five Elements	Congenital Agents	Acquired Emotions
Wood	Kindness	Anger
Fire	Order	Joy
Earth	Trust	Worry
Metal	Integrity	Grief
Water	Wisdom	Fear

Figure 2.13. The Five Agents

5. The Water Agent (the Virtue of Wisdom) represents rationality, clear perception, and self-understanding. This agent is connected to the Zhi-Will (mental drive and determination) and stored in the Kidneys, affecting the energetic channels' flow, brain, inner ear, hearing, spinal cord, cerebrospinal fluid, bones, bone marrow, ovaries, testes, head and pubic hair, anus and urethra, and sexual fluids. After birth, the Kidneys will also store the emotions of fear, loneliness, and insecurity. Once excess fear is eliminated, the mind becomes rational and, therefore, wise.

The energy of the Three Ethereal Souls (Hun) is composed of three separate parts and flows with the Blood as it moves. The energy of the Corporeal Souls (Po) is composed of seven separate parts and follows the Jing as it moves. The Hun and the Po are characterized by their movements. The Po are also referred to as the supernatural Ling (A Moving Spirit). The Hun are also referred to as the supernatural Shen (Mind/Spirit). The Shen is the "active impulse" and Ling is the "active, enabling mover." As the Jing and Blood combine, the fetus's Shen continues to be created.

At the end of the third month, the internal organs, limbs, and external sex organs of the fetus are fully formed, and the nails have developed.

MONTH FOUR

During the fourth lunar month, the mother's Triple Burner Channels, which are connected with the Yang organs, stabilize the fetus's blood vessels (Figure 2.14). The Water Jing is beginning to be accepted by the fetus's body allowing the Yin organs to develop normally.

Beginning in the fourth month and continuing throughout the ninth month, each of the Five Element's energetic nature and the specific characteristics of each element's Essence will be progressively activated and developed within the fetus's body. The first to enter is the Water Jing.

The Water Jing energy supervises the genetic developmental phase of the fetal growth. This energy encompass the fetus's unconscious reservoir of innate and intuitive intelligence, will, and life-force energy, relating to divine love, power,

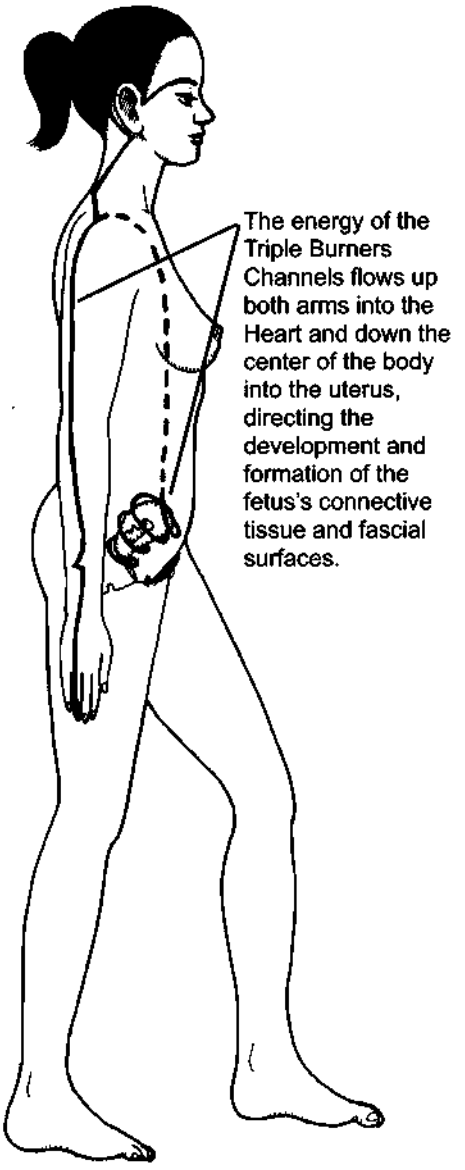

Figure 2.14. The mother's Triple Burners Channels are responsible for the changes in the fourth lunar month of creation. The Water Jing (Essence) is beginning to be accepted by the fetus.

and spirit. Any faltering of this energy (due to the influence of fetal toxins) is associated with both pervasive and subtle neurological disorders, and a predisposition to severe psychological disorders (e.g., schizophrenia).

As the fetus develops, the mother's Triple Burners will direct the development of the connective tissues and fascial surfaces. This process is referred to as "the development of Blood and Qi penetrating to the ears and eyes and circulating throughout the fetus's channels and connecting vessels."

Through the later stages of fetal development the embryo's seemingly homogenous tissues transform into the fetus's differentiated tissues of muscles, bones, and organs (an important part of which is connective tissues). A very large part of the body consists of connective tissues and membranes functioning in such a way as to hold together and maintain the body's external and internal structures.

From a gross anatomical level, the body's structures connect not only through the fascial planes but microscopically through the connective tissues. This internal network facilitates the body's intercellular communication. These structures, both energetic and physical, connect the fetus's body, forming a vast reservoir capable of regulating and transferring the body's Jing-Essence, Qi-Energy, and Shen-Spirit.

MONTH FIVE

During the fifth lunar month, the Spleen Channels become responsible for completing the development of the four limbs (Figure 2.15). The fetus begins its own respiratory movement along with the mother's respiration. The Fire Jing is accepted into the fetus, creating Internal Qi, that stabilizes the fetus's Five Yin Organs' Qi.

The Fire Jing energy generates and controls, protects and integrates, divides and harmonizes the fetus's internal energies to promote emotional/spiritual well-being. Any faltering of the Fire Jing energy is associated with problems of right (Yin) and left (Yang) brain communication (e.g., the correct balance of male/rational and female/intuitive energies).

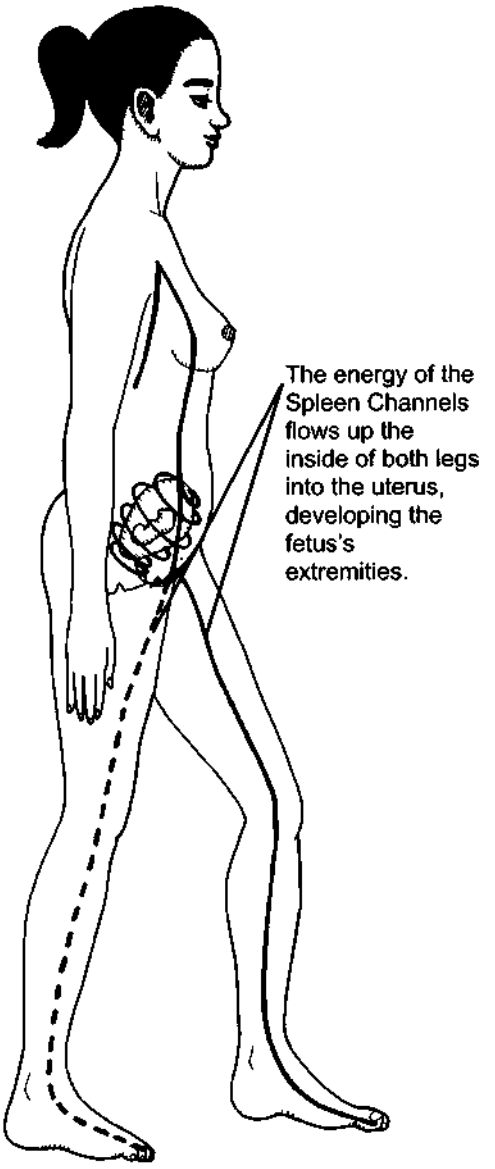

Figure 2.15. The mother's Spleen Channels are responsible for the fifth lunar month of creation. The development of the fetus's four limbs is completed. The Five Agents are distributed within the fetus's Five Orbs (Five Yin Organs). The Fire Jing is beginning to be accepted by the fetus.

At this stage of development, the Five Agents are distributed to the Five Orbs. These Orbs are energetic spheres of influence or energetic spatial cavities (i.e., internal organ tissue chambers). These Orbs pertain to the Essence, Blood, Qi pools and channels of the Five Yin Organs. The Five Orbs also pertain to and encompass all of the areas in the body that the Five Yin Organs influence. The Five Agents are distributed as follows: Kindness to the Liver, Order to the Heart, Trust to the Spleen, Integrity to the Lungs, and Wisdom to the Kidneys. This distribution causes the Hun to stabilize within the fetus's organs, which contributes to keeping the fetus's Shen at peace.

At the end of the fifth month the fetus's body systems develop rapidly. Its head is less disproportionate to the rest of the body, and its spontaneous muscular movements are commonly felt by the mother.

MONTH SIX

In the sixth lunar month of creation, the mother's Stomach Channels create the fetus's muscles. The Metal Jing is established in the fetus's body, stabilizing the sinews and connective tissues (Figure 2.16).

The Metal Jing energy is also responsible for fetal formation and the ability to form and maintain emotional bonding with others. Any faltering of the Metal Jing energy is associated with problems of emotional attachment (e.g., autism).

During the sixth month the Yang organs are in the process of developing. The Essence of the Yang organs receives, moves, transforms, digests, and excretes substances. The Six Storage Areas of the body's Yang organs constantly fill and empty, and include the Bladder, Gall Bladder, Stomach, Large Intestine, Small Intestine, and Triple Burners.

1. The Bladder controls, stores, and releases the urine. This Yang organ is responsible for receiving, storing, and releasing urine at the proper time.
2. The Gall Bladder stores and secretes bile. This Yang organ is responsible for storing and releasing bile at the proper time.
3. The Stomach stores the food. This Yang or-

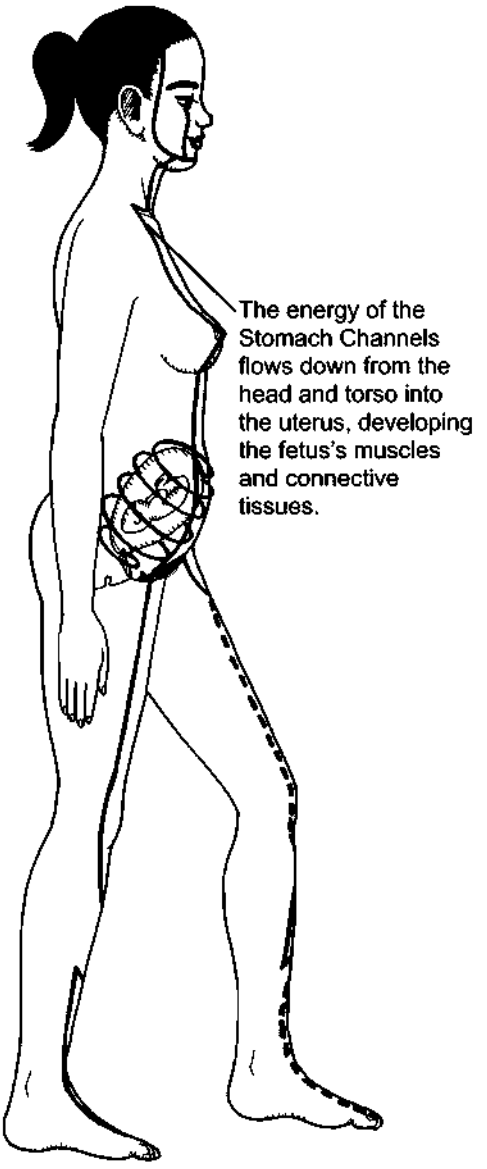

Figure 2.16. The mother's Stomach Channels are responsible for the sixth lunar month of creation. The Six Pitches are established within the body's storage areas. The Metal Jing is beginning to be accepted by the fetus's body.

gan is responsible for the receiving, storing, rotting, and ripening of food at the proper time.

4. The Large Intestine stores the solid waste. This Yang organ receives, stores and absorbs food and releases waste at the proper time.
5. The Small Intestine stores and transforms liquid matter. This Yang organ receives, stores, transforms, and digests food, and releases its waste products at the proper time.
6. The Triple Burners store the body's Qi. This area of the body receives, stores, absorbs, and moves Qi.

At this stage of development, the Six Pitches which support and stabilize the Lower Burners (see Chapter 6) and nourish the Qi are established in the organs known as the Six Yang Organs, also called the Six Storage Areas.

The Six Pitches are six specific tone resonances (notes) that vibrate within the body's internal organs and stimulates specific organ and tissue areas. These Six Pitches relate to the Five Prenatal (Heaven) Elemental Sounds of Jue-Wood, Zhi-Fire, Gong-Earth, Shang-Metal, and Yu-Water. The sixth note Xi relates to the Postnatal (Earth) Fire Element and corresponds to the Pericardium and Triple Burners. The ancient Chinese used these Six Pitches for specific clinical treatments. The sound "Yu" for example, spoken in a low tone, will vibrate the lower abdominal area and is used for the treatment of Kidney and Bladder problems.

In the sixth lunar month of formation, the fetus's eyelids separate and eyelashes form, and its skin is wrinkled.

MONTH SEVEN

During the seventh lunar month, the mother's Lung Channels create the bones, skin, and hair (Figure 2.17). The Wood Jing is beginning to be accepted by the fetus's body.

The Wood Jing energy supervises the assertion and direction of the fetus's emotional/spiritual aspects. Any faltering of the Wood Jing energy is associated with severe psychological problems (e.g., passive-aggressive personality disorder).

In the seventh lunar month, the fetus's Stom-

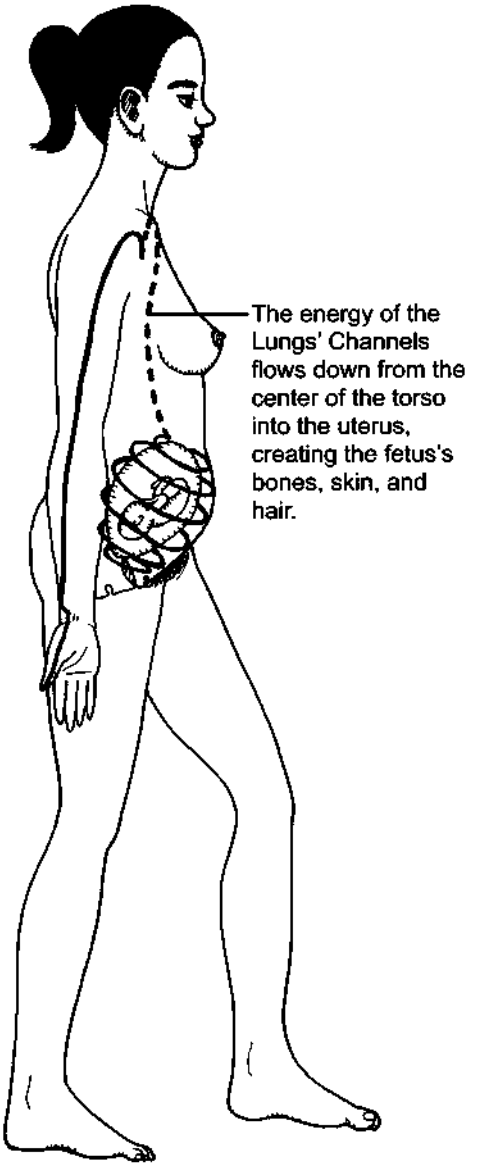

Figure 2.17. The mother's Lung Channels are responsible for the seventh lunar month of creation. The Seven Essential Stars open the orifices to let in the light from Heaven and Earth. The Wood Jing is beginning to be accepted by the fetus's body.

ach and Intestines are stabilized, and the Seven Essential Stars open the body's orifices to absorb the light from Heaven and Earth. These stars consist of the sun, moon, and five planets: Mars, Venus, Mercury, Saturn, and Jupiter. Each star is associated with one of the body's orifices: eyes, ears, nostrils, mouth, anus, and urethra. These orifices serve as receiving and projecting energetic portals for Jing-Essence, Qi-Energy, and Shen-Spirit. They also serve as messengers of the body's Five Yin Organs. Thus the Liver receives messages through observation, the Heart through speech, the Spleen through taste, the Lungs through smell, and the Kidneys through hearing.

These energetic messages are received by the body's Wu Jing Shen and emotionally and energetically interact through the body's Six Openings.

1. The eyes absorb images into the Liver which affect the Hun (The Three Ethereal Souls).
2. The ears absorb sounds into the Kidneys which affect the Zhi (Will Power).
3. The nose absorbs smells into the Lungs which affect the Po (The Seven Corporeal Souls).
4. The tongue absorbs tastes into the Spleen which affect the Yi (Intent/Intellect).
5. The physical body absorbs sensations into the tissues which affect the Shen.
6. The spirit (along with the physical body) absorbs sensations into the Heart which also affect the Shen (Spirit).

Physically, during this lunar month, there is a substantial increase in the fetus's weight and its head and body are more proportionate. The fetus can survive if born prematurely (between 27 and 28 weeks); however, its hypothalamic temperature regulation and the Lungs' production of surfactant (a phospholipid substance important in controlling the surface tension of the air-liquid emulsion present in the lungs) are still inadequate.

MONTH EIGHT

In the eighth lunar month, the mother's Large Intestine Channels complete the formation of the fetus's skin, harmonizing the Heart (the Shen), and quieting the breathing. As the fetus receives the Zong Qi-Essential Qi (energy collected from Heaven and Earth and accumulated within the

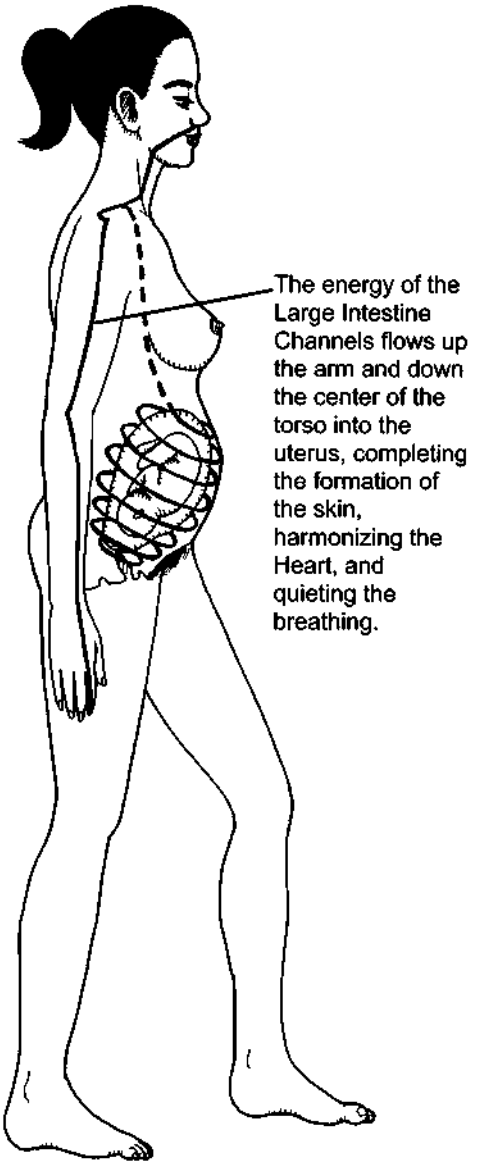

Figure 2.18. The mother's Large Intestine Channels are responsible for the eighth lunar month of creation. The Earth Jing is beginning to be accepted by the fetus's body.

chest) from the mother's Spleen, the Earth Jing begins to be accepted by the fetus's body, completing the formation of the skin (Figure 2.18)

The Earth Jing energy supervises the quality and maturation of the fetus's emotional and spiritual bonding and boundaries. Any faltering of the Earth Jing energy is associated with problems of severe psychological disturbances (e.g., schizophrenia). These psychological disturbances may be evident at birth or develop later in life.

The mother's Large Intestine Channels control the fetus's orifices. At this stage in development, the fetus's muscles and flesh are formed. The formation and consolidation of the fetus's Jing is now completed, along with the fetus's developing Zhen Qi-True Qi (energy that circulates in the body's channels and collaterals which nourishes the Yin and Yang organs and fights disease).

At the end of the eighth month, the bones of the fetus's head are soft, its skin is less wrinkled, and there is subcutaneous fat deposited throughout its body. If it is a male child, its testes will now descend into the scrotum.

At this stage, the fetus will normally assume an upside-down position to prepare for its birth descent. If the fetus is born prematurely, its chances for survival are now much greater.

MONTH NINE

During the ninth lunar month, the mother's Kidney Channels control the amount of energetic intake the fetus absorbs through its connection to the umbilicus (Figure 2.19). Qi, Blood and food nutrition are absorbed into the fetus's body, after they pass through the umbilical vein to the fetus's Liver. From the Liver, the nutrients are processed and absorbed into the Blood to be distributed throughout the fetus's body.

The flexible structure of the umbilical cord is attached to the placenta. The placenta, which formed on the uterine wall after the first week of pregnancy, consists of tissues from both the mother and the embryo. The function of the umbilical cord is to carry away the baby's waste products and pass food, energy, and oxygen from the mother's blood stream to the embryo. The mother's Kidney Channels will regulate the re-

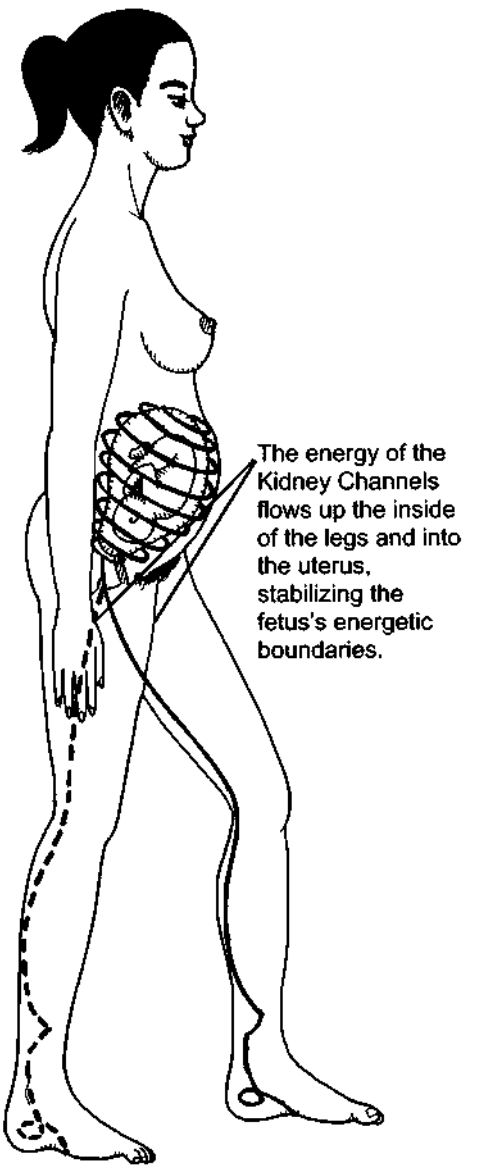

Figure 2.19. The mother's Kidney Channels are responsible for the ninth lunar month of creation. All the fetus's spatial cavities and energetic boundaries are now established.

lease and absorption of Qi and Shen flowing into the fetus's Liver through the umbilical cord.

After the umbilical cord has been severed, the baby's umbilical veins still remain. These umbilical veins eventually become the ligamentum teres that connect from the umbilicus, up along the interior surface of the abdominal wall, through the free margin of the falciform ligament, to the right and left lobes of the Liver. This maintains the baby's connection between its Liver and its Lower Dantian (navel).

At this stage in development, all the fetus's energetic spatial cavities (internal organ tissue chambers) and energetic boundaries are arranged to keep the fetus safely prepared for its birth journey.

Also in this month, the Internal Palaces and Nine Dantian Chambers (the nine internal cavities established within the fetus's Three Dantians (the body's three energetic reservoirs) are arranged and securely established to keep the fetus's Jing-Essence safe.

In the ninth month, additional subcutaneous fat accumulates throughout the fetus's body. Externally, the fetus's fingernails will extend to the tips of the fingers and sometimes beyond.

MONTH TEN

At the tenth lunar month, the mother's Bladder Channels control all Five Yin Organs (Liver, Heart, Spleen, Lungs, and Kidneys) and Five Yang Organs (Gall Bladder, Small Intestine, Stomach, Large Intestine, and Bladder) (Figure 2.20). The baby's energetic reservoirs (the Three Dantians)

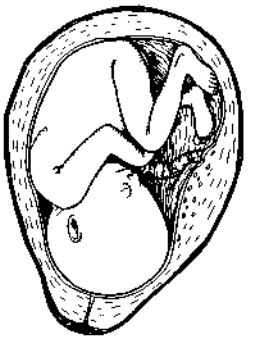

Figure 2.21. Heaven and Earth Qi settle into the baby's Lower Dantian and the process of birth begins.

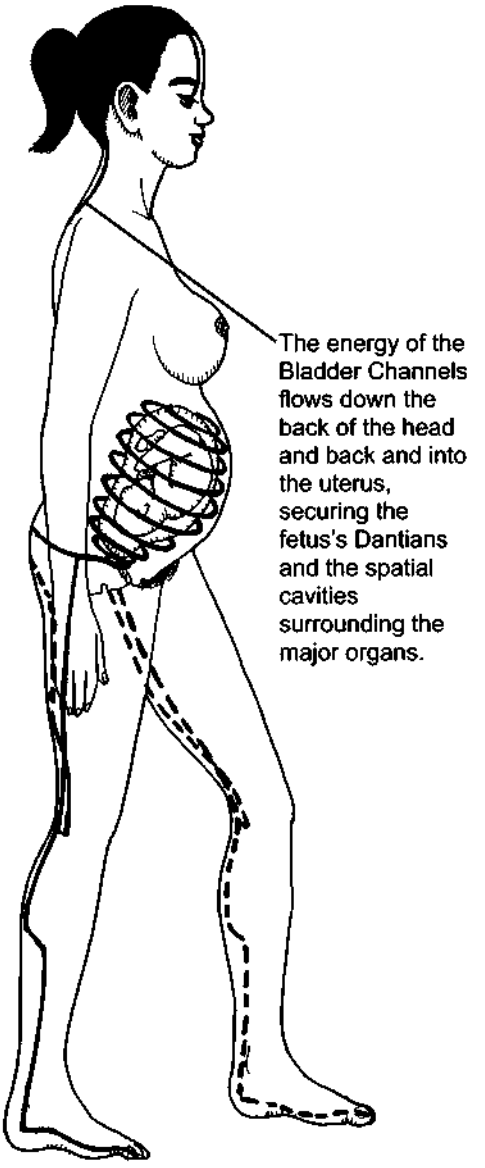

Figure 2.20. The mother's Bladder Channels are responsible for the tenth lunar month of creation. The baby's Dantians, and spatial cavities surrounding the major organs are completely developed to maintain the safety of the baby's Jing. Heaven and Earth Qi settle into the baby's Lower Dantian and birth begins.

and the internal spatial cavities that surround the major organs are developed to maintain the safety of the baby's Jing. The child is ready to be released into the world. The process of birth begins when Heaven Qi and Earth Qi settle into the baby's Lower Dantian (Figure 2.21).

The energy of the Seven Corporeal Souls (Po) is responsible for the first physiological processes after birth, allowing the child's eyes to see, ears to hear, and Heart to perceive. The Po are also responsible for the movements of the hands and feet and the breathing pattern.

The purpose for the Qigong doctor's study of the ten lunar month developmental process, is to create a foundation for understanding the patient's physical development. This knowledge of the patient's physical development establishes a comprehension of the structural formation of the Five Elemental Constitutions. The Five Elemental Constitutions are described in the next chapter.

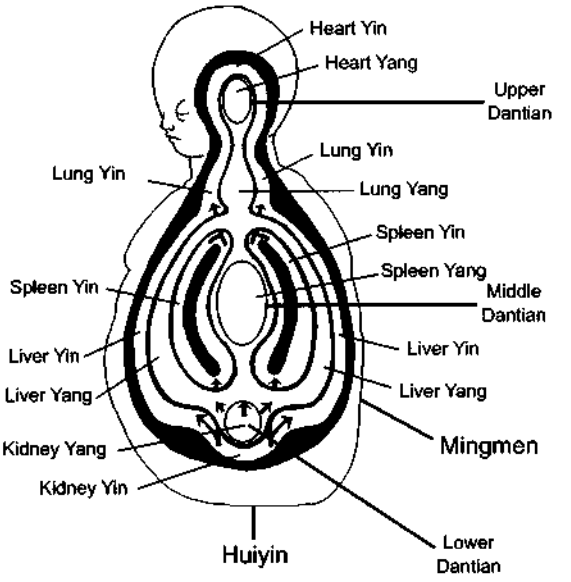

Figure 2.22. As the child develops, the energetic rivers and pools regulate the formation and production of his or her growth.

POSTNATAL ENERGY DEVELOPMENT

Throughout prenatal development, the Eight Extraordinary Vessels (see Chapter 7) were responsible for transporting, transforming, and producing Qi and Blood for the fetus, while the Twelve Primary Channels (see Chapter 6) were still in the process of gradual development. The focus of energetic activity generated from the fetus's Lower Dantian and Eight Extraordinary Vessels, resonates throughout the fetus's body creating tissue development.

Once the umbilical cord is severed, the primary focus of energy shifts, becoming diverted from the Lower Dantian to the Middle Dantian (located in the baby's chest area). After birth, Gu Qi (food energy) flows into the baby's Stomach while it nurses and begins the movement of Blood and Qi within the Twelve Primary Channels. These Twelve Primary Channels will now assume the responsibility of circulating Qi and Blood throughout the baby's entire physical and energetic structure. The Eight Extraordinary Vessels shift their function to regulating the baby's channel Qi. The Taiji Pole (which has been in the process of dropping from the fetus's Mingmen area to the Huiyin area) is now stabilized in the perineum.

The natural resonant vibration of the baby's Taiji Pole (energetic core) causes an energetic expansion and contraction, projection and reception that simultaneously affects the baby at five distinct levels: physical, mental, emotional, energetic and spiritual. Balanced physical growth will only occur when all five levels are in equilibrium. The physical body is generally the slowest realm to respond to physical growth. Matter does not develop at the same rate as energy, mind, or spirit. This being the case, the energy, mind, and spirit must wait patiently for the physical body to evolve before progressing as a whole (Figure 2.22).

ENERGETIC EMBRYOLOGICAL OVERVIEW

Understanding the energetic process of fetal development provides the Qigong doctor with an overview of the energetic factors in tissues, organs, and channel function. This understanding is essential for diagnosing the origin and causes of disease as being either congenital or acquired. Unlike Western medicine, Chinese medicine treats

the root of the illness, not just its symptoms. In Medical Qigong therapy, cases of congenital insufficiency of Qi or congenital disorders of Qi activities, are treated by either tonifying (strengthening) the Eight Extraordinary Vessels or purging (eliminating) the pathogenic energy from the Eight Extraordinary Vessels. This consolidates and regulates the patient's Prenatal Qi.

For acquired diseases, the patient can only be cured when a selection of points and the methods of emitting Qi for purgation or tonification are determined according to the imbalances of Qi circulation in the Twelve Primary Channels. Both congenital and acquired factors should be considered in every case because both the origination and development of diseases may result from either source, or a combination of both sources.

THE ETERNAL SOUL

In Chinese energetic medicine, the Original Spirit differs from the body's Eternal Soul. The Original Spirit (Yuan Shen) is rooted in the combined Jing, Qi, and Shen of the mother and father. Later the Yuan Shen is integrated and sustained through the embryo's own Five Spiritual Essences or Wu Jing Shen (see Chapter 13), which are created from the energy of the Five Yin Organs. The Eternal Soul, however, is absorbed into the mother's egg at the time of conception, as the sperm enters.

The Eternal Soul is rooted into the Heart and Middle Dantian area by a silver cord, which is additionally rooted within the body's Taiji Pole. When the Eternal Soul becomes rooted within the body's Taiji Pole, it is described as "emitting the spark of the supreme fire" (Light of God), and is considered a divine fragment of God, or the Dao. It is from this divine resonating light that the body's Taiji Pole becomes energized and all Three Dantians become interconnected. The rooting of the Eternal Soul is therefore considered the first emanation from the divine source within the human body.

To travel, and receive spiritual guidance and insight, the Eternal Soul can leave the body in the form of an "Astral Body," departing through the Baihui point at the crown of the head. The silver

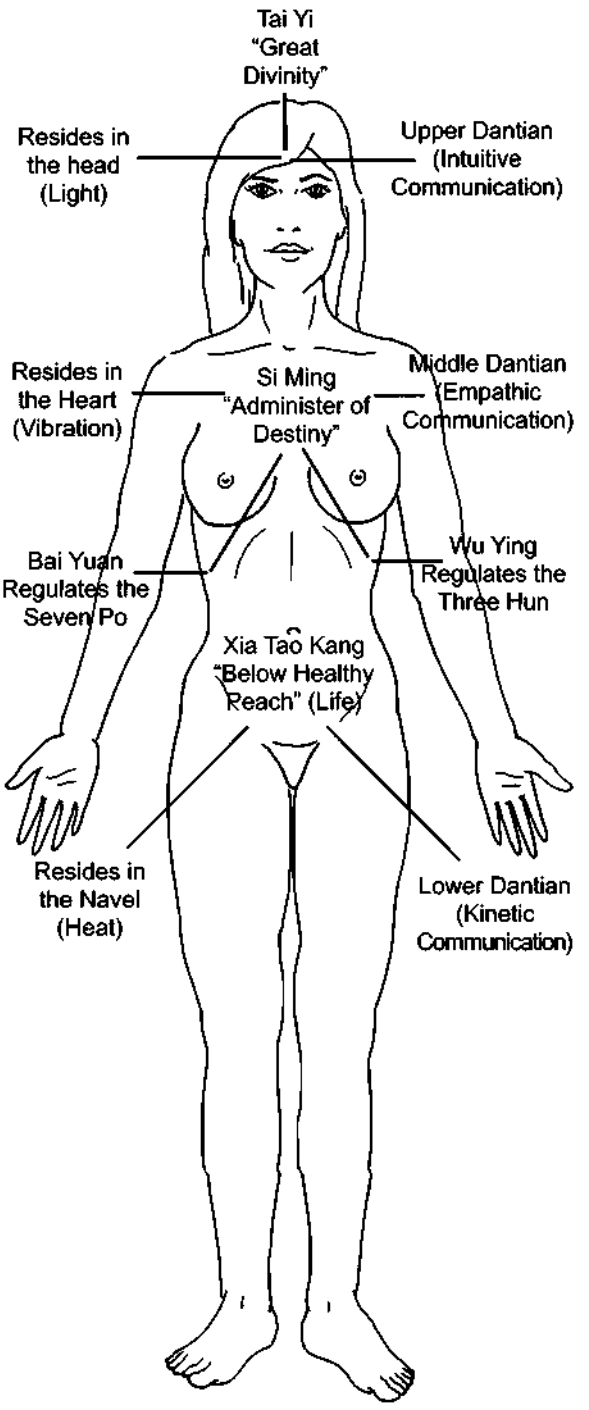

Figure 2.23 The Lords of the Three Dantians: Tai Yi, Si Ming, and Xia Tao Kang

cord, which is connected to the Astral Body, is located at the fifth and sixth thoracic vertebrae. This physical area is the place on the spine where the silver cord lifts off when an individual astral travels. This area also corresponds to the back of the Heart center, between Ling Tai GV-10 (Spirits Platform) and Shen Dao GV-11 (Spirits Gate). The astral travels of the Eternal Soul are generally to one of the nine higher spiritual planes.

The Eternal Soul becomes the intermediator between the divine, the Original Spirit (Yuan Shen), the Acquired Spirit (Zhi Shen), and the body's Soul Extensions (various traits and characteristics). These Soul Extensions manifest in the energetic field, and influence behavior and perception.

Once the Eternal Soul has established its residence, it separates its Yin and Yang spiritual energy into three spiritual energies which are the energizing forces of the body's Three Dantians, and are called Tai Yi, Si Ming, and Xia Tao Kang. These three spiritual energies are referred to as the Lords of the Three Dantians, and are named according to their function: Tai Yi translates to mean Great Divinity, Si Ming translates as The Administrator of Destiny, and Xia Tao Kang translates as Below Healthy Peach (Life).

The Chinese medical terminology, which describes the Eternal Soul as consisting of three spiritual energies called the Lords of the Three Dantians, is extremely metaphoric and is used to describe the many energetic aspects of the human soul.

The Eternal Soul radiates through the physical, energetic, and psycho-emotional domains of human existence (Figure 2.23). Whole-body consciousness is the main characteristic of the Eternal Soul. Without the interactive process of the Eternal Soul, energy would have no specific direction and would remain in meaningless activity. The Eternal Soul radiates energy in all directions throughout the body and is responsible for life and health, as well as the formation and growth of the body.

In the scope of energetic manifestations, the Eternal Soul expresses its innate qualities as energetic movement, functioning through the physical form. It is led by the Shen and is connected to all parts of the body. The light of the Eternal Soul is revealed through the light or energy of the eyes. Through the influence of the Eternal Soul, all of the body's energetic processes seek wholeness. The Eternal Soul knows exactly what is needed in every situation for survival and health preservation.

The distinction between the Eternal Soul and the Yuan Shen is that the Eternal Soul, although spiritual in nature and connected to the Wuji (infinite space), is still considered individuated. The Yuan Shen, however, although individual in its conditioned state, can also be universal. The connection between you and others, for example, is considered a spirit connection (kindred spirits uniting). The connection between you and the divine is considered a soul connection (your true innate nature reconnects with its origin), and relates only to the connection between one's self and the divine.

When the Qigong doctor meditates, the Eternal Soul consciously enters a spiritual realm wherein the doctor perceives the ideal of things rather than the things themselves. The doctor no longer depends on the senses, but upon a clear inner-vision that perceives the whole picture. It is here, within this spiritual state, that the higher knowledge of things unfolds through divine intelligence and all things reveal their true nature.

When conserved and amplified through practice, the energy of the doctor's Eternal Soul reveals a bright radiant quality, which permeates and penetrates the cells, tissues, organs, and external energy fields. These energetic fields create for the Qigong doctor a strong luminous shield of energy, capable of guarding the body against an attack of hostile energy by enabling it to:

- ward off the invasion of External pathogens and harmful electromagnetic fields,
- ward off the negative influences of malevolent spirits,
- ward off ill intentions and spiritual malice projected unconsciously or deliberately by others, and
- ward off the parasitic influences of demonic forces.

At conception, when the sperm enters the ovum, a polar axis that forms the embryo's Taiji Pole is created. The energetic vortex thus created draws spiritual energies into the body from Heaven and Earth. After birth, the degree to which an individual can draw upon, and absorb, spiritual energy depends on his or her karma (previous thoughts, actions and level of consciousness), and course of destiny.

During conception, three spiritual energies are given to each individual from the divine to create and maintain the existence of the Eternal Soul. These three spirit energies, called the Lords of the Three Dantians, reside in the innermost subtle aspect of the body and are described as follows:

1. The Tai Yi (Great Divinity) resides in the head and Upper Dantian, and is considered the Lord of the Nei Wan (Innermost Palace). It governs a multitude of the body's spirits, causing man's Yuan Shen to shine externally. The Tai Yi facilitates awareness of the Three Ethereal Souls (Hun), and advocates for personal spiritual enlightenment.
2. The Si Ming (The Administrator of Destiny) resides in the Heart and Middle Dantian, regulates the body's Qi, and is the source of the mind and its emotional connections. The Si Ming is considered the Eternal Soul (some believe that this soul reincarnates). The Si Ming controls the spirits Wu Ying and Bai Yuan, that directly affect the body's Jing, Qi, and Shen. The Si Ming challenges our reactions to various internal and external obstacles.
    a. The Spirit Wu Ying (Without Excess) occupies the left side of the body, and regulates man's Three Ethereal Souls (Hun), which are called:
        (1) Tai Guang (Eminent Light),
        (2) Shang Ling (Pleasant Soul) and the Five Agents, and
        (3) Yu Jing (Hidden Essence).
    b. The Spirit Bai Yuan (Pure Origin) occupies the right side of the body, regulates the Seven Corporeal Souls (Po), which are called:
        (1) Flying Poison
        (2) Unclean Evil
        (3) Stinking Lungs
        (4) Corpse Dog
        (5) Fallen Arrow
        (6) Yin Bird
        (7) Devouring Robber

Both the Hun (that come from Heaven) and the Po (that come from Earth) are established within the fetus's internal organs at conception but lie dormant until the third month. This is because, at the third lunar month, the fetus's Orbs are sufficiently formed. One belief maintains that the Hun and Po, although residing in the energetic form of the fetus, frequently leave and return to gather and absorb universal and environmental Qi. The Hun will connect with divine spiritual beings, as well as with God. The Po will connect with surrounding environmental spirits.

Note: The Three Ethereal Souls are traditionally referred to as the "Hun" with the assumption that this term depicts all three Hun, thus in Traditional Chinese Medicine the Hun are sometimes referred to in the singular case. The Seven Corporeal Souls are traditionally referred to as the "Po" with the assumption that this term depicts all seven Po, thus in Traditional Chinese Medicine the Po are sometimes also referred to in the singular case.

3. The Xia Tao Kang (Below Healthy Peach/Life) resides in the navel and Lower Dantian and preserves the root of the body's Jing-Essence.

Upon the death of the body, the Hun return to Heaven, the Po return to Earth, and the spiritual energies of Tai Yi and Xia Tao Kang combine with the Eternal Soul stored in the Si Ming (Administrator of Destiny). These three spiritual energies (Tai Yi, Xia Tao Kang, and Si Ming) blend together, combining into one energy that completes the integration of the Eternal Soul. This soul leaves the body and returns back through the tunnel of light to the divine light for judgement, or wanders the Earth becoming a Gui (ghost).

In Western culture, our internal dialogues are sometimes associated with encounters with good or evil spiritual influences. In Chinese medicine

the internal dialogues that influence the patient's psyche are also divided into good and evil; these spiritual/emotional influences are considered to be specific good and evil characteristics in man's Hun and Po. The spiritual components and influences of the Hun and Po are considered to be separate entities, or archetypes, acting upon man's Shen, which in turn affects the Eternal Soul.

These archetypes are regarded as spirit souls that can exert a positive or negative influence on a individual's life depending on the nature of the individual's Eternal Soul. The good internal influences manifest through the Hun. The evil internal influences manifest through the Po. The Hun or Po can motivate personal growth, or can hinder it and cause illness, and even the demise of the body.

THE THREE ETHEREAL SOULS (HUN)

The Three Ethereal Souls are the spiritual part of man that ascends to Heaven upon the death of the body. The Three Ethereal Souls are composed of the Three Hun, that originate from Heaven, reside in the Liver, and resonate from the Three Dantians. The Hun have the following associations: light, Yang, Heavenly soul, Shen, as well as positive emotions and feelings (Figure 2.24). The Three Ethereal Souls are the Tai Guang, Shang Ling, and Yu Jing. They are described as follows:

1. The Tai Guang resonates within the Upper Dantian, and is situated in the cranial cavity, just below the Baihui GV-20 (Meeting of Yin) point. This Hun's name means "eminent light," and it is considered the ultimate balance of pure Yin and Yang energy in harmony. It is connected energetically with the Upper Dantian and Heaven, and always strives for physical, mental, emotional, and spiritual purity.
2. The Shang Ling resonates with the Middle Dantian and is situated in the Heart and corresponding vessels and is linked to the body's Five Agents. This Hun's name translates to "pleasant soul," and it is considered changed (or transformed) Yin energy. It is connected with the Middle Dantian and is a soul that is concerned for others. It is associated with the Five Agents, and produces our desire to be involved in a diversity of social interests and responsibilities.
3. The Yu Jing resonates with the Lower Dantian. Translated, the name means "hidden essence." This Hun is considered mixed (or combined) Yin energy. It is connected with the Lower Dantian and is associated with the Earth, producing our desire for enjoying life's pleasures and comforts, as well as the pure passions of life.

Figure 2.24. The Three Ethereal Souls are composed of the three Hun, that originate from Heaven and reside in the Liver. The Hun represent spiritual consciousness, provide the energetic movement of the mind, and are associated with Heaven Qi and the Five Agents. The Hun are the spiritual part of man which ascends to Heaven after death. The Hun are associated with positive emotions and feelings, light, Yang, Heaven, and Shen.

The Three Ethereal Souls are named (1) Tai Kuang, (2) Shang Ling, and (3) Yu Jing.

The Hun are classified as Yang spirits and are to be cultivated and refined. Imagination, visualization, and positive affirmation in the form of prayer and meditation are needed to awaken and establish an active relationship with the Three Ethereal Souls.

The Hun can be accessed through the Hunmen Bl-47 (Gate to the Hun) point on the back of the body (below the shoulders). It is used clinically to spread Liver Qi and harmonize the Middle

Burner. The Hun respond to Heaven's energetic grids (universal energetic fields). The stars and planets within these Heavenly grids exert an influence on the Hun causing each individual's body to react to certain astrological configurations. The positive or negative reaction is based on the affinity of the vibrational rate of the Hun and the energies of a particular astrological alignment.

THE SEVEN CORPOREAL SOULS (PO)

The Seven Corporeal Souls are closely linked to our body's Jing-Essence. The Po manifest the body's Essence in the form of hearing, sight, and tactile sensations.

The Po pertain to the animal nature of man's instincts and drives and are considered inferior souls to the Hun (Figure 2.25). The Po are passionate and advocate experiencing life in its fullest measure. They are, however, in a constant state of dying. The Po will return to the Earth with the body after death. The Po have the following associations: heavy, Yin, Earthly Spirit, Essence, and negative emotions and feelings.

The Po are a composite of Seven Corporeal Souls, which originate from Earth, reside in the Lungs, and resonate from specific areas in the body. The Po can be accessed through the Pohu Bl-42 (Door to the Po) point on the back of the body (between the shoulders). This point is used clinically to treat energetic imbalances of the Lungs. The Po respond to the Earth's energetic grids (see Chapter 10) and cause each of us to resonate in harmony or disharmony to certain ecological configurations. An individual's attraction, or feeling of not belonging, depends on the vibratory affinity, or lack thereof, between the body's Po and the environmental energy of a particular area.

When the fetus begins its movement, its Yin energy tranquilizes the Po, which act as guardians of the fetus's body. The Po's nature is one of survival, and their energies can be directed towards self-preservation or self-destruction (devouring and robbing the body of life-force energy).

The Seven Po are located along the line between the Huiyin CV-1 and the Baihui GV-20 points, embracing the body's Taiji Pole (also called the Center Thrusting Channel) at the following locations:

Figure 2.25. The Seven Corporeal Souls are composed of the Seven Po, which originate from Earth and reside in the Lungs. The Po are regarded as the animal nature or drive. They provide energetic movement to the body's Essences, and are considered inferior Souls. The Po will return to the Earth with the body after death, and are associated with negative emotions and feelings, heaviness, Yin, Earth, and Jing.

The negative thoughts and emotions of the Seven Corporeal Souls are named (1) Flying Poison, (2) Unclean Evil, (3) Stinking Lungs, (4) Corpse Dog, (5) Fallen Arrow, (6) Yin Bird, (7) Devouring Robber.

1. The Po of Essence (Soul of the Five Element Earth) is located at the midpoint of the Taiji Pole. This Po is the counterpart to the Hun's Earth Agent (the Virtue of Trust). This Po manifests through the acquired emotions of worry, regret, remorse, obsessiveness, and self-doubt.
2. The Po of Qi (Soul of the Five Element Wood) is located below the diaphragm. This Po is the counterpart to the Hun's Wood Agent (the Virtue of Kindness). This Po manifests through the acquired emotions of anger, irritability, blame, rage, resentment, and jealousy.
3. The Po of the Spirit (Soul of the Five Element Metal) is located posterior of the Tanzhong (CV-17) point, inside the mediastinum, near the Middle Dantian. This Po is the counterpart to the Hun's Metal Agent (the Virtue of Integrity). This Po manifests through the acquired emotions of grief, anxiety, sadness, shame, disappointment and guilt.

4. The Po of Yin (Soul of the Five Element Water) is located posterior of the navel, in front of the Taiji Pole. This Po is the counterpart to the Hun's Water Agent (the Virtue of Wisdom). This Po manifests through the acquired emotions of fear, loneliness, and insecurity.
5. The Po of Yang (Soul of the Five Element Fire) is located anterior of the Mingmen (GV-4) point behind the Taiji Pole. This Po is the counterpart to the Hun's Fire Agent (the Virtue of Order). This Po manifests through the acquired emotions of nervousness, shock and excitement.
6. The Po of Sex (Soul of Heaven) is located below the Baihui (GV-20) point in the Ni Wan (Upper Dantian) area.
7. The Po of Life (Soul of Earth) is the only one not located on the Taiji Pole, but is located at the bottom of the feet in the Yongquan (Kd-1) points and is considered a neighbor of the Soul of Essence.

The Seven Corporeal Souls (Po) are also called the "seven animals," or "sentient souls of the body," and "seven turbid demons." When afflicted or restless, the animal nature of the Seven Po quickly becomes hostile, and their names change to express the different negative thoughts and emotions expressed from each Po soul. Each Po has a favorite mantra that it whispers inside a person's mind to influence the individual. The Po's Seven Turbid Demon Natures are described as follows.

1. The Flying Poison (or Quick Evil) suddenly explodes with rage and venomous thoughts of evil intention (e.g., "I'll kill you for that!" "How dare they!").
2. The Unclean Evil (or Shame) entices by tempting and luring an individual into a place or situation from which escape is difficult, and then creates distress in the form of guilt, which generates shame. This spirit creates a feeling of being discredited, dishonored, or disgraced (e.g., "I'm worthless;" "No one has or will ever love me.").
3. The Stinking Lungs (or The Smell of Death) destroys hope, which can lead to a sense of despair (e.g., "I just want to die;" "Just kill me and get it over with!").
4. The Corpse Dog (or Being Scorned) is like a dog that has been beaten and starved, the presence of this spirit intensifies depression by despising itself and holding itself in contempt to a point of no return (e.g., "I'm not worth keeping alive;" "Leave me alone to die!").
5. The Fallen Arrow generates the foregone conclusion that attempting goals is fruitless (e.g., "I'll never be able to accomplish that." "Why even try? I'll never make it.").
6. The Yin Bird (or Night Tormentor) harasses the individual, causing him or her to experience extreme pain and severe anguish (e.g., nightmares and restless sleep).
7. The Devouring Robber (or Sipping Thief) steals the individual's life-force energy by devouring it through negative emotions such as jealousy, envy, and bitterness (e.g., "You love him/her more than you do me;" "I'll never forgive you!").

The Seven Po help in developing the growth of consciousness by providing obstacles to test the individual's faith and devotion. Many times the Seven Corporeal Souls will work in conjunction with outside spiritually hostile forces to test the individual's spiritual endurance.

After the child has been born, enlightened parents can assist the child in facing his or her own internal demons. Once the child is self-aware, he or she can be taught to restrain and control the Seven Po so as to prevent them from taking control. To minimize the effects of these souls on the body, one can learn special meditations, involving visualization, imagination, positive affirmation, and mantras (literally "protections of the mind" or "mind protectors").

A mantra is a word, phrase, or sound, repeated silently or aloud, that one can consciously use as a tool to guide one's own mental, physical, and emotional states. People naturally repeat both positive (self-affirming) mantras and negative (self-destructive) mantras as part of their internal self-talk. When positive mantras are used by an

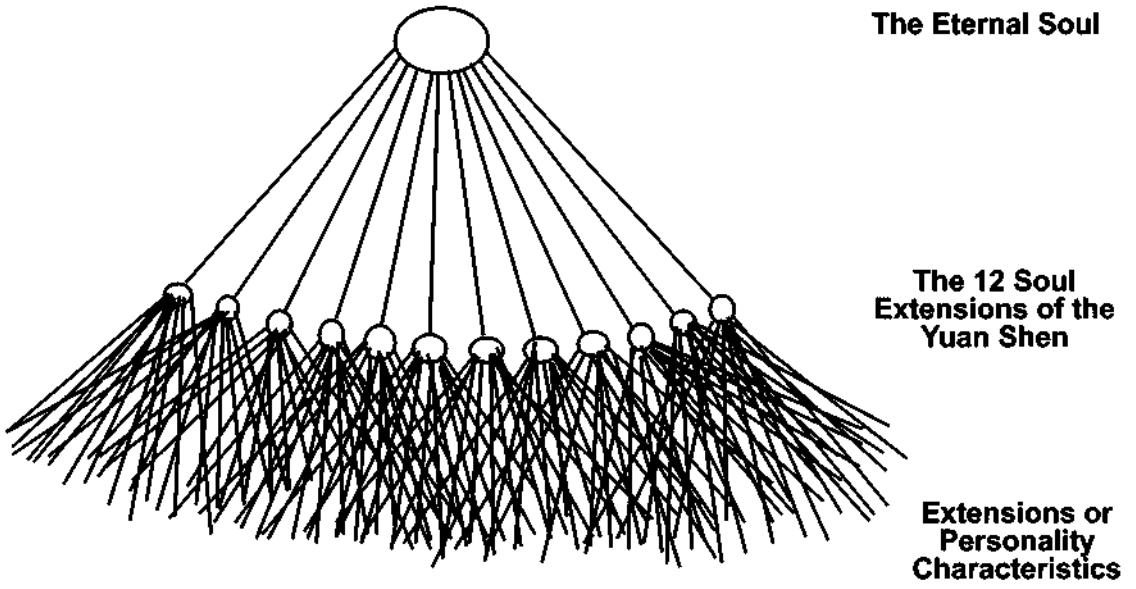

Figure 2.26. The Eternal Soul, Yuan Shen and 144 Soul Extensions

individual who holds them in high regard, they enable that individual to combat the Seven Corporeal Souls' mantras. These mantras also facilitate connecting the individual to the divine. Used consciously, mantras and/or prayers can uplift and maintain the individual's self-esteem.

The Chinese view meditation as a deep spiritual contemplation that results in openness to the divine. They view prayer as energy focused towards the divine. Individuals choose what to focus their attention on; therefore, any chronic detrimental thoughts can be countered with positive affirmations to change self-destructive habits.

THE ORIGINAL SPIRIT (YUAN SHEN)

The Original Spirit (Yuan Shen) radiates and extends from the interior of the Eternal Soul. This spiritual light crystallizes a spiritual body, gradually becoming consciously effective and moving into action. It envelops the body and communicates through innermost thoughts, sensory feelings, and emotions. Although the body's Jing and Qi will degenerate, the Original Spirit is immortal, as it is the expression of the Eternal Soul.

The Shen develops and contains Twelve Soul Extensions. These Twelve Soul Extensions contain the body's different personality characteristics (Figure 2.26). Although Si Ming controls the residence of the Eternal Soul, the body's Shen is free to make decisions that affect life and health based upon the individual's free will (the interaction between the Yuan Shen and the Zhi Shen), which then manifests through the Twelve Soul Extensions.

THE EFFECT OF THE HUN AND PO ON THE YUAN SHEN

The Yuan Shen is a manifestation of the Eternal Soul and is primary to the Hun and Po. The combination of the Seven Corporeal Souls (Yin Souls) and the Three Ethereal Souls (Yang Souls) creates the sustaining energy for the body's Original Spirit (Yuan Shen). The Yuan Shen also controls and organizes the psycho-emotional aspect of the body's Five Yin Organs, called the Wu Jing Shen or Five Essence Spirits.

The ancient Chinese viewed the Shen as an Emperor, seated within the Heart; the Hun are

viewed as a Loyal Minister, seated within the Liver; and the Po are viewed as a Violent General, seated within the Lungs. If the General (Po), is left in control (being only concerned with the survival of self and the body), he will start to dominate (a condition referred to as a rebellious General and a weak Emperor). At the point when the General (Po) dominates, the individual's acquired mind takes over and the individual becomes concerned only with his or her own survival, and thus becomes self-absorbed. The goal for spiritual cultivation is to control the rebellious General, making him into a servant. Once the inner government is orderly, the strong and violent nature becomes tame. Then, through the wise council of the Loyal Minister (Hun), the individual can walk a path of virtue. Virtue is the path that leads the individual's Shen so that even his or her human consciousness is dominated by the Hun and the Yuan Shen.

When the Hun control the energy body and are nourished by the virtues, the energy body then becomes a vehicle for the Heart's Shen, which is non-local and non-linear in terms of time and space.

When the Heart's Shen is no longer dominated by the Yin and Yang souls (Hun and Po) and the Five Element energies of the lower energetic plane (Wu Jing Shen), the individual returns to an awareness of his or her connection to the universe (Wuji) and the divine. This state of consciousness is sustained through prayer and meditation.

When beginning to develop the Heart's Shen, the first separation of the individual's energetic spirit body or "dream body" from the physical body generally leaves the Shen in a weakened state (referred to as Yin Shen). The weakened Yin Shen must be protected. This Yin Shen is part of the Hun, and leaves the body naturally whenever the patient is weak, sick, in shock, or asleep. It may also leave during the early stages of Qigong meditation or Taijiquan practice. The astral travels of the Yin Shen are generally confined to the lower spiritual planes, and it sometimes needs to be reclaimed through "soul retrieval" (see Chapter 19). Once the Shen has been cultivated, refined, strengthened, fortified, and controlled through the development of the energy body, it is then referred to as a Yang Shen. When the energy body spiritually travels, the developed Yang Shen can transverse the Nine Levels of Heaven or the Nine Levels of Earth in an instant.

The Nine Levels of Heaven are nine spiritual planes which exist within Heaven's energetic grids. Within the lower levels there exists enlightened beings coexisting with other spiritual entities. The Nine Levels of Earth are nine spiritual planes which exist within Earth's energetic grids. Within these levels of Earthly spiritual planes there exists various dimensions of animal, vegetable and mineral powers, as well as Earthly spiritual beings.

YIN AND YANG ASPECTS OF THE ETERNAL SOUL

The human soul has an endless source of vitality from the infinite high-frequency force of the divine. This divine energy descends from the Heavens into the body's Taiji Pole, taking up residence and interacting on the physical plane. The body serves as a medium of transformation for the Eternal Soul. The soul's activity extends and expresses its essence through the physical form and through consciousness. As we grow and change, the Eternal Soul maintains stability by providing the energetic blueprint for orderly development. On the spiritual plane, when referring to the energetic dynamics of the Eternal Soul, there are two basic movements: (1) Yin - the downward movement and (2) Yang - the upward movement.

1. The Yin aspects of the Eternal Soul spirals downward. The spiralling movement of the energetic soul results in the energy transforming from the highest divine energetic frequencies to the lowest. Within this spiritual transformation process, there is a parallel gradual decrease in levels of consciousness. The lowest frequency creates matter, and is the bases for all the prenatal transformations. At the higher frequencies, the principles by which Qi operates are difficult to perceive because our lower state of consciousness does not resonate in harmony with the information being

Spiritual Energy	Resides in...	Associated Dantian	Purpose	
Tai Yi Great Divinity	the head as light	Upper Dantian (intuitive communication)	Governs the body's Spirits, makes life shine forth, and encourages man to know the spirits of his Ethereal Soul	
Si Ming Administrator of Destiny	the Heart as vibration	Middle Dantian (empathic communication)	The Eternal Soul—regulates the prime energy of life (Qi) and is the source of the emotions and mind	Wu Ying (Without Essence), occupies the left side of the body and regulates the Three Hun (Ethereal Souls), associated with the Liver
			Controls the Wu Ying and Bai Yuan Spirits	Bai Yuan (Pure Origin) occupies the right side of the body and regulates the Seven Po (Corporeal Souls), associated with the Lungs
Xia Tao Kang Below Healthy Peach (life)	the navel as heat	Lower Dantian (kinetic communication)	Preserves the root of the body's Essence (Jing)	

Figure 2.27. The patient's soul resides in the body's Taiji Pole, connected with Si Ming, the Administrator of Destiny. Upon the death of the physical body, the Three Hun return to Heaven, the Seven Po return to Earth, and the energy of Tai Yi and Xia Tao Kang envelope the Eternal Soul (stored in Si Ming) becoming one energy. The Eternal Soul leaves the body through the specific gate (solar plexus, third eye, or top of the head) associated with the patient's degree of spiritual evolution, returning back through the tunnel of light to the divine.

presented. As energy slows down its resonance, it is more readily perceived by our five senses; this gives matter the quality of hardness, form, and smell, and allows us to observe its energetic patterning.

2. The Yang aspects of the Eternal Soul spirals upward. The spiraling movement of the energetic soul results in energy transforming from the lowest level of consciousness to the highest divine energetic frequencies during postnatal transformation. Spiritual evolution involves a progressive opening up of all of the body's energy centers (Three Dantians) along the Taiji Pole, until a state of absolute unity of body, mind, emotion, energy, and spirit is achieved (known as enlightenment).

In the evolutionary process of the soul, both stability and change become as one when there is a deep connection to wholeness. This soul serves as a pivotal point for the body's Jing, Qi, Shen, Body Fluids, connective tissues, and emotions, all of which express wholeness. Without this connection the patient experiences a serious psychic splitting of his or her energies. The part that is open to change will experience resistance from the part that demands stability.

THE FINAL EXIT OF THE ETERNAL SOUL

As the body begins to die, the Yuan Shen begins to prepare the Eternal Soul for its final journey home. This change of residence for the patient's spiritual energies is crucial. At the time of death the Eternal Soul must disconnect from the Heart and Middle Dantian area, and the soul must exit the dying patient through one of the Nine Orifices. The lower orifices include the anus and urethra, while the upper orifices include the eyes, ears, nostrils, mouth, as well as the Yintang and Baihui areas (Figure 2.27). It is believed that the area from which the patient's soul exits the body determines the state of its spiritual evolution and to which area the patient is most attached (i.e., if the patient is attached to vision, they are

more inclined to leave through the eyes, etc.).

When the Medical Qigong doctor is assisting a terminally ill patient, treatment focuses primarily on purging stagnant spiritual energy from the patient's body. Spiritual purging is required to purify and cleanse the patient's Eternal Soul. Once the patient's soul has been cleansed, the patient becomes peaceful as all material, emotional, and spiritual attachments to this life are released. The patient attains a sense of completion and welcomes the final adventure of going home. The last rites performed by various clergy and ministers in Western culture serve a similar purpose.

The Qigong doctor then guides and encourages the patient's Eternal Soul into leaving the body through the top of the head (Baihui). Souls that are more highly evolved exit the body through this area (at the top of the head), while souls of lesser evolution exit the body through lower portions of the physical structure.

The formation of a Gui or ghost is said to derive from the untransformed energy of the Eternal Soul (see Chapter 19).

SUMMARY

One of the unique aspects of Traditional Chinese Medicine is that it addresses all aspects of the body's energy and spirit. It explores in great detail the spiritual transformations in the body's prenatal state, their relationship to the formation of the body, and to the dying and after-death states. Traditional Chinese Medicine further addresses the potential of spiritual involvement as a cause or cure of specific psychophysical diseases. It is through the complete study of the body's physical, mental, emotional, energetic, and spiritual aspects that doctors of Medical Qigong therapy comprehend when and how to treat their patients.

Chapter 3
Physical Development and Structural Formation

Fascial Development and Energy Flow

According to the *American Medical Association Encyclopedia of Medicine*, "fascia is the fibrous connective tissue that surrounds many structures in the body. One layer of the tissue, known as the superficial fascia, envelopes the entire body just beneath the skin. Another layer, the deep fascia, encloses muscles, forming a sheath for individual muscles, and also separates them into groups. The deep fascia also holds in place the soft organs, such as the Kidneys. The thick fascia in the palm of the hand and sole of the foot have a cushioning, protective function."

In Traditional Chinese Medicine, the fascia is referred to as Huang (meaning any membranous tissue). Fascial development is divided into two stages: prenatal (congenital) and postnatal (acquired). The prenatal fascia is fixed and determined by the combination of the parents' Jing, Qi, and Shen. The postnatal fascia is formed through diet, exercise, and environmental stresses.

Qi is stored within the tissues and inner fascia layers, where it envelops and protects the internal organs. Energy (that has been stored within the body's organs) is available through the fascia for transformation to nourish the patient's body, mind, emotions, energy, and spirit.

The body consists of three tissue layers:

1. The first and innermost layer is made up of the internal organs, which produce and transform Qi.
2. The second layer consists of the body's fascia, tendons, ligaments, and bones, which assist in transporting Qi to the extremities.
3. The third and outermost layer of tissue consists of the muscles and skin, where Wei (Protective) Qi circulates to protect the organism from invasion of external pathogens (Cold, Heat, Wind, and Dampness, etc.).

After being generated within the body's internal organs, Qi is distributed throughout the body's entire energetic network through the channels and collaterals, via the fascia. Each organ has its own layer of weblike fascia, that covers, connects, protects, and nourishes the tissues. The fascia forms the energetic chambers of the body's organs and channel systems. Qi within the body flows between the fascial sheaths and along the channel system. Through trauma, infection, surgery, disease, or chronic muscular tension, areas of the fascia can become stuck together, inhibiting the flow of Qi and Blood.

Our constitutions are formed, in part, by conditions from the environment that affect the innermost layers of fascial development. Traditional Chinese Medicine divides the observation and diagnosis of the physical developments of these inner fascia into Yin and Yang structures and Five Elemental Constitutions.

Yin and Yang Structural Formation

Chinese philosophy teaches that the universe is composed of a pair of opposite forces or energies -- Yin and Yang. Everything in the natural world contains both Yin and Yang. Yin and Yang are interdependent; without Yang, Yin cannot grow; without Yin, Yang cannot develop. The energetic transformation of Yin into Yang and Yang into Yin produces the various observable changes of form and matter (see Chapter 21).

Yin and Yang are the principles governing all things within the human body. Life and death originate from the energies of Yin and Yang, and they are the forces that create all physiological change. In Medical Qigong therapy, the physical structure of the human body is divided into Yin

and Yang organs and substances, as well as Yin and Yang energetic functions (e.g., Qi that expands and flows outward is Yang, while Qi that contracts and flows inward is Yin).

Yin and Yang are in a constant state of waxing and waning (Figure 3.1). If this waxing and waning exceeds the body's normal energetic limits and loses its dynamic equilibrium, Deficient or Excess Yin and Yang will occur, leading to the development of abnormalities and illness.

Yin Qi naturally ascends (e.g., Spleen Qi ascends the Clear Qi). When Yin Qi becomes pathological or destructive, it moves downward, descending like cascading water (e.g., descending Spleen Qi causes diarrhea or prolapse of the viscera). Another example of the effects of pathogenic Yin Qi descending would be edema.

Yang Qi naturally descends (e.g., Stomach Qi flows downward). When Yang Qi becomes pathological or destructive, it ascends like the flames of a fire, moving upward (e.g., Rebellious Stomach Qi ascends, causing nausea and vomiting). An-

	Yang	Yin
Attributes	active, creative, masculine, Fire, Hot, Heaven, light	passive, receptive, feminine, Water, Cold, Earth, heavy
Organs	the six hollow organs (Gall Bladder, Small Intestine, Stomach, Large Intestine, Bladder, and Triple Burners)	the five solid organs (Liver, Heart, Spleen, Lungs, and Kidneys), along with the Pericardium
Respiration	exhalation	inhalation
Time of Day	the 12 hour cycle from 11 p.m. (before midnight) to 11 a.m. (before high noon)	the 12 hour cycle from 11 a.m. (before noon) to 11 p.m. (before midnight)
Seasons	spring and summer	autumn and winter
Normal Movement	outward	inward

Figure 3.1 Yin and Yang are the Principles Governing All Things Within the Body

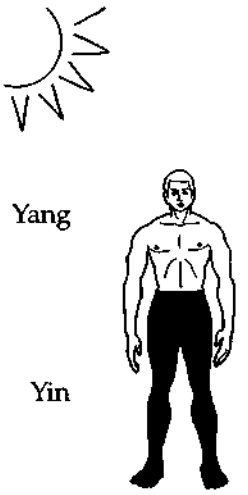

Figure 3.2. The superior aspect of the body's structure is Yang; the inferior portion is Yin. Think of the sun shining on the upper torso, illuminating the body from the waist to the head, while from the hips downward the lower torso is in the shade.

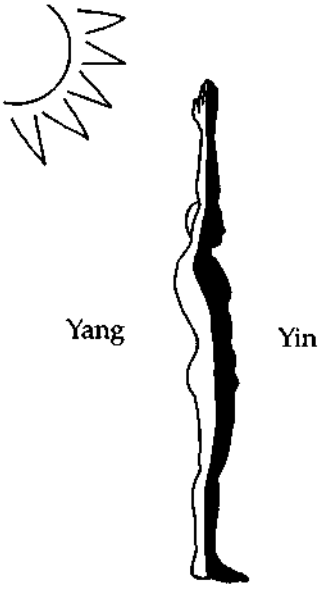

Figure 3.3. The posterior portion (back side) of the body is Yang; the anterior portion (front side) is Yin. Think of the sun shining on the back, while the abdomen is in the shade.

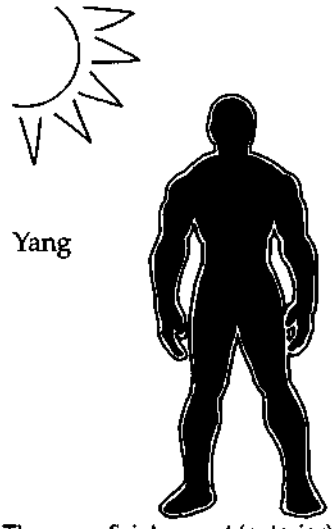

Figure 3.4. The superficial aspect (exterior) of the body is Yang; the deep portion (interior) of the body is Yin. Think of the sun shining on the external surfaces of the body, while the internal organs remain in the dark.

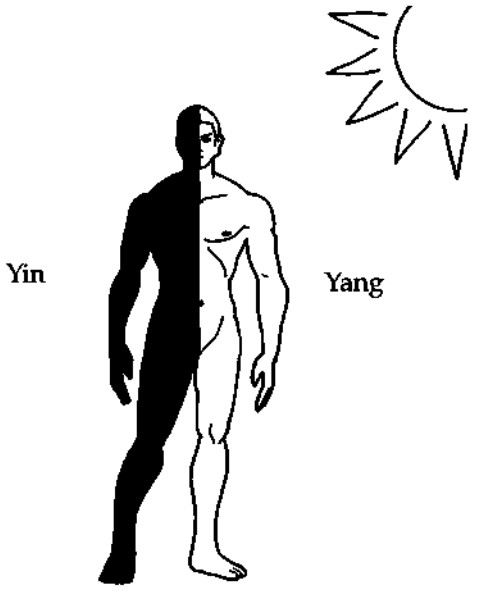

Figure 3.5. The left side of the body is Yang; the right side is Yin. Think of facing south in the morning, while performing medical Qigong practice. The sun will rise in the east, illuminating the left side (Yang) while the right side remains shaded (Yin).

other example of the effects of pathogenic Yang Qi ascending would be the temperature of a rising fever.

THE YIN AND YANG OF BODY ASPECTS

Comparable to Western anatomy, Traditional Chinese Medicine also divides the body into aspects or planes. In TCM, these classifications are divided into Yin and Yang physical planes and anatomical directions. These divisions assist the Qigong doctor in defining and categorizing the patient's external tissues, and in determining the collection and movement of Qi (i.e., energy moving into and coalescing in the patient's Yin or Yang areas of the body). The structural aspects are categorized as follows.

- The cranial or superior aspect (towards the head) of the body's structure is considered Yang; the caudal or inferior portion of the body (towards the feet) is considered Yin (Figure 3.2).
- The posterior or dorsal portion (back side) of the body is Yang; the anterior or ventral portion (front side) is Yin (Figure 3.3).
- The superficial aspect (exterior) of the body is Yang; the deep portion (interior) of the body is Yin (Figure 3.4).
- The left side of the body is Yang; the right side is Yin (Figure 3.5).

Aspect	Yang	Yin
upper/lower surface	superior (upper)	inferior (lower)
front/rear surfaces	posterior (back)	anterior (front)
position from midline/middle	lateral (away from center)	medial (middle)
near to/far from the surface	superficial (external)	deep (internal)
sides	left	right

Figure 3.6. A Summery Diagram of the Yin and Yang Aspects of the Body

The Seven Emotions			
Chinese Word	English Translation	Organ Association	Qi Manifestation
Xi	joy, happiness, excitement, pleasure	Heart	slows down and relaxes the Qi
Nu	anger, irritation	Liver	causes Qi to rise
Si	meditation, contemplation, pensiveness, worry	Spleen	stagnates the Qi
You	anxiety, sorrow, grief	Lungs	obstructs the Qi
Kong	fear, extreme anxiety	Kidneys	causes Qi to descend
Jing	shock (sudden intense fear), fright	Heart then Kidneys	scatters and deranges the Qi
Bei	grief, affliction, sadness	Lungs	disperses and consumes the Qi

Figure 3.7. The Seven Emotions and Their Effects on the Organs

- The lateral aspect (further from the center) of the body is Yang; the medial portion (middle) is Yin.

The aspects are summarized in Figure 3.6.

As Yin and Yang are in a constant state of change, always waxing and waning, two points of reference alone are not enough to aptly classify the many phases and stages of transformation; for example, day (Yang) can be further split into dawn (waxing Yang), midday (peaking Yang), and late afternoon (waning Yang). To fill this descriptive gap, the Chinese developed the theory of the Five Elements.

THE FIVE ELEMENTS

The Five Elements (Wu Xing), also translated as the Five Phases, are Wood, Fire, Earth, Metal, and Water. These Five Elements paint a clear and natural image of the changing cycles of Yin and Yang (see Chapter 23).

Furthermore, each of the Five Elements can also be divided into Yin and Yang, making a total of ten subdivisions. Wood, for example, can be subdivided into Yin Wood and Yang Wood.

The Chinese use this framework of the Five Elements to understand and categorize many different areas of knowledge, from the movements of the Heavens and the land forms of Earth to the workings of human anatomy, physiology, and psychology. Earlier in this chapter, it was noted that our organs and their associated energy channels are divided into Yin and Yang. In addition, each of the organs is also related to one of the Five Elements. The Liver and Gall Bladder relate to the Wood Element; the Heart and Small Intestine to the Fire Element; the Spleen and Stomach to the Earth Element; the Lungs and Large Intestine to the Metal Element; and the Kidneys and Bladder to the Water Element. The organs help to regulate the functional aspects of the Five Elements within the human body as they interact with each other to promote and maintain life.

The Yin organs, in particular, are said to store the Jing of the Five Elements. They share this Essence with their elementally paired Yang organs to assist with the Yang organs' functions. The Yin

organs also store the Five Agents (the Five Virtues), and are more readily disrupted by the Seven Emotions (anger, joy, worry, grief, sadness, fear, and shock) than are the Yang organs.

The emotions are said to be the primal force behind energy transformation; however, each individual will have a separate reaction to specific emotional changes, based on his or her dominant elemental pattern. Five internal organ emotions are associated with the energy of the Five Elements:

1. Anger - Liver - Wood
2. Joy - Heart - Fire
3. Worry - Spleen - Earth
4. Grief and Sorrow - Lungs - Metal
5. Fear - Kidneys - Water

In this way, the energies of the Five Elements shape all aspects of a human being: physical, energetic, mental, emotional and spiritual (Figure 3.7).

CONGENITAL CONSTITUTIONS

Most individuals are born with a dominant element, which will determine the individual's physical, energetic, and psycho-emotional constitution. When in Excess, the body's emotions can create an energetic imbalance, which in turn, can cause a destructive physical pattern within the body. An example of this process is excessive anger leading to hypertension.

The previous chapter on energetic embryology described how, from month four to month eight, the different Five Elemental Jings (Essences) enter the fetus from each of the mother's organs. Depending on the relative strength or weakness of the mother's internal organ energies during her pregnancy, the fetus will inherit a greater or lesser degree of elemental Jing from the mother. If the mother's Liver energy is dominant, then the child will have a tendency to develop a Wood constitution; if the Kidney energy is dominant, then the child develops a Water constitution, and so forth.

In addition, traditional Chinese astrology states that the various Heavenly influences at the time of birth influence the relative Five Elemental strengths and weaknesses in the newborn's constitution. Years, months, days, and hours all occur in separate cycles of five, corresponding to the Five Elements. Thus both the astrological influences at birth as well as the prenatal maternal transmission of Jing, Qi, and Shen, determine each person's congenital constitution.

After birth, the congenital Jing is cultivated and sustained through prayer, meditation, physical exercise, and sleep. In medical Qigong theory, the health of the congenital Jing determines the health and balance of the overall constitution; it determines the level of vitality and resistance to disease, as well as the mental and emotional nature of the individual. The congenital Jing, with its unique balance of the Five Elements, becomes the foundation for an individual's Qi and Shen.

The congenital influence is, however, not absolute. Postnatal factors, such as diet, life-style, environmental factors, and internal belief structures, can also influence the constitution, for better or for worse. Thus, patients with congenital deficiencies can still improve their health by prayer, meditation, medical Qigong, adequate sleep, proper diet and exercise, herbs, medicines, stress management, and other therapeutic modalities.

On the negative side, patients with strong inherited constitutions may develop serious constitutional imbalances through intemperate lifestyles such as: excess stress, overwork, excessive sexual activity, and poor eating habits. Therefore, the Qigong doctor must consider both prenatal (congenital) and postnatal (acquired) constitutional factors to understand and differentiate between the patient's innate constitution and his or her current condition.

CLASSIFICATION OF THE FIVE CONSTITUTIONS

Over the centuries, much has been written in Chinese medical literature about the Five Elemental Constitutions. The following interpretation was developed by Dr. Zhou Qianchuan, a Daoist master from Qi Cheng Shan and reputed by some to be the master of *The Yellow Emperor's Classic of Internal Medicine* (a 2500 year old three-volume text that is still one of the pivotal texts of Chinese medicine).

Dr. Zhou perceived that each of the Five Elemental Constitutions has both a characteristic physical appearance and a psycho-emotional profile. Through observing these aspects, the Qigong doctor determines a patient's Five Elemental Constitution, and from this diagnosis, the doctor discovers much about the balance or imbalance of the patient's physical and mental health.

In Traditional Chinese Medicine, somatic-build type and psyche are closely intertwined. Physical aspects, such as coloring, proportion, dominant tissue (muscle, fat, sinew, etc.), tone, movement, posture and holding patterns, as well as general vitality all express the patient's internal energetic and psycho-emotional matrices. The body type reveals to the trained Qigong doctor not only the patient's emotional history but also his or her innate personality and acquired personality characteristics.

Dr. Zhou subdivided each of the Five Elemental Constitutions into three categories: balanced nature, Yin nature, or Yang nature. The ideal is to have a balanced nature, regardless of one's elemental type. Note that the treatment addresses the mental, emotional, and spiritual balance of the five constitutions. Since the mind is so closely tied with Jing and Qi, it is not enough to simply tell patients how to change their personality to restore balance. The Qigong doctor must work with patients on all levels (physical, energetic, mental, emotional, and spiritual) to help them restore balance. Specific healing methods are discussed at length in later chapters. In general, the Qigong doctor selects treatment principles based on the Five Elements' Creative (Figure 3.8) and Controlling (Figure 3.9) Cycles to help restore balance (see Chapter 23).

For instance, a patient with a Yin Earth nature would tend to have weak or Deficient Spleen energy. Therapeutically, the Qigong doctor would choose one of the three following treatments.

1. Direct tonification of the Earth Element,
2. Tonification of the Fire Element in accordance with the principle, "To nourish the child, strengthen the mother"), or
3. Disperse or reduce the Wood Element (Wood, the "grandmother", may be overcontrolling Earth, the "grandson").

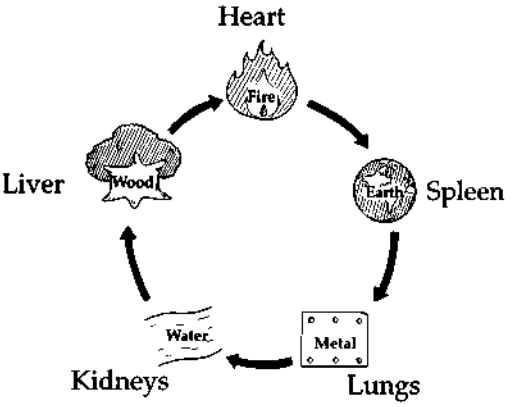

Figure 3.8 The Five Elements' Creative Cycle

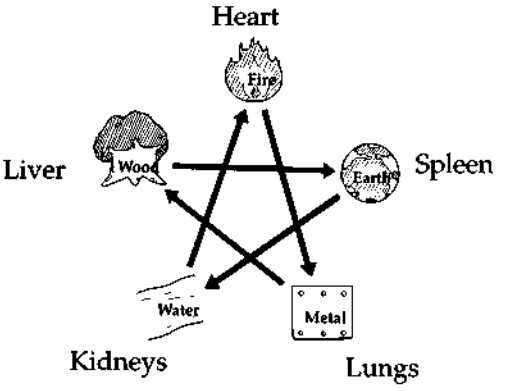

Figure 3.9. The Five Elements' Controlling Cycle

In the instance of Yang Earth nature, the patient would tend to have Excess Earth. In this case, the Qigong doctor could:

1. Use a method to reduce the Earth Element directly; or,
2. Strengthen the Wood Element (the weak "grandmother" may be unable to restrain an overly strong "grandson" without help).

THE WOOD CONSTITUTION

WOOD OUTER APPEARANCE

Wood constitution types usually have a tall and slender body with a small head and a long face. They also have small, nicely formed hands and feet, broad shoulders, and a straight, flat back (Figure 3.10). By nature, they enjoy spring and

summer but dislike autumn and winter. This preference is due to the vulnerability of the Wood constitution and its susceptibility to pathogenic invasion and disease during these time periods. Their dominant features include strong sinews and green-blue facial color. Their note is "jue."

WOOD PERSONALITY

The Wood personality can be divided into three subdivisions.

1. A Balanced Wood nature predisposes individuals to be confident, strong, independent, and intuitive, with a clear understanding of themselves and their goals. They are patient, able to allow things to develop naturally, and express their personality in a relaxed harmonious way. They are kind when communicating with others, creative, free-flowing in self-expression, and display merciful and unselfish traits when dealing with the needs of others.
2. A Yin Wood nature predisposes individuals to feel externally insecure, and to be always cautious. They have a tendency to worry and have a weak sense of their own abilities and potential. They are unassertive and are unsure of their identities and life purpose. They also have difficulty expressing their egos and have weak boundaries. They are timid, lack confidence, and display considerable doubt.

   Treatment for Yin Wood nature individuals involves establishing a sense of inner strength and security by teaching them self-trust and building self-esteem. These individuals need to strengthen their boundaries to avoid the intrusion and domination of others. They need to trust in their intuition, develop a greater degree of confidence, enhance their personal power, and find a stronger sense of spiritual growth.
3. A Yang Wood nature predisposes individuals to manifest their internal insecurity through acting irritable and impatient. Such individuals are intolerant, rude, stubborn, and selfish, and tend to expand their egos without consideration for others. They are domineering, angry, aggressive, and generally known as

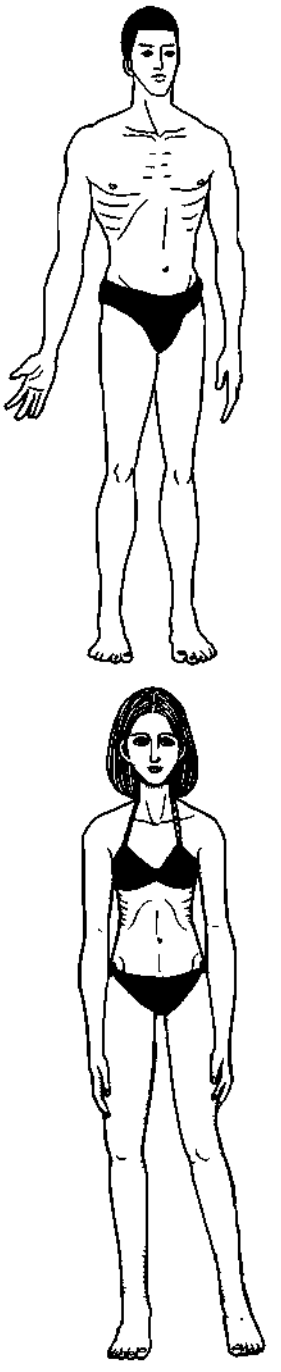

Figure 3.10. The Wood Constitution in Males and Females

overachievers; however, they are easily frustrated and depressed. Their self-esteem is elevated by acquiring higher political (influential) positions or bullying others.

Treatment for Yang Wood nature individuals should focus on cultivating a discipline of inner peace, following the Dao, to harmonize with life. In situations of conflict, they need to learn to relax, slow down, and act out of stillness. They need to surrender to a higher will, relying on their spiritual intuition and inner direction. They also need to learn to respect others.

THE FIRE CONSTITUTION

FIRE OUTER APPEARANCE

Fire constitution types usually have broad paravertebral muscles and well-proportioned shoulders, upper back, and thighs. They have small pointed heads, pointed chins, small hands, and feet, and curly, or no hair, on top of their head (Figure 3.11). By nature, they enjoy spring and summer but dislike autumn and winter. This preference is due to the vulnerability of the Fire constitution and its susceptibility to pathogenic invasion and disease during these time periods. Their dominant features include a strong circulatory system and a red facial color. Their note is "zhi."

FIRE PERSONALITY

The Fire personality can be divided into three subdivisions.

1. A Balanced Fire nature predisposes individuals to be trusting, open-minded, complacent, social, unconcerned about wealth, and fond of beauty. They love themselves and others, and are very expressive of their affection. They are calm, peaceful, happy, lively, spontaneous, funny, and fun to be with.
2. A Yin Fire nature predisposes individuals to be solemn and depressed. They tend to lack interest in life, and have a tendency to become isolated, feeling unloved and unlovable.

   Treatment for Yin-Fire nature individuals requires teaching them how to store and conserve their energy, to use moderation in what

Figure 3.11. The Fire Constitution in Males and Females

they do, and to avoid extremes. They also need to engage in activities that create personal enjoyment, to find simple pleasures that awaken their affection, and to learn how to express their feelings, wants, and needs.

3. A Yang Fire nature predisposes individuals to be arrogant, ignorant, and troublesome. They are restless, excitable, and talk excessively. They always exaggerate and are overenthusiastic. They are socially and sexually overactive and seek every opportunity to assert themselves. They are foolish and display careless behavior. They are overconfident, slightly lazy, irresponsible, and less than truthful. They can be manic, get exhausted, then burnout and become suicidal (e.g., bipolar disorder).

   Treatment for Yang-Fire nature individuals requires teaching them to learn how to stop, slow down, and look for their contentment from within. They should balance their feelings of love with contemplation and wisdom, avoid over-enthusiasm, and allow their inner spirit to radiate through in a more sober way.

THE EARTH CONSTITUTION

EARTH OUTER APPEARANCE

Earth constitution types usually have a somewhat large body, large head, large belly, strong thighs, round face, and wide jaw (Figure 3.12). They are categorized as having excessive flesh, with upper and lower limbs mutually well-proportioned. By nature, they enjoy autumn and winter but dislike spring and summer. This preference is due to the vulnerability of the Earth constitution and its susceptibility to pathogenic invasion and disease during these time periods. Their dominant features include strong muscles and yellow facial color. Their note is "gong."

EARTH PERSONALITY

The Earth personality can be divided into three subdivisions.

1. A Balanced Earth nature predisposes individuals to lead quiet, stable, and peaceful lives, unconcerned about fame or wealth. They are always at ease, calm, generous, forgiving, sincere, and unambitious. They usu-

Figure 3.12. The Earth Constitution in Males and Females

ally have open minds and rarely live in fear, or make excessive demands. They have analytical minds and are logical and practical; they use sound reasoning to convince others of their opinions. They are quite adaptable to changing situations, and rarely use coercion to achieve power. They are kind and gentle with an earnest and well-mannered attitude. They are pleasant, sweet, sympathetic and caring, and are able to maintain boundaries.

2. A Yin Earth nature predisposes individuals to worry endlessly, becoming suspicious and self-centered. They think too much, with not enough follow-through action. Because they feel empty inside, they find it difficult to be nurturing to themselves and others.

   Treatment for Yin Earth nature individuals requires teaching them to learn how to let go of their inner feelings of worry and defensiveness. These individuals need to examine their assumptions, connect with their physical bodies, come out of their shells, and begin to live in the real world. They need to replace their negative thought patterns with positive affirmations, and realistically look at their true potential and abilities for powerful actions.

3. A Yang Earth nature predisposes individuals to cling to others; they are co-dependent, pushy, and possessive. Such individuals try to dominate in a passive-aggressive way while limiting the independence of others.

   Treatment for Yang Earth nature individuals consist of teaching them to develop their inner strength to control the fear, insecurity, and feelings of inner emptiness that make them want to hold on to others. They need to create and establish love as a source of security from within themselves. They need not depend on, or build their lives exclusively on, the praise or presence of others. They must learn to become emotionally independent.

THE METAL CONSTITUTION

METAL OUTER APPEARANCE

Metal constitution types usually have a triangular face with broad, square shoulders, a strong voice, and a strong, muscular build (Figure 3.13). By nature, they enjoy autumn and winter but dislike spring and summer. This preference is due to the vulnerability of the Metal constitution and its susceptibility to pathogenic invasion and disease during these time periods. Their dominant features include strong Lungs and white facial color. Their note is "shang."

METAL PERSONALITY

The Metal personality can be divided into three subdivisions.

1. A Balanced Metal nature predisposes individuals to process their grief, letting go of their past emotional baggage. They believe that they cannot be in the present without cleaning up and being released from their past. They are able to gain knowledge and wisdom by gathering and releasing their emotional bonds while learning and growing from each emotional attachment. They participate in life and form new bonds without fear of loss. They are also generous, just, and bright.
2. A Yin Metal nature predisposes individuals to have a difficult time creating lasting bonds because they are fearful of establishing new relationships due to past losses and emotional trauma. They avoid joining in with others and withdraw from active participation. Living in past remorse, they grieve over lost opportunities. They are also haughty and coldhearted. They are jealous, cunning, sneaky, and furtive. They become angry when they do not have things that others possess. Because they are covetous, they only obtain happiness by possessing certain objects.

   Treatment for Yin Metal nature individuals requires teaching them how to strengthen their physical body, as well as the energy of their Heart, Spleen, and Lower Dantian. They also need to strengthen their abilities to form close emotional bonds with people, reduce their fears of rejection and abandonment, and gain the strength and courage to let go of their past hurts. They need to come out from inside of themselves emotionally and experience the warmth and compassion of life.
3. A Yang Metal nature predisposes individuals

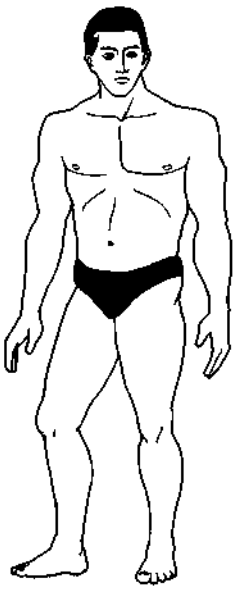

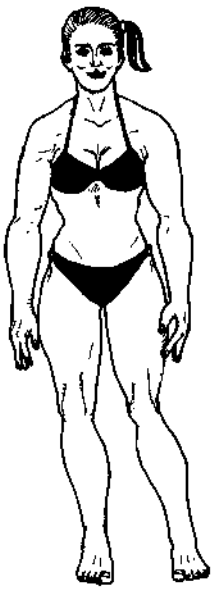

Figure 3.13. The Metal Constitution in Males and Females

to suppress their emotions and hold on to their grief. They are generally considered whiners and complainers, talking to others about their complaints in order to unload their grief. They use new relationships as an emotional bandage to avoid the unprocessed grief of their past relationships. They are also meticulous, independent, and strong-willed.

Treatment for Yang Metal nature individuals requires teaching them how to let go of the need to control and suppress their emotional feelings, and how to genuinely grieve over past wounds. They need to face the truth and be honest about their feelings, instead of selfishly using people and new relationships to cover up their grief. They also need to learn to be sympathetic with the pain and sorrows of others, and put their feelings of grief into perspective.

THE WATER CONSTITUTION

WATER OUTER APPEARANCE

Water constitution types usually have a big round face, head and body (Figure 3.14). They have a long upper back, and unbalanced or uneven physical features. They, by nature, enjoy autumn and winter but dislike spring and summer. This preference is due to the vulnerability of the Water constitution and its susceptibility to pathogenic invasion and disease during these time periods. Their dominant features include their digestive system and black or dark facial color. Their note is "yu."

WATER PERSONALITY

The Water personality can be divided into three subdivisions.

1. A Balanced Water nature predisposes individuals to be skilled negotiators, that are not discouraged by difficulty, and do not take foolish risks. They are sympathetic and loyal to their employer and friends. They have a clear perspective and are sensitive and intuitive. They are powerful, tender, and soft. They have a firm will and know their boundaries and limitations. They are known for their inner strength and strong faith in themselves.

2. A Yin Water nature predisposes individuals to lack spiritual, emotional, mental, and physical energy. They give up on life and surrender the control of their own destinies. They lack the determination to achieve their goals, do everything halfheartedly, and become easily discouraged by difficult challenges.

   Treatment for Yin Water nature individuals requires teaching them how to conserve and strengthen their energy by not attempting to do what's beyond their capacity. They should complete their projects, however, once they have started them, and not procrastinate or leave tasks unfinished. They need to find the strength to overcome their fear of failure by learning to take action through the completion of their goals.
3. A Yang Water nature predisposes individuals to be ambitious overachievers and to live under great stress. They lack consideration for others, and can be reckless and foolhardy. They can also be greedy, ruthless, and cold-blooded. Seemingly modest, they are actually insidious and sinister, concealing their true emotions by suppressing their fears. Because they fear loss of control, their safety lies in dominating others. They only perform duties that are self-serving and blame others for their problems.

   Treatment for Yang Water nature individuals requires that they learn how to act from inner stillness and gain strength and courage from their inner true self. They also need to emotionally and physically slow down, and to balance their activities with rest. They need to learn to gain consideration for themselves and others, as well as to open up their heart and begin to love.

Figure 3.14. The Water Constitution in Males and Females

COMBINED CONSTITUTIONS

In ancient China, The Yellow Emperor's physician Shao Shi taught that the Five Elemental constitutions consist of Five Elemental forms, which can be further divided into five additional shapes depending on the strength or development of the individual's Jing, Qi, and Blood. After establishing the patient's physique (Wood, Fire, Earth,

Metal, or Water), the patient is then classified in terms of five separate colors, and differentiated according to the five prenatal (Heavenly) notes. This system recognizes 25 constitutional types.

The Five Elemental Constitutions are therefore, guidelines for the Qigong doctor to evaluate the patient. These guidelines are not fixed, as the doctor is most likely to encounter combinations of two or more of these elements within one person.

When two constitutions combine in an individual, the combination may be congenital or acquired. The Qigong doctor must evaluate the patient, differentiating between his or her congenital and acquired tissue formations.

A woman who has large hips (Water) and small chest and shoulders (Wood), for example, probably inherited this structure from her parents. This woman's physical structure and personality would then be considered a combination of both Water and Wood (depending on which internal organ characteristic dominates).

A female patient who swims, on the other hand, may be congenitally Wood but may have developed a dominant Metal upper physique through years of physical training. If, through intense physical activity, someone acquires a Metal physique, he or she may also acquire a Metal personality, depending again on his or her psychological format, which is rooted within the internal organs.

The external physical structure serves as a visual guide to the interaction and balance of the internal organs.

PERSONALITY CONSTITUTIONS OF THE EIGHT EXTRAORDINARY VESSELS

Another system of identifying personality traits is practised by observing the four personality constitutions of the patient's Eight Extraordinary Vessels.

Through observation and inspection of the patient's personality and overall energetic and emotional demeanor, the Qigong doctor can further determine which organ and organ system, is Deficient or has an Excess condition and set up a treatment plan.

To begin, the Qigong doctor will first observe the patient's dominant Yin or Yang emotional characteristics and determine which of the Eight Extraordinary Vessels are governing his or her present state of feelings. These personality traits may appear in different combinations, or oscillate from one type of characteristic to another, due to the crossover of acquired and congenital organ energy. This crossover can change with the patient's age (maturation) or situation (environment).

THE PATHOLOGICAL PERSONALITY TYPE OF THE GOVERNING AND YANG HEEL VESSELS

The Governing and Yang Heel Extraordinary Vessels are located on the back and lateral sides of the body and affect the Bladder, Stomach, and Gall Bladder Channels. To "open" and increase the flow of energy within these channels, the Qigong doctor stimulates the patient's SI-3 and Bl-62 points simultaneously (see Chapter 8).

The pathological personality types of the Governing and Yang Heel Vessels are divided into Yin and Yang emotional characteristics. These characteristics are as follows.

1. Patients with Deficient Qi in the Governing and Yang Heel Vessels tend to be weak-willed and spineless. They tend to be overly submissive, and easily give up their personal power. They lack determination, courage, clarity, and inner strength, and have no control over their lives. They participate as little as possible in life for fear of failure.
2. Patients with Excess Qi in the Governing and Yang Heel Vessels tend to be tense, overpressured, stiff, rigid, inflexible, stubborn, and awkward. They are narrow-minded and overcontrolling. Fearful of letting go, they overcompensate and attempt to restrict reality.

THE PATHOLOGICAL PERSONALITY TYPE OF THE CONCEPTION AND YIN HEEL VESSELS

The Conception and Yin Heel Extraordinary Vessels are located on the front and inside of the body. They affect the Lung and Kidney Channels, which in turn affect the Kidneys, Lungs, and Heart organs. To open these channels, the Qigong doctor stimulates the patient's Lu-7 and Kd-6 points simultaneously. These character diagnoses are as follows.

1. Patients with Deficient Qi in the Conception and Yin Heel Vessels tend to be weak and depressed. They live in the past, lack interest in life, have no ambition, and also lack interest in sex. It is hard for them to form new relationships because they fear forming emotional bonds due to past losses, failures, and emotional traumas. They constantly daydream and live in their own world of past memories.
2. Patients with Excess Qi in the in the Conception and Yin Heel Vessels tend to participate in life, but hold on to, and suppress, their grief. They fail to let go of emotional attachments and fear being alone. The female patients usually develop Qi stagnations resulting in breast cysts, tumors, and cancer, as well as uterine fibroids and cancer.

THE PATHOLOGICAL PERSONALITY TYPE OF THE BELT AND YANG LINKING VESSELS

The Belt and Yang Linking Extraordinary Vessels are located around the waist and on the outside of the body. They affect the Gall Bladder and Triple Burner Channels, which in turn, affect the Kidneys, Liver, and Gall Bladder organs. To open these channels, the Qigong doctor stimulates the patient's GB-41 and TB-5 points simultaneously. These character diagnoses are as follows.

1. Patients with Deficient Qi in the Belt and Yang Linking Vessels are considered weak, indecisive, and unproductive. They fear criticism and are touchy, snappy, irritable, and hypersensitive. They have low self-esteem and also lack interest in sex.
2. Patients with Excess Qi in the in the Belt and Yang Linking Vessels are aggressive, angry, resentful, bitter, and vindictive. They are also opinionated, inflexible, intolerant, domineering, selfish, and frustrated, with a sex life based on anger or rage.

THE PATHOLOGICAL PERSONALITY TYPE OF THE THRUSTING AND YIN LINKING VESSELS

The Thrusting and Yin Linking Extraordinary Vessels are located within the center of the body (internally) and on the medial and anterior aspect of the body (externally). They affect the Kidney and Stomach Channels, which in turn, affect the Kidneys, Spleen, and Heart organs. To open these channels, the Qigong doctor stimulates the patient's Sp-4 and Pc-6 points simultaneously. These character diagnoses are as follows.

1. Patients with Deficient Thrusting and Yin Linking Vessels are physically and emotionally weak. They quickly become exhausted and depressed. They easily have their feelings hurt and take a long time to recover from emotional upsets. Their internal world of emotional existence is made up of fear, anxiety, worry, and tension. They do not connect well with the outside world or gain much pleasure from life or relationships.
2. Patients with an Excess in the Thrusting and Yin Linking Vessels tend to participate in life, but have difficulty expressing their affections and communicating their needs in relationships. They are inclined to have stagnant Qi and Blood in their chests, epigastrium, or uterus areas due to fear, anxiety, worry, and sorrow. In their personal relationships, they fear loss of control and cannot make a commitment or a deep emotional connection with others. They also fear surrendering and letting go in their love and sexual relationships.

THE YAO IMAGE AND PHYSICAL ANATOMY

Sometimes because of surgery, congenital deformity, or traumas, it is not possible, nor is it recommended, to directly treat certain areas of the patient's body. The Qigong doctor must then choose an indirect method of treatment to ensure better results. One such method available to the doctor utilizes the understanding of the Yao image and the patient's physical anatomy. In order to better comprehend the complexity of this diagnostic and treatment modality, the Qigong doctor must first understand the energetic origin of the Yao images.

All matter is composed of different proportions of Yin and Yang energy. Within the Void (infinite space or Wuji) both Yin and Yang energy gather or disperse to balance the forces of nature. This interaction causes the Yin and Yang energies

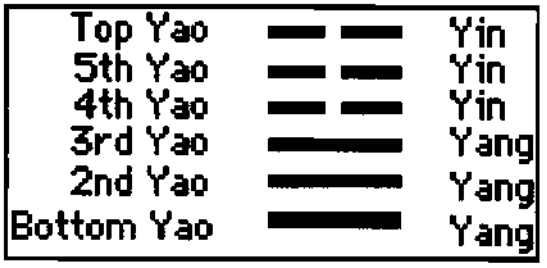

Figure 3.15. This diagram shows a hexagram, composed of an upper and lower trigram. In this particular example, the upper trigram is all Yin lines (symbolized by broken lines), the lower all Yang (symbolized by solid lines).

to develop and transform themselves into four phases of energetic powers or stages: Great Yin, Small Yin, Great Yang, and Small Yang. These four phases can be explained as follows.

1. Great Yin (Tai Yin), is affiliated with midnight and the new-moon phase. Modern physicists associate the Great Yin with a weak nuclear force.
2. Small Yin (Shao Yin), is affiliated with the sunset and the waning-moon phase. Modern physicists associate the Lesser Yin with a heavy force, and gravity.
3. Great Yang (Tai Yang), is affiliated with high noon and the full-moon phase. Modern physicists associate the Strong Yang with a strong nuclear force.
4. Small Yang (Shao Yang), is affiliated with the sunrise and the waxing-moon phase. Modern physicists associate the Lesser Yang with a light force and electromagnetism.

These four solar and lunar energetic phases transform themselves into the energies of the eight foundational trigrams. These trigrams further combine to form sixty-four hexagrams, and manifest as the ancient binary system known as the Yi Jing (I Ching). The formation and pattern of these energetic powers or stages vary according to the composition of Yin and Yang, and can be expressed through the energetic symbols of the Yao.

A Yao is a line that represents either Yin or Yang energy. The lines fall into two categories:

- The negative Yao is symbolized by broken lines (Yin energy).
- The positive Yao is symbolized by solid lines (Yang energy).

When these lines are stacked in combinations of three, they form what are known as trigrams (a group of three Yao lines). When pairs of trigrams are joined, hexagrams (six lines) are formed. The lines are arranged from bottom to top, with the first Yao being on the bottom (Figure 3.15).

The Yao trigrams and their relationship to the body's physical and energetic structure can be utilized by the Qigong doctor for diagnosis and treatment. The doctor applies the Yao image as a template and arranges its pattern alongside the physical form of the patient's body. This arrangement of Yao images is designed by the doctor to assist him or her in recognizing the physical and energetic imbalances within the patient's body. This type of physical Yao image diagnosis has been used in China for centuries.

Knowing that each different region of the human body corresponds to one of the six Yaos in the hexagram, as well as a different aspect of Qi, the ancient masters explained the energetic Yao and physical body interaction as follows.

1. The two lowest Yaos align with the feet and legs and correspond to the body's interaction with the Earth's energy.
   a. The 1st Yao extends from the patient's feet, ankles, and shins, to the knees.
   b. The 2nd Yao extends from the knees to the upper thighs.
2. The middle two Yaos align with the lower and upper abdominal regions, and correspond to the body's interaction with human energy, or "Man's energy" (emotional responses).
   a. The 3rd Yao extends from the perineum to the navel.
   b. The 4th Yao extends from the navel to the xiphoid process in the diaphragm.
3. The upper two Yaos align with the upper chest, neck and head, and correspond to the body's interaction with Heaven's energy.
   a. The 5th Yao extends from the xiphoid process of the diaphragm to the top of the manubrium, at the base of the throat.

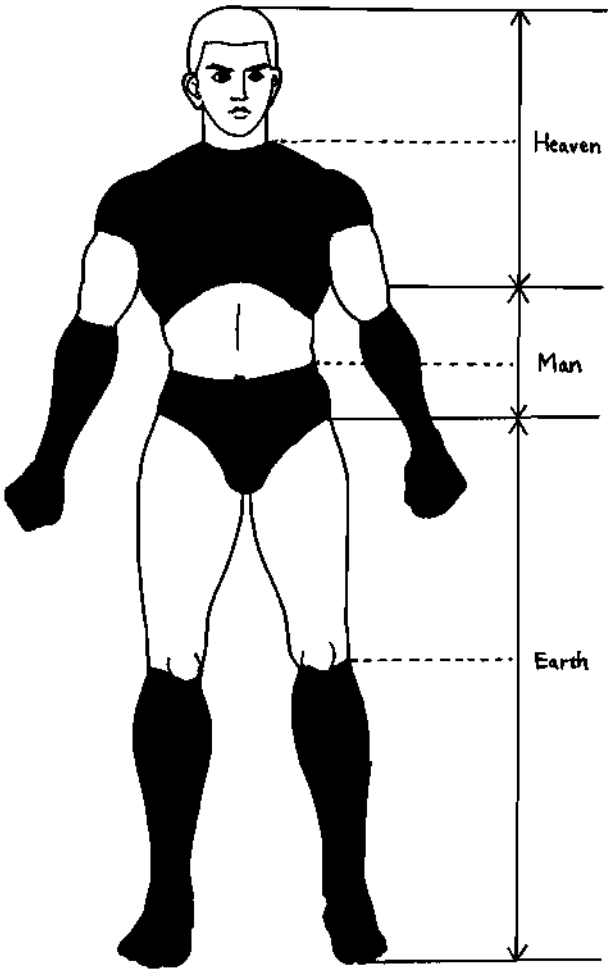

- The top or 6th Yao is from the neck to the top of the head. (Heaven)
- The 5th Yao is from the diaphragm to the neck. (Heaven)
- The 4th Yao is from the navel to the diaphragm. (Man)
- The 3rd Yao is the lower perineum to the navel. (Man)
- The 2nd Yao is from the knee to the top of the thigh. (Earth)
- The bottom or 1st Yao is from the foot to the knee. (Earth)
- The Categorization of the arms are as follows: From the fingers to the elbow represents the Bottom or 1st Yao; From the elbows to the base of the shoulder represents the 2nd Yao; From the base to the top of the shoulder represents the 3nd Yao.

Figure 3.16. Yao Image and the Human Body

b. The 6th Yao extends from the manubrium, at the base of the throat, to the top of the head.

The doctor further divides the patient's body into six upper and lower Yaos, to determine the dominant energetic and emotional patterns (where the patient's Qi is gathering, collecting, and stagnating). Through observation and study, the Qigong doctor is able to determine the energetic association the patient has with the natural environment. This diagnosis is achieved by observing the body's relationship to the three energetic Yao divisions of Heaven, Earth, and Man (Figure 3.16). When observing the body, for example, if the upper Yao is out of harmony with the patient's middle and lower Yaos, the patient's energetic balance may be compromised, and he or she may experience a spiritual disconnection with his or her body. This can result in either a Yang condition (heaviness, restlessness) due to an Excess spiritual "Heaven" state, or a Yin condition (tired, dizziness) due to a Deficient spiritual "Heaven" state.

In addition to diagnosing the hexagram for the body's Yin and Yang relationship to Heaven, Earth, and Man, the ancient Chinese Qigong masters also studied two other hexagrams for clinical evaluation. These hexagrams were known as the Upper and Lower Hexagrams.

UPPER AND LOWER HEXAGRAMS

In the Ming Dynasty (1368-1644), Tang Rongchuan stated in his book *Detailed Explanations of Application of the Book of Changes to Medicine*, "In the clinical environment, the body may be divided into two different sets of hexagram constructions [the upper and the lower hexagram partition] for the purpose of making a diagnosis, detecting Qi, and for performing Qigong therapeutic treatments." This relationship of Yao positioning is suitable to both the channel system and the nervous system.

Physical disorders located within these hexagrams are generally expressed as symptoms manifesting in the extremities. If stagnant Qi or other abnormal conditions occur in any particular part of the body, an imbalance of both Internal and External Qi may be detected in either that specific area of the body or its corresponding area.

The ancient Qigong masters used the body's hexagrams to explain the etiology, pathology, clinical manifestations, and treatment principles of disease.

The body's upper torso, arms, neck, and head are divided into what is known as the upper hexagram partitions, while the body's lower limbs and torso are divided into the lower hexagram partitions. The six Yao of the upper and lower hexagram partitions interlock at the chest and abdomen. By using these sets of hexagrams, the Qigong doctor has a template or guiding pattern with which to understand the patient's body.

The Upper Hexagram Construction

The Upper Hexagrams range from the base of the lower perineum to the top of the patient's head. These six Yaos are organized as follows.

1. The 1st or bottom Yao encompasses the pubic symphysis to the navel. Reproductive, digestive, and urinary tract diseases are ascribed to this area.
2. The 2nd Yao encompasses the navel to the xiphoid process. Malfunctions in digestion, elimination and the transportation of nutrients are assigned to this area, as well as diseases of the Kidneys, adrenal glands, Liver, Spleen and pancreas.
3. The 3rd Yao encompasses the xiphoid process to the supraclavicular notches. Respiratory and circulatory diseases are ascribed to this area.
4. The 4th Yao encompasses the supraclavicular notch to the tip of the nose. Teeth, jaw, and thyroid diseases are ascribed to this area.
5. The 5th Yao encompasses the tip of the nose to the eyebrow. Sinus problems and headaches, as well as ear, nose, and eye diseases are manifest in this area.
6. The 6th or top Yao encompasses the eyebrows to the top of the head. Several types of headaches, brain tumors, and upper cranial dysfunctions are ascribed to this area.

The Lower Hexagram Construction

The Lower Hexagrams range from the bottom of the patient's feet to the base of the patient's throat. These six Yaos are organized as follows:

1. The 1st or bottom Yao encompasses the bottom of each foot to the ankle. Foot, toe and ankle dysfunctions are ascribed to this area.
2. The 2nd Yao encompasses the ankles to the knees. Shinsplints and calf and ankle dysfunctions are ascribed to this area.
3. The 3rd Yao encompasses the knees to the pubic symphysis. Thigh, knee, and quadriceps dysfunctions are ascribed to this area.
4. The 4th Yao encompasses the pubic symphysis to the navel. Reproductive, digestive, and urinary tract diseases are ascribed to this area.
5. The 5th Yao encompasses the navel to the xiphoid process. Digestion, elimination, and the transportation of nutrients, as well as diseases of the Kidneys, adrenal glands, Liver, Spleen and pancreas are ascribed to this area.
6. The 6th or top Yao encompasses the xiphoid process to the supraclavicular notches at the base of the throat. Respiratory and circulatory diseases are ascribed to this area.

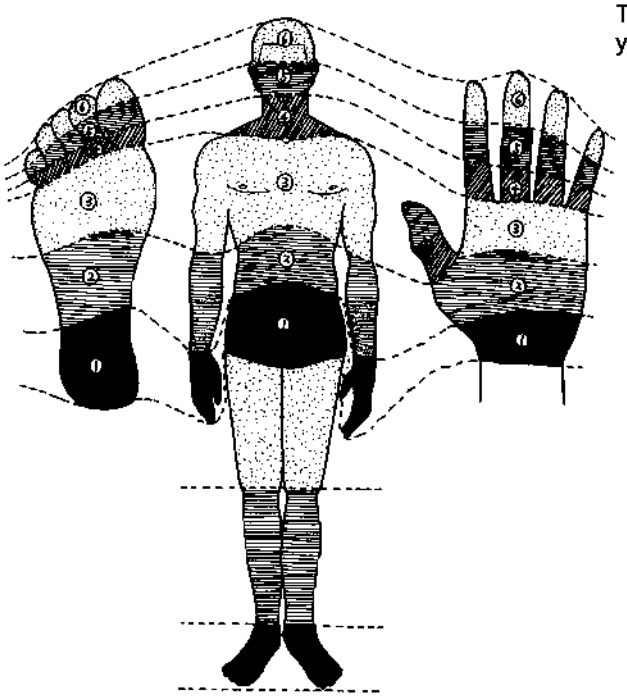

The diagram at left depicts the correspondence of the yaos of the body to the yaos of the hands and feet.

6 The second joint of the toes or fingers pertains to the top Yao and the energy of Heaven.

5 The first joint of the toes or fingers pertains to the 5th Yao and the energy of Heaven.

4 The area below the first joint of the toes or fingers pertains to the 4th Yao and the energy of Man.

3 The ball of the foot or upper palm pertains to the 3rd Yao and the energy of Man.

2 The instep on the midpalm with the thumb pertains to the 2nd Yao and the energy of Earth.

1 The heel or lower palm pertains to the bottom Yao and the energy of Earth.

Figure 3.17. The Therapeutic Use of the Yaos and the Upper and Lower Hexagrams

THERAPEUTIC USE OF THE YAOS

The entire body can be treated by focusing on one small area. When Excess, Deficient, or stagnant Qi occurs in one part of the body, the imbalance of Internal and External Qi is detectable in that area or its corresponding region on one of the body's extremities. This ancient Chinese modality of treatment is popularly called reflexology in the West.

The Yao images can be superimposed onto the patient's body, and the patient diagnosed according to the energetic symptoms expressed through either the patient's extremities (the hands, forearms and arms; or the feet, shins, and thighs), or the six divisions located on the patient's torso and head. A Yao hexagram can additionally be visualized on specific locations of the patient's body such as the face, nose, ears, hand or foot for diagnosis. The base of the palm's heel, for example, corresponds to the lower abdominal area and reproductive organs, which relate to the 1st, or lower, Yao in the hexagram of the hands. These six Yao areas of the hand provide a basis for diagnosis, for treatment of certain diseases, and even for perception and prediction of certain future diseases (Figure 3.17).

As an example of how the Qigong doctor can use the six Yaos of the body for emitting Qi therapy, consider the following situation: An elderly patient with a problem in his prostate area visits the Qigong doctor. The prostate is located in the lower abdominal area, which is located in the 1st Yao of the upper hexagram. Since the six Yao positions can be transferred to the hands, feet, etc., the doctor knows that this particular Yao is congruent to the 1st Yao of the foot. Therefore, as an energetic entry point into the patient's prostate area, the doctor may focus his or her attention on a specific area on the foot.

Dividing the foot into six Yaos, the doctor knows that the 1st Yao of the foot is the heel area. In order to treat the prostate gland, the doctor will

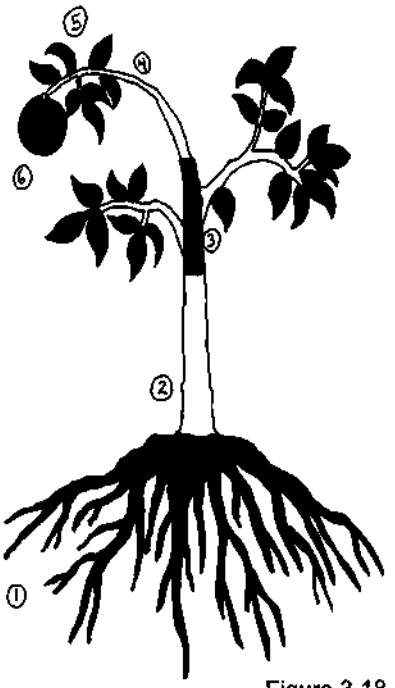

6 The fruit or flower of the herb pertains to the top Yao and the energy of Heaven.

5 The leaf of the herb pertains to the 5th Yao and the energy of Heaven.

4 The branch of the herb pertains to the 4th Yao and the energy of Man.

3 The upper stem of the herb pertains to the 3rd Yao and the energy of Man.

2 The stalk of the herb pertains to the 2nd Yao and the energy of Earth.

1 The root of the herb pertains to the bottom Yao and the energy of Earth.

Figure 3.18. The Yao Image Applied to Plants

focus his or her treatment on the patient's heel and ankle area. Alternatively, the doctor could also have chosen the 1st Yao area of the hand, which is considered the 1st Yao position of the arm. The 1st Yao of the hand corresponds to the prostate and urogenital area.

HERBS AND THE YAOS

Affirming the ancient Chinese belief that the energy of Heaven, Earth, and Man combine as "one," and exist in the same world of energetic dynamics, herbs are also structured and prescribed in accordance with the six Yao hexagram concept. With plants, the following correspondences apply (Figure 3.18):

1. The roots correspond to the bottom or 1st Yao.
2. The stalk corresponds to the 2nd Yao.
3. The upper stem corresponds to the 3rd Yao.
4. The branches correspond to the 4th Yao.
5. The leaves correspond to the 5th Yao.
6. The flowers and fruit of the plant correspond to the top or 6th Yao.

When plants are utilized as a medicine, the part of the plant corresponding to the number and position of the Yao may manifest its energetic properties, affecting the ascending, descending, floating, or sinking action of the patient's Qi. The achyranthes root (Niu Xi), for example, corresponds to the bottom Yao, and leads healing Qi downward, to heal the patient's knees and joints; whereas the chrysanthemum flower (Ju Hua) corresponds to the top Yao, and leads healing Qi up into the patient's head and eyes.

IDENTIFYING INTROVERTED AND EXTROVERTED STRUCTURES

Qi flows through the matrix of the connective tissue and adapts to the postural and structural demands of the body by changing the density and direction of the body's connective tissues and inner fasciae. A postural habit will create an imprint or tissue memory in the supporting connective tissue, as well as an energetic memory in the supporting field of Qi. These imprints result in introverted as well as extroverted postural structures.

Each introverted (Yin) and extroverted (Yang) postural structure has a predictable impact on the

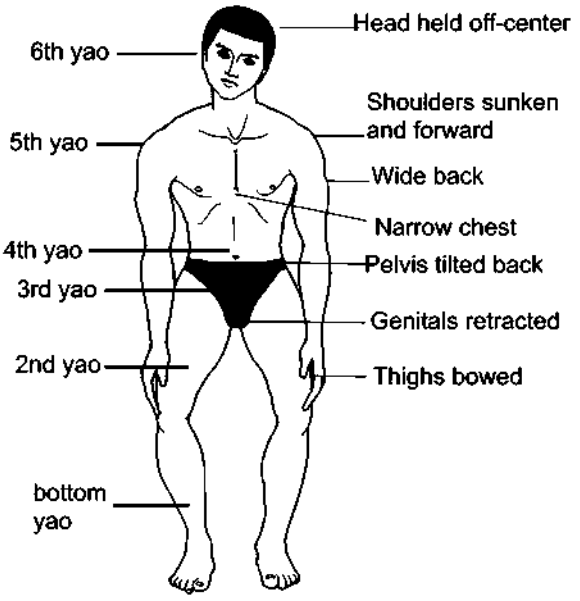

Figure 3.19. The Introverted Structure

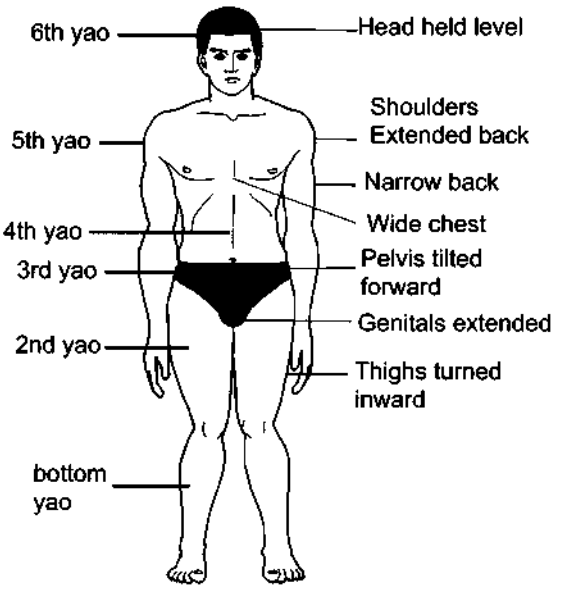

Figure 3.20. The Extroverted Structure

myofascial webbing, as well as a natural emotional response. Emotions respond to changes in breathing patterns and vice versa. Both the prevalent breathing pattern and the patient's general mood affect the body's posture and eventually the body's structure. All chronic stress creates postural imprinting or tissue memory, and a corresponding energetic memory in the supporting field of Qi.

INTROVERTED STRUCTURE

When observing the introverted type of structure, the doctor will notice that the back (Yang) area of the patient is expanded, and the muscle structure is usually well-developed. The front of the body (Yin), especially around the chest and Heart area, is retracted, resulting in a narrow chest. The patient's head is generally held off-center, shoulders are sunken and forward, and the pelvis is tilted back, with the genitals retracted (anterior tilt). This condition is commonly referred to as "extended Yang" and "retracted Yin" of the upper torso (Figure 3.19).

EXTROVERTED STRUCTURE

When observing the extroverted type of structure, the doctor will notice that the back (Yang) area of the patient is retracted, while the front of the body (Yin) is expanded and overly exposed. The head is usually held vertically, the shoulders are extended back (military posture), the chest is wide, and the pelvis is tilted forward, with genitals extended (posterior tilt). This condition is commonly referred to as "extended Yin" and "retracted Yang" of the upper back (Figure 3.20).

COMBINED STRUCTURAL FORMATIONS

As with the Five Elemental Constitutions, the introverted and extroverted structures are guidelines for the Qigong doctor to evaluate the patient. These guidelines are not fixed, as the doctor is most likely to encounter combinations of both introverted and extroverted structures within one person.

When two structures combine in an individual, the combination may be due to a congenital or acquired formation. The Qigong doctor must evaluate and assess the patient, differentiating between his or her congenital and acquired tissue formations.

CONGENITAL AND ACQUIRED CELLULAR PATTERNS

The Qigong doctor evaluates the physical condition according to the congenital or acquired patterns manifested within the patient's tissues. The doctor may ask questions to determine if the condition was acquired through exposure to environmental pathogens, diet, trauma, occupation, or inherited. This information aids the Qigong doctor in understanding and assisting the patient in reprogramming any congenital or acquired cellular patterns, as well as internal disease functions.

1. Congenital Cellular Patterns and disease predispositions are locked within the patient's congenital Jing and can be released like a biological time bomb. This is a similar concept to the Western medical concept of genetic congenital disease. The goal of the Qigong doctor is to alter (if possible) the Toxic Qi patterns and help the patient's body recognize that the formation of the disease is a mistake. In order to reprogram these patterns, the Qigong doctor often assists the patient in using guided meditations that employ vivid imagination, colorful visualizations, and positive affirmations. These images are used to encapsulate the disease and return it to the divine light. While in the presence of the divine light, the Toxic Qi (Xie Qi) will be energetically transformed and recycled back to the patient as healing energy. Patients with a direct family history of cancer, for example, can benefit from this type of medical Qigong imagery.
2. Acquired Cellular Patterns and disease functions arise from either external exposure to pathogens, or the suppression of extreme emotions. The goal of the Qigong doctor is to first assist the patient in discovering the origin of the disease. The next step is to teach the patient to alter the toxic patterns and help the patient's body recognize that the development of the disease is a mistake. In order to reprogram these patterns, the Qigong doctor will assist the patient in learning meditations that employ healing mental imagery, colorful visualizations, and positive affirmation. The patient must encapsulate the disease and return it to the divine light, to be energetically transformed and recycled. A patient who has been experiencing severe headaches, for example, could benefit from this kind of treatment given that most headaches are stress related.

SUMMARY

Through the observation of the patient's physical and structural development, a clear understanding can be obtained as to the strength and weakness of the patient's internal organs and immune system.

The four patterns of physical development and structural formation (The Five Elemental Constitutions, The Yao Hexagram Formations, The Yin or Yang Structures, and The Congenital and Acquired Cellular Patterns) are determined as follows.

1. The doctor first begins to diagnose the patient's physical body according to the Five Elemental Constitutions and the dominant element. This helps the doctor to understand the dominant condition of the patient's internal organs.
2. The doctor further divides the patient's body into six upper and lower Yaos, to determine the dominant energetic and emotional patterns (where the patient's Qi is gathering, collecting, and stagnating).
3. Next, the doctor evaluates the patient's external structure according to his or her body's Yin and Yang characteristics, to understand whether the patient has a dominant introverted or extroverted physique.
4. Finally, the Qigong doctor determines whether the patient's condition is congenital, acquired, or a combination of both. This information helps the doctor to understand the innate cellular patterns that dominate the patient's physique.

Chapter 4
The Five Energies of the Human Body

The study of various forms of energy and their transformations from one form to another have led to one of the greatest generalizations in physics -- the Law of Conservation of Energy, which states, "Energy cannot be created or destroyed. It may be transformed from one form into another, but the total amount of energy never changes."

Physics defines four types of energy: mechanical, electromagnetic, chemical, and thermal. All four types of energy are related to and convert from one another. Electricity, for example, can be converted into sound, light, mechanical energy and into heat. Sound, light, mechanical energy and heat can all be reconverted into electricity.

Western Science is still for the most part, founded on the principles of Newtonion Physics, that views energy as an impersonal and inanimate force. The Traditional Chinese view of energy is much more akin to the theories of Quantum Physics. Both Chinese energetic theories and Quantum Physics hypothesize that energy cannot be studied without taking into account the mind's influence over it. Furthermore, energetic behavior cannot be studied independently of matter.

From a medical Qigong perspective, the entire human body is suffused with energy, which converts within the human organism. Light energy, for example, is absorbed, stored and converted into the various energies of the body, the same way that plants convert absorbed and stored light into chemical energy.

The human body possesses five energies which resonate within the very core of one's being. Sound, light, magnetic fields, heat, and electricity envelop and permeate our very existence; these energies sustain, govern, control, and determine our psychology as well as our physiology. In Medical Qigong therapy, these energies are considered the spiritual reality that governs the physical reality. These energies are observed in both diagnosis and treatment of illness. Research in China confirms the fact that the body emits sound, light, magnetic energy, electricity, and heat.

Sound Energy Resonances

When the body experiences any type of sound, the cell tissues respond to the tone frequency and have either a negative or positive automatic response. The human body both receives and generates sound energy. These subtle sounds resonate from three distinct physical energetic actions. The following subtle sounds are natural tones that resonate as a result of three physical actions.

1. Breathing creates respiratory sound resonances that follow the breath in and out of the lungs mouth, and nose.

2. Muscle movements create somatic and visceral sound resonances that include the clicking sound of the joints, beating of the Heart, gurgling of the Stomach and intestines, etc.

3. Qi activities can produce energetic sound resonances (i.e., when Liver Yang, Liver Fire, or Liver Wind rise, a high-pitched tone is heard in the ears. When the Kidney Yin is Deficient, this sound is like rushing wind, etc.).

Sound Therapy Through Emitted Qi

As sound waves vibrate through the body, crystalline structures within the tissues transform the vibration into pulsed currents. These currents are then conducted to the various corresponding organs and glands, depending on the frequency and amplitude of the incoming wave signal. This tissue transformation (due to wave vibrations) automatically changes the function and flow of energy in the body. Thus sound vibrations have a profound effect on both human psychology and physiology. Sound or tone resonances, have been

used for centuries as an effective healing tool and are currently used as an adjunct to modern Qigong Medicine.

For centuries in China, patients have used healing sound therapy to resonate certain parts of the body, stimulating the flow of Blood and Qi to and from specific internal organs to cure disease. These healing sounds specifically relate to the Five Agents and the Five Elemental aspects of the patient's internal organs (see Chapter 2). According to the Five Elements' Cycle, each of the Five Elements has a note:

- Gong - C = Earth
- Shang - D = Metal
- Jue - E = Wood
- Zhi - G = Fire
- Yu - A = Water

The Qigong doctor can project resonant sound vibrations by first focusing on all three Dantians at the center of the Taiji Pole. This focused concentration is used first to vibrate the doctor's specific internal organs and then to treat the patient. The Qigong doctor can use vibrating sound therapy by:

1. Audibly speaking the healing sounds to fill the Qigong doctor's energetic field with healing sound vibration. This energetic field of sound is then projected onto his or her patient. Audible sound resonation is considered a Jing to Qi level energy projection, and is generally used when the patient is armored and not energy sensitive.
2. Inaudibly speaking the healing sounds and projecting these mental vibrations into the patient. In this case, the Qigong doctor will begin by internally focusing his or her mind on the healing sound. As this internal sound fills the Qigong doctor's energetic field, it is then emitted into the patient's body. To increase the intensity of energy sound projection, the doctor needs only to increase the mind's intention and the pressure of his or her exhalation. Inaudible sound resonation is considered a Qi to Shen level energy projection, and is generally used when the patient is energy sensitive.
3. Both the doctor and patient simultaneously resonate the sound to enhance the synchronization of both their energy fields. As the Qigong doctor resonates his or her own internal organs, both the doctor and patient can modulate the sound and energy patterns as needed.

THREE MODALITIES OF SOUND THERAPY

The resonant sounds produced by Qigong doctors are effective because the patients' energetic matrix is sensitive to the sound resonances. The modulated, yet unpredictable, nature of sound pulsation affects the vibrational structures which shape and maintain the patient's physical structure. Once the patient's vibrational structures have been disturbed, their body must immediately begin its reconstructive process, thereby creating new energetic patterns to restructure and heal the tissues.

There are three modalities used for sound therapy:

1. Characteristic Sound Therapy refers to the sound from musical instruments (flute, guitar, piano, drum, etc.) and their effect on the subconscious mind. This type of musical energy creates an emotional, physical, and spiritual release of energy within the listener.
2. Extraordinary Sound Therapy refers to the vocal resonances used in silent chanting, prayer and singing. Such techniques include the Daoist six-word healing sound method, Zhuang Zi's breath listening method, Lao Zi's sound-voice method, etc. This type of therapy uses the patients' energy to produce the sound and inner vision to direct the vibration within the body. It is also practised in conjunction with breathing techniques that are guided by the Yuan Shen (the intuitive consciousness of the spirit). All of these techniques are combined to achieve physiological and psychological healing.
3. Infrasonic Sound Therapy refers to the low frequency sound waves emitted from the hands of Qigong doctors. These chaotic, low frequency sound waves, inaudible to the human ears, are naturally produced by the hands

of experienced Qigong doctors when emitting Qi. This infrasonic sound resonance affects the central nervous system, changing the body's neurophysiological functions. Extensive research performed by Richard H. Lee of China Healthways Institute in Los Angeles, California, as well as research performed by the Beijing College of Traditional Chinese Medicine, and the Department of Natural Science in Beijing China, confirms that all humans have a very high degree of acoustic activity in the subsonic range below 20 Hertz (infrasonic). This subsonic activity is similar to the alpha rhythm of an EEG (see Appendix #2).

Qigong doctors may combine the characteristic, extraordinary, and infrasonic sound therapies into one treatment modality to facilitate a deeper and more thorough transformation within their patients. The choice of sound prescriptions vary according to each patient's cultural upbringing, religious beliefs, emotional temperament, and comprehension of energetic healing modalities.

Sound therapy can be prescribed to relieve a patient's feelings of uneasiness or extreme depression. Music, for example, has always been acknowledged as a powerful medium for emotional enhancement. Sounds and tones stimulate the cerebral centers creating a wide range of results from enhancement of memory retention, to facilitating certain emotions, and creative inspirations.

Music therapy specifically created for the harmonizing the Five Elements within the Yin and Yang organs is also used in conjunction with Feng Shui training to regulate any imbalances of the body and mind stemming from the changes of seasons. During autumn, for example, when dryness is prevalent and there is a transition from warm to cool, music can help to stabilize the body's response to these external conditions.

Western Sound Therapy

Sound therapy is actively being used in Western medicine. The following are examples of current clinical modalities:

- music therapy for postoperative healing,
- ultrasound therapy for sore muscles and back injuries, and
- shock-wave lithotripsy therapy for kidney stones and calcified gallstones.

Light Energy

All matter produces, radiates, transports, or transmits light, and therefore has properties of color vibration. Matter and light are fundamentally inseparable. Matter can be considered a condensation of photons. Its transformation can be viewed as a result of light interacting with atoms and molecules. All life on Earth, whether plant, animal, or human, is dependent upon light and its miraculous qualities for existence.

All living cells emit units of light called "biophotons." Biophoton emissions radiate from the internal organs, as well as the body's surface tissues, to create the body's auric field.

This interaction of light on the body's tissues and within the body's internal organs has a profound healing effect, especially when activated by the Qi emission from a Qigong doctor. When muscles or nerves are activated through medical Qigong therapy and / or exercises, the intensity of the biophoton emission increases. Studies performed on the healing potential of light and color therapies demonstrate that it is clinically effective. Like sound resonances, light therapy is also being researched further as an adjunct to modern clinical medicine.

The body both absorbs and projects light energy. The divine light that enters at the time of conception continues to reside in our Taiji Pole throughout our lives. This light responds and reacts to the doctor's emitted therapeutic light energy. Emitted light and color resonance are absorbed into the patient's body, causing the energies of Heaven and Earth to fuse inside the tissues; this facilitates the healing process.

In Traditional Chinese Medicine, the early diagrams illustrating the body's internal organs, channels, routes of Body Fluids, and arteries were called Charts of the Hall of Light. These detailed maps of Qi and Blood flow illustrated the energetic organs, as well as the body's Jing and Shen (which are rooted in the Blood). The Shen flows inside of the body, transforming into light and radiating from inside of the tissues outward. The

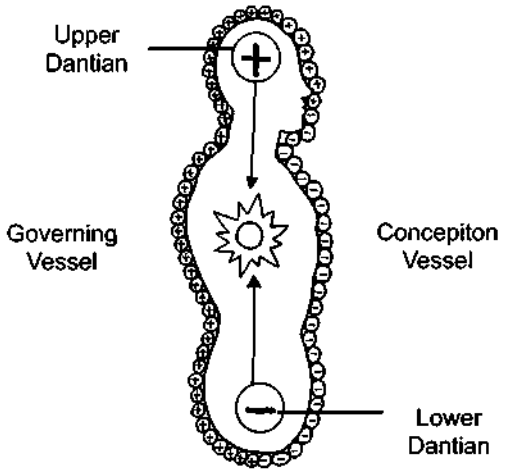

Figure 4.1. Light resonates within the body's Taiji Pole. From the body's Yang Governing Vessel flows a sea of electropositive energy. From the body's Yin Conception Vessel flows a sea of electronegative energy.

light radiating from the physical body spontaneously interacts with the mental, emotional, and spiritual light energy released from other beings.

Light energy can also be accumulated in the storage chambers of the Three Dantians. The Upper Dantian, is called the "peak of Yang energy," and is considered electropositive; it is the doorway to the chamber of Heavenly or divine light. The Lower Dantian, is called the "peak of Yin energy," and is considered electronegative, and the direct root to the Earth.

In time, with Qigong training, the postnatal Heat circulating up the Governing (Yang) and down the Conception (Yin) Vessels can awaken the Prenatal Qi stored in the brain, causing it to unite with the body's nervous system. This is considered a full integration of Yin and Yang energy and manifests as a shimmering white light glowing in the center of the Upper Dantian.

White light is stored in and released from the Upper Dantian, where the spiritual energy is stored. Once white light energy manifests, it should be drawn down the Taiji Pole into the center of the Lower Dantian. By using inner vision to focus the eyes on the center core of the body, the Qigong doctor can concentrate on the white light energy vibration and fuse this energy into one column of light, stemming from the Upper to the Lower Dantian. When the Microcosmic Orbit is completed (i.e., when the Governing and Conception Vessels are energetically fused), the first center column of light can be accessed via the body's five Center Thrusting Channels into the Taiji pole. This column of light runs through the center of the body, connecting all Three Dantians together (Figure 4.1). Accumulated Qi is stored as a golden glowing ball in the Lower Dantian.

COLOR VIBRATIONAL PROJECTIONS

Qigong doctors project light of different colors by first drawing the divine light energy into their Taiji Pole, then focusing on the light energy and releasing it either through the arms and out the hands into the patients, or through a visualization of divine light traveling from the Yin Tang (Third Eye) area into the patients.

When Qigong doctors connect with the divine healing white light energy, they absorb massive quantities of this energy into their Taiji Pole. This white light energy prisms into six color projections of light and energy vibration. As the white light energy transforms into multicolored beams of light, the colors can be either absorbed to strengthen the internal organs, or projected out for Qi emission.

The Qigong doctors use inner vision techniques to connect with the correct color for energy projection. One such technique used by doctors allows the color to naturally develop by mentally focusing both eyes to the back of the head. The color that is observed in the back of the mind is projected into their patients' body. This visualization technique is only performed after connecting with the patients' energetic field.

LIGHT THERAPY THROUGH EMITTED QI

The human body produces light which is visible to both clairvoyants and Qigong doctors (Figure 4.2). In China, doctors of TCM have discovered that light therapy is effective in treating certain diseases because of the light field's ability to penetrate the tissues, and interact with the patients' energetic fields.

Extending the image of the color is an important part of the Qigong doctor's ability to treat

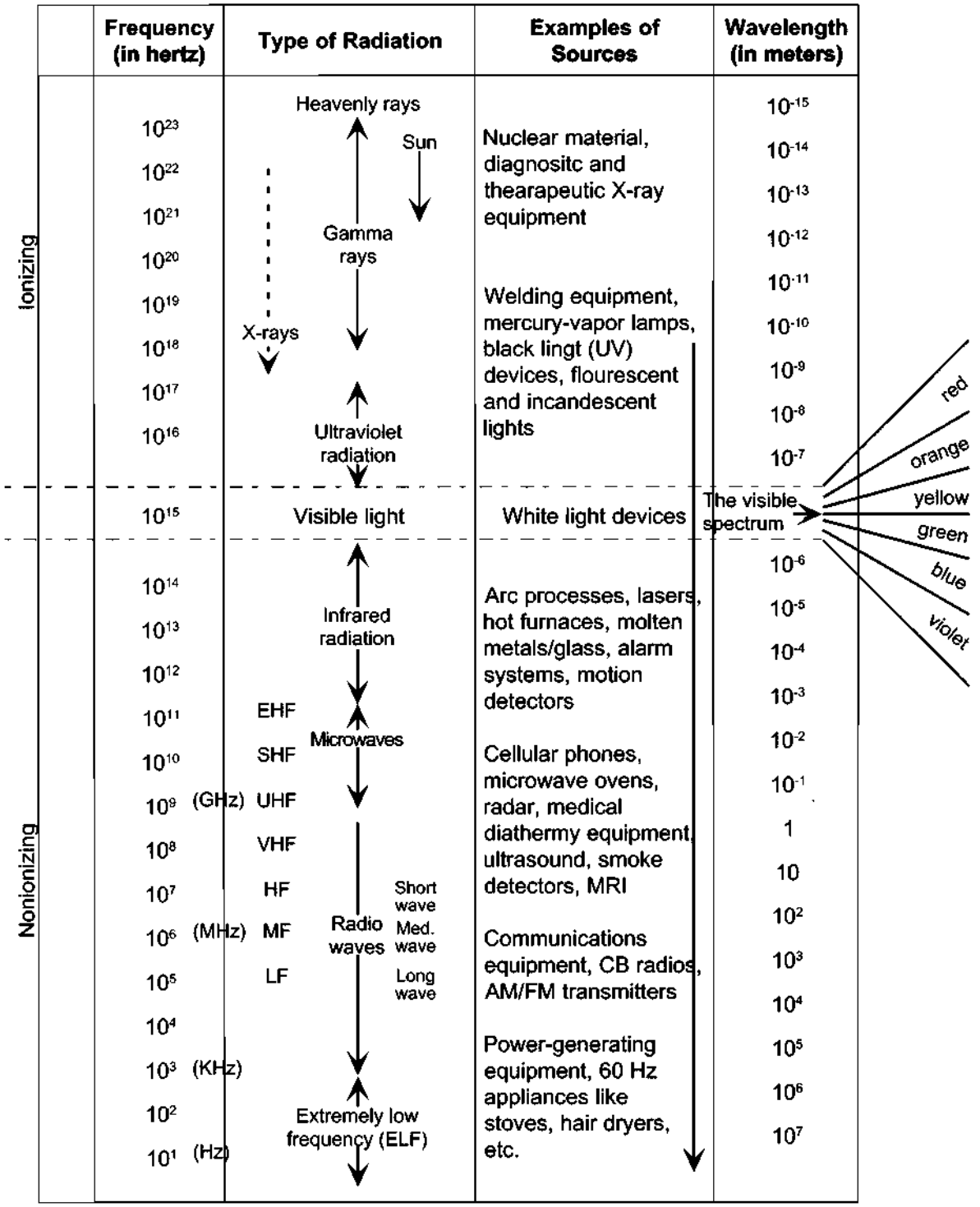

Figure 4.2. Light Spectrum Chart

patients to establish a more gentle healing session.

5. The flame blue color cools the body and is beneficial in soothing and calming a patient's anxiety. Blue can be used to stimulate the Bladder, Kidneys, the reproductive system, skeletal system, and the Water Qi of the body. The color blue is also excellent for relieving inflammation and fever and can be used as a mild anesthetic.
6. The indigo or dark blue color has a deep penetrating property and is used for knitting bones and creating "energetic casts" (used for enveloping wounds and specific internal organs). The color indigo can also be used to stimulate the Bladder, Kidneys, skeletal system, reproductive system, and the Water Qi of the body.
7. The reddish-blue color of violet is known for its purifying force, which facilitates the rapid healing of difficult infections, e.g., pneumonia.
8. White energy extension indicates a fusion of all colors. White energy is the most neutral and can be used when one is not sure which other color is appropriate. White is useful for calming the mind and placing a protective field around an organ or around the body. White stimulates the Large Intestine, Lungs, the respiratory system, and the Metal Qi of the body.

USING HEALING COLOR IMAGERY

Specific color meditations can be prescribed to assist patients in their healing. The patients are encouraged to visualize specific organ colors while the Qigong doctor projects that same color into their body and energetic fields (Wood-Liver-Green, Fire-Heart-Red, Earth-Spleen-Yellow, Metal-Lungs-White, and Water-Dark Blue/Indigo-Kidneys). This treatment technique is successful for tonifying, regulating, or purging all the body's major organs and is often combined with healing sounds.

When using healing color imagery, the patients are encouraged to first visualize the diseased organ as being dull, dark, and impure in color. In cases of Liver Heat, patients might imagine a dull, turbid brownish-green, tinged with red. For a Heart imbalance, the red color may be first imagined as a dull, weak or darkish red, tinged with brownish-red or purplish-red (like the color of stagnant Blood). Patients begin the meditation by concentrating on exhaling the toxic, pathological colors. As the patients inhale, they imagine a pure, vibrant ruby-red color flowing into their body from the Heavens or Earth, energizing, cleansing, and replacing the toxic energetic color of the diseased Heart.

Note: The image of the vibrant ruby-red color is prohibited in cases of Excess Heart Fire.

EXPOSURE TO EXTERNAL COLOR FIELDS

In this type of color therapy, patients are required to sit and meditate in rooms painted in the specific color relating to their condition. A healthy color is chosen in accordance with either the Five Elements' Creative Cycle or a Controlling Cycle, depending upon the nature of the patient's disease and which particular Yin organ (or organs) are involved. One example is using the Five Elements' Creative Cycle to tonify a patient's Deficient organ. The theory of the creative cycle is to stimulate and energize the "mother" in order to strengthen its proceeding "child" organ. For a Liver imbalance, for example, the patient can be placed in a blue room for tonifying the Kidneys (the Liver's "mother" organ). The Kidney color indigo (the mother) is used to nourish the Liver organ (the child). For a Liver Excess, the Qigong doctor would use the Five Elements' Controlling Cycle and place the patient in a white room, allowing the Lungs (the grandmother) white Metal color to control the Liver Wood (the child) organ.

Also specific colors can be worn by the patient, or the patient can surround him or herself with certain natural colors to initiate healing (e.g., emerald green for Liver conditions).

FOOD AND COLOR

Another treatment method requires the presentation of food (diet) as a form of color and light therapy. In this treatment the doctor makes sure that the Five Elemental colors are present within the patient's food. Each color will start a resonance

within the patient's organs (i.e., Green-Liver, Red-Heart, Yellow-Spleen, White-Lungs, and Dark Blue/Indigo-Kidneys).

When eating the food the patient focuses his or her intention on ingesting the color, light, and energy of the food being eaten.

USING DISTANCE AND RANGE

When using color projection, an important factor is the doctor's ability to maintain focused intention. If the doctor becomes distracted or looses visual concentration, the color resonance being emitted becomes degraded, and the projected color transforms back into non-differentiated white-light energy. Since it is the vibratory rate of the specific color that promotes healing, a strong connection between the doctor and patient is vital in distance color therapy projection.

WESTERN LIGHT THERAPY

Light therapy is currently being used in Western medicine through the following modalities:

- Laser-light therapy surgery,
- Full-spectrum light therapy for SAD (seasonal affective disorder),
- Color-light therapy for eye problems and various other illnesses, and
- UV-light therapy for "blue babies" with hyperbilirubinemia.

MAGNETIC ENERGY

Magnetism can influence energetic flows of energy current within the body. It is difficult to separate the energetic properties of magnetism (Yin) and electricity (Yang), as they are almost two aspects of the same energetic field. The movement of electrical currents generate magnetic fields. By establishing different magnetic polarities, the Qigong doctor can influence the electrical flow in the body.

The body's cells carry electromagnetic fields that both attract and repel each other, resulting in a magnetic pull between the body's tissues, organs, and extremities, as well as the body's electromagnetic interaction with the Earth. Clinical research in China demonstrates that the iron in the hemoglobin of the Blood is attracted to the magnetic pull of the body's tissues, as well as the magnetic pull of the Earth.

The Earth, like the body, has both a Yin (magnetic) field and a Yang (electrical) charge. These energetic fields are interdependent. The magnetic

Figure 4.4. The Earth is enveloped with electromagnetic currents, affecting both weather and vegetation.

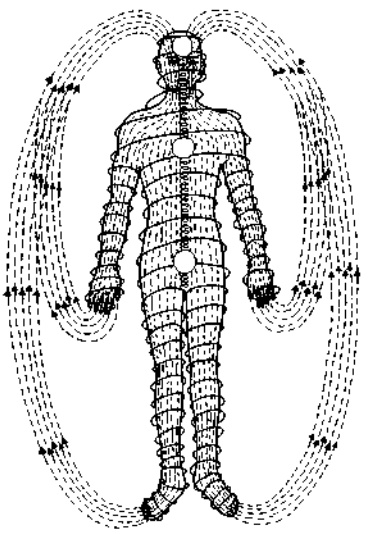

Figure 4.5. The body is enveloped with electromagnetic currents, affecting both internal and external organ functions.

field is caused by the movement of charged particles and spans the circumference of the Earth creating a strong electrical field (Figure 4.4).

Some modern researchers believe that the physical body's channel system (see Chapter 6) charges its field of magnetic flux through movement. It is further believed that the channel system creates an electrical field that attracts electrons into the body's Taiji Pole.

Richard Lee of the China Healthways Institute found that the Yin magnetic substances stored within the body's water molecules align with the electrically conducting structure of the body's channels (see Appendix 2). When the body's magnetic energy field is low, these channels become weakened and the conductivity is lowered. This magnetic energy can be replenished either from ingesting and transforming food, air and water, or gathered directly from the Earth's magnetic field.

The body's magnetic field conforms to the Earth's magnetic field through the energetic exchange within the body's electromagnetic fields (Figure 4.5). The body maintains this electromagnetic connection through the energetic resonance of the Taiji Pole. Within the structure of the body's Taiji Pole are located two major conductive poles of energy. These two conductive poles are located at the opposite ends of the Taiji Pole, positioned at the top of the head and the base of the perineum. The purpose of these energetic poles is to absorb Qi from universal and environmental fields, connecting and integrating the energy into the body's Three Dantians (see Chapter 5).

The electromagnetic lines in the body's force field begin from the at top of the head (traditionally considered the south pole) where the Heaven Qi flows into the body, and end at the at the base of the perineum (traditionally considered the north pole) where the Earth Qi flows into the body (Figure 4.6). Each of these two magnetic poles (the Lower and Upper Dantian) have a different energy influx. The energy originates and converts in the Lower Dantian and eventually flows to the Upper Dantian. The bottom pole, located in the Lower Dantian, converts Jing (Essence) into Qi

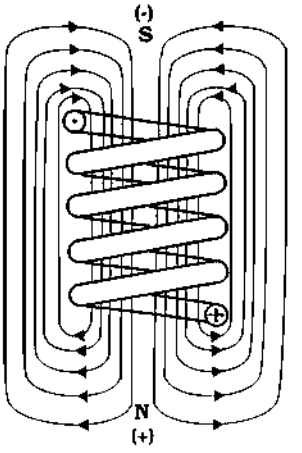

Figure 4.6. Magnetic field around a spiral coil

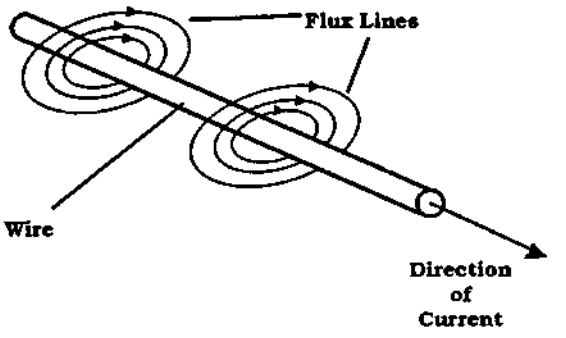

Figure 4.7. Flux lines around current-carrying conductor

(Energy) and increases the body's overall life-force energy. The upper pole, located in the Upper Dantian, converts Shen (Spirit) into perceptual insight and spiritual light.

There are several ways in which the Qigong doctor can manipulate the electromagnetic field which surrounds the body. The doctor can directly absorb Heaven and Earth energy from the bottom of his or her feet, top of the head, and through both palms (called Absorbing Qi from the Five Gates). The doctor can also, through creative visualization, gather and loop the different types of environmental energy around his or her body, increasing the thickness and power of the electro-

magnetic field (the energetic boundary that surrounds the doctor's body). This looping action is similar to wrapping a magnet with wire to increase its magnetic field potential (Figure 4.7). Stronger lines of magnetic force will be produced around the body, thus creating a stronger "energy bubble" (Figure 4.8).

The direction of electromagnetic wrapping should be done in accordance with the natural flow of the surrounding environmental fields. Each individual should remain sensitive as to which technique works better for them, as there are individual variations used in accordance to the doctor's intention and belief.

MAGNETIC THERAPY THROUGH EMITTED QI

Qigong doctors are trained to manipulate their patient's electromagnetic field by extending emitted energy into the patient's tissues. This stimulation of the body's magnetic field is extremely effective for regulating the flow of channel energy, as well as stimulating the activity of the nervous system.

Magnetic therapy is also used as a companion to acupuncture therapy. Acupuncturists use magnetic patches, placing them on various channel points on the patient's body, to induce energy flow and tissue stimulation.

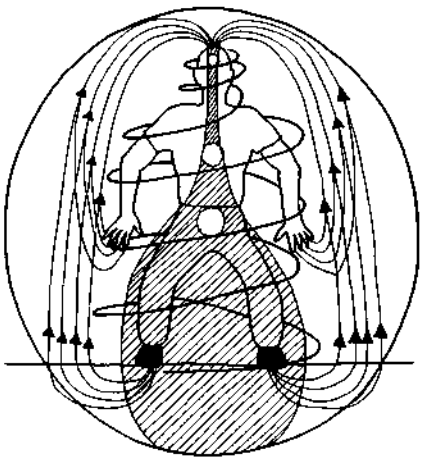

Figure 4.8. Qigong doctors can create a strong energetic field by absorbing Qi into their Lower Dantian. This energy extends into the Earth (like an anchor), and the Wei Qi field surrounding the doctor's body automatically increases and expands.

The negative north magnetic field pole of the magnet is placed in contact with the patient's skin in treating conditions due to Excess Heat and stagnation. The negative north pole is found to have a cooling and calming effect on tissues. Herbal teas used for purgation, dispersing, anti-inflammatory or sedative properties can be augmented by placing the tea on the north pole of a magnetized surface for a minimum of an hour before drinking.

The positive south magnetic field pole of the magnet is placed in contact with the patient's skin in treating Deficiencies, Cold and blockages. The positive south pole is said to have a stimulating and warming effect on tissues. Herbal teas used for warming and tonification can be augmented by placing the tea on the south pole of a magnetized surface for a minimum of an hour before drinking.

WESTERN MAGNETIC THERAPY

In 1990, Dr. Arthur Trappier submitted a paper on "Evaluating Perspectives on the Exposure Risks from Magnetic Fields" to the *Journal of the National Medical Association*. In his article, Dr. Trappier explained that exposing cancer cells to a negative magnetic field discourages the growth of the cancer, while exposing cancer cells to a positive magnetic field encourages their growth. Magnetic therapy is currently being used in Western medicine through the following clinical modalities:

- Permanent magnet therapy for localized pain and inflammation relief,
- Super-magnet therapy for stimulation of the thymus for immune enhancement in cancer patients, and
- Pulsed magnetic therapy for the treatment of arthritic joints.

GENERATED HEAT

Electricity passing through any substance will produce heat. The amount of heat that will be generated depends upon the resistance of the substance and the density of the current's flow. Heat is generated at the electron level by the friction

created through molecular motion. By increasing the motion of the molecules, more heat is generated. Molecules in living organisms are in constant motion, increasing or decreasing their rate of acceleration according to the environmental temperature. In order for heat to have any effect on the body, enough Qi has to be transferred to increase the movement of the molecules.

The heat within the body causes increased electron movement, resulting in more heat being generated on a cellular level. Heat is also caused by cellular metabolism. The body's metabolism produces 75% of the energy being created in the form of heat. Cellular activity is increased through electrical, magnetic, heat, sound, and light stimulation.

From a Medical Qigong perspective, Heat in the body is generated from the accumulation of Three Fires which emanate from specific locations within the body. Within the body's chest cavity is the Heart Fire, located within the abdominal cavity is the Kidney Fire, and all through the body flows the Bladder Fire. When the Heart Fire first awakes, the Kidney Fire responds to it, and when the Kidneys Fire moves the Bladder Fire follows it.

When these Three Fires follow their normal course of energetic movement, they issue and lead the body's life-force energy, creating and sustaining life. The Three Fires are responsible for regulating the Yin and Yang energy of the body by fusing the Five Elemental energies (stored within the body's Wood, Fire, Earth, Metal, and Water organs) with the energy of the Three Dantians. As the Shen from the Heart Fire is drawn into the Lower Dantian, the Bladder Fire fuses with the Kidney Fire, creating the body's True Fire. This action causes the body's Jing to create Qi in the Lower Dantian and then transform Qi into Shen in the Middle Dantian. Once this fusion is obtained, the mind, breath and body connections all become regulated.

The Three Fires also represent the regions of vital Heat responsible for the circulation of energy that sustains the Eternal Soul. Accessing the energy of the three Fires is used for cultivation and spiritual liberation, and is brought about through Qigong practice, prayer and meditation.

1. The Heart Fire, also called the Commanding or Emperor's Fire, is located in the center of the chest. The Heart Fire is responsible for transforming the body's energy into Shen.
2. The Kidney Fire or Mingmen Fire, is located in the back of the body, just below the last floating rib. Qigong masters in ancient times regarded the Mingmen Fire as the motivating force of the body and paid special attention to its training during Qigong exercises. A Deficiency of the Mingmen Fire may lead to decreased sex-drive, hypogonadism and impotency. Conversely, if the Mingmen Fire is in Excess, increased sex-drive or sexual obsession and hypergonadism will occur.

   Dr. Zhao Xianke, an expert on medicine during the Ming Dynasty period, states that "the Mingmen Fire dominates all Twelve Primary Channels. Without it the Kidneys would be weak, the Spleen and Stomach could not digest food, the Liver and Gall Bladder would not give any energy to think or plan, the urine and feces would not be moved, and the Heart would malfunction causing dizziness and endangering life."
3. The Bladder Fire, also called the Common People's Fire, is located in the lower abdominal area by the perineum and is responsible for evaporating water.

The Three Fires are not the Triple Burners, as the purpose of the Triple Burners is to regulate the major internal organs and is a completely different energy system. The physical locations of the Three Fires however, coincides with the locations of the Triple Burners.

HEAT THERAPY THROUGH EMITTED QI

Stimulating the body's tissues through Heat therapy is extremely effective for treating Deficient and Cold syndromes. In China, Qigong doctors use the extension of Heat through their emitted field of electromagnetic energy to stimulate their patients' tissues. This therapy helps to regulate the flow of the patients' channel energy, and tonifies the Blood and Qi.

Heat therapy is also used in the form of moxibustation as a companion to acupuncture therapy. Acupuncturists will use moxa sticks and/or cones, lighting and placing them on or over various channel points of the patients' body. This is practiced to induce Qi flow and tissue stimulation.

WESTERN HEAT THERAPY

Radiant and conductive heat therapy are currently being used in Western medicine for vasodilation and pain relief. These heat therapies can further be broken down and categorized into dry-heat therapy and moist heat therapy.

Dry-heat therapies include the following:

- Dry packs
- Hot-water bottles
- Heliotherapy-sun therapy
- Ultraviolet-heat therapy
- Infrared-heat therapy
- Diathermy therapy

Moist-heat therapies (hydrocolators) include the following:

- Hot bath packs
- Hot wet packs
- Hot foot baths
- Fomentations
- Poultices
- Vapor and paraffin baths

ELECTRICITY

A flow of electrons is called a current. Just as a current produces a magnetic field, a magnetic field, when it moves in relation to a conductor, induces an electrical current. In Medical Qigong therapy, the body's channels are also considered electrical circuits, and the points existing within each channel can be considered booster amplifiers (or step-up transformers) that maintain the current's strength. According to Dr. Robert O. Becker, research scientist and author of the book *Cross Currents*, acupuncture needles have the capacity to act as antennae, drawing charged particles (ions) from the atmosphere into the body. The acupuncture needle delivers a low-level electrical stimulation to the channel points and can be used to charge up, or decrease the energetic potential of these "step-up transformers," affecting the current along the channel.

The human body is an excellent conductor of electricity and contains both alternating and direct electrical currents. The alternating current is responsible for the transformation of the body's magnetic field into the body's electrical field. The direct current is responsible for the body's positive Yang and negative Yin flow of electrical charges.

The friction produced by rubbing the feet on a carpet creates a charge that is stored within the body until touching another conductor (metal, another person, etc.) to release the charge. This normal and common occurrence demonstrates the storage, conductance, and discharging of electrons from the body. Any time electrons travel, heat, or thermal radiation is produced.

According to Swedish Physician and medical research scientist Dr. Bjorn Nordenstrom, the biological circuits of the body are driven by the accumulated charges, which, unlike a battery, oscillate between positive and negative. The body's system of channels and blood vessels act as insulated cables, while the blood plasma acts as the conductor. In the permeable tissue, the fluid between the cells conducts ions. A key component of the body's electrical circuit is the natural electrodes in the capillary walls, known as the lipid bilayers of the electron transport chain.

A myriad of electrical forces work within the body. Every human thought and action is accompanied by the conduction of electrical signals along the fibers of the nervous system. In fact, life would not exist at all without a constant flow of ions across the membranes of cells.

The electromagnetic energy in the body's cells is continuously being generated through the biochemical transformation of food, and air, and is circulated by the electromagnetic fields being generated within the tissues. Perineural cells, or nerve sheaths, carry the direct current of the body's electricity. These cells are responsible for motivating the body to heal, regenerate, and repair itself. Healing is always affected by a change within the body's electromagnetic field. The rate and effi-

ciency of healing is based on the strength and polarity of the body's field of energy. This electricity is one of the primary energy sources responsible for maintaining life itself.

Dr. Becker's research demonstrates that bones are "piezoelectric": when stressed, mechanical energy is converted into electrical energy that produces an increased electrical current. Dr. Becker discovered that running a minute electrical current through a fractured bone will stimulate the reproduction of the cells, creating a healing current similar to the body's natural healing mechanism.

According to Richard Lee of China Healthways Institute, electrostatic waves are observed in the body through EEGs (electro-encephalograms) and EMGs (electro-myograms). Different types of therapies affect the EEGs (sound therapy, meditation therapy, self-regulation Qigong therapy, light therapy, etc.). By controlling their thoughts, Qigong doctors can affect the current in their body and thus affect the EEG measurements. These thought patterns will in turn influence the Qigong doctors' electrical field. Experiments show that EEG measurements in test subjects receiving energy from healers tend to synchronize. Qigong doctors, when treating patients, can produce voltages as high as 190 volts, 100,000 times greater than regular EEG voltages.

The body's natural ability to gather, store, and move Qi increases the body's abilities to gather, store, and move electrical charges. The gathering of these electrical charges can cause a gradual electric buildup within the tissues and internal organs, developing into an Excess Qi condition within the body. Excess Qi conditions often manifest mood swings and are responsible for the energetic circuit overloads that occur spontaneously within the body. Excess Qi manifests as a sudden "explosion" or "release" of emotions such as rage, fear, grief, worry, fright, anxiety, and joy. An excess electromagnetic charge, internally combined with the Qi from a patient's on-going emotions can be drawn into an organ's tissue area and absorbed by the internal organ that is in the most elevated state of energy conversion. This energetic reaction can cause the already overcharged internal organ to spontaneously release emotions. Sometimes the release is physiological, e.g., sudden sweating, blushing, twitching or jerking, yawning, stretching, sighing, burping, passing gas, etc. These can all be ways that the organ seeks to regain hemostasis.

Electrical Therapy Through Emitted Qi

The idea that an electric current can stimulate bodily repair, alert defence mechanisms, and control the growth and function of cells is not a new concept in Western medicine. In fact, the use of bio-electromagnetism dates back at least 200 years. Electrotherapy is found to be very useful in relieving pain by signaling the brain to activate and alter the body's neurochemicals. The insertion of electrically stimulating needles into a patient's body, for example, causes a release of endorphins, and is used for pain management.

Medical Qigong, acupuncture, and Chinese massage likewise, stimulate the peripheral and cutaneous nerves that carry sensory information, via the spinal cord, to the brain. This stimulation of the cutaneous nerves activates the brain's opiates (endorphins - endogenously generated morphine) and facilitates the closure of the body's pain relay gates, killing pain, and is the basis for anesthesia. Because medical Qigong therapy also has an analgesic affect on the body's cutaneous tissues, it is being increasingly used in hospitals for pre- and postoperative procedures.

Western Electrotherapy

Electrotherapy is currently being used in Western medicine through the following modalities:

- Giga-TENS therapy for stimulation of healing,
- TENS therapy for pain relief,
- CES-cranial electro-stimulation therapy-for depression and substance abuse, etc., and
- Micro-stimulation therapy for micro-current stimulation below the threshold of awareness, to stimulate nonspecific healing, the reduction of inflammation and the harmonization of tissue polarity.

Chapter 5
The Three Dantians and The Taiji Pole

The Three Dantians

According to Chinese energetic physiology, humans have three important energy centers, located in the center core of the body, that store collected energy in much the same way as a battery does. These three centers are called the Three Dantians (Figure 5.1). The word Dan literally translates to mean "cinnabar," while the word tian means "field." In terms of Medical Qigong tian is referred to as a field of energy. Together, the characters for Dantian literally translates as "cinnabar field" or "field of elixir."

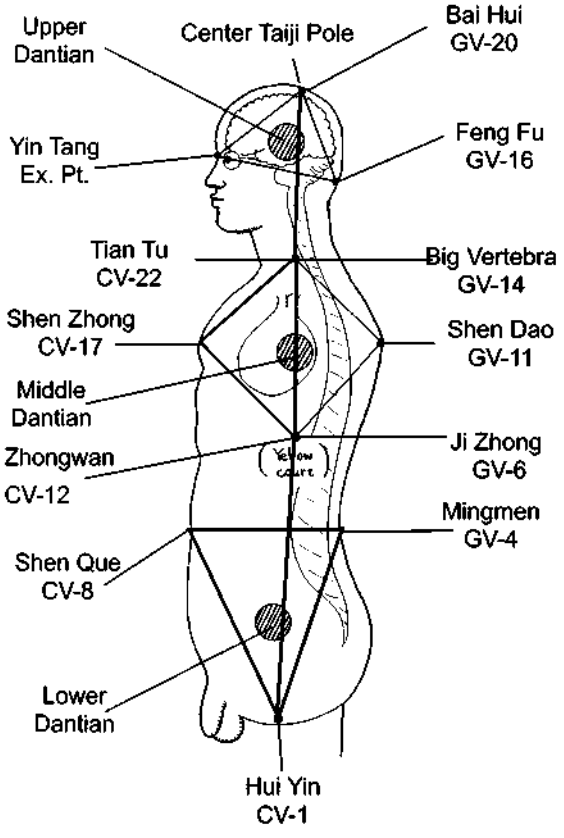

Figure 5.1. The Anatomical Locations of the Three Dantians and Center Core (Taiji Pole)

Cinnabar is mercury sulfide, a bright red or vermillion mineral, which is the principal ore of mercury. Cinnabar was an important mineral in ancient China, the source material needed to manufacture vermillion ink, which could be used only by the emperors. Cinnabar was -- and is today -- also used in Chinese medicine to sedate the Heart and calm the Shen, but always in small doses for short periods due to its highly toxic nature.

Cinnabar was also a vital elixir in Daoist alchemy, as it was discovered to be very balanced in its Yin and Yang properties. Daoist alchemy, like Western alchemy, was practiced in two ways: outer alchemy (Wai Dan) and inner alchemy (Nei Dan). Outer alchemy was the ancestor of modern chemistry. Outer alchemists set up laboratories and experimented with many substances from mineral, animal, and plant sources with the goal of discovering how to turn base metals into gold. Secretly, they were also seeking to discover an elixir, or drug, that would confer immortality or, at the least, greater longevity. Along the way they made many important discoveries, such as gunpowder, medicines, and many other substances vital to the world today.

Inner alchemy was concerned with purifying human nature and transforming the spirit into its most pure and radiant potential without the use of outer agents. Instead, they used Qigong and meditation to circulate and gather the "inner elixirs" of sexual energy, Qi, and consciousness at various locations within the body. The Three Dantians, or "elixir fields," in addition to storing energy, act like an alchemist's crucible, or cauldrons in the role of gathering and transforming vital sub-

stances, energies, and various elements of awareness. The ingredients of the inner elixir are Jing, Qi, and Shen. The inner alchemists kept their work secret by using mineral code words such as "gold," "lead," and "cinnabar" to describe the movement and transformation of energetic and spiritual substances within the body.

The goal of the inner alchemists is immortality, a complete transformation of Jing, Qi, and Shen. Jing, Qi, and Shen are collectively called the Three Treasures and are the three fundamental energies necessary for human life. To accomplish this transformation, alchemists first gather and transform Jing into Qi in the Lower Dantian. They then gather and transform Qi into Shen in the Middle Dantian. Next, they transform Shen into Wuji (the absolute openness of infinite space) in the Upper Dantian. Finally, they merge Wuji into Dao (divine energy). The Three Dantians serve as the inner crucibles for these transformations.

These transformations can be compared to the changes of water (the consistencies and not the temperature), which when heated, can change from solid ice, to a liquid, and then to vapor.

The Three Treasures (Jing, Qi, and Shen) are also connected with the Three Outer Forces or Powers known as Heaven, Earth, and Man. Jing (reproductive essence) is the most substantial and therefore the most Yin of the three, and it is closely linked with Earth Qi. In Medical Qigong practice and Daoist inner alchemy, the Earth energy is gathered in the Lower Dantian and is associated with heat. Qi is a mixture of Yin and Yang and is closely connected with the atmospheric energy, which is a blend of Heaven and Earth Qi and gathered into the Middle Dantian, (which is associated with vibration). Shen (Spirit) is the most insubstantial and, therefore, the most Yang of the three; it corresponds with Heaven Qi, and is gathered in the Upper Dantian which is associated with light.

The Three Dantians are connected to each other through the Taiji Pole. The Taiji Pole acts as a passageway for communication between the Three Dantians, and as a highway for the movement of the various life-force energies. The Eternal Soul is drawn into the body at the moment of conception through the Taiji Pole, and departs through it at death. The Taiji Pole also serves as a transport for the body's Hun.

Regardless of whether or not a modern Qigong practitioner is concerned with spiritual transformation, from a Medical Qigong standpoint the Three Dantians are still vital centers for the cultivation of energy. They are important areas for diagnosis and self-healing, as well as for projecting Qi to patients.

The following is an exploration of the Three Dantians and their individual relationships to the Three Treasures of Jing, Qi, and Shen.

THE LOWER FIELD OF ELIXIR

The Lower Dantian is the Dantian most familiar to martial artists and Zen meditators. It is regarded as the center of physical strength and the source of stamina. Called the "Hara" in Japanese, it is located in the lower abdomen, in the center of the triangle formed by drawing a line between the navel, Mingmen (lower back), and perineum. These three points form a pyramid facing downward. This configuration allows the Lower Dantian to gather the energy from the Earth.

The Lower Dantian is the major storage area for the various types of Kidney energies. The Kidney energies are, in turn, closely linked with our prenatal energies and provide the foundation for all other types of Jing, Qi, Yin, and Yang energies in the body.

The Lower Dantian is connected to the first level of Wei Qi (Protective Qi) circulating outside the body, extending from the body's tissues to about one inch. As the Lower Dantian fills with Qi, the Wei Qi field naturally becomes thicker.

THE LOWER DANTIAN AND JING

The Lower Dantian collects Earth energy and represents the body's physical energy of Jing. The Earth energy that is transformed in the Lower Dantian is a dense, full energy with a thick quality to its texture. In our analogy with the transformations of water, the energy in the Lower Dantian is dense, like ice.

The Lower Dantian is closely linked to the Jing Gong (Essence Palace) located in the perineum, which serves as a reservoir of Jing. Our Prenatal Essence (Yuan Jing), determines our constitutional strengths and vitality, and is stored in the Lower Dantian. It interacts with the Kidney energies to form Kidney Jing. The Kidney energies are all closely intertwined: Kidney Jing, Kidney Qi, Kidney Yin, Kidney Yang, and Kidney Fire. The Mingmen Fire, also called Kidney Yang, helps transform the Jing into steam (Kidney Qi).

Kidney Jing circulates throughout the body via the Eight Extraordinary Vessels, in particular, the Governing, Conception, and Thrusting Vessels, all of which originate in the Lower Dantian.

Kidney Jing controls the reproductive energies and life cycles in the body. Some of the ancient alchemical texts describe the Lower Dantian in women as being located in the Bao or uterus, and it is related to the function of Jing in a woman's body. In men, the reproductive essence is located in the Jing Gong (Essence Palace) or prostate and seminal vesicles. In some Chinese medical, Daoist, and Qigong literature, the term Kidneys is used as a synonym for the testes and ovaries.

The location of the Jing Gong is affected by the different anatomical locations of the male and female reproductive organs. In men, this area is located in the center of the body, at the level of the superior border of the pubic bone, posterior to the Qugu CV-2 (Crooked Bone) point. The Jing Gong area in women is located higher, centered in the uterus, about an inch above the superior border of the pubic bone, posterior to the Zhongji CV-3 (Utmost Center) point.

This difference in location, in turn, affects the storage of Jing (i.e., the testicles in the male cause the transformation of energy to occur lower in the body than in females, due to the higher position of the woman's ovaries).

Jing is the most physical, material form of Qi within the body (corresponding to Yin and Earth energy). The Lower Dantian is the place where Qi of the Earth is drawn into the body and transformed by heat.

The Lower Dantian acts as a reservoir for heat and energy and is associated with the Kidneys. The Kidneys control the Water element in the body. Jing is said to be like the water in the cauldron. Through focused concentration and meditation, the Jing (Essence) in the Lower Dantian is refined and transformed to produce Qi (Energy). When heat is generated as a result of the Heart and Mingmen Fire mixing with the Kidney Water, the alchemical transformation of Jing in the Lower Dantian area transforms Jing into the steam of Qi (the character for Qi is composed of steam rising from a cooking pot). This alchemical transformation is known as "changing Jing into Qi," and takes place within the Lower Dantian.

THE LOWER DANTIAN AND QI

The Lower Dantian is often called The Sea of Qi. It is the place where Qi is housed, the body's Mingmen Fire is aroused, the Kidney Yin and Yang Qi is gathered, and the Yuan Qi is stored. Also called Source Qi, the Yuan Qi is the foundation of all the other types of Qi in the body. The Yuan Qi is closely linked with the Prenatal Essence (Yuan Jing). Together, the Yuan Qi and Yuan Jing determine our overall health, vitality, stamina, and life span.

The Yuan Qi is the force behind the activity of all of the organs and energies in the body. It is closely related to the Mingmen and works to provide body heat. The body's Yuan Qi is the catalytic agent for transforming the food we eat and the air we breath into Postnatal Qi. It also facilitates the production of Blood.

Yuan Qi is housed in the Lower Dantian, and it also flows out to the internal organs and channels through the Triple Burners. Yuan Qi is said to enter the Twelve Primary Channels (the body's twelve major energy pathways) through the Yuan points (sometimes called Source points) in acupuncture theory.

Of the Three Dantians, the Lower Dantian is closest to the Earth, is the most Yin, and has the strongest ability for gathering Earth Qi. In Medical Qigong, once students have learned to conserve and circulate their own Qi, they can increase it by connecting to the unlimited reservoirs of Qi

in the natural environment. Earth energy is the first form of external Qi with which the Qigong practitioner connects. This energetic connection to the Earth is important for several reasons.

1. First, Qigong practitioners need the Yin grounding power of the Earth Qi to counterbalance the gathered active Yang energy from Qigong exercises. Without grounding in Earth Qi, many Qigong practitioners develop Qi deviations in the form of Excess Heat.
2. Second, each person's supply of Qi is limited. When Qigong doctors extend their Qi to heal others, they deplete their personal supply of Qi unless they are able to simultaneously replenish their supply from outside sources.

Even people who do not practice Medical Qigong draw Earth Qi into their Lower Dantians. By practicing Qigong and using conscious intent, the amount of Earth Qi drawn into the body is vastly increased.

THE LOWER DANTIAN AND SHEN

The Lower Dantian itself is considered a center of consciousness. The consciousness of the Lower Dantian is more kinesthetic or physical given its Yin nature and close proximity to the Earth.

The body's Jing is connected with the Po (Seven Corporeal Souls). The Po control our survival instinct and the subconscious physical reflexes associated with survival. For this reason, Oriental martial artists spend many hours cultivating their lower elixir field to have the integration of Jing, Qi, and Shen needed for the split-second clarity of focus demanded in life-and-death struggles.

THE LOWER DANTIAN AND KINETIC COMMUNICATION

Not only is the Lower Dantian the center of physical strength and the source of stamina, but it is also considered the "house" of physical (kinetic) communication, awareness and feelings. The level of awareness referred to as "the intuition of the physical body," or kinetic communication, is stimulated by the subconscious. The subconscious mind picks up many signals from the environment that are not processed by the logical mind. These signals can motivate spontaneous body movements and responses and are sometimes referred to as gut feelings.

Kinetic means "characterized by movement." It is usually felt as a movement in the body or of the body. It is in this kinetic state of awareness that allows Qigong doctors to naturally feel the patient's internal resonant vibrations within their own body. When the doctors' body suddenly feels hot or cold, starts shaking or trembling, this may indicate that their subconscious mind is trying to communicate the location and condition of the diseased area within the patient's tissues.

Most of the time, the feelings experienced in the Lower Dantian are very subtle, but Qigong doctors, with a heightened degree of awareness of their own body, are able to pick up subtle variations of energetic shifts within themselves and others. When doctors collect energy in the Lower Dantian, an increased awareness and sensitivity naturally occurs. Cultivating this ability simply requires practice in paying attention to the physical body. A high level of awareness of the physical body, the surrounding environment, and the relationship between the two is required to maximize kinetic communication. When awareness is increased, perceptual feeling and kinetic body movements happen naturally. These are subtle senses that allow Qigong doctors to feel, smell, or hear energetic phenomena as they are released from the diseased tissues of patients.

According to research conducted by Dr. Michael Gershon, a professor of anatomy and cell biology at Columbia Presbyterian Medical Center in New York, the Lower Dantian sends and receives impulses, records experiences, and responds to emotions. Its nerve cells are bathed in and influenced by the same neurotransmitters as the brain. The Lower Dantian's "brain," known as the enteric (intestinal) nervous system, mirrors the body's central nervous system and is a network of 100 million neurons (more then the spinal cord contains), neurotransmitters, and proteins that can act independently of the body's brain, and can send messages, learn, remember, and produce feelings.

Dr. Gershon explains that active within the neural system of the lower abdominal area are major neurotransmitters like serotonin, dopamine, glutamate, norepinephrine, nitric oxide, enkephalins (one type of natural opiate), and benzodiazepines (psychoactive chemicals that relieve anxiety). The lower abdomen also has two dozen small brain proteins called neuropeptides. Dr. Gershon's research results provide modern scientific verification of what Eastern wisdom has taught for millennia -- that centers of consciousness exist at places in the body besides the brain and that the abdomen is one of the body's major centers of awareness.

ANATOMICAL LOCATION OF THE LOWER DANTIAN

The Lower Dantian is centered below the umbilicus, inside the lower abdomen, forming a downward pointing triangle. It occupies the first three lower Chakra gates. Chakras are small energy centers that originate from the Taiji Pole and have one or more gates.

1. The lowest point of the Lower Dantian extends to the Huiyin CV-1 (Meeting of Yin) point at the perineum. The name refers to the area on the body responsible for gathering and absorbing the Earth energy. This area is responsible for gathering the Yin energy into the body and Lower Dantian area via the three Yin leg channels (Liver, Spleen, and Kidney). This area is sometimes known as the Lower Gate of the Taiji Pole, or the Bottom Gate of the Lower Chakra.
2. The front area of the Lower Dantian is located posterior to the Shenque CV-8 (Spirit's Palace) point at the navel. The name refers to the place where the mother's Qi and Shen enter the embryo during fetal development. This area is sometimes known as the Front Dantian, or the Front Gate of the Second Chakra.
3. The back area of the Lower Dantian is located at the Mingmen GV-4 (Gate of Life) point on the lower back, anterior to the second lumbar vertebra. The Mingmen occupies the place between both Kidneys. It is the root of Yuan Qi, and therefore determines life and death. The Mingmen provides the body's True Fire; it supplies the heat for the Triple Burners, and is responsible for stabilizing the Kidneys and Lower Dantian area. This area is sometimes known as the Back Dantian, or the Back Gate of the Second Chakra.
4. Medical Qigong schools in China differ in their belief as to where the center of the Lower Dantian is located. Some schools teach that the center of the Lower Dantian is affected by the different anatomical locations of the male and female reproductive organs. In these particular schools, the students are taught that in men, the center of the Lower Dantian is located posterior to the Guanyuan CV-4 (Gate of Original Qi) point. The center of the Dantian area in a women is said to be located internally higher, and posterior to the Qihai CV-6 (Sea of Qi) point. This area is sometimes called the Middle of the Dantian, referring to its position between the navel and Mingmen areas.

THE NINE CHAMBERS OF THE LOWER DANTIAN

The human body is viewed as a microcosmic replica of the power of Heaven. Just as Heaven is said to be divided into nine different levels, each containing various palaces, our bodies also are said to contain a large variety of palaces and chambers. The nine stars of the Big Dipper are said to correspond to the Nine Chambers of each of the Three Dantians.

The functional aspects of the body's psyche were described by ancient Qigong masters as "spirits" that lived within the nine chambers of the Lower Dantian. These "spirits" linked the body's energetic channels and vital internal organs into an organic harmony of life-force energy. Qigong masters believed that as each Dantian became energized, it would initiate specific reactions within the body's energetic system, causing certain energetic/spiritual awareness to manifest within the practitioner's psyche.

Each of the nine chambers is several inches in diameter and is numbered in accordance to its en-

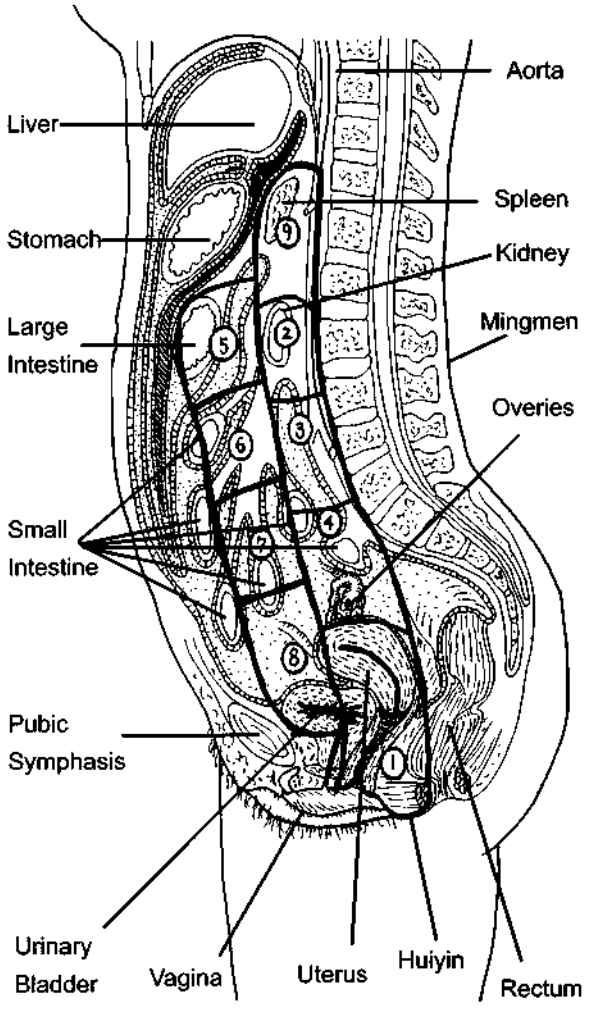

Figure 5.2A. The Nine Chambers of the Lower Dantian are shown here in the female body. Each number encompasses the entire chamber.

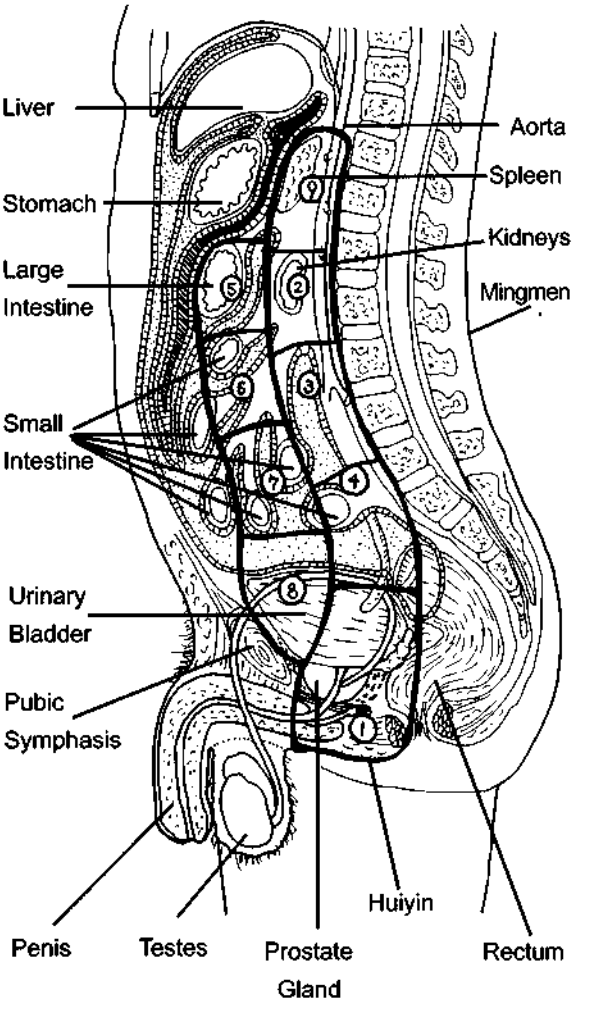

Figure 5.2B. The Nine Chambers of the Lower Dantian are shown here in the male body. Each number encompasses the entire chamber.

ergetic stimulation (Figure 5.2 A-B). This vertical abdominal set of Lower Dantian chambers relates to many cavities of the body's internal viscera. The Nine Chambers of the Lower Dantian are named as follows.

1. The Palace of Jade (Jade Stem or Jade Cave)
2. The Official Health Monitor (Kidneys)
3. The Minister of the Orchard Terrace
4. The Chamber of Moving Pearls
5. The Minister of House Cleaning (Large Intestine)
6. The Palace of Mystical Spirits (Small Intestine)
7. The Chamber of Mysterious Elixir
8. The Spirit of the Jade Court (Bladder)
9. The Spirit of the Yellow Court (Spleen)

ENERGETIC FOCUS OF TRAINING THE LOWER DANTIAN

All Qigong training begins with the focus on

the Lower Dantian. In the beginning stages of Medical Qigong training, the doctor will encourage students to focus their mind and breath on the Lower Dantian. The purpose of this training is to gather the body's Yuan Qi into the Lower Dantian (called "returning to the source"), to strengthen the foundational root for the body's energy.

It is dangerous for Medical Qigong students to bypass the discipline of Lower Dantian cultivation training to progress more quickly to the more advanced intuitive and psychic training of the Upper Dantian. Such an approach to training may lead to Qi deviations (see Chapter 18) and cause emotional instability.

THE MIDDLE FIELD OF ELIXIR

The Heart is the primary organ related to the Middle Dantian; the second organ is the Lungs. In Medical Qigong, the thymus gland is also of primary importance to the Middle Dantian.

In children, the thymus gland is quite large. As the child matures into adulthood, the thymus gland shrinks in size. Until recently, Western biologists thought that the thymus gland became vestigial and inactive in adults. Beginning in the 1980's, however, with the advent of the AIDS epidemic and the increase in cancer cases, intensive new research was launched into the immune system. As a result, scientists discovered that the thymus gland plays a major role in educating and maturing the white blood cells to become immunocompetent. This thymus function continues throughout one's life.

The Middle Dantian collects Qi and represents the body's energetic reservoir for mental and emotional vibrations and energy. The energy of man that is transformed in the Middle Dantian has a fluid quality—like water.

A refining process also takes place in the Middle Dantian, transforming the fluid energy into more steam-like energy that is then transferred to the Upper Dantian. The Middle Dantian transforms Qi into Shen by bringing the transformed Qi into the Heart Fire. This alchemical process is commonly called "changing Qi into Shen" and refers to kinetic energy transforming into spiritual consciousness.

The Middle Dantian is connected to the second level of Wei Qi, circulating about one-and-a-half feet outside the body. As the Middle Dantian fills with Qi, the colors of the student's middle field of Wei Qi change, becoming even more pronounced. The reason for this change is that the Middle Dantian is connected to the Five Agents, which in turn govern the Five Yin Organs and organ emotions. As the students begin to experience various stresses and emotional releases their aura (resonating from the internal organs, throughout the second energetic field) changes its colors.

THE MIDDLE DANTIAN AND JING

The Heart is related to the Fire element. The Heart derives its Yang Fire from the Kidneys. Modern research in Chinese medicine equates the function of the adrenal glands to the traditional function of Kidney Yang. In Western physiology, the adrenal glands help to regulate the pace of the heart.

To keep the Heart Fire in balance, the Heart also needs Yin. Heart Yin is derived from Kidney Yin (Jing is one aspect of Kidney Yin).

In traditional Chinese physiology, the Heart is said to govern the Blood. Not only is the Heart responsible for the circulation of Blood, but in the Chinese view, the transformation of Gu Qi into Blood takes place in the Heart. Food Qi (energy derived from the consumption and transformation of food matter) is a form of postnatal Jing, derived from the Spleen and Stomach. Blood is composed of Nutritive Qi (Ying Qi), Jing and Fluids (see Chapter 22). The Kidneys also send prenatal Kidney Jing to the Heart to make Blood. Therefore, Jing - particularly postnatal Jing - is vital to the Heart's function of governing Blood.

THE MIDDLE DANTIAN AND QI

Similar to the Lower Dantian, the Middle Dantian is also considered to be a Sea of Qi. The Qi of the Middle Dantian is called Zong Qi. Zong Qi is translated as Ancestral Qi, Gathering Qi, Genetic Qi, or Essential Qi. In English translation, it is sometimes confused with the Original Qi (Yuan Qi), but they are not the same. The Zong Qi is a form of postnatal Qi, whereas the Yuan Qi is housed in the

Lower Dantian and is a form of prenatal Qi. Zong Qi and the Yuan Qi assist each other to maintain the healthy function of the Heart and Lungs.

The Zong Qi nourishes both the Heart and Lungs, controls the speech and the strength of the voice, and interacts with the Kidneys to aid in respiration. According to Traditional Chinese Medicine, the Kidneys assist the Lungs in holding and stabilizing the breath when inhaling.

Qi and Blood are closely related. In Chinese medicine, it is often said, "Qi is the master of Blood; Blood is the mother of Qi." Qi gives the Heart and blood vessels the strength to circulate Blood and gives life to the Blood. Blood, on the other hand, houses and carries Qi to all the cells in the body. When one loses Blood, one also loses Qi. Therefore, one should consider Qi and Blood to be inseparable.

Qi is also inseparable from the mind and spirit. According to the teachings of ancient Tibetan Qigong masters, the channels are, metaphorically speaking, the road, the Qi is the horse, and the mind is the rider. Through refining the Qi, the mind and spirit are refined and purified. The Middle Dantian is the main focal point for this refinement of Qi into spirit.

THE MIDDLE DANTIAN AND SHEN

Classically, the Chinese locate the Mind in the Heart. In Chinese, the word for "mind" (Xin) is also the Chinese word for Heart. In Medical Qigong, a distinction is made between the Acquired Mind (Ren Xin) and the Original Mind (Yuan Xin).

The Middle Dantian is said to house the Shen and control all of the other functions of Shen that are attributed to the other Yin organs. Thus the Heart is often referred to as the Heavenly Emperor.

Throughout the world, people relate the heart to emotions and feelings. Emotions and feelings are one important aspect of the spirit. Any type of emotion will have an effect on the Shen.

The negative emotions are sometimes called "the five thieves" because even though negative emotions are necessary for life, chronic states of negative emotions drain the Qi.

The human mind easily falls under the influence of the Po (the Seven Corporeal Soul), that are concerned with survival. When the Po dominate the Heart, their overexaggerated self-concern gives rise to a chronic state of fear, sadness, worry, anger, and defensive arrogance.

The redeeming virtue of the Heart is a sense of propriety and discriminating awareness. The Hun (the Three Ethereal Souls) control the smooth flow of Qi throughout the body and are nourished by the Five Virtues of kindness, order, trust, integrity, and wisdom. These Five Virtues give peace and clarity to the Heart and allow the higher qualities of the Yuan Shen to overrule the Po.

An important relationship regarding the Middle Dantian and Shen is found in the Heart's role of governing the Blood. The ancient classics state that the Shen also resides in the Blood and pervades the body through Blood circulation. This relationship between Blood and Shen is one reason why anemic patients are often restless and suffer from insomnia. Through nourishing the Heart Blood, many forms of spiritual unrest can be treated.

According to Dr. Candace Pert's information on neurotransmitters (stated in *Psychoneuro Immunology*), the brain and white blood cells both contain the same neurotransmitters and biochemical constitutes that are prerequisite for consciousness awareness to exist. These same neurotransmitters and biochemical constitutes which are linked to consciousness are synthesized and created by the white blood cells. This similarity indicates that not only do the brain and abdomen have their own consciousness and nervous system but so does the Blood. This similarity also implies that consciousness is possible anywhere in the body, substantiating the ancient Chinese understanding that consciousness is pervasive throughout the body via the Shen, which resides in the Blood.

THE MIDDLE DANTIAN AND EMPATHIC COMMUNICATION

The Middle Dantian is also considered the "house" of emotional (empathic) communication, awareness, and feelings. Emotional communication is analogous to the feelings of empathy felt within the Heart. Empathy is the means by which

the Qigong doctor will most frequently get in touch with the emotional components of the patient's energetic blocks and imbalances.

Empathic communication is felt as an emotion and originates in the Heart and Middle Dantian area. When Qigong doctors focus on the Middle Dantian area, a line of communication is created with their higher self. We are all born with this ability, but as we grow older, we tend to override this type of emotional communication with our logical mind. These impressions slowly atrophy, eventually causing us to lose this natural empathic ability of communication. We disconnect from this higher perception due to the negative and double messages received from our parents and from society. The way to reconnect with the intuitive self is to look inward and become one with our true self, which is connected to the divine.

ANATOMICAL LOCATION OF THE MIDDLE DANTIAN

The Middle Dantian is shaped like a tetrahedron (four points): one area points toward the Upper Dantian and the Heavens, one area points toward the Lower Dantian and the Earth, one area points toward the front, and one area points to the back .

1. The front lower point of the Middle Dantian is located at the Zhongwan CV-12 (Middle Stomach Cavity) point on the midline of the abdomen, just below the sternum. This area is the master point of the Middle Burner and is sometimes known as the Front Gate of the Third Chakra.

   This emotional storage area is also called the Yellow Court because it reflects the emotions stored from the Heart, (the Heart was sometimes referred to as Suspended Gold in ancient China).

   The back lower point of the Middle Dantian is located on the Jinzhong GV-6 (Middle of the Spine) point. The name refers to the point's location. This area is sometimes known as the Back Gate of the Third Chakra.
2. The front center point of the Middle Dantian is located at the Shanzhong CV-17 (Central Altar) point, on the middle of the sternum at the level of the fourth intercostal space. The name refers to the "place of worship" where the Shen resides. This area is sometimes known as the Front Gate of the Fourth Chakra.

   The back center point is located two inches up from the shoulder blades, at the Shendao GV-11 (Spirit Path) point located at the hollow between the fifth and sixth thoracic vertebrae. The name refers to the easy accessibility into the patient's Shen residence (within the Heart) through this particular area on the back. This area is sometimes known as the Back Gate of the Fourth Chakra.
3. The upper front point of the Middle Dantian is located at the Tiantu CV-22 (Heaven's Chimney) point, at the throat. The name refers to the visceral cavity area at the base of the throat responsible for "pooling" escaped Heaven Qi from the Lungs. This area is sometimes known as the Front Gate of the Fifth Chakra.

   The upper back point is located on the Dazhui GV-14 (Big Vertebra) point on the back. The name refers to the point's location below the seventh cervical vertebra and above the first thoracic vertebra. This area is sometimes known as the Back Gate of the Fifth Chakra.
4. The center of this Middle Dantian area is located in the right atrium of the heart, centered between the SA (sinoatrial) and the AV (atrioventricular) nodes. The center of the Heart is considered the seat of all emotions.

THE NINE CHAMBERS OF THE MIDDLE DANTIAN

The Middle Dantian regulates the body's Heart—Mind connection. The Heart-Mind connection includes both the all pervasive consciousness of the entire body and the Shen. It distributes the flow of Yuan Qi into the Yin and Yang aspects of the body's mental and emotional functions. These functions within the psyche are controlled by the interaction of the body's Wu Jing-Shen or Five Essence Spirits (Hun, Po, Zhi, Yi, and Shen). The energy of the Middle Dantian is also

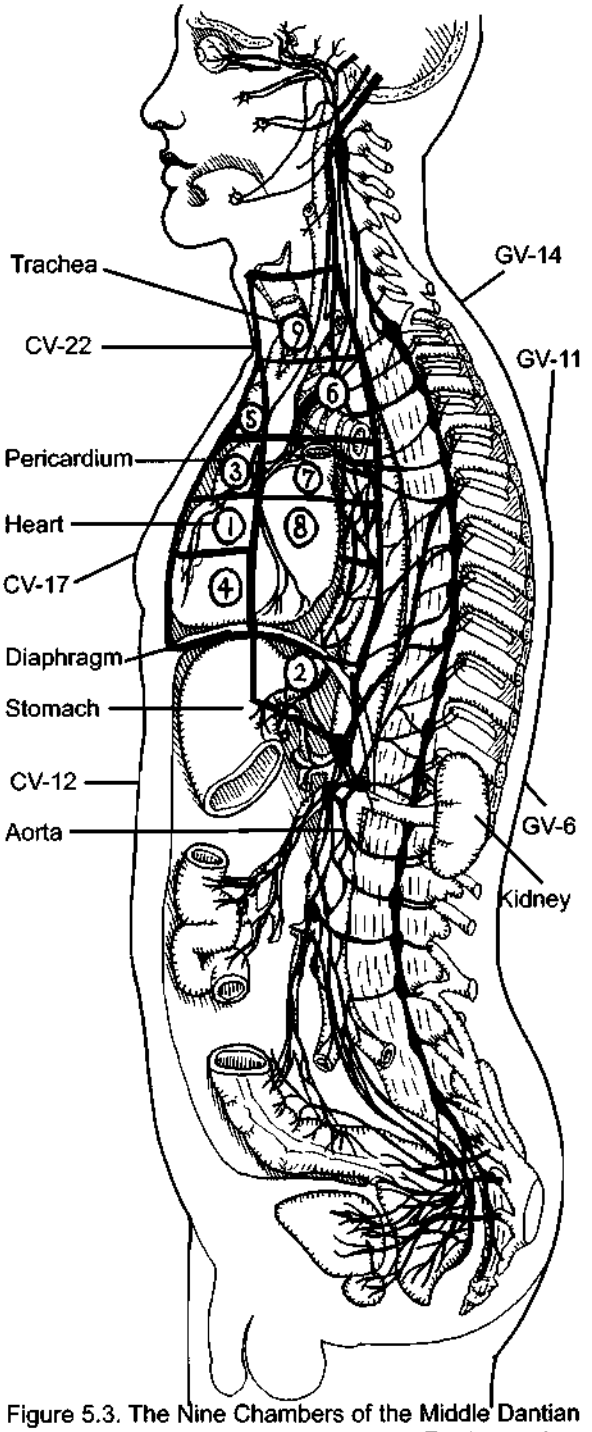

Figure 5.3. The Nine Chambers of the Middle Dantian are identical for men and women. Each number encompasses the entire chamber.

associated with the Spleen and Stomach energies. The vertical thoracic set of nine chambers (Figure 5.3), located within the Middle Dantian, originate around the auricles and ventricles of the heart (especially the pericardial and pleural cavities). The Nine Chambers of the Middle Dantian are named as follows.

1. The Chamber of Mysterious Elixir
2. The Lower Court of the Heart
3. The Chamber of the Ultimate
4. The Chamber of Splendor
5. The Heaven's Cover
6. The Twelve Storied Chamber
7. The Chamber of Government
8. The Purple Chamber
9. The Heaven's Chimney

ENERGETIC FOCUS OF TRAINING THE MIDDLE DANTIAN

In Medical Qigong training the doctors encourage their students to focus their mind and breath on the Middle Dantian to regulate the Heart. Techniques are used for treating Deficient conditions by drawing Qi into the Heart and Middle Dantian area, then regulating the body's energetic fields. For treating Excess conditions, the students are encouraged to lead and purge the Excess Qi from the Heart and Middle Dantian area through the body's extremities. The purpose of this training is to release the toxic Excess Qi gathered in the patient's Heart and Yellow Court areas. These areas of Excess tend to cause disease.

THE UPPER FIELD OF ELIXIR

The Upper Dantian is the collector of Heaven Qi and represents the spiritual aspect of man and his connection to the divine. The Heaven energy that is transformed in the Upper Dantian is of a thinner more ethereal quality—like vapor.

The Upper Dantian is connected to the third level of Wei Qi, circulating several feet outside the body. As the Upper Dantian fills with Qi, the spiritual intuition and psychic perception of the individual increases.

In Chinese physiology, the brain controls memory, concentration, sight, hearing, touch, and smell. These senses stay in close communication with the Heart and Shen.

THE UPPER DANTIAN AND JING

The Jing and Qi form the material foundation for the Shen. In Chinese, the term Jing-Shen means mind or consciousness. Jing-Shen may also mean vigor, vitality, or drive. In China both Western and Chinese doctors use the term Jing-Shen Bing to refer to all types of mental illness. The term Shen is rarely used by itself in a medical context without the concept being connected to the close relationship between the power of the mind and spirit.

The term Wu Jing Shen is used in Medical Qigong to describe the body's Five Essence Spirits (Hun, Po, Zhi, Yi and Shen). These five spirits combine the energetic essence of the Five Yin Organs in order to create the body's innate spiritual consciousness.

The Jing itself is considered the basis for, and ruler of Marrow (a substance derived from the Kidneys that nourishes the brain, spinal cord and forms bone marrow). The brain, is one of the six Extraordinary Organs and is called The Sea of Marrow, and is considered to be a form of Marrow. The six Extraordinary Organs are hollow Yang organs that store Yin Jing. Deficiency of Jing may lead to poor concentration, poor memory, dizziness, and absentmindedness. Deficiency of Prenatal Jing is related to mental retardation and attention deficit disorder (ADD) in children.

In some styles of Qigong, the Jing is intentionally conserved and its energy is drawn upwards from the Lower Dantian through the spine to nourish the brain. Such nourishment benefits the mind and spiritual consciousness.

THE UPPER DANTIAN AND QI

The head is the most Yang part of the body since it is the closest part of the body to Heaven. The Qi that operates in the Upper Dantian is, therefore, Yang in nature. The Spleen and Kidneys send the Clear Yang Qi (pure, light, and insubstantial) upwards to the brain to facilitate mental clarity and activity.

The Upper Dantian is also the place where we connect with the Yang Qi of Heaven. Qigong practitioners consciously absorb Heavenly Qi through the upper doorway, Baihui GV-20. The Heaven Qi is composed of the Qi from the celestial bodies: the sun, moon, planets, and stars.

The Upper Dantian is located in the center of the brain, in an area that encompasses the pineal, pituitary, thalamus, and hypothalamus glands. The pineal gland and hypothalamus have been shown to be extremely sensitive to the influence of light. In his book, *The Body Electric*, Dr. Robert Becker cites experiments with bees and several species of birds that indicated that these animals navigate by the light of the sun. Birds have disproportionately large pineal glands. He also discovered that birds seem to have a backup system of navigation based upon a sensitivity to the electromagnetic fields of the earth.

There are three forms of Qi to which the brain responds and interacts: light, electricity, and magnetism. These particular forms of energy stimulate the pineal, pituitary, thalamus, and hypothalamus glands, affecting and influencing the emotional responses.

THE UPPER DANTIAN AND SHEN

We have already discussed the relationship of the Jing and the Shen with the Upper Dantian. Of particular interest to the alchemists is the opening of the center of the Upper Dantian, called the Crystal Room, where psychic perceptions and intuitive knowing take place. Higher communications, a sense of great bliss, and perceptions that transcend the seeming bonds of time and space are associated with the Upper Dantian. These experiences are particularly valuable to Qigong doctors, who use these heightened perceptions to diagnose illness. Their efficacy is well documented in the works of such authors as C. Norman Shealy and Caroline Myss, who use the term "medical intuitive" to describe this paranormal ability.

The Upper Dantian is also the place where the Eternal Soul connects with the Wuji, and with the Dao. The awareness associated with this union is beyond description, as its unity supersedes the differentiation inherent in conceptual thought.

Although the Upper Dantian is responsible for intuitive and psychic perceptions, the combined energetic properties of all three Dantians establishes the foundation for all psychic perceptions. The steam-like quality of the energy with

the Upper Dantian fuses within the light now existing in this center. As this energy disperses, it travels out into the Wuji, returning back to the divine. This interaction is also responsible for what the Chinese call "receiving the message," which describes the ability of connecting with the patients' subtle energy field to acquire the hidden knowledge stored within the patients' tissues.

While in a state of tranquillity and inner peace, the Qigong doctors' Upper Dantian will also intuitively process information from the environment and universe. This intuitive knowledge provides Qigong doctors with a greater ability to explore both their own consciousness and the patients'. The ancients called this ability "knowing without knowing."

THE UPPER DANTIAN AND INTUITIVE COMMUNICATION

As the Shen is developed and the Upper Dantian is opened, spiritual communications may reveal themselves in a flash of an image or a vision in the mind's eye. These images and visions are sometimes very abstract and short lived. Interpreting images takes practice because the images streaming from the Yuan Shen cannot be interpreted easily by the logical mind.

The Qigong doctors must be able to distinguish between true and false messages reflected through their visions. True visions are received from the divine connection to the Dao or Wuji; false visions reflect the messages from the subconscious. The ability to accurately separate these visions is an another example of "knowing without knowing."

Although communication from within usually makes itself felt as a strong impulse, Qigong doctors must learn to keep the logical mind from interfering by practicing spiritual meditations. These meditations involve the forging of links in the chain of communication with the higher self. They should be practiced again and again until this connection becomes a natural, recurring phenomenon. The more one practices at stilling the logical mind and circumventing the ego, the easier it will be to get a clear communication from the higher self. When the higher self initiates a communication, it does not demand or impose itself, and if ignored it will usually stop sending signals.

Five Elements must be in place before the communication lines become fully open and operational:

1. Purity in intention,
2. No hidden agendas,
3. Surrender to the divine will,
4. Complete trust and faith in success (believe and expect), and
5. A quiet and receptive stillness of mind.

The lines of communication with the higher self are severed by the logical mind through doubt, fear, and disbelief. Strong faith is required to open this line of communication. Faith requires no logical proof; if proof is needed, then doubts interfere and breed failure. The logical mind cannot know absolute faith and, therefore, faith must come from deep within one's true self. Any form of cynicism will lead to the death of spiritual growth, for it strikes at the root of faith itself.

Faith is not something that can be forced. Even after practicing Medical Qigong for many years, Qigong doctors may still have to battle their own questions. However, through successful practice, the seed of faith is established, allowing it to grow and blossom. The opposite of faith is doubt combined with fear. Suppression and denial of fear builds and armors the ego, which leads to further pain. If the fears are accepted and acknowledged, they can be overcome by faith.

ANATOMICAL LOCATION OF THE UPPER DANTIAN

The Upper Dantian is located in the head, approximately three inches posterior to the Yintang point (between the eyebrows). It is shaped like a pyramid, facing upward to gather the energy from Heaven. This pyramidal reservoir houses light.

1. The front point of the Upper Dantian is the Yintang (Hall of Impression) point. The name refers to the ancient tradition of placing a red mark or "seal" over the Bright Hall, or Entrance of the Spirit, this point represents wisdom and enlightenment. This area is sometimes known as the Front Gate of the Sixth Chakra, or the Third Eye point.

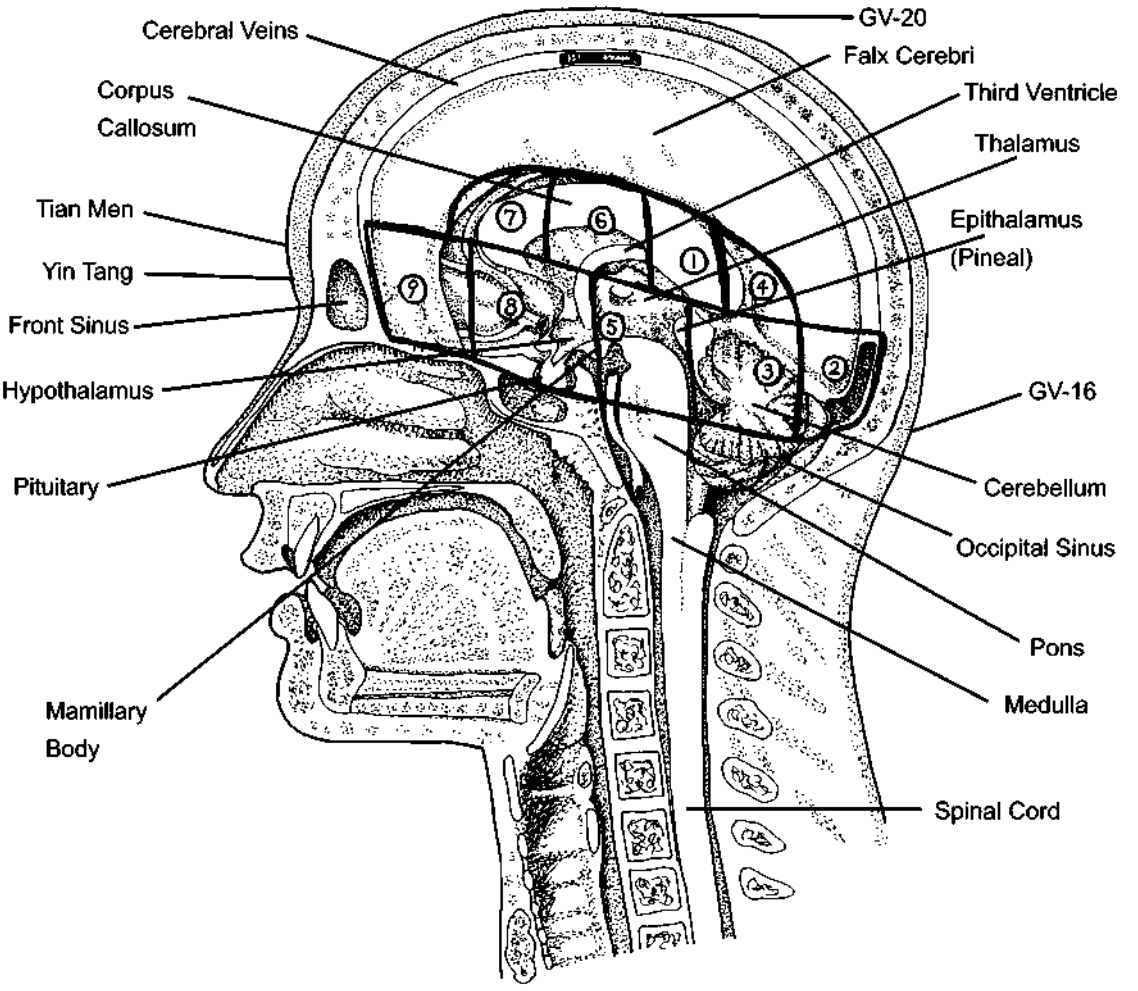

Figure 5.4. The Nine Chambers of the Upper Dantian are portrayed in this drawing. Each number encompasses the entire chamber.

2. The back point of the Upper Dantian is located below the external occipital protuberance, on the Fengfu GV-16 (Wind Palace) point. This area is also connected with and surrounded on both sides by the Bl-10 (Heavenly Pillar) point. The energy field connected to this point may be likened to an antennae receiving messages; it allows Qigong doctors to regulate their state of consciousness. The Governing Vessel 16 point is also a Sea of Marrow point, which is used to affect the flow of Qi and Blood to the brain, and a Window of Heaven Point (one of eleven points used for treating Shen disturbances), as well as one of the thirteen points identified by the famous Daoist physician Sun Simiao as a Ghost Point (points used for treating spirit possession). It has been my personal observation that students with a more prominent occipital protuberance tend to see auras more easily and receive psychic intuition faster. This area is sometimes known as the Back Gate of the Sixth Chakra.
3. The highest point of the Upper Dantian is lo-

cated on the vertex of the crown, on the Baihui GV-20 (One Hundred Meetings) point. The name refers to the ancient tradition that one receives divine messages and spiritual intuition from this point into the Upper Dantian's Chamber of Mysterious Elixir, located within the third ventricle of the brain. This area is sometimes known as the Upper Gate of the Taiji Pole or the Upper Gate of the Seventh Chakra.

It is also said in Traditional Chinese Medicine that all of the body's major channels send a connecting vessel to the Baihui so that at death the Qi can leave the body through this upper doorway and ascend to the Heavenly realms.

4. The center of the Upper Dantian is located in the pineal gland. It is the area where the Shen transcends and merges with the Wuji and then progresses on to the Dao. The Upper Dantian is also considered the house of spiritual (intuitive) communication, awareness, and feelings.

THE NINE CHAMBERS OF THE UPPER DANTIAN

The horizontal cephalic set of nine chambers, located within the Upper Dantian (Figure 5.4) is based on the different ventricles of the brain. The Nine Chambers of the Upper Dantian are named as follows.

1. The Chamber of Mysterious Elixir (Mystical Medicine)
2. The Palace of Jade Emperor
3. The Palace of Moving Pearls
4. The Chamber of Splendor
5. The Hall of the Upper Dantian (Medicine Field)
6. The Chamber of the Ultimate Truth
7. The Cover of Heaven (Palace of the Heavenly Court)
8. The Chamber of Government
9. The Entrance of the Spirit (Bright Hall)

ENERGETIC FOCUS OF THE UPPER DANTIAN

In Medical Qigong training, the Upper Dantian pertains to gathering spiritual intuition and light to advance the doctor's intuitive and psychic ability (see Six Transportations of Shen, Chapter 13).

The Qigong doctor may also absorb universal and environmental Qi into the Upper Dantian through the Yin Tang (Third Eye region) and the Tian Men areas (located in the center of the forehead), and emit healing Qi to patients through either one or both of these points. The Shen can both exit and enter the body from the area in the Upper Dantian by way of the Baihui, Yin Tang, and Tian Men (Heavenly Gate) areas.

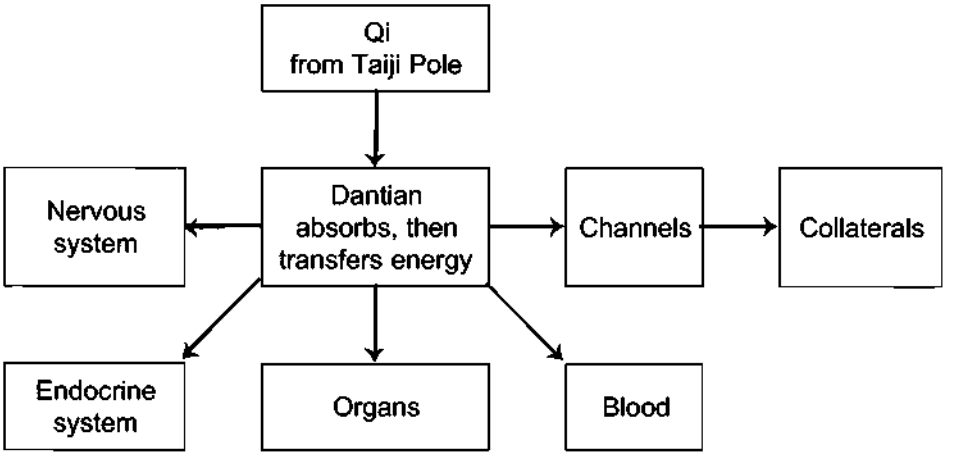

Figure 5.5. Qi Dispersion From the Center Taiji Pole Through the Dantians into the Body

THE FUNCTIONAL ASPECTS OF THE THREE DANTIANS

The three energy reservoirs of the Dantians are linked externally through the Governing and Conception Vessels and internally through the Thrusting Vessels and the Taiji Pole.

The center of each Dantian is penetrated by and attached to the Taiji Pole, which exits from the Baihui at the top of the head to the Huiyin point at the perineum. Each of the Dantians corresponds to anatomical locations that are centers for magnetic and electrical vibration and charge. The body's intensity of vibration and charge is dependent on the mental intention, the posture, and the respiration.

Qi moves into the body's Dantians through the body's Taiji Pole. The energy is then absorbed into the body's major organs and surrounding tissues as it flows out of the Dantians and into the body's internal and external channels and collaterals.

Each Dantian acts like a reservoir, collecting energy and redistributing it into all of the internal organs. This energy projects through the surface of the body into the Wei Qi field. The same energy also projects inward flowing through the energy channels, along the nervous system and endocrine glands, and then through the Blood, to nourish the body (Figure 5.5).

You can visualize this energy transformation as follows: Qi flows into the body like rainwater flowing into a lake (the body absorbing and collecting Qi into the Dantians). The rainwater is then absorbed into the surrounding soil, foliage, and root systems (skin, tissues, and cells) before it gathers, collects, and pools into deep artesian wells (the Dantians). Pressure begins to build up as these artesian wells fill with the rainwater, and eventually overflow, pouring into smaller pools (the organs) before combining with the rushing action of underground streams (the channels).

Another popular analogy is to consider the Dantians as batteries, the body's Taiji Pole as a magnetic bar connecting the batteries together, the channels as the wires, and the Wei Qi fields as the electromagnetic fields manifesting from the energy contained within the structure.

Mental and emotional awareness of a specific tissue area can be heightened through increasing the flow of energy to that location. When energy fills the tissues, a cellular release of energy causes the tissues to either store or release emotions, depending on the body's overall Excess or Deficient Qi.

If an increase of Qi is focused into the Lower Dantian, the result is a more powerful and stable feeling in the body. When an increased amount of Qi is focused into the Middle Dantian, the result

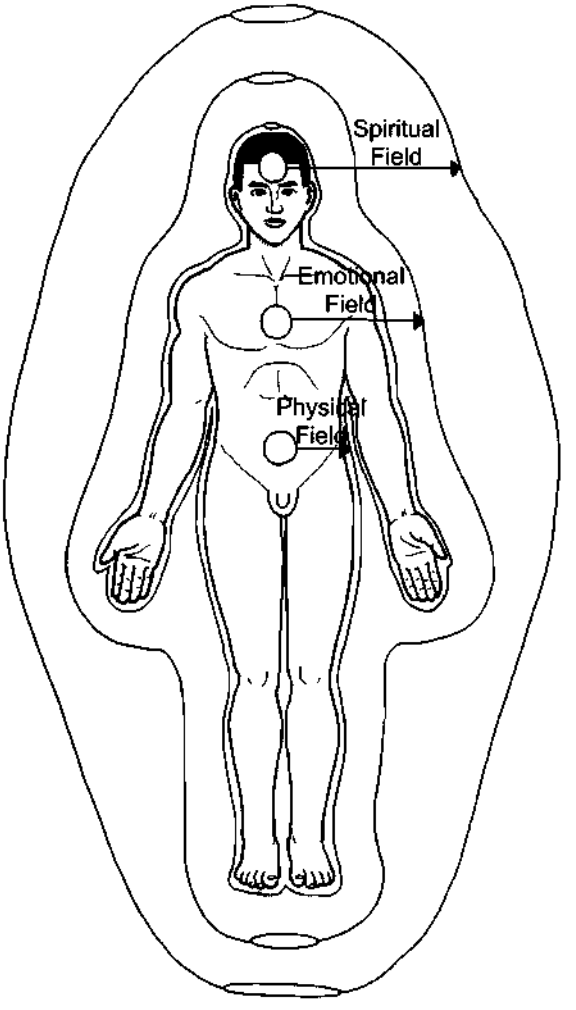

Figure 5.6. The Three Dantians and Their Relationship to the Three External Wei Qi Fields

is a heightened feeling of emotional perception and awareness. If an increase of Qi is focused into the Upper Dantian, a heightened spiritual awareness and sense of connection to the divine occurs. The greater these energies flow, the healthier the individual becomes, and the stronger his or her energetic fields become (Figure 5.6).

THE DANTIAN'S YIN AND YANG ENERGETIC CHAMBERS

Each of the Three Dantians can be divided into Yin and Yang energetic chambers. The Yang chambers relate to each Dantian's upper chambers and the spiritual aspects of the Hun. The Yin chambers relate to each Dantian's lower chambers and the carnal aspects of the Po. The chambers and their energetic potential are described as follows.

THE LOWER DANTIAN

1. The Yang Energetic Chamber of the Lower Dantian relates physically to the upper quadrant of the abdomen, located within the small intestine in men and the uterus in women. When influenced by the Hun, quiescence and serenity are enhanced.
2. The Yin Energetic Chamber of the Lower Dantian relates physically to the lower quadrant of the abdomen, which includes the reproductive organs and the Bladder, urethra, and anus. This chamber is responsible for reproduction and sexuality. When influenced by the body's Po, raw physical power and sexual vitality are aroused.

THE MIDDLE DANTIAN

1. The Yang Energetic Chamber of the Middle Dantian relates physically to the upper quadrant of the Heart, which includes the left and right atrium, the upper portions of the left and right ventricles, and the atrioventricular node. This chamber is responsible for spiritual attitudes and virtues related to the influence of the body's Hun. The Hun are responsible for:
   - gathering and transmitting divine inspirations and spiritual insights,
   - giving and receiving unconditional love, and
   - motivating spiritual growth through prayer, devotion, and commitment.
2. The Yin Energetic Chamber of the Middle Dantian relates physically to the lower quadrant of the Heart, which includes the left and right ventricles. This chamber is responsible for sensual passions, conquests, and conditional love. It deals with actions which are often based on hidden agendas. These emotions are related to the influence of the body's Po. The influence of both the Po and the Yin Energetic Chamber of the Upper Dantian activates, energizes and enhances:
   - biological drives (for food and self preservation,
   - sexuality, lust and desire, and
   - sensuality.

THE UPPER DANTIAN

1. The Yang Energetic Chamber of the Upper Dantian relates physically to the upper quadrant of the brain, often referred to as the third ventricle or higher brain centers. When stimulated, the higher brain centers manifest spiritual intuition and divine insight, related to the influence of the Hun. Such insight is responsible for spiritual growth and maturation. Insights eventually lead to the emergence of extrasensory perceptions (ESP), e.g., clairvoyance, clairaudience, telepathy, psychokinesis, and spiritual enlightenment.
2. The Yin Energetic Chamber of the Upper Dantian relates physically to the lower quadrant of the brain, often referred to as the "reptilian" brain. When stimulated, the reptilian brain activates the thalamus, hypothalamus, cerebellum, and cortex, which awaken the body's intuition, as well as animalistic and primordial instincts of survival. When the Yin Energetic Chamber dominates, the sensory, animalistic nature of the Po emerges full force. This phenomenon sometimes occurs when coma patients begin to recover. As energy begins to fill the lower chambers of the Three Dantians, their initial reactions are basic and carnal in nature, i.e., to either engage in sexual activity or strike out in violence. As the Qi begins to fill the upper chambers of the Three Dantians, the energy balances in the patient's

Taiji Pole and the patients' impulses return to normal.

THE DOCTOR'S PROJECTED AURA FIELDS

In China, Qigong doctors are tested and categorized according to the predominant color of their Qi emissions. The healing color will depend upon which of the three Dantians is dominant (corresponding to either the Lower Dantian, Middle Dantian, or Upper Dantian), and the energetic strength and potential of the individual being tested. The emitted color is observed in the visible-light spectrum projected from the Qigong doctor's hands.

YELLOW EMITTED COLOR

Individuals who have just begun their training will emit a yellow glow around their external energy field. The Qi will naturally overflow from the Lower Dantian area and the color yellow will dominate the aura. This is actually a normal aura color observed from most beginning Qigong doctors, indicating that the energy field is still too weak to treat serious diseases.

RED EMITTED COLOR

Qigong doctors who have mastered their body and mind will emit a red radiant glow around their external energy field. The Qi will also overflow from the Lower Dantian area, and the color red will dominate the aura. This is actually a normal range of aura color observed from the many Qigong doctors who have just graduated from Medical Qigong colleges, indicating that the energy field is at the intermediate stage.

PURPLE EMITTED COLOR

Qigong doctors who have evolved to the next level of mastering the emotions will emit a purple radiant glow around their energy field. These doctors' Qi will naturally overflow from the Middle Dantian area, and the color purple will dominate the aura. This aura color is observed in strong and advanced Qigong doctors.

BLUE EMITTED COLOR

Qigong doctors who have further refined their energy will emit a blue radiant glow around their energy field. These doctors' Qi will also overflow from the Middle Dantian area, and the color blue will dominate the aura. This aura color is observed in very advance Qigong doctors, and is developed only after many years of clinical practice and personal spiritual transformations.

WHITE EMITTED COLOR

The Qigong doctors who have mastered their spiritual life, as well as surrendered their body, mind, emotions, and spirit to a divine or higher calling will emit a white radiant glow around their energy field. These doctors' Qi will naturally overflow from the Upper Dantian area, and the color of the aura is considered the strongest and most powerful.

CLEAR-OPALESCENT EMITTED COLOR

The divine energy is emitted through a clear-opalescent color. This Qi emission is different then the white radiant glow, and is a sign of divine intervention and healing. These times of divine intervention can occur in any stage of the doctor's energetic development, and are a testimony to the healing virtue of the divine.

Although every Qigong doctor uses a combination of all Three Dantians when projecting Qi into patients, the color of the aura surrounding the doctor's body reflects which Dantian's reservoir is predominantly used. Through time, patience, and much practice, the Qigong doctor will be able to transform from a yellow to red, purple, blue, and finally to white-light healer.

THE TAIJI POLE

The Taiji Pole can be observed as a vertical column (or pole) of brilliant white light, full of vibration and energetic pulsation. This energetic channel flows from the Baihui point at the top of the head, through the center core of the body, connecting the Three Dantians. The Taiji Pole roots its energy at the base of the perineum at the Huiyin area.

In Chinese energetic embryology, as the father's sperm enters the mother's egg, it creates the upper or Heavenly vortex point of the Taiji Pole. At this stage of energetic development, the Heavenly vortex creates and connects the Three

Dantians together, rooting the column of white light energy into the Kidneys and Mingmen area. As the fetus continues to grow and develop, the Taiji Pole slowly descends, shifting its energetic root to the base of the perineum. After birth, the Taiji Pole can be observed as a vertical column of brilliant white light, surrounded by a veil of golden spiraling light.

HEAVEN, EARTH, AND MAN RELATIONSHIPS

The Taiji Pole of the body is comparable to the central axis of the Earth, which is known as the Taiji Pole of the Earth. At the end of the Earth's Taiji Pole are the North and South Poles, which are compared to the body's Baihui at the top of the head and Huiyin at the base of the perineum. The Earth's Taiji Pole (or central axis) aligns to the North Star.

The North Star is seen as the Taiji Pole of Heaven and is sometimes called the Pole Star or Taiji. It is sometimes said that the original Chinese character for Taiji means Yin and Yang. While the original meaning of the Chinese character for Yin is the shady side of the mountain, and Yang depicts the sunny side of the mountain, the mountain's peak is considered a Taiji, where both Yin and Yang meet (or the center of Yin and Yang).

The center Taiji is also called the Still Point, because although all of the changes of Yin and Yang occur in the Heavens within the course of a day, and all of the stars seem to make a 360 degree rotation (as the Earth rotates) the Pole Star remains stationary as Heaven's Still Point. In a similar manner, the body has the Taiji Pole as the "still point of man." A great stillness is experienced when a Qigong practitioner gathers Qi into the Taiji Pole.

INTERNAL ENERGY INTERACTIONS

Extending from the body's Taiji Pole are the Three Dantians, Five Jing-Shen, and the Eight Extraordinary Vessels. These vital energetic systems feed all the major organs and the body's Twelve Primary Channels. As the Three Dantians absorb energy from the body's Taiji Pole, they also extend, or "feed," and energize the body's Yin and Yang organs, Twelve Primary Channels, and Eight Extraordinary Vessels. Each individual Dantian is connected to the body's Taiji Pole and is responsible for creating its own alchemical transition in the process of converting Jing into Qi, Qi into Shen, Shen into Wuji, and Wuji back to the Dao (see Chapter 13).

In my clinical experience, the closer I work to the patient's Taiji Pole the more powerful the energies become. Accessing the patient's Taiji Pole, Three Dantians, and Eight Extraordinary Vessels for whole body tonification and regulation is faster and less draining on my energetic reservoirs then emitting Qi into the patient's Twelve Primary Channels to accomplish the same type of treatment.

THE FIVE THRUSTING CHANNELS

Five internal Thrusting Channels connect to and transverse the body's center Taiji Pole. These five internal channels begin at the perineum and spiral up through the center of the body's core, flowing into the upper crown of the head. They connect the Baihui area at the top of the head to the Huiyin area at the bottom of the perineum. These five internal channels absorb the Five Elemental energies of Heaven and Earth (Wood, Fire, Metal, Earth, and Water) into the body.

The Taiji Pole is responsible for absorbing the energy from Heaven and Earth and distributing the collected Qi into the body's major internal organs. Similar to the Earth's central axis, the Taiji Pole is divided into two main energetic polarities: The Five Portals of the Heavenly Yang Gate, located at the top of the head, and the Five Portals of the Earthly Gate, located at the perineum (Figure 5.7).

When the body's internal and external energetic wave patterns become synchronized through prayer or meditation, a rhythmic pulsation occurs within the Taiji Pole. This pulse begins deep within the center core of the body and vibrates outward towards infinite space connecting the Wuji with the Dao.

SPIRITUAL MANIFESTATIONS

When doctors penetrate the outside veil surrounding the center core of a patient's Taiji Pole and extend their intention into the light's center, they experience the sensation of falling into space

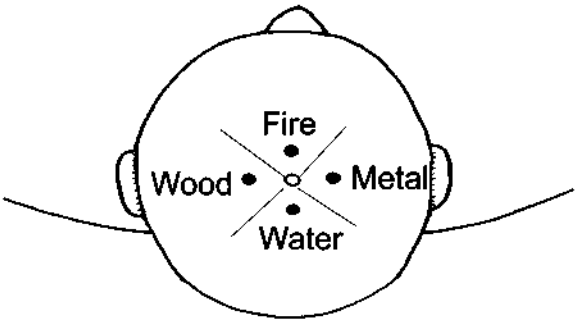

Top of Head

Figure 5.7. The Five Portals of the Heavenly Yang Gate are portrayed here as seen looking down at the top of the head. The Universal Energy is absorbed into the Taiji Pole through the Five Portals of the Heavenly Yang Gates, located at the center of the Baihui (One Hundred Meetings) and Sishencong (Four Spirits Hearing) areas, at the top of the head.

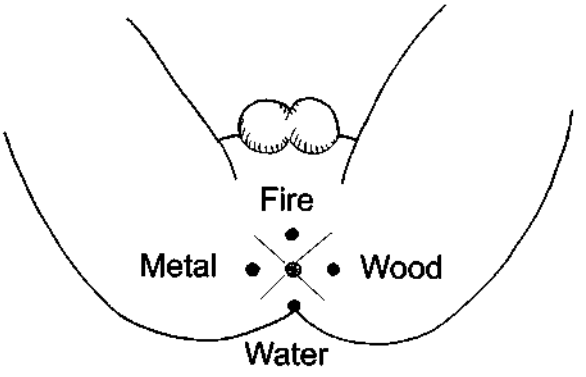

The Five Portals of the Earthly Yin Gate as seen from the perineum. The environmental energy is absorbed into the Taiji Pole through the Five Portals of the Earthly Yin Gates, located at the center of the anal sphincter, between the Huiyin (Meeting of Yin) and the Changqiang (Long Strength) areas, at the base of the perineum.

or shooting through space. This sensation is followed by seeing flashing colors and moving shapes, as the surrounding core dissolves into infinite space itself. As the Qigong doctors continue to extend their intention to reach this area, time and space feels as if they stretch into eternity. This experience is considered the true connection with the Wuji returning back to the Dao. The potential for this experience exists within everyone and can be accessed through deep prayer and meditation. It is quite a normal phenomenon within deep spiritual practices and is sometimes known as accessing the river of God.

ENERGETICALLY OPENING THE TAIJI POLE

When we are born, we are connected to great spiritual wisdom and power through our center core. During the maturation process, this connection slowly fades away, yielding to masks and defense mechanisms, that seek to shield us from our pain and self-hatred (shame). In childhood, every time we repressed the flow of painful feelings connected to an event, we froze that particular event in both energy and time, and locked it within our muscles. Since the external Wei Qi is composed of energy consciousness, a block of frozen psychic energy is formed within the Wei Qi at the moment we inhibit the pain. By walling off our wounds, we also wall off our connection to our deeper core self (Figure 5.8). We pretend not to feel the pain anymore, we block off the memory of the event. Thus, we prevent a natural resolution to the pain and the trauma of the event. Through denying our true feelings we disconnect from our core self and put on masks. We smile when angry, for example, or pretend indifference to our hurts. Since creative inspiration comes from our core, we lose our creative ability. When we stop the negative experiences of anger, pain, or fear, we also stop the positive healing of the physical, mental, and emotional aspects of the experience.

During Medical Qigong treatments, patients regress layer by layer through the pain and fear associated with the blocked energy that gives rise to the disease. Even though the memories may be very strong and frightening, as the emotions

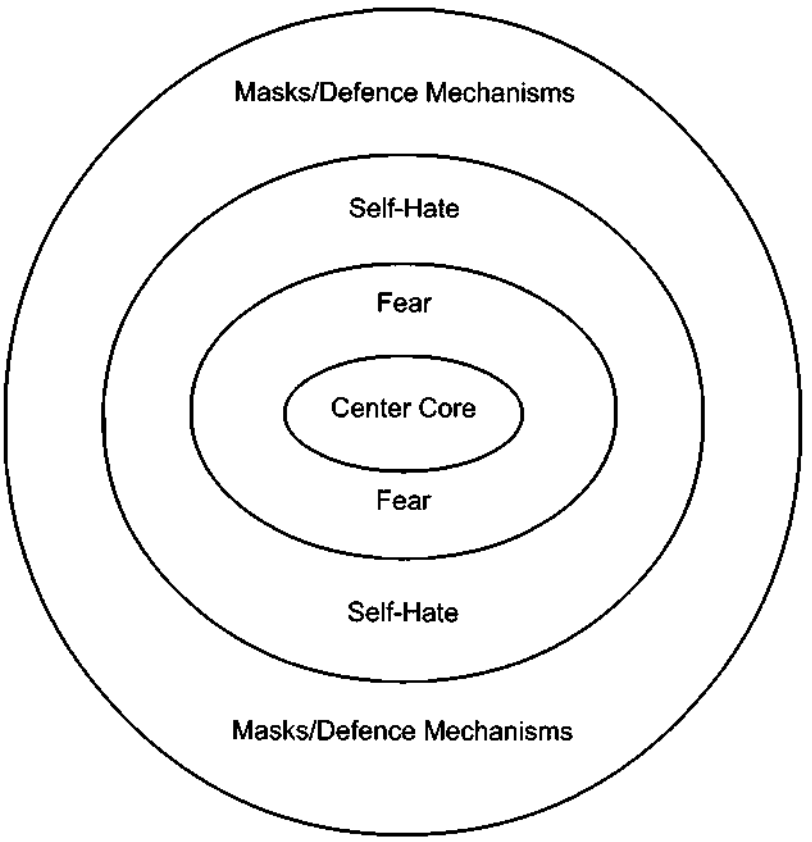

Figure 5.8. The True Self is Contained Within the Core Self

release, the pain decreases with the dispersal of the original trauma.

I have found in my clinical practice that most of the patients' pain comes not from the original trauma but from the unconscious belief system established to protect them from the original trauma. In other words, more pain and illness is created in our bodies by avoiding working through the original trauma (through our habitual defense and avoidance patterns) than was present in the original trauma. It requires enormous amounts of energy to suppress feelings, and each time we do so, we create further injuries to ourselves.

SPIRITUAL AWAKENING

When patients become aware of their spiritual connection to the divine, it is called an "awakening." This change can be observed through the spiritual transitions experienced within the patients' center core through their Taiji Pole. When the center Taiji Pole (which connects all three Dantians) begins to awaken, certain physical, emotional, and energetic reactions may occur within the patients' body. These transformations occur because the tissues of the energetic fascia (that connect to the major organs of the body) are enveloped within the energetic structure and webbing of the Taiji Pole.

THE TWELVE GATES OF THE CHAKRA SYSTEM

Although the body's major internal energy centers are contained within the interacting network of the Three Dantians, the Three Dantians also connect to the body's major energy doors (located on the Governing and Conception Vessels), known as the Twelve Gates of the Chakras. These Chakra gates are superficial, on the surface of the skin, and are not as deep as the Chakra Cores and Three Dantians which are all connected to the Taiji Pole (Figure 5.9).

The word Chakra is Sanskrit for "wheel." The Chakras look like small, colored disks, usually about the size of a silver dollar. Energetically the Chakra gates look like funnels or vortices of Qi. Qigong doctors and sages have for centuries described their perceptions of these gates as resembling energetic wheels or vortexes within the subtle energy body. Each funnel extends and expands its energetic vortex out into the body's Wei Qi field. As energy travels up and down the Taiji Pole it creates an energetic pulse. This energetic pulse resonates out from the body through the Twelve Chakra Gates, and can be felt several feet from the body. The bottom Chakra is located at the perineum and only has one gate, as does the top Chakra located at the top of the head; the second, third, forth, fifth, and sixth Chakras have two gates each, one on the front of the body and the other on the back of the body. These Chakra Gates serve the following different energetic functions:

1. The top or Crown Chakra gate is responsible for absorbing Heavenly Qi and light into the body, as well as energizing the center core's Taiji Pole.
2. The front Chakra gates are responsible for the patient's feelings and emotional activity. They are related to the patient's Shen and the Heart Fire energy. They are connected to the Conception Vessel.
3. The back Chakra gates are responsible for the patient's willpower and determination. They are related to the patient's Zhi and the Kidney Water energy. They are connected to the Governing Vessel.

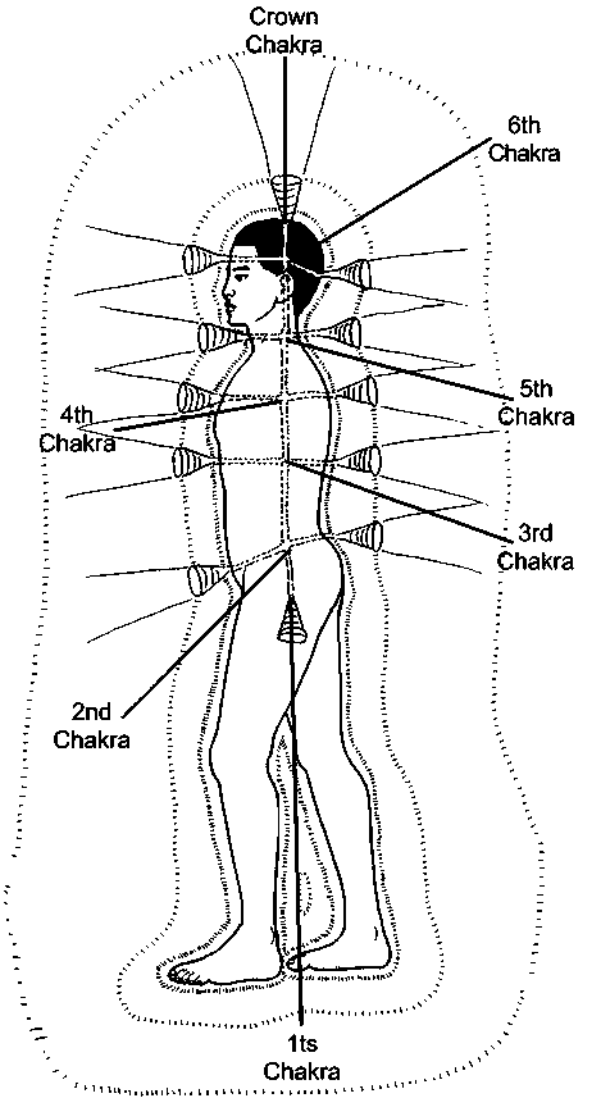

Figure 5.9. The body's Twelve Chakras Gates extend from the Taiji Pole and expand outward into the three external Wei Qi fields.

4. The center of the Chakras are actually deep inside the body's center core, located within the middle of the Taiji Pole.
5. The bottom or Base Chakra gate is responsible for absorbing Earthly Qi and heat into the body, as well as energizing the Taiji Pole.

Generally, when treating a patient, the Qigong

doctor extends energy into the patient's back Chakra gates to stabilize the emotions and to access control over the patient's will and determination. The doctor can, for example, connect with the Heart Chakra back gate, located on the patient's Shendao, GV-11 point, to access the emotions stored within the tissues of the Heart. The front Chakra gates are used to remove Excess emotions from the patient's tissues. Although the treatment approach differs, the Three Dantians system and Twelve Chakra Gate system, mutually support each other, both in the location of the energy centers, and in their physical manifestations of energetic function.

The Yin and Yang polarity of the Chakra gates are opposite in men and women (Figure 5.10). The Twelve Chakra Gates serve as subtle energy distributors, that help absorb and distribute environmental Qi to the patient's organs, tissues, and major nerve plexus areas closest to each gate. Each Chakra gate is connected to its own potential of psychic perception, interfaces with the body's nervous system, and is associated with a different endocrine gland. Any energy extended from the Qigong doctor towards a patient's Chakra gate will affect the patient's physical body. As the patient begins to energetically open the Chakra gates, the external energetic Chakra wheels begin to spin in half-circle rotations, opening and closing with the core's energetic pulse. The energetic action is similar to the centripetal (closing) and centrifugal (opening) action of the body's energetic channels.

Each opening of a Chakra gate may result in a spontaneous emotional release. Some of these releases can involve painful memories that have been dislodged from the energetic filter (or veil) that envelops the Chakra gates. This energetic filter prevents external emotional traumas from entering into the body's center core.

A Chakra gate can become stuck open, closed, or may also tilt out of alignment with the Taiji Pole, causing Qi Deviations that may result in a distorted or obstructed flow of energy. This obstruction may cause physical, as well as psychological, stress or trauma. The release of these emotional

Polarity		
Chakra	**Men**	**Women**
7th	+ Yang	– Yin
6th	– Yin	+ Yang
5th	+ Yang	– Yin
4th	– Yin	+ Yang
3rd	+ Yang	– Yin
2nd	– Yin	+ Yang
1st	+ Yang	– Yin

Figure 5.10. The energetic Yin and Yang polarity of the Chakra Gates are opposite in men and women. The Chakra Gates of a man start from a Yang (+) energetic field (at the Lower Chakra Gate) and change to Yin (-) at the second Chakra Gate, alternating from Yang to Yin up the body, ending at Yang in the Upper Chakra Gate. Women display the opposite energetic polarity in each Chakra Gate.

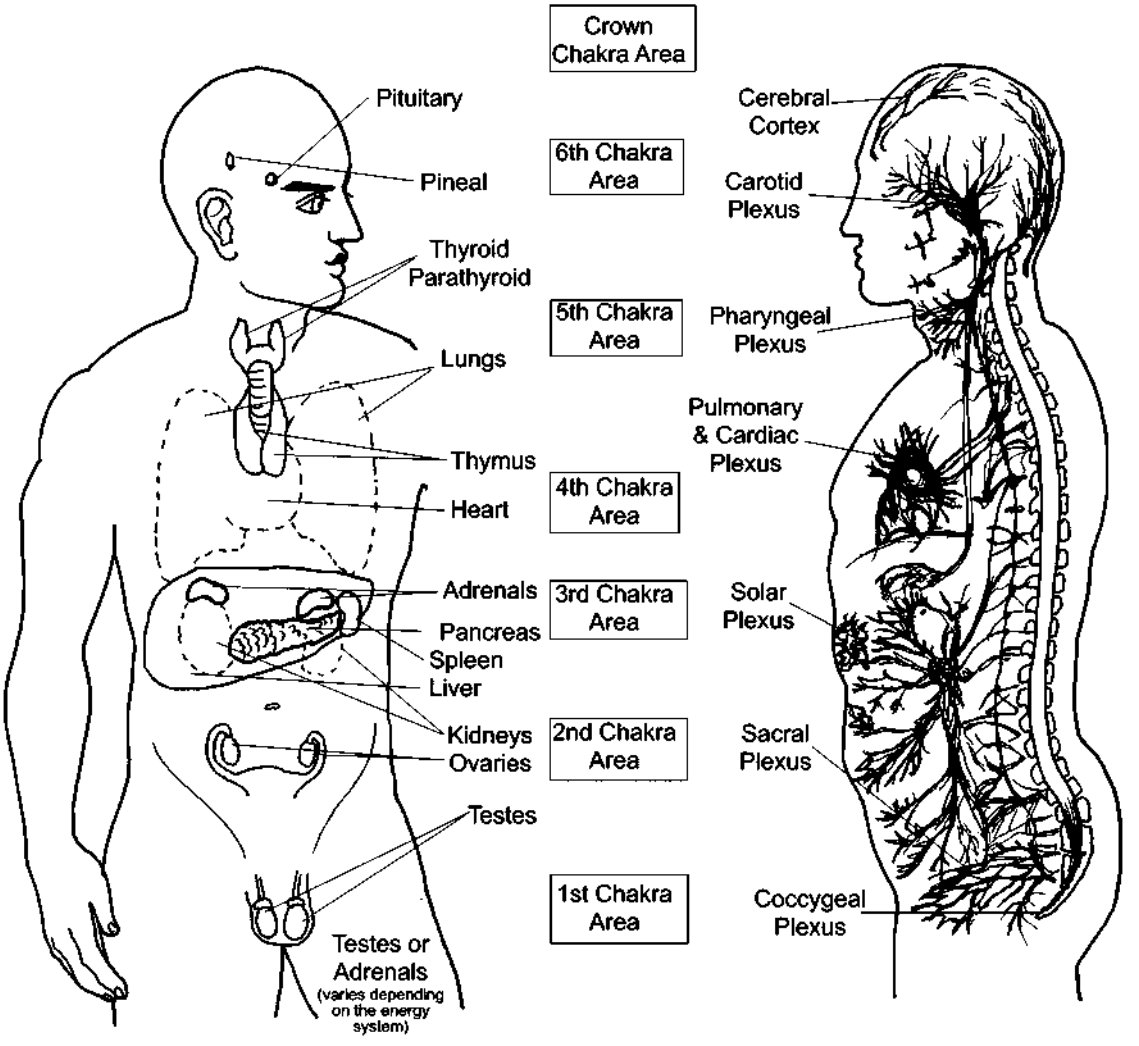

Figure 5.11. The body's Chakra system is connected by the Taiji Pole and extends outward into the body's nerve plexus, affecting the glandular system and both anterior and posterior external energetic fields.

traumas can be overwhelming and painful if the patient has not prepared for, or does not understand the nature of, these transitional energetic malfunctions. These manifestations usually occur when the patient's system has been energized and the body is actively seeking to release and get rid of toxic emotions from certain areas. Qigong doctors should be aware of these strong emotional reactions to assist their patients in facing and working through their fears and pain as the Qi Deviations along the Taiji Pole are corrected. Sometimes these experiences unwind at a rapid rate, stimulating the patient's central and anterior nervous system; this can release a flood of mental and emotional images and sensations, that are sometimes accompanied by shaking, thrashing, and other unusual movements of the body (Figure 5.11).

THE BOTTOM CHAKRA GATE

The bottom or first Chakra gate is sometimes called the Meeting of Yin (referring to the Earth energy), and is located near the perineum, in front of the anal sphincter on the Huiyin CV-1 point. This energy center controls the reproductive system and the urogenital organs and intersects with the Bladder and Kidney Channels. It is associated with survival instincts (the "fight or flight" response), security, tribal power (group acceptance), and the "grounding" or "rooting" of the body.

The first Chakra is associated with the Lower Dantian. Its energetic elemental nature relates to Earth, and its color is red. It connects to the Taiji Pole at the base of the perineum and exits at the top, or Crown Chakra.

The bottom Chakra is associated with the kinesthetic, tactile, and proprioceptive senses. It supplies energy to the spinal column, adrenal glands (in some systems), testicles/ovaries, and Kidneys. This Chakra gate is also connected to both the Conception and Governing Vessels.

The bottom Chakra gate will immediately open in any emergency situation, or when there is danger, to release stored information to ensure survival. Energetic malfunctions caused by stored emotional trauma in this Chakra can cause a massive amount of fear for one's life to be released. The retention of massive amounts of fear, or the sudden energetic release of panic, can cause the following symptoms: lower back pain, sciatica, constipation, hemorrhoids, rectal tumors and cancer, knee problems, and varicose veins.

THE SECOND CHAKRA GATES

The second Chakra core can be accessed through two energetic gates. The front gate is sometimes called the Spirit's Palace Gate and is located at the navel around the Shenque CV-8 point. The back gate is sometimes called the Gate of Life and is located on the lower back at the Mingmen GV-4 point.

This second energetic area is considered the "gateway of the Lower Dantian." Its energetic elemental nature relates to Water, and its color is orange. It is the energy center through which other people's emotions are perceived (kinesthetic perception), allowing one to be sensitive to other people and to sense dangerous situations.

The second Chakra is the energy center for sexuality, sensuality, the hunger for power, and financial issues. It supplies the sexual organs (ovaries and testicles) and the immune system with energy.

When the second Chakra gate opens the patient feels the release of sexual desires, waves of orgasm, and sexual fantasy. Because this area is also associated with the desire for power, sometimes the desire to destroy is released. Energetic malfunctions caused by stored emotional trauma in this Chakra can cause lower back problems, frigidity or impotence. Second Chakra dysfunction can also cause Kidney, uterine, Bladder, and urinary problems.

THE THIRD CHAKRA GATES

The third Chakra core can be accessed through two energetic gates. The front gate is sometimes called the Solar Plexus Center, in this system of Chakra diagnosis it is located between the navel and the xiphoid process (at the level of the pancreas), at the Zhongwan CV-12 (Middle Stomach Cavity) point. The back gate is called the Middle of the Spine and is located on the middle of the back at the Jizhong GV-6 point.

The third Chakra area is associated with the Middle Dantian and is known as the Yellow Court in Medical Qigong therapy. Its energetic elemental nature relates to Fire, and its color is yellow. It is the body's distribution point for psychic energies (gut instinct and intuition), personal power, and self-image. It is the area where the body's Qi transforms into Shen. It is also a storage chamber for severe emotional pain and anger.

This area supplies energy to the Liver, Gall Bladder, Stomach, Spleen, pancreas, adrenal glands, and nervous system. The third Chakra is the center for personal power-storing issues of responsibility, self-esteem, personal honor, and fear of rejection.

When the third charka's energy gates open, feelings of power and waves of anger, rage, fear, greed, jealousy, judgment, and criticism can be released. Energetic malfunctions caused by stored

emotional trauma in this Chakra area can cause ulcers, hypoglycemia and diabetes, as well as Liver and/or adrenal problems.

THE FOURTH CHAKRA GATES

The fourth Chakra core can be accessed through two energetic gates. The front gate is sometimes called the Heart Center and is located at the center of the breastbone, at the Shangzhong CV-17 point. The back gate is sometimes called the Spirit Path and is located on the Shendao GV-11 point on the back, between the scapula.

The fourth Chakra area is associated with the Middle Dantian. Its energetic elemental nature relates to Wind, and its color is green. This energy center is associated with love, compassion, empathy, clairsentience, and intuition. This area supplies energy to the Heart, Lungs, circulatory system, thymus gland, vagus nerve, diaphragm, and upper back.

When this energy center opens, it can be physically painful (the patient may experience feelings of a weight on the chest, heart attack sensations, or the release of tears) as the patient becomes aware of being attached to the personal ego. The feelings associated with the fourth Chakra have to do with our internal world, while feelings associated with the third Chakra have to do with the external world. Energetic malfunctions can cause Heart and Lung diseases.

THE FIFTH CHAKRA GATES

The fifth Chakra core can be accessed through two energetic gates. The front gate is sometimes called the Throat Center and is located just above the hollow of the throat, at the Tiantu CV-22 point. The back gate is sometimes called the Big Vertebra and is located on the back, at the base of the neck on the Dazhui GV-14 point.

This energy center is associated with sound vibration, personal and divine will, and communication. The fifth Chakra area is associated with the Middle Dantian. Its energetic elemental nature relates to sound, and its color is bright blue. It is the center for psychic clairaudience, and the power source for the Qigong doctor's "inner voice" guidance. This area supplies energy to the throat, thyroid and parathyroid glands, neck vertebrae, mouth, Lungs, and alimentary canal (the digestive tube from the mouth to the anus).

When the fifth Chakra energetic center opens, a compulsive urge to sing and chant arises. This area is also where Heat from the Liver Fire sometimes becomes entangled with Phlegm (a viscid substance that is a product and a cause of disease) from the Lungs, forming what is known as "plum pit Qi" (an energetic knot within the throat). Energetic malfunctions caused by stored emotional trauma in this Chakra area can cause stiff neck, sore throat, throat "plum pit Qi" symptom, thyroid problems and swollen glands. The patient sometimes experiences a release of unexpressed grief and anger, resulting in the physical reactions of excessive swallowing, coughing, or laryngitis.

THE SIXTH CHAKRA GATES

The sixth Chakra core can be accessed through two energetic gates. The front gate is sometimes called the Third-Eye Center and is located at the middle of the forehead at the Yintang or Hall of Impression point. The back gate is located on the back of the head, between GV-16 (Wind Palace) and GV-17 (Brain's Door), at the external occipital protuberance.

The sixth Chakra area is the center for psychic intuition, clairvoyant seeing (inner vision), and energy projection. The sixth Chakra area is associated with the Upper Dantian. Its energetic elemental nature relates to light, and its color is indigo (deep violet blue). This area of the body is responsible for enabling the Qigong doctor to see auras, Chakras, and other energetic images. This center is also responsible for mental telepathy, allowing the doctor to sometimes know the patient's thoughts and feelings. This area of the body supplies energy to the pituitary gland, lower brain, ears, nose, eyes, and nervous system.

When the sixth Chakra energy center opens, energetic malfunctions can result in headaches, eye strain, pain around the eyes, distorted or blurred vision, and sometimes blindness. Inaccurate interpretations of events, projections of personal fears and other emotions and motivations onto others may sometimes occur. Reoccurring nightmares and misguided fantasies may also be incurred.

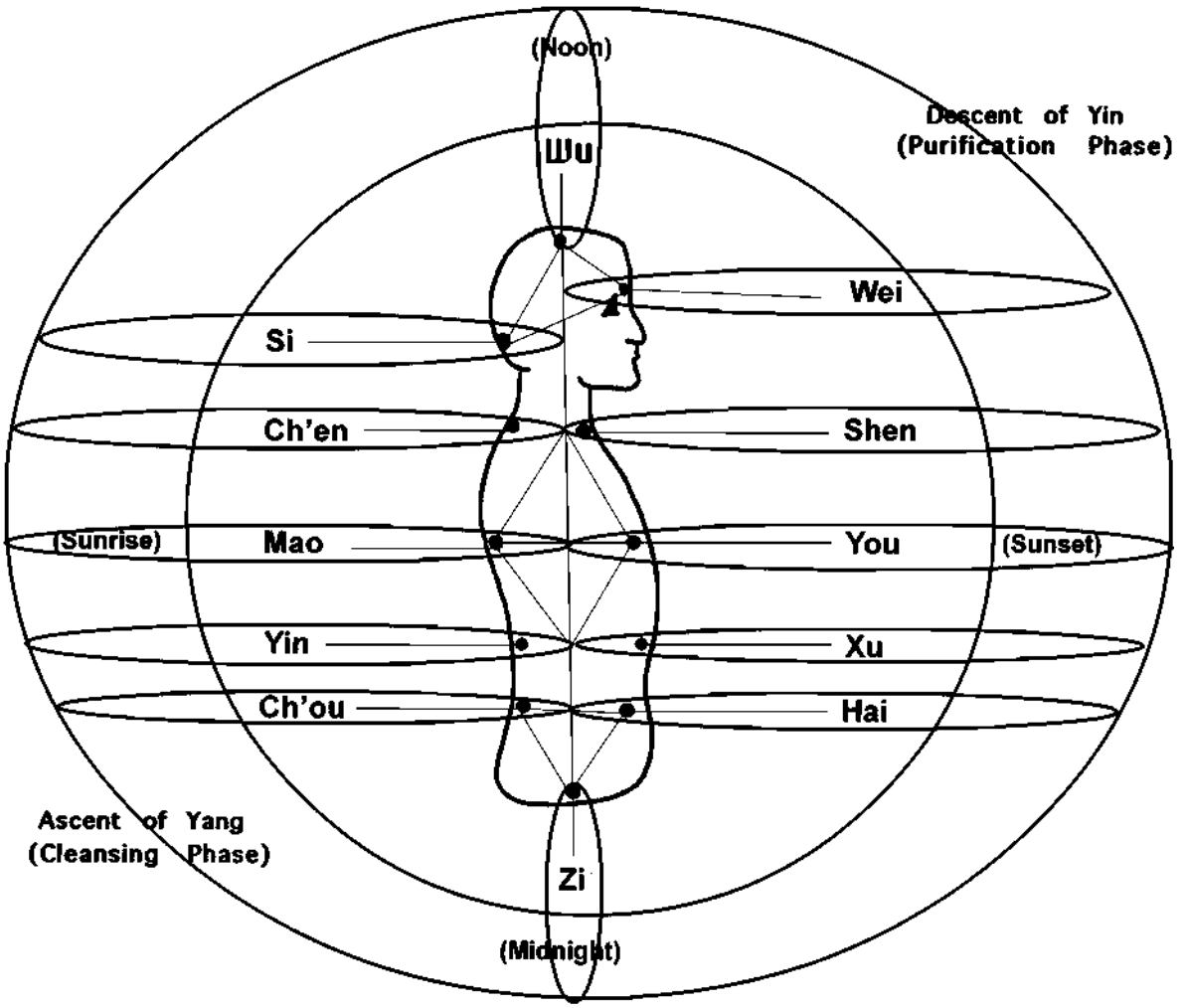

Figure 5.12. This figure shows the Twelve Earthly Branch Relation to the Twelve Chakra Gates. The Governing and Conception Vessels flowing through the middle of the back and front of the body correspond to the ecliptic path of the sun along the Twelve Chakra Gates, and are related to the Twelve Earthly Branches.

THE UPPER CHAKRA GATE

The upper or top Chakra gate is sometimes called the Crown Center and is located on top of the head at the Baihui GV-20 point. This energy center is associated with higher knowledge, understanding, pure intuition, and ecstasy. The upper Chakra area is associated with the Upper Dantian. Its energetic elemental nature relates to infinite space (Wuji), and its color is violet. This area supplies energy to the pineal gland and upper brain.

When the upper Chakra energetic center opens, it is like a golden flower opening, accompanied by a dazzling bright light and a strong, powerful connection with the divine. Energetic malfunctions result in confusion, apathy, alienation, boredom, depression, and a state of incomprehension.

TAKING PRECAUTIONS

When any of the energetic reactions to opening the Chakra gates take place, it is important for the student or patient to realize that these are only transitional stages and are normal phenomena which occur as a sign of energetic and spiritual transformations. The student or patient should take certain precautions, however, like being under the care of a qualified Qigong doctor when beginning any type of energy training.

It is also important not to allow patients to experience these emotional transitions alone. Because these energy transitions, malfunctions, and deviations are new to the Western mode of thinking, they can easily be misdiagnosed by doctors unfamiliar with energetic medicine. Patients should be encouraged to find or establish a support group consisting of advanced practitioners of energetic meditation. Having a support group of experienced practitioners allows these emotional and spiritual transitions to occur in a safe environment, where other experienced practitioners can monitor the patient's feelings, if and when, unfamiliar emotions start to emerge.

THE TWELVE EARTHLY BRANCHES AND THE TWELVE CHAKRA GATES

The body is viewed as a small and complete universe unto itself. The internal organs are influenced by the celestial movements of the sun, moon, planets, and stars. The Governing and Conception Vessels, where the Twelve Chakra Gates are located, are also affected by the Heavenly cycles.

In ancient China, the day was divided into twelve separate time divisions. Each time division corresponds to two hours of the day and was named after one of the Twelve Earthly Branches. These twelve time divisions were further organized into months and seasons (see Chapter 11). The ancient Qigong doctors discovered that the body's Qi and Blood mirror the Earth's seasonal ebb and flow, rising and falling like the lunar tides.

Each of the time periods corresponding to the Twelve Earthly Branches is regarded as having a specific influence on each of the Twelve Gates of the body's Chakra system. The rhythmic variations of the waxing and waning of Qi and Blood is associated to the waxing and waning of Yin and Yang energy, as well as the circulation of Qi following the Microcosmic Orbit (Fire) cycle.

Each of the Twelve Chakra Gates relates to one of the Twelve Earthly Branches following the Microcosmic Orbit (Fire) cycle (see Chapter 41). These Twelve Chakras Gates extend their energy from the patient's Taiji Pole outward, along the center of the body, through the anterior and posterior fields of Qi. Beginning at the bottom Chakra gate (the "Zi" Branch, representing midnight), the energy follows the Fire Cycle of the Microcosmic Orbit, traveling up the Governing Vessel, following the "ascent of Yang." After the Yang Qi reaches its peak, the Yin begins to grow. Starting at the upper Chakra gate (the Wu Branch, representing noon time), the energy travels down the Conception Vessel, following the "descent of Yin" (Figure 5.12).

Chapter 6
The Twelve Primary Channels and Organs

Introduction

According to Traditional Chinese Medicine, a system of channels exists that integrates all the body's separate parts and functions into a unified organism. The understanding of these channels and their energetic function and interactions provides the Qigong doctor with the basis for understanding the relationships among the various physiological, pathological, diagnostic, and therapeutic relationships in Traditional Chinese Medicine.

The study of Chinese medicine rests on, and is inspired by, the circulation of Qi, as many diseases follow a predictable course of development. The pathology in an internal organ will often manifest itself in certain external or systemic symptoms; therefore, understanding the circulation of Qi flow allows the doctor to control each organ's energetic function. By stimulating specific sites on the body's surface, diseases in both the superficial tissues and internal organs can be treated.

A doctor of Medical Qigong uses various techniques that facilitate the opening of the major energetic connectors of the body's internal organs. These connectors, called channels and vessels, are responsible for connecting the flow of Qi within the whole body to transfer Qi both internally and externally.

The channels are also known as meridians or Jing-luo. The Chinese character for this type of Jing means "to move through," while the translation of the character luo means "a net" (the body's inner fascia). Along these channels are major trunks and lesser branches that connect internally with the vital organs and externally with the major channels, limbs, sensory organs, and orifices.

The smaller branches are known as collaterals. The tiny areas along these channels and collaterals where the Qi pools are called points. These points are the spots where the patient's spirit and energy enter and leave the body. When stimulated, these channel points (sometimes also called "acupuncture points"), cause an energetic response from within the internal organs and channels, resulting in internal Qi flowing from organ to channel, from channel to channel, or from point to point along the same channel.

The channels unite the body as one unit. Channel theory is interrelated with organ theory. Traditionally, the internal organs have never been regarded as simply independent anatomical entities. Rather, Traditional Chinese Medicine focuses on the functional and pathological interrelationships between the channel network and the organs. The internal organs and their systems are sometimes known as "orbs" or "spheres of influence."

Qi travels throughout the physical body along the channels and collaterals much as water flows through rivers and streams. An ancient Chinese medical text explains this concept as follows: "Heaven is covered with the constellations, Earth with the waterways, and man with channels." Qigong doctors of ancient China paid much more attention to the Body Fluids and energies circulating through the body than to the physical anatomical structures. The ancient Chinese considered the Body's Fluids and energies much more fundamental.

The channels serve as the link between the energies, such as Jing, Qi, Shen, and the ingredients, such as Blood and Body Fluids, that feed and enliven the tissues. The human body's main energetic rivers are the Twelve Primary Channels and Eight Extraordinary Vessels (see Chapter 7).

CLASSIFICATION OF CHANNELS

The channels are classified into four main categories: Jing, Luo, Muscle Tendon, and Skin Zones.

1. The Jing Channels are the Primary Channels. These channels include the Eight Extraordinary Vessels, the Twelve Primary Channels, and the Twelve Divergent Channels.
2. The Luo Channels are the Collaterals. These collaterals include the Fifteen Major Collaterals, the Minute Collaterals, and the Superficial Collaterals.
3. The Muscle/Tendon Channels consist of twelve channels that serve as external connections to the major channels, flowing through the body's muscles, tendons, and ligaments.
4. The Cutaneous Regions are skin zone areas where the channels surface on the external tissues.

JING CHANNELS

The Jing Channels are the major trunks of the circulatory tree. They generally flow vertically through the body through relatively deep tissues. They also transverse the limbs peripherally and penetrate the body cavities to connect with the internal organs (Figure 6.1). They are the body's main interior and exterior rivers of Qi.

1. The Eight Extraordinary Vessels connect with, and regulate, the Qi and Blood of the Twelve Primary Channels by either absorbing any energetic "runoff" in times of channel Excess, or by replenishing energy in times of Deficiency.
2. The Twelve Primary Channels are bilateral and symmetrical. They can be identified in three specific ways: (1) according to the corresponding Yin or Yang organ to which they are connected, (2) by the arms or legs in which the channels originate or end, and (3) according to the six divisions of Yin or Yang Qi to which the channels relate (i.e., Tai Yang, Yang Ming, Shao Yang, Tai Yin, Shao Yin, and Jue Yin).

   The Yin channels run along the medial and anterior aspects of the body. They are associated with the solid Yin organs and connect with the hollow Yang organs. The Yin channels include the Kidneys, Spleen, and Liver Channels that flow from the feet to the torso, a well as the Heart, Pericardium, and Lung Channels that flow from the torso to the hands.

   The Yang channels run along the lateral aspect of the body. They belong to the hollow Yang organs and connect with the solid Yin organs. The Yang channels include the Small Intestine, Triple Burners, and Large Intestine Channels that flow from the hands to the head, as well as the Bladder Gall Bladder and Stomach Channels that flow from the head to the feet. The interaction between the internal/external, Yin/Yang relationship of the organs and channels results in an alchemical transference between energy and matter.
3. The Twelve Divergent Channels branch off the Twelve Primary Channels. They are mainly distributed on the chest, abdomen, and head. The Divergent channels have the energetic functions of connecting internally and externally related channels, strengthening the connection of the Twelve Primary Channels to their related organs, and serving as extensions of the Twelve Primary Channels.

LUO OR COLLATERALS

The Twelve Primary Channels are connected by collaterals, which are small, interlinking streams. These collaterals are the connecting branches of the energetic circulatory system. They generally flow superficially, in horizontal and vertical energetic directions. They are the body's secondary streams of Qi that form an intricate network that traverses the body's surface and interconnects the main rivers, connective tissues, and cutaneous regions (Skin Zones).

1. The Fifteen Major Collaterals (Luo) transfer Qi and Blood from the Twelve Primary Channels to all parts of the body and link the body's interior with its exterior, connecting the body's internal and superficial channels, as well as the Governing and Conception Vessels and the Great Luo of the Spleen (see Chapter 7).

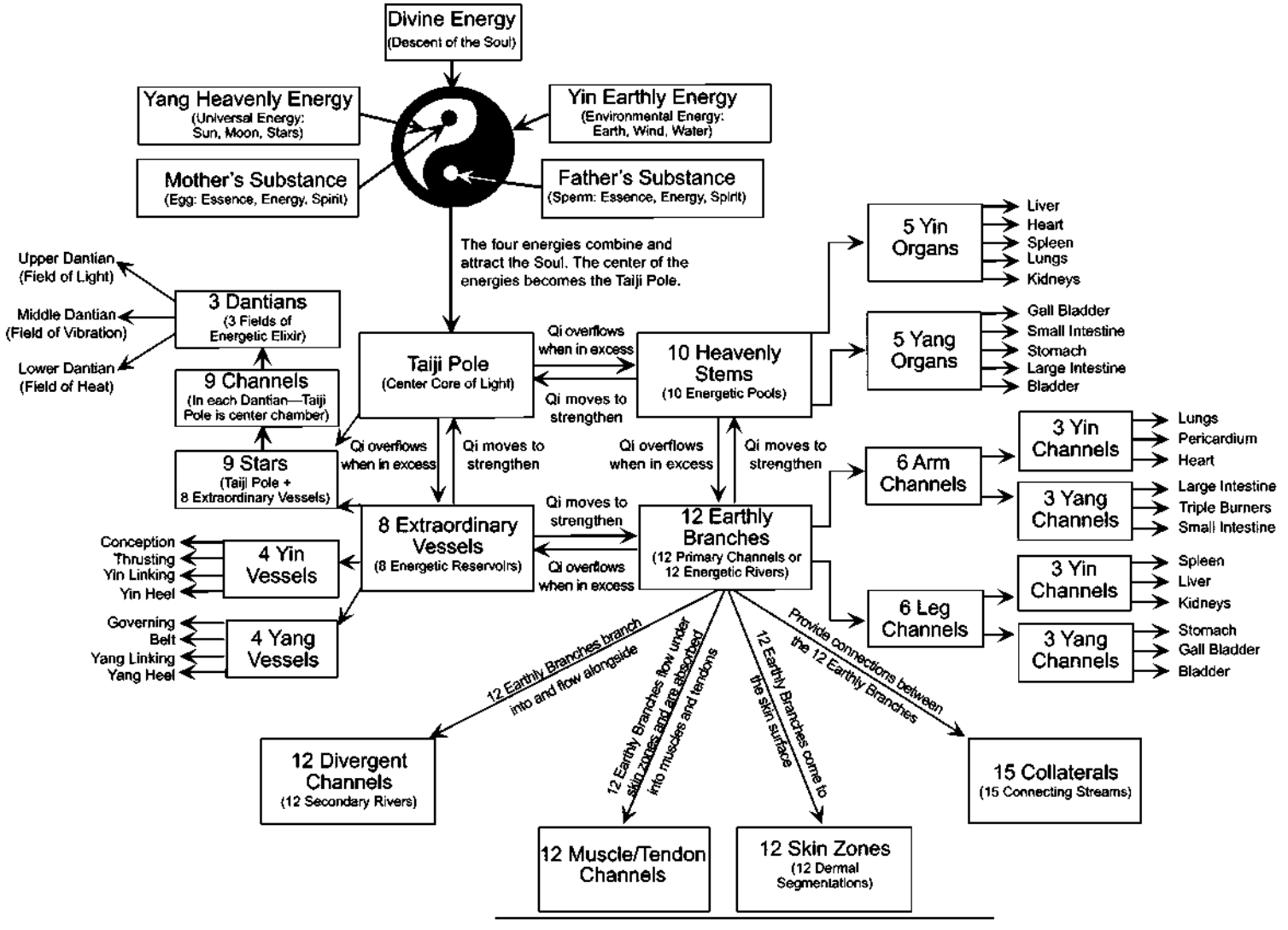

Figure 6.1. Channel and Organ Energy Flow

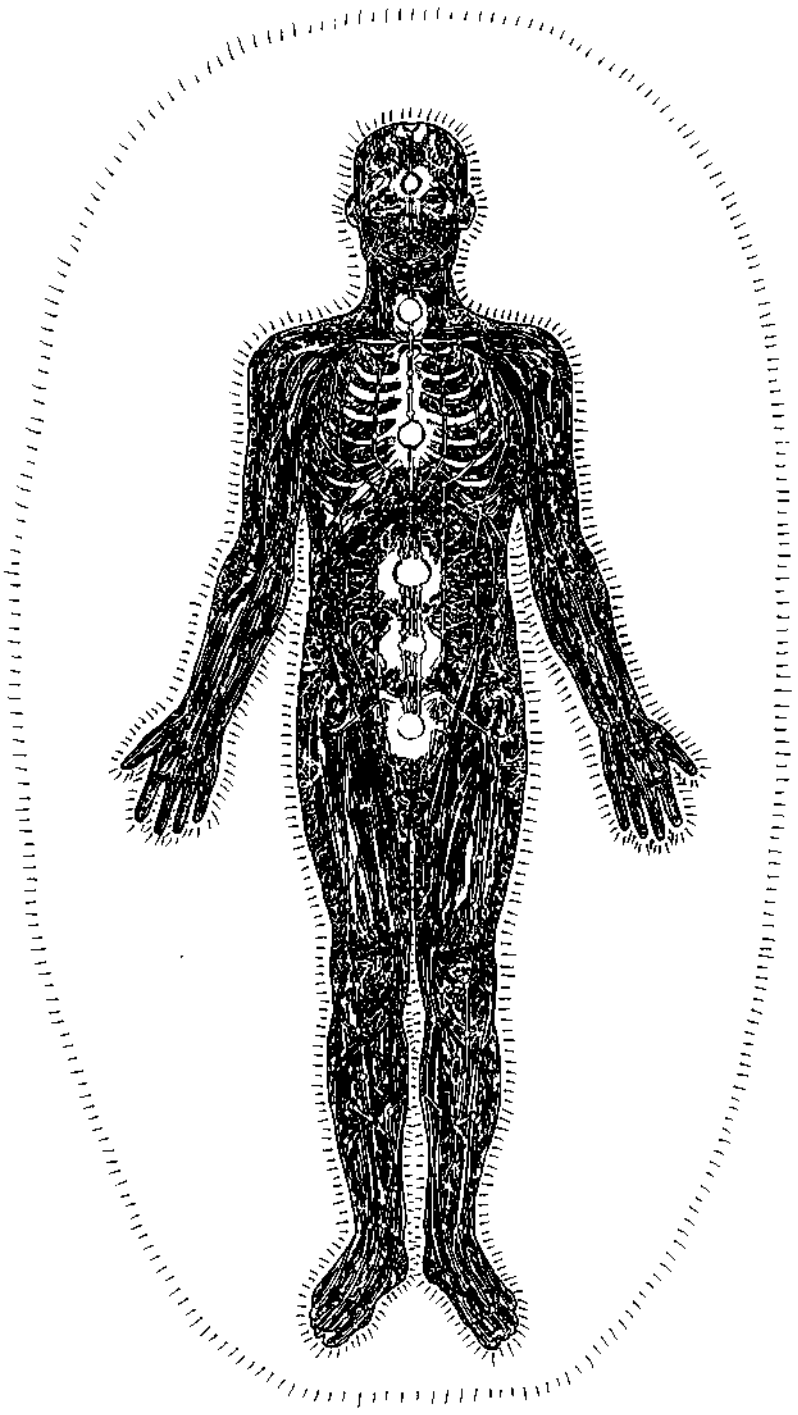

Figure 6.2. The Human Body's Energetic Matrix

2. The Minute Collaterals are smaller branches of the Fifteen Major Collaterals. They are countless in number.
3. The Superficial Collaterals are smaller branches of the Minute Collaterals. They are also countless in number.

MUSCLE TENDON CHANNELS

The Twelve Muscle/Tendon Channels are the external connections of the major channels. They generally flow superficially, traversing the body's surface and serve to join the main rivers, connective tissues, and Cutaneous Regions. The Twelve Muscle/Tendon Channels are also regions of the body where the Qi and Blood of the Twelve Primary Channels nourish the muscles, tendons, and ligaments.

CUTANEOUS REGIONS

The Twelve Cutaneous Regions (also called Twelve Skin Zones) are areas of the body where the Blood and Qi of the Twelve Primary Channels surface and connect to the body's skin tissues. These cutaneous regions have a continuous and direct contact with the external environment.

The body resonates in a continuous interplay of Yin and Yang harmony, balancing the channels' and organs' energy flows. The channels help create the body's external Yin and Yang polarities and create the energetic matrices around which the body's energetic fields can flow. Together these energetic matrices establish the foundation of the body's energetic tissues (Figure 6.2).

THE CHANNELS' RELATIONSHIP TO QI AND BLOOD

The channels transport Qi and Blood to nourish, moisten, and vitalize the whole body. Healthy bodily function depends on the balanced circulation of Qi and Blood. Qi is Yang and provides the energy or force necessary for the body's functional activity (i.e., movement and transportation, warming, containing, transforming, and defending). Blood is Yin and is the source of the body's moistening, nourishment, and lubrication.

The Blood, Qi, and heat circulate through the Twelve Primary Channels every two-hours, ebbing and peaking in energetic flow. The maximum

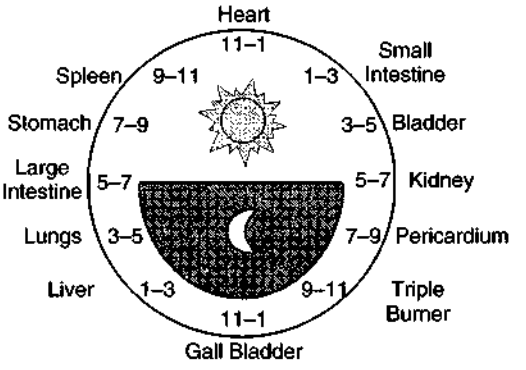

Figure 6.3. The Body's High and Low Energetic Tides

peak of a channel's Qi, or "high-tide," occurs at the time of day when the Qi in that channel is at its fullest. The minimum period of a channel's Qi, or "low tide," occurs twelve hours from the peak time (Figure 6.3).

The connective tissues of the body's fasciae transmit a variety of biological energies. Think of the inner fascia as lubricated linings that cover the muscles and internal organs, allowing the tissues to slide and move easily. Within the lining of the superficial fasciae, the channels are webbed; this webbed network conducts energy in the form of electron, proton, and ion transmission, and is influenced by light and sound.

According to Traditional Chinese Medicine theory, each of the Twelve Primary Channels has its own individual resources of Qi and Blood; however, the energetic quality varies in accordance with the amount of Blood and Qi available in each organ and its particular channels. From a traditional Chinese medical perspective, the Spleen plays two important roles in regard to Qi and Blood. First, it converts food into Gu Qi which, when further refined by the Liver and Kidneys, becomes Ying (Nutritive) Qi; and second, it manages the Blood by keeping it in the channels. Ying Qi secretes Body Fluids that enter into the blood vessels and are transformed into Blood by the Heart. The Heart both creates and governs the Blood; whereas, the Liver stores it and spreads Qi throughout the body. Blood is considered to be a denser, more material form of Qi. Qi and Blood

Organs & Channels	Qi	Blood
Liver	less	more
Lungs	more	less
Large Intestine	balanced	balanced
Stomach	balanced	balanced
Spleen	more	less
Heart	more	less
Small Intestine	less	more
Bladder	less	more
Kidney	more	less
Pericardium	less	more
Triple Burners	more	less
Gall Bladder	more	less

Figure 6.4. The Body's Organ and Channel Relationship to the Proportions of Qi to Blood

are interdependent: Qi moves the Blood, but the Blood nourishes Qi; both flow together.

The chart in Figure 6.4 shows each of the Twelve Primary Channels and the proportion of Qi and Blood each channel carries.

FUNCTION OF THE CHANNELS

The channels are responsible for responding to any malfunction in the body. They can also, however, be disseminators of energetic dysfunction and disease. Disease passes in to the internal organs, or from one organ to another, via the channels. Exogenous diseases progress from the body's skin pores to the tiny collaterals, then to primary channels, and finally, to the internal organs. The channels are affected by disease in a predictable fashion.

1. Diseases and symptoms manifest along the channel pathway.
2. Points along the channels become tender, painful, tight, or flaccid.
3. When in a deficient state, the electrical resistance and heat tolerance diminish on the skin at the diseased point(s).
4. The body's sensory organs (sight, smell, taste, hearing and touch) are affected through channel relationship.

From a traditional Chinese medical perspective, the functions and flow of the channels and collaterals, as well as the internal organs' health can be affected by Medical Qigong, acupuncture, Chinese massage, and herbal medicine. Each system of Traditional Chinese Medicine disperses Excess, moves stagnation, stimulates and nourishing the Qi to tonify Deficiency, and stimulates the Wei Qi to fight External pathogens via the channels. In fact, each time the body's channels and collaterals are trained or regulated, they become thicker with Qi.

INTERNAL AND EXTERNAL CHANNEL FLOW

As the Qi of an internal channel flows into or out from its "primary organ," it generates a current that is similar to a river rushing back into the sea. The moment that energy flowing through the internal channel permeates the primary organ, an energetic connection and reaction is immediately created in the organ tissues. When the Qi of an internal channel flows into its "associated organ," however, the energetic reaction is quite different. Instead of immediately permeating the organ, the channel's energy "spirally wraps" the organ's tissues through the internal fascia that envelops the associated organ. The associated organ tissues then absorb the energy from the surrounding fascia. This difference in energetic penetration and absorption rate is an important factor when working with the body's internal energetic channels. When Qigong doctors extend their energy into a patient's channels, they must be aware that the absorption rate will be immediately felt in the channels pertaining organ, and will have a gradual effect on the organ's associated organ.

Channel Name	Yin or Yang	Associated Organ	Element	Blood Heat Cycle	Qi Blood Cycle	Abbreviation
Gall Bladder	Yang	Liver	Wood	11 p.m.– 1 a.m.	more Qi less Blood	G.B.
Liver	Yin	Gall Bladder	Wood	1 a.m.– 3 a.m.	less Qi more Blood	Liv.
Lungs	Yin	Large Intestine	Metal	3 a.m.– 5 a.m.	more Qi less Blood	Lu.
Large Intestine	Yang	Lung	Metal	5 a.m.– 7 a.m.	balanced Qi and Blood	L.I.
Stomach	Yang	Spleen	Earth	7 a.m.– 9 a.m.	balanced Qi and Blood	St.
Spleen	Yin	Stomach	Earth	9 a.m.– 11 a.m.	more Qi less Blood	Sp.
Heart	Yin	Small Intestine	Fire	11 a.m.– 1 pm.	more Qi less Blood	H.
Small Intestine	Yang	Heart	Fire	1 p.m.– 3 p.m.	less Qi more Blood	S.I.
Bladder	Yang	Kidney	Water	3 p.m.– 5 p.m.	less Qi more Blood	Bl.
Kidney	Yin	Bladder	Water	5 p.m.– 7 p.m.	more Qi less Blood	K. or Kid.
Pericardium	Yin	Triple Burner	Fire	7 p.m.– 9 p.m.	less Qi more Blood	P.
Triple Burner	Yang	Pericardium	Fire	9 p.m.– 11 p.m.	more Qi less Blood	T.B.

Figure 6.5. The Twelve Primary Channels are divided into Yin and Yang. The Yin channels are connected to the solid organs, and the Yang channels are connected to the hollow organs.

ORGAN AND CHANNEL FUNDAMENTALS

The purpose for energetic anatomy and physiology is to understand the fundamental actions of each organ and each channel's unique energetic characteristics. This understanding includes the learning of differential diagnosis to categorize the various symptoms into meaningful patterns of disharmony. This ability to categorize the various symptoms will enable the doctor to analyze and recognize specific pathologies indigenous to specific organs and channel energies (Figure 6.5).

In Chinese medical science, the study of energetic physiology is called Zhang Xiang Xue Shou, which literally translates as "the theory of the phenomena of internal organs." Here, the word "phenomena" means visible external manifestations. The organ's physical structure is of little consequence; whereas, its function in the body is of primary importance. While Western anatomy and physiology are primarily concerned with the physical body in its most concrete form (investigating the structures of the major body systems and organs), energetic anatomy and physiology focuses mainly on the underlying energy that enlivens and sustains the physical form.

In Chinese medical science, the body's internal organs are responsible for creating and distributing Qi, Blood and Body Fluids. Traditional Chinese Medicine divides Body Fluids into two

distinct categories: Jin, which are the body's clear, light fluids, and Ye, which are the body's thick and heavy liquids.

1. The Jin Body Fluids are the Yang Fluids of the Upper Burner that move with Wei Qi. They are fast, light, and clear fluids, such as: sweat, tears, saliva, and mucus. The Lungs control the Jin.
2. The Ye Body Fluids are the Yin Liquids of the Middle and Lower Burners that move with Ying Qi. These are slow, heavy, and thick liquids. These liquids include those that moisten the joints, spine, brain, and Bone Marrow and lubricate the eyes, ears, nose, and mouth. The Spleen and Kidneys control the Ye.

This internal action of creating and distributing Qi, Blood and Body Fluids is manifested throughout the body's tissues through the Blood's Heat Cycle, which actively follows a peak (high-tide) and ebb (low-tide) energetic time period. Each organ and channel has either a Yin or Yang characteristic and is grouped and paired according to its Five Element nature.

This chapter focuses on the Twelve Primary Channels and their relationship to the organs. Most Traditional Chinese Medical texts begin the sequence of these channels with the Lung Channels. In this text, however, due to the energetic waxing and waning of the Yin and Yang Yao Cycles, and the Twelve Pi Hexagrams (see Chapter 11), I will start with the Gall Bladder Channels. The Twelve Primary Channels are described as follows: Gall Bladder, Liver, Lung, Large Intestine, Stomach, Spleen, Heart, Small Intestine, Bladder, Kidney, Pericardium, and Triple Burner.

THE GALL BLADDER CHANNELS

The Gall Bladder Channels are Yang channels. The external branches flow from the head to the feet on both sides of the body (Figure 6.6). The internal branches of the Gall Bladder Channels flow from the head to the Gall Bladder. The internal and external branches of these two rivers originate from the outer canthus of each eye. The external branches zigzag around the side of the head, flowing down the sides of the torso. The internal branches leave the outer canthus of the eye and descend the neck, entering the supraclavicular fossa, where they meet the main channels at the St-12 and Pc-1 points, and pass through the diaphragm, spirally wrapping the Liver, and permeating the Gall Bladder. From there they encircle the genitals and enter deeply into the body to emerge at the sacrum.

The external rivers continue to descend the lateral aspects of the torso and legs, ending at the lateral sides of the tips of the fourth toes.

THE GALL BLADDER ORGAN

The Gall Bladder's associated organ is the Liver; its element is Wood. The Gall Bladder's function of storing and excreting bile depends on the Liver's function of maintaining a smooth flow of Qi throughout the body.

The Gall Bladder also helps the Liver control the sinews, tendons, and ligaments. The Liver provides Blood to the sinews, while the Gall Bladder provides Qi to the sinews in order to ensure proper movement and agility.

PSYCHO-EMOTIONAL ASPECTS

The Gall Bladder is responsible for making decisions and judgments, as well as providing courage and initiative. This organ is sometimes called The Court of Justice or The General's Advisor. Although the Kidneys control drive and vitality, the Gall Bladder provides the capacity to turn this drive and vitality into decisive action.

The Gall Bladder has an influence on the quality and length of sleep. If the Gall Bladder is Deficient, the patient will often wake up suddenly, very early in the morning, and be unable to fall asleep again.

Patient's who are timid, indecisive, and easily discouraged by slight adversity, are said to have a weak Gall Bladder; conversely, decisive and determined patients are said to have a strong Gall Bladder.

GALL BLADDER'S ENERGY FLOW

The Gall Bladder Channels are often used to drain off the energy from an overheated or Excess Liver condition. Energetically, the Gall Bladder Channels store more Qi than Blood, acting more on energetic and nervous functions than on physical substances and Blood functions. At the

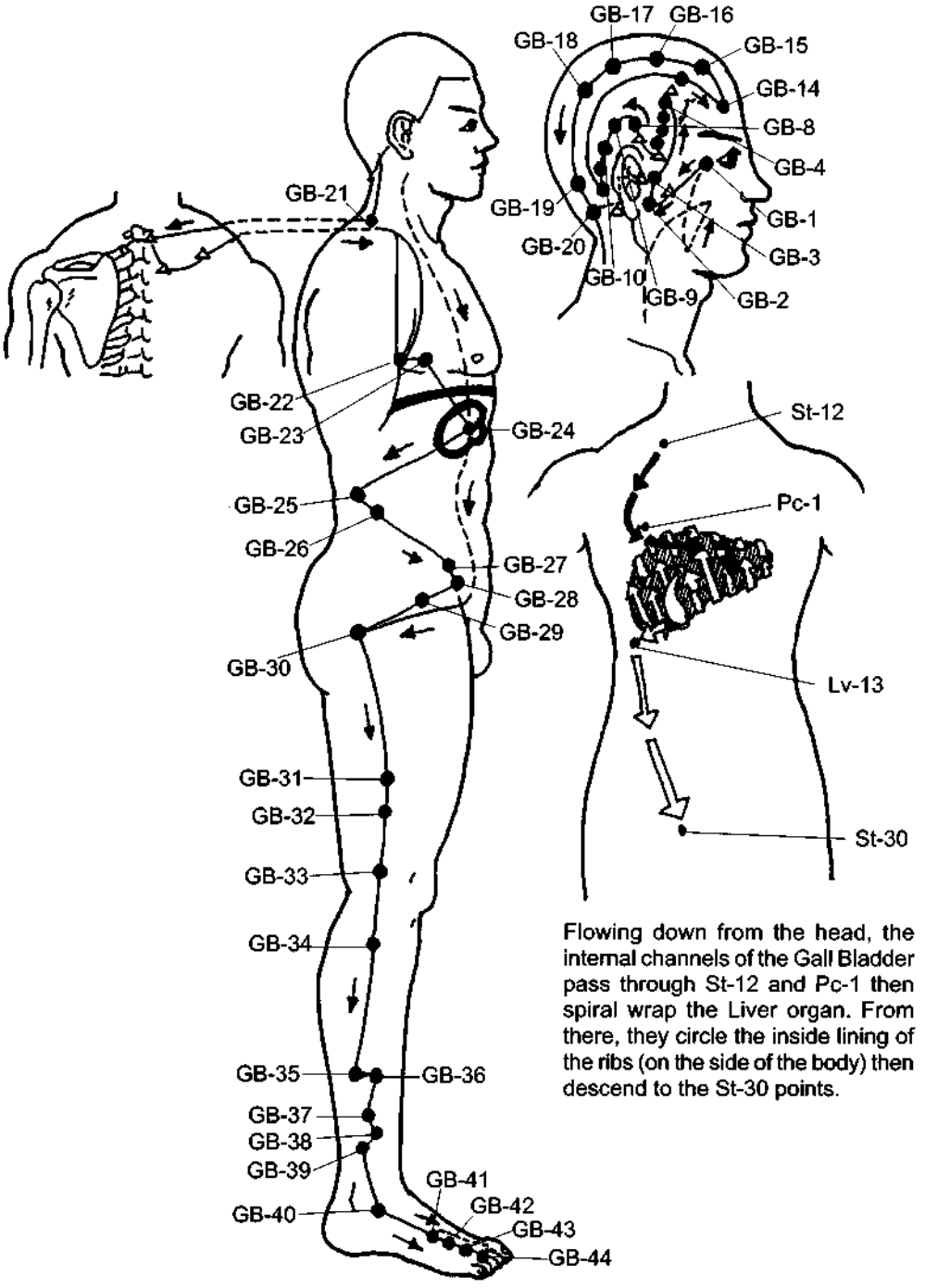

Flowing down from the head, the internal channels of the Gall Bladder pass through St-12 and Pc-1 then spiral wrap the Liver organ. From there, they circle the inside lining of the ribs (on the side of the body) then descend to the St-30 points.

Figure 6.6. The Internal and External Qi Flow of the Gall Bladder (GB) Channels

high-tide time period (11 p.m. to 1 a.m.) Qi and Blood abound in the Gall Bladder, and so the Gall Bladder organ and channels can more easily be dispersed and purged. During low-tide (11 a.m. to 1 p.m.) they can be easily tonified. The Gall Bladder Channels' energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The gall bladder stores then releases bile through the cystic duct into the common bile duct that flow into the small intestine to aid in the digestion of fats.

PATHOLOGICAL MANIFESTATIONS

The main symptoms of the Gall Bladder Channel diseases are:

- pain in the right-and left-upper quadrants of the abdomen,
- disorders of the head, which include the eyes, ears, and face, and
- disorders of the external sides of the legs along the channels' pathways.

THE LIVER CHANNELS

The Liver Channels are Yin channels that flow externally from the feet to the torso (Figure 6.7). These two rivers originate externally from the inside of the big toes and flow upward on the inside the legs, to circle the groin. From there they continue to ascend externally to the lateral aspects of the thorax, where they enter internally and permeate the Liver. They then connect to and spirally wrap the Gall Bladder. From there, they flow to the Lungs, ascend internally into the thorax, and connect with the eyes, cheeks, and inner surface of the lips. They emerge from the forehead and connect with the Governing Vessel at the Baihui GV-20 point (Figure 6.8).

THE LIVER ORGAN

The Liver is responsible for the "free and easy wandering" of Qi in the body, i.e., the Liver makes the Qi flow smoothly in and around the body. The Liver governs the Belt and Thrusting Vessels, as well as the body's Qi flow and circulation. The smooth flow of Qi ensures normal mental and emotional activity, as well as normal secretion of bile. Impairment of this Liver function leads to a "binding depression of Liver Qi," associated with impatience, hasty decisions impulsive actions, and a hot temper.

The Liver's associated organ is the Gall Bladder; its element is Wood. The Liver energy opens externally at the eyes and manifests externally through the fingernails and toenails. The Liver stores the Blood, and serves as a reservoir of Blood to regulate the circulation of Blood volume. In women it assists the uterus and regulates the menses. The Liver regulates the function and control of the muscles, tendons, and ligaments and is the source of the body's physical strength. It also stores the emotion of anger.

PSYCHO-EMOTIONAL ASPECTS

The Liver is responsible for planning and creativity, as well as instantaneous solutions or sudden insights; it is therefore considered The General in Charge of Strategy. The Liver houses the body's Hun and governs fright.

Its positive psycho-emotional attributes are kindness, benevolence, compassion, and generosity; its negative attributes are anger, irritability, frustration, resentment, jealousy, rage, and depression.

The Liver is also called the "root of resistance to fatigue." Whenever the Liver is not functioning properly (stagnate or excessively Hot due to suppressed emotions) the patient can experience fatigue as well as physical weakness.

THE LIVER'S ENERGY FLOW

The Liver Channels move the Qi to the whole body, storing and distributing the Blood. The Liver Channels contain more Blood than Qi, thus they affect physical substances more than they affect energetic functions. At the high-tide time period (1 a.m. to 3 a.m.), Qi and Blood abound in the Liver, and so the Liver organ and channels can more easily be dispersed and purged.; whereas, during low tide (1 p.m. to 3 p.m.), they can be easily tonified. The Liver Channel's energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The liver stores vitamins A, B-12, D, E, and K, and regulates blood volume. It is one of the main

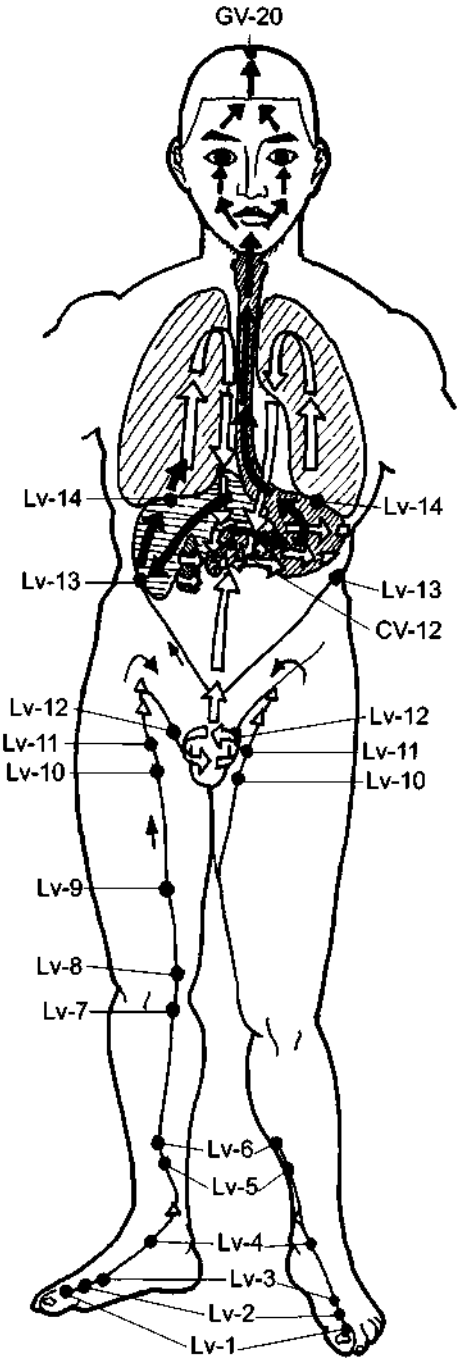

Figure 6.7. The Internal and External Qi Flow of the Liver (Lv) Channels

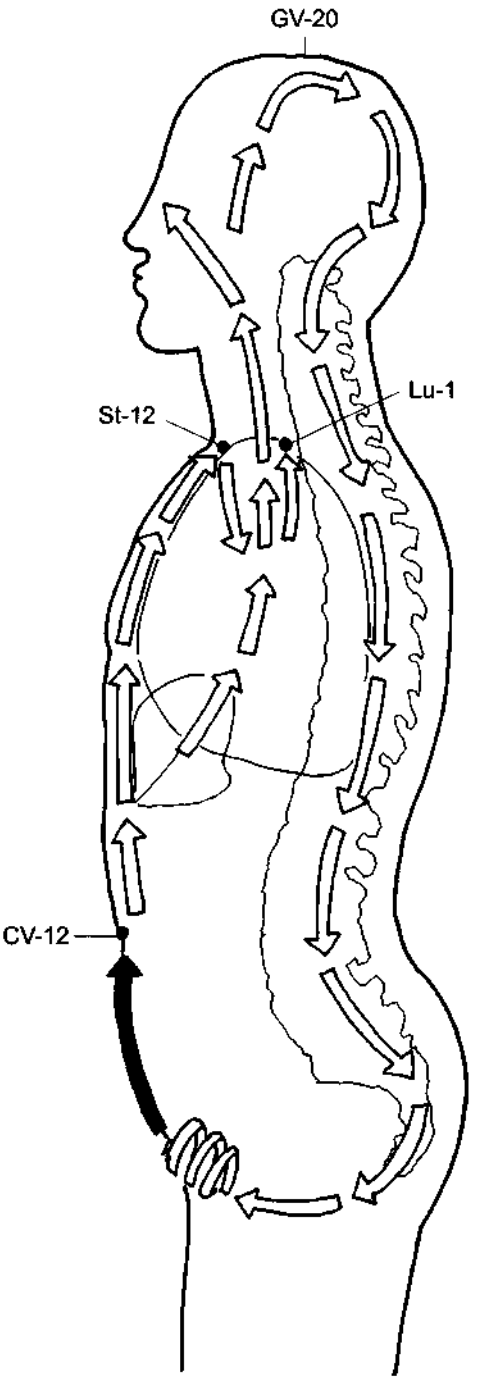

Figure 6.8. Side View of the Liver Channel's Internal Flow of Energy

sources of the body's heat. The liver manufactures cholesterol and functions in lipid metabolism and controls bile secretion.

PATHOLOGICAL MANIFESTATIONS

Diseases of the Liver Channels cause swelling and a distended sensation of the hypochondrium. The Liver Channels also correspond to diseases of the lower abdomen and genital organs.

Since the Liver supplies the tendons with nutrients to develop physical strength, Liver impairment causes numbness, tremors, or spasms of the muscles, and sluggishness in joint movements.

The Liver and Kidneys are mutually dependant upon each other. The Liver stores the Blood that nourishes the Kidney Jing; whereas the Kidneys store Jing that helps produce the Blood. Deficient Kidneys may lead to Blood Deficiency, and Deficient Liver Blood may cause weakness of the Kidney Jing due to lack of nourishment from the Blood. The hair on top of the head is also nourished by the Blood. When the hair turns grey, it is often alleged to be caused by insufficient Blood stored in the Liver, as well as a Kidney Jing weakness.

THE LUNG CHANNELS

The Lung Channels are Yin channels and flow externally from the torso to the hands. The main river originates internally from the Middle Burner, in the middle of the chest, and descends downward, connecting with and spirally wrapping the Large Intestine. From there, it ascends along the upper surface of the Stomach passage and through the diaphragm, where it branches and permeates both Lungs (Figure 6.9).

From the Lungs, the rivers of Qi merge and ascend into the pit of the throat, where they separate again into two channels that transverse below the clavicle. These two main channels then surface externally to descend down the arms, and end on the outer side of each thumb. A small stream of energy branches off each wrist at the Lu-7 point and runs directly to the radial side of the tip of the index finger, where it connects with a branch of the Large Intestine Channels.

THE LUNG ORGAN

Since the Lungs are the uppermost organs, they are compared to canopies that shelter and protect all other internal organs. The Lungs' associated organ is the Large Intestine; its element is Metal. The Lung Qi opens externally at the nose and manifests itself through the voice (i.e., when the Lung Qi is in Excess the voice is too loud; when Deficient the voice is too soft). The Lungs govern the body's Qi and respiration. They regulate the metabolism of Water passages (sweat and Body Fluids), the opening and closing of the pores, the skin and the hair's texture.

The Lungs also control the circulation of Qi in both vessels and channels, as well as the dispersing or spreading of the body's Wei Qi (protective energy). They control the descending and holding functions of the body's Qi and Body Fluids.

All blood vessels lead to the Lungs, i.e., all Blood within the body must pass through the Lungs.

PSYCHO-EMOTIONAL ASPECTS

It is said that the Lungs are "the priest" or The Minister of Heaven and are responsible for establishing the foundation of Qi for the entire body (see Chapter 12). The Lungs house the body's Seven Corporeal Souls (Po) and are responsible for self-protection and self-preservation.

The Lungs positive psycho-emotional attributes are righteousness, dignity, integrity, and high self-esteem; their negative attributes are disappointment, sadness, grief, despair, anxiety, shame, and sorrow.

THE LUNGS' ENERGY FLOW

Functionally, the Lung Channels' energy acts on the Lungs, bronchi, throat, and larynx. If the Lung Qi is combined with Liver Qi and becomes stagnate in the throat area, a condition known as a "plum pit," or knot in the throat, develops. The Lung Channels store more Qi than Blood, thus they have a greater affect on energetic and nervous functions than on physical substances and Blood functions. At the high-tide time period (3 a.m. to 5 a.m.), Qi and Blood abound in the Lung organs and channels. They can therefore be more

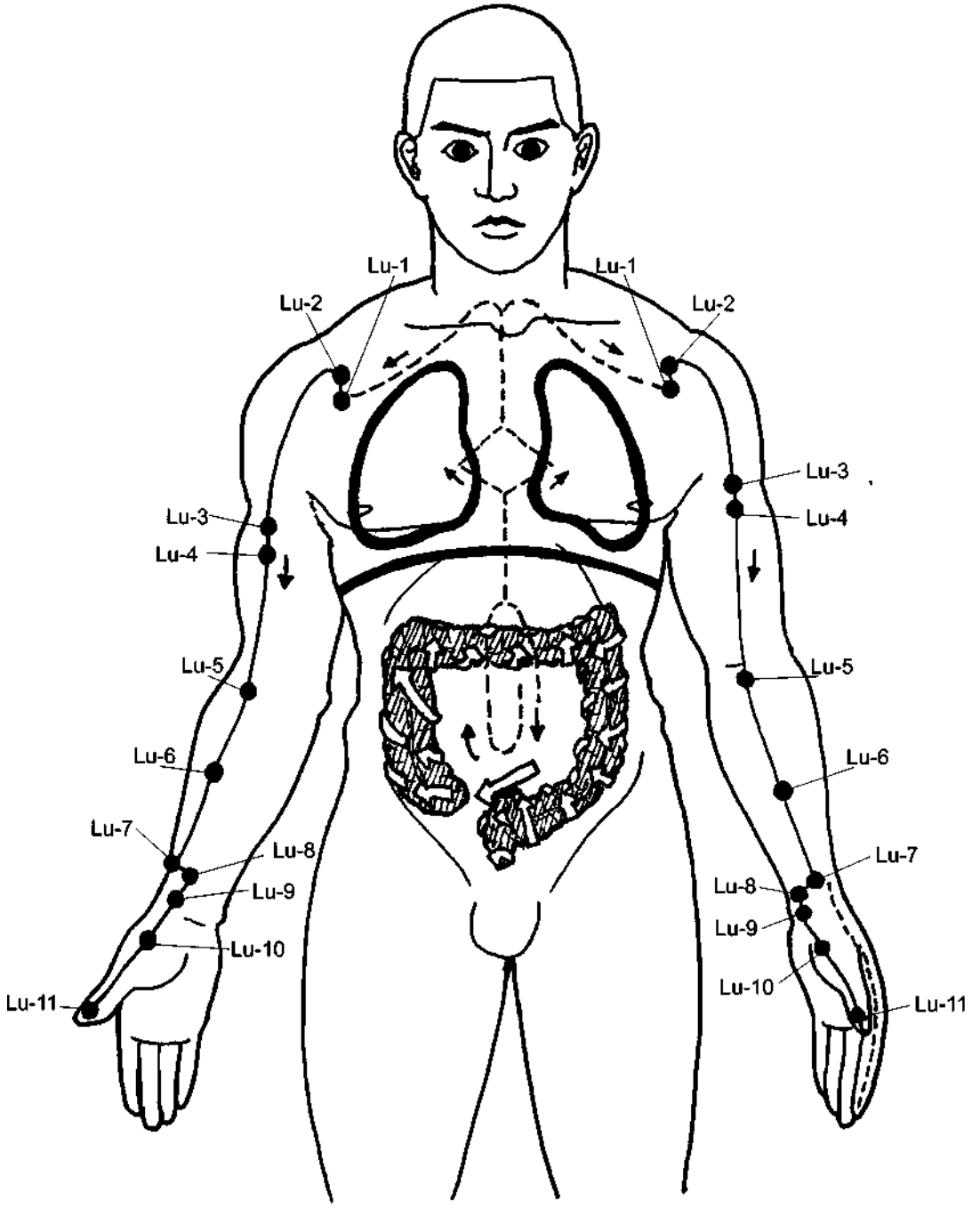

Figure 6.9. The Internal and External Qi Flow of the Lung (Lu) Channels

easily be dispersed and purged at this time period; whereas during low-tide (3 p.m. to 5 p.m.), they can more readily be tonified. The Lung Channels' energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The action of inhaling air introduces oxygen into the lungs; exhaling expels carbon dioxide from the lungs. The heart pumps blood into the lungs. Blood passing through the lungs receives oxygen, and is then delivered back into the heart, where it is circulated throughout the body via the circulatory system.

PATHOLOGICAL MANIFESTATIONS

The Lung Channels' dysfunctions can result in chest and Lung diseases, as well as diseases on the radial side of the upper arm and palmar area of the hand.

The Lungs keep the pathway of air unobstructed and disseminate vital Qi throughout the body. If these functions are impeded, obstructions of the nose, coughing, dyspnea, and fullness of the chest may occur.

The Lungs cleanse the inhaled air and keep the Qi flowing downward. If these functions are impeded, coughing, asthma, oliguria (diminished amount of urine formation), and edema may occur.

Since the Lungs have their external orifice at the nose, stuffy nose, nasal discharge, and impairment of smell are common symptoms when the Lungs are being attacked by a pathogenic invasion of Wind and Cold.

THE LARGE INTESTINE CHANNELS

The Large Intestine Channels are Yang channels and flow externally from the hands to the head. These two rivers originate externally from the tips of the index fingers, ascend up the arms, and cross the shoulders, where they connect with the 7th cervical vertebra and then split into two branches. One set of branches (one branch from the left Lung and its corresponding branch from the right Lung) descends internally and spirally wraps the Lungs before moving through to permeate the Large Intestine. The other set continues ascending externally through the neck and cheek to the gums of the lower teeth. It curves around the upper lip and flows to the opposite side of the nose, where it connects with the Stomach Channels (Figure 6.10).

THE LARGE INTESTINE ORGAN

The Large Intestine's associated organ is the Lungs; its element is Metal. The main function of the Large Intestine is to receive food essence from the Small Intestine. The Large Intestine organ is said to govern humor (any fluid or semifluid substance in the body). It absorbs fluid that was separated by the Small Intestine and controls the transformation and transportation of solid waste in the body. The Large Intestine also controls the throat, teeth, and the drainage of the nose.

PSYCHO-EMOTIONAL ASPECTS

The Large Intestine relationship to the Lungs makes it equally affected by the emotions of sadness, grief, and worry. An energetic imbalance in the Large Intestine can result in physical weakness and provoke emotional introversion, accompanied by feelings of depression, irritability, discouragement, distress and apathy.

Strong emotions of fear or panic can produce an energetic-stool reflex reaction in the Large Intestine resulting in a spontaneous defecation.

THE LARGE INTESTINE'S ENERGY FLOW

The Large Intestine Channels have equally abundant amounts of Qi and Blood, acting equally on the body's energetic and nervous functions, as well as on physical substances and Blood functions. At the high-tide time period (5 a.m. to 7 a.m.), Qi and Blood abound in the Large Intestine organ and channels and can therefore be more easily dispersed or purged at this period; whereas during low-tide (5 p.m. to 7 p.m.), they can be more readily tonified. The Large Intestine Channels' energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The large intestine, sometimes called the "colon," is divided into four quadrants; the ascending, transverse, descending, and sigmoid or pelvic colon. The function of the large intestine is to reabsorb the fluid from the contents of indigest-

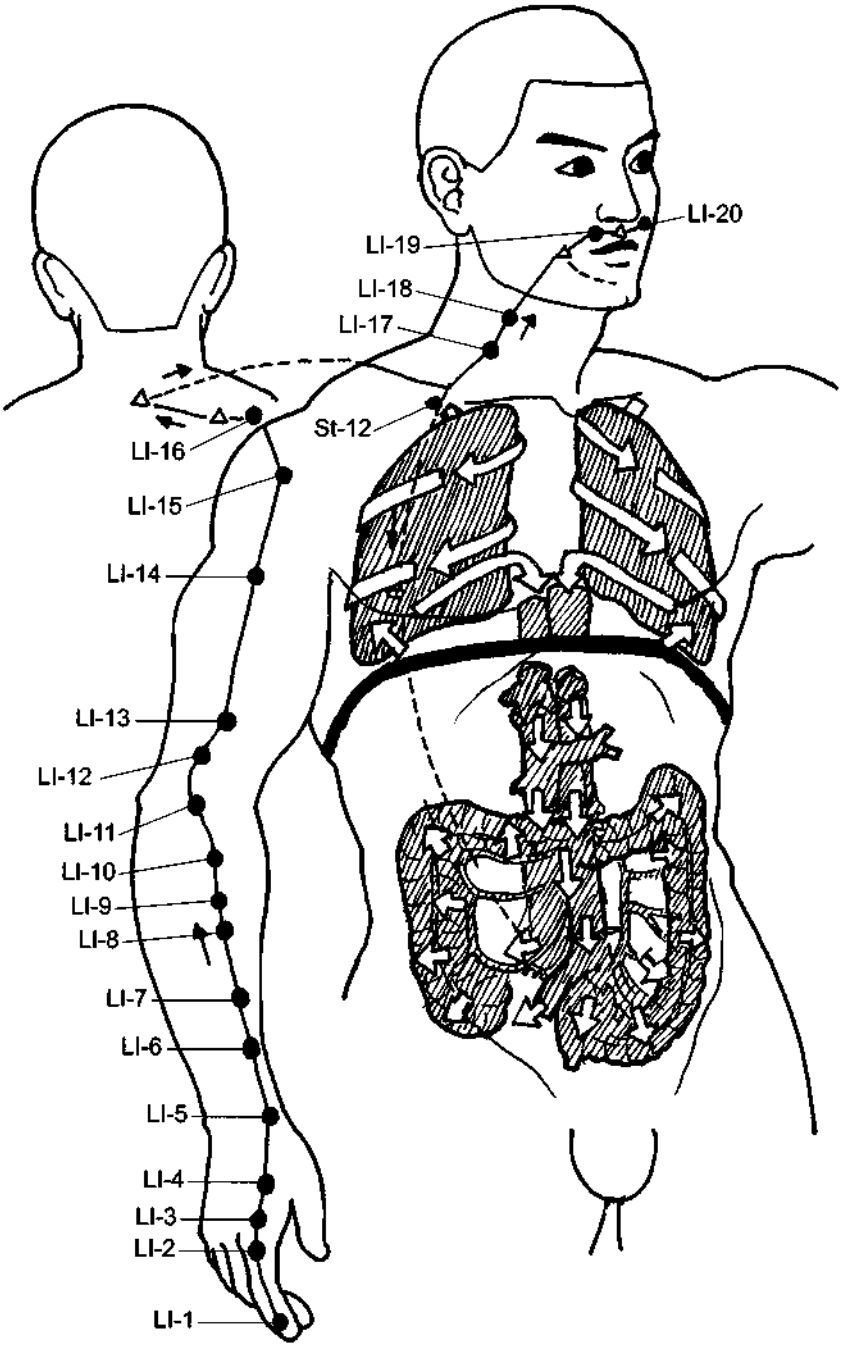

Figure 6.10. The Internal and External Qi Flow of the Large Intestine (LI) Channels

ible food residues moving through the intestines and to eliminate them from the body in the form of semisolid feces.

Whatever digestion takes place in the large intestine results from bacterial action. The fermentative bacteria (found in the middle part of the large intestine) and putrefying bacteria (found in the lower part of the large intestine) may produce toxic products, such as indole and skatol; however, if absorbed into the body, such bacterial decompositions undergo detoxification in the liver. In intestinal obstructions these bacterial decompositions are absorbed and eliminated in the urine in the form of indican.

PATHOLOGICAL MANIFESTATIONS

Dysfunctions in the Large Intestine Channels can result in diseases of the lower part of the face (including the nose, oral cavity, and teeth), throat, and front part of the neck, as well as disease of the back and radial sides of the upper extremities.

Tonification of the Large Intestine can be used to eradicate eye pain, toothache, earache, and to prevent hemorrhages, as well as to greatly reduce excessive menstrual bleeding.

Because of its relationship to the Lungs, the Large Intestine can be purged to treat coughing and asthma caused from Excessive Heat in the Lungs; whereas replenishing the vital Qi of the Lungs can cure constipation in debilitated patients.

The Large Intestines' energetic functional patterns generally relate to disturbances in bowel movements. Disturbances of the Large Intestine's energetic function usually gives rise to one of the two following complications:

1. Excess Conditions of the Large Intestines can result in symptoms of: Heat, Heat obstruction, Damp Heat, or Cold invading the Large Intestine.
2. Deficient Conditions of the Large Intestines can lead to an invasion of Cold or Dryness, and in severe cases of Deficiency, to the Collapse of the Large Intestine.

THE STOMACH CHANNELS

The Stomach Channels are Yang channels, and flow externally from the head to the feet (Figure 6.11). These two rivers originate externally from the lateral sides of the nose (LI-20), ascending upward to the base of the eye and bridge of the nose, where they meet the Bladder Channels. They then descend under the eyes, down the face, winding along the angle of the mandible, then ascend in front of the ears, following the anterior hairline till they reach the forehead. From the St-5 point, the primary branches on each side descend the neck and torso. Externally, these branches continue down the torso and legs and end at the lateral tips of the second toes. A second set of branches separate from the St-12 points and internally permeate the Stomach before spiral wrapping the Spleen and joining the primary channel branches at the St-30 points.

THE STOMACH ORGAN

The Stomach organ's associated organ is the Spleen; its element is Earth. The Stomach is considered the origin of the Body's Fluids. Its main function is to accept and decompose food. It separates the "clean" (pure) and "turbid" (impure) parts of ingested food and transfers the clean, energetically usable portion upwards to the Spleen, while sending the turbid unusable portion downward to the Small Intestine, to be further processed. Both the Stomach and the Spleen are considered the roots of Postnatal Qi and are often called The Ministers of Food Storage.

PSYCHO-EMOTIONAL ASPECTS

The Stomach influences the mental state; an Excess condition can agitate the mind and cause mental symptoms such as: mania or hypomania, confusion, severe anxiety, and hyperactivity.

THE STOMACH'S ENERGY FLOW

The Stomach Channels have equally abundant amounts of Qi and Blood, acting equally on the body's energetic and nervous functions, as well as on physical substances and Blood functions. At the high-tide time period (7 a.m. to 9 a.m.), Qi and Blood abound in the Stomach organ and channels, and can therefore be more easily dispersed or purged at this period; whereas during low-tide (7 p.m. to 9 p.m.), they can be more readily tonified. The Stomach Channels' energy acts on the skin, muscles, and nerves found along their pathways.

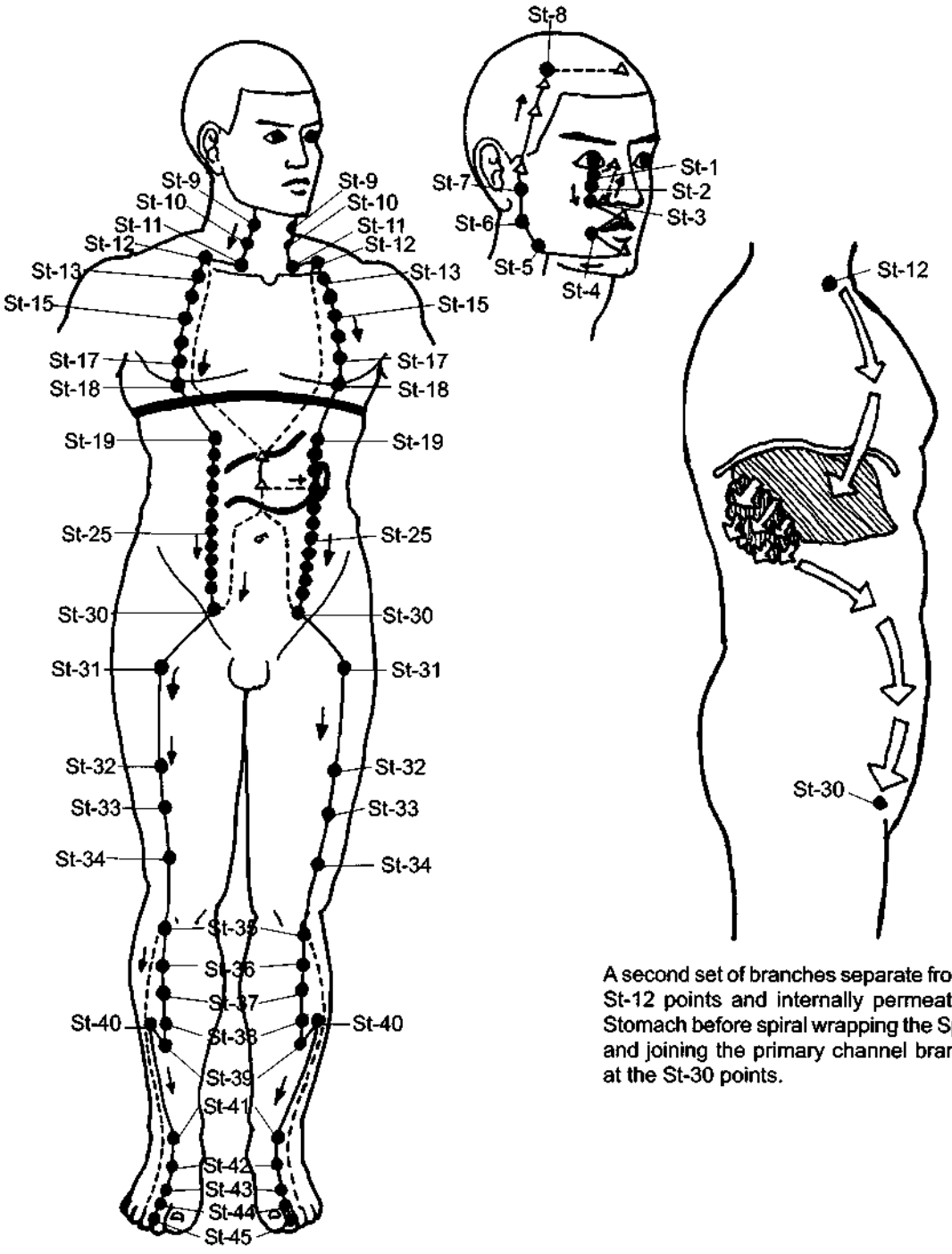

A second set of branches separate from the St-12 points and internally permeate the Stomach before spiral wrapping the Spleen and joining the primary channel branches at the St-30 points.

Figure 6.11. The Internal and External Qi Flow of the Stomach (St) Channels

WESTERN MEDICAL PERSPECTIVE

The stomach secretes gastric juice for food digestion. The proteins are converted into peptones; the stomach then regulates the passage of food to the other digestive organs.

PATHOLOGICAL MANIFESTATIONS

Diseases of the Stomach Channels include diseases of the face (nose, oral cavity, and teeth), throat, front of the neck, the abdomen, the frontal part of the legs and gastrointestinal area. Stomach disease can also induce certain psychiatric diseases.

Diseases of the Stomach organ are primarily caused by improper diet. To determine the root of the disease, the following five areas are considered:

1. The patient's Five Elemental Constitution and present state of health,
2. The type and energetic quality of the foods ingested (Hot or Cold), and whether the food is in season or out of season,
3. The scheduling of meals (This not only includes eating meals at regular times, but also eating a balanced meal, not too fast, and not too late at night),
4. The Yin/Yang balance of the types of food digested (This includes balancing the foods Five Tastes and Five Colors), and
5. The emotional factors surrounding meal time. This includes having the proper mental attitude (being relaxed and calm) and avoiding emotional distress (such as feeling rushed, upset, and so on).

The Stomach easily suffers from Excess patterns (e.g., Fire or Phlegm Fire), which in turn agitate the Shen. When the Shen is disturbed, it can cause manic symptoms such as: inappropriate laughter, pressured speech, unconscious talking, laughing, or singing, violent or otherwise inappropriate behavior (e.g., taking off one's clothes in public). In milder cases, symptoms may include mental confusion, severe anxiety, hypomania (a milder form of mania), and hyperactivity.

Since the Stomach has the function of sending the preliminarily digested food downward, an impairment of this function often causes vomiting.

THE SPLEEN CHANNELS

The Spleen Channels are Yin channels and flow externally from the feet to the torso (Figure 6.12). These two rivers originate externally from the medial tips of the big toes, ascend upwards along the inner thighs, then enter the abdomen (connecting to the CV-3 and CV-4 points) and further up the upper torso (connecting to the CV-12 point). The external Spleen Channels meet at the CV-12 point, enter the body, where the left channel flows into the Spleen, and then spirally wraps the Stomach organ. An internal branch ascends from the CV-12 point into the Heart. At the CV-12 point both left and right main channels meet and separate again to ascend through the diaphragm, up the torso and throat, alongside the esophagus, to reconnect at the base of the tongue. From the Sp-20 points external branches descend along the lateral aspects of the torso and terminate on the mid-axillary line in the seventh intercostal space.

THE SPLEEN ORGAN

The Spleen's associated organ is the Stomach; its element is Earth. In Traditional Chinese Medicine, the pancreas (a gland that produces insulin and is connected to the Spleen) is considered part of the Spleen/Stomach function. The Spleen organ is responsible for transforming food received from the Stomach into Gu Qi. The Gu Qi is then sent to the Liver and Kidneys to be "cooked" and further refined. The Spleen's main function is to govern or oversee this transportation and transformation of Gu Qi. It also controls the Blood by keeping it in the blood vessels, and governs the muscles, flesh, and limbs. The Spleen organ's energy opens externally at the mouth, controlling taste, and connects externally by the lips. The Spleen is sometimes called The Minister of Grains, because it is responsible for distributing what the Stomach has stored. Energetically, the Spleen controls the body's central cavity, and maintains the internal organs in their places.

PSYCHO-EMOTIONAL ASPECTS

The Spleen houses the body's thoughts and intentions (Yi), and is responsible for analytical thinking, memory, cognition, intelligence, and ideas. The Spleen is responsible for directing

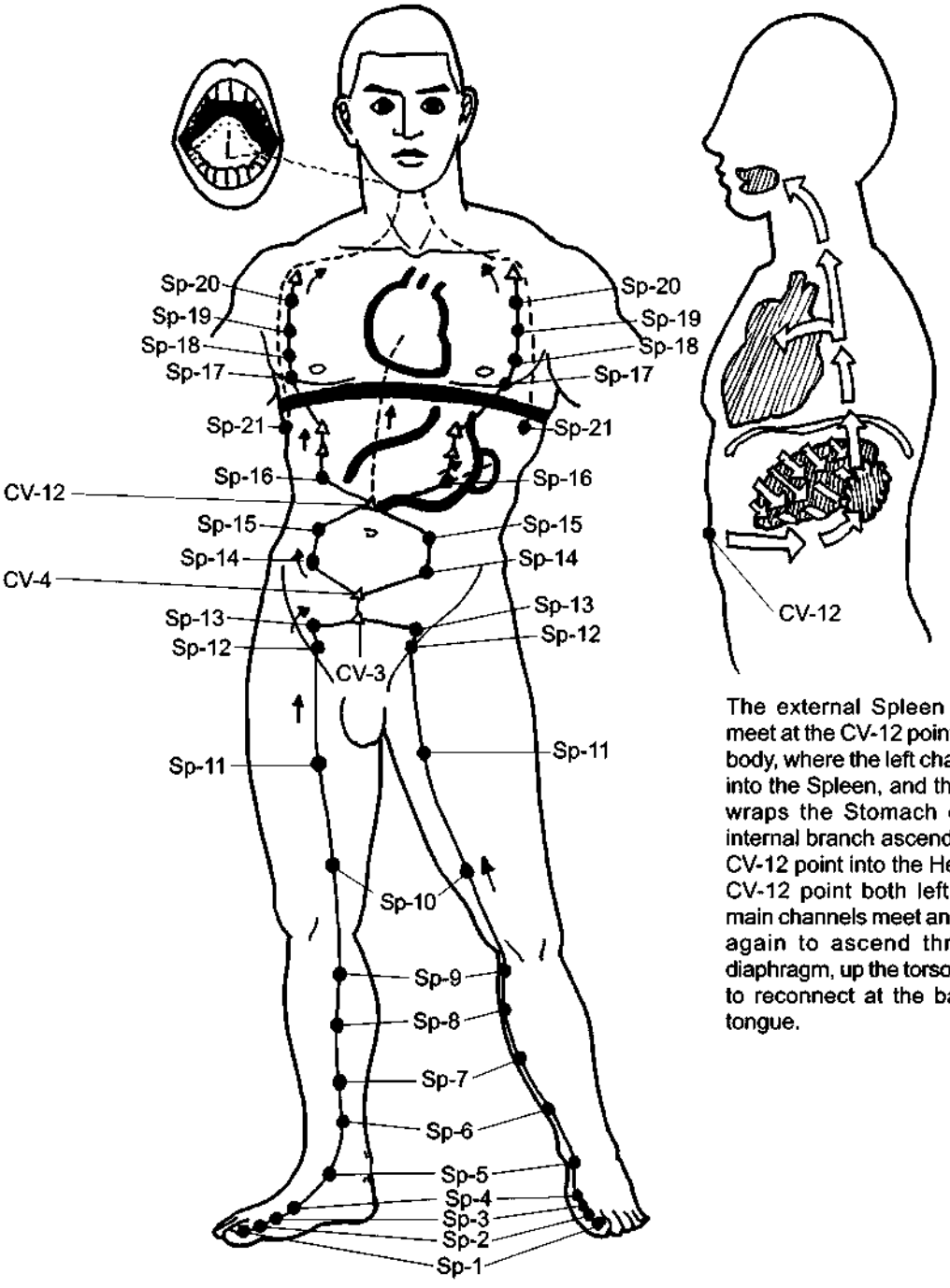

The external Spleen Channels meet at the CV-12 point, enter the body, where the left channel flows into the Spleen, and then spirally wraps the Stomach organ. An internal branch ascends from the CV-12 point into the Heart. At the CV-12 point both left and right main channels meet and separate again to ascend through the diaphragm, up the torso and throat to reconnect at the base of the tongue.

Figure 6.12. The Internal and External Qi Flow of the Spleen (Sp) Channels

memories to the Kidneys for short-term storage. The Kidneys will later transfer these memories to the Heart for long-term memory storage (see Chapter 12).

The Spleen's positive psycho-emotional attributes are trust, honesty, openness, acceptance, equanimity, balance, and impartiality; its negative attributes are worry, excessive thinking, pensiveness, obsessiveness, remorse, regret, obsessions, and self-doubt.

THE SPLEEN'S ENERGY FLOW

The Spleen Channels store more Qi and less Blood, acting more on energetic and nervous functions than on physical substance and Blood functions. At the high-tide time period (9 a.m. to 11 a.m.), Qi and Blood abound in the Spleen organ and channels, and can therefore be more easily dispersed and/or purged at this period; whereas during low-tide (9 p.m. to 11 p.m.), they can be more readily tonified. The Spleen Channels' energy acts on the skin, muscles, and nerves found along their pathway.

WESTERN MEDICAL PERSPECTIVE

The spleen is responsible for blood formation, filtration, and storage. In the embryo, all types of blood cells are formed by the spleen, but in the adult, only lymphocytes and monocytes are formed.

PATHOLOGICAL MANIFESTATIONS

The main diseases of the Spleen Channels include gastrointestinal dysfunctions (disturbances of digestion and absorption of food), and diseases of the tongue and throat. Spleen disorders also affect the inner side of the lower extremities along the Spleen's Channels.

Since the Spleen has the function of sending food essence upwards (to the Lungs), if this function is impeded, diarrhea or prolapse of the viscera may occur.

The Spleen also has the function of keeping the Blood flowing in the blood vessels; impairment usually leads to chronic hemorrhagic diseases.

The Spleen has the function of nourishing the flesh (muscles). A person with a healthy Spleen will usually have a healthy figure and a toned body; a diseased Spleen makes the patient lose muscle definition.

The Spleen nourishes the limbs. Strength of the limbs depends upon the nourishment guaranteed by the normal functioning of the Spleen. A diseased Spleen usually causes weakness of the limbs.

THE HEART CHANNELS

The Heart Channels are Yin Channels and flow externally from the torso to the hand (Figure 6.13). Three rivers originate internally from the Heart on each side of the body. The first bilateral set ascends and connects to the tissues connecting the eyeball. The second set descends, first to permeate the Pericardium, then descends further to connect with and spirally wrap the Small Intestine. The third set flows up into the Lungs, emerges externally at the armpits, then descends the medial aspect of the arms and ends on the inside of the little fingers.

THE HEART ORGAN

The main function of the Heart organ consists of controlling the Blood and vessels, regulating the Blood flow, perspiration, and housing the Shen. The Heart organ's energy opens externally at the tongue and is expressed through the complexion.

PSYCHO-EMOTIONAL ASPECTS

The Heart's associated organ is the Small Intestine; its element is Fire. Long-term memory, thinking, emotions, intimacy, cognition, intelligence, and ideas are all dominated by the function of the Heart. The Heart is sometimes called The Emperor, or "supreme controller of all Yin and Yang organs" (see Chapter 12). The Heart houses the body's Spirit (Shen). The Heart dominates sleep; if the Heart is strong the patient will fall asleep easily and sleep soundly. If the Heart is weak, the patient's mind will "float," resulting in an inability to fall asleep, disturbed sleep, or excessive dreaming.

The Heart's positive psycho-emotional attributes are love, joy, peace, contentment, propriety, insight, wisdom, orderliness, forgiveness, and courtesy. Its negative attributes are hate, guilt,

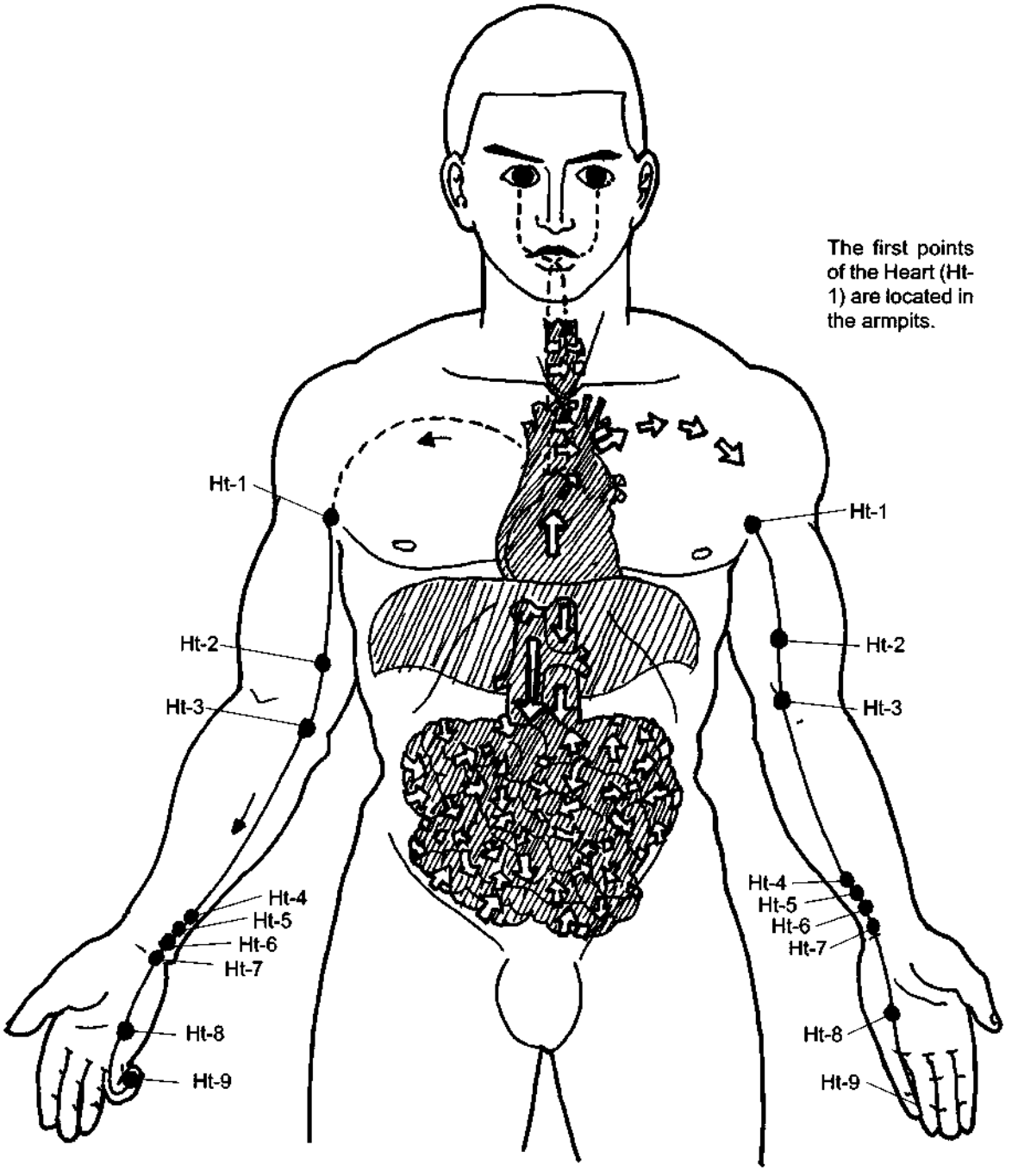

Figure 6.13. The Internal and External Qi Flow of the Heart (Ht) Channels

shock, nervousness, excitement, longing, and craving.

THE HEART'S ENERGY FLOW

The Heart Channels store more Qi than Blood; that is to say, its dominant action affects the energy. This energetic action controls the morale, the spirit of enterprise, and provides the energy required for respiration. At the high-tide time period (11 a.m. to 1 p.m.), Qi and Blood abound in the Heart organ and channels, and can therefore be more easily dispersed or purged at this period; whereas during low-tide (11 p.m. to 1 a.m.), they can be more readily tonified. The Heart Channel's energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The heart provides the propulsive force for circulating the blood throughout the vascular system. The blood circulation distributes the nutrients and oxygen needed for cell and tissue survival. The heart's propulsion also aids in the removal of wastes and other substances through the interconnecting blood vessels.

PATHOLOGICAL MANIFESTATIONS

The main diseases of the Heart Channels include diseases that exert pressure on the brain, eyes, or pharyngeal wall, as well as diseases of the Heart itself, and the lateral side of the chest. The Heart also relates to diseases of the ulnar palmar side of the arm.

The Heart is in charge of mental activities, including consciousness and thinking. Dysfunctions of the Heart can lead to insomnia, impairment of consciousness, amnesia, and psychosis.

The Heart and Kidneys have a mutual energetic relationship of supporting and checking each other. The Heart controls the body's Fire, while the Kidneys control the body's Water. Normally, the Fire of the Heart is sent down to warm the Kidneys, and the Water of the Kidneys is sent up to irrigate the Heart. If this balanced relationship breaks down (especially when the Kidney Water is insufficient to check the Heart Fire), a series of Fire symptoms of the Heart, such as hypertension, hyperactivity, palpitations, and insomnia may result.

Since the Heart has its external opening in the tongue, the condition of the Heart is reflected in the tongue:

1. A dark purple tongue indicates Blood Stasis of the Heart.
2. A pale tongue reveals Deficient Blood of the Heart.
3. An ulcer on the tongue reveals Excess Fire of the Heart.

THE SMALL INTESTINE CHANNELS

The Small Intestine Channels are Yang channels and flow externally from the hands to the head. These two rivers originate externally from the lateral tips of the little fingers (ulnar side) then ascend the arms to the shoulders, where they divide into two sets of branches. One set of branches descends the supraclavicular fossa internally, spiral wrapping the Heart, then continues down the esophagus, diaphragm, and Stomach, before permeating the Small Intestine (Figure 6.14).

The other set of branches ascends externally up the sides of the neck, then divides again into two more sets of branches at the cheek; one set will end at the ears, the other at the lateral sides of the nose and inner canthus of the eyes.

THE SMALL INTESTINE ORGAN

The Small Intestine temporarily stores partially digested food, absorbing the essential substances of the undigested food and a portion of the liquid content. It later transfers the residue (with a considerable amount of liquid) to the Large Intestine, and that is why it is said that the Small Intestine "governs liquid."

The Small Intestine is sometimes called "The Official in Charge of Separating the Pure from the Impure, because it separates the "clean" (reusable) food essence (Gu Qi) from the "dirty, turbid" food essence. The clean Gu Qi is transported throughout the body to nourish the tissues. The turbid is transported to the Large Intestine and Bladder organs to be further processed.

The Small Intestine's associated organ is the Heart; its element is Fire.

PSYCHO-EMOTIONAL ASPECTS

The Small Intestine influences the patient's

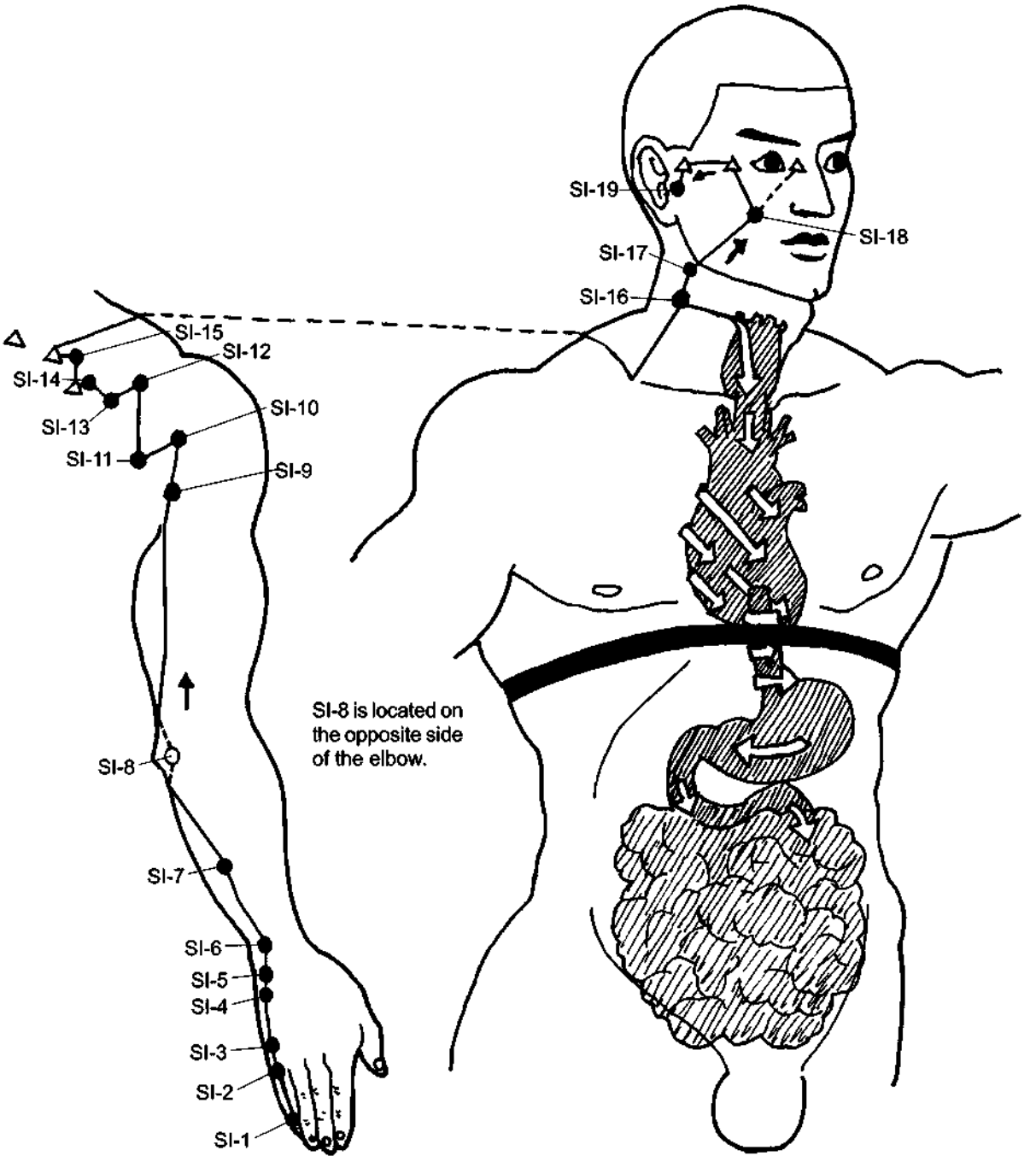

Figure 6.14. The Internal and External Qi Flow of the Small Intestine (SI) Channels

mental clarity, judgement, and powers of discernment. The ability to distinguish relevant issues with clarity before making a decision is attributed to the Small Intestine.

THE SMALL INTESTINE'S ENERGY FLOW

The Small Intestine Channels store more Blood than Qi, and act more on the physical substances and Blood functions than on energy. At the high-tide time period (1 p.m. to 3 p.m.), Qi and Blood abound in the Small Intestine organ and channels, and can therefore be more easily dispersed and purged at this period; whereas during low-tide (1 a.m. to 3 a.m.), they can be more readily tonified. The Small Intestine Channels' energy act on the skin, muscles, and nerves found along their pathway.

WESTERN MEDICAL PERSPECTIVE

The small intestine's function is to receive the food mass from the stomach through the pylorus, the bile from the liver and gall bladder, and the pancreatic juices for digestion and absorption. The small intestine then passes what it doesn't absorb into the large intestine.

PATHOLOGICAL MANIFESTATIONS

Diseases of the Small Intestine Channels include diseases of the face, ear, cheek, lower jaw, the neck, and throat, as well as the dorsal ulnar side of the upper extremities.

In TCM, food and herbs are divided into Yin (Cold) or Yang (Hot) properties. The Small Intestine is easily affected by the type and temperature of food eaten. An excess consumption of "cold" and raw foods, for example, can create a Cold condition within the Small Intestines, while an excess consumption of "hot" foods can create a Hot condition.

Disturbances of the Small Intestine's energetic function usually gives rise to one of the following complications:

1. Excess Conditions of the Small Intestines can result in symptoms of: Full Heat, Qi pain, Knotted Qi, and the infestation of worms in the Small Intestine.
2. Deficient Conditions of the Small Intestines can manifest as: Deficient and Cold Small Intestine.

Pathologic Heart Heat may be transmitted to the Small Intestine, resulting in urodynia (painful urination) and hematuria (blood in the urine). Herbal prescriptions used to dispel Heat from the Heart are also effective in treating these urinary symptoms, which are alleged to be caused by dysfunctions of the Small Intestine.

THE BLADDER CHANNELS

The Bladder Channels are Yang channels and flow externally from the head to the feet. Two rivers originate externally from the inner canthus of the eyes, ascend upward over the head to join the Governing Vessel at the GV-20 point, where they divide into two additional branches that flow into each temple, and into the brain. From there, they then divide into two sets of branches (at the Bl-10 point), which descend the back, and internally connect to and spiral wrap the Kidneys, before they descend to permeate the Bladder. They continue externally down the thigh, the popliteal fossa at the back of the knee, calf, and foot, and end on the lateral sides of the tips of the little toes (Figure 6.15).

THE BLADDER ORGAN

The function of the Bladder is to remove water by Qi transformation. The Bladder receives the "impure" parts of the fluids separated by the Small Intestine and temporarily stores and transforms these fluids into urine, to discharge it when the Bladder is full. The Bladder and the Small Intestine work together to remove Body Fluids from the Lower Burner.

The Bladder Channels activate the Yang aspect of the Kidney's function and are sometimes called The Water District Officials or "the controllers of the storage of waste water." The Bladder's associated organ is the Kidney; its element is Water.

PSYCHO-EMOTIONAL ASPECTS

An imbalance in the Bladder can cause such psychological symptoms as habitual fear, lack of decision making capability and a diminished moral character. If the imbalance becomes chronic, it results in such emotional responses as jealousy, suspicion, and a holding on to long-standing grudges.

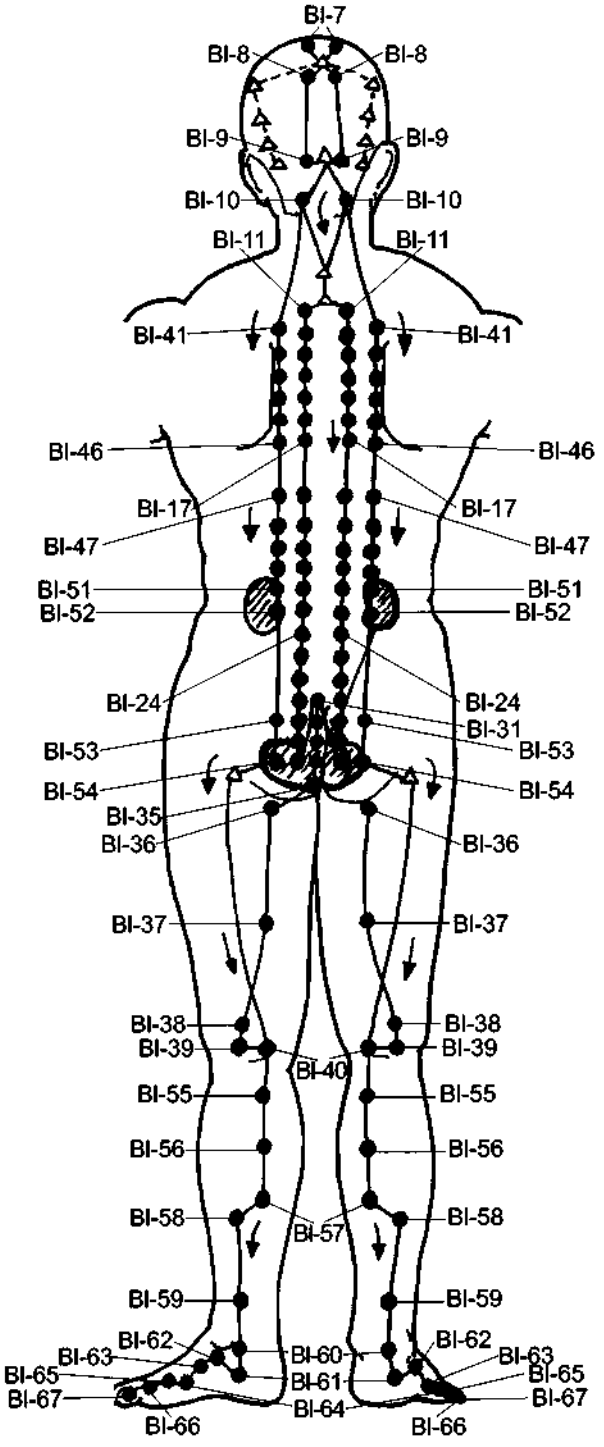

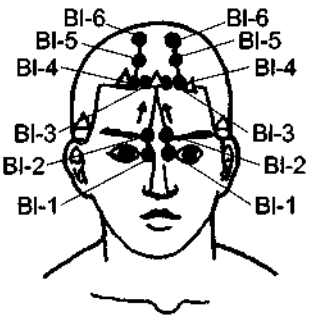

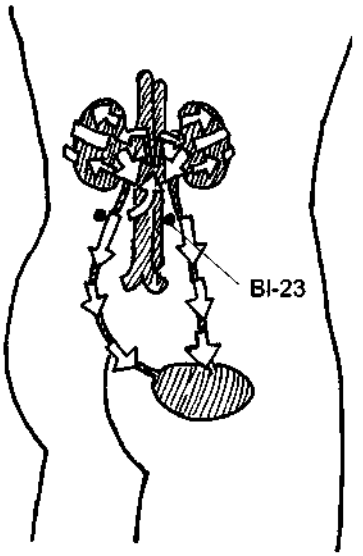

The internal flow of the Bladder Channels rushes into the lower back and lumbar area, passing through the renal arteries, to spiral wrap the Kidneys. From the Kidneys, the energy flows downward, following into the ureter, to permeate the Bladder.

Figure 6.15. The Internal and External Qi Flow of the Bladder (Bl) Channels

THE BLADDER'S ENERGY FLOW

The Bladder Channels regulate the functions of the Kidneys. The Bladder Channels store more Blood than Qi, acting more on the physical substances and the Blood functions than on the energy. At the high-tide time period (3 p.m. to 5 p.m.), Qi and Blood abound in the Bladder organ and channels, and can therefore be more easily dispersed and purged at this period; whereas during low-tide (3 a.m. to 5 a.m.), they can be more readily tonified. The Bladder Channels' energy acts on the skin, muscles, and nerves found along their pathway.

WESTERN MEDICAL PERSPECTIVE

The bladder is a reservoir for the urine received from the kidneys; it discharges urine from the body through the urethra.

PATHOLOGICAL MANIFESTATIONS

The main diseases of the Bladder Channels include:

- Diseases of the top of the head,
- Brain disorders,
- Disorders of the neck and back, especially the lumbar and sacral regions,
- Disorders of the back of the legs and thighs, and
- Disorders of the lateral side of the feet.

Diseases of the Bladder Organ manifest in changes in urine and urination; these changes will reflect a Deficient or Excess condition of the Bladder.

1. Deficient Conditions are attributed to Deficient Kidney Qi which affects the Bladder's ability to transform Qi. This dysfunction causes frequent urination, dribbling, or enuresis (involuntary discharge of urine).
2. Excess Conditions are attributed to Damp Heat in the Bladder, resulting in symptoms such as:

- heat and pain during urination,
- the short release of murky or reddish urine,
- frequent difficulty in urination,
- pus, or Blood in the urine, and
- Bladder stones which cause a urinary block and painful distention of the lower abdomen.

The most common pathological factor in the diseases of the Bladder organ is due to the accumulation of Dampness (e.g., Damp Heat or Damp Cold). Other pathological conditions include: emotional fears, anxieties and insecurities, excessive sex, and Deficient and Cold Bladder.

THE KIDNEY CHANNELS

The Kidney Channels are Yin channels and flow externally from the feet to the torso (Figure 6.16). These two rivers originate externally from underneath the little toes, circling the inside of the heels, ascending through the medial aspect of the legs, where they merge and enter into the coccyx and lower lumbar vertebrae. Dividing again, one branch permeates the Kidneys, while the other branch continues ascending into the cerebral cortex. From the Kidney organs, two additional sets of channels internally emerge. One set descends and spiral wraps the Bladder. The other set ascends into the Liver, diaphragm, and Lungs, then spiral wraps the Heart and travels up the throat, stopping at the root of the tongue (Figure 6.17).

THE KIDNEY ORGANS

The Kidneys store Jing substances, produce Marrow, and control the development of the bones. They also control respiration, reproduction, growth and development, and govern the Body Fluids. The Kidney Jing is the biological basis for the woman's menstrual blood. The Kidneys are the root of the Yin and Yang Qi of all the body's organs. The Kidneys energetically open externally through the ears and are sometimes called The Minister of Ingenuity and Vitality, or "the controller of water" (see Chapter 12).

The Kidney organs' associated organ is the Bladder and it's element is Water. Kidney Yin Qi flows to the Liver, Heart, and Lungs. It is responsible for the body's fluid-like essences and rules the birth, growth, maturation, and reproduction cycle. Kidney Yang Qi flows to the Spleen, Liver, Heart, and Lungs. It supports the Yang of all the body's organs via the Mingmen.

PSYCHO-EMOTIONAL ASPECTS

The Marrow produced from the Kidney Jing flows into the brain. The thinking ability is strengthened when Qi and Blood in the cerebral

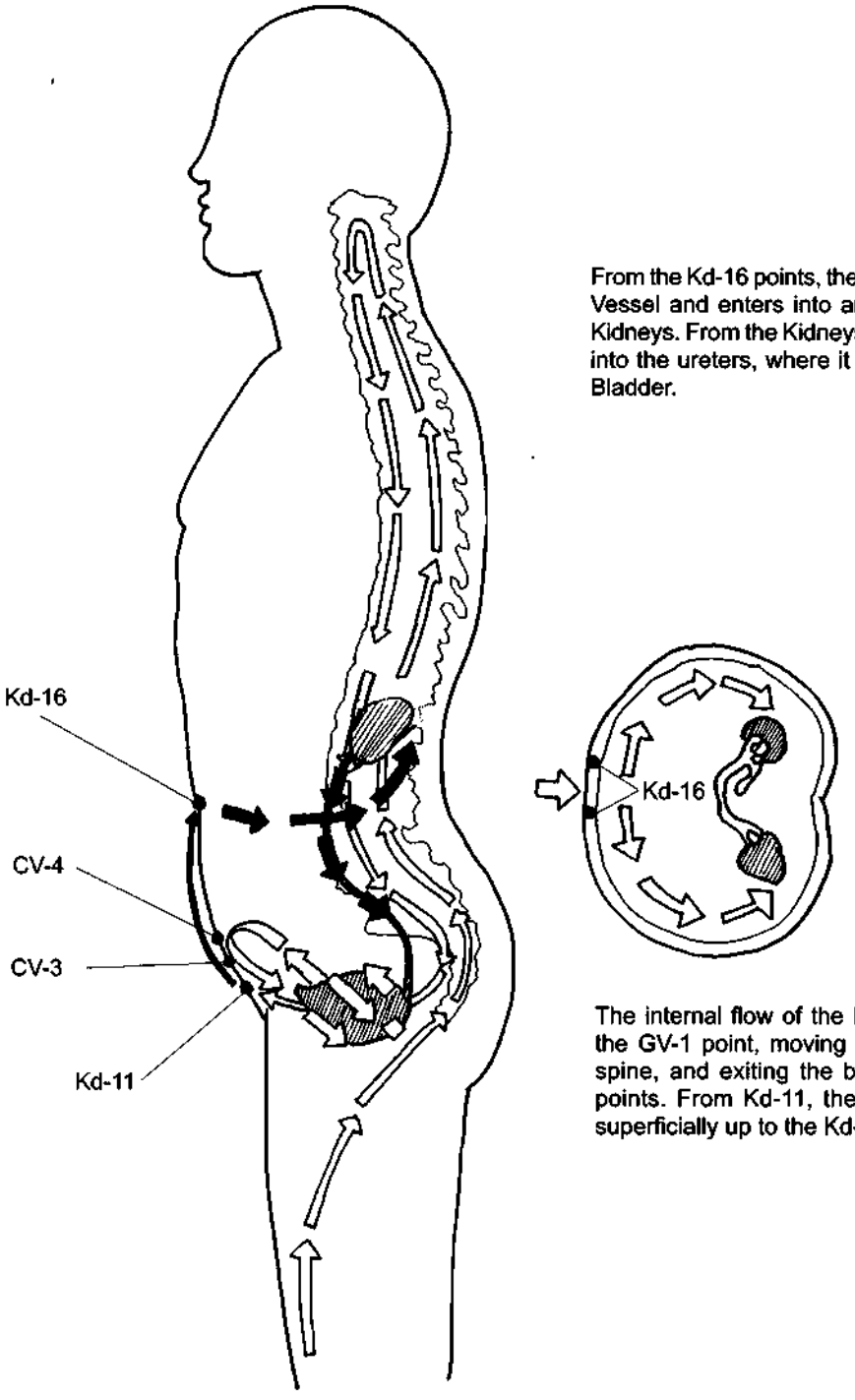

From the Kd-16 points, the Qi follows the Belt Vessel and enters into and permeates the Kidneys. From the Kidneys, the Qi descends into the ureters, where it spirally wraps the Bladder.

The internal flow of the Kidney Qi passes the GV-1 point, moving up and down the spine, and exiting the body at the Kd-11 points. From Kd-11, the energy ascends superficially up to the Kd-16 points.

Figure 6.16. The Internal Flow of the Kidney Qi

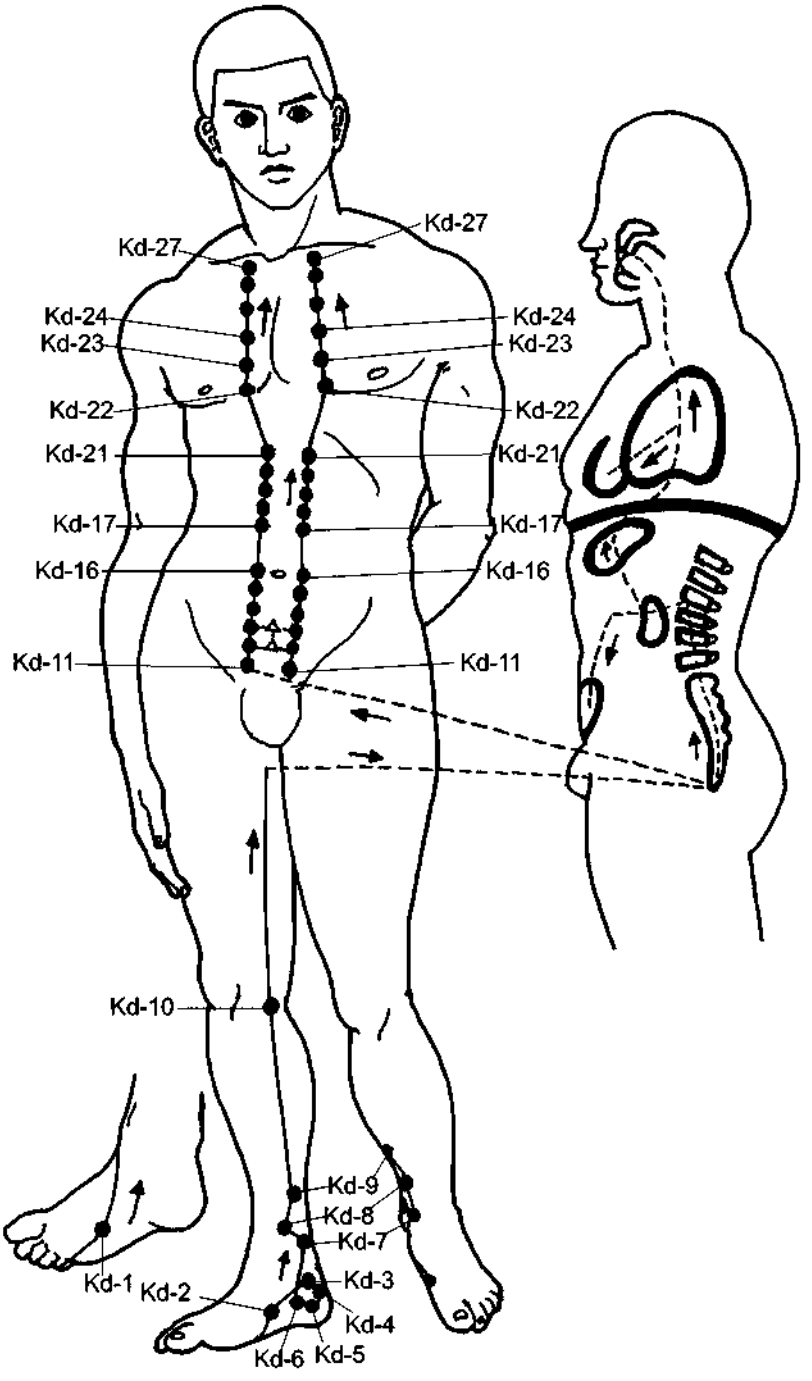

Figure 6.17. The Internal and External Qi Flow of the Kidney (Kd) Channels

cortex are abundant. With the increase of thinking activity, a circle of light develops within the body's Taiji Pole. The individual's innate intelligence (Yuan Shen) is represented by the intensity of light. The degree of accumulated spiritual energy is reflected by the number of light circles developed within the Taiji Pole. These circles of light can be best observed when first waking. By placing slight pressure on the external eye lids the inner light of the Taiji Pole is projected onto the optic nerves, reflecting an image of the circle of light. If the circle of light is complete, it reflects a strong, healthy condition. If the circle of light is dark within its center (similar to a doughnut), this reflects a Deficient condition. If the circle of light is broken or interrupted, it reflects an extreme Deficiency (Figure 6.18).

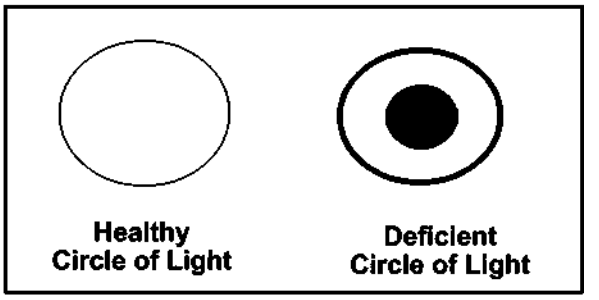

Figure 6.18. The individual's Yuan Shen is represented by the intensity of the light, and the degree of accumulated spiritual energy is reflected by the number of light circles developed within the Taiji Pole.

The "memory zone," as well as the "thought center" are also located in the cerebral cortex and will not develop until the Kidney Channels travel through the spine, along with the Liver Channels, to reach the cortex. When the Qi of these two channels is abundant, the memory function is keen.

The Kidneys house the body's will power (Zhi). They control short-term memory and store data. The Kidneys provide the capacity and drive for strength, skill, and hard work. A patient with strong Kidneys can work hard and purposefully for long periods of time. Consequently, when the Kidneys are in a state of disharmony, the patient can sometimes be driven to a state of excessive-compulsive working habits (a workaholic). A patient with weak Kidneys will lack strength and endurance.

The Kidney's positive psycho-emotional attributes are wisdom, rationality, clear perception, gentleness, and self-understanding. The negative attributes are fear, loneliness, insecurity, and shock (which attacks the Heart first then descends into the Kidneys to become fear).

The Kidneys' Energetic Flow

The Kidney Channels store more Qi than Blood, acting more on energetic and nervous functions than on physical substances and Blood functions. At the high-tide time period (5 p.m. to 7 p.m.), Qi and Blood abound in the Kidney organ and channels, and can therefore be more easily dispersed and purged at this period; whereas during low-tide (5 a.m. to 7 am.), they can be more readily tonified. The Kidney Channels' energy acts on the skin, muscles, and nerves found along their pathways.

Western Medical Perspective

The function of the kidneys is to regulate water and electrolytes and to process the body's urine.

Pathological Manifestations

Kidney Channel diseases cause general deterioration of the entire body, weakness in the lower extremities, lumbar pain, and hot sensations deep inside the feet.

The Kidneys open through the urogenital orifices and the anus. The energetic condition of the Kidneys can be, partially reflected by the condition of the patient's urination and defecation; in males, this includes the ejaculation process.

Since the Kidneys are responsible for concentration and memory retention, poor concentration and loss of memory are common symptoms of Kidney hypofunction.

The Pericardium Channels

The Pericardium Channels are Yin channels and flow externally from the torso to the hands. These two rivers originate internally from the center of the chest, flowing out of the Pericardium. They descend through the center of the body, spi-

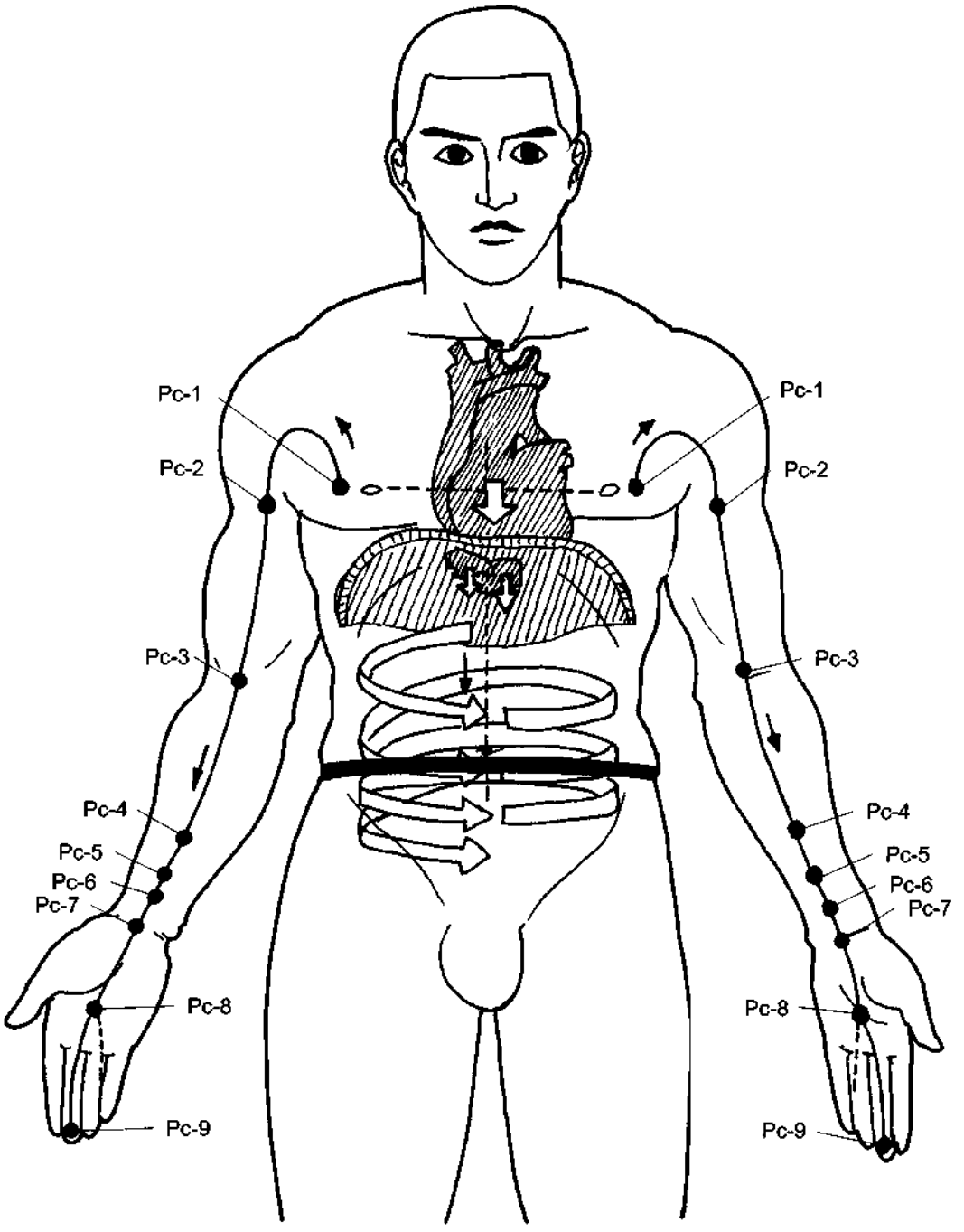

Figure 6.19. The Internal and External Qi Flow of the Pericardium (Pc) Channels

ral wrapping the Upper, Middle, and Lower Burners. Two rivers surface and branch externally by the nipples to proceed down the center of each arm, ending at the tips of the middle fingers. A second branch arises from the center of each palm at the Pc-8 point and flows into the ring fingers to connect with the Triple Burner Channels (Figure 6.19).

PERICARDIUM ORGAN

The Pericardium is associated with the Triple Burners; its element is Fire. The Pericardium is not considered an independent organ, as much as a protective covering for the Heart, that protects the Heart from pathogenic factors. The Pericardium activates, energizes and controls the Yin channel's distribution of the Kidney Yang Qi to the Yin organs. Along with the Heart, it governs the Blood, and houses the Shen. The Pericardium is considered the Prime Minister, or the official who protects the heart.

PSYCHO-EMOTIONAL ASPECTS

The Pericardium has a powerful influence on the patient's mental and emotional states. Its goal is to "create feelings of joy and/or pleasure for the emperor (Heart)."

THE PERICARDIUM'S ENERGY FLOW

The Pericardium Channels have an affect on the body's circulation of Blood. They are considered the "mother of Yin" and are connected to the Mingmen. The Pericardium Channels store more Blood than Qi, acting more on the physical substance and Blood functions than on the energy. At the high-tide time period (7 p.m. to 9 p.m.), Qi and Blood abound in the Pericardium organ and channels and can therefore be more easily dispersed and purged at this period; whereas during low-tide (7 a.m. to 9 a.m.), they can be more readily tonified. The Pericardium Channel's energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

The function of the pericardium is to provide a protective covering for the heart. It contains a thin serous fluid that allows the heart to work in a relatively friction-free environment.

PATHOLOGICAL MANIFESTATIONS

The main diseases of the Pericardium Channels include diseases of the Heart, front of the chest, major blood vessels, and diseases on the midline to upper palmar side of the upper extremities. Mental abnormalities may also manifest.

THE TRIPLE BURNER CHANNELS

The Triple Burner Channels are Yang channels that flow externally from the hands to the head. These two rivers originate externally from the tips of the ring fingers and ascend along the lateral aspect of the arms, over the shoulders to the clavicles, then branch internally and spiral wrap the Pericardium. They circle the diaphragm and permeate the Upper, Middle, and Lower Burners. A set of branches originate internally from the chest CV-17 point at the Heart, or center of the Middle Dantian. Flowing upwards, these branches emerge from the supraclavicular fossa at the St-12 points to ascend up the neck, head, and then circle the ears. Another set of branches flows downward to the cheek, terminating in the infraorbital region; the other set ends above the ears, by the outer canthus of the eyes.

THE TRIPLE BURNERS ORGAN

The Triple Burners' associated organ is the Pericardium; its element is Fire. The Triple Burners are not regarded as an independent organ, but are assigned to specific energy areas, and are a part of the function of the Yin and Yang organs. The function of the Triple Burners' energy is to produce Heat, and to regulate the body's temperature. This Heat is increased through such meditative disciplines as the Microcosmic Orbit (which connects the Governing and Conception Vessels), and the Macrocosmic Orbit (which connects all Twelve Primary Channels with the Governing and Conception Vessels). The main function of the Triple Burners (Figure 6.20) is to regulate the general ingestion and digestion of food and fluids throughout the body.

The Triple Burners are known as The Official of Balance and Harmony, because they govern Water metabolism, control the production of Wei

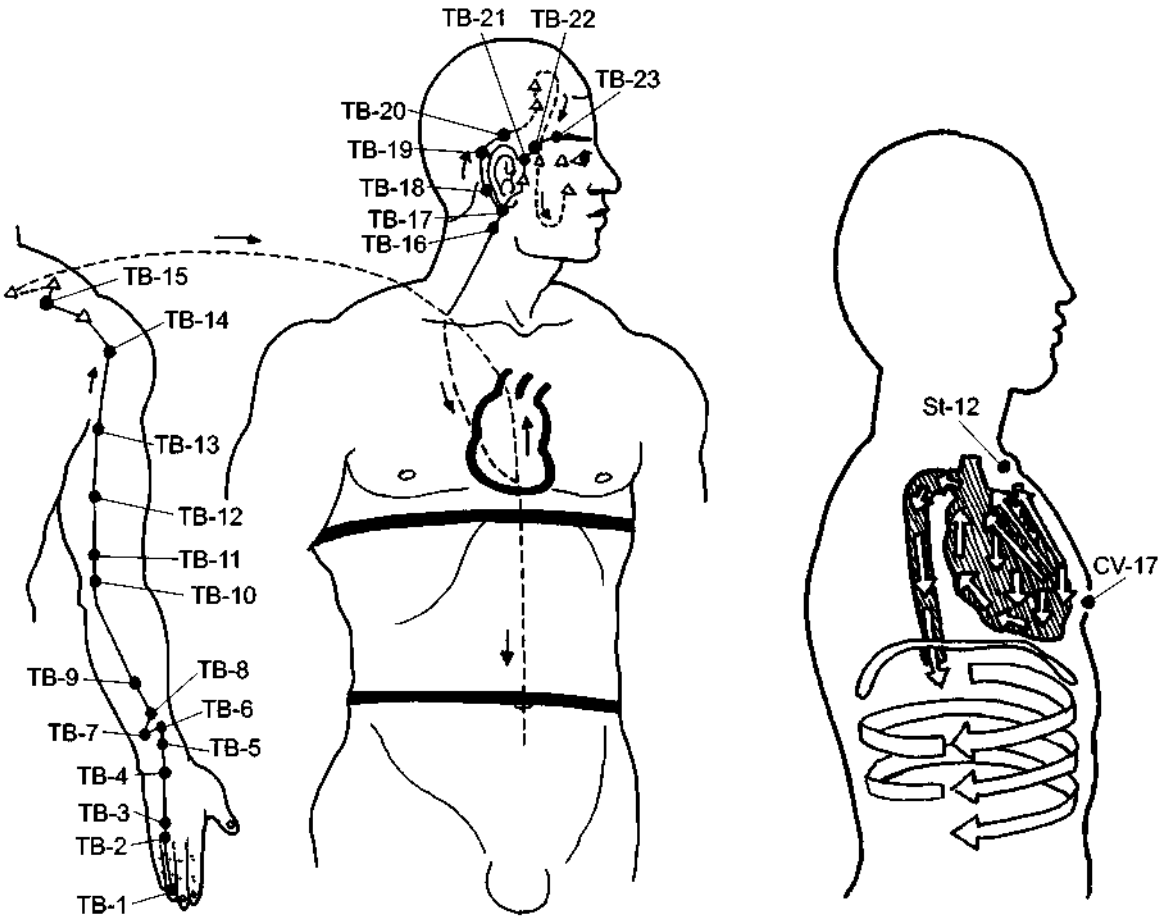

The internal flow of the Triple Burner Channels moves from St-12 down to CV-17, where it disperses into the chest and envelops the Pericardium. From the Pericardium, as the energy flows down through the diaphragm, it circulates through the chest and permeates the Triple Burners (a continuing branch flows upward to the St-12 points).

Figure 6.20. The Internal and External Qi Flow of the Triple Burners (TB) Channel

Qi, and transport Yuan Qi from the Kidneys to all the other organs of the body. This name refers to the Triple Burners' role in regulating metabolic functions, as well as their production of Qi, Blood, Body Fluids, and waste.

The Triple Burners' energy is composed of Zong Qi (Essential Qi). The Zong Qi assists the Heart in circulating the Blood and the Lungs in respiration. The Zong Qi also assists in conveying the Ying Qi (Nourishing Qi) to nourish the Blood, organs, and tissues of the body, as well as strengthens the Wei Qi (Protective Qi) that protects the external body (see Chapter 14).

1. The Upper Burner

   The Upper Burner is formed from the Fire created from the combined energies of the Heart, Pericardium, and both Lungs. The Upper Burner's energy is housed from the area of the head, throat, and upper chest, to the diaphragm. The Upper Burner is responsible for respiratory and cardiac functions. It moves the body's finer energy, circulating and distributing nutrients and Qi throughout the body like a "mist."
2. The Middle Burner

   The Middle Burner is formed from the Fire created from the combined energies of the Stomach, Spleen, pancreas, and Gall Bladder. The Middle Burner's energy is housed from the upper abdomen (the diaphragm) and the umbilicus.

   The Middle Burner is responsible for digestion, fermentation, and transformation of food and drink into nutrients for distribution. In the Middle Burner area, the Small Intestine connects downward to the Bladder. The Small Intestine transforms waste, that is then sent down to the Large Intestine, and also distills the body's fluids, sending them down to the Bladder.

   The Ying Qi (Nourishing Qi) of the Middle Burner receives its nourishment from the Stomach and Spleen. The Spleen extracts Gu Qi from the food "prepared" by the Stomach, churning the food essence into "foam." The Spleen refines this energetic foam and sends the processed Gu Qi to the Lungs. The Lungs further refine the Gu Qi, sending the impure part to the Kidneys (for additional refinement of the Gu Qi). The Kidneys return the Clean Qi to the Lungs and send the turbid part to the Bladder to be expelled from the body. The Qi from the air mixes with the Gu Qi in the Lungs to produce Zong Qi. The Lungs circulate the refined Gu Qi in the form of vapor or mist which is housed in the Upper Burner. The Heart then produces Blood from this vapor.
3. The Lower Burner

   The Lower Burner is formed from the Fire created from the combined energies of the Liver, Kidneys, Bladder, Intestines, and genitalia. The Lower Burner's energy is housed in the area which starts just below the umbilicus and extends to the lower perineum.

   The Lower Burner is responsible for the reproductive functions and for the filtering and elimination of waste products (Figure 6.21). It moves the body's coarser energy, acting as a "channel for water."

The Triple Burners contribute to the process of the three stages of transformation and ais in the distribution of Ying and Wei Qi throughout the body as follows:

- After the Gu Qi (food energy) has been separated into Clean and Turbid Qi, the Upper Burner releases the body's clean Wei Qi, directing it to the Lungs;
- the Middle Burner releases the body's clean Ying Qi, directing it to all of the body's organs and tissues; and
- the Lower Burner releases the body's Body Fluids, directing the turbid part to the Bladder.

PSYCHO-EMOTIONAL ASPECTS

The Triple Burners are considered the Ambassadors or "intermediaries" for the body's Yuan Qi. On a psychological level, they can be used to move Qi and lift depression derived from stagnation of Liver Qi.

When the Triple Burners, which regulate the consciousness, are full, the consciousness becomes stable and the Mind's intent is benevolent and kindhearted. The Triple Burners are also linked

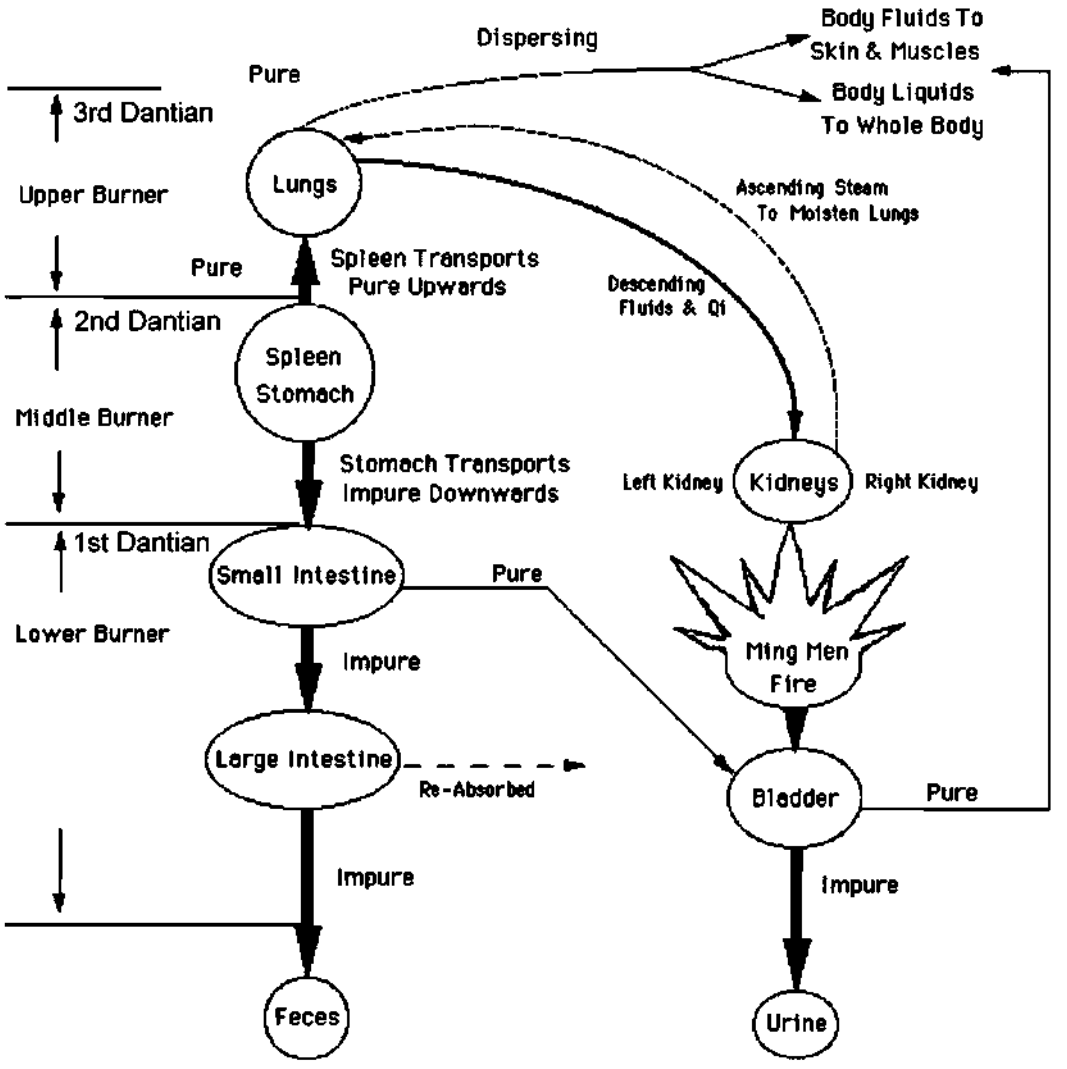

Figure 6.21. The Metabolic Functions of the Triple Burners are divided into three parts or functions: the Upper Burner, Middle Burner, and Lower Burner. These different functions of the Triple Burners control the movement of various types of Qi in the three stages of energy production:

Receiving—The Upper Burner, also known as mist, includes the organs from the diaphragm upwards (the Pericardium, head, throat, Lungs, and Heart). The Upper Burner assists the Spleen in directing the body's clean fluids upwards and helps the Lungs in dispersing and scattering the fluids to the skin and muscles.

Rotting and Ripening—The Middle Burner, also known as the muddy pool, and includes the area between the diaphragm and umbilicus (Stomach, Spleen, and Gall Bladder). The Middle Burner assists the Stomach in the transformation and transportation of Fluids and Liquids and in directing the impure part downwards.

Excreting—The Lower Burner, also known as the drainage ditch, includes the organs below the umbilicus (Liver, Kidneys, Intestines, and Bladder). The Lower Burner assists the Small Intestine, the Blood, and the Kidneys in transforming and transporting liquids and wastes.

with the Heart and Pericardium and are affected by the emotion of joy.

When the energy of the Heart is strong and pure (without guilt), and the desires and thoughts of an individual are at peace, then the energy of the body's sexual essence (Jing) will spread into the Triple Burners, and the Blood will flourish within the individual's vessels. If the "fire of desire" is allowed to Heat and combine with the energy of the Triple Burners, the energy of the individual's sexual essence will overflow, mixing itself with the energy of the Mingmen and will leave the body via the reproductive organs and tissues. This leads to Jing and Qi depletion.

THE TRIPLE BURNERS' ENERGY FLOW

The Triple Burner Channels store more Qi than Blood, and act more on the energetic and nervous functions of the body than on physical substance and Blood functions. At the high-tide time period (9 p.m. to 11 p.m.), Qi and Blood abound in the Triple Burner Channels, and can therefore be more easily dispersed and purged at this period; whereas during low-tide (9 a.m. to 11 a.m.), they can be more readily tonified. The Triple Burner Channels' energy acts on the skin, muscles, and nerves found along their pathways.

WESTERN MEDICAL PERSPECTIVE

Western medicine recognizes no translation of, or reference to the Triple Burners.

PATHOLOGICAL MANIFESTATIONS

The main diseases along the Triple Burner Channels involve the face, ear, cheek, larynx, and neck. Diseases of the Triple Burner Channels also include disorders of the back of the upper extremities from the midline to the upper arm and forearm.

When diagnosing problems due to dysfunctions of the Triple Burners, the Qigong doctor considers the following.

1. A blockage of the Wei Qi located within the Upper Burner causes an impairment of the Lungs' dispersing function. This can result in the invasion of the Lungs by External Evils (e.g., Wind and Heat, etc.), that penetrate the Pericardium (which corresponds to the initial stage of externally contracted Heat diseases).
2. A blockage of the Ying Qi located within the Middle Burner causes an impairment of the Spleen's transporting function. This can result in gastrointestinal Heat stagnation, and cause Spleen and Stomach Damp Heat (which corresponds to the second stage of externally contracted Heat diseases).
3. A blockage of the Body Fluids located within the Lower Burner causes an impairment of the Bladder's transformation function. This results in the deep penetration of Toxic Evils, weakening the body's Kidney Yin. This in turn can cause Deficient Liver Blood, and Wind stirring due to Empty Yin (this corresponds to the advance stages of externally contracted Heat diseases).

UNDERSTANDING CHANNEL PATHOLOGY

Channel pathology is the oldest of all the modes of pathological pattern classification, dating back to the Spiritual Axis from the *Yellow Emperor's Classics on Internal Medicine*. In understanding a channel's pathology, the Qigong doctor takes into consideration several aspects of the patient's energy flow (i.e., the channels are viewed as exterior, whereas the organs are viewed as interior). Channel pathology is often related to organ disturbances, but it can also be distinct from organ pathology (Figure 6.22).

The disease of one channel may cause disease in other channels and organs. Likewise, tonification of one channel may cause a tonification of other channels and organs.

THE FOUR CAUSES OF CHANNEL PATHOLOGY

1. The Invasion of External Pathogens such as Cold, Wind, Heat, and Damp leads to channel pathology. The exogenous pathogenic factors often settle in the joints, causing Bi Syndrome (painful obstruction). Channel pathology is quite closely related to joint pathology. In Traditional Chinese Medicine, joints are important to the circulation of Qi and Blood. Qi and Blood gather and concentrate in the joints. Qi enters and exits the channels at the joints. The Five Source Points, also called Shu Points (see Chapter 8), are usually located on

of near the joints. It is at these points that the External pathogenic influences may enter the body and settle in the joints. These External pathogenic influences upset the Yin and Yang balance and block the flow of Qi and Blood, causing pain and swelling. The body's joints are also affected by Deficient Qi and Blood, causing local weakness and pain from lack of movement.

2. Physical strain or the overuse of certain joints can cause local stagnation that creates pain and weakness.
3. Injuries, trauma, and strain can cause local stagnation resulting in stiffness, bruising, and pain.
4. Internal organ disharmonies may also affect the channels.

DIFFERENTIATION BY CHANNEL FULL/EXCESS AND EMPTY/DEFICIENT

When a channel is too full, its pattern characteristics are that of intense pain, stiffness, contractions, and cramps. A red color along the flow of the channel indicates Heat; a bluish color along the flow of the channel indicates Cold.

When a channel is Empty, its pattern characteristics are that of a dull ache, weakness in the muscles, numbness, and muscle atrophy along the channel.

DIFFERENTIATION OF CHANNEL PATTERNS BY SPECIFIC CHANNELS

This clinical overview of the body's channels was originally expressed through the knowledge found in the Spiritual Axis (for more in-depth dissertation please see *The Foundations of Chinese Medicine* by Giovanni Maciocia).

1. The diseases of the Gall Bladder Channels may cause: Alternating chills and fever, headache, acute onset of deafness, pain in the hip and the sides of the body, pain along the lateral sides of the legs, and pain and distention of the breasts.
2. The diseases of the Liver Channels may cause: Headache, pain and swelling of the eyes, and cramps in the legs.
3. The diseases of the Lung Channels may cause: Fever, aversion to cold, stiffness in the chest, pain in the shoulders, clavicle, and arms.
4. The diseases of the Large Intestine Channels may cause: Sore throat, toothache, nosebleed, runny nose, swollen and painful gums, swollen eyes, and pain along the channels.
5. The diseases of the Stomach Channels may cause: Pain in the eyes, nosebleed, neck swelling, facial paralysis, cold legs and feet, and pain along the channels.
6. The diseases of the Spleen Channels may cause: Vaginal discharge, weakness of the leg muscles, and a cold feeling along the channels.
7. The diseases of the Heart Channels may cause: Pain in the eyes, pain along the scapula, and pain along the inner side of the arms.
8. The diseases of the Small Intestine Channels may cause: Pain and stiffness in the neck, and pain along the lateral side of the scapula, elbow, and arms.
9. The diseases of the Bladder Channels may cause: Fever and aversion to cold, headache, stiff neck, pain in the lower back, pain in the eyes, pain in the backside of the leg along the channels.
10. The diseases of the Kidney Channels may cause: Lower back pain and pain in the sole of the feet.
11. The diseases of the Pericardium Channels may cause: Stiff neck, contraction of the elbow and hand, and pain along the course of the channels.
12. The diseases of the Triple Burner Channels may cause: Alternating chills with fever, acute onset of deafness, pain and discharge from the ear, pain at the top of the shoulders, pain in the elbow, and pain along the course of the channels.

SUMMARY OF TWELVE PRIMARY CHANNEL PATHOLOGY

The clinical significance of studying the Twelve Primary Channels is evident through the observation of certain pathological manifestations that indicate specific patterns peculiar to that channel and its internal organ. The quality, quantity and proportions of Qi and Blood circulation

Twelve Primary Channels	Pathologies
Bladder	• Diseases of the top of the head, brain, neck, back, lumbar and sacral region • Diseases of the back of the leg and thigh and the external side of the foot
Gall Bladder	• Pain in upper right- and left-quadrants of abdomen • Diseases of the head, face, eye, ear • Diseases of the external sides of the lower extremities
Heart	• Diseases that exert pressure on the brain, eyes, or pharyngeal wall • Diseases of the Heart and lateral side of the chest • Diseases of the ulnar palmar side of the upper extremities • Insomnia, impairment of consciousness, amnesia, and psychosis
Kidneys	• Diseases that cause general deterioration of the entire body • Weakness in the lower extremities and lumbar pain • Hot sensations deep inside the feet
Large Intestine	• Diseases of the lower part of the face, nose, oral cavity, teeth, throat, and front part of the neck • Diseases of the back and radial side of the upper extremities
Liver	• Swelling and a distended sensation of the hypochondrium • Diseases of the lower abdomen and genital organs
Lungs	• Chest and Lung diseases • Diseases on the radial side of the upper arm and palmar area of the hand
Pericardium	• Diseases of the Heart, front of the chest, major blood vessels • Diseases of the midline to upper palmar side of the upper extremities • Mental abnormalities
Small Intestine	• Diseases of the face, ear, cheek, lower jaw, neck, and throat • Diseases of the back ulnar side of the upper extremities
Spleen	• Diseases of the tongue and throat • Gastrointestinal diseases (disturbances of digestion and absorption of food) • Diseases of the inner side of the lower extremities
Stomach	• Diseases of the face, nose, oral cavity, teeth, throat, and front of the neck • Diseases of the abdomen, the frontal part of the lower extremities and gastrointestinal area • Certain psychiatric diseases
Triple Burners	• Diseases of the face, ear, cheek, larynx, and neck • Diseases of the back of the upper extremities from the midline of the torso to the upper arm and forearm

Figure 6.22. Pathologies of the Twelve Primary Channels

through each of the Twelve Primary Channels has a vital impact on all the body's organ systems. These Qi and Blood flow concepts define the reciprocal relationships existing between the body's internal organs, channels, and energetic points situated throughout the body.

Figure 6.22 describes some of the most common Twelve Primary Channel pathologies, and their clinical manifestations along the "root and branches" of these channels.

The term "root and branch," is used to describe the difference between the medial and lateral, upper and lower orientations of the channels and their points of origin. They are also used to describe the progression of a disease, as well as the priorities and sequence of the Qigong doctor's treatment.

Specifically, the word "branch" is used to describe the channels' flow of Qi and Blood and the progression and direction of a disease. The word "root" is used to described the channels' internal organ, or the origin of a disease.

Chapter 7
The Eight Extraordinary Vessels and Collaterals

The Eight Extraordinary Vessels

Extending from the body's Taiji Pole are the Three Dantians, Five Jing Shen, and the Eight Extraordinary Vessels. These energy systems feed all the vital organs and the body's Twelve Primary Channels. The Eight Extraordinary Vessels are so called because of they differ in energetic function from the Twelve Primary Channels. These eight vessels have an extraordinary ability to regulate the deeper energetic reservoirs of the body. They are the first vessels (or channels) to form in the developing fetus, and are sometimes called the Eight Ancestral Channels, Eight Prenatal Channels, Eight Preheaven Channels, or Eight Psychic Channels.

These vessels represent the merging of the mother's and father's energy, and the linking of the body's prenatal and postnatal energies. They functionally connect to the Twelve Primary Channels and circulate the Jing Qi (Essence Energy) throughout the body.

The energetic expansion and contraction of the Eight Extraordinary Vessels affects the creation and development of the baby's tissues up until the time of birth. In energetic embryology, the three-dimensional space of the impregnated egg is viewed as an object that can be described by eight different surfaces along four axes. Each of the Eight Extraordinary Vessels corresponds with one of these directions:

- anterior/posterior—Governing and Conception Vessels
- superior/inferior—Yin and Yang Linking Vessels
- right/left—Yin and Yang Heel Vessels
- interior/exterior—Thrusting and Belt Vessels

The Function of the Eight Extraordinary Vessels

The Eight Extraordinary Vessels have neither a direct connection nor an internal/external relationship with the internal organs. Similar to the Three Dantians' function of distributing the body's energy, these Eight Extraordinary Vessels are also reservoirs that regulate the distribution and circulation of Jing and Qi inside the body. They are the foundation of the body's energy, bridging the Yuan Qi (Original Prenatal Energy) with the body's postnatal energy.

The Eight Extraordinary Vessels serve as reservoirs of Qi. When these reservoirs become full, the energy overflows into the center channel or Taiji Pole. This stimulation of the Taiji Pole expands consciousness and increases perceptual intuition.

The Eight Extraordinary Vessels have five main functions: They serve as reservoirs of Qi, store and circulate Jing Qi, circulate the Wei Qi, regulate the body's life cycles, and integrate the six primary Yang organs with the Six Extraordinary Organs and with the Kidneys.

1. They Serve as Reservoirs of Qi. If the Qi flow of the Twelve Primary Channels becomes Excessive, they overflow into the Eight Extraordinary Vessels, which act as Qi reservoirs, receiving the Excess Qi for storage and distribution, while at the same time regulating the energy flow. If the Qi flow of the Twelve Primary Channels becomes Deficient, they can draw from the reservoirs of energy stored within the Eight Extraordinary Vessels which again regulate the body's energy flow, bringing it back into balance.
2. They Store and Circulate Jing Qi. The Eight Extraordinary Vessels draw their energy from the Kidneys and are responsible for storing and circulating the body's Jing Qi throughout the tissues, particularly to the skin and hair and to the Six Extraordinary (Curious) Organs, also known as the Six Ancestral Or-

gans. The Six Extraordinary Organs are the Brain, Bone, Marrow, Blood, and Gall Bladder (also included is the Uterus in women).

3. They circulate the Wei Qi (Protective Energy) to protect the body against invasion by External pathogens. The Governing, Conception, and Thrusting Vessels are primarily responsible for circulating the body's Wei Qi over the thorax, abdomen, and back.

   The Eight Extraordinary Vessels provide the link between the Kidneys Jing and the Wei Qi. Although the Wei Qi is circulated by the Lungs, its root is in the Kidneys. This illustrates how the Kidneys play an important role in supporting the Lungs function of circulating the body's Wei Qi. The Kidneys function on the Wei Qi field and therefore the immune system can become vulnerability to pathogenic factors, as well as in causing allergic diseases, e.g., asthma. It also demonstrates why the Kidneys are always at the root of latent Heat syndromes (chronic fatigue), caused by Kidney Deficiency.
4. The Eight Extraordinary Vessels regulate the body's Life Cycles. In the first chapter of *the Yellow Emperor's Classic of Internal Medicine*, the life changes in women (every seven years) and men (every eight years) are governed by the Conception and Thrusting Vessels. These life cycles are related to the body's Jing and the Eight Extraordinary Vessels' role in moving and circulating the body's Jing (see Chapter 13).
5. They Integrate the Six Extraordinary (Curious) Organs with the Six Primary Yang Organs and the Kidneys. The Eight Extraordinary Vessels provide the link between the body's brain, uterus, blood vessels, Gall Bladder, Marrow and bones, and the body's internal energy flow.
   a. The Brain is Regulated by the Governing Vessel and the Yin and Yang Heel Vessels.
   b. The Uterus is regulated by the Thrusting and Conception Vessels.
   c. The Blood Vessels are regulated by the Thrusting Vessels.
   d. The Gall Bladder is regulated by the Belt Vessel.
   e. The Marrow is regulated by the Thrusting Vessels.
   f. The Bones are regulated by the Thrusting and Conception Vessels.
6. They Integrate the Four Seas. The *Magic Pivot (Ling Shu, Hai Lun)* states, "People have Four Seas... the Sea of Marrow, the Sea of Blood, the Sea of Qi, and the Sea of Grain and Water." The Eight Extraordinary Vessels provide the link between the body's Four Seas and the body's internal energy flow.
   a. The Sea of Marrow is the brain, and it is related to the Governing Yin and Yang Heel Vessels. The Sea of Marrow points are located on the Governing Vessel GV-16 and GV-20. When the Sea of Marrow is Deficient, there will be headaches and dizziness.
   b. The Sea of Qi is located in the chest of the center, and is regulated by the Conception Vessel CV-17. Some Medical Qigong schools maintain that there are two reservoirs of Qi: the Middle Dantian, being the Sea of Postnatal Qi, and the Lower Dantian, being the Sea of Prenatal Qi (which is regulated by the Qihai CV-6 point). When the Sea of Qi is in Excess, there is a feeling of fullness in the chest, dyspnea (urgent breathing), and a red complexion. When the Sea of Qi is Deficient, there is weak energy and insufficient speech.
   c. The Sea of Nourishment (also known as the Sea of Grain and Water) is the Stomach, and it is regulated by the Thrusting Vessels, which are accessed by the St-30 points. When the Sea of Water and Grain is in Excess, there is a feeling of fullness in the abdomen. When the Sea of Water and Grain is Deficient, there is a feeling of hunger with an inability to eat.
   d. The Sea of Blood (also known as the Sea of the Twelve Primary Channels) is related to the Thrusting Vessels, the Liver, and Xuehai Sp-10 points. The points can

also be accessed through Bl-11, St-37, and St-39. When the Sea of Blood is in Excess, the body feels big; When the Sea of Blood is Deficient, the body feels small.

THE EIGHT EXTRAORDINARY VESSELS AND MEDICAL QIGONG THERAPY

The energetic pathways, functions and use of the Eight Extraordinary Vessels and points in Medical Qigong are often quite different than those taught in acupuncture colleges, even though they may sometimes bear the same names.

Most acupuncturists, with the exception of some Japanese researchers, often pay little attention to the Eight Extraordinary Vessels in diagnosis and treatment. One Medical Qigong doctor from China has claimed that a study done in China showed that the Eight Extraordinary Vessel treatments were far more effective than those of the Traditional Chinese medical protocols. The results, however, were not released because officials did not want to disturb the TCM institutional operations. The reason Medical Qigong makes use of the Eight Extraordinary Vessels, is that they are much easier to access through Qi emission and Medical Qigong self-regulation prescriptions than through acupuncture therapy.

The Eight Extraordinary Vessels have been of special importance to Medical Qigong practitioners for thousands of years, and are viewed as the foundation of the body's energy, the bridge between the Yuan Qi (Prenatal Qi) and the Postnatal Qi. These Eight Extraordinary Vessels affect the body on the deepest level of our basic constitutional energy. In Medical Qigong regulation exercises, the focus on opening the flow of energy through the Eight Extraordinary Vessels is a prerequisite for opening the energy flow in the Twelve Primary Channels. The major purpose of opening the Eight Extraordinary Vessels is to provide a container for storing the Three Forces: Heaven Force (absorbing universal energy), Earth Force (absorbing environmental energy), and Man's Force: Jing, Qi and Shen (Essence, Energy and Spirit).

It is essential for the Qigong doctors to open their Eight Extraordinary Vessels to attain mastery of their energetic body. The Microcosmic Orbit is introduced for purgation, fusion, tonification, and regulation of the Governing and Conception Vessels in the first stages of training. This exercise restores a healthy flow of energy throughout all of the channels and vessels creating a healthy and balanced body.

Through the refinement of their energy, Qigong doctors receive more Qi, and the quality of their Blood changes, i.e., its energetic potential changes to contain more Qi and less Blood. At this advanced state of transformation, Qigong doctors rechannel the flow of energy through their body's Three Dantians, including the "mystical pass" (located within the Upper Dantian chambers of the brain). When the flow of energy is directed to stimulate the Mystical Pass, the Qigong doctors acquire greater awareness and control over their own bodies (physical, mental, emotional, energetic and spiritual), and are then able to enhance their perception and communication with all the other energetic planes of the world (mineral, plant, animal, and human), and with the Dao (or divine).

CLINICAL USE OF THE EIGHT EXTRAORDINARY VESSELS

The Eight Extraordinary Vessels form and establish the foundational energetic pattern for the developing fetus's tissues, as well as the adult's entire body. The clinical use of the Eight Extraordinary Vessels can be divided into several different approaches of energy manipulation to change the energetic patterns within the patient's tissues.

One approach divides the Eight Extraordinary Vessels into four pairs of Yin and Yang vessels. Each of the vessels is grouped according to the same polarity, two pairs of Yin and two pairs of Yang. When paired this way, each set of the Yin and Yang Extraordinary Vessels has a common range of energetic action in terms of the patient's body area.

1. The Conception and Yin Heel Vessels affect the energetic flow to the patient's abdomen, chest, Lungs, throat, and face.
2. The Governing and Yang Heel Vessels affect the energetic flow to the back of the patient's legs, as well as the back, spine, neck, head, eyes, and brain.

3. The Thrusting and Yin Linking Vessels affect the energetic flow to the inner aspect of the patient's legs, as well as the abdomen, Stomach, chest, and Heart.
4. The Belt and Yang Linking Vessels affect the energetic flow to the outer aspect of the patient's legs, as well as the sides of the body, shoulders, and sides of the neck.

ENERGETIC FUNCTIONS OF THE EIGHT EXTRAORDINARY VESSELS

The Eight Extraordinary Vessels can also be categorized is according to their energetic functions.

1. The Conception, Governing and Thrusting Vessels are considered the source of all the other Extraordinary Vessels These three vessels affect the patient's energy at a deep constitutional level. They originate directly from the Kidneys and are connected to the body's Jing.
2. The Yin and Yang Heel Vessels are complementary in that they both flow from the legs (controlling the state of the muscles of the legs) into the eyes (controlling the muscles that open and close the eyes).
3. The Yin and Yang Linking Vessels complement each other by linking the body's Yin and Yang Channels.
4. The Belt Vessel is the only horizontal vessel in the body, encircling the main channels. Its energetic influence is in its ability to affect the circulation of energy in the body, especially within the legs.

Each of the Eight Extraordinary Vessels is also connected to one of the Eight Trigrams (or Eight Natural Manifestations), and can be energetically regulated through the use of the Magic Square. For further treatment and clinical protocol see Chapter 31 regarding the Eight Extraordinary Vessel and the Magic Square.

THE GOVERNING AND CONCEPTION VESSELS

The Governing and Conception Vessels are the main rivers of the body's Yin and Yang energies. They are polar aspects of the body, perfectly complementary, like midnight and midday. They are responsible for the formation of the holoblastic cleavage and the first cellar division of the fertilized ovum in embryological development (see Chapter 2).

In China, Dr. Li Shi Zhen was the first to believe that the Governing and Conception Vessels are two branches of the same source, an inseparable Yin-and-Yang, front-and-back duality. These vessels connect the uterus with the Kidneys, Heart, and Brain.

They originate externally at Huiyin CV-1 point, ascend the front and back of the torso, and form a small circle when the tip of the tongue touches the upper palate in the mouth and the anal sphincter is squeezed. Not only does this action complete the balance of Fire (Heart) and Water (Kidneys) energy, it also increases the body's protective Wei Qi.

Regulating the Conception and Governing Vessels is a priority in Medical Qigong practice. Along these vessels, the Qigong practitioner draws the Yang Fire and Yin Essence up and down his or her body, fusing the Water and Fire energies together. This fusion facilitates a Yin and Yang balance throughout the body.

The Governing and Conception Vessels each have two energy flows on the anterior and posterior vertical midline of the body. Each vessel's pathway is complete, being composed of an ascending energetic flow and a descending energetic flow. The duality of these two medial lines joins at the extremities (the head and perineum), forming one complete circle of energetic current (Figure 7.1).

Both vessels are superimposed on each other, with the energy of the Governing Vessel being predominant up the back and inferior down the front (behind the Conception Vessel); the energy of the Conception Vessel is predominant up the front and inferior down the back (behind the Governing Vessel).

The energetic flow of the Conception Vessel corresponds to Yin, negative polarity, the female aspect, and responds to bass tones; while the energetic flow of the Governing Vessel corresponds to Yang, positive polarity, the male aspect, and responds to treble tones.

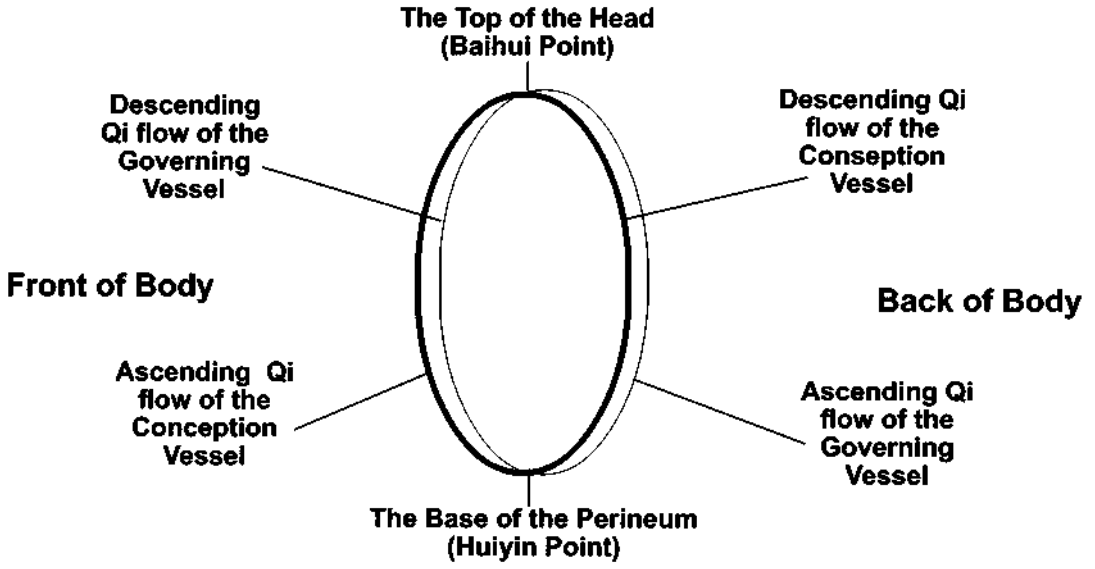

Figure 7.1. The Energetic Flow of the Conception and Governing Vessels

It is important to understand the energetic potential of these two currents flowing in both an ascending and descending direction on the posterior and anterior vertical midline in the body. The energetic movement of these two currents explains why there are two opposite directions of focused concentration used in energy cultivation meditations. One direction follows the Microcosmic Fire cycle along the Governing Vessel (up the spine and down the chest) to stimulate the emotional regulation of the acquired mind (Zhi Shen); the other direction follows the Microcosmic Water cycle along the Conception Vessel (up the chest and down the spine) to stimulate spiritual intuition and activate the perceptions of the Yuan Shen.

THE GOVERNING VESSEL OR DU VESSEL

The word Du translates as "governing," and refers to a general, someone who controls and is in charge. During the development of the embryo, the Governing Vessel is responsible for the development and formation of the medulla oblongata and cerebrum. The Governing Vessel controls all the Yang Channels in the body, and is called the Sea of Yang Channels. It is responsible for nourishing the brain and spinal cord and for consolidating the Yuan Qi in the Kidneys.

The Governing Vessel originates in the Lower Dantian in both men and women. It is composed of many energetic branches, emerging externally at the perineum. The primary branch ascends externally on the midline of the back, over the head and ends in the frenulum of the upper lip. As the Qi flows up the Governing Vessel one branch enters the interior of the spinal column and enters the Kidneys. Another set of branches enters the brain at the Fengfu GV-16 point and ascends internally to the vertex at the Baihui GV-20 point.

From the lower perineum, another set of branches encircles the anus and envelops the external genitals, ascends past the navel, Heart, and throat to circle the mouth. After circling the mouth, it further ascends to the eyes, emerging just below the middle of the eyes. From the inside of the eyes (at the Jingming Bl-1 point), a set of branches follows the Bladder Channels along the forehead, converging at the vertex of the Baihui GV-20 point and enters the brain. From the brain, the Vessel emerges at the Fengfu GV-16 point, and divides into two additional branches which descend the

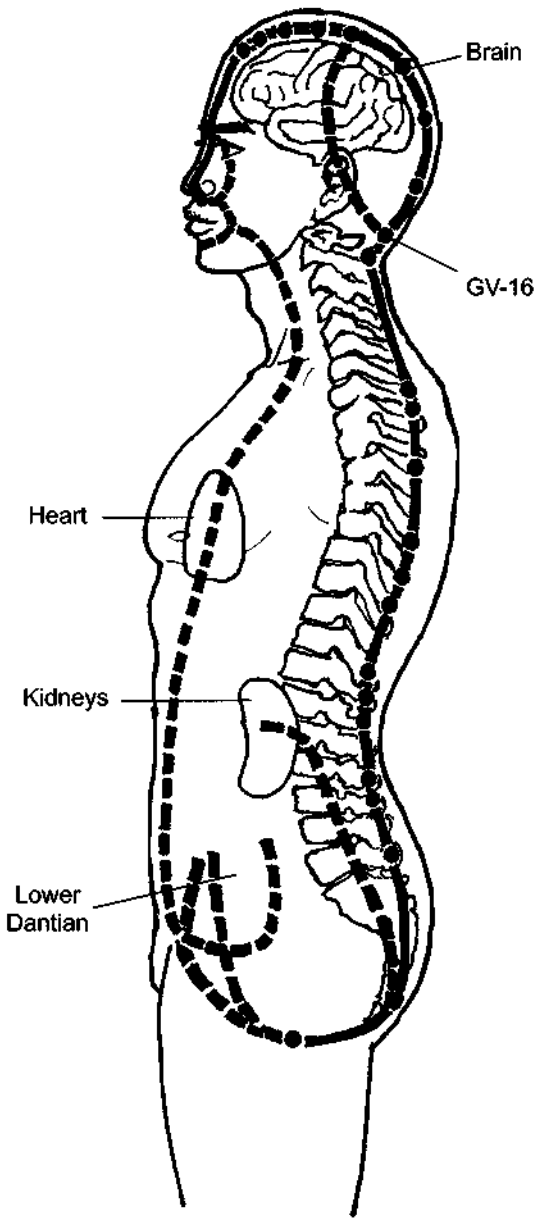

Figure 7.2. The Governing Vessel (Side View)

back, passing through the Fengmen Bl-12 points along the sides of the spine and enter into the Kidneys (Figure 7.2).

The Governing Vessel tonifies the Kidney Yang and strengthens the spine and back. When the Governing Vessel is excessive, the back becomes stiff; when it is depleted, the head becomes heavy, unstable, and shaky (Figure 7.3).

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Governing Vessel are as follows.

1. To strengthen and control all the Yang Channels of the patient's body (particularly in relation to the Kidney Yang and the brain);
2. To tonify the Kidney Yang and strengthen the patient's spine and back (especially in cases of chronic lower back pain due to Kidney Deficiency);
3. To purge External Wind from the patient's body when symptoms are present, such as runny nose, head ache, fever, and stiff neck;
4. To purge Internal Wind from the patient's body when symptoms are present, such as dizziness, tremors, convulsions, epilepsy, or the condition of Wind Stroke;
5. To strengthen and nourish the patient's brain and Marrow, and for treating such symptoms as poor memory, dizziness, and tinnitus; and
6. To treat depression, due to the Governing Vessel's connection to the body's Jing (Kidneys, lack of willpower), Qi (Heart), and Shen (Brain).

Note: In men, the Governing Vessel is generally treated by itself, and in women, its treatment is combined with treating the Conception Vessel.

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include diseases of the head (apoplexy, aphasia, epilepsy, headaches, tetanus, etc.), the back, neck, and Kidneys (pain and stiffness in the spinal column), spastic muscle movement of the extremities, night sweating, and Jing Shen disorders (hyperexcitability, hallucinations, etc.).
2. Symptoms of Deficiency result in shaking of the head along with a feeling of heaviness, instability, and an inability to concentrate. The patient lacks physical and mental stamina, displays weakness in character, and may also experience hemorrhoids, sterility, and impotence.

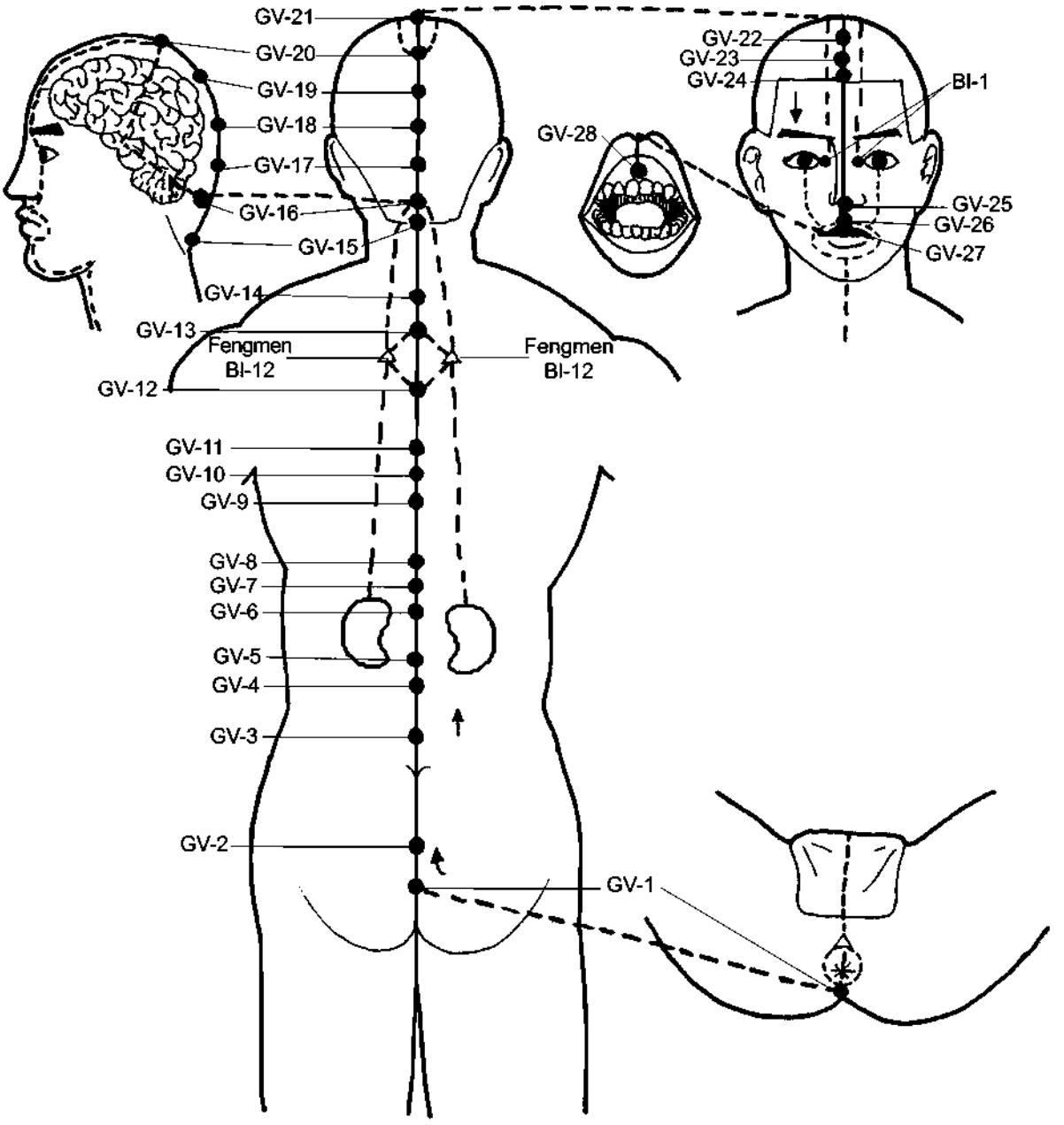

Figure 7.3. The Governing Vessel (GV)

THE CONCEPTION VESSEL OR REN VESSEL

The word Ren translates as Conception, and refers to pregnancy, responsibility, or obligation. It can also mean "to accept." The Conception Vessel governs all the Yin Channels of the body and is called the Sea of Yin Channels. It nourishes the Yuan Qi of all Five Yin Organs. The Conception Vessel originates from the Lower Dantian, and specifically in the uterus in females (Figure 7.4).

Functionally, the upper third of the Conception Vessel, on the sternum, controls respiratory functions; the middle third, on the epigastrium, controls digestive functions; and the lower third, on the abdomen, controls the urogenital functions (Figure 7.5).

In women the Conception Vessel is primarily responsible for nourishing the uterus and the genital system and determines the seven-year life cycles. It links the Yin energy with all aspects of conception and reproduction. The Conception Vessel, along with the Thrusting Vessels, have an important relationship with obstetric diseases related to the development of the fetus, delivery, and menstruation.

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Conception Vessel are as follows.

1. To strengthen and nourish the Yin energy of the patient's body (especially in women after menopause) and harmonize the Lungs and Kidneys;
2. To regulate the energy of the reproductive system, tonifying the Blood and Yin, and to reduce the effects of Heart Empty-Heat symptoms developed from Kidney Yin Deficiency after menopause (i.e., night sweating, hot flashes, anxiety, mental irritability, insomnia and dizziness, etc.);
3. To promote Blood supply to the uterus and regulate menstrual disorders (i.e., dysmenorrhoea, menorrhagia, amenorrhoea, and metrorrhagia);
4. To move the Qi in the patient's Lower Burner and treat abdominal lumps, as well as myomas, fibroids, and carcinoma in the woman's uterus, and hernia in men; and
5. To stimulate the energetic interaction of the Lungs Channels descending Qi function, and the Kidneys' function of receiving and holding the Lung Qi, which can, when malfunctioning, result in asthma.

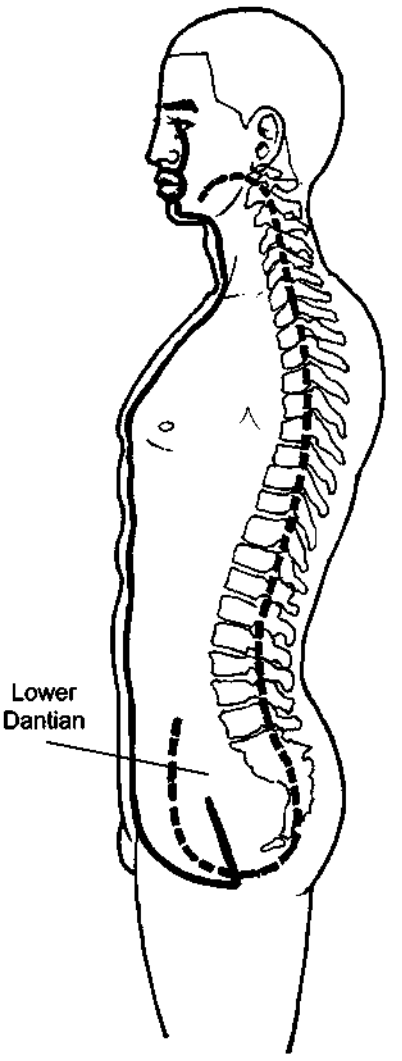

Figure 7.4. The Conception Vessel (Side View)

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include diseases of the reproductive and gastrointestinal systems (hemorrhoids, diarrhea, decreased urination, etc.). In the male, problems in the Conception

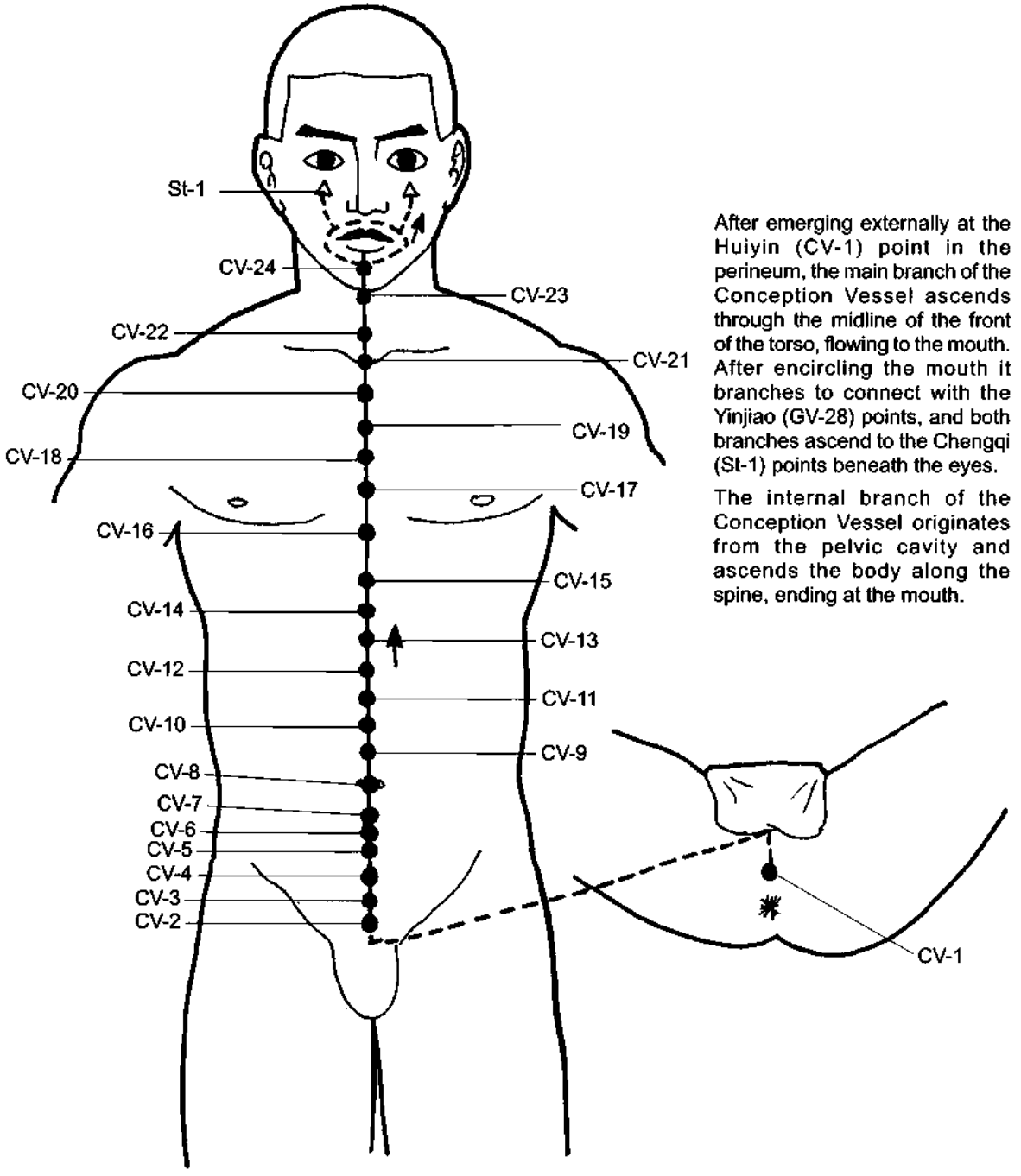

After emerging externally at the Huiyin (CV-1) point in the perineum, the main branch of the Conception Vessel ascends through the midline of the front of the torso, flowing to the mouth. After encircling the mouth it branches to connect with the Yinjiao (GV-28) points, and both branches ascend to the Chengqi (St-1) points beneath the eyes.

The internal branch of the Conception Vessel originates from the pelvic cavity and ascends the body along the spine, ending at the mouth.

Figure 7.5. The Conception Vessel (CV)

Vessel produce sterility. In the female, the Conception Vessel can cause menstruation problems such as leukorrhea and dysmenorrhea. Other female problems include breast pain, paralysis after delivery, emaciation, and sterility. Other problems of the female reproductive system include the external genitalia and vulva, vagina, and cervix disorders.

2. Symptoms of Deficiency include abdominal pains (hernia), pruritus, and a heavy feeling in the hips, lower ribs, and lumbar area.

THE THRUSTING VESSELS AND THE BELT VESSELS

The Thrusting and Belt Vessels balance the external tissues and internal organ energies, controlling an Excess or Deficient condition by regulating the upper and lower, as well as left and right, energetic quadrants.

The Belt Vessel is responsible for the second cellular division of the fertilized ovum in embryological development (see Chapter 2).

THE THRUSTING VESSELS OR CHONG VESSELS

The word Chong translates as "a street" and expresses the idea of passing or penetrating through something. This passing through action refers to its function as the vital pathway for alchemical transformation, used to produce energetic change (Jing to Qi, Qi to Shen and vise versa). The Thrusting Vessels, also called the Penetrating Channel, and are regarded as the Sea of Blood and the Sea of the Twelve Regulating Channels. They regulate both the Qi and Blood of all Twelve Primary Channels and extend to the anterior, posterior, upper, and lower parts of the body. During the development of the embryo, the Thrusting Vessels are responsible for the development of the adrenal glands and the cortex.

The Thrusting Vessels originate in the Lower Dantian. The Qi of the Thrusting Vessels travel to the head and face to flow into the Chong and penetrate the lower limbs, irrigating the body's Yin (Figure 7.6). According to some Chinese doctors, all energetic points that have Chong in their names relate to the Thrusting Vessels (i.e., Qichong St-30, Taichong St-42, and Shaochong Ht-9).

Along with the Conception Vessel, the Thrusting Vessels are responsible for regulating the changes in life cycles that occur every eight years in men, and every seven years in women. Abnormalities of the Thrusting Vessels during the beginning of pregnancy result in the mother's body aborting the fetus. Abnormalities of the Thrusting Vessels during the end of pregnancy result in an inability to expel the placenta.

The Thrusting Vessels control the woman's menstruation in all aspects, influencing the supply and amount of Blood in the uterus, and nourishing the woman's Jing. They also flow along the Kidney Channels and are related to the muscles of the abdomen and the penis (and are responsible for tightening the abdominal muscles).

THE ENERGETIC PATHWAY OF THE THRUSTING VESSELS

The classical description of the Thrusting Vessels' energy flow begins inside the uterus in women (the corresponding lower abdominal area in men), continuing down to the perineum. From the perineum, one branch ascends inside the spinal column, while four other branches flow externally.

Two external energetic rivers ascend up the front of the body alongside the Kidney Channels and enter into the chest. They then ascend through the throat, encircling the lips, and end at the corner of the eyes. When the Thrusting Vessels are full and overflowing (through meditation), they radiate a sparkling white-light energy, which can be observed to extend from the upper chest to the eyes.

From the perineum, two other external energetic rivers descend down the inner aspect of the thighs (one on each leg), along the Spleen Channels. They divide again at the medial malleolus. One set of branches flows into the big toes, a second set of branches terminates at the bottom of each foot.

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Thrusting Vessels are as follows.

1. To strengthen, nourish, and regulate weak

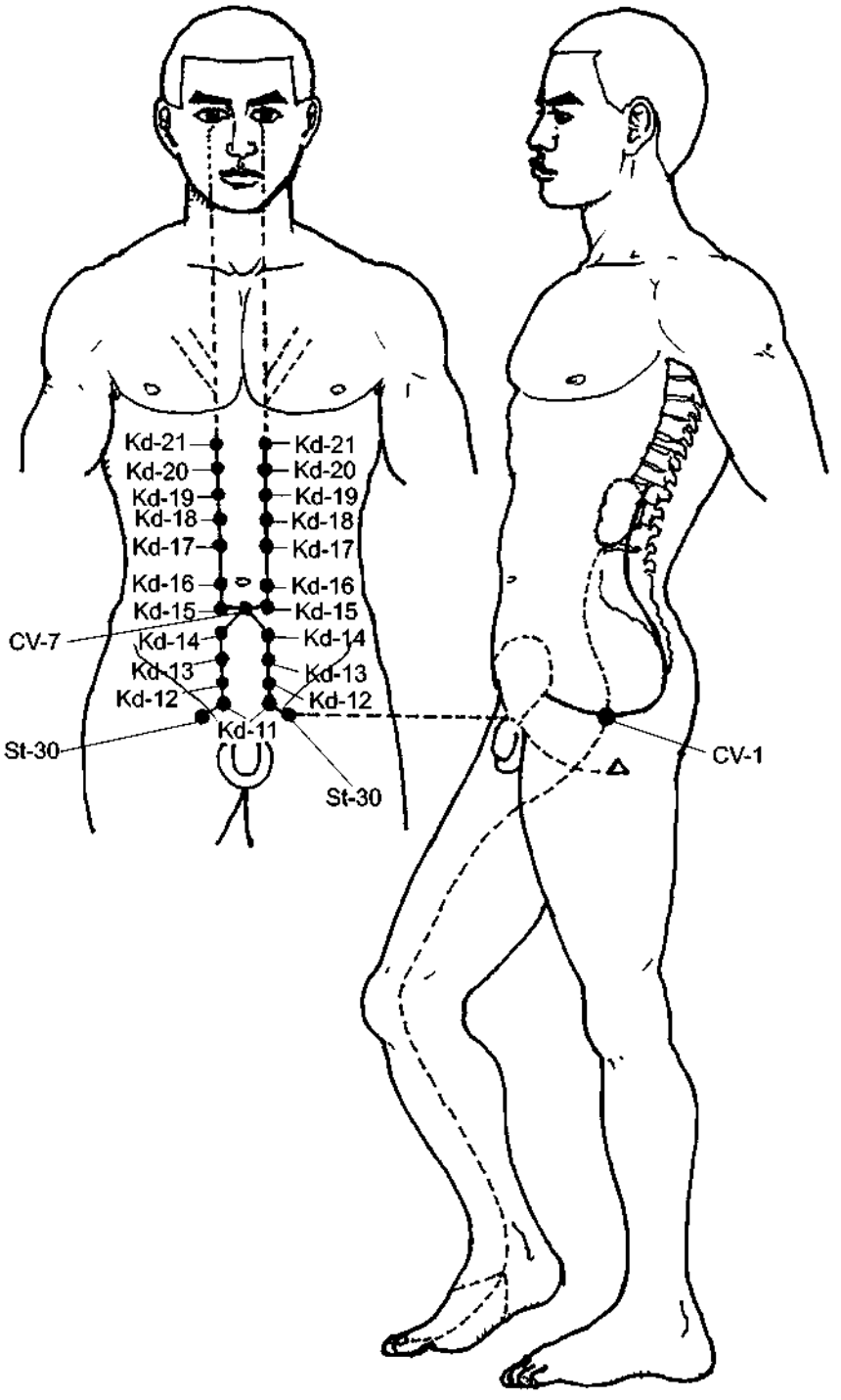

Figure 7.6. The Thrusting Vessels

constitutions with digestive symptoms (e.g., abdominal distension, poor appetite, and poor assimilation of food);
2. To move the Blood of the Heart to relieve symptoms of pain and stiffness of the chest (the Thrusting Vessels control all the Blood in the connecting channels);
3. To purge Qi and Blood stagnation in the abdomen and chest;
4. To treat feelings of anxiety (within the chest) caused by Rebellious Qi; One of the Thrusting Vessels' most important pathologies is Rebellious Qi (Qi that moves in the wrong direction, going upwards instead of downwards). Feelings of anxiety that arise in the patient's abdomen and ascend to their chest are especially indicative of this malfunction;
5. To treat gynecological problems (hot flashes), when the Qi of the Thrusting Vessels rises upwards, and causes the patient's hands and feet to get cold, the face to get hot, and a feeling of fullness in the chest. The treatment is to regulate the Thrusting Vessels and subdue the Rebellious Qi in the Chong Vessel. If there are accompanying emotional problems and Liver Qi stagnation, then also treat the patient's Lv-3 points; and
6. To treat Rebellious Qi caused by the energy of the Thrusting Vessels rebelling upwards; the symptoms are oppressive feelings in the chest, as well as dizziness, nausea, and vomiting.

PATHOLOGICAL MANIFESTATIONS

The main diseases associated with the patient's External Thrusting Vessels include diseases of the Heart, fullness in the chest and abdomen, gastritis, abdominal pain, and convulsive diseases. If a woman's Thrusting Vessels are Deficient or Empty she may develop such conditions as amenorrhoea, scanty periods, or late periods. If there is stagnant Qi and/or Blood in the Thrusting Vessels, she may experience dysmenorrhoea. Abnormalities of the Thrusting Vessels also result in the mother aborting the fetus.

The Thrusting Vessels work with the Qi of the Kidney Channels to control the brain's physiological functions. If the energy from the Thrusting Vessels to the cortex becomes Deficient, this can inhibit the development of the brain.

THE BELT VESSEL OR DAI VESSEL

The word Dai translates as a "belt" or "girdle," and refers to the action of supporting something. The Belt Vessel is the only horizontal vessel in the body. Beginning at the Mingmen, this vessel encircles the waist like a belt, dipping down into the lower abdominal region anteriorly and running across the lumbar region posteriorly. It connects with the Gall Bladder's -26, -27, and -28 points and crosses the Conception Vessel at CV-4. Many sources say that it connects with the Liver -13 (at the free ends of each 12th rib). It binds, joins, and controls all the channels of the body, exerting an influence on the energetic circulation of the body's Governing and Conception Vessels (Figure 7.7).

Medical Qigong schools teach that the Belt Vessel circle wraps the entire body, like a enveloping cocoon, flowing from the feet to the head. The waist is considered the "hub" of the energetic wheel, and the access points of the Belt Vessels center channel (which circles the waist) is used to control the entire vessel. As the energy of the body increases (through Qi cultivation), the Qi within the entire Belt Vessel increases, circle wrapping the tissues from feet to head, increasing the body's Wei Qi fields (Figure 7.8).

In addition, the Belt Vessel keeps both the Yin and Yang Channels under control, connecting all of the leg Yin and Yang channels as they traverse the body's trunk. As a result, the Belt Vessel assists in regulating the circulation of Qi in those channels, especially from the waist down.

The Belt Vessel has an important influence on the body's physiology by encircling the leg channels, influencing the circulation of energy to and from the legs, as well as influencing the energetic actions of the genitals, waist, and hips. This vessel not only restrains the flow of the body's Liver and Gall Bladder Qi, but also harmonizes the ascending and descending flows of energy from the Kidneys and Spleen through its connection with the Kidney Divergent Channel.

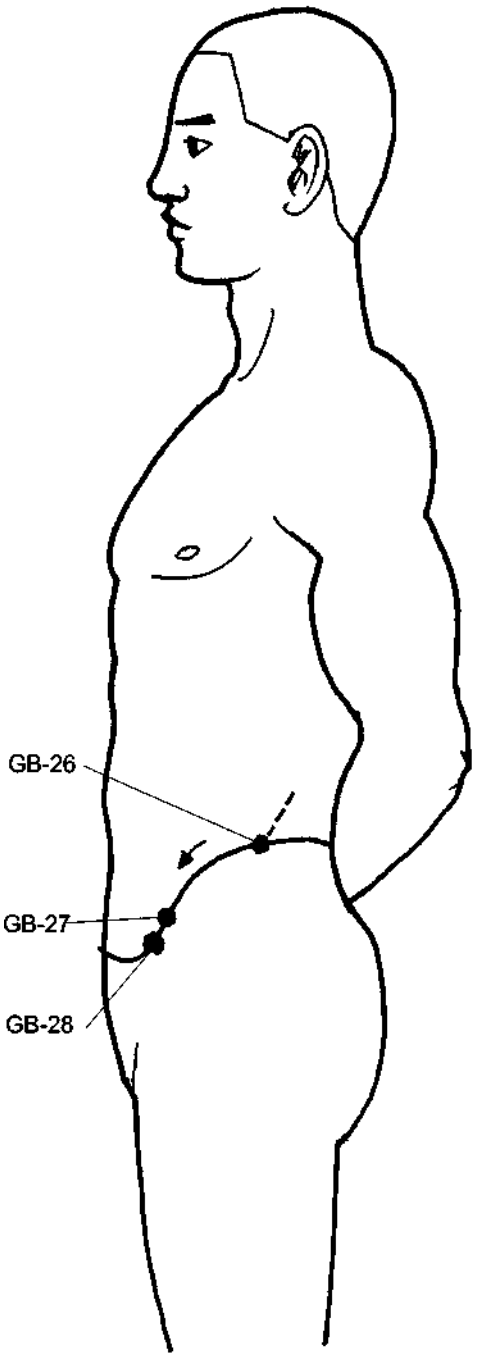

Figure 7.7. The Center of the Belt Vessel

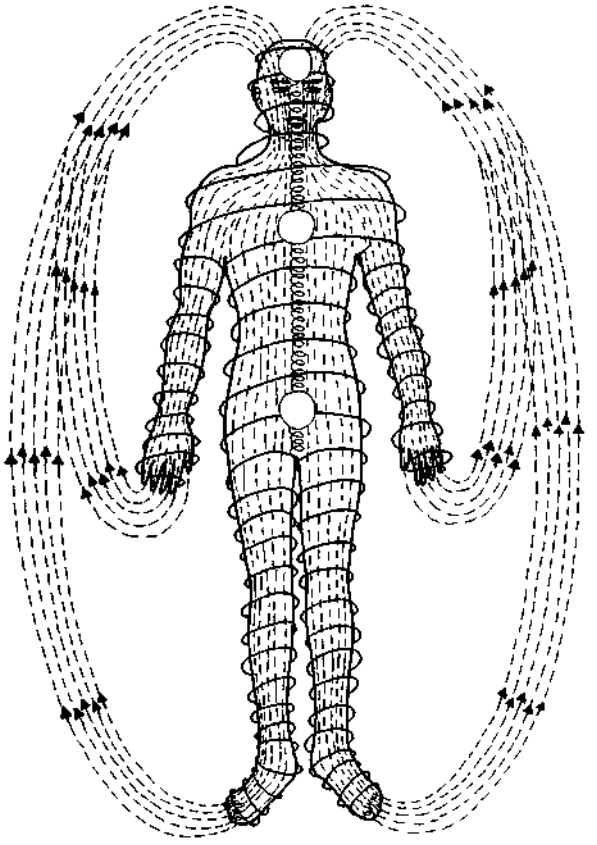

Figure 7.8. The Belt Vessel winds up the body like an energetic coil.

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Belt Vessel are as follows.

1. To treat impaired circulation of Qi in the leg channels resulting in such symptoms as cold legs and feet, or tense leg muscles (gastrocnemius and tibiales). This condition is due to Liver Blood not moistening the sinews of the legs;
2. To treat impaired circulation of Qi and Blood that cause numbness, weakness, atrophy, or motor impairment of the leg muscles, due to a Deficiency of energy in the Stomach and Spleen Channels;
3. To tonify and harmonize the circulation of

Liver and Gall Bladder Qi due to Excess patterns of Liver energy;
4. To disperse Damp Heat in the genitals that has resulted in symptoms such as difficulty or burning during urination;
5. To treat hip pain caused by Deficient Liver Blood (leading to sinew and joint malnourishment and Excess of Liver Yang; and
6. To regulate the lower abdomen due to a Belt Vessel imbalance, causing symptoms such as a sagging waist or bloated abdomen.

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include pain in the back (lumbar region), and sides of the lower abdomen, as well as weakness in the shoulders, upper extremities, and lower limbs. Symptoms may also include weakness in the opposite sides of the body (e.g., eye, breast, ovary, etc.), and a feeling of heaviness in the body and abdomen (as if carrying 5,000 coins) due to exposure to Dampness.
2. Symptoms of Deficiency have physical sensations similar to that of "sitting in cold water" up to the waist. This description generally refers to pain, weakness, and a cold, heavy sensation in the patient's lumbar and sacral regions. Other symptoms include umbilical, abdominal and lumbar pain, as well as a feeling that something like a stick is pressing against the groin. There can also be abdominal fullness and distention. In women, there may be an abnormal white vaginal discharge, and a prolapse of the uterus.

THE YIN AND YANG HEEL VESSELS OR QIAO VESSELS

The word Qiao translates as "the heel" or "to stand on the toes," and refers to the action of kicking one's foot as high as possible. The Yin and Yang Heel Vessels flow along the medial and lateral aspects of the lower legs and torso, connecting at the inner canthus (by the eyes). They link the channel energy of the body's Yin and Yang Channels and regulate the movement of all four limbs. They also control the amount of energy being used by all the other channels in the body. Once these vessels are full, they relax the tissues, enabling the limbs to become more dexterous.

The Yin and Yang Heel Vessels are sometimes called Bridge Channels, because they act like a bridge linking the stored Qi in the body with the areas in need of Qi. When any channel uses more than its share of energy, other channels become Deficient. Thus the Heel Vessels seek to ensure that energy is always distributed in a balanced way.

The Yin Heel Vessels are an offshoot of the Kidney Channels at the front of the body, while the Yang Heel Vessels are an offshoot of the Bladder Channels at the back of the body. Together, the Yin and Yang Heel Vessels can be used to treat structural imbalances and to harmonize the right and left sides of the body.

Because the Heel Vessels cause the motor nerves to develop during the formative stages of the embryo, the Chinese believe the Yang Heel Vessels cause little boys to be more physically active (running, jumping, etc.), while the Yin Heel Vessels cause little girls to be less actively inclined.

THE YIN HEEL VESSELS

The Yin Heel Vessels control the Yin of the left and right sides of the body. The Yin Heel Vessels influences the male and female reproductive system, as well as the lower abdomen in women.

When Yang energy is slowed down in the Heel Vessels, the Yin energy moves more rapidly. The Excess Yin causes the following problems: sleepiness, the inability to keep the eyes open while trying to stay awake, hypotension, choking, painful urination, stomach rumbling, vomiting, diarrhea, difficult bowel movements, and unconsciousness. Excess Yin in women also causes a difficult labor. Also, when the Yin Heel Vessels are in Excess, the inner leg muscles are tight, while the outer leg muscles are loose. Weakness in the Yin Heel Vessels can cause the feet and ankles to invert, whereas an Excess condition can cause the feet to turn outwards.

The Yin Heel Vessels begin at the superficial part of the ankles, just below the medial malleolus of the tibial bones at the Kd-2 points. They continue up the front of the body, ending at the inner

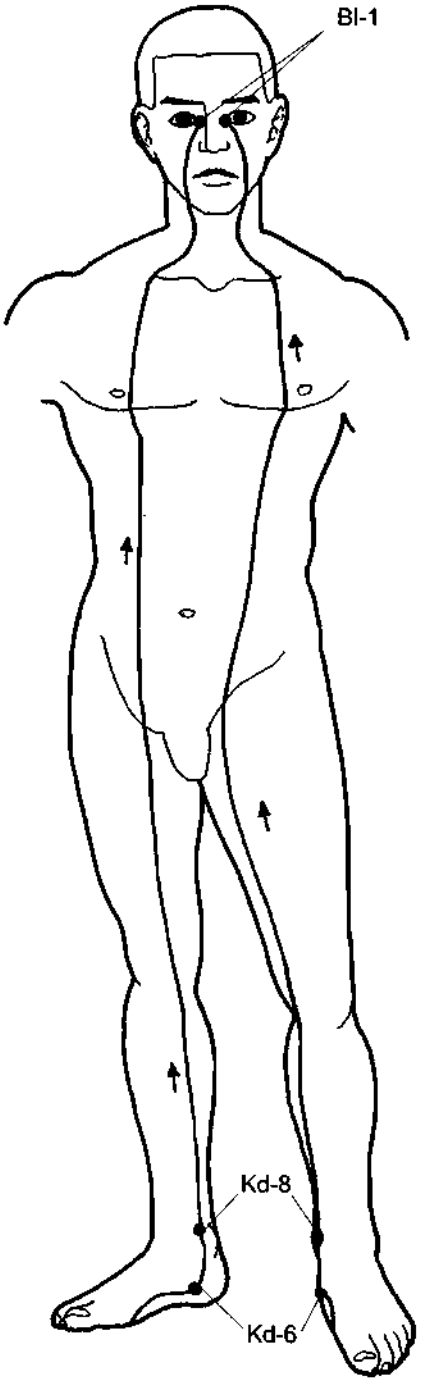

Figure 7.9. The Yin Heel Vessels

corners of the eyes, where they join the Yang Heel Vessels (Figure 7.9).

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Yin Heel Vessels are:

1. To treat symptoms of Excess conditions in the Lower Burner in women (e.g., abdominal distension, difficult delivery, or the retention of the placenta, abdominal masses, lumps, and fibroids);
2. To structurally balance the left and right sides of the body;
3. To treat disturbances of sleep (e.g., insomnia or somnolence); and
4. To treat certain cases of atrophy (e.g., when the muscles of the inner aspect of the leg are loose and the outer leg muscles are tight).

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess of the Yin Heel Vessels include: lower abdominal pain, vomiting, difficult bowel movements, and spasms on the medial side of the legs. The Yin Heel Vessels also control diseases of the eyes (watery eyes, heavy sensations of the eyelids or an inability to open the eyes), migraines, congestive headaches, and hypersomnia. Abnormalities of the Yin Heel Vessels cause pregnant women to have difficult labor.
2. Symptoms of Deficiency include: Aggravations of symptoms during the evening time, nocturnal headaches, insomnia, cramps, or convulsions.

THE YANG HEEL VESSELS

The Yang Heel Vessels control the Yang of the left and right sides of the body. Abnormalities of the Yang Heel Vessels in newborns cause vomiting of milk.

When Yin energy is slowed down in the Heel Vessels, the Yang energy moves more rapidly. The Excess Yang causes the following problems: insomnia, difficulty in closing the eyes, painful eyes, hypertension, stiff back and waist (inability to bend down), thigh tumors, bad colds, spontaneous sweating, headaches, paralysis of the arms and legs, deafness, epilepsy, nose bleeding, swell-

ing of the body, pain in the joints, and head sweating. Excess Yang can also cause the vomiting of milk in infants.

Weakness in the Yang Heel Vessels can cause foot and ankle eversion, while Excess can cause foot inversion. Also, when the Yang Heel Vessel is in Excess, the inner leg muscles are loose and the outer leg muscles are tight.

The Yang Heel Vessels begin on the outer side of the ankles below the lateral malleolus, at the Bl-62 points. From there, they continue to ascend the outside of the thigh and the back to end just below the eyes at the Bl-1 points, where they communicate with the Yin Heel Vessels near the eyes (Figure 7.10).

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Yang Heel Vessel are:

1. To treat acute Excess conditions of the lower back (e.g., aches due to spasm or invasion of Cold) and pain along the Bladder Channels of the legs;
2. To subdue Internal or External Wind from the head (e.g., facial paralysis, severe dizziness, and aphasia); and
3. To purge Wind-Heat and Wind-Cold manifesting in symptoms, such as sneezing, head ache, runny nose, and stiff neck.

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include: Stiffness of the back and waist, lumbar pain, spasms on the outer side of the legs, tumors of the thighs, nocturnal epileptic seizures, and insomnia or restless sleep. The Yang Heel Vessels are also involved with diseases of the eyes such as dry and itchy eyes.
2. Symptoms of Deficiency include: Fatigue, lassitude and weakness during the day, and aggravations of symptoms from stress during the day. These symptoms improve as the night progresses.

According to some Traditional Chinese Medical Classics, if epilepsy occurs during the daytime, Qigong and moxa are given on the Yang Heel Vessels; however, if epilepsy occurs at night, Qigong and moxa are given on the Yin Heel Vessels.

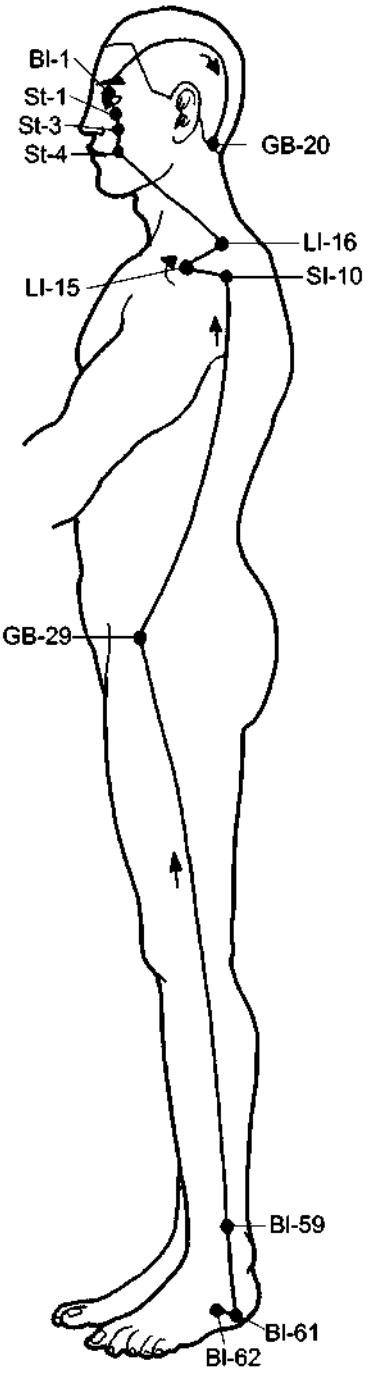

Figure 7.10. Side View of the Left Yang Heel Vessel

THE YIN AND YANG LINKING VESSELS OR WEI VESSELS

The word Wei translates as "to link" or "bind" and refers to a rope that is tied around something, pulling it down and securing it. The Linking Vessels are sometimes called the Regulator Channels. The Linking Vessels are divided into Yin and Yang energetic pathways.

Both Yin and Yang Linking Vessels start at the lower legs and flow upwards to the head, along the medial and lateral aspects of the lower legs and torso. When the Linking Vessels reach the neck and back of the head, they join the Conception and Governing Vessels. Secondary Vessels, called the Yu (surplus) Vessels, branch away from the energetic flow of the major Vessel, connecting the energetic flow of each Yin and Yang Linking Vessel to the hands.

Instead of serving as streams transporting Qi and Blood, these two vessels act as lakes that store Qi and Blood that overflows from other vessels. Together, these four vessels regulate the circulation of Qi and Blood for the whole body, store the overflowing Qi and Blood, and release the Qi and Blood into the channels in the event of insufficiencies.

THE YIN LINKING VESSEL

The Yin Linking Vessels lie on the medial axis of the body. They help maintain the connection to all the Yin Channels. They begin at the Kd-9 points at the inner side of the lower legs and ascend up the sides of the abdomen and chest. They move toward the front of the body, along the sides of the chest to the tips of the nipples. At the Ruzhong (St-17) Breast Center points they split into two sets of branches. One set of branches connects with the Conception Vessel at the neck. The other set of branches becomes the Yin Yu Vessels, and extends from the chest, over the shoulders and down the inside of the arms following the route of the Pericardium Channels. Just above both wrist folds on each arm, each branch energetically pools at the Neiguan (Pc-6) Inner Pass points, before it flows into the palms. The Pc-6 points are therefore considered the Master Points for the Yin Linking Vessels (Figure 7.11).

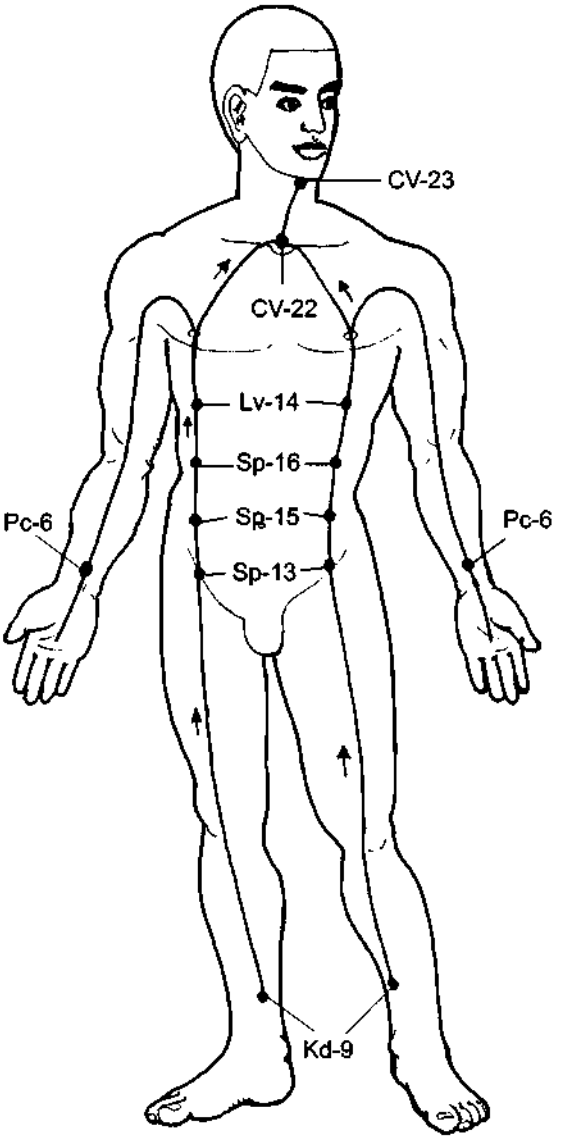

Figure 7.11. The Yin Linking Vessels

The Yin Linking Vessels are responsible for moving the Yin energy and regulating the Blood and inner parts of the body. They connect with all the body's Primary Yin Channels: Liver, Heart, Spleen, Lung, Kidney, and Pericardium. When the Yin energy is slowed down in the Linking Vessels, the Yang energy moves more rapidly. Therefore, if the Yin Linking Vessels become unbalanced, the Excess Yang condition can cause the patient to suffer from Heart pain.

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Yin Linking Vessels are:

1. To tonify the Heart (for symptoms of pain, stiffness, tightness and oppression in the chest, as well as mental depression, anxiety, apprehension, and nightmares);
2. To treat Deficient Yin and Blood conditions, especially if accompanied by psychological conditions, such as mental restlessness, anxiety, and insomnia; and
3. To treat headaches located in the back of the neck due to Blood Deficiency.

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include diseases of the Heart such as hypertension, delirium, nightmares, etc., as well as, cardialgia (tightness and oppression in the chest), difficulty in swallowing, convulsive diseases, contracted feeling in the Lungs, and dyspnea. Diseases of the Yin Linking Vessels also include prolapse of the rectum and diarrhea.
2. Symptoms of Deficiency include timidity or fear, apprehension, nervous laughter, mental depression, hypotension, and weak respiration.

THE YANG LINKING VESSELS

The Yang Linking Vessels lie on the lateral aspects of the body. They serve to maintain and communicate with all the Yang Channels in the exterior portion of the lateral aspects of the body. They begin at the external part of the ankles, just below the lateral malleolus at Bl-63 points, ascend the sides of each leg, up each side of the back of the body, through the shoulder areas to the Naoshu (SI-10) Scapula's Hollow points. The SI-10 points

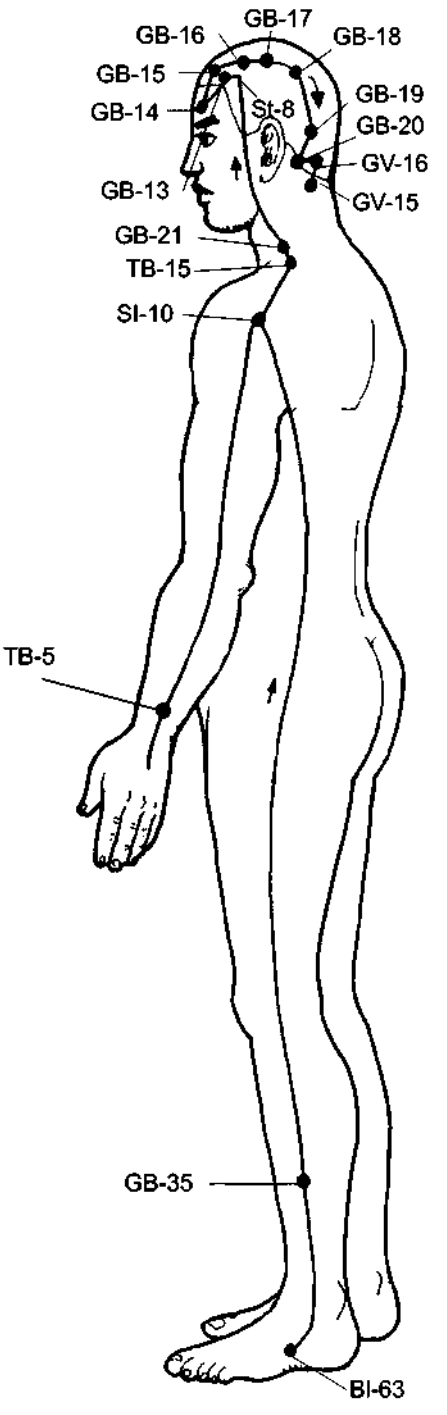

Figure 7.12. Side View of the Left Yang Linking Vessel

are the intersecting points of the Yang Linking and Yang Heel Vessels located on the Small Intestine Channels. From the SI-10 points, both Yang Linking Vessels split into two sets of branches. One set of branches flows up the sides of the neck and head connecting with the GB-20 points (at the lower occipital part of the head), where it communicates with the Governing Vessel. The other set of branches becomes the Yang Yu Vessels. The Yang Yu Vessels extend from the shoulders, down the back sides of the arms, following the route of the Triple Burner Channels. Just above both wrists on the outside of each arm, each of the branches pools at the Weiguan (TB-5) Outer Pass points, before flowing into the back of the hands. The TB-5 points are therefore considered the Master Points for the Yang Linking Vessels (Figure 7.12).

The Yang Linking Vessels are responsible for moving the Yang energy and controlling the Protective Qi, regulating the Wei Qi's resistance to external infections, and regulating the external parts of the body. They connect with all of the body's Primary Yang Channels: Gall Bladder, Small Intestine, Stomach, Large Intestine, Bladder, and Triple Burners. When the Yang energy is slowed down in the Linking Vessels, the Yin energy moves more rapidly; therefore, if the Yang Linking Vessels become unbalanced, the Excess Yin condition may cause the patient to catch colds and fevers more easily.

CLINICAL MANIFESTATIONS

The functions and clinical uses of the patient's Yang Linking Vessels are:

1. To treat ear problems due to the rising of Liver Fire, resulting in conditions such as tinnitus and deafness;
2. To treat ear diseases due to a Gall Bladder disharmony;
3. To treat hypochondriac pain;
4. To treat sciatic pain in the lateral aspects of the legs (along the Gall Bladder Channels);
5. To treat intermittent fevers that alternate between chills and fever.

PATHOLOGICAL MANIFESTATIONS

1. Symptoms of Excess include: Alternating chills and fever; pain on the lateral sides of the neck, trunk and legs, as well as pain in the head. Symptoms also include pains and skin problems during weather changes, sensitivity to changes in climate (aching muscles, skin rashes, etc.), swelling, pain and fever in the joints, diarrhea and night sweats.
2. Symptoms of Deficiency include: Coldness and lack of body heat, loss of energy, and physical strength. Symptoms also include cold knees, stiffness, and fatigue (especially during cold or rainy weather).

SUMMARY OF EIGHT EXTRAORDINARY VESSEL PATHOLOGY

The Eight Extraordinary Vessels link all of the Yin and Yang Channels in the body and regulate the flow of energy in these channels to maintain a state of energetic balance. The clinical significance of the Eight Extraordinary Vessels is manifested through certain pathological indications that are particular to the vessels' intersection with their specific Primary Channel(s). Their symptomatology is therefore not distinct from, but rather a composite of, the pathological symptoms associated with their joining Primary Channel(s).

Figure 7.13 describes some of the Eight Extraordinary Vessels pathologies and the clinical manifestations indicated along their root (beginning) and ending branches.

The Eight Extraordinary Vessels' energetic pathways used in certain esoteric Qigong meditations are somewhat different from the ones seen in Traditional Chinese Medical texts and acupuncture charts. The reason for this uniqueness is because their purposes are different.

The goal of Chinese acupuncture is to restore sick people to health. The energetic points being treated by an acupuncturist must be along the superficial channels, so that they can be activated by acupuncture needles.

Medical Qigong exercises and meditations aim to maximizing health, and to take the individual beyond mere physical health to spiritual enlightenment. In Medical Qigong training the channels and points can be deep within the body, since the energy is guided by the mind or by postures and movements, rather than by needles.

Eight Extraordinary Vessels	Pathologies
Belt	• Pain in the back, lumbar region, and sides of the navel • Weakness in the lower limbs
Conception	• Diseases of the reproductive and gastrointestinal systems (hemorrhoids, diarrhea, decreased urination, etc.) • In the male, sterility • In the female, the menstruation problems such as leukorrhea and dysmenorrhea; also breast pain, paralysis after delivery, emaciation, and sterility; all reproductive system problems, including internal and external genitalia (vulva, vagina, and cervix)
Governing	• Diseases of the head (apoplexy, aphasia, epilepsy, headaches, tetanus, etc.), back, neck, and Kidneys • Stiffness in the spinal column, spastic muscle movements of the extremities, night sweating, and circulatory disturbances around the anus
Thrusting	• In women, amenorrhoea, scanty periods or late periods, dysmenorrhoea, spontaneous abortion, inability to expel the placenta, menopause problems • Diseases of the Heart, fullness in the chest and abdomen, gastritis, abdominal pain, convulsive diseases • Brain dysfunction of physiological origin
Yang Heel	• In newborns, vomiting of milk • Stiffness of the back and waist, lumbar pain, spasms on the outer side of the legs, and tumors of the thighs • Diseases of the eyes
Yang Linking	• Diseases from Cold— fevers resulting in a sensitivity to changes in climate; cold knees; stiffness and fatigue; swelling, pain, and fever in the joints and extremities; and night sweating
Yin Heel	• Lower abdominal pain, vomiting, difficult bowel movements, and spasms on the medial side of the legs • Diseases of the eyes • Difficult labor in women
Yin Linking	• Diseases of the Heart (cardialgia), tightness of the chest, difficulty in swallowing, convulsive diseases • Diseases also include prolapse of the rectum and diarrhea

Figure 7.13. Pathologies of the Eight Extraordinary Vessels

THE FIFTEEN MAJOR COLLATERALS (CONNECTING VESSELS)

The Fifteen Collaterals are also known as the Fifteen Luo. Luo is translated to mean a net or web, and in Traditional Chinese Medicine it refers to the Connecting Vessels. These vessels are the major "passage ways" for the circulation of the body's channel energy, emerging out of the Luo (pathway) points on the Twelve Primary Channels, plus the Governing and Conception Vessels. The Luo points are located below the elbows and knees and provide an additional energetic barrier to keep Evil Winds from affecting the Primary Channels, being somewhat deeper then the Muscle/Tendon Channels. The Collaterals are the streams of energy that connect the paired Primary Channel rivers.

The Fifteen Collaterals are superficial and much thinner in formation than the Primary Channels running through the interior aspect of the body. The collaterals distribute Qi and Blood to those areas not directly traversed by other channels. Flowing out of each Primary Channel's Luo point are two Luo vessels, which are counted as one:

1. The Transverse Luo Vessels connect to the Source Points on the Yin and Yang coupled Primary Channels. They act as a safety valve to maintain balance between Yin and Yang channels by diverting Excess energy from one channel to tonify Deficiencies in the Orb (internal organ and energetic field) of their paired Primary Channel. When a channel is Deficient (Empty) and its paired channel is in Excess (Full), for example, the tonification of the Luo point on the Deficient channel is enough to replenish it, while normalizing the channel previously in Excess.
2. Longitudinal Luo Vessels flow out of the Luo points, but do not connect with the coupled Primary Channels. The Luo Vessels usually flow proximally toward the channel's organ.

The Luo vessels' main function is to transfer Qi and Blood from the Primary Channels to all parts of the body to nourish the tendons, the bones, the skin, and the five sense organs (nose, eyes, ears, lips, and tongue). The Luo vessels also link the body's interior with its exterior, connecting the internal and superficial channels (Figures 7.14 through 7.19).

The Fifteen Major Collaterals have smaller branches, known as the Minute and Superficial Collaterals, extending from them. The Superficial Collaterals are sub-branches similar to capillaries serving to transport Qi and Blood to the surface of the body. Both Minute and Superficial Collaterals, which can be seen beneath the surface as blood vessels, are called Blood Luo Vessels.

PATHOLOGY

The pathology of the Fifteen Major Collaterals are categorized in terms of Excess and Deficient syndromes.

1. Excessive Conditions of the collaterals are due to exogenous invasion if (1) the organ associated with the Luo is in Excess or (2) the body's Wei Qi is weak. Evil Winds enter the body through Jing Well or Wind points, and start moving up the channel. The Longitudinal Luo Vessels provide a route for the diversion of Evil Winds. The Longitudinal Luo Vessels have more Wei Qi then the Primary Channels and can better fight pathogens. Sometimes with a Wind Cold invasion, a blue color is visible along the path of the Longitudinal Luo Vessel. If the invasion is due to Wind Heat, there may be a red color along the vessel.
2. Deficient Conditions of the collaterals are due to: (1) the organ associated with the Luo being Deficient or (2) the patient's Qi is Deficient due to exogenous factors.

POINT LOCATION OF THE FIFTEEN MAJOR COLLATERALS

1. The Foot Taiyin-Spleen 4 Point is located on the Spleen Channel of each foot, on the medial side, just posterior to the base of the first metatarsal bone. This Lou's energy flows downward to connect with the Stomach Channel on each foot. A second branch flows upward along the medial aspect of the inner thigh, passing the abdomen and connecting with the Stomach and Small Intestines (Figure 7.14).

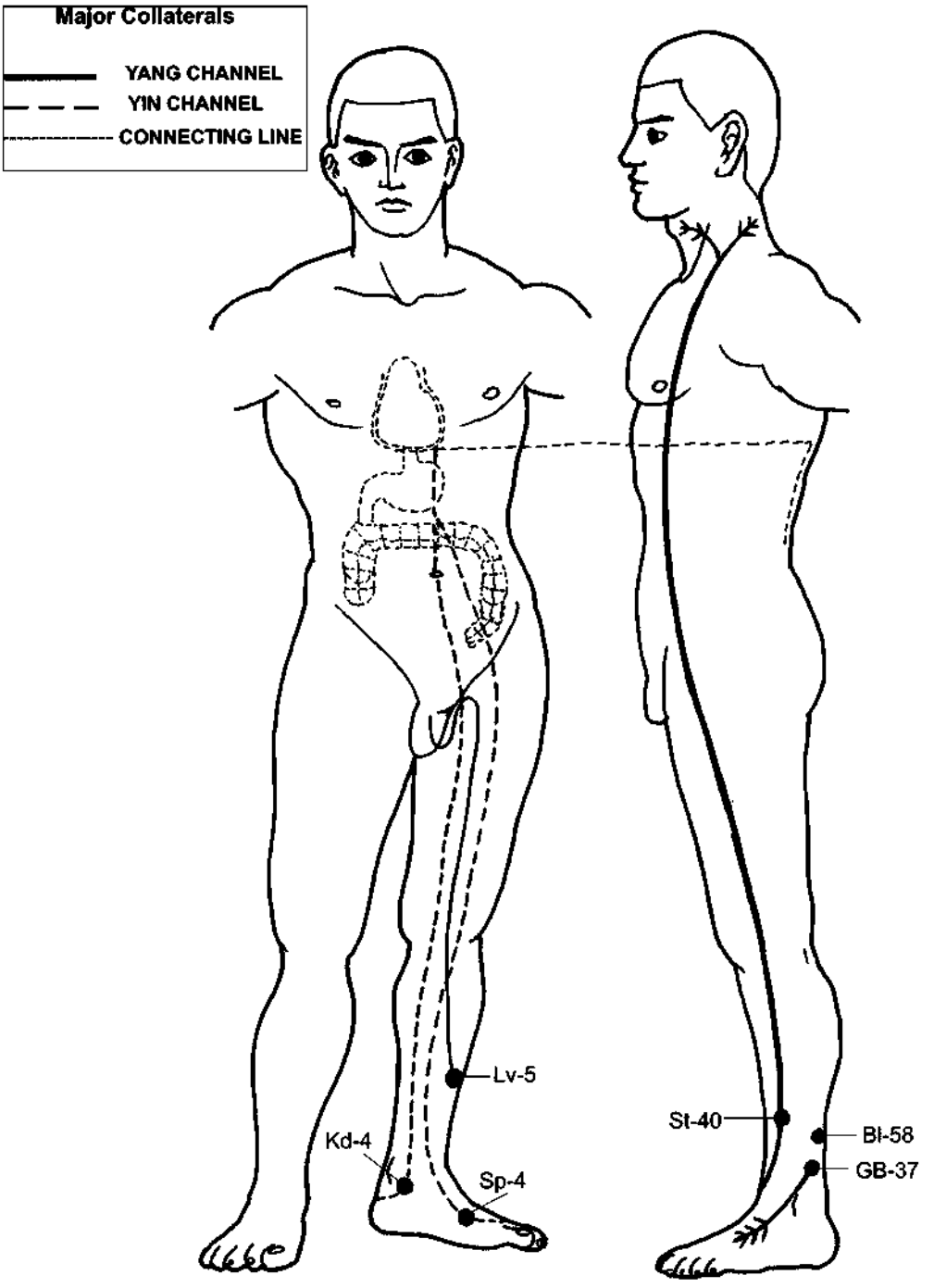

Figure 7.14. The figure at left shows the three Luo points of the Yin Collaterals of the left foot located on the Primary Channels of the Kidneys, Spleen, and Liver. The figure on the right shows the three Luo points of the Yang Collaterals of the left foot located on the Primary Channels of the Stomach, Bladder, and Gall Bladder.

   a. Symptoms of Excess include sharp intestinal pain, vomiting, and diarrhea.
   b. Symptoms of Deficiency include abdominal swelling.
2. The Foot Shaoyin-Kidney 4 Point is located on the Kidney Channel of each foot, just posterior to the medial malleolus. The Lou's energetic flow runs downward, crossing the heel, and connects with the Bladder Channel on each foot. A second branch flows upward along the medial aspect of the inner thigh, following the Kidney Channel. It passes the abdomen and connects with the pericardium of the Heart then flows laterally to connect with the lumbar vertebrae (Figure 7.14).
   a. Symptoms of Excess include enuresis, emotional irritability, and depression.
   b. Symptoms of Deficiency include lower back pain.
3. The Foot Jueyin-Liver 5 Point is located on the Liver Channel of each foot, on the medial side, several inches above the medial malleolus. The Lou's energetic flow connects with the Gall Bladder Channel on each foot and flows upward along the medial aspect of the inner thigh. It connects with the genitals and terminates at the penis in males, and the clitoris in women (Figure 7.14).
   a. Symptoms of Excess include swelling of the testicles.
   b. Symptoms of Deficiency include itching in the pubic region.
4. The Foot Taiyang-Bladder 58 Point is located on the Bladder Channel of each foot, on the lateral side, several inches above the external malleolus. The Lou's energy flows downward to connect with the Kidney Channel on each foot (Figure 7.14).
   a. Symptoms of Excess include nasal congestion, headache, and back pain.
   b. Symptoms of Deficiency include clear mucus nasal discharge and nosebleed.
5. The Foot Shaoyang-Gall Bladder 37 Point is located on the Gall Bladder Channel of each foot, on the lateral side, several inches above the external malleolus. The Lou's energy flows downward to connect with the Liver Channel on each foot, then continues downward to disperse over the dorsum on each foot (Figure 7.14).
   a. Symptoms of Excess include fainting.
   b. Symptoms of Deficiency include weak and flaccid muscles of the feet.
6. The Foot Yangming-Stomach 40 Point is located on the Stomach Channel of each foot, on the lateral side, several inches above the external malleolus. The Lou's energy flows downward to connect with the Spleen Channel on each foot. A second branch flows along the lateral aspect of the tibia, upward to the top of the head where it divides, with one branch converging with the other Yang Channels on the neck and head, and the other branch connecting with the throat (Figure 7.14).
   a. Symptoms of Excess include epilepsy and insanity.
   b. Symptoms of Deficiency include pharyngitis, sudden aphasia, and flaccid or atrophied muscles in the legs or feet.
7. The Hand Taiyang-Small Intestine 7 Point is located on the Small Intestine Channel of each hand, on the dorsal side, several inches above the wrist, on the ulnar side. The Lou's energy flows upward past the elbow and connects with the Large Intestine 15 point (Figure 7.15).
   a. Symptoms of Excess include fever, headaches, and blurred vision.
   b. Symptoms of Deficiency include atrophy of the muscles in the elbow and arm, and a looseness in the joints.
8. The Hand Yangming-Large Intestine 6 Point is located on the Large Intestine Channel of each hand, several inches above the dorsal side of the wrist on the radial side. The Lou's energy flows upward on each arm to the jaw and pours into the area of the teeth. Another branch ascends into each ear, connecting with the Thrusting Vessels which supply energy to the head (Figure 7.15).
   a. Symptoms of Excess include deafness and toothache.

   b. Symptoms of Deficiency include a sensation of coldness in the teeth, as well as fullness and congestion in the chest.
9. The Hand Shaoyang-Triple Burner 5 Point is located on the Triple Burner Channel of each hand, located just above the dorsal transverse crease of the wrist. The Lou's energy flows upward past the arm and over the shoulder, dispersing into the chest and connecting with the Pericardium Channel (Figure 7.15).
   a. Symptoms of Excess include muscle spasms of the elbow.
   b. Symptoms of Deficiency include flaccid muscles in the arm and elbow joint.
10. The Hand Taiyin-Lung 7 Point is located on the Lung Channel of each hand and arises from the cleft of the tendons and bones on the radial side of the wrist, where it flows down into the palm, spreading through the thenar eminence (Figure 7.15).
   a. Symptoms of Excess include hot palms or wrists.
   b. Symptoms of Deficiency include enuresis and shortness of breath.
11. The Hand Shaoyin-Heart 5 Point is located on the Heart Channel of each hand, just above the transverse crease of the wrist. The Lou ascends along the Heart Channel and enters the Heart then continues up the chest into the head, flowing into the root of the tongue, then ascends to connect with each eye (Figure 7.16).
   a. Symptoms of Excess include fullness and pressure in the chest.
   b. Symptoms of Deficiency include aphasia.
12. The Hand Jueyin-Pericardium 6 Point is located on the Pericardium Channel of each hand, just a few inches above the medial transverse crease of the wrist, between the two tendons. The Lou's energy flow follows the Pericardium Channel, connecting with the Heart (Figure 7.16).
   a. Symptoms of Excess include chest pain.
   b. Symptoms of Deficiency include irritability.
13. The Governing Vessel 1 Point is located on the

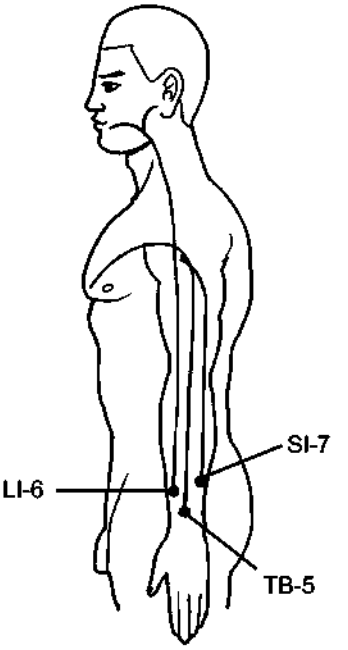

Figure 7.15. The three Yang Collaterals and their Luo points located on the hand and on the Primary Channels of the Large Intestine (LI), Triple Burners (TB), and Small Intestine (SI).

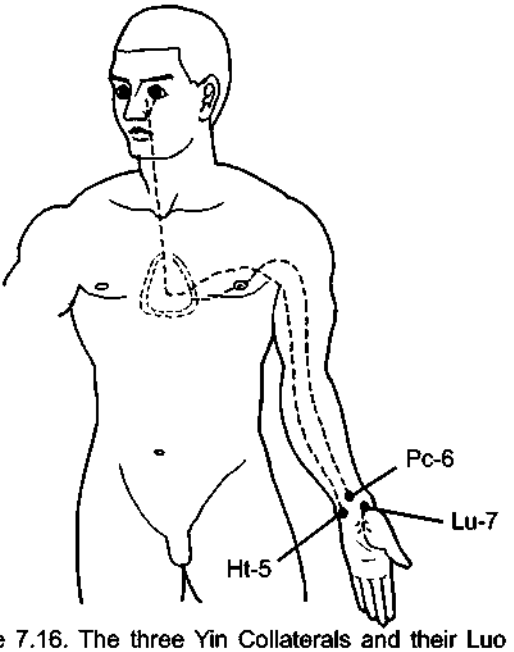

Figure 7.16. The three Yin Collaterals and their Luo points located on the hand and on the Primary Channels of the Heart, Pericardium, and Lungs.

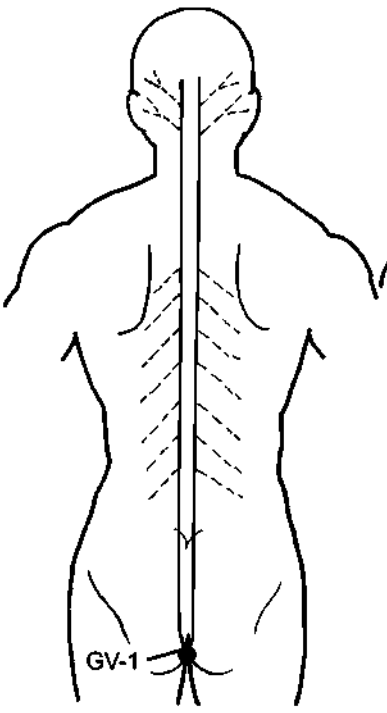

Figure 7.17. The main collateral and Luo point of the Governing Vessel is located on the Governing Vessel (GV) 1 point.

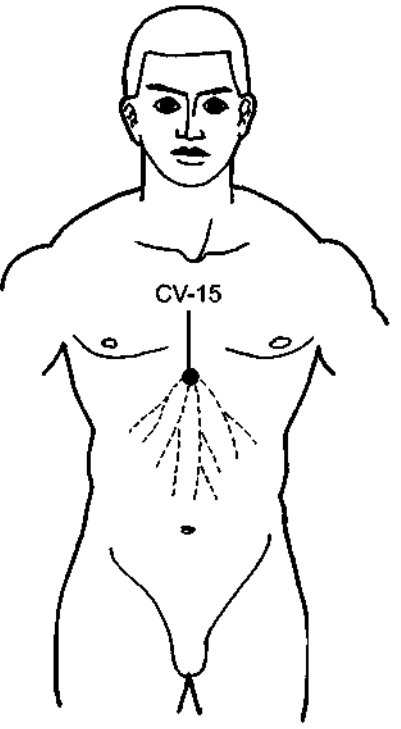

Figure 7.18. The main collateral and Luo point of the Conception Vessel is located on the Conception Vessel (CV) 15 point.

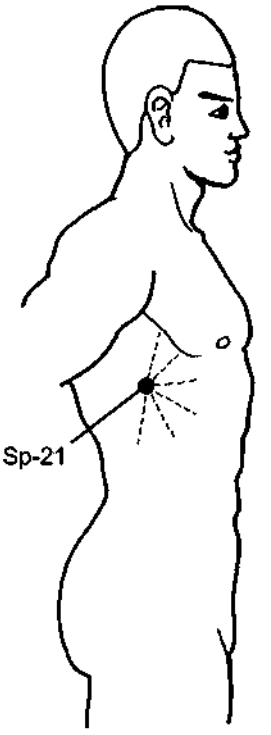

Figure 7.19. The major collateral and Luo point of the Spleen is located on the Spleen (Sp) 21 point.

base of the Governing Vessel, at the perineum. The Lou's energy flows upward along both sides of the spine to the nape of the neck, spreading to the top of the head. It continues flowing into the scalp regions on both sides of the head and connects with the Bladder Channel and merges with the spine (Figure 7.17).

   a. Symptoms of Excess include stiffness along the spine.
   b. Symptoms of Deficiency include dizziness or heaviness in the head.

14. The Conception Vessel 15 Point is located on the Conception Vessel of the chest, just below the xiphoid process. The Lou's energy flows downward, pouring over the abdomen (Figure 7.18).
   a. Symptoms of Excess include pain on the surface skin of the abdomen.
   b. Symptoms of Deficiency include itching on the surface skin of the abdomen.
15. The Major Luo of the Spleen 21 Point is located on the Spleen Channel of the chest, just below the auxiliary fold of each arm. The Lou's energy flow spreads through the chest and hypochondriac region, gathering the Blood like a net (Figure 7.19).
   a. Symptoms of Excess include general aches and pains throughout the entire body.
   b. Symptoms of Deficiency include weakness in the muscles of the limbs and joints.

THE TWELVE DIVERGENT CHANNELS

The Twelve Divergent Channels comprise an important part of the body's channel system. These channels are branches off the Twelve Primary Channels and share the energetic function of circulating Qi throughout the body. The energetic field of the Twelve Divergent Channels forms an enormous web of complex interconnections within the body's Twelve Primary Channels.

Because the area over which the energy of the Twelve Divergent Channels is distributed is quite extensive, they are considered a separate component of the channel system. They are secondary streams that parallel the primary rivers, yet each has its own functional characteristics and clinical application independent of the Primary Channels. The Twelve Divergent Channels run deeper in the body, supplementing the areas along the pathways that the Primary Channels do not reach. They have no points of their own, although there are intersection points where they cross the major channels (Figures 7.20 through 7.25).

One of the primary functions of the Twelve Divergent Channels is to integrate all parts of the body with the Twelve Primary Channels. There are areas in the body which are not traversed by the pathways of the Twelve Primary Channels, as well as internal organs that are otherwise unconnected, or only remotely connected, by the Primary Channels. These areas are more securely linked by the energetic flow of the Twelve Divergent Channels, which strengthen the bonds between the Twelve Primary Channels and the physical areas that are connected to, or adjoining, their pathways.

Another primary function of the Twelve Divergent Channels is to facilitate the connection between pairs of Yin and Yang Primary Channels and Organs. Therefore, all primary Yin and Yang organs are connected by the Divergent Channels. Both Yin and Yang Divergent Channels ultimately connect with the body's Yang Primary Channels.

1. The Yang Divergent Channels complete a cycle of leaving the primary channels (e.g., Primary Gall Bladder Channel) and entering their associated organs (e.g., The Gall Bladder Organ) before they resurface on the neck and reconnect with their original channels (e.g., The Primary Gall Bladder Channel).
2. The Yin Divergent Channels leave their primary channels (e.g., Primary Liver Channel), then join their associated Yang Divergent Channels (e.g., The Divergent Gall Bladder Channel), which then join with the Yang Primary Channels (e.g., The Primary Gall Bladder Channel).

Similarly, within the body's cavities, most of the Twelve Divergent Channels first join with their pertaining Yin or Yang organ and then connect with the associated organ (belonging to the associated channel) in the Yin / Yang pair. Through this interaction, the connection between paired Yin and Yang organs and channels is strengthened.

An understanding of the relationship between the paired Yin and Yang interactions is important to the Qigong doctor, as sometimes a disease affecting a Yang channel can be treated by selecting certain areas on its associated Yin channel, and vice versa. The same theory holds true for diseases of the internal organs.

The Twelve Divergent Channels are paired into six confluences according to their internal and external relationship.

1. Bladder Divergent Channel (Foot Tai Yang) and Kidney Divergent Channel (Foot Shao Yin)
2. Stomach Divergent Channel (Foot Yang Ming) and Spleen Divergent Channel (Foot Tai Yin)
3. Gall Bladder Divergent Channel (Foot Shao Yang) and Liver Divergent Channel (Foot Jue Yin)
4. Small Intestine Divergent Channel (Hand Tai Yang) and Heart Divergent Channel (Hand Shao Yin)
5. Large Intestine Divergent Channel (Hand Yang Ming) and Lung Divergent Channel (Hand Tai Yin)
6. Triple Burners Divergent Channel (Hand Shao Yang) and Pericardium Divergent Channel (Hand Jue Yin)

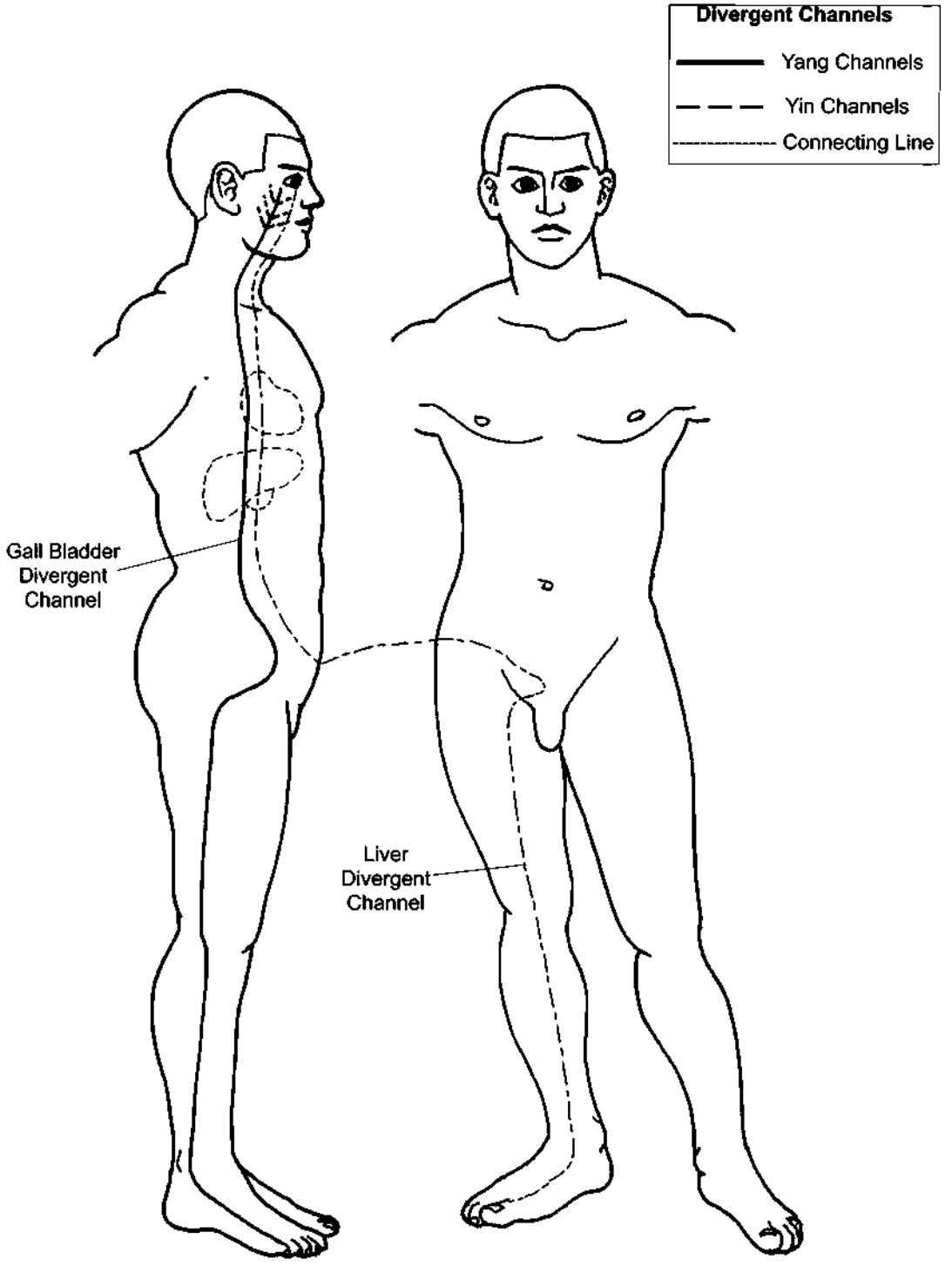

Figure 7.20. The Divergent Channels of the Gall Bladder and Liver

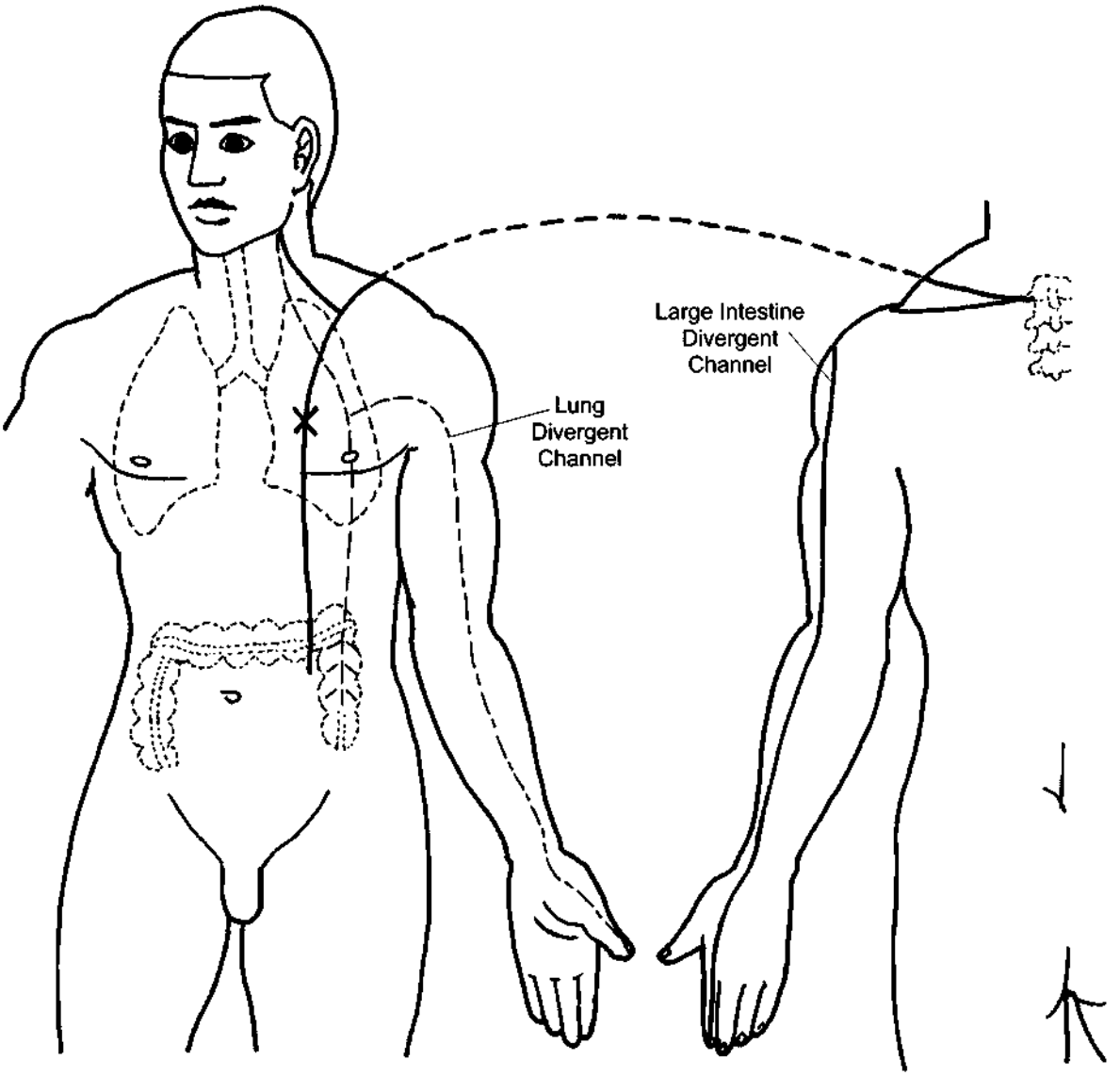

Figure 7.21. The Divergent Channels of the Lungs and Large Intestine

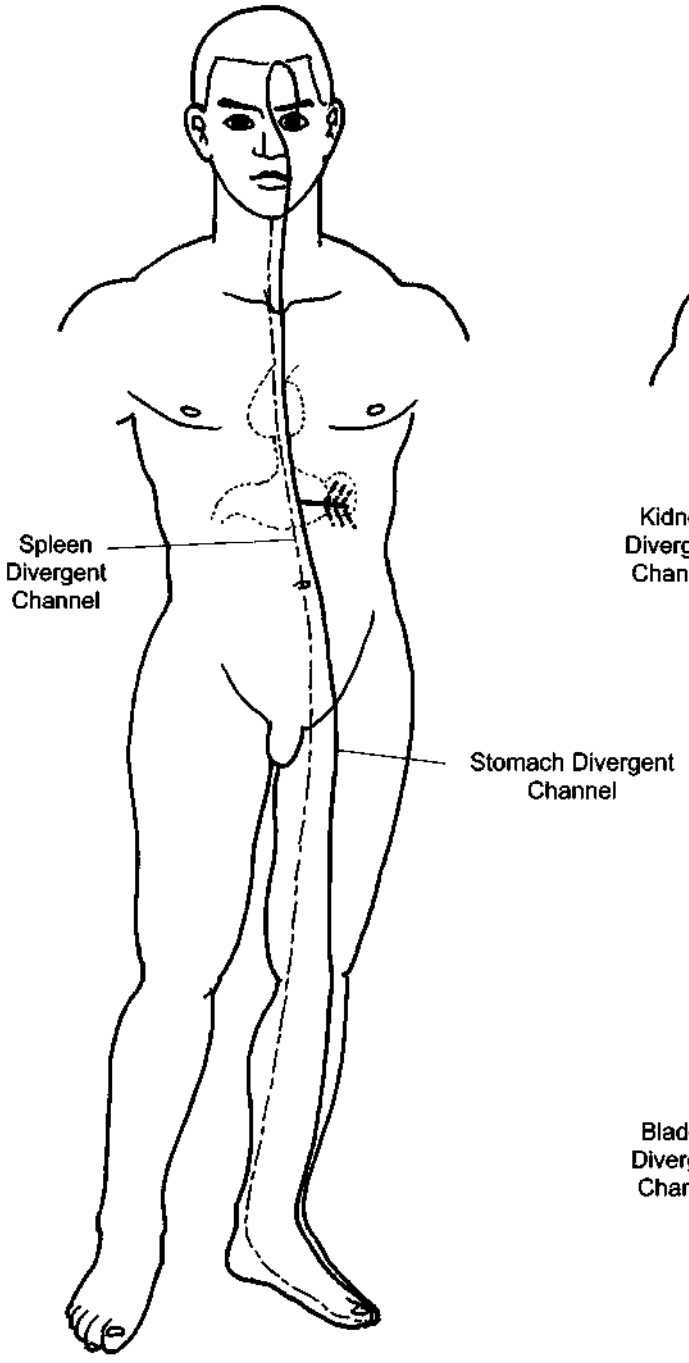

Figure 7.22. The Divergent Channels of the Stomach and Spleen

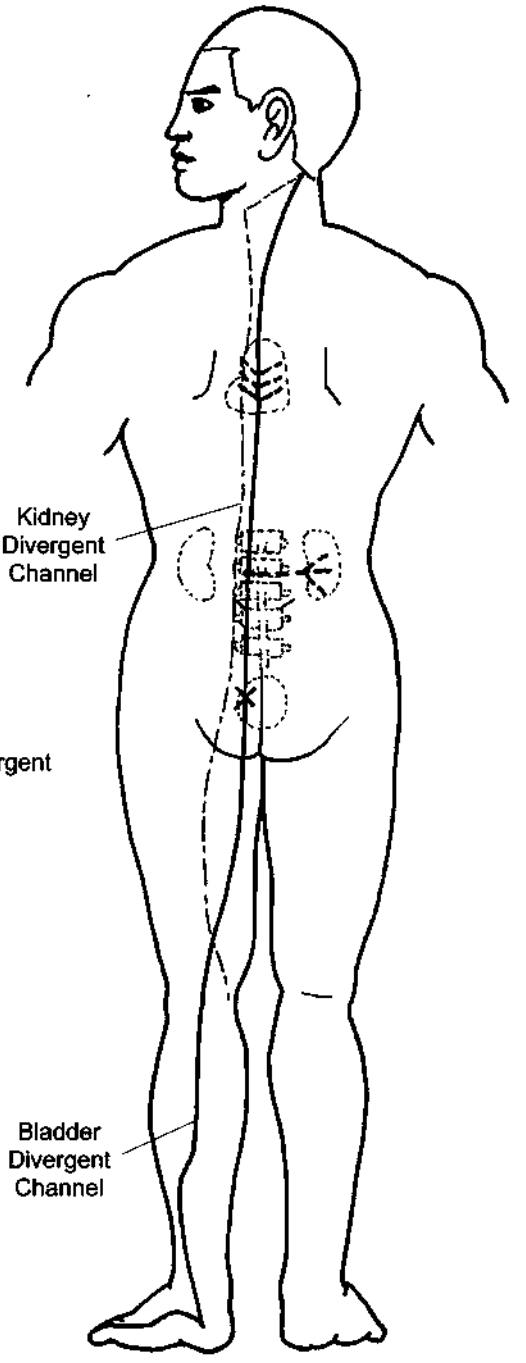

Figure 7.23. The Divergent Channels of the Bladder and Kidneys

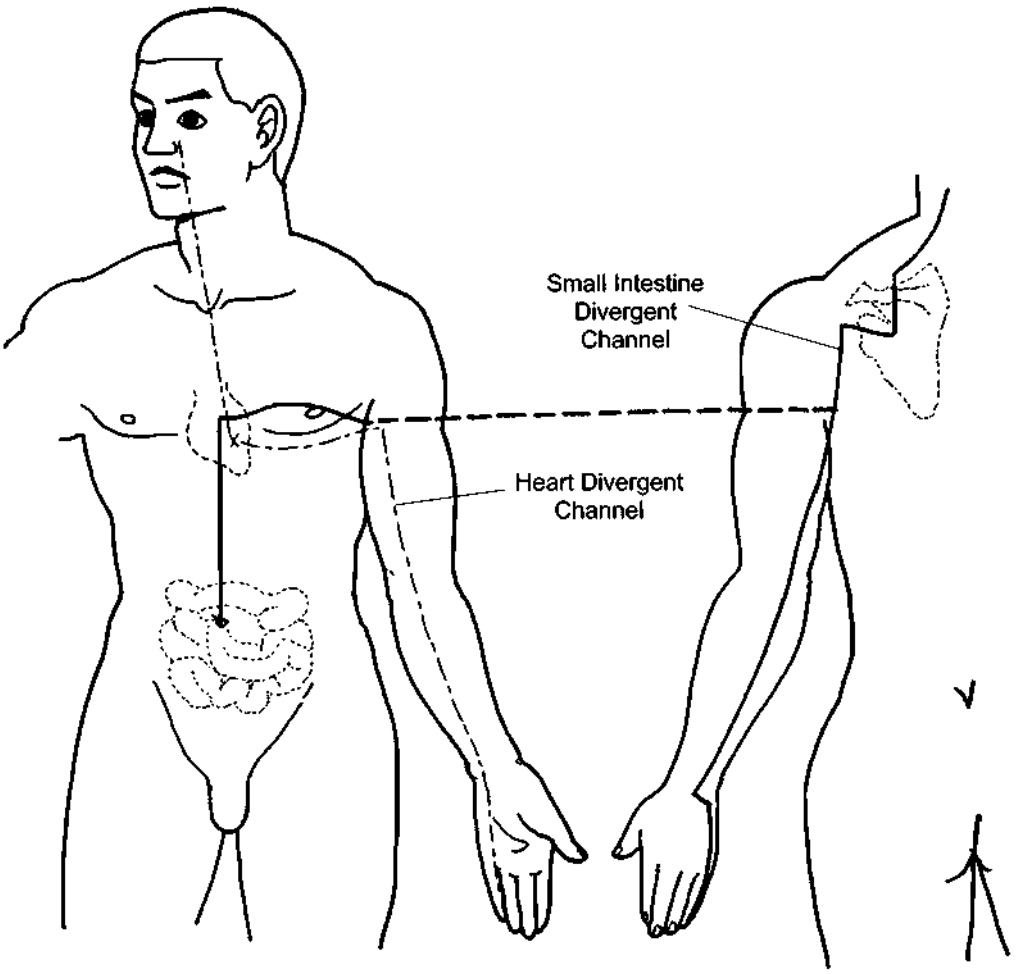

Figure 7.24. The Divergent Channels of the Heart and Small Intestines

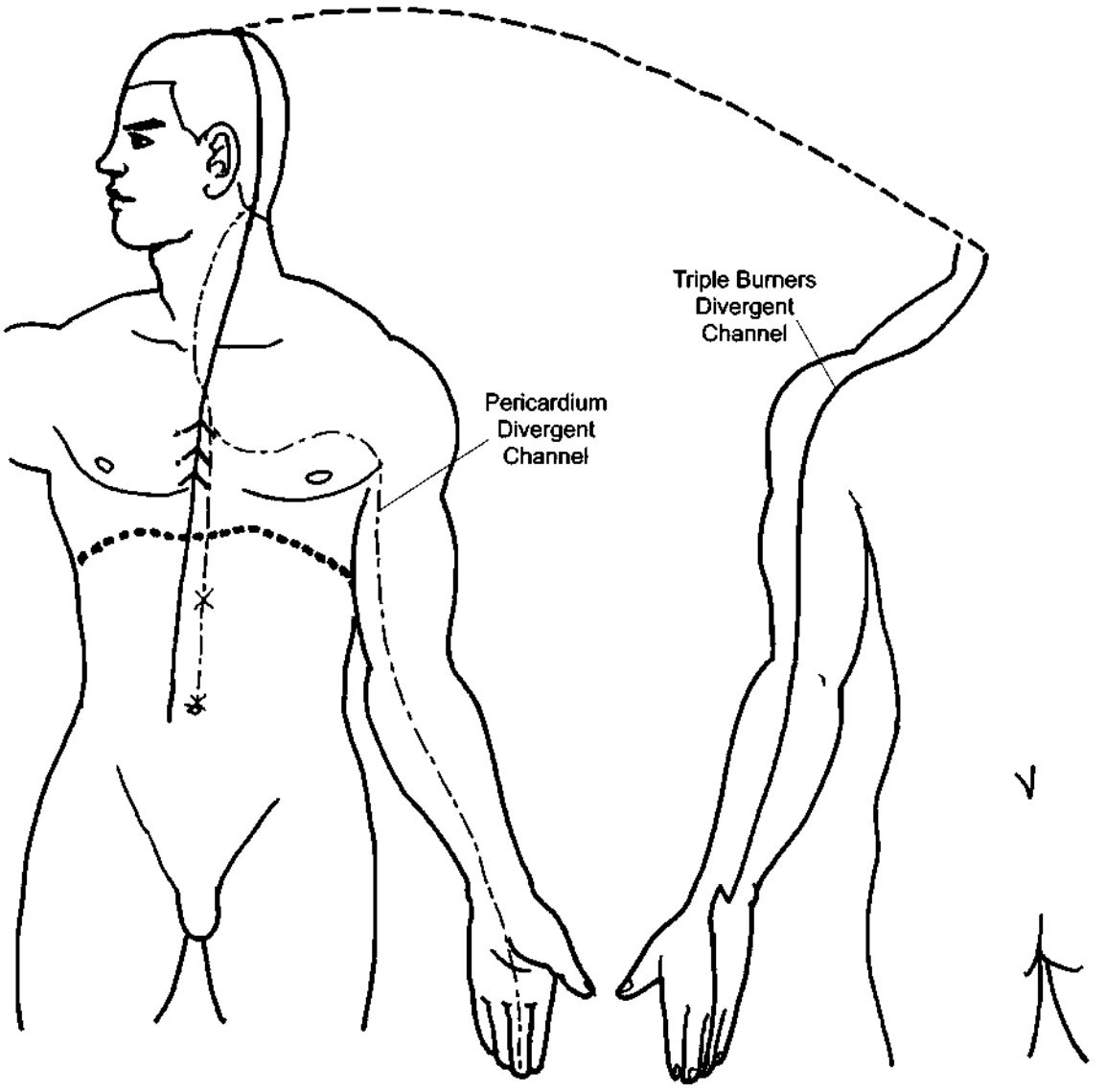

Figure 7.25. The Divergent Channels of the Pericardium and Triple Burners

THE TWELVE MUSCLE/TENDON CHANNELS

The Twelve Muscle/Tendon Channels are the muscle and soft tissue regions of the body where the Qi and Blood of the Primary Channels nourish the skin, muscles, and tendons. They are very superficial in relationship to the Primary Channels and form a capillary network that travels in the depressions and planes between muscles and tendons. The Twelve Muscle/Tendon Channels, subsequently spread over the whole of the epidermis, through its close connection with the cutaneous tissues.

Originating in the extremities, these channels ascend to the head and torso. Physiologically, they do not enter into the internal organs but coordinate the movement of the bones and limbs. The Twelve Muscle/Tendon Channels are connected to the inner fascia of the body's muscles, tendons, and ligaments, as well as other connective tissues. They are affiliated with the channels and collaterals (Luo) systems on the exterior of the body, and serve as mediators between any energetic reactions (trauma, stress, etc.) that vibrate from the body's exterior surface to the deep internal organs.

These channels are found along the four extremities on the surface of the body, as well as along the head, neck, back, chest, and abdomen. The name of each Muscle/Tendon Channel comes from the Twelve Primary Channels whose external energy flow they follow. They also receive Blood and Qi nourishment for their functional activity from and through the Twelve Primary Channels. There are points of connection, as well as intersecting points along these channels (Figure 7.26 through 7.37).

Treatment at these conjunctive points consistently responds successfully to stimulation; therefore, the Qigong doctor can effectively apply Jing Point Therapy to specific areas and points along the Muscle/Tendon Channels.

These channels are responsible for extending and flexing the muscles, tendons, ligaments and joints; their pathology is reflected in symptoms of impaired movement (i.e., pulled, twisted, strained, cramped or atrophied muscles, spasms, etc.).

In Traditional Chinese Medicine the muscles and tendons are described in characteristics of Yin (flexion, contraction, internal rotation, etc.) and Yang (extension, expansion, external rotation, etc.) which balance each other. When the Yin and Yang action of the muscles and tendons fail to balance and regulate each other, Muscle Channel Dysfunction results; for example, when exposed to cold, the muscles/tendons become tense and over-contract; when exposed to heat, muscles/tendons become loose and overextend.

The pathology of the Muscle/Tendon Channels also reflects the symptoms of corresponding groups of muscles and other connective tissues. The connective tissues are divided into three groups: the large, the small, and the membranous connective tissue.

Therapeutically, a local Muscle/Tendon Channel symptom can be treated by stimulating an area located next to the origin of the pain; for example, if the area is Yang (lateral) and overactive, then the Yin (medial) will be underactive and vice versa. Treatment is directed towards restoring the balance between the Yin and Yang Muscle/Tendon Channels.

Being superficial, the Twelve Muscle/Tendon Channels contain Wei Qi; thus, they provide the body's third line of defence against any unfavorable exogenous influence (the first being the body's Wei Qi field, and second being the Wei Qi stored within the skin). Only after overcoming the resistance of the body's Muscle/Tendon Wei Qi can the Evil Exogenous pathogens travel down the length of the channel to penetrate the corresponding Primary Channel at the Jing-Well point. Jing-Well points are points of energetic union, connecting Primary Channel points together with the points where the Muscle/Tendon Channel have their origin.

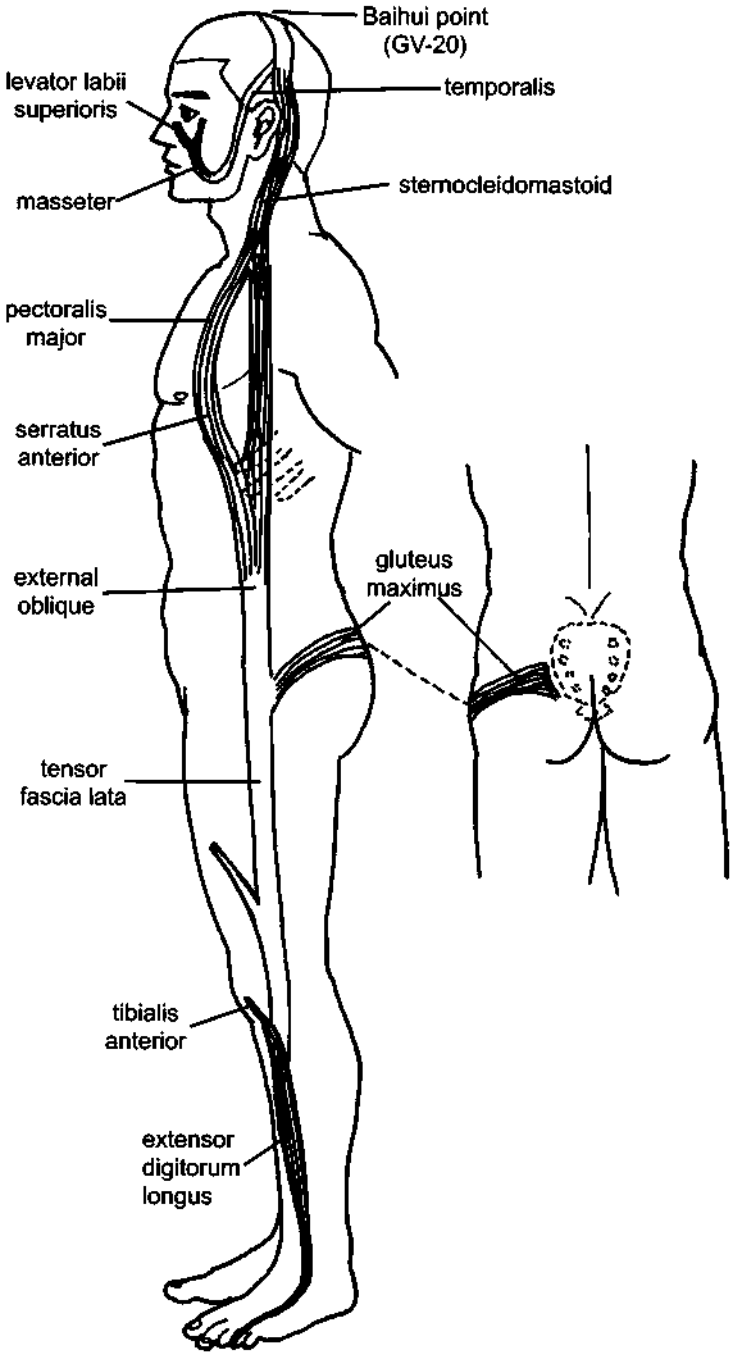

Figure 7.26. The Muscle Region of the Gall Bladder Channel: High Tide is 11p.m.–1 a.m. Pathological symptoms include strained muscles from the fourth toe to the knee upon lateral rotation, with an inability to bend the knee; muscle spasms or stiffness within the popliteal fossa; strained muscles of the sacrum, pelvis, and lower ribs; pain in the hypochondria, chest, and clavicle region; and an inability to turn the eyes to the left or right.

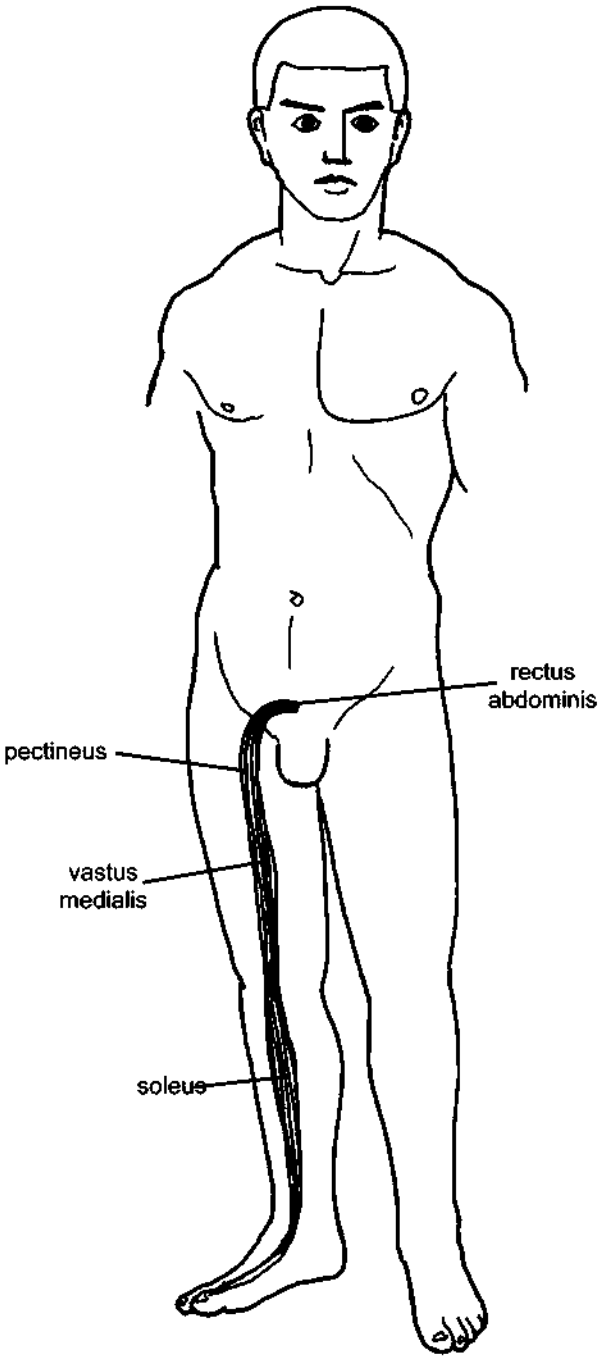

Figure 7.27. The Muscle Region of the Liver Channel: High Tide is 1 a.m.–3 a.m. Pathological symptoms include strained muscles of the big toe; pain in the anterior internal malleolus of the ankle; pain at the medial aspect of the knee and thigh; and dysfunction of the reproductive organs, i.e., impotence.

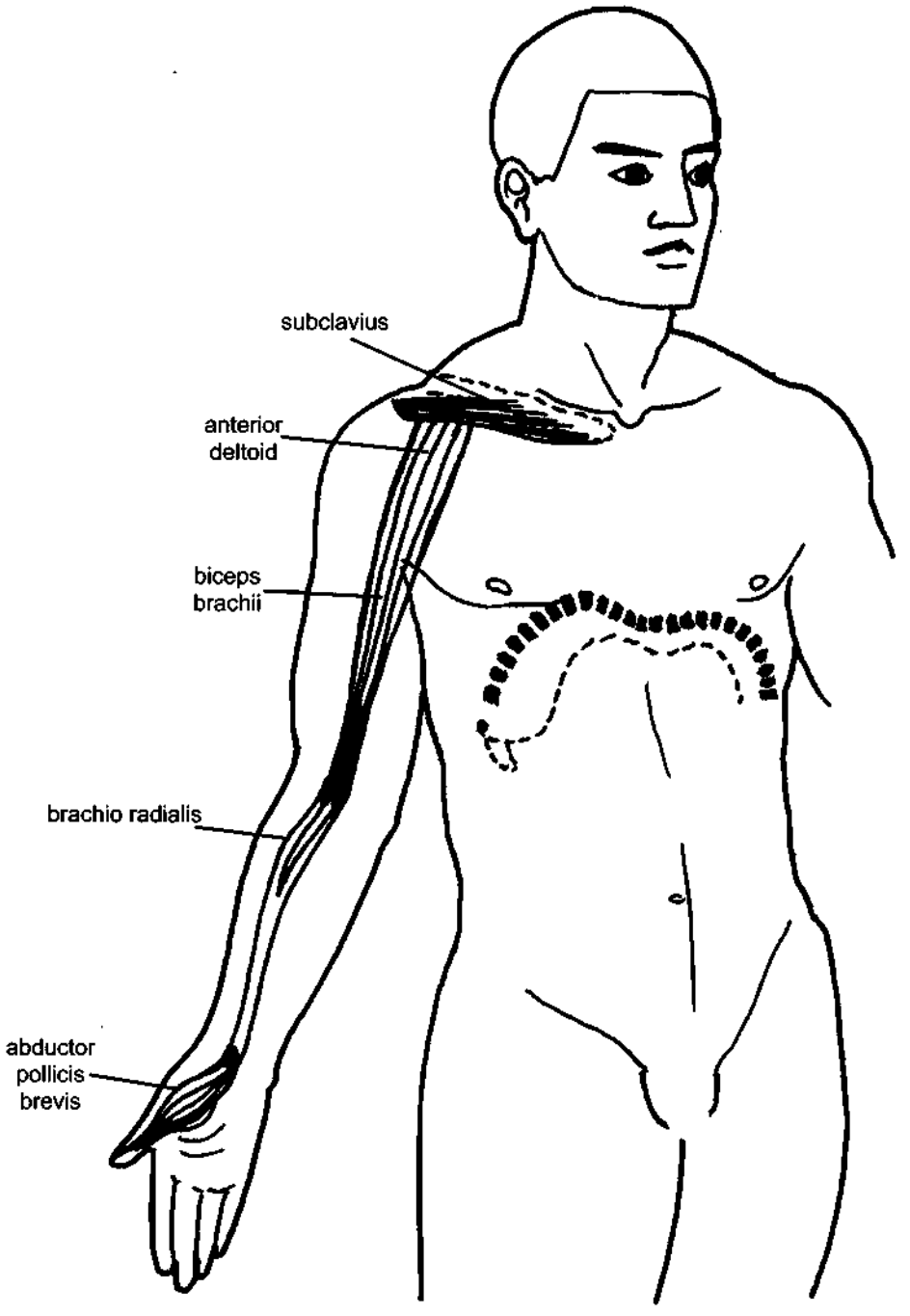

Figure 7.28. The Muscle Region of the Lung Channel: High Tide is 3 a.m.–5 a.m. Pathological symptoms include strained muscles of the thumb; stiff, strained or muscle spasms, and/or pain along the course of the Lung Channel. In more serious cases, there will be muscle spasms over the rib area and spitting of blood.

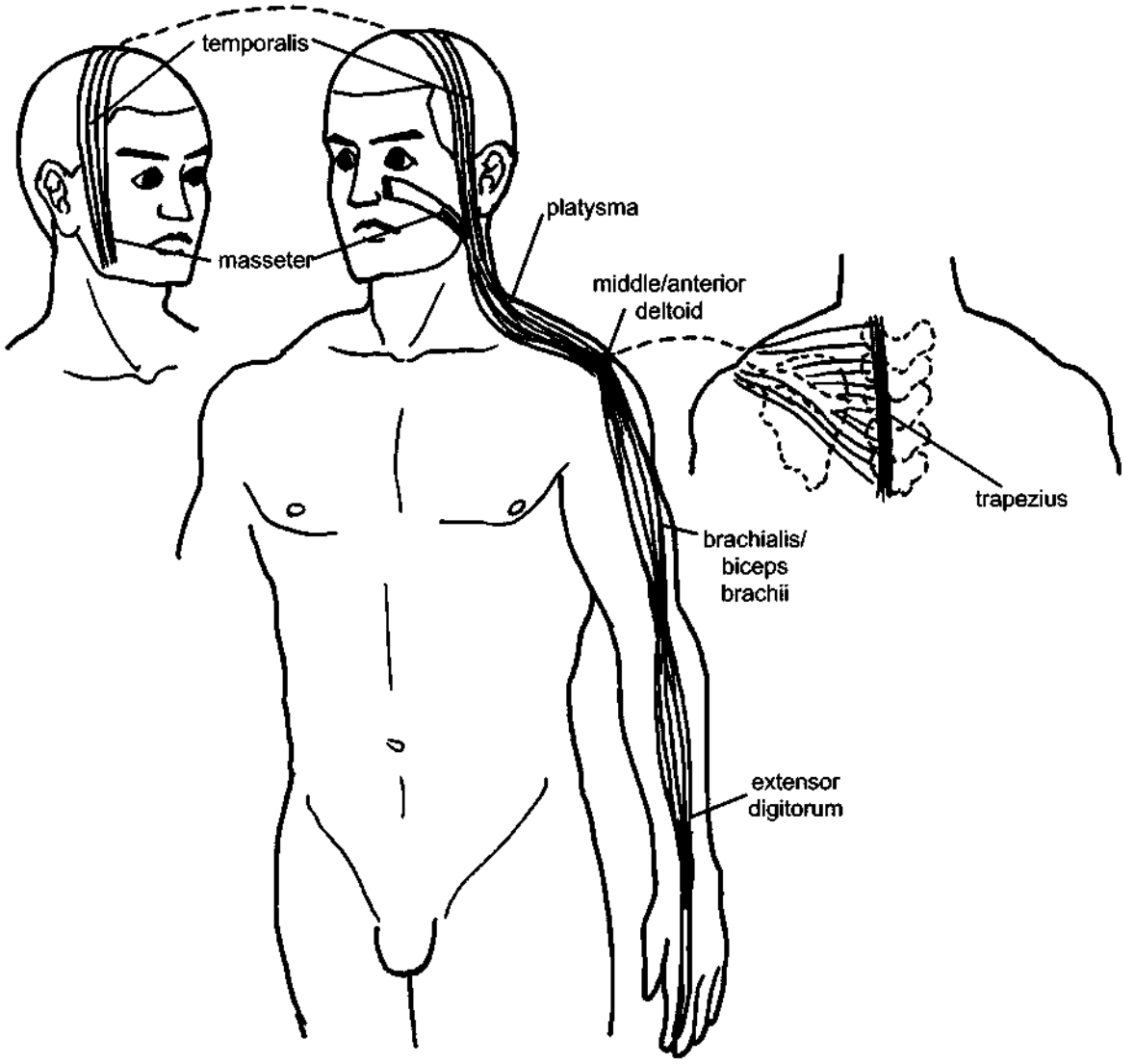

Figure 7.29. The Muscle Region of the Large Intestine Channel: High Tide is 5 a.m.–7 a.m. Pathological symptoms include strained muscles of the index finger; stiffness, strained, or muscle spasms along the course of the Large Intestine Channel, resulting in frozen shoulder; and an inability to rotate the neck from side to side.

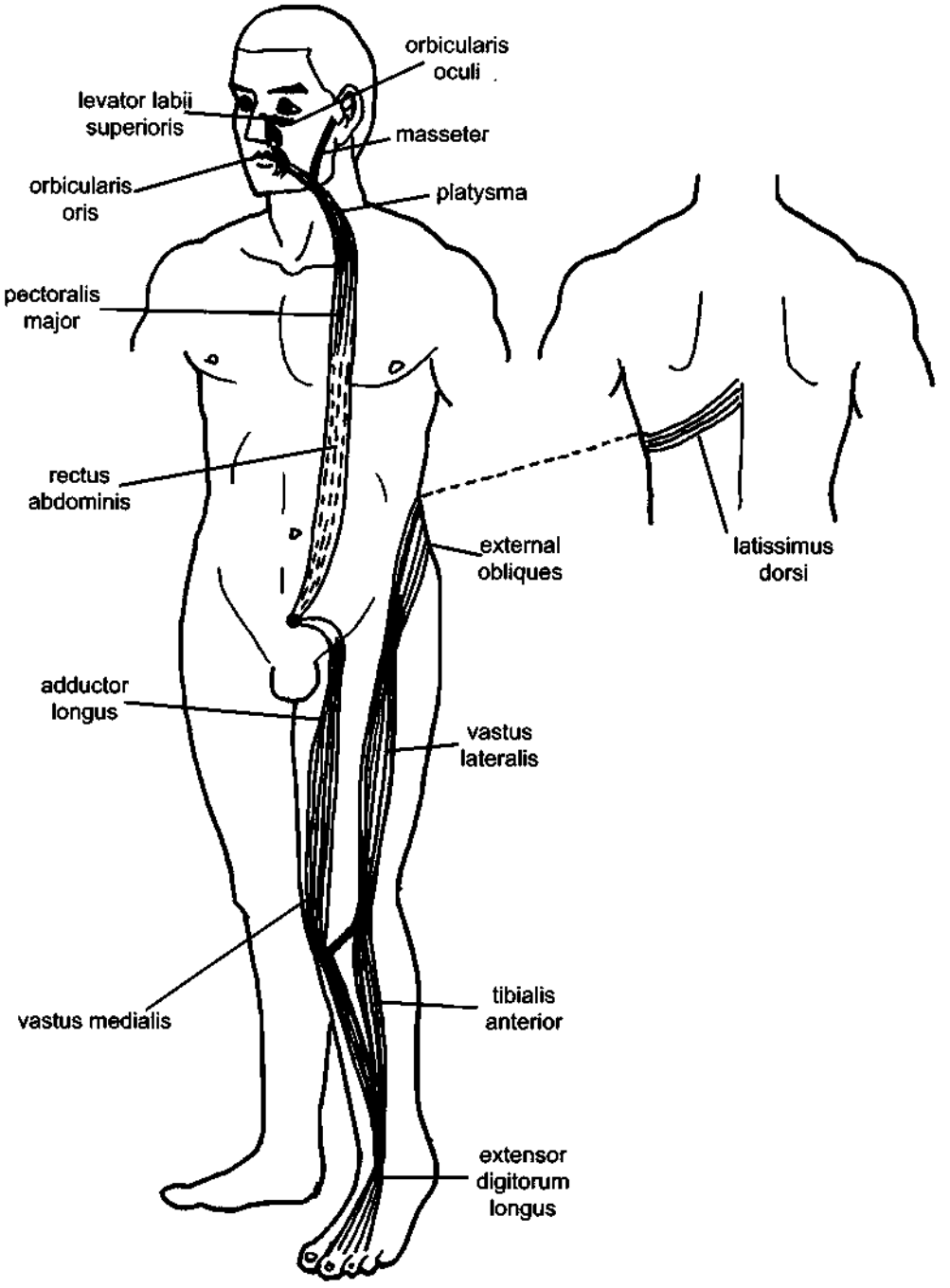

Figure 7.30. The Muscle Region of the Stomach Channel: High Tide is 7 a.m.–9 a.m. Pathological symptoms include strained muscles of the big toe; spasms or hardening of the muscles in the foot; knotted or twisted muscles in the lower leg and thigh; swelling in the anterior pelvis region; hernia; spasms of the abdominal muscles; spasms or stiffness of neck and cheek muscles; and eye spasms.

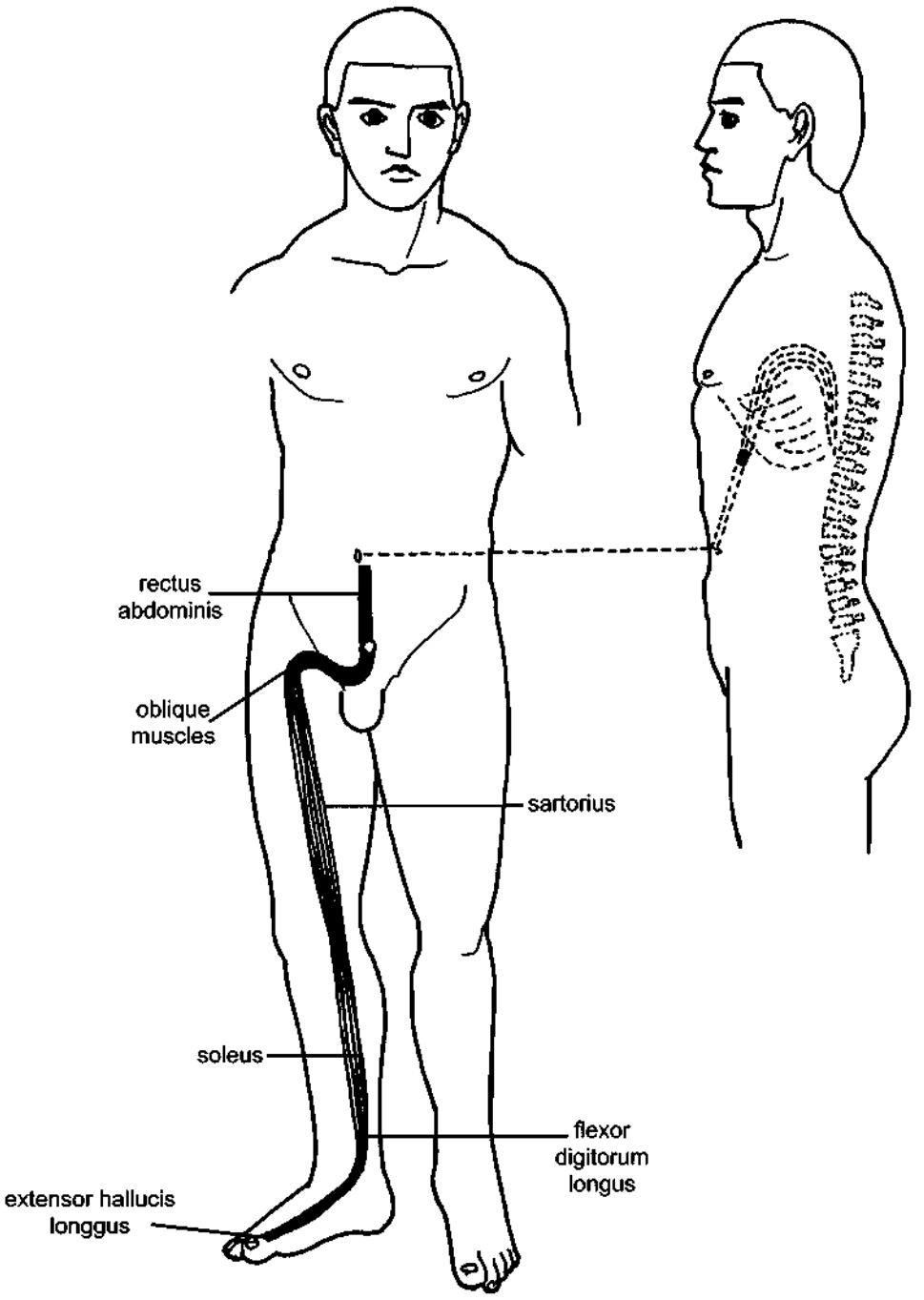

Figure 7.31. The Muscle Region of the Spleen Channel: High Tide is 9 a.m.–11 a.m. Pathological symptoms include strained muscles of the big toe; pain in the internal malleolus of the ankle upon rotation; pain along the medial aspect of the knee and adductor muscles of the thigh; groin strain; and pain due to strained upper abdominal muscles and mid-thoracic vertebrae.

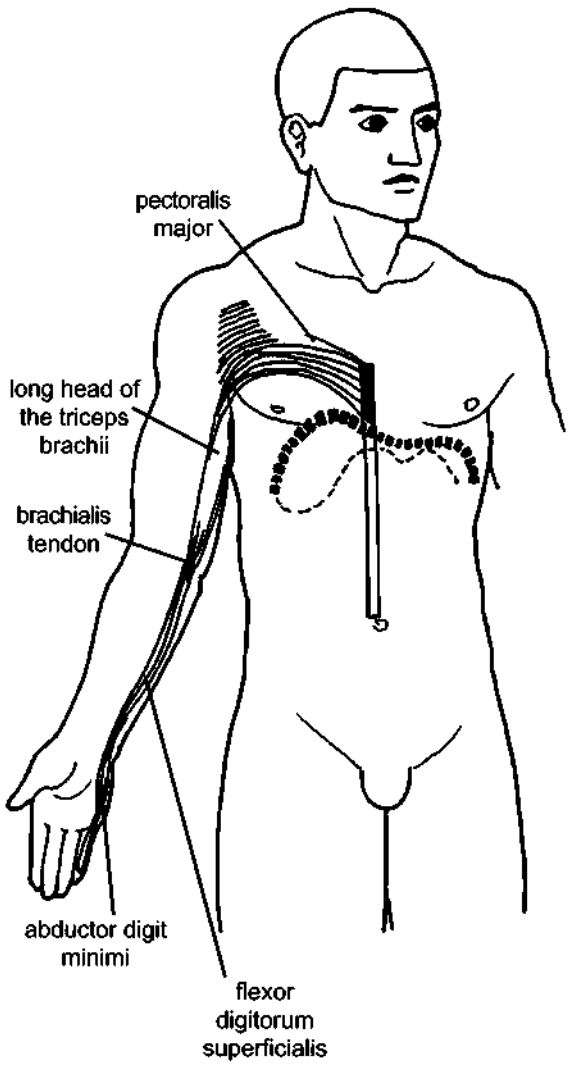

Figure 7.32. The Muscle Region of the Heart Channel: High Tide is 11 a.m.–1 p.m. Pathological symptoms include strained muscles of the little finger; stiff or strained muscles with spasm and/or pain along the course of the Heart Channel, including internal cramping within the diaphragm and upper abdominal area.

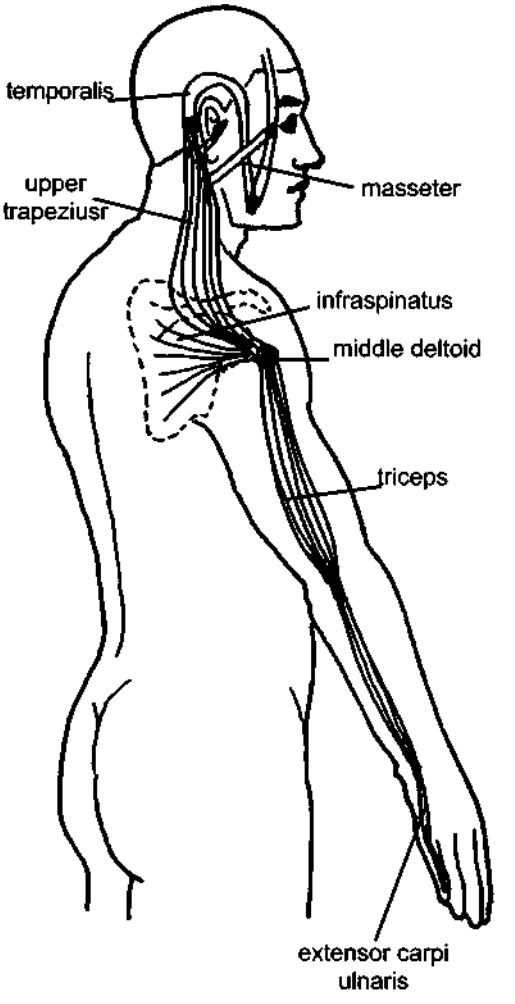

Figure 7.33. The Muscle Region of the Small Intestine Channel: High Tide is 1 p.m.–3 p.m. Pathological symptoms include strained muscles of the little finger; pain along the medial and posterior aspects of the elbow; pain in the posterior aspect of the axilla, neck, and scapula region; tinnitus related to ear ache; and poor vision.

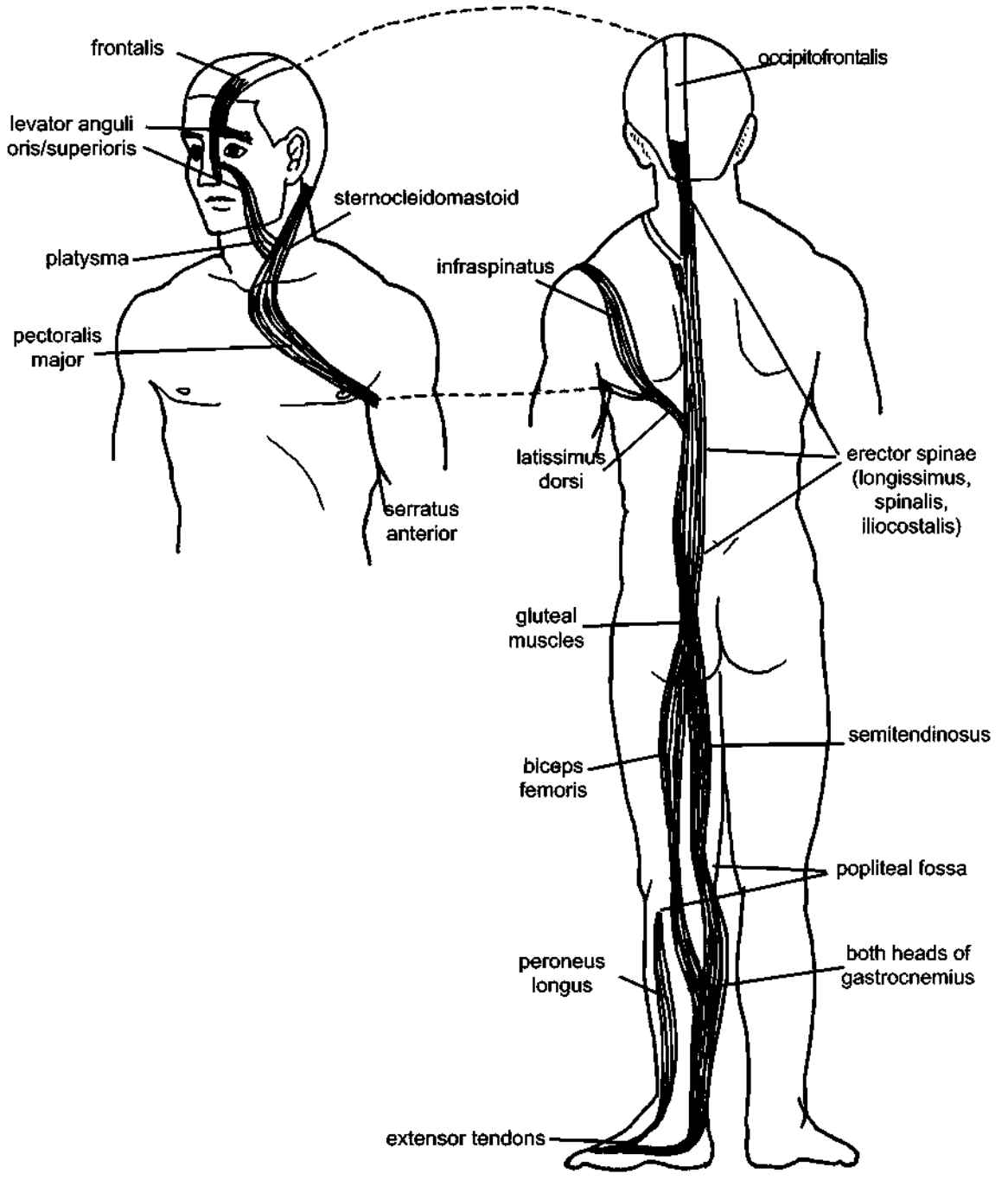

Figure 7.34. The Muscle Region of the Bladder Channel: High Tide is 3 p.m.–5 p.m. Pathological symptoms include strained muscles of the big toe; swelling and pain in the heels; stiffness or spasms along the spine and back area; frozen shoulder; stiffness or spasms in the axillary and clavicle regions.

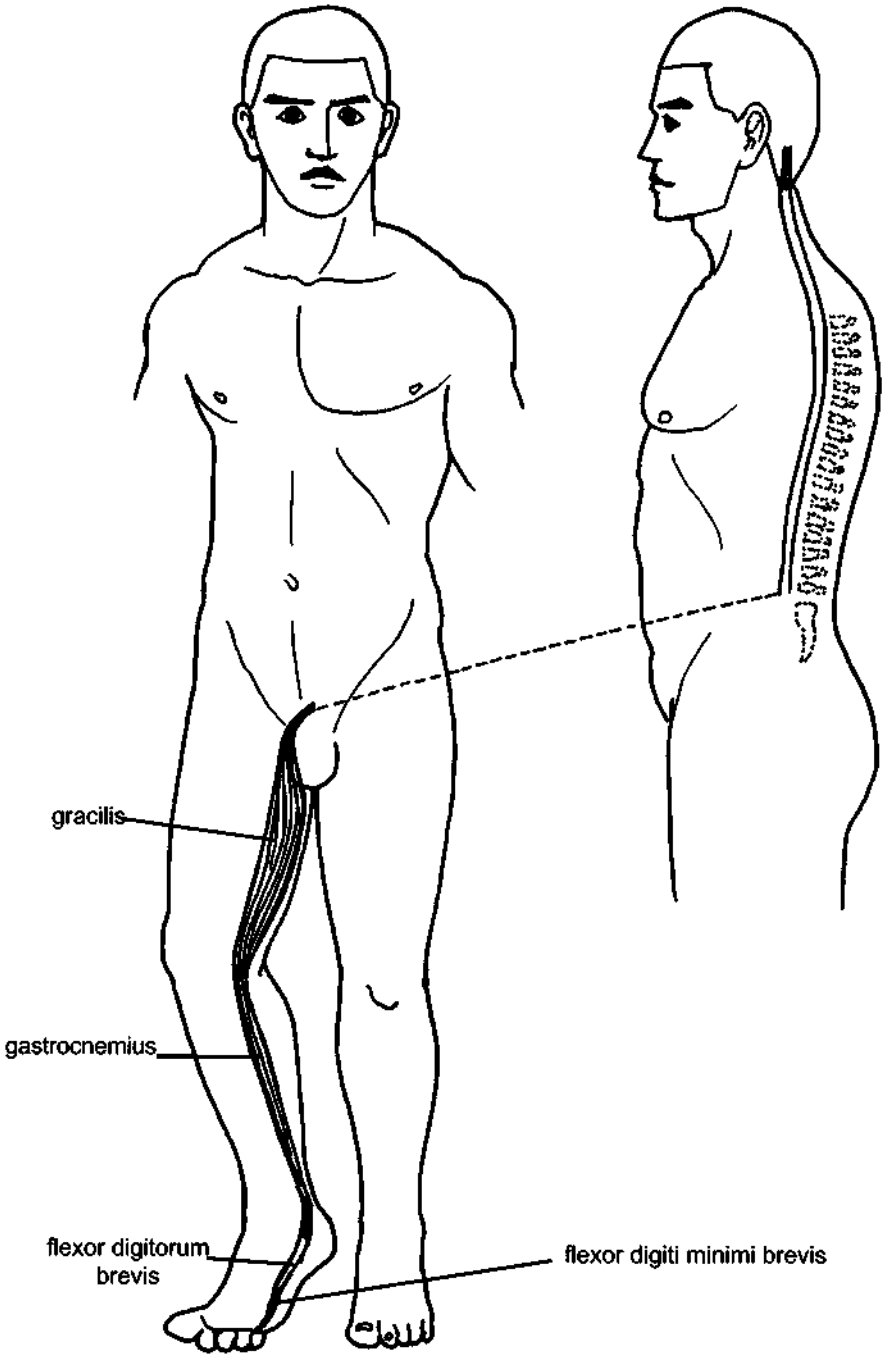

Figure 7.35. The Muscle Region of the Kidney Channel: High Tide is 5 p.m.–7 p.m. Pathological symptoms include strained muscles on the bottom of the foot; spasms or stiffness along the Kidney Channel, resulting in an inability to bend forward (Yang disorder) or backward (Yin disorder), with difficulty in flexing or extending the head.

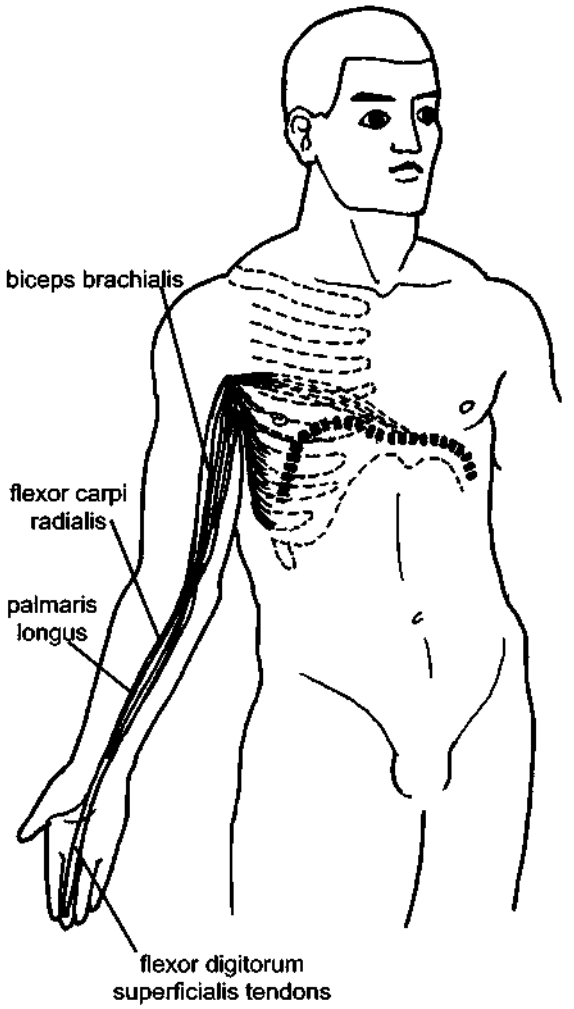

Figure 7.36. The Muscle Region of the Pericardium Channel: High Tide is 7 p.m.–9 p.m. Pathological symptoms include strained muscles of the middle finger; stiff or strained muscles, or spasms and/or pain along the course of the Pericardium's Channel; and chest pain and spasms.

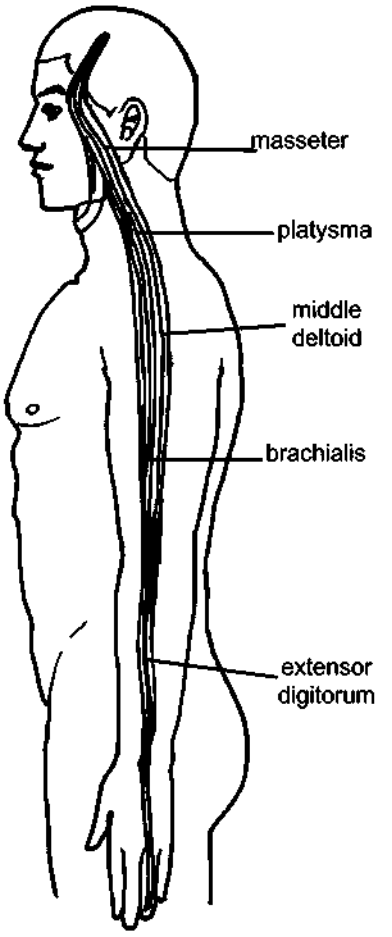

Figure 7.37. The Muscle Region of the Triple Burner Channel: High Tide is 9 p.m.–11 p.m. Pathological symptoms include strained muscles of the ring finger; stiff or strained muscles, or spasms and/or pain along the course of the Triple Burners' Channel.

THE TWELVE SKIN ZONES

Based on the Twelve Primary Channels, their collaterals, and the body's Muscle/Tendon Channels, the surface tissue is divided into Twelve Skin Zones. These Skin Zones are the surface contact areas for the body's channel and collateral systems. These twelve regions (sometimes called the Twelve Cutaneous Channels) are located in the superficial layers of the skin and have continuous and direct contact with the external environment. They are, therefore, the most sensitive to climactic changes and must adapt to protect the body from External pathogenic factors.

Both the Qi and the Blood at the Twelve Skin Zones rely on the collaterals for their nourishment. The Twelve Skin Zones circulate Wei Qi, which in addition to its defensive function, is also in charge of opening and closing the pores. The skin relies primarily upon the strength of the Wei Qi for resistance to the invasion of External pathogenic influences, as these harmful influences must first penetrate the skin before they can affect the body's internal tissues and organs. Since the Lungs rule the skin, weak Lung Qi can allow pathogens to penetrate the skin and affect the Lungs.

Pathological symptoms associated with the Twelve Primary and connecting Channels manifest along the surface of the Twelve Skin Zones, before progressing deeper into the body's connective tissue. The early stages of disease are called Exterior conditions; if the exterior Wei Qi is strong enough, pathogens will be stopped at the external level. The order of pathogenic progression is as follows.

1. The Body's Wei Qi is the body's first line of defense. A healthy body will project a strong, protective, external energetic field, which will maintain a capable defensive boundary. If the patient becomes weak, tired, or stressed, however, External pathogens may advance onto the patient's skin and begin attacking his or her health.
2. The Skin is the body's second line of defence. If the body's Wei Qi is not strong enough to resist an External attack and the skin is not capable of warding off the pathogens, then the pathogens will attack the skin, causing the sweat pores to open, thus allowing the pathogens to advance towards the patient's collaterals.
3. The Collaterals are the third line of defense. If the body's collaterals are unable to redirect or purge the advancing pathogens, the pathogens will then advance into the patient's channels.
4. The Channels are the last line of defense before the advancing External pathogens invade the patient's internal organs. If the body's channels are unable to redirect or purge the pathogens, and the pathogens are allowed to continue their progression, they will advance further into the body's internal organs.
5. The Internal Organs are affected once the pathogens have breached all the outer defences and disease can now begin to establish its residence.

Pathologies associated with the Primary Channels manifest diagnostically through the body's skin, channels, and points. The observation of pimples, moles, discoloration, and changes in electro-conductivity are all valuable signs of pathogens, or obstructions, invading the skin.

A disease of external origin that first lodges within the patient's skin can be treated by the Qigong doctor. The doctor stimulates the Wei Qi in the affected skin zone through external Qi projection before it progresses further into the body's connective tissue. An alternate treatment would be to apply herbal ointments and/or moxa therapy.

THE CONNECTIVE TISSUE OF THE TWELVE SKIN ZONES

The connective tissue always responds to the outside stimulation of the Twelve Skin Zones. The body's connective tissue is just below the skin, and is regarded as one of the largest, most extensive tissue organs in the body. Its function is to support, connect, contain, and transmit. It is a continuous network of structure that binds tissues into their organ shape. It also supplies the internal organ's life support with vessels and ducts, and securely fastens each organ within the body

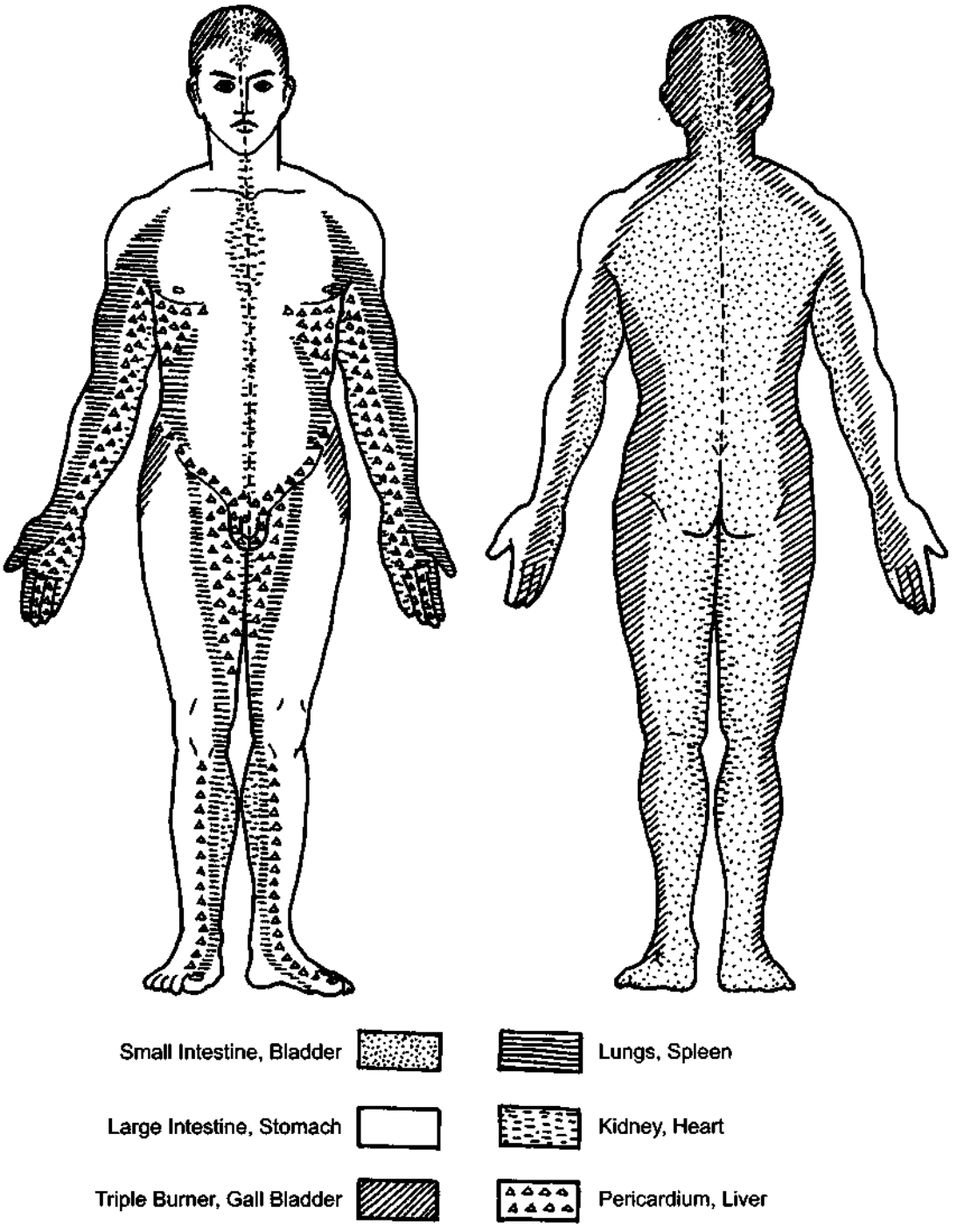

Figure 7.38. The Body's Twelve Skin Zones, Based on the External Flow of Qi from the Twelve Primary Channels and Their Collaterals

cavity. This connective tissue surrounds and anchors the vessels within the muscles, bones, and organ tissue. Its fluid nature supports the entire body structurally by hydrostatic pressure. Any stimulation on one of the body's Twelve Skin Zones will directly affect the body's connective tissue, and will stimulate the corresponding internal organ associated with that particular zone.

The superficial fascia (the connective tissue just under the skin) divides into a top and bottom layer. The top layer is the fatty layer, which constitutes the main fatty tissue of the outer surface of the body and fascia. This fatty layer acts as an insulator, helping to maintain a constant body temperature. It is metabolically active, functionally storing fat as fuel, releasing it in response to nerve and hormonal stimuli. It corresponds to the greasy layer where the Wei Qi circulates throughout the body's tissues. The deeper layer of the superficial fascia envelopes the nerves, veins, arteries, lymph vessels, and nodes.

From a Traditional Chinese Medical perspective, the Qi circulating within the body's inner fascial connective tissue can be stimulated through the external energy stimulation of the Twelve Skin Zones. Heat and movement help maintain the body's connective tissue's base fluids, facilitating movement and the conduction of energy. Any obstruction occurring on the body's surface tissues can result in the binding or thickening of the connective tissue, thus creating adhesions. This obstruction slows the metabolic process and compromises the body's immunity (Figure 7.38).

If the integrity of the connective tissue is compromised, the body's immune system declines. Compartments of connective tissue influence the spread of toxins, diseases, infections, and tumors. The fibrous walls, as well as chemicals in the fluid of the connective tissue, prevent the spread of pathogens from one area of the body to another.

Clinical Diagnosis and the Twelve Skin Zones

Clinically, the diagnosis and treatment techniques relating to the use of the Twelve Skin Zones is quite extensive. In diagnosis, the skin's surface area along these zones is examined for evidence of discoloration or tissue obstruction. Changes in skin color and tissue formations are observed and categorized as follows.

1. A darkish hue reflects obstruction of Qi and Blood.
2. A bluish-purple color indicates local pain.
3. Change in color from yellow to red shows evidence of Heat.
4. A white or pallid skin tone signifies Deficiency or Cold.
5. Boils, pimples (especially on the back), hives, and eczema, as well as hard lumps or nodules beneath the surface of the skin, indicate diseases associated with the Twelve Primary Channels (manifesting through the Twelve Skin Zones).

A palpable lump can develop from a variety of sources, including congealed or stagnant Blood. There are generally eight types of lumps observed in the clinical environment:

1. The Shrimp Lump, is shaped in the form of a shrimp.
2. The Turtle Lump, is named for its shape and multiple lump formations.
3. The Blue Lump, derives its color from the superficial blood vessels on which it forms.
4. The Single Lump, is diagnosed as opposed to multiple lump formations.
5. The Dry Lump, indicates an obstruction.
6. The Blood Lump, relates to congealed Blood.
7. The Abdominal Lump, is named for its physical location.
8. The Yellow Lump, is named because of the yellow pallor in the specific region of the lump.

Palpating the Patient's Skin

Before palpating and diagnosing the skin, the Qigong doctor first scans the patient's body to feel the temperature, moisture, and texture of the patient's tissues.

1. The doctor scans and palpates the patient to diagnose the condition according to the temperature:
    a. If the skin feels hot to the touch it often indicates a presence of a Damp-Heat condition.

   b. When first touching the patient with light pressure if the skin feels immediately hot, and as the pressure is maintained the feeling of heat increases, this indicates an invasion of Exterior Wind-Heat (with a pathogenic factor still on the exterior surface).
   c. If the skin over a blood vessel feels hot on medium pressure, it indicates Interior Heat in the Middle Burner or Heart area.
   d. If the skin feels hot on deep, heavy pressure, it indicates an Empty-Heat condition from a Yin Deficiency.
   e. If the skin feels cold to the touch, it often indicates a Cold condition. This condition is often manifested in the lower back and lower abdominal region, indicating a Deficiency of the Kidney Yang.
2. The doctor scans and palpates the patient to diagnose the condition according to the amount of moisture:
   a. A moist feeling of the skin may indicate an invasion of the Exterior by Wind-Cold or Wind-Heat.
   b. If the skin feels moist due to spontaneous sweating, it indicates a Deficiency of the Lungs' Qi (in the absence of exterior symptoms).
3. The doctor scans and palpates the patient to diagnose the condition according to the texture:
   a. If the skin is scaly and dry, it indicates an exhaustion of the Body's Fluids.
   b. If the skin feels dry, it indicates either a Yin condition of the Lungs or a Blood Deficiency.
   c. If the skin is swollen and an indentation is left visible after pressing, it indicates Edema (called Water Swelling).
   d. If the skin is swollen and no indentation is left visible after pressing, it indicates a retention of Dampness (called Qi swelling).

CHANNEL AND COLLATERAL THERAPY

Because the Yin and Yang organs' Qi flows within the body's internal and external surfaces, all the internal and external channels and collaterals, five tissues (tendons, blood vessels, muscles, skin, and bones), and five sense organs (eyes, ears, nose, mouth, and tongue), together create an energetic network. Through practicing sitting meditations, patients as well as Qigong practitioners become aware of the circulation of Qi along the body's channels and collaterals. The awareness of what the Qi feels like enables the meditators to feel the flow and function of each channel, as well as the Blood and heat cycle in each Skin Zone. This makes it possible to control the Qi circulation through intention and imagination.

Balancing the Conception and Governing Vessels is of the utmost importance in the practice of any Qigong regulation. Along these two Vessels the Qigong practitioner draws the Yang Fire and Yin essences up and down the body, thus fusing the Water and Fire energies. This fusion is utilized by the doctor in every Qigong treatment, and is responsible for balancing the patient's Yin and Yang energy. This balance is created through the discipline of the Microcosmic Orbit meditation, which connects the Governing and Conception Vessels.

The students' awareness of Qi flowing through the body usually develops in three distinct stages:

1. First, they begin to feel the energy flow along the surface channels of the body, especially within the areas of the extremities. Usually at this stage, the students will feel heat and tingling sensations within the body's surface muscles.
2. Next, they begin to feel the energy flow deeper within their tissues, especially along the tendons, deeper muscles, and visceral organs. Usually at this stage, they begin to feel mild electric shocks and vibrations within their muscles, bones, and visceral organs.
3. In the final stage, they feel the Earth and Heaven energy penetrate through their body's

outside channels and inner organs, connecting into their Taiji Pole, and then turning outward again. Usually at this stage, they will feel their entire energized body vibrate. This vibration may be triggered through either universal or environmental changes, as the Medical Qigong practitioner becomes hypersensitive to any form of external energetic disturbance.

CONTROLLING QI EXTENSION THROUGH THE CHANNELS

The Qigong doctor must first be able to control his or her own energy circulation, causing it to flow in or out, expand or contract at will, before beginning to extend energy for the treatment of any patient. This energetic control is gained through specific imagination and visualization techniques. The fundamental theory for these techniques is "The imagination leads the Mind, the Mind leads the Qi." The doctor must be able to utilize energy from the natural environment (trees, waterfalls, ocean, desert, etc.) in order to replenish and facilitate his or her own energy.

By drawing in Heavenly Qi and combining it with his or her body's connection to Earthly Qi, the doctor may mobilize and activate the Qi of the patient. This combining method establishes an energetic healing field of Qi, which responds to the Qigong doctor's own Qi circulation, as well as to that of the natural environment, which includes the patient. This ability must be achieved in order to activate the patient's Qi and then regulate it by purging the Excess Qi, replenishing the Deficient Qi, dredging the channel Qi, and guiding the Qi back to its origin.

CHAPTER 8
THE BODY'S ENERGETIC POINTS

INTRODUCTION TO ENERGETIC POINTS

The Chinese word for point is Xue or Xue Wei, meaning "cavity place, cave, den, hole, or hollow." Although the Chinese word Xue is usually translated into English as "point" or "acupoint," it is valuable for the English-speaking student to understand the word's different connotations. Points are almost always located in hollows or depressions, which are physically palpable and found in over 1,000 locations all over the body. Many, but not all, are located along the channels and vessels. Sometimes when touching a point, it feels as if your fingertip has found the entrance of a small cave or opening hidden by the skin covering it.

The word Xue also implies a den or lair: thus, it is not only a cave but a home for some type of powerful life form. In the human body, our living Qi gathers and pools within these protected hollows (Figure 8.1). For this reason, some writers have preferred to translate Xue as "vital hollow," rather than "point." Because of its popular acceptance, I have chosen to use the term "point" throughout this book.

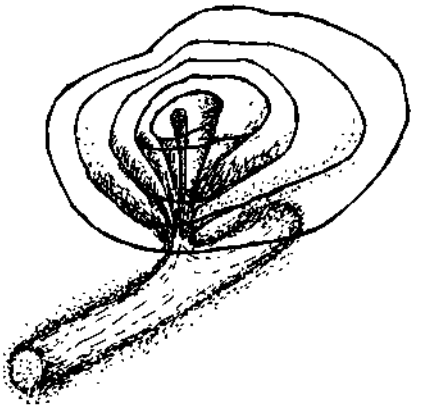

Figure 8.1. The energetic points are considered the body's small energetic pools.

THE FOUR WAYS POINTS ARE FORMED

Generally, points are formed in four ways. The first type of point occurs when two muscles, tendons, or ligaments intersect or overlap in a way that creates a small depression at the area of convergence. To form the depression, the two muscles either come together, separate, overlap, or run parallel to each other. Usually the channels lie under a protective layer of muscle, but at the aforementioned junctures, the channels may be exposed, and thus closer to the surface.

The second type of point occurs when a nerve is exposed in an area without much muscle tissue to cover and protect it. Because the nerve is exposed, such points are especially sensitive, and may cause a sharp pain or an electric shock sensation when stimulated.

The third type of point lies under a protective superficial layer of muscle. It can however, still be stimulated due to its natural sensitivity and because the overlying layer of muscle is thin.

The fourth type of point lies in depressions on the surfaces of the bones and cartilage. These depressions may take the form of grooves, pits, hollows, indentations, fissures, or crevices.

SCIENTIFIC RESEARCH OF ACUPOINTS

In the early 1970's, shortly after President Nixon's historic visit to China, Dr. Robert O. Becker, M.D., a Syracuse University orthopedist, received a grant from the National Institutes of Health to research how acupuncture works. Dr. Becker reasoned that the channels were electrical conductors (independent of the nervous system yet communicating with it) that carried an injury message to the brain, which responded by send-

ing back the appropriate level of direct current (DC) to stimulate healing in the troubled area."

Becker also suggested in his book *The Body Electric*, that "any current grows weaker with distance, due to resistance along the transmission cable. The smaller the amperage and voltage, the faster the current dies out. Electrical engineers solve this problem by building booster amplifiers every so often along a power line to get the signal back up to strength. For currents measured in nanoamperes and microvolts (such as those generated in the human body), the amplifiers would have to be no more than a few inches apart—just like the acupuncture points."

Dr. Becker and his assistant, Maria Reichmanis, a young biophysicist, designed special equipment to measure and map the electrical conductivity along the channels. They found the predicted electrical characteristics along the channels and at half the points. These same points showed up on all the people tested. They suggested that the other traditional points may simply be weaker, or of a different kind, than the ones that their instruments detected.

Each point that they found was electrically positive compared to its surrounding tissue, and each point had an electrical field surrounding it with its own characteristic shape.

Later research (see appendices) in China, France, and the United States has shown not only that these points and channels have electrical properties but that they also emit and absorb light and sound, both of which are vital to healthy biological functions.

THE FOUR CATEGORIES OF ENERGETIC POINTS

Points are divided into four categories (Figure 8.2) and are described as follows.

1. Channel points are the Primary points that are distributed along the Twelve Primary Channels and the Conception and Governing Vessels. There are 365 channel points.
2. Extra points are not regarded as having a specific origin in the fourteen main channels, although they are named and are in definite locations. These points are also called "miscellaneous points."
3. New points are a fairly large group of points discovered since the Communist "Liberation" of 1949, in many cases through electric point detection. These points generally have no energetic description, but do have indications. Combined with the Extra points, there are more than 700.
4. Ahshi Points are tender or painful spots near a diseased or injured area and can be anywhere, on or off of traditional points and channels. They function like trigger points, as they are points of tension or pain. Ahshi points are not given specific names or definite locations as they are mostly used for pain syndromes.

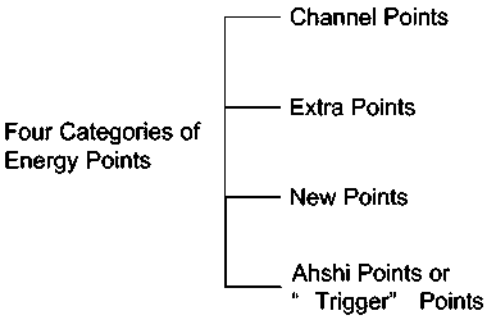

Figure 8.2. The Four Categories of Energetic Points

THE TWO GATES OF ENERGETIC POINTS

Another way of categorizing the points is into the two general types commonly used by the Qigong doctor.

1. The Outer Qi Gates are points through which the patient's Shen and Qi enter and leave the body. The Qigong doctor or patient may gather healing Qi from the outer environment through these gates. In terms of pathology, these points are especially vulnerable to the Six External Pathogens, i.e., Cold, Hot, Wind, Damp, Dry, and Fire invasion (see Chapter 21), which may enter the body through these gates. These same pathogens may also be ex-

pelled through these gates. For this reason, many of these outer Qi gates have the word Feng (Wind) in their names, such as Fengchi GB-20 (Wind Pool).

2. The Inner Qi Gates are points through which the Qi of the Yin and Yang organs and channels is transported back and forth internally and externally, deeply and superficially. These points are more involved with the movement of Qi within the body and are less involved in the exchange with the outer environment. In this way, the Inner Qi Gates enable the Qi to communicate between the different parts of the body.

These two types of points (or gates) are specific areas where the Qigong doctors concentrate their intention and focus their energy extension. Point locations have a greater amount of accumulated Qi, and are used for dispersing or tonifying the body's organ energy, to promote the correct balanced circulation of Qi and Blood.

THE THREE FUNCTIONS OF ENERGETIC POINTS

The points can be used for three clinical functions: to manipulate Qi and Blood, for diagnosis, and to serve as pathways for the elimination of disease.

1. Qi and Blood can be manipulated to purge Excess conditions, tonify Deficient conditions, or for regulation.
   a. To disperse Excess conditions, the Qigong doctor emits Qi over a specific point (or points) and begins to purge, or disperse, the energy in the area (to purge is to remove toxins directly from the organ, whereas to disperse is to lead the toxins out through the channels). The goal of this treatment is to move any Excess, particularly stagnant Qi and Blood. If only Qi is stuck, the pain will move and feel dull. If only Blood is stuck, the pain will not move and will be sharp. This distinction, however, is more important in Chinese herbology than it is for medical Qigong, acupuncture, or massage because, as stated in the classics, "Qi is the commander of Blood"; therefore, moving the Qi in the latter therapies will also move stagnant Blood.
   b. To tonify a Deficient condition, the Qigong doctor emits Qi over a specific point or points, and begins to tonify or strengthen the patient's Qi, Blood, Yin, Yang, or specific organs and tissues. The Qigong doctor uses varying techniques according to the patient's needs (e.g., in order to prevent feeling discomfort, the doctor will tonify weak patients slowly).
   c. To regulate, the Qigong doctor emits Qi over a specific point or points, and allows the body's natural homeostasis to take over and restore healthy function. This type of treatment is also used when a patient has a combined Excess/Deficiency syndrome (such as stagnant Qi in the chest due to a Qi Deficiency in the Lungs and Kidneys).

   The healing potential of point stimulation can be accomplished through various modalities, such as Energy Projection, Energetic Point Therapy, Jing Point Therapy or Invisible Needle Therapy.
2. Diagnosis through point palpation and inspection is an important diagnostic tool in all the branches of Chinese medicine. If a point hurts when touched with light pressure, is hard or swollen, or is purple, black and blue, or red, this indicates an Excess condition. If the point hurts on deep pressure or is soft to the touch, lacks resilience, or is sallow in color, it indicates an underlying Deficiency.

   The skin over points often feels sticky, in contrast to the slippery or smooth quality of the skin surrounding the point. When passing the fingers over a point, the doctor generally feels the energetic pulse of the channel. When touched, the point energetically responds like an echo, vibrating along the channel into the organ and then back again to the

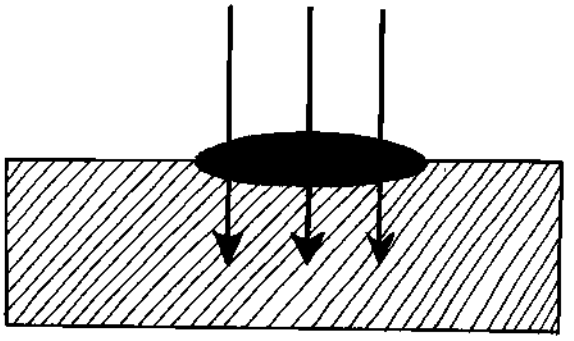

Figure 8.3. Weak or Deficient tissue will naturally pull and absorbe Qi into the surrounding areas.

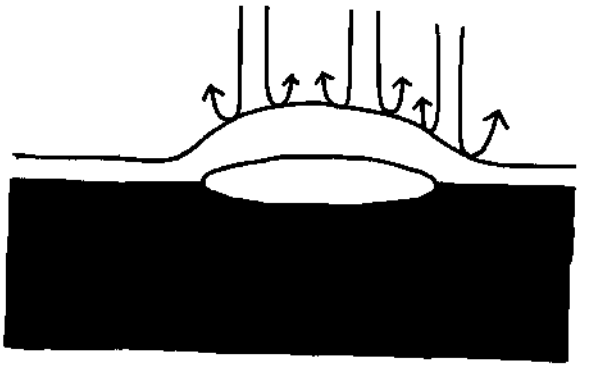

Figure 8.4. Strong, Excess, or Armored tissue will naturally repel Qi from the surrounding areas.

doctor's finger. The doctor can use this energetic response for diagnostic evaluation by sending a pulse along the flow of the channel or against it (into the organ itself). Once sufficient stimulation is applied to the point, its organ or region is "reminded" of its normal function. In this way, diagnosis and treatment are accomplished simultaneously.

Once the location and energy flow of the channel to be treated is diagnosed, the doctor must take into consideration that each patient will react differently in accordance with the severity of symptoms, as well as the individual's constitutional type. Before beginning treatment, the doctor should extend Qi between the energetic point's boundary (the space separating the Wei and Ying energy levels), until the soreness or distention is felt on the tips of the doctor's fingers or palms (which act like a barometer). This form of diagnosis determines the condition of the channel and the area needing treatment. Although the feelings and sensations will vary with each patient, energetic truths remain constant. For example:

a. Weak or Deficient areas will feel like an empty hole or deep well. Deficient Blood or Qi will actually pull the energy into the area and will feel something like a subtle vacuum suction. If the area that the doctor is treating attacks his or her Qi and begins to absorb it, the doctor should tonify that area immediately. Think of this reaction as a dry house plant starving for water. The minute the water touches its soil, the plant immediately absorbs it into its roots (Figure 8.3).
b. Strong or Excess areas will repel the doctor's Qi. If the diseased area repels the doctor's Qi, he or she must immediately dredge the Excess. First, the doctor should focus on the region surrounding the Excess to drain the Excess energy away from the damaged points, then dredge the Excess energy away from the original trauma area. This technique is excellent for damaged or sprained joints. The doctor should focus on the patient's breathing when dredging. As the patient inhales, the doctor exhales and vice-versa. As the patient exhales, he or she releases pathogenic factors; by inhaling when the patient exhales, the doctor facilitates this process, and prevents depletion of his or her own Qi (Figure 8.4).

3. Disease transmission may occur due to the External invasion of pathogenic Qi into the body through the points. Some points are particularly vulnerable to exogenous invasions, especially Wind invasion. Wind-susceptible points usually have the word Feng in their names.

POINT NAMES

Traditionally, each point has a name, which either describes its location, its energetic function, or both. In addition, modern acupuncture texts have assigned a name and number for each point, according to its channel and its order along the natural course of the channel.

Sometimes a point may have several different traditional names, varying according to whether they are being used by medical Qigong doctors, acupuncturists, martial artists, or religious practitioners; for example, GV-1 is called Changqiang (Long Strength) in Traditional Chinese Medicine, and Weilu (Tail Gate) in medical Qigong and Daoist inner alchemy.

The history of point naming and the different terminologies used can be traced back to the different Buddhist and Daoist temples in ancient China. Each religious sect had its own specific names given to certain points, in accordance with the temple's spiritual and energetic needs. Giving the points different names was a form of secret code, used to keep the system pure and to prevent the knowledge from falling into the hands of the uninitiated or unscrupulous.

Sometimes the same name may refer to different points or areas on the body; for example, Yuzhen (Jade Pillow), located in the occipital region on the posterior base of the skull, is the name commonly used for Bl-9 in Traditional Chinese Medicine. However, in medical Qigong and Daoist inner alchemy, Yuzhen instead refers to an entire area the size of one's fist placed between the bilateral Bl-9 points.

CLASSIFICATION OF ENERGETIC POINTS

The points are further classified according to their energetic potential. This classification will assist the doctor of Traditional Chinese Medicine in choosing the right point or points to treat. The following is a list of energetic point classifications.

THE FIVE ANTIQUE SHU POINTS

Like the internal organs and channels, some points have a more powerful influence on the body then others. Each point has an action on the quantity of energy of an organ. Along each of the Twelve Primary Channels lie five specific points below the elbow or the knee called Antique Shu points (also called Transporting points and Command points). These points belong to the oldest classification of points, and are described in water images, comparing each section of the channel to the course water takes as it emerges from the ground and makes its way to the ocean. They are identified as follows: Jing (Well), Ying (Spring), Shu (Stream), Jing (River), and He (Sea). These five points are situated along the flow of energy from the extremities to the torso (running from the fingers to the elbows and from the toes to the knees), occupying the same progressive location along the patient's channels (Well, Spring, Stream, River, and Sea).

Centrifugal and Centripetal Energy Flow

All of the body's channel points energetically progress in two opposite currents according to the direction and flow of the channel's energy. These two energy currents are described as follows.

1. The Channel's Outward Centrifugal Flow of Qi passes from the organ, through the channel, to the point, and is expressed or intensified through the patient's exhalation. The outward centrifugal flow of energy is manifested in channel points and in areas of the body where there are conditions of Excess.
2. The Channel's Inward Centripetal Flow of Qi passes from the point, through the channel, to the organ. The inward centripetal flow of energy is manifested in channel points and areas of the body where there are conditions of Deficiency.

Through stimulation, channel points fulfill a double function. Centrifugally, they inform the doctor of impending internal disorders by discharging Excess energy. Centripetally, they transmit the energetic action placed on them, absorbing energy to supply the body's internal insufficiencies.

Yin and Yang Channels and the Five Elements

Each of the Five Antique Shu points also corresponds to the Five Elements, in the progression of the Creative Cycle. Each Yin channel begins

Points	Yin Channel Elements (Ethereal Soul—Hun)	Yang Channel Elements (Corporeal Soul—Po)
Jing-Well Points	Wood	Metal
Ying-Spring Points	Fire	Water
Shu-Stream Points	Earth	Wood
Jing-River Points	Metal	Fire
He-Sea Points	Water	Earth

Figure 8.5. The Five Antique Shu Points and their Correspondence to the Five Elements

with the Hun progression through the Five Elements, starting with Wood, then Fire, Earth, Metal, and Water. Each Yang channel begins with the Po progression through the Five Elements, starting with Metal, then Water, Wood, Fire, and Earth (Figure 8.5).

Similar to the eyes relationship to Wood (Hun) and Metal (Po), the beginning points on the Twelve Primary Channels also have a relationship to either a Wood (Ethereal Soul) or Po (Corporeal Soul) connection. Hence, in meditation exercises, when specific finger tip points are connected, the blending of the Hun and Po energies are established. The practice of connecting specific finger tip points is sometimes referred to as the connection (or fusion) of the body's Ethereal and Corporeal Soul.

The Five Antique Shu points energetically flow from superficial to deep and are susceptible to external pathogens and climatic changes. The distal points on the feet tend to be more powerful than those on the hands. After the manipulation of the patient's distal points, the local channel points are used according to their feeling of tenderness. The Five Transporting points are explained as follows.

1. Jing-Well points are the first points along the extremities of the channels and are located at the tips of the fingers and toes. These points are where the energy of the channel pools and is at its most superficial and thinnest.

   These points are where the energy of the channels leaves the body moving centrifugally outward. At the end of the fingertips and toes, the channel's energetic polarity changes from Yin to Yang or vice versa. Due to this shift in polarity, the energy at the channel's extremities tends to be unstable, and therefore more easily influenced.

   Due to their outward movement of energy, the Well points can be used by the Qigong doctor to eliminate the patient's pathogenic factors quickly, especially when the Yin organs are affected. The Well points will also have a strong effect on the patient's mental state, quickly changing the patient's mood. These points are generally used for acute disorders, expelling exogenous pathogens, and mental disorders. They are used as "revival" points for loss of consciousness from fainting and heat stroke, convulsions, a feeling of fullness below the Heart, and local neuropathy (tingling, numbness, burning pain). In mental disorders, they are commonly used for irritability, mental restlessness, anxiety, hysteria, mania, and insomnia.
2. Ying-Spring points are the second points along the channels and, in all cases, are located in the second position of the channels' energetic progression up the arms or legs, and are located next to the Well points. These points are where the channel's energetic flow quickens its progression of Qi into the body.

At the location of the Spring points, the Qi in the channels is very dynamic and powerful. Slipping and gliding like the swirling movement of cascading water, the energy in these points can change quickly. The Spring points are generally used to eliminate Internal and External pathogenic factors (especially Heat) from the patient's body. They are also used when a disease effects a color change in the patient's complexion.

In the Yin channels, this point is always a Fire Element. Purging the Spring point in the Yin channels reduces Heat and clears Fire. In the Yang channels, the Spring point is always the Water Element point. The doctor can reduce Heat in the patient's Yang channel by tonifying this Water point.

3. Shu-Stream points are the third points along the channels and are located in the third position in the channels' energetic progression up the arms or legs, next to the Spring point (except for the Gall Bladder's Channel where it is the fourth point). These points are where the channel's energy rapidly pours through and slightly deepens its flow into the body.

   At these points, the external pathogenic factors penetrate deep into the channels and can be "transported" into the body's interior. These points are used to clear Wind and Dampness from the patient's channels or when a disease manifests intermittently.
4. Jing-River points are the fourth of the Five Transporting points; they are, however, not always located on the fourth point along the channel. The points are, however, always located between the wrist and elbow on the arms and between the ankle and knee on the legs. These points are where the channels broaden, and the energy flow continues to increase.

   At these points, the energy current flows wider, deeper, and more irregularly, like a large river, directing the invasion of external pathogenic factors towards the body's tendons, joints, and bones. These points are generally used when there is stagnation of Qi and Blood in the patient's channels, as well as for coughing, asthma, dyspnea, sore throat, and upper respiratory diseases.
5. He-Sea points are the fifth points of the Five Transporting points and, in all cases, are located at the elbows and knees. These points are where the energy of the channels is vast and plunges deep into the body.

   The Qi at the He-Sea points moves centripetally inward, flowing much slower, joining, collecting, and fusing with the general circulation of the body's energy (like a mighty river flowing into the sea). The He-Sea points are generally used for all Stomach and Intestinal diseases and for Internal disorders of the organs.

THE FIVE ELEMENTAL POINTS

Each of the Five Elemental points correspond to the Five Antique Shu points. The Five Elemental points are aligned in the progression of the Creative Cycle. Each Yin Channel begins with the Three Ethereal Souls (Hun) progression through the Five Elements, starting with Wood, then Fire, Earth, Metal, and Water. Each Yang channel begins with the Seven Corporeal Souls (Po) progression through the Five Elements, starting with Metal, then Water, Wood, Fire, and Earth.

THE SIXTEEN XI CLEFT (ACCUMULATION) POINTS

These points are used for purging acute conditions of Excess in the channels and organs. There is one point on each of the Twelve Primary Channels, plus one point on the Yin and Yang Heel Vessels, and one point on the Yin and Yang Linking Vessels. The Yin Channel Accumulation points are Lu-6, Pc-4, Ht-6, Sp-8, Lv-6, Kd-5, Yin Heel Kd-8, and Yin Linking Kd-9. The Yang Channel Accumulation points are LI-7, TB-7, SI-6, St-34, GB-36, Bl-63, Yang Heel Bl-59, and Yang Linking GB-35.

THE TWELVE FRONT MU (ALARM, COLLECTING) POINTS

The energy of the organs collect at these points; therefore, they can be used for both diagnosis and treatment. These points are palpated for diagnosis and may feel tender to the patient, either spontaneously or upon pressure. If they re-

spond to light pressure or feel tight or swollen, the patient has an Excess condition; if the points respond to deep pressure or feel hollow or deflated the patient has a Deficient condition. The Twelve Front Alarm points are: Lungs Lu-1, Pericardium CV-17, Liver Lv-14, Spleen Lv-13, Gall Bladder GB-24, Kidneys GB-25, Heart CV-14, Stomach CV-12, Large Intestine St-25, Triple Burners CV-5, Small Intestine CV-4, and Bladder CV-3.

THE EIGHTEEN BACK SHU (ASSOCIATED, TRANSPORTING) POINTS

These points are all located on the Bladder Channel and are used for both diagnosis and treatment. These points transport Qi very effectively and directly to the internal organs. They can be used for treating the corresponding sense organs. The Eighteen Back Transporting points are: Lungs Bl-13, Pericardium Bl-14, Heart Bl-15, Governing Vessel Bl-16, Diaphragm Bl-17, Liver Bl-18, Gall Bladder Bl-19, Spleen Bl-20, Stomach Bl-21, Triple Burners Bl-22, Kidneys Bl-23, Sea of Qi Bl-24, Large Intestine Bl-25, Gate to the Yuan Qi (Guan Yuan) Bl-26, Small Intestine Bl-27, Bladder Bl-28, Sacrum Bl-29, and Anus Bl-30.

THE FIFTEEN LUO (CONNECTING) POINTS

One of these points is located on each of the Twelve Primary Channels, as well as the Governing and Conception Vessels and the Great Luo point of the Spleen. These points are used to treat channel pathology. The Fifteen Collateral points are divided into Yin and Yang channel points. Yin Channel points include: Lu-7, Pc-6, Ht-5, Sp-4, Lv-5, Kd-4, CV-15, and the Great Luo Channel Sp-21. The Yang Channel points include LI-6, TB-5, SI-7, St-40, GB-37, Bl-58, and GV-1.

THE TWELVE ENTRY POINTS

These points are where the energy from a Primary Channel enters its coupled channel in the Horary Cycle. The entry point is the first point on each channel in all cases, except for the Large Intestine's Channel in which it is LI-4.

THE TWELVE EXIT POINTS

These points are where the Qi leaves the Primary Channel to flow into its coupled channel in the Horary Cycle. The Yin Channel Exit points include: Lu-7, Pc-8, Ht-9, Sp-21, Lv-14, and Kd-

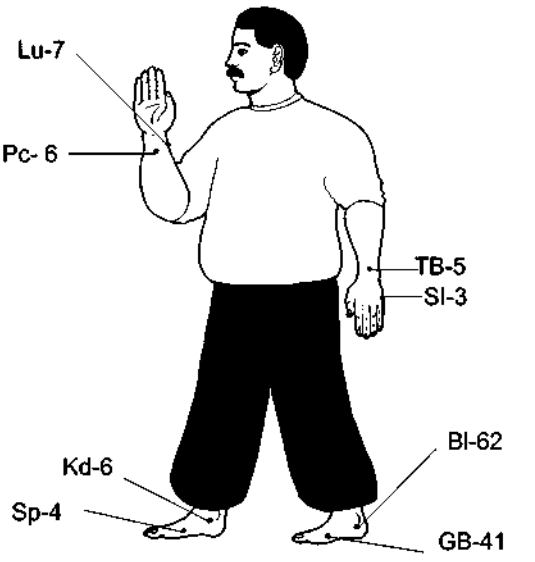

Figure 8.6. Locations of the Body's Master and Couple Points

Channel	Open with Master Point	Complete with Couple Point
Governing	Hand (SI-3)	Foot (Bl-62)
Conception	Hand (Lu-7)	Foot (Kd-6)
Thrusting	Foot (Sp-4)	Hand (Pc-6)
Belt	Hand (TB-5)	Foot (GB-41)
Yin Linking	Hand (Pc-6)	Foot (Sp-4)
Yang Linking	Foot (GB-41)	Hand (TB-5)
Yin Heel	Foot (Kd-6)	Hand (Lu-7)
Yang Heel	Foot (Bl-62)	Hand (SI-3)

Figure 8.7. The Vessels with their Associated Master Points and Couple Points

22. The Yang Channel Exit points include: LI-20, TB-23, SI-19, St-42, GB-41, and Bl-67.

THE EIGHT INFLUENTIAL POINTS

These points have specific effects on their respective organs, substances, and tissues. They affect the body's Qi, Blood, sinews, blood vessels, bones, and Marrow, as well as the Yin and Yang organs. The Eight Influential points are as follows: Yin Organs Lv-13, Yang Organs CV-12, Qi CV-17, Blood Bl-17, sinews GB-34, blood vessels Lu-9, Bones Bl-11, and Marrow GB-39.

THE EIGHT CONFLUENT POINTS

These eight points communicate with the Eight Extraordinary Vessels. The Confluent points are divided into Master and Coupled points. The Master point is the primary point chosen for treatment, its Coupled point is the connecting or secondary point used to open the specific Vessel. Each of the Eight Extraordinary Vessels has both a Master and Coupled Confluent point on the upper or lower limbs.

All of the Eight Extraordinary Vessels can be treated in various combinations according to their specific Master and Coupled point locations (Figure 8.6). If, for example, the Qigong doctor causes Qi to flow from the patient's Master point on the hand (SI-3) to its Coupled point (Bl-62) on the foot, the Governing Vessel will open. To complete the treatment, the doctor must first remove stimulation from the Coupled point then disconnect from the Master point (Figure 8.7).

The Eight Confluent points are as follows: Governing Vessel SI-3, Conception Vessel Lu-7, Belt Vessel GB-41, Thrusting Vessels Sp-4, Yang Heel Vessel Bl-62, Yin Heel Vessel Kd-6, Yang Linking Vessel TB-5, and Yin Linking Vessel Pc-6.

THE TWELVE YUAN-SOURCE POINTS

Each of the Twelve Primary Channels has a Yuan-Source point, where the body's Original Qi surfaces and pools. On the Yin Channels, the Yuan-Source points are always the Shu-Stream points. On the Yang Channels, however, the Yuan-Source points are separate points located between the Shu-Stream and the Jing-River points. These points are usually the fourth point from the distal end of the channel, except in the case of the Gall Bladder Channel, where the Yuan-Source point is the fifth point.

The Yuan Qi originates and resides in the Lower Dantian area and is dispersed to the Yin and Yang organs and then to the limbs by the Triple Burners.

The Yuan-Source points can be used clinically in diagnosis for the Yin organs. The Qigong doctor examines the points by both palpation and visual diagnosis.

The Yuan-Source points are the primary points on the Yin channel for tonifying and regulating their respective Yin organs. On the Yang Channels, the Yuan-Source points are quite different in terms of their importance and energetics. These points generally have a negligible tonifying effect on their related Yang organs and comparatively little Qi regulating effect. Their main functions are to expel various pathogenic factors, and to treat disorders along their channel pathways. The Twelve Yuan points are as follows: Gall Bladder GB-40, Liver Lv-3, Lungs Lu-9, Large Intestine LI-4, Stomach St-42, Spleen Sp-3, Heart Ht-7, Small Intestine SI-4, Bladder Bl-64, Pericardium Pc-7, and Triple Burners TB-4.

THE POINTS OF THE FOUR SEAS

The human body has four seas: the Sea of Qi, Sea of Blood, Sea of Marrow, and the Sea of Nourishment (literally Water and Grain). To access these seas, the Qigong doctor stimulates the following points:

1. The Sea of Qi points include: Bl-10, St-9, CV-17, GV-14 and GV-15. When the Sea of Qi is in Excess, symptoms include fullness in the chest, flushed complexion, and dyspnea. When the Sea of Qi is Deficient, symptoms include fatigue or low energy and an inability to speak.
2. The Sea of Blood points include: Bl-11, St-37, and St-39. When the Sea of Blood is in Excess, symptoms include anxiety, uneasiness, and unrest, and the entire body feels big. When the Sea of Blood is Deficient, symptoms include the body feeling too small for no apparent reason.
3. The Sea of Marrow points include: GV-15, GV-

16, GV-17, and GV-20. When the Sea of Marrow is in Excess, symptoms include sensations relating to that of Excess energy (lightness, feelings of strength and vitality). When the Sea of Marrow is Deficient, symptoms include fatigue, vertigo, dizziness, tinnitus, pain in the lower legs, impaired vision, and a desire to sleep.

4. The Sea of Nourishment points include: St-30 and St-36. When the Sea of Nourishment is in Excess, the abdomen feels distended. When the Sea of Nourishment is Deficient, symptoms include hunger with an inability to eat.

UPPER (UNITING) HE-SEA POINTS

There are three points on the upper arm that have a powerful effect on the Yang organs. The affected organs and their points include the Stomach LI-10, Large Intestine LI-9, and the Small Intestine LI-8.

LOWER (UNITING) HE-SEA POINTS

Each of the Yang organs has a uniting He-Sea point on the leg, which can be used to treat Yang organ problems. The three Yang channels of the feet also correspond to the three Yang channels of the hands. The Lower Six Lower He-Sea points are as follows: Stomach St-36, Large Intestine St-37, Small Intestine St-39, Triple Burners Bl-39, Bladder Bl-40, and Gall Bladder GB-34.

THE ELEVEN GHOST POINTS

In ancient times, these eleven points were traditionally used for spirit possession and have a specific effect on the mind's psychological functions. In traditional Chinese medical clinics today, these points are commonly used to treat emotional disorders. The Eleven Ghost points are as follows: GV-26, Lu-11, Sp-1, Pc-7, Bl-62, GV-16, St-6, CV-24, Pc-8, GV-23, and LI-11.

THE TEN WINDOW OF THE SKY POINTS

These ten points also have a specific effects on the mind's psychological functions and are also commonly used to treat emotional disorders. The Ten Window of the Sky points are as follows: Lu-3, LI-18, TB-16, Bl-10, St-9, CV-22, GV-16, SI-16, SI-17, and Pc-1.

SUMMARY OF POINTS

Understanding the origin and function of the body's energetic points, as well as the Qi flow along the energetic channels, allows the Qigong doctor to emit energy through these energetic cavities to easily access the tissues and internal organs of the patients body. It is through this understanding that the doctor can also lead and purge the Toxic or pathogenic Qi (which has become stagnant or detrimentally active within the patient's body) away from the diseased organs, through the channels and out the body.

The following graph (Figure 8.8) is a basic categorization of the body's points and their descriptions.

Category	Points	Description
Five Antique Shu Points	Jing-Well, Ying-Spring, Shu-Stream, Jing-River, He-Sea	Transporting and Command Points
Sixteen Xi Cleft Points	Yin: Lu-6, Pc-4; Ht-6, Sp-8, Lv-6, Kd-5, Yin Heel Kd-8, and Yin Linking Kd-9 Yang: LI-7, TB-7, SI-6, St-34, GB-36, BI-63, Yang Heel BI-59 and Yang Linking GB-35	Accumulation Points
Twelve Front Mu Points	Lungs Lu-1, Pericardium CV-17, Liver Lv-14, Spleen Lv-13, Gall Bladder GB-24, Kidneys GB-25, Heart CV-14, Stomach CV-12, Large Intestine St-25, Triple Burners CV-5, Small Intestine CV-4, and Bladder CV-3	Alarm, Collecting Points
Eighteen Back Shu Points	Lungs BI-13, Pericardium BI-14, Heart BI-15, Governing Vessel BI-16, Diaphragm BI-17, Liver BI-18, Gall Bladder BI-19, Spleen BI-20, Stomach BI-21, Triple Burners BI-22, Kidney BI-23, Sea of Qi BI-24, Large Intestine BI-25, Gate to the Original Qi (Guan Yuan) BI-26, Small Intestine BI-27, Bladder BI-28, Sacrum BI-29 and Anus BI.30	Associated, Transporting Points
Fifteen Luo Points	Yin: Lu-7, Pc-6, Ht-5, Sp-4, Lv-5, Kd-4, CV-15, the Great Luo Channel Sp-21 Yang: LI-6, TB-5, SI-7, St-40, GB-37, BI-58 and GV-1	Connecting Points
Twelve Entry Points	The first point on each channel except for the Large Intestine Channel in which it is LI.4	Qi enters Channel
Twelve Exit Points	Yin: Lu-7, P-8, Ht-9, Sp-21, Lv-14 and Kd-22 Yang: LI-20, TB-23, SI-19, St-42, GB-41 and BI-67	Qi exits Channel
Eight Influential Points	Yin Organs Lv-13, Yang Organs CV-12, Qi CV-17, Blood BI-17, Sinews GB-34, Blood Vessels Lu-9, Bones BI-11 and Marrow GB-39	Influence Internal Organ Function
Eight Confluent Points	Governing Vessel SI-3, Conception Vessel Lu-7, Belt Vessel GB-41, Thrusting Vessels Sp-4, Yang Heel Vessels BI-62, Yin Heel Vessels Kd-6, Yang Linking Vessels TB-5 and Yin Linking Vessels Pc-6	Master and Couple Points
Twelve Yuan-Source Points	Gall Bladder GB-40, Liver Lv-3, Lungs Lu-9, Large Intestine LI-4, Stomach St-42, Spleen- Sp-3, Heart Ht-7, Small Intestine SI-4, Bladder BI-64, Pericardium Pc-7, and Triple Burners TB-4	Source of Original Qi Points
Four Seas Points	Sea of Qi Points: BI-10, St-9, CV-17, GV-14 and 15 Sea of Blood Points: BI-11, St-37 and 39 Sea of Marrow Points: GV-15, 16, 17, and 20 Sea of Nourishment Points: St-30 and 36	Give Access to the Four Seas
Upper He-Sea Points	Stomach LI-10, Large Intestine LI-9 and the Small Intestine LI-8	Affect the Yang Organs
Lower He-Sea Points	Stomach St-36, Large Intestine St-37, Small Intestine St-39, Triple Burners BI-39, Bladder BI-40, and Gall Bladder GB-34	Affect the Yang Organs
Eleven Ghost Points	Governing Vessel 26, Lungs 11, Spleen 1, Pericardium 7, Bladder 62, Governing Vessel 16, Stomach 6, Conception Vessel 24, Pericardium 8, Governing Vessel 23, and Large Intestine 11	Affect the Mind, Emotion, and Spirit
Ten Windows of the Sky Points	Lung 3, Large Intestine 18, Triple Burners 16, Bladder 10, Stomach 9, Conception Vessel 22, Governing Vessel 16, Small Intestine 16, Small Intestine 17, and Pericardium 1	Affect the Mind, Emotion, and Spirit

Figure 8.8. Point Graph

CHAPTER 9
THE EXTRAORDINARY YANG ORGANS

Besides the six Yin organs (Liver, Heart, Pericardium, Spleen, Lungs, and Kidneys) and six Yang organs (Gall Bladder, Small Intestine, Triple Burners, Stomach, Large Intestine, and Bladder), the body has six Extraordinary Yang organs, also called the "curious organs." These Extraordinary organs function like Yin organs (storing Yin Essence, i.e., Blood, Marrow, or Kidney Essence) but look like Yang organs (they are hollow). These six curious organs include the Uterus, Brain, Marrow, Bones, Blood Vessels, and Gall Bladder. The body's Eight Extraordinary Vessels integrate the Extraordinary Yang organs with the main six Yang organs and the Kidneys.

THE UTERUS

In Chinese medicine, the uterus encompasses the fallopian tubes and the ovaries and has the function of regulating menstruation, conception, and pregnancy (Figure 9.1). The uterus connects to the Kidneys (which provide the uterus with Jing), the Conception Vessel (which provides the uterus with Qi and nourishes the fetus), and the Thrusting Channel (which provides the uterus with Blood). Only when the Jing of the Kidneys is sufficient can the menstrual period occur regularly, the woman become pregnant, and fetal growth become possible. The Qi and Blood of the Twelve Primary Channels pass into the uterus through the Thrusting and Conception Vessels, affecting the amount of menstrual flow and its cycle.

The three Yin organs of the Heart, Liver, and Spleen also energetically connect to the uterus through their relationships with the Blood. The Heart governs the Blood. The Liver stores the Blood and regulates the volume of circulating Blood, which is responsible for normal menstruation. The Spleen controls the Blood.

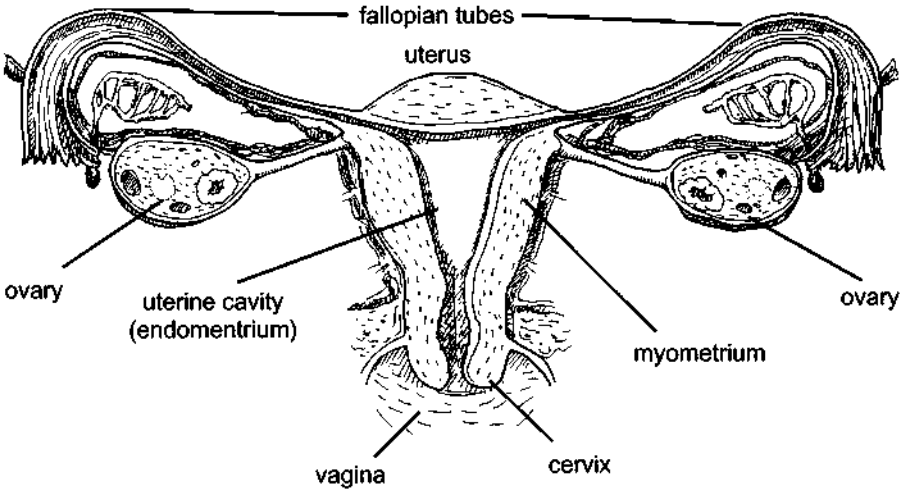

Figure 9.1. The Female Reproductive Organs, including the Uterus, Fallopian Tubes, and Ovaries

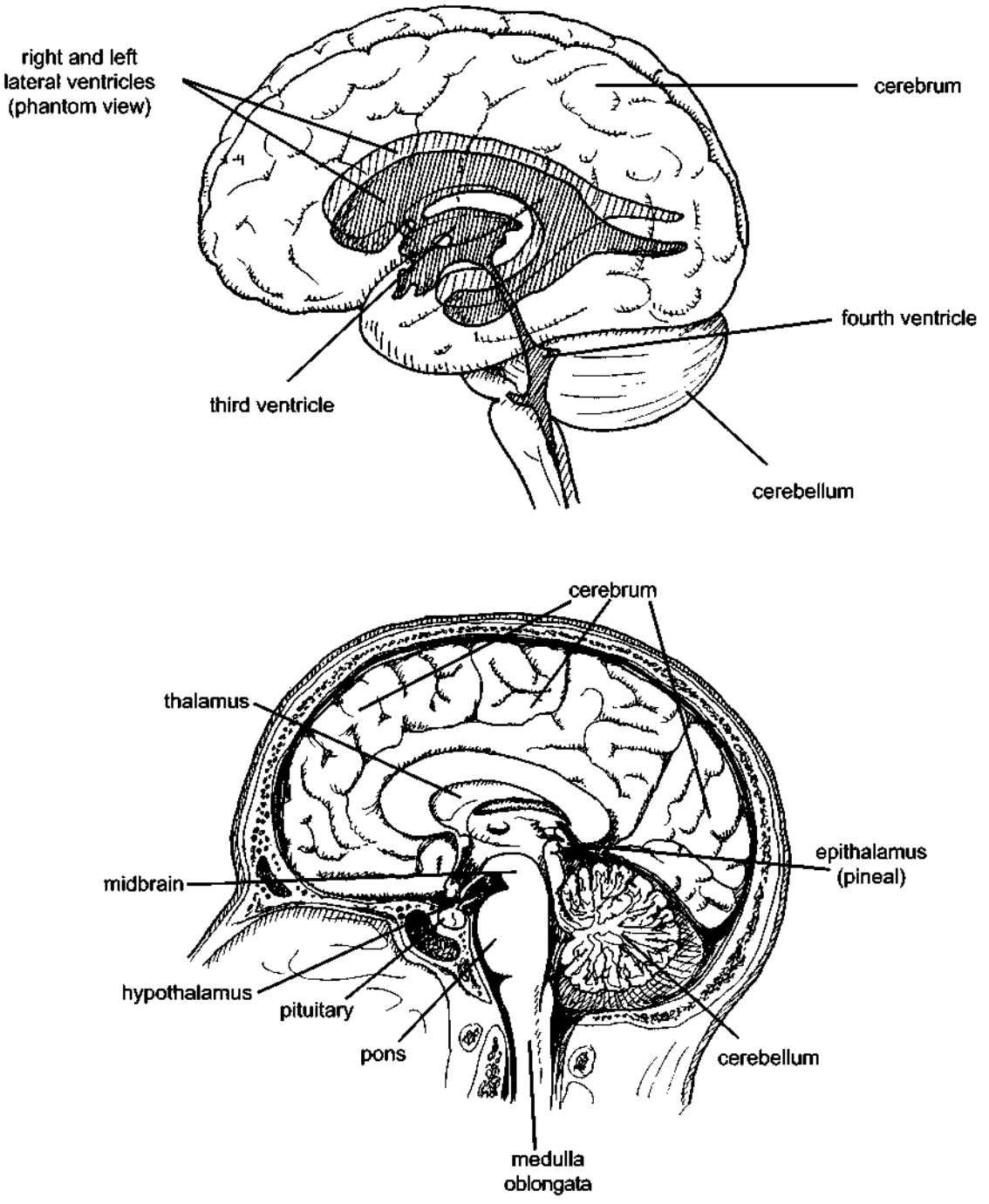

Figure 9.2. The Human Brain

THE BRAIN

The Brain is considered the house of the Yuan Shen, and the seat of mental function. It is believed that the senses and control of the body's physical movements are related to the Brain. The Brain is functionally related to the Kidneys and controls memory, concentration, hearing, touch, sight, and smell. The Brain is also called the Sea of Marrow, extending from the top of the head to the GV-16 Wind Palace point, just below the external occipital protuberance. The Kidney Essence produces Marrow, which fills the spinal cord and Brain. The Brain also depends on the Heart's Blood for its nourishment. Because the Kidneys store the Jing and the Heart governs the Blood, the Brain depends on the balanced state of the Heart and Kidneys for vitality. The Brain is considered a transformation chamber of both Prenatal and Postnatal Essence (Jing) and Energy (Qi). The Brain is regulated by the Governing Vessel, as well as the Yin and Yang Heel Vessels.

This viewpoint is quite different from the Western approach, which views the brain's anatomy as consisting of five regions (Figure 9.2), including:

1. The cerebral hemispheres or cerebrum (the neocortex (neopallium),
2. The thalamus, hypothalamus, and epithalamus (pineal),
3. The midbrain/mesencephalon (the colliculi and cerebral peduncles),
4. The pons and cerebellum, and
5. The medullae oblongata.

In Western medicine, the oldest part of the Brain (situated at the top of the Brain stem) is often called the "reptilian Brain" because its anatomical formation is similar to that found in lizards, alligators, and turtles. Surrounding it is the mammalian Brain, which is called the limbic system. The third part of the Brain is called the neocortex, which wraps itself around the limbic system. All three parts of the Brain (reptilian, mammalian, and neocortex) are viewed as biologically distinct, both in their chemistry and in their structure. The older formations of the Brain are responsible for the autonomic nervous system, whereas the neocortex is responsible for thinking and voluntary movement.

In Chinese energetic medicine, each selective set of the human brain cells absorbs and records sets of vibrations. The Brain receives these vibrations through the skin, eyes, ears, nose, and mouth, and records them in its cells. The mind interprets these incoming vibrations as images, sounds, smells, and sensations, and organizes these into memories. The extent to which the mind interprets the incoming data depends upon the level of consciousness and awareness of the individual at the time of the recording. When a Qigong doctor, attunes his or her vibrations to the patient's energetic field and emits Qi, the brain cells responsible for storing the vibrations are stimulated. When these vibrations are stimulated through the energy projected by a Qigong doctor, the patient's tissues respond and reproduce an energetic pattern similar to the original one used to record the patient's physical, mental, emotional, energetic and spiritual experiences. This energetic tissue reaction occurs only because the patient's cells are held directly to their same consistent vibrational patterning.

One set of selective brain cells receives, records, and maintains the vibrations of the thoughts, actions, movements, and pictures that other forms project. These vibrations can also be reproduced and projected, being received by the Qigong doctor as images from within his or her own mind through inner-vision. The Qigong doctor can arrange his or her cells' energetic pattern in such a way as to reproduce the words and motions of these forms or objects, even the thoughts of those that sent them. Through these cells, the Qigong doctor can assist his or her patient, as well as him or herself, in controlling their thoughts, as it is through these cells that accidents and disease are brought into existence; for example, someone either observes or imagines a specific thing happening. The corresponding vibration is fixed in the cells, sent out to be imprinted on the corresponding cells of anothers' Brain, then projected back until the incident is so fixed that the occurrence actually happens (self-fulfilling prophecy).

Another set of selective brain cells receives, records, and maintains the vibrations of the thoughts and activities of the divine. The divine energy vibration pervades every substance and is always sending out divine knowledge and true wisdom. Stored within the body are the cells that receive and project the vibrations of the divine Mind. If the doctor separates him or herself from the divine in thought, he or she will also separate from the divine in manifestation.

THE GALL BLADDER

The Gall Bladder stores the bile, which is considered a "pure" fluid. The function of the Gall Bladder is to aid digestion, as well as drain off Excess Heat from the Liver (Figure 9.3). The Gall Bladder is regulated by the energy of the Belt Vessel.

THE MARROW

In Chinese medicine the term Marrow (Sui) is different from bone marrow as defined in Western medicine. The Marrow is the substance which is the common matrix of bones, bone marrow, the spinal cord and the Brain. The Marrow is rooted in the Jing and is connected to the Lower Dantian through the Governing Vessel. It is regulated by the energy of the body's Thrusting Vessels.

The Kidney Jing is the origin of the Marrow. The Marrow functions to form the bone marrow, as well as nourish the Brain and spinal cord. When the Mingmen warms and nourishes the body, the Marrow becomes full (which sustains the body's vertical posture and gives strength to both the Brain and the bones). When the Marrow is full, thinking is clear. Too much thinking leads to Excess Fire, which burns the Brain, causing dizziness, blurred vision, and tinnitus.

Both red and white blood cells are produced in the Marrow of the bones. The red blood cells (which circulate oxygen and eliminate carbon dioxide) are produced within the body's long bones (humerus, femur, tibia, etc.). The white blood cells (vital to the body's immune system) are produced within the body's flat bones (skull, sternum, scapulae, pelvis, etc.) The type of blood cells that are produced depends on the type of Marrow that predominates.

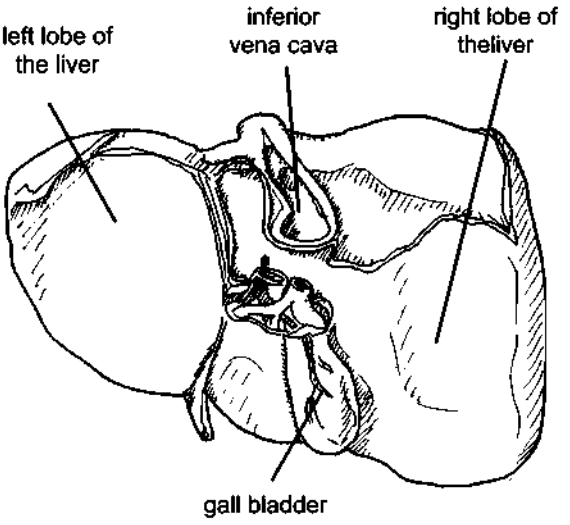

Figure 9.3. The Gall Bladder

When all of the Postnatal energy acquired from the combination of physical (diet, food, and drink), mental/emotional (thoughts and emotions), and spiritual (prayer, meditation, and sex) cultivations is circulated through the Microcosmic Orbit (Fire Cycle), the Prenatal Qi stored in the bone marrow and Brain become stimulated, awaking the spiritual consciousness. This combination and circulation of physical, mental, emotional, and spiritual energy is why the brain marrow is considered to be constructed from the finest and most subtle essences, manifesting the original and hidden power of the Kidneys.

THE BONES

The bones are related to the Kidney's Jing. The bones support the body's structure, strength, and mobility, as well as store the bone marrow (Figure 9.4). The bones are extremely porous and are always "breathing," they are regulated by the energy of both the body's Conception and Thrusting Vessels. The pores of the bones allow Qi and Blood to be absorbed and released, the same way a sponge absorbs and releases water.

There is a natural union between the energetic function of the Marrow and the bones. The Marrow, held within the bones, assures the power and

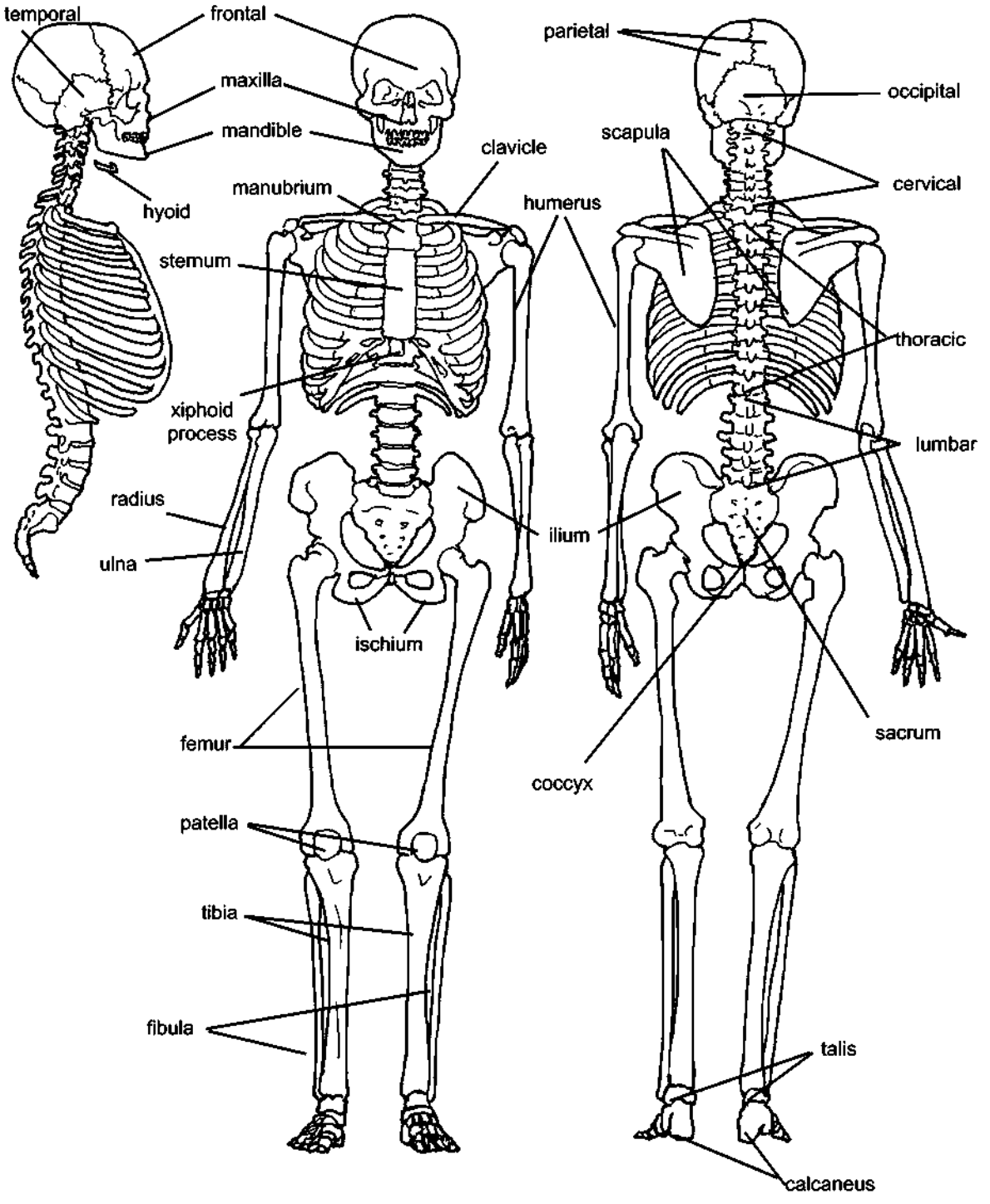

Figure 9.4. The human skeleton consists of 200 bones.

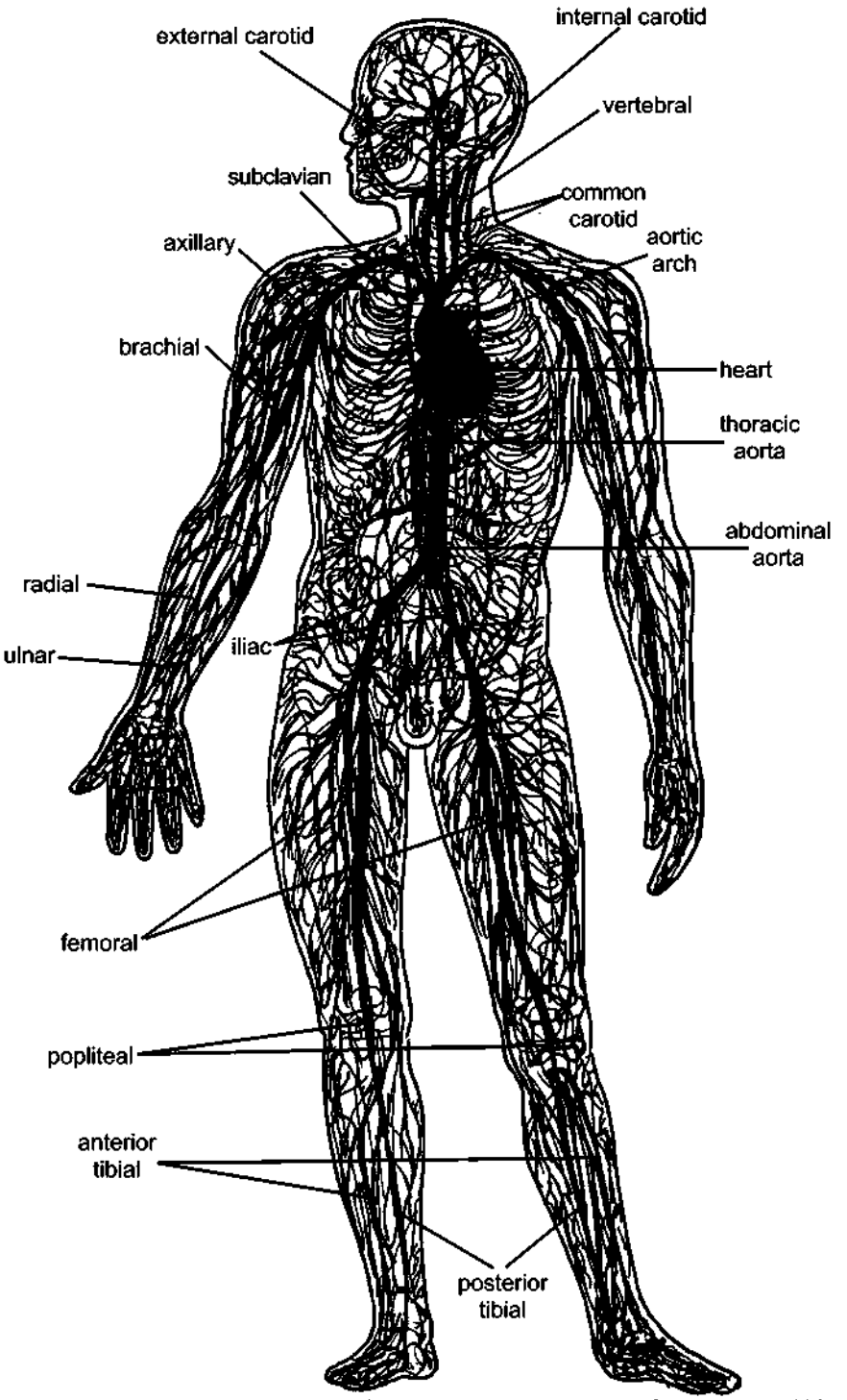

Figure 9.5. The blood-vascular system of the human body consists of the heart and blood vessels.

smooth suppleness of the bones. The bones, in return, prevent the dissipation of the essential richness of the Marrow.

The bones are the only solid crystalline substance in the body capable of generating piezoelectric charges. These electromagnetic charges generate fields of energy that receive and send impulses to the blood cells, tissues, organs, and channels. The Brain, nervous system, Heart, and lower abdomen also generate electromagnetic fields that resonate with the bones, as well as other crystalline-like structures. The crystalline structures of the bones amplify, radiate, and transmit energy, as well as bio-information, to the rest of the body. The rhythmic oscillation of bone-generated electromagnetic fields is released through the transmission of the bones acting as tuning forks. These living tuning forks vibrate the Qi throughout the body's entire physical structure, extending outward into the body's external Wei Qi fields.

THE BLOOD VESSELS

In Chinese medicine, the concept of Blood is different in characteristic and function from that of Western medicine. Blood originates from the transformation of food and drink by the Spleen, which then transfers the refined food energy to be further enhanced by the Heart Qi, Lung Qi, and the Qi of the air.

Qi and Blood flow together, with Qi being the active force that makes the Blood circulate and keeps it within the blood vessels (Figure 9.5). Both Qi and Blood flow within the channels and blood vessels, continuously circulating throughout the body to nourish, maintain, and moisten the tissues. Qi is an energetic form and is considered a Yang substance, while Blood is a liquid form of energy and is considered a Yin substance.

The blood vessels contain Blood and are indirectly related to the Kidneys, because the Kidney Essence (Jing) produces Marrow, which contributes to the production of Blood. The function of the blood vessels is to transport Qi and Blood throughout the body for nutrition and regeneration. The blood vessels are regulated by the energy of the body's Thrusting Vessels, and the Blood is contained in the blood vessels by the Spleen.

Section II
The Three Outer Forces: Heaven, Earth & Man

Chapter 10
Introduction to the Three Outer Forces

The Natural Power of the Three Outer Forces

The Three Outer Forces (Powers) of Heaven, Earth, and Man represent the sum total of all natural forces and energetic factors, which affect the human body on all levels of existence (physical, mental, emotional, energetic, and spiritual). In ancient times, the relationship between the waxing and waning of Heavenly (universal) and Earthly (environmental) energy, as well as the corresponding shifts, changes, and adjustments occurring within the human body, provided the Chinese sages with the theory of the Three Outer Forces. These ancient Chinese masters discovered that the human body's internal network of systems is directly affected by the influences and variations of energetic cycles of the sun, moon, and stars. We now know that these natural influences also affect atmospheric pressures, causing high and low temperatures, which in turn, affect the body's tissues. Recently, Ukrainian physicists found that human DNA vibrates at the same frequency as solar energy.

The Heaven and Earth Powers are responsible for the energetic field changes that cause adjustments and shifts within man's Jing, Qi and Shen (known as the Three Treasures), stored within the internal organs and tissues. Together the combination of Heavenly and Earthly influences affect the functional status of the body's internal organs and the distribution of Qi and Blood throughout the body.

Each of the body's cells, tissues, organs, and organ systems emanates its own specific electromagnetic energy field. This energetic field pulsates at its own particular frequency, regulating the body's internal energy currents and radiating an energetic field that extends outside the body. The body's energetic field (Wei Qi) interacts with and is influenced by the larger energetic fields surrounding it (i.e., power lines, crowds of people, geological formations in the Earth, and the cosmic fields of the solar system).

The Three Outer Force's Nine Treasures

Each of the Three Outer Forces manifest through a secondary triad of Treasures. These Three Treasures complete the energetic matrix that encompasses the Outer Forces unified energetic field.

1. The Three Treasures of the Heavenly Power are the energy fields of the sun, moon, and stars;
2. The Three Treasures of the Earthly Power represent the energy of the Earth (soil and rock), wind, and water;
3. The Three Treasures of Man are contained within man's Essence (Jing), Energy (Qi), and Spirit (Shen).

These three intricate networks exchange their energetic influence and affect the functional status, as well as the distribution of the body's Qi and Blood.

The Three Outer Forces and Chinese Alchemy

Each of the Three Outer Forces and their Three Treasures also constitute the basis of Chinese internal alchemy, whereby Jing (Essence) is transformed into Qi (Energy), Qi is transformed into Shen (Spirit), and Shen is transformed into Wuji (infinite space), and then released back to the Dao (or divine).

The Powers of Heaven and Earth are not only interlinked, but also exist as a microcosm or "small universe" within man's physical body. The human body is an active interaction of two basic elements

of Yin and Yang polarity. Yang energy ascends and is expressed through expansive, active, hard, and aggressive energetic movements. Yin energy descends and is expressed through contractive, passive, soft, and yielding movements. All matter, from the smallest molecular particles to enormous planets and stars, is composed of energy and bound into various patterns of vibration. These matter formations are held in place by electromagnetic and nuclear forces interconnected by the power of Yin and Yang polarity, and are expressed through the Three Outer Forces. The seasonal cycles are an example of Yin Earthly movements, while the solar and lunar cycles are expressions of Yang Heavenly energy.

The creation and manifestation of matter is composed and regulated by what are known as the Five Elemental patterns. In traditional Chinese understanding, it is believed that perfect health and longevity depend largely on man's ability to harmonize with the transitions and five seasonal changes of Heaven and Earth, in accordance with the Five Elemental patterns. In the winter, for example, there is less sunlight, and the temperature can be very cold (Yin), and the Kidneys (Water Element) can easily be overworked; therefore, man should endeavor to lighten his work load and rest more in winter, conserving his Qi to avoid energy depletion.

The principles of Chinese cosmology, Yin and Yang Theory, Five Elements Theory, the *Book of Changes (Yi-Jing)*, and Traditional Chinese Medicine are all incorporated into the study of Medical Qigong. This culmination of knowledge reveals the basic structures of energetic dynamics relating to the universal and environmental energy gathered from the Heavens and Earth, and their relationship with man.

HEAVENLY QI

The first of the Three Outer Forces is known as the Universal Force, Original Force, or Heavenly Energy. This force manifests as the energy of the entire Cosmos. Each life born into human form is not only developed and structured but is also influenced by its own unique group of stars within the Heavenly realm. This particular group of stars (including the sun, moon, planets, and constellations), controls or influences the persons life-force energy (Figure 10.1).

Heaven is the realm that predetermines the energetic cycles of birth and death, as well as the seasons and times of planting, fertility, and harvest. It is the source of the Yuan Shen and the Virtue of Dao, as it manifests through universal awareness (divine inspiration, enlightenment and spiritual communion), and free will. Heaven is the residence of spiritual deities and the Jade Emperor (or Divine Creator), and it manifests its prenatal power in man's life through the mysterious forces of fate, destiny, karma, and reincarnation.

According to the ancient Chinese, we exist in a three-dimensional world that exists within the relative parameters of time and space. Heaven represents time, which is symbolized by the circle. Because time moves in circles, hours and days are defined by the circular rotation of the Earth on its axis; months are defined by the circling of the moon around the Earth, and years are defined by the Earth's orbit around the sun.

PHILOSOPHICAL CORRELATION

Man is constantly absorbing energy from the sun, moon, planets, and constellations. In order to explore the patterns of Heavenly energy in detail, the ancient masters developed the science of Chinese astrology, which includes the study of Twelve Animals and Five Elements, as well as the interactions of the Twenty Eight Constellations, Twelve Earthly Branches, Ten Heavenly Stems, Five Planets, and Lunar and Solar Energy Cycles.

The ancient sciences of astrology and divination evolved as a means to analyze, interpret, and predict how the various forces of Heaven influence and guide man's life on Earth. The study of Chinese astrology involves four elements of comprehension: the study of the Signs, the study of the Five Elements, the study of Yin and Yang, and the study of the Sixty-Year Cycle.

1. The Study of the Signs involves the twelve animals of the Chinese zodiac (meaning circus of animals) that encircle the Earth and are divided into twelve equal parts, called "signs." Each sign of the zodiac has certain

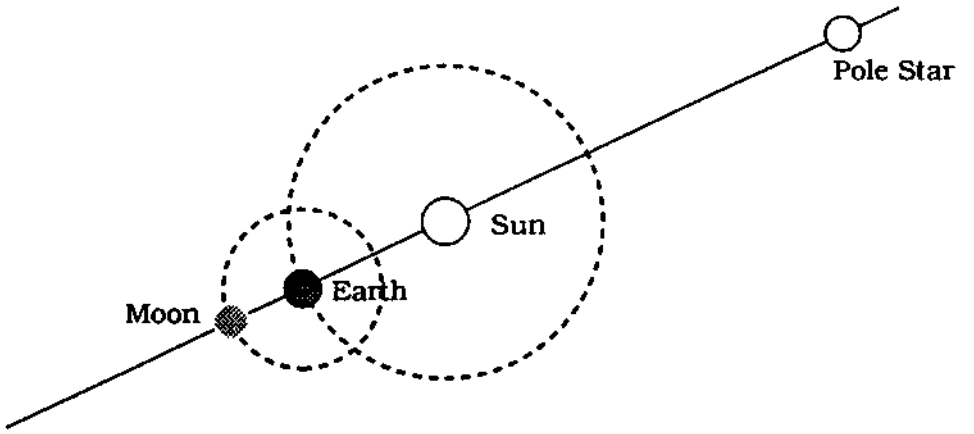

Figure 10.1. The Three Outer Forces of Heaven Consists of the Energy Released from the Sun, Moon and Stars.

characteristics that are determined by a particular planet and constellations. The signs affect the character of a person born under them. Each person is given three animal characteristics: one according to the year, the second according to the month, and the third according to the hour of his or her birth. You might, for example, be a Snake according to the year of your birth, a Boar according to the month, and a Dragon according to the hour. The animal governing your birth year represents your external self (the part you show others) and is said to exert a profound influence over your life. The month animal (known as the lunar animal) represents the emotional and psychological aspects of man's relationships. The hour animal represents the inner self (the part hidden from the rest of the world). The combination of the three determines the uniqueness of each individual.

2. The Study of the Five Elements is the next division involved in the study of signs. Each of the twelve animal signs is further differentiated into one of the Five Elements (Wood, Fire, Earth, Metal, and Water). The year of birth determines the element of the sign. Each element rules for a two-year cycle (e.g., January 27, 1952-February 13, 1953 was the year of the Dragon under the element of Water; February 14, 1953-February 2, 1954, was the year of the Snake under the element of Water. The next Water cycle of Dragon and Snake will be in 2012, based on the sixty-year cycle). These Five Elements display an energetic force that affects the formation of the internal organs in the growing fetus, as well as influences the physical, mental, emotional, energetic, and spiritual changes after the child is born.
3. The Study of Yin and Yang is the third division of the study of signs. Each of the twelve animal signs is also governed by a Yin (passive) or Yang (active) direction. The Yin and Yang cycles alternate each year, with Yang being the even years, and Yin the odd years.
4. The Study of the Sixty-Year Cycle is the final division of the study of signs. The yearly correspondence of the twelve animals of the Chinese zodiac also relates to the Twelve Earthly Branches, and is based on a sixty-year cycle. Every sixty years, the sun, moon, Earth, and the North (Pole) Star are in alignment, and a new sixty-year cycle begins. A sixty-year cycle also completes the rotation of the twelve animals through each of the Five Elements. The Chinese consider sixty years a "century" in terms of the human life cycle.

PHYSICAL CORRELATION

Heavenly Qi relates to the congenital strength and formation of the body's internal organs, as

determined by the Universal Energetic Fields (which include the energy emitted from the sun, moon, planets, and Twenty-Eight Constellations).

HEAVEN'S ENERGETIC GRID

Similar to the grid system imprinted on the body's energetic field, there exists a massive interconnected Heavenly grid extending throughout the entire universe. This Heavenly grid connects the sun, moon, stars, planets, and constellations throughout our universe, and extends to other solar systems outside our celestial sphere. There are pockets of Heavenly energy (like energetic points), as well as subtle frequency pathways (similar to energetic channels), that follow a progression of universal order.

EARTHLY QI

The second of the Three Outer Forces is known as the Environmental Force, Acquired Force, or Earthly Qi. This force manifests as the energy of the entire planet. Each life born into human form is not only developed and structured but also influenced by its own unique environment within the Earthly realm. The Qi of the individual's particular geographic location includes the energy of the plants, soil, water, animals, and all natural formations responsible for controlling or influencing the person's life-force energy.

The Chinese believed that the Earth is the realm that predetermines the abundance of harvest, as well as the temperance of man's physical stamina. Both harvest and man's physical stamina is determined through the cyclic changes of the five seasons and their relationship to the Five Phases (birth, maturation, peak, decay, and death). The Earth is the source of the natural forces and rhythms of nature, as well as the basic elements and energies that compose the material world of soil and water, mountains and valleys, oceans and rivers, plants and animals. The Earth is the foundational base of the Five Elements through the cyclic transformations of nature, which in turn, shape the human body's physiological form and govern the biological functions of the tissues.

The ancient Chinese viewed the Earth as the center, and as the ground on which we stand looking outward toward the four directions. Just as Heaven defines our movement through life in terms of time, Earth defines the space in which we live, providing the energetic field for our unfolding, within the boundaries of time.

In Chinese symbology, the Earth is symbolized by the image of the square, whose walls face the four cardinal directions. This concept of the energetic interaction of Heaven (symbolized by the circle) and Earth's (symbolized by the square) was so fundamental to ancient Chinese thought that they even designed the coinage of the imperial realm to reflect this interconnection (a round coin with a square center).

PHILOSOPHICAL CORRELATION

Earthly Qi relates to the study of Feng Shui (Harmony of Wind and Water). Feng Shui is divided into two prominent schools of study, the Form School and the Compass School.

1. The Form School is the original school of Feng Shui, originating in Southwest China. This school focuses primarily on developing environmental harmony, by observing the shape and form of the terrain in conjunction with the Five Elemental animals.
2. The Compass School is the second school of Feng Shui. It focuses primarily on developing universal and environmental harmony through the directional orientation of the compass, in relationship to the Ten Heavenly Stems, Twelve Earthly Branches, Twenty-Four Solar Compass Directions, and Twenty-Eight Constellations, as well as the Magic Square and the Bagua (Eight Trigrams).

PHYSICAL CORRELATION

Earthly Qi relates to the "acquired" strength (muscular and skeletal development after birth), as well as the formation of the body's internal organs. Tissue development is determined by the environmental energetic fields (which include the energy emitted from the Earth, Water, and Wind/weather). The Earth energy also expresses its power in man's life through the basic instincts for survival and the primal drives for sex and reproduction.

EARTH'S ENERGETIC GRID.

Similar to the Heavenly energetic grid system imprinted in the cosmos, there exists a massive interconnected Earthly grid extending throughout the entire planet. This Earthly grid connects the planet's eight energetic directions into one energetic field. There are pockets of Earthly energy (like energetic points), as well as subtle frequency pathways (similar to energetic channels), that follow a progression of environmental order. One example of the Earth's axial grid system in Western folklore is the "Ley lines," which are energetic pathways that connect energy vortices or places of power on the planet. This understanding of an Earthly energetic grid system is also reflected in American Indian and South American traditional understanding.

MAN'S QI

The third of the Three Outer Forces is known as the Human Force, or Man's Energy. This force manifests as the energy of the entire body (Figure 10.2). Each life born into human form is not only developed and structured, but also influenced by the individual's adaptations to his or her own physical, mental, emotional, energetic, and spiritual energies.

It is believed that within man, the realm of the Dao or divine conscious spirit exists, wherein both the energies of Heaven and Earth coexist in harmonious balance. Man is formed from the cosmic particles of exploded stars that have descended onto the Earth. These particles are absorbed into the soil, water, and foliage, creating sustenance for human life. This constant internal connection, absorption, and regeneration of vibrating energy from Heaven and Earth is the reason that human life is considered to be the highest physical manifestation of the divine energetic field (see Chapter 1).

PHILOSOPHICAL CORRELATION

Man's Qi relates to the study of the Yi-Jing (I-Ching), or Book of Changes. The Yi-Jing is composed of two sections: the Book of Oracles and the Book of Commentaries.

1. The Book of Oracles is the original text by King Wen and the Duke of Zhou. This book is based on the formation of eight trigrams and their various energetic attributes. These eight trigrams combine to form the sixty-four hexagrams of the Yi-Jing, which were later used for divination.
2. The Book of Commentaries is based on the commentaries of Confucius and his followers, and is also called the Ten Wings. The commentaries are called "wings" because each

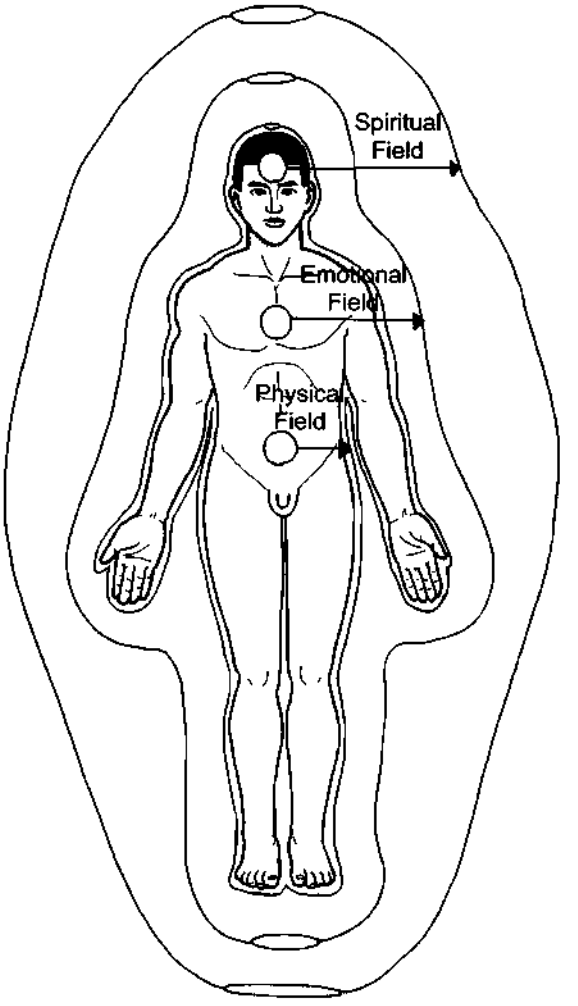

Figure 10.2. The Three Outer Forces of Man's Energy is composed of the Energetic Fields Released from Jing, Qi, and Shen.

wing helps the reader to soar higher in comprehension of the original text.

PHYSICAL CORRELATION

Man's Qi relates to the waxing and waning of man's physical, mental, emotional, energetic, and spiritual biorhythmic cycles.

A Qigong doctor must become proficient at understanding, respecting, and adopting these laws of natural variations between nature and man. Through this understanding the doctor can attain a deeper comprehension of the principles and application of Medical Qigong Dao Yin training (mind concentration methods, respiration regulation, and postural manipulation).

MAN'S ENERGETIC GRID

Similar to the Energetic grid system of Heaven and Earth, the human body is imprinted with a massive interconnected grid that extends throughout the body's tissues into the environment. The body's energetic grid is responsible for transforming energy frequencies from cell to cell, tissue to tissue, and from the body's internal energetic field to its external energetic field. These are known in Traditional Chinese Medicine as the 'Jing Luo' channels and collaterals (or the meridian system). The body's energetic grids are also responsible for maintaining the production, growth, and development of energy and tissue formation, and are influenced through intention, thought, and emotion.

Chapter 11
The Three Treasures of Heaven: Sun, Moon, and Stars

Defining Heaven Qi

The Outer Force (Power) of Heaven's Three Treasures (the Sun, Moon, and Stars) manifests as electromagnetic radiation from the sun, reflected light and energy from the moon, starlight energy, and the gravitational forces and interactions of the above mentioned heavenly bodies. The Outer Force of Heaven's Three Treasures also include the twenty-eight constellations, five major planets, and their energetic and gravitational forces.

Heaven Qi is the energy emitted from the universe outside of the realms of Earth and man. The sun and moon, first five planets (Jupiter, Venus, Saturn, Mars, and Mercury), North Star, Big Dipper, and the twenty-eight constellations are the most easily observed natural Heavenly energies, which have a direct connection to life on Earth. The diagram below (Figure 11.1) shows the Five Elements relationship between the universal treasures of Heaven, the environment of Earth and Man's internal organs.

The sun and moon are the primary Heavenly manifestations of Yin and Yang energy. The sun is Yang and is considered the Spirit Soul (Hun) of the sky. The moon is Yin and considered the Corporeal Soul (Po) of the Earth. This interaction of Heavenly Yin and Yang energy affects and governs the Earthly Yin and Yang energy, as well as the Qi within the human body. The sun and moon each have their own cyclic rhythms and energies, changing their relative degrees of Yin to Yang at different times of the day, month, and year.

To cleanse, purify, and strengthen the body, Qigong doctors absorb the essence of the Heavenly Qi by guiding the star's energy into certain areas of the body. The energy of the stars may also be used to reinforce the circulation of Wei Qi for

Organ	Element	Time of Day	Direction	Planet	Associated Animal
Liver	Wood	Early Dawn	East	Jupiter	Green Dragon
Heart	Fire	Midday	South	Mars	Red Phoenix
Spleen	Earth	Midafternoon	Center	Saturn	Yellow Phoenix
Lungs	Metal	Late Dusk	West	Venus	White Tiger
Kidneys	Water	Night	North	Mercury	Indigo Tortoise

Figure 11.1. Natural Heavenly Transformations

added protection against external pathogenic invasion.

INFLUENCES OF HEAVENLY QI ON THE HUMAN BODY

The body's physical fluctuations work in harmony with the cycles of the sun, moon, and nature. The science that deals with the study of these biological clocks is known as chronobiology. The levels of corticosterone and plasma adrenocorticotropic hormone (ACTH), for example, follow a cyclical pattern during the course of a day. Generally, the body's emotional and menstruation cycle in women follow the changing patterns of the moon (i.e., approximately every 28 days). Additionally, approximately every 23 days, the male body releases stored toxins, changing the smell of the sweat in accordance with the body's physical biological cycle. The smooth functioning of natural biological rhythms can at times be disrupted. The "jet lag" phenomenon, for example, is due to the interruption of circadian rhythms in the body.

There are daily, weekly, monthly, and annual solar and lunar cycles to which the human body responds. Other human physical, emotional, and mental cycles are strongly influenced by the types of life-style chosen, and other environmental factors involved. The body's circadian rhythms influence not only the immune system, but also the Yin and Yang energies of the internal organs. The activities of the cells, glands, Kidneys, Liver, and nervous system are coordinated with one another and with the day-night rhythm of the environment. Hunger, excretion, and body temperature are influenced by the body's ability to respond to the micropulsations of the subtle energy fields within the internal organs and tissues, as well as the body's biological clocks.

In China, clinical scientist Liu Bing, from Beijing Medical University, notes in his research that the human body undergoes rhythmic variations within a 24-hour time period. These physical changes include temperature, oxygen consumption, blood pressure, pulse rate, content of hemoglobin, blood sugar, blood amino acids, blood adrenocortical hormone, hepatic glycogen, metabolic rate of fat absorption, and pace of cell metabolism. The natural clockwork of the body can also be altered by food, drink, drugs, and abnormal sleeping patterns.

BODY RHYTHMS AND ENERGETIC PATTERNS

The prenatal and postnatal energetic patterns of the body are also determined by the time and place of conception. The time and place of conception establishes the patient's spiritual energy and ancestral traits (food preferences, manner of dress, preferences of art, spiritual beliefs, and so on). The time and place of birth also determine the patient's energetic biorhythms (physical, emotional, and intellectual cycles).

PRENATAL ANCESTRAL TRAITS

The time and location of conception determine the nature of the ancestral spiritual influence on the patient. As the divine infuses the fetus's soul, the energy of the Eternal Soul combines with the environmental spiritual influences of the geographic location (e.g., the Orient, Europe, North America, etc.). This infusion of geographic spiritual energy creates within the patient a predisposition towards specific ancestral traits and cultural attractions.

At conception and throughout pregnancy, the mother absorbs the natural environmental energy through respiration (breathing through the mouth, nose, and pores), ingesting food (grown in the soil), and visual/auditory ingestion (observing and experiencing the cultural environment). The energetic history of each cultural environment exists within the memories stored in the natural energetic fields contained within that environment. Therefore, someone conceived within a particular geographic location in the Orient may find him or herself, unconsciously drawn to the social and cultural influences of that particular Asian population. This subconscious attraction is considered a natural phenomenon due to the geographic influences of the country's spiritual/ancestral power, causing an effect, indirectly, on the individual.

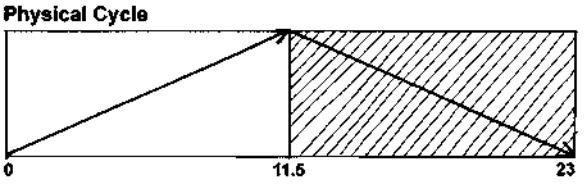

The Physical Cycle is 23 days long. The first 11 1/2 days are the positive side of the cycle. One experiences a feeling of good physical strength and endurance. The second 11 1/2 days are the negative side of the cycle, marked by having less endurance and a tendency towards fatigue.

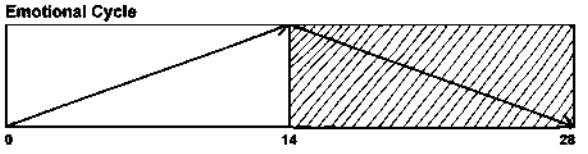

The Emotional Cycle is 28 days long. The first 14 days are the positive side of the cycle. One feels optimistic, cheerful, and cooperative. For the second 14 days, a negative stage of the cycle results in tendencies to be moody, irritable, and pessimistic.

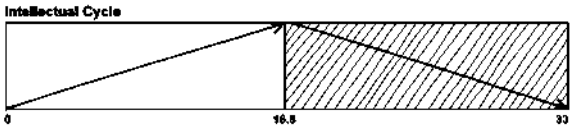

The Intellectual Cycle is 33 days long. The first 16 1/2 days are the positive side of the cycle. One has greater success in learning new material and pursuing creative, intellectual activities. The next 16 1/2 days are the negative side of the cycle; one is encouraged to review old material rather than attempting to learn new concepts.

Figure 11.2. The physical, emotional, and intellectual cycles begin on the day of birth.

1. The natural environment of the location at conception exerts a strong influence, such as a preference, or attraction to similar geological formations throughout the individual's life. People conceived by the ocean, for example, may find within themselves an unconscious need to live by the ocean. Likewise, people conceived in the mountains, valleys, tropics, deserts, etc. may find an energetically calm feeling of peace envelop them when visiting such places.
2. The time of conception also exerts a strong influence. The energetic formation, as well as strength or weakness, of the fetus's internal organs is also determined by the positions of the sun, moon, and stars. These Heavenly energies begin their effect on the fetus at the time of conception and continue influencing the fetus's formation throughout the entire pregnancy.

BIRTH-POSTNATAL ENERGETIC PATTERNS

The time and location of birth determines the biorhythmic patterns of each individual. These biorhythms are developed according to the influence of the Heavenly energy (position of the sun, moon, and stars), as well as the Earthly energy (i.e., geographic location, e.g., mountains, valleys, by the ocean, etc.). This infusion of the Earth's geographic energy and Heaven's constellation energy creates within the individual a predisposition towards specific psychological traits.

1. The location of birth strongly influences the individual's desire to seek out and/or surround him or herself with the familiar environment.
2. The Time of Birth may also have an unconscious influence on his or her living patterns, as certain individuals born at night naturally become "night people," while others born in the morning function better during the morning hours.

The body's biorhythms, which react to universal and environmental energetic vibrations, are divided into three distinct cycles and energy flows (Figure 11.2). Each rhythm is cyclical, waxing and waning, creating and contributing to times of

physical, emotional, and intellectual triumph, as well as times of reflection and withdrawn behavior. These three cycles begin at the moment of birth and continue with absolute regularity until death. The conditions of the cycle are divided into positive (the first half) and negative (the second half) attributes.

The body's biorhythms are but one example of the effects that Heavenly energy has on the physical, emotional, and intellectual cycles of mankind. By understanding the cycles of the sun, moon, and stars and their energetic potential, the Qigong doctor can utilize the universal energy of Heaven to regulate and balance the patient's Qi. The biological rhythms influence the time at which many illnesses occur or worsen, as well as how fast a medication takes effect and how long the effect lasts. Therefore, Medical Qigong therapy, as well as herbal therapy are prescribed at specific times to enhance their effect on the patient's body.

CYCLES OF THE SUN

The Earth's rotation around the sun causes seasonal changes and instigates cyclic metabolic patterns in the human body. The body's entire metabolic function is influenced by its ability to respond to the seasonal micropulsations of these subtle energetic fields.

The Chinese use both a solar and a lunar calendar. The Heavenly cycle of the moon has 12 lunar month divisions, which correspond to man's 12 internal organs and channels: Lungs, Large Intestine, Stomach, Spleen, Heart, Small Intestine, Bladder, Kidneys, Pericardium, Triple Burners, Gall Bladder and Liver. The Heavenly cycle of the sun has 12 periods of the day, which correspond to man's 12 sections of the body. These 12 internal cycles are sometimes called the 12 Blood / Heat Cycles because they affect the Qi, Blood and temperature within the Twelve Skin Zones (see Chapter 7).

The Earth's rotation and the rhythm of the five seasons (the usual four plus late summer) influence the body's internal organs and channels, affecting their energetic activity. In each of the five seasons, a specific pair of internal organs reaches an energetic peak.

1. In the summer, the Heart and Small Intestine are at their energetic peak.
2. In the late summer, the Spleen and Stomach reach their energetic peak.
3. In the autumn, the Lungs and Large Intestines reach their energetic peak.
4. In the winter, the Kidneys and Bladder reach their energetic peak.
5. In the spring, the Liver and Gall Bladder reach their energetic peak.

THE TWELVE PI HEXAGRAMS

The Twelve Pi Hexagrams symbolize the seasonal changes, which cause the waxing and waning of Yin and Yang energy. The trigrams and hexagrams are used to illustrate the movement of energy in Man (see Chapter 5) as well as Heaven. The Twelve Pi Hexagrams were also used to study and comprehend the interactive energetic fields of man and nature that govern growth and development. The interactive energetic fields engender the creation of energy channels and influence the circulation and transformations of Qi, which in turn, create and maintain the body's internal organs. The ancients believed that the human physique reflects the structure of the universe, and that prenatal Heaven and Earth energy fuse with postnatal Heaven and Earth energy at birth (see Chapter 2). The trigrams reflect the twelve hours of the day, the daily fluctuations of Yin and Yang energy, and the Qi of the Five Elements (Figure 11.3).

The Twelve Pi Hexagrams represent "the laws of hardness and softness," domination and yielding of Yin and Yang, the relationship between the seasons, time of day, major organs, channels, and the transformation and circulation of Qi.

THE YANG YAO CYCLES

When studying the Twelve Pi Hexagrams, it is important to examine the first six (from Fu — 11 p.m. to Qian — 11 a.m.), that represent the gradual increasing of the energetic potential of the Yang Yao (see Chapter 5) and the gradual decreasing of the Yin Qi. The Yang Qi rises and expands during this time period; it is the best time for training techniques that emit external Qi and for treat-

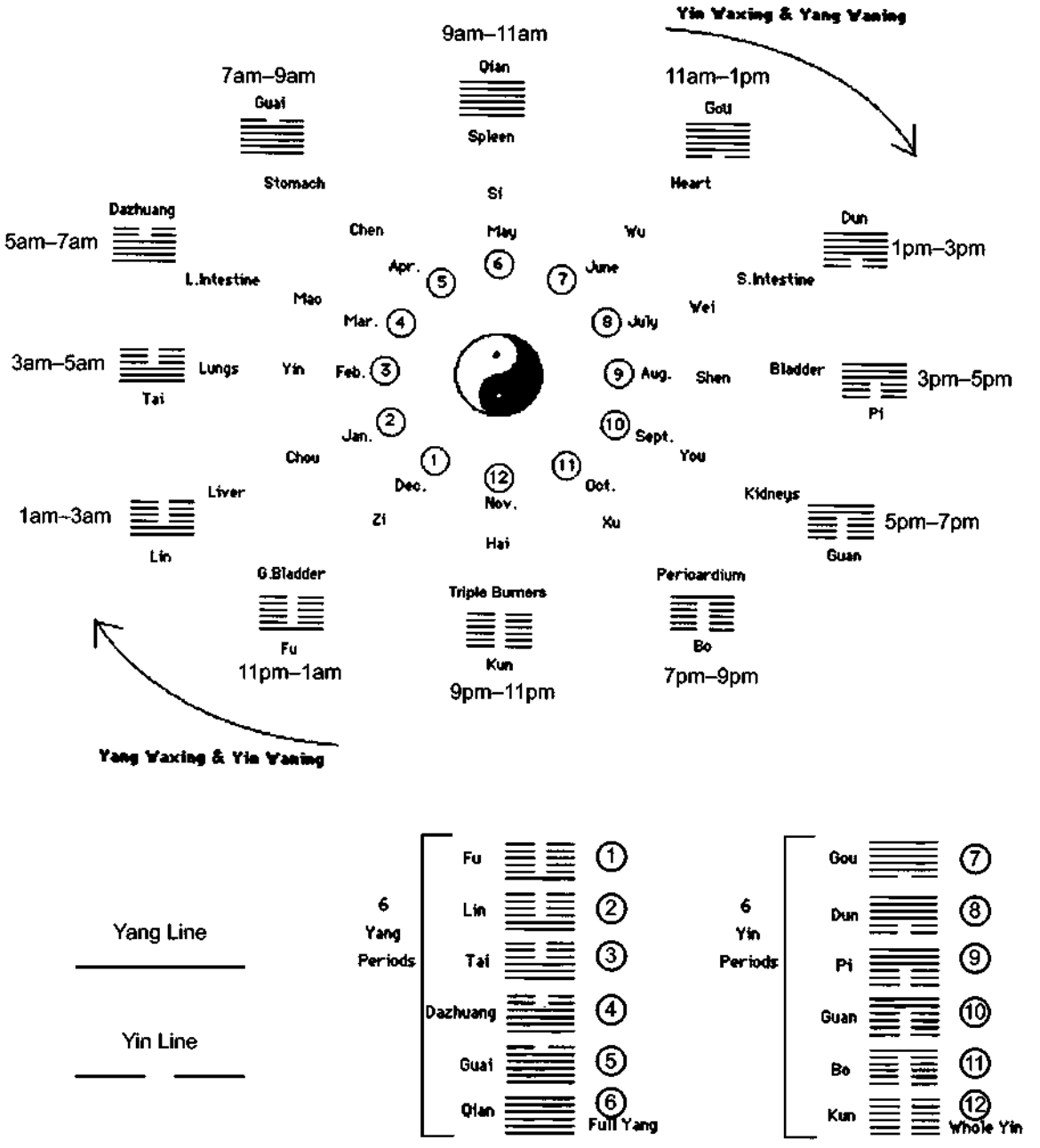

Figure 11.3. The circular figure depicts the Heavenly cycle of the sun and the Twelve Pi Hexagrams. Solid lines in the trigrams and hexagrams represent Yang, and broken lines represent Yin. The hexagrams on the left depict the Yang Yao Cycle (from Fu to Qian), with the gradual increase in Yang and decrease in Yin, so that the last hexagram, Qian, is full Yang. The hexagrams on the right depict the Yin Yao Cycle (from Guo to Kun), with the gradual increase in Yin and decrease of Yang, so that the last hexagram, Kun, is full Yin.

ing patients who suffer from insufficiency of Yang Qi. This time period is called the "time of the living breath," and represents the beginning of energetic harvesting. When training in the morning time, the practitioner should progress from still, relaxed, quiescent Qigong meditations to active forms of dynamic Qigong movement.

THE YIN YAO CYCLES

The last six hexagrams (from Gou — 11 a.m. to Kun — 11 p.m.) indicate a gradual increasing of the energetic potential of the Yin Yao and the gradual decreasing of the Yang Qi. This time period is called the "time of the dead breath," and represents the beginning of energetic planting. The Yin Qi increases and expands in this time period; it is the best time for patients suffering from an insufficiency of Yin Qi to train, nurture, and restore the Kidneys' Yin Essence, which in turn will facilitate the preservation of Yang Qi. When training in the afternoon, the practitioner should progress from active forms of dynamic Qigong movement to gradually slower, relaxed, quiescent Qigong meditations.

When prescribing Medical Qigong for patients, the time for practice should be selected in accordance with the philosophy of Yin and Yang theory, the Five Elemental theory, the circadian rhythms of Qi and Blood circulation, as well as the severity of the illness.

USING THE YANG AND YIN YAO CYCLES

Each of the broken lines represents a Yin Yao and can be used to symbolize an inhalation, while a straight line represents a Yang Yao and symbolizes an exhalation. A hexagram consisting of three bottom Yang Yaos and three top Yin Yaos, for example, represents a balanced respirational pattern. When the Qigong doctor writes out a prescription for the patient, the doctor can adjust the patient's respiration in accordance with the Yao hexagrams, taking into consideration each Yao line as representing an inhalation or exhalation. The basic theory of Yin and Yang Yao cycles is also used to determine the time and direction for Qigong practice, as well as the methods of respiration and mind concentration required to establish proper Yin and Yang balance.

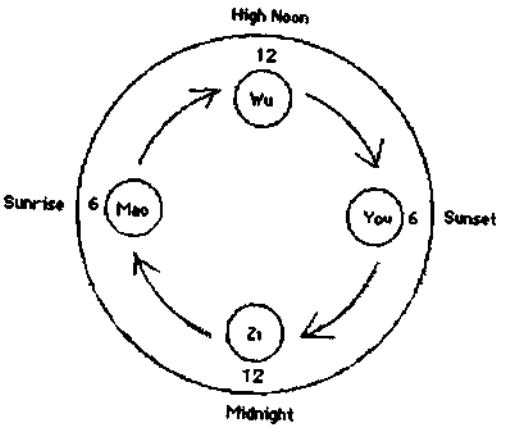

Figure 11.4. The Four Principle Time Periods

When practicing Medical Qigong at the hour of the Fu Hexagram, for example, the Yao indicates there is more Yin than Yang, so the practitioner should regulate his or her body with the intent to nourish the Yang through longer inhalation (Yin) and shorter exhalation (Yang).

At the stage of the Gou Hexagram, the Yao indicates there is more Yang and less Yin so the Qigong practitioner should perform regulation through shorter inhalations (Yin) and longer exhalations (Yang).

THE FOUR PRINCIPAL TIME PERIODS OF QIGONG PRACTICE

Practicing Medical Qigong during the "four principal time periods" (Zi, Mao, Wu, and You) facilitates the vigorous growth of internal energy in harmony with the changes of energy in nature (see Figure 11.4). To nourish energy, practice during the sunrise and/or sunset (Mao and You) periods. To stabilize energy, practice during the periods of midnight and/or high noon (Zi and Wu).

Due to the differences between individual constitutions (Excess or Deficient Yang or Yin), the selection of the proper time for practice and the number of Yin or Yang respirations varies between patients. The following is a brief discussion and

explanation of the four principal time periods.

1. Zi Time Period corresponds to the Fu Hexagram, and has one Yang and five Yin lines or Yaos. The Zi time period is at midnight (11 p.m. – 1 a.m.). It is related to the beginning of the Yang cycle and is perfect for gathering energy to store the Yuan Qi (Prenatal Qi). The Yuan Qi is the root of life, formed through the divine combination of the primordial Yin and Yang; it is stored primarily in the Kidneys' Water energy. The Zi period of time corresponds to the Fu Hexagram. During this time the Earth energy and the Kidney's Yang Qi are in full harmony, continuously combining and accumulating energy. Practice during this period of time results in twice the effect with half the effort.
2. Mao Time Period corresponds to the Dazhuang Hexagram, and has four Yang and two Yin lines or Yaos. The Mao time period is at sunrise (5 a.m. – 7 a.m.). As the sun rises, warming the air, and natural Yang progresses. At this time of the day, the Yang Qi of the body is in full bloom. Practice during this period of time aids the vigorous growth of Yang.
3. Wu Time Period corresponds to the Gou Hexagram, and has one Yin and five Yang lines or Yaos. The Wu time period is at high noon (11 a.m. – 1 p.m.), and is regarded as the Heart's Fire. At high noon, the Heart Channel (considered the Supreme Yang) will naturally manifest the energetic peak of Yang energy. Because the first line is a Yin Yao, however, the Yang energy Yaos tend to wane rather than grow. Therefore, practicing during this period helps the growth of Yin energy and suppresses the hyperactivity of Yang energy.
4. You Time Period corresponds to the Guan Hexagram, and has four Yin and two Yang lines or Yaos. The You time period is at sunset (5 p.m. – 7 p.m.). At this time, the energy of the environment turns from clear and radiant to dark. Qigong practice at this time nurtures the increase of the primordial Yin energy and the conservation and nourishment of Yang energy.

THE FOUR SEASONAL PEAK TRANSITIONS

Another theory maintained by Qigong doctors is that the sun's light during the day represents Yang, and the energy from the moon's light at night represents Yin. The observation that light coincides with heat and that darkness coincides with cool, led to the division of the year into four seasonal peak transitions (which also correspond to the four principal time periods of the day) (see Figure 11.5).

At the time of the equinoxes and solstices, the sun passes through transitional regions: The Palace of Eternal Frost in the North is entered in the winter; The Golden Gate in the East is entered in the spring; The Palace of Universal Yang in the South is entered in the summer; and The Gate of the Moon in the West is entered in the autumn. The four seasonal peak transitions in the northern hemisphere are described as follows.

1. The Palace of Eternal Frost at the Winter Solstice (December 22–25) indicates the time period when the sun is furthest south from the equator. This is a time of maximum Yin or darkness in the northern hemisphere, with the shortest days and longest time of cold and darkness. This energetic transition corresponds to "midnight" within the four principal time periods.
2. The Golden Gate at the Spring Equinox (March 21) indicates the time period when the sun's center crosses the Heavenly equator, creating an energetic balance between the days and nights. Although light and darkness and Yin and Yang energies are in balance, this seasonal time period is a transitional harmony, as Yang energy is growing. The weather is also moderate. This energetic transition corresponds to the "sunrise" within the four principal time periods.
3. The Palace of Universal Yang at the Summer Solstice (June 21–23) indicates the time period when the sun is furthest north from the equator, a time of maximum Yang or brightness, with the longest days and times of light and warmth. This energetic transition corresponds to "noon" within the four principal time periods.

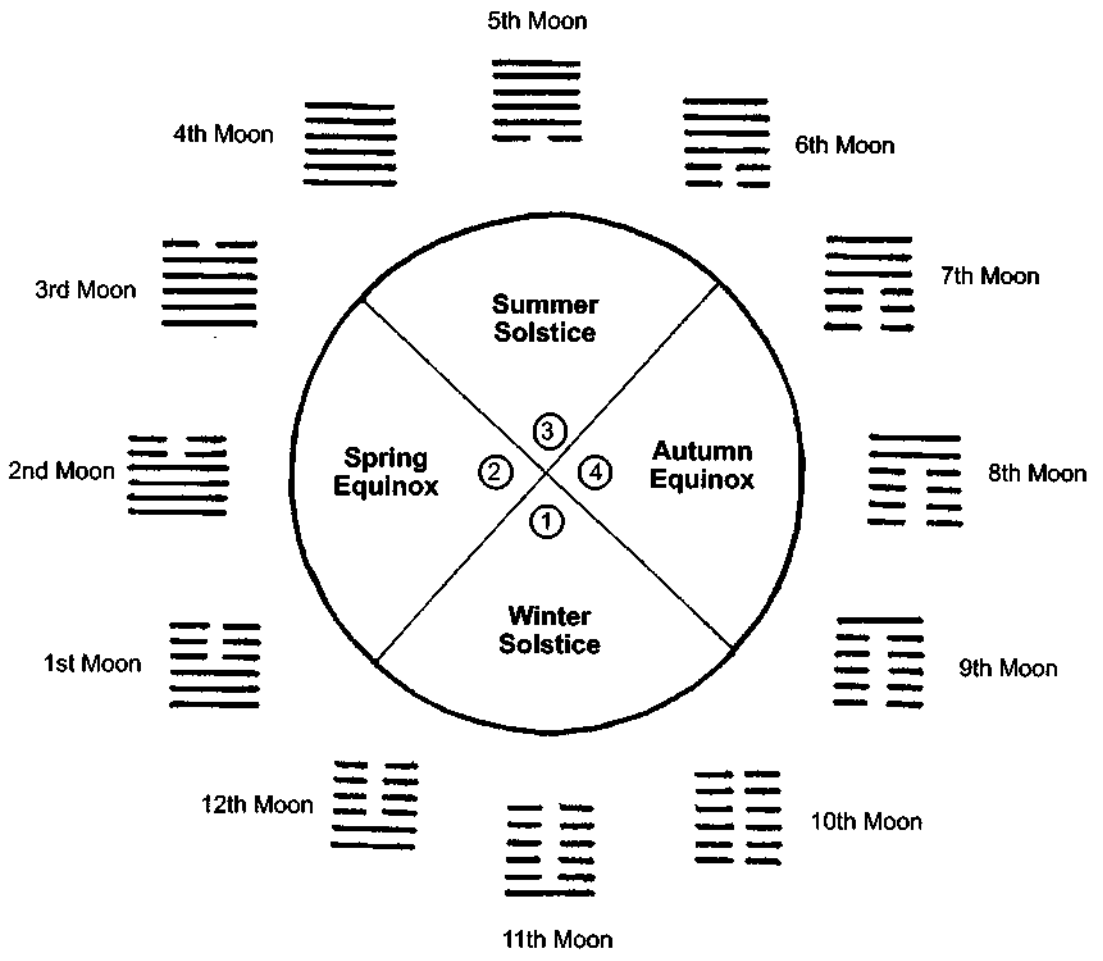

Figure 11.5. Four Season Peak Transitions

4. The Gate of the Moon at the Autumn Equinox (September 22) indicates the time period when the sun's center crosses the Heavenly equator, creating an energetic balance between the days and nights. Although light and darkness and Yin and Yang energies are in balance, this seasonal time period is in transitional harmony, as Yin energy is growing. The weather is also moderate. This energetic transition corresponds to the "sunset" within the four principal time periods.

The energy of these four principal time periods enters the practitioner's Taiji Pole during meditation and regulates the "auspicious powers" located within the five regions of space inside and outside of the doctor's body:

- Front—energy of the Heart
- Back—energy of the Kidneys
- Right—energy of the Lungs
- Left—energy of the Liver
- Center—energy of the Spleen

THE SIX PRINCIPAL SEASONS OF TRANSITION

In Traditional Chinese Medicine, the year is divided into six primary periods of seasonal transitions (wind, heat, damp, fire, dry, and cold). Each season represents the ruling Qi, or expected weather, dominant in that particular season (Figure 11.6).

These six periods delineate the differences between and transitional transformations of Heaven energies (through the Ten Heavenly Stems) and Earthly energies (through the Twelve Earthly Branches). In terms of weather, the first half of the year is governed by the Qi of Heaven, while the second half of the year is administered by the Qi of Earth. The Ten Heavenly Stems are the ten energies of Heaven that rule the changes of the Five Elemental Seasonal Transitions, and are represented in the human body as the Yin and Yang aspect of the Five Elements (represented as the ten major internal organs). The Twelve Earthly Branches are the twelve energies of the Earth that determine the six Qi factors of the seasonal transitions (represented in the body as the Twelve Primary Channels). In accordance with the Creative Cycle of the Five Elemental Seasonal Transitions: summer creates late summer, late summer engenders autumn, autumn gives rise to winter, and winter gives birth to spring.

THE DAILY QI, BLOOD, AND HEAT CYCLE

These four principal time periods and seasonal peak transitions affect the body's Blood, Heat, and Qi Cycles. The daily cycle of Heat, Blood, and Qi flow along the body's Twelve Primary Channels, organs, and tissues, according to the two hour Yin and Yang time table are:

- Gall Bladder (GB) - 11 p.m. to 1 a.m. - (Yang)
- Liver (Lv) - 1 a.m. to 3 a.m. - (Yin)
- Lungs (Lu) - 3 a.m. to 5 a.m. - (Yin)
- Large Intestine (LI) - 5 a.m. to 7 a.m. - (Yang)
- Stomach (St)- 7 a.m. to 9 a.m. - (Yang)
- Spleen (Sp) - 9 a.m. to 11 a.m. - (Yin)
- Heart (Ht) - 11 a.m. to 1 p.m. - (Yin)
- Small Intestine (SI) - 1 p.m. to 3 p.m. - (Yang)

Season	Date
1. Spring Begins	Feb. 5
Rainwater	Feb. 20
Insects	March 7
Spring Equinox	March 22
2. Clear and Bright	April 6
Grain Rains	April 21
Summer Begins	May 6
Grain Filling	June 7
3. Grain Full	June 22
Summer Solstice	June 22
Slight Heat	July 8
Great Heat	July 24
4. Autumn Begins	Aug. 8
Limit of heat	Aug. 24
White Dew	Sept. 8
Autumn Equinox	Sept. 24
5. Cold Dew	Oct. 9
Frost Descent	Oct. 24
Winter Begins	Nov. 8
Slight Snow	Nov. 23
6. Great Snow	Dec. 7
Winter Solstice	Dec. 22
Slight Cold	Jan. 6
Great Cold	Jan. 21

Figure 11.6. Six Principal Seasons of Heaven and Earth Energy Transition (1-6), and the Twenty Four Diagram Chart

- Bladder (Bl) - 3 p.m. to 5 p.m. - (Yang)
- Kidneys (Kd)- 5 p.m. to 7 p.m. - (Yin)
- Triple Burners (TB) - 7 p.m. to 9 p.m. - (Yin)
- Pericardium (Pc) 9 p.m. to 11 p.m. - (Yang)

The body's active high and low heat, Blood, and Qi time periods, reflect its relationship with the Twelve Primary Channels. For instance, every morning during the time period of 3–5 a.m., the strongest energy streams down along the Lung Channels, making the Lungs quickly responsive to treatment.

GATHERING THE SUN'S ESSENCE MEDITATION

The ancient Qigong masters used this meditation to absorb the essence of the sun. By gathering pure Yang energy to tonify the body's Deficiencies, as well as to consolidate the Zheng Qi (Gathering energy), they were able to eliminate pathogenic factors and prevent premature aging. This particular exercise is considered part of the foundational base from which the ancient Qigong doctors replenished any depleted life-force energy.

The gathering the Sun's Essence Meditation must only be practised on a clear day, when the sun is not obstructed. Avoid practising this meditation in times of fog, smog, thick clouds, and solar eclipses, as cultivation during these times will cause the unnatural cultivation of Turbid Qi.

1. While outside on a bright sunny day, face the sun, and assume a Wuji standing posture, hands by your sides, with the feet slightly wider then shoulder-width apart; stand in a relaxed and tranquil state, breath evenly and naturally, and rid your mind of any stray thoughts (Figure 11.7).
2. If the sun is rising above the horizon, slightly close your eyes; you should still be able to see soft, gentle, reddish sunlight. If the sun has already risen, close your eyes and use your inner vision to visualize the sun.
3. Inhale through the nose and imagine filling your mouth with energy from the sunlight's essence. Still facing the sun, with your eyes half open, "infuse," or absorb into the eyes, the energy from the horizon. Blend the energy

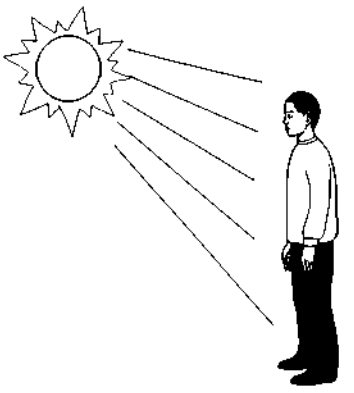

Figure 11.7. Gathering the Sun's Essence Meditation. Step one, stand and face the sun.

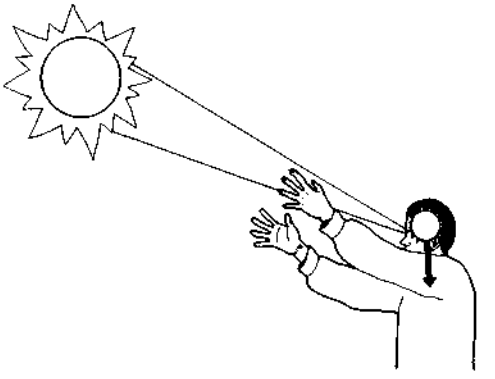

Figure 11.8. Step two, imagine embracing the sun.

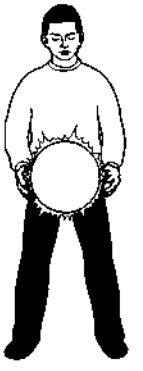

Figure 11.9. Step three, imagine embracing the sun and gently placing it in front of your Lower Dantian.

absorbed from your eyes into your Upper Dantian. Close your eyes and imagine blending the sun's golden light energy with the Qi you inhaled through your nose. Hold your breath and focus the mind, mixing both energies; swallow the energies slowly while exhaling, and send the energy down to the Lower Dantian. Repeat this process for several minutes.

4. Stretch your hands towards the sun and imagine embracing it (Figure 11.8). Point your index fingers toward the center of the sun, and imagine pulling the sun down in front of your Lower Dantian. Keep it positioned there for several minutes (Figure 11.9).
5. Imagine the sun gently rolling and turning itself in front of your lower abdomen (Figure 11.10–11). Keep your elbows at your sides and gently shift, or sway from side to side, imagine that it is the sun's movement that causes both your arms and body to move. Using this image keeps the sun in an energetic power position.
6. Place both hands around the sun as if embracing it (Figure 11.12). Next, imagine the sun slowly moving into your navel. Allow both hands to follow the sun into the navel, ending with your left palm on top of your right palm (opposite for women) (Figure 11.13). With one deep breath inhale and absorb the sun's energy into the Lower Dantian while imagining the sun (beneath the navel) transforming into a luminous ball of golden energy. With each inhalation, this golden ball shines brightly; with each exhalation, the sun's rays extend, spreading throughout the entire body.
7. To end, relax the mind and imagine Heavenly Qi melting down the body, pouring through the front, back and center of the body like warm oil, into the Earth. This ending exercise (sometimes called Pulling Down The Heavens), allows the Qi to sink into the Lower Dantian, and the body, mind, and spirit to come into a state of peaceful rest and tranquillity.

Figure 11.10. Step four, imagine the sun gently rolling and turning itself in front of the Lower Dantian.

Figure 11.11. The energy of the sun moves the entire body rather than the arms.

Figure 11.12. Step five, embrace the sun and absorb it into the navel and then into the Lower Dantian.

Figure 11.13. Each breath transforms the sun's energy into luminous golden Qi.

CYCLES OF THE MOON

The ancient Qigong masters believed that the sun has a Yang nature, emitting enormous amounts of hot, thermal energy, whereas the moon has a Yin nature and emits a much cooler type of energy, by reflecting the light of the sun. The energy of the moon is used to replenish the body's Yin Qi, and follows a comprehensive cycle every 28 days (Figure 11.14). Following the cycle of the moon, the energy of the body completes a full rotation, flowing along the Governing Vessel to the top of the head, and down the Conception Vessel to the base of the perineum. When the moon is full, the body's Blood and Qi reach a crest, filling the Baihui point on the top of the head. At the new moon, the body's Blood and Qi gather at the Huiyin point, in the perineum.

Since the lunar cycle at its extreme (full moon and new moon) activates the top and bottom points of the Taiji Pole, these are said to be the most productive times to perform Taiji Pole Qi practice.

The appearance of the moon during the first half of the lunar month symbolizes the waxing of Yang and waning of Yin Qi. As Yang grows and Yin declines, regulation of breathing at this period of time should be aimed at absorption of the Moon's Essence. The second half of the lunar month symbolizes the waxing of Yin and waning of Yang Qi. As Yin grows and Yang declines, regulation of breathing at this period of time should be aimed at replenishing Yang to help the Yin nourish the Yin Jing-Essence (Figure 11.15-20).

As the moon increases the amount of light it reflects, the body's Qi and Blood become more nourished; when the moon is full, the Qi and Blood become substantial. As the moon begins to decrease the amount of light it reflects, the muscles start to lose their energetic substance. This decrease in energy causes the body's Eight Extraordinary Vessels and Twelve Primary Channels to empty themselves to support the muscles that are slowly becoming Deficient. Qi and Blood are influenced by the gravitational pull of the sun and moon, just as the tides of the sea are influenced. Therefore the ancient Qigong masters described the energetic tonifying and purging principles of Qigong regulation in these specific terms: when treating a patient, perform no tonifying when the moon is full, or when the Blood and Qi are sufficient. Perform no purging when the moon is dark, or when the Blood and Qi are Deficient. This observation explains the effect of the "full-moon phenomenon" on patients who are hypersensitive to energy and become restless when the moon's Qi is "full Yang in Yin."

The waxing and waning of the sun and moon affect the adjustment time for Medical Qigong practice and the methods of breathing regulation. In order to facilitate the intake of Heavenly Es-

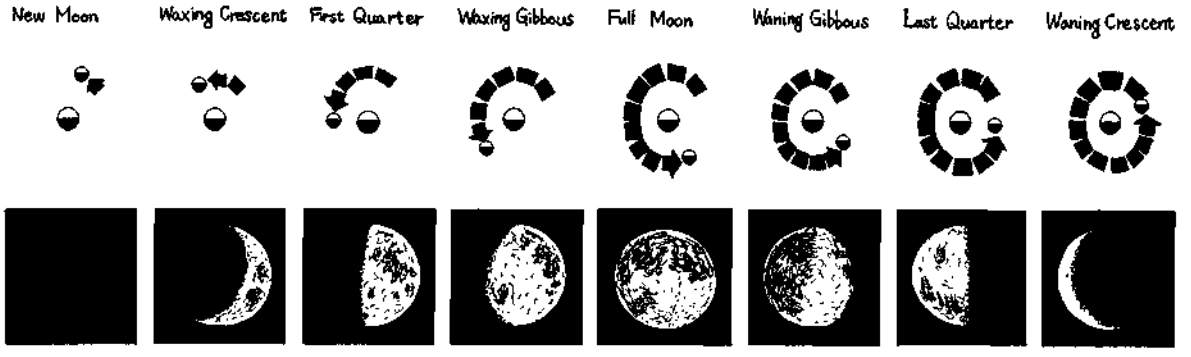

Figure 11.14. The waxing and waning cycles of the moon correspond to the moon's orbit around the Earth.

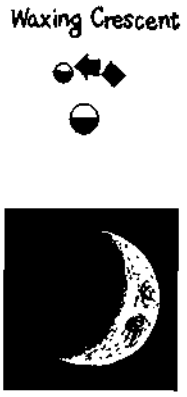

Figure 11.15. From the 1st to the 5th night of a lunar month, more Yang absorption and Yin nourishment can be obtained by performing breathing regulations while facing the west. The crescent surface of the Moon is reflecting less sunlight.

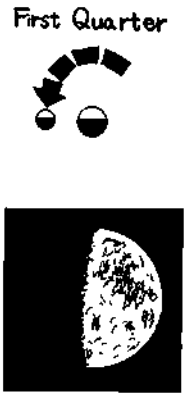

Figure 11.16. From the 6th to the 10th night of a lunar month, more Yang absorption and Yin nourishment can be obtained by performing breathing regulations while facing the south. The surface of the moon is turning from a crescent to half-full Yang, and its surface is reflecting more sunlight.

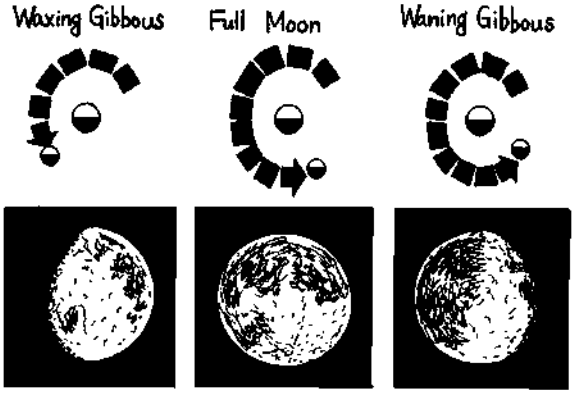

Figure 11.17. From the 11th to the 15th night of a lunar month, equal amounts of Yang absorption and Yin nourishment can be obtained by performing breathing regulations while facing the direction of the moon, as both Yang and Yin energies are plentiful at this time. At this point, the moon is full with its surface reflecting the most sunlight (called "Full Yang in Yin").

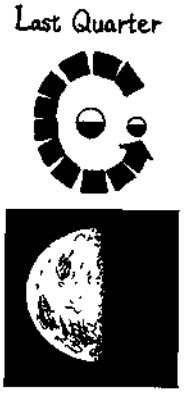

Figure 11.18. From the 16th to the 20th night of a lunar month, the Yin grows and Yang declines. Regulation of breathing at this period of time should be aimed at replenishing Yang to help the Yin nourish the Yin Essence, while facing the west. At this time, the crescent surface of the moon is reflecting less sunlight. The reflected sunlight on the moon's surface decreases as Yang wanes and Yin waxes.

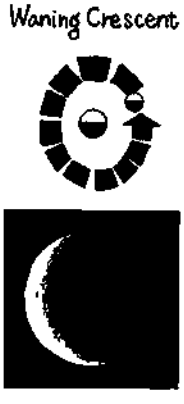

Figure 11.19. From the 21st to the 25th night of a lunar month, Yin continues to grow and Yang declines. Regulation of breathing at this period of time should be aimed at replenishing Yang to help the Yin nourish the Yin Essence, while facing the south. At this time, the crescent surface of the moon's shape is turning to half-full Yin, and its surface is reflecting less sunlight. The reflected sunlight on the moon's surface continues to decrease as Yang wanes and Yin waxes.

Figure 11.20. From the 26th to the 30th night of a lunar month, no absorption of Yang is possible when the moon appears in the east at nightfall and its surface is dark, leading to the period of "Pure Yin." Breath regulation should be performed facing east.

sence to nourish the body, the ancient Qigong masters used a system wherein each month is divided into 6 separate sections (a total of 5 days was assigned to each section).

PRENATAL EIGHT TRIGRAMS AND THE MOON

The symbols on the Prenatal Eight Trigrams represent the appearance of the moon, while the Ten Heavenly Stems represent the positions of the moon. Each trigram embraces one or two of the Ten Heavenly Stems. The following chart of Prenatal Trigrams, Ten Heavenly Stems, moon and tide regulation, as well as the principles of purgation and tonification of Qi and Blood is a reference for Qigong doctors for clinical treatments (Figure 11.21).

In this chart, the Yang energy of the Earth gradually increases from the 11th to the 15th. Influenced by this action, the spring tide occurs on the 15th when the moon is full, inducing both the Qi and Blood to become extremely active. This is a good time for Qigong patients who suffer from energy Deficiencies to replenish their Qi. However, if the patient's energy is abundant, he or she should not try to replenish at this time, or an Excess condition of Qi will occur.

CHOOSING THE PROPER DIRECTION FOR TRAINING QI

Since ancient times, Qigong doctors have placed great emphasis on facing certain directions when cultivating energy. Observing that energy training and practicing should be adapted to nature, each routine is selected according to the season, month, and time of day, as well as the physical conditions of the practitioner. The four directions, as well as the sun (solar cycle), moon (lunar cycle), and stars (four sets of seven constellations, each one grouped in the N, S, E, or W), have a direct influence on the human body.

One example of directional training is in setting up treatment schedules according to the energy emitted from the Heavens. It is generally advised when conducting energetic regulations that:

- Patients with Yang Deficiencies should face east or south, to develop Yang Qi;
- Patients with Yin Deficiencies should face west or north, to help develop the Yin Qi;
- Patients with a Kidney Deficiency should face the north;
- Patients with a Liver Deficiency should face east;
- Patients with a Heart Deficiency should face south;
- Patients with a Lung Deficiency should face west;
- Patients with a Spleen Deficiency should focus their attention on the center, i.e., the Earth.

Generally, when first beginning Qigong exercises and meditations, practitioners are taught to face the south or southeast. When practicing specific cultivation exercises, however (such as Gathering the Sun's Essence), the practitioners are taught to face the direction of the sun. In the evening time, unless practicing specific cultivation exercises (such as Gathering the Moon's Cream), it is best to have the patient face the corresponding direction for the Deficient organ. These cultivation methods train the Yang energy to fuse with the Zhen Qi (True Qi), as well as with the Heavenly Qi and Environmental Qi. The timing and methods of training are based on the increase and decrease of Yin and Yang energy.

It is important to note that although these training methods are effective, the most experienced Qigong doctors often choose the place and direction according to their own intuition. To select the appropriate direction, the doctors start by facing south (sitting or standing). As they begin to feel the body filling with Qi, they may feel that they are being pulled towards a specific direction, and that they cannot stand or sit comfortably without facing that direction. The doctors feel more rooted and stable by following their intuition. Through understanding the proper directions, concentration, breath regulation, and assuming the appropriate postures, Qigong doctors are able to help regulate and increase their patients' energetic activities, while avoiding many Qi deviations (see Chapter 18).

GATHERING MOON'S CREAM QIGONG MEDITATION

Qigong doctors use this particular exercise in conjunction with the Gathering the Sun's Essence meditation for replenishing depleted energy. The vital essence of moon is called the Cream or "cool light" and is used to nourish the Kidneys and strengthen the Jing, Marrow, and brain, while contributing to longevity. It is practiced only nine days a month, three days before, during, and after the full moon, which are the brightest nights of the month. It is prohibited during new moon transitions because there is too little vital essence of the moon to gather.

Gathering the Moon Cream meditation must only be practiced on clear nights, when the moon is not obstructed. Avoid practicing this meditation in times of fog, smog, thick clouds, and lunar eclipses, as cultivation during these times will cause the unnatural cultivation of Turbid Qi

1. Stand outside in the fresh air, while facing the moon. Stand in a relaxed and tranquil state, breath evenly, and rid your mind of any stray thoughts (Figure 11.22).
2. Lower your eyelids until you only faintly see the moonlight. Inhale through the nose and imagine softly "sipping" one mouthful of the moon cream. At the same time, with your eyes half open, visualize "inhaling" the energy of the moon cream with your eyes into your Upper Dantian. Close your eyes and imagine mixing the moon cream with the energy you inhaled through your nose. Slightly hold your breath and concentrate on feeling the moon cream's silvery energetic essence. Swallow this essence slowly, sending it down to the Lower Dantian.
3. Stretch your hands towards the moon (Figure 11.23). Imagine embracing the moon and pulling it out of the sky, placing it just above your Upper Dantian, at your Baihui point (on top of your head). Hold this image for several minutes (Figure 11.24).
4. Next, imagine a second moon forming out of the first moon, and bring it downward with both hands until level with, and in front of, the Middle Dantian (Shanzhong CV-17 point) at the center of the chest. Hold this image for several minutes (Figure 11.25).
5. Finally, imagine a third moon forming out of the second moon, and bring it down to the level of the Lower Dantian, suspended in front of the lower abdomen. Hold this image for several minutes (Figure 11.26).
6. Continue to imagine all three moons suspended (two in front, and one above your body) and inhale, raising both of your arms over your head. Imagine pressing the first moon into your head through the Baihui point, filling the Upper Dantian with the moon cream's silvery white light. As both hands press the moon into the head, allow the left hand to remain on top of the right hand (opposite for women). As you exhale, visualize the light of the moon filling the entire cavity of the Upper Dantian (Figure 11.27).
7. Next, bring both hands to the front of your body. Inhale and press the second moon into your chest through the Middle Dantian, imagining the moon cream's silvery white light filling the chest. As you exhale, visualize the light of the moon filling the entire cavity of the Middle Dantian (Figure 11.28).
8. Finally, bring both hands in front of your lower abdomen. Inhale and press the third moon into your Lower Dantian, imagining the moon's silvery white light filling the abdomen. As you exhale, visualize the light of the moon filling the entire cavity of the Lower Dantian (Figure 11.29).
9. Allow both hands to rest by your sides then slowly raise your left hand (opposite for women) and tap the top of your Baihui point softly nine times. As you tap, imagine that all three moons fuse into a brilliant white-light energy throughout your Taiji Pole, connecting all three Dantians together (Figure 11.30).
10. Relax and perform Pulling Down The Heavens, letting your body, mind and spirit sink into tranquility.

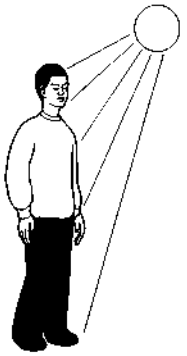

Figure 11.22. Stand facing the moon.

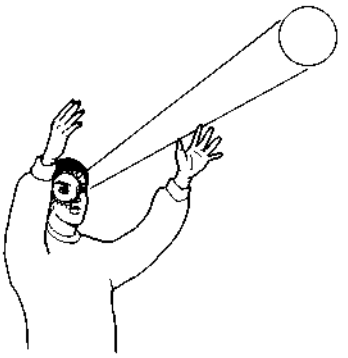

Figure 11.23. Stretch your hands to embrace the moon.

Figure 11.24. Suspend the moon above your Upper Dantian.

Figure 11.25. Suspend a second moon in front of your Middle Dantian.

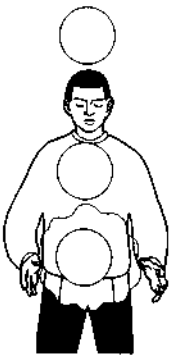

Figure 11.26. Suspend a third moon in front of your Lower Dantian.

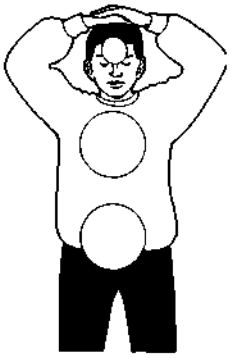

Figure 11.27. Absorb the first moon into your Upper Dantian.

Figure 11.28. Absorb the second moon into your Middle Dantian.

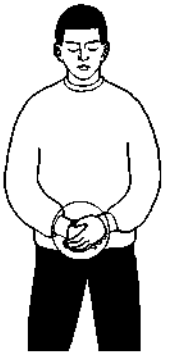

Figure 11.29. Absorb the third moon into your Lower Dantian.

Figure 11.30. Tap lightly until all three moons flow into your Taiji Pole.

CYCLES OF THE STARS

The most influential Heavenly Treasures, other than the sun and moon, are the stars composed of the Big Dipper, Polaris, and the five planets, existing within the twenty-eight constellations.

The North Star is believed to be the unchanging area of Heaven, from which the Heavenly order began (often called the Axis of the Vault of Heaven), and so it was named The Divine Center of the Earth and Sun Cycles. It is also believed that from this star the entire universe expands outward. By placing the North Star in the center of a circle of the Heavens, the circle can be divided into four directions, each containing seven constellations that have a different color energy and sound frequency.

In ancient China, the seven constellations were divided into four sections or directions (north, south, east, and west). In the region of the north was believed to exist the energy of the Tortoise-Snake, in the south was the Red Phoenix, in the east was the Green Dragon, and in the west was the White Tiger. Each of these regions was further divided into twenty-eight constellations or posts (xiu).

According to traditional Chinese belief, the moon travels twenty-eight days from west to east, resting at each post as it circles the Earth. In other words, the twenty-eight days are further divided into twenty-eight regions which are courier stations or travelling houses for the moon.

It was further believed that the Pole Star axis stemming from the North Star traveled downward from the center of Heaven, connecting with the Earth's center core (through the north and south poles). The north pole was regarded as the peak (or Baihui) of the Earth, and was believed to be comprised of seven stars (making it a fifth constellation). The energies of each of the four animals and their seven constellations moved around the Earth's central Pole creating the Five Elemental changes in weather (see Chapter 11). If the weather changes progressed in their expected order, they were considered normal; however, if the weather transition occurred either earlier or later than expected, the result was considered an environmental Evil Qi.

Therefore, the ancient Chinese believed that one could predict the changes of weather by studying the interrelationships between the Five Elements and the cycles of the sun, moon, Polaris, the Five Planets, and the twenty-eight constellations.

THE ENERGY OF THE BIG DIPPER

As the Earth orbits the sun, the angle at which the Big Dipper can be viewed changes on a daily, monthly, and yearly basis (Figure 11.31). These changing angles correspond to the different cycles of the moon as they are arranged in the Twelve Earthly Branches and repeat themselves after completing an orbit (360° rotation of twelve moon cycles). These twelve lunar cycles determine the twelve seasonal periods (Figure 11.32). The beginning part of each month marks the beginning of the seasonal periods of the Twelve Earthly Branches and the beginning of the energy cycle of that month. When the Big Dipper points in the direction of the "lunar month," facing the direction of the Big Dipper will invigorate the practitioner's energy. The Big Dipper is related to the energetic transformations of germinating, beginning, and growing.

There are three kinds of practice centered around the Big Dipper:

1. The first consists of invoking its power for protection;
2. The second consists of ascending into it and pacing its rotation;
3. The third involves gathering the star's essence or star cream into the body.

In ancient times, the Big Dipper was considered the bridge between the energies of the sun and the moon, and the source of "10,000 things." The sun and moon are considered a bipolar energy field, whereas the Big Dipper is considered unipolar.

The sun corresponds to the Heart and Fire energy, which is related to the front area of the body. The moon corresponds to the Kidneys and Water energy, which is related to the back area of the body. The Big Dipper corresponds to the Spleen, which is related to the Taiji Pole.

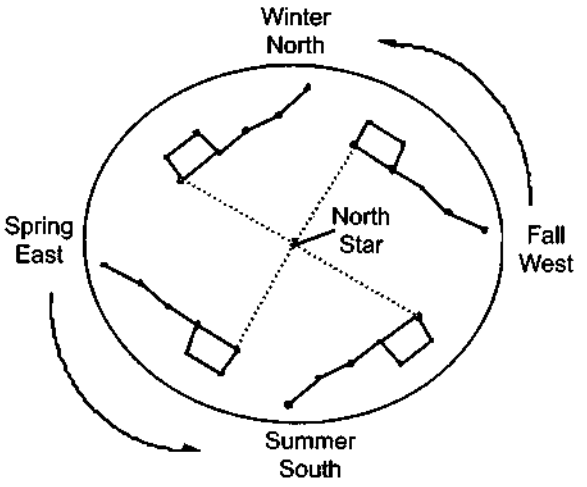

Figure 11.31. The handle of the Big Dipper can be used to determine the season: (1) in winter, the handle points to the northern horizon, (2) in spring, the handle points to the eastern horizon, (3) in summer, the handle points to the southern horizon, and (4) in fall, the handle points to the western horizon. The North Star is positioned in the center of the diagram.

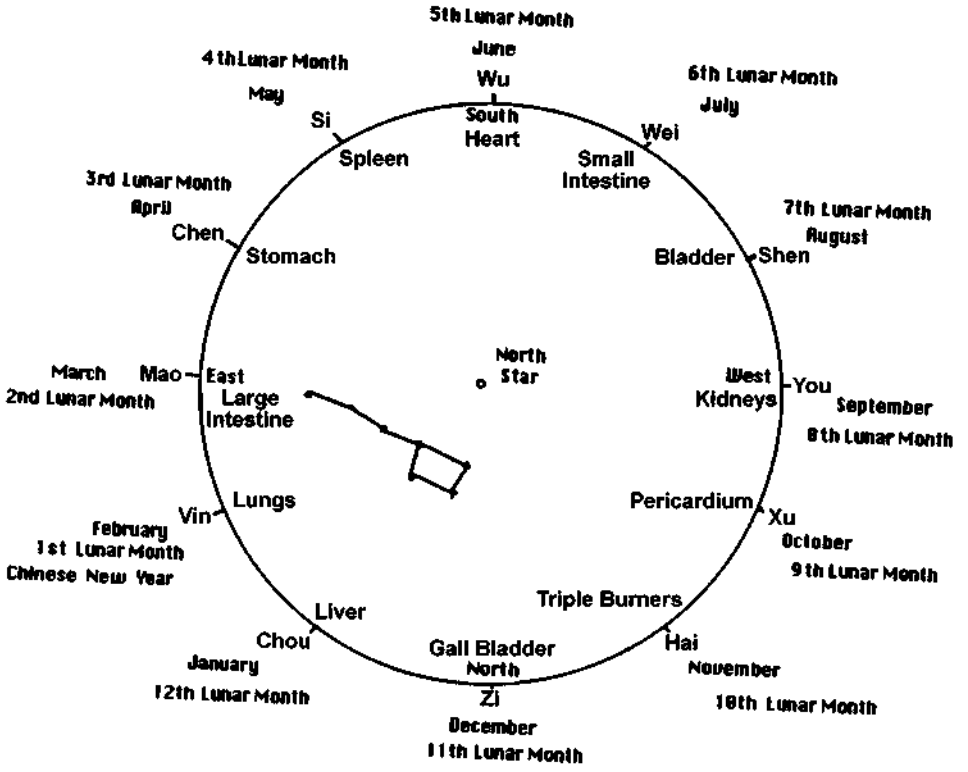

Figure 11.32. The beginning of the seasonal periods of the Twelve Earthly Branches and the twelve moon cycles is determined by the angle of the Big Dipper.

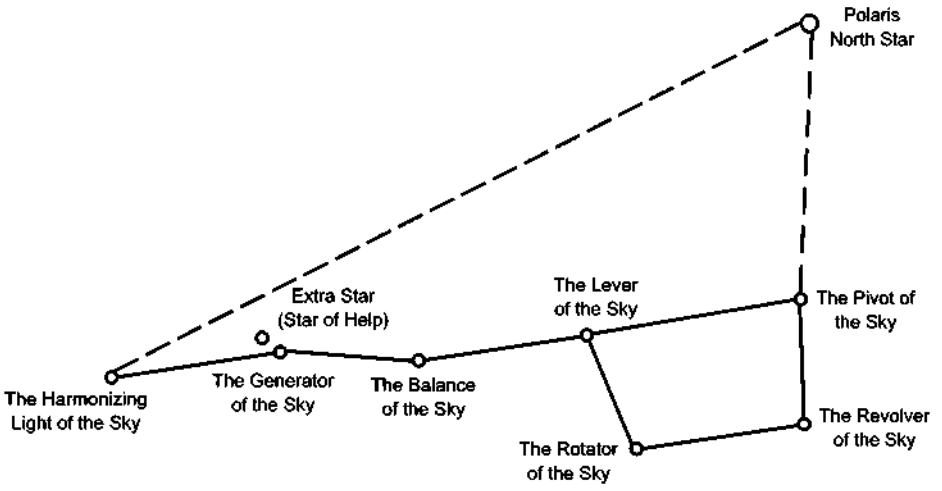

Figure 11.33. The Big Dipper is considered a reservoir of heavenly energy, collecting Qi from all of the other stars and constellations as it moves through the sky.

THE STARS OF THE BIG DIPPER

The Big Dipper represents the foundational base for the Gate of Access in Chinese mysticism, which is considered the spiritual passageway between life and death. Through this gate the individual may obtain knowledge and insight concerning past, present and future events.

The energy from the stars of the Big Dipper is used to balance the body's Five Agents (stored within the body's Five Yin Organs) and can be arranged internally to enhance internal perception of time and space (Figure 11.33).

One example used in ancient China for invoking the powerful protection of the Big Dipper energy is for the Qigong doctor to cover himself - or herself - with the stars of the Big Dipper by visualizing the stars descending and arranging themselves in a specific order around the doctor's body The stars can be arranged in four ways:

- above the doctor's head,
- in front of or behind the doctor's body,
- placed within the doctor's Three Dantians, or
- placed with the bowl of the Dipper in the Lower Dantian and the handle along the spine.

The doctor imagines placing the stars of the Big Dipper into the center of his or her body. The star's energetic function is to govern the front, back, right, and left of the body, thus regulating the doctor's Yin and Yang energy. The star's energetic function can also be used for absorbing energy from the four seasons into the doctor's body.

The stars of the Big Dipper are also considered responsible for opening the Seven Orifices of the embryo's body and for giving the embryo life. These stars also correspond to the Nine Chambers in the Three Dantians. Usually, meditations dealing with gathering energy from the sun and moon are followed by meditations involving the Big Dipper to further stimulate and energize the body's energetic fields.

THE FIRST FIVE PLANETS

The five planets (Saturn, Jupiter, Mars, Venus, and Mercury) are responsible for the internal Yin organ energy formation within the body during fetal development. These planets are the focus of several Qigong meditations because of their connection to color resonations within each internal Yin organ.

1. Of the first five planets in our solar system, Saturn is coupled with Earth and is considered the central force of planetary energy. It takes twenty-eight years for Saturn to make a complete revolution around the sun. Each year, when Saturn enters into another constellation, it is called "Saturn holding authority over that constellation for one year."

   Saturn's position in the sky relates to the Taiji Pole. The planet Saturn represents the Stomach and Spleen (Earth Element) and emits a golden-yellow light energy.
2. Jupiter represents the easterly direction and the Liver (Wood Element), it emits a green light energy; its position relates to the left side of the Taiji Pole.
3. Mars represents the southerly direction and the Heart (Fire Element). It emits a red light energy and relates to the front side of the Taiji Pole.
4. Venus represents the westerly direction and the Lungs (Metal Element). It emits a white light energy and relates to the right side of the Taiji Pole.
5. Mercury represents the northerly direction and the Kidneys (Water Element). It emits a dark blue/indigo light energy and relates to the back side of the Taiji Pole.

GATHERING ENERGY FROM THE FIVE PLANETS

To absorb energy from the five planets, start by quieting your mind while standing in a Wuji posture and facing the direction of the Big Dipper. Visualize yourself absorbing the energetic essence and color of each planet, one by one, into your body, filling each organ's entire Orb (the organs complete system, channels and tissues). Imagine filling the body with each planet's Heavenly energy from the top of your head, through the center Thrusting Channels.

Begin with the energy of Saturn, imagine it flowing into and filling your body through the Taiji Pole. Next, imagine the energy of Mars flowing into your front Center Thrusting Channel. Now imagine the energy of Mercury filling your body through the back Center Thrusting Channel, Venus's energy filling the body by descending into the right Center Thrusting Channel, and Jupiter's energy filling the body by flowing into the left Center Thrusting Channel. Gather the energy from their corresponding Orbs and lead the Qi downward into the Lower Dantian. After collecting and storing the Heavenly Qi, end the meditation with the Fire Cycle of the Microcosmic Orbit meditation.

THE TWENTY-EIGHT CONSTELLATIONS

Since the year 2000 B.C., the ancient Chinese Qigong Masters observed and used the movements and energy of the twenty-eight constellations, the sun and moon, and the first five planets with the Chinese zodiac, to forecast auspicious times for matters of state and war, and to predict weather and natural disasters. Each of these energetic systems has its own cyclic pattern as well as a direct and indirect influence on human life.

The Chinese practised gathering energy from the Heavenly stars, believing that the study of astrology, like alchemy, united the body's inner world with that of the outer. According to ancient divination practices, the celestial bodies exert forces and exhibit personalities that influence people and events on Earth. A person's character and destiny throughout life is based upon the positions of the planets and constellations at the exact time and place of birth. These influences can be determined by mapping the positions of the twenty-eight constellations in the sky at various times.

So important was this belief, that in ancient China, the Emperor was considered the high priest of the Heavens and frequently made sacrifices to the stars to maintain harmony with the universe. The four corners of the Emperor's palace represented the cardinal points in space (the equinoxes and solstices), and he and his family would move from one corner to another as the seasons changed.

GATHERING ENERGY FROM THE CONSTELLATIONS

At night time, when the moon is not suitable for absorbing Qi (new moon), the Qigong doctor can absorb the energy of the twenty-eight constellations into his or her body.

The energy of all five planets and twenty-eight constellations can be drawn into the body's internal organs and tissues through the five energetic Thrusting Channels which envelop and support the body's Taiji Pole. These Channels flow through the center of the doctor's body, connecting the top of the head to the perineum.

Externally, the twenty-eight day constellation cycle can be arranged externally on the body's Governing and Conception Vessels. The "ecliptic" path of the sun follows the Fire Cycle of the Microcosmic Orbit, which correlates to the individual's emotional/mental and physical health.

There are several meditations used in order to absorb the energy of the five planets and twenty-eight constellations into the doctor's body; one of which is known as The Heavenly Five Yin Organ Meditation.

HEAVENLY FIVE YIN ORGAN MEDITATION (TIAN WU ZANG)

This meditation is very popular in China. It focuses on fusing the energy from the five planets and the constellations into the body through the Five Thrusting Channels that surround the core center of the body's Taiji Pole. These Five Thrusting Channels should not to be confused with the TCM perspective of the Five Thrusting Vessels (as seen in Figure 11.34). Each of these Five Thrusting Channels relates to a specific organ energy and element (Figure 11.35).

When practicing this meditation and gathering the energy from the stars, it is important to first absorb the energy into the Five Thrusting Channels, then spiral the energy in a clockwise downward and counterclockwise upward direction through the body's Taiji Pole. This spiralling action allows the energy to balance itself and stabilizes the body's internal organs (Figure 11.36).

In order to perform the Heavenly Five Yin Organ Meditation and gather the Qi of the twenty-eight constellations, assume a Wuji posture, with your arms suspended by your sides. Face the direction of the North Star and Big Dipper (Figure 11.37). This exercise is performed for thirty-six breaths in each direction.

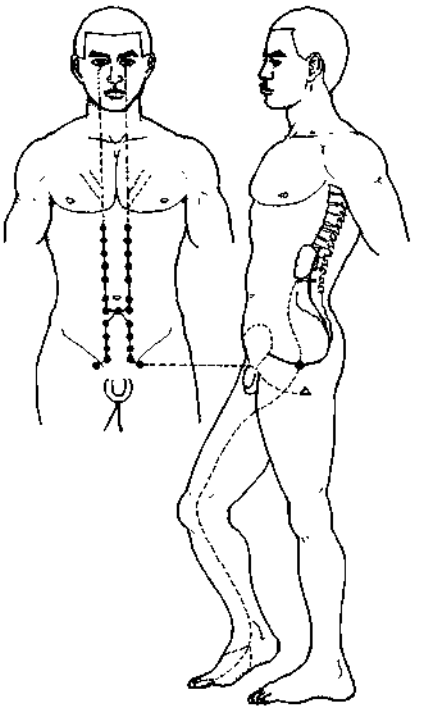

Figure 11.34. The Thrusting Vessels

1. To begin, imagine golden energy pouring out of the Big Dipper and flowing into the center of the Baihui area, at the top of your head. As you inhale, this golden energy fills the center core of your body, and flows into the extremities. As you exhale, this golden energy gathers into your Spleen.
2. Next, imagine drawing in a red energetic mist from the seven constellations in front of your body. This red mist flows into your body from the front side of the Baihui area, filling your entire body as you inhale. As you exhale, the energy coalesces into your Heart.
3. Now focus your attention on the back of your body. Inhale and imagine drawing in the dark blue energy from the seven constellations behind you into the back side of the Baihui area, filling your entire body as you inhale. This energy gathers into and fills the Kidneys as you exhale.
4. Next, focus on the right side of your body and imagine drawing in white energy from the

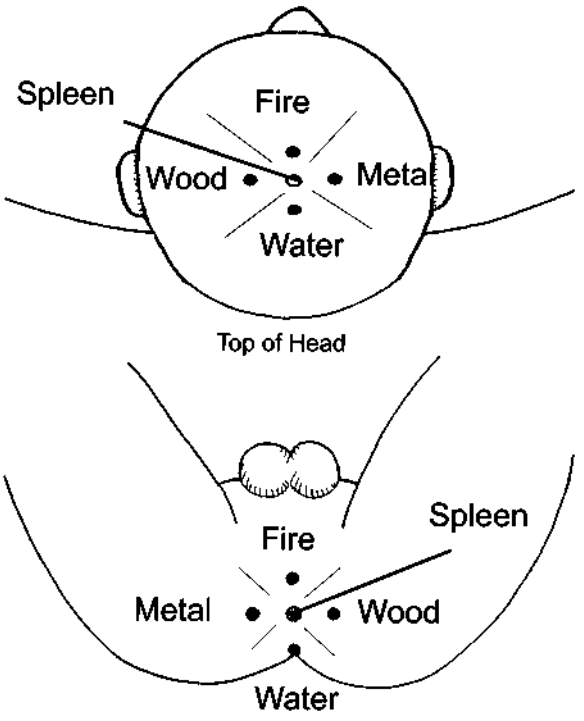

Figure 11.35. Each of the Center Thrusting Channels relates to a specific organ energy and element. Each channel has its own entry point that is positioned either on the top of the head, or on the base of the perineum.

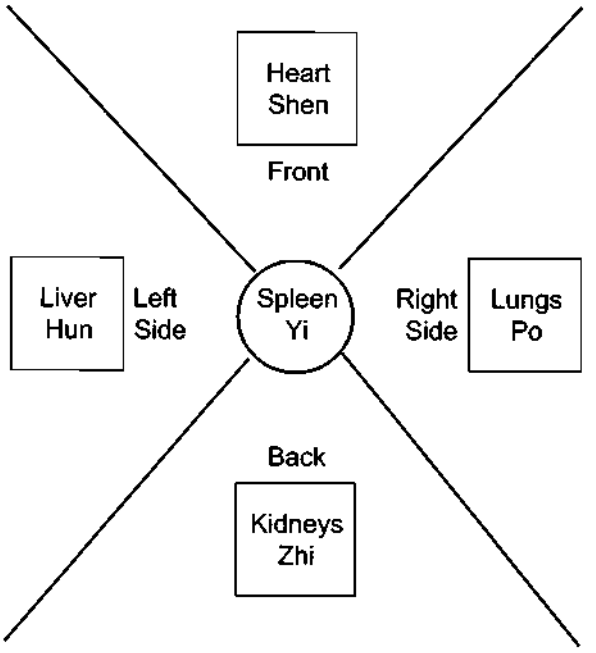

Figure 11.36. The body's Yuan Spirit is stored within the body's Five Yin Organs. The placement of the Five Energetic Houses is maintained throughout many Medical Qigong meditations and is used to tonify, strengthen, extend, and project the body's Shen.

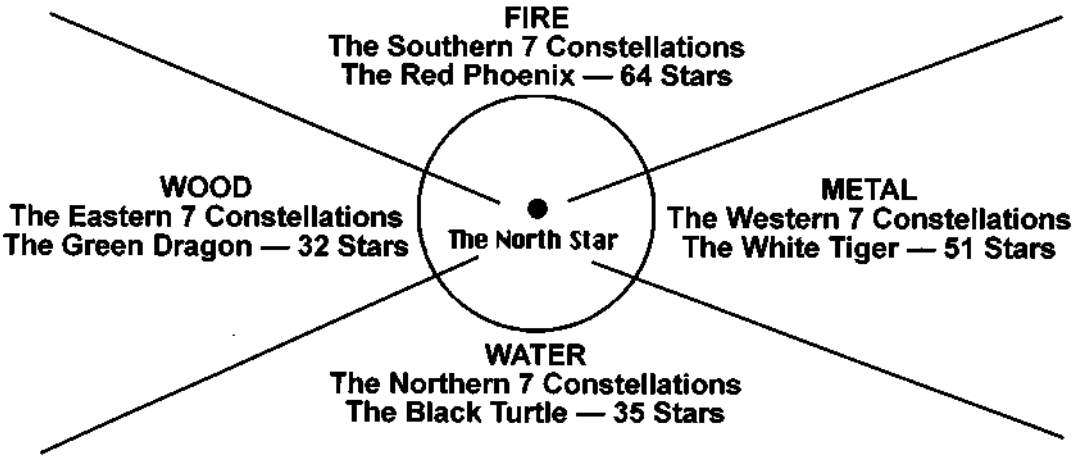

Figure 11.37. The energy of the Twenty-Eight Constellation Stars is absorbed into the body through the same structural pattern as the placement of the Five Energetic Houses of the body's Shen.

seven constellations to your right into the right side of the Baihui area, filling your entire body as you inhale. This energy gathers and fills the Lungs as you exhale.

5. Finally, focus your attention on the left side of your body and imagine drawing in green energy from the seven constellations on your left into the left side of the Baihui area, filling your entire body as you inhale. This energy gathers and fills the Liver as you exhale.

EARTHLY BRANCHES, HEAVENLY STEMS, AND NINE PALACES

There are many relationships between the macrocosm and the microcosm of man, through the Twelve Earthly Branches, the Ten Heavenly Stems, and the Nine Palaces outlined in the Chinese Classics on Internal Medicine. The Twelve Earthly Branches are Earth energies and are represented in Man as the Twelve Primary Channels. The Ten Heavenly Stems relate to the energies of Heaven and are represented in man as the Yin and Yang aspects of the Five Element organs of Wood, Fire, Earth, Metal, and Water (as seen in Figure 11.38). The Nine Palaces are related to the Eight Extraordinary Vessels (corresponding with the Eight Postheaven Trigrams) in addition to the body's energetic Taiji Pole.

The Twelve Earthly Branches, Ten Heavenly Stems, and the Nine Palaces are interwoven into almost all aspects of Chinese culture, arts and medicine. In Chinese divination, as well as Chinese medicine, the temporal cycles of the Earthly Branches and Heavenly Stems form the foundation for these practices. They can be used to explain the physiology, pathology, diagnosis, and treatment of each clinical case. For each year, month, day, and hour there is a Stem and Branch association. By studying the Stem and Branch association, the Qigong doctor can identify patterns (i.e., determine the cycles and diagnose the patterns of the patient's disharmony) and design treatment protocols, depending on the time of year and the time of day.

The yearly cycles of the Stems and Branches are based on a sixty-year cycle, when the sun, moon, Earth, and North Star are aligned (Figure 11.39). The last sixty-year cycle began in 1984. The exact origin of the Ten Heavenly Stems and Twelve Earthly Branches is not known. They were used, however, to mark the hours, days, years, and planetary cycles as early as 1500 to 2000 B.C. Some historians attribute their origin to the legendary emperor Huang-Di (as early as 2600 B.C.). Each cycle was regarded by the Chinese as being a "century" in the life span of the average man. Those who lived past the age of sixty were regarded as living a "second life." During this second life, the person would experience similar occurrences as in the "first life," but would be able to apply the wisdom and maturity gained from his or her first life. The individual can then further his or her spiritual growth and use the knowledge to benefit society as a whole.

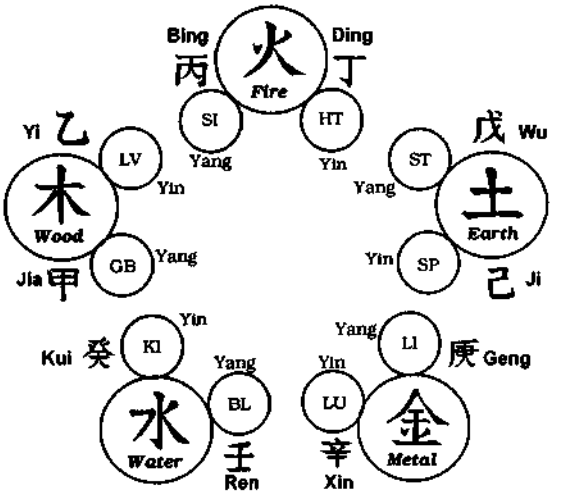

Figure 11.38. The Five Element Chart and Its Relationship to the Ten Celestial Stems

The twelve animals of the Chinese zodiac correlate with the Twelve Earthly Branches and are arranged as follows.

- Zi branch corresponds to the Rat
- Chou to the Ox
- Yin to the Tiger
- Mao to the Rabbit

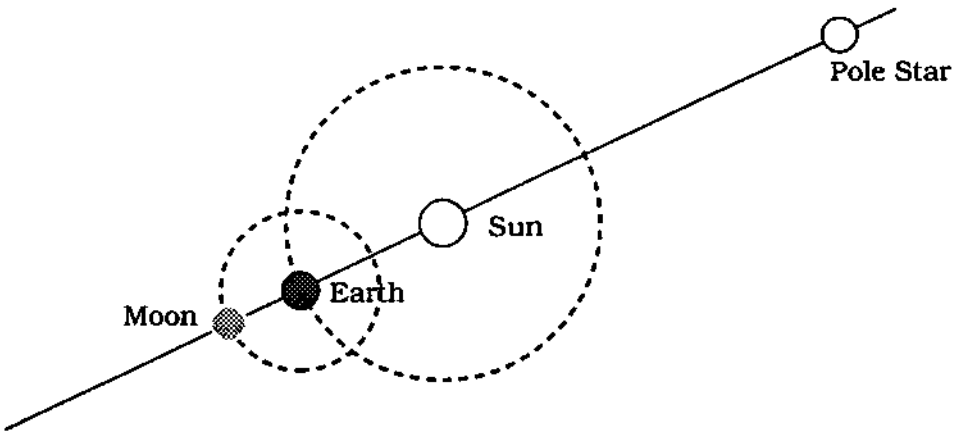

Figure 11.39. The beginning of the sixty-year cycle is based on the alignment of the sun, moon, earth, and North Star.

- Chen to the Dragon
- Si to the Snake
- Wu to the Horse
- Wei to the Sheep
- Shen to the Monkey
- You to the Rooster
- Xu to the Dog
- Hai to the Boar

The first year of the sixty-year cycle is associated with the first Branch and the first Stem. The first Branch, "Zi," corresponds with the Rat; the first Stem, Chia, corresponds with the element Wood. Thus, the first year of the sixty-year cycle is the year of the Wood Rat in Chinese astrology.

The second year of the cycle represents the second Branch and second Stem, and so on. When you reach the 11th Branch, there are no more Stems and, thus, the 11th year of the cycle represents the eleventh Branch and the first Stem. The cycle continues in this manner until it has transitioned through six cycles of Stems and five cycles of Branches and returns to the first Branch and first Stem paired together.

Figure 11.40 shows these yearly cycles; for example, 1997 was the year of the Fire/Ox, so the year 1998 is the year of the Earth/Tiger.

The Ten Heavenly Stems represent Yang, and the higher form of Heaven's vitality (Figure 11.41). The Twelve Earthly Branches represent Yin and the lower form of Earth's vitality (Figure 11.42). Together they manifest the transformation of all natural events expressed through the growing, thriving, declining, and dying of all living things.

1. Each lunar year the Earthly Branch time divisions are divided into 12 separate month divisions.
2. Each day is divided into 12 two-hour Earthly Branch time divisions during a 24-hour cycle.

SUMMARY

In comprehending the energetic potential of the Three Treasures of Heaven, the Qigong doctor evaluates the patient's condition and treats the disease according to the patient's energetic rhythm and flow, which is blended with the Heavenly and Earthly energies. The treatment also includes prescribing homework (the Medical Qigong prescriptions needed to support and maintain the doctor's treatments).

Although mankind is terrestrial, there can be no separation from the influence of the celestial. For mankind is born on Earth in physical form, created through the integration of both celestial (Heavenly) and terrestrial (Earthly) energies. According to statements recorded in the *Canon of Internal Medicine*, ancient doctors had already rec-

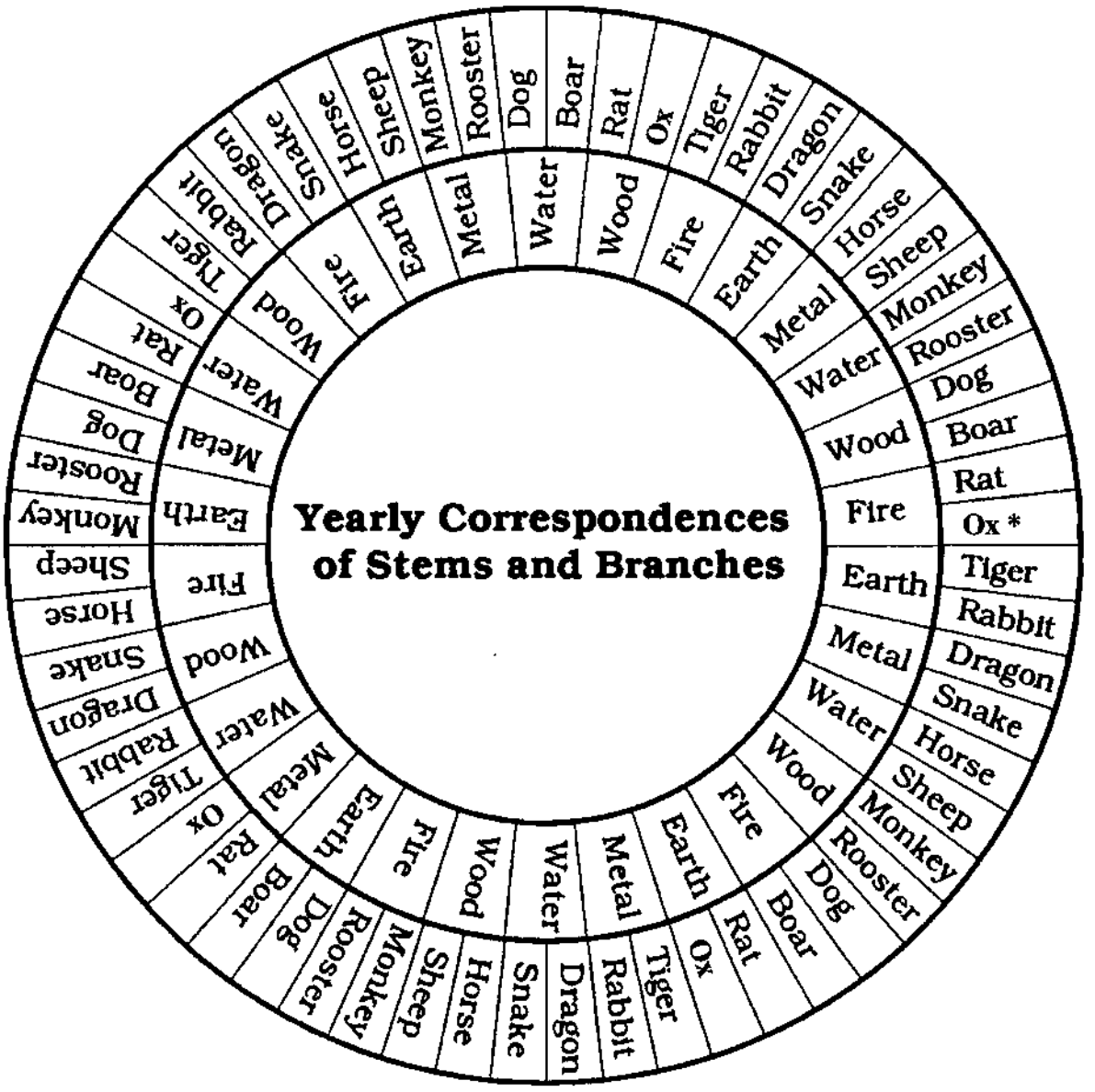

Figure 11.40. The asterisk (*) shows the year 1997, which was the year of Fire/Ox. Each year, one of the twelve animals of the Chinese zodiac flourishes and brings its energy into action. Every two years, a new Element (Fire, Wood, Water, Earth, Metal) dominates in the cycle of creation. The chart moves clockwise, so 1998 was the year of Earth/Tiger.

Character	Name	Number	Animal	Month	Time	Branch	Channel	Image	Element
子	Zi	1	Rat	Nov. 22–Dec. 21	11-1 am	Little Yang	Gall Bladder	Reproduction of Life	Water
丑	Ch'ou	2	Ox	Dec. 22–Jan. 20	1-3 am	Decreasing Yin	Liver	Initial Growth	Earth
寅	Yin	3	Tiger	Jan. 21–Feb. 19	3-5 am	Great Yang	Lungs	Breaking Ground	Wood
卯	Mao	4	Rabbit	Feb. 20–Mar. 20	5-7 am	Bright Yin	Large Intestine	Thick Vegetation	Wood
辰	Ch'en	5	Dragon	Mar. 21–Apr. 19	7-9 am	Bright Yang	Stomach	Full Awakening	Earth
巳	Si	6	Snake	Apr. 20–May 20	9-11 am	Great Yin	Spleen	Preparation for Ripening	Fire
午	Wu	7	Horse	May 21–June 21	11-1 pm	Little Yang	Heart	Peak of Growth	Fire
未	Wei	8	Sheep	June 22–July 21	1-3 pm	Great Yin	Small Intestine	Taste of Full Ripeness	Earth
申	Shen	9	Monkey	July 22–Aug. 21	3-5 pm	Great Yang	Bladder	Time of Harvest	Metal
酉	You	10	Rooster	Aug. 22–Sept. 22	5-7 pm	Little Yin	Kidneys	Resting after Harvest	Metal
戌	Xu	11	Dog	Sept. 23–Oct. 22	7-9 pm	Decreasing Yang	Pericardium	Moving Inward	Earth
亥	Hai	12	Boar	Oct. 23–Nov. 21	9-11 pm	Little Yin	Triple Burners	Seed Awaiting Growth	Water

Figure 11.41. Environmental Energetic Interactions of the Twelve Earthly Branches

ognized the close relationship between the body's Qi and Blood and the influences of the natural environment. In ancient China, the Twelve Earthly Branches represented time units, each of them corresponding to a two-hour period. They are primarily used to represent the 12 months in the Lunar Calendar.

The Ten Heavenly Stems are made up of the Five Elements, each of which is divided into pairs of corresponding Yin and Yang, resulting in a ten-step system of numerology. Using the Ten Heavenly Stems allows the Qigong doctor to determine the ebb and flow of the Qi of Heaven and its corresponding relationship to the Qi of Man.

Both the Ten Heavenly Branches and Twelve Earthly Stems represent the characteristics of growing, thriving, declining, and dying of all living things in the universe, as well as the development and transformation of all natural phenomena.

The energy of the Ten Heavenly Stems can be observed within five energetic movements (front, back, right, left, and center), as well as within the elemental energy of the body's major internal organs.

Chapter 12
The Three Treasures of Earth: Earth, Water, and Wind

Introduction to the Three Treasures of Earth

The Outer Force (Power) of Earth's Three Treasures consists of the Yin and Yang interaction of energy and light, emitted, absorbed, and reflected back from the land, water, and wind. The Three Earthly Treasures are brought about by the waxing and waning of the five Yin and Yang climatic transformations (the five seasonal growth cycles), which in turn are caused by the sun, moon, and stars. Each seasonal change brings a life transforming gift that affects the mind, body, emotions, and spirit (Figure 12.1). The wind (weather) reflects the various conditions and transformations of energy in the sky, and is viewed as an Earthly manifestation of Heaven's moods.

1. Earth Qi consists of the Yin and Yang interactions of energy and light, manifesting as hot and cold energy originating from the Earth's surface.
2. Water Qi consists of the Yin and Yang interactions of energy and light, manifesting as hot and cold energy originating from the vast oceans, lakes, and rivers of the world.
3. Wind Qi consists of the Yin and Yang interactions of energy and light, manifesting as hot and cold air circulation created from the interaction of the sun's heat on the surface of the planet. This interaction includes all cloud and barometric pressure formations (e.g., tornadoes, hurricanes, lightning storms, etc.).

Understanding Heat and Light Interactions

Heat and light are manifested both externally on and from the Earth's surface, and internally within the Earth.

1. Externally, the greater the intensity of the sun's light absorbed into the surface of the Earth, the more heat is manifested from the Earth's surface. Cloudy days diminish the

Natural Earthly Transformations					
Organs	**Element**	**Season**	**Elemental Factor**	**Temperature**	**Transition**
Liver	Wood	Spring	Wind	60– 70° F	Germination
Heart	Fire	Summer	Heat	above 90 F	Growth
Spleen	Earth	Late Summer	Damp	75– 90° F	Transformation
Lungs	Metal	Autumn	Dry	60– 70° F	Gathering
Kidneys	Water	Winter	Cold	below 60° F	Storage

Figure 12.1. The Natural Earthly Transitions

sun's thermal interaction and tend to bring coolness.

2. Internally, heat and light, as well as other natural forces, are contained within the Earth itself. The sun's intense energetic fields draw the heat and light from within Earth, which are then reflected back to the Earth by the atmosphere.

The Earth's air extends only a comparatively short distance out from the Earth's surface, and the effects of the heat rays decrease as you leave the Earth's surface and ascend toward the outer regions of the atmosphere. As the air becomes less dense, there is less reflection. The higher you ascend, the cooler the air becomes. When you have reached the limit of air, you have reached the limit of the Earth's heat.

The heat and light form a protective energetic field around the Earth's surface similar to the body's Wei Qi field. Once you have reached the limit of heat and light, you reach what is called the Great Cold. This cold is considered far more solid than steel, and it presses down upon the Earth's energetic field and atmosphere with an almost irresistible force, holding them together.

Understanding the Earth's Yin and Yang Interactions

Between Heaven and Earth there is an on-going interaction of Yin and Yang energy exchange. When the Earth Qi is in balance, plants grow and animals thrive. Power, in the form of energetic fields, is created by the integration of Yin and Yang. This power directly and indirectly affects the body's electromagnetic field, as well as the regulation and formation of the body's tissues. Visualize the Earth's energy as Qi resonating and emitting from the Earth itself. This energy includes the electromagnetic fields, subterranean radiations, and thermoluminescence (light and heat emitting from the center of the Earth).

The closer the Qigong doctor bonds physically, mentally, emotionally, and spiritually with the Earth and nature, the easier it is to tap into the Earth's energy and vibration. The development of Earth Qi in the body and the body's connection to the energy of the Earth are mutually supportive. The first step in internal cultivation involves focusing the mind on the Lower Dantian (with the aid of breathing techniques) to enhance the mind-body connection; this interactive connection develops a relationship with the Earth Qi.

Gathering Energy from the Earth's Energetic Fields

The ability to gather energy from nature and the environment is extremely important to the Qigong doctor. The energy of the Earth stays within the structural components of the planet, flowing like mighty rivers of Qi. It is absorbed into the terrain and vegetation, as well as the water that we drink. Environmental Qi is specific to each geographic area. It is the energy that has been collected from the structural components of the Earth itself (i.e., soil, fields, deserts, plants, trees, forests, mountains, streams, rivers, lakes and oceans, etc.). The energetic potential of the Earth's Qi changes from Yang to Yin energy with the rising and setting of the sun, and therefore directly affects the environmental energy.

Although food and water are excellent sources for gathering energy, the Qigong doctor cannot continually ingest food, or drink herbal teas while treating patients, without overtaxing his or her digestive system. It is, therefore, important for the doctor to find an alternative source of energy, to replenish his or her system once it becomes depleted. By studying the waxing and waning of the Earth's Yin and Yang energies the doctor can optimize the absorption of Yin and Yang energy.

Techniques for Cultivating Earth Qi

Generally, several meditations are used to cultivate and absorb energy from the Earth by utilizing the energy of trees, bushes, flowers, lakes, etc. The primary objective of these meditations is to first cleanse the body of pathogenic factors, then cultivate and absorb the environmental Qi to replenish the body's energetic field. Practitioners and patients should visualize themselves immersed in a focused environmental field of energy, filled with its vibration, color, and light. They should allow this energized field to envelop their entire body.

CLEANSING THE BODY

One of the most popular cleansing techniques used in the Xi Yuan Hospital's Qigong Clinics begins from a lying, sitting, or standing posture (usually in a Wuji posture) while in front of a natural object, such as a tree.

To cleanse the body's energy, extend both hands towards the tree, as if to embrace it (it does not matter if the tree is actually being touched). Upon inhalation, begin to guide the energy from the tree into your torso through the Laogong (Pc-8) points at the center of your palms, and the Baihui (GV-20) point at the top of your head. Absorb this energy deep into your body. Once you feel that the body is fully saturated with Qi, exhale through the mouth and guide the Turbid Qi down the legs and out of the body through the Yongquan (Kd-1) points at the bottom of the feet. Continue to guide the Turbid Qi down through the Earth into the root system of the tree. Then inhale through the nose, as you absorb the purified energy from the upper part of the tree leading it down your body through the top of your head. Continue this process until you feel totally cleansed. Remember to synchronize breathing in through your nose as you focus on absorbing the Earth Qi, and to exhale through the mouth, as you focus on dispersing and releasing the Turbid Qi.

For tonification, extend your Qi and intention deep into the root system of the tree and imagine absorbing its natural energy through the Baihui point at the top of your head (Figure 12.2).

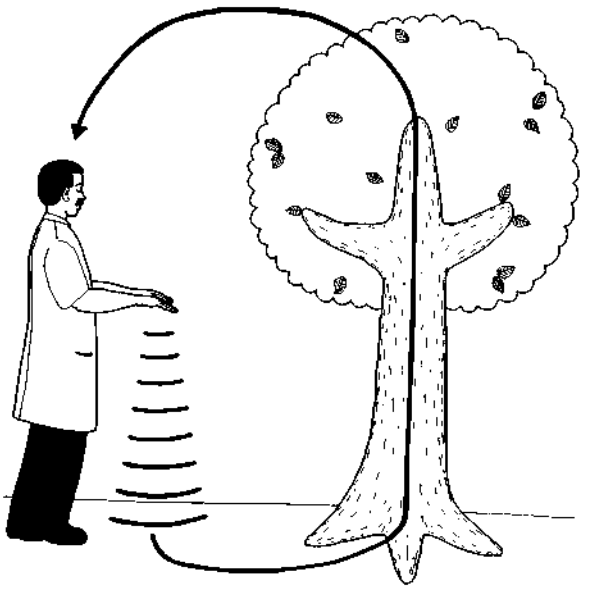

Figure 12.2. A Qigong doctor can extend Qi and intention deep into the root system of the tree and absorb its natural energy through the Baihui point at the top of the doctor's head.

GATHERING QI FROM TREES, BUSHES, AND FLOWERS

Earth Qi and environmental energy saturate all types of foliage, allowing the Qigong doctor to select, gather, and absorb Qi from many botanical sources. Throughout history, the Chinese have used trees, bushes, and flowers for healing and medicine. Trees and plants absorb air, light, energy, water, and minerals. When Heavenly Qi is combined together with the environmental energy of the tree or plant, the result is a powerful invigorating energy source.

In China, I noted that every Medical Qigong clinic I visited had its own garden. Each garden was full of healthy trees, bushes, and beautiful flowers from which the patients could draw energy. The patients could choose from different plants and bushes, each type of foliage having its own unique strengths and benefits. Any combination of healthy plant energies can be absorbed by the patients to improve their health.

The best time for absorbing energy from trees, bushes, and flowers is between the hours of sunrise (Mao: 5 - 7 am.) and noon (Wu: 11 a.m. – 1 p.m.).

It is important to note that, within the differing regions of a specific country, each type of tree and plant will have either minor or major variances regarding its energetic potential. This difference in energetic potential is due to the diverse environmental influences affecting each plant. We in the West, for example, have many different varieties of plants and trees similar to those in Asia, however, because of the energetic continental differences, the quality and quantity of Qi in each plant or herb can vary. This energetic difference is brought about by the various Qi fields produced

by each region's altitude, the mineral content of the soil and water, and the amount of exposure to the energy of the sun. Even herbs of the same name, but grown in different countries, can have different affects on the body's energetic system, slightly altering their clinical potential (e.g., American Ginseng is sweet, slightly bitter and cold, and enters the body affecting the Heart, Lung and Kidney Channels; Siberian Ginseng is sweet, slightly bitter and slightly warm, and enters the body affecting the Lung and Spleen Channels).

Gathering Energy from Trees

Trees are tremendously powerful plants and are commonly used by both doctors and patients to absorb and transform the negative pathogenic Qi into clean, healthy, life-giving energy. Pine trees tend to be one of the most powerful, as they radiate a great deal of Qi. Once an individual has connected with a tree, the primary goal is to:

1. remove stagnation from the channels,
2. tonify the internal organs,
3. stabilize and replenish any depleted energy within the body,
4. nourish the Blood, and
5. strengthen the nervous system.

The following is a brief description of various trees, their Yin or Yang potential, and their energetic affect on the body's internal organ system:

- Apple - slightly Yin - St and Sp
- Bamboo - Yin - Ht, Lu, GB, and St
- Birch - Yin - St
- Cassia (Cinnamon) - Yang - Sp, Kd, and Bl
- Cherry - Yang - Lv, Lu, Kd, and St
- Chestnut - Yang - Sp, St, and Kd
- Cranapple - neutral - Lv, Lu, and Ht
- Elm - neutral - St, SI, and LI
- Fig - neutral - Lu, LI, and Sp
- Ginkgo - neutral - Lu, Kd, and Ht
- Hawthorn - slightly Yang - Sp, St, Lu, and LI
- Magnolia - Yang - Lu, St, GB, LI, and Sp
- Maple - neutral - Sp, Kd, and LI
- Mulberry - Yin - Lu, LI, Sp, and Kd
- Oak - slightly Yang - LI, Sp, Kd, and Ht
- Pine - Yang - Ht, Lu, LI, and Kd
- Willow - Yin - Ht and Sp

Gathering Energy from Bushes

Bushes are an extremely effective source for gathering and ingesting different forms of healing energy. Similarly to trees, each bush has its own energetic properties and causes a specific reaction in the body's energetic field. Bushes, however, are not as powerful an energy source as trees for gathering massive quantities of Qi.

Gathering Energy from Flowers

Flowers are unique in their effect on stimulating the nervous system. Different colors, shapes, and sizes can affect the emotions, causing the individual's spirit to open. Each color can be absorbed into the body in order to facilitate the stimulation of internal organ energy. The gift of flowers has had a long history in soothing emotional pain and bringing relief to patients.

Cultivation and Regulation Techniques

Techniques used in the Qigong clinics for cultivation, absorption and regulation of energy generally begin by having the patient face a tree, bush, flower, etc. Although the hands and body postures are similar to the last meditation, the mind's intention is quite different. In this meditation the patient absorbs Qi from the tree, by inhaling it through his left palm, to draw the energy into his body. The energy is guided down the patient's chest, into his or her Lower Dantian. From there the patient circulates this gathered energy through his or her Microcosmic Orbit. As the patient exhales, the Qi exits the right palm into the tree, and begins the cycle again. This meditation is practiced to replenish the body's energetic field.

Patients should be monitored regularly to prevent Qi deviations, which may occur while absorbing Qi through their pores. For best results, choose a quiet, safe, and healthy environment. Select trees, bushes, and flowers with a stable root, or thick trunks. The color is also very important, as the leaves and flowers should be bright, full, and healthy.

Because the body's internal energy matches that of the external environment, it is important to avoid selecting any area which is unpleasant or unhealthy. Avoid any tree, bush, or flower that is sick, dying, has lost its color, or has just been

pruned. Using trees, bushes, or flowers for cleansing the body, as well as to absorb energy, is forbidden at night, because their oxygen production diminishes after the sun has set.

PRECAUTIONS

It is important not to meditate in front of any tree, bush, or flower that has parasites, or has been poisoned or polluted, since such vegetation will induce an impure energetic resonation within the Qigong doctor's body.

GATHERING QI FROM MOUNTAINS, VALLEYS, AND DESERTS

The mountains, valleys, and deserts absorb and release light, energy, and heat from the sun. These energies are absorbed and released from the structures of the land quicker than from the oceans, lakes, and streams. Environmental energy is also gathered and stored by the geological formations and local ecology. The ancient Chinese Qigong masters viewed the Earth as a living entity, with rivers and pockets of energy similar to that of the human body. Certain altitudes, densities of colors, and structural formations can affect the Earth's energetic potential.

GATHERING ENERGY FROM MOUNTAINS

Mountains are extremely powerful conduits of energy. They act as peak areas, or collection points for energy. The higher the mountain, the more the air is charged with electromagnetic potential. In ancient times, for prayer and meditation, Taoist and Buddhist temples, shrines, and caves were constructed on energetic pockets high within the mountains of China. In fact, all high, mountains that are far from human civilization are regarded as superior places for energetic cultivation, due to the clarity of light and extraordinarily potent energies which include a very high negative ion count in the air.

GATHERING ENERGY FROM VALLEYS

The Earth's valleys act as channels for Earth energy, collecting and carrying energy throughout the natural terrain. Systems of valleys extend through the plains, hills, and mountains, and generally flow towards the ocean. By standing at the "floor" of the valley (surrounded by its walls), energy can be easily absorbed into the body for cultivation.

GATHERING ENERGY FROM DESERTS

The deserts are considered seas of dry heat energy. They are excellent environments for meditations when used to gather Qi into the body, especially for combating diseases pertaining to Wind, Cold, and Damp invasion (which give rise to many diseases).

CULTIVATION TECHNIQUES

Generally there are several meditations used to cultivate and absorb energy from mountains, valleys, and deserts. The primary objective of these meditations is either to cleanse the body of pathogenic factors, or to cultivate and absorb Qi. When cultivating energy from mountains, valleys, or deserts, practitioners should visualize themselves immersed in the Earth's field of energy, filled with vibration, color, and light. The practitioners should allow this energized field of Earth Qi to envelop them completely.

For best results, select mountains, valleys, and deserts with a stable foundation. The color is also very important, as the Earth, soil, rocks, and surrounding area should be clean.

Also, there are certain locations on the planet known as "power spots" which can produce remarkably powerful effects in the body's energetic fields.

Patients should be monitored regularly in order to prevent Qi deviations, which may occur while absorbing Qi through their pores.

PRECAUTIONS

Because the body's internal energy matches that of the external environment, it is important not to meditate in front of any mountain, valley, or desert area that has eroded, is dying, has lost its color, or is polluted. Also prohibited are areas where there is ongoing seismic, or volcanic activity, as such areas will induce unstable resonation within the Qigong doctor's body.

GATHERING QI FROM OCEANS, LAKES, AND STREAMS

The oceans, lakes, and streams retain and release the sun's light, energy, and heat slowly and

are, therefore, important in energy cultivation. The body instantly absorbs the light, energy, and resonant vibrations stored within water. Energized water (sometimes in the form of herbal teas) is often used by Qigong doctors in clinics throughout China. This energetically transformed water provides the patient's body with the basic components necessary for restoration and regeneration, and is considered the "elixir of life" by many Qigong doctors.

GATHERING ENERGY FROM OCEANS

The energy from the ocean has a strong cleansing and purifying effect on the body's Qi. Meditating by the ocean is used extensively for dispersing negative emotions and regulating the body's internal organs. The active rhythm and sound of the waves allows the patient to harmonize his or her internal energetic rhythms with that of the tide, thus quieting the nervous system.

GATHERING ENERGY FROM LAKES

The energy from a lake has a strong calming affect on the body's energetic field. The quiescent solitude of a lake can be used to sedate active emotions, balance any Excess or Deficiency, and calm the body's Shen.

GATHERING ENERGY FROM STREAMS

The energy of a stream can be used to replenish and restore depleted Qi, sedate active emotions, balance any Excess or Deficiency, and also to calm the body's Shen.

CULTIVATION TECHNIQUES

Generally there are several meditations used to cultivate and absorb energy from oceans, lakes, and streams. The primary objective of these meditations is to either cleanse the body of pathogenic factors, or cultivate and absorb Qi to replenish the body's energetic field. When cultivating energy from oceans, lakes, or rivers, patients should visualize themselves immersed in a pool of water, filled with energy, color, and light. The patient should allow this energized water to absorb, cleanse, and invigorate the entire body.

Patients should be monitored regularly to prevent Qi deviations, which may occur while they are absorbing Qi through their pores. For best results, select oceans, lakes, and streams with a calm, stable current. The color is also very important, it should be clear and clean. The water and the surrounding areas should also be clean.

PRECAUTIONS

Because the body's internal energy matches that of the external environment, it is important to avoid selecting any oceans, lakes, or streams that are turbulent, have become dull in color, polluted, or stagnant.

GATHERING QI FROM THE SIX DIRECTIONS

Absorbing Qi from the six directions (Heaven, Earth, and the Four Winds), focuses on gathering environmental energy into the center core of the body (Taiji Pole) from: Heaven, Earth, and the four directions: South corresponds to the front of the body, North to the back of the body, West to the right of the body, and East to the left of the body. The Taiji Pole is considered the central axis, with two directions, above and below. This is a tonification exercise that is used for gathering and absorbing the Earth's environmental Qi, to energize a weakened or Deficient condition.

CULTIVATION TECHNIQUES

There are several meditations used to cultivate and absorb energy from the four directions of the horizon, with the fifth and sixth directions being at the top and bottom of the Taiji Pole. The primary objective of these meditations is to first cleanse the body of pathogenic factors, then to cultivate and absorb environmental Qi. Each direction of energy (N, S, E, W, Heaven, and Earth) has its own unique field of power and vibration, and is assigned a specific color. Each vibration and color stimulates the energy field of one of the five major Yin organs through the body's Heaven and Earth connection (i.e., the Taiji Pole).

When cultivating energy from the horizon, practitioners should face the direction of the south and visualize themselves surrounded in an energetic mist. This mist contains six different colors and light vibrations. From the four directions (N, S, .E, and W) emanate the corresponding following four colors: ruby red, brilliant white, indigo

and emerald green. Each of these colors are associated with a particular Yin organ: ruby red with the Heart, brilliant white with the Lungs, indigo with the Kidneys, and emerald green with the Liver. From the Earth itself arises a golden yellow mist; this color is associated with the Spleen. From Heaven descends a silvery white mist entering the body at the top of the head; this color is associated with the Taiji Pole. These six different colored mists permeate and envelop the body with their healing light vibrations.

To perform this meditation, stand in a Wuji posture as you visualize:

1. A silvery white mist descending from the center of the Heavens to penetrate and envelop your Taiji Pole. This silvery white mist enters your body through the top of the head at the Baihui (GV-20) point, and flows into and fills up the Taiji Pole, saturating and absorbing into your center core.
2. A golden yellow mist, ascending from the center of the Earth, entering the body through the bottom of your feet at Yongquan (Kd-1) points. This golden yellow mist saturates your Spleen as it penetrates and envelops your center core;
3. A ruby red mist, flowing from the horizon in front of you enters your Heart, as it saturates and envelops the front of your body.
4. An indigo or dark blue mist flowing from the horizon behind you enters your Kidneys, as it saturates and envelops your back.
5. A brilliant white mist flowing from the horizon on your right side enters your Lungs, as it saturates and envelops the right side of your body.
6. An emerald green mist flowing from the horizon on your left side enters your Liver, as it saturates and envelops the left side of your body.

Patients should be monitored regularly to prevent Qi deviations which may occur while the patient is absorbing Qi through his or her pores. For best results while absorbing environmental Qi, the color of the energy should be clean, clear and bright.

PRECAUTIONS

Because the body's internal energy matches that of the external environment, it is important to avoid selecting any areas that are windy, turbulent, polluted, or stagnant. Also avoid cultivating energy in storms, during hurricanes, sweltering heat, or blistering cold. Avoid any type of extreme weather condition.

ADDITIONAL TECHNIQUES FOR TRAINING EARTH QI

The following exercises at one time were secretly practiced throughout China, as a means for Medical Qigong doctors and Qigong masters to practice advanced methods of environmental energy manipulation. The purpose of these Qigong exercises is to allow the doctors the chance to practice connecting and infusing their energetic field with the environmental energetic field.

PULLING CLOUDS OUT OF THE SKY

This exercise requires the Qigong doctors to first root and immerse themselves with the vibrational resonance of the Earth (this can be accomplished by practicing the One through Ten Meditation, described in Chapter 26). Next, the doctors extend an energetic line from the Earth into the sky, connecting to and enveloping a specific cloud. Through focused intention, the doctors imagine sucking the cloud out of the sky and down into the Earth, rooting its energetic form into the Earth's energetic field. As the cloud's energy is absorbed into the Earth, it dissolves from the sky.

Once the doctors have rooted the cloud into the Earth's energetic field, they have two choices: either to release the cloud back into the sky by attaching its energetic form onto an already existing cloud, or to allow the cloud to disperse into the energy of the surrounding environmental field.

DIVIDING A CLOUD IN HALF

After connecting and rooting into the Earth's energetic field, the Qigong doctors extend their intention into the sky, connecting with a particular cloud formation. Next, the doctors condense their upward intention, and like a laser beam, be-

gin dividing and separating the cloud into two halves. After the cloud has been divided into two separate formations, the doctors can either continue to further divide and dissect the cloud or reconnect its structure.

THE EARTHLY TREASURE OF FOOD

The Earth's natural energetic forms and transformations affect the flow of the body's life-force energy. Food and water are examples of a natural form of Earth Qi, and are viewed as Earthly Treasures. Although the air we breath is representative of Heaven Qi, due to the influence of environmental energetic fields, it is also viewed as an Earthly Treasure. The objective of self-cultivation work is to continually purify the energy within the Microcosm of Man, and increase the awareness of the pure energy within the Macrocosm of the universe.

Because of its connection to the Earth's Yin and Yang energy fields, the body's life-force energy can be replenished through the consumption of food and herbs. Both food and herbs have Yin or Yang properties which, when consumed, help the body in moving, tonifying, purging or regulating the life-force energy.

UNDERSTANDING THE YIN OR YANG ASPECT OF FOOD

When trying to determine whether a food is more Yin or Yang, several characteristics should be evaluated. Yin foods take less time to grow, are more watery or wet, and are colder, and sweeter. Yang foods take more time to grow, are drier, hotter, and less sweet. The more Yin the food, the more expanded it will become (e.g., a pumpkin); the more Yang the food, the more contracted or dense it will become (e.g., a turnip).

Diet directly influences the body's ability to generate Qi. The body's ability to effectively digest food plays a big part in how efficiently the body utilizes the nutrients it receives.

UNDERSTANDING THE YIN OR YANG ASPECT OF HERBS

Food is a powerful healing tool. Medicinal herbs are considered "special foods," and are divided into Yin and Yang aspects throughout China. They are prescribed to be taken in soups (tang), teas, or as additives to other dishes; for example, Chinese Qigong doctors, as well as many martial arts masters, frequently drink herbal teas to help regulate their body's energies during seasonal changes. The herbal teas are consumed according to the following sequence.

1. The summer is considered the season of maximum Yang; green herbal tea is drunk in order to cool down the body and regulate the internal organ systems.
2. The autumn is the season when Yin and Yang energies balance; however, the Yin energy is increasing, so flower tea is drunk to help stabilize the body's Yin and Yang balance.
3. The winter is considered the season of maximum Yin; black or red tea is drunk to warm the body and regulate the internal organ systems.
4. The springtime is the season when Yin and Yang energies balance; however, the Yang energy is increasing, so flower tea is drunk to help stabilize the body's Yin and Yang balance.

Teas are frequently prescribed for their particular healing properties. Each herb has a specific nature. Herbs that are considered Hot or Warm are used to treat Cold conditions, and herbs that are considered Cold or Cool are used to treat Hot conditions. Herbs are also categorized according to their flavor (sour, bitter, sweet, pungent, or salty) and are used to affect the body's internal organ energy. Herbs help the Qi ascend or descend in order to purge or tonify an internal organ or channel. Herbs are also used in moving the Blood. Specific herbs are also chosen for prescription, based on the Differential Diagnosis according to the Eight Energetic Principles (see chapter 21), the Five Elements (see chapter 23), and the Six Stages (see chapter 24) theories .

Generally, because all herbs have medical uses and contraindications, they are collected and divided into three categories: superior herbs - which consist of tonics, common herbs - which are slightly toxic, and inferior herbs - which are toxic. To gather herbs, the doctor must have an exten-

sive knowledge of the environment (season, place, time, etc.), and the specific herb (roots, bark, leaves, flowers, fruits, etc.) The doctor must also possess the harvesting skill required for gathering the herb. Once the herbs have been gathered, the doctor must then begin the procedure of processing them. The process work is important as some herbs are poisonous and need to be detoxified, while others have their properties enhanced through the extracting process.

ENERGY, FOOD, AND DIET

Many generations have asked the same question, "Is food medicine or medicine food?" An old Chinese proverb states, "To tonify with food is better than with medicine, but to tonify with Qi is better than food." Several decades of nutritional, epidemiological, and clinical studies point to a powerful link between disease and dietary habits.

For centuries, Chinese healers have studied food, discovering the properties of specific foods and the secrets of using them to achieve health and longevity. Chinese nutrition focuses on the energetic properties of food and their qualitative actions on the body as a whole, as well as their influences on the various internal organs and channels. Unless the patient eats correctly, Qigong, acupuncture, Chinese massage, and even herbal therapy will not be as effective, or long standing. In the Tang Dynasty, the great physician Sun Simiao wrote the medical classic *One Thousand Ounces Of Gold*, which described the dietary treatments of several diseases, including night blindness and goiter.

What we eat can either aggravate or enhance the healing of a particular condition. When Gu Qi (food energy) is being generated, strong surges of energy from the Spleen and Stomach (in the Middle Dantian) cause the body to generate more Yang Qi. As the body's Yin aspect weakens, its energetic nature becomes dryer and wanes; the Yang is no longer held in check and an overexuberant Yang begins to generate Heat, which produces, and sometimes releases, emotions.

Emotions begin with, and stem from, the energetic properties of Postnatal Qi. When ministering to patients, the doctor should ensure a healthy physical and social environment (e.g., clean air and a loving support system), as well as monitor the quality and quantity of food consumption. Hostile surroundings interfere with the proper digestion of food and cause toxic Qi. Food, air, and water become the fuel that generates energy in the body. When life-force energy becomes impure from poor diet, Heat accumulates in the organs, creating Excess Yang, or Excess Fire Qi.

One essential skill for harvesting the Earth's Treasures is controlling the intake of food and diet. It is important that a patient not eat foods that are excessively Cold, Hot, spicy, or greasy. If food is ingested while the food is too Yin (Cold) or out of harmony with the seasons, an external pathogenic factor can be created. When a Cold or Yin factor is created (a condition where Cold and Excess Yin consumes the Kidneys Yang, preventing the body's Yang Heat from warming the body), the Qi becomes sluggish, thus blocking the channels or collaterals. These blockages cause pain and damage to the Stomach and intestines and affect the Heart and Lungs.

If food is ingested while the food is too Yang (Hot) or out of harmony with the seasons, a Yang factor is created, causing internal energy to be released, which damages both the Blood and Qi. Because of its turbid nature, food that is too greasy may damage the Stomach Qi, causing boils and pyogenic infections, along with ulcerous skin diseases. Excessive eating may cause too much Gu Qi to develop, generating an excessive amount of power. This Excess power produces an upward reaction of Stomach Qi, which is detrimental to both the Spleen and Stomach, causing the breath to become obstructed (mother/Spleen affecting child/Lungs), and the psychic centers (Shen within the Heart) to become blocked. Many postnatal illnesses result from eating the wrong kinds of food in the wrong season, not eating enough of the right kind of food, overeating, or all of the above.

Balancing the diet in accordance with the cycles of nature and the principles of Yin and Yang

Balancing the Diet					
	Liver	**Heart**	**Spleen**	**Lungs**	**Kidneys**
Excess	Sour	Bitter	Sweet	Pungent	Salty
Controlled By	Pungent	Salty	Sour	Bitter	Sweet
Counteracts	Sweet	Pungent	Salty	Sour	Bitter

Figure 12.3. The Five Flavors and their Controlling and Counteracting Cycles

should be an integral part of the daily practice. In some situations, the body can compensate for an improper or unbalanced diet. To counteract this imbalance, however, the body will expend a great quantity of energy. Eating similar foods all the time results in the accumulation of toxins from those foods and can cause mildly allergic reactions. A balance of the different food groups is the key to dietary success.

USING THE FIVE FLAVORS OF FOOD

The energetic properties of the Five Flavors of food (sour, bitter, sweet, pungent, or salty) can be used to balance and control the energy of each organ. Any excess or deficiency of one flavor affects not only the organ to which it corresponds, but all the other organs as well (Figure 12.3). In the clinics in China, the theory of the Five Flavors or tastes is combined with the theory of the Five Elements to describe the interaction of the different "flavors" on the body's internal organs and energetic systems (Figure 12.4). The Five Flavors and their affect on the body are described in the following sections.

SOUR TASTE, ELEMENT WOOD

Some examples of Sour foods include: lemons, pickles, liver, vinegar, wheat, salad oils, and sour cream. Sour foods affect the Liver, eyes, and tendons. They are also excellent for stimulating the energy of the Liver and Gall Bladder.

1. Sour foods are astringent (causes shrinking), and can be prescribed to achieve the following treatment goals:
   - to prevent or reverse the abnormal leakage of Qi and Fluids,
   - to counteract diarrhea and excessive perspiration by slowing the movement of fluids,
   - to drain the Liver of Excess Qi, thereby indirectly strengthening the Lungs, and
   - to correct an irregular, slow heartbeat.
2. An excess of sour foods can cause the following dysfunctions:
   - injures the muscles,
   - hardening and wrinkling of the skin, and
   - stiffness spreading along the tendons that are controlled by the Liver. As the Liver controls the tendons, patients with Liver trouble should also eat less sour food.

BITTER TASTE, ELEMENT FIRE

Some examples of Bitter foods include: coffee, black and green teas, asparagus, celery, turnips, leeks, cabbage, broccoli, and cauliflower. Bitter foods affect the Heart, tongue, and Blood. They are also excellent for stimulating the energy of the Heart and Small Intestine.

1. Bitter foods are used for draining and drying, and can be prescribed to achieve the following treatment goals:
   - to stimulate the energy of the Heart, control the Heart Fire,
   - to reducing fever and Excess body Heat,
   - to stimulate digestion,

Five Elemental Cycle					
Element	Fire	Metal	Wood	Earth	Water
Season	Summer	Autumn	Spring	Late Summer	Winter
Organ	Heart	Lungs	Liver	Spleen/ Pancreas	Kidneys
Bowel	Small Intestine	Large Intestine	Gall Bladder	Stomach	Urinary Bladder
Superficial Organ	Blood Vessels	Skin	Nerves	Muscles	Bones
Release Point (Sense Organ)	Tongue	Nose	Eyes	Mouth	Ears
Taste	Bitter	Pungent	Sour	Sweet	Salty

Figure 12.4. The Five Flavors in Relationship to the Body's Internal Organs, Seasons, and Elements

- to drain Excess Spleen Qi, and
- to remove obstructions in the upper respiratory tract.

2. An excess of Bitter foods can cause the following dysfunctions:
   - dryness and congestion of the Spleen and Stomach; and
   - hyperactivity of the Heart Fire, and the consumption of Kidney Yin fluids.

SWEET TASTE, ELEMENT EARTH

Some examples of Sweet foods include: honey, sugar cane, orange juice, pecans, snow peas, corn, milk, and sweet potatoes. Sweet foods affect the Spleen, mouth, and muscles. They are also excellent for stimulating the energy of the Spleen, Stomach, and pancreas.

1. Sweet foods are used for tonifying, regulating and sometimes moistening, and can be prescribed to achieve the following treatment goals:
   - to stimulate the digestive Fire,
   - to tonify the Spleen, Stomach and pancreas, and
   - to drain the Heart of Excess Qi.
2. An excess of sweet foods can cause the following dysfunctions:
   - an imbalance in the Kidneys,
   - an aching in the bones,
   - hair loss from the head,
   - muscle dysfunctions, and
   - injury to the Spleen and Stomach. The Sweet flavor spreads through the muscles, so patients with diseases of Spleen, Stomach, or muscles (diabetes, hypoglycemia, systemic candida, fibriomyalgia, chronic fatigue, etc.) should limit their intake of Sweet foods.

PUNGENT TASTE, ELEMENT METAL

Some examples of Pungent foods include: garlic, onions, ginger, black and white pepper, mustard, and chilies. Pungent foods affect the Lungs, nose, skin, and body hair. They are also excellent for the stimulating the energy of the

Lungs and Large Intestine. Because the Lungs control the Qi, the Lungs are very quick in absorbing the energy of Pungent foods.

1. Pungent foods are used for dispersing and moving, and can be prescribed to achieve the following treatment goals:
   - to induce perspiration,
   - to improve circulation of Qi and Blood,
   - to stimulate the digestion,
   - to activate the Lung energy and promote the Lung's function,
   - to expand the Lung Qi,
   - to drain the Lungs of Excess Qi, and
   - to increase Fluids and saliva secretions.
2. An excess of Pungent foods can cause the following dysfunctions:
   - great loss of Lung energy and damage to the Lung organs,
   - knots in the muscles, and
   - withering or decay of the fingernails and toenails.

SALTY TASTE, ELEMENT WATER

Some examples of Salty foods include: shellfish, cheese, soy sauce, salt, ham/pork, and margarine. Salty foods affect the Kidneys, ears, and bones. They are also excellent for stimulating the Kidney Qi and Bladder Qi.

1. Salty foods are used for purging and softening, and can be prescribed to achieve the following treatment goals:
   - to soften hard nodules such as cysts,
   - to purge inflamed lymph glands, and
   - to soften knotted muscles.
2. An excess of Salty foods can cause the following dysfunctions:
   - cause damage to the Kidneys and Bladder,
   - cause the Blood to coagulate or clot,
   - cause Blood diseases,
   - harden the pulse, and
   - cause changes in the complexion.

GUIDELINES FOR THE FIVE ELEMENTAL TASTES

During each season, the five separate extremes in flavors serve as a catalyst to draw Qi into the Deficient organ. Overexposure to the seasonal elements (Cold, Wind, Damp, etc.) is responsible for external pathogenic factors that invade the body and affect the body's Jing, Qi, and Shen. The development of disease is due to an imbalance in the struggle between the body's health preserving Qi and the pathogenic influences. If the pathogenic factors are excessive, they can obstruct the body's normal physiological function, creating illness. If, however, the body's Qi is strong, the pathogenic factors will have a difficult time causing any energetic imbalances.

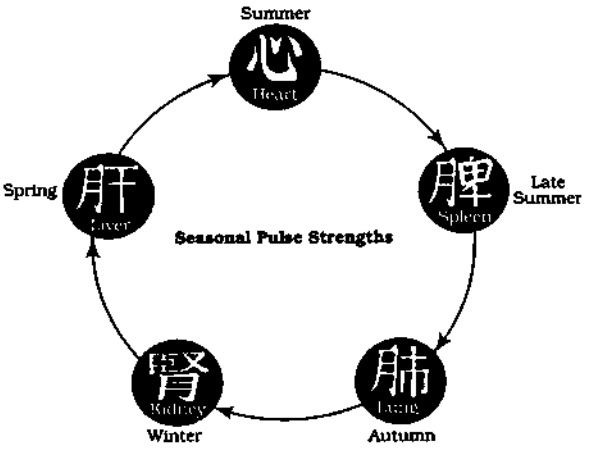

Figure 12.5. The quality of the body's pulse is constantly changing according to the rhythm of the five seasons.

Traditional Chinese Medicine divides the effects of these tastes into five seasons, each with its own unique function and flow of energy affecting the human body. One example of the effects of nature's rhythms on man is that the pulse quality in the viscera constantly changes in accordance with the five seasons (Figure 12.5). The Liver pulse is relatively strong in spring, compared to the other organs; in the summer the Heart is stronger, in the late summer - the Spleen, in the autumn - the Lungs, and in winter - the Kidneys.

Basic guidelines are developed for eating in accordance with the flow of the Five-Element cycle. These guidelines will help train the body to recognize what foods it needs. The food types and

tastes are divided into five categories, which relate to the five seasons of the year, the Five Elements, and the Yin and Yang organs (Figure 12.6).

To achieve overall balance, food and energy must be equally balanced. If the Liver is weak, for example, eating Sour food will help correct it and Salty food will also help. This prescription is based on the Five Element theory, which focuses primarily on two cycles—the Generating Cycle and the Controlling Cycle (Figure 12.7).

Overview of the Five Elemental Tastes

The overall understanding of the Five Elemental tastes empowers the Qigong doctor to accurately assist in prescribing better eating habits for his or her patients. By understanding the seasonal eating patterns (i.e., in the winter eating root food, which is grown under the ground, and in the summer eating food that is grown via branches and flowers) the doctor can observe whether the patient is further compounding his or her disease condition through improper diet.

Summary

In comprehending the energetic potential of the Three Treasures of Earth, the Qigong doctor will be able to evaluate the patient's eating and living conditions and their affect on the patient's disease. This also includes prescribing the Medical Qigong exercises, meditations, diets, and eating habits needed in order to support and maintain the doctor's treatments.

Through monitoring the patient's connection to their environment and eating patterns, the Qigong doctor is able to understand the Earthly influence on the patient's physical, mental, emotional, and spiritual being.

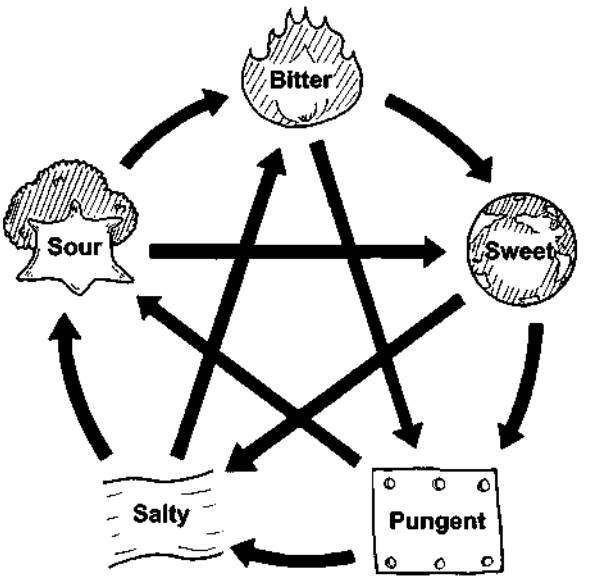

Figure 12.6. The Five Elements' Interaction of the Five Flavors

In the Creative or Generating Cycle—		
Salty Kidney (Water)	generates	(Wood) Sour Liver
Sour Liver (Wood)	generates	(Fire) Bitter Heart
Bitter Heart (Fire)	generates	(Earth) Sweet Spleen
Sweet Spleen (Earth)	generates	(Metal) Pungent Lung
Pungent Lung (Metal)	generates	(Water) Salty Kidney

In the Controlling Cycle—		
Salty Kidney (Water)	controls	(Fire) Bitter Heart
Bitter Heart (Fire)	controls	(Metal) Pungent Lungs
Pungent Lungs (Metal)	controls	(Wood) Sour Liver
Sour Liver (Wood)	controls	(Earth) Sweet Spleen
Sweet Spleen (Earth)	controls	(Water) Salty Kidneys

Figure 12.7. The Creative (or Generating) and Controlling Cycles of the Five Flavors

Chapter 13
The Three Treasures of Man: Jing, Qi, and Shen

The Outer Force (Power) of the Three Treasures of Man are expressed through Jing (Essence), Qi (Energy), and Shen (Spirit). The human body is made up of vibrational frequencies that interact to create energetic fields and substances, or energetic materials ranging in structure from less dense to more dense (Figure 13.1). In order of increasing density, these energetic materials manifest as Spirit (Shen), Energy (Qi), Essence (Jing), Blood (Xue), Body Fluids (Ye/Jin), Marrow (Sui), and Bone (Gu). Of these energetic substances, Essence (Jing), Energy (Qi), and Spirit (Shen) are regarded as the most important. These three materials perform the most important functions in the human body, and are known as the Three Treasures of Man or San Bao.

The energy of the human body, or Man's Qi, is created from and through different interacting rates of vibration and energy fields that combine to form the body's cells, tissues, and organs, creating a living organism. In Chinese philosophy, the Three Treasures of Man also represent the interaction of Heaven and Earth within the human body.

Man is composed of these combined Heaven and Earth energies:

1. The Jing is the body's tangible essence, composed of a morphogenic field of energy that creates and sustains the body's physical form. It is the lower vibrational frequency of the human energy matrix. During the healing process, the patient's Jing directs the proper cells to multiply so that the body can heal rapidly and completely.
2. The Qi is the life-force energy that maintains the body's Jing. It is the electromagnetic body of the channel system and distributes vitality to the body through energetic transference. It

Natural Human Transformations

Yin Organ	Yang Organ	Sense Organ	Taste	Color	Body Smell	Sound	Tissue	Positive Emotion	Negative Emotion
Liver	Gall Bladder	Eyes	Sour	Green	Rancid or goatish	Shout	Nerves & tendons	Kindness, benevolence	Anger
Heart	Small Intestine	Tongue	Bitter	Red	Scorched or burned	Laugh	Blood vessels	Love, joy, respect	Elation, arrogance, impatience
Spleen	Stomach	Mouth	Sweet	Yellow	Sweet, fragrant	Sing	Muscles & fascia	Fairness, openness	Worry, anxiety
Lungs	Large Intestine	Nose	Pungent	White	Tidepool, fishy	Weep	Skin & hair	Righteous, courageous	Sadness, grief
Kidneys	Bladder	Ears	Salty	Blue	Putrid, rotten	Groan	Bones	Gentleness, wisdom	Fear

Figure 13.1. This diagram shows the natural transformations of man's internal organs, energy, and matter, as well as their natural manifestations.

is the middle vibrational frequency of the human energy matrix. The vibrational field of Qi sustains and contains the thoughts and emotions, and interacts between the vibrational fields of Jing and Shen.

3. The Shen is the spirit and psyche which maintains the body's Qi. It is the higher vibrational frequency of the human energy matrix. It is also the energetic field which sustains the vibration of the Mind (the process of awareness and consciousness located throughout the body, not limited to the brain), interfacing between the Mind and Qi.

These three substances resonate at different frequencies and are mutually dependent upon each other for maintenance and survival. Low frequencies are attributed to the resonance of Jing, medium frequencies to the resonance of Qi, and high frequencies to the resonance of Shen. Metaphorically speaking, Jing can be compared to a dense, solid material such as ice, Qi to a flowing material such as water, and Shen to a vapor.

In Chinese medicine, the Qigong doctor uses the Three Treasures of Man for assessing and diagnosing the patient. Observing the state and interaction of the patient's Jing, Qi, and Shen allows the doctor to determine the patient's prognosis and chances for successful treatment. The doctor can assess the Jing, Qi, and Shen by:

1. Observing the general vitality of the patient's Jing through pulse reading and tongue diagnosis,
2. Noting the general vitality of the patient's Qi through observation of the Wei Qi field, and
3. Observing the general vitality of the patient's Shen by the quality of glitter in the patient's eyes.

Within this model, Jing, Qi, and Shen are viewed as layers of energetic fields between the body and the Mind. Jing is the innermost energetic layer, the blueprint which holds the physical body to the desired form. Shen is the outer energetic layer of the body through which the Mind experiences and directs the activity of the body. Qi is the intermediate energetic layer, the medium which allows the Jing and Shen (the energetic fields of the body and spirit) to communicate.

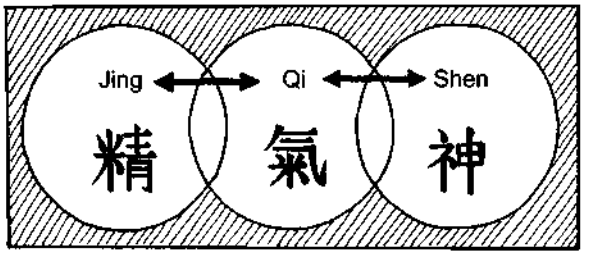

Figure 13.2. The Three Treasures of Man

PRENATAL AND POSTNATAL JING, QI, AND SHEN TRANSFORMATIONS

Jing is the body's foundational substance, responsible for nourishing the tissues. Qi emerges out of Jing circulating through the tissues. It promotes the body's metabolism. Shen governs the body. The body contains both prenatal and postnatal versions of Jing, Qi and Shen.

1. Prenatal Jing (Yuan Jing) is the body's innate and true Original Essence, which determines the constitutional makeup, strength, and vitality. It is not the reproductive Essence (sperm and ovary essence), which is considered Postnatal Jing.
2. Prenatal Qi (Yuan Qi) is the body's Original Energy, extending into the Wuji (infinite space or Void). It is the motivative energetic force linking the Prenatal Jing with the Prenatal Shen. It is not inhaled air (oxygen), which is considered Postnatal Qi.
3. Prenatal Shen (Yuan Shen) is the Original Spirit, that is able to perceive and intuit truth and knowledge (knowing without knowing). It is not cognitive thinking or consciousness, which is considered Postnatal Shen.

Through meditation, the body's alchemical processes of internal energy transmutations can be cultivated. Jing can be used to create or increase Qi; likewise, Qi can be used to create or expand the Shen. This creative cycle also works in reverse order by transforming Shen to Qi, and Qi to Jing (Figure 13.2).

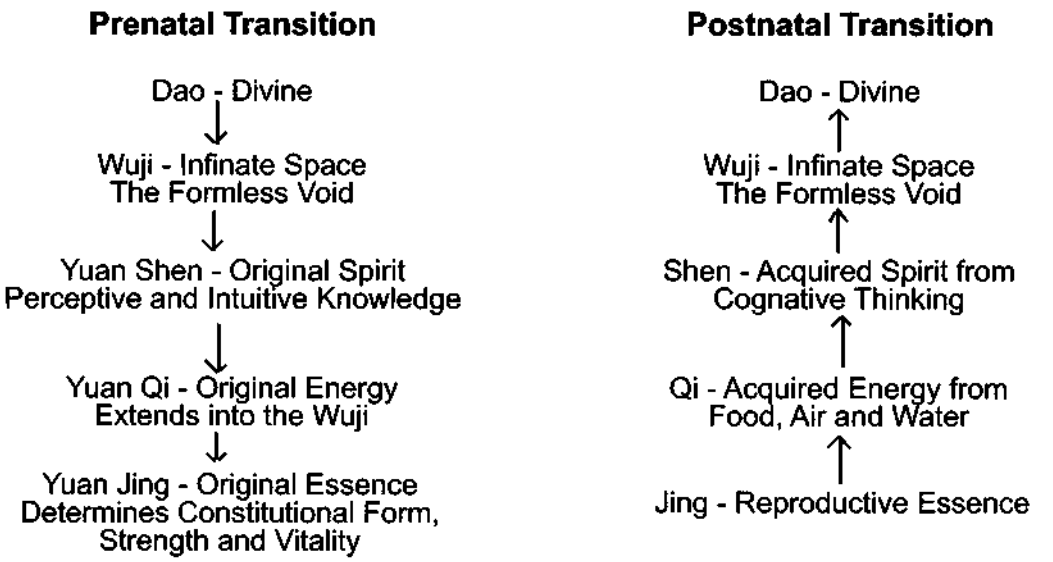

Figure 13.3. The Prenatal and Postnatal Alchemical Transitions of Jing, Qi, and Shen

PRENATAL TRANSFORMATIONS

The following transformations describe the origin and creation process of the Three Treasures within the body of the fetus (Figure 13.3). Through comprehending these transformations, the Qigong doctor can teach individuals how to cultivate their Jing. The body's prenatal energies, which support the body's postnatal Jing, are sustained by prayer, meditation, and sleep. This quiescence state is necessary for the body to reenergize its Prenatal Qi.

1. Divine Energy (Dao) transforms into infinite space (Wuji). At this beginning stage, the spirit of the God envelops infinite space, including the energetic fields of the Heavenly universe and the environmental Earthly fields.
2. Infinite space (Wuji) transforms into Spirit (Yuan Shen). At this transition, the spirit of God descends to permeate, unite, and dwell within the Original Spirit (Yuan Shen) of the forming fetus.
3. Spirit (Yuan Shen) transforms into Energy (Yuan Qi). At this stage of transition, the Original Spirit of the fetus transforms into Original Energy (Yuan Qi).
4. Energy (Yuan Qi) Transforms into Essence (Yuan Jing). At this final stage, the Original Energy of the fetus is transformed into Original Essence (Yuan Jing).

POSTNATAL TRANSFORMATIONS

The following transformations describe the origin and creation process of the Three Treasures within the body after birth. Through comprehending these transformations, the Qigong doctor is able to achieve a harmonious balance between the three energies through Postnatal Jing cultivation. The body's postnatal energies are supported and sustained first of all through food, drink, and air.

1. Essence (Jing) Transforms into Energy (Qi). At this beginning stage, the body's Jing is Heated within the Lower Dantian to create Qi. This transition is similar to ice melting into water.
2. Energy (Qi) Transforms into Spirit (Shen). At this transition the body's Qi is steamed within the Middle Dantian, to be transformed into Shen. This transition is similar to water transforming into vapor.
3. Spirit (Shen) Transforms into infinite space (Wuji). At this stage, the body's Shen fuses with the resonant light of the Upper Dantian

and is transformed and released into the Heavenly and Earthly fields of energetic space. This transition is similar to vapor diffusing into space.

4. Infinite Space (Wuji) Reunites with the Divine (Dao). At this final stage, the Shen is reunited with the divine.

The Shen directs the increased amount and flow of Qi during the transformation process of Jing into Qi and Qi into Shen through conscious intention. Through this soft focused intention an alchemical cycle of transformation is created whereby Jing, Qi, and Shen can then be gathered, refined, and trained.

Transformational Attainment Modalities

Each of these prenatal and postnatal transformations include training exercises and meditations that are either developed in low, medium, or high attainment approaches. The low attainment approach is known as the physical attainment approach; the medium attainment approach is known as the mental attainment approach; and the high attainment approach is known as the spiritual attainment approach. Qigong regulation encompasses all three attainment modalities in order to facilitate the ultimate in energetic transformation. The three attainment approaches for increasing to maximum capacity the body's energy are described as follows.

1. The Physical Attainment Approach concentrates on the development and cultivation of the body's energy by focusing on Dynamic (energetic movement) and Quiescent (stillness) Qigong meditations to fully realize one's energetic potential.
2. The Mental Attainment Approach concentrates on increasing mental power by focusing on symbolic drawings, reciting prayers, or mantras to manifest fully one's mental potential.
3. The Spiritual Attainment Approach concentrates on the development and cultivation of the body's Original Spirit (Yuan Shen) by focusing on Shengong meditations (meditations that focus on spiritual cultivation) to harvest one's spiritual potential.

Jing: Essence of Life

Jing refers to the indispensable bioenergetic substance of all living things (i.e., the energetic matrix of the body's cells, tissues, etc.). In Medical Qigong therapy, Jing is considered the most Yin form of Qi. Jing, as a pure Essence of living matter, is more dense than Qi but more refined than Blood or Fluids. When Jing is cultivated and allowed to arise naturally within the body, the outer surface of the body's tissues becomes harmonized and glows. Deep within the tissues, the Jing pools like a deep spring. The greater the degree of harmony between the individual's physical, mental, energetic, emotional, and spiritual fields, the more Jing is transformed into Qi.

The Yin and Yang Aspects of Jing

Jing can be divided into the functional aspects of Yin and Yang properties. The Yin aspect of Jing provides the material basis for growth, development and reproduction, and is the substratum for the formation of the materials associated with the Marrow and Blood. The Yang aspect of Jing activates transformations, growth, development and reproduction, and is associated with the Yuan Qi, Blood and Body Fluids (Figure 13.4).

As a subtle energy, Jing has a tendency towards downward movement, flowing like water, it fills the Lower Dantian, adrenals, Kidneys, and urogenital organs. Essence originates from two sources and can be divided into Prenatal and Postnatal Jing.

Prenatal Jing

Prenatal Jing is also called Original Essence (Yuan Jing). It is inherited from the Jing of both parents and is considered the root of life. It is created upon conception through the blending of both parents' sexual energies and substances. Prenatal Jing constitutes the original substance of the body, and serves as the material base for growth, development, and reproduction. With the help of the Qi and Blood acquired from the mother, the Jing is responsible for the nourishment and development of the embryo's and fetus's brain, bones, muscles, tendons, skin, and hair. The Pre-

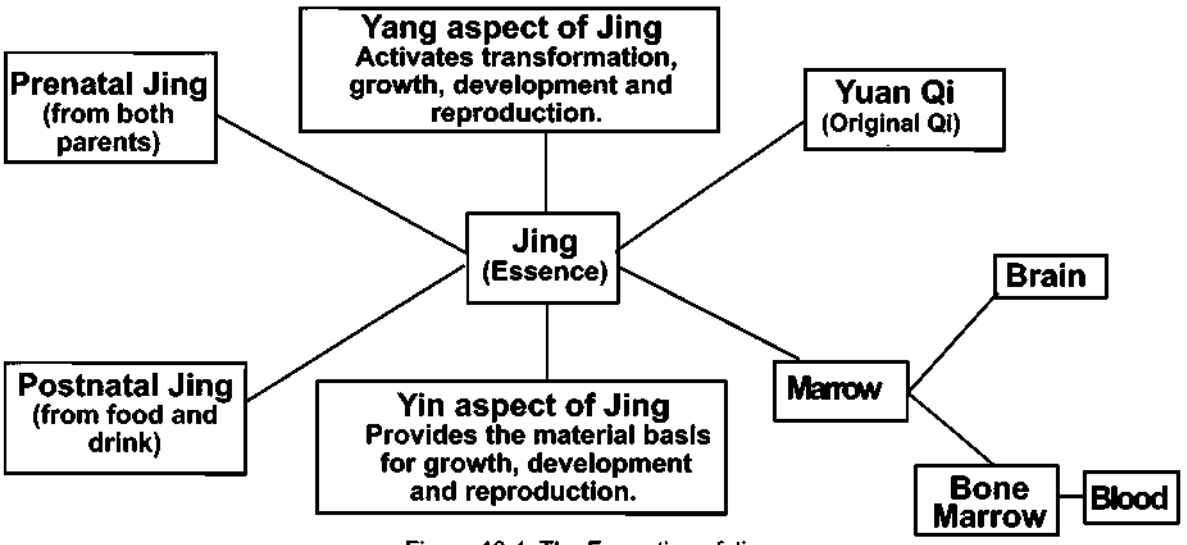

Figure 13.4. The Formation of Jing

natal Jing determines each person's basic constitution, strength, and vitality.

POSTNATAL JING

Postnatal Jing is also called the Acquired Essence. It is the Essence of the body's main organs, derived from air and Gu Qi (produced from food and drink by the transformation process of the Spleen and Stomach) which is transported through the channels and vessels to nourish the body's Yin organs, and to irrigate the Yang organs. Postnatal Jing is the material basis for the functional activities of the body's internal organs and metabolism. It is transported (through the function of the Lungs) to all the Yin and Yang organs where it becomes reproductive Yin and Yang Jing. The Kidneys are responsible for storing any surplus Jing to be distributed when needed.

THE INTERACTION OF PRENATAL AND POSTNATAL JING

The Prenatal and Postnatal Jing are interdependent and contribute equally to the growth and development of each other. Postnatal Jing is continually being used by the body and replenished with food and drink. Only with the nourishment of the Postnatal (Acquired) Jing can the Prenatal (Congenital) Jing be enriched and function optimally. Without the function of the Prenatal Jing, the Postnatal Jing cannot be transformed into Qi.

Postnatal Jing is continually being used and replenished through the Spleen's production of Gu Qi from food and drink. This is why so much emphasis is placed on the first postnatal alchemical transition of changing Jing into Qi. Through Medical Qigong exercises, the body is able to stimulate, nourish, and preserve its Jing.

Both Prenatal and Postnatal Jing are related to the Kidneys, which generate bone growth as well as nourish the brain, memory development, and body stamina. The *Yellow Emperor's Classic of Internal Medicine* states that women are on a seven year developmental cycle, while men are on an eight year cycle. Problems with the body's Jing result in developmental problems (i.e. improper maturation, sexual dysfunction, infertility, and premature aging).

The Kidney Jing is responsible for extending the life-force energy up the Governing Vessel into the brain. The Kidney Jing also transforms into Marrow and is responsible for the production of bone marrow, which fills up the spinal cord and brain. When the Jing becomes exhausted, the memory begins to fail and the spirit becomes fa-

tigued. It is important to remember that all types of Jing do not exist as separate substances, but support, interact with, and transform into one another.

The Kidney Jing also works in conjunction with the Qi to establish the body's state of mind and emotional health, which together determine the development of the Five Elemental Constitutions.

QI: VITAL LIFE-FORCE ENERGY

Qi is the energetic substance from which the entire universe was created. Through the interaction and transformation of Yin and Yang Qi, the various substances of form and matter are produced. This vital life-force energy comprises both material and functional aspects of the body.

Qi is the medium between matter (Jing) and Spirit (Shen). Chinese medicine describes many different kinds of Qi. Qi can assume an infinite number of forms according to its state of condensation or dispersion. When Qi condenses, matter is created, and when Qi disperses, energy is created. Although Qi in the body can assume different forms, that have different functions, it is essentially all one energy. The patient's Jing, for example, may be ready to receive a new energetic pattern for accelerated healing, and the Shen may be ready to send this required pattern. But, if the body's Qi is weak or turbulent, it will not transmit this information from the Shen to the patient's Jing, thus delaying or impeding the healing process.

The body's Qi can be classified into two primary forms of energy: Prenatal and Postnatal Qi.

PRENATAL QI

Prenatal Qi (or Xian Tian Zhi Qi, which translates as, "before the baby sees the sky energy") is also called Yuan Qi, or Original Qi. This is the energy that the baby inherits from his or her parents during conception. It is stored in the sexual glands and adrenal cortex, and it is essential for the growth and development of the fetus.

It is Jing in the form of energy, that is cultivated through Qigong practice. Yuan Qi is the innate or inborn energy that is the original force which maintains normal growth and development, and promotes the functional activities of the internal organs. Its role is to bring into existence the vital mechanisms of the human body according to their genetic pattern, conforming them to the models transmitted by each person's lineage.

Prenatal Qi contains elements of all of one's predecessors and gives rise to the Prenatal Jing, and is seen as a means of transmitting the Deoxyribonucleic Acid (DNA) code. Prenatal Qi relies on nourishment from Postnatal Jing. Through Prenatal Qi, each individual is energetically connected with everything in existence. Prenatal Qi also relies on Postnatal Qi for nourishment.

Methods of training Qi and regulating it include counting respirations as the Mind focuses on rooting the Qi into the Lower Dantian, Mingmen, or Kidneys' area.

There are three types of prenatal energy regulations used for circulating and harmonizing the body's internal energy or Dantian Qi:

1. The first type of Qi regulation focuses on moving energy through the body's main channels and torso. This is the most common type of Prenatal Qi circulation, directing the energy to flow along the course of the body's Conception and Governing Vessels, i.e., the "small" Heavenly cycles (Microcosmic Orbits). This type of Qigong exercise is commonly referred to as an Inner Cultivation and Regulation method.
2. The second type of Qi regulation focuses on moving energy through the body's channels and extremities. In this type of Qi circulation, the body's Prenatal Qi is directed to flow only along specific channels (i.e., being led from one channel out from the torso into an extremities and then back into the body through another channel). This type of energetic balancing is commonly seen in the "large" Heavenly cycles (Macrocosmic Orbits) and bone marrow regulation.
3. The third type of Qi regulation focuses on

moving the energy of Heaven (Universal Qi), Earth (Environment Qi) and Man (Qi of the physical body) through the channels. In this type of circulation, these three types of energy are integrated or merged into one energy and then regulated. Upon inhalation, the individual imagines Prenatal Qi circulating from Heaven through the body's channels into the Earth. Then upon exhalation, the energy is imagined flowing from the Earth, through the channels, back into Heaven.

POSTNATAL QI

Postnatal Qi (or Hou Tian Zhi Qi, which translates as, "after the baby sees the sky energy") is also called acquired or Post-Heaven Qi. This is the energy that the baby derives from air, food, and drink after it has been born. Postnatal Qi relies on Prenatal Qi for development.

Prenatal and Postnatal Qi form the foundation for the body's vital energy. In Traditional Chinese Medicine it is believed that the parents' health and their state of Jing, Qi, and Shen at the time of conception determines the general health of the child. If the parents are sick, or their health has is compromised by drinking, smoking, or drug use, the baby's health will suffer. If the parents are old, or have suffered an emotional shock during the pregnancy, this too will negatively impact the baby's health.

Methods of training Postnatal Qi include deep, tranquil abdominal respiration. This method trains the respiratory system to improve both the respiratory and digestive systems, enhancing both the Lung and Spleen Qi.

EIGHTEEN CLASSIFICATIONS OF QI

The distribution and function of life-force energy can be further divided and classified according to the source and function of the Qi. Below is a description of eighteen transitions of Qi and their energetic effects on the body.

1. Prenatal Qi (Yuan Qi), is often referred to as Original Qi, and includes the Original Yin and Original Yang energies of the body. Yuan Qi has its root in-between the Kidneys and Mingmen area, it is distributed throughout the entire body via the Triple Burners.
2. Postnatal Qi, is an external energy derived from the consumption of food and drink (from the Earth), and air (from the Heavens), and is a term used to describe the Qi which is cultivated after one is born.
3. Heavenly Qi (Tian Qi), is energy that has been developed from the energies of the sun, moon and stars. Tian Qi is absorbed into the Lung Qi as Air Qi (oxygen) through respiration.
4. Earthly Qi (Di Qi), is energy that has been developed from the energies of the soil, water and wind. Di Qi is absorbed into the Stomach and Spleen where it is converted into Gu Qi (food energy); Di Qi is also directly absorbed through the pores from the environment.
5. Food Qi (Gu Qi), is the first stage of energy transformation derived from food and drink. It is also called Qi of the Water and Grain in the digestive system. After food essence is cooked in the Stomach, the Spleen transforms it into Gu Qi. At the first stage of development Gu Qi is a coarse, unusable form of food essence. The Spleen divides the energy it derives from the food essence into Pure (Clear) Yang Qi and Impure (Turbid) Yin Qi. The Clear Yang essence of Gu Qi is transported by the Center Qi (Zhong Qi) via the Middle Burner, sending it upwards into the chest, first to the Lungs where it combines with Heavenly (Tian) Qi to form Gathering (Zong) Qi, then to the Heart where it combines with the Yuan Qi (from the Kidneys) to create the Blood. The Turbid Yin essence of Gu Qi is transported downwards through the gastrointestinal tract to be expelled as waste.
6. Clear Yang Qi (Qing Qi), is the clean, pure energetic essence of Gu Qi, transported by the Spleen, via the Middle Burner, up towards the Upper Burners, and chest area. While in the chest, it is combined with Gathering (Zong) and Yuan Qi to form True Qi.
7. Turbid Yin Qi (Zhou Qi), is the clouded, impure energetic essence of Gu Qi, transported by the Spleen, via the Middle Burner, down

towards the Lower Burner, Small Intestine, and Bladder organs, to be further refined. It is a more coarse, unrefined, polluted energy.

8. Center Qi (Zhong Qi), is the energy generated from the Middle Burner, derived from the Spleen and Stomach. Its primary function is to transport the Gu Qi into the chest, to be blended with the Heart and Lungs' Qi.
9. Gathering Qi (Zong Qi), is also called Respiratory Qi. Gathering Qi is considered the "essence of life," manifested through the conversion of the purest and most potent forms of the body's Jing (particularly sexual fluids, hormones, and neurochemicals). It is essential for the formation of the fetus and is the initial motivating power of life. It promotes vitality and increases stamina; it also enhances the immune system, promotes mental clarity and prolongs life. Gathering Qi combines the Heavenly Qi (inhaled by the Lungs) and the Gu Qi (derived by the Stomach and Spleen), and accumulates these energies within the chest in order to assist the Heart in circulation the Blood, and the Lungs in respiration. It controls the speech and strength of the voice, as well as the Blood circulation to the extremities. Gathering Qi gathers in the chest and is controlled by the Middle Dantian.
10. True Qi (Zhen Qi), is also called Anti-pathogenic Qi. It originates in the Lungs and is the last stage of refinement and transformation of Qi. Gathering Qi and Yuan Qi combine their substances to form the True Qi in the chest area. True Qi fills and nourishes the body as it is further broken down into Nourishing (Ying) and Protective (Wei) Qi. True Qi is the energy that circulates inside and outside of the body, in the channels and collaterals, nourishing the Yin and Yang organs. It is called True Qi because it is the most refined and pure, and is in harmony with the environment. It is opposed by Evil Qi (Xie Qi), also called Toxic Qi, which is disharmonious and thus untrue to the body's essential nature.
11. Nourishing Qi (Ying Qi), is another form assumed by the True Qi and is the Yin aspect of the Channel Qi. Ying Qi has two major functions: to nourish the Blood, organs and tissues, and to link the mind and intention to the body. It flows within the blood vessels, as well as the channels, and is the fuel of the body's metabolism. Its potency depends upon the quality of food and water consumed, the purity of air breathed, and the efficiency of the body's digestive, respiratory, and circulatory systems. Since it is Yin, it is considered the more refined form of True Qi, as it flows in the body's inner layers and internal organs. Being directed by thoughts, it is thereby closely related to the emotions.
12. Protective Qi (Wei Qi), is a second form of True Qi and is the Yang aspect of the channel Qi. It protects the Blood, organs, and tissues from invasion of external pathogenic factors such as: harsh weather conditions, microorganisms, and harmful emotional influences. It also protects the individual from evil spiritual forces. It is the coarser Yang aspect which flows through the outer layers of the body's skin. Its texture is slippery in nature and cannot enter into the channels. It therefore circulates under the skin and in between the muscles. The Wei Qi vaporizes in between membranes, and diffuses over the chest and abdominal area to form a kind of energetic armor. It also warms, moistens, and contributes to the nourishment of the skin and muscles. The Wei Qi also helps regulate the perspiration by opening and closing the pores.

    Wei Qi has its root in the Lower Burner (Kidneys), is nourished in the Middle Burner (Stomach/Spleen), and spreads from the Upper Burner (Lungs) to the outside of the body. Wei Qi is said to be located at the superficial level of the body during the day, in the muscles, skin, hair, etc. At night it sinks to a deeper level to circulate through the viscera. If the Wei Qi is obstructed in some manner from moving inward, insomnia may result. Also, Wei Qi becomes thick and extends outside its normal realm during Medical Qigong practice and may, therefore, take longer to

move inward at night, causing some practitioners to experience difficulty falling asleep after evening Qigong practice.

13. Channel Qi (Jing-Luo Qi), is also called Meridian Qi. This energy flows throughout the body's deep internal and superficial channels, as well as through the collaterals and blood vessels like rivers and streams.
14. Organ Qi (Zang and Fu Qi), is the energy of the physiological activity of the body's internal organs and manifests as a major aspect of its physiological function. Individual pools of Qi are formed within the pairs of Yang-Fu (hollow) bowels and Yin-Zang (Solid) viscera. The Yang organs are responsible for transforming food and drink to produce Qi and Blood. The Yin organs are responsible for storing vital substances. Each organ can be additionally divided into pairs of Yin and Yang energetic aspects.

    Each of the body's organs has its own energy, which is governed by, and corresponds to, one of the Five Elemental energies. These Five Elemental energies respond to the external energetic fields drawn from the universal and environmental energetic fields. The internal processes of thinking and feeling, as well as the physiological process such as metabolism and hormonal production influence the Organ Qi.
15. Evil Qi (Xie Qi), is also called Pathogenic Qi, and Toxic Qi. This usually refers to any harmful external pathogenic factor (especially the Six Climatic factors). However, it also refers to the evil spirits and stuffed toxic emotions, which affect the individual's physical, energetic, and emotional balance.
16. Righteous Qi (Zheng Qi), is the defensive aspect of the True Qi, which protects the body from Evil Qi. This is not actually another type of energy, but a term used to indicate the True Qi's function of protecting the body from invasion by external pathogenic factors. The occurrence and development of disease is directly related to either the hyperactivity or hypoactivity of the Righteous Qi.
17. Spiritual Qi (Ling Qi), is the supernatural energy associated with the most highly refined energy in the human body manifesting through the Eternal Soul. This type of energy enhances spiritual awareness and constitutes the foundation for advanced levels of spiritual conditioning, and the attainment of an enhanced energetic body, and enlightened states of mind and spirit.
18. Divine Qi (Shangdi Qi), is also called Holy Energy or God's Healing Light. It is the supernatural energy associated with the Divine (Dao). The divine energy is the true source of spiritual awareness and constitutes the foundation for advanced levels of spiritual healing, as well as attaining enlightenment.

THE SIX FUNCTIONS OF QI

A Qigong doctor will primarily focus on a patient's combination of Original Qi (Yuan), Gathering Qi (Zong), Nourishing Qi (Ying), and Protective Qi (Wei) when treating or prescribing homework. Initially, Qi has six main functions in regulating the body. Although these functions may seem to overlap, their individual responsibilities are distinct.

1. Qi transforms substances into energy (one example of its transforming nature is changing food into energy).
2. Qi transports the substances it creates.
3. Qi holds and contains energy, Blood and organs, etc., within the energetic and visceral structures.
4. Qi protects against both external and internal pathogenic factors.
5. Qi raises and elevates things (for example, Blood, associated Fluids, and the body's temperature).
6. Qi keeps the body warm (for example, strong Qi will warm the body, while weak Qi makes the body cold).

The normal physiological activity of Qi in the body is a constant harmonious movement, similar to the ebb and flow of a tide. When the body's Qi is in constant motion, it moves in eight primary Yin and Yang directions: ascending and descending, gathering and dispersing, expanding

and contracting, and entering and leaving. If however, there develops a Qi obstruction, or a Deficiency of Qi, the Qi will deviate from its natural course, and may cause Rebellious Qi, disharmony and disease.

Qigong doctors carefully examine the energetic ebb and flow of Qi to comprehend the complexity of the energetic hologram in which we exist as a living energy. As the human body absorbs, stores, utilizes, and releases energy, its natural function of transforming energy promotes health and allows us to live in harmony with the natural environment. However, once an internal organ or organ system develops a Rebellious, Excess, Deficient, or stagnant condition within the body's energetic flow, disease develops. By understanding the energetic pattern and function of each energetic organ and organ system, the Qigong doctor can diagnose the disease by retracing the energetic dysfunction to the root cause. The following graph denotes the function and flow of the body's life-force energy patterns (Figure 13.5).

Qi and Energetic Medicine

The utilization of the Three Regulations (posture, respiration and mental Dao Yin concentrations) enable Qigong doctors not only to disperse any Toxic Qi acquired from patients, but also to regulate their own channels, through gathering energy, and increasing their own energetic fields. Through the proper use of the Mind (whole body consciousness and awareness), the doctor can simultaneously influence the energy flows within the patient's body, as well as his or her own Wei Qi fields.

As the doctor begins to focus on specific goals (i.e., dispersing Toxic Qi from a particular organ, tissue area, or channel), the patient may experience a surge and release of strong emotions and memories that had been stored in that area. The patient's energy field then shifts and moves throughout the body according to the specific emotion(s) elicited and released. This energy field is closely related to the thinking activities of the brain. As the Mind begins to release certain specific memories, the field of energy shifts and moves through the body in accordance with the specific emotions that are activated and released. During treatment, the shape, flow, rhythm, nature, and thickness of this energetic field can be perceived by the doctor who has become highly sensitive to perception of energy through "inner-vision" (see Chapter 25).

By training in the Three Dao Yin Regulations (see Chapter 14), internal energy can be guided to surge not only in the natural direction of flow within the channels, but also against it. Internal energy can also be guided along several channels at the same time, in any given direction or to specific areas of the body. By directing Qi against the flow of a channel, the doctor arrives at the source of the river (or energy). This technique is sometimes used by the Qigong doctor to collect or tonify the Qi within the patient's internal organs. This technique for storing and collecting energy is called "following the river to reach the sea." An example of this technique would be extending Qi from the patient's St-36 points, up the Stomach Channels to root, strengthen and stabilize a Deficient or Rebellious condition within the Stomach organ itself. Conversely, by directing Qi with the flow of the stream, one can disperse energy (purgation) and pull Qi out of an area leading it away from the source (e.g., pulling Liver-Stomach Heat down and out the Stomach Channel to cool an overheated Stomach).

Qi and the Body's Energetic Structure

Similar to the biomechanics of the respiratory, circulatory, and digestive systems, the body's energetic system has its own organization and established rules of action for regulating organ and tissue functions. The adaptability of Qi to the outside environment enables the body to absorb not only healthy energy, but also to expel Toxic Qi.

The nature of Qi is to endlessly gather and disperse, expand and contract, to flow inward and outward, to rise and fall, as it circulates. When a Qigong doctor begins to treat a patient's channels or points, he or she stimulates and activates the patient's Qi, which may arouse muscle movement and sensations which can last for quite some time.

If the frequency and nature of the doctor's Qi is similar to that of the patient's, both energetic resonance and synchronization will synergize, allowing the patient's Qi activities to be regulated and balanced at a rapid rate.

Because people vary in sensitivity to energy, some patients can be treated with Medical Qigong therapy immediately. Sensitive patients are usually taught Medical Qigong exercises allowing them to ingest energy from trees, plants, and other things of the natural world. Patients with low sensitivity may have difficulty in perceiving energy and often dissociate from their body during treatment. These patients should be given Shengong meditations to restore conscious awareness of the toxic emotions trapped within the body, thereby reestablishing a harmonious relationship with the Mind (see Chapter 32). The patient's insensitivity to the doctor's energy extension is an indication that the patient's spirit has gone out of the body in order to avoid feeling the emotions which arise from Medical Qigong therapy.

A patient insensitive to energy projection can still be in touch with basic surface feelings (i.e., hot, cold, tired, etc.); however, the deeper emotions are hidden, or energetically walled off through denial. The better the relationship between the patient and the doctor, the greater the patient's trust and surrender to the doctor's energy.

When observing the patient's Qi and energetic structure, the doctor is able to perceive and enter the patient's five energetic fields. These fields form the matrix of the patient's energetic structure, which constitute a blueprint for the body's physical structure. These energy fields have their own biological components and degree of fluidity.

These five energetic fields form the body's Sea of Energy. The term Sea of Energy (Qi), in this context, refers to the description used to explain the internal and external currents of life-force energy which surround, permeate, and function within the physical body. These energetic fields are described as follows.

1. The External Fields of Wei Qi (Protective Energy),
2. The Internal Current of Ying Qi (Nourishing Energy),
3. The Internal Sea of Blood (Xue Hai),
4. The Internal Sea of Marrow (Sui Hai), and
5. The Center Core of Light (Taiji Pole).

Within these five energetic fields, the protective and nourishing energetic fields of Wei and Ying Qi expand and contract, move and adjust their energetic flow according to the body's respiration patterns. The Sea of Blood resonates within the pulse rhythm established by the heartbeat. The Sea of Marrow undulates from the rhythm established within the body's micropulsation of the sacrum and cranium bones' flexion and extension. The energetic pattern of the Taiji Pole vibrates at the same frequency as divine light (the Dao).

THE THREE EXTERNAL FIELDS OF PROTECTIVE ENERGY (WEI QI)

There are three external energy fields that create the body's Wei Qi field. The Wei Qi field's energy flows from around the regions of the body's external muscles, skin surface, channels, collaterals and channel points, and extends several feet out from the body's tissues. All energetic forms of the physical body, including the internal organs, blood vessels, nervous systems, etc., can be accessed and treated through the three extended fields of Wei Qi.

These three fields are distinguishable from each other by gradations of density, vibrational rate, light, and temperature. All three energy fields communicate with each other, interacting so as to form the body's subtle energetic boundaries.

Enveloped within these energetic boundaries are the body's external "energetic grids," spanning the body's energetic structure like a giant web. These energetic grids are the body's external energetic field patterns, etched through the three fields of Wei Qi like a three dimensional webbed hologram (similar to a three dimensional blueprint).

It is important to note, that any disease within the body's internal structure is also imprinted in this external energetic grid. Disharmony of the body's tissues often appears first in the Wei Qi fields, before manifesting within the body. If the energetic grid is not transformed (through emit-

ted light, sound, and resonant vibration), the disease cannot alter its destructive course, because it follows the patterns dictated within the grid. Thus, for example, a tumor surgically removed often quickly reappears. Trauma, be it physical, mental, emotional, or spiritual, as well as drug and alcohol abuse, distorts, damages, and destroys the delicate energetic web which constitutes the body's external energetic grids, making the patient more susceptible to external environmental influences.

The external energetic grids function to protect the body from external pathogenic factors, as well as to receive and transmit environmental energy. Thus, for example, a person can receive, absorb, and digest other people's emotions. The five senses are constantly receiving on outside environmental influences, which directly and indirectly affect the body's major organs. This constant influx of data, changes the body's emotional patterns, and forces individuals to adjust their emotional perspective frequently.

Researchers conducting tests in San Antonio, Texas, for example, determined that when subjects are being stared at, galvanic skin responses are considerably increased. These increases occurred even though the subjects were not consciously aware of being observed. The research determined that the body has its own expansive field of subtle awareness, which reacts even when the individual is not consciously aware of the body's energetic extension.

By reconnecting the spirit and emotions with the mind and body, the Qigong doctor is able to perceive the subtle Messages that the patient is unconsciously conveying (see Chapter 25).

THE THREE ENERGETIC BARRIERS

The Wei Qi fields are experienced at three different levels. These levels are differentiated by energetic barriers, which protect the body's boundary system. These barriers not only protect and contain the body, they help establish the individual's sense of reality, and sense of self. The third energetic field or "outer spiritual barrier" is depicted in the illustration as the outside speckled field of energy, and affects the second energetic field or "middle emotional/mental barrier." The second field of Wei Qi is depicted in the illustration as the middle white field of energy, which in turn influences the first energetic field or "physical barrier," seen as the black field of energy in the illustration (Figure 13.6).

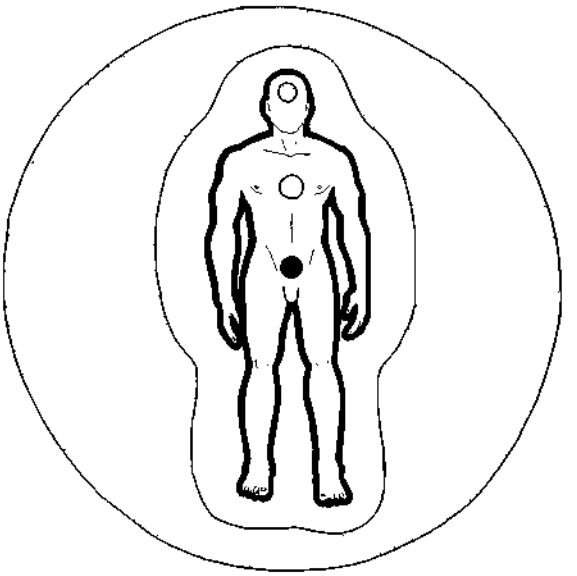

Figure 13.6. The Three External Fields of Wei Qi

These three Wei Qi barriers are always interesting for the doctor to feel, because they change so much from patient to patient, and sometimes from moment to moment. Some patients have very strong energetic fields, they are very palpable and full. Emotions strongly affect this type of energy field. The Wei Qi field of a patient who is armoring out of fear, reticence, or self-protectiveness, can actually repel the doctor's hand back, if their field and intention is strong enough. This repelling reaction is helpful because it lets the doctor know how to pace the treatment, and encourage the patient to let go of the armoring. This allows the patient to consciously focus on relaxing and sensing the areas in the body that he or she was trying to protect.

The energetic boundaries, act as gateways to the next level of energetic field energy. To perceive

the patient's three fields of Wei Qi, the patient's energetic boundaries must be gently palpated. These boundaries are more easily sensed due to a thickening of energy which serves as a barrier to external pathogenic factors. Sometimes the doctor may have to move back into the patient's third or "outer" energetic field, and telepathically let the patient know that he or she will not be violated, and is safe. The doctor waits until the patient exhales (thereby expelling some tension) before entering and palpating the outer Wei Qi field. Once a release in the energetic field is felt, the doctor moves forward into the next energetic field. Because this same process occurs at all three levels, the Qigong doctor responds accordingly, waiting for the exhalation that allows them to proceed deeper into the next level of the patient's Wei Qi.

THE FIRST EXTERNAL FIELD OF WEI QI

The first external field of energy is confined to about one to two inches outside the physical body, and composed of lower etheric matter. It is related to the Lower Dantian and manifests as a holographic energy template for the physical body. It provides the spatial guidance for morphological development during the creation and formational stages of the embryo, as well as the morphological energetic patterns that assist in the repair of damaged tissues. Its energetic boundary is responsible for armoring the body against invasion of external pathogenic factors. This physical energy body is connected to the somatic tissues and cells, thus any physical-energetic interaction stimulates the body's external channels and points. This first layer is very dense and most Qigong doctors get the impression of physically contacting the patient several inches before actually touching the patient's material body. Its resonant vibrational pattern is very broad and slower than the other Wei Qi fields.

THE SECOND EXTERNAL FIELD OF WEI QI

This energy flows through the regions of the internal organs and tissues. It extends about a foot or more outside the body's tissues, and is composed of astral matter. It is related to the Middle Dantian and the emotional energy body. It contains a form of disembodied consciousness that can astral travel, and at times leave the physical body, as in near death experiences. This second layer of Wei Qi interfaces with the limbic system of the brain (the neurobiological seat of emotions) and is also linked with the sympathetic and autonomic nervous system. The second Wei Qi field's energetic boundary is responsible for protecting the body from negative emotions, destructive feelings and criticism from others. It is automatically activated when the patient is placed in a position where a lack of trust exists, or there is unwanted physical touch. The emotional energy body is connected to the visceral organs. Its main function is to receive, interpret, and verify an individual's emotions, feelings, desires, impulses, and thought patterns. It is through this energetic field that the patient's aura is typically observed as colors and light patterns. The second layer is more subtle then the first layer. When physically palpating, the sensations are similar to a magnetic attraction and repulsion. Its resonant vibrational pattern is faster than that of the first layer.

THE THIRD EXTERNAL FIELD OF WEI QI

This field extends a few feet to several hundred yards depending upon the spiritual evolution of the individual, and is composed of ketheric matter or substance. It is related to the Upper Dantian and the spiritual energy body. It is associated with intuition, inspiration, creativity, and visionary insights. Its energetic boundary is responsible for establishing security by informing the body of impending encounters, conflicts, or environmental transitions. This spiritual energy body is connected to the body's Taiji Pole, and is a container for karmic-related illnesses within the physical body. The Taiji Pole is known as the "root with many branches," as it is a repository of the soul's ancestral memories and experiences. Its function is to receive the subtle energy of the finest and fastest vibrations. It senses and interprets the data received from its environmental awareness and universal connection to the divine. The third layer is most subtle in physical sensations and requires delicate, intuitive contact. Usually the first impression when palpating this energetic

field, is one of contact without a material component (like wind). It is sometimes cold, sometimes warm but always "breezy." Its resonant vibrational patterns are the highest and fastest of all the Wei Qi layers.

INTERNAL CURRENT OF NOURISHING ENERGY (YING QI)

The Ying Qi level of internal energy flows within the underlying tissues of the body and sweeps through the torso like a fast wind, expanding and falling with each respiration (Figure 13.7). The Lungs act as a great energy pump; each breath is like a gust of air flowing in and out, in a cycle of expansion and contraction through the entire body. Ying Qi swirls like a breeze; its function is to nourish the Blood, organs and, tissues. It flows within the blood vessels, as well as the channels and links the mind and intention to the body. It is responsible for the organization, construction, completion, and reconstruction of the vitality of the individual. It is integrated with the breath, and extends outward to the body's physical boundaries (skin and body hair).

The internal current of Ying Qi is most palpable when the doctor is gently touching the patient's surface tissue with his or her finger tips, and it feels almost like electromagnetic energy. Feeling the wind of Ying Qi can be likened to falling into "space" after passing through the denser outer field of Wei Qi. The action of Ying Qi, in most cases, is free flowing and connected with the breath. When listening to certain patients, the Qigong doctor may feel the Ying Qi flowing through the patient's channels, wrapping itself around the whole body like a vapor. It feels light, thin, and fairly cool compared to the next River of Blood level.

To access the "current of Ying Qi," the Qigong doctors begin by suspending their hands above the patient's first level of Wei Qi. They imagine dipping their hands into water as they allow their hands to slowly make contact with the patient's body. Once contact is made, the doctors extend their intention under the patient's skin. The doctors should match the patient's respiration and stay connected to the body until they feel the patient relax. Matching their respiration almost always slows the patient's respiratory rate, moving the patient into an altered state of consciousness. Sometimes at this point, age regression can be sensed, as the patient's body memory is triggered.

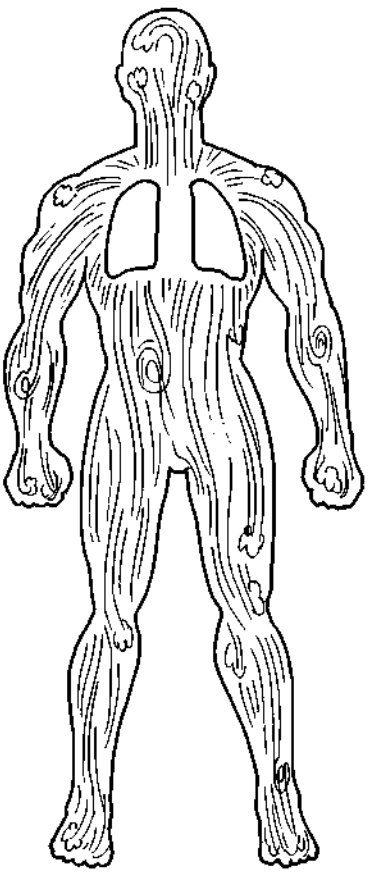

Figure 13.7. The internal current of Ying Qi flows from the Lungs and center of the chest through the entire body like a mighty wind.

SEA OF BLOOD (XUE HAI)

The Sea of Blood and its pathways constitute the body's internal network for circulating and maintaining the individual's life-force, under the direction of the Wu Jing Shen (the five separate fields that encompass the psycho-spiritual energetic transformations of the Five Yin Organs). The

Sea of Blood's energy flows through the blood arteries, vessels, capillaries, and the tissues of the major organs (Figure 13.8). By extending further into the body, the Qigong doctor perceives the patient's Sea of Blood; it feels like a warm watery pool in the center of the Heart, and flows through the entire body. The transition from Ying Qi to Xue Qi (Blood Qi) is easy to detect.

The energetic sensation of Blood is more substantial than the Wei or Ying Qi. The Blood being a liquid, is a denser form of Qi, and flows through the vessels, organs, and channels propelled by the Ying Qi. It is thick (this thickness varies from person to person), warm and somewhat "slick." The Heart's energy itself feels warm, substantial, and very alive.

As doctors gently touches the patient's surface tissue with his or her fingertips, the doctor extends intention deep into the patient's Heart. Upon contacting the Xue Qi, the doctor immediately becomes connected to the heartbeat of the patient. In some cases, the pulsing will connect and merge with the doctor's own heartbeat. Once the doctors encapsulates the patient's Heart, the strong emotions emanating from patients will usually subside. These feelings may be replaced by sporadic spurts of emotions such as relief, peace, or comfort, which sometimes invite the doctor further into the patient. On the other hand, some patients may react with feelings of fear, intense emotional pain, or even panic causing the doctor's hand to "bounce" away.

If the doctor's energy is "bounced back," he or she should immediately disperse the energetic charge into the Earth for ground purposes. The doctor should then either move to a more superficial energy level within the patient's body, or extend Qi into the patient's thorax or extremities. This technique allows the patient to relax after experiencing a Heart energy discharge. Since the pulse is simply another form of energy, circulating, expanding, and contracting with each heartbeat, the doctor should be able to ride the pulse out into the patient's extremities and viscera by listening to the Heart. This is similar to the listening ability of a master acupuncturist who, when reading a patient's pulse, extends his or her energy and intention through the patient's channels and into the organ of the Heart to diagnose the strengths and weakness of its congenital formation and current condition.

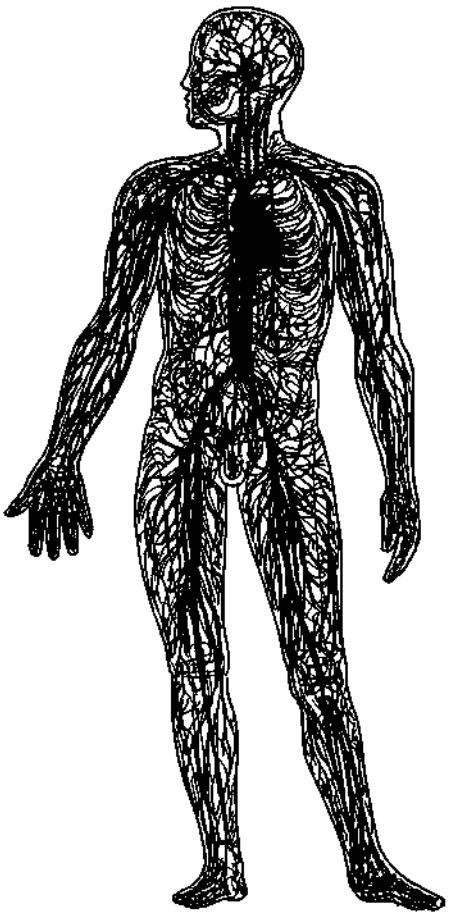

Figure 13.8. The Sea of Blood flows from the Heart through the body like a dense form of Qi.

SEA OF MARROW (SUI HAI)

This energy flows through the central core of the spine into the brain and enters the center core of the bones. In Traditional Chinese Medicine, the Marrow is not the same thing as bone marrow, but the stage prior to becoming bone marrow. Marrow is the pre-substantial Jing that forms the matrix for bone marrow, the spinal cord, and the

brain (Figure 13.9). This flow of Sea of Sui energy is much slower than that of the River of Blood. It flows from the Kidneys' Jing, into the center of the spine, brain, and bone marrow. It has sometimes been called the "cranio-sacral rhythm" in Western medical terminology, and can be accessed from anywhere in the body. The Marrow energy generally feels cool and slick or slippery, with a texture like soft silicone gel. Once contact is made with the Sea Of Sui, it is very easy to utilize this pathway and travel throughout the patient's body. Its rhythm is slow yet manifests as a strong energetic pulse.

As the doctor gently touches the patient's surface tissue by dipping in with fingertips, into the Sea of Marrow, he or she can project intention into the center of the patient's spinal column. This connects the doctor with the rhythmic pulse of the Sea of Marrow. It is from this pulse that the doctor can determine the strength of the patient's Original Essence (Yuan Jing), Energy (Qi), and Spirit (Shen).

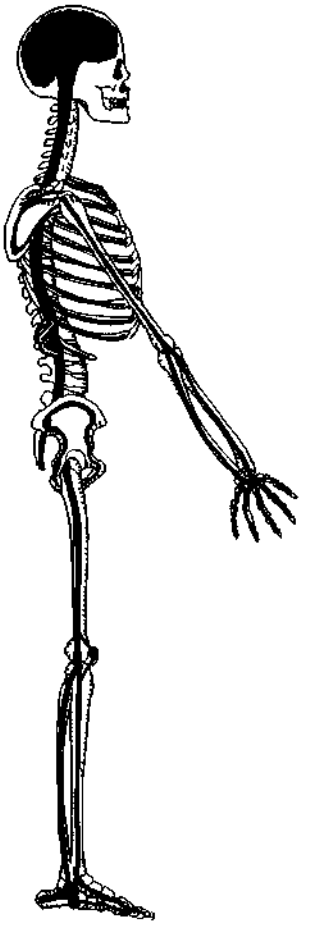

Figure 13.9. The Sea of Marrow flows from the kidneys through the spinal cord, brain, and bone marrow.

THE CENTER CORE OF LIGHT (THE TAIJI POLE)

This energy flows through the very center core of the body, uniting the three reservoirs of life-force energy (the Upper, Middle, and Lower Dantians). The fifth and final level of energy feels like a still, quiet place deep inside of the center core of the body's Taiji Pole structure. In China, Qigong doctors describe it as a holy place that almost defies description. It is observed as a vertical column or pole, of brilliant white light, full of pulsating vibrations. This energetic pole is surrounded by a vale of gold spiralling light which travels from the perineum to the top of the head.

When both the body's internal and external energetic wave patterns become synchronized through prayer or meditation, a resonate pulsation occurs within the Taiji Pole. This pulse begins deep within the center core of the body and resonates outward towards space. The Qigong doctors may also feel a powerful stream of energy leaving the body from the top of the head, connecting the Taiji Pole with the energy of the divine. The center core is a very reverent and special place, as it contains the essence of the patient's Eternal Soul, devoid of all ego, masks, or defense mechanisms (the patient's True Self).

If the doctor penetrates the outside veil surrounding the patient's Taiji Pole, and extends his or her intention into the light's center, the doctor experiences the sensation of falling into space, or stretching out into eternity. Sometimes the sensation of shooting through space is followed by flashing colors and moving shapes, as the surrounding core dissolves into the Void (Wuji) itself. This same sensation and experience can also be personally accessed through deep prayer and

meditation, and is quite a normal phenomena within deep spiritual practices (Figure 13.10).

SHEN: THE SPIRIT OF LIFE

The Chinese character ideogram for Shen is formed to symbolize "that which drops from the sky," and "that which passes through the body." In Medical Qigong therapy, Shen is considered the subtle energy of the spirit, associated with the Heart. It is associated with the spiritual energy and has a radiant nature.

When energized, Shen flows upward like fire, extending through the body's Eight Extraordinary Vessels creating a healthy nervous system. When Shen is gathered in the Upper Dantian, it can be projected as light and energy through the eyes, and the Yin Tang (Third Eye) point. According to Traditional Chinese Medicine, all illness has spiritual roots. The Shen (Spirit) is regarded as an integral part of the diagnosis and treatment process. An old Chinese saying states, "When the Shen is abundant there will be cheerfulness, when it is insufficient there will only be dullness and sorrow."

Shen is developed from Jing and Qi. According to Medical Qigong theory, when the patient's Shen is strong the individual is able to lead energy to an injured area and speed up the healing process. This strong Shen energizes the Qi, enabling it to increase cellular production. When Shen is scattered, the functions of the human body are weak from fatigue, the Shen becomes unsettled, and the mind restless. When the Shen and Qi combine together they form a solid connection of light and vibrational energy. This union is utilized to infuse energy and transfer thought through intention. This can be achieved by either conscious or unconscious intent by the doctor.

SHENGONG SCHOOLS OF MEDITATIONS AND TRAINING

The Shengong (Spirit Skill) meditations emphasize the transformations of consciousness, as well as the development of perceptual insight and the birth of wisdom. From an ancient Chinese energetic perspective, the three primordial qualities

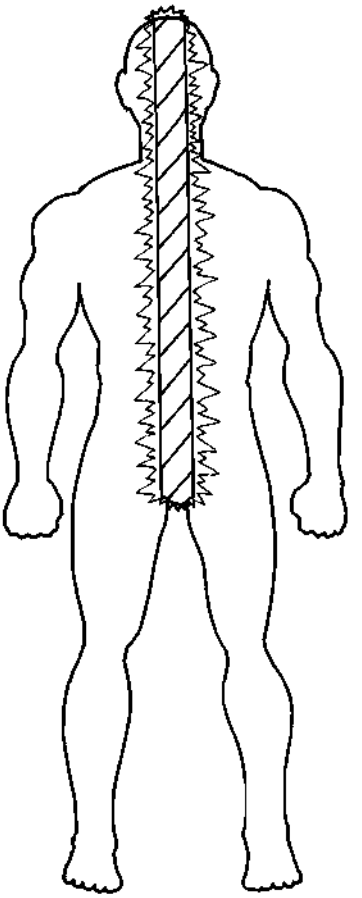

Figure 13.10. The body's center core Taiji Pole spreads from the base of the perineum to the top of the head.

of true wisdom, or divine universal consciousness are:

1. The experience of emptiness within the Wuji (the Void), corresponds to the manifestation of the primal virtue of Wisdom.
2. The light manifested from the Shen's luminosity, corresponds to the primal virtue of Love.
3. The life-force energy inherent in all things, corresponds to the primal virtue of Power.

In China, there are three major schools of Shengong training. These spiritual schools of Qigong are described as follows.

- The Daoist School focuses on strengthening the body and mind equally with an emphasis on contemplating nature. Religious Daoism has its roots in Siberian Shamanism.
- The Buddhist School focuses on tempering the mind while giving little thought to the body.
- The Confucianist School focuses on regulating the mind to reach a state of quiet rest and peace through sincerity and the cultivation of moral character.

PRENATAL AND POSTNATAL SHEN

The body's Shen is the Supreme Yang aspect of the psycho-emotional components, the Heavenly Emperor or "master controller." It can be divided and classified into two primary forms through which the Spirit manifests: the Prenatal Spirit (Yuan Shen) and the Postnatal Spirit (Zhi Shen).

1. Yuan Shen is the body's spiritual element derived from Prenatal Jing (Yuan Jing) and Prenatal Qi (Yuan Qi). This aspect of the body's Shen is considered to be the intuitive Mind of the Dao. It is unborn and undying. It shines brightly and clearly. The Yuan Shen transcends conceptual thinking (which is the Postnatal aspect of the mind). It is immortal, unconditioned, primordial, and constitutes the mind's Yang nature.

   The Yuan Shen is produced and developed by the blending of both the male and female elements at conception (Body Fluids, Jing, Qi and Shen), and develops further with the nourishment from food and water. The Yuan Shen dominates all of the body's vital activities (heartbeat, digestion, motor function, etc.) and is also responsible for all intuitive and perceptive insight. The Prenatal Shen constitutes the true spiritual aspect of the Mind.

   By returning to a state of inner quiet and peace, through prayer, meditation, and adequate sleep, the Yuan Shen and the body's health are restored and maintained.
2. Postnatal Spirit (Zhi Shen) is the spiritual element derived from Postnatal Jing and Postnatal Qi. This aspect of the body's Shen is considered to be the conditioned mind or "will," also known as the discriminating, or acquired mind, and constitutes the mind's Yin nature.

   The Postnatal Shen is produced and developed by mental stimulation through contact with the environment after birth. The Postnatal Shen dominates all mental activity and is responsible for thinking and learned behavior. The Postnatal Shen constitutes the true analytical aspect of the mind.

   Prenatal and Postnatal Shen usually interact intermittently with each other in maintaining the body's health. Continual exhaustion of the Postnatal Shen impairs and suppresses the Prenatal Shen. Excessive studying or sleep depravation, for example, can lead individuals to mistake the projection of their deepest fears and desires for genuine intuitive perceptions.

THE FIVE SPIRITUAL ASPECTS AND YIN ORGAN COMPONENTS OF SHEN

Prenatal Shen affects the spiritual disposition which presides over man at the moment of conception. Closely tied to the Yuan Shen are five important, although seldom discussed outside of China, energies or "spiritual entities" called the Five Agents (see Chapter 2). The function of the Five Agents establishes the foundation for the psychological aspect of the Five Element theory used in clinical diagnosis throughout China today.

Each of these Five Agents is connected to, or said to "reside in" one of the Five Yin Organs. The Three Hun reside in the Liver and embody the virtue of Kindness, the Shen resides in the Heart and embodies the virtue of Order, the Yi resides in the Spleen and embodies the virtue of Trust, the Seven Po reside in the Lungs and embody the virtue of Integrity, and the Zhi resides in the Kidneys and embodies the virtue of Wisdom (Figure 13.11). Whereas each of the Five Agents embodies a virtue, each of the Five Yin Organs embodies the energetic qualities of one of the primordial elements. The Liver embodies the element of Wood, the Heart embodies the element of Fire, the Spleen

embodies the element of Earth, the Lungs embody the element of Metal, and the Kidneys embody the element of Water.

Each of these Five Agent energies are connected to the five separate yet functionally interactive Yin organs, and thus create complex, multidimensional energy fields (Figure 13.12). These energy fields encompass emotional, mental, and spiritual shifts, as well as energetic transformations. The fluctuations depend upon which of the Five Agents is dominating from moment to moment. The psycho-spiritual attributes engendered are sometimes known as the Wu Jing Shen (Five Essence Spirits). As the universal energy flows through the Taiji Pole, these Five Agents are continuously being energized. The cultivation of the five virtues of these Five Agents nourishes the Eternal Soul.

The Qigong doctor needs to comprehend these multidimensional interactions to trace the complex spiritual, mental, emotional, and physical manifestations of Excess or Deficient conditions to the source or "root." Although Jing and Qi form the physical basis for the Shen, the Five Elemental Yin organs form the components for the Shen and the Five Essence Spirits. The energy of the Five Agents continually circulates through the patient's body, and are described below.

Figure 13.11. The Five Agents and Yin Organs

THE LIVER STORES THE ESSENCE SPIRIT "HUN"

The Liver stores the Three Ethereal Souls, also called the Hun. The Hun or Three Ethereal Souls are rooted in the Liver Yin (which includes the Liver Blood). The Liver organ is responsible for the free and easy flow of Qi throughout the body.

The Hun are typically characterized as the Yang, brighter, Heavenly souls. It is through the influence of the Hun that the five virtues of the Five Agents manifest. The Hun leave the body, ascending back to Heaven at the time of death. The ideogram for the Three Hun has two parts. One part is the character for Earthly spirits-Gui (Ghost), represented by a head suspended above a vaporous form of a body, with an appendage (symbolizing the whirlwind that accompanies the movements of the Earthly spirits). The other part of the character is the image for clouds that are seen as vapor rising from the Earth and gathering in the Heavens. The Hun move within the body as freely as clouds, following the Yi (Will) of the "Heavenly breath, within the celestial vault" (following the will of the Eternal Soul stored within the Heart, and originating in the Taiji Pole).

From the ideogram we also get a distinct picture of the spirit rising to the Heavens. The Eternal Soul is different from the spirit in the context of classical Chinese theology, in that the soul is seen as the more personal of the two, whereas spirits are seen as more universal temperaments or as archetypes. The ancient medical classics say that there are Three Ethereal Souls (Hun) and Seven Corporeal Souls (Po) that symbolize different attributes of the human being. The Hun's spiritual energy is said to be able to leave the body and then return, thus indicating a relationship with out of body travel into the spirit world.

The Hun and Po are expressions of the body's "true spirit." When disorder exists (physical, mental, emotional, or spiritual), the Hun may sometimes fly away (like startled birds in a yard), and the Po will either stir about thoughtlessly, in the absence of effective control, or become animalistic in nature and attack.

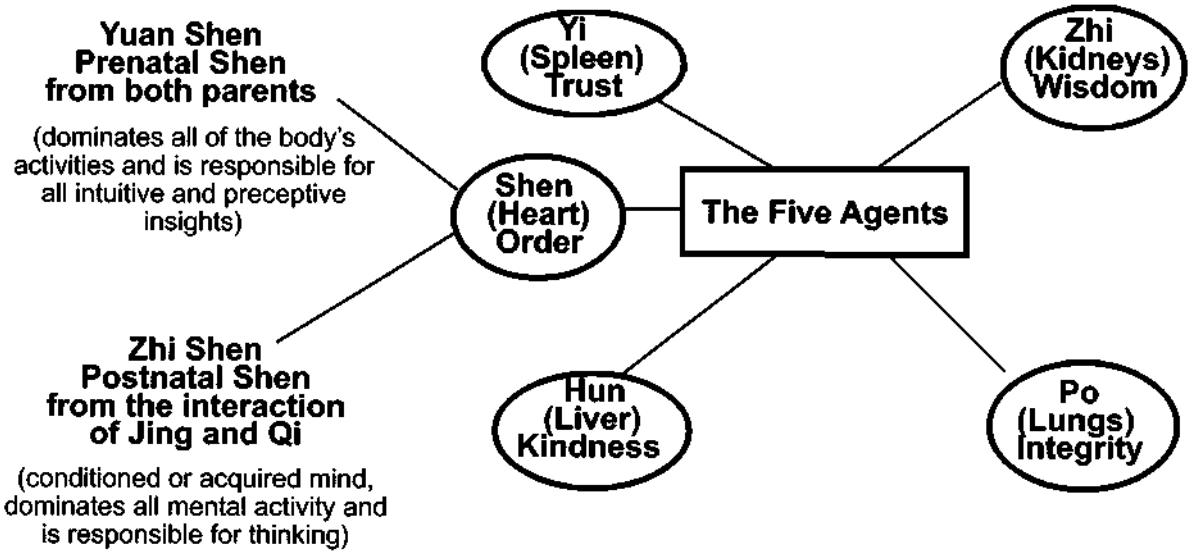

Figure 13.12. Formation of Shen

FUNCTIONS OF THE HUN

1. The Hun control sleep and dreaming. They reside in the eyes during the day and lodge in the Liver at night. When residing in the eyes, they see; when they lodge in the Liver, they dream. Dreams are the roaming of the Three Ethereal Souls. It is the nature the Hun to wander, and it happens easily. At night the Hun must be anchored or rooted in the Liver, so the Liver Blood and Liver Yin must be strong. If they are not, the Hun wanders, and the person dreams too much or has unpleasant dreams. Patients who suffer from severe Deficiency of Yin, may experience a floating sensation just before falling asleep. This condition is due to the Hun not being rooted in the patients' Yin.

   Dreams are an example of the information gathered during the Hun's traveling. The ancient Chinese Qigong masters understood that the body's Hun can traverse the Nine Levels of Heaven or Nine Levels of Earth instantaneously (see Chapter 2).

   The Hun store the sum total of past experiences. The expressions of the Three Ethereal Spirits are manifested through images, symbols and ideas from the divine and Wuji. These images, symbols and ideas emerge into the patient's mind, affecting his or her spiritual life. Without this interaction, the patient's mental and spiritual life would be deficient in images, ideas, and dreams.

   The Hun also controls dreams and daydreaming, as well as the ideals, aims, and direction in life. The absence of these objectives and goals results in feelings of depression. If the body's Liver Yin is depleted, the Hun are deprived of their residence, resulting in such conditions as: fear, excessive day dreaming, insomnia, and a lack of sense of direction or purpose in life (one of the main features of depression).

   Traditionally, sleepwalking is believed to be a function of the Hun. In sleepwalking, the body's Shen is not active and functioning, however the Hun are moving the individual. This is why when treating a patient for sleepwalking, the doctor will emit Qi into the patient's Hunmen Bl-47 (The Door of the Ethereal Soul). In modern research, however, some Qigong doctors have begun to theorize that the Po may take an active role in sleep walking, especially

when the sleep state is related to incoherent trauma (patients who thrash about, hurt people, or destroy things when sleeping).

When using hypnosis or "creative visualization" in psychotherapy (the therapist may suggest a specific image or scene for the patient), the therapist is trying to bypass the patient's acquired mind and bring psychic material from the Hun, to avoid the judging aspect of the Postnatal Shen.

With regard to sleep and herbal medicine, if the patient does not sleep well because the Hun are wandering, the Qigong doctor can prescribe sour and astringing herbs (i.e., Bai Shao, Mu Li, Suanzao Ren) which will encourage the Hun back into the body.

2. The Hun assist the Shen in mental activities. This relationship is very important, as the energy of the Shen and the Hun must continually be coordinated. The Shen is related to rational thinking and inspiration. The Hun gives the Shen a sense of direction, projecting outwards, relating to other people. The Shen needs to direct the Hun, to "gather the Hun." The Hun give the Shen its movement and direction, encouraging the Shen to relate with people, to socialize and bond. The Hun, however, also need to be gathered and restrained by the Shen. Otherwise if the Shen is weak and does not control the Hun, then the Hun move about too much and have lots of ideas, but never accomplish anything, leading to frustration.

   It is important that the Shen allow the Hun to move in and out of the body, but in so doing must give the Hun direction and purpose. The Hun inspire and give us dreams. That is why the words "movement," "coming and going," and "swimming" are often used in connection with the Hun. In fact, many doctors say that the Hun are the coming and going of the body's Shen. In mediumistic trances, when the spirit of one person enters another's body, it is the Hun that come in; the host's Shen is disabled at that time.

   Because knowledge is dependent on the awareness of the Three Ethereal Souls, the Hun are therefore considered the collectors of information. The Hun however, do not interpret, rationalize or analyze the knowledge, they just pass the information on to the Shen, which is responsible for rational thinking, intuition, and inspiration. The Shen helps distinguish between the useful and non-relevant information.

   There is an interesting correlation with the Hun controlling sleep and dreaming, and the Hun being rooted in the Liver Blood and Yin. The Hun's moving in and out of the Liver governs the free flow of Liver Qi and vice-versa; the free flow of Liver Qi is a manifestation of the swimming energy of the Hun, moving in and out of the tissues.

3. The Hun maintain balance in one's emotional life, under the leadership of the Shen.

   Everyone experiences emotions in life; that is normal. The Hun are responsible for keeping a balance, so that the emotions do not become excessive and thus become the cause of disease. The Hun have a regulatory function, closely related to the balance between Liver Blood (Yin), and Liver Qi (Yang). The Hun's function here is the mental equivalent of the Liver's emotional regulating and harmonizing function.

   Due to its acquired nature, the Postnatal Shen discriminates, while the Hun does not. The relationship between the Shen and the Hun is very similar to concepts of consciousness and unconsciousness in Jungian terms. The Hun are a repository of images and archetypes, connecting the (personal) subconscious mind and the collective unconscious. If the Hun are unsettled, then the Shen (consciousness) is cut off, confused, isolated, aimless, sterile, and without dreams. The movement of ideas within the body has to be controlled or it gets out of hand, resulting in madness. This madness occurs to the degree that the Shen doesn't control the Hun anymore, and the patient receives an uncontrolled amount of emotional, mental, and spiritual input. All the energies and symbols coming through the Hun have to be integrated and

assimilated. Otherwise there can be serious mental illness and possibly psychosis (except in young children who are continually full of ideas and have active imaginations). In a child, the Hun are very active and the Shen is not as restraining, so there is a continual flow of energies streaming from the unconscious world of symbols, without the result of insanity.

4. The Hun are responsible for the eyes. When the Hun wander in through the eyes, the eyes can see. The Hun give us vision, both mentally and spiritually.
5. The Hun influence a person's courage. If the Hun are not strong, the person is timid and fearful. If the Hun are strong, the person is fearless, can face up to the difficulties in life and dares to take action. A patient with weak Hun will have difficulty gathering information, making decisions, will lack courage, and become easily discouraged and apathetic.
6. The Hun control planning with the aid of the Shen and the sense of direction. The mental and spiritual confusion about one's role in life, what to do, what goals to set, can be compared to the aimless wandering of the Hun. This is a strong feature of major depression. If the Liver is strong and the Hun are strong and rooted, the person has a strong sense of direction.
7. The Hun control Spirit Travel. By housing the Shen for "spirit travel" (the spirit journeying outside of the physical body), it is possible for the Qigong doctor to consciously direct the Hun's travelling. This is different than Astral Travel, which is the Eternal Soul journeying outside of the physical body, connected to the Middle Dantian by a silver "cord of life." The Three Ethereal Souls, accompanied by the individual's consciousness, act as one unit which is sometimes referred to as the Spirit-Soul. The Spirit-Soul allows the doctor to know the exact location of the "spirit routes" travelled, as well as which path and direction it takes when it leaves the body. Otherwise, when the Hun wonder, the doctor "Shens out" and has no recollection of where he or she has been in the spiritual realms.

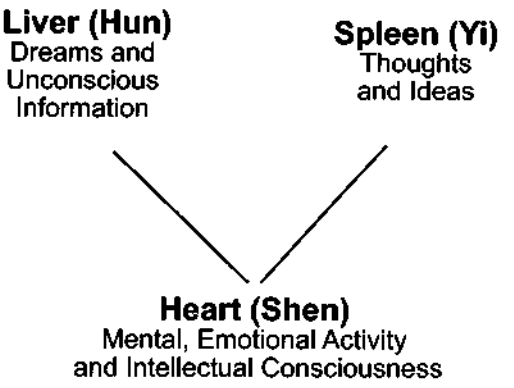

Figure 13.13. Two Ways to Feed the Shen

THE HEART STORES THE ESSENCE SPIRIT "SHEN"

The Heart stores the Shen and is responsible for mental and emotional activity, intelligent consciousness, long term memory, and sleep. It is responsible for organizing mental concepts and activities, and has the capacity to judge.

The Shen is divided into two kinds of energies, Prenatal Shen and Postnatal Shen.

The Prenatal Yuan Shen is associated with the congenital spiritual energy that descends from Heaven. It is the universal divine spirit that is implanted in each person, uniting man to the spiritual realm (that which exists beyond the physical and mental reality). It has been compared to the "Christ within us," or "higher self." This is the energy Qigong doctors attempt to become filled with during sitting meditation practice and prayer.

The Postnatal or Acquired Shen is associated with the wisdom of the five senses and the acquired knowledge of the individual's experiences.

There are two ways to "feed" the Shen. One way is through dreams or unconscious information coming from the Hun of the Liver; the other way is through thoughts and ideas from the Yi of the Spleen (Figure 13.13). A person who has a well-developed, strong, and abundant Shen comprehends things immediately and is able to apply what he or she has learned.

The Hun give the Shen movement allowing the

mind the capacity of self insight and introspection, as well as the ability to project outwards from the body and envelop, as well as relate to, other people.

THE SPLEEN STORES THE ESSENCE SPIRIT "YI"

The Chinese term Yi, is typically translated as mind, thought, opinion, idea, sentiment, inclination, intention, intellect, scholar mind, analytical thinking, and memorization in scholastic learning. Because the Spleen stores the Yi, it is responsible for the transformation and transportation of all thoughts and ideas on an intellectual level, through study, concentration, and memorization. This is different from the Hun's creativity. It is the interaction between the Yi of the Spleen and the Shen of the Heart that allows man to place how he thinks, speaks, and acts into sounds, thoughts, and actions.

Concerning memory, there is a lot of overlap between the functions of the Spleen (responsible for memory in terms of concentration and studying), the Kidneys (responsible for storing things on a day to day basis), and the Heart (responsible for storing past events).

The Postnatal Qi and Blood form the physiological basis for the intellect. A person with well-developed Yi has total recall of events experienced in their personal past, and is able to memorize things easily. A patient with an Excess of Yi will be obsessed with the past, while a patient with Deficient Yi will be absentminded, suffer memory loss, be inattentive, and have problems in maintaining concentration and mental focus. Although all physical pain is registered by the Po, and all psychological pain is registered by the Hun, only the memory of the pain is registered by the Yi (Figure 13.14). Therefore, a Deficient Yi condition can often lead to the phenomenon of transference and countertransference. Transference involves the incorrect attribution of certain emotions and intentions onto another person (usually onto the doctor by a patient). Countertransference involves the same type of projection of one's feelings, colored by one's own expectations in response. In countertransference, the doctor or therapist is doing the projecting.

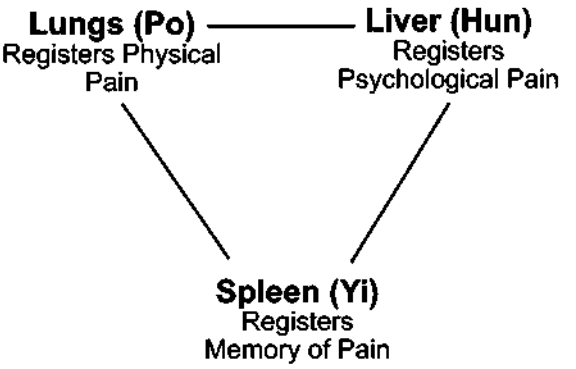

Figure 13.14. Three Ways the Body Registers Pain

Yi also has the meaning of divine purpose when applied to the Yuan Shen energy. Whenever the physical energy is purified by self-cultivation and through connecting to the divine, the intention of the Shen and the divine purpose become one and the same. It is said when the Yi is conserved, it will help build the Zhi (or willpower). The Yi is filled with information from the past along with current knowledge and sensations.

THE LUNGS STORE THE ESSENCE SPIRIT "PO"

The Lungs store the Seven Corporeal Souls (Po), which are physical in nature and are attached to the body's Jing and Qi. The word Po is defined as vigor, animation, or life. There are two parts to the Po ideogram; one is the character for Gui, the spirits of the Earth, and the other represents the color white. Thus, the Po are linked with a descending movement of energy and with the Jing. The Seven Corporeal Souls are also said "to come and go, enter and exit," in association with the body's Essences.

In Medical Qigong therapy, the body's Eternal Soul is seen as being strongly influenced by two main divisions of internal spiritual energies, the Hun and the Po. The Hun are the Three Ethereal Souls and represent the positively charged aspects of the Eternal Soul, while the Po are the Seven Corporeal Souls and are considered the physical, negative, Yin, heavy, and Earthly aspects

of the Eternal Soul. The Po are the counterpart of the Hun and can be described by its following six manifestations.

1. The Po are the somatic expressions of the Eternal Soul, related to the reflexive nervous system and limbic system (the "reptilian brain"). They manifest through the body's sensations of feeling, hearing, and seeing. They have an impulsive tendency towards action and correspond to the deep animal instincts within the Mind (personal subconscious) and cells (our reflexes are a Po reaction). The Po also provide us with the animal strength and resources necessary to mobilize the body and perform incredible feats of power. The "animal within" is driven by the Po. They are the manifestation of the body's Jing in the sphere of sensations and feelings. Just as the Three Hun provide the individual with the energetic movement for the Shen, the Po provides the individual with the energetic movement of the body's Jing.
2. The Po are responsible for all physiological processes in childhood. In the beginning of life, the Po are responsible for the sensations of pain and itching. The Po serve as the intermediary between the Jing and the body's other vital substances. At conception the interaction of the body's Jing not only forms the embryo, but also establishes the Po within the body. Although the Po are stored in the Lungs, they stay attached to the body until death, there upon returning their energy back to the Earth within a few days.
3. The Po are related to weeping and crying. The interconnection between the Po and Lungs is very important from an emotional point of view. When the Po's movement in the Lungs is constricted, grief and sadness are suppressed in the chest through shallow breathing.

   In the morning time, when waking, if the patient feels dull and depressed, it is a sign that his or her Shen is clinging to the body, i.e., the patient's Shen is clinging to the excessive energy of the Po.
4. The Po are closely linked to breathing. Because the Po reside in the Lungs, all meditation systems, breathing exercises, and forms of breath control are methods used to regulate the Po, calm the Shen, and access the higher Hun states. Breathing is the pulsation of the Po. Each emotional change the body experiences is related to a shift in the body's respiration rhythm. Because breath control relies on the Lungs which influence the sympathetic and parasympathetic nervous systems, the quality of Qi and its circulation are dependent upon the method, speed, and quality of the breath. To support the greatest longevity possible, it is important to breathe with a long, slow, and even quality to the breath. The breath (air from Heaven) interacting with the Po in the Lungs, plays a significant role in the Heaven-Man-Earth concept for balancing the emotions.

   The Lungs' virtues are righteousness and courage. These virtues give a person the drive and strength to do the "right thing" when the need arises. These virtues manifest and promote good health when a correct energetic and balanced alignment with the Po is achieved (between the Lungs breathing pattern and the Po).
5. The Po are connected to sexuality on the sensation level. All instinctive sexual reactions and passions come under the authority of the Po. In human life, the Po are linked to the basic instincts and perceptions of the body. The Po provide the fundamental biological energy, and are the source of biological needs and impulses. They are driven by basic instincts and urges, and their sole concern is the immediate gratification of biological needs and impulses (emotional and physical survival, reproductive urges, etc.). Most self destructive behavior, such as an attraction to unhealthy and dangerous life-styles, is due to the Po.
6. Because of the Corporeal Souls' relationship with the Lungs and Large Intestine, the anus is considered the "Po Men" or "the door of the Po." It acts as a doorway for the elimination of the waste products for the Five Yin Organs, through draining off impure liquids and waste.

THE KIDNEYS STORE THE ESSENCE SPIRIT "ZHI"

The Chinese term Zhi (translated as "will") is the prenatal spiritual entity associated with the Kidneys, and is not the personal will of the ego that is driven by our desires. The term Zhi has two meanings. It means memory, but it also means willpower. Both are primary features of the Zhi. The word Zhi can also be used to mean the Mind (whole body consciousness and awareness). In connection with the five mental aspects of the Mind, the Three Ethereal Souls, Seven Corporeal Souls, the Shen, the "intellect," and the "willpower" are sometimes referred to as the Five Zhi.

MEMORY

Memory is defined as the ability to remember information when studying or learning a particular subject or pattern. The Kidneys keep a determined focus on our goals, not forgetting where we are going and what we are working to achieve; they maintain a vital mindfulness. The Kidneys relate to short term memory, whereas, the Heart governs the body's long term memory (Figure 13.15). This is why elderly patients, whose Kidneys are declining, often cannot remember what day or year it is, but can remember events long past.

WILLPOWER

This is the most important aspect of the Zhi, because it is responsible for supplying the mental drive, willpower, determination, and single minded pursuit of goals and aspirations. It enables the realization of ambitions by providing the focussed energy necessary to carry ideas to fruition. A powerful Zhi creates the magnetism and charisma necessary to manifest and materialize our dreams.

Even though a person has acquired all the information available via the Hun, Po, and Yi, without the Zhi there can be no action. Although the Hun give us the goal (thinks of something), the Zhi is needed to accomplish it (decides and acts on it). A person with well-developed Zhi demonstrates perseverance, determination, and a tenacity to complete personal goals. Patients with Deficient Zhi become indecisive and fearful. Patients

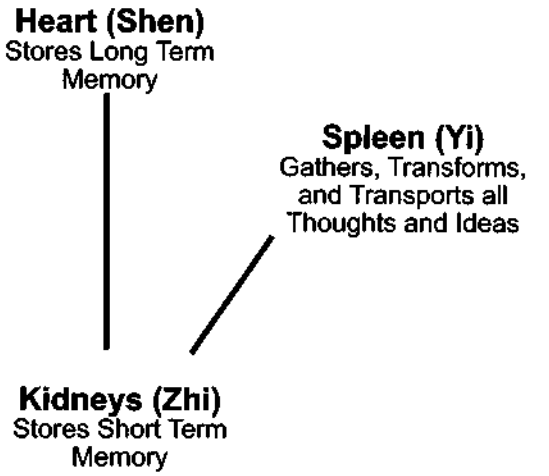

Figure 13.15. Three Ways the Body Stores Memory

with Excess Zhi have a blind obedience to authority, or tend to be fanatics.

The goal of the Qigong doctor is to reach such a level of attainment that his or her personal will merges with Heaven's will (Tian Zhi) becoming one and the same. Tian Zhi is considered the movement of the divine expressed in man as his personal virtue (De).

A man's virtue is defined as his spiritual righteousness, the authenticity of his heart and actions. It is through the acquisition of virtue that man finds and possesses his true nature. If man's virtue is initiated into the "mysterious" (embracing Heaven's will), his intuitive evolution will give way to limitless perception.

Tian Zhi is a divine inner prompting that guides us on our spiritual quest, if we are open to its message. Tian Zhi is what we can call the divine will and carries within it man's purpose in life.

THE FIVE YIN ORGAN CULTIVATION OF SHEN

The Shen indicates the vitality level, and the state of physical, mental, emotional, energetic, and spiritual being. A flourishing vitality is a mani-

festation of the Jing, Qi, and Blood inherent within the Five Yin Organs. These five components of the Shen are expressed through psychological manifestations (Figure 13.16). They form the bases of the patient's emotional characteristics. Each of the emotional components of the Five Yin Organs contribute to the patient's spiritual manifestation; adding or detracting from the natural harmony of the patient's spiritual nature.

The activity of conscious thinking, insight, and intelligence are the foundational aspects of the body's Shen, activated by the patient's Heart (wherein the Shen resides). The Heart is also responsible for the long term memory of the body's sensory memories (the perceptions, feelings and sensations related to hearing, seeing, smelling, tasting, and touching) and sleep. These sensory activities carry over from the other internal organs, due to their relationship with the Five Yin Organs. Emotional disturbances that affect the Heart can cause energetic changes in the patient's body, influencing health, toward recovery from diseases or illness by impeding or facilitating bodily functions (see Healing the Patient's Emotional Pain, Chapter 31).

When cultivating the Shen, it is important for the Qigong doctor to keep in mind that the spirit is indivisible from matter, and that an individual's emotional and spiritual well-being and development depend upon the healthy functions of the internal organs. When the Shen leaves the body (through shock, trauma, stress, depression, guilt, shame etc.), the Qigong doctor can observe a diminishment of glow in the patient's complexion, lack of luster in the eyes, along with changes in the respiration rate and state of mind.

Once the patient's Shen is disturbed, the Qi is affected. This in turn leads to the body's Jing becoming weakened. Patients with this condition are generally taught Medical Qigong exercises and prescriptions to not only tonify and strengthen their body's internal organs to improve their immune system, but also to improve the overall condition of their emotional/spiritual state. Even a low vitality of spirit can cause emotional disturbances that can scatter or stagnate the body's Qi.

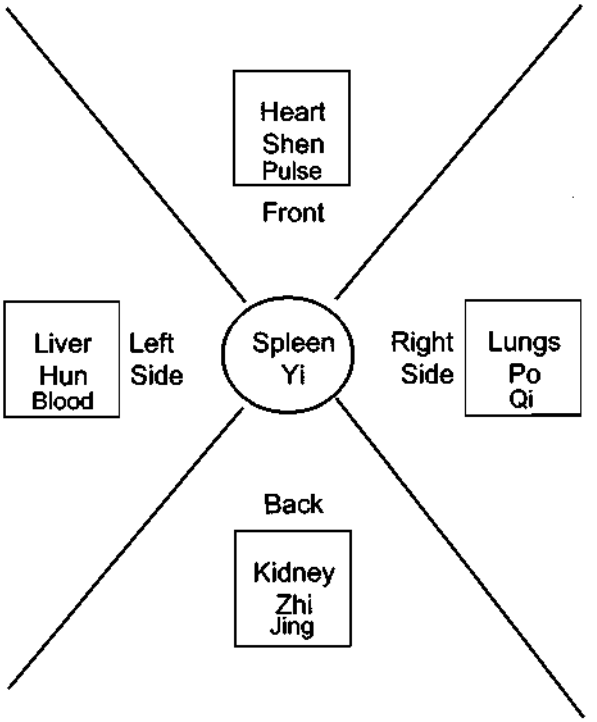

Figure 13.16. The body's Shen is physically housed in the Five Yin Organs. Each Yin organ houses a particular psycho-spiritual and energetic aspect of the human being. For example: The pulse is stored in the Heart, which is the residence of the Shen (Spirit), and placed in the front of the body, the Blood is stored in the Liver, which is the residence of the Hun (Three Ethereal Souls), and placed on the left side of the body, the Jing is stored in the Kidneys, which is the residence of the Zhi (Willpower), and placed on the back, and the Qi is stored in the Lungs, which is the residence of the Po (Seven Corporeal Souls) and placed on the right side of the body.

The Yi (Intention) resides in the Spleen and is placed in the center of the body, governing the Qi of the four aspects of spiritual manifestation, distributing them along the body's Taiji Pole. When Jing and Blood combine Shen is born. The Hun follow the Blood along in all its movements. The Po follow the Jing along in all its movements. The state of Qi and Blood of each organ can influence the Mind and the Spirit, any alteration of the Mind or Spirit affects one or more of the internal organs.

Advanced cultivation methods utilize the energy of the Five Yin Organs, flowing to and from the body's Taiji Pole. It is from the Thrusting Channels along side the Taiji Pole that the energy of the Shen is dispersed into the body's Yin and Yang Organs and then into the extremities (Figure 13.17 - 13.18).

SHENGONG CULTIVATION METHODS

The key to enhancing the Qigong doctor's development of energy, is through learning how to control the vast amount of Qi within the body, without compulsively "Shening out" (allowing the spirit to leave because the body feels uncomfortable). To avoid disconnecting from the body, the Qigong doctor practices several specific training methods of Shengong cultivation. When focusing on Shengong cultivation and regulation, there are four traditional disciplines the doctor must adhere to: Nourishing and Strengthening the Shen, Housing the Shen, Combining the Shen with Respiration, and Combining the Shen with Qi (Figure 13.19).

NOURISH AND STRENGTHEN THE SHEN

The Qi is able to nourish and strengthen the Shen through proper Qigong regulation. This is brought about through a form of coherent light meditation, that focuses the doctor's Shen on a small circle of light (generally about the size of a marble or pearl). The doctor's focus of concentration can extend either externally onto a specific point outside the body, or internally on a specific point inside the body (e.g., the Upper Dantian). Through this focused "coherent light" (light with wave patterns that are all in step or in phase), it is possible to build the Shen's strength and refine its power. Through focused intention on a specific area, the Qi and Shen condenses together forming a more powerful type of energetic projection.

HOUSING THE SHEN

By disciplining (i.e., quieting) both the emotions and thoughts the Shen becomes relaxed and tranquil, and remains in its residence (the Heart). The Shen must not be allowed to become attracted to outside emotional disturbances. The goal is to allow the Shen to be energized but not excited.

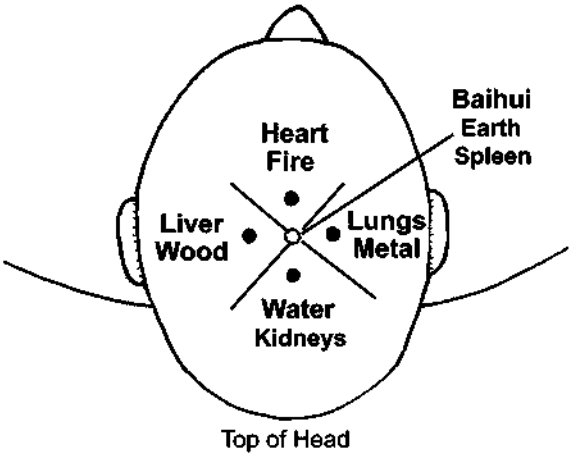

Figure 13.17. The Five Thrusting Channels as seen from the top of the head. Located within the Five Thrusting Channels are the "Five Portals of the Heavenly Gate." These gates include four entry points which surround the Baihui (One Hundred Meetings) point. These four points are known as the Sishencong or "Four Spirit Hearings" and are the access points for the upper spiritual matrix surrounding the body's Taiji Pole, and connect the Five Thrusting Channels of the upper gates with the Five portals of the Earthly Gates.

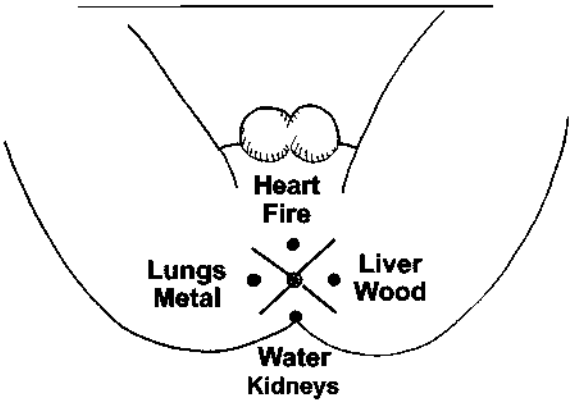

Figure 13.18. The Five Thrusting Channels as seen from the perineum. Located on base of the Five Thrusting Channels are the "Five Portals of the Earthly Gate." The Fire point is at the location of the Huiyin point on the Conception Vessel (CV-1), the Water point is at the location of the Changqiang point on the Governing Vessel (GV-1), the Wood and Metal points are located just below the ischial tuberosity, lateral to the anal sphincter. These points are known as the access points for the lower spiritual matrix surrounding the body's Taiji Pole.

COMBINING THE SHEN WITH THE RESPIRATION

Once the Shen has been nourished, strengthened, and housed, it is then connected with the doctor's breath. Once the Shen is combined with the respiration, maximum healing results can be obtained by releasing Healing Sounds and Qi projection simultaneously.

COMBINING THE SHEN WITH THE QI

The final stage is for the doctor to be able to direct the Shen in coordination with the life-force energy being emitted into the patient. Since Shen projects as light and Qi projects as vapor, this combination of Spirit and Energy projection is very powerful, especially when combined with healing colors and sounds.

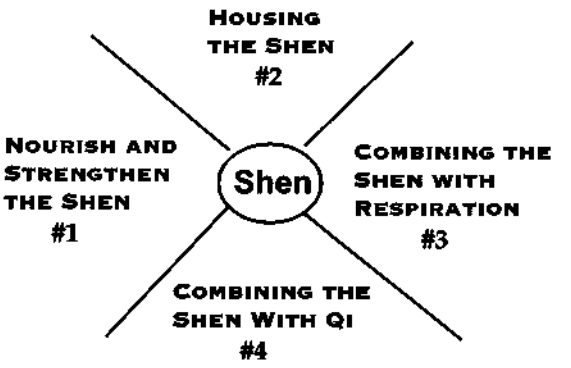

Figure 13.19. Four Ways to Cultivate the Shen

THE SIX TRANSPORTATION'S OF SHEN

The psychic abilities developed in Medical Qigong training result from a well-developed intuitive faculty, brought about through Shengong meditations. Through these meditations the Yuan Shen can transcend the space-time continuum, as both space and time are multidirectional and interconnected.

Shengong meditations cause altered states of consciousness that differ substantially in subjective and objective observation from the general norms for that individual. As the Qigong doctor dissolves his or her Shen into the Wuji, the subconscious will be able to see forward and backward in time, unhampered by distance.

The conscious mind acts as a filter, seeking to analyze every perception, and attempts to identify and categorize each perception. Once the conscious mind is engaged, the flow of perception usually stops because the perceptions arising from the subconscious are usually vague (often with multiple messages). Qigong doctors must train themselves to first root (ground/stabilize) the acquired mind, in order for their perceptions to come through in a pure form, void of thoughts and judgments.

The ancient Qigong masters explained the ability to access the manifestations of Shen as follows: "by rooting the acquired mind (Zhi Shen), the Heart (Yuan Shen) opens up to 10,000 voices (Wuji)." Meaning that, when the "chattering mind" is anchored into the Earth through focused intention, the Heart is able to perceive the spiritual realm (the 10,000 voices), or be aware of its connectedness to the multidirectional space-time continuum.

Extraordinary abilities that develop from the cultivated spiritual consciousness include: telepathy, clairvoyance, clairaudience, precognition, time travel into the past, levitation, and teleportation.

The Qigong doctor experiences different psychological adjustments when opening to the deep spiritual transitions of Shengong meditations. The adjustments the doctor will experience include:

1. Time distortion,
2. Deep mystical states of perception and intuition,
3. Deeper and more powerful levels of self healing,
4. A more spontaneous reaction to movement and sound, and
5. Difficulty communicating verbally.

CULTIVATING THE SPIRITUAL CONSCIOUSNESS TO OBTAIN THE SIX TRANSPORTATION'S OF SHEN

In Shengong meditations, it is through the use of imagery and creative visualization that the doctor's altered states are developed, and a connection is forged with the Yuan Shen and Eternal Soul.

After the doctor's Shen has entered into a quiescent state, his or her altered state of spiritual conscious can be initiated through choosing one of the following five images.

1. The doctor is instructed to go inward into the center of the Taiji Pole to connect with his or her Yuan Shen and Eternal Soul.
2. The doctor is instructed to go into an imaginary temple or sacred place located within the astral plane to connect with his or her Yuan Shen and Eternal Soul.
3. The doctor is instructed to float upwards into the Heavens to connect with the eternal source of his or her Yuan Shen and Eternal Soul.
4. The doctor is instructed to ascend out of the body (after reliving the death of a past life experience) and receive the knowledge learned from that experience collected from by the Yuan Shen and Eternal Soul.
5. The doctor is instructed to allow the Yuan Shen to directly connect with the Eternal Soul and transmit information.

The Higher Self and Eternal Soul are usually considered as the same thing, and are often regarded as the "Master Within." In Jungian psychology, the collective unconscious (Wuji) is accessed through the subconscious mind (Shen) in the form of dreams or directly through "visions." The personal subconscious (Shen) has several elements:

- the anima, which is the wise man (influenced by the Hun)-for males, or
- the animus, which is the wise woman (influenced by the Hun)-for females, plus
- the shadow, which is the individual's dark side (influenced by the Po).

Once the Qigong doctor has cultivated the Shen into a high level of effective energy (absorbing and projecting energy from the universal, as well as the immediate environment), the result is a gradual unveiling of six supernatural diagnostic powers known as the Six Transportations of Shen.

These six metaphysical abilities not only enable the Qigong doctor to accurately evaluate a patient's state, but also to predict the probable future progressions of the patient's life as well as of his or her disease. The Six Transportations of Shen are: Observing the Present, Comprehending the Past and Observing the Future, Knowing a Person's Thoughts, Perceiving a Person's Destiny, Hearing the Sounds of the Universe, and Examining the Universe (Figure 13.20).

OBSERVING THE PRESENT

The Qigong doctor must first quiet the Zhi Shen's (acquired mind) analytical chattering by housing its energy within the Five Yin Organs. As the Mind becomes rooted, the doctor's breathing slows and the Lung Qi harmonizes with the Heart Qi. Once the Seven Po are quieted in their residence and the Zhi Shen is rooted, the Yuan Shen's messages can come through clearly without interference. The Yuan Shen is always connected to the Wuji where all knowledge is stored. The Yuan Shen is always at the "center of time" where it can gather and absorb the patient's past and present experiences, emotional reactions and thought patterns. It is from the Qigong doctor's intention and focus to be at the "center of time" that he or she can observe the present state of "now."

Observing the past is the ability to analyze and accurately discern the actual state of present situations (the here and now). By keeping away from conscious intervention, the Yuan Shen is free to truly listen and perceive as an "observer." The doctor's ego is not engaged and his or her mind's subconscious observer receives and reviews the patient without bias.

This enables the doctor to thoroughly analyze and comprehend events and situations clearly and unambiguously. It is through this state of perception that the Qigong doctor can accurately discern the true emotional problems which disturb his or her patient's energetic balance.

COMPREHENDING THE PAST AND OBSERVING THE FUTURE

Comprehending the past and observing the future is the ability to analyze and understand the thought patterns of the patient, the reasons these patterns take place, and to accurately predict the outcome of future events based upon those pat-

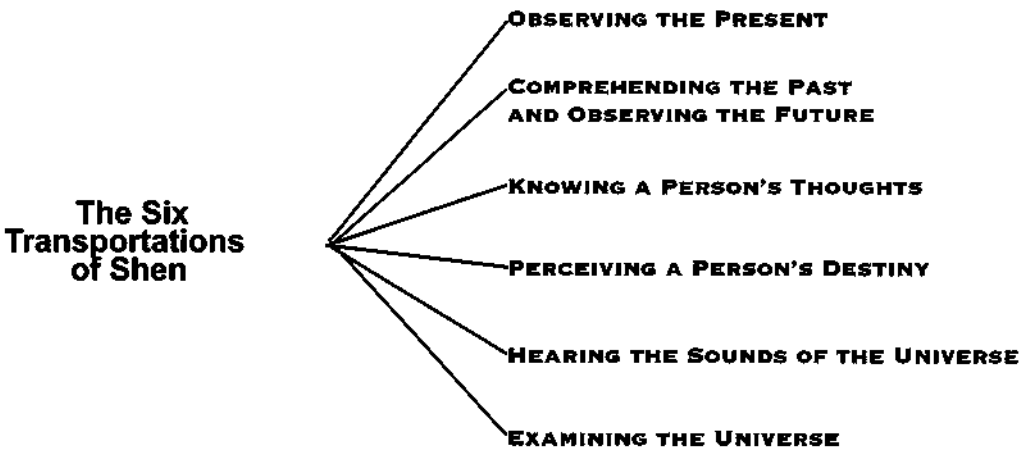

Figure 13.20. The Six Transportations of Shen

terns. By observing the patient from the active state of being in the "present," the Qigong doctor is free to travel within the infinite space (Wuji) enveloped within the patient's tissues. The doctor's Yuan Shen has no need to astral travel to obtain this information. The doctor's energetic connection to the patient's energy body gives him or her direct access to the personal information needed. It is from this internal space that the Qigong doctor can begin to access the memories existing within the patient's body (stored within the cells of the tissues).

At the subatomic level, the body and its cells contain a great deal more energetic space than matter. The doctor can directly access the internal Wuji enveloped within the patient's tissues and cells to retrieve the patient's past memories and emotions. Through tracing the patient's emotional, mental and spiritual development a greater understanding of the patient's present condition is achieved. After the doctor's Yuan Shen has gathered this information, it can be further analyzed by the doctor's Zhi Shen, and organized to accurately determine the cause and effects on the patient's present state.

Through understanding past patterns of thought and emotional reactions, the doctor can then predict future patterns of change and transition. These predictions are quite accurate, since people are prone to repeat programmed patterns indefinitely, unless there is an internal spiritual transition that frees them from this subconscious patterning.

KNOWING A PERSON'S THOUGHTS

This is the ability to sense the thoughts, judgments, fears, and emotions of another person, knowing their innermost fears and subconscious thoughts. The subconscious mind of the doctor communicates with the subconscious mind of the patient. This is a nonverbal, telepathic communication. It is therefore important for the doctor to monitor his or her thoughts and feelings, as they are automatically being projected into the subconscious mind of the patient. After the treatment is over the doctor may discuss with the patient any important information received that would be helpful to the patient.

PERCEIVING A PERSON'S DESTINY

This is the ability to predict future events and upcoming transitions in an individual's life based on the doctor's understanding of the patient's past energetic patterns. Through the Yuan Shen's ability to perceive the past and present, the doctor is able to understand the patient's mind, thoughts, acquired characteristics and personality. Above all, however, the doctor is able to perceive the individual's true nature that exists behind all of

the patient's external masks. The doctor's Zhi Shen (postnatal mind) is then able to analyze and categorize the individual's patterns. Through deductive thinking, the doctor is able then to perceive the probable outcome and development of these repetitive patterns. This enables the doctor to help the patient to identify the patterns that require restructuring and give added encouragement and advice, when needed.

This spiritual counsel or guidance is extremely important for healing transitions since old patterns established in the three energy matrixes (Jing, Qi, and Shen) must be changed together to achieve a more permanent healing. Otherwise, the illness is likely to reappear. The spiritual matrix sets the foundation for the energetic matrix, which in turn sets the foundation for the physical matrix.

HEARING THE SOUNDS OF THE UNIVERSE

This is the ability to hear sounds, music, and voices not audible to the normal hearing. This is not to be confused with schizophrenia -- a mental illness that causes a person to hear voices; the difference is that the schizophrenic cannot think clearly, the mind is very confused and unordered.

The ability to hear the sounds of the universe is also the ability to be aware of, and receive, divine inspiration or messages (clairaudience). These abilities allow the doctor to affect the lives of those they know or soon will know. The doctor's own inner-voice can guide, instruct, teach, and lead the doctor to ever higher states of enlightenment.

Through inner hearing, the Qigong doctor is able to listen to, as well as understand, the resonant sounds generated by life-force energy and spiritual entities. This enables the doctor to tap into an unlimited source of divine knowledge and wisdom, which in turn allows the doctor to be present for the patient's highest good.

EXAMINING THE UNIVERSE

This is the ability to actually perceive current objects, events, or people that may not be discerned through the normal senses. It is the ability to perceive both time and space on a spiritual dimension (clairvoyance), to understand and acknowledge one's part, and to accept one's divine calling in life. It is also the ability to understand how one's spiritual calling affects both the cosmos and mankind. Through inner-vision the Qigong doctor is able to see inner-visions of divine enlightenment, observe and exchange information with celestial beings, and find holy places for spiritual sanctuary.

The metaphysical abilities of the Six Transportations of Shen are spiritual manifestations from the Eternal Soul. Once the Qigong doctor regulates his or her spiritual life, these abilities become a natural course of experience, giving way to the development of eight supernatural powers. A chart describing the interaction of the body's Eternal Soul with the energetic functions of the Three Dantians and Five Yin Organs' Wu Jing Shen (Five Essence Spirits) is depicted in Figure 13.21.

THE EIGHT SUPERNATURAL POWERS

Once an individual has obtained the Six Transportations of Shen, his or her psychic abilities develope into eight supernatural powers. These powers can be utilized in the individual's personal spiritual practice. Through these eight supernatural powers the doctor's Yuan Shen can allow him or her the ability to transcend all physical boundaries and invoke certain spiritual manifestations. The eight supernatural powers are described as follows.

1. The ability to make the one's physical body light.
2. The ability to make the one's physical body heavy.
3. The ability to reduce one's energetic body to the size of an energetic particle. This allows an individual the ability to astral travel into the subtle energetic and spiritual realms of existence.
4. The ability to expand one's energetic body to an infinite size. This allows an individual the ability to connect to, through, or envelop objects, as well as energetically protect people, places and things.
5. The ability to call into existence and attain one's specific needs or desires. Due to the individual's strong connection to the divine,

he or she may manifest through faith that which is desired.

6. The ability to experience and enjoy one's desires fulfilled.
7. The ability to gain authority over one's situations. First and foremost, the individual will obtain the spiritual authority over a specific situation, then the authority over the emotional, mental and physical realms follow.
8. The power to attract and control things. This allows an individual the ability to engender help and security (in the form of outside council, finances, and spiritual and emotional support) in order to exercise power over specific situations.

SOUL PROJECTION, SPIRIT PROJECTION AND ENERGY PROJECTION

The phenomena of Soul Projection, Spirit Projection and Energy Projection is known and accepted as a natural part of existence in almost every culture in the world. The holy men and women, shamans, and energy healers of many primitive societies were required to prove their powers by exercising these spiritual and energetic abilities.

Tibetan Buddhism (influenced by the energetic practices of Indian cosmology) contains elaborate doctrines about Soul Projection (also known as Astral Projection), Energy Projection, the Astral Body, and also describe the feats individuals can perform while out of their physical bodies. Some of these doctrines are quite similar to the traditional Daoist teachings which are evident in advanced Daoist Shengong training.

All Chinese systems used for inducing Shen and Qi projections use visualization, concentration, willpower and the individual's innate skill. The three types of external projections are: Soul Projection, Spirit Projection, and Energy Projection.

- Soul Projection occurs when the body's Eternal Soul is externally projected out of the body, while still attached to the Middle Dantian through a Silver Cord;
- Spirit Projection occurs when the body's Shen is externally projected outside of the body as an energetic vehicle of light;
- Energy Projection occurs when the body's Qi is externally projected out of the body like an energetic vapor (Figure 13.22).

In Soul Projection, Spirit Projection and Energy Projection, the effects of time are not acknowledged outside of the physical realm. Within the Astral Plane, time is omnipresent, there is no past or future, only the individual's perception of it.

The body has an established relationship to both the physical and spiritual world. The physical world of the living is considered a Yang state of existence, while the supernatural-spiritual world is in a Yin state of existence (see Chapter 19). As the Qigong doctor's Shen reaches a high state of sensitivity, he or she can transcend the ordinary senses and normal conscious perceptions. These abilities enable the doctor to observe, communicate and even travel within the "higher" and "lower" spiritual Yin world. There are nine energetic levels of Heaven (i.e., the higher astral planes), and nine energetic levels within the Earthly spiritual realm (or lower astral plane).

It is important to note that the term "higher" and "lower" astral realm has nothing to do with the actual space, but with the energetic and spiritual vibrational levels. The higher and lower astral planes overlap and exist within the same space as the physical plane. This blending between the higher planes, lower planes and the physical plane creates energetic dimensions (or places) where the separation between these worlds is thin. In these energetic dimensions, lower beings can reach and attach onto an individual -- even though the individual is not directly within the astral regions.

The energetic frequency of each astral being determines the spiritual level wherein it exists. Beings of higher frequency, for example, vibrate at a faster rate and reside in the higher, less dense astral dimensions; whereas beings of lower energetic frequency can only dwell in the dense lower astral levels.

Negative feelings (e.g., worry, fear, anger, etc.) produce a lower vibrational rate that can not only keep an individual's spiritual vibration at a lower level, but can also attract lower level astral beings to that individual.

Soul Projection	The Eternal Soul is projected out of the body, attached to the Middle Dantian through a Silver Cord.
Spirit Projection	The Shen is projected outside of the body as an energetic vehicle of light.
Energy Projection	The Qi is projected out of the body like an energetic vapor.

Figure 13.22. Soul Projection, Spirit Projection and Energy Projection

SOUL PROJECTION

Soul Projection is the skill of sending the body's Eternal Soul (at will) to other places, times and dimensions (or worlds) in order to retrieve knowledge and experiences that assist the individual in his or her spiritual evolution. It is a nonphysical world in which time and space have no meaning or influence. The astral dimensions form a parallel universe that exists both within and outside ourselves.

The Eternal Soul is a fluid energetic form that can disengage from the physical body and travel about as a disembodied apparition taking the human consciousness along with it. It can pass through walls, travel to higher dimensional worlds, and encounter nonhuman creatures and mystical masters. Many Qigong masters use Soul Projection to seek spiritual knowledge, travel through time to view the past, explore other spiritual dimensions, engage in astral sex, or view the "infinite knowledge" (i.e., Messages) contained within the Wuji.

When the Eternal Soul begins to leave its energetic chamber, the brain wave patterns slow to a theta pulse. The body may feel paralyzed, and begin to vibrate as if an electrical current were passing through it.

There is also an odd roaring sound heard in the ears before the Eternal Soul separates from the body's tissues, or sometimes buzzing noises, musical notes, humming sounds, or chattering voices can be heard. When leaving the physical body, sometimes a swaying sensation can be felt as the astral body separates from its physical shell. The astral body can either spin out or float out of the physical body. When traveling in the astral body individuals may observe streaks of light flashing behind them as they travel.

As the Eternal Soul travels, a silver energetic cord is attached from either the top of the head (at the Baihui area) or at the Lower Dantian (at the umbilical area). This energetic cord is the media through which an individual retains his or her awareness of the physical self while projecting. This energetic cord is constructed of subconscious spiritual energy and maintains the individual's protective perceptual awareness of his or her physical body. It is believed by some that if this cord is severed the individual will die.

When the Eternal Soul (in its astral form) approaches someone, there is a feeling of electricity and coolness that is general felt. While in its phantom form, the Eternal Soul can display telekinetic powers (e.g., knocking on walls or tables, closing a half open door, etc.).

Warnings and Contraindication

Do not practice Soul Projection just before, or during, thunderstorms as the electromagnetic buildup in the atmosphere can hamper your ability to leave or return to the body. Also avoid approaching any kind of power-line during Soul Projection, there is a risk of getting caught by the power-line and becoming "stuck" (like a fly in a spider web).

1. A Body of Light — This energetic form resembles an energetic duplicate of the individual's physical self. It involves creating a near exact energy body duplicate of oneself (often with improvements, e.g., no wheelchair, or the elimination of other physical challenges).

2. An Animal Form — This energetic form resembles that of an animal (known as Shape Shifting). It is an ancient Daoist Shamanistic skill used to transcend the astral plane, and to take on the consciousness and energetic behavior, skills and perceptions of the animals the shamans assumed.

3. A Ghost or Saint — This energetic form resembles that of a Ghost or Saint (also known as an Invocation). It involves energetically taking on the image, form, and personality characteristics of a departed individual or spiritual deity.

4. The Immortal Observer — This energetic form resembles that of an All Seeing Eye (also known as The Astral Eye). It involves creating an energetic ball of light in the Upper Dantian at the Yin Tang (Third Eye) area. The large eye surrounded by a sphere of light is released from the Yin Tang area to gather psychic impressions via a long energetic cord attached to the Upper Dantian. As the eye returns, its energetic form is absorbed back into the individual's Upper Dantian. These gathered images are then analyzed and the information is assimilated before the energy is dispersed into the individual's Lower Dantian (and then down the legs and into the Earth).

5. The Element Body — This energetic form usually resembles that of different elements of nature, such as wind (as vaporous mist), Water, Earth (the terrain) or Fire. The ancient Daoist would use these elemental forms of nature as a disguise in order to obtain information or spy on hostile intruders.

Figure 13.23. Types of Spirit Bodies Used in Spirit Projection

Do not practice Soul Projection while recovering from an acute sickness (the drain on your energetic reserves can make you more susceptible to further illness).

SPIRIT PROJECTION

Spirit Projection is the skill of sending the body's Shen (at will) to other places, times and dimensions (or worlds) to retrieve knowledge and experiences to assist the individual in his or her spiritual evolution.

Spirit Projection (also known as mind projection, remote viewing, mind travel or traveling clairvoyance) can entail a combination of "genuine" observation with an extrasensory perceptional ability to gather information. When individuals perform traveling clairvoyance in the form of Spirit Projection, they can send their consciousness anywhere in the world. Awareness is not physical in nature, it is experiential, totally nonmaterial and cannot be limited to, or fully contained within the body.

Spirit Projection is practised through the creation of an energetic vehicle for the spirit body, such as a body of light, an energetic form of an animal, or a ball of light. An energetic shape is formed through the imagination and intention. The individual then transfers the energetic consciousness from his or her physical body into the energetic vehicle. This energetic form can resemble various patterns shapes and sizes to serve the individual's purpose (Figure 13.23).

As the individual thinks about a person or place, his or her body will be pulled to that object like a magnet, followed by a flood of images. The spirit body can fly over various terrains as it travels (e.g., oceans of water, deserts, mountains, forests, etc.). Once the spirit body arrives at its destination, the individual is able to feel and experience the area's environmental Qi (e.g., the humidity, wind, cold, heat, light, darkness, etc.).

After traveling in the spirit body the individual must reabsorb the energetic body back into his or her physical body to retain a clearer memory of the experiences.

Warnings and Contraindication

Do not perform too many Spirit Projections within a relative short time span. Excessive Spirit Projection has a tendency to weaken the Kidneys and drains the body's Wu Jing Shen.

While traveling, be careful of what your intentions are, as like begets like. Any negative projection, emotion or evil intention brought into the astral plane will quickly rebound back to the individual, or may attract negative entities that feed off of these lower vibrations.

ENCOUNTERING ASTRAL BEINGS

Within the subtle realm of the spiritual world, the existence of spiritual entities and ghosts are divided into Yin and Yang. While traveling in the astral realm, an individual can encounter either type of spiritual entity.

1. The Yang Beings native to the higher astral realm vibrate at a faster energetic rate, and are associated with more advanced, highly evolved beings, such as angels, guides, beings of the light, and enlightened masters.
2. The Yin Beings native to the lower astral realm vibrate at a slower energetic rate, and are associated with lower, less evolved beings, such as devils, demons, spirits of darkness, evil spirits, and other similar negative spiritual manifestations.

In all truth, the astral body cannot be hurt the same way that the physical body can. The astral body can, however, carry back to the physical body mental, emotional, and spiritual scars, or hitchhiking negative astral beings, all of which can negatively affect the physical body.

All actions and reactions on the astral plane, whether productive or destructive, are a product of the individual's belief system (you bring about each condition according to your faith).

ENERGY PROJECTION

Another type of life-force energy that the body can project outside its physical structure is Qi. Qi Projection is emitted outside the body like a fine vaporous mist, enveloping and sensing everything that it touches. Similar to Soul Projection and Spirit Projection, Qi Projection is directed according to the individual's intention, imagination, will, and faith. Distance therapy, pertaining to Qi emission, can be observed as energy leaving the doc-

tor's hand like heat waves emanating towards an external object. Within this emitted life-force energy is contained the doctor's Shen (Spirit), as well as the energetically encoded "Messages" that the doctor sends to his or her patient. This constitutes the energetic foundation for Medical Qigong therapy.

Section III
Dao Yin Training

CHAPTER 14
INTRODUCTION TO DAO YIN TRAINING

Qigong developed into a systematic healing art for health preservation during the "Warring States" period in Chinese history (476–221 B.C.). Records from that time contain documentation of symptoms, treatments, and specific points of attention given within the body and energy channels, by doctors practicing Medical Qigong, as well as details of the effects of these Qigong exercises.

The Huang Di Nei Jing (*The Yellow Emperor's Classic of Internal Medicine*) states, "to treat diseases it is important to use both Dao Yin and An Qiao." These are two names given to Medical Qigong therapy in ancient times.

"Dao" refers to physical movements, which are guided by the strength of the mind to stimulate the body's Qi and bring about a state of relaxation. "Yin" refers to the fact that with the aid of physical movements the body's Qi can reach the extremities (feet, fingers, and head). Dao and Yin together mean to lead and guide the energy through both motion and quiescence. This therapy includes mental, respiratory, and postural exercises.

"An" has two meanings, "massage" and the "up and down movement of the wrists." "Qiao" means "to lift up." An Qiao refers to the methods of the postural Dao Yin exercises. The basic hand and body methods of postural Dao Yin training are as follows:

- Kai (Opening)
- Fen (Separating)
- He (Closing)
- Tui (Pushing)
- Rou (Rubbing)
- Xuan (Rotating)
- An (Pressing)

These are the foundational movements a Qigong doctor will use in order to purge, disperse, gather, tonify, emit and guide Qi. The training of energy is achieved and implemented primarily through a combination of dynamic (active) and static (quiescent) exercises and meditations. Although Medical Qigong schools are diverse and complex in their form and content, they can all be divided into two main branches of energetic cultivation: Static Qigong and Dynamic Qigong (Figure 14.1).

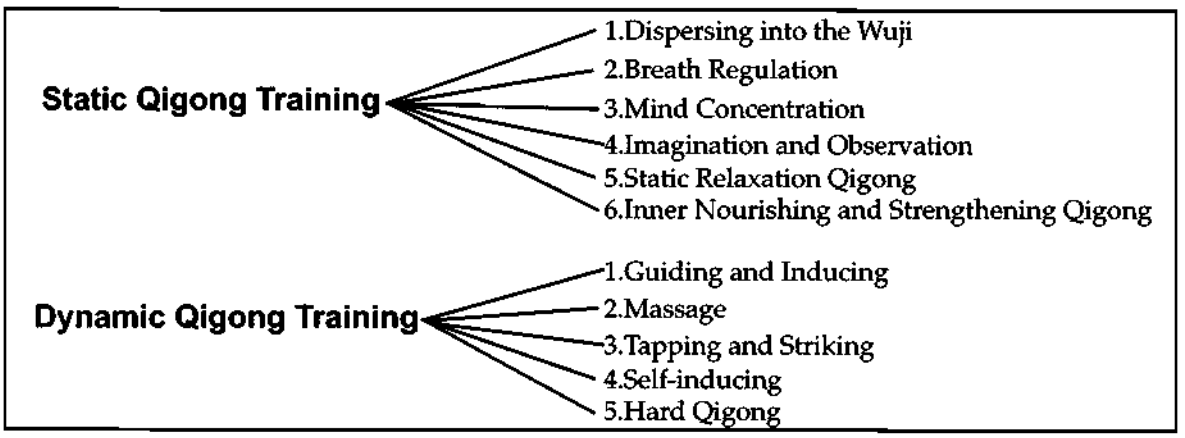

Figure 14.1. Two Main Branches of Energetic Cultivation: Static Qigong and Dynamic Qigong

STATIC QIGONG TRAINING

This training involves bringing about and keeping a quiescent state of mind and breath. In fixed postures (lying, sitting, or standing) the practitioners can train to accumulate substantial Qi in their Lower Dantian, while circulating it through their bodies. Static Qigong training is further divided into six different schools of practice: Dispersing into the Wuji, Breath Regulation, Mind Concentration, Imagination and Observation, Static Relaxation Qigong, and Inner Nourishing and Strengthening Qigong.

1. Dispersing into the Wuji requires the practitioner to dissolve his or her energy into infinite space, or the Void, without focusing or directing their attention on any object from the external environment.
2. Breath Regulation requires moving Qi internally or externally while inhaling, exhaling, or swallowing the breath, etc.
3. Mind Concentration requires concentrating the mind on one fixed internal or external point.
4. Imagination and Observation require disciplining the imagination with vivid, colorful visualizations.
5. Static Relaxation Qigong requires the relaxation of both body and mind, keeping them in a constant state of quiescence.
6. Inner Nourishing and Strengthening Qigong require the use of multiple Static Qigong modalities (for example; Breath Regulation combined with Imagination and Observation).

DYNAMIC QIGONG TRAINING

This involves training the body, mind and Qi simultaneously, to promote the functional activities of Qi and to enhance its free flow throughout the body's channels. These exercises often require standing or walking, and affect muscular tension, weight distribution, Blood and Qi circulation, as well as the functional activities of the major organs. These exercises are differentiated by various kinds of body movements and can be divided into five different schools of training: Guiding and Inducing, Massage, Tapping and Striking, Self-inducing, and Hard Qigong.

1. Guiding and Inducing requires physical movements such as dancing, mimicking animal movements, and gymnastics.
2. Massage focuses on both the manipulation of specific points and channels, as well as on the knowledge of muscles, tendons, and bone structure.
3. Tapping and Striking focus on using patting, slapping, tapping, and striking techniques with the fingers, palm, fist, wooden stick, or material in a cloth bag.
4. Self-inducing training encompasses small to large physically strenuous Qigong movements.
5. Hard Qigong focuses on martial arts training in Iron Palm Training, Iron Body Training, etc.

The incorrect employment of dynamic or static principles of Qigong exercises and meditations can cause energetic deviations which are capable of either hindering, or harming, the individual's health. There are two purposes for Medical Qigong development: To Protect and Strengthen the Body's Health, and To Treat Diseases.

1. To protect and strengthen the body's health: Medical Qigong exercises are prescribed in accordance with the individual's physical constitution, state of health, emotional constitution, climate, and different seasons.
2. To treat diseases: Medical Qigong exercises are prescribed in accordance with the individual's symptoms, pathological condition, and degree of severity, complications, and the constitution of the patient.

PRINCIPLES OF YIN AND YANG IN DAO YIN TRAINING

Both static and dynamic Qigong methods supplement each other when combined equally. No matter which static or dynamic method is practiced, one of the four principles of Yin and Yang will always be adhered to: Quiescence in Motion, Action within Motion, Motion in Quiescence, and Stillness within Quiescence.

1. Quiescence in Motion is referred to as a Yin within Yang technique, and requires being quiet, calm, and still on the inside while being active on the outside.

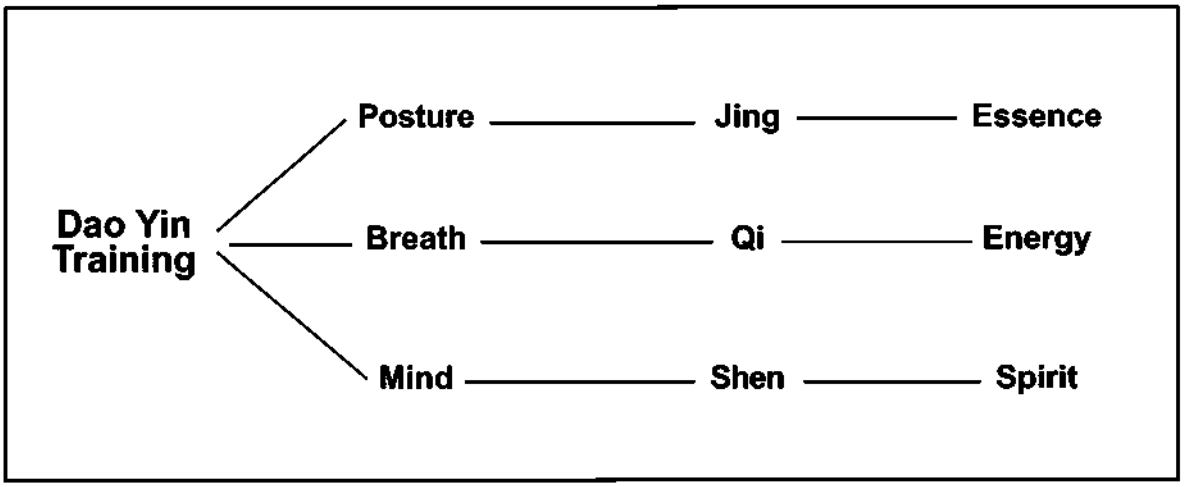

Figure 14.2. Dao Yin Chart

2. Action within Motion is referred to as a Yang within Yang technique, and requires being active both on the inside and on the outside.
3. Motion in Quiescence is referred to as a Yang within Yin technique, and requires being active on the inside while being quiet, calm, and still on the outside.
4. Stillness within Quiescence is referred to as a Yin within Yin technique, and requires being quiet, calm, and still both on the inside and on the outside.

THREE FOUNDATIONAL METHODS OF DAO YIN TRAINING

The diverse methods of practicing Medical Qigong exercises fall within three categories of Dao Yin training: Posture Dao Yin training, Respiratory Dao Yin training, and Mental Dao Yin training.

1. Posture Dao Yin consists of posture training for Medical Qigong therapy. It is divided into six specific types of training: walking, standing, sitting, kneeling, lying, and massaging.
2. Respiratory Dao Yin consists of breathing exercises for Qigong training, and therapy that includes various techniques of inhaling, exhaling, aspirating, blowing, and holding the breath.
3. Mental Dao Yin training requires that the thoughts be concentrated on one object, placing the cerebral cortex into a special inhibitory state. In various Medical Qigong circles in China this method is commonly referred to as "the internal keeping of the mental state."

The Dao Yins are taught in a postnatal energetic progression of Jing (posture) to Qi (respiration), to Shen (mind and emotion). In this way, the body regulates and supports the production of energy, which in turn regulates and supports the production of Spirit (Figure 14.2).

Despite the fact that many postures and movements may vary according to the specific styles of each Medical Qigong school, the primary benefit of each exercise will:

- improve and strengthen the patient's metabolism,
- smooth the Qi of the channels and collaterals,
- strengthen the body and mind,
- emotionally detoxify the internal viscera, and
- facilitate the increased flow of Righteous Qi (the Qi that fights the pathogenic invasion of Evil Qi) within the body.

Chapter 15
Postural Dao Yin Training

The goal of Postural Dao Yin training is to promote the regulation and circulation of Qi. Part of this training involves learning the techniques to guide the internal energy to flow using the movements and changes in the electromagnetic fields of the hands and body.

Success in Medical Qigong training is directly related to the correctness of the body's alignment. Correct posture regulates the Heart, and results in a calm mind; with a relaxed mind it is easy to lead the flow of Qi downward, to affect the Blood circulation and pulse. When the body is incorrectly aligned, it disturbs the smooth flow of Qi; energy then becomes obstructed or deviates, resulting in a restless Mind (both the thinking mind and the whole body consciousness).

The proper sequence of relaxation and energy circulation within the body is as follows:

1. the muscles are first to relax,
2. followed by the tendons and ligaments,
3. next, the nerves relax, and
4. finally the bones.

Once the muscles, tendons, and ligaments relax, the Qi can circulate freely through the channels and collaterals. The skin and muscles are generally the first level of awareness cultivation. The sensations of Qi and Blood circulation are usually experienced by the practitioner as heat, tingling, fullness, and expansion. The Chinese call these sensations the Eight Energetic Touches, which are known as the first of three transformations of energy (also known as the Subtle Wonders, see Chapter 29).

The next level of awareness involves the deeper flows of Qi within the nerves; this feels like an electric vibration, or an energetic current traveling through the body. Sometimes, due to an energetic surge released from within the body's organ system or channels, an electric shock is felt through the extremities or through the entire body.

The final level of Qi circulation awareness involves the Qi circulation within the bones and the Marrow. In the beginning stages it sometimes feels cold and arthritic in the joints (especially within the extremities). These sensations will later develop into a vibrational resonance which is felt deep within the bones.

The main point of Postural Dao Yin is to seek a state of physical and energetic balance. Postural Dao Yin is also divided into two distinct methods of treatment: Static Posture and Dynamic Posture training.

Static Posture Dao Yin Training

This method includes quiet movement while in the position of lying, sitting, standing, or walking, and is used to accumulate and strengthen the practitioner's internal Qi. Before performing the static posture forms for Medical Qigong therapy, it is important to note that static posture training is divided into three basic modalities: Choosing the Proper Beginning Posture, the Inhaling and Exhaling Methods, and Opening and Closing the Lower Dantian.

1. The purpose of the choosing the proper beginning posture is to calm the Heart and relax the mind, and focus on a specific goal for training the body's life-force energy.
2. When the energy begins to flow freely, the practitioner focuses his or her attention on each inhalation and exhalation for the specific goal of tonification, purgation or regulating the life-force energy.
3. The purpose of the "opening and closing" of the Lower Dantian ending postures is to bring the body's energy back down into the Lower Dantian and to root the Qi. Rooting the Qi in the Lower Dantian after Qigong practice

avoids creating Excess conditions within the body's internal organs.

CHOOSING THE PROPER POSTURE

Medical Qigong meditations and prescriptions are not limited to sitting practice alone. Each of the different lying, sitting, standing, and walking postures has its own specific form of meditation.

The lying, sitting, and standing postures create the foundational base for Static Posture Dao Yin training. Each static posture can induce the body's energy to descend quickly into the Lower Dantian. The selection of the appropriate technique and body position is determined by each practitioner's body type (structural formation) and the condition of the individual's physical health. The length of time that a practitioner focuses on the Medical Qigong prescription is also determined by the individual's specific disease as shown in the following examples.

- Patients with digestive problems, gastroptosis, or prolapse of the internal organs should begin their training while lying supine (on their back), with their knees pointing upward, their buttocks elevated 4 inches off the ground, and their feet flat on the floor.
- Patients with gastrointestinal diseases should begin their training lying flat on their backs. As the condition improves, they should combine lying and sitting meditations to promote the digestion and absorption of food.
- Patients with Heart disease, hypertension, or nervous disorders should begin training from a sitting position. Later, they should combine sitting and standing meditations in order to direct their Qi and Blood downward.
- Patients with Lung diseases, asthma, chronic bronchitis, emphysema, or cardiopulmonary function disorders should begin their training from a semi-reclining position (usually a 45 degree angle) to help respiration flow smoothly and to alleviate stress on the Lungs.

  In the hospital, each pillow that the patient uses for elevation represents the degree of strain that is placed on the Lungs. The patient is said to have strong Lungs, for example, if he or she is reclining and breathing comfortably on one pillow. If however, it takes three pillows before the patient is reclining comfortably, the Lungs are considered weak and congested (e.g., in cases of dyspnea).
- Patients with severe physical weakness (e.g. chronic fatigue syndrome and fibromyalgia) should begin their training from a lying or sitting position. Later, they can combine sitting and standing meditations as their constitution improves.

PRIMARY AND SECONDARY POSTURES

Patients are taught a primary and a secondary posture to prevent fatigue, and increase the healing effect of the Medical Qigong prescriptions. A primary standing posture is performed, for example, in the morning when the patient is strongest, and the energy is cleanest. A secondary sitting posture is performed in the afternoon, or evening when the patient is tired, with a focus on quiet regulation.

After a patient has learned a particular lying, sitting, or standing meditation, he or she can be taught the secondary posture without the risk of depleting his or her Qi.

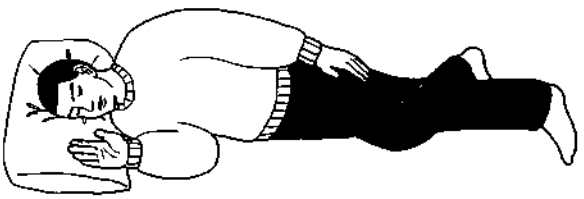

Figure 15.1. Sleeping Dog Posture

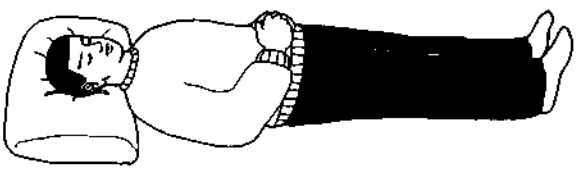

Figure 15.2. Supine Posture (Hibernation Posture)

LYING POSTURES

The Chinese saying, "The body should lie like a bow," is a perfect description of the curled position of the patient's body, while in the Sleeping Dog posture (Figure 15.1). This particular position is beneficial for aiding digestion and the absorption of food.

In prescribing the Sleeping Dog posture, the patient should lie on their right side with the left knee bent and the right leg extended straight. To avoid compressing the Heart, do not allow the patient to lie on their left side. Keep the patient's head raised slightly to allow the Blood to flow downward into the torso. Have the patient bend the right arm at the elbow.

When the patient is chronically ill, however, an exception is made. In this case it is important that the patient lie on the "healthy side" and not the side of the diseased organ (e.g., in cases of Liver disease, patients might lie on their left side). Remember to always adjust the patients' postures as needed and encourage them to practice "natural breathing."

Another popular posture is called the Hibernation posture. By lying supine in the Hibernation posture, the patient will regulate the functional activities of the central nervous system (Figure 15.2). Lying supine is also suitable for patients with serious diseases who are debilitated (this is also a sleep inducing method of training).

SITTING POSTURES

The Chinese saying, "The body should sit like a bell," describes the secure (or rooted) position of the patients' body, especially the lower legs and torso. Sitting is the most commonly used position for Medical Qigong therapy. This position helps the patients to relax and focus their mind's intent.

There are several sitting postures used in Medical Qigong therapy, and are prescribed according to the patient's flexibility: sitting upright on a chair (Figure 15.3), a cross-legged posture called the Full Lotus, another called Half Lotus, or with the legs loosely crossed (Figure 15.4-6). Make sure the patients sit on a raised cushion in order to keep their buttocks slightly higher than their knees.

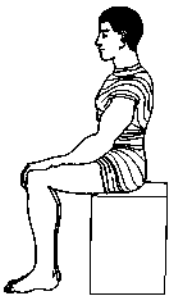

Figure 15.3. Upright Sitting Posture

Figure 15.4. Cross-Legged Zi Wu Posture

Figure 15.5. Cross-Legged Buddhist Greeting Posture

Figure 15.6. Cross-Legged Buddha's Warrior Attendant Posture

One of my Medical Qigong instructors in China suggested elevating the hips at least four inches off the floor when meditating, to avoid undue stress on the lower back, spine, and leg circulation. This elevation of the hips forms a triangle between both knees and the Lower Dantian, establishing a firmer connection to the Earth energy. This allows the Earth Qi to easily flow from the patients' knees and coccyx into their body.

When sitting in a chair meditating, the feet should touch the ground firmly, instead of being suspended in midair. This allows the Earth Qi to flow easily from the patients' feet into their body. Otherwise patients may develop swollen feet and lumbago due to Blood stagnation, or even hallucinations.

Keep the patients' spine straight by aligning the tip of the nose on a vertical line with the navel, to release pressure and tension on the cervical nerves.

STANDING POSTURES

The Chinese saying, "The body must stand like a pine tree," describes a relaxed position of the body's structure, standing with the bones stacked on top of each other, from the ground up. Standing meditations are particularly tonifying in nature, and are absolutely essential for accumulating Qi. The advantage of the standing position is that the flow of energy can be easily regulated and promoted. This posture helps to normalize blood pressure, and calm the Heart. Standing meditations also produce a unique psychophysiological change within the patients, allowing them to shed energetic obstructions, and to create a healthier body, mind, and spiritual awareness. Standing meditations are also essential for the Qigong doctors, as it facilitates the accumulation of Qi that is necessary for the emitting of energy.

Standing meditations, however, are not suitable for patients who are extremely ill or in poor health. Therefore, exercises in the standing postures should only be prescribed for minimal durations during convalescence, to build up the patients' constitution, promote health and to enhance their strength slowly.

The body should be held in an upright posi-

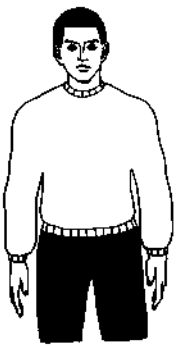

Figure 15.7. Wuji Posture

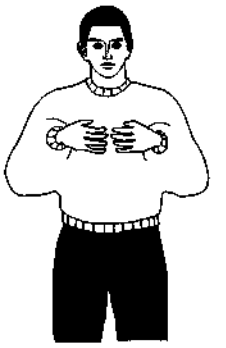

Figure 15.8. Immortal Post Posture

Figure 15.9. Buddhist Greeting Posture

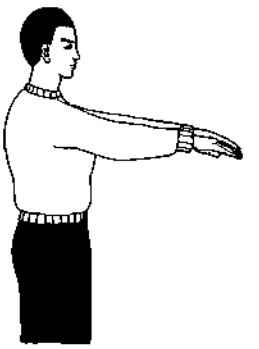

Figure 15.10. Extending Palm Posture

Figure 15.11. Embracing Dantian Posture

Figure 15.12. Square-Round Posture

tion, with three points connected in a straight line: Baihui GV-20 point at the top of the head, Huiyin CV-1 point at the bottom of the perineum, and the Yongquan K-1 point at the bottom of the feet. The patient's posture should be kept relaxed, still, solid, and rooted like a tree. The patient should also imagine their feet growing roots deep into the ground, to absorb the Earth's energy from the soil.

Standing exercises are usually accompanied by a variety of hand positions (Figures 15.7–15.12). The most popular are (1) Wuji: hands hang down by sides, (2) Immortal Post: hands embrace an invisible ball, (3) Buddhist Greeting: both hands press together at the solar plexus level, (4) Extending Palm: both hands press downward, (5) Embracing the Dantian: folding the hands and resting them on lower Dantian, and (6) Square-Round: left palm's heel rests inside the right palm's center.

In each posture, whether lying, sitting, or standing, the function and flow of body energy shifts and changes in relationship to, and as a manifestation of, the patient's mental belief structure.

If, for example, the patient while standing, shifts his or her weight and mental focus onto the balls of the feet, the energy will naturally flow through the front of the body via the front Yin channels. If the patient shifts his or her weight and mental focus onto the back on the heels, the energy will naturally flow through the back of his or her body via the back Yang channels. The center of the feet connect the patient's flow of energy to the Taiji Pole and can be used either to transfer the energy forward or backwards.

Generally, before beginning standing meditations, patients are encouraged to relax, sink, and shift their body weight back and forth between their heels and their toes. This practice massages their internal organs and disperses any blockages by stimulating the corresponding organ areas at the bottom of the feet as described in the therapeutic use of the Lower Hexagram Yaos (see Chapter 3).

Patients should inhale while shifting their weight backwards and exhale while shifting forwards. Their attention should be placed on their internal organs and the body's surrounding field of energy. The patients' awareness is also focused on the body moving back and forth, like the rhythm of an ocean tide.

Women are generally encouraged to practice meditation in the standing position (especially around the time of their menstruation), as the sitting position tends to decrease energy circulation, and may cause energy blockages in their lower abdominal area.

THE EIGHTEEN RULES OF PROPER MEDICAL QIGONG STRUCTURE

The most important basic techniques of Medical Qigong training are guided by eighteen rules of proper form and structure. The main point of Postural Dao Yin training is to relax and seek quiescence while in the various postures. Tension in any area of the body restricts the whole structural system, since the body seeks to balance its structure naturally by shifting its energy and weight. The general function of the muscles is to guide the flow of energy through the channels.

The following is a list of the Eighteen Rules for proper standing postures, these rules apply to every school of energy cultivation:

1. Stand with the feet flat,
2. Bend the knees,
3. Relax the hips,
4. Round the perineal area,
5. Close the anal sphincter,
6. Pull in the Stomach,
7. Relax the waist,
8. Tuck the chest in,
9. Stretch the back,
10. Relax the shoulders,
11. Sink the elbows,
12. Hollow the armpits,
13. Relax the wrists,
14. Suspend the head,
15. Tuck the chin,
16. Close the eyes for inner vision,
17. Close the mouth and turn your hearing inwards, and
18. Touch the tongue to the upper palate,

Each of these eighteen rules is described in detail as follows.

RULE 1—STAND WITH THE FEET FLAT

Stand with the feet flat, parallel to the outside of the shoulders. Weight should be distributed evenly on both feet about an inch and a half inward (anterior) from the heels, and perpendicular to the tibia. Focus on dropping the weight down behind the legs, not down the front. This action takes the pressure away from the knees and places it in the center of the feet (Figure 15.13).

Stretch the feet and let the toes softly grasp the ground to keep the body firmly rooted as you tuck the sacrum under (Figure 15.14). Relaxing is important. Rigid, contracted feet disrupt the flow of energy from the Earth into the body. The Kidney energy flowing within the bone can be accessed by shifting the weight onto the heels. The Heart energy can be accessed by shifting the weight onto the balls of the feet. The weight in the center of the feet accesses the Taiji Pole.

While training, the feet may vibrate or feel hot, as if on fire. This is a normal reaction to correct postural training and is beneficial because it dissolves the calcium deposits stored within the extremities of the feet. If, however, the Fire in the feet is too intense (due to Excess Liver Fire), hit the heels on the ground and rub the lumbar spine, using the mind's intention to send more of the Kidney Yin (Water) down to the feet to cool the Fire.

RULE 2—BEND THE KNEES

The knees should be slightly bent and facing the same direction as the feet. The knee caps should be directly aligned and extended no further than the tips of the middle toes. Do not allow the knees to twist inward.

To secure the structure, imagine holding a large beach ball between the knees. Many patients develop knee problems because they extend their knees too far forward or allow their knees to twist to the side, rather than aligning them with the toes. If pressure is felt on the sides or front of the knees, check the positioning. Knees that are unable to point in the direction of the toes are most often the result of tight hip joints (Figure 15.15). If the energy in the legs is tightly constricted around the knee area, Qi flow will be severely limited. A relaxed knee-joint, on the other hand, will increase

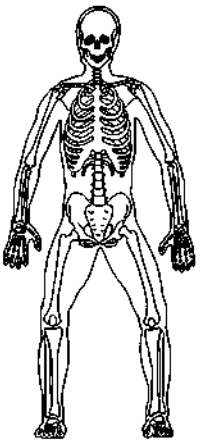

Figure 15.13. Stack the bones on top of each other from the bottom of the feet to the skull.

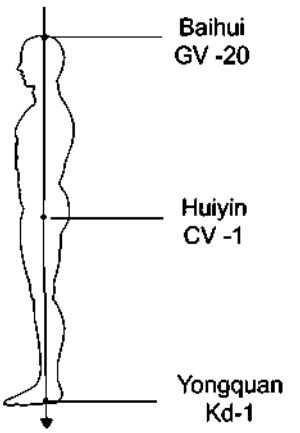

Figure 15.14. The three points (Baihui, Huiyin, and Yong quan) can be connected by a straight line.

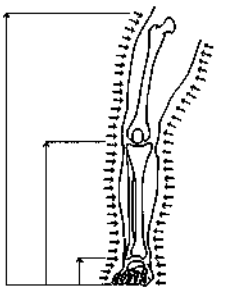

Figure 15.15. Keep the center of the body's weight aligned to the center of the knees, to relax the connective tissue surrounding the knees.

the Qi and Blood flowing through the legs, making it easier to relax the hip and to round the perineal area.

Relaxing the knees also permits free flow of energy through the three descending Yang channels on the outside of the leg, and the three ascending Yin channels on the inside of the leg (Figure 15.16). The techniques for relaxing the knees will vary according to the emotional and structural pattern of each individual, as emotions of fear, etc., have a tendency to gather and pool behind the knees.

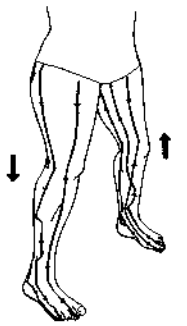

Figure 15.16. Relaxing the knees also permits the free flow of energy through the ascending Yin channels and descending Yang channels of the legs.

RULE 3—RELAX THE HIPS

Drop the buttocks slightly while sinking the Qi from the upper torso into the Lower Dantian, and relax the hips. Keep the hips facing forward. The buttocks should be gently tucked under the body to facilitate straightening of the spine and the keeping the Qi in the Lower Dantian.

Imagine a weight of a thousand pounds hanging from the coccyx (Figure 15.17). As the weight pulls down, tilt the sacrum under the body. When the hip-joints are relaxed, the lower limbs will be able to move freely.

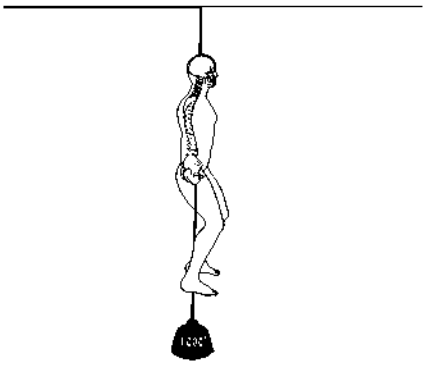

Figure 15.17. Imagine a 1000-pound weight hanging from the coccyx and a heavenly cord suspending the head.

RULE 4—ROUND THE PERINEAL AREA

There are three parts to rounding the perineal area. First, set the knees apart, turning them both outward. This allows the groin and hips to shift to an anterior tilt. Second, bring the knees back together and turn them inward, while also relaxing the hips. This allows the groin and hips to shift to a posterior tilt. Third, suspend the perineal area to lift the perineum and the anus slightly. This allows the groin and hips to come to a center balance and to sink. Rounding the perineal area keeps the perineum free from pressure, yet sealed. This ensures better functional activities of the Qi, and allows the "lower door" (the anus) to remain closed to avoid leakage of vital energy.

RULE 5—CLOSE THE ANAL SPHINCTER

The anus is called the Lower Bridge and it is where the Yang and Yin channels meet and combine. The anus is considered the door of the Seven Corporeal Souls (Po). Although the anal sphincter is held closed, it is important that the perineum remain relaxed. There are three stages in controlling the anal sphincter:

1. In the first stage, the anus is contracted with slight muscle control, and the energy is directed into different energy centers along the Microcosmic Orbit. When first beginning, inhale and expand the abdomen while imagining that the anus is connected to the navel and is pulling up towards it. On the exhalation, contract the abdomen and draw the energy from the navel back down towards the anus. Next, inhale and create a connection between the anus and the Mingmen. On the exhalation, draw the energy from the Mingmen back down towards the anus. It is important to synchronize the drawing up of the anus towards the navel and Mingmen area with the expansion and contraction of inhalation and exhalation. This will facilitate a

sacral-cranial rhythm throughout the body.

2. In the next stage of training, the constriction of the anus is used to lead the energy up the Governing Vessel in the Microcosmic Orbit (Figure 15.18). Upon inhalation, draw the mind's intention from the navel towards the anus and then down to the tip of the spine (the coccyx), allowing the Qi to flow up the spinal column towards the Mingmen, past the Shendao to the base of the skull. Upon exhalation, roll the eyes back into the head and use the intention to meet the energy at the base of the skull. Next, lead the energy over the Baihui at the top of the head and down the Conception Vessel and back down to the naval.
3. At the third stage, imagine twisting the energy of the anal sphincter, spiraling the Qi up the center of the body, to connect with the Baihui area at the top of the head. Close the anal muscle gently, inhale and imagine the energy vibrating and spiraling in a counterclockwise direction up the body's Taiji Pole. This connects the Lower, Middle, and Upper Dantians through the Taiji Pole. Upon exhalation, lead the vibrating Qi down the Taiji Pole in a clockwise spiral ending within the Lower Dantian area. Continue this meditation until the entire body pulses with the rhythm of the Taiji Pole.

The anus is divided into five regions: Front, Middle, Back, Left, and Right. By contracting the anus in different parts, you can bring more Qi to the various organs and glands.

1. The Front region opens the gate to the sexual organs, as well as to the Conception Vessel when it is contracted.
   - For Men, this will affect the prostate gland, Bladder, Small Intestine, thymus gland, thyroid gland, parathyroid gland, mouth, nose and front part of the brain (Figure 15.19).
   - For Women, this will affect the vagina, uterus, vena cava, aorta, Stomach, thymus gland, thyroid gland, parathyroid gland, mouth, nose, pituitary gland, and front part of the brain (Figure 15.20).
2. By contracting and pulling the middle region of the anus, more Qi is drawn into the Thrusting Vessel and Taiji Pole, as well as to the genitals, aorta, vena cava, Stomach, Heart, thyroid gland, parathyroid gland, tongue, pituitary gland, pineal gland, and Baihui area (Figure 15.21).
3. By contracting the back region of the anus the Qi is connected to the Governing Vessel, as well as the sacrum, lumbar, thoracic and cervical vertebrae, and the cerebellum (Figure 15.22).
4. By contracting the left side of the anus the Qi connects to the left side of the body.
   - For Men, this affects the left testicle, Large Intestine, left Kidney, left adrenal gland, Spleen, the left side of the Heart, left Lung, left ear, left eye, and left hemisphere of the brain (Figure 15.23).
   - For Women, this affects both ovaries, both Kidneys and both adrenal glands, Spleen, Liver, Heart, both Lungs, thyroid gland, parathyroid gland, and both hemispheres of the brain (Figure 15.24).
5. The Right Side. By contracting the right side of the anus the Qi connects to the right side of the body.
   - For Men, this affects the right testicle, Large Intestine, right Kidney, right adrenal gland, Liver, Gall Bladder, right side of the Heart, right Lung, right ear, right eye, and the right hemisphere of the brain (Figure 15.25).

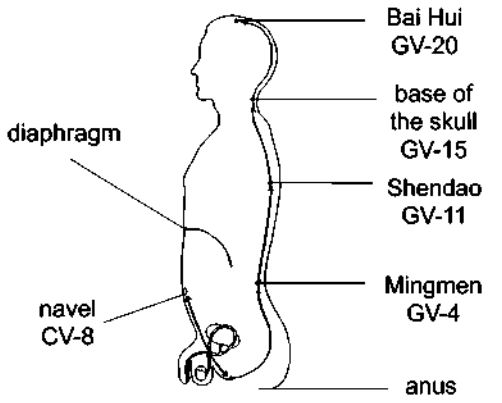

Figure 15.18. The anus is used to draw the Qi from the navel into the Lower Dantian and lead the Qi up the Governing Vessel.

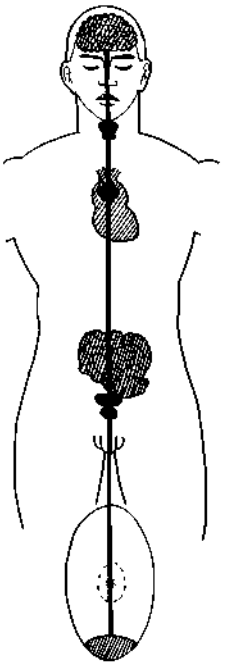

Figure 15.19. The Front of the Anus

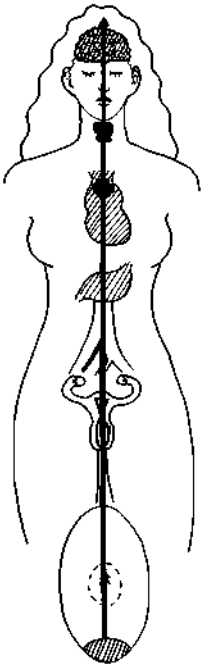

Figure 15.20. The Front of the Anus

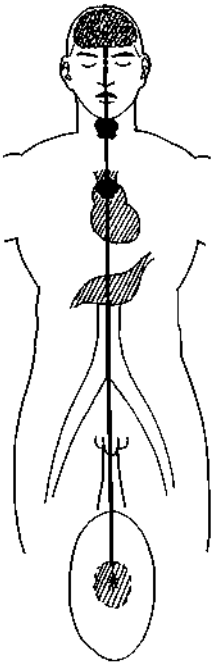

Figure 15.21. The Middle of the Anus

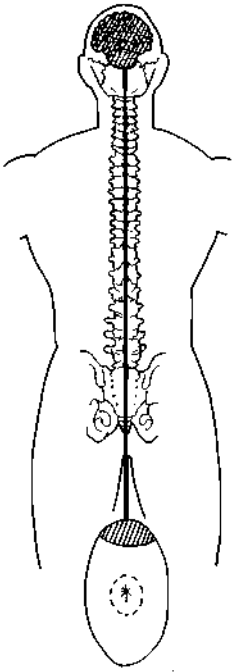

Figure 15.22. The Back of the Anus

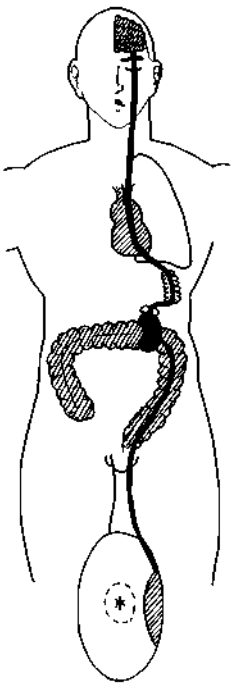

Figure 15.23. The Left Side of the Anus

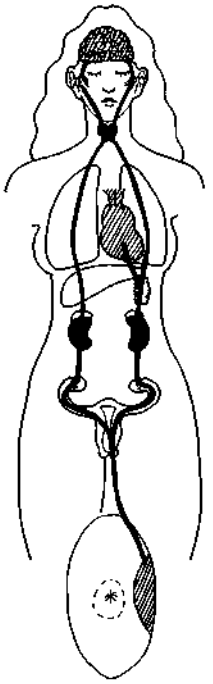

Figure 15.24. The Left Side of the Anus

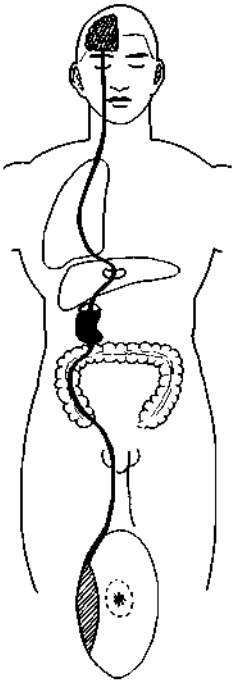

Figure 15.25. The Right Side of the Anus

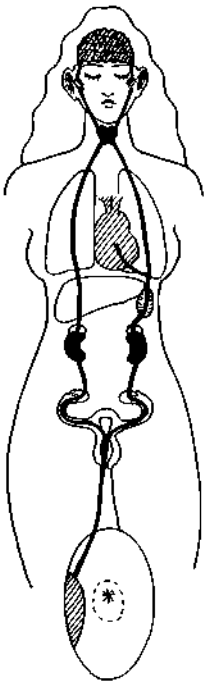

Figure 15.26. The Right Side of the Anus

- For Women, this affects both ovaries, both Kidneys and both adrenal glands, Spleen, Liver, Heart, both Lungs, thyroid gland, parathyroid gland, and both hemispheres of the brain (Figure 15.26).

RULE 6—PULL IN THE STOMACH

Pull the stomach in above the pubic bone, and avoid tensing of the abdominal muscles. This helps to restrain the Yuan Qi, thereby increasing the internal pressure and promoting the flow of internal Qi throughout the whole body.

RULE 7—RELAX THE WAIST

If the waist is not relaxed the Qi can not sink back to the Lower Dantian. Relax the waist by relaxing the hips and bending the knees. When the waist is relaxed, the spine will stand upright, yet remain relaxed.

The waist and the abdomen are two important areas in training and guiding Qi. The abdomen is considered to be the furnace for refining Qi. The waist is the residence of the Kidneys and Mingmen Fire and is an important junction for Qi and Blood circulation.

The waist is considered the master of the body and must be kept sunken and relaxed (Figure 15.27). As the buttocks tuck under and the waist sinks, small pockets should form on the inner thighs where the pelvic bones meet the femur bones of the legs. Most people usually keep the pelvis area tight and immobile, as it is associated with shock, fear, and sexual trauma (when this area becomes loosened, such emotions are often released).

The specific actions to relax the waist are as follows: lift both shoulders in order to stretch the back, then release them downward immediately as you exhale, relaxing the waist. To achieve genuine waist relaxation, you must also relax and tuck the sacrum, this action opens the sacrum. When the sacrum is opened, the Lower Dantian will expand and the storehouse of Yuan Qi will be enlarged. Be sure that the waist and hips face forward in the same direction as the knees and feet.

RULE 8—TUCK THE CHEST IN

The chest should relax inward so that air flows freely and the Qi sinks down into the Lower Dantian. Fill the abdomen with air while relaxing the chest inward. The back should be open and expanded. Relax the scapulae and allow them to sink to their lowest point, this will help the shoulders to sink. Rounding the scapulae (pushing to the sides and forward) will help open and expand the back.

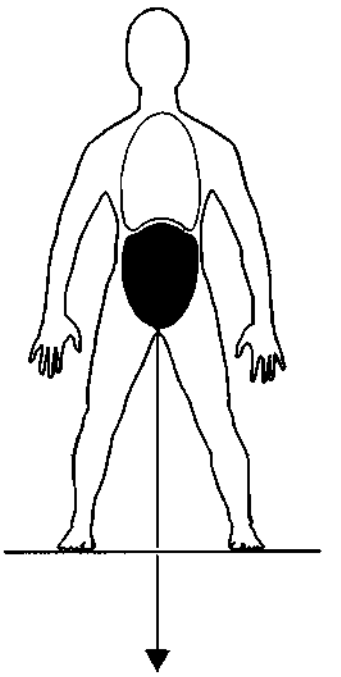

Figure 15.27. Relax and sink the waist, allowing the hips to drop.

Do not thrust the shoulders inward, nor intentionally close the thoracic cavity. The intentional tucking in of the vertebral area requires the outward opening of the ribs and expansion of the intercostal muscles. The action of opening the chest outward, then tucking the chest inward, helps to relax the thoracic cavity and avoids tension in the thoracic muscles.

RULE 9—STRETCH THE BACK

The key point to stretching the back is to hang the shoulders and "open the scapulae." When the two shoulders drop evenly, the lumbar vertebrae straighten out. The function of tucking the chest and stretching the back calms the Heart and Lungs.

The Heart controls mental and emotional activities, and also directs Blood circulation. When the thoracic cavity is spacious and the back is upright, the Heart and mind will be calm, and the Lungs will be clear and free from Heat. Tucking the chest and stretching the back allows the chest and back to relax, permitting the Conception and Governing Vessels to communicate with each other and improve energy movement.

Imagine a weight hanging from the coccyx and a rope pulling up on the crown point of the head. Feel the elongation of the spine with each inhalation and exhalation. Remain relaxed (Figure 15.28), do not hold yourself unnaturally erect and avoid contracting the abdomen to straighten the lower back. The abdomen must remain relaxed. When sinking the body's weight, try to feel the spine press into the heels of the feet.

RULE 10—RELAX THE SHOULDERS

If you relax the shoulder joints and let them hang naturally, the shoulders and neck will relax. If you elevate your shoulders when you are standing or sitting, the energy will not sink and you will begin to feel tired, the shoulders will be stressed, and the flow of Blood and Qi will become blocked.

When the shoulders are encouraged to relax and are allowed to drop and roll forward, this action facilitates the hollowing of the chest and the expanding and opening of the back, allowing the energy to flow into the arms (Figure 15.29). Try to feel your arms link up with the scapulae as the clavicles press downward. Your shoulders should remain very loose and free.

RULE 11—SINK THE ELBOWS

When practicing the Immortal Post posture (refer back to Figure 15.8), and the hands are positioned by the Heart, it is important to bend the elbows slightly at the elbow joint, holding them lower than the hands.

While in a Wuji posture, imagine that a weight is hanging from the elbows, or a sensation of compression will be felt at the shoulder and elbow joints. The elbows should be slightly bent and relaxed, remaining structurally correct and not weak. This will help to roll the shoulders forward

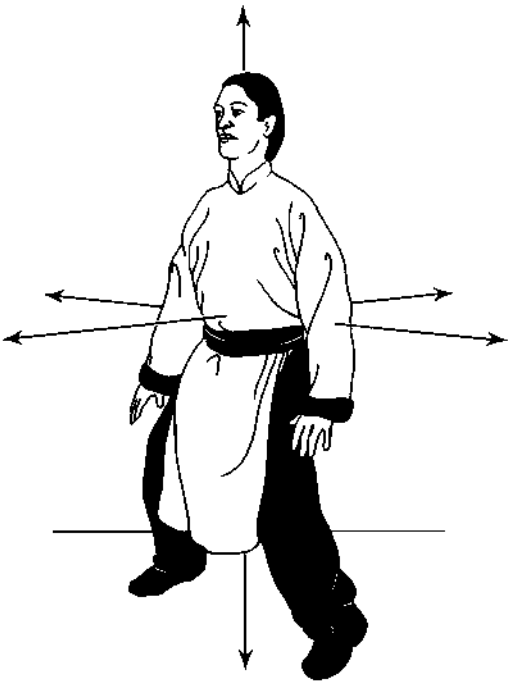

Figure 15.28. By imagining a rope pulling on the head and coccyx, the spine is allowed to naturally stretch, expanding the body's Qi in all directions.

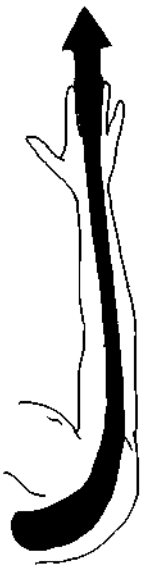

Figure 15.29. When the shoulder (here viewed from above) relaxes, the Qi flow into the arm increases.

and open up the back. If the elbows are not bent, there will be decreased energy flow (Figure 15.30).

RULE 12—HOLLOW THE ARMPITS

Hollow the armpits as if each one is holding an egg, this allows the Qi and Blood to flow freely in the upper limbs. To relax the shoulders, move the tips of the elbows outward to the left and right. Avoid sloping or squaring the shoulders.

When practicing the Immortal Post Posture (refer back to Figure 15.8), the arms must embrace inward as if holding a large ball or barrel. Do not push the elbows out so far that you loose the curve in your arm, this is of extreme importance. Your arms should not bend inward more than 45 degrees. The energy flowing in your arms is like water running through a hose. If you bend it too sharply, much of the supply will be cut off.

RULE 13—RELAX THE WRISTS

This includes hollowing the palm, and the comfortable curling of the fingers. Relaxation of the wrist allows the Shu-Stream points in the wrist to communicate with the fingers (see the Five Antique Shu Points in Chapter 8). Hollowing the palm and curling the fingers allows for the natural stretching and curving of the hand, which prevents the Qi from diffusing. It is important to avoid being rigid and purposefully bending the fingers, as all hand postures effects the brain and the body's Qi flow.

Relaxing the wrists helps to regulate the three Yang and three Yin channels of the hands so that Qi and Blood can flow freely. The wrist must form a line with the shoulders. Do not bend the wrists, but hold them straight so that the middle finger forms a line with the forearm, allowing the hands and fingers to hang relaxed but not limp.

RULE 14—SUSPEND THE HEAD

The classics say that "the head is held aloft not by force, but as if it were placed there by a ruling power." Hold the head as if it were suspended, keeping the Baihui point pointed to Heaven (Figure 15.31). This produces space in the body by elongating the spine. When suspended, the head must be kept upright, positioned in the middle of the chest and shoulders. This helps to set the whole body in the upright position, and

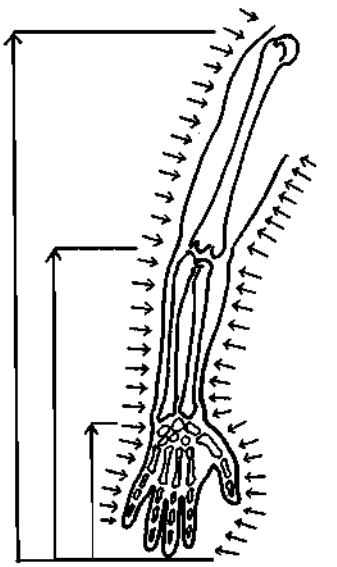

Figure 15.30. Allow the bones in the arms to feel heavy, naturally stretching the tissues and increasing Qi flow to the extremities.

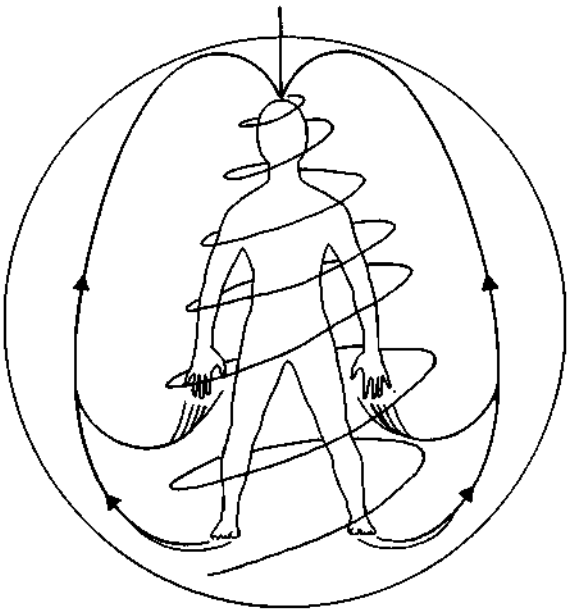

Figure 15.31. Suspending the head allows the body to become sensitive to the surrounding environment and external fields of Qi.

also directs the Qi and Blood to flow upward to nourish the brain and the mind. The Shen will be reinforced while the Jing and the Qi will be invigorated (it is the Shen which controls all the physical activities). An effective visualization is to imagine your head lifting high into space, your waist positioned in the clouds, and your feet sunk deep into the Earth.

RULE 15—TUCK THE CHIN

The head cannot be properly suspended if the chin is not tucked in. Only then can the Baihui point on the top of the head be correctly positioned and the nasal respiration kept free.

Tuck the chin and slightly lean forward to stretch and straighten the spine. You should feel the stretch all the way down into the coccyx. Next, slowly shift the weight backwards, stacking each vertebra on top of the next, starting from the bottom of the coccyx and sacrum and moving upwards.

RULE 16—CLOSE THE EYES FOR INNER VISION

The Chinese have a saying: "close the curtain." This refers to dropping the eyelids to facilitate inner-vision, and focusing on any specific areas where Qi is being trained or circulated. The eyes are of great importance in Medical Qigong exercises. It is said that the functional activities of Qi are determined by the eyes, and that the eyes are the messengers of the mind, and the mind is the residence of the Shen.

Completely closed eyes induce an absolute Yin state which is generally used in meditations for tonifying any Deficiencies. However, when used excessively (with all Yin and no Yang energy), the Qi can become too inactive.

Completely open eyes induce an absolute Yang state which is generally used in meditations for dispersing any Excesses. However, if overused, or if the patient has an Excess Yang condition, this type of meditation can make the practitioner too restless.

When the goal is to regulate the body's energy, slightly open the eyes in order to leave a small thread of light inside the eyes. This will keep the Yang (light) within the Yin (dark), so that the Qi will be more balanced. Because energy leaves the body through the eyes, after performing various Medical Qigong exercises, or prescriptions, allow your eyes to close halfway to continue the cultivation of life-force energy.

Tightly shutting the eyes causes tension in the upper and lower eyelids. Closing the eyelids gently, however, will restrain the vision, which helps to calm the Shen and the mind.

When meditating, if the eyes look to the distant horizon, they should not be focused but stare into infinity, this technique is also called the One Thousand Yard Stare, and it helps in regulating the venous pressure in the cranial cavity.

Strive for balance. Each eye has its own specific responsibility and energetic function.

- The right eye is generally used to project intention and extend emotion, energy, and spirit out from the body. The right eye relates to Water, the Kidneys, Qi, moon, Yin, Earth, Metal, and the Po.
- The left eye is generally used to receive, drawing in images, emotion, energy, and spirit into the body. The left eye relates to Fire, the Heart, Shen, sun, Yang, Heaven, Wood, and the Hun.
- If both eyes look upwards towards the Upper Dantian, the body's energy will draw up into the infinite space of the Wuji and merge with the divine.
- If both eyes look towards the tip of the nose, the Middle and Lower Dantians are linked together for transforming Yuan Qi.
- Crossing the eyes results in the union of the Wood and Metal, the elements of alchemic transition, for increasing the development of psychic energy. This intensification of psychic development is due to the union of the Hun and Po within the body, and is said to connect the meditator with his or her Yuan Shen.
- After meditation, store the Qi of the eyes behind the posterior orbital surface of the eyeballs themselves. This prevents the eyes from overheating and drying out.

RULE 17—CLOSE THE MOUTH AND TURN YOUR HEARING INWARD

In order to enhance the Yang during Medical Qigong exercises, close the lips with the teeth gen-

tly touching. Closing the lips will prevent the internal Qi from flowing out.

The Chinese use the expression: "Stopping the ears," which means to focus the hearing inward so as to be free from outside interference.

RULE 18—TOUCH THE TONGUE TO THE UPPER PALATE

When the tongue touches the upper palate, it forms what is called the Bird's Bridge. The connection of the tongue links both the Governing Vessel (which ends at the nose and upper palate) and the Conception Vessel (which ends in the mouth). As the tongue touches the upper palate, the body's field of Wei Qi expands. This can help to eliminate diseases and prolong life. The belief is that when someone has a disease, the Governing and Conception Vessels are to some extent disconnected.

Some Qigong doctors test their patients' progress by having them meditate with their tongue suspended in their mouth. Upon command, they connect the tongue to the upper palate. The suddenly increased expansion and strength of the patients' Wei Qi, observed by the doctor, indicates the degree of their progress.

1. The technique called "Gathering the Saliva," begins when the tongue touches the upper palate, causing the saliva secretion to be increased. Saliva contains many enzymes, which not only aid digestion, but also benefit the patient's physiology. In ancient China, this practice was called Gathering the Immortal's Water or the Juice of Jade to create the Immortal Pill.

   There is an exchange of Yin and Yang energy within the saliva, as Heaven Qi and Earth Qi are gathered within man's Fluid Essence in order to create the Immortal Pill.

   Before swallowing the saliva, it is important to tilt the head slightly forward (after inhaling). Swallow the saliva three times with three big gulps, using the breath as a cork to enclose the saliva. Send the Immortal Pill, i.e., the combined saliva and air down the Conception Vessel, bathing the Five Yin Organs, and ending at the Lower Dantian. Next, draw the energy up the Governing Vessel into the brain to replenish and nurture the Upper Dantian.
2. There are Five Elemental Tongue Positions. Each tongue position is related to one of the Five Yin Organs and can be used to direct the Qi to that specific organ. Sometimes, while practiscing Medical Qigong prescriptions, if too much Heat is created, the patient will be instructed to "change the tongue position" as well as meditation. These Elemental tongue positions are described as follows.
   a. The Earth (Spleen) position requires that the tongue be placed on the bottom of the jaw at the base of the lower palate, beneath the teeth and gum line (Figure 15.32).
   b. The Metal (Lungs) position requires that the tongue be placed between the maxilla and mandible bones, suspended, behind the teeth (Figure 15.33).
   c. The Fire (Heart) position requires that the tongue be placed on the hard palate, at the front of the upper palate, behind the teeth and gum line (Figure 15.34).
   4. The Wood (Liver) position requires that the tongue be placed on the hard palate, at the middle of the upper palate at the center of the roof of the mouth (Figure 15.35).
   e. The Water (Kidneys) position requires that the tongue be placed on the soft palate, at the back of the upper palate (Figure 15.36).

DYNAMIC POSTURE DAO YIN TRAINING

While Static Qigong exercises accumulate and strengthen the Qi internally, Dynamic Qigong exercises train the channels, collaterals, muscles, and bones externally. The more dynamic movement a patient makes, the more the energy will be converted and transformed inside the body. When dynamic movement is discontinued, some of the accumulated energy will begin to dissipate, while the remainder will flow through the channels and increase the patient's Qi circulation.

Figure 15.32. For the Earth position, which is related to the Spleen, the tongue is placed on the bottom of the jaw at the base of the lower palate, beneath the teeth and gum line.

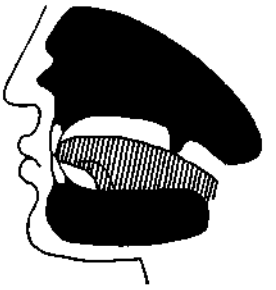

Figure 15.33. For the Metal position, which is related to the Lungs, the tongue is placed between the maxilla and mandible bones, suspended, behind the teeth.

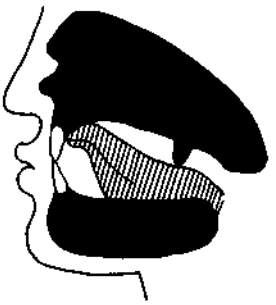

Figure 15.34. For the Fire position, which is related to the Heart, the tongue is placed on the front of the upper palate, behind the teeth and gum line.

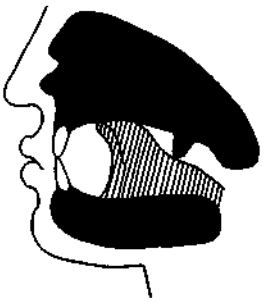

Figure 15.35. For the Wood position, which is related to the Liver, the tongue is placed on the middle of the upper palate at the center of the roof of the mouth.

The lymphatic system is pumped by normal muscular contraction. When a patient performs Dynamic Postural Movements, the lymphatic system is flushed, thus freeing the body of toxins.

Dynamic Qigong is divided into two methods of training: The Yun (Yin) Method and the Dong (Yang) Method.

1. The Yun Method is a more Yin approach, and employs slow, even, graceful movements. The focus of the mind's intention is placed on the internal organs, resulting in emotional relaxation.
2. The Dong Method is a Yang approach, and employs intense physical movements. Focus is placed on the movement of the body's ex-

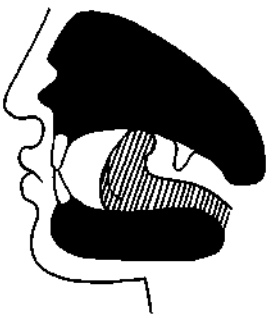

Figure 15.36. For the Water position, which is related to the Kidneys, the tongue is placed on the soft palate at the back of the upper palate.

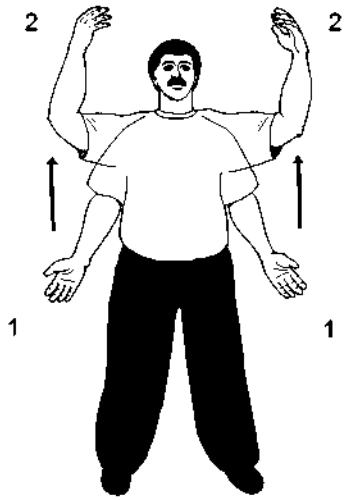

Figure 15.37. Hands Rise, Leading to the Ascending of the Qi.

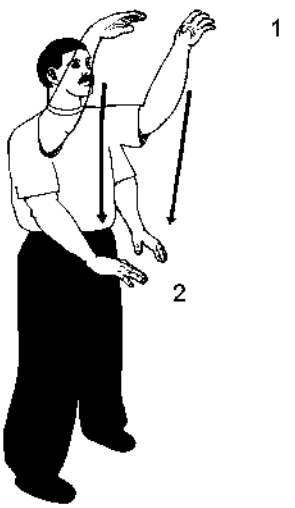

Figure 15.38. Hands Fall, Leading to the Descending of the Qi.

tremities, resulting in tissue regulation.

Both Yin and Yang (Yun and Dong) training methods must be balanced when prescribing proper Medical Qigong exercises. With the Yin method, the patient will experience external quietness with internal energetic movement. With the Yang method the patient will develop internal quietness with external, physically active movement.

USING THE ENERGY OF THE HANDS TO LEAD QI

Dynamic Postural training is performed by the extensive movements of the hands and torso. Because the palms have a stronger electromagnetic field than any other part of the body, the hands are used for leading and guiding the Qi. These movements are in harmony with the rotating, bending and stretching movements of the head, neck, torso, and limbs. Any change of the body's position or movement can change the direction or position of the electromagnetic fields of the hand. Likewise, any change or movement of the hands or palm positions, also changes the direction and flow of the electromagnetic field of the body. In Medical Qigong therapy the Dao Yin Hand Techniques have the following four functions:

- Hands Rise—Qi Ascends (Figure 15.37)
- Hands Fall—Qi Descends (Figure 15.38)
- Hands Open—Qi is Spread (Figure 15.39)
- Hands Close—Qi is Restrained (Figure 15.40)

The positions of these hand techniques can be further divided into three ranges: upper, middle, and lower. These ranges can relate to either the position of the body's Triple Burners, or the body's three Dantian areas, depending on the specific Medical Qigong prescription, and the doctor's intention for the exercise. The directions of these hand movements can further divide a posture into four front and four oblique types of Qi regulations. Moreover, depending on the arm movements, each posture can be divided into Yin (palms facing down) or Yang (palms facing up), as well as half Yin or half Yang regulations (Figure 15.41).

The actions of these methods supplement, regulate, smooth, and reinforce the vital Qi. Using these techniques will improve Blood and Qi circulation, as well as sharpen the sensory nerves. Since all hand postures relate to the brain and the function and flow of the body's energy, they also have a psychological and physiological affect on the nervous system.

When training, posture and Qi movement are

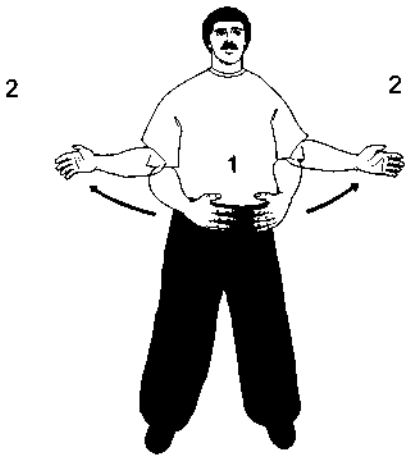

Figure 15.39. Hands Open, Leading to the Spreading of the Qi

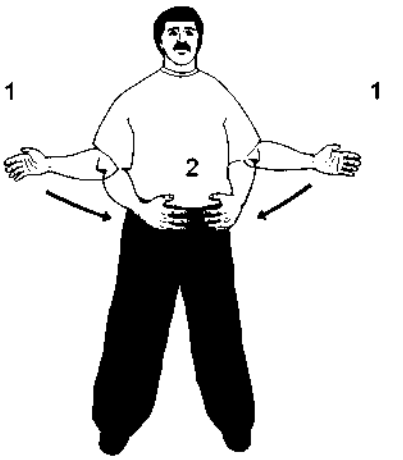

Figure 15.40. Hands Close, Leading to the Restraining of the Qi

sometimes in unity, and at other times proceed in opposite directions. Raising the arms, for example, causes the energy to rise; if the torso also rises, the rising power of the energy increases. This is an example of synergistic promotion of Qi regulation.

The following are three examples of the use of each separate hand action, and demonstrate how the body's reaction to energy can be used to treat patients with Medical Qigong therapy.

1. If you have hyperactive ascending Qi (e.g., hypertension) place your hands, palms facing downward, at the side of your body. Inhale quickly and move your hands quickly upward. Allow the middle fingers on each hand to touch each other, connecting the Pericardium Channels. Exhale, while slowly moving the hands downward along the front and side of the body. Purge and guide the Toxic Qi to descend the Liver and Gall Bladder Channels down the

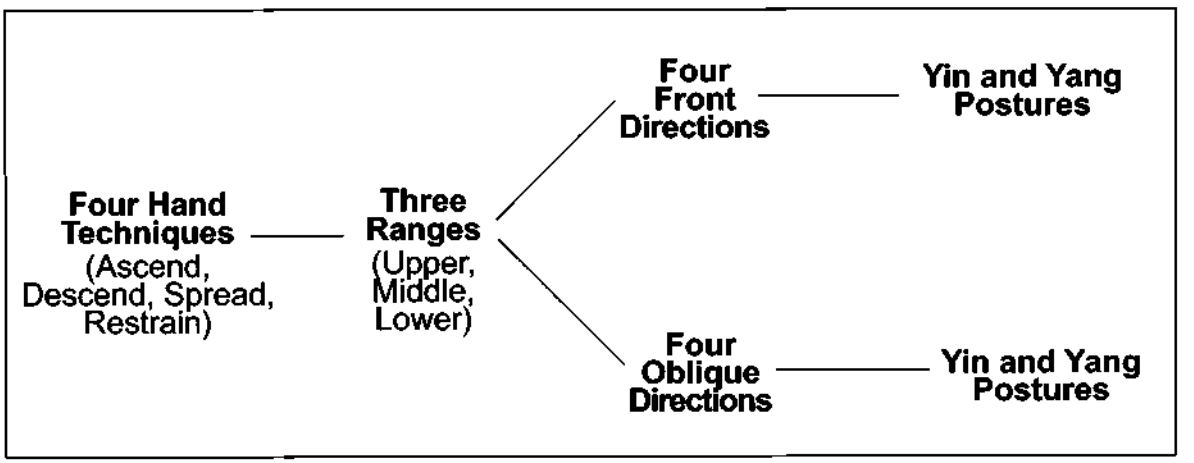

Figure 15.41 Hand Position Techniques

torso to the hips (GB-30), and then to the outside of the legs (Figure 15.42).

2. If you have a Yin and Yang imbalance (e.g., chronic illness) place your palms facing your Lower Dantian and slowly raise them upwards to the chest. At the level of the Heart, turn the palms away from the body as you move your arms outward. Once the hands are extended away from the body begin moving them downward. Regulate the speed of motion of the hands and breath in order to guide and induce the Clear Yang to ascend (as you raise your arms), allowing the Turbid Yin Qi to descend (as you lower your arms). This balances the body's Yin and Yang Qi (Figure 15.43).
3. If you have a Deficiency of ascending Qi (e.g., hypotension or prolapse of the viscera) begin with the palms facing upward, in front of your Lower Dantian. Slowly inhale while gradually raising the palms close to your body. When exhaling, move the hands downward quickly away from the body to avoid any excessive downward flow that would counteract the tonifying upward flow (Figure 15.44).

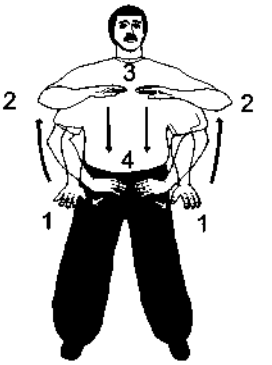

Figure 15.42. With palms facing downward (1), move the hands quickly upward (2). As the hands move slowly downward (3), allow the middle fingers on each hand to touch (4).

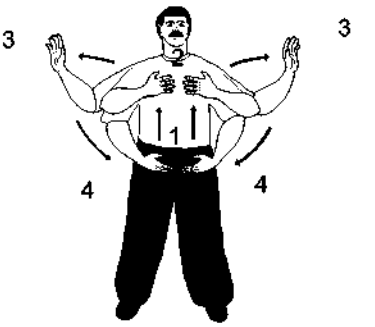

Figure 15.43. With palms facing the body (1), move the hands upward (2). Face the palms away from the body (3) as the hands move downward (4).

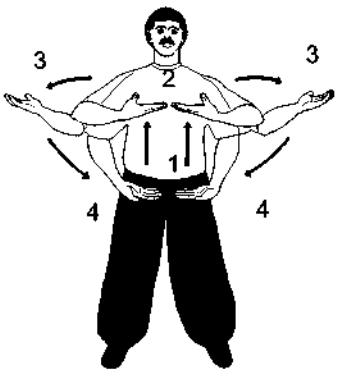

Figure 15.44. With the palms facing upward (1), raise the hands slowly close to the body (2). When moving the hands downward (3) in order to start again, quickly move them away from the body (4).

MEDICAL QIGONG WALKING THERAPY

Dynamic postural training can be performed by keeping the feet stationary and rocking the weight between the heels to the balls of the feet, or by walking. The Chinese saying, "The body must walk like the wind," describes the relaxed placement of the feet and supple stepping techniques used in Medical Qigong Walking therapy. Walking, or Toe-Raised Stepping, as it is commonly called in China, is excellent in treating the diseases of the Five Yin Organs. It can stimulate the Qi of the Spleen and Liver (due to their channels originating on the big toes), and can cause the body's internal Qi to rise and flow vigorously, thus reinforcing the function of Qi and Blood.

With each step of the Walking Meditation, the patient should practice tranquil mind and body balancing. This is the same imaginative technique as is used in standing, sitting, or lying meditations. The inner stillness and outer motion are in harmony. Touching the heel to the ground, with the

toes raised can also activate the Yin and Yang Heel Vessels (which originate from the center of the heel), and allow the energy to flow between both vessels so that the internal energy, exiting from the Yin Vessel, can enter the Yang Vessel, and vice versa. This allows the vessels to be dredged and the Yin and Yang energies to be regulated.

The heel is also stimulated when stepping, thus increasing the flowing action of the Bladder and Kidney Qi (due to their channel placement on the ankle). While stepping, focus the intention on the Lower Dantian to guide downward any abnormal rising of Lung Qi, which can cause shortness of breath, and affect the Heart and blood pressure. Each step is placed deliberately, with intention, and without collapsing of the feet. This stepping action relieves any Excess Qi syndrome of the upper torso and coordinates the balance of both the upper and lower portions of the body's Qi. Medical Qigong walking therapy consists of three training methods.

1. The Preparation (before walking), consists of the following steps:
   - The Opening and Closing of the Three Dantians, and
   - The Stationary Qi Strengthening and Regulating Exercises.
2. The Walking Therapy, consists of one or several prescriptions of the Toe Raised-Stepping techniques.
3. The Ending (after walking), consists of the following steps:
   - Leading the Qi back into the Lower Dantian,
   - Kneading the abdomen, and
   - Closing the Dantians and self-massage.

THE FUNCTIONS AND BENEFITS OF THE PREPARATION STAGE (THE OPENING AND CLOSING OF THE THREE DANTIANS)

Before beginning Medical Qigong Walking Therapy, the Opening and Closing of the Three Dantians must be practiced. In Medical Qigong training there is a saying, "When the body is Open, the Evil Qi will be expelled. When the body's surface is free from Evil Qi, it is better to Close it." The terms "opening" and "closing" refer to the purification of the body by means of Opening (purging) and Closing (sealing) specific areas of the body. The Opening and Closing of the Three Dantians can regulate either an Excess or Deficiency syndrome that is caused by an imbalance between the upper and lower, or interior and exterior parts of the patient's body. The purpose of the preparation stage is to:

- Eliminate the body's Evil Qi,
- Descend the Turbid Yin Qi, and
- Circulate the Clean Yang Qi through the organs and channels before walking.

The focus of this particular technique opens and closes the Upper Dantian (at the Yintang point), the Middle Dantian (at the Shanzhong CV-17 point), and the Lower Dantian (at the Qihai CV-6 point).

The Opening and Closing technique utilizes four specific disciplines:

- Using the Mind's Intention,
- Dividing the Yin and Yang Energy (ascending the Clear Yang Qi and descending the Turbid Yin Qi),
- The Hand Postures for Opening and Closing the Dantian, and
- The Focus on the Breath.

The Opening and Closing of the Three Dantians also requires multiple soft focusing that becomes easier with each practice session. Arm movements and the breath need to be perfectly coordinated; the expelling of Toxic Qi from the internal organs needs to be visualized; and the abdomen needs to be contracted while inhaling, and expanded while exhaling. The mind's intention must assist in the Opening and Closing of each Dantian, the coordinated movements alone do not suffice.

1. When focusing the mind's intention while performing the Opening and Closing techniques, imagine a dark Turbid energy from deep inside the body exiting through the body's pores. As the energy leaves, seal off the tissues to prevent it from returning to the body. Imagine the dark Turbid energy being absorbed into the ground, and being purified by the Earth.
2. The Dividing the Yin and Yang Energy refers

to separating the Yin and Yang energy within the body for healing. The Yin Qi stores the substance of vital energy, and the Yang Qi guards against pathogenic Evils and protects the body.

a. Ascending the Clear Yang Qi. When the Upper Dantian is Opened and Closed it allows the Clear Yang Qi to ascend to the upper orifices. The increased circulation of Clear Yang Qi through the channels and organs of the body stimulates and energizes the body's surface, as well as strengthens the four extremities. When the Clear Yang Qi moves upward its pure nature helps to tranquilize the Shen.

b. Descending the Turbid Yin Qi. When the Middle and Lower Dantians are Opened and Closed, it allows the Turbid Yin Qi to descend and facilitates the storing of the Clear Yang Qi.

3. The hand postures for Opening and Closing the Dantian is described as follows. The action for the Opening of Qi is directed by the outward movement of the hands and arms, and the mind's intent on Opening (or expanding) the abdomen.

   The Closing of Qi is directed by the inward movement of the hands and arms towards the abdomen, and the mind's intent on Closing (or contracting) the abdomen.

   The function of the Dao Yin Posture training, while regulating the breath and reinforcing the body's Qi, relies primarily on the movement of the hands and arms to arouse and invigorate the Qi circulating in the Large Intestine and the Lungs' channels. The action of opening and closing the Upper, Middle and Lower Dantians causes the Turbid Yin Qi to descend and be expelled, while the Clear Yang Qi ascends to the upper orifices of the body.

4. The focus is placed on the breath. The Opening and Closing exercise uses Reversed Breathing, i.e., the abdominal muscles contract while inhaling and relax and expand during exhalation (Figures 15.45 and 15.46).

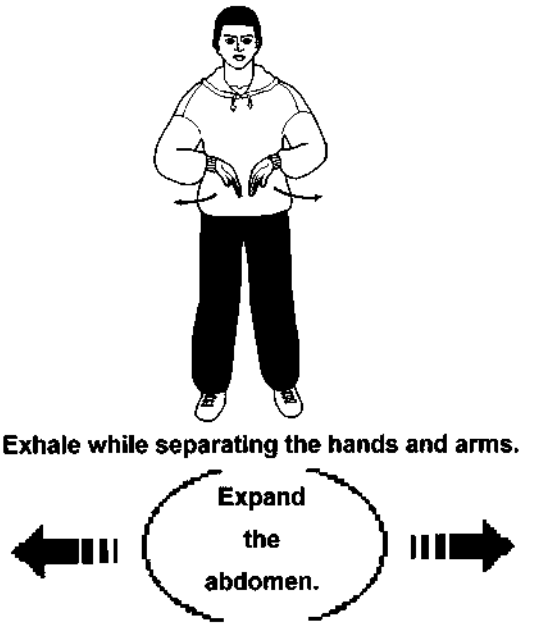

Figure 15.45. The Opening of Qi is directed by the outward movement of the hands and arms and an opening (or expanding) intention in the abdomen.

This method of breathing is also referred to as Daoist breathing. The action of abdominal compression acts as a bellow to purge any Toxic (Yin) Qi from the body. These contractions and expansions of the abdomen are combined with the mental focus on the Lower Dantian. The nerve plexuses in the Lower Dantian area are considered, in modern Medical Qigong theory, to connect the Tai Yang Channels (Major Yang channels). If the mind is concentrated on the Lower Dantian for a long period of time, a conditioned reflex will occur that causes the nerve plexuses to produce bioelectricity, which spreads into the surrounding areas of the Tai Yang channels. This reflex causes the small blood vessels and capillaries to dilate. This reaction reduces the pressure in the blood vessels and improves Blood circulation to the Heart.

- Contraindications:

  It is important to note that Reversed Breath-

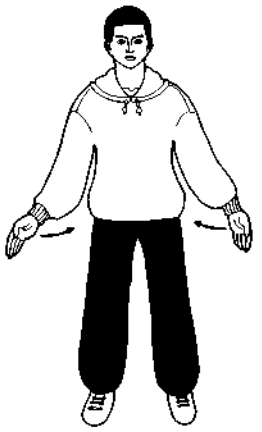

Inhale while bringing hands and arms together.

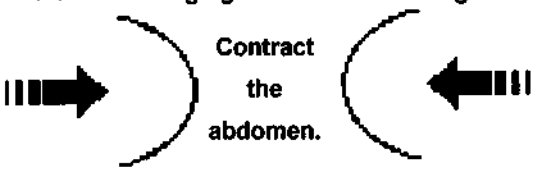

Figure 15.46. The Closing of Qi is directed by the inward movement of the hands and arms toward the abdomen for a closing (or contraction).

ing is contraindicated for young children, older patients and for people suffering from high blood pressure, stroke, or Heart diseases. In these cases, the Reversed Breathing techniques should be replaced with Natural Breathing. When practicing with Natural Breathing, the patients imagine Heavenly Qi descending into their body, filling and expanding the Lower Dantian, as they inhale. This expansion of the abdomen (upon inhalation) allows their Lower Dantian to Open, causing the Heavenly Qi to naturally purge the body of Toxic Qi. Upon exhalation, the patients contract their lower abdominal muscles to Close and seal their Lower Dantian.

THE OPEN AND CLOSE THE THREE DANTIANS METHOD

Normally an exercise begins with an equal number of inhalations and exhalations receptively, as the arms move toward the body, and away from the body. In this particular exercise, however, when approaching each separate Dantian, the first Open and Close action is to be performed by inhaling through the entire movement, without any exhalation. This action stimulates the opening of the Dantians. For the second through fourth Open and Close movements, the patients exhale when Opening and inhale when Closing. Practice the Opening and Closing of the exercise, step by step.

- Begin from Wuji posture. Raise your arms and hands to face the Upper Dantian. As you inhale, sperate your arms outward away from the body as you contract the abdominal muscles, then while still inhaling, bring the arms back to the Dantian. Exhale as you separate the arms away from the Dantian, allowing the abdomen to expand, inhale and contract the abdomen as you bring the hands back together. Repeat this action two more times.
- Place your arms and hands in front of your Middle Dantian. As you inhale, separate your arms outward away from the body as you contract the abdominal muscles, then while still inhaling, bring the arms back to the Dantian. Exhale as you separate the arms away from the Dantian, allowing the abdomen to expand; inhale and contract the abdomen as you bring the hands back together. Repeat this action two more times.
- Place your arms and hands in front of your Lower Dantian. As you inhale, sperate your arms outward away from the body as you contract the abdominal muscles, then while still inhaling, bring the arms back to the Dantian. Exhale as you separate the arms away from the Dantian, allowing the abdomen to expand; inhale and contract the abdomen as you bring the hands back together. Repeat this action two more times.

STATIONARY REGULATING EXERCISES (PREPARATION FOR WALKING)

This next preparation exercise is good for the patient's general tonification and for increasing respiration for Lung cancer patients.

- Start from a Wuji posture, inhale and exhale through the nose. Place your palms facing your lower abdominal area and begin extend-

ing Qi into the naval. Imagine the energy flowing into your navel, extending deep into your Mingmen and Lower Dantian area (Figure 15.47).

- Next, face your palms toward the ground and absorb the Earth Qi into your Lower Dantian (Figure 15.48). Absorb the Earth's energy for a few minutes.
- Turn your palms upwards, towards the Heavens, and begin absorbing the Universal Qi for several minutes (Figure 15.49). Finally, begin to close the exercise by allowing your palms to turn back towards your navel, absorbing and rooting the Qi back into the Lower Dantian

Figure 15.47. Begin by placing the palms toward the navel, in order to stimulate the Lower Dantian Qi.

WALKING COMBINED WITH COLOR THERAPY

In China, to help visualize specific colors for therapeutic use, patients will carry brightly colored silk ribbons while walking. The colors and their affect on the internal organs are matched in accordance with the Five Elemental colors.

WALKING COMBINED WITH SOUND THERAPY

In China, in order to help the patients step with a structured rhythm, coordinate breathing patterns, and improve mental intention, Medical Qigong practitioners beat large wooden drums, click wooden sticks, and clang large metal cymbals. These rhythmic wooden and metal sounds resonate the walking area with an energetic field vibrating with Yin and Yang Qi. The patients, while walking in a circle, naturally absorb the Yin and Yang energy resonating from the instruments and seek to naturally regulate their internal organs.

THE THERAPEUTIC EFFECTS OF MEDICAL QIGONG WALKING THERAPY

The purpose of "raising your toes when stepping" is to invigorate the Yin and Yang channels and vessels of the legs. The energetic nature of the Spleen necessitates walking slowly during this exercise. The Spleen is the source of Postnatal Energy and is responsible for the activity of the muscles and extremities. The movements of the four limbs therefore strengthen the Spleen; this is why "toe-raised walking" and the "hand swaying" methods have both been adopted into the exercises and postures of most Medical Qigong therapies.

Waist rotation plays a leading role in regulating the Liver Channels, as well as invigorating the circulation of Kidney Qi. This is achieved through all activities that initiate the actions of dropping, bending, relaxing, and turning the waist.

The opening and closing actions, combined with the rising and falling movements, and the swaying action of all four limbs, promote a pumping action within the muscles. This action is further intensified with the bending and leaning of the upper body, squatting and crouching of the lower body, and the alternate weight shifting when stepping. This pumping action greatly benefits the circulation of the lymphatic system.

Clinically, the Medical Qigong walking exercises result in increased appetite, strengthening

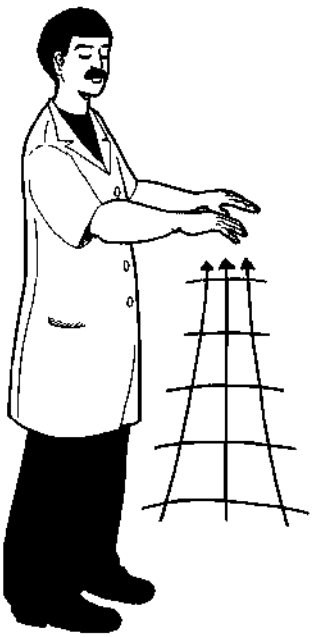

Figure 15.48. Next, begin to absorb the Earth energy into the Lower Dantian and Mingmen areas.

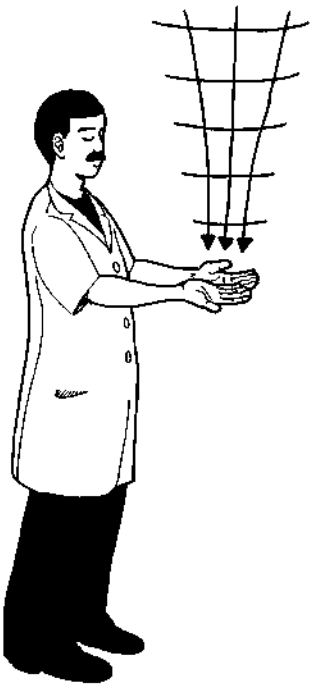

Figure 15.49. Turn the palms up to absorb Heaven Qi into the Lower Dantian Area.

of the patient's body, tonification of the Kidneys, Lungs, Liver, and Spleen, and the strengthening of Heart function.

Cancer patients need to regulate the function of their tissues and Yin and Yang organs to increase their healing potential. The initial goal in treating cancer with Medical Qigong, is to have the patient focus on the condition of the tumor, and its collection of energy. The patient imagines that the tumor area is beginning to soften, and the tissues are gradually transforming back into insubstantial energy. This technique is used to gradually dissolve tumors and certain types of less aggressive cancer.

The following are examples of Toe-Raised Slow Walking therapeutic exercises and prescriptions used in Medical Qigong therapy:

- Dynamic Regulation Walking Therapy
- Lung Tonification Walking Therapy
- Kidney Tonification Walking Therapy
- Liver and Spleen Tonification Walking Therapy
- Heart Tonification Walking Therapy
- Cancer-treatment Prescriptions

The explanation of these walking and breathing exercises and prescriptions are described as follows:

1. Dynamic Regulation Walking Therapy is a good exercise for regulating the Yin and Yang Qi of the patient's entire body. It can be prescribed for general tonification and nourishing of the patient's body, as well as strengthening the "anti-pathogenic" or True Qi. The Dynamic Regulation Walking Therapy is the primary walking exercise used to treat cancer patients.

   In every exercise the patient starts and ends with the Opening and Closing the Lower Dantian method. When stepping, the toes should be raised with the heels touching the ground (rocking back and forth), stimulating the Yin and Yang Heel Vessels of the legs, to strengthen the Kidney and Bladder Channels. As you step forward with the heel of the right foot, the Kidney and Bladder Channels open

up. Swing your left hand up to the center of your Heart (CV-17 point) while your right hand swings to your right hip around and near the GB-30 point (Figure 15.50).

It is important to utilize the mind's concentration in conjunction with the breath. The breathing pattern is as follows:

- First step—inhale through the nose
- Second step—inhale through the nose
- Third step—exhale through the mouth
- Fourth step—hold the breath

The same details of stepping and hand movements apply to stepping forward with the left foot.

2. Lung Tonification Walking Therapy is a good exercise for tonifying the Qi of the patient's entire body. It can be prescribed for nourishing the patient's skin, as well as strengthening the True Qi. It is used for treating Lung Qi Deficiencies, bronchitis, tuberculosis, asthma, emphysema, and sinusitis.

   The heel stepping pattern is similar to the Dynamic Regulation Walking exercise, however, when stepping, the hand postures will now switch from a normal relaxed position to the thumbs and first fingers touching at the tips (Figure 15.51).

   Some Medical Qigong hospitals encourage the patients to rub their thumb and index fingers together when practising the Lung Tonification Walking Therapy. This rubbing action causes friction to develop between the Shaoshang Lu-11 and the Shangyang LI-1 points, which in turn stimulates and invigorate the flow of Qi along the Lung and Large Intestine Channels, strengthening the Lungs.

   The breathing pattern is as follows:

   - First step—inhale, inhale
   - Second step—inhale, inhale
   - Third step—exhale
   - Fourth step—no breath

3. Kidney Tonification Walking Therapy. This exercise will purge the Liver Fire and tonify the Kidney Yin. It can be prescribed for patients who suffer from Kidney Qi Deficiencies, edema, blood diseases, gynecological diseases, and cancer of the Kidneys.

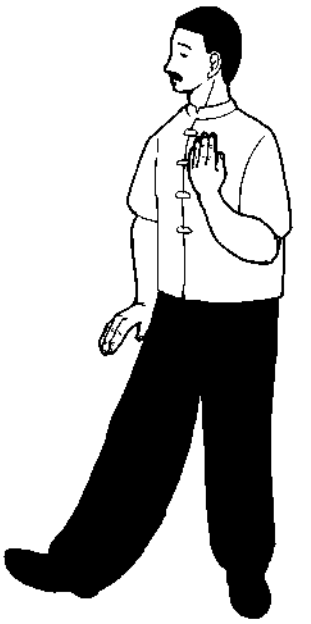

Figure 15.50. With each step, the opposite hand swings up to the Heart and Middle Dantian area.

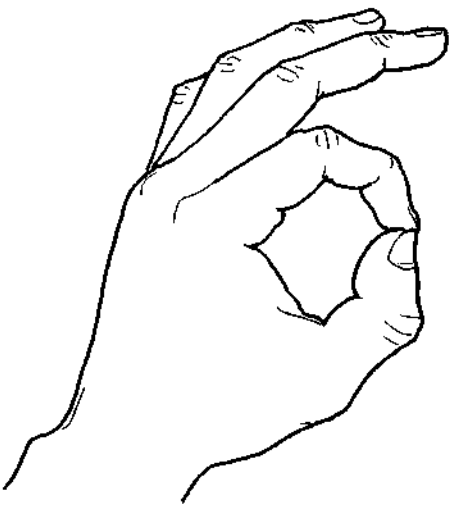

Figure 15.51. Tonification Hand Position for the Lungs

Begin this exercise with the palms embracing an imaginary ball at the naval and Lower Dantian area. This walking therapy causes the Qi to tonify your Lower Dantian.

Step forward so that the toes of the right foot touch the ground first, followed by the heel. This stepping action will open up the Yang Channels on the outside of your foot. Next, step with the left heel and point the toes up. This stepping pattern should be toe, heel, then step with heel (Figure 15.52).

On the first step, inhale through the nose while imagining the Qi filling your thorax. On the second step, sound the tone "Xu" (pronounced Shu) as you exhale. This particular sound is used to purge Toxic Liver Qi out the patient's body, allowing the Kidneys to fill with the rising Earth Qi.

- First step—inhale
- Second step—exhale "Shu"

The breathing pattern is as follows: inhale for the toe and heel, step and exhale on the heel step (all three actions equal one set). After walking in a circle for nine complete rotations, pause and begin again, starting with the left foot as the downward foot that makes the toe heel step as you exhale.

While stepping, keep both palms on your Lower Dantian. Regulate your breathing, while drawing the Earth Qi upward from the Yongquan Kd-1 point at the bottom of each foot. Press the Mingmen area backwards while breathing in the Earth Qi; this reinforces the Kidneys' Yuan Qi.

When ending the Kidney exercise, place both hands at the center of your chest at the CV-17 point. For men the right hand is on the outside, the left hand is on the inside, touching the chest. The hand position is opposite for woman. Make the sound "Shu" three times. End with the Opening and Closing of the Lower Dantian.

4. Liver and Spleen Tonification Walking Therapy activates the Liver's function of storing Blood and the Spleen's function of transforming Blood. It is used to treat digestive and blood diseases, hepatitis, Liver cancer, sclerosis of the Liver, and Gall Bladder stones.

Figure 15.52. The Kidney Strengthening Step is as follows. While stepping, place both palms on the Lower Dantian, regulate your breath and draw the Qi upward from the bottom of each foot. Press your Mingmen area backwards while breathing in the essence of the Qi.

The starting position is similar to the exercise for tonifying the Kidneys with the toes pointing down, except that you step forward with the left toes. Step forward so that the toes of the left foot touch the ground first followed by the left heel. While this step is taken inhale twice through the nose. Then step out 45 degrees with the right heel while inhaling twice more through the nose. Next, step out with your left heel 45 degrees, exhale through your nose twice, then step out with your right foot with the toes pointed down as you exhale once.

- First step—inhale, inhale
- Second step—inhale, inhale
- Third step—exhale, exhale
- Fourth step—exhale

When walking with the toes raised, let the big toe touch the ground to stimulate the Yinbai Sp-1 and the Dadun Lv-1 points on the big toe. This promotes the ascension of the Qi

flowing upward along the Liver and the Spleen Channels. The internal energy of these two channels is then reinforced, and the Liver and Spleen are strengthened.

After walking in a circle for nine complete rotations, pause and begin again starting with your right foot. Spleen and Liver Channels are activated when the toes pull up and the heel steps down.

The hand postures are as follows:

a. For Spleen problems the thumbs touch your ring fingers only when you step out to the fourth step (Figure 15.53).
b. For Liver problems the thumbs continuously touch your ring finger.

5. The Heart Tonification Walking Therapy calms the mind while tonifying the Qi and Blood. It is used for treatment of coronary Heart diseases, arthritis, palpitations, and angina pectoralis.

The starting position is the same as for the Liver and Spleen Walking therapy. The stepping is exactly like the last exercise, with the exception of the hand positions. In this exercise, the hands are opened and relaxed until they reach the chest (CV-17 point) at which point the middle fingers of each hand touches the Pc-8 point at the center of each palm (Figure 15.54).

When breathing, focus your Mind on inhaling the Qi upward from the Earth. When exhaling, imagine that the Qi within your chest is flowing downward.

- First step—inhale
- Second step—exhale

This walking exercise is practiced at a slightly slower speed then the previously described exercises. On the third step, the middle finger of each hand touches the center of your palms. This stimulates the Zhonchong Pc-9 point on each finger and is used to invigorate the flow of internal energy along the Pericardium Channels.

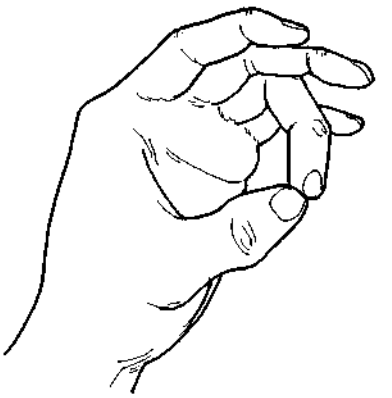

Figure 15.53. Hand Position for Tonification of the Liver and Spleen

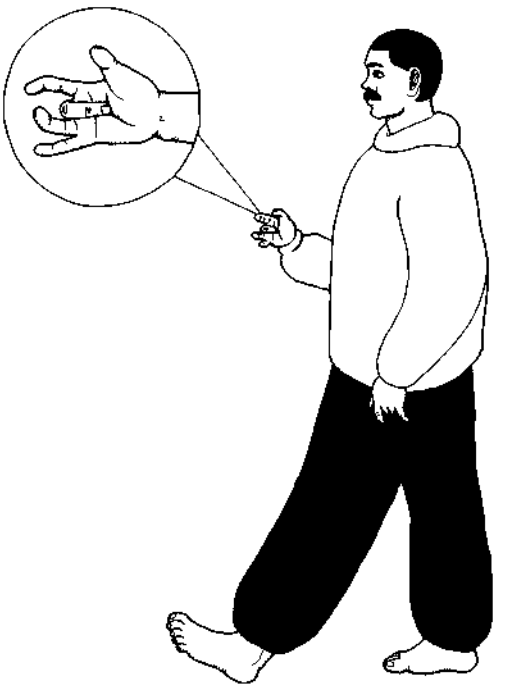

Figure 15.54. The Heart Strengthening Step is practiced at a slightly slower speed. On the third step, the middle finger of each hand touches the center of the palm.

THREE STEPPING METHODS USED TO TREAT CANCER

These supplementary Medical Qigong Step-

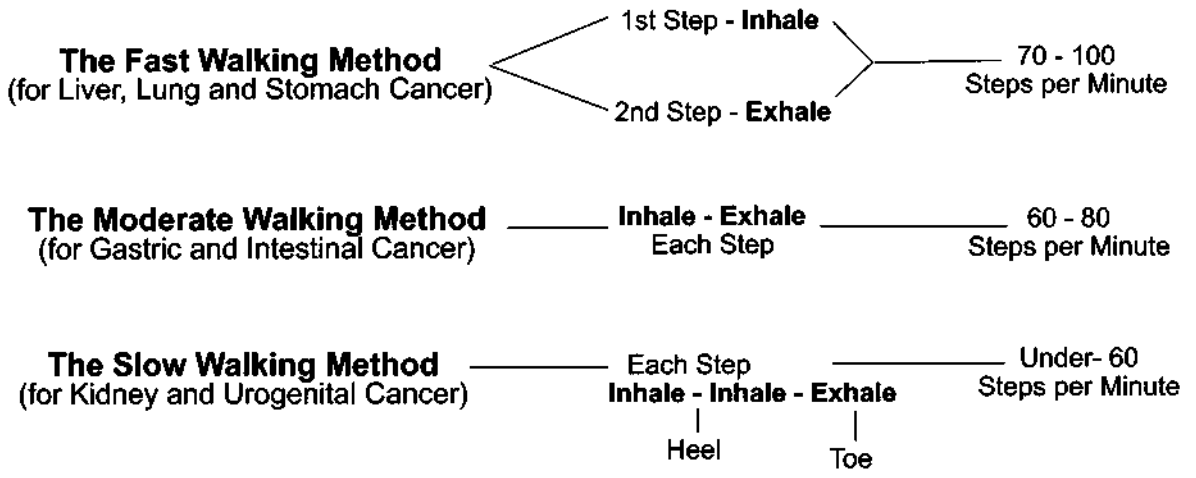

Figure 15.55. Cancer Walking Therapy

ping exercises are given to cancer patients for breath regulating and Qi reinforcement. These breathing methods are applied with the Dynamic Regulation Walking therapy (the first walking exercise taught in this section). These walking methods use the "exhaling method" to strengthen the Kidneys, increase oxygen intake and enhance the patients' immune system.

The stepping methods are performed at three different speeds depending on the patients' symptoms (Figure 15.55). The patients are encouraged to walk at least once a day for 15-20 minutes. These walking exercises are classified into three kinds of prescriptions according to the following breathing rates.

THE FAST EXHALING METHOD

This walking method is mainly prescribed for patients in the early stages of cancer and is especially suitable for patients with Liver, Lung, and Stomach cancer. This exercise is practised using even breathing, inhaling for one step, followed by exhaling for another step. The patient steps out with the left foot, while inhaling through the nose. Then steps out with the right foot, and exhales through the nose. Both hands swing naturally up to the chest, while walking.

The main point to remember while stepping, is that the head leads the waist in turning and swinging the arms. The speed should be 70-100 steps per minute. When practicing the Fast Exhaling method it is important not to overexert yourself, as this would be counterproductive, and would lead to depleting the immune system.

THE MODERATE EXHALING METHOD

This walking method is mainly prescribed for patients in the early stages of cancer and is especially suitable for patients with gastric and intestinal cancer. The patient breathes in and out through the nose with each step taken. When taking each step, focus is on the respiratory rhythm. The speed should be between 60-80 steps per minute.

THE SLOW EXHALING METHOD

This walking method is mainly prescribed for patients with Kidney and urogenital cancer. The patient steps out with the left foot first and then with the right foot. Each step is accompanied by two inhalations and one exhalation. The patient steps out with the heel while taking two inhalations and then touches the ground with the ball of the foot, while exhaling. Because one step involves three breathing movements, the walking speed should be a bit slower, under 60 steps per minute.

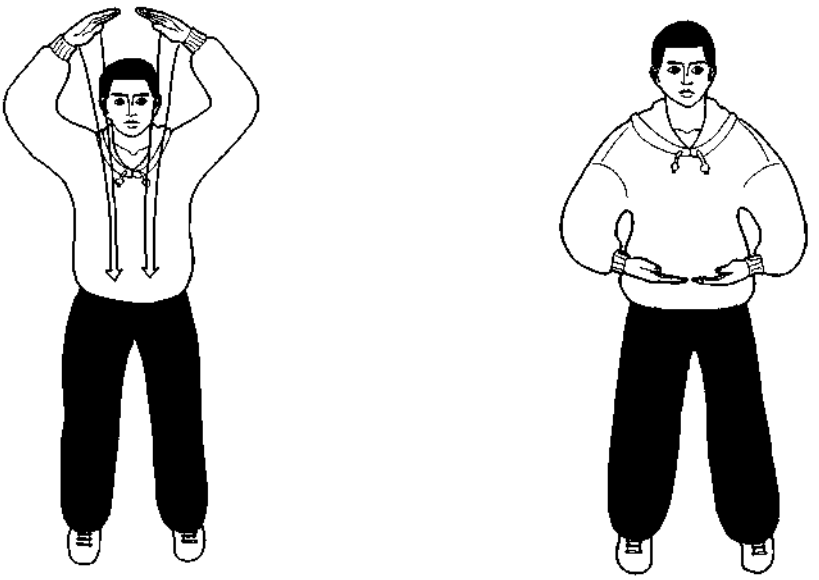

Figure 15.56. Secure the Upper and Middle Dantians in order to come to a tranquil state of relaxation.

ENDING AND CLOSING THE WALKING THERAPY

To end the Medical Qigong Walking therapy, the following exercises are taught to the patients in order to bring their Qi back into their Lower Dantian and to return to a state of quiescence. The Ending and Closing procedures are divided into three forms of practice: (1) Leading the Qi back into the Lower Dantian; (2) The official Closing of the prescription; and (3) Self-massage Regulation. These three ending procedures are described as follows.

LEADING THE QI BACK INTO THE LOWER DANTIAN.

This particular exercise is divided into four separate stages: (1) Securing the Three Dantians, (2) Kneading and Rooting the Lower Dantian, (3) Circle Massaging the Lower Dantian, and (4) Rooting the Qi.

1. The Securing the Three Dantians exercise has three purposes: to initiate a tranquil state of relaxation, to secure a harmonious balance of the body's Yin and Yang organs, as well as to bring the Qi back into the Lower Dantian.

   From a standing Wuji Posture, imagine embracing a ball of energy at the Lower Dantian (hold this posture for several breaths). After exhaling, separate the hands without inhaling, moving, and massaging the Qi along the hub of the body's Belt Vessel (at the waist).

   Inhale and begin raising the palms above the head. Imagine inhaling the Earth Qi into the body while the palms are facing the ground. At hip level, rotate the palms to face the sky, and begin inhaling Heaven Qi into the body. Continue raising the palms until they are positioned above the Baihui area on top of the head (left hand on top, opposite for women).

   Exhale and imagine the combined Earth and Heaven Qi flowing into the Taiji Pole, connecting all Three Dantians together. Descend the palms in front of the body, facing the Yintang, throat, Heart, upper abdomen (at the Yellow Court), and navel, then end by embracing the Lower Dantian. Begin again and repeat this exercise nine times (Figure 15.56).
2. Kneading and Rooting the Lower Dantian fills the Liver and Spleen with Blood and Qi, helping to further detoxify these organs.

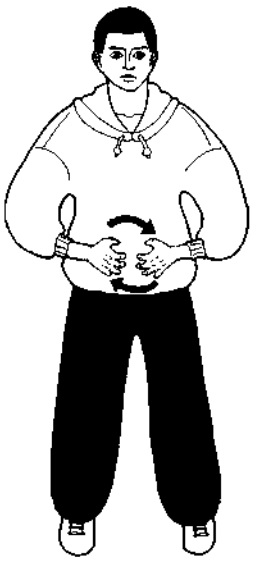

Figure 15.57. Knead the abdomen 36 clockwise then 24 counterclockwise.

After performing the Securing the Three Dantians exercise, secure the Qi in the Lower Dantian and knead the abdomen until it is sufficiently stimulated.

3. Circle Massaging the Lower Abdomen combines the body's organ energy together, thus forming the One True Qi. This allows the body to alleviate any Excess or Deficient conditions which may be caused from the excessive accumulation of Qi, due to the previous Qigong Walking exercises.

   Begin at the navel and start to circle massage the lower abdominal area thirty-six times in a counterclockwise direction (the movement should be directed against the flow of Qi in the Large Intestine). Begin with small and end with large circles, completing the movements at the base of the Lower Dantian. Next, reverse the direction of Qi flow by circle massage twenty-four times in a clockwise direction (with the flow of the Large Intestine), starting with big and finishing with small circles that end at the base of the Lower Dantian (Figure 15.57).

4. Rooting the Qi is sometimes referred to as "leading the Qi back to its origin." Rooting, extending, and stabilizing the energy into the Lower Dantian will facilitate the regulation of the Conception Vessel, Lower Burner, and Water pathways. Rooting the Qi also tonifies the Kidneys, Qi, Blood, and Yuan Qi, and allows the Toxic Qi to be easily expelled from the body.

   Leave the hands on the Lower Dantian and push the Mingmen backwards while inhaling the Qi and heat from the hands into the Lower Dantian (right hand on outside, opposite for women).

THE CLOSING

The closing procedure should be initiated after each practice period. After three deep breaths, click your teeth together thirty-six times (to stimulate the Kidney Qi), then circle the tongue eighteen times in each direction (to stimulate the Spleen Qi). Circle thirty-six times from the bottom of the teeth to the back of the throat. Tilt your head forward slightly, then swallow the saliva three times while imagining the Clear Qi of Heaven and Earth mixing with the saliva and flowing down to the Lower Dantian.

SELF-MASSAGE REGULATION

This method shifts the attention slowly off the area of concentration, while leading the Qi back down to the Lower Dantian. After the mind disengages from the specific point, relax the body, slowly open the eyes and perform self-massage.

Self-massage includes rubbing the hands, bathing the face (rubbing the face with the palms), combing the hair with the fingertips, and dredging the Twelve Primary Channels.

1. After rubbing the hands to heat the palms, place both hands on the face, cup the eyes, and draw the heat in through the eyes, into the Upper Dantian.
2. Next, comb the hair with your fingertips and drain the Excess Qi from off the head and neck area (Figure 15.58).
3. Then, rub from the feet to the abdomen to dredge the three Yin channels of the feet (Figure 15.59).

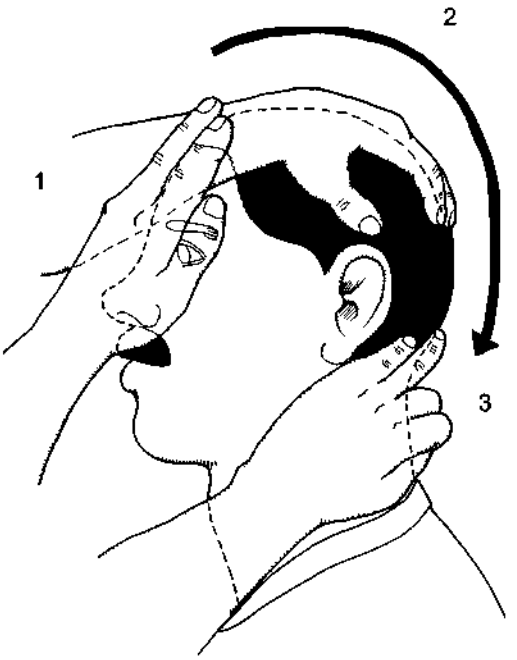

Figure 15.58. After rubbing the hands to heat the palms, place both hands on the face and draw the heat in through the eyes and into the Upper Dantian (1). Next, comb the hair with the fingertips (2), and drain the excess Qi from the head and neck area (3).

4. Rub from the chest to the hands to dredge the three Yin channels of the hands (Figure 15.60).
5. Rub from the hands, shoulders and lateral sides of the head, down the sides of the chest and abdomen to dredge the three Yang channels of the hands (Figure 15.61).
6. Rub from the waist and hips to the feet to dredge the three Yang channels of the feet (Figure 15.62).

These closing and self-massage procedures should be performed seven times each, followed by stretching to end the exercise.

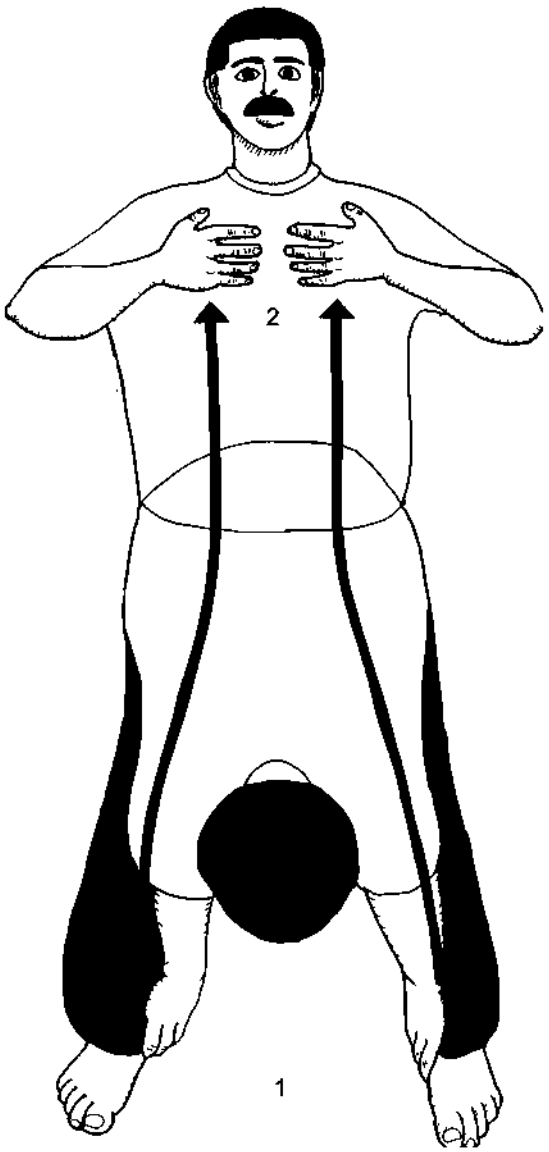

Figure 15.59. Rub from the feet to the abdomen (1–2) to dredge the three Yin channels of the foot.

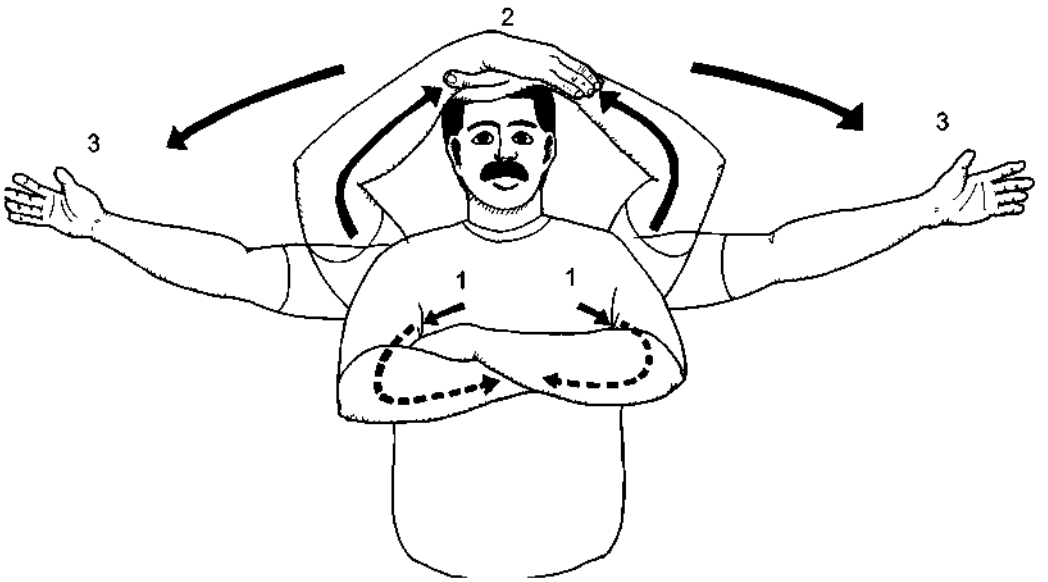

Figure 15.60. Rub from the chest (1) to the hands (2-3) to dredge the three Yin channels of the hand.

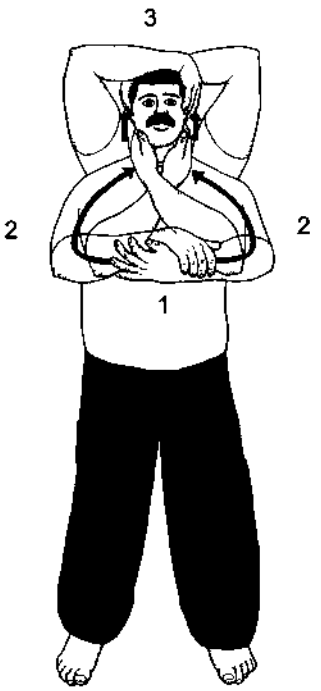

Figure 15.61. To dredge the three Yang channels of the hand, rub from the hands (1), shoulders (2), and lateral sides of the head (3).

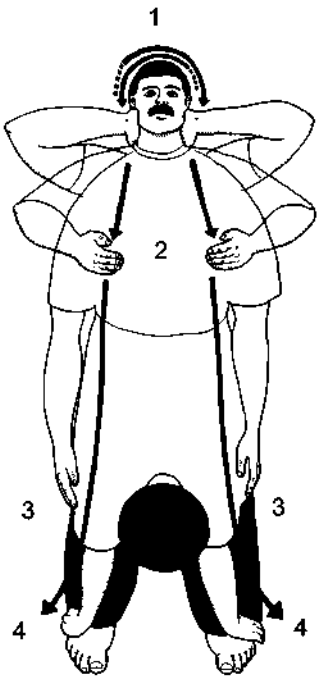

Figure 15.62. Continue down the sides of the chest (1) and abdomen (2). Next, rub from the waist and hips (3) to the feet (4) to dredge the three Yang channels of the foot.

Chapter 16
Respiratory Dao Yin

The Purpose of Respiratory Dao Yin

Respiratory Qigong therapy is often called Tu Gu Na Xin which means "expelling the old, drawing in the new." The purpose of Respiratory Dao Yin is to increase the intake and absorption of Clear Qi through regulating the breath. The extra absorption of Qi enhances the body's vitality, and harmonizes the Blood and Qi to promote health and eliminate disease.

Because the breath is also the link between the body and mind, by controlling the pace and quality of the breath, individuals can affect deep changes in their physiological functions. Breathing exercises have proven to be effective in reducing anxiety, depression, irritability, muscle tension, and fatigue. These techniques are also used in the treatment and prevention of agoraphobia, hypertension, hyperventilation, shallow breathing, and cold hands and feet.

The Role of the Lungs in Qi Cultivation

The Lungs control the body's Qi, although the Kidney Qi is responsible for aiding the Lungs by regulating the respiration (i.e., upon inhalation, as the Qi descends into the thorax, the Kidneys hold down and stabilize each breath). The Yuan Qi stored in the Kidneys must be continuously supplemented by the Gathering Qi derived from air, food, and water.

The internal absorption of air, food, and water rely on the smooth circulation of the Lungs' energy. Because of the significant role the Lungs play in absorbing universal and environmental Qi, the ancient Qigong masters placed a great deal of importance on breathing exercises. They believed that a patient's health and emotional condition were deeply affected by their breathing patterns, and by the amount of oxygen consumed in proportion to the amount of carbon dioxide released.

Through the study of these ancient Qigong observations, modern research confirms that relaxed and natural breathing patterns cause every tissue and cell to decrease its consumption of energy, while increasing its storage of Qi.

The ancient Qigong masters recommended that "vigorous breathing," in the form of Dynamic Breath Regulation, should be used when training Qi, and "gentle breathing," in the form of Quiescent Breath Regulation be used after training practice for nourishing and replenishing the Qi. Each breathing regulation exercise has long been considered a powerful prescription used to balance the patient's health.

Deep Inhalation and Exhalation Breathing Methods

In breathing regulation exercises and prescriptions, the patient's inhalation is used to gather universal and environmental Qi into the body for tonification. Exhalation is used to eliminate Turbid or Toxic Qi from the body through purgation. Once the patients are in the prescribed posture, relaxed and free from distractions, they should, for example, exhale and imagine releasing Turbid Qi from out the mouth, nose, and pores of the body.

Clinical studies show that the Deep Inhalation of Medical Qigong prescriptions can have the following effects on the patient's body:

- increase stimulation of the sympathetic nervous system,
- cause the blood vessels to contract,
- raise the blood pressure, and
- increase the pulse rate.

On the other hand, the Deep Exhalation methods of Medical Qigong prescriptions can also have the opposite affects on the patient's body:

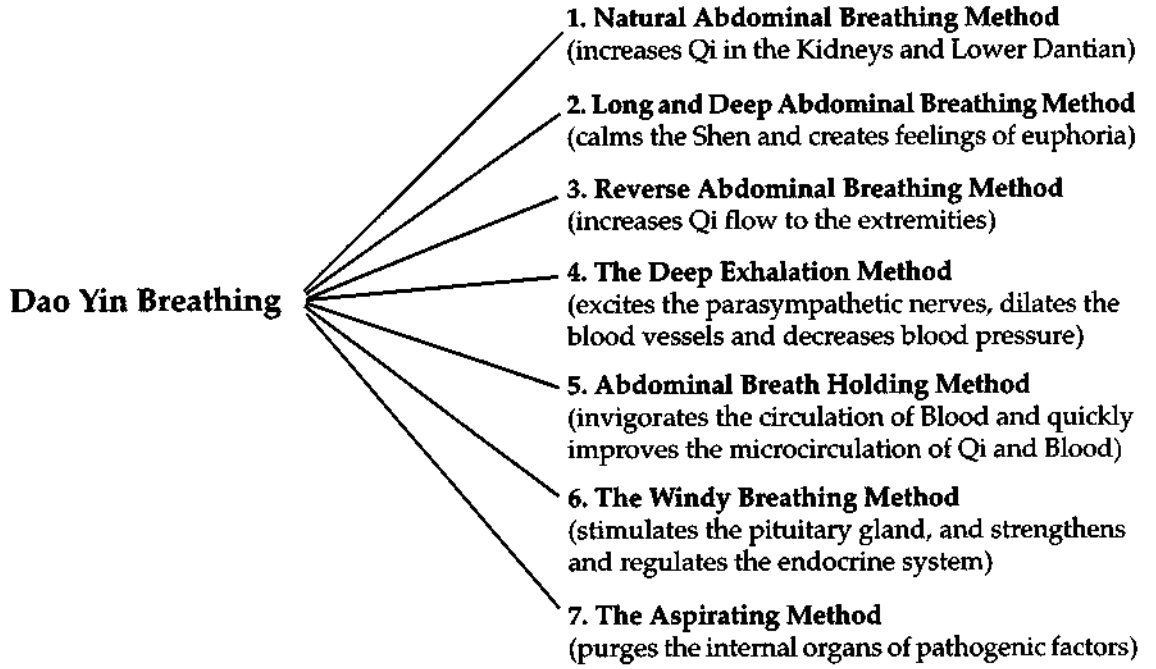

Figure 16.1. The Seven Dao Yin Breathing Techniques

- increase the stimulation of the parasympathetic nervous system,
- dilate the blood vessels,
- lower the blood pressure, and
- decrease the pulse rate.

Deep exhalation helps to keep the body's Yin energy moving downward, and so has a downward regulating action on diseases caused by Yang Qi domination. Deep inhalation helps to keep the body's Yang energy moving upward, and has the effect of sustaining the Yang and tranquilizing the mind.

Students beginning Medical Qigong practice should focus their mind's intention primarily on the method of exhalation, to simultaneously stimulate the parasympathetic system and to relax. Once health is regained, patients will begin to alternate between deep inhalation and deep exhalation. This alternation produces a diastolic and systolic action of the blood vessels that also enhances the elasticity of the blood vessels' walls.

Seven Dao Yin Breathing Techniques

The Seven Dao Yin Breathing Techniques are intended to regulate the symptoms caused by the Excess of Yang and Deficiency of Yin, which are characterized by too much energy in the upper part of the body and a weakness in the lower portion of the body.

Today, in China's Medical Qigong clinics, the breathing regulation exercises employ seven types of Dao Yin breathing techniques (Figure 16.1). Normally, all inhalation is done gently through the nose and exhalation is released slowly through the mouth. Inhalation and exhalation through the nose is also important, but should only be used when a higher state of "stillness" is obtained by the patient. This is to prevent the patient from falling back into his or her old shallow breathing patterns, until the Deep Abdominal Breathing method has been perfected.

1. The Natural Abdominal Breathing Method is also called Natural Breathing, and is used in

conjunction with mental concentration. In this method the abdomen expands upon inhalation and contracts upon exhalation. It naturally increases the body's peristaltic action, massages the internal organs, invigorates and increases the movement of Qi from the Kidneys into the Lower Dantian. Because of the differences in energetic physiology between men, women, and the breathing habits of each individual, Natural Breathing is further divided into Natural Thoracic Breathing, Natural Abdominal Breathing, and a combination of the two.

2. The Long and Deep Abdominal Breathing Method is also called Wen Huo Breathing. It is a gentle breathing method that consists of natural, deep, and full breathing. This results in a relaxed and comfortable feeling of euphoria. This method of breathing is performed as follows:
   a. At the beginning of the breath, inhale all the way down into the perineum, feeling the lower abdomen expanding in all six directions:

- from the bottom - at the base of the perineum,
- from the front - to the pubic bone and navel,
- from the back - to the coccyx and Mingmen,
- from the right - to the hip and lower ribs,
- from the left - to the hip and lower ribs, and
- from the top - at the base of the diaphragm.

   b. While continuing to inhale, feel the oxygen expanding and filling the upper thoracic cavity completely. The entire torso, from the perineum to the collar bones is expanded in six directions:

- from the bottom - at the top of the diaphragm
- from the front - to the solar plexus, Heart, and collar bones,
- from the back - to the base of the ribs, spine and top of the shoulders,
- from the right - to the rib area,
- from the left - to the rib area, and
- from the top - to the throat and neck area (Figure 16.2).

   c. Upon complete expansion, tuck the pelvic bowl under to increase the capacity of storing more energy. On the inhalation the pelvis performs a slight posterior tilt, on the exhalation the pelvis tilts slightly in the anterior direction. These actions will naturally ripple the spine. Exhale the breath from the upper thoracic cavity downward, to the lower abdomen.

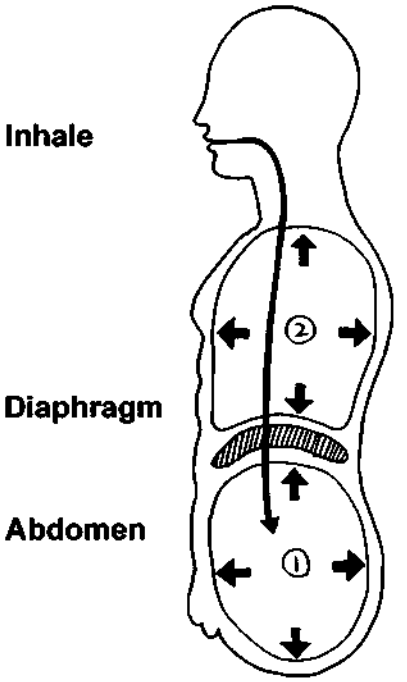

Figure 16.2. Inhale all the way down to the perineum. Make sure that the anal sphincter is closed in order to keep the Qi full and expanded in the Lower Dantian.

3. The Reverse Abdominal Breathing Method is an example, and subcategory of Long and Deep Abdominal Breathing. This method is performed by contracting the abdomen (and anus) when inhaling and expanding the abdomen upon exhaling. This is the primary breathing method used in Qigong training for guiding and emitting Qi, because the quality of air pressure and exertion of energetic pressure is greater. The Reverse Abdominal Breathing method results in superior efficiency in leading Qi to the extremities and has a much greater effect in raising the Qi from the legs into the brain.

However, when prescribing Medical Qigong therapy to treat diseases and alleviate physical stress, the Reverse Abdominal Breathing Method is prohibited except for very specific conditions. The reason it is not encouraged in Medical Qigong prescriptions is because patients with clinical hypertension or Heart disease often practice Reversed Breathing automatically. Scientific studies confirm that 90% of these patients practice reverse breathing chronically, as do most individuals with anxiety problems. Reverse Abdominal Breathing can also cause a constriction of the blood vessels and thus exacerbate problems such as cardiac diseases (i.e., angina) and migraine headaches.

4. The Deep Exhalation Method is often referred to as Wu Huo, which means "vigorous breathing." It is conducted with strong conscious intent. It can excite the parasympathetic nerves, dilate the blood vessels and decrease blood pressure.

   When practicing the Deep Exhalation method, the patient expels the Qi through the mouth, followed by a shallow inhalation.

5. The Abdominal Breath Holding Method invigorates the circulation of Blood and reduces swelling within the tissues, quickly improving the microcirculation. This method is also used to deepen the breath by stopping or holding the respiration for a short period of time.

   One Abdominal Breath Holding Method, known as Two Breathings, consists of inhaling through the nose, deep into the Lower Dantian, with one breath, pausing, then exhaling out through the mouth. The pause should be sustained for as long as possible without feeling tension (although a feeling of slight pressure building up is normal). After practicing deep abdominal breath holding, the breath will begin to develop its own stopping patterns. This stage involves the discipline and interdependence of the Heart and mind (Emotion and Spirit) with the breath.

6. The Windy Breathing Method consists of inhaling and exhaling through the nose. It is often referred to as "Windy" because it employs shallow breathing which resonates in the nasal passages. This kind of breathing purifies and warms the air as it passes through the nasal tract, resulting in air oscillation which stimulates the pituitary gland, thus strengthening and regulating the endocrine system. This method is designed to be used by patients with Lung disease because "the Lung energy opens at the nose."

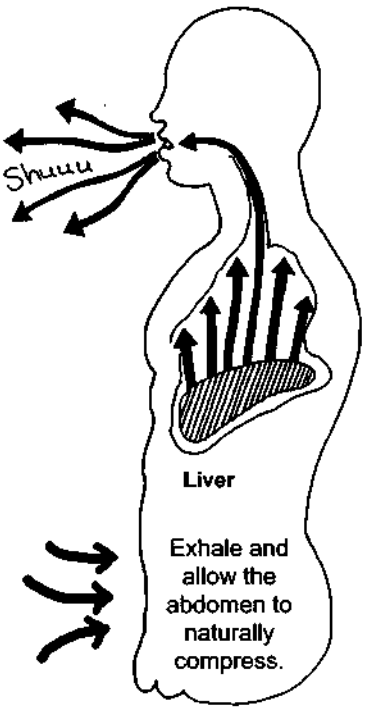

Figure 16.3. An example of tone resonation by aspirating the body's Excess Heat from the Liver is by using the sound "Shu."

7. The Aspirating Method refers to the method of drawing out by suction. This popular method can be used with healing sounds (or "tones") to purge pathogenic factors, or to regulate the body's internal organs. The pronunciation is based on resonating the sounds to stimulate specific organs such as the Heart, Spleen, Lungs, Kidneys, Liver and Triple Burners (Figure 16.3). There are two primary

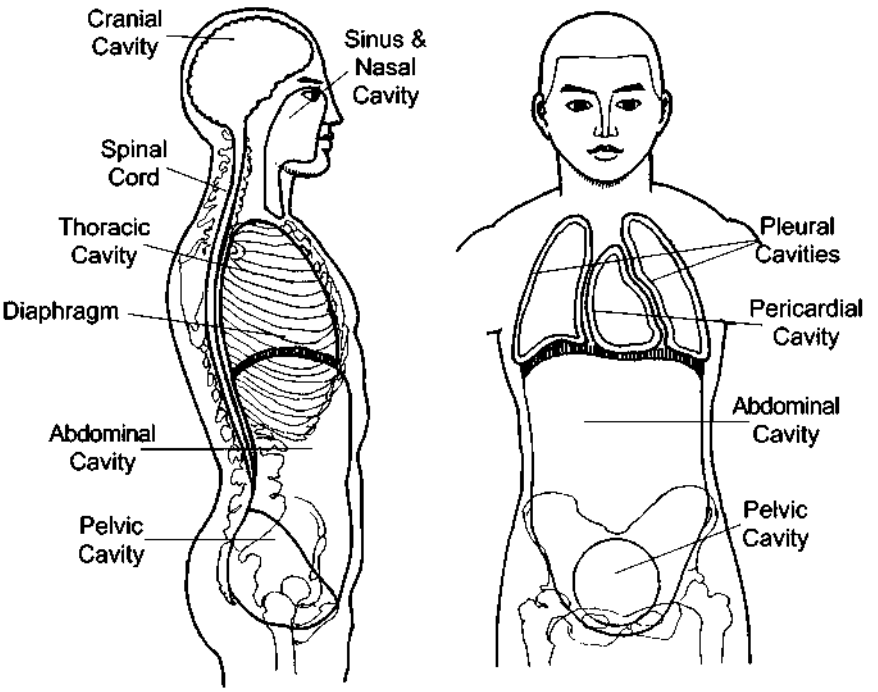

Figure 16.4. The body has seven main spatial cavities, as well as individual spatial cavities that surround the Yin and Yang organs.

sound systems of tone resonation used in Medical Qigong therapy, The Six Healing Sounds and the Tumor and Cancer Tone Resonations. These two healing sound methods are described as follows.

- The Six Healing Sounds are used to regulate, strengthen or detoxify the body's Yin and Yang Organs. This healing sound system is generally prescribed for patients with acute, or less serious conditions such as indigestion, insomnia, or Excess Heat in the organs, etc.
- Tumor and Cancer Tone Resonation Therapy is used to vibrate and destroy malignant tissue and cell growth in patients with chronic and serious organ diseases (see Chapter 40). This healing sound system is prescribed for diseases such as cysts, tumors, and cancer.

The choice of organ, and the number of times to pronounce each sound or character, is determined by the physical and energetic constitution of each individual. Each sound vibrates a specific organ or organ system, and surrounding set of involuntary muscles. Through repetition, the muscles acquire a kinesthetic memory of the vibrational sound. The doctor, or patient, can then trigger this memory by mental concentration alone to produce the desired results. As the patient performs the Sound Therapy, not only are the channels and organs cleansed, but also the spatial cavities (or Orbs) which surround the specific organs (Figure 16.4). For more information on Sound Therapy, see Chapter 40.

RESPIRATORY GUIDING AND REGULATING

There are four Respiratory Dao Yin methods the Qigong doctor can prescribe to regulate the

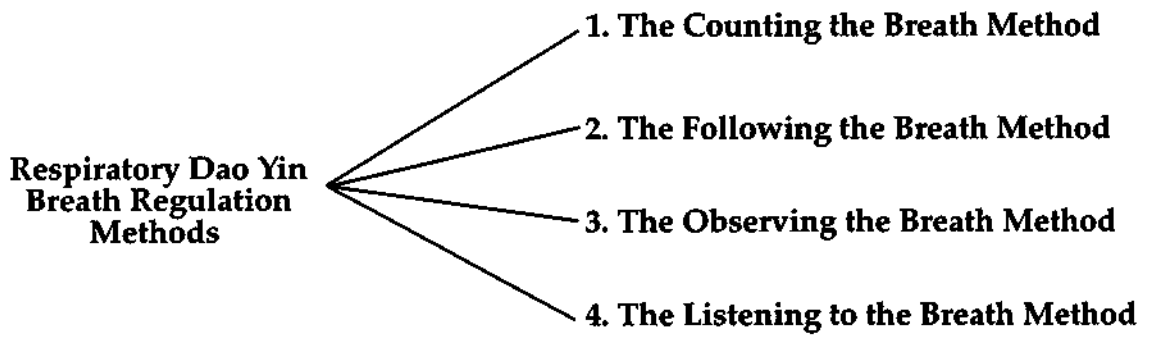

Figure 16.5. The Four Methods to Prescribe Respiratory Dao Yin For Breath Regulation

patient's breath (Figure 16.5): Counting the Breath, Following the Breath, Observing the Breath, and Listening to the Breath.

1. The Counting the Breath Method can be utilized to eliminate distractions of the mind during Walking Qigong Therapy by having patients silently count the number of their breaths. This method is also performed silently to regulate the body. In this particular method, one inhalation and one exhalation equals one breath.
2. When practicing the Following the Breath Method, the patients will contemplate each inhalation and exhalation of breath without counting. The patients mind, free from distractions or thoughts, follows each breath into and out of the body.
3. When practicing the Observing the Breath Method, the patients will observe their body's tissues conforming to the tranquil mental images from their subconscious imagination (e.g., relaxing, sinking, etc.).
4. When practicing the Listening to the Breath Method, patients are encouraged to listen to the "sounds" of their breathing (used in the Windy Breathing Method) to achieve a state of tranquillity.

Respiratory Tonification and Purging Methods

Medical Qigong Respiration Therapy has its own unique methods and techniques for tonifying and purging the body's Qi. The primary technique used is focused concentration on the breathing. Through breath regulation, syndromes of Excess and Deficiency may be brought into balance either through tonification or through purgation.

1. Inhalation is used for tonifying the Qi in cases of Deficiency. The duration of the patient's inhalation should be longer than that of the exhalation. Tonification or Qi reinforcement patterns are created by applying the following methods:
   - more inhalation, and less exhalation
   - long inhalation, and short exhalation
   - focusing the mind on the inhalation
2. Exhalation is used for purging and reducing the Qi in cases of Excess. The duration of the exhalation should be longer than that of the inhalation. Purgation or Qi reducing patterns are created by applying the following methods:
   - more exhalation, and less inhalation
   - long exhalation, and short inhalation
   - focusing the Mind on the exhalation

Basic Essentials of Respiratory Training

Medical Qigong Respiratory training consists of the regulating, tonifying or purging exercises practiced in accordance with the doctor's treatment and specific homework prescriptions. There are four basic essential guidelines used to assist

the patient in achieving maximum results in respiratory therapy, these guidelines consists of: Ensuring the Correct Posture Before Beginning, Purifying and Cleansing the Body's Qi, Tonifying and Purging the Qi, and Regulating the Body's Qi.

1. Before beginning Respiratory Dao Yin training, it is important that the doctor make sure the patient's posture is correct. When prescribing dynamic and static Medical Qigong therapy, it is best to start with a solid foundation and proper structure. Breath training should only begin when the patient becomes proficient in Postural Dao Yin, otherwise adverse effects may occur, (i.e., emotional trauma, headaches, chest stuffiness, or respiratory distress).
2. After their posture has been corrected, have the patients open their mouth and focus on their exhalation. As the patients exhale, they imagine all of the obstructed channels and collaterals being simultaneously purged of Turbid Qi. Each time the patients exhale they are to relax their body, more and more.

   Next, the patients close their mouth, and focus on inhaling clean, fresh Qi in to their body (through the nose). Have the patients practice this method using Natural Breathing. Each time the patients inhale and exhale they are to continue to relax the body.
3. After the body's Qi has been cleansed, the patients will focus their intention on any and all internal organs that specifically need to be purged. Breathing exercises used for purgation include focusing the patients' intention on the exhalation, as well as exhaling specific healing sounds. The patients continue to purge their body in this manner in accordance to the doctor's instructions.

   Having completed the purgation exercises, the patients are free to begin their tonification prescriptions. Breathing exercises used for tonification include the focus of the patients' intention on the inhalation, as well as visualizing specific colors being ingested into certain internal organs.
4. After practicing the tonifying or purgation prescriptions, the final goal of respiratory training is to achieve a long, natural, even and deep respiration. Urgent respiration causes the body's internal Fire to escape into the pores, resulting in uncontrolled Heat, feverish conditions and irritability. Normal breath regulation consists of even inhalation and exhalation patterns. The patient must avoid speeding up their breath, as this will also interrupt the breathing rhythm and lead to deviations of Qi.

Breathing Patterns for Collecting and Regulating Qi

The following are examples of exercises used for regulating and collecting Qi in the Lower Dantian. The doctor or patient will perform the breathing patterns as follows:

1. Collecting Qi in Lower Dantian is used to tonify and increase the collection of Qi gathered in the Lower Dantian.
   a. Inhale through the nose, filling the lower Dantian (expanding the abdomen), pause, then exhale through the mouth. Repeat and continue this breathing pattern for three times then proceed to b.
   b. Take three partial inhalations through the nose, filling the lower Dantian, pause, then complete one exhalation through the mouth. Next, inhale 50% of the breath into the Lower Dantian (expanding the abdomen), hold for three heartbeats, inhale remaining 50% into the Lower Dantian and hold for five heartbeats, relax and slowly exhale. Repeat and continue the pattern for thirty minutes a day (for three months), or until it becomes effortless.
2. Regulating Qi in Lower Dantian is used to stabilize the energetic balance of the Lower Dantian.
   a. Inhale through the nose, filling the lower Dantian (expanding the abdomen), exhale through the mouth, and

then pause. Repeat and continue this breathing pattern for three times then proceed to b.

b. Inhale through the nose, then perform three partial exhalations through the mouth, pause, then one complete inhalation through the nose. Next, exhale 50% of the breath out of the Lower Dantian (contracting the abdomen), hold for three heartbeats, exhale remaining 50% out of the Lower Dantian and hold for five heartbeats, relax and slowly inhale. Repeat and continue the pattern for thirty minutes a day (for three months), or until it becomes effortless.

3. The Mysterious Pass is the pause between the inhalation and the exhalation. The ancient Qigong Masters believed that in the pause was the realm of infinite space (Wuji), existing between the Earthly Heaven (the congenital form of energy) and the Later Heaven (the acquired form of energy) where time and space stands still.

   For clinical practice, the Qigong doctors train in the method of accessing the Mysterious Pass in order to extend Qi through the entire body and to access the energy of the Wuji (Infinite Space). In the clinic, the training is divided into two stages (a and b).

   a. Begin this training by holding the breath from three to twelve counts (known as the "Small Count Breathing Regulation").

   b. Eventually increase to the "Big Count Breathing Regulation," which consists of 120 counts. This method enriches the Yuan Qi by breathing in more and exhaling less, and is sometimes used in Medical Qigong prescriptions to cure specific types of illness. When used with a strong intent, breath holding can constrict the blood vessels and raise the blood pressure; it is therefore sometimes prescribed for patients with hypotension. This Qigong method is, however, contraindicated for patients or doctors with hypertension.

THE FOUR PROGRESSIVE STAGES OF RESPIRATION

There are four progressive phases of difficulties that patients may experience during the beginning stages of their Medical Qigong Respiratory training: The Wind Phase, The Gasp Phase, The Unbalanced Air Phase, and The Quiescent Phase.

1. During the Wind Phase, the breathing is audible and may prove distracting to a beginner. The goal of focused concentration is to allow the energy to become gathered and collected. If the goal of the breathing prescription is to focus on a Deficient internal organ or specific tissue area, for example, and the patient's concentration becomes diverted (shifting to the noise of their own breath), it may disrupt the patient's mind. This can result in the patients collected Qi being dispersed instead of gathered.
2. During the Gasp Phase, the breathing is no longer audible, but any stagnant air, or obstructed air in the throat may disrupt the mind's concentration. Focused concentration on the stagnant air or obstruction may cause a sense of physical obstruction and mental anxiety, resulting in Qi stagnation in the throat (known as Plum Pit Qi).
3. During the Unbalanced Air Phase, the breath remains silent and there is no sensation of obstructed air in the throat. The patient's breathing, however, may be uneven, or unbalanced. Focused concentration at this phase may cause strain in the patient's mental awareness. If the mind becomes overstrained (trying to balance the inhalations and exhalations) the result will be fatigue.
4. During the Quiescent Phase, patients are able to achieve a long, natural, even and deep respiration without sound or stagnation, resulting in a state of extreme quietness. Concentration on this phase will result in a restful peace of mind.

DURATION TIME FOR RESPIRATION THERAPY

Patients in relatively good health should practice for about five minutes a day in the first week, when seeking to regulate their body's internal energy. In the second week patients should increase to ten minutes a day, and in the third week, fifteen minutes a day. Thereafter, five more minutes each day should be added until the patients reach a minimum of twenty minutes and a maximum of forty minutes per day for optimal Qi development.

When treating patients (for general tonification) using multiple standing meditation postures, have them begin by counting up to sixteen breaths per each posture. As the patients progress, the respiratory rate during meditation begins to slow down naturally. Normally, within a few months of training, respiratory rate drops from an average of sixteen breaths per minute, to three or five breaths per minute. This naturally increases the time spent in each posture, extending each posture from one to five minutes in duration.

Qigong doctors, on the other hand, should practice a minimum of forty minutes of standing posture each day to recharge and increase the efficacy of their treatments.

EMOTIONAL EFFECTS ON BREATHING PATTERNS

Breathing patterns are directly related to both the patients' thoughts and emotions. Any shift in one will affect the other. Each of the five primary emotions is associated with a specific breathing pattern as follows.

1. An angry patient's exhalation will be much stronger than the inhalation.
2. A grieving or sad patient's inhalation will be much stronger than the exhalation.
3. A fearful or scared patient's breathing will be fast, held high in the Lungs, and shallow because of the Kidneys' inability to hold the Lung Qi down.
4. A happy patient's inhalation and exhalation will be moderate, and irregular, with quick bursts.
5. When worried or deep in thought, the patient's inhalation will be shallow and weak, sometimes held for long periods of time, followed by a long gulping burst of inhalation and exhalation. The patient may also experience spontaneous sighing for prolonged periods of time.
6. When a patient experiences fright or shock, the breath immediately stops as the Qi attacks the Heart.

RESPIRATORY DAO YIN CANCER PRESCRIPTIONS

Respiratory prescriptions such as the Deep Relaxed Breathing Method described below, are used in treating cancer, and require the patient to combine the use of two methods of exercise and treatments:

1. The Opening and Closing Methods of Qi regulation (see Chapter 41), and
2. The Deep Relaxed Breathing methods for purgation, rather than tonification purposes.

The purpose of these treatment methods is to purge Excess Qi from the body, remove Blood stasis, and disperse Qi stagnations.

THE DEEP RELAXED BREATHING METHOD

The function of this exercise is to purge the channels and collaterals and to promote the circulation of Qi. It is also used to harmonize the ascension of Yang and the descending of Yin. Calming the Yin and suppressing the Yang promotes the flow of Qi and Blood through the organs, and has the effect of eliminating Evil pathogenic factors, and supporting healthy energy.

The Deep Relaxed Breathing method requires the patient to inhale through the nose and exhale through the mouth. The main points to remember in this method are as follows:

1. The patients inhalation and exhalation should be gentle, thin, even and long. They should focus their mind on the Hibernation Breathing Method. This method requires inhaling and exhaling through every pore on the body's surface while lying supine. The patients should not focus on their lower abdomen or the expansion of the upper chest and

Lung region. Instead, they should imagine inhaling through the pores into the Taiji Pole, and exhaling out from the Taiji Pole through the tissues and out the pores.

2. When breathing, the patients' whole body should stay relaxed; the key part to relaxing the whole body is to relax the waist.

Through training in these respiratory methods, the patients' immune system is enhanced and their vital Qi is nourished.

Chapter 17
Mental Dao Yin Training

Introduction

There are two divisions of the Mind (Yin and Yang), each consisting of three different levels. The Yin part belongs to the energy of the Earth and is a more body-oriented type of mind. The Yang part of the Mind belongs to the energy of Heaven and is a more consciousness-oriented type of mind. The three levels of the Mind are as follows.

1. The first and deepest level exists within the Jing and the Shen, and represents the Original (Yuan) and primordial form of the mind.
2. The second or middle level exists within the Seven Corporeal Souls (Po) and Three Ethereal Souls (Hun) and represent the moving and active aspects of the mind (e.g., body movements, reflexes, instincts, drives, and astral projection - when accompanied by the Yuan Shen).
3. The third and superficial level exists within the Will (Zhi) and Intention (Yi) and represents the mind's everyday function (i.e., cognitive thinking). The Zhi is considered the "thinking body," while the Yi is considered the "thinking mind" (for more information refer to the Five Yin Organ components of Shen in Chapter 13).

These different levels of energies create the body, as well as activate the mental and emotional transitional states of the Mind. All three levels of the Mind are interactive and interdependent (Figure 17.1).

Energetic Division (Qi)	Yin	Yang
Energy of the Mind	Earth	Heaven
First Level of the Mind	Essence (Jing) Kidneys	Spirit (Shen) Heart
Middle Level of the Mind	Corporeal Soul (Po) Lungs	Ethereal Soul (Hun) Liver
Third Level of the Mind	Will (Zhi) Kidneys	Intention (Yi) Spleen

Figure 17.1. Mental and Emotional Transitional States of the Mind

Traditional Chinese Medicine believes that the Heart stores the Spirit (Shen). The Shen is further divided into Yuan Shen (the intuitive congenital spirit) and Zhi Shen (the analytical acquired spirit). The Shen is responsible for feeling and controlling the body's mental and emotional activities. The Zhi Shen is generally strong and can be stubborn and suspicious, therefore, it must be led by a master; the Yuan Shen must be that master, and must lead the Heart's Shen as one unit.

The brain is considered the house of the Yuan Shen, and the seat of mental function. It is believed that the senses and control of the body's physical movements are related to the brain. If the Heart has any functional disorder, the mental activities of the brain, and the emotional activities of the Heart also become disorganized. The Heart, which is the seat of all emotions, controls not only the Shen, but also the blood vessels, therefore Blood circulation is also influenced by the emotions.

The preservation of Jing depends on the cultivation of Qi, which in turn depends on the mental focus of the Shen. The mental focus of the Shen is to Qi as a mother is to her child. Mind concentration must combine with Qi; without the Shen

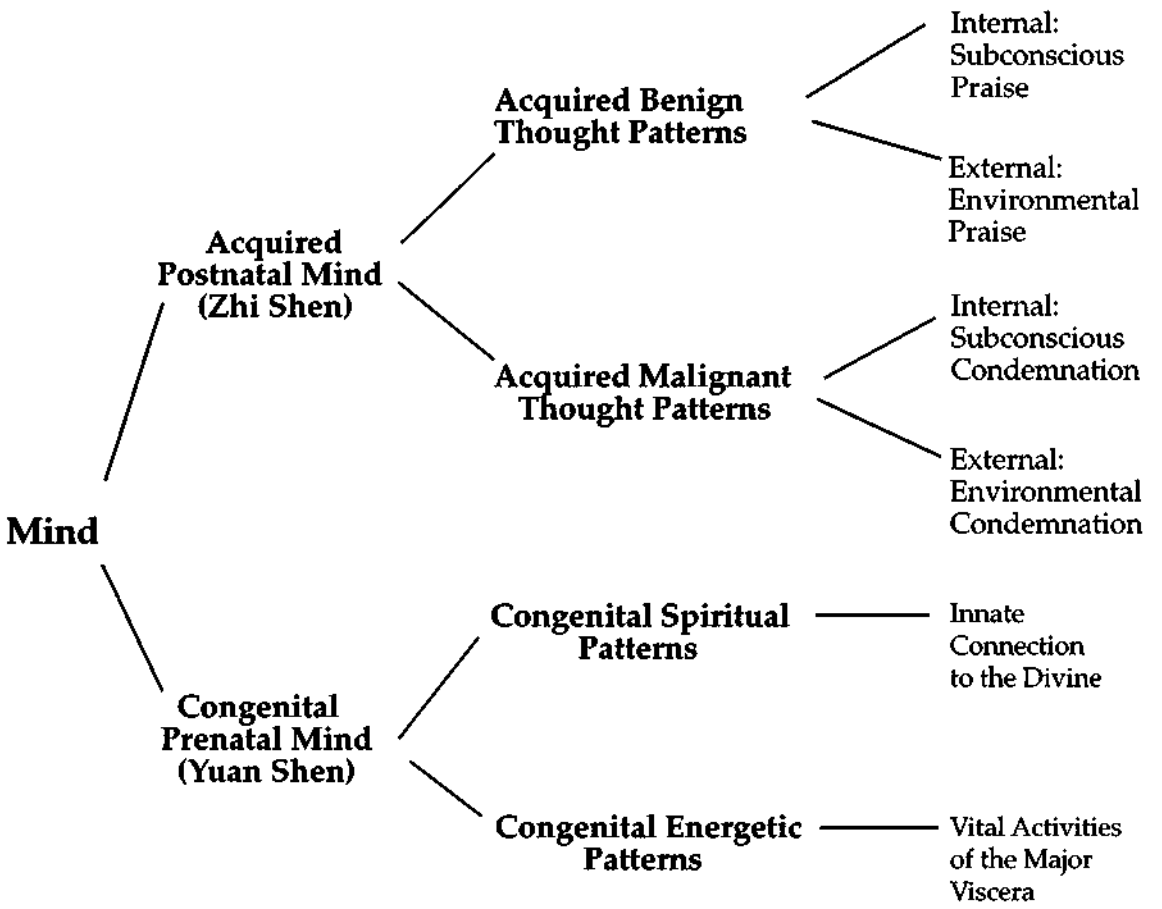

Figure 17.2. The Differentiation Between the Prenatal and Postnatal Patterns of the Mind

guiding it, the body consumes the energy. The concentration of the Shen and Yi (intention) causes Qi to consolidate, while any distraction to the Shen and Yi causes Qi to disperse.

This concept is considered similar to that of regulating the emission of light, because Qi is emitted similar to the wave patterns of rippling water, and Shen is emitted similar to the wave patterns of light. When the Mind begins to focus concentration on the projection of Qi, both Qi and Shen unite, enabling the Qigong doctor to regulate the emitted Qi, changing its form from an expanded energy field to a finely honed beam.

THE PRENATAL AND POSTNATAL MIND

In Traditional Chinese Medicine, it is believed that the cerebral activity of the mind falls into two distinct categories: the Prenatal (Yuan Shen) Mind, and the Postnatal (Zhi Shen) Mind.

1. The Prenatal Mind (Yuan Shen) is inherited from the Jing of both parents and dominates the vital activities of the major viscera, as well as the function of the body's entire energetic organism and spiritual matrix.
2. The Postnatal Mind (Zhi Shen) is developed through interaction with people and the en-

vironment after birth. It dominates thought and interaction, and engages in unlimited mental activity.

The Yuan Shen and Zhi Shen are interactive and interdependent. If the Zhi Shen is active and chattering (sometimes called the Monkey Mind), it is difficult for the Yuan Shen to convey its perceived information. Regulating the Mind is therefore needed to harmonize the analytical and intuitive aspects of the Mind.

Benign and Malignant Thought Patterns

Mental activity and thought processes can also be categorized into two clinical syndromes: benign and malignant thought activity (Figure 17.2).

Benign Emotion and Thought Activity

This is a gentle or favorable belief structure of the subconscious mind, resulting in relaxed, pleasant thoughts. This thought pattern will both improve and regulate the excitation and inhibitory processes of the cerebral cortex. These positive thoughts and beliefs help to restore strength to the Yin and Yang organs, and thus promote health. Benign emotional thought activity can be further divided into internal and external influences:

1. Internal benign thought activities stem from the inner Hun's influences over the subconscious mind. These positive thought patterns tend to enhance self-esteem, by complementing and encouraging our thinking and actions.
2. External benign thought activities consist of praise and encouragement received from others (parents, friends, co-workers, etc.), which have been accepted and believed. These positive thought patterns promote confidence and self-esteem.

Malignant Emotion and Thought Activity

This is a harmful belief structure causing excited, nervous, stressful, and unpleasant thought patterns that interfere with the performance of the cerebral cortex, resulting in internal organ dysfunction and disease. Malignant emotional thought activity can be further divided into internal and external influences.

1. Internal malignant thought activities are the thoughts stemming from the subconscious mind, which tend to destroy self-esteem, cause obsessions, and discourage productive thoughts and actions. This thought pattern extends from the influences of the Po.
2. External malignant thought activities are internalized negative cynical beliefs and criticisms that originated from the surrounding environment (work, parents, teachers, friends, mate, etc.). External malignant thought activities cause thought distortions that destroy our self-esteem and discourage us.

The Importance of Mind Concentration

An essential requirement for training the Qi is the training of mind concentration. If the concentration is forced, the Qi from the Lower Dantian rises up to the head causing the Stomach to become nauseated. If the Qi continues to ascend to the head, the result will be dizziness, headaches, and Qi deviations.

Thoughts and mental activities are reflexes of the brain and cerebral cortex. A Mind (whole body consciousness and awareness) agitated or depressed over a long period of time causes a long-term disorder to the whole nervous system, and leaves the body vulnerable to various kinds of chronic diseases. Long-term anger, for example, leads to the contraction of the blood vessels, sclerosis of the arterioles, gastric ulcers, and hypertension. Long-term emotional disturbances disrupt the endocrine system, and lead to a weakened immune system.

Psycho-neuro immunological research confirms that the Mind (whole body consciousness and awareness) can both cause and cure diseases. Healing visualizations sometimes act as a catalyst, increasing the rate of chemical reaction within the tissues. Improper concentration, however, can transform good Qi into Toxic Qi, and can lead to chemical imbalances that perpetuate the diseased condition. This is especially true when guiding and emitting energy.

According to medical statistics in China, with certain types of cancer, patients whose worry and

anxiety were the main cause of their disease made up about 52% of the patients. These patients had been emotionally upset for half a year before becoming sick. The focus of the patients' mental concentration was directed on detrimental thoughts. It is a fact that chronic diseases are closely related to the patients' thoughts, emotions, and mood swings. To treat chronic diseases, it is necessary for the Qigong doctor to first relieve the patients' depression, irritability, and resentment and then place the patients, when possible, in a quiet comfortable environment.

It is important for the patients to relax their Mind (i.e., mind and body). Relaxation can be achieved through tissue manipulation (massage), or by inducing meditations, or trance states. To relax the Mind the Heart must be regulated. To regulate the Heart means to adjust the agitated or depressed Mind and place it into tranquility. One of my teachers in China, Qigong Master Zheng Zhan Ding would often say, "When the spirit, like a lake, is undisturbed, it mirrors the Heavens perfectly." Meaning that, the clarity of the Mind emerges gradually (or slowly) when entering into stillness, much like mud slowly settling in water. This allows ones true inner nature to be revealed.

According to research published by Dr. Karl Lashley, specific memory is not located in any one place in the brain. He found that destroying a portion of the brain does not destroy the memory assigned to that specific area, and also that memory could not be located in specific brain cells. His observation is that memory is distributed all over the brain as an energy field. Other researchers have made similar observations that support the conclusion that the human brain functions as a hologram, collecting and reading information from a holographic universe.

REGULATING THE MIND

Mental Dao Yin training involves regulating the Mind. This requires the Qigong doctor to diminish the mental activities (or judgements) of the Zhi Shen to prevent interference with the intuitive understanding of the Yuan Shen. The diminished mental activity allows for true relaxation, peace, and inner tranquility.

If the Zhi Shen is allowed to become unbridled through excessive internal chatter, it can become injured by the Excess accumulation of energy attributed to the Seven Internal Emotions: anger, worry, joy, fear, fright, sorrow, and grief; as well as the Four Desires that become pathogenic when in Excess: sex, money, fame, and power. These Seven Internal Emotions and Four Desires engage the mind, robbing the body of its life-force energy by depleting the Yin and Yang organs, disrupting their balance, and causing obstruction in Qi and Blood circulation that results in disease.

All thoughts carry within them emotional reactions, these in turn have a significant physiological as well as psychological effect on an individual's health. The degree of intensity as well as the frequency of returning thoughts determines the extent of the internal transitions experienced in the individual's body.

To illustrate this difficulty, when I began my initial Qigong training, my instructor informed me that the internal training would keep me warm in the winter and cool in the summer. Excited about the possibility of possessing my own internal air conditioner, I practiced diligently.

After three years of difficult training I had not yet developed this ability. I slowly began to lose trust in my instructor, and approached him to inquire about the promised skill. He informed me that it was the "imagination" that changes our thoughts and belief structures, enabling the body's tissues to feel what the mind directs. Stating that, "The Imagination leads the mind, the mind leads the Qi." My teacher further stated, "Whenever training in the summer when the heat is unbearable, focus your mind on the coolness of the sweat and imagine the air around your body as a cloud of cold air. In the winter time, when the cold is severe, focus your mind on the heat that your body is producing and imagine the air around yourself as a circle of hot fire." After applying these principles to my training, I experienced both the warmth and cool sensations that I was trying to achieve, and regained trust in my teacher.

Thoughts and emotions create electromagnetic waves in the brain. Your breath can also create or control these waves and cause your mind to take

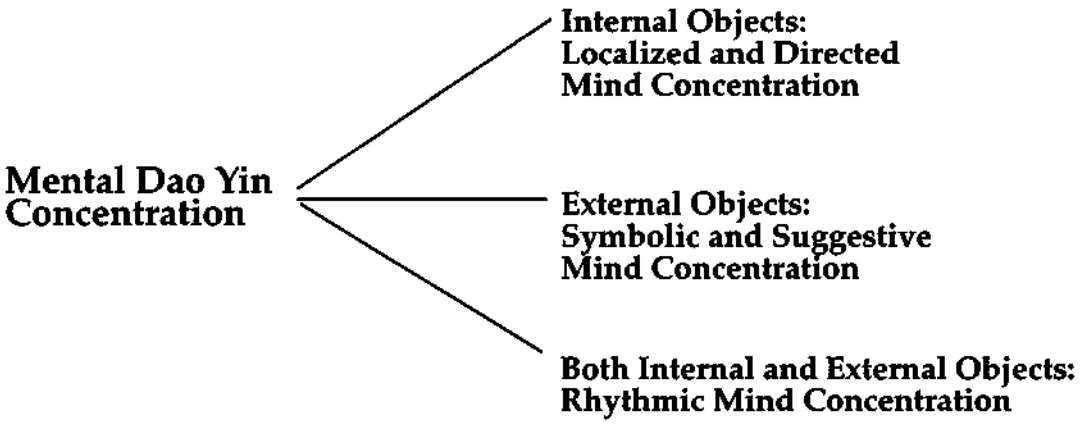

Figure 17.3. The Three Categories of Mental Concentration

on the thought wave patterns of specific emotions. When the mind is tranquilized after certain Medical Qigong exercises, all disturbances stop, there is a quiet and comfortable feeling sensation (produced by the deep inhibitory state of the cerebral cortex) that facilitates the expansion of consciousness and awareness throughout one's entire being. This state of being is referred to as the Mind.

The Three Categories of Mental Concentration

Mental Dao Yin training can be summarized by the following three foundational modalities: concentrating on internal objects, concentrating on external objects, and concentrating on both internal and external objects (Figure 17.3).

These three modalities of mental concentration encompass regulation of both the benign and malignant emotional thought activities which influence our everyday lives. People focus their mental concentration everyday on either benign or malignant internal objects (inner thoughts and feelings), external objects (outer thoughts and feelings), or engage in both internal and external thoughts and feelings through conversation.

Concentrating on Internal Objects

In China, the method of concentrating on internal objects is called "localized" and "directed" mind concentration. In this type of training, the mind is absorbed in concentrating on a specific area of the body. Patients, for example, are directed to focus their eyes downward along the nose in the direction of their navel, while simultaneously using inner-vision to concentrate on their Lower Dantian. Patients can also focus their concentration on other external or internal areas of the body such as:

1. The palms or feet to lead Excess Qi away from the head or torso.
2. A specific channel point (called "energetic point therapy") or pathway, to direct Qi into or away from specific areas of the patient's body, or
3. A Yin or Yang organ to direct Qi into or away from specific internal organs.

The ancient Qigong Master Li Shizhen once said, "When the mind is concentrated upon the inner channels, the practitioner is able to look within his own self." Qigong doctors and patients who are energy sensitive can feel the channels along which their own vital energy flows. This sensitivity is experienced in the more advanced stages of tranquility.

Concentrating on External Objects

In China, the method of concentrating on ex-

ternal objects is called "symbolic" and "suggestive" mind concentration, and is focused through vivid imagery. In this type of training the patient's mind is absorbed in concentration on some form of object outside of the body. As the mind enters a state of tranquility, it focuses through vivid imagery, or energizes through sound vibrations. Some excellent examples of external objects are: music, the sound of rain or water flowing, a calm ocean, the sky, clouds, light, sound vibrations, mantras, a golden or white glowing ball, specific colors, trees, etc. In this type of concentration, the patient's internal vibration connects with and matches the external form of some object in nature or some specific symbol (such as a lit candle).

When focusing on external objects, it is important for patients with high blood pressure to choose low lying objects, such as a meadow, quiet stream, flower, etc. Patients with low blood pressure should choose objects that are eye level, such as a small pine tree, to balance the energy of the Heart.

When practicing this particular method of mental concentration it is important to focus on external objects that can be physically observed without straining. This way if distracting thoughts interfere with the concentration, the patients can return to the real image, or sound, to reestablish their concentration. The focus should never be forced or too intense. Dr. Xu, of the Xi Yuan Hospital in China, once stated, "In the state of emptiness you will see an image through your imagination. This image will arouse your emotions. These emotions help you to form a more colorful image. From these colorful images you will obtain a deeper state of emptiness. This is the state of Mind sought after in order to obtain emptiness and maintain tranquility." In this particular case the patient's mind is like still water, free from expectations or desires. In quietness you become the observer of images, allowing what will unveil itself to occur naturally.

Concentrating on Both Internal and External Objects

These methods employ "rhythmic Mind concentration" and are the primary methods used in Medical Qigong therapy. They are simple, easy, safe, and effective. In this type of mental training, the patient's body responds to their thoughts. Patients focus their attention on the breath as it flows in and out of the body, listening to the sounds of their breathing and sensing the expanding and contracting movements of their abdomen. During this type of mental concentration the patients are sometimes given a mantra, such as thinking the word "quiet" during the inhalation and "relax" during the exhalation, or they are instructed to silently count numbers. Sometimes, the patients are also directed to imagine the feeling of quietness, like a mist, flow from their feet into their head (absorbing quiescent Earthly Qi), or from their head down into their feet (absorbing quiescent Heavenly Qi).

When first teaching patients the methods of mind concentration, keep the images simple. When the patients have recovered from their illness, they can begin to concentrate on either an internal or external object to further strengthen their health.

Essentials of Training Mind Concentration

These three mental Dao Yin techniques can be utilized to their full potential once the Qigong doctor understands the essentials of training the mind, the three stages of mental tranquility, and the skill of regulating the mind.

Mental activities should be coordinated naturally with respiration and posture. In Dynamic Qigong Dao Yin exercises, for example, mental activities must be adapted to the posture and the lifting, opening, and closing manipulations of the hands. When using an active (Yang) posture (if the goal is to regulate the patients' Qi), the inner concentration should be motionless (Yin). The ultimate goal is to combine both physical and mental activities that promote harmony in the body's energetic fields. The Qigong doctor should monitor their patients' mental concentration, making sure that they comprehend the following three concepts: Relaxing the Mind, Being Self-Confident, and Being Mentally and Emotionally Stable.

1. The purpose of relaxing the mind is to allow all mental activities to be carried out (without straining) in a composed state of mind. The mind should be kept clear and all distracting thoughts expelled gently. During concentration, the mental focus should never be forced. Mental concentration can be either strong (active) or mild (motionless).
2. Self-Confidence is a prerequisite, for without it, the training of mind concentration cannot happen. No matter what kind of mental activity the patients train in, they should be confident that they can reach their goal. This establishes a strong faith, which is the root of all mental Qigong projection abilities. Patients should also be realistic about not expecting quick results. Although miracles do happen, healing often takes time. The dynamic or active postures and exercises train the body's Qi, while quiescent or motionless exercises sustain and nourish the patients' Qi.
3. The purpose of being mentally and emotionally stable is to assist patients in not becoming overjoyed or frightened if something unexpected happens, or is perceived, during the Qigong exercise. It is important that patients take advantage of this time to keep their mind concentrated and the Qi consolidated. If patients feel weary, remind them that sleep and food can reinforce their mind and Qi.

CONCENTRATIVE MEDITATION AND INSIGHT MEDITATION

When Medical Qigong practitioners begin their meditative practices, they are generally encouraged to keep their mind focused and under control, this is known as "concentrative meditation." Concentrated power is manifested through silence; when the mind is noisy (distracted by physical sensations and chatty), the internal power becomes diffused. When Qigong doctors reach the place of silence in their Mind, they can connect with the divine power, a place of true power, and a place where "all is one." Through concentrated intention, Qigong doctors can bring all of their energies to bear on one point of focused power or force. At the same time, they contact and connect with the divine in silence (the hookup), and become one with the divine healing power.

This transition and conscious union with the divine occurs only when the Qigong doctors turn from the chaotic external world of sensory input (sight, hearing, smelling, etc.), to the quiescent state of silence. This divine energy is then manifested as power, substance and true intelligence, flowing through the Qigong doctors for healing.

Contact with the divine is only obtained in the deepest part of silence. Within oneself, and within this silence abides a state, or dimension, where the true "Gate of Heaven" can be opened and enlightenment obtained. Ideas conceived in this divine state of consciousness come into expression and can manifest as form. All Jing, Qi, and Shen can be transformed and transmuted into form, through this change in consciousness. When the doctor's Intention (Yi) and Will (Zhi) are aligned with the Dao (or divine will) all things are possible. The doctor is in direct contact with the universal Mind, and can manifest in physical form, that which is needed through faith. The divine energy resides within the body's Eternal Soul as power, substance, and intelligence and is brought into form and expression through consciousness. The degree to which the doctor can tap into and utilize the consciousness imbedded in the infinite Mind of the divine, is determined by the concept, or belief, that is held in the doctor's as well as the patient's conscious and subconscious mind.

In the silent state of quiescence, when the Qigong doctor sees a mental pattern or mold, a template is created into which will flow the substance (Qi) needed to bring it into being. The pattern will manifest into the form intended by the doctor's consciousness. Through the power or process of faith and thought, the doctor (or patient) can transmute and evolve the body or outer conditions and surroundings, by recognizing the divine consciousness within themselves.

As the practitioners advance in ability, they are encouraged to focus their attention indiscriminately on all sensual stimuli they receive, this is known as "insight meditation." In practicing insight meditation, practitioners are encouraged to

reevaluate their experiences and world views according to the cause and effect of their disease(s). Patients are also taught to use this type of insight to observe their physical and mental processes. This self-observer is used as a vehicle through which to observe, scrutinize, and carefully examine the fundamental energy transformations within the body for spiritual growth.

THE THREE STAGES OF MENTAL TRANQUILITY

Before the mind surrenders to a state of tranquility, it must first transition through three stages. The Qigong doctor must experience all three of these stages in his or her effort to become effective when treating patients. In China, Qigong masters have a saying, "When you root the Mind, the Heart will open up to ten thousand voices." This means that when the Mind is removed from all distractions and excess chatter, the Yuan Shen is free to receive intuitive perceptions. This state of "tranquility" or "stillness" also dissolves time perception, allowing time to disperse into nothingness (Wuji). The three stages of mental tranquility are described as follows:

STAGE 1

In the first stage, the doctor's four extremities and Lower Dantian may experience heat and tingling as the mind slowly eliminates distracting thoughts and begins to withdraw from the external world. The doctor's mental focus and concentration, however, is not consistent. While emitting Qi, distracting thoughts still emerge, and the doctor must patiently wait for the chattering mind to subside.

In this stage of training, especially in male Qigong doctors, the cognitive, analytical thinking and speaking may sometimes become sporadically impeded. This is due to the thin energetic field within the corpus callosum that separates the right (intuitive) from the left (analytical) hemispheres of the brain. This makes it more difficult for men to access both hemispheres simultaneously. Men should therefore train to rely more on their intuitive perceptions instead of analyzing (they must feel the energy, and not think it).

This however, is not a problem in female Qigong doctors, as the energetic field which separates the corpus callosum is much wider and already active. This allows female Qigong doctors to easily access both sides of their brain simultaneously, enabling them to draw upon the perceptive, intuitive as well as cognitive, analytical thinking and speaking hemispheres of their brain.

STAGE 2

In the second stage, there is an increase in heat to all four of the doctor's extremities from the Lower Dantian. Through intention, the connection to the Lower Dantian is strengthened and the body's Qi feels like a rushing wind flowing throughout the doctor's torso.

While diagnosing and treating, the doctor experiences one or several of the patient's "eight manifestations of Qi" (also called the Eight Energetic Touches). These manifestations consists of the following physical and sensory phenomena of energy: shaking, rippling, heat, coldness, sinking, floating, itching, and heaviness. As the doctor focuses on extending energy, he or she will be able to remove internal distracting thoughts, but will still hear the distracting sounds from the external world.

STAGE 3

In the third stage, all of the doctor's sensory input (seeing, hearing, tasting, touching, smelling, and perceiving) is sealed from outside distractions. The doctor's Yuan Shen and Zhi Shen are now relaxed and in a state of mental tranquility. The Qigong doctor can now approach the patient free of chattering thoughts, judgments and all outside distractions. This enables the doctor to intuitively perceive and sense the patient's energetic traumas, stagnations, deviations, and energetic clusters.

THE THREE PROCESSES OF THE MIND

The mind can be divided into three separate but interdependent processes, which are responsible for our everyday actions, responses and health (Figure 17.4). Thoughts, ideas, and feelings are constantly being implanted, influencing and affecting the spiritual, emotional, mental, energetic, and physical process of healing. The heal-

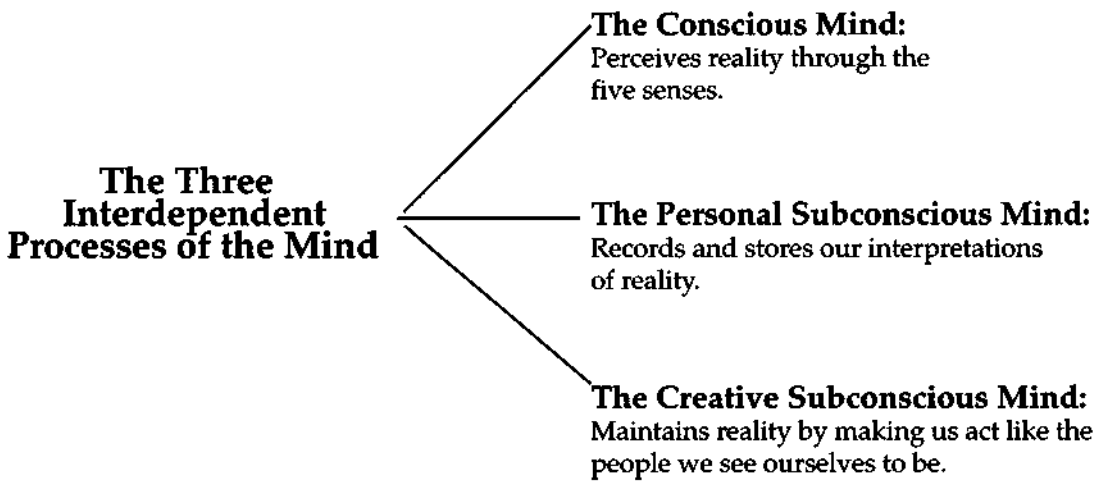

Figure 17.4. The three interdependent processes of the Mind, which are responsible for our everyday actions.

ing process includes reprogramming and regulating the conscious, personal subconscious and creative subconscious mind.

1. The Conscious Mind perceives reality through the five ordinary senses. It evaluates reality by investigating and interpreting the data through the filter of the past experiences. The conscious mind makes decisions based on personal goals, and manifests conscious thinking patterns. It is considered to be the Postnatal Mind (related to the Zhi Shen).
2. The Personal Subconscious Mind records and stores the conscious mind's interpretations of reality. It consists of the personal, perceptual data that were received through our five senses. The personal subconscious mind shares responsibility for how we think, what we say and imagine about ourselves and our emotional and behavioral reactions to those experiences. It is also responsible for the automatic function of the living mechanism (i.e., heartbeat, breathing, digestion, etc.) through its energetic connection to the autonomic nervous system. It is considered to be influenced by the spiritual aspects of the Wu Jing Shen (especially the Hun and Po).
3. The Creative Subconscious Mind maintains our reality by making us act like the people we see ourselves to be. It solves problems and provides the drive and energy to succeed or fail, heal or become sick. It is the center core energy of our innate spirit or soul consciousness. It is considered to be influenced by the spiritual aspects of the Yuan Shen.

CREATING THE BRIDGE OF LIGHT

The Bridge of Light is an energetically patterned wave frequency which consists of three main components of the body's energetic field. Its energetic connection to the body's tissues functionally envelops the conscious, personal subconscious and creative subconscious mind, and is considered to be the bridge between the three process of the mind. It consists of three separate but intertwining threads: the thread of life, the thread of consciousness, and the thread of creativity.

1. The thread of life comes directly from the Eternal Soul and is rooted in the Heart during conception. It is connected to all feelings that stem from the divine higher energy field and is considered the "seat of life."
2. The thread of consciousness also comes directly from the Eternal Soul and is rooted in the pineal gland within the brain. It embod-

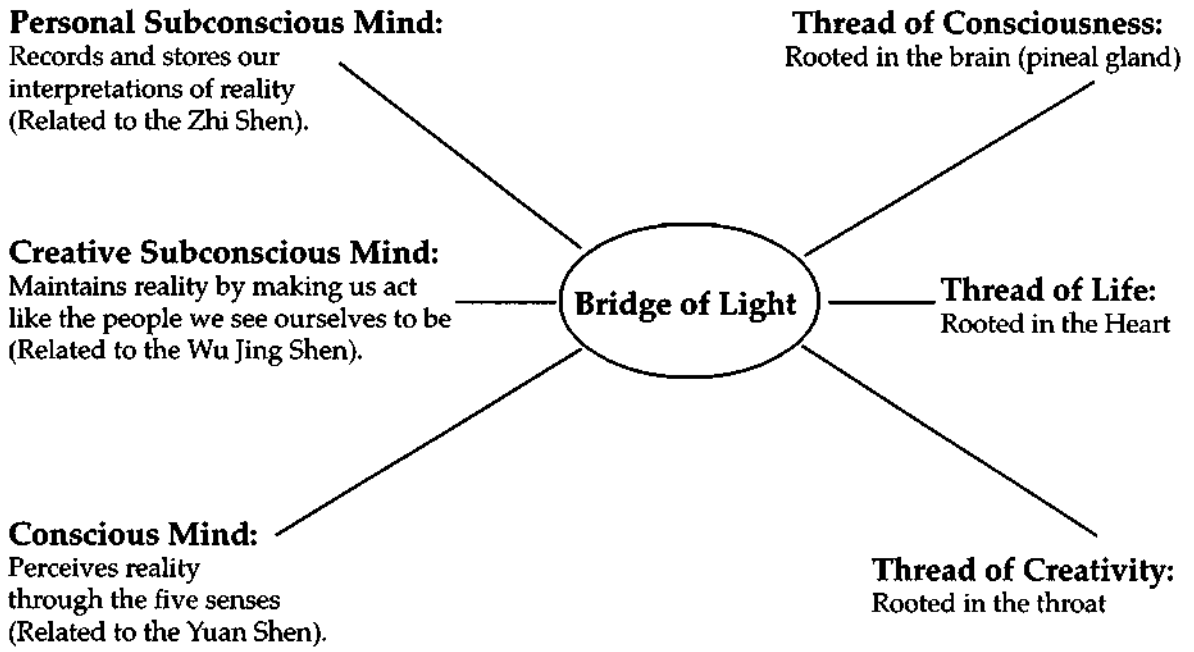

Figure 17.5. The Bridge of Light

ies portions of the energies of consciousness and is considered to be the "seat of consciousness."

3. The thread of creativity is rooted in the throat and is unique in that it is created and specifically constructed by each individual. It is also an extension, or synthesis, of the thread of life and thread of consciousness.

   The thread of creativity is in itself made up of three main components. These three components, or additional threads, intertwine as one unified thread of creativity and are explained as follows.

   a. The first portion of this thread extends from the physical Heart to the Spleen, and is connected from the body to the first external field of Wei Qi.
   b. The second portion of this thread extends from the solar plexus to the Heart and eventually extends and connects from the body to the second external field of Wei Qi.
   c. The third portion of this thread extends from the Yintang (Third Eye) through the brain, ascending through the Baihui region and beyond. This energy field is connected from the body to the third external field of Wei Qi.

After all three threads of creativity have been activated, energized, and developed, the next goal is to align and integrate the Qi of the thread of life and the thread of consciousness, with the frequencies of the thread of creativity.

Because the thread of life is connected to the Eternal Soul, the integration of the three threads allows an individual the direct connection to his or her core self (Figure 17.5). This enables the individual the ability to consciously access his or her true inner voice (the voice of his or her soul) and receive information and guidance from the divine. The goal in accessing the Bridge of Light is to unite these three energetic threads into one powerful and functional energy field.

When all three major threads (which compose the Bridge of Light) are connected as one harmonious cord of light (extending upward through the Taiji Pole), a spiritual gateway is opened that enables access to the Pure Heavenly Sound (also

known as Hearing the Sounds of the Universe) (see the Six Transportations of Shen in Chapter 13).

REPROGRAMMING THE MIND TO HEAL

The mind holds specific energetic patterns which maintain a patient's physical, mental, emotional, and spiritual belief structures. These patterns are maintained by the dictates of the personal subconscious mind and can only be changed when the creative subconscious mind is engaged.

To change specific destructive patterns, the personal subconscious mind must be reprogrammed. There are three things that are needed in order to reprogram the personal subconscious mind: imagination, visualization, and positive affirmation. Imagination combines with vivid pictures, sounds, sensations, etc., and creates a new reality on a creative subconscious level. It is the awakening to this new reality that reconnects the individual to the creative subconscious mind.

If patients do not use imagery and affirmations to change their present personal subconscious representation of reality, the patient's personal subconscious mind will automatically seek to correct any newly made change. The personal subconscious mind views any new deviation from the normal energetic pattern as a mistake, and will automatically resist, or sabotage, any change of pattern, returning the patient back to his or her original state of mind and body sickness.

It is a simple fact that "we bring about what we think about," and act in accordance with the truth that we have come to believe. If we act out of a particular new state of mind and feeling over a sufficient time period, it will become a permanent reality of the self. In using the mind to make transitions, it is important to note that words, images, and sensations have tremendous power, and the spirit behind the intent is the key to any permanent transformation.

Because patients trust their doctor, it is the doctor's responsibility to direct the patients into a healing mental state for the purpose of restoring health. The doctor must never be guilty of "clinical hexing." Clinical hexing occurs when a patient (who completely trusts the doctor) is told by that doctor, that there is no hope. The patients, believing the doctor, may give up their desire to change and heal. Thus, through accepting the inevitability of death, they suppress their desire to live. Qigong doctors are therefore taught to always encourage their patients on their recovery, and to never destroy their hope.

Through positive affirmation and reinforcement, it is possible for the patients to turn around the progression of their disease. Scientific studies in China have proven, for example, that through imagination, visualization (which include using all of the five senses) and positive affirmation, the rate of phagocytosis (the ability of the immune cells to engulf and destroy invading germ cells) greatly increases and enhances the body's immune function.

USING THE IMAGINATION

The Yi (which consists of the imagination and intention) leads the Shen (composed of the thought, emotion and spirit) which in turn leads the Qi (the body's life-force energy). The power of the imagination has a strong influence on health, and can be used to help cure diseases, or to further complicate the condition. If, for example, patients imagine that their immune cells are effectively destroying the cancer cells, Western medical treatments such as chemotherapy or radiation can become more effective. Research from China reveals that patients with a positive belief structure produce certain physical transformations, which manifest in the increased production and release of hormones and immune cells. The imagination is the inner form of all things, the primal inspiration from which reality later manifests. In a sense, patients bring about what they think about. While treating disease, Qigong doctors encourage their patients to imagine healing energy from the divine being directed into the diseased area. Once the treatment is finished, the patients are instructed to imagine that their disease has become completely healed.

During the state of relaxed meditation, the foundational aspect of the patients' disease, which is normally hidden from consciousness, reveals itself in the form of images and impressions. After a Medical Qigong treatment, or meditation, the patients

may describe to the doctor any unusual thoughts, images, or feelings that they may have experienced while in the deep state of relaxation. The doctor then helps the patients find the origin of the image (a past incident, unhealthy belief structure, or trauma, etc.) through the doctor's ability to trace the images and emotions associated with it to the patients' internal organ or organ systems involved in the creation of the illness. Once the connection is made to the patients' disease, and the Medical Qigong homework is prescribed.

Medical Qigong prescriptions initiate energy movement. This energetic movement brings about the release of trapped emotion and energetic feelings. As the emotions unravel, a new level of awareness surfaces that allows the patients to become cognizant of certain mental functions that were previously unconscious. This awareness in turn allows patients to access their creative subconscious Mind to change the conditioned programming of their Zhi Shen (Figure 17.6).

Through creative imagination, the patients' spirit is expressed and the patients' body is spiritualized. The imagination is an energetic world founded on the interrelation of various levels of spiritual, imaginative and physical realities. These energetic dimensions lie between what the Chinese call the "realm of the unfathomable hidden mystery" and the "world of animated physical forms." The imagination is an energetic and spiritual world that exists between the reality within oneself, and the reality outside of oneself. This energetic and spiritual world seems imaginary, but in fact it is very real, in that the patients live in it, and through it create a new belief system and self.

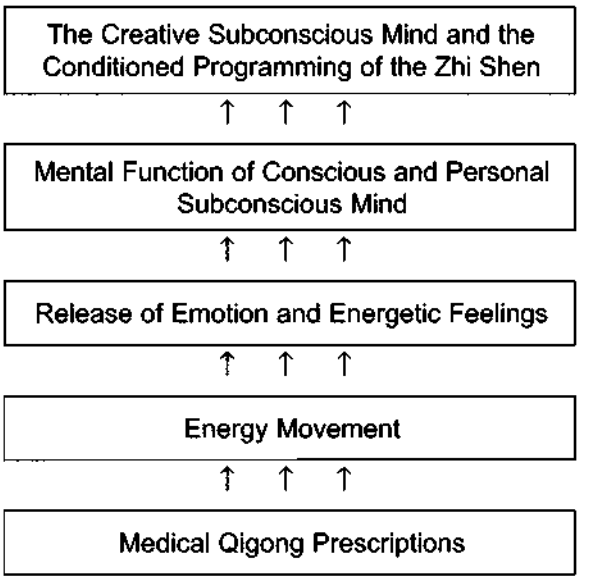

Figure 17.6. Five stages of transition and energy awareness allow patients to access their creative subconscious energy in order to reprogram their initial belief structures.

TWELVE STAGES TO TRANSCEND AND TRANSFORM

During the Ming Dynasty there began to surface twelve specific poems accompanied with twelve pictures, describing the twelve stages to enlightenment through contemplation. In this series there are ten pictures which describe the first ten stages of mental, emotional, and spiritual transcendence, and two additional pictures which describe the last two stages of mental, emotional, and spiritual transformation. These pictures and poems use the image of the ox (water buffalo) to describe man's animal nature, which in the first stage of spiritual training is identical to man's spiritual nature. The image of a young man is used to depict human intention and will. The interaction of the ox and young man reflects the idea that by coming to terms with our own animal nature, we can move toward transformation and arrive at a new way of being.

The images of the ox changing from dark, Turbid Yin, to bright, white Yang, represent the field of consciousness transforming through the controlled deliberate intention of one's Zhi (Will). Such metaphors as capturing and controlling the ox represent an explanation of the difficulties and dangers of transforming one's self, as well as the inner changes of alchemical purification and the reconciliation with one's darker side. These pictures suggest the combination of both the sacred and the natural within Man.

These stages of controlling the mind are described as follows.

1. In the wild, the first stage of training is divided into three separate phases:
   a. The Searching for the Ox phase depicts the state in which the young man is unaware of his own true nature. Although he is not sure what he is seeking, he has begun searching for something he is desperately missing within his life. He is in a state of omnidirectional searching, without an instinctive direction.
   b. The Finding the Tracks phase depicts the young man undergoing the first traces of mental, emotional and spiritual transformation. Realizing that other people have walked along this path, the young man begins to rediscover his own spiritual instincts. He is in the beginning phase of achieving focus and direction.
   c. The First Glimpse of the Ox phase depicts the young man experiencing his first "awakening." He has the first glimpse of the true union of nature and spirit in the form of a spiritual vision. The animal nature, however, is still uncontrollable and in the wild state (due to its connection to the painful memories of the past). The young man must chase after and entice the ox, which displays its horns, bellows aloud, runs away, and is overshadowed by a dark cloud (anger, despair, grief and fear). It tramples the wheat seedlings (beginning moments of spiritual insight) wherever it goes. In this phase the ox is unruly, Yin, and pure black in color (Figure 17.7).
2. The Initial Training Begins with this next stage. The ox is controlled by a rope through its nose, and runs swiftly under the young man's whip. The young man struggles hard to control the ox's willful temper. He begins talking and listening to the ox, matching its consciousness with his own. At this stage the ox is still Yin, and pure black (Figure 17.8).
3. The Ox Comes Under Control through con-

Figure 17.7. The Ox is in the Wild

Figure 17.8. The Initial Training Begins

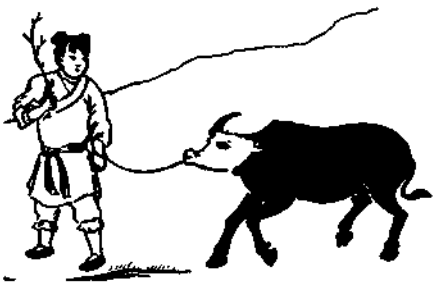

Figure 17.9. The Ox Comes Under Control

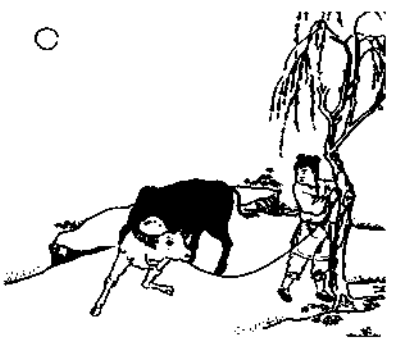

Figure 17.10. A Time of Transition

stant training. The ox stops its dashing about, and begins to follow the young man. In spite of his fatigue, the young man tends the ox all day long, not daring to loosen his control of the whip or his grip on the rope. Gaining control of the ox requires the young man to also become more vulnerable and honest, using less force to control the situation. In this stage only the ox's head, which is under control, is Yang and white, the rest of his body is Yin and black (Figure 17.9).

4. During the Time of Transition, the young man feeds and takes care of the ox with respect. He also does not abuse it. At this stage, the natural strength of the ox harmonizes with the will of the young man. A long time has passed and the restless temper of the ox gradually has turned gentle. However, still not trusting the ox, the young man maintains control of the rope. The ox is one third Yang and white and two thirds Yin and black (Figure 17.10).
5. The Ox Is Now Tamed and moves in harmony with nature. It follows the young man, who no longer uses a rope to lead the ox, but still maintains control of the whip. The ox is half Yang-white and half Yin-black (Figure 17.11).
6. The Ox Is Freed of Worldly Hindrance. The ox no longer needs the whip for control. The young man can begin to experience and enjoy the inherent rhythm of life, because he now has the ox's undivided attention. The ox is three quarters Yang-white and one quarter Yin-black (Figure 17.12).
7. The Ox Is Under Complete Control. After a long stage of struggling against its instincts, the ox is now tamed and free from worldly distractions. It drinks when it is thirsty and eats when it is hungry. The young man can now enter into deep sleep. If he so desires, he can sit atop the ox and play his flute, because the ox knows where its going and the young man does not have to direct it. The ox is now completely Yang-white (Figure 17.13).
8. The Young Man and the Ox Unite With Heaven. The white ox wanders among the heavenly clouds. The young man is free from

Figure 17.11. The Ox Is Now Tamed

Figure 17.12. The Ox Is Freed of Worldly Hindrance

Figure 17.13. The Ox Is Under Complete Control

Figure 17.14. The Young Man and the Ox Unite With Heaven

worldly concerns, and so is the ox. Penetrated by moonlight, the Heavenly clouds grow whiter and drift away (Figure 17.14).

9. The Ox Transcends and A Single Light Remains. The clouds drift away and the ox vanishes. The young man finally enjoys his leisure time, singing under the moon (Figure 17.15).
10. Both the Ox and Young man Transcend and Return to the state of Wuji. As the moon continues to illuminate the vast void, both the young man and the ox vanish into Wuji and are nowhere to be found. Everything is formless, quiet, and pure. Existence is nonexistence and vice versa (Figure 17.16).
11. The Young Man and Ox Transform and Return to the Source. There is a difference between transcendence and transformation. Transcendence is a temporary or periodic experience of unity within the divine, the heavens and the earthly environment. It is a state, or condition of consciousness. Whereas transcendence implies a unifying experience that informs one of a new way of being, transformation is a process and a means to arrive at a new way of being. Mature transformation leads to an all-inclusive way of being that embraces the physical, mental, emotional, energetic, and spiritual existence of everything. In this stage man returns back to the original source of prenatal understanding, and is able to harmonize with Heaven and Earth (Figure 17.17).
12. The Young Man and Ox Transform and Live in the World. This stage depicts what happens after the transformation experience, and the reentry through nature into the everyday world. In this stage, man reenters the world as a transformed person with a new connection to his center core. He is able to become a guiding light to others. When needed, he can instantly return to a deeper state of enlightenment for additional instruction and personal guidance. Living in the world he can be in the seductions and temptations of the world, without being in any way affected by them (Figure 17.18).

Figure 17.15. The Ox Transcends and A Single Light Remains

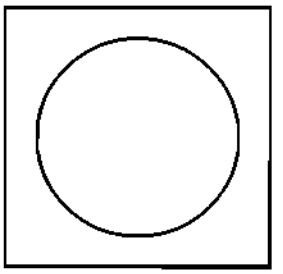

Figure 17.16. Both the Ox and Young Man Transcend and Return to the State of Wuji

Figure 17.17. The Young Man and Ox Transform and Return to the Source

Figure 17.18. Transformation and Living in the World

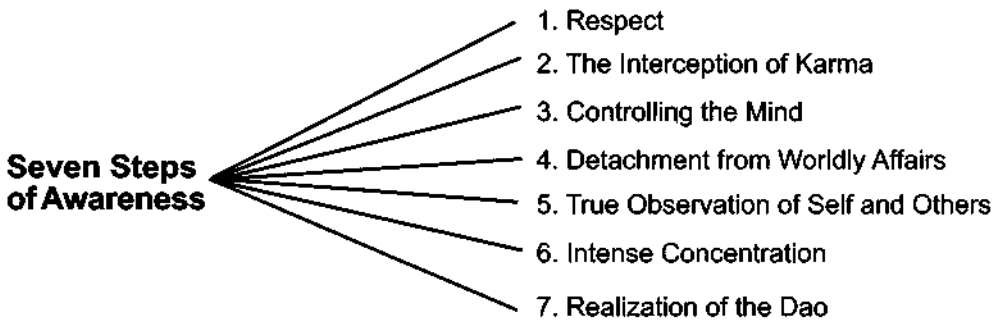

Figure 17.19. The Seven Steps Needed to Transform the Mind

SUMMARY

During mental, emotional and spiritual transformations, individuals undergo stages of physical and psychological purification, as they begin to experience the active, conscious introspection into their mind, body and soul. These individuals are able to eventually identify and connect their own personal will to that of the divine, and begin to lose their attachment to the ego, developing a new and more expansive identity. These individuals will also begin to see themselves as truly spiritual beings that are merely housed in fragile, physical frameworks, which are subject to all the transformations that their spirit must transcend. Generally, when using Medical Qigong as a vehicle for transformation, individuals will evolve through seven steps to awaken the spirit and reach a stage of enlightenment: Respect, The Interception of Karma, Controlling the Mind, Detachment from Worldly Affairs, True Observation of Self and Others, Intense Concentration and Realization of the Dao (Figure 17.19).

1. The first stage, Respect, encompasses the self, others and the divine. Through the cultivation of respect a stronger faith develops.
2. During the second stage, The Interception of Karma, individuals begin to accept accountability for all their actions, deeds, and thoughts. At this stage individuals receive instant karma for all their actions.
3. During the third stage, Controlling the Mind, individuals begin to discipline their conscious actions (Taming the Ox).
4. The fourth stage begins the process of Detachment from Worldly Affairs. At this stage individuals begin to develop and maintain a spiritual priority.
5. The fifth stage of True Observation of Self and Others, enables individuals to perceive themselves and others clearly. At this stage they begin perceiving the universe and environment from a deeper, more spiritually evolved understanding.
6. The sixth stage involves the development of Intense Concentration. At this stage individuals transform thought, through faith, into manifestation. They can now initiate into reality what they focus their intention on.
7. In the final stage to transformation, Realizing the Dao, individuals become aware of their relationship with the divine, not only believing in God, but personally knowing God or the Dao.

Section IV
Qi Deviations in Qigong Training

Chapter 18
Introduction To Qi Deviations

Energetic deviations occur naturally through the course of everyday life, however, the body's energetic constitution quickly corrects any disharmony in energy flow. The difficulty when cultivating Qi is not in the development of large amounts of energy, but in the creation of a constitutional system strong enough to use this energy without being damaged by it. This is one reason why Qigong doctors initially spend a lot of time developing the safety measures and internal reservoirs necessary to ensure that their body will not be damaged by creating too much energy too fast. These alterations of energetic patterns can result in feelings that can range from simple discomfort to an abnormal susceptibility to disease. Through proper Medical Qigong therapy, Qi deviations can be rectified.

Qi deviations can be precursors to disease. In recent years, medical researchers in China have reported that some patients admitted to the Medical Qigong clinics had developed mental as well as physical disorders as a result of Qi deviations. A deviation refers to abnormal phenomena occurring within the patient or Qigong practitioner. The clinical symptoms include abnormalities in perception, thinking, and behavior.

If the Qigong doctor has not been adequately trained in internal purging techniques, his or her body's increased energetic field can act as a magnet and begin to attract the toxic energy from the surrounding environment (including the patient's pathogenic Qi). Once toxic energy enters into the body, it can immediately create a Qi deviation. Qi deviations should be treated immediately if possible. If Qi deviations occur during Qigong exercises or meditations, the practitioner should stop the practice immediately and guide the Turbid Qi (and bad feelings) out from the body, discharging the toxic energy out through the four extremities and into the ground.

The process of Medical Qigong meditations and exercises is said to cause an alchemic transformation of Shi Shen (Turbid Spirit) into Yuan Shen (Original Spirit). This transformation occurs when first beginning Qigong practice, at the "laying a foundation" stage of the workout. If the Turbid Qi is not removed at the beginning of practice, the Qi concentrated in the Dantian areas (or other parts of the body) will also become Turbid. This may bring about internal disturbances when the practitioner encounters unfavorable external factors such as suddenly being startled or becoming angry. Too much concentration and hard focus on the exercises and meditations can also lead to Qi deviations. Turbid Qi can create Turbid Shen.

When Turbid Qi travels along the Governing Vessel to the head, there is a feeling of heavy pressure in the head. In severe cases, psychosis can occur. Turbid Qi that escapes into the body's channels can result in distending or numbing of the body. To avoid such side effects, it is extremely important to establish an equilibrium between the Five Yin Organs. No matter which Medical Qigong system is followed, the primary task is always to dredge or purge the channels of pathogenic Qi, to regulate the Yin and Yang organs and to cultivate the body's Jing, Qi, and Shen.

The Main Causes of Qi Deviations

Mental disorders and personality disorders may exist in some individuals prior to their study of Medical Qigong. Sometimes, individuals with a family history of psychosis and certain other mental disorders (such as bipolar disorder and depressive disorder) may be more predisposed towards these diseases. The practice of Medical Qigong meditations and exercises may trigger the onset of symptoms in predisposed individuals, especially if Qi deviations are not properly addressed.

1. A Week Constitution	From severe disease and weak respiration
2. Improper Dao Yin Qigong Regulation	From forced practice, hastily and indiscriminately training
3. Disbelief and Suspiciousness	From a closed mind, superficial mind, or preoccupied mind
4. Too Much Mental Concentration	From concentrating too hard, resulting in Qi and Blood to stagnation

Figure 18.1. The Main Causes of Qi Deviations

The main causes believed to contribute to Qigong deviations, according to research gathered by Dr. Wei Lin Shen of Shanghai, China, include the person's constitution and pathological state, improper Dao Yin Qigong regulation, disbelief in and distrust of the Qigong exercises and meditations, or too much mental concentration (Figure 18.1).

1. A week constitution can lead to a pathological condition. Patients with a weak constitution should not be required to sit or stand for long periods of time. Patients with severe disease and weak respiration incur Qi deviations if they are allowed to stand too long.
2. Improper Dao Yin Qigong regulation can result in Qi deviations. Qigong deviations may also occur as a result of forced practice (when the state of illness does not allow relaxation), or when individuals hastily and indiscriminately train in the techniques that circulate internal Qi. Lack of proper instruction from a qualified master of Medical Qigong therapy often results in a failure to train in the correct way. The failure to correctly apply the three Dao Yin principles and methods (proper regulation of the body's Jing, breath's Qi, and mind's Shen) in training practice, for example, leads to Qi deviations. Creating new techniques, training recklessly before mastering the primary techniques, or changing the techniques at random can also result in Qi deviations. For this reason the practitioners should be patient when practicing Dao Yin regulations. The goal is to achieve a tranquil, quiet, and empty state.
3. Disbelief, and suspiciousness can induce Qi deviations. Disbelief or an inability to adopt a correct attitude toward Medical Qigong effects (such as extreme suspiciousness), results in mental tendencies that will become deviations over the course of time. Qi deviations can result from: A Closed Mind, A Superficial Mind, and A Preoccupied Mind.
    a. A closed mind, full of fear, pride or bitterness may prevent the patients from connecting with their True Self.
    b. A superficial mind, or lack of commitment and belief in energetic healing, may cause the patient to fail in taking the Medical Qigong prescriptions seriously.
    c. A preoccupied mind may cause the patient's spirit (Hun) to "wander off" while practicing Medical Qigong therapy.
4. Too much mental concentration is the most frequent cause of Qi deviations. The strong focus of mental attention on the flow of Qi can distort its path and lead to Qi deviations. It can cause too much concentrated Qi and Blood to flow into the brain. Concentration on internal objects with too intense a focus can actually cause a stagnation, or Excess of

Qi in the area (e.g., concentrating too hard on a tumor can actually cause it to grow instead of dispersing it). Mild concentration is always preferred when practicing Medical Qigong exercises and meditations. A relaxed mind and body allows the Qi to flow freely.

CORRECTING QI DEVIATIONS

To correct any Qi deviation, it is important to understand the root cause of the deviation. The Medical Qigong doctor should check for the following causes of Qi deviations.

1. Postural Dao Yin deviations result from incorrect postural changes.
2. Respiratory Dao Yin deviations result from improper breathing methods.
3. Mental Dao Yin deviations result from improper mental activities and emotional disturbances. These emotional disturbances (due to the accumulation of toxic emotions within the internal organs) may manifest as spontaneous emotional outbursts.
4. Stressful life activities resulting from an improper balance of work and play, lack of sleep, or an improper diet may likewise cause Qi deviations.
5. Environmental disturbances during Medical Qigong practice such as the phone or doorbell ringing, may startle the practitioner and cause Qi deviations.

To correct the Qi deviation, the Qigong doctor addresses each possible cause separately, beginning with the patient's posture.

POSTURAL DAO YIN DEVIATIONS

To diagnose Qi deviations due to incorrect postural alignment it is important to observe whether:

- relaxation is being achieved,
- the posture is structurally correct to facilitate relaxation, and
- the appropriate tonifying, purging, or regulating technique is being used.

When a deviation occurs, the patient should examine it in accordance with the basic laws of postural alignment. A beginner is more prone to some disorders due to incorrect postures that cause headaches, dizziness, and a stiff neck.

MANIFESTATIONS OF POSTURAL QI DEVIATIONS

If postural deviations occur, first review the Eighteen Rules of Proper Medical Qigong Structure in relationship to the sitting or standing positions, and then review the other Dao Yin Qigong patterns (respiratory and mental Dao Yin training). The following are examples of specific Qi deviations related to improper postural alignment.

1. Eye distention results from excessively staring at external objects during the meditations and exercises. To prevent this type of Qi deviation, encourage the patients to always use a soft focus.
2. A stiff or painful neck is usually caused by forcefully attempting to suspend the head. To prevent this type of Qi deviation, have the patient relax the neck muscles and sink the shoulders.
3. Shoulder and back pain can occur when patients fail to relax the muscles of the shoulders and back, stretch the back excessively, hollow their chest too much, or hold an unfamiliar posture too long. To prevent this type of Qi deviation, have the patients relax and sink their shoulders and imagine the back melting down into the hips and legs.
4. Waist and hip pain (Lumbago) come from several factors.
   a. Tension in the hip muscles causes pain in the hips that extends to the waist.
   b. Twisting the waist without first relaxing the hips can result in both hip and waist pain.
   c. Forcefully twisting the waist may also cause pain.

   To prevent this type of Qi deviation, have the patients relax their waist and hips and sink the energy into the Earth via the feet.
5. Abdomen and lower extremity distention or flatulence results from the forceful pulling-in of the Stomach, or too much concentration of the mind on the lower extremities. To prevent this type of Qi deviation, have the patients relax their abdomen and lower extremities, allowing the Qi to sink naturally.
6. A swollen and painful anus, or dry stool, can

result from raising the anus too forcefully. Also, hemorrhoids can develope from holding the breath too forcefully while focusing on the lower abdominal area during the Abdominal Breathing Holding method. To prevent this type of Qi deviation, have the patients close their anal sphincter softly and relax their buttock muscles.

7. Sore knees are a result of crouching too low, over-bending the knees, or extending them past the toes. To prevent this type of Qi deviation, have the patients keep their knees in proper alignment and guide the pressure of the body weight to flow behind the legs and not in front.
8. Heel pain can be caused by shifting the body's weight excessively onto the heels during walking or standing practice. Heel-ache can also occur if the patients focus too much attention on their heels instead of the center of their feet for balance. Knocking, stomping, or excessively dropping the heels against the ground, as well as sexual Excess, or a Kidney Deficiency can all cause pain in the heels. To prevent this type of Qi deviation, have the patients relax their legs and waist and imagine that their feet are kneading the ground. This squashing and kneading action is used to encourage the free flow of Yin Qi from the Earth into the body.
9. Improper hand movements occur when patients fail to distinguish between Yin and Yang energetic properties, or apply either too much or too little strength in the raising and lowering of the arm movements during Qigong practice. Both the alignment and energetic function of the patients' arms, hands, and fingers should be checked.
    a. If the arm movements are too dynamic, they will cause an abundant amount of energy to become either gathered or dispersed; this results in Qi deviations.
    b. While performing a tonification exercise, if the palms of the hands are turned outward, away from the body (instead of inside facing the body) this can easily cause diarrhea or a Qi Deficiency.
    c. If the fingers move up to point at the chest, the energy released from the hands can cause tightness in the patients' chest. If the patients' hands point obliquely at their neck and face, the emitted Qi can cause dizziness, nausea, and edema of the face in those patients who are sensitive to the energy movement within their channels and collaterals.

RESPIRATORY DAO YIN DEVIATION

Deviations in breathing often result from the incorrect practice of the deep inhalation and exhalation methods, when first starting Qigong meditations. Both inhaling and exhaling should be gentle, thin, even, and long. When practicing, the patient should breathe properly and naturally to regulate the breath and should avoid holding the breath.

1. Deviations can be due to improper exhalation. Determine whether the exhalation is long enough for relaxation and quiescence when sinking the breath. Excessive sinking of the breath, however, can cause pain in the legs by depleting Qi flow to the upper torso, and by increasing the weight and gravitational pressure within the tissues of the lower torso. Exhalations that are too long or too deep can cause shortness of breath, headaches, tightness in the chest, discomfort in the Heart, and abdominal distention.
2. Deviations can be due to improper inhalation. Determine whether the inhalation is long enough for relaxation and quiescence. For example, when practicing the Abdominal Breath Holding technique (the Two Inhaling and One Exhaling Method, which employs Reverse Breathing), the two inhalations should not be connected, for tightness in the chest will occur. Pause, therefore, between each breath and allow the exhalation to be fast and short rather than sustained and drawn out. Otherwise, the condition will cause general weakness and fatigue.

To rectify this condition, when you inhale twice through the nose, simultaneously pull in the navel and perineum area as if to lift your

body. When you exhale through the nose, guide the Qi down into the Middle Dantian.

If this method is applied, the symptoms such as tightness in the chest, shortness of breath, and abdominal distention will disappear (The Rectifying Respiratory Qi Deviations exercise can also be used). When the breath is well regulated there will be no difficulty sinking the Qi down to the Lower Dantian.

3. Deviations can be due to improper tone resonation. Another Respiratory and Mental Dao Yin deviation can be created through the improper use of healing words or tone resonations. The improper use of tones (with too much breath or mental concentration placed on the rising and falling sound) may cause symptoms such as dizziness and slight fever, tightness in the chest, weakness in the legs, foul breath, and bloody stool.

These symptoms cannot be relieved by Western medicine. Some patients, however, have succeeded in rectifying such deviations by practicing the Opening and Closing the Three Dantians exercise (see Chapter 15). This exercise is used to regulate the Excess Yang, and to restore the body's energetic equilibrium.

Some patients are given the prescription of uttering one pitch sounds (known in China as the first or straight tone). This straight sound has a steady tone, and a rising volume, which can easily cause the energy to ascend. After the patients have completed their prescription and ended the exercise, if the energy continues to rise, the Qi deviation will cause dizziness and nausea. In this particular case, the patients should stop the exercise immediately. To rectify this condition, have the patients utter the sound in the third tone (the descending and ascending tone), and by deepening his or her voice, then raising the pitch. This increasing volume and deepening tone relaxes the body and causes the Qi to descend.

This example illustrates the fact that if the patient is allowed to select any prescription at random for mental concentration, without understanding the theory of Medical Qigong, he or she can easily get into trouble.

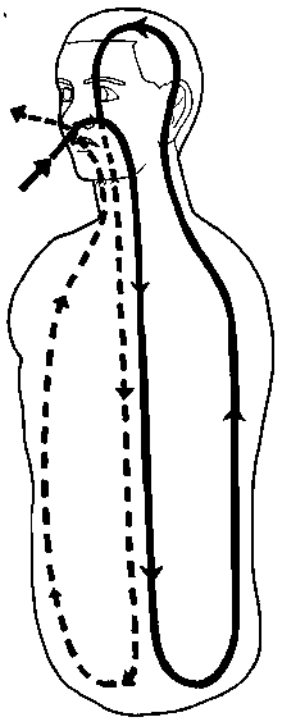

Figure 18.2. Rectifying Respiratory Qi Deviations

4. To rectify respiratory Qi deviations, the following exercise can be used. It will amend respiratory deviations and balance the Yin and Yang Qi, as well as clear any stagnant Qi.

When the practitioner feels uncomfortable after Medical Qigong exercises, practice this method for 20 minutes. This is an alternate nostril breathing exercise and requires both inhaling and exhaling through the nose. The abdomen expands upon inhalation and contracts upon exhalation.

From a seated posture, begin by imagining that there are three channels that start at your tailbone and travel up the body. The first channel intersects with the right nostril, the second channel joins the Baihui GV-20 point and the third channel intersects with the left nostril (Figure 18.2).

Place your left hand on your Lower Dan-

tian, with the right hand resting on the nose. It is important to focus the mind on the energetic flow of the breath. Inhale through the left nostril and allow the Qi to flow down the Conception Vessel into the Lower Dantian and tailbone area. Hold the breath, pinch the nose and draw the Qi up the Governing Vessel into the Baihui area, and then circle the energy down to the Conception Vessel to the coccyx to complete the Microcosmic Orbit. Exhale through the right nostril. Repeat this sequence, alternating the focus of the mind's concentration to follow the beginning flow of energy from the left to right nostril and visa versa.

When training in Medical Qigong prescriptions, it is equally as important to relax the mind as the body. Therefore, this exercise should be practiced in a leisurely manner, with a carefree attitude, and a smile.

MENTAL DAO YIN DEVIATIONS

Deviations in mental activities are primarily caused from excessive thinking and too much focused concentration. These type of mental deviations should be rectified by controlling one's mental activities. It is important to fully understand the foundational principle of the Shen controlling all mental activities that determine the physical, emotional, and energetic activities. Any mental deviation should be regulated and controlled through intention.

It is sometimes difficult for patients who have just started Medical Qigong prescriptions to become absolutely tranquil; this may lead to mental Qi deviations. One way mental Dao Yin deviations can be rectified is by a mantra, or counting breaths (using one thought to replace many thoughts). After this technique is mastered the patients can advance to concentrating their mind on an external object in the surrounding area.

1. The cerebral cortex plays an important role in Qi deviations of the mind. Medical Qigong regulates the cerebral cortex to restore balance to the energetically unbalanced parts of the brain. If the mind is agitated or depressed for a long time, it can cause a long term disorder of the whole nervous system and, thus, cause various kinds of chronic diseases. A healthy nervous system takes the leading role in adjusting, regulating, and unifying all functional activities. It is responsible for maintaining a dynamic equilibrium.

If deviations occur during Medical Qigong practice, the cerebral cortex loses control of the nervous system. Abnormal phenomena may occur and mental and emotional activities may become uncontrollable. If patients are not careful, they can actually develop meditation induced diseases, or meditation induced psychosis known as Tsou Huo Ru Mo, which translates to "the Fire becomes Excessive and the demons enter." In other words, the patient's Heart and Liver become overheated, causing the Hun to leave and Po to take control of the body. This in turn can lead to chronic psychoses or demon possession.

Because Qi deviations can have serious consequences, the Qigong doctor must have an extensive knowledge of Medical Qigong principles to prevent and correct Qi deviations, stagnations, and adverse Qi flow. The mind should, for example, always be free from over-concentration or "distortions of consciousness" during practice. If a beginning patient feels a hot sensation in certain parts of the spine, and tries to force its energetic movement up through the Five Passes of the Governing Vessel (see Chapter 30), this can cause "distortions of consciousness" and mental confusion, which may result in hallucinations.

A deviation caused by excessive focused mental concentration can also lead to a loss of self-control and produce such disorders as uncontrollable head-shaking, shoulder shrugging, hand and leg quivering, stumbling, staggering, uncontrolled crying or laughing, or even stiff and twisted extremities and opisthotonosis. To avoid this loss of self-control, do not allow the patients to use their mental intention and focused concentration at random, but rather have them focus their attention on quiescence to tranquilize the mind and recuperate their health.

Failure to properly lead and guide energy during Medical Qigong practice may also cause adverse deviations of Qi in the patient's Middle Dantian. In the Middle Dantian, the patient's Lung Qi rises and returns through the opening and closing actions of the Shan Zhong CV-17 point. If the Qi within the Middle Dantian begins to deviate, it can condense and cause stiffness, pain, and a feeling of suffocation in the chest region. To correct this condition the Qigong doctor extends energy into the patient's Middle Dantian to regulate and tonify the patient's Qi, and especially the Gathering (Zong) Qi. This treatment also regulates and tonifies the patient's Lungs and Upper Burner, as well as diffuses any Rebellious Lung Qi (see Chapter 22) as it unburdens the emotions of the Heart.

2. There are three rules for determining proper mental focus. The following three rules determine the focus of the patient's mental activities and are implemented to help avoid Qi deviations while practicing Mental Dao Yin training:
   a. Concentrate the mind on a motionless object. A patient suffering from hypertension can, for example, concentrate on still lake water, but not on a stormy sea.
   b. Concentrate the mind on a near object. A patient with Liver trouble can, for example, concentrate on a nearby pine tree. If the patient is at a park, absorbed in concentration on a pine tree that is far away, the patient must mentally trace and locate the pine tree with painstaking effort. This is achieved through expanding and extending the imagination. If the patient suddenly becomes mentally distracted or preoccupied, the purpose of the meditation is defeated. Once distracted, it will be very difficult for the patient to reconnect to the pine tree because of its distance. As a result, the patient's mind wanders and the patient may become discouraged.
   c. Concentrate the mind on a familiar object. Concentrate on something which creates a peaceful, emotional connection. The emotional connection will facilitate the proper attitude and diminish any likelihood of mental strain.

      When deciding on which familiar object to focus the attention on, patients must not choose a person, their own work or creations, or obscene things. Objects that have been used to do harm or evil should also be avoided. Patients are also forbidden to shift their thoughts from one thing to another or back and forth without stopping. Remember that it is the individual's Shen (Spirit) which guides all mental activity and determines the body's energetic actions, therefore the mental concentration should have purpose.

Adjust each technique according to the specific case. When prescribing Medical Qigong therapy, it is important for the doctor to adjust each meditation and exercise according to the patient's specific case. In all cases, the Yi (imagination and intention) must lead the Shen and the Shen must lead the Qi.

The following examples demonstrate how to adjust prescriptions for different patient's needs.

- Patients with hypertension should concentrate on a low place instead of a high place, or on an object below eye level.
- Patients with hypotension (including other Deficient conditions such as anemia) should concentrate on a high place instead of a low place, or on an object placed above eye level.
- Patients with Lung problems such as tuberculosis should concentrate on white and light objects (e.g., white clouds).
- Patients with Spleen and Stomach diseases should concentrate on yellow objects (e.g., yellow chrysanthemum, dahlia).
- Patients with Liver problems like hepatitis should concentrate on green objects (e.g., pine and cypress trees).
- Patients with a Heart Deficiency should concentrate on red objects. Patients with an Excess conditions of the Heart, however, should

never concentrate on the color red, and should only choose pink objects instead. A pure red color is too energetic for patients with Excess conditions and may overexcite their Heart, making it difficult for the patient to become relaxed.

- In Medical Qigong, the color black is sometimes assigned to the Kidneys. Focussing on this color can, however, easily cause the Kidney energy to sink downward, creating an emotional state of depression or anxiety. Therefore, when treating patients with Kidney diseases, it is preferable to choose things of purple, indigo and vibrant blue color.
- Mentally depressed patients (in a severe cases) should not practice any dynamic Qigong exercises until their depression has passed. Otherwise, they may develop headaches, tightness in the chest, or in severe cases, shock. To rectify this condition, the Qigong doctor must lead the toxic and stagnant Qi downward along the channels and out of the body.
- Patients with uncomfortable light or heavy sensations should concentrate on the opposite side on their body instead of the afflicted area. If they feel that their lower limbs are too heavy to lift during the exercises, for example, they can correct this symptom by focusing on the Baihui GV-20 point at the top of the head. If the patients feel that their body is too light and unsteady, they can focus on the Yongquan Kd-1 point located on the soles of the feet.

STRESSFUL LIFE ACTIVITIES

Stressful life activities create a flood of adrenaline within the body. This occurs not only from the core of the adrenal gland in the medulla (which responds to stress by releasing adrenaline in to the blood stream), but also from the endings of the vertebral lumbar division at the core segment of the major internal organs. Adrenaline spreads throughout the body and activates not only the body's sympathetic nervous system, but also the adrenal glands. The Heart rate, respiratory rate, blood pressure, and Blood flow to the muscles are all increased as they respond to the "fight or flight syndrome."

When this happens, the immune system is called upon to balance the whole stress mechanism and is, therefore, called away from its normal activities which include monitoring cellular activity and fighting the growth of disease. A life of constant stress, therefore increases susceptibility to illness. Meditation takes the patient out of the stress mode, thereby shutting down the adrenal glands, and allowing the immune system to return to its normal functioning.

Chronic stress wears down the mind and body, thereby producing anxiety or depression. Stress begins with an overexcitement of the nervous system and then slowly works its way deep into the body like wet cement, causing the shoulders and upper back to become tense and rigid. Happy occasions (such as weddings) and other normally pleasant events, also produce stress, which can be detrimental when the patient's life style is not properly balanced. An unstable life style is very stressful and can lead to depression, anxiety, and Qi deviations. The capacity to bear stress depends upon the individual's constitution, diet, support system (or lack thereof), the nature of the stress, and the congenital strength of the nerves. When stress levels surpass the nervous system's capacity to handle them, "the nerves break down", resulting in all sorts of physical, mental, and emotional disturbances. Certain neurotransmitters are depleted, leading to a chemical imbalance which can be aggravated by self medication (e.g., alcohol or drug abuse). These disturbances, if unheeded can eventually lead to organ malfunctions, cysts, tumors, cancer, and premature death. In order to avoid such states, a balance between work and rest must be maintained.

At a conference of the International Society for Neuro-immunomodulation (entitled *The Effects of Stress and Depression on Physical Disease*) Dr. Philip Gold, of the National Institute of Mental Health, stated that stress and depression cause the body to secrete high levels of hormones; (for example, cortisol) into the bloodstream. These hormones, if unregulated, can destroy the appetite, cripple the immune system, shut down the processes that repair tissue, inhibit sleeping patterns, breakdown bone density, aid the onset of infec-

tion, and even instigate cancer cell growth.

An individual's emotional past determines his or her present state of health, both physical and emotional. Past emotional belief structures are responsible for both creating and healing diseases. Just as thoughts drift through the mind but do not manifest until they reside within a belief structure, so emotional wounding resides within the tissues and cells waiting to be activated by emotional upheavals. Our thoughts materialize via choices and manifest within the body.

In American society, sharing traumatic wounds is often the first act of intimacy and bonding. It provides a common ground for relationships and supports the "pain structure" that deepens the bond. People can become addicted to empowering their wounds which, in turn, support and empower the disease. This exchange of painful personal traumas is reinforced by receiving sympathy and strong empathy, but does not fully release the pain from the tissues.

Although talking about past traumas can begin the process of healing, problems can emerge when these past traumas manifest through the following belief structures.

1. The individuals believe that they can only receive affection and attention when they suffer, and use their "neediness" to keep their significant other(s) from leaving or becoming more independent.
2. The individuals become stuck in one emotion -- anger, grief, fear, worry, or hurt -- and are unable to express a healthy range of emotions.
3. The individuals do not have an adequate support system.
4. The individuals do not have the incentive to heal themselves or the belief that they can be healed.
5. The individuals bond to anyone, out of fear of being alone, as long as they receive the attention they crave.
6. The individuals have low self-esteem and do not seek help or work out their emotional issues; they have difficulty trusting anyone to understand their pain.

The desire for sharing ones pain in order to feel loved can lead to a habitual way of relating to those closest and dearest. When such individuals feel taken for granted, or unappreciated, they may immediately resort to past traumas. If this fails to illicit the desired response, a new trauma or wounding may be unconsciously created to get back the attention and love and need. The individuals may, for example, physically injure themselves in an accident, or manifest a physical illness. This in turn can become an addiction, empowering old wounds and creating new ones, and may lead to chronic illness. The Shen becomes divided to support the new belief structure, and the Qi deviates from its assigned job of protecting the body, thus creating illness. This is not a conscious process, but an unconscious one, which needs to be brought into the patient's awareness to be healed. Then, and only then, can the Yuan Shen and Zhi Shen act as one unit directing the body's Qi towards its proper function of healing.

Because energetic healing occurs in the present and not in the past, victims of past traumas will never heal if their energy continuously regresses to the armored traumatic belief structure. Both the doctor's and the patient's Yi (Intent) must therefore, focus on forgiveness (of self, others and the specific tragic situations) to free the patient from toxic wounds. The patient's desire and determination to be well must reach the degree that they are willing to do anything to get well, including giving up on the "secondary gains" of illness (i.e., risking abandonment, or loss of attention received during the illness). Patients must be encouraged to find new ways to fulfill their needs, and must be encouraged and supported through this difficult transition. This point is illustrated effectively in the following traditional Chinese story.

> There once was a palace official named Cheng Guang Wei who owned a servant named Song Li. As the pressures of life wore on Director Cheng, he began to sink into a deep depression. Soon he began to lose all hope in life and desperately sought relief. Not content with the wine and festivities at hand, his attention soon turned to his servant Song Li, who always seemed to be happy. Song Li was plowing the fields, up to his ankles in

mud, singing and seemingly enjoying his life. Upon observing this, Director Cheng walked up to the edge of the field and called out, "Song Li, why are you so happy? What is the secret of your contentment?" To which Song Li responded, "Sir, come into the field with me, and I will tell you." The director, not wanting to get himself muddy said, "No, tell me from where you are." To which Song Li replied, "I cannot explain everything to you if you do not come into the field." Director Cheng, aggravated by this reply, answered, "Very well, since you refuse to tell me, tomorrow you will work in the stables." Song Li answered, "If that is your wish, sir," and went about his work contentedly.

Two weeks went by, and the pressures of the palace were starting to take a serious toll on Director Cheng. All of his problems, it seemed, were insurmountable. Locked in turmoil, he began to roam his property seeking peace until he heard singing coming from one of the stalls in the stables. Director Cheng went to investigate and sure enough, it was Song Li, now up to his knees in horse manure and still singing as beautifully and joyfully as a bird. At first Director Cheng was enraged at Song Li's contentment, but then became perplexed, because the duties of Song Li's new job were much more difficult than the previous work.

Director Cheng approached the edge of the stables and called, "Song Li, why are you so happy? What is the secret of this contentment you possess?" To which Song Li responded, "Sir come into the stall with me, and I will tell you." Repulsed by the stench of the horse manure and filth, not to mention feeling protective of his royal robe, Director Cheng answered, "Song Li, tell me the secret of this joy and contentment that you possess even in the midst of a barn full of stench and dung." Song Li answered, "I will tell you sir, but first you must come in to where I am." "If that is your answer, then tomorrow you will work in the hog pens!" shouted Director Cheng. To which Song Li answered, "If that is your wish, sir," and went about his work contentedly.

Well, things went from bad to worse for Director Cheng in the palace; seeing that he was about to lose everything, he contemplated taking his own life. Making one last round of his property, he again heard singing, this time from the hog pens. Realizing it was Song Li, Director Cheng slowly approached. Sure enough, there was Song Li, up to his thighs in pig dung, slop and filth, and still singing. Leaning against the fence, Director Cheng called out, "Song Li, why are you so happy? What is the secret of your contentment and joy?" To which Song Li responded, "Sir, come into the pen with me, and I will tell you." Director Cheng, now at the end of his rope, answered, "Very well, I will come in with you," and began to climb the fence to enter the hog pen. "Stop!" shouted Song Li, "I will come over to you, it is not right that you defile yourself on my account. But now you will truly listen to what I have to share and are ready to hear the words I speak. For now you are willing to sacrifice all, even your physical comfort, to receive spiritual knowledge and insight."

The moral of the story is clear: unless we are ready to abandon all masks (pretenses and defence mechanisms) of the emotional ego, it is extremely difficult to free ourselves from the toxic emotions that steal our life-force energy and direct our lives. If we are not intimate with our emotions, we cannot perceive the dynamics behind those emotions. After all, emotions are only energy currents which flow in, out, and through our bodies. Because our emotions reflect our intentions, any awareness of unprocessed emotions will lead to an awareness of deep-seated intentions. It is through this understanding that Qigong doctors train their emotions and mental thinking to regulate the Shen.

SHEN DISTURBANCES AND EMOTIONAL DYSFUNCTIONS

All Shen disturbances relate to emotional energetic dysfunctions. Generally, Shen disturbances can be divided into two categories: Yin disturbances and Yang disturbances (Figure 18.3). These

Yin and Yang disturbances affect the patient's thoughts and emotions.

A thought is energy that has been shaped by consciousness. Every experience, or change in experience, reflects intention, desire, and will. Any discrepancy between intention and emotions leads to a splintering reaction of the energetic self, which can cause a breakdown of the body's life-force energy and ultimately lead to disease.

Emotional energetic currents have different frequencies, resonating between low (fear, anger, worry, etc.) and high (love, forgiveness, joy, compassion, etc.). Lower frequencies deplete the physical body, draining it of its precious reserve of life-force energy. This deterioration begins to manifest in the spiritual fields of energy surrounding the body, and percolates down to the emotional, mental, and finally the physical level. Conversely, high frequency emotional energy raises the body's energetic frequency and begins to radiate outside the physical body. This does not mean that the patient must learn to suppress feelings of anger, hurt, etc. These are natural emotions that serve a positive function in protecting the individual from harm. It is only when emotions are suppressed, denied, and accumulated that they become highly toxic to the body. When this happens, new anger is fueled by old anger. The new hurts are suddenly blown out of proportion (related to the event), fueled by ancient emotional pain, until the patient's physical structure is overwhelmed.

Patients may become overactive and overemotional when under stress, when their energy becomes disrupted. Every emotional disturbance alters the breathing pattern, changing from slower to faster respirations (each breathing pattern varying according to the internal organs involved).

According to *The Yellow Emperor's Inner Cannon* (Spiritual Axis), the Blood, Ying, Jing, Qi, and Shen are stored in the Five Yin Organs (Liver, Heart, Spleen, Lungs, and Kidneys). An Excess condition will cause any of these components to leave their respected organs. This will:

- deplete the patient's Jing (Essence),
- cause the patient's Hun (Ethereal Soul) and Po (Corporeal Soul) to become unsettled,
- cause the patient's Zhi (Will) and Yi (Intention) to become muddled, and
- cause the patient's Shen (Spirit) to leave the patient's body.

Shen Disturbances	
Yin	**Yang**
Qi is compressed.	Qi is expanded.
Patient is depressed, withdrawn.	Patient is manic, expressive, impulsive, volatile.
Patient is too quiet.	Patient is too loud.
Patient avoids feelings.	Patient inappropriately expresses feelings.
Patient is too introverted.	Patient is too extroverted.

Figure 18.3. Shen Disturbances

When emotionally upset, energy literally rises upward, affecting the organs and releasing additional emotions stored within the tissues. To become free from these emotional reactions, patients must be taught to relax and release the energetic charge of emotions. This will allow stagnant Qi to become energetically discharged from the body. By cultivating a healthy attitude, and not holding onto, or suppressing, the emotions, the body will begin to seek its energetic balance naturally. This is initiated by having the patient sink his or her Mind and breath deep into the Lower Dantian to rebalance the life-force energy.

TREATMENT TECHNIQUES

When treating patients with Shen disturbances, the Qigong doctor categorizes the emo-

tional and thought dysfunctions into Yin and Yang Shen disturbances.

1. In Yin Shen disturbances the patient's energy compresses inward. These patients have a tendency to avoid feelings, becoming quiet, withdrawn, and depressed. They also tend towards an introverted personality and posture.

   When treating patients with a Yin Shen disturbance it is important for the Qigong doctor to redirect the patient's Shen towards specific actions, and encourage them to use spiritual mantras and affirmations to gain inner strength and confidence.
2. In Yang Shen disturbances the patient's energy expands outward. These patients have a tendency to express their feelings, are loud, impulsive, volatile, and manic. They also tend to be extroverted in personality and posture.

   When treating patients with a Yang Shen disturbance it is important for the Qigong doctor to redirect the Shen (with a "reality check" towards the patient's actions) and set parameters for their boundaries. A sudden awakening to the responsibility of personal actions will generally send the patient into emotional shock.

   One treatment technique commonly used in the clinic to calm and restore harmony in the patient's Shen (due to a Deficient condition) is for the Qigong doctor to extend Qi into the patient's Middle Dantian and Yellow Court areas. Once this area has been sufficiently balanced, the doctor then ends the treatment by rooting the patient's Qi, by drawing it into the Lower Dantian.

PRESCRIPTIONS AND HOMEWORK

Several of the most recommended meditations used for the purpose of calming the patient's Shen are listed as follows.

1. The Energy Melting Meditation is used to relax the body and reduce stress. Relax and imagine melting from the top of the head to the bottom of the feet, like ice melting into water and water flowing downward into the Earth. This image centers, grounds and roots the Mind.

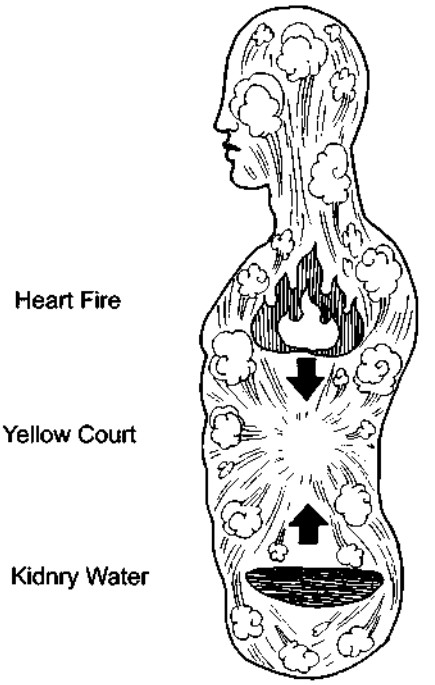

Figure 18.4. During the exchange of Fire and Water meditation, the fusion of Heart Fire and Kidney Water creates steam.

If the patients are lying down, have them feel the upper layers of their body melting through the lower layers and into the Earth. Ice melts into water and pours into the Earth.

2. The Exchange of Fire and Water Meditation unifies the energies of the Kidneys (Water) and the Heart (Fire) and is often called the Fusion of Kan and Li. It is used to unify opposite principles within the body, to balance the energies of the mind, body, and Prenatal and Postnatal Shen for creating wholeness. It also strengthens the immune system and the bones, thus slowing or preventing osteoporosis.

   Sit and begin by breathing naturally, while inhaling and exhaling through the nose. Visualize the Lower Dantian as an ocean of water, and the Heart as a ball of fire. Imagine the waters of the Lower Dantian beginning to flow up the center of the body, reversing their natural flow. Now imagine the Fire of the Heart be-

ginning to descend the center of the body, reversing its natural flow. As the Water and the Fire join in the Yellow Court (located in the lower part of the solar plexus), the Water vaporizes and becomes steam (Figure 18.4). This hot mist travels throughout the entire body. It should feel warm and pleasant.

Next allow the hot mist to enter into your bones and flow through the Marrow. Imagine this mist beginning to solidify and harden making your bones solid and radiant with white light. Upon completion of the meditation, relax and allow the images to disperse as you sink into the Wuji.

These following exercises are a series of meditations used in the clinic for detoxifying emotional stasis.

3. The Sun and Moon Meditation is used to detoxify emotional stagnation and establish physical, emotional, and spiritual clarity.

   Begin from a sitting or Wuji posture (Figure 18.5). Inhale and exhale through the nose. Imagine the sun over the left eye, and the moon over the right eye, appearing side by side over the head. Feel their presence over the Baihui point, at the top of the head. Imagine that the sun (on the left side of the body) pours golden light, and the moon (on the right side of the body) pours silver light. Both streams of light meet at the Baihui point on the top of the head, combining into white light energy. This white light energy pours into the body, filling the entire body from the feet to the top of the head (like a pitcher of water filling a glass). Once the body is completely full, the energy begins to spill out of the pores. At first a thick, black, sticky energy pours out of the pores, and flows down to the ground. This energy contains all the physical, mental, emotional, and spiritual toxins that are being released from the body. As more and more of these toxic substances leave the body, they start turning from black to gray, then from gray to white. Feel the body radiate this white energy in all six directions (front, back, right, left, up, and down) filling the entire room. After several minutes of purging and

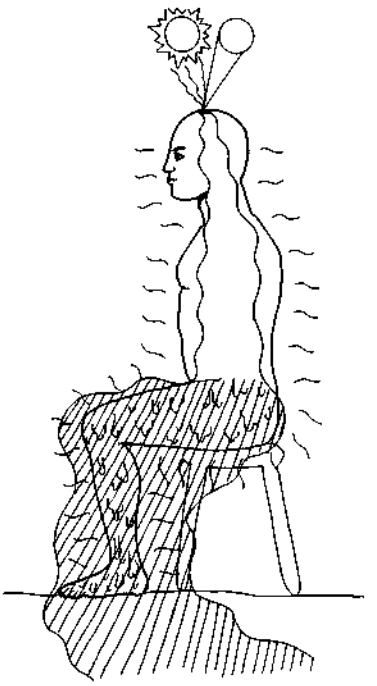

Figure 18.5. During the Sun and Moon Meditation imagine that the white light energy that is pouring down the body, is purging toxins from the internal organs, releasing the Evil Qi out from the pores.

   tonifying the body, relax the mind and focus your attention on to the Lower Dantian, before ending the meditation.

4. The Releasing Emotional Blockages and Energetic Armoring Meditation is used to dissolve emotional blockages from the internal organs. When these blockages are released, the emotions are restored to balance. Begin from a Wuji posture, and inhale through the nose and exhale through the mouth.
   a. Direct your attention to your Liver. Every time you inhale, visualize and feel the emotions of kindness and compassion entering into your Liver. As you exhale, release anger or jealousy. Repeat for 18 breaths.
   b. Direct your attention to your Heart. Every time you inhale, visualize and feel the emotions of joy, contentment, and tranquillity entering into your Heart. As

you exhale, release nervousness and excitement. Repeat for 18 breaths.

c. Direct your attention to your Spleen. Every time you inhale, visualize and feel the emotions of trust, openness, and sincerity entering into your Spleen. As you exhale release worry, obsessiveness, and self-doubt. Repeat for 18 breaths.
d. Direct your attention to your Lungs. Every time you inhale, visualize and feel the emotions of dignity, integrity, and courage entering into your Lungs. As you exhale release grief and anxiety. Repeat for 18 breaths.
e. Direct your attention to your Kidneys. Every time you inhale, visualize and feel the emotions of self-confidence and inner strength entering into your Kidneys. As you exhale release fear and loneliness. Repeat for 18 breaths.
f. Finally, inhale, visualize and feel the emotion of a full-bodied state of peace and bliss. As you exhale, ripple and resonate this feeling into the room, filling the surrounding energetic space with this emotional enlightenment. Repeat for 18 breaths.

Disturbances During Qigong Practice

The patient should carefully choose a safe and quiet environment for Medical Qigong exercises and meditations. Most often a patient is already in a state of relaxation when they become startled by disturbances generally caused by an unexpected sound or event. This sudden disturbance can disrupt the Heart Qi. When training, if you become startled, do not open your eyes. If you open your eyes, the disturbed energy will be thrown into disarray, causing a blockage of vital Qi (usually in the Heart). This reaction will cause deviations which can be difficult to rectify.

If instead you continue exercising with your eyes shut as if nothing had happened, you can restore your mind to a normal state of quiescence, by guiding the Qi up the Governing Vessel and down the Conception Vessel (i.e., the Microcosmic Orbit). Even if you were shocked by the un-

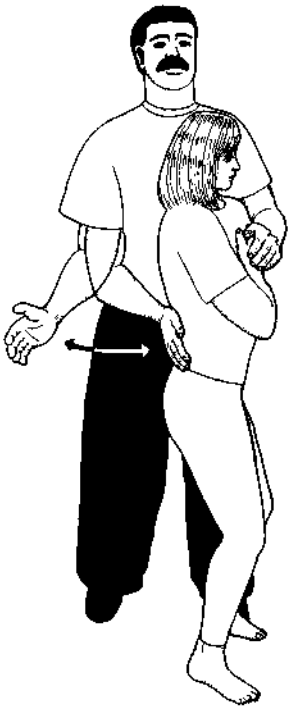

Figure 18.6. The doctor strikes the patient's Mingmen area and focuses his or her attention to lead the disruptive Qi downward into the Earth. This helps the patient stop the uncontrollable muscle deviation spasms.

Figure 18.7. The doctor directs energy into the patient's foot, through the Lv-3 point, rooting the patient's Rebellious Qi into the Earth.

expected sound or event, restore the mind to a normal state of calmness by immediately performing the Opening-and-Closing the Two Dantians technique. The two Dantians refer to the Upper Dantian (Yintang point) and the Lower Dantian (Qihai point) areas (see Chapter 20).

To perform this technique, raise both hands to the lower jaw and breathe in with a hissing sound as if inhaling a mouthful of cold air. After the inhalation, the hands will move up to the Upper Dantian, and perform the opening exercise while exhaling slowly. Next, exhale while closing slowly. After four repetitions move the hands to the lower abdomen and perform the Opening and Closing of the Lower Dantian four times.

Usually the emotions will calm down after performing this exercise four times. If you still feel uncomfortable, you can perform the exercise eight times or more, until you become calm.

Note: It is good to ensure a quiet, safe environment in which to practice, preferably a place outside, with fresh air, among flowers, grass or thick, healthy green trees. Because the inside of the body matches the outside environment, when searching for specific directions to face while practicing Medical Qigong, it is important to avoid training in or near:

- extremely intense direct hot sunshine,
- a cold strong wind,
- a thunder and lightning storm,
- old withered trees,
- old graves or tombs,
- electric generators, power lines or power plants,
- dump sites,
- polluted sites, rivers, etc., and
- do not practice shortly after earthquakes, tornadoes, hurricanes, hailstorms, etc.

Uncontrollable Muscle Deviations

Sometimes a patient's body begins to automatically quiver, shake, tremble, or vibrate, revealing an energetic re-patterning causing muscle movement which cannot be stopped. When this happens, part of the body often keeps moving for several hours, causing exhaustion. Sometimes Qi in the legs and Heart rushes into the head, compounding the problem.

For older patients this is considered a dangerous symptom because their lower extremities are generally weaker. In mild cases the patients feel energy rushing upward into their head. In severe cases the whole body trembles because the Qi leaves the Conception and Governing Vessels and empties into the body itself. In these extreme cases energy muscle patterning should be controlled in the following manner.

1. Advise the patient by saying, "It is time to relax and calm down. You need to end your exercise and rest." This method is usually very effective when repeated over and over, again. If the patient is unable to stop, perform the next method.
2. Direct the patient to place their left hand on the Middle Dantian and the right hand on top of the left hand. Tell the patient that you will help them stop by striking their Mingmen area (Figure 18.6). Press their right hand with your left hand, to compress their Middle Dantian, while using your right palm to strike the patient's Mingmen three times, directing your attention down to their feet. This can help them stop moving.
3. If the above two methods do not help, direct the patients to turn their right foot inward with the big toe pointing at the heel of the left foot. If they cannot do it without help, take their left hand in your right hand and with your foot push the big toe of the patient's right foot to point at the left heel. That should stop the movement.

   Next, touch the patients' Taichong Lv-3 point, between the big toe and second toe, with the "sword fingers" Qi emitting technique. In this technique, the doctor uses the index and middle fingers to emit Qi into the patient and guide their Toxic Qi down into the ground (Figure 18.7).

Rectifying Qi Deviations Using Taiji Ruler

If patients are experiencing too much Heat, they are concentrating too much and need to change the position of their tongue and perhaps

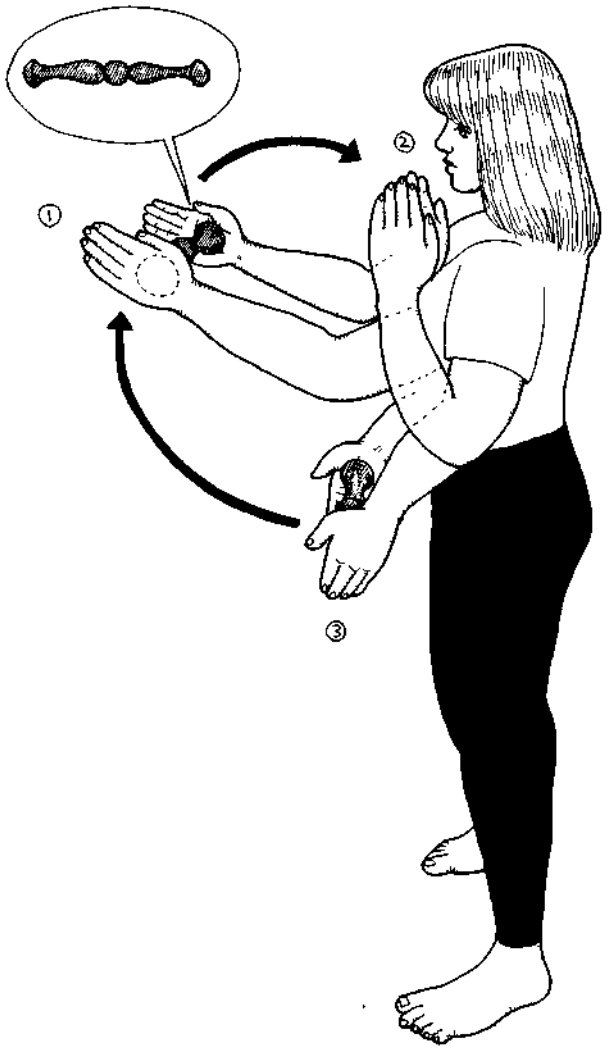

Figure 18.8. The Qi regulation exercises of the Taiji Ruler system are excellent for correcting Qi deviations.

switch meditations. The Taiji Ruler is very effective in rectifying deviations caused by inappropriate tonification or purgation, and can be used to dredge the channels and collaterals to promote the flow of Qi and Blood.

When performing this exercise, the rotation of the Ruler upward and outward (away from the body) is generally used for leading and increasing the energetic flow of Qi and Blood in the upper extremities. The downward and inward rotation of the Ruler is generally used for leading and increasing the energetic flow of the Qi and Blood in the lower extremities.

The purgation of energy blocks are usually cleared through downward movements (from Heaven to Earth). Tonification is implemented through upward movements (from Earth to Heaven). Using these methods, the patients can amend their deviations and promote the increase of Qi (Figure 18.8).

Chapter 19
Disorders and Deviations of the Soul and Spirit

Introduction to Spiritual Dimensions

An accepted reality in Medical Qigong therapy is the body's relationship to both the physical and spiritual world. The physical world of the living is considered a Yang state of existence, while the supernatural-spiritual world is in a Yin state of existence. Once the Qigong doctors' Shen has reached a high state of sensitivity, they can transcend their normal conscious perceptions and senses, to observe, and even communicate with the spiritual Yin world (see Six Transportation's of Shen, Chapter 13).

Within the subtle realm of the spiritual world, the existence of spiritual entities and ghosts are divided into two divisions of Yin and Yang (Figure 19.1). There is a significant difference between spiritual entities and ghosts.

1. A spiritual entity belongs to the Yang category of the Subtle Realm, and comes from the formation of nature. Spirits are considered the ethereal beings of the universe, who depend on the absorption of natural energy and are affected by the energetic cycles of the Earth. They are conscious beings, able to transform themselves into any size, shape, animal, or being (shape-shifting). A spiritual entity can affect changes in electrical current within the body's energy fields, or control certain areas on the body's nervous system. Spiritual entities can be separated into two divisions: Yang (good) and Yin (evil) influences.
   a. Yang spiritual entities are commonly referred to as angels, guides, spirits of the light, enlightened masters, and similar positive beings. These spiritual entities assist mankind (communicating through the body's Hun) in their quest for enlightenment. They assist individuals to make beneficial decisions that promote spiritual maturity.

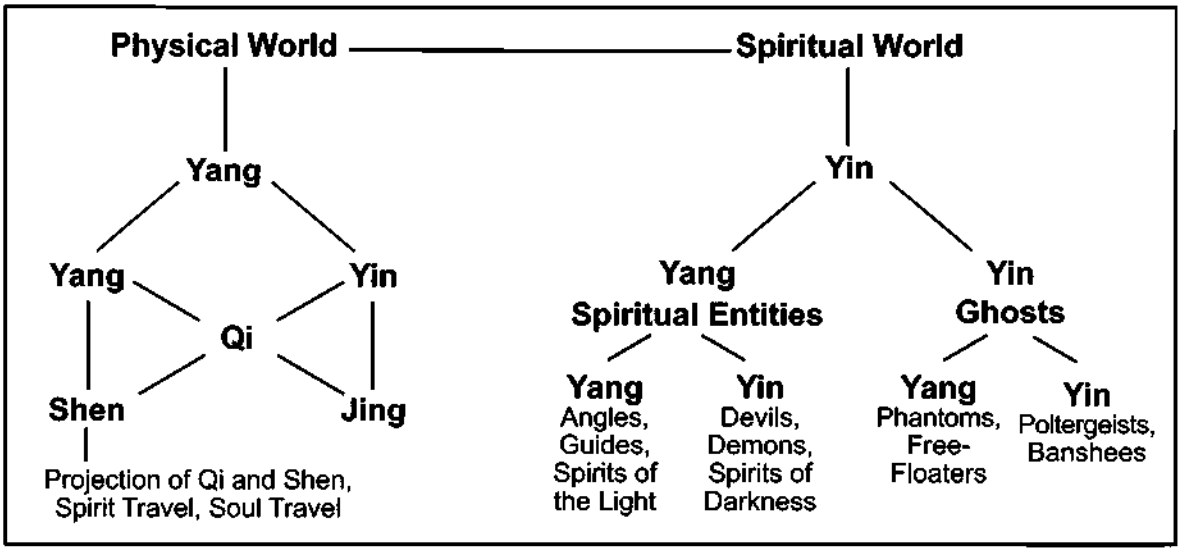

Figure 19.1. The Spirit World

   b. Yin spiritual entities are commonly referred to as devils, demons, spirits of darkness, evil spirits, and other similar negative spiritual manifestations. Yin spiritual entities challenge mankind (communicating through the body's Po) by confusing the human spirit. If given the opportunity, these spiritual entities can possess an individual and become extremely territorial.

2. Ghosts or Gui, as they are commonly called in China, belong to the Yin category of the subtle realm. Ghosts are developed from the subtle form of the combined spiritual essence of an individual's Eternal Soul. When the body dies, the energies of the Corporeal Soul (Po) enter into a state of rest, returning back to the Earth, thus allowing the Ethereal Soul's (Hun) to return back to Heaven. The individual's Eternal Soul then fuses with the energies of the Three Dantians (within the Taiji Pole) and is projected outside the body, entering the tunnel of light to return back to the divine. Sometimes, however, because of unprocessed emotional issues, traumatic death, unfinished business, or extreme attachment to people, places, or possessions, an individual's Eternal Soul can begin to wander the Earth, becoming a Gui or ghost. Generally, it is believed that it takes three days for the Corporeal Soul to withdraw their energy completely from a deceased body. Ghosts are considered Eternal Souls that have departed from human life and are unable to detach from their life experiences; they are bound by their unprocessed issues. Ghosts can also be separated into two divisions of Yang (good) and Yin (evil).
   a. Yang Ghosts are commonly referred to as phantoms and free floaters. These disembodied souls can either be lost, confused, delusional, or purposely return in order to guide and protect the living.
   b. Yin Ghost are commonly referred to as poltergeists, banshees, or other names varying by location. These disembodied souls are angry, malicious, mischievous, and destructive.

It is difficult, if not impossible, to be immune to the influence, or encroachment, of the spiritual world. Spiritual manifestations are usually evident through audible sounds, unusual unexplainable smells, extreme cold, and the displacement of objects. Other phenomena include tactile sensations, visual images, voices, and the apparent psychokinetic movement of objects. Spiritual entities seem to move through solid matter and can appear or disappear abruptly. They can also cast shadows and be reflected in mirrors; some seem corporeal, while others are luminous, transparent, or ill defined. Many spiritual entities have jerky or limited movements, while others are lifelike in movement and speech. Encounters with spiritual entities can be divided into five main categories.

1. Spiritual manifestations of the dead generally occur within a short time after the death of the person. Visits from the departed are usually to bring comfort, to announce their role as a guardian, or to complete unfinished business. If an individual's life ends in an untimely manner, or so violently that the soul does not realize the body is dead, the disembodied soul often goes about its daily routines. Occasionally these souls will manifest as mischievous entities, attempting to get the attention of the living, but they lack the malevolence of an evil poltergeist manifestation.
2. Deathbed phenomena are generally of divine beings, religious figures, or luminous apparitions. Visions of previously deceased loved ones, who come to guide the dying soul into the next level of existence, are common occurrences.
3. Manifestations of impending tragedy are visual images of an entity which usually appears in a "waking vision" or in dreams. When they appear, these spiritual entities either communicate about the death or severe crisis of a loved one, or to give warning of an impending tragedy.
4. Reincarnating spiritual entities sometimes appear in a dream to a member of the family into which they will be born. Such dreams are referred to as "announcing dreams."

5. Manifestations of poltergeists are generally mischievous and often malevolent. They may be either disembodied souls, or demon-like entities (see Chapter 18). These disembodied souls were often extremely dissatisfied and bitter while living, and may be unable to re-integrate into the Earth after death, or to ascend into the Heavens. This may cause spiritual hauntings, either around the location of their death or around a person, or persons, that the disembodied souls blame for their life's misery. They make their presence known by assaulting the living, either human or animal. The most common phenomena include: battering with a rain of small stones or sand, throwing and moving of objects, loud noises and shrieks, strange lights and vile smells.
6. The ghostly images of the astral body can be projected and manifested in distant locations as a disembodied apparition. Sometimes the astral body can travel to other locations and actually appear in holographic-like form to others. This image is not actually considered a ghostly apparition (although it may appear so), but the extension and material form of an individual's Eternal Soul.

   One example of this type of phenomenon was demonstrated in France in 1908 by scholar Hector Durville, who was researching "traveling clairvoyance." In one series of tests, Mr. Durville and a colleague hypnotized a female psychic to facilitate her astral projection to another location. An observer was placed in another part of the house. The experimenter's instructed the female psychic's to touch, hit, or pull at the observer's body while in her astral body. The observer had no idea what to expect, but felt the touches, strikes and pulling on his body by invisible hands. The astral body was even visible as a whitish apparitional figure to some of the people Durville used as witnesses.

EVIL STATES AND MENTAL DELUSIONS

Sometimes the "spirit world" itself can affect the physical body through a subconscious emotional connection with the individual's Shen. These affected subconscious emotions can never be totally repressed because they will continually surface as dreams, visions, flashes of images, etc., and can only be redirected into either positive or negative actions.

Seeing a spiritual entity or ghost is a normal part of Medical Qigong training and is accepted as a natural energetic phenomena; however, disorders such as schizophrenia and psychosis (delusions and hallucinations, etc.) are considered Qi deviations and can be caused by improper Medical Qigong practice. These mental states are known as "evil states" and are difficult to correct. Evil states also include: infatuation, delusions, obsessions, encounters with seductive spirits, demon oppression or possession, and multiple personality disorder. This does not mean, however, that the individuals suffering from these disorders are themselves evil.

INFATUATION WITH THE TREATING DOCTOR

Infatuation is culturally regarded in China as an evil state. This generally refers to the occurrence of deceptions of the subconscious mind during, or after, Medical Qigong healing, which lead to mental derangement. While under the influence of these self-deceptions, patients display intensely amorous affection towards the doctor. As the doctor's energy becomes more intensified within the patients' nervous system, the patients experience a type of biological euphoria which gives way to feelings of unexpressed emotions, suppressed fantasies, and symptoms of eccentric disposition, such as sluggishness, apathy, or elation.

During treatment, patients become extremely open and vulnerable, as their boundary systems completely dissolve under the influence of the doctor's emitted Qi. The Qigong doctor's ability to channel divine light and compassion may easily be mistaken for displays of personal love toward the patients. Sometimes this divine love has never before been experienced by these patients, making them infatuated with the doctor, who is the apparent source of this love. This is an illusion which can usually be dispelled by the doctor's explanation. When the doctor is unable to dispel this illusion by conversing with the pa-

tients, this indicates an underlying, often long standing, mental disorder. Such patients should be referred out to a mental health practitioner for professional counseling.

ENCOUNTERS WITH SEDUCTIVE SPIRITS

On rare occasions, individuals who do not have a strong enough connection with the divine may become susceptible to encounters with seductive spirits. These spirits are known as Incubus (male) or Succubus (female), and tend to manifest in dreams. These dreams can range from the romantic and seductive, to rape and sodomy. Although these encounters occur during the individual's sleep, physical sensations are always a large part of the encounter. Often, once the victim has awakened, the physical sensations continue.

DELUSIONS

This is the occurrence of delusions of the subconscious mind during or after Medical Qigong treatment or training, which lead to mental derangement. A delusion is a false belief brought about without appropriate external stimulation (seen most often in psychoses), and is inconsistent with the individual's own knowledge and experience. Patients suffering from delusions display unsociable and eccentric dispositions, sluggishness, apathy, and trance. Some patients may become very disillusioned and depressed. They may lose confidence in life, and think about committing suicide; others may have symptoms similar to those of psychosis, such as persistent visual or auditory hallucinations. These symptoms occur because of preexisting emotional problems, which the patient has not worked through, or has consistently avoided facing.

In all truth, the practice of Medical Qigong does not create these problems; Medical Qigong can, however, occasionally allow patients to become extremely sensitive to the preexisting unresolved problems that continue to surface into their subconscious mind due to their overactive denial system.

SPIRIT DEMONS

An encounter with the phenomenon known as demon oppression or demon possession rarely occurs during clinical practice, but never the less, it must be addressed. Demon oppression or possession describes the state of mind attributed to the patient who has come under the influence of the "spirits of the objective world." These spirits of the objective world (also called "fallen angles," "spiritually hostile forces," or "demons") can either influence, or inhabit, a patient's thoughts and body. They can affect anyone who becomes open to their influence. Any practice or situation which opens the individual's subconscious mind may increase the person's vulnerability to such states. Spirit demon oppression or possession can occur from:

- misguided or improper use of meditations,
- misguided or improper use of hypnosis, or self-hypnosis,
- indulging in the practice of astral projection,
- meditations that cause adverse psychological side-effects,
- general anesthesia,
- drug and alcohol abuse,
- indulging in the practice of channeling, or Ouija board playing,
- deep emotional or physical traumas,
- indulging in the practice of deviant psychosexual encounters (Tantric sex with the wrong individual)
- exposure to places that are haunted by evil spirits when the individual is very stressed out, or deeply fatigued and depleted, and
- indulging in the practice of "black magic."

When the patient's connection to their Shen becomes extremely Deficient, to a point that they surrender their Hun, the patient's Hun may leave their body and wonder, making them vulnerable to the possibility of spirit oppression or possession.

One of the first things a demon seeks, once it enters a body, is to fulfill its sensual appetite (be it sexual pleasures, rage, or emotional addictions, etc.). A disembodied spirit lacks the ability to feel physical sensations due to the disconnection with its bodily senses (touching, feeling , smelling, tasting, etc.). Thus, it can only satisfy these cravings through someone else's living body. Consequently, if a patient is disassociated from the divine center core, or has little or no boundary system, a condition of oppression or spirit possession may occur. In China this condition is commonly described as, "the Spirit (Hun) leaves and the demon enters, uniting with the body's Po" and must be rectified with spiritual

atonements and soul retrieval.

Although such encounters in the clinic are rare, it is still important to recognize and treat these conditions when they occur. While treating patients in China, I was fortunate enough to share my experiences with demon oppressed or possessed patients with certain doctors at the Xi Yuan Hospital. It was refreshing to talk with another doctor about this particular subject, as in America it is difficult, if not impossible, to find other individuals who can discuss such a topic in a clinically sound manner.

In understanding the phenomenon of spirit demons, it is important to realize that in the clinics in China, encounters with these types of spirits are divided into two categories: Projected Spirit Demons from the Subconscious Mind, and Actual Encounters with Spirit Demons.

PROJECTED SPIRIT DEMONS FROM THE SUBCONSCIOUS MIND

Sometimes through meditation, the subconscious mind will release visions into the conscious mind in the form of ghosts, phantoms, spirits, demons, etc. These energetic visions are subjective projections of part of the self, released through emotional arousal. Each color image represents certain feelings and repressed memories within the organ which the subconscious mind is trying to communicate to the conscious mind. This also applies to dreams and nightmares in which the patient is continually being haunted by certain spirits, demons, or monsters. For example:

- A green demon represents the deeply suppressed emotions of anger, rage, and irritation which are connected to the Liver.
- A red demon represents the deeply suppressed emotions of excitement, panic, and even anxiety which are connected to the Heart.
- A yellow demon represents the deeply suppressed emotions of worry and pity which are connected to the Spleen.
- A white demon represents the deeply suppressed emotions of sadness, grief, sorrow, guilt, anxiety, distress, and heartache which are connected to the Lungs.
- A black demon represents the deeply suppressed emotions of fear, paranoia, horror, panic, and terror which are connected to the Kidneys.

The patient's subconscious demonic images may tend to be culturally influenced. Each patient may find himself or herself observing something quite different, but with the same underlying emotion. In modern Western culture, individuals are more likely to dream of thugs and assassins that are threatening and pursuing them, as well as monsters.

ACTUAL ENCOUNTERS WITH SPIRIT DEMONS

These spiritual encounters have an objective reality, as they are true spiritual entities which exist outside an individuals thoughts or feelings. For obvious reasons it is extremely important for Medical Qigong doctors to have a strong spiritual foundation. Without a powerful connection to the divine, the doctor risks absorbing the patients' pathogenic Qi, and may become more vulnerable to "evil states" that may place him, or her, at the mercy of spirit demons who seek to dominate, control, and feed off of the negative emotions of the human body.

The spiritual state of the energetic field controls the emotional field, the emotional field in turn controls the mental, and the mental controls the physical field. This is the spiritual template used in the Medical Qigong clinics in China for initiating the energetic laws of dominance and control over the body's tissues. When there is a spiritual interaction involved, the emotions manifest the outcome. There are two ways a spirit demon can attach itself to the body; through spirit oppression, or through spirit possession.

1. Demon or spirit oppressed patients tend to first have had severe emotional trauma, resulting in extremely low self-esteem, depression, fear, rage, and so on (these are the emotional energies on which the evil spirit feeds). The spirit demon becomes attached to the patient's second field of Wei Qi, drawing energy and sustenance from the patient's chronic release of negative emotions.

These spirit demons are external energy feed-

ers. They are spiritual parasites which provoke and increase negative emotional reactions. Once the patient discharges these negative emotions into their second field of Wei Qi, the spirit demons then ingest and absorb this energy as food. If, for any reason, the spirit demons leave or abandon the patient's second field of Wei Qi, they will, like a predator, continue to look for their next feeding ground. This is why, in certain families, oppressive dynamics are passed from generation to generation, due to certain congenital spiritual patterns.

2. Demon or spirit possession occurs when the patient's Spirit/Mind (i.e., the focused power of their consciousness) becomes too attached to something; it may leave the patient (becoming a wondering spirit) and not return. The vacuum that is left by the original consciousness leaving its residence can become filled by the spirit of other beings. These alien energies tend to enter the patient's body, replacing their original consciousness (Yuan Shen), which is now lost. The resulting state is one of demon or spirit possession. Because the spiritual quality and stability of the patient's mind is lost, the patient will become increasingly dependent on the alien spiritual consciousness for orientation towards others, and the outside environment.

When either a demon or spirit entity possesses a patient's body, it tends to be extremely territorial and protective. This is because, as the demonic spirit surrounds the very core of the patient's energetic body, it initially has a strangle hold on the patient, feeding and distorting the patient's reality. This results in wild mood swings, and sometimes, in displays of extraordinary intuitions, perceptions, and incredible physical powers.

In most cases the spirits causing the pathology are not of a high order of intelligence; they are more on the level of spiritual bacteria, viruses, or parasites. In some cases, however, spirits can be of a high order of demonic intelligence, such as depicted in the movie "The Exorcist."

Examples from Personal Clinical Experience

Through my personal clinical practice, I have treated several patients who were actually demon possessed, or demon oppressed. One example occurred in 1992, when a patient came to me with a tumor located on her pituitary gland. The Western doctor who was treating her had suggested that she receive immediate surgery, so as a last resort she came to me.

Knowing that she had written several books that were currently being used in a major university as a standard text, I was quite impressed and even intimated by her reputation as an intellectual. She, being the mentor of several of my students who were psychotherapists, did not ease my apprehension. Although she was elderly, she was very strong willed, and quite opinionated. She requested that I lower the treatment table to the floor before starting the therapy. I thought that this was a little strange, but complied never the less, and so we began the initial treatment with the patient lying supine on the table, placed on the floor.

I always begin each treatment with a connection or "hookup" to the divine After connecting with the divine, the energy of the treatment room changes, as the room's energetic field transforms into a divine healing energetic field. Immediately upon "hookup" something in the patient shifted. Although her eyes were closed, the patient began to thrash about on the table like a wild animal, literally snarling, and gnashing her teeth. The power radiating from her body was quite incredible. I knew and believed, that if she wanted to, this elderly, frail woman, could now lift my body up, and toss it across the room like a rag-doll. I was quite aware of the supernatural power and spiritual demonic form that I was now facing, and knew that my 27 years of martial arts training would not serve me in this situation. To my advantage, I had previous exposure to such spiritual demonic phenomena, and had been successful in dealing with demon possessed individuals. Believing that the current healing work was part of my ministry and life purpose, and having participated in several demonic exorcisms, I was aware of the procedure which needed to transpire.

I began dredging and casting out the demons

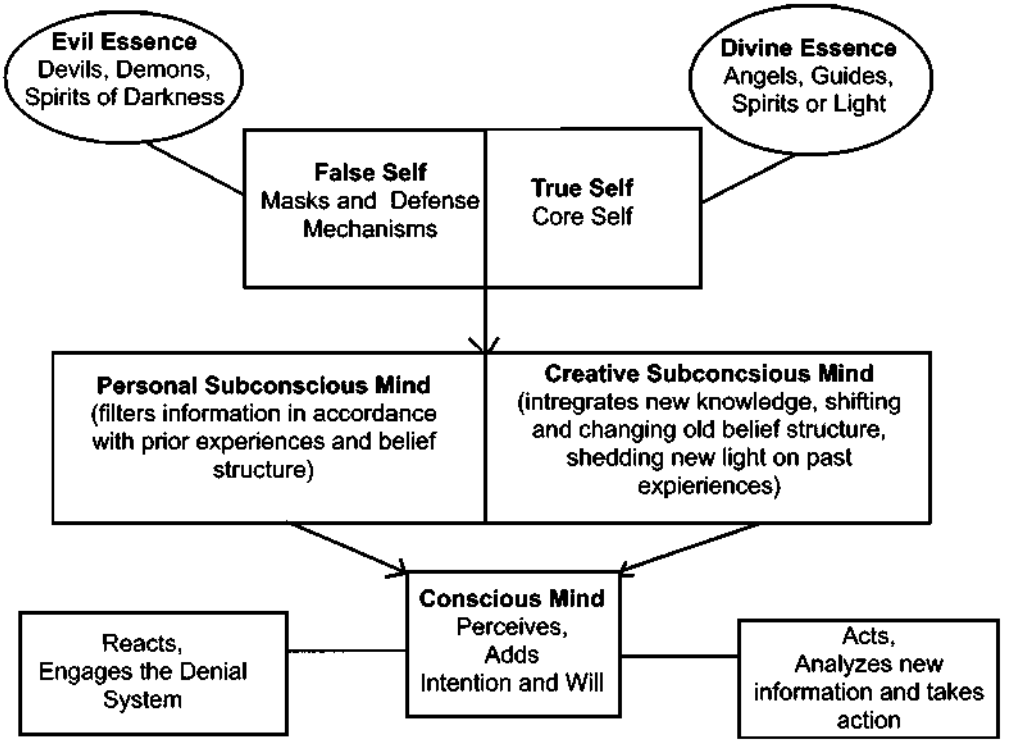

Figure 19.2. All human beings are subject to divine and evil spiritual influences. These influences can affect the subconscious and conscious mind, as well as the sensory perceptions and physical performance.

one by one, claiming each portion of her body for the glory of Christ (my divine authority). This procedure continued for six weeks, each treatment involved reclaiming certain areas of her body. Beginning at her head, I continued treatment down the patient's body. On the sixth week, when I reached her Lower Dantian, the last spirit demon left her body, and she immediately curled up into a fetal position and began to cry. Her Hun then returned to her body, and for the first time in many years she could feel loving emotions again.

It is important to note, that while the treatments were being administered, the patient was not consciously aware that anything out of the ordinary was happening. She had been so completely detached from her body, that she had no conscious recollection of her own emotional-spiritual field of existence, or its affect on her physical body. She had literally hid within the confines of her intellect, where she felt safe. She was also not aware of being demon possessed, or even that her body thrashed about during each treatment. In effect, she had disassociated from her Yuan Shen during childhood, and thus became dissociated from her emotions. After six weeks of treatment her brain tumor had completely dissolved. But, far more remarkable, was the change in her personality, for she became both friendly and courteous.

OVERVIEW

As mentioned before, once the Qigong doctors' Shen has reached a high state of sensitivity, they are able to transcend their conscious perceptions to sense, observe, and communicate with the spiritual world (Figure 19.2). This ability to see disembodied spirits or ghosts is a normal part of Medical Qigong training and a natural part of energy observation.

These spiritual presences can be seen or felt for either brief moments in time (usually as a hovering image of light, or a dark shadow), or for extended periods of time (usually an encounter). Some of these spiritual entities can also take the form of animals.

Some doctors view these energetic entities as either individuals who are astral-projecting (from the past, present, or future), or forms of energy that can either be ascended spirits of light (divine guides or angels), or fallen spirits of light (demons and hostile forces). In any case, encounters with such entities of the spiritual world should not startle or scare the Qigong doctor, but be expected as a part of the existence of the spiritual domain.

A final important note to make is that, although demon possession is real, the location, or type of the patient's disease, has nothing to do with demonic possession. Demonic possession is related to the disassociation from the Yuan Shen and the absence, or suppression, of the patient's Hun. It is not caused by obstructed tissue formations or physical disease.

After helping the patient uncover any severe emotional trauma, the Qigong doctor should assist the patient in "soul retrieval" meditations, in order to return the patient's Hun back into its residence (the patient's physical body) and to facilitate a strong reconnection to the Yuan Shen. During soul retrieval meditations, patients sometimes talk about viewing certain traumas from different visual perspectives, such as: watching the incident from above their body, or watching from a different corner of the room. The reason for this change in visual perspective is due to the displacement of the patient's Hun once it leaves the body. Although the Hun are outside the body, they still observe, listen, and record. This accounts also for the numerous cases of astral projection during surgery, as well as during near death experiences. Under anesthesia, many patients travel out-of-body and observe in fine detail what the doctors and nurses are saying and doing. They accurately recall the doctors' and nurses' conversations, and the experience of viewing the operation from above the body. These experiences are becoming more documented in recent years partly due to modern techniques in resuscitation, that have made such experiences more frequent. First hand accounts of out-of-body experiences abound in "near death experience" literature.

Similar experiences have been recounted by many physically and sexually abused patients, who, as children, learned to dissociate from the body, and observe the abuse from the ceiling, or corner of the room. In most cases, these adults, and children, do not suffer from multiple personality disorder. Only in the most severe cases does the personality fracture and become multiple.

MULTIPLE PERSONALITY DISORDER (DISSOCIATIVE IDENTITY DISORDER)

Occasionally the Qigong doctor may encounter a patient with a multiple personality disorder. The condition of a multiple personality disorder is generally due to extreme sexual, physical, and emotional abuse during childhood; in some cases, demon possession may also occur. This is a condition in which the patient has developed a split in their consciousness, resulting in the development of two or more distinct identities or personalities that recurrently take control of the patient's behavior and consciousness, one at a time.

It is believed that the original personality splinters during childhood (usually around the age of 6 or 7 years, or as early as 3) creating several different personalties, or personality states, that are disassociated from the patient's original whole personality. The different personalities created can number as few as two, or upwards of one hundred. They are often referred to as alternate identities or simply 'alters.' These alters, in fact, often themselves give birth to more fractured alters, each with its own gender, age (corresponding to the fracturing trauma) and function (or role). Some alters may be very aggressive and protective, others will be more passive and submissive.

Some alters will have different medical conditions from the others, which inhabit the same body. As the patient changes personalities (alters), the internal and external energetic fields likewise undergo changes. Each personality can differ in age and stage of development. In most cases, the personalities are usually unaware of the words, actions, and feelings of the other personalities,

especially at the beginning of the treatment. Each personality can exhibit a different set of symptoms, as well as diseases. One personality may have chronic asthma and allergies, but when switching to another personality, the patient may suddenly display healthy lungs but display nearsightedness or high blood pressure.

Usually one personality becomes a helper to the doctor, while another personality may be psychotic, indifferent, and so on. Some of the alters may have access to highly advanced transpersonal states of consciousness, i.e., a finely honed and active psychic realm which may have provided a haven, or sanctuary during the abuse.

TYPES OF ALTERS

Over time, an alter's role in the patient's personality changes. There is a difference between an established personality which maintains both an internal and external role and just a fragment personality (e.g., washes the dishes only). Also, there will usually be a number of child personalities included, as well as adult personalities. The patient's past history of violence is the best indicator of whether there are dangerous alters. Some of the most prevalent personality types of alters are described as follows.

1. The first personality encountered by the doctor, or psychologist, is usually the patient's host personality, not the patient's original personality.
2. The demonic or spiritual personality type is generally found in very religiously oriented patients.
3. The persecutor personality type is generally responsible for the patient's attempts at self mutilation (a very common type syndrome with multiple personality disorder) or suicide. They tend to be children or teenagers. It is believed that these types of personalities are either interjections of the patient's original abuser, or have evolved from "helper" personalities.
4. The helper personality type is generally responsible for providing the patient with the emotional support to counteract some of the self-destructive behavior of the patient's persecutors.
5. The administrator or obsessive-compulsive personality type is often responsible for allowing the patient to earn a living. They generally appear cold and aloof.
6. The imitator, or impostor, personality type generally mimics other personalities and is responsible for handling certain situations that are difficult for the patient to bear.
7. The autistic or handicapped personality type generally emerges when the patient feels that he or she is under intense scrutiny, or feels that he or she is being controlled or confined. They may manifest autistic or catatonic states or become functionally deaf or blind.
8. The promiscuous personality type is generally responsible for the patient's overactive or uncontrollable sexual urges (e.g., nymphomania).

While treating patients with multiple personality disorder, the therapeutic goal is usually to integrate all the different personalities, merging them together through creative visualization (usually using hypnosis). This is achieved by having the patient imagine each personality and subset "alters" merge into one.

Some patients, however, opt to remain multiple, as merging incurs the "death" of others. In such cases, contracts are made with the different alters to keep each other informed of events occurring during their "coming out," and some of the more responsible personalities keep watch over the more self-destructive ones. Due to the complexity of treating multiple personality disorder, and due to the high potential of suicide in multiple personality cases, it is recommended that the Qigong doctor refer these type of patients out to specialists who are familiar with such conditions and their recovery.

SOUL RETRIEVAL AND MEDICAL QIGONG THERAPY

According to the Medical Qigong perspective, one of the major causes of illness is "soul loss" (the loss of parts or memories of the Eternal Soul). On the spiritual plain, the Eternal Soul is the manifestation and sum total of our energetic associations and the energy of the Wu Jing Shen (see

Chapter 2). The Eternal Soul serves as a middle point between the source and organization of all life-force energy. The Eternal Soul is considered the seat of all emotions, feelings, and sentiments. As a crystal grows around a central matrix, so the body grows around the Eternal Soul. In revue, the Eternal Soul radiates energy in all directions, like the sun, and is responsible for life, health, and the formation and growth of the body. In the scope of energetic manifestations, the Eternal Soul expresses its innate qualities as energetic movement, functioning through the physical form (led by the Shen). It is connected to all parts of the body, and its light or energy is reflected through the eyes via the Hun. It is through the influence of the Eternal Soul that all of the body's energetic processes (organs and organ systems) seek wholeness. It knows exactly what is needed in every situation for survival and health preservation, and takes action via the Po. Whole body consciousness is the main characteristic of the Eternal Soul. Without the process of the Eternal Soul, energy would have no specific direction and remain in meaningless activity.

"Soul loss" is not demon possession, but a spiritual illness that causes emotional, mental, and physical disease. When disturbed, the Hun leave the body and the Mind (Shen) wanders off on its own. When the Hun leave and the Shen wanders off for very short periods of time, it is sometimes called, "dissociating" or "spacing out." When the Hun leave for extended periods of time, it is called soul or spirit travel, which generally happens when the patient is asleep. It is believed that if the Hun completely vacate the body, the patient will die. A coma is one example of a chronic physical state where the Hun have left, but are still attached to the body, through the Hun's connection with the patient's energetic Qi field. When a patient is in a coma, the Hun and Shen abandon their residence, wandering about in the astral plane of existence.

The Hun and Po create the sustaining energy for the Wu Jing Shen, which provides the energy for the Yuan Shen. If the Qigong doctor can retrieve the lost parts of the patient's Eternal Soul (the suppressed memories attached to the Hun and Po), then the individual's Shen can be restored back to harmony and health.

Reasons the Ethereal Soul Leaves the Body

In ancient times, disease was attributed to the Hun having strayed away, or having been stolen. It was believed that the Hun would leave the body through three main incidents: they could be stolen (through deep infatuation), frightened away, or simply wander off. In addition to soul theft or "rape of the soul," some Qigong doctors relate Hun loss to the interference of Gui (ghosts, demon spirits), as well as other human beings (i.e., a broken heart or severe trauma).

Soul retrieval is an essential part of Medical Qigong therapy; the body and mind without the Hun, or the spiritual connection of the Yuan Shen, remain in a suspended state of spiritual and emotional shock. When the spiritual needs of the Eternal Soul are neglected, the Shen begins to disassociate, and symptoms of addiction to drugs or alcohol, obsessions, violence, or deep depression take over (see Chapter 32).

Because we are born understanding hidden spiritual realities, patients will inevitably succumb to various mood swings; these are due to deep emotional pain and experiences that stay within their memory and touch their Heart. A spiritual life of some kind is absolutely essential for psychological health. Traditionally, the Hun are said to suspend themselves midway between the conscious and the unconscious, and that their perceptual modality is neither the mind's nor the body's, but the imagination's (i.e., the Creative Subconscious).

From a clinical perspective it has been noted that the Hun leave the body during severe emotional traumas (i.e., surgery, the death of a loved one, miscarriages, abortions, incest, molestations, physical and emotional abuse, the end of a deep relationship, and the stress of combat). Whenever we experience trauma, our Hun, which are part of our vital spiritual essence, separates from us to survive the experience and to escape the full impact of the pain (Figure 19.3). When patients be-

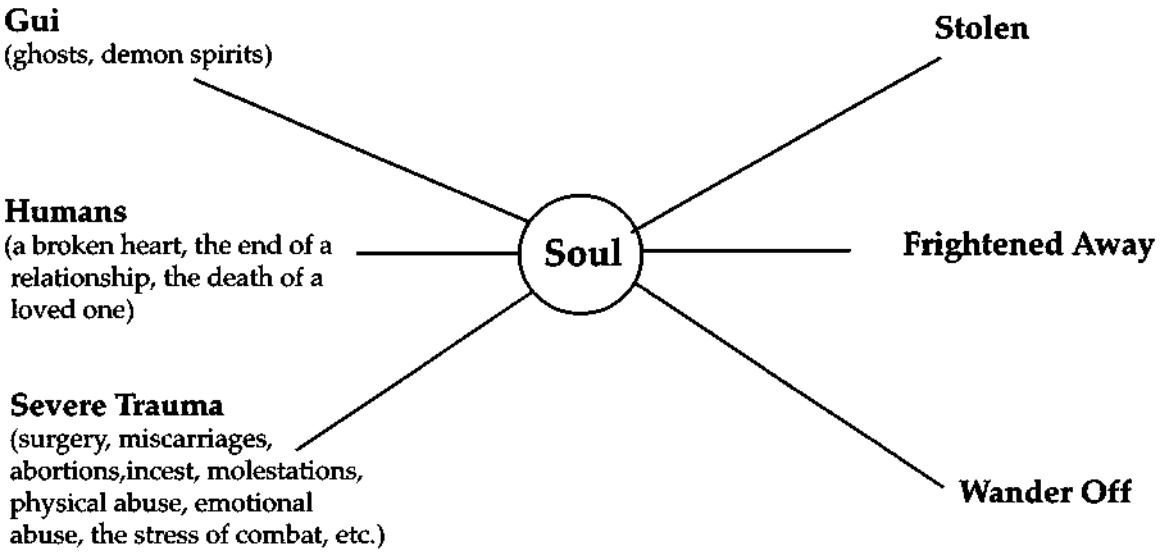

Figure 19.3. Reasons for the Ethereal Soul Leaving the Body

come dissociated, aspects of their personality separate from the mainstream of their consciousness, resulting in gaps of memory loss. An extreme example of personality separation occurs in multiple personality disorder.

When a patient has been violated or wounded in some way and remains in an emotionally present state of mind, within the body, the result usually encompasses feelings of anger from past hurts, grief from present pain, or fear of future harm. If an over-stimulation of the energetic organs occurs, it may wound the patient's Shen, causing the patient to close off from the Yuan Shen, to shut off all emotions. This action is similar to that of a sea-anemone, whose natural response (for the purpose of survival) is to immediately close itself after being touched.

THE PURPOSE OF SOUL RETRIEVAL

The purpose of Medical Qigong soul retrieval therapy (called age regression therapy in Western psychology) is to bring the awareness of emotions back into areas of the physical body, allowing the patient to express and release the feelings and reactions that are the cause and symptoms of his or her disease. This will help the patient transform the trapped, or frozen energy (stagnated Qi), back into its energetic potential to be reintegrated with the Shen.

A Qigong doctor will accompany and tend to the patient's Eternal Soul in times of emotional transformation, including times of crisis, illness, and emotional death and rebirth. This allows the patient to remain in the energetic present time mode. This also results in the relief from symptoms of illness and the return of the patient's personal power, creating the potential for fulfillment in work and rewarding relationships. Some patients may come to the realization that they must quit their job and find another that is more spiritually rewarding. They may also find themselves discarding old friendships and making new ones, as their energetic, emotional, and spiritual fields undergo growth and change.

WOUNDING AND CLOSING THE SPIRIT

The body's Yuan Shen is the main expression of the Eternal Soul as it moves from its inactive state to a state of dynamic activity. The Yuan Shen is the medium or active environment of the Eternal Soul. The Yuan Shen also expresses its energetic influence through a continual interchange between the personal-self and the higher-self

through the act of breathing. The Eternal Soul expresses itself specifically through the Yuan Shen, and the Yuan Shen manifests itself through the physical body.

If a person's Yuan Shen becomes wounded (feels attacked, violated, taken for granted, etc.), it begins to close itself off from its environment. When the Yuan Shen "closes", the emotions begin to shut down, and the Hun wander. Depending upon the patient's set patterns, this entire process can occur within seconds. Once the Hun wander, the acquired (analytical) Zhi Shen and surviving Seven Corporeal Souls (Po) take over the body, and the patient responds like a machine (i.e., the patient can still think and function; reflexes remain intact, but he or she is void of interpersonal feelings). Patients whose Shen have closed down cannot make emotional attachments, and live in a state of perpetual hunger. These patients go through three stages of isolation before their spirit leaves.

1. The first stage involves anger and grief.

   Once a patient has been hurt (before his or her spirit begins to close), his or her natural survival energy immediately affects the Liver and Lungs, causing emotional reactions that are a natural response to feeling attacked. Hurt, sadness and anger are natural responses to feelings of rejection, betrayal and abandonment. These emotions reflect a spiritual, emotional and mental protest to feeling insignificant, excluded, and dis-empowered.

   a. The patient's congenital emotions of kindness and compassion, stored within their Liver, instantaneously shut down as the Liver Qi expands violently outward. This energetic reaction gives way to releasing the patient's acquired feelings of anger and rage, stored within the Liver. The energy of anger and rage is projected outward to protect the patient's emotional boundaries. If the patient has deep seated emotional problems, however, the energy can also implode inward creating self-hate.
   b. If this protective emotional reaction is not effective in obtaining the needed results (being heard, honored, valued, etc.), the patient's energetic field rebounds inward affecting the Lungs. Once the congenital emotions of integrity and dignity stored within the patient's Lungs become effected, the Lung Qi becomes obstructed, and the acquired emotions of grief and sorrow are released. The energy of grief and sorrow is encapsulated internally to encase the patient's wounded spirit.

2. During the second stage anger and grief transform into depression and despair.

   As the patient begins to lose hope, the Shen begins to close, causing two reactions.

   a. The patient's Liver Qi becomes obstructed and stagnant. This in turn transforms the emotion of anger into depression;
   b. At the same time the patient's Lung Qi transforms grief into despair.

   The patient slowly begins to feel helpless, hopeless, and empty inside. Because of the increased depression and despair, the patient becomes physically, mentally, emotionally, energetically and spiritually tired, and gives in to feelings of insignificance, unfulfillment and loss of control over his or her life.

3. During the third stage depression and despair transform into indifference and detachment.

   In the final stage, the patient has lost all hope of resolution and gives up entirely. The Shen closes down, and the Hun wander. The patient feels emotionally detached from people, the surrounding environment, and his or herself. The patient wanders around "dead to the world," isolated, internally unfilled, and alone. This creates what is known as a "depersonalization disorder."

   A depersonalization disorder involves the persistent, recurring episodes of depersonalization, characterized by a feeling of detachment, or estrangement from one's self. The individual may feel as if he, or she, is living in a dream, or movie, and responds to life like

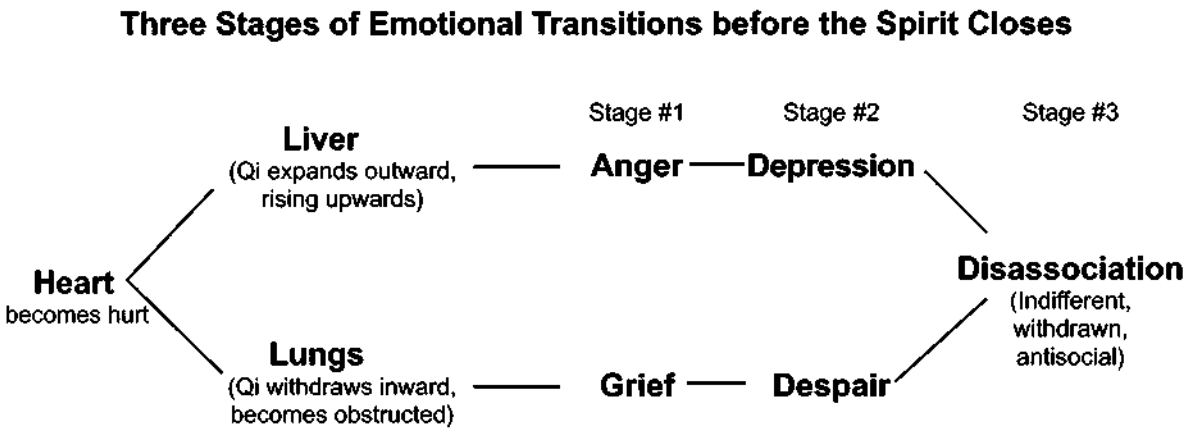

Figure 19.4. There are three stages of emotional transition the patient must experience before their Shen closes and their denial system engages. After these stages are experienced the patient's defense mechanisms take over.

a robot. They may also have the sensation of being an outside observer (to their mental processes, body, or specific parts of the body). This feeling is often accompanied by sensory anesthesia, a lack of affective response, and a feeling of lack of control over their actions (including speech).

Voluntary induced expressions of depersonalization or derealization that are meditative, or cultural trance practices, should not be confused with this involuntary disorder. It is believed that approximately 50% of the population may experiences a single, brief episode of depersonalization, usually precipitated by severe stress. Approximately one-third of individuals exposed to life-threatening danger incur a brief episode of depersonalization. Depersonalization episodes may be accompanied by visual distortions, such as the shape or size of objects, and other people may appear unfamiliar or mechanical. Other common associated features include: anxiety or depressive symptoms, obsessions, somatic concerns, and time distortion. Depersonalization and derealization are some of the symptoms of panic disorders (not due to drugs or medication), which are usually caused by long-standing anxiety and stress. Panic disorder can also be brought on by emphysema and asthma due to the difficulty in breathing.

When the Eternal Soul becomes wounded, the first two stages in closing down the Yuan Shen are caused by the patient trying to repress feelings of anger (stored within the Liver), and sadness and grief (stored within the Lungs). This reaction is incurred because the Liver stores the body's Three Ethereal Souls (Hun), while the Lungs store the body's Seven Corporeal Souls (Po). These two emotions are expressions of the patient's natural protest against the lack of love that their Yuan Shen (which encompasses or contains both the Hun and Po) is experiencing (Figure 19.4).

HEALING THE SPIRIT

The first stage of healing in soul retrieval is to open the patient's Yuan Shen by giving them hope and encouragement. Hope helps the patient's perspective to be positive and restores meaning to life. Once the patient has closed his or her Yuan Shen, it cannot be opened through argument or logic. Instead the Qigong doctor must use a gentle, soft tone of voice expressing compassion and high regard for the patient. The patient must feel honored and valued by the doctor to feel safe enough to release the hurtful and negative emotions.

Praise must be used carefully and gradually, since some patients may be as yet, unable to accept a higher concept of themselves. Too much praise may cause the patient to feel "mocked" or "lied to", given his or her very low self-esteem. This type of healing only happens when the patient's spirit is engaged, stimulating the inner emotions and not just the intellect.

Once the patient's Yuan Shen begins to open, it is important for the doctor to increase the patient's hope for interpersonal relationships. This is initiated by using silent mental affirmation, or prescribing positive affirmations in conjunction with vivid visualizations. The patient's imagination can reengage his or her feelings and return them to the body's organs and tissues. Instilling hope and giving encouragement allows the doctor's influence on the patient to be increased.

As the patient's Shen begins to open, it is important for the Qigong doctor to take the time to energetically and emotionally travel with the patient back into the memories of the past, to encounter the precise moment in which the patient's Hun left the body. The choice to return the emotional spirit back into the body must come from the patient's desire to retrieve his or her original feelings, no matter how painful the process. The patient must be ready to reexperience and release these feelings. It is important that the patient's "adult observer" be present in retrieving these painful memories. The "adult observer" refers to the patient's ability to suspend his or her judgemental attitude towards his or herself, and to observe the events that are being released with compassion (i.e., as if they were happening to a friend to whom loving support can be given). This allows the patient to experience true healing with the help of a compassionate companion (his or herself).

Tears often come as the memory of the original trauma releases from the patient's body or flows back into the Mind. Many patients notice that after these experiences their dreams change significantly, becoming more vivid. Also, their life environment as well as their relationships tend to change drastically.

EMOTIONAL REBIRTHING PATTERNS

Often, when patients experience deep emotional and spiritual traumas, they also experience physical sensations which reflect the trauma of their biological birth. These psychophysical sensations are due to the physical, energetic, and spiritual connection each individual has with the maternal host while inside the womb. Although these experiences are natural, they can sometimes be disturbing and even frightening to patients unfamiliar with deep emotional and spiritual transitions. The following are but a few examples of physical rebirthing patterns, and the emotional reactions related to these types of spiritual transformations.

- In patients born with the umbilical cord wrapped around their neck, each time they experience deep emotional and spiritual changes it will feel as if they are being strangled.
- In patients born through C-section, each time they experience deep emotional and spiritual changes it will feel as if they are being torn asunder.
- In patients born through the natural birth cannel, each time they experience deep emotional and spiritual changes it will feel as if they are falling through space with nothing to support them.
- In patients born breech, each time they experience deep emotional and spiritual changes it will feel as if they are being crushed in by all sides and suffocated.
- In patients with mothers who were heavily sedated, each time they experience deep emotional and spiritual change they will feel mentally disoriented and unstable.

SOUL RETRIEVAL MEDITATION

The following comes from my clinical experiences in dealing with patients who are very eager to heal, but reluctant, or unable to tolerate rapid change within themselves. The patients' family dynamics, as well as the quality of traumatic and nourishing experiences they received while growing up, play an important role in shaping their in-

dividual personalities. It is an accepted fact within modern psychology that an individual's present emotional life is shaped by the events occurring in the "formative" years (especially the years before the individual can articulate their thoughts and feelings). These experiences sink deep into the individual's psyche, hidden from consciousness through repression and denial. This repression is generally due to the inability to understand and express in words the traumas they suffered.

This particular Shengong (which literally means working with spirit) technique involves creative visualization (in a very relaxed, quiescent state of mind), and is used to gain access to the patient's unconscious past emotional experiences. The goal of this meditation is to allow the patient to free him or herself from the repressed emotional material which systematically surfaces during daily life. These programed emotional responses systematically affect the patient's behavior, causing neurotic symptoms, slips of the tongue, associated dreams, and fantasies.

Many patients believe they are ready for this experience, but in reality they are not yet able to deal with such intense pain. These patients are likely to unconsciously choose the least painful memories in order to test how the doctor will handle their feelings, or fail in the attempt to retrieve the lost parts of the soul. Gradually, as trust grows, these patients will be able to access more painful and relevant memories (this is similar to peeling an onion layer by layer). Sometimes patients try very hard to access the memories and obtain nothing, or very little information, leaving them feeling frustrated. This frustration must then be processed and resolved.

The doctor must instill hope and dispel this frustration by explaining to the patients that they have made an important step forward by seeding the unconscious mind with the request, or concept, that past memories must be recalled. In time, this seed will sprout and give forth results. It just needs a little time to incubate. It is extremely important that the doctor never show disappointment or take away the patients' hope.

In such cases, the patient must be reassured that their higher-self (the observer self) senses that the timing is not right. There may be current issues or events, that must first be worked through for a successful soul retrieval to take place. To have done so now would have resulted in more trauma, or more precisely, re-traumatization. They may need to strengthened and develop more self-trust before trying again. Counseling may be recommended, and in time they will succeed.

Some patients may need several sessions before feeling comfortable enough with just entering and surfacing from trance states, before undergoing soul retrieval. It may be necessary to first retrieve pleasant memories that build self-trust and self-confidence before re-attempting soul retrieval (i.e., learning to fly a kite, etc.).

The Qigong doctor should have some training in hypnosis and hypnotic trances before giving this type of trance inducing meditation to their patients. The doctor should know what to do and be able to identify whether or not the patient is able to connect with their Yuan Shen or "higher self." As the doctor induces trance in the patient through this meditation, the following changes in the patient may be noted:

- a change of color in the complexion,
- a relaxation of the facial muscles,
- a change in breathing patterns, and
- sporadic eye movement (behind closed eyes).

If none of the above signs are noted, the patient may need more time to relax deeply before continuing with the meditation. Suggestions of imagining and feeling the body's tissues melting into the Earth may be given, along with suggestions of taking deep relaxing breaths to calm the patient's Shen.

While performing this meditation the patient may experience all the sensory, emotional, and physical sensations of these repressed memories, causing specific core memories (that have been repressed from infancy and childhood) to be brought to the surface and relived. As the patient experiences these memories, his or her facial expressions and demeanor, will often change, regressing to reveal the appropriate age and period of time during which the original trauma occurred.

This particular method of soul retrieval is divided into two stages. The first stage involves locating the body's three storage chambers of past, present, and future emotions. The second stage focuses on accessing the location of, and coming in contact with, the patient's unconscious repressed emotional traumas.

This meditation must first be understood in depth before it is given to the patient. It is very complex, and is not meant to be simply read through to the patient. Also, the doctor should set aside sufficient time to process what the patient experienced after ending the meditation.

STAGE 1. ACCESSING THE ENERGETIC CHAMBERS

The purpose of this meditation is to locate the patient's three storage chambers which access his or her past, present, and future emotions. This meditation also allows the patient to acquire a starting point, or outlet, for removing these painful experiences.

In this meditation, the patient first concentrates on feeling his or her entire body. Begin by having the patient sit comfortably in a chair, both feet on the floor, hands resting on the thighs, eyes closed, tongue on the upper pallet, and breathing naturally through the Lower Dantian. It is important that the patient relax, feel, and experience the body completely. The patient should also be encouraged to accept and feel everything as one unit, to connect with the Yuan Shen or "higher self."

The Storage Chamber of Past Emotional Memories

In order to find the chamber of past emotional feelings, the patient begins to focus attention on remembering and feeling a painful childhood experience. Once the patient has retrieved the memory and is experiencing the painful trauma, he or she points to the tissue area of the body where the feelings are located. This area is considered to be the current storage chamber, where the patient stores the energy of past emotional memories.

The storage areas change over a period of time, given the fact that the patient continues to process emotions throughout life. Each emotional healing causes the previous energetic holding pattern to die, and a new pattern is to be born within the patient's energetic structure. The chamber of the patient's past usually coincides with a tissue area where the patient is already experiencing disease or discomfort.

The Storage Chamber of Present Emotional States

In order to find the chamber of the present emotional states, the patient focuses attention on feeling the doctor's voice within his or her body. As the doctor continues to speak, the patient feels where the sounds are resonating. Once the patient experiences and locates this tissue resonation, he or she points to that area. This area is considered to be the current storage chamber, where the patient stores the energy of present emotional states.

The Storage Chamber of Future Emotions

To find the chamber of future emotional states, the patient focuses on a specific project that he, or she, is planning to do in the near future. Once the patient experiences slight physical sensations, he or she points to the area where the feelings are located. This area is considered to be the current storage chamber, where the patient stores the energy for future endeavors and future expectations. The patient's current ambitions may change as the patient begins to heal from past emotional wounds and makes life-style changes.

STAGE 2. RETRIEVING THE LOST MEMORIES

The final part of this meditation explores the patient's unconscious feelings and reprograms the destructive subconscious patterning. It is used to access the repressed memories stored within the patient's individual Personal Subconscious, which is hidden from through their denial or defense mechanisms. Sometimes after practicing this meditation, patients will not only gain access to the repressed memories of their infancy and childhood, but will also connect to their life within the womb, as well as their birth-process.

1. Begin by having the patient sit comfortably in a chair, both feet should be placed on the floor, hands resting on the thighs, eyes closed,

tongue on the upper pallet, anal sphincter lightly closed. The patient should breathe naturally, expanding the Lower Dantian with each inhalation, contracting the abdomen with each exhalation.

2. The patient focuses attention on the area of the body where the energy of the past emotions is stored. The doctor directs the patient to imagine opening the chamber of the past emotions, allowing the energy, like steam, to release itself from this area. This steam is gathered to the left side of the body. Once all of the energy has been released, it begins to form into a cocoon shaped cylinder of past emotional memories.
3. Next, the patient focuses attention on the area in the body that stores the energy of the present emotions. The patient imagines releasing this energy from out of the body like steam, creating a second cocoon shaped cylinder. The patient places this second cocoon in front of the body, next to the first cylinder.
4. The patient then focuses attention on the area in the body that stores the energy of future emotions. The patient imagines releasing this energy from out of the body like steam, forming a third cocoon shaped cylinder. The patient places this third cocoon to the right side of the body, next to the second cylinder.
5. Next, the patient imagines that all three separate energetic cocoons are joined together. The energetic cocoons are to be connected end to end, in a straight line, with the past on the left, the present in the middle, and the future on the right side of the patient's body.
6. The patient then focuses attention on his or her Taiji Pole, imagining the energy of the Upper Dantian descending and combining with the energy of the Middle Dantian (where the Eternal Soul is stored). Next, the patient imagines the collected energies of the Upper Dantian, Middle Dantian, and his or her Eternal Soul, descending and combining with the energy of the Lower Dantian. The patient uses the collected energies of the Three Dantians to create an "energy bubble" within the Lower Dantian to surround the Eternal Soul. While focusing on the center of the energy bubble, the patient imagines the Eternal Soul transforming into a small energetic form of his or herself.
7. Encapsulated within the energetic bubble, the small energetic form of the patient's self manifests within the physical body. The patient's Eternal Soul, now in small energetic form, begins slowly ascending the Taiji Pole, leaving the body through the Baihui GV-20 point. As the patient's Eternal Soul leaves, it is still connected to the physical body through a silver energetic cord.
8. The patient's Eternal Soul floats over the three energetic cocoons, hovering over the cocoon shaped cylinder on the left side of the body (to access the past emotional memories). Next, the patient observes the black, oval shaped cylinders, imbedded within the structures of the energetic cocoon of past emotional memories. These dark cylinders are energetic emotional clusters. They contain the memories of hurtful feelings and specific times in the life of the patient when he or she felt humiliation, degradation, shame, rejection, or emotional deprivation.
9. The patient descends into the energetic cocoon of past memories and allows the Eternal Soul to find the particular cylinder which currently needs addressing. In choosing a specific area to work on, the patient's Yuan Shen automatically selects the most relevant material from the patient's unconsciousness.
10. The patient then removes his or her Eternal Soul from the energetic cocoon, bringing with it a specific dark cylinder. The cylinder is removed from its webbing within the walls of the energetic cocoon and placed in front of the hovering soul. The cylinder is still connected to the energetic cocoon through an attached energetic cord. Through vivid concentration the patient focuses on the color of the cylinder emitting light from the Yin Tang (Third Eye) point of the little energetic self. This projected light pulsates and changes the dark cylinder, from black to white. As the cylinder pulsates and changes its color, it begins

to open and reveal the lost memories and unresolved feelings. These memories of emotional traumas are brought to the surface. Some of these experiences may be memories of events where the survival or integrity of the patient's physical body was threatened.

11. Next, the patient connects with the divine (God or "higher power") and begins the process of feeling, expressing, understanding, forgiving, and letting go of the emotional charge attached to the memories. This process of emotional purging is connected to the emotions stored within the patient's Five Yin Organs, and are expressed through the following stages:
    a. Anger, blame, and resentment are stored in the patient's Liver.
    b. Hurt, pain, sadness, and disappointments are stored in the patient's Lungs.
    c. Fear and insecurity are stored in the patient's Kidneys.
    d. Remorse, regret, and responsibility for keeping the painful memories and feelings alive are stored in the patients's Spleen.
    e. Love, understanding, and forgiveness are stored in the patient's Heart.
12. As the emotions begin to release themselves from the energetic cylinder, the energetic debris transforms into a vaporous cloud. After understanding and resolving the emotions contained within the energetic cloud, the patient divides the released energy into either a receiving or discharging cloud of energy.
13. At this point, the patient focuses on the energetic cloud and begins separating the pain and hurtful memories from the knowledge and wisdom gathered from the experience.
    a. First, the patient places those memories gathered from the knowledge and wisdom of the experience on the right side of the room, imagining them as sparkling gold, silver, and white light energy.
    b. Second, the patient places those memories gathered from the pain and hurt of the experience on the left side of the room, imagining them as thick, dark, black energy.
14. The patient focuses on the right side of the room, imagining this energy as bright, pure, and illuminating. The patient then inhales, absorbing the knowledge and wisdom gathered from the past experience into his or her small energetic body. Since this is actually the energy of the patient's soul, the patient's body immediately feels the emotion, energy and spirit becoming empowered, as it can now review these past experiences without the feelings of hurt, pain, and judgment.
15. Next the patient focuses on the left side of the room where the feelings of hurt and pain are stored. The patient imagines this hurt and painful energy as a dark, turbid cloud. Because the cylinder has a direct life line connected to the patient's past, the energetic cord attached from the cylinder to the energetic cocoon must be severed. Once the cord connecting the cylinder to the patient's past is severed, the patient is then truly released from the spiritual and energetic connection of the memory. This is initiated by imagining an angelic being, with the "sword of truth," severing the energetic life line connected to the patient's cylinder. The sword of truth represents the patient's decision to regain his or her power by deciding to no longer suppress and carry the painful memories. Once the energetic cord is severed, it causes the cylinder to vaporize, forming an energetic cloud. The patient then imagines severing any last connection or attachment to these toxic emotions, and releases this cloud of hurt and pain, visualizing it floating up out of the room, through the ceiling, out into space.
16. The patient then imagines that God (the patient's divine healing power) is seated in the Heavens, with ripples and pulsations of love and mercy emanating from the center of this divine presence. The patient visualizes one of these waves of love and mercy form the divine descending towards the Earth. As the wave of love and mercy touches the as-

cending dark cloud of hurt and pain, it immediately explodes and destroys the dark cloud. The moment that this dark cloud explodes, the patient sees the cloud's negative energy transforming into blue crystal drops of divine healing energy.

17. Next, the patient visualizes these bright, fluorescent blue, drops of pure, clean energy descending from the heavens and pouring down like rain on his or her small energetic self, saturating it completely. This energy immediately transfers into the patient's physical body. The patient inhales and absorbs this energy flowing into every tissue of the body, allowing the divine healing light to penetrate and radiate throughout his or her entire being.
18. Next, the patient observes the changes created within the three energetic cocoons. The energy in each cocoon will have shifted slightly, revealing an energetic alteration of the patient's present state of mind, and a change in the patient's future. By transforming the past, the patient has altered the present and initiated a change in the future course of events.
19. Finally, the patient returns his or her energetic bubble (containing the small energetic self) back down through the Baihui point into the Taiji Pole, drawing the energy back into the Lower Dantian. From the Lower Dantian the patient's soul energy will return back into the Middle and Upper Dantians, as well as the surrounding tissues. Finally, the patient reabsorbs the energetic cocoons back into the body, and returns to a quiescent meditation.

THE DOOR TO THE CHAMBER OF MEMORIES

A simple visual meditation can also be used to access the patient's suppressed past memories. This exercise is a form of guided meditation, in which the doctor leads the patient into the imagined hidden parts of his or her own soul.

Begin by having the patient lie supine. Ask the patient to close the eyes and imagine walking down a flight of stairs. Lead the patient through three separate doors, descending three separate staircases (this is performed in order to arrive at the patient's "chamber of memories").

After entering through the last door, the patient descends one final staircase until he or she reaches the chamber of memories. This is where all of the memories of the patient's past traumas have been kept, hidden deep within the subconscious mind.

Inside the Chamber of Memories, the patient discovers dark cylinders of past emotional pain. Each cylinder represents a specific trauma experienced and stored within the patient's energetic field. The patient then makes a decision to heal and free the body of the enormous energetic field used to suppress certain memories. To heal and dissolve the energetic cyst, the patient follows the same process of eliminating past memories (repeating section 8 through 15 from the previous meditation).

Once this process is completed, the Qigong doctor guides the patient back up the flight of stairs, through the three doors, and back to consciousness. Because these meditations have a profound affect on the patient's constitution (affecting their physical, mental, emotional, energetic, and spiritual nature) it is important for the patient to be referred to a psychotherapist while undergoing this type of Qigong therapy to further facilitate the patient's healing transformation.

FINDING THE LIFE PURPOSE

Another aspect of Soul Retrieval consists of an exercise that assists the patient in finding his or her purpose in life. Finding the purpose of the patient's life encourages interpersonal healing, and fills the empty space deep within the patient's heart. This in turn increases the healing potential by providing the patient with hope.

1. The first step is to ask patients to write down on paper what is was they wanted to be when they were very young. Have them list the people that they imagined or fantasized being while they were still children (e.g., a super hero, doctor, fireman, etc.). This exercise allows patients to access their emotional past, and to feel and recover pleasant, lost memories, and phantasies.

2. Next, have the patients link all the peak experiences of each imaginary character (e.g., a doctor and fireman possess power to save lives, and can be considered heroes, as they are both admired for their skills, etc.). This knowledge informs patients regarding the underlying nature of each imaginary character and may also reveal hidden talents, passions and ideas.
3. Then, have the patients write down a list of their personal priorities. This list should contain the patients' present state of active priorities, and their current value system.
4. Then, have the patients write down their own "code of conduct," i.e., their conscious value system. The patients' code of conduct represents the ethical standards by which they strive to act. This code of conduct influences feelings, thoughts, and beliefs. It affects the patients' personal priorities and reflects the quality and nature of their interpersonal relationships. It is from this personal code of conduct that they accept, or condemn, themselves and others. By physically writing down these moral conducts, patients can emotionally connect with new found feelings of moral integrity, as well as a establish a stronger connection with their True Self.
5. Finally, have the patients write down a "life purpose" statement, linking together the collected emotions gathered from the peak experiences of their childhood and their code of conduct.

It is important that patients know and feel that what they are writing is a true and accurate account of their thoughts and emotions. The patients' live purpose statement can always be modified and changed, as they undergo personal transformation and spiritual growth through experience and expanding knowledge.

Section V
Differential Diagnosis of Energetic Principles

Chapter 20
Introduction To Differential Diagnosis

Diagnosis in Energetic Medicine

Chinese Medicine developed into a comprehensive and extremely effective diagnostic system, over many centuries of accumulated clinical experiences. The symptomatology to identify disease patterns and their underlying disharmony follows the way of nature in its relationship to cause and effect. To identify the patterns of disharmony, the Qigong doctor combines diagnosis of pathology and treatment principles into one continuum. The identification of the disease pattern is not only developed through categorizing a list of symptoms, but also through observing the pathogenesis of the disease. A symptom is a feeling, or reaction, that is a sign of disease, resulting from certain disorders (physical, mental, emotional, energetic, and spiritual).

Treatment must be aimed at finding and treating the cause of the disease. This is one of the most fundamental principles of Traditional Chinese Medicine in terms of differential diagnosis and treatment. The fundamental purpose of diagnosis is to find:

- the cause of the disease,
- the root of the disease, and
- the location of the disease.

Finding the primary cause (or root) of the disease requires understanding its nature, and allows the doctor to focus treatment on the most important etiological and pathological aspects of the disease. When diagnosing a disease, emphasis is placed on observing the energetic movement (or lack thereof), as well as energetic transformation, and not on the present set structures of the existing tissues. The tissues's structures are temporarily generated by the existing energetic changes and are therefore of secondary interest to the changes themselves.

Etiology in Medical Qigong Therapy

The etiology, or study of the causes of diseases in Medical Qigong therapy can be divided into what is commonly called in Traditional Chinese Medicine as the "three periods of life." These three periods encompass the developmental activities of the patient's Jing, Qi, and Shen formations during the transitional periods of their life, i.e., within the womb, childhood, and adulthood. Each patient's constitution results from the continuous interaction between his or her inherited form and the environment.

Within each period of life Three Stars develop and determine some of the major characteristics and traits of each person. Each group of Three Stars accounts for one third of what, and who, the person is. They combine together to form and complete a Nine Star System of life evaluation.

Etiology within the Womb

Problems arising during the Three Star Period within the womb (and during birthing) encompass the formative time span of 40 weeks. This time period can be influenced by the following factors.

1. The state of the patient's Jing prior to conception. If the Jing of one or both parents is deficient, the sperm and/or ovum will be weakened.
2. The mother's mental state during pregnancy has a deep affect on fetal formation, and directly affects the developmental activities of the fetus's Jing, Qi, and Shen. If the mother is malnourished, ill, emotionally disturbed, or taking alcohol or drugs during pregnancy the development of the fetus will be affected.
3. If the birth is abnormal, difficult and/or prolonged, it can cause an emotional shock within the newborn.

Diseases may originate from one or more of these factors causing the baby to be born with an illness or a predisposition to illness. This predisposition can be manifested as a particular type of emotional or mental imbalance, a diseases of particular Yin and Yang organs (or organ systems), or a general weakness as a whole. These conditions are commonly observed as "prenatal shock," and are indications of active fetal toxins. Prenatal shock can also be indicated when newborn babies are restless sleepers, continually opening and closing their eyes, and/or having fevers.

These problems are sometimes difficult to diagnose; simple observations however, can help the Qigong doctor to determine if the patient has experienced prenatal shock. A bluish color on the forehead of the patient, for example, is one indication of this condition.

ETIOLOGY DURING CHILDHOOD

Problems arising during the Three Star Period of childhood encompass the formative time span of 18 years. These internal problems can result from abuse, malnutrition, trauma and excess sex (during the teenage years). The subconscious mind of a child is extremely impressionable to both positive and negative influences.

If, as children, the patients experienced any physical, emotional, or sexual abuse, suffered a traumatic loss (of a relationship with either or both parents, siblings, peers, etc.), then they may become predisposed to illness later in life, or develop a disease during this time period. These traumas can affect the adolescent developmental activities of the patient's Jing, Qi, and Shen formations, as this is the child's greatest time of physical growth and development.

ETIOLOGY DURING ADULTHOOD

Problems arising during the Three Star Period of adulthood (from the age of 18 onwards), encompassing the time span of 60 years. These problems are caused by the patient's internal emotions and reactions to surrounding environmental factors. Environmental factors include: diet, relationships (be they social, work related, family or other), frequency of sex, and so on, and will affect the continual developmental activities of the patient's Jing, Qi and Shen formations. An adult, although less impressionable than a child, is less resilient than the child to trauma and illness.

PROGNOSIS

If the patient's constitution has been poor since birth, or if a specific disease has been present since birth, the prognosis is generally poor. If, however, the specific disease is acute, or has only developed during the patient's adult time period, the prognosis is more favorable.

There are always energetic interactions between these Three Periods of life. If, for example, a young female patient has a hereditary imbalance between her Conception and Governing Vessels, and also has severe emotional strain during puberty, she may suffer mental problems later on in her life.

THE GROWTH AND PEAK CYCLES OF JING, QI AND SHEN

By studying the physical, mental, emotional, spiritual, and energetic qualities inherent within the human body, the Qigong doctor is able to observe and predict the various changes according to the Nine Star System of life evaluation. It is believed that the body is given specific time periods in which to flourish during the three periods of life. The following chart depicts the body's natural time frame of each physical, mental, emotional, spiritual, and energetic peak (Figure 20.1).

- From birth to age ten represents a time of growth and development on each dynamic level. The child is in a formative stage, growing physically, mentally, emotionally, spiritually, and energetically.
- From age ten to age twenty represents a time of peak physical growth. Within this time frame the child physically enters into puberty, and is able to reproduce; the growing process is stabilizing.
- From age twenty to age thirty represents a time of peak mental growth. Within this time frame the adult actively acquires knowledge for survival sake. He or she is now able to work, produce results and begins planning for the future.

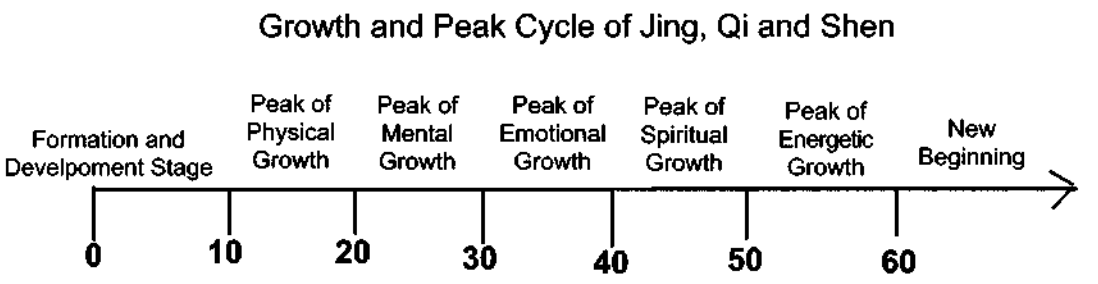

Figure 20.1. Chart of Physical, Mental, Emotional, Spiritual, and Energetic Peak

- From age thirty to age forty represents a time of peak emotional growth. Within this time frame the adult actively acquires knowledge for emotional comprehension of his or her surrounding environment. The adult is now able to creatively express his or her emotions in a civil manner and deal well with emotional disruptions.
- From age forty to age fifty represents a time of peak spiritual growth. Within this time frame the adult actively acquires knowledge for spiritual growth. Now comprehending his or her mortality, the adult begins to actively seek spiritual peace.
- From age fifty to age sixty represents a time of peak energetic growth. Within this time frame the adult's previous experiences come into fruition. If the adult has successfully acquired physical, mental, emotional, and spiritual harmony, the energetic peak will prepare the adult for the rebirth. If the physical, mental, emotional, and spiritual energy is not in harmony, the life-force is terminally exhausted, and the patient dies.

  It is commonly noted that when martial arts masters practice their training excessively or incorrectly, it is within this energetic time frame that they die. The cause of death is generally due to the over exertion of the master's Liver and Lungs, and the weakening of the Spleen, Heart, and Kidneys. This energetic disharmony stems from an improper balance of combat training with little or no spiritual training.
- From age sixty on is a time of new beginnings. This time frame represents new challenges of leadership within the family and the community.

DISORDERS OF THE HUMAN BODY

Disorders of the human body are generally due to three factors: constitutional failure of the body's Prenatal or Postnatal Qi, pathogenic factors and unrestrained Evil Qi, or one or more of the Eight Miscellaneous Factors.

CONSTITUTIONAL FAILURE OF PRENATAL AND/OR POSTNATAL QI

Prenatal and postnatal constitutional failure results in a constitutional Qi Deficiency, disease, or stagnation of the vital energy.

The Prenatal Constitution is determined by the strength of the parents when a child is being conceived, or during the pregnancy. If the parents are weak, sick, drunk, or on drugs during pregnancy or conception, the parents' Qi, Blood, and Body Fluids will be deranged and the child will be affected.

In uterus, if the mother is sick, the energy of the child will be affected. Also, negative emotions, poor nutrition, smoking, drugs, and alcohol used by the mother can affect the child within the womb and predispose the child to illness after birth (e.g., prenatal alcohol syndrome and crack babies are born addicted and with mental and physical defects). The prenatal constitution is inherited from both parents and is unchangeable.

The Postnatal Constitution is determined once the child is born. Proper nutrition and a nurturing

environment enhances his or her constitution. While it is not possible to entirely erase the effects of the patient's prenatal constitutional patterning, it is possible to enhance it through a balanced life-style and development of their postnatal constitution.

PATHOGENIC FACTORS AND UNRESTRAINED EVIL QI

Pathogenic factors and Evil Qi are derived from Six External Factors and Seven Internal Factors.

The Six External Factors arise from the six climatic changes (Wind, Summer Heat, Damp, Dryness, Cold, and Fire). When the patient's energy system is not well balanced, or the Qi is Deficient, the body is unable to adapt to climatic factors. These climatic factors can then invade the patient's Wei Qi fields and penetrate deeply into the channels and internal organs of the body.

The Seven Internal Factors arise from excessive internal emotions (anger, joy, worry, grief, sadness, fear, and shock). These feelings overwhelm the patient's mental state as the individual responds to social, emotional, and environment interactions. Under normal circumstances, emotions in and of themselves do not cause problems, if they are allowed to be expressed and released. The excessive accumulation of one or more emotions can, however, cause Qi deviations, affecting the corresponding organ or organs of the body.

EIGHT MISCELLANEOUS CAUSES OF DISEASE

Sometimes a patient's disease is caused by what is known in Traditional Chinese Medicine as the Eight Miscellaneous Factors (Diet, Overexertion, Sex, Excessive Child Bearing, Exposures to Poisons, Parasites, and Iatrogenic Disorders). The Eight Miscellaneous Factors offset the patient's balance of Yin and Yang energy and are described as follows.

1. An improper diet can throw the patient's body and mind out of harmony. Nutritional problems can be divided into three main categories:
    a. The excess intake of certain particular foods, as well as overeating food in general.
    b. Unwise eating habits such as:
    - eating foods that are inconsistent with the seasons,
    - eating a diet of too many Cold, Damp, Dry, Hot, greasy, spicy or raw foods,
    - eating irregular meals,
    - oscillating from feasting to fasting, or
    - eating while hurrying or emotionally upset.

    c. Malnutrition, which is developed from a deficient intake of the basic requirements needed to maintain a balanced diet. This condition can be caused from ignorance, poverty, or an impaired digestion, absorption and metabolism.
2. Overexertion consumes the Qi and results in energetic deviations. This condition pertains to both mental/emotional and physical exhaustion, and can stem from loss of sleep, inadequate rest, etc.
    a. Mental and emotional overexertion can stem from a dissatisfaction with one's work (or the lack of work), or a dissatisfaction with one's life. It can lead to stress, frustration, boredom, apathy, or depression.
    b. Physical overexertion varies according to the individual's occupation, as each job has its own characteristics hazards to the patient's health. Problems arising in this area can range from structural damage to organs and tissues (caused from Qi and Blood stagnation), to sensory impairment.
    c. Lack of sleep and inadequate rest can also be either a contributing factor or direct cause in the development of Qi deviations.
3. An unbalanced sex life can cause disease. An individual's sex life is innately connected to the personal spiritual qualities of his or her Hun and Po. Therefore, the majority of sexual problems are rarely of purely physical origin, and reflect the energetic balance of each individual's emotional and spiritual passions.
    a. An Excessive sex life: what is excessive for one individual may not necessarily be excessive for another. The condition of Sexual Excessiveness should therefore be based on the individual's con-

stitution. When an individual exceeds his or her body's normal sexual function, the excessive sexual act can burn up the body's Yin, Jing, and Kidney Qi, causing Deficient syndromes (this condition is more prone in men then women). The act of sex itself is considered a Hot and Damp state.

b. A Deficient sex life: when an individual abstains from sex, his or her Jing production begins to increase. If this increased energy buildup is not transformed into spiritual energy, it can overflow into the Sea of Marrow affecting the brain. The prolonged lack of sex sometimes creates an emotional need and dependency towards addictions to replace the need for intimacy.

4. Excessive childbearing injures the mother's Blood and weakens her Qi. Women suffer loss of Jing during childbirth, therefore excessive childbirth can cause a Deficient condition.
5. Traumatic accidents and injuries pertain to physical traumas which disperse or congeal the body's Qi and Blood, resulting in energetic deviations. Even after the physical trauma has healed, a site for potential weakness often remains. As the patient ages, the site becomes vulnerable to further injury due to old age, physical exhaustion, stress, and exposure to cold. All traumatic accidents and injuries also pertain to emotional trauma as they are energetically inseparable.
6. Exposure to poisons pertains to any substance taken into the body by ingestion, inhalation, injection, or absorption that interferes with the patient's normal physiological functions. These poisons include both chemical as well as environmental toxins (e.g., pesticides, carbon monoxide, electromagnetic fields, and radiation).
7. Parasites include infections and infestations, and pertain to the numerous organisms capable of living within the body.
8. Iatrogenic disorders pertain to any adverse mental, emotional, or physical condition induced through medical treatment.

THE DIFFERENTIATION OF SYNDROMES

The essence of Chinese medical diagnosis is holistic and based on the concept that all things and events are interrelated. Thus the Chinese physician takes into account not only the physical symptoms of the disease, but also spiritual, mental, emotional, and environmental factors or events, that both interrelate and interact to form "patterns of disharmony" within the patient. The doctor studies and seeks to understand these patterns of disharmony, called "syndromes," to provide the framework for treatment.

Syndromes can include External or Internal factors, congenital or acquired disorders, and symptoms of stagnation, Excess, and Deficiency, or traumatic injuries to the organs and tissues. The Qigong doctor must first determine whether the patient's disease is primarily due to an energetic disorder (e.g., an Excess or Deficient condition) or a physical disorder (i.e., structural damage). Once this determination has been made, the goal or goals of treatment can be set, and the means of treatment chosen. In the treatment of the lower back, for instance, if lumbar pain is due to a subluxation of the vertebra, caused by external injuries, the doctor should first reposition the vertebra through hand manipulations, by using Tui Na therapy, then remove the Qi stagnation. If the doctor is unfamiliar with such techniques, it is better that he or she first refer the patient out for spinal adjustment, and then remove the Qi stagnation. Only in this way can a satisfactory curative effect be obtained. If, on the other hand, the back pain is due to abdominal distention or a Kidney malfunction (i.e., primarily an energetic disorder) then treatment must proceed through Qi emission.

Several methods can be used singly, or in combination, to diagnose syndromes. They are described as follows.

1. Diagnosis according to the identification of the Eight Energetic Principles.
2. Diagnosis according to the identification of Qi, Blood and body fluid distinctions.
3. Diagnosis according to the identification of

the Five Elemental patterns.
4. Diagnosis according to the identification of the Six Stages.
5. Diagnosis according to the identification of the Four Levels.
6. Diagnosis according to the identification of the Triple Burners' System.

THE CATEGORIZATION OF SIGNS AND SYMPTOMS

In order to categorize symptoms into syndromes, the Qigong doctor must determine: The Onset, Location, Aggravating or Relieving Factors, Type of Pain or Sensation, and Course Since Onset.

1. The Onset includes the date the symptoms first appeared, whether they appeared suddenly, or had a gradual onset, and the order of their appearance.
2. The Location specifies whether the symptoms remain fixed, or migrate throughout the body.
3. The Aggravating or Relieving Factors indicate the specific conditions that affect the symptoms in a positive or negative way. Aggravating or Relieving Factors may include:
   - if the symptoms feel better or worse during daytime or nighttime,
   - if the condition is better with application of warmth or cold,
   - if the condition is better with pressure or worse with pressure,
   - if the condition is relieved by movement or aggravated by movement, and
   - if the condition is relieved by eating or made worse by it.
4. The Type of Pain or Sensation describes the nature of the symptoms, such as:
   - sharp or dull
   - pounding
   - stiffness
   - burning
   - itching
   - intermittent (coming and going)
   - electrifying
   - pulling or shooting
   - nauseated
   - distended
5. The Course Since Onset includes the incidence, progress, and the effectiveness of the treatments received.

The syndromes do not equal the patient's disease, but are the patterns of the illness. In determining the patient's syndrome, the Qigong doctor takes into account that these patterns can occur simultaneously, and vary in degree of severity. The purpose for assigning the patient's disease a syndrome is not merely to classify the disease, but to understand its process. Not all the symptoms listed for a particular illness need to be present in order to properly determine the patient's syndrome.

DIAGNOSIS AND TREATMENT OF THE PATIENT

The assessment and evaluation of the patient generally proceeds in eight stages. The first seven of the eight stages are performed prior to the initiation of the actual treatment. The final stage is undergoing the treatment plan and the periodical re-evaluation of the course of the disease since the beginning of the treatment (Figure 20.2). During these eight stages, the Qigong doctor assess: The Whole Person, The Patient's Constitution, The Signs and Symptoms of the Disease, The Syndrome, The Patient's Organs, The Etiology of the Disease, The Treatment Goal, and the Treatment Plan.

1. The Whole Person must first be evaluated according to his or her whole being. This process involves assessing the patient's:
   a. physical appearance (e.g., is the patient disheveled or appropriately groomed),
   b. energetic demeanor (is the patient very nervous, calm, manic, etc.),
   c. structural build:
   - according to the physical Yao formations,
   - introverted or extroverted features, and
   - Yin or Yang appearance.
2. The Patient's Constitution is assessed according to the Five Elemental Constitutions and their subdivisions of balance, and Yin or Yang predominant element.
3. The Signs and Symptoms of the Disease are then classified as:
   a. Objective Signs that are apparent to the doctor,

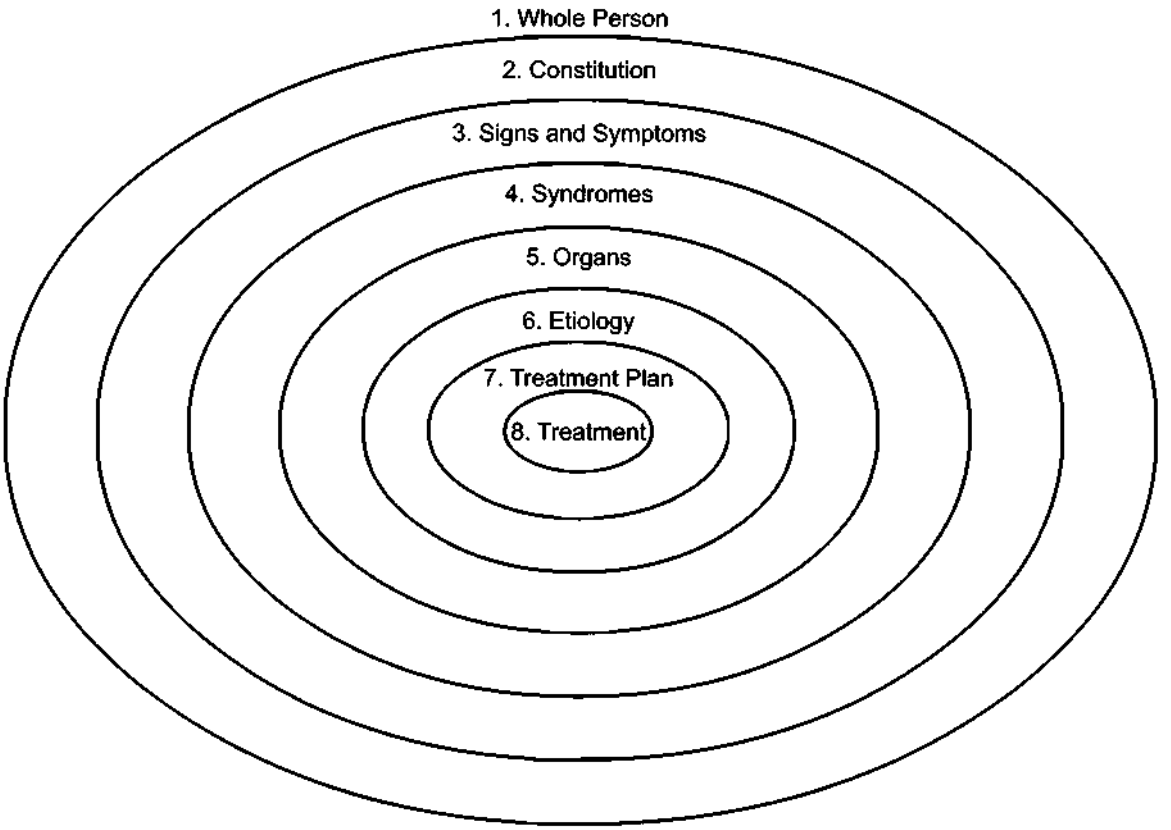

Figure 20.2. The Qigong doctor begins to diagnose the patient by first observing the patient as a whole. Next the doctor observes the patient's constitution, symptoms, syndrome, health and state of the internal organs, and the cause of the energetic dysfunction, before treating the disease. All the acquired knowledge is placed against the different diagnostic templates of the Eight Parameters, Five Element Theory, Qi, Blood and Body Fluid Dysfunctions, etc. This entire process is initiated in order to assist the Qigong doctor in prescribing the correct treatment. The treatment focuses on the specific cause of the disease and how it affects the patient's internal organs. The primary goal being to relieve the patient's symptoms, strengthen the constitution, and return the patients to a state of wholeness.

b. Subjective Symptoms that the patient reports to the doctor,
c. Cardinal Symptoms and Signs that are used for differential diagnosis of disease, and
d. Constitutional Symptoms and Signs that are indicative of a systemic disorder.

4. The Syndrome (a pattern of disease) is then determined according to the patient's symptoms and signs of disordered function, by assessing their relationship to one another.
5. The Patient's Organs are then evaluated according to any pathological changes occurring within the internal organs.
6. The Etiology (or root causes) of the syndrome is determined to complete the comprehensive diagnosis.
7. The Treatment Plan is then formulated, taking into account all the data gathered by the doctor. The Qigong doctor devises a treatment goal and determines a strategy of treatment

that addresses the patient's syndrome or disease, in accordance with the agreed upon goal and needs of the patient.

8. The Treatment is implemented and prescriptions are assigned to initiate the healing process. Over time, the treatment plan is reevaluated, as the patient improves or suffers setbacks (for various reasons). Prescriptions, likewise undergo changes in accordance with the patient's changing condition.

Once treatment begins, the process of the development of the disease is usually reversed, or the symptoms are alleviated. After the initial treatment begins, the causes of the disease are addressed, thus affecting the organs, which in turn changes the syndrome and the symptoms. This process strengthens the constitution and establishes a dynamic balance of health and well being.

UNDERSTANDING THE THEORY OF ENERGETIC COUNTERACTION

When treating patients it is important for the Qigong doctor to understand the theory of Energetic Counteraction. This theory describes the body's natural regulation, wherein no two specific symptoms (affecting the patient's general constitution) can occur at the same time, for any considerable period, within the same system.

Generally as a disease progresses, the old symptoms will give way to the newer ones. Consider, for example, a patient who has asthma, which is brought about by Wind Cold invading the Lungs (resulting in a dyspnea, wheezing, coughing, and severe mucous). If this patient unexpectedly suffers from an attack of gout (a painful inflammation and swelling of the joints), caused from the Wind Damp invading the joints and channels, the sudden attack of gout will cause the patient's asthmatic symptoms to disappear. When the gout subsides, the asthmatic symptoms will return. The new disease naturally prevails over the original condition.

Chapter 21
Diagnosis According to the Eight Energetic Principles

The method of diagnosis according to the Eight Energetic Principles was formulated by doctor Cheng Zhong Ling during the early Qing Dynasty. The Ba Gan or Eight Principles of Differential Diagnosis is a system using four pairs of opposite symptoms viewed in Traditional Chinese Medicine as being essential to the understanding and treatment of disease. In most cases, knowledge of the diagnostic systems and treatment principles of general Yin and Yang conditions is enough to give the Qigong doctor some good guidelines for steering the patient's training program. Similar principles can be found in most ancient healing traditions.

The four opposite pairs are Yin-Yang and the three subdivisions of Yin and Yang into: Internal-External, Hot-Cold, and Deficient-Excess.

1. Internal and External Symptoms inform the doctor of the origin of the pathogenic condition.
2. Hot and Cold Symptoms inform the doctor of the disease's onset (how it came on) and whether the patient's temperature has been altered due to a viral infection or a metabolic change.
3. Excess or Deficient Symptoms inform the doctor whether the condition is either to be tonified or purged, and the strength of the patient's constitution.
4. Yang and Yin Symptoms inform the doctor how to establish a physical (external), as well as energetic (internal) balance.

A detailed knowledge of the Eight Energetic Principles is required to pinpoint more subtle patterns of disharmony. This understanding allows the Qigong doctor to unravel complicated patterns and identify the basic contradictions within them. The main purpose for applying these principles is to understand the etiology of the disease and the nature of the dysfunctions; not simply to categorize the illness. Only then can a treatment pattern be initiated.

Internal and External Pathogenic Factors

Diagnosis according to internal and external pathogenic factors is not based on the etiology but on the basis of the disease's location. If a disease is caused, for example, by an "external" pathogenic factor but is currently affecting the internal organs it is classified as an Interior condition. An Exterior condition affects the patient's skin, muscles and channels, known as an "exterior pattern" of pathogenic factors. An Interior condition will affect the bones and internal organs, known as an "interior pattern" of pathogenic factors.

Exterior Conditions: Six Exogenous Pathogenic Factors

The external pathogenic factors—Wind, Cold, Dampness, Fire, Heat, and Dryness—are the six "evil" factors that come from the environment outside of the body. Under normal circumstances they are good for the health, but can be very harmful when they become abnormal.

Unseasonable weather (weather that is too cold or too hot for the body to tolerate) can make people ill by impeding the normal flow of internal energy thus making the body vulnerable to disease.

Each external factor, once it enters the body can manifest as an internal factor (i.e., External Wind can penetrate and become Internal Wind, etc.). It is also important to know that an external invasion once it penetrates the organ can transform into another internal factor (i.e., an External Cold invasion can give rise to Internal Heat).

These external factors are seen as not only the cause of disease, but also as manifestations of the

disease. A disease may be due to any one of these Six External Pathogenic Factors, or simply manifest as an external "evil," even though that pathogenic factor was not present at the time the patient got sick (e.g., Damp-Heat). Treatment is therefore based on how a disease manifests itself, rather then the specific cause. However, it is wise to have a sense of the etiology of the disease to determine where to intervene and what might be expected next.

The Six External Pathogenic Factors are categorized in China according to the seasons, temperature, and climate. These transitions are explained as follows.

1. The Heat Season is characterized by temperatures that are usually above 90 degrees Fahrenheit. The Heart, Small Intestines, and blood vessels are the most vulnerable at this time. This is most evident in summer.

   Heat is a Yang pathogenic factor that rises and spreads excessively, consuming and diminishing the Prenatal (Yuan) Qi, Body Fluids and Lung Qi. As Heat rises, the body's Qi is drawn upward and dispersed, causing the Yin energy to descend. Symptoms can range from restlessness, anger, delirium, loss of consciousness to even coma. This condition is most evident during the summer. The Heart organ benefits from bitter tasting foods which directly stimulate and enhance the Heart's Qi.

   a. Mild Heat that has been created within the body, causes an ascending action of Qi. This ascending action causes the body's Yin energy to become disturbed creating an energetic imbalance.
   b. Fire (Extreme Heat) is a Yang pathogenic factor and spreads excessively, consuming and diminishing the Yuan Qi, Body Fluids, and the Lung's Qi. It produces an explosive reaction, causing the Qi to flow up into the head and disturb the Blood. This action causes symptoms ranging from nosebleeds, skin infections, swelling, and skin eruptions, to hemorrhaging and vomiting Blood.

2. The Damp Season most often affects the Spleen, Stomach and muscles that are at their most vulnerable time. The Spleen organ benefits from sweet tasting food. The temperature is usually between 75 and 90 degrees Fahrenheit. This is evident in the late summer, during the rainy season.

   Dampness is a Yin pathogenic factor that easily obstructs the body's production of Qi and impairs the Yang. It is considered a Yin pathogenic factor because, as the invasion of Dampness moves downward, it manifests as a heavy and turbid energy, resulting in a full chest, nausea, vomiting, and a sticky sweet taste in the mouth. During the damp season, an invasion of Dampness may affect the urinary organs, causing stagnation of Qi. Once pathogenic Dampness enters the body, it becomes foul in nature. If the body becomes obstructed, the results will become evident in skin diseases with abscesses, and oozing ulcers with turbid, cloudy urination. Disease also manifested through infections, in combination with Heat.

3. The Dry Season is characterized by temperatures that are usually between 60 and 70 degrees Fahrenheit. The Lungs and skin are the most vulnerable at this time. This is most evident in autumn, because of the lack of humidity.

   Dryness is a Yang pathogenic factor because as the Heat rises, dryness consumes the body's Yin Qi, especially in the Lungs. This results in dry, chapped skin, cracked skin, and dry cough with sputum, throat pain, or asthma. The Lungs themselves benefit from pungent tasting foods, which directly stimulate and enhance the Lung's Qi.

4. The Cold Season is characterized by temperatures that are usually below 60 degrees Fahrenheit. The Kidneys, Bladder, and bones are most vulnerable at this time. This is most evident in the winter.

   Cold is a Yin pathogenic factor characterized by astringency of the tissues. During the Cold season the Yin pathogenic factors consume the Yang Qi. Cold blocks the channels and

collaterals, causing pain and damage to the Heart, as well as consuming the Kidney Yang. Pathogenic Cold also causes the channels and collaterals to contract, resulting in the slowing down of Qi and Blood circulation. As the Yin energy moves downward consuming the body's Kidney Yang, the body's Yang is unable to generate heat causing chills, pallor, shivering, diarrhea with undigested food, stiffness, pain, numbness, and clear urine. Internal Cold is characterized by conditions of overall stagnation and contraction. The Kidneys themselves benefit from salty tasting foods which directly stimulate and enhance the Kidney's Qi.

5. The Wind Season affects the Liver, Gall Bladder, and tendons that are at their most vulnerable time. The beneficial taste is sour. The climate in the Wind season, depending on the area, is usually between 60 and 70 degrees Fahrenheit. This is most evident in the spring. Wind is Yang in nature and tends to injure the patient's Blood and Yin. It is divided into both internal and external pathogenic Wind conditions. External Wind is called "the mother of one thousand pathogenic factors," and is responsible for the propagation and growth of the pathogenic environment, because it combines with other pathogenic factors to create Wind Heat, Wind Cold, Damp Wind, Dry Wind, etc.

   In the Wind season the Yang pathogenic factors are in the upper portion of the body, weakening the Wei Qi, and causing derangement of the opening and closing of the pores on the body's surface. The pathogenic Wind tends to move constantly causing abnormal motion and rigidity in the trunk and limbs. External Wind affects the upper part of the body, shifting and moving the pain like blowing a leaf. Once External Wind invades the body, the symptoms are stiff neck, itchy sore throat, watery eyes, headache, nasal obstruction, facial puffiness, aversion to Wind, irritability, abnormal sweating, migrating joint pain, tremoring, convulsions, rigidity, and facial paralysis.

   Internal Wind is manifested through the same symptoms. Because of its serious nature, it can also cause tremors, convulsions, and paralysis throughout the body (with the exception of the face, which is due to External Wind invasion).

INTERNAL PATHOGENIC FACTORS

An interior disharmony is diagnosed when the internal organs have become affected by pathogenic factors, creating an Interior syndrome. Interior syndromes are the pathological conditions which have resulted from one of three factors: (1) the invasion of the channels by external pathogens, which can be transmitted to the body's Yin and Yang organs; (2) the direct attack on the Yin and Yang organs by external pathogens; and (3) sudden emotional changes due to improper diet and stress which directly affect the body's Yin and Yang organs leading to functional disturbances.

1. A Persistent Exterior Invasion by one of the Six Exogenous pathogenic factors can penetrate deeper into the body creating an Interior syndrome, if it is not purged from the patient's body.
2. A Direct Invasion of the Yin and Yang organs can also occur from an Exterior Invasion of pathogens. In such cases, the affected organ will manifest as an Interior Excess or Deficient condition depending on the syndrome.
3. Emotional Factors can likewise cause damage to one of the Yin organs, which in turn can cause damage to the other Yin and Yang organs. People encounter emotional upheavals in everyday activities. Under normal circumstances, the Seven Emotions are good for health (see Chapter 21). Appropriate anger helps to disperse stagnant Liver Qi, preventing stasis of Liver energy and helps the patient to establish a healthy boundary system. Rage, on the other hand, leads to the abnormal increase and ascension of Liver Qi, resulting in a flushed face and dyspnea (shortness of breath). If the pattern continues (i.e., the person is a rage-aholic), the violent and uncontrolled anger may lead to serious disorders of the Liver, including eye injury, fainting due to inadequate Blood flow to the brain,

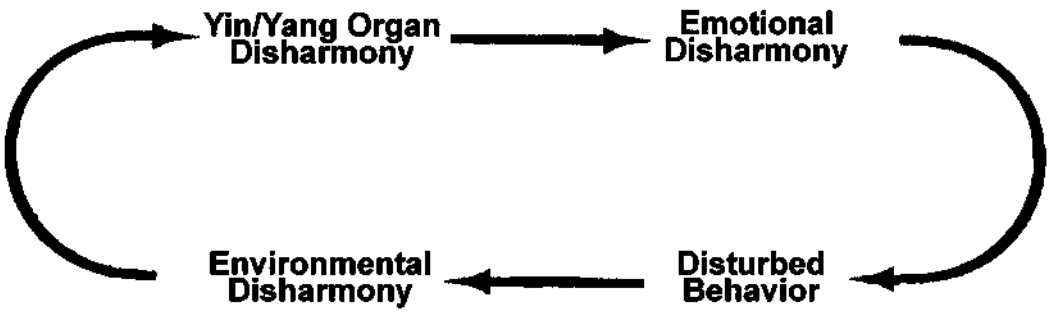

Figure 21.1. Cycle of Disharmony

cerebral hemorrhaging, or even death. It is believed therefore, that Internal conditions can arise from either an Excess emotional condition caused by emotional suppression, or a Deficient emotional condition caused by excessive emotional discharging.

It is also believed that a person's personal emotional history determines his or her biology (life processes). Each person creates this reality through his or her belief system. Hence the patient creates the disease by embracing traumatic past wounds and formulating belief structures that support these traumas. These energetic clusters are then fed via the major viscera by the excessive emotional energy. This pathological emotional process can result in the formation of cysts, tumors, cancer, etc.

Any imbalance of the Seven Emotions leads to the unnecessary consumption, or blockage of, the internal Qi flowing through the channels of the viscera. In either instance, this results in abnormal Qi activity and creates a functional disorder of the cerebral cortex.

Emotional disharmony induces a vicious cycle which affects the mind, body and spirit. Any factors (Yin and Yang disharmony, emotional disharmony, disturbed behavior, or environmental disharmony) can trigger the cycle (Figure 21.1). When caught in this cycle, emotional energy can deplete the physical body.

Anger, for example, generally causes the Qi to rise; however, when anger turns inward it can transform into depression. Mental depression may obstruct the functional activities of Qi and this stagnation may cause Fire. The Fire syndrome is caused by the disorders of the Seven Emotions and may burn up the fluid of the organ related to the predominant emotion.

In Western culture, people are generally not encouraged to acknowledge painful emotions; feelings are usually disregarded and conquered by a strong will. The storage of emotional energy in the muscles and organs of the body leads to tension, stress, and illness. The Qi cannot circu-

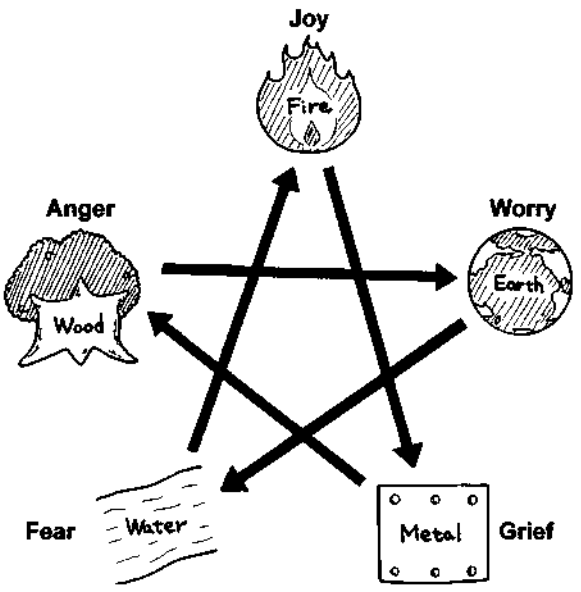

Figure 21.2. Five Elemental Controlling Cycle

late with emotional blocks. Many specialists in Western medicine today agree that a large percentage of diseases being treated are, indeed, caused or aggravated by stress.

The Five Elements have a creating (generating) and restrictive (controlling) relationship. The sequence of the creative relationship of the Five Elements is: Wood creates Fire; Fire creates Earth; Earth creates Metal; Metal creates Water; Water creates Wood. This circle is endless.

The sequence of the controlling relationship of the Five Elements is: Wood controls Earth; Earth controls Water; Water controls Fire; Fire controls Metal; Metal controls Wood. This circle is also endless.

The controlling relationship can be applied to problems with emotions. Anger, for example, belongs to the rising of Excess Liver energy and can be counteracted by descending the Lung's Qi (Figure 21.2). The Lungs control sadness, and sadness may lead to the consumption of abnormal rising Liver Qi (Metal controlling Wood).

Excessive sadness may lead to the extravagant consumption (and depletion) of Lung Qi, which damages the body's Yin and the Heart. The consumption of the Lung Qi can be stopped by the Heart's energetic release of the emotion of joy. Joy causes the rapid rising of the Heart's Qi. It can be regulated by fright and terror, which are controlled by the rapid descending energy of the Kidneys. Terror leads to the abnormal falling of Qi, it therefore counters the abnormal rapid rising of Heart's Qi. Excessive fright and terror may lead to the abnormal sinking of Gathering Qi, which damages the Kidney's Qi (Figure 21.3).

Because over-thinking can cause Qi to gather, it can be used as a tool to help bring back dispersed energy. Over-thinking and anxiety, however, may lead to the depression and stagnation of Qi, which weakens the transporting and converting ability of the Spleen's energy, and causes a lack of appetite. Mild cases of this condition can manifest as dyspepsia (indigestion), abdominal distention and diarrhea. In severe cases, the Qi

The Seven Emotions

Chinese Word	English Translation	Organ Association	Qi Manifestation
Xi	joy, happiness, excitement, pleasure	Heart	slows down and relaxes the Qi
Nu	anger, irritation	Liver	causes Qi to rise
Si	meditation, contemplation, pensiveness, worry	Spleen	stagnates the Qi
You	anxiety, sorrow, grief	Lungs	obstructs the Qi
Kong	fear, extreme anxiety	Kidneys	causes Qi to descend
Jing	shock (sudden intense fear), fright	Heart then Kidneys	scatters and deranges the Qi
Bei	grief, affliction, sadness	Lungs	disperses and consumes the Qi

Figure 21.3. The Seven Emotions Chart

and Blood stagnate in the chest and abdomen, causing a feeling of fullness in the chest or upper abdomen. This stagnated, ever-sinking Spleen energy can be smoothed and aroused by anger (the Liver's energy expanding upward and outward). In short, the hyperactivity of Yin is treated with Yang to check the unnecessary consumption of internal energy, and to promote a mild Yin energy. Then the Qi and Blood can flow without interruption and disease can be prevented.

One effective technique to avoid an emotional and energetic overload or depletion of a Yin organ's Qi, is to apply the Five Elemental counter-emotion to restore emotional balance (see Chapter 53).

OVERVIEW OF EXTERNAL AND INTERNAL CONDITIONS

The internal and external diagnostic parameters locate the depth of the condition of the disharmony and are fairly easy to distinguish, relative to the other pairs of opposites. Thus, determining the internal or external nature is usually the first step in diagnosis of a disorder.

Internal conditions are usually caused by internal disharmonies, such as excessive emotional energy in the form of anger, excitement, sorrow, anxiety, fear, and mourning, or other imbalances associated with the Seven Emotions. Excessive thinking and stress can also lead to an imbalance that is characterized as internal. Internal conditions are often chronic and tend to have a gradual onset and a longer duration.

Conditions of External disharmony are typically caused by the external influences on the body, known in Chinese medicine as "pernicious influences." They are Wind, Cold, Heat, Damp, Dryness, and Summer Heat. Pernicious influences usually invade the body when the body's Wei Qi is weak.

Typical External diseases are colds, influenza, skin eruptions, or diseases caused by injury or shock. Excessive amounts of eating, drinking, working, and sexual activity can also lead to both Internal and External disharmony. External conditions are often acute, with sudden onset, and of short duration.

Many times Internal conditions will develop when an External condition moves inward. This represents a further weakening of Wei Qi and the body's natural immune system. Before the condition has developed into a full Internal sickness, it will go through a stage of being half-external and half-internal.

Examples of conditions which may be considered as being half-internal and half-external are: alternating fever/chills, heaviness in the chest, restlessness, nausea, vomiting, no appetite, dry throat, irritation of the mouth, and dizziness. A bounding pulse is also an indication of this type of condition.

This is one reason why treatment of an External disease (colds and flu) requires sweating therapy to encourage the disease to remain external. The contractile mechanism of the skin is a specific external representation of the body's Yang immune system at work.

When treating extreme cases, such as internal injuries and shock, conserve the patient's Yang Qi by keeping them warm.

HOT AND COLD

Hot and Cold describes whether the condition is the result of a Hot or Cold state and is determined by hot or cold sensations. The nature of this clinical manifestation depends on whether it is combined with a Full or Empty condition.

HOT CONDITIONS

Hot conditions usually arise when there is excess activity of the body's Yang functions, or if there is an insufficiency of Yin Qi or Fluids in the body. A Hot condition can be further divided into either Full Heat or Empty Heat.

1. A Full Heat conditions manifest as the following physiological and mental/emotional symptoms.
   a. Physical symptoms include:

- increased energy and metabolism, i.e., physiological hyperfunction
- fever with thirst, and desire for cold liquids
- dry stool and constipation
- dark yellow and reduced urine
- flushed face, red eyes, hot red skin
- warm extremities
- aversion to warmth
- a rapid, full pulse and a red tongue with yellow fur

b. Mental and emotional symptoms include:

- irritability
- restlessness
- loud voice, talkativeness
- extroverted and aggressive behavior

Inflammations, ulcers, and infections are typical of Full Heat diseases. There are many other symptoms depending upon which organ is affected.

These Full Heat symptoms arise when there is an Excess of Yang energy in the body. Excess Yang energy can be caused from overconsumption of Hot foods (which cause Stomach or Liver Heat), or long-standing emotional problems (which cause Liver or Heart Heat) due to Qi stagnation. Full Heat can also develop from the invasion of external pathogenic factors which have transformed into Heat.

2. An Empty Heat conditions manifest as the following physiological and mental/emotional symptoms.
   a. Physical symptoms include:

- dry mouth and throat (at night)
- night sweats
- afternoon fever
- a feeling of heat in the chest, palms and bottoms of feet (Five Palms Hot)
- dry stool
- scanty, dark urine
- a floating, empty and rapid pulse, with a red, peeled tongue

   b. Mental and emotional symptoms include:

- fidgeting and mental restlessness
- vague anxiety
- insomnia

There are many other symptoms depending upon which organ is affected.

These Empty Heat symptoms arise from a Deficiency of Yin. If the patient's Yin becomes Deficient (usually due to a Deficiency of Kidney Yin), this affects the Yin of the Liver, Heart, and Lungs and causes a relative Excess Yang condition.

Cold Conditions

Cold conditions usually arise when there is excess activity of the body's Yin functions, or if there is an insufficiency of Yang Qi in the body. A Cold condition can be further divided into either Full Cold or Empty Cold.

1. A Full Cold conditions manifest as the following physiological and mental/emotional symptoms.
   a. Physical symptoms include:

- diminished physiological function and lowered immunity
- decreased energy
- aversion to cold and craving for warmth
- cold extremities
- lack of thirst
- clear urine, watery stool
- desire for hot drinks
- white face
- a slow pulse and a pale, white tongue with moist fur

   b. Mental and emotional symptoms include:

- timid behavior and soft speech
- slow movement
- a lack of motivation

Generally, discomfort is increased by cold and reduced by warmth. Cold symptoms may also appear at later stages of fevers and chronic peptic ulcers, denoting a weakening of the body's ability to overcome the disease.

These Full Cold symptoms arise when there is an excess of Yin Qi in the body. Excess Yin Qi can be caused from the direct invasion of External Cold into the body's interior. In this particular condition, the External Cold can either invade the Stomach causing vomiting and epigastric pain, invade the Intestines causing diarrhea and abdominal pain, invade the uterus causing dysmenorrhea, or it can invade the Liver Channels causing pain and swelling in the scrotum. One of the main manifestations of Interior Full Cold is abdominal pain caused from the Cold constricting and obstructing the circulation of Yang Qi. Full Cold can also develop from the invasion of external pathogenic factors which have transformed into Cold.

2. An Empty Cold conditions manifest as the following physiological and mental/emotional symptoms.

a. Physical symptoms include:

- cold limbs and chills
- pale face
- fatigue
- no thirst
- loose stools
- clear, abundant urination
- sweating
- pale tongue with thin, white coating and a deep, slow or weak pulse

b. Mental and emotional symptoms include:

- tiredness and lack of motivation
- slow movement

An Empty Cold disharmony usually arises when the Yang Qi of the body is insufficient, and fails to warm the body. This is caused by a Deficiency of Spleen Yang, Kidney Yang, or Heart Yang (sometimes Lung Qi Deficiency). The most common cause is related to the Spleen Yang Deficiency, which fails to warm the muscles and thereby causes chills. If the Spleen does not receive heat for its function of transforming food, the result will also be loose stools.

COMBINATION OF HOT AND COLD SYMPTOMS

While distinguishing Hot diseases from Cold diseases may appear to be fairly straightforward, the doctor may find that there are many circumstances where both Hot and Cold symptoms appear simultaneously. The use of sensory input is just a general indicator, however, because it provides the doctor with only partial data; it can sometimes be misleading if other considerations are not taken into account. The doctor needs to consider the other symptom characteristics according to Yin-Yang or Deficient-Excess patterns.

1. An External Cold with Internal Heat syndrome manifests when a patient has a preexisting internal Heat condition and is subsequently invaded by External Wind Cold. This condition can also occur in attacks of latent Heat combined with the invasion of Wind Cold. Symptoms can include fever with an aversion to cold, body aches, irritability, and thirst.
2. An External Heat with Internal Cold syndrome manifests when a patient with a preexisting Cold condition is attacked by exterior Wind Heat. Symptoms can include fever with an aversion to cold, chills, headache, sore throat, and thirst.
3. A Heat Above-Cold Below syndrome manifests when a patient's pathogenic Heat rises resulting in Heat above and a Cold syndrome below. Symptoms can include thirst, bitter taste, sour regurgitation, irritability, Herpes Simplex I, borborygmus, loose stools, and pale and profuse urination.

Qigong patients must be aware of these signs of Hot and Cold disharmony. If a patient's training routine is too Yang, this will burn the body's Fluids, thus diminishing the Yin Qi's ability to contain the Excess Yang, which in turn produces a Hot condition. An overactive metabolism can also induce a Hot condition, while a sluggish metabolism can produce a Cold condition. Less extreme conditions are classified as warm, cool, or neutral.

EXCESS AND DEFICIENT

The capacity of an individual to maintain resistance to the invasion of pathogens is relative to the strength of the disease and the strength of the individual. An Excess condition is characterized by the presence of a pathogenic factor (interior or exterior) and by the fact that the body's Qi is still functioning normally. The battle against the pathogenic factors results in the symptoms and signs of an Excess condition. A Deficient condition is characterized by a weakness of the body's Qi and the absence of a pathogenic factor. If the body's Qi is weak, but the pathogenic factor continues to attack, the condition is considered Deficient and is characterized by an Excess.

EXCESS CONDITIONS

An Excess condition will usually occur when a bodily function becomes overactive or Qi accumulates unnaturally due to a blockage. It is characterized by strength, buoyancy of spirits and often acute symptomatic reactions. Disharmonious conditions which begin and end suddenly are due to Excess. Yang Excess can be quickly improved, in most cases, with a diet of predominately vegetables and fruits.

It is not unusual for patients whose diets are heavy in meat proteins, to suffer from Excess diseases. Many Naturopaths advocate the predominant use of raw fruits and vegetables and have experienced outstanding results due to the elimination of Excess Yang (from meat toxins) from the body.

Such a diet is not good therapy for individuals who eat a relatively balanced vegetarian diet, because it serves to make them more Yin and threatens to throw them off balance. This is a good reason to avoid "fad" diets. A diet or method that works well for one person may have the opposite affect for someone else; each case must be considered separately.

Some indications of an Excess condition are as follows: flushed face, loud voice, coarse and full breathing, acute pain, extreme menstrual pains, a tender abdomen, which worsen with the application of heat. A strong pulse can also be a sign of an Excess condition.

In cases of Excess, to expel pathogenic evils, the patient imagines that the Toxic Qi is being expelled from specific channel points upon exhalation. The results are always more effective when Qigong prescriptions are given in conjunction with the treatments.

Any interior pathogenic factor (Heat, Cold, Damp, Wind, Fire, and Phlegm) can give rise to an Excess condition, including the stagnation of Qi and stasis of Blood.

Deficient Conditions

Although Deficiency is characterized by insufficient Jing, Qi, Shen, Blood, and Fluids, it does not generally mean a lack of some nutrient as it does in Western medicine. It is more a statement about the body's inability to find, or produce, what is necessary for its immune function to provide a functional integrity in the body. Deficiency, therefore, is taken in a more general sense and denotes the overall condition of the patient, or of the disease.

Conditions which linger are usually due to Deficiencies. The general indications are: great weakness, inconsistent energy, shallow and rapid respiration, pain characterized by soreness, weak or inconsistent volume of voice, moderate menstrual pains, withered face, low spirits, and abdominal pain. A Deficient condition will generally respond well to heat and pressure. A weak pulse can also be an indication of a Deficient condition. There are four types of deficiencies: Deficient Qi, Deficient Blood, Deficient Yin, and Deficient Yang.

1. Deficient Qi is the first and least severe stage of Deficiency. Most symptoms arise from a weakness of the Lungs' Qi (which fails to control the breathing) and a weakness of the Spleen's Qi (which fails in its function of transforming and transporting).
2. Deficient Blood is caused from a dysfunction of various internal organs. Most symptoms arise from a weakness of the Liver, Heart, and Spleen.
3. Deficient Yin is caused by a dysfunction of various internal organs. Most symptoms arise from a deficiency of Yin within the patient's Liver, Heart, Stomach, Lungs, and Kidneys.
4. Deficient Yang is caused by a dysfunction of various internal organs. Most symptoms arise from a deficiency of Yang in the patient's Liver, Heart, Spleen, Lungs, and Kidneys.

In cases of Deficiency, when replenishing Qi is required, the best effect can be obtained when the patient cooperates with the doctor's extension of Qi through mental concentration and focused inhalation.

Combined Excess and Deficient Conditions

Sometimes Excess and Deficiency conditions can occur simultaneously. Although Excess is one of the characteristics of a Yang disease, this condition can also give rise to certain symptoms of Deficiency. These are mostly a result of Qi being blocked in the utilization of its own vital nutrients.

Yin And Yang Theory

Yin and Yang energy is usually represented through the image of the Taiji symbol. Yang Qi is represented through the color white and Yin Qi is represented through the color black. Through the image of the Taiji symbol the interrelationship of Yin and Yang represent the stages of waxing and waning of energy (Figure 21.4). In Traditional Chi-

Yang - hot, bright, strong, upward, outward, clear, movement. Qi (non-substantial matter) function of an organ

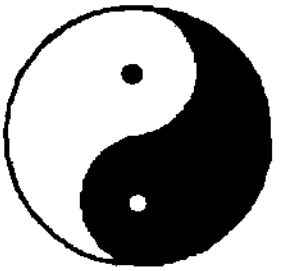

Yin - cold, dark, weak, downward, inward, muddled, stillness. Blood (substantial matter) substance of an organ.

Figure 21.4. In Traditional Chinese Medicine the theory of Yin and Yang represent the dynamic duality of balance and harmony within the body, as well as within the universe itself, and as represented through the image of the Taiji Symbol. There is always Yin within Yang and Yang within Yin. These two energies are always changing and transforming the body's life force energy.

nese Medicine, the theory of Yin and Yang is also used to explain both the psychological and pathological phenomena of the body. It is considered a major principle for diagnosing and treating diseases.

Generally speaking, an Excess of Yang may lead to a Deficiency of Yin, and vice versa. A Hot syndrome can be the result of either Excess Yang or Deficient Yin. A Cold Syndrome can be the result of either Excess Yin or Deficient Yang (Figure 21.5).

The Qi activities of these Yin and Yang aspects unite and regulate the body's internal organs and tissues. The direction and energetic nature of Qi (Excess or Deficient, strong or weak, evil or vital) can be detected at corresponding body surfaces so that information for diagnosis and treatment can be obtained. For example:

A strong, dense, dry, and hot sensation of Qi in the head area may be a symptom of Excess Yang in the upper portion of the body and a Yin Deficiency in the lower portion. This would require the Qigong doctor to guide the Yang Qi to descend and the Yin Qi to ascend to restore the balance of Yin and Yang energy.

To treat patients with an overabundance of Yang Qi and hyperactivity of Fire, the Qigong prescription meditations should be practiced during the Yin periods (11 a.m. to 11 p.m.) while facing north, with emphasis placed on exhaling to purge the Heat. The doctor should adhere to the principle of replenishing the patient's Yin to regulate the Yang, or leading the Yang to descend to supplement the Yin.

Once the nature of Yin and Yang disequilibrium is determined, the proper method of treatment can be selected to regulate the Excess or Deficiency. The doctor always treats Yin for Yang diseases and Yang for Yin diseases. A Yang syndrome, for example, should be treated with Yin herbs, and a Yin syndrome should be treated with Yang herbs. The treatment should be aimed at purging the Excess, replenishing the Deficiency, and regulating the Deficient Yin or Yang to restore a normal balanced state of energy with in the body.

In Medical Qigong therapy, the principle of "using Yin for treatment of a Yang disease and using Yang for treatment of a Yin disease" must be strictly adhered to. It is important to dredge or purge the Excess before replenishing and tonifying any Deficiencies. The intake of cold foods (fruit, salad, ice cream, etc.) or drinks, for example, may lead to an Excess of Yin, which gives rise to a Cold syndrome of the Spleen and Stomach. This manifests as pain, diarrhea, aversion to cold, and cold extremities.

To treat this Excess, the doctor guides the Cold Qi out of the body by way of St-36 and Sp-9 points, then projects Hot Yang Qi towards specific channel points on the patient's body, such as CV-12 and St-25.

DIAGNOSING YIN AND YANG IN THE BODY

Every person has both Yin and Yang elements, but will tend to be predominantly one or the other in terms of personality, physique, life-style pref-

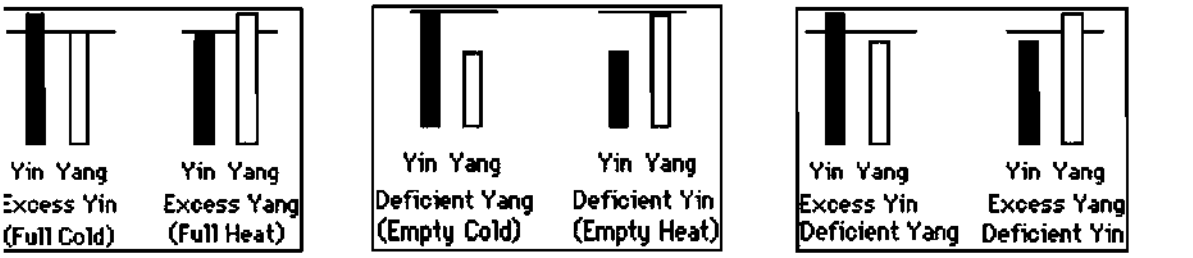

Figure 21.5. Yin and Yang Energetic Diagnosis

erences, speech patterns, mannerisms, etc. Within a general constitution there will be more subtle fluctuations within the Yin/Yang continuum as the body reacts to external and internal energetic movements. In designing the patient's exercise program, diet, or herbal remedies, it is necessary to first determine whether the patient is predominantly Yin or Yang in constitution.

YIN/YANG CONSTITUTION CHART

There are general indications that will help the doctor diagnose a patient's condition as predominantly Yin or predominantly Yang. The patient's basic Yin/Yang constitution, and an analysis of the current Yin/Yang balance of the body will play an important role in determining the type of exercise and the time of day that it will be performed. In most cases, a Yang condition should be balanced by a Yin exercise and vice versa.

There are varying levels of disharmony in the patient's body. Yin and Yang are only relative terms, and they are often not enough to adequately describe the character of the body's condition. Other factors such as Hot - Cold, Deficient - Excess, Internal - External must be considered in more detail. Yin and Yang are never in a permanent state; there is always dynamic movement. All relationships based on Yin/Yang are relative, and their mutual interaction must be considered.

Yin and Yang theory is valuable because it provides a tool for understanding the patient's constitution at a given point in time. This information enables the doctor to determine the best course of treatment, including exercise, food, or herbal formulas that the patient's body needs. Consideration of the patient's inherited and acquired attributes (developed through diet and life-style, environmental influences, natural energy cycles, and other miscellaneous influences such as sleep, work conditions, and relationships) should be based on observation and contemplation of the patient's physical, mental, emotional, and spiritual state of mind.

Designing a program to establish balance and harmony requires a keen awareness of energetic and mental states. In evaluating the patient's condition the doctor takes into account the location and nature of the disharmony, the severity of the condition and the overall physical, mental, and emotional condition of the patient (Figure 21.6). Furthermore, the doctor may notice a combination of both Yin and Yang symptoms or any of the other contrasting pairs be they Hot/Cold, Internal/External, Excess/Deficient. A combination of such symptoms creates a challenge when diagnosing a patient, since symptoms and indicators tend to be more extreme in a person who is ill (Figure 21.7).

YIN CONDITIONS

Primary Yang generates primary Yin. Everything in the universe needs support from Yin. On a basic level, Yin conditions in the body tend to be Cold, internal, Deficient, and degenerative in nature. If a condition becomes overly Yin, it may express some Hot or Yang symptoms. Extreme cold in the form of snow, for example, can cause frostbite. This is called a "false Yang" condition because the condition created is manifested as Yang instead of Yin.

Type of Sign	Yin	Yang
General	• Cool skin temperature • Pale, dark, dull, or yellow complexion • Cold hands and feet • Aversion to cold • Discomfort relieved by warmth and pressure • Senses dull • Curled lying posture	• Warm skin temperature • Red, oily, shiny complexion • Warm hands and feet • Aversion to heat and pressure • Five senses strong • Stretching posture in sleep
Diet	• Prefers warm food and drinks • Poor appetite • Poor sense of taste • Indigestion	• Prefers cold drinks and cold food • Strong appetite • Thirsty, dry mouth
Energy	• Tired • Weak	• Forceful, restless • Strong, stout
Behavior	• Underactive • Quiet, withdrawn	• Overactive • Noisy, outgoing
Breathing & Voice	• Weak, shallow breathing • Weak voice, quiet	• Deep, heavy breathing • Loud, coarse voice, talkative
Excretion	• Copious clear urine • Watery stool	• Scanty dark urine • Hard solid stool
Reproduction	• Sexually underactive • Scanty, pale menses • White leukorrhea	• Sexually overactive • Profuse, red menses • Yellow leukorrhea
Pulse	• Deep, slow • Empty, weak • Fine	• Superficial, rapid • Full, strong • Flooding
Tongue	• Pale, fat body • Moist, thin white coat	• Red, solid, sharp body • Dry, thick yellow coat

Figure 21.6 Signs of Yin and Yang Conditions

Yin conditions are typically characterized by the following: watery stool, clear and copious urine; depression; pale, dull, and yellow complexion; weak, tired, and thin constitution; cool skin, cold hands and feet; dulled senses; curled lying posture when sleeping; soft voice; silent, shallow breathing; preference for warm food; and a tendency towards indigestion. A Yin condition will also be reflected in a deep, weak, fine, slow, or sluggish pulse and a fat, pale, moist, and smooth tongue with possibly a white coating.

YANG CONDITIONS

Yang conditions tend to be Hot, External and Excessive. A Yang disease is generative. Under cer-

Attribute	Progression from Extreme Yang to Extreme Yin
Spirit	Aggressive, outgoing, joyful, sad, fearful, anxious, depressed (The degree of outward expression determines the yangness of the spirit, not so much the emotion itself.)
Body Type	Large and muscular, normal build, thin, emaciated
Posture	Stiff, erect, relaxed, hunched over, limp
Activity	Very animated, normally active, little movement, still
Respiration	Heavy and loud, loud sighing and stretching, breathing heavily through mouth, shallow light breathing, soft intermittent sighs
Voice	Loud, rough, high pitched, regulated and moderate, soft, murmuring, almost inaudible
Skin Cast	Red, yellow, green, pink, white
White of Eye	Red, yellow, blue-green, pink, white
Lip Color	Red, yellow, blue-green, pink, white
Moistness of Lips	Cracked, dry, moist, overly wet
Sputum	Yellow and thick, white and thick, thin, clear
Smell of Breath	Strong, mild, faint
Body Odor	Strong, mild, faint
Urine	Thick, yellow, smelly, thin, whitish, no odor
Feces	Dark, strong smelling, soft, loose, light color

Figure 21.7. The Continuum of Yin and Yang Constitutional Signs and Symptoms

tain conditions, an overabundance of Heat (Yang) may transform into Cold (Yin) to bring about a condition known as "false Yin." Extreme heat and sun, for example, can cause sunstroke. This is called a "false Yin" condition because the condition created manifests as Yin instead of Yang. If an acute Yang condition persists, it will become Yin.

Yang conditions are typically characterized by the following: hard, solid, dry stool; thick, yellow urine; outwardly excited appearance; strong, stout, muscular constitution; restless, active, irritable in character; warm hands and feet and overall warm skin and temperature; strong senses; tendency to stretch frequently; loud voice, talkative; heavy breathing; thirsty, dry mouth; and a preference for cold drinks. A Yang condition will also reflect a floating, flooding, fast, or strong pulse, and a red or yellow, solid, dry tongue with cracks and little or no coating.

SIGNS OF YIN AND YANG

Determining true from false Yang may seem confusing. Yin Deficient people who are very thin and emaciated are often quite hypertensive, this can be seen in their excessive loud talking, rest-

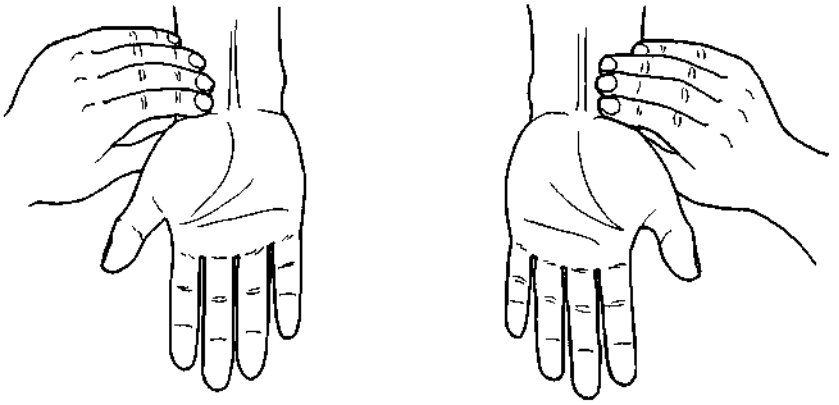

Figure 21.8. The Nine Regions of Pulse Diagnosis

lessness and insomnia. Such individuals can also develop erratically feverish symptoms which usually change from Hot to Cold.

Generally, a true Yin or Yang condition is determined by three or more symptoms that simultaneously manifest either one of those conditions.

False Yin symptoms occur when the Yang becomes overly strong, causing a weakening of the Yin. (Again, the overall condition should be assessed before making a differential diagnosis.) False Yin symptoms include weakness, coldness, wetness, and other Yin symptoms in an otherwise Yang condition. One should bear in mind that there are seldom purely Yin or Yang symptoms because Yin and Yang are so interdependent on each other.

Furthermore, stages of Yin and Yang may change during the course of the day, or over the course of an illness. If a Yang stage is allowed to progress, it can degenerate into weakness described as a Yin stage. Therefore, if a Yang condition changes to Yin it is probably not a good sign, but if a Yin condition changes to an acute Yang condition it may be a positive sign of movement towards overall balance. The focus is to understand that it takes active energy (Yang) to manifest an acute condition, and the stronger the manifestation, the stronger the energy.

YIN AND YANG CATEGORIZATION OF TRAINING

Chinese herbs and foods are typically classified in terms of Yin and Yang, as are Qigong exercises and meditations. With exercises and meditations the state of mind and level of relaxation during the exercise or meditation is critical in determining the Yin or Yang categorization. It is important to be aware of this when developing a patient's program to provide the proper energy adjustments to maintain a healthy balance. If a disharmonious condition develops and the wrong prescription is given, the patient can be thrown further off balance, making it more difficult to restore good health.

PULSE DIAGNOSIS OF THE EIGHT ENERGETIC PRINCIPLES

The body's pulse in considered another form of energy manifestation. The pulse is imagined as waves of various Fluids flowing within the body, originating from within the Heart, where the Shen resides. Pulse diagnosis can give the Qigong doctor detailed information on the state of the patient's internal organs, as it reflects the patient's flow of Qi and Blood, as well as Yin and Yang energy. The pulse is felt at the radial artery, which is divided into three areas (front, middle, and lower), and at three different levels (superficial, middle, and deep), creating "nine regions" of pulse diagnosis (Figure 21.8).

The three areas of the wrist relate to the energetic manifestations of the Triple Burners. The front position corresponds to Heaven and reflects the diseases from the head to the chest; the middle position corresponds to Man and reflects the diseases

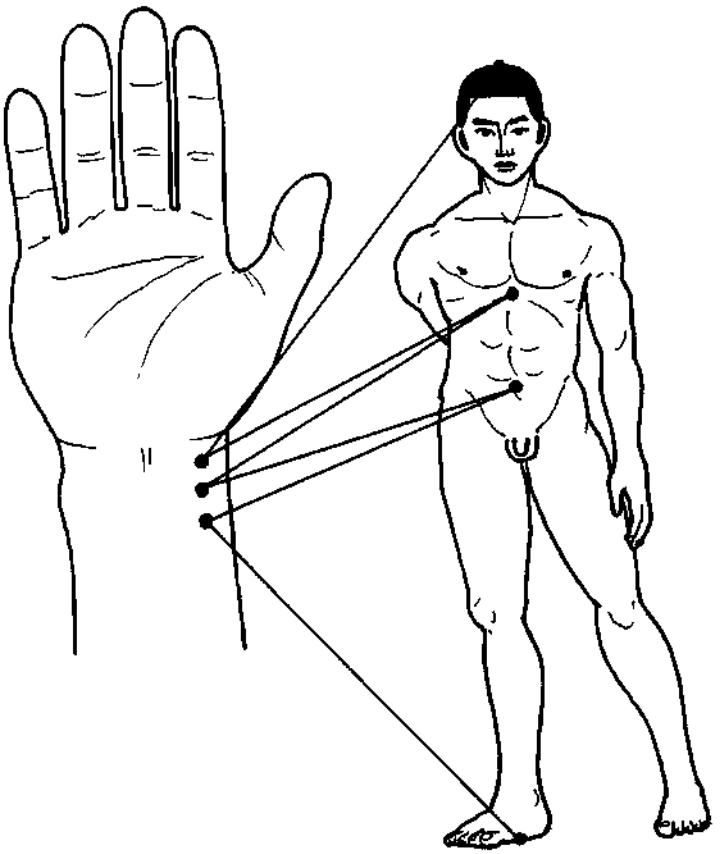

Figure 21.9. Pulse Correspondence with the Triple Burners

from the diaphragm to the umbilicus; the lower position corresponds to Earth and reflects the diseases from the umbilicus to the feet (Figure 21.9).

The three different levels relate to the energetic manifestations of the body's diseases. The superficial level corresponds to exterior diseases, the body's Qi and Yang organ energy; the middle level corresponds to the condition of the Blood, as well as the energy of the Stomach and Spleen; the lower level corresponds to interior diseases, the body's Yin energy and Yin organ energy.

The important thing is to diagnose how the body's energy is flowing, taking into consideration the relationship of the Yin and Yang on the pulse, i.e., whether it is superficial or deep, fast, or slow, Excess or Deficient. The quality of the pulse may also vary according to the patient's:

1. General Constitution and Body Build, with bigger frame patients generally having a stronger pulse then smaller frame individuals,
2. Level of Activity, with patients who engage in heavy physical work having a stronger pulse then those who engage in mental work, and
3. Exposure to Seasonal Weather, as a deeper pulse is generally felt in the winter and a more superficial pulse is felt in the summer.

PULSE QUALITIES AND CLASSIFICATIONS

In China, attention is placed primarily on the overall quality of the pulse. While reading the superficial pulses, it is important to note that they indicate the condition of the patient's Qi and Yang Organs. The deep pulses indicate the condition of

the patient's Jing, and Yin Organs. Pulses can be divided into three main classifications, which are related to either Yin and Yang qualities: The Depth, The Speed, and The Strength (Figure 21.10).

1. The Depth at which the pulse can be felt is considered first.
   a. Superficial / Floating Pulses are felt with a light touch, barely touching the artery. They indicate an Exterior syndrome (e.g., Wind-Cold or Wind-Heat), chronic illness, or a general weakness. This informs the doctor that there is an Excess at the patient's Qi level (or a Deficiency at the Yin level).

- Superficial and Weak (Empty) pulses are felt in Yang Excess diseases (superficial diseases), when the patient's Wei Qi is fighting the pathogenic factors at the superficial level.
- Superficial and Forceful (Full) pulses are felt in interior diseases due to Yin or Jing Deficiency.

   b. Deep Pulses are felt on heavy pressure, near the bone. They indicate an interior syndrome (problems within the Yin Organs), and relate to the patient's Jing.

- Deep and Weak (Empty) pulses are felt in diseases due to a Deficiency of Qi and Yang.
- Deep and Forceful (Full) pulses are felt in deep diseases (when the disease has penetrated into the patient's internal organs). They confirm an Excess at the Yin level, or Deficiency at the Qi level, and point to a stasis of Qi or Blood, and to a Cold or Heat condition.

2. The Speed of the pulse is considered next.
   a. Slow Pulses are less then 4 beats per the patient's breath; they indicate a Cold syndrome.

- Slow and Weak (Empty) pulses indicate Empty Cold and Yang Deficiency.
- Slow and Forceful (Full) pulses indicate Full Cold and Yin Excess.

   b. Rapid Pulses are more then 5 beats per patient's breath and indicate a Heat syndrome.

- Rapid and Weak (Empty) pulses indicate Empty Heat and Yin Deficiency.
- Rapid and Forceful (Full) pulses indicate Full Heat and Yang Excess.

	YANG	YIN
DEPTH	Superficial — Exterior	Deep — Interior
SPEED	Rapid — Hot	Slow — Cold
STRENGTH	Forceful — Excess	Weak — Deficient

Figure 21.10. The Eight Energetic Principles are manifested through the body's pulses.

	LEFT HAND Superficial - Deep	RIGHT HAND Superficial - Deep
FRONT POSITION	Small Intestine - Heart	Large Intestine - Lungs
MIDDLE POSITION	Gall Bladder - Liver	Stomach - Spleen
LOWER POSITION	Bladder - Kidneys' Yin	TB & Pc - Kidneys' Yang

Figure 21.11. Left and Right Hand Correspondence

3. The Strength of the pulse is considered last.
   a. Weak (Empty) Pulses are weak and disappear on heavy pressure; they indicate a Deficient syndrome.
   b. Forceful (Full) Pulses are forceful and are felt on deep pressure; they indicate an Excess syndrome.

- Forceful (Full) and rapid pulses indicate Full Heat.
- Forceful (Full) and slow pulses indicate Full Cold.

THE CLASSICAL PULSE DIAGNOSTIC POSITIONS AND DEPTH

Traditionally the best time to take the patient's pulse is when the patient is calm and relaxed. There are several schools of pulse diagnosis, each one with its own specific methods of approach to understanding the patient's symptoms. The most important aspect in listening to the patient's pulse is to feel the strength, quality, and spirit of the pulse. Only then can the doctor receive accurate information about his patient's condition (Figure 21.11).

Pattern	Signs	Pulse	Tongue
Internal	Vomitting, high fever, gradual onset, chronic, long duration	Deep	Changes in texture and coating
External	Cold, flu, skin eruptions, sudden onset, acute, short duration	Superficial	Changes in coating
Cold	Diminished physiological function, decreased energy, lowered resistance, lowered immunity, white face, aversion to cold, cold extremities, lack of thirst, craving for warmth, clear urine, watery stool, desire for hot drinks, diarrhea, coolness of limbs, timid behavior, soft voice, slow movement, lack of motivation	Slow, tight	White coat, pale body, moist fur
Heat	Physiological hyperfunction, increased energy, increased metabolism, acute pains, fever, thirst, desire for cold liquids, flushed face, red eyes, restlessness, irritabiliity, dry stool, dark yellow urine, reduced urine secretions, aversion to warmth, hot red skin, constipation, warm extremities, loud voice, talkative, extroverted manner, aggressive behavior	Rapid	Red tongue with yellow fur
Deficiency	Great weakness, low syptomatic reactions, inconsistent energy, shallow and rapid respiration, less severe pain, pain characterised by soreness, weak or inconsistent voice, dull menstrual pain, withered face, low spirits, abdominal pain	Empty, weak	Little or no coat
Excess	Flushed face, loud voice, coarse and full breathing, sharp and acute pain, extreme menstrual pain, tender abdomen, condition worsens with apllication of heat	Full	Thick coat

Figure 21.12. Signs of Internal, External Cold, Hot, Deficient and Excess Conditions

Usually, in men, the pulse on the left (Yang) side of the body should be slightly stronger then that of the pulse on the right (Yin) side, and vice versa for women. Also in men, the front (Yang) positions should be slightly stronger, while in women the lower (Yin) positions should be stronger.

OVERVIEW

In the clinic we have a saying, "Where the Qi goes, the Blood flows." Although a patient's pulse is produced by the movement of Blood in the arteries, the activity of that movement is initiated by the force of the patient's Qi. By feeling the movement of Blood in the vessels, the activity of the patient's Qi, Blood, and Body Fluids are diagnosed. This internal communication is summarized in the above chart (Figure 21.12).

Chapter 22
Diagnosis According to Qi, Blood, and Body Fluid Dysfunctions

Introduction

This method of diagnosis identifies patterns on the basis of disharmonies according to Qi, Blood, and Body Fluids. It is used in clinical practice (especially for internal diseases) for diagnosing according to the pathological changes occurring in the internal organs.

The essential cause of disease is due to an imbalance of Qi, Blood, or Body Fluids. When one or more of these substances are unbalanced, the body's normal physiological function is disrupted and sickness results. This can be caused by the effect of the Six Exogenous Pathogenic Factors, Seven Emotional Pathogenic Factors, and is influenced by the patient's general constitution. Each of the patient's organs and channels have sets of symptoms or syndromes of these types of imbalances, which can then be identified for treatment. The Qigong doctor's ability to identify problems based on the pathological manifestations of Qi, Blood, and Body Fluids is founded on clinical observations of Excess, Deficient, Stagnant, and Rebellious patterns (Figure 22.1). These patterns can be further defined as predominantly Yin or Yang. These patterns also described as the various disorders of Qi, Blood, and Body Fluids, and sometimes overlap, for example:

- Excess conditions can give rise to Rebellious Qi and also create stagnation;
- Deficient conditions can give rise to Rebellious Qi and also create stagnation.

Disorders of the Qi

Whenever energy movement is impeded, disorders in Qi functions occur. Generally, these dis-

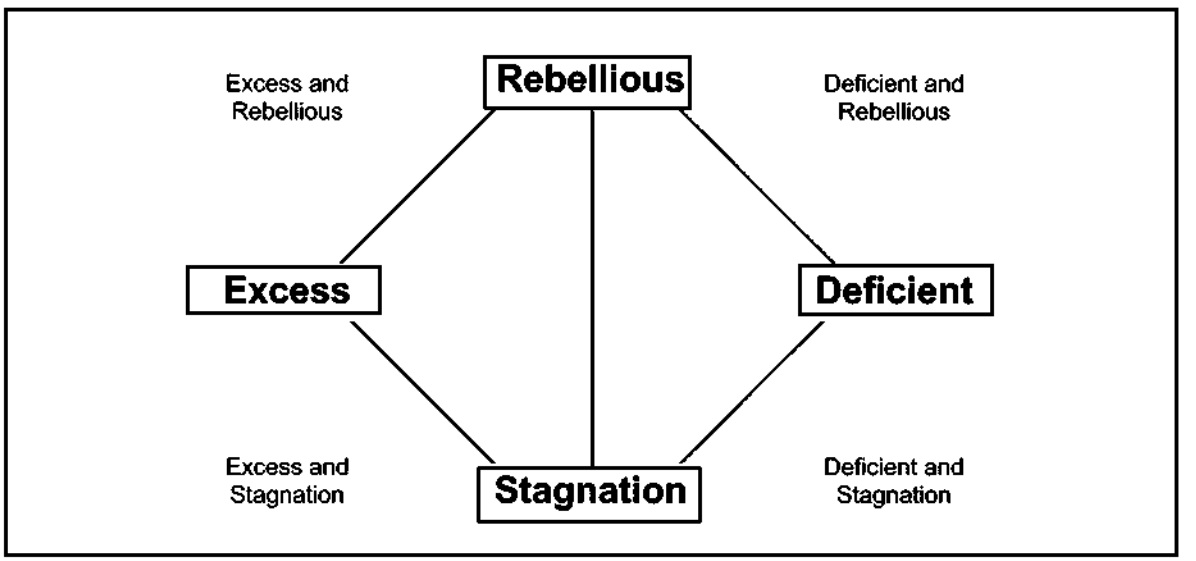

Figure 22.1. Pathological Manifestations of Qi, Blood, and Body Fluids

Fire		Water
Constraint of Qi	First Stage	Stasis of Qi
Arrogant/Agitated	Second Stage	Fluid Builds Up
Full on Fire is Created	Third Stage	Phlegm is Created
Heart Fire is Created	Final Stage ——> Mania <——	Phlegm Fire is Created

Figure 22.2. Disorders caused from the obstruction of Qi flow result in either Fire or Water energetic dysfunctions.

turbances cause either disorders of Fire, or disorders of Water (Figure 22.2).

The cause and progression to these disorders can be further broken down and classified according to their energetic dysfunction (Figure 22.3). There are several types of Qi disorders observed in the clinic and are generally described as follows.

LEAKAGE AND LOSS OF QI

During or after the training practice, the patient may feel that Qi is continuously and uncontrollably leaking out of the body from the genitalia and anus or anywhere else on the body. This loss of Qi can lead to Qi Deficiencies, and manifest through the following symptoms: emaciation, weakness of the limbs, grayish and dull complexion, nervousness, mental disturbances, distractibility, failing memory, spontaneous sweating, night sweats, seminal emission, insomnia, lassitude, and sluggishness.

DEFICIENT QI DISORDERS

Deficient Qi exists when the entire body, or particular organ, is not being sufficiently nourished by the Qi. This results in there being too little energy to maintain proper organ function. This condition is usually caused by a weakness of the Lungs, Spleen, or Kidneys, by chronic illness, or a weak constitution, poor diet, or fatigue. Deficient Qi is unable to:

- transform, resulting in symptoms such as diarrhea,
- transport, resulting in symptoms such as stagnation of Qi,
- hold, resulting in symptoms such as bruising,
- warm, resulting in symptoms such as cold extremities,
- protect, resulting in symptoms such as sickness, and
- raise, resulting in symptoms such as prolapse.

Deficient Qi is divided into three subcategories from which the patient can suffer. These subcategories are Empty Qi, Sinking Qi, and Qi Collapse. Each of these subdivisions can further be divided into Yin and Yang types.

1. Empty Qi is considered the first type of Deficiency. If not treated, Deficient Qi may progress to a condition known as Empty Qi. Diseases that are classified as Empty Qi are characterized by a serious weakness or Deficiency of the body's Qi. Empty Qi, especially Empty Yang Qi manifests as a weakness

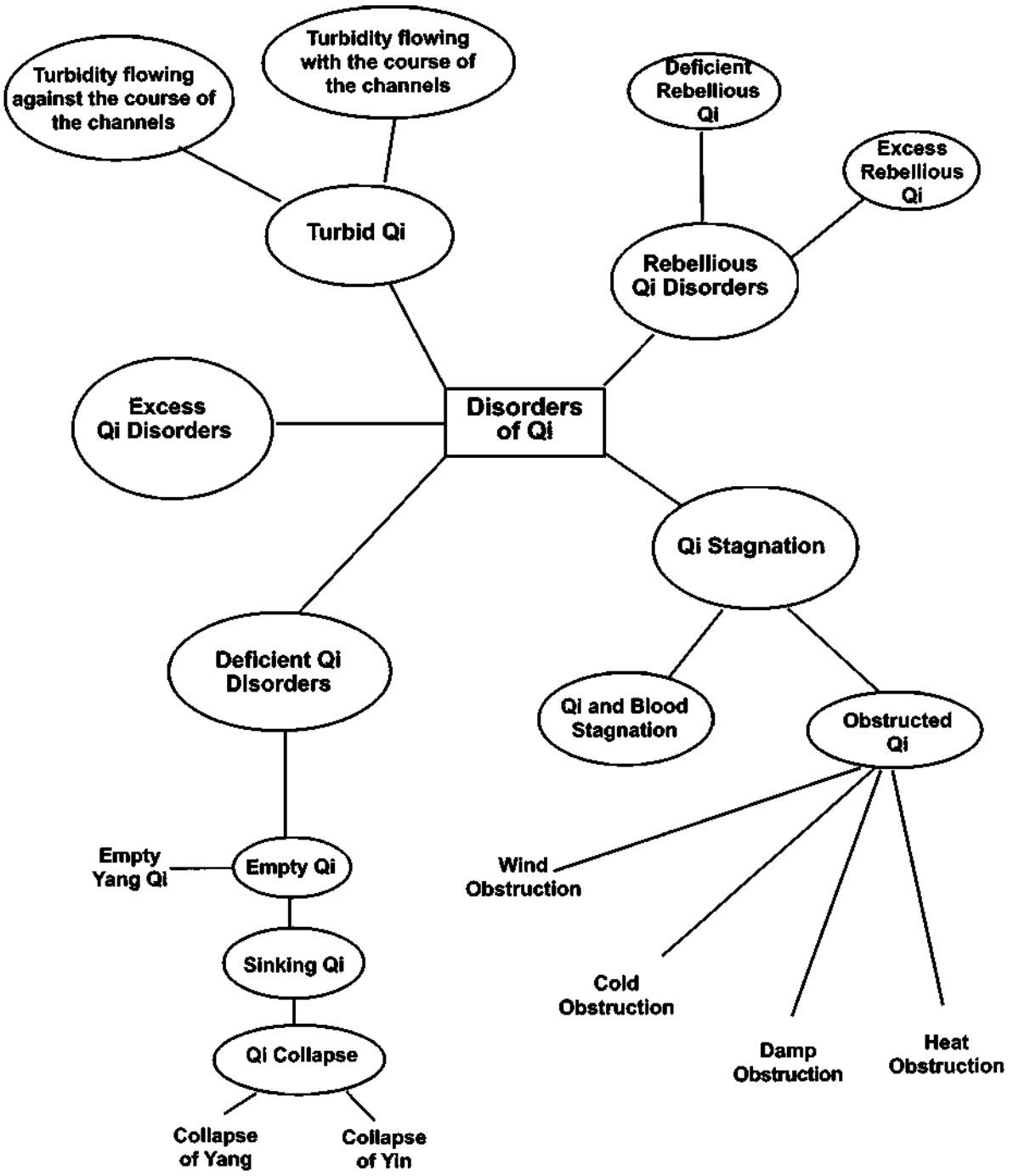

Figure 22.3. Whenever energy movement is impeded or in excess, disorders in Qi function occur, resulting in Qi Deviations.

in the function of holding, moving, and transforming Qi.

a. Empty Qi originates primarily from the patient's constitution and manifests as malnutrition, fatigue, premature signs of old age, and an excess of extreme emotions.
b. Empty Yang Qi belongs to the category of Yang. Because Yang Qi has the function of warming, Empty Yang manifests as an inability to adequately warm the energy, resulting in Cold symptoms. Empty Yang is generally caused by a weak constitution, poor diet (excessive raw, cold food and drink), overwork, old age, and excess sex.

2. Qi Sinking is also a subcategory of Deficient Qi, and is considered the second type of Deficiency. If not treated, Empty Qi may progress to a more serious Deficient condition known as Qi Sinking. This condition results in symptoms such as tiredness, listlessness, and mental depression, and may eventually lead to the prolapse of one or more of the organs.
3. Qi Collapse is a subcategory of Deficient Qi and is considered the third and most severe type of Deficiency. A Qi collapse exists when the Qi is so Deficient that it can no longer hold the internal organs in place. This Qi depletion not only causes a weakness of the body's Righteous Qi, which leads to the prolapse of the organs (Stomach, uterus, intestines, rectal area, vagina, or Bladder), but also induces prolonged diarrhea, upper abdominal distention, and dizziness.

a. The Collapse of Yin results in pure Fire. The main manifestations are abundant perspiration and external tissue, which is hot to the touch.
b. The Collapse of Yang results in pure Cold. The main manifestations are chills and external tissues which are cold to the touch.

EXCESS QI DISORDERS

An Excess Qi condition is caused from too much Qi, which overacts on an organ, affecting its function, and usually produces too much transformation and Heat in a given organ. This can be due to over-energizing the organs and channels, from excessive Qigong exercises and meditations, or too much energy stimulation during a Qigong doctor's treatment.

QI STAGNATION DISORDERS

Qi stagnation exists when the Qi is not flowing smoothly, and becomes sluggish when moving within the body's channels, organs, or tissues. Qi stagnation can be caused by many different factors such as: suppressed emotions, trauma, contraction of microorganisms, poor diet, and weak digestion. Qi stagnation, over time, results in localized pain, distention, cysts, tumors, etc. Qi stagnation disorders have two subcategories: Qi and Blood Stasis, and Obstructed Qi.

1. Qi and Blood Stasis refers to the sensation of local pain, heaviness, soreness, distention, and compression, which are caused by the stagnant Qi and Blood in certain areas of the body. These sensations do not disappear by themselves. This stasis may occur during or after Medical Qigong training practice from Qi disorders and visceral malfunctions.
2. Obstructed Qi is also considered a subcategory of Qi stagnation, and exists when the Qi becomes so stagnant that it no longer flows. At this stage the Qi can not move the Blood. This can be caused by trauma, surgery, and acute Qi stagnation.

When Qi becomes obstructed inside the body, certain clinical manifestations result, such as:

- Cold Obstruction causes Qi to become fixed with local numbness that improves with heat;
- Damp Obstruction causes Qi to become fixed with local swelling;
- Heat Obstruction causes Qi to become inflamed, red, and swollen;
- Damp Heat Obstruction is a combination of Damp and Heat. It is called "summer Damp Heat," and results in poor appetite, dizziness, diarrhea, heaviness of the head, and sensations of chest suffocation;
- Wind Obstruction causes migrating pain that moves from joint to joint.

Organ	Normal Flow	Rebellious Flow	Symptoms
Liver	Upwards	Excessively Upwards Horizontally to Stomach Horizontally to Spleen Horizontally to Intestines Downwards	Dizziness, Headache, Irritation Nausea, Belching, Vomiting Diarrhea Dry Stool Burning Urination
Heart	Downwards	Upwards	Insomnia, Mental Restlessness
Spleen	Upwards	Downwards	Diarrhea, Prolapse of Organs
Stomach	Downwards	Upwards	Hiccup, Nausea, Belching, Vomiting
Lungs	Downwards	Upwards	Coughing, Asthma
Kidneys	Downwards	Upwards	Asthma

Figure 22.4. Chart of Rebellious Qi Flow

REBELLIOUS QI DISORDERS

Rebellious Qi disorders manifest as Qi flowing in the wrong direction (a direction different from its normal physiological progression); this causes a disturbance within the harmonious flow of energy and affects the organs' functions. The symptoms have to be analyzed according to the internal organ which is involved. There are two types of Rebellious Qi, the Excess and Deficient type. Rebellious Qi is categorized as follows:

DISORDERS OF EXCESS REBELLIOUS QI

Disorders of Excess Rebellious Qi occur when the vital Qi increases and forces the pathogenic Qi to move; leading to local sensations of pain, soreness, distention, heaviness, cold or heat, which can develop during a patient's Qigong practice (Figure 22.4).

DISORDERS OF DEFICIENT REBELLIOUS QI

Disorders of Deficient Rebellious Qi refers to the disorderly flow of Qi and Blood during or after the training practice, which causes dizziness, fright, a heavy feeling in the chest, shortness of breath, shaking limbs, trembling of the hands and feet, or fainting. Generally, energy sensitive patients know the location and direction of the disorderly flow of Qi in their tissues.

TURBID QI

While transforming and transporting energy, the body divides ingested and absorbed Qi into Clear and Turbid energy for distribution (keeping and redistributing the clean, while disposing of the turbid). Turbid Qi refers to any dark, murky energy which can originate within, or from outside of the body's organ system, and sometimes travels throughout the body's channel system. Turbid Qi attaches to the body's wounds (physical, emotional, or spiritual), manifesting as dark, discolored clouds of energy. This energy can adversely affect the body's physical, emotional, and energetic balance, especially when combined with any pathogenic internal or external factor.

PATHOGENIC SENSING OF TURBID QI

Feeling the sensations of Turbid Qi is referred to as "pathogenic sensing." This skill is acquired by the doctor while projecting energy to his patients. While emitting energy, the Qigong doctor can sense the patient's Yuan Qi, as well as the Turbid Qi inside the patient's body. This enables the doctor to diagnose and treat their patients' diseases according to the various Qi sensations, and to categorize the patients' Turbid Qi. The Turbid Qi is also called Evil or "pathogenic Qi." The flow

of Turbid Qi within the patient's channels is characterized as follows:

- Turbidity flowing with the course of the channel indicates transference of Turbid Qi towards the body's interior.
- Turbidity flowing against the course of the channel indicates the beginning production of Turbid Qi.

Turbid Qi differs from the pathogenic factors of infectious diseases referred to in Western medicine. According to clinical experience, the pathogenic sense of Turbid Qi can be classified as: Dry or Hot Sensations, Cold or Chilly Sensations, Soreness or Numbing Sensations, Impure or Foul Sensations, The Sensations of The Seven Emotions, and The Sensations of The Six Climate Conditions.

1. Dry or Hot Sensations are considered Yang signs or symptoms of Heat. This type of Turbid Qi feels feverish and flaccid; it can cause perspiration, irritation, etc. The sensations of dry-heat on the body or hands of the doctor often cause the doctor to fidget, as if being scorched by a fire. It may also serve as an indicator of syndromes of Excess Heat and hyperactivity of Fire due to a Yin Deficiency.
2. Cold or Chilly Sensations are considered Yin signs or symptoms of Cold. This type of Turbid Qi feels cold, rigid, and stagnant. It may be so cold that the doctor's fingertips turn cold immediately. This coldness transmits from the doctor's fingertips upward, causing shivering and contractions of the sweat glands ("goose-bumps"). This gives the doctor a particular feeling of cold and discomfort. Cold feelings often serve as a message of Deficiency and Cold syndromes such as rheumatism, rheumatoid disease, Deficiency of the Kidney Yang, and certain types of cancer.
3. Soreness or Numbing Sensation often indicate syndromes of hyperactivity of the Liver Yang and Excess of Wind, Cold, Dampness or Phlegm, as well as arthralgia syndrome and cancer. The doctor may experience an uncomfortable feeling of local soreness or pain, heaviness, numbness, tingling and itching.
4. Impure or Foul Sensations can be felt when the doctor is standing opposite the patient, or when extending energy towards the patient. It is an indescribable unpleasant feeling that is often felt when the open palm and fingers are used to detect a disease.
5. The Seven Emotions (joy, anger, worry, anxiety, fear, shock, and grief) in excess will cause discomfort to the doctor. During treatment, the doctor may detect and feel the different natures of these emotional pathogenic Evils flowing through the doctor's body. The doctor may, for example, have a specific feeling of anger if the disorder of the patient is due to excessive anger. Once these pathogenic emotions are discovered, the doctor must purge or disperse them, as well as determine their origin, and cause.
6. The Six Climate Conditions (Wind, Cold, Summer Heat, Dampness, Dryness, and Fire) will also cause discomfort to the doctor. During treatment, the doctor may detect and feel the different natures of these pathogenic Evils. The doctor may, for example, have a specific feeling of slippery wet ooze if the disorder of the patient is due to Dampness.

RECTIFYING QI DISORDERS

The primary treatment principles for rectifying Qi Disorders are as follows:

- for Qi leakage - tonify
- for Deficient Qi - tonify
- for Empty Qi - tonify
- for Qi sinking - raise and tonify
- for Collapsed Qi - tonify
- for Excess Qi - reduce
- for Stagnant Qi - move
- for Obstructed Qi - move
- for Rebellious Qi - calm and subdue
- for Turbid Qi - remove, dredge, and purge

These are often found in combination with other patterns. Here are some examples of treating combined patterns:

- for Excess and Rebellious Qi, reduce Excess and calm Rebellious Qi;
- for Deficient and Rebellious Qi, tonify Deficient and calm Rebellious Qi;

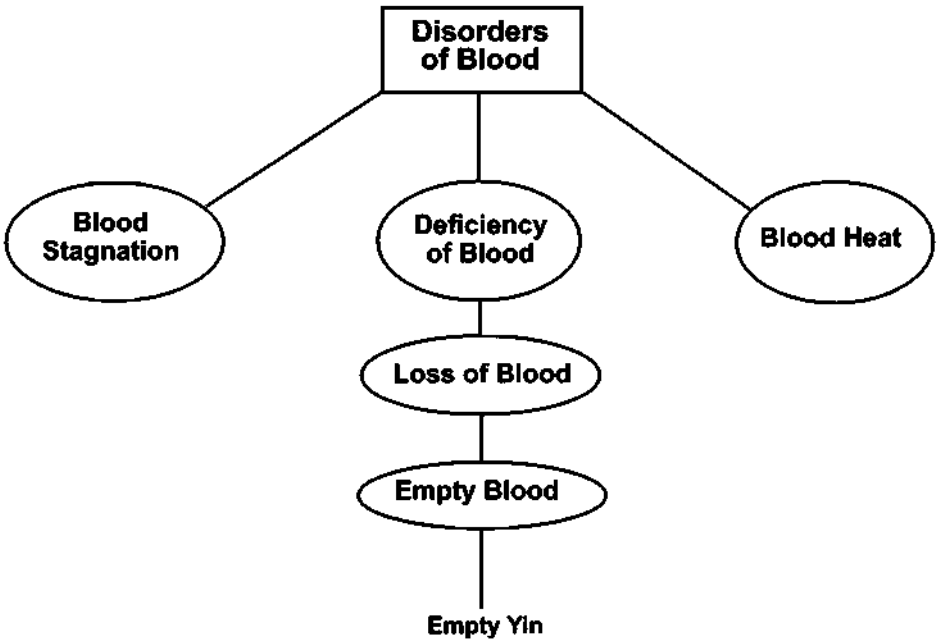

Figure 22.5. Whenever Blood movement is impeded or in excess, disorders in Blood function occur.

- for Excess and Stagnant Qi, reduce Excess and move the Stagnant Qi;
- for Deficient and Stagnant Qi, tonify Deficient and move the Stagnant Qi;
- for Excess and Deficient Qi, drain Excess and tonify Deficient Qi; and
- for Rebellious and Stagnant Qi, calm Rebellious and move the Stagnant Qi.

Disorders of the Blood

To understand Blood disorders it is important to understand the concept of Blood from the perspective of Traditional Chinese Medicine. In Chinese Medicine, Blood is different in concept, characteristics and function from that of Western medicine. Blood originates from the transformation of food and drink by the Spleen, which then transfers the refined food energy (Gu Qi) to be further enhanced by the Heart, Lungs, and air energy. Blood is therefore considered a transformation of constructive energies.

Disorders of the Blood can relate to disorders of the Qi. Qi and Blood flow together, Qi being the active force which makes the Blood circulate and keeps it within the blood vessels. Both Qi and Blood flow within the channels and blood vessels, continuously circulating throughout the body nourishing, maintaining, and moistening the tissues. Qi is an energetic form and is considered a Yang substance, while Blood is a liquid form of energy and considered a Yin substance. The cause and progression to Blood disorders can be further broken down and classified according to their energetic dysfunction (Figure 22.5). There are several types of Blood disorders observed in the clinic and are generally described as follows.

Deficiency of Blood

A Deficiency of Blood exists when the entire body, or a particular organ, is insufficiently nourished by the Blood, or not enough Blood is present to nourish the organs and channels, to support the Qi. Blood Deficiency is usually caused from Blood loss, chronic illness, poor diet, or Spleen Qi Deficiency, which weakens the Qi. This in turn affects the Liver (causing symptoms of dizziness,

blurred vision, and numbness) and Heart (causing symptoms effecting the mind, memory, and Shen).

LOSS OF BLOOD

Loss of Blood is considered a subcategory of Deficient Blood. Loss of Blood is caused by Spleen Qi failing to control the Blood, resulting in the Blood spilling out of the vessels and organs, etc. Loss of Blood is divided into two main types:

- Deficient loss of Blood is caused by an insufficiency of Qi to hold the Blood.
- Excess loss of Blood, is caused by either Blood-Heat pushing the Blood out of the vessels, or by Blood stagnation and Yin Deficiency which causes the Blood to pool.

EMPTY BLOOD

Although Empty Blood is a subcategory of Deficient Blood, it is considered a serious Deficient condition, mostly due to the Blood of the whole body becoming Deficient. Empty Blood corresponds to a Deficiency of Qi, caused by:

- Inadequate nutrition,
- Loss of Blood through accident or disease,
- Loss of Body Fluids through excessive sweating, urination, vomiting, or diarrhea,
- Extreme emotions (e.g., rage, terror and shock),
- Blood stagnation, which leads to poor Blood circulation.

Since the Empty Blood fails to nourish the tendons and muscles, it results in shaking in the extremities and head, dizziness, and blurred vision.

Empty Yin

Blood belongs to the category of Yin. Because Yin Qi has the function of cooling and moistening, when an Empty Yin condition is present, the symptoms manifest as Excess Heat and Dryness. Empty Yin is caused by a weak constitution and a poor diet (overcooked foods and hot liquids). The organs most likely to be effected by the Empty Yin condition are the Kidneys, Lungs, Heart, Liver, and Stomach.

BLOOD STAGNATION

Blood Stasis exists when the Blood is unable to flow smoothly, and becomes obstructed or congeals. Blood stasis is usually caused by an impact trauma, Deficient Blood, stagnant Blood, Blood Heat, Blood Cold, or stagnant Qi. It results in localized pain which worsens with pressure, swelling of the internal organs, cysts, and tumors. The organ most often affected by Blood stasis is the Liver.

BLOOD HEAT

Blood Heat is mostly due to Liver Heat and External Wind. When toxic Heat enters the Blood, the Blood may break out of the vessels and cause: nose bleeding, hemorrhaging, and broken blood vessels. Heat consumes the Blood and Yin, injuring the tendons and muscles, causing spasms and rigidity. The Blood Heat also injures the Governing Vessel, Pericardium, and the Shen.

The Four Main Treatment Principles

- for a Deficiency of Blood, tonify
- for Empty Blood, tonify
- for Blood Stasis, move Stasis
- for Blood Heat, cool down

THREE DISORDERS OF BODY FLUIDS

To understand disorders of the Body Fluids it is important to understand the concept of Body Fluids, from the perspective of Traditional Chinese Medicine. Body Fluids are a denser form of Qi, and depend on Qi for transformation and transportation. Qi occupies and directs the movement of Blood and Body Fluids. The function of the Fluids is to moisten and nourish the body's tissues, as well as thin the Blood to prevent stasis. Body Fluids are formed from ingested food and drink, and are then transported by the energy of the Spleen to the Lungs and Small Intestines for distribution.

Disorders of the Body Fluids can relate to disorders of the Blood. There is a constant interchange between Fluids and Blood, such as, for example, a Deficiency of Fluids can be developed from a heavy loss of Blood. Body Fluids are divided into two categories:

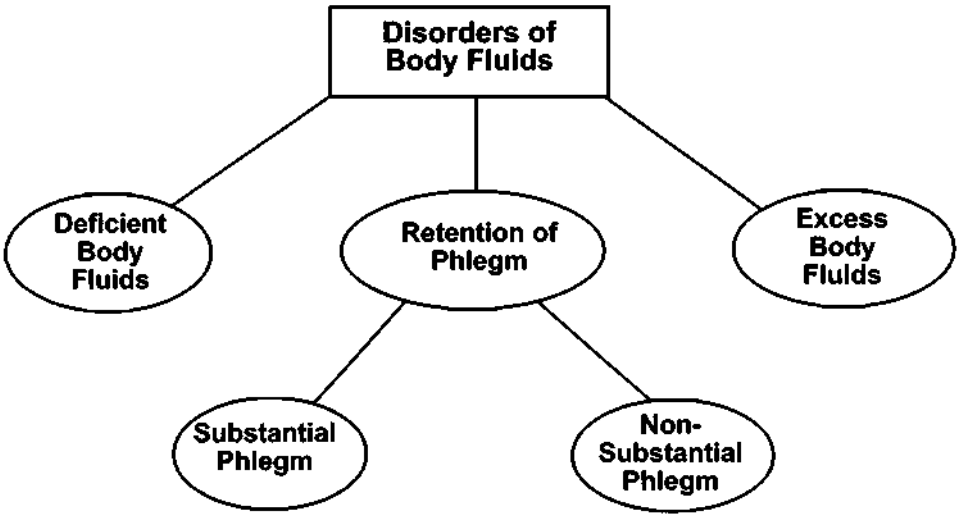

Figure 22.6. Whenever Body Fluid movement is impeded or in excess, disorders in Body Fluid function occur.

1. Jin refers to the light, thin, watery, clear, quick-moving Fluids and is considered Yang. These Fluids are under the control of the Lungs which circulate them with the Wei Qi. These Fluids also permeate and moisten the skin and have the function of warming and nourishing the muscles. The Upper Burner is responsible for controlling the Jin transformation and moving it towards the skin. The Jin is manifested in the body in the form of sweat, tears, saliva, mucus, and parotid serum.
2. Ye refers to the heavier, thicker, turbid, dense, slow moving Fluids and is considered Yin. These Fluids are under the control of the Middle and Lower Burners, which circulate the Ye with the Ying Qi. The Spleen and Kidneys are responsible for controlling the Ye transformation. This Fluid lubricates the joint cavities (synovial fluid), nourishes and lubricates the brain and spinal cord (cerebrospinal fluid), bone marrow and the orifices of the sensory organs (eyes, ears, nose, and mouth).

There are three primary disorders of Body Fluids observed in the clinic, they are described as follows (Figure 22.6).

1. Deficient Body Fluids exists when the entire body, or a particular organ, is insufficiently nourished by Body Fluids. This is generally due to insufficient Yin to create or nourish the body's organs or joints. Deficient Body Fluids are usually caused by prolonged loss of Fluids (sweating, diarrhea, and vomiting), prolonged illness, a Heat condition, or a Yin Deficiency which leads to Dryness. A Deficiency of Body Fluids usually affects the Lungs, Kidneys, Stomach, and Large Intestines.
2. Excess Body Fluid accumulation is usually caused by an Excess Yin and one of three factors, or a combination of all of them. They are:
   - A Lung Qi Deficiency, which affects the top of the body, face and hands,
   - A Spleen Qi Deficiency, which affects the middle part of the body, and abdomen,
   - A Kidney Qi Deficiency, which affects the lower part of the body, legs and ankles.

   If there is a Deficiency within one or all three of these organs, and the Body Fluid is not able to transform properly, it will overflow the channels and settle under the skin.
3. Retention of Phlegm is due primarily to a Deficiency of the Spleen failing to transport

and transform the Body Fluids. If Phlegm is retained for long periods of time, disease of the organs (Substantial Phlegm), as well as channels, skin, and joints (Non-Substantial Phlegm), can form.

The Three Main Treatment Principles

- for Deficient Body Fluids, moisten;
- for Excess Body Fluids, dry or drain;
- for Retention of Phlegm, resolve.

TYPES OF PHLEGM

The concept of Phlegm is an important pathological and etiological factor in Traditional Chinese Medicine. If Phlegm is allowed to accumulate and becomes retained within the body, it causes disease.

The main cause of Phlegm formation is Spleen Deficiency. If the Spleen becomes weak and fails to transform and transport the Body Fluids, these will accumulate and transform into Phlegm. However, Phlegm formation can also occur if the Lungs fail to disperse and lower Fluids, or if the Kidneys fail to transform and excrete Fluids.

In Traditional Chinese Medicine, there are two types of Phlegm: Substantial Phlegm and Non-Substantial Phlegm.

1. Substantial Phlegm is described in ancient texts as "having a form." It can be observed as the thick mucus that collects within the Lungs and spat out during bronchial infections and other Lung diseases. As the Lung disease progresses, the patient's mucus changes color, progressing from clear watery to yellow and thick, then to green and pussy, and finally brown and red.
2. Non-Substantial Phlegm is described in ancient texts as "having no form." This type of Phlegm can accumulate within:
   - the body's organs forming stones,
   - the joints forming arthritic bone deformations,
   - the skin forming lumps or cysts, and
   - the channels causing stagnation of Qi and Blood, resulting in numbness.

Both Substantial and Non-Substantial Phlegm can assume different forms of disease, developing in accordance to its associations with Heat, Cold, Damp, Wind, Qi, and Fluids. For example:

1. Phlegm Heat is a type of Substantial Phlegm that affects the Lungs, Stomach, or Heart. It manifests as yellow sticky phlegm, a red face and a red tongue with sticky yellow coating.
2. Cold Phlegm is a type of Substantial Phlegm that affects the Lungs and Stomach. It manifests as white watery phlegm expectoration, cold feelings in the back and extremities, and a pale tongue with a white and wet coating.
3. Damp Phlegm is a type of Substantial Phlegm that affects the Lungs. It manifests as a profuse white sticky phlegm, feelings of stuffiness in the chest and epigastrium region, and a sticky tongue coating.
4. Wind Phlegm is a type of Non-Substantial Phlegm and is seen in Wind Stroke. It causes dizziness, nausea, vomiting, coughing up of Phlegm, numbness of the limbs, rattling throat, and aphasia.
5. Qi Phlegm is a type of Non-Substantial Phlegm which affects the throat. It manifests as a "plum pit" syndrome within the throat. Its formation is related to emotional problems, created when the Liver Qi rises and stagnates within the throat. Its condition manifests as a feeling of swelling in the throat, difficulty in swallowing, and stiffness in the chest and diaphragm.
6. Phlegm Fluids is a type of Substantial Phlegm which has a fluid or watery nature, and is called Yin in Chinese medicine. There are four types according to their location:
   - Phlegm Fluids located in the Stomach and intestines manifest as abdominal fullness, distension, and vomiting;
   - Phlegm Fluids located above the diaphragm manifest as coughing, asthma, edema, and dizziness;
   - Phlegm Fluids located within the hypochondrium manifest as distension in the hypochondrium area, with pain and coughing;
   - Phlegm Fluids located in the four limbs manifest as heaviness and pain in the muscles.

Chapter 23
Diagnosis According to the Five-Element Theories

Introduction to the Five Elements

This method of diagnosis is based on the interpretation of clinical manifestations according to the creative, controlling, invading, and insulting sequences of the Five Elements. The Five Elements are five phases of transition used in Chinese Medicine and are sometimes referred to as the Wu Xing. Wu translates to mean the number five, Xing translates to mean a process of movement or walking. The concept of the Five Elemental theory began to first appear in documents in China during the Zhou Dynasty (from 1000 to 770 B.C.). This theory classified tangible and intangible substances into five categories for observation and study, as well as diagnosis and treatments.

1. The Wood Element is associated with the active functions of birth in nature's growth stage of development.
2. The Fire Element is associated with maximum functional activity in nature's growth stage of development.
3. The Earth Element is associated with the function of stabilization in nature's growth stage of development.
4. The Metal Element is associated with nature's declining functions of the growth stage of development.
5. The Water Element is associated with the maximum state of rest in nature's growth stage of development.

The Five Elemental theory is used to explain the classifications and characteristics along with the laws of universal cycles (creating, controlling, invading and insulting). These interactions are studied today in Traditional Chinese Medicine to assist the doctor's diagnosis in comprehending the growth and development of the body's energetic anatomy, physiology, disease processes, and symptom development (Figure 23.1).

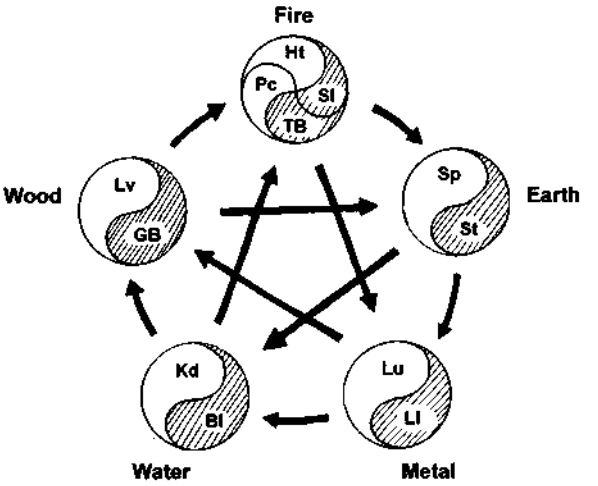

Figure 23.1 The Five Elements

The Five Elements and Yin and Yang Theory

It is important to understand the Five Elemental theory's energetic origin and its interaction with Yin and Yang Qi to appreciate its energetic categorizations.

The ancient Chinese Qigong masters believed that the creation, development, and declining transitions of all things throughout the universe were the result of the interaction of Yin and Yang Qi. The Yin and Yang theory was therefore used to describe the opposing, interdependent, as well as waxing and waning transitions of all things, especially the interactions of the Five Elements (Wood, Fire, Earth, Metal, and Water). Fire and Wood are considered active Yang elements, while Water and Metal are considered quiescent Yin elements. The Earth is considered a balance point between Yang and Yin.

Qigong doctors assign the Five Elements of Traditional Chinese Medicine to the body's organs and tissues. The Five Elements are considered the Jing of the body's Yin and Yang energy pools. Imagine each element organ as a pool of liquid energy. The energetic movement, much like water, flows from element to element. This flowing movement of liquid energy is considered to be the body's energetic pulse, moving Qi to and from these pools.

The rivers of Qi cannot exist without the pools of Jing to nourish their flow and function; and the pools of Jing cannot act without the rivers of Qi stimulating their action. Therefore the principle action of the Five Elements is the circulation of the Yin and Yang Qi.

The human body is like a living Taiji symbol (see Chapter 21). Its back channels are considered Yang; its front channels are considered Yin; and its center channel is contained through the energetic actions of the Taiji Pole. The Taiji Pole produces Yang Qi by the inhalation of life-force energy through the breath. When Yang Qi reaches its peak, it rests, while the Yin Qi begins to increase. When the Yin Qi reaches its peak and comes to rest, then the Yang Qi begins to increase once more. This continuous interaction of Yang energy with Yin energy produces and enhances within the body, the Five Elemental organ energies of the Liver (Wood), Heart (Fire), Spleen (Earth), Lungs (Metal), and Kidneys (Water).

The first stage of Qigong exercises and meditations create an energetic transformation which regulate, refine, and reduce these Five Elemental organ energies into two primary Yin and Yang energies known as Fire and Water Qi. The second stage of transformation consists of combining the Water and Fire energy into one union of Three Human Treasures (Jing, Qi, and Shen). This energetic transformation is responsible for "bringing 10,000 things into being" (Figure 23.2). In China, these meditation stages are used for exploring the stimulation of the energetic functions of the central nervous system, the peripheral nervous system, cardiovascular system, digestive system, reproductive system, etc.

The Five Elemental theory assists the Qigong doctor in examining the energetic correspondences for clinical evaluation. This is only one phase of clinical observation however, and should always be applied with the Yin and Yang theory.

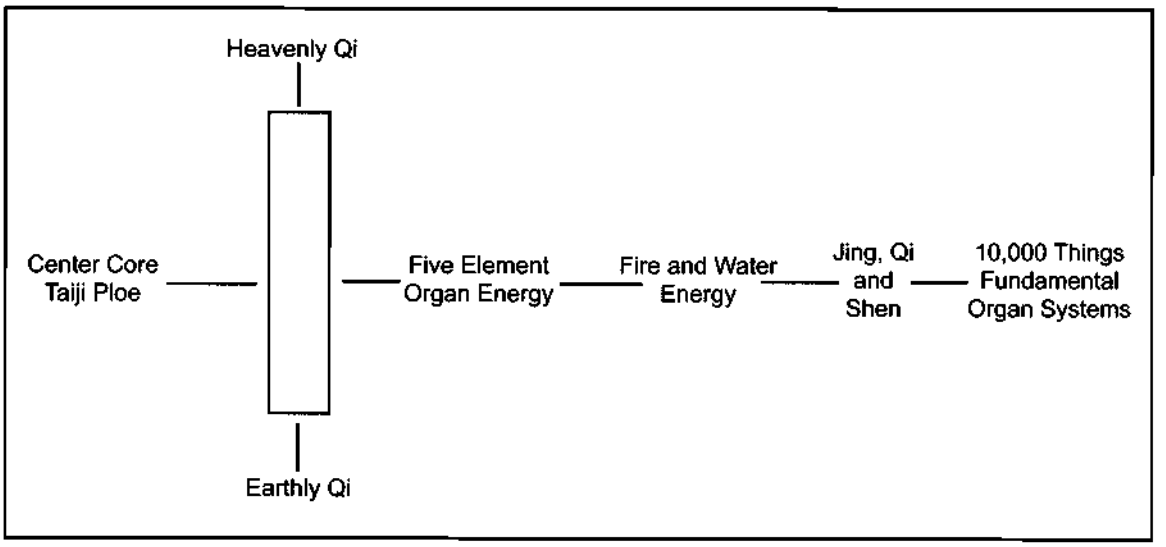

Figure 23.2 Stages of Energetic Transformation

THE CREATIVE OR GENERATIVE CYCLE

Within every Qi cycle each element has two main aspects: it is either (1) creating or being created, or (2) restricting and/or being restricted. In the process of growth and development, both creative and restrictive patterns are needed. Without creation, growth would have no origin, and growth without restriction can create harm. The creative element is called the Mother, and the element created is called the Child. This is the "Mother and Child" relationship referred to in Traditional Chinese Medicine. The Creative Cycle is generally used for tonification, as the stimulation of one organ enhances the function of the next (Figure 23.3). The Five Elemental Creative Cycle and its organ correspondences are as follows.

1. The Liver's element is Wood, which is used to create the Heart's element Fire. The Liver is the Mother of the Heart, which is the Child. The Liver stores the Blood and Blood houses the Shen. If the Mother (Liver) becomes Stagnant, the Child's Heart (Shen) will suffer. Clinical manifestations include indecision, timidity, lack of courage, palpitations, and early morning insomnia.
2. The Heart's element is Fire, which is used to create the Spleen's element Earth. The Heart is the Mother of the Spleen. The Heart's Qi pushes the Blood, thereby helping the Spleen in its function of transporting. If the Mother (Heart) becomes stagnant, the Child (Spleen) will suffer, creating a Spleen Yang Deficiency. This is due to failure of Heart Fire in providing Heat to the Spleen. Clinical manifestations include chills, weakness in the limbs, and loose stools.
3. The Spleen's element is Earth, which is used to create the Lungs' element Metal. The Spleen is the Mother of the Lungs. The Spleen Qi provides Gu Qi (food energy from the Earth) to the Lungs where it combines with air (energy from Heaven) to form Gathering (Zong) Qi. If the Mother (Spleen) becomes Deficient, the Child (Lungs) will suffer, creating Phlegm which obstructs the Lungs. Clinical manifestations include Phlegm in the chest, coughing, and general weakness.
4. The Lungs' element is Metal, which is used to create the Kidneys' element Water. The Lungs are the Mother of the Kidneys. The Lungs send Qi down to meet the Kidney Qi, as well as Fluids to nourish the Kidneys. If the Mother (Lungs) becomes stagnant, the Child (Kidneys) will suffer, due to the Kidneys not receiving enough Qi. Clinical manifestations include breathlessness, loss of voice, coughing, and asthma.
5. The Kidneys' element is Water, which is used to create the Liver's element Wood. The Kidneys are the Mother of the Liver. The Kidneys' Yin nourishes the Liver Blood. If the Mother (Kidneys) become Deficient, the Child (Liver) will suffer (i.e., Liver Yin Deficiency). Clinical manifestations include headaches, blurred vision, dizziness, and vertigo.

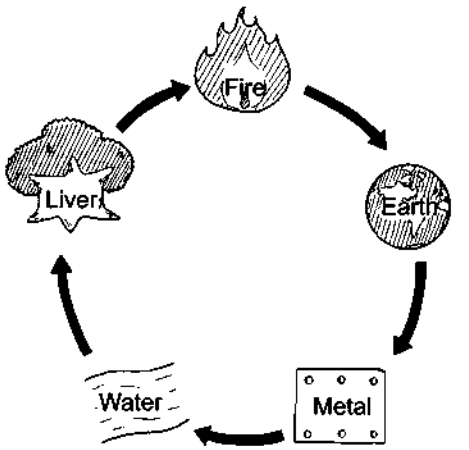

Figure 23.3 The Five Elemental Creative Cycle

THE CONTROLLING OR RESTRICTIVE CYCLE

This is a condition in Traditional Chinese Medicine where one element brings under control, or restrains, a corresponding element, thus

ensuring that a dynamic balance is maintained among the Five Elements. The element that restricts is considered successful, while the element being controlled is in check. It is commonly referred to as "the strong controlling the weak," and is generally used for sedation, to ensure that the Creative Cycle does not over-create and cause imbalances. The element prior to the Mother is commonly referred to as the Grandmother. In the Controlling Cycle, it is the Grandmother who controls the Child (Figure 23.4). The Five Elemental Controlling Cycle and its organ correspondences are explained as follows.

1. The Wood absorbs nutrients from the Earth, i.e., the Liver (Grandmother) controls the Spleen and its paired organ the Stomach (Child). Two of the Liver's energetic functions are to help the Stomach "rot and ripen" the food and the Spleen to transform and transport the Gu Qi.
2. The Earth restricts Water, i.e., the Spleen (Grandmother) controls the Kidneys (Child). Both the Spleen and Kidneys control the transformation of Body Fluids.
3. The Water extinguishes Fire, i.e., the Kidneys (Grandmother) control the Heart (Child). The energetic aspect of the Kidneys' Water controls the energetic balance of the Heart's Fire.
4. The Fire melts Metal, i.e., the Heart (Grandmother) controls the Lungs (Child). The Heart governs the Blood, while the Lungs govern Qi (both Qi and Blood mutually assist and nourish each other).
5. The Metal chops Wood, i.e., the Lungs (Grandmother) control the Liver (Child). If the Lungs' Qi is weak it will not descend thus allowing the Liver Qi to rise.

THE INVADING OR OVERACTING CYCLE

This is a condition in Traditional Chinese Medicine where an element overacts, overcontrols and invades, the element it is supposed to control (Figure 23.5). Instead of the role of checking and restraining, one element severely attacks another element, stealing Qi from its energetic pool. This is generally observed in cases of Excess or Deficiency conditions of the organs. The Five Elemental Overacting Cycle and its organ correspondences are as follows.

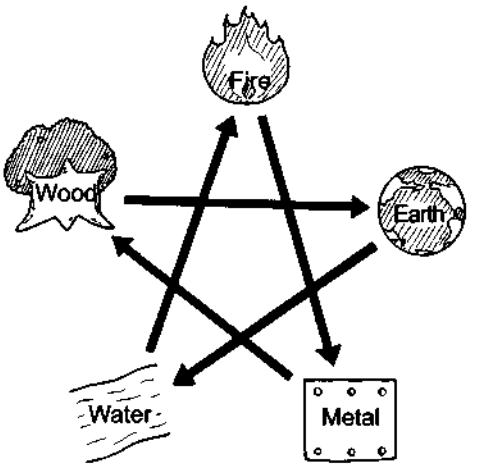

Figure 23.4. The Five Elemental Controlling Cycle

1. The Wood invades the Earth, i.e., the Liver (Grandmother) overcontrols the Spleen (Child) and its paired organ the Stomach. In the clinic, this is commonly called "Liver invading the Spleen." Clinical manifestations include hypochondriac and epigastric pain and distension, irritability, poor appetite, loose stool, and a green face color.
2. The Earth invades the Water, i.e., the Spleen (Grandmother) overcontrols the Kidneys (Child). This occurs when a Deficient Spleen fails to transform and transport Fluids. These Fluids accumulate and obstruct the Kidneys' function of transforming and excreting Fluids. Clinical manifestations include edema, difficulty urinating, and a yellow face color.
3. The Water invades the Fire, i.e., the Kidneys (Grandmother) overcontrol the Heart (Child). This pattern is almost never seen in clinical practice since the Kidneys are rarely in Excess.
4. The Fire invades the Metal, i.e., the Heart (Grandmother) overcontrols the Lungs (Child). This results in Full Heat in the Lungs.

Pulmonary disease can be caused by cardiac disorders, this is known as "Fire Overacting and Invading Metal." Clinical manifestations include cough with yellow sputum, a feeling of Hot sensations, and a red face color.

5. The Metal invades the Wood, i.e., the Lungs (Grandmother) overcontrols the Liver (Child). Clinical manifestations include irritability, a feeling of distension, fatigue, and a white face color.

THE INSULTING OR COUNTERACTING CYCLE

This is a condition in Traditional Chinese Medicine where the elements reverse their restrictive cycle and the Child insults the controlling element, the Grandmother (Figure 23.6). This is generally observed in cases of Excess or Deficiency within the Five Elements. The Five Elemental Insulting Cycle and its organ correspondences are as follows.

1. The Wood dulls the Metal ax, i.e., the Liver (Child) insults the Lungs (Grandmother). If the Child (Liver Qi or Liver Fire) becomes stagnant, it can obstruct and prevent the Lung's Qi (Grandmother) from descending. Clinical manifestations include coughing, a feeling of distension in the chest and hypochondrium area, and asthma. If pulmonary disease is due to the impairment of the Liver, it is explained as "Wood Insulting or Counteracting Metal."
2. The Metal controls the spread of Fire, i.e., the Lungs (Child) insult the Heart (Grandmother). If the Child becomes Deficient, it can cause the Heart Qi (Grandmother) to become Deficient. Clinical manifestations include palpitations, breathlessness and insomnia.
3. The Fire dries up the Water, i.e., the Heart (Child) insults the Kidneys (Grandmother). If the Grandmother (the Kidneys' Yin) becomes Deficient, then the Heart (Child) can become excessive, giving rise to Heart Empty Heat. Clinical manifestations include dizziness, lower back pain, night sweating, insomnia, malar flushes, and dry mouth (at night).
4. The Water erodes the Earth, i.e., the Kidneys

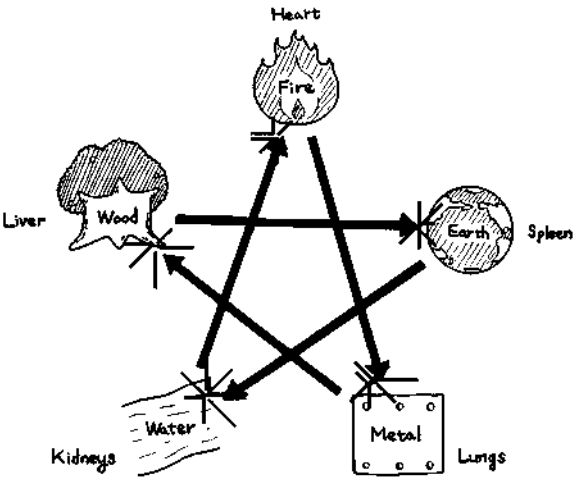

Figure 23.5 The Five Elemental Invading Cycle

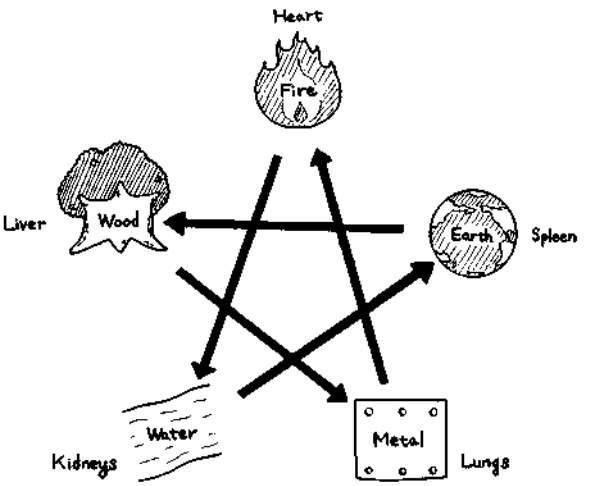

Figure 23.6 The Five Elemental Insulting Cycle

(Child) insult the Spleen (Grandmother). In this case, the Child (the Kidneys' Yang) becomes Deficient causing the Grandmother (Spleen) to become Deficient. Clinical manifestations include weak limbs, fatigue, edema, and loose stools.

5. The Earth resists the Wooden plow, i.e., the Spleen (Child) insults the Liver (Grandmother). If the Spleen (Child) fails to transform Fluids, a Damp condition can result. This Dampness can accumulate and begin to obstruct the flow of the Liver's Qi (Grandmother). Clinical manifestations include hypochondriac pain and distension, bile obstruction, and jaundice.

THE FIVE ELEMENTAL TONIFICATION CYCLE

The Five Elemental tonification cycle can be used for balancing the life-force energy of the body in conjunction with nature. Wood corresponds to spring, Fire corresponds to summer, Metal corresponds to autumn, Water corresponds to winter, and Earth corresponds to the late stage of each season (late spring, late summer, late autumn and late winter). The element Earth is centrally placed, associated with the 18 days of transformation at the end of each of the four seasons. The object of using the Five Elemental Tonification Cycle is to support and strengthen the next organ in the cycle (Figure 23.7).

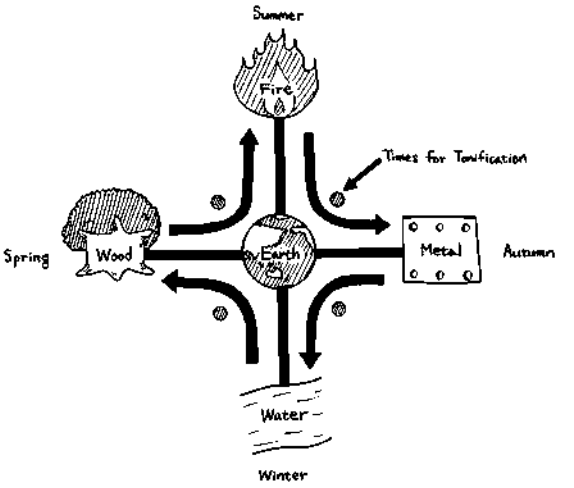

Figure 23.7 The Five Elemental Tonification Cycle

FIVE YIN ENERGETIC ORGAN MANIFESTATIONS

The Five Elemental energies are manifested through five different directions of movement. The Qigong doctor studies the movements and actions of a patient while they are in a meditative state (usually a sitting or standing posture), to diagnose their energetic disposition. After being in a meditative state for awhile, the patient's organs will overflow with Qi. When the organs overflow with Qi, certain physical reactions are evident, indicating which particular element has a problem.

1. Wood or Liver Qi is responsible for the dispersing effect of Qi, and is manifested by expansive outward movements in all directions, causing the body to sway with gentle and soft motions. When the Liver's energy is overabundant the torso makes a gentle, soft movement like a pine tree swaying in the wind. This is caused by the sprouting and branching manifestation of the Liver Qi's rising warm current.
2. When Fire or Heart Qi is overabundant, it is evident through the physical manifestation of the upward ascending actions of the torso caused by the flaring up of Yang Heat. This affects the energetic body and is manifested by upward movements and sometimes jerky actions (like a flame crackling in a fire).
3. Earth or Spleen Qi is generally manifested by stable movements, however, when overabundant, it is evident through movements that are both smooth and swift. This allows the body to progress in a limber, flexible, and free moving action (think of the body movement similar to a spinning ball).
4. When Metal or Lung Qi is overabundant, it is evident through the twitching actions of the torso and is manifested by contracted, inward movements, causing the body to violently jerk from side to side (think of the body as a metal bell being violently struck).
5. When Water or Kidney Qi is overabundant, it

is evident through the clumsy, awkward, heavy downward moving action of the torso (think of a waterfall descending onto rocks).

When the patient's body, unintentionally or unconsciously, rocks or sways gently as a result of a meditative state, the patient does not feel tired upon completing the meditation. However, when a patient consciously tries to force relaxation or augment the movement of his or her body while meditating, he or she will be tired by the end of the meditative session.

Note: While interning at the Medical Qigong Ward at the Xi Yuan Hospital in China, I found it fascinating to observe meditating patients displaying the results of both energetic organ manifestations or consciously induced augmentation of movement. All the above listed energetic manifestations were evident.

Chapter 24
Other Diagnostic Systems and Techniques

Diagnosis According to the Six Stages

This system of diagnosis was formulated by Dr. Zhang Zhong Jing in the early Han Dynasty. The application of the six stages of diagnosis provides the key link in treating febrile diseases which are due to an attack of Cold. The six stages are described as Tai Yang, Shao Yang, Yang Ming, Tai Yin, Shao Yin, and Jue Yin.

The Three Yang Syndromes

The signs and symptoms of these pathological changes result from attacks by exogenous factors, especially cold weather. The first three syndromes describe the pathological changes occurring in the six Yang organs and channels (Small Intestine, Bladder, Large Intestine, Stomach, Triple Burners and Gall Bladder), and are called the Three Yang Stages. In the Three Yang Stages, the pathogenic factors predominate, but the body's energy is still relatively strong. The major symptoms are signs of Heat, and the treatment is directed at eliminating the pathogenic factors. These are the external conditions which can progress from the superficial Tai Yang Stages to the deeper Shao Yang Stages.

1. The Tai Yang or Great Yang Stage affects Qi on the exterior surface of the body and all three Wei Qi levels. This energetic disturbance affects the Small Intestine and Bladder Channels and organs that govern the exterior of the body. Although they are the most superficial channels, they are very rich in Wei Qi.
   - Clinical Manifestations of an Attack of Cold include: Aversion to cold, stiff neck, headache, no sweating, fever, body aches, floating-tight pulse, and shortness of breath.

     The focus of the Qigong treatment is to first open the pores to eliminate pathogenic factors by purging and dispersing, followed by tonification of the Lungs.
   - Clinical Manifestations of an Attack of Wind include: Aversion to wind, stiff neck, sweating, body aches, floating pulse, and fever.

     The focus of the Qigong treatment is to first open the pores to eliminate pathogenic factors by purging and dispersing, then to relax the muscles for diaphoresis (profuse sweating) in order to regulate the Ying and Wei Qi, and finally to prescribe herbs (or refer out for herbal treatment).
2. The Shao Yang or Lesser Yang Stage affects the interior and exterior levels of the body equally. This energetic disturbance affects the Triple Burners and Gall Bladder organs and channels. The patient experiences an alteration of fever and chills with a fullness of the costal and hypochondriac regions, blurred vision, loss of appetite, irritability, and wiry pulse with a white-slippery tongue coating.

   The focus of the Qigong treatment is on dispersing Heat with purging techniques and promoting the production of Body Fluids using herbs.
3. The Yang Ming or Bright Yang Stage affects Qi at the interior level of the body. This energetic disturbance affects the Large Intestine and Stomach organs and channels. The pathogenic factors transform into Heat.
   - Clinical Manifestations of the Bright Yang Channel Stage include: Pure Interior Heat known as the Four Bigs (fever, thirst, sweating, and pulse). In addition the patient also experiences an aversion to heat and has a red tongue with a yellow coating.

     The focus of the Qigong treatment is on dispersing Heat with purging techniques and on promoting the production of Body Fluids through herbs.
   - Clinical Manifestations of the Bright Yang Or-

gan Stage include: Interior Heat and the Four Bigs with constipation, profuse sweating, high fever which worsens in the afternoon, fullness and pain in the abdomen (which becomes worse if you press it), and a red tongue with a dry, yellow or black coating.

The focus of the Qigong treatment is on eliminating pathogenic factors with purging and dispersing techniques, and relieving constipation.

THE THREE YIN SYNDROMES

The second three syndromes are those of the Three Yin Channels. They are based on the pathological changes of the Six Yin Organs and channels (Lungs and Spleen, Heart and Kidneys, Pericardium and Liver). These syndromes are the reflection of pathological changes within the Yin and Yang organs, channels, and collaterals. In the three Yin stages, the pathogenic factors are still present but diminishing. The body's Qi has become weakened, and there are Deficient signs of Cold. The treatment is focused on strengthening the body's Qi. These are internal conditions that progress from the Tai Yin stages deeper into the body until they reach the Jue Yin stage.

1. The Tai Yin or Great Yin Stage affects the Yin organs, as the penetration of pathogenic factors flow deep into the energetic layers. This energetic disturbance affects the Lung and Spleen organs and channels, resulting in a Deficiency and Cold syndrome. The clinical manifestations are: Vomiting and diarrhea, abdominal fullness, absence of thirst, and a slow, deep pulse with a pale tongue.

   The focus of the Qigong treatment is on heating and energizing the Middle Burner and dispersing the Cold using herbs. It is also important to tonify the patient's organ Qi.
2. The Shao Yin or Lesser Yin Stage affects the Heart and Kidney organs and channels. Clinical manifestations are as follows:
   - The transformation of Cold Deficiency to Kidney Yang Deficiency: Aversion to cold, chills, cold limbs, diarrhea, listlessness, lethargy, abundant-pale urine, deep-fine pulse, and pale tongue.

     The focus of the Qigong treatment is on tonifying the patient's organ Qi, preventing the Yang from collapsing and treating with herbs.
   - The transformation of Heat Deficiency to Kidney Yin Deficiency: insomnia, fever, irritability, dry throat and mouth, scanty-dark urine, fine-rapid pulse, and a red tongue without coating.

     The Qigong treatment should focus on tonifying the patient's organ Qi, nourishing the Yin, and dispersing Fire using herbs.
3. The Jue Yin or Terminal Yin Stage affects the Pericardium and Liver organs and channels. This is the final stage of pathogenic invasion before the life-force energy vanishes altogether.

   Clinical manifestations are as follows: cold limbs, diarrhea, vomiting, pain, feeling of heat and energy expanding in the chest, and feeling of hunger with no desire to eat.

   The focus of the Qigong treatment is on purging, tonifying and regulating the patient's organ Qi. Applying Cold and Hot herbal medicines simultaneously can be used to drive out the patient's pathogenic factors and aid in purgation. Herbal tonics can also be used to increase the patient's resistance to pathogenic diseases and aid in tonification (Figure 24.1).

DIAGNOSIS ACCORDING TO THE FOUR LEVELS

This system of diagnosis was formulated by the famous Chinese physician, Dr. Ye Tian Shi in the late 1600's. These syndromes are used to explain the etiology and pathogenesis of febrile diseases. The differentiation of syndromes pertaining to the Four Levels of Diagnosis is concerned with febrile diseases caused by externally contracted Heat. Because exogenous diseases are always developing and changing, by studying the transmission of pathological changes the Qigong doctor is able to deduce the prognosis. These four levels are identified by four types of energy, and are classified as follows: The Wei Qi Level, Qi Level, Ying Qi Level, and Blood (Xue) Level.

1. At the Wei Qi Level (Protective Energy), the

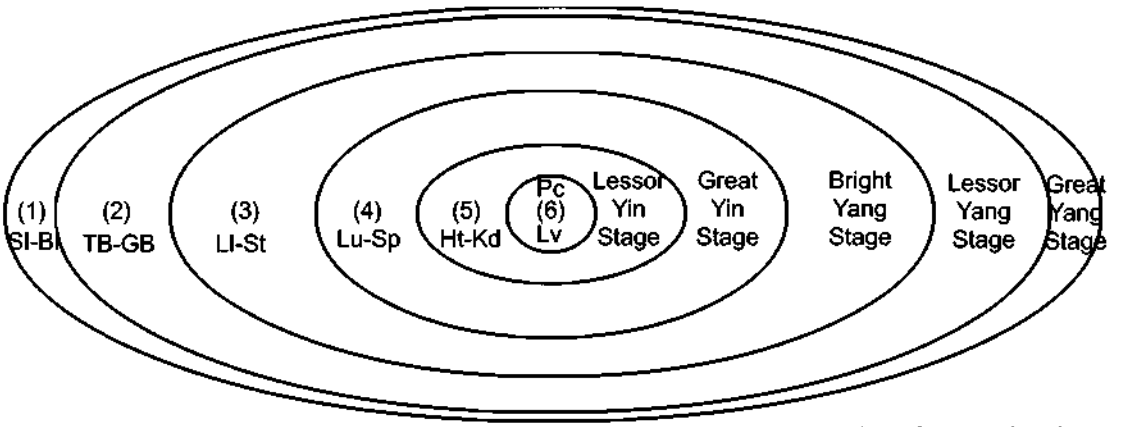

Figure 24.1. The Six Stages of Pathogenic Invasion are illustrated here. The invasion of external pathogenic factors follows a systematic progression through the body's Six Levels of Qi.

1. The Great Yang Stage (Tai Yang)

Affects the Small Intestine and Bladder Organs and channels. At this stage the pathogens are at the superficial level of the body's Wei Qi, caused by an attack of Wind and/or Cold Invasion. This stage is considered an External Cold Invasion at the Wei Qi level.

2. The Lessor Yang Stage (Shao Yang)

Affects the Triple Burners and Gall Bladder Organs and channels. At this stage the pathogens are half Exterior and half Interior, flowing in and out of the body, causing alternating chills and fever. This stage is also considered an Internal condition at the Qi level.

3. The Bright Yang Stage (Yang Ming)

Affects the Large Intestine and Stomach Organs and channels. At this stage the pathogens absorb deeper into the body's tissues, transforming into Heat affecting the internal organs and/or channels. This stage is considered an Internal condition at the Qi level.

- Bright Yang Organ Stage: Results in Interior Heat with constipation.
- Bright Yang Channel Stage: Results in pure Internal Heat with "Four Bigs" (fever, thirst, sweating, and pulse).

4. The Great Yin Stage (Tai Yin)

Affects the Lungs and Spleen Organs and channels. At this stage the penetration of pathogenic factors flow deep into the energetic layers affecting the Yin organs, invading the Middle Burner (affecting the Spleen) causing a Deficient condition. This stage is considered an Internal condition at the Ying Qi level.

5. The Lesser Yin Stage (Shao Yin)

Affects the Heart and Kidney Organs and channels. At this stage the pathogenic factors transforms either into Cold or Heat, causing further Deficient conditions. This stage is also considered an Internal condition at the Ying Qi level.

- Pathogens will transform into Cold due to a Deficiency of Kidney Yang.
- Pathogens will transform into Heat due to a Deficiency of Kidney Yin.

6. The Terminal Yin Stage (Jue Yin)

Affects the Pericardium and Liver Organs and channels. At this stage the pathogenic factors continue to deplete the body's life-force energy. This is the final stage of pathogenic invasion before death occurs. This stage is also considered an Internal condition at the Blood level.

pathogenic Heat invades the outer level of Wei Qi, causing the human body to manifest certain disorders which are clinically observed as fever, aversion to wind and cold, excessive or absence of sweating, sore throat, coughing, headache, red tongue with thin coating, and a floating and rapid pulse.

The Qigong treatment should focus on dispersing pathogenic factors and tonifying the exterior by utilizing pungent tastes and cooling herbs. Points are generally selected from the Lungs, Large Intestine, and Bladder Channels, as well as from the Governing Vessel.

2. At the Qi Level, the pathogenic Heat continues to progress deeper into the body, attacking and affecting the Qi system. At this stage, the body system is still strong, but the normal functions of the Yin and Yang organs are impaired. Because of the different functions of the Yin and Yang organs the manifestations differ. The three conditions associated with this stage of pathogenic invasion are as follows:

- Heat in the chest and diaphragm is the first stage and is not considered a severe syndrome. The symptoms manifest as fever, burning sensation in the epigastrium, thirst, and a yellow coated tongue.

  The Qigong treatment should focus on dispersing pathogenic Heat accumulated in the chest and diaphragm.
- Heat in the Stomach Channel is the second stage, and is considered a more severe Heat syndrome. These symptoms manifest as Heat, thirst, a dry tongue with yellow coating, and a slippery, rapid pulse.

  The Qigong treatment should focus on purging pathogenic Heat, and tonifying the body's Fluids.
- Heat in the Lesser Yang Channel is considered the final stage of Qi invasion. This syndrome is similar to the Lesser Yang Stage of the Three Yang Syndromes (according to the Six Stages), except that there is Dampness.

  The Qigong treatment should focus on purging pathogenic Heat from the Lesser Yang Channel, dispelling Dampness and dispersing Phlegm.

3. At the Ying Qi Level (Nutritive Energy), the pathogenic factors have penetrated deeper to the level of the Ying Qi and the organs, the Blood, blood vessels, and the Heart are therefore all affected. The symptoms in this stage are generally caused by the burning up the Yin. Clinical manifestations include: irritability, insomnia, mental restlessness, fever that worsens at night, dry mouth, absence of thirst, faint skin eruptions, a deep red tongue with little or no coating, and a fine-rapid pulse.

   Focus the Qigong treatment on purging pathogenic Heat from the Ying Qi level, using dispersing techniques. As an auxiliary method, bleeding may be performed by pricking the Heart and Pericardium Channels, as well as the Governing Vessel.
4. The Blood (Xue) Level, is the deepest and final level of pathogenic invasion. This stage contains the most serious manifestations that the disease can cause. Clinical manifestations include: high fever, skin that is hot to touch, Bloody stool, vomiting of Blood, Blood in urine, delirium, skin eruptions of purple or black color, a deep red tongue, a fine-rapid pulse, and in severe cases convulsions.

   The Qigong treatment should focus on purging pathogenic Heat from the Blood using bloodletting techniques (points are mainly selected from the Heart, Pericardium, Liver, Stomach, and Large Intestine Channels, along with the Governing Vessel), Cool the Blood, relieve convulsions, calm the mind, and reduce pathogenic factors with herbs.

DIAGNOSIS ACCORDING TO THE TRIPLE BURNERS

This system of diagnosis was developed by the famous Chinese physician, Dr. Wu Ju-Tong in the late 1700's. This system is concerned with febrile diseases caused by externally-contracted Heat, invading the body's Triple Burners. This Heat syndrome generally proceeds from the Upper Burner to the Middle and ends up at the Lower Burner. However, in cases of diseases due to Damp Heat, the pathogenic invasion of Heat begins at the Middle Burner in the Spleen.

1. The Upper Burner encompasses the body from the top of the head to the diaphragm. This area includes the Heart, Lungs, Pericardium, throat and head, and is responsible for respiratory and cardiac functions. The Upper Burner moves the body's Clean Qi, circulating and distributing nutrients and Qi throughout the body like a mist.

   Clinical manifestations of diseases in the Upper Burner correspond to those of a pathogenic invasion of the Lungs and Pericardium.

   a. When Wind Heat invades the Lungs, it is either manifested at the Wei Qi level or deeper in the Lungs themselves. The symptoms include: fever, sweating, coughing, stiffness and pain in the chest, wheezing, thirst, a red tongue with a yellow coat, and a rapid pulse.
   b. When pathogenic Heat invades the Pericardium, it is manifested at the Wei Qi level. These symptoms include: fever, coldness of the limbs, delirium, aphasia, burning sensation in the epigastrium, and a deep red tongue with spots.

   The Qigong treatment should focus on purging pathogenic Heat and dispersing Phlegm.
2. The Middle Burner encompasses the area from the diaphragm to the umbilicus. This area includes the Stomach, Spleen, pancreas, and Gall Bladder and is responsible for digestion, fermentation, and transformation of food and drink into nutrients for distribution. It moves the body's energy, circulating it like a swamp.

   Manifestations of diseases in the Middle Burner from pathogenic Heat are divided into two syndromes: Heat in the Bright Yang and Damp Heat in the Spleen.

   a. Heat in the Bright Yang include: symptoms of interior Heat and the Four Bigs (severe excess fever, sweating, thirst, and pulse) with constipation, profuse sweating, high fever which worsens in the afternoon, fullness and pain in the abdomen (which becomes worse when pressure is applied), and a red tongue with a dry, yellow or black coating.
   b. Damp Heat in the Spleen include: symptoms that are identical to the early stages of diseases caused by externally-contracted Heat.

   The clinical manifestations include: aversion to cold, fever that worsens in the afternoon, a heavy sensation in the head, body and limbs, fullness of the chest and epigastrium, nausea and vomiting, a white, sticky tongue, and floating or slippery pulse.

   The Qigong treatment should focus on Heating the Middle Burner, tonifying any Deficiency, purging Dampness, and prescribing herbs.
3. The Lower Burner encompasses the area from the umbilicus to the feet. This area includes the Liver, Kidneys, Bladder, intestines, external genitalia for men, and the uterus for women. The Lower Burner is responsible for filtering and eliminating waste products and for reproductive functions. It moves the body's Turbid Qi, circulating it like a drainage ditch.

   Manifestations of diseases in the Lower Burner are caused from pathogenic Heat attacking the Kidneys or Liver and are divided into two syndromes:

   a. Invasion of the Kidneys by pathogenic Heat dries up the Kidneys' Yin causing Heat symptoms due to a Yin Deficiency. Clinical manifestations include: lingering fever, hot hands and feet, dryness of the mouth, deafness, lassitude, a red-peeled tongue, and a rapid, floating or empty pulse.

   Focus the Qigong treatment on tonifying Yin, and purging the Heat.

   b. Invasion of the Liver by Heat occurs after the Kidney Yin has been exhausted. A condition known as Liver Wind is created. Clinical manifestations include: low-grade fever, cold limbs, dry and cracked lips, convulsions and trembling, a dry, reddish-purple tongue, and a rapid-deep pulse.

   The Qigong treatment should focus on tonifying Yin, and purging the Heat and Wind.

Chapter 25
Clinical Examination and Diagnosis

Sensory, Intuitive and Perceptual Diagnosis

Clinical diagnosis can be categorized into two primary methods of energetic examination and treatment: Sensory Diagnosis and Intuitive and Perceptual Diagnosis. The clinical methods of Sensory Diagnosis are quite prevalent throughout China, especially within the acupuncture, massage, and herbal clinics. The methods of Intuitive or Perceptual Diagnosis, however, have been kept secret for many years, and are primarily found only within the Medical Qigong clinics. The latter methods (Intuitive or Perceptual Diagnosis) will be explained later in this chapter.

The root of any disease can be drawn from its complex symptoms and signs, by using the two main methods of Sensory and Intuitive and Perceptual Diagnostic principles. These two main methods of diagnosis serve as guidelines for the Medical Qigong doctor in clinical evaluation. Once the cause and extent of the disease is known, a treatment plan can be developed. There are four main types of Qigong treatment, which are chosen according to the treatment goals:

- a routine treatment (basic or nonspecialized),
- a specialized treatment (designed for the specific patient and his or her condition),
- a treatment aimed at etiology, or
- a treatment focused on alleviating the symptoms and signs.

It is therefore important to determine and assess the cause (root) and the manifestations (branches) of the patient's disease.

Sensory Diagnosis

Before treatment begins, the Qigong doctor performs a clinical intake, examining and evaluating the patient's condition, using various methods of sensory diagnosis. This clinical format involves taking a history of the patient's complaints. Next the doctor inquires about the patient's medical history. The doctor then conducts an examination for diagnosis, and devises a treatment principle on which the treatment plan is based, before implementing the treatment.

Clinical Intake, Examination and Evaluation

It is important that the doctor clearly identify the patient's problem before any treatment may be given. Never treat a patient without first making a diagnosis. The diagnosis is developed from the doctor's sensory examination and is evaluated according to symptom observation.

Both the root (the source and cause of the disease) and its branches (the symptoms or manifestations of the disease) should be examined carefully before treating the patient. In the case of an emergency, the doctor may choose to treat the urgent symptom first before treating its source.

The diagnosis and treatment of each patient traditionally begins by observing the patient as a whole, followed by an evaluation of the patient's individual constitution. Next, the doctor observes the symptoms and syndromes of the individual's organs. From these observations the cause of the disease is determined and treatment is begun. The treatment usually focuses on addressing the cause of the disease, to return the organ or organ system back into harmony with the rest of the patient's body. This affects changes within the patient's constitution and returns him or her back to a normal state of health.

Sensory examination for diagnosis is divided into five primary methods: diagnosis by visual observation, diagnosis by listening, diagnosis by smelling, diagnosis by palpation, and diagnosis

by questioning the patient. By looking, listening, smelling, touching, and asking the patient specific questions, a Qigong doctor is able to diagnose the patient's syndrome (this includes the etiology of the disease).

DIAGNOSIS BY VISUAL OBSERVATION

1. Observe the patient's Shen, overall appearance, spirit, emotional nature, energy field, and composure. Look at the Shen of the patient's face; a healthy patient should have a brightness or vibrant shininess to his or her countenance. The Shen of the face should be checked against the state of the patient's eyes.
2. Observe the patient's eyes, especially the spirit in their eyes -- the glitter or dullness, and the expression of a controlled or uncontrolled emotional state. The eyes manifest the Essence of all the organs, and are the messengers of the Heart. There are two things to look at in the eyes -- glitter and focus.
    a. Are the patient's eyes bright and do they glitter? The less the glitter, the more long-standing the emotional and mental problems. It is said that there are three emotions that make the eyes lack glitter: sadness, grief, and shock. If the patient's eyes are dull, it looks as if he or she is seeing through a mist or film.
    b. Are the eyes focused, is the attention sustained and penetrating or uncontrolled? Uncontrolled attention is actually worse then having no glitter. If the patient has unfocused eyes it means that there is an obstruction of the patient's Shen and mind, generally due to guilt, preoccupation, or anxiety. It is said that Excess joy makes the "eyes uncontrolled."
3. Observe the color of the patient's face, complexion, eyes, ears, nose, mouth, tongue, skin zones, and ask about the discharges (mucus, vaginal, urine, and stool). Anger manifests as a greenish tinge on the cheeks or forehead (if it is affecting the Stomach); worry manifests as a grayish color, pensiveness as a sallow complexion, fear as a white complexion (unless combined with Kidney Yin which turns the cheeks red). Shock creates a bluish tinge on the forehead. A change in the complexion often indicates a deeper and longer-standing psycho-emotional problem. Also, if the eyes show no Shen but the face does, it indicates a recent problem.
4. Observe the patient's body and any outstanding structural features. Are they thin, emaciated, obese, or paralyzed? Are there deviations or obstructions in or on the body, face, head, mouth, teeth-gums, eyes, nose, and ears? Are there blemishes on the skin? Observe the appearance of the nails, hair and so on.
5. Observe the way the patient moves. Do they shake and tremor? Are they rigid or loose? Notice if the movements are fast or slow, and so on. When you shake hands upon meeting for the first time, are his or her hands clammy or dry; is his or her grip strong or weak?
6. Observe the patient's tongue. Is it cracked, serrated, fat, thin, or thick? If you observe a central crack, the deeper it is, the more long-standing the emotional problem. A red tipped tongue can also indicate a Shen disturbance.
7. Observe the patient's channels and points. Are there darkened red blotches, blemishes, swelling, sweat, etc.?

DIAGNOSIS BY LISTENING

1. Listen to the patient's speech for slurring or clarity.
2. Listen to the patient's tone. Is it high, low, loud, or quiet?
3. Listen to the patient's tempo. Is it fast or slow?
4. Listen to the patient's words. Do they make sense? Are his or her thoughts well ordered, or does the patient change subjects abruptly and frequently (if so, the patient may be suffering from a severe mental disorder).
5. Listen to the patient's respiration. Is it loud, strong, weak, or wheezing?
6. Listen to the patient's cough. Is it loud, dry, or wet?
7. Listen to the patient's Stomach and Intestines. Are they gurgling or quiet?

DIAGNOSIS BY SMELLING

1. Does the patient smell strong, weak, or odorless? Does the patient smell of medications, or alcohol?
   - For Liver problems, the patient's body or breath will smell like a goat.
   - For Heart problems, the patient's body or breath will smell like something has been burnt.
   - For Spleen problems, the patient's body or breath will smell fragrant or sweet.
   - For Lung problems, the patient's body or breath will smell like fish or a tide pool.
   - For Kidney problems, the patient's body or breath will smell rotten.

DIAGNOSIS BY PALPATION

1. How does the patient's pulse feel? Is it strong or weak? The pulse shows more about the patient's Qi than the state of his or her Shen. Because the pulse reflects the short-term state of the patient's Qi, it should always be integrated with tongue and complexion diagnosis.
2. How do the patient's channels and points feel? Are there tender areas, movable nodules (Qi stagnation), or fixed nodules (Blood stagnation) along the patient's channels?
3. How does the patient's abdomen feel?

DIAGNOSIS BY QUESTIONING

1. Ask about the history of the patient's main complaint (illness, disorder, or injury).
   - When did it begin?
   - What other signs or symptoms accompany it?
   - Ask about the course of the illness, is it improving or getting worse?
   - What makes it better or worse (i.e., pressure, warmth, cold, and so on)?
   - What other treatments has he or she tried?
2. Ask about the patient's general medical history.
   - Has the patient had any surgeries?
   - Has the patient experienced any past or recent physical or emotional traumas?
   - Ask if the patient is on any medication(s).
   - Ask about self-medication with alcohol or drugs.
   - Ask about his or her current coffee, soft drink and sugar intake.
   - Ask about the patient's extremities, do they feel hot or cold?
   - Ask about his or her sweat.
   - Ask about his or her thirst.
   - Ask about his or her appetite and diet (how often does the patient eat, and how regular are the meals?).
   - Ask about his or her digestion (gas, belching, etc.).
   - Ask about his or her stool (loose, well formed, hot, smelly, cold, fishy, color, etc.).
   - Ask about his or her urine (frequency, urgency, and color).
   - Ask about his or her sleeping patterns (difficulty falling asleep, remaining asleep, or recurring nightmares).
   - Ask for an energetic self-evaluation on a scale of 1 to 10.
   - Ask about current emotional and mental problems or concerns.
   - Ask about his or her current physical exercise program.

EXAMINATION FOR DIAGNOSIS

There are certain general principles used by all doctors of Traditional Chinese Medicine to become proficient in diagnostic skills. In Medical Qigong therapy, becoming skilled and accurate in clinical diagnosis requires the Qigong doctor to become proficient in combining perceptual and mental skills with spiritual understandings and insights. The following is a thorough and systematic approach for arriving at an accurate diagnosis.

1. Record all information observed and gathered as meticulously and impartially as possible. When first encountering a patient, be open minded, but note all first impressions.
2. Organize all the information according to the Eight Energetic Principles or Five Elemental Theories.
   - When diagnosing according to the Eight Energetic Principles, the doctor should first determine whether the condition is Yin or Yang (chronic or acute), then classify the patient's

symptoms according to the condition's general location (External or Internal), followed by the disease's symptomatic appearance (Hot or Cold), and finally, the physio-energetic nature of the disease (Excess or Deficient condition).

Next, the Qigong doctor focuses on the Yin or Yang aspects of the patient's body, in terms of the physiological properties of the patient's disease, noting which is more affected, the Qi and Blood, Yin and Yang organs, etc.

The Qigong doctor then determines the precise depth and severity of the patient's disease, observing whether it is the patient's surface channels which are being affected, or the patient's internal organs. If it is determined that the condition is an internal problem, the Qigong doctor then differentiates the energetic level of penetration into the patient's body. This level of pathogenic penetration is diagnosed according to either the Six Stages, Four Levels, or the Triple Burners method of diagnosis.

- If the doctor is diagnosing according to the Five Elemental Theory, he or she should first determine the condition of the patient's pulse to assess which organ or organs are Excess or Deficient. The doctor must then decide whether the imbalance is attributed to either an individual internal organ or a combination of internal organs. If the patient's pulse does not match with the information gathered through the examination, the doctor must reconsider whether the patient's disorder will in fact conform to a Five Elemental pattern.

3. Evaluate all information: The doctor should evaluate the gathered information according to the patient's signs and symptoms, determining what is of primary and secondary importance. It is in this stage of evaluation that the Qigong doctor determines the "root and branch" of the patient's disease. If the disease is External in origin, the doctor determines what pathogenic factors are involved. If the disease is Internal in origin, the doctor determines whether the cause is emotional, hereditary, dietary, or an energetic charge remaining from a previous external disruption.

Finally, the doctor should determine whether the cause of the disease is still active within the patient's life. If it still is, the doctor must take this factor into consideration before treating the patient and prescribing homework.

DEVISING A TREATMENT PRINCIPLE

In devising a treatment principle, the Qigong doctor should always include the Condition of the disease, Location of the disease, and Possible Cause of the disease.

1. The Condition of the Disease refers to the categorization of the disease, and may be diagnosed according to a combination of the Eight Energetic Principle's criteria. The patient's condition could, for example, be considered Excess or Deficient, Hot or Cold, Internal or External, or a combination thereof, such as: Excess Heat, Internal Heat, Deficient Heat, etc.
2. The Location of the Disease refers to the physio-energetic level of the patient's body that the disease is affecting (whether it is in the Upper, Middle or Lower Burner, or affecting certain Yin or Yang organs, channels, or muscles, etc.).
3. The Possible Cause of the Disease is either a result from a congenital or acquired illness. If congenital, consider the patient's DNA patterns, and all hereditary and ancestral traits. If acquired, consider environmental exposure to toxic poisons, diet, trauma (physical or emotional), electromagnetic fields, etc.

TREATMENT STRATEGY

Once the working diagnosis and treatment principle has been established, it is time to determine a treatment strategy. A treatment strategy consist in applying the treatment principle. It is the foundation from which the Qigong doctor chooses the approach in treating the patient's disease (Figure 25.1). The doctor will choose to treat the internal organs, channels, collaterals, points, and tissue areas which are the primary cause of the patient's disease. These areas are specifically chosen in or-

der to facilitate a rapid affect on the patient's disease, to purge, tonify, or regulate the tissue area.

TREATMENT

The treatment usually focuses on the specific cause of the disease and how it affects the patient's internal organs. The primary goal is to relieve the patient's symptoms, strengthen the constitution and return the patient to a state of wholeness. This process may involve restructuring the patient's belief structure, to emotionally release old traumas.

AFTER THE TREATMENT

After treating the patient's condition, the Qigong doctor explains to the patient in clear, comprehensive terminology, what the doctor has discovered, and his or her approach in rectifying the condition. The more the patient understands the

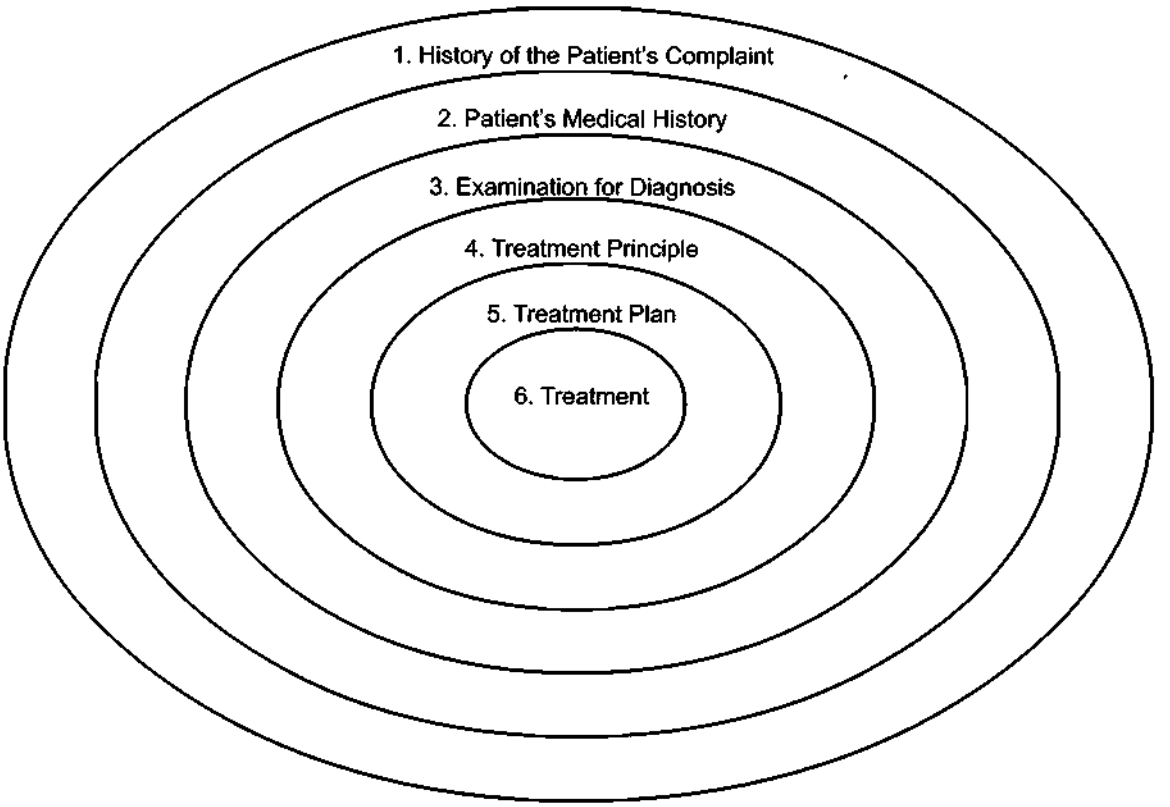

Figure 25.1. Examination, Diagnosis, and Treatment: The Qigong doctor begins diagnosing the patient by taking a "history of the patient's complaint." Next the doctor inquires about the "patient's medical history." Then, the doctor begins the "examination for diagnosis," observing the patient's constitution, symptoms and signs and determines the syndrome(s), health and state of the patient's internal organs, and the cause of the energetic dysfunction. Next, all the acquired knowledge is assessed in accordance with the different diagnostic templates of the Eight Parameters, Five Elemental Theory, Qi, Blood and Body Fluid Dysfunctions, etc. and the doctor "devises a treatment principle." Before treating the disease the doctor "develops a treatment plan." The treatment focuses on the specific cause of the disease and how it affects the patient's internal organs. The primary goal is to relieve the patient's symptoms, strengthen the constitution and return the patient to a state of wholeness. This entire process is initiated to assist the Qigong doctor in prescribing the correct treatment.

doctor's diagnosis and approach in addressing the treatment, homework prescriptions, and suggestions for life-style modifications, the greater the likelihood of a successful healing.

After the initial treatment, it is important for the Qigong doctor to establish a treatment schedule. This establishes a realistic goal and time frame for the therapy. With each treatment, the doctor monitors the patient's progress, and may choose to modify the treatment approach in accord with the patient's changing condition.

As the patient's symptoms improve, the doctor lengthens the time between treatments. This continues until the symptoms are completely relieved, and the doctor is satisfied that the disease will not return.

ALTERNATIVE TREATMENT STRATEGIES

As the human body is in a constant state of change, the doctor's diagnosis and treatment approach will sometimes have to be altered. The doctor may also choose to modify each treatment according to the patient's changing symptoms or disease development. When choosing alternative treatment strategies, it is important that the doctor choose adjunctive therapies that enhance the primary goal of purging, tonifying, and regulating the patient's condition.

INTUITIVE AND PERCEPTUAL DIAGNOSIS

THE METAPHYSICAL DIMENSIONS OF MEDICAL QIGONG HEALING

The dictionary describes "metaphysical" as "the study of psychic phenomena beyond the limits of ordinary or orthodox psychology." There are other dimensions of reality that are very tangible, and access to them is only limited by fear and ignorance. Since theories on the nature of the mind and spirit cannot be easily verified or disproved by intellectual analysis or scientific experiment, sometimes certain kinds of knowledge are disbelieved, ridiculed, and dismissed. The advanced energy theories that are presented in this textbook are based upon the five thousand years of cultivation and experience of Chinese medical healing. The energetic form of Qi is neither good nor evil, it is simply another aspect of matter. The ancient Chinese Qigong masters refined the ability to analyze and diagnose these different forms of energy into an effective healing modality.

The existence of energy and its multidimensional patterns is embraced and accepted by many other cultures and societies, with the exception of Western conventional thinking, which is unfamiliar with this unorthodox approach to healing.

These energetic realms, which form the reality of the Medical Qigong doctor's clinical healings, are actually normal perceptional skills that the doctors have developed and trained within themselves. These doctors have simply rediscovered and trained their sensitivity to energies that they were open to during childhood. These energies encompass more then just the physical world. These perceptive skills and abilities of Shen are actually our natural, energetic "birthright," and have been with us since birth. Shen Gong skills, and all psychic powers, lie within the Eternal Soul of an individual, although in most people these skills are undeveloped and largely unused. Often we fear the most the things we understand the least. It has also been my observation that individuals are taught to ignore these skills because of one or more of the following reasons:

1. They have become frightened of them, because as children they were told that these abilities do not exist;
2. They were told that such abilities were evil, or of the 'devil';
3. Unable to understand them, they do not know how to integrate them into their personal lives;
4. They may fear the emotional and spiritual responsibility of knowing the truth about themselves and others; or
5. The known is familiar and therefore more comfortable then the unknown and new.

Sometimes even facing our own human potential alarms us so greatly (fear bordering on terror) that we are willing to deny empirical evidence that these paranormal skills and abilities are real.

We live, therefore, with a paradox. These paranormal abilities seem to be part of our nature, yet they can disturb us so greatly that we often violently reject them. Medical Qigong doctors are healers who have learned to accept these paranormal abilities and direct their energy, spirit and psychic skills towards the focus of alleviating pain and suffering. They are "wounded healers" who have learned to face their fears, and have the courage to walk through and overcome them.

THE AWAKENING

For the Qigong doctor to understand spiritual insights, three phases of energetic transformation must first be experienced. These three phases are collectively known as "the awakening" and are described as follows.

1. The awakening describes the beginning phase or "opening" of the Qigong doctors' Mind and Spirit to their energetic potential. This acceptance becomes rooted within the doctors' intention, emotion, and thought, and sets into motion the correct vibrational field for accessing their higher consciousness.
2. Entering the inner sanctuary describes the phase wherein Qigong doctors begin to receive greater clarity of mind and an elevated consciousness. The doctors receive information on a multidimensional level and are now able to access, as well as better understand their inner core being. This sets into motion the Qigong doctors' understanding of their interconnectedness to everything in the universe. At this point, the doctors must accept responsibility for their actions and non-actions.
3. Accessing the Wuji through the Creative Subconscious Mind describes the Qigong doctors' ability to access and reprogram their Mind and core vibration. This sets into motion the doctors' personal contact with their higher-self, or Eternal Soul.

LEARNING INTUITIVE AND PERCEPTUAL DIAGNOSIS

Before beginning the primary methods of Intuitive and Perceptual Energy Diagnosis, it is important to understand the initial training needed to access and train these skills. Without an understanding of these subtle energies, the risk of misdiagnosis of the microprojections of life-force energy is high. The subconscious mind communicates within ourselves and the outside world through the Three Dantians, by way of three distinct mechanisms:

- Physical or kinetic communication is established through the Lower Dantian.
- Emotional or empathic communication is established through the Middle Dantian.
- Spiritual or intuitive communication is established through the Upper Dantian.

These three modalities of energetic communication must be finely honed into effective, receptive listening tools.

Memories, thoughts, emotions, and knowledge are stored in the patient's tissues throughout the body at the pre-atomic and pre-cellular levels. They are arranged and structured similar to the way sounds and images are recorded on the magnetic molecules of a video cassette tape. Not only are emotions and sounds stored, but tastes, smells, and touch can be invoked simultaneously in vivid detail as the cells are stimulated. The patient feels that they are actually reliving the event from the past exactly as if it were occurring now.

The Qigong doctor must be ready to recognize, uncover, and be able to feel his or her patient's pain when interceding as an empath. Sometimes the doctor will not only stumble upon pockets of unresolved pain, but also suppressed memories hidden deep within the patient's tissues. When this occurs, the doctor diagnoses the patient's toxic emotional symptoms through his or her own body and spirit. To perform this type of diagnostic technique successfully, doctors must be secure in their established emotional boundaries. Otherwise they might project their own feelings onto the patient, or absorb the patient's pathogenic energy into their own body, where it may become trapped.

The goal is to absorb and receive the patient's symptoms briefly for diagnosis, and then release them by exhaling out the mouth (away from the patient). This expels the Toxic Qi into the ground, and allows the patient's feelings to pass through the doctor's body without harm.

The state of consciousness in which the doctor listens and feels the patient is more important than the technique or modality used. This is why there are so many diagnostic tools available to assist doctors in their evaluation. The patient's body maintains the energetic pattern of trauma until it is released and dispersed. The amount of energy required to neutralize this traumatic charge and return the tissues back to their normal state is in direct proportion to the intensity of the original trauma.

RECEIVING AND INTERPRETING THE PATIENT'S FIELDS OF BIO-INFORMATION

The human body emits several "bio-fields" of energy, varying in density and frequency and resonating within a holographic field. Like radio waves and other modern technological wave transmissions, these fields are encoded with information. The key to what we absorb and radiate lies in the energetic qualities of the rate or frequency of vibration, amplitude, and wave length of these bio-fields.

The physical world as we know it is made up of energetic fields. These energetic fields hold our universe together (Figure 25.2). Matter is simply the temporary expression of these energetic fields as they interact. The human body consists of Shen, Qi, and Jing actively resonating within the cells and tissues. Qi, as energy, is considered both substantial and insubstantial. Qi creates matter and acts as a medium between matter and spirit; it carries their mutual interactions in the form of waves. Because matter manifests as a distinctive type of consciousness, it operates at discreet levels of awareness, differing only in its complexity of structure and degree of freedom. Matter also manifests itself at every level of organization, from fundamental particles in physics, to biological organisms within the human body. The cells are governed by these bio-fields which determine their growth.

It is the conscious aspect of energy that dictates how, where and in what form energy is manifested within the body. This energetic consciousness releases bio-information which transmits encoded

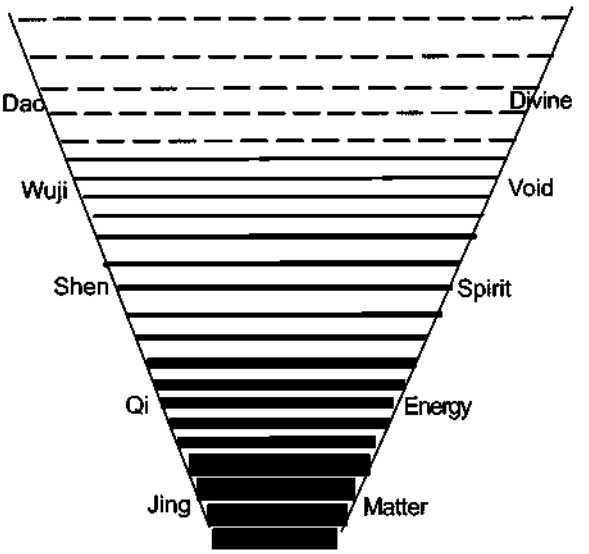

Figure 25.2. The Energetic Fields

information about the patient both internally and externally. Form, force, and medium are three aspects of energy held in dynamic patterns by consciousness. The bio-information released from the patient's consciousness is read and diagnosed by the Qigong doctor before treatment begins.

The body's bio-information resonation Xin Xi or the "message" as it is called in China, is not limited by space or time. This Message refers to the energy fields that emanate to and from the Wuji or Void (infinite space embodied in between matter and energy).

The Wuji is the state of no boundaries, of pure openness, of complete oneness. Its essence is emptiness (as depicted by the empty circle), which relates to the awareness aspect of our Yuan Shen. When it begins to manifest within the relative universe of Qi, Yin, and Yang (referred to as Taiji), its nature appears as clear light which dispels darkness. When it manifests as a pure and tangible physical form, it appears as an enlightened being (saint or immortal) or as the "divinity" inherent within each one of us.

All of these levels exist within each individual, on both a pure level and pathological level. These levels can be detected and interpreted by the trained Qigong doctor as bio-information resona-

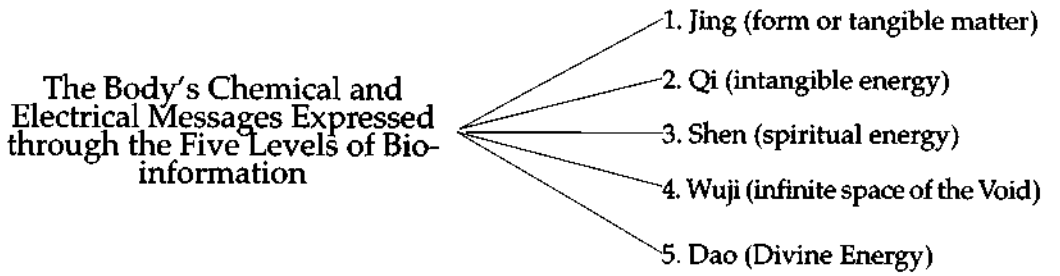

Figure 25.3. The Five Levels of Bio-information

nce. Bio-information resonance is subdivided into five levels of expression:

1. Jing (form or tangible matter) contains the least amount of encoded information which is emitted at the lowest frequency.
2. Qi (intangible energy) contains more encoded information which is emitted at a higher frequency than Jing.
3. Shen (spiritual energy) emits an even higher frequency containing still more encoded information than Qi.
4. Wuji (the infinite space of the Void) contains even more encoded information than Shen which is emitted at a still higher frequency.
5. Dao (Divine Energy) emits the highest, most complete encoded information or Message and is the most powerful of all the emissions.

Medical Qigong views congenital disease as a form of distorted bio-informational vibration. The body's cellular systems internally regulate themselves via communication through these coded Messages. Messages are sent and received both on the energetic level (Shen, Qi, and Jing) and on the biochemical-electrical level. These two different levels interact continuously. Distortions on the energetic level interfere with the necessary transformations of Jing into Qi, Qi into Shen, and vice versa. Failures in energetic transformations also affect and distort chemical and electrical Messages between the different types of cells in the body (blood cells, tissue cells, nerve cells, and so on).

The maturity of the physical body depends on the transference of these Messages as the source of its evolution. Each time the egg cell divides (morula, embryonic, and fetal stages) the Message is transcribed into the newly-generated cells. Some encoded Messages are transformed but, due to the adverse evolutionary conditions or pathogenic factors, some become latent. Germ cell Messages, however, are not restricted by these evolutionary conditions since they multiply, evolve, and transform at an accelerated pace.

Information of the body's disharmonies is received as a distorted, biological resonation, which indicates the location and severity of the patient's condition. All diagnostic scanning techniques utilize this type of perception. The body's cellular systems internally regulate themselves via communication through coded bio-informational signals. This biological information exists in energetic, electrical, and chemical forms which are constantly being transformed from one form into another (Figure 25.3). The function of Medical Qigong therapy is to provide the correct bio-informational instructions (or Message) to the patient's body in the form of Qi emission (or coded energetic bio-informational signals) to initiate healing. By receiving Messages from the patient, the Qigong doctor can project energy while receiving and diagnosing the patient's energetic patterns.

ACCESSING THE KNOWLEDGE STORED WITHIN THE WUJI

When the Qigong doctors emit healing energy to the patient, they are sending healing Messages encoded within the Qi. When these Messages are received by the patient's cells the healing process is initiated. Qigong doctors access the knowledge

needed to treat patients, by remaining receptive to the Messages stored within the patient's Jing, Qi, Shen, and surrounding energetic space (Wuji or Void).

Within the energy of the Wuji is the knowledge stored throughout time. In Medical Qigong practices, accessing the knowledge of the Wuji is the Chinese equivalent of the Sanskrit concept of accessing the Akashic Records. "Akasha" is a Sanskrit term used to describe the all-pervasive space of the universe. There are two kinds of Void: the first type of Void is internal, limited by the material plane (or matter) and can be associated with the enveloping of the internal human form. Matter can be described as consisting of more space then actual physical matter and, therefore, is considered infinite in its internal division of energetic properties. Within this Void forms the foundation for the matter or the body's personality by way of physical forms, sensations, perceptions, mental formations, and consciousness.

The second type of Void is external, unlimited, beyond all description, unbound by the material, yet contains all things material. It is the vehicle for all life, resonating through sound and light, permeating everything in the universe. In the practice of Medical Qigong the Wuji is one of three universal principles, along with Qi and Shen, which form a trinity of sources of intuitive and psychic power. These three universal principles also manifest the Eternal Soul, allowing divine thought to infuse matter.

The knowledge of the Wuji records the vibrational resonance of every action (all thought and emotion), as well as light and sound. These energetic impressions are stored within the astral plane. These records exist as impressions in the astral/spiritual dimension, providing a sort of accessible filing system for those who wish to receive information about past history or past lives, or even for the examination of their own spiritual progress. Admittance to this sea of knowledge and wisdom can be triggered in the hypothalamic limbic system of the brain, and is accessible through the energetic stimulation of the third ventricle of the Qigong doctor's brain.

The body is composed of literally billions of energetic molecules. Each molecule is a hologram of ancestral particles, knowledge, and experiences existing throughout time, spanning our entire history as we know it. These molecules gather together to form and create matter. They function for specific purposes of life transitions and energetic interaction, and then dissolve, and transform back into Qi and Shen. Each molecule stores its energetic experiences, to be later accessed through spiritual intention.

As the molecules gather to form a fetus, energy as well as ancestral history is stored within the tissues and cells of the child via the environmental, universal, mother and father's energetic fields.

Once the Qigong doctor has fused with his or her patient, he or she will be able to access specific information about the patient through the internal connection to the energetic impressions of the patient's Void. This allows the doctor to study and learn about the patient's past history of disease formations, as well as the information contained within the molecular structures of the patient's tissues.

UNDERSTANDING PAST-LIFE REGRESSION

Although seldom talked about, and much less understood, the clinical significance about past-life regression is quite important. Psychiatrists Sigmund Freud and Carl G. Jung both believed that the patients' worst fears, pain, and traumas are buried deep within their unconscious mind. Sometimes the patients' emotional traumas are so deeply entrenched that they can only be expressed through the energetic presence of a different time-space reality. One metaphor used by patients to describe this other form of reality is through a "past-life trauma."

During Medical Qigong treatments, patients will sometimes describe traumas or situations that do not relate to present life experiences. These experiences might be explained through past life theories. There are six major theories used to explain past-life recall (Figure 25.4). These theories are described as follows.

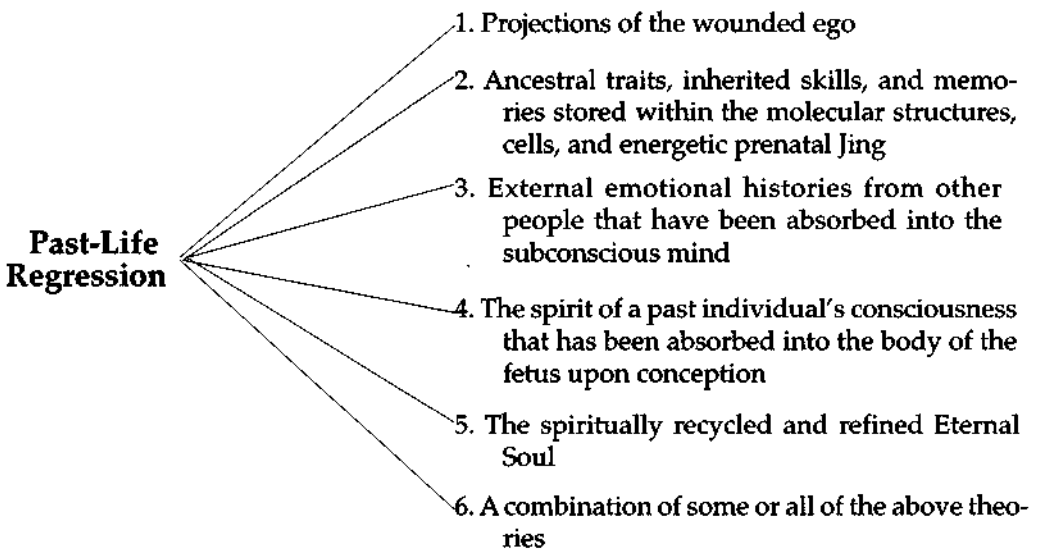

Figure 25.4. The Six Major Theories of Past Life Regression

1. Some Qigong doctors contend that these past-life memories are the projections of the patient's wounded ego, used by the subconscious mind to assist the patient in dealing indirectly and symbolically with life's present painful experiences. These are painful memories that are consciously avoided by the patient, but are necessary for healing to take place.
2. Other doctors believe that these past-life phenomena are the ancestral traits, inherited skills, and memories stored within the molecular structures, cells, and energetic Prenatal Jing of the patient, that periodically surface from time to time and generation to generation.
3. Some doctors believe that apparent memories of past-life regressions, as well as of past-life traumas, are external emotional histories from other people that have been absorbed into the patient's subconscious mind. The patient responds like an energetic empath to sensations of telepathy, registered by the patient's hypothalamic limbic system. These external memories are triggered when the patient accesses the knowledge of the Wuji.
4. Other doctors believe that the spirit of a past individual's consciousness can be absorbed into the body of the fetus upon conception. This means that wherever a child is conceived, the environmental energy, as well as any native hovering spiritual entity, can be implanted into the forming energetic field of the fetus.
5. Other doctors believe that one's Eternal Soul is constantly being recycled and refined through generation after generation, constantly being reborn in order to evolve into a higher plane of consciousness.
6. Still other doctors believe that past-life memories can be a combination of some or all of the above theories.

Some patients feel that they experience spontaneous past-life recall through the treatment of Medical Qigong therapy. While receiving treatments or performing Medical Qigong prescriptions these patients may experience intuitive flashes or visions. Whether the patients' memories actually are of their own historical past lives, or are reconstructions from subconscious material, is a matter of controversy. The primary objective is for the doctor to accept the patients' reality, supporting them in this belief system to facilitate their healing process.

It is the doctor's responsibility to respect the patient's reality and not impose his or her own interpretations on everything the patient says. By accessing the knowledge of the Wuji, the doctor can assist the patient to connect with and benefit from these past life recollections or "reconstructions" to facilitate the healing process. Ultimately it matters not if the memories are reconstructions of subconscious material, true past life events, or even telepathic experiences. What is important, however, is that these memories are processed, learned from, and integrated to promote a better balance within the patient.

PAST-LIFE HEALING THERAPY

Clinically, past-life regression therapy has been effective in treating such problems as chronic fears and phobias, detrimental habits and cravings, suppressed hostility and guilt, depression, the fear of death, sexual dysfunctions, chronic pains and headaches, as well as many physical disorders. It is also used for understanding relationship problems, since the theory maintains that we often meet the same souls in different lives (and bodies) until the problems are worked out.

The Qigong doctor is not qualified to perform past-life regression therapy. This requires a specialist or at least supervision by an expert. The Qigong doctor can, however, facilitate healing by accepting the patient's experience and validating it to prepare the way for the healing process. In Medical Qigong therapy, the doctor accepts the patient's belief that the causes of his or her present physical or psychological problems can be traced to past-life traumas or death experiences. The improvement attained through past-life memories is said to be achieved through the release of the energetic charge that is trapped in the patient's body from a former life. This energetic charge keeps the patient's emotions prisoner, chained to the old feelings that are associated with the painful past-life experience. It is important for the Qigong doctor to realize that the same therapeutic benefits as the retrieval of current-life real memories can be achieved by allowing the patient to relate any images, impressions and so on, that may or may not stem from his or her present life experiences. The foundational base of the emotional trauma will often be rooted in feelings associated with rejection, betrayal, and abandonment. The psychological and physiological reactions to the patient's past-life memories, whether they be real or contrived, will have a profound affect on the patient's healing.

LEARNING MEDICAL QIGONG TECHNIQUES

According to Qigong Master Zheng Zhan Ding from Beijing, China, when learning Medical Qigong techniques, the doctors experience what is known as the Three-Part Wisdoms.

1. The Upper Dantian Wisdom is achieved through divine calling. When the full potential of the Upper Dantian is tapped, the doctor suddenly finds him or herself able to utilize skills and techniques that were previously completely beyond his or her ability. This is a major energetic breakthrough for the doctor, enabling him or her to perform supernatural feats that he or she immediately recognizes and accepts as part of a personal spiritual calling.
2. The Middle Dantian Wisdom is achieved through inspirational observation. Upon seeing energetic techniques performed, the doctor immediately establishes an emotional belief that he or she possesses that same energetic ability. This is a kind of "if they can do it, I can do it" observation and belief structure.
3. The Lower Dantian Wisdom is achieved through practice. This is a type of "practice makes perfect" method of transition which allows the doctor time to accept and integrate new beliefs and abilities through long hours of constant practice, observation, and tutelage.

All Qigong techniques are based on the imagination and spiritual belief. It is necessary to create an image (a spiritual belief) within the mind, to create a positive environment for healing transformations (the spirit transforms energy, and energy transforms matter). Sometimes the Qigong doctor will want to utilize a certain image of his or her belief, but because of certain doubts, is unable to bring it into existence. In order to successfully cultivate this image, the doctor must use cre-

ative thinking to focus his or her life-force energy on this specific objective, accept it as true and know it will happen. To create this image the doctor must use his or her imagination, emotional feelings, unwavering belief, visualization, affirmation, and acceptance.

Energy (Qi) is the bridge between the material and the spiritual, and is the medium through which consciousness interacts with the world. Through intention, Qi is gathered, focused, and used to transform light, sound, and other resonations. Through intention, the Qigong doctor is able to change structural formations, and to transform tangible and intangible forms and vice versa, to dissolve tumors, cysts, and so on. Of the many methods of healing available in Medical Qigong, it is important for the Qigong doctor to explore the healing skills suited to his or her body and personality, to become most effective. Once the doctor has learned and mastered these healing techniques, he or she will no longer need to think about the methods, or when they need to be employed, they will become second nature.

Perceptual Communication Training

Subconscious communications are divided into physical, emotional, and intuitive forms of interaction and perception. The internal-vision techniques required to utilize energetic perception in a clinical setting are expressed and enhanced through these types of communication. These types of communications are realms of perception that can be explored, wherein, the Qigong doctor is so present in "the moment" that his or her attention begins to dissolve the perceptual realities of all five senses, and begins to perceive and diagnosis patients on a spiritual level. At this level, all feelings, sounds, colors, or any combination of the doctor's senses take on new dimensions of reality.

Diagnosis through Dantian Communication

Any treatment, exercise, or meditation the Qigong doctor prescribes must connect with the energetic resonation of the patient's disease. This connection is established through the doctor's ability to communicate with the patient's body via the Three Dantians.

1. The Upper Dantian's perceptional awareness is received through a type of spiritual/intuitive communication. Through this intuitive subconscious communication the doctor is able to interact and perceive the patient's spiritual and energetic disturbances. This allows the doctor to perceive the patient's spiritual condition without bias.
2. The Middle Dantian's perceptional awareness is received through a type of emotional/empathic communication. Through this empathic subconscious communication the doctor is able to interact and perceive the patient's feelings, actively empathizing, listening, and hearing what patients communicate about their pain and problems. This allows the doctor to perceive the patient's true emotional condition by bypassing the person's ego.
3. The Lower Dantian's perceptional awareness is received through a type of kinesthetic communication. Through this physical subconscious communication the doctor is able to interact and perceive the active condition of the patient's physical tissues. This allows the doctor to perceive (through his or her hands and physical body) the patient's physical symptoms, such as pain, Heat, and so on.

Utilizing Internal-Vision As a Clinical Modality

The brain has the ability of receiving and recording the vibrations of any object that the senses see, hear, smell, taste or feel. The vibrations of light, sound, smell, color, and object's shape are all recorded. This also holds true for thoughts, words, and actions. The brain also has the ability of reproducing these vibrations and projecting them out again through the use of inner vision and the imagination.

Before beginning internal Qi diagnosis it is important that the Qigong doctor have a thorough understanding of the internal energy's function and flow within his or her own body. Dr. Li Shi Zhen pointed out during the Ming Dynasty that, "The internal organs and channels can be per-

ceived as unobstructed and free from disease only by those who can see internally."

This is achieved by performing the Nei Guan or Internal Viewing Meditation. The purpose for internal-vision is to carefully examine, through conscious introspection, the energetic flow and structure of the body and mind. Most doctors in the Ming Dynasty studied the Nei Guan Meditation as part of their clinical practice to develop the light for internal viewing. It is believed that light enters the body through the Baihui Point (at the top of the head), the Yin Tang Point (the Third Eye area) and through both eyes. Since internal-vision uses light that has a higher vibration than visual light, it is able to penetrate through the skin deep into the tissues.

Many years ago I was truly skeptical of this phenomenon, although I met many Qigong masters who possessed such skills. After acquiring this skill, however, I was able to demonstrate its effectiveness quite thoroughly while interning in the Qigong hospitals of Beijing, China. It is actually a simple matter of consistent practice and focused concentration which allows this sense of perception to become tangible. It is important to remember that to know something, one must first think it, then feel it in order to integrate the knowledge fully. Always watch as an observer, void of emotional attachment, noticing what is actually there.

Nei Guan—Internal Viewing Meditation

The best way to practice the Nei Guan Meditation is through relaxed, quiescent breathing. Begin from a Wuji posture. After quieting the mind, relax and focus the imagination. Imagine that the left eye is a bright radiant sun, while the right eye is a bright and luminous moon. Both the sun and moon join together at the Yin Tang (Third Eye point). As their energies come together, they form a bright white ball. This light actually gathers around the pituitary gland, illuminating the optic chiasm, filling the occipital lobes (for internal perceptual vision) and the thalamus (for oculomotor control) (Figure 25.5).

As the light expands it stimulates the corpus callosum and penetrates the pineal gland (which acts as a projector for internal vision) (Figure 25.6).

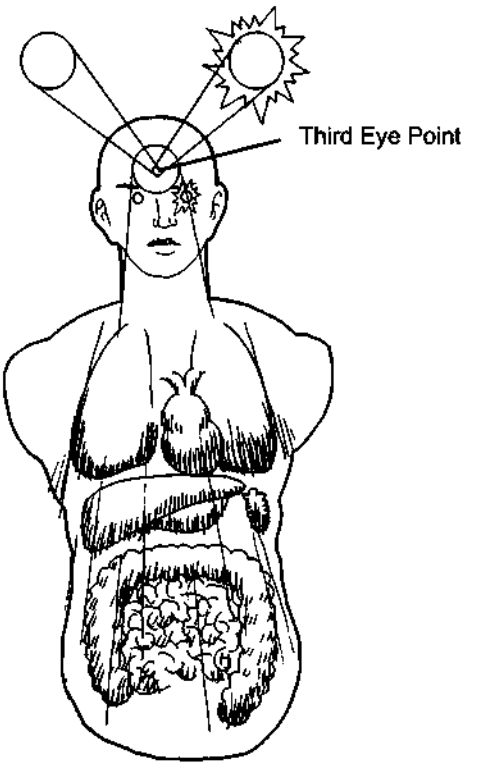

Figure 25.5. The Internal Viewing Meditation

Next, focus your intention on directing this ball of white light, allowing it to shine down into the body, illuminating all the internal organs. This enables you to see directly inside your own body and view each organ. Observe and feel the energetic strengths and individual weaknesses of the bones, organs, and tissues. Allow both energy and information to gather and expose itself through the Third Eye region of the Upper Dantian. After a while, relax and return to Wu Wei (i.e., No Mind), allowing all of these images to settle.

After a relatively short time of constant practice Qigong doctors learn to discern the state of their own organs, and are able to regulate their own physical and energetic body. This internal diagnostic ability sets the foundation for doctors to extend their Internal-viewing capability outside their own body to use on patients.

Once this occurs, doctors find it possible to effectively diagnose patients while scanning and using the Flat Palm Detection technique. The patient's points and areas for diagnosis are revealed to the doctors through this modality of energetic extension.

When using internal-vision, extend your intention as deep into the patient as possible, to slowly scan the patient's tissues, layer after layer, observing any cellular changes and distortions. Use the internal light resonating from inside the patient's body to identify the pathogenic factors. Then, look deeper into the energetic currents to find the root and origin of the patient's disease.

When you use your hands to read the patient's internal organs through Flat Palm Detection or any other diagnostic modality, it is extremely important to use internal-vision to determine the severity of the disease. You may observe a specific color, texture, or feel pools of emotional energy. According to Dr. Zheng Zhang Ding, doctors will be able to determine the condition of the diseased organ by its shade of color. The internal-vision colors most commonly observed in internal-vision diagnosis are as follows:

- A red or yellow color represents a healthy or normal organ;
- A white color signals the beginning of energetic dysfunction, but is not serious enough for treatment;
- A gray color signifies sickness; and
- A black color denotes, tumors, cancer, etc.

Applications of Intuitive and Perceptual Qi Diagnosis

There are a variety of methods concerning the application of intuitive and perceptual diagnosis of diseases. The specific physiological methods such as remote sensing, hand detection and physical body observation are very popular in the Medical Qigong clinics in China today. Five of the most favorite modalities of intuitive and perceptual Qi diagnosis are described as follows.

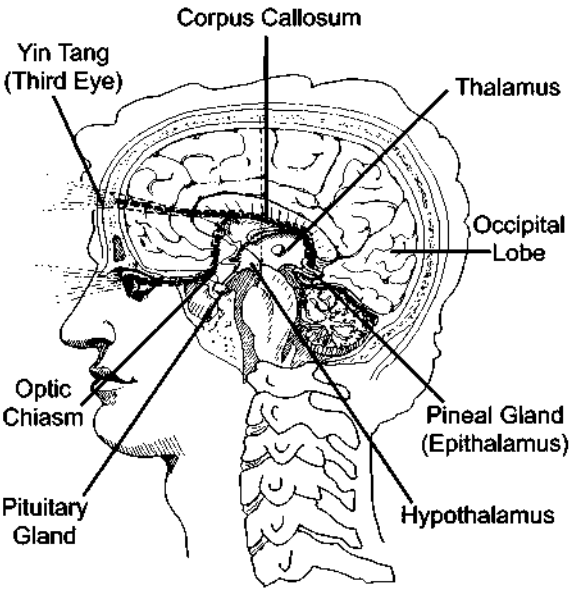

Figure 25.6. The inner light gathers at the pituitary gland, illuminating the optic chiasm, filling the occipital lobes and thalamus, stimulating the corpus callosum and penetrating the pineal gland.

Diagnosis Based on Flat-Palm Detection (Hand Sensing)

Because the body's energetic field reflects the state of health or dysfunctions of the physical body, any changes occurring in the tissues and organs are detectable through sensing this energetic field. Detection of these changes with the palm is termed Flat-Palm Detection.

To perform this technique, the doctor begins by asking the patient to take a standing, sitting or lying posture. The patient's whole body should be relaxed, the mind focused on breathing naturally. The doctor positions his or her palm several inches from the patient's energy field, with the Laogong Pc-8 point or fingertips facing the direction of the patient's body.

The doctor then emits a little energy, slowly, followed by Pushing, Pulling and Leading manipulations used to detect the Qi of the patient's

energetic body. The patient's surface tissue is divided into upper and lower, left and right aspects. The doctor focuses on the surface tissue area first, specifically the area corresponding to the region of the patient's disease. The doctor then determines the energetic nature of the corresponding regions by making comparisons between the sensations gained in different areas to find where energy feels abnormal. Gradually, the doctor's emitted energy is extended deeper into the body to purge, disperse, tonify or regulate the patient's organs and organ systems (Figure 25.7).

The Qigong doctor then analyzes these energetic sensations, comparing how they feel from the different areas of the body (both on the superficial and deep layers). The doctor categorizes the pathological findings (the location, nature, and severity of the disease) in accordance with the Eight Principles of Diagnosis and the energetic patterns of The Five Elemental Theory.

Feeling a great difference in energy intensity between the two sides of the Stomach Channels, for example, indicates a Yin and Yang imbalance of energy circulation between the left and right sides of the body. The Deficiency and Cold syndrome of the Spleen and Stomach may be manifested by a cold and contracted sensation in the epigastric region.

When an acupuncture needle is inserted into an obstructed point the energy grabs the needle and vibrates it. Once this energy block is removed, the needle ceases to vibrate because the channel is now open. This same phenomenon occurs when the palm is placed on an area of stagnant Qi. The palm vibrates until the obstructed energy is dispersed.

Energy blocks are commonly cleared by dredging in a downward direction from the head (Heaven) to the feet (Earth). When treated this way, patients will experience a temporary feeling of fatigue as the stored toxins are released from the body. Tonification is facilitated by bringing the energy current up the patient's body from the feet to the head (Earth to Heaven). This action will sometimes cause patients to have psychic experiences and see visions, as the energy enters the patient's Upper Dantian region.

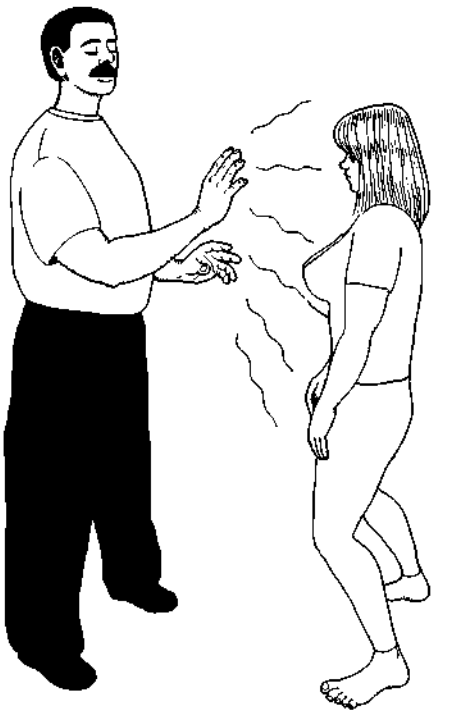

Figure 25.7. In Flat Palm Detection, the Qigong doctor uses the entire palm to sense the condition of his or her patient's internal organs and tissues.

DIAGNOSIS BASED ON KINESTHETIC AND EMPATHIC QI ABSORPTION

There are some individuals who tend to easily absorb the feeling and emotions of other people, even without trying. Sometimes when treating a patient, a Qigong doctor will inadvertently ingest a small amount of their patient's energy. As this energy absorbs into the doctor's body, it infuses throughout his or her entire energetic field. This energetic fusion sometimes causes the doctor to experience abnormal feelings in the locations that correspond to the pathogenic areas of the patient's body. From these feelings, the doctor can diagnose the location and the nature of the patient's disease.

To actively perform this method of Kinesthetic and Empathic Qi Absorption, the Qigong doctor stands facing the patient (Figure 25.8) and projects white healing light energy toward the top of the

patient's head (Baihui GV-20 point). The patient is thus enveloped by the white healing light energy, from the top of the head, to the bottom of the feet. Next, the doctor directs the Qi to flow from the bottom of the patient's feet into the bottom of his or her own feet, absorbing the patient's energy. This energetic action forms a complete cycle of energy between the doctor and the patient's body. The Qigong doctor then begins to carefully feel the sensations of the patient's energy in his or her own tissues and organs. The locality of abnormal feelings, their shape, and/or prominent characteristics reflect the locality and nature of the patient's illness.

Note: It is generally encouraged to avoid this type of body detection on cancer patients, because the risk of pulling in the patient's excessively Hot pathogens into the doctor's body is too high, especially if the doctor's energy has become depleted.

Hand Diagnosis Based on Body Association

A small percentage of energy absorbed from the patient can suffice to diagnose the whole energetic system. Because the law of bio-holograms holds that one part of the body contains information about the whole (including various parts of the body, such as the viscera, Qi, and Blood, etc.), information obtained from certain isolated areas can reflect the condition of the whole body. Such parts may include the hand, foot, eye, ear, nose, face, etc. The location on these parts that represent different areas and organs are termed as "points" or "zones:" they include hand points, foot points, ear points, and so forth.

Hand diagnosis (called Shou Zhen) is used to evaluate the physical predispositions and ailments of patients. This diagnostic technique first appeared in Chinese medical literature during the Sui Dynasty (618-581 B.C.) from the clinical writings of Dr. Chao Yuan Fang, who authored the "General Treatise on the Origin and Symptoms of Various Diseases." To begin diagnosis through hand-body association, the Qigong doctor first neutralizes his or her left palm (by releasing the energy into the Earth) to balance and stabilize its sensitivity. The left hand is generally used for reviewing energy and diagnosing diseases.

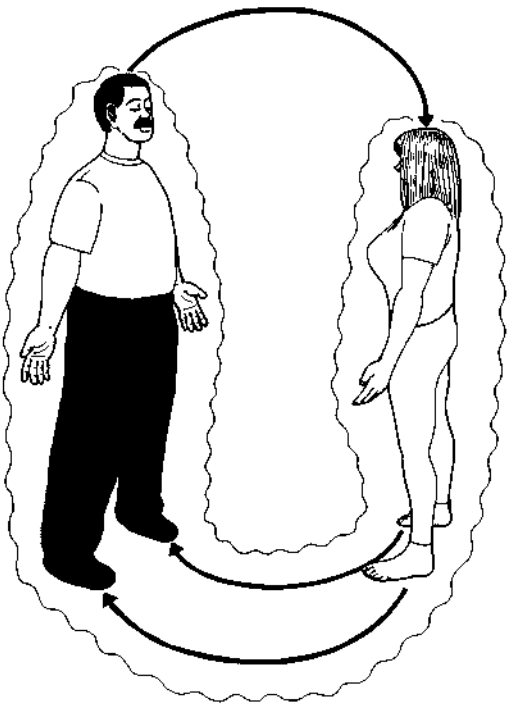

Figure 25.8. In Diagnosis based on Kinesthetic or Empathic Absorption of the patient's Qi, the Qigong doctor temporarily absorbs the patient's energy field into his or her own body.

Once the left palm has been neutralized, the doctor uses his or her intention to gather the patient's Qi into the left palm, distributing the absorbed energy evenly throughout the hand. Focused concentration on any one specific area of the hand should be avoided. The doctor imagines the patient's energy enveloping the left hand and fingers, like an energetic glove. The doctor carefully begins to sense the sensations of the patient's energy on his or her palm. The center and front of the doctor's palm is considered the center and front of the patient's body, while the back of the hand is considered the back of the patient's body. The doctor feels various kinds of sensations on specific areas of the left palm, which indicate the location of the patient's disorders. These different sensations,

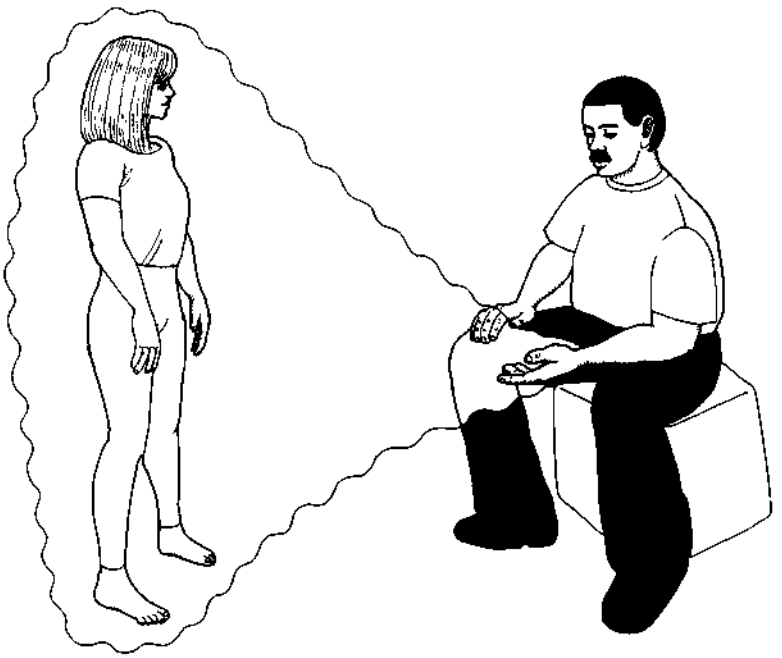

Figure 25.9. Diagnosis through Hand/Body Association

such as distention, heaviness, numbness, heat, cold, itching, and throbbing correspond with the features of the disorders (Figure 25.9).

While in Beijing, China, I was fortunate to study under Qigong Master Zheng Zhan Ding. Master Zheng had a remarkable gift for diagnosis and was compassionate enough to share his particular skills and training with me and two of my senior Medical Qigong students.

There are many schools of teaching for hand diagnosis. I have used several methods with great success in diagnosing and treating patients in both China and North America. The primary requirement for correct diagnosis is the use of the mind's intention. The imagination sets the foundation for the "energetic blueprint" of the patient's body (Figure 25.10). The method for employing this technique is described as follows.

1. Begin to scan the left palm and feel for Hot (Excess) or Cold (Deficient) areas. These areas will relate to specific locations of illness. The doctor begins to treat these regions of disease by using one of the following three methods:
   a. The doctor uses intention to tonify or purge the troubled areas inside his or her own left palm;
   b. The doctor uses his or her right hand (usually with the index and middle finger) to tonify or purge the energy from his or her left palm; or
   c. The doctor extends and treats the patient's body with his or her right hand while reading and diagnosing with the left palm.
2. Another variation of hand diagnosis is practiced by first having the patient breathe evenly into the Lower Dantian. Next, the patient focuses on his or her entire body, while placing the right palm (facing outward) towards the direction of the doctor. The patient is encouraged to relax while keeping his or her palm steady.

   The doctor slowly moves the index or middle finger of his or her right hand towards the patient's right palm. While continuing to focus on the patient's energetic field (emitted from the patient's extended right palm), the

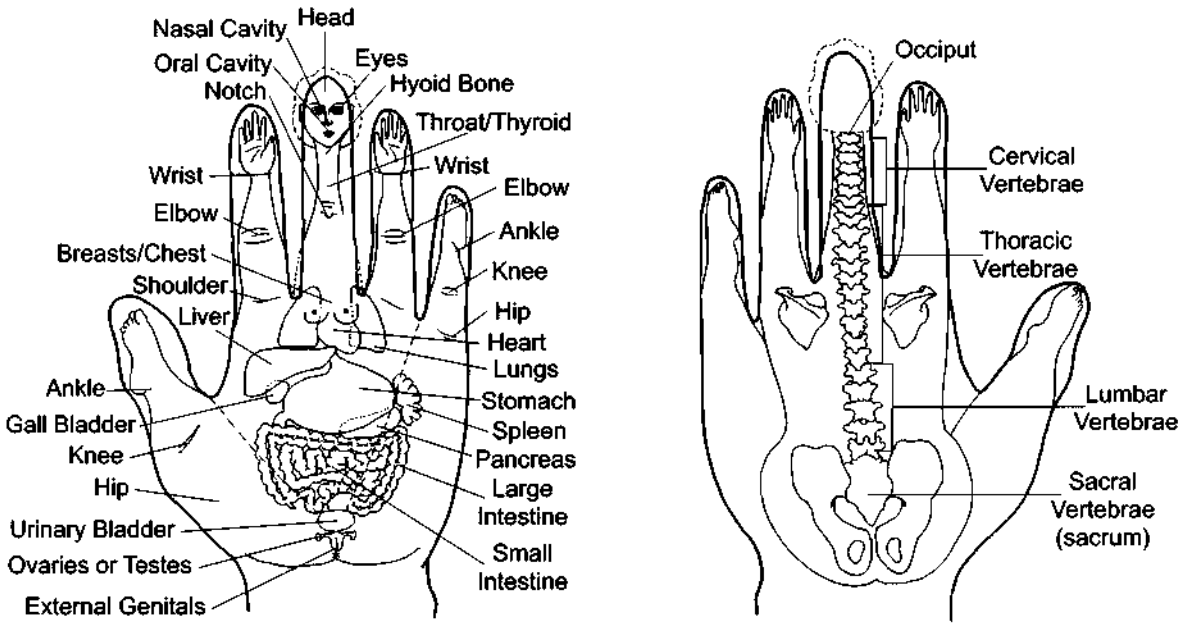

Figure 25.10. Front and Back View of the Hand/Body Association

Qigong doctor gently points to where he or she feels a particular energetic sensation (Figure 25.11). This special feeling or sensation that the doctor is receiving, represents the location of an energetic problem or disease. While scanning the patient's right palm, each different feeling or sensation represents a diversity of energetic manifestations related to the patient's disorder.

Diagnosis by Observing Aura Fields

Some Medical Qigong doctors use aura readings to determine the physical, mental, emotional, energetic, and spiritual health of the patient. Aura colors will sometimes appear in the form of waves or other energy patterns (for example: evenly layered, blotchy, mixed together, etc.). Aura colors are in a state of constant flux, shifting their colors and patterns with each shift of the patient's moods and emotional thoughts. These colors merge and blend as they fluctuate, weaving in and around the patient's field of Wei Qi.

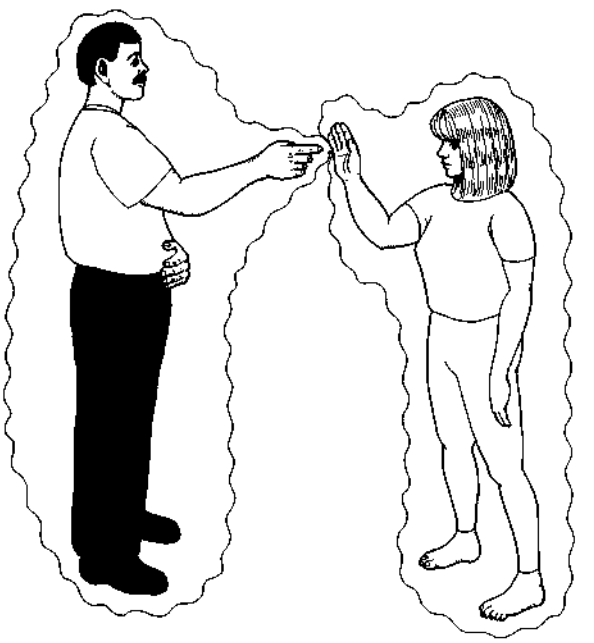

Figure 25.11. Variation of Finding the Patient's Disease Area by Diagnosing the Patient's Hand

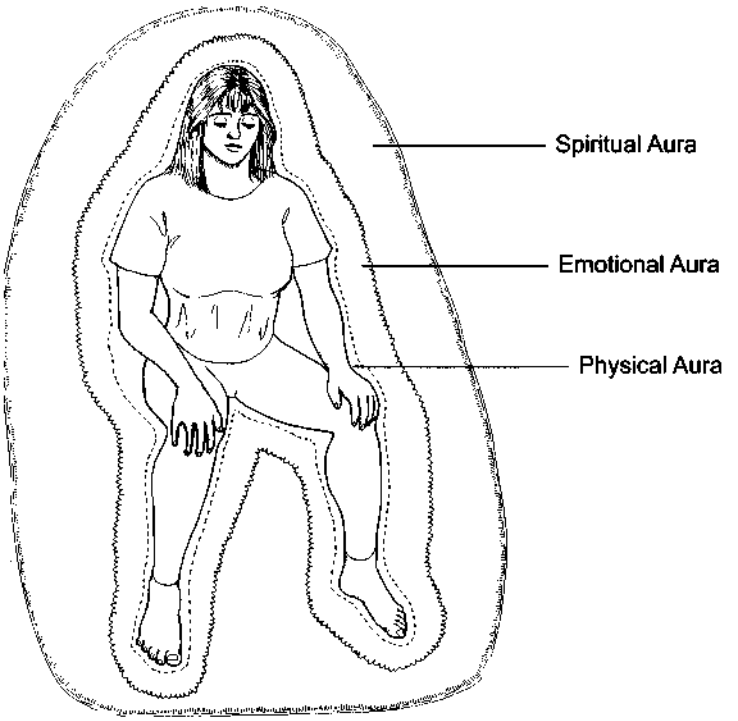

Figure 25.12. Diagnosis by Observing the Patient's Aura Fields.

To begin observing auras, ask the patient to relax his or her whole body, while sitting or standing in front of you. The patient should breathe evenly, to release any distractive thoughts, and then concentrate on the location of the specific disorder. The Qigong doctor focuses his or her attention on the space surrounding the patient's body, while simultaneously concentrating on his or her own Upper Dantian.

Focusing on the Upper Dantian to view the patient's body facilitates seeing the patient's aura field. The patient's aura field may be observed in the form of transparent or opaque Qi flow, or masses of different densities and colors. This may be used as a basis for determining the location and features of diseases (Figure 25.12). Each Yin and Yang organ will have its own color vibration.

When the energy of an organ is healthy, the Qi color is clean, clear and lucid. When an organ is diseased its Qi becomes dark gray and turbid. These colors reveal whether an organ is in an abnormal state and to what extent it has been affected.

COLOR VIBRATIONAL CLASSIFICATIONS

The variety of shifting colors can be interpreted according to their density and tone. The following chart displays the color frequency correlation in nanometers. All living organisms vibrate at a frequency between 300-2,000 nanometers. When analyzed, specific colors emanate consistent frequencies and wave forms. The slower frequencies register in the infrared light spectrum. The highest vibrational frequencies register in the ultraviolet light spectrum (for more information see Chapter 4).

Red	700 nm	Infrared
Orange	600 nm	
Yellow	550 nm	
Green	500 nm	
Blue	450 nm	
Violet	400 nm	Ultraviolet

SEEING AURAS AND EMOTIONAL ENERGY

Seeing auras is a visual phenomenon which occurs after many hours of regular Qigong training. This ability to see the external energy field is not limited to Medical Qigong training; many people are born with this special gift. The word "aura" literally means "breeze," manifesting as shimmering layers of luminous, colored energy that circulate around and penetrate into the physical body. These colors are part of the body's biophoton emissions (radiant light energy that emanates from all living systems). These colors are constantly in motion, reacting to thoughts, feelings, emotional patterns, and environmental influences.

Through the stimulation and physical dilation of the occipital lobe of the brain, the doctor begins to develop this unique perceptual ability. In the beginning stages the doctor may see energy coming off the patient's body like steam.

Later, brilliant, luminous colors become visible. The doctor is actually observing the infrared and ultraviolet radiation color patterns that the patient's body emits. The infrared spectrum is just below the average body's visual spectrum, while the ultraviolet is just above the average visual spectrum. By stimulating and dilation the occipital lobe, the visual spectrum expands to include the infrared frequency, allowing the doctor to observe from a much greater range of colors.

It has been my personal observation that students who possess a large bump on the back of the cranium, specifically between the channel points GV-16 and GV- 17, begin to see auras at a very early stage. These points are below and just above the external occipital protuberance and surround the internal branches off the occipital arteries, veins and nerves. When energy fills this area, the stimulation and dilation of these nerves and arteries causes the visual receptors of the brain to observe certain phenomena at a faster rate, which causes time to seem to slow down (Figure 25.13).

It is very important to note that these observations are all possible due to the occipital membranes being dilated. To maintain this dilation the doctor must remain calm and relaxed. Any tension brought about by stress only diminishes this ability. Auras are generally seen through the peripheral field of vision.

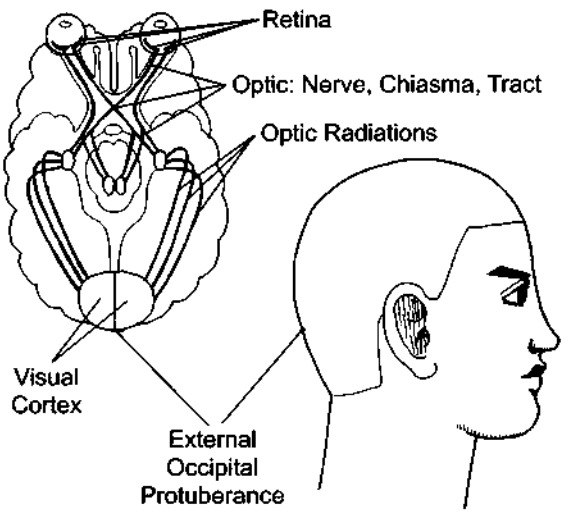

Figure 25.13. As the occipital lobe fills with Qi, the visual spectrum changes.

If the doctor begins to stare at any particular object, focused concentration will contract the occipital membranes, causing tension and pressure that inhibit the dilation process. The secret in maintaining this altered state of observation is to anchor the mind deep into the ground. By focusing the mind on a specific area, focus can be shifted to receiving and observing auras in addition to extending energy without distraction.

The following meditation can be used to stimulate the occipital membrane and enhance the perception of auras.

Seeing Aura Meditation

This meditation can be practiced either sitting or standing. The mind must be free of all distractions and tensions in order for the energy to permeate the occipital lobe. Draw an imaginary line from the top of the head (Baihui) down the spine, down the back of the legs, out the heels and deep into the Earth. This is your mental anchor line

which is used to drain your mind of all thoughts (Figure 25.14).

By continuing to drain your thoughts deep into the Earth, you free your Yuan Shen to rely on intuitive perceptions that allow for this altered enhanced peripheral field of vision. This meditation should be practiced for a period of 15 to 30 minutes each day to establish a pattern of relaxation.

As you scan a patient, look to the sides of the patient's body, observing the silhouette of the outer shell of the patient's Wei Qi. It is important not to stare, but just observe the patient's external Wei Qi field (e.g., observing where the field is large, full, thin, or broken). Sometimes different lighting will affect the dilation of the occipital lobe, enhancing visual receptivity.

Next, allow the silhouette to become different colors. Usually, in the beginning, you can see only two or three different colors. With time and practice you will be able to differentiate more colors, with finer detail.

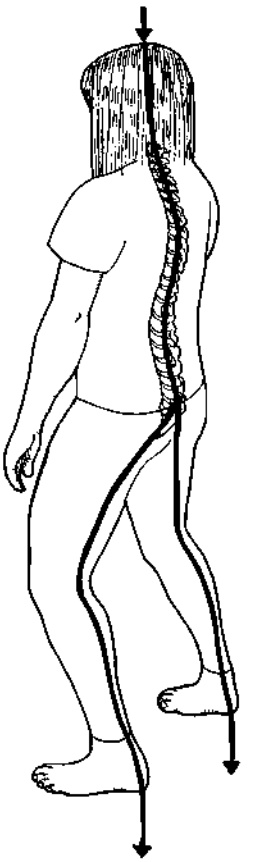

Figure 25.14. Root the Mind deep into the Earth.

DIAGNOSIS BASED ON THE BODY'S EXTERNAL CHANNELS AND AURA COLORS

Each of the five emotions are related to both the Yin and Yang organs and their Yin and Yang natures. These five emotions are also related to five major colors, both inside and outside of the body's physical structure. By comprehending the colors and understanding their connection to the emotions of the body, the Qigong doctor can successfully analyze the abundance or depletion of energy in his or her patient's major organs. Not only will this reveal the patient's present psychological state of being, but will also expose which internal organs are weakened.

The color chart (Figure 25.15) is used to correlate the patient's energetic fields. These colors are similar, yet have their own unique variations from the physical body's tissue colors.

Think of these colors as extensions from the original organ pools. The mist of the organ pools flows into the body's aura fields, and can be observed in the patient's external energy fields. They are generally very vibrant colors and veil themselves around the first two layers of the Wei Qi. Observe their location around the body, whether they are static or pulsing. If a particular body organ malfunctions, or if any disease is present, then certain parts of the aura may become dim, murky, or produce a dark void.

It is important to remember that each patient has his or her own color schemes. When observing the color spectrums of the patient's energy field the most important characteristic is the clarity of the colors. Observe if the colors are sharp, murky, or too concentrated.

The Yang patient's colors will vary in tone and brilliance from the color spectrums of Yin patients. Each aura adjusts to match the patient's mood and temperament. People also often choose for their environment colors that reflect the characteristics

of their aura and emotional spectrum (e.g., clothing, furniture, house, and room color, etc.).

When using color energy for healing, the Qigong doctor chooses which specific color to emit, e.g., using blue to cool the Qi or red to heat the Qi (see Chapter 4). Generally, when treating patients, the Qigong doctor will either wear all white (which is the combination of all colors, and is used to naturally project energy), or all black (which is the absence of all colors, and is used to naturally absorb energy), but never the color red (the color red is too intense or "Hot" for Qi extension).

Diagnosis Based on Intention

The doctor's own developed inner vision can provide a diagnosis through observation of a mental image of the patient. The doctor begins by observing an image of the patient as a complete and whole energy system. Next, the doctor imagines the energetic form of the patient's internal organs (Figure 25.16).

If any part or organ is dark or gives a feeling of turbidness, this indicates the location of the disease. When using this type of energetic diagnosis, the sense of smell, the sense of taste, direct perspective, and remote sensing are also helpful diagnostic skills to enhance detection.

Long Distance Medical Qigong Therapy

Long Distance Medical Qigong Therapy has been with us for centuries. One of the ministers of Huang Di, the Yellow Emperor and patriarch of Chinese medicine, was a shaman named Zhu You. Zhu You was a famous doctor who advocated exorcistic prayer over the use of acupuncture needles and herbs to treat illness. Some scholars believed that Zhu You practiced Qi emission healing at the same time that he prayed for his patients. So effective was this healing approach that The Yellow Emperor's Classics states that, in ancient times, most illnesses were treated according to the methods of Zhu You. In fact, at one time, professional "prayer healers" were once widespread throughout China.

There are several schools of thought on the modalities of long distance healing. Each school

Internal Organ	Aura Color
Lungs	Pure White
Large Intestines	Off-white
Stomach	Deep Yellow
Spleen	Orange Yellow
Heart	Red with Slight Blue Tint
Small Intestine	Pink
Bladder	Deep Blue
Kidneys	Light Flame Blue
Pericardium	Purple Red
Triple Burners	Orange Red
Gall Bladder	Yellow Green
Liver	Deep Green

Figure 25.15. The internal organs are each associated with a specific aura color.

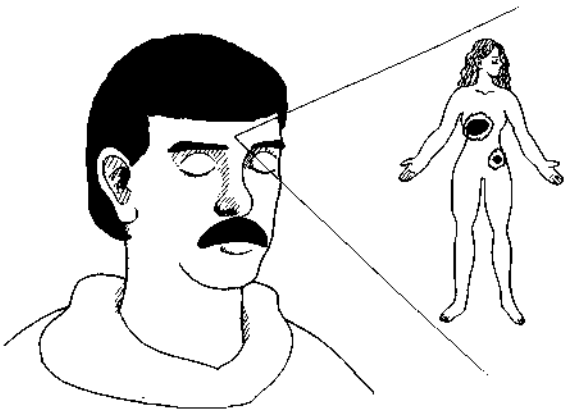

Figure 25.16. The Qigong doctor can diagnose the patient's body through energetic observation and intention.

has its own unique, yet extremely effective application of this esoteric skill.

Although I believe in the effectiveness of prayer, at one time I sincerely doubted the existence of long distance healing. I was thoroughly convinced that it was a matter of projected influential visual and auditory input, similar to hypnotherapy. I expected the doctor to talk to the patient and have him or her close the eyes to facilitate an emotional and mental healing over the telephone. The difficulty in this kind of healing is that if the patient does not trust you, his or her consciousness will not cooperate and will sabotage any healing energy extended in his or her direction.

As fate would have it, one of my Medical Qigong instructors called me one day. As we were conversing, my Kidneys began to heat up. This heat was quite intense, and I was extremely startled because no prior warning of this particular kind of treatment had been given. Yet, I could not dismiss the overwhelming searing heat that I felt in my lower back, Kidneys, and Mingmen area. This healing was done without my conscious consent or foreknowledge! My instructor laughed and explained that as she was talking to me, she was holding a pillow (which represented my body) and visualizing treating my Kidneys with her right hand.

At that point, my beliefs surrounding long distance Medical Qigong healing began to change radically. I began to inquire as to the qualifications needed to treat with that modality of therapy. I learned from my instructor that long distance energy transformation is similar to close range energy transformation. The only difference is that in long distance healing, the doctor's faith and psychic faculty has to be extremely developed and accurate.

To become proficient at long distance therapy, the Qigong doctor must extend his or her thought vibration into the atmosphere, which connects with the thought vibration of the distant patient. Both vibrations collect and blend, drawing together at a selected point on, or within, the patient, creating and reproducing the patient's energetic fields, organs, and tissues.

Zhu You's long distance healing through prayer may be compared to the effectiveness of prayer groups today. Larry Dossey, M.D., for example, documents one double-blind experiment involving nearly 400 patients admitted to the coronary care unit of San Francisco General Hospital for heart attacks or suspected heart attacks. These patients were evenly subdivided into two groups. Both groups received "state of the art" medical care; the only difference was that one group was prayed for by Protestant and Catholic prayer groups throughout the country. These prayer groups had only the patients' first names and sketches. The patients in the experimental group had no idea they were being prayed for; yet when the study was concluded, they experienced significantly fewer complications and deaths than did the non-prayed for control group.

SPACE/TIME AND ENERGY

To study long distance energetic healing, we need to look at a three-dimensional energetic pattern which includes Positive Space/Time, Negative Space/Time, and Energy.

1. Positive Space/Time Energy includes commonly accepted forms of energy (such as electromagnetism, nuclear energy and gravity), and all vibrations ranging from extremely slow to the speed of light. It includes lower vibrations (from inanimate objects) and the higher vibrations of thoughts.
2. Negative Space/Time Energy includes all vibrations which travel faster then the speed of light (super-luminal), and accounts for such phenomenon as telepathy, psychokinesis, precognition, and levitation. In negative space-time, particles have a negative mass and are known as antimatter. When activated to super-luminal speeds, these particles appear to dematerialize, and produce a levitation force which balances the gravitational effects of positive space/time. This also accounts for the Qigong doctor's ability to transmit energy through all known force shields (excluding mirrors, due to their ability to reflect light-energy).
3. Energy and matter form a continuum as does space/time. Energy is the medium between

the positive and negative forms of space. It is the medium between which matter and spirit interact with the space/time continuum, through which heat, light, sound, and resonant vibrations travel.

Matter is composed mostly of space with a minute amount of mass, bound in a particular pattern. This pattern is unique for every form of matter, including the human body. Particles of matter in the human body are constantly vibrating in intermediate stages of energy interaction. Consciousness (the qualitative and directional aspect of energy), acts as a medium for the Qigong doctor's intention to project into the time/space energy field. Consciousness functions as the energy source for resonant vibrations which create the physical world.

To perform long distance healing, the Qi in the Lower and Middle Dantians (the body's Fire and Water energy) must overflow and transform into Shen. The Shen is then united with the divine Qi and extended outside the body for long distance healing of the patient. This allows the energy to cross both spatial and temporal boundaries, thus enabling the Qigong doctor to heal patients in the absence of physical contact.

The first priority in long distance healing, is to establish a connection between all three Dantians through the absorption of divine Qi into the Taiji Pole; this process is called the "empowerment with divine Qi," or simply, the "hookup." This action surrounds the doctor's Wei Qi with Tian Qi (Heavenly Energy), which then is transformed into Tian Shen (Heavenly Spirit).

The doctor then visualizes a long stream of white light extending from the Yin Tang (Third Eye) point, which connects to the patient's body (Figure 25.17).

Once the doctor feels this connection, he or she may now begin the treatment. The physical manifestations of long range healing are the result of the Shen affecting the Qi, and the Qi affecting the body's Jing.

Long Distance Scanning Exercise

Long distance scanning can be develop by practicing the following mediation exercise.

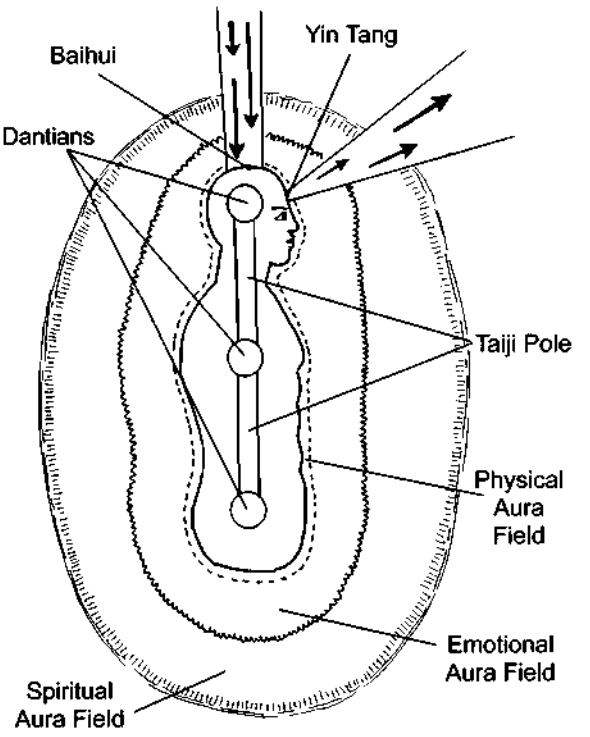

Figure 25.17. The Qigong doctor absorbs divine Qi through the Baihui area, filling the center Taiji Pole, then projects the divine energy out the body through the Yin Tang or Third Eye area.

- The patient sits in front of the doctor. After connecting with the divine, close your eyes and start to scan the patient's external and internal energetic body. Try to feel the patient's different shades of light and different color spectrums, as well as the patient's temperature, projections, resonant vibrational essence, and varying qualities of texture in the patient's electromagnetic fields.
- Next, open your eyes and scan the patient, comparing and contrasting any differences from your initial readings. Continue to practice this modality of distant scanning until your reading and diagnosing abilities become very accurate. Perfecting your long distance scanning abilities may require several months of training.

LONG DISTANCE THERAPY

To dredge the channels, tonify and regulate the patient's energetic fields using long distance energy transformation, the Qigong doctors sometimes practice the two following meditation exercises.

Long Distance Dispersing Meditation

The doctor begins by placing his or her patient in the next room. After the doctor connects with the divine, he or she imagines his or her body surrounded by a ball of brilliant white light. The doctor then extends a stream of this white light energy out from the top of his or her head and onto the top of the patient's head, enveloping the patient's entire body.

As this white light energy descends down the patient's body, the doctor visualizes the patient's diseased energy dispersing and melting away into the ground. The patient's pathogenic energy is extended into the center core of the Earth, where it is transformed by the Earth's center core fire and then recycled back into the patient as pure, refined Earth Qi.

Next, the doctor focuses on specific areas of the patient's body. The doctor visualizes any area which needs specific attention such as dark areas in the patient's body. The doctor imagines these areas becoming brighter until all the dark areas are dispersed. After energizing the patient's diseased area, it is important for the doctor to disconnect from the patient and withdraw his or her projected Shen (Spirit) back into his or her body.

Long Distance Purging Meditation

The doctor begins by sitting on the edge of a chair with both feet firmly on the ground. Next, the doctor brings both palms up in front of his or her body, at throat level (middle fingers pointing straight upwards), and imagines a ball of white light suspended in-between the palms.

The doctor now pulls the Heavenly Qi towards the center of the ball via the fingers. As the ball fills completely, the doctor imagines the Excess Qi beginning to overflow into the center of his or her palms (Laogong points), descending down the arms and spine, and collecting into his or her Kidneys and Lower Dantian area. The goal is to first collect and store Heavenly Qi in the doctor's Lower Dantian and Taiji Pole (Figure 25.18).

To facilitate long distance healing, the doctor imagines the patient in the center of the ball of light. The doctor focuses on the Excess energy no longer overflowing into the palms, but flowing into his or her patients body, cleansing, filling, and healing the disease (Figure 25.19).

FAITH PROJECTION AND MEDICAL QIGONG THERAPY

This technique is a combination of both psychosomatic and visceral healing. It entails speaking to the patient and establishing a curative relationship through belief modalities, similar to those of "faith healing" used in the West.

It is a form of mind projection; the stronger the Qigong doctor's faith and intention, the better the healing will be. It is important for the patient to have an extremely strong faith in the doctor and to feel secure in the healing environment. The stronger the patient's and doctor's faith, the better the healing.

One popular example of this faith projection ability comes from the famous Qigong Master Shen Chang. Master Shen, lecturing at a conference sponsored by the China Ministry of Broadcast, Film and Television (with hundreds of witnesses present), extended Qi into a woman patient (in her 50's) with a three inch tumor on her leg. As Master Shen began his transmission he began to shout "Gone!" Instantly the tumor started to shrink. After shouting "Gone!" two more times, the tumor had completely disappeared. To the astonishment of everyone, Master Shen then shouted "Grow!" and caused the tumor to reappear. After this amazing demonstration, he then removed the tumor, and completely healed the patient.

Perhaps the body manifests what the mind believes and the Heart feels. It then adjusts itself according to the belief structure and forms a new holding pattern (both physically and energetically). Usually, the doctor will say an instructional phrase four times to the patient, intensifying his

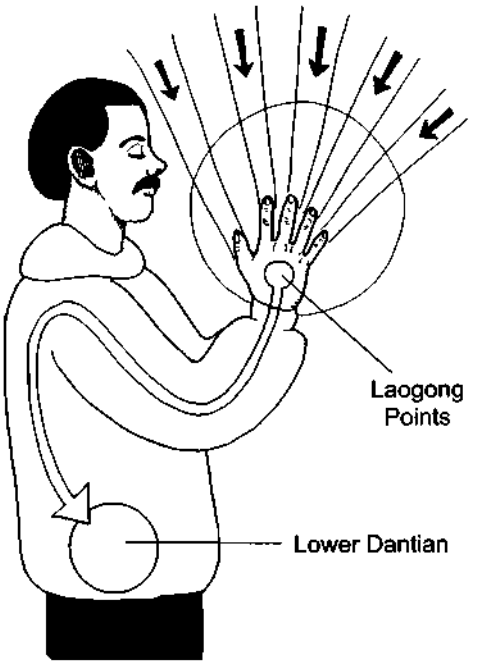

Figure 25.18. The Qigong doctor imagines creating a ball of divine healing white light, suspended between his or her palms.

Figure 25.19. The Qigong doctor imagines that his or her patient is positioned in the center of the ball of divine healing light.

or her intention and instruction each time. The doctor's intention begins to reprogram the holding patterns of the tissues by shocking the system into a new and healthier pattern; a kind of "Be Healed Now!" approach. It is important to know that the energetic field surrounding the patient is strongly affected by either positive emotions and support, or negative emotions, suspicion and disbelief.

To illustrate this fact, I would like to recall an incident that took place in a Santa Cruz bible college in the late 1980's. One morning a colleague was lecturing in an auditorium full of 250 young seminary students. Suddenly, the back door of the auditorium swung open, and a young woman carrying a small baby came walking in. She was crying, and asked for help. She told my colleague that "God" had spoken to her in a dream and told her that if she came to this particular bible college and asked for help, that he would heal her child of a serious disease.

My colleague was both startled and shocked. Not knowing what to do, or even how to handle the situation, he quickly turned the meeting over to a local spiritual elder who was monitoring the lecture. This elder, seasoned in these types of spiritual phenomena, again asked the woman what the problem was. After hearing her story a second time, he informed her that while "God" had not spoken to him directly about the situation, he would be obedient to whatever "God" wished.

Next he looked up to the 250 young seminary students sitting in the auditorium and stated, "If anyone here does not believe that God can and will heal this child instantly, please leave now." All but three seminary students left the auditorium. The elder called to the three remaining students to join him with my colleague in praying for the baby. The child was instantly healed (a follow-up visit confirmed this fact), and the mother left, smiling. My colleague, perplexed by the whole event, turned to the elder and inquired as to how he knew what to

do. The elder responded, "Even Jesus, who was the greatest healer of all time, couldn't heal in his own home town because of everyone's disbelief. Here in this auditorium it would have been five of us who had the faith in healing, versus 247 who were skeptical and full of doubt. It is better to have a few with great unwavering faith than to have many with little faith at all."

AUXILIARY MEDICAL QIGONG HEALING MODALITIES

The following are auxiliary Qigong modalities used by various Qigong doctors in hospitals and clinics, as well as their personal practices throughout China.

One of the methods used for these Medical Qigong therapies is the projection of Qigong Messages into specific material objects (i.e., a liquid, food, a scroll of calligraphy, a talisman, a cloth, a necklace, etc.). Once the object contains the Qigong doctor's Message it will have a powerful effect on the patient's body. This is a form of "transmission of intention" which is a form a Qi and Shen projection. Qi and Shen projection transcend time and space, lasting an indefinite amount of time depending upon the belief of the Qigong doctor and patient.

Certain Qigong doctors can transfer their energy or "thought message" through works of art. I experienced this technique quite accidently while lecturing at the Third World Conference on Medical Qigong in Beijing, China in 1996. I was in the back of the lecture hall sketching while one speaker was sharing his dissertation. Another Qigong Master seated in front of me noticed my artwork and asked to see it. Curious as to what he would do, I gave him my notebook. He placed his hand above my drawing and began projecting Qi into the picture. Immediately energy flooded my being from head to toe. I was literally vibrating all over, being filled with light and sound resonation (that felt similar to a strong electrical current). Since my original piece of art contained a direct connection to my physical energy, the Qigong doctor was able to extend energy into my body, by simply projecting his Qi into my artwork.

The doctor can transmit healing energy through any object which has had contact with or was created by the patient. This technique is possible because creative artwork, or any object touched or created by hand, is imprinted with the person's energy. This energy contains a unique blend of the individual's encoded energy patterns. This information regarding the individual can be retrieved through psychometry (the act of sensing the thoughts, images and so on, with which the object has been imprinted). A connection to the person who created or held the object can thus be established through the Wuji. This object can then serve as a focusing point to send healing to that person, through the doctor's intent.

Energy, in the form of waves, is expressed in the abstract form of thoughts, accessible to the vibrational medium of space and time. This allows for the energetic transformation of the individual's emotional patterning.

USING MEDICAL QIGONG TO HEAL BY PROJECTING CHINESE CHARACTERS

There are other Qigong doctors who draw specific Chinese characters in the air and send them encapsulated in a bright white light ball of energy into their patient's body to initiate healing (Figure 25.20). This projected energy is created through the doctor's intention and is absorbed into the patient's body, through the patient's receptive attitude and desire to heal.

USING MEDICAL QIGONG WITH SUPPLEMENTARY APPARATUSES

There are certain Qigong doctors who will use specific objects ranging from such supplementary equipment as rubber acupuncture dolls to pillows, in order to perform long distance healing. To utilize these objects for long distance healing, these Qigong doctors place the object, a doll for example, on the table in front of them and begin to draw their patient's Essence (from many miles or even across other countries) into the doll. The doctors then treats the patient by draining off the pathogenic excess from the doll (Figure 25.21). Once the doctors feel that the patient has been sufficiently cleansed and the disease dispersed, they begin to tonify the patient's weak organs. While

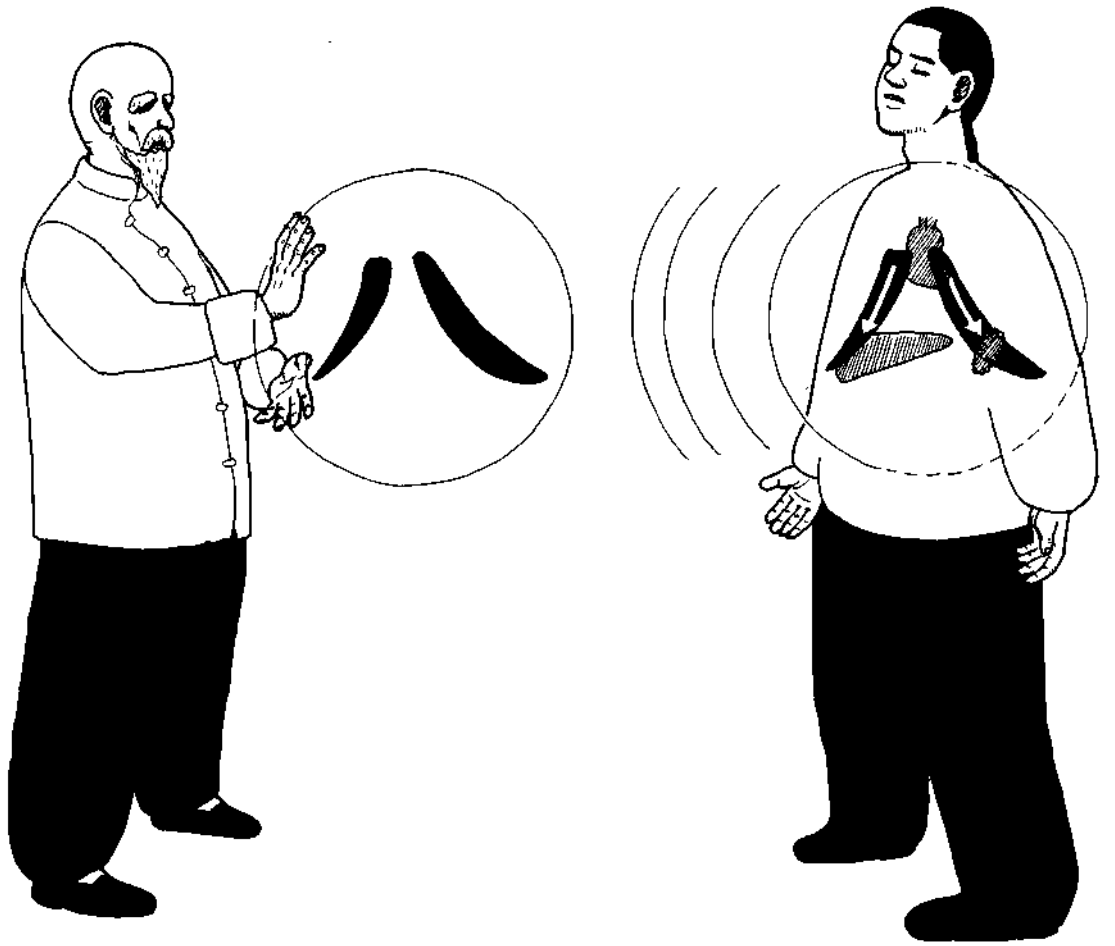

Figure 25.20. Another skill utilized by Qigong doctors, is to create different colored balls of energy to encapsulate specific Chinese characters (or Messages) within them, which are then projected into the patient's body as a form of treatment.

the Qigong doctors work on a patient, you can actually feel hot and cold spots emitting from the rubber acupuncture doll. Several of my students have been able to successfully implement this modality of training and find it fascinating.

USING MEDICAL QIGONG TO ENERGIZE HEALING CLOTHS

Some Qigong doctors extend Qi into pieces of paper or cloth, to be placed on the patient's body to invoke a healing. This is similar to the "prayer

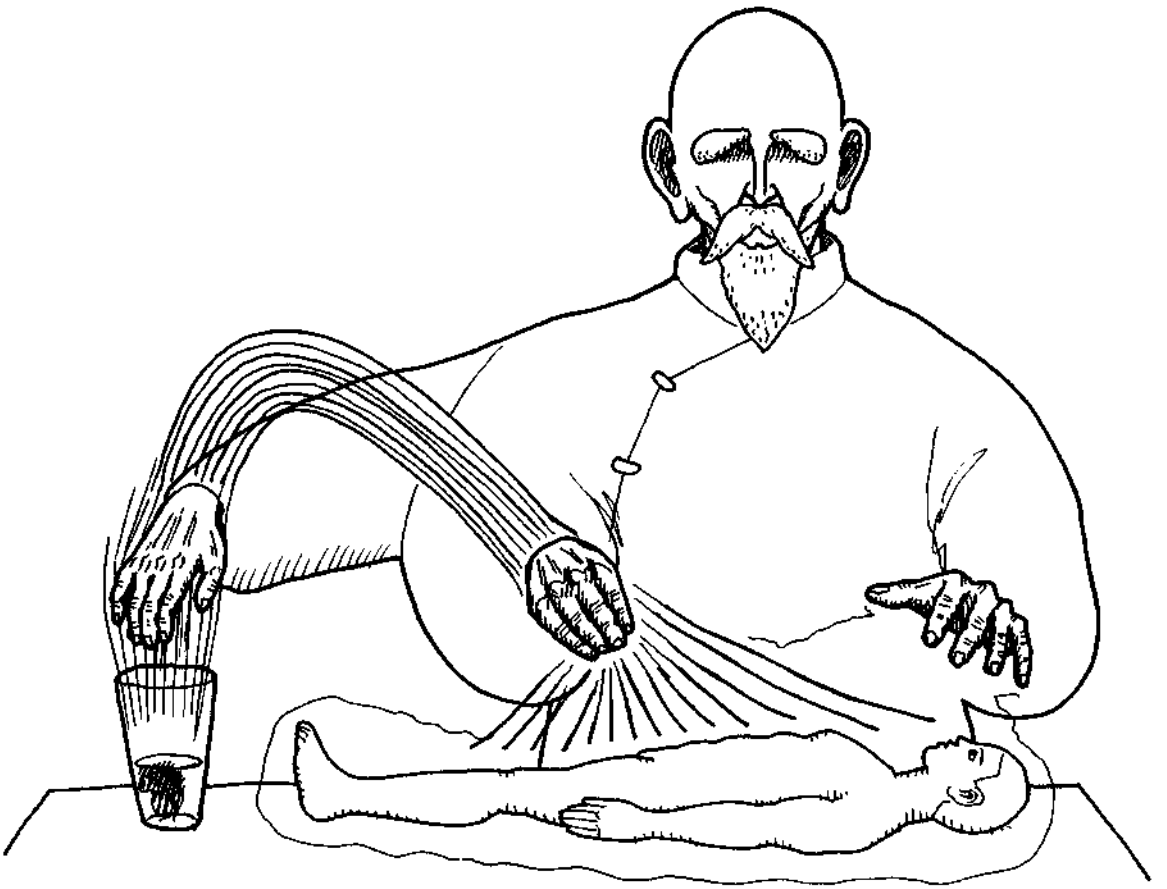

Figure 25.21. Some Qigong doctors use a rubber acupuncture doll (man or woman) as an energetic medium, while treating patients at a distance. The Qigong doctor is removing pathogenic Qi and throwing it into a glass of salt water (used to neutralize the Turbid Qi).

cloths" and other techniques used today in the Pentecostal Churches. The energy stored within the cloth or paper, will last indefinitely, however, the most important component of this type of healing is the patient's belief structure (Figure 25.22-23).

USING MEDICAL QIGONG WITH CRYSTALS

The energy in the human body produces a polarity similar to that present in crystals. Because crystals emit a very strong white light energy, they can be used for energetic surgery, allowing the

Qigong doctor to cut into the patient's energetic field like a laser beam. Crystals can additionally be used for scooping energetic toxins, cleansing and purging the patient's body, and for cutting loose pathogenic Qi within the patient's tissues and external fields of Qi. Crystals can also be used for tonification, by enhancing the doctor's energetic extension and projection abilities.

USING MEDICAL QIGONG TO ENERGIZE LIQUID COMPONENTS

Other Qigong doctors extend their energy into herbal teas, wines, and I.V. fluids, as well as simple components such as water, to energize and utilize these liquids for healing. These doctors send the energized liquid substance to the patient, who ingests the medicine to tonify deficiencies. Water is an excellent repository for electromagnetic energy, and absorbs vibration better then any other substance (Figure 25.24).

USING MEDICAL QIGONG TO ENERGIZE FOOD

There is an ancient Chinese proverb which poses the question, "Is food medicine or medicine food?" Because a basic principle of Traditional Chinese Medicine states that anything ingested is transformed into energy (Gu Qi) by the body, some Qigong doctors extend their energy into the patient's food before it is ingested. This belief is not isolated to the Orient, but is also part of the Western culture, hence the practice of praying and blessing over food before eating it.

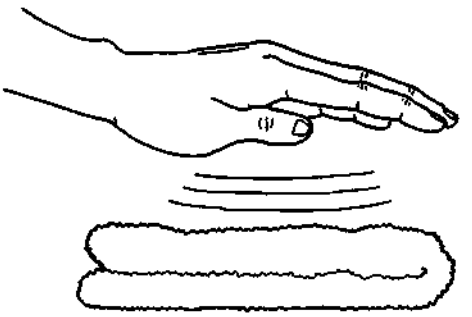

Figure 25.22. Emitting Qi into Cloth

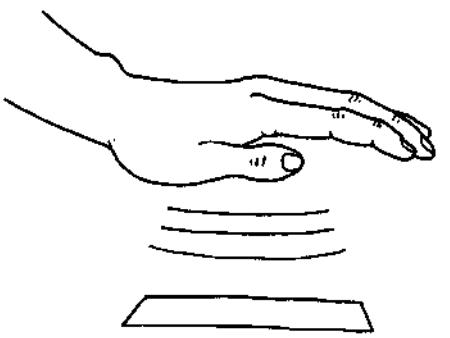

Figure 25.23. Emitting Qi into Paper

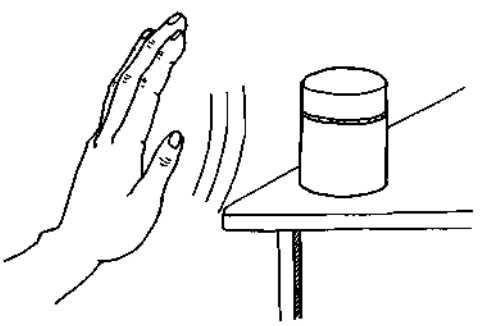

Figure 25.24. Emitting Qi into Liquid

Section VI
Establishing the Medical Qigong Clinic

Chapter 26
Treating the Patient

Setting a Space/Time Foundation

Before treating patients, and to establish a sacred healing space, the Qigong doctor must first bring his or her true self into what is called the center of space and the center of time before performing the divine hook-up.

This establishes a foundation for treating patients, and allows the doctor to fuse with the patient, while accessing the energies of the divine, as well as the universal and environmental energies. Once this is achieved the doctor can allow him or herself to act as an observer, viewing the patient from a non-judgemental position.

Finding the "True Self"

The Qigong doctor's "true self" is defined as his or her pure innate spiritual existence, void of all ego masks and personalities. The "true self" is spiritually connected to, and rooted in, the energy of the divine. It is the part of the soul that unconditionally accepts self and others, and is more in the role of a compassionate observer than a judge. The "true self" allows the doctor to observe the patient's condition (spiritual, emotional, mental, energetic, and physical), void of any personal emotional biases. The "true self" is a state where unconditional love and acceptance is fostered and supported by the divine.

To discover the "true self", the Qigong doctor is trained through special Shengong (Spirit skill) meditations. One such meditation asks the question "Who are You?" This is repeated over and over until the doctor realizes and experiences his or her "true self". Who you are is not determined through expressing a correct answer, but by actually experiencing the spiritual quest. It is through the realization of this innate truth, which is inherent within one's own enlightenment, that the doctor is freed from the ego (known as the "Death of the Ego Fear"). Once the doctor realizes who he or she truly is, the answer is reflected from the light within the doctor's eyes and not through any specific mental concepts. There is a saying from Lao Zi, written in the *Dao De Jing* (The Way and Its Power) that explains this phenomenon: "The Dao that can be named is not the true Dao."

Finding the Center of Space

Before treating a patient, the Qigong doctor must also place his or her body, mind, emotions, energy, and spiritual essence into a place of infinite existence called the center of space. The center of space is actually a spiritual and energetic concept, wherein the doctor imagines him or herself as being the actual center of the universe. This concept and image maintains that all energy, light, and energetic fields extend from the middle of the doctor's center core, expanding outward into infinite space (Wuji). This energy continues to extend and envelop the entire universe and all the energetic dimensions beyond.

To access the center of space the doctor must place his or her "true self" into the Taiji Pole, connecting the core self with the divine. It is from the orientation of the core self that the Qigong doctor accesses the deeper, hidden, spiritual, and energetic fields of the patient's body.

Finding the Center of Time

The final image that the Qigong doctor visualizes before the divine hook-up is to place himself or herself into the space known as the center of time. The center of time is the place of "Now." It is a dimension where infinite future is forever flowing into the doctor's center core, while the infinite past is forever rushing away.

To grasp the center of time concept, think of time as a linear progression of light and energy. The concept of future time is rushing directly into

the front of your body. Within a split second, the Yang changes into Yin and the future transforms into the past, and continues rushing out the back of your body. You must find the still point, inside of your body, where Yang transforms into Yin, and the future transforms into the past - this is the center of time. From the center of time the Qigong doctor brings the patient into the present moment. This process enables the doctor to access the hidden past memories trapped deep within the patient's tissues.

Establishing the Medical Qigong Treatment Room

Before receiving patients it is important to establish an environment that is conducive to healing. The density and quality of energy in the healing room is a very critical factor. Filling both the treatment room and clinic with the energy that flows from the Heavens to the Earth sets up an energetic vortex. Through the creation of this energetic vortex the patient's pathogenic factors will automatically flow into the ground once they are dispersed from the patient's body. The more energy that the healing room contains, the more successful the treatment will be. It is important to cleanse the healing room before and after each patient. This cleaning is achieved through the doctor's divine hook-up.

When establishing a treatment room it is also important to have adequate lighting and clean air ventilation. Avoid fluorescent lighting; if this is impossible, then use a full spectrum light.

It is important to also keep the patient's living quarters and bed energetically cleansed, as pathogens have a habit of collecting in areas of sickness and disease. The patient is encouraged to burn salt with a little alcohol to cleanse the treatment room (at least once a day) and fill the room with fresh air and light. Often neglected is the living space of the patient. Energetically cleaning the entire house or apartment often, during and after there has been an illness, allows the toxic energy to be purified from the patient's home.

One example of how energy stagnates is observed in hospital wards. Each ward has an energetic "feeling," associated with the different types of diseases or conditions treated there. The cancer ward, for example, feels entirely different from the maternity ward, emergency room, etc.

The treatment room must also be kept uncluttered, as energy stagnates in cluttered environments. Also, after each treatment, always change the bedding and energetically clean the clinic or treatment room.

When to Aerate, Illuminate, or Smudge

It is important to daily cleanse the energetic field of the treatment room. This facilities a fresh uncontaminated environment, allowing the next patient to feel safe and protected from any previous contaminants which may have been left from a prior patient. The three most common ways to cleanse the clinic before and after each patient (besides changing the table coverings), are:

1. Aerate by ventilating the clinic, making sure that the air circulation is fresh and clean (free from pathogens, Toxic Qi, dust and pollens, foul orders, smoke, etc.).
2. Illuminate by exposing the clinic to bright sunlight, or divine healing light (through prayer).
3. Smudging is performed by burning fragrant herbs in the form of certain incense (such as, sandalwood, myrrh, frankincense, or sagebrush, etc.). Remember to aerate after smudging.

The Qigong doctor may wish to incorporate either one or several modalities of cleansing. Each particular technique offers its own advantages and disadvantages, depending on the size and location of the clinic and its surrounding environment.

Establishing a Rapport with the Patient

It is important to establish a foundation of trust between the doctor and patient before the treatment begins. This trust is enhanced by: Talking with the Patient to Establish Treatment Goals, Explaining and Reaching Agreements on the Treatment Modalities to be Used, Honoring the Patient's Spiritual Belief System, Receiving the Patient's Consent Before Treating, Matching the

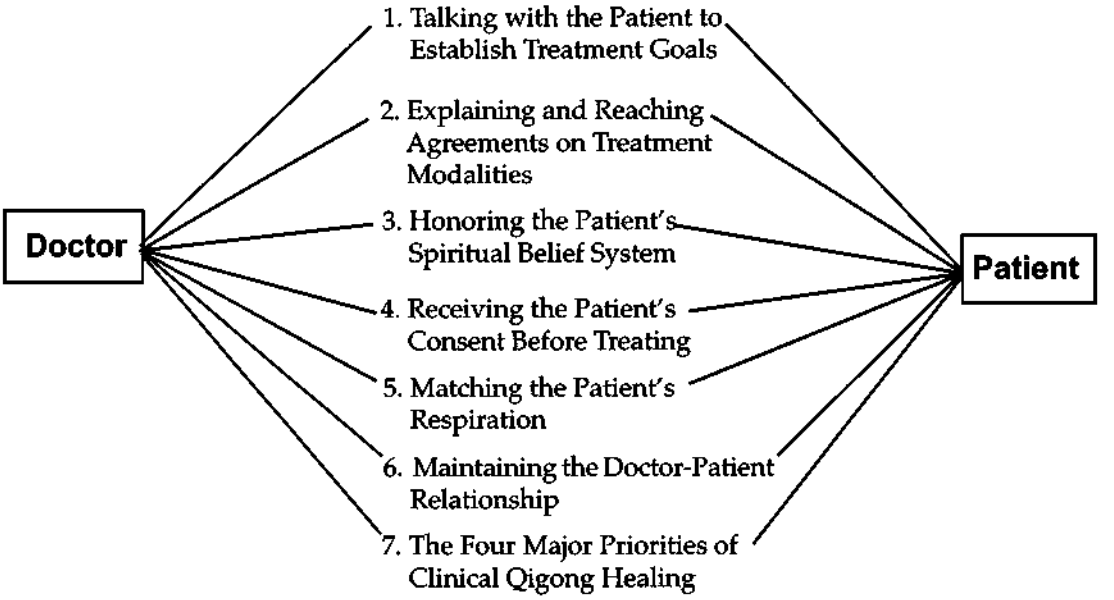

Figure 26.1. Establishing a rapport with the patient begins with trust.

Patient's Respiration, Maintaining the Doctor-Patient Relationship, and The Four Major Priorities of Clinical Qigong Healing (Figure 26.1).

Talking with the Patient to Establish Treatment Goals

After completing the diagnosis, establishing the treatment principle, and determining the treatment strategy, the Qigong doctor discusses with the patient the treatment goal (i.e., which internal organs, channels, and tissue areas are affecting the primary cause of the patient's disease, and how to address it). The treatment areas are specifically chosen to facilitate a rapid affect on the functioning process of the patient's disease. The doctor explains the intended goal of using the purging, tonifying, or regulating techniques, and how they will affect the patient's body.

Explaining and Reaching Agreements on the Treatment Modalities to be Used

The Qigong doctor explains, in clear, comprehensive terminology, what he of she has determined as to the best way of approaching and rectifying the patient's condition (e.g., having the patient in a lying, sitting or standing posture), and what treatment modalities the doctor will be using (i.e., through Qi Emission, Qigong Massage, Sound Therapy, Light Therapy, etc.).

The more the patient understands the doctor's approach in addressing the condition, the greater the likelihood of the patient relaxing during the treatment. This explanation also assists the doctor and patient in developing trust, which will encourage the patient when practicing the homework prescriptions, or in receiving suggestions on life-style modifications.

Honoring the Patient's Spiritual Belief System

When treating patients, it is important that the Qigong doctor not become distracted by the illusion of solid tissue matter, remembering that we are spirit, and that healing begins in this fifth dimension. The primary belief in Medical Qigong therapy is that tangible and intangible energy, through faith, will merge at the highest level of

cultivation. Prayer is an invocation that extends the mind, emotion, and spirit to the divine, while meditation is a state of mental, emotional, and spiritual receptivity for divine inspiration, guidance, and manifestation. Both actions (prayer and meditation) connect the doctor and patient to the divine to bring patients back into awareness of their body and to initiate divine healing.

In China, Qigong doctors have a saying, "train your virtue and morality to increase your energy, allow your Spirit to lead your Qi and the Qi will flow pure." Meaning, the stronger the individual's virtue has been developed, the more powerful his or her spiritual intention will flow, and Qi move.

The healing modality choosen by the doctor must be congruent with the patient's spiritual belief structure. The patient must be connected to his or her own unique interpretation of universal consciousness (God) in order for divine healing to take place.

When the patient disbelieves in a Higher Power -- be it God or a universal consciousness -- the doctor can still help the patient heal, providing the patient has established sufficient trust and hope in the doctor. If the patient feels understood and listened to by the doctor, this can empower the patient to heal, regardless of his or her own conscious belief system.

If the doctor, on the other hand, does not believe that a true healing can take place unless the patient believes in a Higher Power or God - then no healing will take place, for the doctor will lack confidence, hope, and trust. The therapeutic bond between the doctor and patient will be broken and replaced by a battle of wills.

For patients who lack faith, applying a hands on Qigong technique may be more effective. Gradually, over the course of time, the doctor may incorporate other healing modalities as greater trust is built.

The Qigong doctor should always begin treatment in harmony with the patient's spiritual belief system (that may change in time), through touch, verbal conversation and unconditional love (empathy). The doctor should also communicate mind to mind, for this will facilitate trust at the subconscious level.

RECEIVING THE PATIENT'S CONSENT BEFORE TREATING

The treatment modalities should be decided together by the doctor and the patient. It is important for the Qigong doctor to provide the patient with enough information about the type of therapy he or she will receive, so that informed consent can be given for the treatment. This empowers the patient and allows relaxation and trust to occur.

MATCHING THE PATIENT'S RESPIRATION

Another technique to relax the patient is called "matching and pacing." The Qigong doctor matches the patient's breath and breathing patterns, and gradually shifts his or her own breathing to a slower and deeper pace. It is important to note that the patient's physiology affects his or her energy, which in turn affects his or her emotions and respiration. This technique of matching the patient's and doctor's breath and leading it into a state of quiescence is very often used by Medical Qigong doctors to relax their patients. It not only connects the doctor with the patient on an energetic and emotional level, but also provides a strong spiritual connection.

Note: Do not match an asthmatic patient's breathing, as this is disruptive to the flow of Qi within your own body.

MAINTAINING THE DOCTOR-PATIENT RELATIONSHIP

Whenever the doctor begins to judge or formulate negative opinions of a patient, he or she is no longer operating in the divine "present" state of spiritual intuition, but has shifted into the "past" (as all judgements are based on past experiences and emotional encounters). The doctor is then in danger of absorbing the discharged energetic pathogens from the patient, or projecting subconscious biased opinions onto the patient. Whenever the doctor relates, relives, or orients from his or her own personal past (the feelings can be either positive or negative), the doctor is at high risk of absorbing the patient's energetic pathogens.

When the patients come to the doctor, they are giving their consent for the doctor to learn

about personal things which the patient has often withheld from their mate, family, or even themselves. They are further giving the doctor permission to utilize their combined energies to affect changes within their physical, mental, emotional, energetic, and spiritual fields and body.

Each treatment will be different for the patient, as each experience will vary according to the patient's present state of mind and emotional spirit. The patient's willingness to allow the Qigong doctor's emitted energy to penetrate deeper into his or her body with each session will depend upon the level of trust established, as well as any outside influences that may have a positive or negative effect on the patient's ability to be open and vulnerable. Patients who experience ridicule or criticism from family and friends for their choice of a non-Western form of treatment, may temporarily shut down their receptivity in self-defence against others. At times, patients may also close-off as a result of an event that has a strong impact on their emotional and spiritual well-being, such as a death of a friend, a physical trauma, or other upsetting news.

The patient always has the final control over the doctor's emitted energy, and can choose to either absorb and utilize the energy, or disperse and sabotage the doctor's treatment. It is for this very reason that the doctor-patient trust factor, as well as the goal orientation, must be securely established before the treatment begins.

Be sure the patient's arms and legs are not crossed, as this can impede, or "short-circuit," any energetic flow, causing Qi obstructions. The patient should close his or her eyes, but should not be allowed to internally guide or direct the Qi unless specifically instructed to do so by the doctor. A patient's unguided imagery can cause the body's energy to increase, alter, or obstruct the flow of the doctor's energy, which may cause Qi deviations or aggravate an existing condition. Usually the patient is given the image of dissolving his or her tissues into space, which encourages relaxation and freedom from distractions. If the patient is lying down, he or she is given certain visualizations, such as floating on a sea of warm water (or basking in the sun on the beach or shore of a lake). These images relax the patient and enable the Qigong doctor to disperse the patient's armoring. Once the patient's "street armor" is down, the doctor will have easier access into the patient's tissues.

After the treatment, the doctor and patient evaluate each session, discussing any and all feelings, observations, transitions, and sensations that both the doctor and patient experienced. Homework, in the form of Medical Qigong prescriptions are then generally given, in addition to follow-up treatments (depending on the patient's case and condition).

THE FOUR MAJOR PRIORITIES OF CLINICAL QIGONG HEALING

According to China's prominent Qigong Grand Master Pang Ming, clinical Qigong healing is based on four basic priorities. In establishing a clinical environment it is important to inform the patient about the structures of these four priorities: A Strong Faith, Group Healing, Medical Qigong Therapy, and Medical Qigong Prescriptions and Exercises.

1. A strong faith that Qi or life-force energy can heal the patient's specific ailment is built up by the patient listening to testimonials. These testimonials are given by other patients who have recovered from the same type of disease, as well as those patients who are experiencing improvement through Medical Qigong therapy.

   Qigong deals directly with the psychological aspects of diseases. It is well known that two side effects of cancer are depression and fear. A very popular theory maintains that depression (being the suppression of anger) can cause cancer. Even before the cancer patients begin their treatment program, their confidence is bolstered by the positive experiences of more advanced students of Qigong, who at one time also suffered from these particular kinds of cancer. In addition, as part of the Qigong exercises, the new patient's mind is focused on pleasant images or memories. All of this creates a positive mental attitude in the patient.

Sometimes patients come to the doctor for healing, yet at a deeper level they feel that they need or deserve the illness. Sometimes the secondary gain of illness (for example, to keep the wife or husband underfoot) outweighs the benefits of healing completely. If a patient is subconsciously unwilling to be healed, his or her attitude or disbelief will sabotage all clinical modalities of healing (both Western and Eastern). You cannot make someone better against his or her own will. Illness, like health, is often a matter of choice.

2. Before a group of patients begin Qigong, the doctor verbally synchronizes the thinking of the group by absorbing Heavenly Qi (the divine hook-up), and bringing it down into the healing energy field which surrounds everyone including the doctor. The healing effect is enhanced because the group is acting as one unit, with one faith.
3. The doctors initiate the actual Qigong healing by bringing divine healing energy to each individual patient.
4. The patients are taught how to easily follow Medical Qigong exercises and meditations, practicing them over and over again.

When a patient enters a Qigong hospital in China, they are diagnosed by a doctor and then assigned a specific Qigong class for a twenty-four day treatment period. The patient spends eight hours a day practicing Qigong without television, newspaper, or telephone. This is required to help the patient avoid regression into a previously established belief structure or subconscious pattern. Those who are able, practice Qigong from a standing posture. Other patients with limited mobility practice Qigong sitting or while lying in bed. After the twenty-four day treatment program is over, the patient is again diagnosed by a Qigong doctor. The diagnoses is classified into one of four categories for statistical purposes.

1. The patient has been cured: symptoms have disappeared and appropriate instruments (e.g., EKG, ultrasound, etc.) register normal tissue.
2. The treatment has been very effective: symptoms have almost disappeared and allopathic tests indicate great improvement.
3. The treatment has been effective, in that the patient is now able to eat, sleep, and feel good.
4. The treatment has been noneffective: there has been no change, or the condition has worsened.

PREPARING THE SELF TO TREAT THE PATIENT

This section prepares the Medical Qigong doctor to treat patients. The "preparation" sets the energetic ambiance for the clinical treatment and secures the foundation for dispersing pathogens. The preparation includes: The One through Ten Meditation, Creating a Sacred Healing Space, The Divine Hook-Up, Rooting to Prevent Energetic Shock, and The Energetic Circle Drawing Pattern (Figure 26.2).

THE ONE THROUGH TEN MEDITATION

The following is called the One through Ten Meditation and is used to prepare the Qigong doctor for clinical work. It allows the Qigong doctor to relax, sink, and root the mind. This meditation allows the doctor to extend his or her energetic field before connecting with the divine. This meditation is used to create a sacred healing space and is taught in a rhyming one through ten counting format, described as follows.

1. One Is Fun, therefore take pleasure in your work. Imagine a smile melting down the front of your body like warm oil, melting all stress and tension into the Earth. A second smile melts down the back of your body, dissolving all stress and tension down into the Earth. A third and final smile melts down the center of your head, relaxing all thoughts, judgments and feelings, and flows down your shoulders and arms and out your hands. The melting continues to flow down the center of your torso, like warm oil, melting all emotional blocks and tension, then flows down your legs and into the ground. At this point your mind and body should feel content, relaxed, and peaceful.
2. Two Is Shoe, thus imagine your feet melting into the Earth, like ice melting on a hot side-

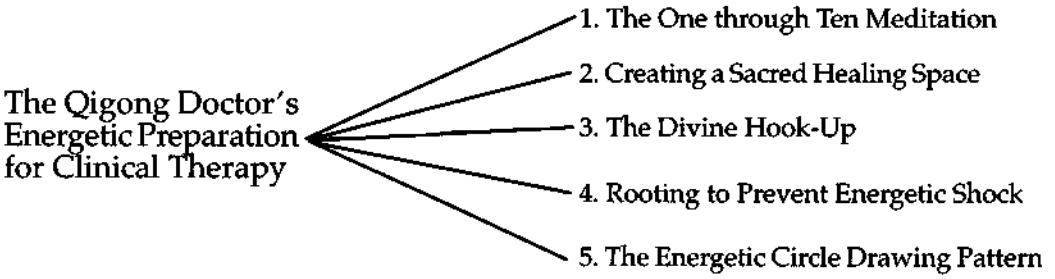

Figure 26.2. The Qigong Doctor's Preparation for Treating the Patient

walk. The energy of the feet fuses with the Earth, melting in five directions (forward, backward, right, left, and down). This connects your mind and body with Earth energy.

3. Three Is Tree, therefore feel yourself extending tree-roots twice your body's height deep into the ground. The roots expand in five directions (forward, backward, right, left, and down), securing your rooting and connection with the Earth energy.
4. Four Is Core, thus imagine your roots extending deep into the core of the planet. The Earth energy flows into these roots, ascending up the legs, spine, over your head, down the chest, and enters your Lower Dantian. This action allows you to draw Earth energy into your body and circulate it through the Microcosmic Orbit. A solid connection to the Earth roots your physical, mental, emotional, and spiritual energies, and fills up your Lower Dantian with Earth energy.
5. Five Is Alive, therefore feel the Earth energy building up within your Lower Dantian. The energy increases to the point that your Dantian can no longer contain its power. It rushes up the center of your chest like a mighty river, dividing into two streams which flow out each palm into the earth. This action releases and emits the energy stored within your Lower Dantian.
6. Six Is Thick, thus imagine the room or environment where you are standing being filled with energy. This energy becomes so thick, it is as if you are submerged under water. This fuses the environmental energy with your energy, and the Earth's energy into one dynamic field of energy.
7. Seven Is Heaven, therefore allow your Baihui point to open up and draw in the divine healing white light into your Upper Dantian. Let the divine light fill your head and the entire Upper Dantian area till it floods and shines down from the Upper Dantian into your chest, filling up the entire Middle Dantian. Finally, the light shines down from the Middle Dantian filling up the lower abdominal area and the entire Lower Dantian. This light connects you with the Heavenly healing white light energy from the divine, filling up all three Dantians and your Taiji Pole. Thus Heavenly and Earthly energies fuse within your body.
8. Eight Is Open the Gates, therefore imagine opening every pore on your surface tissues, and begin to draw the environmental energy into your Taiji Pole upon inhalation. Upon exhalation imagine your center core vibrating and glowing like a neon light. This visualization energizes your center core, harmonizes your energy and breath, and prepares you for Qi and Shen (energy and light) projection.
9. Nine Is Shine, therefore imagine that your center core becomes completely full of energy and overflows by shining (from the Taiji Pole outward) through your pores until it fills up the entire room, like a bright phosphorus flare. This visualization fuses Heaven Qi, Earth Qi, and Man's Qi with the external clinical environment.

10. Ten Is Begin, with all things now in order, you are physically, mentally, emotionally, energetically, and spiritually in harmony, with your body, the Heavenly energy, and Earthly energy. You can now begin treating patients.

CREATING A SACRED HEALING SPACE

After completing the preparation, the Qigong doctor creates a sacred healing space in which to treat patients. Creating the sacred healing space allows the doctor and patients to interact in a safe environment without outside distractions.

The Qigong clinic should be a place of complete sanctuary, a consecrated place of refuge, where the patient feels safe, warm, and cared for (spiritually, emotionally, mentally, energetically, and physically). The patient should experience the peaceful ambiance of the treatment room as being enveloped in unconditional love and security.

To create the sacred healing space, the Qigong doctor performs the divine hook-up. Only after completing the divine hook-up should the Qigong doctor treat his or her patients.

THE DIVINE HOOK-UP

Once the doctor has established energetic grounding, the next step in establishing a clinical environment is to connect with his or her spiritual center through the divine hook-up. From this spiritual center the Qigong doctor observes the patient, void of personal thoughts, feelings, and judgments. This spiritual state of open receptivity allows patients to feel secure and to release their guarded emotions. Lacking a safe environment, patients may feel the need to repress emotions or to be distracted from experiencing and letting go of the original trauma.

The Qigong doctor, once healing has begun, enters into a state of "oneness" with the patient and the divine, in which the doctor's will and intention envelops and fuses together with the divine will and wisdom. Both doctor and patient begin to communicate through deep subconscious interactions. The doctor's success or effectiveness as a Qigong healer depends on a willingness and ability to connect with the patient and the divine healing light. Drawing from this interpersonal communication with the patient, and the deep spiritual connection with the divine, the doctor begins the treatment.

According to Dr. Meng Xian Tong of the Beijing Chengjian Integrated Traditional Chinese Medicine and Western Medicine Experts Clinic, when Qigong doctors perform the divine hook-up, they increase their own body's Righteous Qi, which then extends the energetic Message encoded in their Qi into the patient's body. The doctor's Righteous Qi is then absorbed by the patient's body and fused together with his or her Qi. This fusion empowers the patient to heal his or her disease.

Before contact with any patient the doctor first connects with the divine to purify and stabilize, not only him or herself, but also the treatment room (with a constant flow of Heavenly Qi pouring into the room). This divine hook-up enables the Qigong doctor to not only establish a sacred healing space, but also to access both spiritual insights and divine healing power.

ROOTING THE DIVINE HEALING LIGHT

Rooting the divine healing light is accomplished by visualizing a beam of healing light (the doctor can also choose specific colors) streaming into his or her body via the Baihui and Sishencong points (at the top of the head), and entering into the Taiji Pole. The doctor holds this frequency until the divine healing light becomes rooted or "anchored" within the Lower Dantian.

Next, the doctor brings the healing light vibration up the Taiji Pole to energize each Dantian until the healing light infuses and harmonizes all of the body's tissues. As the doctor feels the healing light reach the Middle Dantian, he or she visualizes the light intertwining with the "bridge of light," which connects the doctor's Heart (Middle Dantian), throat and Yintang (Upper Dantian) areas together. This energetic connection fuses at the Upper Dantian, becoming one unified cord. The healing light is then stored within the doctor's body and released during Qi emission.

USING THREE DIVINE INVOCATIONS

To assist the doctor in rooting the divine healing light, I encourage my students to begin each treatment with a small prayer and three invocations, for example:

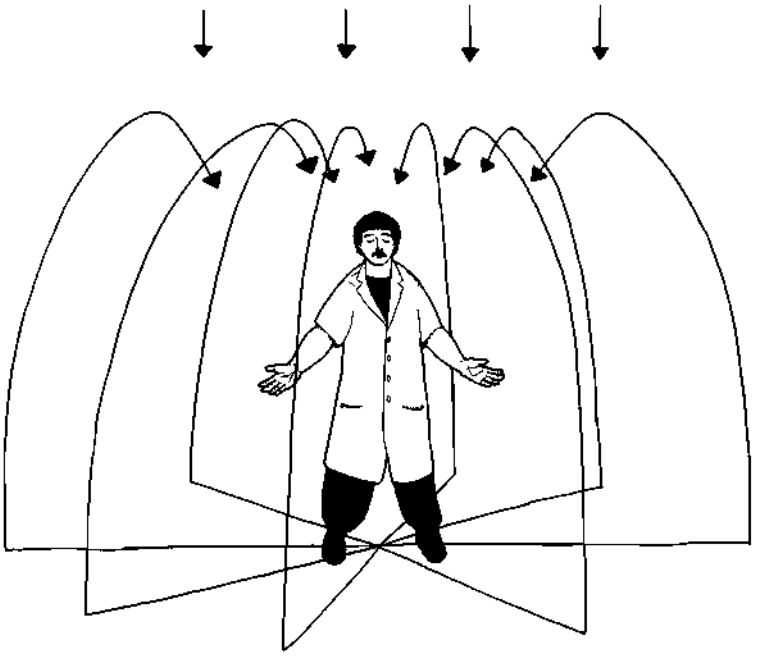

Figure 26.3. As the divine healing Qi absorbs into his or her body, the Qigong doctor expands this field to envelop the entire treatment room.

1. "Lord God, fill me with your Holy Spirit and divine healing power. Increase my skill, power, knowledge, and wisdom and use me for Your Glory." The first invocation connects the doctor to the healing energy of the divine and roots the doctor deep into the Earth. This prevents the patient's pathogenic Qi from entering into and contaminating the doctor's body.
2. "Fill this room with your Holy presence and healing virtue, and let your Glory shine through me into this room." This second invocation connects the doctor and the treatment room to the divine and secures a sacred healing space (or sanctuary) for the patient. It also establishes an expansive divine energetic field by causing the doctor's Wei Qi field to overflow with divine healing light, filling the treatment room. This divine energetic field produces a dynamic field of healing energy (Figure 26.3).
3. "I lift (the doctor will mention the patient's name) before Your Holy Presence, and ask that you may heal these wounds and free him or her from these chains of despair, agony and disease. Thank you, God. Amen." After this final invocation, the doctor envelops the patient with an energetic bubble of light and love.

Next, the doctor roots the patient's energetic bubble deep into the Earth, and creates an energetic vortex underneath the patient. The energetic vortex will spiral clockwise, deep into the center of the Earth. This energetic rooting technique is practiced to purge and drain the patient's Toxic Qi into the Earth, where it is cleansed and then recycled back into the patient's body.

ROOTING TO PREVENT ENERGETIC SHOCK

Rooting (sometimes called "energetic grounding") is an important technique used by the Qigong doctors to establish and maintain a firm physical, mental, emotional, energetic, and spiritual connection to the Earth. Connecting to the Earth is essential to prevent energetic shock (a jolt of energy which flows from the patient into the doctor's body), which can result in the doctor ab-

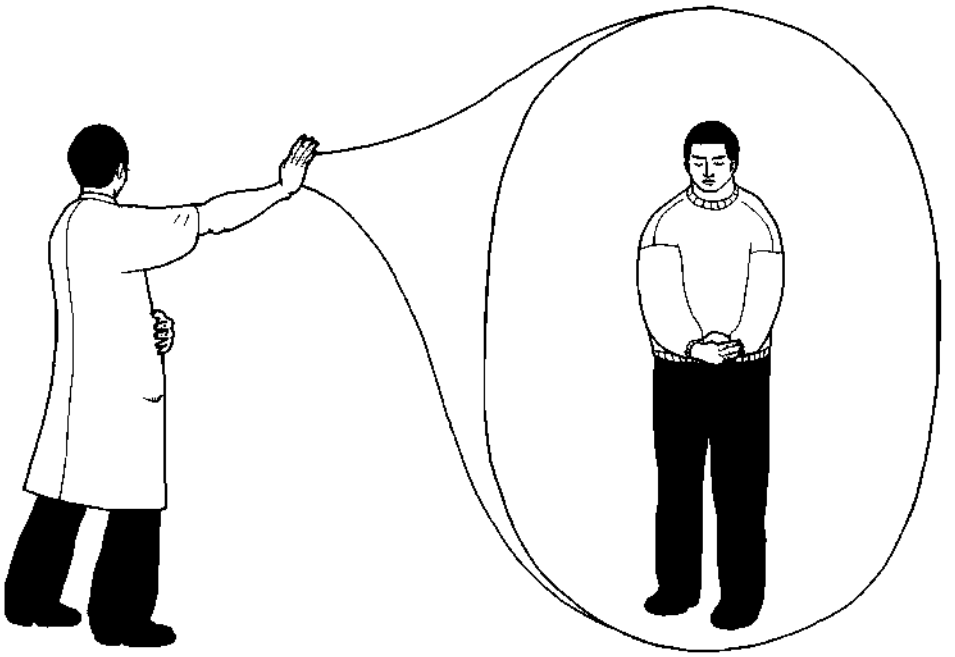

Figure 26.4. The Qigong doctor envelops the patient in an energetic bubble (or healing circle) before beginning the treatment.

sorbing the patient's energetic pathogenic disease. To prevent energetic shock from happening, Qigong doctors go through several steps to prepare themselves and the clinical environment before treating patients. Energetic rooting is utilized in all phases of meditation and allows doctors to maintain a strong physical connection to the Earth. It is especially used when the doctor is absorbing and emitting environmental and universal energy.

- From a Wuji posture, imagine an energetic cord extending from your Lower Dantian, down the Taiji Pole and out the Huiyin point (at the base of the spine) deep into the center of the Earth. This energetic cord will root your energy into the Earth. It is also affected and maintained by your will and intention. The energetic cord follows the doctor's movements smoothly and easily.
- If the patient is lying, sitting, or standing in front of you, extend your energy to envelop the patient within an energetic cocoon called "energetic circle drawing."
- Imagine extending an energetic cord from the patient's Lower Dantian through this energetic cocoon, to root the patient's body deep into the Earth. This process energetically grounds the patient's body, mind, emotion, and spirit.

THE ENERGETIC CIRCLE DRAWING PATTERN

Once the divine hook-up is completed, the doctor grounds the patient by drawing an energetic circle around the patient's body. This is used to charge the patient's energy field. This energetic projection also roots the doctor's intention around the patient and strengthens the doctor's concentration. This circular field changes the patient's static field to a divine dynamic field and enables the Qigong doctor's energy to enter the patient's body with ease.

The enveloping of the patient's body allows the patient's body and energetic fields to become even more accessible to the Qigong doctor, while keeping the patient's pathogens isolated from the doctor's body (Figure 26.4). As the doctor steps into the energetic bubble, he or she is able to treat

the patient's tissues, feeling absorbed and enveloped within the Messages expressed from the patient's energetic fields.

The energetic bubble is created by emitting Qi towards the patient, and enveloping and circle wrapping the patient in a clockwise energetic rotation. This energetic bubble forms a shield, maintaining protection for the patient and the doctor. Next, the doctor creates an anchoring line to root the patient's energetic field deep into the ground. Finally, the doctor creates an energetic vortex (spiraling in a clockwise direction) underneath the patient, to pull any dispersed pathogens deep into the Earth (this helps when the doctor is dredging and purging the patient's energetic fields).

USING THE ENERGETIC CIRCLE DRAWING PATTERN TO PURGE PATHOGENS

The energetic circle drawing pattern helps to facilitate energetic cleansing. Energetic purging facilitates the absorption of Clear Qi and also reduces the risk of contamination within the body's channels and collaterals by expelling energetic toxins and other pathogenic factors.

After creating the energetic circle, the doctor begins using dredging and purging techniques to expel pathogens from the patient's body. Next, the doctor treats the patient with tonification and regulating techniques, ending the treatment by closing the diseased area and sealing the patient's three energetic fields (three Wei Qi fields). This ending technique will securely close the energetic holes in the patient's outer field of Wei Qi (see Chapter 13). Without this sealing, the healing process is hindered due to the patient's Qi having a tendency to leak or disperse itself (even after tonification). Once the sealing is completed, any Excess Qi will be evenly distributed throughout the patient's body, establishing a Yin and Yang balance within the visceral organs.

USING THE ENERGETIC CIRCLE DRAWING PATTERN TO PURGE TOXIC HEAT

Before treating patients who have received radiation or chemotherapy, the Qigong doctor should wrap the patient with an energetic bubble and then purge the Toxic Heat from the patient's body. The Toxic Heat is dispersed into the energetic vortex created under the patient's body, and then released deep into the Earth. The Qigong doctor can then step into the energetic bubble and begin combing, dredging and purging the patient's tissues.

USING THE ENERGETIC CIRCLE DRAWING PATTERN TO PURGE TOXIC COLD

When using the circle drawing method to purge pathogenic Cold, the doctor stands outside of the energetic bubble, and extends energy deep into the patient's Taiji Pole. Once the doctor feels the patient's center core Qi, he or she draws the pathogenic Cold or Hot energy out from the patient's tissues (in all directions), filling the energetic bubble. The doctor, standing outside the energetic bubble, observing the patient's energetic field, waits for an energetic shift which is immediately followed by Toxic Cold (or Hot) Qi filling up the energetic bubble. Once this occurs, the Qigong doctor must drain the pathogenic Cold (or Hot) Qi down into the Earth to rid the patient of the Toxic Qi.

TREATING THE PATIENT

After the Qigong doctor has "circle wrapped" the patient, the treatment begins. First, the doctor dredges the patient's external energetic fields, channels and collaterals (from head to feet). The doctor senses the patient's Qi with his or her hands, changing the depth of penetration of the touch by extending intention deeper into the patient's tissues. Once the patient's pathogenic Qi has been reached, the doctor feels various energetic sensations (vibration, warmth, thickness, etc.) and removes any pathogenic energy from around the patient's body.

The doctor continues the treatment by extending his or her intention deep into the patient's body, purging and dispersing the toxic pathogens from out of the patient's internal organs and channels. It is usually during this deep internal purging that the patient experiences profound emotional discharges, observes flashes of light, patterns of colors, see visions, or relives deep seated past emotional traumas. This purging releases toxic emotions which are generally the cause or contributing factor to the patient's disease.

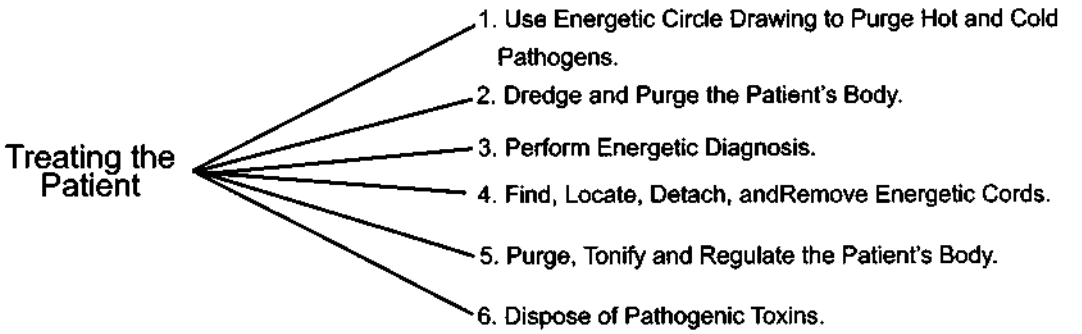

Figure 26.5. The Different Steps Involved in Treating a Patient

After the patient has been sufficiently purged and cleansed of pathogenic energy, the Qigong doctor begins to tonify the patient's internal organs, channels, collaterals, and Righteous Qi. This is done to help the patient build a stronger immune system, and fight or avoid any future complications caused by an Excess or Deficient internal organ condition (Figure 26.5).

Dredging and Purging Techniques

When treating a patient, the doctor purges an internal organ and dredges a channel. The technique of dredging is a particular type of purging method. The energetic circle drawing techniques are always performed with dredging techniques (using the pulling and stroking methods of energy manipulation), to drain the energy into the Earth. These techniques can be initiated with the patients either sitting, standing, or lying.

It should also be noted that the diseased area of a patient's body must be thoroughly dredged and prepared before any kind of tonification or energizing is performed. This technique is similar to a Western doctor cleaning a wound before operating.

If the Qigong doctor does not dredge and purge the pathogens from the patient's body before treating, the patient can suffer adverse reactions when the doctor's clean energy fuses with the patient's Turbid Qi.

Dredging and Purging the Patient

There are two stages of clinical purgation which are described as follows.

1. The doctor dredges and purges the surface pathogens from the patient's body. The doctor moves to the right lateral side of the patient's body and energetically combs the patient's body from head to toes using the Tiger Kneading and/or Extended Fan Palm techniques (in this particular example the patient is lying supine on a treatment table). The combing technique is performed to energetically evaluate the patient's reaction to the doctor's emitted Qi, while dredging the patient's three energetic fields of Wei Qi.
2. The doctor purges from the bottom of the patient's feet. The Qigong doctor stands by the patient's feet and continues to dredge the patient's body by energetically combing the patient from head to toes. This action further purges the patient's body of pathogenic energy.

Energetic Diagnosis

After performing the clinical purgation, the Qigong doctor begins the energetic diagnosis. Some examples of energetic diagnosis are described as follows.

- The doctor can begin energetic diagnosis by first connecting with patient's heels (either by touching or not touching). This particular method and approach to diagnosing allows the Qigong doctor to energetically connect with the patient's inner-fascia. It is through this connection that the Qigong doctor feels the energetic flow of Qi moving through the patient's internal organs. By extending energy

from the patient's heels up to the head (like a rippling ocean wave or sonar), the doctor can "listen" for obstructions or deviations of Qi flow.

- Next, the doctor can use the Flat Palm diagnosing technique to scan the patient's entire body for any Excess or Deficient areas within the patient's Wei Qi fields. This second type of diagnosis serves to verify the obstructions or deviations of Qi flow that the doctor discovered while first connecting with the patient's heels.

PURGING, TONIFYING AND REGULATING THE PATIENT'S BODY

After diagnosing the patient's body, the Qigong Doctor purges, tonifies, or regulates the energetic fields, channels, tissues, organs, and organ systems, according to the etiology and prognosis of the disease.

While dredging and purging the patient's body, the Qigong doctor may discover several energetic cords attached to the patient's tissues and internal organs. These energetic cords may sometimes contribute to the cause of the disease.

UNDERSTANDING THE BODY'S ENERGETIC CORDS

The human body attaches, extends, absorbs, and collects energetic cords. The size and shape of these cords can be big, small, thick, or thin, depending on the amount of emotion invested in their attachment. These cords are located within the Three Dantians and Chakra Gates, and form the spiritual, emotional, mental, and physical connection of the patient to the outside world. Generally, what makes the patient sick is not his or her genetic predisposition, but the negative, co-dependent bonds the patient creates in his or her relationship with others. It is the spiritual, emotional, mental, and physical reactions to these relationships that either promote health or disease. Energetic cords are also formed towards objects, pets and places that have special sentimental or emotional value (be they positive or negative) to the patient. Energetic cords are also sometimes used to feed the formation of the preexisting energetic clusters and cysts, which later transform into the patients' diseases.

Energetic cords are the psychophysical connection between what the patient feels, believes and knows to be true; they represent the connection to the patient's personal reality. This does not mean that the patient's reality is valid, only that the patient has come to believe it to be true. By removing these cords an energetic shift is initiated, allowing the patient to reprogram his or her feelings, thinking processes, and behavior, by becoming proactive instead of reactive. Energetic cords are full of light and energy and can be categorized into two distinct divisions: prenatal (congenital) and postnatal (acquired) energetic cords.

- Prenatal Energetic Cords originate in the fetus, when the baby is still in the womb. They form the strong congenital attachment and permanent bond the child has with the mother and father. Because of the mother's energetic/spiritual connection with her egg, and the father's energetic/spiritual connection with his sperm, when the egg and sperm unite, the energetic cords of each parent fuse together with the universal and environmental energy creating the energetic structure of the child. It is through the parents' energetic cords that inherited talents and defects are passed along to the infant.
- Postnatal Energetic Cords are acquired after the baby is born through interaction with siblings, relatives, and other individuals (in some cases animals or places are involved). These cords will either form the emotional attachments which can help the child through life by being a means of support, or set the foundation for disease by depleting the child of his or her life-force energy. They represent the emotional bonding (positive or destructive) inherent within each one of us.

In a clinical environment, the attachment of these cords (prenatal and postnatal) will affect the healing relationship of both the patient and the doctor.

- The Patient's Energetic Cords are still connected to the patient after the pathogenic Qi has been removed from the patient's body. These small cords are the energetic attach-

ments to part of the patient's old belief structure (which created the disease or emotional attachment). Although there is still an energetic connection to the departed pathogenic Qi, these energetic cords will soon disperse once the patient's Creative Subconscious is able to reprogram the individual's belief structures. Only then can the physical body, as well as the mental, emotional and spiritual energetic Wei Qi fields maintain the new energetic pattern. This new belief structure creates an energetic transformation, allowing the patient to release his or her hold on to the painful past and begin to heal. The patient is encouraged to emotionally disconnect from old emotional belief structures through creative visualization, and by affirming the new belief structure. Through affirmation and positive emotional, spiritual visualizations, the patient is able to "sever" any energetic cords that connect to the pain and disease.

- Energetic Cords between the doctor and patient are formed during healing sessions. These new energetic cords are passed back and forth between the Qigong doctor and the patient. Sometimes this occurs without either party being aware of this energetic connection. Usually, as the doctor steps away from the patient and reconnects with the divine, an energetic purging is automatically initiated, freeing the doctor from the attachment to the patient's energetic cords. If, however, there has been an emotional connection between the doctor and the patient, these cords can remain attached even when the patient leaves the office.

  The doctor should make every effort to disconnect from the emotional attachment of the patient's cords, otherwise the increased energetic pull on the doctor's center will affect the doctor on every level. Staying connected to the patient through an energetic cord can cause not only emotional, but physical and spiritual influences on the doctor. Any remaining cord can be used by the patient to unconsciously project thoughts and feelings onto the doctor. This can result in the doctor being depleted of energy either through direct draining of his or her Qi, or through obsessing about the patient's well-being, long after the treatment has ended. The drain of the energetic cord can lead to either clinical "burnout" from absorbing excessive negative emotions, or deep emotional bonding, which can lead to unethical sexual indiscretions.

FINDING, DETACHING, AND REMOVING ENERGETIC CORDS

Energetic cords manifest through their effects on behavior and emotional responses of the patient. They are relationship based patterns, located within the patient's tissues. Energetic based patterns can evoke certain reoccurring emotional responses, such as attractions, addictions, etc.

1. To assist the patients in removing the toxic energetic cords, the Qigong doctor must first locate the cords.
   a. Through the emission of Qi, the doctor may elicit (from the patient) either an attraction or repulsion response. This response occurs when certain memories are stimulated within the patient's body, indicating that there is an energetic cord attached within the tissues.

- The attraction response causes the patients to experience deep emotional release through laughing, crying, shouting, etc.
- The repulsion response causes a physical jerking of the patient's muscles, anywhere within the patient's body (observed by the wincing and grimacing of the patient's face). Often the patient will "Shen-out" (emotionally and spiritually leave their body) to avoid feeling the painful surfacing emotions.

   b. The doctor locates the origin and entry point of the energetic cord through Flat Palm detection. The root of an energetic cord acts as an open receptor to a specific psychophysical problem that the patient is experiencing. When stimulated, these cords may manifest physical symptoms such as nausea, hot flashes, vertigo, dizziness, headache, and muscle contractions. The patient may also experience

emotional reactions such as momentary panic, fear and so on.

2. Before detaching the energetic cords, the doctor requests the patient's permission to do so either verbally, or silently through mind to mind communication.
3. To remove the energetic cord, the doctor dredges and purges the patient's body, while silently communicating through the Creative Subconscious mind. The doctor encourages the patient to let go of, and fully release, the toxic cords along with the memories that sustain them. To ensure against their recreation, the doctor discusses with the patient any images, emotions or sensations that surfaced during the removal of these cords; through this process the doctor brings the patient's conscious awareness of the fears, pain and major unresolved issues that resulted in the disease. The patient thus gains a clear identification of his or her traumas to facilitate the reprogramming of his or her dysfunctional relationships through affirmations and creative visualizations.

If the patient is not ready for such a transition (feeling scared, unprepared, undeserving, etc.), his or her subconscious mind will sabotage any effort made in that direction, and the energetic cord, emotional cluster and all energetic attachments to the disease will be recreated and reintegrated. It is important in cases such as these, that the Qigong doctor refer the patient out to a psychotherapist for additional support.

In Western society, the Twelve Step Programs (such as Alcoholics Anonymous) are but one example of a pattern based reprogramming of energetic cord attachments. Alcohol and Narcotics Anonymous groups, for example, help detach energetic cords toward illegal substances, whereas, CODA meetings help reprogram the energetic cord attachments to co-dependant relationships. In a co-dependent relationship, both parties rely too heavily on one another, instead of being interdependent. One person usually dominates the other, as both parties base their self-esteem on the partner's approval, or disapproval, thus avoiding the personal responsibility of their own actions.

Energetic reprogramming encourages the participants to take responsibility for filling and replacing the energetic gap that the toxic cord has left with a connection and attachment to the divine, or "Higher Power."

Disposing of Pathogenic Toxins

One problem a doctor may confront when dredging and purging is where to dispose of the patient's toxic and noxious Qi. To maintain a clean treatment room it is essential for this pathogenic energy to be disposed of properly. This will keep both the doctor and other patients from contamination. If the doctor's Qi becomes toxic or contaminated during treatment, this turbid energy may be transmitted to other patients.

Because the patient is in a state of energetic shock (after the therapy), attention must be placed on the patient avoiding contact with the contaminated Qi. Otherwise, there is a possibility of the diseased Qi returning into the patient's body via the energetic cords of attachment connected to the Toxic Qi.

Imagination and visualization are two of the most powerful and widely used techniques employed in healing today for disposing of Toxic Qi. Since we experience reality through creative imagination, pictures, words, and feelings are extremely powerful techniques which can be used to restructure our physical, mental, emotional, energetic, and spiritual foundations. This also holds true for the disposing of the patients' pathogenic Qi.

There are several methods for disposing of the patients' pathogenic energy in the treatment room. These methods include purification by either sound, light, or the Five Elements, in conjunction with disposing of the toxic energy through the energetic vortex.

Purification by Sound and Light

- Sound penetrates any substance and causes profound shifts in energy, quickly breaking up clusters of stagnant energy. Some examples

of sounds used for purifying the treatment room include: music, toning, chanting, singing, wind chimes, gongs, singing bowls, bells, drumming, and clapping the hands.

- Light can be used to cleanse and purify the treatment room of toxic energy, due to the radiant heat emanating from the light source. Some examples of light being used to purify the clinic include: exposure to sunlight, candles, and imagining the divine healing light incinerating any energetic toxic debris.

PURIFICATION BY THE FIVE ELEMENTS

Some Qigong doctors utilize the energy stored within the Five Elements to cleanse the treatment room of toxic debris. This works best in conjunction with the light and sound purification methods. When using one or more of the elements, it is best to consider how much debris has accumulated from the previous treatment and choose accordingly.

1. Dispose of the Toxic Qi through Fire. By burning fire-water (alcohol with salt), lighting a candle, or releasing the Toxic Qi into the Earth's molten core, Toxic Qi can be transformed and purified.
   - To create fire-water, the Qigong doctor places a small amount of alcohol in a round dish and sprinkles a cone of salt (or camphor) in the center of the dish. Next, the doctor lights the salt and allows the smoke to purge the treatment room, making sure that the doors and windows are open to secure clean ventilation.
   - Other Qigong doctors may imagine the center of the Earth as an incinerator. This image is used to purge the patient's Toxic Qi by directing it to the Earth's molten core. Once the patient's Toxic Qi is incinerated (at the speed of thought), the transformed / purified energy is reabsorbed back into the patient's body.
2. Dispose of the Toxic Qi through Water. Water can also be used to absorb toxic energy and for healing and purifying. Some examples of water usages include: Holy Water and salt water. Some doctors use a container of salt water as their disposal unit for the patient's Toxic Qi (Figure 26.6). Once the patient's toxic energy reaches the container of salt water (usually placed underneath the treatment table), it is immediately absorbed due to the molecular structure of the salt crystals. Sometimes it is advisable for the Qigong doctor (after a full day at the clinic, or at the end of a busy week) to submerge him or herself in a baking soda or take an Epsom salt bath in order to cleanse and purify the body.
3. Dispose of the Toxic Qi through Wind / Air. Wind and air can be used to purify the room of toxic energy. Some examples of this include open air ventilation along with the placement of indoor plants.
4. Dispose of the Toxic Qi through Divine Healing Light. Some doctors dispose of the patient's pathogens into the air, where it is immediately incinerated by a divine healing light. Because of the preestablished divine healing field of energy, once the patient's toxic energy leaves the doctor's hand, it is immediately absorbed by the divine healing light and is instantly transformed into purified energy and reabsorbed back into the patient's body.
5. Dispose of the Toxic Qi through Wood. Wood can also be used to purge toxic energy from the treatment room. Some examples of the Wood Element used to cleanse the room are: the burning of incense or herbs such as myrrh, frankincense, cedar, sage (an old American Indian method), sandalwood or camphor.
6. Dispose of the Toxic Qi through the Earth. Certain stones can be used in the clinic because of their ability to absorb Toxic Qi. Strategically placed in the clinic, these Earth Elements can be used as a natural filtering device. Some examples of this include: amethyst, salt, clear and colored quartz, as well as many other minerals or gemstones. These crystals require cleaning at the end of each treatment day to dispose of the toxic Qi they have absorbed, and should be cleansed by placing them in salt water till they are clean, or burying them in the ground for three days.

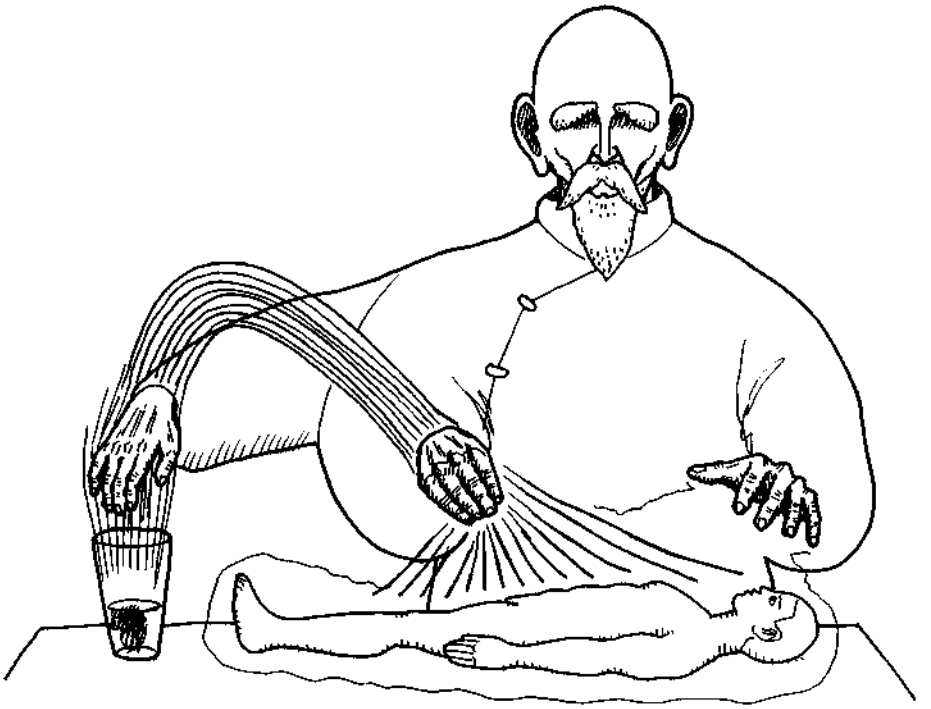

Figure 26.6. One example of a Qigong doctor using a rubber acupuncture doll for treating and disposing of the patient's toxic energy into salt water.

MEDICAL QIGONG TREATMENTS

The following is a clinical procedure that a Medical Qigong doctor will use when treating a patient. The clinical procedure known as the "preparation" remains the same for all Medical Qigong treatments (i.e., the hook-up, dredging and purging the patient, as well as energetic diagnosing). However, the initial treatment will vary depending on the patient's constitution, disease, and personal goals.

After scanning the patient the doctor has a solid understanding of which areas or organs in the patient's body are currently in a state of Excess or Deficiency. The doctor then chooses which area to begin dredging and purging in accordance with the treatment plan. Only after purging all areas of Excess should the doctor then move to tonifying those areas that are Deficient.

TONIFYING A PATIENT'S BODY

After completing the diagnosis, if you have determined that the patient's body is not in an Excess condition, but is instead constitutionally weak or depleted due to Kidney exhaustion, the treatment may be continued as follows.

1. Begin by extending energy through the patient's Yongquan Kd-1 point at the bottom of each foot. Imagine that the Qi is ascending up the patient's legs, via the Yin channels, filling the Lower Dantian, Kidneys, thorax and spinal column into the brain. Hold this position for several breaths, then proceed to the next area.
2. Physically embrace the area of the patient's ankle with one palm, while the other palm embraces the Kd-1 point on the same foot. Start with the right ankle first and then the

left. Project energy into the foot and ankle, by holding the mind's intention on that specific area for several breaths, then begin circling the energy up the Yin channels and down the Yang channels. Hold this position for several breaths, then proceed to the next area.

3. Energize each of the patient's knees (back and sides) by holding the mind's intention on those specific areas for several breaths, then connect each knee to the Yongquan Kd-1 point at the bottom of each foot (the right foot first, then the left). Connect and emit energy into the bottom of each foot to the knee, circling the Qi up the Yin channels and down the Yang channels. Hold this position for several breaths, then proceed to the next area.
4. Energize each of the patient's hips, by holding the mind's intention on that specific area for several breaths, then connect each hip to the Yongquan Kd-1 point at the bottom of each foot (right first, then the left). Connect and project energy into the bottom of each foot to the hips, circling the Qi up the Yin Channels and down the Yang Channels. Hold for several breaths, then proceed to the next area.
5. Energize the patient's Lower Dantian by holding the mind's intention on that specific area for several breaths, allowing the Qi to completely fill up the energetic chamber. Place your left hand on the patient's Mingmen GV-4 point. Your right hand is placed on the patient's navel (CV-8) with your fingers extending down to the patient's Qihai CV-6 point. Mentally connect the Lower Dantian with both Yongquan Kd-1 points on the bottom of the patient's feet and imagine the energy simultaneously traveling down the outside of both legs into the feet. Imagine the energy from the feet continuing to travel along the inside of both legs back into the patient's Lower Dantian area. Hold this intention for several breaths, then proceed to the next area.
6. Energize the patient's Yellow Court by holding the mind's intention there for several breaths. Your left hand is placed on the Jizhong GV-6 point, your right hand should be placed on the Juiwei CV-15 point. Mentally connect the Yellow Court with the patient's Lower Dantian, allowing this energy to connect and fuse both areas. Hold this intention for several breaths, then proceed to the next area.
7. Energize the patient's Middle Dantian by holding the mind's intention there for several breaths. Place your left hand on the Shendao GV-11 point, while your right hand is placed on the Shanzhong CV-17 point. Mentally connect the Middle Dantian area with the patient's Lower Dantian. Hold this position for several breaths, then proceed to the next area.
8. Energize the patient's throat area by holding the mind's intention on that specific area for several breaths. Your left hand is placed on the Dazhui GV-14 point, while your right hand is placed on the Tiantu CV-22 point. Mentally connect the throat area to the Middle Dantian area, then to the patient's Lower Dantian. Hold this intention for several breaths, then proceed to the next area.
9. Energize the patient's Upper Dantian area by holding the mind's intention there for several breaths. Your left hand should be placed to stimulate the occipital region at the Naohu GV-17 point. Your right hand is simultaneously stimulating the Yintang (Third Eye) and Baihui (GV-20) areas. Mentally connect the Upper Dantian area to the Middle Dantian first, and then to the patient's Lower Dantian. Hold this intention for several breaths, then proceed to the next area.
10. Regulate the patient's Microcosmic Orbit, to balance the Heart Fire and Kidney Water energy. Remove your hands from the patient's body, yet still remain energetically connected through your intention. Having stepped away from the treatment table, continue treating the patient with external Qi emission, regulating the patient's Microcosmic Orbit (extending energy up the Governing Vessel and down the Conception Vessel). Hold this intention for several breaths, then proceed to the final step in the treatment.

11. Envelop and seal the patient's three external fields of Wei Qi by connecting the patient's body with the divine energetic field. Hold this intention for several breaths, then proceed to the "closure."
12. Disconnect yourself from the patient and close the healing session. Be sure to disconnect physically, mentally, emotionally, energetically, and spiritually from the patient by willfully detaching all energetic connections to the patient.
13. After disconnecting from the patient, center yourself, then regulate your own energetic fields to balance, recharge, and replenish any energetic depletion.
14. Finally, after you have completed centering yourself, finish the cleansing by washing your hands to purge any of the patient's lingering pathogens which may still be attached to your body.

GENERAL THERAPEUTIC TREATMENT

The following is an example of a clinical routine used in the Medical Qigong Clinic for "emotional purging." The following purging routine is separate from the previous clinical modalities for tonifying a patient. It is important to note that when treating a patient, the Qigong doctor usually purges the patient's Liver and Lungs before tonifying the Spleen and Kidneys.

After completing the diagnosis, if you have determined that the patient has both Excess and Deficient conditions, you may decide to continue the treatment as follow.

1. Begin by dredging, purging, and activating (energizing) the patient's Upper Dantian area to reconnect the patient to the divine, to activate the patient's spiritual/emotional presence.
    a. Start by purging the patient's Upper Dantian.
    b. Then regulate and energize the patient's Upper Dantian by performing a small Microcosmic Orbit within the patient's head.
    c. Finally energize the patient's Taiji Pole through the Baihui area.
2. Purge and dredge the patient's Lungs, to disperse the emotions of grief and despair caused by "rejection, betrayal, and abandonment issues" which are stored in the patient's Lungs.
    a. Start by dredging the patient's neck (trapezius, clavicle, and manubrium) of grief and despair. Begin by standing on the right side of the patient's body, and use the Kneading Tiger Palm and Dragon's Mouth Palm hand techniques (see Chapter 33) to pull the Toxic Qi from the patient's body. Switch from the right to the left side and continue purging.
    b. Then roll the patient's shoulders back to open the Lungs and to facilitate their purging of any deep seated grief. Start on the left Lung first. This area is responsible for storing the emotions related to the patient's mother.
    c. Next dredge the inside Yin Channels of the patient's left arm by using Qi Massage techniques (see Chapter 37).
    d. Regulate and treat the patient's body through "hand diagnosis and treatment" (based on energetic hand/body association, see Chapter 25) by focusing on the patient's left hand.
    e. Finally, begin the entire Lung purging procedure again, this time focusing the attention on the right side of the patient's body. This side reflects the patient's issues with his or her father.
3. Regulate and tonify the patient's Heart to calm the Spirit.
    a. Your left hand connects and extends energy deep into the patient's Shendao GV-11 point, the area in-between the patient's shoulder blades. Your right hand connects to the Shanzhong CV-17 point above the patient's Heart, purging emotional toxins.
    b. Finally, regulate the Heart by circulating Qi through the patient's upper Microcosmic Orbit (between patient's Upper and Middle Dantian). This reconnects the divine light emanating

from the Upper Dantian back with the spiritual emotions (unconditional love, devotion, etc.) stored within the upper chamber of the Heart (see Chapter 5).

4. Purge and dredge the patient's Yellow Court to rid the body of toxic emotions stored within the tissues of the Yellow Court. Your left hand remains secure on the patient's back, at the Shendao point to maintain contact with the Heart Qi. The patient's true feelings are stored within the Yellow Court and expressed through the patient's Heart. Place your right hand on patient's Juiwei CV-15 point, located below the patient's xiphoid process. Sometimes you may see images of the patient's past as traumas are released from the tissues.
5. Your left hand remains secure on the patient's back, at the Shendao point while your right hand purges the patient's Liver organ of anger and depression caused through the storing of "rejection, betrayal and abandonment issues." As you dredge the Liver's Hot toxic emotions from out of the patient's body, purge the pathogens out the patient's right Gall Bladder Channel.
6. Keep your left hand on the patient's back, at the Shendao point while you tonify and regulate the patient's Spleen with your right hand.
7. With your left hand on the patient's back, at the Shendao point, tonify and regulate the patient's Kidneys with your right hand.
8. Maintain contact with the patient's back, at the Shendao point, as your right hand connects with the patient's Mingmen (GV-4) area to regulate all three Dantians. This is initiated through the Microcosmic Orbit (extending energy up the Governing Vessel and down the Conception Vessel), to balance all of the patient's energetic reservoirs.
9. Then slowly remove your hands from the patient's body, but remain energetically connected through intention. Step away from the treatment table, as you continue to regulate the patient's Microcosmic Orbit. Hold this intention for several breaths, then proceed to end the treatment.
10. Envelop and seal the patient's three external fields of Wei Qi, by connecting the patient's body with the divine energetic field. Hold this intention for several breaths, then proceed to the "closure."
11. Disconnect physically, mentally, emotionally, and spiritually from the patient to close the healing session. It is important to shake or whip your palms to completely disconnect from the patient's energy. The shaking or whipping action frees the doctor from any energetic attachment which may have occurred while treating the patient.
12. After disconnecting from the patient, center yourself, then regulate your own energetic field. This balances, recharges, and replenishes any energetic depletion you may have suffered during the treatment session. If you are affected by any pathogenic Qi, immediately expel it from your body.
    a. Next, focus your attention on your Taiji Pole, imagining both the universal and environmental energy collecting, absorbing, and resonating deep within your Lower Dantian and center core. This image draws Qi into your body like a magnet, replenishing any energetic depletion you may have experienced. By placing the fingertips together in front of the Lower Dantian, you will further facilitate the replenishment of the energy.
    b. During this time the patient is allowed to continue relaxing on the treatment table and to slowly come out of the trance state induced by the treatment. The patient should then allow the Yuan Qi to settle back to its origin (the Lower Dantian), by relaxing and calming the mind, breathing, and posture. Instruct the patient not to wash the area that was treated for several hours because water absorbs some of the Qi that was projected into the diseased area.
13. Finally, wash your hands, using tepid water (hot water allows turbid Qi to enter the

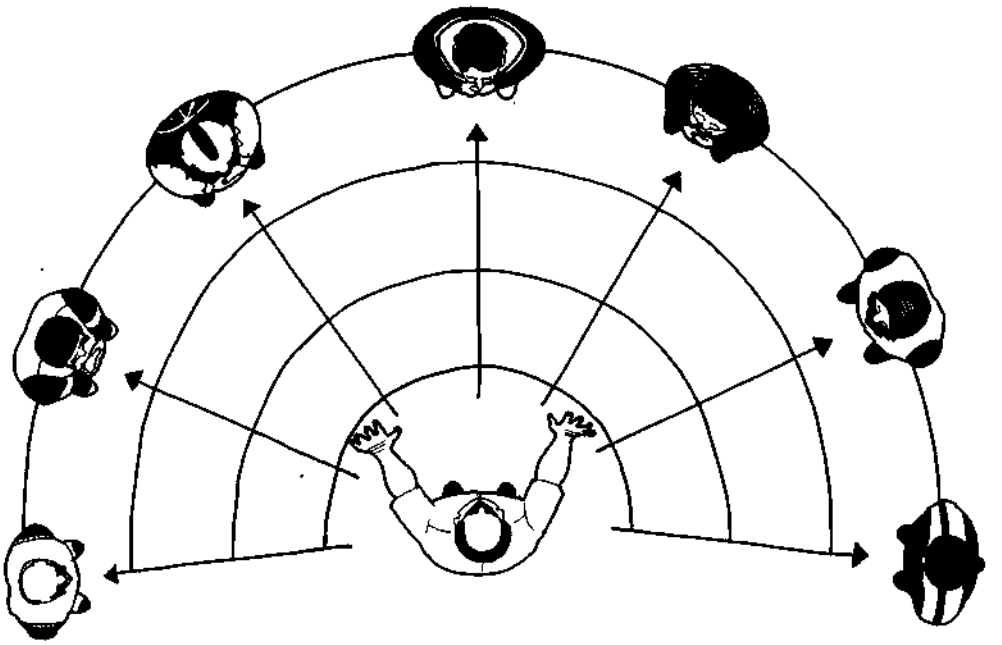

Figure 26.7. As the patients practice their own individual Medical Qigong prescriptions, the Qigong doctor extends energy into the patients, helping to facilitate a stronger therapeutic reaction.

doctor's channels, cold water closes off the channels) to purge any of the patient's lingering pathogens.

Adjusting and Fortifying the Patient's Energetic Grids

At the end of the treatment the doctor regulates the patient's energetic fields by adjusting and fortifying the patient's energetic grids (the webbing within the patient's energetic fields). This keeps the patient's energy in harmony, allowing both his or her internal and external fields to operate at their maximum potential for health and healing.

The Qigong doctor adjusts and fortifies the patient's energetic grids, to initiate a permanent energetic transformation for healing within the patient's energetic fields, tissues, and cells. The body's energetic grids are responsible for tissue formation and for maintaining the production, growth, and development of energy. These grids are influenced by thoughts and emotions.

The creative subconscious mind maintains the body's energetic grid formations and causes the physical body to act (grow stronger or weaker) in accordance with the energetic "blueprint" encoded within the structure or webbing. After the Qigong doctor has changed, or corrected, the energetic grid, the patient is given Medical Qigong prescriptions (homework) in the form of visualizations and affirmation meditations, as well as Qigong exercises.

Treating Multiple Patients

Once an energetic field in the treatment room is established, the patients can begin their individual Qigong regulations. The doctors position themselves according to the number of patients needing treatments; for example, one doctor may be positioned in front of several patients and extend Qi into the patients' energetic fields (Figure 26.7). The doctors' postures and energy extension varies according to their individual skill and energy projection level. It is important for Qigong

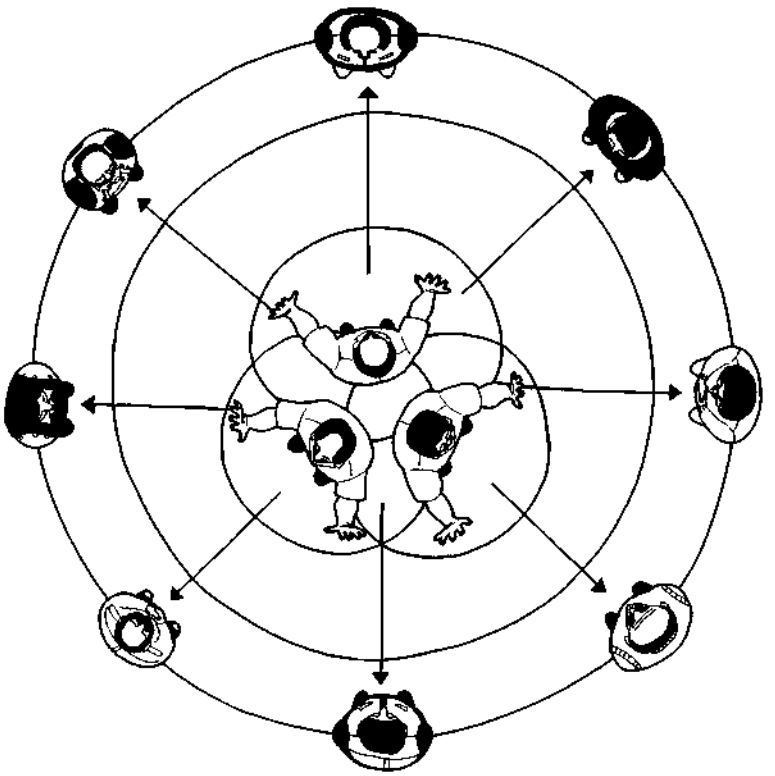

Figure 26.8. The Qigong doctors will position themselves back to back, in the center of a circle, in order to induce energetic movement within the multiple patients' tissues.

doctors to set the pace for treatment. The patients' rhythm is based on the pulse and vibration of the Qigong doctors.

In China, doctors usually rotate every fifteen minutes when treating patients. This prevents the doctors from fatiguing while allowing the patients to absorb new and fresh Qi every fifteen minutes.

If only one or two Qigong doctors are available when treating several patients, then the doctors will position themselves back to back in the middle of the room, with their patients surrounding them in a circle (Figure 26.8). After several minutes the doctors will slowly begin to rotate the center circle extending their energy, and treating each patient individually. The doctor's emitted Qi combines and synergizes with the patient's Qi to produce a much stronger energetic healing field.

By establishing a treatment room that facilitates the regulation of the patients' Qi, the treatments tend to become more effective with faster results. In China, patients are treated in a group treatment room environment three times every day (sunrise, sunset, plus one time before bed).

ENDING THE TREATMENT

When the treatment is over, encourage each patient to relax and then return the patients' Qi back to its origin (the Lower Dantian). The duration of the treatment time, and proper recuperation after Medical Qigong treatment will be addressed next.

DURATION OF TREATMENT TIME

The duration of treatment time varies according to each patient's disease, condition, constitution, and age. A long treatment is usually between twenty and thirty minutes and is generally performed on cancer patients, senior citizens, or for severe traumatic or chronic illnesses. A short treatment is generally between three to fifteen minutes and is usually administered for athletic sprains and ligament dislocations.

PROPER RECUPERATION AFTER MEDICAL QIGONG TREATMENT

Proper recuperation is very important for the replenishment of strength and energy after the treatment session (even after the patient's own prescription practice). This may include having the patient change his or her life activities. The patient must incorporate a balance of work and rest, and acquire regular healthy eating habits (with reasonable nutritional goals). Establishing adequate sleeping patterns is also necessary. Of equal importance is an open-minded positive attitude by the patient, for this reason, a supportive network can be invaluable.

After the Qigong treatment the patient is also encouraged to avoid cold showers, the consumption of alcohol, excessive sex, and recreational drugs. Also prohibited is anything that will emotionally shock the patient, as remaining in a quiet state of mind and spirit is essential.

Chapter 27
Combining Medical Qigong Therapy with Other Healing Modalities

Combining Medical Qigong Therapy with TCM Modalities

Traditional Chinese Medical treatments in conjunction with clinical Qigong modalities are generally broken down into exclusive Medical Qigong Therapy, Medical Qigong and Chinese Massage Therapy, Medical Qigong and Acupuncture/Moxa Therapy, and Medical Qigong and Herbal Medicine Therapy.

Exclusive Medical Qigong Therapy

Medical Qigong therapy can be administered by the Qigong doctor (Figure 27.1) to tonify and promote energy circulation or to sedate the body's energetic channels and collaterals. Qigong prescriptions can also be given for the patient to practice alone. Medical Qigong therapy by itself is excellent for the treatment of ailments such as:

- Insomnia
- Neurasthenia (Chronic Fatigue)
- Hypertension
- Stroke
- Acute abdominal pain
- Injuries to the nerves
- Hemopleura (Blood in the walls of the thorax and diaphragm, along the pleural space)
- Myopia
- Migraines
- Muscle atrophy
- Sprains
- Cancer
- Tumors
- Cysts

Medical Qigong and Chinese Massage Therapy

Medical Qigong therapy in conjunction with Chinese Massage therapy is a powerful form of combined clinical modalities (Figure 27.2). It enhances tissue response as well as the activation of psychophysical reactions within the body. These therapies can be combined to clear the joints before setting the bones (as in Jie Gu therapy), to purge and dredge the channels to adjust the Qi circulation before regulating the body's muscular system (as in Tui Na and Gua Sha therapies), or to disperse toxins before regulating the body's internal viscera

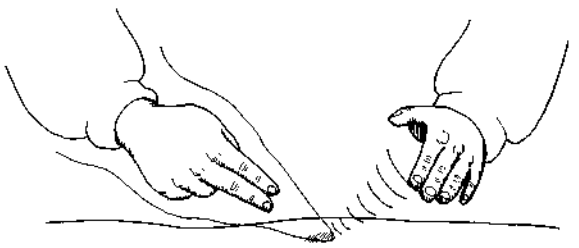

Figure 27.1. Medical Qigong Therapy

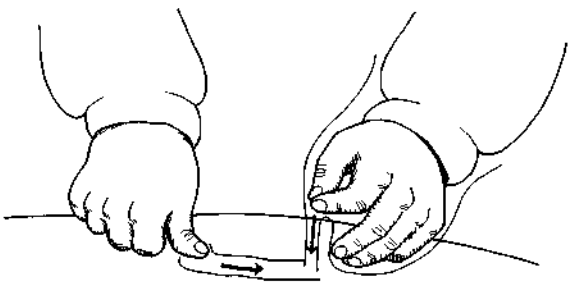

Figure 27.2. Medical Qigong Therapy with Chinese Tissue Regulation Therapy

(as in An Mo and Jing Point therapies). Qigong and Chinese Massage therapy are most commonly used in the treatments of patients with:

- Deep tissue obstruction
- Stiff muscles
- Frozen shoulder
- Low sensitivity to emitted energy

MEDICAL QIGONG AND ACUPUNCTURE/MOXA THERAPY

Acupuncture needles are inserted into the patient's body before the doctor extends Qi into the patient to facilitate healing (Figure 27.3). This also applies in the treatment of Moxa sticks in which the doctor extends energy into the patient through the burning herb. The combined energies (the Moxa heat and doctor's own Qi) initiates increased Qi flow within the patient's channels resulting in a stronger tonification. Moxa is especially beneficial in the treatment of arthritis. Qigong and Acupuncture therapy are combined in tonification or purgation treatment.

MEDICAL QIGONG AND HERBAL MEDICINE

Medical Qigong Therapy in combination with herbal therapies (or with pharmaceutical prescriptions) are becoming more popular. There is ample evidence that the combination of self-applied Medical Qigong therapy and drug therapy is far superior to that of drug therapy alone. In China, this data is reported in several studies of patients with hypertension as well as in cancer patients.

Medical Qigong therapy relaxes the body, promotes the flow of Qi, Blood, oxygen, and nutrients to all cells of the body, as well as promotes the removal of waste products from the cells. Medical Qigong also promotes drug uptake by the cells and tissues by means of increased microcirculation within the body's microcirculatory system. This increased Qi flow through the body's microcirculation nourishes diseased or stressed tissues.

One diagnostic herbal technique I observed at the Xi Yuan Hospital was performed by a Qigong doctor who absorbed into his body the effects of a specific medicine by touching the bottle that contained the herbs. He then extended energy to his patient and began absorbing the patient's Qi to see if the patient's body was affected by the herbal prescription (Figure 27.4).

The Qigong doctor is encouraged to prescribe herbs along with certain of the Medical Qigong exercises. If the Qigong doctor is not qualified to prescribe Chinese medical herbs, then a referral can be made to an acupuncturist/herbalist. The herbal prescriptions will vary according to the patient's condition, constitution and illness.

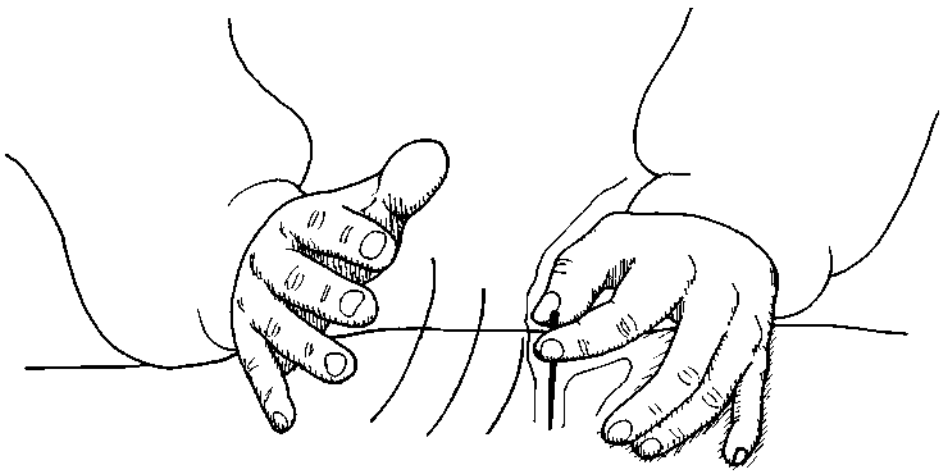

Figure 27.3. Medical Qigong Therapy with Acupuncture

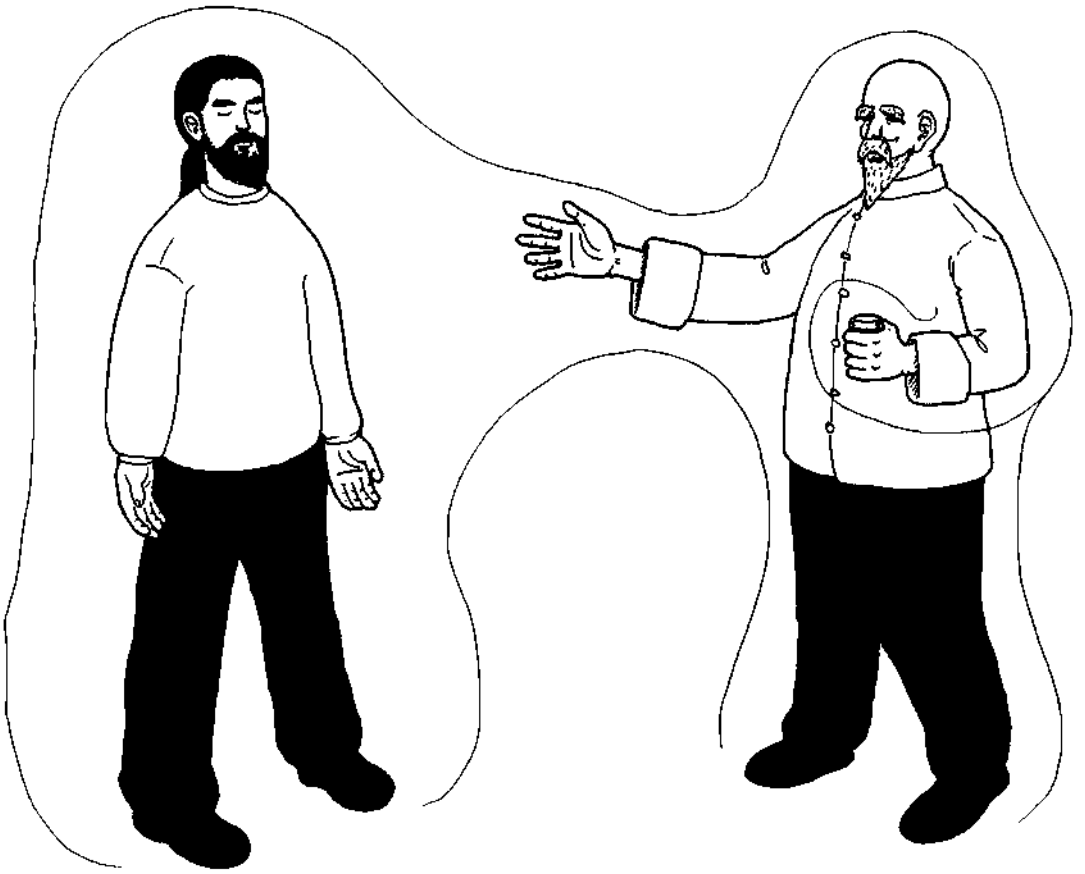

Figure 27.4. A Qigong Doctor Testing the Efficacy of a Specific Herbal Medicine for his Patient

Qigong and herbal therapies are most commonly used in the treatments of:

- Tumors
- Stomach cancer
- Lung cancer
- Hepatitis
- AIDS
- Stroke

COMBINING MEDICAL QIGONG THERAPY WITH WESTERN MEDICAL MODALITIES

Traditional Chinese Medical Qigong serves as a powerful tool in aiding Western medical approaches in alleviating patients' suffering. Because of its emphasis on mental, emotional, energetic, and spiritual approaches to healing, Medical Qigong therapy has been successfully combined as a complementary source of medical treatment with the following Western professional approaches:

- Pediatrics
- Geriatrics
- Gynecology
- Neurology
- Psychology
- Oncology
- Surgery

Chapter 28
Precautions and Ethical Considerations for the Qigong Doctor

Avoiding Energetic Depletion

Because Medical Qigong therapy consumes energy, as long as the Qigong doctor's quantity of energy is higher than that of the patient's, the doctor can transmit energy into the patient with no ill effect. If, however, the doctor is very tired or depleted and tries to treat a patient, the energy that the doctor is able to produce may become weaker than that of the patient.

It is important to note that energy currents flow from high to low (much like water). Therefore, the doctor may, if in a weakened state, absorb the Turbid Qi or disease energies from the patient. Any imbalance in the doctor's organ system can increase the doctor's vulnerability to foreign pathogens. These pathogenic sensations may also be transmitted into the body of healthy people, or other patients as well. Individuals who have not practiced Qigong, however, and whose energy circulation and channel points are not open, are not as prone to interference by these sensations. These individuals have a natural barrier, or to put it plainly, they are not sensitive to energetic fields of transmission and because of their denial system, cannot perceive energy sensations.

If the Qigong doctor already has a tendency towards a particular illness, exposure to pathogens may instigate or intensify the disease. If the doctor is suffering from any energetic Deficiencies, for example, the end result may be that the doctor performing the treatment may experience Qi deviations due to absorbing the patient's Toxic Qi. This means that more Qi and energy have been extended outside of the doctor's body than can be replenished, weakening the doctor's energetic constitution.

When treating patients the doctors receive and diagnose information from their Six Openings (also called the Six Windows of the Body). These Six Openings are described as follows:

- The eyes -- open for seeing energy patterns and colors,
- The ears -- open for hearing energy patterns and tones,
- The nose -- opens for smelling different odors,
- The tongue -- opens for tasting or flavor sensing,
- The body -- opens for energetic feeling sensations, and
- The Spirit (Heart/Mind) -- opens for energetic perceptions of emotions, thoughts, and spiritual insight.

While using the Six Openings for diagnosis, the doctor naturally depletes some life-force energy. Since all five organs (eyes, ears, nose, tongue, and body) are directed by the doctor's Spirit (Shen), the expenditure of energy is considerable. Any imbalance due to organ depletion will cause the doctor to absorb Turbid Qi from the patient. This Turbid Qi can move within the doctor's body causing Qi deviations, especially if it mixes with the doctor's Clear Qi.

1. If this happens within the doctor's Upper Dantian, the symptoms may include mental fatigue, dizziness, headaches, etc.
2. If this happens within the doctor's Middle Dantian, the symptoms may include emotional fatigue, discomfort in the Liver (hepatic region), etc.
3. If this happens within the doctor's Lower Dantian, the symptoms may include physical fatigue, cold in the extremities, discomfort in the lower abdomen, etc.

This is why Qigong doctors must constantly be refilling and rebalancing themselves energetically. It is important to note that if the Qigong doctor has indeed ingested the patient's pathogens, and Qi deviations have resulted, no Western doctor, acupuncturist, or herbalist can help

him or her. Only the doctor with the Qi deviation (or with the help of another Qigong doctor) can change the Turbid Qi back to Clear Qi, by using divine energy and purging the body's Shen, Qi, and finally the Jing. This supports the doctor's Righteous Qi and fights the invasions of the patient's pathogens.

Emission of Qi should also be avoided if the doctor becomes sick, tired, hungry, overfed, deeply grieved, indignant, or drunk. Also, if the doctor is unable to stay in the present mind-frame he or she will inevitably fall asleep or "Shen out." To avoid this state of depletion, the Qigong doctor should:

- Cut back on the number of patients,
- Decrease treatment time—from 25 to 20 minutes maximum,
- Maintain a consistently healthy diet with supplements,
- Receive frequent exposure to fresh air and sunlight, and
- Perform the Microcosmic or other regulating Qi meditations in between patients.

Note: When treating patients with Medical Qigong therapy the doctor should never wear the color red. The color red is too hot and has a dispersing affect on Qi, which tends to scatter the body's energetic fields, distorting the Qigong doctor's Qi emission.

PREVENTING THE INVASION OF TURBID QI

When Turbid Qi enters the doctor's body, it interferes with normal Qi circulation, causing disorders in part of, or in all of the energy circulatory system. In mild cases, Qi may stagnate in a certain areas of the body (i.e., shoulder, arm, chest, or back), causing physical and mental symptoms.

- Physical symptoms may include: tingling, pain, cold, contraction, heaviness, soreness, and distention and stuffiness in the chest; and
- Mental symptoms may include: interference with mental activity, causing dizziness, headache, heaviness in the head, vexation, and restlessness.

In severe cases, the doctor may experience the same symptoms as the patient, but upon physical examination there is no verification of any existing disease. The doctor should therefore be on the alert to avoid any danger of developing symptoms from the patient after Turbid Qi is perceived.

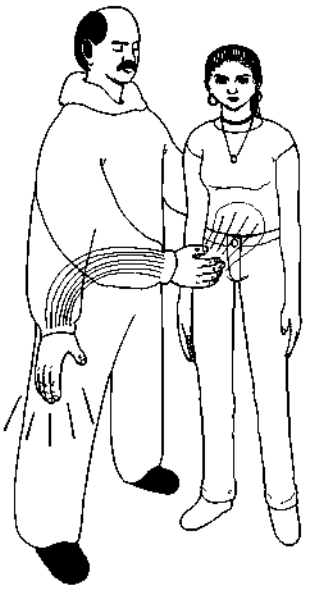

Figure 28.1. In order to disperse the patient's Evil Qi, the Qigong doctor exhales while slinging the toxic energy into the Earth.

It is very important for doctors who treat patients with Medical Qigong therapy to possess the ability to prevent and expel Turbid Qi so that it will not disturb their own energetic activities. Qi deviations are most often seen in those individuals who treat patients after they have gained some knowledge of Medical Qigong but have no experience, though they can occur even to some veterans of Medical Qigong practice. The interference by Turbid Qi is often an important factor in the the doctor's health.

When the interference by Turbid Qi is perceived, the doctor should use proper hand manipulations and readjust energy activities to expel the Turbid Qi immediately. If the Turbid Qi invades the doctor's fingers, or penetrates into certain channels or points, the doctor should guide the Qi to the specific points, channels, and infected areas and then relax and shake the hands to discharge the Turbid Qi while exhaling.

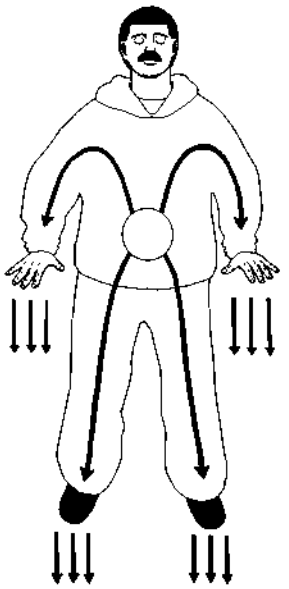

Figure 28.2. The Qigong doctor gathers energy into his or her Lower Dantian and expels any and all pathogenic invasions out through the hands and feet.

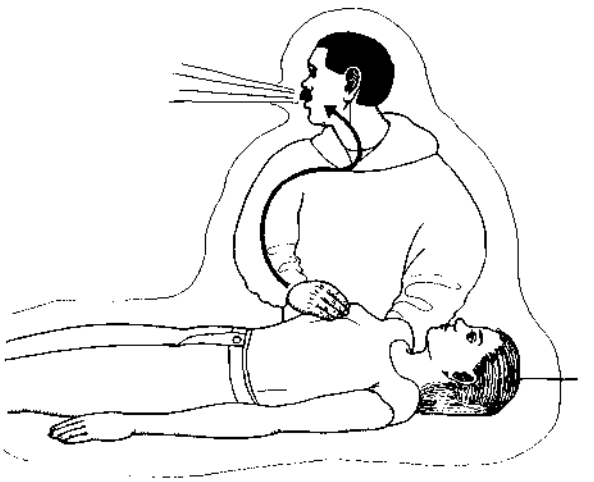

Figure 28.3. To avoid absorbing the emotions from an energetic discharge (released from dissolving an energetic cluster), the Qigong doctor turns his or her head and expels the patient's toxic emotions.

The doctor should be able to stop the Turbid Qi before it reaches the Dazhui GV-14 point on the upper back, Tiantu CV-22 point at the base of the throat, Quepen St-12 points on the front of the shoulders, and the Fengfu GV-16 and Fengchi GB-20 points on the back of the head. It is important to expel the Turbid Qi when it has reached the fingers, wrists, elbows, and at most the shoulders.

When this occurs the doctor should drive the Evil Qi out and regulate his or her Qi circulation as soon as possible. There are several ways to do this:

- Exhale while swinging the arms toward the ground, driving the Evil Qi deep into the center of the Earth. When treating tumors, be careful to disperse the pathogens out your fingers and do not allow the toxins to stick to your palms (Figure 28.1).
- Exhale while "blowing Qi" (extending Qi) out of the palms (Pc-8) and feet (Kd-1) (Figure 28.2).
- Exhale out of the mouth (but never over the patient, or towards anyone else). A shift in breathing is a common reaction when the emotions are discharged, or when an energetic cluster is reached (Figure 28.3).

GUIDELINES FOR THE MEDICAL QIGONG DOCTOR

1. The Qigong doctor must avoid practicing Medical Qigong in wet clothes. If the doctor perspires a little when training, he or she should avoid standing in the wind; if the doctor perspires profusely, practicing should be discontinued as it is liable to damage the doctor's Yin Qi.
2. The doctor should not go to the toilet within half an hour after practicing in order to avoid developing a conditioned reflex. This will help prevent the leakage of vital energy.
3. Patients suffering from cancer may affect the doctor's Qi circulation more seriously. Care should be taken when treating these patients, or avoid treating them completely, until sufficient energy has been cultivated, and sufficient experience has been gained.
4. The doctor must always wash his or her hands

with soap after each patient's treatment to prevent the energetic transference of diseases. It is important to note that washing the hands in cold water immediately after Qi emission is harmful to the doctor's energetic field because of the sudden shock to the system. Washing with hot water immediately after treatment, opens the channels on the doctor's hands and arms, sending the Toxic Qi deep into the doctor's body. To avoid these complications, the doctor should wait several minutes after completing the treatment, before washing his or her hands.

While waiting, the doctor should touch his or her finger tips together and focus on the Lower Dantian, allowing the Qi to settle back into its origin (minimum of three minutes). The doctor then washes up to the elbows with water that is room temperature to reduce the possibility of absorbing the patient's Turbid Qi.

If the doctor is not able, during treatment, to expel the Turbid Qi right away because of some distraction, or if the doctor's internal energy is not substantial, the Turbid Qi may enter his or her body through the fingers traveling up the wrists, elbows, or entering the Baihui GV-20, Tanzhong CV-17, Fengchi GB-20, Yintang (Extra Point) and Yongqauan Kd-1 points. If this begins to happen, the doctor should not continue to extend energy, but should stop the treatment immediately and perform a "closing," expelling the Turbid Qi by flicking the fingers, wrists, and shaking the arms until all discomfort has been eliminated. If any Turbid Qi still lingers, the doctor should practice Medical Qigong exercises to regulate the energetic activities.

5. It is important that doctors, as well as patients, avoid strenuous activities (such as running immediately after Medical Qigong exercises) to prevent the wrong flow of vital energy or pain in the legs. It is always better for the doctors and patients to be active first (running, swimming, forms training, etc.) and then cool down with the Medical Qigong Quiescent exercises (unless otherwise prescribed).

WU ZANG (FIVE ORGAN) MEDITATION FOR ENERGETIC PROTECTION

Even after the treatment of diseases, the doctor must perform certain Medical Qigong exercises to prevent and expel any undetected pathogenic Qi. Otherwise the doctor may develop the symptoms of the illness of the patient in corresponding locations. For instance, if the patient has a headache or pain in the hepatic area, the doctor may also acquire a feeling of discomfort, numbness, itching, and pain in the head and hepatic region. Therefore, in clinical practice, a deep understanding and correct judgment of the pathogenic Evils is compulsory.

Today in China, the Wu Zang meditation is still taught to Qigong doctors for clinical use to prevent invasion from the patient's pathogenic Qi. This meditation requires the doctor's Shen to guide the Qi of the Five Yin Organs (also known as the Wu Jing Shen, see Figure 28.4), to make the body's Qi substantial. The ending of the meditation, which causes the doctor's Qi to be reabsorbed into the Taiji Pole, allows the transformed Qi to flow into the appropriate organs, strengthening the doctor's energetic fields.

When a Qigong doctor enters the space of a diseased patient, the potential for absorbing the patient's pathogenic Qi is high. Noting this potential for harm, the ancient Chinese Qigong masters developed certain meditations to protect themselves from the patient's diseased or Turbid energy.

The Yellow Emperor's Classics on Internal Medicine states that before treating patients of any kind, the doctor should first perform the Wu Zang Energy meditation. It encouraged doctors to practice this meditation before treating patients in a clinical environment and before entering the treatment room, because it surrounds them with a strong field of protective energy (Wei Qi).

The Wu Zang meditation focuses on six directions (north, south, east, west, Heaven and Earth). It is very powerful and can be used to gather environmental Qi at the beginning of each season. The focus of the meditation is to extend each of the five organs' energy far into the horizon to gather the Qi. When practicing the Wu Zang

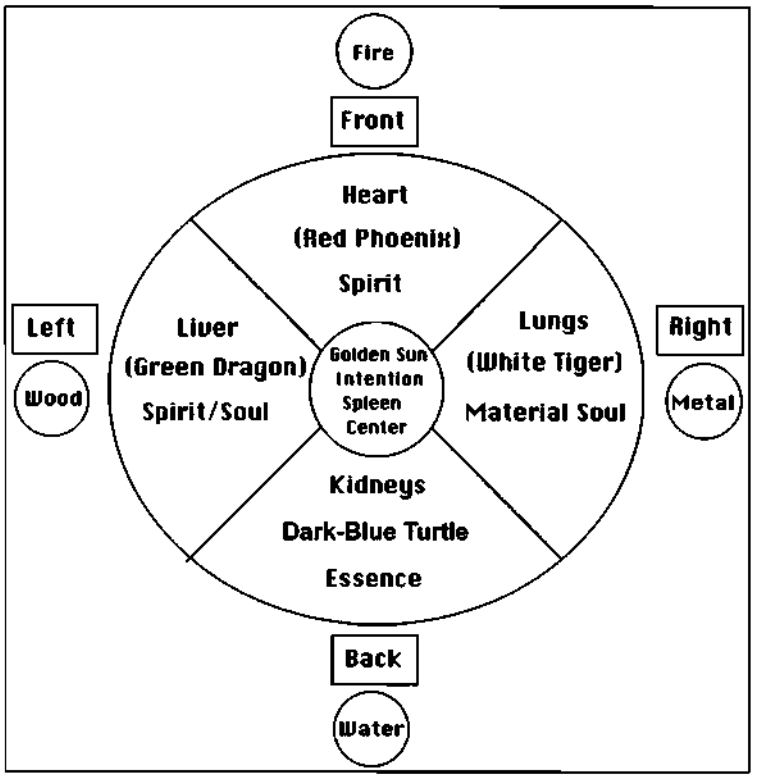

Figure 28.4. The Wu Jing Shen Relationship of the Wu Zang Meditation

meditation the Qigong doctor should:

- face east during the spring equinox;
- face south on the day of the summer solstice;
- concentration on the center of the Earth during late summer, before the fall equinox;
- face west on the day of the fall equinox;
- face north on the winter solstice.

Start by focusing on the center of the body. Imagine opening up the Baihui point (at the top of the head) and begin to pull in the Qi from the Heavens. Imagine the divine light as a bright shining white light, illuminating and filling your entire body through the Baihui. Feel the body radiating this divine white light energy. Next, imagine this white light energy coalescing into the body's center core, forming an energetic tube of Heavenly energy that extends from the Baihui point to the Huiyin point. The center core vibrates and resonates with the divine white light energy.

1. Now, imagine a golden yellow mist of Qi arising from under the Earth and filling your body and connecting with the Spleen organ. Next, feel this golden light Earth energy envelop the center core of divine white light energy, merging together and synergizing. This represents the energy of your Yi (Intention), to root and stabilize your power.
2. Begin to focus on your Heart and imagine a portal opening and the Qi flowing out of your Heart like a red swirling wind in front of you, full of power, protecting you with your Shen and the fire of a red phoenix. This represents your innate spirit, alive, graceful yet powerful.
3. Focus your attention on your back and the Kidneys and Mingmen area. Imagine a portal opening and the Qi flowing out of your Mingmen behind you like water. Out of this water grows an enormous dark blue turtle,

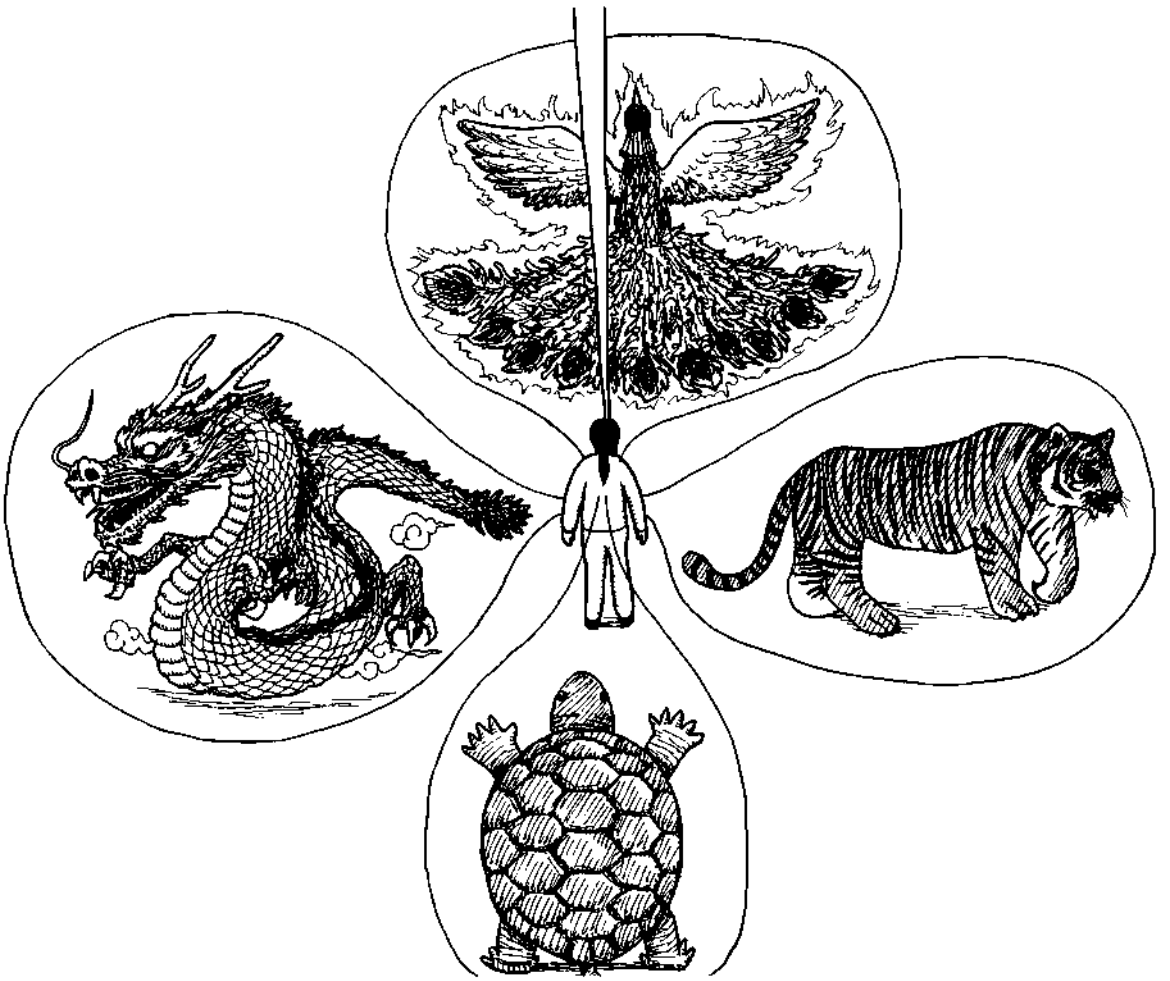

Figure 28.5. The Wu Zang Meditation

whose shell protects you like a mighty shield. This represents the energy of your Zhi (Willpower), and the Jing and Zhi of all your ancestors, backing you and supporting you.

4. Place your attention on your Lungs and visualize a portal opening on your right side of your body, under the right ribs. Imagine the Lung Qi flowing out of to the right side of your body like steam, forming a white tiger, as strong as steel. This represents the Po and the body's animal nature, that guards and protects you with an animal passion for survival.
5. Next, place your attention on your Liver and visualize a portal opening on your left side of your body, under the left ribs. Imagine the Liver Qi flowing out of to the left side of your body like steam, forming a green dragon, sinewy and resilient as bamboo. This represents the Hun and the body's divine nature, guarding and protecting you with a spiritual passion for victory.
6. Each animal begins to rotate to the left, protecting, stalking, and defending the previous animal's position (Figure 28.5). Slowly begin

to circle these energies, then increase their speed (like a mighty wind) counterclockwise around your body, blending these colors together, to form an energy bubble.

After forming a protective rainbow hue around your body, draw the energies back in through the Baihui point and return the energy of each organ color back to its origin (the color red returns back to the Heart, dark blue to the Kidneys, white to the Lungs, and green back to the Liver). As the colors return back to their organ of origin, imagine steam (white light) flowing out of the pores and filling up the energy bubble created by the animal rotation. This forms a solid connection between the body's internal organs and the body's external field of energy.

7. When the protection of the body with the Five Elements is done, imagine that there are many sparkling lights like the Big Dipper above your head. Then you can enter the room of the patient, safe and protected.

Keep in mind that you can send the five organ energy outside of your body instantly, any time you need protection. Some schools teach the doctor to extend his or her energy like mist out through the eyes, enveloping the body with the five organ colors (green, red, yellow, white, and dark blue/indigo).

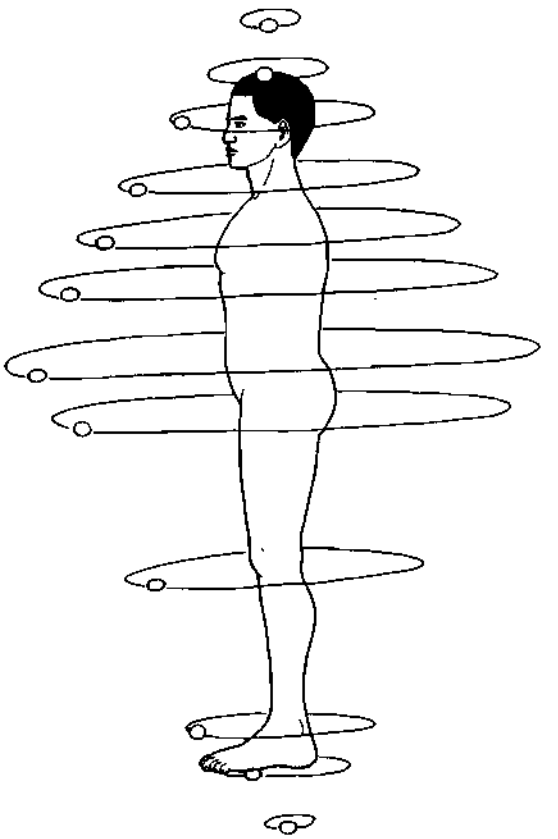

Figure 28.6. Creating a Protective Energetic Forcefield

CREATING A PROTECTIVE ENERGETIC FORCE FIELD

This second meditation also establishes a powerful energetic force field, needed to protect the doctor from any attack or attachment of external pathogenic Qi. It consists of wrapping the doctor's external fields of Wei Qi to increase the energetic field's power.

This is similar to wrapping a magnet with coils of wire to increase its magnetic field (Figure 28.6).

1. Begin from a standing Wuji posture. Focus on all the body's energy collecting into the Lower Dantian. Concentrate the Qi in the Lower Dantian, condensing it into a dense ball of white light energy. Imagine this ball of white light energy exiting the body through the navel and circling the body, spinning in a counterclockwise direction nine times, wrapping the Belt Vessel, Mingmen GV-4 and Shenque CV-8 points.
2. Move the energy ball down to the perineum and continue circling the lower body in a counterclockwise direction nine times, spinning and wrapping the Huiyin CV-1 and Changqiang GV-1 points.
3. Move the energy ball down to the knees and continue circling in a counterclockwise direction nine times, spinning and wrapping the ascending Yin channels and descending Yang channels of the legs.
4. Move the energy ball down to the ankles and continue circling in a counterclockwise direc-

tion nine times, spinning and wrapping the ascending Yin channels and descending Yang channels of the legs.

5. Move the energy ball down to the bottom of the feet and continue circling in a counterclockwise direction nine times, spinning and wrapping the Yongquan Kd-1 points.
6. Move the energy ball several feet into the ground and continue circling in a counterclockwise direction nine times, spinning and wrapping the body's Earth Transpersonal point. This energetic point (under the ground) is responsible for establishing the body's rooted connection to the Earth and for absorbing the Earth energy into the body's internal organs, channels, and collaterals.
7. Next, imagine the energy ball slowing down and stopping its rotation, pulsing for several heartbeats, then reversing its energetic rotation, and beginning to spin in a clockwise direction nine times. The direction and flow of the energetic ball now reverses its orbit, ascending and circling the same areas and points nine times, until it returns back to the navel.
8. From the navel move the energy ball up to the solar plexus area and continue circling the body in a clockwise direction nine times, spinning and wrapping the Jiuwei CV-15 and Zhiyang GV-9 points.
9. Move the energy ball up to the Middle Dantian at the center of the chest, and continue circling in a clockwise direction nine times, spinning and wrapping the Heart, Shanzhong CV-17 and Shendao GV-11 points.
10. Move the energy ball up to the throat and continue circling in a clockwise direction nine times, spinning and wrapping the Tiantu CV-22 and Dazhui GV-14 points.
11. Move the energy ball up to the Upper Dantian at the Third Eye area, and continue circling in a clockwise direction nine times, spinning and wrapping the Yintang and Naohu GV-17 points.
12. Move the energy ball up to the top of the head and continue circling in a clockwise direction nine times, spinning and wrapping the Baihui GV-20 point.
13. Move the energy ball several feet above the head and continue circling in a clockwise direction nine times, spinning and wrapping the body's Heavenly Transpersonal point. This energetic point (above the head) is responsible for establishing the body's extended connection to the Heavens and for absorbing the divine energy into the body's internal organs, channels, and collaterals.
14. Next, imagine the energy ball slowing down and stopping its rotation, pulsing for several heartbeats, then reversing its energetic rotation, and beginning to spin in a counterclockwise direction nine times. The direction and flow of the energetic ball now reverses its orbit, descending and circling the same areas and points nine times, until it returns back down to the navel. The body should now be encircled, above and below, with several haloes of white light energy.
15. Finally, imagine the white light energy ball absorbing back into the body through the navel. As the energy ball descends back into the Lower Dantian, imagine energetic steam filling the entire body.
16. Once the body is completely full, the steam begins to exit the body through the pores and begins connecting and filling the space outside the body with white light energy, forming an energetic cocoon. This cocoon creates an energetic force field which protects the Qigong doctor from pathogenic invasion.

CLINICAL ETHICS

The study of clinical ethics refers to the morality of the Qigong doctor and the ability to set boundaries. The study of morals in the therapeutic relationship involves reflecting upon the ideals the doctor assumes as a professional care giver and the enforcement of these professional standards in his or her actual behavior. Both the morality and the self reflection are engaged, both consciously and unconsciously, to align the doctor's values with his or her actions.

Ethical behavior stems from the doctor's internal values and actions (emotionally, cognitively, and spiritually) and his or her sense of external connection (physically, existentially, and socially). The Qigong doctor's behavior should be always congruent with high ethical standards and in harmony with his or her values, intuition, knowledge, and feelings.

The importance of establishing ethical standards for the doctor-patient relationship is to avoid those behaviors which prove to be counter therapeutic, and encourage those that are most effective therapeutically for the patient. The patient, as well as the doctor, rely upon each others' trust and boundaries. It is the Qigong doctor's responsibility to create a context for the patient, in which the patient can make a change in his or her life in safety.

When patients are treated energetically, they relax into an altered state of consciousness. This causes the patient's boundaries to become relaxed or nonexistent. Because Medical Qigong therapy often reveals intimate knowledge of the patient's life and life-style, there is a danger of enmeshment, i.e., of co-dependent relationships forming (see Chapter 19).

When working with patients, doctors sometimes encounter intense physical, mental, emotional, and spiritual reactions from the patients. These experiences tend to disperse the patients' boundaries and can confuse the roles between the doctor and patients, intensifying transference and triggering countertransference.

When both the doctor and patient have a personal relationship with a divine higher power, it naturally brings them into a state of divine healing and spiritual wisdom. The acknowledgment and honor of this divine relationship should establish ethical boundaries. This is especially true as the doctor begins to see the bigger picture of how his or her intentions and actions (in relationship with patients) affect others in a rippling outward motion. It is important that doctors also see the effect on themselves when they take certain actions towards others, including their patients.

Conscious and Subconscious Clinical Interactions

Clinical experiences are divided into two states of interactions: the body/mind and emotional/spiritual.

- The body/mind interaction deals with ordinary states of consciousness, such as: talking, thinking, analyzing, working, interacting with the material world and other human beings. These different qualities of interactions help the doctor to define and categorize, educate, and establish his or her solid belief structures.
- The emotion/spirit interaction deals with subconscious states of communication, such as: perceiving, sensing, intuiting, interacting with the spiritual/metaphysical world, as well as with energetic fields. Every day people go into states of light trance (daydreaming, spacing-out, etc.) allowing their focus of attention, thoughts, feelings, sensations, and intuitions to interconnect with their environment and that of the divine. This allows access to information and facilitates the healing and understanding of themselves and their life experiences.

Because most wounding involves an emotional/spiritual trauma at the time of the incident, the patients must relive this trauma during their healing process. Through the emotional/spiritual interaction between the Qigong doctor and his or her patients, ingrained habits of thought, feelings, and perceptual understandings begin to recede, diffuse and break down. This causes the patients to find a new understanding of certain traumas and allows them to reclaim disconnected parts of their past (soul retrieval).

Each time patients transcend to a new level of understanding of their fears and belief structures, they change, mature, and expand to adjust to the new mental, emotional, and spiritual growth. The moment that patients break out of their old boundary structure, feelings of emotion rush through their body/mind, followed by a sense of either expansiveness or disorientation as they find themselves in unfamiliar territory.

It is not useful for patients to relive their emo-

tional traumas without the awareness, understanding, and insight of the process they are undergoing. To relive the trauma without this awareness leads to re-traumatization. That is why the Qigong doctor coaxes the patients through the "five stages of emotional healing" (see Chapter 19). The patients can then experience their past emotions in the present time, and become free of them through present awareness, rather then repeating the past through a continuous loop of repression and denial. In the clinic, this is known as "emotional time traveling" and refers to the practice of allowing the patients the experience of reliving past traumas through their presently increased state of awareness and knowledge. At this point of transition, the patients will not only experience the emotions and sensations from their past, but may also experience the motivations and emotions of the perpetrators as well.

The empathic knowledge of the perpetrator's emotions is due to the victim's identification process with the abuser. This phenomenon is well recognized in helpless hostage situations, and is a major contributor to childhood victims of physical, sexual or emotional abuse "acting out" their repressed fears, angers, and pain, in similar ways to the manner in which they were abused.

ESTABLISHING DOCTOR AND PATIENT AGREEMENTS

For the protection and integrity of both the doctor as well as the patients, it is important that a description of the clinical procedures that are to be used, their physical and energetic boundaries, as well as their limitations, be firmly established. The following seven principles are used to establish the foundation of clinical ethics.

1. The Qigong doctor will cause no harm (physical, mental, emotional, or spiritual). The Qigong doctor will maintain a high standard of skill, knowledge, and professional conduct, offering his or her services without favoritism, prejudice, or discrimination with regards to race, religion, nationality, gender, or sexual orientation.

   The Qigong doctor is committed to the patients' education and personal development of practicing Medical Qigong methods that relieve pain, suffering, and other symptoms of illness. The doctor will exercise his or her best judgement to determine if the therapeutic techniques prescribed for patients are contraindicated, dangerous, or not in the best interest of the patients.

   The doctor will never make negative suggestions, criticize, or tell the patients that they will get worse or are in bad shape, as that destroys the patients' hopes and is counterproductive to healing (this is known as "clinical hexing"). Clinical hexing will cause patients, who trust the doctor, to sabotage their own healing potential by succumbing to the doctor's particular beliefs about their conditions.

   One example of trusting a doctor's diagnosis to ruin, happened last year in 1999, when two patients' lab tests were accidently switched. The healthy patient, whose lab test had been switched, was informed by the Western doctor that she had terminal cancer; and the patient with terminal cancer, on the other hand, was given a clean bill of health. The healthy patient died several months later as a result of believing the doctor's diagnosis of having a terminal condition; whereas the patient with terminal cancer (believing that there was nothing wrong) resumed a normal, active life-style, and the patient's cancer went into remission.
2. The Qigong doctor will keep all sessions in confidence. The Qigong doctor will keep all patient information strictly confidential, in keeping with ethical and legal standards held by other health care professionals. This allows patients to experience the treatment in safety and give honest feedback.

   Exceptions to the rule of confidentiality are as follows: when the patient is a danger to self (intending suicide), or others (intending homicide), when the patient has a life threatening emergency, in cases of suspected child abuse (sexual, physical, or neglect), and elderly abuse (sexual, physical, neglect or fiduciary).

3. The Qigong doctor will first receive informed consent from the patient before starting the treatment, or informed consent of the patient's legal guardian. Before treatment, the Qigong doctor explains to the patient the therapeutic goal of the treatment, and what the patient may energetically and emotionally expect to experience. The doctor will respect the patient's boundaries at all times, before, during, and after each treatment. At times the doctor may have to impose boundaries for patients who cannot do so for themselves, in order to avoid total enmeshment, which would endanger the professional relationship.
4. The Qigong doctor and the patient will tell the truth to each other. No part of the Medical Qigong diagnosis should ever be hidden from the patient, yet the truth should always be delivered with hope, since no one can be certain of the future.

   The Qigong doctor should never make unrealistic, inaccurate, or false claims about Medical Qigong therapy, or give the patient false hope. A realistic assessment of the patient's condition should always be conveyed, and if need be, the patient should be referred for additional medical or psychological modalities of treatment.
5. The Qigong doctor will honor all agreements established with the patient. It is important for the patient to be able to rely on the doctor's trust. Because this is a critical factor, the doctor is never allowed to borrow money, cars, etc. from patients.
6. The Qigong doctor and the patient will not act sexually or romantically with each other. The Qigong doctor will not instigate or tolerate sexual advances while interacting with his or her patients. Although there are times that the patient, or doctor, may experience certain attractions towards each other, acting out on these feeling will cause an emotional / sexual entanglement which will be detrimental to the patient's healing.
7. The Qigong doctor and the patient will agree on the time, place, duration of treatment, and fee. The Qigong doctor must be consistent in maintaining an established clinical treatment time and location. This instills a stable security for the patient and doctor. If this boundary is not maintained, patients without strong boundaries will take advantage and hurt both doctor and themselves. The Qigong doctor is responsible for giving adequate advance notice (two weeks) to the patient of any and all treatment or fee changes. If, for example, the original agreement was for six or fewer sessions and the doctor changes fees after the first session, the original agreement must be upheld (new patients however, will be charged the new fee).

POWER DYNAMICS AND ETHICAL BEHAVIOR

In any clinical setting there is an active power dynamic at work. Generally it is the doctor who maintains the power over the patient, as the purpose of the patient's visit is for help or assistance in specific healing. As the patient has come to the doctor with expectations, it is important for the doctor to be congruent with these expectations. These expectations set both the standard of the patient's healing and the power dynamics of the relationship. Through the power dynamics of the doctor-patient relationship there can develop three classical problems: Transference, Counter-transference, and Emotional-Sexual Entanglement.

1. Transference is the process whereby a patient unconsciously transfers feelings, thoughts, beliefs, and patterns of behavior that had been previously experienced towards others onto the doctor.
2. Counter-transference is the process whereby a doctor loses his or her objectivity and unconsciously transfers feelings, thoughts, beliefs, and patterns of behavior to the patient.
3. Emotional-Sexual Entanglement is the process whereby the doctor and patient both lose their objectivity and transfer emotional-sexual feelings, thoughts, beliefs, and patterns of behavior onto each other.

In order to prevent these types of enmeshment

and co-dependent relationships from happening, it is important for the doctor to constantly maintain his or her boundaries. The doctor and patient both must remember that it is the patient who actually does the healing in energy work, the doctor merely creates the situation in which this energetic transformation can transpire.

PITFALLS

There are certain pitfalls the Qigong doctor should be aware of and may experience, if a boundary has already been, or is beginning to be violated. These experiences are described as follows.

- The doctor begins to identify with the patient's problem and feels the need to discuss his or her own similar problems with the patient.
- The doctor begins to become emotionally attached or attracted to a patient sexually and feels the need to act on it (i.e., asks for a date, inappropriate touching or sexual contact).
- The doctor begins to feel the need to go out of the way above and beyond the normal course of responsible treatment to meet a patient's needs.
- The doctor begins to treat the patient for free.
- The doctor begins to find him or herself becoming overprotective, or worrying about a patient at inappropriate times.
- The doctor begins to need validation from his or her patient (this approval can be either as a healer, emotionally, or sexually).
- Arranging an exchange of services with a patient can often lead to the patient feeling abused or hurt.
- Allowing the patient to build up a large bill to be paid back later is unethical and may lead to legal action.
- Disclosing too much personal information regarding self (the doctor) in order to help the client can make the patient feel responsible for the doctor's well-being. Self-disclosure can be used very sparingly when the patient can benefit from solutions that worked for the doctor. It is safer, however, to pretend that these situations came from someone else.
- The doctor does not listen carefully to what the patient is saying, thinking that he or she knows what the problem is in advance.

It is important for the doctor to remember that the patient's emotional/spiritual safety and health must always come first. To avoid sinking into one of these pitfalls, the Qigong doctor is encouraged to constantly monitor his or her own actions and motivations. This is a broad and important topic that is often neglected in professional training and education. Because it is well dealt with in Kylea Taylor's book entitled, *The Ethics of Caring*, I encourage the reader to refer to this work for in-depth treatment of this subject.

CLINICAL BURNOUT AND MEDICAL QIGONG THERAPY

One classic problem all healers encounter is clinical burnout. The condition known as clinical burnout results from chronic job stress, and may sometimes occur to the Qigong doctor. This condition is characterized by extreme frustration, disappointment, physical and emotional exhaustion, and sometimes physical illness. The result of this condition is the doctor's loss of concern for the patients, or the loss of fulfillment with his or her performance as a healer. The Qigong doctor is susceptible to experiencing clinical burnout, especially if he or she feels that:

- There are too many or too few patients;
- Too little time is spent for recreation;
- There is too much stress in his or her life;
- Not enough attention is placed on self care and personal psychological growth; and
- Not enough attention is placed on a personal spiritual path and practice.

If the Qigong doctor's life revolves primarily around the clinic (which is usually the case), he or she will disproportionately come into contact with the patients' pain and emotional traumas, as well as be chronically bombarded with toxic energetic discharges released from the patients.

Sometimes patients, in order to heal their intense emotional traumas, require an enormous amount of spiritual, emotional, and mental support from the doctor. If the doctor does not carefully monitor his or her own energetic reservoir,

this may result in Qi depletion.

If Qigong doctors expend all their spiritual/emotional energy from intense personal interaction and enmeshment with their patients during treatment, the toxic interaction will deplete the doctors, resulting in complete physical and mental exhaustion. If Qigong doctors become depleted in the middle of a treatment, they may abandon their Upper Dantian (psychic) connection with patients (spiritually, emotionally, and/or energetically), and begin to suddenly express feelings of criticism, anger, disappointment, or grief. This reaction occurs when the Qigong doctors' own internal organ energy, depleted and worn, becomes susceptible to absorbing the patients' powerful emotional discharges. The problem of clinical burnout usually stems from energetic boundary invasion. Remember, Medical Qigong healing requires that the doctor heal him or herself first.

Often, a Qigong doctor's clinical burnout is primarily related to the unresolved personal issues and not the number of patients on the case load, or the amount of environmental stress the doctor experiences.

ENERGETIC BOUNDARY INVASION

In understanding clinical burnout due to energetic boundary invasion and its relationship between the doctor and patient interaction, it is important to review seven important factors which control and transform the body's energetic fields.

1. Energy exists on different planes. The body is like a complex hologram, composed of physical, mental, emotional, and spiritual planes of energy. The spiritual field of energy controls the emotional and mental energetic field, which in turn controls the physical energetic field. These energetic planes affect and control the energetic formation of the body's cells, tissues, organs, and organ systems.
2. Because the body produces heat, light, electricity, magnetic energy, and resonate vibrations, these natural energetic releases create a basic Yin (negative) and Yang (positive) polarity, which is found in all manifestations of energy.
3. Everything in the body is in vibratory motion. Various forms of tissue develop from different energetic vibrations. When the body's energy begins to slow down, it begins to take on a denser form of resonant vibration. The impediment of this resonant energetic vibration can stem from trauma or shock to the system (physical or emotional), resulting in energetic stagnations and disease.
4. The body's internal organs collect and store emotional energy, both positive and negative. As any suppressed, or "stuffed," emotional energy begins to culminate, the body will naturally (and quite frequently) disperse these internal emotional charges. They are generally released externally through: the Respiration, the Posture, and the Mental Dialogue.
   - The respiration, (which includes sighing and laughing), is released from the Heart, shouting released from the Liver, groaning from the Kidneys, crying from the Lungs, and singing from the Spleen.
   - The posture includes the body's physical structure adapting or conforming to an Expanded-Yang or Contracted-Yin energetic influence.
   - The mental dialogue includes both benign and malignant thought patterns.
5. The body has three primary energy centers known as Dantians. Each Dantian resonates at its own distinct vibration and is responsible for specific modes of interacting with others in interpersonal communication.
   - The Lower Dantian is considered the most physical energetic base. It is the most dense and has the slowest vibratory rate of the Three Dantians and communicates kinetically with the outside environment.
   - The Middle Dantian is considered the emotional and mental base. It has moderate resonances and communicates empathetically with the outside environment.
   - The Upper Dantian is considered the spiritual base and has the fastest and most delicate of the vibrational interactions. The Upper Dantian functions at an intuitive level.

6. When communicating, the body will interact from all five levels: physical, mental, emotional, energetic, and spiritual. This interactive communication will sometimes energetically fuse with the external environment, including people.
7. Our external and internal thoughts and feelings, as well as tissues and cells are all by-products of energetic interactions, stemming from communication from within ourselves and our environment.

After reviewing the following facts, the Qigong doctor can understand why every time he or she connects with a patient, the patient's energetic fields will automatically be energetically ingested by the doctor. The doctor does this consciously in order to analyze the patient's emotional past, as well as present emotional outbursts. Although the doctor and patient's energies fuse together, the fields of energy around the doctor's internal organs generally protect the doctor from absorbing negative emotions. These energetic boundaries also extend out into the doctor's Wei Qi field.

Both the patient's and doctor's Wei Qi fields are fused during interaction and treatment. It is therefore imperative that the doctor's energetic boundary system maintain its structure (both internally and externally), yet be permeable while treating the patient. The doctor must not lose sight of his or her purpose. Any criticism aimed at the doctor should not be taken seriously, nor should any inappropriate behavior by the patient. The doctor's Wei Qi field should be at maximum strength. If not, the cords of energetic attachment flowing from both the doctor and the patient allow energetic emotional transference to happen. If the doctor, for example, has a preexisting Liver Heat condition, it will be further compounded by the inflowing of the patient's released of anger and rage. If and once this happens, the patient may feel relieved, but the doctor will become quite agitated.

STRENGTHENING THE DOCTOR'S ENERGETIC BOUNDARIES

It is important for the Qigong doctors to allow the patients' emotions to constantly flow through their own bodies, feeling, understanding, then releasing these feelings. If at any one point in this transition, a doctor (because of personal issues) suddenly stops the flow of emotions and begins to focus, or dwell on, a particular type of energetic charge, the patients' discharging emotions will invade the doctor's body.

To avoid energetic boundary invasion the doctor should maintain a regular Qigong meditation and exercise program. This program should include the following exercises and meditations.

1. Practice Qi dredging and emotional dispersing exercises and meditations to release your own emotional traumas.
2. Perform Qi and organ strengthening exercises and meditations to strengthen both your internal organ energies, as well as the three fields of Wei Qi. Since the emotions are stored within the body's internal organs, strengthening these organs will facilitate a stronger control of the body's emotional energy.
3. Practice Qi regulation and balancing exercises and meditations to balance the body's Yin and Yang, as well as internal and external energetic channels, organs, and organ systems. This helps to control the energetic surges released from internal emotional discharges.
4. Maintain emphasis on the energetic grounding and the divine hook-up meditations before treating patients. These meditations are important for establishing an emotional as well as spiritual boundary, and will assist you in avoiding clinical burnout and energetic boundary invasion.
5. Maintain emphasis on personal time, including any and all spiritual, social, and recreational times away from the clinic.

CAUSES OF SPIRITUAL DRYNESS

Sometimes clinical burnout can result from "spiritual dryness." This type of burnout can result from experiencing a "dry period" of spiritual insight and perception. It can occur during clinical observations and treatments, resulting in frustration for the doctor. Spiritual dryness is commonly due to one or more of the following five conditions.

1. If the doctor is tired, hungry, or sick, the fo-

cus will tend to be on the doctor's own particular needs instead of the patient's.

2. A disconnection from the divine is caused by guilt, lack of forgiveness (self-blame), shame, etc., resulting in a loss of spiritual vision. It is important for the Qigong doctor to have an open and honest connection with the divine to receive the more subtle spiritual insights. Without this type of transpersonal relationship, the Qigong doctor's ability to dissolve into the Wuji surrounding the patient's tissues can be hindered.
3. Rushing personal meditation time is caused by failing to relax during the preparation meditation practice (the divine hook-up). This condition is normally caused by worries or preoccupations due to hidden agendas, that disturb the doctor's Shen prior to meditation. It is important for the doctor to relax and return to a state of quiescent peace, in order to truly listen to the divine.
4. Getting into a rut is caused by the doctor performing repetitive Shengong meditations in a mechanical way (i.e., the same way an individual will routinely brush his or her teeth), thus losing the emotional and spiritual connection with the core self. The meditation then becomes meaningless and powerless (just words and no spirit). To avoid getting into a rut, the doctor should try to experience each meditation as a time of new beginnings and enlightenment, and not as a mandatory routine.
5. It is important for the doctor to be able to share emotional and spiritual insights with other colleagues in the same field of work, and when appropriate, with the patient. This sharing of spiritual insights, observations, fears, and triumphs renews the doctor's confidence in his or her spiritual gifts, and maintains a strong faith in the healing potential of Medical Qigong therapy.

Section VII
The Treatment Principles of Medical Qigong Therapy

Chapter 29
Principles and Parameters of Medical Qigong Therapy

The foundational factors of the patient's state of health originate from their actions, thoughts, and feelings. A Qigong doctor, studying a patient's physical problems, understands that the origin and solution to these problems are to be found within a patient's recurring thought patterns, both conscious and unconscious.

The brain processes data consistent with what it is familiar with; patients will generally experience and accept information that coincides with their own belief system. Their consciousness then, creates its own reality, resulting in either health or disease.

Good health is a result of bringing the patient's own unique spiritual and emotional essence back into consciousness and increasing the awareness of the physical body. Both health and disease are created through this process which is the foundational base for clinical Qigong treatments.

The Five Methods for Treating Patients

Qigong doctors generally use five methods for treating their patients' diseases (Figure 29.1). These methods initiate an energetic restructuring within the patient's body. The five methods are described as follows.

1. The doctor uses his or her own Qi to initiate the healing.
2. Qi is drawn, by the doctor, from the surrounding natural environment (from the energetic fields of the Earth) to be emitted to the patients.
3. Qi is drawn, by the doctor, from the surrounding universe (from the energetic fields of the Heavens) to be emitted to the patients.
4. Divine energy is channeled through the doctor to treat the patients.
5. Homework is prescribed in the form of self-regulation exercises and meditations to support the healing process.

The Nine Stages of Treatment

Using these five methods of treatment, the Qigong doctor initiates nine stages of healing within the patient's body. The healing process will always vary according to the belief structure of the patients, their acceptance and performance of the Medical Qigong prescriptions, and their willingness to change. The Qigong doctor's nine specific stages in treating a patient are described as follows.

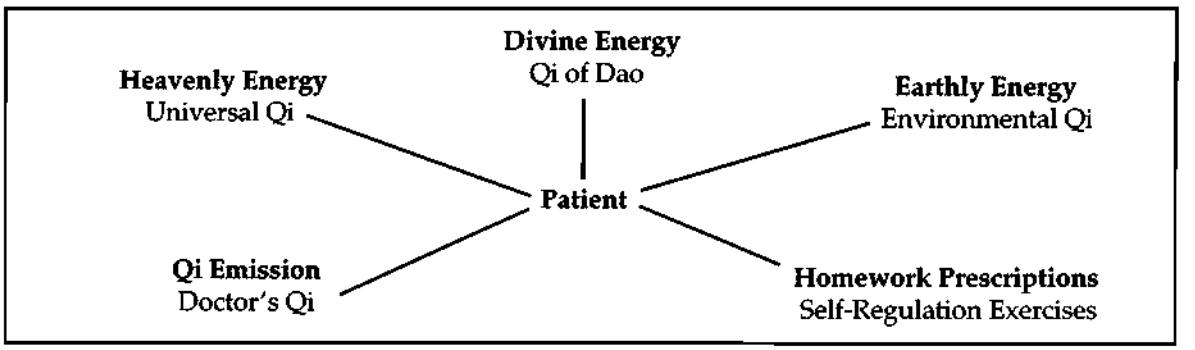

Figure 29.1. Five Methods Used For Treating Patients

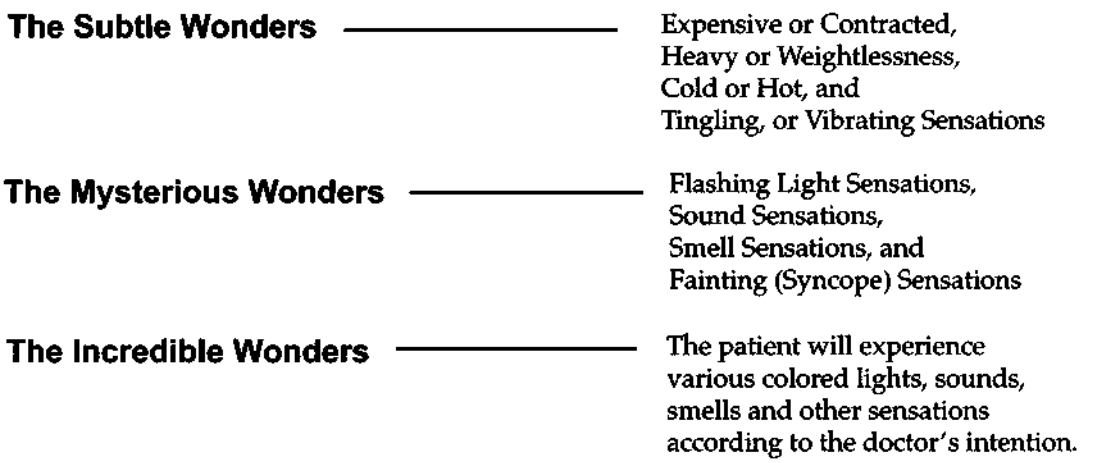

Figure 29.2. The Three Wonders

1. Activate, connect, and energize the patient's energetic field;
2. Dredge the patient's channels and collaterals;
3. Purge and eliminate any energetic Excess;
4. Tonify any energetic Deficiencies;
5. Regulate the Qi and Blood content of the patient's Yin and Yang organs (harmonize the organ Jing);
6. Regulate the patient's Prenatal and Postnatal Qi (harmonize the Qi of the Three Dantians and Taiji Pole);
7. Balance the patient's Yin and Yang Shen (harmonize the Heart/Mind and Emotions);
8. Seal the patient's external field of energy;
9. Give prescriptions.

THE THREE WONDERS OF MEDICAL QIGONG THERAPY

The cultivation of Qi and Shen through Medical Qigong therapy generates what is described as the Three Wonders. These Three Wonders consist of the three separate transformations of energetic abilities that the Medical Qigong doctor and, sometimes, the patients experience (Figure 29.2). The Three Wonders are explained as follows:

THE SUBTLE WONDERS

The Subtle Wonders consist of subtle changes inside and outside the body, known as the Eight Energetic Touches. These interactions of tissue and energy form the physical sensations and manifestations of Yuan Qi. When the doctor emits Qi to treat diseases, involuntary phenomena can occur instantly, or gradually, in local areas of the limbs, or the patient's whole body. In some cases the muscles stir slightly, while in other cases the limbs, or the body, will perform extreme, harsh movements. This results from the patient's external energy (Wei Qi) inducing spontaneous movements.

When the Qigong doctor emits energy to treat diseases, some patients produce, in local areas, electromagnetic, or stimulating, sensations of Qi similar to those felt in Qigong circulation/cultivation exercises and meditations. This includes: cold or hot sensations, feelings of compression or tugging, impressions of creeping or tingling, experiences of heaviness or lightness, and of floating or sinking, as well as other sensations. The Subtle Wonders result from energy in the channels circulating and responding to the doctor's intention.

Generally, the effects of Qi on the body are manifested in physical sensations and sensory phenomena during Qigong exercises. These phenomena are all manifestations of the free movement of Qi in the channels, collaterals, and inner body circulation.

The doctor may also experience these same sen-

sations while extending energy into the patient. The doctor should be able to sense the patient's Qi circulation, density, direction, as well as his or her own energy. The sensations known as the Eight Energetic Touches of the Subtle Wonders are: Expansive, Contracted, Heavy, Light or Weightlessness, Cold, Hot, Tingling or Itching, and either Vibrating, Shaking, Rippling or Moving.

1. When the Qi is circulating freely within the body, the capillaries expand as the body's energetic field expands, resulting in the sensation of being very large, tall, and expanded.
2. When the Qi enters from the outside of the body to gather in the Lower Dantian, the patient experiences the sensation of feeling very small or contracted.
3. When the Qi sinks down (upon exhalation), the body feels heavy, condensed, and solid as a rock.
4. When the Qi rises upward (overflowing the channels), the body feels light and weightless.
5. When the Qi circulates through the Microcosmic Orbit (balancing the Qi of the Heart and Kidneys), the Kidney-Yang becomes sufficient to allow the Kidney Yin to well up; this results in a pleasant cool sensation.
6. When the Qi is vigorous and thermal energy is gathered, the parts of the body where the Qi passes will feel hot.
7. Once Qi circulates vigorously and passes through the body's obstructed channels, collaterals and minute collaterals, the result is itching or tingling of the skin and scalp. This is an energetic manifestation of the body's obstructed channels, collaterals, and minute collaterals being cleansed.
8. When the Qi passes through the channels, collaterals, and parts of the body it has opened, the patient feels electrical and creeping sensations in the extremities as well as the body, causing the tissues to vibrate, shake, ripple, or move, etc.

These are all normal phenomena of Qi cultivation and circulation. As long as the patient remains calm and present, these sensations will appear and disappear as spontaneously as they were formed.

The Mysterious Wonders

Patients may also experience elusive as well as dynamic transitions inside and outside of the body, called the Mysterious Wonders. These energetic changes are sometimes present, but are rare, and may be confusing to the patient. The sensations known as the Mysterious Wonders are: Flashing Light Sensations, Sound Sensations, Smell Sensations, and Fainting (Syncope).

1. Flashing Light Sensations sometimes occur in some patients during Qigong treatment. The photoelectric phenomena is due to the interaction of light with matter. In some cases, patients feel electric sensations in the limbs and body, and in other cases light patterns may be seen in different forms, most of which present as round, sheet light, or lightning patterns.

   One of the manifestations of the Qigong doctor's cultivation through Shen Gong meditations is a flashing light sensation which is seen and felt within the doctor's head and body. This glow may sway back and forth, pulse like a white neon light, or pierce into the doctor's brain, and illuminate the spinal column. It may also appear as a ball of white light rotating at high speed through the Microcosmic Orbit.

   This ball or beam of light may exist continuously at the Qigong doctor's Baihui GV-20 point throughout the duration of the meditation and several hours afterwards. The degrees of light sensations and their colors will vary in accordance with the doctor's skill level. Also, it is this beam of light that the Qigong doctor will later utilize for inner vision diagnosis.
2. Sound Sensations are sometimes experienced during treatment, such as a rustling, rumbling, or high-pitched sound.
3. Specific Smell Sensations may occur, such as the sweet scent of sandalwood, or fragrances of various flowers, or incenses.
4. Fainting (Syncope) can occur during Qigong treatment. A few patients may suffer from perspiration and accelerated heart rate, fol-

lowed by syncope (fainting). When this occurs, the doctor lightly presses the patient's channel points: Baihui (GV-20), Mingmen (GV-4), Jiangjing (GB-21), and Yintang (Extra Point). The doctor then grasps the shoulders and presses down on the GB-21 points with force. Finally, the doctor emits Qi along the Governing and Conceptual Vessels and leads the patient's Qi to the Lower Dantian. This allows the patient to recover consciousness.

THE INCREDIBLE WONDERS

The Qigong doctor's ability to have complete conscious and automatic control over the patient's reaction to energetic projections constitutes what is known as the Incredible Wonders. When the Qigong doctor takes control over the patient's energetic projections, he or she can willfully initiate the patient to experience various colored lights, sounds, smells and other sensations according to the Qigong doctor's will. This procedure is commonly known as Cultivating the Spirit to Generate Wonders.

When the Qigong doctor emits energy towards patients to treat their diseases, most patients will either instantly or gradually feel some form of energetic sensation from the increased life-force energy. The degree of energetic sensation felt by patients is in accordance with their emotional/spiritual sensitivity and degree of connection to their own physical body.

The sensations of Yuan Qi are the most common reactions felt by both the Qigong doctors and their patients. In rare instances some patients display no physical effects and experience no Qi sensations during treatment. These patients can still achieve good therapeutic results by improving the degree of their emotional/spiritual connection to their body.

In some cases, patients may even feel miserable or uncomfortable. When this occurs, they should continue training so that their Righteous Qi can overcome their Evil Qi. This ongoing battle will also affect their spiritual and emotional being. Fear usually arises at this point causing them to question their ability to continue in their practice. This is a normal transition and can be resolved through encouragement, patience and continual practice.

CONTRAINDICATIONS FOR MEDICAL QIGONG THERAPY

There are several contraindications that the Qigong doctor should be aware of before treating patients, or even prescribing Medical Qigong exercises. The following is a list of different personality types that may be encountered in the clinical settings that require special treatment modifications.

1. The very "nervous" type of patient should not practice Medical Qigong, or must be under strict supervision due to the patient's emotional instability.
2. The "extreme temperament" type of patient who has a fanatical type of personality should also avoid Medical Qigong training or remain under strict supervision. Patients of extreme temperament generally suffer from Excess disorders and compulsive overtraining. They are therefore prone to Qi deviations.
3. The "extremely introverted" type should be careful when practicing Medical Qigong meditations because strong emotions may be set into motion, and even certain mental disorders may be violently released that the patient may have been unaware of.
4. The "narrow minded" type will generally condense Qi into smaller areas of the body causing stagnations. Such patients should be instructed to relax and let go of their stress to allow the condensed energy to disperse.
5. Patients with the following conditions should be restricted to very specific Medical Qigong therapy: serious mental disorders, congestive Heart failure and severe organ failure, severe hemorrhaging, menstruation, nerve suppression, bone fracture, pregnancy, geriatric patients, young children, and cancer patients (Figure 29.3).

- Patients with mental disorders such as schizophrenia and bipolar (previously called manic depression) disorders (or individuals with a family history of such mental diseases), should refrain from training. The Qigong exercises and meditations could induce symptoms of these said disorders, or could enhance

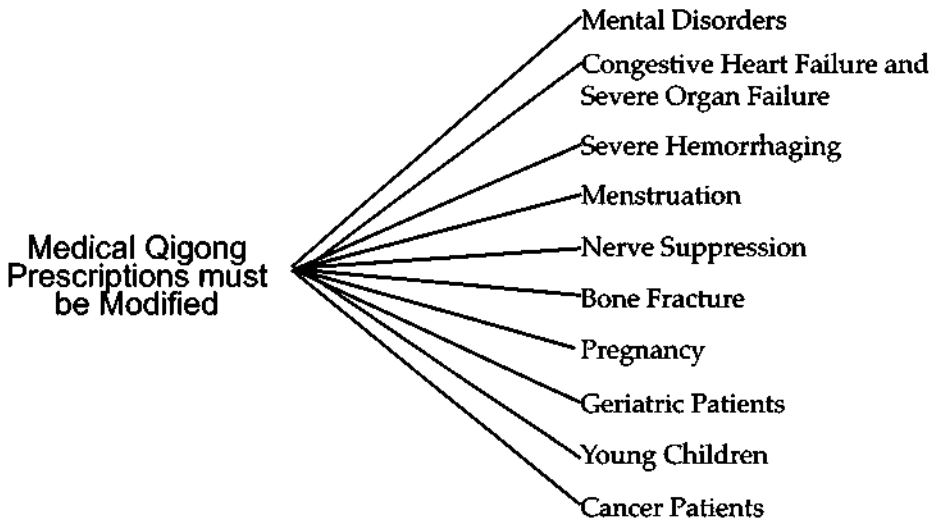

Figure 29.3. Restricted Conditions for Prescribing Medical Qigong Exercises and Meditations

the symptoms due to the patient's mental and emotional instability.

- Patients with congestive Heart failure and severe organ failure (any internal organ that has experienced an energetic collapse), require that the treatment be specifically oriented towards this condition.
- Patients with severe hemorrhaging require prescriptions that prevent the leakage of Blood and Qi, since Blood and Qi flow together.
- Women during their menstruation cycle should not store Qi in their Lower Dantian. Any Blood and Qi stored in the uterus will purge from the woman's body naturally, drawing with it any Qi stored within the Lower Dantian.
- Patients suffering from nerve suppression (cervical spondylosis) may experience a worsening of their condition. In severe cases, the additional pressure on the nerve roots may complicate the patient's condition, especially when the body's energy field expands causing the Marrow within the spinal column to ascend.
- Patients with bone fractures must first have the bones set correctly and immobilized to prevent further injury. The subtle involuntary movements of the limbs during Qigong treatment or practice can disturb the bone's healing process.
- Pregnant women must be treated by a Medical Qigong doctor who specializes in obstetrics, otherwise the risk of involuntary abortion (miscarriage) or other complications can arise.
- The treatment of geriatric patients prohibits Dynamic Qigong because of the delicate nature of their internal tissues. All exercises and meditations should be kept slow, quiescent, and tranquil.
- The treatment of young children requires that all exercises and meditations be age appropriate, and be specifically oriented toward healing his or her disease. Some Qigong exercises, meditations and treatment methods may interfere with the natural development of the child's internal organs and tissues.
- The treatment of cancer patients requires modified prescriptions in accordance to the specific disease. With certain cancers, Dynamic Qigong is contraindicated to prevent the cancer from further metastasizing.

CHAPTER 30
BALANCING THE BODY'S ENERGETIC SYSTEM

PURGING, TONIFYING, AND REGULATING

In Medical Qigong therapy, successful results can be achieved only when the doctor adheres to the principle of "treating Deficient syndromes with tonification and Excess syndromes with purgation." Tonification supplements the insufficiency and strengthens the body's resistance, while purgation reduces the Excess and expels pathogenic factors. The final aim is to balance Yin and Yang to regulate the physiological functions of the body.

Medical Qigong Therapy adheres to the traditional Chinese medical explanations of illnesses and general principles of healing. Only the techniques used during treatment differ. Qigong doctors Purge the patient's body, then emit Hot or Cold Qi in conjunction with the Five Elemental energies, using various hand manipulations, including: pushing, pulling, rotating, leading, and shaking.

Through energy extension, the doctor can reinforce the patients body's resistance to pathogenic factors, replenish the Yin and Yang organ energy and enhance mental clarity.

THE THREE TREATMENT MODALITIES

Medical Qigong therapy is divided into three treatment modalities (Figure 30.1). These treatment modalities enable the Qigong doctor to purge, tonify, and regulate the patients' body. These techniques are described as follows.

1. Medical Qigong Purging techniques are used by the doctor to treat the patient's Excess syndromes, and to detoxify the body of pathogenic Qi. The "lower aspect" of classical Chinese medicine governs the treatment of the patient's illness and corresponds to Earth. It involves purging pathogenic influences and dispersing stagnations in order to cure the patient's illnesses. This allows the patient the ability to remove Excess Qi from organs and tissues.
2. Medical Qigong Tonification techniques are used by the doctor to treat the patient's Deficient syndromes, as well as strengthen and stabilize the organs and organ systems. The "middle aspect" of classical Chinese medicine governs the nourishment of the patient's nature and corresponds to Man. It involves helping the patient prevent illness by tonifying

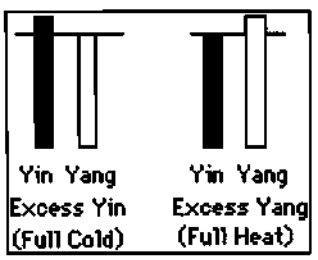

In cases of Excess, the doctor should Purge.

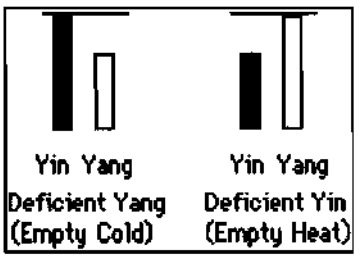

In cases of Deficiency, the doctor should Tonify.

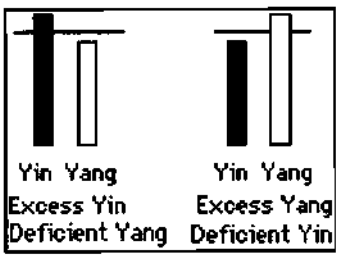

In cases of Excess and Deficieny combined, the doctor should Regulate.

Figure 30.1. Purgation, Tonification, and Regulation

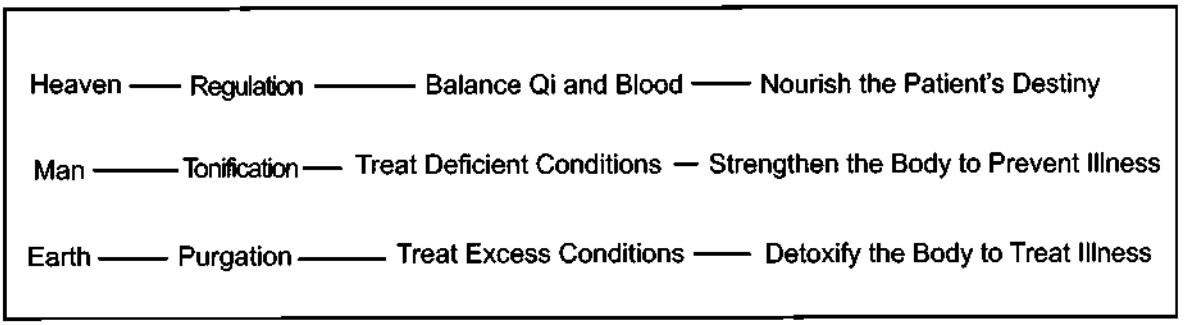

Figure 30.2. Ancient Chinese Perspective on Purgation, Tonification, and Regulation

organ energy Deficiencies. This allows the patient the ability to replenish organ energy depletions and tissue emaciation.

3. Medical Qigong Regulation techniques are used by the doctor to balance the patient's Yin and Yang energy, as well as organ Qi. The "highest aspect" of classical Chinese medicine governs the nourishment of the patient's destiny and corresponds to Heaven. It involves regulating the patient's Three Dantians, Taiji Pole, Yin and Yang organs and energy fields. Regulation techniques promote a balance of Jing, Qi and Shen for the optimal development of all the aspects of man, i.e., body, mind, emotion, spirit and energy. Thus, in China, Medical Qigong regulation is said to "nourish the patient's destiny" (Figure 30.2).

PURGATION TECHNIQUES

The patient's body can be dredged and purged by using two different expelling methods. The first method is the direct removal of pathogens from the patient's tissues and organs. The second method is the indirect purging of the patient's tissues and organs through the channels and points of the patient's body. These two methods serve two different purposes: The Direct Removal of Pathogenic Factors, and The Purgation of Channels and Points.

1. The Direct Removal of Pathogenic Factors is achieved through extending Qi into the tissues and organs where they are lodged, and dredging the Toxic Qi directly out of these locations. This method is used to expel pain due to Excess Heat or Cold. The various techniques used in this type of purging employs stationary Qi-guiding manipulations. The various hand manipulations used for the direct removal of pathogenic factors consists of such techniques as: The Five Thunder Fingers Hand Posture, Shaking and Trembling Hand Posture, Bellows Palm, Vibrating Palm, Dragon's Mouth Palm, Tiger Kneading Palm, and Spiraling Palm (see Chapter 33).
2. The Purgation of Channels and Points techniques are used to expel External pathogenic Evils (such as the invasion of Wind, Fire, Heat, Dry, Damp, Cold, and environmental toxins, etc.), or Internal pathogenic Evils (such as fear, anger, and grief, etc.) from the organs and tissues of the body. It is also used to redirect Rebellious Qi (e.g., Stomach Qi). The various techniques used in this type of purging employs dynamic-linear Qi-guiding manipulations such as the Pulling, Leading, and Guiding methods (see Chapter 34).

TONIFICATION AND PURGATION METHODS

The doctor should always purge before tonifying the patient's body. In the clinical setting, these two methods are often used together in combination with other methods in treatment. These combined methods are as follows.

TONIFICATION AND PURGATION WITH RESPIRATION

Tonification occurs as the doctor exhales while guiding and directing Qi into the channels, points, and the internal organs and tissues of the patient's body. Purgation happens when the doctor inhales while guiding, emitting, and leading the patient's Qi, or pulling the pathogenic Evils out of the patient's body.

During treatment, it is important that the patient cooperate with the doctor by matching (if possible), per the doctor's instruction, his or her breathing rhythm to the doctor's treatment. The patient should assume a proper posture (lying, sitting or standing), relax, and concentrate his or her mind on the location being worked on. When the doctor exhales and emits Qi toward the patient, the patient should inhale to absorb the doctor's Qi into the designated location. When the doctor performs purgation, the patient should exhale to release Toxic Qi out of his or her body.

TONIFICATION AND PURGATION ALONG AND AGAINST THE CHANNEL FLOW

With regard to acupuncture therapy, the classics say that, "puncturing along the direction of the channels yields a tonifying effect, while going against it induces purgation." In Medical Qigong, however, due to the Qigong doctor's nature of emitting, leading and guiding the energetic flow of Qi, certain modifications are used. The following are a few examples of tonification and purgation techniques used along and against the energetic flow of the channels:

- Causing Qi to flow up the Yin channels of the legs and into their associated organs in the torso is considered tonification (think of following the river to the sea). One example of this type of treatment therapy is emitting energy into the base of the patient's feet (at the Kd-1 points); this causes the energy to flow into the torso to strengthen the Kidneys.
- Moving Qi from the torso down the legs against the flow of the leg Yin channels is considered purgation (following the river from the sea). One example of this treatment therapy would be pulling Excess Qi from the Liver organ, down the right Liver channel and out the feet to sedate the Liver Fire (the Gall Bladder Channels can be used to purge Excess energy from the Liver organ down the leg Yang channels).
- Moving Qi against the flow of the arm Yin channels into their associated organs is considered tonification (think of following the river to the sea). One example of this treatment would be emitting energy from the base of the thumbs, at the Lu-11 points, into the torso to strengthen the Lungs.
- Moving Qi against the flow of the arm Yang channels into their associated organs is considered purgation (following the river from the sea). One example of this treatment would be pulling Qi against the flow of the Large Intestine Channels down and out the hands to purge Excess Qi in the head.

TONIFICATION AND PURGATION POINT THERAPY WITH THE HORARY CYCLE

When prescribing Jing Point therapy as a means of self-regulated homework, the Qigong doctor encourages the patients to follow the formula of tonification and purgation according to the energetic flow of the Horary cycle. According to ancient Chinese medical theory, the ebb and flow of Qi and Blood along the different channels is related to designated days and hours (see Chapter 11). This theory applies to two specific tissue manipulations: Holding the Point for Tonification, and Closing the Point for Purgation.

- Holding the point for tonification requires the patient to use the Massage Tapping method (see Chapter 37) on specific points two hours prior to its opening or peak flourishing time (high-tide).
- Closing the point for purgation of the internal organs or channels requires that the Qigong doctor drain the diseased area at high-tide (when it is most full of Qi and Blood). When the patient is applying Jing Point therapy for homework prescriptions, however, the application is quite different. This technique requires the patient to use the Massage Tapping method on specific points two hours after its opening time.

The patients may also be instructed in self-massage using the Tapping method for self-healing. If the patient has a Kidney disease, for example, the specific points should not be tapped during its peak time (5–7 p.m.), but rather two hours prior to its peak time (3–5 p.m.). This will improve the Kidneys' function.

TONIFICATION AND PURGATION GUIDELINES

When the Qigong doctor purges and tonifies a patient, he or she must remember to adhere to the following guidelines carefully.

GUIDELINES FOR THE DOCTOR

When treating the patient, the doctor must always consciously direct and be aware of the movements of each hand.

- Generally, the right hand is used for tonification, while the left hand is for purgation. Diseases that require purgation are treated by draining Toxic Qi with the left hand. Diseases that require tonification are treated by extending Qi through the right hand.
- Turning hands towards the body is used for tonification, while turning the hands away from the body is used for purgation.
- Moving the hands away from the body and upward can regulate the Yang energy, causing it to rise, and is inclined to tonify. Moving the hands downward pulls the Yang energy down, and is inclined to purge.
- Clockwise drilling (the palm or extended fingers move in a clockwise direction over an area) is used for tonification and increasing Qi; counterclockwise drilling is used for purgation and decreasing Qi.

GUIDELINES FOR THE PATIENT

The patient, (like the Qigong doctor), must be aware of hand movements when practicing Qigong prescriptions. In addition, the patient must be aware of his or her posture, respiration, and mental attitude.

- The eyes are open for purgation; closed eyes are used for tonification. The patient should apply these principles according to the symptoms of the disease.
- Inhalation is used for tonification, exhalation is used for purgation. During purgation treatments, the patients assume the proper postures, relax, and concentrate their mind on the disease area while exhaling the pathogenic Qi. This exhalation technique is used not only to promote the removal of the surfacing toxins, but is also used to enhance the doctor's efficacy in purging the diseased area.
- The audible and silent tone resonations (see Chapter 40) also have the function of either tonification and purgation. Speaking the silent tone when inhaling can be used for tonification; while exhaling, the tone is used for purgation.

UNDERSTANDING MEDICAL QIGONG REGULATION

The Qigong doctor must master three main techniques of Qi regulation to facilitate clinical healing through Qi emission. These techniques include: Training the Qi, Guiding and Inducing, Tonifying and Purging the Qi, and Emitting the Qi.

1. Training the Qi exercises and meditations are used to gather Qi and to promote its circulation within the body. The Qigong doctor must have an extensive comprehension of several Medical Qigong techniques used to gather and circulate energy throughout the body. This includes a complete understanding of Postural, Respiratory, and Mental Dao Yin modalities, as well as the static and dynamic clinical modalities. These training techniques provide the Qigong doctor with the ability to regulate and balance the patients' Qi, and set the foundation for the patients' Medical Qigong prescriptions.
2. Guiding and Inducing, Tonifying and Purging the Qi are used to circulate Qi within the external field of energy (Wei Qi). These techniques require a complete understanding of guiding and inducing (leading the Qi), and tonifying and purgation techniques, to being able to rectify Qi deviations and remove energy blocks.

These training techniques provide the Qigong doctor with the foundation for the patients' Medical Qigong therapy.

3. Emitting Qi techniques must be learned and perfected by the doctor. The Qigong doctor must have an extensive understanding of the multiple techniques used to extend Qi into the patient's body. These include electromagnetic energy, light, sound, and hot and cold Qi projections. These training techniques and abilities also set the foundation for the patients' Medical Qigong therapy (see Chapter 34).

Qi Regulation and Guiding Principles

Qi regulation is considered a combination technique for reinforcing and reducing. It is used to readjust and balance the Yin and Yang energy. If the patient's Qi rises adversely, the doctor should guide and secure it downward. The same principle is applicable for any Deficiency or Excess of Qi in the left or right sides of the patient's body.

Qi regulation also includes purgation after tonification, and tonification after purgation. This method of guidance is used when Qi stagnation, stasis of Blood, or disorders of the channel Qi develop. Under pathogenic conditions, Qi of the viscera and channels may become weak and stagnant. This is manifested by symptoms such as listlessness, general weakness, and the hypofunction of certain organs or tissues. Stagnation of Qi and stasis of Blood can also obstruct the channels causing pain. Pain may also be caused by outside pathogenic factors such as trauma, inflammation, muscular spasms, and adhesive degeneration. In these circumstances, the channels are dredged to promote Blood circulation, and to remove the stasis in order to relieve spasms, and dispel pain.

Every organ in the body has its own Qi that circulates and interacts with the rest of the body. When the normal function of the organ is affected, the circulation of Qi may become disturbed. This disturbance of Qi in one organ may influence the functional balance of the whole Qi system.

The doctor regulates the patient's channel Qi by dredging the channels and collaterals. This facilitates Qi circulation and leads Qi back to its origin. In the case of a weak and hypofunctional Lung Qi, for example, emitting Metal-Qi plus Pushing, Shaking and Leading manipulations (see Chapter 34) can be adopted to activate the Lungs' Qi. The combination of these techniques causes the channels' Qi to overflow freely, thus improving the function of the Lungs.

Energy Balancing Procedures

When extending energy into the patient the main emphasis is placed on balancing the patient's energetic fields. The doctor must have both physical and emotional releases from the patient's body, to detoxify and liberate the trapped Qi.

It is important to not let the patients avoid facing their problems; keep them centered around the troubled area, focused on the awareness of what they are feeling. Basic energy balancing procedures are as follows.

1. If the treatment area is Hot, cool it down. The doctor must continue treating the patient until the Hot area has cooled. A strong and quick moving hand gesture is best used to treat a Heat syndrome.
2. If the treatment area is Cold, heat it up. For a Cold syndrome, use a longer treatment to warm up the channel in the area treated, to eliminate the Cold.
3. If the tissue's energy is dark or cloudy, change it to light and clear.
4. If you feel tingling on any area or organ, remain there until the tingling subsides and the organ or area completes its energetic unwinding. Tingling in an area indicates that the patient's body is releasing an energetic cluster. The patient may or may not be aware of any feelings or sensations when this occurs.
5. If the area is emitting electric shocks, dampen or sedate it by connecting it with its associated organ. Connecting Yang (positive) into Yin (negative) will ground the energy.
6. If you sense pressure or Excess, dredge the area, and circulate the Qi.
7. If you feel intense pulsation, decrease the intensity and make it rhythmical.
8. When treating an energetic field that is De-

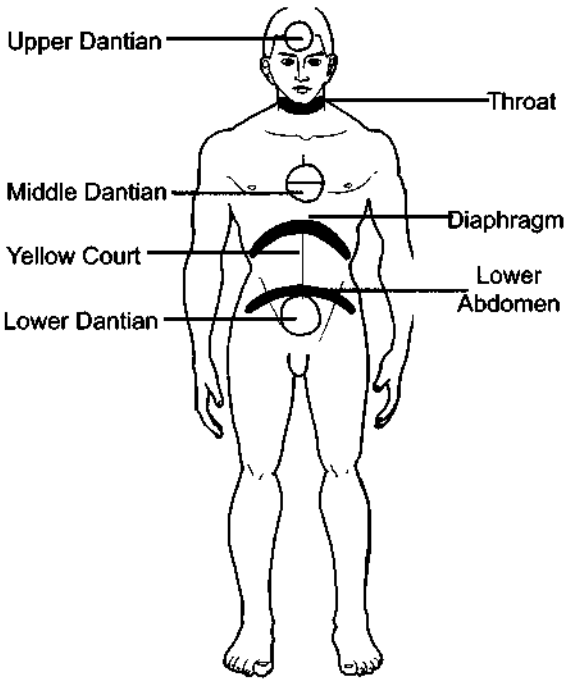

Figure 30.3. Locations of Energetic Blockages

pressed (sinking or contracting inward), use an "ascending method" of Qi manipulation for tonification (i.e., move and emit Qi from the lower areas of the body upwards). Some examples of this type of ailment are:

- Lower Burner Depression
- Middle Burner Depression
- Immune System Depression and Breakdown
- Autoimmune Diseases (Lupus and Fibromyalgia)
- Chronic Fatigue Syndrome
- Heart Failure
- Kidney Failure
- Prolapse of the Stomach

9. Assign Medical Qigong prescriptions for patients, including meditations and exercises, as needed.
10. Treat patients with severe diseases by:
    - Stopping and controlling the spread and development of the disease,
    - Stopping the patient's Excess consumption of Qi,
    - Treating the cause and root of the disease, after the patient's condition is under control, and
    - Assigning homework.
11. For chronic diseases, use the method of purging and dredging stagnation to move any impacted Qi.
12. For sprains, use Qi compression (using the Qi to press the tissues) around the local area. Close the channels surrounding the sprain first, isolating the trauma. Then pull out the stagnant Qi. If the doctor immediately treats the local area, he or she will disturb and further complicate the injury. It is important to close off the surrounding channels around the wound first, leaving only the affected channel open, before pulling out the stagnant Qi. This controls the flow of energy in to the stagnated area.

Check the patient after seven treatments to determine if the therapy has been effective. Re-evaluate each patient according to each individual's constitution.

Clinical Observations of Pathological Energetic Patterns

When the Qigong doctor begins to treat patients, certain energetic observations and phenomenon will be experienced while diagnosing the energy inside the patient's tissues. These energetic experiences are quite different from the Eight Energetic Touches which focus on the feelings of the body after meditation practice (see Chapter 29). The Internal conditions of the patients' disease, its energetic nature, as well as its clinical manifestation, are expressed through the following: Hot, Cold, Deficient, Excess, moving, stagnant, Damp, Dry, Clear (Clean), Turbid (Impure), open (accessible), closed (armored), and leaking.

Locations of Energetic Blockages

In clinical practice we generally observe six main areas in the patient's body where energy becomes trapped and blocked. Each energetic block-

age is an expression of the patient's ability to armor and protect him or herself from emotional wounding. These six main areas in the patient's body can be the foundational base and the root cause for the patient's disease (Figure 30.3). These six main areas are described as follows.

THE AREA OF THE HEAD

The area in the cranium that is most commonly obstructed is within the base of the occiput, at the back of the head. This obstruction is usually noted within patients who suffer from migraine headaches and brain tumors. This barrier is often created through chronic stress patterns which cause the Liver's Heat to rise up the patients' back and become trapped inside the head. This condition is usually caused by intense concentration. Too much hard focusing can also cause Qi to condense and stagnate. The location of Qi obstructions due to physical trauma vary according to each type of trauma, and the and the severity of the injury.

THE AREA OF THE THROAT

This area separates the Upper Dantian (the spiritual/perceptive center) from the Middle Dantian (the emotional/empathic center). Messages of divine inspiration and awareness descend downward from the Heavens through the Baihui area seeking to stir the emotions of the Heart. If the patient is not receptive (due, for example, to a disconnection or even a resistance to spiritual growth) a barrier is sometimes formed within the patient's throat, dividing the Upper Dantian from the Middle and Lower Dantians.

This barrier can also be created to stop emotions from flowing through the Heart and rising upward to be released through the windows and caverns of the soul (the eyes, ears, nose, tongue, body, and spirit). If, for example, the teeth become clenched and the throat tightens from feelings of grief or anger, these emotions can become trapped in the throat, forming a "plum seed" or "knot." When the Lungs' Qi congeals in the areas of the upper chest, shoulder blades, neck and the back of the occiput, this indicates chronic suppression of these emotions. It is also evidence of the mind and body struggling to reconnect and express the emotional and spiritual self.

THE AREA OF THE HEART

The Heart is energetically divided into two main chambers. The upper chamber houses and responds to spiritual emotions, while the lower chamber houses and responds to sensual emotions.

Patients will tend to suffer not only from repressing their basic biological drives (the sensual emotions based in the lower chamber of the Heart), but also by repressing their emotional connections with the divine (by failing to accept their higher spiritual calling or spiritual enlightenment associated with the upper chamber of the Heart). The higher self is the focal point of the superconscious realm; it is all-inclusive and at the very center of our being where individuality and universality blend (center core).

Patients who have chronically armored their Heart tend to exist in a state of guarded suspicion. This pattern of emotional suppression tends to lead to Qi stagnation and the creation of disease. When patients armor their upper chamber, they tend to hide in the emotions of their lower chamber and visa versa. Patients who armor the upper chambers of the Heart, for example, may become involved in relationships of extreme sensual passions related to the Heart's lower chamber, to avoid painful unresolved issues hidden within the past. The deeper and more energetically charged the issues, the stronger the sensual passions. Whereas, patients who armor the lower chamber of the Heart, might become involved in relationships of extreme spiritual, or religious passions related to the Heart's upper chamber to hide from their painful unresolved issues. The deeper and more energetically charged the issues, the stronger the spiritual or religious passion.

THE AREA OF THE DIAPHRAGM

The diaphragm area separates the Middle Dantian (the emotional center) from the Lower Dantian (the physical/sexual center). When a barrier in this particular area is created, it separates the emotional Heart from feeling the sexual passion which rises up from the Lower Dantian and the Kidneys' area.

It is interesting to note that patients with a

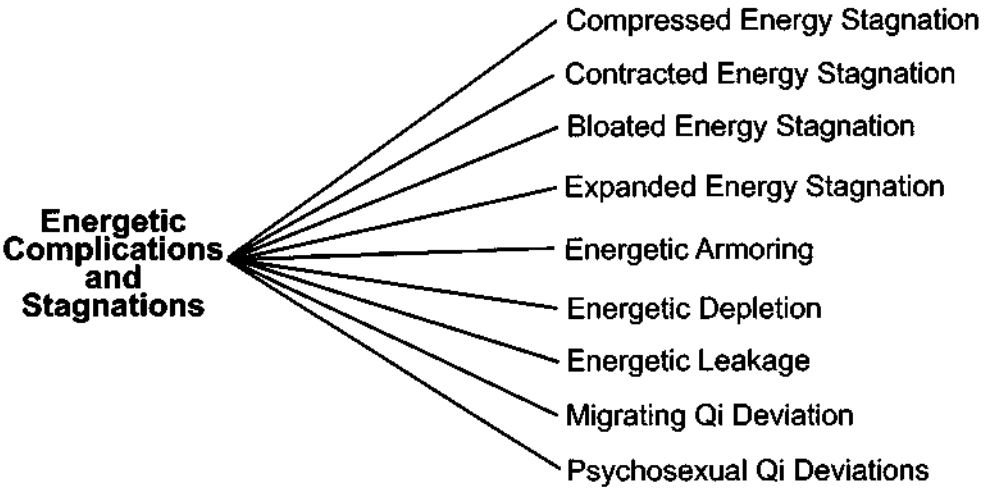

Figure 30.4. The Body's Energetic Complications and Stagnations

barrier in the diaphragm sometimes enjoy the physical sensations of sexual intercourse, but are separate from their spiritual/emotional connection to true bonding or "oneness" with their partner. Again, the connection between the emotional spirit and body/mind has been severed.

THE AREA OF THE YELLOW COURT

The Yellow Court (CV-12) is an area located in the center of the chest, just below the diaphragm and xiphoid process of the sternum. Its function is that of being the access area to release the body's internal organs' emotional memories. Its location is also attributed to the Third (solar plexus) Chakra.

To access the patient's stored emotional memories and release them from the Yellow Court, the Qigong doctor supports the patient's Shendao GV-11 (Spirit Gate) with the left hand while energetically manipulating the patient's Yellow Court area with the right hand. If the patient is not energy sensitive, the doctor uses a slight Compression/Release technique (see Chapter 37) to disperse the patient's armoring system.

The patient should be in a supine position, with knees pointed upward, feet flat, arms by his or her sides, mouth open, inhaling deeply into the Lower Dantian. As the patient exhales, the doctor lightly compresses the patient's Yellow Court until a deep groaning sound begins to resonate from the patient's thorax. The doctor circulates the energy from the patient's Yellow Court into the Shendao, filling up the patient's Heart with energy. The doctor then moves this energy back into the patient's Yellow Court. This process continues until the patient's suppressed emotions surface and are released.

Note: It is important to first purge and release the Lungs of grief before attempting to access the patient's Yellow Court.

THE AREA OF THE LOWER ABDOMEN

This area also separates the Lower Dantian from the Middle Dantian, insulating the sexual feelings from the middle and lower torso. This energetic freezing of the pelvis is usually found in victims of rape, sexual molestation, or in women who have had one or more abortions. The Qi flowing into the lower pelvis and legs becomes blocked due to stored fear, shame, guilt, and sorrow. Sometimes the patient's physiology in that particular area may become obese; the abdomen, thighs or hips may be heavily padded and armored due to Qi stagnation. Often times, victims of childhood sexual abuse become overall obese to avoid attracting the opposite sex, or to block and pacify these hidden traumatic memories.

TYPES OF ENERGETIC COMPLICATIONS

Each organ and channel has the potential to carry or create several types of energetic complications and stagnations. The doctor should observe and feel the shifts in the patient's energetic balance to determine the specific conditions of the disorder (Figure 30.4).

COMPRESSED AND CONTRACTED ENERGY STAGNATION

Compressed or Contracted energy stagnations are sometimes considered a Yin condition due to the type of energetic compression involved in its formation.

- Compressed Stagnation is caused by the patient's energy pressing downward (externally moving inward) and will feel armored and hollow (Figure 30.5). When this type of energetic stagnation disperses it does not energetically unwind, but disperses and dissolves into the surrounding tissue areas. Because the patient's surrounded consciousness has armored the tissue area, the energetic dispersion can sometimes cause spontaneously released emotions or behavior such as crying, laughing, shouting, screaming, sighing, coughing, etc.
- Contracted Stagnation is caused by the patient's energy pulling inward, and will generally feel armored and solid (Figure 30.6). This type of energetic stagnation can be formed by an emotional core, or focused concentration, that draws additional Qi into its center, compacting the belief structure, layer after layer with energy. When this type of energetic stagnation disperses it can sometimes begin energetically unwinding throughout the entire body. This energetic unwinding sometimes creates involuntary muscle twitches and physical undulations.

Body tissues and muscles accumulate emotional energy, becoming hard and tense in the adjacent areas. Denseness indicates the accumulation of pathogenic stagnant Qi. If this energy block remains, disease can manifest as ovarian cysts and tumors, or even in extreme cases as cervical cancer. Breast cysts, tumors, and cancer can result from stagnant Qi in the Lungs, or from a combination of Lung and Liver Qi stagnation. This type of stagnant energy feels very Hot and volatile because of the accumulated anger and rage.

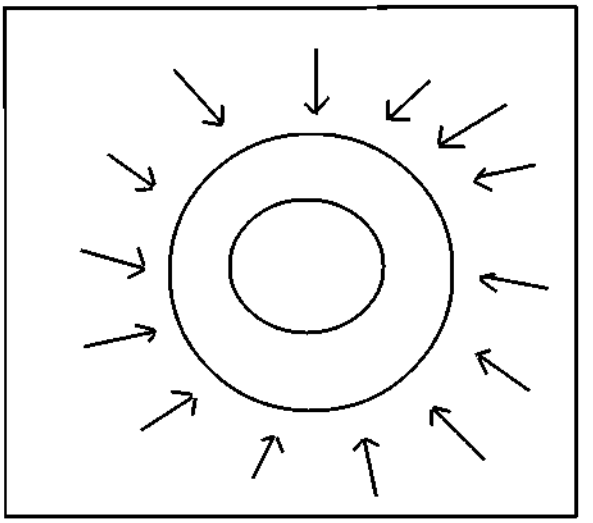

Figure 30.5. Compressed Stagnation

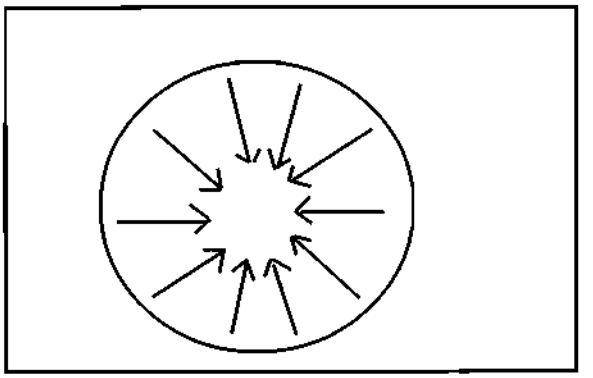

Figure 30.6. Contracted Stagnation

Treatment Principals for Compressed and Contracted Energy Stagnation

The Qigong doctor disperses and purges the patient's stagnant Qi using the Thunder Palm technique, Tiger Kneading techniques, and counterclockwise Circular Spiraling (see Chapter 34).

BLOATED AND EXPANDED ENERGY STAGNATION

Bloated and Expanded energy stagnations are sometimes considered a Yang conditions due to the type of energetic expansion involved in their formation. Qi stagnation, with a characteristically expansive or bloated appearance, can be caused from an accumulation of Phlegm and Body Fluids (in addition to Qi and Blood) in the adjacent tissue areas of the body (Figure 30.7 and 30.8). This type of stagnation usually occurs in the Lower Dantian and abdominal areas. These are examples of Excess syndromes of stagnant energy and manifest as: distending, turbid, leaking, tingling, and dense Qi.

If this type of energy stagnation remains obstructed, the resulting disease can manifest as edema within the tissues, colitis, or angina pectoralis due to unprocessed despair and grief (in the Lungs) with anxiety (in the Spleen). The energy of grief and despair feels thick, heavy, and slimy like phlegm or mucus. Often this energy is felt in the Lungs, as well as in the Spleen.

Treatment Principals for Bloated and Expanded Energy Stagnation

The Qigong doctor disperses or dissolves the patient's stagnant Qi by using the Tiger Kneading, Vibrating Palm, and Shaking Palm techniques (see Chapter 34).

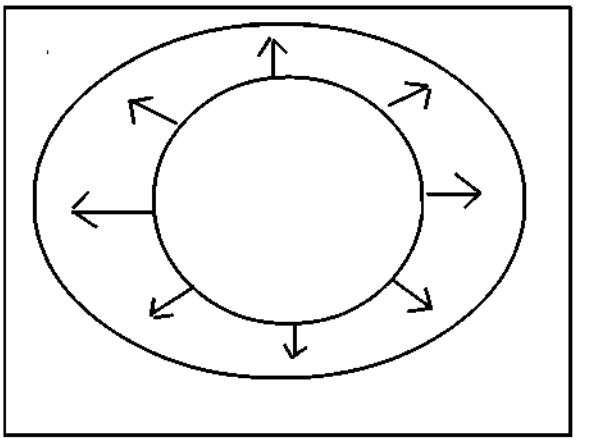

Figure 30.7. Bloated Stagnation

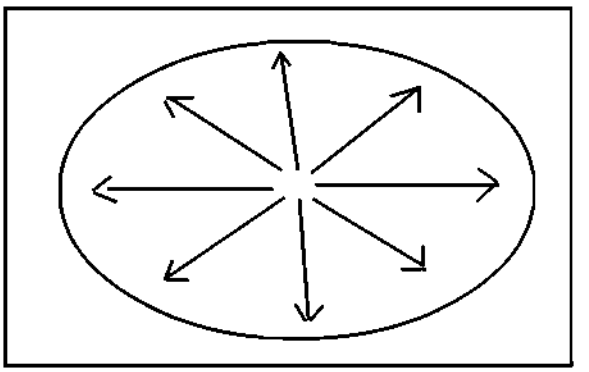

Figure 30.8. Expanded Stagnation

ENERGETIC ARMORING

This condition can result from the patient protecting specific tissues, organs, or areas of the body. Energetic armoring is initiated when the patient freezes certain emotional feelings to maintain the denial system. Patients may be unaware of this armoring condition because they dissociate from the original trauma, or minimizing its severity. Emotions attributed to energetic armoring are generally manifested as anger, fear, guilt, and shame. The angry patient's denial system is maintained through physically or emotionally attacking others; the anxious patient, full of fears, guilt, and shame, copes by "Shening out." Both of these reactions shield the patients in emotional situations from their own feelings, while reinforcing the energetic armoring.

Armoring results in tense organs and tissues. When patients cannot feel their body, other complications can arise, such as compressed, contracted, bloated or expanded energetic stagnations.

Treatment Principals for Energetic Armoring

The Qigong doctor can assist the patient through "soul retrieval" to unlock the feelings logged deep within the body's tissues (see Chapter 19). The primary goal is to first help the patients acquire a sense of security within their own body, then address the root of the disease.

ENERGETIC DEPLETION

Whole body depletion results from the following conditions:

- Not receiving enough Postnatal Qi for restoration, resulting in improper internal organ functioning,
- From suppressing emotions (e.g., worry or fear),
- Experiencing a damaged energetic field due to trauma, or
- Being born with a Deficient prenatal constitution.

Generally, energetic depletion can result in physically undeveloped areas in the body. In some cases, emotional traumas can cause specific organs or tissues to become energetically depleted to the degree that their natural development cannot take place.

Treatment Principals for Energetic Depletion

The Qigong doctor, if qualified, can assist the patient by prescribing herbal tonics. The patient should also be encouraged to eat regular, nutritional meals and to balance work with relaxation time. If the patient's energetic field has been damaged, the Qigong doctor can repair it by using Flat Palm and Circle Spiraling techniques (see Chapter 34).

ENERGETIC LEAKAGE

Energetic leakage is a result of the patients releasing Qi from out of their joints, due to injury or unconscious sabotage. When energy drains from the patients' joints, the specific areas along the channels become depleted, resulting in a Deficient Qi which can cause an atrophy syndrome. Any type of energetic thinness along the Wei Qi field indicates an insufficiency of Qi. A Deficient energetic field can result in an empty, numb, or weak feeling of Qi within the tissue areas.

Treatment Principals for Energetic Leakage

The doctor envelops the patient's depleted tissue area (which is leaking) with Spiral Wrapping techniques to create an energetic cast that allows the patient's energetic field to completely heal (see Chapter 34).

MIGRATING QI DEVIATION

Migrating Qi Deviations can result from either the patient's suppressing and avoiding feelings, or from Wind invasion (either Internal or External). In Traditional Chinese Medicine this condition is known as Wind Bi (Wind Pain) or Wandering Bi (Migrating Pain). Once patients feel cornered by a specific memory, they subconsciously shift the toxic energy to another part of their body; this energetic shifting requires the treatment to be restarted. When treating these patients, it is important to first connect the original trauma to the Heart to prevent these energetic shifts, and to stabilize the condition. Once stabilized, disperse the Wind Invasion and tonify any Deficient organ.

Treatment Principals for Migrating Qi Deviation

The Qigong doctor first envelops the primary area of complaint, isolating the pain, and then begins to internally Spiral Circulate the patient's internal Qi. Once the energy is in motion, the doctor leads the Toxic Qi out of the patient's body.

PSYCHOSEXUAL QI DEVIATION

Psychosexual Qi Deviations can result from an immediate energetic tissue over-stimulation. Patients with this condition experience intense sexual undulations and orgasms when being treated in a safe clinical environment. This reaction is due to their avoidance issues, brought about by an energetic trigger mechanism. This psychosexual reaction usually takes place when touching any part of the torso or extremities. Because the energy seeks balance (much like water), when it flows into the genital area, the sexual neurons become overstimulated, activating and releasing the energetic turbulence already stored therein. This condition is mostly found within patients who have either been raped or molested as children.

Treatment Principles for Psychosexual Qi Deviation

The doctor is encouraged to refer the patient to a psychotherapist who specializes in such trauma. Meanwhile, the doctor continues to treat the patient by rooting the patient's Heart (emotional chamber) to the patient's Lower Dantian (sexual chamber). Once this connection is established, the doctor reconnects the patient's Lower Dantian to the patient's Upper Dantian (spiritual chamber), forming a complete body connection within the patient's Taiji Pole. By reconnecting the sexual chamber with the spiritual chamber, the doctor empowers the patient, allowing the patient to reclaim his or her true sexual/spiritual identity.

PATIENT'S ENERGETIC FACIAL DISTORTION

Sometimes, when treating a patient, the Qigong doctor will notice the patient's facial features energetically distort, changing their facial pattern. These facial distortions can appear and disappear rapidly, or maintain their illusion for several seconds. The cause for the patient's energetic facial distortion can be brought on by several factors: The Patient Reliving A Past Trauma, The Ancestral Patterning of the Patient's Jing, or The Energetic Manifestations of the Patient's Active Spiritual Guardians.

1. The patient reliving a past trauma can release an energetic distortion that expresses itself on the energy field of the patient's face. This projected image reflects the age and time frame wherein the patient received the initial trauma. Often, as the doctor connects with the energetic root of the patient's disease, the patient's face will regress to reveal the delicate features of the patient as a young child. This visual facial pattern of energetic age regression reveals the exact age the patient suffered the initial trauma.
2. The ancestral patterning of the patient's Jing can also be released as energetic distortions that express themselves on the energy field of the patient's face. Occasionally, these projected images can reflect the patient's ancestry, or reveal an ancestral guide. Multiple projections of racially identifying features; images of men, women, and sometimes children will appear to shadow the patient's features, much as a projected image over an original form.
3. The energetic manifestations of the patient's spiritual guardians are believed to project their image onto the face of the patient during treatment. Some cultures accept that these guides manifest in the form of animals. The animal form will appear to flicker across the patient's face and then dissipate. This phenomenon is the most rarely seen of all the energetic facial distortions.

PATIENT RESISTANCE TO ENERGETIC THERAPY

Sometimes, in order to avoid the painful memories, the patient will subconsciously sabotage the treatments. Resistance can manifest in one of four ways.

1. Falling asleep is a form of physical escape.
2. Excessive talking is a mental form of avoidance behavior.
3. Irritability or sexual response is a form of emotional escape.
4. "Shening out," also called "spacing out," is a form of spiritual escape.

When observing these patterns, the doctor encourages the patient back into the body to feel the emotions and memories trapped in the particular areas being treated. It is important for the doctor to let the patient know the cause and effect of the patient's chosen defense mechanism. These personal conversations are necessary for the patient's growth and emotional healing. In cases of sexual response, tact and appropriate professional boundaries are especially important.

When emitting Qi, the doctor can encourage the patient's Shen to stay in its residence by asking the patient to focus his or her breathing on the tissue areas being treated. This focused attention causes the patient's Po to settle and calm themselves within the patient's body, allowing the patient's Hun to communicate the feelings surfacing within the patient's Heart.

UNBLOCKING THE FIVE PASSES

The Wu Guan or Five Passes refer to the five important gates on the Governing Vessel. These gates, or passes, are sometimes called Tie Bi, which translates as the "iron wall," and are the areas of the body where it is most difficult for the energy to pass through when circulating the Microcosmic Orbit. Free passage through the Governing Vessel is important, especially when tonifying the patient's body or regulating the patient's Qi. To circulate the Qi up the Governing and down the Conception Vessels, these five gates must remain open.

Opening these Five Passes are essential for the treatment of diseases in the neck and lumbar-sacral regions. In Medical Qigong therapy, disease is sometimes an indication that both the Governing and Conception Vessels have been, or are, in a state of disconnection. If disorders of Qi, along with Qi obstruction, develop along the Governing and Conception Vessels, the doctor should emit Qi into one of the Five Passes (depending upon the affected area) to facilitate the regulation of Qi (Figure 30.9).

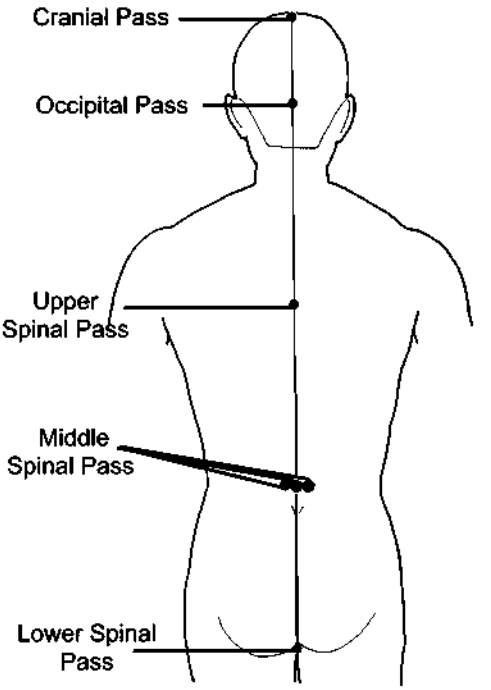

Figure 30.9. The Five Spinal Passes

THE LOWER SPINAL PASS

The Lower Spinal Pass or "Coccyx Pass" (Wei Lu Guan) is located on the lowest segment of the spine just posterior to the anus, near the Chang Qiang GV-1 point. If Qi becomes blocked in this area the patient suffers a dull persistent pain by the coccyx, along with feelings of heaviness.

To treat, have the patient direct energy up the Lower Spinal Pass, using mild or gentle intention; have the patient position the tongue against the upper palate and inhale deeply while gently contracting the anus and abdominal muscles. These gentle contractions of the muscles along with the position of the tongue on the upper palate create an energetic sacral pump, which facilities the release of the energetic block.

THE MIDDLE SPINAL PASS

The Middle Spinal Pass consists of the Mingmen (GV-4) area and two points (Jia Ji Guan) located on the lateral sides of the Mingmen. If Qi becomes blocked in these areas the patient suffers a dull persistent pain in the middle of the spine, or on one or both sides of the Mingmen. This obstruction causes a physical sensation that feels like a spinal rupture, break, or herniated disc near the waist area when Qi circulates through these points.

To treat this disorder, the doctor extends Qi into the patient's Middle Spinal Pass, while leading the patient's energy upward along the Governing Vessel.

THE UPPER SPINAL PASS

The Upper Spinal Pass is located between the shoulders on the Shendao point (GV-11) Spirit Gate. If Qi becomes blocked in this area, the patient suffers a dull persistent pain on the midline of the upper back below the fifth thoracic vertebra. This obstruction causes a physical sensation that feels like a spinal rupture, or causes intense Heart pain when Qi circulates through this point.

To treat this condition, the doctor extends Qi into the patient's Upper Spinal Pass, while leading the patient's energy upward along the Governing Vessel.

THE OCCIPITAL PASS

The Occipital Pass (Yu Zhen Guan) is located just inferior to the occipital bone where the brain originates. If the Qi becomes blocked at this area, the patient suffers a dull persistent pain around the occiput, stiff neck, feelings of heaviness, as if there is something were stuck inside the back of the head.

To treat this problem, the doctor should instruct the patient to close the eyes, raise the head slightly and look upward, while gently concentrating on the Baihui GV-20 point. Have the pa-

tient imagine the energy block as a cube of ice. The ice melts into water, the water dissolves into vapor, and travels upward along the Governing Vessel into (and through) the Baihui area, then proceeds down the Conception Vessel toward the Lower Dantian.

THE CRANIAL PASS

The Cranial Pass is located at the vertex on the midline of the skull. If the Qi becomes blocked at this area, the patient suffers a dull persistent pain around the eyes and the top of the head, as well as feelings of heaviness, as if there is something were stuck inside the top of the head.

To treat this condition, the doctor instructs the patient to close the eyes, raise the head slightly, while gently concentrating on the Lower Dantian. Have the patient imagine the energy block as a cube of ice. The ice melts into water, the water dissolves into vapor, and travels downward along the Conception Vessel toward the Lower Dantian.

FURTHER COMPLICATIONS

In balancing the patient's energetic body, the doctor first locates the Excess or Deficient condition, determines if the tissues should be tonified, purged, or regulated, then ascertains which energetic complications have initiated the patient's disease.

The doctor must also determine if the patient is sensitive to treatment or resistant to energetic therapy. Below is a summary listing several energetic complications and suggestions on how to rectify them.

1. For Compressed Stagnation, break up the stagnation, purge the pathogens, then tonify and regulate the patient's Qi.
2. For Contracted Stagnation, break up the stagnation, purge the pathogens, then tonify and regulate the patient's Qi.
3. For Bloated Stagnation, break up the stagnation, purge the pathogens, then tonify and regulate the patient's Qi.
4. For Expanded Stagnation, break up the stagnation, purge the pathogens, then tonify and regulate the patient's Qi.
5. For Energetic Armoring, access the patient's Heart (through the Shendao GV-11 area), and induce "soul retrieval" (see Chapter 19).
6. For Energetic Depletion, tonify and regulate the patient's Qi.
7. For Energetic Leakage, envelop the patient's tissues creating an energetic cast to stabilize the energetic fields.
8. For Migrating (Wandering) Qi Deviations, purge the pathogens and then isolate and stabilize before tonifying and regulating the patient's Qi.
9. For Psychosexual Deviations, root the patient's Heart, then regulate the patient's Taiji Pole with divine healing light.

CHAPTER 31
THE MAGIC SQUARE OF THE YELLOW RIVER

The configuration known as the Lo Shu (Lo Writings) or Magic Square of the Yellow River, is shown below. It is said to have been derived from markings on the shell of a "spiritual turtle" that crawled out of the River Lo when the Emperor Yu was draining off the floods. It is considered a mathematical model of the universe. The relationship between the numbers presented in this chart may be used to diagnose the energetic relationship between universal and environmental phenomena, as well as the various pathologies within the occurring internal organ correspondence.

It corresponds to the Later Heaven sequence of the trigrams of the Yi-Jing (I-Ching) and is arranged in accordance with the directions of the compass, with the number "5" at the center of the compass, in an arrangement known as the "Magic Square."

The numerals 1–9 are assigned to each position in accordance with the Lo Scroll markings and represent the Acquired Essences (Postnatal Jing).

Understanding the concept of balance is paramount in Qigong medicine. When Yin and Yang energies in the body are balanced, health is established. The Chinese have given numerical relationships to Yin and Yang properties representing this dynamic connection.

Yang energy is represented by all the odd numbers (1, 3, 5, 7, and 9). Yin energy is represented by all the even numbers (2, 4, 6, and 8).

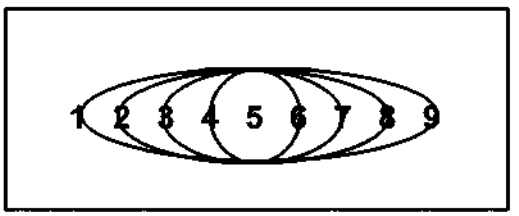

Figure 31.1. Yin and Yang Number Balance

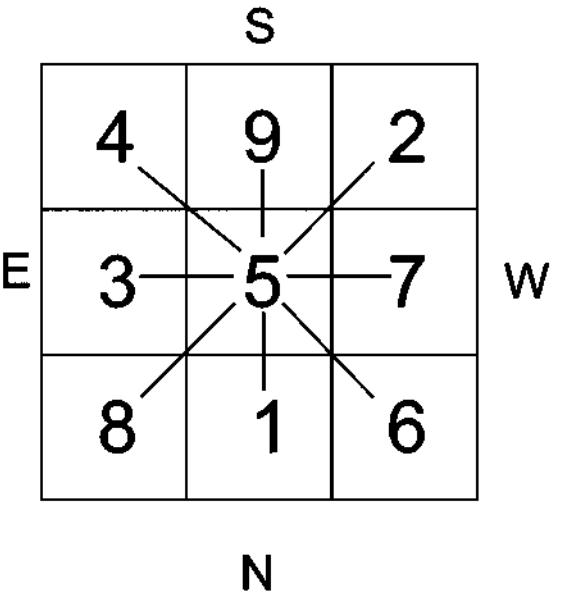

Figure 31.2. The Magic Square

The cycling of Yang (odd numbers) and Yin (even numbers) indicates the law of motion of Yin and Yang in all things. In Chinese medicine the numerical configuration is based on the sum totaling ten (Figure 31.1).

The numbers arranged together create what is known as the Magic Square. Investigation will uncover several numerological correspondences (Figure 31.2). The sum of any two numbers opposite each other in a row, column, or diagonal (with the number "5" between them) equals 10; thus the sum in any of these rows, columns, or diagonals equals 15. Fifteen is the number that represents "Man," who lives between Heaven above (the number being 20, which equals the sum total of the four primary directions) and Earth below (the number also being 20, which equals the sum total

SW =	2 }		SE =	4}	
NE =	8 }		NW =	6}	
	10	+		10	= 20 Yin Earth Qi
S =	9 }		W =	7}	
N =	1 }		E =	3}	
	10	+		10	= 20 Yang Heaven Qi

Figure 31.3. Heaven and Earth Numbers

of the four secondary directions). The numbers in the four primary directions (north, south, east and west) are odd and represent Yang Heaven Energy, while the numbers on the corners are even and represent Yin Earthly Energy (Figure 31.3).

EARTHLY YIN ENERGETIC FLOW

The numbers on the corners of the Magic Square are "terrestrial" in design. All the terrestrial numbers are even numbers. They represent the Earth's energetic field and flow counterclockwise in their circular progression. These terrestrial cycle phases are expressions of Earthly Yin energy and are designed in progressions of "times two." For example, (2) Fire: $2 \times 2 = (4)$ Metal: $4 \times 2 = (8)$ Wood: $8 \times 2 = (16)$ Water (which is reduced to 6, as the ten position is not counted): $16 \times 2 = 32$ (which is reduced to 2). This completes one cycle in the terrestrial progression, which then returns to the element Fire and begins all over again in the same fashion, continuing in an endless progression of "times two." (Figure 31.4).

Through understanding the Yin energetic progression, the Qigong doctor rotates the patient's energy in a counterclockwise direction to purge Excess conditions and expel pathogenic Qi (called "Yin destroying Evils").

HEAVENLY YANG ENERGETIC FLOW

The numbers on the sides of the Magic Square are "celestial." All the celestial numbers are odd numbers. They represent the Heaven's energetic field and flow in a clockwise circular progression. These celestial cycle phases are expressions of Heavenly Yang energy and are designed in progression of "times three." For example, (1) North: $1 \times 3 = (3)$ East: $3 \times 3 = (9)$ South: $9 \times 3 = (27)$ West (which is reduced to 7, as the ten position is not counted): $7 \times 3 = 21$ (which is reduced to 1). This completes one cycle in the celestial progression, which then returns to the North and begins all over again in the same fashion, continuing in an endless progression of "times three."

In understanding the Yang energetic progression, the Qigong doctor will rotate the patient's energy in a clockwise direction to tonify. This technique facilitates the continuous circulation of Yang Qi and is used in order to help the tonification of Qi and Blood and replenish Deficiencies (called "Yang promoting growth").

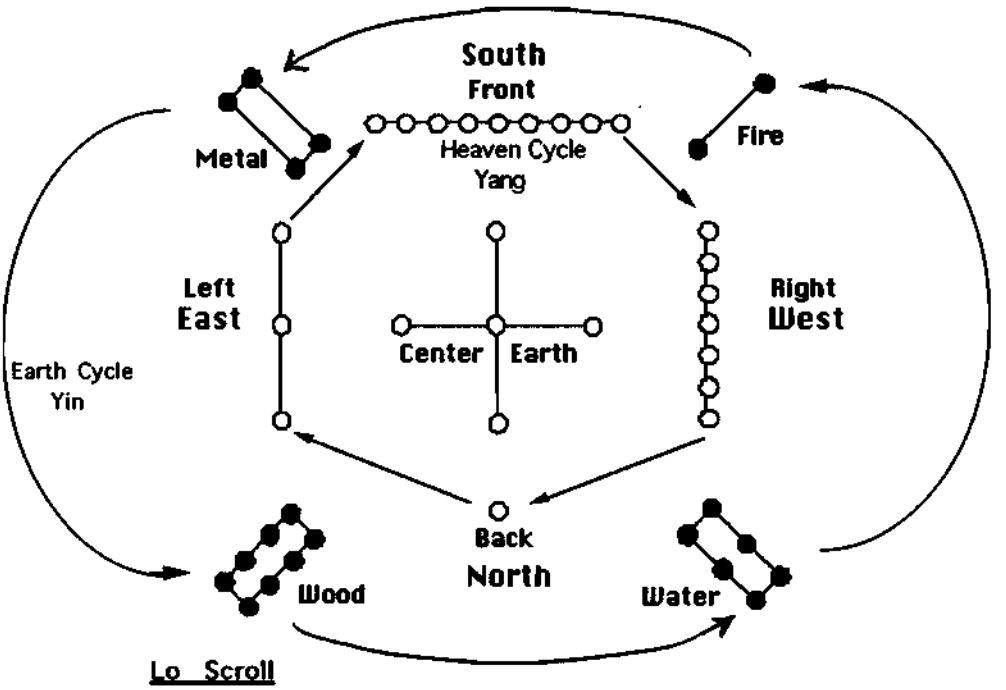

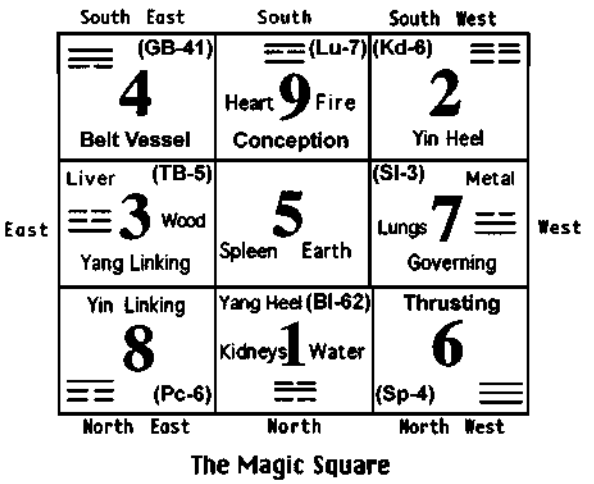

Figure 31.4. The reason the South is positioned on the top of the page is because, in China, maps were specifically designed for the convenience of the Emperor, whose throne was always positioned facing South, the direction of Yang energy. As the magistrates of his court unrolled the maps before him, the East would be positioned on his left, the West to his right, and the South furthest away at the top of the map (whereas, in the Western culture North is at the top).

THE MAGIC SQUARE AND EIGHT TRIGRAMS

The following Eight Trigram Hand chart represents the terrestrial aspect of the body's acquired structures, evolution, and exchange of Yin/Yang energy.

It should be noted that if the trigrams associated with the numbers shown in the Magic Square are placed in their correct positions, the postnatal or "Later Heaven" trigram arrangement will form. The middle number "5" does not correspond to a trigram because it is the unifying number placed in the center.

In order to use the Eight Trigrams in conjunction with the Magic Square, the patient's palm is divided into nine sections. The Eight Trigrams form the exterior of the palm, while the heart of the palm (known as the Bright Hall or Ming Tang) aligns the Magic Square to the patient's internal organs. The Qigong doctor observes the color, luster, sinking or bulging of skin, as well as any prominent blue veins appearing on the surface of the patient's skin. These observations are compared to the organs and functions associated with each trigram that rules that particular area of the patient's palm (Figure 31.5).

1. The Trigram Kan, located at the base of the palm's heel, is associated with the patient's Kidney and Bladder organs, as well as the function of their urogenital and reproductive systems.
2. The Trigram Kun, located on the palm just below the little finger, is associated with the patient's left Lung organ and the left side of the chest (the left breast in women).
3. The Trigram Zhen, located on the upper part of the patient's thenar eminence, is associated with the function of the patient's Liver and Gall Bladder organs.
4. The Trigram Sun, located on the palm, just under the index finger, is associated with the patient's right Lung, and the right side of the chest (the right breast in women).
5. The Bright Hall (Ming Tang), located on the center of the palm is associated with the patient's Heart, blood vessels, and mental health.

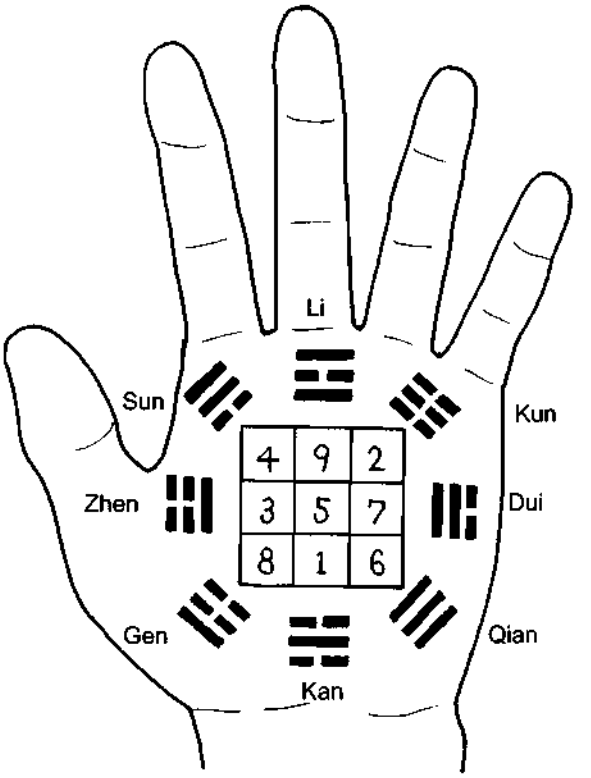

Figure 31.5. The "Magic Square" can be superimposed on the human body for observation, diagnosis, and treatment. For example:

2 and 4 represent the location of the Lungs

3 and 7 represent the location of the Liver and Spleen

8 and 6 represent the location of the Kidneys

9 represents the location of the Upper Burner

5 represents the location of the Middle Burner

1 represents the location of the Lower Burner

6. The Trigram Qian, located on the lateral edge of the palm's heel, just above the wrist crease, is associated with the patient's descending and sigmoid colon.
7. The Trigram Dui, located on the lateral edge of the palm's heel, midway between the little finger and the wrist crease, is associated with the patient's Spleen, pancreas, and Stomach organs.
8. The Trigram Gen, is located on the lower half of the thenar eminence, is associated with

Trigram Correspondences

Trigram	Name	Meaning	Channel	Shu Point	Direction	Number	Season
☲	Li	Fire (Clinging)	Conception	Lu-7	South	9	Mid Summer
☷	Kun	Earth (Receptive)	Yin Heel	Kd-6	South West	2	Start of Fall
☱	Dui	Lake (Joyful)	Governing	SI-3	West	7	Dividing of Fall
☰	Qian	Heaven (Creative)	Thrusting	Sp-4	North West	6	Beginning of Winter
☵	Kan	Water (Abysmal)	Yang Heel	Bl-62	North	1	Absolute Winter
☶	Gen	Mountain (Keeping Still)	Yin Linking	Pc-6	North East	8	Start Of Spring
☳	Zhen	Thunder (Arousing)	Yang Linking	TB-5	East	3	Dividing of Spring
☴	Sun	Wind (Gentle)	Belt	GB-41	South East	4	Start of Summer

Figure 31.6. The Eight Trigram Correspondence

patient's appendix and ascending colon.

9. The Trigram Li, located on the palm between the middle and ring finger, is associated with the patient's blood circulation, Heart and eyesight.

THE MAGIC SQUARE AND THE EIGHT EXTRAORDINARY VESSELS

In Chinese medicine, the Lo Writings and their correspondences form the model which is the basis for the Ling Gui Pa Fa (The Eight Techniques of the Mysterious Turtle) system of acupuncture. In this system there are Eight Confluential Points that are associated with the Eight Trigrams (Figure 31.6). These points are where the Eight Extraordinary Vessels and Twelve Primary Channels intersect each other.

This method describes the theory that all the points on the body are dominated by the Shu Points, which are in turn dominated by the Eight Confluential Points. The confluential points and their trigram correspondences are Kd-6 (Kun Gua), Lu-7 (Li Gua), GB-41 (Sun Gua), TB-5 (Zhen Gua), Pc-6 (Gan Gua), Sp-4 (Qian Gua), SI-3 (Dui Gua), and Bl-62 (Kan Gua).

UNDERSTANDING THE METAPHYSICAL ASPECT OF NUMBERS

The Chinese medical text of the Nei Jing explains numerology and its mystical significance, as well as the practical utilization of the correspondences between numbers and natural phenomena. Man's physical, mental, emotional, energetic, and spiritual form manifest as part of the microcosm of these nine correspondences, and are explained as follows.

1. Number One corresponds to Heaven, the Center Taiji Pole, and represents the skin.
2. Number Two corresponds to Earth and represents the muscles. The number two also cor-

responds to the two primary forms of Yin and Yang.

3. Number Three corresponds to Man and represents the blood vessels. The number three also corresponds to the Triple Burners, Three Powers, Three Treasures, Three Dantians, and Three External Fields of Wei Qi.
4. Number Four corresponds to the four seasons and represents the muscles corresponding to the body's four extremities, the Four Earthly Quadrants and the Four Divisions of Heaven (N.S.E.W.), and the Four Prenatal Trigram Essences (Great Yang, Small Yang, Great Yin, and Small Yin).
5. Number Five corresponds to the Five Notes of the Chinese pentatonic scale and represents the voice. The number five also corresponds to the Five Elements, Five Colors, Five Tastes, Five Planets, and the Five Elemental Constitutions.
6. Number Six corresponds to the Six Divisions (Tai Yang, Shao Yang, Yang Ming, Tai Yin, Shao Yin, Jue Yin) and represents the union of Yin and Yang. The number six also corresponds to the Six Yao lines and their correspondence to the body, and the Six Accomplishments (intelligence, humanity, holiness, sincerity, moderation, and benevolence).
7. Number Seven corresponds to the Seven Luminaries (sun, moon, and the five planets), which represent the Seven Openings of Man (two eyes, two ears, two nostrils, and one mouth). The number seven also corresponds to the Seven Emotions, and the Seven Stars of the Big Dipper.
8. Number Eight corresponds to the Eight Extraordinary Channels from which the body's prenatal energy flows and represents the breath. The number eight also relates to the Eight Trigrams and their various correspondences.
9. Number Nine corresponds to the formless Void or Wuji, as well as the Nine Heavens (one is centered, and the others are in the eight separate divisions of the Lo Pan compass) and the Nine Lo River Chart (Magic Square). The number nine also represents the nine openings of man (two eyes, two nostrils, two ears, one mouth, one anus, and one urethra).

THE FIVE ELEMENT ENERGETIC FLOW OF THE MAGIC SQUARE

The number formations on the Magic Square are not only considered the energetic ebb and flow, evolution and exchange of Yin and Yang Qi, but also correspond to the energetic harmony of the Five Elements. The energetic harmony of the Five Elements are arranged as follows.

- The Kidneys are positioned in the North; their element is Water and number is 1.
- The Liver is positioned in the East; its element is Wood and number is 3.
- The Heart is positioned in the South; its element is Fire and number is 9.
- The Lungs are positioned in the West; their element is Metal and number is 7.
- The Spleen is positioned in the Center; its element is Earth and number is 5.

These five numbers are arranged in accordance to their energetic progression and are used as a templet for observation and diagnosis of the patient's body, according to their Five-Elemental postnatal structure.

CROSSOVER ENERGY PATTERNS

According to the theory of energetic harmony, when one area of the body lacks Qi, there is generally an Excess energy accumulation in another area. Because the body is symmetrical, one can naturally look on the opposite side for the misplaced Qi. The Qigong doctor may dredge the full side in order to drain the Excess and support the Deficient area.

If the imbalance is not on the opposite side, the doctor can scan for Excess Qi using a figure eight pattern (Figure 31.7). Classically, the Crossover Energy Pattern is one of the most powerful pathways by which Qi flow in the body can be stimulated, and is excellent for balancing internal body energy. The figure "8" pattern can also be used in order to balance all sides of the body (top and bottom, as well as left and right).

When the Qigong doctor must balance the energy in the left and right sides of the brain, the patient may be assigned homework that requires them moving Qi in a figure "8" pattern sideways (i.e., drawing the infinity symbol). This exercise prescription stimulates, strengthens, and balances the right and left hemispheres of the patient's brain. It is used successfully in the treatment of patients with dyslexia.

When patients have internal problems that affect the function of the whole body, it may be necessary to treat two areas simultaneously. The Spleen and Stomach areas, for example, may be tonified along with the Lung areas to strengthen and increase the patient's resistance to External pathogenic factors.

Because organ imbalances are deeper, and tend to be the result of years of energetic deviations, they may take longer to reverse.

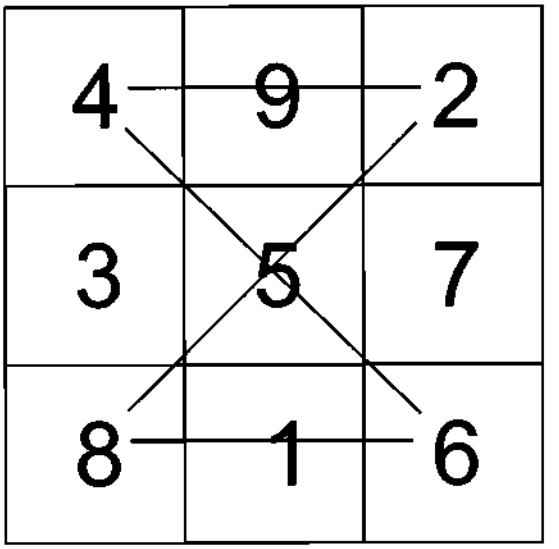

Figure 31.7. In this Crossover Energy Pattern, area 4 is treated using area 6 and so on.

Chapter 32
Healing the Patient's Emotional Traumas

Introduction

In my personal practice I feel the main problem for patients is in dealing with their own "hurt," which may have been inflicted upon them several years prior to the manifestation of their disease. It is a recognized truth that when people isolate themselves from each other, their environment, and their spiritual life, it is because they feel the need to guard themselves.

They guard and protect themselves and their belief structures from invasion, criticism, exploitation, or attacks, whether real or imagined, allowing interchange only if it supports their beliefs.

People build energetic walls, and when the walls are penetrated they often experience anger, self-hatred, pain, fear, and shame. Consequently, masks and defence mechanisms are created to hide and support these hidden belief structures.

How the patients develop and maintain their energetic patterning will determine which clinical modality the Qigong doctor will utilize to initiate healing. To free themselves from personal hurt the patients must reconnect with their anger, pain, fear, or worry. Eventually, with the unconditional loving support of the doctor, patients are able to reintegrate the hurt and anger, and accept parts of themselves they had rejected for so long. This acceptance of painful feelings and memories affects the Heart and frees the patients from the emotional traumas of the past.

To heal and release these pathogenic emotions, the patients go through a five-stage detoxifying process during which they feel, experience, and release the emotional trauma that initiated their disease. This is a natural progression in the process of Medical Qigong therapy and healing.

The Physiological Effects of Benign and Chronic Emotions

Within the clinic it is observed that benign emotions (love, joy, peace, etc.) bring about a calm and restful condition within the patient's physiology. Chronic emotions however, create a detrimental stressful physiology, adversely affecting the quality of the patient's life-force energy. As discussed previously, emotional internal and external environmental factors can and do affect the quality of the body's Qi.

1. Excessive joy from the Heart slows down the Qi.
2. Excessive worry and thinking from the Spleen stagnates the Qi.
3. Excessive sadness from the Lungs obstructs the Qi.
4. Fear from the Kidneys descends the Qi.
5. Excessive anger from the Liver ascends the Qi.

Five Levels of Feeling and Their Governing Organs

To complete their initial healing, the patients go through five stages of emotional resolution. These stages act as a template for the patients' emotional healing, allowing them to progress through, and detoxify each of their Five Yin Organs. The Five Yin Organs store the patients' emotional history in their tissues. Each of the Five Yin Organs also affects different functions and parts of the body (Figure 32.1).

1. The Liver governs the emotions dealing with the past. The Liver stores the negative emotions of irritability, jealousy, anger, rage, blame, and resentment. These emotions and mental states affect the flow of Qi in the channels, influencing the patient's tendons, ligaments, nails, small muscles, peripheral nerves,

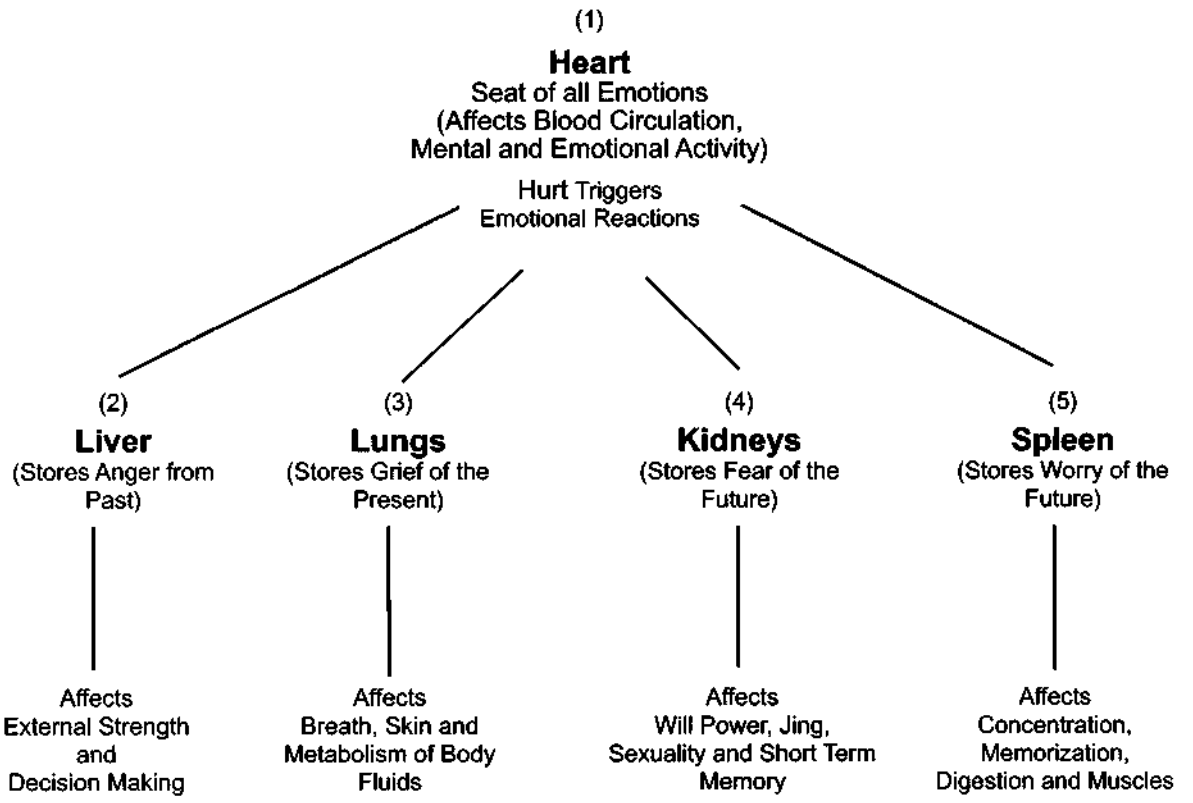

Figure 32.1. Diagram of Five Elemental Emotional Transitions

external strength, the iris of the eyes, vision, tears, the Gall Bladder, bile, decision making, the external genitalia, and the Hun (Three Ethereal Souls).

2. The Lungs govern the emotions dealing with the present. The Lungs store the negative emotions of grief, sorrow, sadness, anxiety, shame, guilt and disappointment. These emotions and mental states affect the flow of Qi in the channels, as well as the patient's breath, skin, Large Intestine, mucous membranes, the metabolism of the Body Fluids, body hair, smell, and the Po (Seven Corporeal Souls).
3. The Kidneys govern the emotions dealing with the future. The Kidneys store the negative emotions of fear, loneliness, and insecurity. These emotions and mental states affect the patient's energetic channel flow, as well as the Jing, bones, brain, bone marrow, inner ear, hearing, head hair, pubic hair, spinal cord, cerebrospinal fluid, ovaries, testes, anus and urethra, sexual fluid, reproduction, short term memory, and the Zhi (Will Power).
4. The Spleen governs the emotions dealing with resolution and responsibility. The Spleen also stores the negative emotions of worry, remorse and regret, which can create obsessions. These emotions and mental states affect the flow of Qi within the channels, as well as the patient's large muscles, lymph and saliva secretions, the mouth, lips, taste, the Stomach, digestion, concentration, the ability to memorize, and the Yi (Intention).
5. The Heart governs the emotions dealing with

shock, nervousness and excitement, as well as the final stages of healing (i.e., peace, love and forgiveness). These emotions and mental states affect the patient's energetic channel flow, as well as the patient's blood vessels and circulation, complexion, perspiration, mental and emotional activity, long term memory, Small Intestine, and the Shen (Spirit).

In the process of forgiveness, the anger and resentment are traversed to reach through to the levels of original hurt, sadness and grief. Only after reaching this level, and working through the pain, can the patient begin the process of letting go of the anger, blame, and resentments that protect them from feeling the full impact of the original trauma. Forgiveness begins only after the anger and crying ends. There are three stages of forgiveness: forgiving oneself, accepting the situation, and forgiving the abuser.

1. The forgiving oneself stage deals with the energy involved in healing oneself, and is divided into two specific stages:
   - Forgiving oneself for allowing the hurt to occur in the first place (even if the patient had no choice in being victimized), or for not fighting back strongly enough, if at all, and
   - Forgiving oneself for hanging on to all that anger and pain for so many years.
2. The accepting the situation stage deals with releasing the energetic emotional charge within the environment, or the unwanted consequences connected to the original trauma (e.g., forgiving the accident, injury, handicap, illness, trauma) within the patient.
3. The forgiving the abuser stage is the most difficult final step. Many factors can interfere with this process, such as the patient's fear of re-abuse or continued abuse if forgiveness is genuinely given. Another major factor is the negative, toxic, external energy projected by the abuser upon the patient, sometimes over many years. This energy is absorbed by the patient over time and often leads to the patient identifying with the abuser. The fear of being, or becoming, just like the abuser can be overwhelming. Anger at the abuser may seem to be the only thing standing between them; and allowing any feelings of love, compassion, or understanding may appear to be an acceptance of "evil," not only within the abuser, but within the patient's own self. An acceptance of a dark side within each of us is necessary to forgive the abuser. Often victims of abuse cannot tolerate the idea that they are anything like their abuser. Only the conscious mind, working in concert with the patient's spirit, can reintegrate this essential part of the self that has been utterly rejected and denied.

Children who have experienced abuse may be especially hard pressed to accept anger as a natural, integral part of themselves without which they cannot feel whole. They frequently view all and any anger as not only dangerous but an "evil" force. Thus, forgiveness of the abuser requires restructuring of belief systems, and the acceptance of one's own dark side, as well as the abuser's.

Through conscious intent and creative subconscious intuition, it is possible to come to an understanding that the "evil" experienced stems not from the devil, but from ignorance and pain. In most cases the abuser's intent was not to harm and destroy, but ironically, to teach and discipline for the good of the patient. The abuser did the best that he or she could at the time, given all the unresolved pain and anger within the self.

When patients experience extreme abuse, or prolonged abuse, they may lose the ability to distinguish the difference between wrong actions and the abuser. The abuser is not evil incarnate though evil deeds were done. This often leads victims to see the world only in terms of black and white with no shades or colors. The true healing requires acquiring the ability to see anew (as a little child), to reawaken to the amazing diversity of life.

These skills sometimes require teaching the patient and may necessitate referring the person out to a professional, especially if the patient suffers from a character disorder (e.g., borderline personality disorder, schizo-affective disorder, and so on).

Generally, after performing specific Qigong

exercises and meditations which release the patient's pent-up, toxic emotions, the patient begins to come out of denial and awaken to genuine spontaneous emotions and feelings. This transition can be very painful at first. I usually tell the patients that this transition is similar to having their arm frozen, and then thawed out.

Imagine if the arm is placed into ice cold water, and left there. The first thing the body would feel is shock, followed by pain. As the feelings slowly begin to leave, the pain begins to diminish, and the arm becomes numb. As the mind shifts its attention away from the feelings in the arm, it begins to establish a denial system, ignoring, minimizing, or suppressing the condition in which the arm has been placed. When first removing the arm from the ice water, the tissues are still numb. After awhile, however, as the numbness begins to wear off, feelings begin to return to that particular area of the body, and pain is felt. The body is no longer in shock and is now feeling the pain and the memory of the past experience.

Our lives are the same way, in regard to physical, mental, emotional, and spiritual pain. While growing up, we are subject to constant trauma on all four levels of existence. Through an instinctive ability, we adapt and learn to become numb to our true feelings in order to survive. When we begin to awaken, we are suddenly thrust into shock, then pain, as we begin to face the source and cause of our trauma.

From a Traditional Chinese Medical perspective, pain is a means by which the body communicates its needs to the mind. In cases of chronic pain, the patient generally learns to divert awareness away from the area of pain through distracting thoughts and emotions. This helps the patient to cope with the pain, but also interferes with the healing process. If the patient reduces conscious awareness of the painful area(s) in the body, the mind/body connection becomes blocked and slows or prevents healing. The initial clarification of the "Message" regarding the disturbance can cause both a sensation of increased pain and an activation of the healing process.

By comprehending the five levels of feeling and their progressive transitions, the patient gains understanding and healing from these past traumas.

STAGES OF EMOTIONAL HISTORY AND RESOLUTION

After the patient understands the five levels of feeling and how they affect their respective organs, the Qigong doctor can assist patients in the cognitive restructuring of their disease-causing belief structures. This emotional re-patterning is initiated through the unveiling of several stages of painful emotional history, which affect the energetic healing abilities within the patient's body.

It is important for the Qigong doctor to remember that all physical matter is conscious energy activated and focused by consciousness. The patient's perceptions create the physical presence of the disease. Since all matter and energy is unified, all matter down to the smallest subatomic particle has awareness, makes choices, and communicates simultaneously with all other matter in the universe. Choices are initiated in the patient's body through the active fields of environmental and universal energy.

Understanding these subatomic communications allows the Qigong doctor to assist the patient in discharging toxic energy trapped and stored within the tissues. The experience of the emotional trauma, and its destructive emotional energetic patterning, is clinically explained and described in the following stages.

1. The patient is hurt (physically, mentally, emotionally, and/or spiritually). The patient receives the original trauma through either an aggressive, direct attack (i.e., being struck, screamed at, belittled, or shamed, etc.), or by a passive, indirect attack (i.e., being abandoned, rejected, ignored, betrayed, etc.). In this stage of development, the patient's trusting connection to life is violated.
2. The patient registers the hurt, feels the pain, and naturally expresses this trauma in an outburst of emotion (i.e., screaming, crying, laughing, groaning, etc.). In this stage the patient recognizes the wounding.
3. The patient seeks attention and looks for a

human emotional response, seeking validation and self-affirmation. In this stage, if the patient does not seek and receive attention for healing the trauma or, if the individual is not free to express his or her real feelings, healing will not take place.

4. The patient's hurt remains unresolved and becomes history. At this point in the transition it is important that the patient feel the hurt, understand the circumstances surrounding the hurt, then discharge the pain. If the patient's hurt does not become completely discharged from the body, it becomes stored within the patient's tissues. Thus, the patient's hurt becomes internalized; the emotions of unexpressed anger, fear, pain, and shame begin to accumulate in the body. The trauma remains as an active charge of unexpressed emotional energy.
5. The patient's whole body stores the distressful emotional memories. This distress gets restimulated in the present (through various trigger mechanisms), and alters or blocks the patient's flow of energy and thinking.
6. The patient learns defense mechanisms to survive. The patient develops strong defense mechanisms instead of healing from the emotional wounds (known as a pathological recovery). At this point the patient's denial system is reinforced, and kept active to protect the patient from any further hurt, in order to ensure survival and maintain at least the semblance of a normal, functional life.
7. A dynamic polarity arises that seems to take on a life of its own. The patient swings back and forth between overcontrolling emotions and loosing control over them completely. The patient becomes obsessed with the painful feelings, either hiding from them or becoming overwhelmed by them. The patient then chooses either one of two options:
   - To become isolated, emotionally removed and distant, or
   - To become needy, co-dependent and attention hungry.
8. The patient develops addictions to continually hide from the pain. The patient's actions become based on the unhealed feelings resulting in four overlapping ways to hide:
   - Physically through sports, excessive exercise, food, sleeping, etc.,
   - Mentally through compulsive behavior (e.g., studying, being a work-a-holic, compulsive book reading, etc.).
   - Emotionally through either chronic rage, grief, obsessive worrying, and chronic fear, or through a compulsive search for love, joy, and excitement (sex/love addiction), etc., and
   - Spiritually through fanaticism of various types, or extreme spirituality.
9. The patient begins to recover from the trauma. To heal and recover, the patient must cease concentrating on the pain and redirect his or her full attention towards setting healthy boundaries and positive affirmations. Some patients' boundaries are too solid and immovable (i.e., they won't allow for any meaningful interaction with others). These patients do not really need to set boundaries, they need to allow their boundaries to become more permeable. Patients' boundaries need to be flexible in order for them to be healthy. Patients must learn when to open and when to close their boundary system, and not just constantly shut everything out (people, relationships, responsibilities, etc.) or let everyone and everything in.

It is important for patients to understand that perpetrators of abuse are in a state of denial of their own shame and imperfection; thus they inflect pain and suffering onto anyone present at the time. Some perpetrators single out one family member as a recipient for their pain. Sometimes the chosen victim reminds the perpetrator of his or her younger innocent self; thus all the accumulated self-hate is projected onto this one child through no fault of the victim. The resemblance may be real (slight physical similarities for instance) or imaginary (the child's vulnerability, for example, or a singled out personality trait that triggers the abuser's anger). The one common factor among abusers is their inability to see their victims for who they really are. Abusers make no ef-

fort to know the victim, to really see the whole person; instead they see a distorting mirror which reflects their own image back to them, magnifying their own flaws and fears. Through setting boundaries and affirming their own self-worth, the patients will be able to release years of toxic emotions stored within their tissues. This can initiate health and healing on every level of their being (physical, mental, emotional, and spiritual).

ASSISTING THE PATIENT IN ESTABLISHING HEALTHY BOUNDARIES

The patient is generally informed that in order to make it through the spiritual, emotional, and mental transitions brought about by Medical Qigong therapy, it is important to establish an active but flexible boundary system. The patients are then taught to divide their relationships into three categories: True Friends, Acquaintances, and Toxic Relationships (Figure 32.2).

1. True Friends consist of people with whom the patient can share and expose his or her most intimate hidden secrets and emotional feelings, without worrying about being judged. In the presence of true friends, the patient feels emotionally accepted and loved unconditionally. The boundary system should be down, and the patient should feel completely open. It is safe to be completely vulnerable.
2. Acquaintances consist of people with whom the patients should share only limited amounts of information regarding their personal/emotional life experiences. The most hidden secrets could be judged, misconstrued, and gossiped about. All conversation with these individuals should, and must be, kept on a fairly superficial level. The patient's boundary system should be up, and the patient should monitor the conversation, as it is not safe to be totally vulnerable.
3. Toxic Relationships consist of people with whom the patient cannot and should never share any knowledge of their personal/emotional life. These individuals chronically abuse, mistreat, belittle, and attack others (whether they are members of the patient's own family, work, or neighborhood). All conversation with these individuals should be kept to a minimum. The patient's boundary system should be on full armor, and whenever possible, these individuals should be avoided.

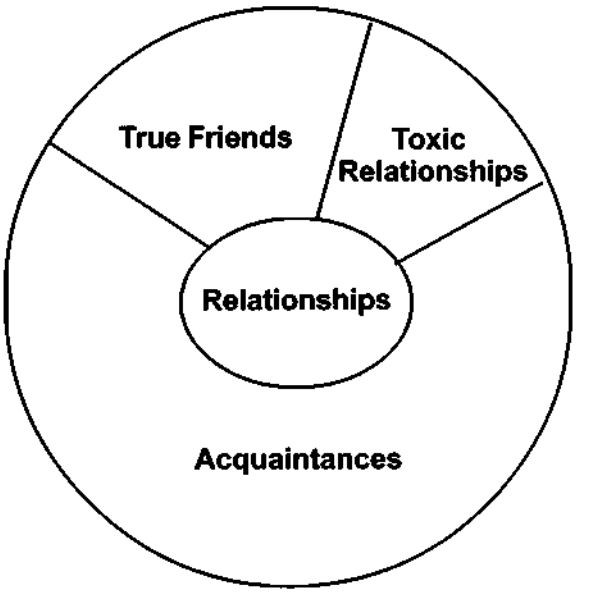

Figure 32.2. Types of Relationships for Setting Flexible Boundaries

REJECTION, BETRAYAL, AND ABANDONMENT

From a young age, people are introduced to the multidimensional experience of being hurt (physical, mental, emotional, and spiritual). This affects the individual's center core and initiates a coping response due to feelings of rejection, betrayal, and abandonment. The normal reaction to such emotions results in experiencing emotions ranging from fear to frustration. These individuals begin to develop masks, that warp and scar their developing personality. As these individuals continue to grow, the illusions of these masks demand more Qi to sustain their form, which in turn drains vital energy from the growing body, and weakens the immune system. This denial system, fortified by the individual's emotional patterning,

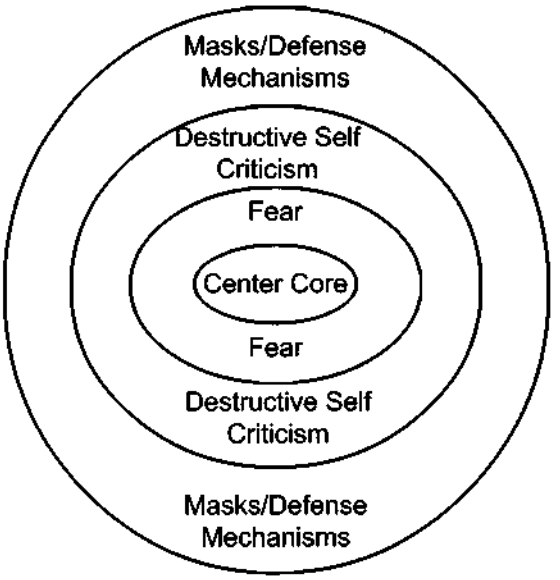

Figure 32.3. The True Self is contained within the Core Self.

sustains him or her until they can heal and re-pattern the no longer beneficial belief system.

To re-pattern their belief systems, patients and Qigong practitioners must first be made aware of their initial programming patterns and the reasons for which these were created in the first place. The following "spiritual template" is applied to all patients, regardless of culture, race, or religion.

To access the patient's center core, the Qigong doctor must help the patient identify the masks which have taken on a life of their own and created the false "ego self." Next, the patient must address personal self-hate issues, which have driven the patient to develop the masks and defense mechanisms. Finally, the patient must face the foundational fear that has severed his or her connection with their "true self" contained within the center core (Figure 32.3).

In the Medical Qigong clinics in China there is a saying, "Patients must first stop running from their fears, and face the "Paper Tiger" (i.e., the illusions and fantasies that have been chasing them); in the West, it is considered "stopping and facing your internal demons."

MASKS AND DEFENSE MECHANISMS

To armor the ego, individuals resort to what Sigmund Freud labeled as "ego defense mechanisms." There are nine strategies; and with the exception of the last one listed, i.e., "sublimation," they serve to mask the core self. The nine defense mechanisms and their strategies are: Repression, Displacement, Projection, Intellectualization, Regression, Fixation, Denial, Reaction-Formation, and Sublimation.

1. Repression is the pushing down of unwanted ideas and emotions into the unconscious;
2. Displacement is the shifting of impulses aroused by one person, or situation on to a safe target;
3. Projection is the attribution of unacceptable impulses within oneself to other people;
4. Intellectualization is an elaborate rationalization of a naked impulse, to justify it;
5. Regression is the return to an earlier childhood stage of behavior to reduce the demands on the ego;
6. Fixation has the same result as Regression, but the person becomes fixated at a particular stage of mental and emotional development;
7. Denial is a conscious refusal of an impulse-evoking fact, feeling or memory;
8. Reaction-Formation is the conversion of one feeling into its opposite, typically seen in love turning into hate;
9. Sublimation is the channeling of unacceptable impulses into acceptable, refined social forms and is the only defense mechanism considered to be a healthy reaction.

The ego mediates between the "id" (i.e., the primordial survival drives and impulses) and the "super ego." The super ego consists of the ideals and conscience of the individual.

EMOTIONAL SECURITY

Each individual has basic emotional needs that must be met to feel secure. Without the comfort of these needs being met an individual will sometimes lash out and react in an antisocial behavior. This reaction is generally due to the individual fostering feelings of rejection, betrayal, and abandonment. The three personal needs required

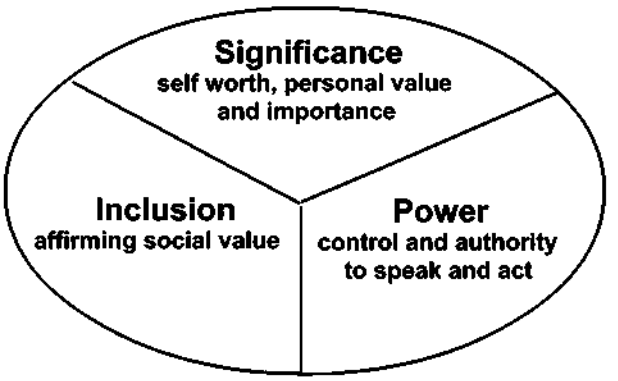

Figure 32.4. The Three Personal Needs That Foster Emotional Security

to foster emotional security are as follows: Significance, Inclusion and Power (Figure 32.4).

1. For an individual to feel significant, he or she must be given self worth, personal value and importance. Without personal value the individual will feel insignificant, unimportant, and worthless.
2. For an individual to feel included, he or she must be given affirming social value (knowing that they play an important role in the family, relationship, or society as a whole). Without personal acknowledgment the individual feels isolated, segregated, and separated.
3. For an individual to feel powerful, he or she must be given the ability to control and the authority to speak and act. Without personal power the individual feels powerless, weak, and incapable.

In addressing the patient's disease, it is important to sometimes address his or her living and work environment, as both can contribute and influence the patient's healing potential.

HEALING EMOTIONAL TRAUMAS

There are several techniques and methods used to assist patients in healing through emotional traumas (Figure 32.5). Such meditations as Pulling out the Pain are often prescribed as homework along with other treatment methods of Medical Qigong therapy. Some of these methods used to heal emotional trauma are described as follows.

1. Medical Qigong Distance Therapy affects the body, mind and emotions. The Qigong doctor alters the patient's energetic tissues and fields to re-pattern the patient's emotional responses.
2. Medical Qigong Massage Therapy and Bodywork involves lightly touching and stimulating the patient's tissues, to release the trapped emotions so that they may be appropriately reprocessed.
3. Medical Qigong Respiration Therapy unites the body, mind, and emotions by moving the energy through specific breathing techniques. By changing the breathing pattern, the Qigong doctor changes the patient's energetic emotional patterns, releasing trapped memories deep within the patient's tissues.
4. Medical Qigong Dynamic Postural Therapy expands and stretches the patient's tissues. This active adjustment of the patient's body alignment increases the flow of Qi and Blood through his or her internal organs, facilitating an emotional release (e.g., the Dry Crying exercise).
5. Medical Qigong Imagery and Meditation Therapy uses awareness meditations and images to sedate the patient's reactive mind in order to connect with the higher self-identity. The doctor interrupts the patient's emotional

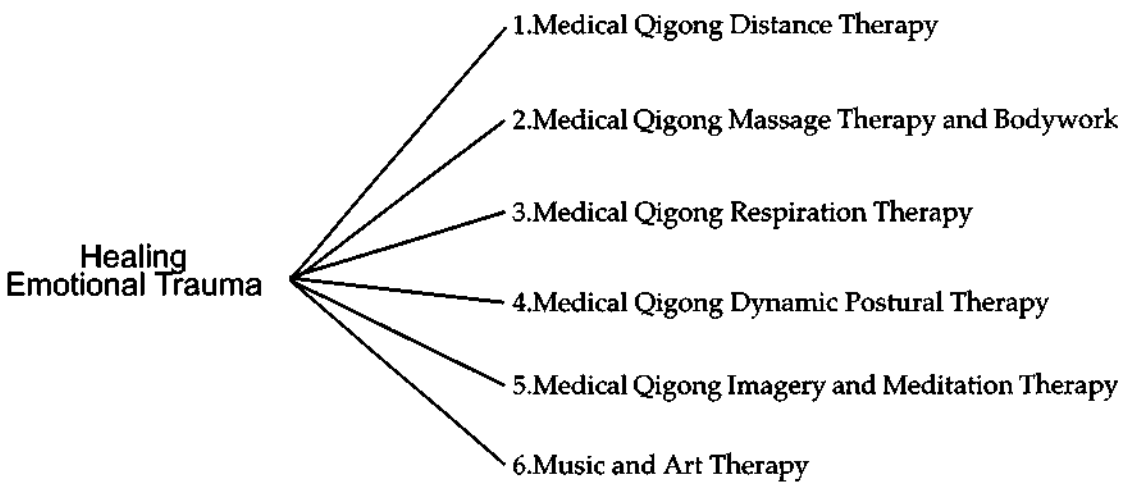

Figure 32.5. Six Methods Used For Healing Emotional Trauma

thought patterns by changing the patient's sequence of sensations, word pictures and feelings. This emotional reforming changes the meaning of the patient's interpretation and challenges his or her self-limiting beliefs.

6. Music and Art Therapy are sometimes prescribed to change the patient's mood and awareness. Through playing a musical instrument, dancing, singing, or creative free-association drawings, sculptures, pottery, and so on, patients can access their Creative Subconscious Mind to repattern old belief structures and enhance the body's energy. Some patients will resist this form of therapy as they do not consider themselves to be good artists. It is vital to explain that these creative endeavors are not for the purpose of creating art, but for expressing feelings and emotions. These art forms need not be pretty, perfect, or shared with anyone if the patient does not desire to do so. They need not even be kept so long as the patient has released some feelings and emotions. The process itself is the healing. This type of therapy is used to help the patient recreate, identify, and release trapped emotions deep within the subconscious mind.

PULLING OUT THE PAIN MEDITATION

This meditation uses part of the guided imagery used in the Soul Retrieval Meditation (found in Chapter 19). It releases and transforms the patient's conscious feelings and helps to change or remove the Personal Subconscious toxic holding patterns.

After the meditation, patients should feel as if they have been cleansed and purified of toxic emotional debris. This is, however, only the first level. Patients can only release and transform the surfacing emotions one level at a time. Like peeling an onion, the patients must continue to work through each level until reaching their core issues. These core issues surround the suppressed feelings of hurt and pain.

The doctor instructs and guides patients through this meditation matching the rhythm of his or her words to the patient's exhalations. Patients draw their painful memories and traumas out of their body in the form of dark smoke; they then separate the distilled wisdom and knowledge from this dark cloud, reabsorbing the healing light into every pore and cell of their body. The dark cloud must then be released with the help of an angelic being who severs the energetic cord(s) still attach-

ing the patients to their pain and suffering. When the patients reach this sixth step, the doctor assists them by clapping his or her hands as the patients visualize the "sword of truth", held by this holy being, severing the dark energetic cord(s). The sword of truth represents the patients' decision to regain their power by letting go of their attachment to their illness. This attachment creates very real energetic cords that bind the patients to their painful memories and toxic emotions. Severing these cords, or cord, symbolizes the end of the patients' investment in their disease, and the beginning of true healing. This releases all the pain and despair, i.e., the black cloud ascending into the Heaven into the hands of God or a "higher power," in accordance with the belief structure of the patients. As the cloud reaches the first wave of love and compassion emanating from God or a "higher power," a mighty explosion transmutes the black despair and pain into divine healing light. The doctor then assists the patients in accepting this healing, loving light back into their body to experience, perhaps for the first time in their lives, true forgiveness and a state of grace.

1. Begin by sitting comfortably in a chair, with both feet on the floor, hands resting on your thighs, eyes closed, tongue on the upper palette. Breathe naturally through the Lower Dantian.
2. Focus your attention on the Yellow Court area below the diaphragm where you store painful memories and trauma. Imagine opening up this area to release the toxic energy out of your body as a stream of dark steam releasing from a pot.
3. As the dark steam flows out of your body you are releasing feelings and memories of guilt, anger, rage, humiliation, abandonment, degradation, rejection, insecurity, and sorrow. These toxic emotions have, until now, prevented your healing through creating a deep distrust of self and others.
4. Focus your attention on this energetic cloud, and begin separating the pain and hurtful memories from the knowledge and wisdom gathered from these experiences. Visualize this knowledge and wisdom in the form of golden, white, and silver light energy gathering on the right side of the room. Continue to drain the dark cloud of misery and pain, now occupying the left side of the room, until you have extracted all the new insights from it. As you do so, you will notice the dark cloud becoming heavier and darker.
5. Focus on the right side of the room. Through your intention, begin to inhale and imagine this bright, illuminating energy flowing back into your body. Absorb this knowledge and wisdom gathered from past experiences, void of any feeling of hurt, pain, and judgement into every cell of your body. This distilled knowledge and wisdom empowers you to heal from your wounds on a physical, mental, emotional, energetic, and spiritual level.
6. Next focus your attention on the dark black cloud containing all your pain and suffering. Imagine an angelic being, righteous and holy, holding a "sword of Truth," standing by your side, ready to sever the dark energetic cord(s) still connecting your physical body to this dark cloud of despair. The sword descends and severs the cord(s) (*the doctor claps his or her hands as the sword severs the cord(s)*.
7. The cloud of darkness begins to float up, through the ceiling, through the sky into space. Far in the distance you begin to perceive God or a "higher power" emanating waves of compassion, love, and mercy descending towards the Earth. One of the waves touches the dark cloud of hurt and pain, exploding it into a brilliant light. The cloud is immediately transmuted into fluorescent crystal blue drops of light. This pure, clean energy descends from the Heavens like gentle rain. Breathe in this crystal blue healing energy, let it penetrate deeply into every pore, every tissue and cell, saturating your body completely. Feel the light cleansing and radiating throughout your being.

UNDERSTANDING WHY A PATIENT WON'T HEAL

Normally, in a clinical setting, 80% of the patients will respond favorably to Medical Qigong therapy. In some cases, complete remission of the

disease is achieved. An additional 10% will improve, but stabilize in their condition, while a final 10% will not respond at all to the treatments and will progressively get worse. When the patient does not respond to the treatments, the reason can usually be related to the following conditions: Failing to Carry Out the Prescriptions, The Pathogens are Just Too Strong, and Divine Will Guides the Outcome.

- Failing to carry out the prescriptions can be caused by the patient subconsciously sabotaging the healing. Refusing to practice is usually due to deep unresolved emotional issues, e.g., feeling unworthy to heal, fear of abandonment by spouse or others, and so on.
- The pathogens are just too strong to be healed by Medical Qigong therapy alone; when an illness is long-standing, additional complementary treatments, i.e., herbs, Western medicine, or surgery may become necessary to achieve healing.
- Divine will guides the outcome in some cases. The patient's time in the physical realm may be complete, and the soul is preparing to return back to the divine.

Sometimes the healing process takes more time then expected. I explain to patients that permanent transitions can sometimes be instantaneous, but are more likely to be gradual. I explain that they are like a sea captain, standing at the helm of a great ocean liner. If the captain decides that the present course is unsafe, and destructive to the ship and its crew, he quickly orders an immediate change in the course of the ship's direction. With a flick of a switch and a hard spin of the steering wheel, the direction of the rudder is immediately changed. However, because of the perpetual inertia of the massive ship, it will take some time to observe any alteration in the course of the ship's current direction. Although the eyes of the captain can be focused on the new direction, the ship still requires enough time to effectively move in the new direction. It is the patient's spiritual intentions and focused goals that eventually direct the patient's emotional belief system, which in turn, redirects their thoughts and body's physical reactions.

Sometimes, toxic emotions and memories are released through diligent Qigong practice and treatments. With some patients, however, although major changes have already occurred in their conscious attitude, belief structure, and spirit, it may take longer for the unconscious reprogramming to take hold and stop reinforcing the old fears, and traumas. This impediment of unconscious reprogramming is due to the patient's conscious mind not being able to fully integrate the new reality and belief structure. A cancer patient may, for example, have been diligently practicing the prescriptions and the disease may now be in remission, but, the patient still visualizes the cancer as all-invasive. Rather then starting with an image of less cancer in the body, the patient continues to start the meditations with the cancer condition visualized at its worst peak. This sends a double message to the subconscious mind (heal and don't heal).

The same thing applies to observing the patient's transitions of chronically programmed patterns. New behaviors and attitudes cannot become habits overnight. It simply takes time, endurance, and constant encouragement in order to make progress. It is important for the patients to keep their eyes focused on their intended goal and not give up hope.

It is also important not to force mental imagery when feeling angry, depressed or upset. To be effective, creative visualization requires a quiescent mind and soft focus; it should not be hard work. Time allotted to creative visualization can be brief (only a couple of minutes), several times a day, for it to be effective.

FACING THE DEATH OF A PATIENT

Because human beings are created from the energies of Heaven and Earth, they are subject to the transitions of nature, death being part of that transition. Sometimes, no matter who the doctor is, or what his or her specific training has been, there is nothing that can be done to physically heal the patient. Because patients have made attachments during their stay on Earth (physical, men-

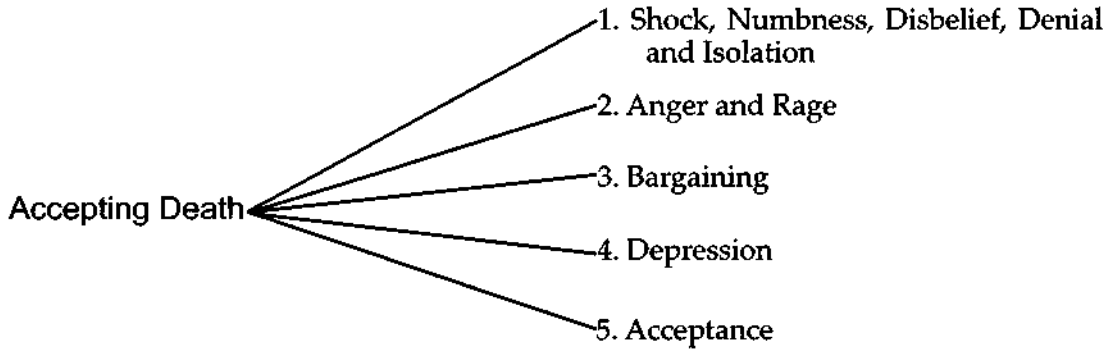

Figure 32.6. The Five Stages and Transitions of Accepting Death

tal, emotional, and spiritual), it is important for the doctor to assist them in their final transitions of releasing and letting go. The fear of death often causes patients to feel loss of control of their life, facing and conquering this fear allows them to regain a sense of control.

According to Dr. Elisabeth Kubler Ross, there are five stages of dying that facilitate closure for patients, especially in the life and death transition (denial, anger, bargaining, depression, and acceptance). These transitions also occur when facing the death and closure of any personal relationship or job, as well as the termination of one's life (Figure 32.6). Although these stages were originally believed to follow each other in an orderly fashion, further research has indicated that these stages need not, and most often do not occur one at a time. The different "stages" can occur at any time going from "denial" to "acceptance," back to "bargaining," etc., (sometimes in just a few minutes). Every individual reacts differently. Some never accept death and struggle to the very end. Medical Qigong therapy describes these transitions as follows: Shock, Numbness and Disbelief, Denial and Isolation, Anger and Rage, Bargaining, Depression, and Acceptance.

1. Shock, numbness, and disbelief occur when an individual is faced with the fact that his or her own death is near. Because of shock, the mind will generalize, rationalize, delete, or distort information to make the information acceptable to the patient's belief system. When these initial feelings of shock, numbness, or stoicism begin to disappear, most patients then experience disbelief. They can not believe or will not accept what is happening to them.

   Some patients bypass this stage all together. They feel great relief at learning of their impending death. They look forward to the cessation of pain and rejoining those close to them who have passed on.
2. Denial and isolation is the first semi-conscious choice the patient makes after hearing the news. The patients' disbelief allows them to establish their own denial system. This denial system functions as a shield to protect them, as they emerge from the shock. Denial and isolation further allows these patients time to gather additional knowledge, hoping that the original diagnosis was incorrect.
3. Anger and rage arise as the denial system breaks down. Patients experience anger, rage, envy, and resentment, as they view their terminal progress as an injustice. The patients' discomfort and anger are usually displaced and projected towards anything and everyone (usually people and God). Patterned, fear-based behaviors get stored in the body and mind. These emotions affect the patients' future perceptions, diminishing their belief system in personal survival.

4. Bargaining is the next stage in the process of adjusting to the verdict. Patients offer counterproposals (usually with God), hoping to change or alter the course of events and postpone the inevitable from happening.
5. Depression replaces hope and the patient experiences a deep sense of loss. Still resisting the outcome, patients sink into depression, sometimes lingering for quite some time before death. Depression is divided into two different categories, each one is different in nature.
   - Regretful depression is caused by guilt and shame for not having lived life to the fullest. The patients regret having given in to fears and having held on to past hurts (both real and imaginary) for so long, that many dreams were abandoned. Opportunities for healing and enjoyment were missed, and old sorrows and conflicts never resolved. Patients with this type of depression often seek to voice their regrets. Many ask to let go of the bitterness and open up to a spiritual healing, rather than a physical healing.
   - Preparatory depression is not caused by regrets, but by mourning the loss of projected future experiences. These patients are usually quiet and reflective, as they face the process of losing everything and everyone that they love.
6. Acceptance is the final stage before death. Having nowhere else to go, patients evaluate what was learned in life. They are now able to express their feelings of envy for the living and the healthy, as well as anger at those who do not have to face their fate so soon. They finally accept the inevitability of death. Depression gives way to a time of rest before the divine journey home. The patients, having faced their life's work, fears, and feelings, now have a new outlook on life and are prepared for the spiritual transition of death.

Facing death is an important transition in life and must be approached with a reverent respect for spiritual transformation. When a patient is dying it is extremely important for the doctor to accept the "higher order" or "divine will" for the patient, and not harbor a win or lose attitude. No matter what stage of transition the patients are in, they will almost always maintain some glimmer of hope, even though they may claim otherwise, to the very last moment of their life. It is the doctor's responsibility to accept and support patients to their inevitable end and not cease to treat them for reasons of personal fears, sorrows, or regrets. Listen to your patients, and allow them to release their fears. This continued support, acceptance, and encouragement for the patient allows them to die in peace and with dignity.

SUMMARY

Death is considered merely a change of residence for the patient's spirit. The ailing body is sometimes viewed as "a house with rotting walls." Once the dying body becomes unusable, it is best to abandon it, and look for another place to stay. The spirit-body is immortal and will exists forever in accordance with the will of the divine. This is why one is taught to be unattached to the physical transformations of this world and accept and embrace death as part of the natural process of existence.

Think of the transition of death as similar to that of a baby chick which is about to be hatched. Although it has lived and existed within its shell all its formative life, as the baby chick continues to develop, it has slowly begun to outgrow its place of existence. The baby chick is now becoming harshly compressed and crushed within the security of its own shell. As the little chick exhausts itself, trying to get free from what has now become its prison, it seemingly faces death. With its apparent last breaths, the little chick shatters the surrounding shell. Immediately, an intense light appears, followed by a whole new world that reveals itself in new wonderment. The baby chick is now reborn into a fresh new realm of existence, with new room to grow and the ability to experience true freedom.

Once, while in China, I was talking to Dr. Wong of the Xi Yuan Hospital, in Beijing. He made the profound statement that everyone he had ever treated had gotten healed. I have never heard such a bold statement being made by a Qigong master,

or by any doctor for that matter, so I immediately began to inquire as to what his special techniques were. Dr. Wong responded, "Everyone I treat gets healed; some get healed spiritually, others emotionally, some mentally, and some physically. Not all get cured, but all do get healed. Some patients that come to me for therapy are supposed to die. It is their time of passage, and I help them accept death with dignity and honor. This is achieved by helping the patients heal their spiritual, mental and emotional wounds before they pass on. Other patients that come to me are in an active stage of energetic transition, and I help these patients to see where they've become stagnant, Excessive, or Deficient in their bodies and release their pathogenic Qi." Life is a pathway of transition and change, and so, in the field of energetic medicine, all patients are moving toward or away from healing their relationship with themselves and others.

Section VIII
Qi Emitting Methods

Chapter 33
Energy Extension And Qi Manipulation Techniques

Energy Projection

The body's energetic constitution is a combined matrix of sound, light, heat, and electromagnetic energy. Studies on the effects of Qi projection conducted by Chinese scientists concluded that energy released by a Qigong doctor into a patient carries the properties of infrasound, electromagnetics, static electricity, infrared radiation, gamma rays, particle and wave flows, organic ion flows, and light. These properties produce the physiological changes in the patient's tissues during the Qigong treatment.

A Qigong doctor can emit energy during a treatment with or without touching the patient. The treatment with the doctor's hand moving at a distance from the patient's body is considered Qi Emission. If the doctor's hand touches the patient's body, it is considered Qi Massage, which combines both tissue manipulation and energy flow. Functionally, it is also helpful if the Qigong doctor also has a thorough grasp of the tissue manipulation skills of Chinese massage therapy (Jie Gu for bone setting, Tui Na for traumatology, and An Mo for Internal diseases and visceral manipulation), as well as acupressure and TCM theory, to ensure a highly proficient quality of treatment and to avoid misdiagnosis and erroneous treatments.

Qi is projected outside the body and travels in ripples and vibrational pulses similar to the ripples of an ocean wave. The frequency of this energy wave can be modulated into dense or dispersed resonating patterns depending on the Qigong doctor's needs.

Shen is projected outside the body as light and travels in light beam particles. This particle light extension can change in color and intensity depending on the doctor's intention. When Qi and Shen are combined, the light and wave frequencies facilitate maximum energy projection.

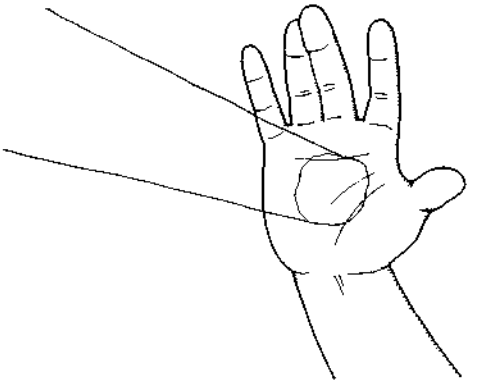

Figure 33.1. Palm Qi Extension

Types of Energy Extension

There are nine types of energy extension and projection skills that are divided into three categories based on the source of the projected energy. The first three are projected from the extremities: palms, fingers, and soles of feet. The next category of Qi projection originates from the three Dantians: Upper, Middle, and Lower Dantian. The third category includes Qi emission from the eyes, throat (sound resonation), and thought projection.

Energetic Projection from the Extremities

The first three energetic projections are released from the extremities (palms, fingers, and the soles of feet) in accordance with the doctor's imagination and intention.

- Palm extension is the ability to release emitted energy through the center of the doctor's palm (Pc-8). It is considered the primary hand posture used by all Medical Qigong doctors for emitting Qi (Figure 33.1).
- Finger extension is the ability to release emitted energy through the extended fingers (usually through the index and middle fingers).

The finger extension techniques allow the Qigong doctors the ability to finely hone their energetic projections into a smaller, condensed energetic beam (Figure 33.2).

- Soles of feet extension is the ability to release energy through the bottom of the feet (Kd-1); this method is usually used to surround and envelop the treatment room as well as the patient (Figure 33.3).

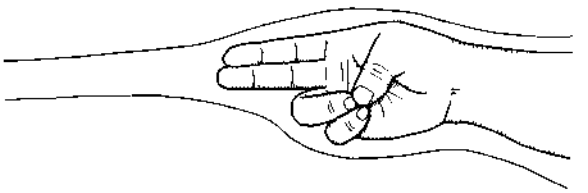

Figure 33.2. Finger Qi Extension

ENERGETIC PROJECTION FROM THE DANTIANS

The next three energetic projections are released from the Upper, Middle, and Lower Dantians. These energetic projections are based upon the doctor's kinesthetic, empathic and intuitive abilities.

- Upper Dantian (Yin Tang) extension from the Qigong doctor's Third Eye area can be used in conjunction with the eyes for intensifying the doctor's Shen projection towards the patient.
- Middle Dantian (CV-17) extension from the Qigong doctor's Heart area can be used in conjunction with projection from the doctor's hands or throat, for vibrational resonation. This technique intensifies the emotional connection between the doctor and the patient.
- Lower Dantian (CV-6) extension from the Qigong doctor's abdominal area can be used in conjunction with Qi emission from the feet for expansion or extension of Wei Qi. This method intensifies the projected External field of Qi around the patient (Figure 33.4).

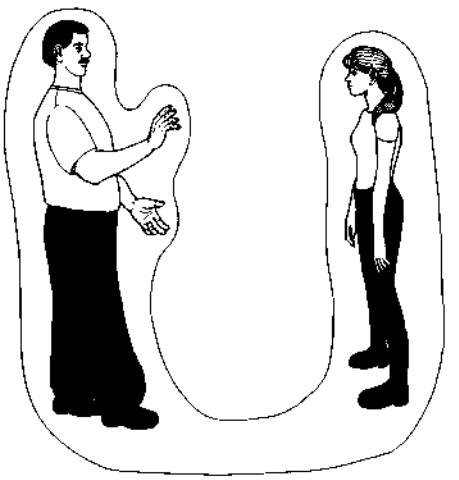

Figure 33.3. Extending Energy from the Soles of the Feet

ENERGETIC THOUGHT PROJECTION OF QI AND SHEN

The last three energetic projections are released from the eyes, throat and mouth (sound resonation) and thought projection. These techniques are a form of long-distance thought projections, based upon the doctor's ability to project Qi and Shen.

- Projection from the eyes releases energy through the eyes and is generally used to increase the doctor's intention and focus of Qi (Figure 33.5).
- Sound resonation projects the voice to tonify or disperse the patient's energy through visceral resonations (Figure 33.6).

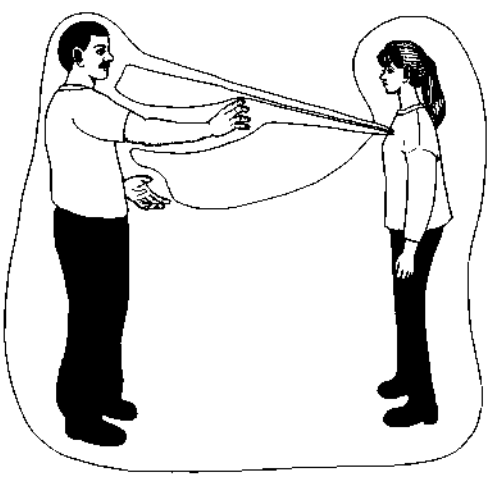

Figure 33.4. Qi Extension. When treating a patient, all Three Dantians extend their energy into the patient.

- Thought projection is another way to release Qi. It is used for long distance energy therapy and is a form of transmuting Qi into Shen, which is transmuted through the Wuji into the patient's Yuan Shen (Figure 33.7).

CONTROLLING ENERGETIC PROJECTIONS

The problem with energy extension lies not in releasing life-force energy but in controlling the power and flow of its projection. If the doctor is distracted or unstable in his or her projection of energy, the doctor may induce more problems in the patient's body. Qi projection can be stabilized in two specific ways:

- First, by visualizing and projecting specific colors (blue, red, violet, etc.) with the energy extension. This causes the Qi to take on a dense and fuller projection, which facilitates the rooting and stabilizing of the energy into the patient's tissues.
- Second, by using intention to mentally focus the size and shape of the projected energy (like a laser), to intensify the Qi projection.

When treating a patient, the diseased tissue must be sufficiently energized. Inadequate energizing results in only slight improvement or a slower rate of healing; over-energizing may cause Qi congestion.

The degree of curative effect depends on the competence and versatility of the doctor, as well as the responsiveness of the patient. If the patient is not responsive, repeated stimulation and regulation of Qi is needed to raise their sensitivity.

Sometimes the patient's emotion and spirit are outside and disconnected from their body and mind. Although this is a perfect adaptation for a military environment, it is not conducive for an energetic healing environment. The patient must undergo a series of Shen Gong training sessions to retrieve their emotional spirit. This training is commonly referred to as "soul retrieval" because the patient's soul is in a state of shock (or suspended animation) due to severe emotional trauma, and must be returned to its Yuan Jing within the patient's tissues. (See Chapter 19).

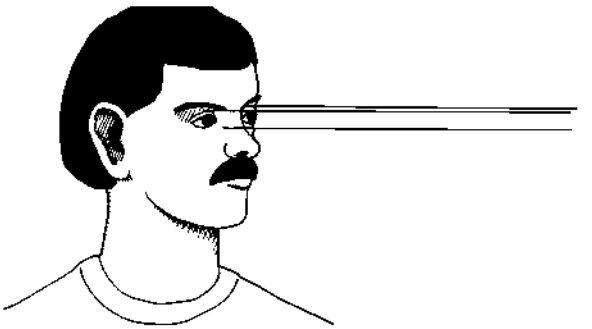

Figure 33.5. Energy Projection from the Eyes

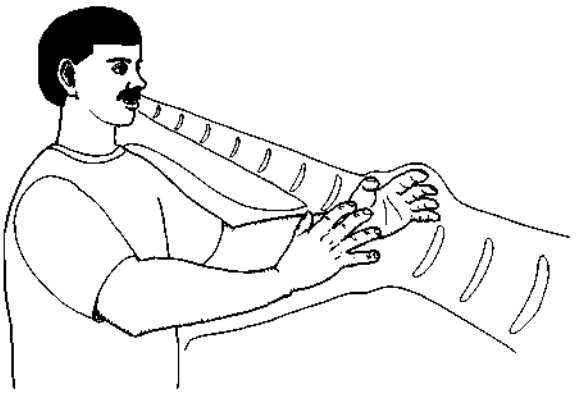

Figure 33.6. Sound Resonation Projection

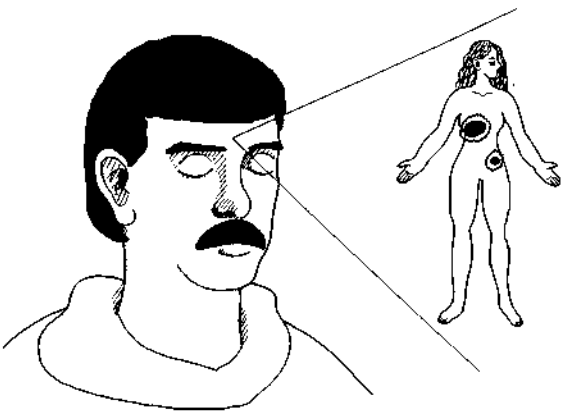

Figure 33.7. Thought Projection

In addition to Shen Gong training, the Qigong doctor must make the patient's Qigong meditations and prescriptions more active so that a satisfactory effect can be achieved. However, a desirable effect can only be attained when the patient is cooperative with the doctor and is consistent with the assigned homework.

HAND POSTURES FOR QI EMISSION

There are many hand postures used in emitting and drawing in energy. Each variation depends on the skill and particular background of the doctor. Generally the doctor uses the entire hand to extend energy, constantly changing the intensity of the Qi being extended. By expanding and contracting the hand and fingers, the "beam of Qi" being emitted into the patient's body will expand and contract. Presented here are six hand postures most preferred by myself and many other Medical Qigong doctors in clinics throughout China.

THE EXTENDED FAN PALM

This first hand posture is the most popular in terms of Qi emission. It releases the widest field of Qi emission. In the Extended Fan Palm hand posture, all five fingers stretch naturally, separate, and open like a Chinese fan (Figure 33.8). There should be no tension, and the focus of the energy should be in the center of the palm (Pc-8). This Extended Fan Palm is the primary hand posture for extending energy because it can be easily used for emitting either Hot or Cold energy. It can also be used in conjunction with other techniques as a reinforcing method to strengthen the flow of energy extension.

Note: Before beginning these exercises, it is important not to eat a heavy meal (at least one and a half hours before practicing).

PALM BREATHING ENERGY EXERCISE—STAGE 1

1. From a Wuji posture, bring both hands up in front of the body, with the palms facing the Lower Dantian. Breathe naturally while concentrating on the Lower Dantian. Next, place

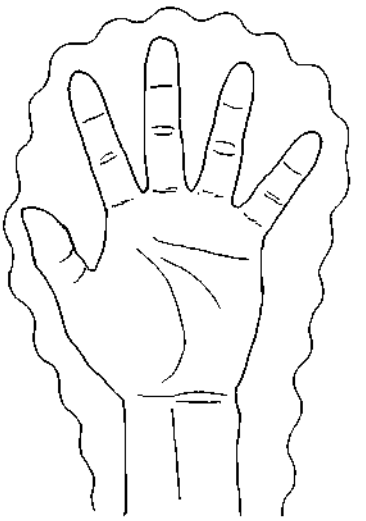

Figure 33.8. The Extended Fan. This palm is the primary hand posture used for emitting Qi.

Figure 33.9. The Image of Holding a Ball of Energy

the left palm facing the right palm, as if holding an imaginary ball. Allow the energy between both hands to build and increase its energetic field (Figure 33.9).

2. Press the Mingmen backwards and feel the energy absorbing through the arms into the Lower Dantian. Next, release the pressure from the Mingmen and feel the Qi return back into the center of the palms.
3. Shift the attention to the center of the right palm, and begin to extend energy into the center of the left palm. Next, shift the attention from the center of the right palm, and begin extending energy into the center of the left palm.
4. As a feeling of pressure begins to build between the hands, perform the "Pushing" (energy extension) and "Pulling" (energy retraction) manipulation technique. This technique is practiced by pushing the Qi of the right palm into the center of the left palm. Hold it there, feeling the pressure mount, then withdraw the Qi back into the center of the right palm. Repeat for several minutes, then move to step five.
5. After several minutes switch the mind's focus to the opposite hand and perform the exercise again. Do this exercise twice a day for 15-30 minutes each practice. Be careful not to let the hands touch when running the energy back and forth between the palms. After 100 days go to Stage #2.

When training to increase their own energetic field, the Qigong doctors must strive to overcome the Pituitary Pain Syndrome. This is a state of transition during which the body is overcome by pain to the extent that the mind gives up and the doctor quits practicing (e.g., feeling fatigue when practicing a Holding the Ball posture). It is important that as the doctor become stronger, the training posture be maintained longer, so that the pituitary gland is challenged to activate the hypothalamus. The hypothalamus causes the body to produce endorphins such as ACTH, which is a natural form of cortisone that helps to escalate the doctor's healing potential. This physical reaction is similar to a runner who must overcome physical cramping when racing to obtain a second wind.

Figure 33.10. Posture for Palm Breathing Exercise

PALM BREATHING ENERGY EXERCISE—STAGE 2

1. Light a candle and place it on a table. From a Wuji posture place the center of the right palm several inches to the right of the tip of the flame (Figure 33.10). The left palm should be placed on the opposite side of the candle, facing the right palm. The Laogong points and the tip of the candle should be in a straight line with each other.
2. Breathe naturally while concentrating on the Lower Dantian. Shift the attention onto the center of the right palm, and begin extending energy into the center of the left palm.
3. Once a feeling of pressure begins to build between the palms, begin the Pushing and Pulling energy manipulation technique. Push the Qi of the right palm into the left palm. Hold it there for several minutes, feeling the pressure mount, then draw the Qi back into the center of the right palm. Practice this exercise for several minutes.
4. Next place the left palm on the Lower Dantian while continuing to extend and retract energy from the right palm. After several minutes, switch hands. Notice that as the Qi is being extended out of the palm that the flame bends away, and as the Qi is retracted back

into the palm the flame bends towards the center of the palm. Practice this exercise twice a day for 15-30 minutes each time.

Note that the Yin Tang area (the Upper Dantian's projection point) can grasp the flame and hold it stationary. Since this technique (grasping and rooting) is used for rooting and securing the patient's Qi, its application can be counter productive when trying to move the flame tip. To avoid this condition, the doctor should relax the mind and use the imagination when projecting Qi.

THE SWORD FINGERS

In this second hand posture, the expansive field of Qi being released is reduced and condensed into a more solid beam of light. In the Sword Fingers hand posture, the index and middle fingers of the right hand are extended and joined together, the ring and little fingers curl into the center of the palm (Figure 33.11). The thumb should rest on the nails of the ring and little fingers forming a circle where Qi is gathered.

The index finger indicates Wood or Liver's Qi, and the middle finger indicates Fire or the Heart's Qi. Together, both fingers activate the Qi of Fire and Wood, which is a catalyst for the Yang energy needed for guiding Yang Heat with the intention (Yi). When extending energy, the Qi is gathered first in the palm and the circle between the thumb and last two fingers, then it is released through the tips of the index and middle fingers.

SWORD FINGER QI EXTENSION—STAGE 1

1. From a Wuji posture, extend both hands to form an imaginary circle of energy in front of the Lower Dantian. As soon as the Dantian is activated and full, bring the ball of energy in front of the body, level with the Middle Dantian (Heart / solar plexus level). Direct the Qi from the Lower Dantian into both hands (Figure 33.12).
2. Point the middle and index fingers of the right hand towards the left palm (Pc-8) and feel the energy press into the tissues (Figure 33.13). After a while, neutralize the energy by turning the palms towards each other, then switch and feel the energy of the left sword fingers

Figure 33.11. The Sword Fingers Technique

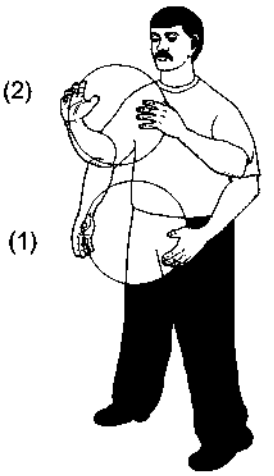

Figure 33.12. Imagine a ball of energy in front of the Lower Dantian, then raise it up to the level of the Middle Dantian.

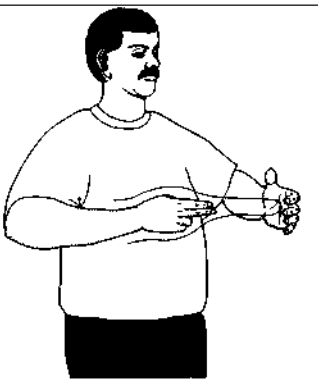

Figure 33.13. Point the Sword Fingers of the right hand towards the center of the left hand.

(index and middle finger) press into the center of the right palm. Practice this exercise twice a day for 15-30 minutes each practice. After 100 days go to the next stage.

SWORD FINGER QI EXTENSION—STAGE 2

1. Light a stick of incense and place it in a standing upright position on a table. From a Wuji posture, place the center of the left palm (Pc-8) several inches to the left of the incense. The right hand sword fingers point through the tip of the incense, extending Qi into the center of the left palm. All three points - left center palm (Pc-8), tip of the incense, and the right sword fingers - should be in a straight line (Figure 33.14).
2. Breathe naturally while concentrating on the Lower Dantian. Shift your attention onto the tip of the incense and focus your concentration there. Continue to extend Qi until you have a strong feeling of Qi in the center of your left palm. After a while switch to the right palm. Practice this exercise twice a day for 15-30 minutes each time.

Figure 33.14. The Sword Fingers point at the tip of the lit incense.

THE ONE FINGER SKILL

In this third hand posture, the field of Qi being released is further condensed into an more solid beam of light. In the One Finger Skill hand posture, the hand forms a soft fist with one appendage (finger or thumb) extended (Figure 33.15). The energy is projected in a straight line (like a laser beam) and can be used to Heat the patient's tissues, channels, or points, as well as to lead, extend, and tonify the energetic field (Figure 33.16).

One Finger Skill can be used to extend long range energy into the patient's channels, or for tissue and channel point regulation. The former technique is regarded as an internal application, and the later technique is regarded as an external application.

- The external application requires that the doctor make physical contact with the patient's tissues, extending the mind deep into the specific areas, channels, or points to be treated. The Qigong doctor physically rotates and shakes a specific finger (or thumb) from side

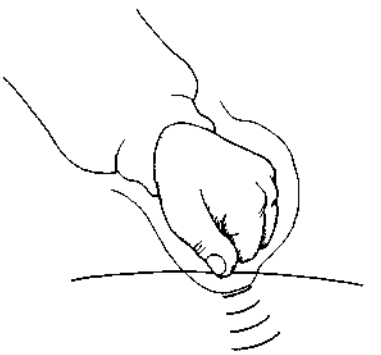

Figure 33.15. The use of the finger or thumb to emit Qi is an example of the One Finger Skill technique.

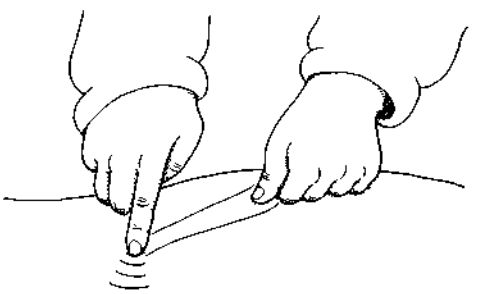

Figure 33.16. Energy is extended through the One Finger Skill technique.

to side while emitting Qi into the patient's tissues or energetic fields (Figure 33.17).

- The internal application requires that the Qigong doctor extend his or her arm, pointing a specific finger at a particular area on the patient's body. The doctor then focuses on that specific channel point, leading and directing the emitted Qi into or out of the patient's body.

ONE FINGER SKILL ENERGY EXTENSION EXERCISE

1. From a Wuji posture, focus the concentration on the Lower Dantian area and bring both arms up to chest level and form an energy ball. Once the Qi in the Lower Dantian becomes activated, direct its energy flow to the tip of the right index finger. Once a feeling of heat and expansion of energy is felt within the right index finger, point the energy beam into the heart of the left palm (Figure 33.18).
2. Once the energy is felt pressing into the left palm, begin to circle-rotate the energy beam in a clockwise direction for several minutes, then in a counterclockwise direction for several minutes.
3. Next, extend and focus the Qi from the Dantian into the left index finger, and repeat the exercise.

SOARING DRAGON TECHNIQUE

The Soaring Dragon technique is a variation of the One Finger Skill energy extension technique. If the pathogens are strong and too much Heat is being emitted from the patient's tissues (as in certain types of cancer), the Qigong doctor may decide to use this particular variation to avoid absorbing the dangerous toxins being released from the patient's body. The Qi is emitted out the doctor's middle finger into the patient's body while the other four fingers disperse the pathogenic Heat into the ground (Figure 33.19).

Before initiating the Soaring Dragon technique, it is important for the Qigong doctor to use his or her mind's intention to seal the wrist. This enables the doctor to pull the patient's Qi into the palm and to disperse it into the Earth via the other four fingers, while avoiding the absorption of the patient's pathogenic Qi.

Figure 33.17. The doctor makes contact with the patient's tissues, extending his or her intention along the patient's channels, leading the Toxic Qi out her body.

Figure 33.18. One Finger Skill Energy Extension Exercise

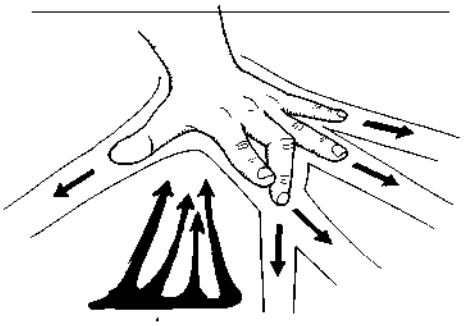

Figure 33.19. Soaring Dragon Hand Posture Technique

I have found this technique very effective in my personal practice. As the pathogenic Heat from the patient's tissues releases upward, the dispersing energy that flows from the four fingers cause the patient's toxic Heat to dissipate and be carried away from the doctor.

BELLOWS PALM TECHNIQUE

Another variation of the One Finger Skill is the Bellows Palms technique, which uses the Lao Gong Pc-8 point at the center of the palm as a pump, to expel Qi out the middle finger. Originally, while treating patients, the palm is Hot (in a Yang state). However, when pulling Qi from the center of the palm and directing it out the middle finger, the polarity of the palm changes from Yang to Yin, causing the center of the palm and the middle finger to turn white (Figure 33.20).

Because this technique is used to pull out Heat from the patient's body, before initiating the Bellows Palm it is important for the Qigong doctor to use his or her mind's intention to seal the wrist. The doctor then pulls the patient's Qi into the palm and disperses it into the Earth via his or her middle finger to avoid absorbing any of the patient's pathogenic Qi (Figure 33.21).

THE BACK BRIDGE BAR TECHNIQUE

The Bellows Palm technique is also used with the "back bridge bar" (where the trapezius muscles join both arms across the doctor's shoulders) to aspirate toxic energy from the patient's body. In this particular technique, the doctor's left palm is used as a vacuum to aspirate a specific area inside the patient's body. The toxic energy travels through the doctor's left arm, across the shoulders and back (never the front), and out through the right palm into the Earth. The right palm applies the "bellows" technique used to create the energetic suction applied by the left palm, for removing Toxic Qi. This technique is contraindicated when treating cancer patients.

THE INVISIBLE NEEDLE PALM

In this fourth hand posture, the field of Qi being released is further condensed into an intense beam of light, similar to that of a laser beam (Figure 33.22). In the Invisible Needle Palm hand posture,

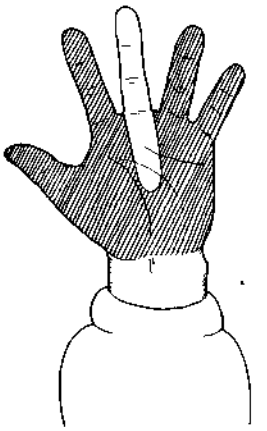

Figure 33.20. When using the Bellows Palm technique, the center of the palm and middle finger remain white in color, while the rest of the palm remains red.

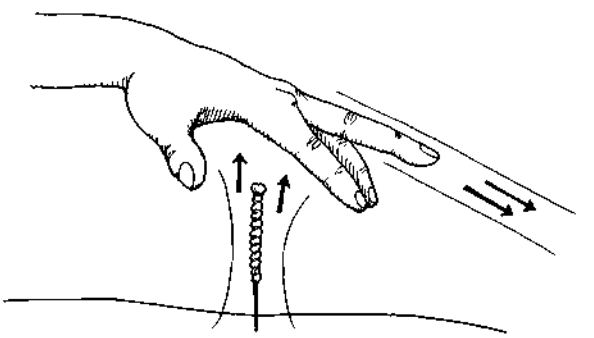

Figure 33.21. Absorb the patient's Toxic Qi from the middle of the palm and disperse the pathogens out the middle finger into the Earth.

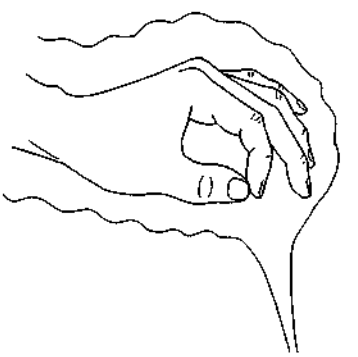

Figure 33.22. The Invisible Needle Palm

three fingers on the right hand are curled into the center of the palm with the thumb resting against the tip of the index finger (see Chapter 35 for Invisible Needle Theory and Application).

THE DRAGON'S MOUTH PALM

This hand posture is sometimes also called the Duck's Bill Palm, and is used to pull energy (like pulling a silk thread). The thumb and all four fingers perform the action of "pulling the golden thread" in order to lead or pull energy along and through the body's channels and points. The intensity of the Qi and movement between the thumb and fingers is determined by the relaxed movements of the wrist and finger joints. This hand technique is often used to purge energy away from specific points when treating areas of Excess (Figure 33.23).

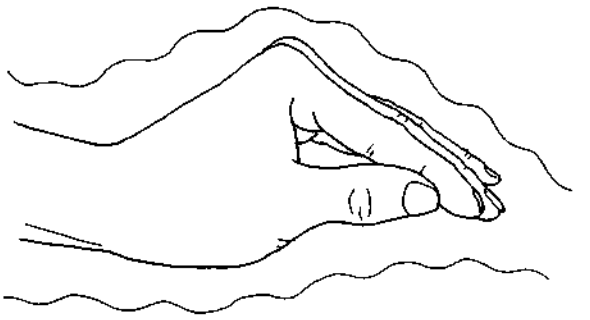

Figure 33.23. The Dragon's Mouth Palm

THE KNEADING TIGER PALM

In this hand posture, all five fingers naturally curl as if embracing a ball. The wrist action is very fluid and supple, allowing the fingers to expand open like the Extended Fan Palm, and then gently close as if kneading a cotton ball. The entire action should be similar to a jellyfish moving in the ocean. This is an excellent technique for pulling, shaking, and rotating energy (Figure 33.24).

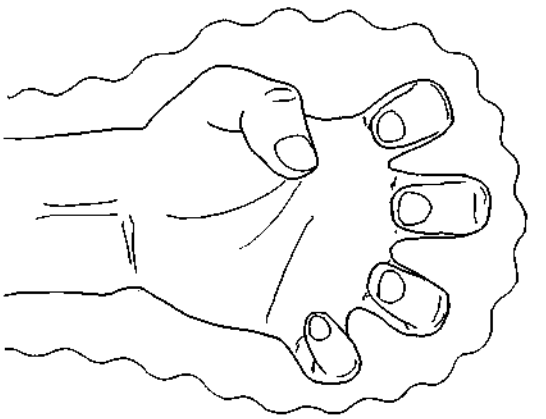

Figure 33.24. The Kneading Tiger Palm

KNEADING TIGER TECHNIQUE

This hand posture is used for dispersing stagnations and dissolving energy blocks. Once the doctor has selected the proper hand posture and the area to be treated, the doctor places his or her hands and fingers above the patient's body, performing a circular kneading action (slightly opening and closing the palm) while simultaneously extending energy into the patient's body. The spiraling energetic frequency should be synchronized with the doctor's hand kneading and the patient's pulse and respiration. Both the pressure and the strength of energy extended into the patient are determined according to the severity of the illness. The Tiger Kneading technique is used for extending energy into energetic points of the chest, abdomen, and extremities to purge Qi stagnation and improve energetic circulation.

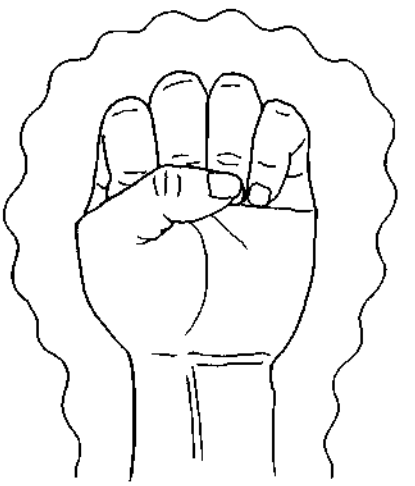

Figure 33.25. The Five Thunder Finger Palm

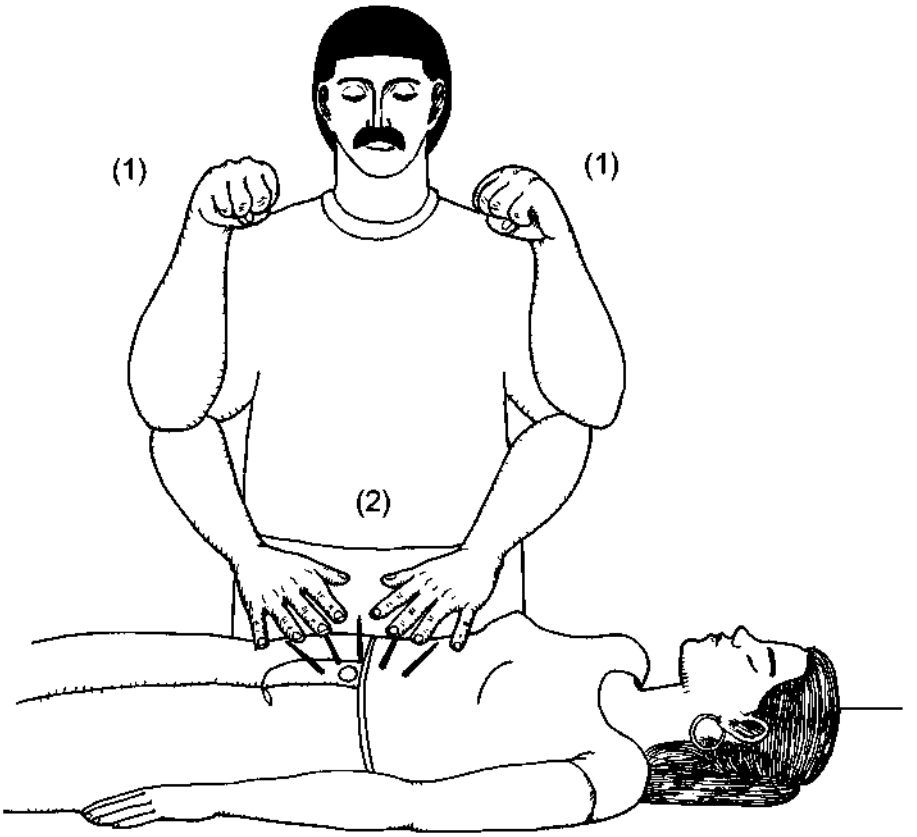

Figure 33.26. The Five Thunder Fingers. This technique is used primarily to destroy cysts, tumors and pathogens.

THE FIVE THUNDER FINGERS

This hand posture is one of the most popular techniques used for dispersing stagnations, dissolving energy blocks and treating tumors and cysts. In the Five Thunder Fingers hand posture, all four fingers curl into the center of the palm with the thumb resting against the nail of each finger. Keep the center of the palm hollow. Qi is gathered and collected there upon inhalation (Figure 33.25).

When emitting or extending Qi, the doctor exhales while suddenly stretching the palm open like "a tiger exposing its claws." After extending the energy, the doctor inhales and resumes the Five Thunder Fingers posture while gathering Qi back into the center of the palm (Figure 33.26).

Note: Because it builds up the doctor's guiding and gathering skill, this is an important technique and should be practiced consistently.

QI BLAST EXERCISE

From a Wuji posture, raise both palms upward to shoulder level. Both hands form the Five Thunder Fingers posture. Concentrate on the Lower Dantian when inhaling. Imagine drawing the Qi up through the chest, gathering the energy into both palms as the arms raise upward. Upon exhalation, sink the body's weight, and suddenly stretch out the fingers (like a claw) at chest level, striking the air. This action should look like each hand is heaving a rubber ball. Perform this exercise once or twice a day, using 24 or 48 breaths each practice time.

Chapter 34
Qi Extension, Guidance, and Regulation Techniques

Qi extension is most effective in activating and balancing the patient's flow of Qi, since both the doctor and patient are enveloped in a strong field of Wei Qi. In Qigong massage the patient's channels are more easily dredged and their Yin and Yang energy are often adjusted much more quickly because of the stimulation produced by the doctor's hand on the patient's channels and points.

Therefore, both modalities - Qigong massage and Qi extension - are usually combined to provide the most effective and efficient means of energetic therapy.

Qi Extension Techniques

The clinical guiding and directing of Qi is performed by extending energy outside of the doctor's body. The energy follows the dictates of the doctor's mind as to the pattern, amount, and direction in which to flow. Qi is emitted in three basic formats: linear, circular/spiral, and stationary flows of energy. The combination of these three forms insures that the patient is receiving the maximum benefit from the treatments, and may be combined with Hot and Cold energy extension, the Five Elemental energy extension, as well as with Qigong massage. These following exercises lay a foundation for guiding and directing the patient's Qi within the channels, points, and Wei Qi fields.

Guiding the Linear Flow of Energy

This method refers to a straight line of energy being emitted either between both hands or between one of the doctor's hands (usually the right) and a certain point or area on the patient's body. This is the primary Qi guiding method used in Medical Qigong therapy to sweep over the patient's body in a straight line in the direction of the outgoing flow of energy.

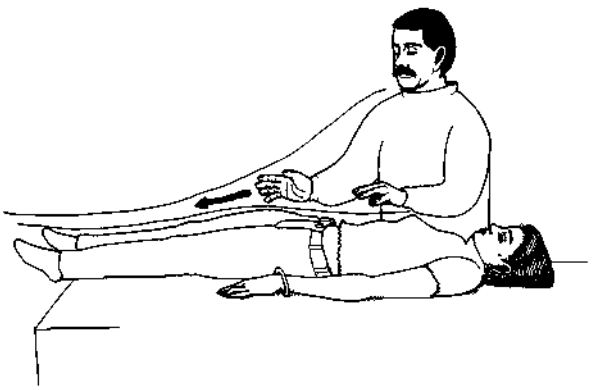

Figure 34.1. An example of a Qigong doctor using the Pushing Energy technique in a Straight Linear energy flow

Because patients vary in their sensitivity to transverse energy wave flow, the doctor should be aware of the influence of the different wave patterns affecting the patient during treatment. Linear energy is relatively mild and often gives the patient a sensation of constriction, of heat or cold, or of heaviness, pressing, tugging, tingling, or pulling. This is the basic means of inducing the channel Qi to purge Excess and to supplement any Deficiencies. Energy is directed within the body through either pushing, pulling, or leading the patient's Qi.

Pushing Energy

Pushing energy is initiated by first extending energy over the surface area of the patient's body (Figure 34.1). Once the doctor has selected the appropriate hand posture above the patient (between 4 inches to 3.5 feet from the channel point or area), he or she will decide whether to push the energy in a linear or circular fashion.

Using intention, the Qigong doctor gently extends energy to the desired area and begins treatment. Pushing energy is an essential energetic

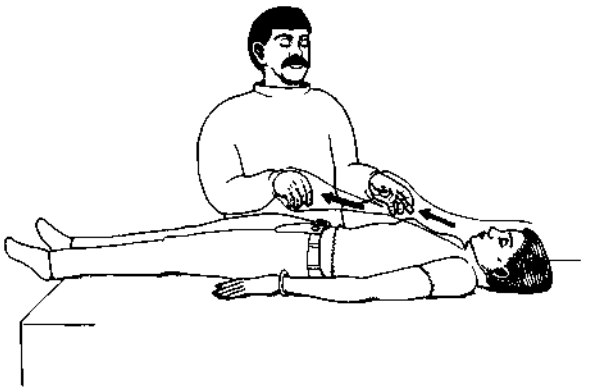

Figure 34.2. An example of a Qigong doctor using the Pulling Energy technique in a Straight Linear energy flow

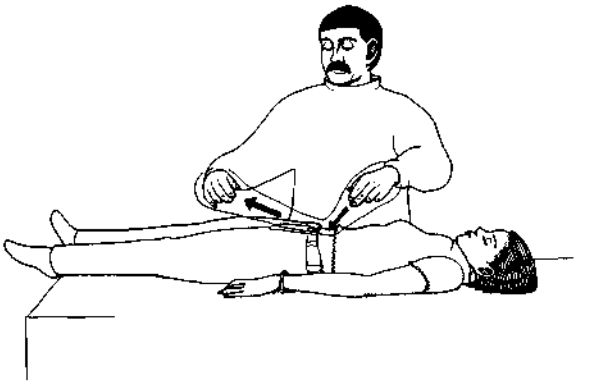

Figure 34.3. An example of a Qigong doctor using the Leading Energy technique (with the left hand) while Pulling Toxic Energy (with the right hand) from the patient's body

manipulation used to open up the points to activate or replenish the body's Qi. The patient feels pressure from the doctor's Qi, and may experience heat, tingling, condensation, expansion, swelling, or heaviness.

Sometimes when the doctor uses the pushing energy technique, the patient may spontaneously lift the stimulated body area towards the hand of the doctor. This spontaneous reaction enables the doctor to implement a combination of manipulation therapies such as push-pull, push-pull-rotate (spiral), push-pull-shake, etc.

PULLING ENERGY

Pulling energy is initiated first by extending energy over the surface area of the patient's body. After selecting the appropriate hand position, the doctor chooses to either pull the energy in a straight line or spiral it along the channels.

Using intention, the Qigong doctor usually begins to pull the patient's toxic energy along the channels while extending clean energy to the affected area (Figure 34.2). Pulling energy is an essential energetic manipulation used for dredging and expelling pathogenic factors from the patient's body, and can also be used to open up channel points to activate or replenish the patient's Qi.

During treatment the doctor actually feels the pathogenic factors being pulled out of the patient's body. This causes the patient to feel heavy, tingling, dryness, heat, cold, or chills. When combining multiple manipulation methods, the pushing and pulling actions cause the energy inside and outside of the patient's body to flow into each other, opening up the patient's channel points.

The combination of pulling and shaking techniques promotes the flow of the patient's Qi, and induces spontaneous reactions of the tissue's energetic fields.

LEADING ENERGY

Leading energy is initiated first by extending energy over the surface area of the patient's body. After selecting the appropriate hand posture, the doctor extends energy towards the affected area and begins to lead the patient's channel Qi up, down, left, right, with, or against the flow of the body's channels (Figure 34.3).

The Qigong doctor bases the decision of whether or not to lead the patient's energy (and which technique should be used) upon the patient's condition and severity of the illness. This manipulation technique is used for guiding the circulation of channel Qi, regulating any Excess or Deficiency of Yin and Yang energy and to transfer Qi back to its origin. Once the channel Qi and point Qi have been stimulated, it is important that the doctor immediately use the "leading energy" technique to guide the patient's energy in as smooth a transition as possible.

CIRCULATING THE QI IN A CIRCLING PATTERN

Emitting a flow of energy in a circling pattern is used to move and circulate stagnant Qi. The flow of energy can be moved in a continuous pattern with or against the channel flow, and is used to regulate the patient's channel and organ Qi (Figure 34.4).

This method refers to techniques of rotating Qi in a circle pattern inside the patient's body. When using circling energy, the doctor extends Qi into the patient's body and implements the circle technique with the right (Yang) hand, while rooting and discharging the patient's toxic Qi with the left (Yin) hand, which points to the Earth. There are many variations of this technique and the doctor must become familiar with each modality of healing and its potential for treating the patient.

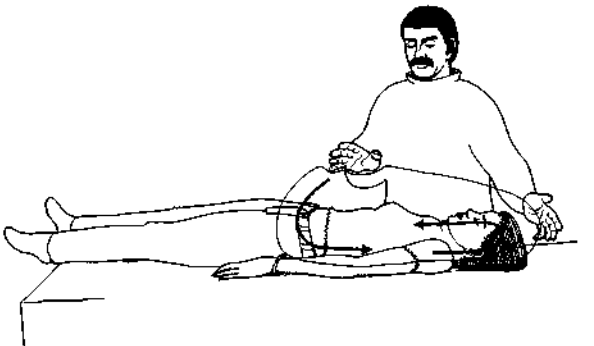

Figure 34.4. An example of a Qigong doctor using the Circling Energy technique to regulate the Heart Fire and Kidney Water, through the Microcosmic Orbit

ENERGETIC CIRCULAR PATTERNS

The following patterns are specific templates used for circulating the body's internal and external Qi. Each pattern has an advantage over the others when used for the regulation of Yin and Yang disharmony. The depth of energetic penetration will vary in accordance with the doctor's intention. Each pattern's movement will utilize the ring of energy that surrounds the center of each Dantian (Figure 34.5).

1. **The Eternity Pattern** is used for balancing the energy between the Lower Dantian and the Middle Dantian. The doctor moves the energy in a figure "8" pattern, Guiding and Leading the Qi from the Lower Dantian

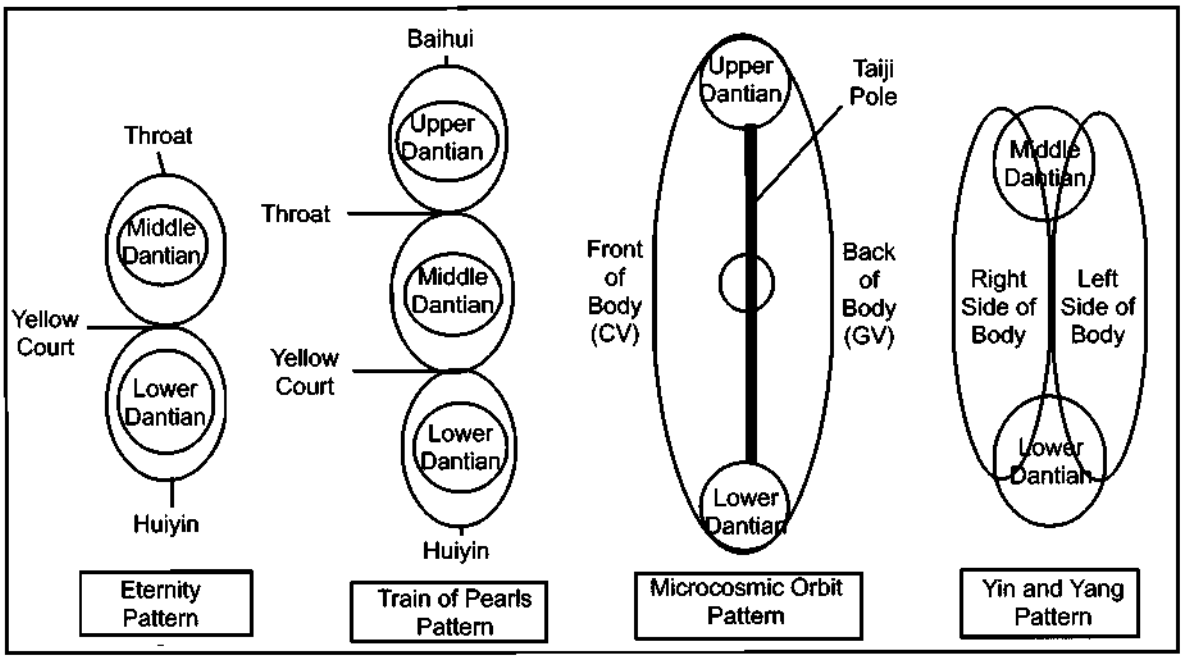

Figure 34.5. A Qigong Doctor Using Circling Energy

(through the Yellow Court) to the Middle Dantian, and back again. The doctor continues this pattern until the patient's energy is regulated. If the patients are suffering from an Excess Yang condition in the upper part of the body, and a Deficient Yin condition in the lower part of the body, the doctor must regulate this condition by using the Eternity Pattern of Qi regulation.

2. **The Train of Pearls Pattern** is used for balancing the energy between all three Dantians. The doctor moves the energy from the Lower Dantian (through the Yellow Court) to the Middle Dantian (through the throat), and into the Upper Dantian, then back down again. The Qi is swept up and down the entire torso, combining and regulating the energies of the patient's Wei Qi, Channel Qi and Organ Qi. The doctor continues this pattern until the patient's energy feels regulated. If the patients are energetically disconnected from the upper and lower parts of their body due to emotional congestion and energetic stagnation in the throat and Yellow Court areas, the doctor reconnects these areas by using the Train of Pearls Pattern of Qi regulation.

3. **The Microcosmic Orbit Pattern** is used for balancing the energy between the Three Dantians, Taiji Pole, the Heart's Fire and the Kidneys' Water. The doctor moves the energy from the Lower Dantian (Mingmen area) to the Middle Dantian (Shendao Area), then back down again, completing the Fire Cycle of the Microcosmic Orbit. The doctor continues this pattern until the patient's energy is regulated. The Microcosmic Orbit Pattern is used for the complete regulation of the body's Yin and Yang energy, naturally purging, tonifying, and regulating any Excess or Deficient condition along the Governing and Conception Vessels.

4. **The Yin and Yang Pattern** is used for balancing the energy between the right and the left sides of the body. The doctor moves the energy in a horizontal figure "8" pattern, Guiding and Leading the Qi through the left and right quadrants of the patient's body. In cases of paralysis after a stroke, for example, the doctor regulates the Qi of the patient's left and right quadrants and energetically balance these areas by using the Yin and Yang Pattern of Qi regulation.

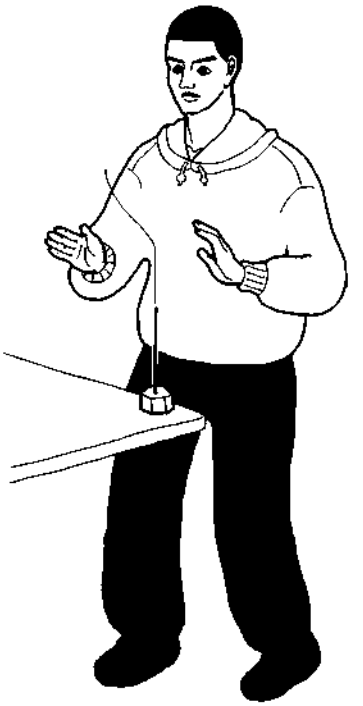

Figure 34.6. An example of a Qigong doctor moving the incense smoke, using the image of an energy ball

The Qigong doctor selects the appropriate energetic pattern according to the patient's condition.

ENERGY BALL ROTATION FOR DEVELOPING CIRCLE ENERGY FLOW

- Light a stick of incense and stand it on a table. From a Wuji posture, place the center of both palms on opposite sides of the tip of the incense. All three points, the tip of the incense, and the heart of each palm (Pc-8), should form a triangle (a tree or flower can be substituted for the incense).
- Breathe naturally while focusing on the Lower Dantian. Slowly shift the attention to lead the energy into the center of each palm to form a ball of energy (basketball size). Concentrate and

imagine the ball condensing to form a powerfully compacted ball of energy (about the size of a marble). Next, imagine a circle or rounded triangle between both palms and the tip of incense. Exhale lightly while extending the energy ball toward the tip of the incense. Imagine the ball of energy moving counterclockwise from the right palm to the incense and then to the left palm, moving in a circle. The right hand pushes while the left hand pulls. The incense smoke should move in accordance with the Qi movement. After a while reverse the flow of the circle. Practice this exercise twice a day for 15-30 minutes each time (Figure 34.6).

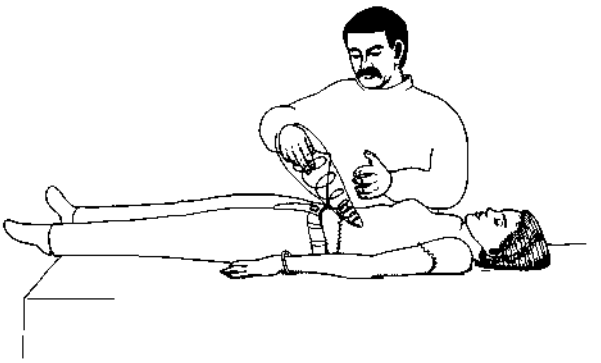

Figure 34.7. A Qigong doctor using the Spiraling Energy technique, to purge Toxic Qi from the patient's body

SPIRALING ENERGY FLOW

A spiraling flow of energy moves the energy in a spiral pattern (clockwise or counterclockwise) to drill the energy deep inside the patient's body (Figure 34.7). This "drilling" action, caused by the spiraling energy, allows for deeper penetration and is excellent for breaking up stagnations when combined with the Kneading Tiger Palm or the Five Thunder Fingers techniques.

Spiraling energy can also be used in the clinic to regulate the patient's Qi activities. Patients may feel the energy penetrating deep into their body and experience light, sound, and mild electric shock. When patients are lying supine, the doctor may choose to spiral the energy superior to the internal organs to pull toxic Qi out of the tissues of the organ; or the doctor may spiral the energy inferior to the internal organs to push the Qi back into the tissues of the organs (Figure 34.8).

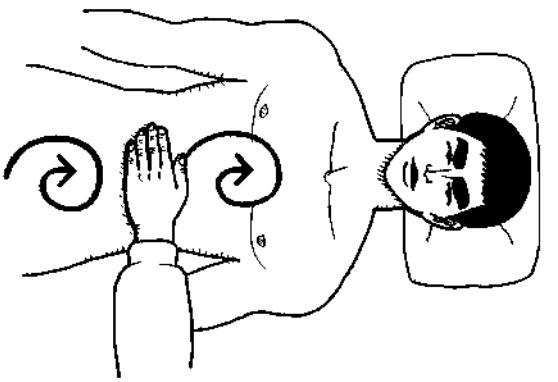

Figure 34.8. A Qigong doctor Spiraling the Qi in order to penetrate the patient's tissues

Spiraling energy is an essential energetic manipulation used for activating the channel Qi, guiding the energy to spiral in, up, or down, much like a cyclone. The Qigong doctor chooses to use either the circle or spiral energy flow, based upon the patient's condition. Most often these two energetic flows are combined to achieve a more functional treatment. The Qigong doctor will, for example, use "spiraling" energy to drill deep into the body to access the toxic energy stored deep inside the patient's organs. Once the patient's toxic Qi has been reached, the doctor utilizes purging techniques to remove the energetic debris. After purging the doctor can circulate the patient's energy to move the stagnant Qi out of the organs. This may be followed by the Microcosmic Orbit to regulate the patient's energy.

CLOCKWISE AND COUNTERCLOCKWISE ENERGY FLOW

The doctor focuses on sensing and creating an internal energy vortex within the Lower Dantian that moves up the body in a clockwise or counterclockwise spiral pattern. Only then is the spiraling Qi projected out through the doctor's right hand into the patient's body.

Using the appropriate hand position, the doctor slowly spirals the energy in either a clockwise direction to guide the patient's energy into the affected area, or in a counterclockwise direction

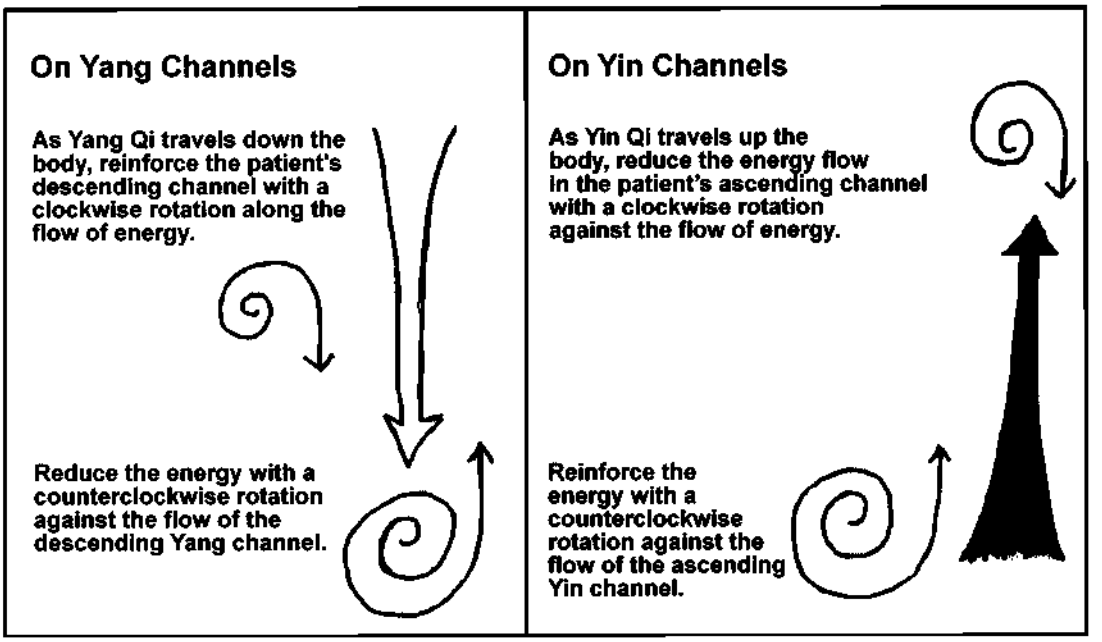

Figure 34.9. The reinforcing and reducing techniques of moving energy along the patient's channels is determined by the direction of the Spiraling Energy flow.

to remove the patient's Toxic Qi out of the diseased area.

- The counterclockwise rotation is considered Yin and is used to reduce Heat and to cool the patient. It is generally used to purge conditions of Excess (think of unscrewing the pathogens from the diseased area when purging).
- The clockwise rotation is considered Yang and is used to increase energy and warm the patient. Generally, it is used to tonify conditions of Deficiency (think of drilling and filling the Deficient area when tonifying).

The clockwise spiraling energy originating in the Lower Dantian is emitted and synchronized with the doctor's circling hand movements to reinforce the patient's Qi. To reduce the flow of the channel's Qi, the counterclockwise spiraling technique is used (Figure 34.9).

The Qigong doctor must cultivate these movements into a conditioned reflex before applying these treatment methods in a clinical environment.

SPIRALING ENERGY EXERCISE

- From a Wuji posture, place the left palm on the Lower Dantian. Slowly extend the right palm (keep elbow bent) in front of the chest, aligned with the center line at the Middle Dantian (CV-17), palm facing outward.
- Breathe naturally, while focusing on the Lower Dantian. With the mind's intention, begin to spiral the Qi in the Lower Dantian in a clockwise circle. Lead the energy up through the chest and out the extended right palm. Make sure that the spiraling of the Lower Dantian is synchronized with that of the right palm, making the inner Lao Gong Pc-8 points the center of concentration (Figure 34.10). Start off slowly, and gradually increase speed. The energy circle spirals outward with increasing or decreasing radius, depending upon the doctor's intent.

Repeat the exercise, only this time use counterclockwise spiraling.

ENERGETIC CUPPING

One popular clinical technique called "energetic cupping" is initiated by creating an energetic vortex which remains on the patient, pulling or drawing in energy, similar to that of an acupuncturist's cupping method. These energetic vortices can be used to drain or purge pathogens from a specific point or area on the patient's body. These energetic vortices can also be used to fill or tonify the patient's body. For example, when the patient is prone, the Qigong doctor can stimulate points LI-15, GV-4, and GV-14 (Figure 34.11). Then, using his or her intention, the doctor can pull with one hand while the other hand pushes, increasing the spiraling action already set in motion. This initiated energetic torque can sometimes cause the patient's body to turn, twist, bend, and sway. This modality of treatment simultaneously activates the patient's channel Qi, regulates the Yin and Yang organs, and balances the patient's Yin and Yang energies.

The doctor is advised to rely on intuition or divine guidance in choosing the right method, after careful consideration of the patient's condition (age, sex, personality, illness, etc.).

Note: If combined with the "shaking" technique, the circle / spiraling energy becomes especially effective for relieving pain.

GUIDING THE STATIONARY FLOW OF ENERGY

Stationary energy is emitted from a non-mobile position and can be used to stimulate the channel Qi, points, and Dantians, while restoring and replenishing the patient's Qi. After selecting the appropriate hand posture, the doctor positions his or her hand above the area being treated and emits energy from a fixed or stationary position. This is the most common energy projection technique, in which Qi flows like dense waves or is spaced like a chain of moving pearls flowing outward one after another (Figure 34.12). The patient often feels the sensation of vibration, tingling, or heat. It is not uncommon for the patient to develop spontaneous involuntary reactions such as full body spasms or shaking, leg jerking, etc.

Stationary energy is emitted from a station-

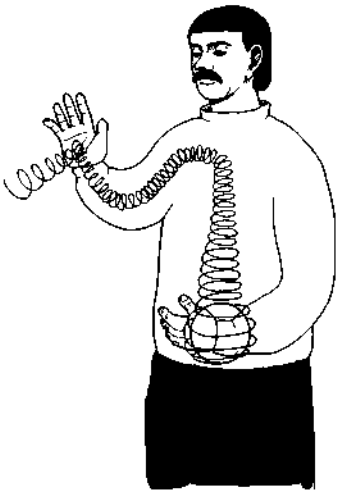

Figure 34.10. An example of a Qigong doctor practicing the Spiraling Energy exercise

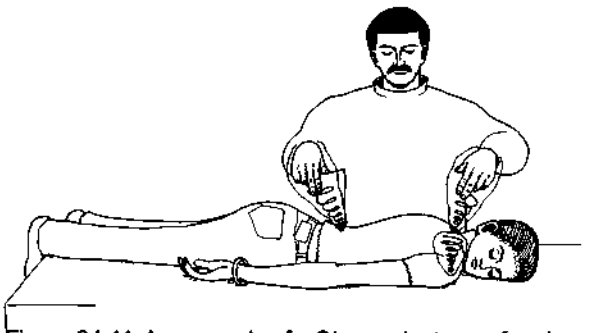

Figure 34.11. An example of a Qigong doctor performing multiple point stimulation with the Energetic Cupping Technique

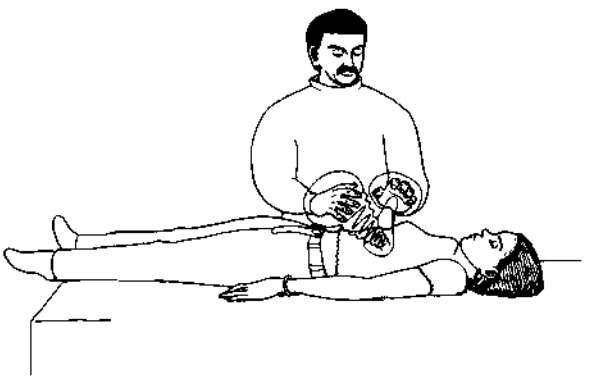

Figure 34.12. When a Qigong doctor extends energy from a stationary position, the Qi flows either like a dense wave, or is spaced like a chain of moving pearls.

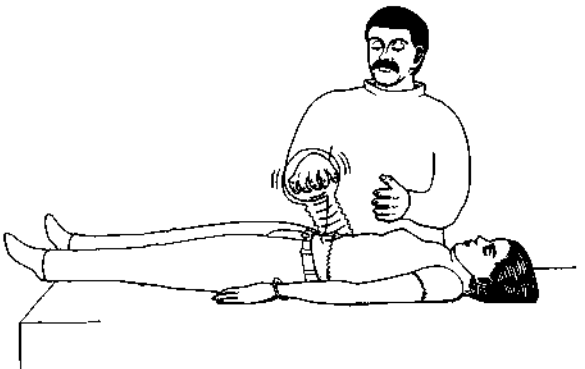

Figure 34.13. An example of a Qigong doctor using the Shaking Energy technique along with the Kneading Tiger Palm

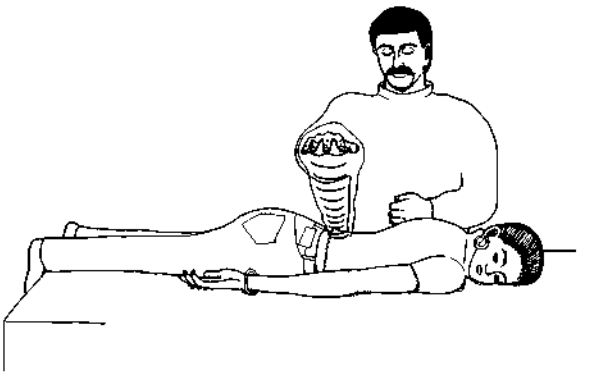

Figure 34.14. An example of a Qigong doctor using Vibrating Energy through the Extended Fan Palm technique

ary palm position. There are two main energetic pulsations utilized in the Stationary Palm techniques: Shaking Energy technique and Vibrating Energy technique.

SHAKING ENERGY TECHNIQUE

The Shaking Energy technique is initiated by the doctor first extending his or her energy over the surface area of the patient's body. After using the Tiger Kneading Palm technique to grasp the Turbid Qi, the doctor slowly begins to guide the patient's Qi out of the tissue area with a stationary manipulation. The doctor then shakes his or her hand from side to side, while continuing to pull the Qi from the area being treated (Figure 34.13).

To practice this particular skill, the Qigong doctor begins from a Wuji posture, using natural and slow breathing. The doctor imagines the waist as the axis and the abdomen as a pump and vibrates the Qi inside his or her Lower Dantian. The doctor then allows the energy to flow upward and out the palm, into the patient. It is important for the doctor to use the mind's intent to follow, guide, and direct this vibration of energy flow, instead of forcing the muscles and palm to shake.

VIBRATING ENERGY TECHNIQUE

Vibrational trembling is one way that memory is stored or processed in the physical body. The Qigong doctor's vibration penetrates the patient's field of "vibrational activity" (the body's natural vibrational rhythm), awakening this memory, allowing the patient to release trapped thoughts and emotions (Figure 34.14).

Qi naturally oscillates and vibrates in the doctor's Three Dantians, each Dantian vibrating at its own unique frequency pattern. The body's bone structure is built with natural formations similar to that of "tuning forks," positioned in both the arms and the legs. These tuning forks are connected together through the body's spinal column and are used to vibrate and increase the body's energetic resonance. Through a balanced interplay of stretching and releasing the body's tendon, ligament, and muscle fibers (in a rhythmic pattern), a natural vibration is produced. After some time of training (through naturally twisting and stretching the tendons), the Qigong doctor, using proper hand postures and intention, is able to direct and lead this vibration throughout his or her entire torso and extend it outwards through the hands.

Vibration is released through three forms of resonation:

1. Jing vibrational resonance is felt within the patient's external tissues and bones. It is related to the energetic release of Heat and the energy of the doctor's Lower Dantian.
2. Qi vibrational resonance is felt deep within the patient's internal organs. It is related to the energetic release of the patient's emotions and the energy of the doctor's Middle Dantian.
3. Shen vibrational resonance is felt within the patient's center core. It is related to the ener-

getic release of the patient's spirit and the energy of the doctor's Upper Dantian.

The release of energetic vibration is primarily used to activate the patient's channel Qi. Clinically, it is most effective when the frequency of the doctor's hand vibrations matches and synchronizes with the vibrational frequency of the patient.

While treating the patient, the doctor's palm usually gets hot and vibrates when coming in contact with Qi stagnation. If a patient's channel point becomes blocked, energy builds up causes Qi stagnation. Once the Qi stagnation is removed, the doctor's hands will cease to vibrate as the channels open and flow freely. When cleared, the patient feels fatigue as the toxins are released from the body and the energy seeks to balance itself.

To apply the Vibrating Technique, the doctor selects the proper hand posture and the area to be treated, then barely touches the patient's body. Any firm pressure should be avoided so as not to hinder the extending and directing of Qi. The doctor initiates the vibrational extension of Qi from the Lower Dantian, slowly turning clockwise or counterclockwise, while directing the vibration out through the hands. The doctor focuses on his or her own breath to adjust the frequency and amplitude of the vibration, the shape and nature of the emitted Qi (Yin or Yang, etc.), and the strength of the energy.

Some examples of hand postures and tissue regulation techniques for emitting vibrational energy include:

a. The Extended Fan Palm is used for activating and regulating Qi activities by:
   - Vibrating the Extended Fan Palm on the Baihui GV-20 point, to descend the patient's Yang Qi, tranquilize the patient's mind, regulate Qi in the Upper Burner, and induce sleep;
   - Vibrating the Zhong Wan CV-12 point to replenished the patient's Qi, to regulate the Stomach's energy and to induce sleep;
   - Vibrating the patient's Lower Dantian, to Lead the Qi back to its origin through supplementing its Qi;
   - Vibrating the Mingmen GV-4 and Da Zhui GV-14 points, to activate Qi in the Governing Vessel.

b. The Sword Finger Palm is used for directing and emitting concentrated vibrational energy into channel points, to stimulate the patient's energetic field.

c. The Invisible Needle Palm is used for directing and emitting the most condensed form of concentrated vibrational energy into the channel points, to stimulate the patient's energetic field.

VIBRATING PALM EXERCISE

The training for this kind of vibrational extension usually begins from a static Wuji posture, then gradually progresses into a dynamic state of energy projection.

- From a Wuji posture, press both palms together at the center of the chest forming a "Buddhist greeting" posture (see Chapter 15). Press the Baihui point upward and the Mingmen backward, while slightly drawing in the chest. Keep hips relaxed, knees bent, tongue on palate, and eyes closed.
- Breathe naturally while focusing the mind on the Lower Dantian. When the Heat and Qi begin to circulate, exhale while mentally guiding the Qi up the chest into both of the palms, by sending the energy through the three Yin channels of the hands.

When inhaling, mentally guide the Qi along the three Yang channels of the hands, back down the back into the Lower Dantian. Maintain natural breathing, and continue to focus attention on both the palms and the fingertips. The palms should heat up and the fingertips tingle, as they expand with Qi (Figure 34.15).

Lead the vibrating energy in the Lower Dantian up into the palms and fingertips, feeling the tissues dissolve inch by inch, cell by cell. The Qi is always centered on the inner Lao Gong Pc-8 point, gathering and collecting but not dispersing. Practice this exercise once or twice a day for 3-10 minutes.

Note: It is imperative that the doctor, when using the technique of "stationary energy pro-

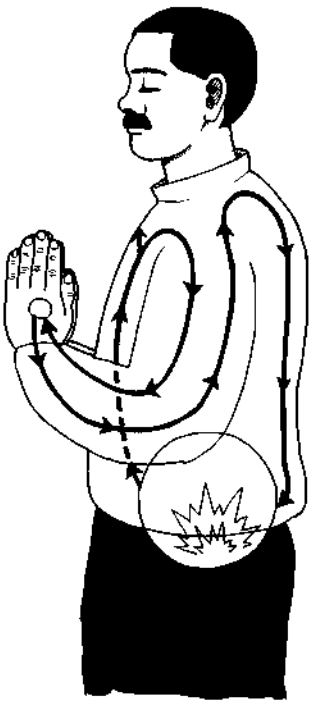

Figure 34.15. The Vibrating Palm exercise helps to increase the Qigong doctor's projected vibration.

jection," never hold his or her breath, or purposely make the hand vibrate by forcefully shaking the muscles. To do so causes Qi stagnation which results in pain and stiffness in the chest and sharp pain in the arms that feels similar to having a fractured bone or a laceration of the muscles. To ensure that there are no difficulties, the doctor should first master the Vibrating Qi method, allowing the vibrating energy to extend and project naturally.

GUIDING THE HOT AND COLD FLOW OF ENERGY

This method refers to the doctor's release of energy being emitted into the patient's body to either regulate Hot syndromes with Cold energy, or Cold syndromes with Hot energy. These two Yin and Yang energetic properties are used to develop the emission of both Hot and Cold energetic flows, through breathing, mental concentration and finger placement.

When Yin Qi is applied, the patient will feel "cold as iron," when Yang Qi is applied, the patient will feel "hot as fire." The mind plays an important role in regulating the doctor's and patient's Yin and Yang energy. When the Qigong doctor thinks of fire, the doctor's body will naturally become hot; conversely, when the doctor thinks of water, his or her body will naturally become cold.

HAND MANIPULATION OF YIN AND YANG ENERGY EXTENSION

The Yin (Cold) and Yang (Hot) energy extension utilizes specific palm and finger arrangements. The index and middle fingers together are assigned Yang properties, whereas the ring and little fingers together are assigned Yin properties. The doctor's left thumb connects with the selected two fingers, to determine the release of Yin or Yang energies. This energy is first gathered from the doctor's left hand, through the arm into the Lower Dantian, then emitted out through the right hand. The Qi that is emitted when the doctor's thumb, index and middle fingers connect, for example, releases the Heart's Yang Qi through the right hand. This technique is used to replenish the patient's Yang and regulate the patient's Heart energy.

GATHERING AND ISSUING YANG (HOT) ENERGY

Before emitting Hot energy into the patient, the doctor's Qi is first gathered into his or her left palm by imagining a small "fiery red sun" radiating heat, light, and fire. This small sun is imagined within the circle created between the thumb and first two fingers on the left hand. The hot energy of the sun is then absorbed through the doctor's left arm into the Lower Dantian. The Heat is then blended with the Lower Dantian's Qi and released out the doctor's right arm through either the tips of the index and middle fingers (the Yang Sword Fingers hand technique) for a deeper, concentrated type of penetration, or through the Extended Fan Palm hand technique for a dispersing type of penetration.

To extend Hot energy deeper into the patient, the right hand Yang Sword Finger posture is used. The doctor's index and middle fingers are extended and joined together, the ring and little fin-

gers curl into the center of the palm. The thumb should rest on the nails of the ring and little finger, forming a circle.

The first or "index" finger indicates the Wood Element, i.e., the Liver's energy, and the middle finger indicates the Fire Element or the Heart's Qi. Together, both fingers activate the Qi of Fire and Wood, which catalyze the Yang energy needed for guiding Heat during point concentration.

Guiding Hot Yang Qi Exercise

This particular meditation is used to increase Heat and light in specific areas of the patient's body (usually for chronic, Deficient, or Cold syndromes). The following meditation, for example, can be used to Heat and tonify the Kidneys in chronic fatigue patients.

- Sit on the edge of a chair in front of a table, feet flat, eyes closed, with the left hand resting comfortably on the left thigh. The right palm is extended face down suspended over the table.
- Breathe naturally while concentrating the mind on the Lower Dantian. Imagine the energy in the Lower Dantian is a hot, burning sun expanding out and enveloping the entire body. Gather the energy back into the Lower Dantian, transforming it into heat and light. Draw the heat and light up into the chest, down the arms, and out the right palm. Concentrate and imagine the heat and light burning and extending into the table, penetrating deep into it. After awhile, switch palms. In China, this exercise is practiced while standing or sitting in the sunshine, facing south or east. Practice for 20-40 minutes (Figure 34.16).

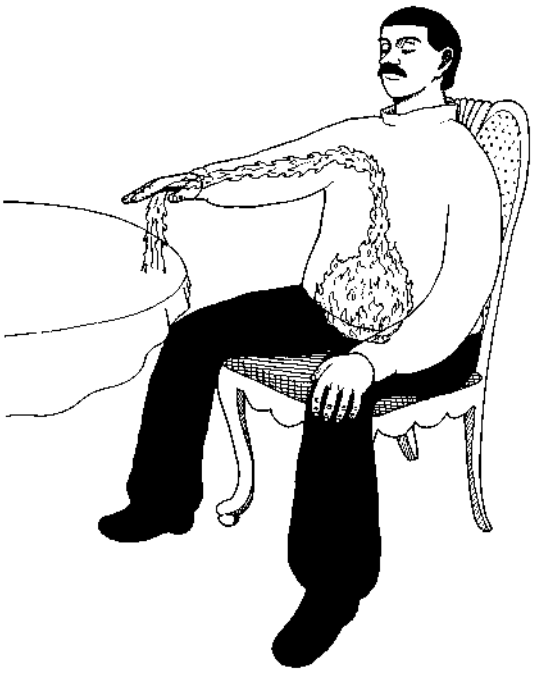

Figure 34.16. Guiding Hot Yang Qi Exercise

GATHERING AND ISSUING YIN (COLD) ENERGY

Before extending Cold energy into the patient, the doctor's Qi is first gathered into his or her left palm by imagining a small, watery blue moon, radiating cool light. This small moon is imagined within the circle created between the thumb and last two fingers. The cool blue energy of the moon is then absorbed through the doctor's left arm, into the Lower Dantian. The cool blue energy is then blended with the Qi of the doctor's Lower Dantian and released out the doctor's right arm through either the tips of the ring and little fingers (the Yin Sword Fingers hand technique) for a deeper, concentrated type of penetration, or through the Extended Fan Palm hand technique for a dispersing type of penetration.

In extending cool blue energy into the patient, the right hand Yin Sword Finger posture is generally used. The doctor's ring and little fingers are extended and joined together, and the index and middle fingers curl into the center of the palm. The thumb should rest on the nails of the index and middle finger forming a circle.

The ring finger indicates the Metal Element or the Lungs' energy, and the little finger indicates the Water Element or the Kidneys' energy. Together, both fingers activate the Qi of Metal and Water, which is a catalyst for the Yin energy needed for guiding cool Yin Qi during point concentration.

Guiding Cold Yin Qi Exercise

This meditation is used to cool specific areas in the patient's body in acute, inflamed Excess or Heat syndromes. It can also be used, to cool down and dredge the Liver in cases of chronic depression.

- Sit on the edge of a chair in front of a table, feet flat, eyes closed, with the left hand resting comfortably on the left thigh. The right palm is extended face down suspended over a table.
- Breathe naturally while concentrating the mind on the Lower Dantian. Begin to gather energy from the heels and Bubbling Well (Kd-1) points, directing the energy through the chest (CV-17), out the arms, and into the right palm. Imagine the right palm turning as cold as ice. Focus the mind on the coldness of the right palm and imagine the cold energy penetrating deep into the table. In China, this exercise is practiced at night, facing north or west for 20-40 minutes (Figure 34.17).

Note: While practicing the Cold Yin Guiding exercise, never imagine that the whole body is cold, also do not direct and keep the cold energy into your body (only through it). Otherwise the Cold energy will affect the balance and energetic harmony of the Qi's flow. You can, however, use the image of cool blue water or vapor flowing through your body into the right hand (which is freezing cold), without causing harm to your body's energetic balance.

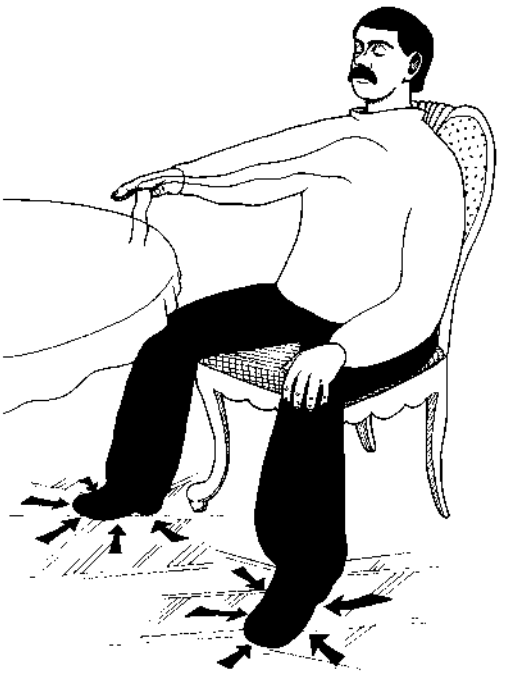

Figure 34.17. Guiding Cold Yin Qi Exercise

CLINICAL APPLICATION OF YIN AND YANG ENERGY EXTENSION

Traditionally, the Qigong doctor would emit Hot Yang Qi during the Yang period of the day (from midnight to high noon) to warm the patient's Cold areas. During the Yin periods of the day (from high noon to midnight) the doctor would apply the Cold Yin Qi to cool the Hot areas of the patient's body.

In China today, the clinical application of issuing Hot or Cold energy is no longer limited to the position of the sun and moon, but is applied according to the doctor's ability to regulate the Excess or Deficient condition of the patient's disease.

GUIDING THE ENERGETIC FLOW OF THE FIVE ELEMENTS

This particular Medical Qigong healing system is divided into two popular methods of energy extension: The Five Elemental Organ Energies Method and The Five Elemental Channel Energies Method. Both systems can be used for diagnosing the patient (using palm detection) or for treating Excess or Deficient conditions within the patient's body (using energy extension techniques). Each of these two powerful systems of treatment has its own unique advantage in application. Both systems combine healing sound resonances with energy light extension of various colors, and are used in accordance with the theory of the Five Elements.

THE SIX CHARACTER FORMULA

When utilizing either the Five Elemental Organ, or Five Elemental Channel system of energy projection, the Qigong doctor will guide the energy of the Five Elements in conjunction with the Six Character Formula. The Six Character Formula includes: The Five Elemental Energies, Time of Treatment, Direction of Energy, Position of the Thumb, Guiding Energy, and Emitting Energy and Sound.

1. The Five Elemental Energies of Wood, Fire, Earth, Metal, and Water relate to either the Five Elemental Channel system of energy projection and the Blood / Heat Cycles; or the relate to Five

Elemental Organ system and the energy of the Five Yin Organs. The decision regarding which of the two methods to choose is determined by the patient's condition.

2. The time of treatment is traditionally determined by the doctor in accordance with the patient's Blood/Heat Cycle, the time of day (sunrise, noon, sunset, and midnight) and the season (summer, winter, autumn, or spring).
3. The direction of energy emitted into the patient's body is determined by the doctor in accordance with his or her intention to purge, tonify or regulate the patient's tissues.
4. The position of the thumb is determined in accordance with the type and amount of energy the doctor wishes to absorb into his or her Lower Dantian.
5. Guiding (Pushing, Pulling and Leading) the energy is determined by the doctor in accordance with the Excess or Deficiency of the patient's Five Yin Organs: Liver (Wood), Heart (Fire), Spleen (Earth), Lungs (Metal), and Kidneys (Water).
6. The type of energy (Qi or Shen) and the choice of sound to be emitted are determined by the doctor's intention and the condition of the patient's organs and channels. Qi and sound are emitted like water, Shen is emitted like light.

EMITTING THE ENERGY OF THE FIVE ELEMENTAL ORGANS

The method of projecting the Five Elemental Organ Energies is utilized by blending a specific organ energy together with the Qi stored in the doctor's Lower Dantian. Both of these energies are combined and then issued out the doctor's right palm into the patient. The fusion of the doctor's Lower Dantian Qi with the selected organ Qi is very powerful. This synergized Qi is further combined with sound resonation and colored light to treat patients with extreme conditions of Deficiency.

The left thumb connects with either the tip of the index (Wood), middle (Fire), ring (Metal), little finger (Water) or upper pad of the palm (Neutral) to connect with the selected organ energy (Figure 34.18).

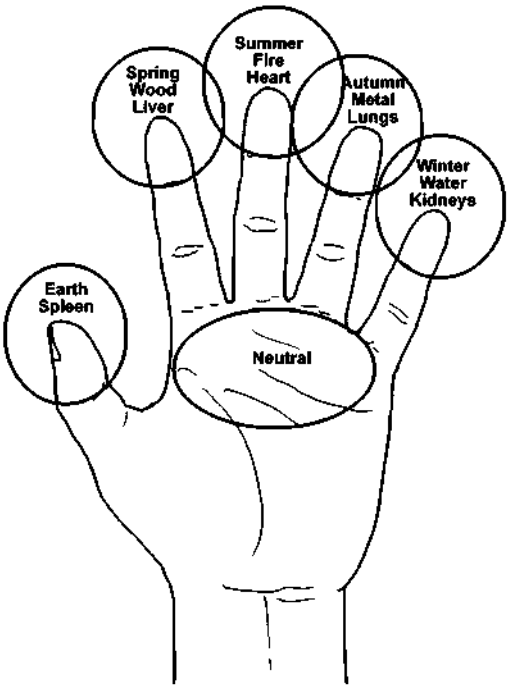

Figure 34.18. Left Palm - The Five Element Organ Energy Pattern: the left hand is used in order to absorb the organ Qi into the doctor's Lower Dantian. This arrangement corresponds to the Five Seasonal Pattern Cycle and the Five Elements.

Five Fingers	Five Elements	Five Viscera
Thumb	Earth	Spleen
Index	Wood	Liver
Middle	Fire	Heart
Ring	Metal	Lungs
Little	Water	Kidneys

Figure 34.19. Hand Chart of the Five Elements

After choosing the appropriate thumb and finger position on the left hand to tap into the selected organ's energy, the doctor descends this energy into the Lower Dantian. This energy is then blended together with the energy of the Lower Dantian and led out of the doctor's body, to be emitted into the patient using the right hand, along with the sound and specific organ color (Figure 34.19).

EMITTING THE ENERGY OF THE FIVE ELEMENTAL CHANNELS

The method of projecting the Five Elemental Channel Energies is utilized by blending a specific channel energy together with the Qi stored in the doctor's Lower Dantian. To tap into the selected channel's energy, the thumb is positioned on the corresponding finger, or palm segment (Figure 34.20). The selected channel's energy is then blended with the Qi stored in the doctor's Lower Dantian. These combined energies are then issued out the doctor's right palm into the patient. The blending of channel and Lower Dantian Qi is strong but not as powerful as the doctor's organ energy.

The resonant sound and light emitted from the combined channel and Lower Dantian energy is considered appropriate for patients with moderate Deficiency conditions. Healing sounds in combination with specific colors can be emitted by the Qigong doctor to stimulate the internal tissues. When healing sounds are directed into the patients tissues they have a tonifying action, as opposed to the purging affect which happens when the patient's practice healing tones by themselves (see Chapter 40).

The treatment is conducted according to the Five Elemental Creative Cycle. First the energy of the "mother" element is gathered into the doctor's Lower Dantian to be combined with the doctor's Lower Dantian energy. After the doctor collects and mixes the mother's elemental channel energy with the Lower Dantian's energy, the doctor switches the left thumb's position to the mother's corresponding "child" element position. This enables the mother's channel energy to support the strength of the child's channel energy, which is emitted into the patient's body (Figure 34.21).

Note: The doctor first connects to the mother element, then to the child element. Thus the mother's elemental channel energy, Lower Dantian energy and the child's elemental channel Qi are synergized and projected into the patient's corresponding "child" organ. The patient's organ, into which the Qi is emitted, has the same elemental attribute as the doctor's "child" transmitted energy.

1. To Emit Liver Energy and Guide Wood Qi proceed as follows:
   - First, from a Wuji posture, press the left thumb into the channel Water bands (9, 10). Inhale this Water energy into the Lower Dantian, mixing it together with your Lower Dantian energy.
   - Second, extend the right hand facing outward from the chest, facing the patient. Then exhale and press the thumb onto the Wood channel bands (1, 2) while uttering the sound "Shu." Guide the Wood energy out of the right palm into the patient's Liver organ or channel. In this particular technique, the doctor is using Water energy to support the extension of Wood energy.
2. To Emit Heart Energy and Guide Fire Qi proceed as follows:
   - First, from a Wuji posture, press the left thumb into the channel Wood bands (1, 2), while inhaling the Wood energy into the Lower Dantian, mixing it together with your Lower Dantian energy.
   - Second, extend the right hand facing outward in front of the chest, towards the patient. When exhaling, press the thumb onto the Fire channel bands (7, 8) with the thumb while uttering the Heart sound "Haa." Guide the Fire energy out the right palm into the treatment area. In this particular technique, the doctor is using Wood energy to support the extension of Fire energy.
3. To Emit Spleen Energy and Guide Earth Qi proceed as follows:
   - First, from a Wuji posture, press the left thumb into the channel Fire bands (7, 8) gathering this Fire energy into your Lower Dantian.
   - Second, extend the right hand in front of the

Colors		Element	Channel
1.	Green	Wood	Gall Bladder
2.	Green	Wood	Liver
3.	White	Metal	Lungs
4.	White	Metal	Large Intestine
5.	Yellow	Earth	Stomach
6.	Yellow	Earth	Spleen
7.	Red	Fire	Heart
8.	Red	Fire	Small Intestine
9.	Blue	Water	Bladder
10.	Blue	Water	Kidney
11.	Red	Fire	Pericardium
12.	Red	Fire	Triple Burner

Figure 34.20. The Twelve Channels are superimposed onto the Qigong doctor's left palm, arranged according to the progression of the Two Hour Qi and Blood/Heat Cycle.

This Blood/Heat Cycle also corresponds to the Four Principle Time Periods and can be divided into quarters and arranged according to the Midnight, Sunrise, Noon, and Sunset patterns of the Sun.

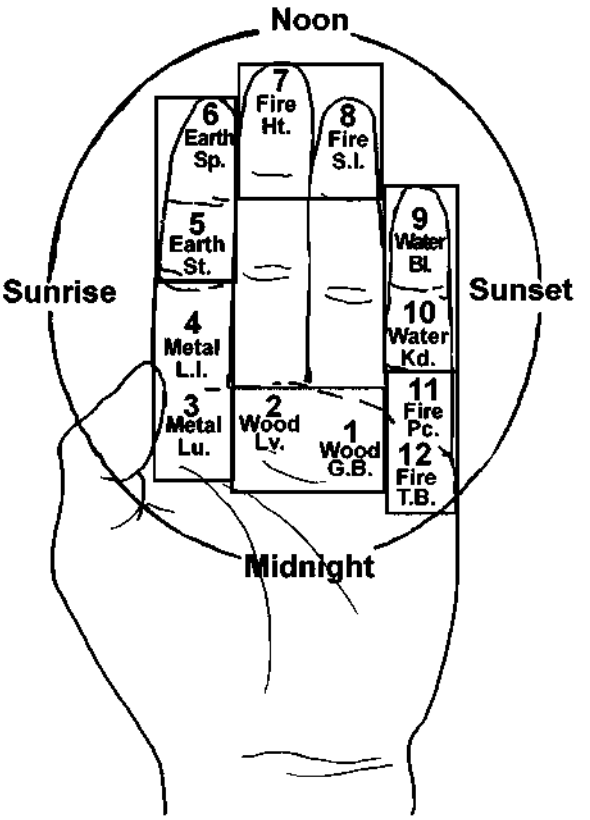

Figure 34.21. Left Palm - The Five Elemental Channel Pattern:

The left palm is used in gathering and absorbing the channel Qi of the doctor's Five Yin Organs. As the Qigong doctor's thumb touches the specific areas on the fingers, the energy is gathered into the doctor's Lower Dantian and released out from the right palm.

chest, facing outward towards the patient. When exhaling, press the thumb into the Earth's channel bands (5, 6) while uttering the Spleen sound "Who." Guide the Earth energy out of the right palm into the treatment area. In this particular technique the doctor is using Fire energy to support the extension of Earth energy.

4. To Emit Lung Energy and Guide Metal Qi proceed as follows:

- First, from a Wuji posture, connect the left thumb onto the tip of the left index finger (i.e., the Earth channel bands #5, 6), thus forming a circle. Imagine this circle full of golden light. When inhaling, draw this golden Earth energy into the Lower Dantian, while also inhaling Heavenly Qi into the Yellow Court area (CV-12) below the solar plexus. Mix all three of these energies together.
- Second, extend the right hand facing outward in front of the chest, towards the patient. When exhaling, press the thumb the Metal channel bands (3, 4) while uttering the Lungs' sound "Sss." Guide the Metal energy out of the body by way of the right palm into the treatment area. In this particular technique, the doctor is using

imagination to draw the Earth's golden light energy into his or her Lower Dantian to support the extension of Metal energy.

5. To Emit Kidney Energy and Guide Water Qi proceed as follows:

- First, from a Wuji posture, press the left thumb into the Metal channel bands (3, 4). Inhale the Metal energy into the Kidneys, mixing it together in the Lower Dantian.
- Second, extend the right hand facing outward in front of the chest. As you exhale, press the Water channel bands (9, 10) while uttering the "Chree" sound (in a very low pitch). Guide the Water energy out of the body by way of the right palm. In this particular technique, the doctor is using Metal energy to support the extension of Water Qi.

Once skilled in these five exercises, the Qigong doctor should continue to practice them in combination with the Linear, Circular, or Spiral Energy Guiding Methods, creating an individualized, structured technique.

COMBINING THE ENERGY OF THE FIVE ELEMENTAL TONGUE POSITIONS

The doctor can also use the Five Elemental Tongue Positions to increase the power and energetic potential of the doctor's internal organ. Each tongue position connects with the organ's Orb (the complete organ system), thereby increasing the power of the doctor's Qi projection. These tongue positions are described as follows.

1. To connect with Earth (Spleen) energy—the tongue is placed on the bottom of the jaw at the base of the lower palate, beneath the teeth and gum line.
2. To connect with Metal (Lungs) energy—the tongue is placed between the maxilla and mandible bones, suspended, between the teeth.
3. To connect with Fire (Heart) energy—the tongue is placed on the hard palate, at the front of the upper palate, behind the teeth and gum line.
4. To connect with Wood (Liver) energy—the tongue is placed on the hard palate, at the middle of the upper palate at the center of the roof of the mouth.
5. To connect with Water (Kidneys) energy—the tongue is placed on the soft palate, at the back of the upper palate.

COMBINING THE ENERGY OF THE FIVE ELEMENTAL COLORS

The doctor can also include the Five Elemental Colors to increase the power of his or her internal Qi projections (see Chapter 4). The Five Elemental Colors are described as follows.

- Earth (Spleen)—The organ color bright yellow, the channel color is soft yellow.
- Metal (Lungs)—The organ color bright white, the channel color is soft white.
- Fire (Heart)—The organ color bright red, the channel color is soft red.
- Wood (Liver)—The organ color bright green, the channel color is soft green.
- Water (Kidneys)—The organ color bright blue, the channel color is soft blue.

SUMMARY OF QI EMITTING METHODS

When the Qigong doctor emits Qi into the patient, it effects the quality of light, sound, heat, vibration, and electromagnetic energy stored within the patient's tissues and cells. There are many variations of Qi emission hand postures and techniques used by Qigong doctors in China. Each differs according to the various schools, colleges, and styles of Medical Qigong training. These changeable and diverse hand postures, as well as the various Qi extension, guidance, and regulation techniques can all be combined and grouped together to assist the Qigong doctor in understanding the clinical treatment potentials. The following is an outline of the aforementioned Hand Postures and Extension, Guidance, and Regulation techniques (described in Chapter 33 and 34), along with their applications.

HAND POSTURES USED FOR EMITTING QI

1. The Extended Fan Palm Hand Posture energy emission has the widest beam of Qi extension.
2. The Sword Finger Hand Posture energy emission has the width and beam reduced into a more condensed form of Qi extension.
3. The One Finger Skill Hand Posture energy emission is further reduced into an even more condensed form of Qi extension.

4. The Invisible Needle Hand Posture energy emission is condensed even further into a finely honed needle of light, similar to that of a laser beam.

HAND TECHNIQUES USED FOR BREAKING UP ENERGETIC STAGNATIONS

1. The Thunder Fingers Hand Technique is the strongest, most aggressive hand technique, and is used to break into the energetic boundary of the Qi stagnation. It is used as a preparation technique before purging the stagnation.
2. The Shaking and Trembling Hand Technique is the second most aggressive hand technique, and is used to purge stagnation and toxic Qi from the patient's body.
3. The Vibrating Hand Technique is a powerful, yet subtle hand technique, which can be used to expand, contract, vibrate, and loosen the patient's Stagnant Qi.
4. The Kneading Tiger Hand Technique is used to separate the Toxic Qi, and to dredge and purge it out of the patient's body.

ENERGY EXTENSION AND GUIDANCE TECHNIQUES FOR MOVING QI

1. The Pushing Technique is used to push and move the energy within the body's tissues, channels, and energetic fields.
2. The Pulling Technique is used to pull and move the energy within the body's tissues, channels, and energetic fields.
3. The Leading Technique is used to lead, guide, and move the energy within the body's tissues, channels, and energetic fields.
4. The Circling Technique is used to lead, guide, and move the energy in a circling pattern within the body's tissues, channels, and energetic fields.
5. The Spiraling Technique is used to spiral or drill energy into or out of the body's tissues, channels, and energetic fields.
6. The Energetic Cupping Technique is used to lead, guide, and move the energy within the body's tissues, channels, and energetic fields.

HAND POSTURES USED FOR PURGING, DREDGING, AND REMOVING TOXIC QI

1. The Bellows Palm Hand Posture is used like a vacuum to remove toxic Qi
2. The Dragons Mouth Palm Hand Posture is used to grasp, pull, and lead toxic Qi from the body.
3. The Sword Fingers Hand Posture is used to circle-wrap toxic Qi (like a fork wrapping spaghetti) and remove it from the body.
4. The Kneading Tiger Hand Posture is used to grasp, seize, and pull toxic Qi from the body.
5. The Shaking and Trembling Hand Posture is used in order to grasp, seize, and pull toxic Qi from the body.
6. The Thunder Fingers Hand Posture is used to shake and release toxic Qi from the doctor's body.
7. The Extended Fan Palm Hand Posture is used to dredge, pull, and purge toxic Qi from the body.

TYPES OF ENERGY RELEASED THROUGH QI EMISSION

1. Hot Qi Emission is used to tonify or sedate a specific area, organ, channel, or energetic field.
2. Cold Qi Emission is used to cool down or sedate a specific area, organ, channel, or energetic field.
3. Color Qi Emission is used to tonify or sedate a specific area, organ, channel, or energetic field.
4. Sound Emission is used to tonify or sedate a specific area, organ, channel, or energetic field.
5. Five Elemental Organ Qi Emission is used to tonify or sedate a specific area, organ, channel, or energetic field.
6. Five Elemental Channel Qi Emission is used to tonify or sedate a specific area, organ, channel, or energetic field.

CHAPTER 35
THE INVISIBLE NEEDLE THEORY AND APPLICATION

INTRODUCTION

In China today, the use of Invisible Needles in Medical Qigong therapy is usually reserved for patients who are hypersensitive to energy flow. As the patient's sensitivity increases, the treatments are modified in order to complement their perceptive abilities.

To perform the Invisible Needle technique, the Qigong doctor must first connect with the divine energy. This is performed by drawing energy from the Heavens through the Baihui GV-20 point at the top of the head and extending it out through the hands, enveloping the patient. Some Qigong doctors imagine that needles of light, from the Heavens, descend through their Baihui point. As this light fills their body, they become empowered with a never-ending reserve of Invisible Needles to treat the patient. In order to use these needles, the doctors rotate their wrist clockwise and the Invisible Needle flows out the Pc-8 Point at the center of their palm (Figure 35.1).

Other Qigong doctors use a single needle image. The doctor imagines needles of light coming out of the Heavens, spiraling around the head like a golden halo. This golden halo is positioned above the head, above the Heavenly Transpersonal Point (located about a foot above the head). To use these needles, the doctors reach above their head and pluck the needles from the Heavens. These needles are then inserted into the patient's body (Figure 35.2). When using either visualization, the important factor is to focus on how deep the needles should penetrate. When treating an area deep in the major organs, a clockwise rotation reinforces and tonifies, while a counterclockwise rotation sedates the organ area.

PREPARATION

Before inserting an Invisible Needle into the

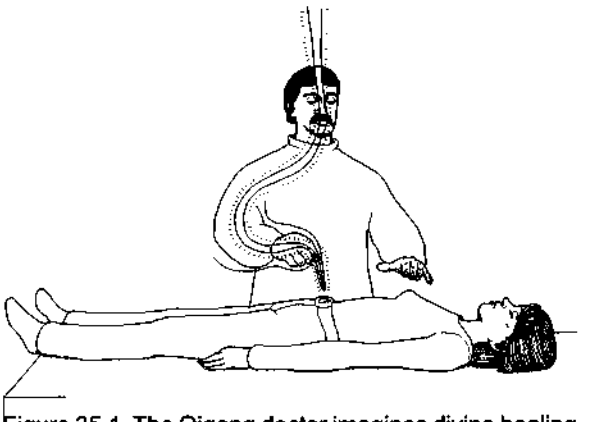

Figure 35.1. The Qigong doctor imagines divine healing light descending from the Heavens, filling the doctor's body with the energy to create the Invisible Needle.

Figure 35.2. Another variation is for the Qigong doctor to imagine divine healing light descending from the Heavens and encircling the doctor's head like a golden halo. Contained within this halo are the Invisible Needles.

patient, it is important for the doctor to dredge the diseased area first. This is similar to swabbing an area with alcohol (or disinfectant) before inserting an acupuncture needle. As one hand extends the Invisible Needle, the other is used to reinforce its energy. The doctor works the Invisible Needle into the patient's tissues until he or she feels it inside the patient's body. Sometimes the patient may feel a cold sensation while being treated by the doctor. This is a normal reaction to the Invisible Needle insertion. The longer that the doctor keeps the Invisible Needle inserted inside the patient's body, the better the healing effect.

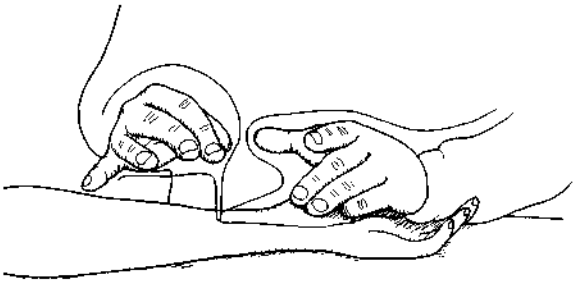

Figure 35.3. The doctor's right hand extends the Invisible Needle perpendicularly into the patient's point or channel, to reduce or sedate the energy flow. The doctor's left hand is used to reinforce the energetic purging of the patient's toxins.

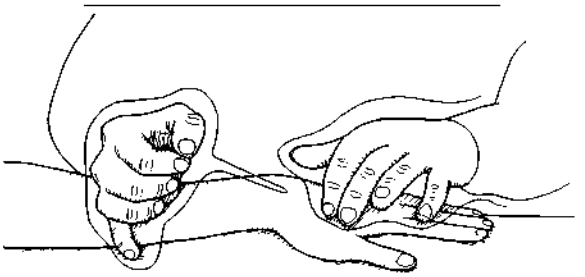

Figure 35.4. Insert the Invisible Needle at a 45 degree angle with the flow of the patient's channel to reinforce or tonify, provided the channel's flow is towards the organ.

In order to prevent the Qi from escaping, when performing any reinforcing or tonifying techniques, the Qigong doctor presses the patient's channel point after retracting the Invisible Needle.

ANGLE OF INSERTION FOR TONIFICATION OR SEDATION

The skill of using Invisible Needles encompasses a complete system of energetics that utilizes both reinforcing (tonifying) and reducing (sedating) techniques. The polarity of the patient's channel (Yin or Yang) determines the angle at which the Invisible Needle is inserted.

- When performing reducing or sedating techniques, it is important to insert the Invisible Needles perpendicularly into the patient's points or channels, forming an energetic dam to slow the flow of Qi (Figure 35.3). The doctor removes the needle slowly, and leaves the point open (this allows the point to continue to release Qi naturally).
- When performing any reinforcing or tonifying techniques, insert the Invisible Needle at an angle, pointed in the direction of the channel's flow (provided that the channel is flowing towards the direction of the intended organ). Then, when retracting the Invisible Needle, remove it quickly and seal the point. This quick retraction method is done to prevent the Qi from escaping the area once it is stimulated, and is followed by pressing the needle hole to seal the point (Figure 35.4).

One favorite tonification technique used by certain Qigong doctors in Beijing, China is to leave the Invisible Needles inside the patient, while regulating the Conception and Governing Vessels. Once they have strengthened the patient's Microcosmic Orbit (Fire Cycle), they retract the Invisible Needles and disperse them one by one into the Earth. The insertion and manipulation of the Invisible Needles is performed with the Invisible Needle Palm technique.

Another favorite technique used for tonification is for the Qigong doctor to first insert the Invisible Needle deep into the patient's Kd-1 point at the bottom of the feet. Once the needle is inserted, the doctor extends his or her intention, causing the needle to grow and extend up the patient's legs and into the Kidneys. Next, the doctor emits energy up the patient's legs to further tonify the Kidneys and Mingmen area.

The Invisible Needles can also be transformed into the specific colors of the Five Elements to enhance tonification. A blue needle, for example,

can be used to intensify Kidney tonification. Each needle can additionally be spiraled in a clockwise or counterclockwise direction to generate an energetic vortex used for either tonification or purgation (Figure 35.5).

THE HAND POSTURES OF THE INVISIBLE NEEDLE

The following is a description of the various hand postures used when treating patients with the Invisible Needle technique.

THE DOCTOR'S RIGHT HAND

The doctor's right hand is generally used for controlling and projecting the energy of the Invisible Needle into the patient. It is not only responsible for the formation but also the insertion of the Invisible Needle. The action and movement of the right palm projecting and stimulating Qi is sometimes referred to as the Chicken Pecking technique. In this hand posture, the thumb connects with the index finger or index and middle finger to form the shape of a bird's beak (Figure 35.6). While these fingers are joined together, the other fingers on the hand relax in an extended, straight position. The doctor's intention is focused on the image of an Invisible Needle which is projected into the patient's body.

The pricking, insertion, and manipulation of the Invisible Needle is only effective when the Qigong doctor connects and roots his or her intention deep within the patient's Jing, Qi, and Shen. This intention connects the doctor with the patient's Qi and Blood, and their animated Spirit.

THE DOCTOR'S LEFT HAND

The doctor's left hand is used to either manipulate the patient's tissues to enhance the Qigong treatment, or to collect Qi into the doctor's Lower Dantian to be projected into the patient. This technique is similar in method to collecting the Yin (Cold) and Yang (Hot) energy before emitting it into the patient. Once the thumb connects with any of the fingers, the released energy bears the nature of the associated element and its Yin and Yang properties (Figure 35.7). The Qi that is collected when the thumb and middle finger connect, for example, is the Yang Qi within the Heart.

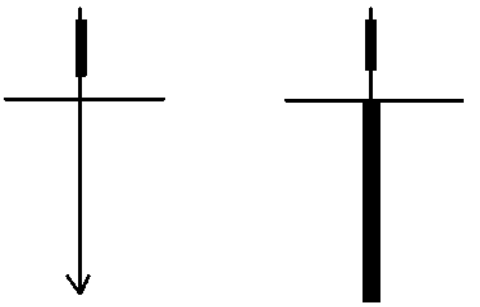

The needle can be made to grow and extend deep inside the patient's tissues or channels.

The needle can be made to grow fat inside the patient's tissues or channels to increase Qi projection.

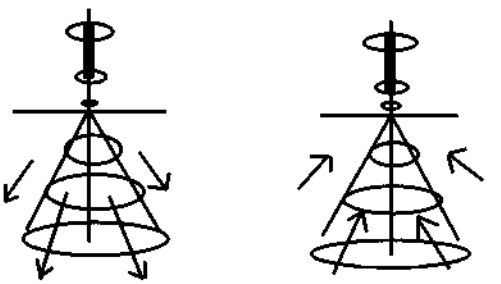

Clockwise spiraling the needle is used to create an energetic vortex for tonification.

Counterclockwise spiraling the needle is used to create an energetic vortex for purgation.

Figure 35.5. The Invisible Needle Techniques

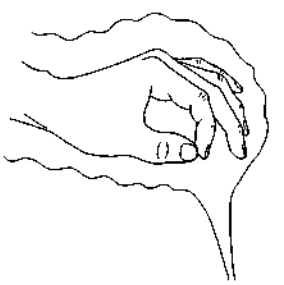

Figure 35.6. The Invisible Needle Palm

This Qi replenishes the Yang Qi and regulates the energy of the Heart (Figure 35.8). If the doctor's hand is positioned over the Pericardium Channel and energy is emitted into the patient, the patient's Shen will become peaceful. When treating with the Five Elemental organ energy, the index and middle finger stand for Fire and Wood; this combination is considered Yang. The ring and little finger stand for Water and Metal; this combination gathers and creates Yin energy.

TIME AND DURATION OF TREATMENT

In general, Medical Qigong Invisible Needle Technique and Point Therapy is applied once a day. A routine therapeutic course includes six to eighteen treatments. Patients with mild diseases may continue the therapy from six to twenty-four treatments. For chronic patients, however, treatment may last as long as one to three months depending on the patient's condition (i.e., for paraplegic patients the treatment is generally from three to six months).

As far as the time sequence of when to treat the patient, or when the patient is to treat themselves, the chronometric rate is based on the high-tide sequence of the patient's channels (i.e., 11 am to 1 pm is the Heart time, which is the best time period to treat patients with Heart disease).

REMOVING THE INVISIBLE NEEDLES AND ENDING THE TREATMENT

During tonifying treatment, the Qigong doctor removes the Invisible Needle quickly from its point of origin while the patient is inhaling. This allows the patient to keep the Qi and Shen within the body's channels and tissues. After extracting the needle, the doctor presses down on the acupuncture point with emitted Qi and lightly rubs it in a clockwise direction until the open point has closed.

During a sedating treatment, the Qigong doctor has the patient exhale to expel the Evil Qi and Heat from the patient's tissues. After extracting the needle slowly, the doctor allows the acupuncture point to naturally drain and eventually close by itself. This aids in draining the Evil Qi and Excess Heat from the patient's body.

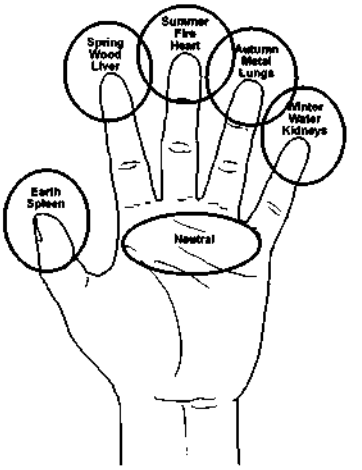

Figure 35.7. When treating patient's with the Invisible Needle technique for tonification, the Qigong doctor emits the required amount of energy into the patient, according to the specific Deficient organ and channel's condition.

The thumb, being the Earth Element and neutral, allows the Qigong doctor the ability to connect and combine the energy of the Five Yin Organs into his or her Lower Dantian, before extending the Qi into the patient.

Five Fingers	Five Elements	Five Viscera
Thumb	Earth	Spleen
Index	Wood	Liver
Middle	Fire	Heart
Ring	Metal	Lungs
Little	Water	Kidneys

Figure 35.8. Hand Chart of the Five Elements

Chapter 36
Energetic Point Therapy

The importance of Energetic Point therapy as a Medical Qigong modality can best be understood when exploring the amount of information stored within the body's tissues. According to theoretical physicist Michio Kaku, the body's DNA contains over one hundred trillion times the information stored in current computers. There is an even greater amount of information stored within the three subtle energy fields outside of the human body. Most of this information is not readily translatable or decipherable, and is hidden from the conscious mind.

By stimulating certain energy points, for a specific length of time, an energetic trigger mechanism, or response reflex is created. This energetic reaction releases memories and stored information unique to each patient. To facilitate the unlocking of this stored information, the Qigong doctor must maintain a deep state of Alpha consciousness when stimulating the patient's energy points.

Energetic Point therapy involves two distinct modalities of treatment: Channel Point treatments and Channel Point meditations. Either can be used in conjunction with the Invisible Needle therapy. In these particular modalities of treatment, the Qigong doctor can either emit Qi into specific channel points on the patient's body to enhance the Medical Qigong treatment, or have the patient meditate on a specific point while the doctor administers the therapy. Both approaches can be used by the Qigong doctor to gather energy, move Qi, or release trapped energy from the patient's tissues.

Channel Point Treatments and Prescriptions

The following treatments are generally used in the clinic by the Qigong doctor for Invisible Needle therapy, but are not necessarily limited to that modality of treatment. These Energetic Point treatments are arranged and categorized according to specific diseases. The Energetic Points are located on the patient's front and back as depicted in the anatomical graphs (Figures 36.1 and 36.2). These points are clinically used for the following treatment goals:

Point Therapy to Tonify Yin Energy

1. To Tonify Yin energy and to reduce a Deficient type of Fire, extend Qi into the patient's Kd-3 point.
2. To nourish the Yin energy and to reduce Fire, extend Qi into the patient's Kd-3 and Lu-10 points.
3. To treat a Deficiency of Yin of the Liver and Kidneys and to reduce the causes of Deficient Fire, extend Qi into the patient's Sp-6 and Lv-3 points.
4. To treat a Deficiency of Yin causing a dryness of the Lungs, extend Qi into the patient's Lu-1 and Bl-13 points on the front and back of the body. Regulate the respiratory tract, as well as the patient's Lu-7 and Kd-6 points, thereby tonifying the body's Yin energy and activating the descending function of the Lungs.

Point Therapy to Tonifying or Disperse Yang Energy

1. To strengthen the Yang of the patient's Kidneys, extend energy into the patient's GV-4, Bl-23, and Kd-3 points.
2. To warm, and tonify the Yang of the patient's Spleen and Kidneys, extend energy into the patient's Bl-20 and -23 points. This treatment is ideal for eliminating Damp fluid caused from Deficient types of edema.
3. To fortify the Yang and avert a state of Yang collapse, tonify the patient's Yuan Qi by extending energy into the patient's Lower Dantian, focusing specifically on the patient's CV-4, -6, and -8 points.

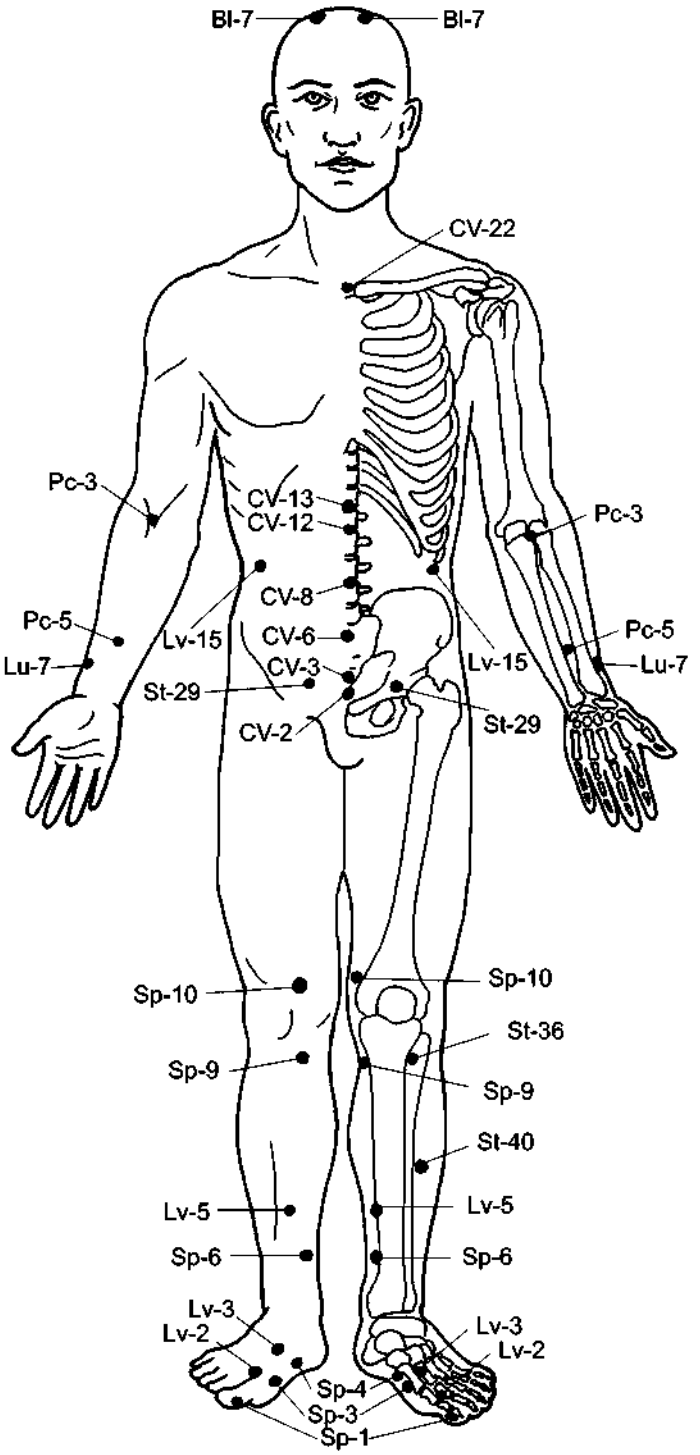

Figure 36.1. Chart of Specific Channel Points

4. To treat a condition of Deficiency of Yang of the Spleen, strengthen the patient's Stomach and Spleen to eliminate Damp and Phlegm. This is done by extending energy and tonifying the patient's St-36, CV-12, and Bl-20 points. Then activate and warm the Qi of the patient's Lungs by extending Qi into Bl-13, and -43 points.
5. To strengthen the Yang of the Spleen, promote the Spleen's transporting function by extending energy into the patient's CV-12, Bl-20, Lv-13, and Sp-3 points.
6. To raise the patient's Yang Qi or the Yang Qi flowing within the patient's Governing Vessel, extend energy into the GV-20 point.
7. To reduce hyperactive Yang of the patient's Liver, first dredge and disperse the patient's GB-20, Bl-18, and Lv-2 points to pacify the Yang of the Liver; then tonify by extending energy into the patient's Bl-23 and Kd-3 points to strengthen the Kidneys.
8. To reduce Excess Yang within the patient's Governing Vessel which has caused a hyperactivity of Heat, dredge and sedate the patient's GB-2O point. Then purge the Heat from the patient's GV-14 and LI-4 points.

Point Therapy to Tonify or Disperse Qi

1. To strengthen the patient's Yuan Qi, extend Qi into the patient's Lower Dantian, focusing on CV-4 and -6 points.
2. To fortify the patient's Qi and reestablish their Yang, extend energy into the patient's GV-20, CV-6, and St-36 points.
3. To subdue the patient's ascending Qi, extend Qi into the patient's CV-22 and Bl-17 points.
4. To disperse the patient's stagnant Qi and Phlegm, extend Qi into the patient's Bl-13 point.
5. To tonify the Kidneys' Qi and Jing and to reduce any Kidney Deficiency, extend Qi into the patient's GV-4, Bl-52, and Kd-3 points.
6. To stimulate the circulation of Qi and Blood, extend Qi into the patient's LI-4 and Lv-3 points.

Point Therapy to Tonify and Nourish the Blood

1. To activate the patient's Blood circulation, extend energy into the patient's Sp-10 point.
2. To stimulate the function of conducting Blood, extend energy into the patient's Sp-1 point.
3. To control the production of Blood, extend energy into the patient's Bl-20 point to control the Blood, as well as Bl-15 to increase the production of Blood.
4. To activate Blood circulation and remove stasis, extend energy into the patient's Sp-6 and Bl-17.
5. To strengthen the source of Blood formation, extend energy into the patient's St-36 and Sp-6 points.
6. To remove Blood stasis of the uterus, extend energy into the patient's Bl-32 and St-29 points.

Point Therapy to Eliminate Cold and Damp

1. To warm the Spleen and Stomach to eliminate Cold, extend energy into the patient's Lower Dantian and CV-12 and -13 area.
2. To disperse Cold, relieve pain, pacify the Stomach and strengthen the Spleen, extend energy into the patient's Sp-4 and Bl-20 points.
3. To strengthen the Spleen to disperse Dampness, extend energy into the patient's Sp-6 and St-36 points.
4. To eliminate edema above the waist, extend energy into the patient's Bl-20 and Lv-13 points.
5. To eliminate edema below the waist, extend energy into the patient's Bl-28, LI-6, and Sp-9 points.

Point Therapy to Eliminate Heat

1. To eliminate Heat from the patient's body, extend energy into the patient's LI-11 points, or dredge and disperse energy from the patient's Shi Xuan points (at the tips of the fingers).
2. To move Heat downwards from the patient's body, dredge and disperse energy from the patient's Kd-1 points.
3. To disperse External Heat, dredge and disperse energy from the patient's SI-3 points.
4. To eliminate Internal Heat, dredge and disperse energy from the patient's Pc-5 points.
5. To eliminate Damp Heat, extend energy into the patient's Bl-20 and Sp-9 points.

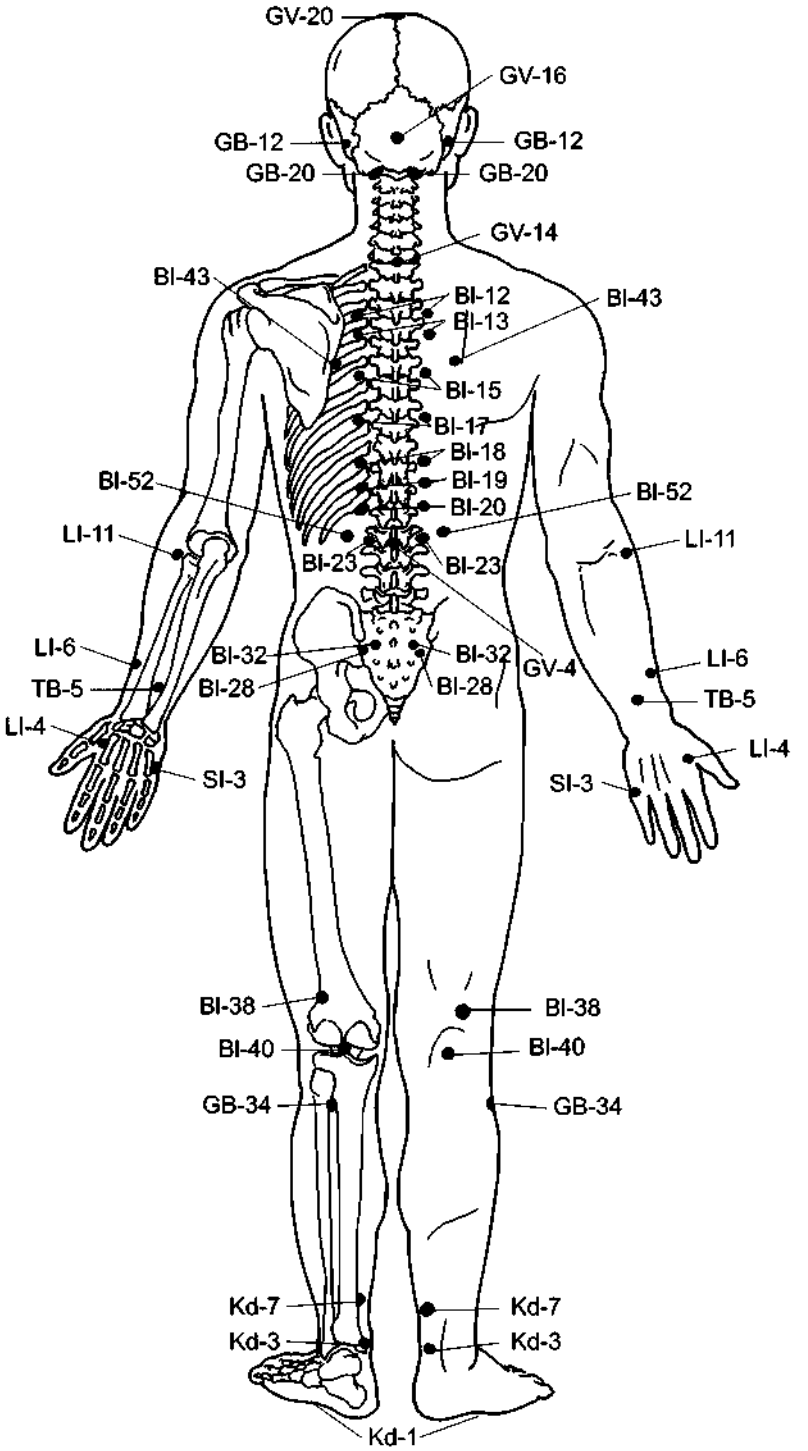

Figure 36.2. Chart of Specific Channel Points

6. To eliminate Damp Heat from the Blood, dredge and disperse energy from the patient's Bl-40 points, then extend energy into the Pc-3 points.
7. To reduce Fire of the Liver, dredge and disperse energy from the patient's CV-3 and Lv-5 points.
8. To reduce Liver and Gall Bladder Upward Fire disturbance, dredge and disperse energy from the patient's GB-12, as well as Bl-19 and -18 areas.

POINT THERAPY TO ELIMINATE WIND

1. To eliminate Wind Cold, dredge and disperse energy from the patient's GV-16, Bl-12, GB-20, Lu-7, LI-4, and Kd-7 points.
2. To eliminate Wind Heat, dredge and disperse energy from the patient's GV-14, LI-4, TB-5, and GB-20 points.
3. To eliminate Wind from the upper portion of the patient's body, dredge and disperse energy from the patients Bl-7, GV-20, and -16 points.
4. To eliminate pathogenic Wind, extend energy into the patient's Lu-7 points to activate the natural dispersing function of the Lungs.
5. To eliminate Wind and reduce Fire, dredge and disperse energy from the patient's GB-20 points.
6. To calm the Wind of the Liver, dredge and disperse energy from the patient's Lv-3 points.

POINT THERAPY TO ELIMINATE PHLEGM

1. To eliminate Damp Phlegm in the Interior, first strengthen the function of the patient's Spleen and Stomach to eliminate the Dampness, by extending energy into the patient's Bl-20 and CV-12 points, then eliminate the Phlegm by dredging both of the St-40 points.
2. To eliminate Phlegm Fire in the patient's Stomach, dredge the patient's GB-34 and St-40 points.

CONTRAINDICATIONS

Never apply Energy Point therapy to patients who are in an acute stage of inflammatory diseases (especially of the abdomen). Also avoid using Energy Point therapy on patients with hypertension, heart diseases, severe cases of pulmonary tuberculosis, hemophilia, purpura hemorrhagic, purpura allergic, and severe skin diseases.

CHANNEL POINT MEDITATION

After applying the Invisible Needle technique or Energetic Point therapy, the Qigong doctor may decide to initiate Channel Point meditation to intensify the treatment. This is achieved by having the patient concentrate on specific points along the channels. This concentration will produce two distinct results. First, it will get rid of any of the patient's distracting thoughts, and second, it will cause different fluctuations of the Qi and Blood circulation through the patient's Yin and Yang organs. This focused concentration will allow the internal organs to supply the patient's body with either: a more concentrated flow of Qi and Blood into the tissue area; or the focused attention will have a stronger dispersing effect on the patient's tissues (depending on the patient's focus).

Each time a patient switches the focus of concentration to a different point in a different area of the body, the circulation and regulation of Qi and Blood will alter to accommodate the mental transitions of intention. In giving the patient a specific point meditation as a prescription, the Qigong doctor should be careful to select the areas and points in accordance with the particular Qigong exercises that will arrest the patient's Yin and Yang organ disease.

Generally speaking, when treating an Excess condition with Channel Point meditation, the Qigong doctor has the patient imagine draining the Excess Qi out through the extremities. In the case of a Deficiency, the doctor has the patient focus on tonifying the Deficient organ(s) by absorbing energy and light into the Deficient area. Below is a list of channel point regulations and their applications.

QIHAI (CV-6) SEA OF QI

The CV-6 point, located in the Lower Dantian, is the most frequently selected point (Figure 36.3). It is chosen for normal conditions to lead the Qi back to its origin. It is this area from which Qi emanates and returns, hence its name, Sea of Qi. Focusing on this point will allow the patient to tonify the Kidneys (Yuan) Qi, and can be used to regu-

late the Lower Burner, Conception Vessel, and Water pathways. The Qigong doctor may also extend energy into this area to:

- restore collapsed Yin or Yang Qi,
- raise the patient's Middle Burner Qi,
- warm a patient's Yang Qi,
- warm a patient's Cold condition,
- treat mental disorders,
- treat male sexual problems,
- treat urinary problems,
- treat local pain,
- treat fatigue, and
- treat Qi and Blood Deficiency.

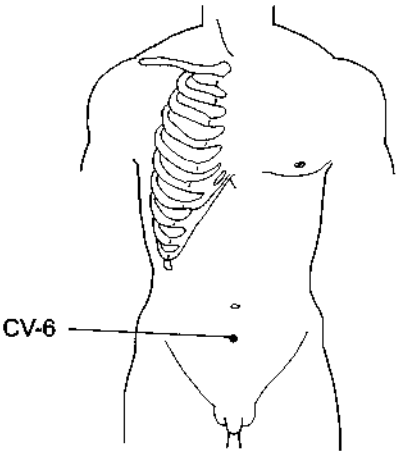

Figure 36.3. Lower Dantian (CV-6)

MINGMEN (GV-4) GATE OF LIFE

This point is also called the Palace of Essence (Figure 36.4). Located between the two Kidneys, this point is used for patients with a Deficiency of the Kidney Yang and declining Fire of the Mingmen (this condition is manifested as lumbago pain, seminal emissions, and an aversion to cold). Focus the patient's concentration on the navel first, then gradually have the patient focus deeper into the Mingmen area. This area is known as the Sea of Blood and Essence. Focusing on this point will allow the patient to tonify and stabilize the Kidney (Yuan) Qi and Jing. A Qigong doctor extending energy into this area can regulate the patient's water pathways, heat the body's Yang Qi, and lower blood pressure. This point is also used to treat lower back pain, sciatica, as well as sexual/genital problems.

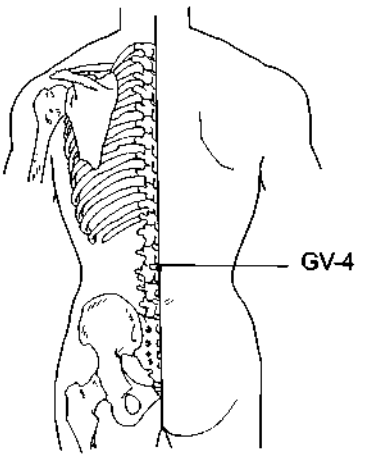

Figure 36.4. Mingmen (GV-4)

SHAO SHANG (LU-11) LESSER SHANG

This point is also called Ghost Sincerity, and is considered the second of eleven ghost points (Figure 36.5). The sound "shang" is a musical note and corresponds to the Element Metal. This particular point is used for patients with a Deficiency of Lung Qi (this is manifested by asthma and coughing). It reinforces the Qi and regulates the Lungs. A Qigong doctor can pull energy from this area to dredge and clear Lung Fire, Heat, and Summer Heat, as well as dispel Wind Heat from the patient's body.

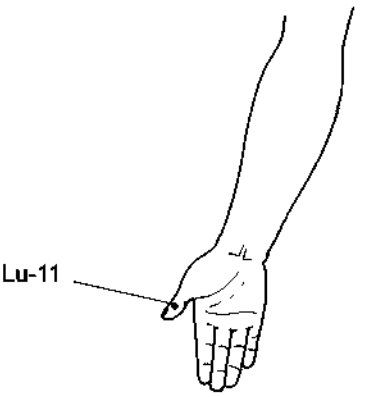

Figure 36.5. Shao Shang (Lu-11)

ZHONG CHONG (PC-9) MIDDLE RUSHING

This point is used for patients with a Deficiency of Heart Qi (which manifests as palpi-

tations and restlessness). It reinforces the Qi and calms the Heart and mind. This area is good for regulating the Heart's Qi, reviving consciousness, and restoring collapsed Yang. It can be used to dredge and clear the patient's body of Heart Fire, Heat, and Summer Heat conditions (Figure 36.6).

Zu San Li (ST-36) Foot Three Miles

This point is used for patients with a disorder of transporting and transforming Spleen and Stomach Qi (which manifests as abdominal distention and pain). This point has a strong tonifying effect (especially for the Spleen) and regulates the Stomach. It also tonifies the Ying (Nutritive) Qi, and regulates the Lower and Middle Burners. It can be used by a Qigong doctor to dredge and reduce digestive stagnation, to redirect Rebellious Qi, to drain pathogenic influences from the Stomach, and to soften hard abdominal masses or tumors (Figure 36.7).

Da Dun (Lv-1) Great Pile

This point is used for patients with hyperactive Liver Yang or overactive Liver and Heart Fire. It calms the Liver to treat diseases of the upper portion of the body (primarily the head). By focusing on this area, the patient can regulate and tonify the Liver Qi and Blood. The Qigong doctor may dredge this area to disperse Liver Qi and transform Damp Heat in the Lower Burner (Figure 36.8).

Yong Quan (Kd-1) Gushing Spring

This point is used for patients with Yin Deficiencies of the Liver and Kidney, hyperactivity of Fire due to Yin Deficiencies, or Excess in the upper torso and Deficiency in the lower torso. Concentration on this area will also calm the spirit, clear Fire and Heat from the head area, restore collapsed Yang, and transform Heart Phlegm (Figure 36.9).

Baihui (GV-20) Hundred Meetings

This point is used for patients with a Deficiency of Qi in the Middle Burner (manifested by a shortness of breath, dizziness, intractable diarrhea, and a prolapse of the internal organs). This point is known as the Sea of Marrow. Focusing on this area will clear the brain and calm the spirit. If the Qigong doctor treats this area, the patient's

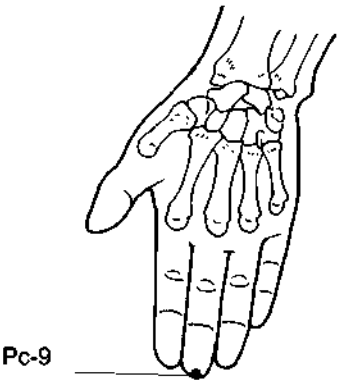

Figure 36.6. Zhou Chong (Pc-9)

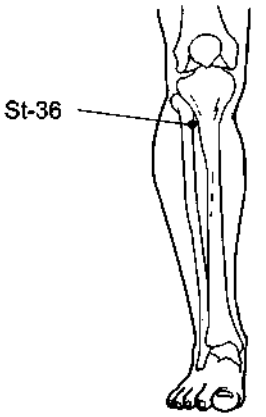

Figure 36.7. Zu San Li (St-36)

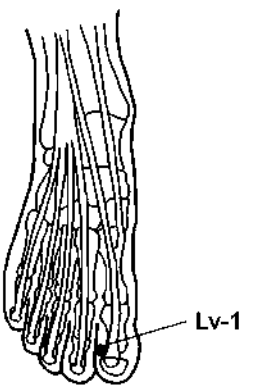

Figure 36.8. Da Dun (Lv-1)

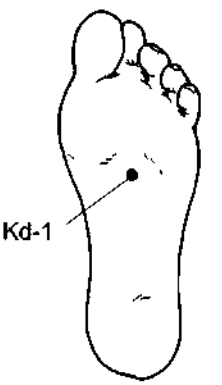

Figure 36.9. Yong Quan (Kd-1)

lower orifices can be stabilized, the Qi can be warmed and tonified, and Yang Qi can be warmed and a collapse can be prevented. This point is also used in order to treat hypertension, insomnia, seizures, dizziness, headaches, and the prolapse of internal organs (Figure 36.10).

HUIYIN (CV-1) MEETING OF YIN

This point is used for patients with a Deficiency of Lung Qi and Kidney Yin (manifested by asthma and coughing). Focusing the patient's concentration on this area stabilizes the patient's Jing and lower orifices, as well as calms the spirit and clears the brain. It can be used by the Qigong doctor to tonify and regulate the patient's Qi, to clear Heat from the patient's body, to treat irregular menses, urethritis, prostatitis, and to raise the blood pressure (Figure 36.11).

YIN TANG (EX. HN. 3) SEAL HALL

This point is used for patients to calm the spirit, and can be used by the Qigong doctor to dispel Wind and clear Heat from the patient's body. This point is also used to treat epilepsy, nausea and vomiting, insomnia, sinus headaches, dizziness, and vertigo (Figure 36.12).

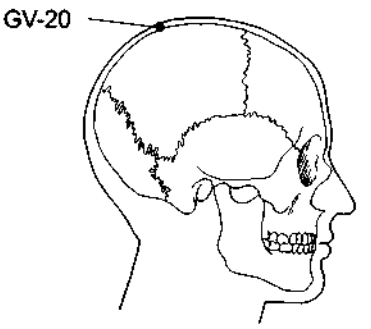

Figure 36.10. Baihui (GV-20)

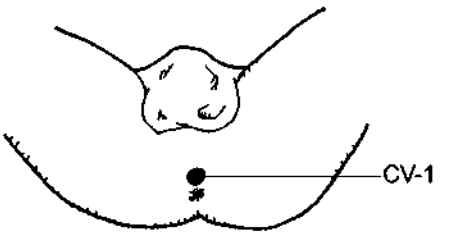

Figure 36.11. Hui Yin (CV-1)

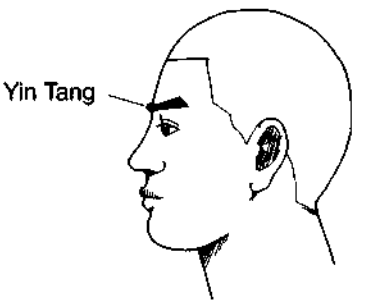

Figure 36.12. Yin Tang (Ex.Pt.)

Chapter 37
Medical Qigong Massage

Introduction to Tissue Function

To understand the energetic function of surface and deep tissue stimulation through Medical Qigong Massage, it is important to first understand the reflexes and spontaneous energetic reactions within the body's tissues. The tissues of the human body are in a constant state of perpetual change. No matter where illness or damage has occurred, everything in the body is linked to the organs' and bowels' functions of producing and governing energy, and their interaction with the body's surface tissues (Figure 37.1–37.2).

In Traditional Chinese Medicine, the human body is viewed as a conglomeration of Qi, Blood, channels, tendons, fascia, bones, Marrow, bowels (Yang organs), and viscera (Yin organs). Each part is interdependent, each having inseparable Yin and Yang relationships and all of them interacting with each other. The following describes the interaction of: Qi and Blood, Tendons and Fascia, Bones and Marrow and the Bowels and Viscera.

1. Qi is considered the Blood's leader: as the Qi leads, the Blood follows. If the Qi ceases to flow, the Blood stops.
2. The tendons and fascia are used for channel energy movement. As the tendons and fascia stretch, they cause the channel Qi to increase its energetic movement and flow. When the tendons and fascia are calm, the channel Qi slows down.
3. The bones are the Marrow's residence. When the bones are hard, the Marrow is solid; when the bones are soft, the Marrow is hollow.
4. The bowels (Yang organs) are the viscera's (Yin organs') manifestations. If the bowels are strong, the organs become robust; when the bowels become weak, the viscera begin to fail.

Medical Qigong massage takes into consideration the function and flow of the body's tis-

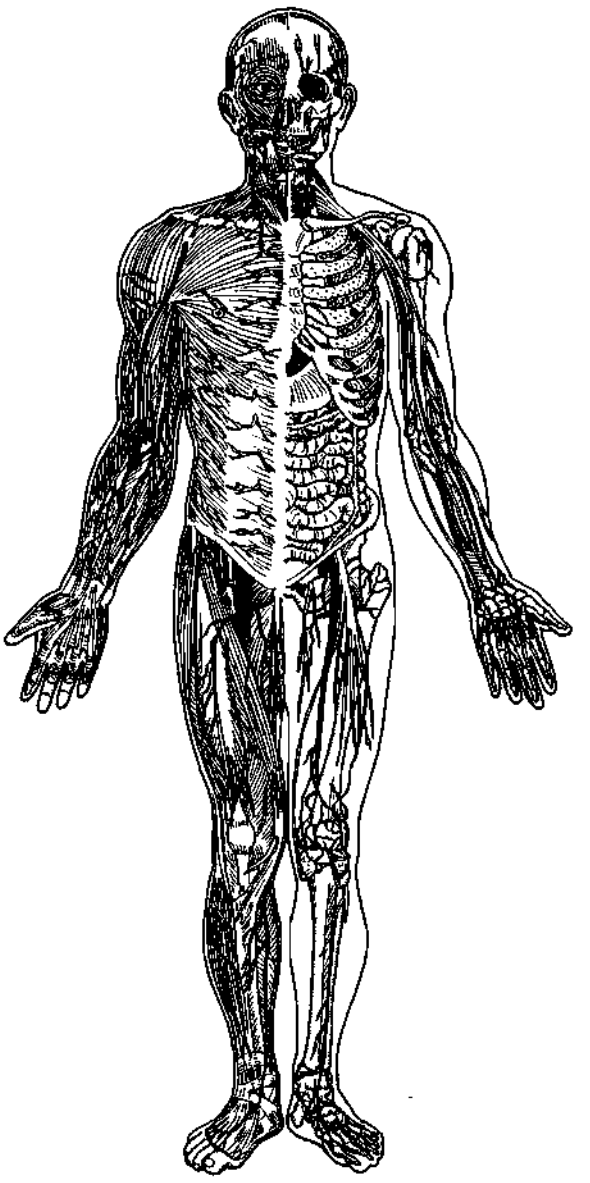

Figure 37.1. The Human Body (Anterior)

sues, in conjunction with the interacting systems of the body's energetic fields, striving to regulate both systems at the same time.

TWO APPROACHES IN TREATMENT

Medical Qigong massage can be divided into two schools of treatment modalities: Surface Tissue Massage Therapy and Visceral Tissue Massage Therapy.

1. Surface Tissue Massage Therapy utilizes the Five Elemental Qi Massage Therapy techniques in conjunction with external tissue stimulation. All external tissue manipulation techniques used in Qigong massage should be light as a feather and should not exceed the pressure one would place on an eyeball. When treating with Surface Tissue Massage, the doctor's focus must be centered on the dispersion of pathogenic Qi and the expansion of the patient's Wei Qi, while softly touching the patient's tissues.
2. Visceral Tissue Massage Therapy utilizes the Five Elemental Qi Massage Therapy techniques in conjunction with deep tissue stimulation. By matching the patient's pulse frequency and respiration with that of the doctor's, a stable, energetic resonance is secured and treatment begins. When treating with Visceral Tissue Massage, the doctor's focus must be centered deep into the patient's internal organs without touching the patient's external tissues.

After external tissue massage is used to treat the patient's tissues, it is important for the doctor to maintain focused intention on the patient's channels while slowly removing his or her hands. If a break in contact with the mind's intention is made, the patient's tissues will return to their pretreatment state. Once the doctor has physically disconnected from the patient in this manner, Distance Qi Emission and Qi manipulation techniques can be applied.

It is believed that the treatment of diseases should be carried out primarily by Qi emission as the main approach, and secondarily through Qigong massage. By combining both external and internal tissue manipulation skills with energy

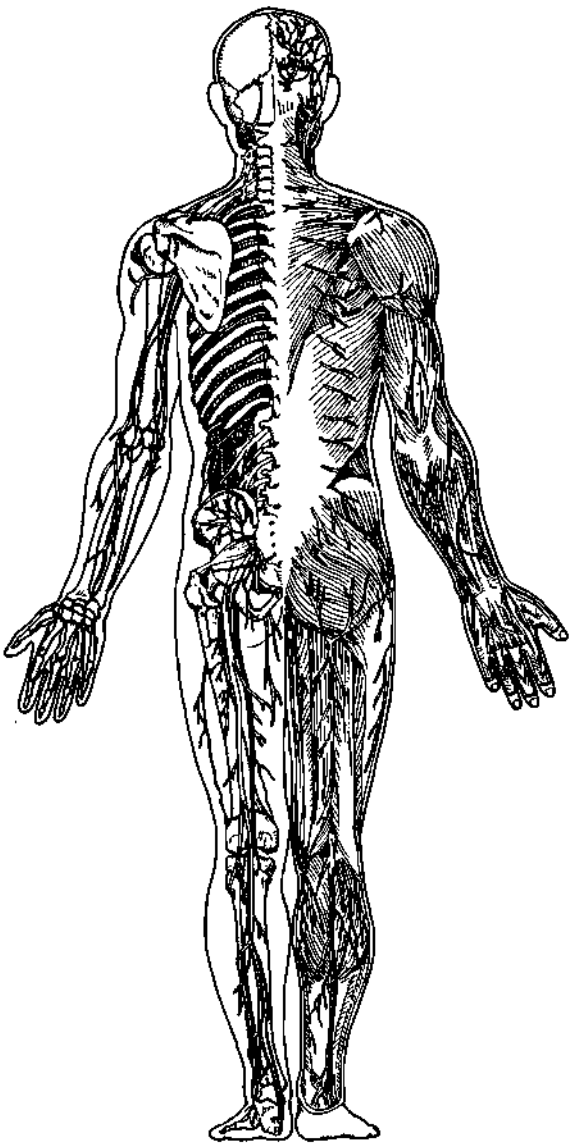

Figure 37.2. The Human Anatomy (Posterior)

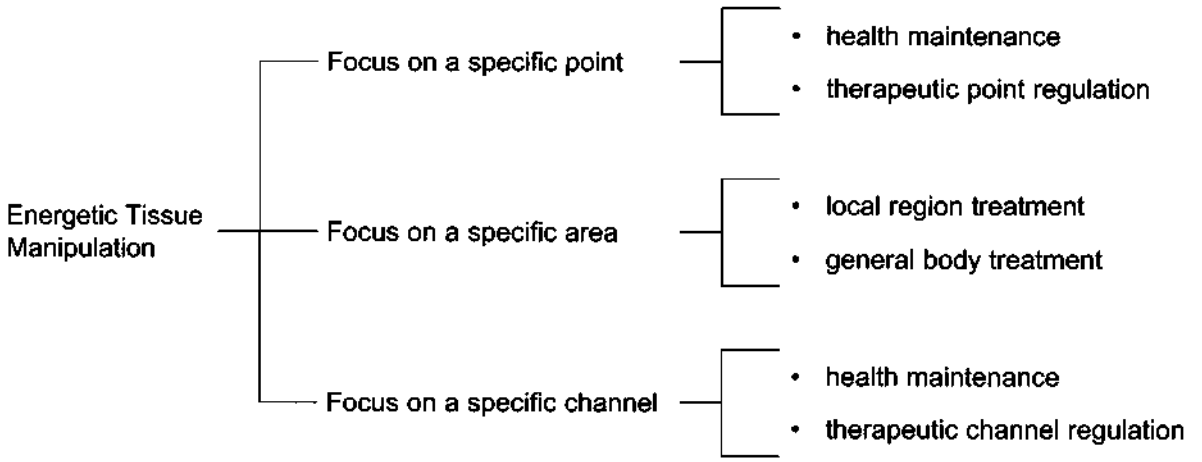

Figure 37.3. Energetic Tissue Manipulation Chart

extension techniques, the Qigong doctor greatly improves the quality of treatments. In the clinical setting, this type of energetic tissue manipulation is utilized before or after energy extension. This facilitates the relaxation of the patient's muscles and joints and the opening or closing of their points. It also aids in dredging the channels, guiding the flow of energy, and in regulating Yin and Yang energy.

TISSUE REGULATION THROUGH MEDICAL QIGONG MASSAGE

The external treatment of the patient's tissues encompasses a wide variety of body manipulation and alignment methods to provide a complete treatment program (Figure 37.3). Used for toning the organs, glands, nervous system, and joints, Qigong massage is applied to treat soft tissue injury. The following are the six treatment goals of Qigong Massage:

- To relax the tendons, activate the channels, promote circulation of Qi and Blood, and relieve pain,
- To disperse Blood stagnation,
- To relieve muscle spasms,
- To expand the tendon sheaths,
- To treat fascia in order to move stagnations and separate adhesions, and
- To correct dislocations.

The following is a list of the five predominant external tissue manipulation techniques used by Qigong doctors in China today.

THE FIVE ELEMENTAL QI MASSAGE THERAPY

Traditionally there are five different techniques for Medical Qigong massage therapy. These five techniques are very important for re-establishing the energetic vitality of the patient's body. Each of these techniques relates to a specific action and organ associated with one of the Five Elements. The objective of these techniques is to influence the muscles, nerve fibers, and deep-lying tissues of the body in order to aid metabolism and stimulate energy flow (Figure 37.4). The applications of these five methods of energy manipulation and their affect on the body's tissues are described as follows.

THE CIRCLE-TWISTING METHOD

This technique relates to the Spleen, which rules and affects the muscles, and is implemented as a quick drilling motion into the body's surface tissues, using the fingers, palms, knuckles, or heel of the palm.

When treating a patient's tissue area, a circle-twisting movement will stimulate the Qi and Blood within the channel points. This will generate a numbing and tingling sensation that will

Circle-Twisting Method	Spleen-Earth Element: affects the muscles, stimulates and improves Blood circulation.
Compression Release Method	Kidneys-Water Element: affects the bones, and regulates the Wei and Ying Qi.
Thrusting Method	Heart-Fire Element: affects the Blood, pulse, and regulates and activates the Qi.
Grasping and Shaking Method	Liver-Wood Element: affects the tendons, ligaments and muscles, promotes, clears, and activates Qi flow, and balances the Yin and Yang energy.
Tapping Method	Lungs-Metal Element: affects the Qi and skin.

Figure 37.4. The Five Elemental Qi Massage Methods

cause the channel points to induce the energy to counterattack the foreign invasion of Turbid Qi and disease. The circle-twisting action will also stimulate and improve Blood circulation and is divided into two modalities of treatment:

- To stimulate, massage the area in a clockwise, spiraling, circular motion from the outside to the center of the point. The purpose of this action is to gather energy from the surrounding areas of the patient's body and collect it into the center point the doctor is treating.
- To sedate, massage the area in a counterclockwise, spiraling circle from the center of the point outward. The purpose of this action is to disperse the energy from the area the doctor is treating. This Excess energy will later be either moved into other organs, or dredged outside the patient's body through an adjacent channel (Figure 37.5).

THE COMPRESSION RELEASE METHOD

This technique relates to the Kidneys, which rule and affect the bones, and is performed by the doctor extending his or her intention into the patient, softly pressing the body's surface tissues, using the whole palm, parts of the fingers, or elbows. The Compression Release method is commonly used to purge or drain the tissues of pathogenic Qi.

The Compression Release techniques are generally used to regulate the Ying and Wei Qi, which travel along the channels and collaterals. Deep pressure reaches the Ying Qi, while shallow pressure stimulates the Wei Qi. Once damage has occurred in the body, the damaged channel points and organ regions cause certain changes in the Wei Qi, Ying, Qi, and Blood areas of the body, resulting in numbness, aches, pain, swelling, etc. Both Circle-Twisting and Compression Release techniques can eliminate these symptoms and create a more stable energy flow.

The Compression Release Technique

Once the proper hand posture and area to be treated has been selected, the doctor guides Qi into his or her palm and fingers using Hot, Cold, vibrating, or spiraling energy. The doctor then initiates a rhythmic compression over the patient's tissues stimulating the patient's energetic field. This action has the function of relieving stagnation or congestion and can be used to dredge the

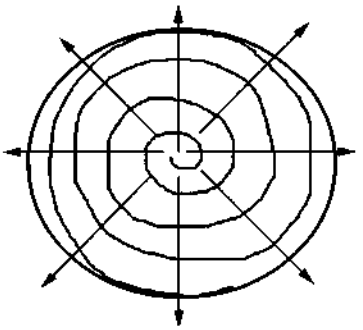

To sedate, purge, or disperse, move the energy in a counterclockwise direction.

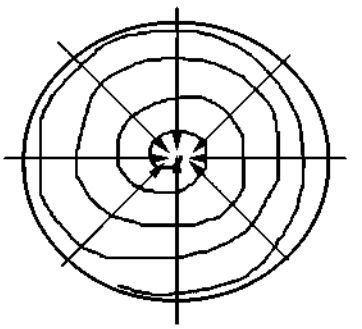

To stimulate, tonify, or gather, move the energy in a clockwise direction.

Figure 37.5. Circle Twisting Method of Energy Therapy

channels and energetic points, as well as to relieve muscle spasms and physical pain.

The doctor must apply the correct amount of pressure for the patient's physical condition:

1. A slow Compression Release method is applied to any kind of hyperactive illness, nervous system disorder, mental disorder, or loss of Blood.
2. A medium Compression Release method is applied to illness for Spleen and Stomach disorders.
3. A fast Compression Release method is applied to hypoactive or Cold illnesses.

It is important to note that when applying the Compression Release method to tonify a specific area, the doctor should energetically press on the channel at a forty-five degree angle, slightly above where the channel flows into the injured area. This augments the flow of energy along the channel.

To disperse or drain a particular area, the doctor should apply slight pressure at an angle past where the channel flows into the injured area. This downward pressure will cause the energy to flow away from the injury. This application is used when treating Excess conditions.

THE THRUSTING METHOD

This technique relates to the Heart, which rules and affects the Blood and Blood pulses. It is utilized to gently push the tissues, extending the Qi and Blood along the patient's surface channels, using the thumb, ball of the thumb, or heel of the palm. The thrusting method can draw energy into a Deficient area or move Qi out of an Excess area.

The Thrusting Technique

Once the proper hand posture and area to be treated has been selected, the doctor guides Qi into his or her palm and fingers using Hot, Cold, vibrating, or spiraling energy. The doctor then rubs lightly or lightly touches above the patient's tissues while simultaneously emitting Qi.

The technique should be synchronized with the frequency of the patient's pulse and respiration. The Thrusting technique has the function of regulating and activating the patient's Qi, alleviating pain, and dredging the channels.

THE GRASPING AND SHAKING METHOD

This technique relates to the Liver, which rules and affects the tendons. It is administered by lightly vibrating the skin (gently at first, then slowly increasing the intensity). The Grasping and Shaking method sends a wave of vibration throughout the patient's body, and is used to increase Qi and Blood flow to the tissue area.

The Grasping and Shaking Technique

Once the proper hand posture and area to be treated has been selected, the doctor guides Qi into his or her palm and fingers using Hot, Cold, vibrating, or spiraling energy.

The doctor then lightly grasps and shakes the

energetic field within the patient's tissues, while extending energy. The Grasping and Shaking technique is used for directing Qi to flow with or against the natural currents in the body's channels. It promotes, clears, and activates the channels and flow of Qi, relaxes the muscles and tendons, and balances the Yin and Yang energy.

THE TAPPING METHOD

This technique relates to the Lungs, which rule and affect the Qi and skin. This technique is administered by lightly and rhythmically tapping the patient's skin (with varying degrees of force), using the fingers, palms or fists (Figure 37.6). The Tapping method sends a pulsating ripple throughout the patient's tissues and is used to disperse stagnation from a point, channel, or organ.

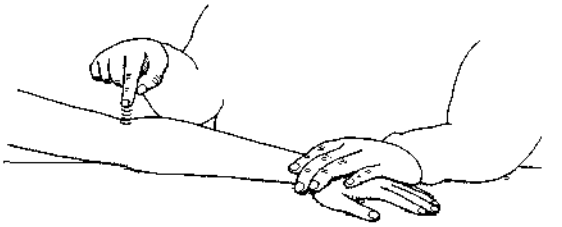

Figure 37.6. In the Massage Tapping Method, the Qigong doctor will extend his or her intention deep into the patient's tissues in order to stimulate the channel point.

YIN AND YANG ENERGETIC POINT MANIPULATION

Before treating patients with Five Elemental Regulation therapy, the Qigong doctor should be aware of the principals of Yin and Yang energetic polarity involved within the Energetic Point Manipulation. This method of treatment is used to regulate the patient's Wei Qi, Ying Qi, and Qi and Blood systems (as a whole), in order to form a governed systemic balance. In the Energetic Point Manipulation methods, the treating techniques are directly based on Yin and Yang theory.

THE YIN THEORY OF QI MANIPULATION

This technique is expressed as a passive, quiet, or motionless action (more energy and less physical movement). The energetically passive Yin movements are used to push, fill, or tonify the patient's Righteous Qi, located within the patient's tissues. It is used for treating external tissue conditions and for internal organ conditions.

- If the external tissue area is in an inactive or Yin state, apply a Yin technique. Treat a Cold area with soft, passive manipulations, while extending the mind superficially onto the patient's surface tissues to fill or tonify anti-pathogenic factors, and to revitalize the Deficient area.
- If the internal organ area is either in an active or Yang (Hot or hard) state, the doctor must apply a Yin, passive, or slow action technique, while extending his mind deep into the patient's tissues and organs.

THE YANG THEORY OF QI MANIPULATION

This technique is expressed as an active technique, in motion. The active energy of the Yang movements are generally used to pull or purge pathogenic factors. It is used for treating external tissue conditions and for internal organ conditions.

- If the external tissue area is in an active or Yang state, apply a Yang technique (treating an External Hot or hard area with fast dredging manipulations) while extending the mind superficially onto the patient's surface tissues. This is done to pull or purge pathogenic factors, or break up the stagnation.
- If the internal organ area is either in an inactive or Yin (Cold or flaccid) state, the doctor must apply a Yang, quick, or active technique, while extending his or her mind deep into the patient's tissues and organs.

This combination of movement (Yang) and non-movement (Yin) is embodied in both the Circle-Twisting and Compression Release Methods of the Five Elemental Regulation Techniques.

APPLICATION FOR YIN AND YANG TECHNIQUES

The following text gives examples of specific Yin or Yang hand techniques, and when to apply them:

1. The Qigong doctor uses Yin hand techniques for tonifying, filling and pushing Qi and

Blood through the patient's organs, tissues, and channels. The Yin hand actions are demonstrated through slow or inactive hand movements.

2. The Qigong doctor uses Yang hand techniques for sedating, purging, and pulling Qi and Blood. The Yang hand actions are demonstrated through fast or active hand movements.

YIN AND YANG TREATING METHODS

The following text gives examples of specific Yin or Yang hand treatment methods, and when to apply them:

1. When a patient's tissues are in an Excess Yang state (Hard or Hot), the Qigong doctor sedates the area with counterclockwise rotations, leading the Excess energy from inside the tissue area out of the body.
2. When a patient's tissues are in a Deficient Yin state (Flaccid or Cold), the Qigong doctor tonifies the area with a clockwise rotation, to bring energy into the Deficient tissue area.

TREATING THE TISSUE AREA OR ENERGETIC POINT

In treating the patient's surface tissue area or specific energetic points, some Qigong schools teach that with a male patient, one should begin with points on the left side, then on the right side; whereas for female patients, one begins working on the points on the right side of the body, then on the left.

DEEP AND SHALLOW PRESSURE

Energy compression (deep or shallow) is controlled by the doctor's release. A deep compression relates to the Ying Qi, while a shallow compression pertains to the Wei Qi. This Compression Release technique affects the body's Blood and vital energy harmony. It seeks to balance the body's energy by preventing the Qi from flowing in the wrong direction. This technique also leads the pathogenic Qi outside the patient's body and is commonly called "The Dispersing Evil Qi Technique."

If stagnant energy remains in the center of a channel point, then the doctor must employ a Compression Release method. The compression causes the channel point to contract, leading it toward a calm, stable state. When the doctor releases the compression on the channel point, it expands and becomes stimulated into an active state.

THE GRADUAL ENERGETIC PENETRATION OF TISSUES

When treating a patient with External Tissue Regulation, there should always be a gradual penetration of energy permeating the patient's tissues. The Qigong doctor first sinks his or her focused intention onto the patient's surface tissues. The intention is then slowly sunk deeper, first into the patient's muscles and inner fascia, then into the bones or internal viscera.

At no time should pressure damage the tissues or compound pain. Treatment or pressure time at each area or energetic point should not be excessive. To establish the correct amount of pressure, determine the normal energetic pulsation in accordance with the Five Elemental Qi Massage methods, then decide if the technique is to be light, medium, or heavy.

ADDITIONAL GUIDELINES

The following are specific guidelines of Qigong massage treatment methods, and when to apply them:

1. Before beginning Qigong massage, the patient must be comfortable and relaxed. Otherwise the patient's body will not be receptive to the tissue stimulation or Qi emission.
2. When first touching the patient, the touch should be slow, as if the doctor is dipping his or her hand to test the water. The movements should have an established rhythm.
3. The doctor should never hold his or her arm, or the patient's arm, rigid or fully extended; the elbows should always be bent to some degree.
4. A symptom or damaged area occurring on one area or point at the extremity of a channel may be effectively treated by stimulating the point at the opposite end of the channel (see Magic Square, Chapter 31).
5. Points which are painful with light pressure

are in a state of Yang and need to be purged and sedated.

6. Points which are painful to deep pressure are in a state of Yin and need stimulation.
7. When an organ is functioning normally, it should receive weak, short stimuli that will increase the function, action, and energetic potential of the organ.
8. Cool skin over a point or channel indicates a Deficiency in that channel and should be tonified.
9. Hot skin indicates Excess Qi accumulation. It also indicates a current or pending illness in an organ, or area associated with that channel, and should be purged immediately.

Section IX
Medical Qigong Exercises and Prescriptions

Chapter 38
Introduction to Medical Qigong Prescriptions and Regulation Exercises

History of Medical Qigong Prescriptions

Many of the earliest known Medical Qigong prescriptions were derived from the movements of animals. Dating back to the second century B.C., the Qigong Classic (Dao Yin Tu) illustrates, in manuscripts written on silk, over 45 Qigong postures with descriptions of the movements as well as the names of the diseases which they treat. Over half of these illustrated postures are animal movements.

In the ancient Chinese text called the *Spring and Autumn Annals*, it is written, "Flowing water never stagnates, and the hinges of an active door never rusts. This is due to movement. The same principle applies to the body's Jing and Qi. If the body does not move, Jing does not flow. When Jing does not flow, Qi stagnates." The soft flowing movements in the Medical Qigong prescription exercises enhance and increase the flow of the body's Qi and Blood.

The Function of Medical Qigong Prescriptions

When a disease develops, certain active points of the disease correspond to different organs, muscles and limbs of the body, and a pathological reflex is formed. Trigger and reflex points which are painful to touch are perfect examples of this phenomenon. The cerebral cortex can be inhibited in specific ways by regulating the Mind and entering a state of tranquility through Medical Qigong prescriptions, thus overriding the pathological reflex pattern, allowing the body time to heal.

Although acupuncture and herbs can, in addition to relieving pain, move Qi, Blood, and Phlegm (the roots of the disease), they fail to address the patient's life-style which is often a major contributing factor. Problems such as stagnation, Excess or Deficient conditions are often exacerbated by a patient's sedentary life style. A responsible doctor of Medical Qigong therapy addresses this particular element by prescribing physical therapy, exercise, and meditations as part of the overall treatment strategy.

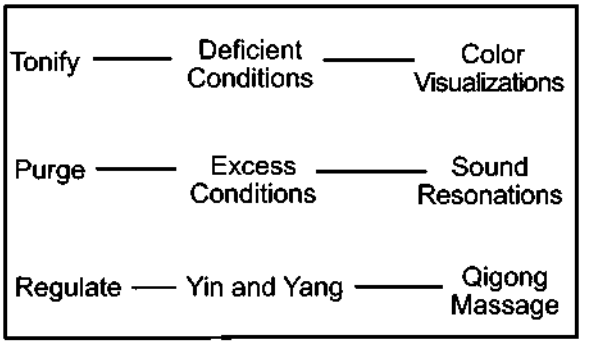

Figure 38.1. Medical Qigong Treatments

The standing rule for treatment in Medical Qigong prescriptions is to:

- Tonify the Deficient organs and organ systems with color visualization, by using the Mind's intention to focus on moving Qi into a Deficient organ, strengthening, thus illuminating its tissues;
- Purge the Excess organs and organ systems with sound resonation, by using the Mind's intention to focus on moving the Qi out from an Excess organ, resonating, and draining its tissues;
- Regulate the body's Yin and Yang organs and organ systems with Qigong massage, by using the Mind's intention to balance the energetic fields by moving the Qi up and down, right and left, and inside and outside of the tissues (Figure 38.1).

The therapeutic effects of Medical Qigong meditations and prescriptions are designed to move Qi and Blood stagnation, to tonify the internal or-

gans and organ systems, and to enhance the autonomic nervous system. These prescriptions stimulate the patient's body, thereby gradually eliminating fatigue, as the normal body functions are restored. Another important aspect of the Medical Qigong meditations and prescriptions is the enhancement of the body's immune system functions.

MEDICAL QIGONG AND THE IMMUNE SYSTEM

The many health benefits of Medical Qigong include increased white blood cell production, stabilized blood pressure, and an improved immune function. The immune system, unlike the vascular circulation system, defies a clear anatomical description. It can only be understood through its functions and interrelationships with the mind and various other parts and systems of the body, such as the lymph nodes, Spleen, tonsils, appendix, Peyer's patches (in the ilium), thymus gland and the bone marrow.

The lymph nodes contain specialized compartments - some contain B cells (B stands for Blood), some T cells (T stands for Thymus), and some contain macrophages. The tonsils likewise contain B and T cells. The appendix and Peyer's patches are components of the lymphatic drainage system, and serve as locations where the B cells mature and where antibodies are produced by the B cells. The body's T cells mature in the thymus gland.

Both B and T cells begin their life in the Liver, when the fetus is only nine weeks old. They then migrate to the bone marrow where they form precursor cells. Afterwards, the T cells migrate to the thymus and the B cells remain in the bone marrow.

The immune system utilizes two major strategies for protecting the body from an infectious disease: The Humoral Immunity and the Cell Mediated Immunity.

- In humoral immunity the B cells play the primary role, and the T cells as well as other related cells play supporting roles.
- In cell mediated immunity the T cells play the main role, while B cells and other related cells play auxiliary roles.

Both T cells and B cells are called "Lymphocytes." They are two types of white blood cells that originate in the body's bone marrow and travel in the blood and lymph circulatory system (Figure 38.2). Both T cells and B cells are concentrated in the lymph nodes, which are found in clusters near groups of veins, and are heavily concentrated under the arm pits, in the adenoids, the Spleen and in the groin area.

When B cells encounter an antigen or foreign substance, they differentiate into plasma cells. These plasma cells secrete antibodies that fight and neutralize bacteria, or coat the antigen to mark it for destruction by other components of the immune system (such as the T cells).

T cells specialize in destroying cells infected by viruses, in attacking tumors, and in rejecting transplanted organs and tissues. The T cell, after leaving the bone marrow, travels to the thymus gland where it undergoes further development before returning to the lymph and blood circulatory systems. The T cells respond to an antigen by differentiating into several kinds of T cells, three of which are of primary importance: Killer T cells (also called cytotoxic T cells), Helper T cells and Suppressor T cells. Killer T cells bind to viral antigens displayed on the surface of infected cells and destroy them. Helper T cells bind to the antigens on the surface of a B cell that has already bound itself to the antigen. Each Helper T cell then releases Lymphokines (one well know class of lymphokines is interferon), that enhance the maturation of the B cells, or signal them to differentiate and multiply into plasma cells that secrete antibodies. The Suppressor T cells function to dampen the immune response and to signal the "all clear."

A third group of important immune cells are the phagocytes. These cells are the body's natural scavengers. They engulf antigens and destroy them. Those that specialize in cleaning up the debris are called macrophages. The macrophages can also signal B or T cells to the presence of foreign material.

Another important group of cells are called Null cells, among which the N.K. or "natural killer" cells are found. These cells are able to identify tumors and virally infected cells, and kill them without having any prior encounter with such an antigen.

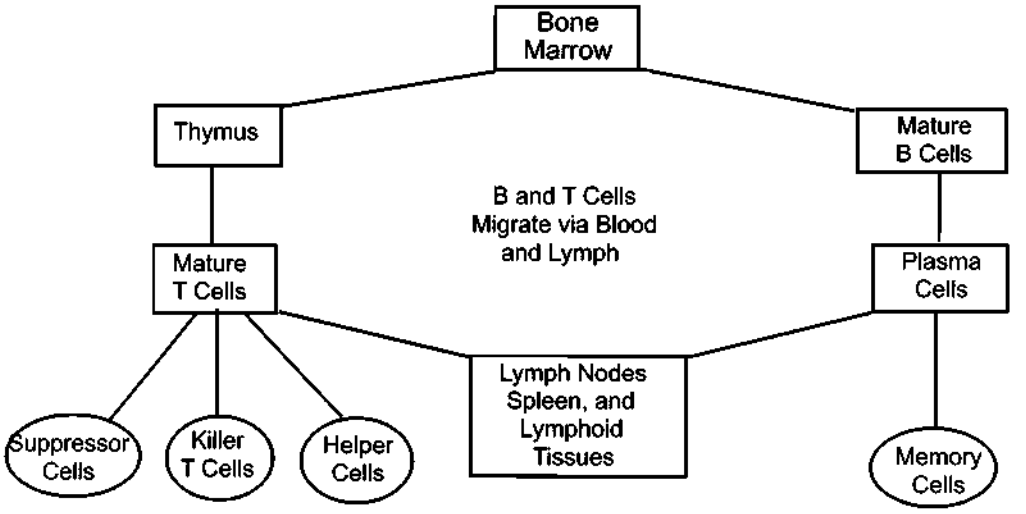

Figure 38.2. The Body's Immune System

A final important group consists of Mast cells. They contain powerful chemicals: heparin - an anticoagulant, serotonin - a neurotransmitter, and histamine - a biochemical released in overabundant quantities in allergic reactions.

These white blood cells live in the blood and lymph fluid, and are commonly known as the leukocytes. There are two main varieties of white corpuscles: The Polymorphonuclear Leucocyte (Polymorphs) and Lymphocyte.

- Polymorphs are found in the bone marrow stem cells; they destroy invading bacteria and remove dead or damaged tissue.
- Lymphocytes are found in the lymph glands, Spleen and thymus gland and circulate in the blood along with the polymorphs. They are the smallest of the leucocytes, and designated the lymphocyte because it is identical with the lymphoid cell derived from the lymphatic glands.

Both the white blood cells called polymorphs and lymphocytes move into the body's surrounding tissues as a part of the immune function. The purpose of these cells is to work together to defend the body from invasion of pathogenic factors. Their function is to identify, ingest, destroy and eliminate disease-causing organisms, as well as to remove any and all dead, damaged, or irregular cells.

Immune cells are produced in the lymphoid tissue and red bone marrow, and are stored in the lymphatic organs and blood. In order to perform their function of protecting and cleaning, these cells must circulate throughout the entire body. The capillaries and lymphatic vessels carry the lymph fluid through the lymph nodes and the lymphatic organs of the thymus gland, spleen, and tonsils, where the lymph fluid is filtered, cleansed of impurities, and infused with new lymph cells.

In order for an external pathogen to affect the body, it must first pass through the protective layers of cells. Generally, the macrophages (specialized white blood cells) present within the tissues ingest the pathogens and dead tissues. This action of the macrophages is reinforced by the action and movement of the Wei Qi. When a pathogenic intruder invades the body, the macrophages are the first to attack the intruder. If the macrophages are not strong enough, more blood and fluid, which contain more immune cells, are brought to the area. The increased fluid engorges the tissue, and brings more cellular activity. The increased

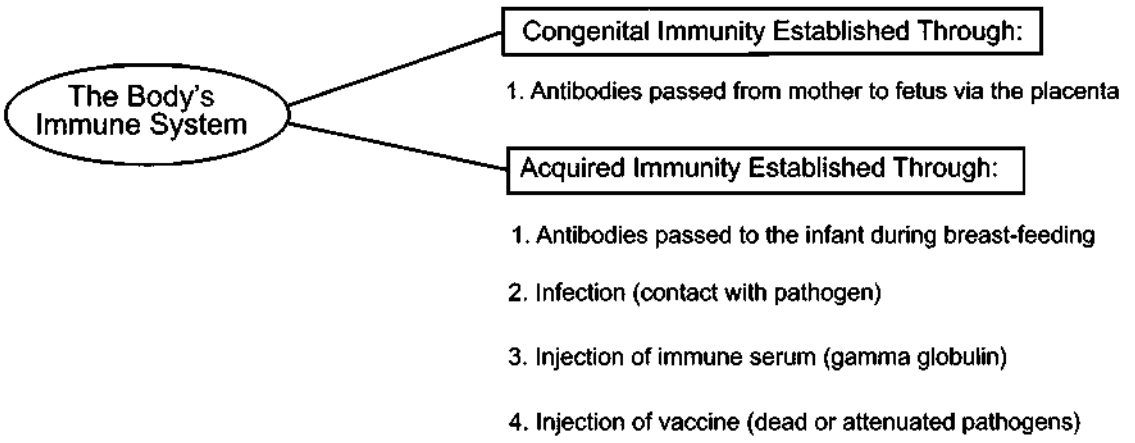

Figure 38.3. Congenital and Acquired Immunity

blood and cellular metabolism increases the local temperature. The immune cells try to break down and ingest the pathogen, creating a process which continues until the disease is eliminated.

Once the battle is won, some of the Killer T cells and Helper T cells will remain circulating in the blood and lymph circulatory system as Memory cells that will be able to deal more efficiently with any future antigen of the same kind. Likewise, some of the mature B cells will also become Memory cells that hover around lymph nodes which they use as a base of operation.

Because Qigong movements generate heat and soften the body's connective tissues, this encourages the flushing of the intercellular fluid throughout the body's tissues and organs. When combined with Breathing, Mental, and Postural Qigong exercises, the entire body is affected. These energetic Qigong actions increase oxygenation of the blood and improve circulation, thereby enhancing lymphocyte production and strengthening the body's immune system.

CONGENITAL AND ACQUIRED IMMUNITY

The body has two ways of establishing or maintaining its immune functions: Congenital Immunity and Acquired Immunity (Figure 38.3).

- Congenital Immunity (Prenatal) is established during gestation, through antibodies that are passed from the mother to the fetus via the placenta.
- Acquired Immunity (Postnatal) is established in the following ways: immediately after birth during breast-feeding (through the colostrum-mother's first milk), through contracting an infection (contact with external pathogens), the injection of an immune serum (gamma globulin), and the injection of vaccines (dead or attenuated pathogens).

Due to the importance of establishing a strong immune system within the body's Prenatal Jing, Traditional Chinese Medicine strongly endorses fetal education, instruction on diet and nutrition, maintaining emotional well-being during pregnancy, and Qigong exercises specifically designed to enhance the child's Prenatal Essence, Energy, and Spirit.

OVERVIEW

One specific goal of Medical Qigong treatments, exercises and meditations is to activate and strengthen the immune function. Qigong therapy can be used to not only strengthen the metabolism of the organs and cells, but also increase cellular energy, thus making the immune system stronger.

In China, even though the lymphatic function itself was unknown and unnamed, its effects were

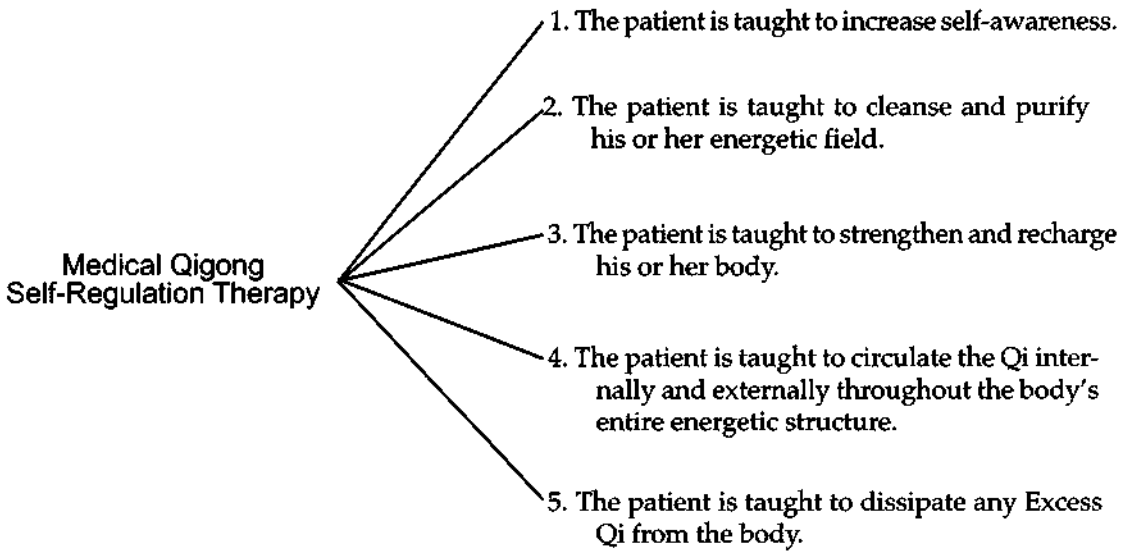

Figure 38.4. The Five Stages of Healing Transitions That Occur Through Self-Regulation Therapy

generally ascribed to the proper action of the Qi and Body Fluids. Therefore, elaborate methods for generating and circulating lymph were developed, and faithfully practiced through Qigong. Breath, movement and postural modification as well as meditations have specific effects on the circulation of the lymph and therefore enhance the overall function of the lymphatic system.

THE FIVE STAGES OF HEALING

When practicing Medical Qigong exercises and meditations, there are five basic stages of healing transitions which occur through self-regulation therapy (Figure 38.4).

1. The patient is taught to increase his or her awareness of the body (physically, mentally, and emotionally) and its current condition.
2. The patient is taught to cleanse and purify the body's energetic fields to rid it of Qi stagnations and toxic pathogenic factors.
3. The patient is taught to strengthen and recharge his or her body to replenish the Qi.
4. The patient is taught to circulate the Qi internally and externally throughout the body's entire energetic structure, thus moving any stagnant Qi and strengthening the body.
5. The patient is taught to dissipate any Excess Qi from the body by way of self-massage (lightly brushing the skin to release stagnant Qi).

THE THREE CATEGORIES OF MEDICAL QIGONG PRESCRIPTIONS

The Medical Qigong prescriptions are divided into the same three categories (or goals) used in Medical Qigong therapy: tonification, purgation and regulation. These three goals are achieved through both Dynamic and Quiescent Qigong exercises, meditations, prayers, and mantras. These prescriptions enable the patient to reinforce the treatments performed by the Qigong doctor, and prevent the patient's energy from reverting back to old destructive patterns.

The Qigong doctor selects the proper Qigong prescription to fit the patient's illness (to Tonify, Purge, or to Regulate) and formulates a rational program that suits the patient's case. The patient should never be allowed to practice at random, otherwise pathological changes or Qi deviations may occur.

The following are but a few examples of Qigong prescriptions, which are interchangeable,

as there are certain variations of purging exercises that can be modified and used for tonification and visa versa.

QIGONG PURGING EXERCISES

Qigong Purging exercises are practiced by the patient to detoxify pathogenic Qi. Some examples are already presented in this textbook are:

- Channel Purging exercise (Chapter 15)
- Cleansing the Body meditation (Chapter 12)
- Dry Crying meditation (Chapter 53)
- Energy Melting meditation (Chapter 18)
- Internal Organ Sound Therapy exercises (Chapter 4 and Chapter 40)
- Old Man and Tide Pool meditation (Chapter 40)
- Pulling Out The Pain meditation (Chapter 28)
- Releasing Emotional Blockages and Energetic Armoring meditation (Chapter 18)
- Sun and Moon meditation (Chapter 18)
- Tumor and Cancer Tone Resonating exercises (see Chapter 40)

QIGONG TONIFICATION EXERCISES

Qigong Tonification exercises are practiced by the patient to strengthen and stabilize the internal organs and organ systems. Some examples are already presented in this textbook are:

- Channel Point meditations (Chapter 36)
- Color Visualization meditations (Chapter 4)
- Cultivating Yuan Qi meditation (Chapter 50)
- Daoist Five Yin and Yang Organ exercises (Chapter 42)
- External Qi Cultivation meditations (Chapter 41)
- Gaining Wisdom meditation (Chapter 49)
- Gathering Energy from the Five Planets meditations (Chapter 11)
- Gathering Moon Cream meditation (Chapter 11)
- Gathering Sun's Essence meditation (Chapter 11)
- Gathering Qi from Mountains, Valleys, and Deserts (Chapter 12)
- Gathering Qi from The Four Directions (Chapter 12)
- Gathering Qi from Trees, Bushes, and Flowers (Chapter 12)
- Improving the Intellectual Facilities meditation (Chapter 49)
- Internal Qi Cultivation meditations (Chapter 41)
- Nei Guan - Inner Viewing Meditation (Chapter 25)
- One Through Ten meditation (Chapter 26)
- Opening and Closing the Three Dantians exercise (Chapter 41)
- Organ Massage exercises (Chapter 39)
- Qigong Walking exercises (Chapter 15)
- Seeing Auras meditation (Chapter 25)
- Soul Retrieval meditations (Chapter 19)
- Tian Wu Zang meditation (Chapter 11)

QIGONG REGULATION EXERCISES

Qigong Regulation exercises are practiced by the patient to balance their Yin and Yang, as well as their internal organ energy. Regulation exercises usually follow Tonification or Purgation exercises, because the goal is to reestablish balance. Some examples already presented in this textbook are:

- Exchange of Fire and Water meditation (Chapter 18)
- Gathering Qi in the Upper and Lower Dantians (Chapter 41)
- Microcosmic Orbit meditations Chapter 41)
- Opening and Closing the Three Burners (Chapter 41)
- Opening and Closing the Three Dantians exercise (Chapter 15)
- Pulling Down the Heavens (Chapter 41)
- Qigong Self-Healing massage (Chapter 41)
- Taiji Ruler exercises (Chapter 18)
- Wu Zang meditation (Chapter 28)

CHOOSING PRESCRIPTIONS ACCORDING TO THE PATIENT'S QI CIRCULATION

When prescribing Medical Qigong prescriptions, the priority is to get the patient to move and circulate the Qi and Blood superficially and deeply within the body. According to Chinese physician, Professor Yan De-xin, the motion and quality of Blood flow in young and middle-aged patients is different from that in the elderly, which should be kept in mind when prescribing exercises.

- When prescribing Medical Qigong therapy for young patients, use mostly Dynamic and some Quiescent Qigong regulations.
- When prescribing Medical Qigong exercises for both adolescent and middle aged patients, it is important to increase Yin Qi cultivation while maintaining and storing the patient's Yang Qi.
- When prescribing Medical Qigong for senior citizens, focus is placed on Quiescent Qigong, with a minor emphasis on Dynamic breathing exercises, depending on their age and constitution.
- When prescribing Medical Qigong therapy for patients with very weak health or constitution, the doctor should prescribe mostly Quiescent Qigong regulations to start with.
- When prescribing Medical Qigong therapy for senior citizens with a strong constitution and health, the doctor can prescribe Qigong regulations that increase Yin Qi cultivation while maintaining and storing the patient's Yang Qi.

MEDICAL QIGONG PRESCRIPTIONS FOR GENERAL SYNDROMES

The following are some examples of the proper application of Dynamic and Quiescent Qigong prescriptions as presented by Dr. He Si Hai of the Zhe Jiang Qigong Hospital in China:

1. For Excess and Heat Syndromes it is recommended to prescribe static (quiescent) Medical Qigong exercises. After the gradual decline of the patient's fever or disease, the Qigong exercises are gradually increased in numbers and duration, and the purging training method is added (provided they have not excessively consumed their constitution).
2. For Deficiency and Cold Syndromes it is recommended to prescribe Dynamic Medical Qigong exercises. Gradually increase the exercises to include methods of lifting the limbs. If however, the pathological state is more serious, then static exercises are prescribed first.
3. For Cerebral Hemorrhage, have the patient practice static exercises such as the Hibernation Breathing exercise (quiescent lying posture, see Chapter 15) while combining it with the Yongquan (Kd-1) purging exercise (once the patient has regained consciousness). Dynamic Medical Qigong exercises that use methods of passing, circulating, or distributing Qi through the head are forbidden.
4. For Cerebral Embolism combine the training methods to include exercises that accelerate Blood flow and strengthen the function of the limbs as well as quiescent tonifying methods.
5. For Malignant Tumors (in a state of non-diffusional transference, in situ), combine an effective Dynamic exercise with a Quiescent exercise. Some examples of non-aggressive tumors/cancers are considered energetically warm and in a non-aggressive state of transition are:
   - Prostate cancer
   - Cervical dysplasia
   - Endometrial adenocarcinoma (uterine)
   - Basal cell skin cancer
   - Squamous cell skin cancer
6. For Malignant Tumors (in a state of diffusion, i.e., metastatic) prescribe Quiescent Medical Qigong exercises which are similar to the Hibernation Breathing exercise, in combination with strengthening exercises for patients with chronic diseases. Dynamic Medical Qigong exercises which accelerate the Blood flow are forbidden. Some examples of tumors that are considered energetically Hot and in an aggressive state of transition are:
   - Pancreatic cancer
   - Leukemia
   - Cervical cancer
   - Clear cell carcinoma (uterine)
   - Melanoma (skin cancer)

NUMBER OF BREATHS REQUIRED IN MEDICAL QIGONG PRESCRIPTIONS

Each Medical Qigong treatment will generally last up to three days. The Medical Qigong prescriptions that the doctors gives their patients will extend the treatment's effects indefinitely, providing the patients do all their homework.

The number of breaths required to Regulate the patient's Yin and Yang energy in a Medical Qigong prescription is often calculated in respi-

ratory cycles, and on the basis of the number of the Yin and Yang aspects of diseases. This is often determined by the Yin and Yang energy numbers. Yang energy is represented by all the odd numbers (1, 3, 5, 7, 9, etc.). Yin energy is represented by all the even numbers (2, 4, 6, 8, etc.). These numbers are related to the Five Elements (Figure 38.5). For example: 6 is the number of the Kidneys, 7 the Heart, 8 the Liver, 9 the Lungs, and 10 the Spleen (Figure 38.6). The cycles of Yin and Yang numbers can be implemented through the utilization of the Magic Square (see Chapter 31).

The Yang number is used to calculate the respiratory cycles for Tonification and Purgation of the Yang channels; likewise, the Yin number is used for the Yin channels. This calculation should only be used as a general reference guide in treatment. Clinically, respiratory cycles should be determined based on the location and nature of the disease (if it is Yin or Yang, Exterior or Interior, Deficient or Excessive). The primary goal for using respiratory calculations is to ensure that sufficient Qi is administered when applying Medical Qigong treatments and therapeutic prescriptions. A disease due to a Deficiency of Yin, for example, should be treated with a tonification method for 18 or 64 respiratory cycles. To treat a Deficiency of Yang, a tonification method is used by the patient for 24 to 36 breaths.

	General Treatment	Moderate Treatment	Strong Treatment
Yin	6	18 or 36	64
Yang	9	27 or 49	81

Figure 38.5. Number of Yin and Yang Respirations

5 Yin Organs	Kidneys	Heart	Liver	Lungs	Spleen
Number of Respirations	6	7	8	9	10
Element	Water	Fire	Wood	Metal	Earth

Figure 38.6. Yin and Yang Five Element Respiration

Chapter 39
Specific Organ Self-Massage Prescriptions

Introduction

The next few chapters of this book include some of China's most popular clinical therapies. It is the author's sincere desire to educate the reader as to the diversity, yet effectiveness of these prescriptions. It is important to remember that it is not necessarily the exercise or prescription's history that matters, what does matter is the initial goal of the prescription (whether to purge, tonify, or regulate) and the correct posture, breath, and mental focus.

This section begins with energy massage techniques, which are prescriptions that require the patient to regenerate his or her own body energy for self-healing, cultivation, and circulation. These exercises are designed to purge, tonify and regulate the Five Yin Organ System. They are not arranged in any particular order, and can be singled out by the doctor and given to patients for specific ailments. Each massage prescription is named after the organ it stimulates. For clinical therapy, perform these exercises three to five times a day.

Heart Massage

The doctor can chose to give the patient either the One Through Four meditation (1-fun, 2-shoe, 3-tree, 4-core; from Chapter 26), or the Stacking the Bones meditation (described below) to prepare for the following meditations.

1. Begin in a Wuji posture to perform the Stacking of the Bones meditation. Imagine the energy in your body sinking and melting into the ground; the bones vertically stack, one by one, on top of each other. Each of the body's articulations stacks on top of the next section of bone, from the bottom of the feet, ankles, knees, etc., to the top of the head.

   The spine is kept straight but relaxed, the anal sphincter is closed, the tongue is touching the top of the upper palate, the Mingmen is slightly pressing towards the back, and the body is completely relaxed.

Figure 39.1. The patient uses the mind's intent to regulate the Qi of the Heart.

2. Perform the Heart Regulation. When prescribing these exercises for male patients, have them place the left hand over the Heart with the right hand on top of the left hand (for women, the hand positions are opposite, and the beginning placement of the hands is below the left breast). Massage in twelve circular rotations clockwise to the left, then twelve rotations counterclockwise. The hand can either lightly touch the skin (using Qi massage), or be slightly off the skin, up to several inches away from the patient's body (using Qi Distance therapy), depending on the degree of energetic sensitivity and projection skill (Figure 39.1). Focus the mind's intention on the Heart organ, allowing the energy within the Heart area to flow and circulate with the movement of the hands.

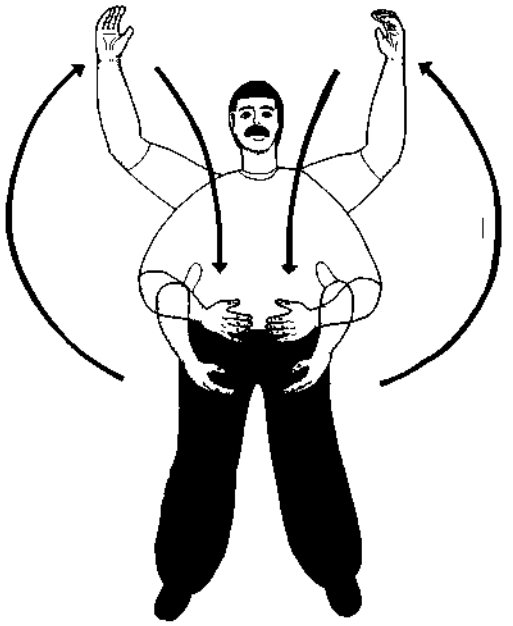

Figure 39.2. Pulling Down the Heavens allows the patient to sink the Qi, returning the excess energy back into the Lower Dantian.

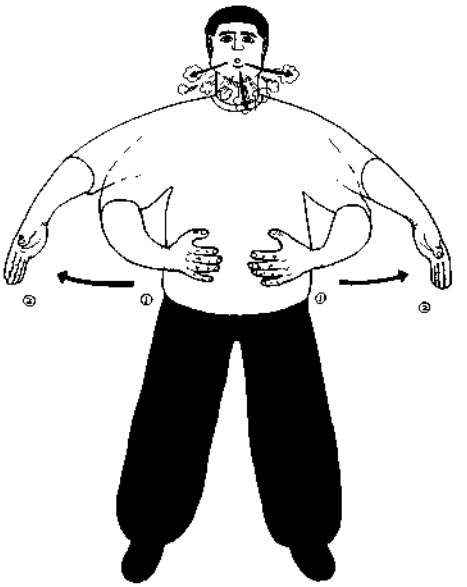

Figure 39.3. Exhaling and Opening the Lower Dantian allows the body to expel the Evil Qi from the internal organs. Expand the abdomen.

The purpose of the rotating action of the Heart's Qi is for promoting Blood circulation and dispersing Blood Stasis, while dredging the channels and collaterals.

3. Perform the Point Respiration. This technique focuses breathing and imagination into the channel points for the specific treatment area. For this particular exercise, the patient should leave the hands over the Heart, while concentrating the focused intention and breath deep into the tissue of the organ. The patient should then exhale while lightly squeezing and pressing the area of the Heart, and imagining divine healing light radiating outward from the tissues. While inhaling, the patient should lift the hands away from the body and imagine divine healing light flowing into the Heart organ area. This action is similar to that of a bellows. This exercise should be performed twelve times, then lead the Qi down into the Lower Dantian.
4. Perform the Pulling Down the Heavens method. Inhale, pause, then exhale while slowly bringing the arms down the center line of the torso, while quietly drawing the energy back down into the Lower Dantian. When lowering the arms, imagine the energy of the Heart like water, melting and flowing down the torso.

   Pause for a breath at the Lower Dantian, rooting the energy. Then slowly raise the hands above the head, while inhaling. Exhale slowly and imagine the energy in the arms and head melting down the body, beginning at the top of the head and tips of the fingers, flowing down and into the Lower Dantian.

   This action is important, because if the Qi is not brought back into the Lower Dantian after each exercise, the energy will be easily dispersed (Figure 39.2).
5. Perform the Opening and Closing of the Lower Dantian. Finally exhale and imagine the Evil Qi being expelled through the mouth. As you exhale, separate both of the hands away from the abdomen (as you contract the abdomen). This is called the Opening (Figure 39.3).

   After completing the Opening of the Lower

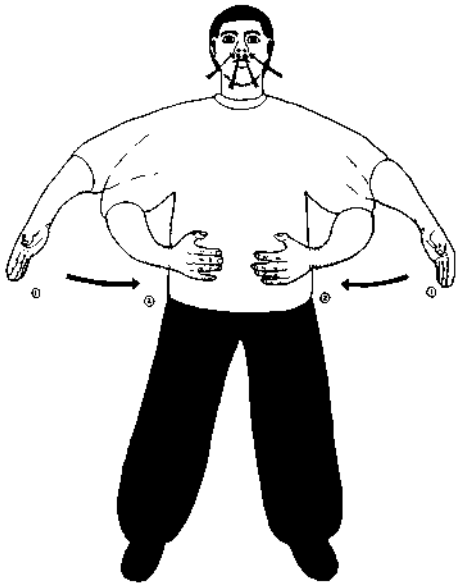

Figure 39.4. Inhaling and Closing the Lower Dantian allows the body to seal itself from outside pathogenic factors. Contract the abdomen.

Figure 39.5. The patient will focus their mind's intent on the Liver area while massaging, allowing their energy to circulate into the organ's tissues.

Dantian, inhale through the nose while bringing both hands back to face the Lower Dantian (as you expand the abdomen). This action is called the Closing. When Closing, imagine sealing the body in a protective energetic field, so that the pathogenic factors cannot get inside (Figure 39.4). Perform the Opening and Closing method three times.

Note: The techniques 1 through 5 are one complete set. Perform a total of three sets. Three sets are necessary because the body will naturally progress through three stages. The first time the body is introduced to a new pattern it will shock the system. The second time the body begins to understand the pattern. The third and final time the body recognizes and accepts the changes the patient is attempting to reprogram.

LIVER MASSAGE

1. Begin from a Wuji posture and perform either the One Through Four or Stacking the Bones method as described in Heart Massage (1).
2. Perform the Liver Regulation. Place the left hand on the Liver with the right hand on top (opposite for women). Massage in twelve circular rotations to the left in a clockwise direction, then twelve rotations in the opposite direction. When massaging, focus the mind on the Liver. Inhale and imagine divine healing light coming down from the Heavens and filling the Liver. Exhale and purge the Liver of Turbid Qi through the mouth.

   The purpose of this exercise is to smooth and regulate the activities of the vital energy flowing inside the Liver, encouraging the hyperactive and Rebellious Liver Qi to flow downward (Figure 39.5).
3. Perform Point Respiration with both hands still over the Liver, for twelve breaths, as described in the Heart Massage (3).
4. Perform Pulling Down the Heavens by leading Qi down into the Lower Dantian, as described in the Heart Massage (4).
5. End with Opening and Closing method as described in the Heart Massage (5).

Figure 39.6. The patient focuses the mind's intent on the Lung area while massaging, allowing the energy to circulate into the organ's tissues.

Note: The techniques 1 through 5 form one complete set. Perform two more sets for a total of three to complete the prescription.

LUNG MASSAGE

1. Begin from a Wuji Posture and perform either the One Through Four or Stacking the Bones method as described in the Heart Massage (1).
2. Perform the Lung Regulation. Place both palms on the Lungs (specifically on an injured or diseased region, if known). Massage in twelve circular rotations from the bottom, up the center to the top and then to the outside of the chest. Then massage twelve rotations in the opposite direction, from the top, down the center and to the outside. When massaging, concentrate on the Lung region. Inhale and imagine divine healing light coming down from the Heavens and filling the Lungs. Exhale and purge the Lungs of Turbid Qi.

   The purpose of this exercise is to bring Blood and Qi into the Lung area, clean and purify the inhaled breath and support the Lungs' Qi flowing downward (Figure 39.6). TB patients with pulmonary holes should concentrate on abundantly filling and expanding the vital energy in the Lungs while visualizing the Qi activating the body's cells to close the holes. If the patient is unable to visualize this, or the reaction is too uncomfortable, have the patient mentally pull the Qi downward.
3. Perform the Point Respiration with both hands still over the Lungs, for twelve breaths, as described in the Heart Massage (3).
4. Perform Pulling Down the Heavens method, leading the Qi back down into the Lower Dantian as described in the Heart Massage (4).
5. End with Opening and Closing method as described in the Heart Massage (5).

Note: The techniques 1 through 5 are one complete set. Perform two more sets for a total of three to complete the prescription.

SPLEEN & STOMACH MASSAGE

SPLEEN MASSAGE

1. Begin from a Wuji Posture and perform either the One Through Four or Stacking the Bones method as described in the Heart Massage (1).
2. Perform the Spleen Regulation. Place the left hand on the Spleen with the right hand on top (opposite for women). Massage in twelve circular rotations to the left in a clockwise direction, then twelve rotations in the opposite direction. When massaging, concentrate the mind on the energy within the Spleen area, imagining the Spleen Qi movement flowing with the movements of the hands (Figure 39.7). Inhale and imagine divine healing light coming down from the Heavens and filling the Spleen. Exhale and imagine the Spleen absorbing the divine Qi.

   The purpose of this exercise is to strengthen and increase the Spleen's function of transporting and converting Qi. This is an excellent massage for patients with splenomegaly (enlargement of the spleen) and dyspepsia (painful digestion).
3. Perform the Point Respiration with both hands still over the Spleen, for twelve breaths,

Figure 39.7. The patient focuses the mind's intent on the Spleen area while massaging, allowing the energy to circulate into the organ's tissues.

Figure 39.8. The patient will focus their mind's intent on the Stomach area while massaging, allowing their energy to circulate into the organ's tissues.

as described in the Heart Massage (3). Then move both hands to the Stomach area.

STOMACH MASSAGE

4. Perform the Stomach Regulation. Place the left hand on the Zhongwan CV-12 point at the middle of the Stomach with the right hand on top (opposite for women). Massage in twelve circular rotations to the left in a clockwise direction, then twelve rotations in the opposite direction. When massaging, concentrate on warming the Stomach area (Figure 39.8). Inhale and imagine divine healing light coming down from the Heavens and filling the Stomach. Exhale and purge the Stomach of Turbid Qi.

   This is an excellent massage for patients with thoracic depression, abdominal distention, gastritis, and gastric ulcers.
5. Perform the Point Respiration with both hands still over the Stomach, for twelve breaths, as described in the Heart Massage (3).
6. Perform the Pulling Down the Heavens method to draw the Qi down into the Lower Dantian, as described in the Heart Massage (4).
7. End with the Opening and Closing method as described in the Heart Massage (5).

Note: The techniques 1 through 7 are one complete set. Perform two more sets for a total of three to complete the prescription.

KIDNEY MASSAGE

This exercise is excellent for tonifying the Kidneys, as well as healing impotence, premature ejaculation, lumbago, lower back problems, and pelvic inflammatory disease (for PID use reverse breathing with static Qigong training).

This is an extremely important exercise for patients and for Qigong doctors to practice; it enables them to increase their Qi projection when treating patients.

1. Begin from a Wuji Posture and perform either the One Through Four or Stacking the Bones method as described in the Heart Massage (1).
2. Perform the Kidney Regulation. Close the eyes and place both hands on the back (waist

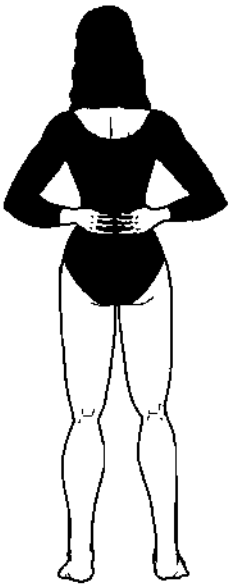

Figure 39.9. The patient will focus the mind's intent on the Kidney area while massaging, allowing the energy to circulate into and warm the organ's tissues.

Figure 39.10. The patient will focus the mind's intent on the bottom of the foot while massaging, allowing the energy to flow through the Kidney Channel into the Lower Dantian.

level), middle fingers touching the Shen Shu Bl-23 points. Focus on the Kidneys. Begin massaging twenty-four times inward, then twenty-four times outward, until the area becomes warm (Figure 39.9).

3. Perform the Point Respiration with both hands still over the Shen Shu Bl-23 points for thirty-six breaths. Exhale as you press the palms into the Kidneys, inhale as you raise the palms from the back. While inhaling, imagine divine healing light coming down from the Heavens and filling the Kidneys completely. While exhaling, imagine the Kidneys absorbing the divine Qi.
4. Perform the Pulling Down the Heavens method, drawing Qi into the Lower Dantian as described in the Heart Massage (4).
5. Perform the Opening and Closing method as described in the Heart Massage (5).

Note: The techniques 1 through 5 are one complete set. Perform two more sets for a total of three to complete the prescription, then proceed to the Closure.

6. Perform the Closure. After completing three sets of the Kidney exercise, place the right hand on the navel and the left hand on the Mingmen. Focus on gathering Heat and Qi in the Lower Dantian. Next, place the right foot on the left knee (opposite for women). With the right hand still on the Lower Dantian, place the left hand at the bottom of the right foot and gently massage the Yongquan Kd-1 point. Massage this area 100 times in a clockwise direction, then 100 times counterclockwise. When massaging the Kd-1 point, work slowly, focusing the mind's intention through the center of the palm into the center of the foot, imagining the Qi flowing up the leg into the Lower Dantian (Figure 39.10).

Note: Some Medical Qigong Clinics in China perform this same exercise while slapping the bottom of the feet (instead of using circular massage). They begin this treatment with 100 strikes on each foot for the first day, increasing an additional 100 strikes each consecutive day (not exceeding 300 strikes) until

the desired result is achieved.

7. Perform the Point Respiration for twelve breaths, with the right hand still on the Lower Dantian and the left hand still on the bottom of the right foot, as described in the Heart Massage (3).
8. Switch feet, placing the left hand on the Lower Dantian while the right hand gently massages the Kd-1 at the bottom of the left foot, 100 times clockwise then 100 times counterclockwise.
9. Perform the Point Respiration for twelve breaths, with the left hand still on the Lower Dantian and the right hand still on the bottom of the left foot.
10. End with the Opening and Closing method as described in the Heart Massage (5).

Note: Do not use this ending method (5 and 10) for patients who suffer from insomnia, as it will have an awakening effect as it invigorates the vital energy. When performed at bedtime it can be used for treating insomnia by following the simple prescription below.

TREATMENT FOR INSOMNIA

This is a very famous prescription for insomnia. I have used it in my clinical practise for many years and have found it to be extremely effective. If the insomnia is due to a Deficiency of Kidneys' Yin, or the patient is restless during the night due to the Liver's Heat rising and causing the patient's mind to wander, this prescription will help. After clinically treating patients for insomnia, the Qigong doctor can prescribe the following exercise to be performed by the patient.

This exercise is to be practiced just before the patient is going to sleep. Begin by sitting at the edge of the bed, repeating the previous Kidney exercises 2, 3, and 6.

1. Perform the Kidney Regulation. Close the eyes and place both hands on the back (waist level), middle fingers touching the Shen Shu Bl-23 points. Focus on the Kidneys. Begin massaging twenty-four times inward, then twenty-four times outward, until the area becomes warm (Figure 39.9).
2. Perform the Point Respiration with both hands still over the Shen Shu Bl-23 points for thirty-six breaths. Exhale as you press the palms into the Kidneys, inhale as you raise the palms from the back. While inhaling, imagine divine healing light coming down from the Heavens and filling the Kidneys completely. While exhaling, imagine the Kidneys absorbing the divine Qi.
3. Perform the Closure. After completing three sets of the Kidney exercise, place the right hand on the navel and the left hand on the Mingmen. Focus on gathering Heat and Qi in the Lower Dantian. Next, place the right foot on the left knee (opposite for women). With the right hand still on the Lower Dantian, place the left hand at the bottom of the right foot and gently massage the Yongquan Kd-1 point. Massage this area 100 times in a clockwise direction, then 100 times counterclockwise. When massaging the Kd-1 point, work slowly, focusing the mind's intention from the Lower Dantian through the leg into the center of the foot, imagining the Qi flowing down the leg into the bottom of the foot (Figure 39.10). As the mind begins to relax, close the eyes and fall sleep. If you become fatigued, do not complete the exercise.

An explanation for the reason for this exercises success is as follows:

1. The Kidney exercise 1 and 2 will root the body's Blood, Heat, and Heart Qi back into the Kidneys and Lower Dantian, where they will become stabilized.
2. The Kidney exercise 3 will draw the body's Heat, Blood, and the Heart Qi away from the torso and Lower Dantian into the extremities of the feet, quieting the mind and causing sleep.

Chapter 40
Healing Sound Therapy and Prescriptions

Introduction and History

As early as the Qin Dynasty (221-207 BC) healing sounds have been recorded in China. For thousands of years, Qigong masters have studied occurrences in nature and in the physical body to develop a holistic approach to health and longevity. One of the many discoveries made is that all humans produce similar sound patterns in certain situations. For instance, after a tense situation many people utter a sigh of relief. This sigh is the body's way of releasing emotional stress. Specific situations will release different emotional sounds, because emotions are stored as tone resonances in the different chambers of the Five Yin Organs.

During the Sui Dynasty (590-618 AD), ancient Qigong Master Zhi Zhuan pointed out that there are six ways of expelling toxic energy from the internal organs, using the six different sounds formula. The silently spoken six sounds are coordinated with the breathing and the movements of the body's extremities to purge and cleanse the organ cavities and particular channels of stagnant Qi. These exercises are excellent for treating muscular injuries and for the Yin and Yang organs. The impure Qi produced by external pathogenic factors (from food, air, and drink) and internal pathogenic factors (toxic emotions and negative mental attitudes) will be expelled directly from each organ.

The healing sound techniques can either be used by the patient as a form of static Medical Qigong prescription (for purgation), or projected into the patient by the doctor as a clinical form of energetic stimulation (for tonification or purgation). The six words are: Xu (Shu), Ke (Haa), Hu (Who), Si (Sss), Chui (Chree), and Xi (Shee). These sounds are also used in chanting (in spiritual Qigong). Ancient documents state that these six sounds denote the Five Yin Organs as well as the five seasons.

It is important to note that there are several healing sound systems used by different Medical Qigong schools and other cultures. These sound systems all affect the body's sympathetic and parasympathetic nerves to some degree. The main emphasis, when performing any healing sound, should be placed on the connection of the mind, breath, and imagination to the area or internal organ focused on by the patient. This will reduce the potential for causing Qi deviations. The patient must have an internal image and actually hear and feel the resonating sound inside the body. It is also important that the patient feel enveloped in the sound, vibration, energy, and light of the therapeutic tone.

Sound Volume Resonation

The pronunciations of the sounds must be correct. The resonant effects of the sounds must be brought into full play to be successfully transmitted to the diseased areas of the internal organs. Therefore, it is extremely important that the patient focus the mind and intention on the area being treated. There are three volume resonations commonly used in Medical Qigong sound therapy: soft, moderate, and loud.

1. Soft volume is spiritual in its energetic nature and is related to the projection of Shen. A soft volume is generally used when beginning sound therapy treatments. With soft volume pronunciation, the patient can easily feel where the sound waves reach and acquire resonant effect, but the amplitude of the sound wave is not wide enough to produce the desired healing effects, and its vibrational force is very weak.
2. A moderate volume of sound is emotional and mental in its energetic nature and is related to the projection of Qi. A moderate volume is

considered the standard for all healing sound treatments. Moderate volume is decided by the individual's own voice. It should be limited to the range in which the patient's voice does not strain and in which the voice can be raised or lowered effortlessly.

3. Loud Volume is related to the projection of Jing. A loud volume is used to shock the patient into feeling the diseased tissue area. This is due to the fact that loud volume is more tangible (or physical) in its energetic nature. With loud volume pronunciation, the patient can easily feel the body's internal organs and tissues vibrate; however, this sound is only used to reintroduce a desensitized patient to his or her body. The problem with prolonged use of loud volume is that the increased volume is liable to create tension and cause Qi deviations.

The volume of sound uttered also depends on the patient's current state of health. People who are physically weak can usually practice the breath regulating and Qi reinforcing exercises, but should not practice the sound pronouncing method until they feel appropriately energetic.

To practice the word pronouncing method, the patient should start from the soft volume and increase it gradually. Diseases of different parts of the body require different volumes. For example:

- Patients with Heart or Lung trouble can comfortably take the soft to moderate volume pronunciation;
- Patients with Liver, Spleen, Stomach, Kidney and intestinal diseases can take the moderate to louder volume pronunciation.

High-, Middle-, and Low-Pitched Sound

The healing sounds have high, middle, and low pitches with different penetrating potentials. When correctly vocalized, they cause resonant vibrations in the body, producing certain states of consciousness that have both a psychological and a physiological effect on the nervous system.

As the tones change from a high to low pitch, they regulate the depth of the tone penetration. Similar to a dimmer switch on a light bulb, the tone adjusts the depth of the vibration resonance in the body.

The three pitch sounds also affect the energy movement of the body's Triple Burners, as well as the internal organs positioned within the thorax.

1. The high-pitched sound is pronounced in a straight tone with the head slightly drooped. The high pitch focuses the energy resonation into the specific organs of the patient's Upper Burner from the sternum to the manubrium. After completing the sound resonation exercise, return back to the Wuji position and relax; regulate the body using natural breathing.
2. The middle-pitched sound is pronounced in either a rising or descending tone, depending on the patient's specific conditions. The rising tone will cause the patient's Qi to ascend, while the descending tone will cause the Qi to drop. The middle pitch focuses the energy resonation into the specific organs of the patient's Middle Burner from the navel to the sternum within patient's body. Middle-pitched sounds are only prescribed for specific conditions (organ prolapse or organ energetic overload).
3. The low-pitched sound is pronounced in a dropping, then rising tone, within one breath. This causes the energetic resonation to saturate the diseased organ from top to bottom, then from bottom to top. This focuses the energy resonation into the specific organs of the patient's Lower Burner from the navel to the perineum. The method of pronouncing the low-pitched sound is usually practiced immediately after sounding the high-pitched tone.

After pronouncing either the high-, middle- or low-pitched sounds, perform the Open and Close the Three Dantians method once, then close with the Pulling Down the Heavens exercise. This completes one set.

Breath and Mind Control

Healing sounds produce an aspirating effect analogous to vacuuming a room. This analogy describes to the patient the desired intention needed to successfully utilize this modality of healing. Toning without proper focused intention,

breath, and mind control placed on the specific internal organ is like trying to vacuum a room while waving the hose in the air. Although the hose is sucking the air, it is not performing the desired result of purging the room of dust and dirt. To become proficient and establish the desired result, the individual must focus the attention and place the vacuum hose onto the specific area that needs cleaning.

Healing sound and toning therapy work the same way. It is not just sounding the tone which allows the technique to work, but the combination of the breath and mind focused on the intended internal organ. When practicing sound therapy, the patient generally uses the Natural Breathing method, along with focused intention and color visualization.

While inhaling, the patient imagines breathing in divine, white light healing energy through the nose and absorbing this healing Qi into the diseased area, vibrating it.

When exhaling, the patient imagines breathing out the dark, diseased, Turbid Qi through the mouth. It is important for patients to maintain the healing color (i.e.: green, red, golden yellow, white, or blue) vibration inside the diseased organ, even when they exhale.

Separating the Breath into Yin and Yang

The breath can be divided into either Yin or Yang qualities. When breathing shallow and focusing the mind on the front of the throat, the breath feels cool and is therefore considered Yin; however, when shifting the mind's attention towards the back of the throat, the breath, when released, feels hot, and is considered Yang. This change in temperature is due to the front of the body being Yin in nature and the back of the body being Yang.

Audible and Inaudible Sound Resonation

Before projecting sound therapy in a clinical setting, the Qigong doctor must vibrate the three Dantians while focusing on his or her Taiji Pole. Once the sound vibration has filled the doctor's body, the resonate healing sounds can be projected into the patient's tissues and organs.

Another way to produce sound is to imagine that the sound is appearing as a specific color and causing a vibration within the body. Clinical sound therapy is further divided into three distinct levels of emitted energies: Obvious Sound Resonation, Hidden Sound Resonation and Mysterious Sound Resonation.

1. The Obvious (Ming) Sound Resonation is audible sound. This energy sound resonation is considered Yang and is produced through the vocal organs. When toning audibly, the healing sounds fills the Qigong doctor's energetic fields. These fields can then be transferred onto the patient to produce a very strong, physical affect on the patient's tissues and organs. The Qigong doctor connects (through intention) with the patient's internal organ, and imagines his or her voice penetrating the diseased organ's tissues. The doctor then imagines the patient's tissues vibrating like rippling water with the sound exhalation, to purge the pathogenic Qi.
2. The Hidden (An) Sound Resonation is slightly audible sound. This energy sound is considered Yin transitioning into Yang, and is produced by softly exhaling sound energy resonation into the patient's body. This slightly audible energy sound resonation affects the patient's tissues and organs more on an emotional plane, enveloping and penetrating the patient's tissues like a mist.
3. The Mysterious (Hua) Sound Resonation is inaudible sound. This energy sound resonation is considered Yin and is mentally produced inside of the doctor's body. The Qigong doctor first focuses and fills his or her body and energetic field with the vibrant sound. The doctor then focuses the mind on the healing sound like a mantra. This inner sound fills the Qigong doctor's field with resonant vibration which can be transferred into the patient's body. This energy sound resonation affects the patient's tissues and organs on a more spiritual dimension, enveloping and purging like a gentle light.

The Qigong doctor can also coordinate the projection of the healing sounds with the patient's

toning to synchronize their energetic fields. All sound techniques have specific postures, breathing, and mind regulations to facilitate whole body integration.

Patients and students are usually encouraged to practice the audible sound vibrations until they can vibrate the tissues of the organs at will, before they proceed to the inaudible sound resonation.

THE SIX HEALING SOUND PRESCRIPTIONS

Before starting any organ sound exercise, there are certain grounding and cleansing techniques that the patient should practice. These preparation exercises are described as follows.

1. Always begin sound resonation from a Wuji standing posture.
2. Breathe naturally from the abdomen, inhaling through the nose and exhaling through the mouth. The body should be relaxed, and respiration should be gentle, thin, even, and extended. The mind should not concentrate on the expansion of the Lungs, but on the Lower Dantian first, and then on the treatment area. Also, breath through every pore of the body into the Lower Dantian.

   Upon exhaling, sound the healing word with a low volume pronunciation, feeling where the sound waves reach. Once the tissue area is stimulated, increase the volume. At the same time draw in the abdomen, draw up the anus, slightly knead the ground with the feet, sink the shoulders, and then shift the body weight to both heels. This will access the Kidneys' Water Qi. When inhaling, close the mouth, raise the tongue against the hard palate, and shift the body weight to the anterior soles of the feet. This will access the body's Fire energy. Exhale the specific sounds through the mouth while imagining the impurities of that specific organ being expelled.
3. Pull Down the Heavens (the ending breath regulation). Inhale and exhale through the nose. When inhaling, slowly raise both arms forward and upward from the sides of the body, with both palms facing downward until reaching shoulder level. Then turn the palms up, and continue to circle the arms over the head. When exhaling, bend the elbows to make a curve in front of the chest, and press the abdomen. Then separate the arms to the sides of the legs, and return to the Wuji posture (Figure 40.1).

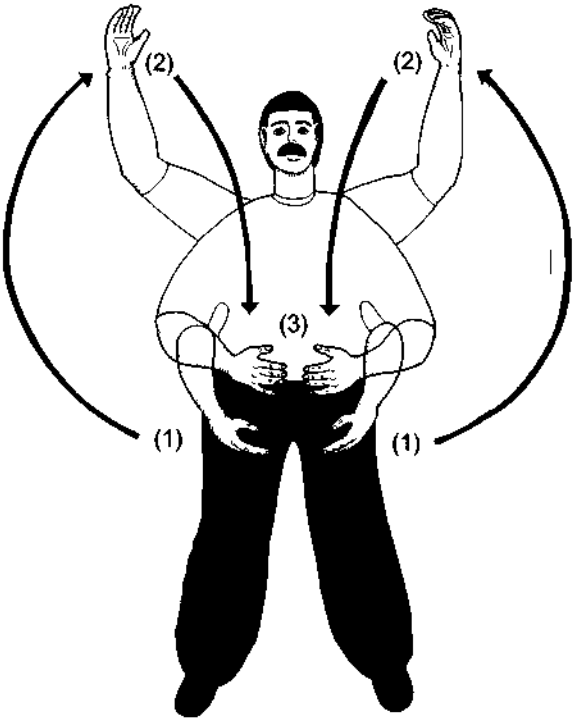

Figure 40.1. Pulling Down the Heavens allows the patient to sink the Qi, returning the excess energy back into the Lower Dantian.

Regulate the breath three times in the Wuji posture after completing the exercise. Breathing Regulation (Pulling Down the Heavens) is required after the exercise of each sound is completed and before the next exercise begins.

THE SOUND "XU" (SHU) NOURISHES THE LIVER

This sound relieves Liver stagnation, aids in correcting certain types of visual distortions, and purges the accumulation of Phlegm in the body (e.g., the condition of Lung Hot Phlegm, due to an already existing cold).

Both hands overlap the inner Laogong Pc-8

points, with the left hand on the outside for men (opposite hand position for women). The Shaoshang Lu-11 point of both thumbs presses against the navel, with the Laogong points pointing at the umbilicus.

When inhaling, expand the abdomen and close the eyes, feeling the breath envelop and penetrate the Liver organ. At the same time direct the Qi of the Liver's Channels to flow upward from the Dadun Lv-1 point on the lateral portions of the big toes. Visualize the Qi rising through the lower abdomen, linking the Gall Bladder to the Lungs, traveling to the throat, and eyes, to the forehead, and then to the Baihui GV-20 point.

When exhaling, contract the abdomen and release the pathogenic factors. Focus the attention and imagination on the Qi flowing down the face, to connect with the Lungs' Channels, flowing downward to the Shaoshang Lu-11 points on the medial portions of the thumbs. The Qi is then directed and rooted into the Lower Dantian. Open the eyes wide, and sound the word "Shu" (the lips are slightly brought together, the tongue tip stretches forward with the lateral sides slightly curling toward the middle). Exhale completely.

In this particular exercise, the breath should feel lukewarm as you exhale (Figure 40.2). Perform six times.

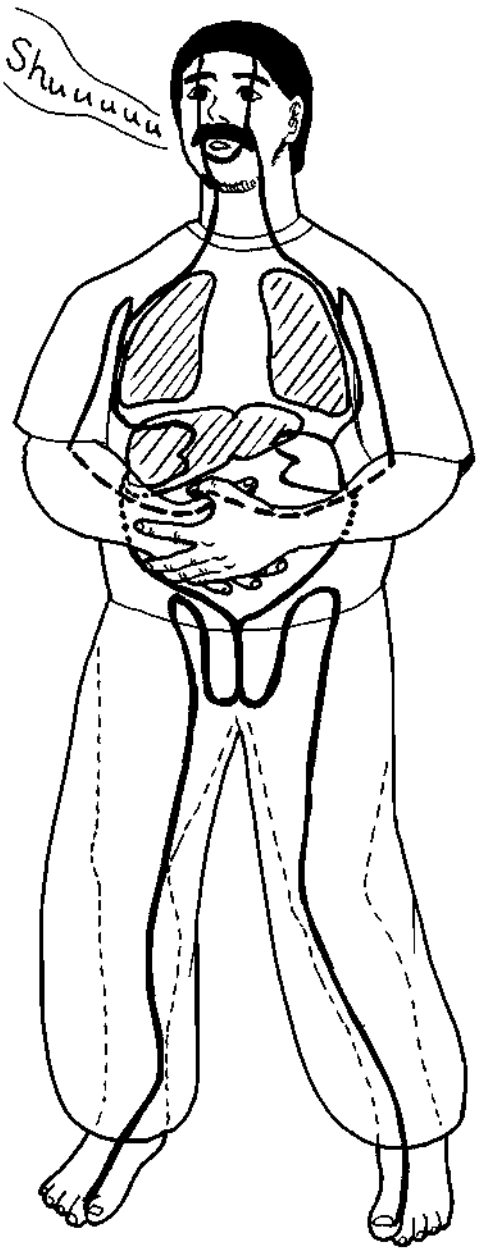

Figure 40.2. The sound "Xu" (Shu) is used to purge Liver stagnation as well as to disperse the accumulation of Phlegm in the body (Lung Hot Phlegm).

THE SOUND "KE" (HA) REPLENISHES THE HEART

This sound relieves Fire from the Heart and expels Heat from the body; it also improves poor circulation and reduces fevers. The respiration patterns are the same as those in the previous (Liver) sound prescription.

When inhaling, raise both hands to shoulder level as if embracing a post. Both palms should face each other with the arms making a curve in front of the chest. Expand the abdomen and close the eyes; feel the breath envelop and penetrate the Heart organ. At the same time direct the Qi of the Spleen's Channels to flow from the Yinbai Sp-1 point on the medial portion of the big toes, along the inner portions of the legs, upward to the abdomen to meet with the Thrusting Channels, and enter into the Heart.

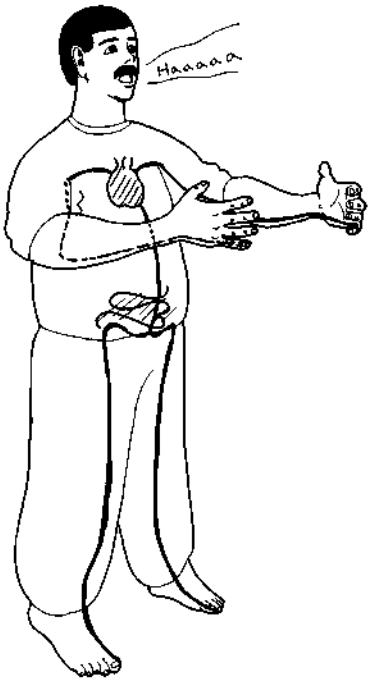

Figure 40.3. The sound "Ke" (Ha) is used to purge Heart Fire as well as expel Heat from the body.

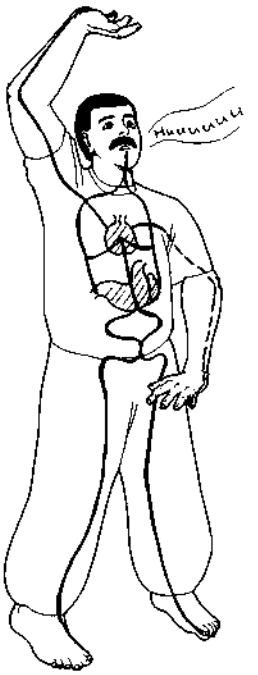

Figure 40.4. The sound "Hu" (Who) is used to treat digestive problems, by purging Stomach and Intestinal stagnation.

When exhaling, softly open the eyes and draw the Qi out from the Heart, past the Lungs, through the armpits, along the inner portions of the arms, to the Shaochong Ht-9 point on the medial portion of the little fingers. Point the fingers forward to release the pathogenic Qi, and sound the word "Ha." The mouth is half closed with the tongue placed against the lower mandible. Exhale completely. This breath should feel hot (Figure 40.3).

Return to the beginning position and perform six times.

THE SOUND "HU" (WHO) STRENGTHENS THE SPLEEN

This sound is used to correct digestive problems, especially when the Stomach or intestines feel full or sluggish.

When inhaling, raise both hands upward in front of the abdomen, as if embracing a ball in the Lower Dantian area. Both palms should face each other with the arms making a curve. Expand the abdomen and close the eyes; feel the breath envelop and penetrate the Spleen organ. Direct the Qi of the Spleen's Channels to flow from the Yinbai Sp-1 points on the medial portion of the big toes, up to the abdomen to enter the Spleen, and to link up with the Stomach.

When exhaling, the right palm turns outward, rolling over and pushing above the head, thus forming the posture of Holding the Heavens. At the same time, imagine the Qi ascending up to the throat, to the root of the tongue, and spreading under it. Imagine a secondary river of Qi flowing from the Stomach to the Heart, and ascending along the Heart's Channels to the Shaochong Ht-9 point on the medial portion of the little fingers, and exhale the sound "Who." The lips are brought together as if playing a flute, the tongue is level and stretched forward as much as possible to allow the ascending energy of the Thrusting Channels to rush out. Exhale completely while the left palm turns downward and presses down to the outside of the left hip (Figure 40.4).

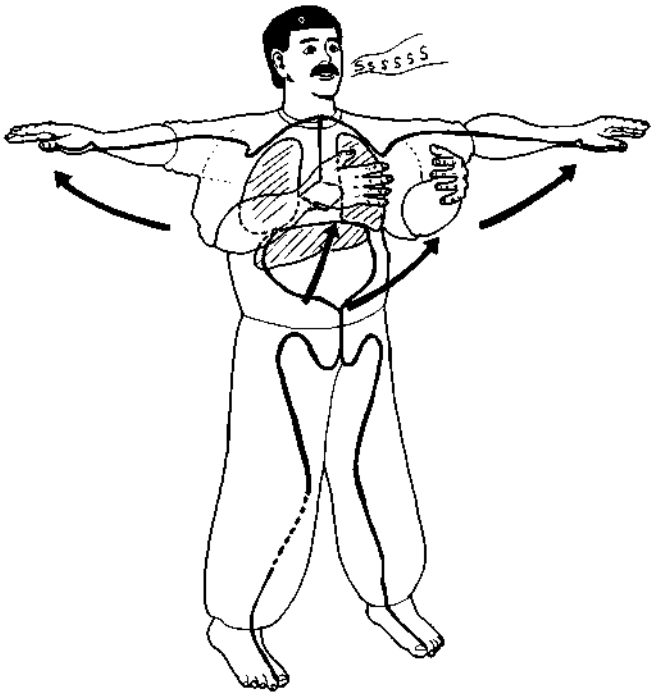

Figure 40.5. The sound "Si" (Sss) is used in order to Purge the Lungs.

Next, inhale and turn the right palm over to face the body; slowly descend the right arm in front of the body, while the left arm turns towards the body and ascends. The two hands cross in front of each other (with the ascending arm on the inside, and the descending arm outside). Now the left hand pushes up and the right hand pushes down. At the same time, exhale and repeat the sound "Who." Pressing both left and right hands form one set. Perform six times. At the end, cross both arms in front of the chest and return to the beginning position.

THE SOUND "SI" (SSSS) MOISTENS THE LUNGS

This sound is used to nourish the Lungs, treat problems such as tuberculosis, abscesses, and dermatitis.

From the beginning Wuji posture, inhale and raise both hands as if holding a ball, moving it upwards, until the hands face the Shanzhong CV-17 point at the front of the chest. Direct the Qi of the Liver's Channels to ascend from the Dadun Lv-1 point on the lateral portions of the big toes, along the inner portion of the legs, through the lower abdomen into the Lungs.

When exhaling, turn over both palms to face downward, then separate the palms horizontally to the sides. Guide the Qi along the Lungs' Channels to the Shaoshang Lu-11 points on the inner portion of the thumbs, while exhaling the sound "Sss" The lips are slightly drawn back, the upper and lower teeth are slightly brought together forming a small slit; the tip of the tongue is placed against the slit in-between the teeth to articulate the sound. Exhale completely, then allow both arms to descend to the sides of the body (Figure 40.5). Repeat six times.

THE SOUND "CHUI" (CHREE) STRENGTHENS THE KIDNEYS

This sound is used to regulate the Kidneys, expel chills, and to maintain the Internal Heat of the Lower Dantian and Mingmen Fire.

Inhale and raise both arms to embrace an imaginary ball in front of the chest (Middle Dantian area).

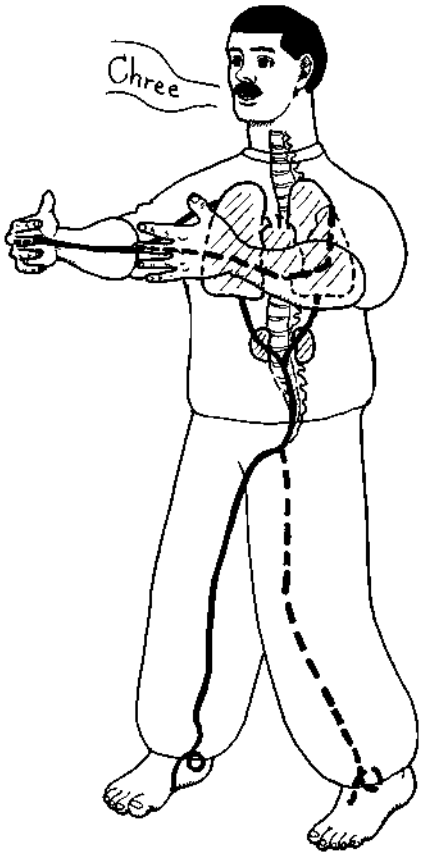

Figure 40.6. The sound "Chui" (Chree) is used to regulate the Kidneys and the Mingmen Fire, as well as to expel chills from the body.

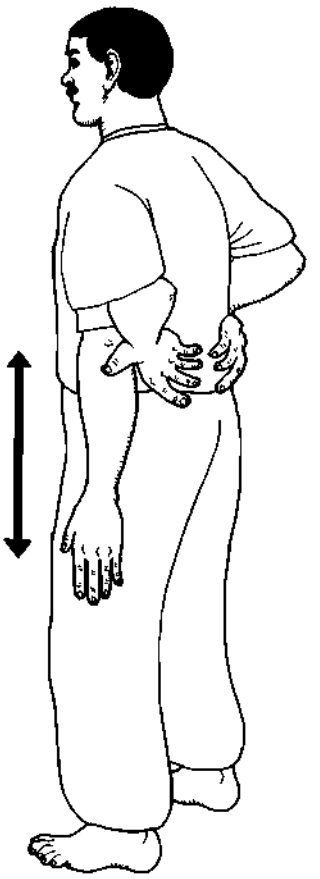

Figure 40.7. Massage the sides of the body.

The joints in between the thumb and index finger of both hands are stretched wide open. Lead the Qi to flow upward from the Yongquan Kd-1 points of the Kidney Channels, through the inner portions of the thighs, along the spinal column, and into the Kidneys.

When exhaling, hold the posture and stretch the fingers, while leading the Qi from the Kidneys into the chest and then to the Lungs. The channel Qi then transfers into the Pericardium Channels and flows down the arms to the Zhongchong Pc-9 points at the tips of the middle fingers. While exhaling, sound the word "Chree." The mouth is nearly closed with the corners slightly drawn back; the tongue moves forward. The breath should feel cold (Figure 40.6).

Slowly straighten the body as the hands circle downward, from the lower back to the thighs. Rub the lower lumbar region (Shenshu Bl-23 points) and the sides of the thighs (Huantiao GB-30 points), moving the hands upward while massaging the buttocks. Return to the holding the ball posture and repeat six times (Figure 40.7).

THE SOUND "XI" (SHE) REGULATES THE TRIPLE BURNERS

This sound is used to eliminate Excess Heat, for treating rheumatism, poor circulation, and problems of the Triple Burners. This exercise helps

to recharge the body's Qi metabolism, regulate Internal Qi, and balance the eight systems of the body (respiratory, digestive, reproductive, circulatory, lymphatic, nervous, muscular/skeletal, and excretory systems).

The "She" sound of the Triple Burners is always prescribed for patients undergoing radiation or chemotherapy. This allows the patient to disperse the toxic Heat left within the tissues.

From a beginning Wuji posture, inhale and raise both hands as if holding an imaginary ball up in front of the chest at the Middle Dantian. Direct the channel Qi of the Triple Burner Channels in the arms to flow downward to the Lower Dantian, then down the legs via the Gallbladder Channels to the tips of the fourth toes of the feet at the Qiaoyin points (GB-44).

Exhale the sound "She," at the same time rotating both arms upward to form the Embracing the Heavens posture. The lips are slightly open and drawn back; the tongue suspends behind the teeth. When exhaling, direct the Qi to flow from the Qiaoyin GB-44 points on the outer portion of the fourth toes upward, along the Gall Bladder Channels, through the outer portions of the legs to the head, and transfer the energy flow into the Triple Burner Channels, directing it along the outer portions of the arms to the Guanchong TB-1 points at the ends of the ring fingers. Exhale completely.

Inhale, while turning the palms over to face downward, and begin lowering both arms along the front of the chest. Imagine the Qi flowing down from both arms into the Lower Dantian. Exhale without sounding "She," and press both palms down along the front of the abdomen to the sides of the hips, returning to the Wuji posture (Figure 40.8). Repeat the entire sequence six times.

This exercise is different from the others in that the energy circulates back and forth through the channels but does not disperse outside the body. Meaning you inhale Qi from fingers to toes, exhale Qi from toes to fingers and sound, inhale Qi from fingers to Lower Dantian, exhale Qi from Lower Dantian to toes, without sound, then begin entire sequence again.

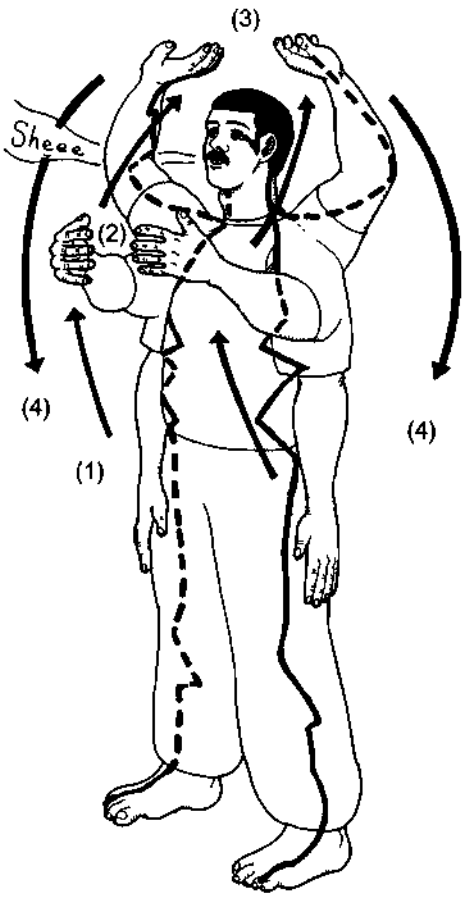

Figure 40.8. The sound "Xi" (She) is used to purge Excess Heat from the body.

THE PROPER NUMBER OF BREATHS FOR HEALING SOUND PRACTICE

When practicing all six healing sounds, each sound should be practiced a minimum of three to six times before proceeding on to the next sound. If the patient wishes to practice the six healing sounds daily, the patient should perform each sound no more than twenty-four times. If the patient is practicing one or more healing sounds for a specific therapy, then the number of times for tone resonances should be thirty-six.

Practice the six healing sounds in the sequential order of the Fire Cycle (i.e., Liver, Heart, Spleen, Lungs, Kidneys, and Triple Burners) to enhance the

Yang energetic field. Practice the six healing sounds in the sequential order of the Water Cycle (i.e., Liver, Kidneys, Lungs, Spleen, Heart, and Triple Burners) to enhance the Yin energetic field.

It is advisable to practice the healing sounds at the end of a meditation practice. This is because the free circulation of Qi is already in motion and freely accessible after meditating.

COMBINING MULTIPLE ORGAN SOUNDS

The six healing organ sounds may be performed as in the prescribed series, or as individual therapies ranging from single to multiple organ sounds. Some examples are:

1. Single organ sound regulation, like the "Haa" sound for the Heart, is used followed by swallowing the collected saliva (after Qi purgation) to relieve a fast, irregular heartbeat.
2. Multiple organ sound regulations, like the sounds of "Shu" (Liver), "Haa" (Heart), and "Sss" (Lungs), are used in sequence to quench the pathogenic Fire inside the patient's body (for mild symptoms).
3. All six healing sounds are used for regulation and balance to treat "False Cold" (a feverish sensation followed by a feeling of cold all over the body). This symptom is caused by Excess Fire. The Internal Fire drives the Yin to the body's surface, thus producing the cold sensation. To treat, the Qigong doctor guides the patient's Yin Qi back to its original organs and uses all six sounds to regulate the body.
4. Sounding according to the Five Seasons will also be beneficial to the patient's Qi regulation. The five sounds are divided according to each season, and the vulnerability of each organ. They are categorized as follows:
   a. "Shu" sounding in the springtime will benefit the Liver.
   b. "Ha" sounding in the summer will benefit the Heart.
   c. "Ssss" sounding in the autumn will benefit the Lungs.
   d. "Chree" sounding in the winter, and during all seasons, will vitalize the Kidneys and harmonize Qi and Blood.
   e. "Who" sounding in all seasons helps vitalize the Spleen and regulates the function of Postnatal Qi.
5. Combining healing sounds according to the specific prescriptions is similar to taking combinations of Chinese herbs. The Six Healing Sounds may be combined in order to target specific areas on the body's energetic system. Generally, the doctor gives the patient specific healing sound combinations as prescriptions to purge stagnation, and to increase the energetic movement within the diseased tissues or organs.

   One such combination prescription used to treat overall Shen disturbances due to emotional depression, from suppressed anger, guilt or grief is called, "Old Man Searching for the Reflection of the Moon at the Bottom of the Tide Pool." In Medical Qigong Soul Retrieval, this healing sound prescription is used to bring the patient back in touch with his or her painful emotions.

OLD MAN SEARCHING FOR THE REFLECTION OF THE MOON AT THE BOTTOM OF TIDE POOL

This particular exercise was introduced into the United Stated in the early 70's by Dr. Her Yue Wong. Doctor Wong believed that after the Qigong student has spent a sufficient amount of time practicing the Five Elemental Daoist Qigong tonification exercises, his or her deep seated emotions will begin to surface and must be purged from the body. In order to purge the toxic emotions, this healing sound prescription was given:

1. Begin this exercise prescription from a standing posture. Both feet are facing forward, shoulders width apart. Inhale, and imagine divine healing light filling the Lungs. While inhaling, separate and stretch both arms to the sides of the body, forming the shape of a "T" (Figure 40.9).
2. Lean over and begin to exhale, making the "Sh-h-h-h-h" sound. While exhaling imagine Toxic Qi from both Lungs flowing down each arm and pouring into the ground. Both arms should swing from one side to the other, crisscrossing

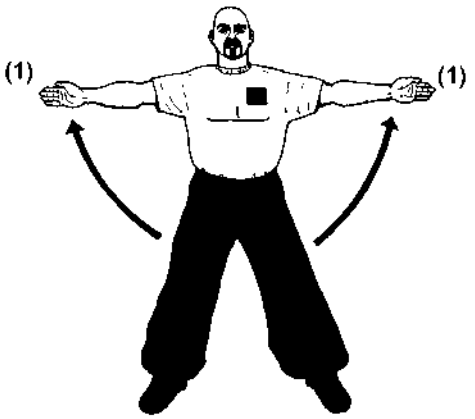

Figure 40. 9. Old Man and Tide Pool (a)

Figure 40. 10. Old Man and Tide Pool (b)

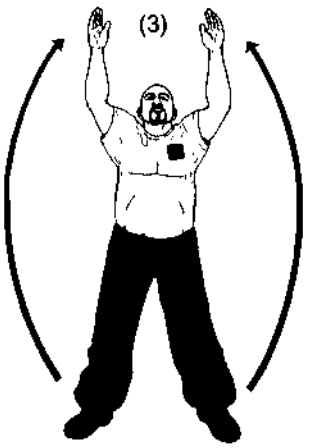

Figure 40. 11. Old Man and Tide Pool (c)

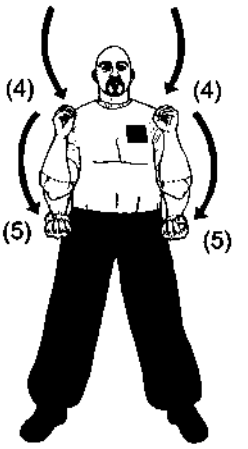

Figure 40. 12. Old Man and Tide Pool (d)

while making the purging sound (Figure 40.10).

3. Return to an upright position, while inhaling and imagining divine healing light filling the chest (especially the Heart, Liver and Spleen areas). When inhaling, look upward and raise the hands over the head (Figure 40.11).
4. When exhaling, both hands should descend to shoulder level, making soft fists (as if embracing two sparrows). Focus the mind's intention on the center of the chest and imagine the Toxic Qi releasing from the Heart while making the "Haa-a-a-a" sound. Exhale only half of your breath. Next, exhale the second half of your breath while imagining Toxic Qi releasing from the Liver and Spleen and making the "Who-o-o-o" sound. While exhaling, move both hands down to the hips while keeping the fists soft (Figure 40.12). Repeat the last two steps (c. and d.) three times. This equals one set. Practice 36 sets to complete the exercise. It should take about 25 minutes.

There is an story associated with this ancient healing sound prescription; it is described as follows.

One night, on a full moon, an old man on the southern coast of China, went looking for sea crustaceans to feed his family. Holding his lamp upward, he gazed down and saw a large beautiful

pearl at the bottom of a tide pool. "Oh My!" He exclaimed, as he quickly placed his lamp on a rock. "Look at the size of that pearl! With a pearl that large, I'll be able to retire! Even my family won't have to work, and we'll all live in the lap of luxury for the rest of our lives!"

So the old man stretched his hands wide and began splashing his arms in the tide pool, trying to grasp the large pearl. Sh-h-h-h-h-h-h-h-h! went the water as the old man frantically grasped at nothing. Perplexed, the old man looked up. Reaching into the night sky, the old man's eyes widened as he saw the full moon. "Ha-a-a-a-a-a-a!" exclaimed the old man, "It's the moon!" "Whooo-o-o-o-o-o" cried the old man, "There's no money!"

CONTRAINDICATIONS FOR THE SIX HEALING SOUND THERAPY

There are several counter-indications for the use of the Six Healing Sound Therapy:

- The resonating sounds have a strong affect on the tissues, therefore patients who have broken or fractured bones are forbidden to practice sound therapy. Only after the bones tissues have mended are the patients allowed to practice the healing sounds.
- Due to the stimulating effect of the Six Healing Sound Therapy, it is advisable for the Qigong doctor not to prescribe the practice of the six healing tones in a very acute stage of illness. Vibrating the patient's internal organs in the beginning stages of a disease (i.e., a high fever) may stimulate the patient's virus or bacterial growth.
- Women are prohibited from practicing Tone Resonation therapy when pregnant, as the tone resonations have a pattern of dispersing clots and may lead to spontaneous miscarriages.
- Women are prohibited from practicing Tone Resonation therapy when menstruating, as it is important for the woman's body to be allowed to naturally Purge Toxic Blood from the body.

SOUND RESONATION THERAPY FOR TUMOR AND CANCER

Cysts, tumors, and cancer are characteristic of Excess stagnation of Qi and Blood, as well as stagnations of Heat and Cold. Chronic diseases, marked by obstruction of channel Qi, disorders of Qi and Blood, and the breakdown of Yin and Yang balance, are also included as Excess stagnation syndromes. The following sound methods involve a special series of tone resonation exercises (similar to, but stronger then the six healing sounds) which are utilized to disperse stagnations.

In order to find the correct pitch, the patient starts with a soft volume sound to experience the physical characteristics of the internal organ vibrating. While pronouncing the tone with the vocal cords relaxed, the patient gradually increases the sound to a louder volume.

While exhaling the sound, the patient focuses on an internal image of the diseased tumor dissolving. The patient must actually hear and feel the sound resonating the body's tissues, saturating the organ with sound vibration, energy, and light.

The following sounds are prescribed for the treatment of tumor and cancer therapy: the "Guo" sound is used by patients with Liver diseases, the "Zheng" (pronounced as jang) sound is pronounced by patients with Heart trouble, the "Gong" sound by patients with Spleen diseases, the "Shang" sound by patients with Lung trouble, and the "Yu" sound by patients with Kidney diseases. The relationship between the five pronunciations and the five solid organs as well as the number of pronunciations are shown in Figure 40.13.

PREPARATION FOR TUMOR AND CANCER SOUND THERAPY

Have the patient begin this exercise in a Wuji posture, and encourage the patient through the One Through Four meditation (One-Fun, Two-Shoe, Three-Tree, and Four-Core) described in Chapter 26.

Each tumor and cancer healing sound is pronounced in a straight tone, facing the left and exhaling the tone while rotating the body to the right. This allows the patient to purge the specific diseased organ. After completing the required number of straight tone exhalations, the patient faces forward and pauses.

The patient then begins the second half of the

		Elements				
		Wood	Fire	Earth	Metal	Water
Yin organs	solid organs	Liver	Heart	Spleen	Lung	Kidney
Yang organs	hollow organs	Gall Bladder	Small Intestine	Stomach	Large Intestine	Bladder
body turns left to right ——— body turns right to left	high-pitched straight tone ——— low-pitched descending-ascending tone	guo	zheng	gong	shang	yu
number of repetitions		8	7	10	9	6

Figure 40.13. Tumor and Cancer Sound Therapy Chart

prescription by facing the right direction and exhaling a descending tone while rotating the body to the center of the room, then rising tone while rotating the body towards the left side of the room. This application causes the patient to purge the diseased organ's channels of Toxic Qi.

Upon completion the patient performs the Pulling Down the Heavens technique to cleanse the body of any leftover energetic residue.

THE PROPER AMOUNT OF TONE REGULATIONS

The beginning patient should not be too anxious to perform the required number of pronunciations. By gradually reaching the required number, and slowly adapting themselves to the Tone Resonation method, the patients avoid getting tired. The sound "Shang," for example, is pronounced nine times for each exercise in the case of Lung disease. However, a beginner may start by pronouncing the tone three times, and then gradually progress to six times in twenty days. Then, in another thirty days, the patient can reach the required number of times. The number of repetitions is always dependent upon the patient's age, type of constitution and the severity of the disease.

In other words, the amount of times in a day that the patient performs the healing sounds depends upon the patient's general condition. The sounds used in tumor and cancer therapy, for example, will be prescribed more frequently with less volume then that of the regular six healing sound therapies. For Lung cancer, for example, the patient should perform the "Shang" sound eighteen times a day, nine breaths in each direction, right and left; for Lung congestion, perform the "Sss" sound three times a day, 36 breaths for each set.

SPECIALIZED PRESCRIPTIONS FOR TUMORS AND CANCER

The sound therapies used for treating tumors and cancer are quite different and much more powerful then the six healing sounds previously prescribed to purge and regulate the body's internal organs. Because of the dramatic difference in power and energetic potential between these two healing sound systems, the cancer patient will be given a lower number in tone respirations, but an increased number of times of practice per day.

The healing sounds used for treating tumors and cancers are as follows: for Liver/Gall Blad-

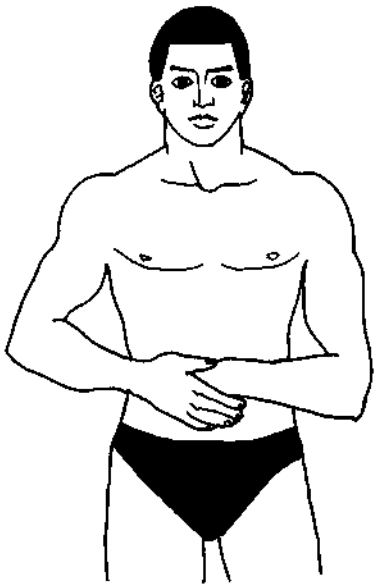

Figure 40.14. For Liver diseases the sound is "Guo."

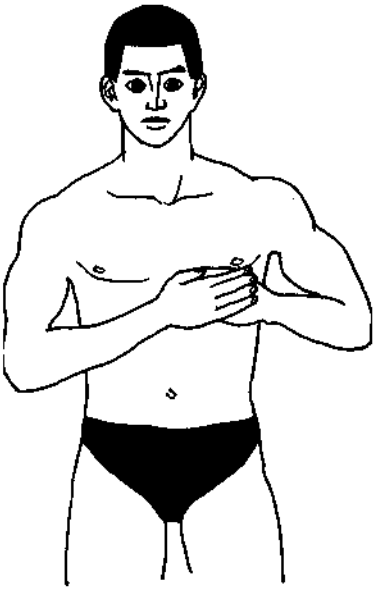

Figure 40.15. For Heart trouble, the sound is "Zheng" (Jang).

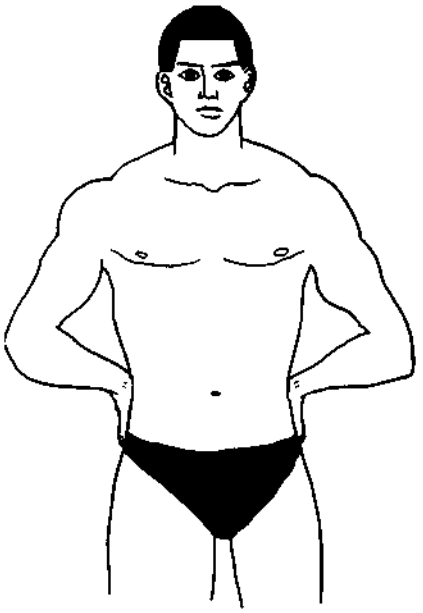

Figure 40.16. For Spleen diseases, the sound is "Gong."

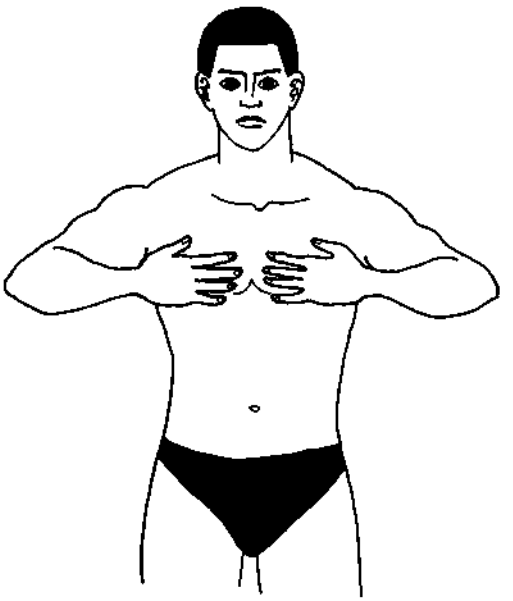

Figure 40.17. For Lung trouble, the sound is "Shang."

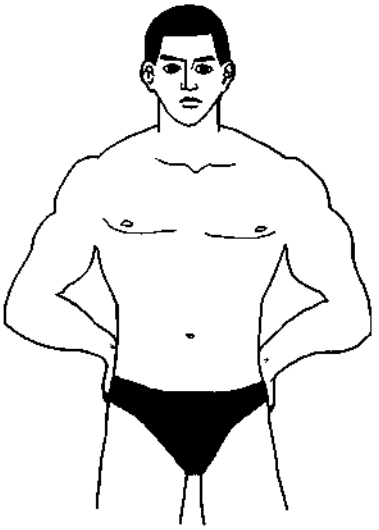

Figure 40.18. For Kidney diseases, the sound is "Yu."

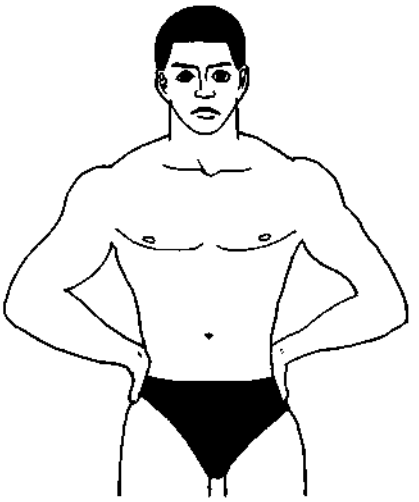

Figure 40.19. For chemotherapy, the sound is "Xi" (She).

der tumors, use the sound "Guo" (Figure 40.14); for Heart/Small Intestine tumors, use the sound "Zheng" (Jang - Figure 40.15); for Spleen/Stomach tumors, use the sound "Gong" (Figure 40.16); for Lung/Large Intestine tumors, use the sound "Shang" (Figure 40.17); and for Kidney/Bladder tumors, use the sound "Yu" (Figure 40.18). The Triple Burners' sound "Xi" (She) is used to purge Heat from the body after radiation and chemotherapy (Figure 40.19).

The choice of sound resonation must suit the patient's specific disease. Generally, in the beginning, patients with cancer should mainly pronounce the purgation sound "Haa" nine times to purge the Heart of stagnant emotions (Figure 40.20). After pronouncing the sound "Haa" for a certain time period, the patient begins to become emotionally vulnerable. The doctor then adds the specific sounds for the treatment of the diseased internal organs. The "Shang" sound, for example, is prescribed for patients with Lung cancer.

1. The tones for Radiation and Chemotherapy patients should include the Triple Burners' sound "She." This toning should be done when their blood count is low after chemotherapy or radiation therapy and is used to purge Excess Heat from the body. The sound "She" is pronounced six times. Its high-pitched sound is in the straight tone (perform six times), and its low-pitched sound is in the dropping and rising tone (perform six times).

   After the patient has stabilized and the red and white blood count has reached a normal level, the "She" sound is dropped and replace by the sound "Haa." This is done to stabilize the patient's emotions. Instead of "Haa," the doctor can also replaced the healing sound with the specific sound needed to treat the diseased internal organ.
2. The tones for Stomach cancer patients should include the sound "Dong." The Dong sound has a deeper penetrating affect than the "Gong" sound (which is usually prescribed for Stomach diseases). The "Dong" sound should be pronounced ten times (Figure 40.21). Its high-pitched sound is "Dong" in the straight tone (perform ten times), and its low-pitched sound is "Dong" in the dropping and rising tone (perform ten times).
3. The tones for Brain tumor patients (with cerebral carcinoma) should include the sound "Duo." The "Duo" sound should be pronounced ten times (Figure 40.22). Its high-pitched sound is "Duo" in the straight tone (perform ten times), and its low-pitched sound is "Duo" in the dropping and rising

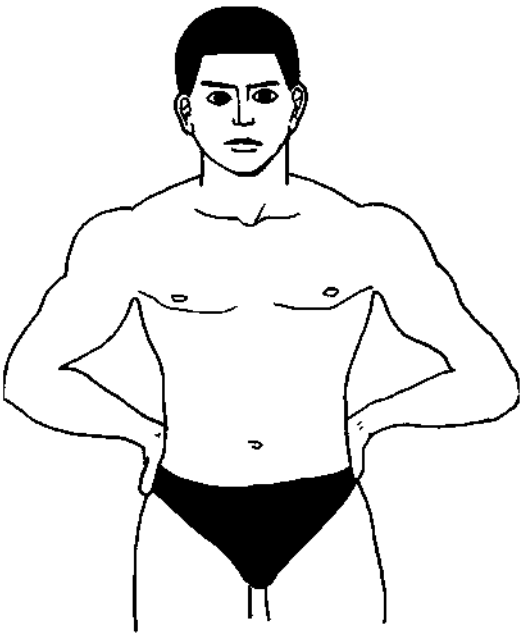

Figure 40.20. For cancer in general, the sound is "Ha."

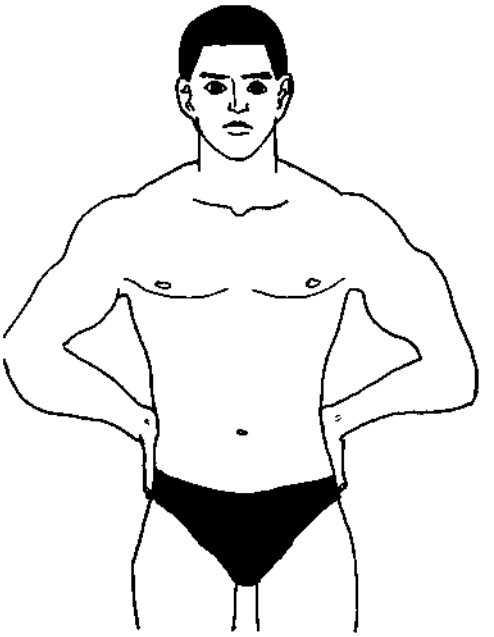

Figure 40.21. For Stomach cancer, the sound is "Dong."

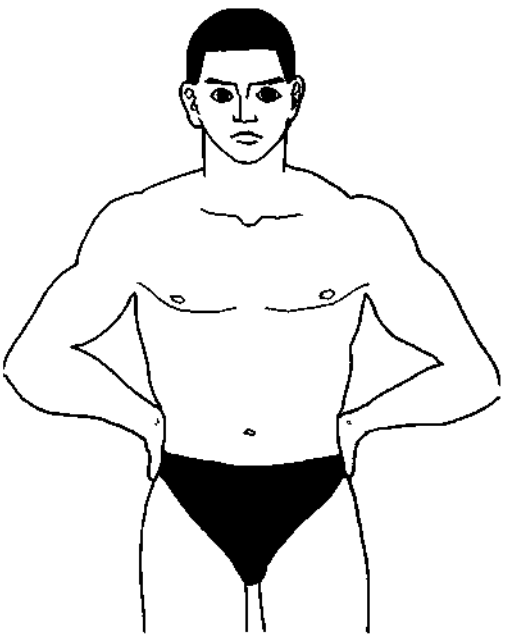

Figure 40.22. For brain cancer, the sound is "Duo."

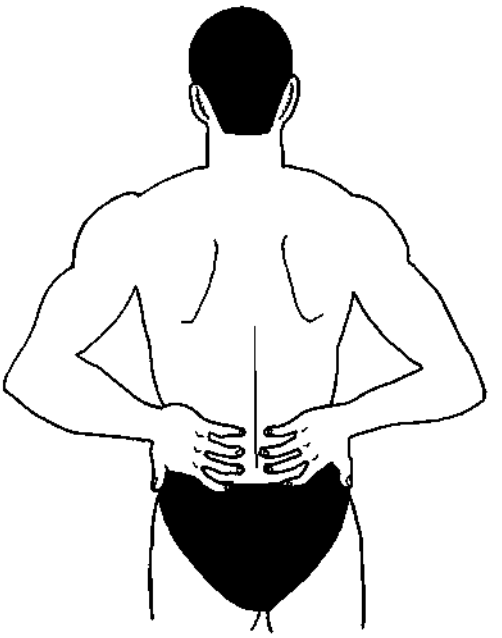

Figure 40.23. Back View for the Cancer Prescriptions

tone (perform ten times). In addition the patient should also practice techniques to strengthen the Kidneys and Heart.

4. The tones for Lung tumor patients (with carcinomas of the Lungs) should include the "Shang" sound. The "Shang" sound should be pronounced nine times. The patient should also use the Fast Breathing Method technique (2 inhalations, followed by 1 exhalation of the sound "Shang"), in addition to practicing Lung and Kidney strengthening exercises.
5. The tones for Large Intestine tumor patients (with carcinomas of the Large Intestine) should include the "Shang" sound. The "Shang" sound should be practiced nine times using the Fast Breathing Method technique, in addition to practicing Lung strengthening exercises.
6. The tones for Nasopharyngeal tumor patients should include the "Shang" sound. The "Shang" sound should be practiced nine times using the Fast Breathing Method Walking technique (see Chapter 15), in addition to practicing Lung strengthening exercises.
7. The tones for Small Intestine tumor patients (with carcinomas of the Small Intestine) should include the "Zheng" sound. The "Zheng" sound should be practiced seven times, using the Fast Breathing Method technique, in addition to practicing Heart strengthening exercises.
8. The tones for Liver Cancer and Gall Bladder tumor patients (with carcinomas of the Liver and Gall Bladder) should include the "Guo" sound. The "Gou" sound should be practiced eight times, using the Fast Breathing Method technique, in addition to practicing Lung, Liver, and Spleen strengthening exercises.
9. The tones for the Bladder and uterus tumor patients (with carcinomas of the Urinary Bladder and uterus) should include the "Yu" sound. The "Yu" sound should be practiced six times, using the Fast Breathing technique, in addition to practicing Kidney strengthening exercises.

   While in a Wuji posture, the patient places both hands on the Kidneys and presses the middle fingers at the Shenshu Bl-23 point beside the Mingmen before pronouncing the sounds (Figure 40.23).
10. The tones for Prostate cancer patients should include the "Yu" sound. The "Yu" sound should be practiced six times, using the Fast Breathing Method technique, in addition to practicing Kidney strengthening exercises.
11. The tones for Skin Cancer patients (with dermal carcinomas) should include the "Shang" sound. The "Shang" sound should be practiced nine times, using the Fast Breathing Method technique, in addition to practicing Lung, Liver, and Spleen strengthening exercises.

CONTRAINDICATIONS FOR TUMOR AND CANCER SOUND THERAPY

As previously mentioned, the tumor and cancer healing sounds are only prescribed for purging Excess conditions within the patient's diseased organs, and not for treating Deficient organ conditions. If a specific internal organ is already in a state of Deficiency and the patient is allowed to focus on that organ with one of the tumor and cancer sounds, the patient's condition will worsen. This increases the potential for rapid growth of the disease.

Chapter 41
Medical Qigong Regulation Exercises

Introduction

The following chapters explore several systems of Medical Qigong exercises used in regulation, purgation, and tonification prescriptions. Conceived in ancient China, these exercises originate from the various medical, martial, and Daoist schools of energy cultivation. It is from these ancient energetic systems that today's modern clinical Qigong prescriptions originate.

Each Qigong system has its own unique approach to circulating, balancing, and storing the body's life-force energy. No one particular style of energetic healing is superior to the next, only different in its approach. The primary goal of each of these systems is removing stagnant pathogenic energy and replenishing and circulating clean life-force energy.

The Xi Yuan Hospital in Beijing, China is famous for its advanced Medical Qigong clinics and Medical Qigong prescriptions. These exercises utilize both Static and Dynamic Postures and are generally taught in both the inpatient and outpatient clinics. The static exercises are used to store the Qi, while Dynamic Qigong exercises are used to open the patient's channels and circulate the Qi.

Each prescription should be practiced for five to ten minutes for each organ or organ system on a daily basis; or if the patient is practicing only one set (e.g., Regulation of Spleen and Stomach Qi), they should practice for thirty minutes. Unless otherwise indicated, all breathing should be "natural."

The goal is for patients to empty their body and mind, so that their emotions can be felt and activated. In the Medical Qigong clinic there is a saying, "The patient can only heal what they feel."

Starting and Ending the Prescriptions

Before starting any Medical Qigong prescription, it is important for the patient to understand that every Qigong exercise must start and end with specific preparations.

- Before starting the Medical Qigong prescription, the patient must always purge his or her body. It does not matter if the exercise they are about to begin is used to purge, tonify, or regulate the internal energy; they must always purge first. This is similar to washing a dirty glass before filling it with clean water.
- After ending the Medical Qigong prescription, the patient must always gather the generated Internal Qi and the return to its origin. The term "Return to its Origin" refers to a three fold process:
  - cultivating, collecting, and accumulating the prenatal energy,
  - developing and transforming it into postnatal Jing, Qi, and Shen, and
  - returning it back to prenatal Jing, Qi, and Shen.

This allows the Post-Heaven Kan and Li (Water and Fire energies) to return to their origin and restores them to Pre-Heaven Qi (Heaven and Earth energies). This fusion into one energy, often called the Hun-Yuan or Blended Originals, requires the patient's original substances to condense into one energetic substance and be merged with the patient's Lower Dantian energy.

In order to collect the energy, the patient is taught to apply the Three Natures Become One technique of focused concentration (all thinking, seeing, and listening is focused into the Lower Dantian). The Three Natures are as follows: the eyes represent the perceptive nature, the ears rep-

resent the spiritual nature, and the Heart represents the courageous nature. When all three natures unite into one, the energetic refinement is called "collecting the body's true nature." The patient can then collect the body's power.

MEDICAL QIGONG CULTIVATION EXERCISES

The body is composed of different densities of energy and matter in the form of internal organs, organ systems, channels, and collaterals. When practicing Qi cultivation methods both students and patients are instructed to train in a progressive order of Qi cultivation.

First, the students and patients are taught how to purge, tonify, and regulate their internal and external channels. Once the Yin and Yang energy of the channels are balanced, the practitioners learn how to balance the Yin and Yang energy of the internal organs. This training likewise involves purging, tonifying and cultivating methods. The directed focus of intention on specific points, channels, or areas of the body causes the Qi to gather in those locations and to be absorbed into the body's tissues through the Mind's intention (whole body awareness and consciousness). The final step of training the Yuan (Original) Qi is undertaken only after the first two steps have been accomplished.

All cultivation practices of Medical Qigong therapy can be divided into two main categories of gathering and training Qi: the External Elixir Cultivation (Wai Dan Shu) and the Internal Elixir Cultivation (Nei Dan Shu). These two Qi cultivation training methods are described as follows.

EXTERNAL QI CULTIVATION

The External Elixir Cultivation (Wai Dan Shu) involves several methods of gathering energy from the external environment (Heaven and Earth) to strengthen the body's organs, organ systems, channels, and collaterals.

HERBS AND FOOD

The first method is developed through food and herbal soups, teas, and pills to increase the body's energy. When herbs are prescribed as a tonic, they stimulate the organ's energy by increasing the flow of Qi in the patient's channels. Qigong and herbology go hand-in-hand with respect to the energetic regulation and balance of the body's life-force energy. Herbs can be extremely important for maintaining the physiological balance of the metabolism and restoring any depletion of the body's energetic mechanism. Herbs act as a form of energetic nutrient, allowing the Earth energy to be ingested into the body through a natural substance.

MEDITATION

The second method is developed through meditation. Qi is cultivated through the body's extremities from energy originating outside of the body's torso (i.e., both palms, both soles of the feet, and the top of the head). The External Elixir Cultivation meditation focuses the concentration on either the Heaven or Earth energy fields to draw their energy into the torso for increased Yin or Yang Qi regulation. The Postural Dao Yins in External Elixir Cultivation may be either static or dynamic.

Two examples of External Elixir Cultivations are: the Earth Yin Qi Regulation and the Heaven Yang Qi Regulation. The Earth Yin and Heaven Yang Qi Regulations are used to balance the energy along the body's ascending and descending energetic channels. To balance along the horizontal energetic channel, perform the Turning and Winding the Belt Vessel exercise described later on in this chapter.

- **Earth Yin Qi Regulation**

  The Earth Qi is considered Yin Qi or electronegative energy. Blood also pertains to Yin Qi. Through Earth Regulating Qigong meditations, the body's Blood cells can be replenished with Earth Yin energy.

  Begin the Earth Qi Regulation meditation from a Wuji posture, while using Natural Breathing. In this particular exercise, the practitioner takes advantage of the Kd-1 points at the bottom of the feet, and the Pc-8 points at the center of the palms which are sensitive to the magnetic pull of the Earth.

  After standing in the Wuji posture for several minutes, inhale and begin to absorb the

Earth Qi up from the ground through the centers of the palms and the bottom of the feet (Figure 41.1). After several more minutes of drawing the Earth energy into the Lower Dantian, begin circulating the energy through the Microcosmic Orbit's Fire Cycle. The palms should begin to expand and feel almost swollen; the red and white blotches on the palms and feet indicate that the exercise has been practiced correctly.

- **Heaven Yang Qi Regulation**

  Heaven energy pertains to the sun's Yang Qi or electropositive energy, which is used to tonify the body's Yang Qi.

  Begin from a Wuji posture, placing both palms above the head, facing upwards, like two antennas collecting the sun or Heaven's Qi into the Middle Dantian. Use Natural Breathing. Imagine the sun's golden light showering the outside of your body. Open your mouth and imagine swallowing the sun's Qi, allowing it to mix with your saliva. As you swallow, feel the energy flow down into your Lower Dantian, and then out of your pores. Once the Dantian is full, the body should feel expansive. Always end the meditation by returning the energy to the Lower Dantian to avoid any Qi deviations (Figure 41.2).

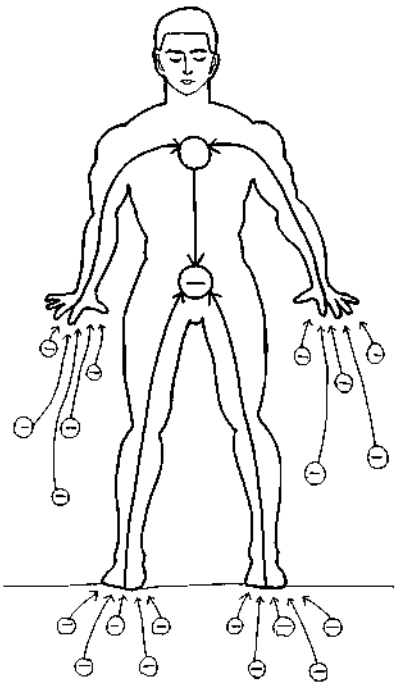

Figure 41.1. Absorb the Earth Qi into the body through both hands and feet, and store the Qi in the Lower Dantian.

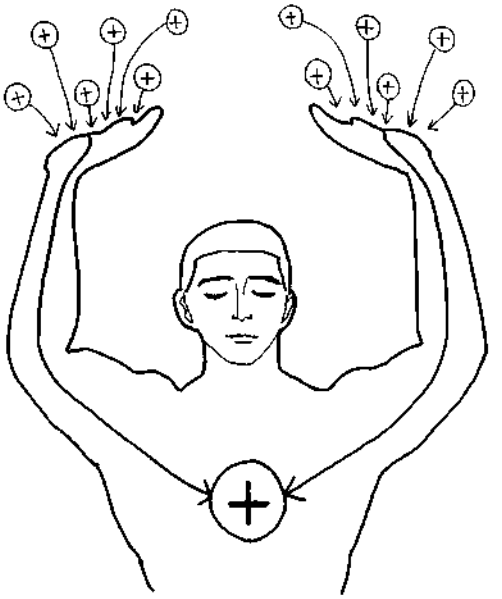

Figure 41.2. Absorb the sun's energy into the body through both palms, moving it into the Middle Dantian, and store the Qi in the Lower Dantian.

INTERNAL QI CULTIVATION

The Internal Elixir Cultivation (Nei Dan Shu) method focuses on first training the energetic substances already gathered and existing inside the torso, and then extending this accumulated energy out into the extremities. Since it first appeared in the Han Dynasty, the training and theory of Internal Elixir Cultivation has become the primary focus of many Qigong masters, working with postnatal energy transformations. Internal Elixir Cultivation focuses on transforming the body's Jing, Qi, and Shen. When practicing this exercise, ancient Qigong masters imagined the Lower Dantian as a stove, the Shen as a Fire, and the

body's Jing, Qi, and Shen as the internal medicine.

At birth, the energy flows up the front of the body (Conception Vessel) and down the back (Governing Vessel). This is considered the circulation of the Yuan Qi (generated from the prenatal Jing stored in the Kidneys). It is considered the Perceptual Yin or Water Cycle of the Microcosmic Orbit. This Perceptual Yin Cycle allows the newborn child to possess powerful psychic, empathic, and kinetic abilities; it enables the child to energetically connect with the environment in order to ensure survival.

As the child advances in age, he or she begins to encounter and experience some hostile messages in the form of physical or emotional frustration and pain from both parents, siblings, and the environment. For protection, the child armors and creates a denial system, which insulates him or her from the energetic and emotional wounding. The child begins to instinctively stop the energetic flow of the perceptual Yin Water Cycle and begins to activate the acquired rational mind, trying to cope with his or her feelings and the stress of his or her surroundings. Whenever the child begins to experience painful emotions, he or she learns to avoid experiencing these hurtful feelings through certain mental and physical actions by contracting the throat and thorax. These acquired actions further create an energetic restriction and impede the flow of Qi along the Conception and Governing Vessels. This physical activity naturally causes the Yin Water Cycle to stop its perceptual flow of energy, and allows the child's body to deal with the trapped emotional experiences by storing them within the tissues. Although this is not a healthy response, it allows the child to survive and develop in a sometimes difficult environment. In cases of deep traumatic wounding (physical, emotional or sexual), the child becomes void of deep emotional connections, while still allowing for certain perceptual survival instincts.

Also, our culture emphasizes left brain thinking for educational purposes, and later to enable young adults to rival others in the competitive job market. The child thus must forgo most of his or her innate intuitive perceptions to succeed in school and to appropriately integrate society's values and belief structures. Very little encouragement is given to right brain activity; it is in fact discouraged by society at large.

REGULATING THE BODY'S QI

The first stage in circulating and cultivating the Qi is to regulate the Yang or Fire Cycle of the Microcosmic Orbit. This allows the trapped emotions within the tissues to be released. This is initiated through mental concentration, focusing the flow of the Qi up the back and down the front of the body. It is extremely important to allow the trapped energy to release itself naturally from the body through the Fire Cycle of the Microcosmic Orbit. Otherwise, trapped emotions deep within the tissues can cause Qi deviations within the body, which may lead to energetically induced psychosis.

When regulating the Microcosmic Orbit, there are three primary methods of energetic cultivation that harmonize the body's Jing, Qi, and Shen. They relate to the sun (Fire and Heaven), moon (Water and Earth) and stars (Wind and Man).

THE FIRE PATH OF THE MICROCOSMIC ORBIT

The Yang or Fire Path is the most popular method of cultivating energy along the Small Heavenly Cycle or Microcosmic Orbit (Figure 41.3). Because it joins together the body's Yin and Yang rivers of Qi, which regulate the Twelve Primary Channels, it is considered the foundational meditation for the Internal Elixir Cultivation methods. The circulation of Postnatal Qi is generated from the Acquired Essence (food, air, and water). In this cycle, the Qi moves up the Governing Vessel and down the Conception Vessel, and is considered the ascension of Yang or the opening of the Fire Channel. The initial goal is to circulate the Fire energy from Yang to Yin to convert Jing to Qi and then to Shen. The Yang (Fire) Qi supports awareness of the emotional side of consciousness.

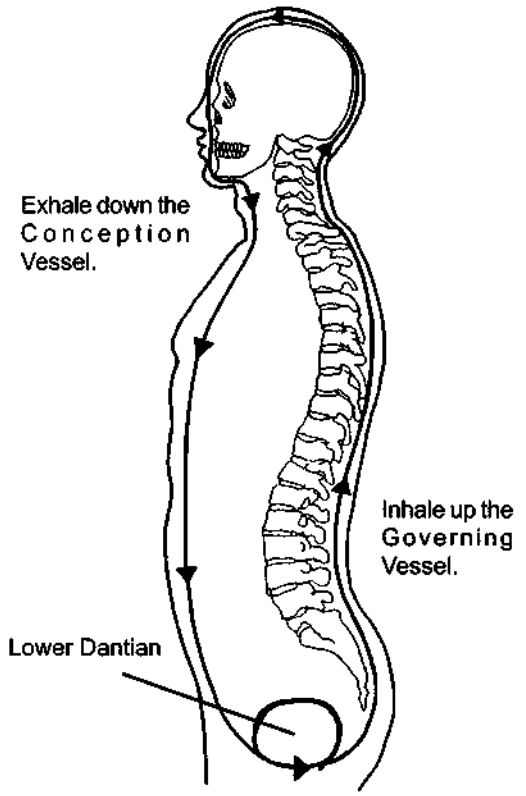

Figure 41.3. The Fire Path of the Microcosmic Orbit flows up the back and down the front of the body.

The Heart and Middle Dantian are considered the House of Shen; Fire and passion (Qi that manifests as emotions) and are related to the flow of the Conception Vessel. The Kidneys and Lower Dantian are considered the House of Jing, Water and pleasure and are related to the flow of the Governing Vessel. It is important to use Reverse Breathing while uniting the Heart's Fire and Kidneys' Water, to cause the alchemical transformation of Jing into Qi in the lower abdomen.

When moving the Qi along the Governing Vessel, practitioners must move the energy through the Five Gates (see Chapter 30). The energy first gathers at the Lower Dantian, then overflows into the Governing Vessel, collecting, building, and then passing through to the next gate, one gate at a time. As the energy gathers at these gates, the Qi and Blood begins to Heat and vibrate the tissues. This energetic reaction affects the patient's emotions that correspond to or are embedded in each specific gate, causing a powerful emotional release. As the Qi passes through to the next gate, a new set of emotions is experienced, then released.

THE JIAJI POINTS' EFFECT ON THE GOVERNING VESSEL'S ENERGETIC FLOW

Jia translates to mean "besides." Ji translates as "the spinal column." These points are located lateral to the lower border of each spinous process of the cervical, thoracic, and lumbar vertebrae. Each point has its own Luo pathway (energetic channel), which intersects with the spine and connects to the Jiaji point located on the opposite side of the Governing Vessel. It is believed that one pair of the ascending Governing Vessel's Luo Channel intersects and connects to all of the Jiaji points along the spine.

This being the case, when the two energetic flows from the Jiaji points (via the Luo pathways) are superimposed, the reaction causes a crisscrossing and intertwining of Qi flow, which resembles the intertwining energies of the caduceus or double snakes.

THE TWELVE EARTHLY BRANCHES' RELATIONSHIP WITH THE MICROCOSMIC ORBIT

Within the Fire Cycle of the Microcosmic Orbit, there are twelve channel points located along the Governing and Conception Vessels which relate to the Twelve Earthly Branches and the waxing and waning of the Yin and Yang cycles (see Chapter 11). The Fire phase of the Microcosmic Orbit starts at the Zi branch located at the Sheng Si Qiao area at the root of the penis in men and at the vagina in women. Moving up the back of the body, there are four phases of Qi ascent in the Governing Vessel. The four phases are: from Zi to Chou, from Zi to Yin, from Zi to Chen, and from Zi to Si. The Mao point is one of the four cardinal points (along with Zi, Wu, and You) and is a point of purification. The path up the Governing Vessel cleanses the energy through this point of purification.

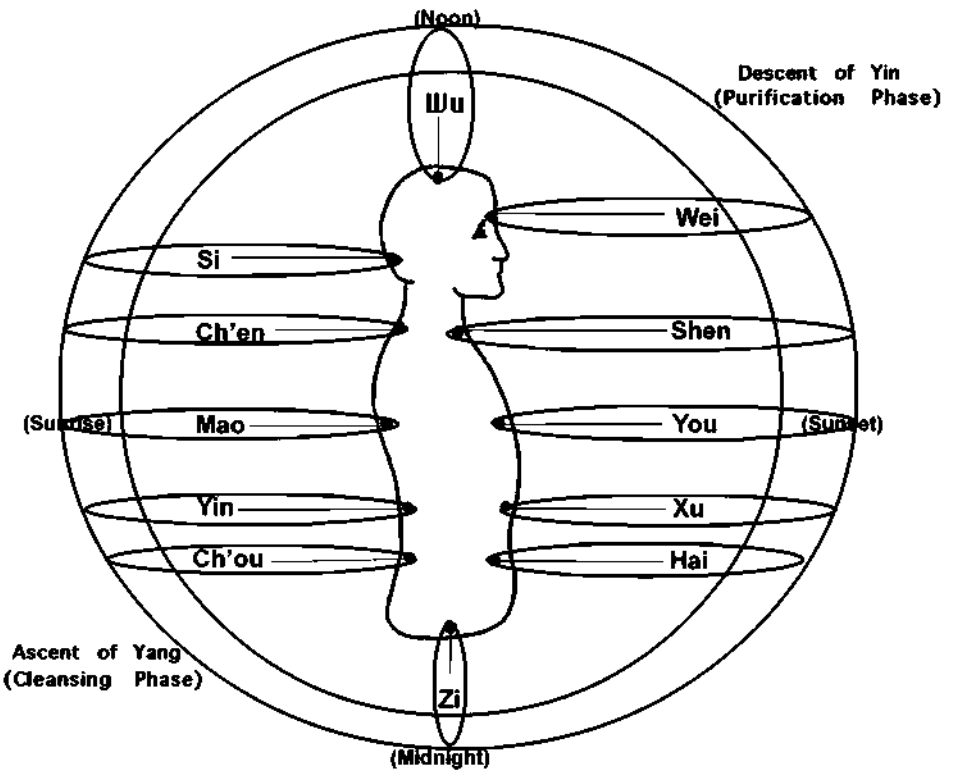

Figure 41.4. Twelve Earthly Branch Relation with the Microcosmic Orbit: the main channels of the back and front of the body correspond to the ecliptic path of the sun. These twelve special energy points are associated with the Twelve Chakra Gates.

When the energy reaches the Wu point at the top of the head (also known as the Ascending point), it stays there briefly before beginning the descent of Yin in the Conception Vessel. The descent down the Conception Vessel purifies the energy (Figure 41.4).

While at the perineum and Zi point in the orbit, the Yang Qi begins to develop as the Yin Qi reaches its zenith. Once the energy reaches the Mao point at the middle of the back, the Yang energy has developed fully and begins to prosper. At the Wu point at the top of the head, the Yin Qi begins to develop while the Yang Qi reaches its zenith. This point represents the turning point from Yang to Yin.

If the energy is to flow properly down the Conception Vessel, there must be an opening of the energy centers via a connection with the Shen. This purification of energy commences at the Wu point when the Yang Qi turns to Yin Qi. While the Earth's daily orbit around the sun has the same Yin-Yang transitions, the body absorbs the Yang energy during the hours of Zi and Wu, and expels Yin energy during the hours of Mao and You.

At the Zi hour (11 p.m.–1 a.m.), the Jing naturally collects at the Sheng Si Qiao point at the root of the penis (prostate area) in men causes a natural erection while the man is sleeping. This hour also marks the commencement of the Yang half of the day. This period of the day is the best for collecting Jing and, thus, is the best time to perform Wuji standing practice.

CONTRAINDICATIONS

Whenever the practitioners are weak, it is important that they practice Natural Dantian Breathing and avoid practicing the Microcosmic Orbit. If patients attempt to practice Circular Breathing while in a depleted state, the Qi may become trapped in their head causing Qi Deviations, and initiating more problems. Circular Breathing is achieved by guiding the Qi in a circular pattern through even inhalation (e.g., up the spine) and exhalation (e.g., down the front of the body).

THE WATER PATH OF THE MICROCOSMIC ORBIT

The Water Path is trained only after the completion of the Fire Path circulation exercise. After the patient's Prenatal Qi has been cultivated and accumulated to a substantial level, the patient may lead the Qi up the Conception Vessel and down the Governing Vessel (Figure 41.5).

This is opposite the direction of the flow of the Fire Path, and is considered the ascension of Yin or the opening of the Water Channel. The purpose for the Water Path circulation is to change, regulate, and charge the body's Yuan Shen. The Water cycle supports the perceptional side of consciousness, cools down the body's overheated Yang Qi, and regulate the Qi circulation of the Fire Path to rebalance the body.

THE WIND PATH OF THE MICROCOSMIC ORBIT

The Wind Path of the Microcosmic Orbit is the third method of circulation and requires practitioners to lead energy up the center of their body through the Taiji Pole (Figure 41.6). This energy pathway flows up through the Marrow of the spine, through the brain, and washes over the falx cerebri into the pineal and pituitary gland. It then descends down along the Conception Vessel and back into the Lower Dantian.

The purpose of the Wind Path is to increase divine perception (by accessing the energy of the Wu Jing Shen), and to regulate the body's glandular and endocrine systems, to enable the practitioner to slow down the aging process.

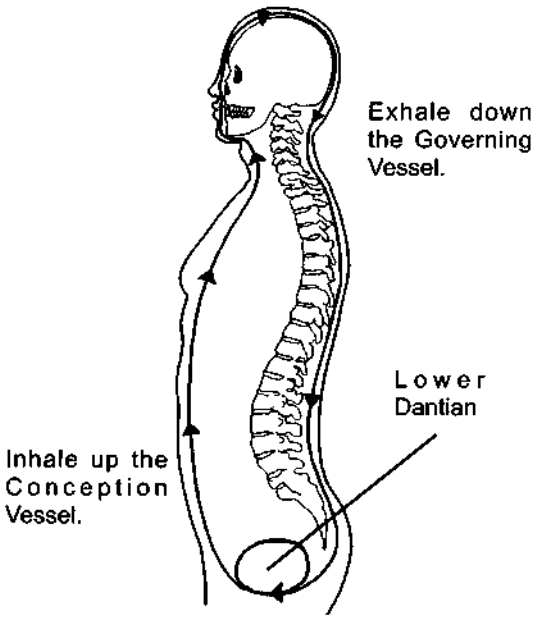

Figure 41.5. The Water Path of the Microcosmic Orbit travels up the front and down the back of the body, ending at the Lower Dantian.

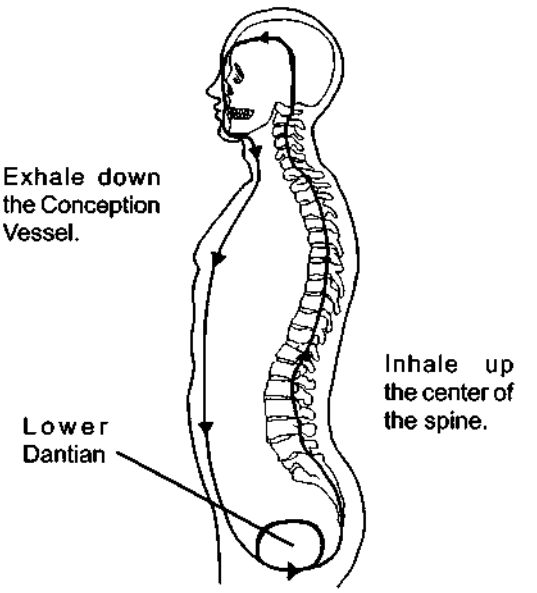

Figure 41.6. The Wind Path of the Microcosmic Orbit travels up the center of the spine into the brain and third-eye point, down the front of the body, ending at the Lower Dantian.

MEDICAL QIGONG PRESCRIPTIONS

The following exercises are taken from various hospitals, universities, and institutes of Medical Qigong. These regulation prescriptions are used throughout China.

DESCEND THE QI AND CLEANSE THE ORGANS

This exercise was developed to utilize the body's Hun-Yuan Qi (the body's internal combined organ energy) to flush and cleanse the Triple Burners and the Five Yin Organs. This is a purging exercise, used to:

- eliminate the body's Turbid Qi,
- unclog the channels and collaterals,
- wash the bones,
- transform the Marrow, and
- combine the remaining pure energy with the body's Yuan Qi.

It can be prescribed for patients with Excess conditions to descend the Liver's or Heart's Fire.

PULLING DOWN THE HEAVENS

This exercise requires the focus of energy to flow down the body in three directions (front, center, and back) to complete one set.

1. Begin in a Wuji posture, with both feet facing forward, a little wider than shoulders width apart. Both hands are at the sides of the body. The spine is kept straight, with the body relaxed and centered (see Chapter 15 for proper alignment). Stand with the eyes focused on the horizon. Pull the Qi from the horizon into the eyes and down to the Lower Dantian, filling the entire body. Hold this posture for one to three minutes (Figure 41.7).
2. Inhale through the nose. With the palms facing downward, begin to scoop the energy from the Earth into the body, gathering and absorbing the environmental energy. Focus on slowly filling the body with Earth Qi while moving the hands upwards to about waist level (Figure 41.8).
3. Continue inhaling, turning the palms to face the Heavens and drawing both hands upwards at a forty-five degrees angle. As both palms continue to move upwards, begin pulling in and absorbing the Heavenly Qi while guiding the hands above the head. Complete the inhalation with the arms above the head, palms facing the top of the head. Pause when the hands are above the Baihui area (Figure 41.9).
4. Exhale through the nose, and begin descending the palms in front of the body. Allow the palms to face the body and direct the Qi flow through the head and throat area (Figure 41.10).
5. Imagine the energy continuing to pour down through the chest and abdominal areas (Figure 41.11).
6. While exhaling, slowly lower the hands in front of the body in one continuous movement, until they reach just above the knees (Figure 41.12).
7. Inhale and begin the sequence again. Each time the hands pass in front of the body, exhale and imagine the Qi being emitted through the hands into the tissues. Three passes over the front of the body equal one set, practice 36 sets. The energetic pathway of each set is explained as follows:
   a. The first pass begins by leading the Qi down the front of the body from the Baihui area. Each palm facing the body divides the energy into two rivers, which flow from the top of the head, over the ears, and down the throat. Continue guiding the two rivers down the front of the chest, joining again at the navel. From there lead the Qi down into the Huiyin CV-1 point at the perineum, then separate them again into two rivers which continue to flow down the Yin channels on the inside of each leg, ending at the Yongquan Kd-1 point at the bottom of each foot.
   b. Start the next pass at the middle of the head above the Baihui area. Lead the Qi down the center of the body, and absorb the Heavenly Qi as it passes through all the body's internal organs, till it reaches the Lower Dantian area. From the Lower Dantian divide the energy into two rivers and descend the Qi down the center of the legs ending

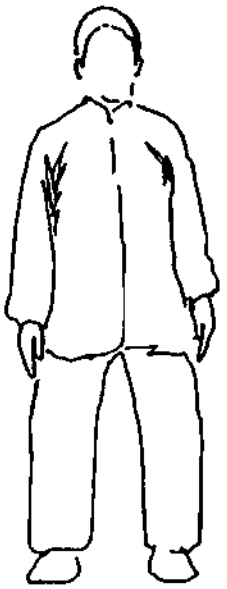

Figure 41.7. Wuji Posture

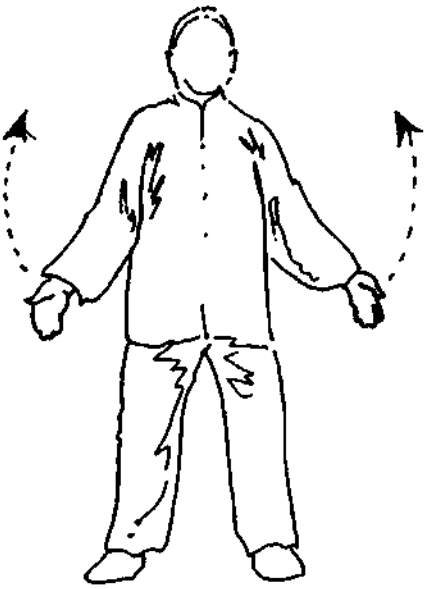

Figure 41.8. Pulling Down the Heavens (A)

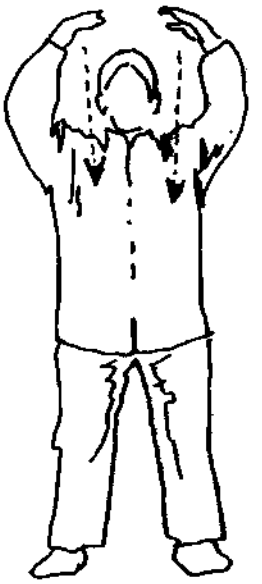

Figure 41.9. Pulling Down the Heavens (B)

Figure 41.10. Pulling Down the Heavens (C)

Figure 41.11. Pulling Down the Heavens (D)

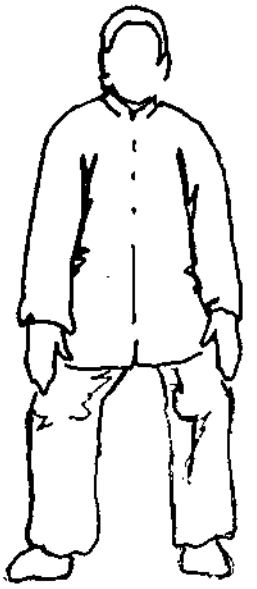

Figure 41.12. Pulling Down the Heavens (E)

at the Yongquan Kd-1 point at the bottom of each foot.

c. The final pass likewise begins at the top of the head, at the Baihui area. Imagine the energy flowing like a river, down the midline of the back of the head and back, until it reaches the Mingmen GV-4 point. From there it divides into two rivers, descending into the Huantiao GB-30 point at the side of each buttock, and continues to flow down the outside of each leg and ends at the Yongquan Kd-1 point at the bottom of each foot. As the Qi descends (on each pass), it washes the organs from the top of the head (Baihui point) to the bottom of the feet.

d. To end the exercise, relax the whole body and return to the Wuji posture, allowing the Qi to return to its origin. As the Qi descends through the body, imagine the environmental energy fusing with the body's Yuan Qi, forming a mist and dew. Imagine this mist slowly flowing down (from top to bottom) and bathing, cleansing, and purifying the entire body. As the mist descends, if a certain organ is diseased, pause for a while to bathe the area with the vapor before continuing the flow of energy. Consciously disperse the pathogens out the extremities.

GATHERING QI IN THE UPPER AND LOWER DANTIANS

This exercise is designed to strengthen, tonify, and regulate the body's internal organs and energetic fields. It is excellent for promoting and maintaining health, and can be used for tonifying the Kidneys, as well as to treat impotence, premature ejaculation, lumbago, lower back problems, and pelvic inflammatory disease (PID). When treating PID, use reverse breathing with Static Qigong training.

This is a tonification exercise, used to increase the production of Jing (sperm or ovary energy), transforming it into Qi, and to lead the Jing up the spinal cord to support the brain, as well as nurture the bone marrow. This exercise adds Fire to the Mingmen, simmering the condensation of energy within the Kidneys. When the Kidney (Water) and Heart (Fire) energies are sufficient, their energies merge to form the True Qi which cultivates one's nature, spirit, and life. This exercise also assists the Microcosmic Orbit and establishes a base for refining and gathering energy in the Upper and Lower Dantians and Huiyin.

GATHERING QI IN THE UPPER DANTIAN

Begin from a Wuji posture. Inhale, as both hands gather energy while moving up the sides of the body and embrace the Qi into the Upper Dantian. Pause and exhale while separating the hands (Figure 41.13).

Inhale and imagine the middle fingers of each hand gathering the Heaven and Earth Qi into the Upper Dantian. Imagine the body absorbing these energies through the Yin Tang point (Third Eye), into the pineal gland at the center of the brain. Imagine the light of the Upper Dantian getting brighter as the energy begins to increase (Figure 41.14). Repeat this exercise nine times.

Upon completion, focus on the Upper Dantian and begin to gather and fuse the body's Yuan Shen along with the collected Heaven and Earth energies into one energy. As this energy collects, imagine it forming into an energetic ball of white light and allow the hands to guide the light downward into the Lower Dantian.

During the process of descending the Qi from the Upper to Lower Dantian, the focus should be on feeling, guiding, listening, and seeing the energy traveling downward. As the energy of the Shen descends, the Jing energy naturally ascends. This descending and ascending action of Jing and Shen energies cultivates an abundant amount of Qi in the Lower Dantian. After the Qi has been gathered and stored there, pause a moment, allowing the energy to settle. Then proceed to regulate the Lower Dantian.

GATHERING QI IN THE LOWER DANTIAN

Both hands sink down to waist level and form an embracing posture in front of the navel. Inhale while slowly drawing the palms inward towards the navel, gathering the Qi into the center of the Lower Dantian. Pause a moment and relax, allow-

Figure 41.13. Gathering Qi in the Upper Dantian (A)

Figure 41.14. Gathering Qi in the Upper Dantian (B)

Figure 41.15. Gathering Qi in the Lower Dantian (A)

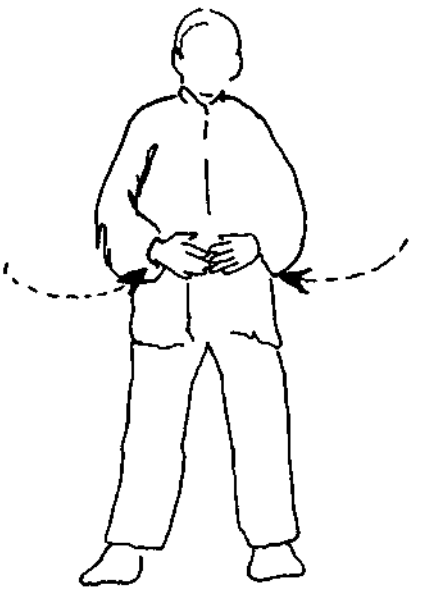

Figure 41.16. Gathering Qi in the Lower Dantian (B)

Figure 41.17. Gathering Qi in the Huiyin Area (A)

Figure 41.18. Gathering Qi in the Huiyin Area (B)

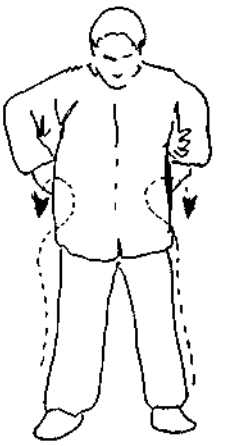

Figure 41.19. Gathering Qi in the Huiyin Area (C)

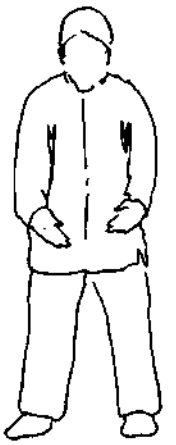

Figure 41.20. Gathering Qi in the Huiyin Area (D)

ing the energy to settle, then exhale and separate the hands (Figure 41.15).

Inhale and imagine the body absorbing the universal and environmental energies in through the navel and Lower Dantian areas (Figure 41.16). Repeat this exercise nine times.

Imagine the Lower Dantian as a reservoir, storing but never overflowing. The expansion and contraction of the abdominal muscles creates a "beating and drumming" movement which improves the abdominal muscles' elasticity while massaging the digestive system. The "beating and drumming" movement strengthens and increases peristalsis.

GATHERING QI INTO THE HUIYIN AREA

Continuing from the last posture, both hands begin to move downward from the Lower Dantian (Figure 41.17).

As you inhale, bend over and imagine scooping the Earth energy along the inside of the legs, directing the Qi through the three Yin channels into the body's Huiyin, coccyx, and Mingmen areas. While inhaling, it is important to pull up on the anal sphincter and imagine gathering the Earth Qi directly through the lower body's orifices (testicles and penis, or vagina) into the Kidneys and Mingmen area (Figure 41.18).

Move both hands from the insides of the thigh, groin, and lower abdomen backward, along the Belt Vessel, expanding the energy into the Kidneys and Mingmen area. Hold this posture and exhale, imagining the Qi flowing into the Kidneys and Mingmen areas (Figure 41.19).

Next, circle the Qi down to the Lower Dantian and Huiyin area. Pause for a moment to allow the Qi to settle and root (Figure 41,20). Repeat this exercise nine times and end this exercise.

ROLLING THE BALL WITH BOTH PALMS

The purpose of this exercise is to regulate the Yin and Yang balance of energy in the body. This exercise also causes the capillaries along the Microcosmic Orbit to open up, improving the Qi circulation and nerve stimulation in the extremities.

It is excellent for purging and regulating emotions from the Heart and Yellow Court, as well as for descending Rebellious Lung Qi downward and purging Yang Qi Rising.

SHAKING THE SUN AND MOON

Begin from a Wuji posture. Both arms raise up in front of the shoulders, palms and fingertips pointing upward. Imagine the left palm embracing the sun and the right palm embracing the moon. Vigorously shake the palms, focusing the mind's intention on the center of the palms and fingers (Figure 41.21).

Place both palms in front of the chest and Middle Dantian area, and imagine the energy of the sun and moon melting into each other, creating a huge ball of energy. Make sure the eyes focus on the center of the ball (Figure 41.22).

ROLLING THE BALL

Wait until you can feel the sensation of the energy ball before beginning the rotations. Imagine the energy ball in the hands and the energy ball in the Lower Dantian blending naturally into one energy, simultaneously rotating and rolling together both internally and externally.

Begin rolling the ball, keeping the mind's intention focused on the center of each palm. Imagine the ball is slowly growing between the hands. Roll the ball, with the hands opposite each other, (one hand is up while the other is down), eighteen times in a clockwise direction, then reverse the direction and repeat another eighteen times (Figure 41.23). After the last rotation, relax the arms and return to Wuji posture.

Figure 41.21. Shaking the Sun and Moon (A)

Figure 41.22. Shaking the Sun and Moon (B)

OPENING AND CLOSING THE UPPER, MIDDLE, AND LOWER BURNERS

This exercise is used to regulate the body's Yin and Yang energy, tonify the Yin organs, calm and harmonize the Yang organs, Regulate the Triple Burners, and help open the Conception and Governing Vessels. This is an excellent exercise for purging and regulating Excess conditions within the Triple Burners, as well as for purging the patient's Liver Fire.

There is an ancient Chinese saying, "Open, close, and come and go, one hundred illnesses will be healed." When opening, the Qi circulates into the muscles. When closing, the Qi sinks and gathers into the bones. The purpose of this exercise is to train the mind's intention, making it easier to increase the body's external field of Wei Qi.

OPENING AND CLOSING THE UPPER BURNER

Begin from a Wuji posture. Both arms raise up to shoulder level. Vigorously shake the hands, palms facing down. Before opening and closing the Upper, Middle and Lower Burner areas, the awareness must settle in the Laogong area (center of the palms) for a few minutes. Wait until heat

Figure 41.23. Rolling the Ball with Both Palms (A)

Rolling the Ball with Both Palms (Side View)

Figure 41.24. Vigorously Shake the Hands

Figure 41.25. Open and Close the Upper Burner (A)

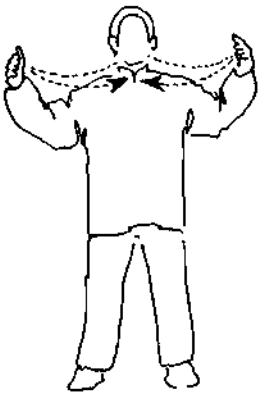

Figure 41.26. Open and Close the Upper Burner (B)

Figure 41.27. Open and Close the Middle Burner (A)

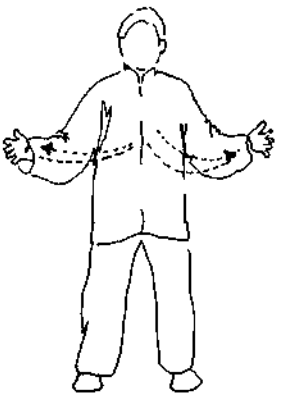

Figure 41.28. Open and Close the Middle Burner (B)

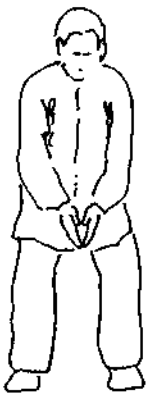

Figure 41.29. Open and Close the Lower Burner (A)

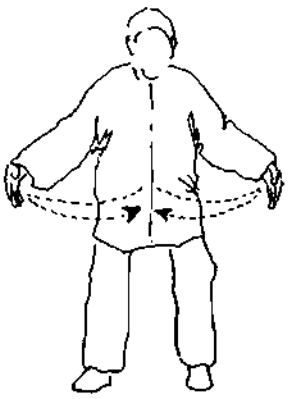

Figure 41.30. Open and Close the Lower Burner (B)

is felt in the center of the palms before beginning (Figure 41.24).

After a while, bring both hands close to each other in front of the throat and manubrium sterni area (the upper segment of the sternum). Both palms face each other, with the fingers facing upwards. Pause a moment, focusing the mind's attention on the center of the palms, forming an energetic ball (Figure 41.25).

Slowly begin to open by pulling the arms apart, while imagining the energy between the center of the palms stretching like warm taffy. When the hands separate and open, the mind and body (chest and abdomen) also open. Slowly begin to close by bringing both palms together, pushing and condensing the stretched energy to form an energetic ball. When the hands close, the mind and body close by removing the attention away from the outside world (Figure 41.26).

When inhaling, imagine extending the fingers deep into the body and the Qi pouring deep into the tissues. When exhaling, separate the hands while imagining the Excess Heat and toxic energy being purged from the body. Repeat the exercise eighteen times.

OPEN AND CLOSE THE MIDDLE BURNER

Both hands sink down in front of the diaphragm and xiphoid process (just above the navel). Pause a moment, keeping the eyes on the energy ball and an imaginary line which connects the inner Laogong Pc-8 points at the center of the palms (Figure 41.27).

Slowly begin to open by pulling the arms apart, while imagining the energy between the center of the palms stretching like warm taffy. While exhaling, separate the hands while imagining the Excess Heat and toxic energy being purged from the body (Figure 41.28).

Slowly close by bringing both palms together, forming an energetic ball as you push and condense the energy. While inhaling, imagine extending the fingers deep into the body and the Qi pouring deep into the tissues. Repeat the exercise eighteen times.

OPENING AND CLOSING THE LOWER BURNER

Both hands sink down in front of the reproductive organs and perineal area. Pause a moment, keeping the eyes on an imaginary line which connects the inner Laogong Pc-8 points at the center of the palms (Figure 41.29).

Slowly begin to open by pulling the arms apart, imagining the energy between the center of the palms stretching like warm taffy. When exhaling, separate the hands while imagining the Excess Heat and toxic energy being purged from the body (Figure 41.30).

Slowly close by bringing both palms together, forming an energetic ball by pushing and condensing the Qi. While inhaling, imagine extending the fingers deep into the body and the Qi pouring deep into the tissues. Repeat eighteen times.

To end the exercise, draw the Qi back into the Lower Dantian, and return to a Wuji posture.

SUN AND MOON ROTATING TECHNIQUE

This exercise will massage the internal organs of both the Heart and the Lungs. In Medical Qigong, the sun is sometimes referred to as the energy of the Heart, which is the considered the master of the three Yang energies. The moon pertains to the Lungs, which are the masters of the three Yin energies. Through the harmony of these dual powers the body's Yuan (Original) Qi is born. This exercise increases the elasticity of the Heart muscles and arteries and improves Blood circulation. It also flushes the Eight Extraordinary Vessels, increases vitality, and causes the upper half of the body to become lighter while making the lower half more solid.

This exercise can also be used in conjunction with the healing sound "Shang" to treat Lung diseases (i.e., asthma and chronic bronchitis), as well as breast cysts and tumors by purging Toxic Qi from the tissues of the Lung.

ROTATING THE PALMS

Begin from a Wuji posture, start by vigorously shaking the hands and then rubbing the palms together (Figure 41.31).

Place both hands on the chest, and draw the heat from the center of the palms into the chest, inhaling three times. Once the chest has absorbed a certain amount of heat, both palms begin to ro-

Figure 41.31. Vigorously Shake the Hands

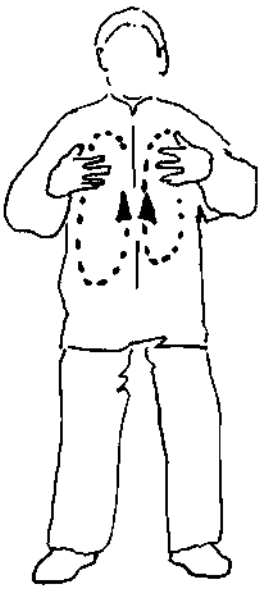

Figure 41.32. Sun and Moon Rotating Technique (A)

Figure 41.33. Sun and Moon Rotating Technique (B)

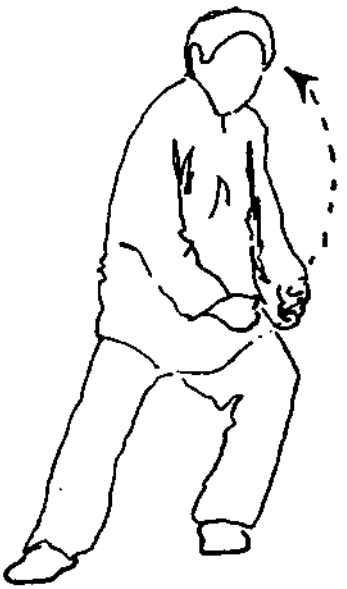

Figure 41.34. Expanding and Contracting the Rings (Forward-A)

Figure 41.35. Expanding and Contracting the Rings (Forward-B)

Figure 41.36. Expanding and Contracting the Rings (Forward-C)

tate up the center line of the chest. The rotation of the arms forms two circles, that circulate the energy from the inside to the outside of the breast. The focus of the intention should be on the "chest opening and the back closing" of the thorax. Repeat this exercise 18 to 36 rotations, depending on the severity of the condition (Figure 41.32).

Next, rotate the circles in the opposite direction, moving from the outside towards the center line of the chest and then down, circulating the energy from the outside to the inside of the breast. Repeat 18 to 36 rotations, depending on the severity of the condition (Figure 41.33).

When the rotations are completed, the middle fingers of both hands slightly press the Conception Vessel downward to descend the Qi into the Lower Dantian. Rub the abdomen three times and resume a Wuji posture.

Expanding and Contracting the Rings

Expanding and contracting the rings refers to the expansion and contraction of the spinal vertebra. This exercise reinforces the flow of the Microcosmic Orbit, invigorates and strengthens the Yuan Qi, aids in transforming Jing to Qi, and strengthens the entire spine. The patient's coordination and balance are also positively affected.

While performing this exercise, the body should move like a "dragon playing in the ocean waves" by appearing and disappearing, rising and sinking, and twisting and coiling. The goal is to stretch and loosen the spinal column, rib articulations, and the back. This will cause the body's Fire to descend and Water energy to ascend naturally through the body's center channels.

This exercise can be modified into a stationary position for convalescing patients or patient's confined to a wheelchair. The patient bends forward, allowing the spine to slowly stretch, shifting the body to a forty-five degree angle.

Begin this exercise from a right Bow Stance (weight is shifting 70% to the back, 30% forward) with both hands positioned in front of the Lower Dantian (Figure 41.34).

Both hands raise upward and stretch forward, creating an arc and stretching the spinal column. When extending and stretching the spine forward, imagine the Earth Qi traveling up the back leg, through the spine and Governing Vessel to the top of the head (Baihui point), and extending down to the Yin Tang and both Laogong points at the center of the palms (Figure 41.35).

While extending the energy outward, use intention to connect with the Heavenly Qi, the energy of the horizon, or a tree (Figure 41.36).

As both hands withdraw, shift the weight to the back leg, allowing the spinal column to contract. As you shift your weight back to the starting position, imagine drawing Qi up from the Earth into your body. Repeat nine times. End in the Wuji posture. Then switch directions by switching the position of the feet and repeat the entire sequence while reversing the rotation.

To perform the second half of the exercise, shift the body's weight forward and begin moving the body in the reverse circular direction (Figure 41.37).

Imagine the Heaven Qi traveling from the Baihui point down the Conception Vessel and out the front foot, extending deep into the Earth (Figure 41.38).

As the weight shifts back, imagine drawing Qi from the Heavens back into the body through the head and hands (Figure 41.39).

Sink the Qi deep into the Earth allowing the body to be cleansed and purified (Figure 41.40). Repeat the exercise nine times. End in the Wuji posture. Then switch directions and repeat the entire sequence.

Descending the Yang and Ascending the Yin Technique

This exercise cultivates Qi in the channels and collaterals of the lower body, aids the free flow of Qi to the Lower Dantian, strengthens the Kidneys, Spleen, Stomach, and the Liver Qi, while regulating the Gall Bladder Qi.

It is an excellent exercise for pulling the Earth Qi (Spleen Qi) up while sinking the Stomach Qi, and is good for treating problems such as irritable bowel syndrome and problems caused from Excess Heat in the Middle and Lower Burners. In order to treat such conditions, the exercise should be performed for twenty minutes, twice a day.

Figure 41.37. Expanding and Contracting the Rings (Reverse-A)

Figure 41.38. Expanding and Contracting the Rings (Reverse-B)

Figure 41.39. Expanding and Contracting the Rings (Reverse-C)

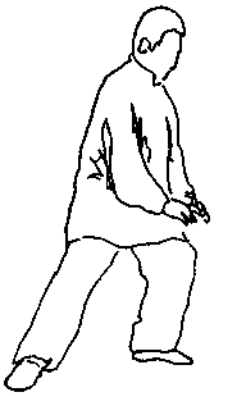

Figure 41.40. Expanding and Contracting the Rings (Reverse-D)

This exercise can furthermore be used in conjunction with the healing sound "Yu" to treat reproductive organ diseases (i.e., uterine and ovarian cysts, tumors, and cancer, as well as prostate cancer). The patient should practice a total of one to four hours each day, depending on the severity of the condition.

Begin from a Wuji posture and embrace the abdomen (Figure 41.41).

Gather Qi into the Lower Dantian and turn towards the left, both hands move into the Huantiao GB-30 point at the side of the hip (Figure 41.42).

Both hands slowly descend the three Yang channels down the outside of the left leg with a "pushing" action, ending on the outside of the left foot at the Bubbling Well point (Kd-1) at the bottom of the foot. As both hands reach downward to the foot, stretch the body and allow the waist to follow the descending Qi with a downward crouching movement (Figure 41.43).

Next, shift the hands around the foot and begin ascending the three Yin channels with the hands inside the left leg. Continue the movement all the way up into the Huiyin point, pubic bone, and Lower Dantian area with a "pulling" and "drawing" action. Pull the anal sphincter upward while drawing the Earth Qi into the body. When both hands raise and gather Qi upward, the body and waist must follow the ascending and rising movements (Figure 41.44).

Pause for a few seconds and let the Qi settle into the Lower Dantian (Figure 41.45).

Shift the body's weight, and repeat the entire sequence on the opposite leg. The turning of the waist should match the movements of the thighs. The toes should naturally grasp the ground and the soles of the feet should feel full of Qi. Repeat nine times on each leg, and end in a Wuji posture.

End the exercise by ascending and descending the Earth Qi through both legs.

From a Wuji posture, both hands embrace the abdomen to gather the Qi of the Lower Dantian and to separate the energy into two balls of energy (Figure 41.46).

Both hands then slowly descend the outside Yang channels of each thigh, all the way to the outside of the feet, ending at the Bubbling Well points (Figure 41.47).

Move the hands along the front of the feet, toward the inside of the foot, slowly ascending the inside Yin channels of each thigh all the way up the body into the Huiyin and Lower Dantian areas (Figure 41.48)

Pause and allow the Qi to settle in the Lower Dantian, then begin again (Figure 41.49). Repeat

Figure 41.41. Descend the Yang and Ascend the Yin Technique (Single-A)

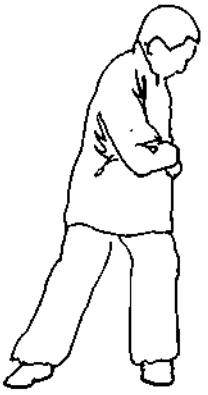

Figure 41.42. Descend the Yang and Ascend the Yin Technique (B)

Figure 41.43. Descend the Yang and Ascend the Yin Technique (C)

Figure 41.44. Descend the Yang and Ascend the Yin Technique (D)

Figure 41.45. Descend the Yang and Ascend the Yin Technique (E)

Figure 41.46. Descend the Yang and Ascend the Yin Technique (Double-A)

Figure 41.47. Descend the Yang and Ascend the Yin Technique (B)

Figure 41.48. Descend the Yang and Ascend the Yin Technique (C)

Figure 41.49. Descend the Yang and Ascend the Yin Technique (D)

this exercise 18 times, then return to the Wuji posture and end the exercise.

TURNING AND WINDING THE BELT VESSEL TECHNIQUE

This tonifying exercise is divided into two methods: the Small Turning and Winding, and the Large Turning and Winding techniques. Each method of exercise causes a different action between the rotation of the energy's circle, the form's circle, and the internal turning action of the Lower Dantian.

Practice the Small Turning and Winding technique first, then proceed to the Large Turning and Winding technique. The small method uses a 180 degree semicircular rotation in addition to the Belt Vessel and Lower Dantian circle rotation.

When practicing the Large Turning and Winding method, the patient's mind must imagine a 360 degree circle rotation of the Belt Vessel. The body moves externally in one direction, while the energy in the Lower Dantian rotates in the reverse direction.

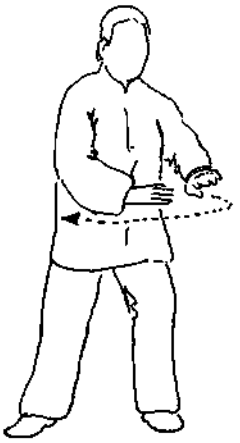

Figure 41.50. Small Turning and Winding (A)

Figure 41.51. Small Turning and Winding (B)

Figure 41.52. Small Turning and Winding (C)

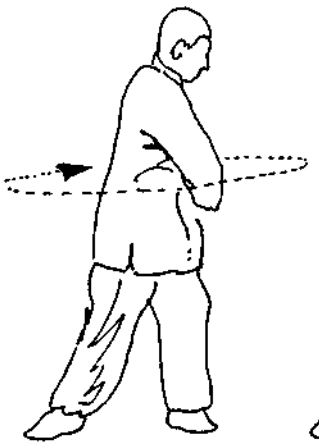

Figure 41.53. Large Turning and Winding (A)

Figure 41.54. Large Turning and Winding (B)

Figure 41.55. Large Turning and Winding (C)

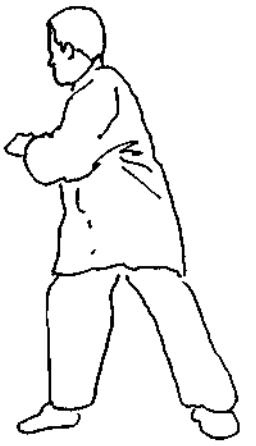

Figure 41.56. Large Turning and Winding (D)

The back and forth, side to side movements of the Turning and Winding action move the body's Qi, and stimulate the energy moving within the Belt Vessel's Qi circle. This energy circle fuses with the external rotation of the hands, allowing the energy from both external and internal Qi circles to be absorbed into the Lower Dantian. Once absorbed into the Lower Dantian, the Qi expands into the body's center core and blends with the Yuan Qi. This strengthens the waist, spine, and enables the Middle Burner's Qi to pervade through the upper and lower parts of the body. This exercise also develops strong and vigorous Kidneys and thus promotes the transportation of the Kidney's Jing and Qi.

SMALL TURNING AND WINDING TECHNIQUE

From a Wuji posture, step forward with the left foot to form a Leaning Horse stance. Raise both palms to waist level, in front of the Lower Dantian, with the palms facing the ground (Figure 41.50).

Inhale and shift the body forward towards the right direction and begin to rotate, turning and twisting the body in a clockwise direction. Imagine gathering the Earth's Qi into the Lower Dantian (Figure 41.51)

Exhale, but allow the mind to focus on absorbing the Earth Qi into the Lower Dantian. Pause for a minute, allowing the Qi to settle after filling the Lower Dantian (Figure 41.52). After nine circle rotations switch directions, moving in the opposite direction nine times.

LARGE TURNING AND WINDING TECHNIQUE

Bring the hands to the right side of the Mingmen and right Kidney area, while placing the mind's intention onto the Lower Dantian and navel area (Figure 41.53).

Inhale, as you extend both hands forward, and begin gathering the Earth's Qi (Figure 41.54).

Begin to circle rotate a 270 degree turn towards the left, while internally the energy of the Lower Dantian circles in the opposite direction to the right (Figure 41.55). Imagine the navel to be the center of the external circle and the Belt Vessel to be the internal circle. The mind's intention leads the energy which guides the hands and moves the body and the waist. The hand movements and center of weight shifting must be synchronized.

Exhale and gather the Earth's Qi into the left Kidney and Mingmen area; repeat nine times. Allow the Qi to fill the Mingmen and Kidneys, then switch directions for nine times (Figure 41.56). End in the Wuji position.

OPENING AND CLOSING THE HEAVEN AND EARTH TECHNIQUE

The purpose of this exercise is to cultivate and strengthen the Lower Dantian energy by blending it together with the Heaven and Earth Qi using the Beating and Drumming the Qi method of Qi cultivation. This cultivation method roots and stabilizes the body, causing the Five Hearts to return to their origin. The Five Hearts (sometimes called the Five Palms) are as follows:

- The Heart of the Baihui area (the Crown Chakra)
- The Hearts of each Laogong area (the palm Chakra)
- The Hearts of each Yongquan area (the bottom of each foot Chakra)

When the energy of the Lower Dantian disperses through the body, as the Mingmen pushes back, the Yuan Qi returns and gathers into the navel. This gathering and extending, back and forth action of energy of the Five Hearts transforms the body's Yuan Qi, strengthens the Yin and Yang energy, opens the body's channels, and encourages the merging of the Heart's Fire and the Kidneys' Water Qi. This method is divided into two techniques: Open the Heaven and Close the Earth, and Open the Earth and Close the Heaven techniques.

OPEN THE HEAVEN AND CLOSE THE EARTH

Begin from a Wuji posture with the left hand on the Lower Dantian and the right hand resting on top of it, both Laogong points face the navel (Figure 41.57).

Keep the mind's intention focused on the navel as the center base. Inhale as both arms raise up the center line of the body (Figure 41.58).

Extend the intention into the Heavens and begin to gather the universal Qi (Figure 41.59). Imagine Heavenly Qi descending and completely

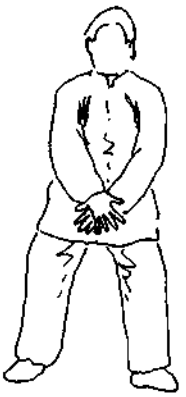

Figure 41.57. Open the Heavens and Close the Earth (A)

Figure 41.58. Open the Heavens and Close the Earth (B)

Figure 41.59. Open the Heavens and Close the Earth (C)

Figure 41.60. Open the Heavens and Close the Earth (D)

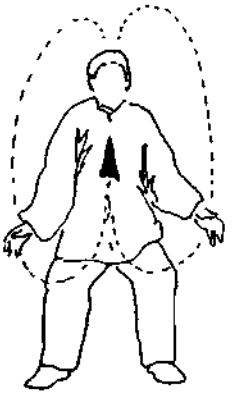

Figure 41.61. Open the Heavens and Close the Earth (E)

Figure 41.62. Open the Heavens and Close the Earth (F)

Figure 41.63. Close the Heavens and Open the Earth (A)

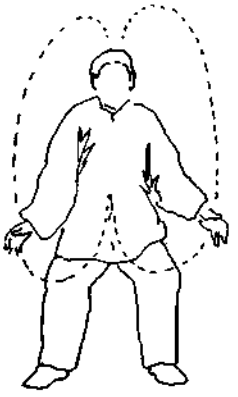

Figure 41.64. Close the Heavens and Open the Earth (B)

Figure 41.65. Close the Heavens and Open the Earth (C)

Figure 41.66. Close the Heavens and Open the Earth (D)

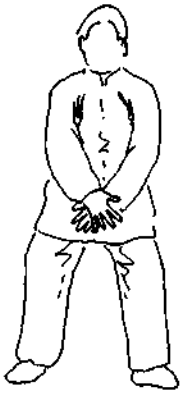

Figure 41.67. Close the Heavens and Open the Earth (E)

Figure 41.68. Collect the Qi and Return it to the Lower Dantian (A)

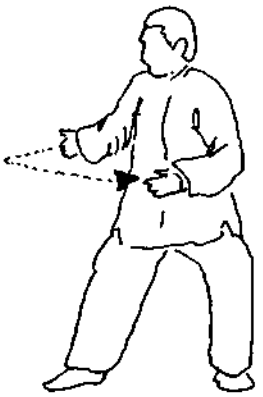

Figure 41.69. Collect the Qi and Return it to the Lower Dantian (B)

Figure 41.70. Collect the Qi and Return it to the Lower Dantian (C)

filling the body (Figure 41.60). Exhale and gather the Heavenly Qi deep into the body's center core (Figure 41.61).

Lead the energy from inside of the body's center core to the outside, imagining Heavenly Qi, like steam, releasing through the pores and filling up the body's external energy bubble like a mist (Figure 41.62). Repeat 18 times.

OPEN THE EARTH AND CLOSE THE HEAVENS

This is the exact reverse action of the Open the Heaven and Close the Earth technique. Begin from a Wuji posture with the left hand on the Lower Dantian and the right hand resting on top of it, both Laogong points face the navel (Figure 41.63).

Inhale and begin to separate the hands, moving them to the outside of the body (Figure 41.64). Imagine gathering the Earth's Qi into the body as the hands raise upwards towards the head (Figure 41.65). Exhale and gather the Earth's Qi deep into the body's center core (Figure 41.66).

Lead the energy from inside of the body's center core to the outside, imagining the Earth's Qi, like steam, releasing through the pores and filling up the body's external energy bubble like a mist (Figure 41.67). Repeat 18 times, then pause and relax, returning to the Wuji posture.

COLLECT THE QI AND RETURN TO THE LOWER DANTIAN TECHNIQUE

The purpose of this exercise is to gather both universal and environmental energy and to store it in the navel. This exercise is used for treating Deficient conditions.

COLLECT AND RETURN

Begin from a Wuji posture and step out to the right, forming a Horse Stance. The left hand swings to embrace the navel and Lower Dantian as the body shifts its weight and twists toward the right (Figure 41.68).

The body slowly begins to shift from side to side while the opposite hand gathers the universal and environmental energy, gathering and packing it into the navel and Lower Dantian area (Figure 41.69).

During the exchange of left and right hands collecting Qi, imagine that the body is swimming in water. Imagine the energetic consistency of the air, like water, following each arm as it moves, flowing into the center of a whirlpool located in the navel and Lower Dantian area (Figure 41.70). Repeat 18 times. End in Wuji posture.

QIGONG SELF-HEALING MASSAGE AND POINT THERAPY

Qigong Massage and Point therapy is usually practiced after the Qigong meditations and exercise prescriptions. It involves having the patient lightly massage or tap the skin, while extending Qi into the various channels, points, and tissues. These self-healing massage techniques are specifically designed to disperse stagnations and Excess conditions, as well as to activate and regulate the energetic flow within the body's external and internal channels, thereby increasing the energy flow.

These massage techniques can be practiced from either a lying, sitting, or standing posture.

WASH THE FACE

This exercise stimulates the skin and facial muscles. Begin from a Wuji posture. Shake the hands vigorously to remove any External pathogenic Qi. Then slap the palms and rub the hands together vigorously until they get hot. Gently place both hands over the eyes and inhale, absorbing the heat into the face and Upper Dantian. While inhaling, allow the Qi to enter the Taiji Pole.

Exhale and imagine the energy gathered in the Upper Dantian descending down the center of the body, flowing into the Lower Dantian. Perform this gathering and descending action three times.

Next, both hands begin to wash the face, in an outward circular motion. Allow the hands to massage the face, up from the nose, eyes, and forehead, down along the temples, cheeks, and across the chin and mouth, returning back to the nose. Perform this face massage technique for 9 breaths.

Shake the hands vigorously to remove any External pathogenic Qi, then proceed to the next exercise.

MASSAGE THE HEAD

Guide all ten fingers over the head and down over the back of the neck (this is called Ten Dragons Run Through the Forest). Repeat nine times. This can be performed either by touching or not touching the head (Figure 41.71).

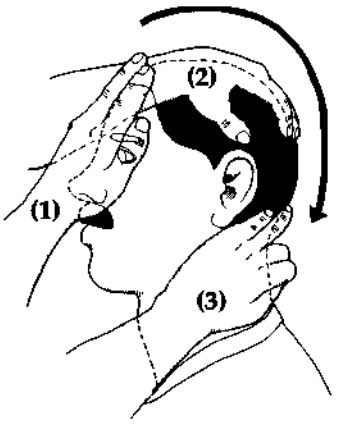

Figure 41.71. Wash the Face and Massage the Head: After rubbing the hands to heat the palms, place both hands on the face and draw the heat in through the eyes and into the Upper Dantian (1). Next, comb the hair with the fingertips (2), and drain the excess Qi from the head and neck area (3).

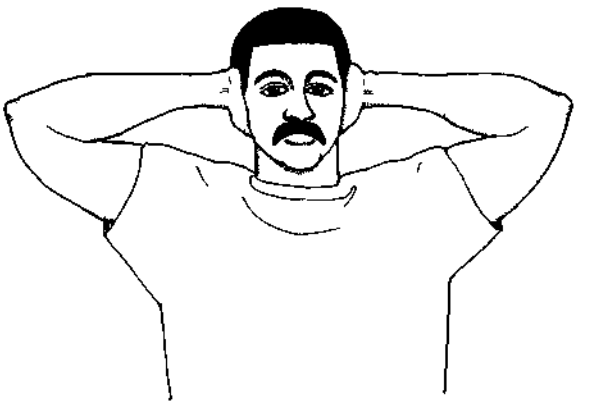

Figure 41.72. Beating the Heavenly Drum

BEATING THE HEAVENLY DRUM

This exercise balances the air pressure in the eustachian tubes and ear canals, relieves tinnitus, helps prevent vertigo, relaxes the mind, helps to improve hearing, expels stagnant Qi collected at the back of the head (within the Jade Pillow), and also stimulates the pineal gland and Kidneys' Qi.

Begin by interlacing the fingers and place both hands on the back of the head. The palm of each hand should cover the ears. While compressing the ears, close your eyes and practice the Beating and Drumming thumping method at the back of the head in the rhythmic sequence of a heart beat. This causes relaxation and creates an altered, in-utero state of consciousness. The index fingers of each hand should thump the Jade Pillow (Bl-9) at the back of the occiput pass 36 times (Figure 41.72).

After thumping the back of the head, clench the teeth, close the mouth, and bend the body over. Exhale while bending over and bring the head between the legs. The legs are straight, waist and buttocks are relaxed, and both eyes look towards the back from in-between the legs, while holding the breath (Figure 41.73).

Next, raise the body up, inhale and again perform the Beating the Heavenly Drum sequence. Practice this exercise 14 times.

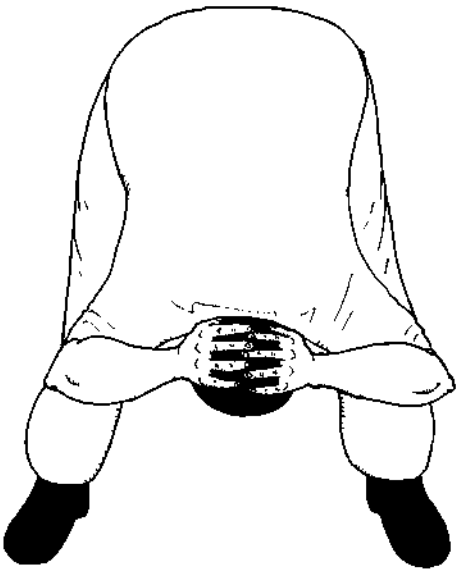

Figure 41.73. Bend the Body Over While Holding the Breath

PRESSING THE EARS

This exercise is used to enhance hearing, stimulate mental energy and also to stimulate the Kidneys' Qi. Use the Laogong areas at the center of each palm to compress the ears (like a plunger). Repeat this exercise nine times (Figure 41.74).

Next, move the right hand behind the head and pull the left ear (at a 45 degree angle) towards the back, with the left hand is placed on the Lower Dantian. Hold this posture for 9 breaths, then reverse for 9 breaths.

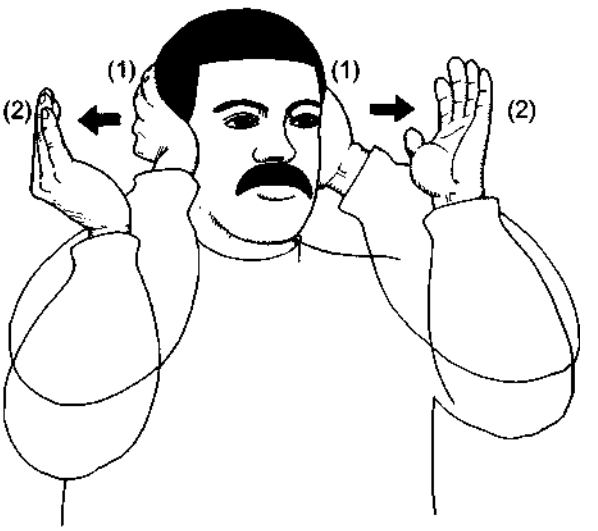

Figure 41.74. Pressing the Ears

RUBBING THE EYES

RUBBING THE EYES (SEQUENCE #1)

This exercise is good for enhancing Qi and Blood circulation to the eyes for improving vision, treating eye diseases (especially glaucoma), relieving fatigue (caused by eye strain), and also for stimulating the Liver Qi.

With both thumbs resting on the cheekbones, form two soft fists and, using the edge of the index knuckles, begin to massage in a circle the top of the eyelids (from the bridge of the nose out along the eyebrows). Next massage just bellow the bottom of the eyelids from the bridge of the nose. Alternate from top to bottom 18 times (Figure 41.75).

RUBBING THE EYES (SEQUENCE #2)

With the thumbs still resting on the cheekbones, use the tip of the index fingers to massage the points around the eyes, from the inner corners of the skin, in a circular motion. Start rotating in a small circle, at the Bl-1 point. Circle nine times towards the inside, then nine times towards the outside, for a total of three breaths.

Next massage the middle of the eyebrows at the Extra Point Yu Yao. Then proceed to the outside of the eyes at the GB-1 point. (3) End at the base of the eyes at the St-1 point. Each area should be massaged 18 times (9 times towards the inside, then 9 times towards the outside) (Figure 41.76).

Figure 41.75. Rubbing the Eyes (Sequence 1)

MASSAGING THE NOSE

This exercise is performed to treat colds, reduce swelling of the sinus tissues, eliminate mucus from the airways, stimulate the sinus nerves, open the nasal passages, and also stimulate the Lungs' Qi.

Begin by making soft fists and use the sides of the thumbs to massage the sides of the nose at the LI-20 points in an up and down motion 9 times pressing inward, and then 9 times pressing outward (Figure 41.77).

Next, use the tips of the index fingers and press deeply at the base of the nose at the LI-20 points, for a period of ten seconds, then circle-massage for 18 rotations. Press deeply midway up the nose, on both sides at the Bitong points for a period of ten seconds, then circle-massage 18 times. Finally, both fingers press deeply at the upper point at the bridge of the nose at the Shangen points for ten seconds, then circle-massage 18 times.

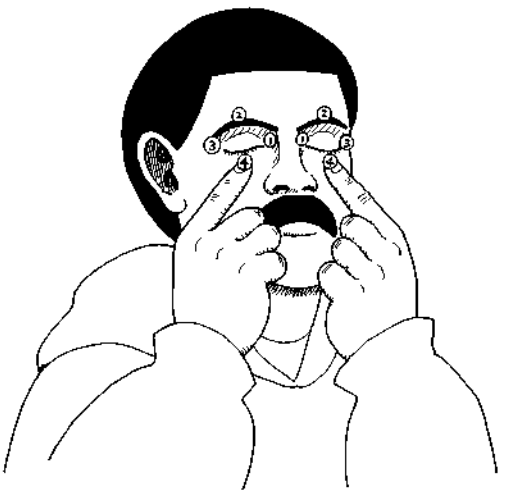

Figure 41.76. Rubbing the Eyes (Sequence 2)

CLICKING THE TEETH

This exercise is good for strengthening the teeth and gums, tonifying the jaw muscles, im-

proving the Qi and Blood circulation to the gum tissues, and also to enhance the Kidneys' Qi. Clamp the jaws shut so that the teeth are pressing together and the jaw muscles flex. Click the teeth 36 times.

WAGGING THE TONGUE

This exercise is good for stimulating the salivary ducts beneath the tongue, and also for stimulating the Heart's Qi. Wag the tongue on the outside gums 18 times in one direction, 18 times in the opposite direction, then 18 times from the lower to upper palate, and finally, 18 times pressing the tip of the tongue against the back of the teeth (Figure 41.78).

SWALLOWING THE SALIVA

Saliva contains many kinds of enzymes which aid in digestion. In ancient China, this practice was sometimes called the Immortal's Water or Juice of Jade, because the saliva is energized during the Qigong meditation and believed to contain special healing properties.

To begin, inhale and swallow the saliva with a big gulp (three times), using the breath as a seal or bubble to enclose the air, then send it down the Conception Vessel to bathe the Five Yin Organs, ending at the Lower Dantian. It is important to tilt the head slightly forward (after inhaling) before swallowing the Immortal's Water.

WHIRLING THE NAPE AND TURNING THE NECK

The purpose of this exercise is to massage the thyroid and larynx as well as to stretch the muscles and tendons throughout the neck and cervical vertebrae.

To begin, place the back of the hands on the Kidneys. While relaxing, allow the head to relax and naturally hang, slowly rotating its motion to the left and right nine times (Figure 41.79).

Next, suspend the head and slowly twist the nape of the neck to the right and left direction nine times. While performing this exercise, focus the mind's intention on the Lower Dantian. When finishing, focus the mind's attention on the Bubbling Well points at the center of the feet.

Figure 41.77. Massaging the Nose

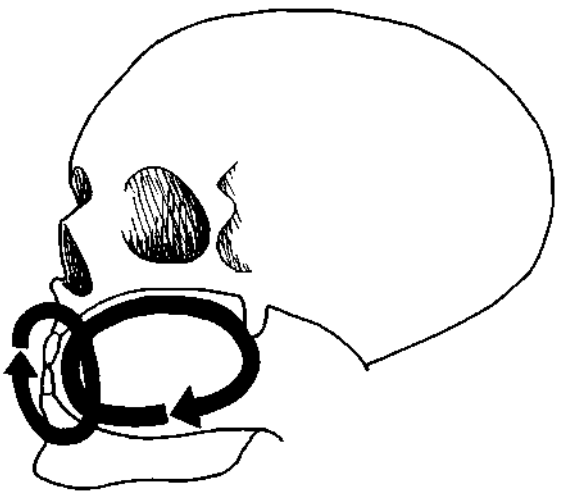

Figure 41.78. Wagging the Tongue

MASSAGING THE CHEST AND ABDOMEN

The purpose of this exercise is to disperse Excess Qi from the chest and abdominal area. This allows the body to balance the energy of the upper torso with that of the lower torso.

Beginning with the mind's attention focused on the Laogong areas at the center of each palm (Pc-8), brush the chest and abdomen downward nine times, starting from the collar bone and ending by the pubic bone (Figure 41.80).

MASSAGE TAPPING THE HANDS (LI-4)

Stimulating the Hegu or Joining of the Valleys points. The purpose of this exercise is to clear and activate the channels and collaterals, regulate, tonify and promote the circulation of Qi, to dispel pathogenic Wind, clear Fire and Heat, and to tranquilize the mind.

Begin by extending both arms in front of the body and allow both hands to collide into each other, thus tapping the Hegu points located between the thumb and first finger. Repeat nine times (Figure 41.81).

MASSAGE TAPPING THE FOREARMS (PC-6)

Stimulating the Neiquan or Inner Border Gate points. The purpose of this exercise is to regulate and tonify the Qi and Blood of the Heart and Stomach, to clear the Heart Fire, transform the Heart Phlegm, and to calm the Heart.

Begin by forming a hollow fist with the right hand and then lightly tap the Neiquan point located three fingers up from the wrist fold, on the lower left forearm area, nine times. Switch arms and repeat (Figure 41.82).

MASSAGE TAPPING THE ELBOWS (LI-11)

This exercise stimulates the Quchi or Crooked Pond points. The purpose of this exercise is to help dispel pathogenic Wind from the body, to regulate the Stomach and intestines, eliminate stasis, relax the muscles and tendons, lubricate the joints, and to cool the Heat in the Blood.

To begin, the right hand forms a hollow fist

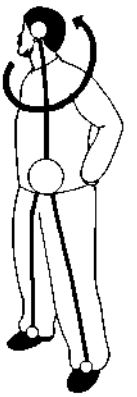

Figure 41.79. Whirling the Nape and Turning the Head

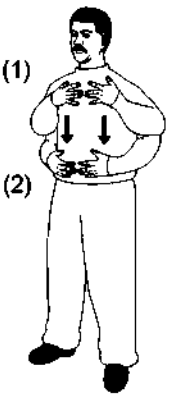

Figure 41.80. Massaging the Chest and Abdomen

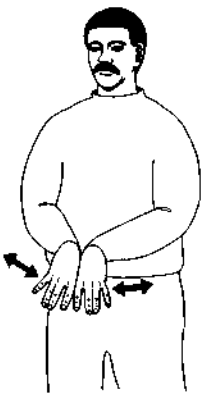

Figure 41.81. Massage Tapping LI-4

and lightly taps the Quchi point located at the end of the left elbow-fold, nine times. Switch arms and repeat (Figure 41.83).

MASSAGING UNDER THE ARMS (HT-1)

This exercise stimulates the Jiquan or Supreme Spring points. The purpose of this exercise is to regulate the Qi of the Lungs and Heart, promoting the circulation of Qi and Blood, as well as to regulate the blood vessels.

To begin, the right hand reaches under the left arm pit and circle massages nine times. Switch sides and repeat nine times (Figure 41.84).

MASSAGE TAPPING THE UPPER SHOULDERS (GB-21)

This exercise stimulates the Jianjing or Shoulder Well points. The purpose of this exercise is to regulate the body's Qi activities, disperse Liver Qi stagnation, extinguish Liver Wind, dispel Wind and Cold, redirect Rebellious Qi downward, and to dredge Excess Qi from all the Yang channels.

To begin, the right hand forms a hollow fist or soft palm and taps the left Jianjing point located on the upper ridge of the neck, while the left hand alternately taps the right Jianjing point. Both left and right tapping count as one set. Perform nine times (Figure 41.85).

MASSAGING THE ARMS

This exercise stimulates the six channels of the arms (the three Yang channels located on the outside, three Yin channels located on the inside).

Begin by placing the right palm on the inside of the left shoulder. Exhale and rub the entire arm from inside the shoulder and arm to the fingers. Next inhale and rub the entire outside of the arm from the fingers to the outside of the shoulder. Continue this movement for 18 breaths, then repeat on the other side (Figure 41.86).

MASSAGE TAPPING THE LOWER DANTIAN (CV-6)

This exercise stimulates the Qihai or Sea of Qi points. The purpose of this exercise is to energize and tonify the lower abdominal organs, as well as to stimulate the Qi of the Lower Dantian.

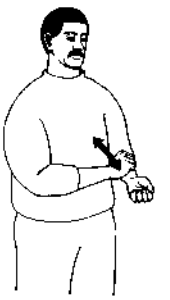

Figure 41.82. Massage Tapping Pc-6

Figure 41.83. Massage Tapping LI-11

Figure 41.84. Massaging Under the Arm Ht-1

Figure 41.85. Massage Tapping GB-21

Begin by stroking the chest, gathering the body's Qi down into the Lower Dantian. Using either soft fists, palms, or fingers, both hands lightly tap the Lower Dantian and navel area for three breaths (Figure 41.87).

MASSAGE TAPPING THE BACK OF THE WAIST (GV-4)

This exercise stimulates the Mingmen or Gate of Life point. This exercise stimulates and tonifies the Kidneys, adrenal glands, and the Mingmen. It is used to regulate the Governing Vessel, excite and strengthen Kidneys' Yang Qi, to replenish the Kidneys, as well as to strengthen the lower back and bones.

Begin by slightly leaning the body forward. Using the right and left soft palms or hollow fists, lightly tap the back of the waist, Mingmen and the Kidneys' area for three breaths (Figure 41.88).

MASSAGE TAPPING THE SIDES OF THE HIPS (GB-30)

This exercise stimulates the Huantiao or Jumping Circle points. The purpose of this exercise is to dispel Wind and Cold, reduce pain in the thighs and legs, as well as to strengthen the lower back, and tonify the lower extremities.

Using the right and left hollow fists or soft palms, lightly tap the hip bone Huantiao points nine times (Figure 41.89).

MASSAGE TAPPING THE THIGHS (GB-31)

This exercise stimulates the Fengshi or Wind's Market points. The purpose of this exercise is to dispel Wind and Cold, clear Heat, tonify the legs, reduce flaccidity and numbness of the lower extremities, and to transform Dampness.

Using the right and left hollow fists or soft palms, lightly tap the upper thighs at the Fengshi Points nine times (Figure 41.90).

MASSAGE TAPPING THE OUTSIDE OF THE KNEES (GB-34)

This exercise stimulates the Yanglingquan or Yang Mound Spring points. The purpose of this exercise is to relax the muscles and tendons, acti-

Figure 41.86. Massaging the Arm Channels

Figure 41.87. Massage Tapping the Lower Dantian

Figure 41.88. Massage Tapping the Mingmen GV-4

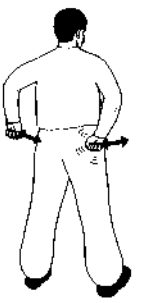

Figure 41.89. Massage Tapping GB-30

vate the flow of Qi and Blood in the channels and collaterals, relieve spasms and pain, clear away Damp-Heat, and disperse stagnant Liver and Gall Bladder Qi.

Using the right and left hollow fists or soft palms, lightly tap the outside of the knees at the Yanglingquan points nine times (Figure 41.91).

MASSAGE TAPPING THE INSIDE OF THE KNEES (SP-9)

This exercise stimulates the Yinlingquan or Yin Mound Spring points. The purpose of this exercise is to regulate and tonify the Spleen (Yang), Stomach (Yin), and Lower Burner, to resolve Dampness and Damp Heat, as well as to treat knee pain and problems with difficulty in urination.

Using the right and left hollow fists or soft palms, lightly tap the inside of the knees at the Yinlingquan points nine times (Figure 41.92).

MASSAGE TAPPING THE BACK OF THE KNEES (BL-40)

This exercise stimulates the Weizong or Entrusting Middle points. The purpose of this exercise is to relax the muscles and tendons, activate the flow of Qi and Blood in the channels and collaterals, cool the Blood to stop bleeding, transform Damp Heat in the Bladder and intestines and to strengthen the waist and knees.

Using the right and left hollow fists or soft palms, lightly tap the back of the knees at the Weizhong points nine times (Figure 41.93).

MASSAGE TAPPING BELOW THE KNEES (ST-36)

This exercise stimulates the Zusanli or Foot Three Miles points. The purpose of this exercise is to regulate the Stomach and intestines, facilitate the flow of Qi to relieve bloating and distention, to dissipate stagnation and obstructions, to promote the circulation of Ying Qi, to alleviate water retention and subdue swelling, and to activate the flow of Qi and Blood in the channels and collaterals.

Using the right and left hollow fists or soft palms, lightly tap the lower leg Zusanli points nine times (Figure 41.94).

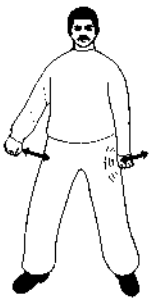

Figure 41.90. Massage Tapping GB-31

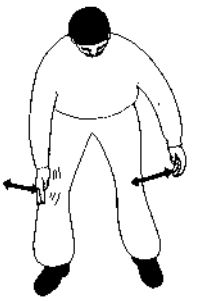

Figure 41.91. Massage Tapping GB-34

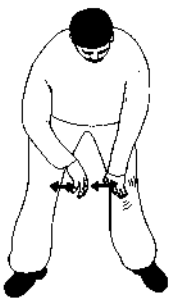

Figure 41.92. Massage Tapping Sp-9

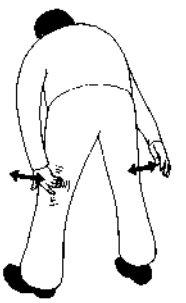

Figure 41.93. Massage Tapping Bl-40

MASSAGE TAPPING ABOVE THE MEDIAL MALLEOLUS (SP-6)

This exercise stimulates the Sanyinjiao or Three Yin Crossing points. The purpose of this exercise is to tonify and regulate the Qi and Yang of the Spleen, as well as regulate the Qi of the Stomach, Middle and Lower Burners, reduce digestive stagnation, and to facilitate Blood flow.

Using the right and left hollow fists or soft palms, lightly tap the inside of the lower leg at the Sanyinjiao points nine times. (Figure 41.95).

MASSAGE TAPPING THE HEELS (KD-1)

This exercise stimulates the Yongquan or Bubbling Spring points. The purpose of this exercise is to tonify the Kidneys' Yin and Jing, tranquilize the mind, clear away Heat, purge pathogenic Fire, calm the Liver and to stop pathogenic Wind.

To begin this exercise make sure that the knees are slightly bent. Quickly rise and fall on both heels to stimulate the Yongquan points and shake the back nine times (Figure 41.96).

TREMBLING THE KNEES

The purpose of this exercise is to disperse stagnant Qi, as well as to relax the perineum.

To begin this exercise, relax, then bend and straighten the knees quickly for nine times. Next shake them from side to side quickly in order to tremble and shake the entire body. Repeat nine times (Figure 41.97).

CIRCLING THE ABDOMEN

The purpose of this exercise is to balance the Lower Dantian Qi, stimulate the Stomach and bowels, and enhance digestive peristalsis.

To begin, place the center of both palms on the Lower Dantian, embracing the navel (for men, the left palm is on the top, opposite for women). Focus the mind's intention deep into the Lower Dantian. While using the navel as the center, connect the energy of the Lower Dantian with the center of the palms as they rotate.

Begin to circle 36 times counterclockwise for men (from the patient's point of view), whereas the rotation is clockwise for women. Allow the circle to gradually move from a smaller to a larger

Figure 41.94. Massage Tapping St-36

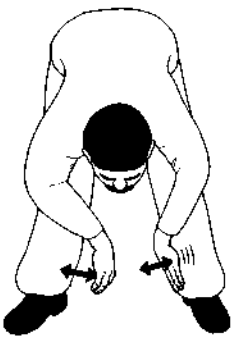

Figure 41.95. Massage Tapping Sp-6

Figure 41.96. Dropping the Heels to Stimulate Kd-1

rotation (as the hands circle, imagine that they are dispersing the Qi). Pause and reverse the circle, rotating 24 times in the opposite direction, gradually reducing the circle's size. This will draw the Qi from the outer portion of the body and collect it into the Lower Dantian. Pause for a moment then return to the Wuji position (Figure 41.98).

COMPLETING THE EXERCISE

Upon completion of the exercise, close the Four Doors (the center of each palm and foot) and cultivate the Qi with stillness, allowing the energy to return to its origin. Hold a quiet Wuji postue for about 15 minutes.

The purpose for the first circle rotation is to release the Yuan Qi which has been collected and gathered in the Lower Dantian. This is to avoid any stagnation which may cause the energy flow to slow down. This also disperses and releases the Yuan Qi, allowing it to blend with the Essential Qi of the Five Yin Organs.

When performing the reverse or second circle rotation, allow all the dispersed energy to gather together and return back to the Lower Dantian. This accumulates and stores the organ energy, blending it together with the Original Qi.

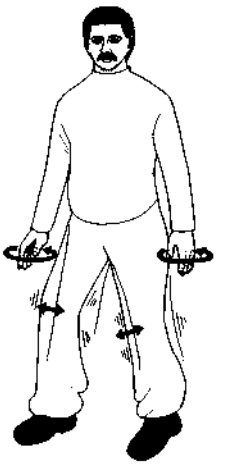

Figure 41.97. Trembling the Knees

Figure 41.98. Circling the Abdomen to Finish

Chapter 42
Daoist Qigong Regulation Exercises

This particular school of Daoist Medical Qigong Regulation was first introduced in the West by one of my teachers, Dr. Her Yue Wong. These techniques have become increasingly popular, as they are simple, yet extremely effective in tonifying and regulating the body's organ energy.

The interesting thing about Western healing practices is that they focus on the neuromuscular skeletal system to the exclusion of the visceral system, not recognizing that the visceral system is necessary to supply the fuel for the neuromuscular system. These following exercises focus on the visceral system and enhance the quality of life of the viscera.

The system as a whole is divided into two sections. The first section stimulates, energizes, and regulates the body's Yang organs and channels. The second section stimulates, energizes, and regulates the body's Yin organs and channels.

The exercises can be practiced as a complete system, or singled out individually and practiced as tonification prescriptions. As with any Medical Qigong prescription, the patient must purge his or her body of Toxic Qi before starting the tonification exercise and return the Qi back to the Lower Dantian upon completion.

Daoist Five Yang Organ Regulation Exercise

This exercise massages the five Yang digestive organs, strengthens the peristaltic action of the body's digestive system, as well as increases the capillary circulation through the stimulation of the autonomic nervous system. The Yang digestive organs (Stomach, Small Intestine, Large Intestine, Urinary Bladder, and Gall Bladder) are used by the body to release waste and Turbid Qi; therefore, it is important to keep the Yang organs strong and functioning smoothly.

The Beating and Drumming the Qi Breath Regulation (which is employed within this exercise) is beneficial for those patients who suffer from digestive problems and irregularity (i.e., spastic colon, chronic diarrhea, irritable bowel syndrome, etc.).

When the patient's arms swing rhythmically throughout the exercise, the nerves and Qi channels of the shoulder joints become stimulated. The swaying action of the arms increases the circulation in the energetic channels which connect the different internal organs and terminate at the hands.

Although this exercise is simple, the result in strengthening the body's peristaltic action and curing digestive illnesses is very effective. The patient is therefore cautioned not to eat prior to practicing this exercise.

Swaying the Arms while Beating and Drumming the Qi

Assume a wide stance with the arms suspended by the sides of the body. While inhaling, swing the arms up straight out in front of the body and then bring the hands in by the chest (Figure 42.1). Expand the abdomen fully focusing the mind's inten-

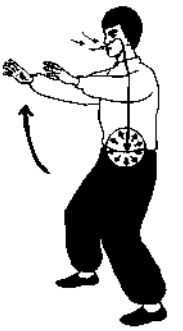

Figure 42.1. The Daoist Five Yang Organ exercise. Inhale and draw the Qi into the Lower Dantian while swinging the hands forward.

tion on filling the lower abdomen with Qi.

When exhaling, swing the arms back behind the body while compressing the abdomen down and inward directing the Qi to flow from the lower perineum, circulate back into the sacral area, then to the navel and back down to the perineum (Figure 42.2).

Continue to swing the arms back and forth at a pace that is comfortable using natural breathing. The abdomen should expand and contract without forcing the respiration. The patient must have the anal sphincter closed throughout the entire exercise. Continue this repetition for at least 50 breaths. Try to work up to 250 breaths or more for chronic conditions of abdominal obstruction and Qi stagnation within the digestive system.

The pressing and releasing action of the abdomen stimulates the energetic functions of the autonomic nervous system. The autonomic nervous system has two divisions:

1. The fight or flight mechanism of the sympathetic division -- which shuts down the digestive system due to the production of adrenaline or norepinephrine and redirects Qi and Blood flow to the brain and skeletal muscles, and
2. The vegetative, renewal mechanism of the parasympathetic division -- which draws Qi and Blood from the brain into the digestive system.

The centers for neuronal control of the autonomic nervous system and also control the digestion and tubal contraction are located in the cranium and in the sacrum. The accessory nerve and vagus nerve carries from the brain stem, its nucleus (or center), all of the information to supply the digestive system with impulses to stimulate peristaltic contraction. At the lower end of the digestive system, the sigmoid colon, rectum, Bladder and uterus are controlled by nerve fibers coming from the first, second, and third sacral foramina. The action of the cranial-sacral division of the parasympathetic nervous system is to stimulate peristaltic action (hence the movement of nutrients through the digestive system).

The movement of the abdominal cavity, diaphragm, and thoracic cavity changes the position of each organ and enhances its function. By tightening the anal sphincter and compressing and releasing the urogenital diaphragm, the reproductive organs are also stimulated, including the uterus, prostate, urethra, and testicles. Finally, the Daoist Five Yang Organ Regulation exercise also enhances the peristaltic action of the body's lymphatic system, circulatory system, and tubal systems.

Figure 42.2. Exhale and compress the abdomen, allowing the hands to swing behind the body.

DAOIST FIVE YIN ORGAN TONIFICATION AND REGULATION EXERCISES

Each of the following exercises are designed to stimulate the specific internal Yin organ, as well as the paths of energy that flow from the channels of each organ. Since the Yin organs have the responsibility of storing energy, each exercise is named for the organ it tonifies.

The Yin exercises are performed in the sequence shown below without pausing in-between transitions. Unless specifically prescribed as a therapeutic modality, each exercise should flow directly into the next. The transitions are very important for continuity of energy flow. This particular Five Yin Organ series begins with an opening exercise and ends with a closing exercise.

OPENING, COLLECTING, AND MOVING THE QI

The opening exercise is designed to stretch and loosen the spinal vertebrae and to facilitate the energy flow through the patient's Governing Vessel. The spinal stretch also stimulates the flow of fluids and electrical impulses in the central nervous system (brain and spinal cord), which is nurtured by

the cerebral spinal fluid. When the fluid starts to move, it awakens the nervous system causing more nutrients to enter the cellular structure of the nerves. The stretching, compressing, and pumping action of the spinal cord stimulates the movement receptors located in all of the ligaments and fascia energizing the body's entire proprioceptor mechanism.

The opening exercise is also designed to stretch the connective tissue, warm the body's intercellular matrix and tissues, stimulate the somatic system, free adhesions, as well as enhance the elasticity and compressibility of the ligamentous structure.

After finishing the Daoist Five Yang Organ Regulation exercise, return both hands to the Lower Dantian. Next, raise both hands above the head as you inhale (Figure 42.3).

Imagine energy (like a rushing river) flowing up from the feet, filling the legs, hips, waist, chest, arms, and head. Every square inch of the body is absorbing and being saturated with this Earth energy. When the entire body is completely full, the hands should still be positioned above the head (Figure 42.4).

Begin to exhale and feel the hands getting very heavy. The heaviness pulls the hands forward and then slowly starts to pull the body over. Slowly bend the head forward and feel the cervical vertebrae stretch. Let the hands pull the arms, which in turn will pull the shoulders and torso, followed by bending at the waist. The purpose of this movement is to feel each vertebra of the spine stretch sequentially so that a rippling effect descends down the spine. This will facilitate maximum stretch of the spine. While bending over, exhale and imagine the energy melting away from the entire body (like ice melting into water) slowly dissolving and rushing down through the feet and out into the ground (Figure 42.5).

Once completely bent over, imagine picking up a ball. Bend the knees and slowly stand up. While standing up, reverse the rippling of the spine from the coccyx, sacrum, and lower lumbar vertebrae to the base of the skull (Figure 42.6). Repeat these movements five times. Remember to inhale while raising the body, bring both arms over your head, and exhale as the body descends.

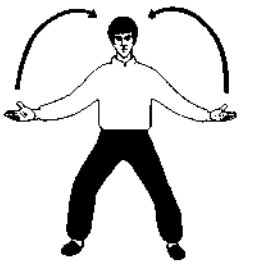

Figure 42.3. The Daoist Five Yin Organ Opening exercise. Begin by stretching the arms above the head.

Figure 42.4. Inhale and imagine the Earth Qi like water filling the entire body.

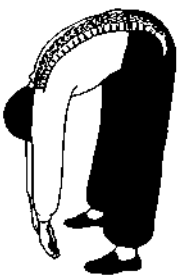

Figure 42.5. Exhale, bend the body and imagine any tension melting out the body into the Earth.

Figure 42.6. For the transition movement to the Lung Tonification exercise: inhale, bend the knees and slowly stand up.

LUNG TONIFICATION AND REGULATION EXERCISE

This exercise is designed to massage the Lungs' tissues and nerves, as well as tonify the entire Lung organs and channels. In the Lung exercise, both the sympathetic and parasympathetic divisions of the autonomic nervous system are stimulated. The compression and release action of the scapulae and thoracic vertebrae stimulate the nerves, arteries, veins and capillary system in the thoracic region.

Compressing and releasing of the muscles and blood vessels in the back and chest areas stimulates the transforming of the Qi and Blood and enhances the health of the individual tissue cells. The compression and release of the thorax also increases the stimulation of the nervous system in the Lung area, as well as stimulates the "release and return" action of the lymphatic system. All the major lymphatic ducts are located in the posterior portion of the thoracic wall.

The compression and release of the second, third, and fourth thoracic vertebrae stimulates the sympathetic preganglionic fibers from the spinal cord, which in turn stimulates the postganglionic fibers and the sympathetic outflow to the Lungs and bronchi. Patients practice this exercise to strengthen their respiratory system as well as increase the production of their Wei Qi to enhance their body's immune system.

Upon completion of the Opening exercise, the patient brings the hands above the head and places them in front of the torso at shoulder level while exhaling. The patient's palms should be facing downward parallel with the floor (Figure 42.7).

Inhale and bring the arms straight out to the sides (both hands should not go any higher than the shoulders) (Figure 42.8).

As the arms reach the sides of the body, rotate the palms until they face upward. Keep the shoulders stable and relaxed (Figure 42.9).

While exhaling, bring the arms straight out in front of the body returning to the beginning posture (Figure 42.10).

Allow the scapulas to gently push the arms forward. The sternum at this point is pushed inward so as to hollow the chest. Once the hands are aligned in the front of the shoulders, rotate the arms and

Figure 42.7. The Lungs Tonification exercise: Inhale as the hands separate.

Figure 42.8. Separate the Hands and turn the palms upward.

Figure 42.9. Exhale as you bring the arms toward each other.

Figure 42.10. Draw the hands toward each other and turn the palms facing the Earth.

inhale to begin again. Repeat 20 times.

Note: Do not let the hands touch when bringing the arms back together towards the center line of the body. The body will short circuit itself, resulting in a mild shock or a sick feeling inside the thorax by the Heart.

KIDNEY TONIFICATION AND REGULATION EXERCISE

This exercise is designed to massage the Kidneys' tissues and nerves, as well as tonify the entire Kidney organs and channels. According to Western physiology, the Kidneys maintain the chemical, pH (potential of hydrogen), and temperature balance of the Blood. The Kidneys function like a rheostat changing the body's ability to absorb, retain, or release water according to the environment (e.g., retaining water in hot climates).

The twisting back and forth, pumping action of the exercise stimulates an opening and closing action within the Kidney organ. The Kidneys receive the major Blood supply from the abdominal aorta. In the Kidney exercise, the action of raising the torso upwards will literally suck Qi and Blood into the Kidney area.

Patients practice this exercise to strengthen their reproductive system, as well as increase the production of their Jing. It also helps balance the body's general energy condition, and can be used to treat sexual disorders and malfunctions.

Upon completing the Lung exercise, both arms are extending straight out in front of the body (Figure 42.11).

Inhale and drop the elbows and bring the hands down in front of the Lower Dantian (Figure 42.12).

Exhale and shift the weight to the left. As the left outer palm wraps around the back, resting itself on the right Kidney, the right palm extends towards the left direction (Figure 42.13).

The right palm, facing outward towards the left direction, begins to circle upwards in front of the face at eye level. As the palm begins to move, the eyes watch the back of the right palm (Figure 42.14).

Shift the weight towards the right side of the body and begin leaning towards the right direction. The eyes continue to follow the right palm as it begins to circle downwards in front of the body. Ex-

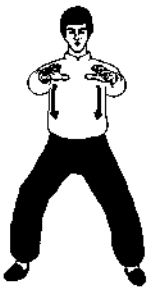

Figure 42.11. After completing the Lung exercise, center the body to prepare for the Kidney Tonification exercise.

Figure 42.12. Preparation for the Kidney Tonification Exercise

Figure 42.13. Kidney Tonification Exercise: exhale as the left outer palm wraps around the right kidney, and the right palm extends outward in a left direction.

Figure 42.14. Begin to inhale as the right palm circles upwards and turns outward at eye level and begins to descend.

hale while shifting the weight (Figure 42.15).

Shift the weight, bend the knees and begin to lean over. While continuing to exhale, imagine scooping water with the right palm. Bend at the waist and scoop with the right arm. Keep the back relaxed and straight (Figure 42.16).

Allowing the right arm to follow the motion of the body, begin rising up slightly while turning forming an arc in front of the torso. As the palm raises, imagine the energy (which has been scooped into the arm) draining down the right arm across the shoulders and down the left arm into the right Kidney. Repeat this side for ten breaths (Figure 42.17).

After completing 10 breaths switch directions by shifting the weight onto the right leg (Figure 42.18 and Figure 42.19).

The right hand wraps the torso ending at the left Kidney and Mingmen area while the left palm is positioned in front of the face. Begin to inhale and repeat 10 times on the opposite side.

LIVER TONIFICATION AND REGULATION EXERCISE

This exercise is designed to massage the Liver's tissues and nerves, as well as tonify the entire Liver organ and channels.

According to Western physiology, the Liver is the body's master filter, collecting all of the nutrients that are being absorbed from the digestive system via the hepatic portal vein. The Liver functions like a series of channels. The cells of the channels are considered the processing factory for the entire body. If the body has a need for a particular nutrient, the Liver will create the enzymes for digestion, breaking down into components that which the body needs (or storing the components until needed). The Liver is also responsible for detoxifying, producing antibodies, and creating new cells to handle foreign substances recently absorbed by the body (storing substances of which it has no need).

The compression and release action of the torso causes a physical compression within the Liver organ itself, flushing Qi and Blood from the digestive system through the Liver and into the Gall Bladder where bile is stored.

Figure 42.15. Continue inhaling as you bend over at the waist. Once your head sinks below your hips begin to exhale. Allow your right palm to circle downward to the left.

Figure 42.16. Continue exhaling as your weight shifts to the other foot and imagine the palm scooping up water as the body begins to circle upward.

Figure 42.17. As the torso begins to arch upwards, allow the right arm to follow the body's movement. As the arm reaches the chest level, turn the outer palm towards the face and begin inhaling.

Figure 42.18. Preparation to switch hand positions: Shift the body's weight onto the right leg as the right arm begins to move to the back left Kidney and the left arm leaves the right Kidney to move forward.

Figure 42.19. Kidney Regulation exercise final movement: begin to inhale as the left palm circles upwards and turns outward at eye level and begins to descend to the left.

Patients practice this exercise to strengthen their tendons and ligaments. This exercise helps to regulate the patient's emotional state.

Upon completing the Kidney exercise, begin to unwind the arm from behind the back and rotate the hips so they face forward (Figure 42.20).

Place the right arm straight out in front of the body, shoulder level, palm facing down. Place the left hand by the left hip, palm facing up (Figure 42.21).

Simultaneously draw the right palm back and extend the left palm forward while inhaling. The left hand moves forward passing the right hand which is moving backwards (Figure 42.22).

The hands continue in this motion extending outward from the center line of the body. Use long, slow inhalation and exhalation, inhaling and exhaling every three moves. Relax and continue to repeat this sequence for 20 breaths (Figure 42.23).

HEART TONIFICATION AND REGULATION

This exercise is designed to massage the Heart's tissues and nerves, as well as tonify the entire Heart organ and channels.

The compression and release of the skeletal muscles squeezing and releasing the cardiac muscle energetically stimulates the pericardium surrounding the heart. The twisting movement and compression of the torso also enhances the fluidity of all the connective tissues that are involved with the Heart. Every time the thoracic wall moves, expands, contracts, or twists, the tissues of the Heart are pulled, stretched, and released.

Patients practice this exercise to strengthen their circulatory system. This exercise helps to

Figure 42.20. Preparation for the Liver Tonification Exercise: upon completing the Kidney exercise, begin to unwind the arm from behind the back and rotate the hips so they face forward.

Figure 42.21. Liver Tonification Exercise: place the right arm straight out in front of the body, shoulder level, palm facing down. Place the left hand by the left hip, palm facing up.

Figure 42.22. Simultaneously draw the right palm back and extend the left palm forward while inhaling. The left hand moves forward, passing the right hand which is moving backwards.

Figure 42.23. Use long, slow inhalation and exhalation, inhaling and exhaling every three moves.

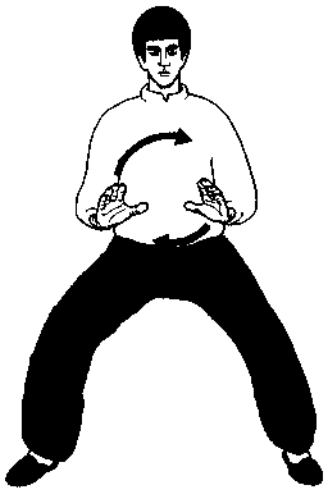

Figure 42.24. Preparation for the Heart Regulation Exercise: upon completing the Liver exercise allow both hands to sink down in front of the lower abdomen.

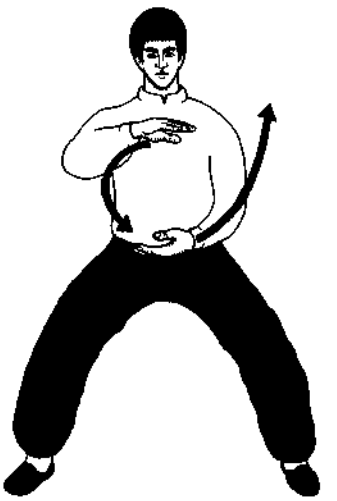

Figure 42.25. Heart Tonification Exercise: imagine the hands embracing a ball, placing the right hand on top, and the left hand on bottom: inhale.

stimulate the patient's intellectual activity and mental acuity or clarity.

Upon completing the Liver exercise allow both hands to sink down in front of the lower abdomen (Figure 42.24).

Imagine the hands embracing a ball, placing the right hand on top, and the left hand on bottom (Figure 42.25).

Exhale and twist the hips to the left, simultaneously raising the left hand up over the head while extending the right hand towards the left (Figure 42.26).

Continue pressing until both hands extend to the furthest point (Figure 42.27).

Inhale and turn the right palm upwards facing the sky as the body twists back to the center allowing the right hand to end up in front of the navel (Figure 42.28).

The left hand simultaneously turns so that the palm faces the center of the right hand following it to the center line of the body (Figure 42.29).

As the body reaches the point where it faces forward, twist to the right side and push in the same manner while exhaling. Repeat 10 times on each side (Figure 42.30).

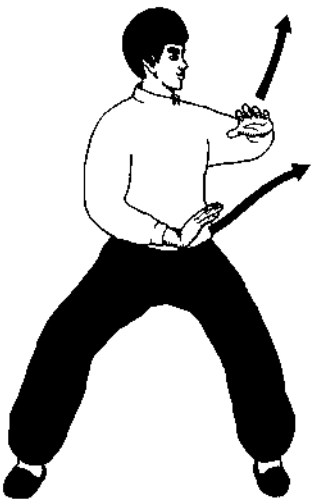

Figure 42.26. Exhale and twist the hips to the left simultaneously raising the left hand up over the head while extending the right hand towards the left.

Figure 42.27. Continue pressing until both hands extend to the furthest point.

Figure 42.28. Inhale and turn the right palm upwards facing the sky as the body twists back to the center allowing the right hand to end up in front of the navel.

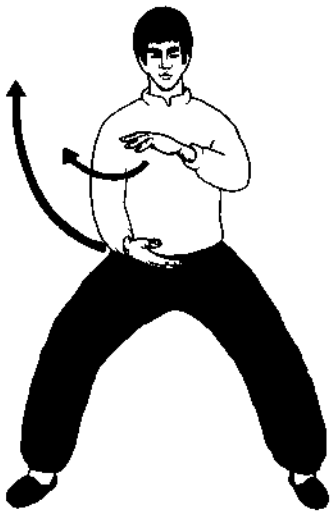

Figure 42.29. The left hand simultaneously turns so that the palm faces the center of the right hand following it to the center line of the body.

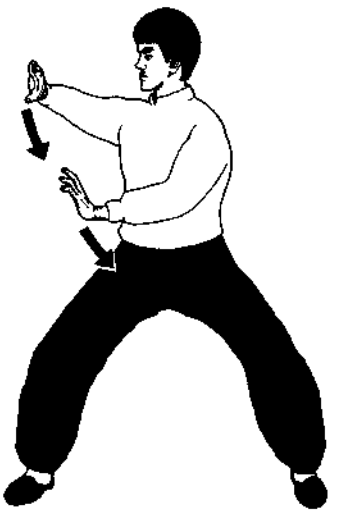

Figure 42.30. As the body reaches the point where it faces forward, twist to the right side and push in the same manner while exhaling.

SPLEEN TONIFICATION AND REGULATION EXERCISE

This exercise is designed to massage the Spleen's tissues and nerves, as well as tonify the entire Spleen organ and channels.

Raising the arms above the head stretches all of the suspensory ligaments of the Spleen making the Spleen energetically accessible by the twisting movements of the torso. The compression and release action on the connective tissue and fascia that support the placement of the Spleen allows the internal channels to become dilated facilitating a greater flow of Qi and Blood into the organ.

While looking up and turning to the right, the left brain is stimulated. Consequently, by looking up and turning to the left, the right brain is stimulated. According to Western physiology, light waves come into the eyeballs through the retina stimulating the optic nerve, chiasma, tract, lateral geniculate body (stimulating the thalamus), superior colliculi (in the brain stem where visual reflexes are initiated), optic radiations, cerebral cortex, and occipital (visual) cortex, which integrates both visual and memory impulses responsible for the perception of the image. Half of the information received from the right eye goes to the right side of the brain, while the other half of the information crosses over and stimulates the left brain.

Patients practice this exercise to strengthen their digestive system, as well as to enhance their visual equilibrium.

Upon completion of the Heart exercise, bring both hands down to the waist level, palms facing downward. Circle them above the head and perform the Pulling Down the Heavens exercise. Next, move the palms towards the outside of the knees while twisting the thumbs to point towards the back of the body (this stimulates the Luo points of the arms and squeezes the Wei Qi of the hands and arms deep into the bones) (Figure 42.31).

The thumb and index fingers touch and form a triangle as the hands slowly raise above the head (Figure 42.32).

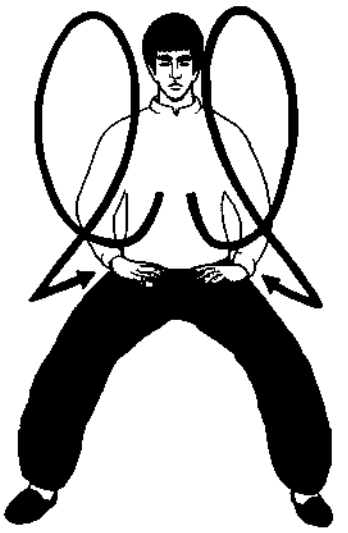

Figure 42.31. Preparation for the Spleen Regulation Exercise

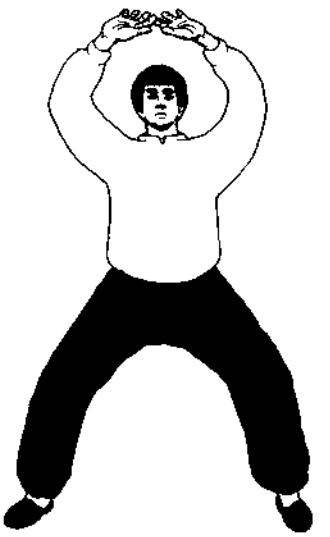

Figure 42.32. Spleen Regulation Exercise: the thumb and index fingers touch and form a triangle as the hands slowly raise above the head.

The eyes look through the center of the triangle as the upper torso is turned from side to side. It is important that the hips remain stationary and that the upper torso rotate in order to massage the digestive organs. Inhale in the center. Exhale on each side. Repeat 10 times on each side (Figure 42.33).

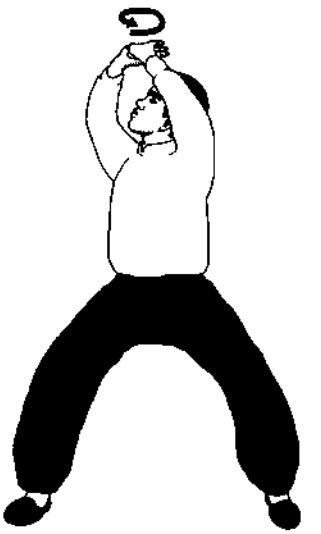

Figure 42.33. The eyes look through the center of the triangle as the upper torso is turned from side to side. Inhale in the center, exhale on each side.

ENDING, ROOTING, AND STABILIZING THE QI

The purpose of the ending is to gather the Qi back into the patient's Lower Dantian rooting and stabilizing the patient's Qi. This ending exercise is very important as its initial goal is to gather any excess Qi developed from the over stimulation of the Five Yin Organs and to collect the runoff energy into the Lower Dantian (where it can be absorbed and used by the Eight Extraordinary Vessels). Otherwise, if the individual unknowingly has a preexisting Excessive condition in a particular Yin organ, the additional tonification can exasperate the organ's condition. To avoid this Excess condition, certain Medical Qigong schools will use external massage and lightly brush the energetic channels after practicing certain Qigong exercises and meditations to disperse any excess Qi.

The soft compression used during the ending exercise increases the partial pressure of oxygen in the Blood as more oxygen passes into the cells. The action of moving oxygen into the cells creates a movement of carbon dioxide out of the cells increasing the exchange rate and establishing a greater metabolic breakdown.

The breathing initiated for the ending exercise is known as "Turtle Breathing." The Turtle Breathing method requires slow respiration and stimulates the center hub of the Belt Vessel.

Upon completion of the Spleen exercise, exhale and start to separate both hands (as if embracing a ball) (Figure 42.34 and 42.35).

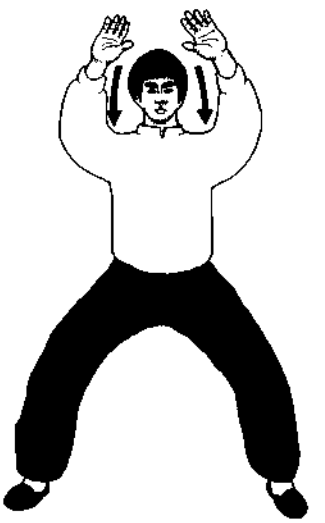

Figure 42.34. Preparation for Ending the Daoist Five Yin Organ Exercise (a)

Bring both hands down to waist level and separate the arms, moving the hands away from the center of the body (Figure 42.36). Inhale and raise the arms up over the head. Each hand is placed above the head as if embracing a ball (Figure 42.37).

Exhale and form loose fists with the hands (Figure 42.38).

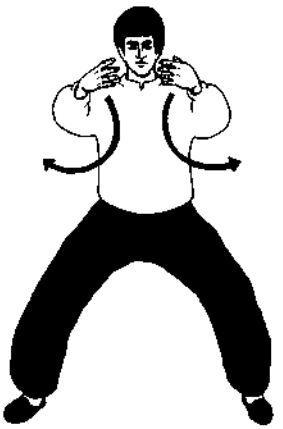

Figure 42.35. Preparation for Ending the Daoist Five Yin Organ Exercise (b)

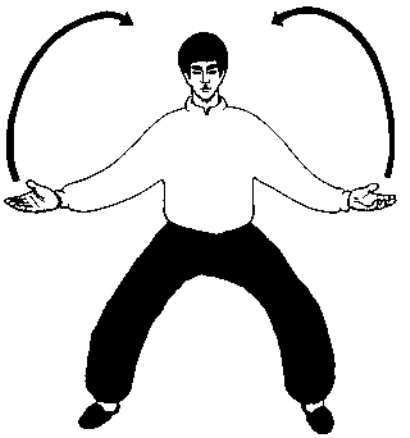

Figure 42.36. Preparation for Ending the Daoist Five Yin Organ Exercise (c)

Figure 42.37. Ending the Daoist Five Yin Organ Exercise: each hand is placed above the head as if embracing a ball.

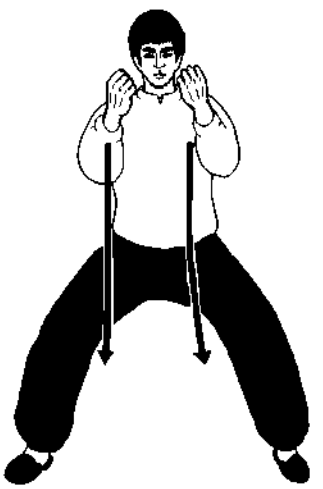

Figure 42.38. Exhale and form loose fists with the hands.

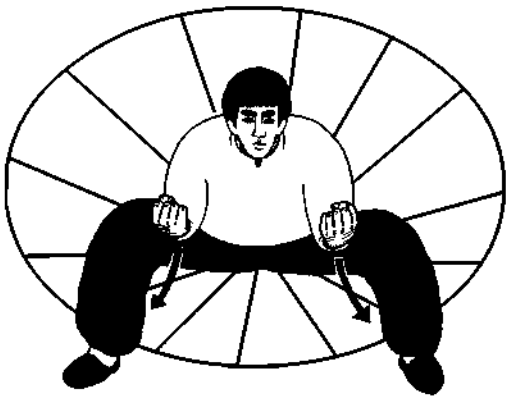

Figure 42.39. As you bend over, slowly turn the soft fists so that the curled fingers face the body and begin squatting, forming a Turtle Posture.

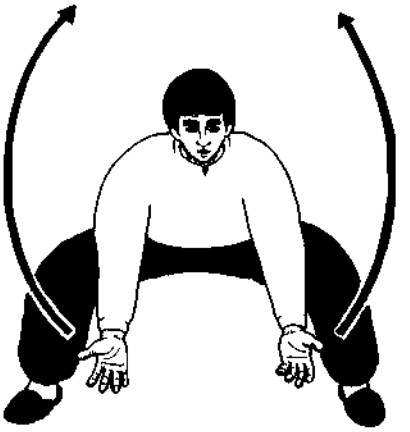

Figure 42.40. Inhale and slowly begin to raise the body up while opening the fists, and allow the hands to return back to their original position at the sides of the body.

As you bend over, slowly turn the soft fists so that the curled fingers face the body and begin squatting forming a Turtle Posture (Figure 42.39).

Inhale and slowly begin to raise the body up while opening the fists and allow the hands to return back to their original position at the sides of the body (Figure 42.40). Repeat five times and end in the Wuji posture.

When practicing the Turtle Breathing method, the mind's intention and respiration should be focused onto the Lower Dantian, navel, and Mingmen areas of the body.

The Lower Dantian is divided into eight sections (see Figure 42.41). Each section is numbered, beginning with the front of the Lower Dantian at the navel area (1), increasing in number as one continues over the left and right sides of the waist (4), ending at the Mingmen area (8).

Think of the anal sphincter as a great funnel, attached in eight different segments (like canals) which progress up the torso. As you focus your mind on each section (begin with the navel at section 1), allow any excess energy to flow downwards from that particular section to be gathered into the Lower Dantian. With your imagination, direct the breath and Qi from your torso to flow into each of the eight areas.

The breath and Qi should be slowly inhaled and guided into the Lower Dantian via the anal sphincter area for an even three counts. Then, proceed to gather Qi from the next consecutive area of the body. By pulling upwards on the anal sphincter and perineal areas, an energetic vacuum is created within the pelvic diaphragm and urogenital diaphragm. This energetic vacuum is used to gather the internal organ's excessive Qi.

Begin with collecting Qi from the front of the body, to the navel via the anal sphincter. Hold the Qi in the Lower Dantian area for three counts, then proceed to the next areas at the sides of the body absorbing the Qi into the Lower Dantian via the anal sphincter for three counts.

Next, proceed to the sides of the body continuing in progression until you reach the Mingmen area (8). Then, reverse the progression beginning with the Mingmen and working around

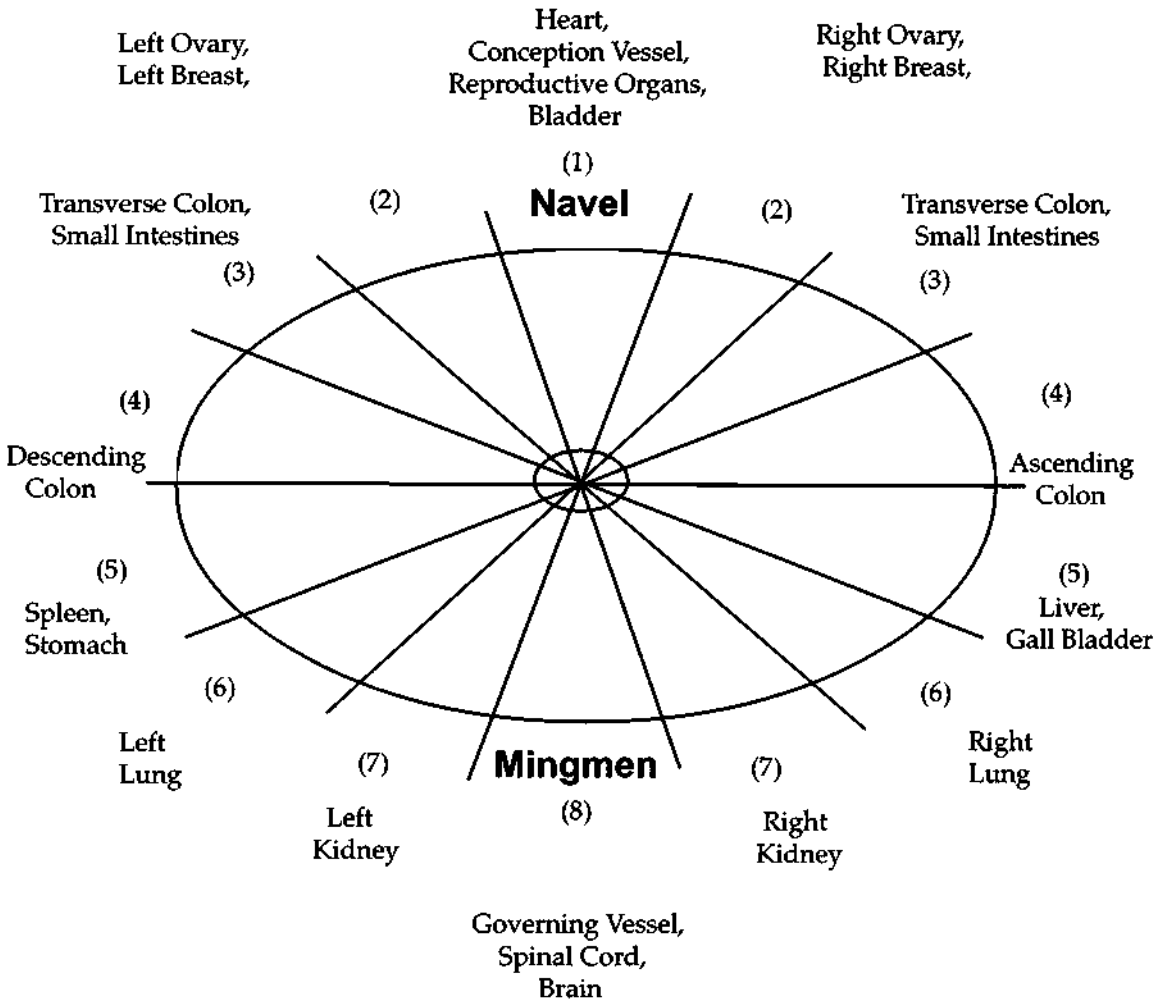

Figure 42.41. When practicing Turtle Breathing, inhale and slowly begin drawing the Qi from the front of the body into the navel area (1), absorbing the energy from the Heart, Conception Vessel, reproductive organs, and Bladder into the Lower Dantian. This absorbing action is created by pulling upwards on the anal sphincter in the direction of the intended energy. Next, proceed to the sides of the body. In women, the next area (2) will include the excess energy gathered from both the left and right ovaries, as well as the left and right breasts. In men, however, this area (2) is considered general and not specific to certain internal organs or tissues. Continue in the progression of circling the waist until you have reached the Mingmen area (8). Then, reverse the order of the tissue areas (8, 7, 6, etc.).

the waist until you reach the navel (8, 7, 6, etc.). Make sure that you push your anal sphincter towards the direction of the area of the body from which you are absorbing Qi.

After perfecting the Turtle Breathing, a practitioner can create the energetic vacuum and initiate the absorption of excess Qi into the Lower Dantian by moving his or her intention from the anal sphincter through the Lower Dantian and torso at an extremely fast speed.

Section X
Treatment of Internal Diseases with Qi Emission Therapy

INTRODUCTION

Clinical records from China verify that Medical Qigong treatments are most effective on nervous system diseases, migraines, bronchial asthma, nocturnal enuresis, psychosomatic diseases, gastric ulcers, arthritic pains, sterility, and in the elimination of ovarian cysts and benign tumors.

The following chapters are designed to assist the Medical Qigong doctor in his or her professional clinical practice, by explaining the various techniques and prescriptions used in several Medical Qigong Hospitals, Institutes and Colleges throughout China.

These Medical Qigong techniques are presented as basic guidelines for the Qigong doctor to use, and need not be followed exactly to the letter. They are presented as an example to advise Qigong doctors in treatment and prescription protocols.

I have personally found these various approaches of Chinese energetic medicine to be extremely effective in my own clinical practice, and have therefore encouraged the directors of the International Institute of Medical Qigong to instruct their students in the following techniques.

This particular section of the book (Section X) deals with the treatment of Zang (Yin) and Fu (Yang) disharmonies in clinical practice, and discusses general and specific diagnosis, treatments, and prescriptions. I will begin by exploring several examples of the Five Elements' disease patterns and the various techniques used to treat them (Chapter 43-48). Starting with the treatment of Liver diseases, I will progress to the treatment of Heart, Spleen/Stomach, Lung and Kidney Diseases.

In the ending chapter in this section emphasis will be placed on the practical application and theoretical principles of "Miscellaneous" diseases and their treatments.

Chapter 43
Qi Emission Therapy for Liver Diseases

Introduction

The Five Yin Organs' interrelationship with each other, and their complex interrelationship with the energetic ebb and flow of Qi must constantly be regulated to maintain health. The constant flux of energetic flow within the body sometimes causes an Excess or Deficiency of Qi requiring specific organ therapy for restoration and balance. This therapy is designed to bring the specific organ or organ systems back into balance by using various meditations, visualizations and breathing exercises.

This section focuses on specific Liver diseases and how to rectify them. The Liver is responsible for the circulation and smooth movement of the body's internal Qi.

The Liver is a solid (Zang) organ which stores the Blood and is attributed to the element Wood. The Liver is sometimes referred to as the Green Emperor. The Liver is in charge of strategy without hesitation. It is energetically paired with the Gall Bladder (a hollow organ) which carries out the decisions made by the Liver (Figure 43.1).

The Liver houses the Hun. The Liver's association with the environment is through the eyes. Through observation, the Qigong doctor's eyes can receive images that reveal the status or intention of the patient. These images are absorbed into the doctor's Shen via the Hun. There is an old Chinese saying, which goes, "When the Hun swim to the eyes, a person can see."

In the springtime, Liver Qi becomes more active in individuals with strong Liver Qi; whereas, it may become Deficient in those with weak Liver Qi. When Liver Qi is Deficient, the patient becomes fearful; when the Liver Qi is in Excess, the patient becomes consumed by anger. The excessive eating or drinking of sour foods, and overexposure to wind depletes the Liver.

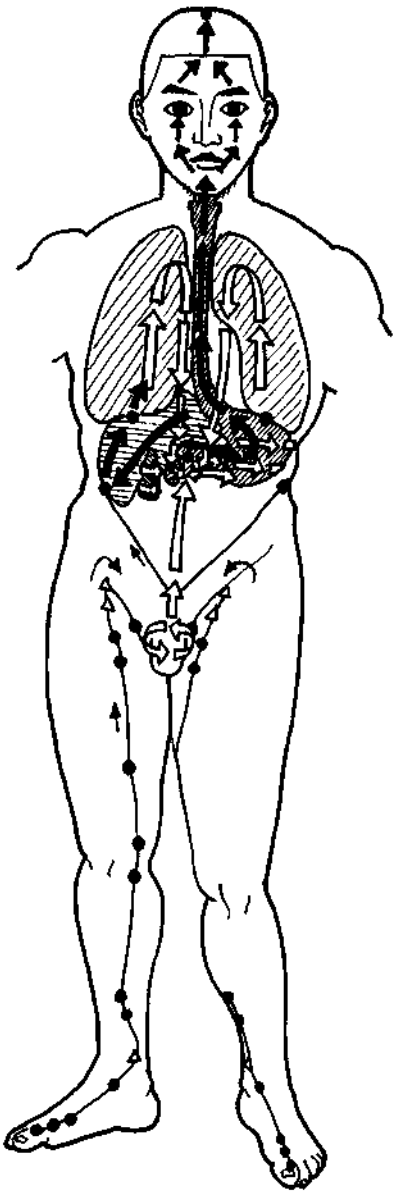

Figure 43.1. The Liver (Lv) Channel

LIVER COMPLICATIONS AND SYMPTOMS

Liver diseases often manifest with the following symptoms which are common to the organ's energetic dysfunction: headaches, dizziness, tiredness, and mental and emotional problems. When Liver disorders occur, the patient may experience Qi movement below the left side of the navel (which feels hard upon pressure), pain and distention in the hypochondria, cramps, drowsiness, blurred vision, etc. A list of Liver syndromes and their symptoms are described as follows.

1. Stagnation of Liver Qi can cause such symptoms as: headaches, mental and emotional problems, hypochondriac pain, abdominal pain and masses, diarrhea, constipation, painful urination, dysmenorrhea, and premenstrual tension.
2. Stagnant Liver Qi Invading the Stomach can result in epigastric pain.
3. Stagnant Liver Qi Invading the Lungs can cause wheezing.
4. Liver Yang Rising can cause such complications as: headaches, dizziness, and tiredness.
5. Liver Fire Blazing can cause such symptoms as: severe headaches, dizziness, breathlessness, wheezing, coughing, mental and emotional problems, insomnia, tiredness, painful or scanty urination, and constipation.
6. Liver Wind can cause headaches, dizziness, seizures, tremors, muscle spasms and tiredness.
7. Liver Blood Deficiency can cause such symptoms as headaches, mental and emotional problems, tiredness, hypochondriac pain, constipation, and premenstrual tension.
8. Liver Yin Deficiency can cause such symptoms as wheezing, mental and emotional problems, insomnia, tiredness, and hypochondria pain.
9. Stagnation of Liver Blood can cause such symptoms as headaches, mental and emotional problems, hypochondriac pain, abdominal pain, and dysmenorrhea.
10. Damp Heat in the Liver and Gall Bladder can cause such symptoms as jaundice, headaches, mental and emotional problems, hypochondriac pain, and abdominal pain.

GENERAL TREATMENT FOR LIVER DISEASES

The following is a description of a general protocol used for treating common Liver diseases. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body towards which Qi is emitted or Turbid Qi is removed. Once the Qigong doctor becomes proficient at locating these specific points, the treatment flows more smoothly.

The reader will notice that after comparing the various Liver and Gall Bladder therapies, certain patterns repeat themselves.

1. Generally, the Qigong doctor accesses the patient's Liver through either direct energetic insertion into the Liver's anatomical location, or through the patient's channels or external energetic fields.
2. After purging, tonifying, and regulating the patient, the Qigong doctor stimulates the back gates to the patient's Liver and the Yellow Court.
3. Next, the doctor roots the patient's Middle Burner Qi into the Lower Dantian.
4. Finally, the Qigong doctor leads any remaining Turbid Qi down the right Gall Bladder Channel and out of the patient's body (Figure 43.2).

Keep in mind that these areas are general, and that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

MEDICAL QIGONG THERAPY FOR LIVER QI DYSFUNCTION

The primary therapies used to treat Liver diseases include the Windy Breathing Method (see Chapter 16) to strengthen the Liver, Spleen, Lungs, and Kidneys, and Quiescent Qi Regulating meditations (see Chapter 14).

1. Patients with Deficiency of Qi and Cold syndromes of the Liver may feel cold and are li-

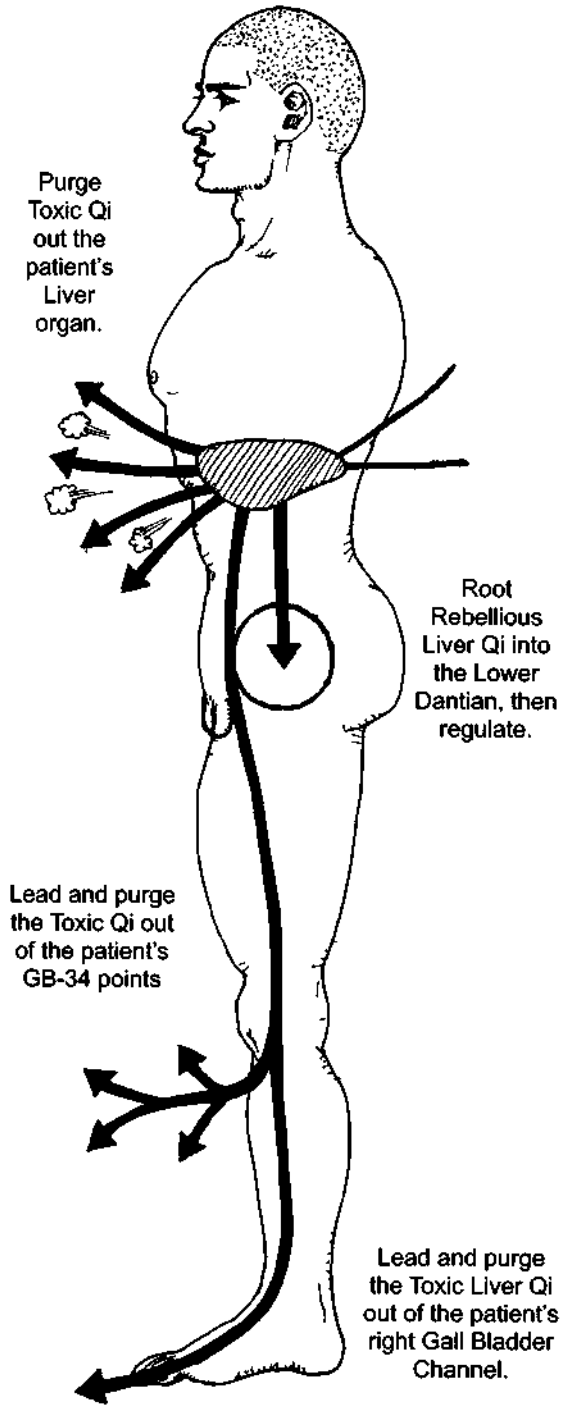

Figure 43.2. Basic Treatment for Liver Stagnation

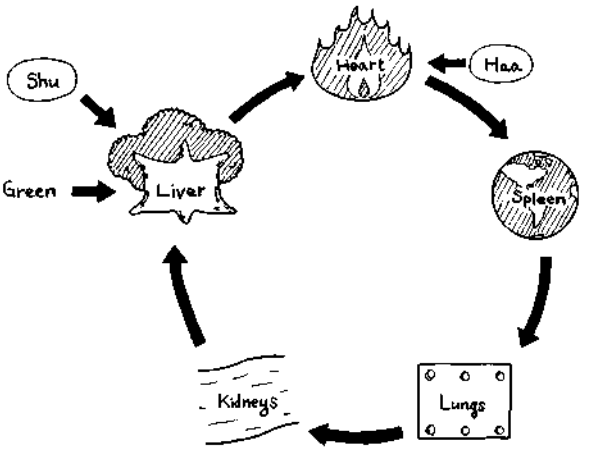

Figure 43.3. Purging the Child to Treat the Mother

able to feel frightened. To treat this condition, the patient can practice the meditation of Taking in the Green Qi to nourish the Liver and also Taking in the Blue Qi to nourish the Kidneys (Formula: nourishing the mother to replenish the child).

2. Patients with an Excess of Qi and Heat syndromes of the Liver may have dry eyes, pain in the hypochondria that may radiate down to the lower abdomen, and changing moods accompanied by flushed cheeks. To treat this condition, the patient can practice uttering "Xu" (pronounced Shu) for the Liver, and "Ha" for the Heart (Figure 43.3. Formula: purging the child to treat the mother).

   Note: In treating Liver diseases, exhaling the sound "Shu" purges and sedates, while inhaling "Shu" replenishes and tonifies (see Chapter 40).

3. Stagnation of Liver Qi and Liver Fire Rising (anger or rage impairing the Liver) may cause an abnormal dispersing and impair the Liver's function. The patient may experience headaches, deafness, and swelling cheeks. To stabilize the hyperactive Liver Yang (and guide the flaring up Liver Fire to descend), the Qigong doctor guides the patient's Qi back to its origin with external energy projection. If treatment of Liver stagnation is not undertaken, there may be an organic change in the

Liver, resulting in hardening of the Liver or Liver cancer.

4. Patients with Rebellious Liver Qi resulting in hypochondriac pain and stiffness with spasms, should be treated by guiding their Qi back to the origin of the Liver with external Wei Qi therapy.

Liver Qigong Prescriptions

The following system of exercises can be used to regulate the Qi and Blood of the Liver Channels, soothe and regulate Qi circulation, and suppress hyperactive Yang. These exercises can also be used to prevent and treat diseases and syndromes such as hypertension, psychoneurosis, chronic hepatitis, and hepatosplenomegaly (the enlargement of both Liver and Spleen), as well as bitter taste in the mouth, dry throat, dizziness, vertigo, and fullness in the chest and hypochondrium.

Color Visualization and Organ Correspondence

In China, the clinical use of color therapy is prescribed according to the Five Color Correspondence Theory. Each of the five major colors are assigned to specific organs and their channels (see Chapter 4). If an organ is diseased, it will generally appear in various shades from gray to black. To heal the disease, the patient imagines taking in the organ's clean color, while dispersing the turbid pathogenic color. This visual meditation helps to return the organ's Qi back to its origin, in order to achieve balance and health.

Prescriptions for Tonifying the Liver

Taking in the Green Qi can be used to tonify the Liver. The properties inherent within the color green have a persistent vibratory rate also used for tonifying the Liver and Gall Bladder.

1. Assume a standing, sitting, or lying posture. Relax the whole body, breathe naturally, and get rid of any stray thoughts. Place the tongue against the soft palate on the roof of the mouth.
2. Visualize green energy in front of you. Draw from a visual/emotional association with green trees, grass, bushes, etc. from your imagination, or if possible, actually look at a green object. Inhale the green light energy in through the nose and down into the Liver organ. As you exhale through the mouth, the dark, pathogenic Qi leaves the Liver; however, the bright, clean color remains in the organ, stimulating and vitalizing it. With each breath the organ retains more clean energy and begins to glow. Repeat for five breaths.

   Next breathe the color green in through the nose, filling the entire mouth. When exhaling, send the Qi slowly to both costal portions at the sides of the Lungs, and then down to the Lower Dantian. Practice eight to sixteen times.

Prescriptions for Purging the Liver

Purge the Liver by having the patient rub his or her chest while sounding "Shu." Have the patient assume a sitting or standing posture, and place both palms flatly on both sides of the chest and inhale slowly. When exhaling, the patient should sound the word "Shu," while gently rubbing both costal regions in a clockwise circular motion with both palms. Practice for ten to twenty breaths.

Prescriptions for Soothing the Liver and Conducting Qi

The following exercise is used to regulate and soothe the Liver Qi; it is used after the purging or tonifying exercises.

1. Stand relaxed with both arms naturally hanging down, palms facing downward, with the five fingers of each hand slightly held up. Press down with slight force and imagine Qi reaching the palms and extending to the fingertips. Press the palms down three times (Figure 43.4).
2. Lift both hands up in front of the chest, with each palm facing forward. Focus the mind on both palms. Push the palms forward three times, first drawing them closer to the body and then pressing them further away from the chest (Figure 43.5).
3. Stretch both hands horizontally out to the sides of the body (as if imitating a bird that is stretching out its wings) with all the fingers pointing upward, and the palms pushing to

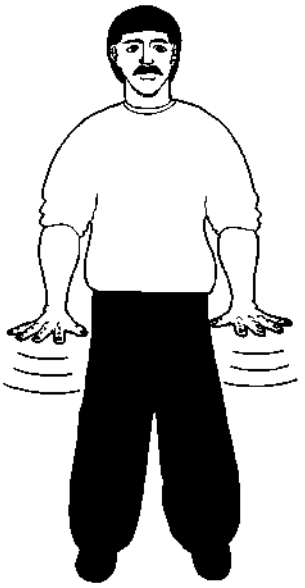

Figure 43.4. Press the palms downward three times.

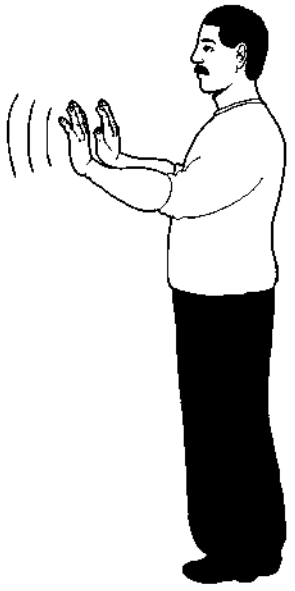

Figure 43.5. Press the palms forward three times.

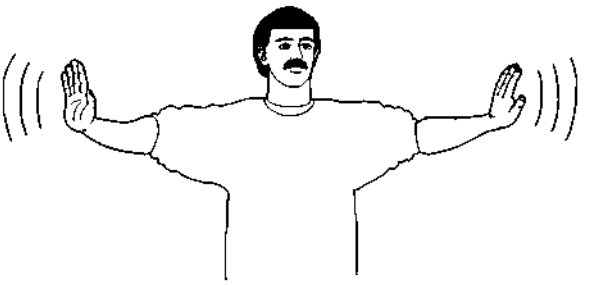

Figure 43.6. Press the palms to the sides of the body three times.

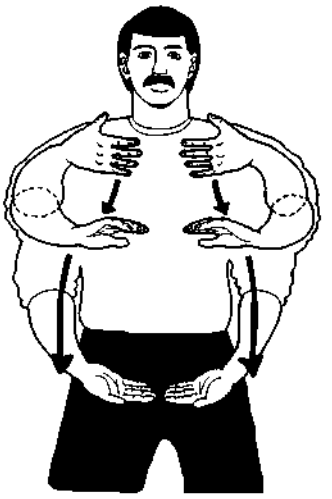

Figure 43.7. Direct the Qi to flow downward from the Middle to the Lower Dantian three times.

the sides. Focus your attention on extending the Qi out the palms to the fingertips. Press the palms out to the sides three times (Figure 43.6).

4. Draw both palms back to the front of the chest, palms facing upwards, elbows down. Rotate the palms to face downwards, and circle them down to the pubic arch, while focusing the mind on both palms (Figure 43.7). When Qi flows to the Lower Dantian turn the palms to face upward as if embracing a ball at the Lower Dantian.

Perform this exercise three times, then place both hands against the sides of the body. This completes one set. Do three sets.

MEDICAL QIGONG THERAPY FOR SPECIFIC LIVER DISEASES

The following are several Medical Qigong treatments used in China to treat specific Liver diseases.

DISORDERS OF THE BILIARY TRACT

The biliary tract includes the organs and ducts that participate in the secretion, storage, and delivery of bile into the duodenum.

ETIOLOGY

Disorders of the biliary track mainly include cholecystitis (inflammation of the Gall Bladder), cholelithiasis (formation of calcium or bile stones in the Gall Bladder), and ascariasis of the biliary tract (infestation by ascaris lumbricoides parasites). Traditional Chinese Medicine teaches that the first two diseases belong to the category of hypochondriac pain or jaundice, while the last condition is called biliary ascariasis.

Disorders of the biliary track can be caused by mental depression, stagnation of Gall Bladder Qi, the excessive intake of fatty foods, exopathogenic invasion, failure of biliary drainage system resulting from stagnation of Dampness and Heat, or obstruction by ascarid parasites. Although the causes and symptoms of these disorders are different, the Medical Qigong treatments and prescriptions are the same.

SYMPTOMS

The onset of biliary tract disorders are usually acute, and the pain is felt on the right upper abdomen and the right hypochondrium area of the thorax. Other symptoms include nausea, vomiting, rigor, high fever, yellow-colored skin pigmentation (jaundice), yellow sclera of the eyes, and whitish-grey stool.

Patients with biliary ascariasis may experience severe colic or a tearing pain below the xiphoid process. The pain is sometimes so severe that the patient experiences extreme perspiration accompanied by nausea and vomiting. If the ascarid parasites withdraw from the biliary tract, the pain is immediately relieved, but can return intermittently. If the ascarid parasites move completely into the Gall Bladder, the pain will be continuous, causing Gall Bladder distention. Symptoms such as jaundice, rigor, and high fever may appear, and a tenderness on the upper right quadrant of the xiphoid process can be felt with deep pressure.

TREATMENT

Cholelithiasis (gall stones) and cholecystitis (inflammation) are often treated by guiding the Toxic Qi downward and out of the patient's lower extremities along the Liver and Gall Bladder Channels, and by balancing the Qi activities between the upper and lower quadrants of the patient's body, as well as the right and left sides.

1. To begin treating disorders of the biliary tract, place the patient in a sitting position on the table. Stimulate the Bl-18, -19, -20, -21 points beside the patient's lower thoracic vertebrae, paying particular attention to the right side of the patient's body.
2. Next, extend Qi into the Gall Bladder area for 24 breaths (on the front of the patient's body), stimulating this area with the Tiger Kneading Palm technique, using Pushing, Pulling, and Shaking Qi manipulations.
3. To regulate the patient's Qi, and relieve epigastric distension, the doctor purges the patient's Toxic Qi, guiding it to flow out of the body downwards along the patient's Gall Bladder and Stomach Channels and out of the feet.
4. Using the Vibrating Palm technique, stimulate the patient's Bl-18, -19, -20, -21 points on the right side of the body once more, this time for 28 breaths. Then use the same Vibrating Palm technique on the front side of the body while directing the energy towards the Gall Bladder for 28 breaths.
5. Finally extend energy into the patient's Bl-19 point on the right side of the body for 12 breaths, and using the Sword Fingers technique, lead the Qi down the right Bladder Channel to the foot and out the small toe three times.

TREATMENT MODIFICATIONS

When treating the condition of ascariasis of the biliary tract, also include rubbing the abdomen 18 times in a counterclockwise direction.

PRESCRIPTIONS AND HOMEWORK

In prescribing homework, place the patient in a standing Wuji posture, with both palms placed against the hypochondria. Have the patient slowly massage the Gall Bladder area while purging the organ with the sound "Shu" for 24 exhalations.

Next, have the patient sit or lie down in a comfortable setting. As the patient inhales, he or she should meditate on the word peace; as the patient exhales, he or she should focus on relaxation. The patient should focus on releasing all tension in the head, chest, Liver, Gall Bladder, back, abdomen, and waist, for 36 breaths.

GALLSTONES

A gallstone is a Gall Bladder stone formed as a result of an excess of cholesterol in relation to the bile acids. The formation of calculi which results from this skewed relationship of cholesterol and bile is believed in Traditional Chinese Medicine to be dependent on the Liver Qi.

ETIOLOGY

Stagnant Liver Qi is believed to be a prerequisite for the formation of gallstones. If the Liver Qi stagnates, the bile will not secrete properly, leading to an accumulation of Damp Heat in the Gall Bladder. The steaming action of Heat on Dampness over prolonged periods of time, leads to the formation of gallstones.

It is generally believed that gallstones are related to cholestasis, an infection of the biliary tract, and metabolic disturbances of cholesterol. Gallstones form when the bile contains more cholesterol than it can keep in solution. The cholesterol precipitates out to form gallstones. The incidence of gallstones in women is approximately twice that in men. Any factor which increases the patient's cholesterol or decreases bile acids may lead to the formation of gallstones (i.e., obesity, high fat diet, Liver disease, and bile stasis increase the risk of developing gallstones). There are three types of gallstones: Cholesterol Stones, Mixed Stones, and Pigment Stones.

1. Cholesterol stones are usually single stones, which are composed almost entirely of cholesterol, and correspond to the pattern of Damp Heat in the Liver and Gall Bladder.
2. Mixed stones are the most common type of stones, consisting of lamellated layers of cholesterol, bilirubin, and calcium.
3. Pigment stones are less common and are always numerous. They are composed of bile pigment.

Gallstones are clinically manifested as pain in the right upper abdominal quadrant and right costal region, and are classified in Traditional Chinese Medicine as being placed in the categories of either hypochrondriac pain or jaundice.

SYMPTOMS

- Liver Qi stagnation is manifested by pain and distention in the right upper abdominal quadrant and right hypochondriac region. The pain can range from mild to severe. The patient may experience a distention and fullness in the Stomach with no obvious fever or jaundice.
- Damp Heat in the Liver and Gall Bladder is manifested by persistent pain in the right upper abdominal quadrant and right hypochondriac region. The pain manifests proximally or radiates up to the right shoulder. The patient experiences abdominal distention, fever, and jaundice.

TREATMENT

Have the patient sit on the edge of the table. Begin stimulating the patient's middle-back area, focusing on the Bl-21, Bl-20, BL-19, and Bl-18 points, on the right side of the back and drain the Toxic Qi down the torso and out the GB-34 point below the knee.

Use the Vibrating Palm hand technique and emit Qi into the patient's mid-back area for 14 breaths at each point. Then emit Qi into the painful area of the front side of the patient's body for 28 breaths.

Next, applying the Extended Fan Palm hand technique, emit Qi into the patient's Gall Bladder

for 24 breaths using the Pulling and Leading manipulation skills to draw the Qi down through the Gall Bladder and Stomach Channels and out the patient's feet.

TREATMENT MODIFICATIONS

When treating a patient with a Liver Qi stagnation, use the Pulling and Leading manipulations to draw Qi down the lower limbs of the patient's body.

When treating patients with Damp Heat in the Liver and Gall Bladder: use the Extended Fan Palm hand technique and emit Qi into the patient's CV-12 and St-21 points, leading the Qi down the right Stomach Channel to the feet.

PRESCRIPTIONS AND HOMEWORK

Have the patient practice Liver Massage described in Chapter 39, while exhaling the sound "Shu" for 36 breaths.

PRESCRIPTION MODIFICATIONS

- For patients with Liver Qi stagnation, have the patient practice rubbing the hypochondrium while imagining the Toxic Qi descending down and out the body. Instruct the patient to practice the Descending the Yang and Ascending the Yin Technique (see Chapter 41).
- For patients with Damp Heat in the Liver and Gall Bladder, have the patient practice rubbing the hypochondrium while imagining the Toxic Qi descending down and out the body as he or she sounds the "Hu" sound to purge and regulate the Spleen.

CIRRHOSIS

Cirrhosis is a generalized disease marked by hepatic lesions. It is a chronic disease of the Liver characterized by the formation of dense lobular connective tissue, degenerative changes in the parenchymal cells, structural alterations in the Liver lobules, and sometimes fatty and cellular infiltration within the Liver.

ETIOLOGY

Cirrhosis refers to a series of pathological changes of degeneration, necrosis and regeneration of Liver cells, as well as the proliferation of fibrous tissue due to prolonged or recurrent damage of the Liver caused by various pathogenic factors. Cirrhosis is clinically manifested as a series of symptoms caused by a hypofunction of the Liver and portal hypertension.

SYNDROMES

1. Liver Qi stagnation and Spleen Deficiency results in lassitude, weakness, fullness in the chest and abdomen, hypochrondriac distension and pain, occasional nausea, belching, and vomiting.
2. Qi and Blood stagnation results in poor appetite, hypochrondriac distention and pain, and enlargement of the Spleen and Liver marked by spider nevus and Liver spots.
3. Water retention results in hardness and fullness of the abdomen with a severe fullness in the Stomach, distention of the abdomen or intestines (by gas), nausea, vomiting, and anorexia. Patients with an insufficiency of Spleen and Kidney Yang suffer from symptoms of cold limbs, pale complexion, and an aversion to cold. Patients with a Deficiency of Liver and Kidney Yin experience sporadic fever, irritability, and a dark complexion.

TREATMENT

Place the patient on the edge of the table and stimulate the Bl-18 and BL-20 points on the mid-back, as well as the Lv-13 and Lv-14 points (at the sides of the body), and the CV-12 point (at the center of the body). Use a Vibrating Palm hand technique to emit Qi into these points for a period of 14 to 18 breaths.

Use the Extended Fan Palm technique and emit Qi into the patient's mid-back at the Bl-18 points, as well as the sides of the torso at the Lv-13 and Lv-14 points. Purge and drain the Toxic Qi down and out the patient's body along the Gall Bladder and Liver Channels.

TREATMENT MODIFICATIONS:

When treating patients with Liver Qi stagnation and Spleen Deficiency, use the Vibrating Palm to emit Qi into the Bl-20 and CV-12 points.

When treating patients with Qi and Blood stagnation, use the Extended Fan Palm technique to emit Qi into the Lv-13 and Lv-14 points, conducting the Qi along the Gall Bladder Channel down the leg to GB-34, and out the body.

When treating patients with water retention, use the Extended Fan Palm technique to emit Qi into the Sp-21 points. Lead the Qi down the Spleen Channels into the lower limbs. For patients with a Spleen and Kidney Yang Defeciency or a Liver and Kidney Yin Deficiency, use a Vibrating Palm technique to emit Qi into the Lower Dantian and Mingmen areas.

PRESCRIPTIONS AND HOMEWORK

Have the patients practice self-regulation exercises to tonify the entire body's energetic system.

PRESCRIPTION MODIFICATIONS

1. For patients with Liver Qi stagnation and Spleen Deficiency, have the patients practice the Old Man Searching for the Reflection of the Moon at the Bottom of the Tide Pool (see Chapter 40).
2. For patients with Qi and Blood stagnation, have the patient perform the Liver Massage while exhaling the sound "Xu."
3. For patients with water retention, have them practice rubbing the Yellow Court area (CV-12) and sounding the word "Hu" to dredge the Spleen and Stomach. For patients with a Spleen and Kidney Yang Deficient, have them practice Gathering the Sun's Essence (see Chapter 11), and for patients with a Kidney and Liver Yin Deficient, have them practice Gathering the Moon Cream. (see Chapter 11).

CHOLECYSTITIS

In Traditional Chinese Medicine, both sides of the hypochondrium are related to the Liver Channels. In Western medicine, however, only the right side reflects a possible Liver pathology. Thus, it is important to have a distinction between left and right hypochondriac pain. Cholecystitis consists of the inflammation of the Gall Bladder with or without gallstones. It is related to hypochondriac pain on the right side of the body. It is created when cholesterol is maintained in the bile solution within the bile acids. Hypochondriac pain on the left side of the body extending to the epigastrium and left scapula is often related to acute pancreatitis.

ETIOLOGY

Cholecystitis is mostly caused by a bacterial infection or an obstruction of the bile duct. Clinically it is characterized by pain in the upper right quadrant of the abdomen and dyspepsia, and may be accompanied by nausea, vomiting, and sweating.

SYNDROMES

- Damp Heat manifestations are alternating attacks of chills and fever. Sometimes there is fever without chills, nausea, vomiting, loss of appetite, and pain in the right hypochondrium region.
- Qi stagnation manifestations are distending or moving pain in the right hypochondrium, belching, acid regurgitation, nausea, and anorexia.

TREATMENTS

1. Have the patient sit at the edge of the table. Stimulate the patient's mid-back, emitting Qi into the Bl-18, Bl-19, and Bl-20 points as well as the GB-34 point below the right knee.
2. Using the Vibrating Palm, first emit Qi into the patient's mid-back for 14 breaths, then directly into the painful area on the front side of the patient's body for 28 breaths.
3. Using the Extended Fan Palm hand technique, emit Qi into the patient's Gall Bladder region for 24 breaths, then purge the Toxic Qi down their right Gall Bladder Channel to the base of the foot and out of the body.

TREATMENT MODIFICATIONS

- For patients with Damp Heat, use the Extended Fan Palm hand technique to emit Qi into the patient's CV-12 area, then purge the Toxic Qi down the Stomach Channels to the base of the feet and out the body.
- For patients with Qi stagnation, use mostly purging and dredging Qi manipulations, focusing on the patient's lower torso.

PRESCRIPTIONS AND HOMEWORK

It is advisable to have the patient perform the Six Healing Sound Regulation exercise (see Chapter 40).

PRESCRIPTION MODIFICATIONS

- For patients with Damp Heat, it is advisable to have them perform the Spleen Massage (see Chapter 39) while exhaling the sound "Hu" to purge the Spleen and Stomach, allowing the Toxic Qi to flow down the Spleen and Stomach Channels into the ground.
- For patients with Qi stagnation, it is advisable to have them perform the Liver Massage (see Chapter 39) while exhaling the sound "Shu."

HYPOCHONDRIAC PAIN

Hypochondriac pain is a syndrome characterized by pain in one or both sides of the hypochondrium. The hypochondrium is located on the part of the abdomen beneath the lower ribs on each side of the epigastrium.

Chronic hepatitis, hepatolithiasis, cholelithiasis, cholecystitis and other diseases related to the Liver and Gall Bladder can be differentiated and treated in accordance with the exercises described in the prescription section.

ETIOLOGY

Hypochondriac pain may be caused by different factors such as trauma, the accumulation or blockage of Qi, stagnation of Phlegm and the Deficiency or Excess of Liver Qi (commonly seen in patients with Excess Liver Fire or Liver Qi stagnation). The symptoms of hypochondriac pain may occur in one or both sides.

SYNDROMES

- An Excess syndrome occurs when a patient suffers from Excess Liver Fire. This condition manifests with symptoms such as severe pain in the hypochondrium area with difficulty in breathing. The pain may radiate from both sides of the body, or from one side only.
- A Deficient syndrome occurs when a patient suffers from a Liver Yin and Kidney Yin Deficiency (often caused by mental depression or hemorrhage). This condition is observed clinically with symptoms such as a dull or sharp pain in the hypochondrium areas.

TREATMENT

1. Begin by stimulating the patient's Middle Dantian and Lv-14 and Lv-13 points at the front of the chest in the hypochondrium area (on both sides or the right side only). Next, stimulate the patient's mid-back around the Bl-17 and Bl-18 points and the base of the outside of the knees around the GB-34 areas.
2. Using the Extended Fan Palm hand technique, emit Qi into the patient's Lv-13 and Lv-14 points and the painful region of the chest and hypochondrium and begin purging the Toxic Qi, dredging it down the body and out of the extremities through the patient's Liver and Gall Bladder Channels.

TREATMENT MODIFICATIONS

- For patients with an Excess syndrome, extend energy into the patient's mid-back at the Bl-18 points. Then grasp and softly rock this tissue area to free the trapped Qi.
- For patients with a Liver and Kidney Yin Deficiency, emit Qi into the patient's Lower Dantian and Mingmen area using the Extended Fan Palm technique for 12 to 24 breaths.

PRESCRIPTIONS AND HOMEWORK

1. Have the patient perform the Liver Massage (see Chapter 39) and sound the healing tone "Shu" for 36 breaths.
2. If the pain is on the left side of the patient's chest, have the patient place his or her palms on the painful area and begin to purge the Toxic Qi from the midline of the thorax, down the left side of the body, following the Gall Bladder Channel to the ground, for nine breaths.
3. Finally, have the patient stand in a Wuji posture and focus the mind's intention on his or her palms. The patient then raises the arms sideways, like a bird stretching its wings (creating a "T" formation). Next, both arms embrace (as if holding an imaginary ball) at the Middle Dantian level. The patient imagines the Qi from the middle chest flowing downward and rooting into the Lower Dantian.

CHAPTER 44
QI EMISSION THERAPY FOR HEART DISEASES

INTRODUCTION

The Heart is a solid (Zang) organ and controls Blood circulation. The Heart corresponds to the element Fire and is sometimes referred to as the Red Emperor. The Heart houses the Shen and is in charge of mental activities and long term memory. It is energetically paired with the Small Intestine (a hollow organ), which is in charge of separating the pure, clean energy from the impure Qi (Figure 44.1).

The Heart's upper external connection with the outside is through the tongue, hence sensations of the tongue (from food, kissing and so on), as well as talking can travel directly into the spirit, mind, and emotion, affecting the Heart's desires and senses.

In the early summer months, the Heart energy becomes more active in individuals who already have strong Heart Qi, but can become Deficient in those who already have weak Heart Qi. Excessive eating and drinking of bitter foods, and overexposure to heat depletes the Heart.

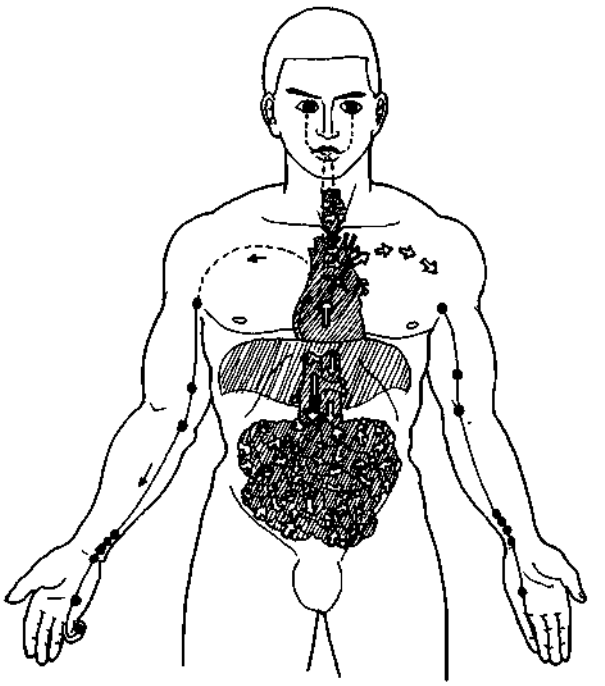

Figure 44.1. The Heart (Ht) Channels

HEART COMPLICATIONS AND SYMPTOMS

The Heart is responsible for governing the flow of Blood through the body's arteries and veins. Coronary artery disease (CAD) is a disease in which the patient's coronary arteries begin to harden, or impede adequate vascular flow to the myocardium, resulting in an insufficient supply of Qi and Blood throughout the body. This causes such diseases as hypertension, vasculitis, myocarditis, congenital Heart disease, rheumatic Heart disease, nervous malfunctioning of the Heart, organic pathological changes of the Heart, and arteriosclerosis of the brain.

In general, patients with Heart disease may have an arterial pulse above the navel which often disappears upon pressing, as well as a hot sensation in the soles of the feet and palms, dry mouth, stiffness of the tongue, and absentmindedness. A list of Heart syndromes and their symptoms are described as follows.

1. Heart Qi Deficiency can cause such symptoms as: physical tiredness, palpitations, sweating, pallor, and shortness of breath when exerting oneself.
2. Heart Yang Deficiency can cause such symptoms as: tiredness, tightening in the chest, and edema.
3. Heart Blood Deficiency can cause such symptoms as: headaches, mental and emotional problems, tinnitus, and tiredness.

4. Heart Blood stagnation can cause such symptoms as: mental and emotional problems, as well as tightness or pain in the chest.
5. Heart Yin Deficiency can cause such symptoms as: tiredness, insomnia, and mental and emotional problems.
6. Heart Fire can cause such symptoms as: insomnia, painful urination, and mental and emotional problems.

General Treatment for Heart Diseases

The following is a description of a general protocol used for treating a patient's Heart. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body towards which Qi is emitted (or Turbid Qi is removed). Once the Qigong doctor becomes proficient at locating these specific points, the treatment will flow more smoothly.

After comparing the various Heart therapies, the reader will notice that certain patterns repeat themselves.

1. Generally, the Qigong doctor can access the patient's Heart through four methods:
   - direct energetic insertion into the Heart's anatomical location,
   - the patient's channels,
   - the external energetic Wei Qi fields, or
   - the patient's Taiji Pole (Figure 44.2).

   To avoid energetic armoring (while accessing the Qi in the front of the Heart), it is important for the doctor to already be connected to the patient's Shendao point (through the back of the Heart).
2. After treating the patient (purging, tonifying, and regulating), the Qigong doctor stimulates the patient's Heart and Shendao area, and roots the Upper Dantian Qi into the Lower Dantian.
3. Next, the Qigong doctor leads any remaining Turbid Qi down the Pericardium and Heart Channels and out from the patient's hands (Figure 44.3).

   Keep in mind that these areas are general and

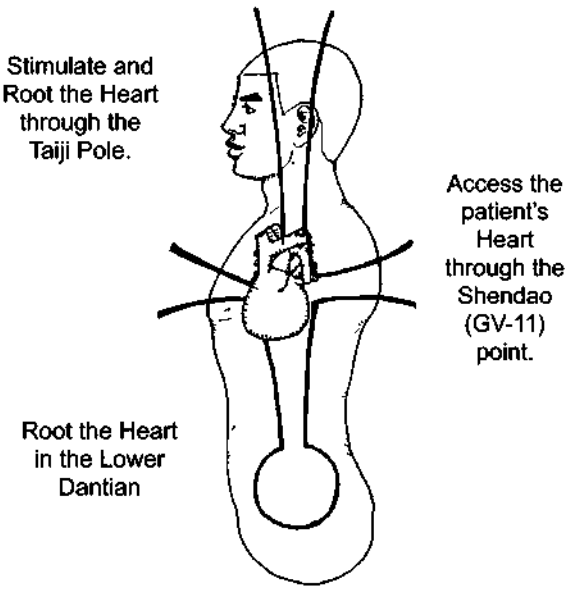

Figure 44.2. Treating Heart Conditions

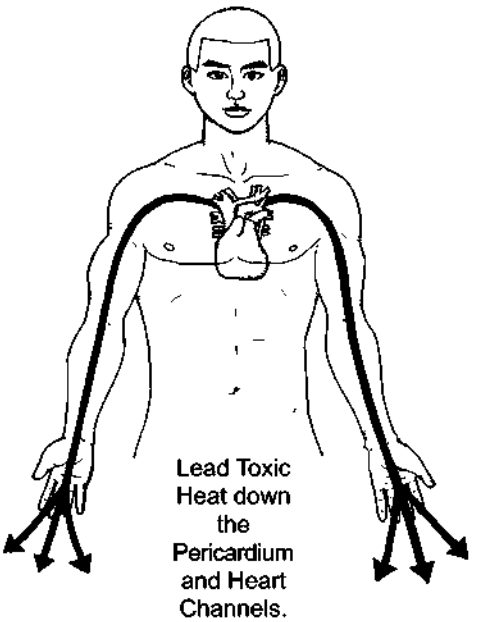

Figure 44.3. Lead the Toxic Qi out of the body through the patient's Pericardium Channels.

that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

MEDICAL QIGONG THERAPY FOR HEART QI DYSFUNCTION

The primary therapies used to treat cardiovascular diseases include: the Windy Breathing method to strengthen the Heart and Kidneys, Toe-Raised Walking, Heart Massage, and Quiescent meditation (see Chapter 15).

- Patients with an Excessive Qi syndrome of the Heart with extreme Heat may have a flushed complexion, full pulse, and excess sputum; they may feel pain in the chest, hypochondrium, back, shoulders, and arms. This syndrome can be treated by having the patient utter the "Ha" sound while guiding the Kidney Water Qi upwards to suppress the Heart Fire (Figure 44.4). Alternatively, the Qigong doctor may guide the Evil Qi out of the patient's body along the Heart and Small Intestine Channels with Pulling and Leading Qi manipulations.
- Patients with Deficient Heart Qi may dream of flames and red colored objects and have a radiating pain in the abdomen. This condition can be treated by having the patient perform the Taking in Yellow Qi meditation (see Chapter 4) which replenishes the child (Spleen), and Taking in Pink Qi meditation to nourish the mother (Heart); or, by using the Pushing and Guiding Qi manipulations to reinforce the Heart Qi and the Qi in the Lower Dantian.

In this particular case (Deficient Qi syndrome of the Heart), the reason the patient should not take in the energetic color red is because the Heart has already established a draining pattern, and any energy pouring into the Heart will only continue to drain away.

HEART QIGONG PRESCRIPTIONS

To tonify the Heart, tranquilize the mind, promote Blood circulation, and remove obstructions in the channels, prescription exercises can be used. The following exercises can be used to prevent and

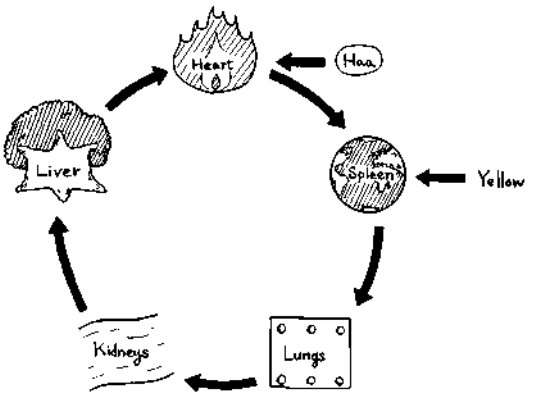

Figure 44.4. Treating Patients with an Excess Qi Syndrome of the Heart

treat diseases and syndromes such as coronary Heart disease, hypertension, angina, arrhythmia, rheumatic Heart disease, cardiac neurosis as well as palpitations (ranging from mild to severe), pericardial pain, and insomnia.

PRESCRIPTIONS FOR TONIFYING THE HEART

Taking in the Red Qi can be used to tonify the Heart. The properties inherent within the color red have a persistent vibratory rate used for tonifying the Heart and Small Intestine.

1. Assume a standing, sitting, or lying posture. Relax the whole body, breathe naturally, and get rid of any stray thoughts.
2. As you inhale, visualize red energy in front of you. Inhale the red light energy in through the nose and down into the Heart organ. As you exhale through the mouth, the dark, pathogenic Qi leaves the Heart; however, the bright, clean color remains in the organ, stimulating and vitalizing it. With each breath the organ retains more clean energy and begins to glow. Repeat for five breaths.
3. Next breathe the red energy in through the nose and fill the entire mouth with it. When exhaling through the nose, send the Qi slowly to the Heart, then to the Lower Dantian, to connect the energy of the Heart and Kidneys and to remove obstructions in the whole body. Perform this exercise seven or fourteen times. Return to the first step and close the training.

Figure 44.5. Hands rest in front of the Lower Dantian.

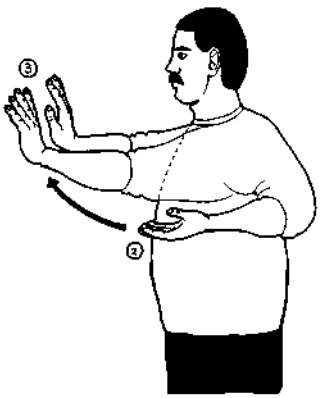

Figure 44.6. Both palms simultaneously press forward.

PRESCRIPTIONS FOR PURGING THE HEART

Purge the Heart by having the patient rub his or her chest while sounding "Ha."

1. The preparatory postures are the same as above.
2. Begin by clicking the teeth, stirring the tongue, and swallowing the saliva, then place the palms on the pectoral region of the left side of the chest (left hand on the outside for men, opposite for women). Inhale slowly, then gradually exhale the sound "Ha," focusing the mind on the Heart area. Repeat for six to twelve breaths altogether while rubbing with the palm lightly in a clockwise circle.

PRESCRIPTIONS FOR REGULATING THE HEART AND CONDUCTING QI

The following exercise is used to regulate the Heart after purging or tonifying.

1. Assume a standing or sitting posture. Relax the whole body, breathe naturally, and raise the tongue against the hard palate, just behind the teeth. Bring both palms loosely together (left over right for men, opposite for women) at the Lower Dantian; stand still for several minutes and concentrate the mind on the Lower Dantian (Figure 44.5).
2. Turn both palms outward, and push the arms along the sides of the body towards the back. Hold this posture for several minutes.
3. Turn both palms upward and lift them to the sides of the chest.
4. With both palms facing forward, stretch both hands level and forward. Focus your attention on the ends of the middle finger of each hand, while the thumb and little fingers stretch and separate (Figure 44.6).
5. Clench both hands into fists and pull them along the sides of the body towards the back, as if dragging heavy weights. Perform this movement three times (Figure 44.7).
6. Raise the right palm, as if holding a heavy weight in front of the chest, and push the palm out vertically to the right. Then, draw the right hand back to the side of the body near the hip. Repeat on the left side, and finally return to the starting posture. Perform these movements three times (Figure 44.8). This completes one set. Perform three sets.

SPECIFIC MEDICAL QIGONG THERAPY FOR HEART DISEASES

The following are several Medical Qigong Treatments used in China to treat specific Heart diseases.

HYPERTENSION

Hypertension is considered a condition in which the patient has higher blood pressure then what is determined to be normal for his or her

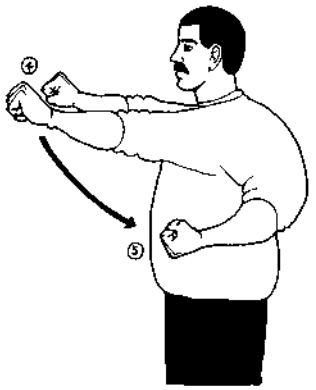

Figure 44.7. Both hands simultaneously clench into fists and pull to the hips.

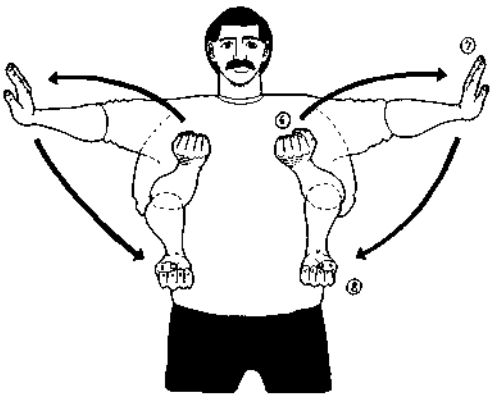

Figure 44.8. Alternate each palm as it presses towards the side of the body.

chronological age and physique. Generally, Traditional Chinese Medicine places it in the categories of vertigo and headache.

ETIOLOGY

Hypertension is one of the most common problems impacting the Heart. It is the result of an imbalance of the Yin and Yang functional aspects of Deficient Kidney Yin and Excess Liver Yang, and/or an overabundance of Phlegm and Dampness within the body.

Hypertension can be caused by the patient eating too much food or salt, by too much stress, or not enough exercise. A renin imbalance within the patient's Kidneys, increased cholesterol, a pre-existing genetic predisposition, a secondary illness (diabetes, nephritis, or hyperthyroidism), or even pregnancy can also lead to hypertension. These causes of hypertension can result in one of three internal factors: high cardiac output due to stress, reduced elasticity of the vessels, and resistance to Blood flow.

1. When the body experiences emotional tension it releases adrenaline, which speeds up the Heart rate and causes the blood vessels to narrow, increasing the body's blood pressure.
2. A buildup of plaque and normal aging reduces the vessel's elasticity and can lead to hypertension.
3. Old age, certain hormonal imbalances or disorders, or a genetic predisposition can likewise cause high blood pressure.

The overall goals in treating hypertension patients are to:

1. Lower blood pressure,
2. Stabilize blood pressure,
3. Establish a quiescent state of mind (generally, meditating 20 minutes, twice a day provides the patient with a prolonged state of deep relaxation needed to combat stress), and
4. Encourage life-style changes (i.e., monitor potassium intake, decrease sodium intake, weight control, and stress reduction management). Treatment programs are established as described below.

SYNDROMES

As previously stated, there are three underlying causes or syndromes relating to hypertension: Excess Liver Yang, Deficient Yin, Excess Liver Fire, and Kidney Yin and Yang Deficiency.

1. If the body's Kidney Yin is Deficient, it fails to nourish the Liver Yin, which leads to a condition of hyperactivity of Liver Yang. The clinical manifestations are feelings of fullness in the head, daydreaming, headaches, dizziness, tinnitus, insomnia, and dysphoria with feverish sensations in the chest.
2. Excess Liver Fire can cause headaches, dizziness, restlessness, irritability, flushed face, and constipation.
3. If the body's Kidney Yang is Deficient the Yin (Water) accumulates, if the Yang does not move, the blood vessels cannot relax. This results in

obstructed Blood flow. The clinical manifestations are dizziness and tinnitus, daydreaming, palpitations, amnesia, lassitude and weakness in the legs, as well as insomnia.

TREATMENT FOR PATIENTS SENSITIVE TO ENERGY

1. Use Medical Qigong therapy, and have the patient sit in a chair with his or her feet flat on the ground. Begin the treatment by cleaning the patient's Conception and Governing Vessels, using purgation methods. Focus specific attention on clearing the patient's head area (Figure 44.9). Literally sweep with the entire hand, and comb the patient's Wei Qi fields with the fingers.

   By scanning the occipital region of the patient, you can verify that the Excess Qi in the patient's upper extremities has abated. Once these vessels are clean, you can focus on treating the hypertension.
2. Stand behind the patient, using the Extended Fan Palm technique (with both hands) extend energy from the left hand into the top of the patient's head at the Baihui GV-20 area, while your right hand extends energy into the back of the patient's head, beginning at Yuzhen Bl-9. The two streams of Qi flow downward to the Dazhui GV-14 area, where they join into one river, which continues to flow downward through the patient's Taiji Pole. Continue to visualize these two streams joining and filling the Lower Dantian, for a period of 6 to 12 breaths (Figure 44.10).
3. Next, move your left hand and extend energy into the patient's Yellow Court, while your right hand is placed above the patient's Mingmen area. Lead the Qi from the Yellow Court into the patient's Lower Dantian, continuing to root the Qi, for a period of 6 to 12 breaths.

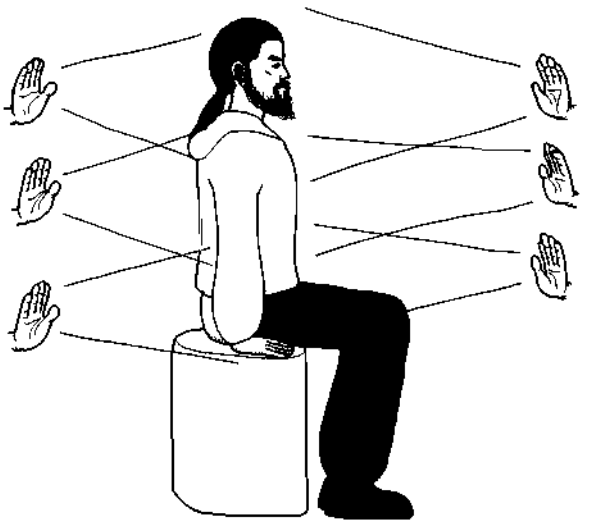

Figure 44.9. The Qigong doctor begins by dredging, purging and cleaning the patient's Conception and Governing Vessels.

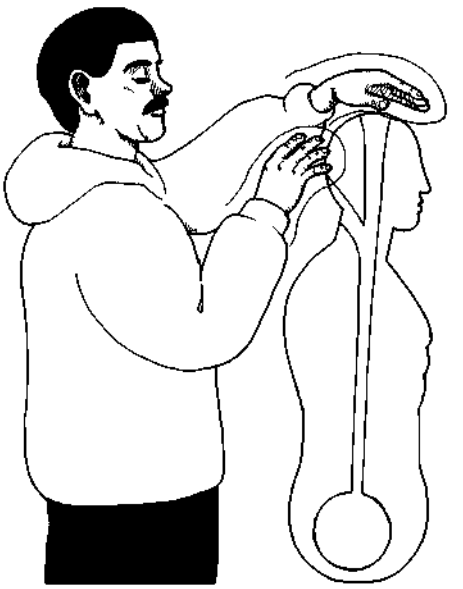

Figure 44.10. The Qigong doctor emits Qi into the patient's Baihui, Yuzhen and Dazhui points, in order to access the Taiji Pole and fill the patient's Lower Dantian.

TREATMENT MODIFICATIONS

These modifications are additional formulas which are added onto the previous treatment according to the specific cause and condition of the patient's Heart.

1. When treating patients with Excess Liver Yang and Deficient Yin, use the Extended Fan Palm

hand technique and emit Qi into the patient's mid-back, drawing the energy down and rooting it in the patient's Lower Dantian and Mingmen.

2. When treating patients with Excess Liver Fire, it is important to treat the Lv-13 and -14 points, by dredging and purging the Excess Qi, and leading it down the patient's right Gall Bladder Channel, through the foot and into the Earth.
3. When treating patients with Kidney Yin and Yang Deficiency, use the Extended Fan Palm technique to emit Qi into the patient's mid-back, drawing the energy down and rooting it in the patient's Lower Dantian and Mingmen.

TREATMENT FOR PATIENTS NOT SENSITIVE TO ENERGY

Use Jing Point therapy in conjunction with Medical Qigong therapy (see Chapter 36). Have the patient lie prone. Using the Sword Finger technique, touch the patient's head with the left hand and extend energy into the Baihui GV-20 point. Guide this Qi down to the Lower Dantian through the Taiji Pole, while your right hand embraces and energizes the patients' Mingmen GV-4 point, thereby filling the Lower Dantian and rooting the patient's Heart Qi (Figure 44.11). Next, treat the patient's LI-11, St-36, Lv-2, and Sp-6 points on both sides of the body to lower the patient's blood pressure.

Figure 44.11. If the patient is not sensitive to energy, have them lie prone, and apply Jing Point Therapy in conjunction with Qi emission.

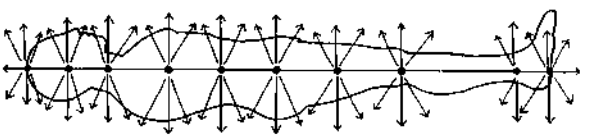

Figure 44.12. In this Static posture used to treat high blood pressure the patient lies supine and performs the toning sound "Zheng" (Jang), for dispersing Qi.

PRESCRIPTIONS AND HOMEWORK

1. A static posture can be given to convalescing patients as part of a meditative homework prescription for treatment of high blood pressure. The prescription is as follows.
   a. Have the patients lie supine (the patients may use a pillow under the head for comfort) and have him or her imagine that they are floating in warm water.
   b. The patients should perform the toning sound "Zheng" (prenounced Jang), and imagine dispersing Qi out of his or her body. The patient should use natural breathing while toning and dispersing the Toxic Qi. There are ten major areas, from the top of the head to the bottom of the feet, from which the patients must discharge the toxins. These areas include: the top of the head, Upper Dantian, throat, Middle Dantian, Yellow Court, Lower Dantian, the center of the thighs, knees, ankles, and bottom of the feet (Figure 44.12).
   c. After several minutes the patients will relax and focus their attention on the Lower Dantian or Bubbling Well points at the bottom of the feet.
2. Another meditation prescription given to patients with hypertension is to have them sit and imagine the feeling of warm water pouring down over the head, torso, extremities, and feet. This meditation should be practiced several times a day, using 36 breaths each time.
3. The patient can also be given the prescription of rubbing the hypochondrium and toning the sound "Shu" to purge Excess Heat from the Liver.

PALPITATION

A palpitation is an abnormally rapid throbbing or fluttering of the Heart. The symptom is characterized by nervous feelings or restlessness due to strong anxitey or fright. Clinically, it mostly attacks paroxysmally and is caused by emotional stress or overexertion. Symptoms such as insomnia, vertigo, tinnitus, etc. often accompany palpitations.

Diseases with palpitation as the main manifestation include arrhythmia, iron-deficiency anemia, aplastic anemia, hyperthyroidism and anxiety disorders. These diseases may all be differentiated and treated in reference to the prescriptions described in this section.

ETIOLOGY

There are several factors which contribute to palpitations. These factors and their symptoms are described as follows.

1. In patients suffering from Deficient Qi and Blood, and Deficient Heart Qi, palpitations may occur following sudden mental irritation. The patient may note unduly rapid heartbeat accompanied, in cases of Deficient Heart Qi, by pallor, restless sleep at night, dizziness and vertigo. This condition may also be caused by Deficient Heart Blood that fails to nourish the Heart.
2. Phlegm Fire disturbing the Heart may also give rise to palpitations. In cases with internal disturbances of Phlegm Fire, symptoms also include fidgeting and disorientation.
3. Another factor causing palpitations is a Deficiency of Heart Yang that leads to fluid retention. In cases of fluid retention with epigastric stiffness symptoms will also include: dizziness, excessive salivation and mental fatigue.

TREATMENT

1. Begin by extending Qi into the patient's Bl-14, Bl-18, CV-15, and CV-17 points. To open up these points, emit Qi into the tissue areas surrounding these points using the Extended Fan Palm technique.
2. Next, use the Sword Fingers hand technique and vibrate Qi into each of these points for the duration of six to twelve breaths at each point. Upon completion, the doctor will then guide the Qi back down the patient's torso and root it into the patient's Lower Dantian.
3. Finally, the doctor emits Qi into the patient's Yellow Court area using the Extended Fan Palm technique and then guide the Heart and Pericardium Channel Qi down the patient's arms using Pushing, Pulling and Leading techniques. This ending is performed to balance the Qi in the upper and lower aspects of the patient's body.
4. As with every treatment, end the procedure by regulating the patient's Microcosmic Orbit (Fire Cycle).

TREATMENT MODIFICATIONS

These modifications are additional formulas which are added onto the previous treatment according to the specific cause and condition of the patient's Heart.

1. In cases of insufficiency of Heart Blood, add Bl-17 and Bl-20 to the treatment points.
2. In cases of internal disturbance of Phlegm Fire, purge from the CV-12 to St-40 points.
3. In cases of Fluid retention, add Bl-21 and Bl-22 to the treatment points, for 14 to 24 breaths. Then, guide the Qi to flow down the patient's Gall Bladder Channels into their Bl-40 points.

PRESCRIPTIONS AND HOMEWORK

1. For treatment of palpitations due to Deficient Heart Blood, have the patient practice the method of Taking in the Red to nourish the Heart (see Chapter 4). Have the patient send the red Qi slowly down into the Heart and then to the Lower Dantian during the exhalation. Practice should be for several minutes, according to the patient's strength and constitution.
2. For treatment of palpitations due to Phlegm Fire, have the patient place both hands on the Heart and slowly inhale. As the patient exhales, he or she should pronounce the sound "Ha." This exercise should continue for several minutes.
3. For Heart regulation, have the patient practice the Heart exercise from the Daoist Five Yin Organ prescriptions (see Chapter 42).

RHEUMATIC HEART DISEASE

Rheumatic valvular Heart disease is a condition where there is chronic damage of the cardiac valve caused by rheumatosis. It clinically manifests with palpitations, dyspnea and edema.

SYNDROMES

1. Heart Blood stagnation is manifested through symptoms such as severe palpitations, bad cough with hemoptysis, lassitude and weakness, purplish-red color of the lips, nails and zygomatic facial regions, pain in the Heart, chest, or both.
2. Deficient Qi and Blood manifests through such symptoms as shortness of breath, palpitations which are aggravated on exertion, perspiration and pale complexion.
3. Heart and Kidney Yang Deficiency manifest through such symptoms as palpitations, pale or darkish complexion, edema, cough, cold hands and feet and dyspnea.

TREATMENT

1. Have the patient sit at the edge of the table, and begin to stimulate the Shendao (GV-11) and Middle Dantian areas.
2. Use the Vibrating Palm hand technique and emit Qi into the patient's Yellow court and Shendao (GV-11) area for 6 to 12 breaths.
3. Use the Extended Fan Palm hand technique and emit Qi into the patient's Heart region, leading Qi down the Heart and Pericardium Channels to the tips of the fingers (on both sides of the body).

TREATMENT MODIFICATIONS

1. When treating patients with Heart Blood stagnation, use the Extended Fan Palm hand technique and emit Qi into the patient's Middle Dantian, leading the stagnant Qi down the Heart and Pericardium Channels and out the hands (on both sides of the body).
2. When treating patients with Deficient Qi and Blood, use the Extended Fan Palm technique and emit Qi into the patient's Middle Dantian (both Shendao GV-11 and CV-17 areas), leading the Qi down the Conception Vessel to the Lower Dantian to root and stabilize the patient's Qi.
3. When treating patients with Heart and Kidney Yang Deficiency, use the Extended Fan Palm technique and emit Qi into the patient's Shendao (GV-11) and Mingmen (GV-4) for 24 breaths.

PRESCRIPTIONS AND HOMEWORK

When prescribing homework for patients with rheumatic Heart disease, have them begin with a quiescent sitting meditation, while focusing on their Lower Dantian.

PRESCRIPTION MODIFICATIONS

1. Have patients with Heart Blood stagnation perform the Heart Massage exercise (see Chapter 39), while toning the sound "Ha."
2. It is advisable for patients with Qi and Blood Deficiency to practice the method of Taking in the Yellow Qi into the Spleen and Red Qi into the Heart from the natural environment.
3. Have patients with Heart and Kidney Yin Deficiency practice Gathering the Moon Cream (see Chapter 11), as well as the method of Taking Yellow Qi into the Spleen and Red Qi into the Heart from the natural environment (see Chapter 4).

CONTRAINDICATIONS

The Heart may either have functional or structural problems. In either condition, Medical Qigong is contraindicated when working directly over a pacemaker.

Also, when treating Heart conditions, make sure the patient is under a Western doctor's care, and inquire as to any medications the patient may be taking.

Chapter 45
Qi Emission Therapy for Spleen/Stomach Diseases

Introduction

The Spleen is a solid (Zang) organ and it stores and nourishes Ying (Nourishing) Qi. The Spleen corresponds to the element Earth and is sometimes referred to as the Yellow Emperor. It houses the Yi, which governs the intention, thought, study, concentration, and memorization. It is energetically paired with the Stomach (a hollow organ). The Spleen is in charge of transporting, distributing and transforming nutrients and Qi into Gu Qi, as well as controlling Blood circulation (Figure 45.1).

The Spleen's external connection with the outside world is through the mouth, hence any connection with the mouth can affect the body's acquired constitution, developing a tolerance or intolerance to specific substances (allergies), as well as affect concentration and thought.

In the late summer months, Spleen Qi becomes more active in individuals who already possess strong Spleen Qi, but can become Deficient in those individuals who already have weak Spleen Qi. Excessive eating and drinking of sweet foods, and overexposure to dampness weakens the Spleen.

Spleen Complications and Symptoms

Because of the importance of both the Spleen and Stomach, this chapter is divided into two separate sections. The first section focuses on specific Spleen diseases and how to rectify them. The second section explores the energetic dysfunctions of the Stomach.

The following discussion of treatment begins with an explanation of Spleen complications and symptoms. Spleen syndromes have symptoms which are common to the organ's energetic dysfunction such as: diarrhea, tiredness, and edema. A list of Spleen syndromes and their symptoms are described as follows.

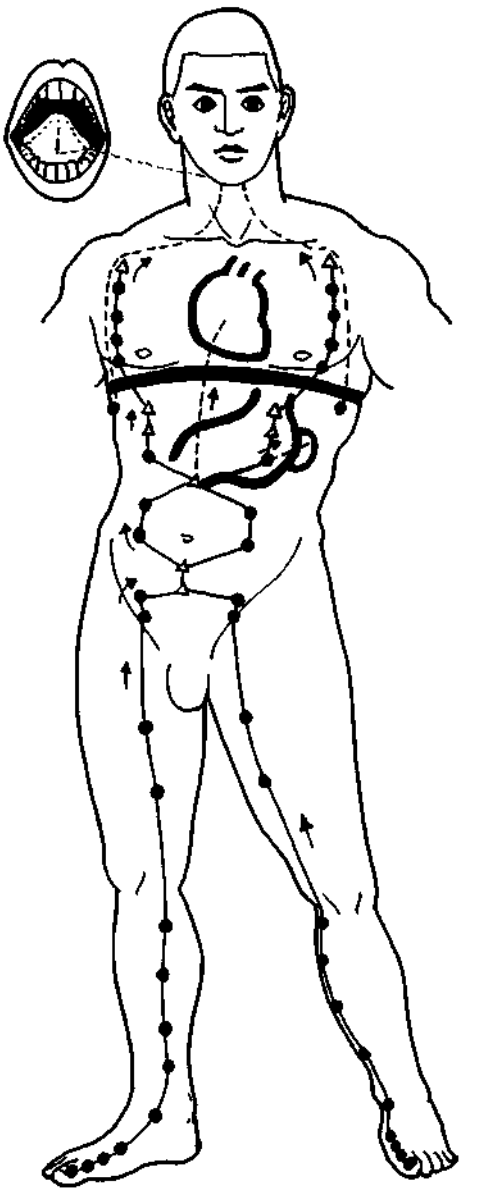

Figure 45.1. The Spleen (Sp) Channels

1. Spleen Qi Deficiency can cause such symptoms as: wheezing, tiredness, abdominal pain, diarrhea, constipation, painful urination, enuresis, bleeding and menorrhagia.
   a. Patients with a failure of normal transporting and transforming Qi activity in the Spleen may have a poor appetite, abdominal distention, loose stools, edema and retention of Phlegm.
   b. Deficient Spleen Qi may cause the Qi in the Middle Burner to sink. This results in shortness of breath, unwillingness to talk, persistent diarrhea, prolapse of the anus or uterus, or gastroptosis (downward displacement of the Stomach).
   c. Spleen Qi Deficiency can result in failure of the Spleen to control the Blood circulation and may be manifested by the following symptoms: bloody stool, bleeding from the uterus, and subcutaneous hemorrhaging.
2. Spleen Yang Deficiency can cause such symptoms as: tiredness and edema.
3. Spleen Blood Deficiency can result in fatigue.
4. Spleen Yin Deficiency can result in tiredness.
5. Damp Heat in the Spleen can cause such symptoms as: sinusitis, edema, common cold, and influenza.
6. Dampness in the Spleen can cause such symptoms as: diarrhea, tiredness, edema, and Wind Stroke.

General Treatment for Spleen Diseases

The following is a description of a general protocol used for treating the Spleen. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body towards which Qi is emitted (or Turbid Qi removed). Once the Qigong doctor becomes proficient at locating these specific points, the treatment will flow more smoothly.

After comparing the various Spleen therapies, the reader will notice that certain patterns repeat

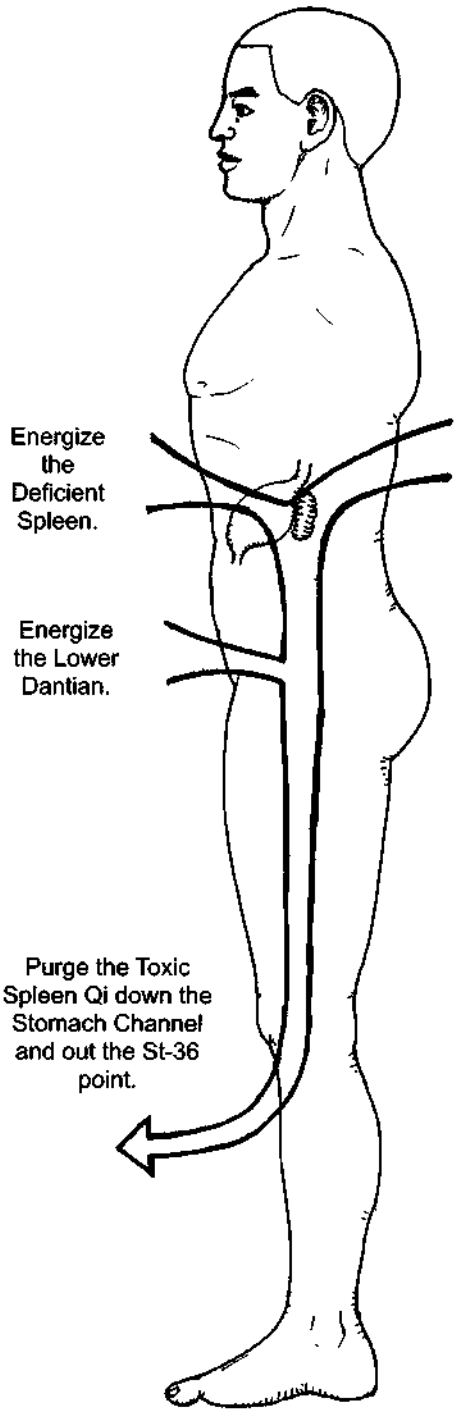

Figure 45.2. Treating Spleen Conditions

themselves.

1. Generally, the Qigong doctor accesses the patient's Spleen through either direct energetic insertion into the Spleen's anatomical location, or through the patient's channels and external energetic fields.
2. After treating the patient (purging, tonifying, and regulating), the Qigong doctor stimulates the patient's Spleen and Yellow Court areas, and roots the patient's Middle Burner Qi into the Lower Dantian.
3. Next, the Qigong doctor leads any remaining Turbid Qi down the Stomach Channels and out of the patient's St-36 points (Figure 45.2).

Keep in mind that these areas are general and that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

MEDICAL QIGONG THERAPY FOR SPLEEN QI DYSFUNCTION

The primary therapy used to treat the Spleen and gastric diseases include the Windy Breathing method (see Chapter 16) to strengthen the Liver, Spleen, Lungs, and the Kidneys.

1. Spleen diseases should be treated by vocalizing the "Hu" sound, which is effective for removing Turbid Qi accumulated in the Spleen, as well as for aiding digestion (Figure 45.3).
2. To treat insufficiencies of the Middle Burner, the doctor emits Qi into the patient's Zhong Wan CV-12 point and Lower Dantian points to reinforce the patient's Qi in the Middle Burner area.
3. Patients with an Excess Heat syndrome of the Spleen should be treated by guiding the Qi out along the Spleen and Stomach Channels with Pulling and Leading Qi manipulations to expel the Turbid Qi from both the Spleen and Stomach.

SPLEEN QIGONG PRESCRIPTIONS

The following exercise regulates the Qi and Blood of the Spleen Channels, strengthens the Spleen and replenishes Qi. It also regulates the Stomach and promotes digestion. It can be used to prevent and treat diseases and syndromes such as: gastritis, gastric and duodenal ulcers, colitis and gastrointestinal neurosis, abdominal distention, diarrhea and constipation.

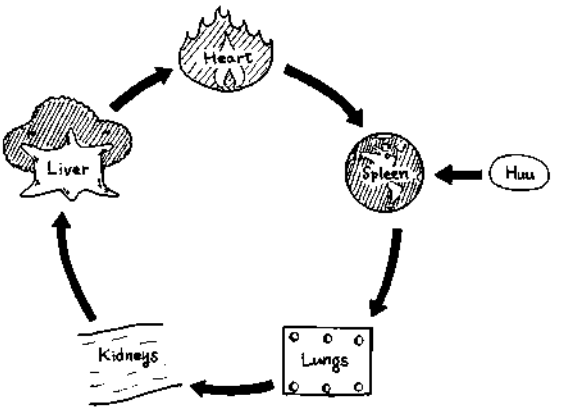

Figure 45.3. The "Hu" sound will purge the Spleen.

PRESCRIPTIONS FOR TONIFYING THE SPLEEN

The method of Taking in the Yellow Qi can be used to tonify the Spleen. The properties inherent within the yellow color have a persistent vibratory rate used for tonifying the Spleen and Stomach.

1. Assume a standing or sitting posture. Relax the whole body, breathe naturally, and get rid of any stray thoughts.
2. When inhaling, imagine yellow energy in front of you. Inhale the yellow light energy in through the nose and down into the Spleen organ. As you exhale through the mouth, the dark, pathogenic Qi leaves the Spleen; however, the bright clean color remains in the organ, stimulating and vitalizing it. With each breath the organ retains more clean energy and begins to glow. Repeat for five breaths.
3. Next breathe the color yellow in through the nose, filling the entire mouth. When exhaling through the nose, send the Qi slowly to the Zhongwan CV-12 point, then out to the four limbs, skin, and hair. Repeat five to ten times. Return to the beginning posture and close the training.

Figure 45.4. Twist at the waist, swing the arms, and look towards the opposite direction, focusing the mind's intention on the heel.

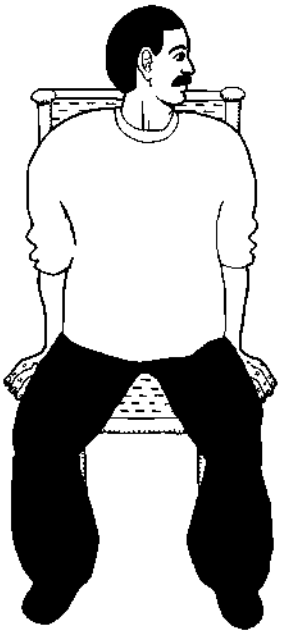

Figure 45.5. Turn and look over the shoulder with both eyes wide open.

PRESCRIPTIONS FOR PURGING THE SPLEEN

Purge the Spleen by having the patient rub his or her epigastrium while toning the sound "Hu."

Assume a sitting or standing posture. Gently place both palms (left on the outside for men, opposite for women) flatly on the Zhongwan CV-12 point on the upper abdomen. Exhale, rubbing the palms in a clockwise direction while sounding "Hu". Perform ten to twenty breaths.

Dredging the Spleen and Stomach

The following exercise is used to purge Toxic Qi from the Spleen and Stomach.

1. Assume a standing posture and breathe naturally. While relaxing the whole body, twist at the waist as you swing both arms in front of the body to the left, then to the right. Look in the opposite direction when turning the torso. As you turn your torso, your mind should be focused on your heels. Continue until you feel all tension has left your body (Figure 45.4).
2. Assume a sitting posture. While sitting on a bed, press the palms level on the mattress and meditate until you feel peaceful and relaxed. Turn the head towards the left and look over your left shoulder into the distance. Then turn the head to the right and look back over your right shoulder into the distance. Pause in the center, facing forward (Figure 45.5). When looking over the shoulders, both eyes should be wide open. Repeat five times in each direction.

PRESCRIPTIONS FOR REGULATING THE SPLEEN AND CONDUCTING QI

The following exercise is used to regulate the Spleen after purging or tonifying.

1. In a Wuji posture, begin by placing the hands on the Yellow Court and begin circle rotation in a clockwise direction for 36 rotations, ending at the Lower Dantian. Pause for 18 breaths to root the Spleen Qi in the Lower Dantian.
2. Next, rotate the abdomen in a counterclockwise direction for 36 rotations, ending at the Lower Dantian. Pause for 18 breaths and return to Wuji posture.

SPECIFIC MEDICAL QIGONG THERAPY FOR SPLEEN DISEASES

The following Medical Qigong treatment is used in China to treat specific types of Spleen disease.

DIABETES

Diabetes refers to a syndrome characterized by polydipsia (excessive thirst), polyphagia (excessive eating), and emaciation. It is a general term used to describe diseases characterized by insufficient secretion of insulin and excessive urination.

The prescriptions described in this section can also be used for the treatment of such disorders as: psychogenic polyuria, polyphagia due to hyperthyroidism, hyperhidrosis (excessive sweating), and emaciation.

ETIOLOGY

According to Traditional Chinese Medicine, diabetes is caused by disturbances in the Spleen and Stomach functions of transforming and transporting energy and the accumulation of toxic Heat in the body. These malfunctions can be due to eating too much sweet and greasy food, or drinking too much alcohol.

From the Western medical perspective, there are two types of diabetes, one type can be controlled through diet, the other cannot (usually hereditary). Diabetes is included in metabolic diseases (the Beta cells in the pancreas do not produce enough insulin) and caused by pathogenic factors relating to genetic predispositions, environmental stress, diet, obesity, and alcohol consumption.

In the Medical Qigong clinic there are three main factors that can contribute to the origination of diabetes: improper diet, emotional factors, and congenital predisposition.

1. The first factor is due to improper diet, including the excessive intake of alcohol, acrid, sour, pungent and greasy foods. The excessive intake of these types of foods can cause stagnation at the Middle Burner (which houses the Stomach and Spleen), and failure of the Stomach and Spleen to transport the accumulated Heat inside the body. This in turn can give rise to failure of the body's Yin fluids to nourish the Lungs and Kidneys, resulting in diabetes.
2. The second factor is due to a state of constant emotional upheaval. Emotional upsets can lead to stagnation of Qi which in turn impairs the body's Fluids, causing a Yin Deficiency with a hyperactivity of Evil Fire, resulting in diabetes.
3. The third factor is due to a genetic predisposition that can eventually surface if the patient is negligent with his or her diet and emotional health.

The Qigong doctor focuses on strengthening the patient's Spleen and Stomach, regulating the Liver Qi, and tonifying the Lung, Stomach, and Kidney Yin (which has been consumed by the Toxic Heat). It also is helpful to monitor the patient's eating habits to correct the disturbed metabolic rate and promote the regeneration and secretion by the patient's pancreatic islet cells.

SYMPTOMS

1. Diabetes involving the Upper Burner is characterized by excessive thirst, dry throat, dry tongue, and frequent urination.
2. Diabetes involving the Middle Burner is characterized by consuming abnormally large quantities of food during meals, emaciation, or constipation.
3. Diabetes involving the Lower Burner is characterized by frequent sweet smelling urination, or chyluria (passing of fat globules in the urine), and weakness and softness in the waist and knees.

TREATMENT

1. Begin by stimulating the Bl-23, Bl-20, Bl-13, St-36, and Sp-6 points on both sides of the patient's body.
2. Then purge and dredge the patient's CV-12, CV-4, and St-21 points.
3. Next, use the Extended Fan Palm hand manipulation with the Vibrating Palm technique to emit Qi into the patient's Bl-23, Bl-20, Bl-13, CV-12, and CV-4 for six to twelve breaths.
4. Continue emitting Qi into those points and into the Middle Dantian to regulate the Qi

activities of the Upper, Middle, and Lower Burners.

5. End the treatment by softly holding on to the patient's LI-11, LI-4, and Ht-1 points on both sides of the body, and with a gentle rocking or shaking motion allow the Qi to flow into the patient's body, settling into the patient's Lower Dantian.

PRESCRIPTIONS AND HOMEWORK

The "Inner Health" cultivation meditation is given to patients with diabetes, and is prescribed as follows.

1. Have the patient begin in a sitting posture, eyes closed, body relaxed using natural abdominal breathing.
2. While inhaling, the patient places the tongue against the hard palate, and begins to mentally repeat the mantra "I am quietly sitting."
3. While holding the breath, the patient mentally continues by saying the words "I am healthy."
4. The patient then exhales, releasing the tongue from the palate, while thinking the last phrase.

MEDICAL QIGONG THERAPY AND STOMACH DISEASES

This second section focuses on specific Stomach diseases and how to rectify them (Figure 45.6). The following discussion of treatment begins with an explanation of Stomach syndromes and symptoms. Several Stomach diseases have symptoms which are quite common to the organ's energetic dysfunction, such as epigastric pain.

STOMACH COMPLICATIONS AND SYMPTOMS

A list of Stomach syndromes and their symptoms are described as follows.

1. Stomach Heat can cause headache, epigastric pain, and bleeding.
2. Stomach Damp Heat can cause sinusitis and epigastric pain.
3. Stomach Phlegm Fire can cause epigastric pain and mental and emotional problems.
4. Stomach Deficiency can cause epigastric pain, diarrhea, atrophy syndrome, and bleeding.

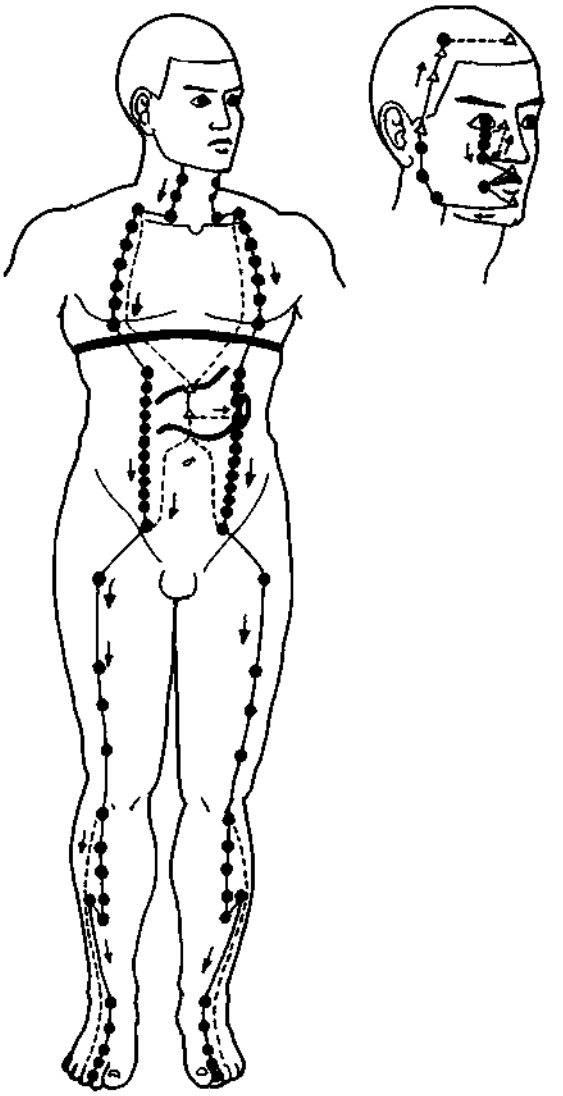

Figure 45.6. The Stomach (St) Channels

5. Stomach Yin Deficiency can cause tiredness, epigastric pain, and bleeding.
6. Cold invading the Stomach can result in epigastric pain.
7. Stagnant Blood in the Stomach can result in epigastric pain.

GENERAL TREATMENT FOR STOMACH DISEASES

The following is a description of a general protocol used for treating the patient's Stomach. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body towards which Qi is emitted (or Turbid Qi removed). Once the Qigong doctor becomes proficient at locating these specific points, the treatment will flow more smoothly.

After comparing the various Stomach therapies, the reader will notice that certain patterns repeat themselves.

1. Generally, the Qigong doctor accesses the patient's Stomach through either direct energetic insertion into the Stomach's anatomical location, or through the patient's channels and external energetic fields.
2. After treating the patient (purging, tonifying, and regulating), the Qigong doctor stimulates the patient's Stomach, Spleen, and Yellow Court areas, and then roots the patient's Middle Burner Qi into the Lower Dantian.
3. Next, the Qigong doctor leads any remaining Turbid Qi down the Stomach Channels and out of the patient's St-36 points (Figure 45.7).

Keep in mind that these areas are general and that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

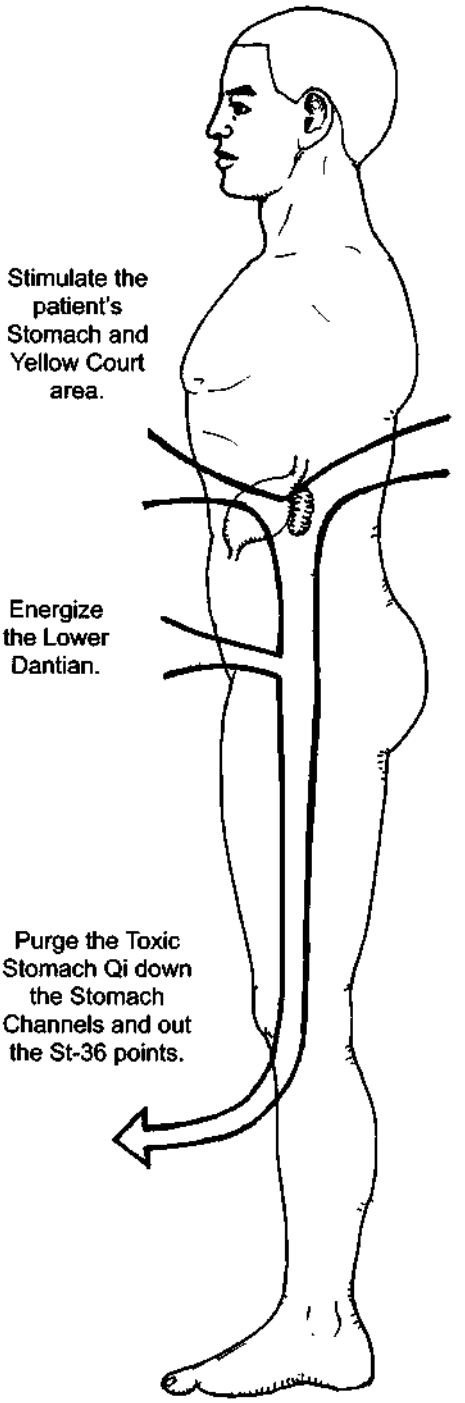

Figure 45.7. Treating Stomach Conditions

SPECIFIC MEDICAL QIGONG THERAPY FOR STOMACH DISEASES

The following are several Medical Qigong treatments used in China to treat specific Stomach diseases.

ABDOMINAL PAIN

Abdominal pain is an abnormal condition of the abdomen in which there is a sudden, abrupt onset of severe pain in any part of the abdomen below or just around the umbilicus.

Diseases such as acute pancreatitis, gas-

trointestinal spasm, stress induced abdominal pain, dyspeptic abdominal pain, and peritonitis, etc., in which abdominal pain symptoms appear, should be differentiated. Each differential diagnosis can be treated according to the exercises taught in the prescription section.

ETIOLOGY

The treatment for abdominal pain that is primarily intestinal in origin is different then that of gynecological abdominal pain, which is related to the menstrual cycle (see Chapter 51). There are four main factors which can contribute to the intestinal type of abdominal pain: abdominal pain due to the internal accumulation of Cold in the Lower Burner, abdominal pain due to dysfunction of Spleen Yang, abdominal pain due to food stagnation, and abdominal pain due to emotional stress.

1. Internal Cold in the Lower Burner may accumulate from eating too many cold foods and drinks, or can be due to the invasion of pathogenic Cold caused by exposure to the elements. Women in particular are more prone to Cold invading the abdomen during or immediately after menstruation. When Cold contacts the tissues, it slows down the movement of Qi and Blood, thus causing pain. External Cold may invade the patient's intestines directly without causing exterior symptoms, resulting in a sudden onset of pain and diarrhea.
2. Patients who are usually Deficient in Yang Qi often have a weak digestive system and a dysfunction of the Spleen Yang Qi. In this condition, pain often follows a pathogenic invasion, no matter how mild it may be. The pathogenic invasion may be due to overeating, overexertion, or brought on by eating after fasting and dieting, or simply by an Exterior Cold invasion.
3. Food stagnation is related to food intake or constipation, and is induced by Qi stagnation. The Stomach fails in digesting the food and the Spleen fails in separating and transporting the Clear and Turbid Qi.
4. Emotional stress is related to the circulation of Qi and Blood in the abdomen, and thus affects both the Liver and Spleen. Anger, frustration, and resentment can cause Liver Qi stagnation in the intestines, resulting in abdominal pain. Pensiveness and worry affect the Spleen and Lungs, impairing the transforming ability of the Spleen Qi and the downward descending ability of the Lung Qi, and likewise result in abdominal pain.

SYMPTOMS

1. Abdominal pain due to the internal accumulation of Cold, occurs abruptly, and may be relieved by defecation.
2. Abdominal pain due to Spleen Yang dysfunction, is characterized by continuous recurring pain, which may be relieved by pressure. Symptoms include loose stool, mental fatigue, and aversion to Cold.
3. Abdominal pain due to food stagnation, is characterized by gastric and abdominal distention, severe tenderness in the abdominal area, aversion to food and belching with acid regurgitation.
4. Abdominal pain due to emotional stress, is characterized by crying and vomiting.

TREATMENT

1. Have the patient lay on his or her side and begin stimulating the Bl-21, Bl-20, CV-12, St-36, and St-25 points on both sides of the body.
2. Purge the patient's Bladder Channels from the mid-back and waist area down to the feet three to five times.
3. Using the Vibrating Palm, emit Qi into the patient's CV-12, St-25, Bl-21, and Bl-20 points on both sides of the body. Purge and guide the Toxic Qi through the abdomen and down the lower extremities along the Stomach and Bladder Channels and out the patient's feet.
4. Using the Extended Fan Palm technique, extend Qi into the patient's CV-12 and both St-25 points for 14 breaths. Using Pulling and Leading manipulations, guide the patient's Qi down along the Stomach Channels and out both of the patient's feet.
5. Finally, Circle Rotate the patient's abdomen for 81 breaths in a clockwise direction.

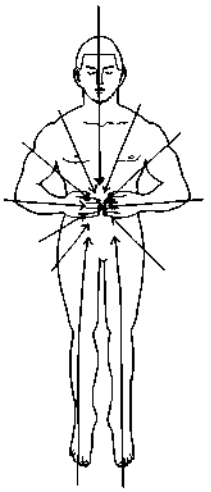

Figure 45.8. To tonify Deficient Stomach Qi, the patient must imagine drawing Qi into the body through the Baihui point at the top of the head, and the Yongquan points at the bottom of the feet. All three rivers of energy must meet to form a pool of energy within the Stomach area, which the body will absorb and store.

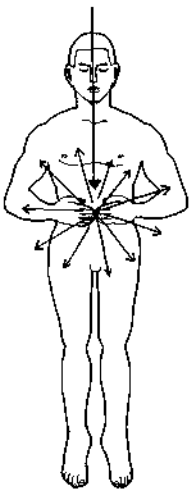

Figure 45.9. To treat Excess Stomach Qi, begin from a supine posture. While inhaling, imagine the Qi flowing down the Stomach Channels from the Baihui point ending just below the sternum at the Stomach area. Exhale and imagine the Turbid Qi dissolving and melting into the Lower Dantian, then disperse it from the body, out the pores.

TREATMENT MODIFICATIONS

1. In cases of abdominal pain due to the internal accumulation of Cold, add the method of extending Hot Qi.
2. In cases of pain due to Spleen Yang dysfunction, extend Hot Qi into the patient's Bl-21, Bl-20, and Mingmen area.
3. In cases of pain due to food stagnation, emit Qi using the Extended Fan Palm with clockwise then counterclockwise Spiraling methods into the patient's CV-12, CV-4, and St-25 points.
4. In cases of pain due to emotional stress, emit Qi using the Extended Fan Palm hand technique into the patient's Ht-7 and Pc-6 points on both sides of the body. Purge and Circle Massage the Shendao (GV-11) area in a counterclockwise direction.

PRESCRIPTIONS AND HOMEWORK

1. Have the patient place his or her right palm on the CV-12 area and begin to Circle Massage 36 times in a clockwise and then 36 times in a counterclockwise direction.
2. After completing the circle rotations, the patient pauses for a moment, and then leads the Qi down to the navel and continues the 36 rotations, in both clockwise and counterclockwise directions.
3. Next, the patient inhales and presses the fingers of both hands gently below the xiphoid process. The patient exhales and directs the Qi down along the midline of the body to the pubic symphysis area for 36 times.
4. Finally the patient overlaps his or her hands (right over the left in men and opposite in women) and places them on the midpoint of the lower abdomen to knead the tissue area clockwise and then counterclockwise 36 times.

PRESCRIPTIONS MODIFICATIONS

- In cases of Stomach pain due to Deficient Stomach Qi, have the patient lie supine. The patient must imagine drawing Qi into his or her body through the Baihui point at the top of the head, and the Yongquan points at the bottom of the feet. All three rivers of energy

must meet to form a pool of energy within the Stomach area, which the body will absorb and store into the Stomach's spacial cavity (Figure 45.8).

- In cases of Stomach pain due to Excess Stomach Qi and to treat Excess Stomach Qi symptoms, have the patient lie supine. As the patient inhales, he or she is to imagine the Qi flowing down the Stomach Channels (from the Baihui point) ending just below the sternum at the stomach area. As the patient exhales, he or she imagines the Turbid Qi trapped within the Stomach dissolving and melting into the Lower Dantian. Next, the patient disperses the Toxic Qi from the body out through the pores (Figure 45.9).

CHRONIC GASTRITIS

In Traditional Chinese Medicine, this disease belongs to the category of epigastralgia. Gastritis is described as an inflammation of the Stomach. Inflammation of the gastric mucosa is the main clinical manifestation of chronic gastritis, and results in chronic epigastralgia and dyspepsia (air hunger, resulting in difficult breathing, shortness of breath, sometimes accompanied by pain).

ETIOLOGY

Generally, emotional factors such as worry, anxiety, or anger may cause stagnation of Qi. Stagnant Qi, by impeding the function and flow of the body's energy, causes Qi deviations and obstructions that result in a stomach ache.

Gastritis can be superficial (affecting only the superficial layers of the Stomach) or atrophic (causing thinning of the Stomach mucosa). Its main manifestations are epigastric pain, which occurs about one hour after eating, followed by nausea, belching, and vomiting with sour regurgitation.

SYNDROMES

1. Liver and Stomach Qi stagnation, manifests as a distending pain, fullness, and discomfort in the Stomach, which is aggravated after a meal. The pain is not fixed to any specific Stomach location and worsens under emotional stress, causing belching with acid regurgitation and nausea.
2. Stomach Yin Deficiency due to Stomach Heat manifests as a stomach ache accompanied by a scorching sensation. The pain is not fixed to any specific Stomach location and is aggravated when the Stomach is empty, and is alleviated after a meal. The symptoms are expressed as irritability, dysphoria, and excess appetite.
3. Weakness of the Spleen and Stomach manifests as a dull stomachache which is relieved by Heat and pressure. Symptoms are expressed as abdominal distention, dim complexion, lassitude, cold limbs, and anorexia. If the patient has congenital insufficiency of Yang in the Middle Burner (the functional area of the Spleen and Stomach), Cold may originate from the interior of the body.

TREATMENT

1. Have the patient lie supine and relax his or her whole body, focusing especially on the Stomach area. The patient imagines the Toxic Qi dispersing upon exhalation.
2. Begin to purge and dredge the patient's CV-15 point (just below the xiphoid process), leading the Qi down to the Lower Dantian.
3. Next, use a Vibrating Palm hand technique to emit Qi into the patient's CV-12 point and both St-21 points for 14 to 28 breaths.
4. Applying the Extended Fan Palm hand technique to the patient's CV-12 and Middle Dantian, begin drawing Qi downward along the Conception Vessel and Stomach Channels to the bottom of the patient's feet.
5. Finally, have the patient lie prone and stimulate the Bl-20 and Bl-21 points on the lumbar-dorsal region, directing the energy from the upper back down to the Mingmen area.

TREATMENT MODIFICATIONS

1. For Stagnant Liver and Stomach Qi, use the Extended Fan Palm hand technique to emit Qi into the patient's Bl-18 points, pulling and conducting Qi along the Gall Bladder and Liver Channels down the legs and out the feet on both sides.
2. For Stomach Yin Deficiency due to Stomach Heat, use the Vibrating Palm hand technique

to emit Qi into the patient's Bl-20 and Bl-23 points, leading the Qi down the patient's Bladder Channels to the feet.

3. For Spleen and Stomach Deficiency, use the Extended Fan Palm hand technique to emit Qi into the patient's Lower Dantian area.

PRESCRIPTIONS AND HOMEWORK

Have the patient practice the Descending the Yang and Ascending the Yin technique (see Chapter 41).

PRESCRIPTION MODIFICATIONS

1. For patients with Liver and Stomach Qi stagnation, have the patient practice the Spleen and Stomach Massage (see Chapter 39). Then perform the healing sounds "Hu" to regulate the Spleen and "Shu" to regulate the Liver.
2. For treating patients with Stomach Yin Deficiency due to Stomach Heat, have the patient first dredge the Spleen and Stomach and then perform the "Chui" (pronounced Chree) healing sound to regulate the Kidneys. Next, have the patient practice the tonification method of Taking in the Yellow Qi (see Chapter 4).
3. For treating patients Deficient Spleen and Stomach Qi, have the patient first practice the Daoist Five Organ Regulation exercise (see Chapter 42). Next, have the patient practice the tonification method of Taking in the Yellow Qi to strengthen the Spleen and Taking in the Red Qi to strengthen and regulate the Heart.

GASTRIC AND DUODENAL ULCERS

An ulcer is an open sore or lesion of the skin or a mucus membrane, accompanied by sloughing of inflamed, dead, or dying tissue, that causes the Stomach's lining to become more vulnerable to acids. If the sore becomes infected puss is discharged.

ETIOLOGY

A gastric or duodenal ulcer refers to a chronic ulcer seen only in the regions where the gastrointestinal tract contacts the patient's gastric juice. Its formation and development is closely related to the digestive functions of the acidic gastric juices and pepsin. Clinically this type of ulcer is characterized by chronic recurring epigastralgia, lasting for a few weeks, with pain occurring from 30 minutes to two hours after eating.

Currently, Stomach ulcers are also being treated through either herbs or antibiotics (from Western medicine). They are caused by bacterial infections resulting from either Qi and Blood stagnation or a Deficient Cold syndrome of the Spleen and Stomach.

SYNDROMES

- Qi and Blood stagnation results in a distended pain and fullness in the Stomach, tenderness, belching, and acid regurgitation, which becomes aggravated by emotional stress.
- A Deficient Cold syndrome of the Spleen and Stomach results in a dull pain within the Stomach which is relieved by heat and compression and aggravated by cold. There can also be vomiting with watery regurgitation, shallow complexion, cold extremities, lassitude, and weakness.

TREATMENT

1. Have the patient sit at the end of the treatment table, and begin extending energy into the patient's mid-back along their Bl-18, Bl-20, and Bl-21 points using the Extended Fan Palm technique.
2. Next, use the Vibrating Palm to extend energy into the patient's Yellow Court area. When the area has been sufficiently stimulated, purge the Toxic Qi out of the patient's body by leading the Qi down to the Lower Dantian for 14 to 28 breaths.
3. Finally, use the Extended Fan Palm hand technique to emit Qi into the patient's CV-12 and St-34 points for 14 breaths. Then lead the Qi down the Conception Vessel into the Lower Dantian to root and stabilize the patient's energy.

TREATMENT MODIFICATIONS

- When treating patients with Qi and Blood stagnation, use the Extended Fan Palm hand method to emit Qi into the CV-12, CV-13, and St-21 points. Next, direct the Qi along the patient's Conception Vessel and Stomach Channels, leading the Toxic Qi down the

patient's legs and out of the body via the St-36 points.

- When treating patients with a Deficient Cold syndrome of the Spleen and Stomach, use the Extended Fan Palm hand method to emit Qi into the patient's Mingmen and Lower Dantian areas.

PRESCRIPTIONS AND HOMEWORK

In treating patients with ulcers, have them practice the Old Man Searching for the Reflection of the Moon at the Bottom of the Tide Pool exercise (see Chapter 53).

PRESCRIPTION MODIFICATIONS

- For patients with Qi and Blood stagnation, have them perform the Spleen and Stomach Massage (see Chapter 39) while sounding "Hu." Next, have the patient dredge the Spleen and Stomach using the sound "Shu" to purge the Liver and regulate Liver Qi.
- For patients with a Deficient Cold syndrome of the Spleen and Stomach, have them practice the method of Taking in the Yellow Qi from the natural environment.

CHRONIC CONSTIPATION

Chronic constipation refers to the prolonged retention of feces in the intestinal tract and difficulty in discharging the fecal matter. This condition is not only painful to the patient, but also increases toxicity in the body. It is clinically characterized by decreased times of fecal discharge or small amounts of feces which are considered either too dry and hard, or too difficult to be discharged.

Generally, the transitional time for food to pass through the digestive tract for humans takes 24 to 40 hours. The postponement of defecation over two days is considered constipation, although some normal patients may have regular defecation every two to three days.

ETIOLOGY

The common causes of constipation are: Diet, Febrile Diseases, Emotional Stress, and A Sedentary Life-style.

1. Diet plays a major role in causing constipation. Constipation can result from the excessive consumption of hot, spicy, or greasy foods. This excess consumption of hot and greasy foods can dry up the fluids of the Stomach and intestines, thereby drying up the stool so that it cannot properly move through the intestinal walls.

   An excess consumption of Cold foods can block the Spleen's function of transporting and thus prevent the stool from moving downwards.

   Finally, a lack of fiber in the food, lack of sufficient fluid intake or excessive alcohol consumption can cause constipation.
2. Febrile diseases can be caused by External Wind Heat invasion, which if not rapidly expelled from the body, can turn into an Interior Heat condition. The Interior Heat usually attacks the Lungs, Stomach, and intestines causing the Body Fluids to dry up. A Deficiency of Body Fluids from the retention of Heat within the intestines (even after the febrile disease has passed) can cause dry stool and constipation.
3. Liver Qi stagnation (due to mental depression, anger, resentment, or frustration) can cause a Qi obstruction in the Lower Burners that affects bowel movements and leads to constipation, abdominal distention, and pain. Excessive studying, worrying, and thinking affects the Spleen, slowing down its transportation of food in the intestines, this in turn can lead to constipation.
4. A sedentary life-style, whether from choice or due to a weak constitution from a chronic or severe illness (or surgery), can cause constipation. Patients in convalescent homes often suffer from constipation due to a lack of exercise and poor diet, which can lead to Spleen Qi and Blood Deficiency. Lack of exercise weakens the Spleen Qi and can cause Liver Qi stagnation. When Spleen Qi becomes Deficient for long periods of time, the Spleen energy fails to provide the Qi to move the stool, resulting in constipation.

SYNDROMES

- Constipation due to an Excess condition is caused by decreased times of fecal discharge

(once every three to seven days), and is usually accompanied with fever, thirst, poor appetite, and emotional anxiety.

- Constipation due to a Deficient condition is mostly seen in patients who have just recovered from an illness, or have just given birth and have become Deficient in Qi and Blood. It may also be observed in patients who suffer from a congenital insufficiency of Yang Qi in their Lower Burner and an accumulation of Yin Cold, which makes it difficult for the intestines to perform their normal transporting function. Patients with a Deficient condition may have bowel movements every three to seven days. The stool may be very dry, hard, and difficult to pass. This condition is clinically manifested by a pale and dull complexion, listlessness, and cold pain in the abdomen which is relieved by heat. The patient may also experience emotional fright due to a Kidney Qi Deficiency.

TREATMENT

1. Have the patient sit at the end of the treatment table, and begin to stimulate the patient's mid-back between the Bl-23 and Bl-25 points. Then stimulate the patient's lower lumbar and coccygeal areas, dredging and purging the Toxic Qi down the patient's thighs and the feet, while stimulating the Bl-31 through Bl-34 points.
2. The doctor will then have the patient lie supine and begin to stimulate the patient's Yellow Court and Lower Dantian areas, using the Vibrating Palm hand technique for 14 breaths.
3. Next, apply the Kneading Tiger Palm with the Vibrating and Quivering hand manipulations to emit Qi into the back of the patient's head at the Bl-10 points for 12 breaths, and then onto the patient's Lower Dantian for 14 breaths.
4. After energizing the patient's Lower Dantian, emit Qi, using the Extended Fan Palm technique, into the patient's middle epigastrium and navel area, as well as into the Lower Dantian. Finally, use the Spiraling and Quivering hand manipulation in a clockwise direction to gather the stagnant Qi and to lead it down the patient's Stomach Channels and out the legs.

TREATMENT MODIFICATIONS

- When treating patients with an Excess type of constipation, use the Extended Fan Hand Palm technique to emit Cold Qi into the patient's lower abdomen. Rotate the hand in a counterclockwise direction, while purging the Toxic Qi from the patient's body. Repeat for 14 breaths.
- When treating patients with a Deficient type of constipation, use the Vibrating Palm technique to emit Qi into the patient's Lower Dantian and Mingmen area for 8 to 16 breaths.

PRESCRIPTIONS AND HOMEWORK

To treat chronic constipation, have the patient practice the Daoist Five Yang Organ Regulating exercise (see Chapter 42) for 250 breaths twice a day.

PRESCRIPTION MODIFICATIONS

- For patients with an Excess type of constipation, place them in the Wuji posture with their hands resting on their lower abdomen. Begin with a clockwise rotation, imagining the Toxic Qi draining from the patient's Spleen and Stomach areas, down into their Stomach Channels and out their feet.
- For patients with a Deficient type of constipation, have them practice rubbing their Lower Dantian to strengthen the abdominal Qi, and have them practice the Gathering the Sun's Essence meditation (see Chapter 11).

Chapter 46
Qi Emission Therapy and Lung Diseases

Introduction

The Lungs are solid organs that control the cycles of Qi circulation in the body, and are sometimes referred to as the White Emperor. They correspond to the element Metal. The Lungs house the Po (Corporeal Souls) and are in charge of respiration and regulating the metabolism of the Body's Fluids (Figure 46.1). The Lungs are also responsible for keeping Qi pure and extending it downward. The Lungs are energetically paired with the Large Intestine (a hollow organ).

The Lungs' upper external connection with the outside world is through the nose, hence any fragrance or odor inhaled through the nose affects the senses and evokes emotional responses from the Po.

In the fall months, the Lung Qi becomes more active in individuals that already possess strong Lung Qi, but becomes Deficient in those who already have weak Lung Qi. The excessive eating and drinking of pungent foods and the overexposure to dryness drains the Lungs.

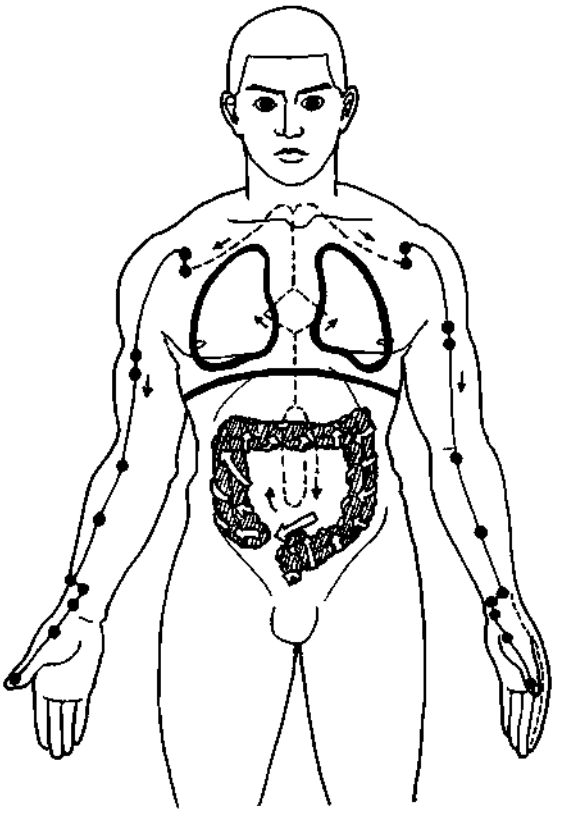

Figure 46.1. The Lung (Lu) Channels

Lung Complications and Symptoms

This section focuses on specific Lung diseases and how to rectify them. The following discussion of treatment begins with an explanation of Lung syndromes and symptoms. Several Lung diseases have symptoms which are quite common to the organ's energetic dysfunction, such as headaches, cough, the common cold and influenza. A list of Lung syndromes and symptoms are described as follows.

1. Wind Cold invading the Lungs usually enters the patient through the pores of the skin and body hair (which are ruled by the Lungs). If the Lungs' energetic field is invaded by Wind Cold, it may cause the Lung Qi to become impure, ascend, and cause obstructions in the pores, resulting in a Wind Cold syndrome. This can cause the following symptoms: severe aversion to cold, headache, cough, the common cold or influenza, breathlessness, asthma, and allergic rhinitis.
2. Wind Heat Invading the Lungs usually enters the body by way of the mouth and nose; the nose being the orifice to the Lungs. If the Lungs' energetic field is invaded by Wind Heat, it may cause the Lung Qi to become impure, ascend, and impede the ability of the

pores to expel pathogenic Evils, resulting in a Wind Heat syndrome. This can cause the following symptoms: slight aversion to cold, headache, cough, the common cold or influenza, asthma, allergic rhinitis and sinusitis.

3. Wind Dampness is a type of Wind Cold syndrome. It consists of both Wind and Dampness together, invading either the skin (causing itching and rashes) or the channels and joints (causing painful obstruction syndrome). If the Lungs' energetic field is invaded by Wind Dampness, it causes the following symptoms: skin rashes, swollen joints, body aches, headaches, the common cold and influenza.
4. Wind Dryness invading the Lungs causes the following symptoms: dry, itchy sore throat, dry lips, dry mouth, the common cold and influenza, cough and bleeding.
5. Lung Heat causes the following symptoms: restlessness and a feeling of heat, common cold and influenza, cough, sinusitis, breathlessness and atrophy syndrome as the body's functions begin to shut down.
6. Lung Phlegm Heat causes the following symptoms: common cold and influenza, cough with expectoration, breathlessness and a sensation of oppression in the chest.
7. Cold-Damp Phlegm invading the Lungs causes the following symptoms: a feeling of heaviness, cough with profuse expectoration, wheezing, nausea, poor appetite and breathlessness.
8. Lung Qi Deficiency causes the following symptoms: breathlessness, wheezing, slight cough with no phlegm, asthma, allergic rhinitis, tiredness, spontaneous sweating, and enuresis or incontinence.
9. Lung Yin Deficiency causes the following symptoms: night sweating, extreme tiredness, breathlessness, asthma, dry cough in short bursts, and Five Palms Hot (a condition also known as "Five Center Heat," in which the patient feels a hot sensation in the palms and soles of the feet, accompanied by heat and agitation of the chest and/or head area).

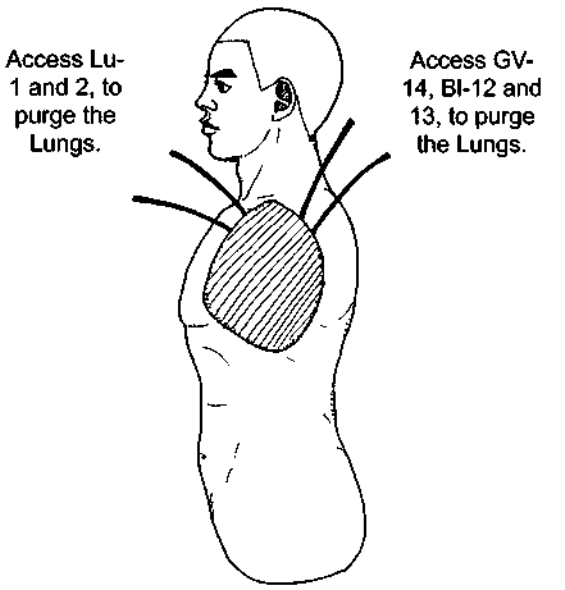

Figure 46.2. Treating Lung Diseases

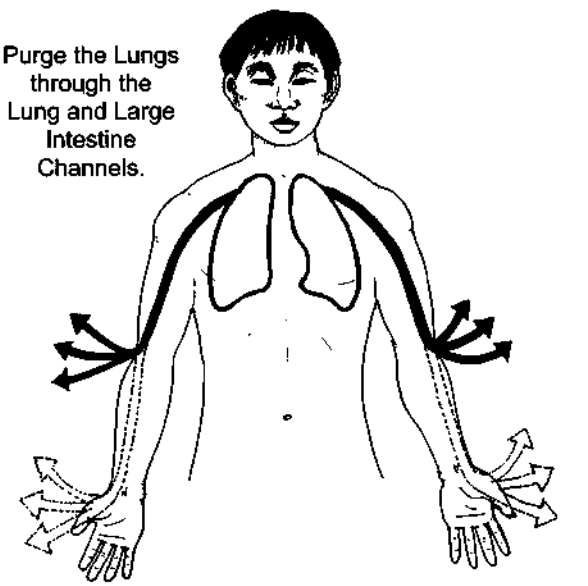

Figure 46.3. Drain the Turbid Qi out of the Lungs, down the Lung Channels and out of the hands.

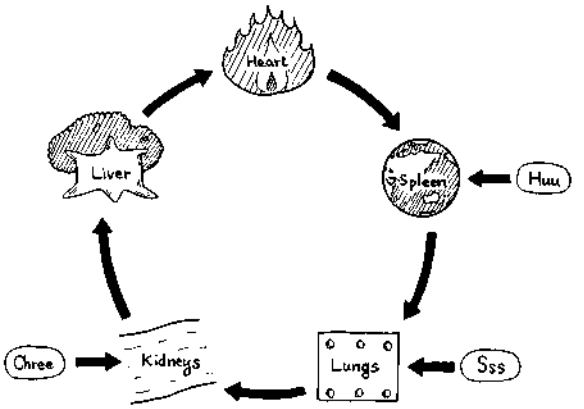

Figure 46.4. Replenish the mother (Spleen) to nourish the child (Lungs).

General Treatment for Lung Diseases

The following is a description of a general protocol used for treating a patient's Lungs. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body towards which Qi is emitted (or Turbid Qi removed). Once the Qigong doctor becomes proficient at locating these specific points, the treatment will flow more smoothly.

After comparing the various Lung therapies, the reader will notice that certain patterns repeat themselves.

1. Generally, the Qigong doctor accesses the patient's Lungs through either direct energized insertion into the Lungs' anatomical location, or through the patient's channels and external energetic fields (Figure 46.2).
2. After treating the patient (purging, tonifying, and regulating), the Qigong doctor stimulates the patient's Lungs and Upper Burner areas and roots the patient's Qi into the Lower Dantian.
3. Next, the Qigong doctor leads any remaining Turbid Qi down the Lung Channels and out the patient's hands (Figure 46.3).

Keep in mind that these areas are general and that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

Medical Qigong Therapy for Lung Qi Dysfunction

Patients with Lung disease may have a pale complexion, dry hair, dyspnea (difficult breathing), hyposmia (a deficient sense of smell), stuffy nose, dryness and itching of the skin, or discomfort and pain in the chest and back. Patients may dream of the sun, moon, clouds, or of having sex. The primary therapies used to treat Lung diseases include the Breath regulation and Qi reinforcing meditations (see Chapter 16).

- Patients with an Excess Heat syndrome of the Lungs may have a flushed right cheek. To treat this type of syndrome, have the patient utter the sounds "Si" (Sss) for the Lungs and "Chui" (Chree) for the Kidneys. Guide the Evil Qi out of the patient's body along the Lung and Large Intestine Channels using the Pushing, Pulling and Guiding Qi manipulations.
- Patients with a Deficient syndrome of the Lungs may have shortness of breath and be unable to regulate their breathing. To treat this type of syndrome, have the patients inhale the sound "Hu," as they visualize absorbing the color yellow to replenish the Spleen (the mother); this will nourish the Lungs (the child). Next, the patient guides the Qi back to the Lungs (Figure 46.4).

Lung Qigong Prescriptions

These exercises regulate the Qi in the Lung Channels, tonify the Lungs, replenish Qi, ventilate the Lungs, and relieve asthma, coughing, and sputum. These exercises can be used to prevent and treat the following diseases and syndromes: bronchitis, pulmonary emphysema, and bronchial asthma, as well as dyspnea and abundant expectoration.

Prescriptions for Tonifying the Lungs

The Taking in the White Qi meditation can be used to tonify the Lungs. The properties inherent within the color white have a persistent vibratory rate used for tonifying the Lungs and Large Intestine.

1. Assume a standing, sitting, or lying posture.

Figure 46.5. Inhale

Figure 46.6. Exhale

Figure 46.7. Inhale

Figure 46.8. Exhale

Relax the whole body, breathe naturally, and get rid of any stray thoughts.

2. When inhaling, imagine a white energy in front of you. Inhale the white light energy in through the nose and down into the Lungs. As you exhale through the mouth, the dark, pathogenic Qi leaves the Lungs; however, the bright clean color remains in the Lungs, stimulating and vitalizing them. With each breath the Lungs retain more clean energy and begin to glow. Repeat for five breaths.
3. Next breathe the color white in through the nose, filling the entire mouth. When exhaling through the nose, send the Qi slowly into the Lungs, then down to the Lower Dantian, and then further out into the skin and hair of the whole body. Repeat nine to eighteen times. Return to the beginning posture and close.

PRESCRIPTIONS FOR PURGING THE LUNGS

Purge the Lungs by having the patient rub his or her chest while sounding "Sss."

The patient should assume a sitting or standing posture. Both palms are placed flat on the sides of the chest as the patient inhales slowly. When exhaling, the patient sounds the word "Sss" while rubbing the chest with both palms (circling up and down, from the center outward). This exercise is performed for six to twelve breaths.

PRESCRIPTIONS FOR REGULATING THE LUNGS AND CONDUCTING QI

The following exercise is used to regulate the Lungs after purging or tonifying.

1. Sit with the legs crossed, breathe in with the spine arched backwards and the hands by the sides pressing against the ground; extend the chest, and inhale until the chest is full (Figure 46.5).

   Pause, then push the upper back in a posterior direction and draw in the chest while exhaling through the nose (Figure 46.6). Repeat four to nine times.
2. Next, still sitting with the legs crossed, place the palms on the knees. Inhale with the spine erect and turn the head allowing the torso to turn slightly to the left (Figure 46.7). Then bend forward and exhale while facing the center (Figure 46.8). Next, inhale and turn to the right, then again bend forward and exhale while facing the center. Always inhale when turning to the sides, and exhale while facing the center.

SPECIFIC MEDICAL QIGONG THERAPY FOR LUNG DISEASES

The following are several Medical Qigong treatments used in China to treat specific Lung diseases.

TREATING THE COMMON COLD AND INFLUENZA

Upper respiratory tract infections belong to the category of common colds, while influenza

belongs to the category of seasonal epidemic colds. Both conditions may be treated by referring to the prescriptions described within this section.

ETIOLOGY

The common cold is a generic term used to describe an Exterior condition caused from the invasion of pathogenic Wind (Wind Cold, Wind Heat, Wind Damp Heat or Wind Dry Heat). It is generally associated with coryza or inflammation of the respiratory mucous membranes.

Upper respiratory tract infection is caused by viruses or bacteria. Influenza is known as an acute, contagious respiratory infection, characterized by sudden onset. The chief clinical manifestations are stuffy nose, nasal discharge, coughing, sneezing, sore throat, fever, headache, chills, and an aversion to wind.

If the pathogenic Qi is on the Exterior level of the body, the internal organs are not affected, and only the patient's Wei Qi is involved. If the pathogenic factor becomes Interior, the patient's internal organs are affected, especially the Lungs and Spleen. If the pathogen is not cleared and purged from the patient's body, it may either penetrate more deeply into the patient's body and cause serious problems, or give rise to residual Heat which causes chronic post-viral fatigue syndromes.

SYNDROMES

- A Wind Cold syndrome has the following symptoms: chills, headache, aches and painful joints, coughs and sore itchy throat, stuffy nose, low fever, and no sweating with profuse, watery nasal discharge.
- A Wind Heat syndrome has the following symptoms: fever, cough, headache, slight aversion to cold, swollen and sore throat, thick yellow sputum, slight thirst, and perspiration. Once the pathogenic factor penetrates into the patient's interior, the body's Qi begins to fight against it, causing a fever and feeling of heat inside the body, with an aversion to cold, and shivering.

TREATMENT

1. Have the patient sit at the end of the treatment table.
2. Begin by stimulating the energy within the patient's head, purging and leading the Toxic Qi down the patient's arm and out the LI-11 and LI-4 points.
3. Then stimulate the patient's Yintang (Third Eye) and Taiyang (temple) points. Using Pulling and Leading Qi manipulation techniques, purge and guide any remaining Toxic Qi downward, along the Conception Vessel and the Stomach Channels, out the patient's feet, three to seven times.
4. Next, to balance the functional activities of the body's Qi, stimulate the tissue area on the patient's upper back and head (GV-14 and GV-16, Bl-12 and Bl-13) using the Extended Fan Palm technique, and guide the Qi downward along the Bladder Channels to the patient's feet.
5. Finally, softly grasp the patient's LI-4 and LI-11 points and gently shake the arm, stimulating the patient's Lung Qi. This technique is performed on each of the patient's arms.

TREATMENT MODIFICATIONS

1. When treating patients with Wind Cold syndrome, extend Hot Qi into the GV-14 and Bl-12 points, using the Extended Fan Palm technique, and guide the Qi downward along the Bladder Channels to the patient's feet and out the body.
2. When treating patients with Wind Heat syndrome, extend Cold Qi into the GV-14, Bl-13, and GB-20 points, using the Extended Fan Palm technique, and guide the Qi downward along the Stomach Channels to the patients' feet and out the body.
3. When treating patients with nasal obstruction, extend Vibrating Qi, using the Sword Fingers technique, into the LI-20 points for 9 breaths.
4. When treating patients with cough, chest stuffiness, and Phlegm, extend Vibrating Qi, using the Sword Fingers technique, into the CV-17, Lu-1, and Lu-2 points for 8 breaths.

PRESCRIPTIONS AND HOMEWORK

The patients should be given the Ten Dragons Run Through the Forest exercise (see Chapter 41) to sweep and purge the Gall bBladder

Channels. Most of the attention should be placed on feeling the Qi beneath the hands, with emphasis placed on exhalation to expel the pathogenic Wind from the body. Perform this prescription for 24 to 50 times.

CHRONIC BRONCHITIS

Chronic bronchitis is a condition caused by the chronic inflammation of the mucous membranes of the bronchial tubes.

ETIOLOGY

Chronic inflammation of the bronchial mucosa and peribronchial tissues is mostly due to lingering and recurrent acute bronchitis, or may occur after an infection from other diseases. The chief clinical manifestations are chronic recurring cough, expectoration and dyspnea. Bronchitis can be divided into acute and chronic conditions.

1. Acute bronchitis corresponds to the Qi level of infection within the four level identification patterns. It is the easiest to treat, and normally manifests with Hot Phlegm symptoms.
2. Chronic bronchitis takes a little longer to heal and the doctor should focus treatment on attending to the root and manifestation of the disease simultaneously (purging Phlegm and dispersing the Heat or Cold).

SYNDROMES

- For Phlegm Dampness attacking the Lungs, the main symptoms are abdominal distention, cough with copious white sputum, stuffiness in the chest and loss of appetite.
- For Lung and Spleen Deficiency, the main symptoms are cough with sputum, shortness of breath, spontaneous sweating, loss of appetite and loose stool.

TREATMENT

1. Have the patient sit at the edge of the table. Begin to purge the patient's Lungs, dredging the Toxic Qi down the Lung Channels and out of the hands.
2. Use the Vibrating Palm technique to stimulate the patient's Middle Dantian, Lu-1, -2, Bl-13, GV-16, and St-40 points. Use 8 to 12 breaths for each point.

TREATMENT MODIFICATIONS

- For Phlegm Dampness attacking the Lungs, use the Extended Fan Palm technique to emit Qi into the patient's Lungs; purge the Spleen and Stomach Channels, leading the Toxic Qi down the channels and out of the St-40 and Sp-6 points on each leg.
- For Spleen and Lung Deficiency, emit Qi using the Vibrating Palm technique into the patient's Bl-20, Bl-23, Bl-13 and CV-12 points for 6 to 12 breaths.

PRESCRIPTIONS AND HOMEWORK

Have the patient practice the Lung exercise from Daoist Five Yin Organ Tonification and Regulation exercises (see Chapter 42) to strengthen and balance the Lungs.

PRESCRIPTION MODIFICATIONS

- For patients suffering from Phlegm Dampness attacking the Lungs, have the patient perform the Sun and Moon Rotating technique (see Chapter 41), sounding "Sss" to regulate the Lungs and the sound "Hu" to regulate the Spleen.
- For patients suffering from Lung and Spleen Deficiency, have them perform the Taking in the White Qi to tonify the Lungs, and the Taking in the Yellow Qi to tonify the Spleen.

ASTHMA

Asthma is a chronic disorder of the respiration organs characterized by difficulty in breathing, wheezing, and tightness in the chest. Bronchial asthma, chronic bronchitis and pulmonary emphysema are all included in the category of this disease.

ETIOLOGY

Asthma is an Excess condition which is caused mainly by a retention of Wind, Cold, Heat or Damp Phlegm in the Lungs. When a patient is affected by invasion of pathogenic Dampness, disorders in Qi mobility develop. Phlegm mixes with Qi and obstructs the air passages, causing dyspnea (shortness of breath) and wheezing.

Asthma may also result from an obstruction of the Lungs due to Phlegm retention caused by a failure of the Spleen to transport, or from a Defi-

cient condition of the Kidneys. The diagnosis of this disease can be divided into two types of asthma: early onset asthma and late onset asthma.

1. Early onset asthma (also called extrinsic or atopic asthma), usually starts during childhood and is divided into non-allergenic and allergenic asthma. Allergic asthma is associated with eczema and it tends to be difficult to treat because it stems from a congenital Lung and Kidney Qi Deficiency and is often hereditary. Early onset asthma can be affected by diet (e.g., lactose intolerance), emotional problems, fatigue, chronic illness and invasion by external pathogenic factors. It is related to an allergic hypersensitivity of the immune system.
2. Late onset asthma (also called intrinsic asthma) normally starts later in life and is due to bronchial hyperreactivity. In late onset asthma there is no hereditary basis. It is generally characterized by a Lung, Spleen, or Kidney Deficiency and a retention of Phlegm. In some cases, asthma can be caused by Liver Qi stagnation or Liver Fire obstructing the descending action of Lung Qi. Late onset asthma can be affected by overwork, excessive sexual activity, emotional stress and the excess consumption of sour, greasy or cold foods.

SYNDROMES

1. For Wind Cold asthma due to External Evils, the main symptoms are dyspnea, coughing, abundant, thin expectoration and clear Phlegm accompanied with external Wind Cold syndrome.
2. For asthma due to the accumulation of Phlegm Dampness in the Lungs, the main symptoms are dyspnea, cough, abundant, thin and sticky expectoration, stuffiness in the chest and in the epigastric region.
3. For asthma due to Deficient Lung and Spleen Qi, the main symptoms include dyspnea, spontaneous perspiration, aversion to Wind, an expectoration of clear, thin Phlegm, weak voice, loss of appetite and general lassitude.
4. For asthma due to Deficient Lung and Kidney Yin, the main symptoms are dyspnea, dry throat and mouth, dry cough, inconsistent fever, night sweating, and with some patients there may be hemoptysis (the expectoration of Blood).

TREATMENT

The therapeutic effect of Medical Qigong is better for patients who have had this disease for a short time period. In chronic asthma, improvement usually takes more time.

1. Begin by stimulating the patient's CV-22, CV-17 and CV-4 points along with the Bl-13 points.
2. Using the Vibrating Palm technique and emit Qi with the left palm into the patient's lower neck and upper back area, while simultaneously extending energy into the patient's Lower Dantian with the right hand for 14 to 28 breaths.
3. Purge the Toxic Qi from the patient's CV-22 and Bl-13 areas, then lead and guide the patient's Lung Qi down the Governing Vessel and Bladder Channels into the Mingmen GV-4 and Bl-23 points. Repeat for 3 to 7 respirations.
4. Using the Sword Fingers hand posture, vibrate energy into the patient's CV-22, -17, Lu-1 and Lu-2 points. Then guide the patient's Qi to flow downward from the chest to the Lower Dantian along the Stomach Channels and Conception Vessel to stabilize the patient's Qi.

TREATMENT MODIFICATIONS

1. To treat a case of Wind Cold syndrome due to exogenous Evils, purge and sweep the patient's Gall Bladder Channels, concentrating on the head area. Then extend Qi into the patient's Lu-1 and Lu-2 points. Use Pulling and Leading manipulations to draw the Toxic Qi along the patient's Lung Channels, expelling the pathogenic Qi out of the fingertips on both hands.
2. In treating cases of Deficient Lung and Spleen Qi, use the Extended Fan Palm hand posture and Vibrating Palm technique to emit Qi towards the patient's CV-12, CV-6, Bl-20 and Bl-13 points for 9 to 18 breaths.

3. In treating cases of Deficient Lung and Kidney Yin, use Extended Fan Palm hand posture and Vibrating Palm hand technique to emit Qi towards the patient's Lower Dantian, Mingmen, and Bl-13 points for 6 to 12 breaths.

PRESCRIPTIONS AND HOMEWORK

Patients are encouraged to practice physical exercises to strengthen the body and enhance their resistance to pathogenic invasion. These exercise prescriptions however, must not be too strenuous. Two prescriptions used for relieving asthma and respiratory pain are described as follows.

Exercise to Relieve Asthmatic Pain. For chronic conditions of asthma, patients are given the following prescription:

1. From a sitting or standing posture, slightly close the eyes and relax. Stimulate the energy of the chest by kneading the sternum from the sternal notch to the xiphoid process 36 times.
2. Inhale and place the right palm on the left side of the chest. Exhale, and begin dredging the left Lung Channel using a sweeping motion to purge the Toxic Qi down the arm and out through the hand. Perform this Purging exercise 10 times, then repeat 10 times on the opposite side.
3. Finally, perform the Kidney Rub exercise (see Chapter 39) for 18 breaths.

Exercise to Relieve Asthma Attacks

For acute asthmatic attacks, patients are given the following prescription.

From a sitting or standing posture, slightly close the eyes and relax the muscles of the chest and back. Take a deep breath and say "relax" silently, while simultaneously imagining the Lungs relaxing and descending the body's Qi down to the toes along both lateral sides of the body. As the Qi descends from the Lungs, imagine this energy flowing like water, down your body into the Earth. Repeat this procedure until the asthma attack has receded.

PRESCRIPTION MODIFICATIONS

- Patients with Deficient Lung Qi should practice the previous exercises in combination with Taking in the White Qi.
- Patients with a domination of pathogenic factors should practice the previous exercises in combination with rubbing their chest and uttering the sound "Sss."

BRONCHIECTASIS

Bronchiectasis is the chronic dilation of the bronchi, with a secondary infection that usually involves the lower portion of the Lungs. Dilation may involve an isolated segment or can spread throughout the entire bronchi.

ETIOLOGY

This disease is characterized by hypertrophy of the mucus-secreting glands in the bronchial tree. The dilation and deformation of the bronchi are caused by the damage of the vessel walls due to chronic inflammation of the bronchi and the peribronchial Lung tissue. In advanced cases the bronchi themselves can become inflamed with infection. The clinical manifestation is a chronic cough with an excessive expectoration of sputum. If followed by infection, there may be night sweating, fever and lassitude.

SYNDROMES

1. Liver Fire attacking the Lungs can manifest with pain and distention in the chest and hypochrondium, flushed face, cough, expectoration of yellow, thick sputum and repeated hemoptysis (Blood discharging from the larynx, trachea, bronchi, or Lungs).
2. Dry Heat scorching the Lungs manifests as a dry throat and dry cough with little sputum, which is bright red and bloody.
3. Qi and Yin Deficiency manifests through shortness of breath, lassitude, emaciation, repeated hemoptysis, cough with little sputum, erratic fever and flushed face (especially around the cheeks).

TREATMENT

1. Have the patient sit at the edge of the table, and begin to stimulate the upper chest at the Lu-1 and Lu-2 points and the upper back around the patient's Bl-13 points.
2. Using the Extended Fan Palm hand technique, emit Qi into the patient's Middle Dantian directing the energy to flow into the Lu-1 and Bl-13 points for 6 to 12 breaths.

3. Using the Leading and Guiding hand techniques, purge and dredge the Toxic Qi out the Lung Channels (i.e., down the arms and out of the hands).

TREATMENT MODIFICATIONS

1. When treating patients with Liver Fire attacking the Lungs, include the Vibrating Palm technique, and emit Qi into the patient's Bl-13 and Bl-18 points for 12 breaths. Then purge the Liver Channels down the torso and out of the legs.
2. When treating patients with Dry Heat scorching the Lungs, apply the Vibrating Palm technique to emit Qi into the patient's Bl-23 and Bl-13 points for 24 breaths.
3. When treating patients with Qi and Yin Deficiency, apply the Vibrating Palm technique to emit Qi into the Bl-13, Bl-20, and Bl-23 points for 12 breaths.

PRESCRIPTIONS AND HOMEWORK

It is advisable for patients to practice regulating Lung exercises with Natural Breathing to strengthen the Lungs.

PRESCRIPTION MODIFICATIONS

1. For Liver Fire attacking the Lungs, have the patient perform the Sun and Moon Rotating technique (see Chapter 41), while sounding the word "Sss" for 36 breaths, to purge the Lungs in addition to performing the Lung tonification and regulation exercises (see Chapter 42). Next, have the patient rub the hypochrondrium area and sound the word "Shu" for 36 breaths.
2. For Dry Heat scorching the Lungs, (from a Wuji posture) have the patient bring both hands up to the sternum and begin kneading the sternum down to the xiphoid process 36 times. Next, the patient places both palms on the chest with the fingers touching the sternum to allow the Qi to flow into the Lungs for 10 breaths. Finally, the patient rubs the hypochrondrium and purges the Toxic Qi from the body while exhaling and rubbing the sides of the chest, starting at the armpits, to direct the Qi to flow downward into the Lower Dantian.
3. For Qi and Yin Deficiency, it is advisable for the patient to practice Lung tonifying exercises and the Gathering the Moon Cream exercises (see Chapter 11), as well as the methods of Taking in the White Qi.

SINUSITIS

Sinusitis is described as the inflammation of the sinuses. Infections stemming from the common cold or influenza frequently cause secondary infections in the sinuses, these infections tend to become chronic. The body's frontal and maxillary sinuses are very prone to infection and inflammation.

ETIOLOGY

An invasion of pathogenic Wind Cold into the Lungs through the nose (the orifice of the Lungs) can bring about the accumulation of Heat and cause an obstruction of the Lungs' Qi. This condition further impairs the Lungs' dispersing and descending function, giving rise to sinusitis.

The excessive consumption of greasy, hot foods leads to a buildup of Phlegm and Heat toxins within the body and may predispose the patient to sinusitis. Greasy, hot foods may also lead to the formation of Damp Heat within the Stomach and Spleen, which can be transported upwards into the sinuses by way of the Stomach Channels.

Excess conditions, such as Wind Heat, Lung Heat, Stomach and Spleen Damp Heat, and Liver and Gall Bladder Fire, should all be purged from the patient's body, whereas chronic conditions caused by Spleen Deficiency should be tonified.

SYNDROMES

Sinusitis is characterized by consistent yellowish and foul smelling nasal discharge accompanied by cough, impairment of smell, and dull pain in the upper part of the cranium. The headache caused from sinusitis is located on the face and corresponds with either the frontal ethmoidal or the maxillary sinuses.

TREATMENT

1. Begin by stimulating the patient's frontal sinuses, focusing specific attention on the LI-20, GB-20, and Yintang points.

2. Then emit Qi into both of the patient's hands and wrist areas, focusing specific attention on the LI-4 and Lu-7 points.
3. Next, using either the Sword Fingers or Extended Fan Palm hand posture, emit Qi into the patient's LI-20 points. Begin using the Pushing, Pulling, and Leading manipulations to guide the patient's Toxic Qi down the Stomach Channels, purging it out through the St-36 point on each leg.

PRESCRIPTIONS AND HOMEWORK

The following prescription is used for relieving sinusitis.

The patient, from a seated posture, rubs his or her palms until the dorsal sides of each thumb are very hot. Then the patient places the thumbs on the sides of the nose and begins to gently rub up and down for 10 breaths. This exercise is called Bathing the Nose.

Next, the patient places the tips of the middle fingers on each side of the nose (LI-20), and begins kneading these points. This is followed by using circular rotations from the cheeks to the nose five times during inhalation, and then from the nose to the cheeks five times during exhalation. This part of the exercise is called Kneading the Apex of the Nose. This exercise is performed for 10 breaths.

CHAPTER 47
QI EMISSION THERAPY FOR KIDNEY DISEASES

INTRODUCTION

The Kidneys are solid (Zhong) organs that store the body's Jing. They correspond to the element Water and are sometimes referred to as the Black Emperor. The Kidneys house the Zhi, which is the will power, and they are in charge of life and reproduction. The Kidneys are also responsible for bone, brain and Marrow formation. They govern the Mingmen Fire and are the root of the Yin and Yang energies within all the organs (Figure 47.1). The Kidneys are energetically paired with the Bladder (a hollow organ).

The Kidneys are responsible for inhalation. Upon inhalation the Kidneys grasp the Lungs' Qi and hold it. This "holding" action secures the body's ability to maintain deep, slow inhalation. Therefore, when the Kidneys become weak (due to shock, trauma or disease), one of the clinical manifestations of Deficient Kidneys includes dyspnea (shortness of breath and gasping for air).

The Mingmen, or Gate of Life, is the root of the Yuan Qi, the residence of Water and Fire energy. The Yin Qi of the Five Yin Organs cannot be nourished without it, and the Yang Qi of these organs cannot be lifted without it. Kidney Qi flows to the brain. The ears (Yang orifice), anus and urethra (two Yin orifices) are the orifices of the Kidneys.

The Kidneys' upper external connection with the outside world is through the ears, hence any sound or tone resonation affects the core essence of the individual's spiritual and emotional will power.

In the winter months the Kidneys become more active in individuals who already possess strong Kidney Qi, but becomes Deficient in those with weak Kidney Qi. The excessive eating and drinking of salty foods and overexposure to cold depletes the Kidneys.

Kidney Yin energy flows to the Liver, Heart, and Lungs. It is responsible for the body's Jing

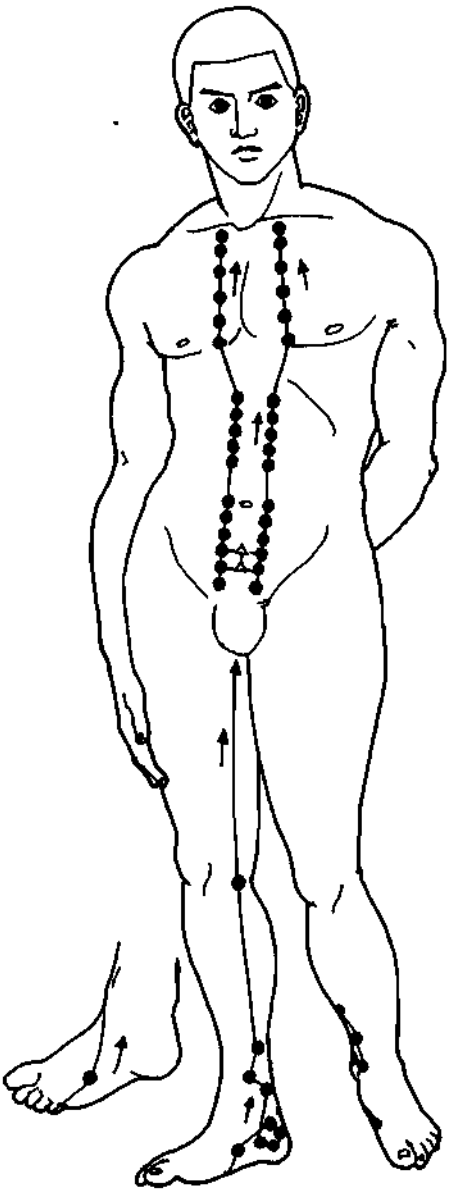

Figure 47.1. The Kidney (Kd) Channels

and produces the birth, growth, maturation, and reproduction cycle. Kidney Yang energy flows to the Spleen, Liver, Heart, and Lungs. It supports the Yang of all the body's organs via the Mingmen (Figure 47.2).

KIDNEY COMPLICATIONS AND SYMPTOMS

This section focuses on specific Kidney diseases and how to rectify them. The following discussion of treatment principles begins with an explanation of Kidney syndromes and symptoms. Several Kidney diseases have symptoms which are common to the organ's energetic dysfunction, such as mental and emotional problems, lower back pain, tiredness, and breathlessness. A list of Kidney syndromes and their symptoms are described as follows.

1. A Kidney Yang Deficiency syndrome manifests through such symptoms as headaches, breathlessness, wheezing, asthma, tiredness, mental and emotional problems, lower back pain, diarrhea, constipation, painful urination, enuresis, edema, menorrhagia and premenstrual tension.
2. A Kidney Yin Deficiency syndrome manifests through such symptoms as tiredness, chest tightness, asthma, breathlessness, mental and emotional problems, constipation, enuresis, lower back pain, bleeding, Parkinson's disease, menorrhagia and premenstrual tension.
3. A Kidney Jing Deficiency syndrome manifests through such symptoms as tinnitus, dizziness, and mental and emotional problems.

GENERAL TREATMENT FOR KIDNEY DISEASES

The following is a description of a general protocol used for treating a patient's Kidneys. The goal is to introduce the Qigong doctor to the basic hand positions and areas of the patient's body through which Qi is emitted (or Turbid Qi removed). Once the Qigong doctor becomes proficient at locating these specific points, the treatment will flow more smoothly.

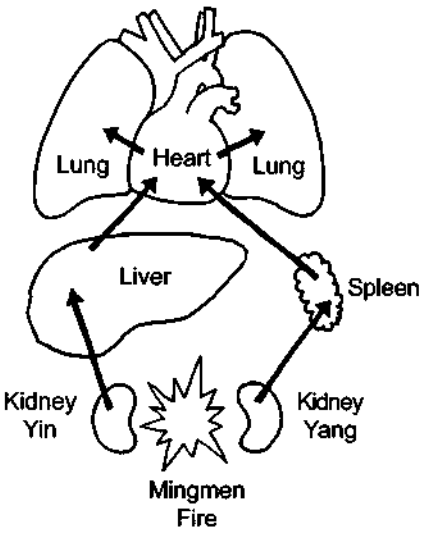

Figure 47.2. Kidney Yin flows from the Kidneys to the Liver, then to the Heart and Lungs. Kidney Yang flows from the Kidneys to the Spleen, Liver, Heart and the Lungs.

After comparing the various Kidney therapies, the reader will notice that certain patterns repeat themselves.

1. Generally, the Qigong doctor accesses the patient's Kidneys through either direct energetic insertion into the Kidneys' anatomical location on the back, through the naval and Mingmen access gates, or through the patient's channels and external energetic fields (Figure 47.3).
2. After treating the patient (purging, tonifying, and regulating), the Qigong doctor will stimulate the patient's Kidneys, Mingmen, and Lower Burner areas, and roots the patient's Qi into the Lower Dantian.
3. Next, the Qigong doctor stimulates the patient's Kidneys and Lower Dantian through the Taiji Pole and Bubbling Spring (Kd-1) points, regulating the body's Yin and Yang Qi via the Microcosmic Orbit (Fire Cycle).

Keep in mind that these areas are general and that specific treatment patterns must change as they apply to the patient's exact condition (Excess, Deficient, etc.).

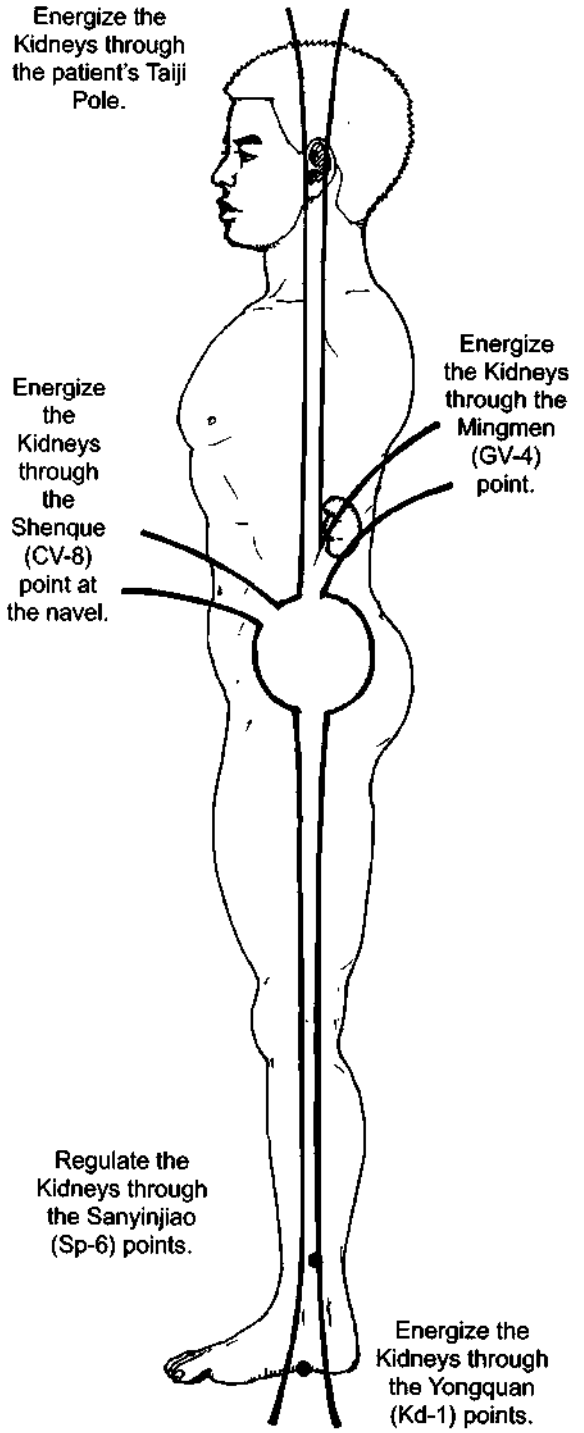

Figure 47.3. Treating Kidney Diseases

MEDICAL QIGONG THERAPY FOR KIDNEY QI DYSFUNCTION

Some symptoms of Kidney disease can manifest as dark circles under the eyes, decaying teeth, distended abdomen, dyspnea, and perspiration. The primary therapy used to treat Kidney diseases include: the Windy Breathing method to strengthen the Kidneys, Toe-Raised Walking, and Kidney massage (see Chapter 15).

1. An Excess Heat syndrome of the Kidneys should be treated by purging through uttering the "Chui" (Chree) sound, and reinforcing its effectiveness by focusing intent on the exhalation (Figure 47.4). This gradually relieves sluggishness and stagnation of the Kidney's Qi.
2. A Kidney Deficiency syndrome manifests mid-lower back pain at the waist level, and should be treated by Taking in the Blue Qi (see Chapter 4) into the Kidneys, Mingmen, and Lower Dantian.
3. A Deficiency of Mingmen Fire should be treated by emitting Qi into the patient's Lower Dantian and Mingmen area with the Pushing technique along with clockwise Qi rotation. This manipulation invigorates the Kidneys' Qi and replenishes the Fire of the Mingmen.

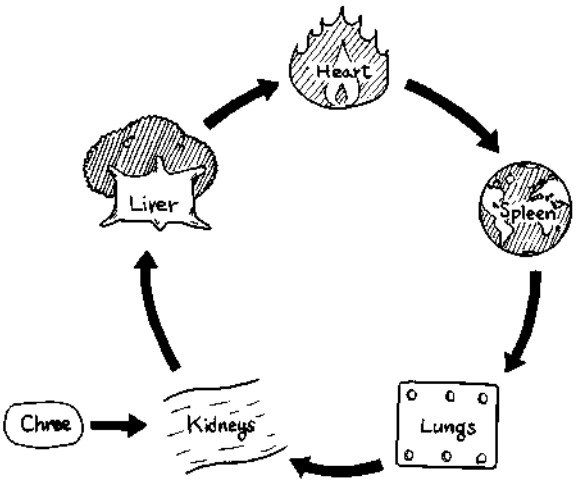

Figure 47.4. The Kidney sound is "Chui" (Chree).

KIDNEY QIGONG PRESCRIPTIONS

These exercises promote the flow of Qi and Blood of the Kidney Channels, nourish the Kidneys, strengthen Yang, and increase the Yuan Qi. These exercises can also be used to prevent and treat the following diseases and syndromes: nephritis, psychoneurosis, lumbago, rachialgia (spinal inflammation), tinnitus, deafness, frequent micturition and aversion to cold due to having a Cold condition.

PRESCRIPTIONS FOR TONIFYING THE KIDNEYS

The Taking in the Blue Qi can be used to tonify the Kidneys. The properties inherent within the color blue have a persistent vibratory rate used for tonifying the Kidneys and Bladder.

1. Assume a standing, sitting, or lying posture. Relax the whole body, place the tongue against the hard palate behind the teeth, and get rid of any stray thoughts.
2. When inhaling, visualize blue energy in front of you. Inhale the blue light energy in through the nose and down into the Kidney organs. As you exhale through the mouth, the dark, pathogenic Qi leaves the Kidneys; however, the bright clean color remains in the organ, stimulating and vitalizing it. With each breath the organ retains more clean energy and begins to glow. Repeat for five breaths.
3. Next breathe the blue color in through the nose, filling the entire mouth. When exhaling through the nose, send the blue Qi slowly down to the Kidneys, then into the Lower Dantian. Perform six to twelve times. Return to the beginning posture and close.

PRESCRIPTIONS FOR REGULATING THE KIDNEYS

Remove stagnation from the Kidneys by having the patient rub the abdomen while sounding "Chree."

Assume a sitting or standing posture. Place both palms flatly on the lower abdomen (left hand on the outside for men, opposite for women), inhale slowly, and exhale the sound "Chree" while rubbing the lower abdomen clockwise, gently with the palms. Perform ten to twenty breaths.

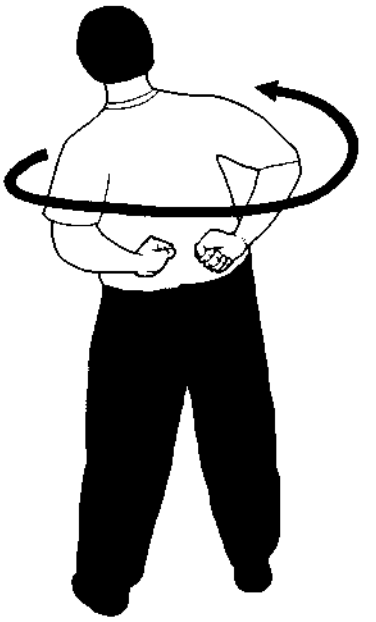

Figure 47.5. Rotate the waist in a clockwise and counterclockwise direction.

PRESCRIPTIONS FOR STRENGTHENING THE KIDNEYS AND CONDUCTING QI

The following exercise is used to tonify the Kidneys.

1. Assume a standing posture. Clench both hands into fists, and place them against the soft tissue on both sides of the Mingmen. Rotate the waist, turning towards the left in a clockwise direction for six rotations. After the six rotations pause in the center, then rotate in the opposite direction for six times (Figure 47.5).
2. Assume a standing or sitting posture. Rub the sides of the Mingmen with both hands, up and down thirty-six times, focusing the mind on the lumbar region (Figure 47.6).
3. Tuck the sacrum under (to stimulate the renal capsule), placing both palms on the groin, under the junction of the pubic bone (left hand on the outside for men, right for women).

   Support and gently pull up the area around the perineum with both hands eighty-one times (Figure 47.7). Switch hands and repeat. Note: The Kidneys are injured by irregular

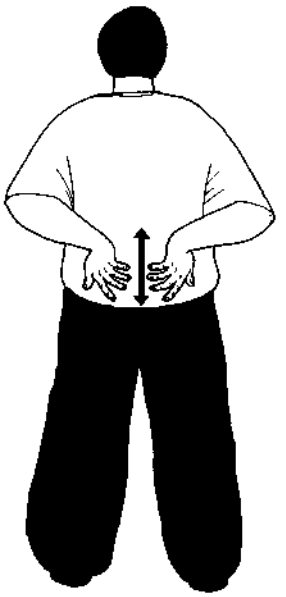

Figure 47.6. Rub the Kidney and Mingmen area.

Figure 47.7. Support the groin and perineal area.

sleep patterns, fear, excessive caffeine, sex, drugs, alcohol, and smoking. Excess saltiness and Cold (climate and food) have a draining effect on the Kidneys.

Specific Medical Qigong Therapy for Kidney Diseases

The following are several Medical Qigong treatments used in China to treat specific Kidney diseases.

Tinnitus and Deafness

Tinnitus is a condition of a high-pitch or rushing-wind sound within one or both ears. The sound may be a consistent pitch or vary in intensity and modulation.

Etiology

Although the ears are the opening of the Kidneys, there are other influences which must be addressed when dealing with tinnitus. Tinnitus is most commonly caused by stagnation of the Triple Burner and Gall Bladder Channels. These channel stagnations are due to three adverse conditions: the rising of Liver Wind Fire which may be induced by violent rage, the obstruction of the orifices in the head due to External Wind invasion, or by failure of the Kidney Jing to reach the ears due to a Kidney Deficiency.

This disease can be divided into Full and Empty Types of tinnitus:

1. The Full Type of tinnitus is caused by the flaring up of pathogenic Wind, Yang, Fire, Phlegm, or Phlegm Fire. It is most noted in the Excess rising of Liver and Gall Bladder Fire, or Phlegm Fire flaring upwards. This type of tinnitus is experienced as a sudden onset with a loud sound and is aggravated by cupping one's hands over one's ears.
2. The Empty Type of tinnitus is caused by a Deficiency of Kidney Qi, Kidney Jing, Lung Qi, or Heart Blood that is unable to extend to the ears. It is most noted in Kidney Jing Defi-

ciency, Deficient Upper Burner Qi and Heart Blood Deficiency. This type of tinnitus manifests clinically through a gradual onset with a low sound and is improved by cupping one's hands over one's ears.

Symptoms

1. The Excess Type of tinnitus manifests as a sudden deafness or distending pain in the ears accompanied with a loud-pitched ringing noise. The adverse rising of Liver Wind Fire or Gall Bladder Wind Fire causes vexation and irritability, and often manifests as a flushed face and dry mouth.

   The Excess condition caused by an invasion of External Wind also includes symptoms such as chills, fever, and headache.
2. The Deficient Type of tinnitus can either occur constantly or intermittently, and may be aggravated by overstraining and relieved by hand pressure. This condition is often accompanied by dizziness, soreness of the waist, seminal emission, or leukorrhea.

Treatment

1. Begin by stimulating the patient's TB-3, TB-17, SI-19, and LI-4 points on both sides of the body.
2. Emit Qi towards the patient's Lower Dantian, using the right Sword Finger hand posture and left Extended Fan Palm hand posture.
3. Next, extend energy into the patient's affected ear and focus the Qi emission around the patient's TB-17 and TB-21 point areas. Next, guide the Qi to flow down the head, neck, shoulders, and arms along the Triple Burner Channels and out of the hand 3 to 7 times.
4. Finally, extend Qi into the patient's affected ear and guide the Qi down and out of the body along the corresponding Gall Bladder Channel ending at the corresponding foot.

Modifications

- In cases of adverse rising of Liver Wind Fire, use the Vibrating Palm to emit Qi into the patient's Bl-18 and -19 points for 14 breaths on both sides of the body.
- In cases of Kidney Deficiency, emit Qi into the patient's Bl-23 points for 14 breaths.

Prescriptions and Homework

In the following three prescriptions make sure the patient heats his or her hands before beginning.

1. Have the patient perform the Beating the Heavenly Drum exercise (see Chapter 16) for 24 breaths.
2. Have the patient press the ears with the palms in a compression-release fashion 10 times each. Be sure to warn the patient to avoid forceful or violent compression. The patient's intention should focus deep within the orifice of the ears.
3. Have the patient pinch the top of the auricles of the ears gently, and massage them from the top downwards 24 times.

Lumbago

Lumbago is a general non-specific term for dull aching pain in the lumbar region of the back.

Etiology

Lumbago is a common symptom observed in many diseases, such as acute and chronic muscular strain of the lower back, subluxation of the discs, prolapse of the lumbar vertebra, etc. Patients may suffer from lumbago with pain radiating down to their lower limbs. Lumbago pain can also be aggravated by weather changes. Traditionally, there are three general causes of lumbago: lumbago due to Wind Cold and Dampness, lumbago due to Kidney Deficiency, and lumbago due to trauma.

1. Lumbago due to Wind Cold and Dampness, is caused by retention of Cold and Damp pathogens in the channels and collaterals. This in turn leads to the obstruction or stagnation of Qi and impairs Blood circulation.
2. Lumbago due to Kidney Deficiency is caused by an over consumption of the Kidney Jing due to an overactive sex life. This results in the failure of the Kidneys to nourish the Triple Burner Channels.
3. Lumbago due to trauma occurs from an injury to the tissues and muscles (e.g., dislocated vertebra, fractures, ruptured spinal disks, etc.), and leads to stagnation of Qi and Blood. Qi and Blood stagnation leads to obstructions in the channels and collaterals.

SYMPTOMS

1. Lumbago, due to Wind Cold and Dampness, is manifested by heaviness and pain at the waist, which may radiate to the hips and down the legs, or may be accompanied by muscular stiffness. In chronic cases, the pain is intermittent with various degrees of severity. On wet and cold days the patient often feels cold at the waist and lumbar area.
2. Lumbago, due to Kidney Deficiency, is manifested by continuous, dull pain, accompanied by soreness and weakness of the waist and knees, cold limbs and nocturnal emission.
3. Lumbago due to trauma is manifested by localized pain along with tenderness and limited mobility.

TREATMENT

1. Place the patient in a sitting position on the table. Begin stimulating the patient's Mingmen area with your left hand while the right hand guides the energy down to the patient's Bl-40 points behind the knees.
2. Using the Extended Fan Palm hand manipulation emit Qi into the patient's Mingmen and Bl-18 areas, guiding the Qi to flow along the Bladder Channels down the legs.
3. Next, place the patient in a supine posture, knees pointing upwards and feet flat on the table. Position yourself over the patient allowing the weight of your chest to support and compress the physical structure of the patient's knees, lower legs and feet. Embrace the patient's hips and imagine separating the inner fascia and tissues. The purpose for this compression is to initiate a strong internal stretching action within the tendons and smaller muscles of the patient's lower back and sacral area. This technique is used to disperse stagnant Qi and Blood within the patient's lumbar vertebra, sacrum and femur articulations. At the same time, direct the Qi upwards along the patient's spine and Governing Vessel. Hold this compression for several minutes.
4. To avoid respiratory congestion (while your weight is stretching the patient's sacrum and lower lumbar), the patient is instructed to raise the arms above the head.
5. As the patient experiences the lower back compression, he or she imagines the stagnant energy (trapped within the lumbar area) melting like ice into water and flowing through the Microcosmic Orbit (Fire Cycle). With each exhalation the patient relaxes to a deeper level, imagining him or herself sinking deeper into the table.

TREATMENT MODIFICATIONS

1. For lumbago due to Wind Cold and Dampness, purge the pathogenic Qi out of the patient's body first, and then emit Heat into the channel points associated with the specific location of the patient's pain.
2. For lumbago due to Kidney Deficiency, use a Vibrating Palm technique to emit Qi towards the patient's Mingmen, Bl-23 and Bl-18 points for 14 breaths each point on both sides of the body.
3. For lumbago due to trauma, extend Qi for 28 breaths into any Ah Shi point (painful tissue area).

INSOMNIA

Insomnia is described as a sleeping disorder that disrupts the patient's normal sleeping pattern. In mild cases, the patient may have difficulty falling asleep or remaining asleep (waking numerous times during the night). In severe cases the patient may be unable to fall asleep at all. Diseases with insomnia as part of their manifestation include anxiety disorders and menopausal syndrome.

ETIOLOGY

The amount and quality of sleep depends on the state of the patient's Shen, which is rooted in the Heart (specifically, the Heart Blood and Heart Yin). If the Heart is agitated or Deficient, the Shen cannot root, and sleep will be affected. Any disharmony of the body's internal organs due to an Excess or Deficient condition affects the patient's Jing and Blood. Since the Jing and Blood root the Shen, the Shen will have no residence and insomnia may result.

Insomnia can be caused by insufficient Blood due to impairment of the Spleen Qi, or from malnourishment of the Heart Qi due to a Deficiency of Heart Blood. This condition can also result from overfatigue, anxiety or irritability. This may be due to a disharmony between the Heart and Kidneys (resulting from Deficient Kidneys), irritability (due to mental depression) or from disharmony between the energetic function of the Stomach and Spleen (resulting from an improper diet).

Since the Hun (rooted in the Liver Blood or Liver Yin) play an important role in the length and quality of sleep, Liver Blood Deficiency can cause the Hun to be deprived of their residence and to wander at night causing restless sleep.

SYMPTOMS

The main symptom is an inability to sleep, which based on the different conditions of this illness can be further classified as:

- An inability to get to sleep,
- Sleepwalking, and an
- inability to fall asleep after waking.

The symptoms vary with the causes of the disease.

1. Insomnia due to a Deficiency of the Heart and Spleen (resulting from severe worry) may cause shallow sleep, or dream disturbed sleep. It is manifested by palpitations, poor memory, vertigo, dizziness and spontaneous sweating.
2. Insomnia due to Kidney Deficiency (resulting from excessive sexual activity) is manifested by dizziness, tinnitus, soreness in the loins and back area, as well as involuntary seminal emission.
3. Insomnia due to upward stirring of Liver Yang is manifested by pain and distention of the chest and epigastrium, belching, and acid regurgitation, as well as mental hyperirritability, dizziness and headaches.

TREATMENT

1. Begin by having the patient sit at the edge of the table. Your right hand emits Qi into the patient's CV-12 point, directing the energy to flow down into the patient's Lower Dantian. The left hand extends energy into the patient's mid-back around the area of the patient's Bl-18, Bl-19, Bl-20 and Bl-21 points, and leads the Qi down the Bladder Channels to the feet on both sides.
2. Next, use the Vibrating Palm technique to extend energy into the patient's Baihui, GV-14, Mingmen, CV-12 and Lower Dantian areas for 9 to 18 breaths each.
3. Emit Qi into the patient's Baihui area and leads the Qi from the top of the patient's head down the Conception Vessel into the Lower Dantian.
4. Finally, emit Qi into the patient's GB-8 point by the top of the ears and guide the Qi down the patient's Stomach Channels to the St-36 points.

TREATMENT MODIFICATIONS

1. For treatment of insomnia due to Deficiency of Heart and Spleen, emit Qi into the patient's Bl-20 and Bl-15 points, guiding the Qi down along the Bladder Channels to the feet.
2. For insomnia due to Kidney Deficiency emit Qi into the patient's Mingmen and Bl-23 points for 18 respirations.
3. For insomnia due to emotional depression, emit Qi towards the patient's Lv-3 and Lv-4 points (on both sides of the body), guiding the Qi down to the patient's lower extremities along the Liver and Gall Bladder Channels.
4. For insomnia due to Spleen and Stomach disharmony, use the Vibrating Palm hand technique to emit Qi into the patient's CV-12, St-36, and St-21 points on both sides of the body.

PRESCRIPTIONS AND HOMEWORK

For the best results, have the patient practice Medical Qigong prescriptions one to two hours before going to bed. For chronically ill patients, the causes of the insomnia should be removed first, followed by Medical Qigong prescriptions and regular physical exercise for lasting therapeutic results.

Have the patient perform the Kidney Massage for treating insomnia prescribed in Chapter 39.

PYELONEPHRITIS

Pyelonephritis is an infectious disease caused by bacteria invading the renal parenchyma and

renal pelvis unilaterally or bilaterally. It clinically manifests through the following symptoms: fever, lumbago and abnormal discharge of urine.

SYNDROMES

1. Damp Heat in the Bladder is clinically manifested through symptoms such as frequent and painful urination, fever, distention and pain in the lower abdomen, lumbago and aversion to cold.
2. Stagnation of Liver and Gall Bladder Heat is clinically manifested through symptoms such as fever with or without chills, nausea, loss of appetite, lumbago or pain in the lower abdomen, frequent urination with cloudy urine and feeling agitated.
3. Spleen and Kidney Deficiency with Heat stasis is clinically manifested through such symptoms as edema of the face, swelling of the feet, abdominal distention, thin stools and frequent urination, lassitude and weakness in the entire body (especially the legs), dizziness, tinnitus and anorexia (lack of appetite).

TREATMENT

1. Have the patient sit at the edge of the table and begin stimulating the Mingmen and Lower Dantian areas using a Vibrating Palm technique for 11 to 22 breaths.
2. Next, have the patient lay supine on the table and stimulate the patient's Sp-6 and Kd-3 areas on both sides of the body.
3. Use the Extended Fan Palm hand technique to emit Qi into the patient's Lower Dantian, guiding it down the Kidney Channels to the bottom of the feet.

TREATMENT MODIFICATIONS

1. When treating patients with Damp Heat in the Bladder, use a Sword Fingers hand posture and apply the Vibrating technique, emitting Qi into the patient's Mingmen and Lower Dantian for 14 to 28 breaths.
2. When treating patients with stagnant Heat in the Liver and Gall Bladder, use the Extended Fan Palm hand posture to emit Qi into the patient's mid-back and Liver, purging Toxic Qi down the Liver and Gall Bladder Channels and out of the body via the legs.
3. When treating patients with Deficient Spleen and Kidneys, use the Extended Fan Palm hand posture to emit Qi into the patient's mid-back Bl-20, and Bl-23 points, CV-12 and Lower Dantian areas.

PRESCRIPTIONS AND HOMEWORK

Have the patients practice the Standing Post Posture with arms suspended at the Middle Dantian, and the mind's intention focused on the Lower Dantian. Use natural abdominal breathing (see Chapter 16).

PRESCRIPTION MODIFICATIONS

1. For patients with Damp Heat in the Bladder, have them practice rubbing the costal area and sounding "Who."
2. For patients with stagnant Liver and Gall Bladder Heat, have them practice massaging the costal area and sounding the word "Shu."
3. For patients with Spleen and Kidney Deficiency, have them practice the method of Taking in Yellow Qi, as well as the Gathering the Moon Cream exercise (see Chapter 11).

IMPOTENCE

Impotence is a weakness and inability of the male to achieve or maintain an erection. Symptoms vary from premature ejaculation to partial penile erection (the penis is erect but not hard, resulting in the incapability of sexual intercourse), to a complete failure to achieve any erection at all. Impotence indicates a weakness in all Five Yin Organ energies. The combined energies must be sufficient to culminate an erection, as described below.

1. The Heart energy quality is strongly affected by the nature of the sexual encounter. Casual sex may not involve the highest spiritual energy of the Heart's upper chamber (see Chapter 5), only the basic instincts and drives of the lower chamber. The Heart may also be affected by the individual's moral values and beliefs, as well as the quantity and quality of emotional passion (i.e., with or without guilty feelings) at the time of arousal. Heart energy also pertains to the energy of the Blood.
2. The Spleen energy pertains to what the man

is thinking and his intention at the time of arousal. This also affects the man's muscles.
3. The Liver energy pertains to visual stimulation that affects a man's sexual drive. This affects the man's strength. Many aspects of man's sexuality are relate to the Liver's functions, i.e., visual images evoking emotions, Blood filling the erectile tissue, and the power of desire.
4. The Kidney's Qi pertains to the Jing energy stored within the Marrow, and relates to the man's will power and endurance. It is associated with audible stimulation and affects the man's endurance.
5. The Lung Qi is man's somatic expression of sexual passion and is stimulated through touch and smell. This energy also affects the man's endurance.

ETIOLOGY

There are two main factors ascribed to impotence: psychogenic and organic. In the first case, the patient's physical, mental, emotional, and spiritual energies are out of harmony. This can be caused by fear, excitement, performance anxiety, etc. In the second case, impotence can be caused by medications, drugs, alcohol, etc. In most organic cases, however, impotence is caused by prostate failure, cardiovascular disease or diabetes. If this condition persists long enough the man looses sexual interest and the condition becomes psychosomatic.

SYNDROMES

- Insufficiency of Kidney Yang is clinically manifested through symptoms such as impotence, lumbago, weakness in the knees, dizziness, tinnitus, aversion to cold, cold limbs and a cold sensation in the external genitalia, listlessness and shortness of breath.
- The downward flow of Damp Heat is clinically manifested through such symptoms as impotence, itching and pain around the external genitalia and scanty, dark urine.

TREATMENT

1. Stimulate the patient's Mingmen and Lower Dantian areas using the Vibrating Palm technique for 12 breaths.
2. Next, stimulate the patient's Sp-6 areas on each leg, leading the Qi up into the Lower Dantian for 12 breaths.
3. Finally, return back to the Mingmen and Lower Dantian areas using the Extended Fan Palm hand technique. Emit Qi for 24 breaths, rotating in a clockwise direction to gather the Qi in the Lower Dantian.

TREATMENT MODIFICATIONS

- When treating a patient with an insufficiency of Kidney Yang, vibrate the energy using the Sword Fingers Hand technique, while emitting Qi into the Lower Dantian for 16 to 18 breaths.
- When treating a patient with a condition of Damp Heat flowing downward, purge the Qi along the Kidney Channels down into the Lower Dantian. Use the Extended Fan Palm hand technique and emit Qi into the patient's Lower Dantian, Kd-13 and Kd-14 points on both sides of the body, as well as the navel area, for 24 breaths.

PRESCRIPTIONS AND HOMEWORK

It is advisable to have the patient perform the Deer exercise, prescribed for increasing the body's Jing.

1. Have the patient sit on the edge of the chair, rubbing the palms to create heat. This right hand will cup his testicles so that the palm completely covers them with slight pressure. The left hand is placed on the area of the Lower Dantian just below the navel. The left hand moves in a circular clockwise direction 81 times. Next, the hands are rubbed together again, reversing the hand positions so that the left hand cups the testicles and the right hand is on the Lower Dantian. The circle rubbing is repeated in the opposite direction 81 times. Concentrate on the heat and Qi filling up the Lower Dantian and genital area.
2. The patient should tighten and draw up the anal muscle while inhaling, feeling the Qi being drawn up the rectum and prostate area, filling up the Lower Dantian. He should hold the breath as long as possible, then exhale, release and relax. The anal contraction exer-

cise should be repeated beginning with 25 breaths, and eventually working up to 250 breaths.

PRESCRIPTION MODIFICATIONS

1. When treating patients with Kidney Yang Deficiency, it is advisable to have them practice Beating and Drumming the Qi with lower abdominal breathing (see Chapter 42).
2. When treating patients with a downward flow of Damp Heat, it is advisable to have the patient rub the Lower Dantian and sound the healing tones "Chree" for 36 breaths and "Shu" for 36 breaths.

Chapter 48
Qi Emission Therapy for Miscellaneous Diseases

Introduction

This chapter deals with miscellaneous diseases that are classified as either complicated multiple diseases, or energetic conditions which have not yet been classified. This section describes the conditions, symptoms and treatment for these syndromes. The discussion of these various treatments begins with energetic dysfunctions stemming from the Qi of the Three Dantians, and expands further to include other tissues, internal organ and energetic organ system complications.

Deficient Dantian Qi

One of the most common problems found in the body's energetic system is Deficient Dantian Qi. The symptoms vary according to the location of the Deficiency, as well as the patient's constitution.

1. If the energy is Deficient within the Lower Dantian, the symptoms and syndromes cover a large range that includes: chronic diarrhea, asthma due to Kidney Deficiency, hypertension due to Yin Deficiency, Blood Deficiency, insomnia, spermatorrhea, collapsing syndrome due to Deficiency, abandoned-type Wind Stroke, abandoned-type coma and all types of organ prolapse.
2. If the energy is Deficient within the Middle Dantian, the problems may include shortness of breath, bronchitis, asthma, chest pain, palpitations, intercostal neuralgia, all breast disorders including acute mastitis and breast abscesses.
3. If the energy is Deficient within the Upper Dantian, the problems may include frontal headaches, dizziness, vomiting, fainting due to Blood loss, insomnia, eye soreness, febrile convulsions and insanity.

Prescriptions for Regulating the Three Dantians

The following meditations are prescriptions used to regulate the heat, vibration, and light in the Lower, Middle, and Upper Dantians.

1. The Lower Dantian meditation solidifies the Qi in the Lower Dantian that allows for stable energy transference to take place. The purpose for Heat Regulation in the Lower Dantian is to cause the internal organs to steam; this transfers energy from organ to organ to nurture and regulate the body's Qi.

   Have the patient focus on breathing into the center of the Lower Dantian. Upon inhaling, the patient imagines drawing Qi into the body from the nose, urethra and anus, and directs it into the Lower Dantian. After inhaling, the patient closes the lower orifices and circulates the Qi up through the coccyx and Mingmen area, then down into the navel and into the Lower Dantian. It is important that the patient visualize a ball of energy rotating in the lower abdomen like a spinning wheel. As this Qi begins to collect in the Lower Dantian, heat and vibration begin to resonate in the lower abdominal area.
2. The Middle Dantian meditation expands the patient's Wei Qi, which in turn enhances the body's protection against an attack of Hot or Cold pathogenic factors. The patient should draw the Toxic Qi out of the Yang Channels of the arms, through the center point of the palms. This is an excellent meditation for treating diseases caused from Excess Heat, such as insomnia, headaches, hypertension, and arthritis of the joints:

   To regulate the heat of the Heart Fire and Middle Dantian area, the patient focuses the

breath and mind's intention on the center of the chest (CV-17) while placing the right thumb inside the heart of the left palm (Pc-8), while resting both hands on the lap.

3. The Upper Dantian meditation not only expands the patient's Wei Qi, but also fills the body with sound and light vibration. Sound and vibration are used in the Qigong clinic to purge Toxic Qi out of the patient's body. This is an excellent meditation for balancing and energizing all Three Dantians.

   The patient begins in a standing or sitting Wuji posture, with the spine straight, Mingmen pressed back, anal sphincter closed, tongue on upper palate, and breathing naturally. This particular exercise follows the opening and closing pattern of Qi regulation. The focus is placed on each Dantian area for a period of 18 to 24 breaths. Each Dantian area needs a specific sound and light visualization to open, purge, close, and regulate its energy. The sounds and physical actions are as follows.

- To open, energize and regulate the Upper Dantian, use the sound of "Om." The arms separate and come together above the Baihui area (above the head) in order to open and close the Upper Dantian. The focus of the mind's intention is placed on drawing in divine healing light while inhaling, to fill the Taiji Pole. When exhaling, imagine the energy rushing into the Upper Dantian while toning the first vowel sound "O." Then imagine light shinning outside of the body while sounding the consonant sound "m." On the beginning of the vowel sound, the tongue is placed on the lower palate. As the tone and breath reach its midpoint, the tongue rises to connect with the upper palate to finish the sound "Om."
- To open, energize and regulate the Middle Dantian use the sound of "Ha." The arms separate and come together above the chest at the CV-17 point while opening and closing the Middle Dantian. The focus of the mind's intention is placed on drawing in divine healing light while inhaling, to fill the Taiji Pole. When exhaling the tone "Ha", separate the arms and imagine that the Qi rushes into the Middle Dantian and then expands to shine outside of the body. On the beginning of the tone "Ha," the tongue should be placed on the lower palate. As the tone and breath reach its midpoint, the tongue maintains its connection to the lower palate.
- To open, energize and regulate the Lower Dantian use the sound of "Hai-riem." The arms separate and come together above the lower abdomen at the CV-8 point while opening and closing the Lower Dantian. The focus of mind's intention is placed on drawing in divine healing light while inhaling, to fill the Taiji Pole. When exhaling, imagine the Qi rushing into the Lower Dantian with the first syllable "Hai," then shines outside of the body when the syllable "reim" is pronounced. At the beginning, the tongue is placed on the lower palate to pronounce the sound "Hai." As the tone and breath reach its midpoint, the tongue changes its position to behind the teeth to tone the sound "reim."

All three sounds are used to activate and energize the body's Three Dantians by practicing these sounds in the following two step progression:

1. Upon inhalation, focus the mind's intention on drawing divine healing light into the body to fill the Taiji Pole.
2. While exhaling, sound the specific tone of each Dantian, while both hands perform the opening (the expanding movements of the arms and hands) and closing (the contracting movements of the arms and hands) technique at each Dantian. The mind visualizes the light resonating and shining out from the body at each Dantian during the toning.

IMPROPER YIN AND YANG ENERGY BALANCE

Another common problem observed in the clinic is an imbalance of Yin and Yang Qi within the patient's body. Converting and balancing the Yin and Yang energy diverts the Qi before it has a chance to overload the body's system. The Qigong

doctor first removes any obstruction in the patient's Governing Vessel and then harmonizes the patient's Yin and Yang energy by extending Qi into the patient's back, on the GV-13 and -14 points.

The following meditations are used as prescriptions to develop a strong electrical charge in the body, that balances the Yin and Yang currents:

Have the patient place the thumb in the heart of his or her palm (Pc-8), fingers touching the back (dorsal) side of the hand, opposite the (Pc-8) point (Figure 45.1). To energize the Lower Dantian the patient concentrates on his or her lower abdominal area. To energize the Middle Dantian the patient should concentrate on the area at center of the chest. The only difference between the Lower Dantian exercise and the meditation used to heat the Middle Dantian is the focal point of the patient's concentration. In these particular exercises, the hand postures are the same, however, the mind is focused on either the hands near the Lower Dantian, or on the middle of the chest.

- For men to develop a stronger electropositive Yang energy field, the right hand should cover the top and center of the left hand. To develop a stronger electronegative Yin energy field, the left hand should cover the top and center of their right hand.
- For women to develop a stronger electropositive Yang energy field, the left hand should cover the top and center of the right hand. To develop a stronger electronegative Yin energy field, the right hand should cover the top and center of the left hand.

Note: In generating energy within each Dantian area it is important to understand basic Yin and Yang polarities and their relationship to male and female. The female chest is considered Yang while the female genital area is considered Yin. The female Middle Dantian (or Heart area) is the focal point of female Yang (positive) energy; the genital area is the focal point of female Yin (negative) energy. Conversely, the male chest is considered Yin while the male genital area is considered Yang. The Middle Dantian (or Heart area) is the focal point of male Yin (negative) energy; the genital area is the focal point of male Yang (positive) energy (see Chapter 5).

DISORDERS OF THE QI

Whenever energy movement is impeded, disorders in Qi functions occur. Generally, these disturbances cause either disorders of Fire, or disorders of Water (see Chapter 22).

The cause and progression to these disorders can be further broken down and classified according to their energetic dysfunction. There are several types of Qi disorders observed in the clinic and they are generally described as follows.

LEAKAGE AND LOSS OF QI

During or after training practice, the patient may feel that Qi is continuously and uncontrollably leaking out of the body from the genitalia and anus or somewhere else on the body. This loss of Qi can lead to Qi Deficiencies and manifest through the following symptoms: emaciation, weakness of the limbs, grayish and dull complexion, nervousness, mental disturbances, distractibility, failing memory, spontaneous sweating, night sweats, seminal emission, insomnia, lassitude and sluggishness.

To treat this condition apply the Extended Fan Palm technique, use the Pushing, Pulling, and Shaking manipulations to emit Qi into the Mingmen; then use Vibrating and Shaking manipulations to emit Qi into the Lower Dantian.

QI STAGNATION DISORDERS

Qi stagnation exists when the Qi becomes sluggish when moving within the body's channels, organs, or tissues. Qi stagnation can be caused by many different factors such as suppressed emotions, trauma, contraction of microorganisms, poor diet, and weak digestion. Qi stagnation, over time, results in localized pain, distention, cysts, tumors, etc. Qi stagnation disorders have two subcategories: Qi and Blood Stasis, and Obstructed Qi (see Chapter 22).

1. Qi and Blood Stasis refers to the sensation of local pain, heaviness, soreness, distention, and compression, which are caused by the stagnant Qi and Blood in certain areas of the body. These sensations do not resolve by themselves. This stasis may occur during or after

Medical Qigong training practice from Qi disorders and visceral malfunctions.

2. Obstructed Qi is also considered a subcategory of Qi stagnation, and exists when the Qi becomes so stagnant that it no longer flows. At this stage the Qi can't move the Blood. This can be caused by trauma, surgery, and acute Qi stagnation.

Reconstructive Qi therapy, for conditions of Qi stagnation use the following two methods:

1. Select corresponding channel points in the region of the Qi and Blood stasis. Knead the selected channel points, then push and rub along the obstructed channel.
2. Finish the treatment by applying the Extended Fan Palm technique; use the Pushing, Pulling and Shaking manipulations to emit and conduct Qi along the channels to open them.

REBELLIOUS QI DISORDERS

Rebellious Qi disorders manifest as Qi flowing in the wrong direction (a direction different from its normal physiological progression); this causes a disturbance within the harmonious flow of energy and affects the organ functions. The symptoms have to be analyzed according to the internal organ which is involved. There are two types of Rebellious Qi, the Excess type and the Deficient type. Rebellious Qi is categorized as follows.

DISORDERS OF EXCESS REBELLIOUS QI

Disorders of Excess Rebellious Qi occur when the vital Qi increases and forces the pathogenic Qi to move. This causes local sensations of pain, soreness, distention, heaviness, coldness or hotness which can develop during Qigong practice. To treat for conditions of Rebellious Qi, use the following two methods:

1. From the head and torso, follow the routes of the channels and collaterals out to the extremities. Pinch and lightly pull on the extremities (fingers and toes). Then press, knead, push and rub the location of the discomfort, guiding and leading the Qi along the channels away from the area of discomfort.
2. Apply the Extended Fan Palm method; use the Pulling and Leading manipulation to pull and guide the Qi, or open up the channel points to disperse the Qi.

DISORDERS OF DEFICIENT REBELLIOUS QI

Disorders of Deficient Rebellious Qi refer to the disorderly flow of Qi and Blood during or after training practice, which can cause dizziness, fright, a heavy feeling in the chest, shortness of breath, shaking limbs, trembling of the hands and feet or fainting. Generally, energy sensitive practitioners know the location and direction of the disorderly flow of Qi in their tissues.

To treat conditions of Deficient Rebellious Qi use the following two methods:

1. Open the appropriate channel points to regulate the functional activities of the Eight Extraordinary Vessels.
2. Select appropriate regions and channel points and apply the Extended Fan Palm or Sword Fingers technique. Use Pushing, Pulling, and Shaking manipulations to activate the channel Qi of that particular channel or region. Then, use the Leading manipulation to direct the Qi into specific channels or return it to the Lower Dantian.

ARTHRITIS

Arthritis is defined as inflammation of the joints, usually accompanied by pain, swelling and frequently changes in structure. This is a chronic, multiple arthropathy and can be divided into the peripheral type (pertaining to the four limbs), and the central type (pertaining to the spinal column, i.e., rheumatoid arthritis or ankylosing spondylitis).

ETIOLOGY

Arthritis is caused by pathogenic Wind, Cold and Dampness attacking the body's channels and hindering the Qi and Blood circulation. This invasion can give rise to pain, soreness, heaviness, and numbness of the tendons and muscles, as well as swelling and difficulty in moving the joints. This condition can be caused from an unstable lifestyle weakening the body's Wei Qi, overexposure to a draft after sweating, wading in water, exposure to cold weather, or laying on a damp ground for long periods of time.

SYMPTOMS

Arthritis is clinically manifested primarily as arthralgia and dysfunction of the joints and can be accompanied by muscle spasm, loss of muscle tone, loss of muscle mass and deformity. Symptoms can be divided into early and late stages.

- In the early stages of arthralgia, the local swelling usually starts from the small joints of the fingers and toes, wrists and ankles, or from the iliosacral joint and spreads upward into the body. Several weeks or months later, the patient may feel local tenderness and inflexibility of the joints with some clicking or cracking sounds. In this stage the pain is worse at night and early in the morning, and may be alleviated with gentle exercise. In the early stages of arthritis, the patient's condition can be controlled and even restored back to normal through Medical Qigong prescriptions.
- In the later stages of arthritis, the articulation of the joint movement is markedly limited, and patients may experience deformity in the joints, as well as stiffness, muscular atrophy and paralysis. The phalangeal and carpal joints of the patient's hands may become rigid and deviate to the ulnar side of the arm. The fingers may also become deformed with restricted mobility, and the elbow and shoulder joints may also be affected. In the late stages of arthritis, the treatment can only control the progression of the disease and alleviate local symptoms. The patient's locomotive function can only be gradually improved.

If the patient's lower limbs are affected, the ankle, knee and hip joints may become rigid, and he or she may experience motor impairment. If arthritis occurs in the patient's spinal column, it may cause kyphotic deformity and dyspnea, as well as restriction in neck movement. At this stage a sudden backward flexing of the neck may cause sudden death in patients with rigid forward bending neck deformity.

When treating an External invasion of pathogenic factors, the Qigong doctor observes three main symptoms of arthritis:

1. Wind or migratory arhtralgia is manifested by pain that has no particular fixed location, but moves throughout the body's extremities and joints, and is sometimes accompanied by chills and fever.
2. Cold arthralgia is manifested by localized pain of the joints, which may be relieved by heat and aggravated by cold.
3. Damp arthralgia is manifested by fixed pain and swelling in the joints and extremities, or by numbness of the skin which may be aggravated in cloudy and rainy weather.

TREATMENTS

1. Place the patient in the standing posture and begin dredging the Governing Vessel, drawing the energy into the ground.
2. Use the Extended Fan Palm hand technique and begin to emit Qi into the patient's GV-14, Mingmen, and Lower Dantian areas.
3. While emitting Qi into the painful joint areas, purge the pathogenic energy out of the patient's body, leading the Toxic Qi along the channels and out of the extremities.

PRESCRIPTIONS AND HOMEWORK

In treating arthritis it is important to prescribe exercises which lubricate the joint articulations to increase the production of Qi and Blood to the extremities. The Daoist Five Yin and Yang Organ exercises will accomplish this goal quite easily.

The patients are required to perform Qigong prescriptions which improve the body's resistance, but do not cause fatigue. Patients should also improve their diet and should be encouraged to consult a nutritionist for natural supplements that can help rebuild healthy cartilage and reduce pain. They should also make every effort to keep their body warm.

For patients with osteoporosis, stretching techniques, as well as sudden forward flexing of the neck are absolutely prohibited.

PRESCRIPTION MODIFICATIONS

1. When treating patients who suffer from arthritic pain in the upper limbs, advise them to practice shoulder and arm Dynamic Medical Qigong, moving at a slow, fluid pace.
2. When treating patients who suffer from ar-

thritic pain in the lower extremities, advise them to practice Dynamic Walking Medical Qigong (see Chapter 15), moving at a slow, fluid pace.
3. When treating patients who suffer from arthritic pain in the waist and lower back, advise them to practice the Expanding and Contracting the Rings exercise (see Chapter 41).
4. When treating patients who suffer from arthritic pain in the neck, advise them to practice slow-moving non-forceful neck rotation exercises in conjunction with stationary neck massage.

VERTIGO

Vertigo is a syndrome manifested mainly by dizziness and dim eyesight. It is defined as a sensation of moving around in space or having objects move about the person as a result of a disturbance of equilibrium. Vertigo is sometimes used as a synonym for dizziness, feeling light headed, or giddy.

Patients with mild vertigo may experience relief from this condition after a short bed rest, with their eyes closed. In severe cases, patients may suffer from a serious rotary vertigo and will not be able to stand or walk straight (e.g., sea and air sickness), sometimes followed by nausea, vomiting, perspiration, or even syncope (fainting).

Diseases that have vertigo as their main manifestation include cerebral arteriosclerosis, auditory vertigo, hypertension, anemia, and psychosomatic illnesses such as hyperventilation (which often accompanies anxiety disorders, especially panic disorders). These diseases may be diagnosed, categorized, and treated with reference to the prescriptions described in this section.

ETIOLOGY

Several factors contribute to the vertigo syndrome. In ancient times, Chinese physicians believed that vertigo was caused by Yin Deficiency and Excess Liver Wind, or by a head trauma. In Excess conditions, vertigo is caused by Phlegm Fire or Wind Phlegm. Currently, the clinical protocol for treating vertigo is divided into three conditions:

1. Hyperactive Liver Yang causing an insufficiency of Kidney Yin,
2. A Deficiency of Qi and Blood in the Heart and Spleen causing a Deficiency in the Marrow reservoir, and
3. Stagnation of Phlegm Dampness caused by a Deficiency of Spleen and Stomach Qi (which fail to transport the Phlegm).

Vertigo may be caused by a variety of factors affecting the ear, the eighth cranial nerve, and the brain stem; including middle ear disease, infectious diseases, trauma, tumors, toxemia due to food poisoning, hypertension, sun stroke, and toxic conditions such as those caused by alcohol and drugs. Over medication and malnutrition (especially in the elderly who suffer from dehydration) also cause vertigo.

SYMPTOMS

1. In cases where the patient has hyperactive Liver Yang, the syndrome of vertigo is characterized by severe dizziness, splitting headache, blurred vision, nausea, soreness and weakness of the waist and legs, mental fatigue (caused by emotional upset and anger), flushed face, constipation and tinnitus.
2. In cases of Qi and Blood Deficiency, the symptoms include rotary vertigo, blurred vision or night blindness, listlessness, disinclination to talk, palpitations, insomnia and anorexia.
3. In cases of stagnation of Phlegm Dampness, the symptoms include chest pain and distress, nausea and vomiting, poor appetite, listlessness of the body and heaviness in the head.

TREATMENT

When treating patients with vertigo, begin with the upper body working downward and from the medial aspect of the body towards the lateral part of the body.

1. Begin with the patient sitting on the edge of the table. Stimulate the patient's Baihui, the sides of the head, (GB-4, GB-8, and Taiyang areas), GV-14, Shendao, Mingmen, and the Lower Dantian.
2. Next, use the Vibrating Palm hand manipulation to emit Qi into the patient's Baihui, GV-14, Yellow Court and Lower Dantian for 12 to 24 breaths.

3. Use the Extended Fan Palm hand technique to emit energy into the patient's St-8, St-21 and St-36 points on both sides of the body.
4. With the left palm, emit Qi into the patient's Baihui point while using the right hand Sword Fingers to guide the patient's Qi from the Yellow Court down the Conception Vessel into the Lower Dantian.
5. Next, direct the Qi from the patient's St-8 points down to the St-36 points via the Stomach Channels.
6. Purge the energy of the upper torso out through the hands via the Large Intestine Channels.
7. Finally, lightly pat and knead the patient's Baihui and GV-14, softly rocking their upper limbs to end the treatment. Softly pressing and kneading the patient's tissues along their channels can push Qi and Blood downward to free the patient's mind from Toxic Qi and can improve the eyesight. The soft grasping can relieve stasis of Qi and Blood in the patient's blood vessels and promote circulation, thus reducing and relieving vertigo.

TREATMENT MODIFICATIONS

1. In cases of hyperactive Liver Yang, use the Extended Fan Palm hand method to emit Qi into the patient's Bl-18, Mingmen, and Lower Dantian. Guide the Qi to flow along the channels (or in a clockwise direction) to nourish the patient's Yin and to suppress the hyperactive Yang.
2. In cases of Deficient Qi and Blood, use the Extended Fan Palm hand method to emit Qi into the patient's mid-back (Bl-17, Bl-18, and Bl-20 points) and Lower Dantian to nourish the patient's Qi and to replenish the Blood.
3. In cases of stagnation of Phlegm Dampness, use the Extended Fan Palm hand method to emit Qi into the patient's Yellow Court. Guide the Toxic Qi down the Stomach Channels and expel the pathogens out from the patient's St-36 points.

PRESCRIPTIONS AND HOMEWORK

To treat vertigo, have the patient practice the Descend the Qi and Cleanse the Organs exercise (see Chapter 41).

PRESCRIPTION MODIFICATIONS

When treating patient's who suffer from a Deficiency of Kidney Yin and a hyperactivity of Liver Yang, prescribe the following meditation. Have the patient take a standing or sitting posture, breathing naturally, and relaxing. While inhaling through the nose, the patient imagines blue energy filling the mouth. When exhaling, the patient imagines this dark blue energy slowly pouring down the throat, like warm water, filling the Kidneys and Lower Dantian area. The patient should practice this meditation for 7 breaths.

HEADACHES

A headache is defined as a diffused pain in different portions of the head which is not confined to any one nerve distribution area. It may be acute, chronic, frontal, temporal, occipital, confined to one side of the head, or affect the region immediately over one or both eyes. The character of the pain may vary from dull and aching, to acute stabbing pain that is almost unbearable. There may be intermittent, intense pain, a throbbing pain, a pressure in the head which feels as if it will burst the head, or a penetrating pain driving through the head.

ETIOLOGY

Transient, acute headaches may vary in their etiology. Disease of the perinasal sinuses, teeth, eyes, ears, nose or throat, acute infections, invasion of Wind Cold pathogens into the channels of the head, or trauma to the head are among the most frequent causes of headaches.

Chronic headaches may also be caused by a variety of conditions including physical, emotional, psychosomatic, or psychogenic factors, including fevers, metabolic conditions (hypertension, etc.), or even exposure to toxic chemicals.

SYNDROMES

Headache syndromes can be divided into five categories which are described as follows.

1. A Shaoyang headache (migraine) is clinically manifested through symptoms such as a severe headache (splitting pain) in the temple region accompanied by Excess Heat in the

head, conjunctive congestion, and sometimes intercostal fullness or pain. Nausea often accompanies a severe migraine attack.
2. A Taiyang headache (occipitocervical headache) is clinically manifested through such symptoms as a headache and pain in the back of the head which can be accompanied by fever, aversion to cold, and rigidity at the back of the neck.
3. A Jueyin headache (vertical ache) is clinically manifested through such symptoms as a vertex headache, vertigo, insomnia, dizziness, and irritability with a flushed face.
4. A Yangming headache (frontal ache) is clinically manifested through such symptoms as a headache in the upper part of the cranium accompanied by dysphoria (depression and anxiety) with a smothering sensation, thirst, bad breath and constipation.
5. A Deficient Qi and Blood headache is clinically manifested through such symptoms as a lingering headache with a heavy sensation in the head, blurred vision, lassitude, and weakness.

TREATMENT

Begin by purging and dredging the patient's Upper Dantian, focusing on the Yintang, Taiyang, Baihui, GV-16, GV-20, and GB-4 points. Purge the pathogenic Qi down the patient's arms and out the LI-11 and LI-4 points, as well as down the Gall Bladder Channel out of the GB-41 points. The point and channel purging is specific to the location (right or left side) of the headache.

Next, using the Extended Fan Palm hand technique, emit Qi into the patient's headache region, purging it down the Conception Vessel to the Lower Dantian.

TREATMENT MODIFICATIONS

1. When treating a patient with a Shaoyang headache, apply the Extended Fan Palm hand technique to emit Qi into the GB-4, GB-8, and TB-20 points, leading the pathogenic Qi out of the Triple Burners and Gall Bladder Channels.
2. When treating a patient with a Taiyang headache, apply the Extended Fan Palm hand technique to emit Qi into the LI-11 and Bl-10 points, Purging pathogenic Qi down the Large Intestine and Bladder Channels and out of the hands and feet.
3. When treating a patient with a Jueyin headache, start at the head using the Circle Spiraling hand technique in a counterclockwise direction, purging the Toxic Qi out the patient's Gall Bladder Channels and out of the legs.
4. When treating a patient with a Yangming headache, use the Extended Fan Palm hand technique to emit Qi into the patient's Taiyang, Yintang, and St-8 points, purging the Toxic Qi down the Stomach Channels and out of the legs.
5. When treating patients with Deficient Qi and Blood, use the Extended Fan Palm hand technique to emit Qi into the patient's mid-back, at the Bl-17 and Bl-20 points, and the chest at the CV-17 point. Then emit Qi into the patient's CV-12 and Lower Dantian areas.

PRESCRIPTIONS AND HOMEWORK

1. It is advisable to have the patient practice the Ten Dragons Run Through the Forest exercise found in the Wash the Face and Massage section of Chapter 39.
2. It is beneficial to prescribe the following meditation to prevent the advancement of an acute attack. The main focus of this meditation is to direct Blood, Heat, and Qi to the body's upper extremities (the arms and hands), away from the original source of pain (i.e., the head).
   a. From a sitting, semi-reclining, or lying posture, the patient begins to relax and quiet the mind, with the eyes closed.
   b. The patient imagines that it is summertime and he or she is at the beach. Next, the patient focuses on both arms and hands, imagining them growing warmer and warmer in the hot sun. The patient imagines feeling massive amounts of heat radiating from the arms and hands, redirecting the Blood flow away from the head.
   c. Then, the patient imagines the face becoming cooler, as the pressure and pain

melts down the neck, shoulders, arms, forearms and out of the hands.

Prescription Modifications

1. For patients with a Shaoyang headache, focus the prescription meditations and exercises on treatments that purge the bilateral sides of the patient's head along the Triple Burners and Gall Bladder Channels, dredging the pathogenic Qi down and out of the patient's arms and legs.
2. For patients with a Taiyang headache, focus the prescription meditations and exercises on treatments that purge the patient's occiput and cranium, the Small Intestine and Bladder Channels, and that dredge the pathogenic Qi down and out of the patient's arms and legs.
3. For patients with a Jueyin headache, focus the meditations and exercises on treatments that purge the patient's vertex cranium, dredging the Toxic Qi down the Liver Channels and out of the legs.
4. For patients with a Yangming headache, focus the prescription meditations and exercises on treatments that purge and dredge the energy from the patient's forehead down the Large Intestine and Stomach Channels and out of the legs.
5. For patients with a Deficient Qi and Blood headache, focus the prescription on Lower Dantian Cultivation exercises and meditations.

MIGRAINE HEADACHES

This type of headache initially consists of a constriction in the head arteries, followed by vasodilation of the extracerebral cranial arteries.

ETIOLOGY

Migraine headaches are usually brought about by stress, and can also be initiated by an allergic reaction to what the patient's body considers to be a toxic invasion (e.g., cheese, chocolate, red wine, contraceptive pills, etc.). These types of stresses on the body's system result in internal organ dysfunction, which is generally caused by one or more of the following three factors.

1. The energy of the Heart and Spleen are not regulated.
2. A rising up of Liver Heat and Fire occurs.
3. A Deficiency of Kidney Yin and rising of Heart Fire occurs simultaneously.

The result of stress-related internal organ dysfunctions causes the initial constriction of the arteries in the head, followed by vasodilatation and distention of the vessels.

SYMPTOMS

The clinical manifestations of migraine headaches are hypersensitivity to light and sound, followed by severe, throbbing pain (most commonly felt on only one side of the head), nausea, dizziness, and sometimes vomiting. Some migraine patients experience seeing an aura or visual disturbances (colors, shapes, lines, flashing spots, or temporary reduction in the field of vision) before the head pain begins.

TREATMENT

For treatment, the Qigong doctor must pull the pathogenic energy out of the patient's head, from the location of the pain; then lead the Excess Toxic Qi out of the patient's extremities, and open up the channels so that Qi can rise and fall to the patient's head unobstructed.

1. In a severe case, combine Medical Qigong therapy with Jing Point therapy.
   a. Begin the treatment by pulling out (with strong intention) the stagnant Qi trapped in the patient's head. First, purge the patient's Wei Qi field, then enter the patient's Jade Pillow at the base of the head. Next, emit Qi along the falx cerebri and circulate it using your intention to create a small Microcosmic Orbit (circling from the back of the head to the nose and back). This encourages the patient's stagnant Qi to move.
   b. Next, dredge around the area of the patient's eye (from the inner corner of the eye to the side of the eye), starting at the Bl-1 point to the Yin Tang point (Third Eye), following the sphenoid arch across to the temple at the Taiyang point, then to the back of the ear at the

TB-17 point. Next, lead the pathogenic Qi down the neck and pull out the stagnant Qi through the extremities (Pc-6 and LI-4 on the hand). If the patient is feeling nausea, purge the Toxic Qi from the Yellow Court and lead the Toxic Qi down and out the body through the St-36 point on the leg and Lv-3 point on the foot.

c. To remove sluggish Qi stagnation, squeeze the patient's trapezius muscles, draining the pathogenic Qi out of the axillary fold of the patient's arm. The patient should breathe into the painful areas, and imagine any remaining Toxic Qi descending down the arm into the fingertips when exhaling. The doctor should squeeze the patient's arm as the patient exhales, to support the descending action of the Toxic Qi.

d. The patient should be given homework, depending on his or her constitution.

2. In treating chronic migraine headaches, combine Medical Qigong therapy with An Mo therapy, working from the branch to the root.

a. Begin the treatment by pulling out the stagnant Qi trapped in the patient's head. This is done by first purging the patient's Wei Qi field, then entering the patient's Jade Pillow (at the base of the head) to purge and remove Toxic Qi and stagnation. Then emit and guide the Qi with your intention, to flow along the patient's falx cerebri. This forms a small Microcosmic Orbit (circling from the back of the head to the nose and back) and encourages the patient's stagnant Qi to move.

b. Extend Qi into the patient's Bl-1 point (on the inside of the eye).

c. Next, focus energy into the patient's Yin Tang point and begin circulating the Qi along the orbicularis oculi muscle of whichever eye is in pain (along the eyebrows to the ear). Work from the inside of the eye, out along the eyebrows (Figure 48.1).

Figure 48.1. For treating chronic migraine conditions (which dominate behind the left eye), begin by extending Qi into the patient's Bl-1 point and start to dredge the Toxic Qi from the patient's Yin Tang area, circulating the orbicularis oculi muscle of the eye in a clockwise direction.

d. After several rotations, follow the sphenoid arch to the back of the ear at the TB-17 point (if the pain is bilateral, for men treat the left side first; for women treat the right side first).

e. Next, beginning at the TB-21 point, outline the outside of the ear, then massage the lateral aspect of the ear's ridge (upper auricle) (Figure 48.2).

f. Hold both of the patient's ears firmly and begin to apply slight pressure at a 45 degree angle towards the sides of the patient's head. This allows the Qi trapped within the patient's head to escape. Using intention, move the Qi from the Jade Pillow (along the tentorium cerebelli) into the patient's pituitary gland. Then divide the energy into two rivers of Qi that circulate through the middle of the cerebrum and end back at the Jade Pillow.

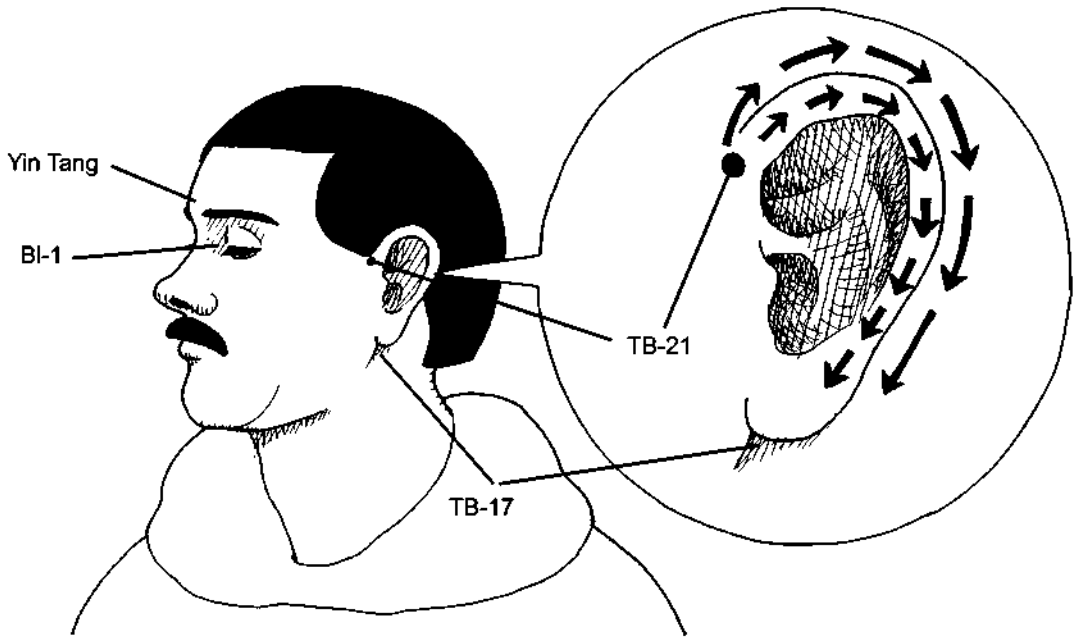

Figure 48.2. Outline the outside of the patient's ear, then massage the lateral aspect of the ear's ridge.

g. From the front of the head, at the edge of the hair, gather the Qi and lightly scratch the patient's head, as you use the Kneading Tiger technique. Visualize pulling the Toxic Qi down the front and sides of the patient's head (down the Gall Bladder Channels) to the base of his or her neck (Figure 48.3).
h. From the base of the neck, pull the Toxic Qi down and out of the arms.
i. The patient should be given seated Quiescent Qigong meditation homework, the length of meditation time will depend on his or her constitution.

Note: When treating migraine headaches, the head should always be treated first before treating the extremities.

Figure 48.3. Using the Kneading Tiger technique, visualize pulling the pathogenic Qi out of the patient's head, down the side of the neck and down along the sides of his or her arm.

Section XI
Specialized Qi Emission Therapy for Pediatrics, Geriatrics, Gynecology, Neurology, Psychology, Oncology, and Surgery

Introduction

In this section we will explore disease treatment techniques and prescriptions unique to Medical Qigong doctors who specialize in Pediatrics, Geriatrics, Gynecology, Neurology and Oncology.

The last two chapters will address Medical Qigong therapy and the treatment of radiation, chemotherapy, and surgery.

Chapter 49
Qi Emission Therapy for Pediatrics

Introduction

Pediatrics is the branch of medicine which deals with the care of children and the treatment of childhood diseases.

From a traditional Chinese medical perspective, children are different than adults in several important ways. First, the Yin and Yang energy in children is fresh and pure, and their vitality usually flourishes. Second, although the internal organs of children have begun to take shape, the organs are still in the process of developing Qi; the organs are still maturing and are not yet fully developed. Because children are still growing organs and tissues, stimulating the channels and channel points has a different effect on their body than on an adult.

Specifically, the Lungs, Spleen, and Kidneys are especially delicate in children. The Lungs and Spleen are weak, and the Kidneys are particularly vulnerable. The Lungs control the Qi of the whole body. The Spleen is responsible for the transformation of food and the transportation of Gu Qi (food Qi). The Lungs and Spleen are the postnatal foundation of health. The Kidneys are in charge of the bones and Marrow and are the prenatal foundation of health. Children are still full of Prenatal Qi; they are just beginning to use their Lungs and Spleen for the function of acquiring Postnatal Qi. Consequently, their energetic system is vulnerable and unstable.

If children are born without congenital defects or weakness, are nursed properly, and avoid contracting major diseases, the internal organs should develop normally. However, because of inherent weakness or immaturity of the digestive system, almost all pediatric diseases of children under the age of six usually begin with some element of indigestion. A child's tiny digestive system makes him or her prone to the creation of Phlegm. Since the Spleen is the root of Phlegm production, and the Lungs are the storehouse of Phlegm, then a congenitally weak Spleen can lead to the creation of Turbid Dampness within the child's body. This Turbid Dampness can congeal into Phlegm and lodge within the child's Lungs. These symptoms can be observed in young children as runny noses, ear infections, phlegmy coughs, and other respiratory difficulties.

Early Stages of Child Growth and Development

In childhood, growth and development occur rapidly. In the ancient Chinese medical classic entitled *"Prescriptions Worth a Thousand Gold Ducats"* it states, "A newborn is feeble and tender; two months later, its pupils begin to become well developed, it can smile and distinguish parents from strangers; 150 days later, its sacral bones have been well developed, it can sit independently; 210 days later, its metacarpal bones have been well developed, it can crawl; 300 days later, its patellae have been well developed, it can stand alone; at one full year of life, its shank and occipital bones have been well developed, it can walk and speak."

In the natural course of childhood growth and development, there may be fever, irregular pulse signs, or perspiration due to the imbalances of Yin and Yang. The child usually recovers spontaneously within a day or two. Such episodes are called Changing and Steaming. Changing implies the transformation of the Five Yin Organs, with the accompanying variations of emotions, and the development of the child's intelligence. Steaming implies the vaporous exchanges within the six Yang organs induced by accumulated Heat. The ancient Chinese discovered that there is one Changing every 32 days, and one Steaming every 64 days. Thus, within 320 days, there are 10

Changings, and within 576 days, there are 9 Steamings. Every Changing or Steaming is an ordinary event in the course of growth and development, and should not be mistaken for a condition of childhood disease. However, if children are not cared for properly during Changing and Steaming, they are more apt to fall ill.

PATHOLOGY

In *"Detailed Analysis of Epidemic Febrile Diseases,"* Dr. Wu Tang stated that children's diseases are apt to change because the internal organs are frail and their defense mechanisms are incomplete; children contract infections easily because the skin and muscles are still tender, and the vitality is timid and weak. Propensity to illness, inclination to Excess and Deficiency, and being prone to suffer from Heat and Cold syndromes are common features of pediatric pathology. Since children are full of pure Yang, the course of disease is changeable and unpredictable. Nevertheless, recovery of health is generally easy.

DEFICIENT LUNGS

Children are apt to suffer from internal organ disorders, especially of the Lungs, manifested by symptoms of cough, dyspnea, retention of Phlegm and Dampness in the Lungs, seasonal febrile diseases, allergies, asthma, and other Lung disorders.

The Lung is a delicate organ in charge of the skin and hair. Therefore, particularly in children, junctures between the skin and muscles are not compact enough to resist the invasion of Exogenous Cold, Heat, Dampness, Wind, and other pathogens. Seasonal pathogens may attack the Lungs through these slackened junctures and through the nose, thereby interfering with the descending and dispersing functions of the Lungs. This results in the accumulation of Heat, fullness in the chest, productive cough, or dyspnea.

DEFICIENT SPLEEN

Since the Spleen is not yet matured and thus usually Deficient, it may be harmed or damaged due to improper diet, irregularity of meals, or imbalances caused by excessively Hot or Cold diets. Consequently, Clear Yang fails to rise, Turbid Yin fails to descend, and Stomach Qi becomes disharmonious. Therefore, children frequently suffer from abdominal masses, abdominal pain and distension (stomachache), belching, hiccups, vomiting and diarrhea, infantile malnutrition, and other digestive disorders. These conditions often lead to children becoming hypersensitive to the foods they consume.

According to Five Elements theory, the Spleen (Earth) generates the Lungs (Metal) and the Lungs (Metal) generate the Kidneys (Water). The elements work in coordination and influence each other. In children suffering from Spleen Deficiency, there will also be a Deficiency of Lung Qi; in children suffering from Lung Deficiency, there will also be a Kidney Deficiency.

DEFICIENT KIDNEYS

Kidney problems can manifest in two different ways: Kidney Jing Deficiency, which can cause retardation, or Congenital Qi Deficiency (i.e., Deficiency in the Sea of Marrow), which can lead to Down's Syndrome, Attention Deficit Disorder (ADD) and learning disabilities. Since the Kidneys control the lower orifices, Deficient Kidney Qi can also lead to chronic bed wetting.

If the child was improperly nursed when they were young, the Deficient Kidney Yin not only fails to nourish the bones and Marrow, but also fails to nourish tendons. During depletion of Liver and Kidney Yin, there can be atrophy, weakness of tendons, five types of developmental retardation, as well as five kinds of flaccidity.

LIVER YANG EXCESS

By contrast, Liver Yang is usually Excessive, and Liver Wind may be brought on by Heat or Fire, resulting in infantile convulsions, twisting, and even opisthotonos.

HEART (SHEN) IMBALANCE

The Heart is responsible for the child's mental stability. The Heart Fire and the Kidney Water must constantly be balanced to stabilize the child's Wu Jing Shen. An imbalance of the Heart can lead to Shen disturbances which can result in mental instability or disability.

According to the active energetic balance of the child's Wu Jing Shen, the Hun tend to naturally be overactive, and the Shen of the Heart is generally unstable. The reason for this instability is because the Hun are very active within a child. The Hun are responsible for creativity, enthusiasm, dreaming, going in and out of the body, and seeing into the Spirit world. The Shen, which is responsible for the child's discriminating mind, respect and conveying the appropriate behavior, is not fully developed. Consequently, young children tend to often be wild, hard to control, and get easily bored.

In treating a child's overactive Hun and unstable Shen, the Qigong doctor harmonizes the child's Heart Fire and Kidney Water energy, and opens the Heart's orifices (using Qi massage on the child's eyes, ears, nose, mouth and all upper sensory orifices) to stabilize the Wu Jing Shen.

HOT AND COLD EXOGENOUS FACTORS

Susceptibility to Exogenous Cold and Heat reflects the characteristics of puerile Yin and Yang. When children are invaded by Exogenous Evils, for example, there will be Excess Heat syndromes; when the child's healthy energies are depleted, there will be Deficiency Cold syndromes.

Although various defects and Deficiencies do exist in children, their Yang, Liver, and Heart are in a hyperfunctional state. Therefore, children are full of vitality and their anti-pathogenic responses are sensitive and immediate. The causes of childhood diseases are usually comparatively simple, relative to adults, and their convalescence is easier and quicker provided they receive appropriate treatment and care.

THERAPY

Because the internal organs of children are still forming and are, therefore, still frail and tender, children are much more sensitive than adults, and cannot stand strong energetic stimulation. This is why the primary modality for treating young children is gentle pediatric Tui Na, which is usually on the child's hands, feet or abdomen, or Qigong massage (lightly touching the child's body). Acupuncture is used only infrequently, and when it is, the needles are usually not retained for long - the points are quickly and lightly stimulated and then the needles are removed. Similarly, when using Medical Qigong emission therapy, a milder stimulation is applied than would be used for adults when purging, tonifying, and regulating.

Medical Qigong is useful for treating pediatric neurological disorders, and particularly for such conditions as epilepsy, hyperactivity, attention deficit disorder (ADD), and mental retardation. Effective points for tonification include Tianzhu (Bl-10), Sishencong (four extra points, located around the Baihui area at the top of the head), Baihui (GV-20), Yamen (GV-15) and Fengfu (GV-16).

When children under the age of six practice self-regulation Medical Qigong exercises (such as Qigong to increase intelligence), they frequently develop special abilities. These abilities include ESP (e.g., telepathy and telekinesis), and special Qigong healing abilities.

ENERGETIC MOVEMENT AND FLOW

The child's Microcosmic Orbit naturally flows in the direction of the Water cycle, moving up the front (CV) and down the back (GV) in order to facilitate the child's spiritual, intuitive, and psychic perceptions. This energetic movement continues in this direction until the child reaches puberty, at which time the energy reverses its direction and flows up the back (GV) and down the front (CV), in the direction of the Fire cycle. This energetic switch in direction facilitates the child's cognitive development and the ability to control emotions and impulses. The time of the Microcosmic Orbit's energetic reversal varies depending on the child's physical constitution, state of health, and his or her environment.

MEDICAL QIGONG EXERCISE PRESCRIPTIONS FOR CHILDREN

The following Medical Qigong exercise is considered a basic training method for children. This exercise is specifically developed for children of all ages and physical conditions, and is used to improve a child's physical and mental health, as well as aid in curing some common childhood

diseases. This exercise can also help to cure food allergies, loss of appetite, malnourishment, a weak immune system, neurasthenia, insomnia, dreaminess, and disturbances of the Spleen and Stomach. It is believed that this exercise also helps moderate a child's stubbornness and impatience.

IMPROVING INTELLECTUAL FACILITIES QIGONG (DA-ZHI-GONG)

This particular Medical Qigong exercise is excellent for children who range from 3 to 12 years old. The time and frequency of the following Qigong exercise is not fixed. It is important, however, that the child be consistent with the practice, and that the body and mind remain relaxed while training.

It is important that the child practice the entire Qigong sequence in its proper order. The child is not allowed to practice only a part of the exercise.

Prohibited from this particular exercise are children who have weak constitutions (i.e., have difficulty in standing up) or suffer from serious diseases.

1. Begin by having the child assume a standing Wuji posture. Have him or her relax the body, with the eyes either open or closed. The child then raises both hands in front of the Upper Dantian. Boys will place the left hand facing the forehead, about three inches from the Yintang point. Girls will place the right hand facing the forehead, about three inches from the Yintang point. At the same time the opposite hand should be level with the other palm and should be facing outwards (Figure 49.1).
2. Both hands begin to make a clockwise circle rotation (from the child's point of view). The child keeps the Yin Tang point as the center of the circle, for 18 breaths. Next, the child moves both hands to the front of the right eye and continues the same clockwise movement while keeping the right eye at the center of the circle. Rotate for 18 breaths. Then, the child moves both hands to the front of the left eye and continue the clockwise movement for 18 breaths. Finally, the child returns to the front of the forehead and continues the rotation, keeping the Yintang point as the center for 18 breaths, then

Figure 49.1. Improving Intellectual Facilities (1)

Figure 49.2. Improving Intellectual Facilities (2)

Figure 49.3. Improving Intellectual Facilities (3)

ends the meditation (Figure 49.2).

3. The child places both hands in front of the ears, with the center of the palms facing the external opening of the ear canals; breathing naturally, the child moves both hands forward and backwards while emitting Qi into the ears. Make sure the child does not concentrate on any specific thing, but simply relaxes (Figure 49.3).
4. Next, the middle fingers softly touch the navel with the left hand, and the right hand softly touches the Mingmen. Have the child imagine that there is a big red ball of fire in his or her abdomen (where the child's two middle fingers are pointing). The child's fingers should remain is this position until warmth is felt in the abdomen. If the heat becomes too hot, have the child exhale the sound "Ha" three times to release the Excess Heat (Figure 49.4).
5. To end the exercise, have the child cover his or her tailbone with both hands and jump up and down gently for several minutes. Do not allow the child to become tired from jumping. Again, make sure that the child does not concentrate on any specific thing (Figure 49.5).

Figure 49.4. Improving Intellectual Facilities (4)

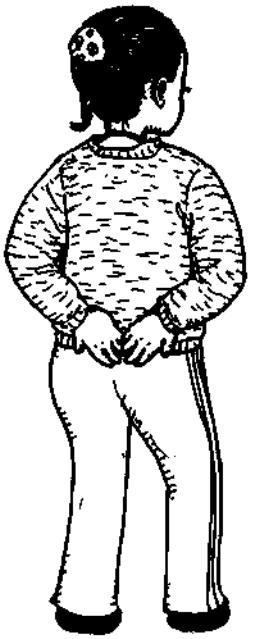

Figure 49.5. Improving Intellectual Facilities (5)

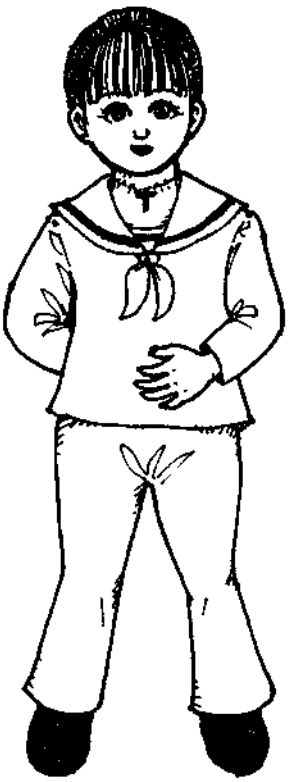

Figure 49.6. Gathering Wisdom Qigong (1)

Figure 49.7. Gathering Wisdom Qigong (2)

MEDICAL QIGONG FOR GAINING WISDOM QIGONG (TONG-LING-GONG)

This particular Medical Qigong exercise is excellent for children who range from 3 to 16 years of age. The time and frequency of this particular Qigong exercise is not fixed, and may be decided by the child. Also, there are no contraindications for this particular Qigong exercise.

1. The child begins by standing with his or her feet flat, shoulders width apart. The child should place one hand on the Lower Dantian (below the navel) and the other hand at the back, below the Mingmen (opposite the Lower Dantian). Have the child close his or her eyes and relax the body and mind for about three minutes. The child is to imagine that the upper part of the body (above the waist) is extended into the blue sky above, and that below it (around waist level) are clouds (Figure 49.6).
2. Next, the child imagines that he or she has changed into an Immortal (a Super-Hero). Encourage the child's imagination to flow freely with this concept, allowing the child to move about, gently shaking the knees (Figure 49.7). After several minutes end the meditation.

CHAPTER 50
QI EMISSION THERAPY FOR GERIATRICS

Geriatrics is a branch of medicine which deals with the problems of the aging. Geriatric specialists addresses the physiological, pathological, psychological, economic, and sociological problems of the elderly. The importance of geriatrics is emphasized by the fact that the expected life-span of the average person is increasing.

Diseases of the internal organs can spread throughout the body via the channels and collaterals, and vice versa, as channel diseases can be transmitted to the internal organs. If Qi and Blood lose their harmony due to old age, and the patient's internal organs, channels, and collaterals become obstructed, then Phlegm and Stasis will develop internally. The accumulation of Phlegm, Qi and Blood stasis may lead to a chain reaction of pathological transformations, such as Hot, Cold, Excess or Deficiency Syndromes in the patient's internal organs. The following are examples of some of the pathological transformations.

1. If the patient's Qi and Blood in the Liver lose their harmony, the patient may experience fatigue and depression with dry eyes or diminished vision. The patient may also experience numbness in the extremities and muscle spasms due to a weakening of the sinews and blood vessels.
2. If the patient's Qi and Blood in the Heart lose their harmony, the patient may experience poor memory, insomnia, heart palpitations, and shortness of breath (which may be aggravated by movement).
3. If the patient's Qi and Blood in the Spleen lose their harmony, the patient may experience fatigue and general weakness in all four limbs. The patient may also experience loose or bloody stools, and there will be abdominal distention after food consumption.
4. If the patient's Qi and Blood in the Lungs lose their harmony, the patient may experience coughing with Phlegm and panting, as well as spontaneous sweating.
5. If the patient's Qi and Blood in the Kidneys lose their harmony, the patient may experience poor memory, anxiety, tinnitus or deafness, as well as a sore or weak lower back, knees, and teeth.

The Chinese have a saying, "When the Heaven (Heart Qi) connects with the Earth (Kidney Qi), all seven emotions are kept in moderation." When Qi becomes scattered the Heart Fire and the Kidney Water cannot converge. This results in an unbalanced and unstable energy flow.

The Kidneys are extremely important for health maintenance and healing in all patients, and especially in senior citizens. As one gets older, the Kidneys, lower back, and legs are the first things to be affected.

It is important to stabilize the Heart because the Heart is responsible for mental and emotional orientation. Traditional Chinese Medicine holds that, "when the Heart is moved, all the other organs will be shaken."

In teaching Medical Qigong to senior citizens, first quiet the Heart, so that the other organs can begin to relax. When the mind becomes disturbed, the body becomes disturbed. To affect one is to affect the other.

The eyes are considered the seedlings of the Heart as they receive information, gathering it and feeding it to the brain. It is important for the Heart's Qi to descend into the Lower Dantian to calm the mind. When the patient is in a hurry, the Heart is in a hurry, thus inducing the Qi to rise to the head. This results in nervous tension and anxiety. It is only through rest and quiet training that the mind and the Heart can begin to settle.

One method of quieting the mind is through

prayer and meditation. This is considered "active rest." Sleep is considered "passive rest." When focusing inward and not using the eyes to see or the ears to hear, the Qi begins to converge in the middle of the body and the energy is drawn back into the organs, settling down into the Lower Dantian. This convergence of Qi nourishes and cultivates the natural energetic structure of the internal organs. Senior citizens are encouraged to sit for longer periods of energy cultivation. If they practice Taijiquan they are to avoid low postures and big motions. The arm movements should be kept small, soft, and slow.

TREATING THE PATIENT'S EMOTIONAL STABILITY

When treating the elderly, the Qigong doctor bases the regulation therapy prescriptions on two major priorities. The first is to achieve emotional stability and the second is to improve the Qi and Blood circulation.

The first priority in working with healing prescriptions is to focus on the patient's psychological profile. When teaching Medical Qigong to senior citizens, first teach them how to quiet the Heart. Once the Heart is calm the other internal organs begin to relax. Always keep in mind that when the mind becomes disturbed, the body becomes disturbed. To affect one is to affect the other.

Depression and sadness can have a profound effect on the patient's healing ability. Medical Qigong regulation can be a strong aid in releasing an elderly patient from a chronic, detrimental attitude that complicates the healing cycle. Take for example the three stages of emotional transition the patient endures before his or her Spirit closes (see Chapter 18).

If anger and grief are not allowed to be expressed by the patient (which is the first stage of energetic expression and release of emotional pain), then anger transforms into depression, and grief transforms into despair. This is the second stage of the energetic/emotional transformation due to emotional pain. If the patient's depression and despair are not alleviated, then indifference, the final stage of energetic/emotional transformation, is developed. The patient becomes withdrawn, apathetic and either antisocial, or obsessive/compulsive in his or her thinking and behavior.

When the patient's Spirit closes, they tend to be extremely difficult to work with, and can easily sabotage their own healing potential. Though the use of Soul Retrieval meditations (see Chapter 19), Medical Qigong prescriptions can be used to reconnect the patient with their disassociated emotions. This allows the patient the ability to feel and regain contact with his or her true feelings.

Pleasant emotions bring about a calm and relaxing physiology, while strong, chronic negative emotions cause Qi and Blood stagnation, as well as Excess conditions within the patient's body, effecting the quality of the body's life force energy.

ENERGIZING THE PATIENT'S QI CIRCULATION

The second priority is to get the patient to move and circulate the Qi and Blood deep and superficially within his or her body. Static Blood is considered the primary mechanism of senility. All growth, development, decline, and debility of the human body, is related to the condition of the patient's Qi and Blood.

Pathophysiologically, both Qi and Blood affect each other; if one becomes diseased, the other is affected. Due to the Kidney's influence, as seniors get older, their hearing, hair, memory, lower back, and legs become adversely affected. Traditionally, all senility-combating formulas of Medical Qigong stress treating the patient's Spleen and Kidney Deficiency by supplementing the patient's Yin and/or Yang. Then, by applying the balancing methods of activating the patient's Blood and rectifying the Qi, the doctor can also combat the patient's senility.

Senility is also frequently caused by dehydration and malnutrition. Both conditions are frequently overlooked by Western medicine. The dehydration is usually due to a breakdown of the body's thirst signal. The patient does not feel thirsty, and thus forgets to drink. Malnutrition may be caused by a lack of enzymes that aid in absorbing nutrition from foods. Overmedication

likewise can cause senility. These issues should always be addressed when treating the elderly, along with Medical Qigong exercises and meditations.

One example of a Medical Qigong exercise for aiding Qi and Blood circulation for geriatric patients is the Microcosmic Orbit (Fire Cycle) which can be practiced in a sitting position.

The elderly are more subject to musculoskeletal disorders and visceral diseases, especially in the Kidneys and Liver. As the Kidney Yang rises, it begins to restrict the heat in the upper portion of the body, thereby affecting the Heart. Also, as the patient gets older the Lungs cannot sustain liquid retention; this affects the Wei Qi, and results in a thinner layer of skin covering the body.

The Qigong movements prescribed for the elderly should be kept slow and smooth. Qi regulation can be cultivated safely by focusing the patient's intention on the center of the palms while keeping the mind's intention moving downward. The patient must not exert strain when using the muscles. When the patient turns his or her body, make sure that the center of each palm (Pc-8) faces the other. Slow and even breathing will calm the patient's emotions and sedate the mind.

It is important to begin Medical Qigong regulation training for senior citizens with natural breathing. Natural breathing allows their respiration to become soft, natural, gentle and quiet. The focus of the mind should be on relaxation. In dealing with senior citizens, if the focus of their mind's intention is allowed to become too concentrated, it can cause the Qi in their body to constrict and develop into Qi or Blood stagnation. Redirect their focus of intention on their breathing by practicing the Small Heavenly Cycle meditation. The Small Heavenly Cycle meditation is used to regulate the body's Yin and Yang energy and to strengthen the patient's mind and spirit. The Large Heavenly Cycle meditation can be prescribed to increase the patient's Qi and Blood circulation, to rejuvenate the body and the sense organs, to clear the complexion, and to improve mobility.

TAPPING THE KNEES TO PREVENT SENILITY

One exercise prescription that the doctor can use to assist the patient in combating senility is to have the patient lightly tap above, below, and around his or her knees. This exercise stimulates the Kidneys' energy and can also be used as an important adjunct to maintaining health for senior citizens, especially when combined with the foot tapping (Kd-1) Kidney Tonification exercise (see Chapter 39). Combined, both of these exercises can help to strengthen the patient's Kidneys, lower back, and legs. When combining both exercise prescriptions, the Knee Tapping exercise should follow after the Kidney Tonification exercises.

To begin the Knee Tapping exercise, have the patient sit in a chair, with both knees lower then the thighs. Encourage the patient to direct the focus of his or her attention in and around the knee area. As the patient taps or softly slaps the tissue surrounding the knees, he or she should imagine the energy and vibration flowing into the Lower Dantian. After several minutes (about 36 breaths) the patient can stop.

CULTIVATING THE PATIENT'S YUAN QI BY ABSORBING ENERGY FROM NATURE

Another priority of focus for older patients is the gathering, storing and cultivation of his or her Yuan Qi. In China, in order to tonify the Yuan Qi, elderly patients practice their Qi Tonification and Regulation Exercises facing a cypress tree daily (a cypress tree is considered very powerful and full of energy). If a cypress tree is not available, then the patient can use a pine or oak tree. This exercise prescription is considered a slow and gentle Dynamic cultivation. Any Dynamic exercise for senior citizens should always be practiced slowly, and gently, in order to replenish the Yuan Qi during the Static Qigong posture (in this case, standing).

The flexion and extension of the muscles relates to the interaction of Yin and Yang within the body's energetic tissues and muscles. This flex-

ion and extension of the muscles becomes the foundation of energy balance. Relaxation of the body results in soft, gentle movement, peacefulness and tranquillity. Muscular rigidity, on the other hand, results in hardness, restlessness and disease.

In order to practice Medical Qigong exercises, senior citizens are encouraged to keep their body's energy connected with the energy of the Earth. This connection is obtained via their energetic attachment through the bottom of their feet and the center of their palms. If the patients are confined to wheelchairs, or are bedridden, they can still focus the mind's intention on the Lower Dantian, and then extend their energy deep into the Earth.

As with all Medical Qigong prescriptions, the patients must first purge and cleanse their body before gathering, collecting, tonifying and regulating the body's energy. To purge the body of Toxic Qi, the patients imagine divine healing energy pouring down from the Heavens, filling the entire body, as they inhale. This vibrant healing energy is absorbed into their tissues and the Toxic Qi stored within the patient's body is dispersed into the Earth.

As the patients exhale, they imagine the Toxic Qi melting out their tissues and flowing downward, deep into the ground. The patients perform this purging and dispersing sequence for several breaths until they feel cleansed. Next, the patients begin to fill and regulate their body.

To fill and regulate the body, the patients imagine circulating the energy downward, deep into the Earth, and into the root system of a tree.

Next, the patients imagine the Earth's energy ascending up through the top of the tree, blending with the energy of Heaven, and then descending through their head, filling their entire body from the feet upward like water being poured into a glass and filling it up (Figure 50.1).

The inhalation and exhalation should follow the Natural Abdominal Breathing method, and the mind's intention should be focused on filling, gathering and circulating the universal and environmental Qi.

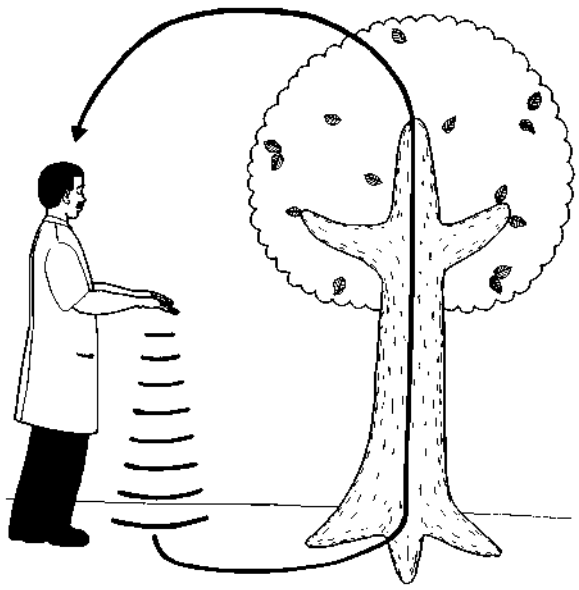

Figure 50.1. Extend Qi and Intention deep into the root system of the tree and absorb its natural energy through the Baihui point at the top of the head.

FURTHER OBSERVATIONS AND INSIGHTS ON GERIATRIC PATIENTS

According to Mark Johnson (an expert who has been treating "Seniors" with Medical Qigong Therapy and Taijiquan since 1987), any encouragement to undertake new experiences is very cathartic for older patients. Getting involved in anything creative seems to prolong the quality of their life.

Understanding the physical and emotional transitions that geriatric patients undergo in their every day life helps the Qigong doctor establish a better awareness of the patient's energetic dynamics. These physical and emotional transitions can best be understood when realizing the internal and external conflicts senior patients must constantly address.

COMPANIONSHIP

Many people tend to lose meaning in their life when they retire, lose a spouse, witness the death of countless friends, or when their children

move away. Patients who lose their life purpose (or their meaning of life) usually do not live long. Elderly patients, who have lost their friends, usually have an extremely strong emotional attachment to any pet they may own. If the pet dies, this is usually as devastating as the loss of a close family member.

According to clinical observation, most older patients who become involved in spirituality, social service or voluntary work tend to be the most fulfilled and therefore most healthy. Humor and laughter as a means of internal emotional medicine for older patients cannot be overemphasized. Socializing with an understanding yet active support group also tends to bring healing to their heart.

In addressing the issue of being lonely, it has been found that the healing quality of having a pet to love can be very helpful for seniors who have become solitary or isolated.

OVERMEDICATING

Too many older patients are overly medicated. Taking up to ten pills a day is not unusual for many seniors. In a book initiated by Ralph Nader, titled "Worst Pills, Best Pills" the author emphasizes the fact that if an older person is taking over three different drugs, they are taking too many and should consult their doctor with the expressed purpose of cutting down to a maximum of only three types of medication.

The drugs given to seniors are usually tested on 30 year old individuals who are generally much stronger than most 70 year olds. Therefore half dosages are usually considered safer. In addition, there is a minimum of thirty-three drugs on the market today that can give the symptoms of Parkinson's disease. Several healers have gotten their patients off Parkinson's medication after demonstrating the fact that one of their other medications initiated the patient's symptoms.

SEDENTARY LIFE-STYLE

Too many older patients are sedentary, especially men. It is generally agreed that people living today move only 35% as much as people living 100 years ago. This has got to have a major impact on one's health, especially on older people whose circulation is not what it once was. Our bodies are designed to move; to become sedentary violates one of our basic needs. The studies conducted at Emory College confirm that the safest and most beneficial exercises for seniors is Medical Qigong, Taijiquan, walking, mild aerobics and light weight training. Seniors are encouraged to stay away from running.

IMPROPER DIET

Because of the patient's age and changing metabolic needs, diet is as equally important for seniors as exercise. Proper nutrition can be used to augment the benefits from the patient's prescriptions, as well as to increase the patient's healing potential. The diet in senior housing communities is usually atrocious. Sugar, canned vegetables and too many heavy meats are the norm. When prescribing Medical Qigong exercises for seniors, the Qigong doctor must also take into consideration the patient's diet and fluid intake, making sure that it is not sabotaging the healing effect of the Qigong prescriptions.

SLEEP DEPRIVATION

As patients gets older, their Kidney Jing becomes weak, their hair begins to turn grey, the hearing and sight becomes affected, the bone structure, mental comprehension and sleeping patterns also undergo changes. These physical transitions can and do affect the patient's emotional outlook on life. This however, is all part of the natural course of ageing.

Due to the weakening of the patient's Kidneys, sleep deprivation is more common in seniors than most people realized. More training in dealing with insomnia and changing sleeping patterns is necessary for Western doctors, as the serious impact on health by sleep deprivation is poorly understood in Western society.

Sleep is needed to invigorate and stabilize the patient's Wu Jing Shen (Five Essence Spirits). Without sleep, the patient's Hun (Spirit Soul), Shen (Spirit), Yi (Intention), Zhi (Willpower) become depleted and they lose control of their Po (Corporeal Soul). This affects the patient's intuitive perceptions, mental comprehension, drive and willpower, and can result in dementia.

UNDERSTANDING DEATH AND DYING

Classes and workshops on death and dying should be more available, and both patients as well as doctors should be encouraged to attend them. The doctor can benefit greatly by learning specific meditations being taught to facilitate this major transition, and also how to relate better to their elderly and young dying patients. The patients can benefit greatly by increasing their awareness and understanding of this process, as well as learning the numerous meditations that help resolve unprocessed emotions. Furthermore, patients can meet others with whom they can share their fears and hopes openly.

Too often the elderly do not wish to share these feelings, even with those closest to them for fear of burdening their family and friends. Patients may also be very reluctant to disclose their personal concerns for fear of being alienated, even with Qigong doctors, especially if the doctor's fear of death becomes evident through too much encouragement to get well and not lose hope.

Chapter 51
Qi Emission Therapy for Gynecology

Introduction

Gynecology is the study of diseases of the female reproductive organs. The earliest records of Chinese gynecological medical writings date as far back as the Shang Dynasty (1500–1000 BC). From a Traditional Chinese Medical perspective, a woman's physiology is characterized and diagnosed in accordance with her menstrual flow and vaginal discharge (also included are the energetic formations and transitions during pregnancy and childbirth). A woman's physiology is dominated by, and rooted in Blood. Her Lower Burner houses the uterus, which stores Blood, and corresponds to her Lower Dantian.

Menstrual Flow

Normally, a woman will follow the cycles of the moon and will menstruate every 28 days. Her cycles can be categorized into either new moon or full moon periods. The length of days between menstruation and the time of duration vary; four days of flow is considered average.

A woman's menstrual cycle can be categorized into four distinct time periods: Irregular Menstruation, Early Menstruation, Late Menstruation, and Prolonged Menstruation.

1. An irregular menstrual cycle is never consistent: sometimes early, sometimes late. The cause of an irregular menstrual cycle can be due to either a stagnation of Liver Qi (from suppressed anger or emotional shock), Liver Qi invading the Spleen (emotions affecting the Liver invades the Spleen), or a constitutional weakness of the Kidneys.
2. The cause of an early menstrual cycle can be due to either Heat in the patient's Blood or Qi Deficiency.
3. The cause of a late menstrual cycle can be due to either Cold stagnation of Blood, Blood Deficiency, stagnation of Qi (caused from emotions), or Deficiency of Qi.
4. The cause of a prolonged menstrual cycle can be due to either Qi Deficiency or Heat in the Blood (this is because Blood that is Hot wanders out of the vessels).

Qi and Blood Regulation

Due to periodical menstruation and the complex changes that occur in the uterus and the organs (ovaries, cervix, and vagina) associated with reproduction, women tend to become especially vulnerable to Blood damage. The formation, circulation, and control of Blood depends upon the transformation, regulation, and production of the woman's Qi. This interdependence of Qi and Blood is regulated through the harmony of the body's Five Yin Organs. For example:

1. The Liver stores the Blood.
2. The Heart controls the Blood.
3. The Spleen contains or keeps the Blood in its vessels. In addition, the body's Spleen and Stomach are also known as the source of reproduction and transformation of Qi and Blood.
4. The Lungs store the Qi, which commands or moves the Blood.
5. The Kidneys store the Jing, which transforms or creates the Blood.

The woman's Sea of Blood can only flow freely when the Qi and Blood of the Five Yin Organs are in harmony. When a woman's Sea of Blood is full and exuberant, then her menstruation will be healthy and normal.

Regarding the Eight Extraordinary Vessels, a woman's Governing, Conception and Thrusting Vessels all originate within her uterus. The Governing Vessel governs the body's Sea of Yang and represents the Yang aspect of a woman's repro-

ductive functions. The Conception Vessel governs the body's Sea of Yin and provides the Yin substances for all physiological and hormonal transitions, including puberty, conception, pregnancy, childbirth, and menopause. The Thrusting Vessels function as the Sea of the Twelve Primary Channels, and influence the supply and proper movement of Blood in the uterus, and control all aspects of menstruation.

The Belt Vessel encircles the Governing, Conception, and Thrusting Vessels, and governs, guides, and supports the energetic flow of Qi and Jing to the uterus.

Regarding the Twelve Primary Channels, their internal network is distributed throughout the uterus and is connected to both the Heart and Kidneys. In addition, the energetic connection with the uterus is further strengthened by the convergence of the Liver, Spleen, and Kidney Channels, along with the Conception Vessel, through the connecting vessels in the genitalia.

ETIOLOGY AND PATHOLOGY OF GYNECOLOGICAL DISEASES

In order for the Qigong doctor to make a correct diagnosis pertaining to a woman's menstrual flow and reproductive organ function, attention must be placed on identifying the primary etiology of the imbalance in the patient's Qi and Blood.

The Governing, Conception, Thrusting, and Belt Vessels are the most important vessels in terms of diagnosing gynecological pathophysiology. Consequently, any damage or disease of the these vessels are believed to be the main causes of gynecological disorders.

Either a direct or indirect attack to the Conception and Thrusting Vessels can cause disharmony of Qi and Blood, resulting in a loss of internal organ regulation.

DIRECT CAUSE

A direct cause of damage to the Conception and Thrusting Vessels can result from either Evil Toxin infections or from hygienically unclean sexual encounters. If the Conception and Thrusting Vessels become damaged, the result can manifest in symptoms such as profuse abnormal vaginal discharge or uterine bleeding.

INDIRECT CAUSE

Indirect causes of damage to the Conception and Thrusting Vessels can result from internal damage due to: The Seven Emotional Factors, Invasion of the Six Exogenous Factors, and An Inconsistent and Undisciplined Diet.

1. The Seven Emotional Factors tend to be the major factors in determining the root causes in most gynecological diseases.

   The suppression of anger, rage, resentment, and jealousy often results in Liver Qi depression, which eventually leads to Blood stagnation. This can result in such symptoms as delayed, painful, or blocked menstruation. If a hyperactive Liver Yang condition occurs, the patient can develop symptoms as serious as pre-eclampsia or eclampsia (coma and convulsive seizures that can occur between the 20th week of pregnancy and first week postpartum; symptoms include edema of the legs and feet, puffiness of the face, hypertension, severe headaches, dizziness, epigastric pain, nausea, sudden convulsive seizures and coma). The Liver's Blood Heat can lead to profuse uterine bleeding, leaking of Blood, hemoptysis (throwing up Blood) or epistaxis (bleeding of the nose).

   The suppression of worry and regret, or obsessiveness, can harm the Heart and Spleen. This can lead to amenorrhea (the absence or suppression of menstruation) or a fetal leakage (after conception, if a small amount of bloody fluid discharges from a woman's vagina, it is known as Tai Lou or fetal leakage).

   The suppression of fright, fear, loneliness, and insecurity can damage the Kidneys and lead to miscarriages.
2. Invasion of the Six Exogenous Factors, in particular, Cold, Heat, and Dampness, are the primary causes for gynecological diseases.

   If the Blood is invaded by Cold, it congeals, causing delayed menstruation, painful menstruation, or severe contractions and thick conglomerations of Blood.

   If the Blood is invaded by Heat, it moves, causing the Blood to flow recklessly. This reckless movement of Blood leads to early men-

struation, excessive menstruation, and uterine bleeding.

If the Blood is invaded by Dampness (Damp Evils invading the Spleen), it can lead to abnormal vaginal discharge, uterine bleeding, and irregular menstruation.

3. An Inconsistent and Undisciplined Diet can lead to a Spleen and Stomach disharmony. If the Spleen and Stomach's ability to transform and transport food becomes hindered or weakened, the Sea of Blood becomes Empty. This can lead to delayed menstruation or scanty menstruation.

   If the Spleen loses its ability to restrain and contain the Blood, both Blood and Qi leak out of the vessels. This leaking of Qi and Blood can lead to excessive menstruation and uterine bleeding.

   If the Spleen's Yang does not perform its transporting function, Dampness and Turbidity will descend, resulting in abnormal vaginal discharge.

VAGINAL DISCHARGE

In Traditional Chinese Medicine, abnormal vaginal discharge (Dai Xia) is considered a disease of the Belt Vessel. If the Belt Vessel loses its restraint on the other vessels, then abnormal vaginal discharge is produced. This is usually caused by a Spleen Deficiency, Dampness, and descending Turbid Qi.

CONSISTENCY

The consistency of the patient's vaginal discharge can be divided into three categories: Turbid, Watery, and Clotting (thick and pasty).

1. A Turbid discharge refers to Blood Heat and an infection in the uterus. It also refers to signs of Cold stagnation.
2. A Watery discharge is considered a Cold Damp and/or Deficient condition.
3. Clots (thick and pasty) are considered a Damp Heat and Excess condition.

SMELL

The smell of the patient's vaginal discharge can be divided into conditions of either Damp Heat, indicated by a leathery smell, or Cold Dampness, indicated by a fishy smell. Also, if the patient's menstrual Blood has a strong, foul smell, it usually indicates a Heat condition.

COLOR

Vaginal discharge color is divided into five colors (Wu Se Dai): white, yellow, red, green-blue, and dark brown or black. The pathology of the discharge color is mostly caused from a Deficient Conception Vessel, loss of restraint from the Belt Vessel, Spleen Dampness, or Evil Wind invading the uterine vessels. These conditions create Heat, which descends into the uterine area causing disease.

Only profuse vaginal discharge, which bears an unnatural color and gives off a malignant odor, is considered pathological. The five colors of vaginal discharge are as follows.

1. White vaginal discharge (Bai Dai) is the most commonly seen type of vaginal discharge. It is a Cold condition caused by a Spleen or Kidney Yang Deficiency, or from Exterior Cold Dampness. It manifests as a white, sticky, slimy fluid discharge from inside the patient's vagina with a fishy smell. Symptoms include sore lower back, weakness, and irregular menstruation.
2. Red vaginal discharge (Chi Dai) is caused from Damp Heat in the Lower Burner or Fire Blazing through the Heart and Liver channels. The latter eventually causes a Yin Blood Deficiency. Red vaginal discharge manifests as thick and sticky, white with red mixed together, pale red, or red vaginal discharge with a foul odor. Symptoms include thirst, bitter taste in the mouth, and reddish urine. Continued red vaginal discharge may be a sign of cancer, and the patient should immediately be referred out to an oncologist.
3. Yellow vaginal discharge (Huang Dai) is caused from Heat, usually Damp Heat in the Lower Burner produced from a Deficient Spleen not transporting the Dampness. This condition causes Water Dampness to brew and bind, which then transforms into Damp Heat. The Damp Heat invades the Conception Vessel which causes the Belt Vessel to lose its ability to restrain. It manifests as a yellow, sticky, and

slimy vaginal discharge with a foul odor. A vaginal discharge that has yellow and red with white pus (after menopause) is considered a manifestation of Toxic Damp Heat in the uterus and can indicate endometrium cancer.

4. Green-blue vaginal discharge (Qing Dai) is caused by Damp Heat in the Liver or Gall Bladder Channels. A yellow-green color with pus accompanied by itching and soreness is also a sign of Damp Toxic invasion.
5. Dark brown or black vaginal discharge (Hei Xia) is seen as a form of Blood stagnation.

All gynecological disorders are closely related to the patient's whole constitution, even though the manifestations appear in the reproductive organs. The patient's general constitution, age, dietary habits, home and work environment, should all be taken into account when diagnosing clinical pathophysiologies.

MENSTRUAL COMPLICATIONS

DYSMENORRHEA

Dysmenorrhea is one of the most frequent gynecologic disorders observed in the clinic today. It is described as pain associated with menstruation and refers to cyclic pain (before, during or after menstruation) felt in the lower abdomen or lumbosacral area of the woman's body before, during, or after menstruation. Serious cases of dysmenorrhea can be accompanied by headache, nausea, vomiting, and even syncope.

ETIOLOGY

From a Traditional Chinese Medical perspective, a woman's body is more susceptible to an attack of external pathogens and injury from internal emotional disturbances during her menstrual period. Mental depression may injure the Liver and cause Qi and Blood stagnation.

The invasion of Cold into the Thrusting and Conception Vessels may also cause stagnation and coagulation of Blood, which in turn causes Qi and Blood Deficiency (leading to poor nourishment of the uterus). Excessive exposure to Cold and Dampness can cause Cold to invade a woman's uterus, causing stasis of Blood. A women is prone to Cold invasion when her uterus and Blood are in a weakened state, during and soon after her period.

There are four different phases identified during a woman's menstrual cycle: Before Menstruation, During Menstruation, After Menstruation, and During Mid-cycle.

1. Before menstruation, the woman's Yang rises in preparation to move Blood during her menses; Liver Qi also moves into the lower abdomen in preparation to move the Blood. If a woman's Liver Qi stagnates, it can cause the Blood stagnation in the uterus, leading to pain, especially before her period. This type of stagnation is the most important pathological condition causing dysmenorrhea. Liver Qi stagnation can be caused from emotional strain resulting from suppressed emotions, such as anger, resentment, hatred, and frustration.
2. During menstruation, the woman's Blood is moving. The movement of Blood relies on Liver Qi and Liver Blood. If a woman's Liver Blood stagnates, it will cause pain during her period.
3. After menstruation, the woman's Blood and Yin are Empty.
4. During mid-cycle, the woman's Blood and Yin gradually fill up the Thrusting and Conception Vessels.

According to Western medicine, dysmenorrhea is related to mental stress, emotional instability, mental depression, and fright. Dysmenorrhea can also be due to diseases of the ovaries, uterine, or endocrine glands.

The menstrual pain may appear one to two days before the onset of the menstrual period, and remain until the start of the menstrual flow. It usually lasts from just a few hours to one to two days.

SYMPTOMS

In Traditional Chinese Medicine, dysmenorrhea is classified into two types of syndromes: the Excess type and the Deficient type.

- The Excess type of dysmenorrhea can be caused by either Qi and Blood stagnation, Cold stagnation, or Damp Heat. An Excess

condition manifests as distention and pain in a woman's lower abdomen and/or lumbago, occurring before or during menstruation. Symptoms also include obstructed menstruation with pale-purplish color and clots.

- The Deficient type dysmenorrhoea can be caused by either Qi and Blood Deficiency or Kidney and Liver Yin Deficiency. Symptoms of this condition manifest as pain in the lower abdomen, occurring before or during menstruation, which can be relieved by heat and compression. The patient will experience soreness and distention of the waist and legs with pale and scanty menses.

TREATMENT

1. To begin, have the patient sit at the edge of the table and begin stimulating the Yellow Court, Mingmen, and Lower Dantian areas, using the Vibrating Palm technique, for 6 to 8 breaths.
2. Emit Qi, using the Extended Fan Palm technique, into the patient's Lower Dantian, purging the Qi down the Stomach Channels to her feet.

TREATMENT MODIFICATIONS

- When treating patients with the Excess type of dysmenorrhea, emit Qi into the patient's Lower Dantian, St-21, and Lv-14 points, then purge the Stomach and Liver Channels down to and out of the feet.
- When treating patients with the Deficient type of dysmenorrhea, emit Qi into the patient's Lower Dantian, then guide Qi along the Stomach and Spleen Channels to regulate the body.

PRESCRIPTIONS AND HOMEWORK

Have the patient practice the Descending the Yang and Ascending the Yin techniques (see Chapter 41).

PRESCRIPTION MODIFICATIONS

1. For patients with the Excess type of dysmenorrhea:
   a. Have the patient sit at the edge of a chair, relax and breath naturally, with the tongue placed up against the hard palate. The patient's mind should concentrate on her Lower Dantian and navel area.
   b. The patient should imagine the navel as the center of a wheel. When inhaling, she should move the Qi upwards, rotating the energy clockwise, from the lower portion of the right side of the abdomen. The patient silently chants the phrase: "The white tiger hides in the east." Exhaling, she rotates the Qi from above the navel to the left side of the abdomen back to the beginning point, while silently chanting the phrase: "The blue dragon shelters in the west." The patient continues circulating the Qi around the navel, rotating it in a clockwise direction for 36 breaths. In this particular meditation, it is important the patient start with small circles and gradually increase the circumference of the energy circle, in order to disperse the accumulated Heat in the uterus.
2. For patient's with a Deficient type of dysmenorrhea:
   a. Have the patient sit at the edge of a chair, relax and breath naturally, with her tongue placed up against the hard palate. The patient's mind should concentrate on the Lower Dantian and navel area.
   b. Imagine the navel as the center of a wheel. When inhaling, she should move the Qi upwards, rotating the energy counterclockwise, from the lower portion of the left side of the abdomen. The patient silently chants the phrase: "The blue dragon shelters in the west." Exhaling, she rotates the Qi from above the navel to the right side of the abdomen back to the beginning point, silently chanting the phrase: "The white tiger hides in the east." She continues circulating Qi around the navel, rotating from large to small circles in a counterclockwise direction for 36 breaths. In this particular meditation, it is important that the patient start with large circles and gradually decrease the en-

ergy circle's circumference in order to gather energy into the uterus.

MENOXENIA

Menoxenia refers to the pathological changes of menstruation occurring in the cycles, such as the color, quantity, and quality. This includes extended or delayed menstrual cycles, as well as menorrhagia (excess bleeding) and scanty menstruation.

SYMPTOMS

1. Blood Heat symptoms include: prolonged menstrual cycle, profuse menstruation of bright red or purplish color, viscous in quality, and a heavy feeling in the chest.
2. Deficiency of Qi symptoms include: prolonged menstrual cycle, profuse, pale and watery menstruation, listlessness, palpitations, shortness of breath, and an empty or dropping sensation in the lower abdomen.
3. Blood Stasis symptoms include: delayed menstrual cycle, purplish and massed menstruation with pain and distention in the lower abdomen.

TREATMENT

1. Have the patient sit at the edge of the table and begin to stimulate her Yellow Court, Lower Dantian, and Mingmen areas using the Vibrating Palm, for 8 to 16 breaths.
2. Use the Extended Fan Palm hand posture to emit Qi into the patient's Mingmen and Lower Dantian using the Spiral Rotating method of Qi manipulation. Rotate the energy in a counterclockwise direction for conditions of Excess and a clockwise direction for Deficient conditions.

TREATMENT MODIFICATIONS

- When treating a patient with Blood Heat, emit Qi into her Yellow Court and Lv-14 points, drawing the energy down her Liver Channels and out of her feet.
- When treating patients with a Deficiency of Qi, use a Extended Fan Palm hand method while tonifying and filling her Mingmen and Lower Dantian areas.
- When treating a patient with Blood Stasis, use the Extended Fan Palm hand method to emit Qi into her Lower Dantian and rotate the Qi in a clockwise direction.

PRESCRIPTIONS AND HOMEWORK

In order to move the energy and allow Qi and Blood to flow smoothly in the uterus, have the patient practice the Microcosmic Orbit Fire Cycle (see Chapter 41).

PRESCRIPTION MODIFICATIONS

- For patients with Blood Heat, it is advisable to have them practice the Liver Massage method (see Chapter 39) and sound the word "Xu" (Shu).
- For patients with Qi Deficiency, have the patients perform Natural Breathing meditations, as well as the Daoist Five Yin and Yang Organ Exercise (see Chapter 42).
- For patients with Blood Stasis, have the patient practice Circling the Abdomen, for 36 breaths in a clockwise direction (see Chapter 41).

CYSTS AND TUMORS

BREAST CYSTS AND BENIGN TUMORS

A breast cyst or benign tumor is a lump or nodule found within the breast tissue.

ETIOLOGY

The fibrocystic changes that can occur in a woman's breast tissue are commonly divided into three levels of benign breast disorders. Beginning with Level-1 breast cysts (which include the development of benign lumps, nodules or fibroadenoma), progressing onto the development of Level-2 breast cysts (which include the development of mastitis or carbuncles), and ending with Level-3 breast tumors.

The Qigong doctor's treatment will vary according to the type and condition of the lump enclosed within the patient's breast tissue.

DIAGNOSIS ACCORDING TO DIFFERENT TYPES OF BREAST LUMPS

The Qigong doctor differentiates among the types of breast lumps and initiates treatment ac-

cordingly. Breast lumps can be divided into three major categories: Phlegm, Blood Stasis, and Toxic Heat.

1. Phlegm lumps are soft with distinct edges, mobile and slippery. They are not swollen, and the skin surface around the area is white.
2. Blood Stasis lumps are hard, immobile nodules. The skin surface around the surrounding area is purple.
3. Toxic Heat lumps are hard, immobile, with indistinct edges. The skin surface of the surrounding area is indented and red.

LEVEL-1 BREAST CYSTS (BENIGN LUMPS, NODULES OR FIBROADENOMA)

These are lumps that feel like hard nodules; they are usually painless, round, flat, and mobile. The lumps do not feel hot or cold to touch, the skin color is unchanged, and the size of the lump may vary depending on the patient's mood changes.

ETIOLOGY

Level-1 cysts are usually caused by the patient's Liver and Spleen being affected by anger, worry, and depression. The Spleen Qi is weakened, thus disrupting the free-flow of the Liver Qi. This leads to conditions of nodules due to both Qi and Phlegm stagnation. Long term Qi stagnation eventually leads to the accumulation of Phlegm and Stasis of Blood.

SYMPTOMS

These type of cysts are characterized by their process of development; they generally start off small and increase in size after several months.

TREATMENT

Eliminate the stagnation and remove the Phlegm using Qi purging and dispersing techniques.

LEVEL-2 BREAST CYSTS (MASTITIS OR CARBUNCLE)

This condition is a painful inflammation of the breast skin and underlying tissue.

ETIOLOGY

Level-2 cysts are usually caused by Qi and Blood stagnation, resulting from the stagnation of the Liver or Gall Bladder Qi, which is accompanied by excessive stagnation of Toxic Heat in the Stomach Channels. Breast cysts can be internally induced by suppressing the emotions, especially grief. Generally mother issues relate to the left breast and Lung area, while father issues relate to the right breast and right Lung area.

TREATMENT

1. After clearing the diseased area of Toxic Qi, the Qigong doctor uses the Sword Fingers technique to stimulate CV-17, St-18, Lu-1, Bl-18, and -21 points, to open the points along the Liver, Lung, and Stomach Channels.
2. Next, the Qigong doctor emits Qi, using the Vibrating and Shaking techniques, to disperse the cyst.
3. The doctor then applies the Dragon Mouth manipulation to dredge the patient's body, by pushing, pulling, and leading the Stagnant and Toxic Qi down the patient's Lung Channels (out the arms), and Stomach Channels (out her legs), via the St-36 points.
4. The patient is given homework, consisting of Jing Point Therapy, and of kneading the surface and surrounding tissue of the cyst at least once a day. This prescription should also include the use of the "Shang" sound tone resonation to further dissolve the cyst, and to dispel the Toxic Qi out of the breasts.

LEVEL-3 BREAST TUMORS

This type of breast cyst corresponds to a severe condition of dysplasia.

ETIOLOGY

Level-3 cysts are usually caused by Liver Fire, accompanied by Heart and Lung Qi stagnation due to the accumulation of grief, sorrow, exasperation, and being upset, or due to the derangement of the patient's Thrusting and Conception Vessels.

TREATMENT

1. After clearing the diseased area of pathogenic Qi, the Qigong doctor uses the Thunder Palm technique to disperse the tumor.
2. After several minutes of blasting the area, the Qigong doctor uses the Spiraling and Circling Energy techniques to circle the tissue areas

surrounding the tumor, drawing the pathogenic Qi down and out of the patient's nearest arm via the Lung Channel (Figure 51.1).

3. The Qigong doctor then uses energetic Pulling and Shaking techniques to release the pathogenic Qi from the patient's body and to draw it out of the arm. The doctor must then pull and snap each of the patient's fingers and thumbs, to release and disperse the Excess Heat and pathogenic Qi.
4. Next, circle rotate the energy within the patient's Lower Dantian, pulling the Qi down the lower legs and out the St-36 points.
5. Finally, fill her Lower Dantian and circle regulate her Governing and Conception Vessels using the Microcosmic Orbit to balance the Yin and Yang energy.
6. Give the patient homework consisting of Jing point therapy that stimulates the GB-21, St-36, CV-17, and Sp-6 points, once a day. If the patient is using magnetic therapy, she should place the magnets on the points for 1 hour. This prescription should also include herbs, and the use of the "Shang" sound tone resonation (straight tone and descending/ascending tone prescriptions) to further dissolve the tumor.

OVERVIEW OF TREATMENT

The general treatment for breast diseases, depending on the severity of the condition, is divided into five main components: Medical Qigong therapy, Medical Qigong massage, prescriptions, Jing point therapy, and herbal teas.

MEDICAL QIGONG THERAPY

The doctor's emitted energy can assist the patient in dispersing stagnations, as well as dissolving breast tumors and cysts. Generally, the doctor's treatment lasts for a period of three days, and can be indefinitely prolonged and increased in effectiveness if the patient is given additional Medical Qigong prescriptions as homework.

MEDICAL QIGONG MASSAGE PRESCRIPTION

This therapy is most important as it allows the patient to reconnect with her tissues and further allows her to feel and release emotions trapped

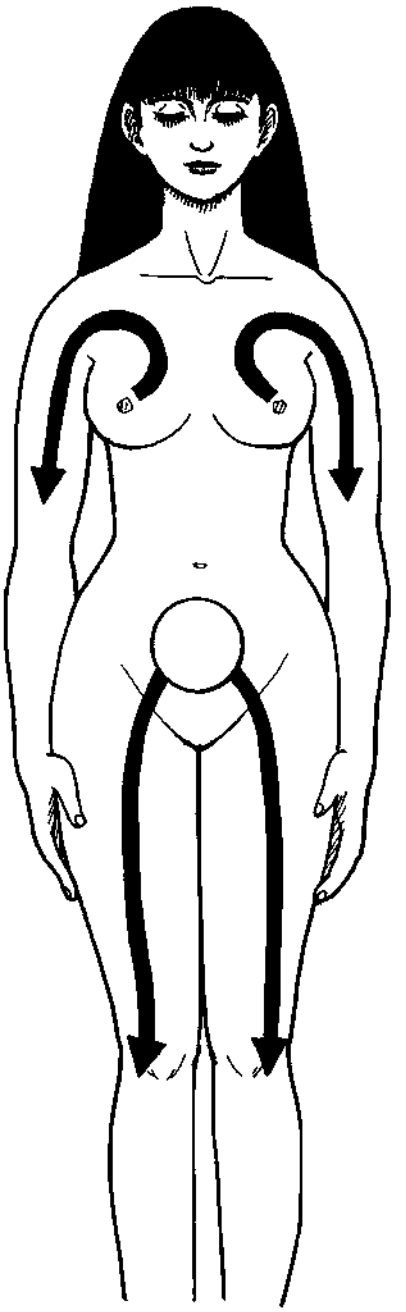

Figure 51.1. After purging the Toxic Qi from the patient's upper body, the Qigong doctor continues to disperse the patient's Toxic Qi from the lower abdomen, leading it down the patient's leg and out of the St-36 points.

within her body (remember, you can only heal what you feel). This healing process is as follows.

1. The patient begins by rubbing her hands together to get them hot.
2. Placing her hands on her breast, the patient inhales and draws the heat from her hands into the breast tissue, while imagining divine healing light flowing from the Heavens, and pouring into her body to fill up her chest.
3. The patient circle massages her breasts 36 times towards the outside of her body, concentrating on the breast tissue filling up with the divine healing energy that destroys any and all pathogens stored within her breast tissues.
4. After completing 36 times in one direction, the patient reverses directions but maintains the same visualization.
5. Next, the patient exhales the straight healing sound "Shang" for 9 breaths, toning, while turning the body from the left to the right side. The patient focuses on purging the pathogens out of her breast area through her mouth. This purges her Lungs and the surrounding breast tissues.
6. The patient then exhales the descending/ascending healing sound "Shang" for 9 breaths as she turns at the hips, toning from the right to the left side of her body, and focuses on purging the pathogens out of her breast area. This purges her Lung Channels and the surrounding energetic connections to the breast area.
7. The patient then rubs 36 times in a clockwise direction, from her abdomen to her Lower Dantian, leading the Qi downwards. This is performed to root the energy back into her Lower Dantian.
8. The patient ends the prescription in a quiescent state of mind.

MEDICAL QIGONG PRESCRIPTIONS

This therapy allows the patient to purge the organs that are found to be the root cause of the disease. In Medical Qigong, the doctor views the patient's cysts or tumors as a flower. If, through surgery, the top of the flower is plucked from its stem (and the branch, stem, and root cause of the disease is left still intact), the tumor or cyst will return again. In order to heal the patient's condition, the doctor must also address the original cause of the disease and destroy the entire support system. The purpose for these prescriptions is to destroy the disease's entire root system to kill the flower.

1. The Dry Crying prescription is given to purge the emotions of grief and sorrow from the patient's Lungs (see Chapter 53).
2. The "Guo" healing sound is given to purge the patient's Liver Fire.
3. The "Shang" healing sound is given to dissolve the cyst or tumor.
4. Prescribe Jing Point Therapy. Specific points are prescribed for the patient to enhance the doctor's treatments, and increase her own healing potential. The patient is encouraged to stimulate specific areas of her body, by emitting Qi while pressing and focusing her intention into the following points:
   a. The Small Intestine 3 point affects the patient's breast disease caused by Rebellious Qi and Qi depression.
   b. The Stomach 18 point frees Qi flow locally in the patient's breast.
   c. The Stomach Channel transverses the breast, and the Stomach 36 point regulates Qi of the patient's entire body.
   d. The Spleen 6 point is specifically chosen for treating breast cysts.
   e. The Gall Bladder 21 point (Shoulder Tapping) is prescribed to assist the patient in sinking Liver Qi Heat.

HERBAL TEAS

All herbal teas are administered to move the Qi and assist the doctor's treatment. Dandelion tea, for example, is mixed with green tea to clear Heat from the patient's body; or green orange peel is added to help move the Qi.

OVARIAN CYSTS AND UTERINE TUMORS

In an ovarian cyst, there is a closed sack or pouch containing fluid, semifluid, or solid material, usually characterized by Phlegm, Damp Heat, and Stasis of Blood.

ETIOLOGY OF OVARIAN CYSTS

Ovarian cysts can be caused by psychological upheavals which lead to enlarged follicles that fail to rupture, as well as by Liver Fire stagnation. Ovarian cysts are usually related to the anger from the Liver turning inward and attacking the body.

ETIOLOGY OF UTERINE TUMOR

A uterine tumor, or myoma, is a solid benign growth in the myometrium, and is often called a fibroid. It contains muscle tissue. Excessive uterine bleeding is a common effect of myomas. Ovarian cysts and uterine tumors are generally divided into three types of myomas:

1. The subserous type is located on the outside wall of the uterus;
2. The interstitial type is located within the wall of the uterus;
3. The submucous type is located on the inside of the uterus.

TREATMENT

The same treatment is used for both ovarian cysts and uterine tumors. To treat these conditions, the doctor uses Medical Qigong therapy in conjunction with Jing point therapy and herbs.

1. Begin with the patient in a supine position and purge and clean the diseased area of pathogenic Qi, using the Thunder Palm technique in conjunction with the Vibrating Palm, to disperse the stagnation in the ovaries or uterus.
2. Disperse pathogenic Qi out the patient's body via the Gall Bladder Channels.
3. Tonify the patient's Lower Dantian with Qi and circulate the energy through the Microcosmic Orbit.
4. Press and stimulate with Jing point therapy the Sp-6, Sp-9, St-36, GB-34, and GB-38 points (Figure 51.2).

PRESCRIPTIONS AND HOMEWORK

The patient should be given homework, in accordance with her constitution. The prescriptions should include:

1. The "Guo" sound to disperse Liver Fire.
2. The "Yu" sound to disperse ovarian cysts.
3. Prescribe Lower Dantian regulation exercises to access and regulate the ovarian energy.
4. Prescribe herbs for chronic conditions.

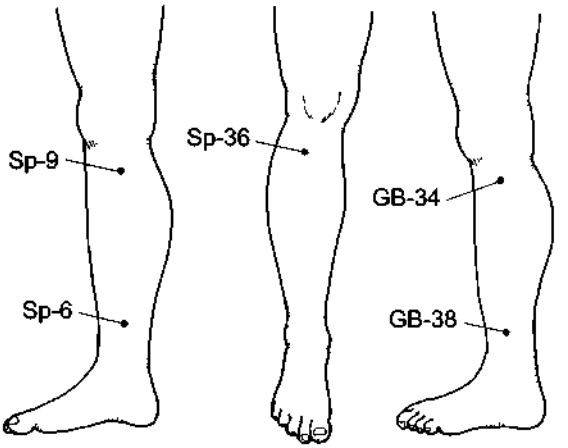

Figure 51.2. When treating ovarian cysts, use Jing Point therapy in conjunction with Qi emission, to stimulate Sp-6,-9, St-36, G.B.-34 and 38 points.

UTERINE COMPLICATIONS

MISCARRIAGE

A miscarriage is the termination of a pregnancy, at any time before the fetus has attained extrauterine viability. Miscarriage occur usually between conception and the fourth month of pregnancy.

In Traditional Chinese Medicine, a miscarriage can have several stages and levels of severity, ranging from such conditions as Fetal Leakage, Restless Stirring of the Fetus, Falling Fetus, and Small Birth. Within each of these conditions there are several patterns of disharmony.

ETIOLOGY

There is an ancient Chinese saying which states "A miscarriage is more serious than child birth." According to Traditional Chinese Medicine, there five basic mechanisms associated with the cause of a miscarriage: Empty Conception and Thrusting Vessels, Blood Deficiency, Depressed Liver Fire, Blood Stasis, and External Injuries.

1. An Empty condition of the Conception and Thrusting Vessels causes miscarriages. The mother's Kidney Qi consolidates the fetus and is responsible for constricting the anal and vaginal orifices. If the Conception and Thrust-

ing Vessels become empty, they cannot consolidate and secure the fetus within the womb. If any of the following three conditions occur singly or in concert, both the Conception and Thrusting Vessels may indeed become Empty: (1) the mother's Yin Essence is depleted or consumed; (2) the Mingmen Fire is insufficient, and (3) both the Yin and Yang Qi are Deficient. Any of these three conditions may be due to: congenital weakness and insufficiency, chronic disease, extreme or prolonged stress, unrestrained sex after conception, or the mother's age (over 40).

2. Blood Deficiency from an irregular diet, excessive worry and anxiety may deplete the Spleen and Stomach organs resulting in a miscarriage. Since the Spleen is the postnatal root for Blood generation and transformation, an Empty or Deficient condition of Spleen Qi may cause Blood Deficiency. Furthermore, as the Spleen Qi restrains and supports the mother's abdomen, a Spleen Qi Deficiency, or Empty Spleen Qi, may lead to the prolapse of the Central Qi and produce insufficient Blood to nourish the fetus. Both the Central Qi prolapse and the Blood Deficiency can present the Conception and Thrusting Vessels from consolidating the fetus and securing it in the womb.
3. Depressed Liver Fire due to suppressed emotional frustration (with mental agitation, anger, jealousy, and envy) may cause a miscarriage. The excessive Heat generated by the depressed Liver Fire may in turn attack the mother's Sea of Blood, scorching and injuring the Thrusting (Chong) Vessel. This injury, in turn, may cause the mother's Yin Blood to flow recklessly downward, leaving no place for the fetus to rest.
4. Blood Stasis may be due to three different factors: past internal injuries, iatrogenic disorders, and long term Qi stagnation. The excessive accumulation of Qi and Blood within the mother's womb during conception can sometimes aggravate a preexisting condition, and thereby cause hemorrhaging, as well as initiate energetic patterns which fails to stop her from bleeding.
5. External Injuries from accidents (sustaining a sprain or strain in the abdominal region), or battery (being hit or struck) can lead the body into a state of shock. This shock to the mother's body may damage either the Conception or Thrusting Vessels, preventing them from securing the fetus within the womb.

TREATMENT

In the Medical Qigong clinics in China, doctors are cautioned to be extremely careful when treating pregnant patients. Qi emission can cause a spontaneous miscarriage if done incorrectly. It is therefore recommended that only Medical Qigong doctors, who have specialized in the specific treatment of pregnant women, be allowed to diagnose and treat them. The interdependencies of the mother's and the fetus' energy circulation is too complex and delicate for a generalized practitioner to handle.

Treatments for miscarriage vary, based on pattern discriminations of Kidney Deficiency, Qi and Blood Deficiency, Blood Heat or physical trauma. An example of an ancient Chinese prescription requires the doctor to treat Yingu Kd-10 for miscarriages with vaginal bleeding, dark urine, abdominal distention, and fullness with an inability to lie down.

If the patient has already experienced a miscarriage, and is in the state of recovery, specific treatments vary according to the doctor's diagnosis concerning the etiology and pathology of the patient's condition.

HOMEWORK AND PRESCRIPTIONS

Each consecutive miscarriage causes further injury to the patient's Kidneys, creating or aggravating the stagnant Blood condition in the uterus. Doctors of Traditional Chinese Medicine therefore encourage their patients to take herbal medicines, and to practice Medical Qigong for six months before attempting to conceive again.

When they do become pregnant again, they are encouraged to continue to practice Medical Qigong meditations and exercises for strengthening and balancing their body's energetic fields and internal organs.

A patient recovering from a miscarriage is given specific prescriptions according to her emotional condition, organ dysfunction, and the etiology of the condition.

UTERINE COMPLICATIONS DUE TO ABORTIONS

Another important aspect of Medical Qigong and gynecology is helping a patient face the loss, or termination of a pregnancy. This can occur either intentionally (through an abortion), or unintentionally through a miscarriage, spontaneous abortion, or the death of a fetus by other causes.

When a woman has undergone an elective abortion, the Qigong doctor must not only consider the potential for scar tissue formation and physical complications within her uterus, but also the energetic and emotional complications resulting from the abortion.

While treating the patient, the doctor may discover within the uterus what appears to be the energetic remains of the aborted embryo. These phantom embryos may in fact be thought forms created by the mother's feelings of guilt and shame at having undergone an abortion. These difficult emotions are further compounded by deeper feelings of self-hate, that go unnoticed by others.

Most people feel little compassion for women who suffer a miscarriage, and discourage them from grieving. They are frequently advised by well meaning friends to believe that the miscarriage was all to the good, preventing a possible deformed or sickly baby from being born.

If women who miscarry are discouraged from grieving, those who make the painful decision to abort often face scorn and disbelief when they grieve their loss. Silently they mourn as best they can, haunted by feelings of shame imposed upon them by others and their own conscience.

Most women struggle long and hard before resorting to abortion. Afterwards, they often obsess about the living embryo, and what it felt like to be pregnant, centering all their attention on the uterus. Such intense, emotional concentration creates phantom embryos that, in fact, take on the form of ghostly embryos. These thought forms or energetic imprints are clearly visible to the doctor's inner vision. The energetic imprint contains the location, exact age and size at the time of the embryo's termination. The unprocessed energetic charge of the embryonic ghost's location creates an energetic vortex. This vortex, in turn, draws emotions such as rage, anger, guilt, and shame into itself. If this area is not purged, the resulting accumulation of negative emotions will develop into cysts, tumors, and possibly cancer.

This energetic reaction to surgical abortions has been confirmed by several Western doctors (all wishing to remain anonymous). These doctors observed that after many years of performing abortions, within a very short time period several patients (whose ages ranged from 16 to the mid 30's) developed reoccurring cysts and tumors. The location of the cysts or tumors in the majority of the patients uteri was at the exact tissue area of the embryo.

HEALING THE ENERGETIC TRAUMA

When the patient has decided to heal from her loss, she must not only address her physical condition (scar tissue formation, etc.), but also heal from the spiritual and emotional woundings as well. To assist the patient to heal emotionally and disperse the energetic charges, the doctor must help the patient transform the energy stored within her Wu Jing Shen, which is responsible for maintaining the toxic energetic pattern. Only after experiencing and releasing the emotions stored within the Wu Jing Shen (see Chapter 13) is the patient ready to heal. The healing process is divided into three distinct steps:

1. The patient is encouraged to completely forgive herself for losing the child and to reconnect with her higher power.
2. The patient is encouraged to completely forgive herself for being in the situation, and assume the responsibility of the pregnancy and the loss.
3. The patient is encouraged to completely forgive the person responsible for making her pregnant.

It is important for the patient to completely feel and experience all three stages of forgiveness in order to begin healing these energetic wounds.

Withholding the smallest bit of guilt or anger will seek to sabotage the healing process, and will also allow the toxic energetic charge to remain within the patient's tissues. Even the smallest bit of anger or guilt that remains will continue to recreate a destructive energetic cycle, storing and retaining the patient's toxic emotions.

RELEASING THE EMBRYO'S ETERNAL SOUL

The purpose and goal of releasing the embryonic thought form is to free the patient from the energetic remnants of the phantom embryo. The patient is encouraged to make peace with herself and with the energetic form of her unborn child, as well as the divine (God or higher spiritual force incorporated in the patient's own belief system). The patient does this through deep, meditative prayer, positive affirmation, and an attitude of honor and respect for the relationship between herself and the embryo's energetic remains. Even though the Eternal Soul does not remain present during the abortion, the mother may still need to atone for her decision not to bring the baby to term. This atonement may be necessary to fully release all feelings of guilt in accordance with the patient's religious belief system.

The patient must also make peace with the embryo's Eternal Soul, by enveloping the phantom embryo in a circle of divine healing light and love, to return it back to the divine. In order to achieve this, it is helpful for the patient to visualize creating a small energetic bubble, full of love and healing light, to house the departed embryo's energetic remains before returning it back to the divine. This serves to complete the emotional closure. Once closure is established, the energy of the embryo's energetic remains will leave her body, allowing the patient to feel a fulfilling sense of release, completion, calmness, and inner-peace.

UNDERSTANDING ENERGETIC ABORTIONS

The gift of life is an incredible miracle. If a difficult decision is made to not keep a pregnancy, however, then the patient should consider contacting the embryo's Eternal Soul. Through prayer, meditation, imagination, and visualization, the mother and father can connect to the developing embryo and request that the embryo's Eternal Soul return back to the light of the divine. Sometimes called an energetic abortion, this energetic transformation can take place within the first developing stages of the mother's pregnancy.

Since the Eternal Soul is ageless, it is possible to carry on a mind to mind conversation. When a baby is born, its brain must have time to develop before it can grasp complex information; the mind itself must have time to direct the brain's growth and the body's maturation. Once the Eternal Soul is freed from the body, however, it is not confined by the physical limitations of the infantile brain and should be spoken to as an equal. This method is used by psychotherapists on the leading edge today, using hypnosis to facilitate the patient's connection to the Eternal Soul through visualization.

Patients who have undergone age regression psychotherapy to the state of conception and embryonic state often describe visiting the mother's womb during the time of conception, then leaving and returning at various times during the embryonic stage of development. The Eternal Soul's residence does not appear to be permanent until the end of the first trimester (see Chapter 2). Until then, the Eternal Soul may come and go as it chooses, staying, at times, just long enough to insure the continued growth and development of its physical body.

It may be for this reason, that talking mind to mind with the embryo's Eternal Soul to request its departure, is often successful in precipitating a miscarriage. As the Eternal Soul leaves the embryo's body (sometimes observed as a small ball of white light energy), all that remains in the mother's womb is an empty, lifeless mass of tissue. Usually the mother's body will naturally abort the lifeless tissue mass, either immediately, or by the next morning.

Chapter 52
Qi Emission Therapy For Neurology (Stroke, Coma, Paralysis, and Multiple Sclerosis)

Introduction

Neurology is a branch of medicine that deals with the nervous system and its diseases, as well as neuropathology. Neuropathology is the study of diseases of the nervous system and the structural and functional changes occurring within them. Neurological diseases are divided into either congenital predispositions that develop over time into full-blown disorders, or those in which acquired destructive pathogenic factors act upon the brain. The latter are usually caused by toxic, traumatic, mechanical, inflammatory factors or neoplastic types of diseases (abnormal tissue formation).

The following is a description of several treatments and prescriptions used in various Qigong clinics and hospitals throughout China. Please be aware that specific treatments will vary according to each patient's constitution and the nature of his or her diseases.

Stroke (Wind-Stroke)

A stroke is a sudden loss of consciousness followed by paralysis, and may be caused by one of several different factors, including a brain hemorrhage, the formation of an embolus or thrombus in an artery, or the rupture of an extracerebral artery causing subarachnoid hemorrhage.

Etiology

Although a stroke occurs suddenly, in actuality, the causal factors build up for several years. A stroke can be caused from high blood pressure, diabetes, high cholesterol, chronic dehydration, overwork, emotional stress, irregular diet, excessive sexual activity and severe migraines. Strokes usually occur at night, or early in the morning (the same is true regarding heart attacks).

There are four pathogenic factors involved in causing stroke. These factors are: Wind, Phlegm, Fire and Stasis. The Liver is dependent on the Kidney Water (Yin Qi) to moisten and soften it. If, however, the Kidney Yin becomes Deficient, this may cause the Liver Yang energy to grow, and to generate Fire. Excess Liver Fire may stir up Internal Wind which causes the Qi and Blood to rebel upwards. Phlegm is then formed, which obstructs the cavities and vessels, causing the patient to lose consciousness. This can further develop into Penetrating Wind (i.e., stroke). Internal Wind may also develop from Heat and Phlegm caused by the patient eating too many sweet and fatty foods (irregular diet), overwork, emotional stress, excessive sexual activity, and inadequate rest.

In the clinic, conditions referred to as stroke (Wind-Stroke) include cerebral hemorrhage, cerebral thrombosis, cerebral embolism, and cerebrovascular spasm. These four conditions are termed in Western Medicine as "Cerebro-Vascular Accident" (CVA), and include: Cerebral Hemorrhage, Cerebral Thrombosis, Cerebral Embolism, and Cerebrovascular Spasm.

1. Cerebral Hemorrhage consists of bleeding, which is caused from a rupture of a sclerosed, or diseased vessel in the brain;
2. Cerebral Thrombosis is an obstruction of a cerebral artery by a thrombus (blood clot);
3. Cerebral Embolism is a condition which occurs when an embolus (bubble of air, or piece of a thrombus) detaches from a thrombus and obstructs a cerebral artery; and
4. Cerebrovascular Spasm (Ischemia) is a condition which occurs when a cerebral vessel temporarily contracts, or constricts, impeding Blood flow. Hence, the oxygen supply is obstructed sufficiently to cause symptoms. When reversible, or when there is no permanent damage, they are known as Transient Ischemic Attacks, or TIA's. The TIA's are pre-stroke symptoms, commonly known as a mini-stroke.

SYMPTOMS

In dealing with stroke patients, it is important to differentiate between the severe type (which attacks the internal organs and channels), the mild type (which attacks only the channels), and the chronic type.

Stroke manifestations can either arise independently from an attack on the channels, or as a result of an attack on the internal organs. After a severe type of stroke, the patient enters into the next stage, clinically manifesting symptoms similar to that of the mild type. The shorter the time lapse before beginning treatment on a stroke patient, the better the chances are for recovery.

THE SEVERE TYPE OF STROKE

In a severe type of Wind-Stroke, the energy attacks the patient's internal organs and channels. It is characterized by a loss of consciousness, aphasia, numbness, paralysis and/or coma. If the right side of the brain is damaged, there will be paralysis on the left side of the patient's body with accompanying memory defects and language difficulties. If the left side of the brain is damaged, there will be paralysis on the right side of the patient's body, speech and language difficulties, slow, cautious movements, and memory problems.

Clinically, severe stroke patients are further classified into two categories: Tense or Flaccid. The Tense type (also referred to as the Closed type) corresponds to the Collapse of Yin. The Flaccid type (also referred to as the Open type) corresponds to the Collapse of Yang. These conditions and symptoms are further described as follows.

1. The Tense Stroke Symptoms include: clenched hands, open eyes, clenched jaw, red face, coarse breathing, and a forceful pulse.
   - **Treatment for Tense Stroke conditions.** Rescue the patient's Yin by giving herbs, as well as extending Qi into the patient's GV-20, -26, Kd-1, Lv-3, St-40, and the 12 Jing-Well points on both hands (Lu-11, LI-1, Ht-9, SI-1, Pc-9, TB-1). The patient should be given homework upon recovering, depending on his or her constitution.
2. The Flaccid Stroke Symptoms include: limp hands, closed eyes, open mouth, weak breathing, and a weak pulse.
   - **Treatment for Flaccid Stroke conditions.** Rescue the patient's Yang by giving herbs, as well as extending Qi into CV-8, CV-6, and CV-4 points, and GV-20 points (with or without the application of Moxa), to increase the patient's Yang. Patient should be given homework upon recovering, depending on his or her constitution.

THE MILD TYPE OF STROKE

In the Mild Type of Wind-Stroke, the energy attacks only the patient's channels. This is characterized by numbness, slurred speech, and unilateral paralysis. Clinically, mild stroke patients are further classified into two categories that are determined by the type of channels that are attacked.

1. An attack of the main channels causes no loss of consciousness or coma; however, there will be unilateral paralysis (hemiplegia), numbness of the limbs and deviation of the eye and mouth. Clinical manifestations vary according to the location of the channels and collaterals that have been affected.
   a. Symptoms of an attack on the channels include: facial paralysis, hemiplegia, motor impairment and numbness of the limbs.
   b. Symptoms of an attack on the collaterals consists of a unilateral numbness of the face and extremities.
2. An attack of the connecting channels is characterized by numbness.
   - **Treatment for mild stroke conditions.** In order to treat a Mild stroke condition combine Medical Qigong therapy with acupuncture therapy and herbs, to:
     a. Remove obstructions from the patient's channels,
     b. Purge Wind and transform Phlegm,
     c. Invigorate the patient's connecting channels,
     d. Regulate the circulation of Qi and Blood in the patient's channels, and
     e. Prescribe homework in accordance with the patient's constitution and condition.

In the acute stage, stroke patients should im-

mediately be treated in combination with Western medicine, utilizing Qigong, acupuncture and herbal therapy. Treatments should be given everyday (usually every six hours) for the first month, and every other day for the second month. The general treatment is aimed at relieving the patient's spasms, and lowering his or her blood pressure (if the condition is due to hypertension). The primary points treated are determined by the type of stroke, which internal organs were affected, and the extent of damage to the patient.

THE CHRONIC TYPE OF STROKE

This condition is characterized by slurred speech or an inability to talk or eat, and involves either a unilateral (hemiplegia) or bilateral (paraplegia) paralysis.

- **Treatment for Chronic Stroke conditions.** In order to treat a chronic stroke condition the Qigong doctor must invigorate the patient's Blood, tonify the Spleen and open the patient's channels. The specific points will vary according to the area and location where the channels are blocked. The most commonly used points include: St-4, St-6, St-7, TB-17, GB-14, LI-4, SI-18, Tai Yang (Temple), and Yin Tang (Third Eye Point).

  If the body is in a state of unilateral paralysis, the doctor also treats the opposite side of the patient's head using Jing Point Scalp Therapy, in order to move stagnation, purge any Excess, and stimulate and fill any Deficiencies.

COMA

A coma is an abnormal, deep stupor occurring during illness, as a result of the illness, or due to an injury.

ETIOLOGY

From a Traditional Chinese Medical perspective, a coma results from Qi obstruction to the brain. More then 50% of coma cases result from trauma to the head, or circulatory accidents in the brain. A coma can be initiated from several different types of conditions.

1. A trauma induced coma is caused by an injury to the head as a result of accidents and internal hemorrhages. Electrocution can also induce a coma.
2. Insufficient Blood flow to the brain can cause a coma. This can result from circulatory accidents within the brain caused from hypertension, arteriosclerosis, thrombosis, and tumors.
3. An overdose of drugs, alcohol or medications, poisoning, gases or fumes such as carbon dioxide or carbon monoxide can all induce a coma.
4. Temperature abnormalities, such as hypothermia or sunstroke can cause vomiting, diarrhea, shock and then coma.
5. Insulin shock, epilepsy, electrolyte abnormalities, endocrine problems, meningitis, uremia or renal problems, and hyperglycemia can all induce a coma.
6. An infection induced coma is caused by an acute infection and bacterial intoxications as in fevers, botulism, and other infectious diseases; or as a result from abscess formations.
7. Psychogenic comas are also known as a hysterical coma.
8. Windstroke comas are caused by tension, hyperactive Liver Yang and Phlegm Fire overheating the brain. This results in urine and stool incontinence, cerebral hemorrhaging, and thrombosis. This is often located at the union of the anterior and posterior cerebral arteries, called the Circle of Willis.

SYMPTOMS

When a patient is in a coma, the Shen is completely out of its residence and the patient cannot be aroused by external stimuli. The patient's Shen is inactive, yet the Hun and Po are still there. For death to occur, it is not enough for the patient's Shen to leave, but the energy of the Hun and Po must also leave.

TREATMENT

In treating coma patients, it is mandatory to use methods that will activate the patient's Qi, remove the Blood stasis, and return the Shen back into the body. In the acute stages of treatment, use Medical Qigong therapy in addition to the Invisible Needle technique (see Chapter 35). It is most important to treat the coma patient as soon as pos-

sible. I have trained with three doctors of Traditional Chinese Medicine who were proficient in coma revival. Below are two accounts of coma revival cases from Dr. Lu Guo Hong's clinic at the Hai Dan Medical Qigong College in Beijing, China.

Case Study #1. Dr. Lu's patient had been in a coma for four hours prior to treatment. The patient regained consciousness within fifteen minutes during the treatment. Dr. Lu treated his patient using the Vibrating Palm technique (on points GV-20, Yin Tang, GV-15, CV-17, Bl-15, Pc- 6, TB- 5, and the extra points Shi Xuan at the tips of the fingers). By squeezing the Shi Xuan points, the Excess Heat was allowed to disperse (Figure 52.1).

Case Study #2. A female patient apparently incurred a series of Transient Ischemic Attacks (TIA) over a period of two years prior to coming to Dr. Lu. As the condition progressed, she developed a thrombosis on the left side of the brain, which paralyzed the right side of her body. The patient then apparently incurred thrombosis of the right side as well.

Because there were thrombosis on both sides of the brain, the patient was expected to die within a month. Dr. Lu, assisted by two other doctors, treated the patient for three days using the Extended Fan Palm technique, Invisible Needles, and Vibrating Palm technique. In this particular case, the doctors used the same points as in the previously mentioned case to cultivate the patient's Yuan Qi, adding points Bl-23, GV-4, CV-4, and CV-8. The patient was treated twice a day for 15 minutes, both morning and evening.

On the fourth day, the patient regained consciousness, and the treatment was continued once a day for a month using the Conception and Governing Vessel circulation points (to move the Qi along the Microcosmic Orbit), in addition to points on the arms including LI-4, LI-11, LI-15, TB-5, and TB-14 points.

When treating the lower limbs, he used GB-30, GB-31, GB-34, Sp-6, Sp-10, and St-41 points. The patient was given prescriptions and homework, specific to her constitution, state of consciousness, and motor control.

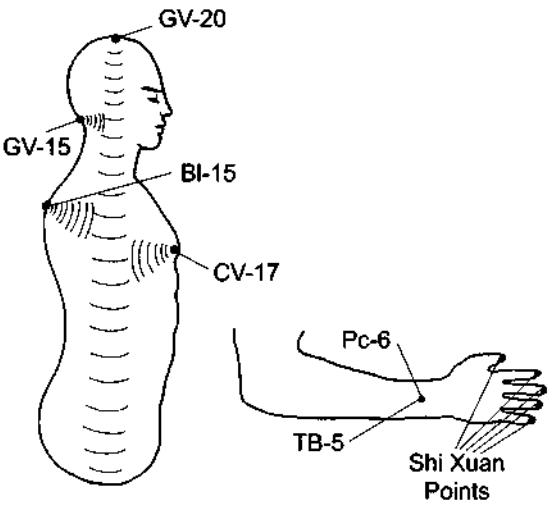

Figure 52.1. Common Points used for Coma Revival

The patient gradually regained movement in her limbs. Once the patient could move her limbs, she was given Dynamic Qigong to increase the flow of energy to her extremities. This included meditations and exercises that used guided imagery to regain muscle cellular memory. After two months, the treatment time was changed to every other month until the patient was fully restored.

FACIAL PARALYSIS (BELLS PALSY)

This condition is known as the sudden onset of unilateral facial paralysis.

ETIOLOGY

The patient experiences the swelling of the seventh facial nerve due to the External Wind and Cold invasion.

SYMPTOMS

The disease is characterized by hemiparalysis of the face which manifests as numbness of the affected area, deviation of the eye and mouth, distorted mouth with the corners tilted on the healthy side, and a half closed eye with dacryorrhea (excess tear flow).

TREATMENT

For this type of paralysis, it is important that the Qigong doctor treat the patient as soon as possible. The shorter the duration time from the ini-

tial onset and the treatment, the more successful the therapy tends to be.

1. Begin by purging the Toxic Qi out from the patient's face and head area, dredging the Toxic Qi down the arm and out the LI-4 point.
2. Using the Extended Fan Palm hand technique, emit Qi into the affected area, guiding the Qi to circulate in the Microcosmic Orbit from the anterior to the posterior of the patient's head.
3. Finally, initiate the Fire Cycle Microcosmic Orbit to regulate the patient's Qi.

TREATMENT MODIFICATIONS

- For treatment of the first stage of paralysis, the doctor is advised to apply gentle Pressing and Kneading techniques to the patient's face before using the Extended Fan Palm hand technique.
- To treat patients whose paralysis has remained in a chronic state, the doctor is advised to use deep pressing and kneading techniques before using the Vibrating Palm technique.

PRESCRIPTIONS AND HOMEWORK

1. Have the patient massage the affected side of the face from the corner of the mouth to the ear and forehead, down over the side of the ear and down the side of the neck 81 times.
2. The patient then focuses on specific areas on the face, circle massaging with the tips of the thumbs for 24 times.
3. Finally, the patient is given the Wash the Face and Massage the Head exercise to perform for 18 times (see Chapter 39).

MULTIPLE-SCLEROSIS (MS)

In Chinese medicine, multiple sclerosis is considered a type of Atrophy Syndrome. It is an inflammatory disease of the central nervous system in which infiltrating lymphocytes (predominantly T cells and macrophages) deteriorate the myelin sheath of nerves. Its pathology consists in the partial destruction of the myelin sheath around the spinal cord, brain and optic nerves.

ETIOLOGY

Multiple sclerosis is suspected to be an autoimmune disease, somehow linked to a viral infection originating from an invasion of External Dampness (especially in the beginning stages). As the External Dampness invades the body it begins to obstruct the channels, causing heaviness, numbness, and tingling in the limbs.

Diet is another contributing factor. The excessive consumption of greasy fried foods, dairy foods, or Cold foods can impair the Spleen, leading to the formation of Dampness.

In the later stages of MS, excessive sexual activity can also be a contributing factor for weakening the body and escalating the disease's progression. Excessive sexual activity can weaken the patient's Kidneys, contributing to such symptoms as dizziness, blurred vision, urgency or hesitation of urination, and extreme weakness of the legs. If excessive Liver Yang develops, symptoms will also include stiffness of the legs, severe vertigo, and vomiting. In the later stages of development, Liver Wind can cause tremors and severe spasms of the patient's legs.

Clinically MS is categorized as either a passive aggressive type of disease, in which episodes of neurologic dysfunctions are followed by times of remission, or a steady progression of neurologic dysfunction.

SYMPTOMS

The symptoms of MS were once thought to develop gradually; however, this is not necessarily true. In about 40% of clinical cases, the onset may occur in less than a few hours. In about one half of the patients, at onset the symptoms include weakness, or numbness in one or more limbs; later, the tendon reflexes become hyperactive.

In young patients the first obvious symptom is often retrobulbar neuritis (inflammation of the nerves behind the eyeball) causing blurred vision. In older patients the most common symptom is weakness of the legs.

Patients may experience vertigo, retrobulbar or optic neuritis, double vision, unstable walking, vomiting, and difficulty urinating. Also included are numbness or tingling of the extremities, as well as periodical electric shocks radiating through the limbs. These symptoms may be due to optic nerve, brain stem, cerebellar and spinal cord involvement.

Traditional Chinese Medicine divides these

symptoms into two categories of clinical manifestations: Damp Phlegm with Spleen Deficiency, and Liver and Kidney Deficiency.

Clinical manifestations in patients with Damp Phlegm and Spleen Deficiency include feeling weak and tired, dizzy, as well as numbness, tingling and feeling of heaviness in the legs.

Clinical manifestations of patients with Liver and Kidney Deficiency include progressive weakness of the back, legs and knees, blurred vision, dizziness, poor memory, and a hesitancy, or an urgency to urinate.

TREATMENT

There are two basic treatment patterns in Medical Qigong for multiple sclerosis. If the treatment is started within its early stages, the symptoms can be completely eliminated, and the progression of the disease indefinitely stopped. This, of course, must be done in conjunction with an alteration in the patient's eating habits (no red meat, processed meat, sugar additives, or high fat diary products). The patient should reduce the amount of sexual activity, get plenty of rest and exercise, and avoid allergy causing agents. Treatments are described as follows.

1. To treat a patient with Damp Phlegm and Spleen Deficiency, first resolve the Dampness by purging the patient's torso and extremities. Next Dredge the Toxic Qi down the legs and out the Sp-9, and Sp-6 points. After purging, emit Qi into the Yellow Court (CV-12) to tonify the Spleen. Finally tonify the patient's Lower Dantian and regulate his or her Microcosmic Orbit (Fire Cycle).
2. To treat a patient with Liver and Kidney Deficiency, first tonify the patient's Kidneys and Liver by emitting Qi into the patient's Mingmen and Lower Dantian. Next emit energy into the patient's Bubbling Spring (Kd-1) points and direct the Qi to flow up the patient's Yin Channels into the patient's Lower Dantian and Kidney area. Finally, regulate the patient's Microcosmic Orbit (Fire Cycle).

PRESCRIPTIONS AND HOMEWORK

Patients often benefit from Medical Qigong exercises such as the Descending the Yang and Ascending the Yin Technique, Walking Therapy, Daoist Five Organ Exercises, as well as Taijiquan (Tai Chi Chuan) practice. One prescription I have found to be very effective in treating MS patients is as follows.

1. Have the patient sit in a chair, feet flat on the ground, hands resting on the knees, anal sphincter closed, tongue touching the upper palate while inhaling and exhaling through the nose.
2. While using natural breathing, the patient focuses on the Lower Dantian to create an energy ball. With each inhalation, divine healing light is absorbed into the body and stored in the Lower Dantian. With each exhalation, this healing light radiates within the Lower Dantian. After several minutes, the patient notices the Lower Dantian becoming full of heat and light.
3. Next, the patient imagines the energy ball in the Lower Dantian leaving the body through the coccyx into the Earth upon exhalation. Upon inhalation, the patient imagines the energy flowing up the center of both legs and filling the Lower Dantian. This meditation should continue for at least 20 to 30 minutes per sitting.

Chapter 53
Qi Emission Therapy for Psychology

Introduction to Energetic Psychology

The object of Chinese psychology is to study and understand the interplay of internal and external events on physical, mental, emotional, energetic and spiritual dimensions of human existence. These interactions include the human qualities and characteristics, as well as the fundamental attributes that exist and evolve within the changing environment and evolutionary development of nature. These interactions at the most fundamental level can be viewed as the transformational interactions of Yin into Yang, and Yang into Yin vibrational energy.

All matter vibrates regardless of its form (gaseous, liquid, solid, or in a transitional state such as ice melting into water). The human body receives these vibrations through the skin, eyes, ears, nose, and mouth, and records them in its cells. The mind interprets these incoming vibrations as images, sounds, smells, and sensations, and organizes these into memories. The extent to which the mind interprets the incoming data, depends upon the level of consciousness and awareness of the individual at the time of the recording. In times of danger, alertness normally increases and consciousness either expands or focuses more sharply until the danger is past; or if an injury occurs consciousness and awareness may be lost (e.g., a car crash).

When a Qigong doctor, attunes his or her vibrations to the patient's energetic field and emits Qi, the body's cells responsible for storing the vibrations are stimulated. The doctor's intention to heal the patient by releasing traumatic memories, combined with his or her projected Qi, often causes the patient to relive the original traumatic experience as the recorded vibrations are released. The Qigong doctor (still in tune with the patient's energy) is receptive to the patient's reaction and is able to interpret the released energy in the form of images, sensations, smells, sounds, and emotions while they are being reexperienced by the patient. If the doctor is sufficiently attuned, he or she may even pick up the conscious thoughts of the patient during this process.

As doctors tune in to their patients' cell emissions they are also able to project their own thoughts and interpretations of these memories back to the patients. This creates a positive feedback system, wherein the doctors' thoughts can influence the patients' thoughts and emotional reactions. Through thought transmission, Qigong doctors are often able to break the vicious cycle of negative thinking that so often leads to disease in the body.

In Western psychology, it is believed that a person's tendency to interpret events - even negative imaginary events (e.g., assigning malicious intentions to peoples' actions), can result in a self-fulfilling prophecy. By assuming and expecting the worst behavior in people, such a person always feels on the defensive and provokes others around him or herself to anger or irritation, thus reinforcing the negative viewpoint.

Chinese energetic medicine adds to this simple behavioral understanding of self-fulfilling prophesies, a new level of comprehension based on energetic interchange between people. When someone observes, or imagines, a specific negative thing happening, certain brain cells record this information in the form of vibrations. These vibrations can be received by another person's corresponding brain cells and projected back to the original sender, reinforcing the negative interpretation of the event(s). If this feedback loop continues - an imaginary wrong may become manifest, i.e., the negative event imagined actually occurs.

It is believed that different cells store differ-

ent types of information, received in the form of vibrations. The silent thought communications between doctors and patients is believed to involve different sets of cells than those used to receive and record emanations of divine energy. These cells interrelate with the patient's emotional changes that are stored and released from the Yin and Yang organs and tissues, and are expressed through the patient's Wu Jing Shen.

The patient's ontology also includes the patient's growth and self-realization in relationship to the Wu Jing Shen (Five Essence Spirits) and the emotions stored within the body's Yin and Yang organs. Each of the Five Yin Organs has a Yin and a Yang aspect within its energetic substance, as well as emotional factors, and dynamic interconnections. The Yin and Yang aspects give rise to the Creative and Controlling Cycles and the Five Yin organs with their associated elements and emotional energies (Figure 53.1 - 53.3).

Summary of the Five Elements		
Wood	Liver	Anger, irritation and rage
Fire	Heart	Joy, happiness, pleasure and excitement
Earth	Spleen	Worry, sympathy, anxiety, contemplation and meditation
Metal	Lungs	Grief, sorrow, anguish, distress and heartache
Water	Kidneys	Fear, terror, panic, horror and fright

Figure 53.1. The Five Elements, Organs and Acquired Emotions

THE EMOTIONAL ENERGY STORED WITHIN THE FIVE YIN ORGANS

Traditional Chinese Medicine classifies the etiology of diseases into Internal and External physical, mental, emotional, energetic, and spiritual influences. In Chinese psychology, the primary focus is placed on the "root" of the energetic/emotional dysfunction. The root of the energetic/emotional dysfunction is often the unprocessed emotions which are stored in their associated organs. Once the patients' mental and emotional symptoms have been alleviated, the energy that was being used to suppress the excessive emotions, is then freed to be focused on their physical healing.

Traditional Chinese Medicine also recognizes the power of thoughts, images (including psychotic delusions and hallucinations), and fantasies to generate and release emotions. Qigong doctors study these images and emotional reactions of attraction or aversion to evaluate their patient's condition. When traumatic memories and emotions are suppressed over a long period of time, or are still fresh in the mind, any minor incident can precipitate a tidal wave of emotions. A rapid influx of thoughts and images sweeps through the mind, too fast for the conscious brain to register. These thoughts and images are of past painful experiences, and are loaded with emotional energy. Getting cut off by someone on the freeway, for example, may cause a momentary reaction of surprise, or an explosive enduring rage, depending upon the condition of the Five Yin Organs. In the latter case, the driver is overwhelmed by the Liver's sudden release of rage, triggered by the traumatic images and emotions from the past.

Clinical pathology is considered an Excess or Deficiency of the emotions at the level of the Five-Elements and their corresponding organs. The Excess or Deficiency of an internal organ can cause a release of thoughts or images that sweep through the patient's mind, bringing a sudden emotional response. In some instances these emotions first affect a specific organ, and then the entire balance of energy, as the first organ's energetic field deteriorates or adversely expands. When emotionally charged Qi is trapped within the tissues of the patient's internal organs, it travels through the channels, affecting the metabolic order of the viscera, glands and nervous system.

Creative Cycle			
Wood	Anger	Creates Joy	Fire
Fire	Joy	Creates Worry	Earth
Earth	Worry	Creates Grief	Metal
Metal	Grief	Creates Fear	Water
Water	Fear	Creates Anger	Wood

Figure 53.2. The Creative Cycle

Controlling Cycle			
Wood	Anger	Controls Worry	Earth
Earth	Worry	Controls Fear	Water
Water	Fear	Controls Joy	Fire
Fire	Joy	Controls Grief	Metal
Metal	Grief	Controls Anger	Wood

Figure 53.3. The Controlling Cycle

Emotions consist of energetic light that is either tempered and softened by the patient's belief structure and energetic fields. When the emotions and life purpose are in harmony, the Wu Jing Shen become focused; the Hun and Po do not disperse, grief and anger do not arise, and the Five Yin Organs effectively combat pathogenic influences. If this energetic light becomes unstable, i.e., too Excessive or Deficient, the patient's inner strength and individual nature begins to undergo dramatic changes.

The body's internal organs and their relationship to the Five Elements are as follows.

Excessive Anger Injures the Liver (Wood)

The Chinese character for anger (Nu) is depicted by the Heart ideograph underneath two characters, a woman (placed on the left) and someone who has the upper hand (placed on the right). It expresses the feeling and frustration of an enslaved woman being dominated by someone.

Pathological Manifestations of Anger

Pathological anger is considered the perverse movement of the element Wood. Anger is a generated force that has the potential to unleash explosive amounts of Qi, pushing the energetic manifestations to the extreme.

The Yin and Yang Aspects of Anger

The emotion of anger can be divided into Yin and Yang tendencies. The Yang type of anger can burst out due to accumulated pressure, resulting in the upward flow of massive amounts of Blood and Qi. The Yin type of anger implodes, remaining buried or held inside, thereby causing internal agitation and dissatisfaction which generates blockages.

The Liver's negative nature is one of being stubborn and rude; its positive nature is one of being compassionate, unselfish, kind, and merciful. The rising of Heat from the Liver's Qi corresponds to the level of anger; since the Liver stores the Blood and the Blood stores the Hun (Ethereal Soul). When the Hun leaves the body due to anger and rage, the animal nature of the Po take over. As the individual's Liver Fire rises, it causes the eyes and the face to become red. Liver Fire can also injure the Liver as well as the Blood, bile and Body Fluids associated with this organ.

Anger Affecting the Liver

When Liver Qi becomes depleted it retracts, causing the emotion of fear to arise. When Liver Qi fills to Excess, the result is progressive restlessness, irritability, anger, and rage. In some instances, these emotions affect the entire balance of energy so that the organ begins to deteriorate.

Anger can cause trembling of the entire body due to the Liver's control of the tendons and ligaments.

When an individual experiences any type of boundary invasion, the Liver Qi triggers the Heart (Shen) to recall from its long term memories past traumas (containing both anger and fear). At the same time, the Liver also drains the Kidney Qi to meet the apparent life-threatening situation; this prepares the body for the flight or fight response. The power of the emotional response causes the Heart to go into shock and prevents the Shen from directing the mind. Thus another trauma is experienced by the patient's interpretation of the event (e.g., getting cut off on the road) and will automatically trigger an exaggerated emotional response in the future.

Given that the Liver is the mother of the Heart (responsible for long term memory) and the child of the Kidneys (responsible for short term memory), the Liver can drain the Kidneys and flood the Heart with anger, causing one's mind to go blank and the face to turn red.

ANGER AFFECTING THE SPLEEN AND STOMACH

Anger can damage the Spleen and Stomach, causing digestive problems, loss of appetite, and a sour taste in the mouth. These symptoms are directly related to the level of anger.

ENERGETIC PATTERN OF ANGER

The Qi pattern of anger has a very hot energy associated with it. When discharged, this hot energy swells up like a tidal wave expanding from behind the person's back over the head (Figure 53.4). It crests over the head and rushes forward like a wild animal attacking. The emotion also travels from the groin up the back of the body and out through the eyes.

Grief controls anger as metal cuts wood. At the root of anger is pain and sorrow. The anger protects the patient from feeling the initial hurt that festers like an infected wound. When the doctor lances the wound, allowing the toxic anger to drain, the uncovered original hurt can heal cleanly. Anger is transformed to sorrow and grief. The compassionate, non-judgmental attitude of the doctor allows the patient to grieve openly. The release of toxic anger and pain enables the patient to listen to the Hun. By focusing on the patient's emotional hurt from past experiences, which are the root of his or her anger, a shift from anger to hurt occurs. This exchange of emotions allows the patient to confront the hurtful past memories and discharge the toxic anger.

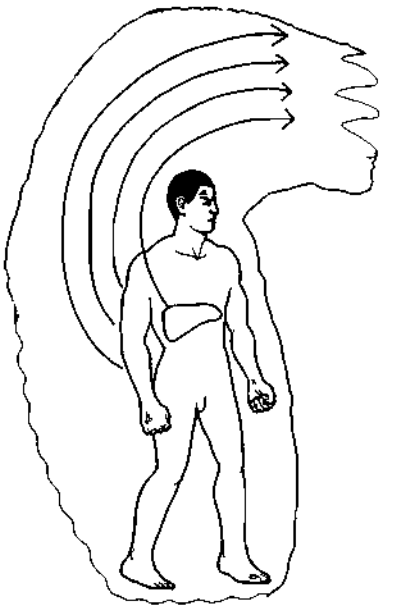

Figure 53.4. Anger rushes from the Liver over the back like a tidal wave, causing the Qi to ascend.

EXCESSIVE JOY INJURES THE HEART (FIRE)

The Chinese character for joy (Le) is depicted by the ideograph of a large drum, framed by bells mounted on a wooden stand. It expresses the feeling of rhythmical ceremonies and excitation. The character gives the image of a hand beating a drum during a festival (this same character is used for music).

THE YIN AND YANG ASPECTS OF JOY

When the Heart's emotions are balanced, they can be experienced as love, joy, happiness, excitement, and pleasure. This warmth radiates through the body affecting the expansion of free and easy Qi circulation. Joy is communicated and felt throughout the body, mind and soul.

PATHOLOGICAL MANIFESTATIONS OF JOY

Excessive joy and laughter can injure the Heart and scatter the spirit; the Qi becomes congested and the Heart flutters erratically. When the Heart Qi becomes depleted, it can no longer control the Lungs: the emotion of grief arises, and when the Qi fills to Excess, hysteria results. Water extinguishes Fire, therefore the emotion of fear controls the emotion of joy. By supporting a hysterical patient to become aware of his or her underlying fears, the doctor can startle the patient into a sense of sobriety.

Pathological joy and laughter are considered the perverse movement of the element Fire. If the patient's Fire becomes uncontrollable, the Qi - which expands outward towards the periphery - will cause the patient to become hysterical. After Fire has exhausted the patient's life-force, it leaves the patient exhausted, dazed, and disenchanted. The Heart's negative nature is confused, doubtful, and greedy; the positive nature is open-minded, loving, non-judgemental, and trustful.

ENERGETIC PATTERN OF JOY

Joyful feelings make the body's Qi become soft and relaxed. This energetic pattern is expansive, and causes a slower movement of the Qi. As the Heart controls the blood vessels and stores the Shen, a joyful spirit produces a clear, calm mind and a healthy body. This energy bubbles out from the center core of the body and ripples out in all directions (Figure 53.5). A light energy gently flows from the recipient back to the person expressing the emotion. While in this state, the patient's head is usually held erect, the face is full of color, and the limbs are relaxed.

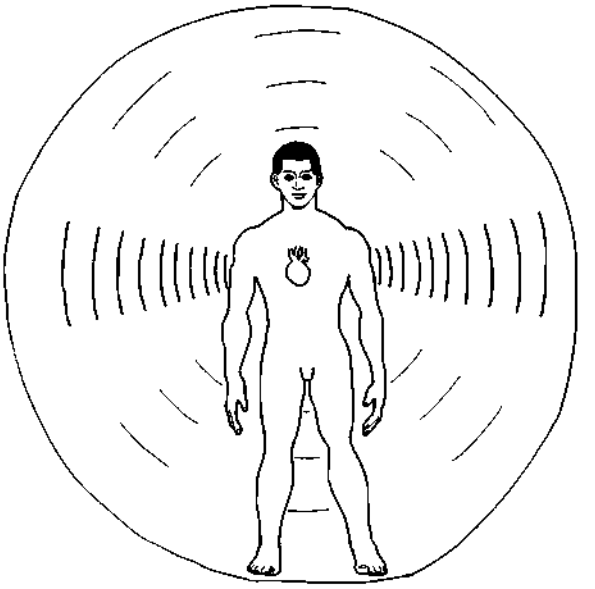

Figure 53.5. Joy bubbles out from the center core of the body, rippling out in all directions, causing the Qi to slow its flow.

EXCESSIVE WORRY INJURES THE SPLEEN (EARTH)

When the Spleen Qi becomes depleted, all four limbs lose their strength and the Five Yin Organs become unstable. When the Spleen Qi becomes Excessive, the body becomes swollen and the flow of urine and menses loses its smoothness.

THE YIN AND YANG ASPECTS OF WORRY

The emotions associated with the Spleen are relative to the energy expended in contemplation, meditation, anticipation, and worry. Too much worry and thought produces Qi stagnation. A stagnant condition causes Stomach disorders, such as poor appetite, indigestion, ulcers, constipation, or diarrhea. Stagnation can also block the Shen, which is responsible for emotional and mental balance, and thus result in a lack of common sense. The Spleen's negative nature is suspicious and self-centered; the positive nature is truthful, sincere, and compromising.

WORRY AFFECTING THE MEMORY

The Spleen stores the Yi, and the Yi stores ideas. The Spleen transfers short term memory to the Kidneys; the Kidneys later transfers the acquired memory to the Heart, which is responsible for long term memory. In trauma victims, the Kidneys' role in transferring memories, can also account for the loss of memories that are too terrible to accept, since these memories are transferred along with great fear, or fail to get transferred at all.

THE ENERGETIC PATTERN OF WORRY

When one is worried, the energy comes up from the Earth and congests in the Middle Dantian area, thus weakening the Wei Qi (Figure 53.6).

CONTROLLING THE EMOTION OF WORRY

Because the element Wood controls the element Earth, the emotion of anger controls worry. It is very important that any anger uncovered be directed at the root cause, and not at the doctor who is trying to help a patient end a negative pattern. The doctor will gently challenge toxic belief structures held by the patient, until the patient begins to confront whatever issue is at the root of the anger.

When the patient becomes angry with the doctor, it is generally a condition known as "transference." If and when transference arises, the Qigong doctor can ask the patient, "Who do I remind you of right now?" or "When was the last time you felt this way?" Trace the patient's feelings as far back as possible. If the doctor gets mad at the patient, it is called "countertransference." Both transference and countertransference can involve any emotion (e.g., falling in love, feeling afraid, etc.).

EXCESSIVE SADNESS AND GRIEF INJURES THE LUNGS (METAL)

The Chinese character for sadness (Bei) is depicted by the Heart ideograph underneath the character for the back (placed on the top). It portrays a picture of a person who has turned his or her back on the true feelings of the Heart. The Chinese character for grief (Ai) is depicted by the mouth ideograph (wailing, groaning, and lamenting) placed within the center of the character of someone dressed in a special garment for mourning. Pathological grief is considered the perverse movement of the element Metal.

When grief is experienced, its natural movement of condensation begins to compress the Heart, interfering with Blood circulation. This obstruction destroys both the respiratory flow of the Lungs, as well as the body's liquids. The Lungs store the Qi, the Qi stores the Po (Corporeal Soul). When the Lung Qi becomes depleted, shortness of breath develops. When the Lung Qi becomes excessive, the result is a feeling of discomfort in the chest, panting, and difficult breathing.

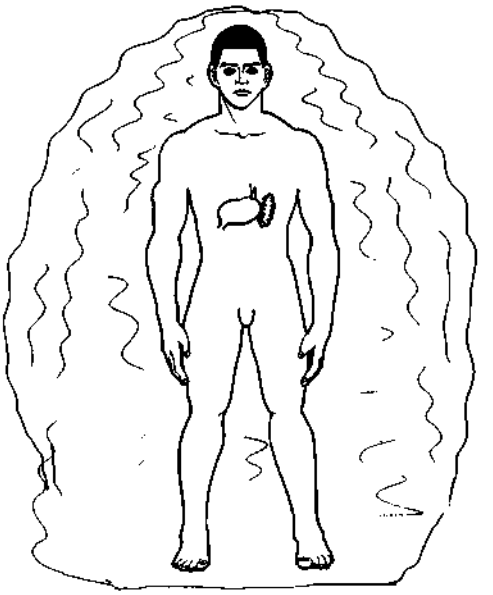

Figure 53.6. Worry binds the Qi, causing the Qi to stagnate.

THE YIN AND YANG ASPECTS OF GRIEF

The feelings associated with the Lungs are sadness, melancholy, grief, sorrow, and anxiety. The negative nature is cunning, jealousy, and pessimism; the positive nature is generosity and righteousness. In the Five Elemental Controlling Cycle, the Lungs (Metal) affect the Liver (Wood). Excessive sadness from the Lungs can cause the Liver Qi to stagnate the Blood (Metal Overcontrolling Wood), leading to possible intercostal and hypochondriac pain, bloating, and depression.

GRIEF'S AFFECT ON THE INTERNAL ORGANS

Grief disperses the Qi, and thus injures the Lungs. Crying can lead to the release of toxic anger (that suppresses the feelings of sorrow) and grief. Depression and despair may also be manifestations of abnormal Liver Qi stagnation. When grief from the Lungs is excessive, the Spleen may be affected (this almost always happens after a major loss, such as a death in the family).

THE ENERGETIC PATTERN OF GRIEF

The external energetic patterns of grief and sorrow have a heavy, downward moving energy (Figure 53.7). The internal energetic patterns and manifestations of grief have a very thick, sticky energy, and a denseness like gelatin. Long periods of extreme grief also injure the Heart, Pericardium, and the Triple Burner Channels.

CONTROLLING THE EMOTION OF GRIEF

Because Fire melts Metal, the emotion of joy controls grief. The grieving process is a very important part of healing; however, chronic grief can be extremely detrimental, and when it is extreme and prolonged it can lead to spiritual oppression or possession. If the survivor cannot accept the death, he or she may prevent the departure of the loved one's spirit for many years on end. The patient may beg the Eternal Soul not to leave and cling with unrelenting grief to the lost one's energy. This type of dependency deepens, rather than lessens over time, as the patient opens more to receive the loved one's spiritual essence. In so doing, other Gui (spirits) are given power to enter as well.

After a death of someone loved, the patient may consciously suppress any joy or pleasure. The patient may believe that to allow any relief to suffering is tantamount to a betrayal of the deceased. This belief structure must be addressed by the doctor and patient. Establishing a sense of empathy with the patient will provide a safe environment for the patient to release the emotion of grief. The doctor can work towards empowering the patient to begin to recognize times of joy, and learn, or remember, how to count his or her blessings, to let go of sadness and grief, and reclaim lost joy.

Grief may give way to despair and anxiety. Because anxiety suppresses respiration, anxiety lowers the body's resistance to pathogenic factors by weakening the Wei Qi; anxiety also damages the Large Intestine, resulting in symptoms that range from constipation to ulcerative colitis.

Just as too much grief can cause inappropriate laughter, or gallows humor; too much laughter masks the accumulated and suppressed grief. Gallows humor is a syndrome whereby the patient laughs instead of grieving about hurtful past,

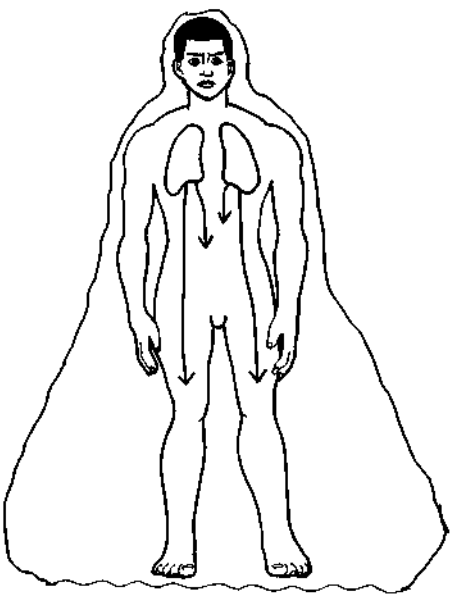

Figure 53.7. Grief causes the Qi to become obstructed.

or current experiences. Gallows humor is a defence mechanism of the patient's denial. Grief and humor are examples of opposites (Yin and Yang) transforming into each other.

The concern in dealing with many grieving people (pertaining to the death of a patient's mate or close friend, etc.) is that the patient may be using grief to suppress other unresolved emotions, such as: guilt, fear and loneliness.

1. Fear of forgetting the deceased voice, appearance, etc. may be due to feelings of guilt over not having expressed enough love towards the person when it was possible to do so.
2. Guilt over any expressed feelings of joy or happiness, may seem morally wrong because they cannot be shared by the departed.
3. Guilt may arise from too many hurtful things said, or too many things left unsaid to the departed.
4. Guilt over never having had the chance to really say good-bye (as with victims of accidents and sudden death) may become all consuming.
5. Loneliness and isolation may result from the loss of friendships.

6. Worry that loss of income and security may cause financial difficulties and health problems may cause the patient to cling to the past.

To assist the patient to heal from these toxic beliefs, the doctor prescribes creative visualizations, such as the following.

"Imagine, see and feel yourself and your loved one clothed in your astral bodies. Embrace and express your feelings and thoughts, knowing that these will be heard and received. Listen to your loved one's answer.

Ask forgiveness for any cruel remarks or failures to be as loving as you wish you could have been. Visualize your loved one accepting the request for forgiveness; embrace with love, and release him/her to be with God with your blessings."

In cases where the patients could not attend the funeral, have the patient imagine the funeral and perform a ritual closure (e.g., lighting a candle at home and saying a prayer).

Finally, encourage the patient to give him or herself permission to experience some joy in life and to go on living.

EXCESSIVE FEAR INJURES THE KIDNEYS (WATER)

The Chinese character for fear (Kong) is depicted by the Heart ideograph underneath two characters, a structure (placed on the left) and repeated strokes by the small blows of a hammer (placed on the right).

THE AFFECT OF FEAR ON THE INTERNAL ORGANS

The Kidneys store the Jing, the Jing stores the Zhi (actions that the mind expresses). Pathological fear is considered the perverse movement of the element Water. Fear is the unrestrained sinking and uncontrolled descent of Water Qi. When the Shen of the Heart is no longer supported by the Kidneys' Jing, the Shen leaves its residence. This results in the emotional release of panic. If the Heart Fire becomes weak, the Kidney Water rapidly draws downward and freezes. Insecurity, hesitation, immobility, and paralysis ensue. If the Heart Fire become Deficient, it cannot radiate warmth, causing the patient to crouch and hide.

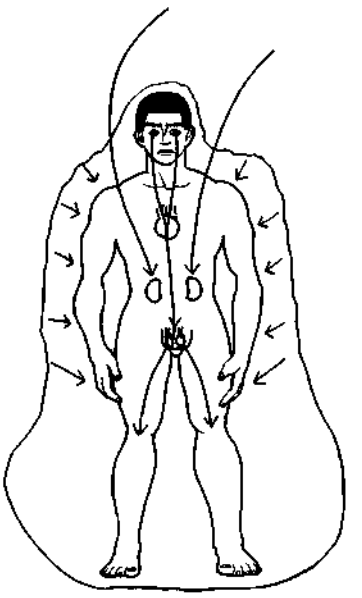

Figure 53.8. Fear causes the Qi to move inward and downward.

If the Kidney Yin is Deficient, the vision deteriorates, there is a ringing in the ears, dizziness, night sweats, and nocturnal emissions. If the Kidney Yang is Deficient, the Mingmen Fire becomes Deficient, and causes a counter-flow of energy affecting the hearing. Kidney Yang Deficiency also results in shortness of breath, cold limbs, and impotency. When the Kidney Qi becomes Excessive, swelling occurs and the Five Yin Organs become unstable. The feelings associated with the Kidneys are fear, paranoia, and panic.

THE YIN AND YANG ASPECTS OF THE KIDNEYS

The Kidneys' negative nature is arrogant, troublesome, and ignorant; the positive nature is peaceful, soft, and tender. Fear can cause loss of Bladder control, weakening of the knees, renal failure, and permanent damage to the Kidneys. It can injure the Heart, affecting the speech, eyes, and the Shen.

When fear injures the Kidneys, this can affect the Liver, causing muscle spasms, trembling, and disruption of the menses cycle. When the Gall Blad-

der is affected, decision-making becomes more difficult.

THE ENERGETIC PATTERN OF FEAR

The energetic pattern of fear is very cold and implodes into the center of the body, drawing all the energies inward and downward. Fear travels from the eyes down the front of the body into the groin (Figure 53.8).

Because Earth absorbs Water, contemplation controls fear. Therefore, the doctor can help the patient control the fear through visualization and meditation. The purpose of the visualization is to resolve and reprogram the patient's thinking patterns.

THE EMOTION OF FRIGHT

The emotion of fright is distinguishable from fear by the sudden, unexpected shock to the system. The Chinese character for fright (Ju) is depicted by the ideograph of a small bird opening its frightened eyes, in fear, anxiety, and dread. Fright startles the Shen, which then scatters the Qi and injures the Heart. Persistent fright causes damage to the Kidney Qi and results in a negative cycle of chronic fear.

FIVE YIN ORGAN EMOTIONAL RESPONSES

The common ingredient in any emotional dysfunction is the power element maintaining it. Holding on to original traumas, whether consciously or unconsciously, requires a great deal of energy. It is possible to stop this negative pattern by releasing the toxic emotional energy, thereby creating the opportunity for the mind, body, and spirit to heal. A new pattern of harmonious balance can be maintained, however, only after the old dysfunctional patterns are consciously recognized during their occurrence. Old habits die hard; new patterns require time and continuous effort before becoming as automatic as the previous dysfunctional habits. Every emotion is meant to serve a positive function, even anger, fear, and grief. Patients often require reminding of this fact. Every emotion also has its darker side when repressed for too long and when avoided at all costs.

1. Learning how and when to express anger is as important as not holding on to it for extended periods of time. Anger serves as a warning sign that personal boundaries are being violated, threatened, wounded, or that injustices are being committed. Patients must be taught better communication skills so they need not resort to screaming or insulting others to protect themselves. Appropriate assertiveness skills must be learned, and may require either psychotherapy, or classes in assertiveness training. Patients must also learn how to ask for what they need and desire, without expecting those close to them to mind read. Without learning how to set appropriate boundaries, without the ability to say "no" to those who take advantage of them, they will fall into the old habit of accumulating resentments; or they will alienate their employer, friends, and family through unguarded candor when angry.
   - On its negative side, anger can cause rage and destructive patterns (both internally and externally).
   - On its positive side, anger can cause constructive boundary setting and the righting of wrongs.
2. Fear, like anger, serves as a warning sign. Fear informs patients when they are in danger, so that appropriate measures can be taken to insure safety and survival. Some patients do not recognize the danger signals until it is too late to avoid falling victim to unscrupulous people. Some may require counseling and instruction in how to establish healthy relationships, and in how to identify individuals who are potential abusers before it becomes too late to avoid the ensuing violence.
   - On its negative side, fear can cause disabling panic.
   - On its positive side, fear can cause an awareness of the need for self-protection.
3. Joy in excess can lead to disharmony. Nervous laughter, or always playing the clown to gain acceptance, can be extremely difficult to unlearn. Often professional help is needed to increase socialization skills and self-esteem.

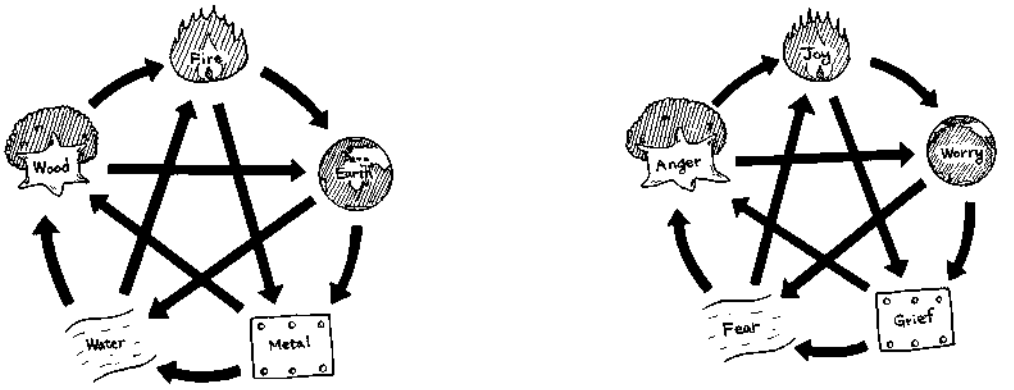

Figure 53.9. The Five Element Cycles

- On its negative side, joy can cause hysteria.
- On its positive side, joy can be a source of happiness to the spirit.

4. Sorrow is necessary at times to motivate patients to change. The old self must periodically die to make room for new experiences and learning. Risking sorrow is part of the process of bonding and maturing. Sadness is often a signal of imbalance in the patient's life, indicating insufficient rest or recreation, and far too much work.
   - On its negative side, sorrow can cause self-pity, rather than compassion for oneself.
   - On its positive side, sorrow can release distress.
5. Worry and anxiety are normal reactions to change. When these emotions become pathological in intensity of duration, patients may need professional help in the form of medication (e.g., for obsessive compulsive disorders), and/or psychotherapy (e.g., in the case of generalized anxiety disorder and posttraumatic stress disorder).
   - On its negative side, worry can cause great anxiety.
   - On its positive side, worry can be a motivating source for change.

The healing stages used in Medical Qigong Therapy employ these transitions in order to assist the patient's emotional and spiritual growth.

The picture in Figure 53.9 summarizes the Five Elements, their associated organs, and their associated emotions.

The cycles serve a functional importance for emotional transitions. The elements can be arranged in a number of ways. For clinical purposes, the main emphasis is on the Creative and Controlling Cycles.

EMOTIONAL DISHARMONY

It is becoming more common in the Western belief system that if a patient concentrates his or her mind and emotions on healing the illness, they can accelerate the recovery. Some Western research suggests that when the patient stops thinking and trains the mind to relax (reaching an alpha state), the healing is accelerated.

Emotional disharmony can resonate and penetrate one's entire being, thereby creating a vicious

Major Organ Disharmony	→	Emotional Disharmony
↑		↓
Environmental Disharmony	←	Disturbed Behavior

Figure 53.10. The Cycle of Emotional Disharmony

circle affecting the body, mind, emotion, energy, and spirit. As evidenced by the diagram (Figure 53.10), any disharmony in one of these four factors can trigger the cycle.

This vicious circle can be set in motion by any major disharmony, be it environmental, physical, emotional, or behavioral. Once in motion the disease can feed on itself. The power of emotional energy generated can at times overwhelm the conscious mind. The mind then has three options: to give in to the emotional tidal wave, to become eventually paralyzed through the effort of controlling it, or simply to deny that anything is wrong.

When emotional energy is suppressed it accumulates within the body, causing the Qi to flow incorrectly or to condense. The unresolved emotions cause chronic blocks in the body, particularly in the back, neck, Stomach, and intestinal areas. This toxic energy stored in the muscles and organs leads to tension, stress, and illness. The root cause of chronically tense shoulder muscles, for example, can be traced to: tensing the muscles to suppress the emotion(s), a strong negative belief system, and an accumulation of unresolved past traumatic memories, which continue to resurface.

Unless the initial cause of tension is released, the tissue memory associated with the initial trauma will repeat its programmed pattern, resulting in chronic tension and pain. Painful and negative emotions are not the only emotions suppressed. Many people also suppress feelings of joy and love. Most do so out of fear, guilt, and sense of unworthiness. Some do so out of religious beliefs, believing that suffering is good for the soul, or that the are being punished by God for sins of omission and/or commission to test their faith.

All emotions are triggered by sensory associations with pleasant and unpleasant past memories. In many cases patients are completely unaware of the triggering smell, image, sensation, or sound. To them it seems that the trauma, or memory, resurfaces from nowhere. This inability to pinpoint the trigger mechanism may indicate the progression of the patient's illness. Patients suffering from panic attacks, for example, have no idea what stimulus may have caused the overwhelming terror that they feel. Quite often panic attacks increase in frequency, partly out of the anticipatory fears of having another one, and partly due to their fear spreading and generalizing.

The first panic attack may have taken place in a restaurant, triggered by one of the five senses registering similar data (a smell or image for instance) which occurred during one of their traumatic memories. Henceforth they will avoid this restaurant, or perhaps all restaurants because new data has been added to the original trigger mechanism. New smells and images occurring during the attack may now stimulate the old memory of the trauma. Eventually, such patients may become home bound as they try to limit themselves to only safe places; their panic attacks have generalized to agoraphobia (fear of places or situations from which escape might be difficult or embarrassing). Each panic attack requires more energy to suppress both the original trauma and all of the new traumas added to it from surfacing.

Outgoing, successful people can thus transform themselves into anxiety ridden hermits. They can also develop physical symptoms, or turn to alcohol and drugs in attempts to cope. In less extreme mental/emotional diseases, changes in skin colors, tone of voice, mannerisms, and nervous twitches may manifest. As the mind tries to suppress uncomfortable emotions, these unresolved feelings often manifest as physical symptoms.

At times, however, the symptoms manifest more on the mental level, as in obsessive compulsive disorder. The logical mind, failing to completely suppress the emotion, may develop frantic obsessive thinking patterns, that seem to take on a life of their own. Some patients may obsess about dying, even if they seem by Western medical standards to be physically completely healthy; or they may obsess about killing their own child, or forgetting to lock all the doors when leaving the house and so on. They have no control over their repeating thoughts, and are aware of the unrealistic and unreasonable nature of these obses-

sions. Nevertheless, they are helpless to stop themselves.

Obsessions often manifest with compulsive addictions such as washing the hands so often during the day that they are raw and bleeding, or pulling out the hair on their head, or folding and unfolding their clothing. Any ordinary daily activity may turn into a compulsion, requiring the patients to continue performing a meaningless action again and again.

Another frequent disease found in traumatized patients goes by the name of posttraumatic stress disorder. Patients suffering from this condition have flash backs, i.e., they can not stop having moments of releasing the original traumas again and again with full intensity.

In posttraumatic stress disorder patients' symptoms are often disabling. Anxiety is chronic, they are in a state of hyper-alertness. They have become good at disassociating from their body, since it has become a very uncomfortable place to be. The Shen wanders and the patients may, or may not, be aware of where their spirit goes or what it experiences at these times. In extreme cases the ego fractures, usually during early childhood, and a full blown identity disorder (previously called multiple personality disorder) ensues.

Patients suffering from obsessive compulsive disorders, posttraumatic stress disorder, agoraphobia and panic attacks, or identity disorders should be referred out for extra help to a mental health professional specializing in these disorders.

Ideally, the doctor can teach and encourage the patient to get in touch with their body, and learn how to achieve and maintain a balance between the physical, mental and emotional planes. The doctor can also teach the patients how to transition detrimental energy into a higher level of consciousness, when the patients become aware of an unpleasant emotion. When patients learn how to channel their own energy in a more healthy way, the cycle of reliving the past can be broken. A negative emotion can be transmuted and expressed as a positive emotion; emotional energy can be converted to positive life-force energy.

EMOTIONAL FREQUENCY RESONATION

When the Qigong doctors are appropriately sensitive to the patients' emotional transitions, they are able to detect, and recognize, recurring energetic patterns. These energetic patterns are in constant resonation throughout the body's tissues. As patients shift their emotional thinking, their energetic frequency resonation (the body's Hz rhythm) shifts. These different emotions establish specific patterns of energy in the body. Each individual has a brain wave pattern that is as unique as their fingerprints. According to Richard Lee, director of the China Healthway's Institute, individuals resonate at different frequencies depending on their state of consciousness. Mr. Lee's research reveals the following.

1. Those motivated by fear and instinct will resonate at the delta wavelength, between 0 and 4 Hz (hertz, i.e., cycles per second). This level of energetic resonation, as measured by an electroencephalograph (EEG), is normal in an awake infant and a sleeping adult. This delta wavelength, however, indicates brain pathology in adults that are awake.
2. Those motivated by attachment and desire will resonate at the theta wavelength, between 4 - 7 Hz. This level of energetic resonation is generally common in children and in adults in the early stages of sleep. This frequency range also occurs when an individual creates mental imagery, and often manifests when a person is involved in deep altered states of consciousness. This level of energetic resonation also occurs in many brain disorders.
3. Those motivated by service and compassion will resonate at the alpha wavelength, between 8 and 13 Hz. These low amplitude alpha waves usually occur when the brain is in a calm, and the mind is relaxed (in a state of wakefulness). It was discovered that Qigong masters emit energy within this frequency range.
4. Those motivated by organization and planning will resonate at the beta wavelength, between 14 and 25 Hz. This level of energetic

resonation usually occurs when the nervous system is active and the body is awake. It manifests during sensory input and mental activity. This frequency range is usually common for those suffering from nervous overload and excessive thinking.

When the patients' vibratory rate shifts towards the alpha rhythm, they begin to experience deep relaxation and clarity of mind. Relief from chronic pain and symptoms associated with low energy is achieved.

According to Richard Lee, the infrasonic sound produced by Qigong masters is effective because it causes decreased resonation in the theta and beta ranges. This simultaneously decreases attachments and desires, calms the emotions, and reduces excess thinking, thereby freeing the patient's vital sources to be redirected towards healing.

DIFFERENTIATION OF PSYCHO-EMOTIONAL DISORDERS

Traditional Chinese Medicine has, for centuries, recognized the fact that psycho-emotional states, energy, and physical health are intertwined. In the Huang Di Nei Jing, the emperor's medical adviser, Qi Po, outlined the Internal Factors (emotions) as primary causes of disease.

Within the context of Traditional Chinese Medicine, Medical Qigong therapy is useful for treating many types of psycho-emotional disorders. Qi emission therapy can be used to calm the patients' Shen, as well as accelerate the patients' recovery time. In China, psycho-emotional problems are commonly called Jing Shen disorders and are differentiated as follows: Obstructed Shen, Unsettled Shen, and Weakened Shen.

1. Obstructed Shen is a condition due to the Shen becoming obstructed with Phlegm, or in mild cases, becoming obstructed by Qi or Blood. Symptoms are characterized by confused thinking, clouding of the mind, and in severe cases, complete loss of touch with reality. Degrees of severity range from very mild disorders to severe schizophrenia or mania.
2. Unsettled Shen is a condition due to the Shen becoming unsettled from Blood or Yin Deficiency (in mild cases), Qi stagnation, Blood Stasis, Fire, Empty Heat, Phlegm Fire, or Internal Wind. Symptoms are characterized by agitation, restlessness, and anxiety.
3. Weakened Shen is a condition due to Deficiency of Qi, Yang, Blood, or Yin. Symptoms are characterized by depression, mental exhaustion, and melancholy (dysthymia).

ETIOLOGY

The cause for psycho-emotional disorders can range from a variety of factors, including prenatal or postnatal constitutional imbalance, diet, unbalanced sexual activity, overwork, alcohol or drug abuse, trauma, stress, emotional immaturity, and instability, as well as a lack of love or spiritual perspective.

TREATMENT PRINCIPLES

There is a considerable degree of overlap among Jing Shen disorder symptoms. Therefore, the treatment principle must be based on a clear distinction between Excess and Deficiency, as well as the cause (root) and manifestation (branch) of the symptoms. The main treatment principles are as follows:

1. Nourish the Heart and calm the Shen to treat Shen weakness due to Qi, Yin, Yang, Blood, or Body Fluids Deficiency.
2. Purge the Excess, move stagnation, and calm the Shen to treat Shen obstruction or Shen agitation (unsettled Shen) due to Excess conditions of Qi, Blood, Phlegm, and/or Fire stagnation.
3. Purge the Excess, nourish the Heart and calm the Shen to treat Shen obstruction due to Yin Deficiency with Empty Heat.
4. Resolve the Phlegm, open the Heart's orifices, and calm the Shen to treat Shen obstruction due to Phlegm or Phlegm Fire.
5. Sink and calm the Shen to treat unsettled Shen due to rising Qi.

The term "calm the Shen" is used to describe the treatment principles in all psycho-emotional disorders. It should be understood to mean not only calming the mind, as in anxiety, but also lifting the patient's mood (as in depression), or clearing the mind (as in schizophrenia or mania).

SELF-TREATMENT PRESCRIPTIONS FOR PSYCHO-EMOTIONAL DISORDERS

Most meditations are difficult for patients with psycho-emotional disorders due to several factors. One factor is the problem of maintaining focused attention, as well as retaining the memory of specific medical Qigong prescriptions. The success, or failure of the treatment will also depend on the severity of the disorder.

POINT MEDITATION FOR EMOTIONAL TRAUMA

In China, Channel Point meditation is used in conjunction with the Massage Tapping method for treating patients with conditions such as anxieties, phobias, and addictions. In acupuncture, 135 of the original 365 acupuncture points are used to treat mental, emotional, energetic, and spiritual disharmonies. In fact, many of the "new" points can be applied for the treatment of Jing Shen disorders.

The cause of fear and anxiety is the disruption to the body's energy system from emotional trauma. When a patient is focusing on a particular anxiety or fear, the Shen becomes disrupted, and the energetic harmony of the body becomes unbalanced. This energetic imbalance causes certain physical reactions within the patient (abnormal breathing, pulse, etc.), and results in pathological behaviors.

TREATING EMOTIONAL ANXIETIES, PHOBIAS, AND ADDICTIONS

To treat anxieties, phobias, and addictions, the doctor encourages the patient to focus attention on the specific fears, or cravings for the particular addiction, to initiate a maximum emotional charge of distress. When the patient reaches maximum emotional distress, the doctor calls out specific channel points for the patient to tap.

The patient is given a specific mantra to repeat while tapping, to discharge the accumulated emotionally charged Qi, such as; "I accept this fear (or other emotion or craving)" or "I am being healed." The treatment continues for five to ten minutes, as the patient focuses on feeling the distress as much as possible, until all the trapped emotion has been discharged. Some energetic points commonly chosen for treating emotional anxieties, phobias, and addictions are GV-26, Ht-7, and Pc-6. These specific points are used to draw the energetic charge away from the Heart and into the extremities; this action facilitates calming the patient's Shen.

The initial tapping method, in conjunction with vivid imagination and positive affirmation, disperses the energy away from the Heart and other organs and calms the Shen. The spontaneous dispersing of the emotional charge, stored within the patient's tissues, releases all feelings of stress and anxiety. This type of guided Tapping Meditation therapy not only reduces and disperses the patient's emotional trauma, but also causes an energetic reprogramming within the patient's psychophysical dynamics.

MEDICAL QIGONG TREATMENT OF THE PHOBIA AND ANXIETY OF DEMON POSSESSION

These specific treatments are used in China to treat specific mental, and emotional disorders, that lead the patient to imagine that they are being haunted by spirit demons. In rectifying this type of psycho-emotional disorder, it is recommended that the Qigong doctor proceed as follows.

1. Perform Channel Point therapy to open the energetic points of the Eight Extraordinary Vessels (Figure 53.11).
2. Press and knead the Baihui GV-20, Dazhui GV-14, Lingtai GV-10, and Feishu Bl-13 points. Then apply the Extended Fan Palm or Sword Fingers method (see Chapter 33), using the Pulling and Shaking manipulations (see Chapter 34) to emit and conduct Qi along the Governing Vessel.
3. Press and knead the following channel points Baihui GV-20, Yintang (Ex.Pt.), Renzhong GV-26, Tinggong SI-19, Jiachè St-6, Quchi LI-11, Hegu LI-4, Weizhong Bl-40, and Chengshan Bl-57 points.
4. Apply the Sword Finger technique, using the Vibrating and Shaking manipulations to emit Qi into the Jiuwei CV-15 and Zhongwan CV-12 points and conduct Qi along the Conception Vessel to return it to the Lower Dantian.

MEDICAL QIGONG TREATMENT FOR SPECIFIC SPIRIT/GHOST HALLUCINATIONS

These specific treatments are also used in

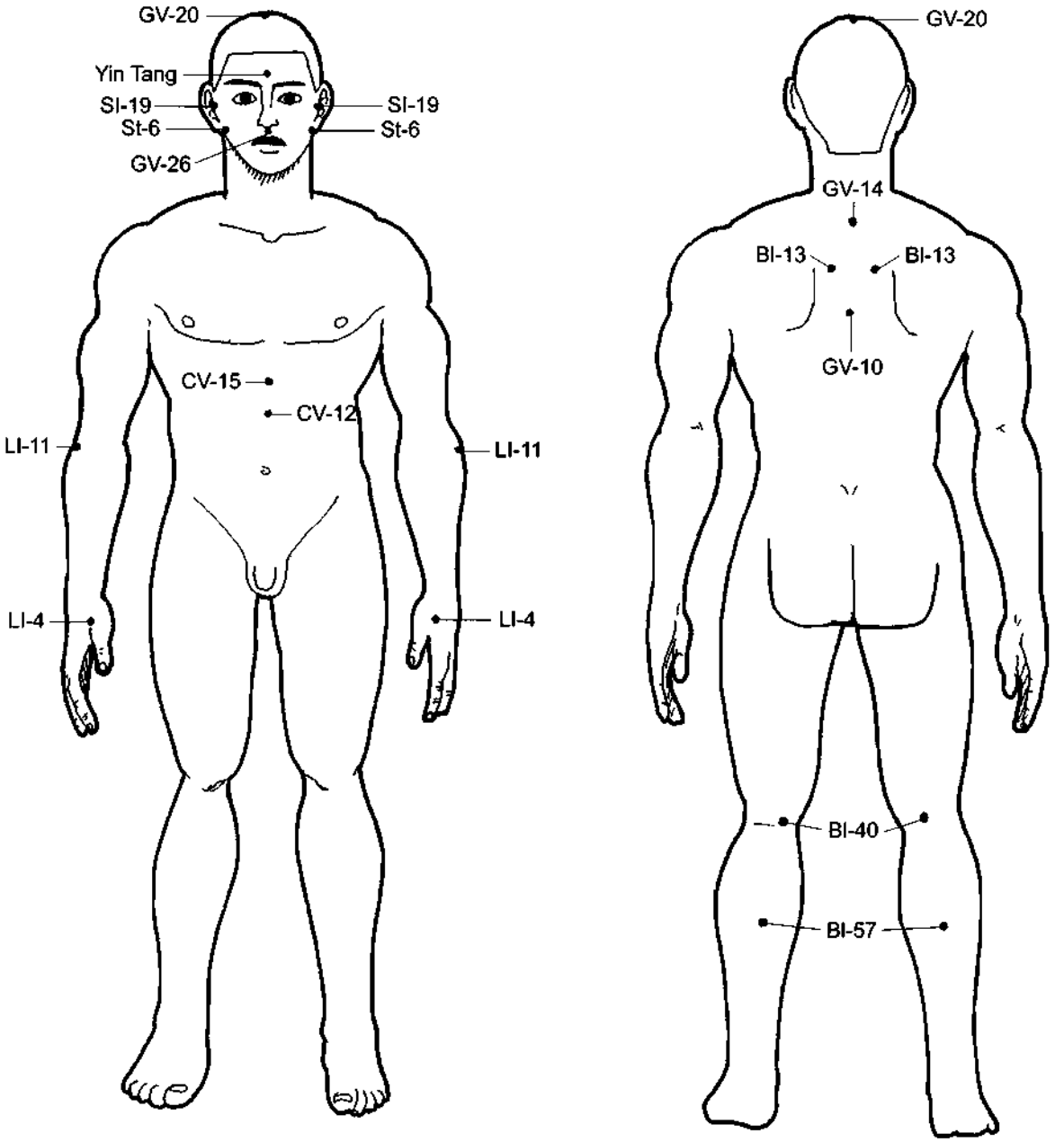

Figure 53.11. Medical Qigong Channel Point Therapy for the Treatment of Energetic Delusions

China to treat specific mental and emotional disorders that lead the patient to see spirit/ghost hallucinations. The Qigong doctor may additionally treat the patient according to the following therapeutic point stimulation:

- If the patient is disoriented, sees and hears floating corpse ghosts, or hears crying ghosts, treat the Tianfu Lu-3 points.
- If the patient is manic-depressed, sees and hears ghosts talking, treat the Tianchuang SI-16 points.
- If the patient is having seizures, sees and hears ghosts talking, treat the Tianzhu Bl-10 points.
- If the patient is manic, suicidal with incessant wild talking and actions, treat the Fengfu GV-16 point.
- If the patient experiences chronic nightmares, confused dreaming, and restless sleep, treat the Tianyou TB-16 points.

MEDICAL QIGONG TREATMENT FOR DEMON OR SPIRIT POSSESSION

Since the creation of Traditional Chinese Medicine in the People's Republic of China, the notion of spirits has been down-played. However, within the confines of the Medical Qigong clinics, I have been fortunate enough to be able to discuss with several Qigong doctors the cause, effect, and treatment of demon and spirit possession.

These following Thirteen Ghost Points are listed in the *Thousand Ducat Formulas*, prescribed by the famous physician Dr. Sun Simiao in the 7th century China, and were once used for the treatment of spirit possession (Figure 53.12). Today in China, these points are now used in the TCM clinics for the treatment of manic and depressive mental disorders, as well as for treating epilepsy. In extreme manic cases (with Heat) the doctor bleeds all of these points as well as all twelve Jing-Well points on the patient's hands. Classically, the patient is treated by bleeding each of these points, or by inserting an acupuncture needle into each point and then immediately withdrawing it. These Ghost Points are stimulated in a sequence of progressive point therapy, wrapping and enfolding the patient's body in five consecutive circles.

1. The Guigong (Ghost Palace), also known as the Renzhong GV-26 (Middle of Man) point, is the first point to be stimulated and is treated to calm the Shen and clear the brain.
2. The Guixin (Ghost Faith), also known as the Shaoshang Lu-11 (Lesser Metal's Note) points on both thumbs, are treated to calm the Shen and restore Collapsed Yang.
3. The Gullei (Ghost Fortress), also known as the Yinbai Sp-1 (Hidden Clarity) points on both big toes, are treated to calm the Shen, clear the brain, in order to instill clarity of thought and mind.

These first three points are used to complete the energetic pass of the first circle, covering the head, tips of the thumbs and tips of the big toes. The GV-26 point is considered the meeting point of Yin and Yang in the body, while the Lu-11 points on both hands and the Sp-1 points on both feet are located on the body's Hand and Foot Tai Yin Channels.

Next, the following two points are used to complete the second circle:

4. The Guixin (Ghost Heart), also known as the Daling Pc-7 (Big Mound) points on both wrists, are treated to calm the Shen and clear the brain.
5. The Guilu (Ghost Path), also known as the Shenmai Bl-62 (Extending Vessel) points under both outside ankles, are treated to calm the Shen.

The Ghost Heart and Ghost Path points complete the energetic pass of the second circle, covering and wrapping the patient's wrists and ankles. The Pc-7 points on the wrists are located on the body's Hand Jue Yin, and the Bl-62 points on the outside of the ankles are located on the body's Foot Tai Yang Channel points.

The following set of four points are stimulated to complete the energetic pass of the third circle:

6. The Guizhen (Ghost Pillow), also known as the Fengfu GV-16 (Wind's Palace) point just below the occiput, is treated to clear the brain.
7. The Guichuang (Ghost's Bed), also known as the Jiache St-6 (Jaw Vehicle) points on both sides of the jaw, are treated to dispel Wind and Cold and to clear Heat.
8. The Guishi (Ghost Market), also known as the Chengqiang CV-24 (Receiving Liquid) point under the lower lip, is stimulated to treat mental disorders, dispel Wind and Cold, clear

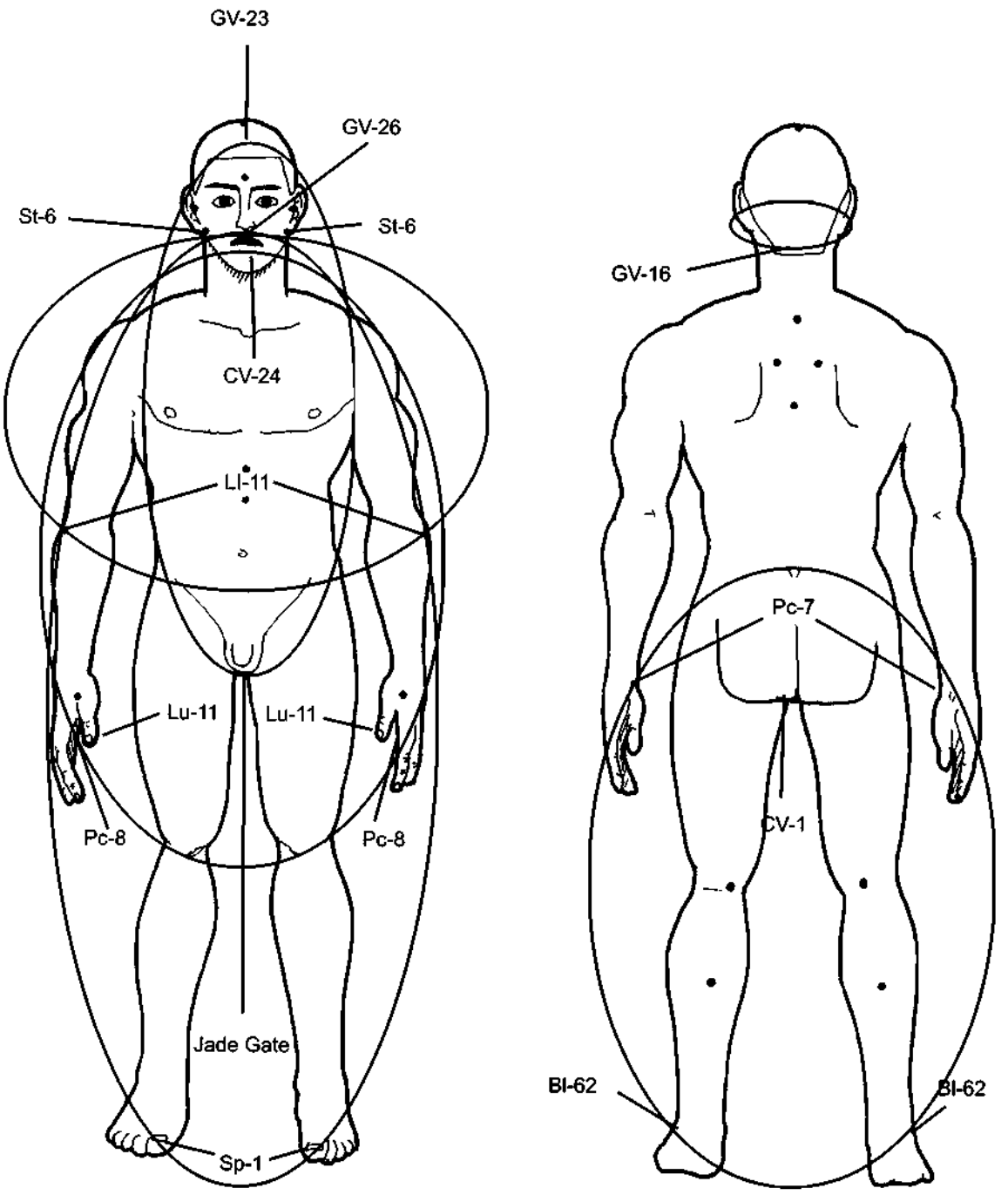

Figure 53.12. Medical Qigong Treatment for Spirit Possession

Heat, and to transform Dampness and Phlegm.

9. The Guicu (Ghost Cave), also known as the Laogong Pc-8 (Palace of Labor) points at the center of both palms, are stimulated to treat mental disorders and to clear the brain.

These four points complete the energetic pass of the third circle, by covering and wrapping the patient's head, then drawing the energy into the center of the patient's palms. The GV-16 point on the back of the patient's head is located on the back gate of the Upper Dantian, the St-6 points are located on the sides of the mandible, and the CV-24 point is located in the depression in the center of the patient's mentolabial groove (jaw).

The next two points complete the energetic pass of the fourth circle:

10. The Guitang (Ghost Hall), also known as the Shangxing GV-23 (Upper Star) point, is treated to brighten the Shen and clear Heat.
11. The Guicang (Ghost Store), also known as the Yumentou (Jade Gate) in women, and Yinxiafeng (Below the Hidden Seam) in men, is used to treat mental disorders. The Jade Gate is located at the opening of the vagina, the Below the Hidden Seam is located in the Huiyin area in men.

These two points complete the energetic pass of the fourth circle, by covering and wrapping the patient's body from the head to the lower perineum. The GV-23 point is located on the anterior hairline, at the top of the patient's forehead, and the Ghost Store point is located in the lower perineum.

The following two points are stimulated to complete the fifth energetic pass:

12. The Guitui (Ghost Leg), also known as the Quchi LI-11 (Crooked Pool) points, are treated in order to drain the pathogenic influences from the Lungs and to calm the Po (Corporeal Soul).
13. The Guifeng (Ghost Seal), also known as the Haiquan (Sea Spring) and She Xia Zhong Feng (Under Tongue Middle Frenulum) are two Extra points located below the tongue. They are stimulated in order to treat mental disorders.

These final two points complete the energetic pass of the fifth circle, by covering and wrapping the patient's body from the arms to the head. The LI-11 points are located in the depression on the lateral end of the elbow crease, and the Haiquan Sea Spring points are located under the tongue.

TREATING PHOBIAS AND DEPRESSION USING "THE WINDOWS OF THE SKY" POINTS

If we observe the body as a figure 8, with the head being the upper portion and the torso being the lower portion, the neck would represent the area where the two circles meet. The points and orifices of the head, face and neck are like great windows in which Qi moves.

The trunk of the body is considered Earth and the realm of the physical; the head pertains to Heaven and the realm of the spirit. The neck is where all of the classic "window" points are located. The neck is the junction between Heaven and Earth, and is considered the Earth's window to Heaven. With the exception of Lu-3 (upper arm) and Pc-1 (chest), eight of the ten Windows of the Sky points are located on the neck itself, and seven of the ten points have the word Tian (Heaven) as part of their name.

Over the last quarter century, the Chinese have used the Windows of the Sky points in treating such psychological disorders as depression and phobias. In the Qigong clinic, we look for three indications before prescribing the Windows to the Sky points.

1. According to the Nei Jing, the Windows of the Sky points are used when the Yang Qi is unable to ascend to the patient's head. The result is that the patient will have physical symptoms in the head or Heart (i.e., loss of hearing, or pain described as being behind the Heart.
2. The second indication is that there is something missing in the Heavenly aspect of the patient's spiritual life. When the patient becomes stuck in their own negative patterns, these particular points can be used to open a window of hope by bringing into the patient's body the illuminating light from Heaven.

In these cases, the patient's disconnection

from emotions and spiritual insight is due to the chronic negative patterns that block the descent of Heavenly light.

3. The third indication is a constant attitude of despondency by the patient. This behavior is not in accordance with his or her own values and beliefs, but the patient cannot control this pattern. Some patients know that something is amiss but cannot discern the source of the problem.

The Window points induce a hypnagogic state (a transitional state between sleeping and awaking) that allows some patients to experience out-of-body projection and past life regressions.

TREATMENT

When treating patients with the Windows of the Sky points, the Qigong doctor should use slow, gentle pressure on the skin to dip into the tissues, and then proceed with pure intention. The ten Windows of the Sky points are described as follows.

1. The Tian Fu Lu-3 (Heaven's Residence) point is sometimes called the Celestial Palace. The word Heaven represents divinity, clarity of vision, and the sense of the spirit (Figure 53.13). This point has a powerful psychological effect on all emotional problems deriving from Lung Qi disharmonies (e.g., depression, claustrophobia, agoraphobia, mental confusion, and forgetfulness).
2. The Fu Tu LI-18 (Support the Prominence) point is also known as Support and Rush Out. It is used on patients who feel out of touch with their own inner strength (Figure 53.14). This point relieves coughing, resolves Phlegm, and disperses masses (cysts and tumors) in the neck area. It is also used to treat a patient's inability to speak.
3. The Tian You TB-16 (Heaven's Opening) point can be used to calm the patient of anxieties and to soothe Heart palpitations (Figure 53.15). This point is also used for dizziness, sudden deafness, and diminished visual acuity.
4. Tian Zhu Bl-10 (Heaven's Pillar) is a Sea of Qi point. It is used to clear the brain, open the orifices, brighten the patient's eyes, and re-

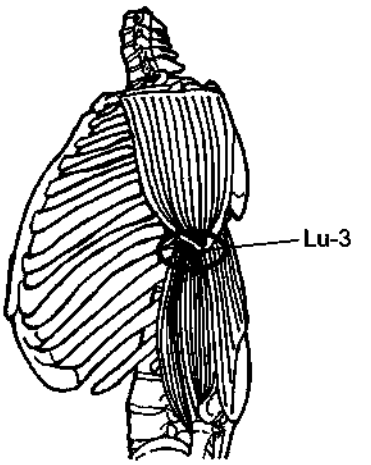

Figure 53.13. Heaven's Residence

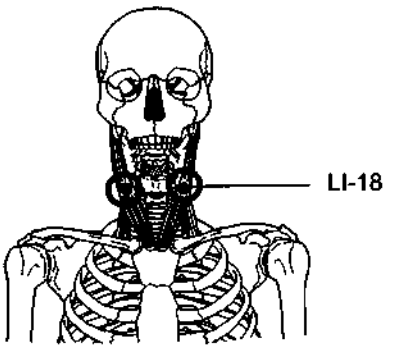

Figure 53.14. Support the Prominence

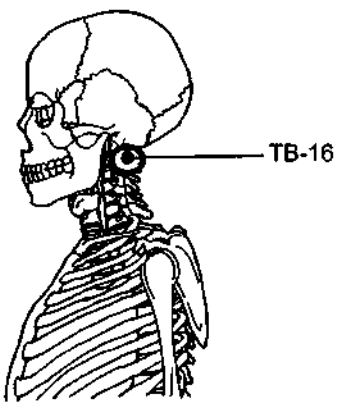

Figure 53.15. Heaven's Opening

move obstructions from the channels. The energy that moves and is located at these points has to do with the patient's will, ambition, and inner fortitude (Figure 53.16). Energetic dysfunction located at the Heaven's Pillar may manifest as deep sadness or anxiety, and be related to a lack of inner strength, or will. This point is also used when the patient's feet are unable to support the body.

5. Ren Ying St-9 (Man's Welcome) is a Sea of Qi point. The ancient Chinese philosophers associated this area of the body with Man in the triad of Heaven, Man, and Earth. This point is known as a place where energy is being welcomed into the body (Figure 53.17). It is a very sedating point of Blood and Qi, and is used to reduce blood pressure. Opening up this point allows the patient to become receptive to nurturing energy (Ying Qi). The doctor should be gentle and only treat one side at a time. It is also used to disperse Lung Qi and Regulate Qi.
6. The Tian Tu CV-22 (Heaven's Rushing Out) point is also known as the Celestial Chimney, and is an area where the body's internal energy and spirit leaves the body through sound (Figure 53.18). Heaven Rushing Out is related to emotional and spiritual expression, and is relevant when the patient's spiritual self (i.e., the individual's life purpose) is not being supported by physical actions (his or her code of conduct). In other words, the patient's life purpose is not in alignment with the patient's behavior. This point can also be used to regulate the Lungs, stimulate the descending action of the Lung Qi, clear Heat, and resolve Phlegm.
7. Feng Fu GV-16 (Wind's Palace) is a Sea of Marrow point, and is also a very good point for strengthening the body's Wei Qi (Figure 53.19). This point connects directly to the brain, and is used to eliminate Wind, clear the mind, open the sensory orifices, and benefit the energetic function of the brain (used for treating convulsions, epilepsy, or palsy).
8. The Tian Chuang SI-16 (Heaven's Window)

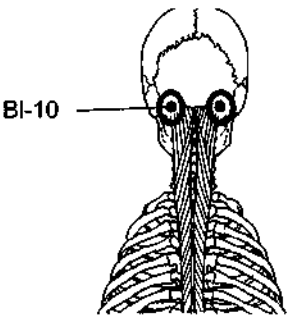

Figure 53.16. Heaven's Pillar

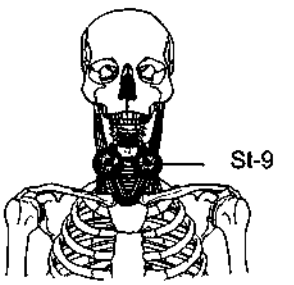

Figure 53.17. Man's Welcome

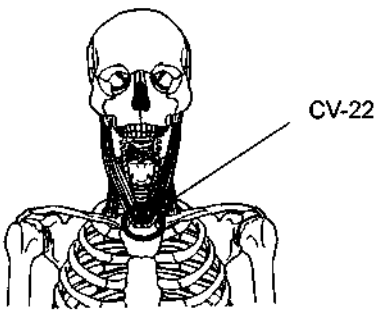

Figure 53.18. Heaven's Rushing Out

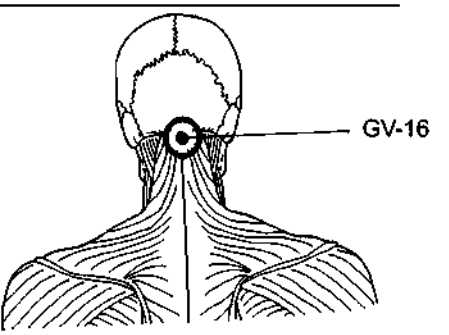

Figure 53.19. Wind's Palace

point is used to open a window to Heaven, especially in patients who need help in perceiving how to change a negative behavior pattern into a productive and harmonious one (Figure 53.20). This point is used for dispersing the Liver's Qi and for eliminating buzzing, pain, or deafness of the ears.

9. The Tian Rong SI-17 (Heaven's Appearance) point is also known as the Celestial Countenance. This point is where the Small Intestine's Channel Qi is received by, and enters into, the Heaven's Body Chamber (the head or skull). It can be used to produce a strong movement of energy from the head downward into the body.

   This point is used in spiritual emergencies, when patients have lost their connection with Earth energy, and remain blissed out, and oblivious of reality. It is often used in cases of addictions, once the patient is conscious of the addiction (Figure 53.21). This point is also used in order to expel Excess Fire and remove obstructions from the patient's channels.

10. The Tian Chi Pc-1 (Heaven's Pond) point is also known as the Celestial Pool. The term pond represents a source, resource, or reservoir of energy for the spirit. This point influences the area where the Shen gathers or pools in the chest region (Figure 53.22). It is capable of enhancing the transition from normal consciousness to feelings of being submerged in a sea of energy.

    It affects the Heart and Pericardium which govern the Shen, and whose symbolic home is Heaven. The doctor uses this point to remove the patient's street armor, and to begin the process of opening the patient's Heart protector at its source. This point is also used to disperse the Lungs' Qi, expand and relax the chest, regulate Qi, and clear Heat.

    Note: Because of the proximity of the breast tissue, the Heavenly Spring points (Pc-2) are sometimes used in women instead of the Heaven's Pond points (Figure 53.23). The Heavenly Spring point is located halfway down the anterior face of the biceps muscle.

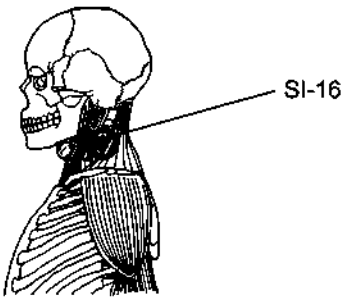

Figure 53.20. Heaven's Window

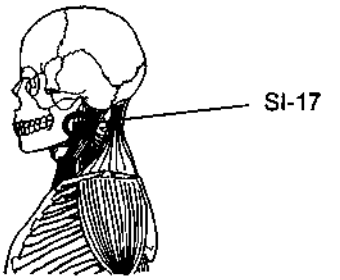

Figure 53.21. Heaven's Appearance

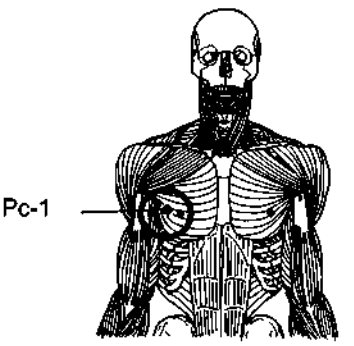

Figure 53.22. Heaven's Pond

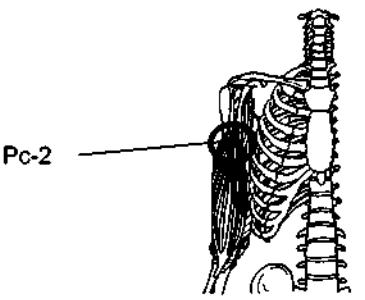

Figure 53.23. Heavenly Spring

TREATING PSYCHO-EMOTIONAL DISORDERS RELATED TO STRESS

The following prescriptions are used in order to assist the patient in dealing with suppressed anger and grief, for additional prescriptions used in order to treat emotional problems (see Chapter 19).

TREATING EXCESS LIVER FIRE AND THE REPRESSION OF ANGER

One of the most common problems observed in the clinic is Excess Liver Fire. One of the many causes of Excess Liver Fire is the repression of anger and a suppression of the spiritual components of the Hun. When anger is suppressed, its volatile Heat will sometimes attack and drain the Kidney Yin (Water). Therefore, Excess Liver Fire is generally related to a Deficiency of the Kidney Yin energy. When Qigong doctors reduce the Excess Liver Heat, they must also increase the patient's supply of Kidney Yin (Water) Qi (see note #2).

If the Liver's Yin becomes Deficient, the body's Qi will not be able to keep the patient's Internal Fire from rising. This causes the Yang to rise to the patient's head, and the Blood to become Deficient. The patient becomes irritable as the Liver's Yang begins to rise. This in turn, causes high blood pressure, which is associated with such problems as headaches, dizziness, insomnia, tinnitus, hypertension, and migraine headaches. Deficient Liver Yin, if unchecked, turns into Liver Fire, which causes severe high blood pressure, and heats the patient's Blood. As the Blood heats, it becomes Deficient, and causes Liver Wind. Unchecked Deficient Liver Yin results in shaking and trembling. If the Liver Wind mixes with the patient's Phlegm, it blocks the patient's channels resulting in paralysis, aphasia, memory problems, and eventually stroke.

The method of treatment is chosen according to the patient's syndromes:

1. For patients sensitive to energy, use Medical Qigong therapy while the patient is lying supine.
   - Purge and disperse Qi from the patient's Liver;
   - Pull pathogenic Qi out the patient's Liver Channels;
   - Tonify the patient's Kidneys through the Lower Dantian;
   - Give Liver purging and Kidney tonification prescriptions and homework.
2. For patients not sensitive to energy, use Tui Na and An Mo in conjunction with Medical Qigong therapy while the patient is lying prone.
   - Purge and reduce the Fire in the patient's Governing Vessel and Bladder Channels;
   - Start at the Mingmen and dredge the patient's Liver Fire, ending at the sacrum, using a counterclockwise circle rotation to reduce the Liver's Qi;
   - Give Liver purging and Kidney tonification prescriptions and homework.

Note #1. If the Liver Fire attacks the Stomach, resulting in vomiting and migraine headaches, have the patient lie supine. Because the Liver's Fire can travel transversely along the hypochondrium area, the Qigong doctor rocks and gently shakes the patient from the center of the thorax down to the Kidneys using intention, lead and disperse the Heat out from the patient's torso. Next, pull the Stomach Qi down and out of the patient's feet.

Note #2. Tonify the patient's Kidneys by using Jing Point therapy on the following points: St-36, GB-34, Sp-6, Lv-3, and Kd-1 on both sides of the body.

BEATING THE BAG AND SHOUTING TO DETOXIFY LIVER HEAT AND RELEASE TRAPPED ANGER AND RAGE

Beating the Bag and Shouting is the most common Medical Qigong homework given to patients with Excessive Liver Fire. The concept of Beating the Bag and Shouting is best comprehended when the function and flow of Liver Qi Heat is understood. When striking the bag and shouting, the shaking movements of the body will:

- facilitate an energetic discharge from the Liver organ,
- help alleviate pressure stored within the Liver organ itself (detoxifying suppressed feelings), and
- purge the body of Excess Liver Heat.

It is important for the patients to understand, that when shouting and striking on the surface of the bag (while focusing their intention deep into the bag's center), they are releasing deep seated pathogenic rage. This is why it is prohibited for patients to substitute such things as pillows, bed, etc., for the bag. If a patient takes a pillow and pounds it, for example, screaming and shouting to release the aggression, he or she is releasing and discharging pathogenic Qi into the pillow. If after releasing this Toxic Qi into the pillow, it is returned to the bed for a person to sleep on, the patient will reabsorb the discharged energy. To avoid this occurrence, patients are encouraged to set aside a space where they can safely discharge internal pathogenic Qi (preferably outdoors). This is similar to isolating and storing garbage away from living quarters.

While striking the bag, in addition to feelings of anger and rage, sometimes the patient may start crying or experience overwhelming feelings of grief and despair. This is also a normal reaction to dispersing toxic emotion. It sometimes occurs while discharging Stagnant Liver Qi, because the Lungs, which store the emotion of grief, have the function of keeping the Liver organ in check, in accordance with the Five Elemental Controlling Cycle.

What the patient needs to perform this exercise is two wooden dowels (1–1.5 inches in diameter and three feet long), a large bag of rice from the grocery store, and some duct tape. Completely encase the bag of rice with the duct tape to prevent spilling. Place the bag on a table, or a hard surface, level with the Lower Dantian. Hold a dowel in each hand, strike the bag, and focus on the Liver's Qi traveling up the back, down the arms, and through the wooden dowels.

With each impact, imagine the body releasing Toxic Liver Qi into the bag. It is important for the patient to exhale completely and deeply from the lower abdomen when shouting and striking the bag. Sometimes the patient is encouraged to shout "no" or "stop." These words will help the patient to facilitate complete emotional discharging, while also reestablishing a patient's broken energetic/emotional boundary system.

Bag striking should be performed for 10–15 minutes to achieve maximum benefit. Afterwards patients may feel euphoric and exhausted due to the heightened endorphin activity now occurring within the tissues. If the patient still feels angry, he or she should try writing out the rest of the rage on paper, which is then discarded. In order to end the exercise, patients should sit for five minutes in quiet solitude. It is important for the patient to reflect on any emotional memories which have been released and brought back into consciousness. The patient may then begin sharing these feelings and memories with the doctor, and commence the process work for healing the unexpressed emotions.

Some patients may become absolutely horrified at themselves for getting so angry during bag beating that they feel terrified afterwards; especially if so much rage was built up that is seems there is no end to it. Often patients are forced to stop from overwhelming fatigue, aches, and pain caused by this purging exercise. If the patient allows the rage to build and never completely processes the rage, it may cause the patient to feel that without the anger he or she would literally cease to exist, or that he or she is innately evil. The patient may feel that he or she "is" the anger, and that the exercise is making it worse, and may strive to control the anger even more than before.

Some patients will get so mad, they will walk out on the Qigong doctor without processing anything. This unprocessed rage can be extremely dangerous, especially if the patient is prone to beating his or her mate, kids, or pets. Many people are completely unaware of how much anger they have suppressed. Some patients are like bottomless wells, especially patients with borderline personality disorder. Patients with this disorder should never be given this exercise, as it could lead to self-mutilation. Refer such patients out for psychotherapy.

In our culture, women are not allowed to express anger, much less rage. If the patient has ever been beaten, or witnessed a loved one being abused, he or she may believe that he or she is just like the abuser, and that he or she has been lying to him or herself about not being bad and may become suicidal.

The Qigong doctor should never prescribe this exercise unless he or she fully understands the complexity of the patient's circumstances. Some patients require a period of time, in a safe place, with supervision to help them deal with such intense emotions.

Other possible reactions might be that the patient goes into stronger denial of the rage, blames the doctor for causing him or her to beat their mate or children, or blames the doctor for causing the rage. The Qigong doctor must make sure there is sufficient time for the patient to process all the reactions aroused. The patient must not feel hurried.

ANGER MANAGEMENT

With some patients it is best to start them off journalizing the anger, not in a dairy, but on sheets of paper. They address the letters to the person, or persons, with whom they are angry. They continue writing until all the anger has been discharged. They are not to mail the letters, or give them to the addressee, or show them to anyone including the Qigong doctor. In writing the letter, they allow themselves to fully express the anger without judging themselves. The patient should not be concerned about grammar, foul language, etc. No matter how trivial the upsetting incident was, it should be written down. The flow of consciousness is initiated and continued until the end of the letter. No event (no matter how silly or insignificant) that comes to mind should be left unexpressed.

When finished, the letter is to be torn up, or safely burned in a ritual of healing and letting go (e.g., light some incense or candles, then blow them out after the paper has been incinerated). Symbolically the patient must let go of the anger for good, and that is why the letter is destroyed in a ritualistic act.

Only later, as the patient continues to practice this purging technique, slowly gaining control of the emotions, can the angry letters be kept for a few days and reread. In rereading the letters the patient engages his or her discriminating, judging faculties (i.e., "Was I right to get upset over this incident? Did I over-react? What did this incident remind me of from my childhood?"). This is a safe and very powerful method of discharging anger from the patient's body. The patient is encouraged and allowed to say everything he or she thinks of when writing, holding nothing back. It is nonthreatening, and allows the patient to come to understand him or herself better in time.

TREATING STAGNANT LUNG QI AND THE REPRESSION OF GRIEF

The Lungs dominate the Qi and respiration. A common problem observed in the clinic is stagnant, or obstructed Qi within the Lungs, from the toxic buildup of sorrow, grief, and worry. Sadness and sorrow can cause a Deficiency of Lung Qi, while worry can cause the Qi in the chest to stagnate. Stagnant Qi within the Lungs is usually directly or indirectly related to the suppression of emotional issues.

The right Lung is considered more Yang than the left Lung; it therefore tends to reflect, and sometimes manifests physically, any unresolved, or suppressed emotional conflicts experienced within the father-child relationship (or other main male figures in the patient's childhood). These unresolved emotional issues tend to carry over and help shape the nature of subsequent conflicts experienced in other male relationships. These ongoing emotional reactions provide a further opportunity in life to express, work through, and resolve these emotional issues.

The left Lung is considered more Yin and thus reflects emotional issues stemming from the mother-child relationship (or main female figure in childhood). The left Lung may likewise manifest these issues in subsequent female relationships.

Generally, cysts, tumors, or cancer originating in these corresponding regions reflect the emotional history. Because of these emotional patternings, the method of treatment for Lung diseases (that are Internally induced) is chosen according to the patient's syndromes in relationship to the root of the original trauma. After determining the specific Lung which dominates and manifests the patient's pathogenic condition, the Qigong doctor proceeds as follows.

1. For patients sensitive to energy, use Medical Qigong therapy while the patient is supine.
   - Disperse Qi over the patient's throat and Lungs;
   - Purge pathogenic Qi out the afflicted Lung Channel;
   - Tonify the patient's Spleen and Kidneys;
   - Prescribe Homework.
2. For patient's not sensitive to energy, use Medical Qigong therapy in conjunction with An Mo Qi therapy while the patient is supine.
   - Disperse Qi over the patient's throat and Lung area;
   - Purge pathogenic Qi out the afflicted Lung Channel;
   - Dredge Fire from the patient's Liver;
   - Tonify the patient's Spleen and Kidneys;
   - Prescribe Homework.

DRY CRYING TO DETOXIFY STAGNANT LUNG QI AND RELEASE TRAPPED SORROW AND GRIEF

The most common homework prescription given to patients with stagnant Lung Qi is the Dry Crying exercise. The concept of "dry crying" is best understood if we look back to when we were little children. When little children cry hard, they generally release full body resonances. They shake and undulate from the middle of the body, allowing the pain to resonate outwards. When children reach puberty, they learn (through parental or peer pressure) to suppress their feelings, and to restrain full body resonance, by tensing the muscles in the throat. The constant pressures from society, parents and peers, result in self-conscious feelings and shame regarding the loss of control over the emotions. The following exercise allows the patient to experience full body resonation and to release deeply suppressed emotions.

Begin the exercise from a standing position. Stand with the feet more than shoulders width apart, toes pointing straight and the knees comfortably bent. With each hand, touch the thumb to the index finger to form a circle. Relax the arms letting them hang naturally. Close the anal sphincter, and breath naturally from the abdomen. Tilt the head backwards, opening the mouth wide,

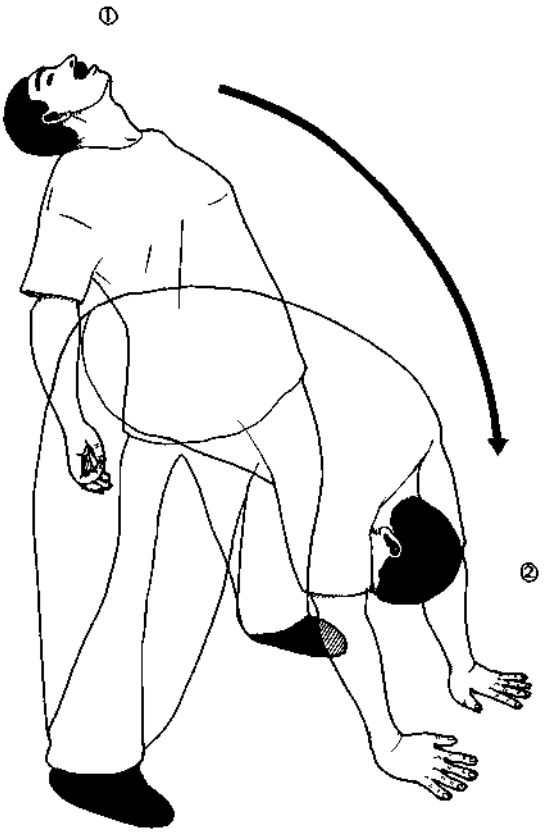

Figure 53.24. Dry Crying

and relax the jaw. Allow the upper body to lean and bow backwards (without straining the spine), but stretching the psoas muscles. Hold this posture from 5 to 15 minutes, concentrating on relaxing the body, and allowing it to resonate (Figure 53.24).

The psoas muscles are located in the lower back and Mingmen area. They articulate from the transverse process of the lower lumbar vertebra. These muscles travel near the center of the abdomen down to the inner thigh. These particular muscles are associated with the storing and releasing of powerful emotions. As the psoas muscles stretch, the body begins to resonate and shake from the pelvic cavity upward. This action returns patients back to the preadolescent state of

energy release, allowing them to detoxify deep seated grief within the tissues.

In order to complete the exercise, it is extremely important to ground. This prevents the uprooted toxic emotions from causing Qi stagnations in the throat and chest area. After holding the posture for the prescribed amount of time, slowly lean forward and tilt the chin down. Allow the arms to continue to hang naturally. Slowly lean forward until the hands touch the floor. Imagine Qi, flowing like water, from the torso out your arms, cleansing your body, sending the pathogenic Qi deep into the center of the Earth.

CONTRAINDICATIONS

Patients should avoid this particular exercise if they have previously injured their back. For patients who have difficulty with the stretching of the cervical or lumbar vertebrae, it is encouraged that they wear a cervical collar or lumbar support to prevent injury to the spine. Also, the exercise can be modified to allow the patient to sit comfortably on the edge of a chair while stretching the psoas muscles if the standing stretch is too difficult.

Chapter 54
Qi Emission Therapy for Oncology

History of Cancer Treatments

The ancient doctors of Traditional Chinese Medicine understood about the formation of tumors. The earliest records found were inscriptions recorded on "Oracles of Bone," unearthed from the ruins of the Yin Dynasty (16th–11th century B.C.). The word "ai" (cancer) first appeared in the Chinese Medical classic *Wei Ji Bao Shu* during the Song Dynasty, in the year 1171.

In Traditional Chinese Medicine, cysts, tumors, and cancers are considered multifaceted diseases, originating from imbalances in one or more of the five following sources: environmental, chemical, biological, physical, and psychological. According to the *General Treatise on the Etiology and Symptomatology of Diseases*, a tumor is one of the many diseases that responds to Dao Yin (Medical Qigong) exercises and meditations. To prevent the formation of cysts, tumors, or cancer, and to increase the strength of the immune system, Qigong doctors encourage patients to monitor their diet, maintain emotional stability, increase physical exercises through Medical Qigong prescriptions, and avoid exposure to pollutants.

From a Western Medical perspective, tumors and cancer are likewise considered multifaceted diseases. They are generally viewed as being created and formed through a constant bombardment, attack, and weakening of the tissues, caused by the following three factors:

- A congenital tendency towards specific types of tumors and cancers (inherited weakness);
- Exposure to radiation, environmental pollutants, and chemical poisoning, and
- An inability to repair weakened DNA, leading to uncontrolled replication.

In Traditional Chinese Medicine, cancer cells are considered "infant bodies" which absorb nourishment from the host (mother) body for their own growth; thus they are called "pathogenic or evil embryos." Cancer cells are actually components of the "original" or "mother" body.

Categorization of Tumors

In Chinese Medicine, tumors and cancers are commonly referred to as "a retention of mass." Retention has the meaning of stagnation. Tumors and cancer originate from flowing substances within the body such as Qi, Blood, Phlegm, and food. These substances stagnate when they are attacked by pathogenic factors, and they gradually take on the form of a lump as a result of excessive accumulation. If the lump subsides spontaneously, it is commonly referred to as a cyst, or benign tumor. Many benign cysts and tumors, however, persist indefinitely.

Benign Tumors

A benign tumor grows slowly, and can spontaneously stop growing, or disappear by itself. A benign tumor also grows in expansive ways. Its margin is clearly defined with firm boundaries, and is easily manipulated through palpation. There is no temperature differentiation between the skin surrounding a benign tumor and normal skin tissue.

Often, no symptoms surround the internal location of a benign tumor. As the tumor grows in certain areas of the patient's body, however, it can disrupt the functional activity of an affected organ. Benign tumors have been known to cause bleeding and inflammation. If the tumor is located within the endocrine glands, it can cause an abnormal function within the gland itself. A tumor located within an endocrine gland does not usually endanger the patient's life. Benign tumors can, however, become life threatening if the location compresses specific areas of the patient's brain or vital organs.

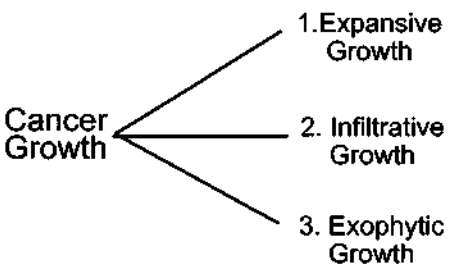

Figure 54.1. The Three Formations of Cancer Growth

MALIGNANT TUMORS

A malignant tumors grow very fast (potentially doubling every two months). Degeneration, festering, and hemorrhaging often accompany malignant tumors. A malignant tumor is infiltrative in its growth, with no clearly defined boundary. Its appearance is irregular and fastened (not easy to move through palpation). The skin temperature surrounding the malignant tumor is considered energetically Hot, as it is warmer than the normal surrounding tissue.

Most malignant tumors either metastasize to nearby, or distant areas of the body. The body's symptoms include fever, pain, anemia, fatigue, and general weakness. In many cases, if left untreated, they can cause death. Malignant tumors, and cancers can be divided into two main categories: a Carcinoma, and a Sarcoma.

1. A carcinoma is a malignant growth or tumor that occurs in the epithelial tissue (the outer surface or first layer of tissue that lines the body's cavities, as well as the principal tubes and passageways leading to the exterior of the body). Skin cancer, esophageal squamous cancer, adenocarcinoma of the Stomach, and breast cancer all belong to this type of carcinoma. A carcinoma may affect any organ, or part of the body, and may spread by direct extension, or indirectly through the lymphatic system and bloodstream.
2. A sarcoma is a malignant growth, or tumor, that occurs within the connective or mesenchymal tissue. It may affect the muscles, bones, fat, blood vessels, lymph system, Kidneys, Bladder, Liver, Lungs, Spleen, or parotid glands. Rhabdomyosarcoma (sarcoma of the muscles), osteosarcoma (sarcoma of the bones), and lymphosarcoma (sarcoma of the lymphatic system) all belong to this type of sarcoma.

THREE FORMATIONS OF CANCER GROWTH

According to Dr. Pan Mingji, Director of the Fuzhou Cancer Institute of Integration of Traditional Chinese and Western Medicine, there are three forms of cancer growth: Expansive Growth, Infiltrative Growth and Exophytic Growth (Figure 54.1).

1. Cancers of the Expansive Growth type consist of tumor cells crowded together on certain parts of the body. These cells proliferate, grow constantly, and expand towards the outside. The cells of the surrounding tissue form a wall to resist the tumor's expansion. The wall becomes the external membrane of the tumor, which has an evident boundary separating it from the normal tissue. Tumor growth begins in this way in the early stages of both benign tumors and malignant sarcomas.
2. Cancers of the Infiltrative Growth type consist of cells that not only group together, but, also separately invade the intercellular spaces, and tubular tissue of normal cells. They establish their foundation within the tissues, and proliferate daily, expanding outward with no boundary system between the cancer tumor and the normal tissue. Since there is no surrounding wall of membrane, the growth spreads in mass. Malignant tumors, especially carcinoma growth, infiltrate in this way.
3. Cancers of the Exophytic Growth type consist of cancer cells that occur on the skin, body cavity, or gastrointestinal mucosa; they often form on the surface of the body's tissues through papillary masses, projecting outwards on the skin and mucosa. Polyp, papilla-

shaped tumors, papilloma, gingival cancer, esophagal cancer, Stomach cancer, and intestinal cancer all grow in this way.

Benign tumors do not spread; they only grow in an expansive or exopathic way. The malignant tumor is different, however, as the cancer cells do not remain in their original location but expand from the mass outward. This expansion extends into other organs and tissues by way of the body's lymphatic plexus and blood circulation. This phenomenon is known as metastasizing.

ETIOLOGY, THE SIX PATHOGENIC EVILS THAT CAUSE CANCER

The following is an analysis of the causes of tumor formation. Traditional Chinese Medicine maintains the concept that a tumor is a systemic disease (affecting the whole body). It can be summarized as a disorder of the internal organs caused by emotional strains, and an imbalance of the viscera, that has allowed the pathogenic Evils to enter the body and obstruct the channels and collaterals. These pathogenic Evils cause problems, that may eventually lead to the stagnation of Blood and Qi and develop into tumors. The pathology of cancer is as follows: Qi stagnation, Blood stagnation, Retention of Toxic Dampness, Retention of Phlegm, Toxin Attack, and Weakness or Deficiency of Energy (Figure 54.2).

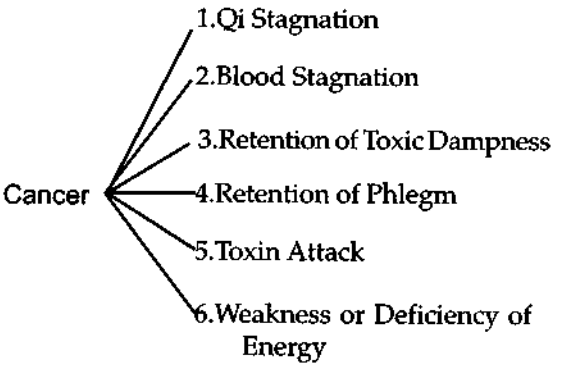

Figure 54.2. The Six Pathogenic Evils That Cause Cancer

1. Emotional strains, depression of Liver Qi, or External pathogenic Evil factors can lead to a stagnation of Qi. Long term Qi stagnation can cause stagnation of Blood, which eventually causes clots. It is known that pathogenic Cold and Heat, and the prevailing pathogenic Evil factors, inevitably cause Blood clots.
2. Since Blood and Qi flow together, the obstruction of Qi can lead to an interference in Blood circulation. This interference gradually leads to Blood stasis; Blood Stasis is always further complicated by stasis of Qi. Blood stasis is sometimes referred to as "Dead Blood," due to the fact that the Blood is not moving. When Dead Blood accumulates in a certain area of the body, it eventually develops into an immovable mass or lump.
3. A weakness of the Spleen and Stomach, as well as indigestion, can cause retention of fluid in the body. Long term fluid retention will produce toxic materials that can accumulate and form lumps.
4. Functional disorders of the Lungs and Spleen lead to poor digestion of watery food, and poor distribution of Body Fluids. Fluid retention causes Phlegm, especially when it is complicated by Excess Heat. If Phlegm is unable to move upward to be dispersed out of the body, it collects and stagnates. The stagnation of Phlegm in the Lung(s) leads to asthma. The stagnation of Phlegm in the Stomach causes gastric disorder and nausea. If Phlegm goes beneath the skin, it will take the form of a movable mass or lump.
5. Toxic Evils may come from poisonous external environments (exposure to chemicals, asbestos, ultraviolet rays, radiation, etc.) or may be generated by the stagnation of Excess Heat within the body. This Excessive Heat causes abnormal cell fusion and growth within the body, leading to cancer formation, and a systemic breakdown of normal cell growth.
6. Deficiency of both Qi and Blood, as well as a weakness of Yuan Qi, make the body more vulnerable and susceptible to the formation of new growth. When pathogenic Evils enter the body, they damage the Blood and Qi. If the Yuan Qi cannot be restored, the disease will lead to a vicious, destructive cycle, mak-

ing the individual more and more debilitated.

These six pathological changes may occur either alone or in combination: i.e., Qi and Blood stasis, Phlegm stagnation and Toxic Dampness, Phlegm stagnation and Blood stasis, a weakness of the body's Yuan Qi and strong pathogenic Evils.

The choice of which Medical Qigong therapy to use should be based on differentiation of symptoms and signs. Since cancers are primarily caused by emotional strains, strong pathogenic Evils, and a weakness of the patient's Yuan Qi, clinical therapy should be focused on tonifying the patient's Yuan Qi, and purging the Evil pathogenic factors.

EMOTIONAL COMPONENTS OF CANCER FORMATION

From the clinical perspective, if the cancer is internally induced through emotional suppression, there will be a series of emotional transitions the Qigong doctor will observe during its development. When there is an accumulation of negative emotions, for example, the patient's body begins to wall off this type of energy, and creates an energetic cyst, instead of dissipating and disposing of the Toxic Qi. The patient's suppressed internal emotions intensify the production and formation of the cyst, and feed the cancer cells, which result in an uncontrolled, rapid growth rate of these cells.

The body creates potential tumors and cancer cells every day. The macrophages or monocytes (large phagocytes) in the immune system aggressively attack and dissolve the cancer cells once the body becomes aware of them. Areas in the body, however, which are armored in denial, tend to attract and protect these distorted cells, allowing them to cluster and mass together.

Cancer cells can grow and accumulate wherever emotions are being repressed. The patient's denial maintains the constant unconscious flow of energy to these tissue areas. The phagocytes and other components of the immune system do not attack these toxic pockets of emotional energy, because of the patient's continuous denial of their existence. Consciousness and awareness exists even at the cellular level of the body. The continuous emotional energy bombarding the cells and tissues causes these tissues to go into an emotional state of shock. Emotional shock causes a release of endogenous opiates and corticosteroids, that deplete the white blood cells, and prevent the immune system from protecting the body. Because of the immune system's weakened state of resistance, infection and even the formation of cancer cells are now free to enter and coagulate within the tissue areas.

Scientific studies based in China, and the West, have shown that stress can stimulate the neuroendocrine system to the extent that it leads to depression of the immune system. Furthermore, the creation and growth of cancer can be influenced by stress. Removal of psychological stress alone can alter the neuro-immunologic functioning of the body to the extent that it can prevent and even change the course of cancer development.

In a patient with emotional blocks, chronic tension begins to interrupt the flow of Qi. If the emotional block is deep and long standing, this tension becomes constant. The capacity to express or discharge the trapped emotion becomes very difficult.

As the awareness dims, the natural communication between the conscious and subconscious mind breaks down. The original conscious decision to suppress certain emotions becomes a habit; it thus becomes an unconscious aberrant automatic function. When emotions are expressed, the conscious and subconscious mind are in harmony and synergized. When emotions are suppressed, the subconscious mind can no longer perform its job of healing the body; it diverts all its energy to shield the patient's denial system. Thus, the Shen itself, becomes misaligned with the patient's life purpose. The patient's posture, movements and lack of spiritual growth, reflect this misalignment. Changes also occur in skin temperature, body chemistry, and skin tone. The overall level of vital life force visibly drops.

Dr. Xu, at the Xi Yuan Hospital in Beijing, China, often pointed out that emotional upheaval, and the restriction of the breath, could cause the patient's energy to stagnate or deviate from its path. The deviated Qi draws more energy to its pathway, compounding the disease. The unstable emotional and mental focus of the patient further

causes adverse effects to the body. Medical Qigong therapy and exercises expose the patient's deepest secrets, and thus reveal the underlying causes of the disease, which can then be treated. The patient's being is energized through his or her personal perceptions and belief structures. Therefore, it is necessary to change the patient's belief structure to increase the level of awareness and perceptual accuracy. The patient must be enabled to let go of suppressed emotions to fully experience deep emotional and spiritual changes. The Qigong doctor initiates the release of Toxic Qi to begin this healing process that can thereafter be maintained through appropriate prescriptions.

When cysts, tumors, or cancer are internally induced, they are formed from long-standing suppressed emotions which have become trapped within the tissue itself. These emotions usually consist of anger, guilt, grief, shame, and disappointment. The energetically formed cyst, or tumors, will remain walled off until the emotional energy is dissipated. Cysts, or tumors, can lodge themselves anywhere, penetrating deep into the major viscera causing visceral dysfunction; or they can superficially lodge themselves beneath the skin.

If the nature of the emotional energetic matrix (i.e., belief structure) is negative, the patient retains the energy of the injury, making it difficult to heal the trauma. If, however, the emotional matrix is positive, then the energy of the injury can be easily dispersed.

Once the Qigong doctor's energy reaches the cyst or tumor, the patient's energetic resonance supporting the tumor formation is interrupted. As the doctor continues to break up the cyst or tumor's physical mass, the frozen energetic pattern begins to unwind. The doctor continues to unravel the energetic mass until all the Heat has been released from the tissues, and the energetic pattern's unwinding is completed.

The underlying pathophysiology of healing can be broken down into four components:

1. The mind affects tissue matter through the emotions.
2. The emotions cause neuropeptides to be released.
3. The emotions (via the neuropeptides) influence the direction and movement of the immune cells (e.g., monocytes), sending them to various parts of the body.
4. The immune system (e.g., monocytes and phagocytes) heal the body.

The neuropeptide receptor sites are located on the immune cells, linking the body's immune system with the functions of the mind, emotions, and spirit. Neuropeptides are produced in response to the individual's state of mind and emotions; they influence the state of health of all the internal organs.

Through Dynamic Medical Qigong training, neuropeptides, in the form of endorphins, are released within the body's system. This release of energy and endorphins helps to facilitate the patient's healing.

Through the use of Medical Qigong therapy, exercises, and meditations, areas of denial and subconscious energetic patterning can be altered. The energetic matrix which supports the tumor(s) or cyst(s) thus dissolves.

When a healing session occurs, the Qigong doctor's external energy field envelops the patient's tissues, thus allowing the patient's cells to receive new information to reprogram the toxic energetic patterns. This reaction occurs providing the patient's tissues are open to receive the informational structures needed to either rebuild them, or disperse the disease's cell formation.

CANCER FORMATION AND THE PATIENT'S MIND, EMOTIONS, AND SPIRIT

Emotions strongly influence the increase or decrease of tumor size; therefore, it is important to regulate the patient's mind, emotions, and spirit. When the patient's mind, emotions and spirit are free from distractions and are in harmony, the patient is able to manage negative emotions. Regulating the Mind (whole body awareness and consciousness) is considered the primary Medical Qigong technique used for teaching patients how to avoid creating the dark abyss of negative emotions.

The patient must learn to let optimism pre-

vail over pessimism. The practice of Medical Qigong not only cultivates vital energy and builds up the patient's health, but promotes the development of optimism through creating a quiescent mind. Tranquility and optimism improve circulation of Qi and Blood (which strengthens the immune system) thereby inhibiting cancer cells until they gradually perish.

While visiting in Maui, Hawaii, I came in contact with four people who had been diagnosed with terminal cancer, and had a life expectancy of two weeks according to their physicians. Each person had their own unique story as to how they had come to the Hawaiian Islands to die. What struck me as fascinating was the fact that each one of these individuals had either left successful but extremely stressful businesses, or long term abusive relationships. Each made amends the best they could with relationships from their past (those who had anger against them or those whom they had hurt). They had come to paradise to live their last weeks in peace. That was several years ago! It seems that upon resolving all personal conflict, and leaving their stressful environment, their cancers went into spontaneous remission. Each individual was now concentrated on enjoying the pleasures of a simpler life, and on focusing on their own spiritual growth.

STRESSFUL LIFE ACTIVITIES AND THE IMMUNE SYSTEM

Stressful life activities create a flood of adrenaline within the body. This occurs not only from the endings of the vertebral lumbar division at the core segment of the major internal organs, but also from the core of the adrenal gland in the medulla (which specifically is a sympathetic ganglion, and responds to stress by releasing adrenaline into the blood stream). Adrenaline spreads throughout the body and activates not only the body's sympathetic nervous system, but also the adrenal glands; the heart rate, respiratory rate, blood pressure, and Blood flow to the muscles are increased in response to the Fight or Flight Syndrome.

When the release of adrenaline causes the mind and body to react, the immune system must then seek to balance the chemical imbalances created within the body, before it can return to its normal job of monitoring cellular activity, and defending against pathogens. If a patient is already vulnerable to a specific disease, added stress causes the patient to get sick quicker. Meditation takes the patient out of the stress mode, deactivates the adrenal glands, and normalizes the function of the immune system.

An unstable life style is very stressful and can lead to depression and Qi deviations. Conflict produces stress which causes anxiety; chronic stress wears down the mind and body, which leads to anxiety, or depression. Stress begins with an overexcitement of the nervous system, slowly working its way deep into the body like wet cement. It causes the shoulders and upper back to become tense and rigid. Stress can result from happy occasions (such as weddings) and other normally pleasant events. When the patient's life style is not properly balanced, over time Qi deviations, and illness can result. The capacity to bear stress is related to the strength of the nerves. When stress levels surpass the nervous system's capacity to handle them, the nerves "break down"; this results in all sorts of physical, mental, and emotional disturbances. These disturbances, if unheeded, can eventually lead to organ malfunctions, cysts, tumors, cancer, and premature death. To avoid such states, a balance between work and rest must be maintained.

At a conference of the International Society for Neuro-immunomodulation (*The Effects of Stress and Depression on Physical Disease*), Dr. Philip Gold, of the National Institute of Mental Health stated that stress and depression send hormones (e.g., cortisol) flowing into the bloodstream. An imbalance of hormones, if unregulated, can:

- destroy the appetite,
- cripple the immune system,
- shut down the processes that repair tissue,
- inhibit sleeping patterns,
- break down bone density,
- aid the onset of infection, and
- instigate the growth of cancer cells.

An individual's emotional past determines

his, or her, present state of health, both physical and emotional. Past emotional belief structures are responsible for both creating and healing diseases. Just as thoughts drift through the mind (but do not become active until they reside within a belief structure), so emotional wounding resides within the tissues and cells waiting to be activated by emotional upheavals. Our thoughts become form via choices, and manifest within the body.

In most societies, sharing traumatic wounds is often the first act of intimacy and bonding. Traumas provide a common ground for relationships, and support the pain structure that cements the relationship. People become addicted to empowering wounds, which in turn supports and empowers the disease. The exchange of painful personal traumas is reinforced by receiving sympathy and strong empathy, which binds rather than releases the pain from the tissues. Desire for sharing one's pain in order to receive love can lead to a habitual way of relating to those closest and dearest. When such individuals feel taken for granted, or unappreciated, they may immediately resort to sharing past traumas to illicit the desired response. When such techniques fail to elicit the desired response, a new wounding is experienced. Many of these individuals will continue to unconsciously create new traumas, in the hope that, this time, the desired outcome will be achieved. This in turn can become an addiction, empowering old wounds as it creates new ones, including illness. Thus, the spirit becomes divided to support the new belief structure (i.e., that pain and misery grin love and attention), and the life-force energy deviates from its assigned job of protecting the body, which creates illness. Setting the self up for new wounds is not a conscious process, but an unconscious one, which needs to be brought into the patient's awareness in order to be healed. Then and only then can the mind and spirit act as one unit, directing the body's Qi towards its proper function of healing.

Because energetic healing occurs in the present, not in the past, victims of past traumas will never heal if the energy continuously regresses to the armored traumatic belief structure.

USING MEDICAL QIGONG TO STRENGTHEN THE IMMUNE SYSTEM

Medical Qigong increases leukocyte production, stabilizes the body's blood pressure, and improves the immune function. The immune system is not so much an independent system, but is rather an interactive functional system throughout the body. Immune cells which live in the Blood and lymph fluid are commonly known as leukocytes (white blood cells); lymphocytes are a type of leukocytes that is created in the Spleen. The purpose of these cells is to work together to defend against pathogenic factors. The function of leukocytes and lymphocytes is to identify, ingest, destroy, and eliminate disease-causing organisms, as well as remove all dead, damaged, or irregular cells.

Immune cells are produced in the lymph tissue and red bone marrow, and are stored in the lymphatic organs and the Blood. To perform the function of protecting and cleaning, immune cells must circulate throughout the entire body through the capillaries and vessels that carry Blood and lymph fluid. Immune cells travel from the lymph nodes and the lymphatic organs of the thymus gland, Spleen, and tonsils, which are responsible for filtering the lymph fluid to remove impurities, and produce more lymph cells.

For an External pathogen to affect the body, it must first pass through protective layers of cells. Generally, the macrophages present within the tissues ingest the pathogens and dead tissues. Macrophages are reinforced by the action and movement of the body's Wei Qi. When a pathogenic intruder invades the body, the macrophages are often the first to attack the intruder. If the macrophages are not strong enough, more Blood and fluid are brought to the area, which contain more diverse immune cells. The increased fluid engorges the tissue, which engenders more cellular activity. The increased Blood and cellular metabolism increases the local temperature. The immune cells break down and ingest the pathogens, creating a process which continues until the disease is eliminated.

The dynamic movements of Medical Qigong

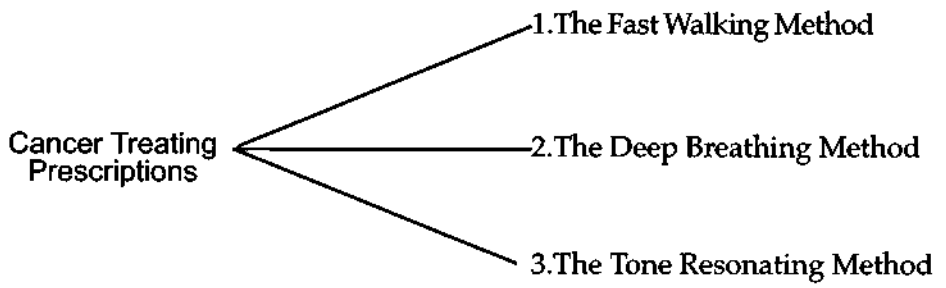

Figure 54.3. Three Prescriptions Used For Treating Cancer

exercises generate Heat, soften the body's connective tissues, and encourage the flushing of the intercellular fluid throughout the body's tissues and organs. Energetic Qigong practices increase oxygenation in the Blood and improve circulation, thereby enhancing leukocyte production, and strengthening the body's immune system.

CANCER TREATMENT METHODS

Tumor and cancer cells make their own room within the body's tissues by crowding the normal tissues. The tumor and cancer cells grab nourishing energy at the expense of the host, thus damaging the patient's body.

Medical Qigong cancer treatment methods are techniques designed to purge the energy that supports the tumor. These techniques are based on the fundamental Qigong patterns mentioned previously. The goal of these patterns focuses on treating the patient's Excess syndrome first, by purgation. Purgation is then followed by tonification, then regulation. The rapid growth of healthy energy, and the fast expulsion of Evil factors, should lead to normal body function restoration, and create more vigorous metabolic activity. More nourishment can be absorbed, delivered and distributed throughout the body, leaving no room to feed the tumor cells.

In Medical Qigong clinics, tumors are viewed as being similar in their expansion and growth to that of the energetic pattern of a plant's Qi flow. When tracing the origin of a tumor, the Qigong doctor begins at the tumor's location (considered the flower or fruit of the disease) and traces its energetic branches to the organ of origin (the actual root of the disease). If the disease is internally induced, the original source, i.e., the dysfunctional internal organ, feeds the tumor through suppressed emotional trauma.

To address this problem, the doctor prescribes the following three cancer treatment methods as homework, in addition to Medical Qigong treatments and herbal therapy: the Fast Walking Method, Deep Breathing Method, and the Tone Resonation Method (Figure 54.3).

1. The Fast Walking Method stimulates the electromagnetic fields within the tissues and reinforces the patient's Yuan Qi. By walking fast and changing the normal breathing patterns, the cancer cells can be destroyed. This is because the dual action of shocking the system with more Qi and Blood flowing through the body tends to stimulate the electromagnetic fields within the tissues, causing the tissue cells to become stimulated and the immune system to be aroused and thus enhanced.
2. The Deep Breathing Method tranquilizes the patient's mind, and enhances their Yuan Qi. The Deep Breathing method is used to treat various cancers due to mental and emotional factors, by changing the patient's normal breathing patterns.

   By changing the normal breathing into rapid

exhaling, slow deep exhaling, or relaxed toning, Blood clots and tumors can be dissolved. This breathing technique has a special effect on reinforcing the patient's Yuan Qi. When prescribing Medical Qigong therapy, it is important to match the patient's Yin disease with a Yang method of treatment, and a Yang disease with a Yin method of therapy. For example: rapid exhalation (a Yang method) would be used when treating an abdominal mass caused by a Cold (Yin) condition.

3. The Tone Resonating Method is utilized to purge any residual Evil pathogenic factors from the patient's body.

When first starting the Medical Qigong Cancer Tone therapy, a patient's practice time should be short. The performing time can be extended gradually with the increase of the patient's physical strength. To bring the Medical Qigong exercises to peak efficiency, a patient should practice a minimum of four hours (including 15 minute breaks), and up to six hours each day. The patient can take a break after half an hour to avoid fatigue.

Through various kinds of breathing and fast walking therapies, Qi can be energized to flow so vigorously through the Conception Vessel that the patients' Yin and Yang is balanced and their Lung Channels are strengthened. In the course of treating the tumor or cancer, True Qi (Zhen Qi) is fostered and the immunity of the body strengthened. Research from China proves that persistent training, vigorous enough to increase a person's heartbeat up to 70-80% of its maximum rate, helps dissolve Blood clots. Other reports state that long distance running can be effectively used to cure cancers. These reports may help explain why fast walking, and breathing methods, are effective for preventing and treating cancer.

Social Oncology—Establishing a Cancer Support Group

In China, cancer patients join support groups to practice Medical Qigong. This form of treatment is called social oncology; it was created by the Cancer Recovery Society for the purpose of supporting human interaction and the recovery of health by cancer patients.

Cancer recovery groups meet daily in parks throughout China, practicing self-healing (in particular, Guo Lin's Cancer Recovery Qigong and Walking Qigong Therapy). After practice, the groups gather together for about an hour to socialize in a nearby tea house. The patients sing songs, tell jokes, laugh, introduce new members, read poems, and tell stories that highlight the possibilities of recovery from cancer. As part of the social meeting, the group regularly sings "Happy Birthday" to each patient who has an anniversary after his or her cancer diagnosis. Laughter becomes a top priority in social oncology, and is considered the strongest medicine for healing.

According to Dr. Roger Jahnke, O.M.D., the advantages of social oncology are three fold: stress reduction, positive reinforcement of hope, and the establishment of deep interpersonal relationships.

1. Stress is reduced through socializing rather than isolating and fretting. The social healing aspect of the patient's recovery program serves as a constant reminder that the physical healing is enhanced when he or she becomes lighthearted and free of worry.
2. Increased hope and faith is achieved through the power of personal testimony. Each day during the social healing session, patients hear stories of close friends whose recovery process proves the benefits of healing from various forms of Medical Qigong.
3. The value of love and encouragement from friends mitigates depression, fear, and worry. Isolation is like a food to cancer; social oncology provides fun, encouragement and a deep, caring interpersonal connection within the recovery group.

Social Oncology within the Hospitals

In several Medical Qigong hospitals in China, when the patients first check-in, they are assigned a support group. The support group consists of previous and current patients, who have survived the same type of cancer as the entering patients.

To assist patients in healing and to give them every emotional advantage during recovery, visitors, phone calls, letters, TV, and newspapers are

forbidden for six weeks; this ensures a controlled environment in which neither family nor friends can adversely affect the healing process (through critical comments or attitudes). Patients are immersed in a support group full of caring, motivated individuals all working towards the same goal. Furthermore, patients who have been there the longest share their success stories, boosting everyone's moral.

The concept of clinical social oncology is based on the belief that the patients' high spirits affect the emotional perspective, and thus mental thinking. These emotional and mental changes alter the physical body. It was recently discovered that the group of breast cancer patients, who participated in the Stanford Hospital Cancer Support Group, lived twice as long as the women who refused to join the group. This difference in longevity was attributed to the love, support, and social aspect of the cancer support group. This recently discovery has given rise to the increase of several support groups in the United States now being established for patients recovering from AIDS, heart attacks, and many other illnesses including several types of cancer.

CANCER RESEARCH

Noted research scientist Feng Lida pioneered cancer research in China by showing that emitted Qi from Qigong masters produced marked changes in cancer cell cultures from mice. Several studies reported the effects of emitted Qi on tumors in animals. The emission of Qi, for example, was reported to inhibit the growth of implanted malignant tumors in mice, but did not destroy the tumors. Encouraged by the results with animals, researchers carried out clinical research on the effects of Medical Qigong on human subjects with cancer.

In one study, 127 patients with medically diagnosed cancer were divided into a Qigong group of 97 patients, and a control group of 30 patients. All patients received drugs, and the Qigong group practiced Medical Qigong for more than two hours a day over a period of 3 to 6 months. Both groups improved, but the Qigong group showed improvements four to nine times greater than the control group for strength, appetite, and weight gain. The Qigong group also did not experience bouts of diarrhea. The phagocytic rate, which is a measure of the immune function, increased in the Medical Qigong group, but decreased in the control group. These cancer treatment results were gathered and compiled from clinical research by Dr. Kenneth M. Sancier, available in the first Appendix of this text.

MEDITATIONS FOR CANCER PATIENTS

The following meditations are frequently used within the Medical Qigong clinic to aid healing. As previously discussed, it takes focused concentration to initiate an energetic transformation. Focused concentration is achieved through proper imagination, visualization and positive affirmation; it is practiced to reprogram the body's energetic cell patterns, and initiate healing.

DIVINE HEALING LIGHT MEDITATION

A very effective Medical Qigong meditation called Divine Healing Light is practiced by cancer and tumor patients throughout China to dissolve and disperse energetic pathogens. This meditation begins as follows:

Begin in a seated posture. Relax, and feel a quiet comfort. Imagine yourself seated on a quiet mountain overlooking the ocean, resting under a clear, dark blue evening sky. At the rim of the ocean, the full moon begins to rise. It continues to ascend until it faces you, suspended in the sky above your head. Slowly the moon begins to shrink, becoming smaller and smaller, yet brighter and brighter until it becomes the size of a small luminous pearl. This brilliant white pearl begins to pulse and expand, as it grows it opens to form a large orb, vibrating with divine power. From the center of the divine power flows unconditional love, healing, and compassion.

Breathe in this vibrant, healing light; allow it to penetrate deep into your body, permeating every cell, illuminating and dispersing all illness. Open fully to the divine healing. Feel the love and compassion enveloping you, and penetrating all the diseased areas of your body. Continue to breathe the healing energy in through your nose and exhale out through your mouth (imagining

all the unclean energy descending into the ground). Continue this breathing pattern until all the negative energy has been expelled and replaced with divine love and healing light.

PULLING OUT THE PAIN MEDITATION

This meditation is an effective treatment prescription for treating many illnesses, including cancer and tumors. The goal is to eliminate all toxic belief structures that stand in the way, and sabotage the patient's healing. Gentle acceptance of the illness and emotional pain opens the pathway to understanding and unveiling hidden traumas. Force does not work in trying to change the tumor or cancer energetic patterns. Only honesty, respect, tenderness, and understanding will begin the healing process. As pain and suffering are allowed to surface into consciousness, the immune system is able to recognize diseased cells, and can mobilize an army of immune cells. These are then able to effectively identify, dissolve, and remove any tumors and disease.

The doctor instructs and guides patients through this meditation matching the rhythm of the words, to the patients' exhalations. Patients draw their painful memories and traumas out of their body in the form of dark smoke; they then separate the distilled wisdom and knowledge from this dark cloud, reabsorbing the healing light into every pore and cell in their body. The dark cloud then is released with the help of an angelic being who severs the energetic cord(s) that still attach the patients to their pain and suffering. The doctor assists the complete severance by clapping his or her hands as the patients visualize the "Sword of Truth" (held by this holy being), severing the dark energetic cord(s). The sword of truth represents the patients' intent to regain their power by letting go of their attachment to their illness. This attachment created very real energetic cords that bound the patients to their painful memories and toxic emotions. Severing these cords, or cord, symbolizes the end of the patients' investment in their disease, and the beginning of true healing. All the patients' pain and despair is released, as the black cloud ascends into the Heavens, and into the hands of God (or a higher power, in accordance with the belief structure of the patients). As the cloud reaches the first wave of love and compassion emanating from God (or a higher power), a mighty explosion transmutes the black despair and pain, into divine healing light. The doctor then assists the patients in accepting this healing, loving light back into their body, to experience, perhaps for the first time in their lives, true forgiveness and a state of grace.

1. Begin by sitting comfortably in a chair, with both feet on the floor, hands resting on the thighs, eyes closed, tongue on the upper palette. Breathe naturally through the Lower Dantian.
2. Focus your attention on the Yellow Court area below the diaphragm where you store painful memories and traumas. Imagine opening up this area to release the toxic energy out of your body as a stream of dark steam releasing from a pot.
3. As the dark steam flows out of your body you release feelings and memories of guilt, anger, rage, humiliation, abandonment, degradation, rejection, insecurity, and sorrow. These toxic emotions have, until now, prevented you from healing through creating a deep distrust of yourself and others.
4. Focus your attention on this energetic cloud, and begin separating the pain and hurtful memories from the knowledge and wisdom gathered from these experiences. Visualize this knowledge and wisdom in the form of golden, white, and silver light energy gathering on the right side of the room. Continue to drain the dark cloud of misery and pain, now occupying the left side of the room, until you have extracted all the new insights from it. As you do so, you notice the dark cloud becoming heavier and darker.
5. Focus on the right side of the room. Through you intention, begin to inhale and imagine this bright, illuminating energy flowing back into your body. Absorb this knowledge and wisdom gathered from past experiences, void of any feelings of hurt, pain, or judgement, into every cell of your body. This distilled knowledge and wisdom empowers you to heal from

your wounds on a physical, mental, emotional, and spiritual level.

6. Next focus your attention on the dark black cloud containing all your pain and suffering. Imagine an angelic being, righteous and holy holding a "Sword of Truth" standing by your side, ready to sever the dark energetic cords still connecting your physical body to this dark cloud of despair. The sword descends and severs the cords (the doctor claps his or her hands at this moment).
7. The cloud of darkness begins to float up, through the ceiling, through the sky into space. Far in the distance you begin to perceive God, or a higher power, emanating waves of compassion, love, and mercy descending towards the Earth. One of the waves touches the ascending dark cloud of hurt and pain, exploding it into a brilliant light. The cloud is immediately transmuted into fluorescent crystal blue drops of light. This pure, clean energy descends from the Heavens like a gentle rain. Breathe in this crystal blue healing energy, let it penetrate deeply into every pore, every tissue and cell, saturating your body completely. Feel the light cleansing, healing, and radiating throughout your being.

SUMMARY

Cancer is defined by Traditional Chinese Medicine as, "an obstruction of Qi and Blood circulation resulting in stagnation." The root cause for cancer is the breakdown and stagnation of the patient's Yuan Qi. Once cancer becomes established within the patient's body, or metastasizes, it is difficult to heal.

In order for cancer to form, it must elude the body's immune system, undergo many divisions, and produce countless generations of cells without resistance. By the time the cancer cells have formed into a cluster mass, a fixed energetic pattern has been established to support its existence and survival.

Only when the patient's Yuan Qi is returned to its original state, can the body begin to heal itself. Medical Qigong Cancer treatment methods strengthen the True Qi which in turn strengthens and cultivates the Yuan Qi. In this manner, the body is returned to its natural state of Yin and Yang balance.

It is the author's hope that these effective methods of treating cancer will soon be available to the American public. To this end, I have established a three-year master's and plan to offer a five-year doctorate program in Medical Qigong Science at the Five Branches Institute, College of Traditional Chinese Medicine, in Santa Cruz, California.

TREATING TUMORS AND CANCER WITH MEDICAL QIGONG THERAPY

The following are several Medical Qigong techniques and treatment modalities, currently used in China, to treat different types of energetically induced cysts, tumors, and cancers. It is advisable to accompany the prescriptions with various herbal prescriptions.

BRAIN TUMORS

A brain tumor is a generic term used to describe any intracranial mass, which includes: neoplastic, cystic, inflammatory (abscesses), or syphilitic.

ETIOLOGY

There are many causes for intracranial tumors. The most common cause is Kidney Yin (Water) failing to wash over the brain to disperse the pathogens. This condition can be caused by Excess Liver Fire dissolving the body's Kidney Water.

SYMPTOMS

Intracranial tumors produce symptoms primarily by two mechanisms: the infiltration and destruction of the normal brain tissue; or the tumor mass affecting the surrounding tissue, which causes edema, thus increasing the intracranial pressure.

General symptoms include headache (due to intracranial pressure), changes in the retina, and vomiting (without nausea). Additional symptoms include mental and emotional changes such as dullness, giddiness, or epileptiform convulsions.

TREATMENT

1. The doctors first step is to analyze the syndrome and the patient's emotional outlook.

When treating brain tumors, the growth of the disease must first be stopped. Check the patient's external living conditions, and do a psychological profile to determine any detrimental patterns.

2. Dredge and disperse toxic Heat out of the patient's Yang channels. Remove any Excess Liver Fire by drawing it out the Liver organ; then dredge the patient's Liver Channels, dispersing toxins out through the Lv-3 points.
3. The doctor must reverse the process of tumor development to dissolve the tumor. Instruct the patient to visualize energy from the Lower Dantian rising up to the tumor and transforming the mass back into Qi. The tumor growth must be reversed by first converting the solid tumor into soft tissue, then into fluid Qi that is then dispersed.

   In cases of cranial thrombosis, tumors must be dissolved slowly; otherwise other tumors will be created. The tumors must be softened, then slowly dispersed to avoid any recreation of the energetic channels' dysfunctions.
4. Extend Qi into the patient to reinforce the Kidneys' Qi by extending Qi into the patient's feet via the brain tumor point, Shihmein, at the bottom of the heels (Figure 54.4). Next, lead the patient's Kidney Water up into the brain to rinse over and slowly dissolve the tumor.
5. Finally, regulate and balance the patient's Yin and Yang energy.

PRESCRIPTIONS AND HOMEWORK

1. Have the patient practice the healing sound "Duo" (10 times in a straight and 10 times descending/ascending tone) five times a day.
2. Assign tonifying exercises for the Kidneys and Heart.
3. Prescribe herbal teas to enhance the patient's Kidney Yin.

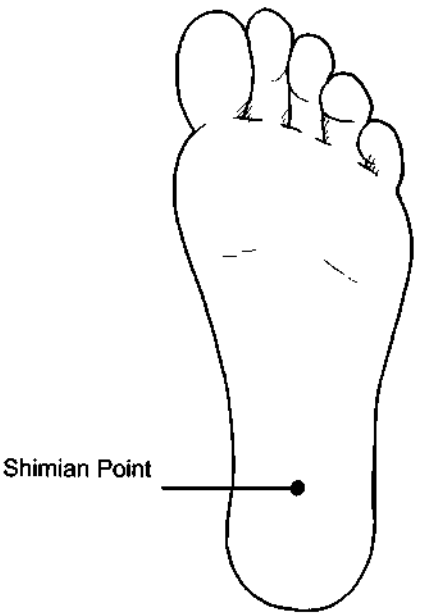

Figure 54.4. The Qigong doctor will emit Qi into the patient's "Brain Tumor" point (also called the Shimian, meaning insomnia point) located at the bottom of the patient's Heel.

BREAST CANCER

Mammary cancer is one of the most common types of malignant tumors in women; it is considered a malignant neoplasm of the breast.

ETIOLOGY

There are multiple factors associated with breast cancer. These factors can be categorized under genetic family factors, hormonal factors, dietary factors, environmental factors, and benign breast disease. Heredity can play an important role, especially if the patient's mother (or close relative) had bilateral breast cancer diagnosed prior to menopause. Also, a history of chronic breast disease (especially epithelial hyperplasia), or obesity can predispose the patient to breast cancer.

SYMPTOMS

Symptoms consist of hard lumps which lack mobility, and progressively increase in size. The hard lumps may be concave, convex, or protrude; or the nipple may be inverted. Breast cancer is usually related to stagnation of the Liver's Qi, stasis of Blood, Phlegm and Toxic Heat, as well as weak Kidneys. The emotional components which lead to breast cancer are suppressed grief, worry, sorrow, and depression.

TREATMENT

1. Purge and eliminate the stagnation from the breast tissue (Figure 54.5).
2. Subdue the Rebellious Qi.
3. Clear the Liver and tonify the Kidneys. When treating breast cancer, the doctor should use the Vibrating Palm in conjunction with projected Tone Resonation (projecting both vibration and the "Ni" tone resonation into the cancerous area).
4. Tonify the patient's Conception and Thrusting Vessels, and end with the Microcosmic Orbit regulation (Fire Cycle).

UTERINE CANCER

Uterine cancer is considered a malignant neoplasm of the uterus.

ETIOLOGY

The etiology of uterine cancer is unknown. Possible causes of the disease may be:

- chronic stress
- toxins
- suppression of emotions
- pathological changes of the endometrial hyperplasia, or
- cervical carcinoma spreading onto the uterus.

SYMPTOMS

A uterine carcinoma is generally more common in women after menopause, roughly 75% of uterine cancers occur in postmenopausal women, 15% peri-menopausal women and 10% of menstruating women. The main clinical manifestations include pain in the lower abdomen, waist and thighs, abnormal uterine bleeding with a bloody, purulent discharge.

TREATMENT

One Medical Qigong therapeutic technique used in China to treat uterine cancer is as follows.

1. Purge the diseased area of stagnant Qi using the Thunder Palm technique in conjunction with the Vibrating Palm technique.
2. Project the sound "Yu" into the uterus to disperse Heat from the cancer cells.
3. Disperse Excess Heat from the patient's Liver and uterus, leading the Toxic Qi out the patient's body via the right Gall Bladder

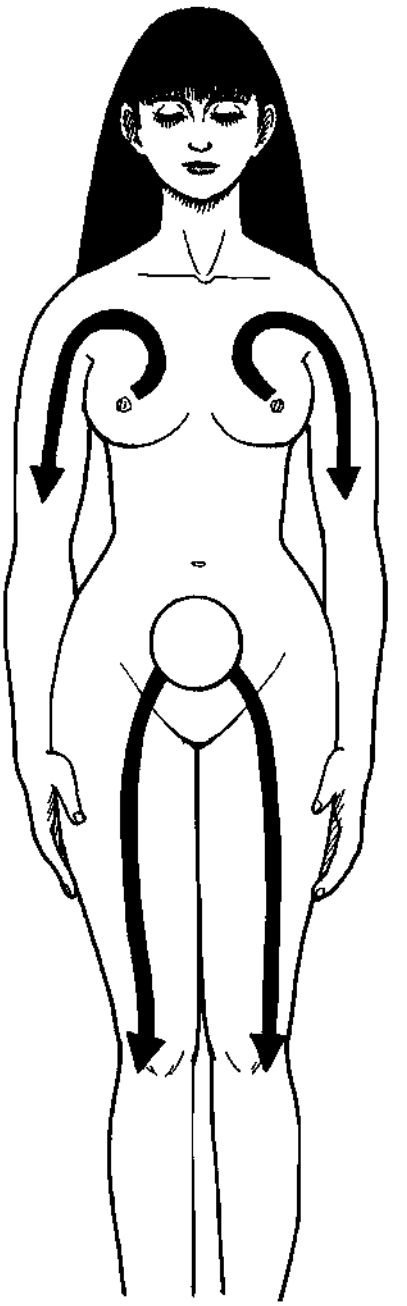

Figure 54.5. After Purging the pathogenic Qi from the patient's upper body, the Qigong doctor continues to disperse the patient's Toxic Qi from her lower abdomen, leading it down her legs and out her St-36 points.

Channel.

4. Fill and tonify the patient's Lower Dantian and Kidneys with Qi. Circulate the energy through the Microcosmic Orbit to improve Qi and Blood circulation through the Governing and Conception Vessels.

PRESCRIPTIONS AND HOMEWORK

The Conception Vessel moves Qi in the Lower Burner and uterus; it is the primary Vessel used in treating uterine and cervical cancer. Sexual activities are therefore prohibited from the start of the treatments, until treatment is no longer needed.

1. Have the patient practice the Descending the Yang and Ascending the Yin Technique (see Chapter 41), ending with the healing sound "Yu" for 24 breaths, 9 times a day.
2. Prescribe the Fast Exhaling Breathing Method along with the Cancer Walking methods for treating Kidney disease (see Chapter 15).
3. Have the patient practice the method of Taking in the Blue Qi, three times a day for 15 minutes each session, to strengthen the Kidneys.
4. Have the patient practice the Filth Dispelling meditation, while focusing on her uterus. This meditation is practiced as follows:
   a. From a sitting posture, with the eyes closed, and the body relaxed, place the tongue up against the upper hard palate, behind the teeth.
   b. Breathe naturally and evenly.
   c. Imagine Qi whirling in through the upper portion of the uterus, circulating clockwise, building momentum as the energy flows downward to the base of the uterus.
   d. Once the energy has reached just above the cervix area, imagine the whirling Qi absorbing the noxious Heat and Toxic Qi from the uterus, transforming it into wind, and dispelling it out the vagina. Repeat this sequence 10 times.
   e. Next, gently close the vagina and anal sphincter, then inhale, and imagine the Qi flowing into the body through the vagina. As this energy flows into the uterus and Lower Dantian area, it transforms into wind. This wind circulates in a counterclockwise direction, spiraling up the body, through the Thrusting Vessel and exits the body through the mouth with each exhalation. Repeat this visualization 10 times.
   f. Finally, focus attention on the Lower Dantian, imagine the Qi returning to its origin, and rub the abdomen 36 times in a clockwise direction to end the prescription.

CERVICAL CANCER

Cervical cancer is considered one of the most common malignant tumors in China. It is considered a malignant neoplasm of the cervix of the uterus, and can occur at any age.

ETIOLOGY

Cervical cancer is suspected to be an oncogenic papilloma virus that is transmitted sexually. Risk factors include:

- sexual intercourse at an early age,
- multiple sexual partners and promiscuous male sexual partners (especially those whose previous partner had cervical cancer),
- serious cervical lacerations caused from the penis being too long, or the insertion of foreign objects,
- unsanitary sexual relationships,
- closely spaced births, and
- a family history of cervical cancer.

Excessive sexual activity predisposes young teenage girls to cervical cancer, because, with the onset of ovulation and the changes in vaginal PH, active squamous metaplasia is taking place in the cervix. During this time of cellular immaturity and vulnerability, a carcinogen is most likely to have an influence on the squamous epithelium; this can predispose the teenager girl to cervical cancer later on in life.

THE DEVELOPMENT OF CERVICAL CANCER

There are two main types of cancer of the cervix. The squamous cell carcinomas make up 85-90% of cervical cancer, the rest (a small 10-15%)

are developed from a malignant adenoma arising from a glandular organ known as a adenocarcinoma.

Cervical cancer begins with the growth of abnormal precancerous cells and tissues called dysplasia. Dysplasia is first detectable in the squamous epithelium of the cervix (the muscle lining of the cervix), and spreads to create a tumor called a cervical intraepithelial neoplasm (CIN). The cervical intraepithelial neoplasm progresses through three levels of severity, from mild, to moderate, to severe. At the severe level of CIN, the precancerous growth turns malignant; it becomes a carcinoma in situ (localized). If left untreated, the carcinoma progresses through four more stages of development, each of which is subdivided into two grades of severity. These grades indicate the location and spread of the carcinoma. The four stages and their subdivisions are described as follows:

In the beginning stages of the disease, cervical dysplasia is characterized by three stages of abnormality and severity (CIN-1,-2,-3), which later progress onto four stages of invasive carcinoma (Stages I through IV).

- CIN-1: Corresponds to a mild condition of dysplasia.
- CIN-2: Corresponds to a moderate condition of dysplasia.
- CIN-3: Corresponds to a severe condition of dysplasia, and carcinoma (in situ). The cancer, however, is found only in the layers of the cells lining the cervix, and has not yet extended deeper into the tissue lining.
- Stage I-A: Corresponds to a microinvasive carcinoma. The cancer is beginning to spread from the lining of the cervix into the deeper connective tissue.
- Stage I-B: Corresponds to an invasive carcinoma confined to the cervix. The cancer has now spread from the lining of the cervix into the deeper connective tissues.
- Stage II-A: Corresponds to a tumor extending beyond the cervix, into the upper third of the patient's vagina, but is still inside the pelvic area.
- Stage II-B: Corresponds to a tumor extending beyond the cervix, into the loose connective tissues around the patient's uterus (parametrium), but is still inside the pelvic area.
- Stage III-A: Corresponds to a tumor extending into the lower third of the patient's vagina.
- Stage III-B: Corresponds to a tumor extending into the patient's pelvic wall. At this stage, the cancer may be blocking the ureters (responsible for carrying urine from the Kidneys to the Bladder).
- Stage IV-A: Corresponds to a tumor extending into the patient's Bladder or rectum.
- Stage IV-B: Corresponds to a tumor extending into the patient's Liver or Lungs.

SYMPTOMS

Clinical symptoms include bleeding after sexual intercourse and between periods, abnormal bowel movements, or fatigue. Bleeding may also be noticed after severe exertion or straining during defecation. As the disease develops, the leukorrhea (vaginal discharge) may become filthy and mixed with blood, or foul and mixed with sloughed pieces of Body Fluid or tissue. Additional symptoms include lumbar, sacral and abdominal pain, Bladder irritation, frequent and urgent urination, blood-tinged vaginal discharge, unilateral lymphoedema, and unilateral ureteral obstruction (this indicates a very advanced stage).

TREATMENT

When Righteous Qi is increased through Medical Qigong therapy and prescription homework, the energy feeding the patient's cancer begins to decrease.

One Medical Qigong therapeutic technique used in China to treat cervical cancer is as follows:

1. Purge the diseased uterine area of pathogenic Qi using the Thunder Palm technique in conjunction with the Vibrating Palm to disperse the stagnation.
2. Use the "Yu" sound Qi projection into the uterine and cervix area to disperse Heat from the cancer cells.

3. Disperse the Excess Heat from the patient's Liver and cervix areas, leading the Toxic Qi out the patient's body via the right Gall Bladder Channel.
4. Fill and tonify the patient's Lower Dantian and Kidneys with Qi. Circulate the energy through the Microcosmic Orbit to improve Qi and Blood circulation through the Governing and Conception Vessels.

PRESCRIPTIONS AND HOMEWORK

The Conception Vessel moves Qi in the Lower Burner and uterus, and is the primary vessel used to treat uterine and cervical cancer; therefore, sexual activities are prohibited from the start of the treatments, until treatment is no longer needed.

The prescriptions and homework required for cervical cancer treatment are exactly the same exercises that are used for the treatment of uterine cancer.

PROSTATE CANCER

Prostate cancer is considered a malignant neoplasm, and is usually an adenocarcinoma of the prostate gland. It is the major type of cancer in males. Prostate cancer occurs in less than 1% in men under 50. Men with a family history of prostate cancer are three times more likely to develop it then the general public. Many prostate cancers remain dormant, but once awakened, can become life-threatening.

ETIOLOGY

The etiology of prostate cancer is unknown. Speculations suggest that prostate cancer can be related to an imbalance between male and female hormones. From a Western Medical perspective, the carcinogenesis is a multistep accumulation of genetic lesions. These lesions may result in uncontrolled cellular proliferation, a decrease in cellular death or an apoptosis, invasion, and the metastatic spread of the disease.

From a Traditional Chinese Medical perspective, prostate cancer is due to Excess Liver Fire and Kidney Deficiency. The suppression of anger and fear, as well as a diet consisting of a high alcohol intake, or consumption of too many hot spicy foods, may also cause, or contribute to prostate cancer.

SYMPTOMS

In the early stages there are no symptoms; however, as the disease progresses the inflamed prostate gland impedes urination and results in outflow obstruction, preventing the Bladder from emptying completely. Dull pain is experienced around the external genitals and Bladder. There is frequent burning, unfinished and dripping after urination with white discharge. Also, in some cases, there will be sexual function disorders (an inability to attain erection) as well as sciatica-like symptoms with pain radiating downward to the perineum and anus.

If the prostate is hard and firm, it indicates cancer; if the prostate is large and swollen, it indicates an infection. Inflammation of the prostate can be divided into acute and chronic conditions.

In acute prostatitis caused from Damp Heat in the Lower Burner, symptoms include pain and discomfort in the genital and Bladder areas, fever, and chills.

In chronic prostatitis, symptoms include dull pain in the urogenital area, discharge from the penis, discomfort during sexual intercourse, and frequent urination (especially during the night).

TREATMENT

One of the Medical Qigong therapeutic techniques used in China to treat prostate cancer is as follows.

1. With the patient supine, begin to purge the diseased prostate area of pathogenic Qi using the Thunder Palm technique in conjunction with the Vibrating Palm to disperse the stagnation.
2. Next, use "Yu" sound projection into the prostate area to disperse the Heat from the cancer cells.
3. Disperse Excess Heat from Liver and pathogenic Qi from the prostate, out of the patient's body via the right Gall Bladder Channel.
4. Fill and tonify the patient's Lower Dantian and Kidneys with Qi, and circulate the energy through the patient's Microcosmic Orbit to improve Qi and Blood circulation within the Governing and Conception Vessels.

PRESCRIPTIONS

Depending on the patient's condition, one or more of the following prescriptions may be given:

1. The "Guo" sound resonation is used to disperse the Liver Fire.
2. The Kidneys' "Yu" sound resonation is used to disperse Toxic Qi from the prostate.
3. Tonification and regulation exercises are prescribed for the Lower Dantian, Spleen, and Kidneys.
4. The following three exercises are used to treat prostate cancer, and were made popular in the West by Dr. Hong Liu.
   a. Sit at the edge of the chair with your feet flat on the floor. The right leg crosses over your left leg. With your left hand grasp the bottom of the right foot.

      Then extend your right hand out in front of the body, palm facing upward, while you imagine releasing toxic energy from your body through the mouth as you exhale. As you inhale, twist your hand as far as possible towards the right side keeping your eyes on the palm, while simultaneously pulling your foot towards the body and contracting the anus and perineum. This opens the Liver Channel and directs Qi into the Kidneys and prostate area.

      After completing the movement, hold your breath for a moment. Imagine Blood and Qi flowing into the prostate area and exhale while returning to the starting position. The exercise is repeated for 18 breaths per each side.
   b. The next exercise begins from a Wuji posture. Bend over as you flex your toes upwards. Hold this position as long as you can before standing erect, focusing on breathing naturally from the abdomen. This movement increases the flow of Qi and Blood into the prostate area. It is important to make sure this exercise is performed slowly. The exercise is repeated 9 times.
   c. This last exercise is done sitting on the floor while facing a wall. Place the balls of your feet against the wall while resting your heels on the floor. Wrap your arms around your bent knees, while keeping the back straight and breathing naturally through the Lower Dantian.

      While inhaling, focus on breathing from the lower abdomen instead of the chest. This causes the Qi of the Thrusting Vessel to stimulate the prostate gland, and increases the flow of Qi and Blood into the prostate area. The exercise is repeated for 18 breaths.
5. The "Filth Dispelling Meditation," is also prescribed, with the patient focusing on his prostate area. This meditation is practiced as follows:
   a. From a sitting posture, with the eyes closed, and the body relaxed, place the tongue up against the upper hard palate, behind the teeth.
   b. Breathe naturally and evenly.
   c. Imagine Qi whirling in through the upper area of the Bladder, circulating clockwise, building momentum as the energy flows down to the prostate area.
   d. Once the energy has reached the prostate, the patient will imagine the whirling Qi absorbing the noxious Heat and filthy Qi from the Bladder and prostate areas, transforming it into wind, which is dispelled out through the penis. The exercise is repeated 10 times.
   e. Next, gently close the anal sphincter while inhaling and imagine the Qi flowing into the body through the penis. This energy flows into the Lower Dantian, becoming transformed into wind. This wind begins circulating in a counterclockwise direction, spiraling up the body, through the Thrusting Vessel and exits through the mouth with each exhalation. This is also practiced for 10 repetitions.

f. Finally, focus the attention on the Lower Dantian; imagine the vital Qi returning back to its origin, while rubbing the abdomen in a clockwise direction to end the prescription.

LUNG CANCER (PULMONARY CARCINOMA)

Lung cancer, also called a "Bronchial Carcinoma," is a malignant Lung tumor that originates in the bronchi. It can also spread to the trachea appearing as an ulcer in the windpipe, a small flattened bump or nodule. It can extend into the body's lymphatic system, as well as into the blood vessels.

The most common type of bronchogenic tumor is the squamous cell or epidermoid (on the airway lining). The oat cell and adenocarcinoma are the next most common.

ETIOLOGY

Squamous cell cancer is usually associated with a history of cigarette smoking and second-hand smoke. Statistically it is the most common of all carcinomas and accounts for 40% of all male deaths. Other chemical carcinogens may cause Lung cancer, especially among workers in industrial and mining areas.

SYMPTOMS

The main clinical manifestations include: chest pain, coughing with scanty sputum (sometimes with blood), pectoralgia, fever, loss of appetite, loss of weight, weakness and breathlessness in the later stages due to a Lung Yin Deficiency.

TREATMENT

Purge the Excess Heat from the patient's Lungs and Liver. Tonify and regulate the patient's Kidneys and Mingmen area, then strengthen the patient's Spleen and Lungs.

PRESCRIPTION AND HOMEWORK

1. Have the patient practice the Dry Crying exercise for a period of 15 minutes twice a day (see Chapter 53).
2. Have the patient practice the Sun and Moon Rotation Technique (see Chapter 41), ending with the healing sound "Shang" for 24 breaths, 9 times a day.
3. Prescribe the Fast to Moderate Exhaling Breathing Method along with the Cancer Stepping Method for treating Lung diseases (see Chapter 15).
4. Have the patient practice the method of Taking in the White Qi, three times a day for 15 minutes each time to strengthen the Lungs.
5. Have the patient practice the method of Taking in the Blue Qi, three times a day for 15 minutes each time in order to strengthen the Kidneys.

LIVER CANCER

The Liver is the most usual site for the metastatic spread of tumors that disseminate through the Blood system. Carcinoma of the Liver is quick in development, high in mortality, and is regarded as one of the common malignant tumors.

ETIOLOGY

The etiology of Liver cancer is unknown. There are speculations suggesting that the following list of items may cause, or contribute, to the creation of Liver cancer:

- exposure to chronic stress and the suppression of anger,
- toxic poisoning (Liver cancer is usually associated with a long history of alcohol, drug abuse and chronic hepatitis), and
- a congenital weakness, with heredity being the predisposing factor.

SYMPTOMS

The Liver may have a single nodule, or multiple nodules. The main clinical manifestations include: distension and severe hypochondriac pain, hemorrhage of the digestive tract, and progressive hepatomegaly (enlargement). Its surface feels irregular on palpation (central depression or umbilications can often be detected).

TREATMENT

Purge the Excess Heat from the patient's Liver and Gall Bladder Channels, then tonify and regulate the patient's Kidney and Mingmen areas. Strengthen the patient's Spleen and Lungs, then regulate the patient's Liver.

PRESCRIPTIONS

1. Have the patient practice the Descend the Yang and Ascend the Yin Technique (see

Chapter 41), ending with the healing sound "Guo" for 24 times, 9 times a day.
2. Prescribe the Fast to Moderate Exhaling Breathing Method along with the Cancer Walking Method for treating Liver disease (see Chapter 15).
3. Have the patient face, or embrace, a tree while practicing the method of "Taking in the Wood Element Qi," but only upon inhalation. With each exhalation the patient should purge the toxic Qi, sending it into the ground. This prescription is practiced three times a day for 15 minutes each time.
4. Have the patient practice the method of "Taking in the White Qi," three times a day for 15 minutes for each session to strengthen the Lungs.
5. Have the patient practice the method of "Taking in the Green Qi," three times a day for 15 minutes for each session to strengthen the Liver.
6. Have the patient practice the method of "Taking in the Yellow Qi," three times a day for 15 minutes for each session to strengthen the Spleen.

ESOPHAGEAL CANCER

Carcinoma of the esophagus is one of the common malignant tumors, caused from a carcinoma of the squamous epithelium of the esophagus. This type of carcinoma is called "Ge Shi" or dysphagia in Traditional Chinese Medicine.

ETIOLOGY

The cause of esophageal cancer is unknown. There is speculation that the following list of items may cause or contribute to the creation of esophageal cancer:

- consumption of foods with a high content of nitrates,
- large quantities of spicy, hot foods, or mouldy food,
- chronically eating too fast, thus irritating the throat,
- strong alcoholic drinks,
- smoking,
- poor oral hygiene, resulting in tooth decay, and
- chronic stress and the suppression of emotions.

There are three types of esophageal cancer that invade the wall of the esophagus.

1. An ulcerous carcinoma of the esophagus that grows towards the outside of the esophagus. Dysphagia (difficulty in swallowing) is not evident in this type of cancer.
2. A tumor which grows in a circular formation. In this type of cancer, the lumen is narrow and easily obstructed.
3. The tumor attaches itself to one side of the esophagus, while the other side is still healthy and can still dilate. In this type of cancer, symptoms of obstruction appear slowly.

SYMPTOMS

More common in men over 40, carcinoma of the esophagus causes pain in the epigastric and sternal area. Swallowing aggravates the symptoms. The main clinical manifestations include the following symptoms:

- enlarged lymph nodes in the neck,
- difficulty in swallowing (dysphagia),
- excessive salivation,
- poor digestion,
- vomiting,
- loss of weight,
- pain in the chest and back, and
- emaciation and weakness.

TREATMENT

Purge the Excess Heat from the patient's throat, Lungs and Liver area. Tonify and regulate the patient's Kidney and Mingmen area, then regulate the Qi of the patient's esophagus, rooting it within the Lower Dantian.

PRESCRIPTIONS

1. Have the patient practice the "Dry Crying" exercise for a period of 15 minutes twice a day (see Chapter 53).
2. Have the patient practice the healing sound "Shang" for 24 breaths, 9 times a day (see Chapter 40).
3. Prescribe the Fast to Moderate Exhaling Breathing Method along with the Cancer Walking method for treating Lung disease (see Chapter 15).

4. Have the patient practice the method of "Taking in the White Qi," three times a day for 15 minutes for each session to strengthen the Lungs.

STOMACH CANCER

Carcinoma of the Stomach is regarded as one of the common malignant tumors. It is sometimes categorized as a carcinoma, lymphoma or sarcoma.

ETIOLOGY

The etiology for Stomach cancer is unknown. Speculations suggest exposure to chronic stress, and a suppression of emotions, may cause, or contribute to this disease. There is also an association between the development of gastric cancer and previous partial gastrectomies for benign diseases.

SYMPTOMS

The symptoms of Stomach carcinoma often do not appear until they have developed to the middle and late stages. Most common in men over 40, carcinoma of the Stomach causes a continual pain and burning sensation in the epigastric and sternal area, which is usually aggravated by swallowing. The main clinical manifestations include: shallow complexion, lack of appetite, loss of weight, extreme anemia, blood in the stool, debility, vomiting of partially digested food, and sometimes Blood that looks like coffee-grounds. The Liver may also be enlarged with nodules.

TREATMENT

Purge the Excess Heat from the patient's Stomach, Liver and Gall Bladder Channels, then tonify and regulate the patient's Heart and Spleen. End by regulating the patient's Kidney and Mingmen areas.

PRESCRIPTIONS

1. Have the patient practice the Descend the Yang and Ascend the Yin Technique (see Chapter 41) ending with the healing sound "Dong" for 24 times, 9 times a day (see Chapter 40).
2. Have the patient practice the method of "Taking in the Yellow Qi," three times a day for 15 minutes each time in order to strengthen the Spleen.
3. Have the patient practice the "Taking in the Red Qi," three times a day for 15 minutes each session to strengthen the Heart.

PANCREATIC CANCER

Carcinoma of the pancreas is regarded as one of the common malignant tumors. Statistics state that 22% of deaths from gastrointestinal cancer are due to cancer of the pancreas.

ETIOLOGY

The etiology for pancreatic cancer is unknown. Speculations suggest cigarette smoking and diet (in particular, a high intake of fat and/or meat) may cause, or contribute to the cancer. Recent investigations have identified a number of factors that may also contribute to the cause of pancreatic cancer, including: environmental factors, surgical or associated medical factors, genetic factors, and occupational exposures to toxins.

SYMPTOMS

This type of cancer is more common in men between 50 and 70. A carcinoma of the pancreas causes pain in the epigastric area, which starts as a dull ache and usually becomes aggravated by lying down. The main clinical manifestations include dyspepsia, diarrhea and constipation, loss of weight, nausea, vomiting and fatigue.

The symptoms of pancreatic cancer can sometimes vary in accordance to its exact location. The head of the pancreas is close to the duodenum, while its tail reaches to, and energetically connects with, the Spleen. The middle of the pancreas lies horizontally across the upper aspect of the abdomen.

1. Carcinoma of the Pancreas's head has as for its main symptom jaundice, due to the common bile duct of the Gall Bladder becoming obstructed. This obstruction causes the bile to back flow into the Liver and thus contaminates the Blood. This causes both the Gall Bladder and Liver to swell. As the amount of bile and Blood increases, it causes the skin, mucous membrane and sclera to become yellow, and the urine to turn brown. During the later stages, the skin color changes from a yellowish color to orange or dark yellow.
2. Carcinoma of the Pancrea's body has for its

main symptoms sharp abdominal pain and swelling. The abdominal pain reacts to the compression of the abdominal cavity nerve. This type of pain can occur sporadically, radiating to the patient's shoulder and back. The patient will notice this type of pain becoming aggravated when sitting up or lying down. Bending forward, however, can ease the pressure on the celiac nerve plexus and reduce the pain.

3. Carcinoma of the Pancrea's tail usually does not have detectable, early symptoms. At times, it can only be discovered when the tumor has metastasized to the peritoneum, Lungs, bones or other organs. Once the tumor has developed to sufficient size, the manifestation of symptoms include anorexia, fatigue, and loss of body weight.

TREATMENT

Purge the Excess Heat from the patient's pancreas, then dredge the Stomach, Liver and Gall Bladder Channels. Next, tonify and regulate the patient's Heart and Spleen, then regulate the patient's Kidney and Mingmen areas.

PRESCRIPTIONS

1. Have the patient practice the Descend the Yang and Ascend the Yin Technique (see Chapter 41), ending with the healing sound "Dong" for 24 times, 9 times a day (see Chapter 40).
2. Have the patient practice the method of "Taking in the Yellow Qi," three times a day for 15 minutes each session to strengthen the Spleen.
3. Have the patient practice the "Taking in the Red Qi," three times a day for 15 minutes each time in order to strengthen the Heart.

COLON AND RECTUM CANCER

Carcinoma of the Large Intestine or rectum is regarded as one of the common malignant tumors of the digestive tract.

ETIOLOGY

It has been long accepted that colorectal cancer is caused, or promoted, by environmental factors, especially diet. It is suspected that carcinogens are present in the patient's feces.

Also, chronic ulcerative colitis is considered a predisposing factor for colorectal cancer. The following chronic diseases are believed to be related: benign tumors of the colon and rectum (especially frequently occurring Large Intestine polyps), and chronic colitis (especially chronic amoebic dysentery and chronic ulcerative colitis).

SYMPTOMS

Colorectal cancer is more common in patients over 50 years of age. A carcinoma of the colon causes pain in the lateral abdominal area, which also may be umbilical. The main clinical manifestations include a sudden change of bowel habit (constipation or diarrhea), loss of weight, fatigue and Blood in the stool.

Large Intestine cancer can be divided into two quadrants of right and left intestinal dysfunction.

- Cancer on the right half of the Large Intestine is measured from the cecum to the right half of the transverse colon. The early symptom of this disease is dull pain and discomfort within the right epigastrium, or lower abdominal area. As the disease progresses, the pathological changes of the tumor initiate poisoning symptoms which appear as: weakness of the body, poor appetite, loss of weight, and anemia. In the midterm, or late stages, the patient can sometimes feel the tumor on the right side of their abdomen (located where the right Large Intestine stores food residue from the Small Intestine).
- Cancer on the left half of the Large Intestine is measured from the center of the transverse colon to the junction of the sigmoid colon and rectum. Symptoms of cancer in the left half of the Large Intestine appear earlier because the frequency of defecation increases with mucus and Blood in the stool. Moreover, because the narrow opening of the Large Intestine is now occupied by the tumor, it is difficult for the fecal matter to pass through, causing inflammation, as well as alternating diarrhea and constipation. If the tumor continues to grow, the intestinal cavity can be clogged, causing abdominal distention and toxicosis of the whole body.

TREATMENT

Purge the Excess Heat from the patient's Large Intestine and rectum area, purging and dredging the toxic Qi out the body and down the Stomach, Liver and Gall Bladder Channels. Next, tonify and regulate the patient's Kidney and Mingmen areas, emitting Qi through the soles of the patient's feet. End with regulating the patient's Fire and Water Qi through the Fire Cycle of the Microcosmic Orbit.

PRESCRIPTION AND HOMEWORK

Have the patient practice the "Filth Dispelling Meditation," focusing on the Large Intestine and rectum area. The meditation should be practiced as follows.

1. Begin from a sitting posture, eyes closed, body relaxed, with the tongue placed up against the upper hard palate, behind the teeth.
2. The breathing should be natural and even.
3. Imagine Qi whirling in through the upper orifice of the Stomach, circulating clockwise through the Small Intestine, building momentum as it flows to the Large Intestine.
4. Imagine the whirling Qi driving through the colon. As it moves through the colon, the whirling Qi begins absorbing the noxious Heat and filthy Qi from the Large Intestine, transforming it into wind, and dispelling it out the anus. This is practiced for 10 repetitions.
5. Next, gently close the anal sphincter while inhaling; imagine the Qi in the lower abdomen again becoming transformed into wind. This wind begins circulating in a counterclockwise direction, spiraling up the body, through the Stomach, and is expelled out the mouth. This is also practiced for 10 repetitions.
6. Finally, focus the attention on the Lower Dantian; imagine the vital Qi returning back to its origin, and begin rubbing the abdomen clockwise to end the prescription.

Chapter 55
Qi Emission Therapy for Radiation and Chemotherapy

The purpose of Cytotoxic treatments (radiation and chemotherapy) is to kill the dividing cells responsible for the formation of the tumor mass. The well-known side effects of these types of therapy are loss of hair, loss of appetite, nausea, vomiting and damage to the patient's skin and gastrointestinal tract. When facing radiation and chemotherapy, the damage to the patient's immune system, although less obvious, is the major concern for the Qigong doctor. The cure of the cancer inevitably lies in activating and increasing the function of the immune response, so that it can recognize and eliminate the malignant tissue.

In China, Medical Qigong Therapy is commonly prescribed as an adjunct to both radiation and chemotherapy. The value of Medical Qigong Therapy is that it is very useful in reducing the harmful side effects caused by both radiation and chemotherapies, as well as enhancing the patient's immune system. Both radiation and chemotherapy assist the body in weakening a pathogenic cluster, but do not completely kill all of the tumor or cancer cells. That function is still left to the patient's immune system (which has consequently been weakened by the radiation or chemotherapy). Because Medical Qigong treatments, prescriptions and meditations enhance the body's immune system, its utilization as a adjunctive therapy is paramount.

Medical Qigong Therapy and Radiation Therapy

In most cases, radiation is much safer than chemotherapy because it can be directed into one specific area of the patient's body. However, it may also cause scarring that can interfere with the patient's internal organ function. Although radiation therapy is strong, its effect on the patient's body can be corrected by the Qigong doctor with dredging, purging, dispersing and tonifying techniques. The tissue damage left after radiation therapy should be rectified by dredging, purging and dispersing the afflicted area first. Then, after the toxic Heat has been purged, begin to tonify the patient's supporting organs and tissues surrounding the treatment area.

Sometimes the harmful side-effects of radiation therapy can be avoided by giving the patient Resonant Sound Therapy. In order to alleviate the patient's toxic Heat and pain, it is important for them to practice the "She" sound to cool the tissues after radiation treatments. After the organs have been sufficiently cleansed, the doctor may then tonify the patient's tissues, as well as the Wei Qi Fields, which have been damaged by the radiation therapy.

Medical Qigong Therapy and Chemotherapy

All forms of chemotherapy are cell-killing agents that damage the DNA and injure actively dividing cells, including those of the body's immune system. The tissue damage after chemotherapy is extremely extensive; the white blood cells decrease, causing secondary infections. Unlike radiation therapy, which is generally isolated to specific areas of the patient's body, chemotherapy affects all of the body's internal organs.

When treating patients who have undergone chemotherapy, it is important for the Qigong doctor to dredge, purge and disperse all the patient's Yin and Yang organs. As with radiation therapy, Sound Resonation Therapy is also mandatory in alleviating the patient's pain.

It is important for the patients to practice the "She" sound to cool the tissues after chemotherapy treatments. Specifically, cancer patients should pronounce the "She" Healing Sound

therapy several times a day when their blood count is low, after both chemotherapy or radiation therapy. The sound "She" is pronounced six times. Its high pitched sound is in the straight tone, and its low pitched sound is in the dropping and rising tone. This sound is dropped and replaced by the sound "Ha," or the sound for the specific internal organ, as soon as the red and white blood count reaches a normal level.

After pronouncing the sound "Ha" for a certain period of time, add the sounds for the specific internal organs that have been affected (for example, add "Shang" for a patient with Lung cancer, and "Guo" for a patient with Liver cancer, etc.).

When treating the patient, after the diseased organs have been sufficiently cleansed, the doctor may then tonify the patient's Blood, Jing and tissues, as well as their energetic fields, which have been damaged by the chemotherapy.

RELIEVING SYMPTOMS ASSOCIATED WITH RADIATION AND CHEMOTHERAPY

After receiving radiation or chemotherapy, patients may suffer from several internal complications due to the severe organ and tissue trauma caused by these therapies. The following are six common problems resulting from radiation and chemotherapy.

1. A gastrointestinal infection can result from both radiation and chemotherapy, which have a tendency to burn up the body's Yin. This frequently results in causing Rebellious Qi, which is accompanied by such symptoms as nausea, vomiting, and poor appetite. Treat by tonifying the patient's Stomach Yin by prescribing herbs, and use Jing Point Therapy to quiet the digestion by tonifying Pc-6, St-36 points, as well as the Ear Shenmen points.
2. An infection of the Large Intestine can occur from the accumulation of toxins in the Lower Burner creating Damp Heat Symptoms (caused from radiation and chemotherapy). These toxins can cause abdominal pain, constipation or diarrhea with bloody mucous. Treat by tonifying the patient's Yin to prevent loss of Body Fluids (also give astringent herbs), and use Jing Point Therapy to stop any internal bleeding, by tonifying St-25, St-36, St-37, St-38, LI-4 and LI-11 points.
3. A Urinary Bladder infection can be caused by both radiation and chemotherapy that have a tendency to create Damp Heat in the Lower Burner. Damp Heat in the Lower Burner can result in cloudy, bloody and scanty urination, with a feeling of an urgency to urinate but an inability to do so. To treat, use Jing Point Therapy and tonify Sp-6, Sp-9, CV-2, CV-3, Bl-23 and Bl-29 points.
4. Edema in the limbs can occur from both radiation and chemotherapy that have a tendency to create Wind Damp and Deficiency, which leads to an accumulation of Body Fluids in the extremities. Treat by tonifying the Spleen and draining the body of Dampness. Use Jing Point Therapy to tonify Sp-6, Sp-9, Lu-7, LI-4, and Bl-20; also prescribe herbs.
5. A diminished white blood cell count can be caused by radiation and chemotherapy and can lead to secondary infections. Treat by tonifying the patient's Blood and Jing, and prescribe herbs.
6. Pneumonia can be caused by radiation and chemotherapy that have a tendency to cause damage to the Lungs. When both the Lung Qi and Yin Qi are damaged, pneumonia can result. Treat by tonifying the patient's Yin and Lung Qi, and prescribe herbs to enhance the immune system.

Chapter 56
Qi Emission Therapy For Surgery

Medical Qigong Therapy is useful for treating patients before, during and after surgery. Qi emission can be used to reduce the patient's bleeding, enhance the immune system, minimize the risk of infection, strengthen the body, and to accelerate the recovery rate. Medical Qigong modalities are involved in preoperative therapy, surgery, postoperative therapy, follow-up therapies and remedial prescriptions.

Medical Qigong and Preoperative Therapy

Although Medical Qigong Therapy has had incredible results in healing and in stopping the progression of certain diseases, it is not a "cure-all." As with other clinical modalities, it has its own limitations. Currently, conventional medicine only utilizes three modalities for treating tumors and cancer; these include surgery, radiation and chemotherapy. In the healing process, undergoing surgery is sometimes unavoidable, and should never be viewed by the patient as a defeat, but only as a necessary step in the healing transition.

Having to face surgery should not be viewed as a negative reflection of a Qigong doctor's healing potential, nor as a patient's inability to heal. Surgery should be viewed as a necessary life saving intervention, that can firmly establish the patient on the road towards health and recovery. It is a positive affirmation of the patient's commitment to getting well and taking responsibility for the healing. Sometimes, surgery is a necessary step towards health and healing.

Before surgery, it is important for the doctor to consider the emotional relationship that the patient has developed with his or her diseased tissues. The mental, emotional, energetic and spiritual aspects of a disease must not be ignored.

The doctor's involvement with the patient and the tissues which are about to be surgically removed is extremely important, since this emotional interaction affects the patient's healing potential. For healing to take place, a trusting relationship with the patient must first be solidly established; this includes a compassionate attitude of the doctor towards the tissues that will be removed. The doctor models the correct attitude to facilitate an accelerated healing for the patient. It is believed that scar tissue formation is in direct proportion to the patient's fears and negative expectations surrounding the surgery. These fears and expectations form energetic and spiritual attachments to the physical body. Often the patient attempts to disconnect these spiritual attachments out of fear and survival instinct.

A patient is spiritually, emotionally and energetically interconnected with his or her body. This energetic attachment includes any and all organs, organ systems, or areas of the body which can be involved in the operation.

A patient may sometimes feel disillusioned about his or her own interpersonal relationship with the body, and try to disconnect all energetic attachments to the body's tissues out of fear and survival instinct. It is important for the Qigong doctor to help the patient get in touch with the suppressed feelings of loss surrounding the tissues which will soon be operated on. This is because surgery represents the death of a relationship with part of the self. Although the relationship that the patient has with the diseased organ is not considered a healthy one, it exists nevertheless. Allowing the patient to deny his or her true feelings related to the surgery interferes with the healing process. Denial may lead to increased scar tissue formation, and can promote the return of certain disease formations.

The Qigong doctor therefore encourages the

patient to talk to, and "brief," each organ and tissue area regarding the surgical procedure to prevent further denial, and to promote the release of feelings. Otherwise, the patient may experience feelings of loss, grief and depression; this reaction can of course also be due to the aftereffects of the anesthesia. It is important that these feelings be experienced and expressed before the surgery. After the surgery, the patient may then experience feelings of relief and gratitude about the new changes in his or her body.

To prepare for surgery, the patient is usually given Medical Qigong meditations and prescriptions that strengthen the Lower Dantian, Kidney and Mingmen areas. One, or several sessions may be specifically devoted to allowing the patient to connect with the diseased organ(s), as well as the regions that are to be operated on. A request for divine intervention can facilitate the patient's relinquishing control, and for the removal of any and all energetic armor surrounding the diseased area (and the subsequent release of emotions associated with this armoring). The patient is then encouraged to disconnect any energetic attachments that the diseased tissues have formed with the surrounding cells, facilitating a final closure. This gradual process allows for an easier transition, as the patient's body must completely release any attachment to the diseased tissues during surgery.

Just before surgery, the patient is given a meditation, and encouraged to imagine a divine white light energy submerging and enveloping the regions of the body which are to undergo the operation. The Lower and Middle Dantians, as well as the areas which will soon be operated on, should also be energized. In addition, the Liver should also be energized to make sure that the Blood coagulates properly during the surgery.

USING MEDICAL QIGONG FOR ANESTHESIA

According to research on Western Surgeries (presented at the Second International Symposium on Memory and Awareness in 1992), patients who undergo anesthesia may be aware of both the pain and conversations within the operating room. Many kinds of drugs used to supplement anesthesia, such as neuromuscular blocking agents, paralyze all the muscles in the body but do not affect the central nervous system and consciousness. During surgery, patients have been observed flinching, twitching and making other facial expressions. Many patients later can give an accurate detailed account of the surgical procedure and conversations between the doctors and nurses. Even when unconscious, patients (whether energetically inside or outside of their bodies), can record, see and remember everything.

Qigong energy emitted during surgery, can however, reduce pain and wound shock, as well as calm the patient's Shen. Qi emission also reduces postoperative complications such as respiratory tract infection, functional disorders of the gastrointestinal tract, retention of urine, etc. The energy received by the patient also speeds up the healing process.

Medical Qigong therapy is found to be very useful in relieving pain by affecting the body's neuro-chemicals. The energy stimulates the peripheral and cutaneous nerves that carry sensory information, via the spinal cord, to the brain. This stimulation of the cutaneous nerves activates neurotransmitters which carry pain messages to the brain, and facilitates the closure of the body's pain-relay gates. The brain produces endorphins, or endogenously generated morphine-like chemicals in response to this closure. The body's opiate receptors are then able to dull the pain. This process is the basis for Qigong Anesthesia. Because Medical Qigong therapy safely produces an analgesic affect on the body's cutaneous tissues, its use in hospitals for surgery as well as for pre and postoperative procedures is gradually increasing.

The first operation in which Qigong anesthesia was applied (recorded in modern times), was performed successfully for the removal of a thyroid tumor in the Shanghai #8 People's Hospital, on May 9, 1980. Qigong Master Lin Hou-sheng demonstrated the ability to induce anesthesia during surgery by pointing his fingers at specific acupuncture points, using external Qi projection without the use of any Western anesthetic. The patient's blood pressure, pulse and respiration rate

remained stable during the operation, and the patient's physiological function remained normal after the operation. The success of the Qigong anesthesia boosted the resident doctor's confidence and laid a solid foundation for future applications of Qigong anesthesia in surgical operations.

Qigong anesthesia has begun to follow in the wake of the widely accepted acupuncture anesthesia, as a holistic alternative to conventional pharmaceutical methods. The number of cases treated in China with Qigong anesthesia is steadily increasing, primarily for the following six benefits.

1. Arresting the patient's pain,
2. Resisting the pulling reflex action or shock reaction of the body's internal tissues and organs when the scalpel is inserted,
3. Reducing infection,
4. Reducing the body's opposition or contrary action/reaction to operative wounds,
5. Preventing wound shock (response of the body to the tissue trauma), and
6. Promoting the healing of wounded tissues.

Since Qigong analgesia is effective through the stimulation of certain points on the body's surface, both the location of the points, and the type of energetic application are crucial. There are three methods commonly used in selecting points: According to the Channels, According to the Segmental Innervation, and According to the Auricular Points.

1. The analgesic approach used according to the patient's channels includes two main applications:
   - The selection of points according to the course of the channel which traverses the site of the operation, and
   - The selection of points according to the differentiation of symptoms and signs of a disease, as well as the responses that may be elicited from the patient's body during the operative procedure.
2. The analgesic approach used according to the segmental innervation includes three main applications:
   - The selection of points according to the adjacent segment, or an area that is supplied by the same spinal nerve, or an adjacent spinal nerve of the operative site,
   - The selection of points according to the remote segment, in an area not supplied by the same spinal nerve, or an adjacent spinal nerve (on the operative site), and
   - The selection of points according to the stimulation of the nerve trunk within the same segment, stimulating directly the peripheral nerve of the operative site.
3. The analgesic approach used according to the Auricular Points employs the insertion and stimulation of acupuncture needles with Medical Qigong Therapy, and includes three main applications:
   - The selection of points according to the corresponding Auricular areas pertaining to the operative site and its involved internal organs,
   - The selection of points according to the theory of the Yin and Yang Organs pertaining to the operative site and its involved internal organs, and
   - The selection of points according to such things as tenderness, reduction of electro-resistance, the appearance of deformation and/or discoloration when a certain internal organ or area of the body is affected.

It is important preoperatively that the patient have confidence in the doctor's method of Qigong application. Any misgivings should be dispelled by explaining the procedure to gain the patient's full corporation and trust. In order to know the level of response that the patient will experience, it is necessary to test the patient's response to Qigong anesthesia prior to any surgery.

To use external Qi as an anesthetic, the Qigong doctor must first focus Qi into his or her Lower Dantian, increase its charge and density and then extend it out through the palms, or sword fingers, into the patient's body through specific channel points. The goal is to numb a specific area on the patient's body without touching the patient.

When Qigong anesthesia is being administered successfully, 96% of the nerve fibers responsible for pain sensation become anesthetized and the patient loses consciousness within ten minutes. Ten minutes after cessation of the Qigong

anesthesia emission, 24% of the anesthesia has disappeared; while 72% of the tissue remains numb. The remaining tissue quickly recovers from the anesthetic effect and the patient quickly returns to consciousness.

Patients suffering from pain caused by such conditions as cancer or dysmenorrhea also respond positively to Qigong anesthesia.

MEDICAL QIGONG THERAPY AND SURGERY

Surgery has been performed in China for thousands of years. In ancient times, the legendary physician Hua Tuo was noted, not only for his expertise in Medical Qigong, acupuncture, massage and herbs, but also for his surgical skills as well. In Western culture, surgical therapies are applied for the removal of tumors, cysts, and abnormal tissue growth, as well as the transplantation of organs (heart, lungs, and kidneys) and the replacement of dysfunctional systems (joint replacement). Surgery, however, having a potential to both hinder and obstruct the body's flow of life force energy, is generally considered a last resort modality.

During surgery, the Qigong doctor assists the surgeon by applying External Qi Emission to the patient's body, energizing and strengthening specific areas. This is done to reduce pain and alleviate or eliminate the pulling reflex action (shock reaction) of the body's internal tissues and organs when the scalpel is inserted, prevent infection, and reduce bleeding.

When assisting surgeons during an operation, I personally have found that it is important to maintain a physical connection with the patient's body before beginning the Qi emission, until the anesthesia has fully taken effect. As the anesthesia relaxes the patient's tissues, the Qigong doctor can feel and see the patient's spirit leave the body.

Just before the scalpel begins its first incision, it is important for the Qigong doctor to physically disconnect from the patient's body. Even though the Qigong doctor has physically disconnected from the patient's tissues, it is extremely important for the Qigong doctor to increase his or her energy extension deeper into the center core of the patient's body. This protects the Qigong doctor from experiencing the shock, and initial trauma from the scalpel's first incision, which resonates throughout the patient's entire body.

It is also important for the Qigong doctor to focus the attention on extending and circulating his or her energy deep into the patient's Taiji Pole while the surgery is being performed. As the patient begins to lose Qi and Blood due to the operation, the Qigong doctor replenishes the patient's lost Qi, as well as energizes the incoming Blood from the transfusion. The Qigong doctor should also slow down the bleeding by slowing the patient's pulse.

During surgery, the surgeon's scalpel will sever several of the patient's channels as the doctor cuts through the surface of the skin and continues into the deeper regions of the patient's body. Each channel that is being disconnected will weaken the patient's energetic field corresponding to that specific organ or organ systems. It is the Qigong doctor's responsibility to maintain connection with the patient's energy field, and also to monitor and maintain the patient's energy level. The Qigong doctor maintains this connection as the surgeons open up the patient's body cavity, move internal organs, remove the diseased tissues (and any associated structures), and then sutures and closes the patient's body cavity.

When the patient is being sutured, the Qigong doctor must facilitate the patient's circulation of Qi through the Microcosmic Orbit; this stimulates the re-connection of any of the patient's internal and external channels which have been severed. The Qigong doctor must also change and rebuild the Energetic Grid formations in the body's internal and external energetic fields. The patient's Energetic Grid is reconstructed to a pre-diseased pattern to prevent the regrowth of the disease.

MEDICAL QIGONG AND POSTOPERATIVE THERAPY

The separation and restructuring of the inner fasciae that occurs during surgery can cause serious postoperative problems by either stopping the Qi from flowing (causing stagnations), or alter-

ing the energy's natural course (causing deviations). This is why after the surgery has been completed, it is extremely important for the Qigong doctor to immediately dredge and disperse the Turbid Qi from the patient's body. This is performed by energetically combing over the fresh incisions, to reconnect the patient's energetic preoperative patterns. Energetic combing also promotes the rapid healing of the patient's wounded tissues, reduces the formation of scar tissue, and continues to alleviate the effects of the surgery.

To facilitate an escalated healing, the Qigong doctor must also energize the patient's Kidneys and any energetic field which may have been depleted. Also, to bring the patient's temperature back to normal, and to disperse any feelings of nausea after the anesthesia and shock of surgery wear off, certain Heart, Pericardium and Stomach Channel points require stimulation.

It is important to note that after an operation, the patient's Dantians and all the body's tissues have been depleted, and are in need of revitalization. While the patient is healing, the color of the aura (located in the Wei Qi field surrounding the area of the surgical trauma) is usually dark to light gray. To increase the healing potential, the Qigong doctor gives the patient specific prescriptions in accordance with the internal organ(s) affected, such as white light meditation images. This is prescribed to energize and replenish the patient's damaged tissues and energy fields. The Qigong doctor also continues to work on rebuilding, reconnecting and reinforcing the patient's channels and Energetic Grids which the surgeon has severed during the operation.

MEDICAL QIGONG THERAPY AND RECREATING ORGAN ENERGY

Once an organ has been removed, there remains an energetic "void" within the spatial cavity of the patient's tissues. The energy of the organ, however, still exists within the patient's body as a "Phantom Organ." This energetic phenomena is due to the creative "blue-printing" of the prenatal and postnatal formation of the body's tissues. Because mass and energy are interconnected and interchangeable, it is therefore possible to energetically stabilize, as well as energize, the spatial cavity wherein the surgically removed organ once resided. To assist the patient in recreating active organ energy, the Qigong doctor prescribes the following meditation:

Lungs	Brilliant Pure White
Large Intestines	Abalone-Shell White
Stomach	Deep Yellow
Spleen	Orange Yellow
Heart	Red with Blue Tint
Small Intestine	Pink
Bladder	Deep Blue
Kidneys	Light Pastel Blue
Pericardium	Purple Red
Triple Burners	Orange Red
Gall Bladder	Pale Chartreuse
Liver	Dark Green

Figure 56.1. Organ Color Chart

STAGE 1 - THE HOOKUP

Generally several days after the surgery, while the patient is still recovering, the Qigong doctor has the patient imagine him or herself being connected to the Heavens and rooted to the Earth. Next, the patient uses color visualization.

STAGE 2 - CHOOSING THE APPROPRIATE COLOR

To prescribe the correct color, it is important for the Qigong doctor to know which organ or organ systems have either been removed, or seri-

ously affected by the surgery. The patient is then assigned specific color meditations to tonify and strengthen the energetic fields that support the traumatized tissues. These meditations are also used to reestablish a physical, mental, emotional, energetic and spiritual connection to the area of trauma.

Figure 56.1 categorizes the general colors associated with the body's organs and channels. These colors can be viewed as extensions of energy originating from the original organs.

STAGE 3 - CLEANING AND ENERGIZING THE SPATIAL CAVITY

After the doctor has selected the proper organ color, the patient is given specific images used to cleanse, purify, and energize the tissues. These meditations create a solid energetic transformation that stabilizes the patient's energetic field.

1. The Cleansing and Purifying meditation is as follows. The patient imagines that his or her fingers and toes are straws. As the patient inhales, he or she will imagine divine white light energy flowing from the Heavens and Earth into the fingers and toes, filling the specific area which has been traumatized by the surgery (Figure 56.2). While exhaling, the patient imagines any pathogenic Qi leaving the tissues and body via the fingers and toes. The patient continues to perform this cleansing meditation for several minutes until he or she feels that the specific area has been purified.
2. The Creating and Energizing meditation requires that the patient imagine a clean, vibrant color (the Five Element Color associated with the particular organ), flowing into the spatial cavity, and areas, surrounding the removed organ. As the patient inhales, the organ color fills the vacant cavity, energizing the remaining energetic structure and surrounding tissues. The patient continues with this imagery until the specific organ area is full of heat, light and vibration (Figure 56.3). Because the surgery has permanently removed the organ from the patient's body, it is important for the patient to continue with this meditation every day for the rest of his or her life.

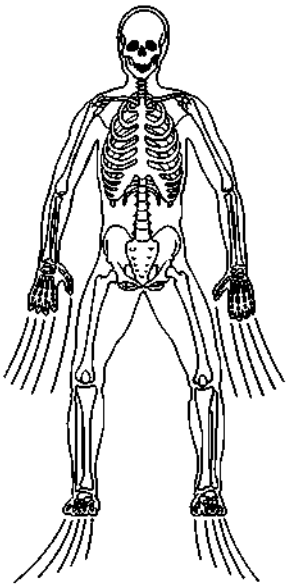

Figure 56.2. As the patient inhales, he or she will imagine the divine white healing light flowing into his or her body through the fingers and toes. This image is used to purge the patient's body and cleanse the tissues.

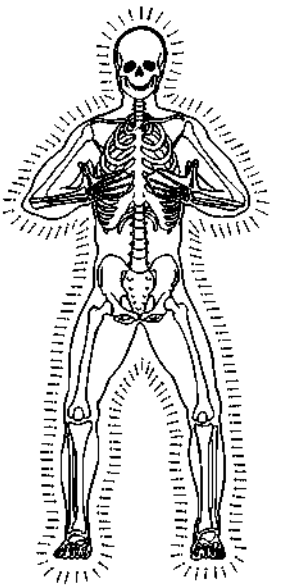

Figure 56.3. Once the patient is cleansed, in order to energize the tissues, he or she will imagine a clean vibrant energy color flowing into the specific spatial cavity associated with the removed organ.

MEDICAL QIGONG THERAPY AND ORGAN TRANSPLANTATION

Each particular organ in the human body has its own unique history and experience. This emotional memory and experience is active in the donated organ, as well as in the patient's diseased organ. Before the body can, or will receive a foreign organ, there must first be a time of reconciliation between the memories stored within the negative (as well as positive) physical cells of the organ soon to be replaced, and that of the donor's organ. To assist the surgeon in transplanting an organ, the Qigong doctor must perform visceral cleansing, preparation and purification of the transplanted organ. This method is explained in the following three stages:

STAGE 1

The patient must release all attachment to the departing organ. This includes all negative (as well as positive) physical, mental, emotional, energetic and spiritual memories and experiences.

STAGE 2

The history and emotional memory of the transplanted organ must be cleansed. This includes all negative (as well as positive) physical, mental, emotional, energetic and spiritual memories stored within the donor's organs.

STAGE 3

The relationship between the patient's tissues and the spatial cavity wherein the initial diseased organ was, or is located, must be established and harmonized.

The patient's body will either receive or reject the transplanted organ due to unresolved emotional trauma stored within the patient's tissues, or within the transplanted organ itself. Current research reveals that emotions trapped within transplanted organs can surface within the patient's subconscious mind, affecting his or her behavioral patterns. This is manifested through certain unnatural behavioral traits, which are transferred via the donated organ to the patient.

A famous example of a lingering emotional connection between an organ donor, the organ, and the recipient is described in the following true story. A few years ago a young woman (vegetarian) received a heart transplant from a young man who died in a motorcycle accident. Upon being discharged from the hospital, the woman began craving Chicken McNuggets, which was the young man's favorite food. This was in direct opposition to her previous diet and eating habits.

It is important to note here that organ rejection is not always due to the donor or patient's unresolved emotional issues. Organ rejection can also be caused from biological reactions complicating the acceptance of the foreign tissue.

FOLLOW-UP AND REMEDIAL PRESCRIPTIONS

The follow-up and remedial prescriptions will be determined according to the specific type of surgery the patient has undergone. The prescriptions must be designed to purge, strengthen and regulate any organ(s) that have been weakened by the surgery. Follow-up and remedial prescriptions must also circulate the patient's energy to reduce any energetic stagnations which may have been caused by internal organ movement and fascia damage. This will assist the patient in an escalated recovery, as well as reduce postoperative depression, which often follows after major surgery.

Sometimes, when assisting a patient who is healing from a severe disease (i.e., malignant tumors), additional Western therapies such as radiation or chemotherapy are required. The following is a testimonial by a patient of mine, Thea Sagen (female - age 50), illustrating the use of Qigong therapy in combination with radiation therapy.

Here is a summary of events surrounding my pancreatic surgery, June 16, 1997 at Community Hospital of the Monterey Peninsula.

"On June 16, 1997, emergency surgery to remove a fist-sized tumor from the tail of my pancreas, resulted in my former Sifu (Martial Arts Master), Jerry Alan Johnson, changing roles to become an "Energy Therapist." Thanks to my admitting physician, Dr. Stephanie Taylor, who facilitated the arrangement, Dr. Johnson was the first representative of Chinese Medical Qigong therapy allowed to enter surgery at the Community Hospital of the Monterey Peninsula.

As my Energy Therapist, Dr. Johnson conducted a preoperative session during which he facilitated the energetic and emotional release of my tumor. He then accompanied me into the four hour surgery, during which he maintained my energy levels, while reminding my tissues of their preoperative energetic patterns in order to facilitate rapid healing. He continued to work with me through the postoperative healing, and followed up several days after surgery. It was his vital support and insights that helped me to undergo the recommended course of radiation therapy.

The following is a synopsis of the Medical Qigong therapy that I experienced along with the traditional Western modalities used to treat my pancreatic islet-cell tumor.

Phase 1. The Preoperative Stage. Consisted of a Medical Qigong session directed toward putting me in touch with the tumor, my relationship to it, and the emotions associated with it. This was followed with an atonement with the Divine and relinquishment of control, removal of the armoring around my tumor, and subsequent release of emotions with it. I actually "saw" the disconnected energetic attachments of the tumor as they detached from my organs and were blowing like ostrich feather segments in a wind. I also saw a bright neon sign on the tumor that identified its emotional source. This entire process took only an hour, yet it facilitated closure with the tumor in order for me to easily release it during the surgery, which immediately followed the session. It also provided me with insights that helped my emotional healing over the months following surgery.

Phase 2. Surgery. I entered surgery without any sedatives and was filled with a tremendous sense of peace and empowerment in knowing that the hospital was honoring my energetic, as well as my physical needs. The surgery lasted for four hours during which Dr. Johnson connected with my energy fields and monitored, as well as maintained, my energy levels. He continued treating me, and working with my energetic fields, as the anesthesia was administered, and as the two surgeons opened my cavity, moved structures, removed the tumor (along with the tail of my pancreas and the spleen), and then sutured and closed my abdominal cavity.

Throughout the surgery Dr. Johnson stood at my head, where energy enters through the crown, and facilitated the running of energy into my center channel in the core of my body. He described his work as following the actions of the surgeons, and my body's response to these actions: the incision, the movement of internal organs, the resection of the tumor, and the final suturing. He used this opportunity to change the energetic grid formations in the tumor bed to prevent regrowth of the tumor, which was malignant.

Phase 3. The Postoperative Stage. This stage involved a continuation of the mitigation of the effects of surgery. He worked to tonify my Kidneys, to bring my temperature up, and to offset the shock of surgery, as well as used acupressure points to calm my heart and stomach during the nausea. I was reminded upon awakening, to do my Microcosmic Orbit exercise. Dr. Johnson then proceeded to "dredge" or comb over the incision to reconnect my pre-energetic channel and tissue patterns in order to facilitate healing, and to reduce scar tissue. The healing of the incision was fast. My doctors later remarked at how quickly I healed, and how little scar tissue there was compared to similar surgeries.

Phase 4. Follow-Up and Remedial Prescriptions. During the days following surgery, Dr. Johnson taught me several meditations: The "Divine Healing Light Meditation" for healing the tumor bed and incision, and the "Heaven and Earth Spleen Meditation" that fuses a ball of energy where the spleen once was – allowing me to continue to produce the energetic pattern of the spleen within my body. I began doing these meditations the day following surgery for the week of hospitalization, and continued to practice them along with the Microcosmic Orbit exercises throughout my recovery.

Phase 5. Radiation. After several weeks of recuperation, I was scheduled to received radiation treatments daily (Monday through Friday) for six weeks. Each day I would perform the Medical Qigong exercises (vocal and physical prescriptions) outdoors in a field overlooking the ocean.

Then I would drive to the hospital for the 15 minutes of radiation, followed by a session with Dr. Johnson every other day. I understood that the Medical Qigong exercises and sessions would offset the heat in the tissues while protecting the surrounding organs from unwarranted harm. There was concern about the possible loss of function in one kidney, but blood tests during the treatments showed no noticeable effects on them, or on my liver. In addition, unexpected by-products of the Medical Qigong sessions involved the release of emotional memories and an experience of the Divine in my healing process.

On alternate days after radiation, I had acupuncture and pranic healing with Jason Gill L.Ac. who teaches classes in Chinese Herbs and Traditional Chinese Medicine at Dr. Johnson's International Institute of Medical Qigong. Through these treatments, and the use of Chinese herbs, my immune system was strengthened. These complimentary modalities, combined with my body's own healing abilities and visualization practice, enabled me to avoid the typical side-effects of nausea and diarrhea. Aided by the positive energy from these two therapists, I was able to maintain my energy levels in sufficient quantity to continue driving to the radiation treatments on my own.

It is hard for me to imagine what this entire experience might have been like without the support of a doctor of Medical Qigong. I am truly grateful for Dr. Johnson's dedication, discipline and expertise that enabled him to be present for me throughout all aspects of this illness. It was a gift that I would encourage other patients to utilize for themselves in combination with any traditional allopathic program for cancer. I had the best of both worlds working for me in a remarkable manner thanks to all of my doctors."

PHANTOM PAINS OF AMPUTATED ORGANS

Amputation may be necessary as a result of severe injury or massive infection, such as gangrene. During surgical amputation, the soft tissues are cut in such a way that they cover the end of the remaining bone to heal completely. This allows the body's tissues to seal and protect themselves from the external environment. "Ghost" or "phantom" pains are caused by the patient's energetic connection with the amputated tissues, through the internal "energetic spacial cavity," or external "energetic boundary system." The phantom limb (usually one of the body's extremities, e.g., finger, hand, arm, etc.) exists in an energetic state and continues to interact with the patient's external Wei Qi field, as well as with the patient's Shen. Any interaction with the space, or energetic field of the amputated organ, will produce a direct response in the patient, similar to that of contacting the actual physical limb.

Rehabilitation programs generally do not prepare the patient for such reactions as phantom pains, which tend to leave the patient perplexed and frustrated. To alleviate the symptoms of phantom pains, the Qigong doctor sedates the patient's Wei Qi field that surrounds the amputated limb, and assists the patient in re-patterning the old energetic field to fit the postoperative tissue formation. The Qigong doctor can also prescribe Juniper Berries, which will relieve the phantom pain symptoms.

MEDICAL QIGONG THERAPY AND THE TREATMENT OF SCAR TISSUE

Medical Qigong therapy may be effective for treating pathologies caused by scarring due to surgical procedures. The formation of scar tissue often becomes the source of other physical problems by either obstructing, or weakening, the flow of Qi within the body's channels. In most cases of pathological scar tissue, the scar itself transverses several channels within the superficial and deep tissues.

The topological relationships of each scar will vary according to each patient. Therefore, different therapeutic approaches may be required for treatment, depending on the patient's strength, weakness, Elemental Constitution, and the patient's emotional state surrounding the surgery. Manifestations of scar tissue pathology include some of the following symptoms:

- a feeling of discomfort, or unpleasant sensations that originates around the scar area,

- radiating sensations that occur when the scar is being pressed, and
- a sharp, pulling type of pain that originates from the scar.

These conditions can be present, even if it has been several years since the surgery was performed.

TREATMENT

Medical Qigong treatment for scar tissue formation follows the principle of emitting Qi along the pathway of the channels. Before treatment, the doctor should take into consideration the energetic flow and function of the channels that have been affected by the surgery. If, for example, a patient's Yang channel (e.g., Stomach) becomes obstructed due to surgery, it can create an Excess condition within the Stomach Channel, which in turn creates a Deficiency of the Spleen Channel. Therefore, the treatment of both the Stomach and Spleen channels should be addressed.

After surgery, some scar tissue formation is inevitable, since both the body's inner-facia and channels (which are responsible for the lubrication of the tissues) have been severed. To minimize the degree of scar tissue formation, the Qigong doctor uses Qi extension techniques on the sutured area, extending his or her intention deep into the patient's body. The doctor's focuses on dispersing stagnations and regulating the flow of the undercurrent of Qi through the sutured tissues. Emphasis should be placed on reconnecting the patient's channels and collaterals. Next, the doctor focuses on regulating the external and internal flow of energy from within and without the patient's tissue area.

In treating scar tissue formation which has laid dormant for quite some time, tissue regulation through Tui Na therapy is required. After using the proper tissue regulation method (see Chapter 37), the Qigong doctor ends the treatment by using the One Finger Skill technique along the line of the patient's external scar. To perform this method, one thumb is placed on the end of the scar, while the doctor's other thumb presses into tissue, slowly outlining the entire scar (this heats and energizes the patient's tissues). The doctor ends the treatment with both thumbs placed at the beginning and ending of the scar, extending his or her energy through the patient's tissue in a circular pattern. This technique naturally induces an energetic emotional release of the memories trapped within the scar tissue.

Section XII
Medical Qigong Appendices

INTRODUCTION TO THE APPENDICES

There are many documents discussing the experimental research of Medical Qigong Therapy written within the past ten years. Among these documents, are listed a collection of abstracts from five national congresses on Medical Qigong researches as well as four World Conferences. The research has covered a variety of topics ranging from Medical Qigong and its relationship with: Physics, Chemistry, Biology, Western and Traditional Chinese Medicine, Optics, Magnetism, Electromagnetism, Acoustics and the Projection of Sound Resonation, Fluid Mechanics, Nuclear Physics, Electro-Chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry, Physiology, Bio-Chemistry, Molecular Biology, Micro-Biology, Cytology, Genetics, Pathology, Pharmacology, Psychology, and Sports Medicine.

The experimental research of Medical Qigong is actually a study with multiple sciences. Of all the research reported, Biology and Medicine are in the forefront of the material collected.

The following research was conducted by distinguished scholars at various Universities, Scientific Academies, and Institutes through out the world (i.e.: Beijing Medical University, Qinghua Medical University, Nanjing Medical University, Tokyo Medical University, Tokyo Electro-engineering University, Higher Energy Institute, Physics Institute, International Institute of Medical Qigong, China Healthways Institute, etc.).

This research was focused on the Extension of Emitted Qi by various Medical Qigong Masters/Doctors, the result being positive in it's conclusion on the effectiveness of Medical Qigong Therapy as a solid and effective clinical modality.

This section of the text is devoted to the scientific approach of analyzing and scrutinizing the claims made as to the actual effectiveness of Medical Qigong Therapy as a clinical modality.

For this purpose, I have elicited the help of my good friend, the renowned scientist and research investigator, Dr. Kenneth M. Sancier. Dr. Sancier (a Material Scientist) is the president of the Qigong Institute, of San Francisco, California, and an active Council Board Member of the World Academic Society of Medical Qigong (Beijing, China). His many years of extensive research in the field of Energetic Medicine has led him to help organize the first International Congress of Qigong in conjunction with the Fifth International Congress of Chinese Medicine (at the University of California, Berkeley) including maintaining an active annual Qigong Science Forum for scientists. He is also responsible for developing the first computerized Qigong Data Base, which is currently being sold worldwide.

Dr. Sancier has actively collected scientific information on Qigong by attending international conferences, and meeting scientists in China, Japan, Canada and the United States. He has published several reviews of clinical and experimental studies of the medical aspects of Qigong therapy in many scientific journals and magazines. Although the following information in this appendix represents but a fraction of Dr. Sancier's findings, I am confident that the reader will find the data fascinating.

Dr. Jerry Alan Johnson May 2000

APPENDIX 1A
MEDICAL APPLICATIONS OF QIGONG

Kenneth M. Sancier, Ph.D.
Qigong Institute
Menlo Park, California

ABSTRACT

This article reviews selected scientific studies of medical applications of Chinese Qigong. The intention of the review is to outline research on Qigong and its potential for improving health care in western countries. The review centers on clinical and experimental studies to show that Qigong exercise can beneficially affect many functions of the body and improve health. The studies were selected to illustrate the following points: medical applications of Qigong are diverse, some studies were conducted in depth, and many applications hold promise to improve western health care.

Several specific clinical and experimental studies are outlined. The study using electroacupuncture according to Voll shows that almost all organs and functions of the body can be balanced by Qigong. The research on hypertension serves as a model to illustrate the many ways that the effects of Qigong on the body can be measured. Studies on brain waves are included to show that the mind is involved in Qigong and probably in the healing process. Research on Qigong's role in high altitude adaption suggests some practical applications for treating cardiovascular disease. A combination of Qigong and drug therapies is superior to drug therapy alone, as indicated in the case of two diseases, hypertension and cancer. In conclusion, there is a plea to medical practitioners and scientists to collect existing information on medical Qigong, promote research if needed, and identify applications that hold promise for improving western health care.

INTRODUCTION TO MEDICAL QIGONG

Traditional Chinese Medicine (TCM) is a holistic system for promoting health and for healing that includes several therapies such as acupuncture and moxibustion, herbal medicine, acupressure massage, nutrition, and Medical Qigong. These therapies are often used in combinations. The underlying theory of TCM is based on balancing Qi, the vital energy in the body, according to the theory of "yin-yang" and the Five Elements, that has been used for more than three thousand years. In practice, the flow of Qi is regulated, and "blocks" to the flow of Qi are removed. Energy blocks or Qi in excess or deficiency may result from disease, injury or stress. Qigong (pronounced chee gong) has a history of thousands of years, and it is unique among TCM therapies because almost anyone can learn and practice Qigong. However, it best to study Qigong with a qualified teacher to avoid adverse side effects. It is claimed that 60 million people in China practice Qigong daily, primarily to maintain health and achieve long life.

The word Qigong is a combination of two ideas. Qi is the vital energy of the body, and gong is the skill of working of the Qi. Medical Qigong for health and healing consists primarily of meditation, physical movements, and breathing exercises. Qigong practitioners develop an awareness of Qi sensations in their bodies and use their mind, i.e., intention, to guide the Qi in the body. It is said that the benefits of Qigong extend beyond health and healing to enhance spiritual life and even special abilities, such as psychic powers. Qigong is also used in martial arts to help develop physical and mental powers for self defense and healing.

Medical Qigong is divided into two parts: internal and external. Internal Qi is developed by individual practice of Qigong exercises. When Qigong practitioners become sufficiently skilled, they can use external Qi to "emit" Qi (Wai Qi in Chinese) for the purpose of healing another person. There are many reports of the medical efficacy of emitted Qi. This therapy has limited ap-

plication on a large scale because there are a limited number of skilled Qigong masters. The present article will focus mainly on internal Qi because almost everyone can learn Qigong exercises for maintaining health and for self-healing.

In the early 1980s, scientists in China began investigating the many medical benefits claimed for Qigong. Since then, research on hundreds of medical applications of Qigong has been reported in the literature, which, unfortunately for the West, is written primarily in Chinese. A wealth of material is published in English in the proceedings of international conferences of Qigong. The proceedings contain abstracts of talks given at the conferences, and since 1986 there are 837 abstracts, more than half in English.

EXAMPLES OF MEDICAL APPLICATIONS OF QIGONG

Some examples of the applications of medical Qigong and emitted Qi on humans, animals, cell cultures, and plants were reviewed. Clinical and experimental evidence showing that Qigong exercise and external Qi affects various functions and organs of the body have been discussed. A short list of some of the functions and organs affected by Qigong, and the measurement techniques employed, include: the brain (EEG and magnetometer); blood flow (thermography, sphygmography, and rheoencephalography); heart functions (blood pressure, EKG, and UCG); kidney (urinary albumin assay); biophysical (enzyme activity, immune function, sex hormone levels); eyesight; and tumor size in mice.

In the following discussion, some clinical and experimental research studies will be discussed to illustrate the scope of research on medical applications of Qigong. The studies have been selected because they contain scientific information on important chronic medical conditions, such as hypertension and aging. Most of these studies on Qigong used controls and statistical analysis. This review focuses on the main accomplishments of selected research studies. Details may be omitted because of space limitations or because relevant information is not available. The critical evaluation of research studies will be left to medical specialists.

THERAPEUTIC BALANCING OF THE CHANNELS AND FUNCTIONS OF THE BODY

Electroacupuncture According to Voll (EAV) can monitor the effects of Qigong practice on therapeutic balancing of the Channel system, the classical TCM organs, and body functions. In EAV the electrical conductance of the skin above individual acupuncture points is measured using a low voltage and low current. Diagnosis depends on measuring the relative electrical conductance and its time dependence. An important diagnostic criterion of degeneration of an organ is an "indicator drop" that may occur during the measurement when the conductance reaches an apparent maximum value but then decreases before leveling off.

Measurements were made at 24 acupuncture points at the ends of the Channels of the fingers and toes of subjects and were made by the same operator and equipment. The subjects were asked to perform a Qigong exercise of their choosing, for example, sitting or standing meditation or moving Qigong. Two series of EAV measurements were made before and after healthy subjects practiced Qigong. In the first series, four subjects were examined by EAV before and after they practiced Qigong for 10 to 15 minutes. Qigong exercise decreased the average of the EAV measured values in the range of -19 to -31% ($p<0.004$) for the four subjects. Qigong essentially eliminated the indicator drops. In the second series, each of seven subjects was examined by EAV three times in a blind protocol so that the operator did not know whether a subject had practiced Qigong before the second or third examination. In the second series, Qigong exercise changed the average EAV measured values in the range of -17% to -35% for four subjects and in the range of 4% to 15% for three subjects. Indicator drops again were decreased.

These preliminary results show that Qigong can make significant changes in the therapeutic balancing of the Channel and organ systems, the goal of TCM.

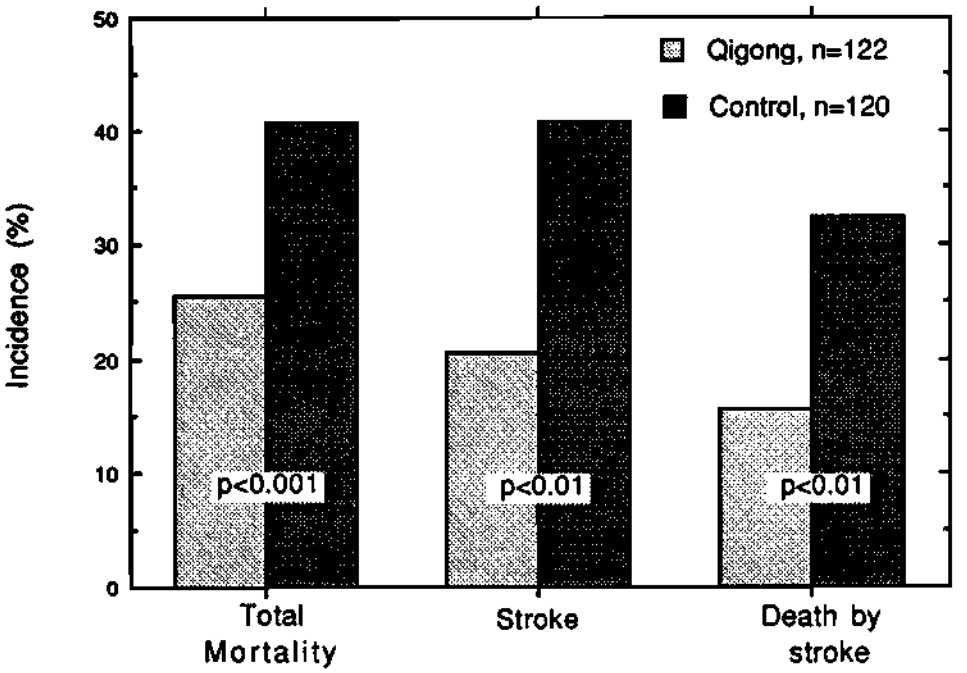

Figure 1. A 30-year folow-up of the effect of Qigong on mortality and stroke of 242 hypertensive patients. Both groups received drug therapy. (Qang. Xu, et al. ref. 7)

HYPERTENSION

Several groups in China have investigated the effects of Qigong on hypertension (i.e., high blood pressure). Research on the short- and long-term effects of Qigong practice on hypertensive patients has been carried out at the Shanghai Institute of Hypertension by Wang Chongxing, Xu Dinghai and their colleagues. Their research is reviewed extensively because it serves as a model of the effects of Qigong on many functions of the body. For these studies, the patients practiced "Yan Jing Yi Shen Gong" for 30 minutes twice a day. This Qigong is claimed to be especially valuable for therapeutic purposes and delaying senility. The Qigong exercise consists of a combination of sitting meditation and gentle physical movements that emphasizes a calm mind, relaxed body, and regular respiration.

PREVENTION OF STROKE AND MORTALITY

In 1991, the researchers reported a 20-year controlled study of the anti-aging effects of Qigong on 204 hypertensive patients. Recently, the researchers performed a 30-year follow-up on 242 hypertensive patients who were divided randomly into a Qigong group (n = 122) and a control group (n = 120). All patients were given drug therapy to control blood pressure, but only the experimental group practiced Qigong 30 minutes a day, twice a day. The results show that the accumulated mortality was 25.41% in the Qigong group and 40.79% in the control group ($p<0.001$). The incidence of stroke was 20.49% and 40.73% ($p<0.01$), and death rate due to stroke was 15.57% and 32.50% ($p<0.01$), respectively. These results, which are shown graphically in Figure 1, indicate that Qigong has potential for preventing strokes and extending life.

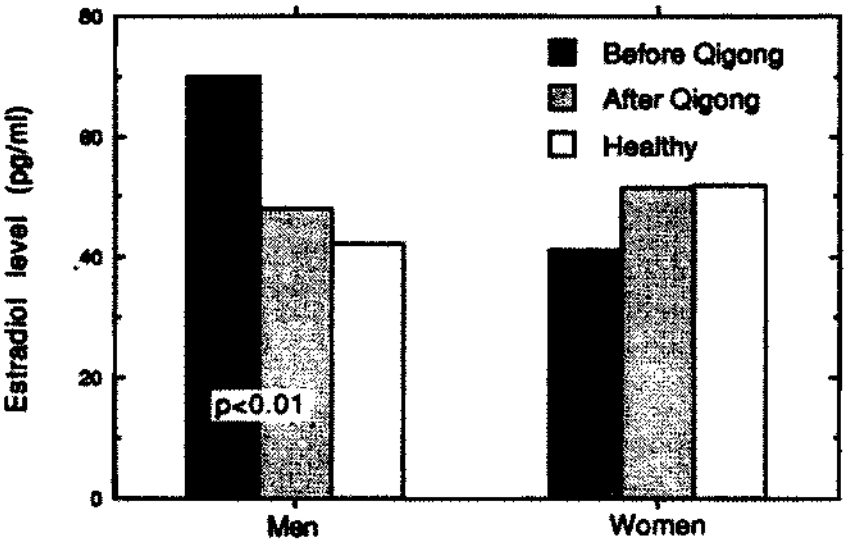

Figure 2. Serum estrdiol levels of hypertensive men (ages 40–69) and women (ages 51–57) who practice Qigong one year compared to healthy controls. (Ankun, Eang, et al. ref. 6)

The researchers also reported that over the 20-year period, blood pressure of the Qigong group stabilized while that of the control group increased. Remarkably, during this period the drug dosage for the Qigong group could be decreased and for 30% of the patients could be eliminated. However, the drug dosage for the control group had to be increased. These results suggest that Qigong activated the natural healing process of the body.

Improvements in Heart Function and Microcirculation

Aged hypertensive patients usually are found to have a deficiency of Heart-energy, which often leads to a weakened function of the left ventricle and a disturbance of microcirculation. The researchers evaluate the effects of Qigong by using ultrasonic cardiography (UCG) and indices of microcirculation. The 120 male subjects, 55 to 75 years of age, were divided into three groups: 46 cases of hypertensive subjects with Heart-energy deficiency, 34 cases without Heart-energy deficiency, and 40 cases with normal blood pressure. Patients whose blood pressure measured more than 160/95 mm mercury were accepted as subjects after regulation with anti-hypertensive drugs for 4 weeks.

The results showed that subjects with Heart-energy deficiency experienced several improvements: increases in cardiac output, ejection fraction mitral valve diastolic closing velocity, and mean velocity of circumferential fiber shortening, while the total peripheral resistance decreased ($p<0.05$-0.01). Significant changes did not occur in the group without Heart-energy deficiency.

Multiple quantitative evaluation of nailfold disturbance in microcirculation was made on the above three groups by observing 10 indices of abnormal conditions: configuration of micrangium, micrangium tension, condition of blood flow, slowdown of blood flow, thinner afferent limb, efferent limb and afferent limb ratio, color of blood, hemorrhage, and petechia. At the beginning of the study, the incidence of microcirculation obstruction for the above three groups was 73.91%, 26.47% and 17.50%, respectively. After practicing qigong for one year, the group with

Heart-energy deficiency showed a decrease in nailfold microcirculation obstruction from 73.91% to 39.31% ($p<0.05$). Significant changes did not occur in the group without Heart-energy deficiency.

These studies show that proper TCM diagnosis is essential for qigong therapy. The investigators emphasized that the kind of qigong must be selected according to the patient's condition.

Improvement in Sex Hormone Levels

One consequence of aging is that the levels of sex hormones change in unfavorable directions. For example, female hormone (estrogen) levels tend to increase in men and decrease in women. Two studies indicate that this trend can be reversed by qigong exercise. The effect of qigong exercise on plasma sex hormone levels was determine for hypertensive men and women. The sex hormones levels were measured before and after qigong practice for one year.

The 70 male patients with essential hypertension (ages 40 to 69; disease stage II) were divided into two groups. For the qigong group ($n = 42$), the estradiol level (E2) decreased from 70.12 to 47.71 pg/ml, a decrease of 32% ($p<0.01$), while no significant changes occurred in the control group ($n = 20$). The testosterone levels (T) of both groups decreased about 7%. The value of E2 for the qigong group (47.71 pg/ml) approached that of healthy men (42.23±5.82 pg/ml) of the same age but without hypertension or cardiovascular, pulmonary, hepatic, renal, or endocrine diseases ($p<0.05$). For women (ages 51 to 67, the number in group not available), the aging process was associated with failure of ovarian function manifested by decreased E2 and increased T levels. Qigong resulted in an increase of E2 from 40.9±.3.5 to 51.6±3.5 pg/ml, a value about equal to that of normal menopausal controls without hypertension or cardiovascular, pulmonary, hepatic, renal, or endocrine diseases. The value of T was also increased by qigong from 25.5±2.2 to 37.2±2.2 ng/dl. These favorable changes in estradiol levels, E2, brought about by qigong are summarized in Figure 2 for both men and women.

In an auxiliary study, the 24-hour urinary estradiol levels were determined in 30 men ages 50 to 69. Qigong for one year resulted in a decrease of 31% in E2 and a decrease of 54% in the estradiol/testosterone ratio (E2/T). These changes were accompanied by improvements in symptoms associated with Kidney deficiency hypertension, such as soreness, dizziness, insomnia, hair loss, impotence, and incontinence. The average score for these symptoms was changed by qigong from 5.53±2.31 to 2.83±1.32 ($p<0.001$).

Ye Ming and co-workers reported similar favorable changes in plasma sex hormone levels E2 in 77 male and female qigong exercisers after 2 months qigong compared with 27 controls. They did not observe significant changes in testosterone.

The above studies show that qigong exercise can help restore the sex hormone levels that had deteriorated because of aging.

Increased Bone Density

Aging may result in a decrease in bone density, especially in women. As a consequence, bones become more brittle and subject to fracture.

Bone density of male subjects was found to increase by practicing qigong for one year. For subjects 50 to 59 years of age (18 cases), the bone density increased from 0.627±0.040 to 0.696±0.069 g/cm3 ($p<0.01$). For subjects 60 to 69 years of age (12 cases), the bone density increase was somewhat less, namely, from 0.621±0.039 to 0.672±0.083 g/cm3 ($p<0.05$). For both age groups, the bone density increased to values exceeding those of normal men of the same age, 0.695±0.096 and 0.657±0.102 g/cm3, respectively. The results are shown graphically in Figure 3.

It is likely that qigong therapy also would help restore the bone density of women, especially menopausal women. If so, hormone replacement therapy and its side effects could be reduced.

Changes in Blood Chemistry in Hypertensive Patients

Auxiliary studies by Wang, Xu and co-workers on the effects of qigong exercise on blood chemistry of hypertensive subjects include improvements in plasma coagulation firbrinolysis

indices, blood viscosity, erythrocyte deformation index, levels of plasma tissue-type plasminogen activator (tPA), plasminogen activator inhibitor (PAI), VIII factor related antigen (VIII R:AG), and anti-thrombin (AT-III). In another study, they reported that qigong exercise significantly and beneficially changed the activities of two messenger cyclic nucleotides (cAMP and cGMP).

These results provide further evidence that qigong affects many complex functions of the body.

CANCER

Feng Lida pioneered in research showing that emitted qi from qigong masters produced marked changes in cell cultures of cancer cells from mice. Several studies reported the effects of emitted qi on tumors in animals. For example, emitted qi was reported to inhibit the growth of implanted malignant tumors in mice but did not destroy the tumors. Encouraged by the results with animals, researchers carried out clinical research on the effects of qigong on human subjects with cancer. Detailed results are not available in English for all these clinical studies.

Some results are available for a clinical study of qigong as a therapeutic aid for patients with advanced cancer. In this study, 127 patients with medically diagnosed malignant cancer were divided into a qigong group of 97 patients and a control group of 30 patients. All patients received drugs, and the qigong group practiced qigong for more than 2 hours a day over a period from 3 to 6 months. Both groups improved, but the qigong group showed improvements four to nine times greater than the control group for strength, appetite, diarrhea free, and weight gain of 3 kg. The phagocytic rate, which a measure of the immune

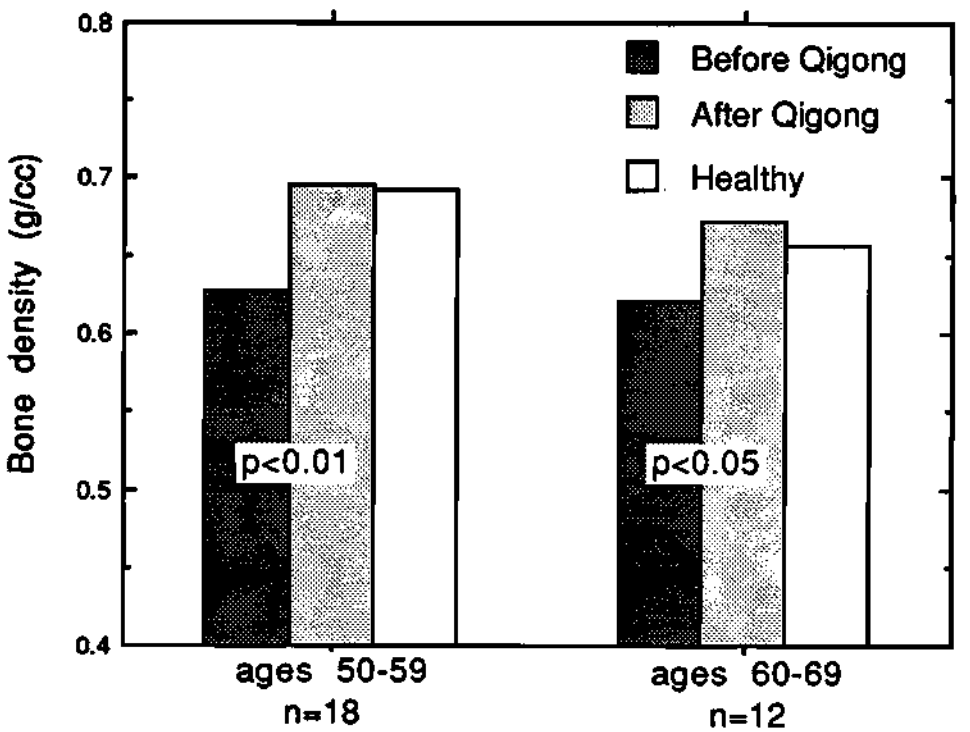

Figure 3. Changes in bone density of hypertensive men who practice Qigong one year compared to healthy males of the same age. (Xu Wang, et al. ref. 9)

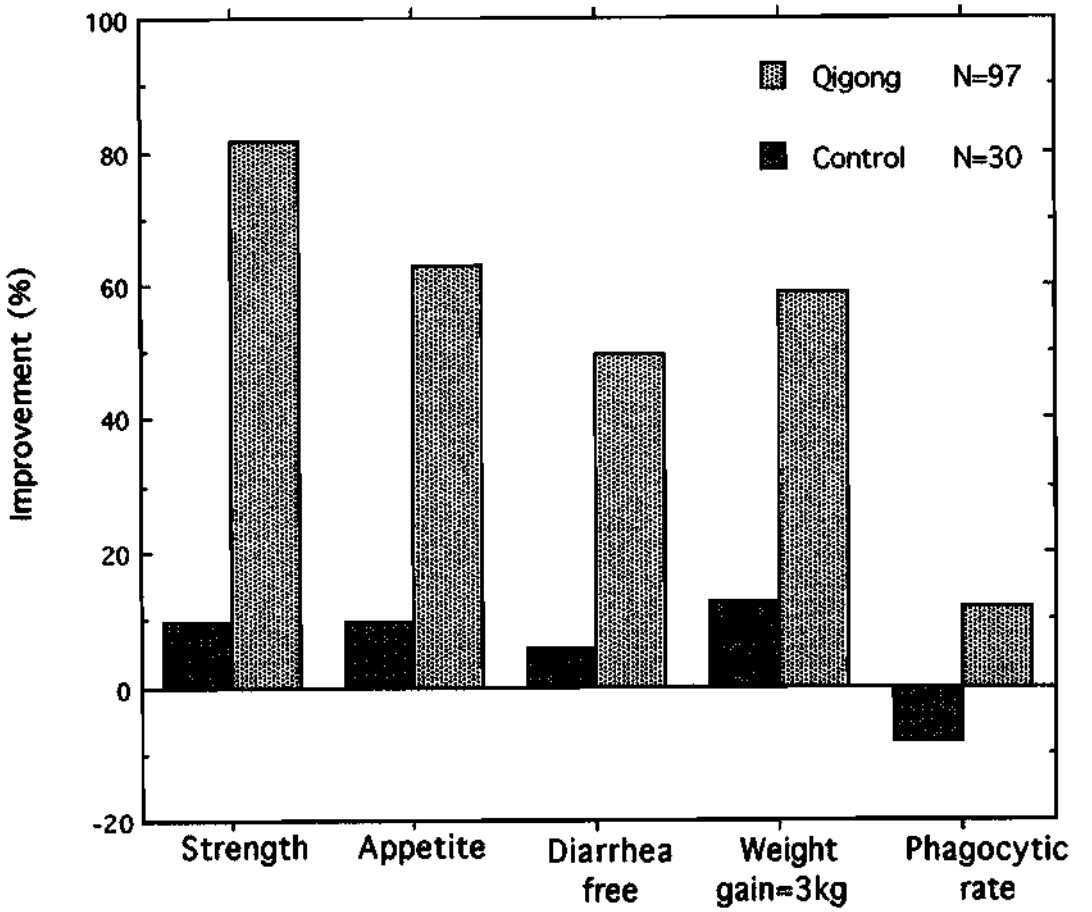

Figure 4. Comparison of Qigong, drug and drug-alone terapies for patients with advanced cancer. (ref. 25)

function, increased in the qigong group but decreased in the control group. These results are shown in Figure 4.

REVERSING SENILITY

To study the mechanism of keeping fit by qigong, a controlled study was made of 100 subjects classified either as presenile or with senile impaired cerebral function. The subjects were divided into two groups of 50 people each with a mean age of 62.7 years and with a similar distribution of age and sex. The qigong group practiced a combination of static and moving qigong. The control group exercised by walking, walking fast, or running slow. According to TCM method of classifying the vital energy, more than 80% of the patients in each group were classified as deficient in vital function and vital essence of the Kidney. Criteria for judging outcome were based on measuring clinical signs and symptoms including cerebral function, sexual function, serum lipid levels, and function of endocrine glands.

After six months, 8 of the 14 main clinical signs and symptoms in the qigong group were improved above 80%, whereas none of the symptoms in the control group was improved above 45%. These results suggest that qigong can reverse some symptoms of aging and senility.

MIND-BODY REGULATION

The main function of qigong is to regulate the mind, and according to TCM theory the mind leads the qi. The mind-regulating function of qigong mainly refers to the regulation of the functions of the brain and related body reactions. One tenant of qigong is that "the mind leads the qi, and the qi leads the blood." This somewhat mysterious statement can be interpreted to mean that intention (the mind) can direct the qi within the body. This mechanism is perhaps similar to the role of volition in biofeedback self-regulation.

BRAIN WAVES

The main focus of research has been on the effects of qigong on brain waves as measured by electroencephalography (EEG). During static, e.g., sitting meditation, alpha brain waves dominate over beta waves and spread to the frontal areas of the brain. Kawano and Wang have found differences in the EEG of Zen Buddhist priests and qigong masters. During almost all types of qigong training, the frequency of the alpha waves increased in the range from +0.6 to 1.0 Hz. During deep Zen meditation, the frequency decreased in the range from -1.0 to -1.5 Hz, and sometimes theta waves appeared. Also, frontal and occipital alpha waves tended to synchronize with a phase difference that depended on the type of meditation. This phase difference became smaller with qigong meditation (i.e., better synchronization) and larger for Zen meditation. According to Kawano and Wang these differences in brain function suggest that internal qigong involves a "semi-conscious" process, which involves some awareness and activity, while Zen meditation is a neutral process that releases the meditator from all concerns. This difference may relate to qigong being a healing art, whereas Zen is generally not considered to be one.

As mentioned earlier, a qigong master can emit qi to heal a patient, and the literature contains many references to this subject. The interaction between the qigong master and his subject has been followed in double blind tests. Both qigong master and subject were simultaneously measured by EEG, polygraphs, biochemical blood tests, and psychological tests. The EEG studies showed that brain wave patterns of the subject and qigong master were synchronized in type of brain waves and their location in the brain. Such synchronism may be required for healing by emitted qi.

Machi has studied qigong masters by combining EEG measurements with simultaneous measurements of physiological changes. He found that while the qigong master was emitting qi, the alpha-1 waves showed extremely high potential on the right frontal lobe, and there were increases in blood pressure, heart rate, and skin surface temperature. He also detected a far infrared emission with 1 Hz modulation signal coming from the Laogong point (a major acupuncture point in the palm of the hand.)

BLOOD FLOW TO THE BRAIN

Qigong exercise has been shown by rheoencephalography to increase blood flow to the brain. For 158 subjects with cerebral arteriosclerosis who practiced qigong for 1 to 6 months, improvements were noted in symptoms such as memory, dizziness, insomnia, tinnitus, numbness of limbs, and vertigo headache. During these studies, a decrease in plasma cholesterol was also noted. These results may offer hope to people with cerebral arteriosclerosis.

EFFECT OF RAPID AND LARGE CHANGES IN ALTITUDE

Studies have been made to determine whether qigong exercise would protect pilots from altitude stress when they increased altitude by going rapidly from low altitudes to the Tibetan highlands.

CARDIAC FUNCTION

Before entering the Tibetan highland, 66 persons were divided into two groups: a qigong group of 32 young men who did Qiyuan Qigong exercise for 4 weeks, and a control group of 34 young men who exercised to radio music. The two groups of men suddenly entered the highlands from a lower altitude. Before and after entering the highland, measurements were made of symptoms of altitude sickness and physiological

changes. The qigong group suffered less altitude stress than the control group as measured by blood pressure, heart rate, oxygen consumption, microcirculation on epex of tongue and nail fold, and temperature at Laogong point (P8) of the left hand ($p<0.01$). The researchers suggest that qigong can prevent stresses from altitude changes.

These results with healthy subjects suggest that qigong also should be effective in improving the health of people with cardiovascular conditions. In fact several research studies have been reported the beneficial effects of qigong on cardiovascular diseases.

Microcirculation Disorders

Air force pilots were randomly divided into two groups: a qigong group of 22 persons who had practiced Qiyuan Qigong exercise for eight weeks, and a control group of 18 persons who did physical exercise for eight weeks before entering the Tibetan highlands. Microcirculation was measured at tongue apex and the nail fold, and also from the temperature at the Laogong point in palm of the left hand. When the men entered the high altitude, abnormal blood pressure and microcirculation of tongue apex and nail fold occurred in both groups. However, the abnormalities were statistically less in the qigong group than in the control group ($p<0.01$). The temperature at Laogong kept steady in the qigong group, but was reduced in the control group ($p<0.05$).

Study of Lung Function

The men were divided into three groups. Forty young males were in the qigong group and practiced Qi Yuan qigong for 4 weeks prior to entering the highlands; 40 young men were in the control group and exercised to radio music for 4 weeks prior to entering the highlands; and 40 young males were residents living at high altitudes. The results show that the integral value of symptoms of acute mountain sickness was lower in the qigong than in control group ($p<0.05$—0.01). Pulmonary ventilation of the qigong group was significantly improved compared with the control group ($p<0.05$—0.01), and nearly equal to the resident group.

The favorable outcome of these studies suggests that qigong may be a valuable therapy for people suffering from cardiac, microcirculation and lung disorders.

Summary and Conclusions

This review deals with only a small fraction of a large collection of research already performed on medical applications of qigong, mainly in China. Hopefully, the information presented is sufficient to illustrate the potential of qigong exercise for restoring normal body functions. The main conclusion from many studies is that qigong enables the body to heal itself.

Medical practitioners and scientists are encouraged to evaluate the potential value of medical applications of qigong. They should collect as much information as possible from original sources, develop bibliographies, and then determine whether additional research is required to validate given medical applications. They should then recommend those applications most likely to be suitable for western health care. It is recommended that TCM and qigong be considered to complement western medicine.

There are several issues that should be addressed for the successful introduction of qigong into western health care. It is necessary to win the support of scientists, medical practitioners and the public who know very little about TCM and qigong. A crucial step is to collect scientific evidence from research already performed. Regrettably, there are few research reports in English, and original scientific reports in Chinese are often difficult to obtain and translate. Further, some of the best technical research papers are incomplete scientifically. Recently this has become less of a problem in China. Although some scientific reports have flaws, we must not reject all research on qigong. We must give credit to China for developing the science of qigong and recognize that it is a science in development.

On the positive side, qigong is emerging rapidly among a public interested in improving their health. Qigong is a subject being addressed by the public press and in books and magazines. Increasing numbers of medical practitioners are becom-

ing active in alternative medicine, although few physicians have studied TCM. At least one insurance company has paid for qigong therapy. HMOs and state and federally funded medical programs would benefit from paying for qigong therapy because it is effective and inexpensive. Pharmaceutical companies are already exploring many herbs, and these companies also could benefit from qigong research because of the synergic effect between qigong and drugs mentioned in this review. The Office of Alternative Medicine (OAM) of the National Institutes of Health is working to develop a basis for evaluating the merits of different alternative therapies, and in 1994 it funded one grant involving qigong. Incidentally, the Japanese Ministry of International Trade and Industry (MITI) is reported to be taking a pragmatic approach to alternative therapies by encouraging the development of industrial applications of therapies such as acupuncture and qigong.

There are many medical applications of qigong. Some of the most promising for introducing into western health care are chronic problems such as hypertension, cardiovascular disease, aging, asthma, allergies, neuromuscular problems, and cancer. These areas of public health deserve consideration by the western medical establishments.

*The p-value is the probability that two quantities are not different: the smaller the p-value greater the difference.

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APPENDIX 1B
ANTI-AGING BENEFITS OF QIGONG

Kenneth M. Sancier, Ph.D.

INTRODUCTION

In the early 1980s, scientists in China began to study the medical benefits claimed for qigong. Since then, research on hundreds of medical applications of qigong have been reported in the Chinese literature. Of special interest for the present article are clinical reports of the medical benefits of qigong that claim to retard or reverse some diseases associated with aging.

Most of the original research was reported in Chinese, but access in English to most of this material is possible by reference to the proceedings of international conferences of qigong. Since 1986, ten such proceedings contain about 840 abstracts of talks given at the conferences, more than half of which are in English. These abstracts, along with about 160 abstracts of articles in the scientific literature, have been organized as a computerized database. The database enables searches and development of bibliographies across this entire body of information by using any key word. The clinical outcomes reported in this article are partly based on material in the database and partly on the author's person contacts with researchers.

The word qigong is a combination of two ideas: qi the vital energy of the body, and gong the skill of working of the qi. Medical qigong for health and healing consists primarily of meditation, physical movements, and breathing exercises. Qigong practitioners develop an awareness of qi sensations in their bodies and use their mind, i.e., intention, to guide the qi in the body. The benefits of qigong are said to extend beyond health and healing to enhance spiritual life and even special abilities, such as psychic powers.

Medical qigong is divided into two parts: internal and external. Internal qi is developed by individual practice of qigong exercises. When qigong practitioners have sufficiently mastered the skill, they can "emit" qi (external qi or waiqi in Chinese) for the purpose of healing another person. There are many scientific reports of the medical existence and efficacy of emitted qi. The present article focuses mainly on internal qi because almost everyone can learn qigong exercises for maintaining health and for self-healing, whereas, there are a limited number of skilled qigong masters available for healing.

There are numerous reports of the effects of emitted qi on living systems and the functions and organs of the human body. The present author reviewed some examples of medical applications of qigong and emitted qi on humans, animals, cell cultures, and plants, and he also published some of his experimental research on physiological effects of qigong. He discussed some clinical and experimental evidence showing that qigong exercise and external qi affects various functions and organs of the body. A short list of some of the functions and organs affected by qigong, and the measurement techniques employed (in parentheses), include: the brain (EEG and magnetometer); blood flow (thermography, sphygmography, and rheoencephalography); heart functions (blood pressure, EKG, and UCG); kidney (urinary albumin assay); biophysical (enzyme activity, immune function, sex hormone levels (laboratory analysis); eyesight (clinical); and tumor size in mice.

CLINICAL STUDIES INDICATING THE ANTI-AGING BENEFITS OF QIGONG

Several clinical studies will be described to illustrate the scope of research on medical applications of qigong to treat chronic medical conditions that may affect the aging process. Some details may be omitted because of space limitations. The critical evaluation of the research studies will be left to medical specialists.

THERAPEUTIC BALANCING OF THE CHANNELS AND FUNCTIONS OF THE BODY BY QIGONG

The profound effect that internal qigong practice may have on balancing the energies of the organs and functions of the body is illustrated by measurements using Electroacupuncture According to Voll (EAV). In EAV the electrical conductance of the skin above individual acupuncture points is measured using low voltage and low current. Diagnosis depends on measuring the relative electrical conductance and its time dependence. An important diagnostic criterion of degeneration of an organ is an "indicator drop" that may occur during the measurement when the conductance reaches an apparent maximum value but then decreases before leveling off.

Measurements were made at 24 acupuncture points at the ends of the 12 Channels in the fingers and toes of subjects and were made by the same operator and equipment. The subjects were asked to perform a qigong exercise of their choosing for 10 to 15 minutes, for example, sitting or standing meditation or moving qigong. Two series of EAV measurements were made before and after healthy subjects practiced qigong.

In the first series, four subjects were examined by EAV before and after they practiced qigong. Qigong exercise decreased the average of the EAV measured values of the four subjects in the range of -19 to -31% ($p<0.004$). Qigong eliminated almost all the indicator drops.

In the second series, each of seven subjects was examined by EAV three times in a blind protocol so that the operator did not know whether a subject had practiced qigong before the second or third examination. The results showed that qigong exercise changed the average EAV measured values in the range of -17 to -35% for four subjects and in the range of 4 to 15% for three subjects. Indicator drops again were markedly decreased.

These preliminary results show that internal qigong practice can make significant changes in the therapeutic balancing of the Channel and organ systems.

In a similar type of study, the electric current at acupuncture points on 14 Channels was measured using a single square wave voltage pulse technique. Both a qigong master, who emitted qi, and a qi-receiver were measured simultaneously and continuously. The results show that internal and external qigong produce different values in some measurement parameters, and also some synchronous behavior was observed between the sender and receiver.

BLOOD PRESSURE

The effect of qigong exercise on blood pressure is shown graphically in Fig. 1. The blood pressure (systolic and diastolic) in millimeters mercury is plotted as a function of time over 20 years for the group consisting of 242 patients, 122 in the qigong group and 120 in the control group. During the first two

Fig. 1. Effect of qigong on blood pressure of hypertensive patients over 20 years. Qigong group (n = 104) practiced 30 min/day twice/day, control group (n = 100).

months, the blood pressure of all patients dropped in response to the hypotensive drug. Subsequently, and over the period of 20 years, the blood pressures of the qigong group stabilized while that of the control group increased. Remarkably, during this period the drug dosage for the qigong group could be decreased, while the dosage for the control group had to be increased.

MORTALITY AND STROKE

The incidences of mortality and stroke for the 30-year study are shown in Fig. 2. These results show that qigong exercise decreased by about 50 percent the incidence of total mortality, mortality due to stroke, and morbidity due to stroke. At the end of 30 years, 86 patients survived in the qigong group and 68 in the control group. These results clearly show that qigong has significant potential for preventing strokes and extending life.

Fig. 2. Effect of qigong on mortality and stroke of hypertensive patients over 30 years. Both groups received drug therapy; qigong group (n = 122) practiced qigong 30 min/day twice/day; the control group (n = 120).

IMPROVEMENTS IN HEART FUNCTION AND MIRCROCIRCULATION

Aged hypertensive patients usually are found to have a deficiency of Heart-energy, which often leads to a weakened function of the left ventricle and a disturbance of microcirculation. The researchers evaluated the effects of qigong for120 aged patients by using ultrasonic cardiography (UCG) and indices of microcirculation.

Experiments showed that the left ventricular function (LVF) in the hypertensive aged group (80 cases) was lower than that in the aged normal blood pressure group (40 cases), while the LVF in the deficiency of Heart-energy hypertensive patients (46 cases) was lower than in the non-deficiency Heart-energy hypertensive patients (34 cases).

After practicing qigong for one year, cardiac output was increased, the total peripheral resistance decreased, and the ejection fraction mitral valve diastolic closing velocity and the mean velocity of circumferential fiber shortening tended to be increased. Significant changes did not occur in the group without Heart-energy deficiency.

Quantitative evaluation of nailfold disturbances in microcirculation was made on the above groups by observing 10 indices of abnormal conditions: configuration of micrangium, micrangium tension, condition of blood flow, slowdown of blood flow, thinner afferent limb, efferent limb and afferent limb ratio, color of blood, hemorrhage, and petechia. The results showed that hypertension had an accelerating effect on the disturbance of microcirculation. The incidence of disturbance of microcirculation disturbance was 73.9% in the deficiency of Heart-energy hypertensive patients. After a year of qigong practice, the incident of disturbance was 39.1% ($p<0.01$).

The results suggest that qigong exercise has beneficial effects on Heart-energy and regulation of the blood channel, and qigong seems to have improved abnormal conditions of blood circulation.

ENHANCED ACTIVITY OF ANTI-AGING ENZYME SOD

Superoxide dismutase (SOD) is produced naturally by the body but its activity declines with age. SOD is often called an anti-aging enzyme because it is believed to destroy free radicals that may cause aging. The effects of qigong exercise to treat disorders of retired workers were studied by Xu Hefen and coworkers and included determinations of plasma SOD.

For their study, 200 retired workers,100 males and 100 females, ranging in age from 52 to 76 were divided into 2 groups: the qigong exercise group and the control group, and each group consisted of 50 males and 50 females. The main qigong exercise was Emei Nei Gong (one kind of qigong exercises of the Emei School), and was practiced at least 30 minutes a day.

The result showed that the mean level of SOD was increased by qigong exercise. For example, the SOD level was larger in the qigong group (about 2700 μ / g Hb) and than in the control group (1700 μ / g Hb), and this difference was significant ($p<0.001$). This study shows that qigong exercise can stimulate physical metabolism, promote the circulation of Channels and regulate the flowing of qi and blood, thus preventing and treating disorders of aging and promoting longevity.

CARDIOVASCULAR FUNCTION

Several studies reveal the potential benefits that qigong may have for improving the cardiovascular function of those with heart disease as well as old people. This conclusion is based on three studies reporting that qigong exercise can protect healthy pilots from altitude stress when they flew rapidly from a low altitude to the high altitude of the Tibetan highlands.

Before entering the Tibetan highland, 66 healthy young men were divided into two groups: a qigong group of 32 men who did Qiyuan Qigong exercise for 4 weeks, and a control group of 34 men who exercised to radio music. The two groups of men rapidly entered the highlands from a lower altitude. Before and after entering the highland, measurements were made of symptoms of altitude sickness and physiological changes.

The qigong group suffered less altitude stress than the control group as measured by blood pressure, heart rate, oxygen consumption, microcirculation on the epex of tongue and the nail fold, and the temperature at the Laogong point of the left hand ($p<0.01$). The researchers suggest that qigong can prevent stress from altitude changes.

In another study of changes in altitude, healthy young men were divided into three groups. Forty males were in the qigong group and practiced Qiyuan qigong for 4 weeks prior to entering the highlands; 40 men were in the control group and exercised to radio music for 4 weeks prior to entering the highlands; and 40 males were residents living at high altitudes. The results show that the integral value of symptoms of acute mountain sickness was lower in the qigong than in control group ($p<0.01$ to 0.05). Pulmonary ventilation of the qigong group was significantly improved compared with the control group ($p<0.01$ to 0.05), and nearly equal to the resident group.

In another study, air force pilots were randomly divided into two groups: a qigong group of 22 men who had practiced Qiyuan Qigong exercise for eight weeks, and a control group of 18 men who did physical exercise for eight weeks before entering the Tibetan highlands. Microcirculation was measured at tongue apex and the nail fold, and also from the temperature at the Laogong point in palm of the left hand. When the men entered the high altitude, abnormal blood pressure and microcirculation of tongue apex and nail fold occurred in both groups. The abnormalities were statistically less in the qigong group than in the control group ($p<0.01$). The temperature at Laogong kept steady in the qigong group, but was reduced in the control group ($p<0.05$).

The results of these three studies with healthy subjects lead to the conclusion that qigong also should be effective in improving the health of people with cardiovascular conditions including the aged. In fact several research studies have reported such beneficial effects of qigong on cardiovascular diseases. The three studies also provide evidence that qigong exercise is superior to physical exercise such as calisthenics.

COMBINATION OF MEDICAL QIGONG AND DRUGS THERAPY

There is ample evidence in the literature that therapy by a combination of qigong exercise and drugs is superior to that of drugs alone. The advantages of a combination therapy of qigong and drugs over drugs alone were discussed earlier in this paper for hypertension and cancer.

The mechanism of this apparent synergism is not entirely understood, but undoubtedly relates to the fundamental mechanism of qigong. Qigong is believed to remove blocks to the ready flow of the qi (energy), blood, oxygen and nutrients to all cells of the body as well as to promote removal of waste products from cells of the body. Blocks to energy (qi) flow may result from injury, disease or stress.

Increases in qi flow and blood circulation help nourish diseased or stressed tissue, providing a means for the body to heal itself. This mechanism suggests that qigong also could promote drug uptake to tissue and cells via increased blood circulation. Omura's research shows that drug uptake was increased by using qigongized paper (i.e., paper to which emitted qi was sent) applied to afflicted area of the body.

CONCLUSIONS

This review deals with a small fraction of the large collection of clinical research on medical applications of qigong. The information presented is intended to illustrate the potential of qigong exercise for restoring normal body functions in people with chronic conditions, many of which accelerate the aging process. The main conclusion from many studies is that qigong exercise helps the body to heal itself. In this sense, qigong is a natural anti-aging medicine. Two studies indicate that qigong exercise is superior to some physical exercises.

Qigong can complement Western medicine in many ways to provide better healthcare. For example, qigong has special value for treating chronic conditions and as a preventive medicine, whereas Western medicine has special value for treating acute conditions. There are many medi-

cal applications of qigong that can complement Western medicine to improve health care. Some examples include chronic problems such as hypertension, cardiovascular disease, aging, asthma, allergies, neuromuscular problems, and cancer. These areas of public health deserve consideration by the Western medical establishment.

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3. Qigong Database™ is available from the Qigong Institute, East West Academy of Healing Arts, 450 Sutter Street, Suite 2104, San Francisco, CA 94108, USA.
4. The p-value is the probability that two quantities are not the same: the smaller the p-value smaller the probability and the more significant the result.
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APPENDIX 1C
THE EFFECT OF QIGONG ON THERAPEUTIC BALANCING MEASURED BY ELEXTROACUPUNCTURE ACCORDING TO VOLL (EAV): A PRELIMINARY STUDY

Kenneth M. Sancier, Ph.D.

ABSTRACT

Electroacupuncture According to Voll (EAV) was used to monitor the effects of qigong practice on therapeutic balancing of subjects. In EAV the electrical conductance of the skin above individual acupuncture points is measured using low voltage and current. Diagnosis depends on measuring the relative electrical conductance and its time dependence. An important diagnostic criterion of degeneration of an organ is an indicator drop which occurs during the measurement when the conductance decreases from an apparent maximum value and then levels off. Two series of EAV measurements were made before and after healthy subjects practiced qigong. Measurements were made at 24 acupuncture points at the ends of the Channels of the fingers and toes of a subject and were made by the same operator and equipment. The subjects were asked to perform a qigong exercise of their choosing. In the first series, four subjects were examined by EAV before and after qigong exercise. Qigong exercise decreased the average EAV measured values of the four subjects in the range of -19 to -31%. Qigong eliminated indicator drops for three subjects and reduced the indicator drop by 80% for the fourth subject. In the second series, each of seven subjects was examined by EAV three times in a blind protocol so that the operator did not know whether a subject had practiced qigong before the second or third examination. Qigong exercise changed the average EAV measured values in the range of -17 to -35% for four subjects and 4 to 15% for three subjects. Indicator drops appeared for three subjects, and they were eliminated for two subjects and reduced by 50% for the third subject. These preliminary studies indicate that EAV can monitor the effects of qigong on changes in the therapeutic balancing of the Channel-organ system. Suggestions are made of how EAV can provide basic information about qigong and its applications.

INTRODUCTION

Electroacupuncture According to Voll (EAV) is one of several electroacupuncture techniques for measuring local skin electrical conductance for diagnostic and therapeutic purpose(1). In general, EAV emphasizes preventive medicine by providing the medical practitioner with a diagnosis of a subject's health and its change at every stage of therapy. In the present study, EAV was used to monitor the effects of qigong practice on therapeutic balancing of subjects (2,3). The equipment is basically a D.C. resistance meter that measures relative changes in electrical conductance of the skin above an individual acupuncture point. Diagnosis depends on measuring the relative electrical conductance and its time dependence. The relative conductance is measured by a meter that is calibrated from 0 to 100. The "normal" value of 50 is expected when the acupuncture point and associated organ are in a physiologically balanced condition. Higher values (higher conductance) are associated with inflammation and lower values (lower conductance) with degenerative disturbances. The indicator drop is an important diagnostic criterion in EAV of a functionally disturbed organ. An indicator drop occurs during a measurement when the conductance of a given acupuncture point increases to an apparent maximum value and then decreases to a lower equilibrium value. In the present study, EAV was used to moni-

tor the effects of qigong practice on therapeutic balancing of healthy subjects.

Two series of EAV measurements were made by the same operator and equipment. In both series, the subjects were asked to perform a qigong exercise of their choosing, usually sitting or standing meditation or moving qigong. The first series was performed during an international conference (4) at which qi and the human Channel system were among the main topics. About six months later, the second series was conducted in San Francisco with different subjects (5).

MATERIALS AND METHODS

The EAV instrument, a Computronix Acupro II system (Synergy Health Systems, 1223 Wilshire Boulevard #321, Santa Monica, CA 90403) was designed and operated by Douglas C. Leber. The instrumental test parameters were: 1.25 volts D.C. output voltage, 12.7 microamperes current output at full scale, and 95,000 ohms resistance at midscale of 50. A schematic of the electrical circuit is shown in Fig. 1. The instrument was calibrated from 0 to 100, and the value of 50 indicates that an organ associated with the acupuncture point was free of pathological problems. The tester pressed the brass probe electrode (0.13 cm diameter and connected to the positive side of the circuit) gently onto the acupuncture point as shown in Fig. 2. To minimized variations of skin conductance due to perspiration, tap water was applied to the skin in the region of the acupuncture point before the measurement. The cylindrical brass hand electrode (1-inch diameter and connected to the negative side of the circuit) was held in the subject's free hand, which was also moistened with water. Twenty four acupuncture points at the ends of the Channels of the fingers and toes of a subject were tested in about 5 minutes. The computer was programmed to provide information on the right and left side of the body for twenty organs and physiological functions of the body.

The subjects were 30 to 65 years of age. They were examined by EAV before and after practicing a qigong exercise for 10 to 15 minutes. The subjects went to a secluded spot to practice their own style of qigong, which was sitting or standing meditation or a form of moving qigong. The subjects were asked to balance their energies, and they were examined within 15 minutes after practicing qigong. One subject was examined by EAV before and after receiving qigong therapy from a qigong master and was also examined by EAV three more times within 22 hours.

RESULTS AND DISCUSSION

Series 1: In Series 1, four subjects were examined by EAV before and after qigong. Subjects A, B, and C, who had practiced qigong for more than 10 years, practiced their own style of qigong for 10 to 15 minutes. Subject D, who had studied qigong for about one year, was given a qigong balancing treatment for about 10 minutes by subject A, a qigong master who used a combination of acupressure massage and emitted qi to balance the Channels and organs of subject D. Subject A was not aware of that variations in the polarity of qi may exist in different parts of the his hands and of the body of the subject (6).

Examples of the EAV measurements before and after qigong are shown for subject D in Fig. 3 and for subject C in Fig. 4. The 20 pairs of horizontal bars represent the measured values at the acupuncture points associated with specific organs and functions of the body as described below the pair of bars. For a given pair of bars, the upper bar represents the value on the left side of the body and the lower bar that on the right side of the body. For example, LUCL and LUCR represents the lung Channel on the left and right side of the body, respectively. The scale for the measured values is shown at the bottom of each graph in the figure. A vertical line at the "normal" reading of 50 is a convenient reference for comparing changes that resulted from qigong practice. The two numerical values to the left of each bar are the actual measured values. The maximum value is on the left and the equilibrium value, which may be lower if there is an indicator drop, is on the right. The magnitude of the indicator drop is represented by a "white" bar and its numerical value is the difference between the maximum and the minimum measured values.

Visual inspection of Fig. 3 and Fig. 4 shows

that qigong had decreased all measured values and had either eliminated indicator drops or reduced their numbers. However, qigong did not restore balance to some of the Channels and the corresponding organs. For example after the qigong balancing treatment for subject D, the measured values for the spleen, liver and gall bladder Channels on the right side of the body remained elevated with respect to the others at values of 66, 69 and 67, respectively. In the case of subject C, the measured values remained elevated for the stomach at values of 77 and 66 and for the urinary bladder on the right side of the body at a value of 68, and two of the nine indicator drops remained. These observations suggest that EAV can be used to monitor the effects of qigong therapy on individual organs of the body.

The results of the EAV measurements obtained before and after qigong for each of the four subjects are summarized in Table 1. For each subject, average measured values were calculated from the 40 values, 20 on the left and 20 on right side of the body (see Fig. 3). For each subject, a percentage change (change %) was calculated from the average measured values obtained before and after qigong. The results show that qigong had changed the average measured values of each practitioner in the range of -19 to -31%. The sum of all indicator drops (in meter divisions) for a given EAV examination were either eliminated or reduced markedly by qigong. The style of qigong of each subject and the duration of the practice are noted in a separate column in Table 1.

In Table 1, the plus and minus value that follows an average EAV value is an apparent "standard deviation" that indicates that individual Channels or body functions have measured values greater or less than the average value. This standard deviation would be zero if all the Channels and body functions were balanced and had the same measured AEV values. Individual Channels and body functions may not be balanced for many reasons, including chronic, acute, stress, and emotional factors. The magnitude of the apparent standard deviation may be regarded as a semiquantitative indicator of imbalance in the Channel system.

In a preliminary study to determine possible lasting effects of qigong, subject D was examined by EAV a total of four times over a period of 22 hours. The average measured value was 75.1±5.2 before qigong, 51.5±9.9 twenty minutes after qigong balancing, 55.7±10.4 four hours later after lunch, and 59.0±8.1 twenty-two hours later after breakfast. The increases in the standard deviations after the first 20 minutes were mainly due to large elevations in the measured EAV values of the Channels of the liver at a value of 85, spleen at 85, large intestines at 68, and kidney at 65. These changes are probably caused by food eaten at lunch.

Series 2. A blind protocol was used in Series 2 so that the EAV operator did not know when the seven subjects practiced qigong. This was accomplished by measuring the EAV of each subject three times, and in between measurements the subject left the examination room. After the initial EAV examination, the subjects were given a random selected card instructing them to practice qigong after the first or after the second EAV examination. Later the subjects informed the examiners when they practiced qigong. Of the seven subjects, E, F, G, H, I and K were experienced qigong practitioners, while subject J had studied qigong one year. Computer printouts similar to those in Fig. 3 and Fig. 4 were analyzed for each subject. The averages of the 40 measured values and the sum of indicator drops are tabulated in Table 2. The average measured values obtained just after qigong practice are indicated in boldface.

The results show that qigong practice changed the average measured readings of most subjects. The average measured values decreased for four subjects (E, F, G, H) in the range of -17% to -35%, increased for two subjects (J and K) in the range of 12% to 15%, and remained essentially unchanged for subject I. For subject I, a decrease in the average measured values was observed after qigong, that is, from the second to the third examination (82.7±2.7 to 61.2±11.8, respectively). This decrease may be due to a delay in the effects of qigong exercise. Indicator drops were present

in the EAV of only three subjects before qigong, and these drops were either eliminated or decreased by qigong.

In series 2, the average measured values for four subjects (E, F, G, H) showed similar decreases in magnitude as those in series 1. However, the average measured values for the other three subjects (I,J, K) increased. This difference in response of individual qigong practitioners can be accounted for in many ways, such as by differences in qigong style, intention of the practitioner, and physical and emotional states. For example, we had asked the subjects to balance their energies, but subject J later told us that she had tried to increase her qi, thus perhaps explaining the increase of 12%.

Because of scheduling problems, we were unable to carry out control experiments. However, the reproducibilities of successive AEV measurements before or after qigong were satisfactory for five of the subjects. This can be seen in Table 2 by comparing the second and third measurements (after qigong) for subjects E, F, H, and J, and by comparing the first and second measurements (before qigong) for subject G. These successive readings changed less than 4%.

CONCLUSIONS

Our preliminary studies suggest that the EAV technique can monitor the effects of qigong on the therapeutic balancing of the Channel-organ system. EAV also should be valuable in other applications of qigong: 1) evaluating the effectiveness of different types of personal qigong exercises for balancing organs of the body, 2) measuring the receptivity of subjects to emitted qi, 3) evaluating the effects of different kinds of emitted qi, for example, positive and negative qi (8), 4) determining the duration of the balancing effects of qigong, 5) determining the relative healing power of qigong masters for certain medical problems, 6) comparing the relative effectiveness of energy balancing by qigong with other therapies, such as acumassage, acupuncture, healing with hands, Reiki, as well as conventional physical exercise, 7) investigating the therapeutic effectiveness of qi energy stored on materials such as paper (7), 8) investigating the therapeutic effectiveness of electrical, mechanical and laser stimulation(8), and 9) investigating the interaction between a qigong master and a subject (9).

ACKNOWLEDGEMENTS

The author acknowledges the cooperation of Douglas C. Leber of the Computronix Electro-Medical Systems, who designed and operated the EAV instrument. He also acknowledges support in arranging the experiments by Jim Jose of Synergy Health Systems, qigong master Gong Xin Xiong, Harry Kung, Linda Kung, and the qigong practitioners.

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Table 1. The effect of qigong exercise on the average measured EAV values and sum of indicator drops for each of 4 subjects before and after qigong (Series 1).

Each subject was tested before and after practicing qigong. Subject D was given qigong balancing therapy by subject A. The change (%) refers to the difference between the measured values before and after qigong. The indicator drop (ID) divisions are the sum of all such drops for a given subject. The style and duration of qigong practice is shown in the right-hand columns. Average measured values for before and after qigong were calculated from the average of 40 readings, 20 on the left side of the body and 20 on the right side (see Fig. 3).

Average measured values Sum ID Divisions Qigong
Before After Change Before After Time
SubjectQigongQigong(%)QigongQigongStyle(min.)
A69.0±3.351.4±4.4-26200Moving15
B72.0±3.953.3±7.1-26220Standing10
C67.0±6.654.6±5.7-1912928Sitting10
D75.1±5.251.5±9.9-31530Therapy10

Table 2. A blind study of the effect of qigong exercise on the average measured EAV values and sum of indicator drops for each of 7 subjects before and after qigong exercise (Series 2).

Each subject was tested 3 times. The bold faced numbers indicate measured values obtained just after qigong practice. Secret instructions informed the subjects to practice qigong either after the second or third EAV test. The change (%) refers to the difference in measured values before and after qigong practice. Indicator drop (ID) divisions are summed for a given subject. The style and duration of qigong practice are shown in the right-hand columns. The average measured values before or after qigong were calculated from the average of 40 measured values, 20 on the left side of the body and 20 on the right side (see Fig. 4).

Average Measured Values Sum ID Divisions Qigong
Change Before After Time
SubjectFirst testSecond testThird test (%)QigongQigongStyle(min.)
E61.3±15.439.6±11.238.6±9.7-35140Moving 15
F74.8±3.052.0±5.251.7±4.0-3000Sitting10
G76.1±2.6 79.1±4.258.1±8.6-2700Sitting10
H74.4±3.262.1±12.758.9±10.5-1700Sitting10
I79.2±4.182.7±2.761.2±11.8400Sitting10
J67.5±8.974.5±7.071.1±4.2122814Moving15
K67.2±11.5 53.9±13.562.1±14.71580Sitting10

APPENDIX 2

INTRODUCTION

This second Appendix includes research information on Medical Qigong therapy, collected by my good friend Richard H. Lee, Director of China Healthways Institute, San Clemente, California. Mr. Lee, a council board member of the World Academic Society of Medical Qigong, in Beijing, China, is a specialist in Western medical technology. He has worked extensively with the research department of the Beijing College of Traditional Chinese Medicine, studying the relationship of infrasonic waves emitted as Qi.

This research, focused on the Extension of Emitted Qi by various Medical Qigong Masters/Doctors, was motivated by the pioneering research of Professor Lu Yan Fang at the National Institute of Electro-Acoustics in Beijing, China. Professor Lu developed prototype devices which simulated the frequency output of Medical Qigong doctors.

Mr. Lee has spent many years in China and abroad researching and collecting scientific data which led to the development of several Infratonic Medical Qigong Therapeutic Machines (in Chaotic resonances), which are currently being sold worldwide.

This second Appendix is a continuation of the research devoted to the scientific approach of analyzing and scrutinizing the claims made as to the actual effectiveness of Medical Qigong Therapy as a clinical modality. The result on the effectiveness of Medical Qigong Therapy as a solid and effective clinical modality being positive in conclusion.

The following information in this second appendix represents but a fraction of Mr. Lee's findings, however, I am confident that the reader will find the data fascinating.

Dr. Jerry Alan Johnson May 2000

SCIENTIFIC INVESTIGATIONS INTO CHINESE MEDICAL QIGONG THERAPY

Richard H. Lee
Director China Healthways Institute
San Clemente, California

INTRODUCTION

In the years since the first edition of "Scientific Investigations" was published, the debate over the existence of Qi, the legitimacy of healers, and the reality of PSI phenomena has heated up. While most readers embrace energetic concepts like Qi as a useful framework for unde°rstanding otherwise unexplainable phenomena, some continue to reject Qi. Even in China, while an estimated 100 million people practice Qigong, many professionals remain skeptical. Scientists who actually investigate Qigong generally conclude that the phenomena really do happen, but still try to maintain an arms-length distance from it. Many doctors are also reluctant to discuss Qi openly even though most of the general public is quick to identify Qi as feelings of abundant vitality, and the absence of Qi as fatigue.

There appear to be three principal barriers to serious consideration of Qi.

1. Inertia: "There is not enough data." "These studies have not been replicated." This seems to stem from an unwillingness to explore the studies that have been done. This book presents enough information to satisfy the open-minded investigator and the Qi explorer, but nothing was added in this edition to satisfy those who demand overwhelming evidence.
2. Hidden Bias: This is probably the biggest resistance that Qigong research faces. Many people simply refuse to consider the possibility of action at a distance, as exhibited in Qigong and PSI research. On the basis of this single assumption, all empirical data which supports such phenomena must be rejected as mistakes, experimenter bias, or falsification. Nothing was added to this edition to try to overcome this hidden bias.
3. Need for a framework: While the information presented in the first edition of this book answered the question, "Is the phenomenon of Qigong scientifically measurable?," It left readers without a framework other than faith by which they can understand these phenomena. Without a framework of understanding, many are reluctant to accept these strange experimental results.

Others are less concerned about physical substance and seek to understand Qi as an aspect of intention or consciousness. This more closely parallels the approach of most Qigong masters who, through years of training, gradually gain mastery over their own mind (through focus of attention), emotions (through calmness and releasing desires), and physical body (through discipline). Interestingly, this second viewpoint is similar to the view of many skeptics who insist that phenomena of Qi are simply "a product of the mind." Combining the idea that Qi is strongly influenced by the mind, with the research in this book which shows that Qi is measurable in the physical world, we get a picture of Qi as a mind/body connection which is appealing to most readers.

The Chinese do not view Qi as a scientific substance, but rather, as the essence of life, the bridge of consciousness between mind and body, and the "eternal now" in which all activity occurs. The physical body supports physical fields (Qi) which support vibrational frequency patterns (Qi) which allow communication (Qi) between some kind of abstract consciousness (mind) and a physical body which is our vehicle.

Richard H. Lee, January, 1999

QIGONG MASTERS AND ENERGETIC MEDICINE

For thousands of years, China has been a major source of the world's technology. We are surrounded by Chinese inventions such as paper, movable type, gun powder, and surgical anesthesia. And while the West has shot past China in many technological areas, there are still areas where China holds an edge. The Chinese investigations into the phenomenon of Qigong over the last ten years have, in some ways, placed Chinese researchers at the forefront of energetic medicine. Many findings of this research are presented on the following pages.

Qigong has been practiced for thousands of years in China. Yet it has never before had the broad acceptance that it has today. This is because the scientific investigations into the nature of Qigong show clearly that something is going on beyond what physics might predict. Measurable energy is emitted from the hands of those who have mastered these Qigong techniques. These masters can influence events from a distance with energy (or signal) emitted from their hands. Further, these energy emissions and Qigong training exercises have scientifically measurable, beneficial effects on health and healing.

Qigong masters have demonstrated many remarkable feats. Some can soften and bend steel. Some can light fluorescent tubes with their bare hands. Others can kill cancer cells in laboratory experiments, and many can, from another room, alter the brain wave patterns of test subjects including test animals.

The energy they emit from their hands is measurable with scientific equipment in the forms of infrared, magnetic, and acoustical energy. In one test, a strong pulse of static electricity was measured at a point 50 mm above the head of a Qigong master. In another, a strong magnetic field was measured just at the instant that a heavy iron bar hit a Qigong master's head. The bar bent as it would against Superman's head. He was unharmed with no sign of a lump or a bruise.

In 1979 and 1980, the leaders of China decided to put Qigong to the test. The Western scientific test. High technology government organizations across the country, many as prestigious as the National Atomic Energy Lab in Shanghai, and the Space Science and National Electro-Acoustics Institutes in Beijing, started testing Qigong masters and promptly discovered that the phenomenon of emitted Qi was measurable. Some of these laboratories went further and actually developed therapy equipment such as the Infratonic QGM which reproduces the infrasonic component of the emitted Qi. This research has led me into Qigong and taught me many things I didn't think I ever wanted to know.

Today's Western scientists know little about Qigong, but it is an important healing technology in the world today. It is the basis of acupuncture and traditional Chinese herbal medicine, yet it presents effective medical intervention when used alone. Americans have been radiating cancer with energy emitted from machines for the last few decades. The Chinese have been using energy emitted from the hands of Qigong doctors to treat cancer for thousands of years, finding that, in many cases, tumors can be shrunk without side effects.

These scientific experiments are repeatable. Scientific laboratories in America will reach the same conclusions as those in China. The evidence is persuasive that systematic Qigong training produces real benefits. And advanced practitioners can emit energy from their hands that is measurable with scientific equipment. Further, therapeutic equipment has successfully reproduced many of the beneficial effects observed. The Chinese scientific investigations into medical Qigong are indeed at the heart of a medical revolution that is improving the science of health and healing around the world.

THE SCIENCE OF CHINA

For thousands of years China has been a center for the advancement of civilization. The science of China has produced a wide variety of technologies. Gunpowder is the central ingredient to modem warfare. Paper and printing with movable type have for centuries been at the center of education, communication, and information stor-

age. Despite the growth of computers, this system will continue to be the world's dominant information storage method.

Many centuries ago, a physician named Hua Tou invented surgical anesthesia and performed many kinds of surgeries like appendectomies and other of today's popular surgeries. While the Chinese contributed to what has today become modern medicine, they also created "Chinese medicine," a system of medicine based on the Chinese science of "Qi" or vital energy. It is this system from which acupuncture and Chinese herbal medicine have evolved. And at the heart of this system lie the science and practice of Qigong.

QIGONG'S LONG HISTORY

Through the millennia Qigong has been an influential force in the molding of China. Until recently it has been hidden from public view. Like many other disciplines, the art of Qigong has been taught from father to son or from master to disciple only after a strict oath of secrecy has been given. Knowing a science that others don't know gives a practitioner a decided advantage in earning a living. Thus, until recently, very few books have been written about Qigong, particularly about the more advanced techniques of study. The exception is the secret books that have been maintained in religious monasteries, being copied and recopied by studious monks through the centuries.

Even this activity in monasteries came to an abrupt halt with the Communist government in China when Mao put an end to most religious activities. Through the Cultural Revolution, monasteries and temples were shut down. Many of the ancient texts and artifacts were destroyed. Others were stored in government libraries. Many of the Qigong masters were killed. A few went into hiding or escaped from the country.

At the end of the Cultural Revolution, Deng Xiao Peng set about rebuilding much of the cultural heritage of China, allowing limited freedom of religious expression. He also promoted the rediscovery and preservation of traditional Chinese science and medicine, which included Qigong.

It is interesting to note that much of the willingness to share the secret teachings of Qigong came from outside countries. Masters who had emigrated to the West had started teaching the techniques openly without the strict code of silence. And some of the secret Qigong texts that had been taken from the temples and monasteries were published for people around the world to read. Qigong was no longer a secret so there was no longer any value to secrecy in China and Qigong masters became much more willing to teach what they knew.

The most influential factor in the Qigong revival was, perhaps, the new policy on the part of the China government to allow freedom of religion, particularly religion that had a basis in China's cultural heritage. Thus, Taoists and Buddhists who had preserved its teachings in secret for centuries were free to share their knowledge. This allowed Qigong practitioners to demonstrate their skills freely in public without fear of being condemned to death as witches or evil beings. Paranormal skills were again publicly accepted as a product of China's cultural heritage.

The big boost to Qigong came in the early 1980's when modern science turned to study the tradition of Qigong. The leaders of China reasoned that, if Qigong is to be accepted, it must pass the rigorous screening of scientific scrutiny. Studies were funded in the prestigious scientific institutes of China to determine whether the special skills of the Qigong masters could be scientifically verified. The results were most impressive. Many forms of energy were measured coming from the hands or bodies of Qigong practitioners in reproducible scientific experiments.

Scientific investigations into the effectiveness of medical Qigong quickly showed that, for many illnesses, medical Qigong was unsurpassed by any other medical system in the world. The discovery that energy emitted from the hands of Qigong doctors under controlled laboratory conditions was highly effective in killing cancer cells, gained extensive press coverage around the world.

Qigong science is a very new field with valuable technologies just beginning to surface. But given the fundamental nature of these discoveries, Qigong science could easily dominate the

world of the 21st century.

SIMULATION OF EMITTED QI

Simulation of emitted Qi has been the goal of much of the Chinese Qigong research that has been conducted since about 1980. Many devices have been developed and tested, some of which have considerable potential. The following is a description of the most common forms:

Infrared devices have been developed some of which, through rare-earth emission surfaces, emit characteristic frequency bands, while others modulate the infrared output according to recorded patterns emitted by Qigong masters. These devices tend to have the most effect where coldness in the body is effectively treated with heat.

Electrical devices are often adapted to deliver current through the skin at frequency patterns that follow patterns produced by Qigong masters. These units have been used principally by acupuncturists.

Acoustical devices, which reproduce the subsonic output of the emitted Qi in the form of deep acting massage action, have been shown to be effective in pain management, circulation of Qi, blood, and endocrine fluids, and relaxation. The Infratonic QGM was used in several of the laboratory tests described in this book to simulate the emitted Qi in experiments. Because this device offers many insights into the nature and function of emitted Qi, and because many of the readers of this book use the Infratonic QGM at home or in their medical practices, much of the research around this device is included in this book.

SCIENTIFIC PLAUSIBILITY OF QI, THE HUMAN ENERGY FIELD

Some readers might tend to reject the findings of this study based on their assumption that the existence of human energy fields and the altering of a person's energy field are outside the laws of physics, and therefore impossible. It is therefore appropriate here to briefly review some of the findings of researchers mostly within the last decade to show that these energy fields are quite measurable with existing equipment and that there is strong evidence that known biophysical mechanisms can account for the observed phenomena.

First, the human body clearly has a vibrating electrical field, measurable for decades through such techniques as EMG, EEG, and EKG. How is this possible? The classical view of the human cell as a bag of water with a nucleus has been, for the most part, rejected in favor of models in which a highly structured collection of filaments, tubes and fibers connect the cell's nucleus not only to the surface of the cell but beyond, in a matrix which connects and interrelates the cells of the entire body (Oschman 1994) and (Pinta and Coffee 1991). Second, helical molecules within the body, such as DNA, keratin, collagen, actin, and myosin have piezoelectric qualities. As they elongate and contract they produce voltages. Also, when voltages are applied, they expand or contract producing mechanical activity and acoustical energy.

While it is well established that electrical signals are produced and received by the body, readers are more likely to question whether a magnetic field interpenetrates and surrounds the body. In 1963 researchers at Syracuse University reported the first measurements of the magnetic field of the human heart, just a millionth the strength of the earth's magnetic field, yet highly coherent and measurable throughout the body and beyond. Then in 1971, the SQUID, a highly sensitive superconducting magnetometer, was developed which was used to measure the magnetic field of the brain, 100 times weaker than that of the heart (Cohen 1972).

Many researchers now believe that the magnetic field of the heart, which extends throughout the body plays a role in regulating biological functions. Then, in 1991, Seto and colleagues measured the magnetic field between the hands of healers to be as strong as 1 milligauss. This is less than 1% the strength of Earth's magnetic field, but 1000 times as strong as the magnetic field produced by the heart. If the heart regulates biological functions with it's weak field, it is certainly feasible that a magnetic field from the hands of healers, measured to be many times stronger than the heart field might influence biological functions.

But, how can a magnetic field be produced

from the hands? The Josephson junction, a superconducting semiconductor which is the basis of the SQUID's extremely high sensitivity to weak magnetic fields, has been predicted in quantum physics calculations to be present in living tissue. This was verified just ten years ago. (Del Giudice et al 1989). DNA is one of the biochemical structures shown to act as a superconducting magnetic field detector, able, through the Hall effect, not only to detect very weak magnetic signals, but also to produce magnetic signals (McCraty 1993). Thus DNA may act as a signal amplifier, releasing its energy coherently into passing magnetic waves, much as the ruby rod of a laser releases its light energy coherently with a passing photon to produce a laser beam. This provides a mechanism by which healers might produce the observed relatively strong biomagnetic signals, and by which a test subject or patient might be influenced by such signals (Oschman 1993).

Thus, modern advances in science now provide mechanisms by which it is possible for healers to produce magnetic and electric signals of significant magnitude to influence patients. For those who seek a more indepth overview of this rapidly advancing field of knowledge, "The Scientific Basis of Energy Medicine" by James L. Oschman, 1998, is highly recommended.

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THE FUTURE OF QIGONG

Chinese research has found that Qigong training increases balance, quickness and endurance in athletes, and that fighter pilots trained in Qigong have quicker reactions and greater tolerance for the G-forces of sudden turns. Qigong has provided revolutionary treatments for hypertension and cancer, and has the potential for much more.

If, as the Chinese claim, Qi is the fundamental substance of the universe making up both matter and energy, and if we can through our bodies and our awareness, control and direct this Qi, not only within our own bodies, but as has been seen, beyond the limits of our bodies, the fantasy of "the Force" in Star Wars comes within the grasp of reality. Psychic phenomena like telekinesis and mental telepathy become minor extensions of the human manipulation of Qi. The Western ideas of positive thinking take on new meaning:

"The mind is the builder" and "Your thoughts

create your reality."

The Chinese science of Qigong gives us proven tools to strengthen our ability to structure the world around us by training our minds and bodies to feel and understand Qi.

Remember that Western science and technology gave us electric motors which, when coupled with man-made equipment, can do the work of a thousand men. This came with our understanding of the principles of electricity. Emitted Qi simulation devices such as the Infratonic QGM provide this work-saving feature of machines. As we learn more about Qi, how it functions, and how it is directed by the human body, we will learn how to construct more and more powerful machines. We will see Qigong devices not only in hospitals but also in agriculture, in building air conditioning systems, in chemical processing plants and in space flight. The scientific Qigong research that started just a decade ago will grow and grow, and perhaps dominate our world of the 21st century.

However, the real emphasis of the Qigong movement and the intent of most Qigong teachers is not just to heal patients with illness, but to expand human potential. The research presented in this book shows that Qigong exercises help people to develop, not only the ability to heal themselves and others, but to do things which scientists considered impossible just a few years ago. Through a study of Qigong, there is strong evidence that we can become more than we ever thought possible.

Infrasonic Qigong Research

The discovery that specific bands of very low frequency sound influence healing and vitality was an accident. A "friend of the family" walked in to the National Electroacoustics Laboratory in Beijing and asked Prof. Lu Yan Fang, an acoustics scientist, if she would test his hand to see if any sound was coming out of it when he emitted Qi. She thought he was crazy but went along because she didn't want to dishonor her family by turning out a friend.

Prof. Lu's discovery that he did indeed emit a very strong signal in the infrasonic range was quite a surprise. This signal was 100 times stronger than that of a healthy, normal person. Elderly and sick people had even lower readings.

To verify that this infrasonic sound had a physiological effect, she built a device to simulate this output and tested it in hospitals. It worked to relieve pain and assist recovery in a wide variety of patients.

Prof. Lu's patent for the Infratonic QGM was the first ever filed in China and her device was awarded three awards for outstanding contribution to science and medicine from Chinese national science organizations.

It is clear from the Chinese infrasonic research presented in this chapter that infrasonic sound is an important component of emitted Qi.

Infrasonic Simulation of Emitted Qi from Qigong Masters

by Professor Liu Guo-long, MD, PhD
Beijing College of Traditional Chinese Medicine
with Richard Lee

Summay of Research

Emitted Qi from Qigong masters clearly has a strong effect on the central nervous system, not only in humans but also in animal subjects. Qigong meditation and the Infratonic QGM have similar effects. These findings are summarized below:

Repetition of these tests with animals confirmed that these changes are physiological and not psychological phenomena by eliminating placebo effects.

Doubts about Emitted Qi

At the beginning of my research with Qigong, I was confident that a study of neurophysiology would prove that the "Wai-Qi" emitted by Qigong masters was nothing more than a psychological factor induced by the waving of hands and hypnotic suggestion.

Qigong is a system of physical and mental exercises which has been practiced in China for thousands of years. Up until the 1980's, most Chi-

nese considered Qigong masters (those who have mastered this Qigong training) to be mythical story book characters with super-human powers. However, as the Chinese government began to support scientific research into Qigong, the few remaining true Qigong masters began to surface, amazing researchers with feats like killing bacteria in test tubes and causing previously paralyzed people to get up and walk.

I thought that these were all tricks of one sort or another, perhaps magicians' sleight-of-hand, hypnosis, or optical illusion. When I got the chance to work with people claiming to possess these abilities, I was fascinated. This was my chance to test with scientific equipment, whether there was any truth behind the excitement about Qigong masters. I was confident that I could disprove the myths.

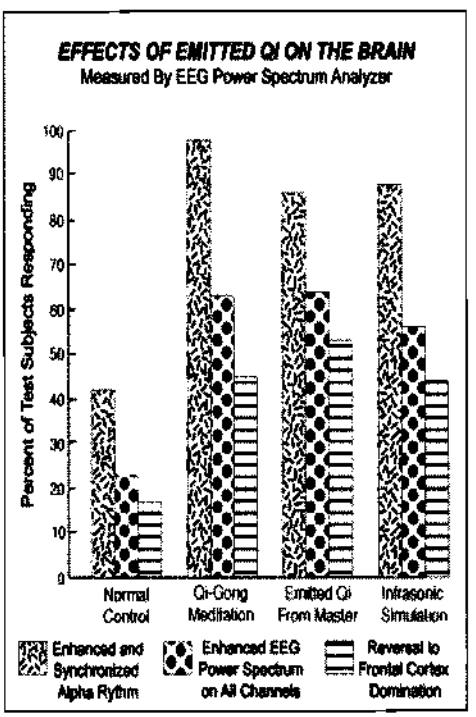

Emitted Qi has a pronounced and repeatable effect on EEG. It enhances frontal and occipital EEG power spectra, and often enhances the frontal so much that frontal becomes the dominant EEG activity whereas occipital dominance is more common. Emitted Qi also enhances and synchronizes the Alpha.

BACKGROUND

I was a specialist in Western medical technology assigned to the research department of the Beijing College of Traditional Chinese Medicine. The project was sponsored by the China Government Department of Education and the Department of Natural Sciences. My research group was assigned to study the relationship of infrasonic waves to emitted Qi. These research grants were motivated by the pioneering research of Prof. Lu Yan Fang at the National Institute of Electro-Acoustics in Beijing, who developed prototype devices to simulate the output of Qigong doctors.

Research has confirmed that humans have a very high degree of acoustic activity in the subsonic range below 20 Hertz (infrasonic), similar to the alpha rhythm of EEG. Also, people with chronic illnesses were found to have a much lower level of infrasonic activity, while Qigong masters had a much higher level of infrasonic output when they were emitting Qi.

The implication was that infrasonic sound might be related to human functioning, and further, that it might be in some way involved in the mechanism of brain functioning. We searched the available scientific literature for research papers for relationships between sound waves and brain waves but found none that had been done.

Extensive clinical research, based on infrasonic Qigong simulation, showed it to be effective for a wide variety of hospital problems. These results are what motivated the National Departments of Education and Natural Sciences to look further into the importance of infrasonic sound and what led to the research I am about to describe:

THE BRAIN AS A DETECTOR OF EMITTED QI

I had learned in my many years of research with the Electro-Encephalograph (EEG) that the human brain responds to even the most subtle of stimuli to the body, so I reasoned that, if there were

really any scientific basis to emitted Qi, it would show up in the brain waves of test subjects who were placed in the path of these emissions. I expected to see no difference between the resting states and the Qi emission states.

What we saw was extraordinary. Within a few seconds after the Qigong master began to emit Qi, the subject's EEG would begin to shift. The EEG power spectrum was enhanced on all channels while the most pronounced increase was in the frontal lobe. Also, there was an enhancement and synchronization of the Alpha Rhythm in all channels. When the Qigong master stopped emitting Qi the EEG would gradually shift back toward the baseline readings.

To determine whether infrasonic energy was a significant part of the emitted Qi, we used the infrasonic Qigong prototypes in the same experiment. It was located 18 inches away, directly behind the back of the head of the test subject. The EEG electrodes were attached as before. The simulator was activated for short periods of time and the results recorded. We found that the effects on the receiver's EEG were quite similar to those of the emitted Qi.

Our further research involved monitoring the various sensory-cortical evoked potentials during Qigong meditation, emitted Qi, and infrasonic Qigong simulation. We again found very similar results from all three stimuli. We found that a large portion of the cerebral cortex was inhibited while other somatosensory cortex were excited. One of the significant findings of this study is that the inhibition of the cerebral cortex during Qigong meditation is clearly different from the excitation of the cerebral cortex that is measurable during sleep.

Through Acoustical Brainstem Evoked Response (ABER) it was found that the brainstem structures from the medulla to the hypothalamus were significantly facilitated. The brainstem plays an important role in regulating the functions of the inner organs, motor function, and emotion.

The implications of these studies were startling. Qigong masters can, without touch, voice, eye contact or any other traditional communication means, induce a clear, strong, and highly measurable change in a subject's brain functioning. A synchronization of alpha rhythm indicates deep relaxation, and is closely associated with accelerated healing. Enhanced power spectrum in the frontal lobe is especially significant because the association cortex of the frontal lobe is concerned with higher motor action, higher sensory function, emotional and motivational aspects of behavior, and integration of autonomic function. Facilitation of the brain stem, with its regulation of internal organs, may be a mechanism by which physical healing is induced or accelerated.

Despite these highly significant changes in EEG and evoked potentials, the subject had felt nothing and had no idea of the profound changes taking place within them.

The findings of these studies are solid evidence that a Qigong master can induce real physiological changes in a subject from several feet away, and further, may help to explain the high rate of recovery from chronic degenerative diseases in groups of hospital patients under the care of Qigong masters. These studies also show that the infrasonic Qigong simulator can induce similar changes in brain function and that, through Qigong meditation, a Qigong master can induce these same changes in his own brain.

SCIENTIFIC CONTROLS

There is much disagreement on how emitted Qi affects the brain. Many doctors insist that brain changes are psychologically induced, and that verbal suggestion, impressive hand motion, and expectation of the subject account for the observed phenomena.

To test this, we had several Qigong masters and people pretending to be Qigong masters treat the test subjects. The subjects were told that all were Qigong doctors, and all moved their hands in similar ways. We saw no significant changes in brain wave patterns with the fake Qigong masters, but when the real doctors emitted their Qi, or when we used the infrasonic Qigong simulator, we repeatedly got the highly significant changes.

Even this did not satisfy many of the doctors who reviewed our work, so we repeated the study with animals. We monitored EEG in awake rabbits and ABER in anesthetized cats as Qigong masters emitted Qi toward them. Even though there was no voice or eye contact between the Qigong masters and the animals, and the masters emitted Qi from several feet away, we saw shifts in EEG and ABER (Acoustical Brainstem Evoked Response) similar to those observed in the human subjects. This is a highly convincing result because all kinds of placebo effects are eliminated, yet modification of brain function at a distance remains.

Infrasonic vs. Electromagnetic Interference

Extremely low frequency (ELF) electromagnetic signals can affect EEG. There is growing concern about the low frequency radiation produced by 60 Hz electrical power lines located close to people's homes and schools because of apparent disruption of brain and cellular function. ELF signals will cause the principal EEG power spectrum to show a spike at the frequency of the ELF signal. This is because the EEG is easily entrained by ELF signals. When the signal is discontinued, the EEG abruptly returns to normal. Electrical power lines operate at 60 Hz, which corresponds to EEG in the high Beta range, associated with mental anxiety and confusion. The entrainment of EEG to 60 Hz around power transmission lines may be why researchers are finding that people who live close to these power lines show a higher incidence of brain tumors.

The results using the infrasonic Qigong simulator were quite different from ELF signal entrainment. The shifts in EEG were gradual rather than abrupt, and while dominant EEG frequency did drift toward the dominant peak infrasonic frequency, it was a broad spectrum of EEG activity rather than a spike. The enhanced power spectrum continued after simulation was stopped, gradually decreasing and returning to the pretest state. From these observations it is clear that the effects of infrasonic are quite different from the entrainment of ELF electromagnetic signals.

Summary

When I started this project in 1976, I had serious doubts about Qigong masters and emitted Qi. Now I am convinced that emitted Qi is very real and that Qigong is a very valuable art. With the support of the China government, an estimated 50 million Chinese are practicing Qigong daily, and many Western hospitals have added Qigong departments for patients with chronic and degenerative diseases. In addition, the China government has funded extensive scientific research into the nature of emitted Qi with the goal of advancing science and medical technology.

The study of emitted Qi and infrasonic sound, as they relate to human health and functioning, is a broad and exciting field. The use of Qigong in treating chronic degenerative diseases such as cancer and hypertension in China has proven very effective. It has been employed to accelerate healing for thousands of patients with a wide variety of diseases in Chinese hospitals. I am confident that emitted Qi, Qigong meditation, and the infrasonic Qigong simulator will play an increasing role in health care around the world.

Secondary Acoustic Biological Response

(The following is from a technical paper presented in Beijing, China by Professor Lu Yan Fang, the inventor of the Infratonic Qigong Machine.)

"People often talk about sound. Common sense suggests that sound is what the ear can hear, the frequencies between 60 Hz. and 20,000 Hz.

Secondary sound is that sound that is outside of the range of the human ear, specifically low frequency sound below 60 Hz. Secondary sounds travel long distance with little attenuation.

In the 20th century, in the 1930's, this secondary sound was discovered, but it wasn't until the 1960's that it started drawing much attention. Since then the study, measurement, and analysis of the physical features of secondary sound have

included:

1. Physical Features
2. Secondary Sound Measurement
3. Technology of Analyzing, and
4. Protecting the Body Against Strong Secondary Signals

Initial secondary sound biological response studies emphasized protecting against high level secondary sound which can damage the human body. Laboratory studies showed that strong secondary sounds beyond 150 dB are harmful to biological bodies. The American Environmental Protection Agency sets standards for secondary sound, concluding that secondary sounds below 130 dB are not harmful.

To this date there had been almost no studies investigating how secondary sounds affect biological processes. And never before has there been any thought of testing of the human body as a secondary sound source. Since 1983, we have worked with more than 70 Qigong masters, and have discovered for the first time that the human body actually emits a secondary sound signal. The frequency distribution peak of the signal is located in the secondary sound region of the sound spectrum, at about 10 Hz.

Through more than 100 repeated lab experiments we found almost identical results of frequency distribution. According to the analysis of test results in 1984, the first infrasonic Qigong prototypes were constructed. These machines used electroacoustic technology to simulate the frequency distribution of the Qigong master's low frequency signal, but stronger. This simulation of the human body life signal emission is then fed back to the human body. In the two years that followed, many clinical and animal tests proved that weak secondary sounds benefit the human body. The discovery that infrasonic sound is a basic substance of Qigong emission opens Qigong science's big door, opening an exciting new field for medical science.

Through hospital and clinical use, 1,134 patients were treated by the Infratonic QGM. Animal studies were also performed. Clinical use and animal use prove that this kind of secondary sound signal can strengthen many functions of the human body. The Qigong machine can have significant treatment value to the human body and works by reproducing the acoustic waves produced by the human body. It can promote circulation, regulate Qi and blood, open channels, and relieve pain.

The Qigong master is not alone in this ability to emit the secondary acoustical signal. Most everybody generates a similar signal. Young people with good health can emit the signal to a degree similar to that of a Qigong master. People with a weak body and elderly people have similar signals but much lower in power. People having Qigong training have a signal that is strong all the time, but especially strong during Qi emission. However, in normal people, as age increases or health condition worsens, the signal decreases. This explains why the human body is only sometimes a source of secondary sound. In the meantime, the body is also a receptor of secondary acoustical signals, and can be benefited by receiving the weak secondary acoustic signals.

Very early in the development of traditional Chinese medicine, this effect had been shown to exist. Anmo, and tuina, Chinese therapeutic massage techniques, give the human body this kind of low frequency stimulation. This stimulation through acupuncture points follows the cell as the basic pathway, and then goes to the meridian, and reaches the problem area. Then the problem can improve. Just like an old Chinese saying: "If you can get enough energy into the problem area, you can use that energy to treat the problem."

The human body's secondary acoustical biological effect is a scientific reality. The human body produces, delivers, emits, receives and controls this low frequency energy. This weak secondary acoustic effect has beneficial biological effect on the human body. It and its relationship with traditional Chinese medicine are of great value to the medical world. It is hoped that all scientists do research in this area.

MEASUREMENT AND ANALYSIS OF INFRASONIC WAVES FROM EMITTED QI

Niu Xin, Liu Guolong and Yu Zhiming
Beijing College of Traditional Chinese Medicine, Beijing, China

The theory of traditional Chinese medicine suggests that Qi is one of the fundamental substances in human bodies. Modem scientific research of the essence of the emitted Qi has yielded some positive results. In order to find out the relation between the emitted Qi and infrasonic waves, to explore the mechanism of the emitted Qi, to find out how a person generates and receives the emitted Qi, and to provide a quantitative physical scale for indicating the strength of the emitted Qi for experimental studies of the effect of it, we measured and analyzed the infrasonic waves from the Qi emitted by Qigong masters.

The test, which was done by an infrasonic testing system made in Denmark, was conducted in a noise-proof room in the Institute of Sound and Electronics under the Ministry of Electronic Industry. The background noise in the room was lower than 30 dB (decibel). The microphone was hung in the air over Laogong (P-8, acupuncture designation for a point in the center of the palm), the distance being 2 cm with no contact.

The experiment tested the release of emitted Qi at Laogong (P-8) in the palm, Mingmen (Du-4), Baihui (Du-20), Dantian, and Jianzhi. Special attention was paid to the test of Laogong (P-8).

1. The peak frequency of the infrasonic waves from the tested Qigong and non-Qigong masters ranged from 8 to 12.5 Hz. In one case the frequency reached 16 Hz. In another two, it reached 6 Hz.
2. The infrasonic waves from the Qigong masters ranged from 45 to 76 dB and those from the non-masters, 45-50 dB. Comparison of the intensity of infrasonic waves during the Qigong state and the non-Qigong state before and after the emission of Qi showed a statistically significant increase ($P<0.01$).* The increase of wave intensity of the Qigong masters compared with that of the non-Qigong masters was also obviously significant ($P<0.01$).* **The energy of the Qigong masters was over 100 times higher than that of ordinary persons.**
3. The masters who had practiced Qigong for many years and often emitted Qi to treat patients had a higher intensity of infrasonic waves, reaching over 70 dB. Those who started to practice Qigong a short time before and mainly practiced *Nei Yang Gong* had a lower intensity of the infrasonic waves (lower than 60 dB.)

Infrasonic and ultrasonic waves are all sound waves which cannot be detected by human ears. The frequency of infrasonic waves is below 20 Hz. Many natural phenomena and artificial actions may generate infrasonic waves. Human bodies may act as a source or a receptor of infrasonic waves giving rise to a biological effect. The infrasonic information we acquire a from the measurement of the Qi makes it possible to study the effect of the emitted Qi.

The Valsalva state in which a Qigong master emits his Qi, is the breath regulating state of Qigong and also the state of emitted Qi in the breath holding exercise. Non-Qigong masters who simulate the Valsalva state also send out more intense infrasonic waves. It shows that every person has infrasonic characteristics. A long period of practicing Qigong helps increase the radiative intensity of infrasonic waves. Entering the Valsalva state helps in the emission of Qi. The Qi emitted by masters who adopted Song Jing Gong (relaxed Quiescent pattern) had more intense infrasonic waves (reaching 72 dB). Thus, the mechanism of the emitted Qi released by different exercise patterns is different.

We have found by a series of tests that very able Qigong masters can keep the energy of infrasonic waves at a relatively high level (over 70 dB). So tests on infrasonic waves can be used to screen Qigong masters.

The human body can generate and emit infrasonic waves. As far as acoustics is concerned,

the most suitable resonant frequency of human tissues is within the range of infrasonic waves. It shows that the human body easily receives infrasonic waves. Infrasonic waves are a strong, effective part of the emitted Qi because of their quick, long distance transmission, strong penetration, and non-decreasing vibration. It is possible that infrasonic waves themselves transmit the messages between the Qigong masters and the subjects, or serve as a carrier.

[(P<0.01) means that the probability that these test results would occur by chance is less than 1%. This measure of "statistical significance" tells us that the sample size was large enough and causative factors strong enough that the results of this study are reliable.]*

NEURO SCIENCE—NERVE IMPINGEMENT AND EMITTED QI

China Healthways Newsletter's Interview with Liu Guo Long, MD, PhD
Beijing College of Traditional Chinese Medicine
by Richard H. Lee in Palos Verdes, CA, August, 1991
(This interview came about as a result of requests by readers of China Healthways Newsletter for an explanation of neuroscience as it relates to vital energy and healing.)

Dr. Liu provides a fresh view into the role of vital energy in the nervous system and how vertebral nerve impingement affects Qi.]

China Healthways Newsletter: How has your research changed your views on Qi?

Dr. Liu: I started my research with the intention of proving that there was no physiological basis for Qigong, that it was nothing more than a circus trick. As my research progressed, I became more and more convinced that emitted Qi is both measurable and effective for healing. This was not before I eliminated all possible psychological effects by replacing human subjects in my experiments with laboratory animals and got similar results. In my view, emitted Qi is quite real because it is easily measurable using the human brain as a detector.

CHN: How does Qigong affect the function of the nervous system?

Dr. Liu: This is a very complex question because emitted Qi affects different organs quite differently. First, it clearly increases Electro-Encephalograph (EEG) activity throughout the brain and nervous system, principally in the frontal cortex and in the range of alpha, 8 to 14 Hz. This greater mental activity in the alpha range is associated with clear relaxed state of deep thought, which many agree is effective to relieve tensions and clear the mind. The frontal cortex of the cerebrum is at the top of the hierarchy. It is the center of awareness within the body, directing the cerebellum and brain stem. Increased EEG activity in the frontal cortex would indicate expanded awareness.

Secondly, emitted Qi inhibits the sensitivity of the cerebrum to outside stimulation while facilitating the sensitivity of the hypothalamus and medulla of the brainstem. The cerebrum performs high level conscious activities. When inhibited it receives less visual, auditory, and sensory input, and presumably sends fewer and clearer signals to the brain stem, which, in turn, is responsible for automatic functions such as respiration, vasodilation, and the complex functioning of internal organs. Because the brainstem is facilitated, it is more able to "tune-in" to the needs and illnesses of the body and to activate the needed repairs to restore health. I believe that this enhanced awareness of internal stimuli in the brain stem, combined with reduced sensitivity to outside stimuli, is the primary product of emitted Qi that brings about accelerated healing throughout the body.

CHN: Then, would you say that emitted Qi directed only to the central nervous system can enhance healing in all parts of the body?

Dr. Liu: That's right.

CHN: How can Qi applied to the local injury accelerate healing?

Dr. Liu: Neurons in all parts of the body are in constant oscillation, producing measurable output in the range of 8 to 14 Hz, the frequency of the alpha pattern. Neurons can both emit and receive energy in this frequency band. Therefore nerves throughout the body can be facilitated by the

emitted Qi. The application of emitted Qi to the site of an injury facilitates the signals to the brain stem. Stronger and more accurate signals to the brain means a more effective healing response directed to the area of injury, including greater vasodilation, increased lymph flow, and an increased supply of nutrients for cell regeneration.

CHN: Is there any direct effect of emitted Qi on the injured tissue.

Dr. Liu: Yes, of course. Qi is the vital energy that drives the regeneration of tissue. Supplementing the available Qi can directly increase the metabolic activity of the injured tissue just as it increases the EEG activity of the brain.

CHN: How can emitted Qi strengthen the immune system against bacteria and viruses?

Dr. Liu: The mechanisms are the same. A facilitated brainstem and nervous system are able to identify the invader more quickly and accurately and to direct the immune system response more precisely to the area of infection. And, as before, the added supply of Qi fuels a more furious response from the immune system. Chinese herbs such as Huang Qi (Astragalus) are also highly effective at enhancing Qi to accelerate the immune response.

CHN: Can mis-position of spinal vertebrae disrupt this healing process?

Dr. Liu: Most definitely. There are basically three types of nerves, the sensory, the motor, and autonomic. Vertebral pressure on any type of nerve cell can inhibit sensitivity or create false signals. If sensory nerves are affected, important information may never reach the brain, or may arrive confused, misdirecting the healing effort. Affected motor nerves can result in spasm or dropsy, and most importantly, impingement of autonomic nerves affects the function of internal organs and if it continues over a long period, can result in serious degeneration or dysfunction.

Often, impingement of motor nerves can perpetuate the problem. As muscles spasm from false motor nerve signals, they may tend to pull the vertebrae further out of alignment, increasing the impingement. In this case, the problem tends to get worse with time as greater impingement further increases the muscle spasm.

The best way to deal with this sort of nerve impingement is through adjusting the position of spinal vertebrae. Often just the vertebral adjustment is sufficient to release pressure on the motor nerve and release the muscle spasm, allowing complete recovery. However, in many cases the impinged nerve is slow to recover, showing some immediate release of spasm but not complete release. The remaining muscle spasm is sufficient to pull the vertebra out of adjustment again and re-establish the motor nerve impingement.

In these cases of muscle spasm aggravating the nerve impingement, better results are achieved if a nerve facilitation technique is used in conjunction with the adjustment. Emitted Qi or the Infratonic QGM applied a few minutes before or after the adjustment facilitates the nerve to provide greater muscle relaxation and quicker regeneration of the nerve. In upper back disturbances the Chinese herbal formula, Hsiao Yao Pien is also excellent to accelerate progress by promoting improved Qi circulation through the motor nerves and through the muscle itself.

Infrasonic Treatment of Asthma

by Su Cheng Wu,
Department of Pediatrics,
The First Affiliated Hospital Guangxi Medical University,
Nanning, Guangxi, China.

(This clinical study finds that infrasonic sound is effective in treating symptoms of childhood bronchial asthma, and in strengthening immune function as measured by T-lymphocyte population.)

Fifty cases of child bronchial asthma were treated with the Infratonic QGM and routine drugs. T lymphocyte subpopulation (CD2 , CD4, CD8, and CD4/CD8) of peripheral blood was measured to evaluate this treatment's clinical effectiveness on raising immunity. The control group of 15 cases was treated with routine drugs only.

TREATMENT METHOD

Based on the features of child bronchial asthma and a dialectical therapeutics of traditional Chinese medicine, the following four points were treated for 5-10 minutes each morning for 5 days:

Dingchuan (located on the back, 0.5 cun lateral to the lower border of the spinous process of the 7th cervical vertebra). Indications: Facilitating the flow of the lung-qi to relieve asthma. Feishu (Located on 1.5 cun lateral to the lower border of the spinous process of the 3rd thoracic vertebra). Indications: Facilitating the flow of the lung-qi to resolve cough. Tiantu (located on the neck, on the anterior midline, in the center of the suprasternal fossa). Indications: Cough, asthma, chest pain and so on. Danzhong (located on the chest, on the anterior midline, on the level of the 4th intercostal space, on the midpoint of the line connecting the two nipples). Indications: Checking upward adverse flow of the lung or the stomach-qi).

OBSERVATION CRITERIA—FOUR GRADES

1. Clinically controlled: Remission from symptoms. Occasional mild asthma attacks are remitted without taking any medicine.
2. Obviously curative effect: Asthma attack is relieved within a short time.
3. Improvement: Some abatement.
4. Inefficacy: Symptoms, signs and reproduction rate of T lymphocyte subpopulation are unimproved or exacerbated.

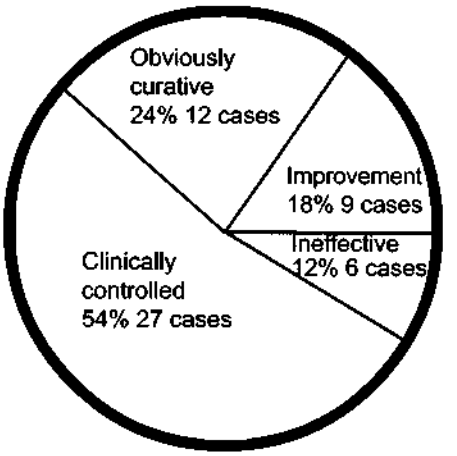

T- lymphocytes in Control vs Experimental Groups

THERAPEUTIC RESULTS

94% of the experimental group showed improvement (as shown to the right). In the control group 80% showed improvement as follows: Clinically controlled - 6 cases; obviously curative - 3 cases, improvement - 3 cases, inefficacy - 3 cases. X^2 determination indicates that there is a more obvious therapeutic effect in the treatment group than that in the control group ($P<0.01$).

LABORATORY RESULTS

T Lymphocyte subpopulation showed a significantly greater increase in the experimental group than in the control group treated by routine drugs alone as shown below:

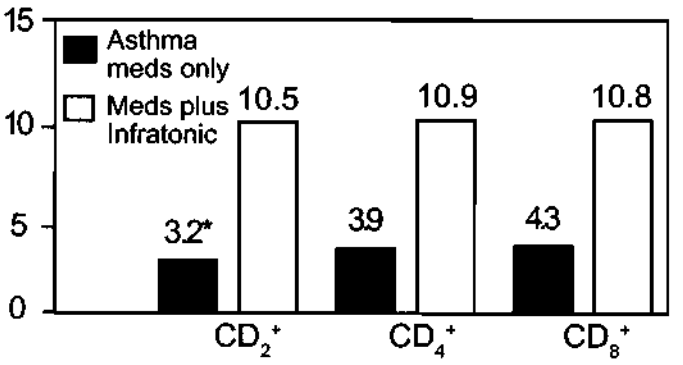

*Notes: Comparison before/after treatment P<0.01 unless noted: * = P>0.05*

In this study, clinical symptoms of wheezing, coughing and asthma caused by infection of the upper respiratory tract are obviously relieved using the Infratonic device. Testing of peripheral blood showed that the reproduction rate of T lymphocytes subpopulation in treatment group is greater than those receiving routine treatment, indicating increased level of immunologic function of human cells. The Infratonic QGM reduces the course of treatment without discomfort or side-effect. Its biological mechanism of action should be explored in the future.

The Infrasonic Signal from the Qigong Perspective

Sun Hua Ling, MD, Beijing Military Qigong Research Institute

(Dr. Sun, a physician and gifted Qigong doctor presents her analysis of the mechanism of emitted Qi and infrasonic signal.)

With the development of human society, health care has become an important part of daily life. Qigong training and techniques and devices like the Infratonic QGM can provide valuable influence. This instrument simulates the low frequency sound of Qigong doctors, which penetrates tissues and organs of the human body, influencing the function of cells, providing clinical results. This study reflects clinical treatment with the QGM of more than 1000 patients.

Cells are units of the human body. Biological electric waves transfer information between cells, forming a biological field of consciousness. The aim of Qigong training is the unification of this field, making the human body more in tune with nature and able to affect nature.

Some "hard Qigong" masters can break stones but can't treat disease because their emitted Qi's amplitude and frequency can not be absorbed by the human body. To be effective, emitted Qi or simulated emitted Qi must be close to the biological waveform of the patient. Then it is easily absorbed and treatment is more likely to be successful. Effective treatment protocols for 30 disease conditions were developed.

Mechanisms of the QGM

1. Relieves pain and edema.
2. Strengthens immune function and reduces inflammation.
3. Normalizes autonomic nervous system.
4. Relieves some symptoms of heart disease.

Relieves Pain and Edema

When applied to sprain of joints, fracture, and arthritis, the QGM has the obvious result of reducing pain distention and edema. It also relieves pain due to sciatic neuralgia, cancer, lumbago, periarthritis of shoulder and stiffness of neck and shoulder muscles. Thus the QGM can effectively treat disease caused by disturbance of blood circulation and can improve local blood circulation.

Patients may feel a sensation of heat, relaxation of muscles, and gradual reduction of pain. This phenomenon may be due to excitation of cells, nerves, and blood vessels around the diseased area. This excitation may contribute to the reduction in pain.

Strengthens Immune Function and Reduces Inflammation

The QGM has a function similar to short wave and ultrashort wave diathermy which strengthens immune function and reduces inflammation. It strengthens metabolism of organs and cells, increasing cellular energy, thus making the immune system stronger.

Diseases such as nephritis, inflammation of intestines and gall bladder, pancreatitis, gas, duodenal ulcer, and infantile dyspepsia, all respond favorably to treatment with the QGM, probably because of this factor of increased cellular energy.

Normalizes Autonomic Nervous System

Where the autonomic nervous system is disturbed, the QGM is often useful. This includes

neurasthenia, tenseness of the cerebral cortex, and fatigue. Research shows that the low frequency signals emitted by the QGM penetrate the tissues and organs, altering the internal environment of cells, improving cellular metabolism, and relaxing nerves and muscles, thus regulating the balance between internal and external environment of nerve cells.

Some scholars suggest that emitted Qi may increase cerebral bioelectricity, balancing cell environment, resulting in disappearance of disease. In traditional Chinese medicine, this corresponds to "regulating the meridians and collaterals", "improving blood circulation", and "nourishing internal organs".

Relieves Some Symptoms of Heart Disease

The QGM can relieve symptoms such as lack of blood in the heart muscle, arrhythmia, pressure on the chest, palpitation, and shortness of breath for pulmonary heart disease. This result may be due to improved metabolism of cells and improved local blood circulation.

Emitted Qi Training Increases Infrasonic Sound Emission of Healers

Prof. Lu Yan Fang, National Institute of TV and Electroacoustics, Beijing
Richard H. Lee, Director, China Healthways Institute, USA

(This study supports the premise, proposed by researchers earlier in this chapter, that infrasonic sound can be used as a measure of Qigong ability and indicates that Qigong skills, in this case, the ability to emit infrasonic sound from the palms, can be increased through intensive training.)

Can students in an intensive Qigong training increase the output of infrasonic sound from their hands after one week of training?

To answer this question (and others), 29 Americans traveled to China. The strength of their infrasonic emission was measured before and after the training at the Institute of TV and Electroacoustics, a national institute of technology and standards. Prof. Lu Yan Fang, who conducted the seminal research on infrasonic sound emission two decades ago, conducted the testing. In her research she had found that Qigong masters, powerful healers in China, were able to emit high intensity low frequency sound, 100 to 1000 times stronger than average individuals. Before the experiment she expressed strong doubts as to the possibility of increasing energy emission within one week because Qigong masters require many years to cultivate powerful Qi emission.

Prof. Lu had seen that strong young adolescent males could produce sound as high as 60 dB while average individuals emitted in the 40's and 50's. She was not surprised when in the initial testing 21 of 25 produced scores in the 40's. She felt that an improvement to 60 dB (only one participant had scored in the 60's in the pretest) would suggest improvement to supernormal ability, and that scores above 70 dB would be in the range of the powerful and well known Qigong healers.

A powerful Qigong healer who had scored well in this test before was invited to demonstrate. After several tries, the best he could do was 67 dB, which was 100 times what an average adult could produce, and still in the range of powerful healers, but not nearly as good as he had done previously. He was rather embarrassed and the translator explained that he had worked late the night before and had exhausted his Qi. An hour later he returned covered with perspiration. Apparently, in an effort to redeem himself, he had been building up power doing Qigong exercises for the past hour. This time his score was 78 dB, 10 times the power he had generated just an hour earlier. Participants applauded as he came out of the testing chamber. He had redeemed himself. Interestingly, he was massaging his shoulder as if he had strained it during the Qi emission.

This was a most interesting scenario. First the failure of an experienced Qigong doctor to produce high power, then his performing Qigong exercises to build up his Qi, and finally, his pow-

erful sound emission, offered a persuasive picture that some sort of energy can be stored in the body during Qigong exercises and discharged rapidly through the shoulders to the hands to create intense sound, and possibly straining muscles.

Supporting this finding, one participant was experimenting with the equipment afterwards, emitting Qi into the microphone. At first he could produce high levels of infrasonic sound in front of the microphone, but after five minutes of emitting he could produce only 10% of the power he had produced earlier. He did not feel tired, but as he tried to emit sound, he found that his hand would no longer tremble as it had before. He had apparently exhausted his supply of this form of Qi!

Test Scores: The average score for the group before the training was 47 dB with only four participants scoring above 50. Under the guidance of Master Wan Sujian, a well known Qigong teacher and physician, the group began a 10-day intensive which included climbing mountains and the Great Wall, practicing emitted Qi, and receiving extensive emitted Qi. The group also received physical therapy treatments to open meridians and remove potential blockages in the arms and shoulders which would otherwise restrict the flow of Qi to the hands. The results of both tests are shown below.

After the emitted Qi intensive, the number scoring above 50 dB tripled from four to 13. Five scored above 60 and two above 70. An average increase of 7 dB (to 54 dB) means that students were producing five times the infrasonic energy they had produced before the training. (Statistical significance $t < 0.0005$) Professor Lu was quite impressed. She felt that five of the participants had both the amplitude and spectral distribution associated with powerful Qigong healers.

An interesting technique: While four of the five participants who scored above 60 were men with strong musculature, one petite woman scored 64 dB, which is 10 times the power that anyone else of similar build had scored. When asked her secret, she answered, "Well, to be honest, as I was waiting to emit Qi I silently asked our teacher for help. As soon as I did, I felt a surge of energy flowing through my arm and my hand started trembling powerfully. When I was done, my arm was sore clear up to the shoulder." She had massaged her shoulder after emitting her Qi much as the Qigong master who first demonstrated had done.

SCIENTIFIC QIGONG RESEARCH

Measuring the emitted Qi from Qigong masters has been the purpose of scientific research in many major scientific research institutes in China,

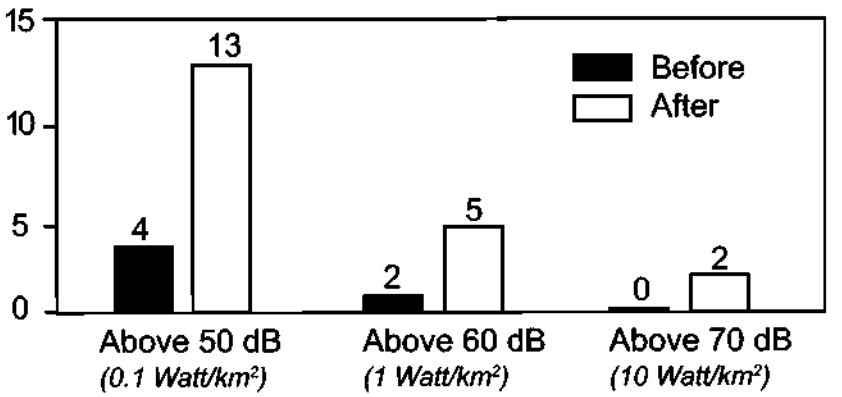

Participants were able to emit substantially higher levels of infrasonic sound after a week-long Qigong training. On the average, scores increased from 47 dB to 54 dB, a five-fold increase in infrasonic energy.

including the following:

- China Immunology Research Center, Beijing
- Institute of Space Medico-Engineering, Beijing
- National Research Institute of Sports Science, Beijing
- Institute of Psychology, Academia Sinica, Beijing
- China Academy of Traditional Chinese Medicine, Beijing
- Institute of Traditional Chinese Medicine, Beijing
- Beijing College of Traditional Chinese Medicine, Beijing
- Tangshan Health Institute for Women and Children, Hebei
- Zhejiang Research Institute of Traditional Chinese Medicine, Hangzhou
- Guiyang College of Traditional Chinese Medicine, Guizhou
- Shanghai Academy of Traditional Chinese Medicine, Shanghai
- The Second Military Medical College, Shanghai
- Shanghai Qigong Institute, Shanghai
- Xing Cheng Air Force Sanitarium
- Zhao Baofeng Beidaihe Qigong Rehabilitation Hospital, Hebei
- Shanghai Institute of Hypertension, Shanghai
- Shenyang Institute of Traditional Chinese Medicine, Shenyang
- Institute for Industrial Health, Xian
- Shandong Medical University, Shandong
- Anti Epidemic Centers of Henan Province, Xin Xiang
- Institute of High Energy Physics, Beijing
- Jiangxi Chinese Medicine and Pharmacy Institute, Jiangxi
- Nanjing Aeronautical Institute, Nanjing
- Institute of Space Medical Engineering, Sichuan
- Chinese Academy of Sciences, Chengdu

While thousands of investigations have been done, just a few have been described here, principally those that are reproducible either with Qigong masters or with Qigong simulation equipment. These studies show that emitted Qi is effective in treating digestive problems, infectious diseases, and bone fractures; that measurable changes in blood chemistry occurs a result of Qigong exercises; and that emitted Qi affects electricity and light in physics experiments.

Effects of the Emitted Qi on Healing of Experimental Fracture

Jia Lin and Jia Jinding
National Research Institute of Sports Science, Beijing, China.

(This study offers laboratory evidence that Qigong masters can accelerate recovery from fractures. From 1988 FWCAEMQG Proceedings)

The emitted Qi has been found to have a good curative effect on soft tissue injuries such as muscle soreness, scleroma in muscles, acute muscle sprain, muscle contusion and pains. Fracture is also a common injury in sports medicine. We have cured some cases of fracture with the emitted Qi. The purpose of this experiment was to investigate the biological effect of the emitted Qi on healing of fracture.

Sixteen healthy male rabbits, weighing between 1.9 and 2.5 kg, were divided into two groups: the control group and the emitted Qi group. A fracture with a gap of 3 mm was made in the left radius. The rabbits in the emitted Qi group were given the emitted Qi treatment for three minutes per day after fracture. X-ray films were taken every week. Each week specimens for light microscopy from two rabbits were cut into slices of 8*u*m thickness along vertical axis of radius, stained with H.E., and studied by a light microscope. The morphological observations are as follows:

1. Based on some radiographic indexes, such as reaction of fracture section, periosteal reaction and amount of callus formation and callus density, we found that the amount and density of callus formation were better in the emitted Qi group than in the control group. The difference was significant in the 2nd week

(n=16. P<0.01) and 3rd week (n=12. P<0.05).

2. Ultrathin sections were produced with LKB-III ultrotome, stained with uranyl acetate and lead citrate, and studied with a DXB electron microscope (EM). The changes in myofibrils were observed and photographed (x13000). Injured myofibril volume density in the pictures were calculated by means of point-count method.

The ultrastructural examination revealed that overstrain caused pathological changes such as muscle fiber edema, shortening or lengthening of sarcomeres, disorganization, breaking and disappearance of myofibrils as well as Z lines, accompanied by edema and damage of mitochondria. These changes could be seen less frequently in the emitted Qi group than in the control group. The result of quantitative analysis showed that the volume density of myofibrils of the injured muscle in the emitted Qi group was 2.47%, and that in the control group, 20.41 %.

MEASURING QI IN THE BLOOD

A Preliminary Study of the Relationship Between Qigong and Energy Metabolism—The Changes of the Blood ATP Content in Qigong Masters in the Qigong State

by Wang Zhenchang, Huang Jian, and Wu Zijuan
Shanghai Qigong Institute, Shanghai, China

[This revealing study quantifies a physiological change in the blood during Qigong exercise and Qi emission. When Qigong masters do Qigong exercises, blood ATP level increases, indicating a storing of energy. When they emit Qi, blood ATP level drops, indicating a depletion of energy. This is measurable evidence that physiological changes are occurring when a healer says he is collecting energy or emitting energy. It is also evidence that healers may be exhausted after treating patients and need rest and energy building activities to remain in good health themselves. From the 1988 FWCAEMQG Proceedings.]

Recently it has been reported that the emitted Qi by Qigong masters may have material foundation and the internal Qi cultivation can promote health. In this paper, the relationship between Qigong and energy metabolism was studied. The ATP content was measured with 20*ul* of blood drawn from the ring finger of the Qigong masters before and after the Qigong exercise, and, at rest, by the method of bioluminescence assay.

The instrument (FG-30 Type Luminescence Meter) and the chief reagent (luciferase-luciferin) were produced by Shanghai Plant Physiology Institute. The experiments were conducted in three groups:

1. The experimental group: The blood was drawn from each Qigong master's ring finger after he had taken a short rest, and before he exercised Qigong and entered the Qigong state. If he could emit Qi, he would do it for 5-10 minutes. If he exercised internal Qi cultivation, he would do it for half an hour. After the Qigong exercise the blood was drawn again. After rest for half an hour the blood was drawn once more.
2. The control group: The above procedure was repeated on the second day but the Qigong masters did not exercise Qigong.
3. The healthy group: Healthy persons did as the Qigong masters did at the same time. The results are as follows:

In 10 healthy persons the blood ATP contents were constant during the experiment. For nine Qigong masters in the control group the blood ATP contents did not change markedly. The blood ATP contents in 11 Qigong masters after emitting

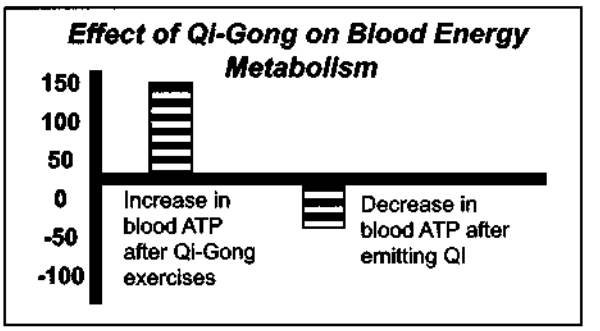

their Qi decreased markedly (the mean decrease was .000131 M compared with that of the healthy group ($P<0.01$). The blood ATP contents in 16 Qigong masters after cultivating the internal Qi increased markedly (the mean increase was .000054 M) compared with that of the healthy and the control group ($P<0.05$). The duration of Qigong practice influenced the changes of the blood ATP content.

The blood ATP contents in both groups of Qigong masters recovered after rest. Qigong masters were observed continually. First they exercised Qigong, cultivating the internal Qi. Then they emitted their Qi. The blood ATP contents changed as above. Conclusions were discussed. The emitted Qi may have a material foundation because the blood ATP contents decreased after the Qi was emitted. The internal Qi cultivation process promotes anabolism and increases CAMP level so that health may be improved.

EFFECTS OF QIGONG ON NEUROTRANSMITTERS

Liu Binghuai, Jiao Jie and Chen Quanzhu
Anhui College of Traditional Chinese Medicine, Anhui Province, China
Li Yefu, Shang Lili (Affiliated Hospital)

[This study shows that you don't need to be a Qigong master to gain healing benefits from Qigong exercises. New Qigong practitioners with chronic illnesses showed significant normalization of neurotransmitter concentration after Qigong practice. From the 1988 First World Conference for Academic Exchange of Medical Qigong (FWCAEMQG)]

It is well accepted that Qigong contributes to preventing and curing of diseases and prolonging life. To study its mechanisms, the authors observed by means of fluorescence spectrophotometry in 68 subjects the variations in blood content of the following monoamine neurotransmitters before and after the Qigong exercises. (5-hydroxytamine: 5-HT, norepinephrine: NE, and dopamine: DA) Forty-four of the subjects were male, 24 females. Their age ranging from 25 to 68 years old, with an average of 48. They all had practiced the Qigong exercise for one month. All were patients of common chronic diseases such as hypertension, coronary heart disease, gastric ulcer, gastritis, pulmonary emphysema, chronic bronchitis, joint system diseases, neurasthenia and neurosis. Results are as follows:

1. A comparison of monoamine neurotransmitter contents in the blood of the subjects pre- and post-exercise showed a general reduction in 5-HT, averaging from 0.42 to 0.21 *ug*/ml, close to the normal value of 0.15 *ug*/ml. The difference was notable ($P<0.001$) Variations in NE and DA tended to go up. The average NE was from 0.27 to 0.35 *ug* /ml, and DA increased from an average of 0.86 to 1.19 *ug* / ml. The above description showed that the effect of the Qigong exercise is closely related to the monoamine neurotransmitters in the body fluid.
2. Effects of the Qigong exercise on the blood monoamine neurotransmitters of patients of different diseases: The subjects were divided into five groups according to the nature of their disease. Subjects in each group showed reduction in blood 5-HT content after they had practiced the Qigong exercise. In all the groups, the content of vasoconstrictor substance 5-HT dropped to the normal concentration level, resulting in sufficient blood supply for the local tissues and organs. It also improved blood flow, promoted metabolism and strengthened the physiological function of the cells in the tissues thus helping to restore health, adding to the efficacy of Qigong.
3. The Qigong exercise helps regulate the neurobody fluid inner environment. Through regulating the 5-HT blood concentration in the neurotransmitters of parasympathetic nerve, it causes the extra high blood 5-HT of the cardiovascular patients to drop to the normal level. It also dilates the coronary artery and improves the physiological functions, resulting in the relief of symptoms.
4. The Qigong exercise helps build or strengthen

the physiological function of the digestive system. The exercise exerts an influence on the control of nerves that govern the activities of the internal organs. It is shown by variation in the blood content of neurotransmitters NE, DA and 5-HT, with 5-HT getting lower and DA getting higher, facilitating local blood flow and metabolism in the tissues.

5. Through regulating the concentration of pain producer 5-HT in the peripheral blood, the Qigong exercise achieves an analgesic effect. The drop of 5-HT content is relative to the result of analgesia. This fact shows that the drop of 5-HT is good for invigorating blood circulation and reducing extravasation, which is a proof of the TCM principle: "pain is removed when block is eliminated."

The Qigong exercise results in preventing and curing of diseases. It helps regulate the neurobody fluid inner environment, promotes activities of organs and maintains dynamic equilibrium of the organism through self stabilization.

PHYSICAL CHARACTERISTICS OF EMITTED QI

Gui Yongfan, Chen Qi, Li Yinfa, and Jiang Shen
Nanjing Aeronautical Institute, Nanjing, China

[Emitted Qi can alter the results of common physics experiments shown in this study from 1988 FWCAEMQG Proceedings.]

In this paper, three functions of the emitted Qi which were discovered with the aid of some physical instruments, such as the Van de Graaff generator and light sensitive plate are discussed.

1. The emitted Qi can restrain the discharge process. The discharge between the two balls in the Van de Graaff generator will be stopped or the period of discharge will become longer when the emitted Qi is exerted on the instrument. The Van de Graaff generator was used for testing. The two discharge balls in the generator were pulled apart until the critical state was reached. Then the Qigong master aimed his emitted Qi at the discharge space. The distance between the fingers or palm of the Qigong master and the discharge space was 10 cm to 3 M. We have discovered the following phenomena:
   a. The emitted Qi stopped the discharge or made the period of discharge longer.
   b. The Qigong master had no sensation of getting an electric shock when he emitted his Qi near the discharge space. Nevertheless, when he stopped emitting his Qi, he had the sensation of an electric shock if his hand was still near the discharge space.
   c. In the restraining process, a series of restraint and discharge, such as restraint—intermittent bursts of discharge—restraint, sometimes appeared.
2. The emitted Qi can cause the exposure of light sensitive plates wrapped in a piece of black paper. By false color image processing with a picture processing instrument, we obtained a color photograph, in which the image of fingers and the Laogong (P-8, center of palm) can be seen clearly. The Qigong master emitted his Qi at the emulsion layer of a light sen-

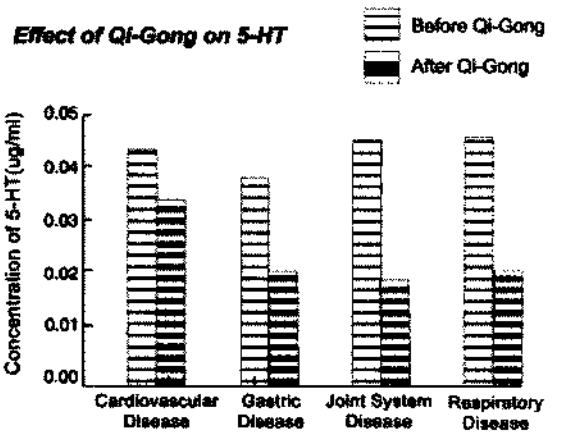

The concentration of the monoamine neurotransmitter 5-hydroxytamine decreased toward the normal value of 0.15 ug/ml in the above groups of patients after one month of Qigong exercises.

sitive plate from about 10 cm away for about 10 minutes.

RESULTS

a) The color of the controls was darker than that of the affected plates. b) After development, white speckles, various patterns or orderly stripes appeared on the affected plates.

SUPERCONDUCTING MAGNETOMETER MEASURES CHANGES DURING QIGONG

Wu Benjie, Dept. of Biophysics, Beijing Medical University
Wang Xiubi, Institute of Somatic Sciences, Beijing,
Wang Zijun, Nanjing University
Liu Jianben, Institute of Geophysics, Beijing

[Here we see that Qigong masters can produce magnetic fields from their palms, and that these fields have characteristic frequency bands. From 1988 FWCAEMQG Proceedings.]

A dynamic study of Qigong (QG) magnetic signals (MS) by a flux-gate magnetometer was conducted in a magnetically shielded room. Under the QG state, MS was <2Hz in frequency and several *n*T (T = Tesla, the unit of magnetic flux density, 1*n*T = 10^{-9} T) in amplitude. For deeper understanding of the MS dynamic properties, human weak MS were investigated by a superconducting biomagnetometer which is wider in frequency response (DC to 10 kHz instead of DC to 10 Hz) and higher in sensitivity. Through a frequency-power spectrum analysis by a computer, the MS changes under QG state were analyzed quantitatively.

Twenty persons (38 tests) were selected as subjects, and divided into two groups. (1) The control group consisting of three persons did not practise Qigong, 46.3 years old in average; (2) The Qigong group (practising for 1-20 years) consisted of 17 persons (31 tests), 48.3 years old in average.

The subjects took off all magnetic things; then came into a magnetically shielded room, with the acupoint to be measured aiming at the probe. The distance between the probe and Laogong (P 8) was about 6 cm, and that between the probe and head acupoints was about 4.5 cm. The MS dynamic changes were recorded continuously, before, during, and after QG state (3 minutes each).

MS was measured by a superconducting biomagnetometer, Model M-601. The frequency power spectra were analyzed by a signal processor, Model 7T17-S. In this paper the power changes were all of relative values.

The experimental results indicate that under the QG state three kinds of MS (1Hz, 3 Hz and <2 kHz) are measured from different acupoints Laogong (P 8), Baihui (Du 20), Yintang (Extra); there are three kinds of MS changes in intensity: increasing, decreasing and no change; and there is a good repetition of the change patterns and signal frequency of MS. Two novel phenomena were found, i.e. decrease of power and the change of frequency spectrum in MS during QG.

QIGONG AND CANCER

Cancer is one area where western science can use some help. Our government has pumped billions into cancer research, yet the problem continues to grow. Chemotherapy and radiation have such negative side effects that the time has come to look beyond therapies of killing "bad" cells, toward therapies with which the individual patient brings his own body into order.

In China, the obvious answer is Qigong. Cancer occurs when the cells of the body follow the will of an outside influence, perhaps a bacteria or a virus or a genetic predisposition. If Qi is strong and flowing smoothly within the individual, many Chinese believe that the cells will do the will of the organism, not of an outside influence.

A very interesting experiment that illustrates the will of an individual influencing cell growth is presented in a study by Dr. Feng Lida, MD, Ph.D., a famous Beijing researcher. She had Qigong masters treat vials of E-coli bacteria. The first vial was held but not treated. The Qigong master emitted Qi to the second one to try to "kill" the bacteria. He directed "health-promoting" Qi

to the third one. Dr. Feng reported that, with over 40 repetitions, the health promoting dose resulted in a seven- to tenfold increase in the number of E. coli. The health destroying dose lowered the number of bacteria by one half or more. This experiment illustrates the power of the Qigong master in influencing cell growth. Every one of us has the latent ability to do the same, directing Qi to control disease within our own bodies. This can be seen from the success of programs emphasizing visualization and meditation.

If Qi is weak in an area of the body, abnormal growth will appear. Qi is weakened by poor nutrition and lack of exercise. It is also weakened by mental and environmental stress. Chemotherapy and radiation put heavy additional loads on the body, draining it of Qi. This is why methods to strengthen Qi are so valuable.

This chapter is devoted to Qigong as it is applied to cancer. It is clear from these studies that Qigong is an option that every person trying to beat cancer should consider, regardless of whether western techniques are also pursued. Chemotherapy and radiation in many cases have been shown to be of little value improving quality or length of life. They are not the only option. The following evidence shows that Qigong is an important therapeutic modality for treatment of cancer.

The Effect of the Emitted Qi on Carcinoma Cells

Feng Lida, Qian Ju Qing, Chen SuQing, et.al.
China Immunology Research Center, Beijing, China

[This influential paper is the first presented in the 1998 FWCAEMQG Proceedings, and shows that emitted Qi can kill cancer cells and alter chromosomes in vitro, providing clinical evidence that cancer patients would do well to learn Qigong.]

We used the techniques of tissue culture, cytogenics and electron microscopy to study the Hale cells and SCG-7901 human gastric adenocarcinoma cells, the change of the cellular ultrastructure and abnormal structure of the chromosomes of the cells. The results showed:

1. The effect of the emitted Qigong on the Hale Cells:

We repeated the experiment 20 times under identical conditions. After the Hale cells received the emitted Qi for 20 minutes, the survival rate of the cells in the experimental group was 69.28% of that in the control group, i.e. 30.72% of the cells in the experimental group were killed. At the same time we observed the Hale cells with a translation electron microscope, and found that degeneration and swelling took place in some of the cells which received the emitted Qi. The endoplasmic reticula were dilated obviously, and the nuclei of the cells were destroyed.

The effect of emitted Qi on the gastric adenocarcinoma cells:

After the gastric adenocarcinoma cells received the emitted Qi for one hour, the survival rate of the cells was 74.98% of that in the control group. i.e. the average destruction rate of the cells was 25.02%. We repeated the experiment 41 times under identical conditions, and through statistical analysis, found a difference between the two groups ($P<0.01$). In the meantime, a scanning electron microscope was used to study the cells. The results showed that the microvilli of the cells which received the emitted Qi had remarkably dwindled or disappeared and tiny holes could be seen on the surface of the cells.

3. The effect of the emitted Qi on the chromosomes of the gastric adenocarcinoma cells: We repeated the experiment 10 times under identical conditions. 1420 tumor cells in the control group and 1,428 tumor cells which received the emitted Qi for 60 minutes were analyzed. The subdiploid in the control group was 2.11%, the superdiploid was 0.14%, whereas the subdiploid in the experimental group was 3.29% and supertriploid was 0.56%. The statistical significance in these findings ($P<0.05$).

The structure of the chromosomes of the gastric adenocarcinoma cells also varied. In the experimental group, the total abnormality rate was

5.39%. The total abnormality rate in the control group was 1.40%. (P<0.01).

SUMMARY:

Tumor is a common disease which endangers man's life and health. The study on the effects of the emitted Qi on carcinoma cells, especially on the study of the structure and the chromosomes of tumor cells, has not been reported in the world before. The human chromosome is a material base of human heredity and a carrier of the genetic material. The results of our studies showed that the abnormality of the chromosomes of the gastric adenocarcinoma cells was significant after they received emitted Qi. The rate of exchange, breaking, and the dicentromere in the structure of the chromosomes of the gastric adenocarcinoma cells is increased. The results suggested that the emitted Qi could kill the chromosomes of the gastric adenocarcinoma cells. The study may start a new way to cure carcinoma.

QIGONG AS A THERAPEUTIC AID FOR ADVANCED CANCER PATIENTS

by Sun Quizhi and Zhao Li, Kuangan Men Hospital China Academy of Traditional Chinese Medicine, Beijing, China

[This article shows that, in clinical trials, cancer patients were far better off when they combined Qigong exercises and chemotherapy as compared to chemotherapy alone.]

One hundred and twenty three cases of advanced cancer treated simultaneously with drugs and Qigong has been reported in this paper. These were inpatients of our department during the past five years. Among them there were 60 males and 63 females. The youngest was 20 years old. The average age was 47 years old. These patients were diagnosed pathologically as malignant cancer, 70 cases were in the III stage, 53 were in the IV stage, of which, cancer of the stomach accounted for 42.23%, cancer of the large intestine 31.70%, mastocarcinoma 11.29%, and cancer of the esophagus and cardinal carcinoma, 8.1% each.

The 123 patients were divided into two groups. The experimental group included 93 cases treated with drugs and Qigong exercises. The control group, which consisted of 30 cases, was treated by drugs alone. Similar drugs were given to the two groups. Each patient who received the therapy of drugs and Qigong did the Qigong exercises for over two hours a day, three months as a course. Symptoms, signs, body weight, and immunological indices, etc. were recorded before and after treatment. The results were as follows:

1. Amelioration of general symptoms: In the experimental group, 81.7% of the patients regained strength, 63% improved appetite, 33.3% were free from diarrhea or irregular defecation in the experimental group, while in the control group the rates of patients were

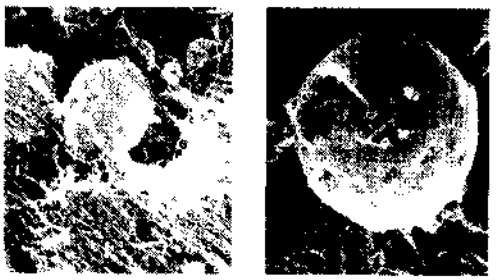

Cells of lung cancer before irradiation with emitted Qi

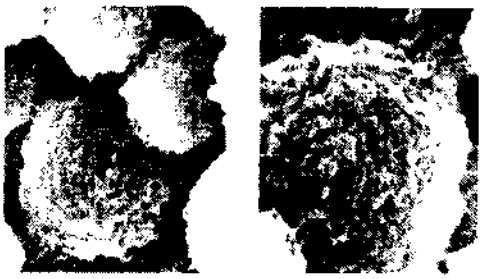

Villus exfoliation of lung cancer cells after irradiation with emitted Qi.

10%, 10% and 6%, respectively. The difference between the two groups is significant. (P<0.01)

2. Body weight: In the experimental group, 50.54% of the patients' body weight increased more than 3 kg, and 5.4% of the patients' body weight decreased more than 3 kg. In the control group, the rates were 13.3% and 30.0%, respectively. The difference between the two groups is, again, quite significant.
3. Phagocytosis of macrophages: In the experimental group, the phagocytic rate of macrophages increased by 12.31 % and the index of macrophages increased from 0.45 before the combined therapy to 0.63 after. In the control group, the phagocytic rate did not elevate, but decreased by 7.87% while the phagocytic index also dropped from 0.63 to 0.50.
4. In addition, it has been observed that, in the experimental group, the erythrocyte sedimentation of 23, and hepatic function of 20 of the 93 patients returned to normal, while in the control group, there were only three patients with normalized erythrocytic sedimentation, and two patients with normalized hepatic function, out of the 30 control cases.

To sum up, these studies suggest that the Qigong therapy is helpful to some extent to ameliorating the symptoms, improving appetite, strengthening constitution, and increasing the ability of self-cure. Qigong can regulate the mind, heart, Qi, and blood so as to get rid of pessimism and eliminate evil factors. Therefore, it is really an effective, simple supplementary treatment with no side effects.

The Effect of Emitted Qi on Leukemia in Mice

Feng Lida and Zhao Xiuzhen
China Immunology Research Center, Beijing, China

[This study by Feng Lida, MD, PhD shows that emitted Qi can decrease the reproduction rate of leukemia cells in mice and that infrasonic Qi simulators can play a similar role. From the 1988 FWCAEMQG proceedings.]

With the rapid development of modern science and technology and the enhancement of people's living standard, the constitutive proportion of diseases has changed and most infectious and parasitic diseases have been brought under control or eliminated, whereas, tumors are becoming a common problem and are endangering man's life and health. In our country, the number of patients suffering from tumor diseases is over 1,000,000 a year, and the number of patients who died from tumors has exceeded 800,000. Therefore, it is important for us to explore a new route to cure tumors.

Leukemia is a malignancy, which has a high incidence and is difficult to cure. As there are some similarities between leukemia in mice and human leukemia, we chose DBA mice as a research model to study the effect of the emitted Qi on L_{1210} cells of leukemia in mice.

The experiment chose DBA mice with a weight of 20±2 gm, and both male and female mice were used. In the experiment we killed the mice, which had been injected with the L_{1210} cells 7 to 9 days before we collected the celiac liquid and adjusted the concentration of cells to 4.70-31.00 million/ml (avg. concentration was 1.20 million/ml). 0.2 ml L_{1210} cells was injected i.p. into the abdominal cavity of mice. And after one day we randomly divided the mice into groups.

One Group Treated With Emitted Qi

Among these groups, the mice of the experimental group received the emitted Qi once per day, for between 10 and 40 minutes for 10 days, while in the control group, no treatment was given. After 10 days the mice were killed and the number of L_{1210} cells were counted with a light microscope. The average value in the control group was 200.435x0.5 million per mouse, while in the experimental group 66.458x0.5 million per mouse and there is significant meaning between the two groups. (P<0.01).

Second Group Treated With Infrasonic Qi Simulator

At the same time, we used an infrasonic qi

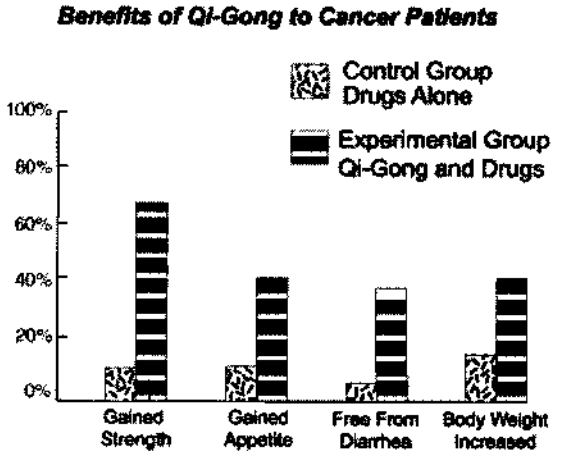

123 advanced cancer patients were treated for 6 months. The control group with drugs, the experiemental with drugs and Qigong exercises. The results show the value of Qigong exercises in cancer treatment.

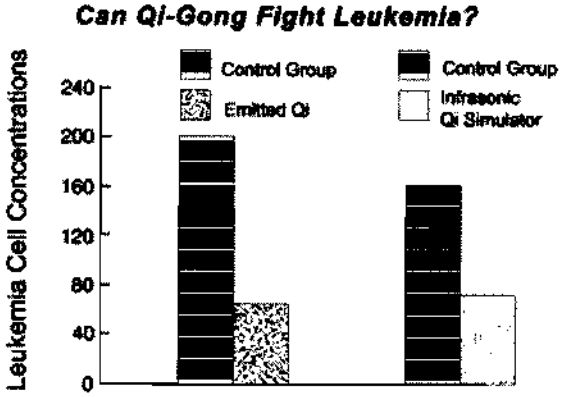

Concentration of leukemia cells in mice after 10 days' treatment with emitted Qi and the infratonic Qi stimulators

simulator to stimulate the mice injected with the L_{1210} cells, once per day, two hours at a time for 10 days, after which the number of L_{1210} cells was observed. The number in the control group was 160.826x0.5 million per mouse, while in the experimental group 70.870x0.5 million per mouse. This difference is of statistical significance ($P<0.1$). The results showed that the number of L_{1210} cells which were injected into mice could be remarkably reduced after the mice received emitted Qi, and the fact suggested that the emitted Qi could kill or inhibit the L_{1210} cells in mice.

Qigong is a part of traditional Chinese medicine, which is a therapy with Chinese characteristics. In recent years, Qigong has been used to cure a lot of diseases, especially difficult diseases and tumor diseases. It is an important issue whether Qigong can kill or inhibit malignant tumor cells or not. The result of this experiment shows that the emitted Qi could kill or inhibit the L_{1210} cells of leukemia in mice. After a body received it many times, the emitted Qi could significantly reduce the number of L_{1210} cells in mice. The experimental study laid a theoretical basis for the treatment of tumors with Qigong. Qigong therapy will be a new way to cure carcinoma. However, the mechanism and way that the emitted Qi kills or inhibits L_{1210} cells of malignant tumor cells in mice needs to be further investigated.

EFFECTS OF QIGONG ON MALIGNANT TUMOR

Luo Sen, Tong Tianmin, et al.
Zhejing Institute of Traditional Chinese Medicine
Hangzhou Qigong Hospital, Hangzhou, China.

[This study, also from the 1988 FWCAEMQG proceedings shows the benefits of combining traditional and modern cancer therapies in maintaining healthy blood cells.]

Under observation in this experiment were 80 patients with 17 kinds of malignant tumors including nasopharyngeal carcinoma, breast cancer, lung cancer, and gastric carcinoma. Their diagnosis was confirmed by cytological and radiological exami-

nations. Within this group, 48 were male and 32 female. Most of them had been operated on before hospitalization. They were at their I or II stage of the disease and had received radiation or chemotherapy before. These patients were randomly divided into three groups. 30 of them, as the first group, received Qigong treatment.

The second group, composed of 25 cases, were treated with routine chemotherapy. And the third group, another 25, received chemotherapy combined with Qigong exercises. The parameters adopted included WBC and RBC count, serum hemoglobin and platelet count in blood before and after treatment, T-lymphocyte conversion test (H3TdRLT) and urine excretion of 17-hydroxy steroids within 24 hours before and after the last week of Qigong therapy in some patients. The total period of observation lasted 60 days. Results are reported as follows:

1. Group I, the Qigong group, developed a significant rise in their WBC, RBC count and serum hemoglobin after treatment ($P<0.01$). Group II, treated with chemotherapy, presented a significant lowering in these measures ($P<0.01$). Group III, which both practiced Qigong and received chemotherapy, showed an obvious elevation of serum hemoglobin, RBC and platelet count ($P<0.005$-0.01). Their WBC remained at the same level as before the treatment ($P>0.05$)
2. T-lymphocyte conversion test in Group I also showed a significant rise ($P<0.05$). It was seen to be maintained at the original level in Group III ($P>0.05$).

This experiment proves that this kind of Qigong exercise, by exciting the circulation of Qi along meridians and modulating the functions of blood circulation, immune response and endocrine tissues, can minimize the toxic side-effects of chemotherapy and enhance energy supply to the body. This practice is effective in treatment of cancer and supported by confirmed scientific experiment.

Effects of Patient Tumors on Kirlian Images of Healthcare Providers

Su Cheng Wu, Guangxi Tumor Hospital, Guangxi, China
Richard H. Lee, China Healthways Institute, USA

The process of emitting Qi during a Qigong treatment, while valuable at jump-starting a patient's recovery, is exhausting and requires extensive Qigong exercises to replenish the depleted Qi. However, as Qigong practitioners become more skilled, they can treat more patients with less depletion, probably through a combination of becoming more proficient at collecting Qi and more efficient at utilizing the Qi that they do have. This is an important field of study because of the prevalence of "burnout" which affects many practitioners in all the medical professions. Perhaps doctors and nurses can be taught the principles of efficient use of their Qi. The following is offered to illustrate this point:

The top two Kirlian photographs on this page show images of fingertips of healthy individuals and healers. The light recorded by the photos is created as electrons moving between the fingers and the film ionize air. In the first photo, the balls are created as electrons leaving the finger create pools of light. And the streamers are created as electrons stream back from the film to the finger. A balance between balls and streamers indicates that electrons move both to and from the fingers. The second photo shows that, around the fingers of healers, the electrons travel more as waves than particles, creating a smooth glow instead of balls and streamers.

In cancer patients, research has shown that balls appear around the cancer (not illustrated, reference Dumitrescu and Kenyon in "Electrographic Imaging in Medicine and Biology", 1983) and streamers appear around all other parts of the body, as shown in the fourth picture. (reference "Bioelectrography" by Konikewicz and Griff 1984 and Dumitrescu, 1983). This strongly

suggests that the rapid growth of cancer cells is fueled by high electrical vitality at the cancer site, and that the rest of the body is devitalized as the high energy electrons are somehow attracted by the cancer.

The lower three Kirlian photos were taken in a tumor hospital. A typical cancer patient (the third photograph) shows virtually no Kirlian image. This indicates a very low flow of electrons, either in or out of the finger, and thus, low vitality. After increasing the patient's electrical conductivity using an Infratonic QGM on the foot (K-1), the patient's image brightened, but showed only streamers but no balls, as electrons shot to the fingers but did not return from the fingers to the film. Had high energy electrons returned to the film, we would have seen balls in addition to streamers in the photographs. This suggests that the entire patient, not just the photographed finger, is depleted in electrical vitality, and may be drawing electrical vitality from the Kirlian camera as high voltage electrons stream into the patient's body, but do not return to the film. This supports the common belief that cancer draws vitality from everything in the surrounding area while fueling the very rapid growth of the cancer cells.

Several doctors in the tumor hospital were photographed and those with patient contact showed a similar image dominated by streamers with almost no balls. This suggests that the doctors were in some way devitalized by the patients' low energy condition, and were, themselves, drawing electrical vitality from the camera. It appears that cancer drains the vitality of everyone, the patient, health care providers, family, and even those who visit to show their support.

Why does vitality flow to the cancer site? Qigong practitioners believe that intentionality moves Qi, which suggest that intentionality might be acting. We might suspect the intentionality of the patient, the family or the doctor. All seem to be convinced that the cancer will win. It seems that we should also look at the possibility that the cancer, itself, has intentionality, and is causing the patient to give up hope and the doctor to say things like, "You have no more than 3 to 6 months

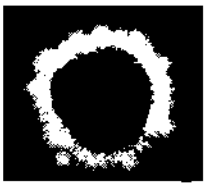

Kirlian image of typical healthy person shows balance between balls and streamers.

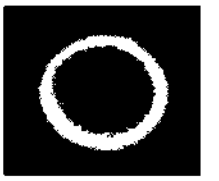

Kirlian image of typical healer

Cancer patient shows low conductivity.

Cancer patient shows increased streamers after QGM treatment.

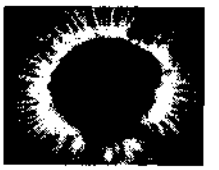

Doctor with patient contact also shows streamer dominance.

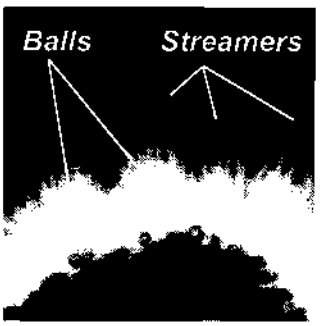

to live." Perhaps the fight against cancer is a battle of wills over the flow of vitality more than simply the biologically understood multiplication of ignorant cancer cells.

Can we reverse this flow of vitality, and will this reverse the growth of cancer? The preceding research in this chapter shows that Qigong practice and emitted Qi can kill and decrease the growth rate of cancer. Perhaps intentionality is a new weapon against cancer. And maybe the Kirlian camera will be the biofeedback technique which shows patients and researchers when their intentionality is properly applied and when they are winning the battle.

As is concluded in most research studies, "More research is necessary."

Chaos and Consciousness

The study of Qi as the relationship between the physical world and consciousness is often avoided by scientists because this violates a basic tenet of science, the experimental method, that the experimenter is not to interfere with the experiment. However, this appears to be exactly what Qigong masters are doing. Whereas religious groups have long held that our thoughts, wishes, desires, and prayers can influence our own lives and the lives of those around us, the scientific world has, for the most part, denied this possibility.

If, in our study of Qigong, we discount the conscious intent of the practitioner, we are ignoring what Qigong practitioners claim is the vital ingredient, intentionality. Thus, we are led to study the physics of the phenomenon, the interaction of electric, magnetic, and acoustical fields. However, if we allow intentionality to enter the equation, a very different view of Qigong emerges with enormous implications.

To accept that consciousness can influence the physical world, science needs some sort of field or substance which can be shaped by consciousness such as the rhythmic movement of electrical charges in the body as measured by EEG, which is shown to be influenced by Qigong masters.

From a broader perspective, this field is chaos, which might be described as uncertainty regarding the future, or instability such that subtle influences can guide the field's reorganization. In the case of EEG, the chaos is the available instability of free electrons, molecular ions, and neurochemicals. There are probably many other forms of chaos within the body including magnetic, acoustical, and electromagnetic. It is chaos, or uncertainty in these fields, which allows consciousness to enter and shape reality.

Qigong therapy is often broken into three phases. First, the practitioner "adds Qi" increasing the available energy, or chaos of the patient. Then he "sweeps the bad Qi out the feet" to remove crystallized structures which are interfering with the patient's health. Finally, he "smooths the Qi" to help bring order out of the chaotic state which results from the adding of chaos and removing of "bad Qi."

Thus, a Qigong treatment might be viewed as adding chaos to liquefy a crystallized structure, removing undesired, loosened crystals, then smoothing and harmonizing the field to "bring a higher order out of the chaos." Softening and bending metal, altering EEG in anesthetized animals, and accelerating recovery from cancer might all be explainable by "consciousness creating and guiding chaos."

Low Dimensional Chaos in Practicing Qigong

Yagu Lin, Jijun Gao, and Huo Lu
Shanghai Qigong Research

[In our research at CHI, we have found that chaos is a key ingredient in the effectiveness of a therapeutic signal, allowing greater penetration into the body. This Chinese chaos research shows that Qigong exercises result in reduced complexity of the EEG in the brain, providing calmness and mental clarity (bringing order out of chaos). From the FWCAEMQ.]

Recently, researchers such as Kaczmark, I.K. (1977), Nicolis, G. (1985), Skarda, C.A. and Freeman, W.J. (1987), and Xu Jinghua and Xu Nan (1987) have reported the systematic complexity and chaos of the brain electroencephalographic techniques (EEG) by the analysis of dimensionality in studies of chaotic dynamics of biological systems. However, there are few reports analyzing the Qigong functional state using this method.

In this paper, we analyze change in attractor dimensionality d values of the occipital EEG before, during, and after Qigong exercises. The results show that before exercises, d=1.8, during exercises d increases to 2.1, and after Qigong exercise, it remains at the increased value of 2.1. These results show that Qigong exercises can lower the complexity under conscious conditions, increase the orderliness, and decrease the randomness. This may explain Qigong's effect of "warding off distraction, thoughts, or evils," and may be a principal mechanism of Qigong's effectiveness.

Qigong Training and Coherence of EEG

Yang Sihuan, Yang Qinfei, Shi Jiming, Cao Yi
Institute of Qigong Science,
Beijing College of Traditional Chinese Medicine,
100029, Beijing, China

[This study shows that Qigong training increases coherence between the right and left sides of the brain. From the perspective of chaos theory, this means that Qigong helps to bring "order out of chaos" in the brains of practitioners. From Second World Conference on Academic Exchange of Medical Qigong.]

In this study, we analysed the coherence of EEG to observe the trainees' EEG regularly. The young students, who were 17 to 20 years old, had been practicing "Zhanzhuang Gong" for one year. We try to find out the effects of the Qigong training period on coherence of EEG. Thirty two persons in the Qigong group and 35 persons in the control group were involved in this experiment. During one year period of observation the subjects of the Qigong group practiced Qigong for 40 minutes every day. The EEGs of the Qigong group were analysed every half year in meditation, and the EEGs were also recorded before learning Qigong. The students in the control group did not take part in the Qigong training and their EEGs were investigated at rest twice with an interval of one year. In the test, eight channels of EEGs were simultaneously processed by a computer on line for 20 minutes. The program, "computer evaluation system for the Qigong state" was provided by the "Laboratory of Bio-Control, Department of Electrical Engineering, Zhejiang University".

After one year of Qigong training, total coherence between the left and right frontal regions increased from 0.84 ± 0.07 to 0.87 ± 0.06 ($p<0.05$). Before Qigong training, the total coherence between the left and right occipital areas was 0.68 ± 0.14. After half year's training, it increased to 0.79 ± 0.10, and after a year's training, it was 0.76 ± 0.10. Self comparison showed the probability $p<0.001$. The total coherence between the left and right temporal areas before Qigong training was 0.48 ± 0.17. Half year after Qigong training it was 0.55 ± 0.13, compared with that before Qigong training ($p<0.05$). One year after Qigong training it was 0.64 ± 0.12. Comparing before and a half year after Qigong training $p<0.001$.

Total coherence did not change significantly in the control group

Vibrational Trembling, Chaos, and EEG

Dale M. Patterson, MS, CACB, BCIA Certified
Richard H. Lee, China Healthways Institute, USA

[This article, published in China Healthways Newsletter, provides data collected from biofeedback research conducted by Dale Patterson which shows that chaos increases alpha EEG induction.]

Vibrational trembling appears to be a way memory is stored or processed in the physical body. Chaotic sound penetrates this field of vibrational activity, softening this memory and al-

lowing us to more easily let go of fixated thoughts, addictive desires, and compulsive actions.

When someone is full of anger at being blocked from acquiring the object of desire, he may tremble extensively in the theta range of EEG. And when someone is overloaded with the stress of excess thinking (worry) and approaching a nervous breakdown, he will also tremble, but this time in the beta range. This excess vibrational activity consumes the body's Qi and causes the person to become emotionally, mentally, and physically rigid.

Applying chaotic sound breaks up these repeating patterns, often freeing the patient from frustration and worry. As the patient relaxes, capacity to process thoughts and emotions increases, new answers are found, and the increased freedom and flexibility are experienced as increased vitality. Thus, where physical memory inhibits healing, adding a chaotic alpha signal can accelerate recovery.

Laboratory Testing

Dale Patterson, a board certified EEG technician trained in biofeedback became intrigued with the QGM when one of his patients brought one in. He recorded EEG brain maps first with an early model of the QGM which produced a clinically significant 18% increase in Alpha. He then used the Q4 with chaos which provided eight times the increase in alpha activity, showing that chaos increases induction of alpha rhythm in the EEG.

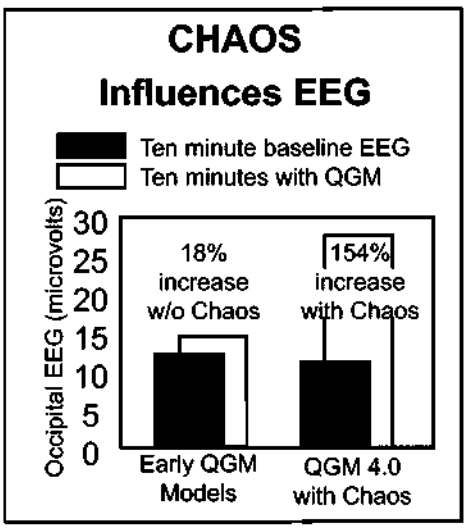

Chaos and the College Entrance Exam

Su Cheng Wu, Guangxi Medical Hospital

[From China Healthways Newsletter: A medical researcher applied the Infratonic QGM to high school students preparing for the college entrance examination.]

There was little chance that Li Wen Chao could ever attend college. As a high school senior, he had achieved only moderate grades in his courses and had done poorly on previous national examinations. Without very high scores in the China College Entrance Examination, Li would almost certainly spend his life in a menial factory or farming job. The College Entrance Examination is terrifying, because everyone who faces it knows that only half of high school graduates will enter the nation's college system. *Failure in this examination is a common cause of suicide in China.*

Enter Su Cheng Wu, a medical researcher and Li's uncle. He had just completed a successful study involving infrasonic treatment of bronchial asthma (see page 28) and was searching for other subjects to study. He felt that stress, nervousness, and mental overload were the principal reasons that high school seniors failed the examination, and believed that the Infratonic QGM would induce the deep calmness and mental clarity of Alpha into the students' minds and bodies, helping them to relax and overcome the mental overload that causes brains to lock up during tests.

For three days before the examination, Dr. Su went to visit his nephew's class and treated each patient by holding the machine on the upper back for five minutes and encouraging the student to talk about fears and tensions regarding the upcoming test. For students suffering from symptoms such as headaches, dizziness, poor appetite, insomnia, and menstrual pain, he instead selected

and treated an appropriate point, usually along the front midline of the body.

The results of this small test drew much attention. Li's class was average among the seven senior classes, yet performed the best by far. Whereas the average pass rate for the other six senior classes was 50%, 86% of the students in this class passed the examination and were placed in five year colleges! The other 14% got high enough scores that they were accepted to three year trade schools. Thus, 100% made it to some sort of college. Li Wen Chao enrolled the next year at Guangxi Medical University to become a physician.

While it sounds unreasonable that a little chaotic infrasonic sound can cause such a large increase in scores, the opposing view makes more sense. *Stress and worry can shut down the thinking process.*

SEARCHING FOR JING, QI, AND SHEN IN WESTERN SCIENCE

Traditional Chinese medicine (TCM) holds that three "vital treasures", Jing, Qi, and Shen, are real substances which envelop the human body and are essential to life and healing. These are the fields through which Qigong masters work. Jing provides the genetic structure or the physical strength of the body. Qi is the life or vitality of the body, our energy level. And Shen provides the mind, or conscious aspect. TCM goes further, introducing three seeds of consciousness, the lower, middle and upper Dan Tians located in the lower abdomen, chest, and above the head respectively, which are born and mature through cultivation, providing awareness of the physical world through Jing, Qi, and Shen.

This parallels the writings of Alice Bailey which present a three fold personality: the etheric body (Jing) is shaped by the emotional body (Qi) which, in turn, is shaped by the mental body (Shen). The substance of each body is produced by the physical body whereas the function of each body is to support a mode of consciousness.

In "A New Science of Life" by Rupert Sheldrake a "morphogenetic field" is described as a vibrational field which surrounds and shapes living things as they organize. He argues that our genetic structure doesn't contain, but rather tunes into the blueprint of the physical body through this morphogenetic field. He supports this with laboratory findings that as more and more animals and humans are taught a new behavior, others of similar genetic makeup but physically separated from the first, learn the new behavior more and more quickly. Jing appears to be the TCM equivalent to the morphogenetic field of the physical body. Qi and Shen might also support morphogenetic fields of their own. According to Sheldrake, these morphogenetic fields are programmable, obtaining their initial programming from genetic structure, and being reprogrammed through experience and learning.

Jing, from the standpoint of physics, might be a field of electrons in constant flux suspended in salt water throughout our bodies. The rhythmic movement of this electric field is measurable by EEG, EMG, and EKG. Electrostatic forces are very strong and it is conceivable that such a field can shape a physical body by catalyzing certain chemical reactions and moving certain molecules to the right place at the right time, causing, for example, differentiation between liver cells and brain cells in the embryo.

If Jing is to vibrate freely it requires sufficient energy to have free flowing electrical charges both to resonate with the morphogenetic field and to fuel biochemical reactions. Ilya Prigogine, in "Order Out of Chaos", proposes that life requires chaos, that higher forms of organization emerge out of chaos, and that raising the energy of a system allows it to reconfigure into a higher order of organization. From the standpoint of Jing, when biochemical activity exhausts the available electrochemical potential, chaos in the field of electrons has been exhausted. Then the physical body may become unresponsive, and illness may result. Research during long airline flights shows that, where crowding and recirculated cabin air reduce

the availability of electrical energy in the air, people become depleted and develop exhaustion and succeptibility to illness and infection. When passengers wear portable air ionizers, which add electrical instability (chaos) to the air by ionizing it, they do not suffer from exhaustion and avoid illnesses from airborne bacteria. From the standpoint of physics, Jing might be the available electrical instability or chaos in the sea of electrons in the body.

Qi might be a field of magnetic substance which can be measured because it makes the body more electrically conductive. Such diagnostic equipment as Ryodoraku and EAV are claimed to measure the Qi by measuring the electrical conductivity of meridians. High and balanced conductivity are associated with good health and vitality, and low or imbalanced conductivity is associated with illness and debility. While the Qi may have little direct influence on the physical body, its ability to increase local electrical conductivity gives it the ability to provide selective pathways of decreased resistance which allows it to influence the flow of electrons, and thus, shape the Jing. Electrically conductive needles may give acupuncturists a similar ability.

Analysis with Kirlian photography shows that washing the hands with tap water causes the electrical conductivity of the hand to decrease considerably. However, when the hands are washed with the same water which is first passed through a strong magnetic field, the electrical conductivity of the hands increases. (ref: Bioelectric Vitality — The Science of Human Energy by Lee) This tells us, first, that water can store and transport some sort of magnetic substance, and second, that this substance can be removed from or added to the human body. To illustrate this, Kirlian research on long jet flights reveals that reduced magnetic fields on airliners often cause those who have a TCM condition called Yin deficiency to have severe exacerbations of symptoms such as anxiety, nausea, headaches, dizziness, and rising heat. Placing a magnet on the body during the flight provides a source for magnetic substance and reduces the symptoms considerably. Qi might be describable by physics as available magnetic activity within the body, though there appears to be much about magnetism that physics doesn't yet know.

Shen is described in traditional literature as mind or awareness, and often as light. If it is light, why can't we see it? Modern physics tells us that an electron is really an electromagnetic wave, an x-ray, high energy light which has been somehow captured by the nucleus of an atom. Thus, it is conceivable that a field of light or electromagnetic energy could resonate around our physical bodies and remain unmeasurable, just as electrons orbit around a nucleus undetected.

Shen may become visible when excited by electricity. Most people have Kirlian images which show small balls of light surrounding the finger during the negative pulse and streamers, lines of light perpendicular to the finger surface, during the positive pulse. However, healers and artists who use their hands with enhanced awareness, often have a smooth glow around their fingers. (Kirlian photos of the balls and streamers and smooth glow are shown on page 58.) Some even have certain fingers with a smooth glow while others show the balls and streamers. It appears that only those fingers used intelligently have the glow. For instance, a person who principally uses three fingers for massage will find that those three will have the glow while the others have the balls and streamers. The fact that electrons act differently around a healer's fingers is a big opportunity for physicists to investigate the nature of Shen, and to give us a better understanding of the special function abilities of Qigong masters and other healers.

CONCLUSION

Jing, Qi, and Shen are measurable with physical equipment, and thus are subject to scientific study. These measurements correlate with states of health and rates of healing. Thus monitoring the strength of these fields in hospitalized patients and supplementing them when low may prove of value in reducing recovery time and saving lives. In addition to studying, monitoring and

supplementing these fields, it might also be productive to study how to increase a patient's resonance with his own morphogenetic field while decreasing his resonance with that of a disease process. This may be a principal area where Qigong masters and other healers excel, while western medicine has little knowledge. Jing, Qi, and Shen, long considered nothing more than useful metaphors by western scientists, may be very real substances which unlock the door for western scientists to understand human vitality.

THE ROLE OF CHAOS IN DISEASE AND HEALING

Richard H. Lee, China Healthways Institute

In the book, "Order Out of Chaos," Ilya Prigogine offers that, when a structured system is energized, its chaos increases, allowing it to reconfigure spontaneously into a higher order of organization. This may explain the evolutionary progression on Earth from the simple structures to the highly organized life forms, from the helpless child to the capable adult who chooses to serve a yet higher organization, humanity.

How can chaos be healing? Chaos is often thought of as unpredictable and destabilizing. It is the enemy of structure and overturns the law of the land. How is it possible that chaos can be harnessed to serve us? As an example: When someone's life is not working, when the basic order upon which they depend is failing them, and when they just want to run away, it may be time to "let go of life" in a way that nurtures the creation of a new order within which the world again makes sense.

Chaos is opportunity. Where there is rigid organization, there is little opportunity for restructuring. The best solutions often go ignored because their implementation would require destruction of some of the structure which holds an organization together. An organization which is flexible, receptive to new ideas, and free to adjust to changing circumstances, is willing to break down old structures for the sake of growth and efficiency. Structure provides for certainty. Chaos injects uncertainty. With a high degree of chaos, an organization can quickly adapt to strange and unfamiliar circumstances without being held back by the inertia of structure.

Within the human body, there is a great deal of structure. Physically we can have unnecessary chronic muscle tension, purposeless lumps, and other structures which don't serve us. Emotionally, we can hold onto desires which repeatedly carry us down pathways of misery. Mentally, we can so fill ourselves with conflicting thoughts that we are unable to sleep and on the edge of nervous breakdown. Whenever a structure within us becomes inflexible, we experience pain. Blocked desire provides emotional pain, and conflicting world views cause mental pain. Flexibility allows us to face the unexpected with capability and enthusiasm. We can run from the path of an approaching car, or stop to pick up a dime. We can eat a bowl of bean sprouts and tofu as comfortably as a hamburger, attend a religious service of any denomination without concern for the clothing of our creator, and be comfortable considering philosophies of strict child rearing alongside newsletters promoting chaos.

Random, unexpected events provide the chaos which exposes our rigidity, our unyielding habits, our crystallized beliefs. Sometimes these crystallized structures within us yield to the pressure but often they resist, sustaining the old ways despite conflicting forces and pain. And sometimes the strain even becomes so great that a person's entire world view shatters. This can be a hugely transformative event:

The initial stress is experienced as pain, uncertainty, or fear of the unknown. We become desperate to avoid further stressing of the crystallized structure so we hang on even tighter. Then the order governing our emotions and thoughts snaps, pops, or shatters. We burst into tears and watch as our life falls to shambles before our eyes, with seemingly nothing left for us to hang onto. We may feel an abrupt shift. Perhaps we experience an immediate release or an exhilarating feeling of freedom and relaxation. At other times, we

find ourselves drowning in the unknown, trying to hang onto the structure which just crumbled, unwilling to relax and trust that a new better structure will form in its place. Sometimes we spend years trying to hang onto a crumbled, useless, and painful structure.

Chaos is an opportunity to restructure our beliefs, habits, and physical bodies into a more flexible arrangement, more suitable to the unknown but anticipated future. Whenever we face a new situation, we have this opportunity. Every time we make a new choice or break an old habit, we increase our flexibility and expand our opportunities.

How do we nurture chaos? We start by looking for patterns which restrict our choices, consume our resources, and limit our beliefs. Watching TV, smoking, recounting past experiences or gossip, consuming countless grams of animal fats and alcohol, spending endless hours or repetition in a job or relationship. Changing these patterns may be quite painful because of deep and extensive crystallization, but the result will almost certainly be free time, vitality, new experiences, and an opportunity to make less restricted new choices. While choices made in anger are easiest, and often create more chaos, choices made with love usually provide a greater opportunity for growth. If shattering and reorganization occur within the emotion of anger, the new order will embody anger. If we immediately forgive and "love our enemy", the new order within us will embody love and harmony.

THERAPEUTIC CHAOS

Richard H. Lee, China Healthways Institute

[This article describes how chaotic infrasonic sound might work to penetrate the body, break up stagnation and accelerate healing.]

Over the past ten years CHI has been studying the Infratonic QGM, trying to determine why it is effective at accelerating recovery and decreasing pain. Until recently, our focus has been on the broad spectrum frequency band of infrasonic sound produced by the QGM which infuses the local area, facilitating nerves and inducing Alpha brainwave activity, facilitating nerve transmission between the brain and the local site of pain. This is a plausible mechanism, but there appears to be more to it.

As we experimented chaos surfaced as an "active ingredient." We built prototypes with advanced microprocessor technology which produced an almost purely chaotic signal. In testing we found that these new units penetrated more deeply and stimulated resistant areas of the body which other therapies could not penetrate.

It appears that our thoughts and emotions are strongly affected by sound, and that the body defends itself against outside vibrational signals by anticipating and setting up signals which cancel them out. This may be why someone speaks loudly when he wants to persuade us of an idea, and why we may shout back to defend our own position, and why it is difficult to read or think clearly while sitting in a noisy park in a big city, or in a windstorm, or with loud music playing. It seems that it is difficult to sustain one's own complex thoughts when noise is jumbling them.

Many of the emotions and thoughts we hold within us can be the cause of chronic illness, pain, and slow healing. We might even be carrying some of these patterns from childhood, or pick them up from chance encounters or spooky movies. Like a computer virus, they are lurking among thoughts and beliefs which make up our personality. Those emotions and thoughts which are causing health problems are part of what Qigong therapists call "bad Qi."

Our ability to filter out recognizable sounds, while allowing us to maintain our own thoughts and emotions, is a major barrier to the effectiveness of therapy devices like TENS, ultrasound, and massagers. If we receive a therapeutic treatment from such a device, it may provide some relief but will only affect those surface vibrational patterns which are ready to let go. Thus many therapy devices relax muscles to some degree. But as soon as the therapy begins to intrude on dominant beliefs or emotions we automatically identify the invading signal and filter it out. Thus, pre-

dictable therapeutic signals can only do so much.

While we can defend against rhythmic signals, our old attitudes and emotions are defenseless against the random sound of a chaos therapy device because it is unpredictable. It simply goes past our vibrational defenses and softens all thoughts and emotions in the target frequency range. This may be why, after a treatment, people feel calm, clear thinking, and liberated from the problems and worries of life. A big part of what they are feeling may be the abundance of energy which is released when old unnecessary thought and emotion patterns dissolve, releasing the Qi, the substance that was vibrating to maintain them.

It is not just "bad Qi" that is softened by chaotic infrasonic sound. All structures, thoughts and emotions, may be softened as acoustical chaos increases in the body. Since accelerated healing of broken bones and sprained tendons is often reported, chaotic sound may soften these solid physical structures as well. This parallels the first step in Qigong therapy, emitting Qi to soften and liquefy the stagnant Qi.

The second step is to sweep "bad Qi" downward and out the feet. This may be a process of removing old vibrational structures which have been freed to move but have not entirely dissolved. Therapists have found that using chaotic infrasonic sound to sweep from the area of pain down the body and out the feet after treating the pain is often more effective than treating the point of pain alone.

The third step in Qigong therapy is to create a nurturing Qi field to allow the remaining Qi to harmonize, nurturing the emergence of a new order out of the chaos. The Infratonic QGM helps to do this by infusing the body with alpha EEG activity. Whereas the theta rhythm is associated with our individual identity and our relationship with the physical world (and our sense of ego and self importance), and the beta rhythm is associated with planning and thinking (stress and worry), alpha is all about relationships, putting the group before the individual. This may be why, after a QGM treatment, patients become more "compliant" in a doctor's office and people find that interpersonal conflicts are easier to resolve. This process may also occur on the cellular level toward healing and disease resolution as "bad Qi" is removed and the body's cells and organs can reorganize along the lines of teamwork and harmony.

Qigong therapy can be understood in terms of chaos theory. As we let go of old structure, we have an increase of chaotic or undefined energy, which then can transform into a higher order of organization which handles all previous requirements in a new way and has left over capacity for new endeavors.

Implications of Scientific Qigong Research

The findings of the scientific research into human vitality have implications in broad areas of science and medicine.

1. Emitted Qi has strong measurable effects in health, healing, physiology and mental functioning. The presented research will encourage scientists around the world to seek deeper understanding of this phenomenon.
2. As human vitality becomes better understood, both in terms of measurable fields which surround the body, and chaos and consciousness, it will be integrated into the American health care system. Monitoring and treating patients accordingly will significantly improve recovery rates and shorten hospital stays.
3. Qigong exercises are effective tools for the individual to cultivate rapid healing and vitality. In addition, many who overcome chronic illness through Qigong practice will develop the ability to help treat others through the emitted Qi.
4. For those who are caught in the frenzied thinking of busy city life, practice of Qigong and other forms of concentration and meditation exercises is an answer. Qigong simulators help to get people started in their relax-

ation and Qigong exercises by relieving pain, promoting deep relaxation and mental clarity, and providing evidence that the phenomenon is real.

5. As the principles of human vitality are accepted in families, children will learn that their feelings of energy flowing through their bodies are normal, and that their awareness of these feelings is valuable. Just as children quickly learn the language that their parents speak, these children will learn to understand and use Qi if their parents accept and discuss it.

The Chinese scientific investigations into Qigong establish the phenomenon of emitted Qi as a real and fertile area of scientific study. Qigong teaching centers and Qigong simulation devices are already making a difference. Further studies into the nature of human vitality and inventions coming out of this ongoing research will do much to shape the 21st century.

APPENDIX 3

INTRODUCTION

This third Appendix includes research information on the physiological and energetic mechanisms triggered within the body, when stimulated through Medical Qigong therapy, Taijiquan or Yoga. This information was collected by my good friend Roger Jahnke, OMD, Director of the Qigong Department at the Santa Barbara College of Oriental Medicine, Santa Barbara, California. Mr. Jahnke is a doctor of Acupuncture and Oriental Medicine, and has studied extensively in China and abroad, learning Traditional Chinese Medicine and refining his clinical ability since 1967.

Doctor Jahnke is also the Director of the Health Action Clinic in Santa Barbara, California, and was one of the founding Board members of the National Qigong Association. He has written a Medical Qigong book entitled, "The Healer Within: Using Traditional Chinese Techniques to Release Your Body's Own Medicine."

This third Appendix is a continuation of the research devoted to the scientific approach of analyzing and scrutinizing the claims made as to the actual effectiveness of Medical Qigong Therapy as a clinical modality. The result on the effectiveness of Medical Qigong Therapy as a solid and effective clinical modality being positive in conclusion.

The following information in this third appendix represents but a fraction of Dr. Jahnke's findings, however, I am confident that the reader will find the data fascinating.

Dr. Jerry Alan Johnson May 2000

THE PSYCHOLOGICAL AND ENERGETIC MECHANISMS TRIGGERED IN THE HUMAN SYSTEM BY THE SELF-APPLIED HEALTH ENHANCEMENT METHODS QIGONG, TAIJI, AND YOGA

Roger Jahnke, OMD
Director of the Qigong Department
Santa Barbara College of Oriental Medicine

Western science has very clearly delineated numerous physiological systems: the digestive system, the nervous system, the cardiac system, etc. However, what might be called the "healing system" has not been discussed or clearly defined until recently. Medicine has uncovered many of the pathological processes that occur within the recognized systems and defined clinical strategies for their resolution. Strategies for enhancing the "healing system," however, have not been addressed by conventional science or medicine.

Numerous cultures, typically considered to be scientifically unsophisticated, actually noted and described the "healing system" long ago. The Chinese in traditional Chinese medicine, and the Asian Indians in Ayurvedic medicine, simultaneously developed elaborate theories of the function of the "healing system," and over thousands of years refined strategies for enhancing its function to produce a remarkable endogenous resource for self-repair. This internally generated healing resource is called an "inner elixir," literally a medicine produced within the human system.

In addition to specific clinical methods such as acupuncture, herbal therapies and tissue manipulation (massage and articular adjustment), these ancient cultures also created comprehensive health enhancement and self-healing systems to assist people in improving their own capacity to heal. Collectively such methods have been called the self-applied health enhancement methods (SAHEM). 1 Typically SAHEM includes breath practice, relaxation and regulation of the mind and nervous system through meditation, purposeful adjustment of the body posture with gentle movements and self-applied massage.

Qigong (also Chi Kung) from China and Yoga from India are ancient methodologies developed and refined over thousands of years specifically for sustaining and enhancing the "healing system." Qigong and Yoga, while they are historically based on the cultivation of factors unknown to the West (China—Qi and India—Prana), actually have specific effects on well known physiological mechanisms that are fully understood by Western science.

While there are many subtle aspects of human physiology that are triggered or accelerated by the practice of the SAHEM (including an emerging new understanding of "energetics," "bio-energetics" or "the electro-physiological system) the following three areas of conventional physiology make up a major portion of the physiological function of the "healing system" and are enhanced by the practice of the SAHEM.

1. Oxygen Delivery
2. Lymph Generation and Propulsion
3. Brain and Neurological Activity

The following sections will address each of these aspects. Other important mechanisms effected by the SAHEM including co-enzymes, antioxidants, connective tissue, precursor hierarchies, stem cell morphology , etc. do not fall into the scope of this paper and their discussion must be held for the future. The domain of subtle energy based mechanisms for the SAHEM effect will be explored briefly in conclusion.

OXYGEN

The Chinese knew about the circulation of the blood approximately 2000 years before William

Harvey described it in 1616 (Temple and Needham, 1986; Veith, 1972)). They knew about the energy generating relationship of food and air 2300 years before the elaboration of the oxidation feature of the Krebs cycle. The simplicity of the ancient Chinese formula for metabolic activity, understandable even by children, encourages wise use breath and food as health enhancing factors This is how Chinese grandmothers have passed health wisdom to children. Note that such simple wisdom is uncommon in the grandmothers of scientific cultures today.

It is often asked what difference there is between Qigong, Yoga (or other mild SAHEM) and the more vigorous conventional fitness methods like running, lifting weights, power biking and aerobic exercise. One way to discuss this is to trace the oxidation and energy cycle. In both aggressive, vigorous exercise and mild exercise the body naturally produces a powerful mix of metabolic resources. In vigorous exercise this is typically called a fuel. In the mild fitness systems of ancient cultures this inner resource has historically been called a medicine, or an elixir.

In vigorous exercise this oxygen induced resource is spent as fuel for hungry muscles. In the milder forms of SAHEM this resource is not completely spent, instead it is circulated internally and utilized as an internal reserve of self-repair factors to sustain and heal the tissues, organs and glands. At the advanced levels of Qigong this endogenous medicine is believed to be transformed into an elixir of longevity and wisdom.

Increased oxygen availability from practice of SAHEM has three potential effects, it:

1. supports energy (ATP, AMP, ADP) generation.
2. generates water as a by product of energy metabolism.
3. enhances immune function.

ENERGY GENERATION

The energy necessary for cellular processes and body heat regulation is supplied through the reaction of oxygen and glucose, in the presence of adenosine triphosphate (ATP). The combination of oxygen from air and sugar from food is catalyzed by ATP releasing chemical energy (ergs) which accomplishes all cellular processes. ATP is the basic energy storage and energy transfer molecule in the body.

The oxygen carrying capacity of the blood and the energy catalyzing ability of ATP are critical factors in the ability of the human organism to sustain a high level of vitality. This suggests that oxygen and ATP may be related to what the Chinese call "Qi" and what the Asian Indians call "Prana," the vital force or life energy. Chinese medicine distinguishes several aspects of Qi. Zhen Qi (Genuine, True or Normal Energy) is the basic dynamic force of all vital function. Ying Qi (Nutrient Energy) is the dynamic force which fuels cellular work (Kaptchuk, 1983). The interaction of oxygen, nutrients and ATP is apparently a physiological process that is a direct correlate of one particular aspect (there are many) of the activity of the Qi.

In Chinese research it was observed that blood levels of ATP increase with practices which cultivate Qi (Wang, 1988). When the mysterious practice of Qi emission (projecting Qi) was performed, the practitioner's ATP levels decreased significantly. Emission of Qi results in a decrease in stored ATP (or potential energy) as recognized by Western physiological science.

The SAHEM activate the body's energy metabolism cycle. The Chinese call this the "cycle of the transformation of energy" (Jahnke, 1989). In the West it is called the Krebs cycle, and has been nicknamed the "bioenergetic cycle."

In the West, ancient medicine is generally characterized as unscientific, superstitious or even primitive. Therefore, the Chinese "formula" for the transformation of energy (Qi) seems overly simplified:

Gu Qi + Kong (Qing) Qi = Zhen Qi

or energy of food + energy of air = essential body energy

Gu Qi (grain Qi, or food Qi) is the essence or life force of food. It mixes with Kong Qi (Kaptchuck, 1983) or Qing Qi (Kendall, 1989) (natural air Qi), the essence or life force of air to form Zhen Qi (Genuine, True or Normal Qi)) which is the life force of the body (Veith, 1972;

Kaptchuck, 1983; Kendall, 1989).

However, it is this same basic formula, hidden in the complex vocabulary of Western science, that is used in modern physiology:

$6O_2 + C_6H_{12}O_6 = ATP = ergs + 6CO_2 + 6H_2O$

air + glucose = catalyst = energy + carbon dioxide + water

It seems that the Chinese knew, without a particularly refined scientific method, that only a portion of the air and food, the Qi or essence, was employed in the process. In fact only 21% of air is oxygen and glucose is approximately 60% of food. (Guyton, 1992)

Science has been exploring energies, beyond metabolic energy (ergs), within the human system including the migration of ions, the ionic gates in cell membranes, the ionic discharge along neurological pathways and the electrical discharge that causes the beating of the heart. The overall understanding of body energetics will increase significantly as science explores the extent to which Qi is linked to these known physio-energetic mechanisms. The interaction of oxygen, glucose and ATP is likely only one energetic aspect of the beneficial effects of Qigong and other SAHEM.

WATER PRODUCTION

A second critical benefit of increased oxygen metabolism is linked to the cellular production of water as a by-product of the energy production cycle noted above. (Shields, 1989) This water is incorporated in interstitial fluid, lymph, blood serum, cerebrospinal fluid, synovial fluid, tears, sweat, etc.

Coincidentally, the energy which fuels the work of the cells as well as much of the water which contributes to the lymphatic fluid and other body fluids have the same source: metabolism. Metabolism is gently increased by all of the SAHEM. In addition, while the metabolic production of ergs also produces water, it is also interstitial water that has been found to conduct the physiologic flow of ions internally.

The benefits of the practice of health enhancement and self-healing methods upon the water component of the endogenous self-repair resource will be further explored in the section below on the lymphatic system. The bionic conductance will be explored briefly under energetic mechanisms.

IMMUNE FUNCTION

ATP drives the activity of every cell. Immune function as well as the production of immune resources (white blood cells, lymphocytes, T-cells, killer cells, etc.) are dependent on oxygen availability. It has been shown that exercise can mobilize the effect of natural killer (NK) cells. (Pedersen, 1988) However, in individuals who exercise so vigorously that they exceed the aerobic level and cross the anaerobic threshold, immune function is actually decreased (Brahmi, 1985; Fehr, 1989).

The scientific evidence is strong on two points: 1) oxygen deficiency leads to decreased immune function and 2) moderate amounts of mild exercise increase immune function.

In his research, Nobel Prize recipient Otto Warburg found that oxygen deficiency was typically supportive of cancer cell proliferation (Warburg, 1966). There are numerous studies that associate reduced lung volume and oxygen exchange capacity with increased mortality and reduced resistance to disease (Gordon, 1970; Cullen, 1983). In studies with elders, immunodeficiency was found to be one consequence of reduced oxygen metabolism. (Saltzman, 1987).

Oxygen's effect on immune function was demonstrated in a German study. It was found that in elderly injured, stressed and hospitalized individuals the arterial oxygen content is often reduced from normal levels. Administration of oxygen was found to elevate the arterial oxygen content and increase recovery rates. Interestingly, the experimental addition of germanium to the treatment protocol in the study further accelerated the healing process (Liem, 1985). Germanium is known to accelerate oxygen metabolism.

These mechanisms associated with oxygen's role in the endogenous "healing system," are naturally occurring and optimal in healthy individuals. One or several of these mechanisms may be deficient in individuals who are ill or at risk for disease. These mechanisms are all enhanced by

the gentle movement, focused breath practice and relaxation that occur in the practice of Qigong, Yoga and other SAHEM.

LYMPH SYSTEM FUNCTION

The lymphatic system has been largely neglected in the conventional Western scientific tradition. Contrasted with cardiac function, for example, the lymph function is relatively unexplored. Perhaps, because lymph and lymph vessels are generally translucent, they drew little attention in early anatomical study compared to organs, blood vessels, muscles and bones.

Hippocrates and Aristotle referred to "white blood" and "colorless fluid." In the Middle Ages medical knowledge declined and the lymph was temporarily forgotten. Not until 1627 did Asellius, in Milan, recover the knowledge of the lymph (Rusznyak, 1976). The structure and action of the lymph system was still undefined by 1900 (Yoffey, 1970) and both the immunological function of the lymph and the actual lymphogenic process are still not clearly understood even as we enter the 21st century.

However, in Asia, medical practice is based on meticulous observation of whole organisms—the whole person and the totality of integrated functions. Even though the discrete lymphatic function itself was unknown and unnamed, its effects were generally ascribed to the proper action of the Qi and fluids in China or the Prana and fluids in India. Even though the lymph, as such, was unnamed by Asian physicians, elaborate methods for generating and circulating lymph were developed, and faithfully practiced through Qigong, Yoga and other self-care practices.

When these practices are viewed in relation to what is now known about lymphatic function and its healing role, it appears that much of Qigong, Tai Chi, Yoga and Pranayama were developed specifically with the enhancement of lymphatic function in mind. Breath, movement and postural modification as well as meditation have specific effects on the circulation of the lymph and therefore enhance the overall function of the lymphatic system.

In the West science has divided the body fluids into specific categories: blood, lymph, cerebrospinal fluid, synovial fluid, extracellular fluid, intracellular fluid. From the paradigm of the West it seems that the unsophisticated Chinese may have overlooked important information with their broad, non-specific view of "Qi, blood and body fluids." However, the lymph fluid is largely interstitial biological water. This becomes an aspect of blood plasma (Rusznyak, 1976). Plasma and lymph both contribute water to the cerebrospinal fluid, part of which migrates back into the lymphatic system (Bradbury, 1985). This cycling of fluid (essentially water) from one system into another validates the Chinese approach of thinking of the all various fluids in a single continuum: simply as "body fluids."

Recent discoveries have demonstrated that electrical energy in the form of ion streams migrate throughout the body (Nordenstrom, 1983). The conductance medium for this energy flow system (which will be discussed in the energetic section of this article) is biological water in its numerous contexts including lymph, blood serum, interstitial fluid, etc.

The practice of SAHEM activates a number of remarkable self-healing mechanisms associated with the lymphatic system:

1. Lymph generation
2. Lymph propulsion
3. Immune function
4. Cerebrospinal fluid circulation
5. Nutritive function

LYMPH GENERATION

The actual generation of the lymph has long been attributed to the filtration of blood plasma from the capillaries (Adair and Guyton, 1985). As recently as 1985 this was recognized as the primary source of the lymph. This idea overlooks a significant detail that is at the crux of the tremendous health benefits of Qigong and Yoga: a significant portion of the water in the body's fluids is produced by the identical physiological process that generates the body's biological energy as discussed in the previous section on oxygen (Shields, 1989). Just as an individual respires to sustain life,

each cell is also respiring. For each gram of glucose metabolized, in excess of a gram of water is produced.

In a moderately active 70 Kg human, between 2100cc and 2800cc of lymph enters the blood stream daily at the sub-clavian vein through the thoracic duct. In a resting individual the calculations of the Krebs cycle show that the cells produce approximately 950cc (Shields, 1989) of this daily water flow. In a person engaging in moderate exercises, such as Qigong or Yoga (or walking), up to 1400cc of aerobically generated water can be produced daily. When an individual is practicing some sort of moderate body activity, as much as one half of the water that is produced and propelled through the lymph system is a by-product of cellular metabolism. Increased lymph flow improves the elimination of the by-products of metabolism and pathogenic factors (both considered toxins) and increases the circulation of immune factors.

Lymph Propulsion

The blood's circulatory system has the powerful heart muscle to propel its fluid. The lymph, however has no distinct heart in humans. It was understood that the movement of lymph against gravity is accomplished by the contractions of the skeletal musculature through vessels with one way valves in a uni-directional system. Nothing new emerged until the mid 1900's when studies revealed that birds and reptiles have specific lymph hearts (Shields, 1980). Even as late as 1941 important aspects of lymph propulsion mechanism remained obscure (Drinker and Yoffey, 1941).

By 1949 "spontaneous, intrinsic pulsatory contraction of the peripheral lymphatic vessels" was demonstrated in humans with a rhythm unassociated with either the heart or the breath (Smith, 1949; Olszewski, 1979).

The current literature is crowded with a wide range of questions raised by research specifically on lymph propulsion: What factors might stimulate the intrinsic contractile mechanism? Is it consistent throughout or differentiated, by what regional factors? By what autonomic and neuroendocrine factors is intrinsic contractility modified? These are just a few of the questions. The study of SAHEM will accelerate our ability to answer these and other more general questions on the lymph system such as: What regulates lymph protein concentration? What effect does passage through the lymph nodes have on the proliferation of immune cells from within the nodes (Olszewski, 1985)? And what is the nutritive role of the lymph (Shields, 1972)?

The breath, through two mechanisms, has a significant effect on the propulsion of the lymph: 1). aerobic production of water and 2). mechanical pumping of the breath apparatus, lungs and diaphragm. Several additional propulsive mechanisms are initiated by body movement and body posture.

Tentative agreement now exists on at least five mechanisms which comprise the "lymph heart" and are activated by the SAHEM, including:

1. aerobic production
2. intrinsic smooth muscle contraction
3. contraction of striated skeletal muscles
4. gravity
5. breath apparatus: lungs, rib cage and diaphragm

Aerobic Propulsion. The aerobic production of water contributes to lymph propulsion mechanically. The cellular production of water, as a by-product of oxygen metabolism, is increased by dynamic Qigong and Yoga practice. The liquid holding capacity of the tissue spaces is naturally limited. As the limit is reached, the presence of additional lymph drives the excess into the terminal lymphatic vessels, the initial vascular openings of the lymphatic system (Yoffey, 1970: Adair, 1985; Shields, 1980, Olszewski, 1985). Like a cup that is running over, the interstitial space fills, building volume and pressure, and then flows over into the lymph vessels.

Intrinsic Smooth Muscle Contraction. The automatic response of the smooth muscle tissue of the lymphatic vessels and the peripheral lymphatic capillaries is to contract when filled and stretched to a certain tolerance (Olszewski, 1985). This contraction moves the lymph forward, with the assistance of the one way valves, in much the same

way as the contraction of the heart moves the blood (Bradbury, 1985). In Qigong and Yoga this mechanism is accelerated by the increase in metabolism from gentle movement which contributes to lymph volume.

A number of studies have demonstrated that the intrinsic mechanism is also triggered when the overall sympathetic aspect of the autonomic nervous system is modified by the parasympathetic. Therefore, he intrinsic contractility mechanism is accelerated or enhanced by the shifting into the deeply relaxed state that is a primary feature of SAHEM practice.

Striated Skeletal Muscle Contraction. Even slight contraction of skeletal muscles in mild health enhancement practices propels the lymph in the one way vessels. In the more dynamic practices the pumping of the skeletal muscles and compression of the body parts increases interstitial. The effect of muscle contraction on lymph is one of the classic explanations for lymph motion (Adair, 1985, Bradbury, 1985). In Qigong and Yoga this mechanism is triggered by the mechanical action of the musculature and the action of the skeleton through the relaxation and contraction of the striated muscles in the movement forms of the practice.

Gravitational Propulsion. Because gravity exerts such a substantial force and because lymph has so far to climb to get to the thoracic duct's entry into the sub-clavian vein (at the base of the neck), any inversion of the limbs or even the prone body position allows for a more free flow of lymph. In keeping with this, elevation of the limbs is often prescribed for health problems characterized by a pooling of interstitial fluids, edema.

In SAHEM, many postures and movements create this mechanical dynamic where the lymph is actually propelled by gravity. In certain walking forms, Tai Chi and Guo Lin Qigong are the most renowned, the practitioner is constantly but slowly moving all of the limbs in beautiful circular motions that recurrently activate this mechanism. In Yoga many of the asanas (postures) invert the limbs. In the head and shoulder stands the whole body is inverted.

Breath Apparatus: Mechanical Propulsion. The most powerful of the array of mechanisms that work together to form the "lymph heart" is the mechanical action of the breathing apparatus itself (Sheilds, 1980). The concentration of lymphoid tissue above and below the diaphragm is many times more dense, and contains greater fluid volume, than any of the lymphoid tissue at the periphery, or even in the moderately prolific lymphoid areas of the axilla or groin (Adair, 1985). Lymph that has been carried from all over the body, accumulates centrally and is then propelled by the breath/diaphragm in a final rush through the thoracic lymph duct into the blood at the subclavian vein where it leaves behind its identity as lymph and is transformed into blood serum (Shields, 1981).

Above the diaphragm the thoracic duct of the lymphatic system is a central collecting vessel. Its size is many times that of the peripheral lymph vessels. Below the diaphragm a substantial dilation of the thoracic duct forms a collecting capsule for lymph, called the cisterna chyli. Chyle is a milky fluid of nutrients absorbed from the small intestine, which is passed into the circulating blood through the thoracic duct.

When full inspiration of the breath occurs, the diaphragm drops downward. A tremendous pressure is exerted on the cisterna chyli and a great negative pressure is generated in the thoracic cavity. The compressed cisterna chyli shoots lymph upward through the thoracic cavity. As air rushes in to balance the negative thoracic pressure, the lungs are fully expanded. This creates a powerful positive pressure which compresses the thoracic duct. Due to the one way lymphatic valvular system, lymph is forced upward where it enters into the sub-clavian vein with a rush.

Simultaneously, when the diaphragm drops downward on full inspiration it also compresses the abdominal and pelvic organs. The contents of the lymphoid reservoirs and vessels are forced by the same arrangement of one way valves forward in the system. In research with moving X-ray film, study subjects explored various actions and breath patterns. It was demonstrated that deep inspira-

tion pumps the lymph at a rate that is dramatically greater than resting inspiration and other activities, including massage and walking (Shields, 1981).

It is fascinating to note that in Traditional Chinese Medical theory it has been taught for several millennia that the "lungs regulate the water passages" (Xie Zhu Fan, 1988). To Westerners this seems quite strange. The kidneys are considered to be responsible for water regulation. How could the Chinese have known that the activity of the lungs and diaphragm were linked to moving the body's internal water supply? Even now as we enter the 21st century Western science, and especially average Western citizens, have little idea that the simple act of regulating the breath is such a profound healing tool. However, here we can see that the Chinese somehow arrived at a kind of remarkable wisdom about how the lungs, the breath and the oxygen literally cooperate to produce and circulate the healing resource of water in the body.

Immune Function

The immunoactive aspect of the lymphatic system is well represented in the conventional literature of Western physiology (Drinker, 1941; Bradbury, 1985; Olszewski, 1985; Van Rooiijen, 1987). The bone marrow, thymus, spleen and lymph nodes participate in the interaction of the lymph and immunity. The composition of the lymph fluid itself includes a number of immune active agents such as lymphocytes and macrophages (Olszewski, 1985).

Lymphocytes that exit with the lymph fluid from the nodes come from three sources: 1) inflowing with lymph from the tissues in the peripheral vessels, 2) exchanged from the blood that enters the node's own vascular system and 3) formed by local proliferation in the node itself (Bradbury, 1985). Lymphocytes naturally collect within the node, especially when lymph flow is sluggish. Greater numbers of cells proliferate when lymph flow is greater and the numbers circulated out of the node increase with flow volume as well (Adair, 1985). Both the numbers immunoactive cells and their circulation rate are increased by the deepening of the breath, relaxation and the alternating contraction and releasing of the musculature in the gentle practices of Qigong and Yoga.

Excellent recent research has clearly delineated, localized and quantified the development of specific antibody forming cells in lymph nodes (Van Rooijen, 1987). In addition, it has been found that there are neurotransmitter receptor sites on lymphocytes where they actually interface with the neuropeptides that drive immune function (Smith, 1985). This is one of the important links between neurochemistry and immunity that is mediated through the lymph system and optimized by the practice of the SAHEM which also increases the numbers of circulating immune cells and accelerates their rate of delivery.

Cerebrospinal Fluid (CSF)

The cerebrospinal fluid (CSF) system was classically perceived as a closed system, though another view, unconventional for many years, held that CSF was actually circulating in an open system that allowed the fluid to flow through the aracnoid villi and into the venous blood. By the 1970's it was generally acknowledged that the CSF travels along the cranial and spinal nerves and into the perineural lymphatics (Kimber, 1977).

Research using the microinjection of tracers has suggested several possible pathways for the passage of both the CSF and the cerebral interstitial fluid (CIF) to exit the aracnoid space (Bradbury, 1985). By 1985 the flow of CSF and CIF into the lymphatics was well documented (Bradbury, 1985). Consideration has even been given to the effects of pressure and posture on this flow (Bradbury, 1985), both of which are primary effects that are enhanced in the practice of Qigong, Taiji and Yoga.

The presence of CSF in the lymphatic system and the presence of neurotransmitter receptors on immune cells (Covelli, 1988) suggests a powerful benefit of the SAHEM on the interaction between neurotransmitters and immune function in the reticulo-endothelial system.

Nutritive (Trophic) Function

The importance of a broad availability of nu-

speech, irrational or catatonic behavior, such as stupor, rigidity, or flaccid movement of the limbs. The ability to interact with others is greatly impaired.

Sclera - a tough white fibrous tissue that covers the white of the eyes.

Sea of Blood (Sea of the Twelve Channels) - pertaining to the Energy located in the Thrusting Vessel.

Sea of Energy - Energy located in the Lower Dantian, or Qi Hai area.

Sea of Grain and Water (Sea of Nourishment) - pertaining to the Energy located in the Stomach.

Sea of Marrow - pertaining to the Energy flowing in the spinal column and brain, originating from the Kidneys.

Sea of Qi - the chest center. Some Medical Qigong schools maintain that there are two reservoirs of Qi: the Middle Dantian, being the Sea of Postnatal Qi, and the Lower Dantian, being the Sea of Prenatal Qi (which is regulated by the Qihai CV-6 point).

Sea of Yang Channels - pertaining to the Governing Vessel.

Sea of Yin Channels - pertaining to the Conception Vessel.

Self Regulation Therapy - pertaining to the patient's Qigong prescriptions (meditations and/or exercises).

Seven Emotions - see Seven Internal Factors.

Seven Essential Stars - the Sun, Moon, Mars, Venus, Mercury, Saturn and Jupiter, associated with the body's seven orifices.

Seven Internal Factors - pertaining to the seven emotional pathogenic factors that cause disease, when in an Excess condition (Joy, Sorrow, Worry, Grief, Fear, Fright, and Anger).

Seven Material Souls - pertaining to the seven Earthly spirits that reside in the body as the Po.

Seven Orifices - ears, eyes, nostrils, mouth, anus and urethra, which are considered the gates and windows of Essence, Energy and Spirit.

Seven Turbid Demon Natures - see Po.

Shaman - an ancient Tungus term meaning "between the worlds." A Shaman is a tribal priest or priestess who heals the physical, mental, emotional, energetic and spiritual aspects of the patient.

Shao Yang - Small Yang, also called Lesser Yang, Minor Yang, or Young Yang, is affiliated with the sunrise and the waxing-moon phase. Modern physicists associate the Lesser Yang with a light force and electromagnetism.

Shao Yin - Small Yin, also called Lesser Yin, Minor Yin, or Young Yin, is affiliated with the sunset and the waning-moon phase. Modern physicists associate the Lesser Yin with a heavy force, and gravity.

Shen - meaning Spirit; when speaking about physical development, it is derived from Qi, and can be divided into both Prenatal and Postnatal Shen.

Shen Deviations - mental and emotional disorders which have caused the Three Ethereal Souls (Hun) to leave the patient's body.

Shengong - training of the spirit through meditation and visualization.

Shening Out - terminology used to describe the Ethereal Soul (Hun) wandering away from the body.

Shi Qi (Turbid Qi) - also known as Evil Qi, Toxic Qi, and Pathogenic Qi, it is coarse, unrefined, polluted or dirty energy.

Sishencong (Four Alert Spirit) Points - four points at the top of the head (that surround the Baihui Point) used to absorb Heavenly Qi into the body.

Shou Zhen (Hand Diagnosis) - a form of diagnosis, wherein, the doctor assess the "energetic blueprint" of the patient's body transformed onto the doctor's left hand.

Shu Points - five specific points below the elbows and knees identified as the Well, Spring,

Stream, River and Sea points. Each point has an affect on the quantity of the energy of an organ.

Sishencong (Four Spirit Hearings) Points - a group of four points located at the top of the head (surrounding the Baihui point), used for absorbing Heavenly Qi into the body's Taiji Pole.

Six External Factors - also known as the Six Pernicious Influences, these factors pertain to the six climatic changes (Wind, Summer Heat, Heat, Damp, Dryness, Cold, and Fire).

Six Storage Areas- body's Yang organs constantly fill and empty, and include the Bladder, Gall Bladder, Stomach, Large Intestine, Small Intestine, and Triple Burners.

Skin Zones - twelve dermal-zones, based upon the surface location of the body's Twelve Primary Channels.

Soaring Dragon Technique - hand technique for Qi emission, where the energy is emitted through the middle finger bent and pointing downward, while the other fingers are extended straight outwards.

Solid Organs - the body's Yin organs, which include the Liver, Heart, Spleen, Lungs, and Kidneys (also included in this list is the Pericardium).

Soul - immaterial Spiritual Essence of an individual's life, stored within the Heart and Middle Dantian.

Soul Body- see Astral Body.

Soul Extensions - the Shen develops and contains Twelve Soul Extensions. These Twelve Soul Extensions contain the body's different personality characteristics.

Soul Loss - the loss of parts of the Eternal Soul.

Soul Retrieval - to spiritually search for and bring back one's forgotten memories (soul), which have been isolated from consciousness due to trauma and shock.

Soul Travel - see Astral Travel.

Sound Energy Therapy - sound projected as audible and inaudible tone resonation, used for healing.

Sound Resonation - healing tones used for tonifying or dispersing the patient's Energy.

Spider Nevus - a branched growth of dilated capillaries on the skin, that resemble a spider.

Spinal Pass (Jia Ji Guan) - two points located on the lateral sides of the Mingmen (GV-4), where energy has a potential to stagnate.

Spinous Process - the single midline posterior projection arising at the junction of each vertebra.

Spiraling Energy Technique - hand manipulation, that extends and spirals the doctor's projected energy.

Spirit - the energetic manifestation of the Eternal Soul.

Spirit Body - the energetic vehicle inwhich the body's Shen can travel throughout the Astral Plane. The Spirit Body can manifest through many forms (Body of Light, animal forms, etc.).

Spirit Demons - see Demon Possession and Oppression.

Spirit Soul - the Three Ethereal Souls, accompanied by the individual's consciousness, acting as one unit for spirit travel.

Spirit Travel - the spirit (Hun) journeying outside of the physical body.

Splenomegaly - the enlargement of the Spleen.

Squamous Metaplasia - the conversion of tissue into a form of scalelike cells, that is abnormal for that tissue.

Stacking the Bones - allowing the bones to stack upon each other from the bottom of the feet to the top of the head.

Stagnation - not moving, inactive; pertaining to Qi, Blood, or thought patterns.

Static Qigong - the process of stationary, quiescent Energy gathering.

Stroke (Wind Stroke) - caused by the buildup of Excess Liver Fire creating Internal Wind.

This Internal Wind causes Qi and Blood to rebel upwards causing Phlegm to form and obstruct the cavities and vessels, creating Penetrating Wind or Stroke.

Subarachnoid Hemorrhage - bleeding internally, within the spaces at the base of the brain, between the pia proper and arachnoid contain the cerebrospinal fluid.

Subconscious Mind - part of the mind associated with the recording and storing of personal interpretations of reality (not readily accessible to the conscious mind).

Sublimation - the channeling of unacceptable impulses into acceptable, refined social forms and is the only defence mechanism considered to be a healthy reaction.

Substances - pertaining to the body's essential parts of physical and energetic material.

Sui - Marrow.

Super Ego - Dr. Sigmund Freud's terminology for the division of the psyche in psychoanalytic theory, responsible for the psychic reward and punishment system.

Sun's Essence - energy gathered from the sun, ingested as warm light.

Sword Fingers Technique - hand manipulation that emits Qi through the extended index and middle fingers.

Symptoms - a subjective manifestation of a pathological condition, reported by the patient.

Syndromes - a grouping of signs and symptoms, based on their frequent reoccurrence, that may suggest a common underlying pathogenesis.

Systemic - affecting the entire body.

T

Taiji Pole - the Center Core of light which joins the body's three Dantians and the Eternal Soul together.

Tai Yang - Great Yang, also called Strong Yang, Major Yang, or Old Yang, is affiliated with high noon and the full-moon phase. Modern physicists associate the Strong Yang with a strong nuclear force.

Tai Yi - meaning Great Divinity or God.

Tai Yin - Great Yin, also called Strong Yin, Major Yin, or Old Yin, is affiliated with midnight and the new-moon phase. Modern physicists associate the Great Yin with a weak nuclear force.

Ten Heavenly Stems - the ten energies of Heaven that rule the changes of the Five Elemental seasonal transitions, and are represented in the human body as the Yin and Yang aspect of the Five Elements (represented in the human body as the ten major internal organs).

Ten Thousand Voices - pertaining to the state of open receptivity of the Qigong doctor's Heart, after rooting the mind.

Ten Wings - consisting of ten commentaries from Confucius and his disciples, pertaining to the study of the eight trigrams, sixty-four hexagrams, and the Yi-Jing.

Third Eye Point (Yin Tang) - located in the center of the forehead, responsible for spiritual intuition and communication.

Thought-forms - images of concentrated thought patterns that manifest on the vibrational resonance of the Astral Plane.

Three Ethereal Souls (Hun) - pertaining to the three heavenly spirits that reside in the body.

Three Fires - the heat in the body, generated from the energy radiating from the Heart Fire, Kidney Fire, and Bladder Fire.

Three Outer Forces - pertaining to the three natural powers of Heaven, Earth and Man.

Three Parts Wisdom - knowledge obtained through the doctor's connection and communication with his or her Upper, Middle, and Lower Dantians.

Three Periods of Life - the developmental stages of the patient's Jing, Qi and Shen divided into the womb, childhood and adult-

hood.

Three Stars - pertaining to the three periods of life, each period is divided into three stages of development, known as the three stars.

Three Treasures of Earth - pertaining to the energy of Soil, Water and Wind, and the study of Feng Shui (Wind and Water).

Three Treasures of Heaven - pertaining to the energy of the sun, moon and stars, and the study of Chinese astrology.

Three Treasures of Man - pertaining to the energetic interaction of the body's Essence, Energy and Spirit, and the study of the Yi-Jing (I-Ching or Book of Changes).

Three Wonders - Clinical manifestations of Qi, categorized as Subtle, Mysterious and Incredible Wonders.

Thrombosis - the formation and development or existence of a Blood clot (thrombus) within the walls of the vascular system.

Thrusting Channels - the Five Energy Channels which surround and penetrate the body's center core via the Taiji Pole.

Thrusting Vessels - also called the Chong Vessels, they are the Five Energy Vessels which originate from the center of the body and internally transverse the legs and torso.

Ti - referred to as the Divine Center.

Tian Qi (Heavenly Energy) - the transformed energy of the Yuan Qi and the divine.

Tian Shen (Heavenly Spirit) - the transformed energy of the Yuan Shen and the divine.

Tie Bi (Iron Wall) - the areas of the body where it is most difficult for the energy to pass through when circulating the Microcosmic Orbit.

Tinnitus - a ringing, tinkling, or buzzing sound in the ear.

Toe Raised Stepping - pertaining to energetic walking therapy, wherein the toes are stretched when stepping in order to facilitate the increase of Qi flowing into the body via the leg channels.

Tonification (Tonify) - to supplement the insufficiency and strengthen the body's resistance.

Traditional Chinese Medicine - Chinese Energetic Medicine, divided into four branches of healing modalities (Acupuncture, Herbal Therapy, Medical Qigong Therapy, and Tissue Regulation Therapy (Chinese Massage).

Transference - the process whereby a patient unconsciously transfers feelings, thoughts, beliefs and patterns of behavior that had been previously experienced with others onto the doctor.

Transient Ischemic Attacks (TIA) - temporary interference with the Blood supply to the brain.

Treatment - the medical care given to a specific condition.

Trigger Points (Ashi Points) - places on the body which are tender spots, or painful areas near diseased or injured tissue.

Trigram - pertains to three Yao lines stacked upon one another forming a specific symbol, which represents certain characteristics.

Triple Burners (San Jiao) - also known as the Triple Heaters and Triple Warmers, they correspond to three main body cavities (perineum to navel, navel to base of solar plexus, solar plexus to throat), and are responsible for heating the body and transporting Body Fluids.

True Fire - the original Heat or Fire Energy that regulates the body's Yin and Yang Qi, created from the radiating energy of the Heart's Fire, Kidneys' Fire and Bladder's Fire.

True Nature - one's innate nature in harmony with life.

True Qi - the energy that circulates in the body's channels and collaterals which nourishes the Yin and Yang organs and fights disease.

True Self - one's true nature, connected to the subconscious mind.

True Spirit - pertains to the spiritual nature of the True Self. The Hun and Po are expressions of the body's True Spirit.

Tsou Hou Ru Mo ("the Spirit leaves and the Demon enters") - describes self induced psychosis, pertaining to improper Qigong training, wherein the patient's Hun leave the body and the Po take over.

Tui Na Therapy - a tissue manipulation therapy that focuses on the adjustment and/or stimulation of the muscles and tendons.

Tumor - an abnormal growth, either benign or malignant, caused by a retention of mass due to the cultivation and stasis of Qi, Blood, Phlegm, etc.

Turbid Qi - also called Evil Qi, is coarse, unrefined, polluted, and dirty energy.

Twelve Pi Hexagrams - the twelve symbols pertaining to the twelve time periods of the day and year.

Twelve Primary Channels - the body's twelve main energetic rivers (Liver, Lungs, Large Intestine, Stomach, Spleen, Heart, Small Intestine, Bladder, Kidneys, Pericardium, Triple Burners, and Gall Bladder).

Twelve Earthly Branches - twelve energies of the Earth that determine the six Qi factors of the seasonal transitions (represented in the human body as the Twelve Primary Channels).

Two Breathings - pertaining to the abdominal breathing method of holding the breath.

U

Umbilications - a depression resembling a navel.

Universal Qi - energy pertaining to the Heavens, the divine and the celestial influences.

Upper Burner - pertaining to the body's complex system of Fluid distribution via the Lungs and located within the upper chest cavity.

Upper Dantian - area within the center of the head, attributed as the body's chamber of light and door to psychic and intuitive powers. The Upper Dantian is also known as Seal Palace, Ancestral Opening, Calm Fountain, Heaven's Valley, Inner Source, and Clay Pill Palace.

V

Vasculitis - the inflammation of a blood or lymph vessel.

Vertigo - the sensation of moving in space, resulting in such symptoms as dizziness and light-headedness.

Virtue (De) - pertaining to the function of the divine in man.

Virtue of Dao - pertaining to the commendable quality of the divine.

Viscera - the body's internal organs.

Void - also called Wuji, it pertains to the infinite space between matter and energy.

W

Wai Dan Shu - external elixir cultivation, that focuses on cultivating Qi from outside the individual's body.

Wai Qi - external, extended energy.

Walking Therapy - Postoral Dao Yin walking exercises and dynamic "moving" meditations used for the treatment of organ Deficiencies.

Wandering Bi - migrating pain within the body's cavities.

Waning - to grow smaller.

Water Element - one of the Five Elements, pertaining to Kidneys and Bladder.

Water Jing - energy that controls the genetic development phase of the fourth fetal month.

Waxing - to grow larger.

Wei Lu Guan (Coccyx Pass) - located on the lowest segment of the spine just posterior to the anus, near the Chang Qiang (GV-1) point.

Wei Qi - the body's external field of Defensive and Protective energy (divided into three fields of Qi).

Wen Huo - pertaining to the gentle breathing

method of Respiratory Dao Yin training.

White Blood Cell - any of a group of Blood cells that have no hemoglobin and migrate into tissues to fight infection and digest cell debris.

Wind Bi - pain in the body created by toxic Wind invasion.

Wind Stroke - Stroke caused by the buildup of Excess Liver Fire creating Internal Wind. This Internal Wind causes Qi and Blood to rebel upwards causing Phlegm to form and obstruct the cavities and vessels, thus creating Penetrating Wind or Stroke.

Windy Breathing Method - pertaining to the method of breathing through the nose.

Wood Element - one of the Five Elements, pertaining to the Liver and Gall Bladder.

Wood Jing - energy that controls the development phase of the direction of the fetus's emotional and spiritual aspects during the seventh month of pregnancy.

Wu Guan (Five Passes) - five important gates on the Governing Vessel located at the coccyx, Mingmen, Shendao, occiput, and Baihui areas where energy tends to stagnate.

Wu Huo - pertaining to the vigorous breathing method of Respiratory Dao Yin training.

Wuji - pertaining to infinite space or the formless Void.

Wuji Posture - a quiet standing posture used in meditation to allow the practitioner to return to a state of tranquility.

Wu Jing Shen (Five Essence Spirits) - the spiritual energy radiating from the core of the Five Yin Organs. Combined, these energies create the foundation of the body's Shen (Spirit).

Wu Se Dai - pertaining to the five colors of vaginal discharge - white, yellow, red, green-blue, and dark brown or black.

Wu Wei - a state of "no mind," i.e., no thoughts.

Wu Zang - the Five Yin Organs. Wu translates to mean "five," Zang translates to mean "to store or hold."

X

Xie Qi (Evil Qi) - energy that causes disease or harmful effects to the body.

Xin Xi (The Message) - knowledge stored within the Wuji or the Void.

Xiphoid Process - the lowest part of the sternum bone (sometimes referred to as the Doves Tail).

Xue - Blood.

Y

Yang - the positive charged energetic polarity, opposite of its companion Yin, pertaining to man, hard, light, hot, etc.

Yang Channels - the body's Yang energetic rivers, consisting of the Governing Vessel, Belt Vessel, Yang Linking Vessels, Yang Heel Vessels, Large Intestine Channels, Triple Burner Channels, Small Intestine Channels, Stomach Channels, Gall Bladder Channels, and Bladder Channels.

Yang Fire - also called Emperor's Fire, energy of the Heart Fire.

Yang (Fu) Organs - also known as Hollow Organs, that consist of the Gall Bladder, Small Intestine, Stomach, Large Intestine, Bladder. Also included is this category are the Triple Burners.

Yang Shen Disturbances - an emotional Yang state of energetic dysfunction.

Yang Ming (Yang Brightness) - indicates Yang Qi developing its final stage and then reverting into Yin.

Yao - a solid or broken line which is representative of either Yang or Yin energy, used in combination of three as Trigrams or six as Hexagrams.

Yao Cycles - the progression of twelve hexagrams (six Yang and six Yin) flowing in a waxing and waning cycle.

Ye (humor) - thick, turbid Body Fluids.

Yellow Court - located in the center of the diaphragm, just below the xiphoid process of the sternum. Its function is that of being the access point to releasing the body's internal organ emotional memories. Its location is also attributed to the 3rd Chakra.

Yi - the intention or thought (the cognitive mind).

Yi Jing - Chinese "Book of Changes," pertaining to the natural transitions of life.

Yin - the negative charged energetic polarity, opposite of its companion Yang, pertaining to woman, soft, dark, cold, etc.

Yin Channels - Yin energetic rivers, consisting of the Conception Vessel, Thrusting Vessel, Yin Linking Vessels, Yin Heel Vessels, Lung Channels, Pericardium Channels, Heart Channels, Spleen Channels, Liver Channels, and Kidney Channels.

Yin (Zang) Organs - also known as the Solid Organs, that consist of the Liver, Heart, Spleen, Lungs and Kidneys. Also included in this category is the Pericardium.

Yin Shen Disturbances - an emotional Yin state of energetic dysfunction.

Yin Tang (Third Eye Point) - located in the center of the forehead, responsible for projecting the Spirit for psychic intuition and communication.

Ying Qi (Nutritive Qi) - the body's nourishing energy.

Yu (Surplus) Vessels - secondary vessels that branch away from the energetic flow of the major Linking Vessels (at the chest and back), connecting the Linking Vessels energetic flow to the hands.

Yuan Jing (Original Essence) - the Original Kidney or Prenatal Essence.

Yuan Shen (Original Spirit) - the Original Prenatal Spirit.

Yuan Qi (Original Energy) - the Original Kidney or Prenatal Qi.

Yun - the Yin method of dynamic postural Dao Yin training.

Yu Zhen Guan (Occipital Pass) - the area located just inferior to the occipital bone where the brain originates, known as a specific point where Qi often stagnates.

Z

Zang Organs - Yin or solid organs (Liver, Heart, Spleen, Lungs, Kidneys and Pericardium).

Zang/Fu Organs - the body's Yin and Yang organs.

Zhang Xiang Xue Shou - in Chinese medical science, the study of energetic physiology.

Zhen Qi - see True Qi

Zheng Qi - Righteous Qi, pathogenic fighting Energy.

Zhi - the Will power, mental drive and determination.

Zhong Qi - Center Qi, Energy of the chest.

Zhou Qi - Turbid Qi, Evil Qi, Impure Qi

Zong Qi - Gathering Qi, and/or Respiratory Qi.

Zygomatic Facial Regions - pertaining to the sides of the cheeks below the eyes.

Teleportation Wingmakers Manual

Introduction
Teleportation is the ability of moving matter from one point in time and space to another point in time and space instantaneously. There are different types of teleportation available at this time both visual and physical teleportation are possible and we use visual teleportation as our starting point. The different types of visual teleportation are. visual body or astral body teleportation, or visual object teleportation but before we can master teleportation we must first learn the art of Telekinesis/Psychokinesis and Clairsentience and the higher state of consciousness the seventh sense. Other abilities useful in teleportation are Tele-Visualization and ESP (Extrasensory Perception). The ability of teleportation is used in Time travel, Interstellar travel, and Dimensional travel. Teleportation is the near instantaneous transport of the Psychic from one location to another and there is no other form of travel faster then teleportation
Teleporting An Visual Object

Visual Technique
Step One
Charge your physical body with energy.

Step Two
Then place an object in front of you.

Step Three
Next close your eyes and visualize the object in front of you.

Step Four
Then visualize the energy around the object and see your energy blending with the objects energy. This will look like the two energies will be knitting together

Step Five
Then focus and feel the object feel the object leaving and if you need to visualize that the object is disappearing

Step Six
Then focus your mind on the new destination six feet in front of you.

Step Seven
At the new destination six feet way in front of you and feel the object reappearing at the new position in front of you and if you need to visualize that the object is reappearing at the new destination. Then open your eyes.

Remember
This is a visual exercise so you are only teleporting the object visually.

Teleportation Portal

The image above is what a energy portal should look like

Introduction

A Portal is a wormhole of energy made within the light matrix of the physical plain. We can make Portal from the chakra energy, prana energy, and kundalini energy found at the base of the spine and merkaba energy found in the light matrix of the physical body and auric field. Portals can be used in Time travel, Interstellar travel, Dimensional travel and Blank Slate Technology.

Visual Technique
Step One
Charge your physical body with energy.

Step Two
Then close your eyes and see your visual body standing in front of you.

Step Three
Then construct a Portholes like you learnt in the section on Portal in front of your visual body.

Step Four
Then visualize that your energy is blending with your visual body.

Step Five
Next focus your mind on traveling a distance of one kilometre from where you are.

Step Six
Then see your visual body walking into the Portal.

Step Seven
Next see the Portal opening one kilometre away from where you started and see your visual body walking out of the Portal

Step Eight
Then walk back into the Portal and back out to your starting point.

Remember
Practice this exercise by expanding the distance but always make sure you can do this one before moving on.

Teleportation Portal

Visual Technique
Step One
Charge your physical body with energy.

Step Two
Then close your eyes and see your visual body standing in front of you.

Step Three
Then construct a Portholes like you learnt in the section on Portal in front of your visual body.

Step Four
Then visualize that your energy is blending with your visual body.

Step Five
Next focus your mind on traveling to the USA the destination is The white house, washington DC

Step Six
Then see your visual body walking into the Portal.

Step Seven
Next see the Portalopening in front of the white house and see your visual body walking out of the porthole

Step Eight
Then walk back into the Portal and back out to your starting point.

Teleportation Porthole

Visual Technique
Step One
Charge your physical body with energy.

Step Two
Then close your eyes and see your visual body standing in front of you.

Step Three
Then construct Portholes like you learnt in the section of Portal in front of your visual body.

Step Four
Then visualize that your energy is blending with your visual body.

Step Five
Next focus your mind on traveling to italy the destination is the coliseum in rome

Step Six
Then see your visual body walking into the Portal.

Step Seven
Next see the porthole opening in front of the coliseum and see your visual body walking out of the Portal

Step Eight
Then walk back into the Portal and back out to your starting point.

Teleportation Porthole

Visual Technique
Step One
Charge your physical body with energy.

Step Two
Then close your eyes and see your visual body standing in front of you.

Step Three
Then construct a Portholes like you learnt in the section on Portal in front of your visual body.

Step Four
Then visualize that your energy is blending with your visual body.

Step Five
Next focus your mind on traveling to egypt the destination is the great pyramids.

Step Six
Then see your visual body walking into the Portal.

Step Seven
Next see the Portal opening in front of the great pyramids and see your visual body walking out of the Portal

Step Eight
Then walk back into the Portal and back out to your starting point.

Teleporting The Visual Body
Beginners Technique

Visual Technique
Step One
Get comfortable and relax.

Step Two
Now close your eyes then charge your physical body with energy. Then see your visual body standing in front of you.

Step Three
Then visualize that your energy is blending with your visual body.

Step Four
Now focus your mind on teleporting to a destination of your choice.

Step Five
Then see your visual body teleporting to that destination and when you arrive look around and take note of your observation and check them when you come back.

Step Six
Then see your visual body teleporting back to the point in front of your physical body and in your own time open your eyes.

Remember
Then check with books or other information on that destination to see if your observations are correct. If they are then well done now try another destination.

Added 16/04/2005
Teleporting Your Visual Body
Advanced Technique

Visual Technique
Step One
I want you to get comfortable and relax.

Step two

Now close your eyes then charge your physical body with energy. Then see your visual body standing in front of you.

Step Three
Then visualize that your energy is blending with your visual body.

Step Four
Now here's were things change in the past i would have told you to spin the core star and become the light being this time I want you to focus on the hara line see it running through your visual body from the higher point above your head down through the crown chakra passing through the sixth and fifth chakra's into the soul seat down through the lower chakra's and the ten tien and out through the base chakra and down into the earth. Feel and see the visual body grounding with the earth see the tan tien changing from a reddish brown colour to a reddish colour like the earths core and feel this connection with the earth.

Step Five
Now focus your mind on teleporting to a destination of your choice.

Step Six
Now as we spin the core star i want you to stay focused on the hara line and this connection with the earth and in your own time spin the core star as you've done a thousand times before and this time pay attention

Step Seven
Then see your visual body teleporting to that destination and when you arrive at the destination return the visual body to normal and as you do focus on the hara line once again.

Step Eight
Then see your visual body and spin the core star once again and teleporting back to the point just in front of your physical body and return the visual body back to normal once again. And in your own time open your eyes.

Note
Now if you've done this technique you'll see what was missing when I tried teleporting in 1986. Write down every little detail of your observations during this technique and if you wish post your finding under the section Hara line Tech on the message board and we will Develop this technology together as a group. Because this technology benefits each and every one of us as a whole.

Remember
Master the visual technique before moving on to the physical technique it is important that you know the visual technique inside out before moving on.

Teleporting A Psi Ball
Beginners Technique
Introduction
Creating psi balls is the act of shaping energy with the mind. Energy is much easier to manipulate than physical objects, so this is a great beginners exercise.

Two Person Technique
Step One
Work out who will teleport for this exercise and who will be the receiver for this exercise.
Step Two
(Teleporter) Hold your hands out in front of you, with both palms facing. Close your eyes and relax. Concentrate on the space between your hands feel the energy ball between your hands. Try to strengthen this energy field by

visualizing the ball growing stronger. If you cannot feel the ball, move your hands away from each other, then closer and closer, trying to feel the point of energy. To me, this feels like a tingling sensation between my hands and in my third eye.

Step Three
(Teleporter) Now i want you to open your eyes But stay focused on the energy between your hands feel the psi ball.

Step Four
(Receiver) Now i what you to hold your hands out in front of you, with both palms facing.

Step Five
(Teleporter) Focus your mind on the point between the hands of the receiver and when you are ready feel the psi ball teleport to the new destination between the hands of the receiver and if you have done this right the receiver should be able to feel the psi ball between their hands. If you need to use visualization for this technique then you can but remember to feel the energy movement.

Physical Teleportation

Introduction
Physical teleportation is the near instantaneous transport of the Psychic from one location to another.

Because Teleportation is an extension of Clairsentient ability, there are two categories of Teleportation: Extensive Teleportation and Projective Teleportation. As the names imply, each is based on the type of Clairsentience which must be used to target the correct location.

Although Teleportation is nearly instantaneous, the Psychic may be disoriented upon arrival at the new location. During this period of disorientation, the Psychic suffers a penalty to all Perception/Awareness/Observation Trials, and may take no action other than Perception/Awareness/Observation Trials until the disorientation passes, or until the Psychic achieves a Superior Success or better on an Intellect (Perception) Trial. However, disorientation may continue even after a successful Perception Trial, and the penalty to Perception then applies to any action taken until the period of disorientation passes. Increasing degrees of success on the Teleportation Trial can reduce or eliminate disorientation.

Extensive Teleportation
is the ability to teleport one's body a short distance, overcoming intervening barriers to normal travel. In order to use Extensive Teleportation, the targeted location must be sensed via Sense Extension, or must be in physical sight of the Psychic. Teleportation is nearly instantaneous once activated, and can generally be accomplished in the same OP during which Clairsentience was used to locate the target. The Psychic remains subject to possible disorientation at the new location.

It is possible to use Extensive Teleportation to dodge an attack, so long as the teleportation trial is successful, and the new location is not in the path of an attack. However, the possibility of disorientation makes this a potentially dangerous technique that is normally attempted only as a last resort.

Using Extensive Teleportation requires the psychic to make a Fatigue Trial with a difficulty equal to the difficulty of the Extensive Teleportation Trial.

Projective Teleportation
Is the ability to teleport to any location the Psychic can see clearly via Sense Projection. Seeing clearly means the Psychic must have achieved a Superior Success or better on the Sense Projection Trial. The Psychic may apply a

-1 modifier to the difficulty of the Projective Teleportation Trial for each degree of success above Superior on the Sense Projection Trial.

Projective Teleportation requires a minimum of one OP to perform, in addition to whatever time and effort was required to sense the target location using Sense Projection.

Teleporting Physical Objects

Introduction
When it comes to teleporting physical object there are two types of teleportation the first is by blending your energy with the atoms of the object and the other form of teleportation is by using an electromagnet light chamber to teleport the object because light particles penetrate the atoms of the object and once the light particles Blend with the object then you can move the object but before you can move the object you build a electromagnet light energy generator

Added 05/11/2002
Teleporting Physical Objects
Physical Technique
Step One
Find a small object of your choice. (I used a teaspoon)

Step Two
Then hold the object in between your hands and hold your arms so that they are comfortable.

Step Three
Then i want you to sit quietly breathe deeply and get comfortable and relax.

Step Four
Empty your mind of all extra thoughts and remain clear minded and focused on the task at hand.

Step Five
With your eyes closed feel the energy of the spoon and blend your energy with the objects energy Feel around the object and knit your energy with the energy of the object remember feel it don't think about it. (Your hand may feel hot as your energy blends this is normal)

Step Six
Get into the flow of the object and feel the energy around the object and within the object. Once your energy has kintted with the object feel the force of the energy and stabalize it before you move to the next step.

Step Seven
Then visualize or feel the object leaving your hands in a word disappearing from between your hands and reappearing at the desired destination and as it leaves your hands open your eyes and see the object appearing at the destination before you

Remember
Remember NEVER apply force! You aren't there to physically force the object to move through the fabric of time and space. That's not point of the exercise.
(The thoughts and comments expressed in this exercise are from personal experience it was first done by Donna on the 05/11/2002 the object was a teaspoon)
You may experience problems with your destination don't worry it takes practice to learn to control it.

Meta-Physical Teleportation
Etheric Body : Lesson One

Visual Technique
Step One
Get comfortable and relax.

Step Two
Now close your eyes then charge your physical body with energy.
Then visualize the etheric layer of your auric body (the First Layer of the auric field).

Step Three
Then visualize that your energy is blending with the etheric layer of your auric field.

Step Four
Now focus your mind on teleporting the etheric body across the room. visualize the destination point.

Step Five
Then see your Etheric body teleporting to that destination and as you do this stretch out your feelings and feel the etheric body leaving the auric field when you arrive at the destination look back at your physical body and take note of your observation and feelings and when you are ready teleport your etheric body back into your auric field.

Step Six
Then in your own time open you eyes but be careful you may feel a little disoriented at first this is normal.

Step Seven
Then write down your findings on how you felt during this exercise and of what you seen during this exercise

Remember
Master this technique before trying to teleport the other layers of the auric field or Physical objects or the physical body.

A Method On Physical Teleportation
Teleportation 'the practice'

The first order of things that you must understand is that teleportation is a natural way of travel for all beings of light. Whether it be on the third dimensional or fourth, fifth, and higher dimensional existence. It is natural and very easy for any light being because it all deals with "light ". Different colors of light give you different level of awareness. Thus your experience will be varied. Also throughout each level of light expression.

Physical Teleportation
Abilities Used In Teleportation

Tele-visualization
Tele-visualization is the ability of 3 dimensional visualization with its dimensions being sound, shape, and form just like the picture that we can view with our own eyes in the physical reality and is the channel by which we can travel through interstellar space and time in the visual and physical forms.

Psychokinesis

Psychokinesis or PK is The ability of movement of an object or the physical body of a term coined by the famous researcher J. B. Rhine. It can be defined as the direct action of the mind on a physical object without the mediation of any known physical energy. Phenomenon of this kind have been reported from as far back as St Ben edict up to the modern day spoon bending of Uri Geller! There are various forms including Macro-PK where the influence is upon large objects and Micro-PK where the target is from the quantum world.

Clairsentience
Sometimes called "psychic feeling". There are two forms of clairsentience: empathy and psychic knowing. Clairsentience is the ability to "know" about someone or something without the use of the five senses for input. Clairsentience is probably the most common type of intuitive ability. (Often we refer to it as a Hunch, a Gut Reaction, or Instinct.)

Hara Line Development
Hara line development is designed to bring your awareness to the grounding and ungrounding process of the hara line in the visual techniques of time travel, dimensional travel, levitation, teleportation, and interstellar travel.

Added 16/04/2005
Energies Used In Teleportation
In teleportation we use two main energy systems. The first being the hara line and the second being Kundalini energy from the base of the spine. All our hidden Siddhi powers come from an awakened Kundalini. Examples of the Siddhi powers are supernatural abilities of strength, sight, hearing, levitation, bi-location, teleportation, and instant manifestations, etc... Basically anything you can imagine beyond the everyday world is possible when your Kundalini is awakened. The Siddhi powers are our natural abilities, yet through social conditioning they have been suppressed and we have been programmed to believe they are malicious or wrong. They are as natural as the warmth from the sun above. Rising Kundalini along the spinal column and moving it out through the chakra and blending it with the atoms of the physical body is what make teleportation possible. The hara line on the second hand is the anchor that grounds us to the physical and earth plains of existence it is here that we must first start with hara line development because teleportation will not work if we stay grounded to the earth all you will feel is the body shunting as it tries to jump through the fabric of time and space so we must learn the technique of grounding and ungrounding thoroughly before trying teleportation remember safety comes first and if you are not well trained in the grounding and ungrounding technique before trying the this teleportation technique because it could be fatal upon arrival at your new destination if you are not well trained.

Warning
This Technique is not for beginners and I would suggest you try this technique with your visual body first it is dangerous and could be fatal if not studied properly.

Added 16/04/2005
Physical Body Teleportation

Physical Technique

For preparation find a quiet place and a soft surface and lay down.

Step One
Now in your own time close your eyes and take a couple of deep breaths feel the chest rise and fall and relax.

Step two
Then visualize the base chakra. At the base of the chakra there is a well of energy, this well is know as the jewel of the lotus within the jewel there is a light golden energy. Visualize that this golden energy is trickling out of the

jewel and spreading out into the chakra. As the chakra spins see the chakra becoming golden in colour with its light radiant energy. Feel that energy.

Step Three
Now focus on the second chakra and do the same, see the jewel at the centre and see this radiant energy trickling out into the 2nd chakra fill it with its radiant energy.

Step Four
Then move on to the 3rd chakra and do the same for this chakra and the other chakras till all twelve chakras are filled with the radiant Golden wheels of Kundalini energy and feel how light this energy feels in your body.

Step Five
Now once you have reached the twelveth chakra see the twelven chakras and feel this light golden energy continually flowing into the chakras till it starts to over flow into the physical body do this for around about ten minutes.

Step six
Now as the golden energy begins to flow out into the physical body see the energy spreading through your entire body feel how light your body feels as the golden energy blends with your body and relax.

Step Seven
Then in your own time I want you to visualize the hara line and feel your connection with the earth and the physical plain and in your own time draw the hara line out of the earth and into the base chakra and hold it there.

Step Eight
Now as you do this you may feel your body becoming unstable this is normal because you are no longer linked with the earth and the physical plain

Step Nine
After a couple of minutes when your physical body is feeling more stable in this new plain beyond time and space see the three tan tiens and expand the energy of the tan tiens thought your being one by one starting with the lower tan tien and moving through the middle tan tien and through to the top tan tien and hold it there for a moment.

Step Ten
Now at this point you are ready for physical teleportation but before you can teleport you need a destination for this technique choose a destination close by like in the same room or a room close by see that destination.

Step Eleven
And in your own time feel your body leaving it's current position and teleporting to the new destination and as you arrive at the new destination drop the hara line back down into the earth. feel this connection with the earth and the physical plain and allow your physical body to stabilize in the physical plain. Focus on this for a couple of minutes

Take Note
You may feel disoriented at this point don't freak out this is normal after teleporting in time this will pass and as you get better at teleporting this disorientation will pass.

Step Twelve
Now relax and feel at one with all things and in your own time open your eyes and well done.

Warning
Practice this technique with your visual body first this technique is very dangerous and cloud be fatal if not done right. Remember this is not a race safety comes first so be careful. You can also do this technique in the lotus or half lotus position as well and if it makes it easier put this technique on a audio tape so you can play it back while your doing this technique but if you do this make sure you remember step eleven for when you arrive at the new destination.

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HOW TO SURVIVE IN A WORLD WITHOUT ANTIBIOTICS

A top MD shares safe alternatives that work, some better than antibiotics

by Keith Scott-Mumby MD, MB ChB, PhD
"The Alternative Doctor"

Title Quote

Put bluntly, medicine's successes at vaccination and antibiotics treatment are trivial accomplishments relative to natural selection's success at generating the immune system. Recognizing this fact has important repercussions for the long-term control of infectious diseases. We will probably obtain better disease control by figuring out how to further tweak the immune system and capitalize on its vastly superior abilities than by relying on some human intervention such as new antimicrobials (antibiotics, antivirals, or antoprotozoal agents).

Paul W. Ewald Plague Time

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Quotes And Facts

The mass of a single cell of the E coli bacterium is 665 femtograms. A femtogram is one-thousandth of a picogram, which is one-thousandth of a nanogram, which is a billionth of a gram.

Journal of Applied Physics.

Not only does the Earth contain more bacterial organisms than all others combined (scarcely surprising, given their minimal size and mass); not only do bacteria live in more places and work in a greater variety of metabolic ways; not only did bacteria alone constitute the first half of life's history, with no slackening in diversity thereafter; but also, and most surprisingly, total bacterial biomass (even at such minimal weight per cell) may exceed all the rest of life combined, even forest trees, once we include the subterranean populations as well.

Stephen Jay Gould, "Planet of the Bacteria," Washington Post Horizon, 1996, 119 (344): H1; Reprinted here with permission; This essay was adapted from Full House, New York: Harmony Books, 1996, pp. 175-192.

Bacteria inhabit effectively every place suitable for the existence of life. Mother told you, after all, that bacterial "germs" require constant vigilance to combat their ubiquity in every breath and every mouthful, and the vast majority of bacteria are benign or irrelevant to us, not harmful agents of disease. One fact will suffice: during the course of life, the number of E. coli in the gut of each human being far exceeds the total number of people that now live and have ever lived.

Stephen Jay Gould, "Planet of the Bacteria," Washington Post Horizon, 1996, 119 (344): H1; Reprinted here with permission; This essay was adapted from Full House, New York: Harmony Books, 1996, pp. 175-192.

Numerical estimates, admittedly imprecise, are a stock in trade of all popular writing on bacteria. The Encyclopaedia Britannica tells us that bacteria live by "billions in a gram of rich garden soil and millions in one drop of saliva." Human skin harbors some 100,000 microbes per square centimeter (note:

"microbes" in-cludes nonbacterial unicells, but the overwhelming majority of "microbes" are bacteria).

Writer Dorion Sagan and biologist Lynn Margulis, Garden of Microbial Delights

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Fully 10 percent of our own dry body weight consists of bacteria, some of which, although they are not a congenital part of our bodies, we can't live without.

Writer Dorion Sagan and biologist Lynn Margulis, Garden of Microbial Delights

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We could not digest and absorb food properly without our gut "flora." Grazing animals, cattle and their relatives, depend upon bacteria in their stomachs to digest grasses in the process of rumination. About 30 percent of atmospheric methane can be traced to the action of methanogenic bacteria in the guts of ruminants, largely released into the atmosphere—how else to say it—by belches and farts.

Stephen Jay Gould, "Planet of the Bacteria," Washington Post Horizon, 1996, 119 (344): H1; Reprinted here with permission; This essay was adapted from Full House, New York: Harmony Books, 1996, pp. 175-192.

In another symbiosis essential to human agriculture, plants need nitrogen as an essential soil nutrient but cannot use the ubiquitous free nitrogen of our atmosphere. This nitrogen is "fixed," or chemically converted into usable form, by the action of bacteria like Rhizobium, living symbiotically in bulbous growths on the roots of leguminous plants.

Stephen Jay Gould, "Planet of the Bacteria," Washington Post Horizon, 1996, 119 (344): H1; Reprinted here with permission; This essay was adapted from Full House, New York: Harmony Books, 1996, pp. 175-192.

A group, led by microbiologist William. B. Whitman, estimates the total number of bacteria on Earth to be five million trillion trillion -- that's a five with 30 zeroes after it. Look at it this way. If each bacterium were a penny, the stack would reach a trillion light years. These almost incomprehensible numbers give only a sketch of the vast pervasiveness of bacteria in the natural world. "There simply hadn't been any estimates of the number of bacteria on Earth," said Whitman. "Because they are so diverse and important, we thought it made sense to get a picture of their magnitude."

The study was published in the June 1998 Proceedings of the National Academy of Sciences.

For the first half of geological time our ancestors were bacteria. Most creatures still are bacteria, and each one of our trillions of cells is a colony of bacteria.

Richard Dawkins

"Love: Before I heard the doctors tell The dangers of a kiss; I had considered kissing you. The nearest thing to bliss. But now I know biology and sit and sigh and moan; six million mad bacteria and I thought we were alone!"

Song lyrics

A probe sent two miles underground in a South American gold mine found bacteria living there. Their dinner? Radioactive emissions from the rocks around them. Above ground, the aptly named Deinococcus radiodurans can handle radiation exposure nearly 10,000 times the fatal dose for humans.

Somewhere in cyberspace...

Everything we do with food is an attempt to keep from being poisoned by our microbial competitors.

Professor Paul Sherman, Cornell University.

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Terminology

Let's just go over a few terms so that when you meet them you will be clear about the meaning.

Antibiotic means a substance which will KILL bacteria and similar organisms (but not viruses).

Viricidal. A substance which will kill viruses (but not bacteria).

Bacteriostatic means a substance which will handicap bacteria, by preventing them growing and multiplying. It means does not actually kill bacteria but holds them in check, while the person's immune system gets to work, mopping up the invader.

Antiseptic. A substance (or process, like UV light) which kills all living organisms on a surface. In reality most antiseptics will kill 95% or more. But nothing is ever 100%.

Hygienic. Germs reduced to a level where the body is not at risk.

Sterile. No surviving viable germs on any kind.

MRSA... What's all the fuss?

MRSA (pronounced "mersa") is an abbreviation for "methicillin-resistant Staphylococcus aureus", the hospital superbug. Staph. aureus is a common bacteria but certain strains have become resistant to almost all known antibiotics, including powerful modern penicillins (such as methicillin). Today, methicillin is no longer made and has been replaced by newer variants, such as oxacillin, flucloxacillin and dicloxacillin.

(this began as a kick to his ankle, while playing indoor soccer; on the second day he was rushed to ER and almost died)

It has raised extreme concern, not because of its own damaging powers (which are not inconsiderable), but because it is seen as the flagship of worse to come. As you will read, antibiotic-resistant bacteria have been around almost from the beginning of the "antibiotic era". But something about the MRSA problem makes it clear that we have to the end of a golden age of healthcare, where infectious disease were seen to be only an occasional or trivial problem. Those who chanced to die of an infection were seen as just "unlucky".

We no longer fear pneumonia, bacterial endocarditis, brain abcesses, and other terrible conditions that swept away our loved ones in a matter of days. We have become complacent. It's been a great period in which to live. I was born in 1945, just as antibiotics hit the market. We lost nobody in my family due to infections in the years since!

But we will soon return to the days when antibiotics are of little help. People will die in huge numbers, unless they take the trouble to learn the alternatives. The irony is, as I keep saying, that there are hundreds of alternatives. But arrogant colleagues sneer at these, as if they were just old wives' tales and superstitions.

In fact the real folly and superstition has been mainstream medicine, which has continued to believe in the silly fairy tale of endless life with antibiotics. I

repeat: the threat of resistance has been there right from the start. They just ignored it.

Now you are lucky, you can re-learn about the old remedies, which really worked. But I'm going to give you the science too, lots of science and studies, which show this is no folklore but perfectly genuine and humble remedies, which are easy to self-administer and cost very little to obtain or make.

I'm sorry to do this, in a way, but I need to raise your concern level so that you understand how critical this is. Take a look at this picture, which is a man's leg after surgery to clean up an infection of "flesh eating bacteria". You can see how it got that name. Cutting away his infected skin and tissues was the only way to save his life, when antibiotics no longer work.

There's worse still at the end of section 28. Please! I urge you, take the end of antibiotics as something very serious.

#1 The Fear Erupts

MRSA "fever" struck the country with the publication of a telling article in the Journal of the American Medical Association (JAMA 17th Oct 2007). That morning I was invited on a radio show to discuss the problem and get it into perspective. I had recently published an article likening the community active form of MRSA (as opposed to the hospital "superbug" version) to the Black Death from ages past.

Illustration of the Black Death from the Toggenburg Bible (1411)

One of the other guests, who I suppose I should not name, was being interviewed by several radio stations, including the one I was on. He blamed illegal immigrants, claiming it was their dirty habits and lack of personal responsibility that had caused the problem; he also blamed foreigners for tape worms, TB, Chagas' disease and a whole host of other dangerous health conditions.

I followed him and declared his opinion "fascist, unscientific, irrational and inciting prejudice and hatred". Fortunately, he had left to spread his poison somewhere else by the time I said this, otherwise a war of bitter words would have broken out.

No matter, I stand by my condemnation of this foolish and ignorant tirade. It's akin to hysteria. The studio presenter, normally a very mild and civilized man, ended up raising his voice in shock at what "these people are doing to our country".

This is how mob violence gets started.

The presenter only calmed down when I pointed out the stupidity of blaming foreigners, when Americans travel overseas and are just as capable of bringing back pathogens as newcomers! And what about legal immigrants? Does he suppose that bacteria have a way of knowing who's legal and who isn't?

I myself contracted Cholera while working on my 2004 Tsunami rescue mission to Sri Lanka and brought that to Pasadena (much to the shock of the public health officials):

http://www.scott-mumby.com/mission1.html

I was not an illegal alien.

As to the tapeworm, that was just pig ignorance (slight pun intended!) Parasites have been endemic in the US, especially the Deep South, for centuries. Transmission is by food and from pets, rarely by direct human contact. There are some bad beasties here, as you will know if you have visited my parasite page: http://www.alternative-doctor.com/allergies/parasites.htm

For example, 25- 30% of the population of the south-eastern USA, mainly children, have whip worm (Trichuris species) and my textbook sources are impeccable: *(Schmidt GD, Roberts LS, Foundations of Parasitology, Times Mirror/Mosby College Publishing, St. Louis, 1989, p. 418).*

Ironically, I might be warning healthy Europeans to take care when they come to the USA!

So with the political frenzy disposed of, what do we know?

MRSA was actually caused by doctors, not immigrants. It's an inevitable result of overuse of antibiotics, followed by tougher strains of penicillin (like methicillin), used to try and clean up the stubborn bugs, and the eventual emergence of resistance even to methicillin.

It's uncertain what the true incidence is because it is not at this time a notifiable disease. But the 2008 JAMA article worked by extrapolating from earlier 2005 figures and is, in effect, a mere guess. There were 5,287 invasive infections reported that year in the regions studied, which would translate to an estimated 94,360 cases nationally. There were 988 reported deaths among infected people in the study; around 20% and this was simply extrapolated up to 18,650.

IF THE STUDY FIGURES ARE CORRECT — and I emphasize they are only an intelligent guess, which I accept as such — then MRSA is killing more people

than AIDS. 988 out of 94,360 cases gives a rate of 6.3 per 100,000. That would translate to 18,650 deaths annually (the researchers admit they don't even know if MRSA was the cause in all cases). AIDS killed an estimated 17,011 Americans in 2005.

Scare Talk? I don't think so

You might think this is scare talk' "Of course this thing will never get out of control". You are wrong. It is already out of control. The unanswered question is will it spread like wildfire, or just continue as a grumbling danger lurking below the surface?

Let's just hope that the pandemic model won't happen. As I said there are strong parallels with the Medieval "Black Death" but microbial disease is just not predictable. The important point to keep in mind is that pandemic infections, like any other infection, are NOT caused just by pathogenic microbes.

Infectious disease is caused by a lowered immune system. Period.

Healthy individuals, with a vibrant immune system and a positive mental attitude will not succumb to pathogens, no matter how vicious they are. I lived in a malarious country for years, with no prophylaxis, got bitten a dozen times a day by mosquitoes and caught nothing (there was even dengue fever present in our city).

We are in balance with Nature. She has invented NOTHING we cannot handle, if our defence mechanisms are working properly. Always remember that; it's important. But disease gets started because individuals are weakened by negative factors, such as overload, malnutrition, shock and stress. If we avoid these factors, or correct them quickly, there is no reason to fear disease.

Be healthy, that's your best protection. Remember my #1 motto in this: any good health measure is an anti-infection measure (same with cancer).

If you are struck down in a pandemic of any kind, you can forget the idea that the doctor will come along and help you. Even if the medical profession knew how to deal with such a problem, which it doesn't, there would simply not be enough doctors to go around. You will be on your own.

You need to read this report carefully and NEVER throw it away.

How many valiant men, how many fair ladies, breakfast with their kinfolk and the same night supped with their ancestors in the next world! The condition of the people was pitiable to behold. They sickened by the thousands daily, and died unattended and without help. Many died in the open street, others dying in their houses, made it known by the stench of their rotting bodies. Consecrated churchyards did not suffice for the burial of the vast multitude of bodies, which were heaped by the hundreds in vast trenches, like goods in a ships hold and covered with a little earth.

Giovanni Boccaccio

#2 What are bacteria?

Bacteria are single-celled organisms. They come in a variety of shapes: round spheres (called a coccus, plural cocci), rod-shaped (called a bacillus, plural bacilli), spiral- shaped (called a spirochete, plural spirochetes) and a few odd-balls (no plural!)

rod forms

Bacteria are the oldest living organisms on planet Earth. Since they don't produce "babies" (offspring), but reproduce by just splitting in two, you could say that bacteria represent an original founding organism which is now billions of years old!

Estimates of how many cells make up a human being vary—between 1 trillion and 100 trillion. I've seen both.

But what is clear is that there are 10 TIMES more bacteria in you and on you than the actual number of cells that go to make up YOU!

You are about 10% dry weight of bacteria: that's you, your body and your cells, minus the water in your tissues.

If you took away all the connective tisues of a human being, just leaving the cells, you'd have the equivalent of 9 human beings in your gut, so far as cell numbers were concerned; THAT'S how big a deal bacteria are for us.

Bacteria have only one single strand of DNA that encodes their nature. We humans have about 25,000- 30,000 genes that make up our humanness.

But there are over 100 times more bacterial genes, on you and in you, which all that matters. That's 3 million genes, set against your measly 1%. **What happens to your bacteria, happens to you. Trust me.**

We need lots of respect for those single-cell organisms that are all-but part of us. In fact bacteria keep us alive. The friendly ones act like body armour and prevent pathogenic invaders from destroying us. They keep the outer environment under control, so we stay healthy. They digest our food. They make certain vitamins for us.

Remember, the vast majority of bacteria are friendly or at least harmless. There are just a few troublemakers that create disease and death.

However, there is a real mystery. How do they do anything at all? I mean, there is no brain or nervous system. They don't have any obvious means of communicating or interacting. How do bacteria get organized to make somebody sick or healthy? They are so tiny and inconsequential, it seems unreasonable they could affect us at all, while acting individually.

Well, according to Professor Bonnie Bassler at Princeton there has been a breakthrough discovery. Bacteria, it seems, have a secret chemical conversation system. It's called "quorum sensing." As it turns out, every type of bacteria makes and secretes small molecules (a bit like hormones). When a bacterium is alone, these molecules have no effect (no receptors).

But when there's a large enough group of bacteria, these secreted molecules reach a critical level and suddenly all the bacteria begin to act as a synchronized group, based on the characteristic behavior programmed into the genes.

This was first discovered by Bassler, observing a marine bacterium called Vibrio fischeri. This little organism emits light. But when a suspension of bacteria is so dilute they are, in effect, isolated, nothing happens. Only when the bacterial concentration—and hence the level of quorum sensing signals—reaches a certain level, then all the bacteria "switch on" at once and begin to glow in the dark. It seems remarkable that tiny organelles, without any apparent sense organs, can suddenly tell who is in the neighborhood and how many neighbors there are!

Incidentally, they can talk inter-species too. A second quorum sensing mechanism, possessed of all bacteria and working interspecies, is what Bassler calls a "bacterial Esperanto".

The implications of this are devastating. Consider a pathogenic organism inside your body. If a few bacteria released their virulence, it would have no effect. You are at least a trillion times bigger than they are.

But they grow and multiply and when their quorum sensing tells them there are enough cronies present, they all launch their virulence attack at the same time. This way they are able to suddenly overwhelm an enormous host and bring it down.

Neat huh? But not good if you are the victim.

However this remarkable discovery by Bassler has two important consequences, both with enormous medical implications.

A whole new type of antibiotics can be looked for, which will effectively block the quorum sensing molecules (like jamming the enemy radar).

Health can be built, helping to block out bad bacteria, by supporting and provoking the chemical sensing of the good, friendly bacteria that support us!

Watch out, this is the way it's going to go.

Meantime, we have to worry about protecting ourselves.

What about viruses?

Viruses, are dangerous and can cause many infectious diseases, some of which can be fatal to humans. Smallpox, for example. However, viruses are not the same as bacteria. While a bacterium is a single celled organism, a virus is not even a single cell; technically it's the equivalent of part of a nucleus—just a package of DNA, wrapped up in a protein envelope.

The virus cannot live and cannot reproduce, unless it breaks into a cell and hijacks the cell's reproductive mechanism. It does this by taking over the DNA of the cell and forcing the cell to replicate its own viral DNA. This results in making lots of new viruses, but the cell will usually die in this process, releasing the new viruses to go and infect more cells. So the disease spreads.

The trouble is, viruses are not killed by antibiotics so, although they may be very dangerous, they don't come under the material covered by this report. Only a few anti-viral substances are available, and none which are fully safe. But that's a different story.

What about parasites?

Parasites are different again. They may cause disease and can be either single celled or multicellular animals. A worm, for example is multi-celled; as well as mechanisms for digestion, it has muscular fibers for movement.

Segmented worms, like tapeworms, are certainly multicellular, but each segment is more or less identical to the segment above and segment below. So parasites of this type work a bit like a duplicating or photocopying machine, breaking off new pieces of identical infected tissue and eggs. It's more like a colony than an animal, really.

But we also have single cell parasites such as Giardia lamblia and malaria.

Yes, malaria is a parasitic disease; the killer organism of the species Falciparum invades the blood and reproduces itself destroying blood cells in the process. The patient will sometimes die of too much blood loss as much as the severe fever which can ensue.

Note that the infamous mosquito is only the spreader of the malaria parasite. It does not otherwise cause malaria and you may be bitten by a mosquito and not get malaria. Conversely, you cannot get malaria unless you are bitten by an infected mosquito. The mosquito is an essential intermediate we call a "vector".

There are many treatments for parasites depending on the nature of the organism concerned. None of these fall within the definition of antibiotic, and so will not be considered in this report.

Where there is a clear vector, such as in the case of malaria, wiping out the vector is an obvious way to block transmission of the disease. However trying to eliminate mosquitoes has met with only very limited success. That doesn't seem to be the way to go.

Historic antibacterials

Many cures for infectious diseases existed prior to the beginning of the twentieth century which were based on medicinal folklore. That didn't mean they did not work; just that doctors weren't interested in them!

Cures for infection in ancient Chinese medicine, using plants with antibiotic-like properties, began to be described over 2,500 years ago. Many other

ancient cultures, including the ancient Egyptians, ancient Greeks and medieval Arabs already used molds and plants to treat infections.

Cinchona bark (quinine) was a widely effective treatment of malaria in the 17th century, the disease caused by protozoan parasites of the genus Plasmodium.

According to legend, the first European ever to be cured from malaria fever was the wife of the Spanish Viceroy, the countess of Chinchon (hence the name).

The court physician was summoned and urged to save the countess from the waves of fever and chill that were threatening her life, but every effort failed to relieve her. At last the physician administered some medicine which he had obtained from the local Indians, who had been using it for similar syndromes. The countess survived the malarial attack and reportedly brought the cinchona bark back with her when she returned to Europe in the 1640s.

The birth of homeopathy (see section #41) was based on quinine testing. The founder of homeopathy, Dr. Samuel Hahnemann, when translating the Cullen's Materia medica, noticed that Dr. Cullen wrote that quinine cures malaria and can also produce malaria. Dr. Hahnemann took daily a large non-homeopathic dose of quinine bark. After two weeks, he said he felt malaria-like symptoms. This idea of "like cures like" was the starting point of his writings on "Homeopathy".

The Love Triangle

Gonorrhea, together with syphilis and HIV, make a "love triangle" of the most famous sexually transmitted diseases. Indeed, gonorrhea, caused by the Neisseria gonorrhoeae bacterium, affects 62 million people, aged mainly 15 to 29, and represents world's second most widespread STDs after the infection with Chlamydia trachomatis (930,000 cases of Chlamydial infection and 360,000 of gonorrhea were assessed in the United States in 2004).

But the power of gonorrhea is what really have shocked the scientists (as revealed in a new research published in PLoS Biology): relative to its weight, the Neisseria bacterium is the strongest organism on Earth: it can pull up to 100,000 times its body weight (could you drag 7,000 tons?).

Many bacteria move around using up to 10 contractile filaments named pili. The pili can be 10 times longer than the bacterium itself. Neisseria bacteria employ pili, but no one has seen before that these bacteria can join the force of their pili for achieving long, strong pulls.

The team led by Michael Sheetz at Columbia University in New York

#3 Staphylococcus and Co.

Now let's get back to bacterial disease and the problems we face trying to eliminate them.

I want to emphasize that Staphylococcus infections have been with humankind since forever. Most infections affect the skin and are mild. S. aureus was first identified in Aberdeen, Scotland, in 1880 by the surgeon Sir Alexander Ogston in pus from surgical abscesses [Classics In Infectious Diseases. "On Abscesses". Alexander Ogston (1844-1929)].

The name Staphylococcus aureus (abbreviated to S. aureus or Staph aureus in medical literature), literally means the "golden cluster seed" or "seed gold" . It is named on account of its golden appearance when it grows in colonies. You have probably seen the color too, in the golden-yellow crusts that form on the face, around the mouth, called impetigo.

About 20% of the population are long-term carriers of S. aureus. It can cause a range of illnesses from minor skin infections, such as pimples, impetigo, boils, cellulitis, folliculitis, carbuncles and abscesses, to life-threatening diseases such as pneumonia, meningitis, osteomyelitis, endocarditis, Toxic shock syndrome (TSS), and septicemia.

The new antibiotic resistant MRSA monster has been created by doctors, not by Nature. For years it has been the feared hospital bug that no-one talks about, because it's something given to you by doctors and nurses when you enter their environment. A survey earlier this year suggested that MRSA infections, including noninvasive mild forms, affect as many as 5 percent of hospital patients. Nobody wants suing; hence the secrecy.

Nobody likes to be a bringer of bad news but it is clearly going to get worse. More deaths. Hospitals are becoming a horribly unsafe place to be.

Beware of the hospitals!

hospital contracted MRSA

Hospitals are just about the most UN-healthy places a person can find themselves. The very people who are looking after you, may be giving you a very unpleasant disease. One in every 20 healthcare workers carries methicillin-resistant Staphylococcus aureus (MRSA), researchers in Switzerland said.

But the vast majority is without symptoms and only 5% have full-blown clinical infections, according to Stephan Harbarth, M.D., of the University Hospitals of Geneva, and Werner Albrich, M.D., of University Hospital Bern.

One implication is that screening efforts aimed at symptomatic infections are likely to miss a large proportion of colonized healthcare workers who might transmit the bacteria, according to a review in the May 2008 issue of Lancet Infectious Diseases.

Instead, the study authors said, "aggressive screening and eradication policies" should be used in an outbreak and in situations where MRSA has not reached highly endemic levels. The researchers looked at 127 studies published from January 1980 through March 2006, to see how likely healthcare workers are to be infected or colonized by MRSA and to assess their role in MRSA transmission.

On the basis of the published evidence, the study said, healthcare workers are usually vectors, rather than the main sources of MRSA transmission, implying that "good hand hygiene practices remain essential to control the spread of MRSA."

Among 33,318 workers screened in the studies, 4.6% on average were carrying MRSA, the researchers found -- usually in the nose, although other sites were found. Most (94.9%) had no symptoms.

Risk factors included chronic skin diseases, poor hygiene practices, and having worked in countries with endemic MRSA.

Research revealed 18 studies with proven, and 26 studies with likely, transmission to patients from healthcare workers who were not clinically infected with MRSA.

"Staphylococcal dispersal is mainly dependent on whether the person is a nasal carrier," researchers said, so that "screening of infected healthcare workers only will likely miss a large number of asymptomatic personnel capable of transmitting MRSA to patients."

So beware!

Source reference: Albrich WC, Harbarth S "Health-care workers: Source, vector, or victim of MRSA?" Lancet Infect Dis 2008; 8: 289-301.

Pets Can Give You MRSA Too

Pet owners are blithely unaware that life-threatening pathogens can be picked up from their beloved pooch or pussycat.

According to Dr. Richard Oehler, of the University of South Florida College of Medicine in Tampa, and colleagues writing in the July 2009 issue of The Lancet Infectious Diseases.

Dog and cat bites account for about 1% of emergency department visits each year in the United States and Europe. Severe infections occur in about 20% of all cases and are caused by bacteria from the animal's mouth, plus possibly other bacteria from the human patient's skin.

About one in every 10 dogs or cats carries S. aureus. About a third (35%) of those were found to carry the MRSA strain, according to a study done at the University of Pennsylvania Veterinary School.

Of course infections travel both ways. More human cases of community-acquired MRSA leads to more MRSA colonization in domestic animals.

In fact, the study found that in some cases, pets may be picking the pathogen up from humans. "A growing body of clinical evidence has documented MRSA colonization in domestic animals, often implying direct acquisition of S. aureus infection from their human owners," the team noted. MRSA-related skin infections in pets can then easily spread back to humans, so your pet may pose considerable danger.

Sepsis, a potentially fatal bloodstream infection, can be a complication following bite wounds from a pet infected with MRSA or other types of bacteria.

Animals bites are a major cause of injury in the USA and Europe each year, particularly in children. Bites to the hands, forearms, neck and head are usually the worst.

Treatment of MRSA infections in pets is similar to that used in humans and for the most part, the danger to pet owners -- even those most vulnerable to MRSA -- remains low.

SOURCE: The Lancet Infectious Diseases, news release, June 21, 2009 The worry now is that MRSA has spread beyond hospitals into the community. It's fancy name is CA-MRSA (community-associated methicillin-resistant staphylococcus aureus). In recent years, the resistant germ has been spreading through prisons, gyms and school locker rooms, mostly in poor urban neighborhoods.

An especially dangerous form is brought about by inhalation; the bacteria goes straight to the lungs, produces a sudden and violent pneumonia and the victim can die WITHIN HOURS, coughing up frothy blood and unable to breathe.

This is why I likened it to the Black Death (Bubonic Plague or just "The Plague"). The so-called respiratory form of Plague in olden times was also very sudden; it often killed the same day as it was inhaled. Remember the kid's nursery rhyme "Tissue, aTissue, We all Fall down" (dead)? That was said to commemorate respiratory Bubonic plague.

Suddenly, queues and public gatherings are potentially dangerous places. You are just as likely to catch this modern killer in a queue at the supermarket, from some young all-American sports youth or cheerleader, as you are from a foreigner, so please do not start or join any aversion campaign against "dirty immigrants". It's ignorant and could cost YOU your life by having you focus on the wrong thing.

Community Active MRSA

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#4 The Danger Is Increasing

Exactly as I predicted in the first edition of this book, things are falling apart rapidly. We are just a few years from total meltdown.

In 2009 a new strain of MRSA arose which is more deadly than anything we have seen previously. According to a report (November 1st 2009) this new strain of MRSA is five times more lethal than what has gone before. The mortality is 50%, compared to 11% for the "normal" MRSA

[Henry Ford Hospital study presented at the 47th annual meeting of the Infectious Diseases Society of America Oct. 29-Nov.1 in Philadelphia].

Why aren't the newspapers and TV programs screaming about this?

Bear in mind, the problem here is not just MRSA. Now we have Vancomycin resistant enterococcus (VRE). That's much more to be feared: if it reaches the septicemia stage it is 100% fatal. Nothing can stop it (Vancomycin is known as the "last defence" antibiotic).

Our old killer enemy TB has now morphed into a new strain which is resistant to ALL KNOWN ANTIBIOTIC DRUGS.

Also we now have PRSP (penicillin-resistant Streptococcus pneumoniae). It is reported that out of 100,000 hospitalizations for pneumonia, 40% are now due to this organism.

Then there is GISA. Never heard of that one?

In December 2002 the microbiology department at Monklands Hospital, Scotland isolated only the third Glycopeptide Intermediate Staph Aureus (GISA) in the United Kingdom.

The press were involved due to the rarity of this organism and the fact that this infection had a fatal outcome for the patient (the first fatal case in the UK).

After a press conference, Dr Alistair Leanord, consultant microbiologist, invited TV crews into the microbiology department to film biomedical scientist staff using the Vitek Autoanalyser, which was used to initially detect the GISA organism.

The problem is, GISA is not susceptible to vancomycin or teicoplanin. Vancomycin and teicoplanin are considered the last line of defence against

MRSA. However, fortunately, all GISA isolates to date have been susceptible to other antimicrobial drugs that have been effective in treating cases.

But what happens when that lucky state of affairs runs out?

C. difficile and membranous ulcerative colitis

You may have heard of C. difficile (or C. dif and various other appelations). Its real name is Clostridium difficile and that says it all. Most of the Clostridia species are nasty and cause diseases like botulism and gas gangrene. Diff causes membranous ulcerative colitis, a severe and often fatal bowel inflammation.

Dif comes about from overuse and abuse of antibiotics. It's just another example of where good turns bad; the wonders of antibiotics become a deadly liability.

In recent years, C. difficile infections have become more frequent, more severe and more difficult to treat. he European Center for Disease Prevention and Control recommend that fluoroquinolones and the antibiotic clindamycin be avoided in clinical practice due to their high association with subsequent Clostridium difficile infections.

The emergence of a new, highly toxic strain of C. difficile, resistant to fluoroquinolone antibiotics, such as ciprofloxacin (Cipro) and levofloxacin (Levaquin), said to be causing geographically dispersed outbreaks in North America was reported in 2005. The Centers for Disease Control in Atlanta has also warned of the emergence of an epidemic strain with increased virulence, antibiotic resistance, or both *[McDonald L (2005). "Clostridium difficile: responding to a new threat from an old enemy" (PDF). Infect Control Hosp Epidemiol 26 (8): 672–5. doi:10.1086/502600. PMID 16156321].*

When severe, symptoms include watery diarrhea 10 to 15 times a day, abdominal cramping and pain, fever, blood or pus in the stool, nausea, dehydration and loss of weight.

Some people may be symptom free carriers (as with amebic dysentry).

Treatment is difficult, wouldn't you know!

Antidiarrheals are strictly contraindicated because a life-threatening dilation of the bowel called toxic megacolon may result.

Different antibiotics may be called for. Treatment with oral vancomycin or parenteral metronidazole usually will result in abatement of symptoms within 3 to 5 days.

This is certainly one puppy that isn't going to yield to yoghourt and roughage!

But unless the patient needs hospitalizing for support, chlorine dioxide therapy (section #18) should be tried; hydrogen peroxide (section #19); or colloidal silver (section #21).

Probiotics are essential. The orthodox treatment of choice is rapidly becoming a human faecal transplant (see section 40b).

A SCENAR (section #44) and homeopathics (section #41), would bring in useful energetic support. Try Cantharis, Colchicum, Colocynthis, Arg.Nit., Brom., Lach.

Aloe vera is the best herb to try (section #35).

#5 The Golden Age Is Over!

> In an article which appeared in Medscape, 2/3/2010, Dr Paul Auwaerter, MD, MBA, Clinical Director, Division of Infectious Diseases at Johns Hopkins University School of Medicine, was quoted as saying that, "The patients are sicker than ever before, so we are using antibiotics more intensively, and the bacteria are changing in response. At the same time we have really lost ground in incentive mechanisms for creation and production of new antimicrobial compounds.
>
> *Emerging Antibiotics: Will We Have What We Need? Laura A. Stokowski, RN, MS*

Unfortunately, the general public are still not getting this problem of antibiotic resistance or the absence of effective new antibiotics. People generally have faith or have been lulled into believing that medical scientists can develop effective new antibiotics whenever needed because they have always done so in the past.

By the time most people wake up to the realities of the situation, it will be too late. Antibiotic-resistant infections are becoming the next great equalizer, and this is not just a problem for the elderly or the immune-suppressed. Friends and family, rich and poor alike, will succumb to infections that should be curable but aren't, and everyone will be looking around for someone to blame.

The many factors that have contributed to the current crisis have already been debated, but these sobering facts remain:

- More US patients die of MRSA infections than HIV/AIDS and tuberculosis combined.
- Only 2 new antibiotics -- doripenem and telavancin -- have been approved in the past 3 years.
- We have no drugs to treat infections with some strains of multi-drug-resistant gram-negative bacilli, like Pseudomonas aeruginosa and Actinobacter baumannii.

We may finally have arrived at the era of the untreatable bacterial infection.

Livermore DM. Has the era of untreatable infections arrived? J Antimicrob Chemother. 2009;64(Suppl 1):29-36.

Mechanisms are varied

Resistance can be either inherent -- as exemplified by the inability of vancomycin to penetrate the cell wall of gram-negative bacteria -- or acquired. Acquired resistance is a change in the bacterium's genetic composition that permits clinical resistance to drugs that were once active against it. Acquired resistance can reduce the effectiveness of an antibiotic or render the antibiotic completely ineffective against the bacterium.

Bacteria can also become resistant to other classes of antibiotics (cross-resistance) or transfer their resistance genes to other microbes and species (co-resistance). The strategies used by bacteria to resist the actions of antibiotics include:

- Reduced outer membrane permeability;
- Reduced cytoplasmic membrane transport;
- Increased efflux/decreased influx of antibiotic;
- Neutralization of antibiotic by enzymes;
- Target modification; and
- Target elimination

SOURCE: Chen LF, Chopra T, Kaye KS. Pathogens resistant to antibacterial agents. Infect Dis Clin N Am. 2009;23:817-845

Escape Pathogens

(usually labeled ESKAPE)

These are pathogens of highest concern; the most serious, life-threatening infections as classified by the Infectious Diseases Society of America (IDSA), so-called because they effectively escape the effects of antibacterial drugs.

These include:

- E Enterococcus faecium Third most common cause of health-care associated blood stream infections. Increasing resistance to vancomycin
- S Staphylococcus aureus (MRSA) Emerging resistance to current drugs and significant
- drug toxicities. Lack of oral agents for step-down therapy
- K Klebsiella
- Escherichia coli
- K pneumoniae Extended beta-lactamase producing organisms increasing in frequency and severity; associated with increasing mortality. K pneumoniae carbapenemases causing severe infections in LTCF. Few active agents; nothing in development
- A Acinetobacter baumannii Increasing worldwide, recent surge reported in hospitals. Very high mortality. Carbapenem-resistant
- P Pseudomonas aeruginosa Increasing P. aeruginosa infections in US and worldwide. Resistant to carbapenems, quinolones, aminoglycosides
- E Enterobacter species MDR HCA infections increasing; resistance via ESBLs, carbapenemases, and cephalosporinases

(**key:** HCA = healthcare associated; BSI = bloodstream infection; MRSA = methicillin resistant S aureus; ESBL = extended-spectrum beta-lactamase; LTCF = long-term care facility; MDR = multiple drug-resistant)

No New Antiobiotics On The Way

The trouble is, according to Brad Spellberg, MD, Associate Professor of Medicine, Geffen School of Medicine at UCLA, "The economic and regulatory climates have changed so that the drug companies aren't making new antibiotics. We've been talking about antibiotic stewardship since the 1950s. It used to be 'new bug, new drug,' but not anymore. We are already seeing infections resistant to all of the antibiotics that we have now, and the number will increase at a geometric rate over the next 5 years."

It's not that there aren't any antibiotics in development. There are, but they won't solve our real problems. The antibiotics aimed at gram-negative infections that are currently in development have mechanisms of action similar to the drugs we already have available. Ceftobiprole and ceftaroline, for example, have both completed phase 3 trials, but they are essentially the same as cefepime, a drug already on the market. A gram-negative organism resistant to cefepime, then, will also be resistant to both ceftobiprole and ceftaroline. So, explains Dr. Spellberg, the real problem is that there are no gram-negative antibiotics in the pipeline that will work against bacteria already resistant to the drugs we have. The number of drugs that have made it through the developmental process and received FDA approval has plummeted in recent years. From 1983 through 2007, systemic antibacterial approvals declined by 75%. *[Boucher HW, Talbot GH, Bradley JS, et al. Bad bugs, no drugs, no ESKAPE! An update from the Infectious Diseases Society of America. Clin Infect Dis. 2009;48:1-12. Abstract].*

What the Rest of Us Can Do

Dr. Paul Auwaerter has 2 suggestions: First, education and awareness of this issue must increase among the medical community. Second, political, and scientific forces must work together to recognize the scope of the problem and develop solutions. "We learned a lesson from the H1N1 pandemic: the importance of being prepared. Right now, we are not close to being adequately prepared."

We need to realize that it isn't just our patients who are at risk, it's all of us. But nothing will change if we sit back and think this problem is too big, too complex, that it's someone else's problem, or that there is nothing we can do. There is something we must do, according to Dr. Spellberg. "Only when constituents start putting pressure on elected officials will things change."

"We need [physicians' and nurses'] voices because right now the FDA is dominated by statisticians and the clinicians are being shouted down. We have lost our voices. They are making drug approval decisions based on statistical results and have lost all sight of clinical reality."

Dr. Spellberg recommends writing letters to the editors of professional journals or other media, expressing concern -- and yes, outrage -- about the current situation. People can also inform regulatory officials and politicians that the current approach to approving drugs is unacceptable; that physicians are being excluded from these conversations, and that statisticians should not have the sole voice. Demand that the FDA stop insisting on perfection and demand that clinicians have a say in the approval process. DO YOUR PART: read this important information manual and raise your voice. Only by wide public action will anything change. The dangers are real; they are here NOW and are not (ever) going to go away. So take immediate action.

The Bottom Line

"As the Medscape article concluded: We are literally inches away from a crisis in public health that will severely hamper our ability to transplant organs, replace hips, provide cancer chemotherapy, perform dialysis, or keep premature babies alive. Then, it will only be a matter of time before otherwise healthy individuals will die because they contracted infections after routine surgery or were infected by pathogens that are common in the community but for which we no longer have a cure." Death is stalking everybody. Get wise; get educated and take effective action.

My Advice

I can tell you that the usual trite advice: using chlorox or Lysol and washing your hands is a waste of time against the pneumonic form. Shocked? You shouldn't be. Count on "official" recommendations to be stupid, inadequate and/or worthless.

They don't even listen to their own science.

The question remains: if there is a pandemic of this organism, what should you do? Please note that my answers amount to good health advice for the present, when and while you remain fit and well. This is not just "disaster

talk". Any good health measure is a good protection measure in the event of an epidemic or pandemic. Those who survive will do so because they have strong physiology and a vibrant immune system.

You can forget the idea that the doctor will come along and help you. Even if the medical profession knew how to deal with such a problem (which it doesn't), there would simply not be enough doctors to go around. You will be on your own.

But don't panic. Contact does not mean inevitably going down with the disease. Millions did not die in the Plague years. Those who worked the carts to carry off the dead bodies generally survived: it was NOT a suicide job! Doctors don't all fall over with the diseases they treat, even though they are in intimate contact with infected patients.

What is important is to build good health; overall health.

In addition, you need to know some very handy treatments that will kill pathogens as effectively as prescription drugs. You have not been told about these—and you are not likely to be, with the establishment taking its orders from the trans-national pharmaceutical cartels (trans-national really translates as they don't obey any country's laws).

The fact is these humble remedies I shall list are mostly cheap and there is not much profit in them. Not enough for greedy directors and stockholders of the drug companies.

This eReport will introduce you to DOZENS of modalities for treating and eliminating infectious bacterial pathogens. Many of the treatments, incidentally, will also work against viruses AND parasites, which is more than can be said for antibiotics.

But first, we have some study to do! As the sun begins to set on the magic of antibiotics and the (apparent) safety they brought, you need to learn what we are up against for the future.

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Part 1

Understanding The Enemy

#6 Our fight with bacteria

There are approximately ten times as many bacterial cells as human cells in the human body, with large numbers of bacteria on the skin and in the digestive tract. The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, and a few are beneficial.

However, a few species of bacteria are pathogenic and cause infectious diseases, including cholera, syphilis, anthrax, leprosy and bubonic plague. The most common fatal bacterial diseases are respiratory infections, with tuberculosis alone killing about 2 million people a year, mostly in sub-Saharan Africa.

For a time we got ahead in the war against infectious diseases. Better nutrition and public hygiene have been the main reason for the improvements. Vaccinations seem to be mainly a waste of time and have made no real impact on the gradual disappearance of infectious diseases.

There is no question that antibiotics, too, made a huge impact in this war. For a time we had better weapons and ammunition than the enemy; it was only natural we would win. But even as antibiotics triumphed, within just a few years of their birth, resistant germs began to appear.

The implications of this were being discussed even in my time as a med. student in the 1960s. But nobody really paid much attention. The relentless advertizing and heavy pushes of the antibiotic manufacturers, coupled with the natural human tendency to laziness on the part of doctors, meant that the drug industry went on making huge profits. And all the while, the time bomb was ticking.

Back then we were just too naïve to understand or care about the possible long-term consequences of excessive prescriptions. Today, with 20/20 hindsight, we can say the path to where we are has been marked by reckless folly and greed.

We have arrived at a place where the short-comings of drug-based medicine are all too plain.

Antibiotics are gradually ceasing to work; most drugs have little real benefit and lots of side effects; the costs of prescriptions has risen to the point where drugs are now a huge proportion of the gross national product and deaths due to medicines has soared to the point where, in the US alone,

iatrogenic deaths—deaths caused by doctors—are now over 100,000 per year.

That's more citizens than were killed by the entire 10 years of the Vietnam war!

And when I say drug deaths, I mean where the CORRECT drug, was CORRECTLY PRESCRIBED. Mistakes and blunders account for a further 7,000 deaths per year. And that's from a study carried out by a professor of medicine at Johns Hopkins School of Hygiene and Public Health, not "statistics" from left wing agitators or Ralph Nader.

[By the way, since it is germaine to the topic in question, you can throw in another 80,000 deaths a year from infections acquired in hospital and despite the very best of antibiotic therapy].

Not a pretty picture.

But the othere way that other way our world has been SERIOUSLY DAMAGED is by the obsession with finding the pharmaceutical "holy grail" is that basic medicine and health care has been lost.

Doctors don't even consider hygiene these days. They just fall back on antibiotics.

A study published in the Annals of Internal Medicine (2004), brought to light the fact that doctors, even surgeons, who thought they were not being watched, didn't bother to wash their hands much. They were caught on a hidden video camera.

This is despite the proof from Dr. Ignaz Semmelweiss, going back over a century, that surgeons washing their hands before an operation saved the lives of countless women in childbed (puerperal sepsis or "childbed fever" had over 50- 100% mortality and it was mainly caused by poor hygiene technique).

In this study, under an infection control expert with the University of Geneva Hospitals, researchers sought to better understand doctors' attitudes. They secretly tracked 163 doctors to monitor their hand washing during the day. Each doctor also completed a survey about their attitudes on hand hygiene.

They observed just 57% of doctors washing their hands between patients. Internists and medical students were the most diligent about washing their hands. Surgeons and anesthesiologists washed their hands least often.

On days when doctors had a busy workload, they were less likely to wash, the report shows. If they thought they were being watched, they were more likely to wash.

If doctors carried hand-wipe packets with them, or if hand-rub solutions were at the patient's bedside, they were more likely to use them. These solutions don't require water and a sink.

In fact, an expert infection-control panel recently issued a national recommendation promoting the use of these hand-rub solutions for disinfecting hands that are not grossly soiled, writes Robert A. Weinstein, MD, with Chicago's Cook County Hospital, in an accompanying editorial.

It's "excellent advice," he writes. Doctors "must use these products as a matter of ritual on entering and leaving every patient's room." Also, doctors must act as role models for medical students to ensure that each generation of doctors follows good hand hygiene -- and infection control -- practices.

It's not just hygiene

It's worse. Doctors no longer think of healthy nutrition. Yet that's the whole reason we beat TB. This disease was nearly gone before the first antibiotics arrived in the 1950s. TB is a disease of under-nutrition. Good food is the cure, not drugs and certainly not the vaccine (BCG).

Rest, calm, good food and love are the main ingredients of any good medical practice. Yet these are ignored, in the stupid belief they are unimportant and that drugs are the "real" medicine. Hell, people recovered all over the place before these drugs were ever invented.

There are some truths that will never go away, no matter what scientific advances may come about. Doctors who lose sight of these healing elements are a danger to the community.

Finally, as you know, countless safe and effective remedies from popular culture were summarily dropped as if they had no place in modern medicine. Herbs and other remedies have been around for centuries: they are not here because people are gullible and believe in folk myth and snake oil—but because these herbs really do work!

Homeopathy too has proven itself time and again. Now it is virtually banned and doctors who practice it treated as outlaws.

The result?

We are going downhill rapidly to a dangerous new time, when drugs may not be able to dig us out of the mess caused by doctor folly. I am concerned.

#7 Killing Bacteria Has A Downside

Even killing pathogens can wreak havoc. Consider this cautionary tale: it shows we have a lot more to learn.

When scientists discovered that a bacterium Helicobacter pylori, not stress, caused most stomach ulcers, two researchers were awarded a 2005 Nobel Prize and medical practice changed significantly. Now antibiotics are used to treat ulcers. It is satisfying to note that ulcers and even stomach cancers have declined dramatically in numbers.

However microbiologist Martin Blaser and his colleagues at New York University began to document an odd medical trend. As Helicobacter pylori, virtually disappeared among children, cases of asthma tripled. So did rates of hay fever and allergies, such as eczema.

After analyzing health records of 7,412 people collected by the National Center for Health Statistics, Dr. Blaser and NYU epidemiologist Yu Chen reported this summer (2009) in the Journal of Infectious Diseases that children between three and 13 years old who tested positive for H. pylori bacteria were 59% less likely to have asthma. They also were 40% to 60% less likely to have hay fever or rashes.

Among adults, gastro-esophageal reflux disease (GERD) became more common, as did some forms of esophageal cancer.

Dr. Blaser soon reasoned that eliminating the harm these bacteria cause is at the expense of the protection they provide us. He may be right. The jury is still out.

One thing is for sure: we are landlords to an immense host of bacteria and most of these species, and what effects they may have, are still unknown to science. But we must now suspect that they interact with us in diverse ways and can influence obesity, heart disease and cancer, as well as many other conditions.

As many as 500 species of bacteria may inhabit our guts, like H.pylori. Maybe 500 or so other species make themselves at home in our mouth, where each tooth has its own unique bacterial colony. No one knows how many species we contain in all. This past August, researchers at Kings

College London identified yet another new species of oral bacteria between the tongue and cheek.

We are the equivalent of an Amazonian rain forest, where they discover new species every week!

Until recently, half of humanity carried Herlicobacter pylori stomach bacteria, according to a 2002 study in the New England Journal of Medicine. Indeed, we appear to have evolved together. Among those born in the U.S. under the age of 25 or so, only 5% or so still carry Helicobacter, largely due to the indiscriminate use of antibiotics.

The connection to allergies is just one of the pressing public health puzzles posed by our complex relationship with the trillions of microbes that call us home. "Recent studies have shown that changes in bacteria can be correlated with some pretty serious diseases," says Jane Peterson, head of the National Human Genome Research Institute's comparative sequencing program.

Childhood diabetes also is on the rise in developed countries, for instance. Last week, University of Chicago immunologist Alexander Chervonsky and his collaborators at Yale University reported that doses of beneficial stomach bacteria can stop the development of Type 1 diabetes in lab mice.

Common stomach bacteria also can stop the development of Type 1 diabetes in lab mice, researchers have reported. The researchers believe their findings could one day be used to develop bacteria-based treatments for patients.

Other bacteria are just as crucial to our well-being, feeding us the calories from food we can't digest on our own, bolstering our immune systems, tending our skin and dosing us with vitamins, such as B6 and B12, which we are unable to synthesize unaided.

So indiscriminate use of antibiotics may carry a whole host of complications that cannot be foreseen. For sure, we will disturb the natural balance and for that we have a term: dysbiosis. It is particularly important in the gut, where dysbiosis can lead to multiple health problems, including food allergies and overgrowth of less friendly yeasts and bacteria.

Metagenomics May Give Us The Edge

Now scientists are trying to sequence bacterial genes (like plotting the human genome). No-one knows what will emerge from an investigation like this. But it's being taken very seriously. In 2008 the National Institutes of Health launched a 5-year, $125 million Human Micro-biome Project to analyze hundreds of microbial species that make your body their home.

Making the project possible is a new gene-mapping technique called metagenomics.

To start, researchers at the Baylor College of Medicine in Houston, the Washington University School of Medicine in St. Louis, the Broad Institute in Cambridge, Mass., and the J. Craig Venter Institute in Rockville, Md., have been sequencing the genomes of 200 microbe species isolated from 250 healthy volunteers. They are sampling bacteria from the skin, gut, vagina, mouth and nose, then attempting to identify them by cataloging variations in a single gene sequence that all bacteria share.

Working with similar metagenomics projects in Europe, Japan, China and Canada, they hope to assemble a reference collection of genomic information covering 1,000 microbial species that infest us. If all goes as planned, they may soon find themselves trying to analyze 200,000 genes, compared to a feeble 20,000 for the human genome.

These data sets are so huge, and we don't have the tools yet to analyze them. But the diversity is more than anyone expected. Dr. Segre, who specializes in the study of the skin, found one set of microbial communities thriving in the bend of the typical elbow and an entirely different set of colonies on the average forearm.

In all, she identified 113 different kinds of bacteria living in concentrations of about 10,000 per square centimeter on the surface and, just beneath the skin, in densities of one million microbes per square centimeter, she reported last May.

In a real sense, the history of all these many microbes is the history of humanity itself. "We are living beings that co-evolved with micro-organisms," Dr. Segre says. Evidence suggests that strains of helicobacter bacteria evolved along with humankind from its beginnings in primitive organisms a billion years ago. Every mammalian species appears to have its own unique variety of these microbes. Human-strain Helicobacter pylori accompanied our anatomically modern ancestors on their great walk out of Africa about 58,000 years ago. Molecular epidemiologists at the Max Planck Institute for

Infection Biology in Berlin have so far identified 370 strains of the bacteria that seemed to reflect the migrations and settlements of their human hosts.

It is vital that we understand bacteria better, like this, rather than just thinking in crude terms of antiseptics and antibiotic drugs.

#8 The rise of the superbugs

The greatest old-time "superbug" was the one that brought the ravages of the "Black Death". That's the dread plague that swept the world in waves, over the 13th – 17th century. At its peak, it wiped out one third of the known population of the world. Imagine that today. Two billion people; where would we put all those bodies? We'd need machinery to dig graves fast enough. Decayed people would ooze into our water table.

However today, I don't think we wouldn't lose such a big proportion of folks, because of antibiotics. But what would happen if antibiotics began to fail us, as they are beginning to do? It's hard for younger people born today to imagine what such a world would be like.

You'd have to be over 70 years to remember back to a time like that. I'm in my sixties and, as a baby boomer, was born right at the start of the penicillin era.

But there were still cases walking the streets that you just wouldn't see today. Like the kid in our village who had his right arm amputated at the shoulder. I was puzzled and upset by his deformity. Then the adults explained he'd nicked his finger on a tin can, got gangrene and had to lose his arm to save his life.

Later in life, while I was at med school, there were still cases showing the era of the "old medicine". Congenital syphilis, for example. It shows with a collapsed nose bridge and punched out holes, like extra nostrils , sucking air right through the sides. You could see that on a public 'bus quite regularly (though of course the syphilis had eventually been eradicated in that person's body, by the judicious use of antibiotics).

The late stages of syphilis were in evidence right up to the 1970s. General paresis of the insane (GPI, so-called) was the outrageous one, almost funny, characterized by megalomania. One patient when I was a medical school declared he was God, escaped the hospital and tried to buy a building for a million (he had no money), swept up to a minor radio celebrity and proposed to her and was finally picked up by the police "shooting the rapids" in a sewage facility.

It has been speculated that Nietsche, a megalomaniac philosopher if ever there was one, suffered with GPI. Following a psychotic breakdown in 1889, at the age of 44 years, he was admitted to the Basel mental asylum and on 18 January 1889 was transferred to the Jena mental asylum. He remained in

demented darkness until his death on 25 August 1900. In Basel, a diagnosis of general paralysis of the insane (GPI; tertiary cerebral syphilis) was made.

This diagnosis was confirmed in Jena and is still widely accepted.

But easier to see, walking down the street, was Tabes dorsalis. This wretched condition is characterized by a stamping gait, due to loss of leg co-ordination. But the worst aspect, from the patient's point of view, are the stabbing agonizing pains in the back and down the leg. Poor Delius, the composer, had this.

Ironically, normal nerve signals didn't get through. The patient would smash up their own knee joints, etc. because the protective mechanisms were not in place. It's a moral lesson in the fact that pain is really there to protect us from harm, not make us miserable.

Why am I wasting my time on this despicable disease, some may ask? Because syphilis was one of the most feared of all diseases for centuries and kept young men and women in terror of the act of union. It cast its dark shadow over saints and sinners alike and many a creative genius was snuffed out by its chill wind.

Trust me, you would not want this monster to break loose again. Yet antibiotic-resistant syphilis has been with us for decades, certainly since the Vietnam war. GIs on furlough, young tarts who want to make cash giving them sex and bad prescribing by military MDs made it almost inevitable.

All those romantic Victorian novels

Who hasn't read Dickens and Jane Austen and all those great old-time stories? Often one of the characters takes ill and dies, almost immediately. You wonder why?

The dreaded diseases were TB (a very slow death, due to consumption) and lobar pneumonia. The latter was once nicknamed "Captain Of The White Horsemen Of Death", due to its terrifying swiftness. A person would get wet on Friday and take a chill, develop a fever on Saturday and be dead by bedtime on Sunday. There was no treatment as such, all the doctor and family could do was wait for the "crisis".

This is the moment you have seen often in movies and on TV; the patient's fever rages higher and higher and they rave in delirium. The loving wife sits

there helplessly mopping the sweat from the patient's brow (and her own, I imagine). Over the space of a critical couple of hours, with the mother of all battles raging in the victim's body, fate was settled. Either he or she expired, or the immune system suddenly got the upper hand (like an arm wrestling contest, where the loser suddenly gives in).

In which case the fever peaks, the patient stirs, opens their eyes in confusion and draws their first free breath for what seems like a month (actually less than 12 hours, usually).

Those were the days when you simply had few resources. The important thing was not to get the infections in the first place.

Well, I 'm telling you all this, not to make you feel gloomy and afraid, but to really celebrate antibiotics. They really have been one of the most, if not THE most, telling medical discovery of all time. Antibiotics have saved inestimable billions of lives.

In fact it's my firm opinion that the wonder of antibiotics is what really led us into the gullible belief that drugs were great and that there must be a chemical cure for everything. Antibiotics (and a couple of other amazing substances, like ACTH as it was prescribed then, or steroids as we prescribe them today) did seem to usher in a new era of amazing pharmaceutical cures.

Most of us are well aware that the rest of the promises of the drug industry also have not been, and will not be, fulfilled. Diseases cannot be treated as a "drug deficiency", as many doctors seem to think. It has taken decades to realize that antibiotics do not come without a price and that they will eventually fail.

The problem of this legacy today is NOT the antibiotics. It's resistance to them.

Resistance and the fact that antibiotics have made us careless; we are not nearly cautious and guarded enough of pathogens (being careful does not require being fearful, just levelheaded). Doctors and public alike have learned to be cavalier and have grown up with the attitude that antibiotics will save the day. To use antibiotics is a kind of failure; it means the important preventative basics were not being applied. Trouble is as inevitable as night follows day.

You saw the movie "Jurassic Park". You will remember Jeff Goldblum's character repeating, over and over, the warning that "Life will find a way".

Life is incredibly ingenious and tough when it comes to surviving; it will get round almost any barrier, just as the dinosaurs engineered their way round an amino acid deficiency that was supposed to keep them infertile [OK, I don't normally use fictional sources—but this movie made a very important and valid scientific point].

Well—here's the thing—bacteria (and viruses and parasites, for that matter) are also life forms! They too are tough, very ingenious and swift to adapt their abilities to their needs. So in the course of time they have developed new metabolic tricks, so that antibiotics cease to work.

Man then developed newer and deadlier antibiotics. But pretty soon organisms started to adapt to those too. It's been a war of attrition. Unfortunately, Man is showing every sign of eventually losing this war. We are running out of ideas for new drugs to kill pathogens, without killing the patient.

Pathogens, it seems, will never run out of ideas to counter our efforts.

So the outcome was never in doubt. It's just that armies of irresponsible doctors have hastened the whole end by assiduously prescribing antibiotics when they are not necessary. Add to that the fact that antibiotics are used in various agricultural processes, treating livestock to enhance their growth, so the food chain is also a risk in creating antibiotic resistance.

See, the more times pathogens are exposed to toxic antibiotics, the more likely it is—just on the law of averages—that sooner or later one of them would figure out a way round the antibiotic.

As soon as a resistant strain emerges, obviously that bacterium can multiply unchallenged by therapy. Bacteria are capable of dividing every 20 minutes or so. That means in just 10 hours a single bacterium could become 268,000,000—enough to fill a bucket (at 10 hours and 20 minutes, they would divide and fill 2 buckets!)

Of course this won't happen in real life, because the food supply wouldn't keep up with demand. But you get the idea? What was once just a few lucky cells, pretty soon becomes a torrent of billions, then gazillions of cells. MRSA, the hospital resistant staphylococcus, was once just such a handful of cells. Now this dreaded organism is in almost every ward in every hospital; on people's skin; in their nostrils; on their towels and clothing… just about EVERYWHERE.

That's why there is a problem.

#9 Agribusiness is to blame

It's true that doctors have abused antibiotics for decades. But the really guilty party and the truly reckless fools are those in the agribusiness (big shot farmers, livestock merchants, food manufacturers and all their hangers on).

Did you know that 70% of all antibiotic consumption goes, not to hospitals for administration to humans, but the farmers, to feed their livestock? That's according to a careful study by the Union of Concerned Scientists — and that is the main reason we're seeing the rise of pathogens that defy antibiotics.

While doctors are being urged not to use prophylactic antibiotics, even to protect human babies, farmers use them in huge quantities to protect baby calves, pigs and poultry. It's worse than criminal. It's INSANE.

It inevitably gives rise to resistant strains of bacteria, as you have learned. But these resistant, dangerous bugs don't just hang out in the farmyard! They turn up in our food supply! We swallow them!

According to Pultizer prize winning New York Times writer Nicholas Kristof , "Five out of 90 samples of retail pork in Louisiana tested positive for MRSA — an antibiotic-resistant staph infection — according to a peer-reviewed study published in Applied and Environmental Microbiology last year.

"Another recent study of retail meats in the Washington, D.C., area found MRSA in one pork sample, out of 300, according to Jianghong Meng, the University of Maryland scholar who conducted the study.

"Regardless of whether the bacteria came from the pigs or from humans who handled the meat, the results should sound an alarm bell, for MRSA already kills more than 18,000 Americans annually, more than AIDS does. A new strain called ST398 is emerging and seems to find a reservoir in modern hog farms. Research by Peter Davies of the University of Minnesota suggests that 25 percent to 39 percent of American hogs carry MRSA." Public health experts worry that pigs could pass on the infection by direct contact with their handlers, through their wastes leaking into ground water (one study has already found antibiotic-resistant bacteria entering ground water from hog farms), or through their meat, though there has been no proven case of someone getting it from eating pork.

Thorough cooking will kill the bacteria, but people often use the same knife to cut raw meat and then to chop vegetables. Or they plop a pork chop on a plate, cook it and then contaminate it by putting it back on the original plate.

Yet the central problem here isn't pigs, it's humans. Unlike Europe and even South Korea, the United States still bows to agribusiness interests by permitting the non-therapeutic use of antibiotics in animal feed. That's unconscionable.

The peer-reviewed Medical Clinics of North America ran an article last year that concluded that antibiotics in livestock feed were "a major component" in the rise in antibiotic resistance. The article said that more antibiotics were fed to animals in North Carolina alone than were administered to the nation's entire human population.

"We don't give antibiotics to healthy humans," said Robert Martin, who led a Pew Commission on industrial farming that examined antibiotic use. "So why give them to healthy animals just so we can keep them in crowded and unsanitary conditions?"

The answer is simple: greed.

Legislation to ban the non-therapeutic use of antibiotics in agriculture has always been blocked by agribusiness interests, a rich and very powerful lobby.

Louise Slaughter of New York, who is the sole microbiologist in the House of Representatives, said she planned to reintroduce the legislation this coming week. "We're losing the ability to treat humans," she said. "We have misused one of the best scientific products we've had."

That's an almost universal view in the public health world. The Infectious Diseases Society of America has declared antibiotic resistance a "public health crisis" and recounts the story of Rebecca Lohsen, a 7-year-old New Jersey girl who died from MRSA in 2006. She came down with what she thought was a sore throat, endured months in the hospital, and finally died because the microbes were too virulent for the drugs.

Again, let Nicholas Kristof speak: "This will be an important test for President Obama and his agriculture secretary, Tom Vilsack. Traditionally, the Agriculture Department has functioned mostly as a protector of agribusiness interests, but Mr. Obama and Mr. Vilsack have both said all the right things about looking after eaters as well as producers.

"So Mr. Obama and Mr. Vilsack, will you line up to curb the use of antibiotics in raising American livestock? That is evidence of an industrial farming system that is broken: for the sake of faster-growing hogs, we're empowering microbes that endanger our food supply and threaten our lives".

#10 Turning back the clock

Surgeons had a whole different attitude to infections in days past. They talked of healing by first intention and second intention. They knew how to nurse an abscess into discharging safely. These were MAJOR skills because if you got it wrong and it went to septicemia, you were likely dead.

But there were many bad problems. You wouldn't want to go back to those days. For example, cavernous sinus thrombosis. What that means is an abscess forming in the veins of the base of the brain (the cavernous sinus) and this can happen because of wounds or infected sores or spots on the head and face. Typically, the infection would travel backwards through into the skull, because there are no valves in these veins.

The cavernous sinus would sludge up and clot and the whole mass become a seething mass of infection. As a result, the brain could also become infected, a brain abscess form and death was the usual result.

That's why concerned parents of old would urge their children not to pick spots on the face and I had many a slap from my mother for trying to do so. I thought it was silly—till I went to med school years later and learned where this ancient injunction came from.

Country people didn't know much medicine but they had learned, over the centuries, that a spot around your face could kill you if it went wrong.

Teeth Infections

One of the biggest dangers of death by infection was a tooth abscess, as I wrote about in my book Virtual Medicine. At the beginning of the 20th century, the single biggest predictor of whether you are likely to die of heart disease, was teeth. You could die of a coronary, but you could die of a disastrous heart disease caused by bacteria getting loose in your blood and settling on the valves in your heart.

And of course it is not confined to the heart; bacteria that are thrown off from the teeth can travel to the brain, the kidneys and other organs.

According to one informed dentist, if we were to spread tooth infections all together on to our skin, we would have a huge infected ulcer as large as the

back of our hand. Yet because this is all hidden around the roots of teeth, we ignore it and don't take the danger seriously enough.

We make light of a visit to the dentist these days, we've got used to not living with these dangers, but believe me these were very serious matters and a lot of people found themselves sick unto death quite unexpectedly, and there were many, many tragedies.

If we lose the control of microbes that antibiotics promised, we will be back in a primitive era when even the simplest health problem COULD turn out to be a fatal event.

One day, everything changed.

Along came sulphonamides. They were pretty toxic substances but the benefits far outweighed their harm.

Then penicillin arrived. It is probably the most wonderful medical breakthrough ever discovered. It has saved billions of lives. Yet penicillin remains one of the most non-toxic drugs in the entire medical armoury. It's virtually harmless (allergy is the only real problem).

Penicillin was literally a miracle. It transformed the medical landscape. For a time it looked like medical science was actually going to conquer the world.

Nobody ever considered this idea that we could go backwards; that we might lose this wonder therapy; that it could be misused and start messing up our bodies. Nobody saw that far.

Today we know that so-called "broad spectrum" antibiotics, which kill just about everything, can lead to disastrous upset of the whole bacterial colony which lives on and in our bodies. The fact that we so much depend for our health on this entire set of organisms (as described in section #2) means that antibiotics, as often as not, end up causing chronic disease; not fixing it. We call this condition dysbiosis (dys- means "bad" as in dyslexia, bad words; dysentery, bad guts; dyspepsia, bad digestion).

But of course, if you've got pneumonia, and you might die within two to three days without treatment, you are not going to care much about whether it upsets the fine balance your intestinal flora.

The real crime was the abuse of antibiotics for trivial conditions, that would self-resolve anyway. Patients became demanding and doctors became lazy and inattentive of medical basics. But there were other serious mistakes made…

One of the worst abuses was the way the STDs are treated (sexually transmitted diseases; formerly called venereal disease). It has traditionally been very difficult to treat and monitor STD cases. The shame and embarrassment mean that patients will often not re-attend for further treatment and follow up, even when strongly urged to do so, in their own interests.

Knowing this, STD clinics eventually took to trying to eradicate the infections with one-off huge doses of antibiotic.

Trouble was inevitable.

We now have antibiotic resistant gonorrhea.

Then there is resistant syphilis. This started out in the far east, with the Vietnam war. It isn't yet widespread. But it's ominous. Because if syphilis comes back as it once was, it was among the most feared diseases in civilization. Not a nice way to die. Many famous people have died of syphilis, including King Henry VIII, Schubert the composer, Lenin, Christopher Columbus and quite a few Popes by all accounts. But that's another story.

Serves them right, some people might say. That would be unkind but what about children born with this infection? It's not their fault.

Chlamydia is an organism recognized as mainly sexually transmitted and is the commonest infection in your women here in the US. So it's not a time to get supercilious or puritanical. It's just the way things are.

Now in my medical school days there was a saying about syphilis. Among the many damaging effects is the fact that it attacks the main vessel from the heart and leads to deadly aneurisms. So the saying was that "The chickens of an intemperate youth come home to roost in a middle-age aorta".

Ironically, Chlamydia also attacks blood vessels, causing coronary artery inflammation and thrombosis. So we might, perhaps, modernize the saying

to: The chickens of an intemperate youth come home to roost in middle-aged coronary arteries!

I'm not just being flippant. These jokey-type sayings often help memorize aspects of the data.

It was not always mistaken usage. To a certain extent, antibiotic resistance was inevitable, even given proper usage. It was just a matter of time. In fact it came very early 1950s. A hospital in Japan had an outbreak of Shigella, the bacterial form of dysentery. The organism was found to be multiple drug-resistant (MDR that's another term you'll hear more about) and could not be controlled by sulfonamides, chloramphenicol, tetracyclines or streptomycin.

It sent shock waves through the scientific community.

But of course it isn't just the fault of doctors. Worldwide very many antibiotics have been freely available over the counter and been taken by people who have no idea of the correct use of these powerful medicines. This is all to support sales and profits of the pharmaceutical industry and has nothing to do with medical best-practise.

Drug resistant TB is also on the rise, especially in inner cities. It's often a disease of poor people because they don't eat properly and TB is mainly a disease of malnutrition.

The overall number of tuberculosis (TB) cases in Texas has declined during the past few years, but the rate of multidrug-resistant (MDR) cases has increased, making treatment more difficult. These findings were presented at the 135th annual meeting of the American Public Health Association.

The most recent national data (2005) showed 124 of 10,662 tuberculosis cases as being MDR-TB; resistant to both the main treatment drugs. The rate is higher in immigrants.

Texas ranks second in the United States in terms of number of TB cases, after California, while New York has slipped to third, and Florida is fourth.

Even if treatment is successful it takes a LONG time. The average time to complete therapy for a drug-resistant case is a year; it doubles to 2 years for MDR-TB, while some individuals can take up to 3 years to rid themselves of the disease. Most treatment is conducted as directly observed therapy (DOT). The patient is watched, to ENSURE that he or she swallows it!

Part 2

What Can You Do To Kill Bacteria?

#11 Plain water

Let's start with simple remedies first. What's cheap, plentiful, non-patented and very effective for eliminating bacteria? Chlorhexidine? Dettol? Give up?

It's water. Plain water, not saline. Plain water, not antiseptic scrub even! That's according to a study published in January 2008.

Don't forget, water is very cleansing. It can dilute toxins and wash away toxins and organisms. That will help the body fight infection. Doctors, pharmacies and hospitals use saline, which is a salt solution at the same concentration as the body tissues. This is gentler. But at a pinch, water will do fine. In fact just as well and is much cheaper, of course. If it's healthy enough to drink, it's healthy enough to use on an open wound is the basic message from a recent extensive study, published in the Cochrane Database of Systematic Reviews, January 24, 2008.

The results might seem surprising: compared with hospital saline, tap water was more effective in reducing the infection rate in adults with acute wounds but not in children. To me that evens out at about the same. No real difference in other words.

There were lots of easy criticisms of the methodology used in this study. Some of the comparisons were based on a single trial. But I don't think the little details detract from the main overall finding: water works just fine. Besides, drugs get into the market place at huge profits with far less credible science than this.

Although wound care has changed significantly in the last decade, there has been limited focus on the types of solutions used for wound cleansing. Antiseptic preparations have been traditionally used, but animal models suggest that antiseptics may actually hinder healing.

Saline irrigation has been the natural alternative for doctors. But plain water is just fine for the rest of us.

No getting away from it: washing your hands is a good protection against the transmission of germs. I have already pointed out to you that it won't protect you against the pneumonic form of MRSA. But the likelihood of transmitting almost any other bacteria, including the regular MRSA, is proven to be reduced.

Heck, this was the story told over a century ago by Ignaz Semmelweiss. He pointed out that if surgeons would just wash their hands after dissecting dead bodies and BEFORE they put their fingers into the intimate parts of women in labor, that dreaded childbed fever (puerperal sepsis) was virtually eliminated.

Since this fever had almost 100% mortality, you would think doctors would rejoice in the discovery. But in fact they attacked Semmelweiss with such a fury and vengeance that the poor man eventually committed suicide. Thus passed one of my great heroes and a medical giant, brought down by ignorant pygmies.

But his message remains clear and bright. Hand washing is good; dirty hands and fingers, bad.

Antibiotic Soap?

Contrary to what you may think, antibiotic soaps are a BAD idea. They are not only not necessary, they may contribute to the development of antibiotic-resistant strains, which is definitely a bad thing.

Despite the proven health benefits of hand washing, many people don't practice this habit as often as they should — even after using the toilet. If you don't wash your hands frequently enough, you can infect yourself with these germs by touching your eyes, nose or mouth. And you can spread these germs to others by touching them or by touching surfaces that they also touch, such as doorknobs.

Infectious diseases that are commonly spread through hand-to-hand contact include the common cold, flu and several gastrointestinal disorders, such as infectious diarrhea. While most people will get over a cold, the flu can be much more serious. Some people with the flu, particularly older adults and people with chronic medical problems, can develop pneumonia. The combination of the flu and pneumonia, in fact, is the eighth-leading cause of death among Americans.

Inadequate hand hygiene also contributes to food-related illnesses, such as salmonella and E. coli infection. According to the Centers for Disease Control and Prevention (CDC), as many as 76 million Americans get a food-borne illness each year. Of these, about 5,000 die as a result of their illness. Others experience the annoying signs and symptoms of nausea, vomiting and diarrhea.

The moral is clear: wash 'em. And often. Sanitizers are merely an option. As I said, we don't need these. But if you must, the US Center For Disease Control (CDC) recommends choosing products that contain at least 60 percent alcohol.

To use an alcohol-based hand sanitizer:

- Apply about 1/2 teaspoon of the product to the palm of your hand.
- Rub your hands together, covering all surfaces of your hands, until they're dry.

If your hands are visibly dirty, however, wash with soap and water, if available, rather than a sanitizer.

When should you wash your hands?

- After using the toilet
- After changing a diaper — wash the diaper-wearer's hands, too
- After touching animals or animal waste
- Before and after preparing food, especially after handling raw meat or poultry
- Before eating
- After blowing your nose
- After coughing or sneezing into your hands
- Before and after treating wounds or cuts

- Before and after touching a sick or injured person
- After handling garbage
- Before inserting or removing contact lenses
- When using public restrooms, such as those in airports, train stations, etc.

Kids need clean hands, too

You can help your children avoid getting sick by insisting that they wash their hands properly and frequently. To get kids into the habit, teach by example. Wash your hands with your children and supervise their hand washing. Place hand-washing reminders at children's eye level, such as a chart by the bathroom sink for children to mark every time they wash their hands.

Make sure the sink is low enough for children to use, or that it has a stool underneath so that children can reach it. Tell your children to wash their hands for as long as it takes them to sing their ABCs, "Row, Row, Row Your Boat" or the "Happy Birthday" song. This works especially well with younger children, who may rush when washing their hands.

Hand washing doesn't take much time or effort, but it offers great rewards in terms of preventing illness. Adopting this simple habit can play a major role in protecting your health.

#12 Drawing Salve and Ointments

Here's another "golden oldy".

"Drawing" is a very ancient technique that needs to be kept in view. Sometimes it works instead of antibiotics; sometimes it needs to be used in conjunction.

It simply means to draw the fluid out of a swollen infected sore, boil, wound or abscess. A highly concentrated substances, such as icthammol or zinc oxide paste is smeared over the infected site and kept in contact with a bandage or poultice. It sucks out the moisture by the scientific principle of osmosis.

The dehydration effect has two benefits: bacteria don't like it, it sucks moisture from them and they die (that's the principle of using a strong sugar density in jelly, jam and conserves). But it also draws moisture from the inflammation site, which lessens the pressure and so makes it less painful.

What was red, swollen and tense tissue turns soft, crinkly and less painful. It's a sort of halfway house to lancing a boil or abscess; reducing the pressure without needing to actually make a cut.

Very often the use of a drawing salve alone will eradicate an unpleasant boil or infection resulting from a splinter or small wound. But beware: it does not remove diseases which make skin infections a hazard, such as diabetes or compromised immunity.

One of the simplest is 25% zinc oxide paste, from the regular pharmacopeia. It is readily available in small tubes or tins.

Close favorite is 20% icthammol ointment or "black drawing salve". It stinks and looks unpleasant—but it does the job. Herbs such as Calendula, Echinacea and others in a base of beeswax and Vitamin E or olive oil may be added to the icthammol salve. Cover with a bandage since it stains clothing.

Hylands Homeopathic Drawing Salve: An oldie but a goodie, Hylands (also called PRID Drawing Salve) includes components of both a drawing salve and homeopathic remedy. Eight physicians invented this salve in 1903. PRID contains the homeopathic ingredient acidum carbolicum along with herbs such as calendula and Echinacea. Other ingredients include ichthammol, sulphur and silicea.

At a pinch you can make your own drawing salve, using the strongest solution you can make of table salt or Epsom salts in hot water. Soak a bandage or compress in the mixture and then apply. Unfortunately, this remedy needs frequent repeat applications over many hours.

You could also try a lavender and tea tree oil compress: Both lavender and tea tree oil contain antibacterial agents particularly useful against boils (see section #39).

Drop tea tree oil directly onto the boil for one to two days during the first phases to bring it quickly to a head. Lavender, however, is too irritant for direct application.

Margosa or Neem is a very effective natural antibiotic. You can make an ointment for boils by boiling some neem seeds in water till they are soft. Then take some neem leaves and smash them to make a pulp. Mix these boiled neem seeds and neem leaves and you get a natural ointment for boils which can be directly applied to the area. More over this poultice even prevents the infection from spreading as well.

You can even use castor ointment for boils. All you need to do is to make a powder out of the castor bark and add some water to turn it into a paste. You can even add grind the root of the herb biskhapra for additional effect.

Another effective ointment for boils can be made by grinding onion and garlic paste. This can aid in healing the boil quickly.

Always wash your hands thoroughly after treating boils. The bacteria spread easily from person to person, and can spread from one area of the body to another.

#13 Blue light

Next comes a pretty simple method of sterilization from the world of physics. Light.

One of the miracles of the amazing electromagnetic spectrum, which I explain to people is the fact that although most of the electromagnetic spectrum is very hostile to life (such as microwaves, ultraviolet light, and gamma rays), the fact is that a very narrow band of the electromagnetic spectrum, that we call "light" is not only friendly, but is actually essential to life.

However, here is a useful reminder that even light is part of that dangerous spectrum, and can have destructive effects on living organisms, blue light especially (red light, which spills over into the infrared range is warmth, and therefore also somewhat supportive of life).

Blue light, being close to the ultraviolet range, can itself be quite harmful, and we can cash in on this property and make it useful. We find the bluelight is great for killing resistant bacteria, as a study published in Photomedicine and Laser Surgery, April 2009, shows.

Specifically, blue light NOT including dangerous UV frequencies, kills MRSA (see section 45 for news about the safe use of UV light as an antibiotic).

The finding comes from Chukuka S. Enwemeka, PhD, and colleagues at New York Institute of Technology. Their study was funded by Dynatronics Corp., which makes the blue-light device used in the study.

In earlier studies, Enwemeka's team found that MRSA died when exposed to blue light that included part of the ultraviolet (UV) spectrum. Even though the total UV dose was less than that of a few minutes of sunlight, it would be safer not to expose humans to any more UV light than necessary.

So the researchers used a LED device that emits only blue light, not UV, and found it worked nearly as well!

"Irradiation with [blue] light energy may be a practical, inexpensive alternative to treatment with pharmacologic agents, particularly in cases involving cutaneous and subcutaneous MRSA infections," Enwemeka and colleagues conclude. The researchers tested two MRSA strains: one typical of the strains that bedevil hospitals, and one typical of the strains found in the community. Both strains were susceptible to the blue light.

Relatively low doses of blue light, less than 2 minutes, killed off about 30% of MRSA in laboratory cultures. Obviously, longer exposure was better, but 100% death of organisms did not come about, even through very long exposures.

Exactly how blue light kills MRSA, or whether the bacteria can become blue-light resistant, isn't known.

Tell your doctor about this study if you get any resistant surface infection. But remember also, light penetrates well below the skin layer (shine a torch through your hand on a dark night and you will see what I mean).

See just how valuable light is by viewing this YouTube video by Dr. John Ott, one of the pioneers in light and health (I featured his work in Virtual Medicine, first published 1999).

http://www.youtube.com/watch?v=bw6hcTGND3c

And let me close by commenting that fresh air and sunlight have traditionally been recognized for their healing powers. Moms always knew it! To expose an infected wound to bright sunlight would do far more good than covering it with bandages, most especially if the organism is one of these resistant toughies anyway.

I always do away with the band aid at the earliest available moment, for this reason.

Get a UV Light Nano To Protect Yourself Against Dangerous Bacteria

Note: You can always get a Nano UV germ zapper. It's a handy electronic gardget that looks like a cell phone and is about the same size. But it delivers a powerful light punch; a mixture of UV-A, UV-B and UV-C.

Read more in section #47.

Soon, we are going to do some nutrition stuff. But this next few are different. It's from the larder but not quite nutrition!

Let's start with a surprising contender: HONEY! What's surprising is not that it works as an antibtioic but that conventional doctors and hospitals openly admit its efficacy!

#14 Manuka Honey!

Honey has been known for its healing properties for thousands of years - the Ancient Greeks used it, and so have many other peoples through the ages. Even up to the Second World War, honey was being used for its antibacterial properties in treating wounds. Then along came antibiotics, as I explained, and it was promptly forgotten.

But in recent times there has been a renaissance of the use of honey in the medical profession: an editorial in the Journal of the Royal Society of Medicine (Zumla and Lulat 1989) discussing this expressed the opinion "The therapeutic potential of uncontaminated, pure honey is grossly underutilized".

I know for example that bandages soaked in manuka honey were given to patients at the Christie Cancer Hospital in Manchester to reduce their chances of contracting the MRSA superbug and to lessen wound inflammation following surgery.

Honey is used routinely at the Manchester Royal Infirmary for dressing wounds, and other research has found it can fight gum disease, ease digestive problems and soothe sore throats (I got my bachelor of medicine and bachelor of surgery at Manchester University and so I know the Christie and the Royal Infirmary very well).

The way honey works is that it is very rich, it is like jam or preserves you know; adding the sugar to the fruit is what makes it impossible for the bacteria to grow, it just sucks the water out of them so they can't grow and honey does the same thing. So remember diluted honey does not work and will cause bacteria to flourish!

A British team from the famous University of Oxford and the Radcliffe Hospital in Woodstock Road, Oxford (I added that for you Morse fans out there), have done a systematic review of the use of honey as a wound dressing, compared to other dressings and treatments *[BMC Complement Altern Med. 2001; 1: 2. Published online 2001 June 4. doi: 10.1186/1472-68821-2].*

Time for healing was significantly shorter for honey than all other treatments but, the researchers complained, the quality of studies was low. However the results were pretty clear, taken over the number of studies. Honey won every time.

There was one study in which the healing of infected postoperative wounds compared honey with antiseptics in addition to systemic antibiotics after culture and sensitivity. For all outcomes honey was significantly better, with much shorter times for healing, eradication of infection, use of antibiotics and hospital stay.

[Al-Waili NS, Saloom KY. Effects of topical honey on post-operative wound infections due to Gram positive and Gram negative bacteria following Caesarean sections and hysterectomies. Eur J Med Res. 1999;4:126–30]

Another study I found in the British Journal Of Surgery (which was not included in the Oxford group review) showed dramatic benefits from honey in treating infected wounds and ulcers.

Fifty-nine patients with wounds and ulcers most of which (80 per cent) had failed to heal with conventional treatment were treated with unprocessed honey. Fifty-eight cases showed remarkable improvement following topical application of honey. Only one case, later diagnosed as Buruli ulcer, failed to respond (Buruli ulcer is caused by Mycobacterium ulcerans, a relative of TB). *[Br J Surg. 1988 Jul;75(7):679-81].*

What's especially interesting is that honey allows wound healing with little or no scarring. It seems that honey is able to restrain the excessive growth of collagen which takes place during wound healing. The less collagen, the less scarring.

[Topham J. Why do some cavity wounds treated with honey or sugar paste heal without scarring? J Wound Care. 2002 Feb;11(2):53-5].

Propolis

Propolis is the resinous substance collected by bees from the leaf buds and bark of trees, especially poplar and conifer trees. Bees use the propolis along with beeswax to construct their hives. Because of antimicrobial properties of propolis, it helps keep hives free of germs.

The great violin makers Stradivarius and Guaneri used unique blends of oils, resins, beeswax, and propolis, to varnish their instruments and no doubt protect them against mold and microorganisms.

Propolis has a long history of use in folk medicine and was even used as a conventional doctor's drug in London in the 1600s. It appears to have antimicrobial and anti-inflammatory

activities. In the past, propolis has been taken by mouth to fight bacterial infection including tuberculosis, fungal infection such as Candidiasis, parasitic infections such as malaria, and viral infections such as colds.

A study published in the November 2001 of the journal Mycoses investigated the effect of propolis on 80 strains of Candida yeasts, including:

- 20 strains of Candida albicans
- 20 strains of Candida tropicalis
- 20 strains of Candida krusei and
- 15 strains of Candida guilliermondii

The yeasts showed propolis had a clear antifungal activity and was especially useful against Candida albicans.

While not conclusive evidence has yet been produced, propolis may offer a number of other health/medicinal benefits including the following:

Popolis contains a special compound which may interfere with inflammatory messengers in the body. This potential effect may help to relieve inflammatory conditions such as arthritis.

Propolis may enhance the function of the immune system.

A few studies have shown some activity against cancer cells.

Several other laboratory studies found that propolis may protect the liver from damage by alcohol or environmental toxins.

A recent study of individuals with second-degree burns, compared propolis cream and a prescription burn cream and showed the two were about comparable in preventing infection. But propolis cream promoted earlier

healing and seemed to decrease inflammation more than the prescription cream. (I would use homeopathic calendula cream, for burns).

Other studies have also shown that an alcohol-based mouth rinse of propolis may help eliminate oral bacteria: those that can cause dental cavities, gingivitis, and periodontal disease.

For instance, a 1996 study tested the antibacterial properties of propolis and honey against oral bacteria. The antibacterial effects of propolis and honey on oral streptococci were determined using bacterial culture plates. The researchers also clinically checked the short-term antibacterial effect of propolis solution and honey on salivary total bacteria and Streptococcus mutans was tested in 10 volunteers.

Propolis demonstrated an antibacterial effect both in vitro on isolated oral streptococci and in the clinical study on salivary bacterial counts. Honey induced bacteria growth at low concentrations, while at high concentrations honey had an inhibitory effect on bacterial growth in vitro.

Salivary counts of total bacteria and Streptococcus mutans were lower for 1 hour after application of honey.

[Steinberg D; Kaine G; Gedalia I, Antibacterial effect of propolis and honey on oral bacteria. American Journal Of Dentistry 1996;9(6):236-9].

#15 Stolle Milk

This is something that's really useful to know, when antibiotics have run out. Talking about cheap!

Moo!

Suppose there existed a cheap, safe, widely available effective oral "vaccine" that was:

- 100% safe for all who use it;
- can be taken orally and tastes good;
- can be manufactured in virtually every country in the world, with the humble technology available to many third-world nations;
- so cheap that virtually everyone in the world can afford it;
- able to protect against a wide variety of organisms, including viruses, rickettsia, parasites, protozoan, bacteria, mycoplasm, yeast/fungus, amoeba;
- capable of reducing or eliminating allergic reactions to vast numbers of exogenous and endogenous substances;
- boosts the immune system, accelerates healing of injuries, helps repair nervous system damage, burns fat and builds lean muscle, increases vitality and stamina, and elevates mood;
- and might – just might – deal a deadly blow against a number of cancers?

Suppose, moreover, there were over 4,000 clinical studies worldwide which describe the efficacy of this oral vaccine in the treatment of hundreds of different infectious diseases.

Would you be interested to know what it was?

I'll bet you would.

It's milk protein concentrate. Why do I call it an oral vaccine? Well, that's the really interesting part. Let Anthony di Fabio take up the story:

> Bessie, our former pet milk cow, lived in a small pasture of not more than three acres. She munched on uncooked grasses during the summer and uncooked dry hay during the winter, licked mineral block, and drank from a rain-filled, surface-drained pond whose waters were loaded with a wide variety of microorganisms. The pond also held frogs, snakes, bugs, worms, snails, and so on. She often drank and urinated at the same time, recycling fluids from the pond even as she drank.
>
> When she was ready to drop her calf, we led her to an old barn that had held forty head of cattle. One's nose almost stifled from sediments of dust, mold, fungi, and dried manure layered fifty years deep. When Bessie's calf, Nina (pronounced "Neenya"), was born, she lacked effective defensive mechanisms against the blizzard of microorganisms that assailed her in every cubic inch of the air she breathed, the ground she stood on, or on the inexperienced tongue she extended to various surfaces. Almost by magic, thousands of potentially deadly microorganisms invaded her immature body.
>
> Nina, as with all calves, was also born with a leaky gut! Now pay attention here, because I know that many readers have a leaky gut, a condition where the stomach lining is so thin that whole, undigested protein molecules pass directly from the stomach into the blood stream. Once inside the bloodstream these protein molecules are identified as foreign invaders, and we create antibodies to counteract them. This situation brings about food allergies.
>
> Patients and their doctors both work very, very hard to get rid of the patient's leaky gut. Their leaky gut is considered the source of many degenerative diseases – or at least a major component of them. But Bessie and Nina had found a way to make the leaky gut
>
> a beneficial survival mechanism! When Nina wobbled to her feet and gently nudged at Bessie's milk sac, the very first milk to come was colostrum. As Nina prodded the milk sac with her nose and sucked as saliva dripped, she also injected her blizzard of rapidly multiplying microorganisms into Bessie's teat, and up into Bessie's milk sac into a portion called the ""cistern."
>
> Inside Bessie's cistern specialized cells that had been lying dormant came alive, and they started manufacturing – guess what? – "disease-

specific antibodies," and immune-boosting "complement," and also flooding her cistern with "immunoglobulins" and "growth factors"!

Very shortly after Nina introduced her stream of potentially dangerous microorganisms into Bessie's teat – then into Bessie's cistern – her mammary biochemical factory stimulated specialized cells that became active and began to create disease-specific antibodies and activated complement that mingled with Nina's first fluids, the colostrum, which Nina sucked back into her leaky gut from Bessie's teats. Bessie was generating vaccines for her calf!

The immunoglobulins, growth factors and these disease-specific antibodies and their helpers, the complement, passed directly into Nina's stomach, and there they attached themselves to whatever corresponding organisms were present inside the gut, killing many. Because of Bessie's leaky gut many of these specially prepared biological agents also passed directly into Nina's bloodstream, and within her blood plasma they attached themselves to whatever microorganisms they'd been designed to destroy and killed them. Never once was Nina placed in danger from the surrounding hostile environment whose every biological niche was filled with a wide variety of deadly microorganisms.

Milk is thus the ideal vaccine! At least dedicated and immune-competent milk is.

According to Herbert Struss, PhD, former Senior Chemist, Food Chemistry Laboratory, Minnesota Department of Agriculture Laboratory Services Division – and also a scientist who was involved in much of the early clinical work testing this wondrously universal vaccine – those interested in "immune milk" (as it is called) during the '60s, made their astounding oral vaccine discoveries when they were trying to answer the question: "What's the survival advantage to being a mammal?"

All animals evolve traits that persist because they have a survival advantage. So what is the advantage to being a mammal? (a mammal, remember, defines a creature with teats or "mammary glands", hence the name) Clearly, Nina's suckling at Bessie's teat, drawing a blood-like liquid called "colostrum" from Bessie's cistern was a possible answer to their question. The survival advantage was simply that an "acquired" or "adaptive" immunity could be transferred from mother to offspring and that this adaptive immunity would extend for some period of time, thus providing the offspring with a distinct survival advantage.

Human milk may not have quite the same importance for survival, as it is with multilayered placentas such as horse, goats, and cattle. But some immunity does pass from the mother to the human child. It is obvious that a breast-fed human baby usually has an advantage over bottle fed. Breast-fed infants have a far lower incidence of early disease and also allergies.

They have been vaccinated by Nature, through nurture. Colostrum is a very special form of milk immune concentrate. See the next section.

But we will continue with our discussion of milk protein concentrate or "hyper-immune milk", as it is known. Thousands of good scientific papers have been published on its power immune properties. We can start the story with Drs. Wlliam "Pete" Peterson, Barry Campbell, and other colleagues working at the University of Minnesota from 1950 to 1958. They used killed bacterial antigens injected into the teat of a cow (ouch!!) and collected the first ten days' colostrum. Peterson's interest was in treating rheumatoid arthritis and allergies, which he did successfully.

In the late 1950s a wealthy businessman called Ralph Stolle, owner-operator of the San-MarGale Farm in Lebanon (Ohio), stepped into the picture. Stolle took an interest in hyper-immune milk, simply as a hobby. He developed a better way of using the cow to provoke a beneficial antigen response, by injecting pathogens into the cow's bloodstream and then harvesting the milk. Using his personal fortune he gave out thousands of portions of hyper-immune milk and asked the users to report back its benefits. Over a total of some 35 years a total of 8000 people reported a variety of benefits, from joint pain relief (85%) to improvement in fatigue (74%) and lowering cholesterol (71%). This series probably constitutes one of the largest open clinical trials ever carried out.

Stolle went into partnership with the New Zealand Dairy Board to make very pure hyperimmune milk concentrate or "Stolle milk" as it was known. In 1988 it went on sale in Asia for the first time. It is freeze dried and shipped to third world countries, where it is a very valuable vaccination and therapy resource. It can also be rendered homeopathically, so that the cost is even less. In 1999 Spencer Trask purchased Stolle Milk Biologics Inc (SMBI).

It seems to me there is an important dimension that has been missed for decades. The family cow was the manufacturer of home-grown vaccines for humans. Folks lived mainly in a rural environment and milked their own beasts. Not just landowners; even farm workers had access to a Bessie-type vaccine factory. The cow would be infected with all present human pathogens, make antibodies and give these back in the milk.

That’s why most of those country folks were so darned healthy, I believe. They had a constant supply of free and effective personalized vaccines down on the farm. Far better than modern vaccine attempts manufactured in a test tube and under the pretense that everyone is in the same circumstance and health status.

#16 Colostrum

Milk brings me to colostrum, the thin yellowish fluid secreted by the mammary glands at the time of parturition that is rich in antibodies and minerals, and precedes the production of true milk. It is also called foremilk.

Mother's colostrum, incidentally, is vitally important to human babies. It transfers mother's immunity to infection to the child and protects it for the first few weeks of life. There are no antibodies, of course, in milk formulas.

Commercial colostrum is produced by cows that were previously vaccinated with certain kind of pathogens. These cows will then produce antibodies in their blood and then transferred them to milk they produced, just like hyperimmune milk. But the highest concentration of antibodies is transferred in Colostrum, the first drops expressed from the teat.

According to research data, there are around 90 known immunologically-active substances in colostrum, including growth factors, lipids, lactoferrin (iron-binding protein with antimicrobial qualities), cytokines [released from T cells, they inhibit replication of viruses and chemicals (cytotoxins) that kill the infected cell], etc.

Immune Factors in colostrum have been shown to help the body fight off harmful invaders such as viruses, bacteria, yeast and fungus. Each factor plays a specific role in our body's defense against these attackers. In addition, colostrum contains over 20 antibodies to specific pathogens including E coli, salmonella, rotavirus, candida, streptococcus, staphylococcus, H pylori, and cryptosporidia.

In addition to immunoglobulins, medical studies show that PRP in colostrum also supports an under active immune system. Some workers say it has great benefit in treating cancer immunologically. PRP also helps balance an overactive immune system present in autoimmune diseases.

A 2003 study by the Health Sciences Department of the University of South Australia suggests that taking concentrated bovine colostrum supplements could reduce the incidence of respiratory tract infections. The study involved subjects being randomly allocated to consume 60g/day of Colostrum for eight weeks, then examining their occurrence of symptoms. Results from the first week were kept separate from those from the last seven weeks.

The results showed that during the first week of supplementation, there was no measurable difference in symptoms in the proportion of subjects taking

the supplement as opposed to those who didn't. During the subsequent seven weeks, however, a much lower percentage of the subjects taking Colostrum reported upper respiratory infection related symptoms.

Symptom duration, however, did not differ. This suggests that the immune benefits achieved by Colostrum can be very good in terms of being a preventative, but that it does not have any measurable effect on an infection once it has already taken hold. That is why it is important to use Colostrum properly, as a preventative, and not depend on it to cure illness.

Another study by Susanna Rokka of MTT Agrifood Research Finland, showed the same thing, testing the ability of Bovine Colostrum to help fight Helicobacter Pylori infections. Helicobacter is a kind of bacteria that is often responsible for Gastritis, Gastric ulcer, and Stomach Cancer.

The research also showed that immune milk combined with lactobacilli that's extracted from fermented cabbage can effectively help in preventing Streptococcus and Helicobacter Pylori. Streptococcus is the most responsible bacteria in causing dental caries from adhering to tooth surface.

So, logically, it makes sense to take colostrum (60 gr daily) alongside whatever alternative antibiotic treatment you are engaged in. What we English call "belt and braces" (I suppose for Americans it would be belt and suspenders).

#17 Marine Quinton

Shockingly, I only got to know of Quinton recently, while staying at Dr. Garry Gordon's home. He'd only just found it too. My ignorance was despite years of practice in Europe, where Quinton has been big business in the healing arts for over a century. A well kept secret, you might say.

What is Quinton? Sea water!

Well, not just any old sea water. It's special vortex water from certain blooms in the oceans, that are very rich in nutrients. It seems to have energetic properties too, above and beyond the mere presence of rare minerals etc.

Let me back up a tad, before we come to the product. The floor of our oceans is indescribably rich in minerals. Think about this: EVERYTHING that ever lived and died goes into the water system, down the rivers and ultimately finds its way to the ocean. Added to that is all the ocean life which lives, dies and is recycled, all the plankton, corals, fish, feces, EVERYTHING, which falls to the ocean floor as organic debris.

There is thick mud at the bottom of the ocean that contains dense nutrients and some minerals that are otherwise incredibly rare, like iridium, osmium, yttrium and so on.

But it doesn't just stay on the ocean bed, lost to the biosystem. Quite the contrary. This nourishing mud is carried around the ocean floor by submarine currents which have only recently begun to be understood. There are certain places where this nutrient deposit wells up to the surface. Giant surges of ocean currents that we call convergences stir up the seas and bring the nutrients back to the bio system.

The polar oceans are classic sites for this. The huge bloom of algae that takes place in the Arctic and Antarctic every year yields a staggering abundance of life where the ocean, literally, changes color due to the density of life it carries. Waters turn red with krill and other plankton.

This bloom is so rich it feeds the greatest animals of all: the whales. So much nutrition is absorbed into the biosystem at these sites in the summer time that whales can double their weight and deposit enough fat or blubber to live on it through the winter months.

But there are the birds, fishes and other animals too, so that the polar oceans literally burst with life every spring when the returning sun ignites

the nutrition chain. Given the right wind and currents, then these blooms can be carried far and wide. Scientists report this year there has been a huge upsurge in nutrients and an explosion of sea life off Monterrey, California, from currents brought all the way down from the Arctic.

The polar regions are not the only upsurges, however. In fact they can take place anywhere, if the wind blows the water out to sea; then underwater currents draw up deeper water to fill the gap.

That's what I mean by ocean nutrients, OK?

Enter Messieur Rene Quinton...

Rene Quinton (pronounced cahn-ton) was a Frenchman, a doctor, biologist, biochemist and physiologist. He discovered the healing merits of marine plankton plasma, drawn from deep ocean water upsurges, right at the end of the nineteenth century. It is a little known fact that by 1907 Quinton had established 69 Marine Dispensaries and the product was already saving countless lives throughout the deadly pandemics of the early 20th century (tuberculosis, typhoid, cholera, syphilis, influenza).

When Quinton was finally buried in 1925, his fame had reached such proportions that tens of thousands of men, women and children, not to mention generals, dignitaries and statesmen, attended the funeral. Yet we have never heard of him. How can that be?

Think "Pharma" and think "eliminating the competition", no matter how good the product. The stark truth is I never heard of this cure, all through my medical training. No libraries have editions of his work; no pharmacy has heard of it; no learning institutions teach it. He's been deleted! Especially in his native France.

Quinton's marine plasma (or QMP) was considered so effective for a wide range of common afflictions that is was reimbursed under two French laws, including Social Security. It was, of course, absurdly cheap. But that didn't suit the drug barons, who wanted to peddle their costly and dangerous garbage for huge profits. Through their bribes and malign abuse they got a law passed, requiring QMP to be heat treated. That would effectively ruin its properties and so put Quinton out of business.

However, Quinton manufacture did not fold up. The operation was moved to Spain instead.

Thanks to the more liberal scientific climate in Spain it has survived until today.

Now QMP has arrived in the US and is being sold by Original Quinton of Buena Park, CA.

Properties of QMP

As I write this I have in front of me a translation of the entry for Quinton Marine Plasma in the French Medical Dictionary of 1975 (a kind of PDR). It describes the product as a sterile apyrogenic solution (pH 7.2) of seawater, prepared under aseptic conditions by special processes without rise in temperature or exposure to electric potential or field, in order to preserve its molecular balance and its character as an "alive medium".

The seawater is extracted from a 30-metre depth (zone of solar penetration) under special conditions and from special locations.

It contains 92 elements of the periodic table (all primary and trace minerals).

The entry goes on to add "Rene Quinton showed, in 1904, that QUINTON MARINE PLASMA is identical physically, chemically, and physiologically, to our interior milieu (extracellular fluid) and provides optimum conditions for red blood corpuscles and leucocytes and other blood fractions. It is possible to replace the entire blood volume of an animal with QUINTON MARINE PLASMA without any disorders for the organism." Sacrebleu! Shades of Ringer's solution!

Without any intellectual prowess, one can therefore deduce that QMP is very safe, helps stabilize the internal milieu, provides every conceivable nutrient mineral and provides low concentration homeopathic-type mechanisms for healing. It's a miracle!

Well, it isn't really. It's just Nature at her best. But you can see why Rene Quinton was adored by millions and hated by Big Pharma. Here is a substance that's cheap to manufacture, no patents, is readily available and works wonders as a natural "antibiotic".

The “indications” (reasons to use it) are manifold and include: childhood gastroenteritis, poisoning, malnutrition and eczema; anemia, asthma, exhaustion, anti-aging, dysentery, tuberculosis and atherosclerosis; uterine and vaginal infections; rhinitis, sinusitis, respiratory allergies; skin allergies, dermal infections, histaminic reactions and psoriasis; energy restoration; bioterrain restoration and burns.

The official French pharmacopeia (1975) even lists it as an “antibiotic solvent and carrier”.

I have even found that dentists can use it to save teeth, by injecting this healing balm into the surrounding gums. The abcesses and periodontal disease simply disappear.

There are DOZENS more uses.

How To Take It

QMP is taken by injections or orally. When injected, there is an isotonic form, which does not sting. Orally, the full-strength version is fine.

Sprays work well for skin conditions.

It can even be taken by nebulizer, just breathed in. Or I find it very soothing for tired eyes.

Just the whiff of “sea air” is very restorative to me!

It’s so safe there are no real limits on the number of ampoules. It’s only body fluid, after all!

You can’t OD on it like water (too much water will kill you).

QMP comes in 10 ml ampoules. 2, 3, 5, 10 ampoules are fine, depending on the seriousness of the complaint. It’s so cheap, cost is not an issue (around $3 an ampoule) Note that Quinton is not FDA approved for injection in the USA.

#18 Chlorine Dioxide Protocol

Next we come to a modern surprise. The story of how it was discovered is interesting. One of those serendipity things!

The idea of using chlorine dioxide was developed by Jim Humble, a gold miner and metallurgist, on an expedition into the jungles of Central America, looking for gold. It was a response to a need to help a member of his expedition who came down with malaria, more than two days away, through heavy jungle, from the next mine.

After many years of experience, Humble always carried "stabilized oxygen" (sodium chlorite) with him on such expeditions, to make local water safe to drink. Facing the possibility of a quick loss of life, he gave it to the stricken man. To everyone's amazement, the patient was well within a few hours. That seemed like a miracle, but Humble wanted to better understand what had just happened.

Over the course of several years, Jim Humble figured out that what made stabilized oxygen so effective in some malaria cases, was not the oxygen at all, but the trace amounts of chlorine dioxide it contained. Further research led him to come up with a way to produce hundreds, if not thousands more units of chlorine dioxide than what is found in stabilized oxygen. This is done by using a higher concentration of sodium chlorite (28% vs. 3% for stabilized oxygen), in conjunction with an activator.

Humble went on the have great success using his new formula which, unscientifically, has been named "Magic Minerals Solution" (there are no minerals in it). But MMS (for short) does seem to work, though I doubt some of the claims. It is said to been successful in helping over 75,000 people in several African nations – including Uganda and Malawi – rid themselves, primarily of malaria, but also hepatitis, cancer, and AIDS.

Anyone can be overloaded with toxins. Most people probably are but won't admit it or, more likely, don't know it. Others would prefer to think they're not. If your health is not perfect, you're habitually low on energy, have trouble keeping your weight down or your blood pressure in the normal range, or constantly dealing with inflammation or pain, or indeed have any medical condition that is adversely affecting your health, then there's likely to be a toxin, heavy metal, virus, bacteria, fungus, or parasite playing a part. Mainstream medicine will typically respond by loading you up with additional pollutants, many of which indiscriminately kill healthy tissue while going after

"the bad guys" to deal with the symptoms. Not so with chlorine dioxide. It only acts on anything harmful. Miracle or not, the effects can be amazing!

Over the next few s, the MMS protocol will be described. When followed, it will produce and distribute chlorine dioxide to your red blood cells, which are the most effective and intelligent pathogen killers known to Nature, although your white blood cells are assumed to do all the work.

But first, a little background on the chemistry. Chlorine dioxide and chlorine are not the same. Chlorine is a chemical element. In ionic form, chlorine is part of common salt and other compounds, and is necessary to most forms of life, including human. A powerful oxidizing agent, it is the most abundant dissolved ion in ocean water, and readily combines with nearly every other element, including sodium to form salt crystals, and magnesium, as magnesium chloride. Chlorine dioxide is a chemical compound that consists of one chlorine ion bound to two ions of oxygen. Oxidizing agents are chemical compounds that readily accept electrons from "electron donors." They gain electrons via chemical reaction. This is important because relative to chlorine dioxide, all pathogens are electron donors.

Chlorine dioxide is extremely volatile. You might call it "hot tempered," but in a very beneficial way. This volatility is a key factor in chlorine dioxide's effectiveness as a pathogen destroyer. The compound is literally explosive, so explosive, it's not safe to transport in any quantity. Therefore, it is common practice to generate chlorine dioxide "on site" at the point of use. Most chlorine dioxide production is done on a scale that would prove deadly for individuals, for example, in municipal water treatment systems, where it is beginning to replace chlorine because it produces no carcinogenic by-products.

Chlorine dioxide is approved by the Environmental Protection Agency in safely removing pathogens and contaminates like anthrax. So you know it must be effective. However, the concentrations used in such applications can vary from 500 to over 6,000 parts per million (ppm), which would clearly be deadly to an individual. Using the MMS protocol you will produce chlorine dioxide around 1 ppm. You will use the MMS solution, which is safe to transport, to make nature's harmless pathogen destroyer.

The MMS solution is 25% sodium chlorite in distilled water. You can produce chlorine dioxide with a single drop, when an "activator" of vinegar, lemon juice, or a 10% solution of citric acid is added. Citric acid is recommended because of its simplicity. The natural pH of sodium chlorite is 13. Adding vinegar, lemon juice, or citric acid creates about 3 mg of unstable but still harmless chlorine dioxide.

The Process

Let's talk a bit more about how and why chlorine dioxide works by giving the immune system a new lease of life. Volatility is what makes chlorine dioxide so effective when it contacts pathogens. As we've already mentioned, chlorine dioxide is a safe and effective disinfectant in many municipal water delivery systems, hospitals, and even in bio-terrorism response. It stands to reason that chlorine dioxide would be just as effective working in the waters of the human body at the appropriate dose.

Chlorine dioxide's extreme volatility prevents pathogens from developing a resistance, mainly because when they "clash," the pathogens no longer exist. Yet, healthy cells and beneficial bacteria remain unaffected. While normal levels of oxygen in the blood cannot destroy all of the pathogens present under disease conditions, delivery of chlorine dioxide changes everything. "Halt! Surrender Your Electrons, Now!" When a chlorine dioxide ion contacts a harmful pathogen, it instantly rips up to five electrons from the pathogen, in what can be likened to a microscopic explosion… harmless to us, but terminal for pathogens. The pathogen – an electron donor – is rendered harmless due to the involuntary surrendering of its electrons to the chlorine dioxide – an electron acceptor – and the resulting release of energy. Oxidized by the chlorine ion, the former pathogen becomes a harmless salt.

This process benefits a body that has become toxic. Throughout the body, anywhere chlorine dioxide ions – transported via red blood cells – come into contact with pathogens, the pathogens give up their electrons and cease to exist.

The chlorine dioxide-armed cells only "detonate" on contact with pathogens, which include harmful bacteria, viruses, funguses, toxins, heavy metals, and parasites. All of these will have pH values that are out of the body's range of good health. They will also have a positive ionic charge. The chlorine dioxide equipped cells do not oxidize beneficial bacteria, or healthy cells, as their pH levels are 7 or above, and hold a negative ionic charge. Chlorine dioxide ions will oxidize – meaning vaporize – diseased cells… anything that is acidic, with a positive ionic charge. If the chlorine dioxide ions encounter no pathogens or other poisons, they deteriorate into table salt and in some instances, hypochlorous acid, which the body can also use.

A Pathogen Terminator

Research has proven chlorine dioxide to be much safer than chlorine, as it is selective for pathogens when used in water. Furthermore, it does not create harmful compounds from other constituents in the water as chlorine does. Numerous scientific studies have demonstrated that chlorine – part of the halogen family of elements – creates as least three carcinogenic compounds when it enters the body, principally Trihalomethanes (THMs). There has been no such evidence of harmful compounds being produced from chlorine dioxide. This is why, in 1999, the American Society of Analytical Chemists proclaimed chlorine dioxide to be the most powerful pathogen killer known to man. It has even been used to clean up after anthrax attacks.

A Journey into Chemical Alchemy

Once it is introduced into the bloodstream, chlorine dioxide performs a highly energetic acceptance of up to five electrons when it comes across any cell that is below a pH value of 7.

This means that diseased cells are essentially vaporized (i.e., "oxidized") while healthy cells are unaffected.

This is how it happens. Red blood cells that are normal carriers of oxygen throughout the body do not differentiate between chlorine dioxide and oxygen. Therefore, after you have swallowed the MMS/chlorine dioxide-rich solution, red blood cells pick up chlorine dioxide ions as they pass through the stomach wall. When the red blood cells, armed with chlorine dioxide, encounter parasites, fungi, diseased cells or anything that has a pH below 7 and a positive ionic charge, the "aliens" are destroyed along with the chlorine dioxide ion.

If the chlorine dioxide doesn't hit anything that can set it off, it will eventually deteriorate, by losing an electron or two. This will allow it to be converted into hypochlorous acid. This compound kills pathogens and even cancerous cells. Hypochlorous acid is so important that its diminished presence in the body is described medically by the term 'myeloperoxidase deficiency'. Many people are afflicted by this condition. The immune system needs a great deal more hypochlorous acid when disease is present. Facilitated by the MMS solution, chlorine dioxide delivers it in quantity.

The most salient point to know is that chlorine dioxide has 100 times more energy to do what oxygen normally does, and yet, will not harm healthy

cells. By the way, if you are totally healthy and have nothing in your body that is at an acidic level below 7, there are no ill effects from taking chlorine dioxide at the appropriate dose. However, your stores of hypochlorous acid will be increased.

MMS works best to destroy pathogens that may be present in the body, when 2 or 3 mg of free chlorine dioxide are in the solution at the time it is swallowed. However, the body is supplied with chlorine dioxide in a "timed release" manner lasting about 12 hours. Be aware, that before you feel better, it is likely you will feel ill in one way or another.

Nausea

The nauseating feeling that you may possibly experience, especially if you take too big a dose, is the result of chlorine dioxide encountering and destroying a large number of pathogens. We are generally oblivious to the pathogens that are present in our bodies, but there is an increasing awareness in the medical and scientific literature of their importance to our health, or more to the point our ill health. Since they build up over time in various organs of the body, they generally affect our health slowly and cumulatively. If chlorine dioxide takes them out too suddenly, the result will be a dramatic reaction. However, the time it takes to clear the pathogens and toxins is much less than it took for them to accumulate. It has probably taken many years, possibly almost a lifetime, for some of them to accumulate.

As a person always feels unwell when they contract a case of, say, acute hepatitis, dengue fever or Lyme disease, they may continue to feel unwell for a while, in which case it will be difficult to tell whether it is the condition or the chlorine dioxide that is causing the unwell feeling. However, if the condition is treated with chlorine dioxide in its early stages, the pathogens will be killed off quickly as they are still in the blood stream and therefore available to be attacked easily by the circulating chlorine dioxide-rich red blood cells. Under these circumstances, the symptoms should be over very quickly.

In chronic conditions, especially Lyme disease and dengue fever, nearly every organ of the body can be affected to a greater or lesser extent, which is why the symptoms can be so variable, and the person can feel so ill. This variability is almost diagnostic of such conditions, especially as there are no satisfactory blood tests to prove the diagnosis. The reason for this is that there may be a number of different organisms involved, each having

a different life cycle. In these cases it will take a little longer to achieve a resolution of the condition, as each organism is destroyed in its own time.

Years of "leeching" from dental amalgams can "innocently" deposit enough mercury in one's system to steal innocence, rob vitality, and erase precious memories. Lead can accumulate over the years from atmospheric exposure. Dislodging and vaporizing either or both of them may feel uncomfortable for a short time compared to the time it took for them to accumulate.

If there is nothing for chlorine dioxide to encounter, it deteriorates into constituents that are totally non-toxic. Nothing poisonous is left behind to build up, as is the case with many medical protocols. Medical treatments currently provide you no way of removing the poisons when they don't work. Chlorine dioxide, on the other hand, lasts long enough to do its job, and then the amount that does not furnish the immune system with needed ions becomes nothing more than micro amounts of salt and water. The chlorine dioxide has just a few minutes to do its job, and then it no longer exists, leaving nothing behind that can build up, or do additional harm.

The Procedure

The procedure for taking MMS is simple. All you need is your bottle of MMS, a clean, empty, dry glass, an eyedropper and the activator citric acid.

Note: When following the instructions below, keep this paragraph in mind. Always activate the MMS drops with one of the food acids, either lemon juice drops, or limejuice drops, or citric acid solution drops, the citric acid drops being the simplest.

Always add 5 drops of citric acid to each 1 drop of MMS, mix in an empty dry glass and wait at least 3 minutes, then add 1/3 to 2/3 glass of water and drink it. (You can expand the 3 minutes to 10 before drinking.)

Repeat this dose in between one and two hours, ideally doing all of this after your evening meal, possibly starting about ¾ hour after you have eaten, as it can sometimes make some people sleepy, apart from which your body does most of its detoxifying during the night.

Start modestly with as little as 1 drop of MMS plus 5 drops of citric acid on your first day (never forget to wait at least 3 minutes for the mixture to react to create chlorine dioxide, which will turn yellow and smell of chlorine, and repeat the dose in one to two hours). Take your time and do not rush. You

could stay on this low dose for a few days, and then increase the number (2 and 10, 3 and 15, etc) on subsequent days, but I repeat – TAKE YOUR TIME. There is no point in going higher than 15 and 75 respectively, but it is rare for anyone to reach this level.

Your body will tell you when you've reached the optimum dosage for you, and, if in doubt, drop the next dose. Clearing may be a bit uncomfortable, but it need not be intolerable. You may feel like you've been through a battle, and, in a sense, you have. However I suggest that, if you develop any symptoms of any sort, assume you have taken too high a dose, so put up with the effect, take the antidote, and drop the next dose, possibly even not taking any for a day.

Before you can be healthy again, you need to destroy toxins, pathogens, parasites and anything harmful to you. In order to do so, they have to be uprooted and released from their "strongholds" in your body tissue. You have no idea what they are or where they are. Remember they may be buried deep in your organs.

You don't have to reach your maximum tolerated dose. Whatever dose you use will have its value, but the higher you can comfortably reach the better. It is just that the whole process will take that much longer.

This gentle approach applies to any chronic condition, and especially if you want to clean up your body. However, if you develop an acute medical condition such as dengue fever or malaria, for example, start straight in at at least 5 drops of MMS to 25 drops of citric acid, although you could possibly start at 8 drops of MMS to 40 drops of citric acid, and don't forget to repeat the dose in between one and two hours.

With any luck you will feel remarkably better by the next day. If you are not quite symptom free, repeat the same the next day, increasing the dose by about one third. In an acute situation, you can take three doses a day, each one repeated one to two hours later.

Antidote. If you develop any symptoms you don't like, assume it is the chlorine dioxide working too hard within you. To clear these symptoms, either take a few doses of ½ teaspoonful of sodium bicarbonate in a glass of water or a few grammes of vitamin C in water. Don't take both. Then either don't take a dose of MMS for 24 hours or drop the next dose and gradually work back up again.

IMPORTANT. Please be aware that, as I have already said, chlorine dioxide is a very potent chemical and literally destroys anything potentially harmful it

comes across. Whatever dose you take, it will do its job. It is understandable that you want to reach as high a dose as possible as soon as possible, but I would encourage you not to think like that. As most of us have accumulated a lot of undesirable things within our bodies over the years, some of which may now be causing a major illness, it is not unreasonable to suggest that it may take some time to get rid of it all, possibly six months or more.

A number of people have reported to me that they did not feel any nausea, nor did they vomit, but started to feel generally unwell, or some of their old symptoms started to come back a bit, when they had reached a certain dose of chlorine dioxide. Fortunately they rang me. My advice was that they should go back to a lower dose, possible even not taking any chlorine dioxide for 24 hours before restarting at the lower dose. This approach has worked in every case. Unlike an antibiotic, nothing can develop a resistance to chlorine dioxide, as has already been said.

So what I am really trying to say is that, if you have ANY undesirable effects, even if you become a bit more tired than before, ASSUME that the chlorine dioxide is being too active for your body's current ability to eliminate the toxins. Take a lower dose next time, and be prepared to stay low for a while. Please don't overdose. It will only make you feel unnecessarily ill.

Overall you may feel the effects, but this is a good thing. You will also feel healthy again. Any sick feeling will be TEMPORARY, a small price to pay for the longer-term possibility of lasting restored health, no matter what stage of life you happen to be currently experiencing. When the clearing is done, you won't need to take the maximum dose. You can go on a maintenance application (1 or 2 drops of MMS) to keep your insides pathogen free and your immune system strong or take a dose every so often. I hope you have found this information helpful. In summary, when MMS is combined with citric acid it produces chlorine dioxide, which, at the appropriate dose is a safe and effective way to boost your immune system and eliminate a full range of harmful organisms, toxic metals and chemicals which may well be making you ill.

Dr. Patrick Kingsley. February 2008.

Next, while we are on the topic of simple chemical substances, let’s look at two others: first, hydrogen peroxide…

#19 Hydrogen Peroxide

The bleach story continues!
Hydrogen Peroxide: A Powerful Antibiotic

Hydrogen peroxide is like water (H2O) with an extra oxygen atom added (H2O2). It's the extra oxygen and the power to release it right in the tissues that makes this substance a powerful medicine. Oxygen is good for us and bad for a great many pathogens, notably anaerobic bacteria, yeasts and viruses. It also cripples cancer cells and renders them vulnerable to the immune system.

Nature supplies us with abundant hydrogen peroxide. Every time it rains, falling drops of water bring down ozone from higher in the atmosphere in the form of hydrogen peroxide. The extra life-giving oxygen is undoubtedly one of the reasons plants do better when watered from the sky than from a watering can. It is also why rain is so refreshing. Don't hide indoors! Go out and get the extra oxygen: it's Nature's gift of energy!

In fact hydrogen peroxide from the sky is so good that farmers are known to mimic it by spraying their crops with diluted hydrogen peroxide. Feed it to your plants, using one ounce of 3% hydrogen peroxide solution to a quart of water. They'll love it!

Unfortunately, because of current atmospheric pollution, much of the peroxide never reaches the ground. It gets used up interacting with chemicals in the atmosphere and in urban areas this has lowered oxygen levels from the 20% you were taught in school, down to as little as 10%.

Despite its health-giving properties, our oxygen needs are not being met. The oxygen-generating rain forests are being destroyed worldwide, which further reduces available oxygen. Chlorination of drinking water removes oxygen. Cooking and over-processing of our foods lowers their oxygen content. Unrestrained antibiotic use destroys beneficial oxygen-creating bacteria in the intestinal tract.

Dr. Johanna Budwig of Germany has shown that for proper cellular utilization of oxygen to take place, our diets must contain adequate amounts of unsaturated fatty acids, rich in pi electrons. Unfortunately, the oils rich in these fatty acids have become less and less popular with the food industry. Their very reactive nature means they require more careful processing and it gives them a shorter shelf-life. The food industry, which has no apparent

interest in human health, has therefore turned to the use of synthetic fats and dangerous processes like hydrogenation.

A Bit Of Biochemistry

Ozone is an unstable coupling of 3 oxygen atoms and it easily gives up the third oxygen atom which, once alone, becomes a violent reactor and can cause damage. That's why ozone is potentially hazardous. Hydrogen peroxide also has an extra oxygen atom, which is gives up easily, reverting to water. It too is potentially dangerous—but only if you misuse and abuse it, which of course is true of any medicine!

The fiery "singlet oxygen", as it's called, that is given up in the tissues is what creates the powerful medicinal properties of hydrogen peroxide. It's deadly to pathogens and deadly to cancer cells, yet does our bodies little harm.

The bubbling you see when hydrogen peroxide comes in contact with a bacteria-laden cut or wound is the oxygen being released and bacteria being destroyed.

You've probably understood the anti-oxidant story and you no doubt take antioxidants to protect yourself. However the missing half of the story, which rarely gets told by half-educated health "experts", is that we need oxygenation in our bodies. Hydrogen peroxide is the exact substance by which our own white blood cells kill bacteria, molds (yeasts) and viruses. Cells release it on the spot and then rapidly re-absorb and neutralize it when it has killed the pathogen.

If this ability was totally swamped by excessive anti-oxidants, then we wouldn't be able to fight off infections. Please remember this point. The ability of our cells to produce hydrogen peroxide is essential for life. H_2O_2 is not some undesirable by-product or toxin as orthodox medicine would have you believe, but instead a basic requirement for good health.

Hydrogen peroxide is involved in many other important processes in the body. For example, vitamin C helps fight infections by enhancing hydrogen peroxide production, which in turn stimulates the production of prostaglandins. Also lactobacillus found in the colon and vagina produce hydrogen peroxide. This destroys harmful bacteria and viruses, preventing colon disease, vaginitis, bladder infections and a host of other common ailments *(Infect Dis News Aug.8,91:5)*. It is required for the production of

thyroid hormone and sexual hormones. *(Mol Cell Endocrinol 86;46(2): 149-154) (Steroids 82;40(5):5690579)*. It stimulates the production of interferon *(J Immunol 85;134(4):24492455)*. It dilates blood vessels in the heart and brain *(Am J Physiol 86;250 (5 pt 2): H815-821 and (2 pt 2):H157-162)*. It may improve glucose utilization in diabetics *(Proceedings of the IBOM Conference 1989, 1990, 1991).*

The good thing is that hydrogen peroxide is dirt cheap and readily available. BUT YOU MUST TAKE CARE TO USE ONLY THE CORRECT FOOD GRADE FORM. More about that later.

We don't yet fully understand the complete workings of hydrogen peroxide but we do know that it is a prolific source of free oxygen. 1 pint of food-grade (35% solution) contains the equivalent of 130 pints of oxygen. 1 pint of 3% hydrogen peroxide found at the local drugstore contains 10 pints of oxygen. And 1 pint of the 6% solution (the kind used to bleach hair) contains 20 pints of oxygen.

We also know that when H_2O_2 is taken into the body (orally or intravenously) the oxygen content of the blood and body tissues increases dramatically. Early researchers felt these increases were simply due to the extra oxygen molecule being released. This is unlikely. Only very diluted amounts of H202 are ever introduced into the body. The small amount of oxygen present couldn't be solely responsible for the dramatic changes that take place.

Dr. Charles Farr, a strong proponent of intravenous use, has suggested another possible answer. He believes that hydrogen peroxide stimulates enzyme systems throughout the body. This triggers an increase in the metabolic rate, causes small arteries to dilate and increase blood flow, enhances the body's distribution and consumption of oxygen and raises body temperature *(Proceedings of the International Conference on Bio-Oxidative Medicine 1989, 1990, 1991).*

A Little History

The therapeutic benefits of hydrogen peroxide were reported as far back as 1920. The prestigious English medical journal, The Lancet, carried the story that IV hydrogen peroxide was used to successfully treat pneumonia in the flu epidemic following World War I.

In the 1940's Father Richard Willhelm, a pioneer in promoting peroxide use, reported its extensive use in treating everything from bacterial-

related mental illness to skin disease and polio. Father Willhelm founded of "Educational Concern for Hydrogen Peroxide" (ECHO, a nonprofit organization dedicated to educating the public on the safe use and therapeutic benefits of hydrogen peroxide).

Much of the interest in hydrogen peroxide waned in the 1940's when prescription medications came on the scene. Since that time there has been little economic interest in funding peroxide research. After all, it is inexpensive and non-patentable, so worthless to drug companies, who pursue profits above patient care. Yet despite this lack of apparent interest of orthodox medicine, over 7,700 articles relating to hydrogen peroxide have been written in the standard medical journals.

Thousands more, involving its therapeutic use, have appeared in alternative health publications. The number of conditions helped by hydrogen peroxide is astounding. The reported dangers and side effects are few and often conflicting.

Again, I repeat, that it is quite safe if handled properly. But deadly if not.

Only 35% Food Grade hydrogen peroxide is recommended for internal use. See overleaf for notes about grades of hydrogen peroxide.

Even at this concentration, however, hydrogen peroxide is a very strong oxidizer and if not diluted, it can be extremely dangerous or even fatal. Any concentrations over 10% can cause neurological reactions and damage to the upper gastrointestinal tract. There have been two known fatalities in children who ingested 27% and 40% concentrations of H202.

Recently, a 26 month old female swallowed one mouthful of 35% H202. She immediately began vomiting, followed by fainting and respiratory arrest. Fortunately, she was soon under emergency room care and although she experienced erosion and bleeding of the stomach and esophagus, she survived the incident. When she was re-examined 12 days later, the areas involved had healed *(J Toxicol Clin Toxicol 90;28(1):95-100).*

What Diseases Can Be Treated With Hydrogen Peroxide?

All infections will benefit, whether viral, bacterial, fungal (yeasts and molds) or parasitic. The list would be long but would include colds, influenza, Herpes, sore throats, gum (periodontal) disease, infected wounds and burns, MRSA certainly, pneumonia, hepatitis, infectious mononeucleosis, Lyme, vaginal Thrush, bowel disorders (proctitis, colitis, Crohn's etc), prostatitis, trichomoniasis, systemic Candiasis and cystitis.

Veterinary parasitology also suggests it is effective against toxoplamosis, which is otherwise almost impossible to treat *[Veterinary Parasitology, Volume 153, Issues 3-4, 31 May 2008, s 209-213].*

Even claims have been made for the successful treatment of AIDS (these are never investigated for their worth; the doctors are just treated as liars and quacks).

How Is Peroxide Used?

In serious situations and if local political matters permit, there is no question that hydrogen peroxide (and ozone) therapies are best administered by a qualified health professional, who know what he or she is doing.

But you can do it for yourself, if you can get the correct grade of hydrogen peroxide. For the avoidance of confusion, here is information about all the common forms of hydrogen peroxide. Be sure you understand what you are buying, if you want to use it for self-therapy.

Grades of Hydrogen Peroxide

Hydrogen peroxide is available in various strengths and grades.

1. 90%: This is used as an oxygen source for rocket fuel!

2. 3.5% Pharmaceutical Grade: This is the grade sold at your local drugstore or supermarket. This product is not recommended for internal use. It contains an assortment of stabilizers which shouldn't be ingested. Various stabilizers include: acetanilide, phenol, sodium stanate and tertrasodium phosphate.

3. 6% Beautician Grade: This is used in beauty shops to color hair and is not recommended for internal use.

4. 30% Reagent Grade: This is used for various scientific experimentation and also contains stabilizers. It is also not for internal use.

5. 30% to 32% Electronic Grade: This is used to clean electronic parts and not for internal use.

6. 35% Technical Grade: This is a more concentrated product than the Reagent Grade and differs slightly in that phosphorus is added to help neutralize any chlorine from the water used to dilute it.

7. 35% Food Grade: This is used in the production of foods like cheese, eggs, and whey-containing products. It is also sprayed on the foil lining of aseptic packages containing fruit juices and milk products. Only 35% Food Grade hydrogen peroxide is recommended for internal use. At this concentration, however, hydrogen peroxide is a very strong oxidizer and if not diluted, it can be extremely dangerous or even fatal.

You must handle it without getting it on your skin. Direct contact will burn the skin. Rubber gloves from Home Depot or similar are recommended. If you do get any on your skin, wash it off immediately with copious water.

It needs to be diluted down to 3%. Diluting 10 times would result in 3.5%, so if we dilute it 1 in 12, that's close to 3%. You can do this easily by pouring 1 ounce of H2O2 into a pint jug or jar, then adding 11 ounces of distilled water. This will make 12 ounces of 3%.

I recommend that you transfer the H_2O_2 as you need it to a small glass eyedropper bottle, which you can get from your local drugstore. Leave the rest in the tightly sealed bottle it came in and store it at the back of the refrigerator, where it will be quite stable chemically, for long periods (make sure children cannot access it).

Suggested Dose Regime

Based on years of experience and thousands of cases reports, the following dose regime is known to work well and should be right for you.

Drops can be added to 6- 8 ounces of liquid in a glass, either more distilled water, fruit juice, milk or aloe vera (juice or gel). DO NOT USE TAP WATER: the chlorine in tapwater would deactivate the hydrogen peroxide.

Hydrogen peroxide must be taken only on an empty stomach. If there is food in the stomach, the reaction on any bacteria present may cause excess foaming, indigestion, and possibly even vomiting. Additionally, some animal research indicates that when it is given orally, peroxide combines with iron and small amounts of vitamin C in the stomach, hydroxyl radicals are created *(J Inorg Biochem 89;35(1):55-69).*

Day	Number of Drops	Time Per Day
1	3	3
2	4	3
3	5	3
4	6	3
5	7	3
6	8	3
7	9	3
8	10	3
9	12	3
10	14	3
11	16	3
12	18	3
13	20	3
14	22	3
15	24	3
16	25	3

Please don't go above 25 drops. It may be counter-productive.

Transplant patients should not take hydrogen peroxide. It strongly stimulates the immune system and could, theoretically, cause a rejection of the organ. If you feel nauseated and sick, this could be a healing crisis. As you detox and kill off lots of pathogens in your system, your body may not be able to remove the breakdown products fast enough. The answer is just to persist until the toxins are cleared.

Try to keep going at the dose you are on; just don't increase it until the reaction wears off. Then resume the climbing dose (maximum, 25 drops, 3 times a day).

You should also take vitamin E (alpha and gamma mixed forms, not synthetic alpha-tocopherol). It enhances oxygen metabolism and is quite safe, whatever the current scientific frenzy to discredit it.

You should also actively engage in pre- and probiotics (section #40a), to start repopulating your body with good friendly bacteria.

You can get food grade 35% hydrogen peroxide online at this website:

http://www.dfwx.com/h2o2.htm

Other Administration Routes For Hydrogen Peroxide

1. Three tablespoons mixed with a quart of distilled (or any non-chlorinated) water makes a good vaginal douche, for those stricken with bacterial or yeast (Candida) vaginitis.

   Remember the need to re-populate with good flora. The pH of the vagina is important.

   It is normally kept slightly low by malic acid. This deters bacteria and yeasts. I have heard (but don't recommend) women douching with yoghurt to increase friendly flora.

   One case was found with a raspberry seed stuck in her cervix: she'd used supermarket sweetened fruit yoghurt, which was very silly!

Enemas. The above formula can also be used effectively for colon infection (Candida, Giardia and other).

2. It makes an effective full strength mouthwash or can be mixed with baking soda for toothpaste.

3. It can be used full strength as a foot bath for athlete's foot. (Diabetics have found relief from circulation problems by soaking their feet in 1 pint of 3% peroxide mixed with 1 gallon of warm, non-chlorinated water for 30 minutes nightly.)

4. A tablespoon added to 1 cup of non-chlorinated water can be used as a nasal spray. Depending on the degree of sinus involvement, one will have to adjust the amount of peroxide used. If it causes excess catarrhal discharge, reduce the proportions.

#20 Hydrochloric acid Injections

What? That's right. Only 1:1,000 strength! It's more barefoot doctoring from the days before fancy antibiotics. Burr Ferguson M.D. of Birmingham AL first wrote about it around 1925. Dr. Ferguson had been a battle surgeon during World War 1 and he had seen the wounded die by the hundreds from infections. He quickly found that when 10 mls of 1:1,000 hydrochloric acid is given IV, there is a rapid and significant increase in the white cell count. Infections melted away and fever subsided.

You can treat virtually any infection with this simple protocol. It's quite safe!

Begin as soon as there are signs of fever. Shots are given daily. Usually after a week the fever is cleared and the patient feeling well.

The doctor was William Howell M.D. of Lexington, Tennessee told of the following case in a 1930s journal Medical World:

The patient was age 15 and she was delivered of a very large baby that lived only for two hours. She lived in a log cabin in the woods. The delivery was done with the best aseptic condition that could be had in a log cabin. The patient weighed only 90 pounds. There were some small lacerations. On day three after delivery there was a message that the patient had a chill and high fever. She lived in a river bottom and I was in hope that it was malaria and I sent quinine. On the fifth day there was another message telling of the grave condition of the patient. In going into the sick room I saw at once that the message had been urgent. The girl was delirious, temperature was 106, pulse was 140, respiration was 40 and there was a discharge from the vagina with a fetid odor. Every other case I had seen like her had died of the infection.

I had some one in 1,500 hydrochloric acid with me but had feared to use it. I injected 10 cc of 1 in 1,500 hydrochloric acid into a vein with much trepidation. The following minutes were anxious ones for me as I hardly knew what to expect. I had never heard of hydrochloric acid being used to treat puerperal sepsis. I was thinking of the warnings of the fatal results of an injection of acid in the vein. I was holding the radial pulse when all of a sudden there was sweat on the patient's neck and forehead and a slowing of the pulse. In a few more minutes the patient was bathed in a profuse perspiration and there was a stop to the chatter of her delirium. Thirty

minutes after the injection she was conscious and I asked her how she felt. She said that she felt much better. She wanted to go to sleep.

Within an hour of the injection, her temperature had dropped to 103, her pulse had dropped to 100 and respiration had decreased to 22. On the next four days I repeated the injections. On day six, temperature was 99, pulse was 72 and respiration was 19. Two days later I was called and told that her fever had returned. Her temperature was 101 and there was a free discharge from the vagina. I gave her one more injection of 10 cc of acid.

All signs of the infection she had had completely disappeared.

The story was later retold by Barry Groves in Townsend Letter for Doctors, December 2001 issue.

Obviously this is one remedy that should probably only be done by an MD or RN. But in an emergency, in the jungle, anywhere, just do it!

I've administered hydrochloric acid to myself IV on two occasions. It worked and was entirely without side effects. If you end up with MRSA or any other dangerous or intractable infection, don't trust to antibiotics to save you: get some holistic practitioner to do this protocol for you.

I need hardly say that I believe it would be wise for decent MDs to re-learn these older techniques which certainly worked. Moreover they were cheap and safe (that was partly the problem, of course: no major drug company would ever promote such profit-less remedies).

One more case from Dr. William Howell, then we're done:

The acid gives the same happy results in nephritis. Give an injection every day---in five or six days the albumin diminishes until there is none. I saw a case of acute nephritis September, 1933, following scarlet fever. A boy, nine years of age, swollen till he looked as though he would burst. I tried everything I could get at; salt-free diet, potassium citrate in large doses, milk diet. The hospital authorities said his urine showed four plus albumin. After six weeks he showed no improvement.

I decided to try the acid. I gave him 3 c.c. of a 1:500 solution in the gluteal muscle every day, alternating hips each day. In seven days the albumin began to decrease. After twenty-one injections he was entirely well. I have reports from him almost weekly; no albumin.

I saw him May 6th, 1934. He was out on the road with other children, was just as busy in their games as they were, showed no signs of his former trouble, looked well, ruddy like the others. Since that time I saw another case of acute prostatitis, urine loaded with albumin. After six injections his urine was entirely cleared up. I have given him about twenty-five injections. He sleeps well at night; no more bladder trouble.

I have a man under my care who had tuberculosis of the lungs. The bladder became involved. I gave him an injection every day for thirty days. He missed his fever, all bladder symptoms are gone, eats plenty, sleeps well, has had no fever in ten months. His weight has gone up from 140 to 180 lbs. I am still giving him an injection once a week. He is doing light work, coughs very little. He has taken more than one hundred injections with never the slightest harm.

#21 Colloidal Silver

If you've been into alternative and holistic medicine for any length of time. You must have heard of colloidal silver is an anti-septic. You've probably heard that Alexander the Great's troops kept their water supply in silver vessels and how wagon train pioneers, travelling through the Wild West, used to put a silver dollar in the water barrel, to keep the water pure.

There is really no argument that it is effective. In fact, silver has even reached the mainstream in the form of silver-soaked bandage line from Curad. According to the bandage company: "Laboratory testing showed that silver reduced bacterial growth like Staph. aureaus, E. coli, E. hirae and Pseudomonas aeruginosa -- a powerful germ that does not respond to many antibacterials -- in the dressing for 24 hours."

Even washing machines are now, for better or worse, using silver ions to kill bacteria.

Meanwhile, silver-coated urinary catheters are used to help reduce urinary tract infections (UTIs) -- studies showed they reduced the incidence of UTI by 47 percent.

Silver inhibits the growth of bacteria by deactivating the bacteria's oxygen metabolism enzymes. In turn, this destroys the bacteria's cell membranes, stopping the replication of the bacteria's DNA. *[Source- Acupoll Precision Research, April 2003 Beiersdorf, Inc.]*

The real problem is not credibility with colloidal silver antisepsis. The problem is that there's an awful lot of junk products, manufactured in garage and kitchen top businesses, with small and inadequate electrolysis machines. These are really not potent enough to have any noticeable effect. Yet the people who peddle these goods like to quote science to give them credibility.

Don't be fooled, make sure you get a good product. It's not just a matter of the particle count but particle size also (surface area)—and ionic silver content.

Silver ions are silver atoms which have an electron missing in the outer shell. Silver particles are metallic silver consisting of clusters of silver atoms and can range in size from less than a nanometer up to 1,000 nanometers (1 micron). Silver ions will combine with chloride ions readily where they are present. The human stomach contains a strong solution of hydrochloric acid. Silver chloride forms immediately in the stomach when silver ions enter it. The same thing happens to silver ions in the bloodstream by virtue of the

high chloride content due to the presence of sodium and potassium chloride. Silver ions, therefore are of little value inside the body as they are quickly combined with the available chloride ions to form worthless silver chloride.

Let me suggest a product called Advanced Colloidal Silver. It has approximately 20% ionic silver and 80% silver particles with a mean average of about 2 nanometers. This small particle size, combined with small particles results in a vastly larger surface area of silver for a given concentration. Because of this, ACS is potentially more effective than those products with much larger particles and much higher ppms.

The difference between good and bad products is illustrated by a study carried out by Dr. Ron Leavitt of BYU University, and reported by Deseret News, Tuesday, May 16, 2000.

According to Leavitt "The data suggests that with the low toxicity associated with colloidal silver, in general, and the broad spectrum of antimicrobial activity of this colloidal silver preparation, this preparation may be effectively used as an alternative to antibiotics."

The original study compared a good quality colloidal silver against tetracyclines, fluorinated quinolones (Ofloxacin), the penicillins, the cephalosporins (Cefaperazone) and the macrolides (Erythromycin). Among the microbes tested were streptococcuses, pneumonia, E. coli, salmonella, and shigella.

There has since been considerable dispute about Leavitt's right to publish this data publicly, with BYU has been sending intimidating cease and desist orders out to individuals and organizations referencing the study. These letters go beyond reasonable demand that copyrights be respected and further demand that BYU not be mentioned in conjunction with the study at all, despite the fact this information now exists in the public domain.

Safety Of Colloidal Silver

Up until the advent of chemical antibiotics which came about in the 1940's, some very strong silver products were being used as antibiotics. Of the millions of people who used these concentrated silver products, there were no reported deaths and only 239 reported cases of generalized Argyria (EPA Report ECAO-CIN-026 Jan "91" Pg. VI-3). In that same EPA report on VI-4 it states that Gaul and Staud (1935) suggested 8 grams of silver arsphenamine (used by injection at 145,000 ppm strength) as a safe total (lifetime) dose.

They also noted that other authors suggest safe total doses of 12-15 grams, based on clinical experience. The work of Furchner et al (1968) as stated above showed that small amounts of silver did not build up in the system of primates.

According to the EPA IRIS Report on silver (Integrated Risk Information Systems) (5th , 1st paragraph) it states that a number of tests were completed to investigate the absorption and retention of ingested silver in a number of animals (including primates). In conclusion, the test work indicated that between 90-99% of ingested silver was excreted on the second day after ingestion and greater than 99% was excreted in less than a week.

In other words, almost all the ingested silver was out of the body in only two days, which indicates that silver does not build up in the system when consumed in small amounts.

Overdose (Argyria)

However, it is possible to overdose with silver, and this may lead to a rare cosmetic condition of blue skin. Its scientific name is argyria or silverism and is an irreversible blue-gray discoloration of the skin, nails and gums that's linked to colloidal silver. It can happen gradually and sneak up on you unawares, after a number of years.

You have to be pretty excessive (in fact really daft) to get it. It would require an intake of 1,000 mgm or more from the use of any silver compound, including its salts. Once established, the condition is usually permanent and is a kind of disfigurement.

The US Federal Register listed the silver products that cause argyria as silver salts, including; silver nitrate, silver arsphenamine, silver chloride and possibly silver iodide. These products were sold until about 1975 under various labels consisting of silver solutions ranging from 5-30% silver [50,000-300,000 ppm (parts per million) of silver] *(Federal Register, FDA-21CFR Part 310, pg. 53685).*

In comparison American Biotech Labs silver supplement products are only 10 ppm and 22 ppm. American Biotech Labs' EPA approved hospital/home surface disinfectant is only 32 ppm.

Other potential side effects of the liquid include: seizures and other neurological problems Kidney damage Indigestion Headaches and fatigue Skin irritation

#22 Nutritional factors

Now let's look at nutritional factors against infections. It's CRITICAL!

I have already explained that the main reason TB was conquered had nothing to do with vaccines or antibiotics; it was just improvement in nutrition for the population. It's the same story for most infectious diseases. The usually touted nonsense that we've conquered disease with antibiotics and vaccinations is completely wrong but it's believed with all the passion of religious fervor, directly against all evidence to the contrary.

Here's the proof:

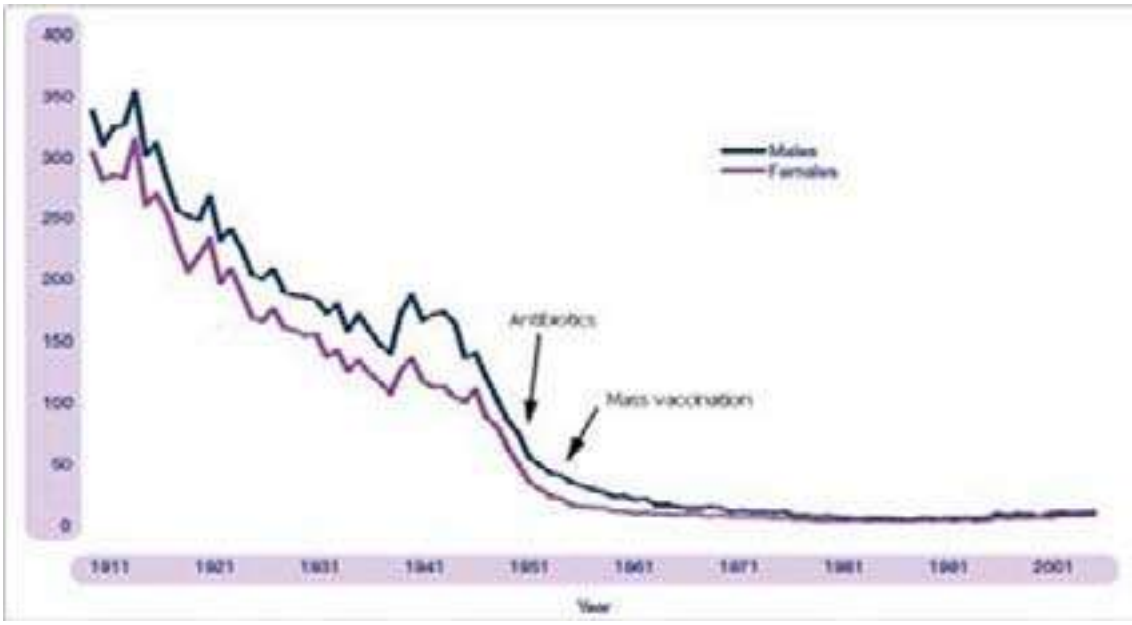

These figures are from Britain but the trend is the same the whole world over.

And TB (overleaf):

Note the sudden surge during the Second World War. This was due to temporary malnutrition and further re-inforces the point I am trying to make.

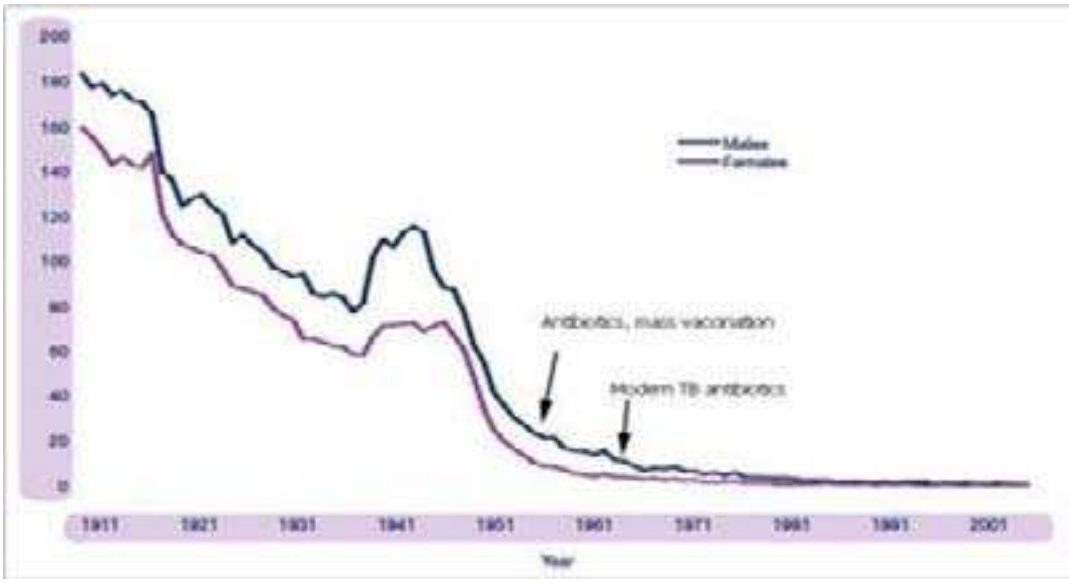

If the Americans want to ignore facts from elsewhere in the world (they usually do!), here is proof you're covered too:

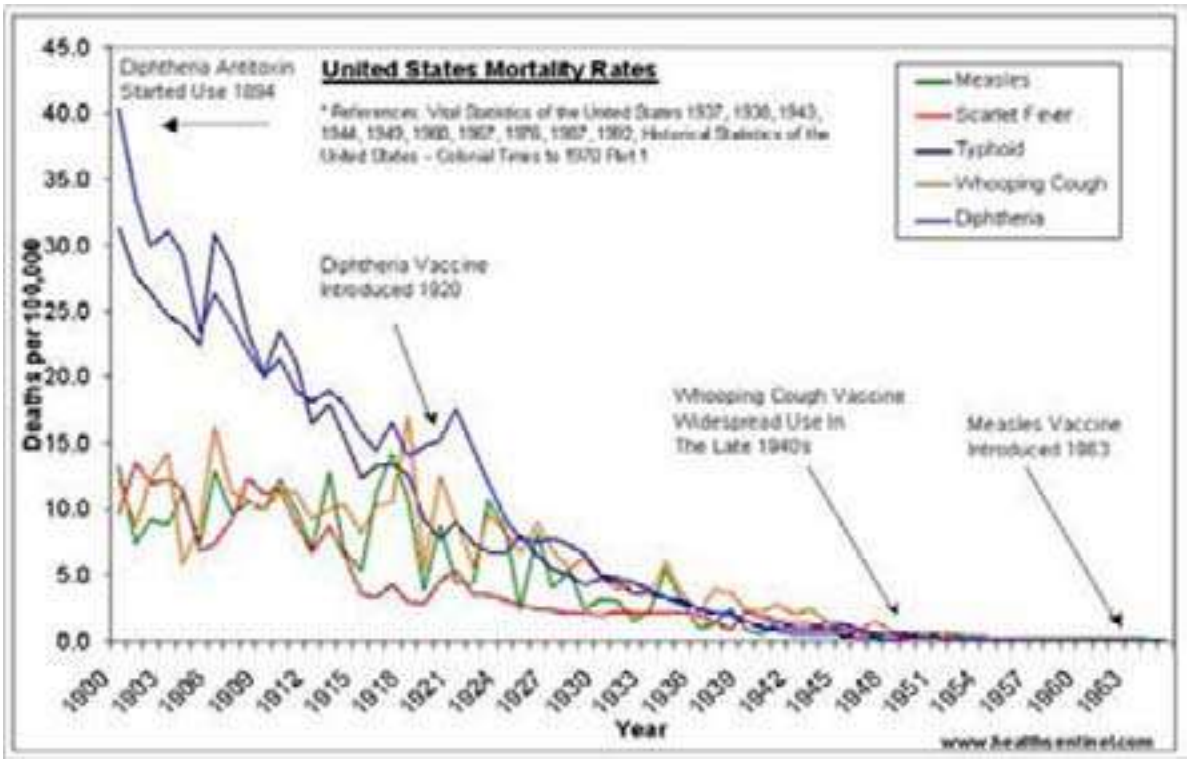

The depiction of Diphtheria vaccine introduced in 1822 is completely misleading: it was an anti-serum to the toxin, not the bacterium. Only one of these featured diseases is viral in nature (measles) but the principle applies

just fine to immunity against all pathogenic organisms. General standards of hygiene and wellbeing, good housing, plus adequate nutrition make a big difference in general immunity in the population.

Nutrition bullets

This is not a book on nutrition but here, in a nutshell, is what you should do.

Avoid sugar at all costs. You probably know that in the US the average per capita is 150 lbs. That's 3 lbs a week! Over 150 years ago Native American Indians warned against sugar: they said it weakened the body. It makes the immune system sluggish for up to 6 hours afterwards and the last thing you would want is tardy white blood cells that show up late for the action! Also it removes zinc which is very important for immunity.

Eat well. By that I mean a natural diet of natural foods with enough calories. Infectious diseases prosper only where there is malnutrition. Almost all endemic diseases (diseases which run permanently in society, not just in epidemic fashion), such as measles, TB and cholera, all declined significantly in the decades BEFORE antibiotics. The cause was better nutrition.

Remember being overweight does not mean you have "extra" nutrition: it means you have mal- or dys-nutrition. You are eating badly, eating the wrong things and ruining your body defences.

Alcohol, caffeine and tobacco are also known to lower immunity.

Instead of junk you must eat more foods containing anti-oxidants. These are contained in colored fruits, especially berries, blue, red and black. Manufactured foods which contain none of these essential life-giving food properties. It's astonishing how little infectious disease you will ever get, if you eat like this.

#23 Vitamin A

You will hear talk from some people who do not do their research properly that vitamin D is the "antibiotic vitamin". It is not. Vitamin A is the clear winner. For my subscribers to the Wholesome Living Letter (now ceased publication) I cited important clinical trials in the years before antibiotics that vitamin A in very large doses (50- 100,000 IU) killed virulent bacteria as well as antibiotics. Mortality rates moved from 100% fatal to 100% survival. That's BETTER than antibiotics!

In 1929 a milestone study was conducted by Sir Edward Mellanby, Professor of Pharmacology in Sheffield, England, for the Medical Research Council of the UK. Up to that time, puerperal sepsis was a highly fatal and untreatable condition (for instance in 1928, just one year earlier, there were 16 cases on Mellanby's pitch and all the women died). Mellanby administered high doses vitamin A to 5 women in his study—one of the first controlled clinical trials ever—and all 5 women survived! It was a triumph for science but also nutrition.

Unfortunately, antibiotics lay just around the corner and that soon put paid to the idea of a humble vitamin being remarkably effective against a killer fever. Well, please remember, just 80 years on, the clock has turned completely and we are now almost post-antibiotics. *[Mellanby E, Green HE (1929). Vitamin A as an anti-infective agent. Its use in the treatment of puerperal septicaemia. BMJ 1:984-6]*

In 1931, Mellanby published another keynote paper with the title 'Diet as a prophylactic agent against puerperal sepsis'. In it he measured the incidence of 'sepsis' in a group of 550 post-natal women. Yet the list included cystitis (9 cases), mastitis (7 cases), influenza (1 case), gonorrhea (1 case), cervicitis (1 case) and septic perineum (2 cases), endometritis (7 cases) and 1 case of streptococcal septicaemia.

Again the response to Vitamin A was remarkable. [Green HN, Pindar D, Davis G, Mellanby E (1931). Diet as a prophylactic agent against puerperal sepsis, with special reference to Vitamin A as an anti-infective agent. BMJ 2:595-598].

What is meant by high doses of vitamin A? 25,000 – 50,000 units. "But that's toxic", say the pundits, aghast. Well, which would you choose: vitamin overdose or death? The fact is that vitamin A is not toxic at these levels in the short term. Your fate is decided in 48- 72 hours! Not long enough to worry about liver toxicity, surely?

#24 Vitamin C

Now come to what is probably the most powerful of all antibiotic substances known to man. Incredibly, it's also one of the safest pharmaceuticals we have. If you are caught in a vicious pandemic, yet you can gain access to this therapy, you should do fine!

I'm talking about humble vitamin C (ascorbic acid). Actually not so humble—it has brought people out of septicemic coma when nothing else worked and regular antibiotics were powerless to save the patient.

But only when administered IV in huge doses, hundreds of times greater than doctors today would even consider.

The full story of its power is told in an important book, entitled Vitamin C Infectious Diseases And Toxins (Curing The Incurable) by Thomas E. Levy MD, JD. The author cites over 12,000 medical and scientific journal references, which is far more than I can do here.

Levy's book leans a great deal on the work of an earlier doctor called Frederick R. Klenner MD, chief of staff at the Memorial Hospital in Reidsville, North Carolina, who worked in the 30s and 40s, when vitamin C first became readily available as an affordable pharmaceutical.

Klenner pioneered his treatment on hundreds of cases and had outstanding results against many infectious diseases, using intravenous vitamin C.

Klenner maintained hospital records and fever charts that told of case after case of recovery from meningitis, encephalitis, pneumonia and serious complications following scarlet fever (Streptococcus). Many fevers from 100-105 degrees F began to diminish within minutes of intravenous vitamin C. Both viral and bacterial diseases responded. The only requirement seemed to be that the dose was large enough and treatment continued for long enough.

Polio Teasers

Adelle Davies, famous authoress of the classic text Let's Eat Right to Keep Fit, was fortunate enough to meet Dr Klenner, and she tells us one of his stories; of an 18-month-old girl suffering from polio. The mother reported that the child had become paralysed following a convulsion, after which she soon lost consciousness. When Dr Klenner first saw the child her little body was blue, stiff, and cold to the touch; he could neither hear heart sounds

nor feel a pulse; her rectal temperature was 100°F. The only sign of life, he could detect was a suggestion of moisture condensed on a mirror held to her mouth. The distraught mother was convinced that the child was already dead.

Klenner injected 6000 mg of vitamin C into the child's blood; four hours later she was cheerful and alert, holding a bottle with her right hand, though her left hand was still paralysed.

A second injection was given; soon the child was laughing and holding her bottle with both hands, all signs of paralysis gone. She recovered fully.

To show just how far this can be pushed, Levy cites an adult case, a woman, also a polio victim. She had considerable pain in the hamstring area, pain in neck and pain in the lower back. She had a natural desire to keep her entire body static to avoid painful moments. Her fever reached 104.6°F, along with a sore throat that had relapsed after initial treatment with antibiotics, aspirin and fruit juice two weeks earlier.

Although the patient weighed less than 120 lbs. Klenner nevertheless immediately administered 22,000 mg (22 g) of vitamin C. by slow intravenous injection, using a large 100 cc syringe. Plus he prescribed 1500 mg of vitamin C with juice every two hours by mouth.

Twelve hours later, the woman was free of her headache, and her fever was down to 101.4°F. Klenner gave her another 22,000 mg injection; this caused nausea and vomiting which lasted for around 30 minutes. Then, 24 hours later, her temperature had further dropped to 100.8°F, with a definite clinical improvement.

She was continued on 18,000 mg injections given every 12 hours (equivalent to 36 g a day). After a few days, the IV vitamin C. was discontinued, but the patient was asked to continue by mouth for an additional week taking 1500 mg every three to four hour.

Klenner noted that the patient had an almost complete elimination of pain, except at the knees, after the first 48 hours. The temperature normalised in 84 hours. The patient finally made a complete recovery.

Although these are viral cases, similar outstanding results are to be obtained with potentially fatal bacterial infections, such as tetanus, diphtheria, pneumococcal pneumonia, TB, leprosy and typhoid fever. Klenner came to speak of vitamin C as "the antibiotic par excellence".

Blood Levels

Significantly, Klenner found that vitamin C levels vanished completely from the blood when the patient was under the stress of an acute infection. Nor could any vitamin C be found in the urine. This severe deficiency might be why patients respond so dramatically to massive doses of the vitamin. We now know that this lack is caused by vitamin C being used up by neutralizing toxins and blasting viruses and bacteria; it effectively eliminates the danger, but is lost in doing so.

The rational basis of the high dose technique is therefore to administer vitamin C intravenously until it began to spill over into the urine and could be detected once again. Monitoring blood levels is obviously even more accurate but not always possible and not necessarily desirable when urgency can save a life; after all, vitamin C is pretty harmless. In any case, it is the intracellular levels that count, which may be much depleted, even when blood plasma levels appear reasonable.

Hence Klenner's urgency and the need to administer the doses as rapidly as possible, to be sure the plasma was overloaded and thus that the vitamin C would be sure to flood into the cells. Modern research, by the way, shows us that white blood cells may carry up to 80 times the residual blood levels of vitamin C, thus being sure to bring plenty of it to the site of an infection. So Nature knows how good this stuff is!

Klenner published at least 20 significant papers and in 1949 addressed the American Medical Association, to tell colleagues what he'd achieved. Yet his work is now virtually lost and any mention of it is dismissed a myth and nonsense. The truth is now known only to a few physicians and practitioners [it was my "drug of choice' to take with me to the danger zone rescue mission after the 2004 tsunami and kindly donated by friend of Deseret Biologicals, Sandy, Utah].

Klenner achieved outstanding recoveries in diseases which at that time were considered to be virtually untreatable.

Bacterial Diseases

Thomas Levy also quotes extensive research by other scientists and doctors, using large doses of vitamin C to overcome severe and sometimes fatal bacterial infections, including the following:

- Rocky Mountain spotted fever.
- Pseudomonas, a notoriously difficult to treat bacteria.
- Bacillary dysentery and even amoebic dysentery.
- Brucellosis.
- Malaria (not a bacterial disease, but transmissible parasite called Plasmodium).
- Typhoid fever (not to be confused with typhus, which also responds but is viral in origin)
- Leprosy
- Staphylococcus
- Streptococcus (leads to rheumatic fever).
- Tuberculosis
- Tetanus,
- Whooping Cough (Pertussis)
- Diphtheria

Note also: studies have proven that large doses of vitamin C helps to prevent allergies of varying kinds. I've given IV gallons of the stuff over the years. It even counters the effects of poison oak, poison ivy, snakebite, black widow spider bite and carbon monoxide poisoning.

So if treatment with intravenous vitamin C is so effective in such a wide variety of conditions, how is it that most doctors have never even heard of it, much less use it in their office?

Klenner Protocol

The trouble is that the scientific literature is dogged with studies which purport to investigate the effects of vitamin C but which used such tiny doses as to be worthless. It is an almost universal mistake among doctors to believe that ascorbic acid has only vitamin like properties and these manifested only a few hundred milligrams at most. It is even cited in the literature that the body will block blood levels above about 300 mgms. What Thomas Levy turns to calling "Klenner-sized doses" of vitamin C are very large—around 500- 700 mgms per kg of body weight, repeated several times a day. That would range from 20 grams daily for an infant; 40 grams for a child; to 25 grams for a slight-built woman; to 50 grams for a hefty man.

Clearly this is beyond the vitamin nature of ascorbic acid and indicates that it has a very important detoxing and antimicrobial property.

This is critically important because most bacteria exert their deadly effect by means of a toxin. So a substance which both destroys the pathogens and their toxins is indeed a godsend.

Take diphtheria, which once had a dreadful mortality rate of 80% (now down to 5- 10%). This disease kills by the secretion of a sticky dense membrane, which forms in the throat and suffocates the child. But there is also a deadly toxin, Diphtheria A, which itself is rapid fatal once present in sufficient quantity.

To treat this condition, Klenner recommended huge dose, as described, of 500- 700 mgm per kilogram of bodyweight, run into a vein through a wide bore needle "as fast as the cardiovascular system would allow". This is several thousand times what most doctors (in their ignorance) would consider safe. Yet even in these very high doses, ascorbic acid shows no ill effects on the patient, making vitamin C one of the most remarkable substances in human physiology.

There have been many published studies on this topic but in one report Klenner describes the fate of three children living in the same neighborhood, each with diphtheria. All three children had different doctors. The little girl under Klenner's scare was given 10 g of vitamin C in an intravenous push with a 50 cc syringe, every eight hours for the first 24 hours and then every 12 hours. She was also given 40,000 units of diphtheria antitoxin, injected into her abdomen. The other two children received the antitoxin as well, but they did not receive any vitamin C. They both died but Klenner's patient survived, later becoming a nurse.

[Klenner F. Observations of the dose and administration of ascorbic acid, when employed there are in the range of the vitamin in human pathology Journal Of Applied Nutrition, 23 (3&4); 61-88.]

It should be noted that Klenner's work with diphtheria is ably supported by other studies of the time. Harde and Philippe, demonstrated that lethal doses of diphtheria toxin premixed with vitamin C were no longer lethal when injected into guinea pigs. Without the vitamin C, the toxin killed the guinea pigs in just a few days. *[Harde E and Phillippe M. Observations sur le pouvoir antigene mélange toxine diphtherique et vitamin C. Compt rende Acad d sc 9:738-739]*

Levy cites several other studies from different countries, also showing vitamin C protected guinea pigs from the fatal effects of diphtheria toxin.

Streptococci and Staphylococci

What about these common human pathogens, which can produce infections varying from minor suffering to a fatal outcome? After all, we are very interested in Staph, because of MRSA.

Same great story. Vitamin C triumphs.

One study looked at two children with defective abilities of their white blood cells to kill bacteria. They are especially susceptible to repeated skin infections with staphylococcus. The study reported that vitamin C. was effective in delaying and eventually suppressing infectious episodes. *[Rebora A. and Crovato F. F Dallegri, and F. Patrone (1980) Repeated staphylococcal pyoderma in two siblings with defective neutraphil bacteria killing. Dermatologica 160(2):106-112].*

A much earlier study (1941) was able to demonstrate an inhibition of the growth of Staphylococcus aureus, even at relatively low doses. *[Gupta G. and B. Guha (1941) The effect of vitamin C and certain other substances on the growth of microorganisms. Annals of Biochemistry and Experimental Medicine 1(1):14-26]*

Kodama and Kojima were able to demonstrate the ability of vitamin C. to render staphylococcus related toxin, harmless. (Remember, I explained that the main deadly effect of virulent bacteria is the toxins that they produce). *[Kodama T. and T. Kojima (1939) Studies of the staphylococcal toxin,*

toxoid and antitoxin; effect of ascorbic acid and staphylococcal lysins and organsisms. Kitasato Archives of Experimental Medicine 16:36-55].

Yet another case report described an elderly woman with an ulcer on her left cheek infected with the presence of staphylococcus aureus. She had had the condition over three years, but it rapidly healed with vitamin C therapy. *[Lederman E. (1962) Vitamin C deficiency and ulceration of the face. The Lancet 2:1382].*

Nakashini reported that the direct (topical) application of vitamin C to a bedsore was able to remarkably enhance the bacteria killing effect of antibiotics. He also noted that MRSA subsequently disappeared from the wound. *[Nakanishi T. (1992) [A report on a clinical experience of which has successfully made several antibiotic-resistant bacteria (MRSA etc) negative on a bedsore] Article in Japanese. Igaku Kenkyu. Acta Medica. 62(1):31-37.*

It even works in animals, test-tube experiments showed that the presence of vitamin C. significantly increase the ability of white blood cells to kill staphylococcus aureus.

[Andreason C. and Frank D. (1999) The effects of ascorbic acid on in vitro heterophil function. Avian Diseases 43(4):656-663.]

Remember the work I already alluded to, by Kelly (1944), showing that pathogens are almost universal in the mouths and on the tonsils of healthy hosts. It is only when immunity is compromised by nutritional deficiency—in this case lack of vitamin C—that infections can become established and overcome the host.

So in a way we are going round in circles and saying that good nutrition is your best protection against pathogens. If you do it right you may never even contract a disease, never mind succumb to it, even during a worldwide pandemic in which others are dying by the million!

But if you get MRSA, epidemic or not, make sure you call this section to the attention of a competent practitioner who is licensed to carry out this procedure. You will survive.

Administration

You will gather from reading this far that intravenous vitamin C can be a lifesaver, even for a patient afflicted with the most deadly infection and almost at the point of death.

But obviously not everyone will be able to find the help of a physician to administer IV vitamin C, especially in the event of a worldwide pandemic. To administer therapeutic doses to yourself, you only need to take vitamin C powder using the "fill and flush" method; that means to take doses by mouth, increasing by a teaspoonful at a time, until it causes diarrhea. We believe this happens only when the tissues have become saturated with the vitamin.

For a child, Adelle Davis suggests putting one cup of hot water in a liquifier, adding 50 tablets of vitamin C (500 mg each), blending well, sweeten to taste with honey, pour into a glass jar, and keep refrigerated. Doses can be administered mouthful at a time, or teaspoonful at that time.

If one does not have a liquifier, Davis suggest crushing 50 tablets and dissolving these in a cup of hot water. Each teaspoon of such a solution contains 500 mg. If 100 tablets (500 mg each) are dissolved in a cup of water, each teaspoon a solution would supply 1 g (1000 mg).

For any infectious disease in a sick child, mild or severe, administering a teaspoon more of vitamin C solution, sweetened in this way, can be a godsend when a physician cannot be reached, as for example, during the night.

Note that synthetic vitamin C does not contain enzymes found in natural foods; therefore it is quite stable to heat and storage. But once stirred into foods, such as fruit juice, enzymes will begin to activate and readily destroy it.

[Davies without any and L. let's eat right to keep fit, Harcourt Brace Jankovich, New York, 1954, 1970, 132 to 134]

There are no right and wrong doses of vitamin C as such. All these treatments are based on empirical experience (basically trial and error). But this wonderful natural substance is very tolerant of error, and it's almost impossible to overdose a person on it.

Important note:

Vitamin C vs. Ascorbic Acid

Don't listen to the ignorant nonsense widespread on the Web that vitamin C is "good" and "natural", while ascorbic acid is "bad" and synthetic. They are both IDENTICAL in physiological properties; just different names for the same thing.

All the good recovery stories I have just cited were all with synthetic vitamin C. It simply isn't possible to find the therapeutic high doses I have described from natural sources. So there is no question that synthetic vitamin C does the same job, or better.

What I did find, though, was that the manufactured source of vitamin C could cause unpleasant allergic reactions. The most common starting point is corn, so a sensitive corn-allergic individual could react to it.

But other plant sources are available, such as palm. These would be safer.

#25 Vitamin D

Throughout this section, I'll be referring to the D3 form (cholecalciferol or calciol), which has powerful immune booster properties. Without doubt D is the most powerful immune booster vitamin we know. It is highly effective at reducing mortality from all causes (recent 2007 studies). It lowers the cancer risk by over 60%. You want to be taking adequate amounts as of now. Don't wait for an emergency.

In April 2005, a virulent strain of influenza hit a maximum-security forensic psychiatric hospital for men that's midway between San Francisco and Los Angeles. John J. Cannell, a psychiatrist there, observed with increasing curiosity as one infected ward after another was quarantined to limit the outbreak. Although 10 percent of the facility's 1,200 patients ultimately developed the flu's fever and debilitating muscle aches, none did in the ward that he supervised. Even though they had mingled with patients from infected wards before their quarantine, none developed the illness.

A few months later, Cannell ran across a possible answer in the scientific literature. In the July 2005 FASEB Journal (Federation of American Societies for Experimental Biology), an article reported that vitamin D boosts production in white blood cells of one of the antimicrobial compounds that defends the body against germs.

Immediately, Cannell realized, the high doses of vitamin D that he had been prescribing to virtually all the men on his ward were the reason for the mass immunity.

Vitamin D stimulates cathelicidin production. The cathelicidins are an important group of antimicrobial proteins. They work by punching holes in the external membrane of a microbe, permitting its innards to leak out. They also trigger the congregation of white cells when we get an infection.

You can think of these as "on-board" antibiotics; part of our innate immunity.

The FASEB Journal article also triggered Cannell's recollection that children with rickets, a hallmark of vitamin D deficiency, tend to experience more infections than do kids without the bone disease. He shared his flu data with some well-known vitamin D researchers, and they urged him to investigate further.

On the basis of more than 100 articles that he collected, Cannell and seven other researchers now propose that vitamin D deficiency may underlie a

vulnerability to infections by the microbes that cathelicidin targets. These include bacteria, viruses, and fungi, the group notes in a report available online for the December 2006 Epidemiology and Infection.

This is only a hypothesis, "but a very credible one" My take on this too is that the population malnutrition I was referring to in the previous sections, which was the main reason the infectious diseases declined, could be as much due to improved vitamin D status as other factors.

Scientists are beginning to suspect that would hold true for the decline in TB, also. A study published in 2006 investigated the relationship between vitamin D and susceptibility to tuberculosis and showed dramatically better recovery in patients supplemented with 10,000 IU daily. 100% of patients survived, while normally 40 - 50% will die, despite treatment *[Acta Med Indones. 2006 Jan-Mar;38(1):3-5]*

Maybe vitamin D status is the MAIN reason we fight infections better when we are properly nourished. In any case, the moral is clear: don't let yourself be deficient.

This article in the prestigious New England Journal Of Medicine made it clear that cathelicidn defiency was associated with increases susceptibility to Staph. infections (hence MRSA) *[Ong, P. Y., Ohtake, T., Brandt, C., Strickland, I., Boguniewicz, M., Ganz, T., Gallo, R. L. & Leung, D. Y. (2002) N. Engl. J. Med. 347, 1151-1160.]*

Ignored stupid and criminal government advice here in the USA and take at least 1,000 units a day. 2,000- 5,000 units would make more sense in an epidemic or if you are battling MRSA.

Vitamin D Cream

Vitamin D as a cream may have important potential for those with MRSA of the skin.

Independently, dermatologist Mona Ståhle of the Karolinska Institute in Stockholm reached a similar conclusion. Her team administered an ointment containing a drug mimic of 1,25-D to the skin of four healthy people. The salve hit "the jackpot, right away," Ståhle says. In the May 2005 Journal of Investigative Dermatology, her team reported that where the ointment had been applied, cathelicidin-gene activity skyrocketed as much as 100-fold.

The team also found evidence of a localized increase in the concentration of cathelicidin.

Scientists found that vitamin D was also effective against TB. The sunlight/ vitamin D effect might explain why blacks are racially more prone to TB. It would also tell us one reason why the sanitoriums, with their keen emphasis on fresh air and sunshine, had some measurable therapeutic results, even before the days of hospitalization.

120 or so reports over the past 70 years have pointed to a link between vitamin D and resistance to infections. Five studies since the 1930s that have linked reduced risks of infectious disease to dietary supplementation with cod liver oil, a rich source of vitamin D.

Just think about what you do know for a moment--- in winter, colds, flu, and other respiratory diseases are more common and more likely to be deadly than they are in summer. During winter, ultraviolet-light exposure tends to be low because people spend more time indoors and the atmosphere filters out more of the sun's rays, especially at mid and high latitudes.

Sun exposure—in moderation—might also prove therapeutic, Ståhle's team suggested in the November 2005 Journal of Investigative Dermatology. The scientists showed that in eight fair-skinned people, a single dose of ultraviolet-B radiation—just enough to evoke some skin reddening the next day—activated the vitamin D receptor and the cathelicidin gene in the exposed skin.

This reminds me that in preantibiotic days, tuberculosis patients were put on a fresh-air-andsunshine regimen. Could the vitamin D so acquired account for the cures this system sometimes produced?

Take a minimum of 2,000 IU a day, double or treble that in an epidemic. Ignore official advice that you don't need more than 200 IU a day. It will kill you. A tablespoon has around 1400- 1500 IU.

#26 Iodine

Here's a much neglected mineral deficiency that has profound effects of the performance of the immune system.

According to the WHO, 2.2 billion people worldwide are at risk for Iodine Deficiency Disease. Iodine deficiency impairs immune function. The myth that it only affects people in areas remote from the sea is made nonsense by these figures. Deficiency is everywhere. According to Dr David Brownstein iodine intake in the USA has fallen by 50% during the last 30 years.

We had iodized table salt but any intelligent doctor can see the clear evidence that iodine is not absorbed from salt. It was iodine in bread that actually helped the problem. But 30 years ago manufacturers ceased adding iodine to bread and instead used bromine, which counteracts iodine! Any wonder then?

Test For Iodine Deficiency

Dip a cotton bud in iodone solution, such as Lugol's or tincture of iodine and make a patch on your skin. If the yellowish stain disappears in less than an hour; it means your body is lacking crucial iodine and has soaked it up. If the stain remains for more than four hours, you iodine levels are fine.

Iodine levels are not just important for immunity. Low levels of iodine will impair thyroid function. Since the thyroid too is involved in the immune response, it's a double-whammy for your immune system if you are low.

If there is an epidemic pending or occurring, get yourself plenty of iodine fast. When times are safer, be more concerned about regulating the dose

Remember, women are naturally prone to iodine deficiencies. That's because the thyroid gland in women is twice as large as in men -- so under normal circumstances, women need more iodine. However, when there is increased stress (and when is a woman's life not stressful?), the need for iodine can double or triple.

Take 5 mg a day minimum, start now, don't wait for infections to strike. Ignore claims that iodine is toxic. So is anything if you take too much. The necessary doses are 10- 50 times higher than fashions claim. One of the best ways to boost your iodine levels is to add seaweed sea vegetables to your

diet. Just one teaspoon of sea vegetables a day can help you regain normal iodine levels. Incorporating seafood and fish into your diet can also help. Other foods that contain iodine are eggs and dairy products, including milk, cheese and yogurt, onions, radishes, and watercress. Some foods, called goitrogens, should be omitted for a while as they hinder iodine utilization.

These included kale, cabbage, peanuts, soy flour, Brussels sprouts, cauliflower, broccoli, kohlrabi and turnips.

Tincture of iodine is often found in emergency survival kits, used both to disinfect wounds and to sanitize surface water for drinking.

When an alcohol solution is not desirable, Lugol's iodine, an aqueous solution of iodine in potassium iodide solution, or povidone iodine (Betadine), a PVPI solution, can be used.

When using free iodine to sanitize surface water, it should be left to sit for 30 minutes before drinking, allowing time for all viruses and bacteria to be killed. If the water temperature is less than 20 °C (68 °F), sitting time should be extended to several hours. To purify 1 L (34 oz) of water, 0.3 mL (0.01 oz) of 2% tincture should be used. Cold or cloudy water should be given 2.4 mL (0.08 oz) of 2% iodine, and should be left to sit for several hours.

Following disinfection, the iodine odor and taste can be removed by adding powdered vitamin C, which converts the iodine to iodide. A similar reaction also removes chlorine from chlorinated water.

Iodine used to sanitize water is also available in tablet or crystal form. One form or another should be available at health stores, and trip outfitters.

#27 Zinc

Who doesn't know that zinc helps fight infection? It also helps with wound repair and a number of other key healing functions.

Zinc is an essential mineral that is naturally present in some foods, added to others, and available as a dietary supplement. Zinc is also found in many cold lozenges and some overthe-counter drugs sold as cold remedies.

Zinc is involved in numerous aspects of cellular metabolism. It is required for the proper functioning of approximately 100 enzymes and it plays a role in immune function, protein synthesis, wound healing, DNA synthesis and cell division.

The critical point to note is that a daily intake of zinc is required to maintain a steady state because the body has no specialized zinc storage system. Yet our diets are notoriously lacking in zinc. Studies show that an average diet does not meet the recommended requirements (15 mg daily).

Partly it is removed in the processing of food, especially in refining grains. Phytate inhibition further reduces the bio-availability of zinc. To make matters worse, crops grown in Europe and the US may be short of zinc because the soil has become exhausted.

Signs of a lack of zinc are said to be white flecks in the finger nails and an impaired sense of taste. Professor Bryce-Smith's zinc status test rests on the fact that zinc-deficient individuals cannot taste the metal in solution as zinc sulphate. After adequate supplementation, taste appears to return.

Zinc works in concert with other vitamins and co-enzymes. For example, vitamin A metabolism needs zinc. B6, so helpful in many conditions, is far more effective in the presence of zinc and magnesium. Zinc appears to counteract copper and an imbalance of the ratio of these two metals is associated with an increased tendency to allergies.

Zinc supplements reduce the average duration of the common cold. Other clues suggest the importance of zinc in immunity.

Supplements

Zinc is available in a large number of proprietary preparations such as in the gluconate or orotate form. Doses of around 15 mg are required, but beware: quoted weights usually include the whole formula. A tablet with 100 mg of zinc as gluconate may have only 2 mg of elemental zinc!

Research has not determined whether differences exist among forms of zinc in absorption, bioavailability, or tolerability. However I recall a paper suggesting that the citrate form is best absorbed. For cheapness and convenience I often give zinc sulfate as a powder, 7 g dissolved in a pint of water. The patient takes a teaspoon per day of this liquid, providing about 15 mg daily.

In addition to standard tablets and capsules, some zinc-containing cold lozenges are labeled as dietary supplements.

Ironically, after what I said about the returning sense of smell, there have been several case reports of anosmia (permanent loss of smell) from the use of zinc-containing nasal gels or sprays, and so this raises questions about the safety of intranasal zinc.

Health Risks from Excessive Zinc

Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches. Intakes of 150 - 450 mg of zinc per day have been associated with such chronic effects as low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins. Reductions in a copper-containing enzyme, a marker of copper status, have been reported with even moderately high zinc intakes of approximately 60 mg/day for up to 10 weeks.

Therefore I do not recommend that you exceed 15- 20 mg a day of elemental zinc.

However- it may not be that simple.

Although zinc is clearly needed for competent T-cell mediated immunity, it has the opposite effect on neutrophils and macrophages, causing a reduction in their motility and ability to ingest invaders. That could explain a recent

cautionary finding: that zinc may favor the growth and activity of bacteria over the cells of the host (rather like excess iron, see next section).

In an article appearing in the Dec. 1 2008 online edition of Proceedings of the National Academy of Sciences, researchers in UC's department of molecular genetics, biochemistry and microbiology detailed findings that the presence of zinc is crucial to the formation of infection-causing biofilms.

Staphylococci can grow as biofilms, which are specialized communities of bacteria that are highly resistant to antibiotics and immune responses. They are remarkably adhesive and can grow on many surfaces, including implanted medical devices such as pacemakers, heart valve replacements and artificial joints. Preventing or inhibiting the growth of such biofilms would dramatically reduce the incidence of staph infections.

UC researchers in the lab of Andrew Herr, PhD, found that zinc causes a protein on the bacterial surface to act like molecular Velcro, allowing the bacterial cells in the biofilm to stick to one another. Zinc chelation, or removal, prevented biofilm formation by Staphylococcus epidermidis and Staphylococcus aureus.

So zinc is a definite immune booster but has the surprising effect of favoring staphylococci and other invaders. Stay tuned for updates.

#28 Iron Overload

Here's where nutrition gets tricky, even dangerous. Excess iron in the human body causes fulminating fatalities, whenever there are serious bacterial infections. Iron favours the invader far more than the immune system.

The public has it so hammered into them that virtually everyone is iron deficient and "Better take some extra, just to be safe". This is the grossest nutritional mistake that is made by ignorant or foolish MDs today. Iron EXCESS is far from rare and is very dangerous indeed. If you have it and land in an epidemic or pandemic, you are for it!

Did you know that patients with iron overload disease are told not to walk on beaches barefoot? This is on account of a bacterium common in all sea water called Vibrio vulnificus. This bacterium, when it encounters stored iron in our bodies, becomes catastrophically toxic in the presence of excess iron. But how common is iron overload disease?

About 20% of the population is in danger. There are 42 million people at risk for iron overload in the U. S. population alone. Some population segments such as the Scott/Irish and the African Americans have twice the double gene frequency and an amazing 20% carrier rate in the U.S.

You may be risking your health if you take otc multi vitamins or minerals with iron or vitamin C without knowing your iron storage status. Vitamin C has been found to mobilize stored iron into the heart muscle where it sets up arrhythmia or heart rhythm disturbances. It can also cause people to over absorb iron even from their ordinary diets. Do not take vitamin C supplements if you have, or might have this condition, until you have found out for sure.

Meanwhile stupid or ignorant doctors go on prescribing iron pills (huge doses around 250 mgm) as if they were sweeties and not a compound which is more lethal than arsenic to millions of people!

Never mind iron deficiency; it is much more important to know if someone is in iron overload.

Maybe you are? Two lab tests will settle it: Transferrin saturation. Serum Iron (SI) divided by Total Iron Binding Capacity (TIBC) and Serum Iron (SI) gives Transferrin Saturation TS. It should be 12-45%.

Serum Ferritin. Normal range is: 5 to 150.

Without being in possession of this important laboratory information, remember you have a

1:5 risk of iron overload and you will die very swiftly if a plague of any organism does occur. Get it fixed before the problem occurs (the cure is chelation or, in an emergency, blood letting).

Overleaf there's a picture of what vibrio vulnificus did to one man's leg, just before the amputation. I DON'T RECOMMEND YOU LOOK AT THIS, UNLESS YOU HAVE A GOOD STOMACH.

This is a man who went fishing one day, got a tiny scratch on his leg and just wiped the blood off. This bacteria moves fast. He complained next morning about tightness in the leg and was running a fever that evening and he all but died that night in agonizing pain that no meds could relieve.

The irony is he never even got out of the boat.

An above-knee amputation saved his life and after 10 days in a coma in intensive care he pulled through.

I urge you to take all care, get your iron levels checked now and learn EVERYTHING you can about antibiotic substitutes. Get rid of any MD who scoffs. Find a good one.

Doctor's do not give warnings about vulvificus to immune compromised patients (Kidney, Liver, Hepatitis C, Cancer, Leukemia, immune suppressant drugs, the list is long). If that applies to you, stay out of the water on the Gulf Coast between April and October.

Remember: vulnificus can enter the body through a tiny cut or bite. If you must go fishing, take with you a bucket filled with bleach water or hydrogen peroxide and dip your hands in it several times an hour.

If you suspect you (or a loved one) got unlucky, use the MMS protocol immediately, while en route to the hospital.

#29 What About Herbs?

We hear about tropical rainforests and the medicinal wonders they produce. Actually the ordinary garden also contains many such substances, as some of you may know.

Even conventional medicine is getting on to this; 20 years ago kids with leukemia were in trouble; 4 out of 5 died. Now it's 4 out of 5 survive, thanks to the periwinkle plant (Vinca major). This humble little ground cover plant has given us vinblastine and vincristine, two very powerful chemo agents.

But really, when we say "herbs", we usually mean gentler phytotherapies than this!

Probably the most famous herb for beating infections is Echinacea (Coneflower). It's not the best, in my opinion, but certainly deserves a favorable mention. It fortifies the immune system.

But I find the results of using just this herb disappointing. Moreover numerous clinical trials have failed to show much positive effect. Not all studies are corrupt and bent only on rubbishing natural therapies! I would not ask anyone to rely much on Echincea as protection in an epidemic or real pandemic.

The best way to take Echinacea is as a homeopathic compound. I have in mind one product in particular, which is Echinacea compositum, by the German manufacturer HEEL. It's best taken as liquid vials: if no doctor is available to administer it IV, a patient can still take the ampoules, one dissolved in water every third day (one day ON, two days OFF).

There are other immune fortifying herbs, such as Astragalus, Boneset, Calendula, Lady's Mantle (Alchemilla) and yarrow. Ginger has powerful anti-infective, anti-parasitic, and anti-inflammatory properties.

Compare these also with the benefits of fungi and mushrooms, described in another section (#38).

Thing is, herbs have a place but I wouldn't really rely on them if an infection was raging in my body. I'd want something that killed bacteria (bactericidal) or at least held them down while the immune system got to work beating them to death (bacteriostatic)!

There are some plant sources which are definitely powerful antibiotics. They hold in check, and even kill, bacteria.

Best-known by far, of course, is common garlic. Some others are probably better.

We can use herbs in a variety of ways, apart from just eat them. For example, herbal infusions, herbal baths and herbal wraps, as well as dried leaf powders and capsules.

Then there is essential oil therapy. This, as you will see in a later section, is very different from recreational "aromatherapy". Essential oils were in fact the first serious antibiotics that we had in the 20th century. These oils are still there and still work. Doctors ignore them but that doesn't mean they are not to be preferred to synthetic manufactured compounds with complicated side effects!

Herbs can also be smoked! I found this study on PubMed from the Department of Pharmacy and Pharmacology, Faculty of Health Sciences, University of the Witwatersrand in South Africa (Abstract): "Validation Of Smoke Inhalation Therapy To Treat Microbial Infections."

Aim Of The Study: In traditional healing, the burning of selected indigenous medicinal plants and the inhalation of the liberated smoke are widely accepted and a practiced route of administration. This study elucidated the rationale behind this commonly practiced treatment by examining the antimicrobial activity for five indigenous South African medicinal plants commonly administered through inhalation (Artemisia afra, Heteropyxis natalensis, Myrothamnus flabellifolius, Pellaea calomelanos and Tarchonanthus camphoratus).

Material And Methods: An apparatus was designed to simulate the burning process that occurs in a traditional setting and the smoke fraction was captured for analysis and bioassay. Methanol and acetone extracts as well as the essential oil (for the aromatic species) were prepared and assayed in parallel with the smoke fraction.

Results: Antimicrobial data revealed that in most cases, the 'smoke-extract' obtained after burning had a better effect than the corresponding solvent extracts and essential oils. So the "smidging" tradition of the North American indians was validated.

The report concluded that "These results suggest that the combustion process produces an 'extract' with superior antimicrobial activity and

provides in vitro evidence for inhalation of medicinal smoke as an efficient mode of administration in traditional healing."

[J Ethnopharmacol. 2008 Oct 28;119(3):501-6. Epub 2008 Aug 19.]

Homeopathy: Section #41

Finally, don't forget that many homeopathic remedies (section 41) are also derived from herbs and have similar or related properties.

#30 Calendula

This plant sits halfway between the immune fortifiers and actual antibiotic herbs. It has a definite antispectic action and a measurable antibiotic action. It's great for minor skin infections, such as wounds and abcesses.

Calendula officinalis (pot marigold) comes from Latin and means "the first day of the month". This wonderful annual, which grows up to 28 inches tall, produces cheerful flowers that have a faint but distinctive scent. Its leaves can be added to salads while the flowers add a colorful garnish to many dishes (some people even eat the garnish!)

Medicinal Calendula preparations are usually made from either the whole flower heads or just the petals. The flower head contains an essential oil that has an antibiotic effect and lends the flower its characteristic scent. Other components include calendon, which also has a strong odor, and a carotene-like dye calendulin.

Calendula works well as a fairly strong antiseptic properties both topically and internally. Applied externally to the skin, the plant's antibiotic action helps promote the painless healing of minor wounds by reducing inflammation and pus formation.

I've prescribed calendula ointment for decades as a burn remedy. It helps keep the wound antiseptic and promotes healing without scarring.

Calendula can also be used as a gargle to relieve sore throats.

Making Calendula tea:

Pour 1 cup of boiling water over 1-2 tsp. of dried calendula petals. Steep for 10 min, then strain. Drink 2-3 cups of warm tea daily. Use as a gargle for sore throats.

For immediate dressing of wounds pluck (or buy) fresh flowers and squeeze to extract the juice, which you can apply directly to wounds.

Calendula ointment can be bought in stores or prepared at home by mixing a few drops of calendula oil with skin lotion. Apply it to minor burns, bruises, cuts and scrapes. The homeopathic form of Calendula is best taken as 30C tablets. So-called homeopathic Calendula ointment is also available but at 1X (ten times diluted) it's hardly homeopathic. It cost just a few dollars.

#31 Garlic

It was used by the ancient Egyptians, Chinese, the Greeks and Romans. In 1858, Louis Pasteur demonstrated the powerful antibacterial properties of garlic. It was used in both World Wars. When no other antiseptic or antibiotic was available wounds were smeared with crushed garlic juice and then bandaged. In WW2 the Russians used it when antibiotic supplies ran out. It was called "Russian Penicillin".

Modern research has shown that garlic juice can slow the growth of (and even kill) more than 60 species of mould, and more than 20 species of bacteria, including some that are very virulent. It is also currently attracting attention because of its ability to lower blood pressure, cholesterol, and for its possible anti-cancer properties.

The active ingredients are ajoene and allicin. Ajoene breaks down via sulfenic acid to allicin when it is crushed. Allicin is the chief antibiotic compound. Allicin gives rise to the characteristic garlic smell. Don't be fooled by sales talk that garlic oil and capsules have the same effect as raw, stinky garlic!

1 mgm of allicin is said to be equivalent to 15 standard units of penicillin. The standard dose of penicillin is around 1500 Units, so 100 mgms of allicin could be equivalent to a penicillin dose!

There are over 2,000 studies on the antibiotic efficacy of garlic.

Microbiologist Dr Ron Cutler, based at the University of East London, claims that the garlic compound allicin not only kills established varieties of MRSA, but also destroys the new generation of 'super-superbugs' that have evolved resistance to Vancomycin and Glycopeptides, the powerful antibiotics widely considered to be the last line of defence against MRSA.

Allicin can cure patients with MRSA-infected wounds within weeks, according to in vitro research presented at the Institute of Biomedical Scientists congress in Birmingham during October 2003 and was published in the Journal of Biomedical Science 2004.

[Cutler, RR; P Wilson (2004). "Antibacterial activity of a new, stable, aqueous extract of allicin against methicillan-resistant Staphylococcus aureus (PDF file)". British Journal of Biomedical Science 61 (2): 71-4. http://www.allimax.us/Cutler.pdf. Retrieved on 20 Feb 2009.]

After showing that allicin destroys the MRSA microbe in laboratory trials, Cutler has now teamed up with the firm Allicin International to develop topical treatments including a nasal cream, oral capsules and soaps that have proved effective against both MRSA and GISA.

Another study published in 2002 found that raw garlic consumption could help limit the dam-age done to the heart after surgery because of its natural antioxidant properties. Supplements of allicin have also been shown to reduce risk of colds, prevent high blood pressure and kill cancer cells. So eat it!

Garlic may be one of the reasons the so-called Mediterranean diet prolongs life; it includes lots of garlic, fresh and cooked. If you are not used to using this amazing plant flavor, it's time you got it into your diet.

Just make sure some of it is raw, chopped up or blended in sauces and salsas etc. Cooked garlic has little of the properties it is famous for.

Kyolic is aged garlic and rather different but a powerful medicinal in its own right.

Note: garlic can interfere with the action of some anticoagulant drugs.

Use Garlic Tea as an Antibiotic

Here's how to make it: Place a few cloves of garlic, pre-crushed, into a saucepan of water and bring it to a boil.

Remove the pan from the heat. Stir in the honey and lemon juice or a little of some other suitable sweetener, such as maple syrup.

Strain into a warmed teapot and sip about half a cup.

Repeat 3 times a day, either hot or cold. Refrigerate the remaining tea.

Surface Application: In an emergency it can be crushed and the juice applied to the site of an open wound to kill bacteria such as staph and strep. These strains of bacteria cannot become immune to garlic's effect as it has modern synthesized antibiotics because garlic kills in a different way.

#32 Artemisia annua

Better Than Garlic? I Think So!

Artemisia is a large, diverse genus of plants with between 200 to 400 species belonging to the daisy family Asteraceae. It comprises hardy herbs and shrubs known for their volatile oils. They grow in temperate climates of the Northern Hemisphere and Southern Hemisphere, usually in dry or semi-dry habitats. The fern-like leaves of many species are covered with white hairs.

It is said that the genus Artemisia (which includes over 400 plants) may be named after an ancient botanist. Artemisia was the wife and sister of the Greek/Persian King Mauseolus (from whose name we get the word mausoleum). Artemisia, who ruled for three years after the king's death, was a botanist and medical researcher, and died in 350 B.C. *(Wikipedia).*

The two best known plants are Artemisia annua (Sweet Wormwood, Sweet Annie, Sweet Sagewort or Annual Wormwood. Chinese : pinyin) and Artemisia absinthum. The latter has no significant medicinal properties and is the basis of the drink absinthe. It has been banned in many countries, for its brain-rotting effects.

Vermouth (from the German Wermut) was originally made with wormwood but now uses more innocent herbs for flavor.

Other members of this family include the cooking herb Tarragon.

Most members of the genus are bitter. This led to the plant being used by wet-nurses for weaning infants from the breast, as in this speech by Shakespeare from Romeo and Juliet Act I, Scene 3:

Nurse: ... And she [Juliet] was wean'd, – I never shall forget it, – Of all the days of the year, upon that day: For I had then laid wormwood to my dug, ...

Scientific Interest

There is a lot of interest in the medical properties of Artemisia annua, which I shall call simply Artemisia from this point. Its chief ingredient, artemisinin, is a potent anti-malarial, anti-fungal and even anti-cancer substance. A search of PubMed with the term artemsinin yields hundreds of papers.

Artemisinin is a terpene which contains peroxide bridges. Taken along with section #19 on hydrogen peroxide this can be seen why it would benefit infections, even including the very difficult case of toxoplasma cysts.

Two other important active ingredients which are widely being studied are artesunate and artemether. They seem to have pretty good anti-infective properties too. To quote a study carried out at the Centre for Infection, Division of Cellular and Molecular Medicine, University of London, and published in the journal Trends in Pharmacological Science *[Trends Pharmacol Sci. 2008 Oct;29(10):520-7]:*

"Artemisinins are derived from extracts of sweet wormwood (Artemisia annua) and are well established for the treatment of malaria, including highly drug-resistant strains. Their efficacy also extends to phylogenetically unrelated parasitic infections such as schistosomiasis. More recently, they have also shown potent and broad anticancer properties in cell lines and animal models. In this review, we discuss recent advances in defining the role of artemisinins in medicine, with particular focus on their controversial mechanisms of action. This safe and cheap drug class that saves lives at risk from malaria can also have important potential in oncology."

Malaria

Artemisinin has become well-known for its powerful anti-malarial effect. At a time when the world is steadily losing control of the disease, due to widespread drug resistance of the malaria parasite Plasmodium falciparum.

Systematic reviews on Artemisinin show that it is as effective as quinine in treating both uncomplicated and severe malaria. Unfortunately, the relapse rate was still high when used alone.

But artemisinin in conjunction with a suitable anti-biotic, a protocol called "Artemisia combination therapy" (ACT), has been found to be highly effective. Coartem, from artemisinin combined with an antibiotic lumefantrine, wipes out malaria in more than 96 percent of patients in

regions where malaria has become resistant to older drugs. Traditional meds such as chloroquine work in only 50 percent of patients where the parasite is drug-resistant. There were an estimated 247 million malaria cases in 2006, and nearly 881,000 patients died, according to the World Health Organization.

Coartem was approved by the Swiss in the late 1990s and put on the World Health Organization (WHO) essential drug list in 2002. The USA was typically way behind world progress, with the FDA holding it back till early 2009 (the USA mistakenly believes only their doctors and scientists are competent to make these decision).

Other Pathogens

To be included in this report Artemisia would have to affect more than just malaria, though this disease is actually the world's number one killer.

I found a paper which showed artemisinin in combination with ampicillin or unasyn (a complex of ampicillin and sulbactam) decreased mortality in mice subjected to a lethal live E. coli challenge from 100 to 66.7% or 33.3%, respectively *[Antimicrob Agents Chemother. 2006 July; 50(7): 2420–2427].*

It seems clear it has widespread anti-biotic applications. Studies published on the Sloan-Kettering website show anti-parasitic properties. In vitro studies indicate that artemisinin may be an effective treatment for other protozoal infections such as leishmaniasis, Chagas' disease, and African sleeping sickness. *[http://www.mskcc.org/mskcc/html/69126.cfm, accessed June 27th 2009, 10.40 am PST]*

Another study from the University of Nizwa, Oman, showed in vitro antimycoplasmal activity of six Jordanian medicinal plants, including a related Artemisia, against three Mycoplasma species. Trop Anim Health Prod. 2007 Oct;39(7):515-9.Links All Mycoplasma species showed susceptibility to Artemisia herba-alba and Artemisia arborescens with MIC ranges from 3.125-12.5 mg/ml.

Incidentally, this study compared garlic and pomegranate with Artemisia arborescens and showed they had only limited activity against some Mycoplasma isolates.

Another Artemisia was helpful with Helicobacter pylori, the scourge of stomach ulcers (and stomach cancer). Increasing drug resistance means we

are now losing ground in this "breakthrough" treatment of ulcers. Artemisia may be the answer.

A study in Mexico published in the Journal of Ethnopharmacology showed Artemisia ludoviciana (also Persea americana, Annona cherimola, Guaiacum coulteri, and Moussonia deppeana) had high antHelicobacter pylori. *[J Ethnopharmacol. 2009 Mar 18;122(2):402-5].*

How To Take It

The good news is that it is free. Artemisia annua flourishes in almost any garden, worldwide.

A 2004 test reported that Artemisinin is absorbed faster from the tea preparations than from capsules. The maximum plasma concentrations were observed after 30 minutes. Artesunate is rapidly absorbed and reaches maximum plasma level within 45-90 minutes *[Rath K, et al. Pharmacokinetic study of artemisinin after oral intake of a traditional preparation of Artemisia annua L. (annual wormwood). Am J Trop.Med Hyg. 2004;70:128-32]*.

Making The Tea: One litre (2 pints) of boiling water is poured onto 5 g dried leaves (large tablespoonful, loose, or teaspoon if crushed to a powder) of Artemisia annua. It is allowed to brew for 10 to 15 minutes, and then poured through a sieve. This tea is then drunk in four portions in the course of the day. The period of treatment is between 5 and 7 days.

Patients with gastrointestinal disorders or those taking antacids should not take Artemisia because it increases the production of stomach acid *[Skyles AJ, Sweet BV. Alternative therapies. Wormwood. Am J Health Syst.Pharm. 2004;61:239-42].*

It is also unwise to use this remedy if you are taking antiseizure medications; Artemisia can induce seizures resulting in decreased efficacy of antiseizure medications [previous reference].

#33 Samento
(Uncaria tomentosa)

You may not have heard of this powerful antibacterial and anti-inflammatory. It's in the Cats Claw family but reputedly 1,000 times stronger in its immune enhancing effect than ordinary Cats Claw.

Samento is the name given to the plant by the Ashaninka Indians in the Peruvian rainforest. They have ancient knowledge of the plant and use it for a wide variety of complaints.

The Indians are a crucial source of the plant materials because they can recognize the correct strain, without the need to elaborate tests. Let me explain why this is important:

Ordinary Cats Claw contains important oxidole alkaloids, one of the many important groups of phyto-nutrients found in the plant. One strain of plants contains pentacyclic oxindole alkaloids (POAs); the other contains both POAs and tetracyclic oxindole alkaloids (TOAs).

POAs act on the cellular immune system and TOAs act on the central nervous system. TOAs are not good because they interfere with the benefits of the POAs. This is confirmed by studies.

Uncaria tomentosa plants may contain as much as 80% TOAs. According to studies in Austria, as little as 1% TOAs can cause a 30% reduction in the acquired immune benefits that POAs provide. So even a little TOAs, if present, can go a long way to neutralizing the benefits of Cats Claw.

This explains why lots of the common herb were needed by Western herbalists, to produce any real effect. But the amazing strain found by the Ashaninka Indians does not have the destructive TOAs. Make sure when you buy Samento, that the packet specifically states no TOAs. Otherwise it isn't Samento anyway!

Samento has shown dramatic benefits in virtually every kind of inflammation, such as asthma and arthritis.

It can also fight infections from AIDS to hepatitis' flu to salmonella. Its broad spectrum effect helps to increase T-lymphocyte and microphage production. It also helps repair the lipid matrix in the cell walls and is particularity good for stopping the expansion of virus laden cells.

The 2 active ingredients are berberine and hydrastine. These are good for killing many of the bacteria that cause diarrhea, such as E. Coli, Salmonella, Shigella, Klebsiella and the cholera bacterium. Also parasites like ameba, giardia and trachoma. It also has antifungal properties, so would suit Candida patients. It's even effective to some degree against TB.

Samento may even have anti-cancer action. Renato Rizzi, at the University of Milan, led an experiment with Samento as it relates to cancer causing (mutagenic) substances in smokers. It is well known that the urine of smokers contains mutagenic substances. When given Samento for two weeks, the smoker's urine returned to normal. This is important because it shows Samento may help lessen the risk of developing cancers and other degenerative diseases.

Dose: all these benefits can be had on a dose of just 3 to 6 capsules a day (good for people who hate swallowing lots of tablets and capsules).

#34 Tea Tree (Melaleuca alternifolia)

I put this plant substance here, though it could just as easily slot into the aromatherapy section coming up.

The plant was named tea tree after Captain James Cook set foot on the shores of Australia back in 1770. The story goes that Cook brewed up a tea from the leaves of the Melaleuca tree and liked it. It has been used for centuries as an antiseptic by the aborigines.

In 1933, the world-class British Medical Journal described Tea Tree Oil as a powerful disinfectant, non-poisonous and non-irritant. In 1930 the Australian Medical Journal reported extremely good results when using tea tree oil to treat everything from septic wounds to scar regeneration. The report stated that the oil dissolved pus, leaving wounds clean without any apparent damage to the tissues.

In 1937 the same journal noted that blood, pus or other organic matter actually increased the antiseptic properties of tea tree oil by about 10-12%. The Australian Government issued little bottles of Tree Oil in the first aid kits of soldiers serving in the tropical regions during the Second World War. In 1955 by the way the United States dispensaries still had Tea tree oil listed as an active germicidal, with an antiseptic action 11 to 30 times more strong than carbolic acid (phenol).

Tea tree oil is very complex, containing over 100 complex chemical components called terpenes (these are what give it its powerful pine-odor). These terpenes make up 80 to 90 percent of the oil.

Tea tree oil is known to be active against many bacteria, including streptococci, staph, E. coli, and various fungi, such as Candida. In a study of 30 patients who had infections that were resistant to a common antibiotic, one-third were completely cured by tea tree oil compared to just 13 percent who received conventional treatment.

Although tea tree oil is seen by the scientific establishment as very much a quaint folk remedy, science is forcing a reexamination of these outdated attitudes towards folk remedies and alternative medicine. Treatments that were once dismissed as nonsense or even quackery, are now been justified through rigorous scientific testing (in facts drugs are often the real quackery and nonsense).

Now I'm going to shock you all and incense thousands of rabid dogmatists in favor of Tea Tree oil, and point out that it may not be what you want at all.

Beware: Tea tree oil may lead to antibiotic resistance

Repeated exposure to low doses of Tea Tree Oil - a common ingredient in many beauty products - can increase the chances of suffering from "superbug" infections, University of Ulster scientists have revealed.

They discovered that exposure to low doses of Tea Tree Oil make pathogens such as MRSA, E. coli and Salmonella more resistant to antibiotics, and capable of causing more serious infections.

Dr Ann McMahon and Professor David McDowell, members of the University's Food Microbiology Research Group, said: "We have been growing pathogens such as MRSA, E-coli and Salmonella in low concentrations of tea tree oil. These concentrations are not sufficient to kill the bacteria, but can switch on their defense mechanisms. Unfortunately, these defense mechanisms have the added effect of making bacteria more resistant to antibiotics, and able to cause "harder to treat" infections."

Tea Tree Oil is used commercially in many products including shampoos, body lotions and toiletries, but there is no legislation requiring manufacturers to state the concentration of tea tree oil in these products.

This increases the risks that people will use low concentrations of tea tree oil, which fail to kill bacteria, but increase their resistance to antibiotics. So, if a person uses tea tree oil products on their skin repeatedly, any MRSA on their skin could develop increased resistance to the antibiotics which are used to control MRSA infections.

"The bottom line is that tea tree oil should not be used at low concentrations - less than 4% - to make sure that bacteria are killed, not just stressed. Otherwise we are just arming the bacteria against treatment by antibiotics."

Publishing their findings in the Journal of Antimicrobial Chemotherapy, the scientists said: "Although tea tree oil may be an effective antimicrobial agent when appropriately used at high (bactericidal) concentrations, its application at low (sub-lethal) concentrations may contribute to the development of antibiotic resistance in human pathogens".

http://www.ulster.ac.uk

The best advice therefore seems to be: if you want to use it, use plenty and make sure you wipe out the bacteria population all at once. Otherwise it's counter productive.

There is one other word of caution too: several cases of gynaecomastia, male breasts in young boys, came about through topical applications of tea tree oil (a shampoo, actually); not many but enough to cause concern.

I pointed this out in one of my publications and was venomously attacked by numerous supposed guardians of "truth". How dare I attack a near sacred old and venerable cure? The mere fact it was hurting young boys was seen as irrelevant. All sorts of arguments were brought forth, including even Robert Tisserand (see Aromatherapy section #39) writing to me and telling me it was probably an estrogenic substance in the plastic shampoo bottles. He didn't even accept that the condition cleared up when the use of the tea tree shampoo was discontinued. It must all be faked propaganda science was his attitude.

Denial is a silly attitude and yet it seems to be almost a requirement to be a card-carrying "holistic therapist". Me? I'd rather stick with at least a semblance of science. All I was asking them was to avoid repeated applications of tea tree in young boys. You'd think I was attacking a sacred cow or even trying to butcher one!

#35 Aloe Vera

The virtues of Aloe vera have been well known since ancient times. The name was derived from the Arabic alloeh meaning 'bitter' because of the bitter liquid found in the leaves. It is also known as 'lily of the desert', the 'plant of immortality', and the 'medicine plant'.

The fresh gel was said to have been used by Cleopatra to keep her skin soft and young. Aloe vera is truly one of Nature's absolute miracle plants. It seems to be able to cure almost anything. Always think if it with infections, including Candida and yeast.

The outstanding property of Aloe seems to be its gentleness. It is non-irritating and soothes any and all inflammations, whether infective or not. This makes it ideal to take internally and it is also great for vaginal overgrowths, from Candida, to Trich.

If it does seem to be irritating, that is almost certainly due to additives from the manufacturer. If you suspect that, switch to pure Aloe, direct from the plant.

The chief grower and manufacturer of Aloe, worldwide, is an operation called Univera and their flagship product, "Aloe Gold" I highly recommend. I can tell you how to get it, without joining an MLM (admin@informed-wellness.com)

Think of Aloe in situations like dysbiosis, due to excessive use of antibiotics.

It also works as an anthelminthic [an agent that destroys or expels intestinal worms and/or parasites; vermicide; vermifuge]; an antibacterial; an antifungal/yeast; an antiviral and as a parasite treatment.

It may even prevent cancer: that's from the Mayo Clinic website, no less! *[http://www.mayo-clinic.com/health/aloe-vera/NS_patient-aloe/DSECTION=evidence]*

That's pretty versatile.

Dosage

Adults (18 years and older)

Pure Aloe Vera gel is often used liberally on the skin three to four times per day for the treatment of sunburn and other minor burns. Creams and lotions are also available. There are no reports that using aloe on the skin causes absorption of chemicals into the body that may cause significant side effects. Skin products are available that contain aloe alone or aloe combined with other active ingredients.

For internal use, take 1 – 3 ounces daily.

Children (younger than 18 years)

Topical (skin) use of aloe gel in children is common and appears to be well tolerated. Oral dosing is NOT recommended for kids.

#36 Green Tea

I could, I suppose, have put this with the helpful foods and nutrition section; but I have chosen to feature it in herbs, right after the tea tree!

It may be that green tea can help antibiotics be three times more effective in fighting drug-resistant bacteria, even superbugs. This is according to research at Alexandria University in Egypt, in a paper presented in April 2008 at the Society for General Microbiology in Edinburgh, Scotland.

Green tea is a common drink in Egypt, and that means that many people will drink it while taking antibiotics. The researchers wanted to determine if green tea would help or interfere with the effectiveness of antibiotics. That's reasonable.

"We tested green tea in combination with antibiotics against 28 disease-causing microorganisms belonging to two different classes," Dr Mervat Kaseem, of the university's pharmacy faculty, said in a prepared statement. "In every single case, green tea enhanced the bacteria-killing activity of the antibiotics. For example, the killing effect of chloramphenicol was 99.99 percent better when taken with green tea than when taken on its own in some circumstances."

Kaseem and colleagues also found that green tea made 20 percent of drug-resistant bacteria susceptible to cephalosporin antibiotics, an important type of antibiotics to which new drug-resistant strains of bacteria have evolved resistance.

In almost every case and for all types of antibiotics they tested, the researchers found that drinking green tea at the same time as taking the antibiotics appeared to increase the action of the antibiotics and reduce drug resistance in bacteria. In certain cases, even low concentrations of green tea were effective.

Dr. Kassem has a good point to make: "Our results show that we should consider more seriously the natural products we consume in our everyday life," he said. "In the future, we will be looking at other natural herb products such as majoram and thyme to see whether they also contain active compounds which can help in the battle against drug resistant bacteria."

But wait a minute: I found another study that said we could dispense with the antibiotics altogether! It was carried out for USDA and published in a peer reviewed journal, the Journal of Food Protection. Researchers

investigated the antibiotic activity of 11 catechins from green tea and compared these to the strength of 5 medicinal antibiotics.

Their findings and conclusion was startling: three of the catechins beat tetracycline and vancomycin (effective at lower dilutions). I quote: "The results show that three of the catechins exhibited exceptional bactericidal activities at very low levels in the nanomolar range. They were more active than medicinal antibiotics such as tetracycline and vancomycin."

You may remember vancomycin as the "last ditch antibiotic", 30?

So farmers and food suppliers are getting the story, even if your doctor is not!

[Journal of Food Protection. 69:100-107.]

White Tea

But white tea extract seems to be even more powerful, according to a 2004 study conducted at Pace University. Researchers found that White Tea Extract (WTE) may have prophylactic applications in retarding growth of bacteria, viruses and fungi. Their findings were presented at the 104th General Meeting of the American Society for Microbiology.

The anti-viral and anti-bacterial effect of white tea (Stash and Templar brands) is greater than that of green tea. Moreover, the anti-viral and anti-bacterial effect of several toothpastes including Aim, Aquafresh, Colgate, Crest and Orajel was enhanced by the addition of white tea extract.

White tea was more effective than green tea at inactivating bacterial viruses. Results obtained with the bacterial virus, a model system; suggest that WTE may have an anti-viral effect on human pathogenic viruses.

Studies have also indicated that WTE has an anti-fungal effect on Penicillium chrysogenum and Saccharomyces cerevisiae. In the presence of WTE, Penicillium spores and Saccharomyces cerevisiae yeast cells were totally inactivated. It is suggested that WTE may have an anti-fungal effect on pathogenic fungi.

#37 Spices Are Hot Stuff!

Professor Paul W. Sherman and undergraduate student Jennifer Billing prepared a great report on the antibiotic qualities of spices, published in the March 1998 issue of the journal Quarterly Review of Biology.

Sherman credits Billing, a Cornell undergraduate student of biology at the time of the research, with compiling many of the data required to make the microbe-spice connection: More than 4,570 recipes from 93 cookbooks representing traditional, meat-based cuisines of 36 countries; the temperature and precipitation levels of each country; the horticultural ranges of 43 spice plants; and the antibacterial properties of each spice.

Garlic, onion, allspice and oregano were found to be the best all-around bacteria killers (they kill everything), followed by thyme, cinnamon, tarragon and cumin (any of which kill up to 80 percent of bacteria). Capsicums, including chilies and other hot peppers (killed or inhibited up to 75 percent of bacteria), while pepper of the white or black variety inhibits 25 percent of bacteria, as do ginger, anise seed, celery seed and the juices of lemons and limes.

So even mild spices has some measurable effect it seems.

The Cornell researchers noted that in hot countries nearly every meat-based recipe calls for at least one spice, and most include many spices, especially the potent spices, whereas in cooler counties substantial fractions of dishes are prepared without spices, or with just a few." They theorize that spices were a development chiefly intended to inhibit the bacteria of food spoilage.

If that's correct then it is only natural that spices would have a potent antibiotic capacity— and that's what they found.

As decent scientists, they did consider several alternative explanations for spice use and discounted all but one. The problem with the "eat-to-sweat" hypothesis -- that people in steamy places eat spicy food to cool down with perspiration -- is that not all spices make people sweat, Sherman says, "and there are better ways to cool down -- like moving into the shade." The idea that people use spices to disguise the taste of spoiled food, he says, "ignores the health dangers of ingesting spoiled food." However the micronutrient hypothesis -- that spices provide trace amounts of anti-oxidants or other chemicals to aid digestion -- could be true and still not exclude the antimicrobial explanation, Sherman says. However, this hypothesis does not

explain why people in hot climates need more micro-nutrients, he adds. The antimicrobial hypothesis does explain this.

"I believe that recipes are a record of the history of the coevolutionary race between us and our parasites. The microbes are competing with us for the same food," Sherman says. "Everything we do with food -- drying, cooking, smoking, salting or adding spices -- is an attempt to keep from being poisoned by our microscopic competitors. They're constantly mutating and evolving to stay ahead of us. One way we reduce food-borne illnesses is to add another spice to the recipe. Of course that makes the food taste different, and the people who learn to like the new taste are healthier for it."

The following are their Top 30 Spices with Antimicrobial Properties (best to least):

1. Garlic
2.Onion
3.Allspice
4. Oregano
5. Thyme
6. Cinnamon
7. Tarragon
8. Cumin
9. Cloves
10. Lemon grass
11. Bay leaf
12. Capsicums
13. Rosemary
14. Marjoram
15. Mustard
16. Caraway
17. Mint
18. Sage
19. Fennel
20. Coriander
21. Dill
22. Nutmeg
23. Basil
24. Parsley
25. Cardamom
26. Pepper (white/black)
27. Ginger
28. Anise seed
29. Celery seed
30. Lemon/lime

Source: "Antimicrobial Functions of Spices: Why Some Like It Hot," Jennifer Billing and Paul W. Sherman, The Quarterly Review of Biology, Vol. 73, No.1, March 1998

#38 Mushrooms and Fungi

Fungi and mushrooms are related to herbal medicines but not quite the same. Remember most antibiotics come from molds, which are related directly to fungi. According to mycologist expert Paul Stamets, fungi are closer to human life than to bacteria. In fact, they too HATE bacteria, which is why they produce powerful antibiotics (bacteria would attack fungi).

The fungi are a remarkable group of organisms that don't need light to synthesize their own food. What we call mushrooms and toadstools are simply the visible fruiting bodies on what is a much larger organism, covering sometimes up to hundreds of square feet, called the mycelium.

The medicinal properties of fungi have been known since ancient times. In fact Oetzi, the "Ice Man" found in the Tyrolean Alps knew about fungi. His body was frozen 5,200 years ago and found to be remarkably preserved when he thawed out after being discovered intact above the 10,000 line in 1991.

His gear was preserved too and that included a medicine pouch, containing a few walnut-sized dried fungi of the species Piptoporus betulinus, known to have antibiotic properties. It shows that Europe was in there with medicinal mushrooms, though not perhaps to the vast extent of Chinese herbal lore.

Now modern science backs up virtually all that has been claimed for mushrooms and fungi. They are immune modulators, anti-viral, antibacterial and anti-cancerous.

Broadly speaking the edible fungi can be divided into those with culinary merits and those which are purely medicinal. There is some overlap; for example, the shiitake mushroom is a well-known Japanese delicacy and has now spread to the West.

Shiitake stimulates the immune system about a hundred times more than the common white button mushroom. Maitake does much more to aid the immune system than morels, portobellos and chanterelles etc. The very tasty oyster mushroom (Pleurotus ostreatus) is an exception and is enjoyed for its antibacterial, anti-viral, blood pressure moderating and cholesterol reducing qualities.

The key to the effectiveness of mushrooms is a substance called beta glucan, a large and complex polysaccharide (sugar chain), which stimulates the

immune system to fight pathogens and malignant cells. Maitake is known to be an effective antitumor agent.

Note that yeast beta glucan, commonly sold via MLM networks, is largely ineffective. They love to quote the science but this, if you look closely, is always experiments on the mushroom beta glucan and is NOT applicable to the products they sell (I have a saying: there is science, damned science and then MLM science!)

Mushrooms contain more than just beta glucan, of course: amino acids such as lysine and tryptophan and vitamins such as C, K, nicotinic acid (vitamin B3), riboflavin (B2) pantothenic acid (B5). There are also other complex substances, such as terpenes and steroids.

Reishi

Let's start with the Reishi mushroom (Ganoderma lucidum). To the ancient Chinese this mushroom was called Lingzhi meaning "spirit plant". According to legend, Taoist priests in the first century were supposed to have included the mushroom in magic potions that granted those who consumed them longevity eternal youth and immortality. In Chinese art the Reishi mushroom is a symbol of good health and long life; symbols of it abound everywhere.

Clinical studies have confirmed Reishi has properties as an anti-inflammatory, antioxidant, BP and blood sugar moderator and cholesterol reduce. Reishi contains over 100 bioactive immunomodulatory substances, including beta glucan.

More importantly, studies have shown that Reishi significantly increases three immune signalers known to help the immune system destroy invaders. Japanese researchers say that a hardy system may be able to resist invasions and microbes that weaker host systems may not.

It should also be mentioned that Reishi does not produce some of the negative effects associated with the use of antibiotics, which can often stop the invasion of microbes, but will further weaken the immune response after continued use and are also ineffectual in cases of viruses, pollens and malignant cells.

Maitake

Next let's look at Maitake (Grifola frondosa). Maitake means "dancing mushroom". In Europe it is known as "Hen Of The Woods " and is sometimes called the King Of Mushrooms because of its size.

Maitake is a delicious culinary mushroom but also valued for its medicinal properties. It has known antibiotic activity, although I could only find one really meaningful study to support this. In combination with vancomycin, one of the few remaining antibiotics with some activity against methicillin-resistant Staphylococcus aureus (MRSA), Maitake led to very enhanced survival against Listeria bacteria injected into the abdominal cavity of mice (an often fatal form of food poisoning).

[Kodama N, Yamada M, Nanba H. Jpn J Pharmacol 2001;87:327-332].

Suggested doses: For general protection, 300 mg to 2 grams extract daily, between meals. For therapeutic use against an active infection: 25 to 35 grams extract or more daily until results evident, then taper back to 15 to 30 grams daily, or as recommended by a health care practitioner.

Next, the most famous of all.

Shiitake

It produces a growth inhibiting beta glucan called Lentinan (from shiitake's scientific name Lentinula edodes). Scientists now believe that lentinan and virus-like particles found in shiitake trigger the increased production of various serum factors associated with immunity and inflammation. These so-called lymphokines, such as interferon and interleukin, stimulate the defense system through the proliferation of phagocytes, including macrophages and other immune fighters that attack cancer cells, bacteria, and viruses.

A substance called cortinelin, a broad-spectrum antibacterial agent, which has been isolated from shiitake, kills a wide range of pathogenic bacteria. A sulfide compound extracted from shiitake has been found to have an effect against the fungus that causes ringworm and other skin diseases.

Inonotus obliquus (Chaga)

Stimulates the production of macrophage and NK cells, essential to healthy immune system function. It is rich in immuno-modulating polysaccharides and has been found to be an effective natural anti-inflammatory, anti-tumor, anti-oxidant, anti-viral, and antibiotic.

Pleurotus species

This includes Pleurotus ostreatus (Oyster mushroom). It is enjoyed for its interesting taste, plus anti-bacterial, anti-viral, blood pressure moderating, and cholesterol reducing qualities. It is actually easy to grow at home and is cheap; it should be eaten more widely than it is.

A polycyclic aromatic compound pleurotin has been isolated from P. griseus which possesses antibiotic properties.

Trametes versicolor (Turkey Tail)

Turkey tail mushroom is one of the most widespread mushrooms in the world. Turkey tail can be found on dead trees in just about any hardwood or deciduous forest in North America, Europe, China, Japan and Siberia. As its name indicates, the mushroom looks exactly like a turkey's tail and can be very colorful.

Turkey Tail produces a very powerful immune stimulant polysaccharide, called PSK.

PSK has also been proven as a potent antibiotic, in particular against strains of Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans, Cryptococcus neoformans, Escherichia coli and Listeria monocytogenes.

[Sakagami, H. & M. Takeda, 1993. "Diverse biological activity of PSK (Krestin): a protein bound polysaccharide from Coriolus versicolor (Fr.) Quel." In Mushroom Biology & Mushroom Products, eds. S.T. Chang J.A. Buswell & Siu-wai Chiu, The Chinese University Press, Hong Kong. pp. 237-

245. Mayer, J. & J. Drews, 1980. "The effect of protein-bound polysaccharide from Coriolus versicolor on immunological parameters and experimental infections in mice." Infection 8: 13-21.

Ng, T.B., J.M. Ling, Z.T. Wang, J.N. Cai & G.J. Xu, 1996. "Examination of courmarins, flavonoids and polysaccharopeptides for antibacterial activity." General Pharmacology Oct; 27(7): 1237-40.]

Turkey tail is a little tough to eat so it is usually found in teas, tinctures, capsules and pills.

It just remains to enter a few words of caution:

Firstly, on no account go out and start harvesting mushrooms yourself and trying to make home-brew extracts. You'll likely kill yourself. The Fungi are an enormously large range of organisms and the difference between safe ones and those which kill can be very subtle. It takes an expert to safely identify edible mushrooms. Of course if you live in France or anywhere civilized which really KNOWS food, you can go into any pharmacy and they will identify any mushrooms you gather. But really, you are safer not collecting your own, unless you are a botanist or better still a mycologist (fungologist).

There is an additional problem, which may not be obvious to you, which is getting a predictable dose. It's something which bugs even commercial fungi extracts which you may find for sale on the Net. Let me warn you that the vast majority of products offered are totally worthless, no matter even if the vendor is sincere and well-meaning. It is very difficult to get a regular, effective dose and keep it consistent.

See, part of the difficulty is that fungi are protected by a membrane coat of chitin. That's same stuff insect cases and your fingernails are made of. Just grinding up mushrooms isn't going to get at the best of the content. It needs a heat process to get at the good stuff, by breaking down the chitin. This, of course, is counter-intuitive to most alternative healers and practitioners, who know that heat normally destroys nutrients.

Let me assure you that in this case it's a waste of money, if not extracted properly, and 99% or manufacturers don't even know this, never mind practice it!

To get you over this problem I have identified a range of mushroom products that meet all the necessary requirements for health and effectiveness. They are organically grown, under strict natural conditions, in a special facility Oregon State (which also, incidentally, supplies the WHO with fungal medicines, for treating the populations of Third World Countries). These are the most potent full-spectrum myoceutical products ever produced.

You can get purchase details at:

http://www.powershroom.com

#39 Essential oils (aromatherapy)

Well, let's move on. Can you see now there is SO MUCH you can do to fight active infections, without the use of antibiotics.

For instance, did you know that essential oils (aromatherapy oils) have powerful antibiotic properties? That was one of their main uses, when first developed. Remember, this was long ago, in the days before antibiotics or any other significant drugs had emerged.

Aromatherapy oils were once not merely for relaxing and getting in touch with the inner self! They were the best pharmaceuticals of the day!

The story goes back a long way, beginning with a man called Chamberla in 1887. He studied a mixture of oregano, cinnamon, angelica and geranium, and he found that each of these inhibited bacteria growth in a petri dish (special culture dish for microbes).

This is exactly the same test that led to the discovery of penicillin. Yet you never hear that these things do essentially the same! Chamberla found the oils very effective against meningococcus (the cause of meningitis), typhus and Staphylococcus (MRSA is a Staphylococcus, remember). But they were not so good against diphtheria and didn't work at all for anthrax—but then, hardly anything ever does.

Another man called Clavell in 1918 showed that clove bud (Syzygium, also a good homeopathic remedy) kills the TB bacillus at 1 part in 6,000. That was an important stepping stone.

In 1928 a famous case was that of Rene-Maurice Gattefosse, who burned his hand. It became infected and smelled very bad. Gattefosse put it in lavender (to ease the smell, presumably) but was surprised when the lavender clearly had a very beneficial effect. He recovered. Gattefosse went on to learn more about plants and their oils and he was the person who invented the term aromatherapy.

In WW2, a French surgeon called Jean Valnet used essential oils to treat injuries and infections and psychiatric disorders. He was able to use these things to treat gangrene successfully. You never get to hear of this today! Nobody ever says that simple herbal oils could be effective against gangrene.

Whoever has been told "You don't need an amputation yet, let's try lavender oil"?

Valnet did a lot of studies and published a book in 1960 called The Practice of Aromatherapy: A Classic Compendium of Plant Medicines and Their Healing Properties.

If you write down Valnet and Aromatherapy and Google that, you will find it. I saw a second-user copy on sale on Amazon for just 5 bucks.

Scientific Testing or Aromatherapy Oils

What astonishes most people (including me, when I first learned it) is that aromatherapy has a good tradition of scientific testing and screening. In the USA it may be looked on askance but in France aromatherapy is quite the thing!

Valnet, in fact, was dedicatedly scientific. He tested numerous plant oils against bacterial culture in petri dishes, exactly the way that led to the discovery of penicillin and other antibiotics. Some were astonishingly good.

1960: Maruzella demonstrated antibacterial and antifungal effects of hundreds of aromatic compounds.

1987: Deininger and Lembke demonstrated antiviral activity of essential oils and their isolated components.

1973: Wagner and Sprinkmeyer did research on a 170 year old blend of distilled oils still available in Germany. The effects of melissa and the other oils in Kosterfrau Melissengeist had been empirically known since Paracelsus (about 1500). They concluded that, with varying degrees of intensity, there was an inhibiting influence on all the bacteria tested, (Pneumococcus, Klebsiella pneumoniae, Staphlococcus aureus haemolyticus, Neisseria catarrhalis, Streptococcus haemolyticus, Proteus vulgaris, Hemophilus influenza, Haemophilus pertussis, Candida albicans, Escherichia coli-Aerobacter group, various Corynnebacteria, and Listeria) and stated the large spectrum of this inhibitory action is as broad as or even greater than that of wide-spectrum antibiotics.

One of the most interesting experiments I came across in my research was carried out in the 1960s by Professor Griffon, Director of the French Police Toxicology Laboratory. He researched the use of aromatherapy or essential

oils in cleansing the air. Bottom line… dispersing essential oils into the atmosphere dramatically cut down airborne pathogens. After only 30 minutes of airborne spray cultures were down to zero.

He used a mixture of cinnamon, clove, peppermint, lavender, pine, rosemary and thyme.You probably think these are just sissy smells. But actually these are very very powerful substances, I think I will have time to explain these to you before I open for questions.

(This has enormous implications for CA-MRSA …the respiratory form. If I am not careful, I may run out of time, so let's just do a couple of quick specific…

Drs. Jean-Claude Lapraz and Christian Duraffourd, two Paris-based physicians, organized the world's first phytotherapy conference in Tunisia in May 1993.

Durrafourd and Lapraz have suggested that dosing with essential oils may not be linear in the same way as antibiotics. They found a very small quantity of essential oil had a far greater effect when used in the body than effects measured in vitro (in glass dishes). They also somewhat abandoned the quest for finding one oil for each pathogen. That's something of an allopathic nonsense.

Instead, they see the need for matching the oil to the constitution and make up of the patient in question.

Oregano

Origanum vulgare, also known as Greek or Mediterranean oregano, has good claim to be a natural antibiotic. This is not the cooking oregano however but a rather rare wild herb which grown in the mountainous regions of the eastern Mediterranean. Its scent and flavor are due to the essential oil which has been renowned for its potent antiseptic properties.

When oregano oil was first tested in 1910 it was described as "the most powerful plant-derived antiseptic known" (H. Marindale). It has been found effective both in killing multiple bacteria and preventing their growth. It was shown to be many times more potent than phenol (carbolic acid).

Carvacrol activity crucial. Carvacrol or isopropyl-o-cresol is the active ingredient with powerful antimicrobial properties; it is more potent than carbolic acid.

Oregano has been found to contain several powerful antioxidants such as phenolic acids and flavonoids which protect your tissues against harmful toxins like cancer-causing free radicals *[Tian H, Lai DM. Zhong Yao Cai. 2006;29(9):920-1; Hazzit M, et al. J Agric Food Chem. 2006;54(17):6314-21].*

Oregano oil may be the 'best of the best' among essential oils in killing microbial pathogens, killing bacteria, fungus, yeasts and molds. It was shown to be very effective against Candida (1.5 times more potent than the drug Nystatin).

Specifically, it has activity against:

- Escherichia coli (E. Coli)
- Candida albicans
- Bacillus cereus
- Proteus
- Cryptococcus neoformans
- Staphylococcus aureus (Hence MRSA)
- Streptococcus pneumoniae
- Pseudomonas aerugiosa
- Salmonella

Researchers from the Agricultural Faculty, Selcuk University in Turkey studied essential oils from several different plants, including oregano, laurel, marjoram and mint. They tested these oils on certain bacteria (including Bacillus, which can cause bowel infections and diarrhoea) in the laboratory. All of the herbs, including oregano, were found to successfully block the growth of the bacteria studied *[Ozcan MM, Sagdic O, Ozkan G. J Med Food. 2006 Fall;9(3):418-21].*

In an animal study, performed by scientists at the National Agricultural Research Foundation in Greece, oregano was found to be just as effective as the prescription-only antibiotic neomycin for curing diarrhoea caused by the E.coli bug, which is notorious for causing bowel infections.

Commenting on the findings the scientists said: This study indicates that dried oregano leaves may be as effective in the treatment of coli infection as neomycin *[Bampidis VA, et al. J Vet Med A Physiol Pathol Clin Med. 2006;53(3):154-6].*

Dose: Oregano oil for products intended for internal use can be used by adding four drops to a small amount of water and take up to three times a day. For external use it can be applied liberally up to three times a day.

Cinnamon

There are two kinds of cinnamon oil, Cinnamomum zeylanicum and Cassia (next section).

Zeylanicum stands for Sri Lanka. I know that because I lived in Sri Lanka for a couple of years. I was professor at a university there. And it's very effective and wonderful to smell. I love it. But it must be said the other cinnamon (Cassia) is more powerful.

A nice idea I found is to make a special flavored honey with this oil:

> To 2 oz. of maple syrup or 2 oz. of honey add: 3 drops of Ginger Essential Oil 1 drop Cardamom 1 drop Cinnamon bark oil 3 drops Vanilla Essential Oil, pure 8 drops of certified organic Orange or Mandarin Orange oil.

Cassia

Cassia (Cinnamomum cassia, or "hot cinnamon") is native to the south-eastern parts of China and to a lesser extent in Vietnam, Burma and India. It is cheaper and more abundant than the Sri Lanka variety. Its value dependant mainly on the percentage of cinnamic aldehyde which it contains. It is heavier, less liquid, and congeals more quickly than the Ceylonese variety.

Cassia has recognized antimicrobial properties and is often used for diarrhea. The essential oil is a powerful germicide, but being very irritant is rarely used in medicine for this purpose.

One study carried out at the Department of Agricultural Biology and the Research Center for New Bio-Materials in Agriculture, College of Agriculture

and Life Sciences, Seoul National University (Koera) showed Cassia had 1/5th - 1/10th the power of tetracycline and chloramphenicol against intestinal bacteria.

Not a problem, since we could always take more Cassia than antibiotic capsules. Interestingly, Cassia had no effect on Lactobacillus, a prime probiotic organism. So there would not be the disastrous after effects of the two antibiotics used in the trial. *[J. Agric. Food Chem., 1998, 46 (1), pp 8–12].*

An interesting analysis from the University of Hong Kong showed that typical Cassia preps. have around 98% cinnamaldehyde and were effective against a wide range of pathogens, including Staphylococcus aureus, E. coli, Enterobacter aerogenes, Proteus vulgaris, Pseudomonas aeruginosa, Vibrio cholerae, Vibrio parahaemolyticus and Samonella. *[Am J Chin Med. 2006;34(3):511-22].*

Thyme

Thyme was used medicinally by the Egyptians, Greeks, and Romans. Most present day research has centered on thyme's ability as an antibacterial and anti-infectious agent, even when diffused in the air.

Thyme oil is composed of several different components that show antimicrobial activity (at least: carvacrol, thymol and linalool).

In vitro studies have shown that thyme oil has valuable broad spectrum activity against Salmonella typhimurium, Staphylococcus aureus, Escherichia coli, and a number of other bacterial species.

Thyme essential oils showed some of the strongest killing power against MRSA and VRE antibiotic-resistant bacteria, according to studies at the Western Infirmary, Glasgow, UK. According to Jean Valnet, M.D., thyme oil kills the anthrax bacillus, the typhoid bacillus, meningococcus, and the agent responsible for tuberculosis and is active against salmonella and staphylococcus bacteria.

The College of Pharmacy study at Oregon State University, also confirmed thyme is substantially more effective than most others in killing MRSA, including the virulent strain USA300. Oregano and thyme together are consistently the most effective in inhibiting the growth of all three bacteria; MRSA, Escherichia coli, and Acinetobacter calcoaceticus. Dr. Ihsan Edan

AlSaimary, of the Univ. of Basrah, has also confirmed these other research results.

Thyme is also a broad spectrum disinfectant that helps to kill germs (including E.coli) on surfaces all around your home. *[Marino M, Bersani C, Comi, G. Antimicrobial Activity of the Essential Oils of Thymus vulgaris L. Measured Using a Bioimpedometric Method. Journal of Food Protection, Volume 62, Number 9, September 1999, pp. 1017-1023(7)].*

In another study, published in Bionews online, it was found that Escherichia coli and Salmonella typhimurium were susceptible to thymol and carvacrol (both found in thyme oil) and eugenol (found in clove oil).

Activity of natural antimicrobial compounds against Escherichia coli and Salmonella enterica serovar Typhimurium Letters in Applied Microbiology *[N.A. Olasupo, D.J. Fitzgerald, M.J. Gas-son and A. Narbad]* Volume 37 Issue 6 448 - December 2003.

Thyme oil is very strong stuff by the way, don't go rubbing it on your skin without diluting it. Something like a massage oil.

Black Seed Oil

Black seed oil is not often included in Western reviews of essential oils. Maybe there is a certain amount of prejudice in this. But I think black seed oil could stand as high as Oregano oil and does not taste as repelling.

Black seed oil (Nigella sativa) has been known for centuries in Middle East countries. The black seed is known in Arabic as the habbutual barakah (the seed of blessing). It is sometimes called the Black Cumin Seed, however this is not the same as Black Cumin which the Indians refer to as Jeera/Zeera.

The Prophet Mohammad stated in his "Hadith" that black seed oil cures every illness except death. A small phial of it was apparently found in the tomb of Tutankhamen.

Now modern science has come to its support. Researchers around the world have confirmed the anti-bacterial and anti-mycotic effects of black seed oil. Health practitioners in various countries around the world are using the oil against inflamation of all sorts as well as fungi infections. Black Seed extracts have been found to stimulate bone marrow and immune cells, raise interferon production and increase B cells (which produce antibodies).

The active ingredients of black seed are nigellone, thymoquinone, and fixed oils. Beta si-tosterol has also been identified as a key marker in black seed oil. Beta sitosterol has been shown to exert protective effects and reduce symptoms of BPH (benign prostatic hyperplasia). *[Lancet 1995;345(8964):1529-32]*

Black seed also contains significant proportions of protein, carbohydrates and essential fatty acids. Other ingredients include linoleic acid, oleic acid, calcium, potassium, iron, zinc, magnesium, selenium, vitamin A, vitamin B, vitamin B2, niacin, and vitamin C.

Dose: a teaspoonful 3 times a day of the oil. It's bitter and irritating but can be mixed with tea, coffee, carrot juice, yoghurt or other carriers. For respiratory infections it can be rubbed in the chest; for sinusitis and catarrh, 3- 4 drops in each nostril.

General use: Ibn Senna known in the West as Avicenna (980-1037 AD) the Persian-born Islamic philosopher and physician who wrote the great medieval medical text, described the power of the black seed to stimulate the body's energy and banish fatigue.

A teaspoon of black seed oil mixed in a glass of orange juice with breakfast keeps you active all through the day. A teaspoon of black seed oil mixed in a hot drink after supper gives you a quiet sleep all through the night.

Mountain Savory

Long established as an antibiotic substitute, mountain savory (Satureja montana) was in third place, behind lemongrass oil and lemon mytle oil, according to a 2008 study *[Inhibition of methicillin-resistant Stapphulococcus aureus (MRSA) by essential oils; Sue Chao, Gary Young, Craig Oberg, and Karen Nakaoka; Flavour and Fragrance Journal, 2008; 23: 444-449]*.

One important study examined in vitro antimicrobial activity of the essential oils of the aerial parts of Satureja montana L. and Satureja cuneifolia. The major compound of S. montana oil was the phenolic monoterpene carvacrol (45.7%).

The antimicrobial effects of S. montana and S. cuneifolia oils were found to have a broad spectrum activity against multidrug-resistant pathogens. These oils were active against all the test strains, with the exception of

Pseudomonas aeruginosa. Compared with S. cuneifolia, savory oil exhibited greater antimicrobial activity.

The maximum activity of savory oil was observed against Escherichia coli, MRSA and against the yeast (Candida albicans). The essential oil of S. cuneifolia was also found to inhibit the growth of medically important pathogens such as S. aureus and E. coli. Fungicidal activity for both oils against C. albicans and S. cerevisiae (food yeast) was also observed. *[Volume 18 Issue 12, s 967 – 970].*

Useful antibiotic formula:

Mix together the following: 10 drops lemon; 8 drops mountain savory; 3 drops oregano; 1 tablespoon of V6 food grade oil. 2 ounces of grape juice.

Take 2 tablespoons a day of this mix. (based on a suggestion by Dr. Gary Young).

V6 is an essential oil carrier, consisting of fractionated Cocos Nucifera (Coconut) Oil, Sesamum Indicum (Sesame) Seed Oil, Vitis Vinifera (Grape) Seed Oil, Prunus Amygdalus Dulcis (Sweet Almond) Oil, Triticum Vulgare (Wheat) Germ Oil, Helianthus Annuus (Sunflower) Seed Oil, and Olea Europaea (Olive) Fruit Oil.

If you want, put it in a Double O gelatin or vegetable capsule instead of the V6. In which case use these proportions: 5 drops Lemon Essential oil 3 drops Oregeno Essential oil 5 drops Mountain Savory Essential oil.

Take one capsule 3 times daily.

Pregnancy and Strep B

For pregnant women, Strep B can be a hazard (and to the neonate too). Signs, Symptoms of Neonatal GBS Infection Unaffected by Intrapartum Antibiotics *[Medscape Summary]*

"Antibiotic exposure also does not delay the onset of clinical signs of infection . . ."

[The Influence of Intrapartum Antibiotics on the Clinical Spectrum of Early-Onset Group B Streptococcal Infection in Term Infants. Bromberger P, Lawrence JM, Braun D, Saunders B, Contreras R, Petitti DB, Pediatrics 2000 Aug;106(2):244-250]

In fact it probably causes it! [Potential consequences of widespread antepartal use of ampicillin. Towers CV, Carr MH, Padilla G, Asrat , Am J Obstet Gynecol 1998 Oct;179(4):879-83]

"The increased administration of antenatal ampicillin to pregnant women may be responsible for the increased incidence of early-onset neonatal sepsis with non-group B streptococcal organisms that are resistant to ampicillin. At this time penicillin G, rather than ampicillin, is therefore recommended for prophylaxis against group B streptococci. In addition, future studies are needed to determine whether alternate approaches, such as immunotherapy or vaginal washing, could be of benefit."

So, do the following:

Soak an ORGANIC tampon in 15 drops Lemon Essential oil 9 drops Oregeno Essential oil 15 drops Mountain Savory Essential oil 1 tsp carrier (V-6 food grade) oil Leave soaked tampon in overnight.

The Journal of the Science of Food and Agriculture Sep 2006 did a nice piece on growing savory (Satureja hortensis) in Scotland!) *[ref: S.G. Deans and K.P. Svoboda, Antibacterial activity of summer savory (Satureja hortensis L.) essential oil and its constituents. J. Hort. Sci., 64, 205-210 (1989)].*

Lavender

If you Google 101 essential oil uses, the first 23 are lavender!

Long prized for its healing properties, written records of the use of lavender for medicinal purposes date back as far as 60 AD and the writings of Dioscorides. In ancient Rome lavender was recognized for its healing and antiseptic qualities, its ability to deter insects, and for washing. In fact, its name stems from the Latin "lavare", meaning to wash. During the First World War, when modern antibiotics were sparse, lavender was used to dress wounds and helped to heal scar tissue and burns.

Lavender's Antibiotic Properties

Lavender is renowned for its antibiotic properties. Studies have shown that the essential oil of lavender, particularly when combined with Geranium oil, is capable of killing some Staph infections. Other studies have reported that lavender is good for treating ear infections, and is mild enough to treat such symptoms in children. Recently, four new chemicals have been isolated from lavender plants, and are believed to be beneficial for the treatment of Candida. Lavender tea (infusion) may be made from the dried flowers, 1 1/2 tsp. flowers to 8oz.water.

This can be drunk up to 4 times a day.

Lavender reduces fever and is a strong antiseptic and has been used to fight diphtheria, strep throat and pneumonia.

Lavender tea, or a few drops of oil in a glass of water, used as a gargle eases sore throats and laryngitis, can also soothe toothache.

Wounds and topical application

Lavender oil is an exception to all the other essential oils, in that it does not need to be diluted in a carrier oil because it is so gentle. It is also safe to use on infants and children.

Lavender is often used to treat scalds, minor burns, cuts, grazes, inflammation, eczema and dermatitis.

Geranium

This is Pelargonium sidoides, or South African Geranium NOT P. graveolens, the garden variety geranium. It's excellent for bronchitis. This is a big problem in primary care.

South African geranium, Pelargonium sidoides (NOT the familiar pot plant)

One study followed 476 adults with a clinical diagnosis of bronchitis from primary care medical centers in Germany. It excluded patients who had antibiotic therapy in the previous 4 weeks or asthma, severe heart, renal, or liver disease; immunosuppression; drug or alcohol abuse; and pregnancy or lactation.

This was a randomized, double-blind, placebo-controlled prospective study. Treatment consisted of 1.5 mL of aqueous ethanolic extract (11%) of Geranium root 3 times daily for 7 days. Placebo was matched for color, taste, smell, and viscosity. The breathlessness severity scale scores (BSS) improved in the geranium group over the placebo group. This was a well-structured trial.

[Matthys H, Eisebitt R, Seith B, Heger M. Efficacy and safety of an extract of Pelargonium sidoides (Eps 7630) in adults with acute bronchitis. A randomized, double-blind, placebo controlled trial. Phytomedicine 2003; 10(Suppl 4): S7-S17.]

Pelargonium is also an effective treatment for throat infections. Severe sore throat in children is often due to Streptococcus. In a double-blind clinical trial carried out in the Ukraine, children aged 6 to 10 with acute Strep throat infections were treated with pelargonium root extract or a placebo. Pelargonium resulted in much greater improvements than placebo, reduced the severity of symptoms and shortened the duration of illness by two days on average *[Altern Health Med 2003; 9(5): 68-79].*

Another study showed it was great for acute sinusitis, which is usually due to a bacterial or fungal infection after a cold. A recent study in Germany, involving 361 people with acute sinusitis who were treated with pelargonium

root extract, found that at the end of the four week treatment period 80 per cent of patients recovered or experienced a clear improvement in their symptoms *[Z Phytother 2007; 28: 58-65]*.

One in vitro study showed killing drug-resistant Staph, so it may have a place in therapy for MRSA [Phytomedicine 2003; 10 (Suppl 4): 18-24]. The recommended dosage is 20mg of the root extract, three times a day, or 800mg of dried, powdered root, taken twice a day, for 10 days.

General Warning: All I have written applies ONLY to therapeutic grade essential oils and not to recreational products, so please do not try some of its recommendation unless the oils you are using are at least AFNOR or ISO certified. Merely the word "pure" is not enough.

#40 Competitive Inhibition

In this section I'll be explaining another good strategy for controlling pathogenic bacteria. That's to encourage competition, so that safe, friendly organisms proliferate and occupy so much of the available territory (our bodies) that there is no room for wild forms to get started.

If the friendly horde that we carry should be replaced by nasty disease-causing renegade bacteria from the wild, our health can be compromised, even up to the point of death. All that really stops this happening is the massive presence of largely friendly—or at least nonhostile—forms. They are our main allies in fighting disease. Yet doctors ignore them and, indeed, even ravage and kill them in massive numbers, by the careless and unnecessary use of antibiotics.

Don't be smug. You do your part in hurting our friends too. Antiseptic soaps, sprays and body washes, that the TV ads convince you are really necessary, will kill off good forms as well as the ones you're scared of.

1. It's been said that we are landlords to the host of bacteria that live on us. As such, we should be responsible and caring owners and look after our guests! We can tend our crop of healthy organisms in several ways. We can feed the good bacteria.

2. We can import more good bacteria and add to them.

3. We can get other non-bacterial life forms to attack bacteria, much as introducing a new predator into the eco-landscape can result in wiping out the species on which it preys.

It may surprise you that the scientific study of these three strategies is well under way.

Adding to bacterial colonies is called "probiotics" and nurturing what's already present, with helpful nutrition, is called "pre-biotics".

Eubiotics, which covers both, means simply "good life"; in other words eating and drinking well and behaving sensibly. Synbiotics is another term you may encounter. I'll explain it further along.

The third approach we do using bacteria-hostile viruses which we call bacterio-phages; that means "bacteria eaters". We usually say phages for short. You can probably guess how that one works.

Next I'll cover each of these processes in more detail.

Probiotics

Probiotics, as I just remarked, means adding to the quantity of friendly organisms we carry. It is rather like artificially re-stocking lakes and rivers with fish. If you do it well—and actually ban fishing—you can build up stocks rapidly, because the fish will naturally reproduce and multiply. It's the same with helpful bacteria.

The first ever recognition of this process of probiotics was the use of yoghourt.

Russian scientist and Nobel laureate Eli Metchnikoff was the first to suggest that it would be possible to modify gut flora by adding friendly microbes to squeeze out the damaging ones.

At the beginning of the 20th century Metchnikoff, at that time a professor at the Pasteur Institute in Paris, introduced the theory that the aging process results from the activity of putrefactive (or proteolytic, meaning "breaks down protein") microbes producing toxic substances in the large bowel. According to Metchnikoff these compounds—including phenols, indols and ammonia—were responsible for what he called "intestinal auto-intoxication", which caused the physical changes associated with old age.

Metchnikoff knew that milk fermented with lactic-acid bacteria inhibits the growth of proteolytic bacteria because of the low pH (acidity) produced by the fermentation of lactose. He had also observed that certain rural populations in Europe, for example in Bulgaria and the Russian Steppes who lived largely on milk fermented by lactic-acid bacteria (yoghurt) were exceptionally long lived.

Based on these facts, Metchnikoff proposed that consumption of fermented milk would provide the intestine with harmless lactic-acid bacteria and decrease the intestinal pH and that this would suppress the growth of proteolytic bacteria (something else for the fans of alkali foods to think about).

Metchnikoff himself introduced in his diet sour milk fermented with the bacteria he called "Bulgarian Bacillus" and found his health benefited.

In 1900 Henry Tissier, also from the Pasteur Institute, isolated a Bifidobacterium. Tissier showed that bifidobacteria are predominant in the gut flora of breast-fed babies, and he recommended administration of bifidobacteria to infants suffering from diarrhea.

The stage then switched to Japan. In the 1920s Japan was not the wealthy nation it is today. Many children lost their lives to infectious diseases and other maladies brought on by malnutrition. In 1930. Dr. Minoru Shirota, working in a microbiology lab at Kyoto Imperial University's School of Medicine, succeeded in developing a stronger strain of lactic acid bacteria which would work to destroy the harmful gut bacteria. This bacterium was named Lactobacillus casei shirota after Shirota. It produced a yoghurt-like drink called Yakult, which was introduced to the market in 1935.

Subsequently, other species have been introduced to conventional medicine, including Lactobacillus rhamnosus, Lactobacillus casei, and Lactobacillus johnsonii, because they are normal intestinal species with beneficial properties.

Symbiotics

The old days of just "Lactobacillus acidophilus", basically a bovine form, are gone. As I said in my 1993 book, we need human strain Lactobacillus. The rest just don't thrive and soon die. Lactobacillus bulgaricus had the same problem.

But more importantly we need lots of Bifodobacteria, which is our main friendly passenger down there in the gut.

My more recent caution has been to get properly prepared organisms. The general technique of just crushing them into a tablet just kills the organisms, as you would expect, making a joke of the supposed population values given on the label.

Look instead for non-compacted preparations.

The other new trend is feeding your bowel flora the right stuff. No question that lots of yeasty foods to support the invaders, plus all the sugary and

starchy foods that they can ferment for food, is a recipe for disaster. You need sugar-free healthy foods.

Keeping off ALL sugary and starch foods is tough. But you can take prebiotics, including galactooligosaccharides from human breast milk. Not for everybody but at least the conventional doctors have access to it. Mixing pre-biotics and probiotics like this is called synbiotics (syn- just means coming together, as in synthesize).

If you are not in a doctor's program for synbiotics, you need to consider rice bran and Inuflora, from the jerusalem artichoke. These are fiber products and provide a matrix in which the probiotics can establish themselves. One is soluble and one insoluble and the balance between the two makes an ideal, relatively inexpensive and natural substitute for fancy oligosaccharides.

There is the additional benefit of binding heavy metal complexes, when these are excreted into the gut via the hepato-biliary axis (liver and gallbladder excretion route).

Of course you probably know that holding yeasts, ferments and fungals in check is also a matter of avoiding dietary sugar, which feeds these organisms. Also the avoidance of all dietary fermented products will help, notably cheese, mushrooms, bread and so on.

So, you see, we've gone way beyond just adding yoghourt to our diets!

To summarize:

Bad foods (avoid):

- Yeasty, starchy, sugary, all artificial foods
- Limit fruits (sugar and fructose)
- Yoghourt preparations that have been sweetened for taste (rather defeats the purpose)

Good foods (eat plenty):

- Rice bran
- Inuflora. Jerusalem artichoke
- Any and all fiber vegetables, legumes and salad foods

If you Google "Inuflora" you will find scores of references and places where you can buy online.

This Is So Good The Veterinarians Are Onto It!

Presenting his work at a Society for General Microbiology meeting in the UK on 2 April, 2009, Colin Hill of University College Cork described how his team had used three animal models of disease that had human counterparts — bovine mastitis, porcine salmonellosis (a gastrointestinal disease) and listeriosis in mice (an often fatal form of food poisoning) — to demonstrate the protective effects of probiotics.

The researchers used their own probiotic preparations containing safe bacteria such as Lactobacillus species newly isolated from human volunteers. Hill said that in all three animal diseases, the research group observed a positive effect, in that the animals were "significantly protected" against infection.

The team also used probiotics to control disease in animals that were already infected. The results of these tests, said Hill, showed that administering these safe bacteria to an infected animal was as effective as the best available antibiotic therapies in eliminating the infectious agent and resolving the symptoms.

In each instance the protection was linked to a particular bacterial species, and the mechanism of action varied from direct antagonism, where the probiotic directly kills the pathogenic bacteria, to effects mediated by the host immune system.

For example, Lactobacillus salivarius UCC118 protected mice against listeriosis (a disease which can affect pregnant women) by producing an antimicrobial peptide that eliminates Listeria monocytogenes, the causative organism of Listeria.

Probiotics directly help the effects of antibiotics!

It gets better!

Helicobacter pylori is present in about 25% of patients treated for gastritis or peptic ulcer disease (many now consider this microbe to be the "cause" of peptic ulcers). Standard treatment with two antibiotics (clarithromycin plus amoxicillin) and a fancy drug called a "proton pump inhibitor" (esomeprazole) failed to eradicate the troublesome microbe.

But when a team from the University of Pisa in Italy added supplementation with probiotics (lactobacillus etc.), the cure rate was boosted and side effects reduced (less nausea, diarrhea, metallic taste in the mouth, inflamed tongue, and abdominal pain).

So now scientists think all 5 together are great.

You know what the joke is? If they just gave the probiotics they would work as well as or better than all the other drugs put together. And without any side effects. Duh!

[Am J Gastroenterol. 2007;102:951-956]

How To Take Probiotics

Forget the cheery TV ads with celebrity backing. Most commercial gut flora yoghurt products are of little value. They come with sugar! The bacteria are usually dead.

You need a good source of HUMAN strain lactobacillus. But also Bifidobacteria, which is normally the most common friendly organism in our gut, should be in the supplement as well.

Even then, the probiotic is not bound to establish itself successfully in our gut, so be very selective about what product you choose.

Beware of the tablet delivery. Most of those contain only crushed (dead) bacilli, no matter what claims of bacteria count! Capsules or liquid presentation are the safest.

Human Probiotic Therapy

(Faecal Transplants)

Are you ready for this? One of the ultimate ways to enhance bowel flora is to transplant faecal matter form healthy people into those who are sick and in danger.

Thye Yuck! factor is high but it does work and is practiced in many orthodox medical facilities around the world. In Sweden, human faecal transplants are the treatment of choice of life-threatening membranous ulcertaive colitis, a diosease typically caused by overuse and abuse of antibiotics, leading to overgrowth of Clostridium difficile. It is often fatal.

In fact the faeces are administered either via a nasogastric tube, straight into the stomach, or via an enema. The latter is surely to be preferred, since the colon is where these probiotic bacteria belong.

Of course there are precautions, like testing the "donor" for other pathogens and parasites, HIV and hepatitis.

Family members are preferred as donors, since we share about 80% of the bacteria colonists in the gut with our mother and siblings. But anyone can be a donor, provided he or she is healthy. Donors usually provide faecal material for free (well, you could hardly charge for it, come now!)

So what has all this to do with Clostridium difficile? This is a pretty toxic organism, as are most Clostridia species. But it's not native to our gut. It only takes hold when overuse of antibiotics have displaced the good guys. So it's a man-made complaint.

When healthy human gut flora is ploughed back, so to speak, C. difficile is squeezed out, exactly as we explain probiotics working. And before you ask: yoghourt won't work. This is a killer bug.

But faecal transplants seem to work very well indeed: close on 100% success in fact. People stretchered into hospital at death's door make a remarkable recovery, often in as little as 48 hours! That's amazing. It does suggest that the mechanism is specific toxins produced by friendly bacteria from a healthy gut being able to kill the C. difficile pretty quickly.

One study even resorted to my jokey approach and was titled: Bacteriotherapy using gut flora: toying with human motions" *[Journal of Clinical Gastroenterology, vol. 38, p. 475]*.

However some 200 or so other studies were more serious.

One by Borody and colleagues details 6 cases of severe chronic ulcerative colitis treated using faecal bacteriotherapy. Complete reversal of symptoms was achieved in all patients in just 4 months, by which time all colitis medications had been discontinued as unnecessary *[Borody T, Warren E, Leis S, Surace R, Ashman O (2003). "Treatment of ulcerative colitis using fecal bacteriotherapy.". J Clin Gastroenterol 37 (1): 42–7].*

Bacteriophages

Phage – means eating in science. Esophag(e)us, the gullet, is the same word in a different form and phagocytes ("cell eaters") are immune cells that gobble up bacteria and viruses.

A bacteriophage is any one of a number of viruses that infect bacteria. Bacteriophages, or "phages" for short are viruses that invade only bacterial cells where they take over the genetic code and release more phages. When the bacterium dies, it releases these new phages and so they grow on and on. They can wipe out bacteria in no time.

Phages are estimated to be the most widely distributed and diverse entities in the biosphere. These ubiquitous organelles can be found in all reservoirs populated by bacterial hosts, such as soil or the intestines of animals. One of the densest natural sources for phages and other viruses is sea water and up to 70% of marine bacteria may be infected by phages.

You can find out more by visiting http://www.phage.org, which defaults to the Mansfield Ohio State University website.

A Historical Note

Following the discovery of bacteriophages by Frederick Twort and Felix d'Hérelle early in the 20th C, phage therapy was immediately recognized by many to be a key way forward for the eradication of bacterial infections.

Phages have since been used for over 60 years as an alternative to antibiotics in the former Soviet Union and Eastern Europe. In the USA during the 1940s, commercialization of phage therapy was undertaken by the large pharmaceutical company, Eli Lilly.

Whilst knowledge was being accumulated regarding the biology of phages and how to use phage cocktails correctly, early uses of phage therapy were often unreliable.

Unfortunately, when antibiotics were discovered and marketed widely in the USA and Europe, Western scientists mostly lost interest in further use and study of phage therapy for some time. But research continued in Russia and the Eastern Bloc.

I was taught about phages in med school in the early 1960s; then they seemed to disappear from view.

Phages are now making a comeback. They are seen as a possible therapy against multi drug resistant strains of many bacteria.

Pros and Cons Of Phage Therapy

There are some very important benefits with phage therapy. There are also some drawbacks.

Important benefits of phage therapy:

- Specific to the bacteria so it doesn't wipe out gut flora
- Harmless to the host
- Few side effects and do not stress the liver
- Only needs one dose because they replicate

Disadvantage:

• Will only kill the exact bacterium so needs a cocktail approach for multiple infections.

Biofilm, no not a Bond movie

Pseudomonas aeruginosa—which can cause a number of unpleasant and highly intractable infections, notably of the genito-urinary tract, but also ear infections—is particularly hard to treat because it typically wraps itself in a biofilm - a layer of sugars and proteins that make it up to 1000 times more resistant to antibiotics as a non-biofilm from the same species.

Now it has been found that a single dose of a phage called Biophage-PA, selectively attacks P. aeruginosa, breaks down the biofilm, and destroys the bacteria. It has been used successfully to treat long-term sufferers of antibiotic-resistant ear infections. Andrew Wright from University College London Ear Institute and colleagues studied 24 people with severe ear infections (Clinical Otolaryngology, accepted for publication). Half the volunteers were given Biophage-PA and the rest received a placebo.

Pain, pus secretion and inflammation were reduced in both groups, but the relief was double in the group on the treatment. The number of target bacteria in the ear was significantly reduced in the phage-treated group, while there was no significant reduction in the placebo group.

By the end of the six-week trial, three patients on the phage were clear of infection. Big promise there!

One of the important advantages of phage treatment is that it only takes one dose; this gets round the problem that patients often forget to complete their course of antibiotics, thus inviting resistance.

Of course it is entirely possible that bacteria might evolve resistance to phages too. It might almost be predicted. But so far it isn’t documented.

#41 Homeopathy

Now a New Science Altogether

Now, pay close attention, because this section will probably save more lives than any other in this report. I'm going to briefly describe homoeopathy, and explain why it is a wonderful, effective and safe approach to dealing with infections of all kinds (not just bacterial).

Homoeopathy has been around over two centuries, predates the vaccination and has demonstrated its effectiveness against countless infectious diseases and epidemics. In epidemics of the past, people who took homeopathy often survived unscathed, while others died in significant numbers. Yet, you will still hear it maligned and most conventional doctors and a pseudo-scientists claimed that it's been "proven not to work".

This is nonsensical logic. You cannot, logically and scientifically, prove something doesn't work! You can only fail to prove that it does work!

In fact detractors and bigots simply ignore the volumes of scientific evidence that homoeopathy works. Criticisms come from ignorant, mis-informed critics.

For example I always quote a major study reported in the prestigious journal The Lancet, [Lancet Dec 10, 1994:344, p 1585]. It caused a great deal of controversy and the then editor took the unusual step of mocking it in an editorial. But he did have the decency to admit the trials were done to a very vigorous standard (most drugs trials find their way to publications with far inferior standards).

Because he had to admit that using a double-blind randomized trial clearly showed that homeopathy worked, he wrote in his editorial:

"... we must ask if the technique of randomized controlled trials is fundamentally flawed, and capable of producing evidence for effects that do not exist, by, for example, the effects of clinicians' expectations of outcome transmitting by subtle effects that circumvent double blinding?" (Lancet 1994; 344;1601- 06) I regard this as the worst kind of bigotry. Instead of drawing the conclusion that homeopathy is indeed highly effective, he dared to suggest that randomized double-blind studies, the benchmark of medical science, maybe didn't really work!

Well, in reading this I know you are not too swayed by conventional rhetoric. Nevertheless, I urge that you do not permit this crass ignorance to enter your thinking. To go along with it could some day save your life.

If you trust your author, let me assure you that homeopathy works and it will save innumerable lives in a pandemic. As I indicated in an earlier section, I relied on it entirely when I lived in a malarious zone for 2 years. I took no prophylactic. I simply took a few doses of homeopathic anti-malaria preparation and then after a few weeks didn't even continue. I was bitten many times a day by mosquitoes but remained quite healthy.

Dana Ullman has done a great job of compiling lots of science papers showing uncontrovertibly that homeopathy does work. You can read her findings here:

http://www.homeopathic.com/articles/view,132 *[DANA ULLMAN, MPH, is one of America's leading advocates for homeopathy. He has authored 10 books, including The Homeopathic Revolution: Why Famous People and Cultural Heroes Choose Homeopathy, Homeopathy A-Z, The Consumer's Guide to Homeopathy, Homeopathic Medicines for Children and Infants, Discovering Homeopathy, and (the best-selling) Everybody's Guide to Homeopathic Medicines, with co-author Stephen Cummings, MD].*

Background

Homeopathy is a discipline developed during the 1790s entirely by one man: Samuel Hahnemann, a German physician. Experimenting on himself with the anti-malarial drug quinine, Hahnemann noticed that large doses of the medicine actually caused malaria-like symptoms, while smaller doses cured the symptoms. From this, he advanced his concept of Similia similibus curentur, or "let like be cured with like." Hahnemann then developed an extensive system of medicine based on this concept. He named it homeopathy, from the Greek words homoios (the same) and pathos (suffering).

As the homeopathic healing system grew in popularity during the 1800s, it quickly attracted vehement opposition from the medical and apothecary professions. Since the early 1900s, when the American Medical Association and pharmacists waged a battle against it, homeopathy has been neglected and sometimes ridiculed by mainstream medicine.

Proponents of homeopathy over the years have included Louisa May Alcott, Charles Dickens, Benjamin Disraeli, Johann Wolfgang Goethe, Nathaniel Hawthorne, William James, Henry Wadsworth Longfellow, Pope Pius X, John D. Rockefeller, Harriet Beecher Stowe, William Thackeray, Daniel Webster, and W. B. Yeats. England's royal family has employed homeopathic practitioners since the 1830s *[Source: About.com]*.

The only problem with this wonderful, gentle therapy, is that it takes some skill to administer. I hope, if there is a pandemic scare, or if you developed a drug-resistant strain of bacteria, you can get advice from someone properly trained.

Before you ask, Homeopathic Medicines are generally regarded as safe by the FDA (GRAS).

Homeopathy in 3 bullet points

Homeopathic remedies are almost always made from natural materials—plant, animal, or mineral substances or even venom from snakes or stinging insects. Some remedies may be given in a spray, ointment, or cream, but the most common forms of administration are liquid dilutions or dropped onto tablets or tiny pillules.

Here are the key points in how the preparations are made.

1. The key principle is "like treats like". A remedy which mimics the disease is chosen = similimum. This is the origin of the name "homo-" means: same as. It's completely different to the conventional idea of fighting and suppressing the symptoms.

2. The remedy diluted many times: 10x10x10 (the X series, for example, 10X) or 100x100x100x100 etc (the C series eg. C30). Note that in Europe the X series is usually named D (for decimal), such as D8. Because this process makes the remedy work more effectively, it's called potentization.

3. After each dilution, the bottle is shaken or succussed as it's called.

The part that drives conventional thinkers crazy is the idea that diluting something makes it more effective. They "know" that diluting only makes it weaker. In fact they get very angry about the fact that most dilutions are so high that there cannot be even one single molecule of the original substance left in the remedy bottle.

But that's because they are bound by ridiculously constraints to their ideas and beliefs, which is that the only valid model is biochemical. In other words it needs "stuff" present to make it work.

The real nature of homeopathy seems to be acting as a signal to transfer a "message". This message can be passed onto the next solution and the next, no matter how many times the dilution process takes place.

I haven't time here to go into the whole science of homeopathy but let me offer you an illustration (overleaf), showing a spectrographic study of increasing dilutions of a remedy called belladonna. It should be a kind of "proof" to encourage you.

Read from the bottom up. The first solution is what we call the mother tincture (1:250). Each step in dilution, D1, D6, D12 and so on are progressive dilutions of this tincture, in the 10X sequence (decimal, hence D).

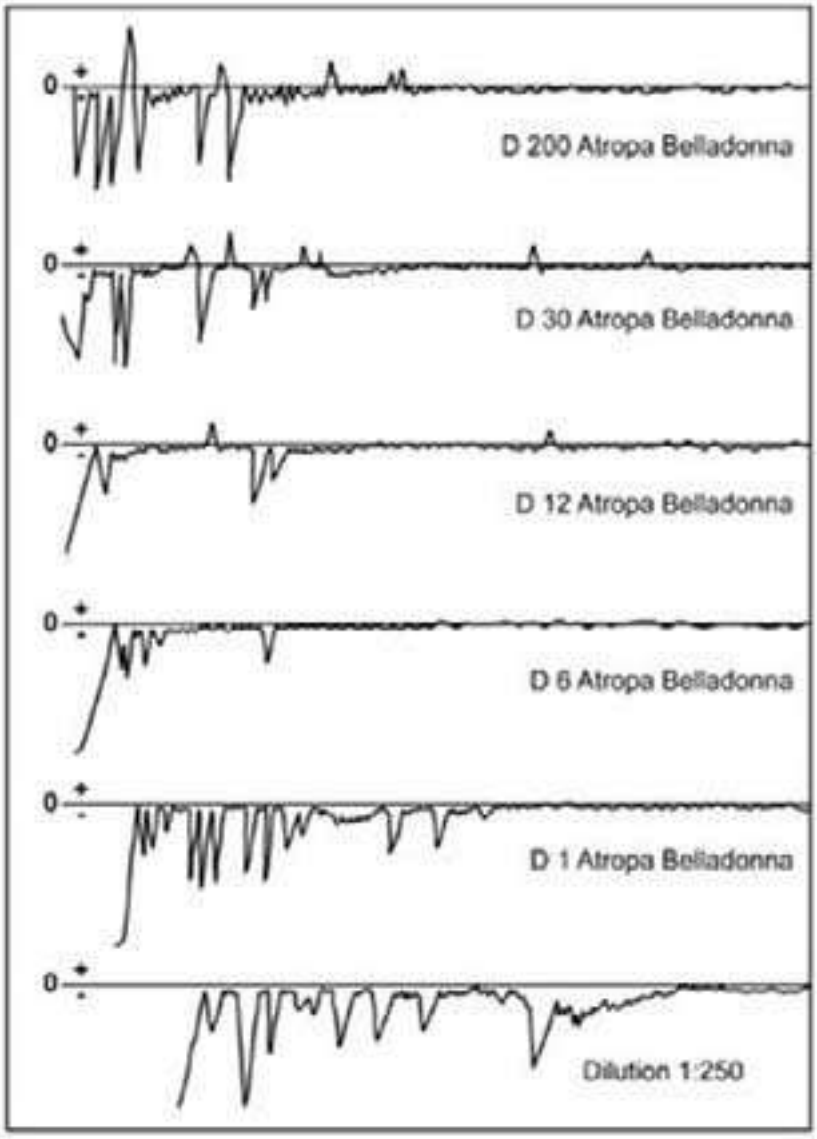

In this chart, any spikes above the horizontal line means that the belladonna solution is actually transmitting electro-magnetic energies (like radio or light waves). You will see that by D200 (diluting one drop to ten drops, repeated 200 times) the spikes are at their strongest.

I christened this chart "Radio Belladonna". What is remarkable is that the transmissions take place long after any of the belladonna substance has vanished.

Need I say more?

Homoepathy In Acute Infections

Much homeopathy is directed towards lifting chronic or inherited disease traits. It requires what is called constitutional prescribing, meaning taking the person whole physical make up and psychological character into the equation. Treatment is NEVER directed towards symptoms but towards changing the individual's make up or "constitution" and driving out disease tendency.

Prescribing for acute illnesses is rather different. Symptoms may be considered in their own right.

Homeopaths classify symptoms according to a hierarchy of four categories for purposes of acute prescribing:

- Peculiar symptoms. These are symptoms unique to the individual that do not occur in most persons with the acute disease. Homeopaths make note of peculiar symptoms because they often help to determine the remedy.

- Mental and emotional symptoms. These are important general symptoms that inform the homeopath about the patient's total experience of the disorder.

- Other general symptoms. These are physical symptoms felt throughout the patient's body, such as tiredness, changes in appetite, or restlessness.

- Particular symptoms. Particular symptoms are localized in the body; they include such symptoms as nausea, skin rashes, headache, etc.

During homeopathic case-taking, the practitioner will evaluate the intensity of the patient's symptoms, assess their depth within the patient's body, note any peculiar symptoms, evaluate the modalities of each symptom, and make a list of key symptoms to guide the selection of the proper medicine.

Medicines (called "remedies") can be general (against any infection) or specific for that disease.

General Remedies To Look Out For

Aconitum napellus: This remedy is often indicated when fever and inflammation come on suddenly, sometimes after exposure to wind and cold, or after a traumatic experience. The person may be very thirsty and often feels fearful or anxious.

Belladonna: Intense heat, redness, swelling, throbbing, and pulsation indicate a need for this remedy. The person's face may be flushed and hot (though hands and feet may be cold) and the eyes are often sensitive to light. Thirst may be lower than expected during fever. Discomfort is worse from motion or jarring, and relieved by cold applications. This was the classic remedy for scarlet fever.

Ferrum phosphoricum: This remedy is indicated in the early stages of many inflammations. Taken at the very first sign of a cold or sore throat, it often helps a person throw the infection off and not get ill. Fever, pink-flushed cheeks, a general weariness, thirst, and moderate pain and swelling are typical symptoms suggesting Ferrum phos in illness or infection.

Bryonia: Feeling worse from even the slightest motion is a strong indication for this remedy. When ill, the person wants to stay completely still—to be left alone and not interfered with in any way. Fever with chills, a very dry mouth, and thirst are also likely. Tearing pains that feel worse from any motion, but improve from pressure if it adds stability, may accompany local infections.

Calcarea carbonica: People who need this remedy tire easily and have low stamina. They tend to feel chilly and sluggish, with clammy hands and feet (though their feet may heat up in bed at night, and their heads may perspire during sleep). Swollen lymph nodes, frequent colds, sore throats, ear infections, and skin eruptions are common. Children who need this remedy are often slow to walk and may have teething problems, frequent colds, and ear infections.

Hepar sulphuris calcareum: A person who needs this remedy feels extremely sensitive and vulnerable when ill, especially if exposed to cold or drafts. Ear infections, sore throats, sinusitis, bronchitis, and skin eruptions are often seen, and cheesy-smelling discharge or offensive pus may be produced. Areas of inflammation can be very sore and sensitive, and splinter-like pains are often felt (in the tonsils when swallowing, in a boil when the skin is touched, etc.).

Silica: A person who needs this remedy can be sensitive and nervous, with low stamina and poor resistance to infection—leading to swollen lymph

nodes, frequent colds, sore throats, tonsillitis, sinusitis, bronchitis, and other illnesses. Boils, easy infection of wounds, and abscessed teeth are often seen. Although very chilly in general, the person often perspires during sleep. Offensive foot sweat with an inclination toward fungal infections is also common.

Mercurius solubilis: This remedy is needed when a person has swollen lymph nodes, offensive breath, and is extremely sensitive to any change in temperature. A tendency toward night sweats and profuse salivation during sleep are other indications. Infections of the gums, ears, sinuses, throat, and skin often respond to this remedy when the other symptoms fit.

Sulphur: This remedy is useful in many kinds of infection characterized by irritation, burning pain, redness of mucous membranes, and offensive odors and discharges. Skin problems are very common—eczema, acne, boils, lymphangitis, and inflammations on or around the genitals. Symptoms are often worse from warmth and worse after bathing. Colds, bronchitis, and other illnesses that have been neglected, or infections that drag on for a very long time, may be helped with this remedy.

Specific Remedies Or Nosodes

Another approach entirely is to use disease pathogen of diseased tissues as a remedy. Remember, it will be diluted many times and so quite harmless. So hoemopathically-potentized malaria can be used as an anti-malaria remedy and that's what I referred to earlier. I took it in Sri Lanka.

The use of actual disease substances we call a "nosode". Nosodes exist for TB, cancer, rubella, 'flu, Streptococcus and Staphylococcus, to name just a few.

A nosode can act like a vaccine and be used as a preventative. In fact Samuel Hahnemann should be credited with the development of vaccination, not Edward Jenner (but try telling that to orthodox doctors!)

Nosodes are really only available through a homeopathic prescriber. In the event of an epidemic or pandemic, I expect supplies will be limited.

But if you are OK ordering online, you can get ANYTHING homeopathic from India, where homeopathy is huge. That's thanks to the former ruler of Punjab, Maharaja Ranjit SinghMaharaja, who espoused it in 1830. It

worked for him and he spent some of his fabulous fortune disseminating it throughout India (which included Pakistan at that time).

Every major city in India has pharmacies dispensing homeopathy medicine. Many states in India also have homeopathy colleges teaching this type of alternative medicine to prospective students. Currently there are 186 homeopathic medical colleges in India.

The Indian government created the Central Council Of Homeopathy which requires uniform education at the graduate level and diploma level in homeopathy. This has lead to standardized practice in India preventing unqualified homeopaths to prescribe medicine and treatments. Currently, there are over 300,000 homeopathic doctors practicing medicine in India.

Just to finish, if you have not heard the term “allopathic”, it means conventional medicine. It comes from the Latin alli- meaning “other” (same word as AL-ternative). So it’s the direct opposite of treating like with like. Allopathic medicine fights against a condition, trying to suppress it, rather than working along with it, to bring it to a close.

#42 Homotoxicology

Also know as comlex homeopathy and German homeopathy.

A similar and closely related discipline is that of homotoxicology, sometimes called "complex homeopathy". It's also sometimes called "German homeopathy", since around 40% of German MDs use it regularly. But I think that's confusing, because Hahnemann was German so both methods are really "German homeopathy".

Complex doesn't really mean convoluted and difficult; it seems means by the use of mixtures and formuals, instead of single pure substances.

In fact complex homeopathy, as it is practiced today, was largely developed by another German doctor Hans-Heinrich Reckweg. He sold out his company in Baden-Baden and re-started in Albuqueque, New Mexico, so you have it in the US too. It's called HEEL (short for herba est ex luce, or plants are from light).

Complex homeopathy, as its name suggests, uses compound solutions; mixes of different remedies. This is anathema to classic homeopaths, who insist that Hahnemann described a science based on one remedy, one disease, at one time (they just ignore the fact that even Hahnemann later experimented with mixes.

Different formulations

Because of the very nature of homeopathy, mixtures can take two forms: mixtures of different substances or mixtures of the same substance only but at different potencies or dilutions. The latter we call a chord (like in music, several notes sounding at once).

But there are other, more subtle differences too. In complex homeopathy we tend to use lower (not so extreme) dilutions. Thus D4, D6 and D10 are often encountered; D30, D60 and D200 are also encountered a lot. Whereas a classic homeopath works more in dilutions (potencies) of C12 and upwards to 1M and 2M. M means a 1:100 dilution, repeated 1,000 times.

In classical homeopathy, the teaching is that as soon as you get a result, you stop the medication and leave the recovery process to run un-aided. A complex homeopathy prescriber would tend to smile with satisfaction and write the patient up for another week or two! Then, as well as the scandal of using more than one substance at a time in a mixture, a complex homeopathy prescriber might also use more than one mixture at a time!

This is typical where we would add what's called a "drainage remedy". This is to increase removal of toxins which accrue in an illness, especially when being treated effectively. As the pathogens are destroyed, the body may reach an overload state, due to its inability to remove resulting toxins fast enough. Drainage remedies stimulate that process and so make sense.

Here an example of a complex homeopathic remedy (Lymphomyosot) and what it contains and simplified notes on what each is for:

> Geranium robertianum 4X, diarrhea, painful urination, ulcerations Nasturtium aquaticum (watercress) 4X, liver and gall bladder, mouth ulcers Ferrum iodatum 12X, scrofula (TB), glandular swelling Myosotis arvensis 3X, chronic bronchitis
>
> Scrophularia nodosa (knotted figwort) 3X, inflammation and swelling of lymph glands and breast, eczema Teucrium scorodonia (germander) 3X, chronic rhinitis, bronchitis, tuberculosis
>
> Veronica officinalis (speedwell) 3X, chronic bronchitis, cystitis, dermatosis
>
> Equisetum hyemale (horsetail) 4X, cystitis, kidney stones
>
> Fumaria officinalis (fumitory) 4X, blood purifier, excess toxin levels
>
> Natrium sulphuricum 4X, liver problems, gastroenteritis, asthma Pinus sylvestris (Scots pine) 4X, rickets, bronchitis, scrofula
>
> Gentiana lutea (yellow gentian) 5X, chronic gastritis, flatulence and diarrhea.
>
> Aranea diadema (spider orchid) 6X, exudations, worse in wet and cold
>
> Sarsaparilla 6X, herpes, painful urination, cystitis and kidney inflammation
>
> Calcarea phosphorica 12X, gastroenteritis, rickets

Note some similarities with herbal preparations.

What To Take

Complex homoepathy prescribing is a complex art in itself. I cannot do more than give an outline here. However it's definitely the one for home prescribing. There are four main reason why it is good for the layman to use:

1. It's safe, you can't mess up.

2. Reactions are milder, it's hard to overdo it!

3. The very nature of a mixture means something should hit the target!

4. The names often help with knowing what to choose (no such help in classic homeopathy).

Here are some suggestions what to do for a severe infection.

Engystol N (HEEL). Great for boosting defence mechanisms and increasing resistance to infections of all kinds, especially viral infections. Good for pneumonia, bronchitis, rhinitis and hepatitis. It's also good after vaccinations, to prevent adverse after effects.

Echinacea compositum

I have already remarked I wouldn't put much faith in just Echincaea for my family. But this Echinacea compositum (complex) is brilliant!

Euphorbium Compositum Spray

Great for nasal, sinus and pharygeal infections.

Galium-Heel is a non-specific drainage remedy, perhaps more suitable for chronic conditions.

Gripp-Heel. This is the one you want in a swine flu or bird flu pandemic. Grippe is the French word for influenza. It contains Aconite (shock and chills, which is the onset of most infectious diseases); Bryonia (inflammation of mucus membranes and cough); Lachesis (bushmaster snake), worsening condition and congestive bronchitis; Eupatorium, influenza with excruciating pains; and Phosphorus, bronchopneumonia and laryngitis, with hoarseness.

Lymphomyosot. Chronic and repeated tonsillitis and lymph gland swellings.

Tonsilla compositum. This is one of my favorites for stimulating the immune system. It has no less than 29 logical ingredients and increases body defences in all ways, but especially the lymphatic system. It goes to chills, bronchitis, emphysema, abcesses, suppurating wounds, gingivitis, as well as the obvious sore throats and tonsillitis.

There are many other compounds which can be called into action by the experienced and knowledgeable prescriber. It takes years to learn the full repertoire of this kind of prescribing.

But here is information enough to get you started on searching and, hopefully, to give you confidence that here is a wonderful, safe and gentle approach to healing. No matter how it is mocked and despised by conventional colleagues who only prescribe poisonous drugs as a "cure", trust me, complex homeopathy works!

Where To Buy

HEEL have distributors and outlets in many parts for the world, from Colombia to Bielorus! For the UK and several other centers, contact my good friend Roger Wilson via his website, http://www.biopathica.co.uk (or biopathica.com).

HEEL's headquarters are in Germany: Dr.-Reckeweg-Str. 2-4 D-76532 Baden-Baden or:

P.O. Box 100349 D-76484 Baden-Baden Phone: +49 72 21 50 10 0 E-Mail: info@heel.de Web: http://www.heel.de

HEEL USA (www.heelusa.com) is related by the Reckeweg range of products but is a separate corporate entity to the original HEEL.

There are several other very good complex homeopathic pharmacy suppliers:

Deseret Biologicals in Sandy, Utah.

Deseret Biologicals are now working with Bruce Shelton MD, former US advisor to HEEL. 469 West Parkland Drive Sandy, UT 84070-6403

phone: 801-563-7448 fax: 801-563-7455 orders: 800-827-9529

Pascoe. Not so much for otc remedies or direct mail but you will recognize these products from certain prescribers. [http://www.pascoe-global.com/sites/content/e7639/e16201/index_ eng.html]

#43 Biochemic Tissue Salts

Also known as Schüssler Salts

Biochemic tissue salts were developed as homeopathic remedies by Samuel Hahnemann, and further investigated by Dr Wilhelm Heinrich Schuessler in the late nineteenth century. They are remedies based on the inorganic salts and are intended to increase the body's ability to absorb and use the mineral salts found in a person's everyday diet in order to maintain or restore good health.

According to Schuessler, illnesses arise when there is an imbalance or deficiency of these minerals in the body - when they are not in the right place at the right time, in other words. Schuessler salts, which he called 'means of functioning,' are meant to redress the imbalance. Schuessler himself worked with 12 salts. His successors added 12 more.

Modern Tablet Form

Biochemic tissue salts are available in tablet form similar to that of most homeopathic remedies. They are made up of the salt ground with lactose powder (a process called trituration) in a ratio of 1:9, and then further diluted six times at a 1:9 ratio so the final product is a 1,000,000 to 1 dilution. These tablets then dissolve on the tongue. They are both individually available as one kind of salt, or come in combinations to address particular illnesses or ailments. There are no known side-effects, and taking them in excess will not result in overdose as biochemic tissue salts occur naturally in the body. Waste will be excreted.

We don't need all the Schuessler salts here but two are useful for infections:

Ferrum Phosphate (ferrum phos) D12 or 12X: great for acute infections, the quicker you nip them in the bud, the better.

Kali Muriaticum/ Potassium Chloride (kali mur) D6 or 6X: the second good infection remedy, can be taken alternately with Ferr Phos.

#44 The Russian SCENAR

I strongly recommend every home have a SCENAR in the medicine cabinet. I have seen this amazing device blow away serious infections in a day or less.

Actually, the SCENAR is a whole family of machines developed in Russia and I predict they will completely change the face of medicine in the next 20 years. They are fast, portable, cheap and effective against almost any condition, from treating sports injuries, strokes, angina, acute infections, back pains and irritable bowel disease (as well as pre-menstrual tension and post-surgical complications) and even defibrillating hearts!

The promise of a small hand-held device that is capable of curing most illness, such as was portrayed in the cult 1970s TV series "STAR TREK", has become a reality. The device weighs around 300 gm, resembles a TV remote control and is powered by an ordinary 9v. battery. It is placed on the skin of the chest, head, abdomen or any diseased part, where it collects electromagnetic signals. These are then modulated according to the on-board software programme and played back to the tissues.

Essentially, SCENAR is using the patient's own endogenous signals on a cybernetic feedback basis, scanning and re-transmitting many times a second. As described to me, the device 'evolves' a new signal pattern for the disordered tissues, the machine literally entering into an information dialogue with the body. New frequencies and energy patterns are established, which in turn become fresh input signals, to be further modified, and so on.

This output-equals-new- input is much the way that fractals are generated and thus, biologically-speaking, we seem to be on good ground here. On the premise that disease signals are generally fixed and unnatural, anything which breaks up the existing order has the capability of disease-busting.

SCENAR casebook from Dr Keith MD (quoted in my book "Virtual Medicine").

Male, 69 years old. This man who was a gardener by profession had chronic suppurating osteomyelitis of the foot (deep bone infection) which could not

be controlled. He was scheduled for an amputation of the lower leg in four days time, largely due to intractable pain. Someone decided to try a SCENAR device on him. It was run over the affected limb for about 30 minutes. Next day, the pain had vanished for the first time in 8 months. Later that day another 30-minute treatment was given.

By next morning the recovery was so dramatic the amputation was called off. A third treatment was given and seven days after the first SCENAR this man was back at work, digging in the garden. His leg has completely recovered.

Clinical Aspects

The device is very safe; the impulse times are very short. No pain is felt but the patient is usually aware of a tingling sensation while it works. The practitioner seeks for what the Russians term asymmetry, meaning something different about the tissue characteristics in the vicinity. There are five main criteria: discolouration (reddening or pallor) sensation (numbness or hyper-aesthesia) stickiness' in which the machine drags with a magnet-like quality as it is drawn over certain tracts of the skin sound changes (the machine begins to chatter electronically as it hits certain zones) change in numerical output display.

Even though it may not coincide with the obvious area of symptoms or pathology, the important point is to treat the asymmetry. For reasons we do not fully understand, when this is eliminated, recovery will rapidly follow.

Couldn't resist reporting just a simple application... My lovely wife Vivien was working in Los Angeles (she's a fashion designer). She had a respiratory infection and felt rough enough for antibiotics. However she was still suffering when she came home Friday night. I broke out the SCENAR and ran it over her chest and back. Within 5 minutes there was what the Russians called an "asymmetry": on the left side there was pain under the tip of the scapula and over the pecs at the front. We worked this for about 10 minutes.

That's all! She reported feeling tons better. All night she didn't cough and woke feeling much better. Who needs antibiotics or even herbs and homeopathy when you have a SCENAR!

You can find out more about this device in my book "Virtual Medicine". Get it here:

http://www.alternative-doctor.com/scenar/

#45 UV Light As An Antibiotic

Back when (in the days before antibiotics) there were many treatments which worked for infections. One almost lost technique was the use of Ultra Violet Light irradiation of the blood to kill pathogens and even cancer cells.

This is a version of what we technically call plasmapheresis or, in Europe "auto sanguis" therapy (meaning "own blood" therapy).

You can do a number of things to blood while it is outside the body that you could not do while it is inside… For example, you can expose it to ozone and so enrich it with oxygen. A high local concentration of oxygen is known to provide a hostile environment for cancer cells. Some deadly organisms, too, like the gas gangrene bacteria (Clostridium welchii), are killed by a high-oxygen environment. Even viruses succumb.

But here I am describing the use of ultra-violet light to treat infections. UV is accepted as a sterilizing agent; city water supply is treated with it; indeed, you may have a UV unit fitted to your spa or pool. There is no scientific argument over its cleansing capabilities. It zaps pathogens!

It's toxic to humans too (sunburn!) but that problem is solved by focusing the UV on blood which is OUTSIDE the body. We call this ultra-violet blood irradiation or UVBI for short. It's also sometimes known as photoluminescence.

The treated blood is returned to the body, where it spreads its good message throughout the tissues. Surprisingly, only about 5% of the total blood volume needs to be treated in this way. This small proportion spreads through the entire body and works its magic, in much the same way a therapeutic drug gets everywhere.

UVBI kills viruses, parasites and bacteria and was popular in the 1930s for polio and other viral infections. The reason is simple enough: it works! But then it became unpopular, as it was gradually sidelined by mass vaccination programs, which were believed to work, despite evidence to the contrary. Finally, UV blood therapy fell into disrepute, except among dedicated holistic physicians.

That's a great pity because it is very safe (no side effects ever recorded, when used properly), highly effective and cheap to do. It's so easy, as a

matter of fact, that it's something a lay persons, with the right equipment and clear instructions, can administer it to themselves.

History

Research into the use of UV light for therapy goes back as far as the 1870's. Niels Ryberg Finsen won the Nobel Peace Prize for "Physiology of Medicine" in 1903 for his UV treatments of 300 people suffering from Lupus in Denmark.

One of the early pioneers of UVBI was Kurt Naswitis, who directly irradiated the blood with UV light through a shunt in 1922.

Another pioneer of this treatment was Emmett K. Knott, who started up in 1928. Dr. Virgil K.

Hancock and Mr. Knott published the first article on the therapeutic efficacy of phototherapy in June of 1934. By June of 1942 they had treated 6,520 patients with ultraviolet therapy. Their work was reported in the most prestigious medical journals. One respected physician of the time, Dr. Rebbeck, wrote in the early 1940s that Hancock and Knott "had in the irradiation of blood with ultraviolet spectral energy, a therapy of more pronounced value than any other method known to date." During a 50-year period, doctors performed more than 300,000 clinical tests that repeatedly showed photoluminescence works and not a single patient was harmed.

Factually, there are very few contraindications for UVBI and unsuitable patients are easily screened out: porphyria, hereditary metabolic disorders such as phenylketonuria, exeroderma pigmentosum, acute photodermatitis, and a hypersensitivity to sunlight or other forms of ultraviolet light are not suitable for UVBI.

On September 11, 1928 Emmet K. Knott patented his device as a "Means for Treating Bloodstream Infections" and later he received another patent, in 1943, which was slightly different.

This is very fortunate for us today because the machine received an FDA "grandfather" status as a device that was sold and distributed in interstate commerce prior to 1976.

Procedure

If you are lucky enough to locate a practitioner who will do this for you, you will find it's very quick and virtually painless. It takes about 20 minutes in total.

A catheter is placed into one of the veins around the elbow (usually with a butterfly needle -- a small plastic catheter attached to a short needle). Drawn blood travels through a small glass chamber, called a cuvette, where it is exposed twice to ultraviolet light before getting re-introduced to the patient's blood stream.

Many patients feel significant improvements after just a few treatments. In severe cases, patients may require 10 or more treatments. But usually, 3 to 5 treatments are sufficient. Even chronic, intractable problems will likely recover.

What Conditions Can Be Benefited?

Actually, a knowledgeable practitioner would probably say almost any non-optimum condition might respond, even cancer. Bear in mind my rubric that "Any good health measure is an anti-cancer measure."

Other conditions which may be significantly improved include:

- Viral Infections
- Candidiasis (fungal infections)
- Bacterial Infections
- Chronic Fatigue
- Poor Oxygen
- Blood Poisoning
- Chronic infections (skin, etc.)
- Colitis
- Leg ulcers
- Diabetes Complications
- Poor Immune Function

UVBI or photoluminescence seems poised to make a come back. It is free of (legal) molestation by the FDA, though the FDA has scant regard for the niceties of law!

But with the obvious dangers and lack of efficacy of vaccination; the development of dangerous antibiotic resistant species of bacteria; and with the difficulty eradicating many viruses, such as hepatitis and AIDS, it is good to know we have a PROVEN, safe, fast, cheap and effective alternative therapy. It won't suit the mindless pill-pushers, who seem to have lost the true art of the healer.

#46 Cold Lasers

The local application of low-level laser (cold laser) energy has been found to be effective in a variety of inflammatory conditions, including infections. Lasers produce coherent light, which is critical. Color light therapy is a different topic altogether. LED light sources are non-coherent.

The 630- 640 nanometre wavelength (red) has considerable effect on the tissues, stimulating cell metabolism, decreasing inflammation and increasing endorphin release, which reduces pain.

One other important consideration is the optimum power necessary for bio-stimulation. The Arndt-Schulz Law of photo-biological activity, essentially states that "less is more" when it comes to energy for improved cellular physiology. A good cold laser, such as the Erchonia cold laser provides the best wavelength (635 nm) for cellular physiology at very low energy (2-5 mill Watts) to stimulate cells to function better. If the stimulation is too intense, there may actually be an inhibitory effect, or possibly degeneration or destruction of cells.

The advantage of lasers, like the SCENAR is that they can be focused on the area of concern. There is no local thermal effect and no recovery time. Normal healing requires certain mediators to be released at the wound site. These cell mediators call inflammatory cells to the wound which clean up damaged tissues, fight bacteria, and stimulate specialized cells to grow to try to heal the zone of injury. The physiologic concept is that cold laser improves cellular metabolism and accelerates the process of healing to a more rapid and efficient state.

Now it happens that 405 nm (violet) laser light works differently. It is soothing and calming.

It helps the body fight infections at a deeper level and even seems to bring in an emotional response to healing.

Stress, overwork, improper diet and the environment can all contribute to a toxic overload in the body which reduces the body's ability to maintain a healthy immune system. The immune system is the body's defense against viruses, bacteria, molds, fungus and other opportunistic infections which

would like to set up a “home” in your body. The laser can help detoxification protocols work faster and on a deeper cellular level.

There are over 1500 published studies and not one of them mentions any negative side effects of semi-conductor diode lasers at the 5mW range, such as the Erchonia lasers. Cold lasers are safe, non-toxic and non-invasive - there have not been any recorded side effects in over 1500 publications. There are some necessary common sense precautions that need to be considered, such as avoiding pointing the laser beam directly into the eye and maintaining it there, which could prove to be damaging to the eye.

Note: If you hear the term “scalar wave laser” run a mile. There is no such thing in the universe and it’s science baloney. Find a real science-grounded practitioner, not someone who speaks pseudo-quantum psychobabble.

#47 Nano UV Zapper

This is another device which should be in every home. Manufacturers claim it is the "world's first compact disinfection light" and say the technology could be used for germ-busting in homes, schools and hospitals.

The Nano-UV Portable Disinfection Light looks like a mobile phone but flips open to reveal an ultraviolet lamp.

Those behind the product say it is certified to kill 99.99 per cent of the potentially deadly H5N1 strain of avian flu in five seconds, and harmful bacteria, such as MRSA, E.coli and salmonella, in 10 seconds.

By using "multi-wavelength" UV technology, combining UVA, UVB and UVC rays, manufacturers say the light is more effective than standard UV disinfection products at killing the DNA of viruses, bacteria and fungi.

The light has a sterilising effect when passed over objects like baby's dummies, nappy changing tables, cutlery, toilet seats and towels.

The Nano UV zapper has a built-in safety device to ensure each use only lasts 10 seconds, which is all it takes to kill 99% plus of all germs.

The beauty of this product is that it's small enough to carry everywhere and powerful enough to give you peace of mind in any situation.

The Nano zapper can be used to sterilize any surface except the skin.

Microbiologist Professor Hugh Pennington, the emeritus professor of bacteriology at Aberdeen University, said UV technology is well known for its germ-killing properties and has a place alongside other good hygiene practices, such as hand-washing.

#48 What Goes In The Medicine Cupboard?

Let's finish up by considering what should every home have in the medicine cupboard. Having got this far, you may have your own opinions about what would be good to include, to be ready in the event of an infection, whether mild or severe.

These are the items I suggest:

- 1 oz. or 25 grams of icthammol ointment (20%)
- Drawing salve for acute, small inflammed infections
- 4 oz. spray of colloidal silver; 100 ml. bottle Grazes, skin abrasions, dental hygiene, sore throat, puncture wounds
- A bottle of MMS (chlorine dixiode) Severe systemic infections, viral and bacterial, bronchitis, wounds, abcesses
- Engystol (if you can't get it, use propolis) General defence for any infectious disease, especially viral.
- 30 ml. bottle of Samento (TOA-free) Chronic infections and "stealth pathogens" (eg. Lyme's)
- 30 ml. Oregano Oil Acute infections of all kinds
- 30 ml. Black seed oil Acute infections of all kinds
- 30 ml. Lavender Oil Mainly skin conditions but could be used for abscesses, acne, athlete's foot, fungal infections, boils, bruises, cuts, insect bites and stings, lice, sunburns, wounds, bronchitis, coughs, colds, congestion, flu, laryngitis, throat infections, whooping cough, and sinus infections.
- Also You Need One Of Two Electrical Healing Devices.

    A SCENAR

    Learn to use it first; don't wait till somebody gets sick!

A low-level laser

Also learn to use it first!

- High Dose Vit C and Vit A for acute viral infections. Have vitamin C powder on hand and vitamin A capsules. There are 25,000 IU capsules coming in from China. Buy them only if you trust the source (I don't).

- Vitamin D capsules, 5,000 IU, improve your immunity whenever an epidemic threatens.

Appendix

The official FDA version

I thought you might like to supplement what I am telling you with the "official" story. This section is from the FDA Consumer magazine (September 1995). I think it's worth reading it over again in a different way. It re-inforces what I have been saying.

You can also listen to some useful recordings and download PDF files here too:

When penicillin became widely available during the Second World War, it was a medical miracle, rapidly vanquishing the biggest wartime killer--infected wounds.

Discovered initially by a French medical student, Ernest Duchesne, in 1896, and then rediscovered by Scottish physician Alexander Fleming in 1928, the product of the soil mold Penicillium crippled many types of disease-causing bacteria. But just four years after drug companies began mass-producing penicillin in 1943, microbes began appearing that could resist it.

The first bug to battle penicillin was Staphylococcus aureus. This bacterium is often a harmless passenger in the human body, but it can cause illness, such as pneumonia or toxic shock syndrome, when it overgrows or produces a toxin.

In 1967, another type of penicillin-resistant pneumonia, caused by Streptococcus pneumoniae and called pneumococcus, surfaced in a remote village in Papua New Guinea. At about the same time, American military personnel in Southeast Asia were acquiring penicillin-resistant gonorrhea from prostitutes.

By 1976, when the soldiers had come home, they brought the new strain of gonorrhea with them, and physicians had to find new drugs to treat it. In 1983, a hospital-acquired intestinal infection caused by the bacterium Enterococcus faecium joined the list of bugs that outwit penicillin.

Antibiotic resistance spreads fast. Between 1979 and 1987, for example, only 0.02 percent of pneumococcus strains infecting a large number of patients surveyed by the national Centers for Disease Control and Prevention were penicillin-resistant. CDC's survey included 13 hospitals in 12 states. Today, 6.6 percent of pneumococcus strains are resistant, according to a re-port in the June 15, 1994, Journal of the American Medical Association by Robert F.

Breiman, M.D., and colleagues at CDC. The agency also reports that in 1992, 13,300 hospital patients died of bacterial infections that were resistant to antibiotic treatment.

Why has this happened?

"There was complacency in the 1980s. The perception was that we had licked the bacterial infection problem. Drug companies weren't working on new agents. They were concentrating on other areas, such as viral infections," says Michael Blum, M.D., medical officer in the Food and Drug Administration's division of anti-infective drug products. "In the meantime, resistance increased to a number of commonly used antibiotics, possibly related to overuse of antibiotics. In the 1990s, we've come to a point for certain infections that we don't have [antibiotics] agents available."

According to a report in the April 28, 1994, New England Journal of Medicine, researchers have identified bacteria in patient samples that resist all currently available antibiotic drugs.

Survival of the Fittest

The increased prevalence of antibiotic resistance is an outcome of evolution. Any population of organisms, bacteria included, naturally includes variants with unusual traits--in this case, the ability to withstand an antibiotic's attack on a microbe. When a person takes an antibiotic, the drug kills the defenseless bacteria, leaving behind--or "selecting," in biological terms--those that can resist it. These renegade bacteria then multi-ply, increasing their numbers a millionfold in a day, becoming the predominant microorganism.

The antibiotic does not technically cause the resistance, but allows it to happen by creating a situation where an already existing variant can flourish. "Whenever antibiotics are used, there is selective pressure for resistance to occur. It builds upon itself. More and more organisms develop resistance to more and more drugs," says Joe Cranston, Ph.D., director of the department of drug policy and standards at the American Medical Association in Chicago.

A patient can develop a drug-resistant infection either by contracting a resistant bug to begin with, or by having a resistant microbe emerge in the body once antibiotic treatment begins. Drug-resistant infections increase

risk of death, and are often associated with prolonged hospital stays, and sometimes complications. These might necessitate removing part of a ravaged lung, or replacing a damaged heart valve.

Bacterial Weaponry

Disease-causing microbes thwart antibiotics by interfering with their mechanism of action. For example, penicillin kills bacteria by attaching to their cell walls, then destroying a key part of the wall. The wall falls apart, and the bacterium dies. Resistant microbes, however, either alter their cell walls so penicillin can't bind or produce enzymes that dismantle the antibiotic.

In another scenario, erythromycin attacks ribosomes, structures within a cell that enable it to make proteins. Resistant bacteria have slightly altered ribosomes to which the drug cannot bind. The ribosomal route is also how bacteria become resistant to the antibiotics tetracycline, streptomycin and gentamicin.

How Antibiotic Resistance Happens

Antibiotic resistance results from gene action. Bacteria acquire genes conferring resistance in any of three ways.

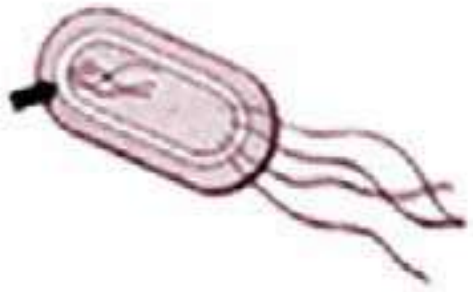

In spontaneous DNA mutation, bacterial DNA (genetic material) may mutate (change) spontaneously (indicated by starburst). Drug-resistant tuberculosis arises this way.

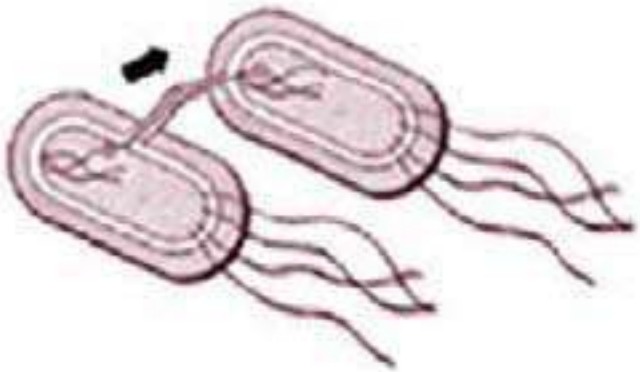

In a form of microbial sex called transformation, one bacterium may take up DNA from another bacterium. Pencillin-resistant gonorrhea results from transformation.

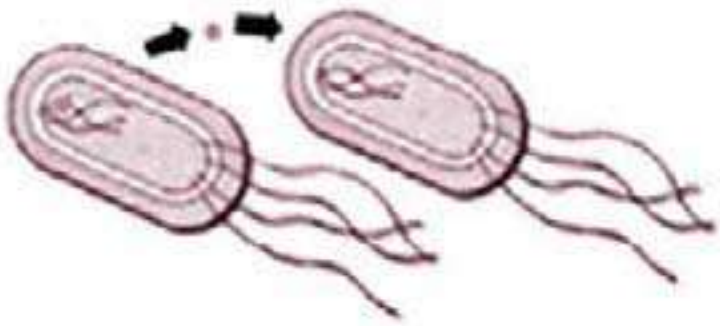

Most frightening, however, is resistance acquired from a small circle of DNA called a plasmid, that can flit from one type of bacterium to another. A single plasmid can provide a slew of different resistances. In 1968, 12,500 people in Guatemala died in an epidemic of Shigella diarrhea. The microbe harbored a plasmid carrying resistances to four antibiotics!

A Vicious Cycle: More Infections and Antibiotic Overuse

Though bacterial antibiotic resistance is a natural phenomenon, societal factors also contribute to the problem. These factors include increased infection transmission, coupled with inappropriate antibiotic use.

More people are contracting infections. Sinusitis among adults is on the rise, as are ear infections in children. A report by CDC's Linda F. McCaig and James M. Hughes, M.D., in the Jan. 18, 1995, Journal of the American Medical Association, tracks antibiotic use in treating common illnesses. The

report cites nearly 6 million antibiotic prescriptions for sinusitis in 1985, and nearly 13 million in 1992. Similarly, for middle ear infections, the numbers are 15 million prescriptions in 1985, and 23.6 million in 1992.

Causes for the increase in reported infections are diverse. Some studies correlate the doubling in doctor's office visits for ear infections for preschoolers between 1975 and 1990 to increased use of day-care facilities. Homelessness contributes to the spread of infection. Ironically, advances in modern medicine have made more people predisposed to infection. People on chemotherapy and transplant recipients taking drugs to suppress their immune function are at greater risk of infection.

"There are the number of immunocompromised patients, who wouldn't have survived in earlier times," says Cranston. "Radical procedures produce patients who are in difficult shape in the hospital, and are prone to nosocomial [hospital-acquired] infections. Also, the general aging of patients who live longer, get sicker, and die slower contributes to the problem," he adds.

Though some people clearly need to be treated with antibiotics, many experts are concerned about the inappropriate use of these powerful drugs. "Many consumers have an expectation that when they're ill, antibiotics are the answer. They put pressure on the physician to prescribe them. Most of the time the illness is viral, and antibiotics are not the answer. This large burden of antibiotics is certainly selecting resistant bacteria," says Blum.

Another much-publicized concern is use of antibiotics in livestock, where the drugs are used in well animals to prevent disease, and the animals are later slaughtered for food. "If an animal gets a bacterial infection, growth is slowed and it doesn't put on weight as fast," says Joe Madden, Ph.D., strategic manager of microbiology at FDA's Center for Food Safety and Applied Nutrition. In addition, antibiotics are sometimes administered at low levels in feed for long durations to increase the rate of weight gain and improve the efficiency of converting animal feed to units of animal production.

FDA's Center for Veterinary Medicine limits the amount of antibiotic residue in poultry and other meats, and the U.S. Department of Agriculture monitors meats for drug residues. According to Margaret Miller, Ph.D., deputy division director at the Center for Veterinary Medicine, the residue limits for antimicrobial animal drugs are set low enough to ensure that the residues themselves do not select resistant bacteria in (human) gut flora.

FDA is investigating whether bacteria resistant to quinolone antibiotics can emerge in food animals and cause disease in humans. Although thorough cooking sharply reduces the likelihood of antibiotic-resistant bacteria surviving in a meat meal to infect a human, it could happen.

Pathogens resistant to drugs other than fluoroquinolones have sporadically been reported to survive in a meat meal to infect a human. In 1983, for example, 18 people in four midwestern states developed multi-drug-resistant Salmonella food poisoning after eating beef from cows fed antibiotics. Eleven of the people were hospitalized, and one died. A study conducted by Alain Cometta, M.D., and his colleagues at the Centre Hospitalier Universitaire Vaudois in Lausanne, Switzerland, and reported in the April 28, 1994, New England Journal of Medicine, showed that increase in antibiotic resistance parallels increase in antibiotic use in humans. They examined a large group of cancer patients given antibiotics called fluoroquinolones to prevent infection. The patients' white blood cell counts were very low as a result of their cancer treatment, leaving them open to infection.

Between 1983 and 1993, the percentage of such patients receiving antibiotics rose from 1.4 to 45. During those years, the researchers isolated Escherichia coli bacteria annually from the patients, and tested the microbes for resistance to five types of fluoroquinolones. Between 1983 and 1990, all 92 E. coli strains tested were easily killed by the antibiotics. But from 1991 to 1993, 11 of 40 tested strains (28 percent) were resistant to all five drugs.

Towards Solving the Problem

Antibiotic resistance is inevitable, say scientists, but there are measures we can take to slow it. Efforts are under way on several fronts--improving infection control, developing new antibiotics, and using drugs more appropriately.

Barbara E. Murray, M.D., of the University of Texas Medical School at Houston writes in the April 28, 1994, New England Journal of Medicine that simple improvements in public health measures can go a long way towards preventing infection. Such approaches include more frequent hand washing by health-care workers, quick identification and isolation of patients with drug-resistant infections, and improving sewage systems and water purity in developing nations.

Drug manufacturers are once again becoming interested in developing new antibiotics. These efforts have been spurred both by the appearance of new

bacterial illnesses, such as Lyme disease and Legionnaire's disease, and resurgences of old foes, such as tuberculosis, due to drug resistance.

FDA is doing all it can to speed development and availability of new antibiotic drugs. "We can't identify new agents--that's the job of the pharmaceutical industry. But once they have identified a promising new drug for resistant infections, what we can do is to meet with the company very early and help design the development plan and clinical trials," says Blum. In addition, drugs in development can be used for patients with multi-drug-resistant infections on an "emergency IND (compassionate use)" basis, if the physician requests this of FDA, Blum adds. This is done for people with AIDS or cancer, for example.

No one really has a good idea of the extent of antibiotic resistance, because it hasn't been monitored in a coordinated fashion. "Each hospital monitors its own resistance, but there is no good national system to test for antibiotic resistance," says Blum.

This may soon change. CDC is encouraging local health officials to track resistance data, and the World Health Organization has initiated a global computer database for physicians to report outbreaks of drug-resistant bacterial infections.

Experts agree that antibiotics should be restricted to patients who can truly benefit from them--that is, people with bacterial infections. Already this is being done in the hospital setting, where the routine use of antibiotics to prevent infection in certain surgical patients is being reexamined.

"We have known since way back in the antibiotic era that these drugs have been used inappropriately in surgical prophylaxis [preventing infections in surgical patients]. But there is more success [in limiting antibiotic use] in hospital settings, where guidelines are established, than in the more typical outpatient settings," says Cranston.

Murray points out an example of antibiotic prophylaxis in the outpatient setting--children with recurrent ear infections given extended antibiotic prescriptions to prevent future infections. (See "Protecting Little Pitchers' Ears" in the December 1994 FDA Consumer.)

Another problem with antibiotic use is that patients often stop taking the drug too soon, because symptoms improve. However, this merely encourages resistant microbes to proliferate. The infection returns a few weeks later, and this time a different drug must be used to treat it.

Targeting TB

Stephen Weis and colleagues at the University of North Texas Health Science Center in Fort Worth reported in the April 28, 1994, New England Journal of Medicine on research they conducted in Tarrant County, Texas, that vividly illustrates how helping patients to take the full course of their medication can actually lower resistance rates. The subject--tuberculosis.

TB is an infection that has experienced spectacular ups and downs. Drugs were developed to treat it, complacency set in that it was beaten, and the disease resurged because patients stopped their medication too soon and infected others. Today, one in seven new TB cases is resistant to the two drugs most commonly used to treat it (isoniazid and rifampin), and 5 percent of these patients die.

In the Texas study, 407 patients from 1980 to 1986 were allowed to take their medication on their own. From 1986 until the end of 1992, 581 patients were closely followed, with nurses observing them take their pills. By the end of the study, the relapse rate--which reflects antibiotic resistance--fell from 20.9 to 5.5 percent. This trend is especially significant, the researchers note, because it occurred as risk factors for spreading TB--including AIDS, intravenous drug use, and homelessness--were increasing.

The conclusion: Resistance can be slowed if patients take medications correctly.

Narrowing the Spectrum

Appropriate prescribing also means that physicians use "narrow spectrum" antibiotics--those that target only a few bacterial types--whenever possible, so that resistances can be restricted. The only national survey of antibiotic prescribing practices of office physicians, conducted by the National Center for Health Statistics, finds that the number of prescriptions has not risen appreciably from 1980 to 1992, but there has been a shift to using costlier, broader spectrum agents. This prescribing trend heightens the resistance problem, write McCaig and Hughes, because more diverse bacteria are being exposed to antibiotics.

One way FDA can help physicians choose narrower spectrum antibiotics is to ensure that labeling keeps up with evolving bacterial resistances. Blum hopes that the surveillance information on emerging antibiotic resistances from

CDC will enable FDA to require that product labels be updated with the most current surveillance information.

Many of us have come to take antibiotics for granted. A child develops strep throat or an ear infection, and soon a bottle of "pink medicine" makes everything better. An adult suffers a sinus headache, and antibiotic pills quickly control it.

But infections can and do still kill. Because of a complex combination of factors, serious infections may be on the rise. While awaiting the next "wonder drug," we must appreciate, and use correctly, the ones that we already have.

Big Difference

If this bacterium could be shown four times bigger, it would be the right relative size to the virus beneath it. (Both are microscopic and are shown many times larger than life.)

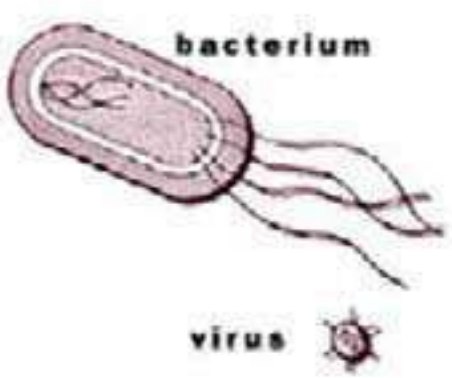

Although bacteria are single-celled organisms, viruses are far simpler, consisting of one type of biochemical (a nucleic acid, such as DNA or RNA) wrapped in another (protein). Most bi-ologists do not consider viruses to be living things, but instead, infectious particles. Antibiotic drugs attack bacteria, not viruses.

Vancomycin Resistance Crisis

When microbes began resisting penicillin, medical researchers fought back with chemical cousins, such as methicillin and oxacillin. By 1953, the antibiotic armamentarium included chloramphenicol, neomycin, terramycin, tetracycline, and cephalosporins. But today, researchers fear that we may be nearing an end to the seemingly endless flow of antimicrobial drugs.

At the center of current concern is the antibiotic vancomycin, which for many infections is literally the drug of "last resort," says Michael Blum, M.D., medical officer in FDA's division of anti-infective drug products. Some hospital-acquired staph infections are resistant to all antibiotics except vancomycin.

Now vancomycin resistance has turned up in another common hospital bug, enterococcus. And since bacteria swap resistance genes like teenagers swap T-shirts, it is only a matter of time, many microbiologists believe, until vancomycin-resistant staph infections appear. "Staph aureus may pick up vancomycin resistance from enterococci, which are found in the normal human gut," says Madden. And the speed with which vancomycin resistance has spread through enterococci has prompted researchers to use the word "crisis" when discussing the possibility of vancomycin-resistant staph.

Vancomycin-resistant enterococci were first reported in England and France in 1987, and appeared in one New York City hospital in 1989. By 1991, 38 hospitals in the United States reported the bug. By 1993, 14 percent of patients with enterococcus in intensive-care units in some hospitals had vancomycin-resistant strains, a 20-fold increase from 1987. A frightening report came in 1992, when a British researcher observed a transfer of a vancomycin-resistant gene from enterococcus to Staph aureus in the laboratory. Alarmed, the researcher immediately destroyed the bacteria.

Writer Ricki Lewis is a geneticist and textbook author.

Extraction Technologies for Medicinal and Aromatic Plants

ICS UNIDO
INTERNATIONAL CENTRE
FOR SCIENCE AND HIGH TECHNOLOGY

1 An Overview of Extraction Techniques for Medicinal and Aromatic Plants

S. S. Handa

Abstract

A wide range of technologies is available for the extraction of active components and essential oils from medicinal and aromatic plants. The choice depends on the economic feasibility and suitability of the process to the particular situation. The various processes of production of medicinal plant extracts and essential oils are reviewed in this paper.

1.1 Introduction

Asia is the largest continent and has 60% of the world's population. It has abundant medicinal and aromatic plant species, well documented traditional knowledge, a long-standing practice of traditional medicine, and the potential for social and economic development of medicinal and aromatic plants (MAPs). Asia is one of the largest biodiversity regions in the world, containing some of the richest countries in plant resources. The continent has diverse plant flora but species richness is concentrated mainly in tropical and subtropical regions. Six of the world's 18 biodiversity hot spots, namely eastern Himalaya, North Borneo, Peninsular Malaysia, Sri Lanka, Philippines and the Western Ghats of South India, lie in Asia. The countries of the region have large flora: China has 30,000 species of higher plants; Indonesia, 20,000; India, 17,000; Myanmar, 14,000; Malaysia, 12,000; and Thailand, 12,000. The total numbers of plant species and the endemics in the region are given below:

Region	Species	Endemics
South East Asia	42-50,000	40,000
China and East Asia	45,000	18,650
Indian Subcontinent	25,000	12,000
South West Asia	23,000	7,100

Sustainable industrial exploitation of such a valuable bioresource, through use of appropriate technologies, can substantially contribute to the socio-economic growth of Asian countries. The International Centre for Science and High Technology (ICS-UNIDO) has thus organized this regional workshop on "extraction technologies for medicinal and aromatic plants" for South East Asian countries.

1.2 Medicinal Plant Extracts

Extraction, as the term is used pharmaceutically, involves the separation of medicinally active portions of plant or animal tissues from the inactive or inert components by using selective solvents in standard extraction procedures. The products so obtained from plants are relatively impure liquids, semisolids or powders intended only for oral or external use. These include classes of preparations known as decoctions, infusions, fluid extracts, tinctures, pilular (semisolid) extracts and powdered extracts. Such preparations popularly have been called galenicals, named after Galen, the second century Greek physician.

The purposes of standardized extraction procedures for crude drugs are to attain the therapeutically desired portion and to eliminate the inert material by treatment with a selective solvent known as *menstruum*. The extract thus obtained may be ready for use as a medicinal agent in the form of tinctures and fluid extracts, it may be further processed to be incorporated in any dosage form such as tablets or capsules, or it may be fractionated to isolate individual chemical entities such as ajmalicine, hyoscine and vincristine, which are modem drugs. Thus, standardization of extraction procedures contributes significantly to the final quality of the herbal drug.

1.2.1 General Methods of Extraction of Medicinal Plants

1.2.1.1 Maceration

In this process, the whole or coarsely powdered crude drug is placed in a stoppered container with the solvent and allowed to stand at room temperature for a period of at least 3 days with frequent agitation until the soluble matter has dissolved. The mixture then is strained, the marc (the damp solid material) is pressed, and the combined liquids are clarified by filtration or decantation after standing.

1.2.1.2 Infusion

Fresh infusions are prepared by macerating the crude drug for a short period of time with cold or boiling water. These are dilute solutions of the readily soluble constituents of crude drugs.

1.2.1.3 Digestion

This is a form of maceration in which gentle heat is used during the process of extraction. It is used when moderately elevated temperature is not objectionable. The solvent efficiency of the menstruum is thereby increased.

1.2.1.4 Decoction

In this process, the crude drug is boiled in a specified volume of water for a defined time; it is then cooled and strained or filtered. This procedure is suitable for extracting water-soluble, heat-stable constituents. This process is typically used in preparation of Ayurvedic extracts called “quath” or “kawath”. The starting ratio of crude drug to water is fixed, e.g. 1:4 or 1:16; the volume is then brought down to one-fourth its original volume by boiling during the extraction procedure. Then, the concentrated extract is filtered and used as such or processed further.

1.2.1.5 Percolation

This is the procedure used most frequently to extract active ingredients in the preparation of tinctures and fluid extracts. A percolator (a narrow, cone-shaped vessel open at both ends) is generally used (Figure 1). The solid ingredients are moistened with an appropriate amount of the specified menstruum and allowed to stand for approximately 4 h in a well-closed container, after which the mass is packed and the top of the percolator is closed. Additional menstruum is added to form a shallow layer above the mass, and the mixture is allowed to macerate in the closed percolator for 24 h. The outlet of the percolator then is opened and the liquid contained therein is allowed to drip slowly. Additional menstruum is added as required, until the percolate measures about three-quarters of the required volume of the finished product. The marc is then pressed and the expressed liquid is added to the percolate. Sufficient menstruum is added to produce the required volume, and the mixed liquid is clarified by filtration or by standing followed by decanting.

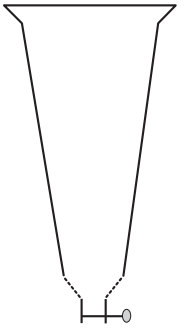

Figure 1: Percolator

1.2.1.6 Hot Continuous Extraction (Soxhlet)

In this method, the finely ground crude drug is placed in a porous bag or “thimble” made of strong filter paper, which is placed in chamber E of the Soxhlet apparatus (Figure 2). The extracting solvent in flask A is heated,

and its vapors condense in condenser D. The condensed extractant drips into the thimble containing the crude drug, and extracts it by contact. When the level of liquid in chamber E rises to the top of siphon tube C, the liquid contents of chamber E siphon into flask A. This process is continuous and is carried out until a drop of solvent from the siphon tube does not leave residue when evaporated. The advantage of this method, compared to previously described methods, is that large amounts of drug can be extracted with a much smaller quantity of solvent. This effects tremendous economy in terms of time, energy and consequently financial inputs. At small scale, it is employed as a batch process only, but it becomes much more economical and viable when converted into a continuous extraction procedure on medium or large scale.

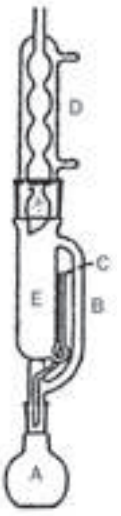

Figure 2: Soxhlet apparatus

1.2.1.7 Aqueous Alcoholic Extraction by Fermentation

Some medicinal preparations of Ayurveda (like *asava* and *arista*) adopt the technique of fermentation for extracting the active principles. The extraction procedure involves soaking the crude drug, in the form of either a powder or a decoction (*kasaya*), for a specified period of time, during which it undergoes fermentation and generates alcohol in situ; this facilitates the extraction of the active constituents contained in the plant material. The alcohol thus generated also serves as a preservative. If the fermentation is to be carried out in an earthen vessel, it should not be new: water should first be boiled in the vessel. In large-scale manufacture, wooden vats, porcelain jars or metal vessels are used in place of earthen vessels. Some examples of such preparations are *karpurasava, kanakasava, dasmularista*. In Ayurveda, this method is not yet standardized but, with the extraordinarily high degree of

advancement in fermentation technology, it should not be difficult to standardize this technique of extraction for the production of herbal drug extracts.

1.2.1.8 Counter-current Extraction

In counter-current extraction (CCE), wet raw material is pulverized using toothed disc disintegrators to produce a fine slurry. In this process, the material to be extracted is moved in one direction (generally in the form of a fine slurry) within a cylindrical extractor where it comes in contact with extraction solvent. The further the starting material moves, the more concentrated the extract becomes. Complete extraction is thus possible when the quantities of solvent and material and their flow rates are optimized. The process is highly efficient, requiring little time and posing no risk from high temperature. Finally, sufficiently concentrated extract comes out at one end of the extractor while the marc (practically free of visible solvent) falls out from the other end.

This extraction process has significant advantages:

i) A unit quantity of the plant material can be extracted with much smaller volume of solvent as compared to other methods like maceration, decoction, percolation.
ii) CCE is commonly done at room temperature, which spares the thermolabile constituents from exposure to heat which is employed in most other techniques.
iii) As the pulverization of the drug is done under wet conditions, the heat generated during comminution is neutralized by water. This again spares the thermolabile constituents from exposure to heat.
iv) The extraction procedure has been rated to be more efficient and effective than continuous hot extraction.

1.2.1.9 Ultrasound Extraction (Sonication)

The procedure involves the use of ultrasound with frequencies ranging from 20 kHz to 2000 kHz; this increases the permeability of cell walls and produces cavitation. Although the process is useful in some cases, like extraction of rauwolfia root, its large-scale application is limited due to the higher costs. One disadvantage of the procedure is the occasional but known deleterious effect of ultrasound energy (more than 20 kHz) on the active constituents of medicinal plants through formation of free radicals and consequently undesirable changes in the drug molecules.

1.2.1.10 Supercritical Fluid Extraction

Supercritical fluid extraction (SFE) is an alternative sample preparation method with general goals of reduced use of organic solvents and increased sample throughput. The factors to consider include temperature, pressure, sample volume, analyte collection, modifier (cosolvent) addition,

flow and pressure control, and restrictors. Generally, cylindrical extraction vessels are used for SFE and their performance is good beyond any doubt. The collection of the extracted analyte following SFE is another important step: significant analyte loss can occur during this step, leading the analyst to believe that the actual efficiency was poor.

There are many advantages to the use of CO_2 as the extracting fluid. In addition to its favorable physical properties, carbon dioxide is inexpensive, safe and abundant. But while carbon dioxide is the preferred fluid for SFE, it possesses several polarity limitations. Solvent polarity is important when extracting polar solutes and when strong analyte-matrix interactions are present. Organic solvents are frequently added to the carbon dioxide extracting fluid to alleviate the polarity limitations. Of late, instead of carbon dioxide, argon is being used because it is inexpensive and more inert. The component recovery rates generally increase with increasing pressure or temperature: the highest recovery rates in case of argon are obtained at 500 atm and 150° C.

The extraction procedure possesses distinct advantages:

i) The extraction of constituents at low temperature, which strictly avoids damage from heat and some organic solvents.
ii) No solvent residues.
iii) Environmentally friendly extraction procedure.

The largest area of growth in the development of SFE has been the rapid expansion of its applications. SFE finds extensive application in the extraction of pesticides, environmental samples, foods and fragrances, essential oils, polymers and natural products. The major deterrent in the commercial application of the extraction process is its prohibitive capital investment.

1.2.1.11 Phytonics Process

A new solvent based on hydrofluorocarbon-134a and a new technology to optimize its remarkable properties in the extraction of plant materials offer significant environmental advantages and health and safety benefits over traditional processes for the production of high quality natural fragrant oils, flavors and biological extracts.

Advanced Phytonics Limited (Manchester, UK) has developed this patented technology termed “phytonics process”. The products mostly extracted by this process are fragrant components of essential oils and biological or phytopharmacological extracts which can be used directly without further physical or chemical treatment.

The properties of the new generation of fluorocarbon solvents have been applied to the extraction of plant materials. The core of the solvent is 1,1,2,2-tetrafluoroethane, better known as hydrofluorocarbon-134a (HFC-134a). This product was developed as a replacement for chlorofluorocarbons. The boiling point of this solvent is -25° C. It is not flammable or toxic. Unlike chlorofluorocarbons, it does not deplete the ozone layer. It has a vapor pressure of 5.6 bar at ambient temperature. By most standards this is a poor solvent. For example, it does not mix with mineral oils or triglycerides and it does not dissolve plant wastes.

The process is advantageous in that the solvents can be customized: by using modified solvents with HFC-134a, the process can be made highly selective in extracting a specific class of phytoconstituents. Similarly, other modified solvents can be used to extract a broader spectrum of components. The biological products made by this process have extremely low residual solvent. The residuals are invariably less than 20 parts per billion and are frequently below levels of detection. These solvents are neither acidic nor alkaline and, therefore, have only minimal potential reaction effects on the botanical materials. The processing plant is totally sealed so that the solvents are continually recycled and fully recovered at the end of each production cycle. The only utility needed to operate these systems is electricity and, even then, they do no consume much energy. There is no scope for the escape of the solvents. Even if some solvents do escape, they contain no chlorine and therefore pose no threat to the ozone layer. The waste biomass from these plants is dry and “ecofriendly” to handle.

1.2.1.11.1 Advantages of the Process

- Unlike other processes that employ high temperatures, the phytonics process is cool and gentle and its products are never damaged by exposure to temperatures in excess of ambient.
- No vacuum stripping is needed which, in other processes, leads to the loss of precious volatiles.
- The process is carried out entirely at neutral pH and, in the absence of oxygen, the products never suffer acid hydrolysis damage or oxidation.
- The technique is highly selective, offering a choice of operating conditions and hence a choice of end products.
- It is less threatening to the environment.
- It requires a minimum amount of electrical energy.
- It releases no harmful emissions into the atmosphere and the resultant waste products (spent biomass) are innocuous and pose no effluent disposal problems.
- The solvents used in the technique are not flammable, toxic or ozone depleting.
- The solvents are completely recycled within the system.

1.2.1.11.2 Applications

The phytonics process can be used for extraction in biotechnology (e.g for the production of antibiotics), in the herbal drug industry, in the food, essential oil and flavor industries, and in the production of other pharmacologically active products. In particular, it is used in the production of top-quality pharmaceutical-grade extracts, pharmacologically active intermediates, antibiotic extracts and phytopharmaceuticals. However, the fact that it is used in all these areas in no way prevents its use in other areas. The technique is being used in the extraction of high-quality essential oils, oleoresins, natural food colors, flavors and aromatic oils from all manner of plant materials. The technique is also used in refining crude products obtained from other extraction processes. It provides extraction without waxes or other contaminants. It helps remove many biocides from contaminated biomass.

1.2.1.12 Parameters for Selecting an Appropriate Extraction Method

i) Authentication of plant material should be done before performing extraction. Any foreign matter should be completely eliminated.
ii) Use the right plant part and, for quality control purposes, record the age of plant and the time, season and place of collection.
iii) Conditions used for drying the plant material largely depend on the nature of its chemical constituents. Hot or cold blowing air flow for drying is generally preferred. If a crude drug with high moisture content is to be used for extraction, suitable weight corrections should be incorporated.
iv) Grinding methods should be specified and techniques that generate heat should be avoided as much as possible.
v) Powdered plant material should be passed through suitable sieves to get the required particles of uniform size.
vi) Nature of constituents:
    a) If the therapeutic value lies in non-polar constituents, a non-polar solvent may be used. For example, lupeol is the active constituent of *Crataeva nurvala* and, for its extraction, hexane is generally used. Likewise, for plants like *Bacopa monnieri* and *Centella asiatica*, the active constituents are glycosides and hence a polar solvent like aqueous methanol may be used.
    b) If the constituents are thermolabile, extraction methods like cold maceration, percolation and CCE are preferred. For thermostable constituents, Soxhlet extraction (if non-aqueous solvents are used) and decoction (if water is the menstruum) are useful.
    c) Suitable precautions should be taken when dealing with constituents that degrade while being kept in organic solvents, e.g. flavonoids and phenyl propanoids.

d) In case of hot extraction, higher than required temperature should be avoided. Some glycosides are likely to break upon continuous exposure to higher temperature.
e) Standardization of time of extraction is important, as:
   - Insufficient time means incomplete extraction.
   - If the extraction time is longer, unwanted constituents may also be extracted. For example, if tea is boiled for too long, tannins are extracted which impart astringency to the final preparation.
f) The number of extractions required for complete extraction is as important as the duration of each extraction.

vii) The quality of water or menstruum used should be specified and controlled.
viii) Concentration and drying procedures should ensure the safety and stability of the active constituents. Drying under reduced pressure (e.g. using a Rotavapor) is widely used. Lyophilization, although expensive, is increasingly employed.
ix) The design and material of fabrication of the extractor are also to be taken into consideration.
x) Analytical parameters of the final extract, such as TLC and HPLC fingerprints, should be documented to monitor the quality of different batches of the extracts.

1.2.2 Steps Involved in the Extraction of Medicinal Plants

In order to extract medicinal ingredients from plant material, the following sequential steps are involved:

1. Size reduction
2. Extraction
3. Filtration
4. Concentration
5. Drying

1.2.2.1 Size Reduction

The dried plant material is disintegrated by feeding it into a hammer mill or a disc pulverizer which has built-in sieves. The particle size is controlled by varying the speed of the rotor clearance between the hammers and the lining of the grinder and also by varying the opening of the discharge of the mill. Usually, the plant material is reduced to a size between 30 and 40 mesh, but this can be changed if the need arises. The objective for powdering the plant material is to rupture its organ, tissue and cell structures so that its medicinal ingredients are exposed to the extraction solvent. Furthermore, size reduction maximizes the surface area, which in turn enhances the mass transfer of active principle from plant material to the solvent. The 30-40 mesh size is optimal, while smaller particles may become slimy during extraction and create difficulty during filtration.

1.2.2.2 Extraction

Extraction of the plant material is carried out in three ways:

i) Cold aqueous percolation
ii) Hot aqueous extraction (decoction)
iii) Solvent extraction (cold or hot)

1.2.2.2.1 Cold Aqueous Percolation

The powdered material is macerated with water and then poured into a tall column. Cold water is added until the powdered material is completely immersed. It is allowed to stand for 24 h so that water-soluble ingredients attain equilibrium in the water. The enriched aqueous extract is concentrated in multiple-effect evaporators to a particular concentration. Some diluents and excipients are added to this concentrated extract, which is then ready for medicinal use.

1.2.2.2.2 Hot Aqueous Extraction (Decoction)

This is done in an open-type extractor. The extractor is a cylindrical vessel made from type 316 stainless steel and has a diameter (D) greater than the height (H), i.e. the H/D ratio is approximately 0.5. The bottom of the vessel is welded to the dished end and is provided with an inside false bottom with a filter cloth. The outside vessel has a steam jacket and a discharge valve at the bottom.

One part powdered plant material and sixteen parts demineralized water are fed into the extractor. Heating is done by injecting steam into the jacket. The material is allowed to boil until the volume of water is reduced to one-fourth its original volume. By this time the medicinal ingredients present in the plant material have been extracted out.

1.2.2.2.3 Filtration

The extract so obtained is separated out from the marc (exhausted plant material) by allowing it to trickle into a holding tank through the built-in false bottom of the extractor, which is covered with a filter cloth. The marc is retained at the false bottom, and the extract is received in the holding tank. From the holding tank, the extract is pumped into a sparkler filter to remove fine or colloidal particles from the extract.

1.2.2.2.4 Spray Drying

The filtered extract is subjected to spray drying with a high pressure pump at a controlled feed rate and temperature, to get dry powder. The desired particle size of the product is obtained by controlling the inside

temperature of the chamber and by varying the pressure of the pump. The dry powder is mixed with suitable diluents or excipients and blended in a double cone mixer to obtain a homogeneous powder that can be straightaway used, for example, for filling in capsules or making tablets.

1.2.2.3 Solvent Extraction

The principle of solid-liquid extraction is that when a solid material comes in contact with a solvent, the soluble components in the solid material move to the solvent. Thus, solvent extraction of plant material results in the mass transfer of soluble active principle (medicinal ingredient) to the solvent, and this takes place in a concentration gradient. The rate of mass transfer decreases as the concentration of active principle in the solvent increases, until equilibrium is reached, i.e. the concentrations of active principle in the solid material and the solvent are the same. Thereafter, there will no longer be a mass transfer of the active principle from plant material to the solvent.

Since mass transfer of the active principle also depends on its solubility in the solvent, heating the solvent can enhances the mass transfer. Moreover, if the solvent in equilibrium with the plant material is replaced with fresh solvent, the concentration gradient is changed. This gives rise to different types of extractions: cold percolation, hot percolation and concentration.

1.2.2.3.1 Cold Percolation

The extraction of plant material is carried out in a percolator which is a tall cylindrical vessel with a conical bottom and a built-in false bottom with a filter cloth. The percolator is connected to a condenser and a receiver for stripping solvent from the marc.

The powdered material is fed into the percolator along with a suitable solvent (ethyl alcohol or another non-polar solvent). The material is left in contact with the solvent until equilibrium of the active principle is achieved. The solvent extract, known as *miscella*, is taken out from the bottom discharge valve of the percolator. Fresh solvent is added into the percolator and the miscella is drained out after acquiring equilibrium. Overall, the plant material is washed four to five times until it gets exhausted. All washes from the percolator are pooled and concentrated.

The solvent in the marc is stripped out by passing steam from the bottom of the percolator. The solvent and steam vapors rise and are condensed in a tubular condenser. The condensate, which is a mixture of alcohol and water, is collected in a receiver and then subjected to fractional distillation to get 95% pure ethyl alcohol which is again used as a fresh solvent.

This type of percolation is not efficient as it takes a long time to reach equilibrium due to the slow mass transfer rate. The mass transfer

rate can be enhanced if some sort of movement is created between the particles and the solvent.

This can be achieved either by providing inside agitation with a mechanical stirrer or by repeated circulation of the extract back to the percolator. The first method is cumbersome and power intensive whereas the latter has been successful. A circulation pump that continuously circulates the miscella back to the top of the percolator gives a better mass transfer rate and reduces the equilibrium time considerably. Still, this type of percolation is energy-consuming as large amounts of miscella from multiple washes must be concentrated to remove the solvent.

To overcome this problem, a battery of percolators can be connected in series. If three washes are required for completion of the extraction, four percolators are connected in series with their respective miscella storage tanks.

At a particular time, one percolator is out of circuit, for charging and discharging the material and also for stripping solvent from the marc, whereas the other three percolators are in operation. Material is fed into all the percolators and the solvent is fed into the first percolator. When the equilibrium in the first percolator is reached, the extract from the first percolator is sent to the second percolator. The first percolator is again filled with fresh solvent. The extract of second percolator is transferred to the third, the extract of first is transferred to second, and fresh solvent is added to the first. The extract of the third percolator is transfered to the fourth percolator. After attaining equilibrium, the extract from the fourth percolator is drained off. The extract of the third percolator goes to fourth, the extract of second goes to third, and the extract of first goes to second percolator. The material of the first percolator, which has received three washes, is completely exhausted. This percolator is taken out of the system for stripping the solvent and discharging the extracted marc. This is again filled with fresh plant material and the sequence is repeated with other percolators. In this way, solvent of each percolator comes in contact three times with solid material and gets fully enriched with active principle. The enriched extract is sent for solvent recovery and concentration. Thus, instead of concentrating three volumes of solvent, only one volume has to be concentrated; this saves energy and the process is efficient.

1.2.2.3.2 Hot Percolation

Increasing the temperature of the solvent increases the solubility of the active principle, which increases the concentration gradient and therefore enhances the mass transfer of active principle from solid material to the solvent, provided the active principle is not heat sensitive. This is achieved by incorporating a heat exchanger between the circulation pump and the feed inlet of the percolator. The extract is continuously pumped into

a tubular heat exchanger which is heated by steam. The temperature of the extract in the percolator is controlled by a steam solenoid valve through a temperature indicator controller. This sort of arrangement can be incorporated in single percolators or in a battery of percolators as needed.

The percolators that are tall cylindrical towers must be housed in sheds of relatively great height. Tall towers are difficult to operate, especially when charging material and discharging the marc from the top and bottom manholes, which are time-consuming and labor-intensive procedures. Tall towers have been replaced by extractors of smaller height for which the H/D ratio is not more than 1.5.

These extractors have perforated baskets in which the material to be extracted is charged. These perforated baskets, when loaded outside, can be inserted into the extractor with a chain pulley block and, after the extraction, they can be lifted out from the extractor for discharging the marc. Some extractors have an electrical hoist for the charging the material and discharging the marc, which makes the operation less labor-intensive, quick and efficient.

The other type of instrument for extraction of medicinal ingredients from plant material is the Soxhlet apparatus, which consists of an extractor, a distillation still, a tubular condenser for the distillation still, a tubular condenser for the recovery of solvent from the marc, a receiver for collecting the condensate from the condenser, and a solvent storage tank. The plant material is fed into the extractor, and solvent is added until it reaches the siphon point of the extractor. Then, the extract is siphoned out into the distillation still, which is heated with steam. The solvent vapors go to the distillation condenser, get condensed and return to the extractor. The level of the solvent in the extractor again rises to the siphon point and the extract is siphoned out into the distillation still. In this way, fresh solvent comes in contact with the plant material a number of times, until the plant material is completely extracted. The final extract in the distillation still, which is rich in active principle, is concentrated and the solvent is recovered.

1.2.2.3.3 Concentration

The enriched extract from percolators or extractors, known as miscella, is fed into a wiped film evaporator where it is concentrated under vacuum to produce a thick concentrated extract. The concentrated extract is further fed into a vacuum chamber dryer to produce a solid mass free from solvent. The solvent recovered from the wiped film evaporator and vacuum chamber dryer is recycled back to the percolator or extractor for the next batch of plant material. The solid mass thus obtained is pulverized and used directly for the desired pharmaceutical formulations or further processed for isolation of its phytoconstituents.

1.3 Aromatic Plant Extracts

The types of volatile isolates that are obtained commercially from aromatic plants are essential oils, concretes, absolutes, pomades and resinoids. Essential oils are isolated from plant material by distillation whereas other volatile isolates are obtained by solvent extraction.

1.3.1 Concrete

This is an extract of fresh flowers, herbs, leaves and the flowering tops of plants obtained by the use of a hydrocarbon solvent such as butane, pentane, hexane and petroleum ether. Concrete is rich in hydrocarbon-soluble material and devoid of water-soluble components. It is generally a waxy, semisolid, dark-colored material free from the original solvent.

In practice, concretes are produced in static extractors. These extractors are fitted with numerous perforated trays so that the flowers do not get compressed by their own weight. Each perforated tray has a spacer so the number and distance between them are predetermined.

The set of perforated trays can be within a removable cylindrical basket. In the centre of the lower tray, there is a rod on which the spacers and the perforated trays are fitted while at the top there is a ring or a hook so that the entire contents of the extractor can be readily removed by a chain pulley block.

While stacking the flowers on these trays, care should be taken to minimize bruising and damage of the flowers, because such damage can result in the release of enzymes in the flower juice which deteriorates the quality of concrete. The basket stacked with flowers is inserted into the extractor and the solvent of choice is introduced from the bottom into the extractor until the material on the perforated disc assembly is completely immersed. Four to five such washes are given until the material is exhausted.

The enriched solvent from the extractor is pumped into an evaporator for solvent recovery and the solvent content is reduced to about one-tenth the original volume. The recovered solvent is pumped to the solvent tanks to be used again. The concentrated material from the evaporator is pumped into a vacuum evaporator where the solvent is removed more carefully under high vacuum and the recovered solvent is returned to the solvent tanks for repeated use. The resultant concrete has an odor similar to but stronger than the material from which it was extracted.

In concrete manufacturing, it is a normal practice to circulate fresh solvent through a battery of extractors. At each cycle, the solvent becomes more enriched with the flower volatiles until extraction is complete.

The number of extractors has to be synchronized with the number of solvent washes.

1.3.2 Absolutes

Concretes are not widely used in perfumery in their native form but are generally converted into an alcohol-soluble volatile concentrate known as an absolute, i.e. they have to be extracted with alcohol.

To make an absolute, the concrete is mixed with absolute alcohol and agitated thoroughly in a vessel with an agitator. During agitation, the temperature is kept at 40°-60° C and the concrete is immersed in the solution. The solution is cooled down to -5° to -10° C to precipitate out the wax, since waxes are normally insoluble in alcohol below -1° C. The precipitated wax is removed by passing the solution through a rotary filter. The filtrate from the rotary filter is pumped into a primary evaporator, where it is concentrated to about 10% alcohol content. Finally, the concentrated extract is pumped into an agitating-type evaporator, where the alcohol is carefully removed under high vacuum.

1.3.3 Resinoids

Resinoid is an extract of naturally resinous material, made with a hydrocarbon solvent. Resinoids are usually obtained from dry materials. The extraction process is same as that of concrete production, except that perforated discs are not used for stacking the material; instead powder from dry plant material is fed into the extractor.

1.3.4 Pomades

Pomades are obtained by a process known as enfleurage, which is a cold fat extraction method. The fat is spread out on glass plates contained in wooden frames, leaving a clear margin near the edges. The absorptive surface of the fat is increased by surface grooves made with a wooden spatula.

Fresh flowers are spread out on the surface of the fat and the frames are stacked in piles. After the perfume oils have been absorbed from the flowers, the spent flowers are removed by hand. Fresh flowers are again spread on the fat surface. This is repeated until the fat surface is completely enriched with perfume oils. The pomade so obtained is ready for cold alcoholic extraction.

1.3.5 Essential Oils

Essential oils are used in a wide variety of consumer goods such as detergents, soaps, toilet products, cosmetics, pharmaceuticals, perfumes,

confectionery food products, soft drinks, distilled alcoholic beverages (hard drinks) and insecticides. The world production and consumption of essential oils and perfumes are increasing very fast. Production technology is an essential element to improve the overall yield and quality of essential oil. The traditional technologies pertaining to essential oil processing are of great significance and are still being used in many parts of the globe. Water distillation, water and steam distillation, steam distillation, cohobation, maceration and enfleurage are the most traditional and commonly used methods. Maceration is adaptable when oil yield from distillation is poor. Distillation methods are good for powdered almonds, rose petals and rose blossoms, whereas solvent extraction is suitable for expensive, delicate and thermally unstable materials like jasmine, tuberose, and hyacinth. Water distillation is the most favored method of production of citronella oil from plant material.

1.3.5.1 Sources of Natural Essential Oils

Plant organs containing natural essential oils are illustrated in Figure 3. Essential oils are generally derived from one or more plant parts, such as flowers (e.g. rose, jasmine, carnation, clove, mimosa, rosemary, lavander), leaves (e.g. mint, *Ocimum* spp., lemongrass, jamrosa), leaves and stems (e.g. geranium, patchouli, petitgrain, verbena, cinnamon), bark (e.g. cinnamon, cassia, canella), wood (e.g. cedar, sandal, pine), roots (e.g. angelica, sassafras, vetiver, saussurea, valerian), seeds (e.g fennel, coriander, caraway, dill, nutmeg), fruits (bergamot, orange, lemon, juniper), rhizomes (e.g. ginger, calamus, curcuma, orris) and gums or oleoresin exudations (e.g. balsam of Peru, balsam of Tolu, storax, myrrh, benzoin).

Specialized plant structures that produce and store essential oils are shown in Figure 4. Depending upon the plant family, essential oils may occur in specialized secretary structures such as glandular hairs (Labiatae, Verbenaceace, Geraniaceae), modified parenchymal cells (Piperaceae), resin canals (conifers), oil tubes called vittae (Umbelliferae), lysigenous cavities (Rutaceae), schizogenous passages (Myrtaceae, Graminae, Compositae) or gum canals (Cistacae, Burseraceae). It is well known that when a geranium leaf is lightly touched, an odor is emitted because the long stalked oil glands are fragile. Similarly, the application of slight pressure on a peppermint leaf will rupture the oil gland and release oil. In contrast, pine needles and eucalyptus leaves do not release their oils until the epidermis of the leaf is broken. Hence, the types of structures in which oil is contained differ depending on the plant type and are plant-family specific. Unfortunately, not enough is known even today about these oil secretary structures to carefully categorize them. From the practical standpoint, they can be categorized into superficial and subcutaneous oils. Based on the currently available information, it may be inferred that oils of the Labiatae, Verbenaceae and Geraniaceae families are the only superficial oils known; consequently, the others are considered subcutaneous oils.

During handling, some flowers continue to produce aroma while other quickly loose their odor. Flowers collected at different times may also give different perfumery values. Regarding the rose, half-open flowers with plump anthers give higher oil yield than fully opened flowers with shrivelled anthers. Humidity, wind, rain and surface temperature also affect the oil yield considerably. Harvesting schedule affects both quantity and quality of the oil.

1.3.5.2 Essential Oil Constituents

Major constituents of essential oils are shown in Figure 5, from which it is clear that most essential oils consist of hydrocarbons, esters, terpenes, lactones, phenols, aldehydes, acids, alcohols, ketones, and esters. Among these, the oxygenated compounds (alcohols, esters, aldehydes, ketones, lactones, phenols) are the principal odor source. They are more stable against oxidizing and resinifying influences than other constituents. On the other hand, unsaturated constituents like monoterpenes and sesquiterpenes have the tendency to oxidize or resinify in the presence of air and light. The knowledge of individual constituents and their physical characteristics, such as boiling point, thermal stability and vapor-pressure-temperature relationship, is of paramount importance in technology development of oxygenated compounds.

1.3.5.3 Methods of Producing Essential Oils

Methods for producing essential oils from plant materials are summarized in Figure 6. Regarding hydrodistillation, the essential oils industry has developed terminology to distinguish three types: water distillation; water and steam distillation; and direct steam distillation.

Originally introduced by Von Rechenberg, these terms have become established in the essential oil industry. All three methods are subject to the same theoretical considerations which deal with distillation of two-phase systems. The differences lie mainly in the methods of handling the material.

Some volatile oils cannot be distilled without decomposition and thus are usually obtained by expression (lemon oil, orange oil) or by other mechanical means. In certain countries, the general method for obtaining citrus oil involves puncturing the oil glands by rolling the fruit over a trough lined with sharp projections that are long enough to penetrate the epidermis and pierce the oil glands located within outer portion of the peel (*ecuelle* method). A pressing action on the fruit removes the oil from the glands, and a fine spray of water washes the oil from the mashed peel while the juice is extracted through a central tube that cores the fruit. The resulting oil-water emulsion is separated by centrifugation. A variation of this process is to remove the peel from the fruit before the oil is extracted.

Often, the volatile oil content of fresh plant parts (flower petals) is so small that oil removal is not commercially feasible by the aforementioned

methods. In such instances, an odorless, bland, fixed oil or fat is spread in a thin layer on glass plates. The flower petals are placed on the fat for a few hours; then repeatedly, the oil petals are removed, and a new layer of petals is introduced. After the fat has absorbed as much fragrance as possible, the oil may be removed by extraction with alcohol. This process, known as enfleurage, was formerly used extensively in the production of perfumes and pomades.

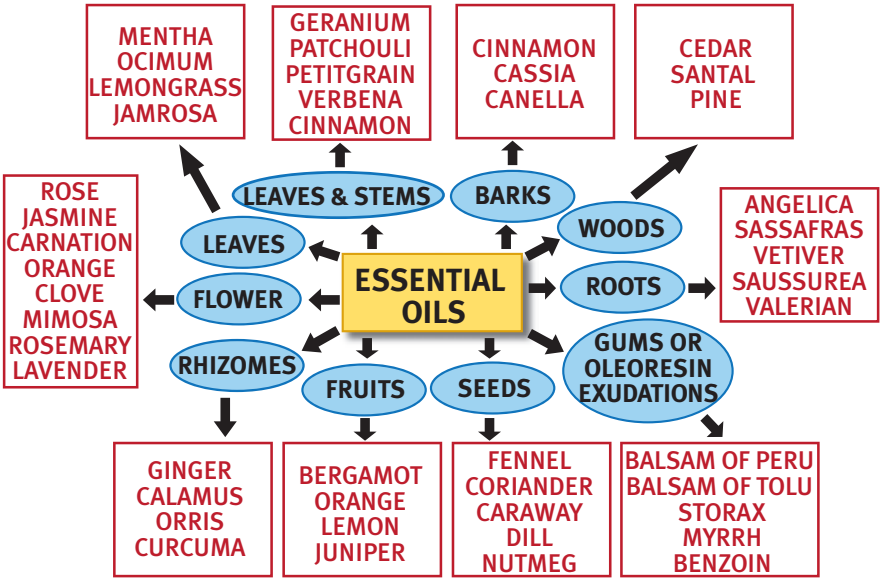

Figure 3: Plant organs containing essential oils

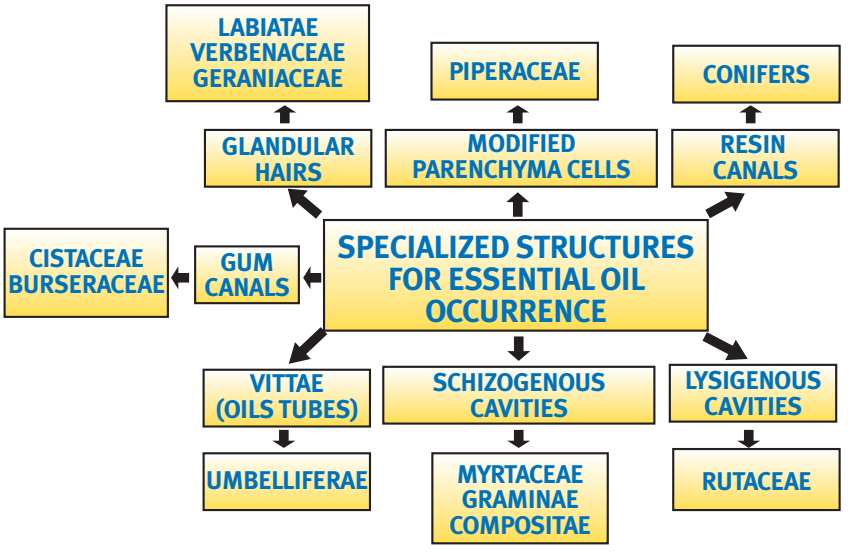

Figure 4: Family-specific plant tissues responsible for producing or storing essential oil

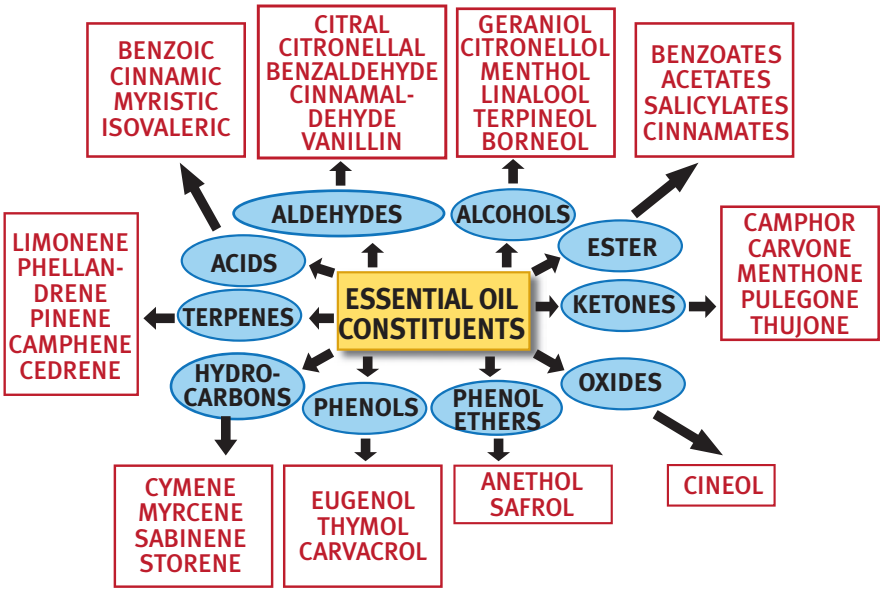

Figure 5: Heterogeneous chemical groups present in essential oil

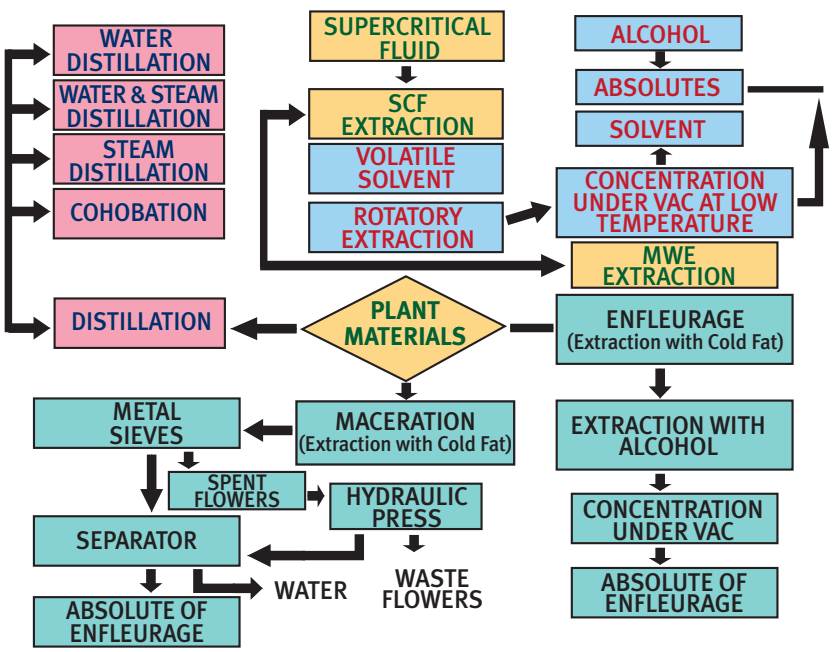

Figure 6: Methods of producing essential oils from plant materials

In the perfume industry, most modern essential oil production is accomplished by extraction, using volatile solvents such as petroleum ether and hexane. The chief advantages of extraction over distillation is that uniform

temperature (usually 50° C) can be maintained during the process, As a result, extracted oils have a more natural odor that is unmatched by distilled oils, which may have undergone chemical alteration by the high temperature. This feature is of considerable importance to the perfume industry; however, the established distillation method is of lower cost than the extraction process.

Destructive distillation means distilling volatile oil in the absence of air. When wood or resin of members of the Pinaceae or Cupressaceae is heated without air, decomposition takes place and a number of volatile compounds are driven off. The residual mass is charcoal. The condensed volatile matter usually separates into 2 layers: an aqueous layer containing wood naptha (methyl alcohol) and pyroligneous acid (crude acetic), and a tarry liquid in the form of pine tar, juniper tar, or other tars, depending on the wood used. This dry distillation is usually conducted in retorts and, if the wood is chipped or coarsely ground and the heat is applied rapidly, the yield often represents about 10% of the wood weight used.

1.3.5.3.1 Hydrodistillation

In order to isolate essential oils by hydrodistillation, the aromatic plant material is packed in a still and a sufficient quantity of water is added and brought to a boil; alternatively, live steam is injected into the plant charge. Due to the influence of hot water and steam, the essential oil is freed from the oil glands in the plant tissue. The vapor mixture of water and oil is condensed by indirect cooling with water. From the condenser, distillate flows into a separator, where oil separates automatically from the distillate water.

1.3.5.3.1.1 Mechanism of Distillation

Hydrodistillation of plant material involves the following main physicochemical processes:

i) Hydrodiffusion
ii) Hydrolysis
iii) Decomposition by heat

1.3.5.3.1.1.1 Hydrodiffusion

Diffusion of essential oils and hot water through plant membranes is known as hydrodiffusion. In steam distillation, the steam does not actually penetrate the dry cell membranes. Therefore, dry plant material can be exhausted with dry steam only when all the volatile oil has been freed from the oil-bearing cells by first thorough comminution of the plant material. But, when the plant material is soaked with water, exchange of vapors within the tissue is based on their permeability while in swollen condition. Membranes of plant cells are almost impermeable to volatile oils. Therefore, in

the actual process, at the temperature of boiling water, a part of volatile oil dissolves in the water present within the glands, and this oil-water solution permeates, by osmosis, the swollen membranes and finally reaches the outer surface, where the oil is vaporized by passing steam.

Another aspect of hydrodiffusion is that the speed of oil vaporization is not influenced by the volatility of the oil components, but by their degree of solubility in water. Therefore, the high-boiling but more water-soluble constituents of oil in plant tissue distill before the low-boiling but less water-soluble constituents. Since hydrodiffusion rates are slow, distillation of uncomminuted material takes longer time than comminuted material.

1.3.5.3.1.1.2 Hydrolysis

Hydrolysis in the present context is defined as a chemical reaction between water and certain constituents of essential oils. Esters are constituents of essential oils and, in the presence of water, especially at high temperatures, they tend to react with water to form acids and alcohols. However, the reactions are not complete in either direction and the relationship between the molal concentrations of various constituents at equilibrium is written as:

$$K = \frac{(\text{alcohol}) \times (\text{acid})}{(\text{ester}) \times (\text{water})}$$

where K is the equilibrium constant.

Therefore, if the amount of water is large, the amounts of alcohol and acid will also be large, resulting in a decreased yield of essential oil. Furthermore, since this is a time-dependent reaction, the extent to which hydrolysis proceeds depends on the time of contact between oil and water. This is one of the disadvantages of water distillation.

1.3.5.3.1.1.3 Effect of Heat

Almost all constituents of essential oils are unstable at high temperature. To obtain the best quality oil, distillation must be done at low temperatures. The temperature in steam distillation is determined entirely by the operating pressure, whereas in water distillation and in water and steam distillation the operating pressure is usually atmospheric.

All the previously described three effects, i.e. hydrodiffusion, hydrolysis and thermal decomposition, occur simultaneously and affect one another. The rate of diffusion usually increases with temperatures as does the solubility of essential oils in water. The same is true for the rate and extent of hydrolysis. However, it is possible to obtain better yield and quality of oils by: (1) maintaining the temperature as low as possible, (2) using as

little water as possible, in the case of steam distillation, and (3) thoroughly comminuting the plant material and packing it uniformly before distillation.

1.3.5.3.2 Three Types of Hydrodistillation

Three are three types of hydrodistillation for isolating essential oils from plant materials:

1. Water distillation
2. Water and steam distillation
3. Direct steam distillation

1.3.5.3.2.1 Water Distillation

In this method, the material is completely immersed in water, which is boiled by applying heat by direct fire, steam jacket, closed steam jacket, closed steam coil or open steam coil. The main characteristic of this process is that there is direct contact between boiling water and plant material.

When the still is heated by direct fire, adequate precautions are necessary to prevent the charge from overheating. When a steam jacket or closed steam coil is used, there is less danger of overheating; with open steam coils this danger is avoided. But with open steam, care must be taken to prevent accumulation of condensed water within the still. Therefore, the still should be well insulated. The plant material in the still must be agitated as the water boils, otherwise agglomerations of dense material will settle on the bottom and become thermally degraded. Certain plant materials like cinnamon bark, which are rich in mucilage, must be powdered so that the charge can readily disperse in the water; as the temperature of the water increases, the mucilage will be leached from the ground cinnamon. This greatly increases the viscosity of the water-charge mixture, thereby allowing it to char. Consequently, before any field distillation is done, a small-scale water distillation in glassware should be performed to observe whether any changes take place during the distillation process. From this laboratory trial, the yield of oil from a known weight of the plant material can be determined. The laboratory apparatus recommended for trial distillations is the Clevenger system (Figure 7).

During water distillation, all parts of the plant charge must be kept in motion by boiling water; this is possible when the distillation material is charged loosely and remains loose in the boiling water. For this reason only, water distillation possesses one distinct advantage, i.e. that it permits processing of finely powdered material or plant parts that, by contact with live steam, would otherwise form lumps through which the steam cannot penetrate. Other practical advantages of water distillation are that the stills

are inexpensive, easy to construct and suitable for field operation. These are still widely used with portable equipment in many countries.

The main disadvantage of water distillation is that complete extraction is not possible. Besides, certain esters are partly hydrolyzed and sensitive substances like aldehydes tend to polymerize. Water distillation requires a greater number of stills, more space and more fuel. It demands considerable experience and familiarity with the method. The high-boiling and somewhat water-soluble oil constituents cannot be completely vaporized or they require large quantities of steam. Thus, the process becomes uneconomical. For these reasons, water distillation is used only in cases in which the plant material by its very nature cannot be processed by water and steam distillation or by direct steam distillation.

Figure 7: Clevenger-type laboratory-scale hydrodistillation apparatus

1.3.5.3.2.1.1 Traditional Method of Producing Attar Using Hydrodistillation

Floral attars are defined as the distillates obtained by hydrodistillation of flowers (such as saffron, marigold, rose, jasmine, pandanus) in sandal wood oil or other base materials like paraffin.

Attar manufacturing takes place in remote places because the flowers must be processed quickly after collection. The apparatus and equipment used to manufacture attar are light, flexible, easy to repair, and have a fair degree of efficiency. Keeping in view these facts, the traditional "deg and bhapka" process has been used for centuries and is used even now with the following traditional equipment (Figure 8).

- Deg (still)
- Bhapka (receiver)
- Chonga (bamboo condenser)

- Traditional bhatti (furnace)
- Gachchi (cooling water tank)
- Kuppi (leather bottle)

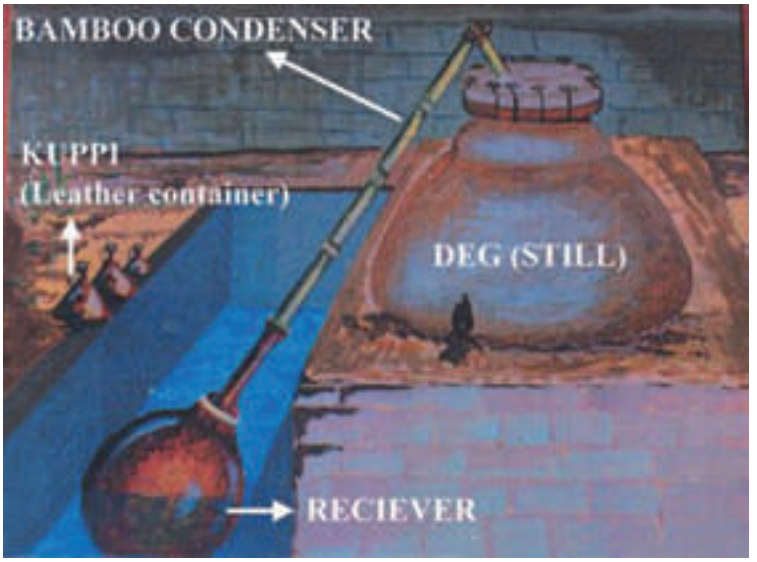

Figure 8: Traditional process of water distillation for making attar

1.3.5.3.2.1.2 Disadvantages of Water Distillation

- Oil components like esters are sensitive to hydrolysis while others like acyclic monoterpene hydrocarbons and aldehydes are susceptible to polymerization (since the pH of water is often reduced during distillation, hydrolytic reactions are facilitated).
- Oxygenated components such as phenols have a tendency to dissolve in the still water, so their complete removal by distillation is not possible.
- As water distillation tends to be a small operation (operated by one or two persons), it takes a long time to accumulate much oil, so good quality oil is often mixed with bad quality oil.
- The distillation process is treated as an art by local distillers, who rarely try to optimize both oil yield or quality.
- Water distillation is a slower process than either water and steam distillation or direct steam distillation.

1.3.5.3.2.2 Water and Steam Distillation

In water and steam distillation, the steam can be generated either in a satellite boiler or within the still, although separated from the

plant material. Like water distillation, water and steam distillation is widely used in rural areas. Moreover, it does not require a great deal more capital expenditure than water distillation. Also, the equipment used is generally similar to that used in water distillation, but the plant material is supported above the boiling water on a perforated grid. In fact, it is common that persons performing water distillation eventually progress to water and steam distillation.

It follows that once rural distillers have produced a few batches of oil by water distillation, they realize that the quality of oil is not very good because of its still notes (subdued aroma). As a result, some modifications are made. Using the same still, a perforated grid or plate is fashioned so that the plant material is raised above the water. This reduces the capacity of the still but affords a better quality of oil. If the amount of water is not sufficient to allow the completion of distillation, a cohobation tube is attached and condensate water is added back to the still manually, thereby ensuring that the water, which is being used as the steam source, will never run out. It is also believed that this will, to some extent, control the loss of dissolved oxygenated constituents in the condensate water because the re-used condensate water will allow it to become saturated with dissolved constituents, after which more oil will dissolve in it.

1.3.5.3.2.2.1 Cohobation

Cohobation is a procedure that can only be used during water distillation or water and steam distillation. It uses the practice of returning the distillate water to the still after the oil has been separated from it so that it can be re-boiled. The principal behind it is to minimize the losses of oxygenated components, particularly phenols which dissolve to some extent in the distillate water. For most oils, this level of oil loss through solution in water is less than 0.2%, whereas for phenol-rich oils the amount of oil dissolved in the distillate water is 0.2%-0.7%. As this material is being constantly re-vaporized, condensed and re-vaporized again, any dissolved oxygenated constituents will promote hydrolysis and degradation of themselves or other oil constituents. Similarly, if an oxygenated component is constantly brought in contact with a direct heat source or side of a still, which is considerably hotter than 100° C, then the chances of degradation are enhanced. As a result, the practice of cohobation is not recommended unless the temperature to which oxygenated constituents in the distillate are exposed is no higher than 100° C.

In steam and water distillation, the plant material cannot be in direct contact with the fire source beneath the still; however, the walls of the still are good conductors of heat so that still notes can also be obtained from the thermal degradation reactions of plant material that is touching the sides of the still. As the steam in the steam and water distillation process is wet, a major drawback of this type of distillation is that it will make the plant

material quite wet. This slows down distillation as the steam has to vaporize the water to allow it to condense further up the still. One way to prevent the lower plant material resting on the grid from becoming waterlogged is to use a baffle to prevent the water from boiling too vigorously and coming in direct contact with the plant material.

1.3.5.3.2.2.2 Advantages of Water and Steam Distillation over Water Distillation

- Higher oil yield.
- Components of the volatile oil are less susceptible to hydrolysis and polymerization (the control of wetness on the bottom of the still affects hydrolysis, whereas the thermal conductivity of the still walls affects polymerization).
- If refluxing is controlled, then the loss of polar compounds is minimized.
- Oil quality produced by steam and water distillation is more reproducible.
- Steam and water distillation is faster than water distillation, so it is more energy efficient.

Many oils are currently produced by steam and water distillation, for example lemongrass is produced in Bhutan with a rural steam and water distillation system.

1.3.5.3.2.2.3 Disadvantages of Water and Steam Distillation

- Due to the low pressure of rising steam, oils of high-boiling range require a greater quantity of steam for vaporization - hence longer hours of distillation.
- The plant material becomes wet, which slows down distillation as the steam has to vaporize the water to allow it to condense further up the still.
- To avoid that the lower plant material resting on the grid becomes waterlogged, a baffle is used to prevent the water from boiling too vigorously and coming in direct contact with the plant material.

1.3.5.3.2.3 Direct Steam Distillation

As the name suggests, direct steam distillation is the process of distilling plant material with steam generated outside the still in a satellite steam generator generally referred to as a boiler. As in water and steam distillation, the plant material is supported on a perforated grid above the steam inlet. A real advantage of satellite steam generation is that the amount of steam can be readily controlled. Because steam is generated in a satellite boiler, the plant material is heated no higher than 100° C and, consequently, it should not undergo thermal degradation. Steam distillation

is the most widely accepted process for the production of essential oils on large scale. Throughout the flavor and fragrance supply business, it is a standard practice.

An obvious drawback to steam distillation is the much higher capital expenditure needed to build such a facility. In some situations, such as the large-scale production of low-cost oils (e.g. rosemary, Chinese cedarwood, lemongrass, litsea cubeba, spike lavender, eucalyptus, citronella, cornmint), the world market prices of the oils are barely high enough to justify their production by steam distillation without amortizing the capital expenditure required to build the facility over a period of 10 years or more.

1.3.5.3.2.3.1 Advantages of Direct Steam Distillation

- Amount of steam can be readily controlled.
- No thermal decomposition of oil constituents.
- Most widely accepted process for large-scale oil production, superior to the other two processes.

1.3.5.3.2.3.2 Disadvantage of Direct Steam Distillation

- Much higher capital expenditure needed to establish this activity than for the other two processes.

1.3.5.3.3 Essential Oil Extraction by Hydrolytic Maceration Distillation

Certain plant materials require maceration in warm water before they release their essential oils, as their volatile components are glycosidically bound. For example, leaves of wintergreen (*Gaultheria procumbens*) contain the precursor gaultherin and the enzyme primeverosidase; when the leaves are macerated in warm water, the enzyme acts on the gaultherin and liberates free methyl salicylate and primeverose. Other similar examples include brown mustard (sinigrin), bitter almonds (amygdalin) and garlic (alliin).

1.3.5.3.4 Essential Oil Extraction by Expression

Expression or cold pressing, as it is also known, is only used in the production of citrus oils. The term expression refers to any physical process in which the essential oil glands in the peel are crushed or broken to release the oil. One method that was practiced many years ago, particularly in Sicily (*spugna* method), commenced with halving the citrus fruit followed by pulp removal with the aid of sharpened spoon-knife (known as a *rastrello*). The oil was removed from the peel either by pressing the peel against a hard object of baked clay (*concolina*) which was placed under a large natural sponge or by bending the peel into the sponge. The oil

emulsion absorbed by the sponge was removed by squeezing it into the *concolina* or some other container. It is reported that oil produced this way contains more of the fruit odor character than oil produced by any other method.

A second method known as equaling (or the *scodella* method), uses a shallow bowl of copper (or sometimes brass) with a hollow central tube; the equaling tool is similar in shape to a shallow funnel. The bowl is equipped with brass points with blunt ends across which the whole citrus fruit is rolled by hand with some pressure until all of the oil glands have burst. The oil and aqueous cell contents are allowed to dribble down the hollow tube into a container from which the oil is separated by decantation. Obviously, hand pressing is impractical because it is an extremely slow process, e.g. on average only 2-4 lbs oil per day can be produced by a single person using one of these hand methods. As a result, over the years a number of machines have been designed to either crush the peel of a citrus fruit or crush the whole fruit and then separate the oil from the juice.

1.3.5.3.4.1 Pelatrice Process

In the *pelatrice* process, citrus fruits are fed from a hopper into the abrasive shell of the machine. The fruits are rotated against the abrasive shell by a slow-moving Archimedian screw whose surface rasps the fruit surfaces causing some of the essential oil cavities on the peel to burst and release their oil-water emulsion. This screw further transports the fruit into a hopper in which rollers covered with abrasive spikes burst the remaining oil cavities. The oil and water emulsion is washed away from the fruit by a fine spray of water. The emulsion next passes through a separator where any solids are removed, after which it passes through two centrifugal separators working in series to yield the pure oil. Most bergamot oil and some lemon oil are produced this way in Italy.

1.3.5.3.4.2 Sfumatrice Process

The *sfumatrice* equipment consists of a metallic chain that is drawn by two horizontal ribbed rollers. The peels are conveyed through these rollers during which time they are pressed and bent to release their oil. As in *pelatrice*, the oil is washed away from the *sfumatrice* rollers by fine sprays of water. Again, the oil is initially passed through a separator prior to being sent to two centrifuges in series, so that purified oil can be produced. At one time, *sfumatrice* was the most popular process for citrus oil isolation in Italy; however, today the *pelatrice* method appears more popular.

1.3.5.3.5 Essential Oil Extraction with Cold Fat (Enfleurage)

Despite the introduction of the modern process of extraction with volatile solvents, the old fashioned method of enfleurage, as passed on

from father to son and perfected in the course of generations, still plays an important role. Enfleurage on a large scale is today carried out only in the Grasse region of France, with the possible exception of isolated instances in India where the process has remained primitive.

The principles of enfleurage are simple. Certain flowers (e.g. tuberose and jasmine) continue the physiological activities of developing and giving off perfume even after picking. Every jasmine and tuberose flower resembles, so to speak, a tiny factory continually emitting minute quantities of perfume. Fat possesses a high power of absorption and, when brought in contact with fragrant flowers, readily absorbs the perfume emitted. This principle, methodically applied on a large scale, constitutes enfleurage. During the entire period of harvest, which lasts for eight to ten weeks, batches of freshly picked flowers are strewn over the surface of a specially prepared fat base (corps), let there (for 24 h in the case of jasmine and longer in the case of tuberose), and then replaced by fresh flowers. At the end of the harvest, the fat, which is not renewed during the process, is saturated with flower oil. Thereafter, the oil is extracted from the fat with alcohol and then isolated.

The success of enfleurage depends to a great extent upon the quality of the fat base employed. Utmost care must be exercised when preparing the corps. It must be practically odorless and of proper consistency. If the corps is too hard, the blossoms will not have sufficient contact with the fat, curtailing its power of absorption and resulting in a subnormal yield of flower oil. On the other, if it is too soft, it will tend to engulf the flowers and the exhausted ones will adhere; when removed, the flowers will retain adhering fat, resulting in considerable shrinkage and loss of corps. The consistency of the corps must, therefore, be such that it offers a semihard surface from which the exhausted flowers can easily be removed. The process of enfleurage is carried out in cool cellars, and every manufacturer must prepare the corps according to the prevailing temperature in the cellars during the months of the flower harvest.

Many years of experience have proved that a mixture of one part of highly purified tallow and two parts of lard is eminently suitable for enfleurage. This mixture assures a suitable consistency of the corps in conjunction with high power of absorption. The fat corps thus prepared is white, smooth, absolutely of uniform consistency, free of water and practically odorless. Some manufacturers also add small quantities of orange flower or rose water when preparing the corps. This seems to be done for the sake of convention. Such additions somewhat shade the odor of the finished product by imparting a slight orange blossom or rose note.

1.3.5.3.5.1 Enfleurage and Defleurage

Every enfleurage building is equipped with thousands of so-called chassis, which serve as vehicles for holding the fat corps during the process. A chassis consists of a rectangular wooden frame. The frame holds a glass plate upon both sides of which the fat corps is applied with a spatula at the beginning of the enfleurage process. When piled one above the other, the chassis form airtight compartments, with a layer of fat on the upper and lower side of each glass plate.

Every morning during the harvest the freshly picked flowers arrive, and after being cleaned of impurities, such as leaves and stalks, are strewn by hand on top of the fat layer of each glass plate. Blossoms wet from dew or rain must never be employed, as any trace of moisture will turn the corps rancid. The chassis are then piled up and left in the cellars for 24 h or longer, depending upon the type of flowers. The latter rest in direct contact with one fat layer (the lower one), which acts as a direct solvent whereas the other fat layer (beneath the glass plate of the chassis above) absorbs only the volatile perfume given off by the flowers.

After 24 h, the flowers have emitted most of their oil and start to wither, developing an objectionable odor. They must then be removed from the corps, which process, despite all efforts to introduce labor-saving devices, is still done by hand. Careful removal of the flower (defleurage) is almost more important than charging the corps on the chassis with fresh flowers (enfleurage) and, therefore, the persons doing this work must be experienced and skilled. Most of the exhausted flowers will fall from the fat layer on the chassis glass plate when the chassis is struck lightly against the working table, but since it is necessary to remove every single flower and every particle of the flower, tweezers are used for this delicate operation. Immediately following defleurage, that is, every 24 h, the chassis are recharged with fresh flowers. For this purpose the chassis are turned over and the fat layer, which in the previous operation formed the top (ceiling) of the small chamber, is now directly charged with flowers. In the case of jasmine, the entire enfleurage process lasts about 70 days: daily the exhausted flowers are removed and the chassis are recharged with fresh ones. At the beginning of, and several times during, the harvest, the fat on the chassis is scratched over with metal combs and tiny furrows are drawn in order change and increase the surface of absorption.

At the end of the harvest, the fat is relatively saturated with flower oil and possesses the typical fragrance. The perfumed fat must then be removed from the glass plates between the chassis. For this purpose, it is scraped off with a spatula and then carefully melted and bulked in closed containers. The final product is called pomade (pomade de jasmine, pomade de tuberous, pomade de violet, etc.). The most highly saturated pomade is pomade no. 36, because the corps on the chassis have been

treated with fresh flowers 36 times during the whole process of enfleurage. At the beginning of the harvest, every chassis is charged with about 360 g fat corps on each side of the glass plate, in other words, with 720 g per chassis. Every kilogram of fat corps should be in contact with about 2.5 kg (preferably with 3.0 kg) of jasmine flowers for the entire period of enfleurage, which lasts from 8 to 10 weeks. The quantities differ somewhat for different flowers. At the end of enfleurage, the fat corps has lost about 10% of its weight because of the various manipulations.

1.3.5.3.5.2 Hot Maceration Process

In this process, the long enfleurage time is reduced by the immersion of petals in molten fat heated at 45°-60° C for 1 to 2 h, depending upon the plant species. After each immersion, the fat is filtered and separated from the petals. After 10 to 20 immersions, the fat is separated from waste flowers and water. Absolute of maceration is then produced from fat containing oil through the process of extraction and concentration under reduced pressure. It is mainly used for highly delicate flowers whose physiological activities are lost rapidly after their harvest, such as lily of valley.

1.3.6 Modern (Non-traditional) Methods of Extraction of Essential Oils

Traditional methods of extraction of essential oils have been discussed and these are the methods most widely used on commercial scale. However, with technological advancement, new techniques have been developed which may not necessarily be widely used for commercial production of essential oils but are considered valuable in certain situations, such as the production of costly essential oils in a natural state without any alteration of their thermosensitive components or the extraction of essential oils for micro-analysis. These techniques are as follows:

- Headspace trapping techniques
  - Static headspace technique
  - Vacuum headspace technique
  - Dynamic headspace technique
- Solid phase micro-extraction (SPME)
- Supercritical fluid extraction (SFE)
- Phytosol (phytol) extraction
- Protoplast technique
- Simultaneous distillation extraction (SDE)
- Microwave distillation
- Controlled instantaneous decomposition (CID)
- Thermomicrodistillation
- Microdistillation
- Molecular spinning band distillation
- Membrane extraction

Some of these techniques are discussed in other chapters. Here, a few important, relevant references are provided.

1.4 Conclusions

Some of the major constraints in sustainable industrial exploitation of medicinal and aromatic plants (MAPs) are due to the fact that the countries of South East Asia have poor agricultural practices for MAPs, unscientific and indiscriminate gathering practices from the wild, poor post-harvest and post-gathering practices leading to poor quality raw material, lack of research for the development of high-yielding varieties of MAPs, poor propagation methods, inefficient processing techniques, poor quality control procedures, lack of research on process and product development, difficulty in marketing, non-availability of trained personnel, lack of facilities and tools to fabricate equipment locally, and finally lack of access to the latest technologies and market information. This calls for co-operation and co-ordination among various institutes and organizations of the region, in order to develop MAPs for sustainable commercial exploitation.

The process of extracting MAPs determines how efficiently we add value to MAP bioresources. In the case of essential oils, the extraction process affects the physical as well as internal composition. External appearance, at times, can result in rejection of the batch even if the analytical results are within acceptable limits. Furthermore, essential oils are evaluated internationally for their olfactory properties by experienced perfumers and these olfactory qualities supersede analytical results. Variations in the chemical constituents of the extracts of medicinal plants may result by using non-standardized procedures of extraction. Efforts should be made to produce batches with quality as consistent as possible (within the narrowest possible range).

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2 Role of Process Simulation in Extraction Technologies for Medicinal and Aromatic Plants

M. Fermeglia

Abstract

This paper illustrates the role of process simulation in the field of extraction technologies for medicinal and aromatic plants. The paper starts with a brief introduction to process simulation fundamentals and the role of process simulation in the industry today. It describes procedures to follow in simulating a process and the benefits of process simulation. In the second part of the paper, phytochemical processes that have been simulated at ICS-UNIDO are listed, followed by two case studies to illustrate the applicability of the methodology proposed: (i) turpentine oil batch distillation and (ii) menthol recovery by crystallization of mentha oil. At the end, recommendations are given advocating the importance of process simulation for developing countries.

2.1 Introduction

Developing countries are rich in medicinal and aromatic plants (MAPs) but, due to difficulty in accessing efficient extraction technologies, value addition to this rich bioresource is difficult. In most cases, and particularly in very poor countries, the technologies used are inappropriate and not economical. The crucial problem is related to the quality of the product: primitive extraction technologies do not guarantee a stable and high-quality product and, in some cases, inappropriate technologies and procedures result in producing contaminated product which has low market value.

In order to assist developing countries to achieve the objective of using rich MAP resource for producing value-added products, dissemination of knowledge of existing extraction technologies and of the latest developments in these technologies is essential.

Commercial process simulation software can be used to predict, on a computer, the real plant and consequently is a useful tool for optimizing the process conditions and enhancing the capacity of managing the phytochemical processes. In particular, process simulation can assist developing and emerging countries in optimizing an advanced process rather than managing a primitive process, which should be substituted by more efficient and standardized procedures. The focus in this case is more related to practical problems such as the quality of the materials and of the water to be used for the extraction. In most cases, developing countries face problems in the type of vessel, quality of water and stability of the product during the processing.

This paper describes the use of process simulation software in the extraction and purification of essential oils at both pilot and industrial scales. Such processes have been developed and are in operation in developing and emerging countries. The goal of this paper is to illustrate a procedure for obtaining better knowledge of the extraction process and, therefore, for optimizing the process in terms of energy use, raw material consumption and environmental impact.

2.2 Process Simulation Goals and Definitions

Simulation is the act of representing some aspects of the real world by numbers or symbols which may be manipulated to facilitate their study. A process simulator is an engineering tool that performs several tasks, including automated calculations, material and energy balances, physical property estimations, design or rating calculations, and process optimization. A process simulator is not a process engineer, and a process engineer is always needed to analyze the problem and the output of a process simulator. A process simulator solves material and energy balances by means of computer code.

In principle, a process simulator for the study of a chemical process goes through the procedure outlined in Figure 1. One starts from the definition of the problem (problem analysis) and then develops the process model, i.e. the system of equations (algebraic or differential). Furthermore, one collects the necessary additional data and solves the model with a suitable method, depending on the system of equations. Finally, the process engineer analyzes the results and perhaps starts over again to develop a more realistic model.

The same picture applies to steady-state simulation, dynamic simulation and optimization problems; only the process model and the method of solution change. Solution of the system of material and energy balance equations is not an easy task because it must be solved considering many components, complex thermophysical models for phase equilibrium calculations, a large number of subsystems (equipment), rather complex equipment (e.g. distillation columns), recycle streams and control loops.

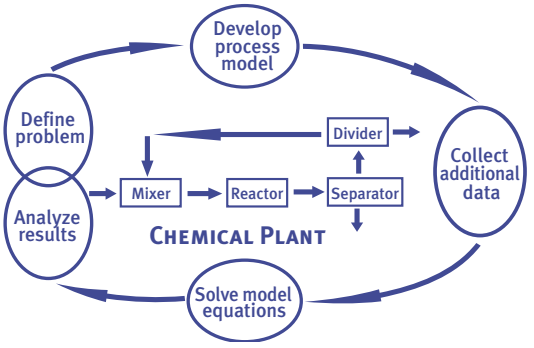

Figure 1: Fundamental steps in running process simulation software

A typical process simulation scheme, with the most important elements and their connections, is shown in Figure 2. Clearly, a process simulator includes cost estimation as well as economic evaluation. The importance of the database is shown in the figure as a necessary source of information for different objects in the structure.

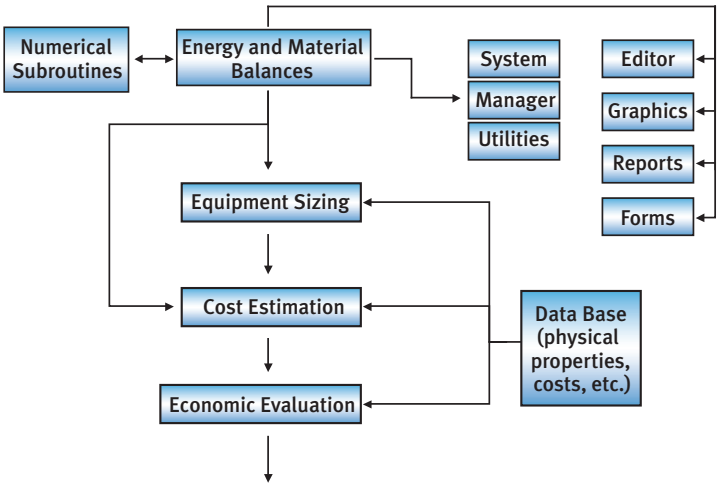

Figure 2: General scheme of a steady-state process simulator

The following approaches are available in process simulation:

- Steady state simulation, which considers a snapshot in time of the process.
- Dynamic simulation, which considers the evolution in the time domain of the equations describing the process.
- Integrated steady-state–dynamic simulation, which combines the previous two approaches.

These three approaches may be used in different ways when dealing with process simulation. One possibility is to perform *process analysis*, in which an existing process is studied and alternative conditions as well as dynamic behavior are investigated in the appraisal of effectiveness of the design. The second is *process synthesis*, in which different process configurations are compared in order to identify the best choice of units and the connections between them. The third possibility is *process design and simulation*, which aims at establishing the optimal operating conditions of a given process.

In all these possibilities, impact on industry is pervasive rather than restricted to a single moment in the development of the process. Process simulation has strongly affected the way engineering knowledge is used in processes. The traditional way of using process simulation was mainly focused on designing flowsheets and on defining critical equipment parameters, such as distillation column stages and column diameter. Today,

engineers are oriented to a more comprehensive use of process simulation in the entire "life" of the plant, as in designing control strategies, optimizing process parameters, studying process time evolution for understanding startup and shutdown procedures, performing risk analysis, training operators, and defining procedures to reduce non-steady-state operations.

The main benefits gained from such a comprehensive use of process simulation are the partial or total replacement of pilot plants (reduction of the number of runs and planning), the reduction of time to market for the development of new processes, and the fast screening of process alternatives to select the best solution in terms of economics, environmental aspects, energy consumption and flexibility. Due to the high complexity of chemical processes, to get these benefits one must critically simplify the process and apply process simulation techniques in the entire life cycle of a process.

Steady-state simulators are considered the core products of process simulation and are used for designing processes, evaluating process changes and analyzing what-if scenarios. Steady-state simulation is normally performed before all other kinds of simulation: dynamic simulation, process synthesis with pinch technology, detailed equipment design, off-line and on-line equation-based optimization, and application technologies for vertical markets (e.g. polymers).

The problems involved in a process simulation run are the definition of an accurate thermodynamic model (equations of state or excess Gibbs energy model), the necessity of defining dummy operations (not always easy to identify), and the tear streams identification to achieve rapid convergence.

The logical procedure for performing a simulation is as follows. First, one defines all the components to be used in the simulation, including conventional and non-conventional components. Next, the most important step in the definition of the simulation is the selection of physicochemical properties to be used in the calculations. Having done this, one proceeds to flowsheet connectivity and to the definition of the feed conditions. The next step is the unit operation internal definitions. At this stage, it is possible to run a base case and check that the system is converging.

Process specification definition, control parameters, and equipment hold-up definition are added later to refine the simulation and to obtain results similar to the reality. Various different results are obtained from a simulation run. The most important are the validation of phase equilibria models for the real system to be used in similar conditions, the verification of the process operating conditions, information on intermediate streams and enthalpy balance, verification of plant specifications, and influence of the operative parameters on the process specifications.

All this information is useful for de-bottlenecking the entire process, or part of it, for identifying process control strategies, and for tuning the instrumentation. This is important since it allows one to verify the behavior of security systems when process conditions are varied.

As far as dynamic simulation is concerned, applications can be found in continuous processes, concurrent process and control design, evaluation of alternative control strategies, troubleshooting process operability, and verification of process safety.

The most important benefits of dynamic modeling are: the capital avoidance and lower operating costs through better engineering decisions; the throughput, product quality, safety and environmental improvements through improved process understanding; and the increased productivity through enhanced integration of engineering work processes.

2.3 Biotechnological and Phytochemical Processes Studied at ICS-UNIDO

This section summarizes ongoing work involving the simulation of important biotechnological and phytochemical processes.

2.3.1 Brief of Biotechnological Processes

2.3.1.1 Alcohol Production from Biomass

The goal of the process is the steady-state simulation of the production of ethanol from biomass fermentation. The process is divided into two parts: (i) biomass fermentation that produces a mixture of ethanol, water and other components, and (ii) separation using a distillation column that concentrates the ethanol. The modelled reactors are continuous stirred tank reactors in series or parallel.

2.3.1.2 Soybean Oil Refining and Treatment of the Waste

The goal of this work is to simulate the soybean oil refining process. This is a complex biotechnological process that involves many reactions and the treatment of solids. The process is divided into three sections: (i) degumming and neutralization, (ii) bleaching, and (iii) deodorization. The main objective of the simulation is to reduce the consumption of steam by applying the pinch technology concept. Steam is consumed in the heat exchangers to heat the oil, in the bleacher equipment, and in the deodorizer. The difficulty of this simulation lies in the large number of undefined components that must be characterized in order to obtain a reliable simulation. In addition, an alternative way of reducing the free acids, by using extraction

with ethanol, is being examined. Key features are the achievements of the required product quality by minimizing the capital and operating costs.

2.3.1.3 Production of Synthetic Hydrocarbon Fuels from Biomass

Starting from natural gas, coal, or wood, a syngas of suitable composition can be produced by gasification. Then, water-gas shift reaction, Fischer-tropsch synthesis and hydrocracking can be applied to the syngas to obtain a mixture of liquid hydrocarbons that can be used as synthetic fuel. This is a complex process that can be simplified by neglecting the kinetics of the chemical reactions involved. The purpose of this project is to quantify the mass and energy consumption and the emission of carbon dioxide. Key features are: the selection of the thermodynamic model to achieve a realistic simulation; the heat integration among different process sections to minimize the environmental impact during recovery and recycling of the entrainer; and the reduction of energy duties.

2.3.1.4 Production of Bio-ethanol from Corn

By fermentation of sugar cane, corn or wheat, ethanol (bio-ethanol) can be easily produced. This process includes the steps of liquefaction, cooking, fermentation, distillation, dehydration, evaporation and drying of the solid by-product. By a careful simulation of the operations involved, the needs for water and energy can be minimized, and the use of fossil fuels can be avoided. Key features are the energy balance starting from the content in the feedstock biomass, and the water saving.

A second problem can be addressed by accurately simulating the distillation and dehydration aspects, which have the highest energy demand of this process. Key feature is the use of pressure as an operating variable.

2.3.2 Brief of Phytochemical Processes

2.3.2.1 Citral Recovery by Distillation of Lemon Peel Oil

The goal of this process is the production of citral. Lemon peel oil is fractioned by a traditional method of separation to get an oxygenated substance (citral). A simulation model of the distillation helps identify the optimal operating conditions. The objective of this simulation is to separate the oxygenated compounds from terpenes.

2.3.2.2 Menthol Recovery by Crystallization of Mentha Oil

Mentha oil contains menthol, a commercially important product. Menthol is separated from the other components on the basis of differences in melting temperatures. Crystallization from solution is an industrially important unit operation due to its ability to provide high purity separations.

The crystal growth and nucleation kinetic parameters must be determined experimentally before systematically designing a crystallizer and computing optimal operations and control procedures.

2.3.2.3 Carvone Recovery from Spearmint Oil

Spearmint oil contains the major component carvone that must be separated from other components. The separation of carvone is done by continuous distillation and the process is optimized after identification of the relevant parameters worked out by sensitivity analysis. The objective of this simulation is to obtain carvone at 95% purity or more.

2.3.2.4 Peppermint Oil Extraction by Steam Distillation

For the steam distillation of peppermint, the peppermint leaves are placed at the bottom of a distillation flask and steam is percolated through. The peppermint oil evaporates, and the emerging mixture of vaporized water and oil moves through a coil, usually cooled with running water, where the steam condenses. The mixture of condensed water and essential oil is collected and separated by decantation or, in rare cases, by centrifugation.

2.3.2.5 Multiple-effect Evaporation of Milk Serum

Evaporation is a widely used operation for the recovery of valuable products from dilute aqueous mixtures, such as milk serum. In this case, a four-effect process helps minimize the energy consumption and makes this process economically attractive. Key features are the effects of both pressure and heat transfer coefficients on the overall performance of the apparatus.

2.3.3 Case Study: Turpentine Oil Batch Distillation

Turpentine oil obtained from species of *Pinus* (family Pinaceae) is mainly used in paint and soap manufacturing industries, and in the pharmaceutical industry its use is limited to balms and oil bases. Semi-fluid mixtures of resins remain dissolved in the volatile oil, thus it is produced by fractional distillation. The objectives of the process simulation are to: (i) develop the process simulation base case, (ii) understand how to obtain complete fractionation of the oil, (iii) optimize the composition of pinene, carene and longifolene in the product streams, and (iii) optimize the time and energy consumption of the process.

Figure 3a shows the fractional composition profiles of pinene, carene and longifolene versus time obtained in the top of the distillation column. Figure 3b shows the instantaneous energy consumption of a constant reflux operation.

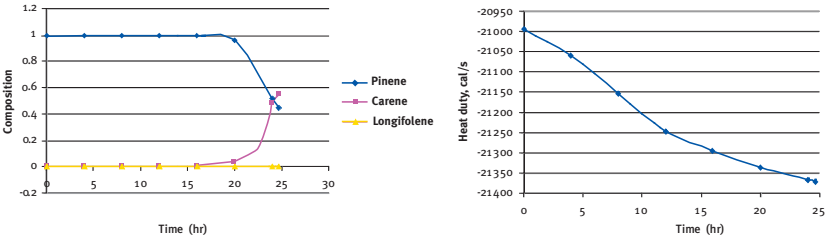

Figure 3: a) Fractional composition versus time, and b) Energy consumption versus time for the base case

Figure 4 shows the same process in which the reflux ratio is varied in order to obtain a constant composition at the top of the column. It is interesting to note that the distillation time as well as energy consumption are greatly reduced.

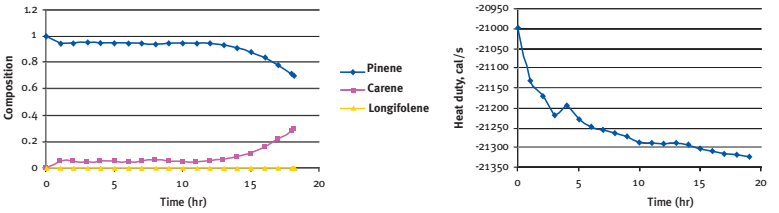

Figure 4: a) Fractional composition versus time, and b) Energy consumption versus time for the constant composition case

Figure 5 shows that a total separation of the oil constituents is achievable.

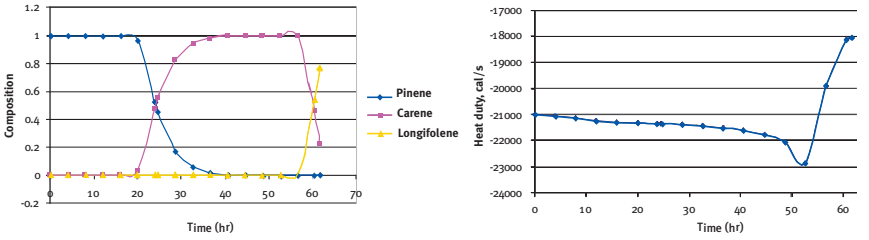

Figure 5: a) Fractional composition versus time, and b) Energy consumption versus time for the total fractionation case

These simulations show that, in the base case with a reflux ratio of 15 and a high consumption of energy (Figure 4), the distillate accumulator collects a high percentage of pinene (93%). If a PID controller is introduced to maintain the concentration constant, the composition of pinene is around 90% and it takes only 12 h and a reflux ratio of 5 to achieve the desired value, thus saving time and energy. In the case of complete fractionation, we can collect 93% of pinene, 88% of carene and 5.7% of dump products at the end of the process.

2.3.4 Case Study: Menthol Recovery by Crystallization of Mentha Oil

Crystallization from solution is an industrially important operation due to its ability to provide high-purity separations. The menthol crystallization process using menthe oil is rather simple, and consists of a cascade crystallization as shown in Figure 6.

The objective of the simulation is to optimize the menthol crystallization process. The oil, composed of 75% menthol and also containing menthyl acetate, limonene and menthone (Table 1), is fed into the first crystallizer where the temperature is 35° F. The menthol crystals produced here are separated by decantation. The decanted liquid is passed to the second crystallizer and the crystals obtained in this second stage are also separated from the liquid by decantation. Thus, the assumptions made are: (i) limonene is present in all the fractions, and (ii) the separation of solid material from the liquid portion is complete. Furthermore, the thermophysical properties of menthone and menthyl acetate are included in the software's database. The feed stream conditions are: temperature, 80° F; pressure, 1 atm; and flow rate, 50 lb · mol/h.

Table 1: Major constituents of mentha oil

Constituent	Concentration
Menthol	75%
Menthyl acetate	11%
Limonene	8%
Menthone	6%

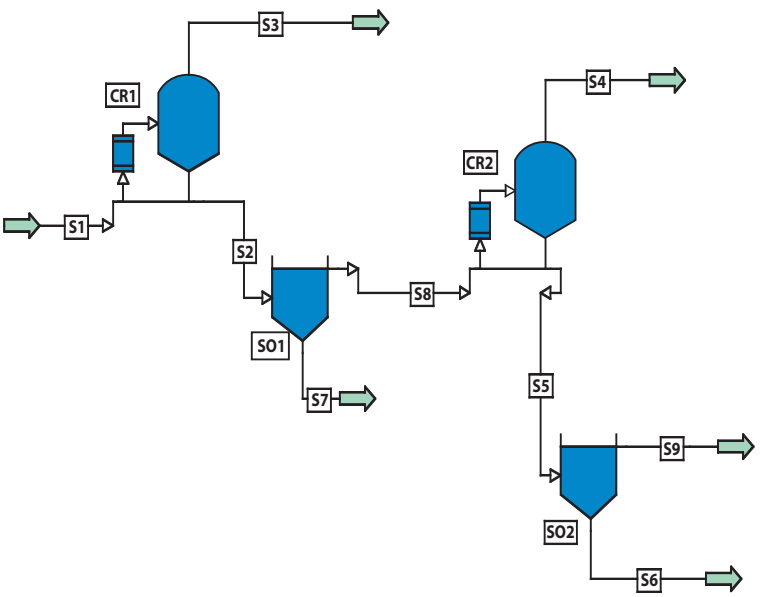

Figure 6: Flowsheet for the menthol crystallization process

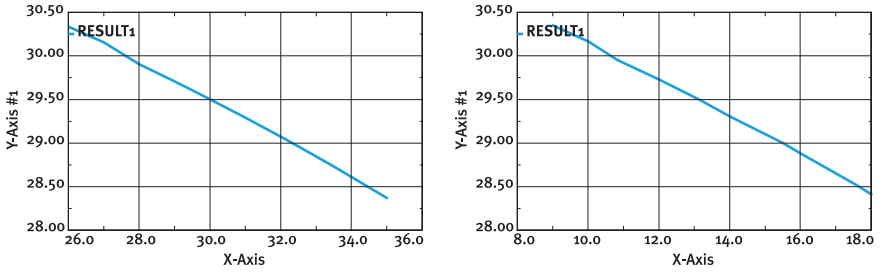

a *b*

Figure 7: Variation of menthol flow rate (Y axis, lb mol/hr) as product of both crystallizers (S6 + S7) versus T (X axis, °F). a) Crystallizer 1. b) Crystallizer 2

Figures 7a and b show on the Y axes the total flow rate (lb mol/hr) of menthol crystal produced in both crystallizers (the combination of S6+S7 of Figure 6). It is evident from the sensitivity analysis that the temperature of the crystallizers has an effect on the total amount of pure product obtained, and consequently on the product yield. In fact, the base case (Table 2) reports a figure of 28.469 lb mol/hr and this amount can be raised linearly if the temperature of the crystallizers is lowered. The sensitivity analysis helps the engineer to select the right temperatures of the crystallizers for a given production.

The material and energy balance of the menthol extraction plant for the base case is listed in Table 2. This is an example of the simulator's output and these values may change if the process conditions are changed. In the first crystallizer, the menthol produced is equal to 5.633 lb mol/hr (purity one) and in the second crystallizer the amount is 22.836 lb mol/hr (purity one). If we compare the total amount of menthol produced by the two crystallizers (22.836 + 5.633 = 28.469 lb mol/hr) with the total amount of menthol fed to the process (37.5 lb mol/hr), we obtain a recovery (amount of pure menthol produced/total amount of menthol fed to the process) of 75.91%, which is rather satisfactory. Table 2 also reports the temperature, pressure, total flow and composition of each single stream considered in the process.

Table 2: Material and energy balance for the menthol crystallization process. The stream names refer to Figure 6

Stream name		**S1**	**S2**	**S5**	**S6**	**S7**	**S8**	**S9**
Phase		**Liquid**	**S/L**	**S/L**	**Solid**	**Solid**	**Liquid**	**Liquid**
Temperature	F	80	35	18	18	35	35	18
Pressure	PSIA	14.696	14.696	14.696	14.696	14.696	14.696	14.696
Molecular weight		159.170	159.170	161.608	156.270	156.270	161.608	163.004
Total	lb mol/hr	50.000	50.000	27.164	5.633	22.836	27.164	21.531
Component mole fractions								
D-limene		0.0800	0.0800	0.1472			0.1473	0.1858
Menthol		0.7500	0.7500	0.5399	1.000	1.0000	0. 5398	0.4195
Menthyl acetate		0.1100	0.1100	0.2025			0.2025	0.2554
Menthone		0.0600	0.0600	0.1104			0.1104	0.1393

2.4 Conclusions

There are two important benefits of the application of process simulation to phytochemical processes of industrial interest.

The first is to improve process knowledge. This is achieved by verifying "in silico" the operating conditions and the estimates of data for intermediate streams, which are difficult to measure. Process knowledge also includes: (i) enthalpy balance information, (ii) verification of plant specifications, (iii) influence of operative parameters on process specifications, (iv) validation of phase equilibrium models for the real system to be used in similar conditions, and finally (v) process de-bottlenecking for each section.

The second important benefit is process optimization, in terms of: (i) consumption of energy and raw materials, (ii) identification of process control strategies, and (iii) clarification of security system behavior when process conditions are varied.

Running process simulation software requires: (i) availability of thermodynamic properties for all components involved, (ii) definition of an accurate thermodynamic model (equations of state or excess Gibbs energy model) for binary and multi-component mixtures, (iii) availability of all necessary interaction parameters, (iv) availability of all necessary unit operation modules, and (v) identification of tear streams to achieve rapid convergence in case of recycles. Furthermore, sometimes it is necessary to define and develop user models and user thermodynamic models.

It is necessary to stress some important principles. First, the program is an aid in making calculations and decisions: the process engineer must ensure that it is "fit for purpose" and is responsible for the results generated and for any use which is made of the results. Second, it is the professional, ethical and legal responsibility of the process engineer to take care and to exercise good judgment. Process simulation is, in essence, a program.

Nonetheless, process simulation is important since it: (i) has high accuracy, (ii) allows one to focus on the interpretation of the results rather than on the methods for obtaining the results, (iii) allows a global vision of the process by assembling theories and models, (iv) is essential in the design of new and existing processes, (v) is essential in the analysis of existing plants in terms of environmental impact, and (vi) is a simple tool for treating real cases.

Process simulation is a well established tool in the chemical industry and has been used for a decade in the petrochemical industry. Process simulation is now applicable in many different fields besides the

petrochemical and fine chemical industries, and is particularly interesting for biotechnological and phytochemical processes.

In summary, process simulation may play an important role in the optimization of phytochemical processes and, therefore, application of process simulation can assist in the development of advanced processes. This paper showed that it is possible to achieve energy reduction and maximization of product yield.

Process simulation perhaps is not a good tool for countries that are using primitive techniques, since they should aim at reaching a stable quality of the product rather than an optimization of energy consumption and environmental issues. Moreover, they should focus on practical problems such as the quality of the materials and the water to be used for extraction.

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3 Maceration, Percolation and Infusion Techniques for the Extraction of Medicinal and Aromatic Plants

J. Singh

Abstract

Techniques of maceration, percolation and infusion have been traditionally used for making galenicals and tinctures from medicinal and aromatic plants (MAPs). This article describes the underlying principals and mechanisms of these extraction techniques, and discusses the various modifications made for the small- and large-scale extraction of MAPs, the factors affecting the extraction process, and the quality of the extracts produced.

3.1 Introduction

Before the nineteenth century, there was no real progress in methods of extraction of plant materials for industrial use. Nonetheless, the various classes of preparations involving simple expression and extraction techniques were in vogue for a long time for the preparation of medicines used in traditional medicine and in complimentary and alternative medicine, practiced throughout the world. The techniques available were limited to expression, aqueous extraction and evaporation; later on, the use of extraction processes was extended by using alcohol as a solvent. Such techniques were highly successful in the phytochemical field and, consequently, single pure molecules were isolated for industrial and medicinal uses. After the nineteenth century, rapid progress was made in extraction processes which led to the isolation and characterization of many groups of plant metabolites of therapeutic importance, including both single chemical constituents as well as standardized extracts of crude drugs. In manufacturing various classes of medicinal plant preparations, such as decoctions, infusions, fluid extracts, tinctures, semisolid extracts (pilular) and powdered extracts, popularly known as galenicals, both simple traditional methods and advanced technologies are used, conforming to the official procedures and specifications as laid down in various pharmacopoeias and codices of the world.

Maceration, percolation and infusion are the general techniques used for the extraction of medicinal plants and are mostly applied for galenical preparations. The sole purpose of such basic extraction procedures is to obtain the therapeutically desirable portion and eliminate the inert material by treatment with a selective solvent known as menstruum. These techniques also play a decisive role in the qualitative and quantitative evaluation of the extracts. The standardized extracts thus obtained are further processed for inclusion in other solid and semisolid herbal dosage

forms. These extracts are also used as sources of therapeutically active chemical constituents for various dosage forms of modern medicines.

Historically, galenical preparations were much more extensively used than they are at the present time. Nonetheless, due to resurgence in interest of herbal drugs throughout the world, these extraction procedures are still relevant and are mentioned in official and unofficial monographs about drug preparations. The preparations involving these procedures are primarily intended for extemporaneous dispensing and must be freshly prepared, due to the fact that they rapidly produce a deposit because of coagulation of inert colloidal material and readily support microbial growth due to absence of preservatives.

This article describes the principal methods of extraction by maceration, percolation and infusion as well as the modifications in these procedures for small-scale, official and large-scale extraction. In addition, the paper discusses the choice of extraction method, quality assurance, and factors affecting the extraction procedures.

3.2 General Principles and Mechanisms Involved in Crude Drug Extraction by Maceration, Percolation and Infusion

The general principles and mechanisms involved in maceration, percolation and infusion for the extraction of the crude drugs are same as to those for the extraction of soluble constituents from solid materials using solvent, which is generally referred to as leaching. The processes of leaching may involve simple physical solution or dissolution. The extraction procedures are affected by various factors, namely the rate of transport of solvent into the mass, the rate of solubilization of the soluble constituents by the solvent, the rate of transport of solution out of the insoluble material. The extraction of crude drugs is mostly favored by increasing the surface area of the material to be extracted and decreasing the radial distances traversed between the solids (crude drug particle). Mass transfer theory states that the maximum surface area is obtained by size reductions which entail reduction of material into individual cells. However, this is not possible or desirable in many cases of vegetable material. It has been demonstrated that even 200 mesh particles contain hundred of unbroken cells with intact cell wall. Therefore, it is pertinent to carry out extraction with unbroken cells to obtain an extract with a high degree of purity and to allow enough time for the diffusion of solvent through the cell wall for dissolution of the desired solute (groups of constituents) and for diffusion of the solution (extract) to the surface of the cell wall.

3.3 Factors Affecting the Choice of Extraction Process

The choice of the process to be used for the extraction of a drug depends on a number of factors.

3.3.1 Nature of the Crude Drug

The choice to use maceration or percolation primarily depends upon the nature and characteristics of the crude drugs to be extracted. Therefore, knowledge of the type of organs and tissues of the plant matter is essential for achieving the best result.

3.3.2 Stability of the Crude Drug

Continuous hot extraction procedures should be avoided when constituents of the drug are thermolabile.

3.3.3 Cost of the Crude Drug

When the crude drug is expensive (e.g. ginger), it is desirable to obtain complete extraction. Therefore, from the economic point of view, percolation should be used. For inexpensive drugs, maceration, despite its lower efficiency, is acceptable in view of its lower cost.

3.3.4 Solvent

Selection of the solvent depends on the solubility of the desired components of the material. If the constituents demand a solvent other than a pure boiling solvent or an azeotrope, continuous extraction should be used.

3.3.5 Concentration of the Product

Dilute products such as tinctures can be made by maceration or percolation. For semi-concentrated preparations, the more efficient percolation process is used. Concentrated preparations, such as liquid or dry extracts, are made by percolation.

3.3.6 Recovery of Solvent

Solvent is preferably recovered under reduced pressure to save thermolabile constituents.

3.4 Quality Assurance: the Extraction Process and Solvent

The type of extraction procedure also plays a decisive role in determining the qualitative and quantitative composition of the extract. Some important points regarding the quality of the extracts need to be considered:

i) The more exhaustive the extraction, the better is the yield of the constituents from the herbal drugs.
ii) If maceration is facilitated by stirring and by use of comminuted material, the additional stirring and shearing forces may lead to better extraction.
iii) Other factors determining the quality of the extracts are extraction time, temperature and solvent volume.
iv) Some drugs (e.g. Hypericum spp.) are extracted very slowly so that exhaustive extraction can only be achieved by percolation or multistage motion extraction. In many cases, the transfer of quality-relevant constituents from the herbal drugs to the extract (i.e. extraction rate) can be considerably improved by raising the temperature. Hypericin, pseudohypericin and biapigenin are extracted better at higher temperature and with longer extraction times.
v) The quality of the extracts and the spectrum of constituents obtained by maceration or digestion (i.e. maceration at higher temperature) are also influenced by the ratio of herbal drug to solvent. The quantity of extracted matter increases with the volume of extraction solvent. For example, maceration of Salvia officinalis flowers achieves almost exhaustive extraction and thus the full spectrum of constituents obtained with percolation can be achieved with a drug:solvent ratio of 1:20.
vi) The composition of an herbal extract depends on the type, concentration and elution strength of the solvent. The spectrum of constituents may vary considerably depending on the hydrophilic or lipophilic nature of the solvent.

3.5 Maceration Processes (Steady-state Extraction)

3.5.1 General Procedure

The general process of maceration on a small scale consists of placing the suitably crushed plant material, or a moderately coarse powder made from it, in a closed vessel and adding the selected solvent called menstruum. The system is allowed to stand for seven days, with occasional shaking. The liquid is then strained off and the solid residue, called marc,

is pressed to recover as much occluded solution as possible. The strained and expressed liquid thus obtained is mixed and clarified by filtration. Plant material in fine powder form is never used, as it makes subsequent clarification of the extract difficult. In the case of vegetable drugs, sufficient time is allowed for the menstruum to diffuse through the cell wall to solubilize the constituents within the cells and for the resulting solution to diffuse out. As the system is static, except for occasional shaking, the process of extraction works by molecular diffusion, which is very slow. Occasional shaking assists diffusion and also ensures dispersal of the concentrated solution accumulating around the surface of the particles, thereby bringing fresh menstruum to the particle surface for further extraction. A closed vessel is used to prevent evaporation of the menstruum during the extraction period and thus avoids batch to batch variation.

At the end of the maceration process, when equilibrium has been reached, the solution is filtered through a cloth; the marc may be strained through a special press. The concentrations of active constituents in the strained and expressed liquids, sometimes called *miscella*, are the same and hence they can be combined. The expressed liquid may be cloudy with colloidal and small particles, and sufficient time (perhaps several weeks) is necessary for coagulation and settling. The settled matter is filtered through a filter press or any other suitable equipment.

3.5.2 Maceration Process for Organized and Unorganized Crude Drugs

Organized drugs have a defined cellular structure whereas unorganized drugs are non-cellular. Bark and roots are examples of organized crude drugs, while gum and resin are unorganized crude drugs. The processes of maceration for organized and unorganized drugs are slightly different, as shown in Table 1.

Table 1: Four differentiating steps of the maceration process, for organized and unorganized crude drugs

Organized drugs	Unorganized drugs
(i) Drug + entire volume of menstruum	(i) Drug + four-fifths of menstruum (in most cases)
(ii) Shake occasionally for 7 days	(ii) Shake occasionally on days 2 to 7, as specified
(iii) Strain liquid, press the marc	(iii) Decant the liquid. Marc is not pressed
(iv) Mix the liquids, clarify by subsidence for filtration. Filtrate is not adjusted for volume	(iv) Filter the liquid and add remaining menstruum through the filter

During maceration of organized drugs, the marc is pressed because a considerable proportion of liquid adheres to it and cannot otherwise be separated. Moreover, the volume is not adjusted because a variable amount of liquid containing soluble matter is left in the marc. If the volume is adjusted, a weak product will result. Omitting adjustment, the volume of liquid expressed influences the product yield and the percentage of soluble matter, regardless of the efficiency with which the marc is pressed in a hand press, screw press or hydraulic press; the strength of the product is not affected. Preparations made by this processes include vinegar of squill (British Pharmaceutical Codex, BPC), oxymel of squill (BPC), tincture of orange (Indian Pharmacopoeia, IP), tincture of capsicum (BPC), compound tincture of gentian, tincture of lemon, and tincture of squill (BPC).

In maceration of unorganized drugs, the marc is not pressed because the desirable material is mostly dissolved and the remaining marc is gummy and slimy. Thus, it is neither practicable nor necessary to press it. Moreover, the volume is adjusted because the clear upper layer is easily separated by filtration from the lower layer. The solution contains practically all the soluble matter of the drug; the small amount adherent to the gummy matter is recovered when the marc is washed by menstruum in the filter. Therefore, adjustment of volume leads to uniformity. Preparations made by this process include compound tincture of benzoin, tincture of myrrh (BPC), and tincture of tolu (BPC).

3.5.3 Modifications to the General Processes of Maceration

Repeated maceration may be more efficient than a single maceration process, as described earlier, because an appreciable amount of active principle may be left behind in the first pressing of the marc. Double maceration is used when the active constituents are particularly valuable and also when the concentrated infusions contain volatile oil. Where the marc cannot be pressed, a process of triple maceration is sometimes employed. The total volume of solvent used is, however, large and the second and third macerates are usually mixed and evaporated before being added to the first macerate.

3.5.4 Large-scale Extraction Procedures

For large-scale, industrial extraction, certain modifications are warranted. When the extraction vessel contains a small amount of solvent (500-1000 ml), occasional shaking is no problem. But, for industrial work where a large amount of solvent and huge vessels are involved, shaking the vessels is difficult. Obviously, there are alternative methods of agitation that are just as effective and much simpler to put into practice. In addition, economics become increasingly important and one of the most important objectives is to improve the efficiency of extraction so that less solvent is needed

and evaporation requirements for concentrated products are reduced. Reducing the cost of evaporation has the further advantage of minimizing the heat damage to thermolabile constituents. Some of the modified maceration procedures used for large-scale extraction are described in the next paragraphs.

3.5.4.1 Circulatory Extraction

The efficiency of extraction in a maceration process can be improved by arranging the solvent to be continuously circulated through the drug, as indicated in the Figure 1. Solvent is pumped from the bottom of the vessel (through an outlet) and is distributed by spray nozzles over the surface of the drug. The movement of the solvent reduces boundary layers and the uniform distribution minimizes local concentration in a shorter time.

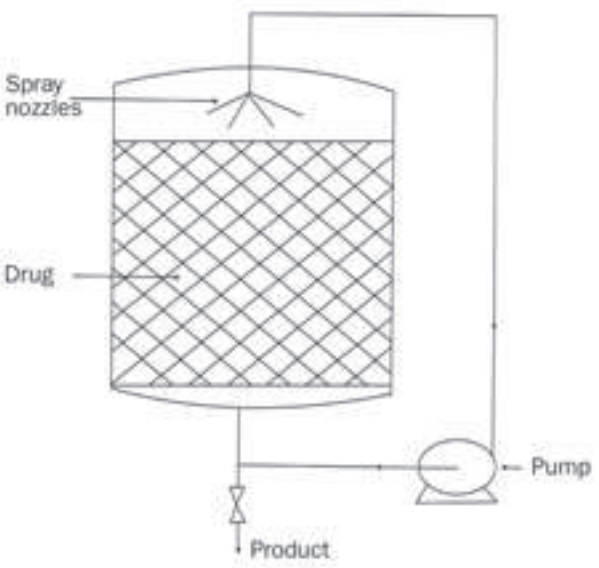

Figure 1: Circulatory extraction

3.5.4.2 Multistage Extraction

In the normal maceration process, extraction is incomplete, since mass transfer ceases when equilibrium is reached. This problem can be overcome using a multistage process. The equipment needed for this method is a vessel for the crude drug, a circulating pump, spray distributors and a number of tanks to receive the extracted solution. The extractor and tanks are connected with piping and valves as shown in Figure 2, so that any of the tanks may be connected to the extractor for transfer of the solution. Each batch of drug is treated several times with solvent and, once a cycle is in process, the receivers contain solution with the strongest in receiver 1 and the weakest in receiver 3.

3.5.4.2.1 Advantages

The crude drug is extracted as many times as there are receivers (in Figure 2 there are three receivers). If more extraction stages are required, it is only necessary to have more receivers. The last treatment of the drug – before it is discharged – is with fresh solvent, giving maximum extraction. The solution is in contact with fresh drug before removal for evaporation, giving the highest possible concentration.

3.5.4.2.2 Procedure

Fill the extractor with crude drug, add solvent and circulate. Run off to receiver 1. Refill the extractor with solvent and circulate. Run off to receiver 2. Refill the extractor with solvent and circulate. Run off to receiver 3. Remove drug from the extractor and recharge. Return solution from receiver 1 to the extractor. Remove for evaporation. Return solution from receiver 2 to the extractor and circulate. Run off to receiver 1. Return solution from receiver 3 to the extractor and circulate. Run off to receiver 2. Add fresh solvent to the extractor and circulate. Run off to receiver 3. Remove drug from the extractor and recharge. Repeat cycle.

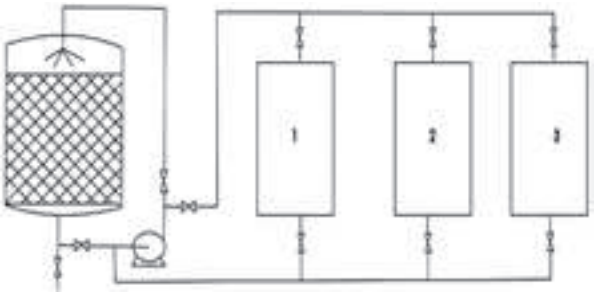

Figure 2: Multistage extraction

3.5.4.2.3 Extraction Battery

In the normal percolation process, the percolate is a very dilute solution, while the ideal situation is to obtain the maximum concentration possible. Continuous extraction devices of battery type are used when large amounts of a single material are handled. Such devices can be achieved by treating percolation as a multistage process. In an extraction battery process, a series of vessels is used and extraction is semicontinuous.

3.5.4.2.4 Equipment

An extraction battery consists of a number of vessels with interconnecting piping. Vessels are so arranged that solvent can be added to and the product taken from any vessel. These vessels can, therefore, be

made into a series with any of vessels as the first of the series. The use of an extraction battery is illustrated in Figure 3, which shows the simplest arrangement of three vessels.

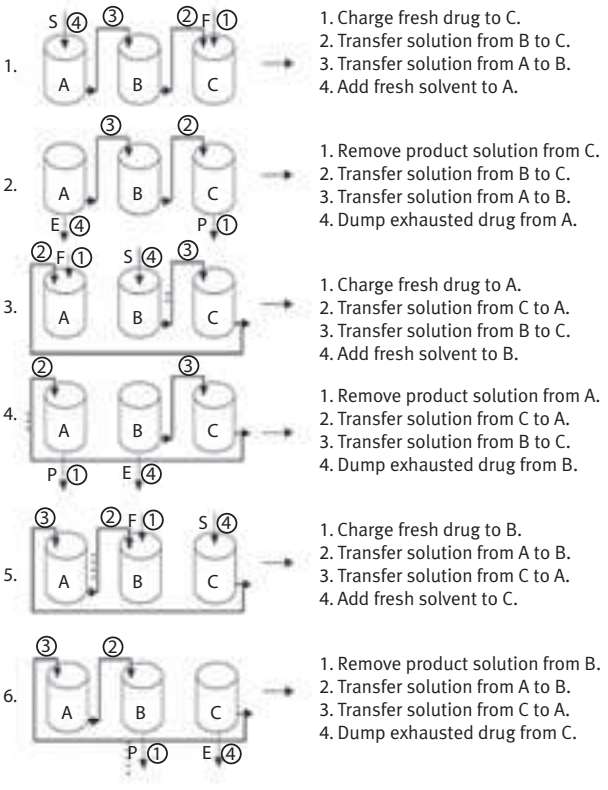

Arrows indicate transfer of material to or from the vessels. An asterisk(,) is added after each contact stage. Key: F = fresh drug. S = solvent. P = product. E = exhausted drug. A, B, C, extraction vessels. Start with C empty and units A and B containing drug, with A more nearly exhausted.

Figure 3: Extraction battery

3.6 Percolation (Exhaustive Extraction)

3.6.1 General Process of Percolation

In this process, an organized vegetable drug, in a suitably powdered form, is packed in a percolator and the solvent is allowed to percolate through it. Although some materials (e.g. ginger) may be packed directly into the percolator in a dry state, this may cause difficulties with other drugs. With the addition of solvent, the dry material swells and this swelling increases with increasing aqueous nature of the solvent. This swelling reduces or blocks the flow of the solvent, thus seriously affecting the extraction process. Fur-

thermore, if the dry powder is packed, fine particles may be washed down the column and settle at the lower levels, reducing the porosity drastically, blocking the column and making the column nonuniform. The finer particles may even be washed out of the column. These difficulties can be prevented by a preliminary uniform moistening of the raw material with the menstruum for a period of 4 h in a separate closed vessel; this process is called imbibition. During this period, the crude drug is allowed to swell to the maximum extent. Hence, when aqueous solvents are used for extraction, more menstruum is needed during imbibition. Also, the occluded air in the drug powder is replaced by the vapor of the solvent, thereby enabling the material to be more evenly packed and allowing the menstruum to flow more uniformly. Uneven packing permits more solvent to pass through channels offering less resistance to the flow of the solvent, thus resulting in inefficient extraction. After imbibition, the drug is packed evenly into the percolator. The imbibed drug is packed over a loose plug of tow or other suitable material previously moistened with the solvent. Even packing can be achieved by introducing the material layer by layer and pressing it with a suitable implement to give even compression; the pressure exerted on the material depends on the nature of the material and its permeability. After packing is over, a piece of filter paper is placed on the surface followed by a layer of clean sand such that the top layer of the drug is not disturbed when solvent is added for extraction. Sufficient menstruum is now poured over the drug slowly and evenly to saturate it, keeping the tap at the bottom open to allow the occluded gases between particles to pass out. Menstruum should never be poured with the tap closed since the occluded air will escape from the top, disturbing the bed. When the menstruum begins to drip through the tap, the tap is closed; sufficient menstruum is added to maintain a small layer above the drug and allowed to stand for 24 h. The layer of menstruum above the surface of the bed prevents drying of the top layer, which may result in the development of cracks on the top surface of the bed. The 24-h maceration period allows the solvent to diffuse through the drug, solubilize the constituents and leach out the soluble material. In this way, the extraction is more efficient than carrying out percolation without the maceration period.

After the maceration, the outlet is opened and the solvent is percolated at a controlled rate with continuous addition of fresh solvent. The volume of percolate collected depends on the nature of the final product. In general, about 75% of the volume of the finished product is collected, the marc is pressed and the expressed liquid is added to the percolate, giving about 80%-90% of the final volume. After assay, the volume is adjusted with calculated quantities of fresh menstruum. If no assay is available, the volume is adjusted after adding the other constituents, if any. In percolation, the expressed liquid is devoid of active constituents as they are already extracted during the percolation period; pressing the marc is only to recover the valuable solvent. This is in contrast with maceration in which the marc is pressed.

3.6.2 Modifications to the General Process of Percolation

In the general process of percolation, particularly in the manufacture of concentrated preparations like liquid extracts, the following problems may arise:

- If the active substances are thermolabile, evaporation of large volumes of dilute percolate may result in partial loss of the active constituents.
- In the case of alcohol-water mixtures, evaporation results in preferential vaporization of alcohol, leaving behind an almost aqueous concentrate. This may not be able to retain the extracted matter in solution and hence the substances may precipitate.

In such cases, the general process of percolation is modified, as described in the next paragraphs.

3.6.2.1 Reserved Percolation

In this case, extraction is done through the general percolation procedure. At the end, the evaporation is done under reduced pressure in equipment like a climbing evaporator to the consistency of a soft extract (semisolid) such that all the water is removed. This is then dissolved in the reserved portion, which is strongly alcoholic and easily dissolves the evaporated portion with any risk of precipitation.

3.6.2.2 Cover and Run Down Method

This is a process that combines the maceration and percolation techniques. This process cannot be used for materials that contain volatile principles or for those which undergo change during the evaporation stage. This procedure is advantageous because industrial methylated spirit may be used for extraction instead of the costly rectified spirit.

The detailed procedure is as follows. After the imbibition stage, the material is packed in a percolator and macerated for a few hours with a suitable diluted industrial methylated spirit. Then, the liquid is run off and the bed is covered with more menstruum. Maceration is done as before and the second volume of the extract is collected. This process is repeated several times with the later weaker extracts used for extraction of a fresh batch of the drug. More concentrated fractions are evaporated under reduced pressure to eliminate the toxic methanol. After the concentrate is assayed for the active principle or for total solids content, it is diluted with water and ethanol to obtain the correct concentration of alcohol and active principle.

3.6.3 Percolators

Different types of percolators are used for small- and large-scale extraction.

3.6.3.1 Small-scale or Laboratory-scale Extraction

The processes for the manufacture of concentrated preparations, maceration and percolations, are involved in extraction followed by the evaporation of solvents. The two operations are combined in a continuous extraction process.

The general procedures and apparatus used for small- or laboratory-scale extraction are described in the following paragraphs.

3.6.3.1.1 Soxhlet Apparatus

On the laboratory scale, the Soxhlet apparatus is used. It consists of a flask, a Soxhlet extractor and a reflux condenser. The raw material is usually placed in a thimble made of filter paper and inserted into the wide central tube of the extractor. Alternatively, the drug, after imbibition with menstruum, may be packed in the extractor taking care that the bottom outlet for the extract is not blocked. Solvent is placed in the flask and brought to its boiling point. Its vapors pass through the larger right hand tube into the upper part of the extractor and then to the condenser where they condense and drop back onto the drug. During this period, the soluble constituents are extracted. When the level of the extract reaches the top of the syphon tube, the entire volume of extract syphons over into the flask. The process is continued until the drug is completely extracted. The extract in the flask is then processed. This procedure is thus a series of short macerations.

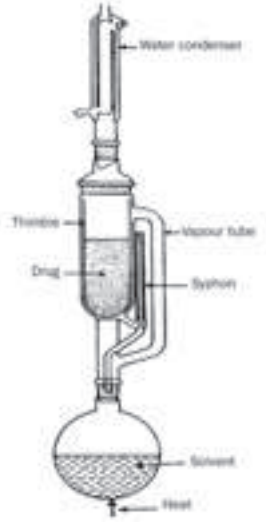

Figure 4: Soxhlet apparatus for hot extraction

3.6.3.1.2 Official Extractor

An official extractor, as described in the official monographs (e.g. IP, British Pharmacopoeia), is illustrated in Figure 5. In this case, the extraction is a continuous percolation procedure. In this apparatus, vapors rise through the extraction chamber passing the drug container; the vapor condenses in the reflux condenser and returns through the drug, taking the soluble constituents to the flask.

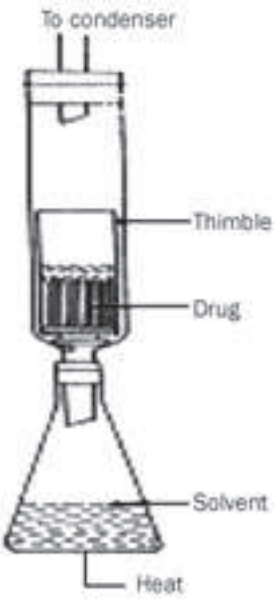

Figure 5: Apparatus for the continuous extraction of drugs

3.6.3.2 Limitations of the Official Extractor

It is not useful when the raw material contains thermolabile active constituents, because the extraction is carried out at an elevated temperature and the extract in the flask is also maintained in the hot condition until the process is complete. It can be used only with pure solvents or with solvent mixtures forming azeotropes. If an ordinary binary mixture is used as the menstruum, the composition of the vapor will be different from the liquid composition.

Similar methods can be used in large-scale production.

A typical industrial set-up for continuous extraction is shown in Figure 6. The principle of operation resembles that of the laboratory equipment.

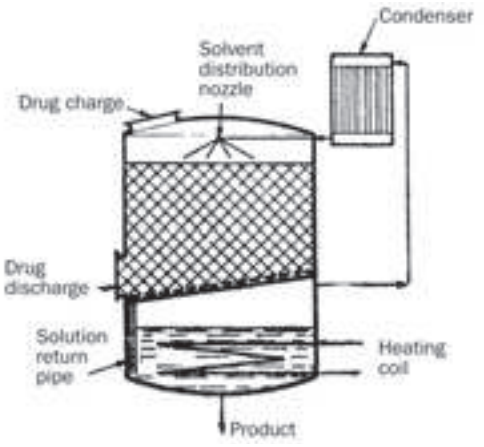

Figure 6: Continuous extraction: large-scale plant

3.6.3.3 Large-scale Extractor

The drug is supported on a perforated metal plate covered with a layer of sacking or straw. The percolator has a removable lid which contains portholes for running the solvent in and for observing the flow of solvent. The outlet from the percolator is fitted with a tap and pipeline. This outlet permits removal of the percolate for subsequent processing or for use as a menstruum in a second percolator in series, resulting in more efficient use of the menstruum by carrying out the extraction in a counter-current manner. On the small scale, copper percolators were originally used but these are now largely replaced with percolators made of glass or stainless steel. A slightly conical percolator is better than a cylindrical one since the sloping sides permit the eventual expansion of the bed and also allow the solvent to permeate the material present near the sides at the bottom, which is a problem with a cylindrical percolator.

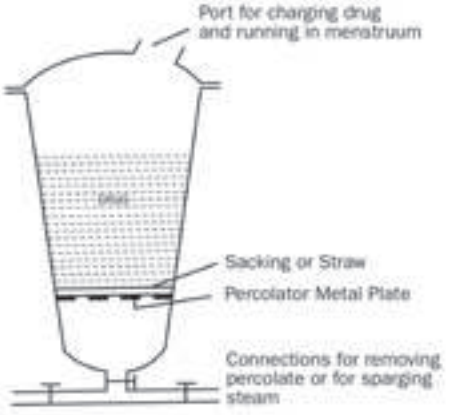

Figure 7: Commercial scale percolator

3.7 Infusion

3.7.1 General Considerations

Infusions are dilute solutions containing the readily soluble constituents of crude drugs. Formerly, fresh infusions, prepared by macerating the drug for a short period in cold or boiling water, were used and diluted to eight volumes but, now, infusions are usually prepared by diluting one volume of a concentrated infusion to ten volumes with water. Concentrated infusions are prepared by a modified percolation or maceration process. After dilution with water, concentrated infusions resemble in potency and aroma the corresponding fresh infusion. Infusions are liable to fungal and bacterial growth, and it is necessary to dispense them within 12 h of their preparation.

3.7.2 General Method for Preparing Fresh Infusions

The coarsely powdered crude drug (50 g) is moistened, in a suitable vessel with a cover, with 50 ml cold water and is allowed to stand for 15 min. Then, 900 ml boiling water is added, and the vessel is covered tightly and allowed to stand for 30 min. The mixture is strained and enough water is passed to make the infusion measure 1000 ml. Some drugs are supplied (accurately weighed) in muslin bags for preparing specific amounts of infusion and as such are used for infusion preparation. If the activity of the infusion is affected by the heat of the boiling water, cold water should be used. As fresh infusions do not keep well, they should be made extemporaneously and in small quantities at the time of use.

3.7.3 Preparation of Concentrated Infusions

The official monographs also recognize certain “concentrated infusions” in which 25% alcohol is added during or after the infusion process and then diluted as per pharmacopoeial (official) requirement. Concentrated infusions are especially prepared in cases in which the active and desirable principles of drug are equally soluble in water and in the menstruum used for both concentrates and infusions.

3.8 Evaporation

One quality-relevant parameter is the evaporation of the eluate from the soft extract. The state of art is cautious vacuum evaporation, in which evaporation temperatures do not exceed 55° C. The temperature in relation to the evaporation time is of special importance for quality of this step, especially if the extract contains volatile or thermolabile constituents.

3.9 Conclusions

The spectrum of constituents obtained by steady-state extraction (simple maceration) differs from that obtained by exhaustive extraction (percolation). With maceration, one can achieve a spectrum of constituents similar to that of percolation. Different extraction procedures may be considered to be equivalent if they respect critical quality parameters and if the analysis of numerous production batches confirms their compliance with standards.

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4 Hydrolytic Maceration, Expression and Cold Fat Extraction

A. K. Singh

Abstract

The incorporation of bioactive ingredients without loss of activity into foods, flavors, pharmaceuticals, pesticides and cosmaceutical products is very important. Extraction of active constituents from raw materials is an important and critical step in maintaining bioactivity. A number of methods are available for extraction, and these are selected in such a way that the activity of the phytoconstituents is retained. This paper discusses the processes of hydrolytic maceration, expression and cold fat extraction.

4.1 Introduction

The extraction of active constituents from plants is one of the most critical steps in the development of natural products for commercial use. The simplest example of extraction may be brewing a cup of coffee, wherein caffeine and tannins are extracted from coffee beans in hot water. All living organisms contain complex mixtures of chemicals, usually held within cellular structural material (protein, lipid, polysaccharides etc.) of which some are desired while others are not. Thus, taking out the desired part from the whole crude drug is referred to as extraction and it is done in solvents where ingredients move from one phase to another.

A number of methods are available for extraction and the choice among them is dictated by the physicochemical properties and stability of the phytoconstituents to be obtained. For the extraction of essential oils, the simplest methods are hydrodistillation and steam distillation while other methods also employed are cold fat extraction, expression, maceration and solvent extraction. Nowadays, more advanced technologies are used, such as supercritical fluid extraction, solid phase micro-extraction and phytonic extraction. The present article deals with extraction by hydrolytic maceration, expression and cold fat extraction.

4.2 Hydrolytic Maceration

The word maceration is derived from the Latin word *maceratus,* which means to soften. In reference to medicinal and aromatic plants, maceration refers to the preparation of a solution by soaking plant material in vegetable oil or water. Maceration methods are based on the immersion of crude drug in bulk solvent, while percolation methods depend on the flow

of solvent through the powdered drug. The rate of extraction depends upon the following:

- The rate of transport of solvent into the mass to be leached.
- The rate of solubilization of soluble constituents into solvent.
- The rate of transport of solute out of the insoluble material and from the surface of the insoluble material into the solution.

In the process of maceration, the powered solid material is placed in a closed vessel (to prevent evaporation) and the chosen solvent (menstruum) is added. It is allowed to stand for a long time (varying from hours to days) with occasional shaking. Sufficient time is allowed for the menstruum to diffuse through the cell wall to solubilize the constituent present in the cells and for the resulting solution to diffuse out. The process takes place only by molecular diffusion. After the desired time, the liquid is strained off; the solid residue (marc) is pressed to recover as much solvent as possible. When the menstruum is water and the period of maceration is long, a small quantity of alcohol may be added to prevent microbial growth.

Cold maceration of crushed grapes is done at room temperature before the onset of fermentation. In this process, the skin and seeds are permitted to soak for one to two days prior to the initiation of fermentation to get more aqueous extraction without the effect of ethanol on grape cells. In certain cases, hydrolysis is done with a suitable agent (enzyme) prior to maceration, e.g. maceration of wine. The quality of wine is judged by its appearance, color, aroma, taste (mouth feel) and flavor. Grape-derived aroma and flavor precursors exist partially as non-volatile, sugar-bound glycosides. Hydrolysis modifies sensory attributes and potentially enhances wine quality. Flavored aglycones potentially affect the wine quality after hydrolysis. Cell wall-degrading enzymes help in the release of grape aroma, when cold maceration prior to fermentation has been carried out.

4.3 Expression Extraction of Essential Oils

Most essential oils are isolated from the respective plant parts by the process of hydrodistillation or steam distillation. A few essential oils such as those present in the citrus fruit peel can be, and in large part are, obtained by pressing, which yields a product of superior quality. The long action of heat with boiling water affects some thermolabile constituents which may decompose due to hydrolysis, polymerization and resinification. Therefore, the essential oil obtained by distillation does not represent the natural oil as it originally occurred in the plant material. In such plant materials, essential oil is extracted by the process of expression or solvent extraction.

Before dealing with the process of expression in citrus oil, it is important to review the structure of a citrus peel. The citrus peel contains numerous oval, balloon-shaped oil sacs and glands or vesicles (0.4-0.6 mm diameter). These are ductless glands which are irregularly distributed in the outer colored (flavedo) portion of the peel of maturing and matured fruit, in the outer mesocarp beneath the epicarp and hypoderm and above the inner mesocarp (albedo), respectively. Albedo is made of cellulose, hemicellulose, lignin, pectin, sugars, glycosides, etc. On maturation, cells of albedo become elongated and branched, with large intracellular spaces which give the ripe peel its spongy texture. The spongy layer plays an important role in the expression of oil, but it easily absorbs the oil ejected from the sacs and causes some mechanical difficulties in oil extraction. The freshness and stage of maturity affect the oil ejection from the peel. The total weight of the peel is about half that of the fruit and the oil content is 0.5%-0.7%. The cells surrounding the oil sac contain salt (colloids) in aqueous solution. In contact with water, the higher osmotic pressure of the cell results in diffusion of water into them, increasing turgor pressure and causing the oil sac to stress from every side. If the spongy tissue is not filled with water, it will absorb the oil as the sacs are broken and hold it with great tenacity. So the pressure exerted yields first aqueous fluid and later oil.

In Sicily, peels are immersed in water for several hours before being subjected to a "sponge" process. A dilute aqueous solution of salt acts as a carrier to prevent loss by spurting. The product of expression is not a simple mixture of oil and water but a thin emulsion which is left to stand; gradually a supernatant layer forms. Filtration through a sponge absorbs the colloidal material and leaves the mixture of oil and water.

4.3.1 Process of Expression

4.3.1.1 Hand Process

In this process, the freshly harvested fruits are cut transversely into two halves. The pulp is removed with a sharp-edged spoon called *rastrello*. The peel is then immersed in water for several hours and finally pressed by hand. The worker holds, with the left hand, either one large or two smaller flat sponges on top of a wooden crossbar and, with the right hand, presses the peel against the upper sponge. Thinner peels can be pressed from inside. The emulsion ejected from the oil sacs is soaked by the sponge, which retains solid matter and absorbs colloidal substances. Squeezing the content of the sponge from time to time, oil is finally decanted and drawn off. This process requires much labor and the yield of this method is 50%-70% of the total oil present in the peel. The quality of oil obtained from hand pressing is near to the quality present in fruit peel. A large number of small units in Sicily and Calabria were formerly responsible for the entire Italian production of lemon and orange oil, but the process is not in use now.

4.3.1.2 Ecuelle Process

This process was common in the south of France. Ecuelle consists of a shallow bowl of copper with a hollow central tube with which it forms a sort of funnel. The bowl is equipped with large brass nails with blunt ends, on which the fruit is rolled by hand with some pressure until the entire surface of fruit yields its oil. The oil and aqueous cell contents drain into the central tube where they are separated by decantation. The yield is only 20% of the total oil present in the peel.

These methods were quite laborious and, with the advance of technology, machines have been invented to do them. Nowadays, rinds are extracted for oil using centrifugal force.

4.3.1.3 Hand Machine

For expression, the peel is placed in a hollow sponge attached with other sponges to a plate actuated by the lever and fixed below with additional sponges to the base. The sponge is fitted with a funnel through which oil and aqueous material pass to the receiving vessel. The part that comes in contact with oil is made of brass or bronze.

4.3.1.4 Sfumatrici and Pelatrici

The machines that treat only the peel after removal of juice and pulp are called *sfumatrici*, while those that process the whole fruit are known as *pelatrici*.

4.3.1.4.1 Special Sfumatrice

This is a specially designed roller type machine in which each peel is bent to expel the maximum quantity of oil. Not much pressure is exerted to expel other contents of the cells. The emulsion is collected and filtered through wool or sponges to yield oil and water. A number of *sfumatrici* have been developed and were in use in many countries.

In expression using *sfumatrici*, two approaches are used. In the first approach (used by Ramino Sfumatrice), only the peel is treated, so halving the fruit, removing the pulp and expressing the peel are the steps involved. In the second approach, the oil is extracted by either puncturing the peel glands or cutting a superficial layer of peel to expose the oil glands; this is followed by washing away the oil with a spray of water.

In whole fruit extraction with a rasping machine, the whole fruit is crushed and oil is subsequently separated from the aqueous phase (juice and cell liquid). As citrus peel oil is a byproduct of the citrus juice industry, both the oil and juice are extracted subsequently, e.g. in a rotatory juice

extractor or Pipkin peel oil press. Here, the fruit is washed automatically, sorted according to size and then cut in two halves. The halved fruit is passed between two cylinders which remove only the juice by gentle pressing without affecting the oil glands on the surface. The residual halved peels are extracted for essential oil. In the Pipkin peel oil press, for example, oil is expressed by two close stainless steel cylinders with capillary grooves running around the circumference. The expressed oil automatically comes out of the grooves and there is no need to spray water..

4.3.1.5 Modern Machines

Nowadays, complete mechanization has been achieved and whole fruit processing machines have been developed. These machines either crush whole fruit and then separate the oil from the aqueous phases by distillation or centrifugation, or they express the oil in such a way that it does not come in contact with the juice during the process. The oil extractor developed by Brown International, California, liberates the essential oil from whole citrus fruit. Oil removal is achieved by lightly puncturing the entire surface of the fruit with over three million sharp stainless steel points configured in the form of rotating rolls. An adjustable speed differential between adjacent rolls controls the amount of pressure applied to the fruit. Whole fruits roll across the brown oil extractor (BOE, Figure 1), which is made of toothed rollers partially set in a flowing bed of water which propels the fruit across the machine and simultaneously punctures the peel to release the oil from the glands. The fruit proceeds to the extractor and the oil-water mixture goes to centrifugation and to the oil recovery chamber.

Figure 1: Brown oil extractor

4.3.1.6 FMC Whole Fruit Extractor

Food Machinery Corporation (FMC) of San José, California, has developed many designs and improved extractors in which both the juice and the volatile oil are extracted without getting mixed with each other. Further details are available at: http://files.asme.org/ASMEORG/Communities/History/Landmarks/5549.pdf.

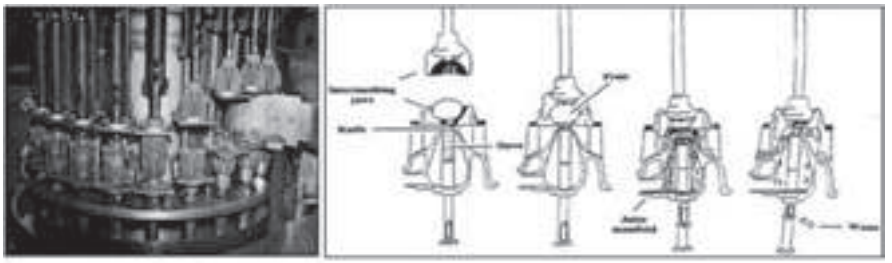

Figure 2: FMC whole fruit extractor

The FMC juice extractor has two inter-meshing jaws which encompass the fruit, crushing it between them. The juice exits through a mesh screen which penetrates the center of the fruit and the juice is separated from the peel, pith and seeds. This crushing action is sufficient to force the oil out of the glands on the surface of the flavado. The FMC machine sprays water onto the surface of the fruit, and the oil-water emulsion is subjected to centrifugation. Traces of water and waxy material are separated by keeping low temperature. About 75% of citrus oil production utilizes this technology. The odor of cold pressed oil is true in nature and similar to that of the oil present in fruit.

4.4 Cold Fat Extraction (Enfleurage)

Certain high-quality odor-producing flowers such as jasmine, tuberose and gardenia yield small quantities of oil and cannot be distilled by hydrodistillation. Furthermore, the oil components are thermolabile and such flowers, even after plucking, continue to emit small quantities of perfume. The oil from these types of flowers is extracted by cold fat extraction, i.e. enfleurage.

Figure 3: Chassis for holding the fat crops

Fat possesses a high power of absorption of volatile oil and, if brought in contact with fragrant flowers, it absorbs the perfume. This principle methodically applied on large scale constitutes enfleurage. The quality of the fat base is important for the quality of the flower oil. It must be odorless and of proper consistency. If the crops (fat) is too hard, the blossoms will not have sufficient contact with it, the absorption will be insufficient, and the quality and yield will be poor. If the crops is loose, it may engulf the flowers so that exhausted ones are difficult to remove and retain adhering fat when removed. The crops must have a consistency suitable to produce a semihard surface from which exhausted flowers can be removed easily. Saturated fragrant fat extract is known as pomade. Enfleurage process of cold extraction is carried out in Bulgaria, Egypt, Algeria, Sicily (Italy), and Grasse (France). France remains the main centre of production of highly prized so-called natural flower oil. Natural flower oil does not include the distilled essential oil but applies only to flower oils obtained by enfleurage, maceration or solvent extraction. The whole process is carried out in cold atmosphere cellars (cold rooms). The mixture of one part highly purified tallow and two parts lard is best suited for enfleurage.

Different bases have been used in the preparation of crops. For example, vegetable fat, mineral oil, esters of polyhydric aliphatic alcohol (ester of glycol, glycerol, mannitol, hexitol), and fatty acids of high molecular weight have been tried, but the best results were from the old-fashioned mixture of lard and tallow. To purify tallow, it is melted after cleaning, washing and removing blood and muscles; the skin is beaten and cleaned, and benzoin (0.6%) and alum (0.15%-0.30%) are added. Benzoin is a preservative while alum causes impurities to coagulate during heating. Warm melted fat is filtered through cloth and left to cool.

The vehicle for holding the fat crops during the process is a specially designed “chassis”. These are rectangular wooden frames (2 in. high, 20 in. long and 16 in. wide) that hold a glass plate (Figure 3). The fat crops is applied to both sides of the glass with a spatula at the beginning of enfleurage: 360 g crops on each side is required. When piled one above the other, the chassis form an air-tight compartment with a layer of fat on the upper and lower sides of each glass (Figure 4). Every morning, freshly picked flowers are cleaned by removing the leaves and stalks and eliminating the moisture from dew or rain. The flowers are strewn (Figure 3) by hand on top of the fat layer of each glass plate. Traces of moisture will cause the crops to go rancid, so precaution must be taken.

Figure 4: Pile of chassis

When chassis are piled one above the other, flowers remain in contact with the lower fat crops which acts as direct solvent, whereas the upper fat layer (beneath the glass plate of the chassis) absorbs only the volatile perfume given off by the flowers. After 24 h, the flowers are removed from the chassis. The time of removal, however, depends on type of the flowers. Removal of the flowers from the crops is known as defleurage. Immediately following defleurage, the chassis are recharged with fresh flowers. For this purpose, the chassis are turned over, thus the fat layer which in the previous operation formed on top (ceiling) of the small chamber is now directly charged with fresh flowers. When the fat crops becomes saturated with fragrance (pomade), the crops is removed from the chassis with a spatula. The pomades are extracted with absolute alcohol in a process called *extrait*. At the beginning and several times during the harvest, the fat on the chassis is scratched over with a metal comb and tiny furrows are drawn in order to change and increase the surface area available for maximum absorption. The most highly saturated pomade is pomade no. 36, meaning the crops on the chassis has been treated with fresh flowers 36 times during the whole process of enfleurage. In the case of jasmine, every kilogram of fat is charged with 3 kg flowers during the entire period. The alcohol washing of pomade no. 36 are called extrait no. 36, which reproduces the natural flower oil to a remarkable degree. Sometimes a fatty note is present in the extrait, which can be removed by freezing and filtering the alcoholic washes.

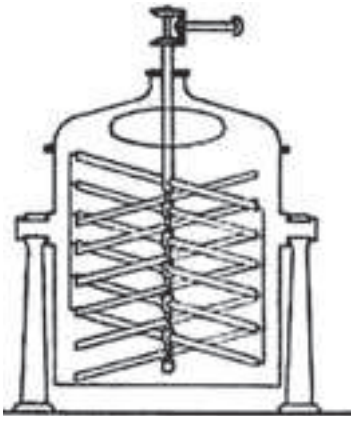

Figure 5: Batteuses

Pomades are processed during winter in cool cellars called batteuses (Figure 5) made of copper and equipped with stirrers. Several batteuses are arranged serially. The alcohol driven from one batteuse is poured in second, third and first washings of successive batteuses. For the last washing, fresh alcohol is used. Extrait no. 36 is cooled in a refrigerator to separate the fat. The exhausted fat is odorless and used for the manufacture of soap. Complete concentration of extrait is done under vacuum at low temperature to remove alcohol, producing absolute of enfleurage which is semisolid in nature. The flowers removed from the chassis are extracted with solvents (petroleum ether) and the concentrated residue is dissolved in absolute alcohol. The fat is removed by freezing. This preparation is known as absolute of chassis. Absolute of enfleurage and absolute of chassis logically supplement one another because each represents only part of the total oil present in the flowers but, due to cost difference, they are kept separately.

4.5 Conclusions

In spite of recent technological development in the field of extraction, hydrolytic maceration, expression and cold fat extraction techniques are inevitable for certain types of raw material. For these materials, no substitutes are available at present, although hydrodistillation or solvent extraction can be used for essential oils of citrus and flower oils or other perfumery materials. Nonetheless, the real replication of essential oil or the true natural fragrances present in these materials can only be produced by expression and cold fat extraction. Only technological improvements for easy extraction can be made without affecting the basic principles of these processes.

5 Decoction and Hot Continuous Extraction Techniques

S. Tandon and S. Rane

Abstract

The chapter describes the techniques, parameters and equipment used for the extraction of plants by decoction and hot continuous extraction. Principles, mechanisms, merits and demerits of conventional solvent extraction and accelerated solvent extraction are also discussed.

5.1 Introduction

Of the traditional methods of extraction of medicinal plant material for making an aqueous extract, decoction is one of the most described. Decoction is a water-based preparation to extract active compounds from medicinal plant materials. In this process, the liquid preparation is made by boiling the plant material with water. Decoction differs from infusion in that the latter is not actively boiled. Decoction is the method of choice when working with tough and fibrous plants, barks and roots and with plants that have water-soluble chemicals. The plant material is generally broken into small pieces or powdered. Different methods have been described for the preparation of decoctions. In the Ayurvedic method, traditionally known as *kwatha*, the crude drug in form of *yavakuta* (small pieces) is placed in earthen pots or tinned copper vessels with clay on the outside. Water is added and the pot is heated on a fire. If the material is soft, four times water is used per 1 part drug; if the drug is moderately hard, eight times water is used and if the drug is very hard, sixteen times water is recommended. The mixture is then boiled on low flame until it is reduced to one-fourth starting volume, in case of soft drugs, and one-eighth in case of moderately or very hard drugs. The extract is then cooled and strained, and the filtrate is collected in clean vessels.

5.2 Solid-liquid Extraction Process

Solid-liquid extraction is one of the most widely used unit operations in the medicinal and aromatic plant industry. One example of solid-liquid extraction is the solvent extraction of herbs. This process, also referred to as leaching, is a separation technique that is often employed to remove a solute from a solid mixture with the help of a solvent. The insoluble solid may be colossal and permeable; more often it is particulate and the particles may be openly porous, cellular with selectively permeable cell walls, or surface-activated. The stream of solids being leached and the accompanying liquid are known as the underflow. The solid content of the

stream is called marc. The stream of liquid containing the leached solute is known as the overflow.

5.3 Process Parameters Affecting Solid-liquid Extraction

The following parameters generally affect the rate of solid-liquid extraction (leaching):

- Post-harvest processing
- Matrix characteristics
- Choice of solvent
- Method of contact
- Temperature of extraction
- Number of washes
- Condition for extraction (e.g. agitation)

5.3.1 Post-harvest Processing

After harvesting, most herbs have a moisture content of 60%-80% and cannot be stored without drying. Otherwise, important compounds can breakdown or micro-organisms may contaminate the material. Drying of the herbs in shade in a thin layer is generally preferred. Some medicinal plants, like pyrethrum, lose their active constituents if exposed to direct sun light for a long period. For drying large quantities of plant material, a hot air drying oven is used where material can be placed on a large number of trays stacked over each other. Oven temperature must be kept at a safe level so as not to damage the active constituents of the medicinal plant.

5.3.2 Matrix Characteristics

Knowledge of the matrix characteristics of the carrier solid is important to determine whether it needs prior treatment to make the solute more associable to the solvent. Grinding of plant material means mechanically breaking down leaves, roots, seeds, or other parts of a plant into small units, ranging from large course fragments to fine powder.

Solute may exist in the inert solids in a variety of ways:

1. On the surface of the solid,
2. Surrounded by a matrix of inert material, Chemically combined, or inside the cells.

Solute adhering to the solid surface is readily removable by solvent. When the solute exists in pores surrounded by a matrix of inert material, the solvent has to diffuse to the interior of the solid to capture the

solute. In the medicinal plant industry, generally ball mills and fluid mills are employed for powdering, and the optimum particle size is established prior to the large-scale extraction.

5.3.3 Choice of Solvent

The following factors should be considered when selecting a solvent for commercial use:

- *Solvent power (selectivity)*. Only the active, desired constituents should be extracted from the plant material, which means that a high selectivity is required.
- *Boiling temperature*. The boiling point of the solvent is as low as possible in order to facilitate removal of the solvent from the product.
- *Reactivity*. The solvent should not react chemically with the extract, nor should it readily decompose.
- *Viscosity*. A low viscosity of the solvent leads to low pressure drop and good heat and mass transfer.
- *Safety*. The solvent should be non-flammable and non-corrosive, and should not present a toxic hazard; its disposal should not imperil the environment.
- *Cost*. The solvent should be readily available at low cost.
- *Vapor pressure*. To prevent loss of solvent by evaporation, a low vapor pressure at operating temperature is required.
- *Recovery*. The solvent has to be separated easily from the extract to produce a solvent-free extract.

5.3.4 Conditions for Extraction

Too fine particle size may result in problems with packing of solids for extraction, preventing free flow of solvent through the solid bed. In such a case, extraction is more difficult, especially when finely divided solids are treated in an un-agitated state. Dispersion of the particles in liquid solvent by agitation facilitates contact of the solid with the solvent. Agitation, while giving good extraction, may cause suspension of fine particles in overflowing solution.

5.4 Method of Solid-liquid Extraction

The three principle types of flow used in leaching systems are:

1. Single-stage system
2. Multistage counter-current system
3. Multistage co-current system

Figure 1: Single-stage solid-liquid extraction

The single-stage system represents the complete operation of contacting the solid feed and fresh solvent. This is rarely encountered in industrial practice because of the low recovery of solute obtained and relatively dilute solution produced. Efficiency of extraction is somewhat improved by dividing the solvent into a number of smaller portions and then carrying out multiple successive extractions instead of only one contact of the entire amount of solvent with the solid.

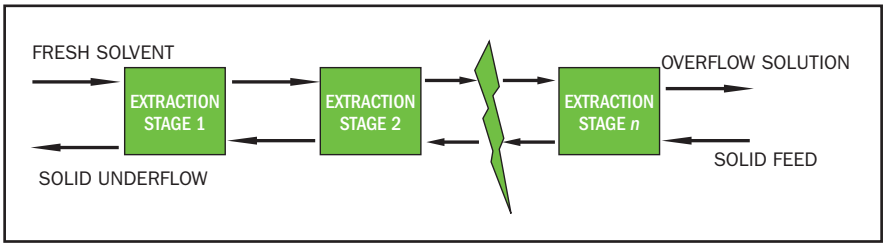

Figure 2: Multistage counter-current solid-liquid extraction

In the continuous counter-current multistage system shown in Figure 2, the underflow and overflow streams flow counter-current to each other. This system allows high recovery of solute with a highly concentrated product because the concentrated solution leaves the system after contact with fresh solid.

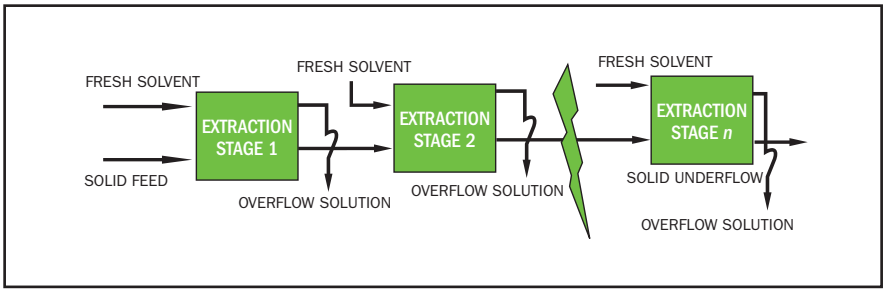

Figure 3: Multistage co-current solid-liquid extraction

In the multistage co-current (parallel) system shown in Figure 3, fresh solvent and solid feeds are contacted in the first stage. Underflow

from the first stage is sent to the second stage, where it comes in contact with more fresh solvent. This scheme is repeated in all succeeding stages.

5.5 Solid-liquid Extraction Equipment

Equipment for solid-liquid extraction is of two types:

a) Batch solid-liquid extractor
b) Continuous solid liquid extractor

The most common batch extractors employed for solid-liquid extraction of medicinal plants are:

- *Pot extractor*. The extractor has a volume of 2-10 m^3 and a mixer is necessary to guarantee good mixing for treatment of fine materials. For structured materials, the mixer is only used for evaporation of the solvent and for emptying the extractor.
- *Rotating extractor*. The extractor is filled with extraction material and solvent and starts then to rotate. The installation of heating coils and the use of a double jacket make it possible to evaporate the solvent at the end of the extraction cycle. A special form of heating coil can act as mixer during the extraction period.

The advantage of batch extractors is that they are simple to operate and are robustly constructed. Disadvantages of batch extractors are the limited capacity and the discontinuous output of the product.

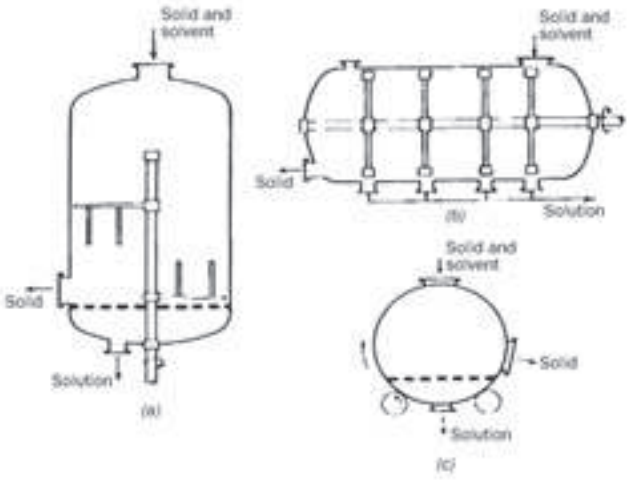

Figure 4: Pot extractor and rotating extractor

5.5.1 Continuous Extraction

For continuously operating extraction, percolation and immersion are used.

5.5.1.1 Percolation

The solvent passes through the non-moving solid material and extracts the soluble active constituents. One advantage of this method is that the solid material requires little mechanical treatment because it does not need to move in the percolator while the product passes in the solution. Moreover, since self-filtration takes place, there is minimum content of fine solid particles in the extract.

5.5.1.2 Immersion

In this process, the solid material dips completely into the solvent and is mixed with it. Therefore, no special percolation properties of the solid material are necessary. The disadvantage is that no self-filtration of the extract solution takes place. Therefore, a filtration step has to be added.

5.5.2 Continuous Extraction Equipment

5.5.2.1 Continuous Horizontal Extractor

The solid material is placed in baskets and comes in contact with the solvent by percolation. The flow of solvent through the extractor is counter-current to the flow of solid material.

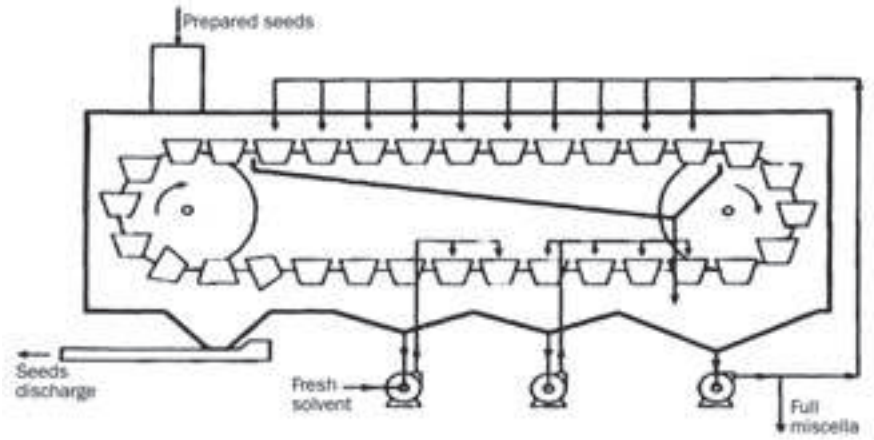

Figure 5: Continuous horizontal extractor

5.5.2.2 Hildebrandt Extractor

The solid material is extracted according to the immersion method. Screw conveyors are installed in the extractor for transporting the solid material. Again, the solvent flows counter-current to the solid materials through the extractor.

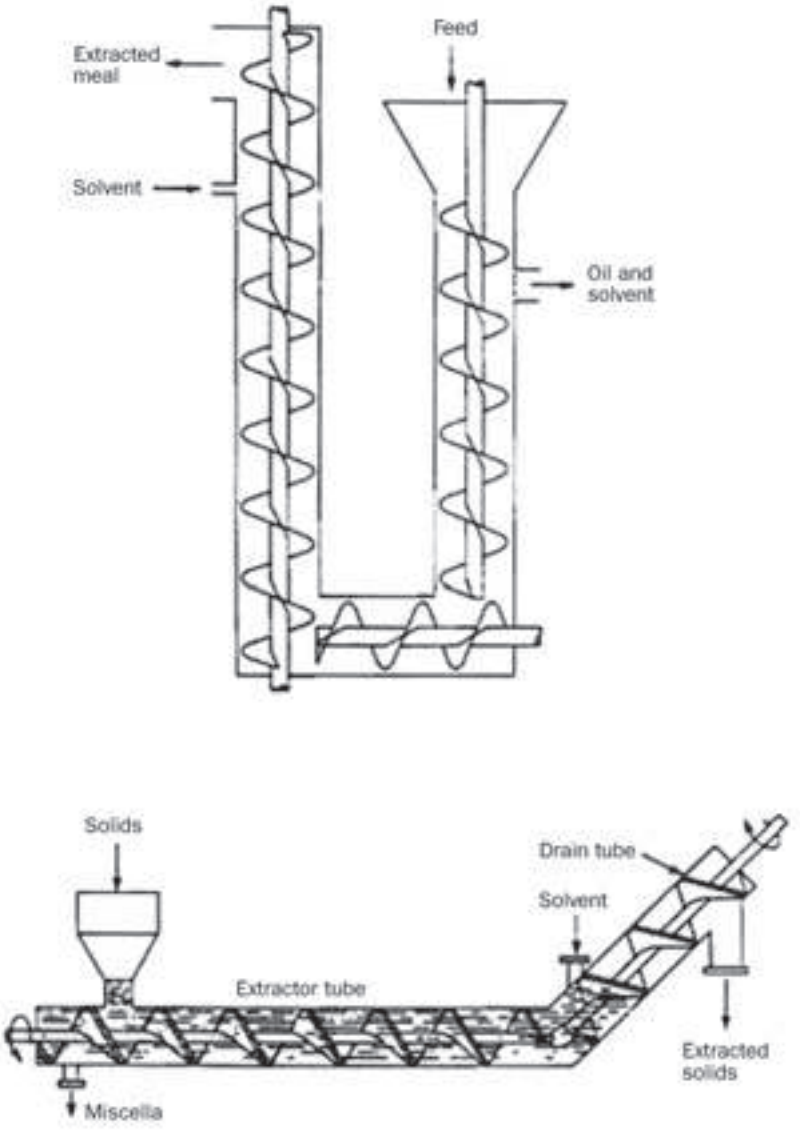

Figure 6: Hildebrandt extractor

5.5.2.3 Bonotto Extractor

The Bonotto extractor is used for counter-current extraction according to the immersion method. The solid material is transported by the mixer on a tray until it reaches the open sector where it falls onto the next tray. The screw conveyor at the outlet withdraws the extracted solid material (underflow) and prevents the solution from flowing out of the extractor.

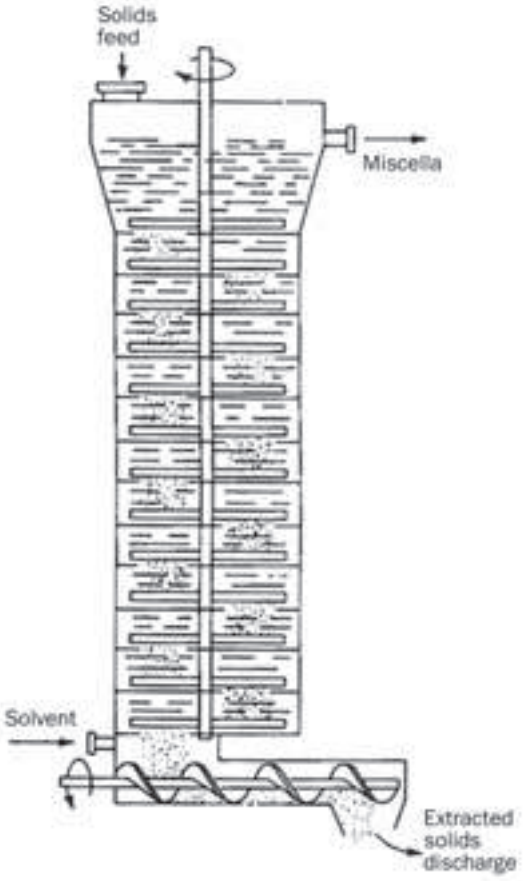

Figure 7: Bonotto extractor

5.5.2.4 Bollmann Extractor

The fresh solvent is added during the upward movement of the baskets so that this part operates in counter current. The already preloaded solution is withdrawn from the bottom of the extractor and enters the downward-moving baskets so that this part of the extractor operates in a co-current way. The full *miscella* is withdrawn at the bottom of the extractor.

In the baskets, self-filtration takes place, so that no further treatment of the *miscella* before distillation is necessary.

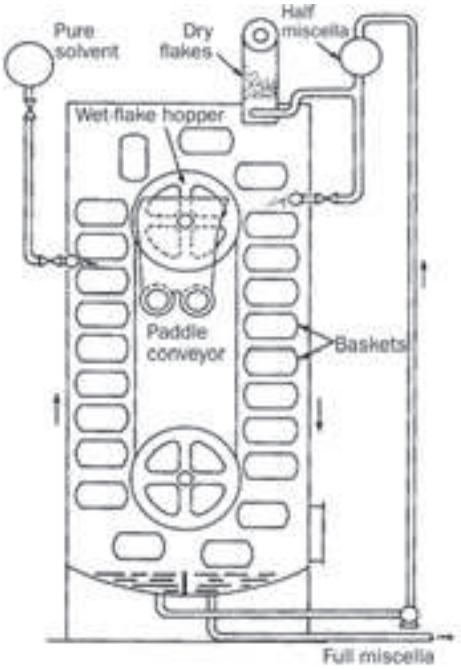

Figure 8: Bollmann extractor

5.5.2.5 Kennedy Extractor

The solid material is transported by paddles from one chamber to the next, in counter-current way to the solvent. The chamber where the *miscella* is withdrawn is used as a filtration unit where fine particles are separated from the extract solution.

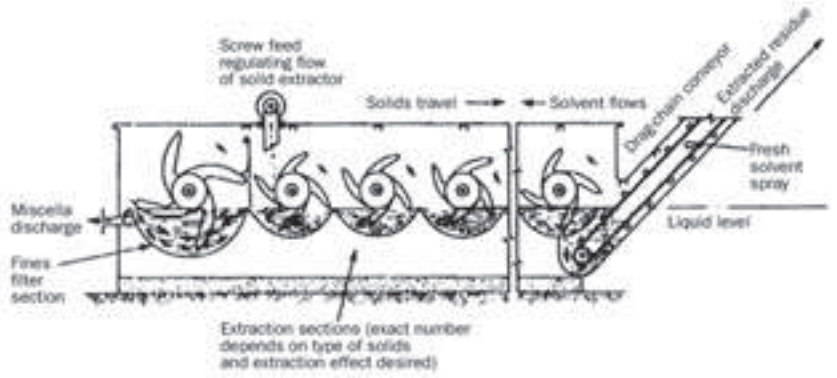

Figure 9: Kennedy extractor

5.6 Conventional Solvent Extraction

5.6.1 Principles and Mechanisms

Classic techniques for the solvent extraction of active constituents from medicinal plant matrices are based on the choice of solvent coupled with the use of heat or agitation. Existing classic techniques used to obtain active constituents from plants include: Soxhlet, hydrodistillation and maceration with an alcohol-water mixture or other organic solvents. Soxhlet extraction is a general and well-established technique, which surpasses in performance other conventional extraction techniques except for, in limited fields of application, the extraction of thermolabile compounds.

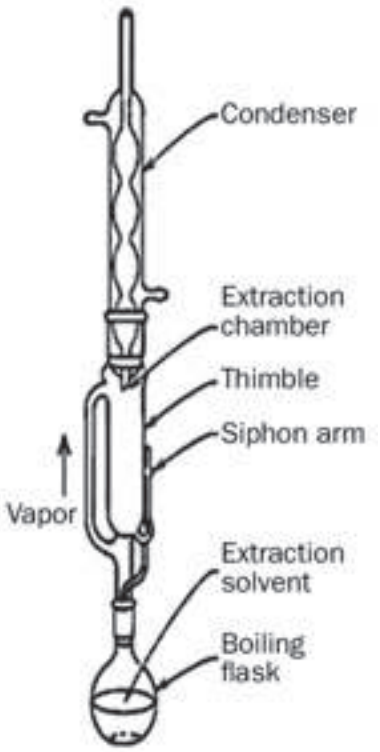

Figure 10: Soxhlet extractor

In a conventional Soxhlet system, as shown in Figure 10, plant material is placed in a thimble-holder, which is filled with condensed fresh solvent from a distillation flask. When the liquid reaches the overflow level, a siphon aspirates the solution of the thimble-holder and unloads it back into the distillation flask, carrying extracted solutes into the bulk liquid. Solute is left in the flask and fresh solvent passes back into the plant solid bed. The operation is repeated until complete extraction is achieved.

5.6.2 Advantages and Disadvantages of Soxhlet Extraction

Advantages:

1. The displacement of transfer equilibrium by repeatedly bringing fresh solvent into contact with the solid matrix.
2. Maintaining a relatively high extraction temperature with heat from the distillation flask.
3. No filtration of the extract is required.

Disadvantages:

1. Agitation is not possible in the Soxhlet device.
2. The possibility of thermal decomposition of the target compounds cannot be ignored as the extraction usually occurs at the boiling point of the solvent for a long time.

Worldwide, most of the solvent extraction units are based on the Soxhlet principle with recycling of solvents. Basic equipment for a solvent extraction unit consists of a drug holder-extractor, a solvent storage vessel, a reboiler kettle, a condenser, a breather system (to minimize solvent loss) and supporting structures like a boiler, a refrigerated chilling unit and a vacuum unit.

Table 1: Some common solvents used for the extraction of medicinal and aromatic plants

Solvent	Boiling point, °C	Miscibility with H_2O	Threshold limit values, ppm
Acetone	56	∞	1000
Acetic acid	116-117	∞	10
Ethyl acetate	77	80%	400
Benzene	80	<0.01%	25
2-Butanol	79.5	19%	2200
Cyclohexane	80.7	<0.01%	300
Dichloromethane	39.7	1.3%	2200
Chloroform	61	8%	50
Carbon tetrachloride	76.77	0.8%	10
Hexane	69	<0.01%	-
Ethanol	78	∞	1000
Ethyl ether	34.6	1.2%	400
Petrol ether	30-50	-	500
Propanetriole	290*	∞	-
Methanol	64.7	∞	200
1-Propanol	91	M	400
2-Propanol	82.4	M ?	400
Toluene	110.6	0.06	100

t = < 0.01%; * with decomposition; M miscible; ∞ completely miscible

5.7 Accelerated Solvent Extraction

5.7.1 Principles and Mechanisms

Accelerated solvent extraction (ASE) is a solid-liquid extraction process performed at elevated temperatures, usually between 50° and 200° C, and at pressures between 10 and 15 MPa. Therefore, accelerated solvent extraction is a form of pressurized solvent extraction. Increased temperature accelerates the extraction kinetics and elevated pressure keeps the solvent in the liquid state, thus achieving safe and rapid extraction. Also, high pressure allows the extraction cell to be filled faster and helps to force liquid into the solid matrix. A typical accelerated solvent extraction system is illustrated in Figure 11. Although the solvent used in ASE is usually organic, pressurized hot water can also be used. In these cases, one refers to pressurized hot water extraction or sub-critical water extraction.

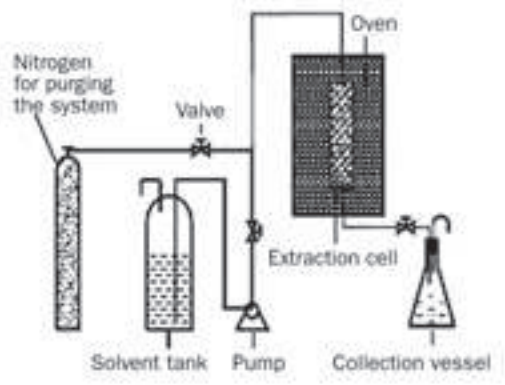

Figure 11: Accelerated solvent extraction

5.7.2 Advantages and Disadvantages of Accelerated Solvent Extraction

Compared with traditional Soxhlet extraction, ASE presents a dramatic reduction in the amount of solvent and extraction time. Particular attention should be paid to ASE performed at high temperature, which may lead to degradation of thermolabile compounds.

5.8 Important Factors for Designing a Solvent Extraction Plant for Medicinal Plants

- High efficiency of extraction
- Minimal solvent loss
- Facilities for cold and hot extractions
- Extraction with agitation

- Multiple solvent extraction systems
- Multiple fraction collection systems
- On-line filtration unit
- Solvent recycling and condensing unit
- Vent lines with breather for minimizing solvent loss and maximizing safety
- Brine circulation unit
- Fractionating column for separation of solvent mixtures
- Efficient evaporating systems like falling film, wiped film or rotary evaporators to work under low pressures
- Vacuum manifold system with cold traps
- GMP compatible
- Automation

Figure 12: Solvent extraction plant at CIMAP, India

5.9 Conclusions

Decoction, a water-based preparation, is one of the most used traditional methodologies for the extraction of active constituents of a medicinal plant. It is generally carried out by boiling the plant part for a fixed period. Hot continuous extraction or solvent extraction technique is one of the most widely used extraction techniques for the processing of medicinal plants. The solvent extraction method is simple, well established and economical. Important factors that can affect the efficiency of extraction, such as post-harvest processing, solid characteristics, choice of solvent, method of contact, and temperature, should be optimized for best yield. The choice of solvent especially for commercial plants and high efficiency usually de-

pends on many factors such as selectivity, polarity, boiling point, chemical and thermal stability, safety, flammability, and costs. Despite the economic advantages of solvent extraction, the use of volatile organic solvents such as hexane, acetone and methanol for processing medicinal plants has been limited due to environmental considerations. Hot continuous extraction technology shall always remain the method of choice for high efficiency, economical extraction and with less capital investment.

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6 Aqueous Alcoholic Extraction of Medicinal and Aromatic Plants by Fermentation

C. K. Katiyar

Abstract

The history of the development of pharmaceutical dosage forms can be traced back to the Vedic era. It provides insight into the innovations made during ancient times when the crude herbs were initially used in powder form and later on they were used as decoctions, self-fermented products, paste, pills and other advanced dosage forms. New drug development involves the search for novel and new pharmacophores. Combinatorial chemistry cannot solve the problem in a satisfactory manner nor can the reductionist approach be applied to medicinal plants. Asava arishta, a fermented Ayurvedic product, is a good source of novel pharmacophores for new drug discovery.

6.1 Introduction

The history of development of pharmaceutical dosage forms can be traced back to *Charak Samhita*, the first systematic documentation of Ayurveda. Ayurveda has recommended a comprehensive *Materia Medica* including medicinal plants, minerals, metals, and products of marine and animal origin. However, the use of herbs has been given priority.

Medicinal plants have been used for therapeutic purposes for centuries. Initially, these were used in fresh or dried powder form, which caused the problems of high dose, high volume and low shelf life. This led to the development of extraction processes. Extracts were found to be more useful as the necessary dose was less, the volume was low and shelf life was higher. Initially the solvents used for extraction were either water or alcohol, or their mixture. This evolutionary phase is continuing even today where solvents of all kinds of polarity are tried and extraction technologies have evolved from simple water decoction centuries ago to supercritical extraction. While this is true for some streams of products, Ayurveda did not exactly follow the same route but adopted a *sui generis* system of innovation.

6.2 Ayurvedic Dosage Forms

During ancient times, various dosage forms were developed. The number of dosage forms that developed over time is given below:

Charak Samhita (12th century BC)	128 dosage forms
Sushruta Samhita (10th century BC)	129 dosage forms
Ashtanga Hridaya (6th century AD)	90 dosage forms

Chakradutta (9th century AD)	90 dosage forms
Sarngadhara (14th century AD)	75 dosage forms
Bhaishajya Ratnavali (18th century AD)	98 dosage forms

The evolutionary phases of dosage forms followed by Ayurveda starting from crude plant material are mentioned in the following paragraphs.

6.2.1 *Swarasa* (Fresh Juice)

The evolution of liquid orals started from the administration of freshly obtained juices of plant material. To obtain fresh juices, green herbs are crushed and the juice is expressed by squeezing the crushed material. The product is referred to as *swarasa*.

6.2.2 *Kalka* (Wet Bolus)

In this method, the crushed fresh plant material is administered as such, without expressing the juices.

6.2.3 *Kwatha* (Decoction)

One part of coarsely powdered herb is boiled with 16 times its weight of water in an earthen pot over a mild fire until the liquid is reduced to one-fourth or one-eighth of the original quantity, depending upon the nature of the plant material.

6.2.4 *Hima* (Cold Infusion)

The plant material is dried and coarsely powdered. As and when required, the powder is soaked in plain water for a defined period. Then it is filtered, the marc is squeezed, and the combined filtrate is used.

6.2.5 *Phanta* (Hot Infusion)

As a further advancement of *hima*, the *phanta* method was adopted. This method uses boiled water for obtaining a hot infusion.

6.2.6 Solids

Anjana, Churna, Mansa potli, Utkarika, Kshara, Gutika, Guda, Dhumravarti, Puplika, Prithuka, Mandura, Modaka, Rasakriya, Vati, Varti, Shashkuli, Saktu, Bhasmas, Rasaushadhis.

6.2.7 Semisolids

Oral: o*dana* (rice preparation), *kalka, krishara, avaleha.*

Topical: *lepa, upnaha* (poultice), *tilapishta, patrasveda, madhucchishta* (beeswax).

6.2.8 Liquids

Oral: *taila, ghrita, asava/arishta, arka, kwatha, kshirapaka, takra, phanta, him, swarasa, peya, phanita, manda, manasa rasa, yusha, vesavara, vilepi, madya*

Topical: *ashchyotana, karna purana.*

6.2.9 Fumes

Dhumrapana, dhupana.

6.3 Shelf Life of Dosage Forms

Sarngadhara Samhita gave the shelf life of various dosage forms. In ancient times, Ayurvedic physicians themselves prepared the recipes for patients. In ancient times, Ayurvedic physicians themselves prepared the recipes for patients; during the fourteenth century AD, they became aware of the problem of poor shelf life of the botanicals in some dosage forms, such as powder and decoction. This led to the discovery of novel dosage forms termed *asava* and *arishtas,* which are self-fermented preparations having approximately 10%-12% alcohol. These are similar to medicated wines. In the preparation of *asava* cold infusion of unprocessed plant material is used, whereas for the preparation of *arishta* decoction of the plant material is used for fermentation.

6.4 *Asava* and *Arishta*: Self-fermented Products

This unique dosage form discovered by Ayurveda is supposed to have indefinite shelf life and it was said that the “older the better it is”. In terms of current understanding, this phrase assumes more importance because this dosage form has an inherent attribute of continuous hydro-alcoholic extraction and probably formation of natural analogues of the chemical compounds present in the medicinal plants. Some of the major self-fermented Ayurvedic preparations are given in Table 1.

Table 1: Major self-fermented Ayurvedic preparations

Product	No. of ingredients	Indication
Aravindasava	27	Pediatric tonic
Arjunarishta	5	Cardiotonic
Ashokarishta	14	Menstrual cycle regulator, especially to control excessive bleeding for prolonged periods during menstrual cycle
Ashwagandharishta	24	General tonic
Dashamularishta	67	Normalization of physiological processes after childbirth in women; also anti-inflammatory
Drakshasava	17	General tonic
Jeerakadyarishta	13	Galactogogue
Kumaryasava	46	Liver disorders
Kutajarishta	6	Diarrhea and dysentery
Lohasava	14	Anemia

6.4.1 Self-fermentation Process for Preparing *Asava Arishta*

Preparation of *asava arishtas* involves complicated processes where the following factors play important roles:

- Ingredients and their ratios
- Process
- Pot
- Season
- Place

The method of preparing *asava arishtas* is known as *sandhana kalpana* in Ayurveda. Briefly, a decoction or cold infusion of several herbs is taken and a defined amount of jaggery (dried juice of sugarcane) is added along with flowers of *Woodfordia fruticosa* as inoculum to initiate fermentation. It is kept for about four weeks for fermentation by anaerobic method to obtain a particular level of self-generated alcohol. The product is then kept for some time for maturation. Spices like cardamom and cinnamon are added as flavoring agents. A brief outline of the process of preparing *asava arishta* is given in Figure 1.

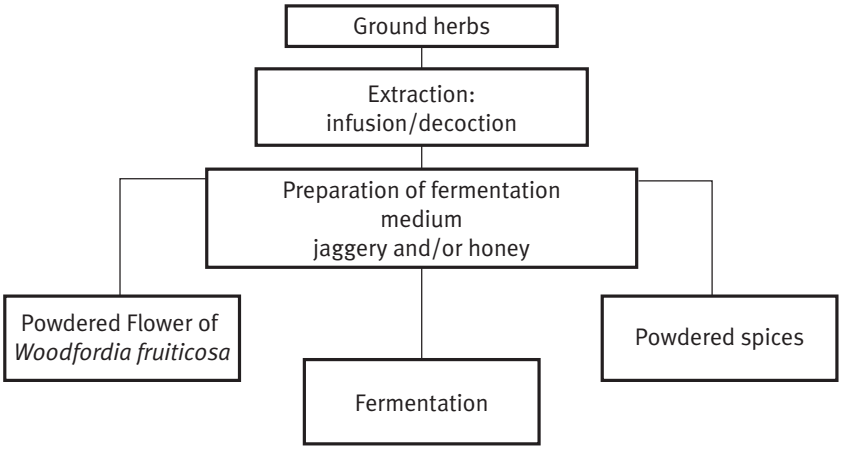

Figure 1: The traditional process of preparing asava-arishtas

A crude match-box method is applied to check whether fermentation has occurred. This method depends upon the release of carbon dioxide during the process. The major role in this dosage form is played by *Woodfordia fruticosa,* which is used as inoculum for fermentation but appears to play a role beyond that.

6.4.2 Merits of the Process

Prahst has mentioned some of the benefits of fermented herbal products which are reproduced below:

- Fermentation removes most of the undesirable sugars from plant material, makes the product more bio-available and eliminates side effects such as gas and bloating.
- Fermentation extracts a wider range of active ingredients from the herb than any extraction method since the menstruum undergoes a gradient of rising alcohol levels.
- Yeast cell walls naturally bind heavy metals and pesticide residues and, therefore, act as a natural cleansing system.
- Not only does fermentation remove contaminants, it can also lower the toxicity of some of the toxic components in plants.
- Fermentation actively ruptures the cells of the herb, exposing it openly to the menstruum and bacteria have enzymes that break down cell walls to further assist in the leaching process. Fermentation also creates an active transport system that moves the dissolved constituents from the herbal material to the menstruum.

6.5 Application of *Asava Arishta* Technology in New Drug Discovery

The Ayurvedic dictum with regard to *asava arishtas* that "older is better" needs to be scientifically evaluated. The process of preparing *asava arishtas* appears to involve:

1. Slow hydro-alcoholic extraction at room temperature of crude plant material particles floating in the liquid. Since the particle size of the plant material floating in the liquid is small, the effectiveness of extraction may be higher because of the larger surface area.
2. During the process, if the product is kept for a prolonged period, the probability of development of analogues of some of the pure chemical compounds of the plant material is high.

With a view to enhance the success rate of isolation of pure "druggable" compounds from medicinal plants, it is advised to start from 2- to 3-year-old self-fermented preparations than from solvent extracts. The chances of successful isolation of effective therapeutic compounds using this approach may be high and need to be evaluated.

6.6 Conclusions

Fermentation was applied hundreds of years ago in Ayurveda to develop *asava arishtas*, a multiherbal product, with a view to increase the shelf life and also to enhance the efficacy profile. The race for discovery of new molecules is getting increasingly competitive; at the same time, lack of new and novel pharmacophores is a big impediment which slows down drug discovery. Nature continues to be a source of pharmacophores, although the compounds isolated may not be "druggable" as such. They need to be derived, mostly to enhance their potency. In *asava arishtas*, the self-fermented products can undergo continuous chemical transformation which goes on beyond hydro-alcoholic extraction of the suspended material. This may result in novel natural molecules with enhanced therapeutic activity.

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7 Distillation Technology for Essential Oils

S. Tandon

Abstract

In many developing countries, the technology employed for extraction of essential oils from aromatic plants is primitive and obsolete. This results in low yield and poor quality of essential oils. Thus, there is great need for attaining adequate technological capability in the area of processing essential oil plants. This article deals with the different techniques of distillation, the principles of distillation, and important processing and design aspects which affect the yield and quality of the essential oils.

7.1 Introduction

Distillation is the most popular, widely used and cost-effective method for producing essential oils throughout the world.

Distillation of aromatic plants simply implies vaporizing or liberating the oils from the plant cellular membranes in the presence of moisture, by applying high temperature and then cooling the vapor mixture to separate the oil from the water on the basis of the immiscibility and density of the essential oil with respect to water.

7.2 Principles of Distillation

The choice of a particular process for the extraction of essential oil is generally dictated by the following considerations:

a) Sensitivity of the essential oil to the action of heat and water
b) Volatility of the essential oil
c) Water solubility of the essential oil

Essential oils with high solubility in water and those that are susceptible to damage by heat cannot be steam distilled. Also, the oil must be steam volatile for steam distillation to be feasible. Most of the essential oils in commerce are steam volatile, reasonably stable to heat and practically insoluble in water; hence they are suitable for processing by steam distillation.

Essential oils are a mixture of various aroma chemicals, basically monoterpenes, sesquiterpenes and their oxygenated derivatives, having a boiling point ranging from 150° to 300° C. When the plant material is subjected to heat in the presence of moisture from the steam, these oils are liberated from the plant. For the oil to change from the liquid to the vapor phase, it must receive latent heat that, within the tank, can only come from condensing steam. Consequently, the temperature of the steam within the

still must be higher than the temperature at which the oil boils in the presence of water on the surface of the plant material, otherwise there would not be a temperature gradient to take the latent heat from the condensing steam to vaporize the oil droplet. Thus, the energy from the steam in form of heat as latent heat of vaporization converts the oil into a vapor. But, as the boiling point of the oil is higher than that of water, the vaporization takes place with steam on the basis of their relative vapor pressures.

It is imperative to note that a liquid always boils at the temperature at which its vapor pressure equals the atmospheric or surrounding pressure. For any two immiscible liquids, the total vapor pressure of the mixture is always equal to the sum of their partial pressures. The composition of the mixture in the vapor phase (in this case, oil and water) is determined by the concentration of the individual components multiplied by their respective partial pressures. For example, if a sample of an essential oil comprised of component A (boiling point, 190° C) and water (boiling point, 100° C) is boiled, after some time, once their vapors reach saturation, the temperature will immediately drop to 99.5° C, which is the temperature at which the sum of the two vapor pressures equals 760 mmHg. In other words, the oil forms an azeotropic mixture with water. Thus, any essential oil having high boiling point can be evaporated with steam in a ratio such that their combined vapor pressures equal the atmospheric pressure; the essential oil can be recovered from the plant by the wet distillation process.

7.3 Methods for Distillation

The following four techniques for the distillation of essential oils from aromatic plants are employed:

1. Water distillation (or hydrodistillation)
2. Water and steam distillation
3. Direct steam distillation
4. Distillation with cohobation

7.3.1 Hydrodistillation

Hydrodistillation is the simplest and oldest process available for obtaining essential oils from plants. Hydrodistillation differs from steam distillation mainly in that the plant material is almost entirely covered with water in the still which is placed on a furnace. An important factor to consider in water distillation is that the water present in the tank must always be enough to last throughout the distillation process, otherwise the plant material may overheat and char. In this method, water is made to boil and the essential oil is carried over to condenser with the steam which is formed. Water-distilled oil is slightly darker in color and has much stronger still notes than oils produced by other methods. The stills based on this principle are

simple in design and are extensively used by small-scale producers of essential oils. Care should be taken during distillation of powdered herbs, as they tend to settle on the bottom of the still and get thermally degraded. Also, for plant material that tends to form mucilage and increase the viscosity of the water, the chances of charring are greater. For plant material that has a tendency to agglomerate or to agglutinate into an impenetrable mass when steam is passed through (like rose petals), water distillation is the preferred method of oil isolation.

The primitive, traditional Indian system of essential oil distillation, *bhapka* method, is also based on water distillation (Figure 1). In this process, the plant material is entirely covered with water in a distillation still, which is made of copper and is known as *deg*. This *deg* is placed in a brick furnace. Another copper vessel with a long neck is placed in a water tank or natural pond to serve as a condenser. A bamboo pipe is used as the vapor connection and mud is used to seal the various joints. The water is boiled, the oil vapors along with steam are condensed in the copper vessel, and oil is separated. The capacity of one *deg* is around 40 kg/batch. These types of units are still being used in Kannauj in Uttar Pradesh and in the Ganjam district of Orissa, India for the preparation of *rooh* and attars of *gulab, kewda, khus, rajnigandha*, and *bela*. These units can easily be transported from one place to another, but are not suitable for large-scale distillation of aromatic crops like grasses and mints.

Figure 1: Traditional Indian deg bhapka method

Although hydrodistillation (water distillation) is still being used, the process suffers from the following serious drawbacks:

a) As the plant material near the bottom of the still comes in direct contact with the fire from the furnace, it may char and thus impart an objectionable odor to the essential oil.
b) The prolonged action of hot water can cause hydrolysis of some constituents of the essential oil, such as esters.
c) Heat control is difficult, which may lead to variable rates of distillation.
d) The process is slow and distillation times are much longer than those of steam distillation.

7.3.2 Water and Steam Distillation

To eliminate some of the drawbacks of water distillation, some modifications were made to the distillation units. A perforated grid was introduced in the still, to support the plant material and to avoid its direct contact with the hot furnace bottom. When the water level is kept below the grid, the essential oil is distilled by the rising steam from the boiling water. This mode of distillation is generally termed water and steam distillation.

The field distillation unit (FDU), also known as a directly fired-type distillation unit, is designed according to the principle of water and steam distillation. The FDU consists of a still or tank made of mild stainless steel with a perforated grid and is fitted directly to a brick furnace. A chimney is connected to the furnace to minimize the pollution at the workplace and also to induce proper firing and draft. The plant material is loaded on the perforated grid of the tank and water is filled below it. The tank is connected to the condenser through a vapor line. The water is boiled and the steam vapors pass through the herb, vaporize the oil and get condensed, mostly in a coil condenser by cooling water. The condensate (oil-vapor mixture) is then separated in the oil separator.

These units are simple to fabricate and can be installed in the farmer's field. Due to their simple construction, low cost and easy operation, FDUs are extremely popular with essential oil producers in developing countries. The furnace is always fueled by locally available firewood or straw. This makes the unit suited for use in remote areas where the raw material is available. This also helps in reducing transportation costs in the production of essential oils. FDUs are currently finding application in distillation of patchouli oil in Indonesia, aromatic grass and mint oil in India, citronella oil in Taiwan and many more all over the world. A local FDU currently being used by rural farmers in India for the distillation of mint oils is shown in Figure 2. Such field units generally can hold 100-2000 kg plant material. Total time for distillation with these units is about 6-8 h.

Figure 2: Local type field distillation unit in India

7.3.2.1 Improved Field Distillation Units

Due to the limited heating surface available, the rate of steam production in the FDU is always insufficient. This results in prolonged distillation periods and sometimes lower oil yields. Refluxing of oil back into the still due to inadequate steam rate may lead to decomposition reactions and poorer oil quality. Experimental measurements made at the Central Institute of Medicinal and Aromatic Plants (CIMAP), India, have shown that firewood consumption in a conventional field still may be up to 2.5-times greater than that of a modern steam distillation unit operated by an external boiler. This factor may not be critical where fuel supplies are cheap and abundant but, in many developing countries, fuel supplies are getting scarce and costly and low thermal efficiency can directly affect the cost of production.

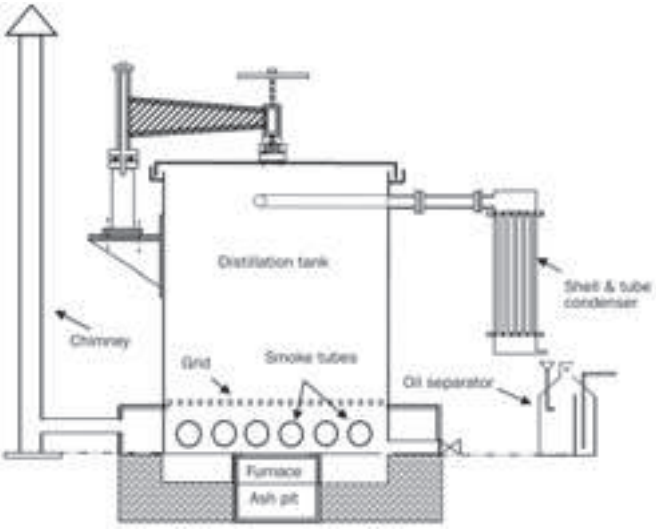

Figure 3: CIMAP's improved field distillation unit

Considering the previously mentioned demerits of FDUs, designs of economical and improved units with capacities 500-2000 kg per batch are now being preferred (Figure 3). The units are fabricated with high quality mild stainless steel, keeping in view the plant materials to be distilled. The improved distillation unit consists of a cylindrical distillation tank fitted on a square inbuilt boiler (calandria) having smoke pipes which reduces the heating time of the water, resulting in a high rate of steam generation and lower fuel consumption (20%-30%). Hot flue gasses of the furnace are led through the smoke tubes where they impart heat to the water, thus raising additional steam. The tank is fitted on a specially designed furnace having fire grate, flue ducts and fire door for proper controlling of the firing and draft. The furnace is connected to a chimney of optimum height to maximize the air draft and control the pollution by smoke in the workplace. A similarly designed stainless steel shell and tube-type condenser having higher condensation capacity are used for cooling the vapors. It prevents loss of oil due to improper condensation. The condensed oil-water mixture is then allowed to pass through a specially designed stainless steel oil separator. The separator has an inbuilt baffle to maximize the retention time of the mixture, thereby resulting in no loss of oil with the outgoing water from the separator. The unit also has a chain pulley hoist system with a support structure that makes work easier and saves time during discharge of the distillation waste material from the tank. CIMAP has designed, fabricated and supplied these improved units to entrepreneurs and farmers in different parts of India.

7.3.3 Direct Steam Distillation

In direct steam distillation, plant material is distilled with steam generated outside the tank in a steam generator or boiler. As in water and steam distillation, the plant material is supported on a perforated grid above the steam inlet. As already noted, the steam in an FDU is at atmospheric pressure and hence its maximum temperature is 100° C. But, steam in a modern pressure boiler operating at, for example, 50 psi pressure will have a temperature correspondingly higher. Moreover, there is no limitation to the steam generation when an external boiler is used as a source of steam. The use of high-pressure steam in modern steam distillation units permits much more rapid and complete distillation of essential oils.

Steam distillation is preferred when a lot of area is under cultivation and more than one unit is to be installed. Also, for distillation of high boiling oils and hardy materials such as roots and woods like sandalwood, cedar wood and nagarmotha, steam distillation is more efficient. Steam distillation also reduces the time required for the extraction of oils. A charge of Java citronella, which takes up to 5 h in an FDU, is processed within two to 3 h in a steam distillation still. In this method of distillation, steam is generated separately in a steam boiler and is passed through the distillation tank through a steam coil (Figure 4). The plant material is tightly packed above the perforated grid. Steam, containing the oil vapor, is condensed in a tube condenser and is separated in

the oil receiver. Fuel costs are generally lower in modern steam distillation units due to higher thermal efficiency at which most of the boilers operate. Capital cost is higher, thus only bigger producers can afford to own such units. Still capacities range from 1 to 3 tonne plant material per batch.

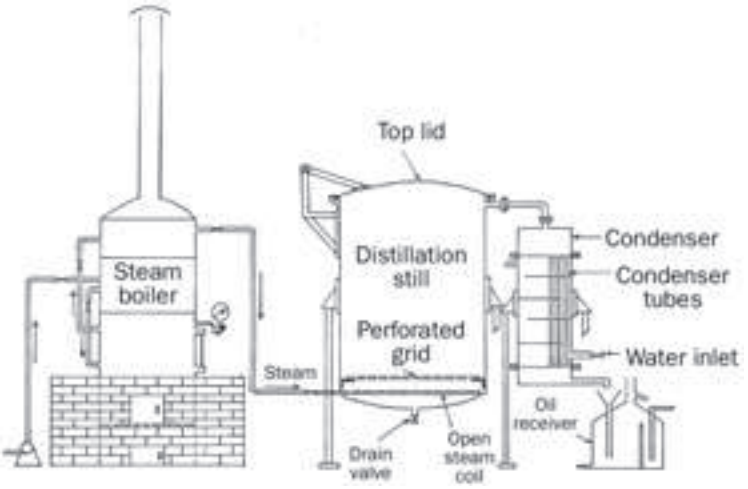

Figure 4: Boiler-operated steam distillation unit

7.3.3.1 Comparison of Boiler-operated Unit with Directly Fired Type

a) It is possible to run a large number of distillation units by a single steam boiler. Hence a boiler system is ideal for large-scale production of essential oils. An FDU is more suited for small and medium-sized farmers.
b) The efficiency of extraction of essential oil in a well-designed FDU can equal that obtained by a boiler unit. But in a poorly designed FDU, oil recovery may be low and fuel wastage may be heavy accompanied by smoke pollution.
c) Steam injection rate in a boiler-operated unit can be adjusted with ease but steam generation rate in an FDU is limited by the heat transfer area provided in the unit. Insufficient steam generation in an FDU can result in low oil yield.
d) Boiler-operated units require a skilled boiler man for operation but an FDU can be operated by relatively low-skilled workers.

7.3.4 Distillation with Cohobation

Cohobation is a technique that can be used for water distillation or for water and steam distillation. It uses the process of returning the distillate water to the still after the oil has been separated from it so that it can be re-boiled. This is basically an improvised methodology of the directly fired type

steam and water distillation units for oils which have partial solubility in water. Although most of the essential oils have finite solubility in water, some oils like those of rose, lavender and geranium have comparatively higher solubility. In such extractions, the loss of oil with the outgoing water of distillation can become alarmingly high. This problem can be solved by returning the condensate water from the separator back to the still; this is known as cohobation. It is evident that this cannot be done with steam distillation as the water level in the still will keep building up due to continuous steam injection.

In a further improved version, a packed column is placed on top of the column for providing mass transfer to the oil-water vapors, so as to increase the concentration of the outgoing condensate and to coalesce the oil droplets in the oil separator (Figure 5). The condenser is placed above the column so that the condensate water from the separator can be recycled back to the still by means of gravity. Additional heat, if required, can be provided by a closed steam coil immersed in the tank bottom. The condenser is moved above the distillation still so that condensed water from the separator can flow by means of gravity to the still. By limiting the total quantity of water in this closed cycle operation, it is possible to obtain increased yields of essential oils that are more water soluble. It is relevant to point out here that prolonged recirculation of the distillation water allows the various impurities and plant decomposition products to build up in the system. This may sometimes affect the quality of the oil. One must always keep this in mind when considering a cohobation distillation system for any application.

Figure 5: Distillation unit with cohobation

7.4 Hydrodiffusion

This system was first described in 1983. Unlike traditional steam distillation, hydrodiffusion works on the diffusion principle of allowing steam to enter the top of the plant charge and diffuse through the charge by gravity. The process uses the principle of osmotic pressure to diffuse oil from the oil glands. The system is connected to a steam source, and low pressure steam is passed into the plant material from a boiler. The condenser, which is directly under the basket within the still, is of the tube type. The oil and water are collected below the condenser in a typical oil separator. Hydrodiffusion is an efficient process that is easy to use, especially regarding the processes of loading and unloading the plant material. The yield of oil is higher and the process is advantageous because of the reduced steam consumption, shorter distillation time and absence of hydrolysis, as the raw material does not come in contact with boiling water. However, because of the downward flow of steam and condensate, co-extraction of other non-volatile compounds (such as lipids, chlorophyll and fatty acids) and polar components makes the process complicated. Although it may seem that hydrodiffusion is a better alternative to conventional distillation processes, the fact remains that commercial ventures based on hydrodiffusion have not been able to take off successfully.

7.5 Parameters Affecting Yield and Quality of Essential Oils

The yield and quality of essential oil from steam distillation is affected by the various process parameters. It is advisable to keep them in mind while designing such systems. Some of the important parameters are being listed below.

7.5.1 Mode of Distillation

The technique for distillation should be chosen considering the boiling point of the essential oil and the nature of the herb, as the heat content and temperature of steam can alter the distillation characteristics. For high boiling oils such as woody oils (e.g. sandalwood, cedar wood) and roots (e.g. *Cyperus*), the oil should be extracted using boiler-operated steam distillation. Since the heat content and temperature of steam depend upon its pressure, a change in steam pressure can alter the distillation characteristics. High-boiling constituents of essential oils normally require high-pressure steam to distill over. For oil of rose and other florals, the material is generally immersed in water, i.e. hydrodistillation, as flowers tend to aggregate and form lumps which cannot be distilled using water and steam distillation or direct steam distillation.

7.5.2 Proper Design of Equipment

Improper designing of tank, condenser or separators can lead to loss of oil and high capital investments. The design of the furnace and chimney affects the firing and heat control of the distillation rates. Tank height:diameter ratio is important. Similarly the use of a condenser with an improper design and without calculating the heat transfer areas based on the steam generation areas will lead to improper condensation and loss of oil.

7.5.3 Material of Fabrication of Equipment

Essential oils which are corrosive in nature should be preferably distilled in stills made of resistant materials like aluminum, copper or stainless steel. The tank still can be made from a cheaper metal like mild steel or galvanized iron, and the condenser and separator can be made from a resistant material like stainless steel. As only vapor is present in the tank still, the rust and other products of corrosion may not be carried over into the oil. This can result in considerable savings in the capital cost of the equipment. Expensive, high-value essential oils like rose, agarwood, *kewda*, sandalwood and lavender should be distilled in stainless steel systems. Although copper was the most common material of fabrication of distillation stills since ancient times, its availability is getting reduced and with the arrival of superior alloys like stainless steel, it is slowly disappearing from the scene.

7.5.4 Condition of Raw Material

The condition of the raw material is important because some materials like roots and seeds will not yield essential oil easily if distilled in their natural state. These materials have to be crushed, powdered or soaked in water to expose their oil cells. Chopping of plants will also change the packing density of the material when placed in the distillation still. One can pack up to 50% more plant material in the same still after chopping of some aromatic herbs like mint. Air drying and wilting the herb prior to distillation also has considerable effect on distillation. If required, drying of the herbs prior to distillation should be done in shaded areas and the dried material should not be kept in heaps.

7.5.5 Time for Distillation

Different constituents of the essential oil get distilled in the order of their boiling points. Thus, the highest boiling fractions will be last to come over when, generally, very little oil is distilling. If the distillation is terminated too soon, the high-boiling constituents will be lost. In many aromatic plants, like vetiver, patchouli, chamomile, sandalwood and agarwood,

these high-boiling fractions are valuable due to the quality of their aromas. Thus, the time of distillation must be chosen with due care.

7.5.6 Loading of Raw Material and Steam Distribution

Improper loading of the herb may result in steam channeling, causing incomplete distillation. The herb should be evenly and uniformly loaded in the tank without leaving any voids. Excessive filling of plant material may also lead to formation of "rat holes" which may allow steam to escape without vaporizing the oil. For powdered herbs, a proper stainless steel wire mesh or muslin cloth should be put at the false bottom to prevent plant material from falling into the tank base.

7.5.7 Operating Parameters

Proper control of injection rates and pressure in boiler-operated units is necessary to optimize the temperature of extraction for maximal yield. Generally, high-pressure steam is not advisable for the distillation of essential oils. The temperature of the condensate should not be high, as it can result in oil loss due to evaporation. In directly fired-type FDUs, the firing of the furnace should be well controlled as it can result in high flow rates and high condensate temperatures.

7.5.8 Condition of Tank and Equipment

The tank and other equipment should not be rusted. If rusted, the tank should be cleaned with dilute caustic solutions. The perforated grids should not be corroded or have large gaps permitting the plant material to settle to the bottom of the tank and emit a burnt odor. The distillation tanks should be well steamed prior to distillation for multiple crop distillation.

7.6 Purification of Crude Essential Oils

Essential oil as obtained from the oil separator is in crude form. It may have suspended impurities and appreciable moisture content. It might even contain some objectionable constituents which degrade its flavor quality. The presence of moisture and impurities adversely affects the keeping quality of oil and accelerates polymerization and other undesirable reactions. Addition of a drying agent like anhydrous sodium sulphate to the oil, standing overnight followed by filtration will remove the moisture and free the oil of suspended impurities. Use of high-speed centrifugation to clarify the essential oils is common.

Essential oils are frequently rectified or re-distilled to remove objectionable constituents. In order to keep the temperature of re-distillation

within permissible limits, the process is carried out under vacuum or with the help of steam distillation.

7.6.1 Continuous Steam Distillation

Steam distillation units involve manual charging and discharging of plant material from the tank still. These operations are labor intensive and time consuming. To overcome these problems, continuous steam distillation plants have been developed in the Soviet Union and have been in operation since the last couple of decades. These units are being used for distillation of lavender and require negligible manual handing. Capacities of 2 tonnes per hour are quite common. Incoming plant material is first chopped with special ensilage cutters and then conveyed to the top of a tall distillation column by means of a belt conveyor. The movement of material inside the column is by gravity or by special helical screw conveyors. Sometimes two columns in series are used for complete removal of oil. Steam is injected at multiple points in the column. Spent material is continuously ejected out of the bottom of the distillation column by special screw conveyors with a vapor lock which does not allow steam to escape.

Fabrication and operation of continuous distillation columns is rather complicated and these have not yet gained acceptance and popularity outside the former Soviet Union. In another development, containerized distillation is also being used for the distillation of *Mentha piperita* and lavender in some parts of the United States. In this method, large capacity containers mounted on wheels are attached to a harvester which directly loads the plant material into the containers from the fields (these containers have inbuilt steam coils); these are then taken to the distillation area where steam is directly connected to the coils and the top is closed and connected through a vapor line to the condenser and subsequently to the oil separator.

7.7 Conclusions

Distillation is the most widely used method for the extraction of essential oils. Proper selection of the distillation technique, design and material of fabrication of the equipment, and processing parameters all play vital roles in determining the quality and yield of an essential oil.

8 Microdistillation,Thermomicrodistillation and Molecular Distillation Techniques

V. G. Pangarkar

Abstract

Medicinal and aromatic plants (MAPs) have assumed considerable significance in view of their special attributes. There are many compounds of great therapeutic value which can be obtained only from the plant kingdom. Most of the ingredients in such extracts and oils are large bulky molecules highly sensitive to processing conditions. The processes for such extractions have been mostly based on "recipes". In the recent past, significant advances have been made in the unit operations which are part of the recipe-based processes. It is imperative that these advances, which are essentially aimed at achieving better yields at lower costs and are termed "process intensification", are incorporated into the processing of MAPs. This paper introduces the theme of process intensification as applied to the processing of MAPs and presents an overview of several new technologies which allow rapid, cost-effective extraction. The application of such innovative technologies can yield significant benefits in terms of the quality of the product and its yield per unit weight of the plant material processed. Recovery of dissolved essential oil components from steam distillation condensates is also addressed and the two available techniques are discussed in detail.

8.1 Introduction

Phytochemicals derived from medicinal and aromatic plants (MAPs) have been important to humans for centuries. Before the advent of modern synthetic chemistry, many aroma and flavor chemicals were derived from sources of natural origin such as flowers, roots and stems. The contemporary system of allopathic medicine, which has gained tremendous importance in the treatment of various diseases, is mainly based on active pharmaceutical compounds made synthetically. However, in recent years increasing attention has been paid to the traditional systems of treatments followed in Asia and Africa. The variety of medicinal plants and their constituents are being discovered only recently. There are many compounds of great therapeutic value which can be obtained only from the plant kingdom. Thus, vincristine, perhaps better known as the chemotherapy agent Oncovin, is only synthesized in the periwinkle plant *Catharanthus roseus*, and the sole source of the compound is this plant species. There are many other compounds which are equally valuable in other sectors such as food flavors, fragrances and cosmetics.

The processing of MAPs for obtaining the required extracts and oils has been based on traditionally established "recipes". Most of the ingredients in such extracts and oils are large bulky molecules highly sensitive to processing conditions. Generally, relatively mild conditions are used in such processes to protect the integrity of the valuable components. The

recipe-based methods are time-tested but arguably not the most efficient in terms of yield, energy consumption per unit of product, etc. With the advent of modern processing techniques, there is an urgent need to revisit the recipe-based processing, understand the science underlying them and develop modern, cost-effective processes. This article deals with some important advances made in the extraction of MAPs and the post-extraction treatment of the products and their byproducts.

8.2 Process Intensification

The modern chemical industry is undergoing drastic changes driven mainly by economic considerations. There is an upsurge of interest in clean, energy-efficient and material-conserving processes. An entirely new discipline, "process intensification" (PI), has become the focus of a large and sustained effort all over the world. Stankiewicz and Moulijn have given a precise definition of PI as "Any chemical engineering development that leads to a substantially smaller, cleaner and more energy efficient technology". India has not been lagging behind in developing innovative PI concepts.

PI can be broadly divided into two categories, with specific reference to processing of MAPs as per the definition of Stankiewicz and Moulijn. These are processes that employ multifunctional equipment (MF) and those that use process-intensifying equipment.

8.2.1 Multifunctional Equipment

This category of PI employs equipment that can perform multiple functions simultaneously. Thus, earlier process plants that required a number of different instruments devoted to individual tasks are being replaced by such MF equipment. A brilliant example of the use of MF equipment is the conversion of a slow and polluting process for the enzymatic hydrolysis of penicillin G to 6-amino penicillanic acid (important intermediate for semisynthetic antibiotics) into an intensified and sustainable process. Since MF equipment-based plants are smaller and consume less energy, they have become popular for globally competitive and sustainable processes.

8.2.2 Process-intensifying Equipment

This category of PI employs equipment that specifically focuses on intensifying the rates of the various steps. In the case of MAP processing, the main resistance in the overall extraction process is the diffusion of the active molecules through the plant cell membrane to the surface before extraction by the fluid. Microwave-assisted extraction (MAE) is highly useful in obtaining rapid and complete extraction without significant damage to the active molecules; this technique is discussed in some detail later. Ultrasound-assisted extraction is also an alternative. However, considering

that ultrasound waves can produce free radicals and that many active molecules are susceptible to such highly reactive species, this approach does not seem feasible.

8.3 Solvent Extraction of MAPs

This process entails the extraction of solid MAPs by liquid solvents. This is a typical solid-liquid extraction process. Two factors that affect the extent and rate of extraction are the thermodynamics and kinetics (rate of mass transfer) of the process.

8.3.1 Thermodynamics of Solvent Extraction and Choice of Solvent

Relative sorption of solutes in the solvent depends on the interactions between the solutes and the solvent. Solubility or miscibility of a component with the solvent depends on their relative solubility parameters. For mutual solubility of two components, their free energy of mixing, ΔG_m should be negative. ΔG_m is defined as

$$\Delta G_m = \Delta H_m - T\,\Delta S_m \tag{3.1}$$

Enthalpy of mixing, ΔH_m can be correlated to cohesive energy density, i.e. solubility parameter (δ) as:

$$\Delta H_m = n_1\, n_2\, V_1\, (\delta_1 - \delta_2)^2 \tag{3.2}$$

In equation (3.2), the solubility parameter is that due to only dispersive forces between structural units of the concerned solute and solvent, since the original regular solution theory of Scatchard and Hildebrand was restricted to non-polar, non-hydrogen bonding solute-solvent systems. However, for many liquids and solutes, contributions from polar and hydrogen bonding forces need to be considered. Accordingly, equation (3.2) becomes:

$$\Delta H_m = n_1\, n_2\, V_1\, [(\Delta\delta_d)^2 + (\Delta\delta_p)^2 + (\Delta\delta_h)^2] \tag{3.3}$$

From equations (3.2) and (3.3), it is clear that to make ΔG_m negative, the difference between δ_i (solvent) and δ_i (solute), i.e. ($\Delta\delta$) for all the three forces of interactions, should be as small as possible. It implies that the solvent and the desired solute to be extracted should have comparable polarity and hydrogen bonding capabilities to achieve similar solubility parameter values. Grulke has given an exhaustive tabulation of solubility parameters for the most common chemical compounds. The in-

dividual δ_h, δ_d and δ_p values for compounds not listed in the tabulation can be obtained using the group contributions due to various different groups given by Grulke. When the individual δ_i (solvent) and δ_i (solute) values are very close, a high solubility of the solute in the solvent is obtained. For instance, it is well known that non-polar solvents dissolve terpene fractions more than oxygenated compounds because both are non-polar. On the other hand, mixed solvents of polar and non-polar compounds can yield better results for oxygenated compounds. Bio-ethanol is a good solvent for such oxygenated compounds on two accounts: (i) it is natural, and (ii) it is "green" (renewable). However, most MAPs contain water and the complete miscibility of ethanol with water implies dilution of the solvent after each use. This is further complicated by the fact that ethanol forms an azeotrope at high concentration (~95 wt%). As a result, ingress of small quantities of water is sufficient to reach the azeotropic composition. Implementation of the Montreal Protocol, the Clean Air Act, and the Pollution Prevention Act of 1990 has resulted in increased awareness of organic solvent use in chemical processing.

8.3.2 Solid-liquid Mass Transfer

The MAPs to be processed are in solid form. Solid-liquid extraction is a typical heterogeneous mass transfer process. In such processes, the rate of extraction depends upon: (i) the interface area, and (ii) the mass transfer coefficient. Both should be high. High effective interface area can be obtained by comminuting the solid material to be processed. During comminution, the ensuing friction can increase the temperature of the solid and thereby possibly lead to degradation of thermally labile components. To avoid this, special water-cooled roll crushers are used.

The mass transfer coefficient depends on the diffusivity of the solute in the solid matrix (main resistance) and the level of turbulence in the extractor. Traditional extraction has relied upon percolation or extraction in stirred vessels. In the case of percolation, the solid is packed in a vessel which is filled with solvent. The latter is allowed to percolate in the solid matrix under stagnant conditions. In the case of extraction in stirred vessels, different types of agitators are used to suspend the solid in the solvent and accelerate the mass transfer process. In both percolation and extraction in stirred vessels, the solvent is first sorbed by the matrix of the solid. This sorption, which causes swelling of the matrix, is a relatively slow process. However, once the matrix is swollen, the diffusion coefficient increases several fold or even by an order of magnitude as compared to the dry matrix. Evidently the controlling step is the diffusion of the solute through the solid matrix to the surface of the solid. Once the solute is available at the surface, the solvent can dissolve it depending upon the rate of transport from the solid surface into the bulk of the solvent. In percolation vessels, this latter transport is predominantly by molecular diffusion and hence is slow, although not as slow as the transport through the solid matrix. The

stirred vessels, on the other hand, provide a high level of turbulence and hence facilitate transport into the bulk solvent phase. In both percolation and stirred vessels, the dominant resistance is diffusion through the solid matrix. It is then clear that even stirred vessels with high power inputs may not intensify the mass transfer process. Therefore, instead of focusing on the transport at the solid surface, it is desirable to increase the rate of transport through the solid matrix by rupturing the cells which contain the solute or oil and consequently bring the same in direct contact with the solvent.

8.3.3 Microwave-assisted Extraction

8.3.3.1 Principle of Microwave Heating

Microwave radiation interacts with dipoles of polar and polarizable materials. The coupled forces of electric and magnetic components change direction rapidly (2450 MHz). Polar molecules try to orient in the changing field direction and hence get heated. In non-polar solvents without polarizable groups, the heating is poor (dielectric absorption only because of atomic and electronic polarizations). This thermal effect is practically instantaneous at the molecular level but limited to a small area and depth near the surface of the material. The rest of the material is heated by conduction. Thus, large particles or agglomerates of small particles cannot be heated uniformly, which is a major drawback of microwave heating. It may be possible to use high power sources to increase the depth of penetration. However, microwave radiation exhibits an exponential decay once inside a microwave-absorbing solid.

The various industrial techniques used for heating are listed in Table 1, which shows that microwaves have the highest efficiency when compared with the other competitive techniques.

8.3.3.2 Mechanism of MAE

In microwave-assisted extraction (MAE): 1) the heat of the microwave irradiation is directly transferred to the solid without absorption by the microwave-transparent solvent; 2) the intense heating of step 1 causes instantaneous heating of the residual microwave-absorbing moisture in the solid; 3) the heated moisture evaporates, creating a high vapor pressure; 4) the vapor pressure generated by the moisture breaks the cell; and 5) breakage of cell walls releases the oil trapped within it (Figure 1).

Table 1: Relative efficiencies of common heating devices

Appliance	Temperature, °C	Rating, W	Time	Energy used, kWh	Energy cost, US$
Electric oven	177	2000	1 h	2	0.17
Convection oven	163	1853	45 min	1.39	0.12
Gas oven	177	36	1 h	3.57	0.07
Microwave oven	High	1440	15 min	0.36	0.03

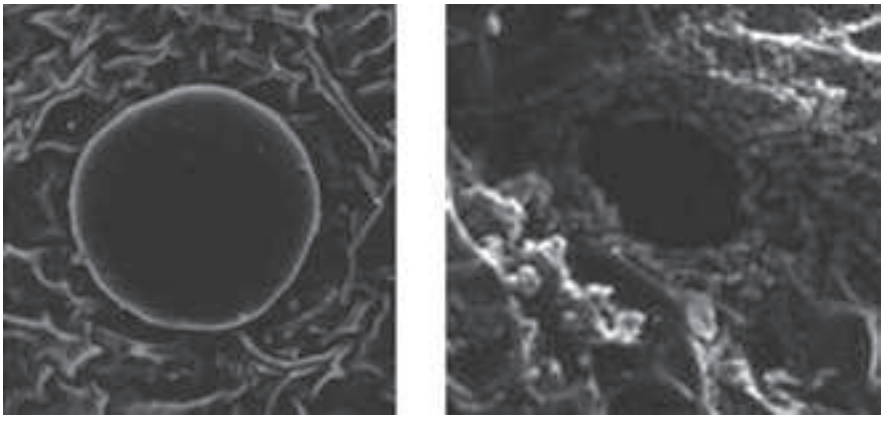

A B

Figure 1: Mint gland: (A) before and (B) after microwave irradiation (Microphotographs courtesy of Radient Technologies Inc.)

It is evident then that the main resistance to solid-liquid mass transfer, the transport of the solute through cell membrane, is eliminated because of the rupture of the cells. Besides cell breakage, the other advantages of microwave heating are:

1. Improved “existing” products
2. Increased marker recovery
3. Increased purity of the extract
4. Reduced heat degradation
5. Reduced processing costs
6. Significantly faster extraction
7. Much lower energy usage
8. Much lower (order of magnitude) solvent usage
9. Potential for “new” products

8.3.3.3 Literature on MAE

Some interesting results on MAE have recently been published. For example, the extraction of vanillin from *V. planifolia* pods using MAE and ultrasound-assisted extraction has been described. Using absolute ethanol as the solvent at room temperature, the yield of vanillin was 1.25 wt% at each of 3 conventional extractions performed over 24 h. Using ultrasound-assisted extraction, the yield was 0.99 wt%, while it was 1.86 wt% using MAE. These investigations clearly showed that vanillin extraction by MAE is superior to other techniques in terms of yield, purity of vanillin, and the time taken to extract the same percentage of the vanillin from the pods. The extraction of vanillin and *p*-hydroxy benzaldehyde (PHB) from vanilla beans using MAE has also been studied: MAE was superior to the conventional, official method of extraction in Mexico, which involves maceration of the beans with ethanol for 12 h. Specifically, extraction time decreased 62-fold and vanillin and PHB concentrations increased between 40% and 50% with respect to the Mexican extraction method. This study also showed that extraction of commercial samples was superior to extraction of dried and lyophilized beans. This observation illustrates the role played by moisture in aiding extraction, as discussed in Section 8.3.3.2. Several other investigations have shown that MAE has gained acceptance as a mild and controllable processing tool. MAE is a simple, rapid and low-solvent-consuming process.

8.3.3.4 Industrial-scale MAE

As mentioned earlier, microwave radiation decays exponentially inside a solid matrix. This aspect must be carefully weighed while designing industrial-scale MAE. The major requirements that must be met are:

1. Free distribution of particles allows uniform heating of all the particles in the solid bed. This criterion also enhances the extent and probability of proximity of the substrate to the wall of the sample holder where the microwave exposure is highest. Most comminuted samples of MAPs which are used for commercial extraction are not of the same shape and size. Therefore, there is a strong tendency to "segregate", which must be curbed by regular renewal of the layer.
2. Thin and uniform spreading of the substrate layers. This permits complete and uniform penetration of microwave radiation even at large water contents.
3. Low depth of the layers. Since microwaves have low penetration depth (~1.5 cm in H_2O at 2.45 GHz), the layers should be <1.5 cm thick.

Large-scale commercial (3 tonne/hour) MAE is available for industrial use (www.radientinc.com). In view of the advantages of MAE and the development of equipment for large-scale commercial operation, MAE has a bright future. Figure 2 shows a flowsheet for industrial-scale MAE.

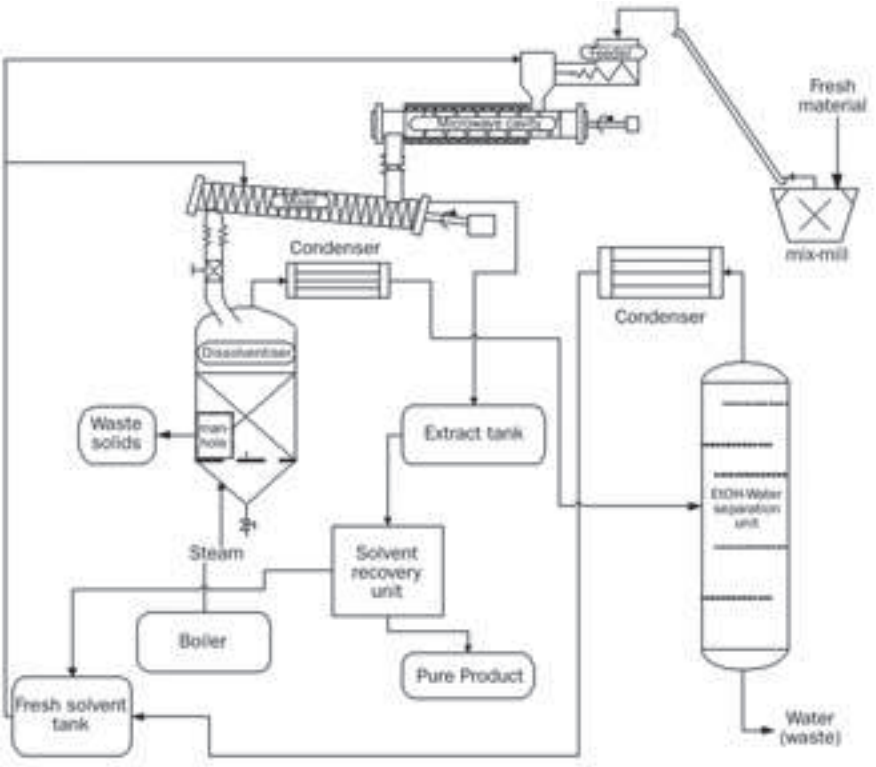

Figure 2: Flowsheet of microwave-assisted extraction (courtesy, Radient Technologies Inc).

8.4 Microwave-assisted Hydrodistillation

The ability of microwave radiation to heat solid material effectively can also be used for obtaining essential oils. Thus, the herb is placed in a microwave cavity and irradiated with microwaves. This process yields essential oils consisting of relatively low volatile fractions as compared to hydrodistillation. For instance, in coriander oil, the percentage of tetradecanoic and hexadecanoic acid increased whereas that of linalool decreased. This is possibly due to the poor stability of linalool, a tertiary alcohol.

Dill seed oil obtained by microwave-assisted hydrodistillation (MWAHD) contained greater quantities of compounds with higher boiling points and lesser quantities of compounds of lower stability. These and other findings indicate that MWAHD is better for extracting stable, high-boiling point components, whereas it is not suitable for recovering chemically unstable compounds.

8.5 Molecular Distillation or Short Path Distillation

Molecular distillation (MD), also known as short path distillation, is a fairly well established technique. In view of this, the discussion of MD is restricted to its principle, advantages and applications in the processing of MAPs.

8.5.1 Principle of MD

The term MD refers to a non-equilibrium process. The still used has an evaporating surface very close to a condensing surface. Under very low pressures, this results in a situation where the distance traveled by the evaporating molecules is comparable to the mean free path of the molecules. The nomenclature MD is derived from this particular condition under which the so-called distillation is carried out.

8.5.2 Advantages of MD

1. Operating pressures as low as 0.001 mbar can yield relatively low processing temperatures, thereby reducing thermal degradation.
2. Agitated film MD units can process high viscosity feeds with very good turndown.
3. Combination of low pressures and high temperatures (up to 300° C) allows processing of extremely high-boiling materials without degradation.
4. Short exposure to high temperature (low residence time) prevents degradation.
5. Very low liquid hold-up allowing use in applications involving low volume, high value materials.
6. Available in low (laboratory scale) to high heat transfer areas to suit the requirements.

8.5.3 Separation Efficiency of MD

For high viscosity liquid films falling under gravity, agitated film MD units perform far better than those without agitation of the film. This is due to the fact that, particularly for high viscosity liquids, the agitation of the film renews the surface more frequently than when there is no agitation. The surface renewal model is useful for predicting the efficiency η of MD stills without mechanical control.

8.5.4 Parameters that Affect the MD Process

The amount of low-boiling volatiles as well as dissolved air, moisture, or other gasses in the feed material has a deleterious effect on the efficiency of MD. This is due to the fact that the non-condensable components cover the condensing surface.

Higher temperature difference between the condensing and evaporating surfaces yields higher efficiency. High viscosity liquids (without mechanical agitation) yield high liquid film thicknesses and hence lower efficiency. As a rule, the relative volatility of organics increases with decreasing pressure, particularly in the very low pressure range common to MD. Therefore, low operating pressure generally yields higher efficiency.

8.5.5 Typical Applications of MD

1. Concretes obtained by solid-liquid extraction are conventionally converted to the absolutes by dissolving in aqueous alcohol solvents and then precipitating the waxes by chilling to sub-zero temperatures. This process is highly energy intensive due to the electrical energy required for refrigeration.
2. Red palm oil (high vitamin E content).
3. Separation of tocopherols from vegetable oil deodorization residues.
4. Natural vitamins A, E, K-1 and K-2 (replacing synthetics in the pharmaceutical industry).
5. Purification and separation of natural extracts into crude fractions.
6. Recovery of lanolin from wool grease, the soft wax from hair of sheep (cosmetic industry).
7. Fragrances derived from fatty acids.

8.6 Recovery of Dissolved Essential Oils from Steam Distillation Condensates

The major prerequisite of the process used for production of essential oils is that the product obtained must resemble the natural aroma and flavor of the original source, which is a combination of different compounds of varying organoleptic characteristics. Oxygenated organic compounds like aldehydes, ketones, alcohols and esters are the dominant contributors to the overall aroma and flavor. The essential oil produced should ideally have all these components in the same proportions as in the original natural product in order to match the natural aroma and flavor. For example, steam-distilled rose oil contains less than 1 wt% phenyl ethyl alcohol (PEA) whereas the solvent-extracted rose oil contains greater than 60 wt% PEA. It is a common experience that the steam distillation condensate has an

odor similar to that of the oil. Thus, this condensate has some value. The sale of rose water (otto of rose) for use in weddings in the sub-continent is probably the only way by which the distiller realizes the value of the condensate. In practically all other cases, the condensate is wasted. Table 2 gives estimates of the values of wasted oil in the condensate in India for some essential oils. The estimate is conservative because it does not include oil physically carried with the condensate. Even this conservative estimate is a mind-boggling number and is particularly important in the social context of developing countries like India where marginal farmers are main contributors to the overall produce. The value of the recovered oil from central distillation facilities and pro rata distribution of the value will be a big bonus to the small farmer and can certainly stop the downslide. Table 2 shows a major contribution from *Mentha arvensis*. If the relatively high value flavor sector is included, for India alone the value of wasted oil can easily reach US$ 100 million. On a rough estimate, the combined number for the South East Asian countries can be upwards of US$ 160 million. It must be noted that these numbers are simple statistics. They do not reflect in any way the high value that can be gained when the recovered oil is blended with the main distilled oil fraction to obtain a premium grade of the respective essential oil.

Table 2: Loss of essential oils in distillation condensate water. Production figures are for India only

Essential oil	Production, 2006, million tonnes	Unit price, 2006	Volume, 2007	Oil lost in water, kg*	Value of oil lost in water, $/yr
Arvensis	28,000	$ 14/kg	35,000 MT	$5.6\text{-}7\times10^{6}$	$46\text{-}58\times10^{6}$
Basil	100	$ 8/kg	100 MT	1×10^{4}	8.2×10^{4}
Citrodora	100	$ 8/kg	100 MT	1×10^{4}	7.4×10^{4}
Citronella	300	$ 8/kg	300 MT	3×10^{4}	2.52×10^{5}
Peppermint	450	$ 23/kg	450 MT	4.5×10^{4}	1.3×10^{5}
Spearmint	250	$ 23/kg	300 MT	2.5×10^{4}	7.2×10^{4}
Total	29,200		36,200 MT	$5.72\text{-}7.72\times10^{6}$	$47\text{-}59\times10^{6}$

** Data refer to 100 kg water per kilogram oil. Solubility of oil in water is 1000 ppm.*

8.6.1 Polymeric Adsorption Process

Various techniques, such as cohobation, poroplast extraction and adsorption, which can be used to recover the dissolved substances, have been discussed in the literature. Polymeric adsorbents can be advantageously used to recover dissolved essential oil components. Several investigators have established the utility of adsorption in this context beyond doubt. One study showed that although cis-rose oxide could not be detected in the condensate, this valuable component was found in the recovered oil

in significant proportions. These investigations show that more than 95% of the oil in the condensate can be recovered. The polymeric adsorbents used are hard cross-linked macroreticular beads which can be used in adsorption-regeneration cycles practically indefinitely. The technique is simple to use and does not require sophisticated instrumentation as the breakthrough can be judged from the smell of the water coming out of the adsorbent bed. The regeneration of the spent bed can be done using low-boiling alcohols or ketones, and the eluate can be distilled in a relatively short distillation column to obtain a relatively high boiling oil fraction.

8.6.2 Pervaporation Process

Membrane separation processes have been receiving increasing attention particularly for situations involving recovery from relatively dilute (~1000 ppm) aqueous solutions. Pervaporation is one such process which yields very high (~1000 ppm or more) selectivity in the very dilute solution range. Essential oil components which have high affinity for organophilic polymers can be recovered at very high selectivities. One study showed that silicone rubber membranes yielded bold menthol crystals when the *Mentha* condensate water was studied under the pervaporation mode. Similar results were also obtained for basil water. Subsequent studies showed that the high selectivity of properly selected membranes results in a permeate concentration far exceeding the solubility limit of the organics, resulting in phase separation.

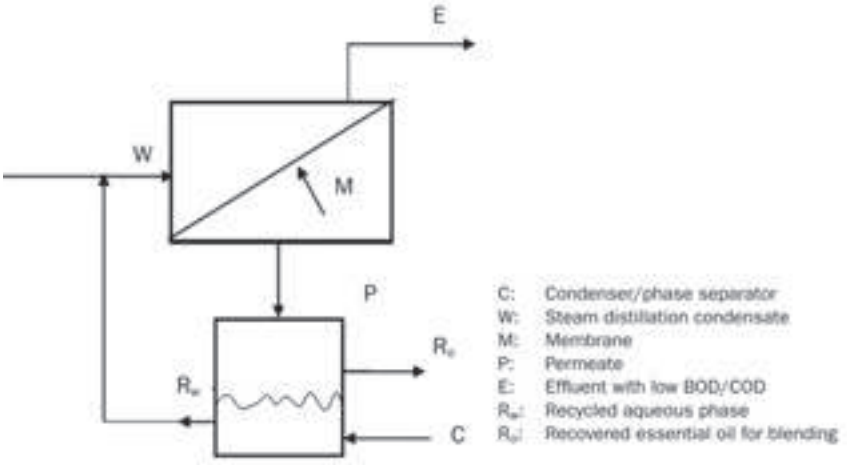

Figure 3: Recovery of dissolved organics using pervaporation

The separate oil layer can be directly recovered to blend with the main oil fraction to obtain premium grade oil. Figure 3 shows a schematic of pervaporation-based recovery of dissolved essential oils in the condensate. It is evident that this technique consists of a closed-loop operation

with only treated water going out of the battery limits. This treated water has very low biochemical oxygen demand (BOD) and chemical oxygen demand (COD), which is another bonus for the processor.

8.7 Conclusions

Various new technologies for efficient and cost-effective extraction of medicinal and aromatic plants have been discussed. Microwave-assisted extraction (MAE) is highly efficient for obtaining extracts under mild conditions. MAE is particularly important since the active components which are thermally labile can be recovered without any damage. The loss of valuable aroma components in steam distillation condensates is estimated to be of the order of US$ 50 million per year from aroma oils for India alone. Two types of separation processes – adsorptive and membrane-based pervaporation – are useful in recovering practically all the oil that is lost with the condensate water. The recovered oil can be sold as such or blended with the main oil fraction to yield a much more natural aroma and hence a high value. This recovered oil will be a big bonus even for the marginal farmer and hence this approach needs to be seriously considered.

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9 Solid Phase Micro-extraction and Headspace Trapping Extraction

R. Harlalka

Abstract

Solid phase micro-extraction (SPME) is a technique used in the quantitative analysis of analytes in aqueous and gaseous phases. This novel technology captures aroma molecules surrounding flower petals without touching the flower or other part of the plant. SPME has gained widespread acceptance as the technique of choice in many fields of application, including forensics, toxicology, and the analysis of flavors, fragrances, and environmental and biological matrices. SPME is ideal for field monitoring. SPME sampling can be performed in three basic modes: direct extraction, headspace trapping and extraction with membrane protection. Headspace trapping is essentially a gas extraction technique permitting the direct analysis of volatile compounds present in a non-volatile matrix. This technique is needed because the aromas of living plant materials are different from those of the extracted oil. Headspace trapping permits getting closer to the natural aroma of the living plant, and gives a clearer view of the differences in volatile constituents between the living plant and the extracted phase. There are two types of headspace trapping: static and dynamic, which is also called the purge-and-trap method. A few examples of headspace trapping of well known aromatic flowers, fruits and leaves, in comparison to the analyses of the extracted oil, are presented in this paper. Some classical perfumes are also discussed.

9.1 Introduction

Solid phase micro-extraction (SPME) was developed in the 1990s by Professor J. Pawliszyn to provide a quick and solventless technique for the isolation of analytes from a sample matrix. The traditional methods by which the analytes of interest were isolated are typically time- and labor-intensive and involve multistep procedures, which could reduce sensitivity. Also, the use of solvents can be hazardous to the operators' health and can damage the environment.

SPME was developed from the technique of solid phase extraction, but the sorbing material is permanently attached to the fiber, allowing reuse of the extracting phase. SPME uses a small volume of sorbent, typically dispersed on the surface of small fibers, to isolate and concentrate analytes from the sample matrix. After contact with the sample, analytes are absorbed or adsorbed by the fiber phase (depending on the nature of the coating). After the extraction step, the fibers are transferred, with a syringe-like handling device, to the analytical instrument, for separation and quantification of the analytes. This technique integrates sampling, extraction and sample introduction, and is a simple way of performing on-site monitoring. Applications of this technique include environmental monitoring, fragrance drug analysis, and in-laboratory and on-site analyses.

SPME was introduced in 1990 as a solvent-free sample preparation technique. The basic principal of this approach is to use a small amount of the extracting phase, usually less than 1 microliter. Sample volume can be large when the investigated material is sampled directly, e.g. the air in a room. The extracting phase can be either a high molecular weight polymeric liquid, similar in nature to stationary phases in chromatography, or a solid sorbent, typically of a high porosity, to increase the surface area available for adsorption.

The configuration of SPME is a small, fused silica fiber, usually coated with a polymeric phase. The fiber is mounted for protection in syringe-like device. The analytes are absorbed or adsorbed by the fiber phase until equilibrium is reached in the system. The amount of an analyte extracted by the coating at equilibrium is determined by the magnitude of the partition coefficient of the analyte between the sample matrix and the coating material.

In SPME, analytes typically are not extracted quantitatively from the matrix. Equilibrium methods are more selective because they take full advantage of the difference between extracting phase and matrix distribution constants to separate target analytes from interferences. Exhaustive extraction can be achieved in SPME, and this can be accomplished for most compounds by the application of an internally cooled fiber. In exhaustive extraction, selectivity is sacrificed to obtain quantitative transfer of target analytes to the extracting phase.

SPME is ideal for field monitoring. It is unnecessary to measure the volume of the extracted sample, and therefore the SPME device can be exposed directly to the investigated material for quantification of analytes of interest. In addition, extracted analytes are introduced into the instrument by simply placing the fiber in the desorbtion unit. This convenient, solvent-free process results in sharp injection bands and rapid separations.

9.2 The SPME Device

The commercial SPME device manufactured by Supelco (Bellefonte, USA) is presented in Figure 1. The fiber glued into a piece of stainless steel tubing is mounted on a special holder. The holder is equipped with an adjustable depth gauge, which makes it possible to control repeatedly, how far the needle of the device penetrates the sample container or the injector. This is important, as the fiber can break if it hits an obstacle. The movement of the plunger is limited by a small screw that moves in the z-shaped slot of the device. For protection during storage or septum piercing, the fiber is withdrawn into the needle of the device, with the screw in the uppermost position. During extraction or desorption, the fiber is exposed by depressing the plunger. The plunger is moved to its lowermost position only for replacement of the fiber assembly. Each type of fiber has a hub of a different color.

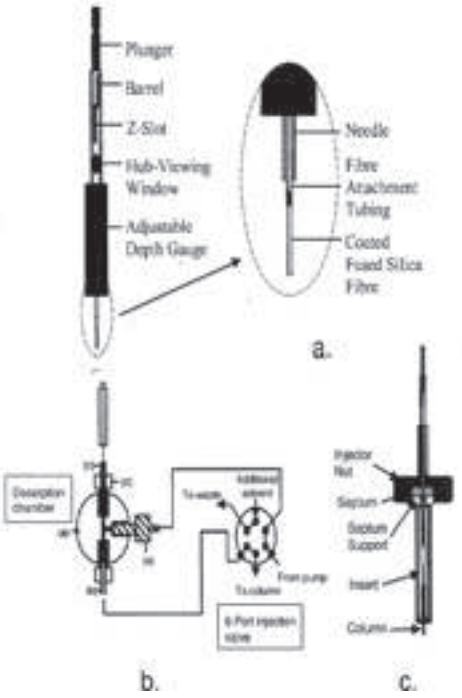

Figure 1: The SPME device

If the sample is in a vial, the septum of the vial is first pierced with the needle (with the fiber in the retracted position), and the plunger is lowered, which exposes the fiber to sample. The analytes are allowed to partition into the coating for a pre-determined time, and the fiber is then retracted back to the needle. The device is then transferred to the SPME instrument. When gas chromatography is used for analyte separation and quantification, the fiber is inserted into a hot injector, where thermal desorption of the trapped analyte takes place.

For spot sampling, the fiber is exposed to a sample matrix until partitioning equilibrium is reached between sample matrix and the coating material. In the time average approach, on the other hand, the fiber remains in the needle during exposure of the SPME device to the sample. The coating works as a trap for the analytes that diffuse into the needle, resulting in integral concentration over time measurements.

SPME sampling can be performed in three basic modes: direct extraction, headspace trapping, and extraction with membrane protection.

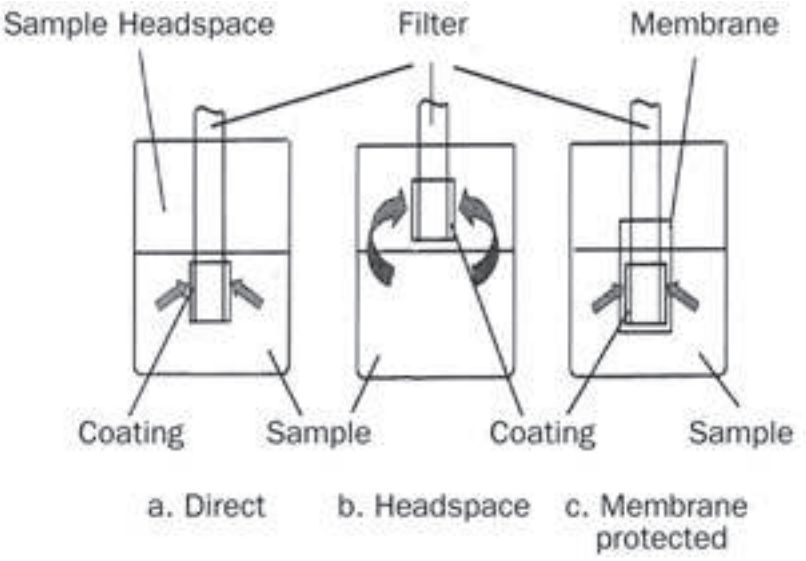

Figure 2: Modes of SPME operation: direct extraction (a), headspace trapping (b) and membrane-protected SPME (c)

In direct extraction, the coated fiber is inserted into the sample and the analytes are transported directly from the sample matrix to the extracting phase. To facilitate rapid extraction, some agitation is required to transport the analytes from the bulk of the sample to the vicinity of the fiber. For gaseous samples, natural flow of air (e.g. convection) is usually sufficient to facilitate rapid equilibrium for volatile analytes.

In headspace mode, the analytes are extracted from the gas phase equilibrated with the sample. The primary reason for this modification is to protect the fiber from the adverse effects caused by non-volatile, high molecular weight substances present in the sample matrix (e.g. human acids or proteins). Here, the amount of an analyte extracted by the fiber coating does not depend on the location of the fiber, in the liquid or gas phase; therefore, the sensitivity of headspace trapping is the same as that of direct sampling as long as the volumes of the two phases are the same in both sampling modes. When no headspace is used in direct extraction, a significant sensitivity difference between direct and headspace trapping can occur only for very volatile analytes. However, the choice of sampling mode has a significant impact on the extraction kinetics. When the fiber is in the headspace, the analytes are removed from the headspace first, followed by indirect extraction from the matrix.

In general, the equilibration times for volatile compounds are shorter for headspace SPME than for direct extraction under similar agitation conditions, because of the following reasons: a substantial portion of the analytes is present in the headspace prior to the beginning of the ex-

traction process; there is typically a large interface between sample matrix and headspace; and the diffusion coefficients in the gas phase are typically higher by four orders of magnitude than in liquids. The concentration of semivolatile compounds in the gaseous phase at room temperature is small, and headspace extraction rates for these compounds are substantially lower. They can be improved by using efficient agitation or by increasing the extraction temperature.

In the third mode (SPME extraction with membrane protection), the fiber is separated from the sample with a selective membrane, which lets the analytes through while blocking the interferences. The main purpose for the use of the membrane barrier is to protect the fiber against adverse effects caused by high molecular weight compounds when dirty samples are analyzed. While headspace trapping serves the same purpose, membrane protection enables the analysis of less volatile compounds. Use of thin membranes and an increase in extraction temperature result in shorter extraction times.

9.3 Calibration, Optimization, Precision and Suitability of SPME

9.3.1 Selection of Fiber Coating

The chemical nature of the analyte of interest determines the type of coating used. A simple general rule, “like dissolves like”, applies very well for liquid coatings. Selection of the coating is based primarily on the polarity and volatility of the analyte. Poly(dimethylsiloxane) (PDMS) is the most useful coating and should be considered first. It is rugged and able to withstand high injector temperatures, up to about 300° C. PDMS is a non-polar liquid, thus it extracts non-polar analytes very well with a wide linear dynamic range. However, it can also be applied successfully to more polar compounds, particularly after optimizing extraction conditions.

Both the coating thickness and the distribution constant determine the sensitivity of the method and the extraction time. Thick coatings offer increased sensitivity, but require much longer equilibration times. As a general rule, to speed up the sampling process, the thinnest coating offering the sensitivity required should be used.

9.3.2 Selection of the Extraction Mode

Extraction mode selection is based on the sample matrix composition, analyte volatility, and its affinity to the matrix. For dirty samples, the headspace or fiber-protection mode should be selected. For clean matrices, both direct and headspace trapping can be used. The latter is applicable for analytes of medium to high volatility. Headspace trapping is always preferen-

tial for volatile analytes because the equilibration times are shorter in this mode than in direct extraction. Fiber protection should be used only for dirty samples in cases where neither of the first two modes can be applied.

9.3.3 Selection of the Agitation Technique

Equilibration times in the gaseous samples are short and frequently limited only by the rate of diffusion of the analytes in the coating. When the aqueous and gaseous phases are at equilibrium prior to the beginning of the sampling process, most of the analytes are in the headspace. As a result, the extraction times are short even when no agitation is used. However, for aqueous samples, agitation is required in most cases to facilitate mass transport between the bulk of the aqueous sample and the fiber.

Magnetic stirring is most commonly used in manual SPME experiments. Care must be taken when using this technique to ensure that the rotational speed of the stirring bar is constant and that the base plate does not change temperature during stirring. This usually implies the use of high quality digital stirrers. Alternatively, with cheaper stirrers, the base plate should be thermally insulated from the vial containing the sample to eliminate variations in sample temperature during extraction. Magnetic stirring is efficient when fast rotational speeds are applied.

9.3.4 Selection of Separation or Detection Technique

Most SPME applications have been developed for gas chromatography (GC), but other separation techniques, including high performance liquid chromatography, capillary electrophoresis (CE) and supercritical fluid chromatography, can be used in conjunction with this technique. The complexity of the extraction mixture determines the proper quantitative device. Regular chromatographic and CE detectors can normally be used for all but the most complex samples, for which mass spectrometry (MS) should be applied.

9.3.5 Optimization of Desorption Conditions

Standard gas chromatographic injectors, such as the popular split-splitless types, are equipped with large volume inserts to accommodate the vapors of the solvent introduced during liquid injections. As a result, the linear flow rates of the carrier gas in those injectors are very low in splitless mode, and the transfer of the volatilized analytes onto the front of the GC column is also slow. No solvent is introduced during SPME injection; therefore, the large insert volume is unnecessary. Opening the split line during SPME injection is not practical, since it results in reduced sensitivity. Efficient desorption and rapid transfer of the analytes from the injector to the column require high linear flow rates of the carrier gas around the coating. This can be accomplished by reducing the internal diameter of the injector insert, matching it as closely as possible to the outside diameter of the coated fiber.

9.3.6 Optimization of Sample Volume

The volume of the sample should be selected based on the estimated distribution constant. The distribution constant can be estimated by using published values for the analyte or a related compound, with the coating selected. The distribution constant can also be calculated or determined experimentally by equilibrating the sample with the fiber and measuring the amount of analyte extracted by the coating.

9.3.7 Determination of the Extraction Time

The equilibration time is defined as the time after which the amount of analyte extracted remains constant and corresponds within the limits of experimental error to the amount extracted after infinite time. Care should be taken when determining the equilibration time, since in some cases a substantial reduction of the slope of the curve might be wrongly taken as the point at which equilibrium is reached. Determination of the amount extracted at equilibrium allows calculation of the distribution constants.

When equilibrium times are excessively long, shorter extraction times can be used. However, in such cases the extraction time and mass transfer conditions have to be strictly controlled to assure good precision. At equilibrium, small variations in the extraction time do not affect the amount of the analyte extracted by the fiber.

On the other hand, at the steep part of the curve, even small variations in extraction time may result in significant variations of the amount extracted. Shorter is the extraction time, larger is the relative error. Autosamplers can measure the time precisely, and the precision of analyte determination can be good, even when equilibrium is not reached in the system. However, this requires that the mass transfer conditions and the temperature remain constant during all experiments.

9.3.8 Optimization of Extraction Conditions

An increase in extraction temperature increases the extraction rate but simultaneously decreases the distribution constants. In general, if the extraction rate is of major concern, the highest temperature that still provides satisfactory sensitivity should be used.

Adjustment of the pH of the sample can improve the sensitivity of the method for basic and acidic analytes. This is related to the fact that unless ion exchange coatings are used, SPME can extract only neutral (non-ionic) species from water. By properly adjusting the pH, weak acids and bases can be converted to their neutral forms, so that they can be extracted by the SPME fiber.

9.3.9 Determination of the Linear Dynamic Range of the Method

Modification of the extraction conditions affects both the sensitivity and the equilibration time. It is advisable, therefore, to check the previously determined extraction time before proceeding to the determination of the linear dynamic range. This step is required if substantial changes in sensitivity occur during the optimization process.

SPME coating includes polymeric liquids, such as PDMS, which by definition have a broad linear range. For solid sorbents, such as Carbowax/DVB or PDMS/DVB, the linear range is narrower because of the limited number of sorption sites on the surface, but it still can span over several orders of magnitude for typical analytes in pure matrices. In some rare cases when the analyte has extremely high affinity to the surface, saturation can occur at low analyte concentrations. In such cases, the linear range can be expanded by shortening the extraction time.

9.3.10 Selection of the Calibration Method

Standard calibration procedures such as external calibration can be used with SPME. The fiber blank should first be checked to ensure that neither the fiber nor the instrument causes interference with the determination. The fiber should be conditioned prior to the first use by desorption in a GC injector or in a specially designed conditioning device. This process ensures that the fiber coating itself does not introduce interference. Fiber conditioning may have to be repeated after analysis of samples containing large amounts of high molecular weight compounds, since such compounds may require longer desorption times than the analytes of interest.

A special calibration procedure, such as isotopic dilution or standard addition, should be used for more complex samples. In these methods, it is assumed that the target analytes behave similarly to spikes during the extraction. This is usually a valid assumption when analyzing homogeneous samples.

9.3.11 Precision of the Method

The most important factors affecting precision in SPME are:

- Agitation conditions
- Sampling time (if non-equilibrium conditions are used)
- Temperature
- Condition of the fiber coating (cracks, adsorption of high molecular weight species)
- Geometry of the fiber (thickness and length of the coating)
- Sample matrix components (salt, organic material, humidity, etc.)

- Time between extraction and analysis
- Analyte loss (adsorption on the walls, permeation of Teflon, absorption by septa)

9.3.12 Suitability

SPME is well suited to the analysis of flavor and fragrance compounds. The typically small, volatile compounds are easily extracted by the fibers, and the simplicity of the method allows easy coupling to analytical instruments. Headspace trapping can reduce the potential for interference peaks and prevent contamination of both the needle and the instrument. Loss of these volatile compounds during sample preparation steps is minimized or eliminated compared to conventional methods, and the method is amenable to field sampling and analysis.

SPME has been shown to be useful for semivolatile compounds, even though these appeared more challenging in the early years. With appropriate matrix modification, one can take advantage of headspace trapping for these as well. SPME provides significant convenience for field and air analysis. Quantification is relatively straightforward, even in the presence of varying air temperature. Finally, the use of SPME for time-weighted average sampling provides simplicity in monitoring flavor and fragrance concentrations over time.

9.4 Headspace Trapping Extraction and GC-FID/MS Analysis

Orange juice volatiles were extracted from the juice headspace using a syringe-like SPME device equipped with a 75 μm Carboxen-PDMS fiber (Supelco). Aliquots (25 ml) of juice were placed in 40-ml glass vials with plastic screw caps and Teflon-coated septa, warmed to 40° C, and gently swirled to coat the walls of the vial. Juices were allowed to equilibrate for at least 15 min prior to fiber insertion and were maintained at 40° C throughout the 35-min extraction period. The fiber was then removed from the headspace and inserted into the heated GC injector, where the volatile compounds were thermally desorbed. Flavor extract was separated using an HP 5890 GC instrument equipped with a 30 m x 0.32 mm i.d. DB5 capillary column. Column temperature was initially 32° C, with a 3-min hold, and was then increased at 6° C/min to 200° C. Helium carrier gas linear velocity was 29 cm/s. A special narrow boar (0.75 mm) injector liner was used to improve peak shape and chromatographic efficiency; the entire separation was conducted in the splitless mode.

9.4.1 History of Headspace

In November 1986, at the 10th International Congress on Essential Oils, in Washington DC, USA, Dr. B. D. Mookherjee presented a paper on the impact of "live vs. dead" on headspace trapping extraction, using as example jasmine flowers.

The SPME needle which is 2- to 3-mm solid glass fiber coated with a high-boiling liquid adsorbent, is placed in close proximity to a flower without touching it and is kept there for a period of 30-60 min depending on the odor strength of the blossom. The aroma molecules around the petals are absorbed onto the fiber. Then with GC/MS, the fiber is analyzed to determine the aroma profile of that particular flower. The aroma of the living flower was brought into space by NASA in 1998.

9.4.2 The Aura

When the Sun is totally eclipsed by the moon, the surrounding glow is called an aura. Similarly, if we consider a drop of fragrance, the molecules surrounding the drop form an aura of that particular fragrance.

It is a common belief that one smells a fragrance, layer by layer, from the top note of the volatile components, to the middle note of components with boiling points in the middle range, and finally to the bottom note of components with the highest boiling point.

In reality, when a drop of fragrance is placed on the skin, several different molecules, from the lowest to the highest boiling types, irrespective of their molecular weights, boiling points and vapor pressures, form an aura, which eventually reaches our nose and gives us our first impression of the particular fragrance. The composition of this aura depends on a characteristic property of each fragrance molecule, knows as its diffusivity.

9.4.3 What is Diffusivity?

Diffusivity is the inherent property of a compound to emit its molecules into the air. One compound is said to be more diffusive than another if its molecules tend to pass into the air to a greater extent than those of other compounds. Diffusivity is independent of boiling point, molecular weight, odor threshold or odor value.

9.4.4 Application of Headspace Trapping

Some examples of headspace trapping are discussed here.

9.4.4.1 Jasmine

The headspace constituents of living and picked *Jasminum grandiflorum* flowers are:

Compound	Living flowers, %	Picked flowers, %
Benzyl acetate	60.0	40.0
Linalool	3.0	30.0
Indole	11.0	2.0
Cis-jasmone	3.0	–
3,5-Dimethyl-2-ethyl pyrazine	–	0.5
Epi-methyl jasmonate	0.5	–
Methyl jasmonate	0.3	–

Differences in the volatile compounds of living flowers from *Jasminum grandiflorum* and *Jasminum sambac* are:

Compound	*J. grandiflorum*, %	*J. sambac*, %
Methyl benzoate	–	5.0
Benzyl acetate	60.0	37.0
Indole	11.0	5.0
Linalool	3.0	9.0
Epi-methyl jasmonate	0.5	–
Methyl jasmonate	0.3	–

9.4.4.2 Yellow Tea Rose

The differences in headspace constituents between living and picked yellow tea rose flowers are:

Compound	Living flowers, %	Picked flowers, %
Cis-3-hexenyl acetate	20.67	5.39
Hexyl acetate	8.40	4.26
Phenylethyl alcohol	5.73	3.30
3,5-Dimethoxy toluene	9.96	18.58
Alpha-elemene	–	4.07
Geranyl acetone	2.17	–
Dihydro-beta-ionol	–	2.62
Isocaryophyllene	0.30	2.12
Alpha-farnesene	5.83	2.96

9.4.4.3 Passion Flower

Volatile constituents of living passion flower (*Passiflora* spp.) are:

Compound	Living flowers, %
Methyl benzoate	90.3
Methyl salicylate	1.1
Methyl cinnamate	1.6

9.4.4.4 Lotus

The major differences in headspace constituents of living and picked lotus (*Nelumbo nucifera*) are:

Compound	Living flowers, %	Picked flowers, %
Sabinene	6.0	12.0
p-Dimethoxy benzene	18.0	8.0
4-Terpineol	3.0	1.5
Alpha terpineol	9.0	1.0
Cis-jasmone	0.1	–
C15 hydrocarbons	20.0	30.0

9.4.4.5 Lavender

The volatile constituents of living French lavender (*Lavandula dentata)* and English lavender (*Lavandula angustifolia*) are:

Compound	French lavender, %	English lavender, %
Limonene	18	6
1-Octen-3-ol	–	7
Hexyl acetate	11	2
Eucalyptol	9	3
Linalool	7	–
Cis-3-hexenyl acetate	17	13
Borneol	–	2
Cryptone	–	6

9.4.4.6 Chamomile

The volatile constituents of living Roman and German chamomile are:

Compound	Roman chamomile, %	German chamomile, %
Ethyl 2-methyl butyrate	–	12
Cis-3-hexenyl acetate	3	22
Isobutyl methacrylate	7	–
Isobutyl angelate	18	–
Ocimene	–	1
Iso-amyl angelate	10	–
Isohexyl angelate	10	–

9.4.4.7 Shefali

The volatile constituents of living shefali (*Nycanthus arbortristis*) are:

Compound	Living flower, %
Benzyl alcohol	11.2
Phenyl acetaldehyde	9.4
Phenyl ethyl alcohol	6.3
Methyl anthranilate	10.7

9.4.4.8 Spearmint

The major differences between living and picked spearmint are:

Compound	Living plant, %	Picked plant, %
Hexanal	0.5	–
Hexanol	–	–
Beta-pinene	0.8	2.0
Sabinene	0.5	–
Myrcene	8.8	4.0
Alpha-phellandrene	0.7	–
Limonene	18.0	2.0
Cis- and trans-ocimene	1.0	–
Dihydrocarvone	0.6	2.6
Carvone	24.0	70.0
Alpha- and beta-elemene	5.0	0.1
Beta-caryophyllene	4.0	0.1

9.4.4.9 Cinnamon Bark

Comparative analysis of fresh cinnamon bark headspace and commercial oil has revealed:

Compound	Fresh cinnamon bark, %	Commercial oil, %
Cis- and trans-cinnamic aldehyde	80.3	71.7
Eugenol	–	12.7
Ortho-methoxy cinnamaldehyde	0.3	–
Eugenyl acetate	–	0.5

9.4.4.10 Ginger

Comparative analysis of the headspace of fresh ginger root and commercial oil has revealed:

Compound	Fresh ginger root, %	Commercial oil, %
Citral	15.3	1.2
Beta-bisabolene	3.3	6.2
Alpha zingiberene	15.2	34.4
Cis- and trans-alpha-farnesene	13.7	6.0
ar-Curcumene	11.3	4.8
Beta-sesquiphellandrene	8.0	11.8

9.4.4.11 Peach

Volatile constituents of living and picked peach (*Prunus persica*) are:

Compound	Living peach, %	Picked peach, %
Ethyl acetate	6.2	–
Dimethyl disulfide	0.6	–
Cis-3-hexenyl acetate	9.7	–
Methyl octanoate	34.2	7.1
Ethyl octanoate	7.4	11.0
6-Pentyl alpha pyrone	Trace	10.6
Gamma decalactone	2.5	39.2

9.4.4.12 Pineapple

Volatile constituents of the interior and exterior of living pineapple are:

Compound	Exterior, %	Interior, %
Methyl hexanoate	13.3	24.6
Ethyl hexanoate	25.6	4.7
Methyl 3-methylthiopropionate	0.9	0.5
Ethyl 3-methylthiopropionate	1.1	–

9.4.5 Classical Perfumes

Almost all successful classical perfumes are based on floral aromas. Perfumers created them using natural flower oil such as rose and jasmine. Few persons are aware of the fact that fruit and flower oils that are made by extraction of picked material exhibit different aromas from those of the living entities. Examples of classical perfumes based on floral aromas are Amarige (Givenchy), Joy (Jean Patou), White Linen (Estée Lauder), Aura (Hugo Boss), Anais Anais (Cacharel) and Beautiful (Estee Lauder). The difference in composition between the oil and the aura of Amarige is as follows:

Compound	Oil, %	Aura on skin after 60 min, %
Linalool	1.7	17.9
Benzyl acetate	4.9	22.7
Styrallyl acetate	1.2	9.7
Cashmeran	–	0.5
Bacdanol	0.2	0.5
Hedione	29.9	4.9
Cedramber	1.5	4.9
Iso E super	7.1	12.1
Ambrox	0.2	0.1
Benzyl salicylate	32.5	1.1
Muskalactone	0.9	0.4

The examples include Joy by Jean Patou; White Linen by Estée Lauder; Aura of Hugo BOSS; Anais Anais by Cacharel; and Beautiful by Estee Lauder.

9.4.6 Need for Headspace

When we go to a rose-field full of bloomed roses, we detect a pleasant smell in the atmosphere and expect the same fragrance when we use the bottled perfume or 100% genuine essential oil extracted from the same roses. However, this is not true. The fragrance we detect in the field is completely different from the bottled perfume or essential oil, for the following reasons:

a) When a flower or herb is processed to obtain the essential oils, the low volatile compounds cannot always be recovered and often evaporate. These low volatiles are important for aroma.
b) During the processing of an herb, many chemical reactions take place, such as saponification, trans-esterification, polymerization and condensation. These reactions actually change the character of the oil, so that its aroma no longer resembles that of the actual plant and the product is different in composition. Many stereoterpenes, which are highly volatile in nature, cannot be extracted and remain in the herbs. These stereoterpenes do not contribute directly to the odor but, in combination with other ingredients, impart a synergic effect to the overall odor quality.

9.5 Types of Headspace Trapping

Headspace trapping can be static or dynamic, which is generally called the purge-and-trap method. In static headspace trapping, gas extraction is carried out in a single step or in a limited number of steps. On the other hand, the purge-and-trap technique consists of two or three separate steps, the first of which is continuous gas extraction.

9.5.1 Static Headspace Trapping

This is a single-step gas extraction procedure (Figure 3). By thermosetting the sample for a certain time at a preselected temperature, equilibrium is reached between the sample phase and the gas phase of the sample vial. Subsequently, a single aliquot of the headspace is introduced into the carrier gas flow, which then carries it to the column where the volatile compounds are separated in the usual way.

The equilibrium of the two phases in the sample vial is characterized by a partition coefficient (Ki) representing the ratio of the analyte's concentration in the sample phase and in the gas phase.

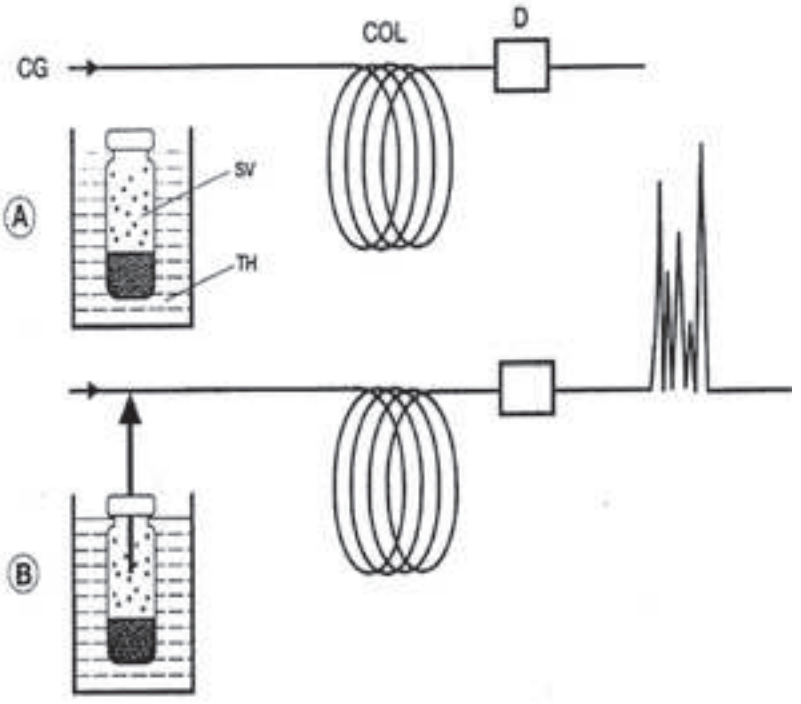

Figure 3: Static headspace trapping technique

9.5.2 Dynamic Headspace Trapping

In this technique (Figure 4), the sample is continuously purged with an inert gas (the purge gas), until all volatile compounds are removed. During this step, the gas effluent leaving the sample vessel is conducted through a trap, either cooled to low temperature or containing an adsorbent. This trap retards the volatile analytes purged from the sample. When gas extraction is complete, the condensed or adsorbed analytes by rapid heating of the trap now get purged with the carrier gas.

In Figure 4, the desorbed analytes are conducted directly into the gas chromatograph. Thermal desorption from an adsorbent is not instantaneous: thus, the sample "slug" might be too long, creating broad peaks, with tailing. This is particularly the case when a capillary column is used in the gas chromatograph. For this reason, usually a second, small trap, cooled to low temperature, is placed in the carrier gas line between the primary trap and the column. When desorption is finished, this small trap is then heated very rapidly: in this way, a sharp band of the analytes enters the column.

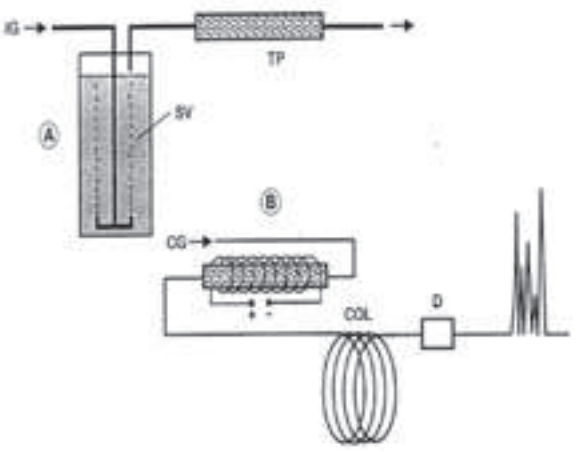

Figure 4: Dynamic headspace trapping technique

This technique is being used more generally after the introduction of Tenax (poly(2,6-diphenyl-*p*-phenylene oxide)) as a universal adsorbent for dynamic headspace GC by Zlatkis and his group, at the University of Houston, in 1973. They used the technique for the investigation of biological fluids and demonstrated the reproducibility of the purge-and-trap method.

9.6 Principles of Static Headspace-GC Systems

Gas from the headspace of a closed vessel can be sampled simply with a gas-tight syringe. However, with such a manual method, it is difficult to reproduce all the conditions necessary for reliable quantitative analysis. Therefore, today, headspace-gas chromatography (HS-GC) is carried out almost exclusively with automated instruments, in which thermosetting, aliquoting the headspace and introducing it into the gas chromatograph are fully automated. In this way and using the proper calibration methods, the required precision, accuracy and reliability are assured.

Present-day HS-GC instruments are of two types. In the first, the headspace aliquot is taken by an automated syringe which then is moved above the injection port of the gas chromatograph and the sample is injected. In essence, such systems are similar to the autosamplers used in GC. In the second case, the aliquot from the vial's headspace is not withdrawn by suction as in the case of a syringe: instead, after equilibrium is reached, the vial is pressurized by the carrier gas. After pressurization there are two possibilities. The carrier gas flow can be temporary interrupted while the pressurized gas in the vial is allowed to expand onto the column; the transferred volume of headspace can be accurately controlled by controlling the time of transfer and the pressure. The second possibility is to have a gas introduced between the sample vial and the column, and fill the sample

loop of the valve by the pressurized headspace gas. Today, automated instruments based on these principles are commercially available.

9.6.1 Trace Analysis by HS-GC

HS-GC in both its dynamic and static versions permits the determination of analytes at low concentrations. Usually the dynamic technique is considered to be more sensitive; however, this is not necessarily true. For example, trace impurities in a water sample, at the parts-per-billion level, can be determined relatively easily by static HS-GC.

9.7 Headspace Trapping Techniques

9.7.1 Static Headspace Trapping

Using the static method (Figure 5), a food sample is normally placed in a heated vessel, which is sealed gas-tight by a septum. The food sample stays inside the vessel for a certain period of time, so that the volatile compounds evaporate to a certain concentration in the air or to certain equilibrium. In order to determine the best conditions for the experiment, the odor of the headspace can be checked by sniffing the vessel. Subsequently, a distinct volume is taken out of the vessel by a gas-tight syringe and directly injected into a gas chromatographic column, with or sometimes without prior concentration (e.g. cryofocussing). The advantage of this method is that it accurately assesses the composition of the odorants. An application of this technique, called GC olfactometry of static headspace samples, has been widely used to identify the highly volatile compounds causing the first odor impression of foods.

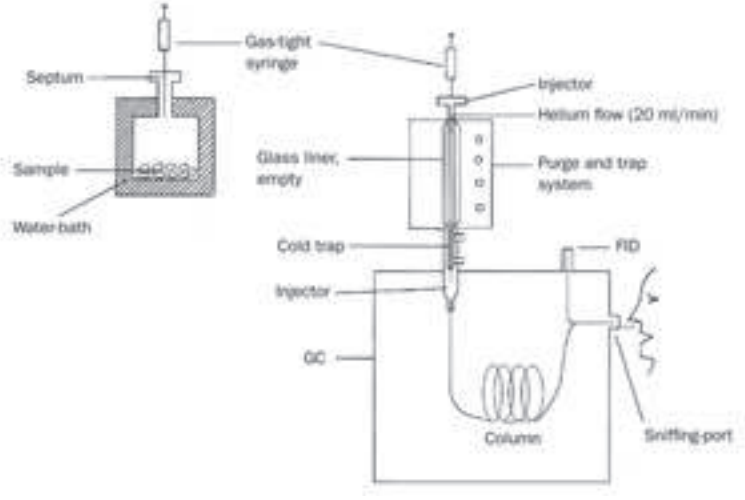

Figure 5: Static headspace trapping technique

However, static headspace samples are normally too small to quantify odorants that are present only at low concentrations in the vapor phase. In other words, one can smell them, but in many cases it is not possible to obtain a signal in a mass spectrometer.

9.7.2 Dynamic Headspace Trapping

To overcome the disadvantages of headspace trapping method, dynamic headspace trapping can be used (Figure 6). Again, the food sample is placed in a heated vessel but the evaporating compounds are continuously swept by a stream of inert gas into a trap containing a porous polymer, which adsorbs more or less the organic constituents. This method yields a much higher amount of trapped volatiles so that, after desorption, it is no longer problematic to obtain an MS signal.

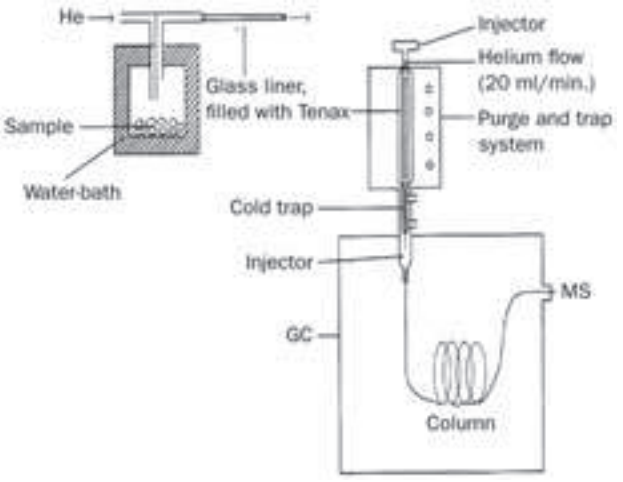

Figure 6: Dynamic headspace trapping technique

However, the disadvantage of this procedure is the strong dependence on the yield of the odorants, on the velocity of the carrier gas and on the selectivity of the adsorption and desorption process for different compounds. It is very difficult to control these parameters precisely and therefore, the results of such quantitative measurements might be inaccurate.

9.7.3 Recovering the Adsorbed Volatiles by Thermal or Liquid Solvent Desorption

Several studies have reported methods of desorption using organic solvents. Drawbacks of the use of solvent desorption include the loss of volatile compounds during removal of excess solvent before GC analysis, solvent selectivity and solvent impurities. We recently developed a sensitive and highly reproducible dynamic headspace (DHS) protocol with thermal

desorption (using injector glass liners packed with Tenax-TA as adsorbent traps for aroma collection at ambient room temperature) and desorption at the interior of a GC injector. This DHS-type protocol was used to characterize fresh tomato flavor compounds; the results were compared with published data from a static headspace method (Table 1).

Table 1: Concentration of selected tomato aromas from heat-processed tomato juice by static headspace trapping (SHT) and dynamic headspace trapping (DHT), expressed in parts per billion (ppb)

Compound	SHT, ppb	DHT, ppb
(E)-2-hexanal	5	340
1-Penten-3-one	61	100
2-Isobutylthiazole	2	450
2-Methylfuran	97	1,060
2-Pentylfuran	26	700
3-Methybutanal	17	750
3-Methylfuran	717	3,200
6-Methyl-5-hepten-2-one	21	1,330
Acetone	325	-
Benzaldehyde	3	30
Dimethyl disulfide	16	630
Dimethyl sulfide	5,205	2,974
Ethanol	311	-
Geranial	2	130
Hexanal	188	6,210
Pentanal	48	470

In the present study, this DHT-type protocol was used to characterize fresh tomato flavour compounds for comparison with related literature methods.

9.7.4 Some Practical Examples of Headspace Technique Use

9.7.4.1 Tomato Juice

Fresh tomato juice was made from vine-ripe fruit by Campbell Soup Company's R&D centre in Davis, USA. Chemicals were reagent grade, supplied from reliable sources.

9.7.4.1.1 Preparation of Traps

Traps were prepared using silane-treated glass tubing (79 mm x 6 mm) packed with 13 mg 60/80 mesh Tenax-TA (2,6-diphenyl-*p*-phenylene oxide) polymers held in place by silanized glass wool. The traps were initially conditioned at 330° C for 2 h under nitrogen gas at a 20 ml/min flow rate. The traps were regenerated at 250° C for 1 h immediately before each purge-and-trap experiment.

9.7.4.1.2 Thermal Desorption

Adsorbed volatile compounds were recovered from the trap directly inside the GC injector. The desorption time and temperature were previously determined. The injector temperature was 200° C and a loop of the analytical column at the injector end was immersed in a liquid nitrogen-filled Dewar flask to cryogenically trap the desorbed volatiles. Subsequently, the injector glass liner (insert) was replaced with the trap to desorb volatiles. Thermal desorption was carried out for 5 min with the split vent and septum purge closed.

9.7.4.2 Headspace of *Hedychium coronium*

Hedychium coronium flower has a delicate, pleasant fragrance, but the essential oil and concrete extracted by traditional methods usually lose this fragrance. Thus, the headspace of the *H. coronium* flower was analyzed. The essential oil of *H. coronium* flowers, which was absorbed by XAD-4 resin, eluted by organic solvent and concentrated, had a fragrance similar to the natural fragrance of *H. coronarium* flowers.

9.7.4.3 Volatiles of White Hyacinths Isolated by Dynamic Headspace Trapping

More than 70 constituents of white hyacinths can be identified by GC and GC-MS. The principal constituents are benzyl acetate and (E,E)-α-farnesene. Beside these, sensorily important substances like indole, oct-1-en-3-ol and phenylacetaldehyde were identified. Minor traces of three substituted pyrazines were detected by GC-sniffing. The advantages of the simultaneous closed-loop stripping technique using various adsorbing agents at the same time were demonstrated. By this method, artifact formation and discrimination of individual components can be determined

9.7.4.4 Medical Materials Testing by Headspace Trapping-GC-MS

The new technology provided by the HS-40 Trap coupled with a sensitive detection method such as GC-MS allows volatile organic compounds in medical sutures to be analyzed easily at trace levels. Individual compounds present in the sutures can be analyzed by GC-MS and identified

by a NIST library search of the acquired mass spectral data. The innovative, patent-pending, headspace trapping technology used in this application provides sensitivity beyond the capability of traditional static headspace. This presents a new level of detection capability for the evaluation of materials used in medical applications, as well as in other types of material testing, including pharmaceutical formulations and food-packaging film.

9.8 Conclusions

Advanced technologies such as SPME and headspace trapping extraction are well suited for the analysis of flavor and fragrance compounds. The typically small, volatile compounds are easily extracted. The simplicity of the method allows easy coupling to analytical instruments. Loss of volatile compounds during sample preparation steps is minimized or eliminated, compared to conventional methods.

These techniques are useful for semivolatile compounds, even though these were more challenging in the early years. With appropriate matrix modification, one can take advantage of this analytical method, which provides significant convenience for field and air analyses.

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10 Supercritical Fluid Extraction of Medicinal and Aromatic Plants: Fundamentals and Applications

A. Bertucco and G. Franceschin

Abstract

The main issues related to supercritical fluid extraction of medicinal and aromatic plants are discussed in view of the development of this separation technique at industrial scale. After an introduction to supercritical fluid extraction, the roles of thermodynamics and mass transfer properties are emphasized, and the effects of the main operating variables on product recovery are briefly examined. Fundamental concepts about the equipment needed and basic technology are presented, including economical evaluation. Finally, a short literature survey of successful supercritical extraction processes of medicinal and aromatic plants is reported and a future outlook is given.

10.1 Introduction

In the second half of last century, an increasing interest has been paid to supercritical fluids as alternate solvents for the extraction of natural bioactive molecules from plants. The main reason for the interest in supercritical fluid extraction (SFE) was the possibility of carrying out extractions at temperature near to ambient, thus preventing the substance of interest from incurring in thermal denaturation.

A thorough review of the results achieved up to the early 1980s is presented in a book by Stahl *et al.*, published in 1986. Clearly, by that time, the fundamentals of this new extraction process were already understood, even though the technical-economical assessment and the design criteria for large-scale application of SFE were still missing. After twenty years of research and development, it is now possible to say that such achievements are at hand, so SFE is currently a well-established unit operation for extraction and separation. Moreover, its design and operating criteria are fully understood, so that it can profitably be applied in the extraction of medicinal and aromatic plants (MAPs).

10.2 Supercritical Fluids

A fluid at supercritical condition, also referred to as a dense gas, is a fluid above its critical temperature (T_C) and critical pressure (P_C) to a certain extent: to be supercritical, the reduced temperature T_r (i.e. T/T_C) must not exceed 1.2 or 1.3, whereas the reduced pressure P_r (i.e. P/P_C) may be as high as allowed by technological limits.

At suitable conditions, any fluid can reach its supercritical state. However, only those having a critical temperature not far from ambient temperature can be used as alternative solvents for the extraction of MAPs. Carbon dioxide (CO_2), with T_C=31.06° C and P_C=73.81 bar, is the most attractive solvent, because of its proprieties regarding toxicity, flammability and cost.

The possibility of using supercritical fluids (SFs) as extraction solvents is directly linked to their density. In fact, according to an empirical correlation proposed by Chrastil in 1982,

$$s = \rho^a \exp\left(\frac{b}{T} + c\right) \quad (1)$$

where *s* is the solute solubility, ρ is the solvent density and *T* is the absolute temperature; *a*, *b* and *c* are correlation parameters to be adjusted to experimental solubility data in supercritical CO_2.

When a fluid approaches the critical conditions, its density gets closer and closer to that of the liquid state. This can be seen, for CO_2, in Figure 1, where density isotherms are plotted against the reduced pressure. For example, at T = 35° C and P = 200 bar, ρ = 866 kg/m$^{3.}$

It is also clear from Figure 1 that, close to the critical point, both the compressibility and expansion coefficient of the fluid are high, so slight changes in the operating conditions can significantly modify the density, i.e. the supercritical fluid solvent power. The importance of the Chrastil equation (Eq. 1) lies in the fact that solvent density is identified as the key factor in a successful SFE process.

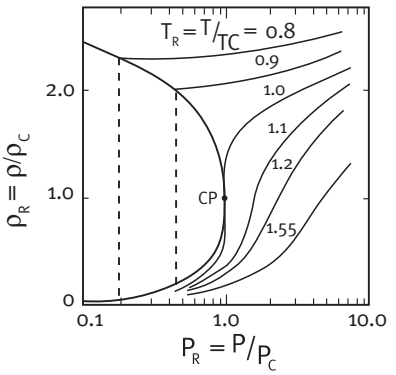

Figure 1: Density vs. pressure diagram for carbon dioxide

When plotted against solvent density, solubility data for supercritical CO_2 always display a regular trend such as that in Figure 2a, whereas a more complex behavior is seen when pressure is improperly used as the independent process variable (Figure 2b).

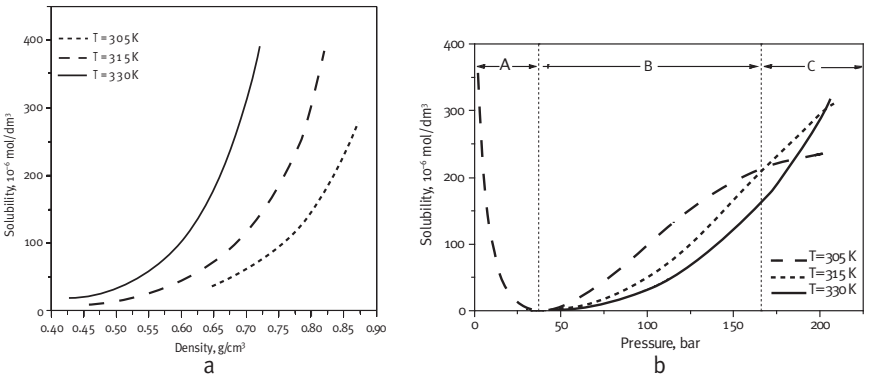

Figure 2: Solubility of 1,4-bis-(n-propylamino)-9,10-anthraquinone in supercritical CO_2: as a function of solvent density (2a) and of pressure (2b)

Coming back to Eq. 1, is important to point out that it is not theoretically correct and must be applied within restricted temperature ranges only.

More importantly, the exponential form of Eq. 1 does not guarantee that the solubility of a solute in SF is high. The solubility depends on parameters *a*, *b* and *c*; in fact, in the case of CO_2, the solubility of a solute of interest for MAP applications is at best in the range of 1 to 1000 by weight or often 1 to 10,000 (Figure 2a illustrates this). This is because CO_2 is a poor solvent, even at supercritical conditions. In addition, this holds for non-polar substances only, as supercritical CO_2 does not dissolve polar molecules at all. Actually, CO_2 is a good solvent only for low molecular weight solutes.

The limit on solubility is dictated by thermodynamics. According to the iso-fugacity criterion applied to the substance to be extracted, between the two phases at equilibrium (the condensed one – either solid or liquid – and the supercritical one), we have:

$$y_i = \frac{P^{sat}}{P} E_i \tag{2}$$

$$E_i = \frac{\varphi_i^{o,v}}{\varphi_i^{v}} \exp\left(v^{S/L} \frac{P - P^{sat}}{RT}\right) \tag{3}$$

where y_i is the mole fraction of *i* in the supercritical phase, $\varphi_i^{o,v}$ and φ_i^{v} are the fugacity coefficients of *i* in the standard state and in the mixture, respectively, at the process conditions, P^{sat} is the solute saturation (or sublimation) partial pressure (i.e. the component volatility), and $v^{S/L}$ is the molar volume of the condensed phase (either solid or liquid). *T* is the absolute temperature and *R* is the universal gas constant. E_i is the so-called enhancement factor, which accounts for the increasing solubility due to system nonidealities with respect of the ideal behavior (given by Eq. 2).

According to Eq. 2, the solubility of *i* in the SF can be calculated at the process condition, provided that the fugacity coefficients φ_i can be evaluated accurately by means of an equation of state. However, the substance vapor pressure directly influences the solubility when P^{sat} is as usual for MAPs, very low. Only an equally low value of the fugacity coefficient, i.e. a high system nonideality, can partially counteract the lack of volatility of the pure component.

Regardless of the way its value has been obtained, i.e. from Eq. 1 or Eqs. 2-3, the solubility is only one of two fundamental pieces of information that must be known in order to assess the feasibility of an SFE process for MAPs. The second one is selectivity, which is defined as the ratio of the solubility of the substance *i* of interest with respect to a reference substance *j*:

$$\alpha_{ij} = \frac{s_i}{s_j} \tag{4}$$

If on one hand high solubility is desirable, to reduce the solvent consumption per unit product extracted, on the other hand selectivity must be as far as possible from 1, to ensure that the substance of interest is extracted as pure rather than in mixture with other components. In summary, to develop a successful SFE process for MAPs, both solubility and selectivity issues must be fulfilled properly.

Coming back to CO_2, it must be kept in mind that this solvent is rather non-selective: when it is able to dissolve a group of similar substances (for example, in terms of carbon atoms), all of them are extracted to a similar extent, provided they have similar polarities.

Therefore, it can be stated that CO_2 alone is not as selective as a good and pure solvent. It is also noteworthy that CO_2 capacity and selectivity may be improved by using an organic solvent as the entrainer, also called the co-solvent, with the function of modifying chemical interactions between CO_2 and the substance to be dissolved in it.

But by doing this, the SFE process becomes more complicated, as an extra chemical component needs to be introduced into the process. However, the co-solvent can be easily separated from the product downstream, due to the high selectivity displayed by supercritical CO_2 in this respect.

10.3 SFE Processes

An SFE process for extracting MAPs is basically composed of two main sections (Figure 3a). The feed, containing the substance of interest, indicated by A, comes in contact with supercritical CO_2, at suitable temperature

and pressure, in an extraction device. In this simple scheme, component A is selectively extracted and must be recovered from the supercritical solution, which is usually a dilute one for the reason explained in the previous section. Product recovery occurs in the separation section, whose temperature and pressure can be adjusted in order to optimize the amount of A produced.

Note that, due to the low solubility in supercritical CO_2, after recovery of the product of interest the solvent must be recycled and pumped back to the extractor, in order to minimize operating costs. It is also noteworthy that the separator can be operated either at the same temperature or at the same pressure of the extractor, the best condition resulting from an economical analysis of the overall production costs.

If the temperature is kept constant, product separation is achieved by depressurization (Figure 3a), and mechanical energy has to be provided to the system to raise the CO_2 pressure from the separator to the extractor conditions. On the other hand, extracted products can be separated from CO_2 by increasing the temperature, and thermal energy must be supplied in this case (Figure 3b), where the circulation of the solvent can be done at nearly isobaric conditions. Of course, the way the separation of products from CO_2 is achieved can be more complex: for instance, both temperature and pressure can be varied when passing from the extractor to the separator sectors, or a solid can be used to promote separation by adsorption.

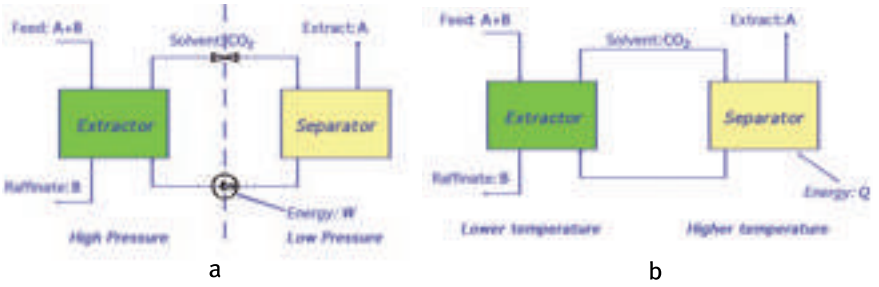

Figure 3: Block flow diagrams of simple SFE processes: with separation obtained by pressure change (a) and by temperature change (b)

If, as it often occurs, many substances are extracted by CO_2 at the extraction conditions because of lower CO_2 selectivity, their fractionation can also be achieved in the separation section, by simply using more than one separator, operated at different conditions. As shown in Figure 4, multiple fractions with different properties can be recovered from the same extraction.

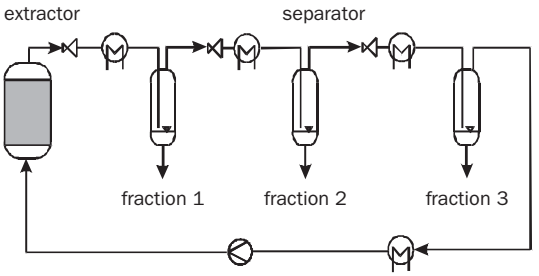

Figure 4: Single extractor, multiple separator scheme

Finally, a multiple extractor scheme can also be envisaged, as represented in Figure 5 with only one separation step, for sake of clarity. This configuration is particularly useful when, as in the case of SFE of MAPs, the substances to be extracted are embedded in a solid matrix, which is initially loaded in the extraction vessel as a fixed bed. In this case, the extractors can be connected either in parallel or in series, depending on specific requirements.

More details on the development of SFE processes are provided in a book by Brunner listed in the bibliography. SFE of solids is a semibatch operation, which can also be operated in a simulated moving bed configuration to obtain a continuous production.

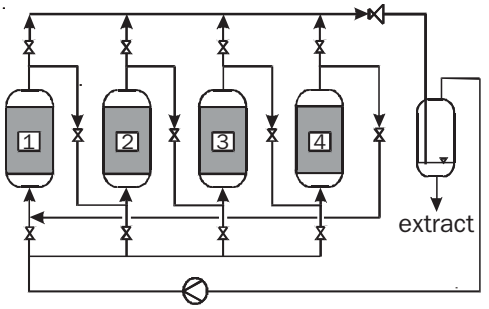

Figure 5: Multiple extractor, single separator scheme

Typical extraction profiles from solid materials (single vessel) are shown in Figure 6 where the extractor yield, i.e. the amount of substance of interest extracted with respect to the total amount initially contained in the solid, is plotted against extraction time. The profiles, which are steeper if the temperature is higher, have two parts: a straight line corresponding to the extraction of the substance "readily available" to supercritical CO_2, and an asymptotic curve representing the extraction of the part attached to the solid matrix. In the first case, the extraction is limited by solubility; in the second, mass transport (diffusion) properties are important and can be limiting and crucial for the success of SFE.

The effects of operating temperature are also clear in Figure 6. Other important operating variables are pressure, CO_2 flow rate and humidity of the material to be extracted.

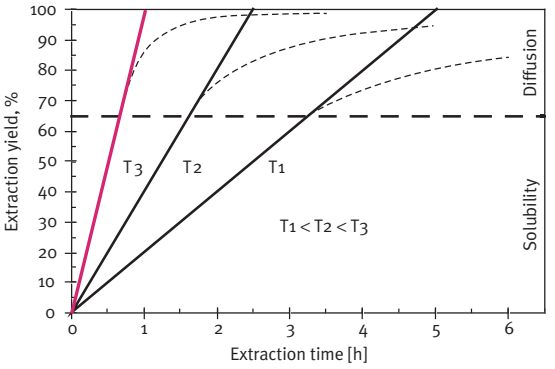

Figure 6: Extraction yield versus time at different temperatures

10.4 The SFE Process and Equipment Development

In order to design and develop an SFE process for MAPs with CO_2 (possibly assisted by ethanol or water as entrainers), we need to know and optimize:

1. The solubility of the substance of interest
2. The selectivity of this substance with respect to others that are extracted simultaneously
3. The extraction profiles (such as those in Figure 6)
4. The way to separate the substance of interest from the total extract

All this information can be obtained by simple measurements performed in a laboratory-scale apparatus of minimum volume such as that illustrated in Figure 7.

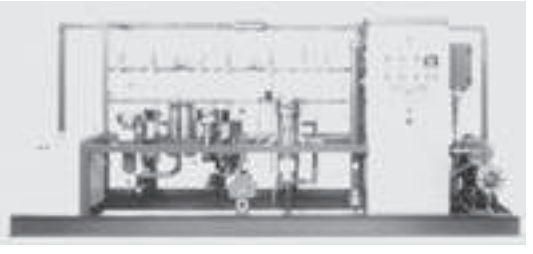

Figure 7: Laboratory-scale apparatus for SFE process design

To measure extraction profiles, a small pilot-scale apparatus can be used. Extractor and separator volumes do not need to exceed 1 liter each. The analytical system must be suitable to measure the concentration and purity of the products of interest. Basic requirements in terms of equipment are:

1. A liquid CO_2 storage tank
2. A pump for liquid CO_2
3. A cooler to prevent CO_2 from evaporating in the pump
4. A heat exchanger to control the temperature of CO_2 entering the extractor
5. An extraction vessel
6. A heat exchanger to control the CO_2 plus solute mixture entering the separator
7. A separation vessel

Note that condensing and recycling of CO_2 after separation is not needed at the laboratory-scale developmental level, whereas these are essential requirements at the industrial production level.

All parts of the SFE laboratory-scale plant must be designed in order to resist the maximum operating pressure. If this does not exceed 300-350 bar, the entire equipment (e.g. vessels, valves, fittings) is pretty much of standard type and relatively inexpensive. If, as usual, stainless steel is used, the thickness of any part of the plant can be easily calculated by applying the Von-Mises equation:

$$P_i \frac{k^2}{k^2 - 1} \sqrt{3} < \sigma_{am} \tag{5}$$

with:

$$\sigma_{am} = \frac{\sigma_s}{S_f} \tag{6}$$

where P_i is the internal pressure, k is the external to internal diameter ratio, σ_s is the yield stress, and S_f is a suitable safety factor (usually S_f=1.5).

From Eq. 5, it can be seen that the thickness of a cylindrical vessel depends on its diameter. Examples are given in Table 1 for a vessel of 0.2 m internal diameter, with both stainless steel and carbon steel construction materials.

Table 1: Thickness (s) of a thick-wall cylindrical vessel of 200 mm internal diameter as a function of pressure (SS=stainless steel, CS=carbon steel)

P [atm]		**50**	**100**	**150**	**200**	**250**	**300**
s [mm]	SS	3.8	8.1	12.9	18.5	25.0	32.7
	CS	2.2	4.6	7.2	10.0	13.0	16.2

Special care must be paid to closures and seals. SFE of MAPs is mostly an extraction operation from solid materials, which is carried out in batch or semibatch mode. Therefore, extraction vessels need to be pressurized, depressurized, opened, filled, and closed again several times per day. In order to ensure fast and safe operation procedures and reliable seals, gaskets like O-rings are useful and closure devices have been specifically designed. Again, the technology needed is already fully developed. We refer to chapter 4 of the book by Bertucco and Vetter for details. The book also describes the machinery for moving fluids under pressure, i.e. pumps and compressors. We conclude that setting up a laboratory-scale apparatus with which to perform feasibility studies concerning the possibility of applying SFE to MAPs is not really an issue, and can be done with a relatively small capital cost.

However, this does not mean that SFE of MAPs is in itself an economically convenient operation. An accurate evaluation of production costs, including both capital and utility costs, must be performed before scaling up a process whose technical feasibility has been demonstrated at the laboratory level. Costs are also discussed in the book by Bertucco and Vetter (chapter 8), but are only indicative. The reader should remember that capital costs have been steadily decreasing in the last years must be taken into account.

10.5 SFE Applied to Medicinal and Aromatic Plants

A large number of MAPs has been considered for possible extraction by supercritical CO_2. The most recent developments suitable to have industrial relevance are listed in Table 2. These examples illustrate the great potential of SFE in this field.

Table 2: Medicinal and aromatic plants extracted by SFE

Plant name (part used)	Product(s) extracted	Reference
Calendula officinalis (flowers)	Oleoresin	Campos *et al.,* 2005, Experimental data and modeling the supercritical fluid extraction of marigold (*Calendula officinalis*) oleoresin, *J Supercritical Fluids*, 34: 163-170 Danielski *et al.,* 2007, Marigold (*Calendula officinalis* L.) oleoresin: solubility in SC-CO_2 and composition profile, *Chem Eng Proc*, 46: 99–106

Plant name (part used)	Product(s) extracted	Reference
Echinacea purpurea (whole herb)	Alkamides, polyphenolics including chichoric acid, carbohydrates	Catchpole *et al.,* 2002, Supercritical extraction of herbs I: saw palmetto, St John's wort, kava root, and Echinacea, *J Supercritical Fluids*, 22: 129-138
Eucalyptus spp. (leaves)	Essential oil	Della Porta, *et al.,* 1999, Isolation of eucalyptus oil by supercritical fluid extraction, *Flavour Fragr J,* 14: 214–218
Ginkgo biloba (leaves)	Flavonol glycosides (flavonoids) and terpenoids	Chun Yang *et al.,* 2002, Extraction of pharmaceutical components from *Ginkgo biloba* leaves using supercritical carbon dioxide, *J Agric Food Chem,* 50: 846-849
Hypericum perforatum (herb)	Naphthodianthones, hypericin and pseudohypericin	Catchpole *et al.,* 2002
Levisticum officinale (dry rhyzomes, roots)	Essential oil	Daukšas *et al.,* 1999, Supercritical CO_2 extraction of the main constituents of lovage (*Levisticum officinale* Koch.) essential oil in model systems and overground botanical parts of the plant, *J Supercritical Fluids,* 15: 51–62
Matricaria chamomilla (flowers)	Oleoresin	Kotnik *et al.,* 2007, Supercritical fluid extraction of chamomile flower heads: comparison with conventional extraction, kinetics and scale-up, *J Supercritical Fluids*, Available online 13 February 2007 (in print)
Mentha spp. (leaves)	Essential oil	Marongiu *et al.,* 2001, Extraction and isolation of *Salvia desoleana* and *Mentha spicata* subsp. insularis essential oils by supercritical CO_2, *Flavour Fragr J,* 16: 384–388
Origanum spp. (herb)	Essential oil	Leeke *et al.,* 2002, *Eng Chem Res,* 41: 2033–2039
Piper methysticum (roots, rhizomes)	Kava lactones	Catchpole *et al.,* 2002
Piper nigrum (fruit)	Oleoresin	Ferreira *et al.,* 1999, Supercritical fluid extraction of black pepper (*Piper nigrum* L.) essential oil, *J Supercritical Fluids*, 14: 235–245.

Plant name (part used)	Product(s) extracted	Reference
Saccharum spp. (crude wax)	Long chain n-alcohols	De Lucas *et al*., 2005, Supercritical extraction of long chain n-alcohols from sugar cane crude wax, *J Supercritical Fluid*s, 34: 163-170
Salvia desoleana (leaves)	Essential oil	Marongiu *et al.,* 2001
Serenoa repens (fruit)	Free fatty acids, phytosterols (low concentrations), fatty alcohols and triglycerides	Catchpole *et al.,* 2002
Solanum lycopersicum (fruit)	Carotenoids, tocopherols and sitosterols	Vagi *et al.*, 2007, Supercritical carbon dioxide extraction of carotenoids, tocopherols and sitosterols from industrial tomato by-products, *J Supercritical Fluid*s, 40: 218–226
Taxus brevifolia (bark)	Taxol	Jennings *et al.,* 1992, Supercritical extraction of taxol from the bark of Taxus, *J Supercritical Fluid*s, 5: 1-6
*Taxus cuspidate (*needles)	Paclitaxel and baccatin III	Moon-Kyoon Chun *et al.,* 1996, Supercritical fluid extraction of paclitaxel and baccatin III from needles of *Taxus cuspidate*, *J Supercritical Fluid*s, 9: 192-198
Vitis vinifera (seeds)	Procyanidins	Cao *et al.,* 2003, Supercritical fluid extraction of grape seed oil and subsequent separation of free fatty acids by high-speed counter-current chromatography, *J Chromatogr* A 1021: 117–124
Zingiber officinale (rhizome)	Oleoresin	Badalyan *et al.,* 1998, Extraction of Australian ginger root with carbon dioxide and ethanol entrainer, *J Supercritical Fluid*s, 13: 319-324

10.6 Conclusions

SFE with CO_2 is a technically and possibly economically valid technique to extract bioactive components from MAPs. Organic solvent-free products can be obtained and the low operating temperature makes it possible to preserve all their natural properties. The feasibility study on specific products can be performed rather easily at laboratory scale. However, accurate evaluation of production costs, including both capital and operating ones, must be done in order to exploit SFE at the industrial level.

11 Process-scale High Performance Liquid Chromatography for Medicinal and Aromatic Plants

M. M. Gupta and K. Shanker

Abstract

High performance liquid chromatography (HPLC) is widely used by chromatographers and by the pharmaceutical industry for the accurate and precise analysis of chemicals and drugs of diverse nature. The systematic scale-up from analytical to preparative and process scale and further scale-up to industrial scale can be used in the medicinal and aromatic plant industry for the isolation and purification of phytomolecules of therapeutic and commercial interest. Due to the gradual increase in the demand for phytomolecules, the importance of process-scale HPLC as a purification tool has been increasing. In this article, we discuss the practical aspects of process-scale HPLC and focus on terminology, operational problems, advantages and applications of this technology to medicinal and aromatic plants.

11.1 Introduction

The term liquid chromatography (LC) refers to a range of chromatographic systems, indicating liquid-solid, liquid-liquid, ion-exchange and size exclusion chromatography. Glass column chromatography is an example of classic liquid column chromatography in which the mobile phase percolates under gravity through a glass column filled with a finely divided stationary phase. Liquid chromatography has overtaken gas chromatography, as high performance liquid chromatography (HPLC) systems now provide features such as:

i) High resolving power
ii) Fast separation
iii) Continuous monitoring of column effluent
iv) Qualitative and quantitative measurements and isolation
v) Automation of analytical procedures and data handling

There has been tremendous growth in this technique since 1964 when the first HPLC instrument was constructed by Csaba Horvath at Yale University. For the isolation of compounds, preparative mode HPLC (prep-HPLC) can be used in pharmaceutical development for trouble-shooting purposes or as part of a systematic scale-up process. The importance of prep-HPLC in pharmaceutical production as a purification tool has been increasing. Chromatographic separation can remove impurities of different polarity and can reduce the content of an enantiomer in a racemic mixture. In both of these instances, crystallization may be used to prepare the pure product. Bench to pilot scale production of natural products needs some

form of automation: thus, developing well-automated preparative chromatographic methods is a necessary but demanding task.

Innovations in micro-analytical to preparative HPLC played an important role in the progress of natural product chemistry. HPLC is used routinely in phytochemistry to pilot the preparative-scale isolation of natural products and to control the final purity of the isolated compounds. The development of hyphenated techniques related to this efficient separation technique in the past 20 years has provided powerful new tools such as LC/UV-photodiode array detection, LC/mass spectrometry (LC/MS) and LC/NMR. The combination of high separation efficiency of HPLC with these different detectors has made possible the acquisition of data on an LC peak of interest within a complex mixture.

11.2 Theoretical Aspects of HPLC

Separation of chemical compounds is carried out by passing the mobile phase, containing the mixture of the components, through the stationary phase, which consists of a column packed with solid particles. The cause for retention is physical and chemical forces acting between the solute and the two phases, on the chromatographic column. The reason for retention is the difference in the magnitude of forces; this results in the resolution and hence separation of the individual solutes. The separation of compounds occurs by distribution of solutes between the two phases.

11.2.1 Chromatography Classification

Chromatography can be classified according to mechanism of separation as: adsorption chromatography, partition chromatography, ion exchange chromatography, size exclusion chromatography and affinity chromatography. In HPLC, separation is mainly governed by adsorption and partition chromatography. In adsorption chromatography, separation is based on the difference between the adsorption affinities of the sample components on the surface of an active site, whereas in partition chromatography separation is mainly based on the difference between the solubility of sample components in the stationary phase and the mobile phase.

There are two modes of analysis depending on the operation techniques viz. isocratic and gradient. Isocratic analysis is the procedure in which the composition of the mobile phase remains constant during the elution process. In gradient elution, the composition of the mobile phase changes continuously or stepwise during the elution process. HPLC can also be classified according to special techniques, such as reverse phase (RP) and normal phase chromatography. Reverse phase is an elution procedure used in liquid chromatography where the mobile phase is significantly more polar than the stationary phase. On the other hand, in the normal phase

procedure, the stationary phase is more polar than the mobile phase. Lipophilic substances like oils, fats and lipids are separated by normal phase chromatography. Commonly used mobile solvents are n-hexane, heptane, chloroform, and alcohols. Most biomedical substances are separated by reverse phase chromatography using aqueous mixture with methanol, acetonitrile and additives (buffers, ion-pairs).

11.2.2 Important Factors that Influence HPLC Separation

HPLC separation is influenced by dead volume, capacity factor, theoretical plate count and selectivity:

- ***Dead volume*** (V_0) is the volume at which an un-retained component elutes.
- ***Capacity factor*** (K') is a measurement of the retention time of a sample molecule, relative to column dead volume. It changes with variations in mobile phase composition, column surface chemistry or operating temperature. Capacity factor is calculated as follows:

  $$K' = \frac{V_1 - V_0}{V_0} E_i$$

  V_1 = Retention volume of peak 1
- ***Theoretical plate count*** (N) is a measure of column efficiency in terms of band-spreading of a peak. The smaller the band-spread, the higher the number of theoretical plates, which indicates good column and system performances.
- ***Resolution*** (R_s) is the distance between the peak centres of two component peaks divided by the average base of the peaks, as follows:

  $$R_S = \frac{V_2 - V_1}{\sqrt{W_1 + W_2}}$$

  W_1 = width of peak 1
  W_2 = width of peak 2
- ***Selectivity*** (α) is the relative retention of two peaks in a chromatogram.

  $$\alpha = \frac{K'_2}{K'_1} = \frac{V_2 - V_0}{V_1 - V_0}$$

  K_1 and K_2 = capacity factors for retention volume of peak 1 and peak 2 respectively.

Capacity factor (K'), selectivity (α) and column efficiency (N) are three fundamental parameters that influence the resolution of a chromatographic separation, as follows:

$$R_s = \frac{1}{4}\left(\frac{\alpha - 1}{\alpha}\right)\sqrt{N}\left(\frac{K'}{1 + K'}\right)$$

11.2.3 Main Components of HPLC

An HPLC system contains the following components:

a) *Reservoir.* This is meant for the mobile solvents. Acetonitrile, methanol, heptane, isopropanol and cyclohexane are the organic modifiers most commonly used. Trifluoroacetic acid, heptafluorobutyric acid, phosphoric acid and triethylamine phosphate are ion-pairing reagents for better chromatographic results. All tubing and fittings should be chemically inert. Solvent must be filtered through a 0.45-µm filter unit.
b) *Degasser.* In analytical operations, the mobile phase should be free of air bubbles. For this purpose, a degasser is used.
c) *Pumps.* These are devices that deliver the mobile solvent at a controlled flow rate to the separation system. HPLC uses reciprocating pumps: a pump with a single or multiple chambers, from which the mobile phase is displaced by reciprocating pistons or diaphragms. Binary gradients are created by the selected mixing of two solvents, on a single-headed two-pump system. Accurate gradient is maintained by microprocessor control.
d) *Injector/autosampler.* This device introduces a liquid sample into the mobile phase or onto the chromatographic bed. An autosampler can perform repeated functions without operator attendance, and thus is a labor-saving device.
e) *Column.* Silica and modified silica columns are available for various applications. Examples are octyl (C_8), octadecyl (C_{18}), phenyl (C_6H_5), and cyno (CN) columns.
f) *Guard column.* This is used to protect the main column.
g) *Detectors.* No universal detector is available for all molecules. However, according to the characteristic of the molecules investigated, various detectors are used (Table 1).
h) *Fraction collector.* This device collects the fractions containing the molecules of interest during the chromatographic run.
i) *Records.* A computer is used for chromatographic data acquisition.

Table 1: Characteristics of various HPLC detectors

Detector	Application	Advantages and limitations
Electrochemical	Responds to substances that are oxidizable or reducible	Commercially available. Non-specific. High LOD

Detector	Application	Advantages and limitations
Fluorescence	Detects trace-level analytes such as aflatoxins, carbamates and polycyclic aromatic hydrocarbons	Very specific. Low LOD. Not everything fluoresces
Infrared	Works for all molecules	Many solvents are infrared-active
Mass spectrometry	Analyte identification	Ability to ionize analyte. Low LOD
Photodiode array	Works for wavelengths 190-800 nm	High LOD
Refractive index	Works for nearly all molecules	Temperature sensitive. High LOD
Scattering	Uniform response	Non-specific. LOD, 5 ng per 25 mL. Interference from solvent
Ultraviolet and visible	Works for molecules with chromophores and for complex samples	Non-specific. All molecules that absorb UV and visible light can be detected.

LOD, level of detection

11.2.4 HPLC Classification

HPLC may be characterized depending on column diameter, which is the governing factor for flow rate from microscale to industrial scale chromatography. Column internal diameter (i.d.) defines the sample load and flow rates (Figure 1).

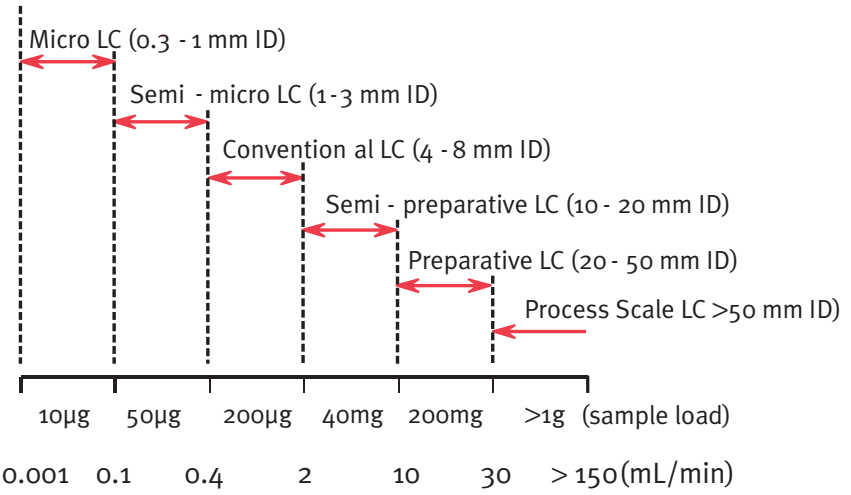

Figure 1: Classification of HPLC according to column diameter

11.2.5 Advantages of HPLC

The use of HPLC in the isolation and purification of complex compounds is increasing tremendously due to its flexibility and efficiency. It has several advantages over traditional methods of isolation and purification:

i) Variety of separating techniques.
ii) Variety of column packings for different techniques.
iii) Separation optimized by alteration of the mobile phase.
iv) Mobile phase easily manipulated in gradient systems.
v) RP technique separates very similar and very different compounds simultaneously.
vi) HPLC can be used as a preparative method.
vii) HPCL can be used as a purification technique. More than one detector can be connected in series (e.g. UV and evaporative light scattering detector).
viii) Most sample analysis is carried out at room temperature.
ix) Short analysis runs. More than 70% of HPLC separations are performed on UV detectors and 15% rely on fluorescence without any derivatization.

11.3 Preparative HPLC

Preparative chromatography is the most powerful and versatile method for isolation as well as purification of complex compounds used in drug development studies. Prior to performing preparative HPLC, the following points must be taken into account to optimize the separation and maximize the sample load on a small column:

- Prior to pilot-plant scale, a systematic method for development is required
- Validated robust analytical methods are required
- Scale-up of parameters from analytical method to prep-HPLC
- In prep-HPLC, buffer is not used
- Stationary phase with large particle sizes to decrease costs for prep-HPLC

11.3.1 Strategy for Preparative Separation

Selection of the appropriate mode of chromatography is followed by the optimization of the separation, i.e. stationary phase, mobile phase, temperature, additives. The next step is optimization of the throughput, i.e. sample amount and column overloading. In the final step, stepwise scale-up of separation is performed to obtain the desired compound.

It is always important to optimize the small-scale separation (which will significantly impact on throughput), the size of packing material and the column needed to obtain the desired throughput, the mobile solvent and the instrument capability. Normal-phase methods are the first choice because: direct transfer from normal-phase thin-layer LC or HPLC to prep-LC is possible; costs of RP packing materials are still high; cleaning normal-phase silica is easier because the material is more robust; removing organic solvents typically used in normal-phase chromatography from the final product solution is easier than removing water from an RP chromatographic fraction and can be achieved at lower temperatures and provides higher product quality and lower energy costs. Particle size of the stationary phase material also plays an important role in the isolation of the desired compounds. The choice of 5-µm particle size in a preparative column is not practical because it not only increases the column pressure but also is extremely expensive. Moreover, when the sample amount is increased, resolution performances of 5-µm and 15-µm particles are not different.

11.4 Practical Consideration in Preparative HPLC Scale-up

11.4.1 Sample Loading

If the tests on analytical columns with analytical loadings show good separations, a scale-up to a larger column diameter can be performed on prep-HPLC. Instead of jumping directly to the largest column diameter, stepwise scale-up should be done. The first step in the scale-up process is the transfer of the analytical separation procedure to a 5 cm i.d. preparative LC column. Optimization in a preparative column is required. The sample injected onto the column usually starts at 1 g and increases to as much as 20 g, depending upon the quality (resolution) of the separation achieved, the quality of the initial material, and the specifications for the pure product. Start with the 1-g injection, collect fractions and re-analyze them for purity using the analytical method, because with an increase in sample loading there is a decrease in resolution.

$$\text{(A) Scale up factor for column size} = \frac{(\text{Diameter}_{prep})^2 \times \text{Length}_{prep}}{(\text{Diameter}_{anal})^2 \times \text{Length}_{anal}}$$

$$\text{(B) Flow rate (prep)} = \text{Flow rate (analytical)} \times \frac{(\text{Diameter}_{prep})^2}{(\text{Diameter}_{anal})^2}$$

$$\text{(C) Gradient duration (prep)} = \text{Gradient duration (anal)} \times = \frac{\text{Length}_{anal}}{\text{Length}_{prep}}$$

11.4.2 Separation Time

In preparative separations, the stationary phase is usually recovered and used again to purify the next batch of the same substance. Often the major operating cost in preparative LC is the solvent rather than the packing material. Therefore, the choice of solvent is important in method development and scale-up. As per the need for separation, isocratic mixture or gradient elution of water with organic solvent (methanol or acetonitrile) is used. Gradient elution has a shorter run time than isocratic elution, but sometimes purity of the isolates is compromised.

11.4.3 Solvent Composition

Methanol is often used in preparative separations. It is an inexpensive and strongly polar solvent commonly used in combination with water as a mobile phase in RP separations. Methanol can be used for flushing normal-phase silica columns to remove adsorbed polar contaminants. It can also be recovered easily from many mixtures. In RP applications, acetonitrile yields better peaks but is too expensive in most situations for process-scale separations.

An initial goal of the scale-up process is to find an acceptable separation. If analysts find more than one set of valid conditions, then the cost of solvents becomes a major criterion. Solvent selection is usually determined during the initial method development with the 4-mm i.d. analytical-scale columns. Sometimes, when the overall costs of the goods is important to a final product, one can perform a systematic solvent selection even at later stages of development.

11.4.4 Washing Steps

The accumulation of impurities on the column can decrease the resolution of the subsequent separation, and late-eluted impurities can spoil the collected fractions of the subsequent separation. Therefore, washing steps are often implemented between chromatographic runs. Solvent gradients and recycling steps are sometimes necessary to increase the resolution for difficult separation problems. Sometimes temperature programming is used to remove strongly held impurities.

11.4.5 Recycling

Sometimes gradients and recycling steps are required for better preparative separation of complex mixture of compounds.

11.5 Stepwise Operations in Process-scale HPLC

Various aspects should be taken into consideration for operating process-scale HPLC and stepwise scale-up, as follows.

- Develop a robust analytical method and scale up the method for process scale using the same stationary phase.
- The main objective of method development is a simple, well-automated and robust separation process able to run 24 h per day.
- Optimize sample loading, flow rate and column pressure.
- Select the best solvent for both sample preparation and elution.
- The injection solvent should be optimized because sharp peaks and high loadability are important goals.
- In process-scale separations, control the first two runs manually and observe the process. If no technical problems occur, subsequent runs can be performed automatically.
- Collect fractions and re-analyze them for purity using the analytical method.
- Peak purity at three points (i.e. up slope, apex and down slope) should be confirmed.

11.6 Problems Encountered in Preparative Scale-up

11.6.1 Purity of Crude Extract

A typical problem encountered in process scale-up is that the plant material or enriched fraction used during method development had been produced in analytical scale and differs in solubility and impurity from the material that is being processed in pilot scale. The process-scale plant material can be either of a different quality or show larger amounts of the same impurities, and, in some instances, even new impurities can arise. If an impurity profile shows larger amounts of the same impurities or new impurities, the chromatographer must retest the separation method at analytical scale before starting the process-scale separation.

If during a process scale up, a compound shows higher purity, the solubility in the weak solvent chosen during optimization may not be good enough. In this instance, productivity can be lower than expected because the amount separated in each run will be less. Because scale-up is linear, the chromatographic run takes the same time in preparative scale as in analytical scale, and the substance is not stressed longer in the separation equipment.

11.6.2 Removal of Chromatographic Solvent

The final work-up after the separation step is removal of the chromatographic solvent. The desired fraction collected is a solution which contains the substance of interest in the range of a small percent by weight and, therefore, large amounts of solvent must be removed. The evaporation of solvents, especially water, takes time, so the purified drug substance can be changed or even destroyed during the concentration process. This step should be performed with care considering the thermal stability of the compound of interest.

11.6.3 Temperature Variation from Laboratory to Pilot Scale

It is useful to test the temperature stability of the substance during analytical method development. Temperature also influences the separation performance. For example, the mixing of organic solvents before they enter the column can result in a strong increase or decrease in solvent temperature and can influence the operating temperatures of the mixing unit and column. Temperature effects at the centre of the column caused by heat dissipation can also influence the separation and ultimately the purity of isolates.

11.6.4 Increase in Pump Pressure Due to Accumulation of Impurities on the Column

Another problem that often occurs during the first separation in process scale is that some impurities accumulate on the column during a series of sequential runs. The quality of the separation deteriorates during the sequence. Because the fraction collection is commonly controlled by peak height, a UV detector does not detect this problem and the purity of the fractions decreases. When impurities accumulate on the column, the peak shapes or the retention times of the components of interest might change, so the chromatographer can see quality problems. Unfortunately, sometimes peak shapes and retention times show no changes. An additional indicator that impurities have accumulated on the column is a pressure increase; therefore, it is helpful to monitor column pressure. The increase in pressure is commonly related to instrument failure.

11.7 Summary: Scale-up Strategy

- Define the problem
- Find the chromatographic mode
- Develop and optimize the separation
- Maximize throughput
- Increase sample mass and volume to the maximum while meeting purity objectives
- Determine recovery

- Scale up to desired column size to meet throughput and load objectives
- Pool fractions of comparable purity and rerun if necessary
- Check fraction purity using an analytical column

11.8 Applications: Natural Products Isolation

A few examples of prep-HPLC for the isolation of natural products are summarized herein. First, tannins from *Guiera seregalensis* can be isolated using the following conditions:

Column	RP-18e (250 x 10 mm i.d.)
Mobile phase	Water:methanol:THF (90:10:0.25) and (80:20:0.25)
Flow rate	2.5 ml/min
Detection	280 nm
Compounds isolated	Galloylquinic acids, namely, 3-*O*-, 5-*O*-, 1,3-di-*O*-, 3,4-di-*O*-, 3,5-di-*O*-, 4,5-di-*O*-, 1,3,4-tri-*O*-, 3,4,5-tri-*O*- and 1,3,4,5-tetra-*O*-galloylquinic acid

Flavonoids from *Lychnophora ericoides* require the following conditions:

Columns	Silica (250 x 10 mm i.d.) and ODS (250 x 10 mm i.d.)
Mobile phase	Water:methanol:THF
Flow rate	2.5 ml/min
Detection	280/225 nm
Compounds isolated	7,4'-dihydroxy-flavonol; 5,7-dihydroxy-3-methoxy-flavonol; galangine, 7,4'-dihydroxy-dihydroflavono l,5,7,4'-trihydroxy-dihydroflavonol,7-hydroxy-4'-methoxy-dihydroflavonol; pinobanksin, 5,7'-dihydroxy-4'-hydroxy-flavanone; 7-hydroxy-4'-methoxy-flavanone; 5,7-dihydroxy-flavone; acacetin; 7-hydroxy-3',4'-dihydroxy-isoflavone; 15-desoxigoiazensolide, 2',3'-dihydro-15-desoxygoyazensolide; eremantholides A and C; 4,5-dihydroeremantholide A and lychnopholide

For the isolation of peptide components of bacitracin, use:

Column	C_8 (250 x 16 mm i.d.)
Mobile phase	Gradient acetonitrile, methanol and phosphate buffer
Flow rate	9.0 ml/min
Detection	254 nm
Compounds isolated	Peptides

The isolation and purification of β-carotene from carrot involves:

Column	Shim-pack PREP-ODS (H) kit (250 x 20 mm i.d.)
Mobile phase	Ethanol (99.5%)
Flow rate	10 ml /min
Detection	480 nm monitor with photodiode array (PDA)
Compound isolated	β-carotene

The isolation of anti-HIV compounds from *Gleditsia japonica* and *Gymnocladus chinensis* requires the following conditions:

Column	C18-μBondpak (300 x 24.4 mm i.d.)
Mobile phase	Methanol-water (varying percentages)
Detection	Refractive index detector
Compound isolated	Saponins

Isolation of procyanidins from *Vicia faba* requires these conditions:

Column	Sephadex LH-20 column (580 × 25 mm i.d.)
Mobile phase	Sequential elution with ethanol, ethanol:methanol, methanol and finally methanol:acetone
Flow rate	Varying
Detection	280 nm
Compounds isolated	(+)-gallocatechin-4-phloroglucinol; (−)-epigallocatechin-4-phloroglucinol; (+)-gallocatechin; (−)-epicatechin-4-phloroglucinol; (+)-catechin-4-phloroglucinol; (+)-catechin and (−)-epicatechin

Isolation of the anticancer compound taxol from *Taxus yunnanensis* is done with:

Column	D1 (4000 x 200 mm i.d.) packed with 956 polymeric resin
Mobile phase	Acetone:water (58:42)
Flow rate	79 ml/min
Detection	228 nm
Compound isolated	Taxol

11.9 Conclusions

Stepwise scale-up starting with analytical scale to process scale is an important issue that needs to be considered. Optimization of operating conditions is always useful for getting high purity phytomolecules. Thus, process-scale HPLC is the choice for isolating valuable molecules with desired purity for commercialization. Its significance will continue to grow because of the increasing requirements for high-purity molecules.

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12 Flash Chromatography and Low Pressure Chromatographic Techniques for Separation of Phytomolecules

S. K. Chattopadhyay

Abstract

Flash chromatography is a rapid form of preparative column chromatography that employs prepacked columns through which a solvent is pumped at high flow rate. Two types of solvent systems are used in flash chromatography: isocratic and gradient. In the isocratic system, a single-strength mobile phase brings about the desired separation. The gradient system, in which the solvent composition changes during the course of elution, is suited for complex samples containing compounds that differ greatly in column retention times. The optimum flow rate for a flash separation is related to the particle size and dimensions of the column. Typical sorbents for normal phase flash chromatography are polar (e.g. silica, NH_2) and elution solvents are non-polar. In reverse phase chromatography, the stationary phase is non-polar (such as C18) and the mobile phase is polar. Compounds are retained by the interaction of their non-polar functional groups with the non-polar groups on the packing surface. Therefore, the most polar compounds elute first followed by other compounds in decreasing order of polarity. To achieve a desired separation, one must select a sorbent that effectively retains the compounds of interest under solvent conditions that are appropriate for the sample's solubility. Sample loading onto a flash column can be done with wet loading (the liquid sample is loaded directly and allowed to percolate into the sorbent bed) or dry loading (when samples are pre-absorbed to a small amount of sorbent which is then loaded onto the column).

12.1 Introduction

Mikhail Semyonovich Tsvet of Russia invented the first chromatographic technique in 1901 during his research on chlorophyll. He used a liquid adsorption column containing calcium carbonate to separate plant pigments. The method was described on 30 December 1901 at the XIth Congress of Naturalists and Doctors in St. Petersburg. The first printed description was published in 1903 in the *Proceedings of the Warsaw Society of Naturalists,* section of biology. He first used the term chromatography in print in 1906 in his two papers about chlorophyll in the German botanical journal, *Berichte der Deutschen Botanischen Gesellschaft.*

In 1952, Archer John Portor Martin and Richard Laurence Millington Synge were awarded the Nobel Prize in Chemistry for their invention of partition chromatography. Since then, the technique has advanced rapidly. Researchers have found that the principles underlying Tsvet's chromatography can be applied in many ways, giving rise to the different varieties of chromatography and allowing increasing similar molecules to be resolved.

12.2 Flash Chromatography

Flash chromatography, also known as medium pressure chromatography, is a rapid form of preparative column chromatography that uses optimized, prepacked columns through which a solvent is pumped at a high flow rate. Initially developed in 1978 by W. C. Stills of Columbia University, New York, USA, flash chromatography is now a method of purification and separation using normal phases. Use of reverse phase packing materials is opening up the technique to a wider range of preparative separations. Currently, it is considered to be a simple and economical approach to preparative liquid chromatography (LC).

Flash chromatography differs from conventional techniques in two ways. First, slightly smaller silica gel particles (250-400 mesh) are used. Second, due to the limited flow of solvents caused by the small gel particles, pressurized gas (10-15 psi) is used to drive the solvent through the column of stationary phase. The net result is rapid ("over in a flash") and high resolution chromatography.

12.2.1 Theory of Flash Chromatography

Chromatography is a separation method that exploits the differences in partitioning behavior between a mobile phase and a stationary phase to separate the components in a mixture. Compounds of a mixture may interact with the stationary phase based on charge, relative solubility or adsorption. Retention is a measure of the speed at which a substance moves in a chromatographic system. In continuous development systems like high performance LC (HPLC) and gas chromatography (GC), where the compounds are eluted with the eluents, retention is usually measured as the retention time (Rt or t_R), i.e. the time between injection and detection. In uninterrupted development systems like thin layer chromatography (TLC), retention is measured as the retention factor (R_f), i.e. the run length of the compound divided by the run length of the eluent front:

$$R_f = \frac{\text{Distance travelled by the analyte}}{\text{Distance travelled by the solvent front}}$$

12.2.2 Converting TLC to Flash Chromatography

TLC separations can be used to help determine effective solvent compositions for flash chromatography. R_f is a common TLC unit and ΔR_f is the distance between the compounds:

$$\Delta R_f = R_{f1} - R_{f2}$$

The ideal solvent system for TLC is one that moves the compound of interest in the mixture to an R_f of 0.15-0.35 and that separates

this component from the others nearest to it by a ΔR_f value of at least 0.15. In contrast to TLC, flash chromatography separations are governed by column volumes.

A column volume (CV) is defined as the volume of solvent required to fill all the adsorbent pores and interstitial spaces between adsorbent particles in a given column. The volume required to elute a compound of interest from a column is expressed in terms of the number of CV. The volume that separates the elution of two substances from the same volume is called column volume difference (ΔCV). The ideal flash chromatography solvent system is one that elutes the desired compound of interest in 3-6 CV and that separates this component from others nearest to it by a ΔCV greater than 1.

The relationship between numbers of CV to R_f for a given compound is $1/ R_f$; therefore, for two compounds $\Delta CV = 1/ R_{f1} - 1/ R_{f2}$. For a particular set of separation conditions, a weakly retained, fast-eluting component with an R_f=0.9 can be eluted in just over 1 CV, whereas a strongly retained, slow-eluting component with an R_f =0.1 requires 10 CV for complete elution (Table 1).

Table 1: Relationship between R_f and CV

R_f	CV
0.90	1.10
0.70	1.40
0.50	2.00
0.30	3.33
0.10	10.0

Due to factors such as change in the TLC solvent flow rate with respect to time and interference from adhesives used to bind TLC sorbents, solvent conditions that provide an acceptable TLC separation will not necessarily work effectively for flash chromatography without modification.

Although some empirical experimentation may be required, the steps below help streamline the process of converting a TLC solvent system into a flash chromatography mobile phase:

1. Use matching sorbent chemistries on the TLC plate and in the flash chromatography column. Stationary phase sorbent chemistries (including silica) can differ from one manufacturer to another. It is important to match these sorbent chemistries if the solvent systems are expected to provide equivalent results.

2. Optimize the TLC solvent mixture so that the compound of interest has an $R_f \approx 0.15\text{-}0.35$ and $\Delta R_f > 0.20$. These conditions will provide the most reliable starting point for a successful flash chromatography separation.

a) *Adjust the solvent selectivity to provide an $\Delta R_f > 0.20$.* Solvent selectivity is defined as the ability to affect the retention of one compound in the mixture relative to the others, therefore affecting ΔR_f and number of CV. Experimenting with different solvent combinations to obtain the desired TLC separation usually reveals appropriate conditions for effective flash chromatography separation. Different solvent mixtures such as hexane:ethyl acetate (1:1) and hexane:dichloromethane (1:2) may provide different solvent selectivities while providing similar solvent strengths. Different solvent mixtures can even reverse the elution order of some of the components in the sample. It is interesting to note that ΔR_f and ΔCV may vary greatly relative to one another for a given separation. ΔCV predicts column capacity, i.e. the amount of material that can be effectively separated in a single column loading (Table 2). Greater the ΔCV, the better the effective capacity of the column.

b) *Adjust the solvent strength to obtain an R_f between 0.15 and 0.35 (CV, 3-6).* Solvent strength refers to the solvent's simultaneous effect on the retention of all compounds in the mixture; therefore, solvent strength affects R_f and CV. Once the optimum separation has been established by modifying solvent selectivity, it may be useful to move some or all of the compounds off the flash column as quickly as possible by increasing solvent strength. Often, slight changes in solvent strength can make large differences in retention. In some cases, a lower-strength mobile phase provides improved separations. It is important to remember that the sample loading solvent should have equal or lower elution strength than the starting strength of the mobile phase. Additional adjustments to the selectivity and strength of the flash solvent system may be necessary to optimize the separation and to achieve a CV≈3-6 and a ΔCV>1. This can often be achieved by using a less polar solvent system or by decreasing the proportion of polar modifier.

Table 2: Approximate capacity of a 20 g/70 ml ISOLUTE Flash Si column (Biotage)

ΔCV	Sample load, g
6	1.0
2	0.5
1	0.25

12.3 Isocratic versus Gradient Chromatography

Two types of solvent systems are used in flash chromatography: isocratic and gradient. The most common is an isocratic (meaning "same solvent strength") system where a single-strength mobile phase mixture brings about the desired separation.

If the mixture is complex and contains compounds that differ greatly in column retention times, chemists may use a gradient solvent system that changes solvent composition during the course of elution. For example, in a normal phase system equipped with a silica column, a non-polar solvent such as hexane is applied to elute non-polar compounds. Then, a more polar solvent such as ethyl acetate is added to the hexane to elute the more polar compounds. The percentage of the polar solvent in the mixture is increased until all components of the mixture have eluted.

In a step-gradient system, the various solvent concentrations are typically changed in large increments (or steps). Alternatively, a linear gradient can be employed whereby a continuous linear change in the concentrations of the solvent (and thus mobile phase strength) is achieved. Chemists can often achieve effective separations more rapidly by using gradient solvent systems. Chemists must select miscible solvents for use in gradient solvent systems. A common solvent system for flash separations using polar sorbents such as silica is hexane and ethyl acetate, where ethyl acetate is the more polar solvent.

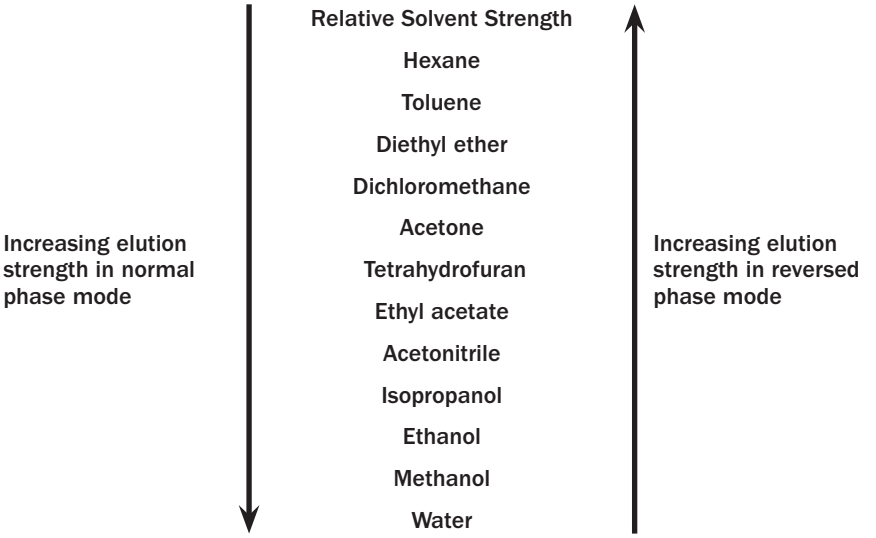

Figure 1: Step-gradient system

12.4 Adsorbent Selection and Mode of Separation

Typical sorbents for normal phase flash chromatography are polar (e.g. silica, NH_2) and elution solvents are non-polar (e.g. hexane, heptane, dichloromethane, sometimes modified with small amounts of more polar solvents such as isopropanol). The sample is usually applied in a weak (very non-polar) solvent, and separation occurs when the elution solvent is applied. In normal phase flash chromatography, the most non-polar sample component elutes first, followed by successively more polar compounds.

12.4.1 Isolute Flash Columns

Isolute flash columns (Biotage) are polypropylene columns prepacked with Isolute flash sorbents. These columns are appropriate for use in both off-line and on-line flash chromatography. In off-line flash chromatography, chemists apply the sample and elution solvent volumes to the top of an Isolute column fixed in a FlashVac Sample Processing Station. In off-line flash chromatography, chemists perform isocratic or step gradient separations. In on-line flash chromatography, an Isolute column is mounted on a system that connects the column to an external liquid pump system to produce a continuous flow of solvent through the column. Depending on the capability of the pump, the solvent composition can be isocratic (a single solvent or solvent mixture) or a gradient with an increasing proportion of stronger solvent (either in a step gradient or a linear gradient).

12.4.2 Method Development Using Isolute Flash Columns

12.4.2.1 Column Equilibration

Prior to sample loading, the column should be prepared for the separation by equilibration (prewetting) with a suitable solvent:

- *Off-line*. Apply the equilibration solvent to the top of the column and allow it to flow through the column under gravity.
- *On-line.* Equilibrate the flash column for on-line mode separation in the off-line mode using a vacuum manifold such as the FlashVac system or by mounting the column on the on-line apparatus and pumping a suitable volume of equilibration solvent through the column.

12.4.2.2 Typical Equilibration Solvents

Suitable solvents are non-polar, e.g. hexane or pentane. For best results, prewet the silica and NH_2 columns prior to use. A suitable volume for column equilibration is approximately two bed volumes (Table 3).

Table 3: Typical column solvent volumes for column equilibration

Column size, g	Approximate column volume, ml	Typical solvent volume, ml
2	2.5	5
5	6.5	13
10	12.5	25
20	25	50
25	31.3	62.5
50	62.5	125
70	88	176
100	125	250
150	188	376

Normal phase flash columns can be used without prewetting, but some column-to-column variation may be experienced.

12.5 Sample Application

There are two popular approaches to flash chromatography sample loading: wet loading and dry loading.

12.5.1 Wet Loading

Load the liquid sample directly onto the top frit of the column, and allow it to percolate through the top of the sorbent bed. For best results, load the sample onto a prewetted column in a non-polar solvent.

12.5.1.1 Practical Tips for Wet Loading

- Dissolve the sample in as non-polar as solvent as possible.
- If compounds are not easily soluble in a non-polar solvent, either dissolve them in a small volume of polar solvent and then dilute with a non-polar solvent to reduce the elution strength, or consider dry loading of the sample (discussed in next section).
- Position column on a FlashVac vacuum manifold equipped with PTFE stopcock needles.
- Apply the sample evenly over the entire area of the top frit. To do so, seal the column by closing the stopcock.
- Alternatively, load samples onto the column in on-line mode using a Flash Master system equipped with a 3-way injection valve.

12.5.2 Dry Loading

Dry loading is the method of choice for loading reaction mixtures consisting of polar solvents onto silica or other normal phase columns. Pre-absorb the reaction mixture onto a small amount of bulk material of the chosen sorbent. Evaporate off the majority of the solvent leaving the compounds bound to the surface of the sorbent.

Add this blend to the top of the prepacked (and prewetted) flash column; allow settling and add a top frit to secure the blend in place. The top frit can be placed using a suitably sized frit inserter.

A popular alternative sorbent for dry loading using the flash sorbent is a diatomaceous earth such as Isolute HM-N. This can be used in the same way as the flash sorbent, but has several advantages including more efficient desorption of the compounds into the mobile phase.

12.5.2.1 Practical Tips for Dry Loading

- Dissolve the sample initially in a suitable solvent, ensuring complete dissolution if possible. Use the smallest volume possible.
- Add the bulk material of choice. The ideal proportion of sample to bulk material ranges from 1:1 to 1:3 by volume.
- Evaporate off the residual solvent using a rotary evaporator to ensure even adsorption of the sample on the bulk material.
- Pack the dry blend on top of the flash column (above the top frit) and add another frit. Push down the new surface to prevent movement of the new blend. When loading with Isolute HM-N, ensure that the material is not crushed at this stage.
- When dry loading using bulk silica, ensure that it is identical to the material in the flash column. If this is not possible, use a lower surface area material, ensuring that the surface pH and moisture content are as similar as possible to the column packing. All Isolute sorbents are available as bulk material.

Table 4: Capacity guidelines

Reaction scale, g	Column size, g
0.1	1-2
0.25	2-5
0.50	5-10
1.0	10-20
2.5	25-20
5.0	50-70
10.0	70-100

As a general guideline, the amount of sample loaded onto the normal phase flash column should be 5%-10% of the column size. Factors affecting the capacity of the column include compounds, sample matrix, concentration of reaction products and elution solvent used.

12.6 Elution

12.6.1 Step Gradient Elution

Step gradients provide controlled elution with discrete changes in eluent strength. Each step is optimized to elute only those components that are soluble in that eluent. This technique can be applied to both off-line and on-line flash chromatography.

1. Use TLC to determine a suitable solvent strength to elute the components at discrete intervals, choosing different solvent mixtures that elute each component separately with an R_f of 0.2-0.5.
2. Calculate the volume of solvent required to elute each component using $CV=1/R_f$. Values of CV for different column sizes are listed in Table 3.
3. Apply between 2 and 5 CV of solvent for each step, starting with the solvent with weakest strength.
4. Collect the eluent from each step in a separate vessel.

12.6.2 Linear Gradient Elution

Liner gradients are a quick way of separating complex mixture, reducing the complexity of the subsequent purification of the fractions collected. This technique is suitable for on-line flash chromatography.

1. Use TLC to find both the weakest and strongest elution solvent. The weak solvent (solvent A) should give retention of the majority of components ($R_f<0.1$). The strong solvent (solvent B) should allow elution of all of the components of interest ($R_f>0.5$).
2. Run a gradient starting with 100% solvent A and ending with 100% solvent B.
3. Collect the eluent at regular intervals.

Automated flash chromatography instrumentation such as the FlashMaster II and Solo systems can monitor the signal from a UV detector, and collect only the fractions of eluent carrying the compounds of interest.

12.6.3 Method Development Using Gradient Elution

Method development can be performed without TLC. Gradient elution analysis offers a useful approach to method development, particularly for non-silica-based flash chromatography (e.g. reverse phase) where suitable TLC plates are not available.

1. Load the sample onto a prewetted (equilibrated) flash column in as weak a solvent as possible (or use dry loading); for example, for normal phase work use hexane for loading.
2. Elute the column with aliquots (2 CV each) of successively increasing solvent strength. A typical scheme for mixing the two solvents is given in Table 5.
3. Collect each fraction and analyze for the presence of the components of interest.
4. Using these data, identify the solvent mixture that elutes the components of interest separately, and set up a step or continuous gradient as described.

Table 5: Typical scheme of mixing solvents for method development. Solvent A is a weak solvent (e.g. hexane) while solvent B is a strong solvent (polar modifier, e.g. isopropanol)

Aliquot number	Solvent A, %	Solvent B, %
1	100	0
2	99	1
3	98	2
4	97	3
5	06	4
6	95	5
7	94	6
8	93	7
9	92	8
10	91	9

12.6.4 Practical Tips for Gradient Elution

1. The use of a gradient does not improve the selectivity of a separation if isocratic elution using the same solvent system does not effectively separate the sample components. However, a gradient can be used to decrease the time required to achieve a separation.

2. The gradient starting conditions must not cause chromatography separation. Start the gradient with a weak solvent that matches the sample loading conditions.
3. The flow rate at the beginning of a gradient can be high but, for best results, it should be reduced to the optimum flow rate at the separation area.
4. To speed up a gradient separation, use either a higher flow rate (most suited to samples with many components, high sample load) or a steeper gradient (most suited to samples with few components, low sample load).

12.6.5 Optimizing Flow Rate

The optimum flow rate for a flash separation is related to the particle size and dimensions of the column. Theoretical optimum flow rate for flash columns of different dimensions can be predicted. However, in practice, increasing the flow rate has not had a significant effect on separation and offers important productivity advantages (Table 6). Other factors, such as mobile phase composition and back pressure, also affect the range of effective flow rates. For recommended flow rates, see Table 6.

Table 6: Recommended flow rates

Column diameter (configuration)	Flow rate range ml/min
16 mm (D)	5-25
20 mm (E)	5-25
27 mm (F)	10-30
37 mm (J)	20-50
40 mm (V, W, X)	20-50

12.7 Fraction Collection

12.7.1 Off-line Flash Chromatography

When performing flash chromatography on a vacuum manifold such as the FlashVac system, successive fractions can be collected as follows:

- Load collection rack with vials of a suitable volume in each position.
- Place a single flash column in position 1 of the collection rack and apply the first solvent aliquot.
- Collect the aliquot in the vial in position 1 of the collection rack.
- Move the column to position 2 and apply the second solvent aliquot.

- Collect the aliquot in the vial in position 2 of the collection rack.
- Continue until all the components of interest have been collected.

Alternatively, multiple columns can be processed by replacing collection vials at each elution step. A typical volume for each fraction is two CV.

12.7.2 On-line Flash Chromatography

Using an automated system equipped with a fraction collector, fractions can be collected in a variety of ways, for example:

- Fixed volume fraction collection.
- Individual peak fraction collection under microprocessor control with UV detector input.

12.8 Low Pressure Liquid Chromatography

In low pressure column chromatography, a column of particulate material such as silica or alumina has a solvent passed through it at atmospheric or low pressure. There are different kinds of low pressure chromatographic techniques:

i) Gel filtration chromatography (separation on the basis of size)
ii) Ion exchange chromatography (separation of the basis of charge)
iii) Affinity chromatography (separation on the basis of specific binding sites on the proteins)

12.8.1 Gel Filtration Chromatography

Proteins of different sizes are separated on a column in which the stationary phase consists of polymerized agarose or acrylamide beads with pores of particular sizes. A small protein in the mobile phase (aqueous buffered solution) can enter the pores in the beads while a large protein cannot due to size restriction. The result is that a smaller fraction of the overall volume of the column is available to the large protein than to the small protein, which thus spends a longer time on the column and is eluted by the mobile solvent after the large protein.

12.8.2 Ion Exchange Chromatography

The material used for this type of chromatography consists of an agarose, acryl amide or cellulose resin or bead which is derivatized to contain covalently linked positively or negatively charged groups. Proteins

in the mobile phase bind through electrostatic interactions to the charged groups on the column.

In a mixture of proteins, positively charged proteins bind to a resin containing negatively charged groups like carboxymethyl ($-OCH_2COO^-$) or sulfopropyl ($-OCH_2CH_2CH_2SO_3^-$), while the negatively charged proteins pass through the column. The positively charged proteins are eluted from the column with a mobile phase containing either a gradient of increasing salt concentration or a single higher salt concentration. The most positively charged proteins are eluted last, at the highest salt concentration.

Likewise, negatively charged proteins bind to a resin containing positively charged groups, like diethylaminoethyl ($-CH_2CH_2NHEt_2^+$) or a quaternary ethyl amino group. These proteins are separated in an analogous way.

12.8.3 Affinity Chromatography

In this technique, the chromatography resin is derivatized with a group that binds to a specific site on a protein of interest. It may be a group that binds to the active site of an enzyme (such as benzamidine-agarose used for the purification of trypsin) or an antibody that recognizes a specific amino acid sequence on a protein.

This method exploits the specific binding of antibody to antigen held on a solid matrix. Antigen is bound covalently to small, chemically reactive beads which are loaded in the column and the antiserum is allowed to pass over the beads. The specific antibodies bind while all other proteins in the serum including antibodies to other substances are washed away.

Affinity chromatography can also be used to purify antigens from complex mixtures by using beads coated with the specific antibody.

12.9 Conclusions

Flash chromatographic systems have been developed for the separation and purification of organic molecules from natural sources and from reaction mixtures. Method development for separations can be optimized with proper selection of adsorbents, solvent systems and flow rate of solvents used for the separation. Scale-up of flash chromatographic methods can easily be achieved with minimum optimization. Therefore, they are considered to be efficient and cost-effective methods to purify compounds in little time.

13 Counter-current Chromatography

S. K. Srivastava

Abstract

Counter-current Chromatography (CCC) is based on liquid-liquid partitioning and is an excellent alternative to circumvent the problems associated with solid phase adsorbents and to preserve the chemical integrity of mixtures subjected to fractionation. The uniqueness of this technique is that it does not use a stationary phase and separation is achieved between two immiscible liquid phases. One phase is used as a stationary phase while the other one is used as mobile phase. The separation takes place on the basis of partition of a sample between the two phases. In contrast to other chromatographic techniques, since there is no irreversible adsorption of sample on the stationary phase, recovery is up to 100%. Centrifugal Partition Chromatography (CPC) and High Speed Counter-current Chromatography (HSCCC) are the two variants of CCC being used today. Separation of compounds with a wide range of polarities is possible with the use of aqueous and non-aqueous solvent systems. Separation of crude plant extracts, semipurified fractions and synthetic mixtures can be carried out, with sample loads ranging from milligrams to grams.

13.1 Introduction

Natural products have been a key source for the discovery of new drugs. Isolation of the active components from a natural product has always been associated with complex separation problems due to the enormous chemical complexity of the extracts, but recent advances in separation sciences have facilitated the isolation of these active components from natural products.

Crude extracts of natural products which show desirable biological activity are subjected to activity-guided fractionation until an active component is isolated and identified. This exploratory process of fractionation typically involves suboptimal chromatographic conditions; hence, in order to avoid destruction of potentially labile components, utmost care must be taken throughout the entire process of isolation.

At present, most of the chromatographic separations of natural products are being carried out on solid supports. However, SiO_2, Al_2O_3 and reverse phase adsorbents are not chemically inert. Separation of a natural product on alumina or silica gel sometimes results in recovery of only 70%–90%. Sometimes severe losses of valuable materials result because of irreversible adsorption on a solid support. In addition, isolation of artifacts has also been reported due to chemical reactions of the substrates with solid phase adsorbents.

Counter-current Chromatography (CCC) is a unique form of liquid partition chromatography which utilizes a separation column free of solid support matrix. Because of this support-free system, the method provides an important advantage over other chromatographic methods by eliminating various complications such as adsorptive loss and deactivation of samples and contamination. During the 1970s, the method was steadily improved by accelerating the separation speed and efficiency. In the early 1980s, an epoch-making advance was achieved by the advent of high-speed CCC (HSCCC) which can yield highly efficient separation in a short period of time. Because of its high performance, the recent research and development of the CCC technology have been almost entirely focused on HSCCC, high performance centrifugal partition chromatography (HPCPC), and fast centrifugal partition chromatography (FCPC).

Recent developments in CCC instruments, explaining the use of CCC for better separation and their applications in the separation of bioactive natural products from plants, are discussed in this paper.

13.2 Principles and Development of Counter-current Chromatography

Anyone conversant with the technique of liquid-liquid extraction (using a separatory funnel) can readily understand the principles of Counter-current Chromatography (CCC), where separation is based on the partition of solutes between two immiscible liquid phases. In CCC, one of the two phases is retained in the column and is called the stationary phase. The second phase, which is called the mobile phase, percolates through the stationary one.

13.2.1 Liquid-liquid Extraction

Liquid-liquid extraction is a simple means of separating large quantities of materials, using a minimum of solvent. After dissolving the sample in a two-phase solvent system (in a separatory funnel), the steps in performing liquid-liquid extractions are as follows:

- Shake vigorously to thoroughly mix the two phases.
- Allow the mixture to settle into two phases.
- Separate the phases from each other.

These steps are crucial to achieve the separation of sample components.

The chief disadvantage of liquid-liquid extraction is that it provides only one plate of separation in the original sense.

Accordingly, either this single-step separation must be designed to suit one's needs, or multiple liquid-liquid extractions must be used to increase the separation.

CCC has its origin in the work of Archer John Porter Martin and Richard Laurence Millington Synge (Martin and Synge, 1941; Synge, 1946) carried out in Britain during World War II. For their pioneering work, Martin and Synge shared the 1952 Nobel Prize in Chemistry. Soon after their work appeared, Lyman Creighton Craig and Otto Post developed an apparatus that essentially consisted of a series of separatory funnels ("tubes") (Craig and Post, 1949). The sample was "automatically" transferred through the Craig-post apparatus (Figure 1). Over 1000 mixing and separation steps could be accomplished in one day.

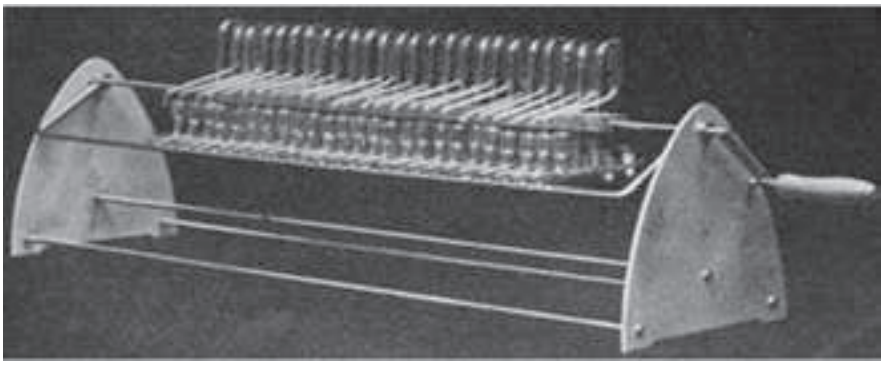

Figure 1: Craig-post apparatus

Individual components were separated based on their partitioning behavior. Craig and Post continuously improved their apparatus and were commercially quite successful. Over 1000 publications on "counter-current distribution" appeared during the period 1950-1970 citing the use of the Craig-post apparatus.

13.2.2 Partition Coefficient

For a given substance A, the partition coefficient KA is defined the concentration of A in the upper phase divided by that in the lower phase (Figure 2).

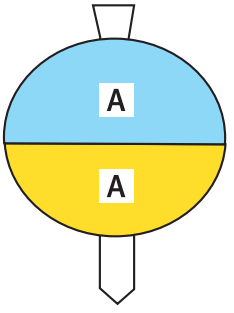

Figure 2: KA= [A] upper phase/[A] lower phase

KA is a constant at any given temperature, and it is unaffected by the presence of other substances or by the concentration of the solute. Usually it is expressed as the amount of solute in the stationary phase divided by that of the mobile phase as in conventional liquid chromatography. For a better CCC separation, the K values of the target compounds should be in the range of $0.5 \leq K \leq 1.0$. A smaller K value elutes the solute closer to the solvent front with lower resolution while a larger K value tends to give better resolution but broader, more dilute peaks due to a longer elution time. In CCC, one can choose either the upper or lower phase as the stationary phase, but before deciding which phase is to be used as the stationary phase, one should temporarily express the partition coefficient as $K_{U/L} = C_U/C_L$, where C_U is the solute concentration in the upper phase and C_L is that of the lower phase. If $K_{U/L} = 2$, the lower phase should be used as the stationary phase, which gives $K = 0.5$. It is important that this preliminary $K_{U/L}$ be clearly distinguished from K using the subscripts to avoid confusion. The measurement of $K_{U/L}$ values may be performed by the shake-flask method.

Add a small amount (a few milligrams) of each target compound (one at a time) to the two mutually equilibrated solvent phases (1–2 ml each) in a stoppered test tube (13 mm × 100 mm). Thoroughly mix to equilibrate the contents. After settling, pipette and deliver an equal volume of the upper and the lower phases (100–200 µl) each into a separate test tube, dilute each with an equal volume (2 ml) of a suitable solvent such as methanol, and measure the absorbance with a spectrophotometer at a suitable wavelength to obtain the $K_{U/L}$ value. If the pure sample is not available, one can subject each phase to HPLC analysis to compare the peak heights (or areas under the peaks). If the sample does not absorb in the UV or visible wavelengths, the $K_{U/L}$ value may be determined by other ways such as thin layer chromatography (color reaction) or evaporative light scattering detection (ELSD). Thin layer chromatography combined with densitometry is effectively used for simultaneous determination of $K_{U/L}$ of multiple components from a sample mixture.

13.2.3 Droplet Counter-current Chromatography

In the early 1970s, Ito and colleagues at the US National Institutes of Health introduced Droplet Counter-current Chromatography (DCCC). In DCCC, as with the Craig-post apparatus, the stationary phase is held in place only with unit gravity.

The apparatus consists of a set of vertical straight tubes serially connected with narrow transfer tubing (Figure 3). The original CCC apparatus was equipped with 300 glass tubes, each 60 cm × 1.8 mm i.d.

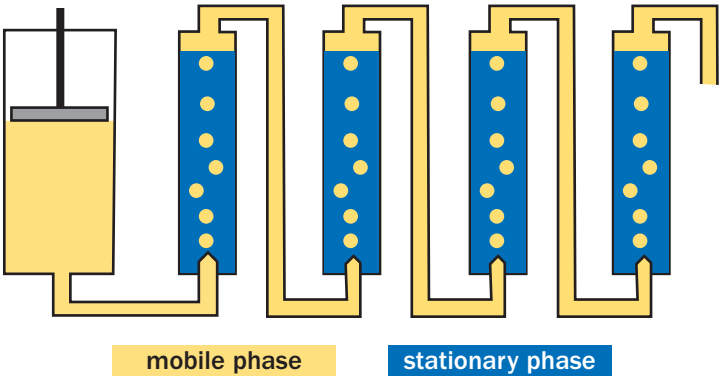

Figure 3: Droplet counter-current chromatography

The total capacity is about 600 ml including the volume in the transfer tubing (about 15% of total capacity). The operation of DCCC is initiated by filling the entire column with the stationary phase of an equilibrated two-phase solvent system followed by injection of sample solution. Then, the other phase is introduced into the first unit in such a way that the mobile phase travels through the column of the stationary phase by the effect of gravity, i.e. the mobile phase is introduced from the bottom if it is the lighter phase, and from the top if it is heavier. Consequently, the solutes are separated according to their partition coefficients. As with all types of chromatography, compounds more soluble in the mobile phase move more quickly, while those more soluble in the stationary phase lag behind. Under optimum flow rate, the mobile phase forms multiple droplets in the stationary phase to divide the column space into numerous partition units; this process is repeated in each partition unit.

DCCC necessitates a proper choice of solvent systems for producing a droplet flow of the mobile phase in the column. The most popularly used solvent system is composed of chloroform, methanol and water at various volume ratios, although a sizable separation usually takes a few days.

13.2.4 Applications of Droplet Counter-current Chromatography

This simple DCCC instrument has been used to perform efficient preparative separations such as:

- Separation of non-polar compounds.
- Isolation of virginiamycin-M1 and parthenolide.
- Isolation of vitamin B12.
- Pharmacognostical studies of *Tabernaemontana* species: ion-pair DCCC of indole alkaloids from suspension cultures.
- Chiral resolution of a carboxylic acid.
- Separation of natural polar substances by reverse phase HPLC, centrifugal thin layer chromatography and DCCC.
- Efficient isolation of ecdysteroids from the silkworm, *Bombyx mori*.
- Analytical DCCC isolation of 20-hydroxyecdysone from *Vitex thyrsiflora* (Verbenaceae).
- Increasing the speed of DCCC separations.
- Complete resolution of isoleucine.
- DCCC of anthocyanins.
- Efficient isolation of phytoecdysones from *Ajuga* plants by high-performance liquid chromatography and DCCC.
- DCCC with non-aqueous solvent systems.
- Use of DCCC in log *P* determinations.
- Purification of *Stevia rebaudiana* sweet constituents (potential sweetening agent of plant origin).
- Water-free solvent system for DCCC and its suitability for the separation of non-polar substances.
- Isolation of phorbol, 4α-phorbol and croton oil.
- Purification of antibiotics such as gramicidins, tyrocidines and tetracyclines.

13.2.5 Limitations of DCCC

- Extremely low flow rates (sometimes solute retention is measured in days).
- Only biphasic solvents systems that form stable droplets can be used.
- Poor mixing of phases, which results in relatively low efficiency.

13.2.6 Modern Counter-current Chromatography

Modern CCC has split into two basic directions. The first, which is called High-speed Counter-current Chromatography (HSCCC), uses an apparatus with a variable gravity field produced by a double axis gyratory motion (Figure 4). The second, termed Centrifugal Partition Chromatography

(CPC), employs a constant gravity field produced by a single axis rotation, together with rotatory seals for supply of solvent. Separation takes place in cartridges or disks. CPC with cartridges or disks is a hydrostatic equilibrium system. If the coil is filled with the stationary phase of a biphasic solvent system and then the other phase is pumped through the coil at a suitable speed, a point is reached at which no further displacement of the stationary phase occurs and the apparatus contains approximately 50% of each of the two phases. Steady pumping-in of mobile phase results in elution of mobile phase alone. This basic system uses only 50% of the efficient column space for actual mixing of the two phases.

A more effective way of using the column space is to rotate the coil around its central axis while eluting the mobile phase. A hydrodynamic equilibrium is rapidly established between the two phases and almost 100% of the column space can be used for their mixing. CCC with rotating coil instruments is an example of this latter mechanism.

- The planetary motion is produced by engaging a planetary gear mounted on the column holder axis to an identical stationary sun gear rigidly fixed to the centrifuge framework.
- This 1:1 gear coupling produces a particular type of planetary motion of the column holder, i.e. the holder rotates about its own axis while revolving around the centrifuge axis at the same angular velocity (synchronous) in the same direction.
- This planetary motion provides two major functions for performing CCC separation. The first is a rotary-seal-free elution system so that the mobile phase is continuously eluted through the rotating separation column.
- The second and more important function is that it produces a unique hydrodynamic motion of two solvent phases within the rotating multilayer coiled column mainly due to the Archimedean screw effect.

13.3 HSCCC Instrument and Mechanism

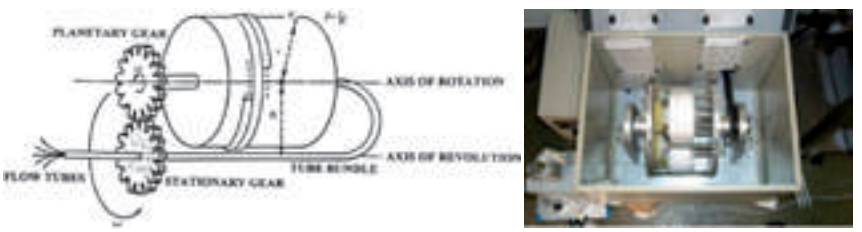

Figure 4: High speed counter-current chromatography instrument

When two immiscible solvent phases are introduced in an end-closed coiled column, the rotation separates the two phases completely

along the length of the tube where the lighter phase occupies one end (called the head) and the heavier phase occupies the other end (called the tail). Although the cause of this bilateral hydrodynamic phase distribution of two immiscible solvents is still unknown, it can be efficiently used for performing CCC. In Figure 5A the coil at the top shows bilateral hydrodynamic distribution of the two phases in the coil where the white phase (head phase) occupies the head half and the black phase (tail phase) the tail half.

This condition clearly indicates that the white phase introduced at the tail end will move toward the head and similarly the black phase introduced at the head will move toward the tail. This hydrodynamic trend is effectively used for performing CCC (Figure 5B). The coil is first entirely filled with the white phase followed by pumping the black phase from the head end (Figure 5B, top). Similarly, the coil is filled with the black phase followed by pumping the white phase from the tail (Figure 5B, bottom). In either case, the mobile phase quickly moves through the coil, leaving a large volume of the other phase stationary in the coil.

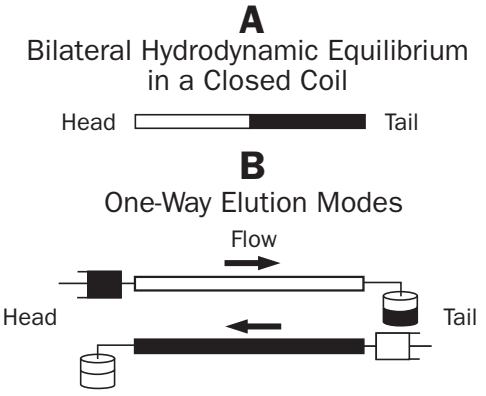

Figure 5: Mechanism of HSCCC. (A) Bilateral hydrodynamic distribution of two phases in the coiled column. (B) Elution mode of both lighter and heavier phases through the rotating coiled column.

- The motion and distribution of the two phases in the rotating coil were observed under stroboscopic illumination, and are illustrated in Figure 6A.
- A spiral column undergoes type-J planetary motion. The area in the spiral column is divided into two zones: the mixing zone occupying about one-quarter of the area near the center of revolution and the settling zone in the rest of the area.
- In Figure 6B, the spiral column is stretched and arranged according to the positions I–IV to visualize the motion of the mixing zones along the tubing.
- Each mixing zone travels through the spiral column at a rate of one round per revolution.

- The solute in the spiral column is subjected to the repetitive partition process of mixing and settling at an enormously high rate of over 13 times per second (at 800 rpm).
- HSCC is highly efficient.

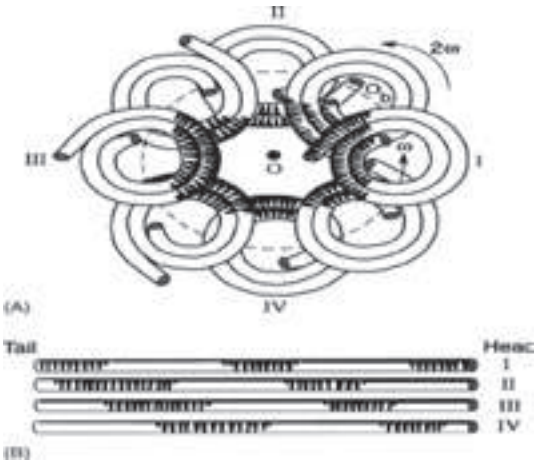

Figure 6: (A) Motion and distribution of two phases in the rotating coil under stroboscopic illumination. (B) Column in stretched position to visualize the motion of the mixing zones along the tubing.

There are numerous potential variants of this instrument design. The most significant of these is represented by the third instrument in the Pharma-tech product line: TCC-1000-toroidal CCC (Figure 7). In some respects it is like CPC, but retains the advantage of not needing rotary seals. In addition, it employs a capillary tube, instead of the larger-diameter tubes employed in the helices of the other CCC models. This capillary passage makes the mixing of two phases very thorough, despite lack of any shaking or other mixing forces.

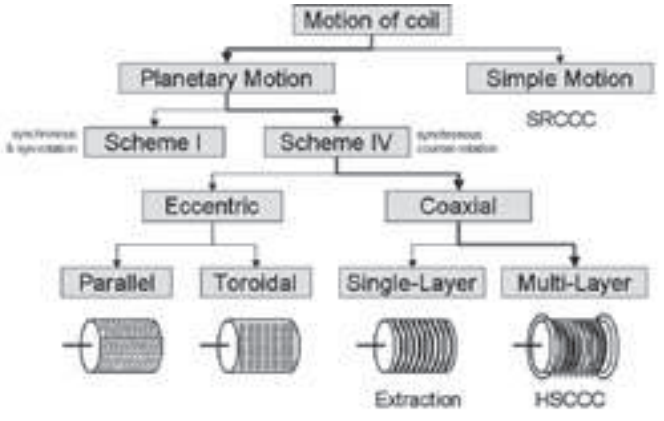

Figure 7: The TCC-1000-toroidal CCC

13.4 CPC Instrument and Setup

Figure 8: Centrifugal partition chromatography instrument

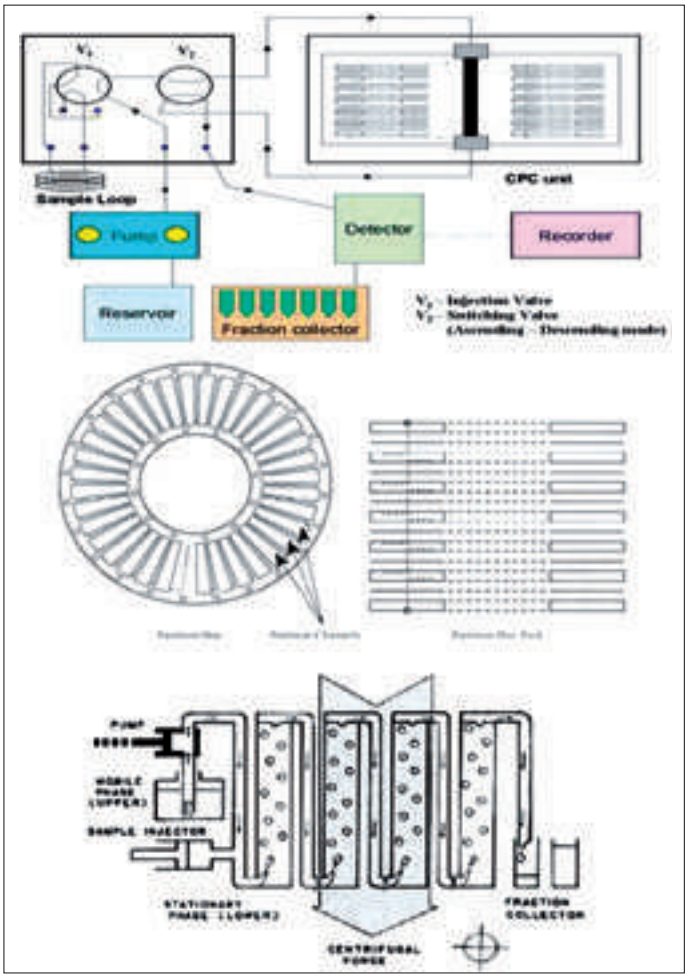

Figure 9: Centrifugal partition chromatography setup

13.4.1 Various Kinds of CPC Instruments

CPC instruments are available in various sizes depending upon

the rotor volume. As per the sample size and the purpose, one can choose on the basis of the following:

Rotor volume	Scale	Sample amount
100 ml	Analytical screening	Milligrams
200 ml	Analytical preparative	<5 g
1000 ml	Pilot scale	<40 g
5000 ml	Production scale	100–200 g
10000 ml	Production scale	200–400 g
Other volumes	On request	Up to one kilogram

13.5 How to Achieve Good Separation of Various Kinds of Natural Products Using HSCCC and CPC

In order to achieve the best separation of a desired natural product, one must systematically follow the guidelines presented in this section on choice of a solvent system.

13.5.1 Search for a Suitable Solvent System

In Table 1, sets of two-phase solvent systems are arranged from top to bottom in decreasing order of hydrophobicity in the organic phase.

Table 1: Solvent systems arranged in decreasing order of hydrophobicity in the organic phase

	n-Hexane	EtOAc	MeOH	n-BuOH	Water	
	10	0	5	0	5	↑ HYDROPHOBIC
	9	1	5	0	5	
	8	2	5	0	5	
	7	3	5	0	5	
	6	4	5	0	5	
	5	5	5	0	5	
	4	5	4	0	5	
START →	3	5	3	0	5	
HERE	2	5	2	0	5	
	1	5	1	0	5	
	0	5	0	0	5	
	0	4	0	1	5	
	0	3	0	2	5	
	0	2	0	3	5	
	0	1	0	4	5	
	0	0	0	5	5	↓ POLAR

When the polarity of the target compounds is unknown, the search may start with the two-phase solvent system composed of hexane–ethyl acetate–methanol–water at a volume ratio of 3:5:3:5, which has a moderate degree of polarity. If the partition coefficient is slightly off from the proper range, it can be adjusted by modifying the volume ratio. For example, if $K_{U/L}$ is slightly over 2, the volume ratio may be modified toward more hydrophobic such as 3.2:5:3.2:5, and if $K_{U/L}$ is slightly less than 0.5, the volume ratio may be modified in the opposite direction to 2.8:5:2.8:5.

If the target compound is mostly distributed in the upper organic phase, the search is directed upward along the arrow. If it is mostly distributed in the lower aqueous phase, the search is directed downward along the arrow. If the sample is an extract of plant material, the search may start at any point according to the polarity of the solvent used for the extraction.

If the sample is an ethyl acetate extract (relatively hydrophobic solvent), the search may start at hexane–ethyl acetate–methanol–water (1:1:1:1), whereas if the sample is a methanol extract (polar solvent), the search may start at 1-butanol–water. The search should be continued until a suitable range of $K_{U/L}$ values for all of the compounds of interest is obtained.

13.5.1.1 Solvent Systems for the Separation of a Large Variety of Natural Products

Table 2 presents different kinds of solvent systems that have been used for the separation of a large variety of natural products, which may be of immense importance for the researcher to find a suitable solvent system for the desired separation of natural products.

Table 2: Solvent systems used for the separation of natural products

Sample	Solvent system		Mobile phase
	Solvents	Ratio	
Aryl ketones			
Phenylethanone derivatives	*n*-Heptane–EtOAc–MeOH–H_2O	4:2:2:1	Lower
Styrylpyrones			
Kava lactones	*n*-Hexane–acetone–MeOH–H_2O	4:1:3:1	Upper
Benzofurans			
Dibenzofurans	*n*-Heptane–CH_2Cl_2–CH_3CN	10:3:7	Lower, upper

Sample	Solvent system		Mobile phase
	Solvents	Ratio	
Phenolic glycosides			
Gastrodin	EtOAc–1-BuOH–H_2O	3:2:5	Lower
Phenylpropanoids			
Honokiol, magnolol	*n*-Hexane–EtOAc–MeOH–H_2O	5:2:5:2	Lower
Phenylpropanoid glycosides			
Verbascoside	EtOAc–CH_3CN–H_2O	13:13:24	Lower
Acteoside	EtOAc–H_2O	1:1	Lower
Hydrolyzable tannins			
Ellagic acid and corilagin	1-BuOH–HOAc–H_2O	4:1:5	Lower
Catechins			
Epigallocatechin	*n*-Hexane–EtOAc–H_2O	1:9:10	Lower
Tea catechins	*n*-Hexane–EtOAc–MeOH–H_2O	3:10:3:10	Lower
Proanthocyanidins			
Tea proanthocyanidins	*n*-Hexane–EtOAc–MeOH–H_2O	1:5:1:5	Lower
Anthocyanins	MTBE–1-BuOH–CH_3CN–H_2O	2:2:1:5	Lower
Bilberry anthocyanins	MTBE–1-BuOH–CH_3CN–H_2O–TFA	1:4:1:5:0.01	Lower
Flavonoids			
Flavones and chalcones	$CHCl_3$–CH_2Cl_2–MeOH–H_2O	2:2:3:2	Lower
	CH_2Cl_2–MeOH–CH_3CN–H_2O	40:11:25:20	Lower
	EtOAc–1-PrOH–H_2O	140:8:80	Upper
Flavonoid glycosides	*n*-Hexane–EtOAc–MeOH–H_2O	1:8:1:8	Lower
	n-Hexane–EtOAc–MeOH–H_2O	2:12:3:15	Lower
	$CHCl_3$–MeOH–H_2O	8:7:4	Lower
C-Glycosyl flavones	$CHCl_3$–MeOH–H_2O	6:25:29	Lower
	EtOAc–1-BuOH–MeOH–H_2O	35:10:11:44	Lower
Icariin	*n*-Hexane–1-BuOH–MeOH–H_2O	1:4:2:6	Lower
Isoflavone glycosides	EtOAc–1-BuOH–EtOH–H_2O	30:10:6:50	Lower
	EtOAc–EtOH–HOAc–H_2O	16:4:1:20	Lower
Flavonol glycosides	1-BuOH–H_2O	1:1	Lower
Flavonolignans			

Sample	Solvent system		Mobile phase
	Solvents	Ratio	
Silymarin	*n*-Hexane–EtOAc–MeOH–H_2O	1:4:3:4	Lower
Lignans			
Arctiin	EtOAc–1-BuOH–EtOH–H_2O	10:1:2:10	Lower
Lignan diglucoside	MTBE–1-BuOH–CH_3CN–H_2O	1:3:1:5	Upper
Coumarins			
Psoralen and isopsoralen	*n*-Hexane–EtOAc–MeOH–H_2O	10:7:10:8	Lower
Inflacoumarin A	*n*-Hexane–$CHCl_3$–MeOH–H_2O	5:6:3:2	Lower
Chalcones			
Licochalcone A	*n*-Hexane–$CHCl_3$–MeOH–H_2O	3:12:6:4	Lower
Quinones			
Tanshinones	*n*-Hexane–EtOH–H_2O	(a) 20:11:9 (b) 10:7:3	Lower
Shikonin	*n*-Hexane–EtOAc–EtOH–H_2O	16:14:14:5	Lower
Diterpene quinone	*n*-Hexane–CCl_4–MeOH–H_2O	1:3:3:2	Lower
Monoterpenes			
Monoterpenes and monoterpene glycosides	$CHCl_3$–MeOH–H_2O	7:13:8	Upper
Iridoid glycosides	$CHCl_3$–MeOH–1-PrOH–H_2O	5:6:1:4	Lower
Sesquiterpenes			
Artemisinine, artemisitene arteannuin B	*n*-Hexane–EtOAc–EtOH–H_2O	6:4:5:4	Lower
Diterpenes			
10-Deacetylbaccatin III	*n*-Hexane–EtOAc–EtOH–H_2O	2:5:2:5	Lower
	n-hexane–$CHCl_3$–MeOH–H_2O	5:25:34:20	Lower
Trachylobanes and isopimaranes	*n*-Heptane–CH_3CN–CH_2Cl_2	10:7:3	Lower
Triterpenes			
Celastrol	*n*-Hexane–EtOAc–CCl_4–MeOH–H_2O	1:1:8:6:1	Lower
Saponins			
Ginsenosides	$CHCl_3$–MeOH–2-BuOH–H_2O	5:6:1:4	Lower
	EtOAc–1-BuOH–H_2O	1:1:2	Upper

Sample	Solvent system		Mobile phase
	Solvents	Ratio	
	n-Hexane–1-BuOH–H_2O	3:4:7	Lower
Phytolacca saponins	$CHCl_3$–MeOH–2-PrOH–H_2O	5:6:1:4	Lower
Glycyrrhizin	EtOAc–MeOH–H_2O	5:2:5	Lower
Carotenoids			
Zeaxanthin	*n*-Hexane–EtOAc–EtOH–H_2O	8:2:7:3	Lower
Lycopene	*n*-Hexane–CH_3CN–CH_2Cl_2	20:13:7	Upper
Alkaloids			
Aporphine alkaloids	CH_2Cl_2–MeOH–5% HOAc	5:5:3	Lower
Naphthylisoquinoline alkaloids	$CHCl_3$–EtOAc–MeOH–0.1 M HCl	5:3:5:3	Lower
Diterpene alkaloids	*n*-Hexane–CH_2Cl_2–MeOH–H_2O	15:15:24:8	Lower
	C_6H_6–$CHCl_3$–MeOH–H_2O	5:5:7:2	Lower
Tetramethylpyrazines			
Chuanxiongzine	*n*-Hexane–EtOAc–EtOH–H_2O	5:5:3:7	Lower
Glucosinolates	PrOH–CH_3CN–$(NH_4)_2SO_4$–H_2O	10:5:12:10	Upper
Cyclodepsipeptides	*n*-Heptane–EtOAc–MeOH–H_2O	2:8:2:8	Lower

13.5.1.2 Retention of the Stationary Phase

- Successful separation in HSCCC-CPC largely depends on the amount of the stationary phase retained in the column. In general, higher the retention of stationary phase, better the peak resolution.
- The amount of stationary phase retained in the column is highly correlated with the settling time of the two phases in a test tube.
- Measure the settling time of the two-phase solvent system to be used for the separation.
- The procedure is as follows: the two phases are first equilibrated in a separatory funnel. Deliver 2 ml of each phase, a total volume of 4 ml, into a test tube or graduated cylinder, which is then capped. Gently invert the container for several times and then immediately place it in an upright position to measure the time required for the two phases to form clear layers with a distinct interface.
- If the settling time is less than 20 seconds, the solvent system will provide satisfactory retention of the stationary phase, usually over 50% of the total column capacity, in a proper range of flow rates.

13.5.1.3 Preparation of Sample Solution

- The sample for HSCCC-CPC may be dissolved directly in the stationary phase or in a mixture of the two phases.
- The recommended sample volume is less than 5% of the total column capacity.
- Introduction of a larger sample volume into the column will reduce peak resolution of the analytes, especially for those having small *K* values.
- Ideally the analyte is injected in a small volume of the stationary phase to preserve the sharpness of the early elution peak.

13.5.1.4 Separation Column

- We must understand the head–tail orientation of the separation column.
- A lower (heavier) mobile phase should be introduced through the head toward the tail, and an upper (lighter) mobile phase in the opposite direction.
- This is extremely important because the elution of either phase in the wrong direction results in an almost complete loss of the stationary phase from the column.

13.5.1.5 Choice of the Mobile Phase

- In HSCCC-CPC, either phase can be used as the mobile phase provided that the *K* value of the analyte is in a proper range.
- If one has a choice, the lower phase may be used as the mobile phase, because the system provides more stable retention of the stationary phase and one can avoid trapping air bubbles in the flow cell of the detector by introducing the effluent from the lower end of the cell.
- On the other hand, when the upper organic mobile phase (excluding the chloroform system) is used as the mobile phase, it will facilitate the evaporation of solvent from the collected fractions.

13.5.1.6 Flow Rate of the Mobile Phase

- The flow rate of the mobile phase determines the separation time, the amount of stationary phase retained in the column, and therefore the *peak resolution*.
- A lower flow rate usually gives higher retention level of the stationary phase and improves the peak resolution, although it requires a longer separation time.
- The typical flow rates for the commercial multilayer coil are as follows:
  i) 5–6 ml/min for a preparative column with 2.6 mm i.d. PTFE tubing (600–800 rpm) (up to 1 g sample load);

ii) 2–3 ml/min for a semi preparative column with 1.6 mm i.d. PTFE tubing (800–1000 rpm) (up to 500 mg sample load);
iii) 1 ml/min for an analytical column with 0.85–1.0 mm i.d. PTFE tubing (1000–1200 rpm) (up to 50 mg sample load).

- These flow rates should be modified according to the settling time of the two-phase solvent system as well as other factors. When the settling time is around 20 s and the *K* value of the analyte is small, a lower flow rate is recommended.

13.5.1.7 Revolution Speed

The optimum revolution speed (revolution and planetary rotation speeds are always same) for the commercial HSCCC-CPC instrument for preparative separation ranges between 600 and 1400 rpm.

- Use of a lower speed will reduce the volume of the stationary phase retained in the column, leading to lower peak resolution.
- On the other hand, the higher speeds may produce excessive sample band broadening by violent pulsation of the column because of elevated pressure.

13.5.1.8 Filling the Column with the Stationary Phase

- In each separation, the column is first entirely filled with the stationary phase.
- Before introducing the stationary phase, the column may be flushed with a column volume of a solvent miscible with the two phases used in the previous run (e.g. ethanol or methanol) to wash out materials remaining in the column.
- This will also ensure a stable, clean baseline before the solvent front emerges.
- Avoid trapping the air in the column, especially in a preparative column. This can be easily tested as:
  i) If no air is present in the column, the flow from the column outlet is ceased shortly after stopping the pumping.
  ii) If the solvent keeps flowing from the outlet for more than several seconds, the air trapped in the column should be eliminated by resuming the pumping of the stationary phase under low speed column rotation (100–200 rpm) in a tail to head elution mode to accelerate air movement toward the outlet of the column.

13.5.1.9 Sample Loading

There are two ways to load samples; both are satisfactory for HSCCC-CPC separations:

- In the first method, the column is entirely filled with stationary phase and this is immediately followed by sample injection.

- The mobile phase is then eluted through the column while the column is rotated at the optimum rate.
- In the second method, after the column is filled with stationary phase, the mobile phase is eluted through the column at a desired rate until the solvent front emerges and hydrodynamic equilibrium is established throughout the column as evidenced by diminished carryover of the stationary phase.
- The sample is then injected into the column through the sample port.

Each method has advantages. The second method gives a clear tracing of the elution curve because of the minimum carryover of the stationary phase from the column.

The first method produces a distinct solvent front and saves separation time by eliminating the waiting period to reach hydrodynamic equilibrium.

One can conveniently use an injection valve with a sample loop as in HPLC.

13.5.1.10 On-line Monitoring of Effluent

- The effluent from the outlet of the HSCCC-CPC columns may be continuously monitored by a UV–VIS detector as in conventional liquid chromatography.
- An important difference between these two methods is that HSCCC-CPC uses the liquid stationary phase which, if carried over from the column, tends to disturb the tracing of the elution curve.
- Avoid trapping the stationary phase in the vertical flow cell by eluting the lower mobile phase upward from the bottom; do the reverse if the upper is used as the mobile phase.
- When the upper mobile phase is eluted from the top of the flow cell downward, it is important to prevent the formation of air bubbles which may become trapped in the flow cell and disturb the tracing of the elution curve.
- Bubble formation can be largely avoided by degassing the two phases in the separatory funnel before use, and also by connecting fine PTFE tubing (typically 30 cm × 0.4–0.5 mm i.d.) to the outlet of the monitor so that the pressure within the flow cell is substantially increased.

13.5.1.11 Measurement of Stationary Phase Retention

- When the separation is completed, rotation is stopped and the column contents are collected into a graduated cylinder by connecting the column inlet to a nitrogen cylinder (ca. 50 psi; 1 psi = 6894.76 Pa).

- After nitrogen appears at the outlet, the column is slowly rotated (100 rpm) in the tail to head elution mode so that solvent remaining inside the column is pumped out by an Archimedean screw force assisted by the nitrogen flow. Measure the retained stationary phase in a graduated cylinder.
- Measurement of the retained stationary phase is useful in efforts to improve the separation: when the peak resolution is unsatisfactory, a measure of stationary phase retention will serve as a guide for the next trial.
- If it is less than 30%, the separation may be improved by increasing retention, by applying a lower flow rate of the mobile phase, increasing the revolution speed, or modifying the solvent system to shorten the settling time.
- If instead the stationary phase retention is over 50%, efforts should be directed to search for a new two-phase solvent system, which provides an improved separation factor (α) between the analytes.

13.5.2 Applications of HSCCC-CPC Technologies in Natural Products Isolation

HSCCC-CPC technologies have applications in the following industries: nutraceuticals, fine chemicals, pharmaceuticals, biomedical, biotechnology, fats and oils, and fermentation.

Compounds that can be isolated in high purity by HSCCC-CPC technologies include: saponins, alkaloids, chlorophylls, tannins, carotenoids, phospholipids, fat-soluble vitamins, mono- and oligosaccharides, anthocyanins, lignans, phenolic compounds, synthetic compounds, other active compounds present in medicinal and aromatic plants (e.g. herbs and spices) and much more. The numerous applications of CCC have resulted in a growth in the annual number of publications in which this separation technology has been cited (Figure 10).

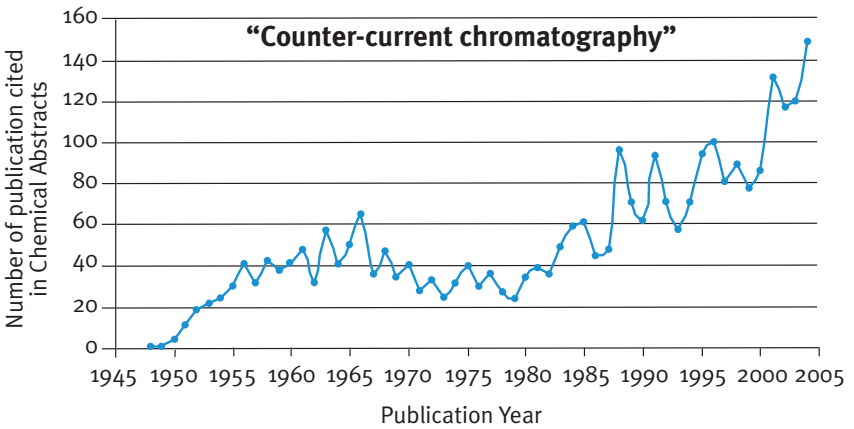

Figure 10: Increasing number of publications on separation by CCC

Examples of some important natural products that have been separated using HSCCC-CPC in the recent past are summarized herein.

13.5.2.1 Purification of Coenzyme Q_{10} from Fermentation Extract: HSCCC versus Silica Gel Column Chromatography

HSCCC was applied to the purification of coenzyme Q_{10} (CoQ_{10}) for the first time. CoQ_{10} was obtained from a fermentation broth extract. A non-aqueous two-phase solvent system composed of heptane–acetonitrile–dichloromethane (12:7:3.5, v/v/v) was selected by analytical HSCCC and used for purification of CoQ_{10} from 500 mg crude extract. The separation yielded 130 mg CoQ_{10} at an HPLC purity of over 99%. The results showed the advantages of HSCCC over an alternative of silica gel chromatography followed by recrystallization. These advantages regard purity, recovery and yield (Table 3).

Table 3: Purification of coenzyme Q_{10} from fermentation extract: HSCCC vs. silica gel column chromatography with subsequent crystallization

	Crude extract	CoQ_{10} purified by silica gel chromatography	CoQ_{10} purified by HSCCC
HPLC purity, %	89.2	96.0	99.2
Absolute purity, %	29.4	93.3	97.8
Recovery, %*	–	74.3	88.0
Yield, %*	–	23.4	26.4

* *Recovery, amount of CoQ_{10} in purified product/amount of CoQ_{10} in crude extract. Yield,amount of purified product/amount of crude extract (Journal of Chromatography A 1127 (1-2), 15 September 2006, 92-96)*

13.5.2.2 Preparative Separation of Gambogic Acid and its C-2 Epimer by HPCCC

For the preparative separation of epimers, gambogic acid and epigambogic acid, from *Garcinia hanburyi,* a two-phase solvent system composed of *n*-hexane–methanol–water (5:4:1, v/v/v) was used. From 50 mg mixture, 28.2 mg gambogic acid and 18.4 mg epigambogic acid were separated. The purities of both were above 97% as determined by HPLC. The chemical structures were then identified by their ^{1}H NMR and ^{13}C NMR spectra.

13.5.2.3 Separation and Purification of 10-deacetylbaccatin III by HSCCC

At present, the most promising approach is the semisynthesis of paclitaxel or its analogs from 10-deacetylbaccatin III, a compound available in a relatively high quantity from the foliage of several yew species. HSCCC was used for the separation and purification of 10-deacetylbaccatin III (Figure 11). A crude needle extract (500 mg/5 ml) from Chinese yew (*Taxus chinensis*) was

first separated with a two-phase solvent system composed of *n*-hexane–ethyl acetate–ethanol–water (2:5:2:5, v/v). The partially purified fraction was again purified with a different solvent system composed of *n*-hexane–chloroform–methanol–water (5:25:34:20, v/v). HPLC analysis of the final fraction showed that the purity of 10-deacetylbaccatin (20 mg) was over 98%.

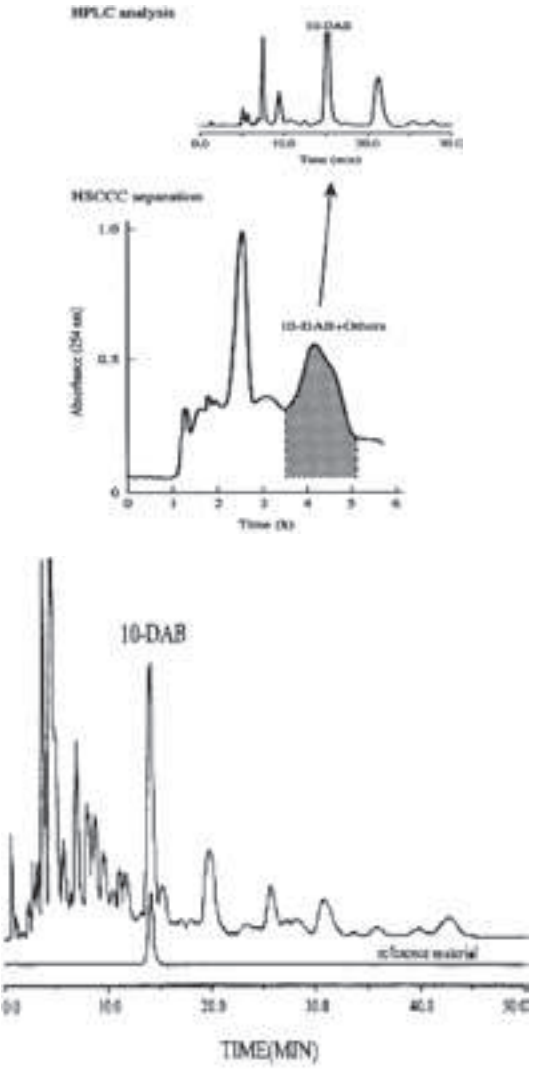

Figure 11: Separation and purification of 10-deacetylbaccatin III (DAB) by HSCCC

13.5.2.4 Large-scale Separation of Resveratrol and Anthraglycoside A and B from *Polygonum cuspidatum* by HSCCC

HSCCC was successfully applied to the large-scale (5 g) separation of resveratrol, anthraglycoside A and anthraglycoside B from a crude extract of *Polygonum cuspidatum* Sieb. et Zucc (Figure 12). A two-phase solvent system composed of chloroform, methanol and water (4:3:2, v/v) was used. The separation yielded 200 mg to 1 g of these three compounds, each at over 98% purity as determined by HPLC. Resveratrol is important as it has a cancer chemopreventive activity.

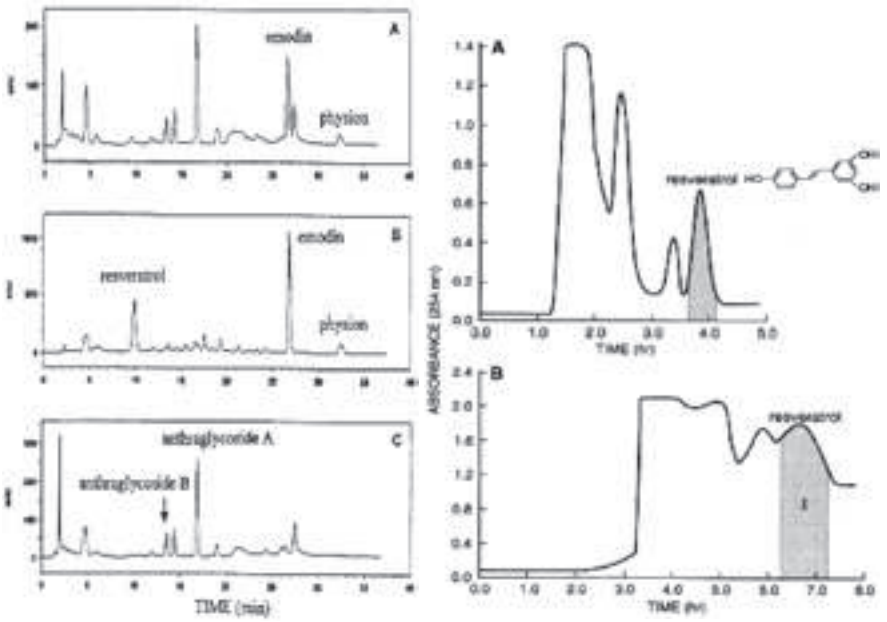

Figure 12: Separation of resveratrol, anthraglycoside A and anthraglycoside B from a crude extract of Polygonum cuspidatum Sieb. et Zucc

13.5.2.5 Separation of Andrographolide and Neoandrographolide from the Leaves of *Andrographis paniculata* using HSCCC

The bioactive diterpenes andrographolide and neoandrographolide from the leaves of *Andrographis paniculata* NEES (Acanthaceae) were successfully separated by CCC (Figure 13). A single 280-min separation yielded 189 mg of 99.9% andrographolide and 9.5 mg of 98.5% neoandrographolide. Water–methanol–ethyl acetate–*n*-hexane (2.5:2.5:4:1) solvent system was used.

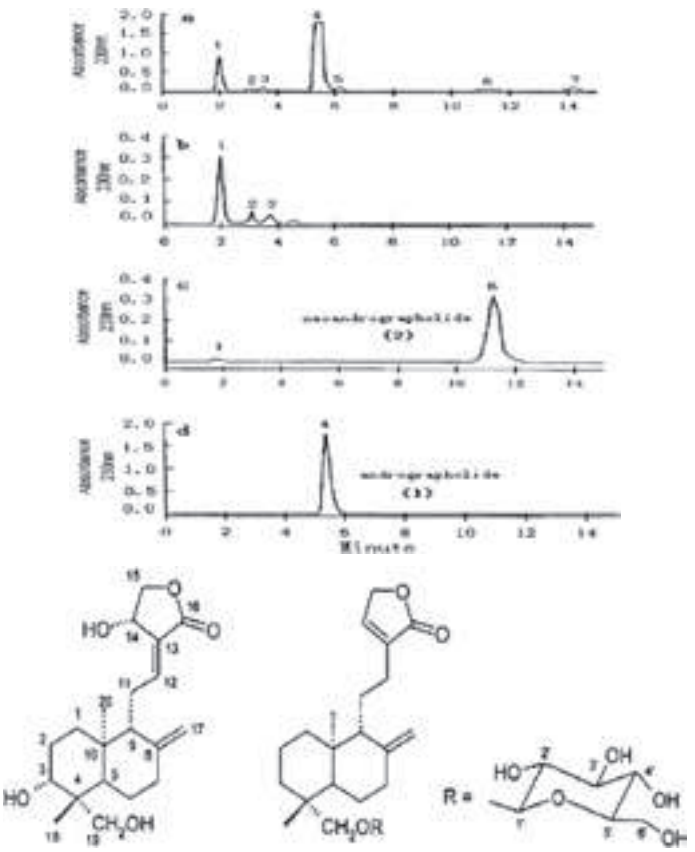

Figure 13: Separation of Andrographolide and Neoandrographolide from the leaves of Andrographis paniculata using HSCCC

13.5.2.6 Separation of WAP-8294A Components, a Novel Anti-methicillin-resistant *Staphylococcus aureus* Antibiotic, using HSCCC

The WAP-8294A complex was isolated from the fermentation broth of *Lysobacter* sp. WAP-8294 (Figure 14). The major component, WAP-8294A2, shows strong activity against gram-positive bacteria including methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococci* in vitro, and also exhibited a potent activity against MRSA in vivo.

The previous separations were unsatisfactory. Hence HSCCC was applied. *n*-Butanol–ethyl acetate–aqueous 0.005 *M* trifluoroacetic acid (1.25:3.75:5, v/v/v) was used as biphasic solvent. A sample size of 25 mg yielded pure fractions of three components (1–6 mg). The method will contribute to the clinical development of WAP-8294A2 as an anti-MRSA agent.

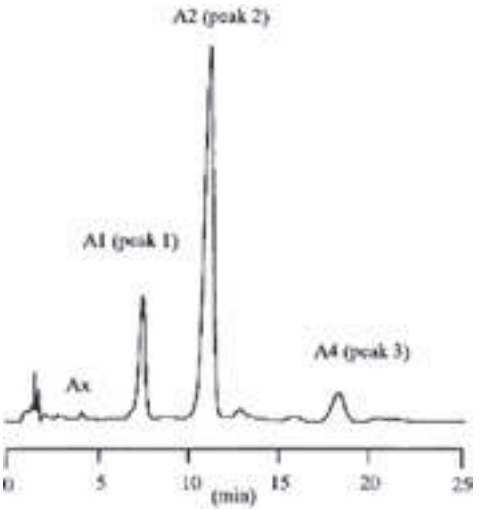

Figure 14: Separation of WAP-8294A components using HSCCC

13.5.2.7 Other Examples of Separation of Phytoconstituents by CCC

Apart from the previously mentioned examples, isolation and purification of polymethoxylated flavones from tangerine peel, catechin constituents from five tea cultivars, rupestonic acid from the Chinese medicinal plant *Artemisia rupestris* L., lycopene from tomato paste, spiramycin, gallic acid from *Cornus officinalis*, lutein from the microalga *Chlorella vulgaris*, naphthopyranone glycosides, salvianolic acid B from the Chinese medicinal plant *Salvia miltiorrhiza*, dammarane saponins from *Panax notoginseng*, isoflavan and pterocarpan glycosides from *Astragalus membranaceus* Bge. var. *mongholicus* (Bge.), glycyrrhizin from the root of liquorice and active principles from the roots of *Sophora flavescens* have been carried out successfully using HSCCC.

13.6 Advantages of CCC

- Quick (high throughput in preparative separation).
- Inexpensive (only solvent costs, which are 5 times less than for other LC techniques).
- Gentle and versatile, for separation of varied compounds, with less chance of decomposition.
- Able to resolve from milligrams to tens of grams on the same instrument.
- Able to switch between normal and reverse phase at will.
- A CCC machine, which is a chromatographic column with a liquid stationary phase, can be used as a liquid–liquid reactor for chemical reactions involving a liquid catalyst.

- No irreversible adsorption to a solid support (100% recovery of sample).
- Increased capacity for the same volume of stationary phase; a CPC column gives a higher capacity than the HPLC one.
- Quantity of sample depends on two factors: solubility of the sample and properties of the solvent system.
- No sample loss as a simple rinsing of the instrument allows a full recovery of the noneluted fractions.
- Easy maintenance, no costly solid phase to change.
- No degradation or denaturation of compounds and no interaction with silica.
- No polarity restriction; all biphasic mixtures can be used.
- Dual mode (off-line and on-line) exchange of stationary and mobile phase (CPC).

13.6.1 Advantages of HSCCC-CPC Technologies over HPLC

HSCCC-CPC	HPLC
No column	Expensive columns
High recovery	Irreversible adsorption
High throughput	Poor loadability
Retention of fragile compounds (molecular integrity)	Loss of biological activity (denaturation)
Volume ratio of stationary/ mobile very high (better resolution)	Ratio is low

13.7 Manufacturers of CCC Instruments

13.7.1 Manufacturers of HSCCC Machines

- AECS (http://www.ccc4labprep.com/)
- Conway Centri Chrom (http://www.centrichrom.com/)
- Dynamic Extractions (http://www.dynamicextractions.com/)
- Pharma-tech Research Corporation (http://www.pharma-tech.com/)

13.7.2 Manufacturers of CPC Machines

- EverSeiko Corporation (http://www.everseiko.co.jp)
- Kromaton Technologies (http://www.kromaton.com/)
- Partus Technologies (http://www.partus-technologies.com)

13.8 Selected Reviews on CCC

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- Jarvis, 1992, Macrocyclic Trichothecenes from Brazilian Baccarin Species: From Microanalysis to Large-scale Isolation, *Phytochemical Analysis;* 3: 241-249
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13.9 Conclusions

Counter-current Chromatography is an excellent alternative to circumvent the problems associated with solid-phase adsorbents and to preserve the chemical integrity of mixtures subjected to fractionation. It provides efficient resolution of samples by a mechanism which relies solely on partition. Separation of compounds with a wide range of polarities can be achieved with the use of aqueous and non-aqueous solvent systems. CCC is very flexible: solvent gradients are possible; flow rates can be varied during a chromatographic run; lower and upper phases can be interchanged as mobile phases during a separation, provided that the flow direction is also changed accordingly; and instruments can be stopped during chromatography and re-started hours later without affecting separation efficiency. A wide range of pH is tolerated in CCC, with implications in the separation of acidic and basic samples, notably in the technique of pH-zone-refining. Separation of crude plant extracts, semipurified fractions or synthetic mixtures can be carried out, with samples of any quantity ranging from 100 mg to 1500 g (for the largest model). With these advantages, CCC is gaining popularity as a separation method for natural products, and especially in the bioassay-guided fractionation of natural products.

14 Quality Control of Medicinal and Aromatic Plants and their Extracted Products by HPLC and High Performance Thin Layer Chromatography

K. Vasisht

Abstract

The interest in medicinal plants and their products has increased manifold in recent years. The increasing public demand for natural medicines has resulted in increased commercial activity and production of these medicines. There is also increasing concern for ensuring quality and safety of plant medicines. Plant drugs, unlike active pharmaceutical ingredients, possess some inherent limitations which deter the process of laying standards for these drugs. This aspect has received considerable attention from different quarters including policy planners, scientists and manufacturers. This paper describes briefly the roles of high performance thin layer chromatography and high performance liquid chromatography in quality assurance of plant products. Some practical aspects of these techniques are also discussed.

14.1 Introduction

The use of medicinal plants products has increased several fold during the last decades. Individual countries are also giving increasing emphasis to promote their use under the direction of the World Health Organization (WHO). Besides this, one finds enormous interest in natural products from the public, which is attributable to several factors. These medicines are affordable, safer and better tolerated by the biological system. This has led to an increased consumption and cross-country movement of raw materials of medicinal plants.

In some parts of the world, e.g. several places in Africa and Asia, traditional medicines are the only affordable option. On the other hand, the same medicines are the option of choice in developed nations like Japan and the United States and in the European States. Despite being the more common medical option in Africa, use of traditional medicines has not matured to the expected level. But, some countries in Asia, especially India and China, have developed them to a level that has benefited all countries of the world.

Europe did not inherit a well-developed traditional system of medicine but it has put in place the strongest evidence-based and scientifically supported system of plant medicines. North America is the most prolific and flamboyant market for plant products, but government regulations are such that except for select plant drugs most are used as dietary supplements or

nutraceuticals. South America, which has given the world some of the all-time great plant medicines like quinine and pilocarpine, follows the medical system of North America. Australia has a strong impact from Chinese medicines on the continent which is otherwise dominated by the modern system of medicine.

14.2 Quality Control of Medicinal Plants and their Products

The quality control of consumer products has become more challenging and demanding. The quality considerations of drugs are the most stringent among all consumer products. The purity of active pharmaceutical ingredients has been stretched to an all-time high with more and more restrictions on the level of the impurities. The situation is opposingly different in the case of plant-derived medicine, where we are still striving to define specifications to ensure consistency and safety. Therefore, the standards of plant drugs are more relaxed and are in the process of development. The inherent problems of plant drugs are obvious; unlike single chemical entities of modern drugs, they are combinations of infinite chemical molecules, known and unknown; the knowledge of the active components is incomplete; the natural variations in content and quantity of the chemical constituents are large and exercising a precise control is impractical; and the complete chemical profiling of plant drugs is beyond scope. Therefore, laying standards for such drugs is not an easy task and a comprehensive system of standards cannot be laid down for such drugs. As our knowledge of plant drugs will advance, the standards for them will become more meaningful and complete.

The quality issue of plant drugs was irrelevant in ancient times when these medicines were dispensed by the medical men for their patients. However, the issue has taken front seat with the commercialization of plant drugs. The matter has been further complicated by the vested interest of manufacturers who are out to exploit the loopholes in the standards and laws governing the production and distribution of plant drugs.

Several national and international agencies have prioritized the issue of assuring the quality of plant drugs. The effort of the World Health Organization is outstanding: over 20 years ago it first published *Quality control methods for medicinal plant materials*, which has been regularly updated and followed by a series of monographs on globally important medicinal plants.

The quality of a plant product cannot be assured without assuring the quality of the raw material. Also required to ensure quality products are in-process control, quality control of the finished product, good manufacturing practice (GMP) controls and process validation. In this regard, it is imperative to define specifications of raw materials to minimize variations in the quality of finished products and to achieve consistency. The specifica-

tions of plant materials include macro- and microscopic descriptions, tests of identity, and analytical and physicochemical determinations. The expected results of these tests and measurements are presented as numerical limits or as a range or discretely observable result.

While fixing the limits of specifications, naturally met variations in plant drugs need to be accommodated. A plant material conforming to the prescribed specifications should be considered acceptable for intended use. Several factors contribute to variation in the content and composition of raw materials. These factors can broadly be grouped in four categories of climatic, nutritional, collection and post-harvest factors. Climatic factors include prevailing temperature, rainfall, humidity, daylight and altitude of the growing region. The nutritional factors are those which affect the health of a growing plant and are reflected in the production of biomass and its composition; several soil factors such as availability of micro- and macronutrients, pH and cation exchange capacity are important for optimal growth of plants. Collection factors control the content of active components by giving due attention to the age, season, collection time and part of the plant collected. Post-harvest factors are important as the collected material is still live and carries out metabolic processes and respires; the enzymatic processes continue after collection until they are deactivated by drying or other suitable treatment; the crushing and cutting of material leads to de-compartmentalization of reactive chemical constituents of plants which were naturally located in intact cells; and the collected material faces direct impact of oxidation by air and light besides physical loss of some components.

The World Health Organization, in its volume *Quality control methods for medicinal plant materials,* has listed several parameters which are valuable in assuring quality of plant drugs. These include identification, visual inspection, sensory characters, macro- and microscopic characteristics, moisture content, foreign matter, fingerprint by thin layer chromatography (TLC), ash values, extractive values, volatile matter, microbial load, heavy metals and pesticide residues, radioactive contaminants and, according to the nature of the drug, one or more determinations for bitter value, tanning test, foaming, hemolytic and swelling indices. The European Medicines Agency's "Guideline on quality of herbal medicinal products" and "Guideline on specifications" more precisely describe the quality-related issues of medicinal plants. These documents define and differentiate herbal substances (equivalent to herbal drugs), herbal preparations (equivalent to herbal drug preparations) and herbal medicinal products (equivalent to traditional herbal medicinal products). The guidelines emphasize the quantification of active or analytical markers and describe procedures to ensure quality of raw material, semifinished and finished products.

14.3 Biological and Chemical Standardization of Drugs

All test procedures ultimately aim to determine the intrinsic potency of a drug, which is attributable to the chemical constituents present. Evaluating the biological potency of a drug provides a direct assessment of its quality. But, the complexity of the procedures and methods forbids implying this assessment. Moreover, it is not the practical option when one handles large numbers of samples. The other option, besides biological testing, is chemical testing, which uses assay procedures to determine the quantity of chemical compounds, preferably the active ones, to assess the quality of a product. This is complementary to recording other specifications like macro- and microscopic characteristics.

14.3.1 Chemical Standardization and Markers

Chemical standardization requires first to identify and select a chemical constituent of a drug and then to elaborate the assay procedure for quantification of the chosen compound. Selection of the constituent, called marker, is a difficult task based on several considerations: the chemical profile of the drug, biological activity of the chemical constituents, successful development of the assay procedure, ease of procuring or isolating the marker, and stability of the marker.

The European Union Guidelines define markers as “Chemically defined constituents or groups of constituents of a herbal substance, a herbal preparation or a herbal medicinal product which are of interest for control purposes independent of whether they have any therapeutic activity.” The WHO defines markers as “constituents of a medicinal plant material which are chemically defined and of interest for control purposes.”

Markers serve to calculate the quantity of herbal substances or herbal preparations in the herbal medicinal product if the marker has been quantitatively determined in the herbal substance or herbal preparations. The European Medicines Agency differentiates an active marker from an analytical marker: an active marker contributes to the therapeutic activity of the drug, whereas an analytical marker serves only the analytical purposes.

The choice of a marker, in first place, should be for a chemical constituent of the drug responsible for the activity. More than one marker can be employed for control purposes, separately or in combination. A second choice of marker is for a defined chemical constituent that is uniquely associated with the drug. This is true when active constituents of the drug are not known or active constituents are unobtainable or unstable for assay purposes. As a last choice, a marker can be selected among more commonly or ubiquitously present phytoconstituents. In rare cases, a chemical compound

not associated with the plant or its activity can also be used as a marker. Such chemical compounds allow the estimation of an active constituent of the plant, which itself is unstable and unfit for the purpose of analysis. For example, dantron is recommended by the European Pharmacopoeia for the estimation of valerenic and acetoxyvalerenic acids in valerian root. Valerenic and acetoxyvalerenic acids, which are active constituents of drugs, are highly unstable and difficult to isolate and to use as markers. The test response measured for these acids in the drug is interpreted from the standard plot of dantron to calculate the concentration of valerenic and acetoxyvalerenic acids in the test solutions. It has been experimentally shown that the standard curves of dantron and these two acids, in the range of estimation, are linear and parallel.

Identification of a marker requires knowledge of the chemical and active constituents of the plant drug. Markers are usually generated in-house and a limited number of markers are commercially available from different sources. Sigma Chemicals, Chromadex, Regional Research Laboratory (Jammu) and Natural Remedies (Bangalore) are some commercial sources of markers.

14.3.2 Analytical Techniques for Quantifying a Marker

After a marker has been identified, it needs to be quantified or assayed in the test material for the purpose of quality control. Any of the major analytical techniques, including high performance liquid chromatography (HPLC), high performance thin layer chromatography (HPTLC), gas chromatography (GC), radioimmunoassay, ultraviolet or infrared spectrometry, and mass spectrometry, can be used to determine the quantities of marker in the test samples. These techniques possess some advantages and disadvantages. Some are more commonly used while the others have limited applications. The assay method requires the procedure and technique to be simple, quick, specific, economical and robust. The ideal method can be used in different laboratories across the world without compromising on the accuracy and precision, which is possible if the procedure has a minimum number of critical variables. Whenever possible, the assay procedure should use simple, inexpensive equipment which is affordable in most places. The assay methods are developed through experimentation and from the existing knowledge of the drug and of techniques.

14.3.3 Validation of Analytical Procedures

Development of the assay method is followed by its validation. The validation procedure considers issues of specificity, linearity, range, accuracy, precision, detection limit, quantitation limit, robustness and system suitability. The International Conference on Harmonisation (ICH) has issued guidelines on validating analytical procedures, which are widely accepted and commonly used. Besides validation of a procedure, the instruments

used are also validated from time to time. Practically all manufacturers of modern equipment supply detailed instructions and methods of equipment validation. The validation record is maintained and, in case a deviation is observed, a service engineer is called.

The ICH guidelines on validation are available from the internet for comprehensive understanding of the subject. A brief explanation to the validation procedure is provided here.

14.3.3.1 Specificity

Specificity indicates the extent to which an assay procedure specifically measures the analyte of interest. It is not always possible to demonstrate that an analytical procedure is specific for a particular analyte (complete discrimination). It may require two or more assay procedures to demonstrate the necessary level of discrimination. Spiking the sample with the analyte or related compounds and observing the effect on the estimations demonstrates assay specificity. If spiking with compounds related to the analyte produces no effect on the result, the procedure is considered specific. Specificity is particularly valuable when analyzing an analyte among several similar compounds present in the sample.

The issue of specificity with respect to herbal materials has lesser relevance as in several instances; we tend to determine the content of total active compounds rather than one active constituent, e.g. total sennosides in senna and not a particular sennoside. In such cases, a procedure that is able to assay all sennosides together is preferred than a specific procedure which discriminates and estimates only one sennoside.

14.3.3.2 Linearity

The linearity of an analytical procedure is its ability (within a given range) to obtain test results which are directly proportional to the concentration (amount) of the analyte in the sample. A linear relationship (between amount of analyte and response) should be demonstrated across the range used in the assay procedure. A minimum of 5 concentrations is recommended. A regression line, using appropriate statistical methods, should be drawn to calculate correlation coefficient, y-intercept and slope. A plot of the data should be included in the test report. Another important feature, which estimates the degree of linearity, is calculation of the deviation of the actual data points from the regression line. In some cases, mathematical transformation of data, prior to the regression analysis, may be required.

14.3.3.3 Range

The range is the interval between the lower and upper analyte concentrations for which it has been demonstrated that the analytical pro-

cedure has a suitable level of accuracy, precision and linearity. It is normally derived from linearity studies.

14.3.3.4 Accuracy

The accuracy of an analytical procedure is the closeness of agreement between the conventional true value (or an accepted reference value) and the value calculated. It tells how closely the analyte amount is determined to its true amount present in the test sample. Accuracy should be specified across the range of analytical procedure and inferred from 9 measurements (triplicates of three concentrations in the range).

Accuracy can be demonstrated by application of the proposed procedure to an analyte of known purity or by comparing the results of the proposed analytical procedure with those of a second well-characterized procedure, whose accuracy is already known. Application of the procedure to test samples after spiking at three different levels of 50%, 100% and 150% of expected analyte concentration helps to determine the accuracy of the procedure.

A sample containing 1.0 mg analyte may, in different analyses, be found to contain 1.2, 0.9 and 0.8 mg. The assay procedure determining 0.9 mg is more accurate than the two other procedures.

14.3.3.5 Precision

The precision of an analytical method is closeness of results for a series of measurements of multiple samples from the same homogeneous material. The precision may suffer upon varying the experimental conditions, which are therefore assumed to be kept constant. System precision demonstrates error in recording the response and can be determined by repeatedly analyzing a sample within a short period of time.

It is possible that the results are precise but not accurate or vice versa. Triplicate measurements of 1.0 mg true quantity as 0.6, 1.0 and 1.4 result in an average value of 1.0 mg which is accurate but the three measurements themselves are not precise. Similarly, triplicate measurements of the same quantity as 0.6, 0.7 and 0.6 are precise but not accurate. Triplicate measurements of 1.0, 0.9 and 1.0 are precise as well as accurate.

Precision is expressed at three levels of short, medium and long intervals, which are respectively referred to as repeatability, intermediate precision and reproducibility.

14.3.3.5.1 Repeatability

Repeatability is precision under the same operating conditions over a short interval of time (intra-day precision). It is demonstrated by a minimum of 9 determinations covering the specified range for the procedure (e.g. 3 concentrations/3 replicates each) or a minimum of 6 determinations at 100% of the test concentration.

14.3.3.5.2 Intermediate Precision

Intermediate precision expresses intra-laboratory variations: different days, different analysts, different equipment, etc.

14.3.3.5.3 Reproducibility

Reproducibility is precision at the inter-laboratory level. It is especially important if the analytical procedure is to be used in different laboratories, for instance, a pharmacopoeial procedure.

14.3.3.6 Detection Limit

Detection limit (DL) is the lowest amount of analyte in a sample which can be detected, but not necessarily quantitated as an exact value. It is determined by analyzing samples containing known concentrations of analyte and by establishing the minimum level at which the analyte can be reliably detected. Other methods of determining DL are based on the signal-to-noise ratio and on the standard deviation of the response and the slope. A signal-to-noise ratio of 3:1 or 2:1 is a fair estimate of DL. Using the standard deviation of the response (σ) and slope of the calibration curve (S), $DL=3.3\sigma/S$.

14.3.3.7 Quantitation Limit

Quantitation limit (QL) is the lowest concentration of the analyte that can be determined with acceptable precision and accuracy under the stated experimental conditions. It is generally determined by the analysis of samples with known concentrations of analyte and by establishing the minimum level at which the analyte can be quantified with acceptable accuracy and precision. QL can also be defined from the signal-to-noise ratio (a typical signal-to-noise ratio is 10:1), or from the standard deviation of the response (σ) and the slope (S) of the calibration curve ($QL=10\sigma/S$).

14.3.3.8 Robustness

Robustness of an analytical method ensures that it performs well and has few variables affecting its performance. For example, a robust HPLC analytical procedure does not show variation when columns of differ-

ent lots or from different manufacturers are used, when there is a slight variation in pH or composition of the mobile phase, or when temperature and flow rate vary. Steps of extraction, purification or enrichment of an analyte in herbal material should be simple and time effective. Solutions used in the analysis should be stable over a reasonable period of time. Lastly, the procedure should be feasible in most laboratories.

If measurements are prone to variations with small changes in the test conditions then such conditions should be suitably controlled or a precautionary statement should be included in the procedure.

14.4 Thin Layer Chromatography in Quality Control of Plant Products

Thin layer chromatography (TLC), also called planar chromatography, is a widely accepted and extensively used separation technique that is over 65 years old. The technique is simple, cost effective, versatile, and useable in all laboratories around the globe. It can be easily adapted to any given situation of qualitative, quantitative or preparative separation. Despite the great variety and complete automation of the technique, it still lags behind other chromatographic techniques when it comes to its use as analytical technique. However, there is no substitute for this technique for situations requiring qualitative analyses of plant extracts. TLC has nearly become indispensable for the standardization of plant materials, be it the fingerprint profiling or analysis of a marker. The advantages of the technique over other analytical techniques are many when handling plant materials. The samples can be applied without undertaking tedious, time-consuming processes of sample preparation. The loss in sensitivity is far compensated by the gain on several fronts, including ease of assays, multiple sample analyses and low cost per sample.

The two prominent uses of TLC in the standardization of plant materials include fingerprint profiling for the assessment of chemical constituents of a drug and quantitative analysis of markers in plant drugs. A typical TLC procedure involves sample preparation, selection of the chromatographic layer and the mobile phase, sample application, development and drying of the plate, derivatization (if required) and chromatogram evaluation.

14.4.1 Sample Preparation

Methods of sample preparation for fingerprinting and estimation of marker differ significantly. Whereas in fingerprinting, only proportionate quantities of components must be extracted, in assaying the marker complete and exhaustive extraction has to be ensured. Correspondingly, particle size of the crude drug, the solute-solvent ratio, extraction period and

number of extractions assume greater significance in marker estimations. Normally 1-2 g of moderately fine powder (unless specified) of plant material is extracted with 25-50 ml solvent at room temperature, in a Soxhlet apparatus or under reflux on a water-bath. The extraction is repeated a number of times to ensure complete and exhaustive extraction of the marker from the drug matrix. The extract is filtered and solvent is removed from the combined filtrate. The residue is dissolved in the solvent, filtered again, and the volume is adjusted. The concentration of the marker is determined in the solution.

On the other hand, in comparing fingerprint profiles, the procedure requires a shorter extraction scheme. A powdered specimen of pharmacopoeial quality may be required as the reference material for comparison of the fingerprint profiles. The test and sample solutions are prepared under identical conditions of extraction and concentration. Usually 0.1-1.0 g material is extracted with 1-10 ml solvent for 5-30 min, by shaking at room temperature or heating to boiling. The extract is filtered, concentrated and used. Sometimes the solvent is completely evaporated and the residue is dissolved in a small volume of solvent (typically less than 1 ml) and filtered to separate the insoluble particles. The solution of a marker, of preferably known strength, is required if marker presence is to be ascertained. Using known strength of marker additionally provides semiquantitative information.

In certain cases, the extracts require further purification using extraction of the residue with another solvent at different pH or using distillation, sublimation or other appropriate method.

14.4.2 Selection of Chromatographic Layer

A wide variety of options is available for the adsorbent layer. Laboratory-made plates have given way to precoated plates marketed by several manufacturers. The precoated plates are machine-made of glass, aluminium or plastic base coated with different adsorbents. The different adsorbents include normal phase silica gel (most commonly used), reverse phase silica gel (RP_2, RP_8, RP_{18}, cyano, diol and amino plates), aluminium oxide, cellulose, kieselguhr, hybrid (capable of being used as normal and reverse phase) and derivatized adsorbent layers. They come in different sizes, from small strips to continuous rolls (20 x 20 cm^2 is most common).

The nature of the compounds defines the choice of adsorbent layer; a stronger adsorbent (aluminium oxide) is used for weakly adsorbed compounds and a weak adsorbent (cellulose) is used for strongly adsorbed compounds. Normal phase silica gel is more suited for non-polar components and reverse phase silica gel is more suited for polar constituents, which are eluted first on reverse phase TLC. The silica gel plates containing fluorescent dye (F_{254}) of aluminium base are most widely used; about 80% of the analyses are done using these plates as they are optimally efficient and cost-effective.

14.4.3 TLC versus HPTLC Layers

High performance TLC (HPTLC) plates use thin layers of adsorbent (100 µm instead of 200-250 µm) and smaller particles (5-6 µm versus 10-12 µm) of more homogeneous size (4-8 µm versus 5-20 µm). Moreover, they give better resolution (5- to 10-fold more) over shorter runs (3-6 cm versus 8-15 cm), reduce separation time (3-20 min versus 20-200 min), accommodate more samples per plate (more than double), use smaller sample volumes (0.1-0.5 µl versus 1-5 µl) with improved detection limits (100-500 pg), and significantly improve the precision, accuracy and sensitivity. HPTLC plates are substantially more expensive (4- to 6-times more) than normal plates but are an efficient alternative when high sensitivity, accuracy and precision are required in situations demanding high performance. More improvements in adsorbent layers include use of spherical particles of narrow size distribution (reducing resolution time and size of spots while improving the detection limit) and ultrathin layers (10 µm) that improve the resolution and sensitivity and drastically reduce the development time.

14.4.4 Selection of the Mobile Phase

Infinite combinations and a wide choice of solvents are available for TLC developments. Unlike HPLC, where choice is limited, TLC provides no or few restrictions. A mobile phase with 1-3 components is preferred over a multicomponent mobile phase. The polarity of the compounds of interest is the key to selection of a mobile phase. Personal experience applied to existing knowledge and a trial and error method is used to select the composition of the mobile phase. The mobile phase is freshly prepared for each run and the constituting solvents are mixed outside before transferring to the developing chambers. It is advised to allow the developing chamber to saturate unless otherwise specified. Saturation of the chamber is quickened by lining half or more of the total area of the inside walls with filter paper and pouring the mobile phase over it. Closing the chamber and allowing it to stand at room temperature saturates the chambers. It is possible to use another solvent alongside the mobile phase for chamber saturation in twin troughs, e.g. ammonia placed in one trough and mobile phase in another.

The TLC results are sensitive to temperature and humidity variations. All operations during which the plate is exposed to the air should be carried out at a relative humidity of 50%-60% under controlled temperature of 20°-30° C.

14.4.5 Application of Sample

Three typical options of delivering the sample solution onto the plate are manual, semi-automatic and automatic application. Manual application is done using a capillary, which can have a specific volume of 1, 2 or 5 µl for quantitative purposes. The solution is applied by the technique of touch

and deliver. The precision and accuracy, as known to the author from personal experience, is fairly high after a short experience. The semi-automatic application uses devices such as Linomat 5 from Camag and Applicator AS 30 from Desaga, which use a syringe that has to be manually cleaned and filled. The remaining part of the application is automated through computer commands. The solution is applied as a spot or band of predetermined size at predetermined points by touch and delivery or spray-on technique. The needle touches the surface of the adsorbent layer and delivers, whereas in spray-on technique the predetermined volumes are sprayed onto the plate. In the fully automated application, all steps are controlled through a computer including washing of the delivery line.

The typical concentration of the applied samples ranges from 0.1 to 1 mg/ml for qualitative analysis but is usually much lower for quantitative purposes, which further depends on the molar absorption of the marker. The typical volume for spot application is 1-5 µl, and 10 µl for band application. These volumes are drastically reduced in HPTLC plates or ultrathin TLC plates. Bands are known to give better resolution and results than spots, as a narrow band is better suited to the optics of the TLC scanner.

14.4.6 Developing the Chromatogram

Development of plates is carried out in chambers which are special purpose jars or simple containers good enough to hold the solvent in an air-tight environment. There is no doubt that special purpose chambers produce better chromatograms. Twin-trough chambers allow use of another mobile phase in the chamber for the purpose of saturation, besides consuming smaller quantities of solvent. The cost of the chamber, which seems high in the beginning, is recovered by way of savings on the quantity of expensive solvents. Presaturation of the chambers decreases R_f values and corrects side distortions of the solvent front. The plate is placed as nearly vertical as possible in the chamber, ensuring that the points of application are above the surface of the mobile phase and the sides of the plate do not touch the container walls.

The developing chamber should always be kept out of direct sunlight. It should be protected from light during development, if the components being investigated are suspected to be unstable. If sun rays fall directly on the developing chamber, they may be refracted to different degrees through the glass walls, producing areas of high temperature on the plate and resulting in erratic flow of the mobile phase.

The technique of development has been largely improved in horizontal developing chambers and completely automated in automated development chambers or automated multiple development chambers. However, the cost of this equipment (except for the horizontal development chamber) is excessively high.

14.4.7 Drying the Plate

After development, the plate is dried. This is an automatic procedure in automated development chambers, but it has to be accomplished in air at room temperature, in a vacuum desiccator or by heating or blowing hot-air over the surface of the plate. In all instances, the mobile phase should be as completely removed as possible before proceeding to derivatization or scanning the plate.

14.4.8 Derivatization

Derivatization involves treatment of developed chromatograms with suitable spray reagents for locating the position of the constituents for qualitative evaluation and for quantifying ultraviolet-insensitive markers. Two methods are employed for derivatization of plates: spraying with a fine mist of a reagent (a traditional method) and dip-in technique, which of late has become more popular. The spray method does not allow the uniform wetting of the plate, producing areas of high wetting and deficient spray. This affects the precision and accuracy in case of quantitative determinations. The dip-in technique produces more uniform wetting; special equipment is available for this purpose. In most cases of derivatization, heating is required after spraying the plate. Heating the plate uniformly in the open air produces better results than heating in an oven. The fumes from heating are strongly reactive and damage the inner walls of the oven. The plate is heated at about 110° C for about 10 min or until the spots are best seen. Special purpose heating plates are available from the manufacturers of TLC equipment.

14.4.9 Evaluation of the Chromatograms

The TLC plate is observed in daylight, under short-wave and long-wave ultraviolet light, for comparing the chromatograms of standard and test samples or for observing the presence of a marker or compounds of interest in the test chromatogram. The centre of each spot is marked with a needle. The distance from the centre of each spot to the point of application is measured to record the R_f value (the ratio of the distance travelled by a given compound to that travelled by the solvent front) or the R_r value (the ratio of the distances moved by a compound and a stated reference substance). R_f values may vary depending on the temperature, degree of saturation, the activity of the adsorbent layer and the composition of the mobile phase.

Quantitative evaluation is done by scanning the plate in a TLC densitometer or scanner. The densitometer uses two modes of transmittance and reflectance depending upon the available optics. It uses fluorescence mode, ultraviolet absorption or visible light for quantitation of the marker depending upon the option exercised. Ultraviolet and visible light absorption modes come as a standard option on a scanner and the fluores-

cence mode is optional. Data acquisition and analysis is through standard PC-based software. Multi-wavelength scanning, recording and comparing ultraviolet spectra, and generating and acquiring spectra libraries are among several options available on the software provided with the TLC scanner.

The determination of analyte concentration is through a standard plot or single or double point calibrations.

14.4.10 Improving the Efficiency of TLC

Several precautions can be taken to improve the efficiency of TLC analysis. These include carefully selecting the range of concentrations for analysis; using correct instrument parameters like slit dimensions, wavelength selection, scanning speed, base line correction; using HPTLC plates for high sensitivity and resolution; use of appropriate sorbent from a wide range of sorption properties to optimize selectivity; use of automated sample application, development and detection; use of precise in situ recording and quantitation of chromatograms; and avoiding derivatization in assay procedures and, if necessary, using dip-in technique of derivatization.

The following example, of one of the Ayurvedic drugs, illustrates the use of TLC in quality control of plant material. The drug was analyzed for one of the active compounds and the TLC fingerprint profile was used for the purpose of positively identifying the plant material.

To prepare the fingerprint profile, about 5 g plant material was extracted with 50 ml methanol for 30 min at 50° C in a conical flask. The extract was filtered and the filtrate was concentrated to about 5 ml under vacuum. One of the active constituents isolated from this plant (code name DPH-1) was used as a reference. The solution of the reference substance was prepared by dissolving about 5 mg in 1 ml chloroform. About 10 µl of each test and reference solution was manually applied in band form on aluminium base, silica gel 60 F_{254}, 0.2-mm thick TLC plates (Merck). The plate was developed using mobile phase containing 95 volumes toluene and 5 volumes ethyl acetate. The plate after development was dried and visualized under 254 nm ultraviolet light (Figure 1A). The same plate was sprayed with anisaldehyde-sulphuric acid reagent and heated for about 10 min to visualize the spots (Figure 1B). These profiles can be used to confirm the identity of the plant material and to obtain semiquantitative information on the amount of DPH-1 present in the drug.

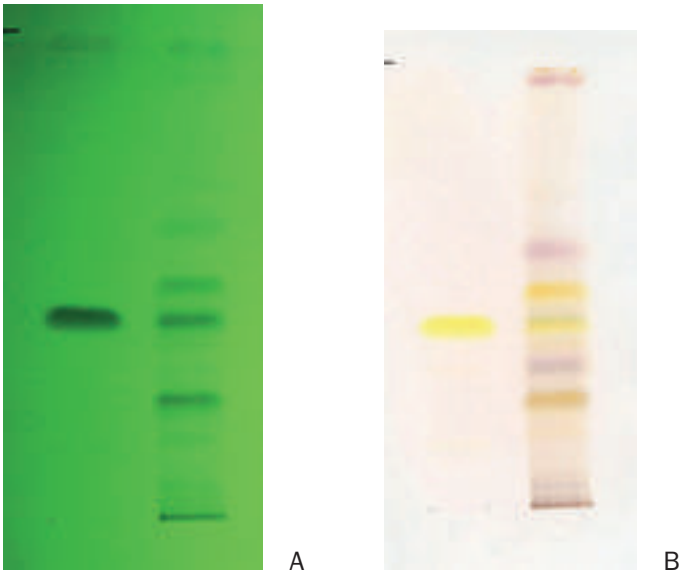

Figure 1: TLC chromatograms as visualized (A) under 254 nm UV and (B) after being sprayed with anisaldehyde-sulphuric acid reagent

Besides developing the fingerprint profile of the drug, the quantity of DPH-1 was also estimated in different samples of the plant material. For the purposes of analysis, 5 g moderately fine powder of drug material was extracted with methanol in a Soxhlet apparatus for 4 h. The extract was filtered and the volume was adjusted with methanol to 50 ml in a volumetric flask. One milliliter of this solution was diluted to 10 ml in a volumetric flask and used for analysis. A standard solution of DPH-1 was prepared by dissolving 4.95 mg DPH-1 in 10 ml methanol and diluting 0.5 ml of this solution to 10 ml in a volumetric flask. Six different concentrations of this solution were applied in triplicate on a precoated TLC plate, which was developed using mobile phase containing 90 volumes toluene and 10 volumes ethyl acetate. The developed and dried plate was scanned at 305 nm in a TLC scanner and the standard plot was constructed (Figure 2). One microliter of test solution was similarly analyzed using the same conditions as used for DPH-1, and the amount of DPH-1 in the test sample was calculated from the response obtained in a TLC scanner. The analyzed drug samples showed large variations in the content of DPH-1, ranging from below 0.3% to over 1.4%. The method was validated according to ICH guidelines.

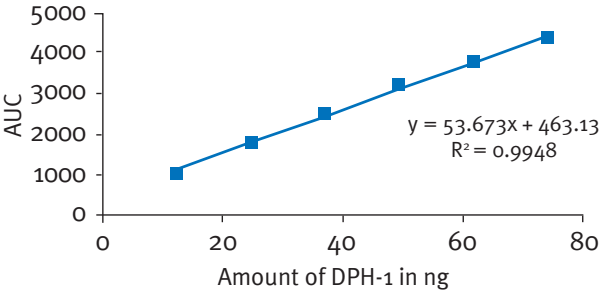

Figure 2: Calibration curve of DPH-1

The TLC-based method of analysis and fingerprint development is quick and reliable, and can be used conveniently in different laboratories. Similarly, it is possible to apply this technique to other plant drugs to develop fingerprint profiles and also to estimate the percentage of marker substances in the crude drugs or in finished products.

14.5 High Performance Liquid Chromatography

In a period of less than 50 years, HPLC has become the most widely used analytical tool in most laboratories of the world. The technique has received great attention for innovations leading to its overall development, regarding both consumables and equipment. HPLC separations are achieved using any of the five basic chromatographic modes: liquid-solid (adsorption), liquid-liquid (partition), bonded-phase (partition), ion exchange, and size exclusion chromatography. The selected mode depends on the nature and properties of the analyte. Bonded-phase chromatography, in which a stationary phase of organosilanes of varying carbon lengths is chemically bonded to silanol groups, is the most commonly used mode of separation. In liquid-liquid chromatography, the solid support (usually silica or kieselguhr) is mechanically coated with a film of high boiling point organic liquid, unlike bonded-phase chromatography where non-polar hydrocarbon chains are chemically bonded to hydroxyls of the silica support. Liquid-liquid chromatography, by virtue of its mechanism, is more susceptible to changes by interaction with mobile phase than bonded-phase chromatography.

A typical HPLC operation includes pumping of mobile phase at moderately high pressure through a narrow-bore column containing adsorbent. The separation of the mixture takes place in the column and separated components are detected by employing a suitable detector. As the mobile phase is being pumped at high pressures, a system is required to inject the mixture into the system without dropping the pressure and disturbing the flow characteristics, i.e. rate and pressure. To accomplish these requirements, an HPLC system requires a pump to push the mobile phase against high pressure, an injector to insert a solution of standard substance or test

mixture, a column to effect separation, a detector to reveal the presence of analyte in the eluate, and a suitable data processing unit.

14.5.1 Pumps

The pump is considered a heart of the HPLC system, as all depends on the composition of the mobile phase and its flow rate accuracy. The pump gives a pulse-free flow of mobile phase; the expected variations in flow rate are less than 1.0%. Online mixing of solvents is preferred to manual mixing. However, compositions containing less than 10% of a particular solvent are better prepared by manual mixing. The composition of the mobile phase is either constant during the analysis (isocratic mode) or it is changed (gradient mode). The type and design of modern pumps allow low pressure mixing of up to four solvents; else, different pumps, one for each solvent, are required for gradient operation and the solvents are mixed at high pressure. A typical analytical procedure uses a flow rate of about 1 ml/min and operating pressure between 1000 and 2000 psi. Higher flow rates generating higher pressure should always be used with justification, as they decrease column life besides requiring frequent servicing of the pump.

The flow accuracy of the pumps is critical for analysis. The constancy of retention time of the last eluted peak is a measure of long-term flow accuracy of the pumps, whereas short-term flow accuracy is checked from the average peak areas of each component and their standard deviations. The mobile phase must be free of dissolved gases to ensure an accurate flow and to minimize noise due to bubbles. Vacuum filtration, sonication and helium gas purging are methods for degassing.

14.5.2 Injector

The injector allows a predetermined volume of test solution to be introduced into the flow channel of the system, without disturbing the flow kinetics. Typically, fixed volume injections are preferred over variable volume injections. When using fixed volume loops, it is advisable to flush higher volumes of the sample through the loop to ensure complete filling of the loop with the sample solution. The mobile phase close to the inner walls of the loop can only be assured to have pushed out after injecting volumes larger than the loop volume, e.g. injecting 20 µl test solution into a 20-µl loop cannot assure accurate injection; if the quantity of the test material is not a problem, flush the loop with over 100 µl test solution. Only the appropriate needle (compatible with the injection port) should be employed for the purpose of making an injection. It is important to select a syringe of appropriate size when giving variable injections; a thumb rule for any analytical technique is not to use the volumetric apparatus if less than 20% of its total volume is being used. Thus, a syringe of 25 µl should not be used to measure or inject volumes less than 5 µl.

14.5.3 Columns

Columns come in varied sizes, structural architecture and chemistry. The chromatographic material is usually packed in stainless steel casing. The material is composed of porous particles which vary in nature (inorganic ceramic, organic polymer, or hybrid), shape (irregular or spherical), size (ranging from 2 to 20 μm; normally around 5 μm) and surface modifications (silanes of different carbon lengths, aminopropyl, diol, cyano, sulphonic acid and ammonium ions). The choice of column is based on the type of analysis. Comprehensive information is available on the websites of the leading manufacturers of HPLC columns, which serves as good guides in choosing columns for analysis. Most analyses are reported on reverse phase columns, usually C_{18}, with increasing emphasis on reducing the column length, diameter and analysis time. Most HPLC separations are successful on columns maintained at ambient temperature, but thermostatted column maintained to ±0.2° C is necessary for reproducible results. This is because all mechanisms of separation are temperature-dependent and any shift in temperature has remarkable bearings on the result.

14.5.4 Detectors

A wide variety of detectors is available to cater to diverse needs of the analysts. Ultraviolet detectors of fixed wavelength, dual wavelength or variable wavelength (photodiode array detector) are most frequently used. Other options are refractive index detector, fluorescent detector, electrochemical detector, evaporative light scattering detector and chemiluminescence detector.

14.5.5 Data Processing

The electrical response from the detector is digitalized and fed to a data processing module, which in present days is invariably a computer, and computations are made using special software. Several software programs are available for data processing, from both manufacturers and third parties. Besides computing the data, they also control the entire operation of the machine.

14.5.6 Factors Affecting HPLC Analysis

Numerous variables affect an HPLC analysis. This topic is beyond the scope of this paper, but some critical variables are discussed briefly. Increased emphasis is now paid to control the temperature of the column within a narrow range to ensure precision of the result. This is desirable, as factors such as solubility, solute diffusion, viscosity of the mobile phase, and column plate number all are affected by temperature. Mobile phase composition is another vital parameter that affects the resolution, retention time and peak area. Pumps contribute the most towards variations of results, as

precise composition of mobile phase and flow rate can only be assured by accurate pumps. Gases dissolved in the mobile phase are a source of flow-rate inaccuracies and errors in detector response.

Retention time variations are often discussed to know the tolerable limits. The retention time is affected by flow rate, column temperature, mobile phase composition and integration. An error in flow rate leads to changes in the retention time to the same extent. Small variations in column temperature have more significant effects on retention time. Ideally, a column is thermostatted to ±0.2° C. However, a high precision of 0.1% in retention time requires the column to be thermostatted to ±0.04° C. Changes in mobile phase composition leave a stronger impact on the retention time. It is estimated that in a typical isocratic elution, a variation of ±1% in mobile phase composition occurs, which introduces an error of 0.4%-0.7% in retention times. The observed variations in composition of the mobile phase are more in the gradient elution. Recording devices also introduce variations in the retention time through faulty recording, but the effect is much smaller (in the range of 0.1% to 0.04%).

Peak area is affected by all the factors that affect retention time. Additionally, the recorder response in marking the start and end of the peak is crucial; this has been seen to be the main source of error in recording peak areas.

Several more factors, like injection volume, connecting tubing, end fittings and detector volume, also have bearings on the final results. Large injection volume and quantity of analyte result in broadening of the peak. Preparing the sample in the mobile phase produces the best result and should be taken as the first choice.

14.5.7 HPLC in Quality Control of Plant Products

HPLC is the most popular technique among all the analytical techniques used today. It is therefore understandable that most happenings are taking place in the modernization of this technique. As discussed in the section on TLC, HPLC can be used for similar purposes. There are two applications of HPLC: one to generate the profile, for which TLC is preferred, and one to estimate the quantity of markers, where HPLC is preferred. The initial steps of sample preparation are similar to those for TLC with the exception that the samples for HPLC are filtered through a filter of 0.45 µm or less. Furthermore, it is assured that the test sample does not contain substances which are permanently retained on the HPLC column, which means in most cases purification procedures are applied to extracts before injecting them onto the column.

After the sample has been prepared, it is injected onto the column and the response is recorded preferably using a variable wavelength ultraviolet detector. As the nature of all the compounds of the extract cannot

be known beforehand, the photodiode array detector is useful, especially when constructing profiles of plant extracts. The fingerprint profile of plant extracts can be used for identification purposes and also for obtaining semi-quantitative information if the sample preparation was not done for quantitative analysis. Similarly, the profile can be generated for the finished product and used to record batch to batch variations. The fingerprint profile can be used to study changes in the composition of the finished product or, in other terms, to indicate the stability of the product.

The most important use of HPLC is in estimation of markers in plant drugs. The steps in HPLC analysis are fundamentally the same as used for any other analytical technique. The response of the test sample is compared to that of a known quantity of the marker to quantify the marker in the test substance. The HPLC method is developed from knowledge of the technique and chemistry of the marker. In chemical analysis, HPLC has no parallel and can be customized to produce the most precise and accurate results. The HPLC analysis is vital in the analysis of a finished product and the expected results are superior to those from TLC, as the separations in HPLC are better. However, run time of HPLC analyses usually varies from 15 to 30 min, which restricts its use if large numbers of samples are to be analyzed.

14.6 TLC versus HPLC

TLC has emerged as a major tool in standardization of plant materials. The advancement and automation of the technique has made it a first choice for plant drugs. Its use has become more popular in developing countries where advancements of HPLC are not cost efficient. TLC offers several advantages over HPLC. Sample and mobile phase preparation do not require elaborated steps of purification, degassing, and filtration, which are essential to protect expensive columns from deterioration. Several samples (up to 18) can be accommodated on a single 20 x 20 cm^2 plate. The test samples and standards are analyzed simultaneously under the same conditions. Several analysts can work simultaneously as each step in analysis is carried out independently using separate equipment. The choice of solvent systems is unlimited, unlike for HPLC where column chemistry disallows the use of extremes of pH in mobile phase. The technique allows enormous flexibility of derivatization with chromogenic spray reagents, making possible the detection of an analyte that is transparent to ultraviolet light. It also allows multiple evaluations of the developed chromatogram, which is not possible in HPLC. There is no leftover from the previous analysis to interfere in the next, as each time a fresh plate is employed. Lastly, it saves tremendously on the time and cost of the analysis.

TLC offers many advantages but also has some disadvantages. It fails to match the sensitivity of HPLC and has not kept with the pace of developments and advancements happening in the area of HPLC. TLC is

an open system and hastens the degradation of compounds sensitive to light and air, which in the case of HPLC pass through an enclosed environment. Detection of the analyte in HPLC occurs in solution, permitting high sensitivity, whereas in TLC the solid phase interaction makes detection less sensitive. Finally, recent advances and efficient flow kinetics of HPLC allow more complex separations than TLC.

14.7 Conclusions

Both TLC and HPLC are vital in the analysis and quality control of plant material and the extracted products. Each of these techniques has its own limitations and advantages. TLC is fast, adaptable and economical, whereas HPLC is more precise and accurate. Based on the preferences and demand of the situation, one can opt to use one or the other for quality assurance of plant products.

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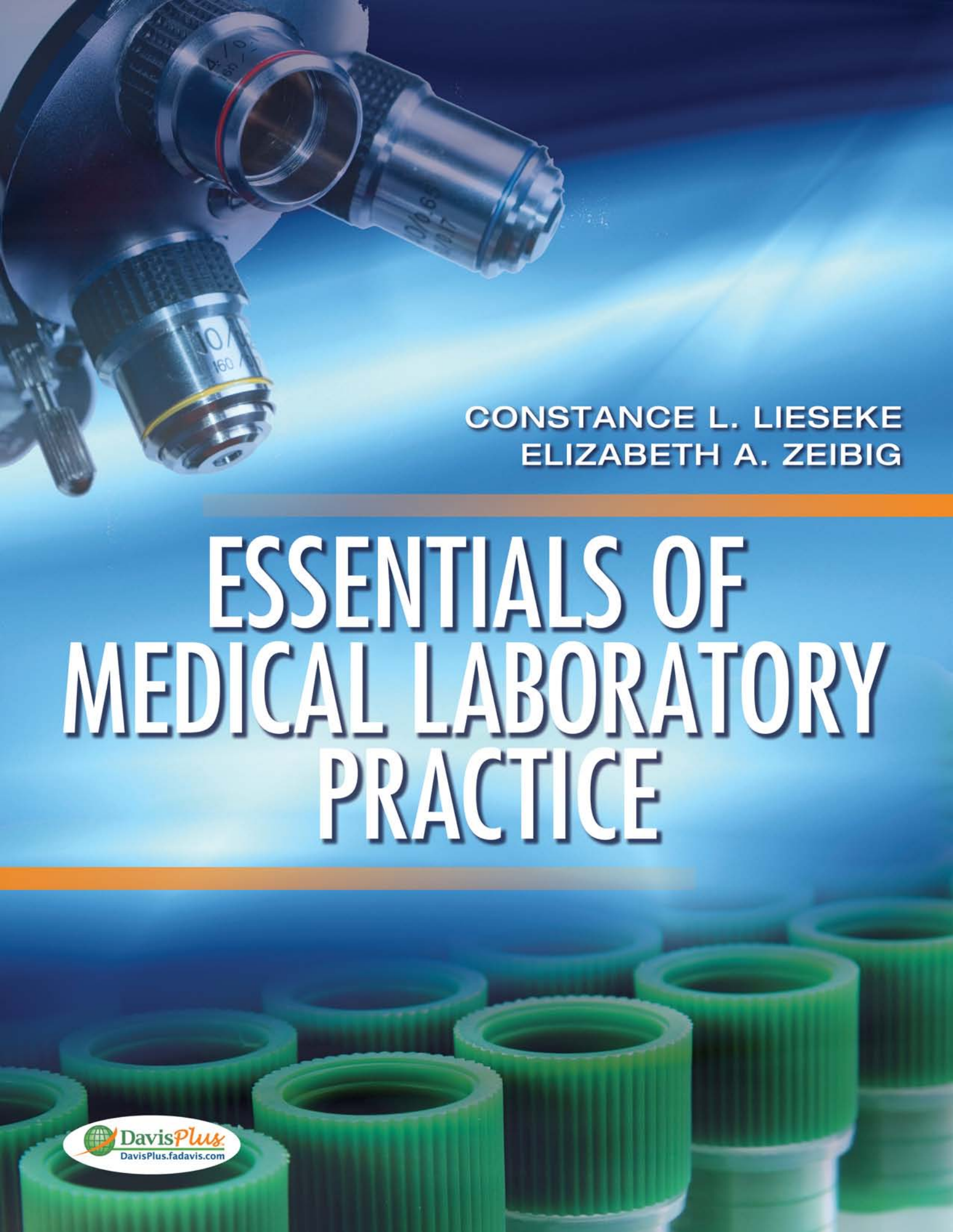

CONSTANCE L. LIESEKE
ELIZABETH A. ZEIBIG

ESSENTIALS OF MEDICAL LABORATORY PRACTICE

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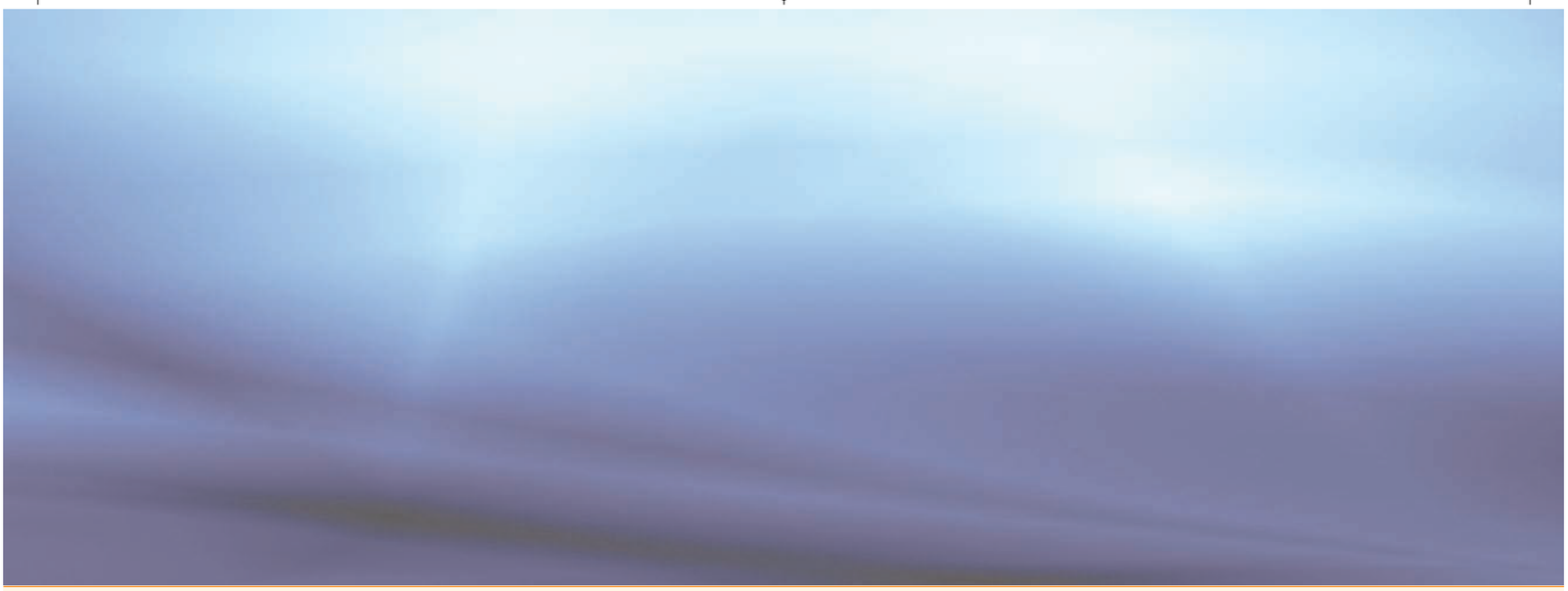

On the Horizon

Laboratory testing is an essential component of effective patient care. The results obtained from laboratory testing provide valuable information that assists physicians and other primary health providers with the diagnosis and monitoring of disease.

Relevance for the Medical Assistant (Health-Care Provider)

Medical assistants and other health-care support personnel are frequently involved in the collection of samples for laboratory testing. In many settings, these individuals perform select laboratory tests that are typically considered basic and uncomplicated. Laboratorians who have completed extensive education and training are able to perform complex laboratory testing. Medical assistants and other health-care support personnel may be responsible for the collection of samples and, in many cases, performance of the tasks associated with the processing and transport of samples to the laboratory for complex testing. On occasion, these individuals may have the opportunity to examine laboratory test results as part of their encounters with patients.

Case in Point

It is the first week of your student practicum at Maple Grove Clinic. You have been assigned to work for Dr. Pueblo under the direction of your clinical instructor, Doris. The second patient of the day is Mr. Hershey. You observe Doris interact with Mr. Hershey and perform the preliminary appropriate tasks associated with Mr. Hershey's appointment. After examining the patient, Dr. Pueblo emerges and informs Doris that he will be ordering laboratory tests. Doris takes this opportunity to introduce you to the laboratory.

Questions for Consideration:

- Compare and contrast the three phases of laboratory testing: preanalytical, analytical, and postanalytical.
- Government regulations allow medical assistants and other health-care support staff to perform what category of laboratory tests?
- What is the purpose of practicing universal precautions when dealing with laboratory specimens?
- True or False. Laboratory test results can be reported only if the quality control samples are tested and found to be in range.
- What is the name of the federal act that regulates laboratory-testing personnel?

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Section I

Overview of the Laboratory

Chapter 1: The Clinical Laboratory provides the reader with basic definitions of terms such as *laboratory test* and *normal range*; identification of the areas of a typical laboratory; and an introduction to preanalytical, analytical, and postanalytical testing. A discussion of the importance of the laboratory and role of the medical assistant and other health-care support personnel as they relate to laboratory testing is presented. The difference between the regulations governing clinical laboratories and laboratories housed in a physician office is introduced in terms of the testing that can be performed in each setting.

Chapter 2: Regulations Governing Laboratory Personnel identifies the individuals who perform testing in clinical laboratories, including the Medical Laboratory Technician (MLT) and the Medical Laboratory Scientist (MLS), along with the range of tasks that each level of practitioner can perform. A detailed description and justification for the role that medical assistants and other health-care support personnel may assume in the laboratory under federal regulations, specifically in a physician office setting, is presented.

Chapter 3: Laboratory Safety and Preventing the Spread of Disease covers associated key concepts and documentation procedures, including those for Material Safety Data Sheets (MSDS); the handling of fire and chemical spills; and biological and electrical considerations. Personal protective equipment (PPE) and handwashing concepts are addressed. This chapter contains sections dedicated to bloodborne pathogen standards, universal precautions, handling of needles and sharps, and preventing the spread of disease.

Chapter 4: Assuring Quality covers the essential aspects and importance of quality assurance and quality control. The performance and documentation of quality control procedures, as well as the recognition and resolution of quality control results that are not in range, are detailed. The concepts, considerations, and reasoning behind proficiency/competency testing are explored.

Chapter 5: Legal and Ethical Issues explores a number of legal and ethical issues associated with laboratory testing. Topics include the Clinical Laboratory Improvement Act of 1988 (CLIA '88), fraud and abuse, informed consent, "the right to know," and the Health Insurance Portability and Accountability Act (HIPAA).

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Chapter 6: Laboratory Equipment introduces the reader to key pieces of equipment used in a typical physician office laboratory, including centrifuges, microscopes, and point-of-care instruments. A brief overview of the principles behind these and other key hematology and chemistry analyzers are introduced and described.

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Chapter 1

The Clinical Laboratory

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

The Clinical Laboratory
- Physician Office Laboratories (POLs)
- Hospital Laboratories
- Reference Laboratories

Laboratory Departments
Why Is Laboratory Testing Performed?
The Role of the Medical Assistant in the Clinical Laboratory
Information Flow in the Clinical Laboratory
- Laboratory Requisitions
- Advance Beneficiary Notice of Noncoverage
- Laboratory Directory
- Laboratory Reports

Three Phases of Laboratory Testing
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

1-1 Define the key terms for this chapter.

1-2 Describe the different types of laboratories presented in the text and the common tests available in each.

1-3 Identify the different departments in a hospital or reference laboratory and list some of the tests performed in these departments.

1-4 Provide several reasons that laboratory testing might be performed.

1-5 Explain the roles a medical assistant might play in a laboratory setting.

1-6 List and justify the various pieces of information that must be included on a laboratory requisition.

1-7 Explain the concept of Advance Beneficiary Notice of Noncoverage (ABN) and how it affects laboratory reimbursement.

1-8 Explain the purpose of a laboratory directory, as well as how a laboratory directory may be used when preparing to collect a specimen.

1-9 Compare and contrast the function of a laboratory requisition and a laboratory report.

1-10 Identify the different phases of laboratory testing, and explain the flow of the laboratory testing process.

1-11 Provide examples of preanalytical, analytical, and postanalytical procedures and how they affect the quality of laboratory testing.

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CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

II.A.2: Distinguish between normal and abnormal test results

ABHES Standards

- None

KEY TERMS

Advance Beneficiary Notice of Noncoverage (ABN)
Ambulatory
Asymptomatic
CLIA-waived
Complexity
CPT code
Efficacy
Hospital laboratories
ICD-9 code
Laboratory
Laboratory directory
Laboratory report
Laboratory requisition
Normal ranges
Panels
Physician office laboratories (POLs)
Plasma
Point-of-care testing (POCT)
Profiles
Quality control (QC)
Reference laboratories
Reference ranges
Serum
Specimens
STAT

The clinical laboratory plays a vital role in patient care. Diagnostic puzzles are solved each day by using results obtained from testing procedures performed on blood, tissue, and other body fluids. Quality patient care depends on excellent laboratory practices, so it is important to build a solid understanding of the structure and function of the clinical laboratory before performing testing procedures. This chapter explains the reasons that laboratory testing may be ordered and identifies the types of laboratories where testing is performed. The role of the medical assistant in the clinical laboratory as well as the roles played by other laboratory personnel are also introduced. To expand understanding of how the clinical laboratory operates, the flow of information in the laboratory setting is also explained.

THE CLINICAL LABORATORY

A clinical **laboratory** is any place where **specimens** from the human body may be collected, processed, examined, or analyzed. With this broad definition in mind, then, a laboratory might be someone's home, a long-term care facility, the office of a health-care provider, a free clinic, a hospital, a small facility used strictly for specimen collection and processing, or a large and complex reference laboratory. As of January 2010, the Centers for Medicare & Medicaid Services identified more than 216,000 clinical laboratories in the United States.[1] To simplify our discussion of the various types of laboratories, we will classify them into three basic groups as described below (Table 1-1).

Physician Office Laboratories

Physician office laboratories (POLs) are clinical laboratories within physician offices where laboratory testing is carried out on specimens obtained from the practices' own patients. More than half of all the laboratories in the United States are POLs. This type of laboratory can be advantageous because the results for tests performed on site are available quickly and patient treatment can begin immediately if necessary. Testing and specimen collection in these office laboratories may be accomplished by various members of the health-care team, such as medical assistants,

[1]Data From CLIA Update—January 2010
Division of Laboratory Services
Centers for Medicare & Medicaid Services
Laboratories by Type of Facility
https://www.cms.gov/CLIA/downloads/factype.pdf

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TABLE 1-1
Types of Laboratories and Sample of Testing Performed

Type of Laboratory	Testing Performed
Physician office laboratory	CLIA-waived tests Moderate complexity testing (with appropriate training, staffing, and supervision) Microscopic examinations (performed by health-care provider or qualified staff)
Hospital laboratory	CLIA-waived tests CLIA moderate- and high-complexity tests (based on the needs of the patients served in the facility) Point-of-care testing Microscopic examinations
Reference laboratory	CLIA-waived tests Moderate- and high-complexity tests Microscopic examinations

clinical or medical laboratory technicians who have been trained in laboratory testing, or phlebotomists who are trained to draw blood and perform some simple laboratory procedures. These **ambulatory** (outpatient) laboratories generally perform low **complexity** tests that are designated as Clinical Laboratory Improvement Amendment–waived (**CLIA-waived**) tests by the U.S. Food and Drug Administration (FDA). CLIA-waived tests are laboratory examinations and procedures that use simple and accurate methods requiring very little interpretation to report correct results. These tests may include the following:

- Rapid microbiology testing for the presence of group A *Streptococcus* and influenza
- Urine analysis
- Pregnancy testing
- Tests such as those for mononucleosis, *Helicobacter pylori,* and HIV
- Coagulation testing to monitor patients who are taking anticoagulants
- Glucose levels and other tests used to monitor diabetic patients
- Fecal occult blood tests for the presence of blood in the stool
- Cholesterol testing

Physician office laboratories may also provide testing that is more complex if staff members are properly trained to perform such procedures. More details about the Clinical Laboratory Improvement Amendment and the classification of laboratory tests are provided in Chapter 2.

Hospital Laboratories

Hospital laboratories generally offer laboratory testing that meets the needs of their respective institution. For instance, if a hospital specializes in a certain type of surgical procedure or treatment, the hospital laboratory will offer extensive testing in that specialty area, in addition to the standard tests required to monitor the health of the other patients in the hospital. In most situations, hospital laboratories perform high volumes of routine test procedures. Hospital laboratories may also serve as a reference laboratory for the local community, especially for **STAT** testing needs. (STAT tests are those that require immediate results.) Tests performed at a hospital laboratory may include the following:

- Electrolytes
- Kidney function tests
- Liver function analysis
- Blood typing and crossmatches for transfusions
- Identification of microorganisms and antibiotic sensitivity testing
- Urine analysis
- Coagulation testing
- Cardiac enzyme assays
- Complete blood counts (CBCs) and other hematology testing

Hospital laboratories may also offer another method for testing samples, called **point-of-care testing (POCT)**. Point-of-care tests are actually performed at the patient's bedside rather than in the laboratory, using a portable instrument that gives immediate results. These tests may be performed by laboratory personnel or in some situations by other hospital employees who have been trained to perform the testing.

Reference Laboratories

Reference laboratories perform more tests annually than either POLs or the hospital laboratories, processing perhaps thousands of specimens per day. These tests include those that are performed at hospital laboratories, but reference laboratories may offer specialized testing that is not performed at either hospital laboratories or POLs. Specimens may be sent to a reference laboratory from all over the country.

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Test Your Knowledge 1-1

Which type of laboratory offers the widest variety of tests? (Outcome 1-2)

LABORATORY DEPARTMENTS

Testing in hospital and reference laboratories is usually departmentalized for efficiency, as presented in Table 1-2. This allows all testing that uses similar instrumentation or methods to be performed in the same area of the laboratory. These departments may include the following:

- **Specimen Processing:** The area of the laboratory where all incoming specimens are sorted, accessioned into the computer system of the laboratory, and appropriately labeled for transport to their respective departments for testing. The specimen processing department may also prepare specimens for transport to reference laboratories.
- **Hematology:** Whole blood testing, which focuses on the formed elements (the blood cells) in the blood. Coagulation testing is also performed in this department.
- **Clinical Chemistry:** Testing performed on **plasma** or **serum** (the liquid portion of the blood) and includes analysis of the substances dissolved in the bloodstream. Most testing is automated, and many of the tests are performed as panels or groups of tests.
- **Serology/Immunohematology:** Testing that focuses primarily on the presence of antigens or antibodies on cells or in the liquid portion of the blood. Blood typing and antibody screens and crossmatches for transfusions may also be performed in this department.

TABLE 1-2

Summary of Laboratory Departments, Common Tests Performed, and Specimen Types

Laboratory Department	Common Tests Performed	Specimen Types
Specimen Processing	Incoming specimens sorted Specimens accessioned into computer system Specimens labeled and prepared for testing in separate department	All types
Hematology	Complete blood count Hemoglobin and hematocrit measurements Coagulation studies Erythrocyte sedimentation rate Differential white blood cell count Platelet counts	Whole blood
Clinical Chemistry	Electrolytes Glucose Blood urea nitrogen Creatinine Thyroid testing Cardiac enzyme testing Comprehensive metabolic panel Cholesterol/lipid testing Many automated chemistry tests and panels	Serum, plasma, urine, cerebrospinal fluid, amniotic fluid
Serology and Immunohematology	Various tests looking for antigens and/or antibodies such as: RPR Mononucleosis testing HIV tests Chlamydia testing Antistreptolysin O test Pregnancy testing C-reactive protein ABO/Rh blood typing Antibody screens and crossmatches for transfusions Newborn testing Prenatal testing	Serum, plasma, whole blood

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TABLE 1-2–cont'd

Summary of Laboratory Departments, Common Tests Performed, and Specimen Types

Laboratory Department	Common Tests Performed	Specimen Types
Urinalysis	Physical appearance of urine Urine chemical analysis Microscopic urine analysis	Urine
Microbiology/Parasitology	Identification of pathogenic microorganisms Streptococcal screens Antibiotic sensitivity testing	Blood, urine, wound specimens, tissue, stool, cerebrospinal fluid, sputum, urethral and vaginal discharge, nails, skin scrapings
Cytology	Examination of various specimens for abnormal cells Chromosomal studies Pap smears	Urine, skin, tissue specimens, sputum
Coagulation	Testing for presence or absence of adequate clotting factors	Whole blood
Histology/Pathology	Examination for abnormal form and structure in tissues	Tissue/organs, biopsy specimens from various parts of the body, preserved and fresh specimens examined

- **Urinalysis:** The physical appearance of urine is assessed, and urine chemical and microscopic analysis is performed.
- **Microbiology/Parasitology:** Identification of pathogenic microorganisms and antibiotic sensitivity testing.
- **Cytology:** Examination of various specimens for abnormal cells, chromosomal studies, Pap smears.
- **Coagulation:** Specimens testing for the presence of various clotting factors.
- **Histology/Pathology:** Tissue samples examined for abnormal function and form.

Test Your Knowledge 1-2

Which laboratory department would perform a test to see if someone had a pathogenic microorganism in a wound? (Outcome 1-3)

WHY IS LABORATORY TESTING PERFORMED?

Laboratory testing is critical for appropriate patient treatment. The results obtained from a blood test or evaluation of other types of specimens from the human body are essential for the health-care provider to gain information that is not available through the patient history or physical examination. Health-care providers generally order laboratory tests for at least one of these reasons:

1. *To assign a diagnosis.* Laboratory testing may be used to help with a differential diagnosis when the patient's symptoms are vague or similar to those of other disease states. Diagnostic testing can also confirm a clinical diagnosis (such as diabetes or a myocardial infarction) when that confirmation could lead to more effective treatment for the patient. Microbiological testing may also fall into this category, as the identification of the bacteria and/or virus involved in the infection will be essential to establish an appropriate plan of action.
2. *Prevention or early detection of disease through screening tests.* Many chronic health conditions are **asymptomatic** in the early disease stages. If these conditions are identified with routine screening tests (such as cholesterol measurements and routine prostate cancer screening) early in the disease process, treatment may be much more effective in keeping the patient healthy. These screening tests are being ordered with more frequency in the general population as more

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information becomes available about the advantages of early diagnosis and treatment.

3. *Ongoing assessment of the patient's progress and treatment.* Once a diagnosis has been established and treatment has begun, it is very important that the patient is monitored closely. This often requires frequent blood tests to determine therapeutic drug levels, hepatic profiles when a particular medication may cause liver damage, or hemoglobin tests to see how effective the treatment might be for someone who is anemic. Patients may need to have their blood drawn daily, monthly, or quarterly. The frequency is dependent on the pathological condition. It may be necessary to use specimens other than blood to monitor the treatment for a patient. Sometimes repeat cultures are also necessary to verify the **efficacy** (effectiveness) of the antibiotic used to fight an infection.

Test Your Knowledge 1-3

When a pregnant young woman sees her nurse-midwife for a routine checkup, the practitioner requests a test to see if the patient is developing diabetes during the pregnancy. Why is the test being performed?

a. To assign a diagnosis
b. To screen for prevention or early disease detection
c. To assess the ongoing status of treatment
d. None of the above (Outcome 1-4)

THE ROLE OF THE MEDICAL ASSISTANT IN THE CLINICAL LABORATORY

A medical assistant can contribute in the clinical laboratory in various ways. The comprehensive training received by medical assistants allows them to perform clinical duties with direct patient contact, as well as offering employment opportunities in an administrative capacity. A clinical medical assistant working in a physician office laboratory may be called on to perform phlebotomy or supervise urine drug screen collections for routine employment purposes, educate patients concerning collection protocols, collect and process microbiology specimens, and perform various test procedures. Medical assistants performing clinical duties may also be asked to prepare microscopic specimens for examination, and focus the microscope for providers to evaluate the specimen. In addition, the medical assistant with appropriate training may also perform microscopic examinations such as white blood cell differential counts and urine microscopy examinations.

A clinical medical assistant working in a hospital or reference laboratory may function as a phlebotomist or may work as a laboratory assistant. A laboratory assistant may be responsible for setting up microbiology cultures, answering phones and responding to requests for laboratory results, assisting with bone marrow aspiration or other collection procedures, processing specimens and delivering them to the various laboratory departments, performing CLIA-waived or moderate-complexity tests available in that laboratory setting, or assisting with preparation of tissue and cellular samples for examination. Medical assistants may also perform point-of care testing and assist with quality assurance in the laboratory.

An administrative medical assistant in a laboratory setting might help with inventory and ordering of supplies, data input, answering telephone calls, scheduling, billing and coding, production and transmission of laboratory reports, creation of other laboratory forms, and various nonclinical patient interactions. These duties are necessary in every laboratory, regardless of size or location.

Test Your Knowledge 1-4

True or False: A medical assistant can work only in an administrative capacity in a hospital or reference laboratory. (Outcome 1-4)

Test Your Knowledge 1-5

Are medical assistants able to perform laboratory testing? (Outcome 1-5)

INFORMATION FLOW IN THE CLINICAL LABORATORY

In addition to understanding the organization of the clinical laboratory setting and identifying the reason laboratory testing might be performed, it is important to know how information is exchanged within the laboratory. To ensure that laboratory test results are as meaningful as possible to the health-care provider, all those involved with specimen collection, processing, and testing must use the required paperwork and database correctly. This information exchange will involve a **laboratory requisition,** a **laboratory directory,** a computer database, and a **laboratory report.**

Laboratory Requisitions

A laboratory requisition (Fig. 1-1) is the form used by a physician (or other qualified health-care professional) to

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CB LABORATORY

Patient (Last, First, MI)

Sex ☐ Male ☐ Female | Date of Birth (required)

Patient Number | Room #

Guarantor Required if insurance or patient billing | Day Phone

Address | PM Phone

City | State | Zip

774911 774911 774911 774911 774911 774911

CLIENT ACCOUNT NO. 790338
Shore Physicians
13 Waterview Dr.
Seattle, WA 98103
☐ CALL RESULTS TO: 425-377-8571
☐ FAX RESULTS TO: 425-792-1608

INSURANCE INFO (PLEASE ATTACH COPY OF CARD, W/GROUP # & ADDRESS)

PATIENT RELATIONSHIP TO SUBSCRIBER: ☐ SPOUSE ☐ CHILD ☐ OTHER

ORDERING PRACTITIONER - FULL NAME(S) REQUIRED
DRS NAME (Last, First, MI): _____
ADDL. COPY TO: _____
ADDRESS: _____
PHONE: FAX:

TESTS HIGHLIGHTED IN RED OR MARKED WITH A △ MAY REQUIRE A SIGNED ADVANCE BENEFICIARY NOTICE (ABN), IF BILLING MEDICARE. ADDITIONAL LCD TESTS NOT LISTED MAY REQUIRE AN ABN.

ADDITIONAL TESTS/COMMENTS - DIAGNOSIS CODES REQUIRED FOR EACH TEST ORDERED

Collection Code: B = LIGHT BLUE FS = FROZEN SERUM L = LAVENDER R = RED TOP (PLAIN)
S = SERUM (GOLD TOP OR TIGER TOP) U = URINE

Specimen Information

■ STAT | ☐ Phone ( ) _____ or ☐ Fax ( ) _____ | Collected by | Date Drawn | Time Drawn A.M. P.M. | ☐ Fasting ☐ Random | 24 Hour Urine Volume _____

CPT	✓	Tests or Panels	ICD9-CM
Panel or Single tests may be selected			
80051		**Electrolytes Panel**	S
84295		Sodium	S
84132		Potassium	S
82435		Chloride	S
82374		Carbon Dioxide	S
80048		**Basic Metabolic Panel**	S
80051		Na, K, CL, CO2	S
84520		BUN	S
82310		Calcium	S
82465		Creatinine	S
82947		Glucose	S
80053		**Comprehensive Metabolic Panel**	S
80048		Basic Metabolic Panel	S
82040		Albumin	S
84075		Alkaline Phos.	S
82247		Bilirubin, Total	S
84450		SGOT/AST	S
84460		SGPT/ALT	S
84155		Total Protein	S
80076		**Hepatic Function (Liver) Panel**	S
82040		Albumin	S
82247		Bilirubin, Total	S
82248		Bilirubin, Direct	S
84450		AST/SGOT	S
84460		ALT/SGPT	S
84075		Alkaline Phos.	S
84155		Total Protein	S

CPT	✓	Tests or Panels (cont'd)	ICD9-CM
Panel or Single tests may be selected			
80069		**Renal Function Panel**	S
84100		Phosphorus	S
80061		**Lipid Profile**	S
82465		Cholesterol	S
84478		Triglycerides	S
83718		HDL Cholesterol	S
80074		**Acute Hepatitis Panel**	S
86709		Hepatitis A Antobidy IGM	S
86705		Hepatitis B Core Antibody IGM	S
87340		Hepatitis B Surface Antigen	S
86803		Hepatitis C Antibody	S

CPT	✓	Single Tests	ICD9-CM
86900		ABO Blood Group	L, R
86901		RH (D) Type	L, R
86850		Antibody Screen	L, R
82150		Amylase	S
86038		Antinuclear Antibody	S
82607		B-12 Vitamin	FS
86141		hs-CRP	S
80156		Carbamazepine/Tegretol ★	R
85025		CBC w/auto diff	L
85007		Manual Diff.	L

CPT	✓	Single Tests (cont'd)	ICD9-CM
82378		CEA	S
82550		CK (CPK)	S
80162		Digoxin ★	R
80101 x7		Drug, Screen, Urine	U
82728		Ferritin	S
82746		Folate	FS
83001		FSH	FS
82977		Gamma GT	S
83036		Hgb A1C (Glycohemo)	L
85014		Hematocrit	L
85018		Hemoglobin	L
86701		HIV 1 Ab w/Western Blot confirmation	S
83540		Iron	S
83550		Iron Binding (TIBC)	S
83615		LD (LDH)	S
83002		LH Luteinizing Hormone	FS
80178		Lithium	R
83735		Magnesium	S
86308		Mono	S
80184		Phenobarbital ★	R
80185		Phenytoin/Dilantin ★	R
85049		Platelet Count Auto	L
84703		Pregnancy, Qual. Serum	S
81025		Pregnancy, Qual. Urine	U

★ REQUIRED LAST CODE
DATE _____ A.M.
TIME _____ P.M.

CPT	✓	Single Tests (cont'd)	ICD9-CM
84702		Beta HCG Quant	S
84146		Prolactin	S
84153		PSA	S
G0103		PSA Screen	S
85610		PT with INR ★	B
Is pt. taking Coumadin? ☐ Y ☐ N ★			
85730		PTT ★	B
Is pt. taking Heparin? ☐ Y ☐ N ★			
85044		Retic Count	L
86592		RPR	S
86762		Rubella Ab	S
85651		Sed Rate	L
84480		T3 Total	S
84479		T3 Uptake	S
84439		T4 Free	S
84436		T4 Total	S
84403		Testosterone Total	S
80198		Theophylline ★	R
84443		TSH	S
81001		Urinalysis w/Micro, auto if indicated	U
82575		Urine Creatinine Clearance 24 hr	U/S
84156		Urine Total Protein 24 hr	U
84540		Urine Urea Nitrogen 24 hr	U

CPT	✓	Microbiology	ICD9-CM
		Aerobic Culture Source _____	
		Anaerobic Culture Source _____	
		Other Source _____	

Other Tests

Only tests or Medicare Approved Panels that are medically necessary for the diagnosis or treatment of a Medicare or Medicaid patient will be reimbursed. Screening tests will not be reimbursed and should not be submitted for payment. The OIG states that a physician who orders medically unnecessary tests for which Medicare or Medicaid reimbursement is claimed may be subject to civil penalties under the False Claims Act.

Figure 1-1 Sample laboratory requisition. Current Procedural Terminology © 2011 American Medical Association, All Rights Reserved.

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document the tests that are to be performed for a patient. The form is filled out by the health-care provider who orders the test or by the provider's office staff. This requisition must be complete with various data linking the patient to the tests ordered, and must provide billing information for that patient. The laboratory staff will use this requisition to enter the orders into their database for the patient, and the form is often used for reimbursement procedures as well. Although all laboratories may use unique formats, standardized information should be present on all requisitions for testing and reimbursement purposes:

- Patient demographic information, including name, address, phone number, and birth date.
- Patient gender.
- Complete patient insurance and billing information.
- Date and time of collection, and identification of the person who performed the collection.
- Documentation of how the results are to be relayed to the health-care provider who ordered the tests, and documentation of any other practitioner who is to receive a copy of the results.
- Appropriate diagnostic information in the form of an **ICD-9 code** to allow for reimbursement for the test ordered. An ICD-9 code is the numeric indicator for the diagnosis or symptom associated with the laboratory test ordered.
- Test selection, clearly marked with a check, circle, or X in the appropriate area on the requisition. Tests may also be written in if they are not preprinted on the requisition used.
- Any additional comments that may assist with the ordering or interpretation of the test.

Test Your Knowledge 1-6

Why is it important to have the name of the ordering physician/practitioner on a requisition when ordering laboratory testing? (Outcome 1-6)

Laboratory tests may be ordered as **panels** or **profiles,** which consist of a group of tests that are designed to indicate a problem with a specific organ system or disease process. Tests may also be ordered individually, or the requisition may contain orders for a combination of both. Often the requisitions are organized according to the general types of tests, such as hematology, serology, or chemistry. On the requisition, each test will have a five-digit procedure code (known as a **CPT code),** which is necessary for reimbursement purposes. There may also be a code or symbol included on the requisition, indicating the type of tube or specimen container that is necessary for that specific test. This information is valuable as a quick reference for the phlebotomist when collecting the specimen.

Most requisitions also include some sort of label that can be peeled off and applied to the specimen container. This label may have numbers, bar-code symbols, or both. These labels link the patient information provided on the requisition with that specific sample once it has been entered into the database for the laboratory.

Advance Beneficiary Notice of Noncoverage

An **Advance Beneficiary Notice of Noncoverage** (**ABN**) is a document that may be necessary to receive

Procedure 1-1: Completing a Laboratory Requisition

TASK

Correctly fill out a laboratory requisition, including all necessary information for reimbursement. Include an ABN if necessary.

CAAHEP/ABHES Standards

None

CONDITIONS

- Laboratory requisition
- Patient demographic information
- Patient insurance information
- Laboratory order from qualified health-care professional
- ICD-9 code for diagnosis or symptoms
- Advance Beneficiary Notice of Noncoverage

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Procedure	Rationale
1. Greet and identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered.	All laboratory test orders should be verified by checking the chart and/or requisition more than once.
3. Fill in the requisition with the patient's demographic information by printing it clearly, or by using a data entry program if available at your location.	The patient's demographic information (including age and gender) is used for reimbursement as well as establishing reference ranges for the tests ordered.
4. Ask patient for an insurance card if he or she is insured.	The insurance card should be used for the information added to the requisition; do not rely on information that the patient provides from memory.
5. Copy both sides of the insurance card, and add the information to the requisition in the appropriate site.	Be sure to include the insurance identification number as well as the group number for appropriate reimbursement. The back of the card is important to copy, as it provides the insurance company's contact information in case of claim questions.
6. Establish the relationship of the patient to the insured. Document that on the requisition.	Sometimes the patient is not listed on the insurance card; it may be a spouse or a child or other dependent.
7. If the patient has a medication level ordered (such as digoxin), ask when the patient took the last dose. Use the laboratory directory if necessary to verify whether it is the correct time to draw the specimen. Note the time of the last dose on the requisition.	Some medication levels are clinically significant only when drawn at a specific interval after the last dose.
8. If the patient has Medicare Part B as his or her primary insurance coverage, verify whether an Advance Beneficiary Notice of Noncoverage is necessary. This must be completed and signed before the specimen collection begins.	The laboratory may have a database established in which the employee can type in the name of the test ordered and the diagnosis code provided, and the software will be able to determine whether an ABN is necessary. If there is no automated system in place, the employee may need to use an alternative reference. Many laboratories provide their clients with a book of covered diagnosis codes for the tests with limited coverage.
9. Clarify which physician ordered the test and document that on the requisition. If additional copies are to be sent to other health-care providers, add this information to the requisition as well.	Many times the requisitions will be preprinted with the name of the physician office or practice group. It is still necessary to document which physician within the practice actually ordered the laboratory test to be performed.
10. Document whether the test was ordered as STAT or routine.	If the test was ordered as STAT, it needs to be drawn and processed immediately. It may be necessary to contact a laboratory courier to pick up the sample immediately, or to notify the technician that there is a STAT order.

Continued

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Procedure 1-1: Completing a Laboratory Requisition—cont'd

Procedure	Rationale
11. Check the requisition for an ICD-9 code for each test to be performed. If a code is not present, contact the health-care provider or check the chart to obtain a code.	An ICD-9 code is necessary for every test for successful reimbursement.
12. Have the patient wait in a comfortable environment until the sample can be collected. Place the requisition in an appropriate location to alert other staff members that a specimen collection is waiting.	Sometimes the employee who fills out the requisition is not the same person who will collect the sample.

reimbursement for laboratory services. It is specifically used for patients who have Medicare Part B as their primary insurance coverage. The purpose of an ABN is to inform Medicare-covered patients that payment may be denied for a specific laboratory test and that the patient will be billed for the full cost of that test if he or she chooses to have it performed. The ABN allows the patients to make an informed decision about whether they wish to have the tests performed, with the realization that they may be responsible for the total cost.

The ABN must be verbally reviewed with the patient, and any questions about potential reimbursement must be answered before it is signed, whether or not the patient wishes to have the laboratory work performed. This process must occur before the specimen is collected from the patient. The person collecting the specimen must ensure that the test ordered has been identified on the ABN form and that there is documentation of the anticipated reason for noncoverage. Figure 1-1 shows an example of an ABN. The employee filling out the form also must provide an estimated cost in writing so that the patient knows what the financial responsibility may be if he or she decides to have the laboratory test performed. The patient's decision about having the test performed must be documented on the form, along with the patient's signature and that day's date. The patient must receive a copy of the form after it is signed, and a copy must also be kept on file with the laboratory.

Medicare coverage for laboratory tests may be denied for various reasons, including frequency of testing, the diagnosis provided by the health-care provider for a specific test, or because the test ordered is considered experimental. Whenever a patient with Medicare coverage has a specimen collected, the laboratory employee responsible for the specimen collection must verify whether the test ordered will be covered by Medicare for the reason that the test is ordered. The regulations affecting coverage are different for geographical regions across the country, and change frequently. Most laboratories now have a way to verify coverage by using a computer database, but it can be difficult to keep abreast of changes. It is unlawful to have every Medicare patient fill out an ABN "just in case"; it is the responsibility of those collecting the specimen to make their best effort to verify coverage before an ABN is signed.

The format for this Advance Beneficiary Notice of Noncoverage document is defined by the Centers for Medicare & Medicaid Services (CMS), and is updated periodically (CMS document number CMS-R-131). Medicare bases its decision for coverage on "medical necessity" rules, which define those tests that the agency deems medically necessary for specific health conditions, and how frequently these tests should be performed. It is important to remember that just because Medicare has limited coverage on specific tests, the patient should never be told that the health-care provider gave a "bad code" or that the test was ordered for the "wrong reason."

Test Your Knowledge 1-7
What is the purpose of an ABN? (Outcome 1-7)

Laboratory Directory

As discussed, laboratory requisitions often provide information about what type of tube to use for a blood draw for a specific test by using a code or symbol, but

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CB LABORATORY 2692 Millenium Rd. • Seattle, WA 98103
425-353-8778

ADVANCE BENEFICIARY NOTICE (ABN)

Patient's Name: John Smith Identification Number: 23995500

ADVANCE BENEFICIARY NOTICE OF NONCOVERAGE (ABN)

***NOTE:* If Medicare doesn't pay for the Laboratory Test(s) Below you may have to pay.**

Medicare does not pay for everything, even some care that you or your health-care provider have good reason to think you need. We expect Medicare may not pay for the Laboratory Test(s) below.

Laboratory Test(s):	Reason Medicare May Not Pay:	Estimated Cost:
PROSTATIC SPECIFIC AG	Denied as too frequent	$50.10
TSH	Denied for your condition	$41.34

WHAT YOU NEED TO DO NOW:

- Read this notice, so you can make an informed decision about your care.
- Ask us any questions that you may have after you finish reading.
- Choose an option below about whether to receive the Laboratory Test(s) listed above.

Note: If you choose Option 1 or 2, we may help you use any other insurance that you may have, but Medicare cannot require us to do this.

OPTIONS: **Check only one box. We cannot choose a box for you.**

☐ **OPTION 1.** I want the Laboratory Test(s) listed above. You may ask to be paid now, but I also want Medicare billed for an official decision on payment, which is sent to me on a Medicare Summary Notice (MSN). I understand that if Medicare doesn't pay, I am responsible for payment, but **I can appeal to Medicare** by following the directions on the MSN. If Medicare does pay, you will refund any payments I made to you, less co-pays or deductibles.

☐ **OPTION 2.** I want the Laboratory Test(s) listed above, but do not bill Medicare. You may ask to be paid now as I am responsible for payment. **I cannot appeal if Medicare is not billed.**

☐ **OPTION 3.** I do not want the Laboratory Test(s) listed above. I understand with this choice I am not responsible for payment, and **I cannot appeal to see if Medicare would pay**.

Additional Information:

This notice gives our opinion, not an official Medicare decision. If you have any other questions on this notice or Medicare Billing, call **1-800-MEDICARE** (1-800-633-4227/**TTY:** 1-877-486-2048).
Signing below means you have received and understand this notice. You also receive a copy.

Signature:	Date:

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0938-0566. The time required to complete this information collection is estimated to average 7 minutes per response, including the time to review instructions, search existing data resources, gather the data needed, and complete and review the information collection. If you have comments concerning the accuracy of the time estimate or suggestions for improving this form, please write to: CMS, 7500 Security Boulevard, Attn: PRA reports Clearance Officer, Baltimore, Maryland 21244-1850.

Form CMS-R-131 (03/08) Form Approved OMB No. 0938-0566

HNL-18 (03/09) WHITE: LAB COPY CANARY: PATIENT COPY **ADVANCE BENEFICIARY NOTICE (ABN)**

Figure 1-2 Example of an Advance Beneficiary Notice of Noncoverage (ABN).

the information provided on the requisition is limited at best. The requisition does not include information about how to process and store the specimen, or what the minimum volume may be for the test ordered. It also does not include information about how often the laboratory performs that specific analysis if the physician needs to know this information. This additional information about specimen collection and handling may be found in a laboratory directory (Fig. 1-3).

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POINT OF INTEREST 1-1
Advance beneficiary notice of noncoverage

If a laboratory accepts Medicare assignment, it is not legal to bill Medicare beneficiaries for laboratory tests that are covered by Medicare Part B. However, Medicare does not cover all laboratory tests, so there are many situations in which the health-care providers may order tests that are not covered by Medicare but that provide valuable information for patient treatment. The only way that the laboratory can be reimbursed for these tests is to have the patient complete a valid Advance Beneficiary Notice of Noncoverage, also known as an ABN. This form must be completed and signed prior to the specimen collection. The ABN form informs the Medicare beneficiary of the test that has been ordered, and specifies the reason that Medicare may not pay for the tests, as well as providing the estimated cost for the test.
The ABN is necessary in these situations:

- When the test ordered is not medically necessary in Medicare's opinion for the ICD-9 code (diagnosis) that is provided. This situation is also present if there is no ICD-9 code given for the test ordered.
- Many screening tests are not covered by Medicare; these are often not covered if there is no evidence of disease.
- Tests that are ordered more frequently than what is recommended by Medicare.
- Any test that is still considered to be investigational or experimental in nature. These tests have not yet been approved by the FDA.

Often those who work with Medicare patients will use the term *limited coverage* to refer to the rules that govern laboratory reimbursement. This means that Medicare will pay for laboratory tests only when they meet certain criteria. These may be national coverage decisions or local coverage decisions. Nationally, there are several tests established that have limited coverage (based on the ICD-9 codes, frequency of testing, or the investigational status) and regional restrictions may add to the list that is established on a national basis.

By signing the ABN, the Medicare patient is giving the laboratory permission to bill him or her directly for the test to be performed. If the employee who draws the blood does not get an ABN signed when appropriate, the laboratory will be performing the test for free, as it cannot have the ABN signed after the process is completed. If the specimen was collected by an employee at a physician office and transported to the laboratory for testing, the physician office will often receive a bill for the service from the laboratory, because that laboratory cannot be reimbursed in any other way.

It is illegal to have every Medicare patient fill out an ABN; these forms are to be used only when necessary for noncovered tests. In addition, the laboratory must retain a copy of the ABN and the patient must also be given a copy. Advanced Beneficiary Notices of Noncoverage are also used for other medical services; it is necessary to have a specific one for each type of noncovered service.

Commonly, a laboratory directory is a computer database of specific information about tests that are performed by that laboratory. The directory may also be provided in a book format, which can be consulted by facilities that do not have Internet access. The laboratory directory (also known as a directory of services) provides the following types of information:

- The internal test number used to enter the test order into the database
- CPT five-digit code used for reimbursement for that test
- Related information if there is more than one place within the directory where the test is addressed
- Acronyms or abbreviations that may be listed on the requisition for that test, or perhaps used to order the test in the computer system for that laboratory
- The type of specimen required, and in some cases the type or color of tubes to use for the blood draw or identification of the additives that must be present in the tubes
- The requested specimen volume and the minimum acceptable specimen volume
- Collection notes and/or specific requirements necessary for some tests
- Storage instructions for the specimen after collection and during transportation (room temperature, frozen, refrigerated, etc.)
- **Reference ranges** (also known as **normal ranges)** for the test ordered
- Clinical significance and interpretation of the test results
- Testing intervals/frequency and testing locations

Once the specimen requirements have been established, the collection process can continue. The employee who is performing the collection must document two unique

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CB LABORATORY

2692 Millenium Rd - Seattle, WA 98103
425-353-8778

GLYCOHEMOGLOBIN

Order	Test
GLYCO	GLYCO

Represents average glucose concentration over a 6–8 week period.

Synonyms	HbA1C; Hemoglobin A1C
Specimen Required	
Container Type	Lavender top tube (EDTA)
Specimen Type	Whole blood
Minimum Volume	1 mL
Specimen Processing	Store and transport refrigerated.
Stability	Room Temp 24 hours Refrigerated 7 days Frozen (–20°C) 2 weeks
Alternate Specimens	Sodium flouride/potassium oxalate whole blood (grey top tube).
Department	Immunochemistry
CPT Codes	83036
Test Schedule	Sun-Fri nights
Turnaround Time	24-48 hours
Method	HPLC
Test Includes	
HbA1c, %	
Reference Ranges	
HbA1c 4.0-6.0 Non-diabetic % The American Diabetes Association considers a result of less than 7% to be the goal of diabetic therapy.	

Figure 1-3 Sample of information found in a laboratory directory.

Procedure 1-2: Use a Laboratory Directory

TASK

Use a laboratory directory to clarify the collection requirements and processing procedures for a laboratory order.

CAAHEP/ABHES Standards

None

CONDITIONS

- Laboratory requisition
- Laboratory order from qualified health-care professional
- Laboratory directory book or database including laboratory service information

Continued

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Procedure 1-2: Use a Laboratory Directory—cont'd

Procedure	Rationale
1. Obtain the laboratory requisition or the laboratory order from the health-care provider. Verify the test ordered, especially if it is a test that may be performed on more than one body fluid.	Some tests, such as creatinine or total protein, are commonly ordered on blood but may also be ordered using a urine specimen.
2. Look up the test alphabetically using the computer database or the laboratory directory reference book.	This can sometimes be difficult if the test is ordered under an acronym or abbreviation or if there are two names used for the test, such as Tegretol, which may also be known as carbamazepine. Many laboratory directories will include a cross-reference that may help the user to find the correct entry.
3. Identify the type of specimen to be collected.	The information may be very straightforward, specifying the color of tube to be used. (For example, lavender-top or green-top tube.) However, sometimes the specimen requirements are described as "heparinized plasma" or "EDTA plasma." The employee needs to know which type of tube to use for this type of specimen.
4. Verify any restrictions on specimen type, or notations of unacceptable specimens.	For instance, many tests cannot use hemolyzed samples, or sometimes samples that are over 2 hours old cannot be used.
5. Verify the acceptable minimum volume, if listed.	There may be a requested volume (e.g., 1 mL) as well as a minimum volume listed. The minimum volume may be important if drawing the specimen from a child or other patient with difficult-to-access veins.
6. Identify the specimen processing instructions.	Is the specimen supposed to be spun within a certain time after the blood draw? Is the plasma or serum to be frozen? The processing instructions are very important for the specimen to be acceptable when it arrives at the testing laboratory.
7. Identify the schedule for performance of the test ordered.	The reference laboratory may list the testing schedule so that the health-care provider will be aware of how long it will take before he or she can expect the results for the test.
8. Prepare the necessary supplies to perform the specimen collection.	If a specimen must be frozen immediately or kept at a certain temperature, it is necessary to have the supplies at hand immediately after the specimen is collected. These should be prepared before proceeding.

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identifiers for the patient, the employee ID (or initials), the date of collection, and the time of collection on the requisition and on the tube or alternative collection container. This same employee may also be responsible for entering the patient information into the computer database, whereas in other laboratories the specimen and paperwork may be prepared for transport to another location where the information will be added to the database upon arrival.

Test Your Knowledge 1-8

Why would a medical assistant use a laboratory directory before performing a blood draw? (Outcome 1-8)

Laboratory Reports

Once the specimen has been processed, delivered to the correct department, and tested within the laboratory, a laboratory report is generated to transmit the test results back to the health-care provider. An example of a laboratory report is presented in Figure 1-4. The laboratory report document will list the results for the tests performed, as well as the reference ranges (also known as normal ranges) that have been established by the laboratory for that test. Reference ranges are the results that are expected in the general healthy population 95% of the time for a particular laboratory test. A range is necessary (instead of a specific value) because of differences in the population due to age, race, and gender. Geographical locations may also affect the reference range, as will the testing methods used by that laboratory. A notation will be present on the laboratory report for all results that are outside the expected reference range for that patient, based on demographics, the testing method, and the test ordered. The gender and age of the patient may affect the reference ranges used for interpretation of the results, so it is critical that this information is provided whenever a sample is collected.

The laboratory report will also include the date and time of the specimen collection, the name and identification number for the patient, and the name and address of the laboratory where the test was performed. The specimen source is identified, as well as the date and time the report was generated.

CB LABORATORY

Patient: Sally Seashore
DOB: 08/07/1957 Sex: Fe
ID# 774909

Date/Time: 7/20/2012 16:50
Report Status: Final

PROCEDURE	RESULT VALUES	ABN	REFERENCE RANGES	UNITS
Rapid strep screen				
Rapid strep screen	*Positive*			
Dipstick UA only				
Appearance-UA	Clear			
Color-UA	Yellow			
Glucose-UA	Neg			
Ketone-UA	Neg			
UA spec gravity	1.010		1.002 – 1.030	
Occult-blood-UA	Neg			
pH-UA	6.0		5 – 7.9	
Protein-UA	Neg			
Nitrite	Neg			
Leukocyte esterase	Neg			
Electrolytes				
Sodium	141		136 – 145	mEq/L
Potassium	4.8		3.5 – 5.0	mEq/L
Chloride	100		96 – 106	mEq/L
CO2	25		22 – 30	mEq/L
Hemoglobin + Hematocrit				
Hgb	10.9	L	12 – 16	g/dL
HCT	33	L	37 – 48	g/dL

Flags: H = High L= Low A = Abnormal Crit = Critical

Tests performed at: CB Laboratory, 2692 Millenium Rd., Seattle, WA 98103

Figure 1-4 Sample laboratory report.

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Procedure 1-3: Distinguish Between Normal and Abnormal Test Results

TASK

Use a laboratory report to identify normal and abnormal test results for a patient.

CAAHEP/ABHES Standards

CAAHEP 2008 Standards

II.A.2: Distinguish between normal and abnormal test results

ABHES Standards

None

Conditions

- Laboratory report
- Pen, pencil, or highlighter

Procedure	Rationale
1. Examine the laboratory report for all necessary information.	All laboratory reports must include the following: 1. The name of the patient 2. The patient ID 3. The gender and age of the patient 4. Laboratory results with documented reference ranges 5. The name of the ordering health-care provider 6. The date and time of specimen collection 7. The date and time that the specimen was tested 8. The name of the laboratory where the test was performed
2. Identify the column on the laboratory report where the reference ranges are noted for each of the test results.	This column is usually near the patient results, and the data are often listed as a range, except in the case of tests that provide a positive and negative test result, or in the case of microbiology testing, antibiotic sensitivity testing, or immunology testing.
3. Compare the patient results to the reference range column.	Remember that the reference ranges may take the age and gender of the patient into consideration; the ranges will not necessarily be the same for all patients tested.
4. Circle or highlight the results that are not within the reference ranges. Document High or Low next to the values in the provided area.	Highlighting or circling these results may bring them to the attention of the provider. When a laboratory report is printed in the office (rather than one used in the classroom) the High or Low results are noted on the laboratory report when it is printed. However, the office protocol may also include highlighting or circling the results when the report arrives in the office to make certain that they are not overlooked.

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Laboratory reports may be hand-delivered to the ordering health-care provider by a medical assistant within an office or via a courier service from a reference laboratory. They may also be faxed, mailed, or in some cases transmitted via e-mail. In some situations, the laboratory reports may also be available online through a dedicated laboratory link so that the provider can view the results on site. These results must be reviewed as soon as possible so that appropriate action can be taken for those outside of the normal reference range. Laboratory reports are a legal document that becomes part of the patient's health record.

Test Your Knowledge 1-9

In which ways are laboratory requisitions and laboratory reports similar? (Outcome 1-9)

THREE PHASES OF LABORATORY TESTING

As we begin to understand the way that a laboratory is organized and how information is transferred through the testing process, it is important to realize that there are three components, known in laboratory jargon as *phases,* associated with laboratory testing: preanalytical, analytical, and postanalytical. A description of each phase of testing is detailed below and summarized in Table 1-3.

- **Preanalytical Phase:** The preanalytical phase of laboratory testing refers to the situations and actions that take place prior to the collection, during the collection, and during the processing/storage/transportation of the specimen. Phlebotomists and medical assistants often participate in this phase of laboratory testing. The importance of this phase cannot be emphasized enough. Generally speaking, the majority of problems associated with laboratory tests result from inadequate or inappropriate specimen collection, processing, storage, and transportation (i.e., the preanalytical phase of testing).
- **Analytical Phase:** The analytical phase of laboratory testing refers to the performance of the tests that have been ordered. This phase also includes maintenance and calibration of laboratory equipment and instruments associated with the testing and performing

TABLE 1-3

Identification of, Definition of, and the Personnel Responsible for the Three Phases of Laboratory Testing

Phase	Definition	Personnel Responsible
Preanalytical	All procedures/processes that occur before the specimen is actually tested. Includes patient preparation, accurate paperwork and data entry, appropriate specimen collection, processing, storage and transportation.	Medical assistant, phlebotomist, CLT or MLT, other laboratory professionals involved in this process
Analytical	All procedures/processes involved in the testing of the specimen. This includes the way the testing instrument was prepared and maintained, how the testing supplies were stored, appropriate training of the personnel performing the test, and quality control to ensure that the testing methods are working properly.	Medical assistant, medical laboratory professional performing the test, supervisor responsible for training and overseeing the process, personnel performing maintenance on instruments
Postanalytical	All procedures/processes that affect how the test results are handled when the analysis has been completed. These may include review and analysis of the results by the person performing the test, appropriate follow-through on extremely high or low results, how the results are recorded (in a computer or on paper, etc.) phone calls, report printing, report sorting, appropriate fax procedures, charting procedures within an office, physician review procedures, contact with patient if necessary for follow-up.	Various laboratory professionals that perform the test, administrative laboratory support personnel that process the results, medical assistants or other physician office personnel who perform charting procedures, physicians and other health-care professionals who interact directly with the patients.

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quality control (QC) measures, which are in place to validate the test reagents/kits, the testing process, and training of the laboratory personnel performing the test.

- **Postanalytical Phase:** The postanalytical phase of laboratory testing includes the processes associated with the recording and reporting of laboratory results, storage and/or disposal of specimens after testing, and provider and patient notification of test results. Even if the other two phases of testing occur without any exceptions, if this phase isn't handled appropriately, then the overall experience will not be a positive one, and may negatively affect patient treatment.

Test Your Knowledge 1-10

List the three phases of laboratory testing. (Outcome 1-10)

Test Your Knowledge 1-11

If a specimen is collected into a tube with the wrong type of anticoagulant for the test ordered, which phase of laboratory testing has gone wrong? (Outcome 1-11)

SUMMARY

Laboratory testing is vital to the diagnosis of patient disease and implementation of proper patient treatment, as it provides critical information that cannot be gathered with a physical examination alone. Testing may occur in physician office laboratories, in hospital laboratories, or in large reference laboratories. The larger laboratories may be organized by departments as needed for efficient specimen handling. Various personnel perform the testing procedures, and their education and titles will vary depending on their responsibilities and the type of testing performed in the respective laboratory. Medical assistants play an important role in the laboratory by providing direct patient interaction, specimen collection, and processing or performance of laboratory tests.

Laboratory information, such as that provided on a requisition, is vital for proper testing procedures, result interpretation, and reimbursement for services provided. The exchange of information begins with a requisition and may involve the use of a laboratory directory for specimen requirements and other specifics. The process ends with the laboratory reports that provide the ordering practitioner with the final test results and reference ranges. Reimbursement procedures may involve laboratory personnel, so it is important that these individuals understand the processes involved with the necessary documentation on a requisition and the use of an ABN.

There are three phases of laboratory testing, including the procedures surrounding specimen collection and handling, the actual testing process, and the manner in which the results are reported back to the physician. These are the preanalytical phase, the analytical phase, and the postanalytical phase. All three phases must be handled correctly for laboratory results to be as meaningful as possible as part of quality patient care.

TIME TO REVIEW

1. If a patient is asymptomatic, it means that he or she: (Outcome 1-1)
   - **a.** Demonstrates specific symptoms of a disease state
   - **b.** Complains of multiple symptoms
   - **c.** Does not exhibit symptoms
   - **d.** Is not ill
2. True or False: A specimen may be defined as a part of something that demonstrates the characteristics of the whole. (Outcome 1-1)
3. What do hospital and reference laboratories have in common? (Outcome 1-2)
4. Is urine analyzed only in physician office laboratories? (Outcome 1-2)
5. A medical assisting student needs to have a blood test performed to see if she has antibodies to hepatitis B in her bloodstream. This test would most likely be performed in this laboratory department: (Outcome 1-3)
   - **a.** Blood Banking
   - **b.** Hematology
   - **c.** Serology
   - **d.** Microbiology
6. Which laboratory department is responsible for accessioning specimens into the laboratory information system when they arrive at the laboratory? (Outcome 1-3)
7. Mr. Earl has a laboratory test performed to see if the diet and exercise changes suggested by (Outcome 1-4)

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his health-care provider have helped to lower his cholesterol levels. Which of these reasons explains why this test is being ordered?

a. Assignment of a diagnosis
b. Ongoing assessment of the patient's progress and treatment
c. Prevention or possible early detection through screening tests
d. None of the above

8. Which of these duties might a medical assistant perform in a laboratory setting? Outcome 1-5

a. Urine drug screen collections
b. Phlebotomy
c. Urinalysis testing
d. Preparation of microbiology specimens for testing and/or analysis
e. All of the above

9. True or False: A diagnosis code does not need to be included on a requisition at the time the laboratory test is ordered. Outcome 1-6

10. True or False: A requisition is used only for ordering the laboratory tests. Outcome 1-6

11. The abbreviation ABN stands for: Outcome 1-7

a. Advance Beneficiary Notice of Noncoverage
b. Advance Beneficiary Notification
c. Action Bulletin of Noncoverage
d. Advance Bulletin of Noncoverage

12. The laboratory directory will include _____ instructions for a specimen after collection and during transportation. Outcome 1-8

13. True or False: The terms *laboratory requisition* and *laboratory report* may be used interchangeably. Outcome 1-9

14. Which phases of laboratory testing might be affected by the actions of a medical assistant in his or her various laboratory roles? Outcome 1-11

Case Study 1-1: Potential for growth

Cindy Lee, a certified medical assistant (CMA) working in a gynecology office, leaves early one Friday before her office closes. When she returns on Monday morning, she finds a box containing agar plates for microbiology specimen growth on the counter in the laboratory area. Cindy notices that the box has KEEP REFRIGERATED printed on the outside, but it appears that the box has been left out all night, and the cold packs within the box are at room temperature.

- Should Cindy be concerned about this situation?
- Which phase of laboratory testing may be affected by this oversight?

RESOURCES AND SUGGESTED READINGS

American Society for Clinical Laboratory Science Consumer Lab Testing Information
http://www.ascls.org/labtesting/index.asp
Numerous questions and answers on general laboratory testing.

American Society for Clinical Laboratory Science Introduction to Laboratory Testing
http://www.ascls.org/labtesting/labintro.asp
Introduction to the three phases of laboratory testing; also basic terms referring to analytical aspects of quality control.

Centers for Medicare & Medicaid Services Overview of Beneficiary Notices Initiative
http://www.cms.hhs.gov/bni
Links to various ABN information, including the new and old forms in use and answers to various commonly asked questions.

Good Laboratory Practices for Waived Sites
http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5413a1.html
An overview of some problems that have occurred in waived test sites and an introduction to the three phases of laboratory testing. Recommendations for good practices overall.

CLIA Update—January 2010. Division of Laboratory Services, Centers for Medicare & Medicaid Services; Laboratories by Type of Facility (Exempt/Nonexempt combined)
http://www.cms.gov/CLIA/downloads/factype.pdf
Lists the number of different types of laboratories registered with CMS as of January 2010.

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Chapter 2

Regulations Governing Laboratory Personnel

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Laboratory Professionals
- Personnel in the Laboratory Setting
- Medical Assistants in the Laboratory

Clinical Laboratory Improvement Amendment of 1988
- History of the Regulation
- Levels of Laboratory Testing Defined by CLIA
- Employee Qualifications for Performance of CLIA Testing
- Oversight of CLIA Laboratories

Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

2-1 Define the key terms.

2-2 List the laboratory professionals present in a typical hospital, reference, or physician office laboratory.

2-3 Describe the personnel structure of the laboratory settings presented in the text.

2-4 Explain how the duties of laboratory professionals may vary, depending on their education and credentials.

2-5 Describe the role of a medical assistant in the clinical laboratory.

2-6 Explain the focus of CLIA '88, and why it was developed.

2-7 Demonstrate understanding of the levels of laboratory testing designated by CLIA '88.

2-8 Identify the laboratory professionals qualified to perform the various levels of laboratory testing as allowed by CLIA '88.

2-9 Identify the agencies responsible for overseeing CLIA '88 compliance.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

IX.C.5: Discuss licensure and certification as it applies to healthcare providers.
IX.C.8: Compare criminal and civil law as it applies to the practicing medical assistant.

ABHES Standards

4.b: Medical Law and Ethics: Federal and State Guidelines
4.f: Medical Law and Ethics: Health laws and regulations
Graduates. f: Comply with federal, state and local health laws and regulations.

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KEY TERMS

Ambulatory care
CLIA '88
CLIA-waived
Centers for Medicare & Medicaid Services (CMS)
COLA
Credentialed
High-complexity tests
Labile
Moderate-complexity tests
Phlebotomist
Proficiency testing
Provider-performed microscopy procedures (PPMPs)
U.S. Department of Health and Human Services (HHS)
U.S. Food and Drug Administration (FDA)

Medical assistants are in a unique situation, as the diverse training they receive allows them to assume numerous roles in an ambulatory setting. A medical assistant may have an opportunity to interact with various health-care agencies and related entities, such as radiology clinics, insurance companies, physical therapy offices, specialty physician offices, or pharmacies. In addition, the duties of the medical assistant will most likely include communication with the laboratory, and many medical assistants also perform laboratory testing in physician office laboratories. It is important to understand who makes up the workforce of the medical laboratory so that effective communication may be established. It is also vital that medical assistants understand the regulations controlling laboratory testing as they apply to the scope of practice in the physician office laboratory to remain compliant. This chapter provides an understanding of how to keep the physician office laboratory operating within the boundaries of the regulations. It will also provide insight into the clinical laboratory by identifying which career paths are available to a medical assistant.

LABORATORY PROFESSIONALS

Laboratory professionals pay a critical role in quality health care. The test results they generate improve patient care by providing information to the physician that cannot be discovered in any other way. Even though many processes in the laboratory have become automated, it is important for those performing the testing procedures to have adequate background knowledge for appropriate interpretation of the test results. It is also imperative that laboratory employees are knowledgeable about the procedures necessary to ensure quality testing methods in the laboratory, laws and regulations governing laboratory processes, and how all the laboratory departments work together.

Personnel in the Laboratory Setting

The personnel involved in laboratory testing are classified according to their education and credentials. Table 2-1 provides a list of the laboratory professionals that may play a role in laboratory testing, including their credentials and education. The basic classifications include the following:

- **Pathologists:** These are board-certified physicians who have specialized training in disease and laboratory interpretation. A pathologist may function as the laboratory director for sites that perform all levels of laboratory testing, and is generally affiliated with hospital and reference laboratories.
- **Physicians:** A physician without any laboratory specialty training may function as the laboratory director of a physician office laboratory. Dentists may also serve as laboratory directors if they perform laboratory testing in their clinics. Physicians may not serve as directors for hospital or reference laboratories unless they have additional credentials specifically qualifying them for this setting.
- **Nurse-practitioners or physician assistants:** These are known as midlevel health-care providers, and they may function as directors of physician office laboratories. Nurse-practitioners have at least 6 years of education; physician assistants generally possess at least a 4-year degree, as well as additional focused medical education. These midlevel providers are not usually employed in a reference or hospital laboratory.
- **Medical laboratory scientists:** Personnel with this title often work in a reference or hospital laboratory as testing personnel or as supervisors. They must have at

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TABLE 2-1
Laboratory professional title, education, and credentials

Laboratory Professional Title	Education	Credentials
Pathologist	Doctorate with at least 8 years of education	MD or DO, board certified as pathologist
Physician	Doctorate with at least 6 years of education	MD or DO
Physician assistant	Bachelor's degree	PA
Nurse-practitioner	Master's degree	NP or ARNP
Clinical laboratory scientist	Bachelor's or master's degree	CLS, certified by National Certification Agency for Medical Laboratory Personnel (NCA)
Medical laboratory scientist	Bachelor's degree	MLS, certified by the American Society for Clinical Pathology (ASCP) or MT if certified by the American Medical Technologists (AMT), or International Society for Clinical Laboratory Technology (ISCLT)
Medical laboratory technician	Associate degree	MLT, certified by the American Society for Clinical Pathology (ASCP) or American Medical Technologists (AMT)
Clinical or registered laboratory technician	Associate degree	International Society for Clinical Laboratory Technology (ISCLT)
Medical assistant	1-year certificate or associate degree	May be certified by the American Association of Medical Assistants (CMA) or registered by the American Medical Technologists (RMA)
Phlebotomist	Varies by state	May be nationally certified by various agencies; not always required; some states may allow training on-the-job with no formal education

Note: Those with an associate degree or higher are generally required to have certification (credentials) to work in the laboratory. Those below this level of education are not necessarily required to have formal certification.

least a 4-year degree in laboratory medicine, and are credentialed by the American Society for Clinical Pathology. Those qualified with a 4-year degree may also be known as medical technologists if they received their certification through the American Medical Technologists.

- **Medical laboratory technicians:** These employees usually perform testing procedures in a hospital or reference laboratory. They may also be employed in physician office laboratories. Medical laboratory technicians must have completed at least an associate degree in laboratory medicine, and are nationally certified through the American Society of Clinical Pathology or through the American Medical Technologists.
- **Medical assistants:** Medical assistants may work in a physician office laboratory, but they can also be employed in a reference or hospital laboratory if the tasks they perform are within their lawful scope of practice. Medical assistants have completed a medical assisting program that included at least an introduction to laboratory procedures. Medical assistants are not required to be certified to work in a laboratory, but if they choose to pursue a certification, they may test through the American Association of Medical Assistants to become a certified medical assistant (CMA), or through the American Medical Technologists to become a registered medical assistant (RMA).
- **Phlebotomists:** A **phlebotomist** may be a medical assistant, but there are also phlebotomists trained in short-term programs, either at technical colleges or on the job, specifically to draw blood and process laboratory specimens. Phlebotomists are primarily employed in physician office laboratories and hospital laboratories. Phlebotomists must have at least a high school

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diploma (or general equivalency diploma [GED]) and have documented training to draw blood. They may become certified nationally, and some states require additional state certification as well.

Test Your Knowledge 2-1

May a physician assistant serve as a laboratory director? (Outcome 2-2)

Those laboratory professionals that are **credentialed** have completed the required education for their specific classification, and they have also successfully passed a comprehensive assessment examination as required by their credentialing agency. To keep their credentials current, these professionals must participate in continuous education every year. Some states also require that laboratory personnel pass an additional state examination in order to work in a laboratory setting.

When entering a clinical laboratory, it may be difficult to tell by observation which employees have which type of credential, as they are all wearing lab coats and all performing what appear to be similar tasks. Figures 2-1 and 2-2 are representative of the personnel structure in a reference laboratory, a hospital laboratory, and an **ambulatory care** setting (such as a physician office laboratory). Laboratory testing may be performed by a variety of classifications, such as medical laboratory scientists, medical or clinical laboratory technicians, medical assistants, or phlebotomists.

Test Your Knowledge 2-2

May a medical technologist serve as a supervisor in a reference laboratory? (Outcome 2-3)

Test Your Knowledge 2-3

What type of credentials must a phlebotomist possess to work in a laboratory setting? (Outcome 2-4)

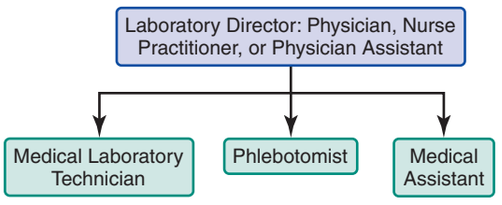

Figure 2-1 The personnel structure of the laboratory professionals working in a CLIA-waived physician office laboratory.

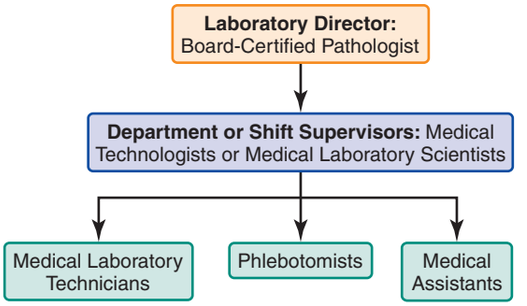

Figure 2-2 The personnel structure of the laboratory professionals working in a hospital or reference laboratory.

POINT OF INTEREST 2-1
Name changes

When working in a large laboratory (such as a reference or hospital laboratory), it is possible that you may encounter various credentials for individuals who are performing the same tasks. This is not unusual, but a recent merger of credentialing agencies may make this even more confusing!

Prior to 2009 there were three widely recognized credentialing agencies for laboratory personnel. They were the Board of Registry for the American Society of Clinical Pathology (ASCP), the National Credentialing Agency for Laboratory Personnel (NCA), and the American Medical Technologists (AMT). In October 2009, the NCA and the ASCP credentialing agencies decided to merge. Those who were previously credentialed by the NCA are now part of the ASCP organization, and those who were already part of the ASCP have not seen very many changes in their credential renewal processes. The certifying agency for the ASCP is now called the Board of Certification.

What has changed, however, are the terms used by these organizations for the various personnel classifications.

- **Baccalaureate degree–level personnel:** The ASCP previously used the designation *medical technologists* to describe this classification, and the NCA used *clinical laboratory scientist*. Now, the new title for those with a 4-year degree in medical technology that have successfully passed the examination is that of medical laboratory scientist, with the abbreviation MLS (ASCP).
- **Associate degree–level personnel:** The ASCP previously used the designation *medical laboratory*

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technician to describe this classification, and the NCA used *clinical laboratory technician*. When the two agencies merged, they retained the designation *medical laboratory technician* for those with a 2-year degree who successfully pass the examination, and the abbreviation used for their credential is MLT (ASCP).

Medical Assistants in the Laboratory

As introduced in Chapter 1, medical assistants may play numerous roles in the clinical laboratory environment. Their education enables them to draw blood, assist with collection of other types of specimens, process specimens for testing, and perform simple or moderately complex test procedures. They may perform these tasks in the physician office laboratory, in a hospital laboratory, or in a reference laboratory. Medical assistants may also work in the microbiology or pathology department within a hospital or reference laboratory assisting with specimen preparation, answering phones, or entering specimens into the computer.

Some laboratory settings, especially a specialist or hospital laboratory, need their medical assistants to do more than draw blood or process specimens. In these settings they may be taught how to perform arterial blood draws, and also may learn how to assist with bone marrow aspirations or bronchoscopy specimen collection. In some situations, medical assistants may be running tests on automated instruments and performing urine microscopy examinations and manual differential procedures on normal blood smears. These specialized tasks require additional documented training beyond that offered in a traditional medical assisting education program, and the qualifications of the personnel performing these tasks may be regulated by state or local laws.

Test Your Knowledge 2-4

Are medical assistants only allowed to draw blood in a laboratory setting, or can they perform other duties?

(Outcome 2-5)

CLINICAL LABORATORY IMPROVEMENT AMENDMENTS OF 1988

CLIA '88 is an acronym for the Clinical Laboratory Improvement Amendment of 1988. This regulation establishes quality standards for all aspects of human medical laboratory testing, with the exception of those tests performed for research only. It was designed to ensure that all laboratory tests, regardless of where they are performed, would produce accurate reliable results and be performed in a timely manner.

History of the Regulation

The original Clinical Laboratory Improvement Act was enacted in 1967. It affected only private laboratories (federal and state laboratories were exempt) that received specimens via interstate commerce. This means that the only laboratories affected by the original act were those that provided services across state borders. These laboratories had to be licensed if they processed more than 100 interstate specimens per year. This act also improved laboratory quality standards overall by adding a requirement for **proficiency testing** to these licensed laboratories. Proficiency testing is used to verify that the results reported for a certain test are accurate. Because this Clinical Laboratory Improvement Act had such a small focus, there were many laboratories that were not affected by these requirements, especially physician office laboratories. It was estimated that of 200,000 laboratories in business in the United States, only about 12,000 were regulated.

In 1987, the *Wall Street Journal* published two articles expanding on the poor quality of laboratory testing in the United States. At that time, there was very little structured supervision of the quality of testing performed in laboratories that were not affected by the Clinical Laboratory Improvement Act of 1967. Specifically, the articles expanded on several situations in which Papanicolaou (Pap) smear tests showed false-negative results, allowing cases of cervical cancer to become advanced before a correct diagnosis was made. The cytology laboratories that were reporting these results were poorly staffed, and the technicians were overworked. Both the U.S. House of Representatives and the U.S. Senate held hearings to investigate the inaccurate Pap smear reports and other laboratory errors. As a result of these hearings, questions began to form about how laboratories functioned and about what kind of quality assurance was in place for the results reported. Therefore, it was decided that more federal oversight was necessary, and on October 31, 1988, the Clinical Laboratory Improvement Amendment of 1988 (CLIA '88) was enacted. Since that time, there have been several revisions, allowing more tests to be included in the **CLIA-waived** category, and giving the **U.S. Food and Drug Administration (FDA)** the

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responsibility to determine the level of complexity for laboratory tests.

Test Your Knowledge 2-5
What was CLIA '88 designed to ensure? (Outcome 2-6)

Levels of Laboratory Testing Defined by CLIA '88

CLIA '88 requires that all laboratories performing tests on human specimens must register with the **Centers for Medicare & Medicaid Services (CMS).** The registration process, and title of the certificate granted to the laboratory, is based on the type of testing performed. The classification of the testing is based on the complexity of the testing procedure and the clinical significance of the results from the test, among other factors. This amendment classifies all tests into one of three categories:

- **CLIA-waived tests:** These are tests that are so simple and accurate that the likelihood of misinterpretation is minimal. This classification also requires that the tests will pose no reasonable risk of harm to the patient if the test were accidentally performed incorrectly. CLIA-waived tests also include procedures that have been cleared for home use, such as glucose testing performed by diabetics at home. Examples of CLIA-waived tests are streptococcal screens, urine pregnancy tests, and mononucleosis testing. Many CLIA-waived tests are performed in physician office laboratories, but they may also be done in hospital or reference laboratories. Table 2-2 lists the types of tests that are CLIA-waived at this time. This list has grown significantly since CLIA '88 first went into effect, and will continue to change.
- **Moderate-complexity tests:** These tests are more complex than CLIA-waived tests. The complexity designation is based on a grading scale that takes into account the difficulty of test performance, the maintenance and troubleshooting required for the instrument used for the test, the amount of knowledge necessary to correctly interpret the results, and other specific aspects of the testing process. Some physician office laboratories perform moderate-complexity testing, but there are restrictions on the personnel performing the tests. Employees must be properly trained in these more advanced concepts in order to meet the requirements of the regulation. These tests also have more requirements for quality control and quality assurance documentation, and laboratories are required to participate in proficiency-testing programs to validate their test results. **Provider-performed microscopy procedures (PPMPs)** are also included in this classification, which concern the microscopic examination of **labile** specimens in the office performed by licensed health-care providers. Labile specimens are those that must be examined shortly

TABLE 2-2
CLIA-waived tests

Test Type	Test Name	CPT Code
Chemistry	Blood glucose by glucose monitoring devices cleared by the FDA for home use	82962
Urine and stool testing	Fecal occult blood	82270 GO 107
	Dipstick or tablet reagent urinalysis—nonautomated; for bilirubin, glucose, hemoglobin, ketone, leukocytes, nitrite, pH, protein, specific gravity, and urobilinogen	81002
	Urine pregnancy tests by visual color comparison	81025
	Ovulation tests by visual color comparison for human luteinizing hormone	84830
Hematology	Hemoglobin by copper sulfate—nonautomated	83026
	Erythrocyte sedimentation rate—nonautomated	85651
	Blood count; spun microhematocrit	85013

Note: This chart recognizes only the original CPT codes and test names listed as waived tests in 1988. There are numerous tests and testing methods that have been added to this list, which can be accessed at http://www.fda.gov/cdrh/clia/cliawaived.html

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after collection because the appearance of the specimen will change rapidly after collection. Provider-performed microscopy procedures may include urine microscopic examinations, semen analysis for the presence or absence of sperm, nasal smear examinations, and other types of analysis that need to be performed on fresh specimens.

- **High-complexity tests:** This category of testing is performed almost exclusively in hospital and reference laboratories by highly trained laboratory professionals. These tests require substantial knowledge of the significance of the test results, complex testing procedures, and stringent requirements for calibration of instruments and quality control procedures to ensure the accuracy of the results.

Laboratories may perform multiple levels of testing; some may perform only CLIA-waived tests, whereas others may perform high-complexity tests as well as waived tests. All laboratories must register and pay a fee to CMS that is based on the complexity of the tests that they perform. Failure to register or follow all the regulations associated with the specified level of testing may result in significant fines (thousands of dollars per day of noncompliance) and potential closure of the laboratory.

Test Your Knowledge 2-6

Describe the minimum level of education required to perform the following types of laboratory testing:

a. CLIA-waived tests
b. Moderate-complexity tests
c. High-complexity tests (Outcome 2-7)

Test Your Knowledge 2-7

What factors are taken into account when assigning the different levels of complexity to the various laboratory tests? (Outcome 2-7)

Employee Qualifications for Performance of CLIA Testing

The CLIA '88 regulations are very specific about the training necessary to perform the different levels of testing that are identified in the amendment:

- **CLIA-waived testing:** Minimum personnel requirements include a high school diploma or a GED, and thorough, documented training for the processes performed by the individual in the laboratory. Those performing CLIA-waived testing must follow the manufacturer's directions provided with the kit used exactly as they are written, and appropriate training for all individuals performing the laboratory test must be documented. These tests may be performed by phlebotomists, medical assistants, or those with more laboratory education.
- **Moderate-complexity testing:** The minimum education requirements are very similar to those of the CLIA-waived category. Moderate-complexity tests are more complicated to perform, and they may have much more clinical significance if they are performed or interpreted incorrectly, so the training must be comprehensive if the individual performing the test has limited formal laboratory education. This additional documented training must include numerous areas of the laboratory, such as quality control testing procedures, maintenance of the testing instruments, clinical significance of the tests, and validity of the test results. In most circumstances, this level of testing is performed by a medical laboratory technician or medical technologist, but it is possible to appropriately train a medical assistant to perform at this level as well.
- **High-complexity testing:** In order to perform tests in the clinical laboratory that have been established as high complexity by the CLIA standards, the laboratory professional must possess at least an associate degree in laboratory science. He or she must also have documented training on site for quality control procedures, maintenance and troubleshooting of the instruments used for the procedures, and more in-depth knowledge of the test parameters. These high-complexity tests usually comprise numerous performance steps, and the results have a high level of clinical significance. High-complexity tests are performed only in larger laboratories such as hospital and reference laboratories, and generally are performed by clinical or medical laboratory technicians, clinical laboratory scientists, or medical technologists.

Test Your Knowledge 2-8

What levels of laboratory testing may a clinical laboratory scientist with 4 years of education perform? (Outcome 2-8)

Oversight of CLIA Laboratories

Various agencies are involved with the enforcement of the CLIA '88 regulations. These include the FDA, the CMS, and the **U.S. Department of Health and**

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Human Services (HHS). The HHS has the overall responsibility for laboratory quality assurance as designated in CLIA '88, but it has delegated various parts of the process to other agencies. The FDA is responsible for determination of the levels of complexity for the various laboratory tests. After the level of complexity has been determined, laboratories that perform these tests must apply for the appropriate certificate that allows them to perform these tests. The laboratory may qualify only for certain testing procedures based on the qualifications of their personnel. They apply to CMS for this certificate, whether it is a **Certificate of Waiver** (allowing them to perform CLIA-waived testing only) or another type of certificate that allows them to perform tests of higher complexity. A laboratory can only begin testing after receiving CMS certification. Compliance is monitored by the CMS or, in some situations, by state or private agencies that have regulations that are at least as stringent as those of the CMS, and have an agreement with CMS to monitor compliance. Some laboratories are affiliated with **COLA,** an independent company that accredits laboratories. COLA uses various educational methods to help laboratories meet the requirements for CLIA compliance, and CMS recognizes COLA as an accrediting agency. If a laboratory retains its accreditation with COLA, it will be assumed that that laboratory is meeting the CLIA requirements and will be granted the certificate that is appropriate for the level of complexity tested without site inspection requirements from the CMS. COLA is most commonly associated with physician office laboratories, but the organization is recognized by larger laboratories for accreditation purposes as well.

The CLIA certificate types are based on the complexity of the tests performed. Here is a summary of the available certificates for laboratories:

- **Certificate of Waiver:** Allows laboratories to perform only CLIA-waived tests.
- **Certificate of PPM:** Allows the licensed health-care providers in an organization to perform designated microscopic examinations.
- **Certificate of Compliance or Certificate of Accreditation:** Allows the laboratory to perform CLIA-waived tests, PPMPs, moderate-complexity tests, and high-complexity tests. These certificates are granted after the laboratory has been inspected. If the inspection was performed by a governmental agency, the laboratory receives a Certificate of Compliance. If the inspection was performed by a private accreditation company, the laboratory receives a Certificate of Accreditation.

Test Your Knowledge 2-9

Which federal agency assigns the CLIA categories to laboratory tests? (Outcome 2-9)

SUMMARY

Within a typical laboratory setting you will find professionals with various credentials and educational levels. Those who work in a hospital or reference laboratory may have different qualifications than those who work in a smaller physician office laboratory. There are regulations that dictate who can perform which type of testing, and what training and supervision must be involved for each test. CLIA '88, applies to all laboratories in the United States that perform testing on human specimens, except for federal laboratories and those that perform only research testing. Every testing site must register and pay a fee to comply. This regulation has established three levels of testing: CLIA-waived tests, moderate-complexity tests, and high-complexity tests. The levels have different requirements for testing personnel, quality control procedures, instrument maintenance, and laboratory supervision. The FDA makes the decision about which complexity level each test will have. Medical assistants with appropriate additional training may perform CLIA-waived or moderate-complexity tests, but those who perform high-complexity testing must have more specialized laboratory training in order to be compliant. All laboratories must register with CMS to legally perform laboratory testing at any level.

TIME TO REVIEW

1. A labile substance is one that: Outcome 2-1
   - **a.** Is not fixed and is easily destroyed
   - **b.** Is not fixed but can be stored for an extended period of time
   - **c.** Is fixed with some sort of preservative
   - **d.** Can easily be transferred to a reference laboratory
2. True or False: Ambulatory care refers to the care provided to those transported to the hospital as an emergency transport. Outcome 2-1

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3. Which laboratory settings may employ a medical assistant? Outcome 2-2
   a. POL
   b. Hospital laboratory
   c. Reference laboratory
   d. None of the above
   e. a, b, and c
4. True or False: Pathologists serve as directors in reference laboratory settings. Outcome 2-3
5. A laboratory professional with an associate degree in laboratory science may work in which laboratory setting? Outcome 2-4
   a. Reference laboratory
   b. Hospital laboratory
   c. Physician office laboratory
   d. None of the above
   e. a, b, and c
6. List three duties that may be performed by a medical assistant in a hospital or reference laboratory. Outcome 2-5
7. CLIA '88 stands for: Outcome 2-6
   a. Clinical Laboratory Incident Act #88
   b. Clinical Laboratory Improvement Amendment of 1988
   c. Consistent Laboratory Improvement Amendment of 1988
   d. Continual Linear Improvement Act of 1988
8. Choose the types of laboratory testing that may be performed by a medical assistant. Outcome 2-7
   a. CLIA-waived testing
   b. Moderate-complexity testing
   c. Provider-performed microscopy procedures
   d. High-complexity testing
9. True or False: Those performing CLIA-waived testing do not need to follow the manufacturer's directions; they may write their own procedures as needed. Outcome 2-8
10. What role does the Centers for Medicare & Medicaid Services play in CLIA '88 enforcement? Outcome 2-9
    a. It is not involved
    b. It inspects each laboratory
    c. It handles all the laboratory registration procedures
    d. It determines the level of complexity for all laboratory tests

Case Study 2-1: CLIA quiz

Rose is starting at a new job in a physician office laboratory today. As part of her orientation, the physician who is in charge of the laboratory asks her a few questions to test her understanding of the laboratory organization. He asks her to answer the following questions about CLIA '88. How should she answer these?

1. Was CLIA '88 created to protect employees or patients?
2. Is it still necessary to be trained in the performance of CLIA-waived test procedures, or can these be performed without documented training?
3. Do laboratories have to be formally registered in order to legally perform testing on human specimens?

RESOURCES AND SUGGESTED READINGS

American Medical Technologists
Certifying agency for laboratory professionals
http://www.amt1.com

American Society for Clinical Pathology
Membership and certification information for laboratory professionals, as well as continuing education information
http://www.ascp.org

Centers for Disease Control and Prevention CLIA-related publications from the Federal Register and the Code of Federal Regulations
Excellent reference for the actual CLIA regulations presented in a time line that is easy to follow
http://wwwn.cdc.gov/clia/chronol.aspx

Centers for Disease Control and Prevention CLIA Subpart A General Provisions
Provides various details about CLIA '88, including compliance requirements
http://wwwn.cdc.gov/clia/regs/subpart_a.asp#493.1

Tests waived by the FDA from January 2000 to present
List of all CLIA-waived tests. Updated regularly.
http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfClia/testswaived.cfm

Information about the COLA accreditation services and education products. Also includes online education programs that may be used to fulfill continuing education requirements.
http://www.cola.org

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Chapter 3

Laboratory Safety and Preventing the Spread of Disease

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Infection Control and Laboratory Safety
Core Concepts of Infection Control
- Microorganisms
  - *Types of Microorganisms*
  - *Microorganism Growth Requirements*
  - *Medical Asepsis*
- Chain of Infection
- Standard Precautions
  - *Centers for Disease Control and Prevention Hand-Washing Recommendations*
  - *Acceptable Medical Hand-Washing Procedures*
  - *Proper Use of Personal Protective Equipment*

Laboratory Safety
- Chemical Safety
  - *Physical Safety*
  - *Fire Safety*
  - *Electrical Safety*
  - *Body Mechanics*
- Bloodborne Pathogen Safety
  - *Universal Precautions*
  - *Bloodborne Pathogens Standard*

Diseases Caused by Bloodborne Pathogens in the Laboratory Setting
- Hepatitis
- Human Immunodeficiency Virus

Postexposure Follow-Up Procedure
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

3-1 Define the key terms.

3-2 List the major types of infectious agents.

3-3 Restate the difference between pathogenic and nonpathogenic microorganisms

3-4 Describe the various shapes of bacteria presented in the text.

3-5 Compare and contrast bacteria and viruses.

3-6 Describe medical asepsis.

3-7 Explain what the chain of infection concept refers to, and describe how the chain may be broken.

3-8 Explain how the CDC Standard Precautions are used in a laboratory setting.

3-9 Analyze the importance of proper hand-washing procedures and appropriate use of personal protective equipment.

3-10 Explain appropriate procedures for hand sanitization for health-care workers.

3-11 Examine the fundamental concepts included in the OSHA Hazard Communications Standard.

3-12 List the required components on a Material Safety Data Sheet.

3-13 Explain how a chemical label provides safety information.

3-14 Describe how a laboratory employee may protect themselves from other physical dangers in the laboratory.

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3-15 Identify who is protected by the OSHA Bloodborne Pathogens Standard.

3-16 Interpret the key terms included in the OSHA Bloodborne Pathogens Standard.

3-17 List the essential components of an exposure control plan.

3-18 Discuss the appropriate use and disposal of sharps in the laboratory environment.

3-19 Define biohazardous waste and explain proper disposal methods for this type of laboratory waste.

3-20 Compare and contrast the major bloodborne pathogens that are considered to be a threat in the laboratory environment.

3-21 Detail the appropriate follow-up procedure in case of an accidental bloodborne pathogens exposure.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

III.P.4. Perform Handwashing
III.C.III.3. Discuss Infection Control Procedures
III.C.III.5. List major types of infectious agents
III.P.III.2. Practice Standard Precautions
X.C.XI.1: Describe Personal Protective Equipment
X.C.XI.3: Describe the importance of MSDS in a healthcare setting
X.C.XI.4. Identify safety signs, symbols and labels
X.C.XI.8. Discuss Fire safety issues in a healthcare environment

ABHES 2010 Standards

- Clinical: Apply principles of aseptic techniques and infection control
- Clinical: Use standard precautions

KEY TERMS

Aerobic
Acquired immune deficiency syndrome (AIDS)
Anaerobic
Asepsis
Asymptomatic
Bacilli
Bacteria
Biohazard symbol
Biohazardous waste
Bloodborne pathogen (BBP)
Bloodborne Pathogens Standard (1910.1030)
Carcinogenic
Carriers
CD4 cells
Centers for Disease Control and Prevention (CDC)
Cirrhosis
Cocci
Contagious
Contaminated sharps
Diplococci
Disinfection
Electron microscope
Engineering controls
Epidemiology
Exposure control plan
Fecal-oral route
Fomites
Fungi
Hazard Communication Standard
Health care–associated infection
Hepatitis
Hepatitis A (HAV)
Hepatitis B (HBV)
Hepatitis C (HCV)
Hepatitis D
Human immunodeficiency virus (HIV)
Infection
Infection control

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Infectious
Material Safety Data Sheets (MSDS)
Medical asepsis
Microorganisms
Mucous membranes
Mycotic
National Fire Protection Association (NFPA)
Nonintact skin
Normal flora
Nosocomial infection
Occupational exposure
Occupational Safety and Health Administration (OSHA)
Opportunistic pathogen
Other potentially infectious materials (OPIMs)
Parasites
Parenteral exposure
Pathogens
Percutaneous
Personal protective equipment (PPE)
Postexposure prophylaxis (PEP)
Protozoa
RACE
Regulated waste
Resident bacteria
Sanitization
Spirilla
Spores
Standard Precautions
Staphylococci
Sterilize
Streptococci
Surgical asepsis
Susceptible
Transient bacteria
Transmissible
Universal Precautions
Vector
Viruses
Window period
Work practice controls

INFECTION CONTROL AND LABORATORY SAFETY

Pathogens, infection, and *contamination* are words that most of us have heard at home or in our communities. What do they really refer to? What impact may they have on our laboratory environment, our health, and the health of our patients? The laboratory setting has stringent safety precautions that must be observed in order to keep our health-care workers safe as they perform their daily routines. Laboratory professionals use various chemicals and equipment that put them at risk for injury. In addition, specimens taken from the human body present a unique challenge as they are naturally **infectious**, or capable of transmitting disease to others. **Infection control** is the term used to describe the process of protecting health-care workers and the patients they serve from the infectious agents in our facilities. In addition, because all the hazards faced in the laboratory are not from infectious agents, further safety methods must be employed to protect our laboratory professionals. It is imperative that as a medical assistant working in a laboratory environment you understand the hazards you may encounter, the laws that are designed to protect you and the patients you serve, and the appropriate use of the safety equipment that is available to you.

CORE CONCEPTS OF INFECTION CONTROL

In recent years, we all have become more aware of the infections that may be transmitted through the water, through the air, or with casual contact in our communities. Severe acute respiratory syndrome (SARS), the Asian flu, *Escherichia coli* outbreaks, and other pathogens such as the monkeypox virus remind us that we are very vulnerable. The presence of AIDS and hepatitis C is further proof of how our world has changed in the past 35 years. Be very mindful of the fact that almost any transmissible infection could find its way into your laboratory at any moment, as it may be present in your community, and you won't be aware of it. An ill patient may come into the office for medical services with an infectious condition, a specimen may be dropped off that is capable of transmission, or a salesperson may arrive and offer her hand, which is covered with bacteria, for a greeting.

Microorganisms

Diseases that may be encountered in your medical office or laboratory (even without any blood exposure) include varicella (chickenpox), tuberculosis, viral respiratory infections, conjunctivitis (pinkeye), gastrointestinal

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infections, and measles. Sometimes these infections affect the personnel, and sometimes they affect other patients within the facility. They are all caused by **microorganisms,** living organisms that are too small to be seen without a microscope. Most microorganisms are harmless to humans. However, a small percentage of **bacteria**, **viruses, fungi, protozoa,** and **parasites** are capable of causing disease in the human body. These disease-causing organisms are known as **pathogens.** An **infection** is the invasion of the body by pathogens that then cause disease symptoms. Not all microorganisms are pathogenic, and some are only capable of causing disease when they enter a part of the body where they don't normally reside. A disease is **contagious** or **transmissible** if it can be spread to other people directly or indirectly.

Test Your Knowledge 3-1
Staphylococcus aureus is a type of bacteria that sometimes functions as a pathogen. What other types of microorganisms may cause disease in humans? (Outcome 3-2)

Test Your Knowledge 3-2
Do all microorganisms cause disease? (Outcome 3-3)

Types of Microorganisms

Bacteria. Bacteria are single-celled organisms that have a cell wall in addition to the cell membrane that our human cells possess. (This is an important property when identifying different types of bacteria with special stains, as is discussed in Chapter 10.) Of all the bacteria known to exist, approximately 4% are known to cause disease in humans. Bacterial infections are treated with medication that will kill the microorganisms or keep them from multiplying, (antibiotics), but for effective treatment, identification of the causative agent is often necessary.

An initial step of the identification process is to examine a sample under the microscope so that the bacteria can be classified according to one of three basic shapes, as seen in Figure 3-1. **Cocci** are round bacteria, which can then be classified further by their appearance when examined microscopically. Cocci that grow in grape-like clusters are **staphylococci,** those that grow in chains are **streptococci,** and those that grow in pairs are **diplococci.** Diseases caused by cocci include streptococcal sore throat, pneumonia, abscesses, food poisoning, gonorrhea, and meningitis.

Long, slender, rod-shaped (oval) bacteria are called **bacilli.** These are especially prevalent in the soil and the air. Many types of bacilli are able to form **spores,** which is a dormant form of the bacteria that is resistant to changes in heat, moisture, and disinfectants. Bacilli cause diseases such as botulism, tetanus, diphtheria, tuberculosis, and salmonella food poisoning. *E. coli* is a normal bacilli that is present on our skin and in our intestines, but if we come in contact with a specific strain, *E. coli* O157:H7, it may lead to serious food poisoning, and may even be fatal.

Spirilla are curve-shaped or spiral bacteria. This type of bacterium is less frequently isolated in specimens from the human body, but the infections may be quite serious when they occur. *Treponema pallidum* is a spirillum that causes syphilis, and cholera is caused by another type of spirillum. This category may also be described as curved rods and microbiologists may subdivide it further into those bacteria that only have a slight curve and those that are tightly wound like a spring.

Test Your Knowledge 3-3
How are staphylococci and diplococci different? (Outcome 3-4)

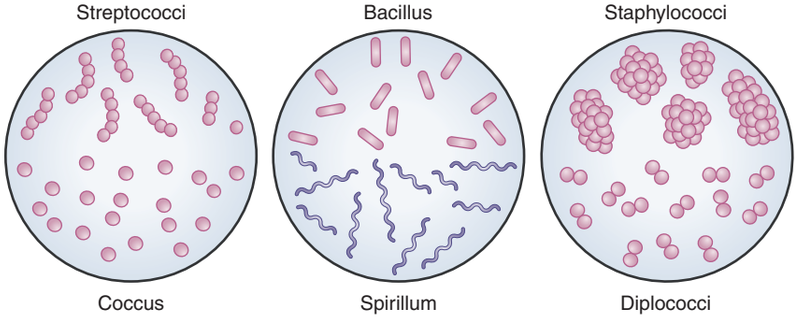

Figure 3-1 Types of bacteria, including cocci, staphylococci, streptococci, diplococci, bacilli, and streptococci.

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Test Your Knowledge 3-4

Describe the appearance of bacilli viewed under the microscope. (Outcome 3-4)

Viruses. Viruses are another common type of pathogenic microorganism. They are the smallest infectious agent, and are not really cells. Viruses are either made up of RNA or DNA surrounded by a protein capsule, and require a host cell to survive and replicate. Viruses cannot be observed using a simple microscope such as is found in most laboratories; they require use of an **electron microscope** for visualization. They invade the cells of our body, and use our own structures to make more virus particles. Viruses cause many of the diseases for which we are vaccinated, including measles, mumps, and chickenpox. The **human immunodeficiency virus (HIV)** is the causative agent of AIDS, and is an example of a retrovirus. Antiviral medications are available for some viral infections, but because of the way virus particles use human cells, the treatment may be quite damaging to the host as well as to the virus. Antibiotics are not effective against viruses.

Test Your Knowledge 3-5

List two ways that viruses are different from bacteria. (Outcome 3-5)

Fungi. Fungi are plant-like organisms that flourish in an environment that is dark and damp. Yeast is a type of fungus, and fungal infections on the body are called **mycotic** infections. Athlete's foot and ringworm are examples of fungal infections.

Parasites. Parasites are similar to viruses because they require a living host to survive. A genus of bacteria known as *Rickettsia* is parasitic. Parasites take their nourishment from the host and require their host cells to reproduce, but they do not utilize the human cell in the same way that a virus does. Malaria is an example of a parasitic disease; the malaria parasite actually works into the red blood cells of the host and causes the patient to become ill. The word *parasite* may also be used to refer to larger, multicellular organisms such as tapeworms, which live inside the human host and use the body to survive.

Protozoa. Protozoa are complex single-cell microorganisms, most of which are nonpathogenic. However, there are a few species that can cause very serious infections in humans. Protozoa live in the soil and water.

Microorganism Growth Requirements

Because we have so many microorganisms present in our environment, we must find ways to eliminate as many as possible, with an emphasis on the removal of pathogens that could cause harm. However, it is impossible and impractical to **sterilize** our environment in the laboratory, which would involve the elimination of all microorganisms. **Sanitization** reduces the number of microorganisms on a surface with cleaning. Heat or chemicals are often used for sanitization in the healthcare environment. **Disinfection** is the process by which a medical assistant applies a chemical to a surface to kill the pathogenic microorganisms that may be present. Sanitization is often performed before an item is disinfected, so that the majority of the microorganisms are already removed before the pathogens are targeted. Items such as examination tables, countertops, and equipment are disinfected on a regular basis. Skin may also be disinfected, as it is impossible to sterilize the skin by eliminating all the microorganisms. Seventy percent isopropyl alcohol or povidone-iodine solutions are used for skin disinfection. Work surfaces and equipment are often disinfected in the laboratory with a freshly prepared 10% bleach solution.

Asepsis means that a surface is without infection. In the medical environment, there are two types of asepsis. **Surgical asepsis** means that all the pathogenic organisms have been destroyed before they enter the body. Invasive procedures such as venipuncture, injections, and urinary catheterization require surgical asepsis to be in place so that pathogenic microorganisms aren't introduced into the body of the patient. Equipment used for these types of procedures must be sterilized, and special care is used to avoid infection. **Medical asepsis** is a term used to describe a procedure or an environment that allows a patient to be treated without exposure to pathogenic microorganisms. For noninvasive procedures and the majority of care provided in the medical office, medical asepsis is adequate to protect the patients from potential infection. The items that are used for this type of care are clean and have been disinfected, but sterility is not necessary. To disinfect the environment appropriately and achieve medical asepsis, we must understand what elements microorganisms need for survival. These include the following:

- **Temperature:** The optimum temperature for each microorganism will vary. Human pathogens tend to prefer our body temperature, so they grow best at approximately 98.6°F.
- **pH:** A neutral pH is best suited for most microorganisms. This is why many disinfectants and cleaning

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agents are basic or acidic, as they will kill the microorganisms by making their environment inhospitable.
- **Darkness and moisture:** Most microorganisms like darkness or dim light, and they all need moisture to survive.
- **Nutrition:** The type of nutrition varies depending on the type of microorganism, but they all need something in their environment to use as a food source.
- **Oxygen: Aerobic** microorganisms need oxygen present for survival. **Anaerobic** microorganisms are best suited for environments that have an absence or low levels of oxygen.

Good aseptic practices for the medical setting will attempt to eliminate the elements necessary for pathogenic microorganisms to survive. These practices may include the following:

- Disinfect work areas (using an appropriate disinfecting agent for the health-care environment) between patients.
- Take appropriate respiratory precautions while working with patients with potentially infectious respiratory conditions. Provide masks and tissues to the patients, and enforce their use by employees as well.
- Close the door of the treatment or blood-draw area if possible when an infectious disease is suspected.
- Limit access of nonessential personnel and visitors to patient care areas.
- Keep the laboratory and waiting room area well lit, well ventilated, and free of dirt and dust.

Test Your Knowledge 3-6

Brittany, a phlebotomist working in the laboratory, is cleaning up at the end of her shift. She uses the disinfectant provided by her employer and some paper towels to thoroughly clean the area where she has been drawing blood from patients. Is this work area now sterile? (Outcome 3-6)

Chain of Infection

Figure 3-2 is a representation of the way pathogens are transmitted from person to person. This is represented as a chain, because all the parts of the circle are sequential and linked to one another. To stop the transmission of disease, the chain must be broken. A medical assistant working in a laboratory environment must practice good infection control techniques to achieve medical asepsis and break the chain. The potential infection needs to be stopped at the source before it can be transmitted. The essential parts of the chain include the following:

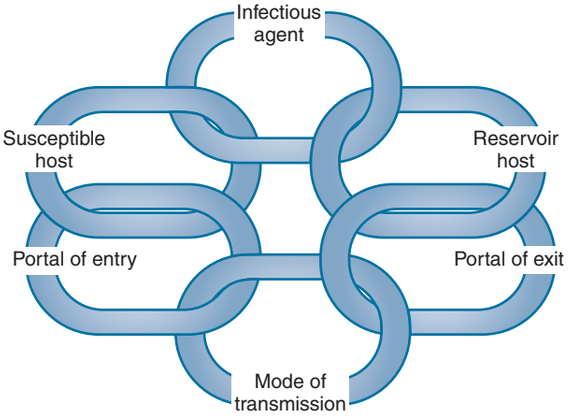

Figure 3-2 Chain of infection.

- **Infectious agent:** A pathogenic microorganism. This may be a virus, bacteria in the environment, or pathogens that are carried in the bloodstream. There may also be microorganisms that are only pathogenic in specific situations. For instance, if an individual is taking antibiotics for an extended period of time, she may develop a yeast infection, because the yeast is taking advantage of the body's imbalance created with the antibiotic use. The yeast would be an **opportunistic pathogen.**
- **Reservoir host:** Someone who is infected or "carrying" the infectious agent. This may be a person or an animal that may or may not have symptoms of the infection. A reservoir host provides the necessary environment for the pathogen to grow.
- **Portal of exit:** The means by which the pathogen leaves the host body, either through the eyes, mouth, ears, intestinal tract, urinary tract, respiratory tract, reproductive tract, or broken skin. Another portal of exit may be through the blood or other body fluids capable of transmitting pathogens.
- **Mode of transmission:** This describes how the pathogen moves from one person to another. It may be transmission through the air as moisture droplets after a sneeze or a cough, other direct transmission occurs as one person touches another or via an insect or other **vector.** Vectors are living organisms that take in the pathogen, allow it to live and multiply in or on their bodies, then transmit it to another host without becoming ill with the pathogen during the transport. Dirty hands are a very common mode of transmission.

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Pathogens may also be transmitted by inanimate objects, known as **fomites.** Doorknobs, telephones, countertops, and writing instruments are common fomites in the laboratory environment. Contaminated food or water may also function as a mode of transmission.

- **Portal of entry:** The pathogens enter the body in the same ways that they leave the body. The **mucous membranes** that line the external openings of our bodies are a common portal of entry and exit for pathogenic microorganisms.
- **Susceptible host:** A susceptible host is not protected from the pathogen as it enters his or her body. The pathogen to grow and multiply within the susceptible host. Age and illness can affect the susceptibility of a patient or an employee. A potential host will protect him- or herself (become less susceptible) in various ways. Protection may include vaccinations against certain viruses or bacteria, appropriate nutrition, or proper use of personal protective equipment.

In addition to understanding the chain of infection, it is important to realize how the chain may be broken by health-care staff members. Appropriate infection control practices and patient education are effective means of breaking the chain. Specifics include the following:

- **Infectious agent:** Although health-care professionals may not always be able to break the chain at this link, it is important to remember that an infectious agent may be eradicated if a patient takes all of his or her antibiotics as directed. Patient education in this area is critical.
- **Reservoir host:** Health-care personnel are sometimes tempted to go to work when they are ill. They are essentially a reservoir host at this time, and if they are not in the facility when they are ill, the chain is broken. In addition, if there is a patient in the waiting room with a suspected illness that is highly contagious, removing the patient from the vicinity of other patients may break the chain at this point.
- **Portal of exit:** Providing respiratory protection and tissues to patients may contain the infectious agent as it leaves the body. Keeping infected wounds covered may also affect this link of the chain.
- **Mode of transmission:** The simplest and most important action that health-care personnel can take to break the chain of infection is washing their hands. In addition, contaminated surfaces should be cleaned immediately after care is provided, and often throughout the workday. Patients should be educated about how to protect themselves if they live in the same household with another family member who is ill. Hand sanitization is also critical for family members and patients to eliminate an opportunity for the pathogens to be transported to another susceptible host.
- **Portal of entry:** Those who are working with patient specimens must wear appropriate protective equipment (such as a face shield to provide mucous membrane protection, gloves, and a laboratory coat) to protect the common portals of entry. Health-care personnel working with patients who have respiratory symptoms should protect their own respiratory passages with a mask. All broken skin should be covered when working with patients, and there should be no eating, drinking, chewing gum, or applying makeup in the area where specimens are collected or processed.
- **Susceptible host:** Health-care personnel should always keep their vaccinations up to date to keep them from being susceptible to vaccine-preventable diseases. In addition, a balanced lifestyle with good nutrition and adequate rest will reduce susceptibility. Patients should be encouraged to keep vaccinations up to date, and those who have impaired immune systems should be cautioned about protecting themselves while in the community.

Test Your Knowledge 3-7

How might a medical assistant break the chain of infection at the mode of transmission link? (Outcome 3-7)

Test Your Knowledge 3-8

Cally Jones just completed a set of vaccinations to protect her from hepatitis A. Where has she broken the chain of infection for this disease? (Outcome 3-7)

Standard Precautions

We have discovered that there are numerous microorganisms in our environment that have specific requirements they need to survive. Some of these microorganisms are pathogens, meaning that they can cause infection in the human body. A **health care–associated infection** is one that is acquired in a health-care facility, such as a hospital, long-term care facility, physician office, or laboratory. If a patient in an inpatient facility enters without any evidence of infection, and develops signs of one more than 48 hours after being admitted, the infection is then investigated as a health care–associated infection. This type of

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infection may also be known as a **nosocomial infection**. Health care–associated infections are more common in inpatient facilities in which patients are in close proximity to one another, but it is also possible to acquire an infection in an ambulatory care setting. For example, chickenpox is highly contagious and can be spread from one person to another via droplets in the air after an infected individual coughs or sneezes. If a susceptible patient is in the same waiting area for an extended period of time with someone who is infected, the patient may develop chickenpox as a health care–associated infection.

Health care–associated infections have become more prevalent, more dangerous, and more expensive to treat in the past few decades. In response, the **Centers for Disease Control and Prevention (CDC)** has developed a set of **Standard Precautions** to assist health-care facilities with their infection control efforts. This standard is based on the premise that every person is potentially infectious with a microorganism that could be transferred to someone else in the health-care setting. Appropriate hand-washing techniques are stressed in the standard, as it has been found that this is the most effective action taken by medical staff to stop the spread of infection. Appropriate use of personal protective equipment, equipment disinfection, good respiratory hygiene, appropriate use of sharps, correct disposal of linen, and environmental cleaning practices are also addressed in the standard. For those working in inpatient facilities, the standard includes information about different types of precautions to be taken in isolation situations. The Standard Precautions expand and enhance the **Universal Precautions** developed in the 1980s, which specifically addressed infections transmitted through contact with blood and other potentially infectious materials. The premise of the Universal Precautions was that everyone was potentially infectious for bloodborne pathogens and that the same care should be used to treat every specimen.

Test Your Knowledge 3-9

According to the CDC recommendations for Standard Precautions, who is to be considered infectious? (Outcome 3-8)

Test Your Knowledge 3-10

What is the most effective action a health-care worker can take to stop the chain of infection? (Outcome 3-8)

Centers for Disease Control and Prevention Hand-Washing Recommendations

Even though research has shown that the hands of health-care personnel are one of the most common modes of transmission for pathogens, there are still issues with hand-washing compliance. The CDC recognized that this issue needed to be addressed, and the guidelines recently released now recommend the use of alcohol-based hand rub for routine decontamination of the hands in many situations, which may be quicker and easier for health-care professionals to use than washing the hands with soap and water. Either hand washing and decontamination using alcohol-based hand rubs remove or kill **transient bacteria,** viruses, or other types of microorganisms that may be present on the hands. Transient microorganisms, which attach themselves to our hands during our day-to-day activities, are responsible for most of the contamination and potential infection as health-care workers move from patient to patient. **Resident bacteria,** or **normal flora,** are bacteria living on and in between the deeper layer of our skin cells, and are not removed during routine hand cleaning. Here are some of the specific recommendations for hand hygiene:

1. Avoid any unnecessary touching of surfaces surrounding the patient.
2. If your hands are visibly dirty or contaminated with blood or other materials, wash them with soap and water. (It is not important at this point whether it is an antimicrobial soap that is used.)
3. Hands should be washed before eating and after using the restroom.
4. If hands are not visibly soiled, or if they were washed with a soap that was not antimicrobial, it is recommended that an alcohol-based hand rub be used. It may be used instead of the soap and water wash, or in addition to hand washing after a nonantimicrobial soap is used.
5. Hands should be decontaminated (washed or cleansed using the alcohol-based hand rub) in these situations:
   a. Before and after direct contact with patients, even if the patient has intact skin
   b. After contact with blood, body fluids or excretions, mucous membranes, nonintact skin, or dressings used for open wounds
   c. If the health-care provider will be going from a contaminated body site to a clean body site on the same patient
   d. After contact with any objects, such as equipment, in the immediate area of the patient
   e. After removing gloves

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5. It is also recommended that artificial nails be avoided if the duties of the health-care provider include direct contact with patients at high risk for infection. Keep natural nails less than one-fourth-inch long.
6. Minimize jewelry on the hands, as bacteria may be present underneath or in jewelry and is not removed during normal hand-washing techniques.
7. Refilling of soap pump dispensers is discouraged. If a refill is necessary, the dispenser should be rinsed thoroughly before more soap is added. Bacterial contamination may be present in the small amount of soap at the bottom of the container.

Test Your Knowledge 3-11
What is an acceptable alternative to hand washing in the laboratory in most situations? (Outcome 3-9)

Test Your Knowledge 3-12
Describe three situations in which a health-care worker should decontaminate their hands. (Outcome 3-10)

Acceptable Medical Hand-Washing Procedures

The CDC recommendations outline specific practices to be employed when washing or disinfecting hands because this is such an important part of infection control practices. These procedures are explained in detail in Procedures 3-1 and 3-2.

Test Your Knowledge 3-13
Why would a clean, dry paper towel be used to turn off the water faucets after hand washing? (Outcome 3-10)

Procedure 3-1: Perform Hand Washing

TASK

Perform hand washing appropriately, using the recommended technique for medical personnel.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

III.P.4. Perform Handwashing

ABHES 2010 Clinical

- Apply principles of aseptic techniques and infection control
- Use standard precautions

CONDITIONS

- Antibacterial soap
- Running water
- Paper towels
- Manicure brush and stick

Procedure	Rationale
1. Remove all rings, and make certain that lab coats, watches, and bracelets are pushed up above the wrist area.	It is not possible to clean appropriately under rings, so they should be removed. Watches and bracelets need to be moved above the wrists so that the wrists can be cleaned.
2. Adjust the water temperature until it is warm but not hot.	Hot water leads to skin breakdown, and should be avoided.
3. Wet the hands and wrists.	To provide the best sudsing action with the soap, the hands should be wet before applying the soap.
4. If using a soap dispenser, use a clean paper towel to dispense the amount of soap recommended by the manufacturer. This is usually 3–5 mL or 1–2 pumps. If an automatic soap dispenser is used, the paper towel is not necessary.	A push-top soap dispenser or an automatic dispenser is recommended. If bar soap must be used, the bar of soap must be kept in the hands until they are thoroughly covered with suds, and a drainable soap dish must be in use to avoid pooling of dirty water around the bar of soap.

Continued

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Procedure 3-1: Perform Hand Washing—cont'd

Procedure	Rationale
5. Rub the hands together vigorously for at least 10–15 seconds. All surfaces of the hands should be covered with soapsuds, as well as between the fingers and up over the wrist area. Keep the hands lower than the elbows.	The friction created helps to minimize the amount of bacteria on the hands. The hands must remain lower than the elbows to avoid having the water run up to the elbows, causing contamination farther up on the arm. Hand washing with all surfaces covered with suds, including wrists
6. Avoid touching the lab coat or scrubs on the front of the sink, and avoid touching the hands to the inside of the sink while scrubbing.	If the lab coat or scrubs touches the front of the sink, it will become contaminated with dirty water. The inside of the sink is considered to be "dirty," so should not be touched during the hand-washing procedure.
7. Clean the top of the fingernails with the brush and clean under the fingernails with the manicure stick.	The cuticle area and the skin surrounding the fingernails harbor bacteria, so special care needs to be taken to clean this area thoroughly. The manicure stick should be used under the fingernails to remove as much contamination as possible.
8. Rinse the hands under the warm water, keeping the hands lower than the elbows.	The hands need to remain below the elbows to avoid contamination. All soap must be rinsed from the hands. Rinsing of hands with fingertips pointing downward.

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Procedure	Rationale
9. Dry the hands thoroughly with paper towels. Dispose of the paper towels in an appropriate receptacle.	Hands should be dried thoroughly before continuing. Special care should be given to the area between fingers.
10. Using another clean, dry paper towel, turn off the water faucets. Dispose of the paper towel in the appropriate receptacle.	A clean, dry paper towel must be used rather than using the damp one that was used to dry the hands. The moisture on the paper towel may draw the bacteria present on the faucets back onto the clean hands.

Procedure 3-2: Sanitize Hands With an Alcohol-Based Hand Sanitizer

TASK

Sanitize hands using an alcohol-based hand sanitizer.

CAAHEP/ABHES STANDARDS

CAAHEP 2008

III.P.III.2. Practice Standard Precautions

ABHES 2010 Clinical

- Apply principles of aseptic techniques and infection control
- Use standard precautions

CONDITIONS

Alcohol-based hand sanitizer containing 60% to 95% alcohol

Procedure	Rationale
1. Remove all rings, and make certain that laboratory coats, watches, and bracelets are pushed up above the wrist area.	It is not possible to clean appropriately under rings, so they should be removed. Rings contain microorganisms that can cause infection. Watches and bracelets need to be moved above the wrists so that the wrists can be cleaned.
2. Verify that the sanitizer to be used is alcohol based.	The CDC recommendations sanction only the use of alcohol-based sanitizers.
3. Dispense the manufacturer's recommended amount of the product in the palm of the hand.	Do not dispense less than is recommended or the hand sanitization will be incomplete. Do not apply more than is recommended or the dry time will be increased.
4. Cover all surfaces of the hands and fingers with the sanitizer solution, and continue to rub these surfaces until the product is completely dry. Don't forget the areas around and under the fingernails, as well as between the fingers and the wrist area.	The skin around the fingernails and cuticles harbors a lot of microorganisms, so pay close attention to this area.
5. Allow the hands to air-dry. Do not use a paper towel to dry hands.	If the hands are not allowed to air-dry, the sanitization process is incomplete. The microorganisms will continue to be destroyed while the solution dries on the hands.

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Proper Use of Personal Protective Equipment

Later in this chapter you will learn about the **Occupational Safety and Health Administration (OSHA)** Bloodborne Pathogens Standard, which is a comprehensive policy addressing **bloodborne pathogen (BBP)** exposure in health-care settings. A key component of this standard, as well as the Standard Precautions, is proper use of **personal protective equipment (PPE).** Personal protective equipment helps to protect the employee from bloodborne pathogens (those pathogens that are transmitted via direct contact with blood and other infectious body fluids), and in addition it helps to protect them from the pathogens in their environment that are not bloodborne. In order to be effective, personal protective equipment must be worn at appropriate times, removed when not needed, and disposed of properly. When considering PPE for a task, the employee must decide what type of exposure is reasonably anticipated while performing that task. Policies must be in effect by the employer to guide these decisions for PPE use.

The most important personal protective equipment in the medical laboratory is properly fitting gloves (see Fig. 3-3). Employers are responsible for providing PPE to employees, and gloves are no exception. Most facilities no longer use latex gloves; latex allergies have become too widespread to continue with this practice. Latex alternatives (such as nitrile gloves) are readily available. Gloves should be worn when contact with blood, mucous membranes, or nonintact skin could be anticipated when performing a certain task. Gloves should also be worn when contact with **other potentially infectious materials (OPIMs)** is anticipated. OPIMs are those that are capable of transmitting bloodborne pathogens.

It is not necessary to wear gloves when touching a patient with intact (unbroken) skin for routine care, such as taking vital signs and helping a patient into the procedure chair. Hands should be washed before and after each glove use, and gloves should always be removed after caring for a patient. The same pair of gloves should never be used for the care of more than one patient. Do not wash gloves. Gloves should not be worn after patient care when leaving that immediate area, as they may be contaminated with unseen microorganisms that will be deposited on door handles, telephones, and the like. Also, do not touch your face or hair while caring for a patient and wearing gloves. Do not wear the same pair of gloves for a patient if you are going from a dirty body site to a clean body site; remove the gloves, wash your hands, and put on a clean pair. Remember, gloves cannot prevent a needlestick injury, but they can prevent a pathogen from entering your body through a small break in your skin under the glove, and they can protect you from transient microorganisms that you may be exposed to while working in the health-care environment.

Test Your Knowledge 3-14

Marni is working hard to successfully draw blood from a patient who has very fragile veins. As she works, the phone keeps ringing. She finally obtains a sample, and just as she completes the draw and has the patient put pressure on the site, she reaches out with her gloved hand and answers the phone. What has she done wrong in this scenario? (Outcome 3-9)

Gloves should be removed promptly after use. The method of removal is critical, as the gloves may be contaminated with unseen microorganisms that must not be spread to the surrounding area. Procedure 3-3 explains the steps involved in aseptic glove removal.

Personal protective equipment also may also include masks, goggles, face shields, or respirators (Fig. 3-3). A mask may be worn to protect others from droplets that may be generated when coughing or sneezing. Masks may be given to patients to wear while they are in the facility, or health-care professionals who have an upper respiratory infection or allergies may wear masks. Remember to keep the mask tight to the face so that it is effective. Masks with goggles or face shields may be worn to protect the employee's eyes, mouth, and nasal passages from moisture droplets or aerosols in the laboratory environment.

Respirators are required when working with patients with pulmonary tuberculosis or when dealing with certain types of specimens considered potentially infectious for airborne transmission. Respirators must also be worn when working with certain chemicals used as preservatives in the laboratory. Respirators must be fit properly to the face of the employee to be effective, and the filters must be maintained as directed.

Gowns may be used when additional protection is required during patient care (Fig. 3-3). These are especially important when entering isolation areas of the hospital or when working in a nursery environment with newborns. Care must be taken to keep the interior side of the gown free of contamination to protect the employee. Gowns are usually made of light, disposable material, and must be disposed of immediately after use. Generally

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Procedure 3-3: Removal of Contaminated Gloves

TASK

Properly remove and dispose of contaminated gloves.

CAAHEP/ABHES STANDARDS

CAAHEP 2008

III.P.III.2. Practice Standard Precautions

ABHES 2010 Clinical

- Apply principles of aseptic techniques and infection control
- Use standard precautions

CONDITIONS

- Nonlatex gloves
- Biohazard waste container

Procedure	Rationale
1. Grasp the palm of the glove on the nondominant hand. Keep the gloves away from the body and the hands pointed toward the floor.	Grasping the palm will allow a firm hold as this glove is removed. Keeping the hands away from the body pointed toward the floor will minimize the risk of splatter in the eyes or mucous membranes.
2. Pulling on the palm of the glove, turn it inside out as it is removed from the nondominant hand.	If the glove is inside out, it will not be able to contaminate the bare skin, as the soiled area will be on the inside of the glove.
3. Crumple up the contaminated glove into the other gloved hand.	This allows the contaminated glove to be held safely while the other glove is removed.
4. Insert two of the ungloved fingers under the cuff, against the wrist of the gloved hand.	Be careful not to touch the contaminated side of the glove with the bare hand.
5. Pulling down with these fingers, turn the second glove inside out over the other glove while slipping it off the fingers.	This method will allow the contaminated surfaces to remain inside the glove bundle.
6. Dispose of the gloves in a biohazard waste container.	Visible contamination on the gloves means that they need to be disposed of as biohazardous waste.
7. Wash hands.	Hands must always be washed after removing gloves because gloves are not foolproof and hand contamination is still possible. It also helps to remove any powder residue that may be left behind on the hands.

there is a disposal area just inside or outside the room where the gowns were worn.

Laboratory coats are also used when there is a potential for splashing or soiling of the clothing worn by laboratory professionals. These should be OSHA approved as fluid resistant to offer the best protection. The coats must have tight cuffs, and should button or snap up to the neckline when worn. Clean laboratory coats should not be stored with dirty coats, and employees must not wear their contaminated laboratory coats into eating areas or the restroom. Laboratory employees are also not to take their coats home to be laundered, as this could contaminate their home environment. If laboratory coats are required at the facility where an employee works, OSHA regulations dictate that the facility is responsible for providing the coats and cleaning them commercially after use.

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Figure 3-3 Medical assistant wearing OSHA-approved laboratory coat, appropriate face protection, and gloves.

Laboratory professionals should never apply makeup, chew gum, eat, or drink when working with blood or OPIMs. Also, food must never be stored in the same refrigerator with specimens or medications, regardless of how it is packaged.

Test Your Knowledge 3-15

What type of personal protective equipment should be worn when a medical assistant is performing a routine blood draw? (Outcome 3-9)

POINT OF INTEREST 3-1
Bloodborne facts

The U.S. Department of Labor, Occupational Safety, and Health Administration (OSHA) has published a series of fact sheets that cover various aspects of the Bloodborne Pathogens Standard. This standard may be difficult to understand and therefore compliance may be complicated. These fact sheets are excellent tools for offices that are struggling to develop their plans appropriately or for anyone who is trying to update knowledge of the subject. They cover many subjects, including the hepatitis B virus, vaccine, and postexposure follow-up, and proper use of personal protective equipment. Single copies may be obtained by contacting the OSHA Publications Office, Room N-3101, 200 Constitution Avenue, NW, Washington, DC 20210.

LABORATORY SAFETY

The laboratory environment is unique because of the types of hazards present. As we have already discussed in this chapter, laboratory professionals are surrounded by potential pathogens as they perform patient care and work with specimens. In addition, employees are using or are in the vicinity of chemicals of various types, as well as electrical testing equipment. Laboratory professionals are also exposed to bloodborne pathogens, as needle use and handling fluids from the human body are part of the daily duties in this environment. All of these potential risks make safety in the laboratory workplace somewhat complicated. This chapter has already provided information about protection from exposure to pathogenic microorganisms in the environment and basic infection control practices. Now we will emphasize chemical safety, physical safety, and bloodborne pathogen safety in the laboratory.

Chemical Safety

Numerous chemicals are present in the clinical laboratory. Some of these are used as cleaning agents or disinfectants, whereas others may function as preservatives for laboratory specimens. Hydrochloric acid (HCl), for example, is often used as a preservative for 24-hour urine specimens, and bleach is used as a recommended method for cleaning surfaces exposed to blood and other potentially infectious materials. Both acidic and alkaline substances can cause severe burns, and mixing various chemicals may have disastrous effects. To protect the employees using these chemicals, OSHA created the **Hazard Communication Standard.** This standard gives all employees the right to know about the potential hazards associated with the chemicals in their workplace. The required components addressed in this standard include the following:

- A hazard communication program to be developed and used within the facility
- Current inventory of all hazardous chemicals used in the workplace

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- Appropriate labeling of those chemicals designated as hazardous
- Material Safety Data Sheets
- Documented training for employees

Test Your Knowledge 3-16

Who is the OSHA Hazard Communication Standard designed to protect? (Outcome 3-11)

The Hazard Communication Standard establishes comprehensive guidelines for labeling chemicals. These guidelines include the name of the chemical; contact information for the manufacturer; physical and health hazards of the chemical; safety precautions; and information pertaining to the storage, handling, and disposal of the chemical. The original container, as well as any transfer containers for the same chemical must be labeled in this manner.

Test Your Knowledge 3-17

The laboratory assistant who is working the evening shift notices that the laboratory is almost out of a disinfectant that staff members use to clean some of the instruments. He wants to be sure that the supervisor orders the same product that is now in use. Where can he look to find the name of the manufacturer to tell his supervisor? (Outcome 3-13)

A **Material Safety Data Sheet** (**MSDS**) must also be available for every hazardous chemical in use. This is a document provided by the manufacturer that provide even more details about the chemical than those printed on the label. A current MSDS must be kept on file for any chemical in use that is considered potentially hazardous, and these sheets must be accessible to employees at all times (Fig. 3-4). The standard requires that the following information be provided on all Material Safety Data Sheets:

- **Identification:** Must include the generic and brand name, as well as the name, address, and emergency phone number for the manufacturer, and the date the MSDS was prepared.
- **Composition of ingredients:** List of the ingredients, and how much of the chemical is considered to be safe for exposure.
- **Physical and chemical properties:** Includes items such as appearance, odor, boiling point, specific gravity, pH, etc.
- **Fire and explosion data:** Will this chemical catch fire or explode if used incorrectly? If so, how should you extinguish the fire?
- **Reactivity data:** How does this chemical react with other chemicals? What types of interactions should be avoided?
- **Health hazards:** Includes information such as the route of entry, signs and symptoms to be aware of in case of overexposure, medical conditions that might be worsened when this chemical is used, and acute or chronic health hazards that may develop with regular exposure to the chemical. This section of the MSDS is very important to the health-care professional who uses this chemical as part of his or her daily tasks. There is also information presented about the **carcinogenic** (cancer-causing potential) classification of the chemical.
- **Emergency first-aid procedures:** What should you do if overexposure occurs as a first aid measure while help is on the way?
- **Precautions for safe handling and use of the chemical:** Includes instructions for handling a chemical spill, how to store the chemical, and how to dispose of the chemical and or container.
- **Control measures:** Includes the personal protective equipment and safety apparatus that should be used when dealing with the chemical.

Test Your Knowledge 3-18

How many required components must be present on a Material Safety Data Sheet? (Outcome 3-12)

The last required component of the Hazard Communication Standard is employee training. All employees who might be exposed to hazardous chemicals at work must be provided information about the chemicals and their potential hazards prior to the beginning of their employment in the area where the chemicals are used, and again whenever the hazard may change with the addition of new chemicals or new duties. There must be documentation of each training session, and the education must be continuous; not only offered at the time of initial employment. There must also be assurance that the employee understood the information presented. The required training elements include the following:

- A general overview of the right to know standard, explaining all the components involved, where to find the inventory of hazardous chemicals in use, and where the written hazard communication program is kept for that facility

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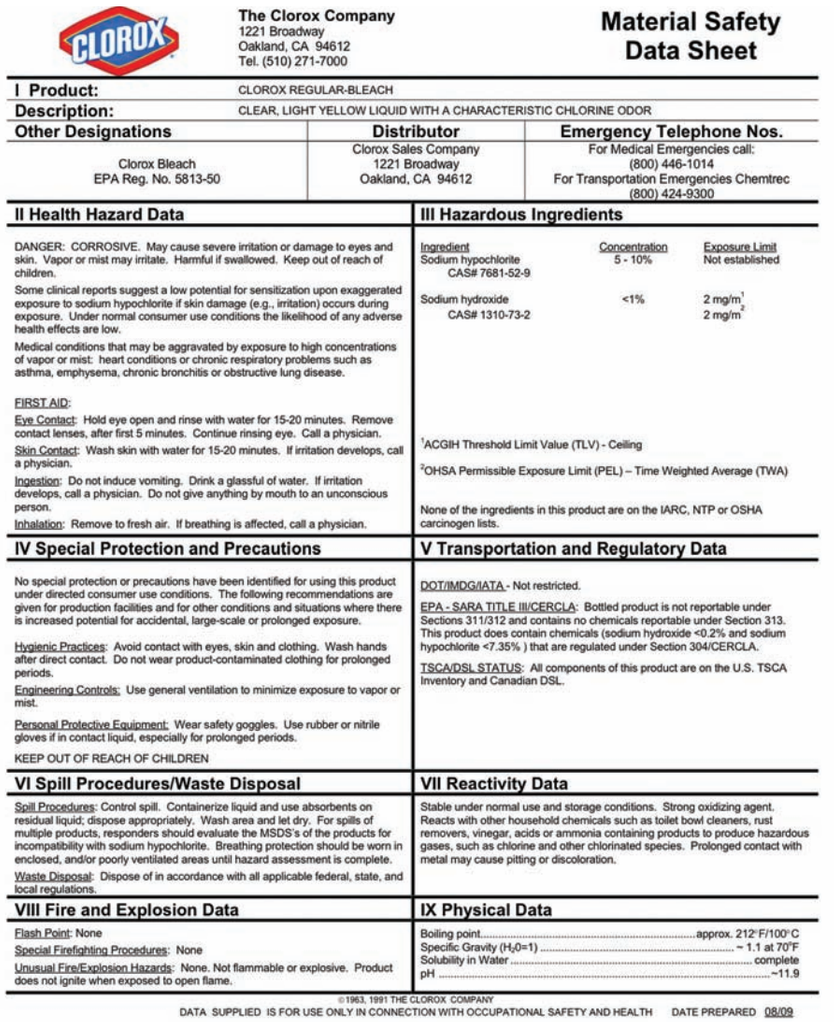

The Clorox Company
1221 Broadway
Oakland, CA 94612
Tel. (510) 271-7000

Material Safety Data Sheet

I Product: CLOROX REGULAR-BLEACH

Description: CLEAR, LIGHT YELLOW LIQUID WITH A CHARACTERISTIC CHLORINE ODOR

Other Designations	Distributor	Emergency Telephone Nos.
Clorox Bleach EPA Reg. No. 5813-50	Clorox Sales Company 1221 Broadway Oakland, CA 94612	For Medical Emergencies call: (800) 446-1014 For Transportation Emergencies Chemtrec (800) 424-9300

II Health Hazard Data

DANGER: CORROSIVE. May cause severe irritation or damage to eyes and skin. Vapor or mist may irritate. Harmful if swallowed. Keep out of reach of children.

Some clinical reports suggest a low potential for sensitization upon exaggerated exposure to sodium hypochlorite if skin damage (e.g., irritation) occurs during exposure. Under normal consumer use conditions the likelihood of any adverse health effects are low.

Medical conditions that may be aggravated by exposure to high concentrations of vapor or mist: heart conditions or chronic respiratory problems such as asthma, emphysema, chronic bronchitis or obstructive lung disease.

FIRST AID:

Eye Contact: Hold eye open and rinse with water for 15-20 minutes. Remove contact lenses, after first 5 minutes. Continue rinsing eye. Call a physician.

Skin Contact: Wash skin with water for 15-20 minutes. If irritation develops, call a physician.

Ingestion: Do not induce vomiting. Drink a glassful of water. If irritation develops, call a physician. Do not give anything by mouth to an unconscious person.

Inhalation: Remove to fresh air. If breathing is affected, call a physician.

III Hazardous Ingredients

Ingredient	Concentration	Exposure Limit
Sodium hypochlorite CAS# 7681-52-9	5 - 10%	Not established
Sodium hydroxide CAS# 1310-73-2	<1%	2 mg/m^3 [1] 2 mg/m^3 [2]

[1]ACGIH Threshold Limit Value (TLV) - Ceiling

[2]OHSA Permissible Exposure Limit (PEL) – Time Weighted Average (TWA)

None of the ingredients in this product are on the IARC, NTP or OSHA carcinogen lists.

IV Special Protection and Precautions

No special protection or precautions have been identified for using this product under directed consumer use conditions. The following recommendations are given for production facilities and for other conditions and situations where there is increased potential for accidental, large-scale or prolonged exposure.

Hygienic Practices: Avoid contact with eyes, skin and clothing. Wash hands after direct contact. Do not wear product-contaminated clothing for prolonged periods.

Engineering Controls: Use general ventilation to minimize exposure to vapor or mist.

Personal Protective Equipment: Wear safety goggles. Use rubber or nitrile gloves if in contact liquid, especially for prolonged periods.

KEEP OUT OF REACH OF CHILDREN

V Transportation and Regulatory Data

DOT/IMDG/IATA - Not restricted.

EPA - SARA TITLE III/CERCLA: Bottled product is not reportable under Sections 311/312 and contains no chemicals reportable under Section 313. This product does contain chemicals (sodium hydroxide <0.2% and sodium hypochlorite <7.35%) that are regulated under Section 304/CERCLA.

TSCA/DSL STATUS: All components of this product are on the U.S. TSCA Inventory and Canadian DSL.

VI Spill Procedures/Waste Disposal

Spill Procedures: Control spill. Containerize liquid and use absorbents on residual liquid; dispose appropriately. Wash area and let dry. For spills of multiple products, responders should evaluate the MSDS's of the products for incompatibility with sodium hypochlorite. Breathing protection should be worn in enclosed, and/or poorly ventilated areas until hazard assessment is complete.

Waste Disposal: Dispose of in accordance with all applicable federal, state, and local regulations.

VII Reactivity Data

Stable under normal use and storage conditions. Strong oxidizing agent. Reacts with other household chemicals such as toilet bowl cleaners, rust removers, vinegar, acids or ammonia containing products to produce hazardous gases, such as chlorine and other chlorinated species. Prolonged contact with metal may cause pitting or discoloration.

VIII Fire and Explosion Data

Flash Point: None

Special Firefighting Procedures: None

Unusual Fire/Explosion Hazards: None. Not flammable or explosive. Product does not ignite when exposed to open flame.

IX Physical Data

Boiling point.....approx. 212°F/100°C
Specific Gravity (H_20=1).....~ 1.1 at 70°F
Solubility in Water.....complete
pH.....~11.9

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DATA SUPPLIED IS FOR USE ONLY IN CONNECTION WITH OCCUPATIONAL SAFETY AND HEALTH DATE PREPARED 08/09

Figure 3-4 MSDS information sheet for Clorox Bleach. *Courtesy of Clorox.*

- An explanation of what an MSDS is, where it may be found in the workplace, and how to use one
- Identification of the specific chemicals used in the work area for that employee, with instructions for the protective measures to be employed, including the personal protective equipment that is appropriate for that specific chemical
- The meaning of the labels and symbols used on hazardous chemicals
- Emergency measures to be taken in case of a spill or exposure

To ensure the safe use of chemicals, remember always to wear the appropriate personal protective equipment and safety equipment for the task at hand. Also, never use a chemical in a fashion other than that for which you were trained to use it. Do not transfer chemicals to unlabeled containers, and do not reuse containers that have been used previously. Remember that mixing chemicals may have disastrous effects; adding even water to some chemicals can be very dangerous. Finally, every employee should know the location of the eye wash station and emergency shower in the vicinity of their work area.

Physical Safety

As is the case with any business, there is always the chance that things will go wrong in the laboratory. This could include a chemical exposure, but it could also be a fire, an electrical emergency, or other personal injuries.

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A laboratory professional needs to be aware of all hazards in the workplace, and also needs to be ready to respond to emergencies appropriately.

It is always essential for any business to have a plan of action in case of an emergency, but it is even more critical for a health-care facility such as a laboratory. Employees are not only responsible for themselves, but also for the patients in their presence at the time of the incident. Appropriate training and careful planning may dictate the difference between a positive or negative outcome of an emergency situation. This includes posting of emergency numbers (such as 911 or another internal number in a large facility for emergency response), maps showing the closest exit from various places within the building, employee training on use of fire extinguishers, and hazard identification.

The **National Fire Protection Association (NFPA)** has developed a labeling system that provides general information to employees and rescuers about the health, flammability, or reactivity hazard of chemicals. These categories are represented by blue, red, yellow, and white diamonds, each containing a number. The colors of the diamonds represent the different types of hazards, and the number contained within each diamond indicates the severity of the hazard. The blue diamond represents the respective health danger with exposure to the chemical. The red diamond indicates flammability hazard, and the yellow diamond indicates the reactivity potential for the chemical if exposed to increased heat or other conditions. There is also a white diamond, which may include a special symbol, indicating whether a chemical is radioactive or reacts with water (Fig. 3-5).

Test Your Knowledge 3-19

How do the NFPA fire labels protect employees? (Outcome 3-14)

Fire Safety

In order to keep themselves and those around them as safe as possible, all employees should know the procedures to follow in case of fire in their facility. Fire safety basics such as Stop, Drop, and Roll (in the case of clothing that has caught on fire) are likely familiar concepts. However, when in the workplace, there are more aspects to consider: Where are the fire extinguishers? How do I use them? What can I do if there is not one nearby? Where is the nearest exit? How do I call for help? These are all questions that should be answered in initial training, and the procedures should be reviewed on a regular basis.

According to the National Fire Protection Association, there are four classifications used to describe fires, each of which has its own type of fire extinguisher to be used. Multipurpose extinguishers are also available to use for Class A, B, or C fires.

- **Class A:** Class A fires involve common household materials such as wood and paper. Water or a water-based

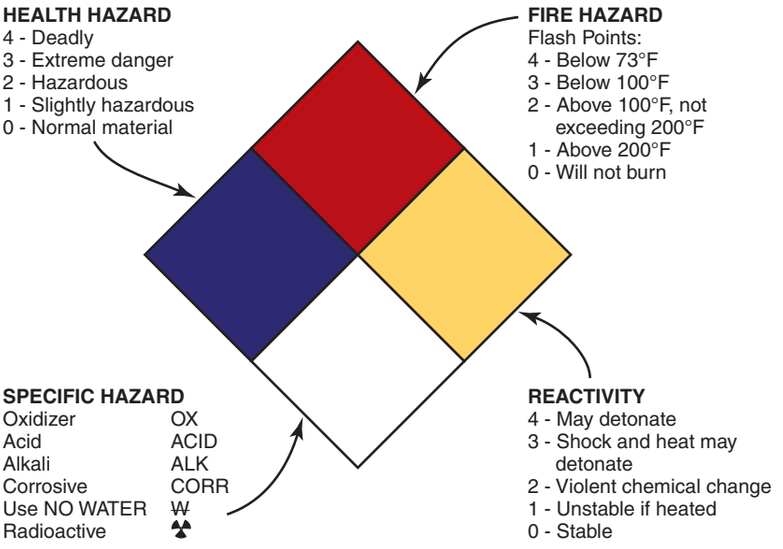

Figure 3-5 NFPA chemical fire symbol.

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solution is needed to put out this type of fire, and these are contained in a Class A extinguisher.

- **Class B:** Class B fires generally involve flammable liquids and/or vapors, and they need to be smothered to be put out. The Class B extinguishers contain chemicals, carbon dioxide or foam.
- **Class C:** Class C fires are related to electrical equipment, so special care must be used to extinguish them. If the solution used to extinguish the fire conducts electricity, the fire will not be extinguished. The Class C extinguishers use chemicals or other types of substances that do not conduct electricity.
- **Class D:** Class D fires frequently lead to explosions, as they occur with reactive metals such as sodium or potassium. They are very difficult to control, and there is not a fire extinguisher available in most sites to extinguish this type of fire. Sand or other dry powder agents work best for this type of fire.

Fast action is critical when a fire is discovered to keep those in the workplace as safe as possible. A common acronym recommended to help those facing a fire remember what to do is **RACE**: Rescue, Alarm, Confinement, Extinguish. Table 3-1 lists the letters and expands on the meaning.

Test Your Knowledge 3-20

What is designated by the different letters assigned to fire extinguishers? (Outcome 3-14)

Electrical Safety

We are surrounded by electrical equipment in the laboratory environment, so that fire and electrical shock are definitely potential hazards. Most hazards can be minimized by appropriate maintenance and service of the equipment and the electrical outlets. The use of extension cords and overloading of electrical outlets should be avoided. Also, only qualified personnel should service electrical equipment. In case of electrical shock, remember that you must stay safe in order to help those who have been injured. Shut off the source of the electricity immediately, if possible. Do not touch the victim if you are unable to shut off the source of the electricity. Call for emergency assistance immediately. If the source of electricity has been eliminated, evaluate the victim and begin cardiopulmonary resuscitation (CPR) if necessary.

TABLE 3-1

RACE: The steps to take in the event of a fire

R	Rescue individuals in danger
A	Activate the alarm system
C	Confine the fire by closing windows and doors
E	Extinguish the fire using an appropriate fire extinguisher

Body Mechanics

As a medical assistant working in a laboratory environment, you may be performing numerous venipunctures each shift. These procedures often require bending over the patient sitting in the phlebotomy chair, or perhaps in a hospital setting, bending over the bed of a patient. This bending can cause a great deal of stress to the muscles of the back and neck, resulting in pain. There are additional duties in the laboratory that may require lifting or carrying equipment trays or supplies. A laboratory professional may need to assist a patient with transfer from a wheelchair to an examination table or other chair. In all these situations, it is important to keep your back as healthy as possible. Stretches and regular exercise help, as well as staying close to an ideal body weight. Remember to use the muscles in your legs when lifting heavy objects, and when carrying heavy objects keep them close to your body and avoid twisting motions. Change your position as often as possible; avoid sitting or standing for prolonged periods without a break. If patient transfer is part of the duties for a medical assistant in your work environment, appropriate techniques should be part of the initial training for employees.

Bloodborne Pathogen Safety

Many of you who are reading this textbook have never lived in a world without the presence of HIV and **acquired immune deficiency syndrome (AIDS).** However, it was not that long ago that these diseases were not yet known. Prior to 1980, there was not a lot of information available about potential bloodborne pathogen exposure in health care. **Hepatitis B (HBV)** was discovered in 1967, but research on the methods of transmission were still in progress for many years. With the discovery of the HIV in 1983, change came quickly. It became evident that health-care workers needed to be protected from the hazards of working with blood and other potentially infectious materials. Studies performed in the 1970s showed that the rate of hepatitis B infection for health-care workers was ten times that of the general population. A reliable vaccination was

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created and released to the general public in 1982, but compliance was voluntary, and many health-care workers had already been exposed to the virus. After HIV was identified, data were gathered to see how many health-care workers were potentially infected as a result of occupational exposure, and although the numbers related directly to exposure on the job were low, they were too high to be ignored.

Bloodborne pathogen is a term used to describe any pathogenic microorganism found in human blood that can cause disease in humans. These diseases are spread through direct contact with the bloodstream of another individual. This means that there must be a piercing of the skin **(parenteral exposure),** direct blood-to-blood contact as might occur when **nonintact skin** touches the blood of another individual, or mucous membrane exposure, as occurs with sexual activity or accidental splashes into the eyes or mouth. These diseases are not carried only in the bloodstream of the infected individual. Other potentially infectious materials include semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva when dental procedures are being performed, and all body fluids that are visibly contaminated with blood. If it is impossible to tell which type of fluid you may be working with, it is also to be assumed that it is a potentially infectious material. Tears, feces, urine, sputum, nasal secretions, sweat, and saliva (spit) are not considered to be infectious unless they are grossly contaminated with blood.

Universal Precautions

Bloodborne pathogen exposure in health care was first addressed by recommendations from the CDC in 1982, specifically referring to the information about the newly identified HIV. In 1985, the CDC published a recommendation to adopt Universal Precautions when dealing with blood or other potentially infectious materials. The concept of universal precautions recognized the fact that it was impossible to identify all patients who may be infected with HIV or other bloodborne pathogens by taking a health history and performing an examination. The recommendation was that all patients (and all specimens of an infectious nature) were to be considered infectious for HIV and other bloodborne pathogens, and the same precautions were to be taken in all situations. Prior to this, gloves were not mandatory in health-care settings, mouth pipetting was still performed in the laboratory, and laboratory coats were not required. Special precautions were taken only if a specimen or patient was labeled as infectious. Currently, the CDC standard precautions have expanded universal precautions to include all means of infection.

Test Your Knowledge 3-21

What are some examples of OPIMs? (Outcome 3-16)

Bloodborne Pathogens Standard

In 1988, OSHA strengthened this recommendation of Universal Precautions with the publication of the **Bloodborne Pathogens Standard (1910.1030)**. This standard provided a rigorous policy to protect health-care workers who had **occupational exposure** to blood or other potentially infectious materials in the workplace. This standard had special significance for those who worked in a laboratory environment, because the amount of potential exposure was quite high for this population. This regulation required that all employers with potential occupational exposure to bloodborne pathogens in their workplace develop an **exposure control plan.** An exposure control plan must include the following components:

- **Exposure determination:** The plan requires that all employers determine which classifications of employees have risk of exposure, and during what types of duties that the risk exists.
- **Methods of exposure control compliance:** Exposure control compliance means that all employees are to be taught how to practice universal precautions by implementing appropriate personal protective equipment. It also required that the employer use and train the employees to use **engineering controls** and **work practice controls** to minimize their risk of exposure. Engineering controls are physical devices (such as needle safety devices or stationary safety shields) that are used by the employees to make their environment safer as they perform their duties. Work practice controls are ways that employees might alter the manner in which they perform a task to minimize the risk of bloodborne pathogen exposure. These include rules banning eating or drinking in an area where there is potential exposure, bandaging cuts before application of gloves, wearing gloves and other PPE appropriately, wearing close-toed shoes, and disposing of **biohazardous waste** and **contaminated sharps** correctly. Biohazardous waste is a classification used to describe substances contaminated with liquid or semiliquid blood or other potentially infectious materials. Contaminated sharps

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are needles or other materials capable of piercing the skin that have been used with blood or other potentially infectious materials.

- **Hepatitis B vaccination** (or documented declination of the vaccine by the employee) must be made available for all employees with occupational risk of bloodborne pathogen exposure.
- Communication of hazards to all at-risk employees, which must occur initially upon assignment, and at least annually. (Retraining must also occur if there are changes to the procedures or hazards in a specific area of the facility.) Records for this training must be kept for at least 3 years. Initial training must include:
- Information about the **epidemiology,** signs, symptoms, and methods of transmission of bloodborne pathogens.
- Instruction about the specific methods employed by that facility (their exposure control plan) to protect their employees, as well as general preventative procedures.
- Information about the hepatitis B vaccine
- An explanation of the procedure to follow for an exposure incident

Test Your Knowledge 3-22

True or False: The OSHA Bloodborne Pathogens Standard was created to protect patients. (Outcome 3-15)

Test Your Knowledge 3-23

List two key components required in an exposure control plan. (Outcome 3-17)

Appropriate Sharps Use and Disposal. Unfortunately, more health-care professionals are exposed to bloodborne pathogens by contaminated needles or other sharp devices than through any other route. This means that safety must be considered at all times when using and disposing of contaminated needles, glassware, or any other instruments that have come into contact with infectious materials. In 1999, there was an update to the Bloodborne Pathogens Standard requiring that employers constantly evaluate new safety equipment for invasive procedures to be certain that they are using the safest methods and products. The addendum also requires that employees who actually use the products on a daily basis have input as to which product is most efficient and easiest to use before the choices are made for which item to purchase. There are many choices available for needle safety devices, and no excuse not to use them. Keep in mind the following when considering sharps safety:

1. Always make sure that employees are trained on the appropriate use of the needle safety device in use. Many of these devices are designed to be "one handed," and if the employee tries to use two hands, he or she is at great risk for a puncture with a contaminated needle.
2. Contaminated needles are never to be recapped with the original needle cover, bent, or broken off. They must be disposed of immediately after use.
3. A biohazard sharps container should always be within reach when drawing blood or giving injections so that the needle can be disposed of immediately. These containers must be rigid and puncture-proof, and should be snapped closed and disposed of when they are three quarters full.
4. If contaminated glassware is broken, use mechanical means to clean up the mess, and then dispose of the glassware in a biohazard sharps container. A small disposable broom and dustpan may be designated for this type of situation, or tweezers may be used to pick up the pieces of glass. Thicker industrial gloves that are puncture resistant may also be used. Clean the area with an appropriate disinfectant (10% bleach solution allowed to sit for 20 minutes) to eliminate potential bloodborne pathogen exposure.
5. When performing capillary blood draws from the finger or foot of a patient, always use a capillary puncture device that recoils into the original holder. Do not try to reuse these devices.
6. Use plastic tubes and other containers instead of glass whenever possible.

Test Your Knowledge 3-24

Are all needle safety devices operated in the same way? (Outcome 3-18)

Regulated Waste and Housekeeping. In a health-care setting, there is a need to sort the waste generated by the facility. Some of the waste may be disposed of in the same way as household trash. Other waste is regulated, and requires special attention for disposal. The OSHA definition of **regulated waste** is quite long. Essentially, the term refers to any liquid blood or other potentially infectious materials. It also refers to contaminated items that are soaked with blood to the extent that the blood could be released if the item were compressed, or items caked with blood so

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that the blood could be released if the item were handled. Regulated waste also refers to contaminated sharps and any other microbiological wastes that may contain blood or OPIM.

Regulated waste must be disposed of in containers that are clearly identifiable as biohazardous. The containers (or bags) must either be red or must be marked with a **biohazard symbol** (Fig. 3-6). When using bags to collect regulated waste other than sharps, care should be taken to avoid adding items to the bag that are not biohazardous in nature. All bags must be closed securely when full, to be enclosed in larger containers for disposal by a regulated waste facility. All sharps containers will also be picked up by regulated waste facilities for disposal. Only companies that are licensed to carry biohazardous waste are allowed to transport and incinerate this type of refuse.

Other housekeeping guidelines in the laboratory include disinfection of counters at the beginning and end of each shift (at a minimum) with a fresh 10% bleach solution or an OSHA-approved disinfectant that is designed to kill the hepatitis B virus and HIV. Also, remember all biohazardous spills must be cleaned up using a spill kit that is designed for this purpose.

Test Your Knowledge 3-25

Is all laboratory waste considered to be biohazardous? (Outcome 3-19)

DISEASES CAUSED BY BLOODBORNE PATHOGENS IN THE LABORATORY SETTING

The OSHA Bloodborne Pathogens Standard is very comprehensive, and is designed to protect employees who work with blood and other potentially infective body fluids. But what exactly are the employees being protected from, and how serious are the diseases?

Figure 3-6 Biohazard symbol.

Hepatitis

Any discussion of bloodborne pathogens usually includes the topic of hepatitis. Essentially, **hepatitis** means "inflammation of the liver." When we discuss hepatitis in relation to bloodborne pathogens, we are referring to hepatitis that is caused by a viral infection. There are numerous types of the hepatitis virus that have been isolated, and not all of them are bloodborne. The ones that we are most concerned with are hepatitis B and hepatitis C, as these viruses are bloodborne pathogens, and they can cause serious illness. Table 3-2 lists details about the different types of hepatitis and other bloodborne pathogens.

Hepatitis B Virus (HBV)

Hepatitis B was first identified as a unique virus in 1967. It was formerly known as serum hepatitis, because there was a high prevalence of infection with the hemophiliac population who had received blood products as part of their treatment. The hepatitis B virus targets the liver, and it is the most serious hazard facing those in the health-care industry. HBV may be present in the blood and other potentially infective fluids of the body. Unfortunately, it may survive on surfaces in dried blood for up to 1 week. Hepatitis B may be transmitted in a health-care setting through needlesticks or other contaminated sharps, by contact with contaminated surfaces, or through mucous membrane exposure with aerosols or splatters created while handling infectious specimens. For those not employed in health care, transmission usually is the result of sharing contaminated needles, or through sexual contact.

Hepatitis B causes flu-like symptoms, and the affected patient may appear jaundiced. The symptoms of infection often do not appear until months after the virus has entered the body. Most of those who are infected recover, but approximately 2% of those infected will develop chronic infection, which causes **cirrhosis** of the liver or cancer. There are also patients that may be **carriers** of the hepatitis B virus who do not know it. These patients often have had no definitive symptoms of the infection, but they are capable of passing it on to others. Fortunately, a series of vaccinations may prevent hepatitis B infection. OSHA requires that these vaccinations be offered free of charge to all employees who have bloodborne pathogen exposure in the workplace.

There is also a newly discovered form of hepatitis virus that affects only those who are already hepatitis B positive. This appears to be a mutant or variant form of HBV, but it is unique enough to be identified as its own

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virus. This is known as **hepatitis D**. There currently is no vaccination available for hepatitis D.

Hepatitis C Virus (HCV)

You may have heard of **hepatitis C (HCV)** as the new "epidemic" disease of the world. This statement is misleading. Although there are millions of cases of hepatitis C infection that have been diagnosed over the past decade, these patients did not necessarily have a recent infection. Hepatitis C infection is usually **asymptomatic,** so most of those who are now being diagnosed with the disease were actually infected more than a decade ago. For many years researchers knew that there was another form of hepatitis virus that was different from both HBV and HAV. They just couldn't isolate it as a unique strain of the virus. In 1989, technology finally allowed the hepatitis C virus to be identified as another cause of post-transfusion hepatitis. The hepatitis C virus is a bloodborne pathogen, and many of those who are diagnosed today shared dirty needles for drug use, received blood transfusions or other blood products, or had tattoos applied prior to the mid-1980s. If there are any symptoms of the HCV infection, they are usually milder than those of hepatitis B, so are often misread as being symptoms of the flu. Unlike hepatitis B, in which it is uncommon to advance to the chronic form of the disease, those with hepatitis C infection usually progress to the chronic stage (approximately 80% to 85% of patients). Of these, a small percentage develop permanent liver damage and/or liver failure. Transmission of the hepatitis C virus in a health-care setting usually requires a larger accidental exposure than would be necessary to transmit HBV. There is no vaccination for HCV.

Hepatitis A Virus (HAV)

Although the **hepatitis A (HAV)** virus is not a bloodborne pathogen, it is important to understand how it is transmitted. HAV attacks the liver of infected patients and causes inflammation just like the other forms of viral infections that we have discussed. The hepatitis A virus is very contagious, and is transmitted by the **fecal-oral route.** The virus is shed in the feces of infected individuals, often before they even know they are infected. The fecal material containing the virus can then be passed on to others through direct contact (such as touching another individual) or indirect contact through food, water, or inanimate objects. Patients with HAV usually show symptoms sooner than those with HBV or HCV, and are often initially more severely ill. However, the hepatitis A virus rarely progresses to cause chronic infection or permanent liver damage. There is a series of vaccinations available to protect against hepatitis A infection.

Test Your Knowledge 3-26

Are all forms of hepatitis considered to be bloodborne pathogens? (Outcome 3-20)

POINT OF INTEREST 3-2
Pathogenic microorganisms

In most situations, the discussion of bloodborne pathogens focuses on hepatitis B, HIV, and hepatitis C. However, the OSHA Bloodborne Pathogens Standard is not only designed to protect employees from infection with these viruses. The standard actually includes any pathogenic microorganisms that may be present in blood or other potentially infectious materials. Examples of other diseases that may be transmitted by direct contact with blood of infected individuals include malaria, syphilis, babesiosis, brucellosis, leptosporosis, Creutzfeldt-Jakob disease, and viral hemorrhagic fever.

Human Immunodeficiency Virus

The human immunodeficiency virus (HIV) attacks the immune system of our bodies. The HIV infection may eventually lead to AIDS. Viruses need the genetic information in our cells to survive and replicate, and HIV is no different. It attacks a type of white blood cells in our body known as **CD4 cells.** This type of blood cell fights infection in our bodies. Those infected with HIV are **susceptible** to opportunistic infections. These infections are caused by microorganisms that would not normally infect individuals who have healthy immune systems. HIV infection also makes the infected patients more prone to develop certain types of cancer.

When patients are infected with HIV, they undergo several stages. Initially, they may have swollen glands, or they might have slight flu-like symptoms. This generally lasts from weeks to months. Also, initially, because the amount of virus particles in the infected patient's body is still low, an HIV test result would be negative. HIV tests are designed to detect antibodies to the virus, and in the early stages of infection, the level of antibodies in an individual are not high enough for detection. The patient is still capable of passing on HIV during this time

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through blood-to-blood contact or sexual activity. This is known as the **window period** of infection, and may last up to 6 months.

The second stage of infection is generally asymptomatic. The infected patient may still not know that he or she is HIV positive. This stage can last for months or even years.

When patients reach the third stage, they often contract one or more opportunistic infections. This can be the first time many patients find out that they are HIV positive. Their symptoms will vary, depending on the infection that they are experiencing.

The final stage of HIV infection is what we know as AIDS. At this stage, the HIV-positive patient has been diagnosed with an opportunistic infection or disease that has been classified by the CDC as an AIDS indicator. These diseases include esophageal thrush, cytomegalovirus infection, a type of cancer known as Kaposi's sarcoma, and invasive cervical cancer in the HIV-positive patient. An AIDS diagnosis may be made based on the number of CD4 cells present in a blood sample as well. Remember, HIV infection causes AIDS, but an infected patient does not have AIDS until he or she reaches this final stage and contracts one of the indicator diseases, or is diagnosed with AIDS because of the blood count.

For many infected individuals worldwide, HIV infection is fatal. The treatment regime has changed significantly in the past 25 years, and more HIV-positive patients than ever before are able to live long lives without acquiring AIDS. Fortunately, HIV is not a very hearty virus; it dies immediately when it comes into contact with air, and the amount of virus necessary for an infection to occur from an accidental exposure has to be quite high. Hepatitis B infection is a much more serious risk from accidental health-care worker occupational exposure than HIV infection. Phlebotomy procedures are most often responsible for HIV exposure that occurs in a health-care setting. As of 2000, the CDC had processed 56 claims in which it appeared that a health-care professional had contracted HIV from an accidental exposure. At this time, there is no vaccination for the human immunodeficiency virus, and accidental infection is battled with rapid administration of antiviral medications.

Test Your Knowledge 3-27

What are two characteristics that hepatitis B and HIV have in common? (Outcome 3-20)

POSTEXPOSURE FOLLOW-UP PROCEDURE

You have taken all the appropriate precautions, read all the training manuals, worn all the right personal protective equipment . . . but your patient jerks his arm right at the end of the phlebotomy procedure, and you are punctured by a contaminated needle. Now what? The Bloodborne Pathogens Standard carefully spells out what type of follow-up care employers must offer to their employees (free of charge) if there is an accidental exposure to blood or other potentially infectious materials in the workplace. Remember, an exposure can be **percutaneous** (through the skin) as in the scenario above, but it may also be a mucous membrane exposure through a splash in the eyes or in the mouth. Here are the steps to follow if there is an accidental exposure:

1. Wash the site thoroughly with soap and water. If it is a mucous membrane exposure, thoroughly flush the exposed area with water.
2. The incident must be reported immediately to the appropriate manager or other contact person within your health-care facility. Many of the antiviral medications used for treatment after an exposure should be started within a few hours, so an immediate report is critical.
3. Fill out an incident report form. The route of exposure and the circumstances surrounding the incident are very important and are required by law.
4. Identification of the source individual needs to be determined as soon as possible. Consent should be obtained for the source individual to be tested for HBV, HCV, and HIV, unless his or her status is already known for these diseases. If the individual refuses to consent for the test, the employer must document that a refusal was made. If allowed by local law, the test will be performed regardless, so that the employee can be treated effectively. The results of these tests will be made available to the exposed employee. A blood sample will also need to be obtained from the exposed employee to test for a baseline level for HBV, HCV, and HIV.
5. The exposed employee will have the opportunity to seek medical attention as soon as possible after the initial report has been completed. **Postexposure prophylaxis** is most effective if initiated rapidly after the exposure. This means that preventive medication (such as antiviral medicine) should be administered within hours of exposure. The health-care professional providing the follow-up care will be provided with information about how the accident happened, any laboratory testing results that might be available,

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and all medical records for the employee that might be relevant (such as vaccination records). The health-care professional also must be provided a copy of the Bloodborne Pathogens Standard.

6. The health-care professional performing the follow-up care will determine whether postexposure prophylaxis is necessary for HBV, HCV, or HIV, depending on the risk evaluation. The route and amount of exposure, the vaccination status of the employee, and the circumstances of the exposure will be taken into consideration. The treatment for the employee often consists of a combination of drugs for an extended period of time.
7. Follow-up blood tests are generally performed on the exposed employee, at a minimum interval of 6 weeks, 12 weeks, and 6 months. It is possible that this series may be extended up to 12 months.
8. The exposed employee also must be offered counseling and reminded that confidentiality must be retained in reference to the source individual. All medical follow-up for the employee is also retained confidentially.

Test Your Knowledge 3-28

What should happen immediately if an employee splashes blood in her eyes? (Outcome 3-21)

Test Your Knowledge 3-29

True or False: All employees who are victims of a bloodborne pathogen exposure will be sent to see a health-care provider for follow-up care. (Outcome 3-21)

SUMMARY

The world we live in is a complex place, with new health hazards constantly emerging. As health-care workers, we must protect ourselves from potential pathogens in our environment, our patients, and our workplace. There are several government regulations that have been designed to protect employees in a health-care or laboratory environment. Education concerning these regulations, and careful adherence to their principles, are essential steps to working safely in this unique environment. Standard Precautions have been developed to assist with infection control efforts. The Hazard Communications Standard establishes guidelines to protect employees from chemicals in the workplace, and the Bloodborne Pathogens Standard educates health-care employees about the risks they face from bloodborne pathogens as they perform their duties. Medical assistants must be familiar with the details contained in these documents to use safety materials in their workplace and to be prepared for accidents when they happen.

TIME TO REVIEW

1. A bacteria that is aerobic needs _____ to survive and replicate: Outcome 3-1
   - **a.** Nitrogen
   - **b.** Oxygen
   - **c.** Carbon dioxide
   - **d.** Water
2. True or False: A substance that produces or causes cancer is carcinogenic. Outcome 3-1
3. The types of microorganisms listed in this chapter that may be human pathogens include: Outcome 3-2
   - **a.** Protons, neutrons, and electrons
   - **b.** Bacteria, viruses, and parasites
   - **c.** Bacteria, viruses, fungi, and parasites
   - **d.** None of the above
4. True or False: Most of the types of bacteria present in our environment are pathogenic. Outcome 3-3
5. True or False: The presence of bacteria anywhere in our bodies is always an infection. Outcome 3-3
6. A round-shaped bacteria that appears in pairs when viewed under the microscope is known as a: Outcome 3-4
   - **a.** Cocci
   - **b.** Spirilla
   - **c.** Bacilli
   - **d.** Diplococci
7. Which type of infection is best treated by antibiotic use? Outcome 3-5
   - **a.** Viral
   - **b.** Bacterial
   - **c.** Viral and bacterial
   - **d.** None of the above

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8. True or False: In a medically aseptic environment, bacteria may still be present on surfaces. Outcome 3-6

9. How does the "chain of infection" have to be broken to keep a pathogen from causing disease? Outcome 3-7
   a. It must be broken at multiple points to keep the pathogen from causing disease
   b. Only vaccinations will break the chain of infection
   c. The chain of infection must only be broken at one point to discontinue the spread of infection
   d. The pathogen must be killed before the chain will be broken

10. What are the elements addressed in CDC Standard Precautions document? Outcome 3-8
    a. Appropriate use of personal protective equipment
    b. Equipment disinfection procedures
    c. Respiratory hygiene
    d. Sharps use
    e. All of the above

11. True or False: Hand washing is designed to remove the normal (resident) flora from our skin. Outcome 3-9

12. When using an alcohol-based hand rub to disinfect the hands, it is important to: Outcome 3-10
    a. Put on gloves while hands are still damp
    b. Rub the solution thoroughly on all parts of the hands and wrists
    c. Use only a drop of the solution
    d. Always wash the hands first before using

13. The OSHA Hazard Communications Standard addresses: Outcome 3-11
    a. The use of personal protective equipment
    b. The formal education required by everyone in the laboratory before they can be hired to perform certain tests
    c. What type of fire extinguisher to use for various types of fires
    d. The brand of hand sanitizer endorsed by the federal government

14. Which of the following components are required for any Material Safety Data Sheet? Outcome 3-12
    a. Identification of the chemical
    b. Color of the chemical
    c. Health hazards
    d. a and c
    e. All of the above

15. True or False: Laboratory employees may protect themselves from occupational back injuries by using appropriate bending techniques when lifting heavy objects. Outcome 3-14

16. Why was the OSHA Bloodborne Pathogens Standard created? Outcome 3-15
    a. To protect employers from lawsuits
    b. To create a revenue source for OSHA
    c. To educate and protect employees from the hazards of bloodborne pathogens
    d. To protect patients from bloodborne pathogens

17. What is an example of parenteral or percutaneous bloodborne pathogen exposure? Outcome 3-16
    a. A respiratory infection contracted when working with a patient with pneumonia
    b. Touching a patient's blood with a bare hand with unbroken skin
    c. An accidental needlestick with a needle contaminated with the blood of a patient
    d. Splashing urine on the arm while pouring a specimen

18. True or False: The OSHA Bloodborne Pathogens Standard requires the development of an exposure control plan. Part of this plan requires that all employees who have occupational exposure to blood or other potentially infectious materials are offered an opportunity to receive a series of hepatitis C vaccinations at no charge. Outcome 3-17

19. True or False: When using a needle to draw blood, it is okay to lay it down on the table next to the drawing chair right after the blood draw, and come back later to activate the safety device and dispose of it correctly. Outcome 3-18

20. Who must transport biohazardous waste? Outcome 3-19
    a. Employees of the laboratory that have been appropriately trained
    b. The local municipal garbage disposal company
    c. A certified, licensed biohazardous waste disposal company
    d. None of the above

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21. What do hepatitis A, hepatitis B, hepatitis C, and HIV all have in common? Outcome 3-20
    a. They are all caused by viruses
    b. They are all caused by bacteria
    c. They all have vaccinations to prevent infection
    d. None of them have vaccinations to prevent infection.

22. Are blood tests part of the follow-up procedure for health-care workers who are are percutaneously exposed to blood in the workplace? Outcome 3-21

Case Study 3-1: Too tired to think

Jackie was really tired. She had been up all night with her 3-year-old daughter who had an ear infection. When she reported to her job at the GI clinic the next morning, she was relieved to find out that she would be working in the laboratory, as this meant that she would be on her feet a bit less than if she were working as the MA for one of the physicians. It was Friday, which was usually a slow day in the laboratory.

In the middle of the morning, Jackie had drawn three glass red-top blood tubes from Mr. Sifton. She was fighting back a yawn, and when she turned around to put the blood in the rack on the counter, she accidentally tapped one of the tubes against the edge of the counter with a great deal of force. The tube flew from her hand and broke against the refrigerator a few feet away.

Jackie was flustered. Mr. Sifton had already left, and she knew that she would have to call him and ask him to return for another blood draw. In addition, she had quite a mess to clean up, as the blood had splattered a great deal. She knew that the bloody mess had to take precedence, because other patients would be entering the laboratory at any time.

Jackie was already wearing her nitrile gloves, so she bent down and started to pick up the pieces of the tube that had broken. Suddenly she felt a sharp pain in her finger, and realized that she had punctured her glove and her finger with a slice of glass.

1. What are two things that could have been done to avoid the parenteral exposure to the patient's blood?
2. What is the first thing that Jackie should do now? What else needs to happen as soon as possible?

RESOURCES AND SUGGESTED READINGS

OSHA Hazard Communication Standard
: OSHA regulation for chemical safety in the workplace http://www.osha.gov/SLTC/hazardcommunications/standards.html

Small Business Handbook
: General reference tool to verify that the OSHA Standards are in place properly at your worksite http://www.osha.gov/Publications/smallbusiness/small-business.html#hazsub/

National Fire Protection Association
: National Fire Protection Association website that includes information about fire, electrical, and building safety http://www.nfpa.org

Updated directives for OSHA Bloodborne Pathogens Standards, 1991
: Additional information added to the OSHA Bloodborne Pathogens Standards in 1991 1910.1030- 29CFR http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10051

"Viral Hepatitis"
: Excellent information about the different forms of viral hepatitis presented by the Centers for Disease Control and Prevention http://www.cdc.gov/hepatitis/index.htm

Hepatitis B Foundation, "Meet Dr. Blumberg"
: Facts concerning the discovery of hepatitis B, and Dr. Blumberg who was awarded a Nobel Prize in 1976 for this discovery http://www.hepb.org/about/blumberg.htm

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Chapter 4

Assuring Quality

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Assuring Quality in the Laboratory
Quality Control and Quality Assurance
What Is Quality?
- The Medical Assistant's Role in Assuring Quality Results
  - Types of Quality Control Specimens
- What Happens When Things Are "Out of Control"?
- Documentation of Quality Control Results
- Accuracy and Precision

Other Methods of Assuring Laboratory Quality
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

4-1 Define each of the key terms.

4-2 Compare and contrast quality assurance and quality control.

4-3 Explain why quality is essential for laboratory testing.

4-4 Describe circumstances when a medical assistant may need to perform quality control testing in the laboratory.

4-5 Classify the types of quality control specimens used in the laboratory.

4-6 Explain the concept of troubleshooting and list various actions that may be taken when quality control samples are not in range.

4-7 Demonstrate the ability to correctly log quality control results with appropriate documentation techniques.

4-8 Provide examples of the ways that quality may be assured with laboratory testing procedures.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

I.P.I.11. Perform quality control procedures
I.A.I.2. Distinguish between normal and abnormal test results
II.C.II.7. Analyze charts, graphs and/or tables in the interpretation of healthcare results
II.P.II.2. Maintain laboratory test results using flow sheets

ABHES Standards

Medical Laboratory Procedures 10.a: Quality Control, and Graduates: a. Practice Quality Control

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KEY TERMS

Accuracy	External quality control specimens	Quality assurance (QA)
Analyte	Internal quality control indicators	Quality control (QC)
Calibration	Mean	Quantitative results
Calibration verification	Oncologist	Reference ranges
Clinical significance	Panic results	Shift
Competency testing	Precision	Trends
Critical results	Proficiency testing	Troubleshooting
Electronic quality control devices	Qualitative results	Valid

ASSURING QUALITY IN THE LABORATORY

Laboratory results are extremely important to patient diagnosis and treatment. However, the results reported back to the physician are only as good as the testing methods themselves. This chapter explains various ways that the quality of the testing process can be monitored, so that the patient results reported will be correct. Quality control (QC) and quality assurance (QA) will be covered in detail, as well as documentation techniques and troubleshooting. Other procedures that are part of overall test quality assessment will be explored, such as proficiency testing and competency assessments, and the rules for quality performance of CLIA-waived tests will be reviewed.

QUALITY CONTROL AND QUALITY ASSURANCE

The terms *quality assurance* and *quality control* seem so similar; you may be wondering why it is important to know the difference. Essentially, they are both part of a plan to provide excellent quality care to the patients we serve. Quality control is part of the quality assurance process, but with a more specific focus.

Try to remember the last time you visited a health-care provider or laboratory to have your blood drawn and tested. How was your experience? Did you receive the information you needed to prepare for the blood draw appropriately? Did you feel that the person who drew your blood was trained adequately? How confident were you that the testing process was done in a way that accurate and valid results were obtained and reported back to your physician? Did your physician contact you in a timely manner with your results? These impressions, even though they were very personal to you, are all part of a quality assurance program at that facility.

Quality assurance (QA) includes all the policies and procedures necessary to provide excellent quality in laboratory testing. Chapter 1, introduced the three parts of laboratory testing: preanalytical, analytical, and postanalytical processes. A good quality assurance program acknowledges every part of the testing process to ensure that the laboratory staff members are doing all they can to contribute positively to the welfare of the patient in a timely manner. Quality assurance may be thought of as the big picture and it may include policies and procedures for collection, patient education, training for those performing the testing, maintenance and record keeping of instruments, monitoring of ordering and storage procedures for testing kits or reagents, and monitoring of turnaround times for results to be available to the health-care provider. Box 4-1 shows more detailed components of a quality assurance plan.

Quality control (QC) practices are used in the laboratory to ensure the quality of the testing process and the accuracy and precision of the results. Although the focus of quality control is specifically on the testing process, these practices are not limited to the details of how the test was performed. A good quality control program includes appropriate employee training, documentation of storage and shipping of reagents or testing kits used for testing, adherence to the manufacturer's instructions, correct interpretation and documentation of results, and verification that the results being reported are accurate and reliable. Quality control focuses on the second part

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BOX 4-1 QA processes

Preanalytical Phase

- Requisition appropriately filled out
- Patient preparation
- Patient identification
- Sample identification; three identifiers must be used
- Correct sample collection techniques; venipuncture performed correctly, etc.
- Correct storage and transportation of sample
- Correct storage of testing kits and quality control materials
- Appropriate training of personnel
- Preparation of standard operating procedures and policy manuals for reference
- Retention of current package inserts for correct instructions

Analytical Phase

- Valid test kit; not expired and stored correctly
- Instrument properly maintained and calibrated
- Proper mixing/preparation of quality control samples
- Proper mixing/preparation of patient samples
- Following manufacturer instructions exactly as written for CLIA-waived tests
- Proper documentation of quality control results; verification of acceptable QC values before patient sample is analyzed
- Order/perform confirmatory tests as recommended by manufacturer

Postanalytical Phase

- Appropriate documentation of patient results
- Appropriate units reported with test results
- Results transmitted to health-care provider in timely manner
- All critical results called immediately
- Include correct reference ranges with laboratory results
- Report all test results to authorities as required by law
- Properly dispose of used testing materials

of the laboratory testing process: the analytical phase. Anything that relates directly to the testing process may be part of quality control. Table 4-1 shows how quality assurance and quality control compare to one another.

Test Your Knowledge 4-1

List two ways that quality assurance and quality control are alike. (Outcome 4-2)

TABLE 4-1

Quality assurance versus quality control

Quality Assurance	Quality Control
Addresses procedures in all phases of laboratory process; includes quality control	Focuses specifically on the testing process, or analytical phase of the laboratory process
Comprehensive plan including patients, employees, and employers	Includes processes performed by employees and influenced by policies of employers
Plan developed by the employer and the quality assurance officer	Policies often established by the manufacturer; also may be developed by the employer
Requires comprehensive and detailed documentation	Requires detailed documentation
Requires critical thinking and analysis to design the plan and keep it current	Requires critical thinking and analysis to decide if the patient sample can be reported based on the quality control results

WHAT IS QUALITY?

The laboratory environment is no different from that of any other business. Customers are essential to the survival of the laboratory, and the testing provided is a service that the customers need. Who are the customers? This is not quite as easy to answer as it might seem at first. The laboratory serves patients; that is pretty clear. The patients may be varied in age, socioeconomic class, race, and gender, but laboratory results are a critical part of their care. However, the laboratory can serve the patients only if the quality of the laboratory performance meets the expectations of the health-care provider who sends the patient (or the specimens from the patient) to a specific laboratory for testing. Therefore, the health-care providers are also laboratory customers.

The performance of the laboratory must be of very high quality to serve both of these types of customers efficiently. Consider this scenario:

*A new **oncologist** opens a practice in your community. He specializes in providing care to patients with cancer, and is very concerned that the laboratory*

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testing available will be sufficient to meet his needs. Within the first week, he orders several screening tests for ovarian cancer to be performed on his patients. The analyzer used to perform these tests breaks down on Monday, and no one in the laboratory contacts the physician to let him know of the delay. He finally receives his screening tests on Friday, and one of the results is positive. He is very upset about the time that it took for him to receive this result in his office, and decides to send all his testing requests to another laboratory.

This is an example of a breakdown in quality assurance. If the physician had been notified of the expected delay for his results, he may still have been upset, but at least the lines of communication would have been open. Another alternative would have been sending the samples to another laboratory while the machine was serviced; the delay would most likely have been minimized, and the physician would have received his results in a timely manner.

Other examples of poor quality performance are incorrect results, improper patient preparation, reporting the wrong **reference ranges** (a range of expected values for a healthy individual for a specific test) for a specific patient's gender and age, or even improper billing practices. All aspects of the customer experience in the laboratory must be of high quality, as the test results may have significant impact on the treatment for the patient. A patient may be put on antibiotics when they are not needed because a streptococcal screen was incorrectly interpreted as positive. Another patient result may show a false elevation in potassium levels when a specimen is mishandled, and the physician may change their medication based on these results. This could be a life threatening situation.

It may be helpful to consider laboratory quality as a series of "Rights":

- Right result
- Right time (both specimen collection and reporting of results)
- Right specimen
- Right patient
- Right reference range for result interpretation
- Right price for the services provided

Test Your Knowledge 4-2

How do incorrect laboratory results affect patient care? (Outcome 4-3)

The Medical Assistant's Role in Assuring Quality Results

Most medical assistants working in a laboratory environment will be performing Clinical Laboratory Improvement Act–waived (CLIA–waived) tests. These are tests that are very simple to perform with results that are easy to interpret. As introduced in Chapter 3 of this text, laboratory tests are categorized under CLIA regulations based on the complexity of the process. Some of the tests are categorized as "waived" tests because they are exempt (or waived) from many of the regulatory procedures of the laboratory tests that are more complex in nature. This does not mean, however, that they are exempt from quality control procedures. Even before the testing process begins, the medical assistant can be checking the sample collection devices (such as swabs or blood tubes) for outdates, and participating in necessary training to be ready for the procedure.

The first opportunity that a medical assistant might have to be involved in quality control is when the testing kit or reagents arrive in the laboratory. Storage instructions are printed on the outside of the box, and these need to be followed precisely to provide accurate test results. Reading the package insert is critical, as the procedure specified by the manufacturer must be followed carefully. When the box is opened, this package insert should be stored in a safe place. Many laboratories have a binder for these sheets, and it is the medical assistant's responsibility to verify that the insert has not changed since the last one was placed in the binder. Laboratories may also keep multiple copies that have the date of receipt documented for reference.

Types of Quality Control Specimens

When the kit (or the reagent) is opened for use, it will be necessary to test a quality control specimen as recommended on the package insert. Some testing procedures may call for two types of quality control specimens to be analyzed. There are three general categories used to describe quality control specimens:

1. **External quality control specimens:** This may be a reference solution that comes with the kit, or a swab that has been treated with material that will cause the test to read positive or negative. External quality control materials may also need to be purchased separately from the testing materials. Regardless of how the materials are provided, the most important concept to follow is that of the analysis of the quality

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control specimens exactly as directed by the test manufacturer, and the comparison of the results from the specimen to the data provided to be sure that the test performance is as expected. These may be **qualitative results** for tests that provide a positive or negative result, or they may be **quantitative results** with a range of expected results. Quantitative tests provide results as numbers indicating the concentration of certain substances. If the results of the external quality control specimen are not as expected, the kit or reagent cannot be used to test patient samples until the problem has been identified and solved.

2. **Internal quality control indicators:** These are quality control indicators that are part of the individual testing kits. They show that the test process was **valid,** but they do not provide a test result. An internal quality control measurement is usually a color indicator, and in the package insert there will be an explanation of acceptable performance before a test result can be reported. Internal quality control specimens are most common in qualitative testing procedures. Remember, if the test is not valid (the indicator does not develop properly), you may not report the patient test result. Figure 4-1 shows how an indicator might appear.
3. **Electronic quality control devices:** Electronic quality control devices are reusable, and are used to verify the function of an instrument used for analysis. The electronic quality control devices are commonly test strips or cuvettes. The devices come with an expected numerical range of results, and it is imperative that the results fall within this range when tested, or no patient results may be reported until the problem has been identified and solved.

Test Your Knowledge 4-3

Do electronic QC devices let you know whether a test is valid? (Outcome 4-3)

Test Your Knowledge 4-4

If a medical assistant is using a machine to analyze a blood sample for a test result, what type of QC may she be required to use?

a. External
b. Internal
c. Electronic
d. a and c (Outcome 4-4)

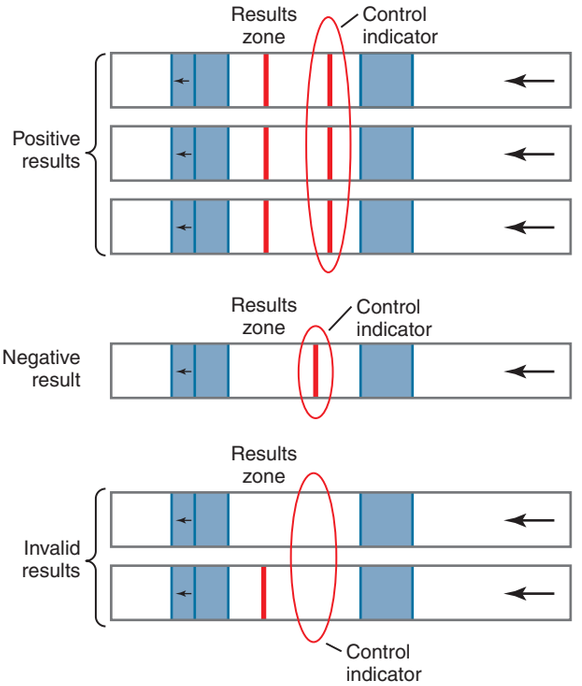

Figure 4-1 Valid and invalid test results.

Medical assistants may also perform tests that have been classified as CLIA moderate-complexity procedures. These procedures may require quality control procedures to be performed with more frequency than the CLIA-waived tests, and there is more training and documentation required for the employee who is performing the tests. Laboratories that perform these moderately complex tests are required either to follow the recommendations for quality control included in the package insert from the manufacturer, or process at least two levels of quality control materials with each analytical run. The CLIA regulations state that the laboratory must use the more stringent option of the two. Tests of moderate complexity utilizing instruments also require calibration, calibration verification, and proficiency testing. These concepts are discussed later in this chapter.

What Happens When Things Are "Out of Control"?

It is very important to recognize the importance of quality control specimens as an indicator of the reliability and accuracy of the testing method to be utilized for

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Procedure 4-1: Documentation of Qualitative Quality Control Values

TASK

Properly perform quality control testing and document qualitative QC values on a chart.

CAAHEP/ABHES STANDARDS

CAAHEP 2008

I.P.I.11. Perform quality control procedures
I.A.I.2. Distinguish between normal and abnormal test results
II.C.II.7. Analyze charts, graphs and/or tables in the interpretation of healthcare results
II.P.II.2. Maintain laboratory test results using flow sheets

ABHES Standards

Medical Laboratory Procedures 10.a: Quality Control, and Graduates: a. Practice Quality Control

CONDITIONS

- CLIA-waived test kit
- External quality control material
- Quality control chart
- Pen

Procedure	Rationale
1. Open the CLIA-waived test kit and secure the package insert.	It will be necessary to have the package insert available for reference as the quality control specimen is analyzed.
2. Verify which type of quality control specimen your laboratory uses for this testing procedure. Find the directions in the package insert for that type of specimen.	The quality control specimen may be one that is provided with the kit or it may be a commercial one that is purchased separately. It is important that the correct procedure be used for the testing process.
3. Wash hands and apply gloves.	Appropriate personal protective equipment should be used when testing quality control materials just as it would be used for testing samples.
4. Following the directions in the package insert, perform the testing procedure using the positive quality control specimen. Repeat with the negative quality control specimen.	The performance of the testing procedure should be verified with both a positive and negative control specimen as recommended by the manufacturer.
5. Verify that the positive and negative quality control specimens provide the appropriate results.	Tests must be valid and the results must be as expected for the test kit to be considered "in control."
6. Remove gloves, dispose of them appropriately, and wash hands.	Gloves should be removed before documenting results.
7. Record the results on the log sheet. Include these factors: **a.** Date and time of test and employee ID **b.** Analyte tested (what type of test was performed?) **c.** Type of quality control (external); brand name if a commercial control was purchased separately	All these factors are very important documentation, and any form should allow for the recording of complete information.

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Procedure	Rationale
from the kit, and lot number of quality control material. **d.** Result (positive or negative) **e.** Was result acceptable? **f.** Corrective action taken, if necessary	
8. Put away testing supplies and disinfect work area.	

Procedure 4-2: Documentation of Quantitative Quality Control Values

TASK

Properly perform and document quantitative quality control values on a chart. Determine whether the values are acceptable according to laboratory protocol.

CAAHEP/ABHES STANDARDS

CAAHEP 2008

I.P.I.11. Perform quality control procedures
I.A.I.2. Distinguish between normal and abnormal test results
II.C.II.7. Analyze charts, graphs and/or tables in the interpretation of healthcare results
II.P.II.2. Maintain laboratory test results using flow sheets

ABHES Standards

Medical Laboratory Procedures 10.a: Quality Control, and Graduates: a. Practice Quality Control

CONDITIONS

- Quantitative testing method
- External quality control material
- Quality control chart with established acceptable ranges provided
- Pen

Procedure	Rationale
1. Consult the instructions for the testing method if necessary before continuing with the process.	With automated testing procedures, the manufacturer's recommendations usually do not change as often as they might with the CLIA-waived test kits. However, consulting the instructions is always appropriate.
2. Verify which type of quality control specimen your laboratory uses for this testing procedure.	The quality control specimen may be one that is provided with the testing method, or it may be a commercial product that is purchased separately.
3. Wash hands and apply gloves.	Appropriate personal protective equipment should be used when testing quality control materials just as it would be utilized for testing samples.
4. Following the directions in the package insert or the laboratory procedure manual, perform the testing procedure using the quality control specimen. Repeat with a second quality control level if recommended by the manufacturer.	The performance of the testing procedure should be verified with both a high and low level quality control specimen as recommended by the manufacturer.

Continued

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Procedure 4-2: Documentation of Quantitative Quality Control Values—cont'd

Procedure	Rationale
5. Put away quality control material.	Many quality control specimens must remain refrigerated, so this should occur immediately after use.
6. Remove gloves, dispose of them appropriately, and wash hands.	Gloves should be removed before documenting results.
7. Record the results on the log sheet by placing a dot at the line at which the date and specimen result intersect. In addition, document the time of the test and your identification. Verify that the correct control level brand and lot number are on the log sheet.	All these factors are very important documentation, and any form should allow for the recording of complete information.
8. Verify whether the quality control is within the established ranges and whether there is a pattern developing that needs attention, such as a trend or a shift in the results. If there is a problem or if the quality control is out of range, do not process patient samples.	Careful documentation of the results and observation of any quality control patterns are absolutely necessary. Patient samples cannot be processed if the sample is out of range or if there is an undesirable pattern forming in the results.
9. Repeat the test if results are out of range. If the condition persists, begin troubleshooting the problem. Document the repeat and also if there are troubleshooting steps taken.	Troubleshooting may include opening a new bottle of quality control material, cleaning the instrument, verifying the instructions for performing the test, verifying that the quality control chart is for the correct lot number, etc.
10. If the troubleshooting is not successful, do not allow the instrument to be used for patient samples, and contact a supervisor or the manufacturer for further action.	It is essential that the problem be resolved as soon as possible to continue with quality patient care.

patients. When the QC results are not as expected, the person running the test or operating the instrument must not report any patient results until the problem has been solved. The systematic process of identifying the problem with the testing procedure is called **troubleshooting.** There are times when the quality control specimen does not provide a positive result as expected, or when the test results appear invalid when running a pregnancy test QC specimen. The medical assistant performing the test must immediately try to identify the problem with the testing procedure before the process can continue. Here are some actions to take when troubleshooting a testing process:

1. Check the expiration dates of the reagents, kit, and quality control reagents in use. If any of these supplies are outdated, document the discrepancy, discard the expired item, and perform the test again using materials that are not past their expiration date.
2. Verify how the specimen, kit, reagent, or quality control material has been stored. Were the manufacturer's recommendations followed? If there is evidence that the storage instructions were not followed, the results provided by this testing method may be inaccurate. The testing component that was mishandled must be discarded, with appropriate documentation of the issue.
3. Verify the specimen type required for the testing procedure. Sometimes a kit is designed to work only with certain types of body fluids. The acceptable specimen type will be provided as part of the package insert.

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Tests performed on body fluids not indicated as acceptable may provide inaccurate or invalid results.

4. Was the control material well mixed and at the correct temperature for the test? The quality control material may require warming to room temperature before use or vigorous mixing prior to testing. These instructions must be followed carefully.
5. Refer to the current package insert. Are you aware of skipping a step, or doing the procedure incorrectly? Has the package insert or instructions changed since you last performed the test?
6. If an instrument was used for the test, is it clean? Check the maintenance documentation, and see if the recommended schedule has been followed for routine instrument care. If needed, perform the recommended maintenance, after which the QC can be analyzed again.
7. Read the troubleshooting portion of the manufacturer's instructions. There is valuable information here that may help to solve the problem.

Usually the problem may be identified by following these suggestions. If the problem is still not apparent, a new quality control specimen should be obtained for a retest. If it is an internal control and the quality control specimen comes with the kit, open a new kit and try the test again. Finally, documentation of the details and troubleshooting process is critical. If there seems to be a pattern emerging, it is imperative that everyone knows what has occurred, and the steps that have been taken to solve the problem. Details also help while communicating with a manager or supervisor about the problem. Sometimes the medical assistant may need to contact the manufacturer for advice, and these details will be necessary to continue the troubleshooting process.

Test Your Knowledge 4-5

Cindy Lou has recently been trained to perform pregnancy testing in the physician office laboratory (POL) where she is employed. She receives a blood specimen from the physician who asks her to test it to see if a young patient is pregnant. Cindy follows the pregnancy testing procedure exactly as she was taught, but the test results show that it is an invalid test. What are two possible explanations? (Outcome 4-6)

Documentation of Quality Control Results

Quality control requirements are different for CLIA-waived tests than they are for those of moderate or high complexity. Many of the waived tests are qualitative in nature, which means that the result provided is either positive or negative, rather than a measurement reported as a number or percentage. The quality control assessment for these qualitative tests may be built in to the individual testing devices or the laboratory may purchase other quality control specimens to verify the performance quality for the **analyte** (substance being tested). Whether the QC is internal or external, it must be documented, and this record must be kept for at least two years. As with any document in the laboratory or in a patient's chart, the results on the quality control chart must be documented in pen, not pencil. This provides a permanent record that is not easily changed. One of the most common sources of laboratory error is that of transcription; it is very important to carefully document all laboratory data. Figure 4-2 is an example of a quality control log sheet to be used for a qualitative test. At a

Date and time of test/ Employee identification	Analyte tested	Type of quality control specimen used; external or internal?	For external quality control; brand and quality control lot numbers	Quality control result	Results acceptable? (yes or no)	Corrective action taken

Figure 4-2 Log used to record quality control results for a qualitative test.

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minimum, the documentation should include the following:

- **The date and time of the quality control test.** Remember, the frequency that the QC is tested must be at least as often as the manufacturer recommends.
- **The quality control material lot number and level.** If it is internal control, this would be documented as additional information. If the testing device has a color change that occurs to verify the validity of the test, this needs to be recorded as well.
- **The lot number for the testing kit in use.** If this test kit was just opened, the kit should also have the date and the initials of the person who opened it written on the test kit box.
- **Results of the quality control test.** This is often just positive or negative for qualitative CLIA-waived tests.
- **Documentation of whether the kit or test can be used to test patient samples.** Remember, this decision is based on whether the quality control results were within the established acceptable ranges.
- **Documentation of troubleshooting or corrective action, if required.**
- **Initials or signature of employee performing test.**

Test Your Knowledge 4-6

Why is it important to document the date of a quality control test? (Outcome 4-7)

Various moderate-complexity tests, as well as some that are CLIA-waived, will provide quantitative results. This means that the quality control results for these testing methods will also be reported as a number, rather than merely a negative or positive result indicating the presence or absence of a substance. Because the results reported for these tests are to fall within an established range, it is very important that the quality control results are monitored closely to verify the method's performance. A common tool used to record these quantitative results is a Levey-Jennings chart, used to monitor the quality control performance over a set time interval. The acceptable quality control ranges are either established by the laboratory before patient samples are analyzed with the kit or instrument, or they are established by the manufacturer and adopted by the laboratory. The values obtained each time the quality control is processed are charted (in pen) according to the date and the value obtained. The chart also has spaces to document the analyte being tested, the QC level, the lot numbers of the kit and the quality controls, and other information that may be necessary for that particular laboratory. Levey-Jennings charts will also include the **mean** (average) expected value, as well as limits for acceptable QC testing results. If an individual quality control test falls outside of these ranges, patient testing cannot continue until the problem has been addressed. This type of graph can also be monitored for **trends** in the data, which show a progressive change in the results from day to day that continue to move gradually in one direction. **Shifts** will also be evident, and can be identified on the graph as a set of results that suddenly move significantly, but still remain within an acceptable range. Sometimes a shift will be evident when the results move from one side of the mean to the other, but a shift may also be evident even if the results remain on the same side of the mean. Both of these situations must be addressed, because they are indicative of a problem with the quality control procedure, the testing method, the operator, or a combination of these factors. Figure 4-3 is an example of a quantitative Levey-Jennings quality control chart.

Test Your Knowledge 4-7

Is a Levey-Jennings chart used to document qualitative QC test results? Why or why not? (Outcome 4-7)

Accuracy and Precision

The Levey-Jennings chart can be a useful tool to verify whether a testing method is demonstrating accuracy and precision. These are very important concepts to keep in mind in the laboratory environment. **Accuracy** is a word used to define how close the result produced for that test is to the real value. This can be visualized by thinking of a bull's-eye target. The true value for a test procedure is at the center of the target. If the test is accurate, then each time the test is performed the results will be near the center of the target.

Precision describes the reproducibility of results. This can also be thought of as a measurement of whether the results are close together if the test is run multiple times on the same specimen. Visualizing the bull's-eye target again, a test shows good precision if the results are all clustered closely together when the test is run multiple times.

A test can be precise but not accurate. This means that the results for a certain test may all be close to the same value, but not near the true value for that test. The goal for laboratory testing is to have results that are both

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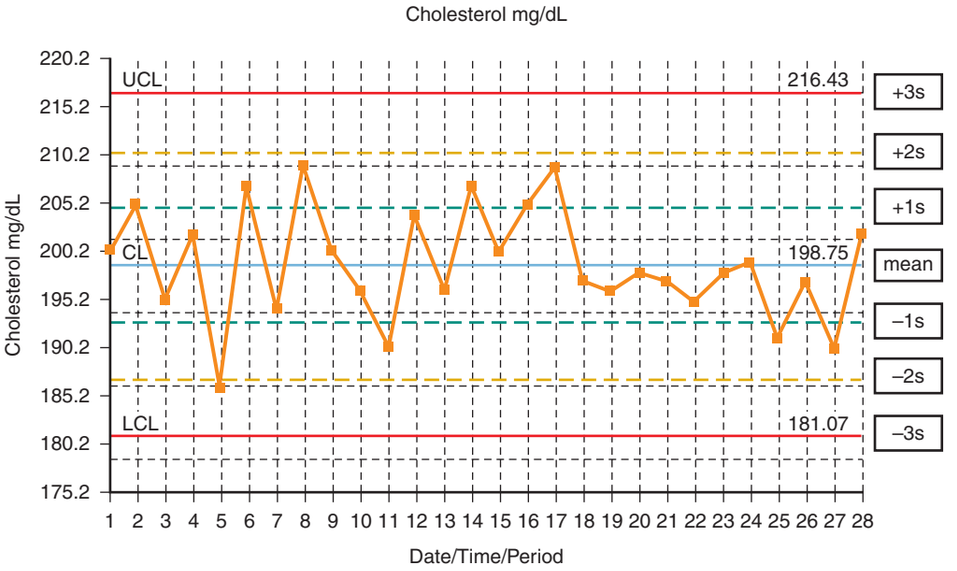

Figure 4-3 Levey-Jennings chart used to record quantitative quality control results.

accurate and precise, and quality control measures help to identify problems in these areas before they affect the quality of the patient results for that test.

OTHER METHODS OF ASSURING LABORATORY QUALITY

All laboratory results have **clinical significance,** meaning that a health-care provider may change the treatment or assign a diagnosis for a patient based on the laboratory results. In addition, there are established **reference ranges** for all laboratory tests. These are the expected values for patients in a normal population for a certain analyte. In order to feel confident that the laboratory results reported are accurate and reliable, all facets of quality assurance must be taken into consideration. The best way to understand how these all fit into patient care is to consider a patient scenario with a negative outcome:

Mr. Butler has developed an atrial arrhythmia and is being treated with the drug digoxin to help increase the efficiency of his heart muscle and correct problems with the electrical impulses that pass through his heart. Mr. Butler visits the laboratory monthly to have his drug level checked, as digoxin has serious side effects if the concentration is too high in the bloodstream. When the laboratory tests the digoxin level, a higher-than-normal level is discovered for someone being treated for his condition, and the result is well outside the reference range. When Mr. Butler's physician receives the report, he calls his patient, verifies his health status, and tells him that he needs to decrease his digoxin dose for a few days. The physician asks Mr. Butler to go to the laboratory to have another specimen drawn at the end of the week. On day three after decreasing his dose, Mr. Butler has his drug level rechecked. This second draw is extremely low, well below the reference range. The result is drastically different from what it was a few days earlier, and is much lower than it should be with the minor medication adjustment based on the previous high result.

Of course, Mr. Butler's health-care provider is eager to find out how the results for the digoxin could be so different in just a few days. He contacts Mr. Butler and confirms that he followed the dosage changes as directed. The physician then contacts the laboratory that performed the testing on the first sample. The laboratory staff rechecks the sample, and finds the result is close to the first reading: still high above the reference range. However, when their quality assurance officer steps in to resolve the issue, she finds that the quality control results for the digoxin test have been slowly reading higher and higher for a few days prior to the test date. This trend has gone unnoticed by the personnel performing the tests, because the results were all within the acceptable range.

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POINT OF INTEREST 4-1
Statistics used for quality control assessment

Statistics is a specific branch of mathematics that deals with the collection, analysis, and interpretation of numerical data. We use statistics in the laboratory to analyze the quantitative data derived from quality control testing. The entire process is quite complicated, but developing an understanding of a few key terms can benefit the medical assistant as he or she works with these data.

To establish acceptable ranges for qualitative QC testing procedures, the mean, standard deviation, and variance must be established.

- **Mean:** The mean is the numerical average of a set of numbers. To calculate the mean, find the sum (total) of a set of values (numbers), then divide that sum by the number of values in the set. For instance, if you were to analyze a specimen ten times for a potassium level, you might generate these numbers: 4.5, 4.4, 4.2, 4.6, 4.5, 4.1, 4.3, 4.6, 4.5, and 4.7 mmol/L. The mean of these values would be calculated by adding them all together, then dividing by 10, because there were ten results used for the calculation. The mean result for these numbers would be 4.4 mmol/L.
- **Variance:** The variance is a bit more complicated to calculate. It gives a numeric indication of how much the values in the set vary or deviate from the mean. The variance is calculated after the mean for the set of numbers has been established. Each number is subtracted from the mean, and this difference is squared, which means to multiply it by itself one time. The sum of the squares is then established, and this sum is divided by the total number of values minus one. (The term used for this calculation is $n - 1$.) Therefore, for our scenario presented above, we would follow these steps from the calculate mean of 4.4 mmol/L:

The sum of the deviations squared is 0.34, and this number divided by $n - 1$ (9 in our example) is 0.036. The variance for this set of numbers is 0.036.

Potassium Value	Deviation; How Far from the Mean of 4.4?	Deviation Squared; Multiplied by Itself
4.5	0.1	0.01
4.4	0.0	0.00
4.2	0.2	0.04
4.6	0.2	0.04
4.5	0.1	0.01
4.1	0.3	0.09
4.3	0.1	0.01
4.6	0.2	0.04
4.5	0.1	0.01
4.7	0.3	0.09

- **Standard deviation:** The standard deviation provides a measurement of how the values we are working with are placed or scattered around the calculated mean for the values. The standard deviation uses the variance that was calculated in the previous step, and is calculated by taking the square root of the variance. For the potassium scenario that we are working with, the standard deviation would be calculated by calculating the square root of 0.036. The standard deviation would be 0.061 mmol/L for this set of potassium results.

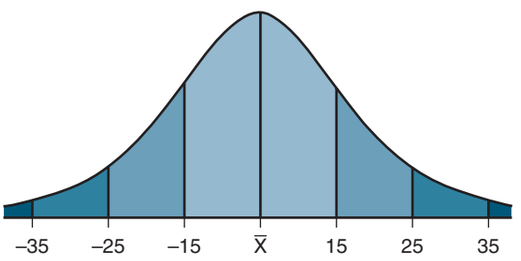

The previous calculations are used to establish acceptable values or allowable standard deviation for their qualitative laboratory results. If the potassium values were analyzed for 100 people who were considered to be of normal health, we would find that their values could be plotted on a graph to form a Gaussian curve (see above), which is sometimes known as a bell curve or normal distribution curve. In a normal curve, half of the values are greater than the mean and half of the values are less than the mean for that test result. Statistically, it has been shown that 68% of the results in a normal population will be within one standard deviation above or below the mean, and 95% will be

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within two standard deviations above and below the mean. Ninety-nine percent of the results will fall within three standard deviations of the mean.

Normally, when establishing acceptable ranges (also known as confidence limits) for a laboratory procedure, the quality control results must fall within a range of two standard deviations above or below the mean in order to be an acceptable result. For our potassium scenario, if this was a quality control material that was tested ten times, the results would need to fall within two standard deviations of the mean. The mean was 4.4, and the quality control results would need to be 4.4 plus or minus 0.122 to be within range. This means that the acceptable ranges for this quality control sample would be 4.28 to 4.52 mmol/L.

She also checks the maintenance logs for the instrument used for digoxin testing, and finds that the machine has not been serviced as recommended by the manufacturer. This is a very serious situation, especially because Mr. Butler may not have been the only patient affected by the instrument's performance.

The QA officer begins to make a plan to correct the issues. The first part of her plan is to have the overdue maintenance performed on the instrument. This includes cleaning the internal components of the machine and changing some tubing and reagents. After the maintenance has been performed, the machine has to be calibrated. **Calibration** is a standardization of the instrument for a specific analyte, meaning that a calibration sample (generally ordered from the manufacturer) is processed using the instrument. If the reading does not come out exactly as it should, the instrument is adjusted (according to manufacturer's instructions) until it does measure the calibration sample at precisely the predetermined level.

Once the calibration is complete, quality control assessment must be performed again. This is called **calibration verification.** The calibration and subsequent verification show that the testing instrument has been reading the digoxin specimen results several increments higher than they really were. This caused Mr. Butler's reading to appear falsely elevated; his specimen was tested once again after the calibration and verification and found to be at the high end of the expected reference range. His dosage should not have been altered. This change in medication may have put his health at risk unnecessarily.

To follow up on this incident, the QA officer documents all that has occurred. Her follow-up includes reeducation of the personnel responsible for the quality control and maintenance for the testing instrument. She develops a plan to follow up with these employees to see if the intervention and retraining were successful. The QA officer also notifies the laboratory director and any other required personnel in the organization who need to be notified of a testing system problem leading to a bad patient outcome.

If the patient's health had been negatively affected by the medication change in response to the first digoxin test result, the laboratory would be at risk for legal action. As a result of this situation, it is likely that the physician may decide to send his specimens to a different laboratory for analysis.

As this scenario draws to a close, the QA officer feels confident that the digoxin levels reported from that instrument are now accurate and reliable. She also has to go back and follow up on reported results for other patients tested close to the time that Mr. Butler had his test performed.

However, another question still exists: How well do the digoxin results from this laboratory compare to others that are performing the same test with the same instrument? This is the final step of assuring quality for the laboratory. It is like taking a standardized assessment to see if the results produced in a certain laboratory compare well to those of others across the country. **Proficiency testing** is a means to measure the performance of a laboratory externally. For laboratories performing moderate- or high-complexity testing, federal regulations require that proficiency testing is performed at least three times yearly. The laboratories are sent specimens from a provider that has been approved by their licensing agency, and these specimens must be tested exactly as a patient sample would be tested. The laboratories then report their results back to the approved provider, and they are compared to other laboratories that perform the same test using the same method. If a laboratory's results are too different from the others used for the comparison, that laboratory may be told that it can no longer offer that specific test until the problem is identified and solved. In addition, if a laboratory is not successful with its proficiency testing, there will usually be a site visit performed by those who certify or license this laboratory for operation.

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For proficiency testing to be valid, it is important to stress that the samples provided are to be run precisely the same as patient samples. Laboratories are not allowed to run the samples in duplicate unless the patient samples would be treated in this way. Proficiency testing is a powerful tool, providing verification for a laboratory that their results are comparable to others performing the same test across the region or country.

By law, laboratories that perform only CLIA-waived tests are not required to participate in proficiency testing. However, they may choose to voluntarily participate. The Centers for Medicare & Medicaid Services (CMS) still recommends that some sort of external quality verification is performed periodically, whether it is through a commercial agency or informally. Informal verification of quality may include splitting a patient sample and sending some of it to another laboratory to see what its result is, or asking for another laboratory to share its patient's samples for the same reason. Many laboratories also perform internal proficiency testing in which they pool patient samples, run them numerous times to get an acceptable range for the results, and then use these to supplement their commercial quality control materials throughout the day. These patient pool specimens are usually separated into small samples and frozen until they can be tested. The internal patient quality control samples are a nice way to supplement the commercial quality control in the laboratory, but they do not help with comparisons to other laboratories unless they are shared.

There is one more recommended method to assure quality in the laboratory. This process is known as **competency testing.** Competency testing actually evaluates the personnel who perform the laboratory tests, by direct observation, or by introducing mock specimens with known values into the patient load and evaluating the results and documentation after the test is complete. This evaluation process can be especially critical with the CLIA-waived tests, as often the person who performs the test has little or no formal laboratory training, and he or she may not realize the significance of cutting corners by not following the procedure exactly as the manufacturer recommends it to be performed. Many laboratories have designed a program in which competency testing of some sort is performed annually for each employee, in which a supervisor provides samples of known results for personnel to test. If the documented results do not fall within the established ranges, then additional training needs to be integrated into the laboratory environment.

Test Your Knowledge 4-8

How is the process of calibration different from running a quality control specimen? (Outcome 4-8)

Test Your Knowledge 4-9

Is proficiency testing required for all laboratories? (Outcome 4-8)

The CMS has performed site visits at CLIA-waived laboratories across the United States over the course of the past few years and the results have been very informative. Because the regulatory requirements for laboratories that perform only CLIA-waived tests are minimal, there is concern for the quality of the services provided by these laboratories. The following is a summary of the issues identified in the site visits:

- The employees performing the tests were inadequately trained. Training must be provided by a qualified person who has knowledge of the test performance, and the actual performance of the test should be evaluated as the trainer observes.
- There were high turnover rates for testing personnel, especially medical assistants.
- CLIA-waived testing sites were performing tests that were not CLIA waived, using personnel who were not adequately educated or trained to perform the procedures. This could be a potentially dangerous situation for patients, as the procedures may not be performed correctly and the testing personnel may not be able to identify significant issues with the testing process due to lack of training.
- Many of the sites did not have the most recent manufacturer's procedural instructions for the tests they were performing. Approximately 20% of the sites reported that they did not routinely check the manufacturer's package inserts to see if there were recommended changes in the procedure. There were also cost-cutting measures in effect in some laboratories, in which urinalysis testing strips or fecal occult blood slides were being cut in half to increase the number of specimens tested per kit. This destroys the integrity of the testing process, and means that the laboratory is noncompliant with the CLIA regulations.
- Quality control testing was not performed as specified by the manufacturer by many of the sites, and units of measure were incorrectly reported with patient results.

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- Problems were identified with expiration dates and storage methods for the testing kits, as well as documentation of the lot numbers and control results for the kits once they were opened. There were also issues with inadequate performance of instrument maintenance and calibration.
- Approximately 6% of the laboratories visited did not perform follow-up confirmatory tests as recommended by the manufacturer.
- Some of the sites were testing specimens that were not acceptable for that waived method. For instance, some tests are designed to be performed on urine, but the laboratory was testing plasma instead.

In 2005, the Centers for Disease Control and Prevention (CDC) published a report summarizing the results of site visits mentioned above. (You can find the link to the report in the Resources and Suggested Readings section at the end of this chapter.) In addition to the summary, the report also includes recommendations for good laboratory practices for waived testing sites. The majority of these recommendations have been included in this chapter. They include specific considerations for all three parts of the laboratory testing procedure: preanalytical, analytical and postanalytical phases.

1. Be certain that there is a written request or requisition for all tests performed.
2. Follow the written instructions for collection methods carefully, and verify what type of specimen is needed for the test ordered before collection.
3. Properly identify the patient and specimen, and store the specimen properly until the testing process begins.
4. Check the kit expiration date.
5. Know the product insert; be sure that copies are kept current at all times, and refer to them often. A sample package insert is reproduced in Figure 4-4.
6. Follow the procedure provided by the manufacturer exactly as written.
7. Run controls often, at least as often as is recommended by the manufacturer.
8. Repeat the test if there is a problem, and troubleshoot if the problem continues. Always verify that the test result is valid if there is an indicator present on the testing device.
9. Accurately record the results; use the correct units and be sure that the reference ranges reflect the population and sample type that you are reporting.
10. Sign and date your results wherever they are recorded in your laboratory setting.
11. Notify the health-care provider that ordered the tests in a timely manner. Be aware of **panic** or **critical results.** These are test results that are far enough outside of the reference ranges that they may be considered to be life threatening, and must be reported *immediately* to the ordering physician or another appropriate responsible party. When notifying the physician's office of these results, document who was notified, what was reported, and when it was reported, and sign and date this documentation.

Test Your Knowledge 4-10

What is the most important step that a medical assistant can take to ensure that he or she is performing a CLIA-waived test for mononucleosis correctly?

(Outcome 4-8)

SUMMARY

Quality assurance in the clinical laboratory is like a big umbrella covering numerous aspects of the process. A good QA plan should address issues such as education of the providers and patients concerning appropriate patient preparation before testing, initial and ongoing education of all personnel, written procedures, thorough documentation of all testing, quality control and maintenance procedures, and plans for how to follow up on problems that may develop. Quality control focuses more on the testing process itself, and includes specimen and testing kit or reagent storage, following directions, and reporting results appropriately. Other means of assuring quality in the laboratory may include calibration, external proficiency testing, and competency testing. The most important aspect of all these measures is to assure quality results for the patients we serve so that they can be cared for appropriately.

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osom

Mono Test

CLIA Complexity: Waived for Whole Blood
Non-Waived for Serum or Plasma

FOR LABORATORY AND PROFESSIONAL IN VITRO DIAGNOSTIC USE ONLY.

INTENDED USE
The OSOM® Mono Test is intended for the qualitative detection of infectious mononucleosis heterophile antibodies in serum, plasma or whole blood as an aid in the diagnosis of infectious mononucleosis.

SUMMARY AND EXPLANATION OF TEST
The diagnosis of infectious mononucleosis (IM) is suggested on the basis of the clinical symptoms of fever, sore throat and swollen lymph glands. The highest incidence of symptomatic IM occurs during late adolescence (15–24 years of age). Infectious mononucleosis is caused by the Epstein-Barr Virus (EBV).[1,2] The laboratory diagnosis of IM is based on the detection of IM heterophile antibodies. These heterophile antibodies are directed against antigens found in bovine, sheep and horse erythrocytes. The OSOM Mono Test utilizes an extract of bovine erythrocytes to give the required sensitivity and specificity.

KIT CONTENTS AND STORAGE
25 Test Sticks in a container
25 Test Tubes
25 Transfer Pipettes
25 Capillary Tubes with 1 Capillary Bulb
1 Diluent (contains buffer with 0.2% sodium azide)
1 Mono Positive Control (contains rabbit anti-beef stroma in tris buffer with 0.2% sodium azide and 0.05% gentamycin sulfate preservatives)
1 Mono Negative Control (contains goat albumin in tris buffer with 0.2% sodium azide)
1 Work Station
1 Directional Insert
2 Additional test sticks have been included in the kit for external QC testing
Note: Extra components (tubes, pipettes, capillary tubes and capillary bulb) have been provided for your convenience.
Store the Test Sticks and reagents tightly capped at 15°–30°C (59°–86°F).
Do not use the Test Sticks or reagents after their expiration dates.

MATERIALS REQUIRED BUT NOT PROVIDED
Specimen collection containers.
A timer or watch.

PRECAUTIONS
- For in-vitro diagnostic use only.
- Follow your laboratory safety guidelines in the collection, handling, storage and disposal of patient specimens and all items exposed to patient specimens.
- The Diluent and Controls contain sodium azide which may react with lead or copper plumbing to form potentially explosive metal azide. Large quantities of water must be used to flush discarded Diluent or Controls down a sink.
- The Capillary Bulb contains dry natural rubber.
- Do not interchange or mix components from different kit lots.

SPECIMEN COLLECTION AND PREPARATION
Serum, Plasma, or Whole Blood Sample
Obtain specimens by acceptable medical technique. Collect whole blood samples using a tube containing EDTA or heparin as an anticoagulant. Other anticoagulants have not been tested. Serum and plasma specimens may be refrigerated (2°–8°C; 36°–46°F) and tested within 48 hours; serum and plasma specimens held for longer times should be frozen (below –10°C; 14°F) and tested within 3 months. Test whole blood specimens within 24 hours. Specimens must be at room temperature (15°–30°C; 59°–86°F) when tested.

Fingertip Whole Blood
Hold the capillary tube horizontally while collecting the sample. Touch the end of the capillary tube to the drop of blood on the patient's finger. Fill the capillary tube completely. Place the small end of the black bulb onto the capillary tube. Place your fingertip over the opening in the bulb. Squeeze the bulb to dispense the whole blood sample into the test tube.

QUALITY CONTROL
External Quality Control
For external QC testing, use the controls provided in the kit. Add one free falling drop of control to the Test Tube and then proceed in the same manner as with a patient sample. Quality Control requirements should be established in accordance with local, state and federal regulations or accreditation requirements. Minimally, Genzyme Diagnostics recommends that positive and negative external controls be run with each new lot and with each new untrained operator. Some commercial controls may contain interfering additives. The use of these controls is not recommended.

Figure 4-4 Package insert. *Courtesy of Genzyme Diagnostics.*

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Internal Quality Controls
The OSOM Mono Test provides two levels of internal procedural controls with each test procedure.

- The red Control Line is an internal positive procedural control. The Test Stick must absorb the proper amount of test material and be working properly for the red Control Line to appear.
- A clear background is an internal negative procedural control. If the test has been performed correctly and the Test Stick is working properly, the background will clear to give a discernible result.

If the red Control Line does not appear, the test may be invalid. If the background does not clear and interferes with the test result, the test may be invalid. Call Genzyme Diagnostics Technical Assistance if you experience either of these problems.

LIMITATIONS
- As with all diagnostic assays, the results obtained by this test yield data that must be used as an adjunct to other information available to the physician.
- The OSOM Mono Test is a qualitative test for the detection of IM heterophile antibody.
- A negative result may be obtained from patients at the onset of the disease due to heterophile antibody levels below the sensitivity of this test kit. If symptoms persist or intensify, the test should be repeated.
- Some segments of the population with acute IM are heterophile antibody negative.(1)

EXPECTED VALUES
A heterophile antibody response is observed in approximately 80–90% of adults and children with EBV-caused IM. This percentage drops to approximately 50% for children under four years of age.(1)

While the incidence of IM reflects wide seasonal, ethnic and geographical variation, a large epidemiological study noted that the highest incidence of symptomatic IM occurred during late adolescence (15–24 years of age)(2).

PERFORMANCE CHARACTERISTICS
A total of 439 specimens (183 serum, 176 plasma and 80 whole blood) were evaluated by two clinical labs in a clinical study. Test results of the OSOM Mono Test were compared to results obtained with a commercially available latex particle agglutination test for the qualitative determination of infectious mononucleosis heterophile antibodies. Discrepancies between the results given by the OSOM Mono Test and the latex particle agglutination test were resolved by Epstein-Barr Virus (EBV) specific serological assays. In these assays, the specific antibodies to the EBV capsid antigen (IgM) and EBV nuclear antigen-1 (IgM and IgG) were determined.

Serum Specimens:

		Comparative Test +	Comparative Test –
OSOM Mono Test	+	74	8*
	–	0	101

*6 out of 8 tested postitive by EBV testing

Whole Blood Specimens:

		Comparative Test +	Comparative Test –
OSOM Mono Test	+	30	3*
	–	0	47

*1 out of 3 tested postitive by EBV testing

Plasma Specimens:

		Comparative Test +	Comparative Test –
OSOM Mono Test	+	67	15*
	–	0	94

*8 out of 15 tested postitive by EBV testing

All Specimens:

		Comparative Test +	Comparative Test –
OSOM Mono Test	+	171	26*
	–	0	242

*15 out of 26 tested postitive by EBV testing

When compared to a commercially available latex particle agglutination test for infectious mono-nucleosis heterophile antibodies, the OSOM Mono Test showed a sensitivity of 100% and a specificity of 90.3%. The overall agreement was 94.1%.

Fifteen of the 26 discrepant samples were determined to be recent or acute EBV infections by EBV serological testing, in which case the sample was considered positive. Including the samples confirmed positive by EBV serological testing, the overall clinical study specificity of the OSOM Mono Test is 95.9% and the overall sensitivity is 100%.

POL Studies
An evaluation of the OSOM Mono Test was conducted at three physicians' offices or clinical laboratories where testing was performed by personnel with diverse educational backgrounds. Each site tested the randomly coded panel consisting of negative (5), low positive (3) and moderate positive (4) specimens for three days. The results obtained had 99.1% agreement (107/108) with the expected results.

Figure 4-4 Cont'd

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TIME TO REVIEW

1. *Analyte* means: Outcome 4-1
   - **a.** A similarity between two things
   - **b.** A substance being tested
   - **c.** A method used for testing samples
   - **d.** A type of proficiency testing

2. True or False: The mean of a set of results is the average of the results. Outcome 4-1

3. A quantitative testing procedure provides results as: Outcome 4-1
   - **a.** Numbers or measurements
   - **b.** Positive or negative
   - **c.** Descriptive analysis by a pathologist

4. Which concept focuses specifically on the analytical phase of laboratory testing? Outcome 4-2
   - **a.** Quality control
   - **b.** Quality assurance
   - **c.** Documentation
   - **d.** Personnel training

5. Which of these statements describes how the details of the postanalytical phase of laboratory testing affects quality assurance? Outcome 4-3
   - **a.** The postanalytical phase of laboratory testing is not considered to be part of quality assurance
   - **b.** When results are reported promptly to the physician as part of the postanalytical process, patient care is positively affected
   - **c.** Postanalytical processes such as appropriate patient education are critical for quality patient care
   - **d.** Postanalytical processes such as performing the test procedures using the manufacturer's inserts are critical for quality patient care

6. True or False: If a medical assistant performs only CLIA-waived testing, will it be necessary for her to perform quality control? Outcome 4-4

7. When is troubleshooting performed? Outcome 4-5
   - **a.** Daily
   - **b.** Quarterly
   - **c.** As needed
   - **d.** When directed by the package insert for the test kit

8. Please provide three examples of data that must be documented when logging quality control for a qualitative test. Outcome 4-6

9. What is the purpose of calibration verification? Outcome 4-8
   - **a.** Calibration verification is performed to see if the internal quality control is working correctly
   - **b.** Calibration verification is performed to see if calibration is necessary for an instrument
   - **c.** Calibration verification is performed when a new reagent lot number is put into use for the first time
   - **d.** Calibration verification is performed after a calibration has been completed on an instrument to verify that the calibration was successful and that the instrument is ready for patient testing

10. True or False: Competency testing addresses only test results. Outcome 4-7

11. Where do laboratories obtain samples for proficiency testing? Outcome 4-7
    - **a.** From the test kit manufacturer
    - **b.** From approved providers
    - **c.** From the CMS
    - **d.** From the CDC

Case Study 4-1: An unexpected delay

A 3-year-old child is brought into the office with a potential urinary tract infection. The mother of the child goes into the restroom and helps with the collection of a very small amount of urine to run a urinalysis test. The physician wants the test run as soon as possible so that the child can be started on antibiotics, as she is very uncomfortable and cries whenever she has to urinate.

The medical assistant turns on the urinalysis instrument, and takes out the quality control material from the refrigerator. While the instrument is performing an internal electronic check, she notices that the quality control material has a printed expiration date that has already passed, but only by a couple of weeks.

1. Would it be acceptable to use this quality control material? What are potential outcomes of this decision?
2. What is one step that could be taken before informing the physician of the situation?

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RESOURCES AND SUGGESTED READINGS

"CDC Report Assesses the State of Proficiency Testing"
A summary of a recent report released by the CDC addressing laboratory quality
http://www.aacc.org/publications/cln/2008/June/Pages/cover1_0608.aspx

"Clinical Laboratory Improvement Amendments Overview"
A written overview of CLIA policies and procedures, and numerous links for more specific information http://www.cms.hhs.gov/CLIA/

"CDC Report on Good Laboratory Practices for Waived Testing Sites"
Summary of site visits to CLIA-waived testing sites, as well as recommendations for quality practices. Also available as a printed document. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5413a1.htm

"Tests Waived by the FDA From January 2000 to Present"
List of all CLIA-waived tests. Updated regularly. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfClia/testswaived.cfm

"Laboratory Quality Control"
Good information about basic quality control standards
http://www.virology-online.com/presentations/index.htm

"Good Laboratory Practice With Waived Systems"
Great information from the WA State Department of Health about laboratories that perform only waived tests
http://www.doh.wa.gov/hsqa/fsl/LQA_Home.htm

"Recommended Elements of a Laboratory Quality Assurance Plan"
Recommendations based on Environmental Protection Agency (EPA) procedures for development of a QA plan
http://www.umass.edu/tei/mwwp/files

"Abbott Diagnostics Practical Application Quality Control Guide"
Summary of the practical application of quality control principles http://www.abbottdiagnostics.com/Your_Health/Thyroid/ Testing/quality.cfm

"Westgard Rules: What Are They?"
Summary of the Westgard Rules interpretation of Levey-Jennings QC charts; the Westgard system for defining quality control limits http://www.westgard.com/mltirule.htm

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Chapter 5

Legal and Ethical Issues

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Legal and Ethical Issues in the Laboratory Environment
Law and Ethics
Legal Concepts Affecting Patient Interactions
- Consent
- Release of Information and Patient Rights and Responsibilities
- Tort Law
- Liability
- Scope of Practice

Health Information Portability and Accountability Act
- The Impact of the Health Insurance Portability and Accountability Act on the Medical Assistant

Ethics
- Professional Behaviors

Risk Management and the Medical Assistant
Summary
Time to Review
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

5-1 Define the chapter key terms.

5-2 Explain the difference between law and ethics.

5-3 Distinguish between informed and implied consent, and describe when consent may be refused.

5-4 Express the principles presented in the Consumer Bill of Rights and Responsibilities.

5-5 Explain who has a right to a patient's medical information, and in what circumstances that right may be waived.

5-6 Compare and contrast intentional and unintentional torts.

5-7 Describe the liability assumed by a medical assistant in the laboratory, and why personal malpractice insurance is recommended.

5-8 Explain what is meant by scope of practice, and how these limitations are established for medical assistants.

5-9 Explain the acronym HIPAA, and explain how it affects the daily activities of a medical assistant in the laboratory environment.

5-10 Define *ethics* and explain the difference between personal and professional ethics.

5-11 Describe several ways that a medical assistant working in the laboratory may be part of risk management for his or her workplace.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

IX.C.1: Discuss legal scope of practice for medical assistants
IX.C.5: Discuss licensure and certification as it applies to healthcare providers

ABHES Standards

#4: Medical Law and Ethics, b: Federal and State Guidelines, f: Health Laws and Regulations
Graduates: f: Comply with federal, state and local health laws and regulations

KEY TERMS

Assault
Battery
Department of Health and Human Services (HHS)
Disclosure
Duress
Emancipated
Ethics
Expressed consent
Fraud
Health Insurance Portability and Accountability Act (HIPAA)
Implied consent
Informed consent
Intentional tort
Laws
Liability
Libel
Malfeasance
Malpractice
Misfeasance
Negligence
Nonfeasance
Patient identifier
Privacy Rule
Protected health information (PHI)
Reportable condition
Risk management
Scope of practice
Slander
Standard of care
Statutes
Tort
Unintentional tort

LEGAL AND ETHICAL ISSUES IN THE LABORATORY ENVIRONMENT

Most of us understand that it is important to obey the law and that there may be consequences if we make the wrong choices. However, in our daily lives, we realize that there are factors other than laws that affect our actions. These factors may include our personal values and ethics. In addition, as health-care employees, medical assistants must adhere to a set of professional laws and ethics to perform our duties as we should. In this chapter, you will learn the difference between law and ethics, and examine how these concepts define the professional actions of those employed in a health-care environment.

LAWS AND ETHICS

Laws are essentially rules of conduct that have been created by government at the local, state or national level. An established rule or law may also be known as a **statute.** Laws are enforced by appointed authorities. For instance, the Occupational Safety and Health Administration has created rules to uphold the federal laws developed to safeguard employees. Generally, laws protect the public by prohibiting activities that may be harmful, and establishing some form of consequences that would discourage those that continue to pursue these activities. Health-care laws are designed to protect the rights of the patients, the employees, or the employers.

Ethics are like laws because they dictate or determine appropriate behavior for individuals. They are different from laws because they are not created by governmental agencies. Personal ethics are behavioral guidelines that an individual develops throughout a lifetime, guided by personal values and morals, and influenced by upbringing. Professional ethics are developed by a well-recognized professional organization, with the anticipation that those working in that profession will use them as a guide for appropriate conduct.

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Test Your Knowledge 5-1

Name one difference between laws and ethics. (Outcome 5-2)

LEGAL CONCEPTS AFFECTING PATIENT INTERACTIONS

There are numerous laws and statutes that play a role in a health-care setting. In addition to federal laws, each state has a medical practice act that dictates the delivery of health-care services in that state. Medical assistants act as agents of the physician office or laboratory where they are employed, which means they have a responsibility to abide by the laws that dictate their actions as they perform health-care procedures and deal with patient information. In order to follow the established rules, it is vital to learn some general legal concepts.

Consent

The law requires that there is consent, or permission, given before any treatment occurs. The consent may be given verbally, in writing, or nonverbally by behavior. **Implied consent** means that the patient's actions send a message of agreement to the treatment offered. For instance, when a patient offers his or her arm for a blood draw, the consent for the procedure is implied by this action. Implied consent also dictates care that occurs in an emergency situation. If the patient is not able to refuse consent, or if there is no legal document stating that emergency care should not be offered, emergency medical assistance may be rendered. It is assumed (implied) that the patient would want to be saved.

Informed consent is necessary whenever the treatment involved includes an invasive surgical procedure, experimental drugs, or any treatment that could be a significant risk to the health of the patient. This may also be known as **expressed consent.** Informed consent requires that the patient is advised of the following details:

- The name of the procedure to be performed and the health-care provider that will perform the procedure
- Risks of the procedure
- Risks involved if the procedure is *not* performed
- Alternatives to the treatment offered

It is essential that the patient understand the components printed on the consent form, as it is a legal document. The patient must sign and date the consent form, and this must be witnessed. As in all situations concerning consent, the responsibility for explaining the procedure and the risks belongs to the health-care provider (such as a physician or nurse-practitioner) but the medical assistant may be asked to verify that the form is filled out correctly, as well as witness the signature of the patient.

Minors generally are not allowed to sign an informed consent. There are exceptions to this rule, which may vary from state to state. The exceptions generally involve requests for birth control or treatment of sexually transmitted infections. There are also exceptions for **emancipated** minors, and those in the armed forces who are still under the legal age of consent. Emancipated minors have been declared by the court to be independent and capable of making their own medical decisions. All other minors must have a parent or legal guardian sign the consent form for them.

A patient has the right to refuse consent at any time. Patients may decline treatment for any reason, based on personal beliefs, cultural differences, or financial considerations. If consent is refused, the patient should fill out and sign a form declining the procedure. This documentation can be very important if there is a negative outcome based on the patient's decision to refuse treatment.

Test Your Knowledge 5-2

When a patient offers an arm for a blood draw, what kind of consent is he or she offering?

a. Informed consent
b. Implied consent
c. Deferred consent
d. None of the above (Outcome 5-3)

Release of Information and Patient Rights and Responsibilities

Every patient who seeks medical care has certain rights and responsibilities. Medical personnel should always be conscious of these principles when dealing with patients, so that they can stay within appropriate boundaries in their interactions. Patient responsibilities include providing the physician with accurate information about his or her medical history and current condition, following the physician's instructions for treatment and follow-up care, and providing appropriate compensation to the health-care provider for services provided.

Patient rights have been addressed numerous times through the years. In 1998, the President's Advisory

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Commission on Consumer Protection and Quality in the Health Care Industry issued a Consumer Bill of Rights and Responsibilities. This document addresses seven distinct areas of patient care:

1. *Information disclosure:* Patients have the right to know the details of their health-care plan, their health-care professionals, and the facilities they may use for care. This means that an interpreter must be provided if needed for understanding.
2. *Choice of providers and plans:* Patients have the right to evaluate different providers and/or health coverage plans to make the best choices for their needs.
3. *Access to emergency services:* If an emergency need arises, a patient has the right to receive services wherever needed without prior authorization. (However, this does not mean that the patient will not have to pay for these services if they are not covered specifically by their health-care plan.)
4. *Participation in treatment decisions:* All patients need to know about their treatment options and have the right to participate in decisions about their medical care. This also means that they have the right to refuse care if they choose.
5. *Respect and nondiscrimination:* All patients have the right to receive respectful treatment from their health-care providers that is considerate of their feelings and without discrimination.
6. *Confidentiality:* Patients have the right to expect their health-care information to remain confidential.
7. *Complaints and appeals:* All patients have the right to an objective review of any complaints they have about their health-care provider or health-care plan. This can include any part of their experience, including billing, accessibility of the building for those with special needs, operating hours, and so on. Of course, the right to review and appeal also pertains to the quality of care experienced.

Even though patients have the right to expect their health-care information to remain confidential, there are limitations. The physical medical record (where the information is documented; also known as "the chart") belongs to the health-care provider, but the information in the record belongs to the patient. Patients have the right to request their medical information, and they also have the right to control who has access to their medical records in most situations. The information contained in the medical record may be requested by numerous parties, such as insurance companies, family members, and legal representatives. Later in this chapter we will learn more about the law which details how personal information may be protected.

There are some situations where the **disclosure** (sharing) of the patient's information is required, even without consent. For instance, if a patient is diagnosed with a **reportable condition,** state and federal laws require that the laboratory or the health-care provider contact the local health department or the Centers for Disease Control and Prevention (CDC). Reportable conditions are diseases or conditions that have been deemed to be dangerous to the general public health. The statistics accumulated by the state or federal agencies allow the prevalence of the disease in the population to be tracked. Examples of reportable conditions include HIV infection, Lyme disease, cholera, hepatitis, measles, and gonorrhea infection. If a laboratory test is positive for these conditions, the result must be passed on to the appropriate authorities as soon as possible. The patient does not have the right to stop this report process, although in some situations he or she may have the right to request anonymity to protect his or her identity.

Test Your Knowledge 5-3

Lily Lee is moving to another city to attend college. She would like to get a copy of her medical records to take with her as she establishes a new physician relationship in her new home. Does she have the right to a copy of her medical record? Is it appropriate for her to take the entire original record from the office?

(Outcome 5-4 and Outcome 5-5)

Test Your Knowledge 5-4

If someone is assaulted, was he or she touched or physically injured? (Outcome 5-1)

Tort Law

Torts are wrongful acts that are committed against a person or property that result in harm. The harm caused by the tort may be physical or emotional. This type of act does not include those that involve violation of a contract. Torts may be classified as intentional or unintentional. In the case of an **intentional tort,** it must be apparent that the action was deliberate and intended to cause harm. Intentional torts include the following:

- **Assault:** An assault involves threatening an individual, or making a person fear harm.

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- **Battery:** Battery is the act of touching another without that person's permission. A person may be committing battery even if the touch does not cause harm.
- **Duress:** If a patient is forced or coerced into an act (such as signing a consent form or undergoing a procedure against his or her will), that person may claim duress.
- **Libel:** If a health-care professional makes a false written statement about a patient (or someone else), he or she may be accused of libel. This is especially a problem when the false statement causes a problem with the victim's reputation or employment.
- **Slander:** Slander is false statement made about someone else orally.
- **Fraud:** Fraud is a dishonest or deceitful act that is performed with the intent to hide the truth.

Unintentional torts are situations in which the harm was the result of an accident. The accuser must believe that the employee was performing his or her job in good faith when the patient was harmed, and the incident was not deliberate. **Negligence** is often involved in unintentional torts, as it means that a professional did not take reasonable care to prevent harm. The term **malpractice** is used if a health-care professional is shown to be negligent in his or her duties. Malpractice accusations are the most common reason for claims against health-care professionals, and the legal decisions are based on the **standard of care** (minimum safe professional conduct) for a reasonable professional with the same training who might be facing a similar situation. Malpractice may be classified in one of three ways:

1. **Malfeasance:** In this situation, the treatment provided was wrong and unlawful.
2. **Misfeasance:** If treatment was provided, but it was performed in an improper manner, it is known as misfeasance.
3. **Nonfeasance:** When the health-care professional fails to perform a necessary act or delays treatment excessively, the act is known as nonfeasance.

Test Your Knowledge 5-5

What is the difference between an intentional and unintentional tort? (Outcome 5-6)

Liability

Health-care professionals assume a certain amount of **liability** in everything that they do, meaning that they are legally obligated to perform their duties to the best of their ability. Liability exists in all areas of our lives: driving a car or while walking the dog, for example. We are responsible for our actions, and obligated to drive the car to the best of our ability, as well as keep our dog on a leash and under control while on the walk. For health-care professionals, their liability insurance is actually malpractice insurance, as they may be held responsible for an intentional or unintentional tort if they make a mistake or they don't perform their jobs to the best of their ability. Anyone who works in a medical office is liable for all interactions with the public, whether performing an invasive procedure, taking a blood pressure reading, or participating in a phone call with a patient. A malpractice suit may be filed against any or all of the employees in an office or laboratory.

In most health-care facilities, the malpractice insurance coverage for the physician or health-care provider generally includes coverage for the medical assistant working for them. Many medical assistants don't pursue their own malpractice insurance coverage. This may be a mistake. If a patient sues the practice (specifically naming each individual involved), for malfeasance, for example, the best outcome for the physician may be to settle out of court. This means that the incident will still be on the record for the medical assistant, who was not part of the decision to settle in this way. For medical assistants (or other allied health-care professionals) who work in the laboratory setting, it is especially important to have appropriate personal coverage. Even though the physician may have malpractice insurance that appears to be adequate, it is possible that when drawing blood or performing laboratory tests outside of the direct supervision of the physician, the medical assistant may be found to be solely responsible for malpractice. In addition, if a physician is sued for malpractice because of a venipuncture or other procedure performed by his or her medical assistant, the physician can even file suit against the medical assistant for financial damages incurred as a result of the incident.

Test Your Knowledge 5-6

Is a medical assistant working in a laboratory liable for his or her actions while working with patients? Is it possible for him or her to be sued for malpractice? (Outcome 5-7)

Scope of Practice

Scope of practice is a term used to describe the activities that an employee in a specific profession can and cannot perform. These limitations are different for each of the

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health-care professionals present in a physician office or laboratory environment. The scope of practice is dictated by licensure and training, and may vary according to the state in which a professional offers his or her services.

Medical assistants are not licensed, meaning that they are required to work under the license of another qualified health-care professional, such as a physician, nurse-practitioner, or physician's assistant. These health-care professionals have a responsibility to train the medical assistant and to establish his or her duties and limitations within the practice. Many states have statutes in place that limit the duties that a medical assistant may perform. Although certification is not mandatory, medical assistants may take a comprehensive examination to become nationally certified by the American Association of Medical Assistants or registered through the American Medical Technologists. In addition, some states require very specific certification or registration for allied health professionals who perform invasive procedures.

Educational programs for medical assistants vary. Some may be just a few months in length, whereas other programs offer a 2-year associate degree. In addition, each state may have different laws that dictate the tasks that may be legally performed by medical assistants. This means that the scope of practice for a medical assistant is based on his or her education and training, as well as the limitations that may be in effect by the state in which he or she practices.

In general, the scope of practice for medical assistants includes the following limitations:

- Medical assistants are not able to make independent medical assessments or diagnose, or give advice independently.
- It is the physician's responsibility to be aware of the medical assistant's scope of practice, whether based on state laws or the medical assistant's training.
- Medical assistants are not able independently to write prescriptions or give out medication samples without specific documented orders from a qualified health-care professional.
- Medical assistants cannot independently interpret test results or treat patients.

In most states, the following are tasks that medical assistants are allowed to perform:

- Assisting with various clinical and patient care procedures
- Carrying out administrative procedures such as answering phones, working with charts, and performing billing and coding
- Obtaining medical histories
- Explaining treatment procedures to patients (within the guidelines established by the facility)
- Preparing and assisting with various routine and specialty examinations
- Collecting specimens, including venipuncture and capillary puncture
- Performing electrocardiograms (ECGs)
- Administering medication
- Assisting with prescription refills
- Performing Clinical Laboratory Improvement Act–waived laboratory tests or those of moderate complexity
- Assisting with various disease management programs, such as tracking laboratory results for a patient on medication
- Administering injections

Test Your Knowledge 5-7

Is the scope of practice the same for medical assistants anywhere in the United States? (Outcome 5-8)

HEALTH INSURANCE PORTABILITY AND ACCOUNTABILITY ACT

Earlier in this chapter, we discussed the Consumer Bill of Rights and Responsibilities. One component addressed the confidentiality of a patient's health record. This is a very complex issue, and it has been addressed in various ways, as the protection of personal health information is one of the most important duties of a health-care professional. It is impossible to establish a good working relationship with a patient if there is no trust in the professional's ability to keep private information secure. Patients share information with those in health care that they do not divulge to anyone else, and the expectation is that this information will only be shared if it is absolutely necessary for patient treatment.

In the early 1990s, it became evident that there were areas of health care that needed reform. Congress passed the **Health Insurance Portability and Accountability Act (HIPAA)** to provide guidelines for this reform. This act was originally designed to improve the efficiency and effectiveness of the health-care system by focusing on the following areas:

- Improvement of the health benefit options for covered workers who leave or change jobs
- Standardization of electronic health data

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- Creation of unique health identifiers for the various entities involved in health-care services
- Development of security standards for handling **protected health information (PHI),** which includes anything in the patient's health record that could be used to identify the patient

One of the standardization methods for handling health data was to increase the use of computers for transmission of health information. This created more concerns about the unauthorized access to personal information that may occur with electronic transmission. To address these confidentiality issues, the **Department of Health and Human Services** (**HHS**) developed the **Privacy Rule,** which is an expansion of the original HIPAA mandate that applies to confidentiality of health information, and the rights of patients to control access to their own records. This rule went into effect April 2003, and it carries significant monetary consequences for noncompliance. This is the first federally mandated set of rules for the protection of health information.

Test Your Knowledge 5-8

Does HIPAA impact only confidentiality of medical information? (Outcome 5-9)

The Privacy Rule outlines very specific precautions that are to be practiced in every health-care facility. There are several standard provisions that all medical assistants should keep in mind, regardless of their specialty of practice:

1. Any document that includes a **patient identifier** must be treated as protected health information. These identifiers include demographic information such as name, address, and phone number, but also include photos, Social Security numbers, birth dates, and other types of unique information that may be linked back to that specific patient. Documents must have all patient identifiers removed before they can be discarded, or they must be destroyed in such a way that this information is not available after disposal.
2. Patients have a right to know how their PHI has been shared, even if it was necessary for treatment.
3. Patients have a right to review and/or to request copies of their medical records. This law does not state that they have the right to walk out of an office with their physical chart, nor does the office have to allow review or copies to be available at any time. A patient can submit a request for the records, with the understanding that it may take some time to process the request and copy the records.
4. Health information cannot be shared with others without the patient's consent. This does not apply to reporting that may be required by law.
5. When any patient information is shared, it is important that it is limited to data that are essential for that situation. This is especially important when dealing with labor and industry claims for injured employees or insurance claims, as the health-care professional should include only records about a specific treatment if it is in question, but not the entire chart.
6. The Privacy Rule also requires every office to have a privacy notice and to train all employees about HIPAA and the Privacy Rule. All patients must receive a copy of the office's privacy notice, and patients must give written consent or permission to disclose their health-care information. A privacy or HIPAA compliance officer must be assigned for every institution to oversee the process within that office.

The HIPAA regulations still allow health-care providers to share information with family members who are directly responsible for the care of a patient, or to other providers or members of the health-care team (such as radiology services, laboratory professionals, etc.) when it is necessary for patient care. Also, the regulations recognize that sometimes it is impossible for oral privacy to be assured in all areas of a practice; there has to be evidence that this has been addressed to the full extent of the facility.

The Impact of the Health Insurance Portability and Accountability Act on the Medical Assistant

The privacy section of the HIPAA regulations may affect phone conversations with or about patients, discussion of patient issues within earshot of the waiting area in a clinic, or the visibility of patient information to visitors in an office. Laboratory requisitions that contain PHI cannot be left where patients may have access to them, computer screens should not be visible to patients as they walk to and from the treatment area, and patient schedules that contain names should not be posted where they are visible by those who are being treated. Fax numbers used to transmit laboratory results must be carefully monitored, as these results need to end up in a secure location once received. Complications arise when protected health information is shared via e-mail, although this method of transmitting information may be more efficient for patient care within a large organization or

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between providers. The need for electronic security measures is great. Also, many clinics have changed the way they call patients from the waiting room for treatment; they now call the patients by the first or the last name, but not both. It is the responsibility of the designated HIPAA compliance officer to decide the specific methods used by an office for compliance with the regulations, and to ensure that appropriate training is provided for all employees.

It is also illegal to gossip about patients, even if it is in a private area where other patients cannot hear. Discussions about patient care are to be limited to those that are necessary for providing quality health care. As health-care professionals, medical assistants are not allowed to share any protected health information with family or friends. Sometimes this is difficult, as health-care professionals may have knowledge about a family friend or relative that others would want to know. It is illegal to share this information, so care must be taken to keep it private.

Another example of illegal action is idle searching of the database within a health-care facility to see who might have had services provided. There were recent reports in the news of employees who lost their jobs and of facilities that were fined significantly when an employee searched for the records of a celebrity rumored to be in a certain facility. Even if this information is not shared with anyone else, it is a HIPAA violation to perform the search. It can (and will) be tracked back to the responsible individual.

ETHICS

Most of the information in this chapter is based on laws and legal terms that dictate the actions of health-care professionals. But there are also ethical decisions that must be made every day in order to interact appropriately with patients, coworkers, and other members of the health-care team. Ethics are standards that define our actions, but they are not created or enforced by governmental agencies. As was explained at the beginning of this chapter, there are two types of ethics that define our actions while at work. We must adhere to a set of personal ethics that are defined by our own sense of what is right and wrong. Professional ethics also define our actions. These are based on the standards of our professions, and although they are not laws, there are consequences to unethical behaviors.

Personal ethics begin to develop in childhood. We generally understand what our parents and community define as acceptable behavior by the time we enter grade school. These are based on our morals and values, and become refined as we approach adulthood. Personal values such as the desire to help others will make a health-care professional much better at performing his or her job. Empathy, honesty, responsibility, and respect for others are also part of our personal ethics; this is often known as our *work ethic*. Remember, if there is something that you are doing at work that you are not proud of, it is probably unethical at the personal level for you.

Professional Behaviors

Professional ethics are standards established by the profession, and usually sponsored by a professional organization that represents the profession. Physicians have several codes of ethics that define their actions, such as the Hippocratic Oath and the Code of Medical Ethics defined by the American Medical Association. One ethical theme present in both codes is the show of respect for patients and to show compassion for those served, while staying within legal limits of practice. By utilizing these standards, physicians may remind themselves why they chose this profession, and also remember what their patients may expect from them.

The American Association of Medical Assistants also has a code of ethics (Box 5-1). These guidelines also include respect for patients and the laws that guide the medical assisting profession, as well as service to the community and lifelong learning. At a minimum, professional ethics for medical assistants must put patients first by honoring their right to confidentiality and by being honest in all professional situations. If this code is supported by a strong set of personal ethics, a medical assistant will be a valuable asset to the profession.

Remember that there are ethical dilemmas that develop. Many times there may be a situation that arises that is not illegal, but it is unethical. This may include situations in which the medical assistant does not agree with the actions of the employer, even though these actions are not illegal. Usually these issues involve disrespect for patients or a poor quality of care due to the attitude of the physician. The medical assistant will need to make choices about whether she can continue employment with this practice.

Test Your Knowledge 5-9

List two professional standards included in the AAMA Code of Ethics. (Outcome 5-10)

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BOX 5-1 American Association of Medical Assistants code of ethics

American Association of Medical Assistants (AAMA) Code of Ethics

Members of AAMA dedicated to the conscientious pursuit of their profession, and thus desiring to merit the high regard of the entire medical profession and the respect of the general public which they serve, do pledge themselves to strive always to:

A. Render service with full respect for the dignity of humanity;

B. Respect confidential information obtained through employment unless legally authorized or required by responsible performance of duty to divulge such information;

C. Uphold the honor and high principles of the profession and accept its disciplines;

D. Seek to continually improve the knowledge and skills of medical assistants for the benefit of patients and professional colleagues;

E. Participate in additional service activities aimed toward improving the health and well-being of the community.

POINT OF INTEREST 5-1
Medical assisting scope of practice

There is a lot of confusion among medical assistants as well as physicians, nurse-practitioners, physician assistants, and other health-care providers about the scope of practice for the medical assistant. The confusion is well earned; the scope of practice for each state differs widely. For those medical assistants who move from one state to another, it can become even more difficult to know what they are allowed to do in any given state.

Governing Agencies

Just finding the regulations for each state can be difficult. A good resource may be the program director for the local CAAHEP or ABHES accredited medical assisting programs. These program directors should have up-to-date information about the scope of practice for the medical assistants in their area, and should be able to provide information about which governing body oversees medical assistants in their state. In many states the department of health oversees the unlicensed members of the health-care teams. In other areas, medical assistants may be part of the state nursing board.

Registration or certification

Medical assistants are nonlicensed members of the health-care team. There is no license available in any state for medical assistants. However, most states do require some sort of registration process for the medical assistants in their jurisdiction. This may include a testing process by which they are registered and certified to perform in that state, or the state may require only that the medical assistant fill out certain paperwork and submit a fee to become registered. Some states require the medical assistant to bear the burden of registration fees, whereas other states require that the medical assistant be registered each time she or he changes employers and the employer is responsible for the fee.

Many medical assistants are under the impression that if they become Certified Medical Assistants through the AAMA or Registered Medical Assistants through the American Medical Technologists that this will cover them regardless of their state of residence and that these credentials somehow expand their scope of practice. This is not true. Many states will grant registration (or certification) if the medical assistant is nationally certified, or they may require those who are not nationally certified complete a state certification process. However, this varies from state to state, so it is very important to find out what the regulations are in your state of residence. Usually the office manager or physician you are working for knows the rules, but occasionally they have decided not to work with the state to register their medical assistants. This is not a safe environment to work in, as the medical assistant may be operating outside of his or her scope of practice and unlawfully performing tasks, which place him or her at risk for legal actions.

Allowable tasks

Every state has limitations for the tasks that can be performed by the medical assistants. The following are some of the tasks that may be limited:

- **Invasive procedures:** Some states allow medical assistants to draw blood, but this task is still limited in a few areas. Many states (e.g., New York) do not allow medical assistants to administer medication through any route, including by injection. It is important to clarify this before performing injections or venipuncture.

Continued

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- **IV access:** Most states limit the IV access of nonlicensed health-care personnel. In some areas, the medical assistant is allowed to stop the IV or remove the catheter when it is no longer needed, but most areas prohibit much more than this.
- **Placement of urinary catheters:** This is an area where many medical assistants are currently operating outside of their scope of practice. Most states prohibit the placement of a urinary catheter by a nonlicensed health-care professional.
- **Administering oral medications:** Although medical assistants are allowed to give injections in most states, the administration of oral medication may still be limited. Washington State, for example, has a list of oral medications that can be administered by health-care assistants, which include medical assistants.
- **Working in a hospital setting:** Some states prohibit medical assistants from working in a hospital or inpatient setting if they are performing clinical procedures. This decision is based on the presence (or absence) of health-care providers in the vicinity while invasive procedures are performed.
- **Suture removal:** Most states allow medical assistants to remove sutures, but there are limitations in a few areas.
- **Botox administration or assisting with other cosmetic procedures:** Medical assistants generally cannot operate laser equipment or administer Botox or other injections that are not considered to be medications.

RISK MANAGEMENT AND THE MEDICAL ASSISTANT

After reading through this chapter, it may appear that the legal aspects of the medical profession are overwhelming. There is a lot of information to remember, but as a medical assistant, there are many things that you can do to avoid risk of harm to yourself, your patients, and your practice. This concept is called **risk management.** These risks may be legal in nature, as in a case in which a malpractice suit is filed for poor quality of care; financial in nature, as in a case in which a laboratory or physician office chooses not to accept patients with specific insurance coverage because of the potential for low levels of reimbursement; or physical in nature, as in a case in which a medical assistant might not use the appropriate technique to perform a capillary blood draw, or when an office staff doesn't notice the puddle inside the front entrance to the clinic and a patient slips and falls.

Because a medical assistant may be the member of the health-care team in an office or a laboratory who spends the most time with a patient, it is important that he or she keep the following risk management techniques in mind to avoid potential harm or legal action:

- Act within the defined scope of practice
- Use all available training to be certain that techniques are performed with the highest level of skill possible
- Use current, up-to-date equipment as available
- Perform regular performance checks on any testing equipment used for patient samples
- Follow the manufacturer's instructions exactly for all laboratory testing performed
- Consult resources (other employees or reference materials) if you have questions
- Verify the identity of every patient before you begin interactions
- Chart when patients call to inquire for test results, and when they are notified of the results
- Be certain that all laboratory results are handled in a timely manner
- Practice confidentiality at all times
- Always practice universal precautions and keep your environment medically aseptic
- Treat all patients with respect and overcome personal biases to treat them all equally
- Act as a chaperone when needed for procedures
- Obtain informed consent when necessary
- Be vigilant for potential safety hazards in the clinic environment
- Document promptly and thoroughly
- Log all phone call correspondence
- Remember not to criticize other members of the health-care team or other health-care providers
- Do not give advice that has not been approved by the office policy
- Do not be afraid to ask for help if you are feeling overwhelmed by the number of patients you are assisting or by the tasks at hand.

Test Your Knowledge 5-10

After drawing the blood from a patient, medical assistant Krissy Clark takes the time to document the blood draw site, the date, and the time of the draw on the laboratory requisition. Is this an example of risk management? (Outcome 5-11)

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SUMMARY

The majority of the time, the relationship between a patient and the health-care team is an amicable one in which both parties are satisfied with the care provided. However, there are unfortunate situations that may arise as a patient is treated that damage this relationship. Sometimes these result in charges of malpractice, and sometimes they may require legal actions because a member of the health-care team ignored the legal guidelines that define their scope of practice. In order to protect ourselves from these situations, it is important to stay insured as a means of protecting our financial security. It is also important to be aware of the legal boundaries for each profession. Ethics play a role as well, as not all inappropriate actions in a medical office or laboratory are illegal. Risk management is a way to provide care defensively; avoid problems before they start!

TIME TO REVIEW

1. What is a statute? Outcome 5-1
   - **a.** A personal set of rules dependent on an individual's sense of right and wrong
   - **b.** A law established by the legislative branch of a government entity
   - **c.** Behavioral standards established by a professional organization
2. If a newspaper article prints information about a local physician that is untrue, what legal term might be used to describe this action? Outcome 5-1
3. What is the meaning of the acronym HIPAA? Outcome 5-1
4. Who establishes laws that affect health-care organizations? Outcome 5-2
   - **a.** Professional organizations
   - **b.** Governmental agencies
   - **c.** Local groups of practitioners
   - **d.** Local health departments
5. The_____ _____ is responsible for explaining the details of a procedure to the patient before the informed consent paperwork is signed. Outcome 5-3
6. Which of these principles are not addressed in the Consumer Bill of Rights? Outcome 5-4
   - **a.** The right to insurance coverage
   - **b.** The right to emergency services when needed
   - **c.** The right to be treated without discrimination
   - **d.** The right to an interpreter if needed
7. What is a reportable condition? Outcome 5-5
8. True or False: It is not necessary for a medical assistant to carry her own malpractice insurance. Outcome 5-7
9. Referring to the medical assisting scope of practice explained in this chapter, which of these duties would be outside the guidelines? Outcome 5-8
   - **a.** Offering medical advice based on personal experiences
   - **b.** Documentation of procedures performed
   - **c.** Assisting with a Pap smear specimen collection
   - **d.** Scheduling appointments
10. True or False: It is a HIPAA violation to fax medical information to a health-care specialist who is functioning as a consultant for a patient's complicated medical condition. Outcome 5-9
11. Personal ethics are defined by: Outcome 5-10
    - **a.** Professional standards of the profession
    - **b.** Local statutes
    - **c.** Experiences and guidance beginning in childhood
    - **d.** HIPAA
12. True or False: Risk management should be a part of the routine for everyone working in the health-care environment. Outcome 5-11

Case Study 5-1: Too much talk

Amy Conner is the receptionist who greets patients at the front desk for a family practice physician. A 17-year-old young man comes in to have his blood drawn a few days after seeing the physician. He enters the reception area by himself, and gives Amy his requisition. She notices that in addition to several routine chemistry tests, the physician has ordered an HIV screen to be performed. Amy puts the laboratory orders into the computer system, and hands the labels to the medical assistant to perform the blood draw.

After the young man leaves the facility, Amy steps into the hallway behind the reception area and starts

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a conversation with the medical assistant. She tells the medical assistant how sad it is that an HIV test has to be done on someone so young, and expands her conversation to include all the potential ways that he could have contracted HIV. After a few minutes she hears someone at the front desk and steps back to her work area.

The 17-year-old patient is now at the front desk again, with his mother standing next to him. He appears to be uncomfortable, and the mother starts to ask questions about the conversation that Amy was having in the hallway.

a. Are Amy's actions in violation of the law?
b. Should Amy assume that the mother knows all about the blood tests that were ordered for her son?
c. How should this situation have been handled?

RESOURCES AND SUGGESTED READINGS

"Office for Civil Rights—HIPAA"
Detailed reference for the HHS Privacy Rule http://www.hhs.gov/ocr/Health InformationPrivacy

"What Is Ethics?"
Article published by Santa Clara University about the meaning of ethics, and how personal and professional ethics differ http://www.scu.edu/ethics/practicing/decision/whatisethics.html

"Quidel Rapid Diagnostic Products"
Links to the Quidel point-of-care test kits, including CLIA-waived tests. http://www.quidel.com/products/product_list.php?cat=1&by=brand&group=1

"Reportable Diseases"
Information about reportable diseases that must be reported to the local authorities or the Centers for Disease Control and Prevention http://www.nlm.nih.gov/medlineplus/ency/article/001929.htm

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Chapter 6

Laboratory Equipment

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Laboratory Equipment
- Microscopes
  - *Compound Microscopes*
  - *Other Types of Microscopes*
  - *How Do Medical Assistants Use Microscopes?*
- Centrifuges
  - *Centrifuge Maintenance*
  - *Centrifuge Safety*
- Laboratory Refrigeration
- Incubators

Equipment Used for Automated CLIA–Waived Testing
- Testing Methodology
- Instruments Used for Chemical Testing of Urine Specimens
- Instruments Used for Coagulation Testing
- Instruments Used for Chemistry Testing
- Instruments Used for Hemoglobin Measurements
- Other Hematology Instruments
- Glassware and Other Miscellaneous Laboratory Equipment

Summary

Time to Review

Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

6-1 Define the key terms.

6-2 Describe the different types of microscopes introduced in this chapter.

6-3 Identify the different parts of a compound microscope.

6-4 Describe maintenance procedures for a compound microscope.

6-5 Explain how to correctly focus a microscope to examine a specimen on a slide.

6-6 Explain the role of a medical assistant in a physician office laboratory that performs microscopic examinations of specimens.

6-7 Explain how to operate and maintain a centrifuge.

6-8 Describe how temperature must be monitored for a laboratory refrigerator.

6-9 Explain why an incubator is sometimes used in a laboratory environment.

6-10 List several advantages of providing CLIA-waived testing in a physician office laboratory.

6-11 Demonstrate understanding of the basic principles used for measurement in laboratory instruments.

6-12 Explain why automated urine analyzers are used.

6-13 Describe similarities between the different types of coagulation testing instruments available for CLIA-waived testing.

6-14 List several types of instruments used for CLIA–waived chemistry testing.

6-15 Describe the operation of an instrument used to measure hemoglobin in a whole blood specimen.

6-16 List the types of hematology instruments presented in this chapter.

6-17 Describe some of the types of glassware found in the laboratory, and how to correctly measure the liquid level in glassware.

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CAAHEP/ABHES STANDARDS

None

KEY TERMS

Agglutination
Anemia
Aperture
Arm
Balanced
Base
Beaker
Binocular
Centrifugal force
Centrifuge
Cholesterol
Coarse adjustment knob
Compound microscope
Condenser
Cover slips
Cylinder
Diluent
Dissecting microscope
Electrical impedance
Electrolyte
Electron microscope
Eyepiece
Fecal occult blood
Fine adjustment knob
Flask
Glass slides
Glucose
Glycosylated hemoglobin monitoring
Graduated cylinder
Hemoglobin
Incubator
International normalized ratio (INR)
Iris diaphragm
Laboratory thermometer
Light source
Lysed
Meniscus
Monocular
Objective lenses
Ocular lens
Oil immersion lens
Pipette
Plasma
Prothrombin time test
Protime
Reagent strips
Revolving nosepiece
Rotations per minute (rpm)
Serum
Spectrophotometer
Stage
Stereo microscope
Tachometer
Water baths

LABORATORY EQUIPMENT

Laboratories use many types of instruments to process, store, and analyze specimens. As the complexity and variety of tests offered by a laboratory expand, so do the number of instruments in use. Because medical assistants are generally working in laboratory environments performing Clinical Laboratory Improvement Act (CLIA)–waived tests, they don't usually use a wide variety of instruments. This chapter focuses on equipment commonly used for specimen processing and storage, as well as performance of CLIA-waived testing procedures. Selected instruments used for laboratory tests of moderate complexity are also presented.

Microscopes

There are several types of microscopes available. These vary by the amount of magnification, the manner by which the image is viewed, and the light (energy) source used. A typical laboratory setting will use a **compound microscope,** and some laboratories may also use a **dissecting microscope,** especially if the laboratory performs blood bank procedures. Specialty laboratories

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may also have personnel trained to operate an electron microscope to create three-dimensional images of the specimens. All microscopes provide magnification so that microscopic structures or organisms that are too small to be seen with the naked eye can be identified or quantified in a specimen. Sometimes it is necessary to apply stain to a specimen before viewing, and sometimes the specimen is viewed in its natural state.

Test Your Knowledge 6-1

What is the most common type of microscope used in the clinical laboratory?

a. Dissecting microscope
b. Electron microscope
c. Fluorescent microscope
d. Compound microscope (Outcome 6-2)

Compound Microscopes

The compound microscope is the most common type used in a general laboratory setting. The magnification for this type of microscope is compounded, or increased by two different sets of lenses. The energy source is a replaceable bulb that sits in the base of the microscope and shines very brightly. Adjustments may be made for the amount of light used for viewing, as well as the strength of the magnification, which makes this microscope very versatile. Compound microscopes are often used to visualize stained blood smears, urine sediment, and various microbiology specimens.

Figure 6-1 shows a compound microscope with its component parts identified. It is important that medical assistants working in the laboratory know how to set up a microscope properly, focus a slide for viewing, and maintain the microscope appropriately after the procedure. To perform these procedures correctly, the medical assistant must be able to identify the parts of the microscope. Although at first glance the microscope itself may appear complex, its parts may be broken into categories to help you to remember their names and understand their function.

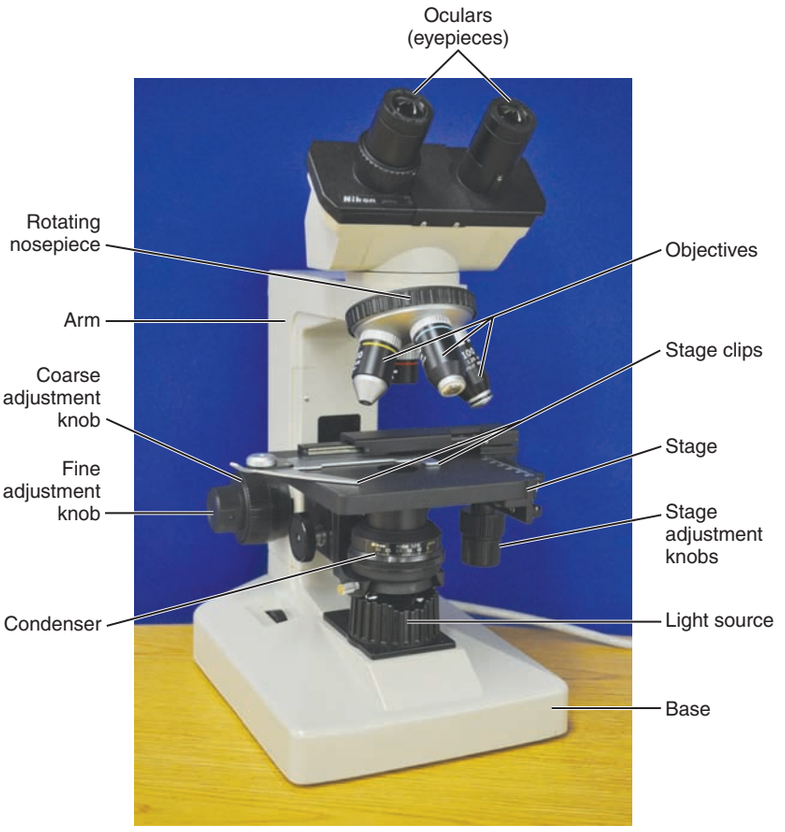

Figure 6-1 Parts of a compound microscope.

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Supportive Structures. The more delicate parts of the microscope are supported by a **base** and an **arm.** The base sits on the surface (tabletop or laboratory bench) to keep the microscope secure. The microscope arm is a curved metal support, and is to be gripped when it is being carried. It is important to remember to use two hands whenever moving the unit; one should grip the arm, and one should be placed under the base.

Another supportive structure is the **stage,** which is the surface on which the slide sits for viewing. Most compound microscopes have metal clips that hold the slide securely in place on the stage and allow the slide to be moved around for viewing by turning a mechanical control knob, located under the stage.

Test Your Knowledge 6-2

On a compound microscope, what is the name of the surface where the slide is placed for observation? (Outcome 6-3)

Structures Used for Specimen Viewing. To view a specimen with the microscope, there are two types of structures used. Some of the structures are designed to provide the necessary light to see the specimen, whereas others are necessary to provide various amounts of magnification. To visualize the specimen as clearly as possible, it is very important that the light and the magnification are both at the correct setting.

Light Sources The **light source** is located in the base of the microscope. The bulb can be turned on and off with a switch or knob, which is usually located on the base toward the back of the microscope. The bulb should not be touched with the bare hands when changing the light source, as the natural oils present on the skin may be transferred to the bulb, and these will overheat when the bulb is turned on, causing the bulb to shatter. The light will come up from the bulb at the base of the microscope, through the **condenser,** then up through the specimen on the stage and finally through the optical magnification components to be viewed.

The condenser is designed to focus the rays of light on the specimen for a clearer image. It may be raised or lowered, depending on the density of the specimen viewed. The knob to adjust the condenser height is on the side under the stage. An **iris diaphragm** is located on the front or just underneath the condenser. The iris diaphragm may be adjusted to increase or decrease the *amount* of light reaching the slide. The amount of light needed to view a specimen depends on its density; generally, the denser the specimen, the more light will be needed. In addition, as the magnification increases, there is more need for light, so the condenser and iris diaphragm need to be adjusted for better viewing.

Test Your Knowledge 6-3

What is the purpose of the condenser on the compound microscope? (Outcome 6-3)

Magnification The compound microscope has two different points of magnification. The first magnification is encountered as the light passes through the specimen from below the stage, and flows into one of the **objective lenses.** These lenses are located on a **revolving nosepiece** and are identified with their respective power of magnification: 4X, 10X, 40X, and 100X. The different objectives also vary by rings of different colors on each, and by the length of each objective tube. When using the microscope, the operator starts with the objective marked with the lowest magnification, and proceeds through the various levels as needed to view the specimen. If the 100X objective is used, a thin layer of oil is placed between the objective and the specimen on the slide to further focus the light and make the image as sharp as possible. This objective is known as the **oil immersion lens.**

The second point of magnification available in a compound microscope is located within the **eyepiece** at the very top of the microscope. An internal mirror actually reflects the image from the slide through this **ocular lens** (eyepiece) where an additional 10X magnification is accomplished. This means that if the 100X oil immersion lens is used to examine a specimen, the object is actually viewed as 1,000 times larger than it would be without magnification. A **binocular** microscope is one that has two ocular lenses (or eyepieces), and a **monocular** microscope is one that has only one ocular lens used to view the specimen.

Focus on the specimen is achieved by using the **coarse adjustment knob** and the **fine adjustment knob**. These knobs project out from the side of the microscope arm. The larger of the two knobs is the coarse adjustment, and is used when the specimen is first being brought into focus at a low magnification. The fine adjustment is the smaller knob, and is used to fine-tune the focus. The fine adjustment knob is used with the higher magnification levels.

Microscope Maintenance Procedures. A microscope must be handled and maintained properly in order to keep it functioning as it should. The following are a few

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guidelines for handling and maintaining a compound microscope that a medical assistant should adhere to:

1. Keep the microscope covered with a plastic cover when not in use. This protects the delicate microscope and lenses from excess dust and potential damage.
2. Always use two hands (as described earlier) to carry a microscope.
3. Do not touch the light source or the lenses with your fingers. The light source may overheat and burst because of the transferred oils, and fingerprints on the lenses can be very difficult to remove.
4. The optical lenses and eyepieces should be kept clean at all times. These may be cleaned *only* using lens paper, as the glass surfaces are very delicate and will be scratched if Kimwipes or other tissues are used. Xylene may be used to assist with removal of oil or other buildup. A small amount should be placed on the lens paper before gently rubbing the lens.
5. When cleaning the objectives, remember always to clean the 100X optical lens last. This one is used with oil immersion, and if cleaned first, the lens paper used may contaminate the other lenses with oil as they are cleaned. Do not apply pressure to the lenses when cleaning.
6. Keep the stage clean between uses.
7. When moving from one objective to another during use or cleaning procedures, always use the nosepiece to change the powers. Do not push against the tubes directly to move them.
8. Slides should be removed or added to the stage only when the lowest power objective is turned down toward the light source. Do not attempt to remove or add slides when the higher power objectives are in place (pointed down toward the specimen), as the objective lenses may be damaged during the process, and/or the slide may be broken.

Test Your Knowledge 6-4

True or False: The 100X objective (oil immersion objective) should be cleaned first when performing maintenance on the compound microscope. (Outcome 6-4)

Test Your Knowledge 6-5

What should be used to clean the eyepieces on a microscope?

a. Kleenex or a similar facial tissue
b. Laboratory tissues such as Kimwipes
c. Lens paper
d. None of the above (Outcome 6-4)

Procedure 6-1: Microscope Use

TASK

Correctly use a compound microscope to obtain specimen focus with all objectives.

CAAHEP/ABHES STANDARDS

None

CONDITIONS

- Compound microscope
- Lens paper
- Specimen slide
- Immersion oil
- Laboratory tissue such as Kimwipes
- Gloves (if needed)

Procedure	Rationale
1. Wash hands and gather necessary supplies. Apply gloves if the specimen is infectious and unfixed (without preservative).	Gloves are not necessary if the specimen is fixed with chemicals that will kill the microorganisms on the slide. If dealing with unfixed specimens (such as vaginal smears or unstained urine) gloves must be applied.
2. Remove the microscope from storage, if necessary. Be sure to use one hand on the arm and one under the base of the microscope.	The microscope may be kept on the countertop, or it may be stored in a drawer or on a shelf. Always support the microscope with two hands to avoid hitting it against surfaces that could damage the instrument.

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Procedure 6-1: Microscope Use—cont'd

Procedure	Rationale
3. Plug in the microscope to the electrical outlet. Verify that the excess cord does not hang over the edge of the counter.	The cord needs to be behind the microscope to avoid catching the cord and accidentally pulling the microscope from the counter.
4. Use lens paper to clean the eyepieces and the objectives. Start with the eyepieces, after which each objective should be cleaned starting with the lowest power and finishing with the 100X objective. Only the optical surface should be cleaned with the lens paper.	The eyepieces should be cleaned before the objectives to avoid possible transfer of oil to the eyepieces from the objectives. It is also important to remember that the 100X objective should be cleaned last because it is used with oil that could be transferred to the other objectives.
5. Turn on the light source and adjust the light to a low level.	The light should be at a low level as you begin to focus the specimen. More light will be required later as the objectives are changed to higher levels.
6. Adjust the eyepieces to be the same width as your eyes. With some models, it may be possible to adjust the eyepieces individually for a sharper focus.	Both eyes should be used at the same time when looking through a binocular microscope. This will be best accomplished when the width of the eyepieces matches that of your eyes.
7. Rotate the nosepiece to bring the lowest power objective straight down where it is pointing at the slide. There should be an audible click when this objective is in the proper position. Watch the stage and objective closely to avoid touching the stage with the objective. The lowest power objective may have a 4X or a 10X printed on it.	Focus always starts with the lowest power objective. Some microscope models may have a 4X objective, but most will have 10X as the lowest possible magnification.
8. Using the coarse adjustment knob, move the stage until it is at the lowest point possible.	The coarse adjustment knob is the larger knob at the back of the microscope. Moving the stage down will allow space to put the slide in place without potentially touching the objective with the slide.
9. Place the slide on the stage with the specimen side up. If the compound microscope used has stage clips, use these to secure the slide in place. Using the stage adjustment knob, position the slide so that the area on the slide to be viewed is directly over the hole where the light will shine through the specimen.	If the slide is not faceup, it will be very difficult to reach optimum clarity when viewing the specimen. It is especially important to center the slide where the specimen viewing area is focused over the hole where the light comes through when the specimen covers only a small area on the slide.
10. If the microscope has a condenser, adjust the condenser all the way up, using the adjustment knob to the side of the condenser. Using the adjustment lever on the diaphragm, open the iris diaphragm to allow the maximum amount of light to be utilized for viewing the specimen. This will be adjusted to a lower level as you work through the focusing process.	As the specimen focus process begins, it is essential to have as much light as possible available. The condenser may be moved farther from the specimen, and the diaphragm may be adjusted as the specimen is brought into closer focus.

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Procedure	Rationale
11. While looking through the eyepieces, slowly turn the coarse adjustment knob until the specimen comes into approximate focus. It may not be possible to bring the specimen into complete focus using only the coarse adjustment knob.	The coarse adjustment knob allows for an approximate focus.
12. Without moving the slide or the objective, use the fine adjustment knob to bring the specimen into complete focus.	The fine adjustment knob is to be used only after approximate focus has been accomplished with the coarse adjustment knob.
13. Adjust the amount of light entering the specimen by moving the condenser down and by adjusting the diaphragm until the specimen appears in crisp, clear focus.	Too much light at a low magnification may cause the specimen to appear washed out, and some of the formed elements may be overlooked. Too little light does not allow for enough contrast to identify some of the structures.
14. Use the stage adjustment knob to move the object viewed directly into the center of the field of vision while looking in the microscope.	If this step is not performed, you may not be able to find the object again after changing to the next level of magnification, especially if the specimen only covers a small portion of the slide.
15. Use the nosepiece to swing the next objective so that it is pointing directly down at the slide. As before, the objective should click into place.	Always watch the objective as you move it into place to avoid touching anything with the objective lens.
16. Use the fine adjustment knob to bring the object into focus. It may be necessary to adjust the amount of light entering the specimen to see the object clearly.	With the objectives above 10X, do not use the coarse adjustment knob for focus.
17. If desired for the type of specimen viewed, continue this process, using the fine focus and adjusting the available light as the objectives are changed to higher levels of magnification.	Some specimens do not require higher levels of magnification if the structures can be identified at the lower levels.
18. If the oil immersion lens (the lens marked with the 100X and a ∞ symbol) is to be used, it will be necessary to place one or two drops of immersion oil on the slide before rotating the objective into place. **a.** Use the nosepiece to move the current objective out of the way, but do not lower the 100X objective until the oil has been added. **b.** Keep the slide as it was with the previous objective and place the drop(s) of oil on the slide right over the light source. **c.** Then, use the nosepiece to lower the 100X lens into place and adjust the focus as needed with the fine adjustment knob.	Resist the urge to make more room for this objective before moving it into place. This objective will be very close to the slide; it will appear that it is going to touch the slide, but if the proceeding steps were performed correctly, it will not touch the slide. The oil will seal the objective with the slide to keep the light focused on the specimen with clarity.

Continued

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Procedure 6-1: Microscope Use—cont'd

Procedure	Rationale
19. After the specimen has been analyzed as needed, lower the stage to the lowest possible point, and remove the slide from the stage clips.	The stage should always be at the lowest point during storage to avoid potentially damaging the objectives.
20. Using the nosepiece, adjust the objectives so that the lowest power is pointing down toward the stage.	This allows the focusing to start appropriately when a new slide is put on the microscope, and also helps to avoid potential damage to the objectives.
21. Turn off the light source, and clean the eyepieces and objectives using lens paper. Remember to clean the 100X objective last, if applicable. Xylene can be used on the lens paper if needed for excessive soiling of the lenses.	Only lens paper should be used for this, as any other type of tissue will scratch the sensitive lenses. If the 100X objective is cleaned first, the rest of the lenses may be contaminated with oil. If xylene is used, be sure to follow appropriate protective measures as described by the manufacturer and the workplace.
22. Wipe off the stage and the rest of the microscope using a laboratory tissue such as Kimwipes. Moisten the tissue if necessary to remove dust. The stage should be disinfected periodically by using an alcohol wipe.	The slides, specimens, and oil can easily soil the stage.
23. Unplug and secure the electrical cord, and put the plastic cover back on the microscope. Be certain to move the microscope to the appropriate storage area as directed by office policy.	Be sure to use two hands when transporting the microscope.
24. Discard the slide or place it in the appropriate storage area as dictated by office policy.	Stained specimens are often stored for a period of time for future study. Slides should be treated as a "sharp" and disposed of in a puncture-resistant biohazard container.
25. Remove gloves (if used for the procedure) and wash hands.	Hands should be washed before and after each procedure in the laboratory setting.

Test Your Knowledge 6-6

Which adjustment knob should be used first when the specimen on the microscope is initially brought into focus? (Outcome 6-5)

Test Your Knowledge 6-7

Is the microscope stage moved when objectives are changed for higher magnification of a specimen? (Outcome 6-5)

Other Types of Microscopes

A dissecting microscope may also be utilized in the laboratory to view specimens that need to be seen in their natural state without compression or those that are too thick to be viewed effectively with the compound microscope. This type of microscope may also be known as a **stereo microscope** because the microscope is designed to allow a slightly different view from each of the eyepieces, providing an image with depth and dimension. The light source for this type of microscope is not focused in the same way that the compound microscope is focused; it is diffused or reflected onto the

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image rather than shone directly through it. The magnification ability of the dissecting microscope is not as extensive as that of the compound microscope, as it is usually only capable of enlarging the specimen by 40 or 100 times its normal size. Dissecting microscopes are often used for blood bank procedures when the technologist is examining different serum and cell combinations to look for **agglutination** of the specimen. Dissecting microscopes may be used for a variety of other purposes in the clinical laboratory when fine, detailed work needs to be performed with some magnification.

An **electron microscope** allows for much greater magnification of specimens, and also provides a three dimensional image. Electrons are utilized to "excite" the specimen, and the resulting interaction with the atoms present in the specimen will produce an image to be recorded and studied. This image is more of a picture that is defined by the properties of the specimen, rather than a true image seen by the eyes while viewing the specimen. The image created by the excitation of the sample is stored and viewed on a computer. Electron microscopes may be used to visualize specimens that are far too small to be seen with a compound microscope, such as viruses and the interior structures of cells. This type of microscope is not routinely found in clinical laboratories, as the user requires specialized training to operate it and interpret the images created with examination.

Test Your Knowledge 6-8

What type of microscope may be used to see viruses?

a. Compound microscope
b. Electron microscope
c. Dissecting microscope
d. Fluorescent microscope (Outcome 6-2)

How Do Medical Assistants Use Microscopes?

The majority of the time, a medical assistant will not perform microscopic examinations for diagnostic purposes. There are a few microscopic procedures that have been classified as CLIA moderately complex procedures, and these can be performed by medical assistants with appropriate documented training. These include urine microscopic analysis (see Chapter 22) and normal blood cell differential counts (see Chapter 12). These are the exceptional cases in specialized offices such as urology offices or physician office laboratories with minimal staffing. Most commonly, a medical assistant's use of a microscope is limited to focusing the specimen for the health-care provider, as well as performing maintenance procedures. It is of great benefit for a medical assistant to be capable of focusing the microscope, as this allows the health-care provider's valuable time to be spent examining the specimen rather than performing the original setup process. Medical assistants may be focusing stained blood smears, urinalysis sediment specimens, vaginal smears, nasal smears, Gram-stained microbiological specimens, and microscopic examinations for the presence of fungal elements on the microscope for examination. Remember, if the health-care provider does perform microscopy examinations, the laboratory must register as a CLIA site that provides this type of service.

Test Your Knowledge 6-9

Is a medical assistant properly trained to perform microscopic identification procedures? (Outcome 6-6)

Centrifuges

A **centrifuge** is an instrument used to prepare blood (or other liquid specimens) for transport or testing. Blood is made up of cells that are suspended in a liquid substance called **plasma.** Chemical analysis is often performed on the plasma, and in order for the results to be accurate, the cells must be removed from the liquid portion of the blood as soon as possible after the specimen is obtained. A centrifuge is used to force the separation of the cells from the fluid portion of the blood (plasma).

If a blood specimen is allowed to sit for an extended period of time in a tube, gravity causes the cells to settle to the bottom of the tube, as they are denser (heavier) than the surrounding fluid. A centrifuge creates a powerful "artificial" gravity source, called **centrifugal force.** The force is formed as the specimen spins around an axis hundreds to thousands of times per minute. When a specimen is processed by a centrifuge, the separation of the different components of the blood is accelerated; the cells are pushed to the bottom of the tube within minutes. This allows the plasma to be removed from the cells in a timely manner so that chemical analysis can be performed. Urine specimens may also be centrifuged to bring the suspended elements (such as blood cells, bacteria, etc.) to the bottom of the tube so that they can be examined under a microscope.

There are various types of centrifuges available for use in a laboratory. Some of the benchtop models are designed to spin 8 to 10 samples at a time for a maximum of 10 minutes each cycle. Others are units the size of a dishwasher, capable of processing hundreds of tubes in each cycle for extended periods of time. The decision about which type of centrifuge to use is based on several

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factors, including the volume of samples to be processed, the requirements for the liquid portion of the blood after separation, and the amount of separation required. The decision may also be based on the recommended maintenance procedures for the centrifuge model of choice, as well as cost. Some centrifuges generate a lot of excess heat as they operate, due to the rapid turning of the unit around the axis. These models require built-in refrigeration to decrease the temperature to keep the specimens from becoming overheated.

Centrifuge Maintenance

Maintenance of all centrifuge models is similar. It is important that the interior and exterior of the machine stay clean and that there is nothing impeding the rotation of the unit around the axis. The **rotations per minute (rpms)** must also be checked at least quarterly using a **tachometer.** If the rotations have changed significantly since the last check, the instrument should be serviced, as there may be a problem that needs to be addressed. Many centrifuge models have a brushed drive motor, and these brushes must be changed at intervals recommended by the manufacturer. All metal components of the centrifuge should be checked for cracks at least once a month. As with all electrical equipment, the electrical cord should also be checked for wear periodically.

Test Your Knowledge 6-10

List two maintenance procedures to be performed on a centrifuge. (Outcome 6-7)

Centrifuge Safety

- All medical centrifuges should have a cover that must be locked in place when in operation. Figure 6-2 shows an example of a centrifuge. The cover keeps the operator safe from potential aerosol formation or splashing that may occur if a specimen breaks or if a tube becomes uncovered during the cycle.
- It is also important that the centrifuge is **balanced** before starting. This means that for every tube inserted into the centrifuge, a tube with the same weight of fluid must be placed directly across from it in the unit. This additional tube may be filled with the same fluid as the specimen (another blood tube filled to the same level, for example), or it may be a balance tube that is filled with the same amount of water. This is a critical step, no matter what type of specimen is to be centrifuged. If the unit is not balanced, it is possible that the centrifuge will rock while operating (like an off-balanced washing machine), fall off the countertop, and break the specimens as they are spinning.
- Be certain that all specimens are capped securely before starting the centrifuge.
- It is very important to follow the manufacturer's recommendations concerning length of cycles and specific maintenance.
- Remember never to open the centrifuge before it stops spinning completely. Never use your hand to try and slow down the final spin; this can be very dangerous.

Test Your Knowledge 6-11

What does it mean to balance a centrifuge? (Outcome 6-7)

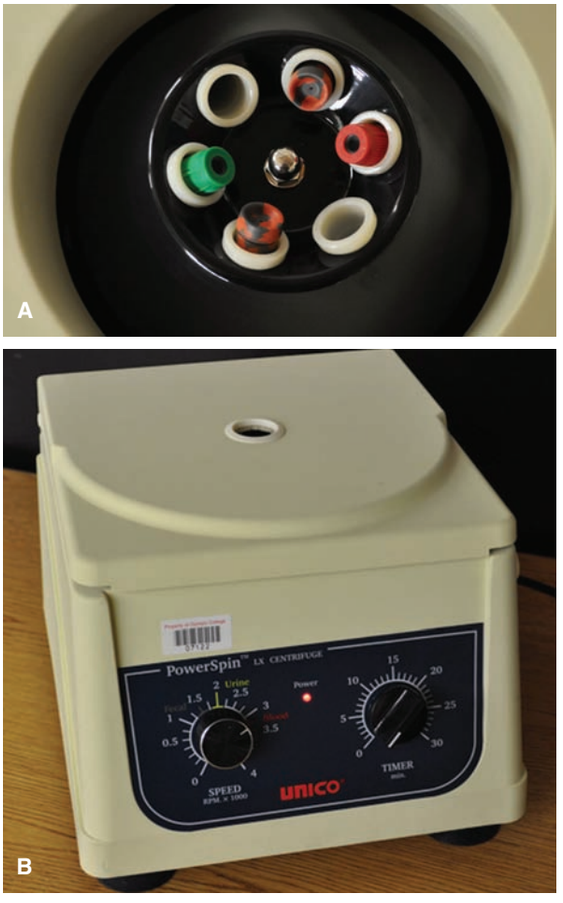

Figure 6-2 The inside (A) and outside (B) of a typical benchtop centrifuge.

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Procedure 6-2: Operating the Centrifuge

TASK

Use a benchtop centrifuge to successfully separate plasma from cells in a blood specimen.

CAAHEP/ABHES STANDARDS

None

CONDITIONS

- Gloves
- Benchtop centrifuge
- Blood specimen in tube
- Balance tube
- Spacers to go inside slots in centrifuge if necessary
- Water and transfer pipette
- Test tube rack
- Disinfectant wipe

Procedure	Rationale
1. Wash hands and gather necessary supplies. Apply gloves.	Hands should be washed before and after performing any procedures in the laboratory, and gloves must be worn whenever handling blood specimens.
2. Verify that the centrifuge is plugged into an electrical outlet. Open the lid and verify that all the slots in the centrifuge are empty.	Occasionally the previous user will have left a tube or a spacer in one of the slots within the centrifuge, which can cause it to become unbalanced while processing the specimen. Care should also be taken to verify that there is no liquid in the bottom of the receptacles in the centrifuge, as this could also cause the centrifuge to become unbalanced.
3. Pick up the blood specimen and hold the tube at eye level. Fill the balance tube with water until the two tubes have an equal volume of fluid.	The tubes must have the same fluid volume for the centrifuge to be balanced. This can also be accomplished with two tubes of blood that are the same and are filled to the same level.
4. Verify that the original rubber cap is on the blood tube securely. The balance tube should also be capped with the original rubber cap.	To avoid aerosol formation, all specimens processed in the centrifuge should be securely capped.
5. For some centrifuge models, it may be necessary to place a rubber spacer or adapter in the centrifuge slot to accommodate the size of tube spun. Consult the manufacturer's recommendations.	The spacer or adapter will allow the blood tube to remain high enough in the centrifuge to be removed after spinning, and it may also allow for a tighter fit within the slot to avoid the breakage from vibration that is possible when the tube does not fit securely.
6. Place the two tubes in slots within the centrifuge that are across from each other. The centrifuge can be operated if the other slots are empty, as long as the two tubes are across from each other.	Balance is essential to keep the centrifuge from vibrating excessively while operating. An unbalanced centrifuge can cause the tubes to break, and it also can cause the centrifuge to fall off the countertop due to the excessive motion.
7. Close the lid securely. Turn on the timer on the centrifuge to the appropriate time for spinning a blood specimen. This will be indicated on the front of the centrifuge or in the manufacturer's insert.	Larger tubes may require a higher rate of centrifugation or a longer time in the centrifuge to achieve the desired separation of cells and plasma.

Continued

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Procedure 6-2: Operating the Centrifuge—cont'd

Procedure	Rationale
8. Monitor the centrifuge for at least 20 to 30 seconds after it has been turned on to see if the instrument is vibrating excessively. If so, turn off or unplug the centrifuge immediately.	An unbalanced centrifuge can be dangerous if it vibrates on the countertop and moves from its original position.
9. Do not attempt to open the centrifuge until it has come to a full stop.	Opening the centrifuge prematurely or placing a hand into the unit while it is still spinning can be very dangerous.
10. When the centrifuge has come to a complete stop, open the lid and carefully remove the tube of blood. Place the blood in a rack for further processing.	Care needs to be taken when removing the tube of blood so that the plasma and cells do not become mixed.
11. Remove the balance tube and the spacers and adapters if used. The balance tube may be discarded or reused for another specimen. The spacers and adapters are to be stored for use with the next centrifuge load.	Some laboratories keep a set of balance tubes close at hand to be used for additional centrifugation. Be sure that the tube cap is securely fastened if using the balance tube again.
12. Use a disinfectant wipe to wipe down the exterior and interior of the unit.	If excessive contamination is evident, it may be necessary to clean the unit to a greater extent. In many units, the slots in which the tubes are placed are removable so that they can be washed if necessary.
13. Remove gloves and wash hands.	Hands should be washed before and after performing any procedures in the laboratory.

POINT OF INTEREST 6-1
"Sally Centrifuge"

In many areas of the world health-care providers do not have access to electricity or funds for purchasing traditional instruments used for diagnosis. The presence of anemia contributes significantly to the diagnosis and subsequent treatment of disorders such as malnutrition, HIV/AIDS, tuberculosis, and malaria. Blood specimens collected from the patients in these areas must be shipped to larger health-care facilities for testing, which is expensive and time consuming.

In 2010, two Rice University college students created an inexpensive centrifuge that allows the cells to be separated from the plasma in microhematocrit tubes in 10 to 20 minutes without the use of electricity. Lauren Theis and Lila Kerr created the centrifuge as a class project, using materials that included combs, yogurt containers, and a salad spinner. The centrifuge cost approximately $30 to build, and it can process 30 samples of 15 microliters each at one time. The centrifuge must be pumped by hand for 10 to 20 minutes, at which point it reaches speeds of approximately 950 rotations per minute and successfully separates the blood cells from the plasma in the tubes. The tubes then can be compared to a reference chart to obtain the hematocrit result, used to diagnosis the presence of anemia.

These students are part of a Rice University program, Beyond Traditional Borders. As part of this program, the students used the centrifuges in several remote locations during the summer of 2010 to test their ability to withstand traditional use in a health-care setting. If successful, "Sally Centrifuge" could have a profound impact on the ability to deliver affordable, timely health care in many locations across the globe.

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Laboratory Refrigeration

Many specimens must be maintained at reduced temperatures to provide reliable test results when analyzed. The instructions for specimen collection and processing for a particular test may include refrigeration of the specimen, or possibly freezing of the plasma or **serum.** To ensure that the specimens are at the correct temperature, the refrigerators or freezers in the clinical laboratory should be monitored each day; in large laboratories with multiple shifts, they may be monitored more than once a day.

A **laboratory thermometer** is used to obtain accurate, reliable temperature readings. Laboratory thermometers are usually made of a measurement device that has the end designed to register the temperature while submersed in a container filled with liquid. The employee who is monitoring the temperature will open the door of the refrigerator or freezer, read the temperature on the thermometer, and record the result on a log sheet nearby. To keep the temperature as stable as possible, the door for the refrigerator or freezer should be opened only long enough to read the thermometer. Some thermometers are designed with systems that allow them to be monitored by a device that is outside of the refrigerator. This is advantageous because it is not necessary to open the door of the unit to take the temperature. In either case, a range of acceptable readings for each refrigerator or freezer must be established, and if the results fall outside this range, corrective action must be taken immediately. The specimens in the unit must be transferred elsewhere until the temperature reading is within the acceptable range again.

In laboratory situations in which refrigeration temperature is especially critical, an alarm system may be installed that sounds whenever there is a fluctuation in the temperature readings. Blood bank facilities have a very small range of acceptable storage temperatures for units of blood, and must have processes in place for critical monitoring of all their refrigeration units. These special refrigerators often have battery backups that activate a cooling system in case of power failure, as well as remote monitoring systems and audible alarms. The temperature for these units must be monitored more frequently than other refrigerators; often there is a continuous recording of temperatures.

Some refrigerators and freezers in physician office laboratories may be used to store specimens as well as vaccines or other medications. These products will have very specific storage requirements, so monitoring of the temperature used for storage will be especially critical. If the unit falls outside the acceptable storage ranges, the medication and vaccines may need to be discarded. Quality control materials may also be stored in refrigerators or freezers with specimens, and these materials will also have specific storage requirements that must be followed.

It is imperative that all refrigeration or freezer units in a laboratory setting are properly maintained to avoid excessive moisture or ice buildup. The refrigeration coils at the back of the unit should be kept free of dust buildup, and the interior and exterior of the unit should be kept as clean as possible. *No food or drink is to be stored in laboratory refrigerators where specimens are kept.* This is a safety precaution designed to protect employees from potential contamination of their food, as well as an Occupational Safety and Health Administration (OSHA) regulation that must be followed.

Test Your Knowledge 6-12

If specimens are to be kept at a certain reduced temperature, how often should the refrigerator temperature be monitored? What other precautions should be in place? (Outcome 6-8)

Incubators

When microbiology specimens are collected from a human for analysis, the pathogens that may be present are reproducing at body temperature. This temperature is approximately 25° to 27° Celsius or 95° to 99° Fahrenheit. To keep these pathogens alive until they can be identified, it is necessary to keep them at this temperature for a few days. A laboratory **incubator** is used for this purpose. The temperature for an incubator must be monitored at least daily, and the results must be documented on a log sheet. Much like a laboratory refrigeration unit, there is a limited acceptable range for these temperature readings, and if the incubator falls outside of that range, the unit must be serviced.

In addition, **water baths** or other types of heating units may be used in a laboratory. Water baths may be used to heat specimens as part of specific testing procedures. Other heating units may be used to "fix" a specimen to a slide, or to sterilize inoculation devices in the microbiology laboratory.

EQUIPMENT USED FOR AUTOMATED CLIA-WAIVED LABORATORY TESTING

Many medical offices choose to perform automated CLIA-waived tests in their own laboratory on site. Performance of these tests in the office environment

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rather than in a reference laboratory may benefit the patient in various ways:

- On-site testing may assist the health-care provider to assign a definitive diagnosis quickly. This allows a plan of treatment to be established before the patient leaves the office. The patient and health-care provider can discuss the plan, and an opportunity is provided for face-to-face communication. This can be especially critical for patients who are acutely ill and those with chronic health conditions requiring frequent laboratory testing to monitor the progress of their treatment.
- CLIA-waived tests performed in the physician's office may be less expensive for the patient. Many times insurance coverage is limited for laboratory testing, so a reduced charge is definitely a benefit.
- Performance of testing on site may allow patients to minimize visits; they can have their specimen collected and tested at the same location that they see their health-care provider, without going to a separate destination for collection and/or testing. This helps improve patient compliance rates.

CLIA-waived automated testing may also be performed in larger laboratories for tests that do not require more advanced methods of analysis. These laboratories may employ medical assistants or phlebotomists to perform these testing procedures with appropriate oversight by other laboratory professionals. Automated methods for CLIA-waived tests include chemical urinalysis, chemistry testing, and hematology testing.

Test Your Knowledge 6-13

List one advantage of performing automated CLIA-waived tests in a physician office laboratory. (Outcome 6-10)

Testing Methodology

Chemistry analyzers may test the liquid portion of the blood (plasma) or the whole blood specimen. Hematology instruments are designed to perform various measurements on the cells present in the specimen. Automated analyzers used for CLIA-waived hematology, coagulation, urinalysis, and chemistry testing (as well as advanced instruments used in more complex testing procedures) are often used to provide quantitative results of substances or cells present in the specimens. Other testing instruments may provide qualitative results, such as those used for **fecal occult blood** testing or urine drug screening. In this case, the presence or absence of a specific analyte provides the necessary information for the health-care provider to develop a plan of action.

Most of the CLIA-waived chemistry testing methods explained in this textbook use reagents that change color when they are exposed to the chemicals present in the specimen. This color change is measured by a **spectrophotometer,** an instrument that measures light intensity. A specific wavelength of light enters a sample, and depending on the amount of color change, a certain amount will continue through the sample to be measured on the other side. The measurement of the intensity of the light at the end of the process is directly related to the concentration of the chemical substances present in the solution. The light intensity measurement may be changed by absorption of the light by the specimen, or by reflecting or scattering the light so that it is not measured directly at the end of the reaction.

Hematology testing often uses **electrical impedance,** a process for counting cells in the whole blood specimen and differentiating them by size. For this type of test, whole blood specimens are added to a **diluent** (a liquid used for dilution of a specimen) that is capable of conducting electricity. An electrical current is applied to the mixture of specimen and diluent as it passes through a small opening, called an **aperture.** Because the blood cells do not conduct electricity, they break the current between the electrodes on either side of the aperture. The amount of impedance (interference of the electrical signal) caused by a certain cell will allow the instrument to count the cell and approximate the size and other physical properties. A similar type of measurement uses the amount of light scattered by a specimen to measure the cell numbers and cell sizes in a hematology specimen.

Hematology instruments (such as those that test only **hemoglobin**) may also use spectrophotometers to measure a specific substance. In this case, the cells must be broken, or **lysed** prior to the testing procedure, so that the hemoglobin present inside the cells may be measured.

When using an instrument to perform any of these tests, it is imperative that the manufacturer's instructions are followed concerning frequency and extent of quality control testing and calibration of the instrument. These procedures must be performed as directed to verify that the instrument is operating as it should before patient samples are analyzed. The reagents used with the analyzers often have storage requirements and expiration dates that must be monitored as well, and quality control samples must be prepared and processed as directed to produce meaningful results.

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Test Your Knowledge 6-14

Electrical impedance is a common term used to describe how the number of cells in a specimen are measured. What process occurs to allow the cells to be counted by the instrument? (Outcome 6-11)

Instruments Used for Chemical Testing of Urine Specimens

Urine specimens are analyzed in various ways. One of the methods used to evaluate the specimen is a chemical analysis to detect and/or quantify the presence of substances in the urine specimen that may indicate disease. Quite often, this analysis will be performed manually in a physician office laboratory, but this analysis may also be performed using an instrument and **reagent strips** that are imbedded with small squares designed to change color when exposed to specific chemicals present in the urine specimen. Although the exact number and types of chemicals analyzed in the specimen may vary according to the manufacturer of the unit, common chemical substances detected include the following:

- pH levels
- protein
- glucose
- blood
- leukocytes
- specific gravity
- bilirubin
- glucose
- ketone
- urobilinogen
- nitrite

The process of reading the reagent strips is time and color sensitive. The chemical measurements are based on changes in color that develop in response to the presence of certain chemicals. These changes do not all occur at the same rate, which means that the reagent pads on the strips must be read at specific time intervals after the strip has been exposed to the urine specimen. Automated urine analyzers are designed to move the strip through the measuring device with the appropriate speed to read these reagent pads at the correct time.

A similar procedure is used for testing urine using any of these machines. Essentially, the reagent strip is immersed in the urine specimen, blotted to remove excess specimen, then applied to a tray that feeds the reagent strip into the instrument for analysis. The instrument times the advance of the strip appropriately for the different reagent pads to be analyzed for color changes. The amount of color change is directly related to the concentration of the chemical substances in the urine, and once analyzed, the results are printed on a strip that may be kept as a permanent record. Some of the instruments are also capable of transmitting the results directly to a computer so that they may be stored electronically. Urine analyzers are quick and easy to use, and eliminate the need for the employee to monitor the reaction of the different areas of the reagent strip for the full time needed for color development.

Common urine analyzers include the Clinitek Urine Analyzer, manufactured by the Bayer Corporation, and the Urisys 1100 Analyzer, manufactured by Roche. Henry Schein also manufactures the One Step Plus Analyzer (Fig. 6-3). The automated chemical analysis testing that is performed with these instruments is CLIA-waived, as long as the manufacturer's directions are followed exactly as printed. Quality control and maintenance for this type of equipment may include the use of commercial quality control specimens of different levels, calibration of the instrument, and cleaning of the instrument at regular intervals. Some general aspects to keep in mind

Figure 6-3 One Step Plus Urine Analyzer. *Courtesy of Henry Schein, Inc.*

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when performing urine testing with an automated instrument include the following:

- Reagent strips do outdate. *Always* check the expiration date before using the strips.
- Reagent strips must be protected from moisture, so the bottle must be closed immediately after removing the necessary strips for testing.
- Automated urinalysis instruments may produce erroneous results in situations in which the urine is discolored by medications or dyes used for diagnostic purposes. The employee performing these tests must keep this in mind and follow the manufacturer's recommendations and the office policy for confirmatory testing before reporting results on discolored specimens.
- As with all testing procedures, documentation of the quality control and maintenance procedures is critical, as well as the appropriate documentation of all patient results.

Instruments Used for Coagulation Testing

Coagulation testing is used to screen patients for blood clotting issues. It may also be used to monitor patients who have been placed on anticoagulant therapy, such as warfarin (Coumadin). As presented in more detail in Chapter 15, coagulation testing is commonly performed as a CLIA-waived test in the physician office laboratory environment. The most common test used for screening or monitoring is the **prothrombin time test.** This test is more commonly known as a **protime,** and it measures the length of time necessary for a blood specimen to form a clot when reagents are added. The result is reported in seconds. Protimes may also be performed in larger laboratories using testing methods that are not CLIA-waived. When the protime test is performed, an **international normalized ratio (INR)** is usually reported in addition to the test result. The INR is a calculation provided by dividing the protime result for the patient by the normal control value for the lot of reagents currently in use for that system.

Protime testing on the CLIA-waived instruments is accomplished by inserting a reagent strip or cartridge into the instrument, then adding one or more drops of blood to the designated area of the strip. The blood specimen is usually obtained from a capillary puncture, and a drop is placed directly onto the testing device or transferred from the finger using a capillary transfer device. There are specific timing and quantity requirements, and if the operator does not follow these guidelines, an error code will result and the test must be repeated with a fresh specimen. Some of these coagulation analyzers provide a printout, others can be connected to an external printer for result documentation, and still other instruments may be interfaced to the computer for the results to be stored electronically. The units do have a display screen where the operator can read the result.

Various CLIA-waived methods and instruments may be used to perform the protime test. These include the ITC ProTime-3 as well as Roche Diagnostic's CoaguChek S, XS, and XS Plus. Other CLIA-waived protime systems include the Hemosense Inratio system, and several products produced by the Lifescan Corporation. Figure 6-4 shows a Roche CoaguChek S with reagents and necessary to perform a protime test. Each type of instrument has instructions that are a little bit different, but all the testing systems share some of the following characteristics:

- All CLIA-waived or home use systems have test strips that are packaged individually so that one test is performed at a time.
- Each lot of test strips has a unique product code that must be entered into the machine to perform the test. Some products have a computer chip with the product code, and this must be inserted into the analyzer prior to the sample testing process.
- All instruments have quality control procedures; some are built-in internal controls that run automatically during the testing process, while other instruments use liquid commercial control materials that are run as

Figure 6-4 Roche CoaguChek S Plus with reagents and quality control materials.

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patient samples. As always, the quality control (QC) values must be documented and interpreted as recommended by the manufacturer.

- The reagents all have specific storage requirements, although these vary from brand to brand.
- All CLIA-waived methods require whole blood samples for testing, and the test is designed to be run on capillary blood. A lancet is used to pierce the skin for the sample.
- Many of the testing methods recommend use of a microcapillary tube with a bulb or a collection cup to assist with obtaining adequate sample volume.
- The blood sample is applied directly to the reagent strip for all methods; generally there is a window or circle that must be covered completely with blood.
- The instruments require very little maintenance. Most have batteries and some also have A/C adapters. The batteries must be changed periodically, and should be removed from the device if it will not be used for an extended period of time. The analyzers should also be kept clean. The instrument (especially the sample application area) may be cleaned with a cotton-tipped applicator moistened with isopropyl alcohol or a 5% bleach solution.
- None of the instruments should be immersed in water or any other liquid.
- All manufacturer's instructions for the testing process must be followed exactly as written.

Test Your Knowledge 6-15

What type of specimen is needed for handheld coagulation instruments?

a. Plasma
b. Serum
c. Urine
d. Whole blood (Outcome 6-13)

Test Your Knowledge 6-16

Are results for CLIA-waived coagulation testing available at the completion of the test? (Outcome 6-13)

Instruments Used for Chemistry Testing

CLIA-waived automated chemistry testing procedures are now available for a variety of analytes. Some of the most common tests performed in the physician office laboratory are **glucose** measurements and **glycosylated hemoglobin monitoring** for diabetes screening and treatment. **Cholesterol** studies and **electrolyte** measurements are also quite common. Many instruments now have the capability of performing chemistry panels that include three or more tests, providing the health-care provider a more comprehensive set of information to work with as they develop a treatment plan. The test results are usually available within an hour of the test onset, and many of the instruments are capable of transmitting these results directly to a computer for documentation. Calibration of these analyzers may be performed internally or with an external cartridge, and many methods include an internal method of quality control that eliminates the need to purchase separate liquid controls. Also, because the CLIA-waived status for these instruments applies to whole blood specimen testing, most of the instruments require only a few drops of blood, which can be accomplished with a capillary blood draw.

There are more CLIA-waived glucose testing methods than any other type of chemistry analyzers. Many of the glucose instruments used in the physicians' office laboratory are also in use as home testing devices. These instruments have become more technologically advanced, and use even less blood for analysis than in the past. It is no longer required to use fingertips for all samples; innovative lancets and reduced specimen volume requirements have allowed the sites for specimen collection to vary. Devices used at home and in the office allow for test results to be stored, and some also may interface directly with a computer system to allow for closer monitoring and better communication with the health-care provider.

Glucose analyzers utilize reagent strips or cassettes that are inserted into the instrument. A capillary blood specimen is obtained and a few drops are placed directly onto the appropriate area of the reagent strip. The strip may be advanced into the instrument, or the specimen may be analyzed through the application area at the front of the instrument. The analyzer includes a display screen on which the operator may view the results, and (as is the case for the other instruments already covered in this chapter) the analyzer may be capable of printing results or transmitting them directly to a computer for electronic storage. Some instruments are even capable of charting or graphing patient data to provide a historical overview of results over a period of time.

Glucose analyzers found in the physician office laboratory may include the Roche Diagnostics Accu-Chek, the Abbott iStat, and the Hemocue Glucose 201 Microcuvette. There are many CLIA-waived glucose analyzer methods, and more information may be found for any specific type by visiting the website for that manufacturer. It is important to remember that each brand of analyzer has unique reagent strips and quality control materials; these are not interchangeable.

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Other chemistry tests may be performed using CLIA-waived automated testing procedures in a physician office setting or other small laboratory. These include measurements for electrolytes, blood urea nitrogen (BUN), triglycerides, cholesterol, and calcium. Instruments used for testing these analytes use individual testing cartridges, which are self-contained. A capillary blood sample may be obtained in some situations, or in others the entire tube of blood collected by venipuncture may be placed in the instrument to be sampled. Because each testing cartridge is self-contained, the blood sample is added to every cartridge individually. The addition of the sample may be performed within the instrument using an automated method, or the person performing the test may add the sample to each cartridge by hand. Results are usually available within 30 minutes, even if the patient has several tests performed at once. The results are printed out on a slip that may be added to the patient record, and many models are also capable of transmitting the information electronically to a computer system.

The CLIA-waived automated chemistry instruments that use individual cartridges are more expensive to operate per test than the large chemistry analyzers found in reference and hospital laboratories, because of the high cost of the individual cartridges. Larger instruments have reagents that cost less per assay, but they are not CLIA waived for operation. The low sample volume and limited variety of testing procedures ordered in a physician office laboratory are served well by the instruments that use the self-contained individual cartridges.

The Abbott iStat Chem 8+ Cartridge analyzer is a common CLIA-waived chemistry instrument that may be used for point-of-care testing in an emergency room, at the bedside of a patient in the hospital, or in a physician office laboratory. It uses whole blood, and can be used to produce results for a variety of tests. Cholesterol testing may be performed using the Cholestech LDX, but this instrument may not be used for very many other types of tests. The Abixis Piccolo Xpress blood chemistry analyzer has a good deal of flexibility, uses tubes of whole blood, and doesn't take up very much space on a countertop. A comprehensive list of the CLIA-waived automated chemistry testing instruments may be found on the U.S. Food and Drug Administration (FDA) website listed in the Resources and Suggested Readings section at the end of this chapter.

Test Your Knowledge 6-17

What is a common chemistry analyzer used in small laboratories to test cholesterol levels? (Outcome 6-14)

Instruments Used for Hemoglobin Measurements

Hemoglobin is the molecule within the red blood cells that carries oxygen to the tissues of the body. Iron is necessary to build this molecule, so the hemoglobin level of the blood is directly related to the oxygen-carrying capacity of the cells, as well as the iron levels of the individual. Hemoglobin (Hgb) is commonly performed as a screening test for **anemia,** and it may also be ordered as a test to monitor progress when a patient is being treated for anemia.

Because hemoglobin is part of the red blood cell structure, the cells must be broken or lysed before the hemoglobin level can be measured. In CLIA-waived automated hemoglobin testing instruments, the cells are lysed within the individual cuvette when the blood is added. For instance, in the HemoCue hemoglobin testing method, the inside of the individual cuvette used for the test is coated with a chemical (sodium deoxycholate) that destroys the red blood cell membranes, allowing the hemoglobin to be measured.

Test Your Knowledge 6-18

Is hemoglobin measured from intact red blood cells? (Outcome 6-15)

Regardless of the type of instrument used, hemoglobin testing is always performed using whole blood. CLIA-waived systems use capillary samples, and the blood is usually applied directly to the cuvette (or testing device such as a strip) from the capillary puncture site. Proper capillary technique must be used to provide an appropriate specimen. One test is performed at a time, and the individual testing device may be placed in the instrument after the blood has been added, or it may be necessary to place it in the machine prior to the addition of the sample. (Check the manufacturer's recommendations for details.) The instruments will have a display screen on which the progress of the test may be monitored once the blood has been added; generally the results are available within one minute. Some of the instruments may be capable of printing the results, whereas others may also be able to send the results electronically to a computer system for documentation.

The CLIA-waived hemoglobin systems are equipped with electronic calibration methods. The HemoCue system has a standardized cuvette with known values that should be checked at regular intervals to be certain that the instrument is operating correctly. The ITC Hgb Pro has an internal calibration that is performed every time a test is

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performed. If the internal calibration process does not show that the instrument is working correctly, an error will result and the instrument cannot be used for patient testing until the calibration is successful. Liquid commercial quality control specimens may also be utilized to verify that any hemoglobin instrument is operating appropriately.

Other Hematology Instruments

Many physician office laboratories use hematology instruments that have been classified as moderately complex according to CLIA regulations. Common manufacturers are Beckman Coulter and Abbott. Remember, when performing tests of moderate complexity, it is necessary to perform quality control and calibration procedures more frequently, and there are more regulations for personnel training.

Test Your Knowledge 6-19

Is a glucometer an example of an instrument used for hematology testing? (Outcome 6-14)

Glassware and Other Miscellaneous Laboratory Equipment

Physician office laboratories don't have as much glassware as larger laboratories, and in many cases, glassware is now replaced by plastic disposable containers. However, there are a few standard items that may be found in the laboratory setting, regardless of the size of the facility:

- **Pipettes:** Pipettes are used to move liquid from one place to another. It is similar to the turkey baster that you may find in your kitchen. Some pipettes are designed to measure small amounts of liquid very accurately. Others are used just to transfer liquids from one place to another, without measurement. Pipettes come in varied sizes, and are often plastic and disposable.
- **Beakers** and **flasks:** Beakers and flasks are both containers that may be used to store, transfer, or heat liquids. Beakers generally are wide at the top and have a flat base, whereas flasks have a narrow opening at the top and a rounded bottom that is much larger than the top.
- **Glass slides** and **cover slips:** Glass slides are still used in the laboratory, even though many items are now made of plastic. Slides made of glass are still the best item to use when viewing items under the microscope, as they do not distort the view in the manner that some plastic slides may. Slides may be completely clear, or they may be frosted partially or completely for specialized uses. Some slides may have a depression in the center for certain types of specimens. Cover slips are small panes of glass or plastic placed on top of liquid specimens on the glass slides before viewing. Cover slips are often used when the specimen is viewed in a natural state without any preservative or staining.
- **Cylinder:** A cylinder is a slim, round container that is used to measure liquids. A **graduated cylinder** is marked with specific units to allow for accurate measurement.

Because glassware is often used to accurately measure liquid in the laboratory setting, it is important to know the correct way to read the amount of liquid present. Liquid in a glass container is not completely flat at the top, because liquid is "attracted" or pulled up or down the sides of the container to form a curve. This curved surface of the liquid is known as the **meniscus.** In a narrow container, the meniscus will be more curved than it will be in a wide container. When measuring liquid in glassware, always perform the measurement at the lowest or highest point of the meniscus; this principle applies whether removing liquid to obtain a certain volume, or adding liquid to a container. Figure 6-5 shows how to measure liquid correctly in glassware using the meniscus.

Test Your Knowledge 6-20

The curved area at the top of a column of liquid in a glass cylinder is called the:

a. Photometer
b. Diaphragm
c. Flask
d. Meniscus (Outcome 6-17)

SUMMARY

Various types of automated instruments may be found in the clinical laboratory. These instruments may be used to process samples for analysis, examine specimens under the microscope, or analyze body fluids utilizing CLIA-waived automated testing techniques. Medical assistants need to know the correct way to use and maintain equipment for specimen processing, focus microscopes, and perform automated testing appropriate to their level of training. It is also important that medical assistants familiarize themselves with the other equipment used in the laboratory setting, such as refrigerators, incubators, and various types of glassware. Care should be taken to maintain all equipment appropriately, and follow the manufacturer's directions to perform testing procedures exactly as directed.

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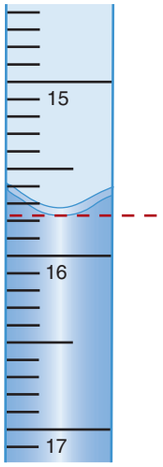

Figure 6-5 Reading the liquid volume using the meniscus. Many liquids curve at the edges of glass containers because of the attraction of the molecules to the glass. This curvature at the top of the liquid is called the *meniscus*. The level is to be measured at the horizontal center of the curvature. Some liquids curve upward instead of downward from the edges of the container, in which case the liquid level is to be read at the top of the curvature. Always hold the container at eye level when measuring.

TIME TO REVIEW

1. What disorder might be monitored by performing periodic glycosylated hemoglobin tests? Outcome 6-1
   - **a.** Diabetes
   - **b.** Hypertension
   - **c.** Hyperlipidemia
   - **d.** Hypokalemia
2. A device used to transfer small quantities of liquids is a: Outcome 6-1
   - **a.** Pipette
   - **b.** Cuvette
   - **c.** Cylinder
   - **d.** Beaker
3. True or False: A tachometer is a type of thermometer used to measure temperatures in the laboratory environment. Outcome 6-1
4. True or False: The objective is a device that can be adjusted to control the amount of light that enters a specimen on a microscope. Outcome 6-1
5. How many eyepieces does a binocular microscope have? Outcome 6-1
   - **a.** One
   - **b.** Two
   - **c.** Three
   - **d.** Four
6. True or False: Centrifuges are used to process all laboratory specimens before testing. Outcome 6-7
7. What are two tasks that a medical assistant may be asked to perform with a microscope? Outcome 6-6
   - **a.** Maintenance and cleaning of the microscope
   - **b.** Prepare and focus specimens on the microscope for examination by the health-care provider
   - **c.** With appropriate training, examination of urine sediment
   - **d.** All of the above
8. True or False: Automated urine analyzers are used to test for bacteria and other suspended objects in urine specimens. Outcome 6-12
9. What are two types of CLIA-waived chemistry instruments presented in this chapter? Outcome 6-14
10. Which company is mentioned in the text as a common manufacturer of hematology instruments? Outcome 6-16
    - **a.** Bayer
    - **b.** Dimension
    - **c.** Beckman Coulter
    - **d.** Piccolo
11. Why is a cover slip used? Outcome 6-17
    - **a.** To view specimens that have been preserved with an additive
    - **b.** To view specimens in their natural state
    - **c.** To view large specimens without the use of a slide
    - **d.** To view chemical reactions

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Case Study 6-1: This test won't work!

The manager for the internal medicine office where Cindy Lou is employed as a medical assistant is on vacation. In her absence, the lead medical assistant has placed a few orders for laboratory supplies, including some test strips for the glucometer used for glucose testing.

On Tuesday morning, Cindy knows that a patient is scheduled for diabetes monitoring. This usually involves a blood glucose level to be performed during his visit. Cindy decides to process the quality control specimens for the glucometer first thing in the morning so that she can be ready for the patient's arrival.

Cindy turns on the instrument, allows it to perform the internal verification that it always goes through, and inserts a test strip to process the quality control specimen. The test strip seems to fit in the instrument a bit differently from the way it has before, but she continues with the process. After inserting the strip and adding the QC material, the display screen flashes an ERROR code, and no result is displayed for the test. Cindy removes this strip and inserts another one, but receives the same result. She checks the QC material to see if it might be expired, and finds that it is not. Once more Cindy attempts to process a QC specimen of a different level (high glucose level) but receives the same code.

1. What is the most probable explanation for the ERROR code?
2. Can Cindy Lou process a patient specimen despite the ERROR codes?

Case Study 6-2: Lack of focus

Lucille has been working in the laboratory at the local obstetrics and gynecology office for several years. She routinely performs blood draws and several different CLIA-waived laboratory tests. The providers in the office have decided that they want to start performing microscopy procedures in the office to better serve their patients.

To perform the microscopy procedures, the providers in the office ask Lucille to demonstrate how well she can focus the microscope. Lucille has not worked with a microscope since she was in medical assisting school, but she does her best to remember the steps involved. She is successful with the initial focus using the 10X objective, but can't seem to bring the specimen into focus when she switches to the 40X objective.

1. What are two possible explanations for the lack of focus with the 40X objective?

RESOURCES AND SUGGESTED READINGS

"US Centrifuge Systems: Frequently Asked Questions"
Frequently asked questions about how a centrifuge works, and types to choose from http://www.uscentrifuge.com/faq.htm

"The Clinical Laboratory Improvement Act and the Physician's Office Laboratory"
Various educational modules and mini quizzes for CLIA waived hematology and chemistry tests http://www.medicine.uiowa.edu/CME/clia/default.asp

"Tests Waived by the FDA From January 2000 to Present"
List of all CLIA waived tests; updated regularly http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfClia/testswaived.cfm

"Principles of Spectrophotometry"
Great explanations about how spectrophotometry works http://www.ruf.rice.edu/~bioslabs/methods/protein/spectrophotometer.html

"Welcome to HemoCue"
Information about the various products manufactured by HemoCue http://www.hemocue.com

"Glossary of Microscope Terms"
Explanations for many of the terms used with microscope use http://www.microscope-microscope.org/basic/microscope-glossary.htm

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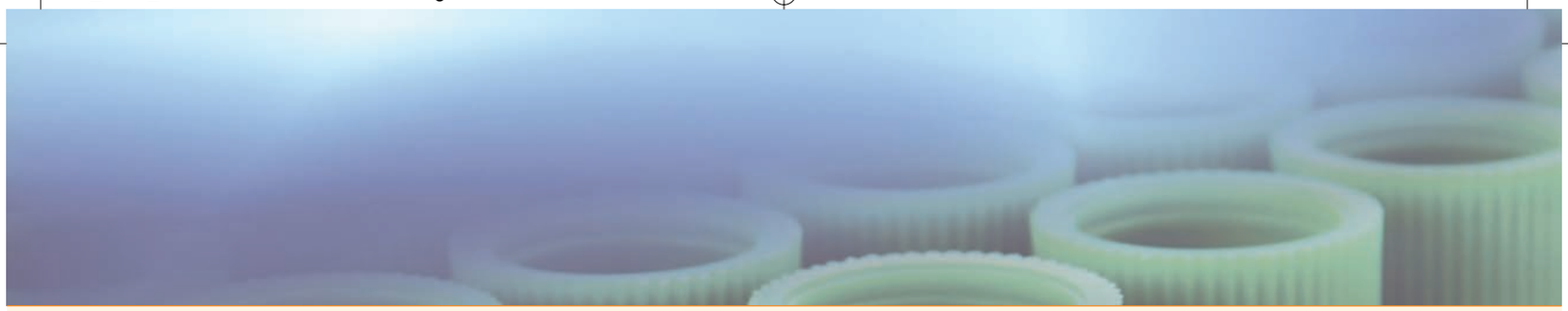

Section I

Overview of the Laboratory

What Does It All Mean?

The purpose of this section is to introduce you to global aspects associated with the clinical laboratory and laboratory testing. As this section clearly indicates, laboratory testing is crucial to the diagnosis and monitoring of patient diseases and conditions, as well as to rule out any diseases and conditions. This being said, an alert medical assistant will have a comprehensive understanding of these aspects. Further, the medical assistant will use appropriate corresponding techniques and procedures to ensure proper laboratory sample collection for testing by appropriately trained and educated individuals. Our Case in Point for this section explores some of these important concepts and serves as a review of the section content.

Case in Point

As noted in this case, during the first week of your student practicum you are introduced to the clinical laboratory by your clinical instructor, Doris. Your patient, Mr. Hershey, presents to Maple Grove Clinic for evaluation. After examining Mr. Hershey, Dr. Pueblo determines that he requires laboratory testing to determine his condition. This situation gives you and Doris a wonderful opportunity to discuss important concepts associated with both the clinical laboratory and laboratory testing. Highlights of this discussion follow for your review and consideration.

There are numerous ways in which laboratories are structured and organized based on a number of factors, including the environment in which the laboratory exists (it may be a small rural hospital or large commercial reference laboratory). Each laboratory determines what tests it will run, what instrument it will use for the tests, and the values considered as normal for the typical patient population the laboratory serves. There are three phases of laboratory testing: preanalytical, analytical, and postanalytical. Every laboratory test passes through all three phases. An error in any of the three phases may adversely affect the laboratory results generated. Most of the problems encountered in laboratory testing occur during the preanalytical testing phase because of a variety of issues, for example, collecting the sample on an individual other than the targeted patient.

Laboratory tests are categorized based in part on the difficulty of the procedure required to obtain the results. Health-care support individuals, including medical assistants, are allowed under government regulations to perform select testing under strict guidelines. Handling every sample using universal precautions is an important point to emphasize, as doing this contributes to the validity of the test results obtained. In addition to running the laboratory tests, quality control samples must also be tested on a regular basis to ensure that the test is working properly. Laboratory test results can only be released (in laboratory jargon this is called "turned out") to the patient's chart if the quality control samples test properly. In the event that quality control results are not in range, investigation and resolution of the problem must occur before patient results can be considered valid. Individuals vary in many ways. Variations in laboratory test values (as well as quality control samples) are no exception. Because of this, laboratory test results considered as being normal fall within a range of values.

In conclusion, laboratory tests provide physicians and other primary care providers with valuable information. In fact, many sources have reported that some 70% to 80% of diagnosis and treatment decisions are based on laboratory results. As this section clearly suggests, there are many important aspects to laboratory structure and testing, all of which contribute to the bottom line: accurate laboratory tests performed in a timely manner.

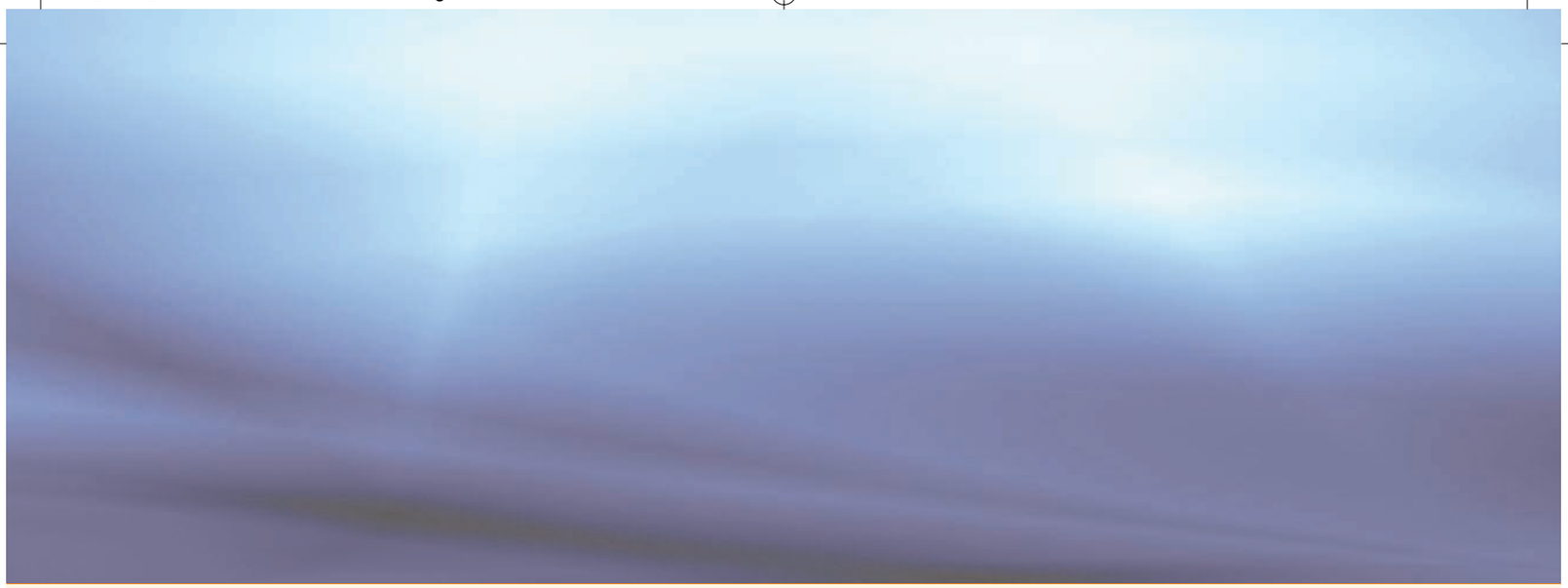

On the Horizon

It has been widely documented that as many as 70% to 80% of all patient treatment decisions are based on laboratory test results. Similarly, there is strong evidence to support the fact that laboratory test results are only as good as the sample from which the testing occurs. Specimen collection and processing, also known as the preanalytical phase (meaning the steps before actual analysis occurs) of testing, is thus a very important factor that contributes to the reliability of the laboratory test results obtained. Results from such samples collected and/or processed improperly cannot be considered valid and thus are of no benefit to the patient. There is widespread evidence that most laboratory testing errors occur in during the collection and processing of specimens.

Relevance for the Medical Assistant (Health-Care Provider)

Medical assistants and other health-care support personnel are often called upon to assist in the collection of, perform the collection of, instruct patients on the collection of and process samples for laboratory testing. To ensure the most reliable results for the patient, an in-depth understanding of specimen collection and processing is of paramount importance.

Case in Point

After a relatively smooth morning, your first patient after lunch is Wilma F., a 70-year-old woman. After reviewing Wilma's file, you notice that she was seen and treated 3 weeks ago, on what just happened to be on your day off, for a urinary tract infection. As you help Wilma get onto the scale to weigh her and then again when you place the blood pressure cuff on her arm, you notice that she is very hot to the touch. Your suspicions are confirmed when you take her temperature and it is 101.5°F! You ask Wilma to identify all symptoms she has been experiencing. She tells you that in addition to feeling hot all the time, she has a burning sensation and pain during urination. You document these details and tell Wilma that the doctor will be in to see her shortly and you leave the examining room. After the doctor examines Wilma, he asks you to collect her blood and assist Wilma in collecting urine for urinalysis and culture.

Questions for Consideration:

- What special considerations must be addressed to collect the blood in an appropriate manner in this case?
- What special equipment do you need to collect this blood sample?
- What type of urine sample should you assist Wilma to collect?
- How is this type of urine sample collected?
- Why are the blood and urine collection processes so important to implement in this case?

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Section II
Specimen Collection and Processing

As one might imagine, there are many things that must be considered in this situation to ensure that laboratory specimens are properly collected and processed. That being said, this section is divided into four chapters, each with a targeted focus.

Chapter 7: Overview of Specimen Collection and Processing consists of an in-depth discussion of the proper ordering and documentation associated with specimen collection. The name of the laboratory test(s) being ordered, methods of collection, patient preparation, and proper information for specimen labeling are all addressed. Specimen collections that involve a process known as the chain of custody are identified and described.

Chapter 8: Collection and Processing of Blood Samples explores the anatomy and physiology of the cardiovascular system as well as body sites both suitable and unsuitable for the collection of blood. The equipment and procedures for successful venipuncture and capillary puncture specimens and the process of creating peripheral blood smears is detailed.

Chapter 9: Collection and Processing of Urine Samples introduces the reader to the most common types of urine samples, including but not limited to catheterized, midstream-clean catch, first morning collection, and timed collection. The purpose of each specimen type is identified.

Chapter 10: Collection and Processing of Samples for Microbial Studies covers the general requirements for proper collection of samples for microbial studies. Samples described include throat swabs for strep screen and culture, sputum, urine, blood (using aseptic technique), wounds, and stool. Samples for saline wet preps and KOH preps are also described. Processing supplies, particularly media and techniques used to support growth of microorganisms, are covered.

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Chapter 7

Overview of Specimen Collection and Processing

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Specimen Ordering
- Required Items for All Laboratory Tests
- Test Specifics
  - *Medicare-Approved Panels*
  - *Standing Orders*
  - *Reflexive Testing*

Patient Identification
- Verification of Patient Identity
  - *Acceptable Patient Identifiers*
  - *Electronic Bar Codes*

Patient Preparation
Specimen Collection at Home
Items That Must Be Documented With Specimen Collection
Labeling Information
Chain of Custody
Summary
Time to Review
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

7-1 Define each of the key terms.

7-2 List the required items necessary for ordering any laboratory test.

7-3 Compare and contrast organ- or disease-specific panels that are approved by the Centers for Medicare & Medicaid services (CMS) to custom panels created by some laboratories.

7-4 Explain how standing orders are used in the laboratory.

7-5 Describe reflexive testing and explain how it may benefit patients.

7-6 Describe acceptable methods used to verify patient identity.

7-7 Demonstrate understanding of the importance of proper patient preparation prior to specimen collection.

7-8 Instruct patients in how to fast for a laboratory test.

7-9 Explain the importance of timing for peak and trough medication levels.

7-10 Explain why thorough documentation of specimen sources is so important.

7-11 Describe what to include when documenting specimen collection.

7-12 Describe appropriate labeling procedures for laboratory specimens.

7-13 Describe the critical aspects involved in a specimen collection that requires a chain of custody.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards Met

IV.P. Psychomotor Skills, Concepts of Effective Communication, #6: Prepare a patient for procedures and/or treatments.

ABHES Standards

10. Medical Laboratory Procedures, Specimens

KEY TERMS

1 or 2 hr postprandial (1 or 2 hr pp)
Chain of custody
Fasting
First morning void
Glucose challenge
Glucose tolerance test
Peak collection level
Random specimen
Reflexive testing
Standing orders
Trough collection level

Proper specimen collection and processing are critical components of laboratory testing as part of the preanalytical phase. As introduced in Chapter 1, certain factors in the collection and processing of specimens are universal: clear, concise patient preparation instructions, verification of patient identification, labeling procedures, and source documentation are all utilized for specimen collection procedures, regardless of the specimen source. To have a positive impact on patient treatment and outcomes, health-care employees who collect specimens or instruct patients to prepare for specimen collection must be knowledgeable about the techniques required for quality procedures.

SPECIMEN ORDERING

Laboratory testing begins with orders for specimens to be collected. Sometimes this step may ambiguous. Communication from the health-care provider may be unclear for various reasons. Examples of potential problems include verbal orders that are misunderstood, the use of nonstandardized abbreviations, and handwritten orders that are difficult to read. It is imperative that everyone involved with the process understand how critical the initial data used to order a test may be.

Required Items for All Laboratory Tests

A laboratory requisition form is used to order specific laboratory testing procedures, but the requisition is also used to provide information needed for reimbursement for these procedures. In addition, the test ordered must always be documented in the patient's chart.

Laboratory requisition forms may vary; some are organized with the tests listed in alphabetical order, whereas others may be organized with the tests listed in categories. Regardless of the organization of the laboratory requisition form, there are certain items that are essential for the collection process to be carried out appropriately. Many of these items are introduced in earlier chapters in the textbook. At a minimum the requisition form should include the following:

1. Complete demographic information for the patient. This includes the full name and birth date, the patient's gender, and the billing information.
2. Name of ordering health-care professional and documentation of any other additional agencies or health-care professionals that should receive copies of the laboratory report.
3. Date for the test collection. A specific date may be a critical factor, or there may be a bit more flexibility for the collection date. For instance, sometimes a laboratory test will be ordered to be checked for a medication blood level after the patient has been on that particular medication for several days; this date should be noted on the requisition form so that the patient knows when to have his or her blood drawn.
4. Specific documentation for the tests ordered. Each test must be marked carefully and completely with an X or a circle around the test. Each test will be accompanied by a current procedural terminology (CPT)

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code (printed on the requisition form next to the test), which may help with definitive choices when a provider is unsure of which test to order.

5. Diagnosis codes (in the form of an ICD-9 code) must be included with all laboratory tests ordered. Each test must have a diagnosis code specifically assigned to it, rather than one or two codes written randomly on the requisition form, as they may not apply to all the tests ordered. A diagnosis code is required for reimbursement.
6. If a test may be performed on more than one type of body fluid, it is very important to specify which fluid is to be used for the analysis. For instance, cortisol levels may frequently be performed using serum or urine; if the source is not documented correctly, then the patient may be required to return to resubmit the specimen.
7. When a medication level is ordered, the time of the last medication dose should be included on the requisition form, or the time of the requested blood draw should be specified. This may be critical for appropriate interpretation of the results.
8. If a wound culture is required, the source must be documented carefully. Specimen processing for microbiological specimens will vary depending on the site of the collection and the type of sample.
9.

Test Your Knowledge 7-1

List three items that must be present on a laboratory requisition form when ordering a specimen collection. (Outcome 7-2)

Test Specifics

Laboratory tests may be ordered in several ways. If a health-care provider feels that only one analyte needs to be tested to assist with diagnosis and treatment, he or she will order a single test, such as a glucose level for a patient who is being screened for diabetes, a potassium level for someone who is taking diuretics, or a hematocrit test for someone who is being treated for anemia. However, it is often beneficial for the health-care provider to order a group of tests that have been designed to enable providers to make more accurate diagnoses. These groups of tests may be *custom panels* that have been designed by a specific laboratory or specialty. A thyroid panel, for instance, may include three different tests that measure different aspects of thyroid function. These custom panels are not universal in nature; what is included in a custom panel by one laboratory will not necessarily be the same as those included in a panel by the same name with another laboratory.

Medicare-Approved Panels

Health-care providers must be careful when ordering panels, especially for those patients who have Medicare coverage for their payment source. The Centers for Medicare & Medicaid Services (CMS) has adopted several organ- or disease-specific panels that were designed by the American Medical Association (AMA). These panels will be the same no matter which laboratory uses them. These are the *only* panels that are always covered by Medicare without the need of an Advanced Beneficiary Notice of Noncoverage (ABN), even though some of the tests included in the panel have limited Medicare coverage. Care must be taken, however, to ensure that all the tests in the panel are really necessary for the treatment of the patient. If there is no documentation in the patient's chart to show necessity for the entire panel, the health-care provider may be held responsible for fraudulent ordering practices. The Medicare-approved organ- or disease-specific panels are the following:

- Basic Metabolic Panel(s); with or without ionized Calcium
- Electrolyte Panel
- Hepatic Panel
- Hepatitis Panel
- Comprehensive Metabolic Panel
- Renal Function Panel
- Lipid Panel

Laboratories must follow strict reimbursement rules for tests that are included in panels. The total cost of the panel may not exceed the totals of the separate tests included in the panel. Table 7-1 itemizes the tests included in the CMS-approved panels.

TABLE 7-1
Medicare-approved panels

Test Name	CPT Code
Comprehensive Metabolic Panel (CPT 80053)	
Albumin	82040
Bilirubin, total	82247
Calcium	82310
Carbon dioxide	82374
Chloride	82435
Creatinine	82565
Glucose	82974
Alkaline phosphatase	84075

Continued

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TABLE 7-1–cont'd

Medicare-approved panels

Test Name	CPT Code
Potassium	84132
Total protein	84155
Sodium	84295
Transferase, alanine amino (ALT, SGPT)	84460
Transferase, aspartate amino (AST, SGOT)	84450
Blood urea $$	84520
Hepatic Function Panel (CPT 80076)	
Total protein	84155
Albumin	82040
Alkaline phosphatase	84075
Transferase, aspartate amino (AST, SGOT)	84450
Transferase, alanine amino (ALT, SGPT)	84460
Bilirubin, total	82247
Total protein	84155
Basic Metabolic Panel With Ionized Calcium (CPT 80047)	
Glucose	82974
Potassium	84132
Sodium	84295
Blood urea nitrogen	84520
Calcium, ionized	82330
Carbon dioxide	82374
Chloride	82435
Creatinine	82565
Basic Metabolic Panel With Calcium (CPT 80048)	
Glucose	82974
Potassium	84132
Sodium	84295
Blood urea nitrogen	84520
Calcium	82310
Carbon dioxide	82374
Chloride	82435
Creatinine	82565
Renal Function Panel (CPT 80069)	
Glucose	82974
Potassium	84132
Sodium	84295
Blood urea nitrogen	84520
Calcium	82310
Carbon dioxide	82374
Chloride	82435
Creatinine	82565
Phosphorus	84100
Lipid Panel (CPT 80061)	
Cholesterol, total	82565
Triglycerides	84478
Electrolytes (CPT 80051)	
Potassium	84132
Sodium	84295
Carbon dioxide	82374
Chloride	82435

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Test Your Knowledge 7-2

How are custom panels similar to the Medicare-approved panels? (Outcome 7-3)

Standing Orders

Frequently health-care professionals will establish a set of **standing orders** for a patient, meaning that the patient is to have a specific test performed at a certain time interval for a period of time. For instance, a patient may need to have a potassium level checked every 3 months to monitor progress while on a certain medication. To set up the standing order, the physician will submit a requisition form to the laboratory with the initial potassium level ordered, but the requisition form may also include additional orders to repeat this test every 3 months. Some laboratories may also have a separate form used to transmit information about standing orders, rather than using the initial requisition form. Standing orders may not be continued for more than a year without a new order being written by the health-care provider. Recently, the practice of using standing orders has been questioned. In 2007, there was a change to the Physician Fee Schedule update, which specified a need for a separate order for every blood glucose test performed for patients in certain settings; the rule emphasized that a standing order was not sufficient for documentation of necessity for these patients. Even though this ruling addressed only blood

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glucose, it does serve as a warning for future policy changes in reference to standing orders.

Test Your Knowledge 7-3

A standing order for a theophylline drug level is written so that the patient is to have her medication level tested monthly for 18 months. Is this order acceptable? Why or why not? (Outcome 7-4)

Reflexive Testing

Another practice that may be used in a clinical laboratory is **reflexive testing.** In this situation, additional testing is automatically performed in response to certain abnormal results. An example of reflexive testing is the antibiotic sensitivity testing performed on culture samples. If a culture specimen has a positive result, an antibiotic sensitivity is automatically performed to provide the physician with additional knowledge about the best way to treat the infection. Without this reflexive option, it would be necessary to contact the physician and request a separate order for this sensitivity to be performed, which would delay patient treatment.

The addition of reflexive tests allows the ordering physician to receive additional information in a timely manner rather than waiting until the initial sample result is transmitted back to the physician and another order is placed for a new sample to be collected. In order for reflexive testing to be performed within the guidelines necessary for reimbursement, it is essential that the ordering physician is made aware of the tests included in the reflexive testing panel, and it is also necessary that the physician be offered the opportunity to order these secondary tests separately without the reflexive option if needed. These reflexive tests are to be documented clearly on the requisition form.

Test Your Knowledge 7-4

List one way that reflexive testing benefits patients. (Outcome 7-5)

PATIENT IDENTIFICATION

As presented in Chapter 1, the medical assistant or phlebotomist responsible for collecting samples for analysis plays a critical role. Appropriate patient identification and documentation of the collection procedures used are very important components of this preanalytical process.

Verification of Patient Identity

Whenever a patient presents for specimen collection, it is imperative that the person performing the collection verify the identity of the patient. This is the most important procedure in the specimen collection process. A minimum of *two* unique identifiers must be used to verify patient identification. Incorrect identification of the patient may result in specimen collection on the wrong patient, and misdiagnosis of the patient because of incorrect laboratory values. Drawing the wrong patient may even have fatal consequences if the treatment plan developed is incorrect.

Acceptable Patient Identifiers

- **Name:** It is always best to ask the patient to state his or her name; do not ask, "Are you Mrs. Smith?" as many patients may say "Yes" without actually hearing or understanding what was asked. Ask the patient to state his or her name, and spell the last name.
- **Birth date:** The patient must also state his or her birth date. It is possible to have two patients with the same first and last name, but improbable that they will also share the same birthday.
- **Social Security number or patient ID:** The use of the Social Security number is no longer recommended in most cases, with the exception of those who are receiving care in a government facility. A patient ID may have been assigned to the patient (especially in the case of managed care clients or hospital settings) and this may serve as a unique identifier.
- **Driver's license or other picture identification:** For legal specimens or those that are associated with employment, a picture ID is necessary for definitive identification. It is an acceptable means of identification in all situations, but not always necessary. In many office settings, the picture ID is part of the patient's permanent health record.

In hospitals or other settings in which the patient may not be able to converse with the collector, it is especially important that the identity of the patient is established before the specimen is collected. Never use the name written or printed above the bed as that of the patient. If the patient has an armband that has been placed on the wrist, this may be used if the patient is not capable of verifying his or her identity verbally. Never use an armband for identification if it is not securely placed on the patient's arm. If the patient is not wearing appropriate identification, it will be necessary to locate the health-care professional responsible

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for this patient (usually one of the nursing staff) and ask him or her to reband the patient and provide definitive ID before collecting the specimen. In this situation, be sure to document the name of the person who provided the identification.

Test Your Knowledge 7-5

Should an armband taped on the side of a hospital bed not be used for patient identification? (Outcome 7-6)

Electronic Bar Codes

Most likely, not many of us remember a time when we didn't have bar codes on our groceries and other items that we purchase in retail stores. Bar codes allow for more specific identification of the product purchased, and provide an efficient way to update prices and product inventory. The health-care industry has also found that the use of electronic bar codes helps to streamline the process of ordering laboratory tests. Using labels with electronic bar codes on the individual tubes and specimen containers helps to assure specimen identification and patient confidentiality, and allows for automated sorting and distribution of the specimens in large laboratory settings. It is especially important to verify identification in situations in which bar codes are used, because the individual specimen containers do not necessarily include the patient's name. The individual specimens may only be identified with the bar code or specimen ID label that represents that patient in the electronic system.

PATIENT PREPARATION

In addition to the verification of patient identity and demographic information, the medical assistant responsible for specimen collection must also verify whether the patient prepared appropriately for the test ordered prior to collection of the specimen. The reference ranges for laboratory tests are based on specific parameters, and if these were not in place for the patient being tested, their results may appear to be abnormal. Examples of specific preparation procedures include the following:

- Fasting: A **fasting** specimen may be required for tests such as blood glucose levels or lipid testing. Fasting means that the individual must go without food and any liquid other than water for 12 hours prior to the blood draw. The patient usually can take medication that has been prescribed if it poses a health risk to skip or postpone a dose until after the period of fasting. If the patient did take medication during this fasting period, it must be documented on the requisition form.
- 1 or 2 hr postprandial: A **1 hr pp or 2 hr postprandial (1 or 2 hr pp)** blood draw means that the specimen is collected 1 or 2 hours (respectively) after the individual eats a meal. These pp samples are usually used for blood glucose testing.
- Glucose challenge: When patients are screened for diabetes (especially for pregnant women) a **glucose challenge** may be ordered. In this situation the patient is given a drink that contains 50 g of glucose to ingest. One hour after the sweetened drink is consumed, the patient has his or her blood drawn again for a glucose test.
- Glucose tolerance test: A **glucose tolerance test** has several steps, and is usually only ordered if the fasting blood sugar, postprandial blood sugar, or glucose challenge results are abnormal. In this situation, a blood sample is drawn from the fasting patient. (The patient usually provides a urine specimen as well.) The patient is then asked to drink a solution that contains 100 g of glucose. Subsequent blood draws are performed every half hour for a period of 3 to 6 hours. (This process is presented in more detail in Chapter 17.)
- Timed drug levels: Reference ranges for blood medication levels are based on the rate at which different drugs are metabolized. Some types of medication peak in the bloodstream relatively quickly after ingestion, while others are slow acting. The medical assistant or phlebotomist needs to verify (and document) when the patient last took their medication before performing the collection. Some drugs may have therapeutic ranges that are very close to the levels where the drug may harm the body, and the timing of the draw is essential to determine whether the dosage should be changed. Drugs may also be ordered as **peak** or **trough collection levels.** These terms mean that the specimen is to be drawn when that particular drug is at the highest level (peak) and/or the lowest level (trough) in the bloodstream. Because each medication is absorbed and cleared from the body differently, the time after the last dose of the medication for the peak and trough draw will vary. The peak levels are generally obtained 1 to 2 hours after a drug is given; the trough levels are usually just before the next dose is due. With peak and trough levels, if the medical assistant does not verify the time of the last dose, the result may appear to be abnormal when in actuality the specimen was just drawn at the wrong time.
- Restricted diets for specimen collection: Some laboratory tests performed on blood, stool, and urine

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require that the patient restrict his or her diet before and/or during collection. Examples may be avoidance of rare meat for a few days before the collection of a stool specimen for fecal occult blood testing, or avoidance of certain foods during the collection time for a 24-hour urine specimen.

- Random specimens: **Random specimens** do not require special preparation before collection. The concentration of many chemical substances and cellular components present in the bloodstream does not change throughout the day, and can be collected at any time. This term is also used to describe urine specimens used for basic urinalysis testing, as well as many microbiology specimens.
- First morning void: During sleep, the body continues to create urine as the blood circulates through the kidneys. The **first morning void** specimen may be requested for specific urine chemistry tests, as the concentration of the analyte will be elevated in this specimen because it has been in the bladder all night. A microalbumin test is an example of a test that is often ordered as a first morning void specimen.

Test Your Knowledge 7-6

Mr. Rider comes in for a blood draw as part of his annual physical. The physician has ordered a fasting blood glucose level. Just as the medical assistant begins to prepare for the blood draw, she notices that the patient has a coffee mug in his hand. What should she ask him before she begins the draw? (Outcome 7-8)

SPECIMEN COLLECTION AT HOME

Urine, stool, and microbiology specimens are often collected by patients in the privacy of their homes and delivered to the laboratory soon after. With this type of collection, special care must be taken to educate the patient properly in reference to specimen collection and storage. Information for patient use should be offered verbally and in writing to ensure understanding and compliance. Collection and storage techniques should be verified again before accepting the specimen at the laboratory. For instance, a urine specimen collected at home should be collected using a sterile container, and the specimen must be refrigerated and transported to the laboratory as soon as possible after collection. In contrast, stool specimens collected for culture are not to be refrigerated, but should arrive at the laboratory within 2 hours of collection. Some specimens must remain protected from light, whereas other specimens need to be added to containers with preservatives immediately after collection. It is the responsibility of the medical assistant who accepts these specimens from the patient to verify that the collection and processing have been performed correctly. Prior patient education is critical for quality specimens.

ITEMS THAT MUST BE DOCUMENTED WITH SPECIMEN COLLECTION

Documentation does not end with the collection of the specimen. It is essential that details about the collection are recorded on the requisition form, as these details help to provide critical information that may affect the test results.

- **Who?** The initials (or other unique identification, such as an employee ID) for the person who collected the specimen must be documented on the requisition form. This information may be critical if there are any problems with the specimen. This information is also placed on the blood tube after collection while in the presence of the patient.
- **What?** What type of specimen was collected? For blood specimens, there should be documentation of the type of specimen collected because venous, arterial, and capillary samples may have different reference ranges for a specific analyte. Reimbursement for the collection may also vary with the type of blood specimen. For urine specimens, there should be documentation as to whether the sample is a random or timed urine collection, and the method used for the collection process. (This is further clarified in Chapter 9.) Body fluids (such as amniotic fluid or synovial fluid) are especially difficult to identify by sight, so clarification of the specimen type is essential at the time of collection; reference ranges are very different for each type of body fluid.
- **When?** Documentation of the date and time of collection is critical. The time must include a.m. or p.m., or military time may be used. Many chemical analytes change drastically with time once the blood has left the body, and these natural postcollection changes may be misidentified as part of a disease process if the specimen is not processed in a timely fashion. For timed collections, it is essential. The date and time of collection are added to the requisition form as well as the tube after a blood draw is complete.
- **Where?** The site of collection must also be documented. For blood draws, this does not need to be absolutely specific; a general location such as right

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hand or left arm will do. This documentation can be very helpful if there are complications at the draw site. For culture specimens, documentation of the collection site should be as specific as possible, because the normal florae present in different areas of the body are not the same. The physical location of the culture collection site needs must be specified (right arm, left leg, opening of fistula, etc.) as well as the type of wound or collection procedure used. A superficial wound sample is different from that collected from a deep puncture wound, and a specimen collected by aspiration is different from a specimen collected by squeezing a pustule. For instance, bacteria that are common on the surface of the skin are *not* part of the normal florae in a deep wound, even if the specimens are both taken from the right great toe.

Test Your Knowledge 7-7

Why is it important to document that a blood specimen was obtained from a capillary puncture rather than a vein? (Outcome 7-10)

LABELING INFORMATION

All collection containers must be labeled immediately after collection, meaning that the specimen must be labeled in an outpatient setting while in the presence of the patient and before another outpatient requisition form is accepted. In an inpatient setting, the specimen labeling process must be complete before the phlebotomist leaves the patient's room. Labeling may involve writing with an indelible pen directly on the preaffixed label on the tube after collection, or by applying a label that has been generated by a computer and adding a few items. Computer-generated labels often include bar codes that may be read by the instruments used for testing. Tubes should never be prelabeled before specimen collection, as this can lead to incorrect patient identification if the collection is unsuccessful and the tubes are not discarded, or if there is more than one patient present in a blood drawing area at the same time. Specimens that are mislabeled can potentially cause serious harm to patients when inaccurate patient results are generated.

The specimen label must include the following information:

- The name of the patient and a unique identifier number. The ID number is generated by the computer at the time of the blood draw, or it may be part of the requisition form available as a small peel-off label. If the patient number is not available, the date of birth may be used instead. Two patient identifiers are required.
- Date and time of collection
- Initials (or other unique ID) for the person who performed the specimen collection
- Other required information may include documentation of a peak or trough draw, or at what time a specimen is taken for a glucose tolerance test. Even though the time of the draw should indicate which specimen is in the tube, it is a good idea to document this in more than one way to avoid any confusion.

For patients who collect their specimens at home, the person who accepts the specimen at the laboratory must verify that the specimen is labeled appropriately while in the presence of the patient. If a patient drops off a specimen that is not labeled and no one is present to accept the specimen, it will need to be recollected.

Test Your Knowledge 7-8

List two items that must be included on the label after a blood specimen is collected. (Outcome 7-12)

CHAIN OF CUSTODY

Sometimes blood or urine is collected in situations in which the test results may be used as legal evidence. Blood may be collected for DNA analysis or blood alcohol level readings, whereas urine may be tested for drugs of abuse. The tests may be ordered in preemployment situations, in the case of on-the-job accidents or suspected drunk driving, or for some athletes. In these situations, it is imperative that medical assistants follow their facility's guidelines very carefully as they perform their duties. The specimens that are collected must have written documentation for their processing and storage from the point of collection through the testing and reporting process. It must be evident that a responsible individual had possession of the specimen, or had secured the specimen at every step of the process. The record of the individuals who have access to the specimen is called the **chain of custody.** A chain of custody is a physical object: a form that is filled out and signed each time that the specimen changes hands. An

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example of a chain of custody form may be found in Figure 7-1. Critical components of the process include the following:

1. **Identification of the patient:** This is the most important part of the process. Sometimes patients are not willing participants in the process, as they may have been placed under arrest, or may have been involved in some sort of incident at their place of work. If the patient is not able (or willing) to show appropriate identification, the arresting officer or supervisor must identify the patient and it must be documented on the form.
2. Explanation of the process and witnessed signed consent form.
3. **Secure collection area and standardized process:** Especially in the case of urine specimens, there are very specific procedures that must be followed to eliminate the opportunity for patients to add water or other substances to the specimen, or to substitute a specimen that they may have brought from outside the premises. For instance, the patient is not allowed to take any coats or purses into the restroom during the collection. The handles of the faucet in the collection area may be secured with tamper-evident tape, or the water supply may be shut off from outside the room. In addition, the toilet water always has a bluing agent added to avoid an opportunity to take water from the toilet unnoticed. The specimen temperature is documented immediately when the collection is complete as a means of quality assurance.
4. **Assignment of a sample number:** Legal specimens should not be identified by name after the initial collection process. This helps to protect the patient's confidentiality, and also limits the opportunities for someone to tamper with a specific specimen.
5. **Securing the specimen and protecting against tampering:** The specimen has a tamper-evident seal that is affixed at the time of collection. The patient and the collector initial this seal and the specimen is sealed in the presence of the patient. If this seal is broken when the sample is accessed for testing, the chain of custody is invalidated.
6. **Documentation of processing:** The specimen must remain in a secure location at all times. The chain of custody form provides an opportunity to document where the specimen was stored, and who placed it in that location at each step of transfer. Legal specimens must be kept in a locked location with limited authorized access until they are tested. The documentation continues until the time that the specimen is disposed of.

There may be times when the medical assistant is called to testify about the collection process of a legal specimen. If the chain of custody process is followed carefully, there should be no problem with testifying regarding the specimen processing. Poor documentation may be reason for dismissal of a legal case, and could have serious repercussions.

Test Your Knowledge 7-9

What are two methods used to protect a legal specimen from potential tampering? (Outcome 7-13)

POINT OF INTEREST 7-1
DOT drug screening

Urine may be tested for drugs of abuse for many reasons. The test is a common part of preemployment screening for many corporations. Most of the large retail store chains now require drug screening as a preemployment procedure, and some of them also use random drug screens as well.

There are also times when the federal government requires drug screen testing. The Omnibus Transportation Employee Testing Act of 1991 set a standard that requires drug and alcohol testing for employees who are employed in professions that the government has designated as "safety-sensitive." This regulation potentially affects more than 10 million individuals. These employees may be working in the following areas:

- Those in the trucking industry
- Railroad workers
- Bus drivers or other mass-transit employees
- Pilots and other aviation employees
- Employees in other types of public transportation
- Those who work on public pipelines

The U.S. Department of Transportation (DOT) has set standards concerning who will be tested, as well as the policies and procedures to be followed for these individuals. The collection process is even more critical in these situations, and the laboratory testing may be performed only at laboratories that have been approved by the DOT. Special chain of custody forms are used for the collection process, and the procedures for processing of the paperwork are very specific.

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NON FEDERAL DRUG TESTING CUSTODY AND CONTROL FORM

18290

SPECIMEN ID No.

STEP 1: COMPLETED BY COLLECTOR OR EMPLOYER REPRESENTATIVE

A. Employer Name, Address, I.D. No.

ABC Temporary Employment Agency 1 Main Street, Hollywood, NY 11111

B. MRO Name, Address, Phone and Fax No.

C. Doyel 6291 Park Ave, Hollywood, NY 11111

C. Donor Name John A. Smith, Jr. Donor SSN or Employee I.D. No. 123888

D. Reason for Test: ☐ Pre-employment ☒ Random ☐ Reasonable Suspicion/Cause ☐ Post Accident ☐ Return to Duty ☐ Follow-up ☐ Other (specify) _____

E. Drug Tests to be Performed: ☒ Hair 5 Drug Panel ☐ Urine 5 Drug Panel ☐ Other (specify) _____

G. Collection Site Address: 1 Main Street Hollywood, NY 11111

STEP 2: COMPLETED BY COLLECTOR

Read specimen temperature within 4 minutes. Is temperature between 90° and 100°F? ☐ Yes ☐ No, Enter Remark

Specimen Collection: ☐ Split ☐ Single ☐ Non Provided (Enter Remark)

☒ HEAD HAIR
☐ URINE
☐ BODY _____

REMARKS

STEP 3: Collector affixes bottle seal(s) to bottle(s). Collector dates seal(s). Donor initials seal(s). Donor completes STEP 5 on Copy 2 (MRO Copy)

STEP 4: CHAIN OF CUSTODY - INITIATED BY COLLECTOR AND COMPLETED BY LABORATORY

I certify that the specimen given to me by the donor identified in the certification section on Copy Z of this form was collected, labeled, sealed and released to the Delivery Service noted in accordance with applicable Federal requirements.

X John Doe — Signature of Collector

2:00 PM (AM / PM) — Time of Collection

John Doe — (PRINT) Collectors Name (First, MI, Last)

01/31/2012 — Date (Mo, Day, Yr)

SPECIMEN BOTTLE(S) RELEASED TO:

UPS Next Day Delivery — Name of Delivery Service Transferring Specimen to Lab

RECEIVED AT LAB:

X _____ Signature of Accessioner

(PRINT) Accessioner's Name (First, MI, Last) _____ Date (Mo, Day, Yr)

Primary Specimen Bottle Seal Intact

☐ Yes
☐ No, Enter Remark Below

SPECIMEN BOTTLE(S) RELEASED TO:

STEP 5a: PRIMARY SPECIMEN TEST RESULTS - COMPLETED BY PRIMARY LABORATORY

☐ NEGATIVE ☐ POSITIVE for: ☐ MARIJUANA METABOLITE ☐ CODEINE ☐ AMPHETAMINE ☐ ADULTERATED
☐ DILUTE ☐ COCAINE METABOLITE ☐ MORPHINE ☐ METHAMPHETAMINE ☐ SUBSTITUTED
☐ REJECTED FOR TESTING ☐ PCP ☐ 6-ACETYLMORPHINE ☐ INVALID RESULT

REMARKS _____

TEST LAB (if different from above) _____

I certify that the specimen identified on this form was examined upon receipt, handled using chain of custody procedures, analyzed, and reported in accordance with applicable Federal requirements.

X _____ *Signature of Certifying Scientist* (PRINT) Certifying Scientist (First, MI, Last) _____ Date (Mo, Day, Yr)

STEP 5b: SPLIT SPECIMEN TEST RESULTS - (IF TESTED) COMPLETED BY SECONDARY LABORATORY

Laboratory Name

Laboratory Address

☐ RECONFIRMED ☐ FAILED TO RECONFIRM - REASON _____

I certify that the split specimen identified on this form was examined upon receipt, handled using chain of custody procedures, analyzed, and reported in accordance with applicable Federal requirements.

X _____ Signature of Certifying Scientist (PRINT) Certifying Scientist (First, MI, Last) _____ Date (Mo, Day, Yr)

Figure 7-1 An example of a chain of custody form. The top copy contains the name of the patient, but this copy does not follow the specimen as it progresses to the testing phase. The copies that are used with the specimen after it is input into the computer are designated only by the specimen ID number.

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SUMMARY

Specimen collection and processing are critical components of the laboratory testing. Care must be taken to fill out the request for testing in the proper manner, educate the patient appropriately for necessary preparation, and thoroughly document the collection procedure. It is also necessary to label the specimen using recommended procedures so that there are no potential problems with identification as the testing process continues. The type of collection, the type of specimen, and the date and time of collection are critical components that must be logged on the requisition form after collection. In legal situations, care must be taken to follow established procedures to ensure that specimens are kept safe from tampering until they are tested and the results are reported. This process uses a chain of custody form, which must be filled out by anyone who has access to the specimen during and after collection.

TIME TO REVIEW

1. When is a trough blood level drawn? Outcome 7-1
2. Which of these items does not need to be included on a complete laboratory requisition form? Outcome 7-2
   - **a.** ICD-9 code(s)
   - **b.** Ordering physician's name
   - **c.** Cost of tests
   - **d.** Demographic information for the patient
3. How are CMS panels different from custom panels created by independent laboratories? Outcome 7-3
   - **a.** The custom panels include fewer tests
   - **b.** The CMS panels have been approved by the AMA
   - **c.** The reimbursement rates are better for the custom panels
   - **d.** They are essentially the same
4. True or False: Reflexive testing causes excessive time to be spent before results are available to the ordering health-care provider. Outcome 7-5
5. True or False: All medication is absorbed and used by the body at the same rate. Outcome 7-9
6. List three items that must be documented on the requisition form after a specimen is collected. Outcome 7-11
7. True or False: It is acceptable to use a computer-generated label on a tube after collection as long as it includes the basic required information. Outcome 7-12

Case Study 7-1: Standing orders

Mr. Johnson comes into the laboratory to have his potassium level checked. He has a standing order to have this test performed every 3 months because of a medication that he takes for a heart disorder. When he arrives at the laboratory, the phlebotomist checks the records for Mr. Johnson in the computer system. He informs Mr. Johnson that he cannot draw his blood today because his standing order has expired.

1. What does the phlebotomist mean by stating that the standing order has expired?
2. What needs to occur before Mr. Johnson can have his blood drawn for the potassium test?

Case Study 7-2: Labeling

Cassy Jones is a medical assisting student who is training in the laboratory. She is trying very hard to get all the information correct for every situation, and she tells her trainer that she is working on anticipating the needs of the practice so that she can be better organized. When her trainer returns from lunch one afternoon, she finds that Cassy has labeled blood tubes for the expected blood draws for the afternoon. Cassy's trainer tells her that although she can see that her intentions were good, this is an unacceptable practice.

1. Why is the prelabeling of the tubes an unacceptable practice?

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RESOURCES AND SUGGESTED READINGS

"University of Washington Laboratory Testing Policies"
Very specific information about testing and collection processes designed for use by practitioners http://depts.washington.edu/labweb/PatientCare/Policies/index.htm

"Errors in Laboratory Medicine"
Information about common laboratory errors including all phases of the testing process http://www.clinchem.org/cgi/content/abstract/48/5/691

"Laboratory Test Ordering and Documentation; List of Do's and Dont's http://www.cap.org/apps/docs/pt_checkup/pol_library/laboratory_test_ordering.pdf

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Chapter 8

Collection and Processing of Blood Samples

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Anatomy and Physiology of the Cardiovascular System
- The Heart
- Blood Vessels
  - *Arteries*
  - *Veins*
  - *Capillaries*

Site Selection
- Most Commonly Used Veins
- Appropriate Capillary Puncture Sites

Contraindications and Areas to Avoid
- Scars and Tattoos
- Mastectomy Considerations
- Intravenous Fluids
- Bruises and Hematomas
- Varicose Veins
- Central Lines and Fistulas
- Edematous Areas
- Obese Patients

Venipuncture Equipment
- Tourniquets
- Gloves
- Sharps Biohazardous Waste Containers
- Alcohol and Gauze Pads
- Needles
- Additional Supplies

Methods Used for Venipuncture
- Evacuated Tube System
- Syringe Method
- Winged Infusion or Butterfly Method

Blood Collection Tubes
- Color Coding of Tubes
- Types of Additives

Order of Draw for Venipuncture

Capillary Punctures
- Order of Draw for Capillary Puncture

Preparation for Blood Collection
- Specimen Processing
- Obtaining Serum for Testing
- Obtaining Plasma for Testing
- Whole Blood Specimens
- Unacceptable Specimen Types

Potential Negative Outcomes of Venipuncture and Capillary Puncture
- Inability to Draw Blood
- Fainting Patients
- Rolling Veins
- Hematoma Formation
- Collapsing Veins
- Nerve Damage
- Infection

Other Processing Procedures

Preparation of a Peripheral Blood Smear for Staining

Wright's Stain Procedure

Summary

Time to Review

Resources and Suggested Readings

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Learning Outcomes

After Reading this Chapter, the Successful Student will be able to:

8-1 Define the key terms.

8-2 Explain the route used as blood moves through the heart.

8-3 Compare and contrast the qualities of veins and arteries.

8-4 Examine the ways that capillaries differ from veins and arteries.

8-5 Locate the most commonly used veins for drawing blood specimens, and explain why they are the best choice for this procedure.

8-6 Describe where capillary blood draws may be safely performed.

8-7 List the major contraindications for blood draws, as well as areas to be avoided.

8-8 List and describe the supplies necessary to perform successful venipuncture and capillary punctures.

8-9 Differentiate when the different methods of venipuncture (evacuated tube system, syringe system, or butterfly system) might be used.

8-10 Describe the significance of the tube stopper colors when drawing blood.

8-11 Explain the order of draw for specimen collection, and describe how it may be different with the various collection techniques.

8-12 Analyze techniques to be used with different age groups when performing venipuncture or capillary puncture.

8-13 Explain why capillary punctures may be preferred as a blood draw technique in some circumstances, and provide examples.

8-14 Summarize appropriate preparation techniques for blood draw procedures.

8-15 Successfully perform venipuncture and capillary puncture procedures using the process outlined in the textbook.

8-16 Demonstrate the ability to create a blood smear on a slide that would be suitable for staining, and explain why staining is important for examination of blood samples.

8-17 Explain how to process samples for various laboratory tests ordered.

8-18 Analyze the differences between serum and plasma.

8-19 Provide examples of inappropriate specimens, and describe how these issues may be avoided.

8-20 Describe how negative outcomes may be avoided when drawing blood.

CAAHEP/ABHES STANDARDS

CAAHEP Standards:

I.C.I.4: List major organs in each body system
I.C.I.5: Describe the normal function of each body system
I.P.I.2: Perform Venipuncture
I.P.I.3: Perform Capillary Puncture
I.A.I.1: Apply critical thinking skills in performing patient assessment and care
III.P.III.3: Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Medical Office Laboratory Procedures: Collect, label and process specimens: Perform venipuncture
- Medical Office Clinical Procedures: Apply principles of aseptic techniques and infection control
- Medical Office Clinical Procedures: Use Standard Precautions

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KEY TERMS

Antecubital area
Anticoagulants
Arteries
Arterioles
Basilic vein
Bevel
Butterfly system
Capillaries
Capillary action
Capillary puncture
Capillary tubes
Cardiovascular
Cephalic vein
Clot activators
Contraindications
Edema
Evacuated tube system
Flanges
Gauge
Hematoma
Hemoconcentration
Hemolysis
Interstitial
Lipemia
Lumen
Mastectomy
Median cubital vein
Microcollection containers
Morphology
Multi-sample needle
Palpation
Plasma
Plasma separator tubes (PST)
Quality not sufficient (QNS)
Serum
Serum separator tubes (SST)
Sharp
Short draw
Syringe system
Tourniquet
Vacuum
Vasodilation
Vasovagal syncope
Veins
Venules
Winged infusion set

The majority of laboratory testing is performed on blood specimens. As part of the preanalytical process, medical assistants and phlebotomists are responsible for greeting and identifying patients, verifying patient identification, making appropriate site selections for collection, using correct collection procedures, and processing specimens prior to the testing stage. It is essential that the health-care professional who performs these duties understands how to execute them correctly, as the potential impact of these processes is profound if they are performed improperly. This chapter provides details about how to collect and process various blood specimens, including necessary knowledge of the anatomy and physiology of the cardiovascular system, an introduction to the various tools used for obtaining blood, and information about how to avoid negative outcomes during the collection process. Procedures for processing specimens after collection are also presented.

ANATOMY AND PHYSIOLOGY OF THE CARDIOVASCULAR SYSTEM

In order to consider the various methods used to obtain blood specimens, it is important to understand the anatomy and physiology of the **cardiovascular** system. Essentially, all the body systems are connected, or linked, by the cardiovascular system, because it offers a means of transportation to and from all the cells of the body. *Homeostasis* is a state in which the body is healthy and in balance. For homeostasis to be maintained in our bodies, the cardiovascular system must transport water, nutrients, waste products, chemicals, and hormones everywhere within the body. The immune system is also dependent on the function of the cardiovascular system. In addition, circulation of the blood helps to keep the body's temperature within normal limits, contributing to homeostasis.

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The Heart

The heart is the beginning and the end of the cardiovascular system, and is approximately the size of a closed fist. It is made of very strong cardiac muscular tissue. Within the structure of the heart are four chambers. The upper two chambers of the heart are the *atria* and the lower two chambers of the heart are the *ventricles*. The two sides of the heart are separated by a wall (called the *septum*) and the atria and the ventricles on each side of the heart are separated by *valves*, which keep the blood from flowing backward within the structure. Figure 8-1 allows us to follow the path of the blood flow through the heart and lungs.

1. Oxygen-poor blood flows into the right atrium through two large veins known as the superior vena cava and inferior vena cava.
2. As the heart contracts, the blood flows through the tricuspid valve (which separates the chambers) into the right ventricle.
3. From the right ventricle, the blood passes the pulmonary semilunar valve and enters the right and left pulmonary arteries. These arteries take the blood into the lungs for oxygenation. (These are the only arteries in the body that do not carry oxygenated blood.)
4. Once the blood has passed through the lungs, where it exchanges oxygen for carbon dioxide, the blood flows back onto the left atria through the right and left pulmonary veins. (These veins are the only veins in the body that carry freshly oxygenated blood.)
5. From the left atria, the blood passes through the bicuspid valve and enters the left ventricle. The left ventricle is the part of the heart where the muscular walls are the thickest, as the left ventricle is responsible for pumping the blood out of the heart into the arterial system to circulate through the body.
6. The blood passes through the aortic semilunar valve, finally exiting the heart through a very large artery, known as the aorta.

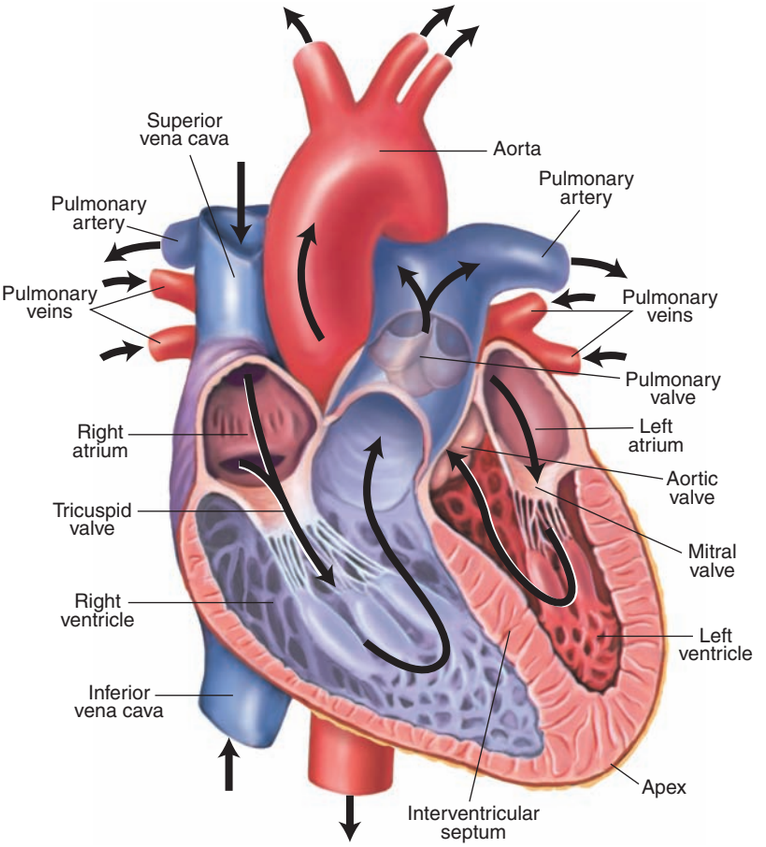

Figure 8-1 The pathway followed by the blood as it circulates through the heart, lungs, and vessels. *Reprinted with permission from Eagle S, Brassington C, Dailey C, and Goretti C:* The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. *Philadelphia: FA Davis, 2009.*

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7. In a single heartbeat, the heart goes through two stages: *systole (*the contraction of the heart muscle) and *diastole* (the relaxation of the heart muscle). During ventricular systole, the blood pressure increases, pushing the blood through the arterial system and adding pressure to the walls of the arterial vessels, causing them to expand. The diastolic (relaxation) phase allows the blood pressure to decrease and the arterial walls to adjust back to their normal size. We feel this increase and decrease in the blood pressure as a patient's pulse in the arteries of the body.

Blood Vessels

There are three types of blood vessels that make up the cardiovascular system: arteries, veins, and capillaries. Each type of vessel has unique characteristics that enable it to perform specific tasks. Blood specimens may be collected from any of these vessels. Figure 8-2 shows the relationship between the types of blood vessels that make up the cardiovascular system.

Test Your Knowledge 8-1
What organs and/or body systems make up the cardiovascular system? (Outcome 8-1)

Arteries

Arteries are the vessels that carry oxygenated blood away from the heart. Arterial walls are quite muscular and have more elasticity than do venous walls, and as the blood flows through the arteries (expanding and relaxing the vessels) it is felt as a pulse. There are three layers that make up the walls of both arteries and veins, but the walls of the arteries are thicker and stronger than those of the veins, and the arterial walls have more flexibility. Arteries get smaller and smaller as they branch through the body away from the heart. Smaller arterial vessels branch into **arterioles,** which then lead into capillaries. The blood that travels through arteries is brighter red than that which travels through the veins or capillaries due to the high level of oxygen present in the arterial red blood cells.

Veins

Veins carry blood back to the heart from the systemic circulation. Because this is not a process that actually follows the laws of gravity, the venous vessels have one-way valves that help to keep the blood from pooling in the extremities. The walls of the veins are made up of

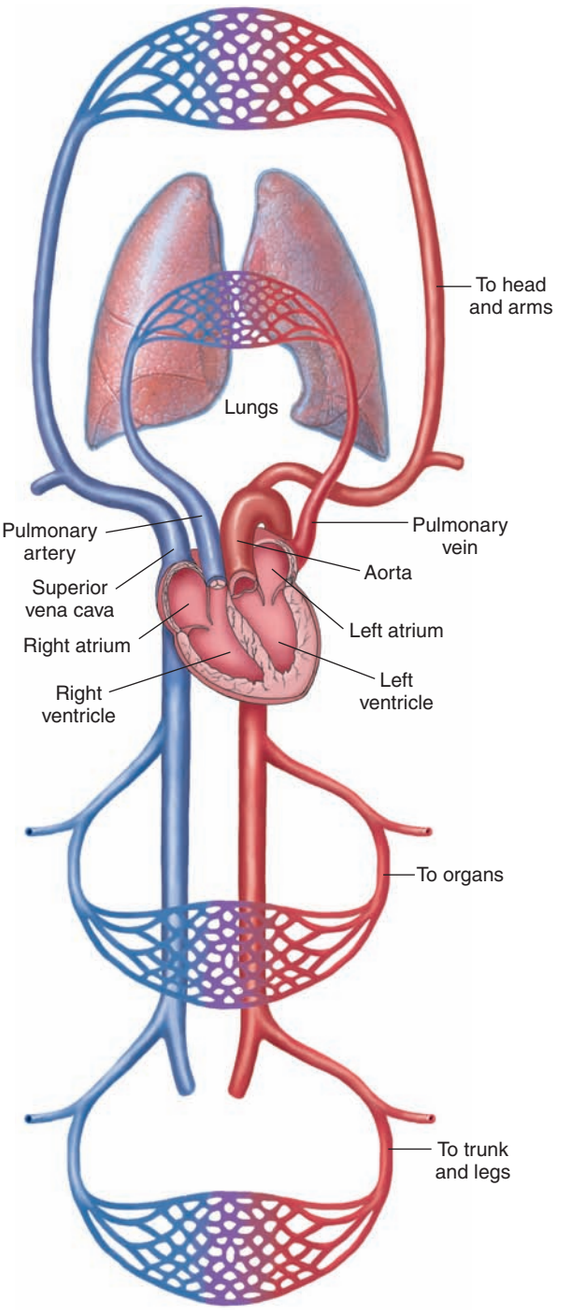

Figure 8-2 The relationships between the arteries, veins, and capillaries. *Reprinted with permission from Eagle S, Brassington C, Dailey C, and Goretti C:* The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. *Philadelphia: FA Davis, 2009.*

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three layers, but the layers are thinner and less muscular than are those of the arterial system. Veins require skeletal muscle movement to propel the blood back to the heart. Veins are smallest where they are attached to the capillaries; these tiny vessels are called **venules.** The veins become larger and larger as they approach the heart. The blood that travels through the veins has less oxygen than that in the arterial or capillary system, and is darker red in color. Veins do not have a pulse, and when palpated, veins feel less rigid than arteries.

Capillaries

Capillaries are so small that they can be seen only with a microscope. The walls of capillary vessels are made up of a single layer of epithelial cells. They are designed to link the arterial vessels to the venous vessels, and the blood that flows through the capillaries is a mixture of venous and arterial blood. As blood travels through the arteries to the arterioles, there is less and less room for the entire volume of blood to make it through the vessels. As the vessels get smaller, more fluids are pushed out of the vessel and into the **interstitial** spaces between the cells surrounding the blood vessels. By the time that the blood makes it to the capillaries, the size of the blood vessel has often reduced to the point that there is room for only one red blood cell at a time to make it through. The capillary beds are the only place in the body where exchange of nutrients, gases, and other molecules may occur, because the liquid portion of the blood is in direct contact with the cells around the vessels. As the capillaries join back with the venous system, they begin to get larger in diameter, and the vessels become venules, which gradually increase in diameter to become veins. Due to their small size, capillaries do not cause a pulse that can be felt.

Test Your Knowledge 8-2
What is one way that veins are different from arteries? (Outcome 8-3)

Test Your Knowledge 8-3
Are capillaries approximately the same size as arteries and veins? (Outcome 8-4)

SITE SELECTION

Appropriate site selection for venipuncture procedures is essential to obtain a blood sample that is acceptable for testing, and to avoid negative outcomes for the patient. The most common area for venipunctures to be performed is the **antecubital area** of the arm, which is the area immediately in front of (the anterior side of) the elbow.

Most Commonly Used Veins

There are several veins in the antecubital area that may be successfully used for withdrawing blood. The **median cubital vein** (Fig. 8-3) is best for venipuncture because it is usually large and well anchored. This means that the median cubital vein doesn't usually move when the needle is inserted. The **cephalic vein,** which is located on the thumb (lateral side) of the antecubital area, and the **basilic vein,** on the little finger (medial side) of the antecubital area, may also be acceptable for venipuncture. If it is necessary to consider these two alternative venipuncture sites, the median cubital vein is the first choice; if this vein cannot be felt, the second choice would be the cephalic vein. The basilic vein is the last choice in the antecubital area because of its close proximity to the brachial artery and median nerve. The basilic vein is also not anchored as well as the other antecubital veins, so it has more of a tendency to move, or roll away, during the puncture.

When performing phlebotomy, finding a vein is one step that requires practice and experience. Applying a tourniquet may allow the vein to be more prominent. **Palpation,** which uses touch to feel for a vein, may be used with or without the tourniquet application to determine whether a vein is suitable for a blood draw. Sight may be helpful initially, but if a vein cannot be felt, that vein should not be used for a blood draw. Palpation is performed by using the tips of the gloved fingers (never the thumb) in a pushing manner as the fingers are moved across the arm. An acceptable vein should have some "bounce," like a soft rubber tube, when palpated. A tendon will feel flatter and harder than a vein, without

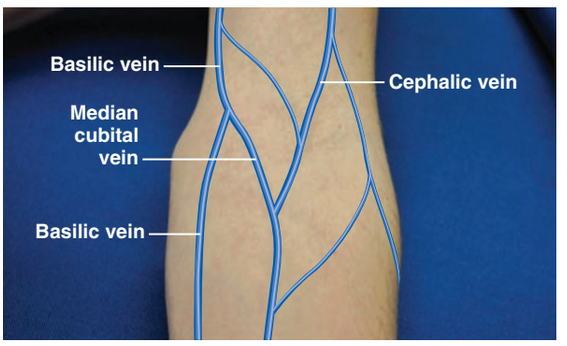

Figure 8-3 Antecubital area with vein selection; identification of the median cubital, cephalic, and basilic veins.

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any elasticity, and an artery will feel like a taut rubber band. Veins may be differentiated from arteries because of the pulse that is felt in an arterial vessel. While feeling for the vein, it is important to establish the depth and size of the vessel, as well the direction of the vein. When the needle is inserted into the arm, it must follow the direction of the vein, and be inserted to the correct depth at which it will be in the vein rather than resting above or piercing through the vein. The angle of insertion is also very important to allow for the blood to enter the vein when it is pierced.

Venous patterns vary from person to person, as the anatomy of each patient is unique. In addition, some patients have vessels that are much more prominent in one arm than in the other. A venipuncture should not be attempted if the health-care professional is not sure whether the vein is suitable for the procedure or until the other arm has been checked for potential sites. If there is no suitable vein identified in the antecubital area of either arm, the back of the hand may also be considered for obtaining a sample. It is especially important to anchor the blood vessels of the hand before inserting the needle, as these vessels are located close to the surface of the skin and often roll away when the needle is inserted. The hand veins are also more prone to bruising and hematoma formation. Venipunctures should not be performed on the inside (or underside) of the wrist because of the presence of various nerves, tendons and ligaments, the close proximity of the radial artery, and the small size of the veins present in this area.

If an acceptable vein cannot be located, it may be necessary to encourage the vessels to become more prominent before venipuncture is attempted. To encourage **vasodilation,** a warm compress may be applied to the area, or the desired site may be massaged. Slapping, thumping, or flicking the draw site is not recommended. Lowering the arm down below the level of the heart may also allow the veins to become more evident. Tourniquet application is definitely beneficial, but it is important to remember that a tourniquet may stay on for a maximum of only 1 minute before it should be removed. A blood pressure cuff (stand-alone type) set at 40 mm Hg of pressure may also be useful in coaxing the veins to become more prominent.

Test Your Knowledge 8-4

What area of the arm should be the first choice for venipuncture? (Outcome 8-5)

Appropriate Capillary Puncture Sites

Capillary blood draws (also known as dermal or skin punctures) may be used for blood collection when the required volume of blood needed for testing is small. The capillary beds in the fingers and heel are the sites generally used in the laboratory. The fingers are often used as sites for capillary punctures for adults and children over the age of 1 year. The puncture should be made on the fleshy central surface on the palmar side of the finger. Capillary draws should never be performed right on the tip of the finger, or on the extreme lateral side(s) near the fingernail, because of the close proximity to the bone. The capillary device should be oriented so that the puncture into the skin is perpendicular to the fingerprints; doing so means that the blood won't pool into the lines of the fingerprint during the collection process. Figure 8-4 shows where it is safe to perform a capillary puncture on a fingertip.

For infants (children below the age of 1 year) capillary blood draws are performed on the heel of the foot. The fingers on infants should not be used for capillary punctures, as there is not enough tissue to make this a safe choice while avoiding potential damage to the bone. The central area of the infant's heel, the arch of the foot, the ball of the foot, and the toes should *never* be used for blood draws. The capillary draw should be done only on the most medial and lateral section of the bottom of the heel. Figure 8-5 shows the safe areas for capillary punctures on an infant's heel. The bone of the foot may be damaged if the procedure is performed incorrectly and *osteomyelitis* (inflammation and/or infection of the bone and bone marrow) may result.

In all capillary draw situations, it is imperative that the site is warmed thoroughly before the process begins. It is also helpful if the hand or foot is held below the level of the heart. Massage may also benefit the process, as it

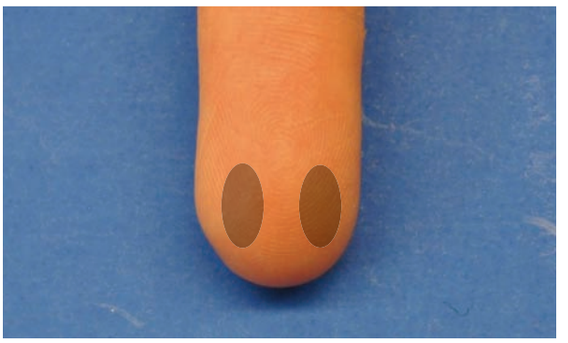

Figure 8-4 Locations for capillary draws for fingers.

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POINT OF INTEREST 8-1
Newborn screening

Each state provides newborn screening to detect disorders that would cause irreversible damage or death if undetected for an extended period of time. These disorders (for the most part) are not visible at birth; the babies appear to be healthy until the damage has already occurred. Irreversible neurological or musculoskeletal damage will result if these diseases are not detected. Most states require that the babies be tested prior to discharge from the hospital, with a recommendation for a second screening 7 to 14 days later. Examples of disorders that may be detected with screening include the following:

- Phenylketonuria
- Maple syrup urine disease
- Carnitine uptake deficiency
- Congenital hypothyroidism
- Cystic fibrosis
- Various hemoglobinopathies
- Galactosemia

The specimen collection usually includes a capillary sample taken from a heel stick. Blood may also be drawn from the veins on the back of the hand and applied to the collection paper. Special filter paper is used for the collection process, and the sample must be handled appropriately to avoid erroneous results or rejection of the specimen.

Test Your Knowledge 8-5

Are capillary draws always performed on the fingers? (Outcome 8-6)

Figure 8-5 Locations for capillary draws in the heel of an infant.

will help to increase the blood supply to the area. When a capillary specimen is submitted for testing, it is important to document that the specimen came from a capillary draw rather than a venipuncture because the reference ranges for capillary blood samples are not the same as those for venous blood.

Blood used for capillary samples should be free flowing. It is important that the area immediately adjacent to the puncture site is not squeezed to increase the blood flow, as this will contaminate the sample with interstitial fluid. This fluid from between the cells has a different concentration of many chemical substances and will dilute the cell counts for hematology specimens. Massaging the finger well above the puncture site will help increase the blood flow. Specimens drawn from the heel may benefit from gentle pressure applied to the calf and ankle area.

CONTRAINDICATIONS AND AREAS TO AVOID

When considering an appropriate site for venipuncture, it is the responsibility of the health-care professional to use best judgment to avoid harming the patient unnecessarily. Also, as part of the preanalytical process, it is important to remember that any substances that may contaminate the specimen during the blood draw must be avoided. To accomplish these goals, there are certain **contraindications** and precautions for venipuncture to keep in mind.

Scars and Tattoos

Excessively scarred skin (as in the case of a burn) should not be used for venipuncture. Scarred areas are more susceptible to infection and often have reduced circulation; further, the veins underneath the scarred skin may be difficult to palpate and anchor. Skin that has been tattooed is also more prone to infection, and the dyes used in coloring the tattoo may cause test interference if they make their way into the specimen.

Mastectomy Considerations

If a patient has had a **mastectomy,** venipuncture should not be performed on the arm on the same side of the body as the procedure. Mastectomy procedures involve the removal of breast tissue. In addition, the lymph nodes surrounding the breast and under the arm also may be removed. The absence of these nodes can cause a decrease in the flow of the lymph fluid in the area, which puts the patient at an increased risk of lymphedema

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(accumulation of lymph in the tissues) and infection, even if the blood draw is not performed and only a tourniquet is applied. The opposite arm should be used for the blood draw. If a patient has a double mastectomy, the health-care professional who ordered the blood draw should be consulted to see what alternative sites may be used for blood collection.

Intravenous Fluids

Intravenous fluids are a potential source of contamination when drawing blood. In situations in which the patient is receiving IV fluids, it is preferable to use the opposite arm for venipuncture. If it is not possible to draw from the other arm, the IV flow must be discontinued (turned off) for at least 2 minutes (depending on the substance being infused) by a physician or other qualified health-care provider before the blood draw is attempted. After the IV fluid drip has been turned off, the tourniquet may be applied *below* the IV insertion site, and the blood draw may be drawn from below the IV site. Even with these precautions, the first 5 to 10 mL of blood withdrawn must be discarded to avoid potential contamination with IV fluid. If a coagulation test is part of the blood draw order, an additional 5 mL of blood should be drawn and discarded before this tube used for the coagulation testing is collected.

Veins that have been used for IV therapy are often irritated and damaged, even after the IV has been discontinued. Ideally, these sites should be avoided for venipunctures for at least 1 or 2 days after the catheter has been removed to allow for the vein to recover. *Phlebitis* (inflammation of the vein) may result if the area is not allowed to heal before venipuncture procedures are performed.

Test Your Knowledge 8-6

Is IV therapy always a contraindication for venipuncture? Why or why not? (Outcome 8-7)

Bruising and Hematomas

Bruises and **hematomas** may occur as complications of venipuncture or IV therapy, and these sites should be avoided for subsequent blood draws. A bruise and a hematoma are similar in that each is a visible sign of damage to a vessel in which blood has escaped and entered the surrounding tissues. Hematomas result from damage to larger vessels such as veins and arteries, whereas a bruise may be the result of injury to a capillary or a small blood vessel. A hematoma is often hard and swollen, and may be quite painful for the patient. If a blood draw is attempted in a bruised area or a hematoma site, it may cause additional discomfort for the patient and the integrity of the sample may be affected because of the pooling of old, dead cells in the area. Drawing from this area may also include the risk of infection due to inflammation of the tissues. If it is absolutely necessary to draw from an area with excessive bruising or a hematoma, the venipuncture should be performed below the injured site.

Varicose Veins

A *varicose vein* is one that is twisted and enlarged and very visible near the surface of the skin. These veins have lost their natural elasticity and integrity, and are prone to inflammation and blood clot formation. Varicose veins should not be used for venipuncture, as the blood flow through these areas has been adversely affected, increasing the chance for infection and bruising. These veins are also not very stable and will often roll away during the venipuncture.

Central Lines and Fistulas

Intravenous lines are used commonly to administer medication, fluids, or blood products, especially when there is a need for continued access for an extended period of time. There are times when a phlebotomist or medical assistant may be asked to withdraw blood from a *central venous catheter* or a *peripherally inserted central catheter* (PICC line). The central venous catheters are inserted into one of the major veins of the body, such as the subclavian, superior vena cava, or jugular vein. There is a piece of tubing extending out of the vein through the skin that is covered with a dressing. The central venous catheter is often left in place for an extended period of time to be used for administration of medication directly into the bloodstream.

A PICC is inserted into the cephalic or basilic vein of the arm or hand. These peripherally inserted catheters are fragile, as they are not inserted into a large vessel. Blood withdrawal from either of these devices generally requires injection of saline and/or a heparin solution into the catheter to clear the line before and after the blood is taken. It is essential to remember that anyone who withdraws blood from these types of lines must have specialized training, and in some states it is unlawful for a nonlicensed person to perform this function. In states where this is allowed, each facility must establish its own policy and training procedures.

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Medical assistants and phlebotomists in most states are not allowed to perform this type of draw.

Another type of venous access device that may be in use is a *cannula*. This is a flexible tube that is used to gain access to the veins for *dialysis* treatment for those who have advanced kidney disease. The cannula is placed under the skin, and has a special port that is designed for insertion of a needle to withdraw blood for dialysis or for testing. A *fistula* is similar to a cannula, except that the device has been implanted in a way that it joins the arterial and venous system for hemodialysis procedures. The fistula is also under the surface of the skin, so it requires the skin to be punctured for access. It is recommended to use the other arm, rather than one containing the fistula. Blood draws should never be attempted from these implanted devices unless the practitioner has received specialized training. In many states, only licensed health-care providers may perform this procedure. In addition, a tourniquet should not be applied to the arm that contains a fistula or cannula.

POINT OF INTEREST 8-2
Arterial blood draws

Respiratory emergencies (such as advanced chronic obstructive pulmonary disease [COPD] or pulmonary edema) may require an arterial blood gas analysis for appropriate treatment to be started. In these situations the oxygen and carbon dioxide levels may be far outside the reference ranges, and the arterial blood pH may be increased or decreased to a life-threatening level. Arterial blood draws are similar to venipuncture procedures in that the site must be stabilized and cleansed properly before the needle is inserted. The angle of insertion, site selection options, and the way the blood enters the syringe are different from those of a venipuncture.

Arterial blood gases are commonly drawn from the radial artery; as a second choice, the brachial artery may be used as long as the patient is not being treated with anticoagulant drugs. The radial artery is easy to identify and secure because it is so near the surface of the body. To choose a site for an arterial blood draw, the health-care professional must palpate until the pulse is felt strongly. The site needs to be cleansed thoroughly, and the specimen needs to be drawn into a special heparinized syringe designed for this type of collection. A cup of wet ice also needs to be on hand, as the sample needs to be placed on ice immediately after the draw is complete.

The health-care provider should have his or her index finger on the pulse of the artery. The needle is inserted at an angle of approximately 45 degrees. The skin is pierced right next to the index finger. When the artery is entered, the blood will pump out through the lumen of the needle because of the pulse pressure. A flash is apparent immediately at the end of the needle attached to the syringe as the artery is pierced, and the blood will continue to fill the syringe without pulling on the plunger. (The plunger is pulled back before the needle is inserted to allow room for the blood in the syringe.) When the syringe is full, the safety device must be activated immediately on the needle. The needle will be removed and the end of the syringe will be plugged with a rubber stopper. The sample must be placed on ice immediately after labeling of the specimen. Firm pressure must be applied to the puncture site for a minimum of 5 minutes after the blood draw, or until the blood stops flowing from the site.

Due to the potential for arterial damage or nerve damage with arterial blood draws, intensive training is required for health-care professionals who perform this as part of their job. Training includes careful observation and supervised performance, as well as identification of risk factors associated with the process. Some states restrict this procedure to licensed personnel such as respiratory therapists or RNs.

Edematous Areas

In some clinical situations, patients may accumulate fluid in the intercellular spaces of the tissues. This accumulation of fluid is called **edema.** The presence of excess fluid may be widespread as a result of heart and/or renal failure, or it can be more localized from trauma or fluid leakage from an IV site. It will be very difficult to palpate a vein in edematous areas, because of the additional fluid in the tissues. If possible, these areas of the body should be avoided for venipuncture, because of the increased opportunity for infection and potential for contamination of the specimen with the additional fluids. If the edema is widespread, the medical assistant may need to apply gentle pressure to the site until the edema is displaced, then perform the venipuncture as quickly as possible. If this is not successful and alternative sites are not obvious, the phlebotomist or medical assistant who is drawing the specimen should notify the physician. Capillary collection procedures are often not an option

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when edema is present because of the excessive amount of fluid contamination.

Test Your Knowledge 8-7
Why is it important to avoid edematous areas when performing venipunctures? (Outcome 8-7)

Obese Patients

Excessive body fat can make venipuncture very challenging. It may be very difficult to palpate veins in obese patients, and sometimes it is even necessary to use longer than normal needles to successfully reach the veins under the surface of the skin. Obese patients may be quite apprehensive about the blood draw process because of past experiences with unsuccessful venipunctures. The anxious attitude may make it even more difficult to carry out a successful blood draw. If the patient suggests a site where others have had success, it is best to attempt this site if there are no other prominent veins. Adipose tissue may also be displaced in some situations by applying gentle pressure with the fingers to "move" the tissue out of the way until the draw site has been established.

VENIPUNCTURE EQUIPMENT

There are various methods used to obtain blood from a vein. Each type of blood draw requires unique supplies and procedures. Blood may be withdrawn from a vein using the evacuated tube system, the syringe system, or the butterfly method. Regardless of the method chosen, tourniquets, gloves, sharps containers, alcohol and gauze pads, needles, and adhesive materials to be applied after the blood draw are necessary for the process.

Tourniquets

A **tourniquet** is a flexible band that is placed around the arm of the patient to make the veins more prominent. Most tourniquets found on the market today are stretchy and made of a nonlatex material. They are approximately 1 in. wide, and approximately 15 in. in length. Tourniquets are designed to apply pressure, which causes distention of the veins. The tourniquet must be placed approximately 3 in. above the site to be used for venipuncture. If it is placed closer, the ends of the tourniquet may interfere with the procedure. Remember, tourniquets are only a tool to help the vein to become more visible; there are times when it is not necessary to use a tourniquet, and some laboratory tests prohibit the use of a tourniquet for the specimen collection.

Tourniquets should not be applied too tightly; this can cause pain for the patient, and may cause **hemoconcentration** in the veins because of the restricted blood flow. Hemoconcentration occurs when excessive pressure builds up in the veins below the tourniquet application site. The increased pressure in the veins will force water and small molecules out of the vessels into the surrounding tissues. Larger formed elements and molecules will remain in the venous blood, and become more concentrated. White blood cells, red blood cells, platelets, calcium, cholesterol, triglycerides, and bilirubin levels may all be affected by this venous concentration. Tourniquets that are left on for more than a minute may also cause hemoconcentration; therefore, the phlebotomist needs to remain aware of this as the venipuncture site is prepared. Extended tourniquet application time may also cause pain for the patient.

When applying a tourniquet, keep in mind that it should be applied in a way that it can easily be released with one hand. Tourniquets do not need to be applied to bare skin; they can be applied over the sleeve. Open wounds, scars, and bruises should be avoided when applying the tourniquet. Some tourniquets are disposable, and these should be discarded after each use. Others are designed to be used for multiple patients, and should be disinfected at least daily, and discarded if they are visibly soiled or lose elasticity.

Gloves

The Occupational Safety and Health Administration (OSHA) regulations designed to protect health-care employees specify that gloves are to be worn when collecting blood. After a blood draw, the gloves are removed, and the employee must sanitize his or her hands. For effective palpation and dexterity during the collection process, gloves should fit snugly. Except in very specific circumstances, it is not necessary for the gloves used for phlebotomy to be sterile. Most health-care settings no longer use latex gloves, due to the increase in latex sensitivity issues. A common substitute for latex gloves, nitrile gloves work well for phlebotomy. Vinyl gloves may also be worn, but they are not advised in all situations because of their tendency to break down when exposed to certain chemicals.

Sharps Biohazardous Waste Containers

A **sharp** is anything that has been exposed to blood (or other potentially infectious materials) that has corners, edges, or sharp projections that are capable of cutting or

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piercing the skin. In venipuncture, sharps include needles and capillary puncture devices. Glass slides may also be classified as sharps because they have sharp corners that may be hazardous. Sharps must be disposed of in a waste container that is specifically designed to be puncture resistant, leakproof on the sides and bottom, and labeled as biohazardous waste. These containers should be placed close to the site where the venipuncture is performed so that contaminated sharps may be disposed of immediately. Sharps waste containers come in various sizes, and should never be overfilled. If a sharps container is filled past the marked fill line, it is possible for injury to occur when an employee adds contaminated sharps to the container.

Alcohol and Gauze Pads

Seventy percent isopropyl alcohol is generally used for cleaning the venipuncture site. It may be applied by using a presoaked commercial square that is individually wrapped and packaged. Alcohol may also be applied by using a gauze pad that has been saturated just prior to use. Isopropyl alcohol is an effective antiseptic that can help to eliminate most transient and surface resident bacteria from the venipuncture site. The alcohol used to cleanse the site must be allowed to dry completely before the procedure is performed. If liquid alcohol is still present when the needle is inserted, it can cause a stinging sensation and irritation to the skin and/or the vein. Alcohol may also cause hemolysis of the red blood cells if it is introduced into the specimen.

When additional cleanliness is essential during the collection process (such as when blood cultures or arterial punctures are ordered), iodine or chlorhexidine gluconate may be used. Chlorhexidine gluconate is ideal for those who are allergic to iodine. Procedures used for drawing blood cultures are presented in more detail in Chapter 10.

Clean 2 x 2 gauze squares are recommended for venipuncture procedures. The gauze is applied after the needle has been removed from the arm and the collection is completed. Cotton balls should not be used because their excess fibers tend to stick to the wound and can cause bleeding to recur when the cotton ball is removed later.

Test Your Knowledge! 8-8

List three items that are needed for all venipuncture procedures, regardless of which technique used.

(Outcome 8-8)

Needles

Needles used to withdraw blood are always disposable and used only once. They are generally 1 to 1.5 in. in length. Figure 8-6 describes the different parts of a needle. The slanted part of the needle that creates the sharp tip is called the **bevel.** This slant helps the needle to enter the skin with a minimum amount of trauma and pain. There is a hole in the bevel where the blood enters the interior hollow portion of the needle, called the **lumen.** The **gauge** of the needle refers to the diameter of the lumen: the larger the needle, the smaller the number used to describe the gauge. Needles used for venipuncture are generally 20 to 23 gauge. Needles that are smaller than 23 gauge will cause **hemolysis** (breaking of the red blood cells with release of hemoglobin) as the blood cells are broken when they enter the small hollow cylinder that forms the lumen. Conversely, if the needle used is too large, hemolysis may also result because of the force at which the blood enters the tube or syringe through the large opening.

When removing the cap from a needle to prepare for venipuncture, it is important to inspect the needle for any defects such as burrs or a blunt tip. If there are problems present, the needle must be discarded immediately into a sharps container and a new one used for the procedure.

Needles used for the **evacuated tube system** are also known as **multi-sample needles.** They have sharp tips at both ends; the end with the beveled tip is designed to be inserted into the vein; the shorter, blunt tip at the opposite end is covered with a rubberized sleeve. The needle is designed to be screwed into a hard plastic holder that holds the tube and the needle. The needle

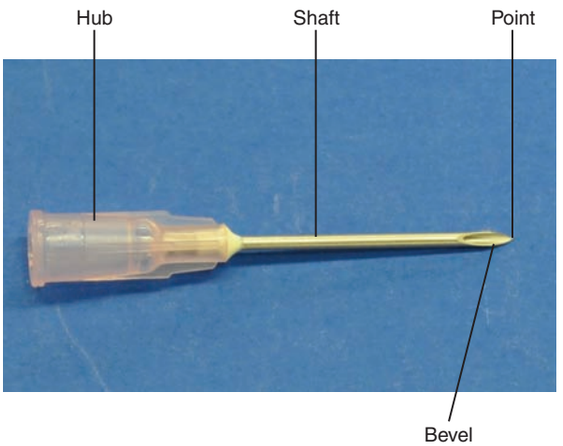

Figure 8-6 Identification of the different parts of a needle.

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or the holder must be equipped with a safety device to protect the employee upon completion of the blood draw. A multi-sample needle and holder are shown in Figure 8-7.

When performing venipuncture utilizing the **syringe system,** a needle of similar length and gauge as that for the evacuated tube method is used (Fig. 8-8). These needles are designed to screw directly onto the syringe, so the needle only has one pointed end; the other end has a hub that attaches directly to the syringe. The needles or the syringe must be equipped with a safety device to protect the employee after the blood draw is completed. Examples of safety mechanisms include a cover that is pushed over the needle and locked in place after the draw, or a retractable needle that moves back into the syringe once the specimen is obtained.

The **butterfly system,** or winged infusion system, consists of a short needle with "wings" (Fig. 8-9). When used for venipuncture, the needle is generally 23 gauge, and is attached to a piece of plastic tubing that is approximately 12 in. long. The wings are held by the fingers while the needle is inserted into the vein. Butterfly needles are used for fragile veins (such as those in the hand) or pediatric draws. The butterfly tubing may be attached directly to a syringe, or an adapter may be used to attach the butterfly setup to a plastic evacuated tube holder. Proper activation of the safety devices included with the butterfly system is critical, as there are more accidental needlesticks attributed to the use of butterflies than there are in either of the other two systems.

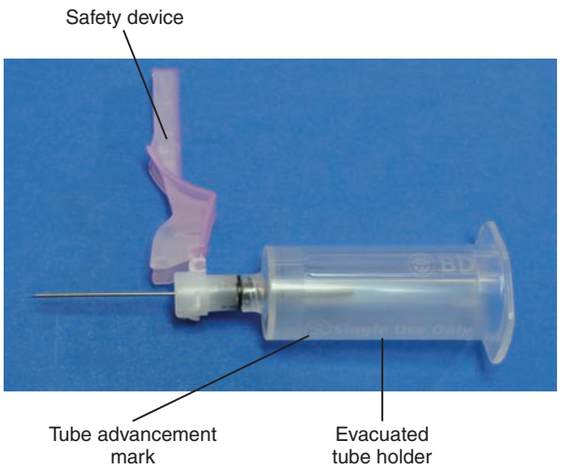

Figure 8-7 Multi-sample needle and holder with identification of parts.

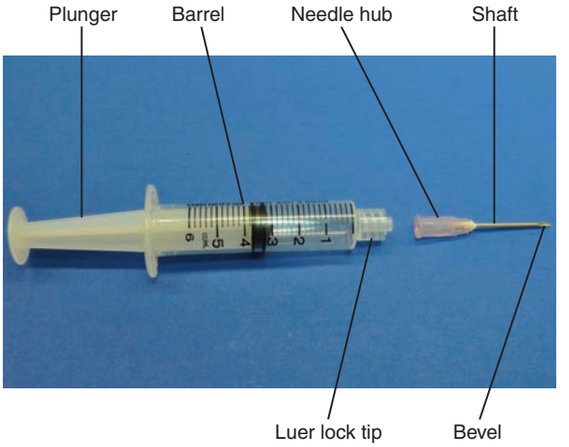

Figure 8-8 Syringe with identification of the various parts.

Test Your Knowledge 8-9

Are the needles used for all venipuncture techniques the same? (Outcome 8-8)

Safety needles are required for all methods of venipuncture. The various safety devices are designed to be easily activated, using either a needle that withdraws into the device while still in the skin, or one hand activation of the safety device. Figure 8-10 shows various safety devices for evacuated tube systems, syringe needles, and butterfly needles. It is essential that the medical assistant performing venipuncture become comfortable

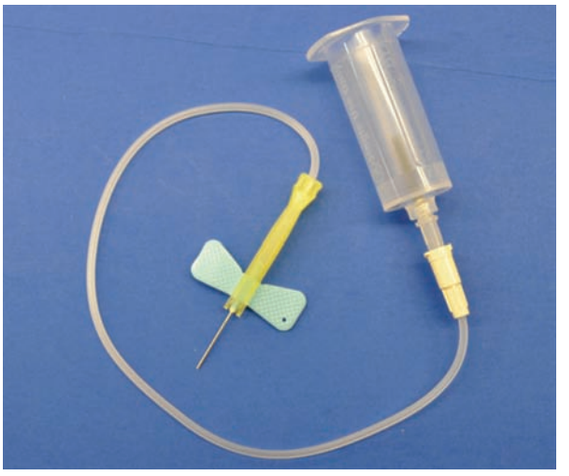

Figure 8-9 Butterfly assembly.

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Figure 8-10 Safety devices for use with the evacuated tube system and syringe draws.

with the safety devices available to him or her so that the device can be activated quickly and safely for protection.

Additional Supplies

Blood spill cleanup supplies should be available near every phlebotomy station, and staff should be trained regularly on their use. In addition, because every tube should be identified while in the presence of the patient, it is important to have at least one functional pen available to identify the tube and document the blood draw information on the requisition. It is also necessary to have backup tubes and needles within reach for use when the procedure does not go as planned.

METHODS USED FOR VENIPUNCTURE

Evacuated Tube System

The most common and most efficient method of performing venipuncture is the use of the evacuated tube system. As described earlier in the chapter, blood is collected directly into an evacuated tube through a needle that has two pointed ends. This method is advantageous because there is no need to transfer the blood from one container to another after the draw, and also because multiple tubes of blood may easily and quickly be drawn with one skin puncture. The needle to be used with the evacuated tube system is screwed into an evacuated tube holder that is made of semirigid plastic. These tube holders are designed to be used only once; if the medical assistant tries to use them more than once, the needle may not screw in securely. The rubber cover covering the shorter, posterior end of the needle is pushed back to expose the sharp needle as the evacuated tube is pushed on during the blood draw. Evacuated tubes have the air removed to create a vacuum, so as soon as the tube cap is pierced with the needle, the blood is pulled into the tube. When the blood draw is complete, the safety device for the needle must be activated, and the evacuated tube holder with the needle attached must be disposed of directly into a biohazardous sharps container.

The plastic evacuated tube holder has flared sections at the bottom, which are known as **flanges.** These are designed to be pushed against as the medical assistant changes tubes during the blood draw process. The flanges help to keep the venipuncture setup stable during the process of drawing blood. There is also a line marked on the tube holder; this is a "safe" mark that shows how far the tubes can be advanced into the holder before the vacuum will be affected. Some health-care personnel prefer to advance the tube to this mark before they begin the blood draw process, whereas others do not. If the tube is advanced past this mark, the vacuum will be affected and the tube may not fill as desired once the needle is in the vein.

Syringe Method

Health-care personnel may prefer to use the syringe method for venipuncture in patients having small or fragile veins. Use of a syringe to withdraw blood allows for more control of the vacuum used to withdraw blood from the vein, as the individual performing the venipuncture can control the speed and force used to pull on the plunger of the syringe. Syringe draws also allow the person performing the venipuncture to see the blood in the hub of the needle as the vein is entered, which can be reassuring when attempting a blood draw on a vein that is difficult to palpate or locate. This return of blood into the hub of the needle is called a "flash" of blood.

Syringes are made of a hollow plastic barrel with graduated measurements in cubic centimeters (cc) or milliliters (mL) printed on the side. Inside the barrel of the syringe is a plunger that is designed to fit tightly enough to create suction when the plunger is pulled backward. The sizes of syringes used for venipuncture may vary from 3 mL to 20 mL, with 5-mL or 10-mL syringes most commonly used. Any size needle may be attached to the syringe, but 20- to 23-gauge, 1-in. needles are most commonly utilized for venipuncture. Safety devices for the blood draw may be attached to the needle, or the syringe may be safety enabled.

One disadvantage of using syringes for venipuncture is that the blood must be transferred into tubes for further processing and testing after the blood draw. This must occur quickly so that the blood does not clot in the syringe. Transfer devices should be used to add the blood from the syringe to the necessary tubes (Fig. 8-11).

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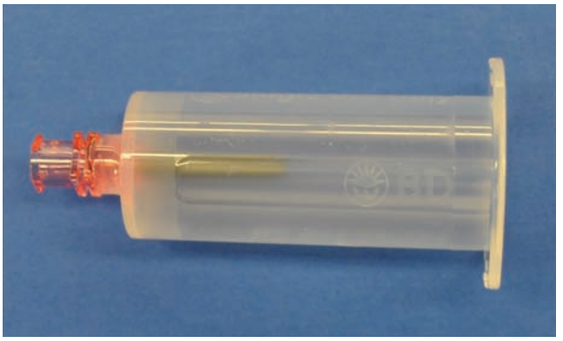

Figure 8-11 Transfer device.

Because the amount of blood obtained with one venipuncture is limited to the size of the syringe used, this must be taken into consideration before choosing the syringe method for blood collection. It may not be advantageous to use a syringe when there is an order that requires more than 10 mL of blood, as the sample may clot in the syringe before it can be successfully transferred to the correct blood tubes.

Winged Infusion or Butterfly Method

Winged infusion sets (also known as **butterfly systems)** are made up of a beveled needle that is attached to a length of tubing with a luer adapter on the opposite end. Just below the needle on the butterfly system are two "wings" that are made of hard plastic. The medical assistant will grasp these wings and use them to guide the insertion of the needle into the vein. Butterfly systems are often used for venipuncture in patients having very fragile veins, such as those in the hands. They are also used for many pediatric blood draws, small fragile veins in areas other than the hand, and sometimes for uncooperative patients. Butterfly sets are preferred in these situations because the needle can be maneuvered easily to gain venous access because of its decreased length. The angle used to enter the vein is smaller when using a butterfly setup. This can be especially important when attempting a blood draw from a superficial small vein, such as those in children. The attached flexible tubing allows for multiple tubes to be collected without danger of moving the needle in the vein. Butterfly systems may be used directly with evacuated tubes (utilizing a Luer adapter for this purpose), or they may be attached to a syringe when there is a desire to use very gentle pressure during the blood draw.

Venipuncture with a butterfly system has a higher risk of an accidental needlestick if the safety device is not activated properly before the medical assistant attempts to process the specimen after the blood draw. Becton, Dickinson has a product with a push-button activation that withdraws the needle into a plastic reservoir before it is removed from the skin. Other products require activation of the safety device after the needle is removed from the patient, and it is imperative that the health-care professional performing the venipuncture follow directions for activation to avoid potential bloodborne pathogen exposure.

POINT OF INTEREST 8-3
Minimizing risks for employees and patients while collecting samples

The collection of blood samples is a very important part of the laboratory testing process. It is important to remember that safety precautions must be followed at all times to protect both the employee and the patient. The appropriate personal protective equipment will offer a layer of protection for the employee, but safety does not stop there. It is very important to follow instructions for the use and activation of all safety devices in order for them to provide protection. It is also important to focus your full attention on the task at hand when performing invasive procedures; it only takes a moment of inattention to provide an opportunity for bloodborne pathogen exposure.

Patient safety is also very important. Invasive procedures can be very traumatic for some patients because of prior experiences or fear of the unknown. Use of phlebotomy chairs with padded support on the arms and across the chest will help to keep the patient comfortable and safe during the process. Careful observation of the patient's response to the invasive procedure will help the employee anticipate fainting or other adverse reactions. All patients should be treated with compassion and care, and the collection process should be completed as quickly and efficiently as possible.

BLOOD COLLECTION TUBES

Evacuated tubes used for blood collection are available in several sizes, and are made of plastic with rubberized stoppers. (Glass collection tubes may still be available, but they are not recommended due to the potential for breakage and blood exposure for health-care personnel.) Evacuated tubes vary by diameter, length, and the additives present in the tubes. They are each designed to hold

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a specific amount of blood and vary from 2-mL tubes that may be used for pediatric or geriatric blood draws, to 15-mL tubes that are used when a high volume of blood is necessary for a particular assay. The medical assistant or phlebotomist drawing the blood will choose the tube size according to the age of the patient, the integrity of the vein, and the amount of blood needed for the test ordered. The different colors used for the stoppers are coded according to the additive contained within the tube.

These tubes are evacuated because the air within the tube has been removed to create a **vacuum.** This vacuum has been artificially created and calibrated by the manufacturer so that a very specific amount of blood will be drawn into the tube. The tube will never fill completely to the top, as they are not calibrated to hold that volume of blood. As long as the vacuum is still present within the tube, blood will continue to flow. If there has been a loss of vacuum in the evacuated tube, blood will not enter the tube, or it will fill incompletely. This is known as a **short draw** and often will require the specimen to be redrawn. Short draws are sometimes caused by dropping a tube prior to the venipuncture, pushing the tube too far onto the double-ended needle used for evacuated tube draws prior to the blood collection, or by accidentally pulling the needle out of the vein during the venipuncture process.

All blood tubes have an expiration printed on the label. There is an expectation that the vacuum and additives in the tube will function as expected until this date. The health-care worker who performs the blood draw is responsible for checking the expiration date on all tubes before they are used, and at the same time examining the tube for any obvious defects or breaks. Any tubes that are near expiration should be removed from the shelves before the printed date has passed.

Test Your Knowledge 8-10

Why are tubes used for blood collection called vacuum tubes? (Outcome 8-8)

Color Coding of Tubes

Evacuated tubes are all sealed with a colored stopper. These closures are made of rubber and/or plastic and are designed to ensure the vacuum within the tube and provide a barrier to the blood once the tube is filled. Some tubes available on the market have a rubber stopper with an outside plastic cap of the same color. The plastic cap provides protection for the employee when opening the tube, because the additional plastic cap hangs over the outside of the tube and forms a barrier to any aerosol formation from the blood in the tube. An example of this type of tube is the Hemogard tube, manufactured by Becton, Dickinson. See Figure 8-12 for an example of the Hemogard tube.

The stopper colors on evacuated tubes are color coded and used to indicate whether additives are present in the tubes, and if so, what types are present. Additives may function as **anticoagulants,** or **clot activators.** The additives may sometimes serve as preservatives of the integrity of the specimen. Anticoagulants will keep the blood from clotting in the tube so that the cells remain suspended in the plasma. Without the addition of anticoagulants, the blood will begin to clot in the tube immediately, and a visible solid clot will form within an hour. Clot activators, such as glass beads or silicone, are designed to speed up the clotting process so that the blood can be spun in the centrifuge within a shorter period of time after collection. Tubes may also contain a thixotropic separating gel that is designed to form a barrier between the blood cells and the liquid portion of the blood after it is centrifuged. The gel in these **serum separator tubes (SST)** or **plasma separator tubes (PST)** is in the bottom of the tube when the blood is collected, but as the tube is centrifuged, the cells move to the bottom of the tube and the gel travels up in the tube to form a barrier between the cells and the liquid. Figure 8-13 shows how the gel separates the sample after centrifugation.

The colors used for tube stoppers are similar from brand to brand, providing a uniform reference for the different types of additives. The type of anticoagulant present in the tube is printed on the label, along with the expiration date and the blood volume for the

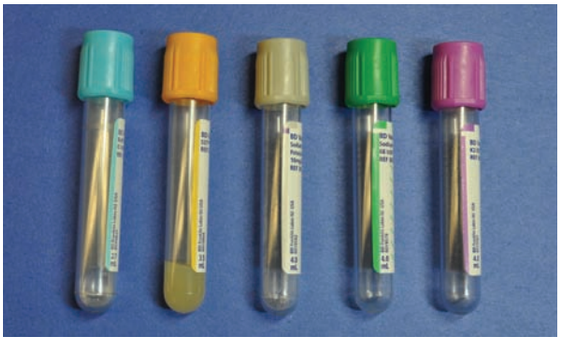

Figure 8-12 Vacuum tubes with Hemogard caps presented in the appropriate order of draw.

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Figure 8-13 The tube on the left shows whole blood before centrifugation. The tube in the middle shows plasma sitting on top of clotted blood cells. The tube on the right is a tube with serum separator gel that has been spun in a centrifuge and shows serum sitting on top of clotted blood cells. *Reprinted with permission from Eagle S, Brassington C, Dailey C, and Goretti C:* The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. *Philadelphia: FA Davis, 2009.*

tube. When using reference materials (such as laboratory requisition forms or laboratory directories) the specimen collection instructions will reference the stopper color needed for the test ordered or the additive present in the tubes. Each laboratory may have different tube requirements for a given test based on its testing methodology, so it is always best to verify the necessary tube before drawing the blood.

Test Your Knowledge 8-11

What is the significance of the different stopper colors used for the vacuum tubes? (Outcome 8-10)

Types of Additives

Types of anticoagulants and/or additives present in the most common evacuated tubes are listed here with their respective color stoppers and summarized in Table 8-1.

- **Yellow:** Sterile tubes used for blood cultures. There are also specific yellow top tubes that contain a red blood cell preservative called acid citrate dextrose (ACD), and these are used for special blood bank procedures. The sterile yellow tubes for blood cultures are by far more common.
- **Light blue:** Contains sodium citrate as an anticoagulant. Light blue top tubes are primarily used for coagulation studies. The ratio of blood to anticoagulant is critical for these tubes and they must always be filled completely to prevent potential dilution and erroneous results.
- **Red:** Glass red top tubes are sterile and contain no additives. Plastic red top tubes contain a clot activator. Red top tubes are used for a variety of tests in which serum is the preferred specimen.
- **Red/gray (tiger top) or gold:** Contains a silica clot activator that increases platelet activity and decreases the time necessary for a clot to form in the tube. Also contains thixotropic gel that separates the cells from the serum when the specimen is centrifuged. Used for chemistry and immunology testing in which serum is the preferred specimen.
- **Black:** Special tubes used only for Westergren sedimentation rates. Contain sodium citrate, but in a different concentration (blood to anticoagulant liquid 4:1) than the light blue top tubes. These tubes are not to be used for coagulation studies.
- **Green:** Contains heparin combined with sodium, lithium, or ammonium as an anticoagulant. These tubes are preferred for chemistry tests in which plasma is suitable for testing and the results must be obtained quickly, as the specimen does not need to clot before the sample may be spun in the centrifuge. Light green Hemogard tubes and those with green and black mottled stoppers contain thixotropic gel in addition to the anticoagulant, which separates the plasma from the cells after centrifugation.
- **Gray:** Contains sodium fluoride, which acts as a glucose preservative (called an antiglycolytic agent) keeping the glucose levels stable in the specimen for a period of time after collection. Also contains an anticoagulant; either potassium oxalate or sodium EDTA. Gray top tubes are not appropriate for general chemistry testing, but are used for glucose testing, as well as blood alcohol determinations.
- **Lavender:** Contains potassium EDTA (dipotassium ethylenediaminetetraacetic acid) as the anticoagulant. Prevents the use of calcium in the clotting process to prevent blood clotting and keep the blood cells suspended in plasma. Lavender top tubes are used for hematology testing because this preservative preserves the integrity and shape of the individual cells better than any of the other anticoagulants.

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TABLE 8-1
Table of common tube colors and additives

Tube Stopper Color	Additives
Red top	None
Tiger top/ speckled top/ gold top	Clot activators/thixotropic gel
Green top	Heparin
Mint green top	Heparin and thixotropic gel
Light blue top	Sodium citrate
Lavender top	Potassium EDTA
Gray top	Sodium fluoride and potassium oxalate

ORDER OF DRAW FOR VENIPUNCTURE

The Clinical and Laboratory Standards Institute (formerly known as NCCLS) has recommended a specific order of draw for venipuncture specimens using the evacuated tube system, syringe collection method, or butterfly draws. There is a different recommended order of draw for capillary specimens. These recommendations were developed because of potential problems with additive carryover from one evacuated tube to another. Reports showed significant increases in potassium and some other analytes when a lavender top tube (containing potassium EDTA for an anticoagulant) was drawn just prior to the tube used for chemistry testing. Other potential carryover issues were also identified.

Test Your Knowledge 8-12
Why is the order of draw so important?
(Outcome 8-11)

The recommended order of draw for the six most commonly used tubes:

1. **Blood culture specimens:** These may be yellow top tubes or a set of bottles used for blood cultures. They must be drawn first to avoid potential for contamination of the draw site.
2. **Light blue top citrate tube:** This tube is primarily used for coagulation studies, so it is important that additive crossover is avoided because of potential interactions. Previous recommendations always called for a red top tube to be drawn before the light blue top tube, but with the current CLSI recommendations, this is no longer necessary. An exception is when a butterfly system is used to draw a light blue top tube; in this case, a red top tube is used as a "clear" tube because of the excessive air present in the tubing of the butterfly. The blue top tubes must be filled as far as the vacuum allows, and if the excess air from the tubing is introduced into the light blue top tube, the tube will not fill adequately.
3. **Red top, tiger top, or gold top tubes with or without clot activator:** These tubes are used when serum is the specimen of choice.
4. **Green top tubes:** These are both tubes that have gel separator and tubes that do not. They may be mint green or dark green. These are to be drawn before the EDTA tubes to reduce the risk of crossover that may increase the potassium levels when analyzed.
5. **Lavender top tubes:** These have potassium EDTA as the anticoagulant, and are primarily used for whole blood testing.
6. **Gray top tubes**: Gray top tubes are used for glucose testing, as well as a few other tests. They need to be drawn after the EDTA tubes because the additives present in the gray top tube could cause abnormal changes in the red blood cells to be analyzed if there is crossover. The gray top tube must be drawn after the tubes used for other chemistry testing, because the potassium oxalate present in the gray top tube could cause falsely elevated potassium results if the specimens were contaminated by the anticoagulant and this test was to be performed on the sample.

CAPILLARY PUNCTURES

Most blood collections are performed by puncturing a vein. However, there are times when a **capillary puncture** is a more appropriate method. During a capillary puncture, an incision is made in through the skin, which passes through the epidermis into the dermal layer. It is critical that the puncture reaches the dermal layer, as this is where the blood supply exists. Remember, the blood present in the capillary beds of the body is a mixture of venous and arterial blood. There is actually more arterial blood represented because of the increased arterial pressure forcing this blood into the capillary vessels. Because of the way that the skin layers are punctured, capillary samples may also include additional fluid from the space between the tissues and cells surrounding the capillary vessels. This is why it is very important to document the source of the blood specimen when collecting a capillary sample, as the reference ranges will be different from those used for venous blood.

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Test Your Knowledge 8-13
Why is it important to document that a sample was capillary rather than venous? (Outcome 8-13)

Capillary samples are never appropriate when the test ordered requires a large amount of blood, or if there are problems with the circulation for the patient. This technique should also be avoided if the patient has edema, as the excessive fluid may dilute the sample and cause erroneous results. CLIA-waived tests require very little blood, so capillary punctures are often performed for these tests. Some patients who are undergoing cancer treatment or dialysis may be better suited for capillary blood draws to allow their blood levels to remain stable. Capillary punctures are also appropriate for most children, some geriatric patients with fragile veins, and infants.

Capillary punctures should always be performed using retractable nonreusable lancets for the safety of the patient and the employee performing the puncture. These devices are calibrated to provide a uniform depth for the puncture, and they lock in place once the puncture has occurred so that they cannot be reactivated. The devices used for capillary punctures are color coded according to the depth of the blade. They vary from those used for infants, which must be less than 2.0 mm (to avoid potentially touching bone), to adult depths up to 3 mm, primarily used for finger punctures. Lancet devices that may be used for home testing or perhaps for an individual CLIA-waived test procedure usually will not provide a puncture that is feasible for collecting enough blood to fill a microtube for analysis. All puncture devices must be disposed of in a biohazardous sharps container.

During a venipuncture, a tourniquet is used to aid in the palpation and visualization of an appropriate draw site. Capillary draws do not require the use of a tourniquet, but it is very important that the site to be used is as warm as possible to help increase the blood circulation. This may be accomplished by soaking the appendage in warm (not hot) water; by using a warm, wet compress; or with use of a commercial hand warmer held on the skin until it is warm to the touch.

The capillary puncture also requires the use of clean gauze (usually at least two sets), 70% isopropyl alcohol to clean the site, and a bandage to be used after the puncture. The employee who is performing the capillary puncture should also prepare the site under the patients' hand or foot by draping the area with an absorbent cloth or sheet to absorb any excess blood.

Capillary samples may be collected in various ways. **Microcollection tubes** may be utilized, which are smaller versions of the evacuated tubes used for venipuncture. These tubes are color coded in a way similar to the evacuated tubes, and many contain anticoagulants or other additives. **Capillary tubes** may also be used, especially for hematocrit testing. Capillary tubes are long, thin, hollow tubes designed to hold blood. The tubes are held horizontally with one end touching the drop of blood created by the capillary puncture. The tube fills with blood via **capillary action.** These tubes may be made of glass or plastic. They may be coated internally with heparin to keep the blood from clotting as it is collected, in which case the tube will have a red ring around it. Other capillary tubes do not include anticoagulant, and these plain tubes will have a blue ring around their diameter. Capillary tubes may also be part of a microcollection container setup, where the capillary action pulls the blood into the container. Figure 8-14 includes examples of devices used for capillary punctures.

Order of Draw for Capillary Puncture

The order of draw for the various microcollection containers using a capillary technique is different from the order used for venipuncture. The order is not the same because the capillary blood clots faster than the blood taken from a vein and because the potential for carryover

Figure 8-14 Devices used for capillary punctures. *Reprinted with permission from Eagle S, Brassington C, Dailey C, and Goretti C:* The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. *Philadelphia: FA Davis, 2009.*

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is not as high. For capillary draws, the order of draw is as follows:

1. **Lavender (EDTA) tubes are filled first.** It is imperative that these are well mixed during the process to avoid blood clot formation.
2. **Other additive tubes,** such as green top tubes or those with heparin and thixotropic gel, are collected next. Microcollection tubes are not used for coagulation studies, so there are no sodium citrate tubes to be filled.
3. **Nonadditive tubes are drawn last,** and will usually clot within 6 or 7 minutes.

Test Your Knowledge 8-14

Is the order of draw the same for capillary draws as it is for venipuncture specimens? (Outcome 8-11)

POINT OF INTEREST 8-4
Waste reduction considerations

Unfortunately, specimen collection generates a lot of waste. Current practice prohibits reusing most items that are exposed to bloodborne pathogens because of the danger of exposure for subsequent patients. The contaminated waste must be disposed of and processed appropriately by a licensed biohazardous waste handler. The waste is packaged according to federal specifications, transported in a standardized manner, and finally incinerated.

However, not all the waste in the laboratory setting is contaminated. Lids from needles, plastic and paper packaging, and alcohol prep pad packages need to be added to the regular trash, not treated as biohazardous materials. Some of the packaging may be recyclable; this option should be employed whenever possible. Any paper may include protected personal information and so needs to be shredded before disposal to protect patients' privacy. Some recycling programs will process shredded paper.

To minimize waste, do not open sterile packaging until you are certain that you will be using a specific device for specimen collection. Many phlebotomists will set up all the sterile supplies before they palpate the vein of the patient. This may be a mistake, as it may become apparent that a different device is needed for the blood draw. The sterility has been compromised for the devices that were set out, so they will all need to be discarded, in addition to the devices actually used for the blood draw. Become aware of recycling options in the laboratory setting, and make use of this service whenever possible.

PREPARATION FOR BLOOD COLLECTION

Several steps are required in the blood collection process prior to the actual puncture of the skin. Specific procedures are utilized regardless of the method used to collect the sample. These critical aspects include the following:

- **A professional atmosphere:** A collection site where phlebotomy is performed should be clean, organized, well lit, and tidy. Many times this collection site is the only contact that the patient will actually have with the laboratory where the testing will be performed, and if they feel as if this is a professional environment, the patient will have more confidence with the testing process to follow.
- **Appropriate introductions:** When first approaching a patient, the health-care employee must identify him- or herself. Proper identification should also be worn, such as a name tag and/or uniform so that the patient feels in the presence of a qualified professional for the procedure.
- **Patient identification:** This is the most critical aspect of the collection procedure. The health-care employee should ask for the patient to give his or her entire name and birth date for verification of identification. This information should be checked against the requisition form for accuracy. It is important that the patient actually says, "I am Sally Smith," rather than the health-care employee asking, "Are you Sally Smith?" Many times patients will answer yes to such a question, even though they did not hear or understand the name given. If drawing blood from a patient in an inpatient setting, armbands may be used for identification, but in addition, the patient identity also needs to be verified in another way. The phlebotomist must document who provided the verification of the patient identity if it is not the patient.
- **Verification of orders and patient preparation:** The medical assistant or phlebotomist needs to verify what tests were ordered before continuing with the collection procedure. This can be accomplished by looking carefully at the requisition form or labels provided for the blood draw. The medical assistant is also responsible to see if patients are prepared properly for the test

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ordered; for instance, if the test is a fasting blood sugar, the medical assistant must ask patients if they have been without food and drink (except water and necessary medications) for 12 hours. If the preparation was not followed appropriately, the specimen is not to be drawn. When drawing blood to test for a therapeutic drug level, the medical assistant needs to ask when the medication was last taken, and verify if that is an appropriate time interval for this particular test.

- **Hand sanitization:** The medical assistant must wash his or her hands (if they are visibly soiled from a previous procedure) or use hand sanitizer appropriately before touching the patient. Gloves must be worn during the venipuncture process and should not be applied until the hands are totally dry.
- **Site selection**: The medical assistant should always start in the antecubital area when looking for an appropriate venipuncture site. The first choice is the median cubital vein, the second choice is the cephalic vein, and the last choice in this area is the basilic vein. The medical assistant should always check the veins in both arms to make the best choice. The back of the hand may also be used for venipuncture if there are no suitable sites in the antecubital area. For a capillary draw on an adult, the middle finger or ring finger is used, and part of the preparation may be warming the site.
- **Preparation of necessary supplies:** It is not possible to prepare fully for the venipuncture before the site selection has been performed, because the choice of which method to use for the blood draw will be dependent on the integrity and size of the veins to be used for the blood draw. Once the site selection is complete, the medical assistant can prepare an evacuated tube setup, a syringe for the blood draw, or a butterfly setup. The tubes to be used should also be checked for expiration and/or defects, and laid out in order of draw close to the patient so that they can be easily reached during the procedure. Gauze and alcohol should be within reach as well.

  Supplies may vary depending on the age and general health of the patient. An infant usually does not have venipuncture performed for most laboratory tests. Small children may need venipuncture, but a smaller volume of blood may be drawn using a butterfly and a 2- or 3-mL tube. Those patients who are over the age of 60 often present veins that collapse or roll easily, and due to complex health issues, it may be necessary to withdraw smaller volumes of blood for these populations. A syringe draw or butterfly setup will often be necessary.
- **Cleansing and support of the site:** Once the site has been selected, it must be cleaned. Seventy percent isopropyl alcohol is usually used to clean the site, and it is applied in a circular motion with the draw site at the center of the circle. The alcohol must be allowed to dry completely before the blood draw is performed. The site should not be repalpated after the alcohol has been used. If repalpation is absolutely necessary, the site should be cleaned again after being touched.

  The venipuncture site should be well supported by using a chair that has arms or a cross support designed for blood-drawing procedures. It may be helpful to have the patient make a fist with the opposite hand and place this under the elbow, which helps to expose the antecubital area fully for inspection and offers additional support. For inpatients, the patient's arm should be settled on a pillow or rolled-up towel to help make the veins more accessible.

  Support of the site may be complicated for small children. It may be necessary to ask the adult who accompanied the child to assist with the process by holding the child and securing the child's upper body for safety. A staff member may also be asked to assist in the process. The medical assistant should be ready for the blood draw as quickly as possible in this situation, and should not allow the child to see the needle for an excessive period of time before the venipuncture.
- **Patient communication:** Whenever the skin is to be punctured, remember to be honest with the patient about what will occur. *Never* tell a patient that the procedure won't hurt, or chastise the patient for expressing fear or discomfort with the procedure. Assure the patient that the procedure is necessary, and that it will be completed in as little time as possible. Try to adapt to the age of the patient by making appropriate small talk. Allowing the child to "blow away the pain" may be beneficial; the act of saying "ow" and blowing out may help to distract him or her from the process.

Test Your Knowledge 8-15

What is the most important aspect of patient preparation for blood collection procedures? (Outcome 8-14)

SPECIMEN PROCESSING

Once the blood specimen is collected, it may require further processing before it can be used for testing. The analysis may call for serum, plasma, or whole blood for

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Procedure 8-1: Venipuncture Using the Evacuated Tube System

The evacuated tube system is the method used most commonly for obtaining blood. It is fast and relatively safe, and allows for multiple tubes to be filled with one invasive procedure.

TASK

Successfully perform a venipuncture using the evacuated tube system. The process must be completed within 5 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Tourniquet
- 70% isopropyl alcohol
- Double-pointed multi-sample needle
- Evacuated tube holder
- Laboratory requisition form or labels with specified test
- Evacuated tubes
- 2 x 2 gauze pads
- Adhesive bandage or wrap
- Test tube rack
- Biohazardous sharps container
- Biohazardous disposal bag

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.2: Perform Venipuncture **I.A.I.1:** Apply critical thinking skills in performing patient assessment and care **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Medical Office Laboratory Procedures: Collect, label and process specimens: Perform venipuncture
- Medical Office Clinical Procedures: Apply principles of aseptic techniques and infection control
- Medical Office Clinical Procedures: Use Standard Precautions

Procedure	Rationale
1. Gather the requisition form and/or labels for the blood draw, and greet the patient. Identify yourself appropriately.	The requisition or labels are necessary to collect the correct type of specimen. It is always correct practice to identify yourself to the patient.
2. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.
3. Verify the identity of the patient by asking for his or her name and at least one other unique identifier (such as the patient's birth date). Compare this information to the requisition form or labels.	Patient identification must always be verified using at least two unique factors.
4. Verify whether dietary restrictions were followed, and time of last medication dose, if needed.	Many laboratory tests require fasting specimens or other dietary restrictions. Drug dosage times are especially important for appropriate interpretation of the laboratory results.
5. Have the patient sit in the phlebotomy chair with appropriate arm support, and extend his or her arm to expose the antecubital area.	The arm should be supported for the venipuncture process, and the antecubital area will be the first area that is considered for the blood draw.

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Procedure	Rationale
6. Apply gloves.	Gloves are required for procedures in which there is reasonable anticipation of exposure to blood or other potentially infectious materials.
7. Apply the tourniquet approximately 3 in. above the antecubital area (or above the wrist if a hand draw is necessary) and select an appropriate draw site using palpation. Use the tips of the ring finger and middle finger in a gentle probing motion as the antecubital area is examined. An appropriate vein will feel flexible and firm. Do not allow the tourniquet to remain on the arm for more than 1 minute.	The tourniquet needs to be placed high enough that it will not block the venipuncture site. Only blood vessels that can be palpated should be used for venipuncture; just looking at them is not sufficient. The thumb should never be used to feel for a vein, as there may be a pulse felt from the thumb that can be misleading. The thumb is also not as sensitive as the fingers.
8. While palpating, have the patient make a fist, but *do not* allow the patient to pump his or her hand.	Pumping the hand can cause erroneous test results due to hemoconcentration.
9. If an appropriate site is not identified on the first arm, examine the other arm. If the antecubital area is not appropriate on either arm, examine the back of the hands for other opportunities.	It is important to choose the best site before inserting the needle. If the first arm examined doesn't provide a vein that is appropriate, check the other arm. If necessary, the back of the hands may be considered as a blood draw site.
10. Once an appropriate site is selected, determine the direction of the vein; is it running straight up and down or at an angle across the arm? Establish a visible landmark (a mole or dimple in the skin, etc.) for reference.	The needle must be inserted in such a way that it follows the direction of the vein for the best chance of success. A landmark is helpful so that the chosen venipuncture site can be identified after cleaning the area.
11. Have the patient open the hand to relax the fist until the tourniquet is reapplied.	Relaxing the hand will help the blood to flow normally as the site is prepared.
12. Remove the tourniquet.	A tourniquet may not stay on the arm for more than 1 minute, or hemoconcentration may result.

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Procedure 8-1: Venipuncture Using the Evacuated Tube System—cont'd

Procedure	Rationale
13. Apply 70% isopropyl alcohol to the area in a circular motion with the draw site at the center of the circle. Allow the site to air-dry.	70% isopropyl alcohol will kill most of the bacterial contaminants on the surface of the skin. Never blow or fan the site to speed up the drying process, as this recontaminates the clean area.
14. As the alcohol is drying, assemble the necessary supplies.	Supplies need to be close by for ease of use and patient safety.
a. Choose a needle of appropriate size and attach it to the evacuated tube holder. Do not remove the cap that covers the long end of the needle until right before the skin is to be punctured.	This should always occur in the presence of the patient so that he or she is assured that the needle is sterile. The cap should not be removed until it is ready to be used to minimize the risk of contamination or possible injury. Needle sizes may vary according to the needs of the patient and the policy of the facility.
b. Arrange the necessary tubes for the tests ordered within easy reach of your nondominant hand, and have them set up in the correct order of draw.	The tubes may be laid out on the counter near the patient, or a small tube rack may work well for this purpose.
c. Verify that the tubes are not expired and that the anticoagulant is placed away from the rubber stopper within the tube. (You may need to shake the tube lightly to get the anticoagulant to move away from the stopper.) Check for any obvious defects in the tubes.	Use of an expired tube may result in a loss of vacuum and an unsuccessful blood draw. Potential crossover of anticoagulant from one tube to another should be minimized as much as possible. Defective (such as cracked or chipped tubes) should be discarded immediately.
15. Verify that gauze pads and an adhesive bandage are within reach. Extra tubes should also be close by so that they can be used if necessary.	The gauze pads and adhesive bandages need to be ready for use immediately when the needle is removed from the skin. If the phlebotomist feels that there may be a chance that the vacuum is exhausted in the first tube, using a second one that is nearby may allow the venipuncture to be successful.
16. Once the alcohol is dry, reapply the tourniquet. Do not repalpate the venipuncture site, or if absolutely necessary, clean the end of the gloved finger with alcohol before touching the site.	If the site is touched after cleansing, it will need to be cleaned again before the venipuncture can begin.
17. Have the patient make a fist.	Forming a fist may help with the visualization of the veins once the tourniquet is reapplied.
18. Remove the cap to expose the end of the needle to be inserted into the arm. Do not allow this needle to touch anything before piercing the skin.	Touching this needle to any surface before it pierces the skin will cause contamination and possible introduction of bacteria into the vein.

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Procedure	Rationale
19. Stabilize the chosen vein by anchoring it with the thumb of the nondominant hand about 2 in. below the draw site, and/or off to the side. Make sure that the skin is pulled taut over the vein.	It is important to stabilize the vein, but if the thumb is placed too close to the draw site, it will be in the way of the needle insertion and could cause interference with the angle used for the process and result in an unsuccessful blood draw. 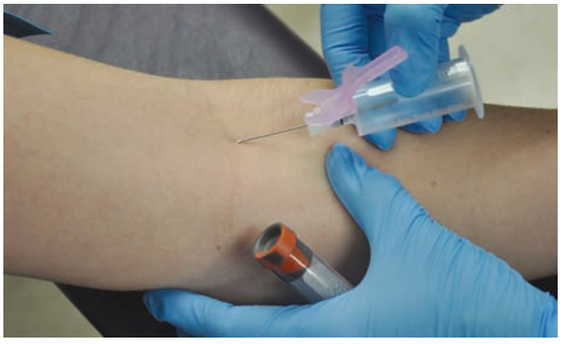
20. As you prepare to pierce the skin with the needle, it is good practice to warn the patient by saying something like, "Here we go; you will feel a stick."	If the patient is not expecting the skin to be pierced, he or she may be startled and move the arm or hand, causing an unsuccessful venipuncture.
21. Insert the needle at an angle of approximately 15 degrees, with the bevel up. The actual insertion site is approximately $^1/_4$ to $^1/_2$ inch below the identified draw site so that the needle is actually inserted into the vein at the chosen site.	If the angle is significantly less or more than 15 degrees, it may slide just above the vein or puncture through both sides of the vein rather than just entering the vein. The bevel facing upward allows the blood to enter the needle with minimal trauma.
22. The needle needs to be inserted quickly, with one smooth gentle motion. As the insertion is accomplished, follow the direction of the vein that was previously identified; if the vein is running at an angle across the arm or hand, this is how the needle should be directed into the vein. Approximately a third of the needle is usually below the surface of the skin when the insertion is complete.	Smooth insertion minimizes the trauma to the patient. It is important to follow the direction of the vein as the needle is inserted; this allows a better opportunity for the blood to enter the needle without obstruction. The needle needs to be inserted far enough to enter the vein, but not so far that it punctures both sides of the vein.

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Procedure 8-1: Venipuncture Using the Evacuated Tube System—cont'd

Procedure	Rationale
23. While keeping the needle firmly seated in the vein, push the first tube into the needle holder, with the label facing downward. Use the index and middle fingers of the nondominant hand by placing them on either side of the flared edge at the bottom of the evacuated tube holder. Place the thumb of the nondominant hand on the bottom of the tube, and squeeze or pull the thumb toward the fingers, pushing the tube into the holder. If the needle is placed appropriately in the vein, blood should start to enter the tube as soon as the needle has pierced the stopper.	The hand used to hold the evacuated tube holder should rest firmly against the arm to keep the needle in place. If the label on the tube is facing upward, it is difficult to see the blood as it enters the tube.
24. If only one tube is necessary for the tests ordered, release the tourniquet once the blood has started to enter the tube. If there is more than one tube necessary, the tourniquet may stay in place until the last tube has been inserted, as long as the length of time has not exceeded 1 minute since the tourniquet was applied.	The tourniquet must not stay on longer than 1 minute. It is always necessary to release the tourniquet before the needle is removed from the arm to avoid bleeding from the venipuncture site and introduction of air into the last vacuum tube used.
25. If it is necessary to use more than one tube for the blood draw, push against the flanges to remove the tube from the holder. Be careful not to disturb the needle placement as the tube is removed. Insert the next tube needed for the tests ordered, following the appropriate order of draw.	It is important to keep applying gentle pressure on the arm of the patient with the back of the fingers that are supporting the evacuated tube holder while removing and inserting tubes to keep the needle in place within the vein. It may be necessary to change tubes more than once when there are multiple tubes necessary for the tests ordered.
26. As each tube with additive is removed from the holder, invert the tube gently at least one or two times. This may be accomplished while the next tube is filling.	Tubes with anticoagulant added must be inverted sufficiently to mix the sample with the additive or the blood will clot and the specimen will need to be redrawn.
27. As the last tube is filling, ask the patient to relax the fist. Verify that the tourniquet has been released, and remove the last tube from the holder.	This is important to avoid a potential bruise or hematoma at the draw site, and also to avoid introduction of excess air into this last tube.

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Procedure	Rationale
28. As the needle is removed from the skin, place gauze over the site without applying initial pressure. The needle is to be removed quickly, and at the same angle as the insertion. Do not apply pressure to the site with the gauze until the needle has been removed completely from the skin, as this will cause pain for the patient.	The gauze placed over the site will minimize bleeding as the needle is removed.
29. Ask the patient to apply pressure to the site for 3 to 5 minutes. Do not allow the patient to bend his or her arm.	The pressure should be adequate to stop any bleeding before the patient leaves the drawing area. Bending the arm increases the risk for bleeding and bruise formation.
30. Once the needle has been removed from the arm, immediately activate the needle safety device and discard the entire setup in the biohazardous sharps container. Do not remove the needle from the evacuated tube holder before disposal. *Never recap contaminated needles.*	The evacuated tube setup is designed to be used one time and discarded without removing the needle before disposal. Recapping contaminated needles increases the risk of needlestick accidents and potential exposure to bloodborne pathogens. A

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Procedure 8-1: Venipuncture Using the Evacuated Tube System—cont'd

Procedure	Rationale
	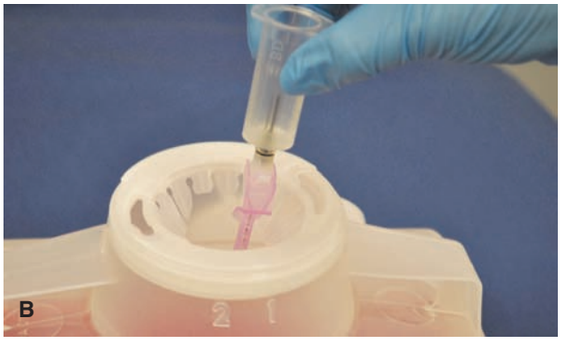
31. As the patient is applying pressure to the draw site, gently invert the blood specimens containing anticoagulant 5 to 10 times.	Insufficient mixing of the anticoagulant with the specimen will result in clotted blood and a sample that must be discarded.
32. Label the tubes, including the full name of the patient, birth date (or other unique identifier assigned by the health-care provider), the date and time of collection, and the initials of the person who drew the sample.	All samples must be labeled using at least two unique identifiers. The date and time provide additional information that may be necessary for interpretation of the results.
	Identification of the phlebotomist may be helpful if there are questions about the procedure or the specimens collected.
33. Use the requisition form or the labels to verify that all the necessary tubes were drawn for the specimens ordered.	Verifying the details of the blood draw once more in the presence of the patient allows for a redraw to be performed immediately if something is missing.

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Procedure	Rationale
34. Observe any special handling instructions for the specimens.	Some types of specimens must remain at room temperature, whereas others may need to be put on ice immediately. This should be information that is ascertained before the procedure starts.
35. Monitor the patient for any signs of distress from the procedure.	These may include pallor, perspiration (especially on the upper lip or forehead), increased anxiety, or light-headedness. If the patient is exhibiting any of these symptoms, it is best to have him or her lie down if possible. This may be easily accomplished if the patient is in a chair that can recline. If not, a cold compress on the forehead and/or the back of the neck may help. Continue to converse with the patient and move the blood out of sight. Ask for assistance if you feel that your patient is feeling faint. If the patient loses consciousness, it may be necessary to lower him or her to the floor from the phlebotomy chair.
36. Once the tubes have been labeled, check the draw site for bleeding. If it has not stopped bleeding, apply pressure for another few minutes, and if the bleeding is still present, contact a physician.	It is important to look under the gauze for 2 or 3 seconds before applying the adhesive bandage to be certain that the site has actually stopped bleeding.
37. If the bleeding has subsided, apply an adhesive bandage, but leave the gauze in place to allow for additional pressure.	Self-adhesive bandages (such as Coban) may be wrapped around the site rather than applying an adhesive to the skin directly. Self-adhesive bandages may be especially effective for those patients who are on anticoagulant therapy.
38. Advise the patient to avoid heavy lifting or excessive exercise of the arm used for venipuncture for at least 1 hour.	Heavy lifting or exercise could cause the site to resume bleeding.
39. Assist the patient to stand (if necessary) and thank him or her for being cooperative.	Patients may be a bit light-headed, and assistance may be needed when he or she first stands up.
40. Discard all trash, and place the tubes in an appropriate vessel for processing. Never touch full tubes of blood without wearing gloves.	Touching the tubes of blood without wearing gloves offers potential opportunities for exposure to bloodborne pathogens.
41. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.

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Procedure 8-1: Venipuncture Using the Evacuated Tube System—cont'd

Procedure	Rationale
42. Document the procedure in the patient's chart as well as on the requisition form. Include the date and time of collection, what was collected, and if there were any circumstances that were out of the ordinary. Also document where the vein was accessed (such as right arm, left hand, etc.). The documentation should include the type (color) of tubes drawn, as well as the identity of the person who collected the sample.	All patient interactions must be carefully documented. The site used for vein access should always be written in the chart or on the requisition form so that if there are any negative outcomes associated with the procedure, the site has been noted.

Date	
1/18/2020:	Phlebotomy performed in right antecubital area for CMP and CBC. Tiger top and lavender top tube drawn.
1100 a.m.	Connie Lieseke, CMA (AAMA)

Procedure 8-2: Venipuncture Using a Syringe

A syringe and needle may be used for venipuncture in situations in which the available veins are prone to move during the blood draw, or when the vein may not be capable of supporting the vacuum exerted from an evacuated tube. This may be the case if the vein is small, or if it lacks "bounce" when palpated. Syringe draws are an excellent choice in the antecubital area when the veins are not quite suitable for a blood draw using an evacuated tube system setup.

TASK

Successfully perform a venipuncture using a syringe. After the blood has been obtained, transfer it successfully into the necessary tubes for analysis. The process must be completed within 5 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Tourniquet
- 70% isopropyl alcohol
- Syringe (5- to 15-mL capacity)
- 21- to 23-gauge safety enabled needle
- Transfer device
- Laboratory requisition form or labels with specified test
- Evacuated tubes
- 2 x 2 gauze pads
- Adhesive bandage or wrap
- Test tube rack
- Biohazardous sharps container
- Biohazardous disposal bag

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.2: Perform Venipuncture **I.A.I.1:** Apply critical thinking skills in performing patient assessment and care **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Medical Office Laboratory Procedures: Collect, label and process specimens: Perform venipuncture
- Medical Office Clinical Procedures: Apply principles of aseptic techniques and infection control
- Medical Office Clinical Procedures: Use Standard Precautions

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Procedure	Rationale
1. Gather the requisition form and/or labels for the blood draw, and greet the patient. Identify yourself appropriately.	The requisition or labels are necessary to collect the correct type of specimen. It is always correct practice to identify yourself to the patient.
2. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.
3. Verify the identification of the patient by asking for his or her name and at least one other unique identifier (such as the patient's birth date). Compare this information to the requisition form or labels.	Patient identification must always be verified using at least two unique factors.
4. Verify whether diet restrictions were followed, and time of last medication dose, if needed.	Many laboratory tests require fasting specimens or other dietary restrictions. Drug dosage times are especially important for appropriate interpretation of the laboratory results.
5. Have the patient sit in the phlebotomy chair with appropriate arm support, and extend his or her arm to expose the antecubital area.	The arm should be supported for the venipuncture process, and the antecubital area will be the first area that is considered for the blood draw.
6. Apply gloves.	Gloves are required for procedures in which there is reasonable anticipation of exposure to blood or other potentially infectious materials.
7. Apply the tourniquet approximately 3 in. above the antecubital area (or above the wrist if a hand draw is necessary) and select an appropriate draw site using palpation. Use the tips of the ring finger and middle finger in a gentle probing motion as the antecubital area is examined. An appropriate vein will feel flexible and firm. Do not allow the tourniquet to remain on the arm for more than 1 minute.	The tourniquet needs to be placed high enough that it will not block the venipuncture site. Only blood vessels that can be palpated should be used for venipuncture; just looking at them is not sufficient. The thumb should never be used to feel for a vein, as there may be a pulse felt from the thumb that can be misleading. The thumb is also not as sensitive as the fingers.
8. While palpating, have the patient make a fist, but *do not* allow the patient to pump his or her hand.	Pumping the hand can cause erroneous results because of hemoconcentration.
9. If an appropriate site is not identified on the first arm, examine the other arm. If the antecubital area is not appropriate on either arm, examine the back of the hands for other opportunities.	It is important to choose the best site before inserting the needle. If the first arm examined doesn't provide a vein that is appropriate, check the other arm. If necessary, the back of the hands may be considered as a blood draw site.
10. Once an appropriate site is selected, determine the direction of the vein; is it running straight up and down or at an angle across the arm? Establish a visible landmark (a mole or dimple in the skin, etc.). for reference.	The needle must be inserted in such a way that it follows the direction of the vein for the best chance of success. A landmark is helpful so that the chosen venipuncture site can be identified after cleaning the area.

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Procedure 8-2: Venipuncture Using a Syringe—cont'd

Procedure	Rationale
11. Have the patient open the hand to relax the fist until the tourniquet is reapplied.	Relaxing the hand will help the blood to flow normally as the site is prepared.
12. Remove the tourniquet.	A tourniquet may not stay on the arm for more than 1 minute, or hemoconcentration may result.
13. Apply 70% isopropyl alcohol to the area in a circular motion with the draw site at the center of the circle. Allow the site to air-dry.	70% isopropyl alcohol will kill most of the bacterial contaminants on the surface of the skin. Never blow or fan the site to speed up the drying process, as this recontaminates the clean area.
14. As the alcohol is drying, assemble the necessary supplies.	Supplies need to be close by for ease of use and patient safety.
a. Open the sterile package holding the syringe	Syringes should remain sterile until the time of use.
b. Pull back and push forward the plunger of the syringe several times to verify whether it moves smoothly. Be certain that the plunger is pushed forward as far as it goes before continuing with the process.	"Exercising" the plunger in this way allows for smooth movement when pulling back the plunger to allow blood to enter the syringe. If the plunger does not move smoothly or is too loose within the barrel of the syringe, it should be discarded.
c. Remove the needle from the sterile wrapper. Do not take off the cap covering the end of the needle until just before insertion into the patient's arm.	The needle must remain sterile until just prior to insertion. It cannot touch other surfaces before piercing the skin of the patient.
d. Attach the needle to the syringe tip.	Verify that this is a secure connection so that blood will not leak out around the needle during the venipuncture process.
e. Place gauze pads and adhesive bandage within reach of the nondominant hand for use at the end of the venipuncture.	Supplies to be used during the venipuncture process should be within easy reach of the nondominant hand to avoid reaching over the site where the needle is inserted in the arm.
f. Organize tubes needed for analysis and unwrap transfer device. Place within easy reach.	When the venipuncture procedure is finished, it is necessary to transfer the blood into the tubes quickly to avoid clot formation in the sample. Organization of supplies before the process is critical.
g. Verify that the tubes are not expired and that the anticoagulant is placed away from the rubber stopper within the tube. (You may need to shake the tube lightly to get the anticoagulant to move away from the stopper.) Check for any obvious defects in the tubes.	Use of an expired tube may result in a loss of vacuum and an unsuccessful blood draw. Potential crossover of anticoagulant from one tube to another should be minimized as much as possible. Defective (such as cracked or chipped tubes) should be discarded immediately.
15. Once the alcohol is dry and the supplies are assembled, reapply the tourniquet. Do not repalpate the venipuncture site, or if absolutely necessary, clean the end of the gloved finger with alcohol before touching the site.	If the site is touched after cleansing, it will need to be cleaned again before the venipuncture can begin.

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Procedure	Rationale
16. Have the patient make a fist.	Forming a fist may help with the visualization of the veins once the tourniquet is reapplied.
17. Remove the cap to expose the end of the needle to be inserted into the arm. Do not allow this needle to touch anything before piercing the skin.	Touching this needle to any surface before it pierces the skin will cause contamination and possible introduction of bacteria into the vein.
18. Stabilize the chosen vein by anchoring it with the thumb of the nondominant hand about 2 in. below the draw site, and/or off to the side. Make sure that the skin is pulled taut over the vein.	It is important to stabilize the vein, but if the thumb is placed too close to the draw site, it will be in the way of the needle insertion and could cause interference with the angle used for the process and result in an unsuccessful blood draw.
19. As you prepare to pierce the skin with the needle, it is good practice to warn the patient by saying something like, "Here we go; you will feel a stick."	If the patient is not expecting the skin to be pierced, he or she may be startled and move the arm or hand, causing an unsuccessful venipuncture.
20. Insert the needle at an angle of approximately 15 degrees, with the bevel up. The actual insertion site is approximately $^1/_4$ to $^1/_2$ inch below the identified draw site so that the needle is actually inserted into the vein at the chosen site.	If the angle is significantly less or more than 15 degrees, it may slide just above the vein or puncture through both sides of the vein rather than just entering the vein. The bevel facing upward allows the blood to enter the needle with minimal trauma.
21. The needle needs to be inserted quickly, with one smooth gentle motion. As the insertion is accomplished, follow the direction of the vein that was previously identified; if the vein is running at an angle across the arm or hand, this is how the needle should be directed into the vein. Approximately a third of the needle is usually below the surface of the skin when the insertion is complete.	Smooth insertion minimizes the trauma to the patient. It is important to follow the direction of the vein as the needle is inserted; this allows a better opportunity for the blood to enter the needle without obstruction. The needle needs to be inserted far enough to enter the vein, but not so far that it punctures both sides of the vein.

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Procedure 8-2: Venipuncture Using a Syringe—cont'd

Procedure	Rationale
22. When using the syringe technique, there may be a "flash" of blood visible in the hub of the needle as soon as it is inserted in the vein. Gently pull back on the plunger of the syringe to create a vacuum and pull the blood into the syringe.	It is important to pull back relatively slowly because if the plunger is pulled back too fast, it can cause hemolysis. It is also possible that if the vein is small, it will collapse with the pressure applied by pulling the plunger back too quickly.
23. Continue to pull back slowly on the plunger and monitor the volume of blood entering the syringe. Keep gentle pressure on the arm of the patient with the back of the fingers holding the syringe.	The medical assistant must continue to pull back on the plunger so that the blood will continue to enter the syringe. To keep the needle from moving during the process, pressure should be applied with the back of the fingers holding the syringe. 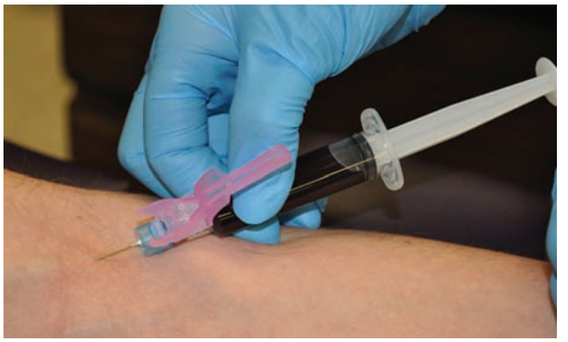
24. When the required amount of blood has almost been obtained, release the tourniquet and have the patient open his or her fist.	The tourniquet must not stay on longer than 1 minute. It is always necessary to release the tourniquet and have the patient open the fist before the needle is removed from the arm to avoid bleeding from the venipuncture site.
25. As the needle is removed from the skin, place gauze over the site, without applying initial pressure. The needle is to be removed quickly, and at the same angle as the insertion. Do not apply pressure to the site with the gauze until the needle has been removed completely from the skin, as this will cause pain for the patient.	The gauze placed over the site will minimize bleeding as the needle is removed.
26. Ask the patient to apply pressure to the site for 3 to 5 minutes. Do not allow the patient to bend his or her arm.	The pressure should be adequate to stop any bleeding before the patient leaves the drawing area. Bending the arm increases the risk for bleeding and bruise formation.

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Procedure	Rationale
27. Once the needle has been removed from the arm, immediately activate the needle safety device. Grasp the needle at its base, and remove it from the syringe. Discard the needle in the biohazardous sharps container. *Never recap contaminated needles.*	The needle must be removed from the syringe so that the transfer device can be applied. Recapping contaminated needles increases the risk of needlestick accidents and potential exposure to bloodborne pathogens.
28. Screw the transfer device onto the end of the syringe filled with blood.	Make sure this is a secure seal so that the blood will flow adequately.
29. While holding the syringe upright, insert each evacuated tube into the open end of the transfer device. Follow the recommended order of draw.	Holding the syringe upright will minimize the opportunity for anticoagulant crossover as the transfer device is used.
30. Dispose of the transfer device and syringe in a biohazardous sharps container.	There is a needle within the transfer device, so this must go into a sharps container.
31. Gently invert the blood specimens containing anticoagulant 5 to 10 times.	Insufficient mixing of the anticoagulant with the specimen will result in clotted blood and a sample that must be discarded.
32. Label the tubes, including the full name of the patient, birth date (or other unique identifier assigned by the health-care provider), the date and time of collection, and the initials of the collector.	All samples must be labeled using at least two unique identifiers. The date and time provide additional information that may be necessary for interpretation of the results. Identification of the phlebotomist may be helpful if there are questions about the procedure or the specimens collected.

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Procedure 8-2: Venipuncture Using a Syringe—cont'd

Procedure	Rationale
33. Use the requisition form or the labels to verify that all the necessary tubes were drawn for the specimens ordered.	Verifying the details of the blood draw once more in the presence of the patient allows for a redraw to be performed immediately if something is missing.
34. Observe any special handling instructions for the specimens.	Some types of specimens must remain at room temperature, whereas others may need to be put on ice immediately. This should be information that is ascertained before the procedure starts.
35. Monitor the patient for any signs of distress from the procedure.	These may include pallor, perspiration (especially on the upper lip or forehead), increased anxiety, or light-headedness. If the patient is exhibiting any of these symptoms, it is best to have him or her lie down if possible. This may be easily accomplished if the patient is in a chair that can recline. If not, a cold compress on the forehead and/or the back of the neck may help. Continue to converse with the patient and move the blood out of sight. Ask for assistance if you feel that your patient is feeling faint. If the patient loses consciousness, it may be necessary to lower him or her to the floor from the phlebotomy chair.
36. Once the tubes have been labeled, check the draw site for bleeding. If it has not stopped bleeding, apply pressure for another few minutes, and if the bleeding is still present, contact a physician.	It is important to look under the gauze for 2 or 3 seconds before applying the adhesive bandage to be certain that the site has actually stopped bleeding.
37. If the bleeding has subsided, apply an adhesive bandage, but leave the gauze in place to allow for additional pressure.	Self-adhesive bandages (such as Coban) may be wrapped around the site rather than applying an adhesive to the skin directly. Self-adhesive bandages may be especially effective for those patients who are on anticoagulant therapy.
38. Advise the patient to avoid heavy lifting or excessive exercise of the arm used for venipuncture for at least 1 hour.	Heavy lifting or exercise could cause the site to resume bleeding.
39. Assist the patient to stand (if necessary) and thank them for their cooperation.	Patients may be a bit light-headed and assistance may be needed when he or she first stands up.
40. Discard all trash, and place the tubes in an appropriate vessel for processing. Never touch full tubes of blood without wearing gloves.	Touching the tubes of blood without wearing gloves offers potential opportunities for exposure to bloodborne pathogens.
41. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.

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Procedure	Rationale
42. Document the procedure in the patient's chart as well as on the requisition form. Include the date and time of collection, what was collected, and if there were any circumstances that were out of the ordinary. Also document where the vein was accessed (such as right arm, left hand, etc.). The documentation should include the type (color) of tubes drawn, as well as the identity of the person who collected the sample.	All patient interactions must be carefully documented. The site used for vein access should always be written in the chart or on the requisition form so that if there are any negative outcomes associated with the procedure, the site has been noted.

Date	
1/18/2020:	*Phlebotomy performed in left antecubital area for H&H. Lavender top tube drawn.*
1100 a.m.	*Connie Lieseke, CMA (AAMA)*

Procedure 8-3: Venipuncture Using the Butterfly (Winged Infusion) System

The butterfly system is often used for obtaining blood from patients with small, fragile veins. It is the system of choice when performing blood draws from the hand of patients. When utilized for venipuncture, 23-gauge needles are usually used.

TASK

Successfully perform a venipuncture using a butterfly (winged infusion) system. The process must be completed within 5 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Tourniquet
- 70% isopropyl alcohol
- Butterfly needle (winged infusion set)
- Evacuated tube holder and luer adapter, or syringe and transfer device
- Laboratory requisition or labels with specified test
- Evacuated tubes
- 2 x 2 gauze pads
- Adhesive bandage or wrap
- Test tube rack
- Biohazardous sharps container
- Biohazardous disposal bag

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.2: Perform Venipuncture **I.A.I.1:** Apply critical thinking skills in performing patient assessment and care **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Medical Office Laboratory Procedures: Collect, label and process specimens: Perform venipuncture
- Medical Office Clinical Procedures: Apply principles of aseptic techniques and infection control
- Medical Office Clinical Procedures: Use Standard Precautions

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Procedure 8-3: Venipuncture Using the Butterfly (Winged Infusion) System—cont'd

Procedure	Rationale
1. Gather the requisition and/or labels for the blood draw, and greet the patient. Identify yourself appropriately.	The requisition or labels are necessary to collect the correct type of specimen. It is always correct practice to identify yourself to the patient.
2. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.
3. Verify the identification of the patient by asking for his or her name and at least one other unique identifier (such as the patient's birth date). Compare this information to the requisition or labels.	Patient identification must always be verified using at least two unique factors.
4. Verify whether dietary restrictions were followed, and time of last medication dose, if needed.	Many laboratory tests require fasting specimens or other dietary restrictions. Drug dosage times are especially important for appropriate interpretation of the laboratory results.
5. Have the patient sit in the phlebotomy chair with appropriate arm support, and extend his or her arm to expose the antecubital area.	The arm should be supported for the venipuncture process, and the antecubital area will be the first area that is considered for the blood draw.
6. Apply gloves.	Gloves are required for procedures in which there is reasonable anticipation of exposure to blood or other potentially infectious materials.
7. Apply the tourniquet approximately 3 in. above the antecubital area (or above the wrist if a hand draw is necessary) and select an appropriate draw site using palpation. Use the tips of the ring finger and middle finger in a gentle probing motion as the antecubital area is examined. An appropriate vein will feel flexible and firm. Do not allow the tourniquet to remain on the arm for more than 1 minute.	The tourniquet needs to be placed high enough that it will not block the venipuncture site. Only blood vessels that can be palpated should be used for venipuncture; just looking at them is not sufficient. The thumb should never be used to feel for a vein, as there may be a pulse felt from the thumb that can be misleading. The thumb is also not as sensitive as the fingers.
8. While palpating, have the patient make a fist, but *do not* allow them to pump his or her hand.	Pumping the hand can cause erroneous results because of hemoconcentration.
9. If an appropriate site is not identified on the first arm, examine the other arm. If the antecubital area is not appropriate on either arm, examine the back of the hands for other opportunities.	It is important to choose the best site before inserting the needle. If the first arm examined doesn't provide a vein that is appropriate, check the other arm. If necessary, the back of the hands may be considered.

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Procedure	Rationale
10. Once an appropriate site is selected, determine the direction of the vein; is it running straight up and down or at an angle across the arm? Establish a visible landmark (a mole or dimple in the skin, etc.) for reference.	The needle must be inserted in such a way that it follows the direction of the vein for the best chance of success. A landmark is helpful so that the chosen venipuncture site can be identified after cleaning the area.
11. Have the patient open the hand to relax the fist until the tourniquet is reapplied.	Relaxing the hand will help the blood to flow normally as the site is prepared.
12. Remove the tourniquet.	A tourniquet may not stay on the arm for more than 1 minute, or hemoconcentration may result.
13. Apply 70% isopropyl alcohol to the area in a circular motion with the draw site at the center of the circle. Allow the site to air-dry.	70% isopropyl alcohol will kill most of the bacterial contaminants on the surface of the skin. Never blow or fan the site to speed up the drying process, as this recontaminates the clean area.
14. As the alcohol is drying, assemble the necessary supplies. Start by opening the sterile package holding the butterfly setup and uncurling the tubing by gently stretching it.	Supplies need to be close by for ease of use and patient safety. The butterfly system should remain sterile until just before use. If the tubing stays tightly curled, it is difficult to use it effectively.
Option 1. Butterfly System With a Syringe	
a. Open the sterile package holding the syringe	Syringes should remain sterile until the time of use.
b. Pull back and push forward the plunger of the syringe several times to verify whether it moves smoothly.	"Exercising" the plunger in this way allows for smooth movement when pulling back the plunger to allow blood to enter the syringe. If the plunger does not move smoothly or is too loose within the syringe, it should be discarded.
c. Attach the end of the butterfly tubing to the syringe.	This tubing needs to be attached securely to allow the blood to enter the syringe.
d. Open a transfer device and place within reach.	There is a limited amount of time allowed to transfer the blood from the syringe to the tubes before it clots, so it is important to have the transfer device ready.
Option 2. Butterfly System With Evacuated Tube Holder	
a. Verify that the butterfly system has a luer adapter to be used with the evacuated tube holder.	The luer adapter has a needle covered with a rubber sleeve that pierces the tubes when using the evacuated tube holder.
b. Screw the butterfly tubing with the adapter attached into the evacuated tube holder.	The tubing and the holder must be securely attached to one another to allow the blood to flow appropriately into the tubes.

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Procedure 8-3: Venipuncture Using the Butterfly (Winged Infusion) System—cont'd

Procedure	Rationale
15. Place gauze pads and adhesive bandage within reach of the nondominant hand for use at the end of the venipuncture.	Supplies to be used during the venipuncture process should be within easy reach of the nondominant hand to avoid reaching over the site where the needle is inserted in the arm.
16. Organize tubes needed for analysis and place within easy reach.	To allow for the blood collection process to proceed smoothly, it is necessary organize the supplies before getting started.
17. Verify that the tubes are not expired and that the anticoagulant is placed away from the rubber stopper within the tube. (You may need to shake the tube lightly to get the anticoagulant to move away from the stopper.) Check for any obvious defects in the tubes.	Use of an expired tube may result in a loss of vacuum and an unsuccessful blood draw. Potential crossover of anticoagulant from one tube to another should be minimized as much as possible. Defective (such as cracked or chipped tubes) should be discarded immediately.
18. Once the alcohol is dry and the supplies are assembled, reapply the tourniquet. Do not repalpate the venipuncture site, or if absolutely necessary, clean the end of the gloved finger with alcohol before touching the site.	If the site is touched after cleansing, it will need to be cleaned again before the venipuncture can begin.
19. Have the patient make a fist.	Forming a fist may help with the visualization of the veins once the tourniquet is reapplied.
20. Remove the cap to expose the end of the needle to be inserted into the arm. Do not allow this needle to touch anything before piercing the skin.	Touching this needle to any surface before it pierces the skin will cause contamination and possible introduction of bacteria into the vein.
21. Stabilize the chosen vein by anchoring it with the thumb of the nondominant hand about 2 in. below the draw site, and/or off to the side. Make sure that the skin is pulled taut over the vein.	It is important to stabilize the vein, but if the thumb is placed too close to the draw site, it will be in the way of the needle insertion and could cause interference with the angle used for the process and result in an unsuccessful blood draw.
22. As you prepare to pierce the skin with the needle, it is good practice to warn the patient by saying something like, "Here we go; you will feel a stick."	If the patient is not expecting the skin to be pierced, he or she may be startled and move the arm or hand, causing an unsuccessful venipuncture.
23. Grasp the butterfly needle with the wings on either side. The textured area of the plastic wings is designed to be against the fingers; this allows the bevel of the needle to face upward.	If the needle is not grasped appropriately, the bevel will point downward and could affect the success of the blood draw.

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Procedure	Rationale
24. Insert the needle at an angle of 5 to 10 degrees, with the bevel up. The actual insertion site is approximately $^1/_4$ to $^1/_2$ inch below the identified draw site so that the needle is actually inserted into the vein at the chosen site.	If the angle is significantly less or more than 5 to 10 degrees, it may slide just above the vein or puncture through both sides of the vein rather than just entering the vein. The bevel facing upward allows the blood to enter the needle with minimal trauma.
25. The needle needs to be inserted quickly, with one smooth gentle motion. As the insertion is accomplished, follow the direction of the vein that was previously identified; if the vein is running at an angle across the arm or hand, this is how the needle should be directed into the vein. Approximately a third of the needle is usually below the surface of the skin when the insertion is complete.	Smooth insertion minimizes the trauma to the patient. It is important to follow the direction of the vein as the needle is inserted; this allows a better opportunity for the blood to enter the needle without obstruction. The needle needs to be inserted far enough to enter the vein, but not so far that it punctures both sides of the vein.
26. When the needle pierces the vein, the blood will immediately be present in the tubing. As soon as there is blood present, begin to pull the plunger of the syringe back slowly, if using a syringe. If the evacuated tube holder is used, push on the first tube to be drawn so that the vacuum pulls the blood through the tubing.	The blood will not flow into the tubing adequately without the vacuum of the plunger or the evacuated tube. Do not pull back quickly, or it may cause hemolysis or collapse the vein.
27. If using the syringe system, continue to pull back slowly on the plunger and monitor the volume of blood entering the syringe. Change the evacuated tubes as needed if using these directly to draw the blood. Keep gentle pressure on the arm of the patient with the back of the fingers holding the butterfly setup.	The medical assistant must continue to pull back on the plunger so that the blood will continue to enter the syringe. To keep the needle from moving during the process, pressure should be applied with the back of the fingers holding the syringe.
28. When the required amount of blood has almost been obtained, release the tourniquet and have the patient open the fist.	The tourniquet must not stay on longer than 1 minute. It is always necessary to release the tourniquet and have the patient open the fist before the needle is removed from the arm to avoid bleeding from the venipuncture site.

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Procedure 8-3: Venipuncture Using the Butterfly (Winged Infusion) System—cont'd

Procedure	Rationale
29. As the needle is removed from the skin, place gauze over the site, without applying initial pressure. The needle is to be removed quickly, and at the same angle as the insertion. Do not apply pressure to the site with the gauze until the needle has been removed completely from the skin, as this will cause pain for the patient.	The gauze placed over the site will minimize bleeding as the needle is removed.
30. Ask the patient to apply pressure to the site for 3 to 5 minutes. Do not allow the patient to bend his or her arm if the draw was performed in the antecubital space.	The pressure should be adequate to stop any bleeding before the patient leaves the drawing area. Bending the arm increases the risk for bleeding and bruise formation.
31. Once the needle has been removed from the arm, immediately activate the needle safety device.	The safety device may be a push-button device that is activated while the needle is still in the skin, or it may be activated right after removal. It is imperative that the medical assistant keeps his or her fingers behind the needle while activating the safety device.
32. If a syringe was used for the procedure, remove the tubing from the end of the syringe and discard the butterfly unit into a biohazardous sharps container. If an evacuated tube system was used, discard the evacuated tube holder with the butterfly setup.	The tubing must be removed so that the transfer device can be applied to put the blood into the tubes.
33. Screw the transfer device onto the end of the syringe filled with blood.	Make sure this is a secure seal so that the blood will flow adequately.
34. While holding the syringe upright, insert each evacuated tube into the open end of the transfer device. Follow the recommended order of draw.	Holding the syringe upright will minimize the opportunity for anticoagulant crossover as the transfer device is used.
35. Dispose of the transfer device and syringe in a biohazardous sharps container.	There is a needle within the transfer device, so this must go into a sharps container.

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Procedure	Rationale
36. Gently invert the blood specimens containing anticoagulant 5 to 10 times.	Insufficient mixing of the anticoagulant with the specimen will result in clotted blood and a sample that must be discarded.
37. Label the tubes, including the full name of the patient, birth date (or other unique identifier assigned by the health-care provider), the date and time of collection, and the initials of the collector.	All samples must be labeled using at least two unique identifiers. The date and time provides additional information that may be necessary for interpretation of the results. Identification of the phlebotomist may be helpful if there are questions about the procedure or the specimens collected.
38. Use the requisition form or the labels to verify that all the necessary tubes were drawn for the specimens ordered.	Verifying the details of the blood draw once more in the presence of the patient allows for a redraw to be performed immediately if something is missing.
39. Observe any special handling instructions for the specimens.	Some types of specimens must remain at room temperature, whereas others may need to be put on ice immediately. This should be information that is ascertained before the procedure starts.
40. Monitor the patient for any signs of distress from the procedure.	These may include pallor, perspiration (especially on the upper lip or forehead), increased anxiety, or light-headedness. If the patient is exhibiting any of these symptoms, it is best to have him or her lie down if possible. This may be easily accomplished if the patient is in a chair that can recline. If not, a cold compress on the forehead and/or the back of the neck may help. Continue to converse with the patient and move the blood out of sight. Ask for assistance if you feel that your patient is feeling faint. If the patient loses consciousness, it may be necessary to lower him or her to the floor from the phlebotomy chair.
41. Once the tubes have been labeled, check the draw site for bleeding. If it has not stopped bleeding, apply pressure for another few minutes, and if the bleeding is still present, contact a physician.	It is important to look under the gauze for 2 or 3 seconds before applying the adhesive bandage to be certain that the site has actually stopped bleeding.
42. If the bleeding has subsided, apply an adhesive bandage, but leave the gauze in place to allow for additional pressure.	Self-adhesive bandages (such as Coban) may be wrapped around the site rather than applying an adhesive to the skin directly. Self-adhesive bandages may be especially effective for those patients who are on anticoagulant therapy.
43. Advise the patient to avoid heavy lifting or excessive exercise of the arm used for venipuncture for at least 1 hour.	Heavy lifting or exercise could cause the site to resume bleeding.

Continued

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Procedure 8-3: Venipuncture Using the Butterfly (Winged Infusion) System—cont'd

Procedure	Rationale
44. Assist the patient to stand (if necessary) and thank him or her for being cooperative.	Patients may be a bit light-headed and assistance may be needed when he or she first stands up.
45. Discard all trash, and place the tubes in an appropriate vessel for processing. Never touch full tubes of blood without wearing gloves.	Touching the tubes of blood without wearing gloves offers potential opportunities for exposure to bloodborne pathogens.
46. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
47. Document the procedure in the patient's chart as well as on the requisition form. Include the date and time of collection, what was collected, and if there were any circumstances that were out of the ordinary. Also document where the vein was accessed (such as right arm, left hand, etc.). The documentation should include the type (color) of tubes drawn, as well as the identity of the person who collected the sample.	All patient interactions must be carefully documented. The site used for vein access should always be written in the chart or on the requisition form so that if there are any negative outcomes associated with the procedure, the site has been noted.

Date	
1/18/2020:	Phlebotomy performed in right hand for BMP and Hematocrit level. Lavender top tube drawn.
1100 a.m.	Connie Lieseke, CMA (AAMA)

Procedure 8-4: Blood Collection From a Capillary Puncture

Capillary punctures are performed frequently to obtain blood for CLIA-waived tests, as well as to draw blood for testing on children and infants. Blood obtained by capillary puncture is the preferred specimen type in these situations. In some situations in which it has been difficult to perform a successful venipuncture for adults, a capillary puncture specimen may also be obtained for testing.

TASK

Successfully perform a capillary puncture and obtain blood necessary for the tests ordered. The process must be completed within 5 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- 70% isopropyl alcohol
- Disposable safety equipped lancet
- Laboratory requisition form or labels with specified test
- Microcollection tubes
- 2 x 2 gauze pads
- Hand warmer (if necessary)
- Adhesive bandage or wrap
- Biohazardous sharps container
- Biohazardous disposal bag

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.3: Perform Capillary Puncture **I.A.I.1:** Apply critical thinking skills in performing patient assessment and care **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Medical Office Laboratory Procedures: Collect, label and process specimens: Perform capillary puncture
- Medical Office Clinical Procedures: Apply principles of aseptic techniques and infection control
- Medical Office Clinical Procedures: Use Standard Precautions

Procedure	Rationale
1. Gather the requisition form and/or labels for the blood draw, and greet the patient. Identify yourself appropriately.	The requisition or labels are necessary to collect the correct type of specimen. It is always correct practice to identify yourself to the patient.
2. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.
3. Verify the identification of the patient by asking for his or her name and at least one other unique identifier (such as the patient's birth date). Compare this information to the requisition or labels.	Patient identification must always be verified using at least two unique factors.
4. Verify whether dietary restrictions were followed, and time of last medication dose, if needed.	Many laboratory tests require fasting specimens or other dietary restrictions. Drug dosage times are especially important for appropriate interpretation of the laboratory results.
5. Have the patient sit in the phlebotomy chair with appropriate arm support, and extend his or her arm so that the hand may be accessed easily. Massage the fingertips if necessary for warmth, or apply a commercial warming device, hand warmer, or warm towel.	The patient should be secure and comfortable for the capillary puncture process. The fingers must be warm for a successful capillary blood draw; warming the site and massaging will allow much better blood flow. A commercial warming device works well, or immersing the finger or heel in warm water will also help. The temperature of the warming device or water should not exceed 42°C (108°F). Three to five minutes is generally sufficient to warm the site.
6. Assemble necessary equipment within reach. This includes the necessary tubes for the tests ordered, gauze, alcohol, and an adhesive bandage.	Once the incision is made, the process will go quickly, so it is important to have all supplies within reach.
7. Apply gloves.	Gloves are required for procedures in which there is reasonable anticipation of exposure to blood or other potentially infectious materials.

Continued

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Procedure 8-4: Blood Collection From a Capillary Puncture—cont'd

Procedure	Rationale
8. Choose the appropriate finger for the blood draw, and disinfect the fingertip with an alcohol swab. Allow the alcohol to dry completely before performing the skin puncture. Do not fan or blow on the site to dry the alcohol.	For both adults and children, the ring finger or middle finger should be used. The index finger is more sensitive and more callused, and the little finger does not have enough flesh to protect the bone from puncture. The thumb should never be used as a capillary puncture site. The alcohol may contaminate the specimen if not allowed to dry completely before performing the puncture. Blowing or fanning the site may recontaminate the skin after cleansing.
9. Choose the correct lancet for the age of the patient and the site selected. The number of tubes to be drawn must also be taken into consideration when choosing a device to use for the incision.	Lancets come with different depths and widths. There are recommendations for ages and uses provided by the manufacturers. Lancet devices designed for home use that produce only a drop of blood do not provide enough blood to be used for microcollection tubes.
10. Remove the cap from the lancet device. Do not allow the surface to be placed against the patient's skin or to touch anything else before it is utilized.	This part of the device must remain sterile until use.
11. Perform the dermal puncture by holding the lancet device firmly against the skin and activating the device. Use the lateral side of the ring or middle fingertip, perpendicular (opposite) to the lines of the fingerprint. Immediately discard the lancet into a biohazardous sharps container.	The lateral sides of the fingers need to be used to avoid potential damage to the bone. The incision needs to be perpendicular to the lines of the fingerprint to keep the blood from following the fingerprint and flowing away from the incision site.
12. Wipe away the first drop of blood, then gently massage the finger to achieve blood flow.	The first drop of blood is contaminated with tissue fluid, and must be discarded. The finger should be continuously massaged from the proximal to the distal end of the fingertip. Do not squeeze right at the collection site as this can contaminate the specimen with tissue fluid and cause erroneous results.
13. Fill the required tubes in the correct order of draw. If anticoagulant is used in the tubes, tap them against the countertop to mix the specimen as the tube is filled. Do not touch the collection device against the incision while collecting the specimen. Instead, touch it to the drop of blood as it forms at the collection site.	The capillary order of draw must be followed to avoid cross-contamination. The tubes must be mixed well during the collection process to avoid clotting. The collection device is to be used only to collect blood that is free flowing; scraping or touching the incision site can cause infection and/or irritation.
14. If a microhematocrit tube is to be filled, hold it horizontal to the site to avoid introduction of air bubbles to the specimen.	Capillary tubes that are held at a slant allow air to enter the microhematocrit tube. The capillary tube will fill with capillary action if held horizontal to the incision site. Plug the end of the capillary tube when filled appropriately.

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Procedure	Rationale
15. When the desired tubes have been collected, apply gauze to the puncture site and instruct the patient to apply direct pressure, if he or she is capable.	Direct pressure helps the bleeding to stop.
16. Tightly cap and invert any microcollection tubes containing anticoagulant 8 to 10 times.	Tubes must be thoroughly mixed to avoid clotting.
17. Label the tubes with the patient's name, birth date (or other unique identification number), your initials, the date and the time of the blood draw.	For microcollection tubes, it may be necessary to write this information on a label to be attached to the tube. The microcollection tubes may also be placed inside larger tubes that are labeled appropriately. Capillary tubes may also be labeled in this way, as it is very difficult to label the actual collection container.
18. Use the requisition form or the labels to verify that all the necessary tubes were drawn for the specimens ordered.	Verifying the details of the blood draw once more in the presence of the patient allows for a redraw to be performed immediately if something is missing.
19. Observe any special handling instructions for the specimens.	Some types of specimens must remain at room temperature, whereas others may need to be put on ice immediately. This should be information that is ascertained before the procedure starts.
20. Monitor the patient for any signs of distress from the procedure.	These may include pallor, perspiration (especially on the upper lip or forehead), increased anxiety, or lightheadedness. If the patient is exhibiting any of these symptoms, it is best to have him or her lie down if possible. This may be easily accomplished if the patient is in a chair that can recline. If not, a cold compress on the forehead and/or the back of the neck may help. Continue to converse with the patient and move the blood out of sight. Ask for assistance if you feel that your patient is feeling faint. If the patient loses consciousness, it may be necessary to lower him or her to the floor from the phlebotomy chair.
21. Once the tubes have been labeled, check the draw site for bleeding. If it has not stopped bleeding, apply pressure for another few minutes, and if the bleeding is still present after 5 minutes, contact a physician.	It is important to look under the gauze for 2 or 3 seconds before applying the adhesive bandage to be certain that the site has actually stopped bleeding.
22. If the bleeding has subsided, apply an adhesive bandage, but leave the gauze in place to allow for additional pressure.	Adhesive bandages should not be applied for capillary punctures on small children as they may pose a choking hazard. Newborns may have adhesive bandages applied if they are not able to remove them. Self-adhesive bandages (such as Coban) may be wrapped around the site rather than applying an adhesive directly to the skin. Self-adhesive bandages may be especially effective for those patients who are on anticoagulant therapy.

Continued

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Procedure 8-4: Blood Collection From a Capillary Puncture—cont'd

Procedure	Rationale
23. Assist the patient to stand (if necessary) and thank them for their cooperation.	Patients may be a bit light-headed, and assistance may be needed when they first stand up.
24. Discard all trash, and place the tubes in an appropriate vessel for processing. Never touch full tubes of blood without wearing gloves.	Touching the tubes of blood without wearing gloves offers potential opportunities for exposure to bloodborne pathogens.
25. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
26. Document the procedure in the patient's chart as well as on the requisition form. Include the date and time of collection, what was collected, and if there were any circumstances that were out of the ordinary. Also document where the specimen was obtained (such as right middle finger, left hand, etc.). The documentation should include the type (color) of tubes drawn, as well as the identity of the person who collected the sample.	All patient interactions must be carefully documented. The site where the specimen was obtained should always be written in the chart or on the requisition form so that if there are any negative outcomes associated with the procedure, the site has been noted.

Date	
1/18/2020: 1100 a.m.	*Capillary puncture performed in right ring finger for CBC. Lavender top microcollection tube drawn. Connie Lieseke, CMA (AAMA)*

the analysis. It is the job of the medical assistant to process the specimen properly so that it can be tested.

Obtaining Serum for Testing

When blood is allowed to clot and is then spun down in a centrifuge, the liquid portion is called **serum.** Serum is plasma that no longer has the clotting factors included, as they have been used up in the blood clot that formed in the tube. Analytes such as glucose, lipids, cholesterol, electrolytes, hormones, enzymes, and antibodies may be dissolved in serum. To isolate this liquid so that the tests can be performed, it is necessary to separate it from the rest of the blood specimen. Whenever drawing blood for serum or plasma, it is necessary to collect approximately 2.5 times as much blood as the volume needed for the testing procedure. For instance, if there is 1 mL of serum required for an electrolyte test, the medical assistant drawing the blood should obtain at least 2.5 mL of blood.

Tubes without anticoagulants are used to collect samples for serum testing. These include red top tubes, as well as those that contain thixotropic gel and clot activators. The blood must be allowed to stand for at least 30 to 45 minutes at room temperature to clot thoroughly before the specimen can be further processed. If the specimen is spun in the centrifuge before there is a chance for a solid clot to form, the clotting factors will not be mixed in with the cells at the bottom of the tube when centrifuged; instead, they will form a large fibrin clot in the serum layer. A *fibrin clot* is a soft, sticky mass that makes it very difficult to separate out serum for testing. Although the tube must be allowed to clot completely before centrifuging, it should not be more than an hour after the blood draw is performed before the tube is spun, as prolonged contact with the cells in the tube may allow chemical changes to take place in the serum, which will affect the test results. Potential changes may include a decreased serum glucose level, an increased serum iron level, and elevated serum potassium levels, among others.

To fully separate the serum from the cells, the specimen should be centrifuged for at least 10 minutes. The serum may then be removed from the specimen and placed in a transfer tube. There are various methods that

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may be used to remove the liquid portion of the blood; remember that regardless of the method used for separation, adequate personal protective equipment should be worn at all times, including a face shield or plastic-mounted barrier shield, gloves and a laboratory coat. (See Fig. 8-15.) The methods that may be used for separation include the following:

- **SST or PST tubes:** These tubes contain a thixotropic gel that forms a barrier between the cells and the serum (or plasma with PST tubes) so that the liquid can remain in the tube, but be separated from the cells. If it is necessary to remove the serum and put it in a transfer tube, it can be poured out because the gel forms a solid barrier to the cells in the bottom of the tube.
- **Transfer pipette:** A pipette may be used to aspirate the liquid out of the tube and transfer it into another tube. Care must be taken not to aspirate out any of the cells that are present in the bottom of the tube; if the serum appears a hazy red color while aspiration is taking place, it should be spun again to remove any cells that may have been accidentally aspirated into the specimen. If the serum still appears to be red after recentrifugation, it is hemolyzed and the specimen will, in most circumstances, have to be redrawn. If the serum is no longer red, separate the serum again from the cells that have settled to the bottom of the tube.
- **Plunger-type separators:** These are devices that have a filter on one end of a plastic tube, with an opening at the other end. After the specimen has been centrifuged, the rubber stopper is removed from the top of the tube and the filter end of the separator is carefully inserted into the specimen tube and pushed down through the serum or plasma. Proper protective equipment must be used when performing this procedure to keep from potentially splashing the liquid into the eyes or mucous membranes. Also, once the separator has been place in the tube, it is important to pull it back up a bit to provide an air barrier between the serum and the cells. This keeps the blood cells in the bottom of the tube from being in contact with the serum, causing chemical changes as they metabolize nutrients in the liquid.

Test Your Knowledge 8-16

How are specimens processed if serum is to be separated from the cells? (Outcome 8-17)

Specimen storage instructions for most chemistry tests will advise that the serum and/or plasma be refrigerated within a few hours after processing to protect the various analytes from changing in concentration. Follow the directions provided in the laboratory directory for handling the serum specimen after it has been separated. Also, if a transfer tube is used, the labeling on the tube is critical. Not only does the patient information need to be included, but there also has to be a notation of the

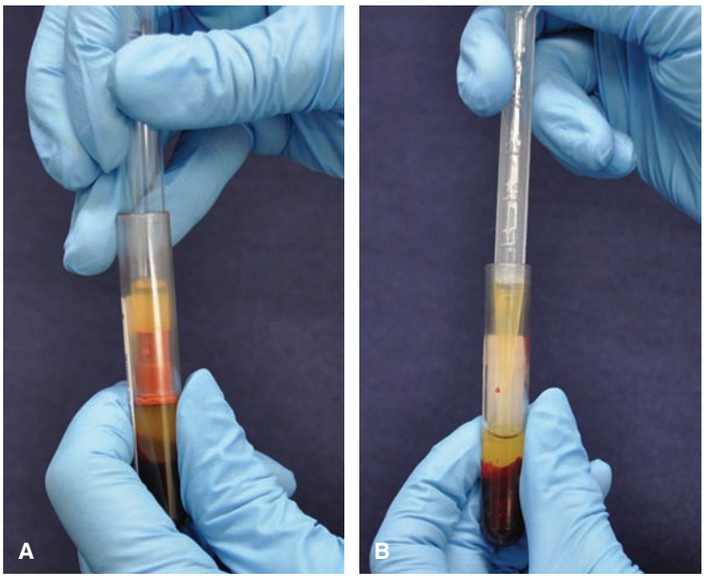

Figure 8-15. A and B. (A) Serum tube after centrifugation and (B) various devices used for separation of serum.

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type of specimen (serum or plasma) and the type of anticoagulant present in the tube, because many body fluids are similar in appearance. Transfer tubes are available that are color coded to match the color tube originally used for the specimen collection, which may help eliminate confusion.

Obtaining Plasma for Testing

The liquid portion of the blood in our bodies is **plasma.** Plasma is made up of approximately 90% water, with dissolved substances making up the remaining portion. Plasma may be analyzed for levels of chemicals involved in the clotting process such as fibrinogen and prothrombin. Other common tests performed on plasma specimens include levels of electrolytes, calcium, glucose, and creatinine.

Because plasma is the liquid portion of the blood that contains factors that contribute to clotting, a specimen that is to be used for plasma testing must not be allowed to clot. A tube that contains an anticoagulant (such as heparin) must be used for the collection. The medical assistant should consult the laboratory directory to see what type of anticoagulant is to be used for specimen collection before the venipuncture is performed. It may be possible to use a PST tube, which contains anticoagulant and a thixotropic gel that will separate the plasma from the blood cells in the specimen after centrifugation. As in the case of serum, it is necessary to collect a blood specimen that is approximately 2.5 times the required volume for the test ordered. Appropriate labeling of the transfer tube is essential; remember to include a notation that the fluid is plasma in addition to the patient's name and other necessary information.

Unlike the process for obtaining a serum sample, plasma samples should be well mixed, then centrifuged as soon as possible. There is no need to allow the specimen to sit for an extended period of time before centrifuging, as the blood is not going to clot in the tube. This makes plasma samples the specimen of choice for most STAT chemistry tests, because the samples can be processed and the test performed quickly after collection.

After centrifugation, a sample that has had anticoagulant added will separate into three layers. This will include a layer containing the red blood cells, topped by a very small layer that contains the white cells and platelets (sometimes called the buffy coat), with the liquid plasma present as the top layer in the tube. The tube in Figure 8-16 is an example of the appearance of a tube to be used for plasma separation after centrifugation.

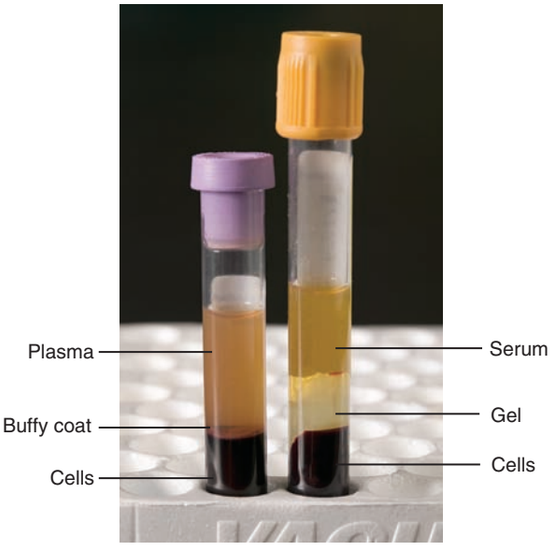

Figure 8-16 The tube on the left shows plasma after centrifugation. Note the cells, buffy coat, and plasma. The tube on the right shows serum separated from the clotted cell by gel. *Reprinted with permission from Eagle S, Brassington C, Dailey C, and Goretti C:* The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. *Philadelphia: FA Davis, 2009.*

The actual separation methods for plasma are the same as those used for serum, including the use of a PST tube, the transfer pipette, or the plunger-type separators. Remember, whenever separating the liquid portion of the blood from the cells, it is imperative that the appropriate personal protective equipment is used to protect the employee from potential exposure. Removal of the rubberized stoppers may create an aerosol that could get into the mouth or eyes, so face shields must be worn in addition to gloves and a protective laboratory coat. Also, all supplies must be disposed of appropriately; the stoppers and any other specimen containers must be disposed of as biohazardous materials.

Test Your Knowledge 8-17

Describe one way that serum and plasma are different. (Outcome 8-18)

Whole Blood Specimens

Tests that count or examine the cells present in the blood require a whole blood specimen. These tests are often performed in the hematology department, and include

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complete blood counts, platelet counts, and hemoglobin and hematocrit tests. For tests requiring whole blood specimens, the blood is drawn into tubes that contain anticoagulants so that the cells are not involved in clot formation, which would make it very difficult to count the cells or examine their appearance. Potassium EDTA is the anticoagulant that is usually preferred; this is present in the lavender top evacuated tubes.

Whole blood specimens are to be well mixed at the time of the initial blood draw, and again just prior to analysis. The specimens used for whole blood testing are not to be centrifuged, as the analysis is performed on the formed elements within the sample. In some small physician office laboratories, the medical assistant may place the whole blood specimens directly on a "rocker" that keeps the specimen mixed until the analysis can be performed. Remember that the mixing and inversion of these samples must be a gentle motion to avoid damaging the cells. Eight inversions of the tube immediately after drawing the blood should provide appropriate mixing of the specimen.

Test Your Knowledge 8-18

True or False: Tests that utilize whole blood specimens require that the specimen be centrifuged before testing. (Outcome 8-17)

Unacceptable Specimen Types

In certain situations, the specimen collected and processed will be rejected for the test ordered. There are numerous reasons for specimen rejection, including the following:

- **Hemolyzed specimens:** *Hemolysis* means that the red blood cells in the specimen have been damaged and broken. It may be a result of a traumatic venipuncture in which the cells were damaged as they entered the needle, or hemolysis may be the result of mishandling the tube after the blood draw. Hemolysis is evident in the specimen after centrifuging by the presence of a pink to red tint in the plasma or serum. (Fig. 8-17 is an example of a hemolyzed specimen.) Potassium, magnesium, and iron levels are examples of tests for which a hemolyzed specimen is unacceptable. To avoid hemolysis, be sure that the tubes used for the blood draw are kept at room temperature, and be sure to use the appropriate sized needle for the draw. Also, if using a syringe, do not pull back on the plunger with a great deal of force, as this may damage the cells. Use good technique when performing venipunctures, and *gently* invert all tubes when mixing.
- **Lipemic specimens: Lipemia** is the presence of excess lipids (fatty molecules) in the blood. Plasma or serum in a lipemic specimen will appear cloudy or milk-like after centrifugation. These lipid molecules interfere with the testing methods for many analytes. Some laboratories are capable of clearing the specimen with a special type of centrifuge, whereas others will reject the lipemic specimens (Fig. 8-17).
- **Quantity not sufficient**: When the medical assistant does not draw enough blood to perform the tests ordered, the specimen may be rejected as **quality not sufficient (QNS)** because the amount drawn is not enough for the tests to be performed on it. In almost all situations, these samples will need to be redrawn so that there is enough specimen to complete the tests ordered.
- **Clotted specimens:** When a whole blood specimen is necessary for the test ordered, a clotted specimen is unacceptable. The clotting process draws in the cells in the specimen to be involved in the clot. This means that even if the clot is small, the cell count in the tube will be inaccurate, because it is impossible to know how many cells are involved in the clot and how many are floating freely in the specimen. To avoid clotted specimens, be sure to invert the specimens thoroughly during the collection process.
- **Incorrect anticoagulant use:** Each anticoagulant uses a different principle to keep the blood from clotting. Some bind up the calcium in the specimen, as it is necessary for the clotting process to proceed. Others make the platelets in the specimen nonadhesive so that they cannot cling to one another. Tests are designed to be performed using a specific anticoagulant, and if the incorrect one is used, it may alter the test results. For instance, potassium EDTA may cause false elevation of the potassium levels if a lavender top tube was used

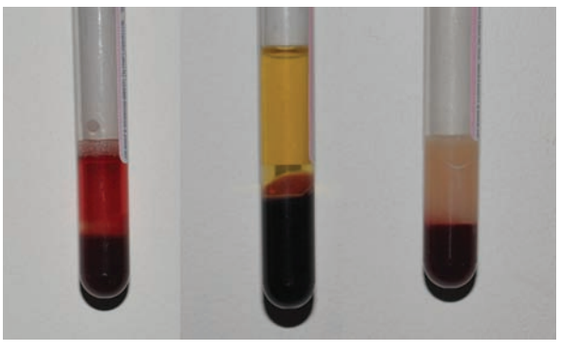

Figure 8-17 Hemolysis and lipemia present in plasma tubes on left and right.

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for the plasma sample. Sodium citrate is an anticoagulant that binds up the calcium in the specimen so that it cannot participate in the clotting process. This means that calcium levels performed on plasma from these light blue top tubes would be very low, as the calcium is not in solution in a way that it can be tested.

- **Fibrin clots:** Tubes without added anticoagulant must be allowed to clot properly before centrifugation, or it may be impossible to obtain enough serum from the specimen to perform the tests ordered. This may result in a request for a specimen to be recollected. It may be possible to physically remove the fibrin clot and recentrifuge the specimen, but this may lead to damaged red cells and hemolysis.

Test Your Knowledge 8-19

Examples of inappropriate specimens may include:

a. Hemolyzed and lipemic specimens
b. Partially filled specimen tubes for multiple tests
c. Blood collected in tubes with the wrong anticoagulant
d. All of the above (Outcome 8-19)

POTENTIAL NEGATIVE OUTCOMES OF VENIPUNCTURE AND CAPILLARY PUNCTURE

Regardless of the skill level exhibited by the medical assistant, sometimes the person who is attempting a venipuncture may be unsuccessful. In addition, even when the person drawing the blood is successful, there may be physical patient complications resulting from the blood draw. It is important to realize that these negative outcomes are sometimes unavoidable, and to know what action should be taken if they occur.

Inability to Draw Blood

Veins are not solid objects that are incapable of movement. Sometimes even when the vein is anchored tightly, it will move just a bit as the needle is inserted. Or, the health-care worker who is drawing the blood may not insert the needle far enough or go in just a bit too far so that the blood does not enter the needle. It is never acceptable to "probe" when drawing blood. However, recommendations from the Clinical and Laboratory Standards Institute do allow the phlebotomist to move the needle a bit further into the vein or a bit further out of the vein to see if the blood will start to flow. Sometimes a slight change in the location or angle of the needle is all that is necessary for the blood to enter the needle. The needle should never be moved from side to side after insertion into the arm, as this will cause damage to the tissues and pain for the patient. If the slight movements (small increments in or out) are not enough to allow blood to enter the needle, discontinue the draw, and try again. Be sure to check for alternative sites before using the same area for a second attempt. If the person drawing the blood is still unsuccessful after two attempts, he or she should seek assistance from another qualified employee.

Fainting Patients

Some patients experience light-headedness, dizziness, or fainting during or immediately after a blood draw. This may be due to **vasovagal syncope**, which is the body's exaggerated reaction to the sight of blood. Some of these patients may have had negative experiences in the past, whereas others cannot identify a specific reason for their reaction. Each person who experiences vasovagal syncope has his or her own triggers, which may include emotional distress, the sight of blood, and/or pain. The trigger causes a response in the body that includes a drop in blood pressure and a decreased heart rate. Young patients, thin patients, nervous individuals, and those who are very quiet (or sometimes *very* talkative) are more prone to fainting. Also, hunger, fatigue, and environmental factors such as excessive heat or strong smells may make the situation worse. There are usually some symptoms that occur prior to the actual fainting episode such as nausea, yawning, dizziness, weakness, perspiring, pallor, and a flushed feeling of warmth. If the patient communicates any of these symptoms, the blood draw should be discontinued. The medical assistant should help the patient to put the head down between the legs if he or she is still conscious. This may help to keep the patient from fainting. If the patient shares a history of fainting, he or she should be drawn in the supine position, and the medical assistant should make additional efforts to talk to the patient during the procedure to monitor the level of consciousness. If a patient does faint when sitting up in a phlebotomy chair, the primary focus should be safety for the patient and the medical assistant. Discontinue the draw, remove the tourniquet and the needle, activate the safety device on the needle, and bandage the draw site. Call for assistance from a coworker. If the patient is still unconscious, it may be necessary to lower him or her to the floor from the chair, with special care taken to protect the head from hitting anything during the process. The patient's legs should be elevated to help the blood flow return to the heart and brain, and a health-care provider should be notified of the situation.

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Rolling Veins

The median cubital vein is usually quite stable, which makes it an excellent choice for venipuncture. If this vein cannot be used for phlebotomy procedures, the other veins in the antecubital area may be considered. However, these are not as well anchored, and have a tendency to "roll" or move away when the venipuncture is attempted. Special care must be taken to anchor these veins very well to avoid this problem.

Hematoma Formation

A hematoma is the result of blood leaking into the tissues from a vein. It can occur in routine venipunctures, but is more common when the process did not go smoothly. If the initial insertion of the needle is too deep, the needle may puncture and go through the vein, which allows excessive blood to leak from the punctures in the vein. Conversely, if the needle does not go far enough into the vein, the bevel may not be totally within the vessel, and blood may leak out around the slant at the end of the needle. (See Fig. 8-18 for examples.) Hematomas can also be the result of too little pressure applied after the venipuncture procedure, with subsequent bleeding around the puncture site. When a hematoma forms, there is a sudden swelling (and sometimes a discoloration) around the site where the needle is inserted. If this occurs, the tourniquet and then the needle need to be removed and pressure should be applied immediately. The medical assistant should be sure to keep pressure on the site for at least 5 minutes, and also should be sure to document the situation. The patient may experience pain and more swelling in the area. The healthcare provider may suggest ice application and anti-inflammatories to help with the discomfort.

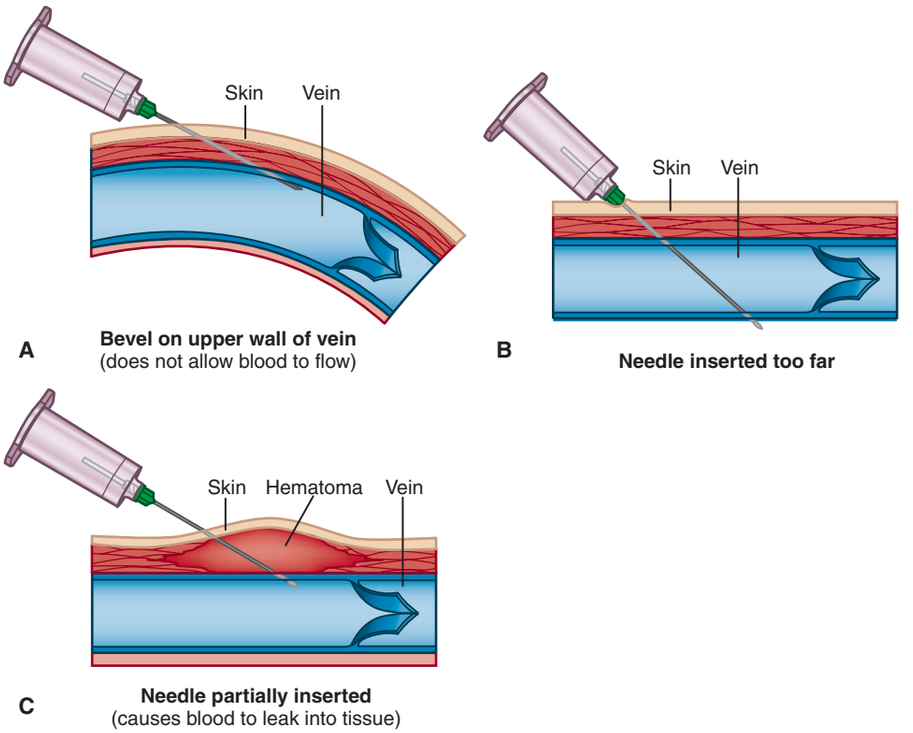

Figure 8-18 Problems with the way in which the needle is entering the vessel. (A) The first drawing shows what occurs if the angle of insertion is too shallow and the needle goes above the vein. (B) The second drawing shows what occurs if the angle of insertion is too high, and the needle goes through the vein. (C) The third shows what can happen if the needle is not inserted far enough into the vein. *Reprinted with permission from Strasinger S, and Di Lorenzo M:* Phlebotomy Textbook, *ed. 3. Philadelphia: FA Davis, 2011.*

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Collapsing Veins

Fragile veins may collapse with the amount of pressure used to withdraw blood during a venipuncture procedure. Small veins or veins that have been damaged with IV therapy or medication treatment are more prone to collapse. If the medical assistant recognizes that the vein is small or appears fragile, the evacuated tube system should not be used for the venipuncture, as this will increase the likelihood of venous collapse. A syringe and needle or a butterfly system should be used instead.

Nerve Damage

Venipuncture procedures performed in the median cubital vein rarely cause irritation to the nerves in the arm, as this vein is not usually in close proximity to the medial nerve. When drawing from the antecubital area, blood draws performed from the basilic vein are the most likely to cause nerve irritation or damage due to the close proximity to the nerve. If a patient complains of excessive pain during a blood draw (especially if he or she describes it as shooting pain that goes up or down the arm), the procedure should be discontinued immediately. Never attempt a venipuncture from the underside of the wrist, as there are numerous opportunities to cause nerve irritation or damage in this area.

Infection

Infection or excessive irritation at the site of a venipuncture is not common, but can occur. To minimize the risk, the medical assistant should always clean the site thoroughly before the procedure, and also allow the alcohol used to disinfect the site to dry completely before the needle is inserted. If the alcohol has not been allowed to dry, it can cause irritation to the skin in the area, which makes the site more prone to infection. Using good judgment when choosing a site for venipuncture will also help to minimize the chances of inflammation and infection.

Test Your Knowledge 8-20

True or False: The angle at which the needle is inserted for venipuncture has no impact on whether the procedure has a negative outcome. (Outcome 8-20)

OTHER PROCESSING PROCEDURES

Processing a blood specimen may include centrifugation, separation of plasma or serum from the cells, and appropriate storage of the specimen until testing occurs. In addition, the medical assistant may be asked to create and stain a smear from a whole blood specimen so that the healthcare provider or other qualified professional may view it.

PREPARATION OF A PERIPHERAL BLOOD SMEAR FOR STAINING

When it is necessary to view the red blood cell **morphology** (appearance and size), identify the types and percentages of various types of white blood cells, and quantitate the number of platelets present in the circulation, a peripheral blood smear may be utilized. Automation has replaced the need to perform a manual examination of the slide for most hematology testing procedures, but there is still a need to examine the slide manually in many

Procedure 8-5: Creation of Peripheral Blood Smear

A peripheral blood smear may be requested at the time of the initial blood draw, or it can be created using blood from a lavender top tube containing EDTA anticoagulant. This procedure will explain how to create a smear using the lavender top tube. If creating a smear at the time of the blood draw, the procedure only differs with the initial application of the sample to the slide.

TASK

Successfully create a peripheral blood smear to be stained and used for a manual differential count or pathologist examination. The process must be completed within 5 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Clean glass slides
- DIFF-SAFE device
- Lavender top (EDTA) tube filled with blood
- Biohazardous sharps container
- Biohazardous disposal bag

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P.2: Practice Standard Precautions

ABHES Standards

None

Procedure	Rationale
1. Sanitize hands (allow them to dry) and apply gloves.	Gloves must be worn for any procedures in which exposure to blood or other potentially infectious materials is anticipated.
2. Invert the blood tube 8 to 10 times to mix the sample.	The specimen must be well mixed or it will provide erroneous results when the blood smear is examined.
3. Insert DIFF-SAFE device into the top of the lavender top tube.	The device has a blunt metal cannula that is inserted through the rubber stopper on top of the tube. This is performed while the tube is in an upright position.
4. Turn the tube upside down and push the DIFF-SAFE device to the slide until a drop of blood is released.	Pushing down on the tube with the DIFF-SAFE device against the slide will release a drop of blood onto the slide. 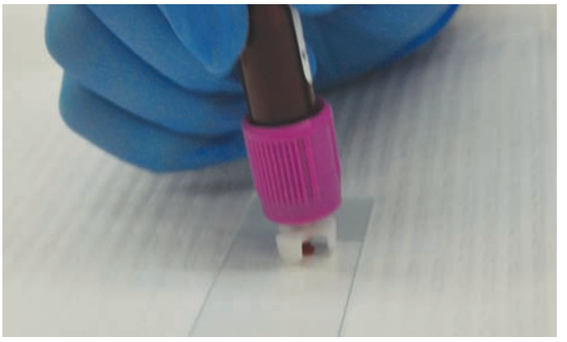

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Procedure 8-5: Creation of Peripheral Blood Smear—cont'd

Procedure	Rationale
5. Pull the second slide back into the drop of blood at an approximate 30-degree angle, allowing the blood to flow along the edge of the slide.	This process must occur quickly. The angle allows for correct application of the blood across the slide. 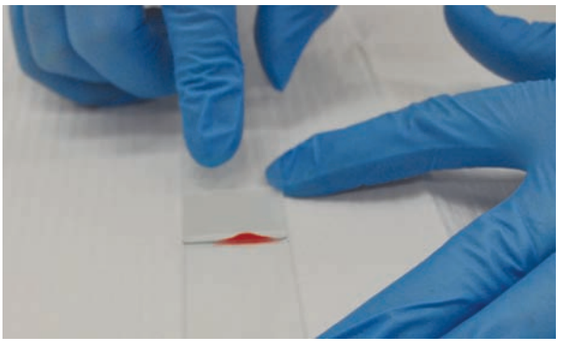
6. Once the blood has flowed to cover approximately three-quarters of the width of the slide, push the second slide forward to spread the blood across the original slide.	Push the spreader slide forward smoothly with a rapid motion. Do not apply weight or additional pressure during this step, or the slide will not move smoothly across the surface. The entire process must occur in less than 15 seconds or the drop of blood will begin to dry and the distribution of the cells will be uneven across the slide. Smears should have a "feathered" edge, with visible edges on the heaviest part of the smear. Ideally there will be no holes or ridges in the blood pattern. If the cell distribution is too thick, it will be difficult to see the morphology of the red blood cells clearly, and it may be difficult to visualize the white blood cells as well. The completed smear should have an appearance that is similar to a thumbprint, with a heavy distribution at the beginning of the smear and a gradual decrease in the thickness across the slide. 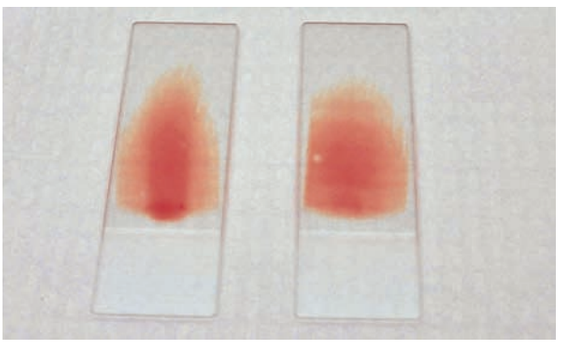

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Procedure	Rationale
7. Allow the slide to air-dry.	The slide must be completely dry before it is stained or the appearance of the cells will be altered during the staining process.
8. Remove the DIFF-SAFE device from the top of the tube and discard the device in a biohazardous sharps container. Also discard the second slide used for spreading in the biohazardous sharps container. Store the tube as directed by the laboratory.	The device and the slide are contaminated with blood and are considered to be a sharp.
9. Label the slide with a pencil or a grease pen with the name of the patient and other identification as required by the laboratory.	All slides need to be properly labeled before staining.
10. Transfer the slide to the appropriate area of the laboratory for drying and staining.	The medical assistant should not touch the slide without gloves on, so the transport should occur before the gloves are removed.
11. Remove gloves and sanitize the hands.	Hands must always be sanitized after removing gloves.
12. Document the procedure in the patient's chart if it is available.	In a physician office laboratory, this procedure should be documented in the patient's chart. If the medical assistant is working in a laboratory setting where the chart is not available, this step is not necessary.

Date	
1/18/2020:	*Blood smear prepared from lavender top tube.*
1100 a.m.	*Connie Lieseke, CMA (AAMA)*

instances. A lavender top EDTA tube may be used or, in some cases, a drop of blood may be taken directly from a capillary puncture and applied to the slide. The safest method of applying the drop of blood to the slide from the tube is to use a DIFF-SAFE device (Alpha Scientific Corporation, Malvern, Pennsylvania), which eliminates the need to open the tube to gain access to the blood.

WRIGHT'S STAIN PROCEDURE

Once the peripheral blood smear has been prepared, it must be stained so that it can be examined. There are various products available for this staining process, including Diff-Quik stain by Dade Behring. Wright's stain is another common stain often used in the physician office laboratory as well as in larger laboratories. It is a hematology stain that is used for staining smears made from blood and bone marrow samples. Wright's stain allows for visualization of the red blood cells and platelets in the sample, as well as differentiation of the various types of white cells that are present. The stain contains methanol, which acts as a fixative for the cells, as well as an acidic red dye and a blue dye that is alkaline in pH. These stains are absorbed differently by the formed elements in the blood to allow for them to be examined and counted.

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Procedure 8-6: Quick Stain of Peripheral Smear Using Camco Quik Stain II

The Camco Quik Stain procedure allows for the cells to be stained appropriately so that they can be identified by an individual who is qualified to perform this microscopic evaluation. This may be performed for a differential examination, in which a technician or technologist will count the various types of white cells present and report a percentage of each type. The stain solution may be poured into small vessels for dipping the slides, or it may be applied with a pipette to a slide on a rack that is suspended over a sink or other receptacle.

TASK

Stain a peripheral blood smear using Camco Quik Stain II.

CONDITIONS

- Air-dried blood smear
- Camco Quik Stain II solution
- Distilled water with a pH of 6 or 7
- Laboratory wipes
- Sink or other receptacle for excess stain

CAAHEP/ABHES STANDARDS

None

Procedure	Rationale
1. Sanitize hands, and allow them to dry completely. Apply gloves.	Gloves must be worn for any procedures in which exposure to blood or other potentially infectious materials is anticipated. In addition, the stain will discolor the fingers if gloves are not utilized.
2. Dip the blood smear in the stain solution for 10 seconds. Alternatively, the smear may be placed on a rack and stain may be added until the slide is covered with the stain for 10 seconds.	The 10 seconds is a minimum staining time. If the smear is thick, additional staining time may be necessary.
3. Allow excess stain to drain from the slide. Apply or dip in distilled water for 20 seconds.	It is necessary to allow at least 20 seconds for the process to be complete.
4. Wipe away any excess stain that may be present on the back of the slide with a laboratory wipe.	Excess stain on the back of the slide will obscure the view when examining the smear under the microscope.
5. Allow the slide to air-dry. Make sure that there is no excess water standing on the slide.	This type of smear does not need to be heat fixed. Excess water may change the staining characteristics or increase the time necessary for the slide to dry.
6. Dispose of the laboratory wipe in the trash and put away supplies.	All work areas should remain clean and organized.
7. Remove gloves and sanitize hands.	Gloves should be removed before proceeding to the next task. Hands must always be sanitized after removing gloves.

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SUMMARY

Blood collection is the most common and most important part of the preanalytical process for laboratory testing. To perform quality venipuncture and capillary puncture, it is imperative that the medical assistant or phlebotomist understands the basics of the anatomy and physiology of the cardiovascular system as well as areas and situations to avoid when collecting blood. Following recommended procedures during the collection process is critical, which includes knowledge of how to safely use the various collection devices.

Patient identification and appropriate preparation are of utmost importance. Knowledge of the various tube types to be used is very important in collecting the sample correctly. Order of draw is critical to avoid crossover contamination. Finally, processing the samples appropriately is the final preparatory step before testing the sample. This may include centrifugation and separation of the plasma or serum, or it may include preparation and staining of slides.

TIME TO REVIEW

1. The bevel of a needle is: Outcome 8-1
   - **a.** The interior hollow space of the needle
   - **b.** The slanted tip at the end of the needle
   - **c.** The diameter of the needle
   - **d.** None of the above

2. The flanges of an evacuated tube holder: Outcome 8-1
   - **a.** Allow for the needle to be screwed on the holder
   - **b.** Provide a space for the tube to be inserted
   - **c.** May be used to provide leverage when inserting and/or removing tubes
   - **d.** Are decorative only

3. True or False: Interstitial fluid is the fluid located between the cells of the tissues. Outcome 8-1

4. True or False: Venules are larger in diameter than are veins. Outcome 8-1

5. Identify all the ways that veins and arteries are the same: Outcome 8-3
   - **a.** Transport blood
   - **b.** Connect to capillaries
   - **c.** May be punctured to withdraw blood for testing
   - **d.** Have multiple layers of cells in the walls of the vessels
   - **e.** Have a distinct pulse that can be felt with palpation
   - **f.** Have valves that prevent backflow
   - **g.** Are varied in size throughout the body

6. Mark the veins below in order of preference for venipuncture procedures by numbering them 1, 2, and 3: Outcome 8-5

   _____ Cephalic vein
   _____ Basilic vein
   _____ Median cubital vein

7. True or False: Capillary punctures on infants may be performed on the great toe. Outcome 8-6

8. An example of an area to avoid when choosing a site for venipuncture is: Outcome 8-7
   - **a.** Scarred skin
   - **b.** Varicose veins
   - **c.** Veins on the back of the hand
   - **d.** None of the above
   - **e.** a and b

9. How is a butterfly (or winged infusion set) different from the needle used for evacuated tube draws or syringe draws? Outcome 8-8

10. Using the following order of draw, create a mnemonic that will help you to remember the order the tubes are to be drawn with an evacuated tube system or a syringe draw. Outcome 8-9

    Yellow, light blue, red, green, lavender, gray

11. Describe one way that a medical assistant might put a child at ease before a blood collection is to be performed. Outcome 8-12

12. Why is it important to verify whether a patient has properly prepared for a test before the medical assistant performs the blood draw? Outcome 8-14

13. Why would a peripheral smear be used? Outcome 8-16
    - **a.** To test for certain hormones
    - **b.** To scan for bacteria
    - **c.** To identify various types of white blood cells
    - **d.** To perform ABO blood typing

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14. What is one practice that can help to protect patients and employees during invasive procedures? Outcome 8-15

15. Capillary specimens may be preferred: Outcome 8-13
    a. When performing CLIA-waived tests that use whole blood
    b. When the patient's medical condition warrants it
    c. For infants
    d. All of the above

16. Which part of the hand is used to hold the evacuated tube holder when the medical assistant performs a venipuncture? Outcome 8-15

17. Do all capillary puncture devices provide incisions that are the same depth? Outcome 8-15

Case Study 8-1: How long was this sitting here?

A blood specimen for a glucose level and electrolyte analysis was drawn on Mr. Dee at 9:30 a.m. Shortly after the blood draw, Shannon, the medical assistant who was covering the laboratory area of the office, was asked to fill in for another employee who became ill at work. At 2 p.m., after lunch, Shannon went back into the laboratory and processed the specimens that she had drawn that morning so that they were ready to be picked up by the laboratory courier at 2:30.

Just before closing, Shannon received a call from the laboratory alerting the health-care provider that the potassium was elevated above the reference range for Mr. Dee, and the glucose levels were well below the reference range. The laboratory suggested that the specimen needed to be redrawn before the health-care provider acted on these results.

1. What event of the day may have affected these blood levels?
2. Do you agree that the specimen should be redrawn before the physician acts on the results obtained from the original specimen?

Case Study 8-2: Clumps

John George is performing a blood draw for a CBC, differential, and platelet count on Mrs. Charrone. As he completes the blood draw, he notices that she is looking really pale and is no longer conversing with him. He removes the tourniquet and the needle with the evacuated tube holder and lavender top tube from her arm just as she loses consciousness. He gently lowers her to the floor as she slides out of the phlebotomy chair, and elevates her feet as he calls for help. Within a few minutes she regains consciousness and after monitoring her for a few minutes, the health-care provider states that she is ready to leave the office. John helps her out to the waiting room to meet her husband, after which he returns to the blood draw area to process the specimen. He labels the specimen appropriately and places it on the blood rocker for the laboratory technician working in the testing area to access it for the CBC, differential, and platelet count.

In about an hour, the laboratory technician comes to find John and asks him if he remembers anything unusual about this blood draw. The laboratory technician said that the platelet count is extremely low with the initial analysis and that the hematology instrument flagged the sample with an error. The laboratory technician is going to recheck the specimen and create a blood smear to look at the sample more thoroughly.

1. How do you think the events of this blood draw may have affected the platelet count?
2. What do you think the technician may find when she looks at the blood smear?

RESOURCES AND SUGGESTED READINGS

"DIFF-SAFE Blood Dispenser: Directions for Use"
Provides step-by-step instructions on how to use a DIFF-SAFE Blood Dispenser http://www.alpha-scientific.com/Diff-safe2.html

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"NCCLS simplifies the order of draw."
by Ernst D, Calam R. Medical Laboratory Observer, May 2004
National Committee for Clinical Laboratory Standards. Procedures for the Collection of Diagnostic Blood Specimens by Venipuncture. Approved Standard, H3-A5, Wayne, PA; 2003.
"Preanalytical Errors in the Emergency Department."
from BD Company, LabNotes. 17, no. 1, 2007 http://www.bd.com/vacutainer/labnotes/Volume17Number1/
"Preparation of Peripheral Blood Smear Staining With Wright's Stain
Directions on how to stain a peripheral blood smear using Wright's Stain http://www.scribd.com/doc/8801750/Preparation-of-Peripheral-Blood-Smear-Staining-With-Wrights-Stain
"Staining the Cells."
How to stain a blood smear; instructions on how to stain a peripheral blood smear http://www.tpub.com/content/medical/14295/css/14295_286.htm
"Venipuncture Technique Using the Multisample Vacutainer System"
Description of the use of the Vacutainer© system with details http://www.phlebotomycert.com/multi_vtainer_systm.htm
"Newborn Screening"
Washington State Department of Health. In-depth information about the various disorders that may be detected by newborn screening. Includes links to more detailed information about the collection process and specimen handling. http://www.doh.wa.gov/ehsphl/phl/newborn/disorders.htm#msud

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Chapter 9

Collection and Processing of Urine Samples

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Types of Urine Specimens
- Clean-Catch Midstream Urine Specimen Collection
- Catheterized Specimens
- Suprapubic Aspiration
- Prostatitis Specimen Collection
- Timed Urine Specimen Collections
  - *Glucose Testing Specimens*
- Urine Collection Procedures for Infants and Pediatric Patients

Urine Specimen Processing
- Refrigeration and Preservation
- Proper Disposal of Urine and Supplies

Summary

Time to Review

Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

9-1 Define the key terms.

9-2 Explain the necessity of obtaining different types of urine samples for laboratory testing.

9-3 Compare and contrast various urine specimen types.

9-4 Describe how urine specimens are to be processed after collection.

9-5 Describe changes that may occur in urine specimens if they are left at room temperature after collection.

9-6 Analyze the details for proper labeling of the various types of urine specimens presented in the text.

9-7 Examine the necessary patient education for collection of samples to be used for specialized urine testing procedures.

9-8 Instruct a patient on the proper collection procedure for a clean-catch midstream urine specimen.

9-9 Instruct a patient on the proper collection procedure for a 24-hour urine specimen.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.6: Anatomy and Physiology: Perform patient screening using established protocols

I.A.I.2: Anatomy and Physiology: Use language/verbal skills that enable patients' understanding

ABHES Standards

- Medical Laboratory Procedures: e. Patient Instructions (collection of urine and feces); Instruct patients in the collection of a clean-catch mid-stream urine specimen.

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KEY TERMS

Aliquot
Distal urethra
Diurnal variation
Fasting urine specimen
First morning void
Formed elements
Glucose tolerance urine specimen
Indwelling catheter
Intermittent (straight) catheter
Prostatitis
Prostatitis specimen collection process
Random
Suprapubic aspiration
24-hour urine collection
2-hour postprandial specimen
Urinalysis
Urinary meatus
Urine culture

TYPES OF URINE SPECIMENS

Urine analysis is one of the most common tests performed in the clinical laboratory. The collection process for urine specimens is noninvasive, and is relatively easy to accomplish because the production of urine by the body is an ongoing process. It is important to remember, however, that proper collection and processing procedures are essential for the urine laboratory results to be accurate and meaningful. (Table 9-1 summarizes the various types of urine specimens.)

Specimen collection procedures may vary based on the length of time for the collection, dietary limitations, specimen volume requirements, and the method of collection. Many urine specimens are collected to diagnose potential urinary tract infections, in which case they are usually **random** collections; they could be collected at any time of the day, as long as the collection procedures

TABLE 9-1
Types of Urine Specimens

Specimen Type	Time of Collection	Uses
Clean-catch midstream urine specimen	Random	Urinalysis, culture, random chemistry testing, urine pregnancy testing
Intermittent (straight) catheter specimen	Random	Urinalysis, culture, random chemistry testing, urine pregnancy testing
Indwelling catheter specimen	Not appropriate for urinalysis, culture, or chemistry testing	Not appropriate for urinalysis, culture, or chemistry testing
Suprapubic aspiration specimen	Random	Urinalysis, culture, random chemistry testing, urine pregnancy testing, urine cytology
Prostatitis specimen	Random as part of procedure	To check for bacterial prostatitis
First morning void specimen	Upon rising	Urine pregnancy testing, specific chemistry tests; urinalysis, culture
24-hour urine specimen	24 hours of collection	Chemistry testing
2-hour postprandial specimen	2 hours after a 100-g carbohydrate meal	Glucose and ketones
Glucose tolerance testing	As part of a glucose tolerance testing procedure	Glucose and ketones
Infant urine specimens	Random	Urinalysis

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are followed appropriately. Other urine specimens are collected for chemical analysis to aid in the diagnosis of specific problems with the kidneys or other organ systems. These chemicals often change in concentration throughout the day, which is known as **diurnal variation.** To provide accurate results, specimen collection in these circumstances is carried out over a specific period of time at a certain time of the day. Procedures for collection may also include dietary restrictions for some tests to limit potential erroneous results because of a diet rich in a particular substance.

The guidelines that should be followed whenever a urine specimen is to be collected include the following:

- All specimen containers must be correctly labeled. In the case of urine collection, this should occur immediately after the patient returns the specimen container to the laboratory or health-care facility. All labels should include the patient's name, birth date or other unique identifier, and the date and time of the collection. Labels must be placed on the container itself, not just on the lid. It is also a good idea to document the type of specimen (e.g., urine) in the container; many body fluids have a similar appearance when received in the laboratory.
- The required specimen volume must be verified before instructing the patient on collection requirements.
- Any medication the patient is taking that may potentially interfere with the test results needs to be documented on the requisition form.
- For timed specimens, the start and finish time (and dates if appropriate) must be documented on the container.
- Dietary restrictions must be communicated to the patient before collection, both verbally and in writing.
- Collection of urine for analysis during the menstrual cycle should be avoided if possible; the presence of red blood cells may interfere with the testing procedures for some analytes. If it is not possible to delay the collection, care must be taken to instruct the patient on proper cleaning techniques to avoid gross contamination, and a notation should be placed on the laboratory requisition form (and/or in the patient chart if available) that the patient is menstruating.
- Specimen containers that have preservatives added need to be clearly marked, and in these situations, there should be an additional container provided for the patient to use during collection to avoid urinating directly into the specimen container with the preservative.
- Patients should *always* be provided with a specimen container, so that they are not using a jar or other container from home. Although these may appear "clean," they may contain chemicals or other substances that can affect the urine test results.
- Any instructions for collection must be given to the patient verbally and in writing. These include storage instructions for the specimen until it is returned for analysis.

Test Your Knowledge 9-1

Please provide two reasons that a urine specimen may be ordered for testing. (Outcome 9-2)

Test Your Knowledge 9-2

List one item that is the same for all urine collection procedures. (Outcome 9-2)

POINT OF INTEREST 9-1
Urine drug screens

Many health-care providers and laboratories are now involved in preemployment physicals. These may include urine drug screens for drugs of abuse. This type of urine collection has very specific procedural parameters designed to prove that the specimen collected was not tampered with prior to the completion of testing. There are guidelines that dictate the steps involved in the collection procedures, as well as guidelines that outline the security of the specimen during transportation and processing. A series of documentation on a standardized form is necessary; this process establishes the *chain of custody* for the specimen. Federal regulations require preemployment, postaccident, and random drug screening for some jobs, whereas other large nonfederal employers choose to ensure a drug-free environment by requiring their employees to undergo testing. The following is a summary of the steps involved in a urine drug specimen collection procedure:

1. Collectors must be appropriately trained for the process.
2. The collector verifies that there is a bluing agent (some sort of dye) added to the toilet before the donor process begins.
3. The donor is greeted and must provide photo identification. In some situations, alternative forms of identification are acceptable from an employer representative.

Continued

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4. The collector fills out the first step of the chain of custody form, and the donor signs to verify the accuracy of this information.
5. The donor leaves all purses, coats, and so on outside of the restroom to eliminate the possibility of smuggling in concealed substances to contaminate the urine.
6. The donor washes and dries his or her hands.
7. The collector must tape the toilet lid and the faucet handles with tamper-proof tape so that there is no access to other water sources.
8. The collector remains in the restroom (if there is a private stall) or outside the restroom door if there is no private stall during the collection process. Sometimes a witnessed collection is requested, in which case the donor must be watched by the collector during the collection.
9. The donor is not allowed to wash his or her hands until the specimen is handed to the collector and the follow-up quality control measures and documentation have been completed. The urine specimen must remain within the site of the donor and the collector during this process.
10. The collector verifies the volume received, the appearance of the urine, and records the temperature of the specimen. If there is a problem with the temperature or the appearance of the urine specimen, the collection process is void.
11. As the donor observes, tamper-proof collection labels are placed over the top of the collection container and the donor initials these labels. The date and time are also added to these labels.
12. These steps are documented on the chain of custody form.
13. From this point forward, every individual involved in transportation, processing, or testing of the specimen must document their actions and the purpose of their actions on the chain of custody form.

Clean-Catch Midstream Urine Specimen Collection

When a urinalysis or urine culture is ordered for a patient, it is important the specimen be as contaminant free as possible. A **urinalysis** includes physical observations and chemical analysis of the urine specimen, and may also include a microscopic examination of the urine sediment. A **urine culture** is designed to test for bacterial growth in the urine specimen. In both these situations, it is imperative that the specimen received for testing is representative of the urine in the urinary bladder and urethra, rather than contaminants that might be present on the outside of the body. A clean-catch midstream urine specimen collection technique is the best noninvasive method to obtain a urine specimen for these tests. This procedure involves cleaning the external opening of the urinary tract and obtaining a midstream urine specimen.

The clean-catch midstream urine collection technique offers an opportunity to obtain a specimen that has less contamination with epithelial cells and bacteria from the distal urethra and urinary meatus than a specimen obtained without proper cleansing and technique. The **distal urethra** is the area of the urethra that is closest to the outside of the body. The **urinary meatus** is the exterior opening of the urinary tract. Because these are both near the outside of the body, they are naturally potential sources of exterior contamination. Even though all urine specimens must pass through this area of the urinary tract as they exit the body, the goal is to obtain a specimen that contains the bacteria and other microscopic structures that are clinically significant, (those that are present in the bladder) and minimize those that are essentially contaminants. This is critical for patients to be properly diagnosed and treated for urinary tract infections.

Test Your Knowledge 9-3

Why is the cleansing process for a clean-catch midstream urine specimen so important? (Outcome 9-2)

Test Your Knowledge 9-4

Should a urine collection container be labeled before or after it is given to the patient for collection? (Outcome 9-6)

Catheterized Specimens

Another way to avoid potential specimen contamination is to use a catheter to obtain the specimen. Only a licensed health-care professional may insert a catheter. This process may also be used when the patient is not capable of following the directions or performing the procedures necessary for a clean-catch urine collection procedure, such as those who are very young or those who may have physical limitations. Catheters may be

(Text continues on page 203)

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Procedure 9-1: Instructing a Patient for Collection of a Clean-Catch Midstream Urine Specimen for Urinalysis and/or Culture

Clean-catch midstream urine specimens are required by most laboratories for performance of urinalysis and cultures. By cleansing appropriately and providing a midstream specimen that comes from the bladder and upper urethra, most extraneous microorganisms will be eliminated from the specimen.

TASK

The student will demonstrate the ability to properly instruct a male or female patient how to collect a clean-catch midstream urine specimen.

CONDITIONS

- Appropriately labeled sterile urine collection container
- Three moist antiseptic towelettes
- Hand-washing facilities
- Paper towels

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.6: Anatomy and Physiology: Perform patient screening using established protocols
I.A.I.2: Anatomy and Physiology: Use language/verbal skills that enable patients' understanding

ABHES Standards

Medical Laboratory Procedures: e. Patient Instructions (collection of urine and feces); Instruct patients in the collection of a clean-catch mid-stream urine specimen.

Procedure	Rationale
1. Wash hands and gather necessary supplies for the patient.	Hand washing breaks the chain of infection.
2. Greet and identify the patient. Verify the test orders and the labeling on the container.	The patient identity should always be verified for every procedure. Verification of test orders and labeling reduces the potential for error.
3. Provide the patient with a sterile container and three antiseptic towelettes.	The patient will need to refer to these items as the procedure is explained. The towelettes will be used for cleansing around the urinary opening area. Strong antiseptics should not be used because of the potential irritation to the external urinary structures.

Continued

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Procedure 9-1: Instructing a Patient for Collection of a Clean-Catch Midstream Urine Specimen for Urinalysis and/or Culture—cont'd

Procedure	Rationale
Instructions for Male Patients	
a. Instruct the patient to wash and dry his hands, and once in the restroom, remove his underwear.	Hand washing breaks the cycle of infection, and removing the undergarments allows for better access during the cleaning process.
b. The patient should carefully remove the lid of the specimen container and place it with the inside up on the counter near the toilet where the container can easily be accessed for the collection process. Emphasize the importance of keeping the interior of the container sterile.	Placing the lid with the inside up prevents contamination from microorganisms that may be present on the countertop.
c. Male patients who are uncircumcised must pull back the foreskin, and keep it withdrawn during the cleaning and collection process.	Pathogenic microorganisms may be present under the foreskin.
d. The tip of the penis must be cleansed three times: • Wipe with the first wipe from front to back on one side of the tip of the penis. • Wipe with the second wipe from front to back on the other side of the tip of the penis. • Use the third wipe over the urinary opening (the meatus) from front to back. Note: A new antiseptic towelette must be used to clean each side of the penis and an additional towelette used to clean the tip of the penis. (A total of three towelettes are to be used for the cleansing process.) • Some laboratories may provide a fourth towelette to clean the outside of the container after the collection.	Thorough cleansing eliminates potential contaminating substances. Once the cleaning process has started, the patient should keep holding the penis until the specimen has been obtained to eliminate the possibility of recontamination. 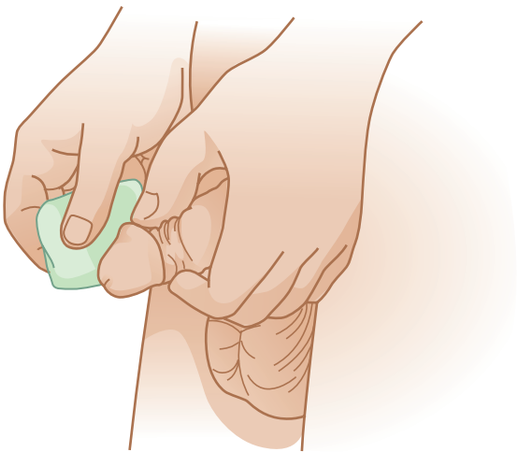

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Procedure	Rationale
e. Instruct the patient to pick up the specimen container so that he is ready when for the collection. Begin to urinate into the toilet. Stop the urine stream, move the specimen container into a position where it will intersect the urine stream, and urinate into the container until it is at least half full. Stop the urine stream again and move the container out of the way. Remind the patient not to touch the inside of the container.	This process flushes out microorganisms that may be present near the opening of the urethra and allows collection of a specimen that represents the urine that was present in the bladder and upper urethra.
f. Instruct the patient to finish urinating into the toilet.	The specimen must be *midstream*; the first and last part of the urine void should not be included in the specimen submitted to the laboratory.
g. The patient must carefully replace the lid on the container without contaminating the interior of the cup or lid. If urine is present on the outside of the cup, dry it off with toilet tissue or a paper towel, and discard the waste.	Contamination must be avoided on the inside of the container so that the specimen represents the urine as it is inside the body.
h. Instruct the patient to wash and dry his hands.	Clean hands prevent the spread of microorganisms.
i. Instruct the patient to place the urine in the designated area of the laboratory if the specimen is collected in the office. If it is a home collection, instruct the patient to refrigerate the specimen until it can be transported to the testing location.	The specimen will need to be refrigerated or tested in a timely manner to preserve the integrity of the test results.
Instructions for Female Patients	
a. Instruct the patient to wash and dry her hands, and once in the restroom, remove her underwear.	Hand washing breaks the cycle of infection, and removing the undergarments allows for better access during the cleaning process.
b. The patient should carefully remove the lid of the specimen container and place it with the inside up on the counter near the toilet where the container can easily be accessed for the collection process. Emphasize the importance of keeping the interior of the container sterile.	Placing the lid facing up prevents contamination with microorganisms that may be present on the countertop.
c. Instruct the patient to move her knees apart until she can easily reach her labia. (These are the structures that cover the urinary opening in females.)	It is important that the patient has full access to the labia to clean the area properly.

Continued

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Procedure 9-1: Instructing a Patient for Collection of a Clean-Catch Midstream Urine Specimen for Urinalysis and/or Culture—cont'd

Procedure	Rationale
d. Instruct the patient to spread apart the labia with one hand to expose the urinary opening (the urinary meatus). The labia will need to remain spread apart until the cleaning and collection process is complete.	The labia must remain apart after the area is cleaned to eliminate the potential for recontamination of the site. 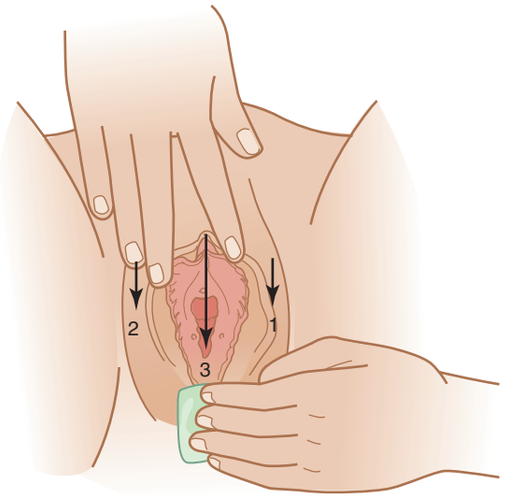
e. The patient needs to clean the area three times, using a clean antiseptic towelette each time. • The first towelette should be used to clean from front to back on one side of the urinary opening. • Use the second towelette to wipe front to back on the other side of the urinary opening. • The third towelette is to be used to wipe front to back across the urinary opening for the final cleansing step. • Some laboratories may provide a fourth towelette to clean the outside of the container after the collection.	Cleansing in this manner avoids potential contamination from the anal area (front to back) and provides an opportunity to thoroughly clean away potential pathogenic microorganisms that could enter the specimen while urinating.
f. Instruct the patient to pick up the urine specimen container in the hand that is not holding the labia apart.	The specimen container must be in hand before the patient starts to urinate.
g. The patient should begin to urinate into the toilet. After a small amount has entered the toilet, stop the urinary stream and place the specimen container under the urinary opening.	This initial urine stream flushes out potential contaminants that may have been around the urinary meatus.

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Procedure	Rationale
h. Instruct the patient to urinate directly into the specimen container, filling it at least half full. Tell the patient to stop urinating and move the specimen container out of the way. Remind the patient to avoid contamination of the interior of the specimen container.	This is a *midstream* specimen that includes urine from the bladder and the upper part of the urethra.
i. Instruct the patient to finish urinating into the toilet.	The first and last part of the urine specimen should not be submitted to the laboratory.
j. The patient must carefully replace the lid on the container without contaminating the interior of the cup or lid. If urine is present on the outside of the cup, dry it off with toilet tissue or a paper towel.	Contamination must be avoided on the inside of the container so that the urine is representative of the conditions on the inside of the body.
k. Instruct the patient to wash and dry her hands.	Hand washing stops the spread of microorganisms.
l. Instruct the patient to place the urine in the designated area of the laboratory if the specimen is collected in the office. If it is a home collection, instruct the patient to refrigerate the specimen until it can be transported to the testing location.	The specimen will need to be refrigerated or tested in a timely manner to preserve the integrity of the test results.
4. Verify whether the patient understood the instructions as given, and check if he or she has any additional questions. Supply contact information for future questions.	This is a critical step for the appropriate collection of the specimen.
5. Provide the patient with a written copy of the instructions.	A written copy will allow patients to refresh their memory when the collection is performed.

Date	
10/24/2016:	Patient provided supplies and written and verbal instructions for a clean-catch midstream urine collection procedure.
11:58 a.m.	Connie Lieseke, CMA (AAMA)

used in various ways (listed below), and it is imperative that the requisition form and the patient chart include documentation of the type of collection performed.

- **Intermittent (straight) catheter:** There may be times that it is necessary to empty the bladder for a patient who is unable to do so. If this is a temporary situation, an **intermittent (straight) catheter** may be used for the process. This catheterization procedure involves a small, stiff, plastic tube that is placed through the urethra into the bladder to allow the bladder to be drained. This procedure may also be used to obtain a specimen for urinalysis and culture, as the potential for contamination is greatly reduced. Catheterization, however, does include risks of bacterial infection because the lining of the urethra may be damaged as the catheter is inserted or removed.
- **Indwelling catheter: Indwelling catheters** are designed for long-term use. They may be inserted in surgery patients for a few days after surgery, or they may be inserted in patients who have permanently lost the ability to control urination. These catheters are larger in diameter than the straight catheters, and have a small "balloon" that is pumped up to keep them in place within the bladder once they have been inserted. Indwelling catheters continuously drain the urine from the bladder into a collection bag. This bag is emptied periodically. Indwelling catheters are *not* recommended

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as a source of urine for urinalysis or urine cultures, as the catheters are kept in place for extended periods of time and become contaminated with bacteria. If a patient with an indwelling catheter needs to have a urinalysis, it is best for the catheter to be removed and for the health-care professional to use a straight catheter to obtain the specimen for analysis.

Test Your Knowledge 9-5

Which type of catheterization procedure is used to obtain a urine specimen for a routine culture?

(Outcome 6-3)

Suprapubic Aspiration

There are times, especially with young children, when it is imperative that a urine specimen be collected quickly, without contamination. Skilled health-care professionals (such as physicians or nurse practitioners) may choose to perform a **suprapubic aspiration** to obtain a specimen for urinalysis and culture. A needle is placed externally through the abdomen directly into the bladder, and a urine specimen is withdrawn. This procedure may also be used to collect urine for *cytology* examination, a procedure in which the cells present in the specimen are examined by a pathologist or cytologist for abnormalities in their appearance.

Prostatitis Specimen Collection

Prostatitis (inflammation of the prostate) may be caused by various factors. Prostate enlargement and/or use of urinary catheters are often linked to this condition. The tissue of the prostate may be inflamed, or there may be an infection with pathogenic microorganisms. In order to plan the correct course of action, it may be necessary to collect a urine specimen utilizing a special procedure. In a **prostatitis specimen collection** process, there are three specimens collected in close progression. The patient is provided with three antiseptic towelettes and three sterile specimen collection containers, numbered sequentially 1, 2, and 3. The patient cleansing process is the same as that required for the clean-catch midstream collection procedure. However, rather than urinating into the toilet at the beginning of the process, the first small amount of urine passed goes into collection cup 1. Next, the midstream specimen goes collected in cup 2. After this collection is completed into cup 2, the health-care provider will massage the patient's prostate to allow prostatic secretions to enter the urethra for collection. After the prostate has been massaged, the patient will immediately urinate into the third cup. Cultures are performed on all three specimens. If the second specimen has a high concentration of bacteria present, the third specimen is considered to be invalid, because of contamination by the bacteria already present in the urethra. Generally, if there is an infection of the prostate, the bacterial count of the third specimen will be much higher than that of the first two specimens.

Timed Urine Specimen Collections

Most urine specimens collected in the office setting are random collections, because the time of day is not significant for the desired results. The clean-catch midstream urine collections used for urinalysis and culture are usually random specimens. Remember, however, that the time of collection still must be recorded accurately. A random collection is not always desirable for all urine specimens. There are situations in which the *time* of collection is critical:

- **First morning void specimen:** A specimen that is collected when the patient first rises from sleep is known as a **first morning void** specimen. This specimen is concentrated (ideally it should be approximately 8 hours since the patient last voided)

POINT OF INTEREST 9-2

Proper documentation for urine collection procedure education

This chapter includes a lot of information about different types of urine collection procedures. The key component in all these processes is patient education. The patient should be provided with the appropriate collection supplies in all situations, as well as verbal and written instructions for the collection process. Every laboratory should develop its own literature to distribute to patients so that there is standardization of information provided for collection and storage of the specimens. Government regulations require that the instructions for patients are to be provided in their native language whenever possible. In addition, it is very important to remember that whenever instructions are provided for the patient, doing so must be documented properly in the patient chart.

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because it has been in the bladder during the night while the patient slept. The first morning void specimen is recommended for urine pregnancy tests (especially if it is very early in the potential pregnancy) and for detection of the presence of protein or albumin in the urine. It may also be used for routine urinalysis and culture, but the clean-catch midstream collection procedure should still be followed. There will be more dissolved substances present in this specimen than in those found later in the day, and it may also contain more microscopic structures.

- **24-hour urine collection:** Routine urinalysis testing reports the presence or absence of numerous chemicals in the urine specimen and provides a rough quantitative estimate of the amount present for that chemical. For some chemical components, however, it is necessary to have an exact measurement of the amount of that chemical present in the urine. These analytes are not present in the same concentration at all times; they may vary with the time of the day (diurnal variation), or their concentration may be changed with exertion or the hydration status of the individual. To account for these variables, it is often desirable to collect all the urine produced by a patient over the period of an entire day. This is called a **24-hour urine collection.** This collection process is used to test for various substances; among the most common are the following:
  - Urea nitrogen: Urea nitrogen is a by-product of protein metabolism, and is used as an indicator of kidney function.
  - Urine electrolytes: Urine electrolyte tests include those that check for the level of calcium, chloride, potassium, and sodium in the urine. These tests may be ordered together or individually. They are often part of a clinical workup for suspected endocrine disorders or hormonal imbalances or kidney dysfunction. Urine calcium levels are sometimes ordered for patients with recurring kidney stone formation. Situations that cause electrolyte imbalances in the bloodstream may also result in abnormal urine electrolyte levels.
  - Catecholamines: Catecholamines are substances that are created by nerve tissue and by the adrenal glands of the body. They include norepinephrine, dopamine, and epinephrine. Urine specimens do not contain the intact catecholamine molecules; instead, we test for the breakdown products of these compounds. The breakdown products include homovanillic acid (HVA), vanillymandelic acid (VMA), normetanephrine, and metanephrine. Urine catecholamines may be ordered as a group or individually. This test may be used when an adrenal gland tumor is suspected (pheochromocytoma), and it may also be ordered for patients with symptomatic hypertension.
  - 17-Hydroxysteroids: This test is often performed when there is suspicion of Addison's disease, which is a type of adrenal insufficiency.
  - Urine total protein: The level of total protein in the urine may be an indicator of kidney damage.
  - 5-Hydroxyindoleacetic acid: More commonly known as 5-HIAA, this test may be performed to detect a specific type of tumor, the carcinoid tumor, of the digestive tract. 5-HIAA is a metabolite of serotonin in the urine, and these intestinal tumors secrete unusually high amounts of serotonin.
  - Urine creatinine: Creatinine is a breakdown product of creatine, present in muscle tissue throughout the body. Creatinine is cleared from the body exclusively by the kidneys, and the test is ordered to screen for possible kidney dysfunction.

In some situations, blood is also drawn and tested for the same analyte as the urine specimen at the end of the 24-hour interval. For example, when urine creatinine is ordered, there is often a blood draw performed for creatinine as well, so that both results can be used to reach a diagnosis.

Urine specimens collected over a 24-hour period may have dietary or fluid restrictions; this is to limit potential erroneous results because of a diet rich in a particular substance. Patient education concerning these restrictions is *critical* for a meaningful urine test result. The patient must be given the instructions verbally and in writing, and documentation of the education should be added to the patient's chart.

It may also be necessary to deliver (or even ship) these urine specimens directly to a laboratory for processing, rather than returning them to the health-care provider's office. These instructions should be explained clearly before the collection process is started. The patient should be provided with all shipping materials and written instructions so that the specimen is delivered successfully.

When refrigeration is not possible (especially when the specimen must be transported over long distances) chemical preservatives may be utilized to keep the 24-hour urine specimen from undergoing changes upon standing. Chemical preservatives (such as boric acid or

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dilute hydrochloric acid) are often added to 24-hour urine specimen containers to keep chemical changes from occurring before the specimen is tested. These additives for 24-hour urine specimen collection are listed in Table 9-2.

Test Your Knowledge 9-6

When providing instructions to a patient for a 24-hour specimen collection, what should the patient be told about urinating directly into the container that contains hydrochloric acid as a preservative? (Outcome 9-7)

There are additional handling procedures that are required by 24-hour urine specimens once they arrive at the laboratory. These procedures include proper documentation of the total specimen volume upon arrival at the laboratory, and verification of the times included in the collection. The specimen must also be well mixed and an **aliquot,** which is a small sample, must be poured off for further chemical testing. Figure 9-1 shows a 24-hour urine collection container.

Procedure 9-2 details the instructions for collection of a 24-hour urine specimen.

TABLE 9-2
Additives used for 24-hour urine specimens

Test Ordered	Preservative Added
Aldosterone	1 g boric acid per 100 mL urine
Amylase	Add NaOH; adjust pH to 6 or above
Urine calcium	Add HCl to adjust pH 1.5–2.0
Catecholamines	Add HCl to adjust pH to 2–3 or add 25 mL 6N HCl
Cyclic AMP (adenosine monophosphate)	10 mL 6M HCl
17-Hydroxy-corticosteroids	Boric acid to adjust pH 5–7
Urine phosphorus	HCl to adjust pH to 1.5–2
Testosterone	1 g Boric acid per 100 mL
Uric acid	NaOH to adjust pH to 8 or above
Dopamine	Glass container with 25 mL HCl
Homovanillic acid (HVA)	Glass container with 25 mL HCl
Iodine	Glass container with 25 mL acetic acid
Vanillymandelic acid (VMA)	Glass container with 25 mL 6N HCl
Urea nitrogen	25 mL 6N HCl
5-Hydroxy-indoleacetic acid (5-HIAA)	25 mL 6N HCl

Glucose Testing Specimens

Glucose is not usually present in the urine at levels high enough to be measured. However, in patients with diabetes mellitus, blood glucose concentrations may reach levels that are high enough to cause glucose to "spill" into the urine. There are several urine collection procedures that may assist with the diagnosis or monitoring of those with diabetes mellitus or gestational diabetes. These include the following:

- **2-hour postprandial specimen:** For a **2-hour postprandial specimen,** the patient is instructed to empty the bladder before a meal that contains approximately 100 g of carbohydrates. Two hours after meal completion, the patient is to collect a urine specimen. Ideally, the patient will also have a blood sample drawn 2 hours after eating so that both results can be used to evaluate the patient's condition. Because there will not be a culture or complete urinalysis performed on the specimen, 2-hour postprandial urine specimens do not need to be collected using the clean-catch midstream urine collection procedures, The specimen is tested only for the presence of glucose. (Additional

Figure 9-1 A 24-hour urine collection container. Notice the large-volume capacity, the measurements along the side of the container, and the amber color, which blocks light exposure, as some chemical concentrations are decreased with exposure to light. This 24-hour urine collection container includes a special closure adaptation to make it easy to pour the specimen when it arrives at the laboratory.

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information about this procedure is included in Chapter 17.)

- **Glucose tolerance urine specimen: Glucose tolerance urine specimen** tests are used for diagnosis of gestational diabetes or diabetes mellitus. Urine and blood specimens are collected at specific intervals after a fasting patient is given a high glucose substance to drink. The first urine specimen collected should ideally be a "fasting" specimen, meaning that it is the second morning void, not the first. The first morning void contains the breakdown products from the food ingested the night before the test; the second morning void should be representative of the body in a state of fasting. After the patient has been given the high glucose substance to drink, a blood and urine collection is performed at least three more times at hourly intervals for 3 more hours. Additional samples may be collected depending on the policy for that particular laboratory. It is not necessary to use the clean-catch midstream collection procedures for this test, as the specimens collected are not used for cultures or complete urinalysis procedures.

Procedure 9-2: Instructing a Patient for Collection of a 24-Hour Urine Specimen

This process collects all urine that is produced by the body over a 24-hour period. It is noninvasive, and provides a great deal of information about the patient's renal function. Remember, urine contains many chemical substances such as sodium, potassium, and creatinine that are dissolved in water. Because the concentration of these chemicals may vary throughout the day, it is important to collect all the urine produced over a 24-hour period for an accurate assessment.

TASK

Provide the necessary supplies and education for a patient to successfully complete a 24-hour urine specimen collection.

CONDITIONS

- An appropriately labeled 24-hour urine collection container (or more than one container if a high volume of urine is anticipated)
- Warning sticker if preservative is added to the specimen container
- An additional smaller container (such as a urinal device) for urine collection
- Written patient instructions, including any dietary restrictions for the collection period

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.6: Anatomy and Physiology: Perform patient screening using established protocols
I.A.I.2: Anatomy and Physiology: Use language/verbal skills that enable patients' understanding

ABHES Standards

None

Procedure	Rationale
1. Wash hands and gather necessary supplies for the patient. Verify any dietary restrictions and/or preservative requirements for the test ordered by checking the laboratory reference guide. Check to see if the instructions for the analyte ordered include a blood draw.	Hand washing breaks the chain of infection. It is imperative that the medical assistant verify all restrictions and special instructions before meeting with the patient. There should be a written copy of all instructions (including dietary restrictions) available so that they can be provided to the patient.

Continued

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Procedure 9-2: Instructing a Patient for Collection of a 24-Hour Urine Specimen—cont'd

Procedure	Rationale
2. Add preservative to the collection container if necessary, using appropriate safety precautions. Apply warning label if acid was added to the container.	Warning labels must be added to the container if there has been preservative added (e.g., hydrochloric acid) that could harm the patient. If there is a harmful preservative added to the container, the patient must be told that he or she cannot urinate directly into the container or splash the specimen on bare skin.
3. Greet and identify the patient. Verify the test order once more.	The patient identity must always be verified for every procedure. Verification of test orders and labeling reduces the potential for error. Some laboratories have labels that include the dietary restrictions that are also attached to the container.
4. Provide the patient with the 24-hour urine collection container and an additional smaller, wide-mouth container for urine collection.	The 24-hour urine collection container will be amber or dark in color. It will hold approximately 3 liters of urine. The dark color protects some of the urine chemicals from decomposing with exposure to light. The smaller container is used to collect the specimen during urination, after which it will be added to the large container.
5. Instruct the patient that the 24-hour specimen must remain refrigerated during the collection process. Also emphasize that *all* urine collected during the 24-hour period must be collected in the container provided.	For accurate results the patient must understand that *all* the urine in the 24-hour period must be collected and preserved appropriately. For convenience, the patient may want to choose a day for collection when he or she will be home most of the time.
6. Instruct the patient that upon arising on the first day of the 24-hour period he or she is to empty the bladder by urinating into the toilet. This is the start time of the collection period, so the patient is to note this time on the collection container and on any paperwork that may have been provided for the process.	For accurate results, this part of the process should be emphasized; it is a bit difficult to understand without a thorough explanation.

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Procedure	Rationale
7. Explain to the patient that all the urine for the next 24 hours (after that initial void) must be saved in the large container. Instruct the patient that he or she may use the smaller collection container during the urination process, but this urine must all be added immediately to the larger container.	It must be stressed that all the urine must be collected during the 24-hour period for the test results to be valid.
8. Explain to the patient that if for any reason all the urine is not put in the container, the collection process must be started over.	The reference ranges for the tests are dependent on 24-hour specimens; any urine not added to the specimen container may potentially affect the results.
9. Explain to the patient that the 24-hour collection period ends the following day at the same time that the process was started. This urine (from the following morning at the same time) is to be added to the collection container to complete the process. Document this time on the collection container and on any additional paperwork as required.	Emphasize that the 24-hour period starts and ends with an empty bladder.
10. Tell the patient to transport the filled container to the laboratory as directed. It may be necessary to collect blood when the specimen is returned to the laboratory.	The patient should be notified before the collection process begins if there is a blood draw necessary so that he or she is anticipating this.
11. Verify whether the patient understood the instructions as given, and check if there are any additional questions. Supply contact information for future questions.	This is a critical step for the appropriate collection of the specimen.
12. Provide the patient with a written copy of the instructions.	A written copy will allow the patient to refresh his or her memory when the collection is performed.

Date	
10/24/2013:	*Patient provided supplies and written and verbal instructions for a 24-hour urine collection procedure.*
11:58 a.m.	*Connie Lieseke, CMA (AAMA)*

Test Your Knowledge 9-7

How is a first morning void specimen different from a 24-hour urine specimen? (Outcome 9-3)

Urine Collection Procedures for Infants and Pediatric Patients

It can be very difficult to collect a urine specimen from an infant or young child using noninvasive procedures. A routine specimen may be obtained by using a special type of collection bag designed to be attached to the skin surrounding the urinary opening of a young child or infant. The area around the urinary meatus must be carefully cleaned to reduce contamination, and care must be used to attach the device securely so that the urine does not leak out around the adhesive. It is also important to inform the parents of the patient (if the collection is to be completed at home) to check for the presence of urine in the bag often so that it can be transferred to an appropriate sterile collection cup and refrigerated. Figure 9-2 shows a pediatric urine collection

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Figure 9-2 Pediatric urine collection device. Note the adhesive surrounding the opening of the bag. The adhesive surface will be applied to the child's cleansed skin surrounding the urinary opening. *Courtesy of Zask, Inc.*

bag. A suprapubic aspiration or straight catheterization procedure may be performed by the physician (or other qualified health-care professional) for young children and infants if a sterile specimen is necessary for proper diagnosis.

Test Your Knowledge 9-8

Why is a special collection device necessary to collect a urine specimen from an infant? (Outcome 9-3)

URINE SPECIMEN PROCESSING

Because urine can be collected relatively easily without invasive procedures, it is often taken for granted. A urine specimen may have drastic changes occur while standing at room temperature, so care must be taken to handle the specimen correctly after collection until the testing process is complete. Urine that is not processed correctly can lead to misdiagnosis and incorrect treatment for the patient.

Although urine is not considered to be capable of transmitting HIV, hepatitis B, or hepatitis C, it is important that the processor uses gloves and a protective laboratory coat when handling urine samples. Other pathogenic microorganisms may be present in the urine specimen, and employees need to be certain to protect themselves appropriately. Protective eyewear may also be considered if there is a potential for splashing the specimen. This may be particularly critical when handling specimens that have acid added as preservative, or those that may have a lot of blood present in the urine.

POINT OF INTEREST 9-3
What now?

Once the specimen has been collected and returned to the laboratory or physician's office, it is up to the medical assistant to process and store it correctly. Here are a few basic guidelines:

- While still in the presence of the patient, verify that the specimen is correctly labeled with name, birth date, and other identifying information.
- Verify and, if necessary, document the date and time of collection on the appropriate paperwork.
- Review the collection process with the patient; ask specifically whether there were any problems with the specimen collection or storage. If the collection or storage of the specimen was incorrect, the specimen should be discarded at this time, and the patient should be provided with materials to perform a recollection.
- Some facilities will have the medical assistant immediately document the color, appearance, and specific gravity of the specimen before it is refrigerated, as these can change once the specimen temperature decreases.
- Specimens for urinalysis, culture, and most other procedures are to be tested or refrigerated as soon as possible, and always within 1 hour of arrival at the laboratory.
- Twenty-four-hour urine collections may need to be mixed well and an aliquot may need to be poured off. This aliquot would then be forwarded to the main laboratory for analysis. (This step will be dependent on the policy of the laboratory performing the 24-hour urine collection container.)

Test Your Knowledge 9-9

Why are gloves worn when handling urine specimens in the laboratory? (Outcome 9-4)

Refrigeration and Preservation

Urine specimens should be refrigerated (at 2° to 8°Celsius) immediately after collection if they cannot be analyzed within 1 hour of collection. If the specimen is collected in a patient's home, instructions about refrigeration are especially critical. The sample should stay cool until delivered

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to the laboratory; if a patient has numerous errands to run, or if the patient is going to work, it is important that the patient use a cooler to keep the urine refrigerated until it is delivered to the laboratory.

There are numerous changes that may occur as the urine is left standing at room temperature, but the most dramatic is the change in the bacterial count. The bacteria present in urine specimens are capable of multiplying very rapidly; the bacterial count of the specimen may double within 2 hours at room temperature. This means that the patient may initially be treated for a urinary tract infection based on a high bacterial count reported as part of the urinalysis, when there were actually very few bacteria present in the specimen at the time of collection. Refrigeration halts most of the changes that may occur in the urine specimen, and reduced temperatures are especially effective at limiting the replication process of bacteria. The potential changes to a urine specimen with extended room temperature storage are listed in Table 9-3.

Test Your Knowledge! 9-10

What change in the urine specimen is most dramatic if the specimen is left out at room temperature for more than an hour? (Outcome 9-5)

TABLE 9-3

Changes in urine specimen when left at room temperature for more than 1 hour

Changes in Urine Specimen	Details and/or Clinical Significance
Decreased clarity and slight color change	Crystallization of solutes; may also cause color interpretation to change as these form
pH increases	Bacteria in specimen convert urea to ammonia and CO_2 is lost
Ketones decrease	Ketones decrease with time at room temperature
Bilirubin and urobilinogen decrease	Exposure to light causes these chemicals to degrade in the specimen
Cells and casts dissolve	Microscopic examination is inconclusive as identification of microscopic features is inaccurate
Bacterial count increases	Bacteria continue to multiply exponentially
Glucose decreases	Glucose is used by bacteria and other cellular components as an energy source

Although it is necessary to preserve urine specimens at reduced temperatures to stabilize some of the analytes, it is important to remember that these reduced temperatures may also affect the specimen. Refrigeration may increase the *specific gravity* of the specimen, and cause some diffuse microscopic crystallization within the urine specimen as well. The specific gravity is a measurement of the amount of dissolved substances in the urine specimen. (More information about specific gravity is covered in Chapter 20.) Urine that has been refrigerated may also change in color and appearance, and these parameters are recorded as part of a routine urinalysis in many situations. In order to counteract the effects of refrigeration on these testing parameters, the urine specimens should be allowed to return to room temperature before routine urinalysis testing is performed. This reverses most of the changes. Also remember the urine specimens must be well mixed with gentle inversion or swirling of the specimen container before testing.

Additives (preservatives) may also be used for specimens that are to be tested for common urinalysis tests and/or set up for urine cultures. Many manufacturers produce tubes with additives for this purpose. An example is BD Vacutainer Plus Plastic Conical urinalysis preservative tubes, which contain chlorhexidine, ethyl paraben, and sodium propionate for preservation of urine specimens for urinalysis. Some of these additive tubes cannot be used for certain types of test procedures; it is imperative that the medical assistant check the package insert to verify whether a specific type of collection container with an additive may be used for the procedure ordered. These special additive tubes are not usually given to the patient for transfer at home; the urine specimen is added to the tube once it arrives at the laboratory or physician office. Because microscopic examinations of the specimens are performed, it is also important that the **formed elements** (substances in the urine specimen such as cells and microorganisms) are preserved so that they can be documented as part of the examination. Additives may assist with the preservation of these substances as well as the chemical components present in the specimen.

Proper Disposal of Urine and Supplies

After testing, laboratories may immediately discard urine samples, or keep them refrigerated for a few days for potential follow-up testing and troubleshooting of test results. When the urine is no longer needed, it may be flushed down the sink, and the specimen containers may be disposed of as regular (nonbiohazardous) trash.

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Urine is not considered a biohazard in the same way that blood and other body fluids are. Sinks used for disposal of urine should be disinfected daily with a concentration of 10% bleach or another approved laboratory disinfectant.

SUMMARY

Urine testing is a common method of screening for disorders of metabolism, pregnancy, and potential infection within the body. Proper patient preparation and education are essential to ensure a quality specimen that will yield meaningful results. Collection methods, required volume, and the need for preservatives will vary, depending on the test ordered. Also, once the urine specimen arrives at the laboratory, it is imperative that the specimen is appropriately processed and preserved in a timely manner to prevent overgrowth of microorganisms and potential erroneous results.

TIME TO REVIEW

1. How is a suprapubic aspiration different from a catheterization? Outcome 9-3
   - **a.** The urine is collected from a different part of the urinary system
   - **b.** The collection device used is different for each procedure
   - **c.** The amount of urine collected is not the same for the two types of procedures
   - **d.** All of the above
2. True or False: The urine collected using the clean-catch midstream collection procedure may be collected at any time of the day. Outcome 9-3
3. Which of these statements is not true of indwelling catheters? Outcome 9-4
   - **a.** Indwelling catheters are inserted and used continuously for an extended period of time
   - **b.** Indwelling catheters are often colonized with bacteria
   - **c.** Indwelling catheters may be used to collect a urine specimen after they have been in place for a few days
   - **d.** Indwelling catheters may be used for patients who have problems with incontinence
4. Which of these measurements may change when urine is left at room temperature for longer than 1 hour? (Circle all that apply.) Outcome 9-5
   - **a.** Color
   - **b.** Glucose concentration
   - **c.** Bacterial count
   - **d.** Appearance of microscopic elements
   - **e.** pH
   - **f.** Specific gravity
5. True or False: It is not necessary to provide two unique identifiers (such as patient name and birth date) on a urine specimen container. Outcome 9-6
6. True or False: Labels for urine specimen containers may be placed on the lid only; it is not necessary to label the container. Outcome 9-6
7. Which of these urine specimen types may be collected at random times? (Circle all that apply.) Outcome 9-3
   - **a.** Clean-catch midstream urine specimens
   - **b.** Specimens to check for prostatitis
   - **c.** Specimens used to check for the presence of glucose as part of a glucose tolerance test
   - **d.** Suprapubic aspiration specimens
   - **e.** Urine pregnancy test specimens
   - **f.** Culture specimens
8. The urinary meatus is: Outcome 9-1
   - **a.** Part of the bladder
   - **b.** The excess skin removed during the process of circumcision
   - **c.** The external opening of the urethra
   - **d.** Part of the prostate gland
9. True or False: Different collection techniques for urine specimens are necessary because chemicals are not present in urine in the same concentration at the same time each day. Outcome 9-2
10. Diurnal variation means: Outcome 9-1
    - **a.** Fluctuations in the value of an analyte that occur during each day.
    - **b.** Concentration of urine in the morning void specimen.
    - **c.** Changes in urinary pH when urine is left at room temperature
    - **d.** None of the above
11. True or False: An aliquot of a urine specimen refers to a small portion (or fraction) of the whole. Outcome 9-1

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Case Study 9-1: Postoperative pain

Mr. Johnson has had pain in his perineal area for more than a week, and he has noticed that he is urinating quite frequently. Mr. Johnson decides that he should call the physician for an appointment, because he now has a fever and doesn't feel as if he can go to work. He recently had abdominal surgery, and was catheterized with an indwelling catheter for several days before he was mobile.

1. What are two possible explanations for his discomfort and frequent urination?
2. How could the physician decide on the correct diagnosis? What procedures might be utilized?

Case Study 9-2: Specimen dropoff

Mrs. Brown brings her 24-hour urine specimen container to the office. The medical assistant who is working at the front desk receives the specimen from Mrs. Brown.

1. What does the medical assistant need to do before Mrs. Brown leaves the office?

RESOURCES AND SUGGESTED READINGS

"Prostatitis"
Neal Chamberlain, computerized teaching materials for the Infectious Disease Course at Kirksville College of Osteopathic Medicine http://www.atsu.edu/faculty/chamberlain/Website/lectures/lecture/prostate.htm

"Acute Bacterial Prostatitis"
Overview of prostatitis, with specific information about diagnosis and treatment http://www.drrajmd.com/conditions/prostate/prostatitis/acute_bacterial_prostatitis.htm

"Care Gram 24-Hour Urine and Food Drug Restrictions"
Information about dietary and medication restrictions for 24-hour urine collections from Licking Memorial Health Systems http://www.lmhealth.org/pdf/CareGrams/Lab%20Tests/24%20Hour%20Urine%20&%20Food%20Drug%20Restrictions%201616-0550.pdf

"CAP Today: Cloudy or Clear? Best Forecasts for Urine Cultures," CAP today online newsletter, November 2006
Details for a study about preanalytical errors with urine specimen collection for cultures http://www.cap.org/apps/portlets/contentViewer/show.do?printFriendly=true&contentReference=cap_today%2Ffeature_stories%2F1106Urine.html

"24-Hour Urine Collection"
Southwestern University Health Library selection about 24-hour urine collection; includes clinical significance and details about the collection process http://www.utsouthwestern.edu/patientcare/healthlibrary/healthtopics/0,,P08955,00.html

"Best Practice: Tips for Urinalysis"
Becton, Dickinson online newsletter, LabNotes, 13, no. 2, 2003
Details about urine processing for urinalysis and urine cultures, including information about preservative tubes that are available http://www.bd.com/vacutainer/labnotes/2003spring/best_practice.asp

"Sample Meal for a 2-Hour Postprandial Glucose Test"
Patient instructions for 2-hour postprandial glucose testing procedure from the Delaware Valley Institute of Fertility and Genetics http://www.startfertility.com/patient_fld/form_pdfs/Sample_Meal-2-hr_PP_glucose_test.pdf

"Laws, Regulations, Standards and Guidelines"
A publication of the New Jersey Hospital Association with a summary of laws, regulations, standards, and guidelines that pertain to language assistance for diverse populations in the health-care setting that may not have English as their native language http://www.njha.com/publications/pdf/Laws_Regulations_Standards_and_Guidelines.pdf

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Chapter 10

Collection and Processing of Samples for Microbial Studies

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Microbiology Sample Collection Guidelines
- Types of Media
- Microbiology Terms

Detailed Microbiology Sample Collection Procedures
- Throat Swab Collections for Culture or Strep Screens
- Sputum Samples
- Urine Samples for Culture
- Blood Culture Collection
- Cerebrospinal Fluid Samples
- Genital Samples
- Wound Cultures
- Stool Specimens
- Nasopharyngeal Specimens
- Eye Cultures
- Ear Cultures

Special Sample Collection and Processing Procedures
- Fungal Sample and Culture Collection Procedures
  - *Potassium Hydroxide Preparation*
  - Wet Mount Procedure
- Sample Collection Procedures for Detection of Parasites
  - *Ova and Parasite Examination*
  - *Pinworm Collection Procedures*

Processing Microbiology Samples
- Slide Preparation and Gram-Staining Procedure
- Plating and Inoculation of Media
- Antibiotic Sensitivity Testing

Microbiology Test Results

Summary

Time to Review

Case Studies

Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

10-1 Define the key terms.

10-2 Demonstrate understanding of the general guidelines to be followed when collecting for microbiology testing.

10-3 List various types of media used for bacterial and viral specimen setup.

10-4 Describe how the collection processes and supplies for bacterial, viral, and fungal specimens may differ.

10-5 Compare and contrast sample collection of throat swabs for streptococcal screens and cultures.

10-6 Explain the collection procedure for sputum samples.

10-7 Differentiate the types of urine specimens that may be used for cultures.

10-8 Describe the procedure for collecting a specimen for a blood culture.

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10-9 Describe how a cerebrospinal fluid (CSF) sample is collected, and explain how the sample should be processed after collection.

10-10 Explain how genital screening samples are processed.

10-11 Demonstrate an understanding of the various types of wound cultures and how their processing differs.

10-12 Compare and contrast collection and processing of stool samples as compared to other common microbiology specimen types.

10-13 State when a nasopharyngeal specimen may be necessary, and describe the collection technique used.

10-14 Describe the technique used for eye and ear culture sample collection procedures.

10-15 Classify the various types of fungal infections, and describe the techniques used to collect fungal culture samples.

10-16 Differentiate the requirements and use of a KOH prep and a wet mount specimen preparation.

10-17 Explain how a stool sample is collected and preserved for an examination for the presence of ova and parasites.

10-18 Summarize the sample collection process used for detecting a pinworm infection.

10-19 Explain the steps involved in performance of a Gram stain, as well as the differential appearance of the stained organisms.

10-20 Explain how a microbiological sample is plated for growth.

10-21 Describe how sensitivity testing is performed and explain the clinical significance of the process.

10-22 Translate a microbiology laboratory report, and explain the clinical significance of the values.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.A.I.2. Use language/verbal skills that enable patients' understanding
III.C.III.3. Discuss infection control procedures
III.C.III.5 List major types of infectious agents
III.C.III.7. Match types and uses of personal protective equipment (PPE)
III.C.III.9. Discuss quality control issues related to handling microbiological specimens
III.P.III.2. Practice Standard Precautions
III.P.III.3. Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations
III.P.III.7. Obtain specimens for microbiological testing
III.A.III.1. Display sensitivity to patient rights and feelings in collecting specimens
III.A.III.2. Explain the rationale for performance of a procedure to a patient
III.A.III.3. Show awareness of patients' concerns regarding their perceptions related to the procedure being performed

ABHES Standards

- Apply principles of aseptic techniques and infection control
- Use standard precautions
- Practice quality control
- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #5: Microbiology testing
- Dispose of biohazardous materials
- Collect, label and process specimens, #3: Perform wound collection procedures, #4: Obtain throat specimen for microbiology testing
- Instruct patients in the collection of a fecal specimen

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KEY TERMS

Aerobes
Agar
Anaerobes
Antibiotic sensitivity testing
Broth
Candle jar
Cerebrospinal fluid (CSF) samples
Colonies
Cover slip
Culture
Culture and sensitivity (C&S) report
Disk-diffusion method
Ectoparasites
Endoparasites
Eustachian tube
Exudate
Gram stain
Hanging drop slide
Hemolytic uremic syndrome
Inoculation
Kirby-Bauer method
KOH (potassium hydroxide)
Lumbar puncture
Medium (pl., media)
Methicillin-resistant *Staphylococcus aureus* (MRSA)
Minimum inhibitory concentration (MIC) method
Motility
Mycoses
Nasopharyngeal collection technique
Nasopharynx
Normal flora
Otitis
Otitis externa
Otitis media
Ova and parasite examination (O&P)
Parasites
Pathogen
Petri dish
Pinworm
Resistant
Scabies
Sensitive
Septicemia
Sequela
Slant
Sputum
Strep screens
Trichomoniasis
Wet mount
Wood's lamp
Zone of inhibition

Microbiology is the study of organisms that require magnification to be seen by the human eye. As introduced in Chapter 3, microorganisms are everywhere! These tiny creatures have been the objects of study since the early 1700s, when Antony Leeuwenhoek first recorded observations of bacteria he watched with his homemade microscopes. These "animalcules" (as Leeuwenhoek called them) were described in great detail, and Leeuwenhoek hired an illustrator to provide pictures of the living creatures that he observed. However, the idea that microorganisms were capable of spreading disease was understood much later. In 1847, Ignaz Semmelweis was working in a maternity hospital in Siena, Italy, when he realized that some sort of "invisible agent" seemed to spread from the mothers who died of puerperal fever after childbirth to the other mothers in the ward. He insisted that the physicians working in the ward begin to wash their hands between patients, and also had the practitioners change their laboratory coats after performing autopsies before they worked with expectant mothers. These small changes resulted in a dramatic drop in the mortality rates in the maternity ward of the hospital. Unfortunately, Semmelweis was ridiculed for his strict enforcement of the rules, and was subsequently fired.

It would still be almost 100 years before observations such as the ones made by Semmelweis began to change the way that the world viewed microorganisms and their relationship to disease. Louis Pasteur and Robert Koch were responsible for many of the theories that we use in microbiology today. In the late 1800s, they conducted a series of experiments to suggest that bacteria cause disease, and these scientists went even further to prove that bacteria did not spontaneously generate, but instead replicated at a very fast pace when introduced to an environment that supported their

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growth. It was also proved during this time that bacteria could be kept from contaminating a certain area if the appropriate precautions were taken. These were revolutionary ideas that continue to shape the way we view microorganisms today.

When working with microbiological samples, it is important to keep these core concepts in mind, as our goal is to avoid extraneous contamination of the specimens, to provide appropriate samples for testing to allow for proper patient diagnosis and treatment, and to nurture the growth of microscopic organisms so that they can be identified. We now know that the microscopic "animalcules" that can cause harm do not include only bacteria. Microbiology testing may also focus on viruses, fungi, and parasites. Because of this variety, collection methods and testing procedures vary, depending on the type of specimen collected and the organism that is thought to be present. The laboratory may process these samples in the general microbiology department, or there may be subdivisions for bacteriology, virology, mycology, and/or parasitology. This chapter presents collection and handling procedures for the most common types of microbiological tests ordered.

MICROBIOLOGY SAMPLE COLLECTION GUIDELINES

In order to provide appropriate treatment, health-care providers need to know which type of pathogen is causing the symptoms exhibited by the patient. A **pathogen** is a microorganism that is capable of causing disease in the body. Most infectious diseases are caused by viruses or bacteria. Treatment choices vary dramatically based on the causative organism present in the specimen collected for testing. Variables for treatment may be based on the type of pathogen present (such as viruses, bacteria, fungi, or parasites), the amount of the microscopic organism isolated, as well as sensitivity testing for antimicrobials suitable for treatment. The microorganism that causes a disease is a pathogen, so health-care providers must always remember which organisms may be present as part of the **normal flora** (resident bacteria present in certain areas of the body) as these may contaminate the specimen, and their presence may be misleading.

Test Your Knowledge 10-1

What is the term used to describe a microorganism that causes disease?. (Outcome 10-1)

To assure quality processes and valid results, specific guidelines should be followed whenever collecting or processing samples for microbiology testing. These include the following:

Specimen collection

- Collect the sample from the area of infection, and avoid contamination from surrounding areas if at all possible. This is especially critical when collecting samples for wound cultures.
- Ideally, bacterial culture specimens should be collected before antibiotics are introduced. If the antibiotics have already been administered, the causative organism may not be present in high enough numbers to identify it appropriately.
- Use the correct collection and transportation methods. Research what type of swab or container is to be used, and how the sample is to be handled after collection until it reaches the laboratory. Package inserts should be consulted for specific collection techniques. Some samples are to be refrigerated immediately, whereas others are to remain at room temperature until they are transported to the laboratory for processing.
- Always collect a sufficient quantity of sample for testing.
- Be certain that the sample is appropriately labeled, including the source (be as specific as possible), the patient's name, the identification of the individual performing the specimen collection, and the date and time of the collection. Document this information on the requisition form appropriately as well.
- Verify and adhere to any sample restrictions for transport time. Also verify whether the sample needs to be protected from light after collection.
- Use sterile supplies, and be careful to maintain sterility while performing sample collection procedures.
- Store all laboratory specimens in a refrigerator or other container dedicated for that use.

Personnel

- All personnel participating in the collection, processing, or testing of microbiological specimens must be appropriately trained in all procedures.
- Personnel should participate regularly in competency testing to assure quality of collection, processing and testing of specimens.
- Wear appropriate personal protective equipment (PPE) when performing specimen collection or specimen processing. This may include items such as gloves, a laboratory coat, face shield, or special respiratory equipment such as that needed for processing samples that may contain tuberculosis.

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Media

- A medium provides nutrition for microorganisms when grown in the laboratory environment. There is an expiration date associated with all media to ensure appropriate performance. Media should be discarded when outdated.
- For a medium to function as designed, it cannot be allowed to dry out or become contaminated. In addition, there are specific storage requirements for each type of medium, and these must be followed carefully.
- Verify that the correct medium is used for each type of specimen collection, as this can have a profound effect on the results.
- Medium performance should be verified on a regular basis by inoculating the medium with a known microorganism to observe growth.

Stains

- All products used for staining microorganisms have expiration dates provided by the manufacturer, after which the stains must be discarded. Stain performance should be verified on a regular basis by staining microorganisms with predictable staining characteristics to observe staining patterns.

Test Your Knowledge 10-2
What must be documented on the sample after the collection of a microbiology specimen? (Outcome 10-2)

Test Your Knowledge 10-3
Should bacterial culture specimens be collected before or after antibiotic therapy has been started? (Outcome 10-2)

Types of Media

The growth of any microorganism in the laboratory is dependent on the presence of an appropriate nutrition source and other chemicals necessary for survival. These are provided in a culture **medium** (plural, **media**). The medium may be in the form of a liquid nutrient broth, a semi-solid gel, or a solid gel. **Agar** is a thickening agent added to the medium that allows the gel to solidify so that the microorganisms will grow on the surface. A medium may be provided in tubes, or it may be provided in a small shallow container, known as a **Petri dish.** Figure 10-1 shows various types of media used in a microbiology setting. Some laboratories create their own media, but most purchase commercially prepared media, which provide a longer shelf life, fewer impurities, and more consistent appearance and performance. All types of media contain nutrients and additives that support the growth of microorganisms. Ingredients may include blood, vitamins, dyes, sugar mixtures, and organic sources of nutrition such as vegetable extracts.

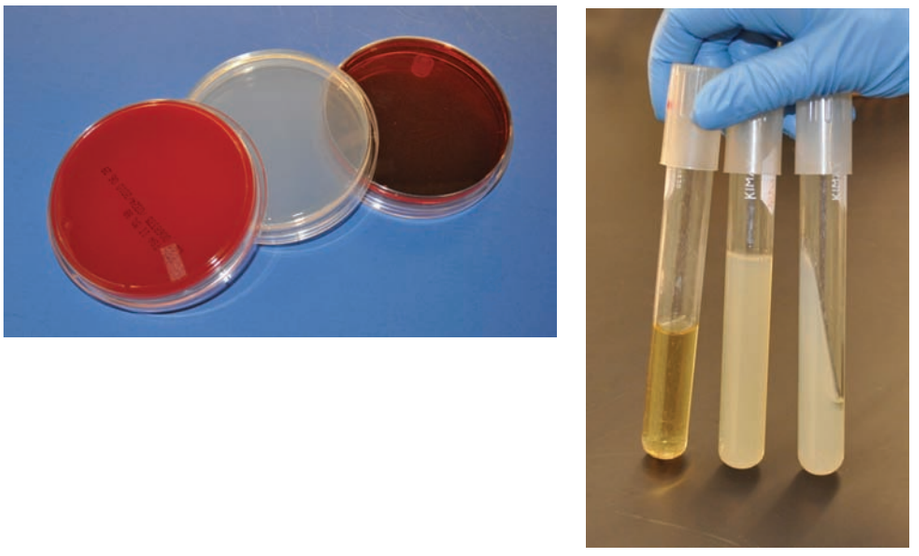

Figure 10-1 Types of media. Note the presence of the agar plate, the slant, and the broth.

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Culture media is classified into categories based on whether the medium enriches the growth of all bacteria or selectively inhibits growth of certain bacteria.

- *Selective media* have additives that prevent the growth of certain types of bacteria while promoting the growth of other select species. One example is Thayer Martin agar, used for specimens when a gonorrhea infection is suspected. It has lysed red blood cells, which provide an easy source of hemoglobin to promote the growth of the *Neisseria gonorrhoeae* organism, but the medium also contains vancomycin, colistin, and nystatin. These are antibiotics that prohibit the growth of other common nonpathogenic microorganisms often found concurrently with gonorrhea.
- *Differential media* allow for different types of bacteria to be identified based on an indicator. A common differential medium used in the laboratory is MacConkey agar, which has a special dye additive. If the organisms growing on the agar ferment lactose (the indicator), their growth will appear pink on the medium plate. This colored growth allows the microbiologists to make a preliminary identification of the pathogenic microorganisms based on their ability to ferment lactose.
- *Enriched media* include nutrients that allow for a wide variety of organisms to grow. Blood agar is an example of an enriched medium that is designed to support growth of microorganisms that flourish in the human body, including both pathogens and nonpathogens.

Solid gel is provided in a tube (called a **slant)** or in a Petri dish. Liquid medium (usually called nutrient **broth)** comes in a tightly sealed tube. It is important to keep all forms of media from drying out or becoming contaminated after receipt at the laboratory or physician office. The media should be refrigerated for storage, but must be brought to room temperature before use. All forms of media have a limited shelf life, so it is important to be aware of their expiration date.

Test Your Knowledge 10-4

What are two ways that culture media may differ?

(Outcome 10-3)

Microbiology Terms

A **culture** is a group of microorganisms grown in a laboratory environment using prepared media. The word *culture* is used whether the sample is bacterial, viral, or fungal. A culture is created when a medium source has a specimen added for potential growth. The culture is the most common test performed in the microbiology laboratory. The process of adding the specimen to a medium source is known as **inoculation.** Inoculation may occur in the physician office immediately after specimen collection, or it may be performed once the specimen arrives at the laboratory. The visible growth that occurs once the specimen has been added to the medium may be seen as **colonies** (or clumps) of growth, especially with bacterial cultures. The unique appearance of the colonies present on the culture may allow for preliminary identification of the microorganism. To accelerate bacterial growth, the specimen is usually placed in an incubator that is kept near body temperature (37°Celsius) for 24 to 48 hours. Some organisms must be placed in an environment with little to no oxygen present for growth **(anaerobes),** whereas others like an oxygen-rich environment **(aerobes).** There are incubators or other devices that are specifically designed to provide these parameters for culture growth.

Preliminary laboratory results for bacterial cultures are often available within 24 to 48 hours after the specimen has been submitted to the laboratory. Each laboratory establishes a definitive time frame before which they will not report a negative result for a bacterial culture. This means that the laboratory gives the sample a chance to grow for at least a few days before posting a negative result. Most pathogenic bacteria are relatively easy to grow in the laboratory, and identification techniques have been established for most of these microorganisms.

Viral cultures require a longer time for growth and identification, and require use of different types of media than those required for bacterial cultures. Because viruses are parasitic intracellular organisms, viral cultures require living tissue and cells to support growth and replication. It is imperative that the person collecting a viral specimen for culture pay scrupulous attention to specimen collection protocol, the technique of collection, and transportation requirements. Viral culture specimens should be collected, in general, within 72 hours of symptom onset. Collection swabs made of calcium alginate should not be used for collection of viral culture specimens, and cotton-tipped swabs with wooden shafts must also be avoided. Generally, viral specimens are refrigerated to preserve their integrity if there will be a delay in transportation. Because it is a complicated process, viral culture processing is usually performed only in large reference laboratories. It may be 7 to 10 days before a viral culture result is confirmed. For this reason, if a viral infection is suspected and the patient's symptoms warrant it, the health-care provider may administer antiviral medication to the patient without a culture result or identification of the organism.

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Fungal cultures are even slower to grow than viral cultures. The fungal elements in a specimen may be difficult to isolate because of the faster-growing organisms present in or on the specimen, such as bacteria. A selective media is used, including nutrition sources such as brain and/or heart extract, blood, dextrose, and natural nutrition sources such as potatoes. Antibiotics may be added to retard the growth of the bacteria in the specimen so that the fungal elements can be identified. The exact type of media used will be dictated by the specific source of the specimen within the body, as, for example, the types of fungus growing on the skin may be very different from those growing in the lungs. A fungal culture may take up to 4 weeks to report results; it is generally a minimum of 21 days before a negative result can be released.

Test Your Knowledge 10-5

Which type of culture (viral, bacterial, or fungal) is quickest to grow? (Outcome 10-4)

POINT OF INTEREST 10-1
Bioterrorism

Prior to September 11, 2001, the threat of widespread bioterrorism was a rare topic in most casual conversations. However, the climate changed with the events of that day and the weeks that followed. The Centers for Disease Control and Prevention (CDC) strongly recommends that all laboratories (even those in physician offices) continue to monitor their procedures and remain aware of those that could create aerosols. An aerosol is a suspension of fine particles (such as bacteria or viruses) in the air. For those facilities in which the risk of aerosol formation is heightened because of the types of procedures performed and the patient population served, a biosafety hood is recommended. The procedures would be performed within the hood workspace, and any microorganisms released into the air would be vented out of the room.

Health-care facilities also must remain educated about what to do in case of an exposure within their facility; fast, appropriate action can save lives. The agents may be bacterial or viral in nature. Most, but not all, agents that could be used for bioterrorism would be spread through the aerosol form. It is difficult to predict which agents may be used for a biological attack, but the following are some that are considered to be most probable:

- **Anthrax:** In the 1800s, Louis Pasteur documented work that he performed with this bacterium, and there are reports of soldiers using anthrax in World War I to deliberately infect animals that were to be eaten by the enemy. In October and November 2001, there were 22 cases of deliberate infection with the anthrax bacterium in the United States. Anthrax is caused by *Bacillus anthracis* and is a gram-positive, spore-forming bacillus. In nature, the spores may be present in the soil, and they are either ingested or picked up on the skin and hair of animals when they are feeding. Humans usually become infected only when they come in contact with animals or products that are contaminated, and infection is rare. There are three routes of infection for anthrax:
  - *Cutaneous:* The most common natural route is cutaneous, or via the skin; humans may be infected when handling contaminated wool, or occasionally from the spores in the soil. The cutaneous infection causes a papule that progresses with time into a necrotic ulcer. If the ulcer penetrates deep enough into the skin, the patient's bloodstream may become infected, which can lead to more serious consequences.
  - *Inhalation:* The route that is used most often for deliberate infection is via inhalation. The exposed patient has flu-like symptoms. Within days, the patient suffers from hypoxia and has difficulty breathing, as pulmonary edema and further damages within the lungs progress. Approximately 50% of those who are infected via the inhalation develop meningitis, and the morbidity rate is quite high. Prior to 2001, there had been only 20 cases of anthrax infection via inhalation reported in the United States.
  - *Gastrointestinal*: The ingestion of poorly cooked, contaminated meat allows anthrax entrance via the gastrointestinal route. The patient may have abdominal discomfort, bloody diarrhea, and vomiting, and may have visible ulcerations in the oropharynx when examined. Essentially, the necrotic lesions that are visible with cutaneous exposure form within the GI tract and impair the patient's ability to digest food properly.

  All forms of anthrax exposure can be treated with antibiotics if caught early. Once the more serious symptoms have developed, it may be difficult treat successfully. Ciprofloxacin or doxycycline is often used successfully for early treatment. Anthrax is not passed from person to person.
- **Brucellosis:** Brucellosis is a disease that is common in cattle, sheep, goats, and pigs in many areas of the

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world. It may also affect domestic animals such as dogs. Humans may be infected by direct exposure to an animal host. There are very few human infections in the United States because of a rigid vaccination program, but the disease is much more frequent in other areas of the world. Infection causes flu-like symptoms in most humans, but can lead to much more serious CNS problems, as well as heart damage. Brucellosis forms an aerosol very easily, so to avoid potential inhalation in the workplace, it is important to remember not to "sniff" cultures in the microbiology area. This practice may be very dangerous.

- **Botulism:** The symptoms associated with botulism are related to the toxin produced by the spore-forming bacterium *Clostridium botulinum*. This toxin is one of the most lethal natural substances known to humans. The toxin paralyzes the muscles of those infected, which eventually leads to paralysis of the lungs, and death. The toxin is not used as an aerosol as much as some of the other microorganisms considered as threats for bioterrorism use, but the bacteria could be very lethal if added to a common food source or used in a contained area. *C. botulinum* may also be introduced into the body through a wound; there is evidence that armies in the past added it to their swords to enhance the damage done during hand-to-hand combat. For those infected, the most important consideration is the treatment of symptoms, as the damage caused by the toxin spreads quickly throughout the body.
- **Plague:** Everyone who has studied world history has heard of the plague in medieval Europe. The plague is caused by the bacteria *Yersinia pestis* and may infect humans through two different routes. One is the bubonic plague, which is usually caused by the bite of a flea or tick carried on a host rodent. The other is through inhalation. This is the method that causes concern for potential use of this bacterium as a bioterrorist weapon. The pneumonic plague may be spread from person to person via droplets in the air after the initial infection, and is relatively easy to isolate and grow in large amounts. Thus, initial infection could lead to wider and wider mortality. Infection may easily cause respiratory failure and death. The bacterium is treatable with tetracycline and/or fluoroquinolone for at least 7 days if given orally, or IV streptomycin or gentamycin, but the infection must be caught early.
- **Smallpox:** Smallpox is different from the other microorganisms that are considered bioterrorist threats because it is a virus instead of a type of bacterium. The last natural case of smallpox in the United States occurred in 1949, and the causative agent (the variola virus) is considered to have been eradicated by a long-term, aggressive, and worldwide vaccination campaign that has been carried out since 1980. There is no specific treatment for the smallpox virus infection except for supportive care of the symptoms. The variola virus appears to infect only humans, and it may be passed from person to person through infected body fluids and contaminated bedding. It is very rarely passed through the aerosol route, and is not naturally present in nature, so use of the virus as a bioterrorist tool would require more effort than some of the other agents discussed here.
- **Hemorrhagic fever viruses:** These viruses are carried by a host or vector, usually a rodent (such as a rat or mouse) or a tick, flea, or mosquito. For some of the viruses (Ebola and Marburg, for instance) the host is still unknown. Once a human has been infected, it is possible to spread the virus from person to person through contaminated body fluids. Outbreaks are sporadic around the world, and usually remain limited to the area where the vector or host is located, but this has the potential to change. Because of the ease of travel today, coupled with the fact that rats and mice can "stow away" on ships and planes, it is possible for these diseases to become widespread within a relatively short period of time. Those who are infected have flu-like symptoms early in the disease process. Then as the disease progresses, there may be evidence of hemorrhaging under the skin, and bleeding from all orifices of the body. Multiple organs are affected by the virus, and it usually is the organ failure that causes fatalities, not the loss of blood. There are no vaccines or cures for these infections at this time; infected individuals are quarantined and treated symptomatically.
- **Tularemia:** Tularemia is caused by the bacterium *Francisella tularensis* and is carried often by rodents, rabbits, or wild hares. It is *very* infectious; only a small number of the bacteria entering the body will cause disease. It is easy to spread this bacterium as an airborne weapon, so it would be a likely choice for bioterrorist activities. It causes a severe respiratory illness and life-threatening pneumonia, and is not difficult to find in nature. It is treatable with early intervention and aggressive antibiotic treatment.

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DETAILED MICROBIOLOGY SAMPLE COLLECTION PROCEDURES

Procedures and supplies may vary for the different microbiology collection processes, but there are common techniques shared by all the systems. Specimens may be collected in a sterile cup or tube or, more commonly, on a swab to be transported to the laboratory. These collection swabs are commercially prepared and supplied in a sterile pull-apart package. The package includes a sterile swab (often made of Dacron) and a transport medium designed to keep the swab from drying out before it reaches the laboratory. Culturette (manufactured by Becton, Dickinson) is an example of a system used for transport. Figure 10-2 includes some of the common sample collection devices available. The following are some techniques to be used for all culture collections:

- Be certain that a laboratory request form has been completed for the patient. The specific source of the specimen must be documented.
- Verify the collection technique necessary for the test ordered, as well as how the specimen is to be handled after collection: refrigeration, room temperature storage, frozen. Most bacterial culture specimens are to be kept at room temperature until transported.
- Always sanitize your hands, and wear appropriate personal protective equipment (PPE). In some situations, this may be a face shield or a disposable gown that covers your scrubs. In patients who have a wound that is positive for methicillin-resistant *Staphylococcus aureus* (MRSA), for example, it is often necessary to take extra precautions and to dispose of all the PPE used in collection before leaving the presence of the patient.
- If using a swab, check the package for signs of potential contamination (e.g., water stains, torn outer packaging) and verify that the expiration date has not passed. If using a different type of collection container, ensure that the package is sterile by examining the outer wrapper or safety seal.
- For swab packages, carefully peel apart the plastic outer envelope, using aseptic technique. Put this down on a flat surface. Pick up the swab by the lid that is attached to the end of the "stick" end of the swab. (The lid is permanently attached to the swab in most cases.) It is very important that the swab does not touch any other surfaces before the specimen is collected, or extraneous organisms may be added to the culture specimen.
- Collect the specimen appropriately, avoiding any other areas of the body except those needed for the collection.
- Without setting down the inoculated swab, remove the cap from the collection tube (still sitting inside the sterile plastic package) and insert the inoculated swab fully into the collection tube until the lid clicks closed. It may be necessary to activate the transport medium present in the tube by breaking an ampule at the bottom of the tube; this will depend on the type of collection device used.
- Remove gloves and other PPE that was used in the collection process, and sanitize the hands.
- Label the specimen carefully, documenting the specimen source, patient's name, the date, the time, the source (be specific), and your initials or identification. Chart the procedure in the patient's chart if it is available to you.
- If the specimen is to be transported via courier to a laboratory for workup, place it in a biohazardous specimen bag. The requisition form goes into the outer pocket of the bag. If the bag has an area for documentation for handling and storing the specimen, mark this appropriately (e.g., room temperature, refrigerated).
- Place the specimen in the pickup area for the courier to transport to the laboratory.

Figure 10-2 Swab collection devices. *Courtesy of BD, Inc.*

Test Your Knowledge 10-6

When using a swab to collect a culture specimen, is it acceptable to set it down on a countertop while getting the patient situated for the collection procedure?

(Outcome 10-2)

Throat Sample Collections for Culture or Strep Screens

Samples may be taken from the throat of patients for group A strep screens for general cultures, or sometimes both types of specimens at the same time. For both a strep screen sample and a culture sample the collection procedure is identical, but the materials used for the collection may differ. Before beginning the collection, it is

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important to verify whether the physician wants a culture to be performed, a strep screen, or both. Once the strep screen is performed, it is not possible to use the sample for the culture setup. If both a culture and a strep screen are ordered, the culture plate may be inoculated before the strep screen is performed, but not afterward. It is also possible to use two swabs (these are packaged as a double swab) at the same time to collect the sample so that one can be used for each procedure. Be careful about the type of collection swab used; strep screens recommend the use of rayon collection swabs. Cotton swabs or wooden tipped swabs are not to be used for strep screens. Some of the CLIA-waived procedures don't recommend the use of liquid or gel transport media after collection.

Throat samples are used most commonly to test for streptococcal infections with a **group A strep screen** rapid test completed in the physician office. Group A streptococcus (a subtype of *Streptococcus pyogenes)* is the most common cause of streptococcal throat infection. Those who are positive for streptococcal infection of the throat should be treated immediately to avoid sequela that can develop as a result of the initial strep infection. A **sequela** is a serious secondary complication or infection that follows as a result of the primary bacterial infection. For a group A streptococcal infection, these complications may include heart damage and kidney damage from glomerulonephritis. Throat specimen collections are performed using a sterile swab, often made of Dacron, rayon, or a cotton mixture. For a throat culture, the sterile swab is part of a packaged culture collection kit, with transport media usually present in the transport tube. The throat culture specimen is transported to the laboratory for processing, whereas a strep screen sample is usually processed immediately after collection by performing a CLIA-waived strep screen test. A sterile swab provided with the strep screen kit is used for the collection, and there is no transport medium present. Remember to verify whether the physician wants both a strep screen and a culture to be performed, as the medical assistant needs to know this information before performing the strep screen.

Test Your Knowledge 10-7

What is one way that a collection for a throat culture and a rapid strep screen are similar? (Outcome 10-5)

Strep screens are one of the most common CLIA-waived tests performed in all types of laboratories. The test is simple to perform, and requires only a sample taken from the back of the throat, a tongue depressor, personal protective equipment, and the supplies in the kit. The entire process takes approximately 10 minutes from the time the order is received to the time the result may be reported. This fast turnaround time and the ease with which the test can be performed allow the patient to be treated immediately if the screen is positive for the streptococcus A antigen. The CLIA-waived group A strep screen procedure is presented in Chapter 24.

Test Your Knowledge 10-8

Is it acceptable to collect only one swab if a strep screen *and* a throat culture are ordered? (Outcome 10-5)

Test Your Knowledge 10-9

Are the samples for a strep screen and for a throat culture collected from different areas of the throat? (Outcome 10-5)

Sputum Samples

When patients are diagnosed with a lower respiratory infection, such as pneumonia, it is important to identify the causative organism if possible. This allows the health-care provider to plan the best course of action for treatment. Sputum samples are necessary for culture and organism identification in these situations. **Sputum** is the substance produced from a deep cough or from aspiration caused by inserting a tube down the patient's throat. Aspiration of sputum is primarily performed on patients who are intubated in an inpatient setting, but sputum cultures may be collected by patients at home without aspiration.

The medical assistant is not usually involved with the actual collection process for a sputum sample if employed in a physician office, but it is important that the procedure is explained thoroughly to the patient so that he or she may produce a quality sample. Sputum samples are collected into a sterile container (such as a urine cup or a centrifuge tube) and transported immediately to the laboratory for processing. Ideally, a sputum collection system will protect the sample from UV light. The system should also prevent the health-care employees processing the specimen from being exposed to the sputum. Becton, Dickinson offers a sputum collection system that does both, composed of a large centrifuge tube enclosed in an amber "funnel" tube with a lid on the top (Fig. 10-3). The amber outer container is important, as *Mycobacterium tuberculosis,* the causative

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Procedure 10-1: Collection of a Throat Specimen for Culture or Strep Screen

Throat culture collections are very common procedures in physician offices. It is important to perform the collection process correctly to ensure meaningful results. Remember to communicate appropriately with the patient to assist with the collection process.

TASK

Collect an appropriate specimen from the throat for a culture or strep screen. Complete the procedure within 5 minutes.

CONDITIONS

- Hand sanitization equipment
- Gloves
- Tongue depressor
- Safety shield
- Sterile culture swab or swab provided with strep screen kit
- Label
- Laboratory requisition form
- Biohazardous waste container
- Biohazardous transport bag

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.A.I.2. Use language/verbal skills that enable patients' understanding, **III.C.III.3:** Discuss infection control procedures, **III.C.III.9:** Discuss quality control issues related to handling microbiological specimens. **III.P.III.2:** Practice Standard Precautions, **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations, **III.P.III.7:** Obtain specimens for microbiological testing, **III.A.III.1:** Display sensitivity to patient rights and feelings in collecting specimens, **III.A.III.2:** Explain the rationale for performance of a procedure to the patient.

ABHES Standards

- Apply principles of aseptic techniques and infection control
- Use standard precautions
- Practice quality control
- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #5: Microbiology testing
- Dispose of biohazardous materials
- Collect, label and process specimens, #3: Perform wound collection procedures, #4: Obtain throat specimen for microbiology testing

Procedure	Rationale
1. Greet and properly identify the patient, using at least two unique identifiers. Introduce yourself.	It is imperative that the identity of the patient is verified before the specimen is collected. The medical assistant should always identify him- or herself with any patient interaction.
2. Explain the procedure to the patient. Answer any questions that the patient may have about the collection process.	Explaining the procedure will help the patient know what to expect and will facilitate cooperation. Answering questions allows the medical assistant to display sensitivity to patient rights and feelings in collecting specimens.
3. Sanitize hands (allow them to dry) and apply gloves.	Gloves must be worn for any procedures in which exposure to blood or other potentially infectious materials is anticipated.

Continued

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Procedure 10-1: Collection of a Throat Specimen for Culture or Strep Screen—cont'd

Procedure	Rationale
4. Gather necessary supplies within reach. If a strep screen is ordered, be certain to use the swab supplied with the kit. If a throat culture is requested, use a sterile swab packaged with the transport media.	Organization of supplies is important so that the collection procedure may continue without interruption.
5. Position the patient in an upright position. If necessary, adjust available lighting so that the back of the throat is well lit.	The back of the throat must be well lit and accessible for the collection to be successful.
6. Put on face safety shield.	Because this procedure may initiate coughing or gagging in some individuals, it is important that the medical assistant protect against potential exposure.
7. While holding the tongue depressor in one hand and the collection swab in the other, instruct the patient to open his or her mouth wide.	The mouth must be opened wide to gain full access to the collection area.
8. Push down on the tongue lightly with the tongue depressor, and insert the swab into mouth. Be certain to avoid touching the tongue, cheeks, gums, or teeth with the collection swab.	Introduction of extraneous microorganisms may result in inaccurate culture results.
9. Gently brush the swab against the tonsillar area and the back of the throat. A gentle rotating motion works best. Be sure to touch any white or inflamed patches present with the collection swab.	Adequate sample must be obtained for the accuracy of the culture results. White areas may represent clusters of bacteria, so it is important that these are included in the sample.
10. After removing the swab from the mouth, place it in the sterile container. If only a throat culture is requested, slide the swab into the container and activate the preservative or coat the swab. If a strep screen was ordered, only rayon swabs may be used for the collection, and liquid preservative is not recommended in the swab container.	It is important that the swab be processed appropriately so that the results are representative of the bacteria present in the throat. CLIA-waived strep screen package inserts will specify whether liquid preservatives (such as Amies or Stuart media) can be used. Rayon swabs with dry transport are recommended for strep screen specimen collection and transport.
11. Dispose of the tongue depressor in the biohazard garbage.	Proper disposal is necessary for quality control purposes.
12. Label the specimen appropriately and place the labeled specimen in a biohazardous transport bag to go the laboratory.	The specimen should always be labeled in the presence of the patient.
13. Remove gloves and safety shield.	Gloves should be removed when no longer necessary.

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Procedure	Rationale
14. Wash hands, and thank the patient for being cooperative. Add documentation to the laboratory requisition form if needed.	Hands must be washed whenever gloves are removed. The requisition form must be completed with the date and time of collection as well as the source of the culture.
15. Chart the procedure appropriately.	All patient interactions should be recorded on the chart.

Date	
1/18/2014	*Throat culture specimen collected.* *Connie Lieseke, CMA (AAMA)*
11:10 a.m.	

Figure 10-3 BD sputum collection container. The inner tube may be removed from the bottom of the container with minimum exposure potential for the employee. *Courtesy of BD, Inc.*

agent of tuberculosis infection, does not live long when exposed to light. The specimen must remain protected from light until it is processed in the laboratory, or this pathogenic microorganism may not be isolated from the culture even though it is present. Once the specimen arrives at the laboratory, the technician will remove the inner "tube" that contains the sputum and process the specimen according to protocol to set up the culture.

Patients collecting sputum samples must be instructed that a deep cough is absolutely necessary to produce an acceptable specimen. If saliva rather than sputum is submitted for testing, the specimen will most likely contain only normal flora for upper respiratory system, and the culture results will be inconclusive. It is recommended that the sample be obtained first thing in the morning, after the patient brushes his or her teeth and rinses the mouth, but before ingesting food or drink. Because the pathogenic microorganisms responsible for many lower respiratory infections are spread by droplets in the air, it is necessary that the patient perform collection in a private area, preferably at home. Do not allow a patient to attempt to produce a sputum culture specimen in the waiting room of the physician office, as this will potentially expose the other patients to the pathogenic microorganisms distributed as aerosol when the patient coughs. The sample must be delivered to the laboratory as soon as possible after collection, preferably within 2 hours. The specimen should not be refrigerated, nor exposed to extreme heat.

Test Your Knowledge 10-10

Why should a sputum specimen *not* be collected in the waiting room of a physician office? (Outcome 10-6)

Once the specimen arrives at the laboratory, the technician (or sometimes, in an inpatient setting, a respiratory specialist) will decide whether the specimen is

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acceptable for culture. The technician also documents the volume and appearance of the specimen. A sputum sample that has too many epithelial cells present and is too "watery" in appearance is often a saliva sample; it was not the result of a deep cough and is not suitable for culture setup. Sputum color and thickness are not indicators of any specific illness, and this information should never be interpreted in this way.

Urine Samples for Culture

Urine specimens used for culture must be collected in a manner that reduces potential contamination by nonpathogenic microorganisms. This may be accomplished by utilizing the clean-catch midstream collection method (see Chapter 9), or alternatively, urine may be collected for culture with a straight catheter or suprapubic aspirate taken directly from the bladder. Urine samples for culture should never be taken from an indwelling catheter, as the potential for extraneous contamination is very high. The medical assistant must be sure to document on the requisition form whether the specimen was obtained from a catheter or via the clean-catch midstream urine method, as the amount of urine applied to the agar plate and the interpretation of the results are different for each type of specimen. Figure 10-4 shows an example of the different sizes of inoculation loops used for urine specimens.

Patients must be provided with a sterile cup for the urine collection, and given instructions in how to perform the collection to provide a satisfactory culture sample. It is also imperative that within 1 hour of collection the specimen is set up for culture, refrigerated, or preserved in some way to keep the bacterial count stable. Urine tubes with preservative are available for this purpose. The bacteria present in the culture specimen will multiply at a very high rate if the urine is left at room temperature for more than an hour, so the culture results may appear to be erroneously abnormal.

Figure 10-4 Urine loops for culture. The larger loop is used to apply urine collected via catheterization and the smaller loop is used for inoculation of urine collected via the clean-catch method. *Courtesy of Fisher HealthCare, Inc.*

Test Your Knowledge 10-11

Which of these urine specimen types may not be used for cultures?

a. Specimens taken from indwelling catheters
b. Specimens obtained using a straight catheter
c. Specimens collected via the clean-catch midstream collection technique
d. None of the above (Outcome 10-7)

Blood Culture Collection

Health-care providers order blood culture collections when they suspect that the patient may have pathogenic bacteria in the bloodstream, a condition known as **septicemia.** The National Center for Injury Prevention and Control is part of the Centers for Disease Control and Prevention (CDC) and is responsible for compiling statistics about injuries and reducing their consequences. According to its statistics, septicemia was the 10th leading cause of death in the United States in 2006, responsible for more than 30,000 deaths. Septicemia is often a complication of urinary tract infections, pneumonia, and infected wounds. Blood cultures assist the health-care provider by providing information about the causative agent of the infection, as well as determining which antibiotics will be best to use for treatment. It is common for blood cultures to be ordered just before or just after a fever has spiked, and they are often ordered as STAT blood draws. Ideally, blood cultures will be drawn before antibiotics have been administered.

Special bottles that contain nutrients capable of supporting all bacterial growth are used for blood cultures, one that includes special nutrition and a unique atmosphere to encourage growth of microorganisms that need oxygen to grow **(aerobes)** and one that is specially designed to support growth of microorganisms that do not do well in the presence of oxygen (anaerobes). There may be special instructions with the order for the timing of the blood draws; some practitioners ask that they are drawn 30 minutes apart, whereas others will

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have them done serially, which means that they are drawn at regular intervals over a set period of time. The order may also be to draw two blood cultures, which means that they are to be drawn one after the other in two different sites.

Test Your Knowledge 10-12

Why are multiple bottles inoculated when collecting blood cultures? (Outcome 10-8)

Because bacteria are not usually present in the bloodstream, the presence of any growth in the blood culture is considered to be abnormal. It is imperative that a detailed, controlled aseptic process is followed to clean and disinfect the skin as thoroughly as possible before the specimens are drawn to avoid contamination with normal skin flora. Contamination of the specimen may lead to thousands of dollars worth of treatment that otherwise would have been unnecessary and additional hospitalization days.

Each laboratory will have established protocol for the blood cultures drawn and processed within its facility. The majority of methods will include the use of a combination of 1% to 2% tincture of iodine provided in applicator sticks or cleaning packets, or 10% povidone provided in cleaning packets. Alcohol pads may also be used for a two-step cleaning process. The blood culture collection supplies may be purchased as a kit; Figure 10-5 shows an example. Surgical asepsis must be followed carefully to keep from contaminating the sample, so the site must not be repalpated after cleaning unless sterile gloves have been applied.

Figure 10-5 Blood culture collection kit containing two bottles, an iodine-based scrub and brush, and alcohol pads. *Courtesy of BD, Inc.*

A syringe with a safety needle may be used to obtain the specimen for the blood cultures (at least a 20-mL syringe for adults; at least a 10-mL syringe for children) or a butterfly setup may be used. The firm bioMérieux has created BacT/ALERT, a blood culture system that includes a butterfly adapter that can be used to fill the blood culture bottles directly during the venipuncture, eliminating the need to transfer the blood from the syringe to the bottles. The BacT/ALERT setup also includes an adapter that allows blood to be drawn directly into other blood tubes if there are additional samples ordered at the same time as the blood culture specimens. This helps to minimize the invasive procedures performed for that patient.

Adult specimens should have approximately 10 mL of blood added to each bottle. The vacuum will automatically pull the blood into the bottle from the syringe or from the vein if a butterfly setup and adapter are used. Monitor the flow carefully, as the vacuum does not always stop when the correct amount of blood has been added, and it is possible to overfill the blood culture bottles. Depending on the manufacturer's recommendations, pediatric draws will most likely call for 2 to 5 mL of blood per bottle.

There are special blood culture bottles available for patients who have already started on antibiotic therapy. These include substances that neutralize or remove the antibiotics from the blood so that they cannot interfere with the growth of the microorganisms. Examples are the Antimicrobial Removal Device (ARD), produced by Becton, Dickinson, or a Fastidious Antimicrobial Neutralization bottle, made by bioMérieux.

Test Your Knowledge 10-13

How many times is the draw site cleaned/disinfected prior to blood culture collections?

a. One time
b. Two times
c. Three times
d. Four times (Outcome 10-8)

Cerebrospinal Fluid Samples

Cerebrospinal fluid (CSF) samples are used to help diagnose various diseases of the central nervous system. These diseases include meningitis and encephalitis caused by bacterial, viral, fungal, or parasitic infections. CSF samples are collected only by a qualified health-care provider by means of a **lumbar puncture,** in which a needle is placed between the lower lumbar vertebrae into

(Text continues on page 234)

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Procedure 10-2: Blood Culture Collection Procedure

Blood cultures are ordered when the health-care provider suspects an infection of the bloodstream with a pathogenic microorganism. The collection process is similar to that of a typical blood draw, but there are specific procedures for disinfection of the puncture site and inoculation of the blood culture media that must be followed carefully. Blood cultures that are contaminated with normal skin flora may result in improper treatment and prolonged hospital stays.

TASK

Perform a venous blood culture collection.

CONDITIONS

- Laboratory requisition form
- Hand sanitization equipment
- Gloves
- Blood culture bottles
- 10% Povidone iodine swab stick or other antiseptic scrub kit
- Alcohol prep pads
- 22- or 23-gauge, 1-in. needle and 20-mL syringe **or** 22- or 23-gauge butterfly setup with luer adapter and special bottle cap for inoculation of blood culture bottles
- Biohazardous sharps container
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.A.I.2: Use language/verbal skills that enable patients' understanding, **III.C.III.3:** Discuss infection control procedures, **III.C.III.5:** List major types of infectious agents, **III.C.III.8:** Differentiate between medical and surgical asepsis used in ambulatory care settings, identifying when each is appropriate, **III.C.III.9:** Discuss quality control issues related to handling microbiological specimens. **III.P.III.2:** Practice Standard Precautions, **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations, **III.P.III.7:** Obtain specimens for microbiological testing, **III.A.III.1:** Display sensitivity to patient rights and feelings in collecting specimens, **III.A.III.2:** Explain the rationale for performance of a procedure to the patient.

ABHES Standards

- Apply principles of aseptic techniques and infection control
- Use standard precautions
- Practice quality control
- Dispose of biohazardous materials
- Collect, label and process specimens

Procedure	Rationale
1. Verify the test ordered on the requisition form. Pay special attention to the time and/or frequency of the blood culture specimen collection. Note the age of the patient.	The test and identification on the specimen label should be verified every time to avoid erroneous results. Blood cultures may be ordered as STAT draws, which must be performed immediately, or they may be ordered at specific frequencies, such as 1 hour apart. The patient's age may be significant, as there are often special blood culture bottles or differences in the required blood volume for pediatric patients.
2. Gather necessary supplies. Verify the expiration date on the blood culture bottles and antiseptic solution.	Expired bottles and antiseptics may not be used.
3. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.

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Procedure	Rationale
4. Apply tourniquet to the desired site and select an appropriate venipuncture site. Release tourniquet.	It is important to establish a visual landmark for the venipuncture site chosen, as it will not be possible to repalpate the site before insertion of the needle. The tourniquet must be removed because appropriate skin cleansing techniques for blood culture collection take more than 1 minute.
5. Cleanse the venipuncture site.	The cleansing process will vary with laboratory policies. Some sites prefer a two-step process, in which the site is vigorously cleansed with alcohol for 30 seconds, followed by use of a povidone or iodine swab stick. If a povidone/iodine swab stick or cleaning pad is used, the solution must be applied using a concentric circle motion, beginning at the chosen venipuncture site and moving outward without going over any area more than once. If an alcohol/chlorhexidine cleansing kit is used, the site must be scrubbed vigorously for at least 30 to 60 seconds. This is the recommended method for cleaning the site for infants older than 2 months of age or for those with iodine sensitivity. Regardless of the cleansing method, the site must be allowed to dry completely before insertion of the needle into the skin.
6. Prepare the setup for the blood draw. This may be a needle and syringe (at least 20 mL) or a butterfly setup with a luer adapter attached to a special cap that goes over the blood culture bottles and allows the blood to be introduced directly into the bottles.	The choice of needle setup is based on the size and condition of the veins. The ideal ratio of blood to the medium in the bottles is 1:10. This means that each bottle should have 10 mL of blood added for optimal results.
7. Mark the blood culture bottles on the side with the minimum and maximum volumes.	Blood culture bottles do have a vacuum that functions to pull in the blood specimen from a syringe or butterfly. However, the vacuum in these bottles is not controlled as carefully as that in the evacuated tubes, so care must be used to monitor the amount of blood added to the bottle. It is possible to overfill the blood culture bottles. It is important to make a mark on the bottle so that the phlebotomist can estimate when the appropriate amount of blood has been added.
8. Prepare the blood culture bottles. Flip off the removable bottle cap and clean the rubber stopper with an alcohol prep pad. Discard this pad and cover the rubber stopper with a clean alcohol prep pad. Leave this pad in place until the blood is added to the bottle.	Asepsis is critical for blood culture collections. Every precaution must be followed to eliminate an opportunity for bacterial contamination of the specimen.

Continued

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Procedure 10-2: Blood Culture Collection Procedure—cont'd

Procedure	Rationale
9. Reapply the tourniquet and withdraw the necessary volume of blood; 20 mL is the desirable volume for most blood culture procedures. Draw the blood using a butterfly setup or a syringe with a needle attached.	20 mL of blood will provide 10 mL per bottle, which is the desired volume for best detection and identification of infective microorganisms.
Option 1: Blood Collection Using a Butterfly Setup	
a. Assemble the butterfly setup with a luer adapter attached to the end of the tubing. Screw the other end of the luer adapter into the special adapter cap designed for the blood culture bottles to be used, or an evacuated tube holder if this works for the bottles.	By using the luer adapter and the special cap, the blood can be added directly into the blood culture bottles without need of additional transfer procedures.
b. Using appropriate venipuncture technique, insert the butterfly needle into the vein. Continue to hold the butterfly device or tape in place.	It is important to secure the needle to avoid damage to the vein and to ensure a successful blood draw.
c. Remove the alcohol pad from the top of the bottle and push down the adapter to pierce the septum of the blood culture bottle. Blood should be added to the aerobic bottle first.	The vacuum in the blood culture bottle will pull the blood from the vein.
d. Monitor the bottle volume and pull up the adapter to remove the needle from the stopper when the desired amount of blood has been added to the bottle.	It is possible to overfill the bottles, so this is an important step to follow.
e. Follow the same procedure to add blood to the anaerobic bottle. Monitor the volume as necessary and pull up the adapter when the desired volume has been reached.	Anaerobic bottles should be filled after the aerobic bottles.

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Procedure	Rationale
Option 2: Blood Collection Using a Syringe and Needle	
a. Open the sterile package holding the syringe.	Syringes should remain sterile until the time of use.
b. Pull back and push forward the plunger of the syringe several times to verify whether it moves smoothly.	"Exercising" the plunger in this manner allows for smooth movement when pulling back the plunger to allow blood to enter the syringe. If the plunger does not move smoothly or is too loose within the syringe, it should be discarded.
c. Remove the needle from the sterile wrapper. Do not take off the cap covering the end of the needle until just before insertion into the patient's arm.	The needle must remain sterile until just prior to insertion. It cannot touch other surfaces before piercing the skin of the patient.
d. Attach the needle to the syringe tip.	Verify that this is a secure connection so that blood will not leak out around the needle during the venipuncture process.
e. Reapply the tourniquet, taking care not to touch the venipuncture site. Using appropriate technique, withdraw 20 mL of blood into the syringe, and have the patient place pressure over the venipuncture site.	Special care must be utilized to keep the disinfected site without contamination; 20 mL of blood is optimal for the blood culture procedures.
f. If the bottle is designed to fit a transfer device, activate the safety device on the needle, remove it from the syringe, and discard it in a biohazardous sharps container. Attach the transfer device to the syringe. Remove the alcohol pad from the top of the bottle and push down the transfer device to pierce the septum of the blood culture bottle. Blood should be added to the aerobic bottle first.	The blood culture bottles may come with a very small neck that is designed for use with a standard transfer device such as that in an evacuated tube system.
g. If the bottle is not designed for a transfer device to fit over the top of the bottle, it will be necessary to add the blood to the bottle with the needle on the syringe. Verify that the blood culture bottle is on a stable, flat surface. Remove the alcohol prep pad from the top of the bottle, and puncture the septum with the needle on the syringe, puncturing the aerobic bottle first.	Do not hold the blood culture bottle with your hand while puncturing the septum, as this will increase the chance of an accidental needlestick. Place the bottle on the counter or tabletop.
h. Monitor the volume in the blood culture bottle as the blood is introduced and remove the needle when 10 mL have been added.	Do not overfill the blood culture bottle.
i. Repeat the process to add 10 mL to the anaerobic bottle. Discard the syringe/needle setup in a biohazardous sharps container.	Avoid contamination of the septum on the anaerobic bottle.

Continued

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Procedure 10-2: Blood Culture Collection Procedure—cont'd

Procedure	Rationale
10. Label both bottles and the requisition form with the date, time and site of the blood draw, as well as the birth date or other patient ID and the initials of the collector. Transport to the laboratory as soon as possible for processing.	Accurate labeling and documentation are always necessary.
11. Clean the iodine solution off the patient's arm using an alcohol swab. Clean up the work area and chart the procedure.	The iodine solution may become irritating to the skin if left on the patient's arm after the procedure.

Date	
3/12/2014:	Blood culture collection X2 from right and left arm. ~~~ Connie Lieseke, CMA (AAMA)
4:40 p.m.	~~~

the subarachnoid space, and a sample of cerebrospinal fluid is withdrawn for analysis. This procedure may also be known as a spinal tap. Generally, four tubes are used for the collection, with 1 to 8 mL of fluid placed in each tube. The tubes are numbered in order of collection, which is a very important part of the procedure. In most situations, the first tube collected during the lumbar puncture is used for chemical analysis, including protein and glucose levels. The second tube is used for culture and other microbiology testing, and the last tube collected is used to perform a cell count to look for presence of red and/or white blood cells.

Medical assistants may aid in the collection procedure for CSF samples, and they may also process the samples to be delivered to the laboratory. All CSF analysis must be conducted on a STAT basis, as the integrity of the cells present in the specimen may deteriorate rapidly once the spinal fluid leaves the body. Some tubes used for CSF collection are already labeled with numerals that are raised on the side of the tube, but if not, the numbering of the tubes as the fluid is added is *critical*, as is the assurance that sterile technique is maintained when handling the specimen. The tubes must be closed securely after the fluid is added and labeled appropriately with all patient demographic information and the date and time of the collection. Ideally, if the medical assistant knows that a lumbar puncture is to be performed in the office, he or she may contact the laboratory to request a STAT courier pickup before the procedure is started, so that the courier will arrive very shortly after the process has been completed. Do not refrigerate or freeze CSF samples after collection before the routine testing can be performed.

Test Your Knowledge 10-14

What is the additional information required on the CSF collection tubes that is not required for other types of microbiology samples? (Outcome 10-9)

Genital Samples

Genital cultures use several types of media to identify microorganisms that cause common genital infections such as cervicitis (inflammation of the cervix), urethritis (inflammation of the urethra), or pelvic inflammatory disease. Not all organisms that cause genital infections can be easily cultured, but common infective agents isolated and identified with culture procedures include yeast infections caused by *Candida albicans*, and bacterial infections (vaginosis) caused by *Gardnerella vaginalis, Neisseria meningitides,* or *Haemophilus ducreyi.* Another common infection of the genitals is **trichomoniasis,** which is a sexually transmitted disease caused by the parasite *Trichomonas vaginalis.* This parasite is identified through microscopic examination of vaginal smears and other testing methods, but not cultures.

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Many sexually transmitted diseases, such as chlamydia, herpes, human papillomavirus infection, and syphilis, are not typically identified through culture, because the causative microorganisms are difficult to grow in the laboratory. More often, these diseases are identified through serological tests that check for the presence of antigens or antibodies. If a culture order is received for these microorganisms, the order should be verified before proceeding with collection. If the health-care provider really wants a culture to be performed, the medical assistant should carefully investigate the collection and processing procedures so that the culture is viable and the results are meaningful.

Cultures from the genitals of patients are usually ordered if the patient complains of itching, discharge, or burning, or if the patient has visible lesions on or near the external genitalia. Remember to use standard precautions at all times when assisting with the collection or processing of these specimens. The specimens may be collected via aspiration (as in the case of abscesses), or more commonly swabs are used to obtain a specimen from open lesions or discharge. When collecting a urethral swab from a male patient, a small swab on a wire may be inserted into urethra to obtain the culture specimen. It may also be necessary to collect specimens from the rectum if the sexual history of the patient makes this a probable site for infection.

Vaginal and rectal culture specimens may also be collected from pregnant women to test for the presence of group B streptococci. This is an important procedure to avoid newborn infection with these bacteria, which can cause pneumonia or sepsis. Women infected with group B streptococci are usually asymptomatic, so this screening process is necessary as part of a routine prenatal checkup. A swab is used for the collection, and the specimen is handled following general bacterial culture guidelines.

If a cervical culture is requested (as in the case of suspected gonorrhea), the specimen collection will require the use of a speculum to widen the vaginal opening and provide access to the cervix. Excess mucus and drainage are to be wiped away from the opening of the cervix, after which a collection swab is inserted into the opening of the cervix and rotated several times to obtain the specimen. Cervical specimens are often collected at the same time that a specimen is collected for a Pap procedure. Specimens collected for gonococci cultures may be transported in a tube that contains charcoal mixed in the transport medium. The charcoal is designed to absorb any interfering substances in the specimen that might decrease the growth rate of the gonococci bacteria.

Test Your Knowledge 10-15

What type of collection device is used for most genital sample collections?

a. An aspirate using a needle and syringe
b. Skin scrapings
c. Swabs
d. Urine samples (Outcome 10-10)

A medical assistant may be asked to inoculate the agar plates used to support bacterial growth from genital culture specimens in the physician office at the time of collection. It may be necessary to inoculate more than one type of agar to isolate the causative organism. Chocolate agar, which contains lysed (broken) red blood cells, is commonly inoculated with the specimen, as it supports the growth of most pathogenic bacteria that may be present in the genital area. Chocolate agar is shown in Figure 10-6. Pathogens commonly present in the genital area need growth factors that are present inside the red cells, so the red blood cells are lysed when preparing the nutrient agar. However, if the health-care provider wants to determine whether the patient may be infected with *Neisseria gonorrhoeae* (the causative agent of gonorrhea), he or she will also want to inoculate a Petri dish that contains Thayer Martin agar. Thayer Martin agar contains lysed red cells just as the chocolate agar. In addition, Thayer Martin agar contains

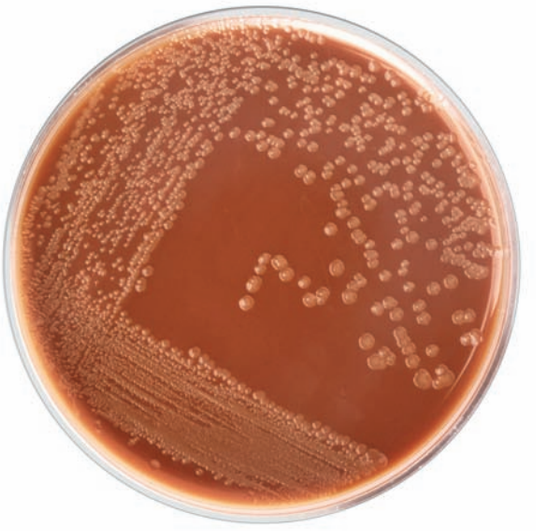

Figure 10-6 Chocolate agar. *Courtesy of Fisher HealthCare, Inc.*

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antibiotics (vancomycin, colistin, and nystatin), which inhibit the growth of other bacteria on the agar plate. This allows for the gonococci to grow without competing with other normal flora from the vaginal area. The gonococci also like to grow in an environment with a low oxygen concentration. A special CO_2 tablet may be added to the bag that contains the agar plate after it has been inoculated to enhance the growing environment, or the inoculated agar plate may be placed in a **candle jar,** a special enclosed container in which the medical assistant places the specimen. After the specimen is added, the medical assistant lights a candle and inserts it into the container until the flame goes out. This process removes oxygen from the environment inside the container and enhances the growth of *N. gonorrhoeae* if present.

POINT OF INTEREST 10-2
Pap smears and human papillomavirus

A Pap smear, or Pap test, is performed on a sample of cells collected from a woman's cervix during a pelvic examination. The Pap test does not detect the presence of infection with sexually transmitted pathogenic microorganisms, but it does detect changes in the cells of the cervix that may develop into cancer. It also detects malignant cervical cells that may already be present. A genital culture may be obtained at the same time that a Pap sample is collected, and this may be tested for the presence of the genital human papillomavirus (HPV), or other suspected infectious agents. A special kit is used for collection of the sample for the Pap smear, which may include a brush-like device, a swab, and/or a wooden spatula. Once the sample has been collected by the health-care provider, it is placed into a solution for preservation and transport to the laboratory. Medical assistants may be responsible for processing the sample appropriately after collection. Once the specimen arrives at the laboratory, a cytotechnologist examines the sample under a microscope to look for evidence of abnormal cervical cells.

Certain strains of the genital HPV may cause genital warts in males and females. Other strains of HPV may cause changes in the cells of the cervix that lead to cervical cancer. The cellular changes are detected with the Pap smear, but the presence of HPV and verification of the type of HPV infection must be accomplished with a separate sample collection. Vaccines are available for protection against many of the most common strains of HPV. Cervarix and Gardasil vaccinations are available for women. If necessary, these vaccinations may begin at 9 years of age, but the recommended age range is 11 to 26 years. Gardasil protects against the strains of HPV linked to cervical cancer, and also protects against most genital warts. Cervarix is specific for the HPV strains that cause cervical cancer. Males may also be vaccinated with Gardasil for protection. These vaccinations are recommended for boys and young men ages 9 to 26 years.

Wound Cultures

A wound is any break in the skin. A wound may be a deep break, an abrasion on the surface of the skin, a surgical incision, or a scratch. Even an ingrown toenail with signs of infection may be processed as a wound. Wound cultures may be ordered when a patient has redness, swelling, drainage, or heat in or around a wound. Cultures collected from breaks in the skin are the most varied in collection techniques, processing procedures, and results. The most important aspects of wound culture collection to remember are the following:

- Only culture the wound; not the area around it. Contamination from extraneous bacteria will complicate the culture process, and may cause inaccurate results and incorrect treatment.
- It is best to collect a culture from a clean wound; the process washes away transient bacteria present in the area that are not involved in the actual infection.
- Deep wounds and aspirates are usually collected and processed as anaerobic culture specimens, as the bacteria growing in this environment do not prefer exposure to environmental oxygen because they are growing well in the deep tissues of the body. Anaerobic culture specimens are collected using special culture kits that protect the specimen from oxygen exposure while providing moisture to keep the specimen viable.
- It is very important that the source is documented thoroughly when working with wound cultures. Details of the culture source will dictate how the culture is set up and which types of pathogens the microbiologist is expecting to identify from the wound. Normal flora may be pathogenic if present as an overgrowth (very high in numbers) within a certain area of the body, or if present in an area that is usually considered to be sterile, such as the eye. Documentation of the patient's name, the date and time of collection, and the source of the sample should be affixed to the collection container as well as added to the requisition form and the patient chart. The source

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information includes details about the side of the body (for instance, wound left hand thumb) for the wound.

- If **exudate** (fluid from the blood vessels in the area of the infection) or pus is present, the health-care provider may culture this drainage. However, in the case of abscesses, sometimes the culture is not performed, as the most important aspect is to clear the area of all the abscess material, not find out what caused the abscess.
- Results obtained from someone with a chronic wound may be very different from those of a patient with a wound that has just become infected. Sometimes the quantitative results (number of colonies or bacteria present in the culture specimen) may indicate whether current treatment is working for a specific wound.
- A **Gram stain** is often performed from the original collection swab at the same time the culture is set up. Gram stains provide information about the shape and staining characteristics of the pathogen. Observation of the slide after performing a Gram stain can provide preliminary information to guide how the culture is to be started, based on the types of bacteria present. For instance, gram-positive cocci often grow better on certain media than do gram-negative rods.
- Swabs are usually used to collect wound culture specimens. Be sure to keep the swab sterile until the specimen is collected. If an aspirate is taken using a needle and syringe, the needle must be removed from the syringe before transporting the specimen. In this situation the aspirate is often transferred into a sterile tube for transport. Identification of the transfer tube is essential; the laboratory will not know what type of fluid is submitted without the documentation, as many body fluids are very similar in appearance. Wound culture specimens should be delivered to the laboratory as soon as possible, and should not be refrigerated or frozen before the culture medium is inoculated.

Test Your Knowledge 10-16

True or False: It is not advisable to wash a wound before collecting a culture specimen. (Outcome 10-11)

Stool Specimens

Cultures for stool specimens differ from many of the other cultures that we have discussed because of the copious amount of normal flora that is present in the digestive tract. The culture medium used to process stool samples is very selective; it has been designed to encourage the growth of known gastrointestinal pathogens, while discouraging the growth of the normal flora of the area. Only pathogenic microorganisms are processed further for identification and treatment. Sometimes the physician may also ask for a specimen to be collected to check for the presence of parasites in the gastrointestinal (GI) tract. This is known as an **ova and parasite examination (O&P)**, during which the microbiologist will be looking for the presence of parasites or their ova (eggs). Stool cultures may be ordered when a patient has diarrhea that lasts more than a few days, or when there is mucus or blood visible in the stool. A patient may be exposed to pathogenic bacteria from eating food or drinking water that has been contaminated. Common sources include water from a contaminated well, lake, or stream, or undercooked eggs, poultry, or beef. Unpasteurized milk is another potential source. When patients travel outside the country, there may be exposure to bacteria that have become part of the normal flora for the occupants of that area, but that will make visitors sick who are not habituated to them.

Stool specimens for bacterial cultures are collected in a sterile cup. The stool specimen must be fresh for culture setup. The specimen should be delivered to the laboratory within 2 hours of collection, and the specimen must be protected from extremes in heat during transport. The sample cannot be taken from the water in the toilet bowl, and the sample cannot contain urine. Toilet tissue also should not be mixed in with the sample. To successfully collect a stool culture specimen, it is recommended that the patient spread plastic wrap across the back half of the toilet seat so that the stool can be collected on this plastic wrap when eliminated. It is important that urine is not introduced to the plastic wrap. For patients who are wearing diapers, it may be necessary to line the diaper with plastic wrap for successful collection.

Test Your Knowledge 10-17

Why is it important for the medium used for stool cultures to be so selective? (Outcome 10-12)

Common pathogens isolated from stool specimens include the following:

- *Clostridium difficile:* Infection with this bacteria often follows use of broad-spectrum antibiotics, which disrupt the balance of normal flora in the body and allow this opportunistic bacteria to flourish. *C. difficile* is a spore-forming bacterium that may live on surfaces

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(hospital beds, walls, etc.) for extended periods of time. The bacteria are shed in the stool of infected individuals, and the infection may be life threatening if not treated appropriately. Patients may form a pseudomembrane, or artificial lining in the intestinal tract that impairs absorption of nutrients from the food they ingest. *C. difficile* is difficult to grow as a culture (hence the name *difficile,* "difficult"), but a toxin is secreted by the bacteria that may be detected in the stool specimen or in blood from an infected individual.

- *Salmonella:* This name actually describes a group of bacteria of the *Salmonella* genus. *Salmonella* species live in the intestines of many animals, such as baby chickens, cattle, or pigs. They may also be present in the feces of turtles and domestic animals. Food that has been contaminated with animal feces is the most common means of transmission. The bacteria are transmitted via the fecal-oral route, and usually cause abdominal cramping and severe diarrhea within 1 to 2 days of infection. Most of the time the infection is resolved without antibiotic treatment within a week, but occasionally the *Salmonella* bacteria may enter the bloodstream and cause more serious illness. To avoid infection with this organism, patients should always wash and cook food thoroughly, keep eggs refrigerated, and wash their hands using soap and clean water after working with or petting animals.
- *Shigella:* This name describes a genus of bacteria that causes diarrhea, including *Shigella sonnei* and *Shigella flexneri*. These two types cause almost all cases of *Shigella* infection in the United States. *Shigella dysenteriae* type 1 can cause deadly epidemics, but is very rarely seen in the United States. *Shigella* is transmitted through fecal material from one person to another. Common methods for transmission include food handlers who do not wash their hands after using the restroom, and small children who share wading pools. Infected patients will continue to shed the bacteria in their stools, which often appear bloody, for several weeks after the symptoms have subsided.
- *Campylobacter:* This spiral-shaped organism causes diarrhea, abdominal cramps, nausea, and fever in infected patients. The most common species of the *Campylobacter* genus to cause disease is *Campylobacter jejuni.* Most cases are spread by the feces of birds or the ingestion of birds, as they are able to carry the bacteria without being ill with it themselves. Infection may occur from exposure to raw or undercooked poultry, but occasionally a dog or cat may be infected and the owner may become infected from them. *Campylobacter* can cause disease with very little exposure, so cross-contamination can occur between, for example, cutting boards in a food preparation area and a preparer's unwashed hands, leading to illness. *Campylobacter* infection is the most common bacterial infection causing diarrhea in the United States. Usually it resolves without antibiotic treatment, but there are many documented cases of infected patients who developed the neurological disorder Guillain-Barré syndrome. The *Campylobacter* infection acts as a "trigger" to cause an autoimmune response in which the body attacks the nervous system, causing paralysis.
- *Escherichia coli:* This family of bacteria is present in our environment, and is part of our normal flora. However, there are certain strains of *E. coli* that can cause illness, especially when they are introduced into areas of our body where *E. coli* is not normally found. Some of the *E. coli* families, also known as enterohemorrhagic or verocytotoxic types of *E. coli,* produce the Shiga toxin. The most common one to cause disease in the United States is *E. coli* O157:H7. When a patient has become infected with this type of *E. coli,* the toxins produced by the bacteria cause the illness. Those who are infected usually start to feel ill within a few days of ingesting the bacteria. Symptoms include severe abdominal cramps, vomiting, and diarrhea, which may be bloody. In most patients the infection resolves within a week. However, approximately 5% to 10% of those who are infected with *E. coli* O157:H7 develop **hemolytic uremic syndrome,** which can be life threatening. Hemolytic uremic syndrome occurs when the toxins produced by the bacteria begin to destroy the red blood cells and platelets of the infected patient. The torn or broken red cells begin to block the small capillaries in the kidneys, which can lead to total renal failure.

Nasopharyngeal Specimens

When an upper respiratory infection is suspected, it may be necessary to collect a specimen using a **nasopharyngeal collection technique,** commonly used when collecting samples to test for presence of viral microorganisms. The **nasopharynx** is the area of the pharynx (throat) that runs from the back of the nasal cavity down to the back of the throat that is visible through the mouth. Nasopharyngeal specimens are usually collected by entering the pharynx through the nose, but they may also be collected by going through the mouth and "sweeping" the area of the pharynx that is above the uvula. Some key points are the following:

- Generally, nasopharyngeal swab specimens will be collected 3 to 7 days after the symptoms have started, and

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before antibiotics or antiviral medications have been administered.

- Always verify the order before collecting the sample. Verify whether a viral culture or a bacterial culture is requested, and have the correct supplies on hand to handle the specimen appropriately after collection. Copan Diagnostics makes several types of "flocked" swabs designed for maximum specimen collection potential. Nasopharyngeal swabs traditionally have a flexible shaft, which may be made of wire or flexible thin plastic. Only Dacron or rayon swabs should be used for viral samples.
- To collect the sample on the nasopharyngeal swab, it is necessary first to measure how far the swab needs to be inserted for the collection. The depth of insertion is approximately half the length from the earlobe to the base of the nose (nostril) of the patient. This should be measured and marked on the nasopharyngeal swab shaft so that it is visible during the collection. The swab is inserted into the nose parallel to the roof of the mouth. Continue to insert the swab until the depth of insertion has been reached and slight resistance is felt, indicating that the nasopharynx has been reached. The swab should be rotated several times, and left in place for a few seconds to absorb any mucus that is present. Remove the swab in the same way that it was inserted. It may be necessary to insert the swab in the other nostril and repeat the process. The swab is then placed immediately into the viral transport media (or bacterial transport media if ordered) and processed according to the directions provided by the testing laboratory.

Eye Cultures

Samples from the eye may be taken from the *conjunctiva,* the mucous membrane that covers the inner area of the eyelid and extends to cover the exposed surface of the eye. The conjunctiva can be accessed just under the upper and lower eyelids. Eye cultures less commonly are obtained as corneal scrapings or an aspirate from the eyeball. In the outpatient setting, conjunctival samples will be the most commonly collected. When assisting with this procedure, it is important to remember that the microbiology laboratory will prefer a sample from each eye, even if the infection is suspected in only one eye. This allows the laboratory to compare any normal flora that may be present, and assists with identification of potential pathogens. Also, the collection swabs should be moistened with sterile saline or nutrient broth before use to minimize discomfort when the collection swab is rubbed across the delicate surfaces of the eye.

Common pathogens present in the eye may be isolated by inoculation of the specimens on 5% sheep's blood agar, chocolate agar, and mannitol salt agar. The pathogens often include *Streptococcus* genus, as well as *Haemophilus* genus, and occasionally *Gonorrhoeae* bacteria may be evident, especially in a newborn infant whose mother had minimal prenatal care.

Test Your Knowledge 10-18

Why is the swab used for eye culture samples usually moistened prior to use? (Outcome 10-13)

Ear Cultures

The human ear is separated into three sections: the outer ear, the middle ear (located right behind the tympanic membrane), and the inner ear. The middle ear is connected to the back of the throat by a small structure known as the **eustachian tube**. Inflammation (with or without infection) of the ear is called **otitis** and is further specified by adding the location to the name. **Otitis media** describes inflammation or infection of the middle ear, and **otitis externa** describes inflammation and/or infection of the outer ear canal.

Otitis media is the most common type of ear infection, and usually develops as a result of blockage of the eustachian tube. When this tube is blocked, fluid builds up in the middle ear, and if there are bacteria or viruses present (such as those causing a sore throat or the common cold), these may be introduced to the fluid within the ear by the eustachian tube. (The middle ear is usually a sterile environment.) This is a common disorder in children, as their eustachian tubes are shorter and straighter than those of adults. If the pressure builds up too much within the middle ear, the tympanic membrane may rupture, and the health-care provider will take a culture specimen of the drainage with a sterile swab. Sometimes it may be necessary to take a culture specimen of the fluid behind the tympanic membrane when it has not ruptured. A procedure called *tympanocentesis* may be performed, in which the health-care provider inserts a needle through the tympanic membrane and aspirates a sample of the fluid that is built up in the middle ear. Another procedure that may allow access to the fluid is a *myringotomy,* in which a tiny incision is made into the eardrum to allow for drainage of the infected fluid. In this situation, a sterile syringe may be used to aspirate some of the sample for a culture, or a sterile swab can be used to obtain the sample as it drains out of the eardrum.

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Otitis externa is a condition that is often known as swimmer's ear. When moisture is introduced into the external ear canal, it can create a perfect environment for bacterial or fungal growth to occur. Otitis externa may also be caused by excess moisture or a break in or irritation to the skin of this area. The introduction of foreign objects (such as cotton-tipped swabs) or chemicals (such as those present in hair-care products or dyes) may contribute to the development of otitis externa. The outer ear usually itches, and there is often discharge and pain in the area as well. If a culture is needed to identify the infective microorganism, a sterile swab is used to swipe the lesions and/or obtain a sample of the discharge. The outer ear canal does contain normal flora, such as *Staphylococcus epidermis, Staphylococcus aureus,* and *Corynebacterium* genus.

Test Your Knowledge 10-19

Which type of otitis is often linked to excessive moisture in the ear?

a. Otitis externa
b. Otitis media (Outcome 10-14)

SPECIAL SAMPLE COLLECTION AND PROCESSING PROCEDURES

The role of a medical assistant does not end with the collection and labeling of the specimens. Sometimes there are special procedures that must be completed after the collection so that specimens can be examined, or unique collection requirements for certain specimens that require prior setup.

Fungal Sample and Culture Collection Procedures

As was presented earlier in this chapter, specimen collection procedures performed to detect the presence of fungal elements may be different from those procedures used for bacterial or viral organisms. Successful isolation and identification of fungal elements are dependent on very specific collection methods, rapid transport, and use of the correct growth medium once the sample arrives at the laboratory. Fungi may be isolated from wounds, abscesses, hair follicles, or lesions on the skin. *Tinea pedis* (athlete's foot) and *Tinea unguium* (a fungal infection of the nails) are frequently seen in the physician office. Fungal infections are referred to as **mycoses** and are further identified by the area of infection and/or the causative organisms. Common classifications of fungal infections include the following:

- **Superficial or cutaneous mycoses:** These infect the outermost (dead) layers of the skin and hair, as well as the epidermis, hair follicles and deeper layers of the visible skin. *Tinea corporis* (ringworm) is an example of this type of infection.
- **Subcutaneous mycoses:** These fungal infections occur in the dermis and subcutaneous layers of the skin, and may affect the muscles and tissue layers beneath the skin. Often these are chronic infections that resulted from an initial wound when the fungus was introduced into the body.
- **Systemic mycoses:** Systemic fungal infections may be present in multiple organs and/or areas of the body. They are often introduced to the body through the respiratory tract. Systemic fungal infections may be caused by opportunistic fungal organisms in patients who have suppressed or inactive immune systems (such as HIV-positive patients), or they may be caused by a pathogen that is introduced to the body.

Sample collection procedures will differ according to the site of infection. It is important that the medical assistant and health-care provider verify which type of specimen is necessary for the infection before the collection process begins. Sometimes the health-care provider will utilize a **Wood's lamp,** which shines a fluorescent light over the infected area. Certain types of fungi will fluoresce when exposed to this light, and the physician may use this information without the need of an actual specimen collection to prescribe treatment. Table 10-1 summarizes the type of specimen needed and the collection method used to identify the fungal elements in various areas of the body. Sample types include scrapings of skin lesions for superficial infections, nailbed samples, aspirates from abscesses, or swabs used to sample vaginal drainage.

Test Your Knowledge 10-20

Are all fungal infections superficial? (Outcome 10-15)

Potassium Hydroxide Preparation

Many times it is not necessary to identify the specific *type* of fungus responsible for an infection; the most important information is whether a fungal element is the causative agent. Patient treatment is based on the presence of the fungi without further identification. An examination of the sample under the microscope with a drop or two of 10% to 20% potassium hydroxide (**KOH)** solution is

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TABLE 10-1
Information needed for collection of samples for fungal cultures*

Type of Infection	Specimen Required	Collection Method
Skin lesions	Skin scrapings	Use the dull edge of a scalpel or a glass slide; scrape across the lesion. If there are not enough loose pieces created with this action, adhesive tape may be used to pick up a sample. Transport dry in sterile container.
Fungal infection of the hair	Pieces of hair with roots attached	Pluck out the hair (including root material) with sterile forceps. Transport dry in sterile container.
Nail infection	Pieces of nail and debris from underneath the nail	Samples from discolored or misshapen parts of the nail preferable; may use microdrill method to provide samples from the more proximal parts of the nail for better capture of the fungi. Samples scraped from underneath the nail may also provide fungal elements. Transport dry in sterile container.
Abscesses and other subcutaneous infections	Aspirate taken with a needle and syringe, or a sterile swab moistened with saline brushed over the surface from deepest area of infection possible	Sample only the actively infected areas for best results. Be certain that the sample amounts are adequate for culture.
Deep tissue infections	Samples of tissue	Tissue to be excised; will be minced, then cultured for fungal elements.

*For all cultures, specimen ideally will be processed within 2 hours of collections.

performed immediately after collection to search for the presence of fungi. The KOH dissolves other organic elements in the specimen such as hair, mucus, skin cells, and bacteria, but it does not dissolve the fungus that may be present. This allows the health-care provider to visualize the fungus and decide on a plan of treatment without waiting for a culture result. Some fungal species do not show up with the KOH treatment, so the health-care provider may order a culture in addition to the microscopic examination if a fungal infection is suspected upon examination. It is important to remember that results from a fungal culture may not be available until weeks after the sample is submitted, so alternative methods of detection are very important to avoid delay in treatment.

Wet Mount Procedure

A **wet mount** is a means by which living organisms may be observed under the microscope. *Trichomonas vaginalis* is a common sexually transmitted parasitic microorganism that needs to be visualized as it is alive and active via a wet mount examination. A wet mount is prepared by adding a few drops of saline to a sample (usually a swab with secretions on it) then placing a drop of saline/sample mixture onto a microscopic slide. A **cover slip** (a small piece of plastic or glass) is applied over the solution on the slide, and the health-care provider examines the sample. Diagnosis is made by examining the structural characteristics and movement of the microorganism. Wet mount examinations (as well as KOH preps) are performed in physician offices only by health-care providers or trained laboratory professionals, but not by medical assistants. The medical assistant may set up the sample appropriately and bring it into focus on the microscope for examination, but the health-care provider or other appropriately trained personnel will be responsible for performance of the examination.

A **hanging drop slide** is another way that a sample, especially those exhibiting a lot of movement, may be examined for live microorganisms. In this case, a special depression slide is used. These slides have a "scoop" out of the center of the slide, which forms a depression. A cover slip is also used and petroleum jelly is applied with an applicator to the four corners of the cover slip. A drop of the sample (often an inoculated swab that has been agitated in saline) is placed on the center of the cover slip.

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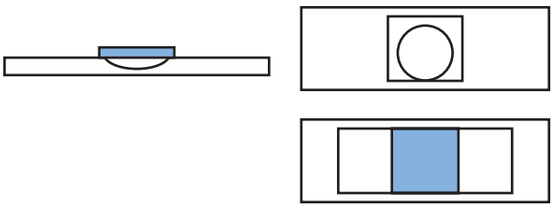

Figure 10-7 A depression slide. Note how the "scoop" is taken from the middle of the slide. This is covered with a cover slip. The sample is actually placed on the cover slip with the depression set over this area and the slide flipped for viewing under the microscope.

The depression slide is placed over the cover slip, where the petroleum jelly seals the edges. The setup is inverted so that the specimen drop is "hanging" from the cover slip over the depression. This allows an excellent opportunity to examine the sample for anatomy and **motility** (movement) of the microorganisms that are present. An example of a hanging drop slide can be seen in Figure 10-7.

Test Your Knowledge 10-21

How are KOH preps and wet mounts similar? How are they different? (Outcome 10-16)

Sample Collection Procedures for Detection of Parasites

Organisms that live on or in a host and use their host for nourishment are known as **parasites.** Pathogenic microorganisms that use the human body for nourishment include **ectoparasites,** which live on the outside of the body, and **endoparasites,** which live within the human body. These parasites feed off the human host, at the expense of the health of the human that they occupy.

Common ectoparasites that use humans as hosts include lice, mites, fleas, and ticks. Diagnosis of these infections usually occurs with the visual examination of the site. For instance, the health-care professional may take a scraping from the skin of the infected individual and examine it under the microscope to see if there are mites present. **Scabies** is a parasitic infection with *Sarcoptes scabiei,* and this may be diagnosed with a skin scraping. The Burrow ink test is another method sometimes used for verification of scabies infections, performed by rubbing the site with an ink pen, then wiping away the ink with an alcohol pad. If there is a parasitic scabies infection then the burrow holes left from where the microorganisms entered the skin will be evident. When a lice infection is suspected, the diagnosis is usually made with careful examination of the hair for the adult lice or the nits that are present near the scalp. Most infections with ectoparasites do not cause the host to become ill; however, secondary infections from the scratching and breaks in the skin may be problematic.

The most common internal parasitic infection in the United States is caused by *Giardia lamblia*. This single-cell parasitic microorganism is passed in the feces of animals. Untreated water in ponds and mountain streams are contaminated with feces from indigenous animals in the area such as beaver, muskrat, elk, and deer. The human host then ingests the parasite by drinking this contaminated water. The presence of the *Giardia* in the water cannot be detected without the use of a microscope, as it does not change the water's color, smell, or taste. Infection by other internal parasites such as roundworms, tapeworms, and hookworms may also occur, but this is not as common in the United States as it is in other areas of the world. Endoparasites can damage their hosts by causing cellular destruction, chewing damage to the gastrointestinal tract, anemia, blood vessel damage, bloody diarrhea, and failure to absorb nutrients.

Ova and Parasite Examination

For most endoparasites, the ova and parasite examination (O&P) is used to make a visual identification of the presence of adult parasites or eggs in the stool. Most parasites have adult forms and produce ova (eggs) or cysts with sexual or asexual reproduction. When the gastrointestinal tract is infected with parasites, the adult parasites or their eggs are shed into the stool of the infected host. The O&P test is performed by placing thin smears of stool (fresh or preserved) onto slides and examining and/or staining them for examination. The sample may need to be spun in a centrifuge for concentration before the slide is prepared to allow for easier detection of any parasites or ova present. The microbiologist will be able to detect the presence or absence of adult parasites or the eggs (ovum), and based on the anatomical structures observed, an identification of the species may also be performed.

When a patient is to be tested for the presence of ova and parasites, he or she is provided with a collection kit that includes a container for the stool specimen, as well as one or two small bottles of preservative solution (Fig. 10-8). The bottles must be appropriately labeled to warn the patient that they contain strong chemicals that could be harmful if swallowed or allowed to remain on bare skin for extended periods of time. The bottles may have a "scoop" built into the cap for the patient to add

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Figure 10-8 Ova and parasite collection kit. There are two different types of preservatives provided, and each bottle has a scoop in the lid that is used to add the stool specimen to the preservative.

the stool specimen to the preservative in the bottle. Common preservatives are 10% buffered formalin and polyvinyl alcohol (PVA). The formalin allows for extended preservation of the parasites and eggs, but the stool sample may be used only for wet mount observation; it cannot be stained for a more permanent record of the examination. PVA does preserve the sample for a reasonable amount of time, but it also allows for staining of the slide for further study. Some laboratories will provide two bottles with different fixatives. The patient should be advised to collect the stool sample into the larger container (provided) or use some other method to collect the sample without contamination of urine or water. Then, the patient should use the scoop or a provided applicator to put a small part of the sample into the provided preservative bottles and return it to the laboratory or physician office.

Sometimes a stool culture is ordered at the same time as the sample for the ova and parasite examination, so it is important that the medical assistant give appropriate instructions for the time intervals before the specimen arrives back at the office. Some laboratories will also prefer a fresh stool sample, in which case it needs to be delivered to the laboratory within 1 hour of collection to preserve the anatomical features of the parasitic microorganisms for identification. It is also common for health-care providers to order multiple sample collections, as the parasites and/or eggs may be shed at random times in the stool. Identification of the specimen collection date and time is very important.

Test Your Knowledge 10-22

How does a collection procedure for an ova and parasite examination differ from a stool culture collection procedure?

a. The O&P collection procedures include containers with preservative solution, but stool culture sample procedures do not
b. Stool specimens for cultures can be kept at room temperature for extended periods of time, whereas specimens for O&P cannot be stored at room temperature
c. The procedures are exactly the same for both types of collections
d. None of the above (Outcome 10-17)

Pinworm Collection Procedures

Pinworm infections, caused by the parasite *Enterobius vermicularis,* are the most common type of worm infections in the United States. The pinworm is a small white worm that can infect the colon and rectum of humans. School-age children and those who are institutionalized are at highest risk for this type of infection, as well as those who care for this population. The adult pinworms are large enough that they can sometimes be seen around the rectum without magnification. The adult female pinworm leaves the rectum at night and lays her eggs around the opening. Within a couple of hours these eggs are infectious, and may be shed into the underwear and bedclothes. This infection often causes intensive anal itching.

Testing for pinworm infection must occur first thing in the morning, before the individual has had a bowel movement or bathed, as these actions may remove the eggs from the rectal area. A piece of clear adhesive tape (sticky side down) may be pressed against the perianal area, and any eggs in the area will stick to the tape. This process may need to be repeated for several days before eggs are identified. The eggs can then be viewed under the microscope when placed on a slide. A "pinworm paddle" may also be used for the collection. Becton, Dickinson produces a tool called the FALCON SWUBE Pinworm Paddle, which is a clear plastic paddle with one adhesive side at the wide end. This sticky side is placed against the perianal area, and then the paddle is placed within a tube to keep it secure until it is examined. The actual paddle can be used as a slide under the microscope, as it is transparent. Figure 10-9 shows the FALCON SWUBE Pinworm Paddle.

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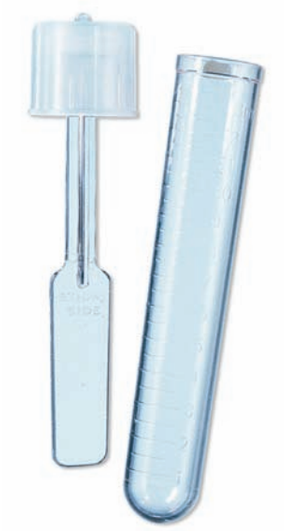

Figure 10-9 The FALCON SWUBE Pinworm Paddle for pinworm collection. The end of the collection device is pressed against the anus to collect the sample. The sample is transported in the outer tube to the laboratory where the actual collection device may be placed on the microscope for examination. *Courtesy of BD, Inc.*

Test Your Knowledge 10-23

What role does adhesive tape play in the collection of the samples for pinworm detection? (Outcome 10-18)

PROCESSING MICROBIOLOGY SAMPLES

This chapter has explained the collection process and immediate handling for many different types of microbiology samples. In a physician office, the medical assistant is often responsible for one more step; the processing of the sample to prepare it for growth of the culture. This may include inoculation of the growth medium, slide preparation, and Gram staining, or even initiating the process for antibiotic sensitivity testing.

Slide Preparation and Gram-Staining Procedure

Developed in 1884, the **Gram stain** is a technique that quickly and inexpensively provides information about the bacteria that are present in a sample. Identification of the microorganisms is based on the fact that almost all bacteria will preferentially absorb different colors of stains, based on characteristics of their cell walls.

When the slide is viewed using the microscope, those bacteria that retain the crystal violet dye will appear purple and be identified as gram positive. Gram-negative organisms will have retained the safranin counterstain, and will appear pink when examined. Figure 10-10 shows gram-positive and gram-negative bacteria after staining. Gram-stained slides also allow the appearance and shape (e.g., cocci, bacilli) microorganisms to be viewed. Complete identification (such as genus and species) cannot be ascertained with a Gram stain, but the microorganism's characteristics that can be determined will assist the physician in making appropriate initial treatment decisions. If the Gram stain is performed at a laboratory outside of the physician office, the preliminary results are often called in to the physician office. The medical assistant must be very careful to document all information and report it to the physician in a timely manner.

Test Your Knowledge 10-24

Why are two different types of stains used for the Gram-staining procedure? (Outcome 10-19)

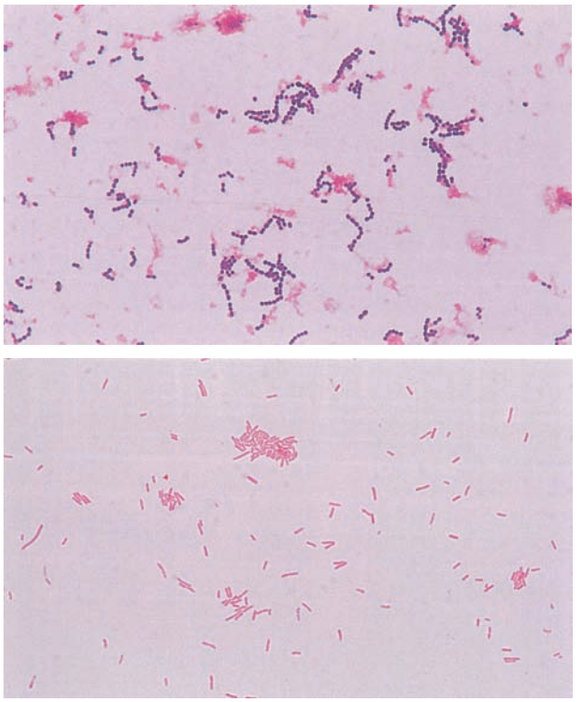

Figure 10-10 Gram-negative and gram-positive bacteria. The purple bacteria *(top)* are gram positive, and the pink bacteria *(bottom)* are gram negative.

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Procedure 10-3: Gram-Staining Procedure

The Gram stain is one of the most common procedures performed in the microbiology department. It is a differential stain that allows bacteria to be classified into one of two groups depending on the way that the cell wall reacts with the dyes used in the staining process. The cell walls of the gram-positive bacteria have a greater affinity for the crystal violet stain than the bacteria classified as gram negative. When viewed under the microscope, the gram-positive bacteria will appear purple in color as a result of the crystal violet stain, and the gram-negative bacteria will appear pink in color as a result of the safranin counterstain.

TASK

Perform a Gram stain on a bacterial smear.

CONDITIONS

- Heat-fixed glass slide with bacterial smear
- Gram stain supplies (crystal violet, Gram's iodine, 95% ethyl alcohol, and safranin)
- Gloves
- Forceps
- Water
- Laboratory wipes

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.C.III.9: Discuss quality control issues related to handling microbiological specimens. **III.P.III.2:** Practice Standard Precautions, **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations, **III.A.III.** Applied Microbiology/Infection Control

ABHES Standards

- Apply principles of aseptic techniques and infection control
- Use standard precautions
- Practice quality control
- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #5: Microbiology testing

Procedure	Rationale
1. Sanitize hands and apply gloves.	The gloves will protect the hands from becoming stained by the materials used in this procedure.
2. Grasp the slide in the forceps. Hold it over the sink or other waste container. Flood the slide with the crystal violet stain and allow it to be covered for 1 minute.	The slide should be held over the sink to allow excess stain to drain. It is important to keep the stain in contact with the slide for 1 full minute.
3. Pour off stain from slide and flush gently with water. Blot against laboratory wipes to remove excess water.	The slide should be flushed until the liquid stain is removed from the slide. It may be necessary to rub the underside of the slide with a laboratory wipe to remove excess stain if it drips onto the back of the slide.
4. Apply Gram's iodine to the slide for one minute.	The Gram's iodine forms a complex to keep the crystal violet attached to the gram-positive bacteria.

Continued

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Procedure 10-3: Gram-Staining Procedure—cont'd

Procedure	Rationale
5. Pour off the Gram's iodine and flush the slide with alcohol. Allow the alcohol to run over the slide until the alcohol runs clear. This may take 20 to 30 seconds, and depends on the thickness of the smear.	The alcohol is a decolorizing agent, and it is imperative that the slide is flushed with this until it runs clear.
6. Rinse the alcohol from the slide with gentle running water. Blot off any excess water by tapping the slide against a laboratory wipe. Clean the underside of the slide with a laboratory wipe if necessary to remove excess stain.	Rinsing the water stops the decolorization process.
7. Cover the slide with safranin stain. Allow the slide to be covered for 20 seconds.	The safranin is the counterstain, which gives color to the gram-negative organisms that did not absorb the crystal violet stain. Without it, they would appear colorless on the slide when viewed under the microscope.
8. Rinse the slide once more with water. If necessary, use alcohol on the underside of the slide to remove any residual stain. Blot the stained slide with a laboratory wipe to absorb excess water.	This is the final stage of the process. It is important to make sure that the residual stain is removed so that the light will not be obscured when the slide is viewed under the microscope.
9. Put away supplies and clean the work area.	The laboratory area must remain clean and tidy.

POINT OF INTEREST 10-3
Tuberculosis and other acid-fast bacilli

Certain types of bacteria resist colorization during the Gram-staining procedure. These bacteria have a higher concentration of lipids in their cell walls, so they do not retain the crystal violet or the safranin stain. At the end of the Gram-staining procedure they remain essentially colorless. In order to identify these bacteria, the Ziehl Neelsen stain is often used to identify these bacteria, known as acid-fast bacilli. The most common group of bacteria that reacts in this way is from the genus *Mycobacterium*. Many species are harmless to humans, but there are a few notable exceptions. *Mycobacterium tuberculosis* is the causative agent of tuberculosis, *Mycobacterium avium* is a bacterium that is capable of causing lung disease, and *Mycobacterium leprae* causes leprosy.

Tuberculosis (TB) is a disease that has been around for a very long time. Active infection is on the rise, and it is imperative that the health-care community remain aware and educated about how to identify and treat this infection. *M. tuberculosis* is most often thought of causing a lung infection, but the bacterium may infect any area of the body. Other common infection sites include the kidneys and the central nervous system. The bacteria are spread through the air when an infective individual coughs, speaks, sneezes, or sings. There are two types of tuberculosis infection:

1. **Latent infection:** A patient has latent tuberculosis infection when he or she has become infected with the bacteria, but does not become actively ill. In the case of latent infection, the patient's immune system has "walled off" or isolated the bacterium to the extent that it does not cause immediate harm. The TB infection may spread at a later date, especially if the patient develops other conditions that lower natural immunity, such as HIV infection. The patients with latent infection will show a positive reaction on the tuberculosis skin test, and they need to be treated to kill the bacteria in their bodies before they cause active infection.

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2. **Tuberculosis disease:** A patient with tuberculosis disease has the *M. tuberculosis* bacteria in the body, but the immune system has not rendered it inactive. The bacterium has caused active illness. Symptoms may include severe coughing for an extended period of time, spitting or coughing up blood, fatigue, anorexia, chills, fever, and night sweats. Patients with tuberculosis disease are infectious, and may infect those around them in their home or workplace. They may also infect the health-care professionals who care for them.

To aid in controlling tuberculosis disease, certain high-risk groups should be tested for latent infection, as well those who show symptoms of the active disease. These groups include those who have been exposed to a TB-positive person, patients who have a compromised immune system, those who have lived in or traveled to a country where TB is widespread in the population, those who are incarcerated, and those who are health-care professionals. The tuberculin skin test is the most common way to screen for latent infection, and this test is offered at local health departments as well as many physician offices. Those who immigrated to the United States from another country may have received the bacille Calmette-Guerin (BCG) vaccine against tuberculosis, which is given in countries outside of the United States. However, the BCG vaccine is not considered to offer lifetime immunity. Individuals who have received the BCG vaccine should still receive the tuberculosis skin test. They may show a false-positive result; if that is the case, patients will require follow-up chest x-rays and a physical examination to determine TB status. There is also a blood test now available for tuberculosis infection, called an interferon-gamma release assay. It does not check for the presence of the TB bacilli; rather, it tests for the body's immune response to the bacteria. It is relatively expensive to perform, and not yet in widespread use. An example of this test is the Quantiferon-GOLD test. Those who have had the BCG vaccine have less of a chance of a false positive with the blood test than they do the skin test.

Fortunately, tuberculosis infection, whether the infection is latent or active, is treatable. Those who test positive with the skin test or the blood test are treated with a regime that may last 6 to 12 months, and includes several medications at once. *M. tuberculosis* has become problematic in recent years, with development of several antibiotic resistant strains. Treatment with more than one medication at once seems to reduce the chance of developing resistance. Common medications include isoniazid, rifampin, ethambutol, and pyrazinamide. Patients with active infection are required to take their medication; if there is a high risk of noncompliance, they may even be placed in a directly observed therapy program in which a local health nurse will monitor their dosages daily. Incarceration is also an option; if the local health authority feels that a patient poses a high risk to other individuals and if that patient is noncompliant, jail time may be required.

Plating and Inoculation of Media

In some situations, laboratories may request that the physician office laboratory inoculate the media at the time of collection. A nutrient broth or slant may sometimes be innoculated. These types of media encourage growth of microorganisms but do not allow for isolation of specific colonies for further growth and identification. To accomplish separation of the growth into definitive colonies, an agar plate is used with a specific pattern of inoculation to create isolated colonies of the organism to be further identified and tested. The pattern of inoculation may be different depending on the type of agar plate or type of specimen. A common method used to add a sample to an agar plate is the quadrant method, in which the agar plate is divided into four parts, either mentally or with a grease pencil if necessary. The sample is applied to one quadrant of the plate fairly heavily with a swab that is twirled for full exposure. Successive quadrants are "streaked" with the sample by passing through the previous quadrant one time to pick up specimen, then continuing with numerous streaks that are close together. The goal is to provide an opportunity for growth of isolated colonies so that these can be further tested for identification and possibly sensitivity tested. Figure 10-11 illustrates the quadrant streaking method.

Test Your Knowledge 10-25

Which of these may be used for inoculation?

a. Agar plates
b. Slants
c. Liquid nutrient broth
d. All of the above (Outcome 10-20)

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Procedure 10-4: Quadrant Streaking Inoculation Procedure

To isolate microorganisms from pure culture or to isolate specific colonies from agar plates that contain mixed flora, it is necessary to set up a streak plate. The most common method used for this procedure is the quadrant streaking method. The plate is divided into four sections, and the sample is streaked across each area, with every quarter slightly overlapping the previous area.

TASK

Prepare a streak plate using the quadrant streaking method.

CONDITIONS

- Agar plate
- Inoculation loops or sterilization equipment
- Gloves
- Culture specimen on swab

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.C.III.3: Discuss infection control procedures, **III.C.III.9:** Discuss quality control issues related to handling microbiological specimens. **III.P.III.2:** Practice Standard Precautions, **III.P.III.3:** Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations,

ABHES Standards

- Apply principles of aseptic techniques and infection control
- Use standard precautions
- Practice quality control
- Dispose of biohazardous materials
- Collect, label and process specimens

Procedure	Rationale
1. Remove the lid of the agar plate and place face down on the countertop.	The lid should be placed so that it does not become contaminated.
2. Sanitize hands and apply gloves.	Gloves protect the hands from the microorganisms in the culture.
3. Mentally divide the agar plate into four quadrants. This may also be accomplished physically by drawing a four-part diagram on the bottom of the agar plate.	The quadrant method requires that the plate be divided into four sections.
4. Use the culture swab to inoculate the first quadrant on the agar plate. Gently roll the swab across this area for complete coverage.	The first quadrant must have an adequate amount of specimen present for the rest of the procedure to proceed correctly.
5. Turn the agar plate so that the second quadrant is at the top. Use the inoculation loop to apply sample into the next quadrant by passing it into the original application two times, then spreading it across the second quadrant without entering the first quadrant again.	The sample becomes less concentrated as it is spread across the second quadrant.
6. Using a new sterile inoculation loop (or sterilize and cool a reusable loop) repeat the procedure with the subsequent quadrants.	Each quadrant will be inoculated in the same way with a very small amount pulled from the previous quadrant and spread out.
7. Label the plate and incubate as directed.	Appropriate incubation will be necessary to allow for specimen growth.
8. Put away supplies and clean the work area.	The laboratory area must remain clean and tidy.

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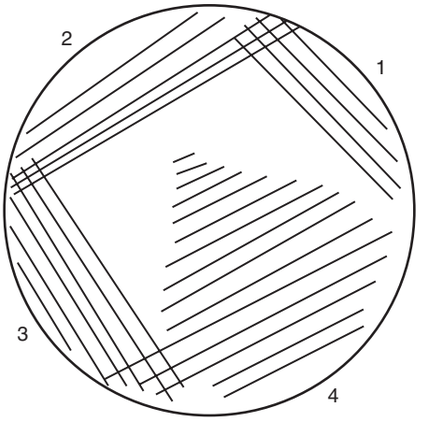

Figure 10-11 The quadrant streaking method of inoculation. The culture swab or a loop of a liquid sample is placed across quadrant 1. A sterile inoculating loop is used for the second quadrant; the streaks overlap quadrant 1 three times, then the swipes continue to fill the quadrant. Another sterile inoculating loop is used for the third quadrant, and the same procedure is used. This process is repeated once more for the fourth quadrant.

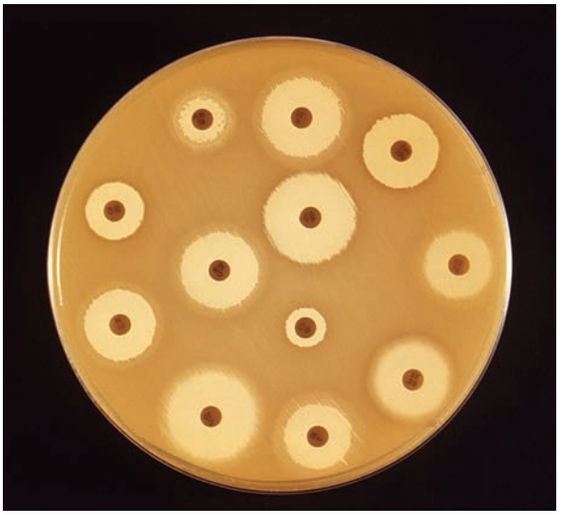

Figure 10-12 Antibiotic sensitivity plate showing the disk-diffusion method. Note the zones of inhibition around some of the antibiotic disks. *From CDC/Gilda L. Jones.*

Antibiotic Sensitivity Testing

Antibiotic sensitivity testing is performed to determine how effective antimicrobial therapy is against a certain type of bacteria. There are numerous methods available for this procedure; instruments such as the VITEK 2 (produced by the firm bioMérieux) are capable of performing antibiotic sensitivities in a fully automated fashion. These automated methods use the **minimum inhibitory concentration (MIC) method** to determine which antimicrobial agent is best to use for a specific pathogenic bacteria. However, many laboratories use an older, more laborious method of testing known as the **disk-diffusion method** (also known as the **Kirby-Bauer method)** for antibiotic sensitivity testing.

To set up the disk-diffusion (Kirby-Bauer) procedure, a solution of the diluted specimen is applied to cover an entire Mueller Hinton agar plate. Absorbent paper discs that have been impregnated with various antibiotics are applied directly to the specimen on the plate (Fig. 10-12). The antibiotics are absorbed into the specimen and the agar as the plate is incubated for a period of 18 to 24 hours. If an organism is **sensitive** to a specific antibiotic, it will have a **zone of inhibition** around the disc for that specific medication, meaning that the antibiotic is able to stop the growth of that particular microorganism so that no growth occurs near the disc on the agar plate. If bacterial growth is present right up to the disc and there is no visible zone of inhibition, this bacteria is **resistant.** A resistant bacteria is not susceptible to the action of a particular antibiotic, so a patient should not be treated with this medication. The zone of inhibition is measured for each type of bacteria, and reported in the laboratory report so that the health-care provider will have the knowledge needed to treat the patient appropriately using antibiotics that will inhibit the growth of the specific pathogen. The Clinical and Laboratory Standards Institute (CLSI) outlines the reporting methods for disk-diffusion antibiotic testing. The technician reading the results in the microbiology laboratory will measure each zone of inhibition for the antibiotics used. He or she will then use the NCCLS to report the antibiotic susceptibility as sensitive, moderately susceptible, or resistant.

The minimum inhibitory concentration testing procedure is usually performed using an automated instrument. A plastic panel with rows of small wells that are filled with a specific concentration of antibiotic is used. The microbiology technician will inoculate each well with a dilution of the culture specimen. (This may also be performed automatically.) After incubating for approximately 24 hours, the wells are checked for evidence of bacterial growth, which presents as a cloudy appearance. The well that has the lowest concentration of a specific antibiotic that does not show evidence of growth is reported as the minimum inhibitory concentration of that specific antibiotic. The laboratory report will include the list of antibiotics tested and the MIC for each of them. It will also interpret these data further to state whether that bacteria is susceptible, moderately susceptible, or resistant to the antibiotic.

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Test Your Knowledge 10-26

Why are antibiotic discs used when performing sensitivities? (Outcome 10-21)

POINT OF INTEREST 10-4
Antibiotic resistance

The discovery and further development of antibiotics has been an incredible asset to public health. Millions of lives have been saved, and our life expectancy has increased as a result of the positive steps we have taken to battle infectious diseases. Unfortunately, these steps are not without complications. As we develop more and more complex drugs, the microorganisms in our environment are beginning to develop resistance to our antibiotics. This is especially evident in the drug classifications that are considered first line of defense: the drugs that are cheapest and easiest to use. This resistance is most recognizable in the types of infections that are most prevalent: those that cause diarrhea, sexually transmitted diseases, diseases of the upper and lower respiratory tract, and especially those that are nosocomial (acquired as a result of hospitalization). Some of the most serious problems include the following:

- Vancomycin-resistant *Enterococcus* (VRE): *Enterococcus* is a genus of bacteria that normally is found in the gastrointestinal system. However, when the bacteria are introduced into other areas of the body (the urinary tract, for instance) they are considered to be pathogenic, and cause serious infections. Many strains have developed a resistance to vancomycin, which was commonly used to treat this type of infection.
- **Methicillin-resistant *Staphylococcus aureus* (MRSA):** Staph is a common bacterium found as normal flora in various areas of our bodies. However, when introduced into a wound or into the bloodstream, it can be a virulent pathogen. Methicillin is a classification of antibiotic that has historically worked well against staph infections, but the levels of resistance are rising dramatically to this drug. MRSA is an aggressive pathogen, and may be difficult to treat effectively because of its virulence. It is estimated that up to 20% of our population may be colonized with MRSA at this point.
- Multiresistant *Mycobacterium tuberculosis*: As the number of cases of TB rises around the world, more and more show resistance to one or more of the drugs used for treatment. The regime used for those who have active or latent TB infection now includes more than one drug, as this seems to slow the development of resistant strains, and accelerate the elimination of the pathogen.

Scientists believe that there are multiple factors that contribute to antibiotic resistance: the widespread use of antibiotics in our food sources, historical prescribing patterns of health-care providers worldwide, and patient compliance issues. Whenever an antibiotic is prescribed as treatment for a bacterial infection, the microorganisms either will be eliminated from the patient or they will not. Those bacteria that are not eliminated have now been exposed to the antibiotic, and many have developed a way to "resist" the effects of that particular medication. As these bacteria multiply, their offspring will also have this natural resistance.

Medical assistants can help with educating patients about the importance of this issue. Encourage patients to keep the following issues in mind with antibiotic use:

Always take antibiotics as prescribed. This includes the frequency of the prescription (e.g., take one pill two times per day) as well as the length of time for the dosage. Many patients are tempted to stop taking the medication as soon as they feel better; this allows the bacteria that are still present in their bodies to survive and develop resistance to the antibiotic that they were taking. Patients need to take the prescription as it was written.

Do not take prescriptions that belong to other people. These medications were not prescribed for the specific type of infection that the patient may be exhibiting. Even if two people have the same infection, the required dosage for a medication may be different for each. Self-medicating in this way is a dangerous practice, and contributes to antimicrobial resistance.

Do not insist on antibiotics when the health-care provider feels that the infection is viral in nature. Antibiotics are not effective against viral infections, and taking them when they are not necessary only exposes the body to these medications when they are not needed.

Do not insist on a "higher grade" antibiotic when the more common drug may be just as effective. Many patients feel that penicillin, tetracycline, and similar first-line drugs could not be the best thing for them, as they are convinced that the newest drug developed must be better. Follow the guidance of your health-care provider and your pharmacist; they are more familiar with the specific dosage recommendations for these drugs.

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MICROBIOLOGY TEST RESULTS

It can be difficult to interpret the results for microbiology testing by identifying the information that is clinically significant. Both the culture report and the sensitivity result may be present on the same document. This may be ordered or reported as a **culture and sensitivity (C&S) report**. Each laboratory has a unique system that it uses for reporting, but there are a few similarities common to all reports. The report will provide information about the microorganisms that are isolated from the culture, as well as relative amounts of these different microorganisms. When the report is final, there may also be antibiotic sensitivity data provided for bacterial cultures so that the health-care provider will be able to suggest treatment with the best medication available. This may be reported in several ways, so it is important for the medical assistant to gain an understanding of the report format used by his or her laboratory in order recognize abnormal values and bring them to the attention of the health-care provider. Figure 10-13 provides an example of a microbiology laboratory report.

Test Your Knowledge 10-27

What is a C&S report used to document?

(Outcome 10-22)

LZ labs

Laboratory Services
P.O. Box 44444
Seattle, WA 98124-1944

Patient: Thompson, Casandra (MR#: 123456)
DOB: 01/25/1930, (81Y) Sex: F
PCP: Grant, D.

Status: FINAL
Collected: 02/02/2012 15:20
Resulted: 02/06/2012 09:12
Printed: 02/09/2012 10:33
LabID: 18081424

Culture, Urine	
SPECIMEN DESCRIPTION	Urine 81yo female with catheter related UTI.
SPECIAL REQUESTS	Report principal pathogen only.
RESULT	Providencia rettgeri
REPORT STATUS	Final 02/08/2012
SUSCEPTIBILITY	
ORGANISM	Providencia rettgeri
METHOD	MIC
Ampicillin	16 Intermediate
Amoxicillin/Clavulanic Acid	32 Resistant
Cefazolin	Resistant
Ceftriaxone	<=8 Susceptible
Gentamicin	<=4 Susceptible
Nitrofurantoin	>128 Resistant
Trimeth-sulfamethoxazole	>4 Resistant
Aztreonam	<=2 Susceptible
**SUSCEPTIBILITY COMMENT	See below: Enterobacter, Citrobacter and Serratia species may develop resistance during prolonged therapy with third-generation cephalosporons. Repeat testing of these organisms is recommended after 4 days of therapy.
Cefepime	<=2 Susceptible
Ciprofloxacin	1 Susceptible
Amikacin	<=4 Susceptible
Imipenem	<=1 Susceptible
Meropenem	<=1 Susceptible
Pip/tazobactam	<=8 Susceptible
Tobramycin	Resistant

Performing Laboratory
LZ Laboratory, Lincoln George, M.D.
42600 1st Ave, Seattle, WA 98168 206-983-4456

Figure 10-13 Microbiology laboratory report.

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SUMMARY

One of the most diverse areas of the laboratory is the microbiology department. Specimen requirements, processing procedures, and culture techniques are very specific and varied. Basic aseptic procedures and labeling techniques are common for all specimen types. As part of their role in quality microbiology testing, medical assistants need to remain knowledgeable about the type of test ordered, the specimen required for each kind of test, and the processing requirements. It is also very important that medical assistants know how to read the microbiology reports used by the laboratory so that clinically significant results are recognized and handled appropriately.

TIME TO REVIEW

1. Inoculation is the: Outcome 10-1
   - **a.** Addition of a specimen to a culture medium for growth
   - **b.** Addition of antibiotics to a culture medium
   - **c.** Separation of colonies on a culture plate
   - **d.** Gram staining of a specimen

2. True or False: Mycoses are the various types of fungal infections that may be present on or in humans. Outcome 10-1

3. Hemolytic uremic syndrome is a severe consequence of which type of infection? Outcome 10-1
   - **a.** *Shigella*
   - **b.** *Salmonella*
   - **c.** *E. coli* O157:H7
   - **d.** *Yersenia*

4. A nasopharyngeal culture specimen is obtained by access through the: Outcome 10-13
   - **a.** Mouth
   - **b.** Nose
   - **c.** Eye
   - **d.** Pharynx

5. Which of these is not a type of culture media? Outcome 10-3
   - **a.** Slant
   - **b.** Broth
   - **c.** Agar
   - **d.** Aerobe

6. True or False: Sample collection supplies and transport media for bacterial, viral, and fungal cultures are all different. Outcome 10-4

7. Why should sputum samples be protected from light? Outcome 10-6

8. Which of these statements is false concerning the collection procedures for blood cultures? Outcome 10-8
   - **a.** Blood cultures are rarely collected
   - **b.** Aseptic technique is essential to avoid contamination of the specimen and misdiagnosis of the patient
   - **c.** Blood is usually added to more than one bottle after collection
   - **d.** Physicians may order blood cultures to be drawn serially at set time intervals

9. Genital samples may be used to detect infections with: Outcome 10-10
   - **a.** *Candida albicans*
   - **b.** *Trichomonas vaginalis*
   - **c.** *Neisseria meningitides*
   - **d.** All of the above

10. Preservatives are used for transport of specimens to be examined for presence of ova and parasites because: Outcome 10-17
    - **a.** The preservatives provide nutrition for the parasites in the sample
    - **b.** The appearance of the parasites and their eggs are kept near those of their natural state in the body
    - **c.** The preservatives keep the parasites alive so that they can grow in the laboratory
    - **d.** All of the above

11. What time of day should a pinworm sample collection occur? Outcome 10-18
    - **a.** Just before bedtime
    - **b.** Randomly; the time of day is not important
    - **c.** First thing in the morning
    - **d.** Right after bathing in the morning

12. Gram-positive microorganisms will appear _____ after the Gram-staining procedure is complete. Outcome 10-19
    - **a.** pink
    - **b.** purple
    - **c.** blue
    - **d.** black

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13. The quadrant method describes: Outcome 10-20
    a. A technique used to inoculate an agar plate
    b. A technique used for Gram stains
    c. A technique used for collection of wound culture specimens
    d. A calculation used for antibiotic sensitivity reporting

14. When reading a microbiology laboratory report, why is it important for the healthcare provider to be familiar with the normal flora commonly present in the area of the body where the specimen was collected? Outcome 10-22

Case Study 10-1: How long is too long?

Marti is a certified medical assistant working in a busy internal medicine practice. There is a new receptionist who is working at the front counter this week, and Marti has found that the receptionist is a bit overwhelmed by the volume of patients the practice is seeing today. The morning appears to be uneventful, but at 2 p.m., the new receptionist brings a urine specimen back to Marti. The receptionist tells Marti that it was dropped off that morning before lunch, but that she forgot to do anything with it until now. Marti sees that the physician has ordered a culture on the urine specimen, and that the urine is in a specimen cup without preservative.

1. What should Marti do?

Case Study 10-2: A sticky situation

Mrs. Oliver brings in her 3-year-old who is complaining of intense anal itching. Lanette, the medical assistant, is asked to collect a sample for examination of potential pinworm infection. This is a procedure she has not performed often, and Lanette is a bit nervous. She decides that the best approach is to speak very little to Mrs. Oliver and the child so that process goes quickly.

1. For this procedure, is this the best approach?
2. If you were Lanette, how would you explain the process to Mrs. Oliver and her child?

RESOURCES

"Antimicrobial Resistance"
World Health Organization
Excellent overview about the progressing issues with antibiotic resistance around the world http://www.who.int/mediacentre/factsheets/fs194/en/

"Antony van Leeuwenhoek (1632–1723)"
History of Leeuwenhoek and the early discoveries of bacteriology http://www.ucmp.berkeley.edu/history/leeuwenhoek.html

BacT/ALERT blood culture collection procedure
An overview of the supplies provided with the culture collection kit and their use. http://www.biomerieux-usa.com/upload/Worksafe-Blood-Culture-Collection-Procedure-1.pdf

"Lumbar Puncture and Spinal Fluid" by John E. Greenlee, MD.
Information about how a spinal fluid specimen is obtained, and how it is processed umed.med.utah.edu/neuronet/pda/2002/HO%20LP%20Spinal%20Fluid%20Greenlee%202002.doc

"Cerebrospinal Fluid Analysis," in Encyclopedia of Surgery: A Guide for Patients and Caregivers
Great article on the clinical indications of a need for CSF collection, the laboratory test results, and potential poor outcomes of the procedure. http://www.surgery-encyclopedia.com/Ce-Fi/Cerebrospinal-Fluid-CSF-Analysis.html

"Disease Listing: Campylobacter General Information"
CDC Division of Foodborne, Bacterial and Mycotic Disease. http://www.cdc.gov/nczved/dfbmd/disease_listing/campylobacter_gi.html

"Disease Listing: Salmonella General Information"
CDC Division of Foodborne, Bacterial and Mycotic Disease, http://www.cdc.gov/nczved/dfbmd/disease_listing/salmonellosis_gi.html

"Disease Listing: Shigella General Information"
CDC Division of Foodborne, Bacterial and Mycotic Disease, http://www.cdc.gov/nczved/dfbmd/disease_listing/shigellosis_gi.html

"Pinworm Fact Sheet"
CDC Division of Parasitic Diseases
Great information about pinworm infestation http://www.cdc.gov/ncidod/dpd/parasites/pinworm/factsht_pinworm.htm

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"Educational Commentary on the Preservation of Fecal Specimens for Ova and Parasite Examination"
Excellent information about pros and cons of different preservatives used for O&P examinations; sponsored by the American Society of Clinical Pathology http://www.api-pt.com/pdfs/2002Amicro.pdf

"Training Material Facilitates Proper Nasopharyngeal Swab Collection"
Training module for nasopharyngeal swab collection http://www.rapidmicrobiology.com/news/2023h4.php

"UV Light Cuts Spread of Tuberculosis," Science Daily, March 19, 2009
Information about studies performed for new methods of controlling the spread of tuberculosis within healthcare facilities http://www.sciencedaily.com/releases/2009/03/090316201505.htm

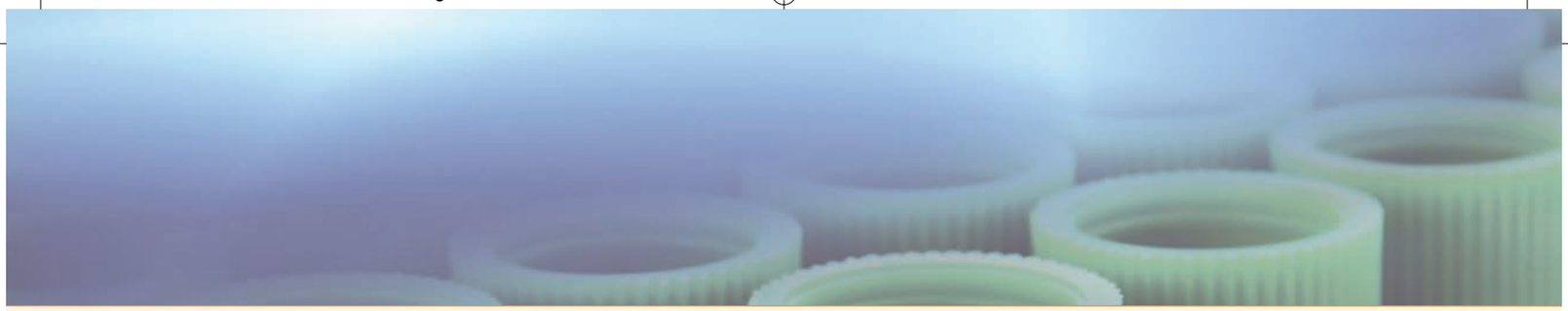

Section II

Specimen Collection and Processing

What Does it All Mean?

As this section clearly points out, proper specimen collection and processing is paramount to obtain accurate and reliable laboratory results. Our Case in Point for this section demonstrates the importance of proper specimen collection and processing.

Case in Point

As you may recall, Wilma F. is a 70-year-old female who presented to the doctor's office where you work complaining of burning and painful urination. She felt hot to the touch as confirmed by her temperature that was 101.5°F. The doctor asked you to collect blood and urine samples for laboratory testing.

Based on the patient's symptoms and the fact that Wilma has a history of urinary tract infections (UTIs), it is likely that she once again has an infection. If she only has a UTI, the urine collected for culture will reveal significant microorganism growth but the bloodstream will be free of microorganisms and the corresponding blood culture results will be reported as "negative." If however, microorganisms establish residence in Wilma's bloodstream, her blood culture results will be considered "positive." It is common for patients to start out with a UTI and then progress into a bloodstream infection. In these cases, the same microorganisms often are found in both the blood and urine culture specimens.

In Wilma's case, she has symptoms of both a blood and urine infection. Wilma's high temperature suggests a possible blood infection whereas her problems with urination indicate a urine infection. The question now is: What microorganisms are causing these problems for Wilma? With the appropriate collection and handling of Wilma's urine and blood samples, the chances of getting reliable and accurate laboratory results is excellent. While the doctor is waiting for the results to come back, he will likely begin Wilma on a suitable treatment known to treat a variety of microorganisms, often referred to a broad-spectrum treatment. He will then adjust treatment if necessary after the microorganisms have been identified and the laboratory results are obtained.

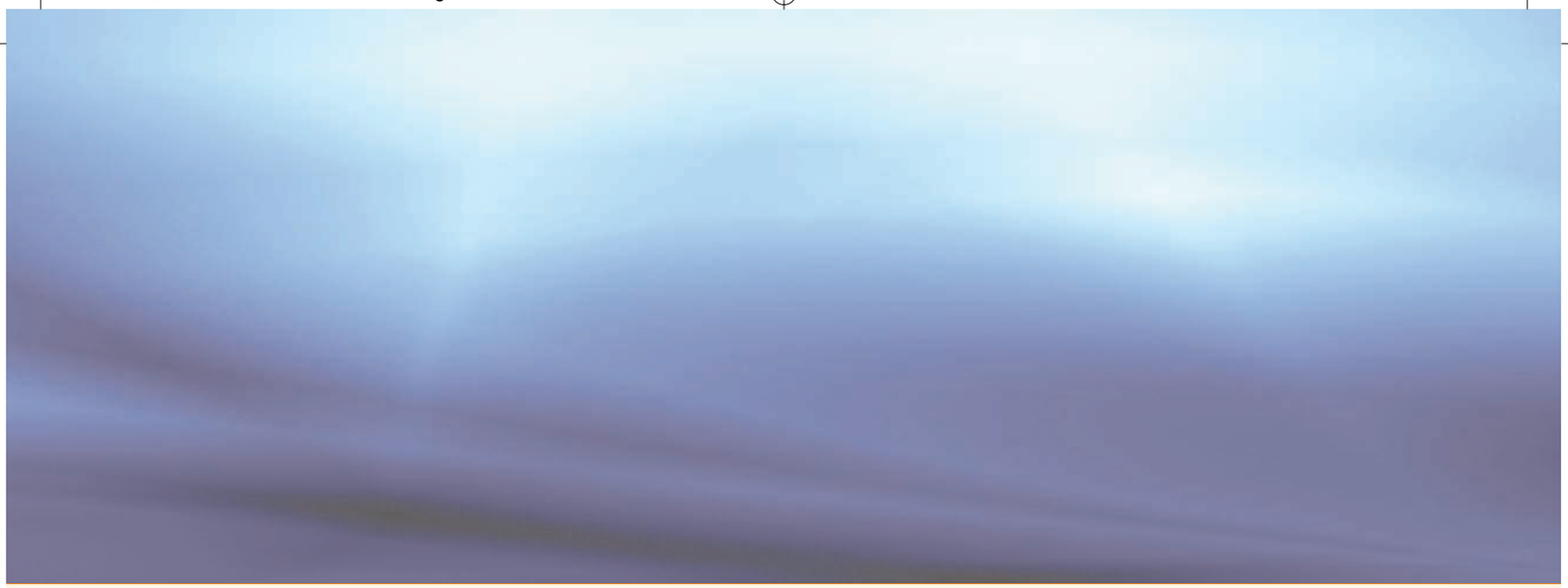

On the Horizon

The study of blood and blood-forming tissues is known as *hematology*. *Coagulation* refers to the clotting of blood. Because these two concepts interconnect, corresponding testing is often conducted in the same area of the clinical laboratory. The results generated by performing hematology and coagulation testing are of monumental importance in the diagnosis and monitoring of a number of diseases and conditions.

Relevance for the Medical Assistant

Medical assistants may be called upon to collect samples and in some instances perform CLIA-waived tests that fall into the hematology and coagulation category. An understanding of this area of laboratory testing is essential to recognize the clinical significance of test results and to anticipate the needs of the health-care provider when dealing with the patients. In addition, medical assistants need to have a full understanding of their role in the preanalytical process while preparing patients and specimens for testing

Continued on page 258.

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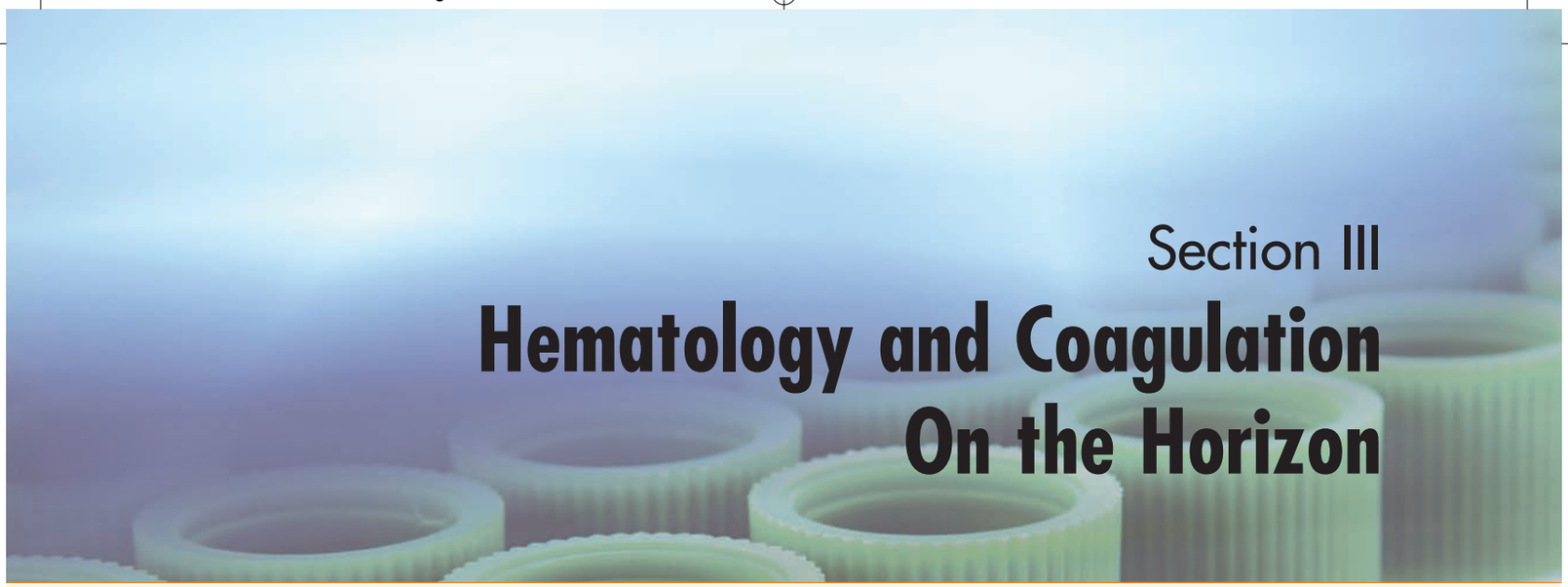

Section III
Hematology and Coagulation On the Horizon

The fundamental concepts associated with hematology and coagulation are covered in six chapters that make up this section of the text, as outlined below.

Chapter 11: Overview of Hematology introduces the reader to the formation, description, and analysis of the three key types of cells in the circulating blood: red blood cells (RBCs), white blood cells (WBCs), and platelets.

Chapter 12: Complete Blood Count With Differential explores the key components of the most commonly ordered battery of hematology tests, known as a complete blood count (CBC).

Chapter 13: Hemoglobin and Hematocrit examines the description, theory, and testing (with emphasis on CLIA-waived procedures) of these two important hematology tests: hemoglobin (Hgb) and Hematocrit (Hct). An independent examination of each test as well as an investigation of the relationship between them are made, because of their importance in the diagnosis and monitoring of hemoglobinopathies, anemia, and polycythemia.

Chapter 14: Erythrocyte Sedimentation Rate covers the description, theory, and testing (with emphasis on CLIA-waived tests) of the erythrocyte sedimentation rate (ESR) test. This test, often in combination with other laboratory tests, is of importance in instances of inflammation changes and in monitoring pregnancies.

Chapter 15: Coagulation Studies introduces the reader to the purpose of coagulation studies, the mechanism of blood clotting, disorders associated with abnormal coagulation test results, and commonly performed coagulation tests. Select coagulation laboratory tests that are useful in the diagnosis of disorders and monitoring of anticoagulant therapy as well as specimen requirements for testing are covered.

Continued from page 256.

Case in Point

You are the primary medical assistant working at Midtown Medical. In the midst of a very busy Monday, Margie, the receptionist, informs you that a new patient, M.J., has been worked into the schedule and is here now to be evaluated. After greeting M.J. and recording his weight and height, you take him into the examination room. While preparing to take his blood pressure and pulse, you ask M.J. what brings him in to see the doctor today. You find out that up until a few weeks ago, this 38-year-old male had been in the best of health. The symptoms he has been experiencing consist of an overall feeling of being tired and weak, and every time he brushes his teeth his gums bleed. After questioning M.J. further, you find out that he was recently hospitalized after a tractor accident and had received a blood transfusion at that time. You notice while talking to him that he looks very pale. The doctor orders blood to be drawn for a complete blood count (CBC), and coagulation studies (PT and APTT). The following results are obtained:

LABORATORY REPORT
PATIENT: M.J.

Complete Blood Count (CBC)

Test	Patient Result	Reference Range for Adult Males
WBC count	10.0	4,000–11,000/mm^3
RBC count	3.0	5.5–6.5 $\times$ 10^6/mm
Hgb	9.0	14–18 g/dL
Hct	30	42%–54%
RBC Indices	>>>>>>>>>	>>>>>>>>>
MCV	86	80–96 femoliters
MCH	31	27–33 picograms
MCHC	35	33–38 g/dL
Platelet count	28	140–400 $\times$ 10^3/mm^3
Differential	>>>>>>>>>	>>>>>>>>>
Neutrophils	65	50%–70%
Bands	5	3%–5%
Lymphocytes	23	23%–30%
Monocytes	6	3%–7%
Eosinophils	1	1%–3%
Basophils	0	0%–1%
Cell morphology	Few schistocytes present	

Coagulation Studies

Test	Patient Result	Reference Range
Prothrombin time (PT)	18 seconds	10–14 seconds
Activated partial thromboplastin time (APTT)	47 seconds	20–35 seconds

Questions for Consideration:

- What type and color of blood-drawing tube should be used for this patient so that the laboratory can perform the complete blood count (CBC) test?
- What type/color of blood-drawing tube should be used for this patient so that the laboratory can perform the coagulation studies?
- Examine the patient's laboratory results. Which of these results is/are considered as "abnormal" (that is, out of the reference range)?
- What laboratory results obtained most likely account for the patient's being pale?
- What is the purpose of the coagulation studies tests (PT & APTT)?

Chapter 11

Overview of Hematology

Nikki A. Marhefka, EdM, MT(ASCP), CMA (AAMA)

CHAPTER OUTLINE

Hematopoiesis—Blood Cell Formation
Types of Blood Cells in the Circulating Blood
- Erythrocytes—Red Blood Cells
- Leukocytes—White Blood Cells
  - *Granular White Blood Cells*
  - *Agranular White Blood Cells*
- Thrombocytes—Platelets

Analysis of the Formed Elements
Summary
Time to Review
Case Studies
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

11-1 Define the key terms.

11-2 Summarize the process of blood cell formation.

11-3 State the three types of formed elements in the circulating blood and the function of each cellular element.

11-4 Describe the appearance of a reticulocyte and provide examples of situations in which there are increased numbers of reticulocytes in the circulating blood.

11-5 Differentiate the appearance and function of the five types of leukocytes normally present in the circulating blood.

11-6 Describe the appearance of a band cell, and explain when there may be an increased number of band cells in the circulating blood.

11-7 Describe the appearance and function of platelets.

11-8 List three CLIA–waived hematology testing procedures that may be performed in a physician office.

CAAHEP AND ABHES STANDARDS

CAAHEP Standards met:

I.C.I.2. Identify Body Systems
I.C.I.4. List major organs in each body system
I.C.I.5. Describe the normal function of each body system
I.C.I.6. Identify normal pathology related to each body system

ABHES Standards met:

None

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KEY TERMS

Agranular
Band cell
Basophil
Bilobed
Blast cells
Complete blood count (CBC)
Diapedesis
Eosinophil
Erythrocyte
Erythrocyte sedimentation rate (ESR)
Erythroid
Erythropoietin
Formed element
Granular
Granulocyte
Granulocyte-macrophage colony-stimulating factor (GM-CSF)
Hematocrit
Hematology
Hematopoiesis
Hemoglobin
Hemostasis
Heparin
Histamine
Interleukin
Intrinsic factor
Leukocyte
Lobulated
Lymphocyte
Lymphoid
Megakaryocyte
Monocyte
Myeloid
Neutrophil
Phagocytosis (phagocytic, phagocytize)
Platelet
Pluripotent
Polychromatic stain
Polymorphonuclear
Red blood cell (RBC)
Reticulocyte
Reticulum
Stem cells
Thrombocyte
Thrombopoietin
Thrombus
White blood cell (WBC)

Blood is a specialized connective tissue that consists of **formed elements** suspended in liquid plasma. Approximately 38% to 48% of the total blood volume is made up of these formed elements, including **red blood cells (RBCs; erythrocytes), white blood cells (WBCs; leukocytes),** and **platelets (thrombocytes).** The cells function in important ways to keep the human body healthy and safe. The primary function of the erythrocytes is to carry oxygen to the tissues of the body, whereas the leukocytes help to fight off infection within the body. The thrombocytes are present to assist with blood clotting and repair of blood vessel damage. Each of the cell types may be identified by characteristics of its nucleus and cytoplasm.

Hematology is defined as the study of blood and blood-forming tissues. However, more specifically, it is the word used to describe the study of the formed elements in the blood. This chapter explores the process involved with the formation of cellular elements in the bone marrow, and discusses identification and functions of erythrocytes, leukocytes, and thrombocytes.

Test Your Knowledge 11-1
List the three formed elements present in the circulating blood. (Outcome 11-3)

HEMATOPOIESIS—BLOOD CELL FORMATION

Blood cell formation, a process known as **hematopoiesis** (Fig. 11-1), occurs primarily in the red bone marrow. In children, most bones contain red marrow. In the adult (individuals greater than age 20), red marrow is found in the flat bones (vertebrae, ribs, iliac crest, and sternum). **Stem cells** are the precursors of all blood cells and are present in the bone marrow. They are pluripotent, which means that they have the ability to differentiate into several types of specialized cells. These stem cells may divide into precursor stem cells classified as **myeloid** or **lymphoid.** Erythrocytes and most of the white blood cells are capable of arising from myeloid precursor cells. Specialty white blood cells responsible for the majority of the body's immune protection, known as **lymphocytes,** arise from the lymphoid precursor

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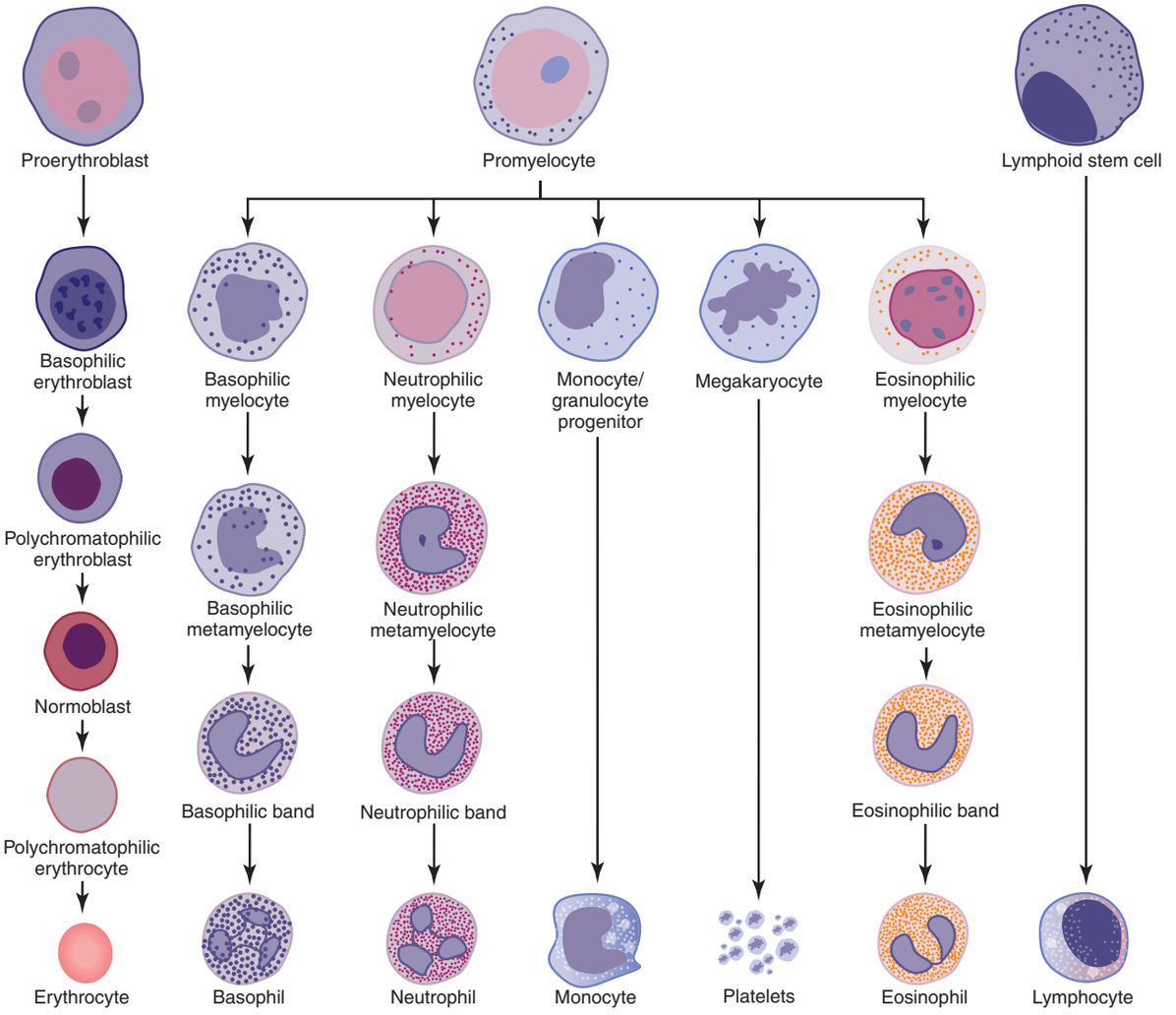

Figure 11-1 Hematopoiesis. The production and maturation of the blood cells and fragments.

stem cells. It is important to note that lymphocytes are also produced and processed in the thymus gland and secondary lymph organs, in addition to their production in the bone marrow. Descriptions of the formed elements in the blood are summarized in Table 11-1.

Myeloid and lymphoid stem cells, once developed, differentiate to produce **blast cells,** which are the first identifiable immature cell stages of what eventually become erythrocytes (RBCs), leukocytes (WBCs), and thrombocytes. Blast cells mature and go through a number of stages before they are transformed into mature cells. Numerous functions of the spleen are associated with the development, storage, breakdown, and removal of specific blood cells, as noted in Box 11-1.

Under normal circumstances, only the mature blood cells will enter the circulating blood. Immature forms of the blood cells may be present in the circulating blood in disease states. For example, immature red blood cells may be evident in the circulating blood with anemia, and immature white blood cells may be present with leukemia. The cellular components of the bone marrow can be studied by making slides of the marrow, staining it, and studying it under the microscope. The sample for evaluation is obtained from the marrow cavity of the flat bones.

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TABLE 11-1
Formed Elements of the Circulating Blood

Blood Cell	Size	Description	Function
		Leukocytes	
Neutrophil	9–15 microns	Multilobed nucleus, grayish purple granules	Phagocytic, increases in bacterial infection
Band cell	9–15 microns	C-shaped nucleus, grayish purple granules	An immature neutrophil, increases in bacterial infection
Eosinophil	10–16 microns	Bilobed nucleus, large red-orange granules	Phagocytic, detoxifying
Basophil	10–14 microns	Bilobed nucleus, large blue-black granules	Release histamine and heparin
Lymphocyte	7–18 microns	Large dark nucleus, little light blue cytoplasm (There are larger ones with larger less dense nuclei and more cytoplasm.)	Produce antibodies, involved in cell-mediated immunity
Monocyte	12–20 microns	Large foamy convoluted nucleus, little or no granules in cytoplasm	Travel to tissue to become macrophage, phagocytic
Erythrocytes	6–8 microns	No nucleus, biconcave discs	Carry oxygen in blood to the tissues
Thrombocytes	0.5–3 microns	Small cytoplasmic fragments	Blood clotting

BOX 11-1 Functions of the spleen associated with blood cells

- Site of red blood cell formation in the fetus
- Site of worn out red blood cell and platelet removal
- Site of old red blood cell breakdown
- Site of hemoglobin (from the worn-out red cells) decomposition
- Stores some iron from hemoglobin decomposition
- Contains red blood cell and platelet pools for use when needed
- Areas of lymphocyte proliferation and immune surveillance and response

A number of factors are produced by the body to stimulate the production of blood cells. **Intrinsic factor** helps with B_{12} absorption in the digestive tract, and B_{12} is critical for red blood cell formation. **Thrombopoietin** from the liver stimulates production of platelets, and **granulocyte-macrophage colony-stimulating factor (GM-CSF)** increases the formation of leukocytes. **Interleukins** influence the growth and activation of the lymphocytes. **Erythropoietin** stimulates the bone marrow to produce more red blood cells when needed in the body. When the oxygen level is low in the tissues, the kidneys produce more erythropoietin to stimulate the differentiation and growth of the **erythroid** (pertaining to erythrocyte) cells in the bone marrow to increase the number of circulating red blood cells. Blood loss, such as from a bleeding ulcer, anemia, or low oxygen levels in the lungs due to high altitude or lung disease cause an increase in erythropoietin.

POINT OF INTEREST 11-1
Bone marrow aspiration

In some clinical situations, medical practitioners need to visualize what is occurring in the bone marrow to make an accurate diagnosis. A bone marrow biopsy is not a procedure that is performed casually because the process may be painful and is very invasive. A sample of the red marrow may be obtained to look for the cell distribution, iron stores, or cell maturity. The information gained from the sample may provide valuable clues needed for a differential diagnosis, and therefore, may be very valuable.

Red bone marrow is found in the ribs, sternum, ilium, vertebrae, and the epiphyses of the long bones of adults. In children, it is found in the shafts of the long bones as well. The red marrow is generally the same in each of these areas, so a sample may be taken from any location. The site for the biopsy and aspiration is usually the posterior iliac crest. The sternum and the broad end of the tibia are other sites that may be utilized, although not as frequently as the iliac crest.

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A sample of the bone marrow can be obtained using a special hollow needle with a stylus insert. The aspiration is completed using sterile technique to prevent infection and/or inflammation of the bone, which is called osteomyelitis. The patient is usually in a prone position so that the iliac crest is fully exposed and supported. The skin, subcutaneous tissues, and the periosteum are anesthetized with a local anesthetic to reduce discomfort to the patient. A special hollow aspirate, needle is used to penetrate through the layers of tissue and into the bone. A twisting motion is necessary for the needle to reach the destination. Once the marrow cavity has been entered, the stylus part of the needle device is removed, and a syringe is attached to the end of the hollow needle that is exposed. Fluid is aspirated, and some of the marrow material is obtained. The medical assistant or laboratory technologist that is assisting with the procedure must verify whether the sample is valid by observing its appearance.

The aspirated sample is placed on a clean glass slide. The liquid sample from the marrow may be spread across the slide using a similar procedure as that used when preparing a blood smear. There will also be solid components of the bone marrow obtained; these are called spicules, and they are slowly rotated across a slide to make impressions for examination. These solid components are then placed in preservative for further studies if necessary. The slides are stained and the preparations are assessed under the microscope by a pathologist or hematologist.

After the procedure has been completed, the medical assistant will prepare the slides, clean up the supplies and assist with the application of a pressure bandage to the puncture site.

Test Your Knowledge 11-2

Define *hematopoiesis*. (Outcome 11-2)

Test Your Knowledge 11-3

Stem cells are described as pluripotent. What does this mean? (Outcome 11-2)

TYPES OF BLOOD CELLS IN THE CIRCULATING BLOOD

As was introduced earlier in this chapter, there are three categories of cells circulating in blood: erythrocytes, leukocytes, and thrombocytes. A description and function of the primary members in each category are detailed in the following sections.

Erythrocytes—Red Blood Cells

Erythrocytes, also known as red blood cells (RBCs), are the most numerous formed element in the blood. The number of red blood cells in the body varies with the gender and age of the patient, but there are approximately 4.2 to 6.5 million in a milliliter of blood. Normal red blood cells measure 6 to 8 microns in diameter. The red blood cells are smaller than the white blood cells in the body, but larger than the platelets. Red blood cells perform their duties within the blood vessels and do not enter the tissues normally.

The primary function of red blood cells is to carry oxygen to all tissues of the body. Each red blood cell contains an iron pigment responsible for oxygen transport known as **hemoglobin.** Oxygen enters the capillaries that surround the alveoli of the lungs and moves to each red blood cell, where it attaches to the hemoglobin. Hemoglobin is a protein composed of an iron-containing pigment and globulin (a type of protein). Hemoglobin gives red blood cells their characteristic reddish color. Blood is a brighter red color in the arteries as more oxygen is attached and is darker red in the venous blood because of less oxygenation. It is interesting to note that some carbon dioxide is carried through the blood via hemoglobin in the red blood cells to be released in the lungs.

Circulating red blood cells have no nuclei and are biconcave (the center is thinner than the thicker edges) in shape. Their unique shape and the lack of a nucleus allow red blood cells to increase their surface area for gas diffusion (oxygen transport) and allow the cells to contain more hemoglobin than a cell with a nucleus. The biconcave shape of the erythrocyte also eases the cells' passage through the capillaries to bring oxygen to the tissues.

Each red blood cell has a life span of approximately 120 days. Mature red blood cells have no organelles and therefore a limited metabolism. Erythrocytes are not capable of producing proteins or enzymes. Red cells undergo much stress as they traverse the blood vessels in the body and they have no repair mechanisms. The red cells are continuously monitored and the old, worn-out ones are recognized and engulfed by the macrophages or the reticuloendothelial system of the liver, spleen, and bone marrow. The functions of the spleen are presented in Box 11-1.

Immature red blood cells, called **reticulocytes,** may also be found in the circulating blood. Reticulocytes exhibit a blue network when stained with a special stain because the cells have not fully matured and still have residual structures present in the cell cytoplasm. The reticulocytes will also appear as large bluish red blood cells when viewed with

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the standard stains used for peripheral blood smears. The blue network is remnant RNA (ribonucleic acid) left in the cell when the nucleus is expelled near the end of the red blood cell maturation. With use of special staining procedures, the remnant RNA is visualized as fine, thread-like strands known as **reticulum.** These immature reticulocytes should remain in the bone marrow until maturity. However, when the demands of the body are increased for red blood cells (as in the event of hemorrhage or massive blood cell destruction), reticulocytes enter the circulating blood. Normally, less than 5% of the circulating red blood cells are reticulocytes. Both erythrocytes and reticulocytes are pictured for comparison in Figure 11-2.

Test Your Knowledge 11-4

Do mature erythrocytes contain a nucleus?

(Outcome 11-3)

Test Your Knowledge 11-5

What type of immature red blood cell may increase if a patient has hemorrhaged due to an injury?

(Outcome 11-4)

Leukocytes—White Blood Cells

Leukocytes are specialized cells that play an essential role in the immune response of the body. White blood cells are the largest blood cells and vary in size from 7 to 20 microns. The total number of white blood cells is 4,300 to 10,800 per cubic millimeter in normal circulating blood. The white blood cells spend most of their life span in the tissues of the body, but the vascular circulation allows white blood cells a mode of transportation throughout the body so that they can respond where necessary. Some WBCs only live a few hours, whereas others live for months or years. Many of them die when they have completed destroying foreign invaders. There are five mature types of white blood cells that are generally found in circulating blood: *neutrophils, lymphocytes, monocytes, eosinophils,* and *basophils* (Fig. 11-3). These cells may be categorized in various ways based on their appearance. One such method is to define them as **granular** or **agranular**.

Granular White Blood Cells

White blood cells that have names ending in –phil (neutrophil, eosinophil, and basophil) have distinct granules visible in their cytoplasm and are known as **granulocytes**. These granules contain digestive enzymes that are designed to destroy or damage foreign cells or microorganisms, or

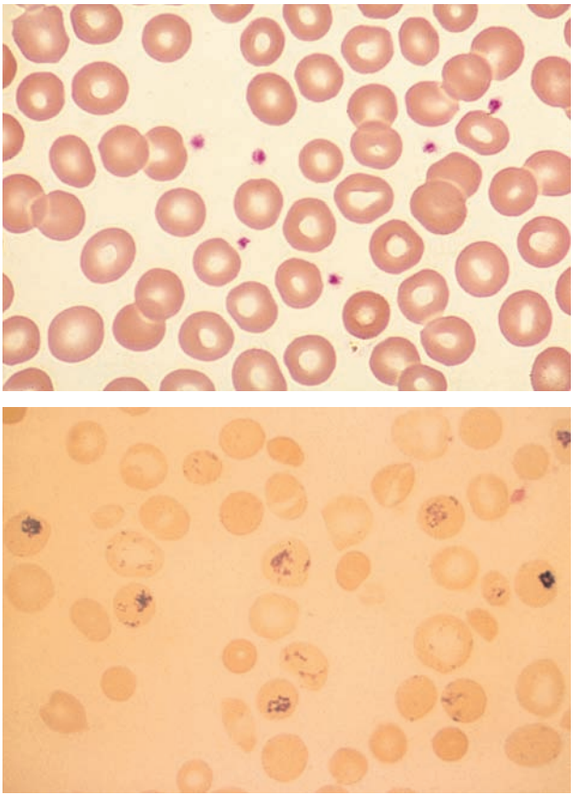

Figure 11-2 Top: Erythrocytes in the circulating blood. Bottom: Reticulocytes The endoplasmic reticulum is visible with new methylene blue stain. *From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed 5. FA Davis, Philadelphia, 2009, with permission.*

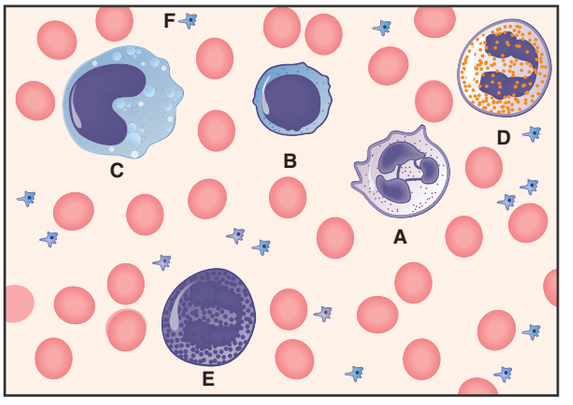

Figure 11-3 Leukocytes and thrombocytes in the circulating blood. A. neutrophil. B. lymphocyte. C. monocyte. D. eosinophil. E. basophil. F. platelet.

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chemicals that assist with the process of destroying invaders. The nuclei of granular cells are arranged in lobes or sections. This appearance of the nucleus is described as **lobulated.** White cells are distinguished by the staining of their nucleus and granules when using a **polychromatic stain** (a stain having many colors, such as Wright's stain). The granular cells live only a few days and dissolve as they age, or are destroyed when they have participated in bacterial destruction.

Neutrophils make up the majority of circulating granular cells, and provide much of the body's protection against infection. A typical neutrophil measures 9 to 15 microns in diameter, has a nucleus with 3 to 5 lobes, and has gray/pale purple granules in its cytoplasm. A neutrophil may also be called a **polymorphonuclear** (PMN) leukocyte, or "poly," because of the multiple lobes of its nucleus. Some laboratories may also describe a neutrophil as a "seg," referring to the segmented appearance of the nucleus in these cells.

The primary function of neutrophils is **phagocytosis,** which is the act of engulfing and destroying foreign invaders. The majority of the circulating white blood cells of adults are usually neutrophils. The number of neutrophils often increases when a bacterial infection is present in the body. A mature neutrophil lives for 10 to 24 hours in the circulating blood. Typically, it takes about 30 minutes for the neutrophil to engulf bacteria. This process destroys the cell, and we often see these dead white cells accumulated as pus.

A **band cell,** as seen in Figure 11-4, is an immature form of the neutrophil that may appear in the circulating blood when there is a high demand for neutrophils by the body. Neutrophils are the first to respond to infection or injury, so the need is increased for an acute infection. The nucleus of a band cell is C shaped as the nucleus has not had a chance to mature into lobes or sections. The cytoplasm of a band cell is the same as that of a mature cell. Normal circulating blood may have some band cells, but they usually make up less than 10% of the total. Band cells may also appear in the circulating blood of patients suffering from disease states that result in overproduction of neutrophils in the bone marrow.

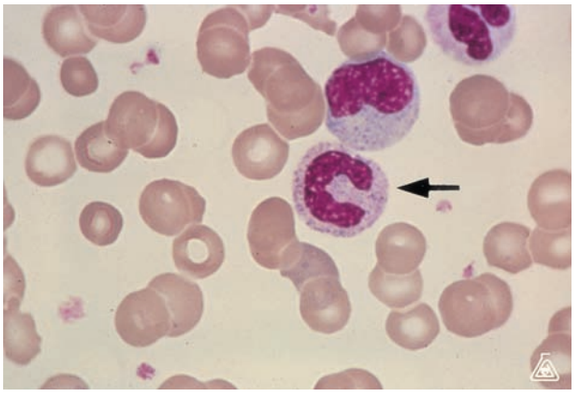

Figure 11-4 A band cell has a C-shaped nucleus and the same granules as the neutrophil.

Eosinophils are 10 to 16 microns in diameter, have **bilobed** nuclei (that is, each nucleus has two lobes or sections), and have large orange/red granules in the cytoplasm. These cells phagocytize invaders attached to antibodies (antigen-antibody complexes) and detoxify foreign substances. (Additional information on these concepts is located in Chapter 24.) An increase in the number of eosinophils is often seen in allergic reactions, myocardial disease, or with parasitic infection. Eosinophils enter the tissues from the blood capillaries and live there for about 6 days.

Test Your Knowledge 11-6

What is the type of white blood cell that will increase in production when a patient has a bacterial infection? (Outcome 11-5)

Test Your Knowledge 11-7

What is the name of the white blood cell that may be increased in number in an allergic reaction? How can this cell be differentiated from the other types of white blood cells? (Outcome 11-5)

Basophils are 10 to 14 micron in diameter, have bilobed nuclei, and large dark blue granules in the cytoplasm. The nucleus is often hard to see, as the granules are so large and dark that they obscure it from view. The granules found in the cytoplasm of basophils contain **heparin** and **histamine.** Heparin helps to prevent blood from clotting, whereas histamine makes blood vessel walls more permeable so that white cells can get into tissues to phagocytize foreign cells and invaders. An increase in basophils is often seen in the presence of chronic infection, when there is healing of infection, in allergic asthma, or in contact allergies. Basophils have a life span of about 6 days.

Agranular White Blood Cells

Lymphocytes and monocytes are considered agranular, as they have few visible cytoplasmic granules**. Monocytes** are the largest of the white blood cells with a diameter of 12 to 20 microns and have a large, convoluted, less densely

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stained nucleus. The cytoplasm often has a "ground-glass" appearance and a pale blue or light gray color. In addition, the cytoplasm of monocytes often contains vacuoles (holes) when viewed under the microscope. Monocytes travel through the vessel walls and out of the circulatory system into the tissues as needed in a process called **diapedesis.** Monocytes are phagocytic in function as they destroy and remove dead cells from tissue. They defend the body against microorganisms and malignant cells. Monocytes live in the circulating blood for 8 to 24 hours and then as macrophages in the tissue for several months. The macrophages assist with removal of all types of old, damaged, or nonfunctional blood cells.

Lymphocytes are the smallest of the white blood cells, with dark, dense nuclei that often take up most of the cell. Lymphocytes traditionally have a small amount of light blue cytoplasm. Lymphocytes may vary in size from 7 to 19 microns in diameter. Lymphocytes appear slightly larger than red blood cells when viewed on a stained slide. Lymphocytes mature into B cells, T cells, and natural killer cells. B lymphocytes become plasma cells and form antibodies. T cells and natural killer cells are active in cell-mediated immunity. (More information about the body's defense system may be found in Chapter 24.) Lymphocytes are usually the most predominant white blood cell in the circulating blood of children until about age 10 years, but they are the second most prevalent type of white blood cell in adults. An increase in number may be seen in viral infections at all ages. The life span of the T cells is months to years and the B cells live only a few days.

Test Your Knowledge 11-8

What type of white blood cell has forms that make antibodies and are active in cell-mediated immunity? (Outcome 11-5)

Thrombocytes—Platelets

Thrombocytes, or platelets, are spherical or ovoid cell fragments which are 0.5 to 3 microns in diameter (Fig. 11-3). There are normally 150,000 to 450,000 platelets per millimeter of blood. Platelets are cytoplasmic fragments of large bone marrow cells called **megakaryocytes.** Two-thirds of the platelets are in the circulating blood at any given time, whereas the other third is stored in a pool in the spleen. The typical platelet life span is 8 to 10 days.

Platelets actively participate in **hemostasis** (the stoppage of bleeding or of circulation). Platelets prevent blood loss and have three functions that begin the clotting process (for more information on hemostasis see Chapter 15). When a capillary is damaged, platelets stick together and adhere to the sides of the cut to form a plug that fills the opening. While forming the plug, platelets secrete a chemical known as serotonin designed to help constrict the blood vessels. Platelets also activate the complex chemical process of coagulation to enhance the platelet plug. Younger platelets are larger and more metabolically active and are more effective in hemostasis.

Platelets sometimes clot within the blood vessels when there is no vessel wall damage. This may result in a **thrombus** (blood clot), which adheres to the wall of a vessel or organ. These clots can occlude (block) the vessels and potentially stop the flow of blood. When the body's tissue does not receive oxygen from the blood, body cells will die. A thrombus may be the cause of a heart attack or a stroke.

Test Your Knowledge 11-9

What are the three hemostatic functions of platelets that prevent blood loss? (Outcome 11-7)

ANALYSIS OF THE FORMED ELEMENTS

In reference and hospital laboratories erythrocytes, leukocytes, and platelets may be identified and counted by automated analyzers capable of processing large volumes of specimens. The cells that make up the formed elements in the blood are typically identified by size, appearance, and other specific characteristics. A **complete blood count (CBC)** is the most commonly ordered hematology test. As the test name implies, this comprehensive test provides practitioners with important information about all three formed elements in the circulating blood. The process of cell formation (hematopoiesis) may be studied by collecting and microscopically examining bone marrow samples in large laboratories. Types of hemoglobin can be identified by the technique of hemoglobin electrophoresis. (More information about these tests is presented in Chapters 12 and 13.)

In the physician office and at the bedside in hospitals, CLIA-waived hematology testing is often performed. The hemoglobin concentration of the blood cells is often measured using a CLIA-waived procedure. The **erythrocyte sedimentation rate** and the **hematocrit** value are other common CLIA-waived tests performed in physician office laboratories. The hematocrit is the percentage of red blood cells in a given volume of blood, and the erythrocyte sedimentation rate is a screening test

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for inflammation that measures the speed at which erythrocytes settle out of anticoagulated blood. Medical assistants or phlebotomists often perform these tests in the physician office laboratory.

Test Your Knowledge 11-10

Name three CLIA-waived hematology tests. (Outcome 11-8)

SUMMARY

Hematology is the study of the cellular (or formed) elements in the blood. The cells of the circulating blood are predominantly formed in the bone marrow by the process of hematopoiesis. Each type of cell matures from the same pluripotent stem cell. The stem cell differentiates into blast cells for each kind of blood cell and then continues to mature into the functioning cells that are released into the circulating blood. These functioning cells include erythrocytes, leukocytes, and thrombocytes. Erythrocytes carry oxygen, leukocytes are part of the immune system, and platelets participate in blood clotting.

Erythrocytes contain hemoglobin, which enables them to transport oxygen throughout the body. An increase of a more immature form of the erythrocyte, the reticulocyte, in the circulating blood can show that the bone marrow is trying to provide sufficient red blood cells at times of crisis. This may mean that the body has increased its demands for oxygen, or that there is a need to replace lost blood cells.

There are five types of leukocytes normally seen in the circulating blood. These white blood cells are neutrophils, eosinophils, basophils, lymphocytes, and monocytes. Each cell is identified by the properties of its nucleus and cytoplasm and has a specific function in the immune process. Thrombocytes are small round cell fragments that are involved in the clotting process.

Blood cells and platelets can be counted and tested for their ability to function. Large analyzers in the reference and hospital laboratories can perform many tests on a large number of specimens or highly specialized testing. The medical assistant can perform the CLIA–waived testing of hemoglobin, hematocrit, and the erythrocyte sedimentation rate. An abnormal number of the formed elements or an abnormal test result can be indicative of a disease process. Testing procedures and clinical significance of the formed elements in the blood are discussed in the following chapters.

TIME TO REVIEW

1. What is the difference between erythropoietin and thrombopoietin? (Outcome 11-1)
   - **a.** Erythropoietin stimulates red blood cell formation and thrombopoietin stimulates white blood cell formation
   - **b.** Erythropoietin stimulates platelet production and thrombopoietin stimulates white blood cell production
   - **c.** Erythropoietin stimulates red blood cell formation and thrombopoietin stimulates platelet production
   - **d.** Erythropoietin stimulates platelet production and thrombopoietin stimulates red blood cell production
2. True or False: During hematopoiesis all blood cells are derived from stem cells. (Outcome 11-2)
3. Which of these statements does not describe the appearance or function of erythrocytes? (Outcome 11-3)
   - **a.** Erythrocytes are biconcave in shape
   - **b.** Erythrocytes assist in blood clot formation
   - **c.** Erythrocytes carry oxygen throughout the body
   - **d.** Erythrocytes are the most numerous found elements in the bloodstream
4. What is the substance in the red blood cells to which oxygen attaches? (Outcome 11-1)
   - **a.** Nuclei
   - b. Vacuoles
   - **c.** Reticulum
   - **d.** Hemoglobin
5. Immature red blood cells that still contain some endoplasmic reticulum which may be visualized in the circulating blood in periods of high demand are called: (Outcome 11-5)
   - **a.** Granulocytes
   - **b.** Reticulocytes
   - **c.** Band cells
   - **d.** Lymphocytes
6. The number of white blood cells in the circulating blood is 4,300 to 10,800 per milliliter and their main function is in: (Outcome 11-3)
   - **a.** Participation in the immune response of the body
   - **b.** Carrying oxygen to the cells of the body
   - **c.** Blood clotting
   - **d.** Liver function

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7. The cytoplasm of these cells have large dark granules that contain heparin and histamine: Outcome 11-6
   a. Neutrophils
   b. Eosinophils
   c. Basophils
   d. Monocytes

8. The type of white blood cells that are most prevalent in adults and that phagocytize foreign invaders are called: Outcome 11-6
   a. Neutrophils
   b. Eosinophils
   c. Basophils
   d. Monocytes

9. The function of these cells is to remove dead cells from tissue. They are called macrophages when they have traveled into the tissues: Outcome 11-6
   a. Neutrophils
   b. Eosinophils
   c. Basophils
   d. Monocytes

10. An immature neutrophil that may be visualized in the circulating blood in a severe infection is called a: Outcome 11-7
    a. Granulocyte
    b. Reticulocyte
    c. Band cell
    d. Lymphocyte

11. Which of the formed elements are involved in hemostasis and prevent blood loss? Outcome 11-3, Outcome 11-8
    a. Reticulocytes
    b. Thrombocytes
    c. Erythrocytes
    d. Leukocytes

Case Study 11-1: Meaning of abnormal results

Dr. Stewart has ordered a CBC to be collected on Mr. Marcus. Lily, the medical assistant, draws the blood sample and sends it to the local reference laboratory with the courier that afternoon. The next day, the results are available and Lily reviews them before placing them on the chart for Dr. Stewart to read. The leukocyte count and the neutrophil count are both flagged as elevated above the normal range.

1. What do you think these two elevated results may mean?

RESOURCES AND SUGGESTED READINGS

"Fun Science Gallery: Let's Observe the Blood Cells" Contains pictures and descriptions of the various blood cells. http://www.funsci.com/fun3_en/blood/blood.htm

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Chapter 12

Complete Blood Count With Differential

Nikki A. Marhefka, EdM, MT(ASCP), CMA (AAMA)

CHAPTER OUTLINE

Complete Blood Count
- Complete Blood Count Specimen Requirements
- White Blood Cell Count
- Red Blood Cell Count
- Hemoglobin and Hematocrit
- Red Blood Cell (Erythrocyte) Indices
- Platelet Count
- Leukocyte Differential Count
- Peripheral Blood Smear
  - *Manual Leukocyte Differential*
  - *Red Blood Cell Morphology*
  - *Platelet Morphology and Estimated Count*
- Manual Blood Cell Counts

Automated Analyzers for Complete Blood Count Testing
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

12-1 Define the key terms.

12-2 Identify the component tests of a complete blood count (CBC).

12-3 Recognize the normal reference ranges for each CBC component.

12-4 Identify examples of disorders that are characterized by an increased red blood cell, white blood cell, or platelet count.

12-5 Identify situations where the white blood cell count may be decreased.

12-6 State the clinical significance of the erythrocyte indices included in a CBC.

12-7 For the five types of normal white blood cells identified on a differential, state the normal reference range in the form of percentages.

12-8 Identify examples of diseases characterized by an abnormal white blood cell differential.

12-9 Differentiate terms used to describe normal and abnormal red blood cell morphology using appropriate medical terminology.

12-10 Describe the appearance of platelets when viewed under the microscope.

12-11 Summarize the general principle of electrical impedance as it relates to automated CBC testing.

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CAAHEP AND ABHES STANDARDS

CAAHEP 2008 Standards

I.C.1.6. Identify common pathology related to each body system
I.A.I.1. Apply critical thinking skills in performing patient assessment and care

ABHES 2010 Standards

None

KEY TERMS

Anemia
Anisocytosis
Blast
Complete blood count (CBC)
Differential
Electrical impedance
Hematocrit (Hct)
Hemoglobin (Hgb)
Hemocytometer
Histogram
Hyperchromic
Hypochromic
Leukemia
Leukocytosis
Leukopenia
Lysed
Macrocyte
Mean corpuscular hemoglobin (MCH)
Mean corpuscular hemoglobin concentration (MCHC)
Mean corpuscular volume (MCV)
Microcyte
Morphology
Normochromic
Normocytic
Ovalocyte
Poikilocytosis
Polychromatic stain
Polycythemia
Red blood cell index
Sickle cell
Spectrophotometrically
Spherocyte
Target cell
Thrombocythemia
Thrombocytopenia
Thrombocytosis

A complete blood count (CBC) provides physicians and other health-care professionals with an overview of cells and cell fragments in the circulating blood. The amounts of different types of cells in the specimen as well as physical characteristics of these cells are included in the CBC results. Used alone or along with other diagnostic and laboratory tests, the CBC helps the physician diagnose disorders, follow the course of treatment, and determine prognoses. This chapter introduces the reader to each of the major CBC components as well as presents an overview of automated analyzers used in CBC testing.

COMPLETE BLOOD COUNT

The **complete blood count (CBC)** comprises a series of tests, each with its own reference range, as listed in Table 12-1. The tests are usually performed using an automated hematology analyzer, but some of them may also be performed using manual methods. Components of a CBC include the following:

- *A white blood cell (WBC) count*, providing the number of white blood cells present in the sample.
- A *red blood cell (RBC) count,* which provides the total number of red blood cells present in the specimen.
- **Hemoglobin** concentration, which is the concentration of the iron-containing pigment in red blood cells which binds to oxygen.
- **Hematocrit**, which is the percentage of red blood cells in a given volume of blood.
- Three **red blood cell indices,** defined as numerical descriptions of the RBCs present.
- A *platelet count,* which provides a quantitative measurement of the platelets present in the specimen
- The *white blood cell differential,* which provides quantitative information about the types of white blood cells present in the specimen.

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TABLE 12-1

Suggested Reference Ranges for Component Tests of the Complete Blood Count

White blood cell count	4,300 to 10,800/mm^3
Red blood cell count	Adult female: 4.2–5.9 $\times$ 10^6/mm^3
	Adult male: 4.6– 6.2 $\times$ 10^6/mm
Hemoglobin concentration	Adult female: 12 to 16 g/dL
	Adult male: 13 to 18 g/dL
Hematocrit	Adult female: 37%–48%
	Adult male: 45%–52%
Red blood cell indices	MCV 80–100 femtoliters
	MCH 27–31 picograms/cell
	MCHC 32–36 g/dL
Platelet count	150 to 450 $\times$ 10^3/mm^3
Differential	
Neutrophils	54%–65%
Lymphocyte	25%–40%
Monocyte	2%–8%
Eosinophil	1%–4%
Basophil	0%–1%

The hemoglobin and hematocrit tests included in the CBC are CLIA-waived test procedures. However, the other tests included in the complete blood count are categorized as moderately or highly complex by CLIA. Medical assistants may perform moderately complex automated hematology testing with appropriate documented training and supervision. Medical assistants can also perform a normal manual differential from a stained blood smear if they are specially trained and appropriately supervised for this moderately complex procedure.

For the CLIA moderately complex tests, the following additional steps must be taken for appropriate documentation, training, and quality control:

1. All laboratories that perform tests of moderate complexity must be registered with the Centers for Medicare & Medicaid Services (CMS) as a moderately complex laboratory. The Certificate of Waiver that is used for CLIA-waived testing procedures will not be valid if the tests of higher complexity are also performed in the laboratory.
2. The requirements for quality control increase with the higher level of test complexity. This includes the documentation of daily calibration and maintenance, the testing of two levels of quality control performed routinely, and participation in a proficiency testing program.
3. Those employees who perform these tests must also have documentation of all training, and regular documented updates when the process changes.

Test Your Knowledge 12-1

What tests are components of the CBC? (Outcome 12-2)

Complete Blood Count Specimen Requirements

Blood samples for the complete blood count can be collected by venipuncture or capillary collection. The CBC requires a well-mixed lavender top tube containing EDTA as an anticoagulant. There is an emphasis on the mixing of the sample for CBC analysis because the whole blood tested must represent the circulating blood in the body. If the sample is not inverted five to ten times immediately after collection, small clots may form, leading to inaccurate results.

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A lavender Microtainer tube will be used in the capillary collection process for a CBC. As in the case of the tube used for venipuncture, the specimen in the Microtainer tube must be mixed during and immediately following the collection process. A steady, consistent blood flow is necessary so that small clots do not form during the blood collection. CLIA-waived analyzers have special collection chambers that can be filled directly with blood from a capillary puncture, eliminating the need for a Microtainer tube. These collection chambers are placed in the instrument for testing.

White Blood Cell Count

The total number of WBCs in the circulating blood (known as a white blood cell count) is another component of a CBC. There is no distinction between types of white blood cells in this total white blood cell count. Since there are so many blood cells, a method known as *scientific notation* is used to express the values for the white blood cell count and the red blood cell count. Scientific notation is used when numbers are too large to be written in the common decimal format, in which the numbers are reported as a number $\times 10^6$. The normal reference range for the WBC count is approximately 4.3 to 10.8 $\times 10^3/mm^3$ (4,300 to 10,800 cells per cubic mm).

Leukocytosis is the term used when the white blood cell count exceeds the normal range. The most frequent cause for an elevation of leukocytes is infection. Increased WBC counts may also be associated with stress, intense exercise, trauma, inflammation, and pain. Smoking may also cause slight leukocytosis.

In addition, white blood cell counts are usually elevated well above the normal range in the presence of **leukemia.** In cases of leukemia, white blood cell counts may range from 30,000 to 200,000 per cubic millimeter of blood. Leukemia is a cancer of the bone marrow in which a large number of immature white blood cells are being produced or disease states in which mature forms live an exceptionally long time. These white blood cell clones are not capable of performing their roles as part of the immune system. Leukemias are classified according to the predominant cell type present, and whether the disease is acute or chronic in nature. Table 12-2 provides more information about the various types of leukemia.

Leukopenia refers to a WBC count that is below the normal range (values below 4,000 per cubic millimeter). The number of white blood cells may be decreased in a chronic viral infection. Exposure to lead, mercury, some chemotherapy agents, and radiation may also cause the white blood cell count to be diminished.

Test Your Knowledge 12-2

What is the reference (normal) range of the red blood cell count for an adult? (Outcome 12-3)

Red Blood Cell Count

Red blood cells are the most prevalent formed element in circulating blood. Because there are so many red blood cells, scientific notation is used as it is for the white blood cell count to express these values. There are millions of red blood cells present in each specimen, so these are reported as 10^6. The reference (normal) ranges for red blood cell measurements will vary based on the age and gender of the patient. For instance, adult males normally

TABLE 12-2
Types of leukemias

Type	Abbreviation	Description
Chronic myelogenous (granulocytic) leukemia	CML	A large number of all types of white blood cells and platelets; subtyped according to the type of predominant cell
Acute myelogenous (granulocytic) leukemia	AML	The bone marrow produces a large number of granulocytic blast cells; predominantly an adult leukemia
Chronic lymphocytic leukemia	CLL	Accumulation of lymphocytes that live a long time; predominately identified in older adults
Acute lymphocytic (lymphoblastic) leukemia	ALL	Abnormal growth and development of lymphocytes; diagnosed most frequently in children
Hairy cell leukemia	HC or HCL	Excess B lymphocytes are produced; these lymph have projections that make them look "hairy"; generally affects middle-aged and older adults

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have more red blood cells present in their bodies than do adult females. Red blood cell counts are performed using an automated hematology analyzer. The reference ranges will vary from 4.2 to 6.2 $\times$ 10^6 cells per microliter.

Red blood cell counts that exceed the normal range may be present in various diseases, including **polycythemia** (a condition that results in an excess of RBCs). Those results below the normal range suggest a reduction in the oxygen-carrying capacity of the blood known as **anemia.** The various types of anemia are further described in Chapter 13.

Test Your Knowledge 12-3

List two disorders that are characterized by an increased white blood cell count. (Outcome 12-4)

Hemoglobin and Hematocrit

Hemoglobin (Hgb) is an iron-containing pigment present in all red blood cells and is responsible for oxygen transport. The Hgb concentration is typically measured in grams per deciliter (g/dL). For this test, RBCs are **lysed** (broken open) and the free hemoglobin enclosed in the cell is then measured **spectrophotometrically.** Spectrophotometric measurements measure color changes produced by the hemoglobin present in a sample using a specific wavelength of light. The reference ranges for hemoglobin also vary by gender and age. The hemoglobin normal range for adults is 12 to 18 g/dL.

The **hematocrit (Hct)** is the amount of space occupied by the red blood cells in a whole blood sample as compared to the total sample volume. A hematocrit can be measured directly utilizing hematocrit tubes after centrifugation, or the hematocrit result may be calculated using the hemoglobin and one of the red blood cell indices, called the mean corpuscular volume (MCV). This red blood cell index represents the average volume of the individual red blood cells in a sample. The hematocrit is always reported as a percentage, and the reference ranges vary with gender and age of the patient. Adult normal ranges include values from 38% to 52%. More details of hemoglobin and hematocrit testing and further evaluation of their clinical significance are provided in Chapter 13.

Red Blood Cell (Erythrocyte) Indices

A typical CBC includes three calculated values that help classify RBCs in terms of size and hemoglobin concentration. The calculations use the word *corpuscular* in referring to the red blood cells. These calculations are known as **red blood cell indices:**

1. **Mean corpuscular volume (MCV),** defined as the average volume of a red blood cell in a sample
2. The average weight of hemoglobin in the red blood cells in a sample, known as **mean corpuscular hemoglobin (MCH)**
3. **Mean corpuscular hemoglobin concentration (MCHC),** the average weight of hemoglobin in a given volume of packed blood cells

These values are calculated from the hemoglobin concentration, the hematocrit value, and the red blood cell count. The indices are most often used to classify various types of anemias. Table 12-3 includes more information about each of the indices, including a brief description, the

TABLE 12-3
Red Blood Cell (Erythrocyte) Indices

Red Blood Cell Index Units	Description	Formula	Suggested Reference (normal range)
MCV: Mean corpuscular volume Femtoliters	The average volume of red blood cells in the specimen	$\frac{\text{Hematocrit (\%)} \times 10}{\text{RBC count (millions)}}$	80–100 fL
MCH: Mean corpuscular hemoglobin Picograms per cell	Content or weight of hemoglobin in the average red blood cell	$\frac{\text{Hemoglobin (g/dL)} \times 100}{\text{red blood cell count (million)}}$	27–31 pg/cell
MCHC: Mean corpuscular hemoglobin concentration g/dL	The average concentration of hemoglobin in a volume of packed cells	$\frac{\text{Hemoglobin (g/dL)} \times 100}{\text{hematocrit (\%)}}$	32–26 g/dL

fL is the abbreviation for femtoliters, and pg is the abbreviation for picograms.

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formula used for calculation, and a suggested reference range. These indices provide clinicians with valuable information about the size and condition of the red blood cells in the sample as well as more details about the amount of hemoglobin present. The calculated indices may be compared with the appearance of the corresponding red blood cells as noted on a stained blood smear to verify their clinical significance and the accuracy of the values.

Test Your Knowledge 12-4

What information is provided by the red blood cell indices? (Outcome 12-6)

Platelet Count

As was introduced in Chapter 11, platelets are small cell fragments that interact with chemicals in the bloodstream to assist in the clotting process. The reference ranges for platelet counts may vary with the blood sample collection technique employed. Capillary collection values are lower than those in venous blood because some of the platelets in the area are immediately involved with the formation of the plug for the injury of the skin puncture. The venous reference range for the platelet count is 150×10^3 to $450 \times 10^3/mm^3$ (150,000 to 450,000 per cubic millimeter).

Thrombocytopenia means a decreased platelet count. Platelets may be decreased with some types of infection and in situations where the individual has been exposed to certain medications or toxic substances. **Thrombocytosis** refers to an increased platelet count in the circulation, and may be associated with a variety of diseases. If the platelet count is increased in response to a specific "trigger," it is known as *reactive thrombocytosis*. When the elevated platelet count becomes pronounced over an extended period of time and the bone marrow begins to produce excessive amounts of abnormally functioning platelets, the condition is known as **thrombocythemia.** Thrombocythemia is considered to be a serious condition, as these excess platelets can cause small clots to form intravascularly, or the platelets may not function properly to stop bleeding when needed.

Leukocyte Differential Count

A **differential** is a process by which the percentage of the five normal types of white blood cells in the circulating blood is calculated. These cell types include the following:

1. **Neutrophils:** First responders to foreign invasion of the body
2. **Eosinophils:** Assist with allergic reactions, parasitic infections, and chronic inflammation
3. **Basophils:** Play a key role in the inflammatory process
4. **Lymphocytes:** Ingest and kill microorganisms and play a key role in the immune response with antibody formation
5. **Monocytes:** Attack and eliminate foreign substances; monocytes function as macrophages in the tissues of the body

As introduced in Chapter 11, immature neutrophils, known as *band cells*, are also identified and reported separately when a leukocyte differential is performed. The band cells may be increased in number during a bacterial infection because the bone marrow is attempting to produce an increased amount of white blood cells (especially neutrophils) to meet the body's need. Immature cells that are earlier in the developmental stage than band cells are not normally present in the bloodstream, and their presence indicates a serious infection or other blood disorder. The immature forms of other white blood cell types may occasionally be present and must be identified, as their presence may assist with a diagnosis or prognoses.

When reporting the leukocyte differential, each type of white blood cell is reported as a percentage (%). This procedure is completed utilizing automated methods or performed manually with visualization of a stained blood smear by a properly trained clinical laboratory professional. In blood samples for most adults, neutrophils are typically seen in the greatest numbers (between 54% and 65%). Lymphocytes are next in frequency; 24% to 40% would be the normal range. Monocytes make up approximately 2% to 8% of the white blood cell count. The rest of the white blood cells are made up of eosinophils, which total 1% to 4%, and the basophils, which make up 1% or less of the circulating white blood cells. The immature neutrophils (band cells) may total up to 5% of the normal differential as well. The cells are identified on a stained slide by their size, shape, color, and the structures within the cell. Automated instruments may also report these parameters. Table 12-4 provides a summary of information about the various types of white blood cells.

The results of the differential can be used for initial diagnosis or to monitor treatment. An increase in neutrophils often indicates a bacterial infection. With acute infections, there usually will be an increase in the number of the immature band cells as well as an overall increase in neutrophils. Eosinophils may increase in number with allergies and parasitic infections. Lymphocytes often

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POINT OF INTEREST 12-1
Bananas in the blood?

The order of frequency for the presence of the five types of white blood cells may be remembered by using this simple sentence: **N**ever **L**et **M**onkeys **E**at **B**ananas! Starting with the most prevalent to the least, the five types of white blood cells identified in the circulating blood are **N**eutrophils, **L**ymphocytes, **M**onocytes, **E**osinophils, and **B**asophils.

exceed the normal range in viral infections. In immediate hypersensitivity reactions (such as asthma) basophils are often increased. An increase of monocytes may suggest a chronic infection (tuberculosis is an example) or the presence of a malignancy.

Lymphocytes may be elevated with infectious mononucleosis. In addition to the increase in the percentage of lymphocytes, many of the lymphocytes may be larger than normal. *"Reactive" lymphocytes* are also identified with mononucleosis; these are larger than the typical lymphocyte, and when visualized under the microscope, they have a nucleus that is less dense than a typical lymphocyte. An increase of regular, larger, and reactive lymphocytes accompanied by other physical signs and symptoms and a positive mono screening test will be used to diagnose infectious mononucleosis.

The white blood cell differential is significant for patients with leukemia because the various types of leukemia are categorized by the type of predominant white blood cell present in the bone marrow and bloodstream. Leukemia classification is also based on whether the disease process is acute or chronic in nature. The acute leukemias primarily present with immature white blood cells in the form of **blasts** (the earliest form of the white blood cell that is identifiable), while the chronic types of leukemia are characterized by dramatically increased numbers of dysfunctional mature cells. In acute lymphoblastic leukemia, the differential would have many immature lymphocytes, referred to as *lymphoblasts*. The blood smear of a patient with chronic myelogenous leukemia typically has an increased number of the granulocytic white blood cells, (neutrophils, eosinophils and basophils). The granulocytic white blood cells have granules present in their cytoplasm.

Test Your Knowledge 12-5

Describe the appearance of a normal red blood cell on a stained blood smear. (Outcome 12-9)

POINT OF INTEREST 12-2
Infectious mononucleosis

Clinical Facts

- Viral infection caused by the Epstein-Barr virus
- Virus enters through the oropharynx, transmitted in saliva; called "the kissing disease"
- Most prevalent in adolescents and young adults
- Virus infects the B-cell lymphocytes

Clinical Symptoms

- Fatigue
- Fever
- Sore throat
- Swollen lymph glands

Hematological Features

- Slight elevation in the white blood cell count (12,000 to 25,000)
- Increased percentage of lymphocytes (60% to 90%)
- Presence of reactive (atypical) lymphocytes
  - Larger T cells than normally visualized
  - Larger; nuclei with more open chromatin and deep indentations
  - Cytoplasm with basophilia, azurophilic granules, and vacuoles

Immunology Features

- Positive rapid-screen mono test
- Increased heterophile antibody titer

Treatment

- Rest
- NSAIDs, such as ibuprofen
- No lifting or contact sports if the spleen is enlarged

Peripheral Blood Smear

A peripheral blood smear may be used for a manual white blood cell differential as well as visualization of other formed elements in the blood. A blood smear consists of a slide with a drop of blood spread across it. The blood sample may be created directly from a capillary puncture or from an EDTA-anticoagulated venous blood sample that is less than 2 hours old. The smear is then dried, stained, and viewed under the microscope. White blood cells, red blood cells, and platelets are observed. Examination of cell **morphology** (appearance

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TABLE 12-4

White Blood Cell Types in the Circulating Blood and Reference Ranges for the Leukocyte Differential

White Blood Cell	Image of Cell	Description of Morphology	Percentage Normally Present (suggested reference range)
Neutrophil	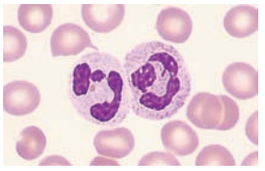 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	Multilobed nucleus; lavender gray granules in cytoplasm	54%–65%
Lymphocyte	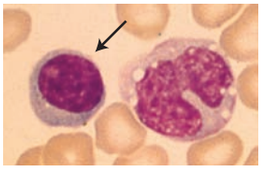 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	Large, dense, dark blue nucleus; small amount of pale blue cytoplasm	25%–40%
Monocyte	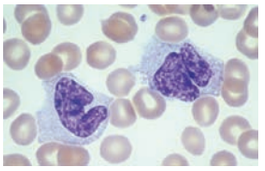 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	Foamy, convoluted nucleus; ground glass–looking cytoplasm	2%–8%
Eosinophil	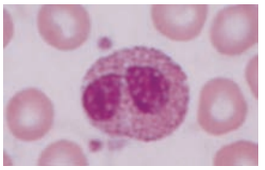 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	Bilobed nucleus; large orange-red granules in cytoplasm	1%–4%

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TABLE 12-4—cont'd
White Blood Cell Types in the Circulating Blood and Reference Ranges for the Leukocyte Differential

White Blood Cell	Image of Cell	Description of Morphology	Percentage Normally Present (suggested reference range)
Basophil	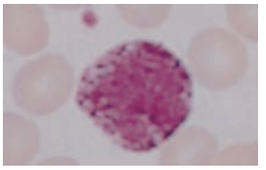 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	Bilobed nucleus (difficult to see clearly); large dark blue granules in cytoplasm	0%–1%
Band cell (immature neutrophil)	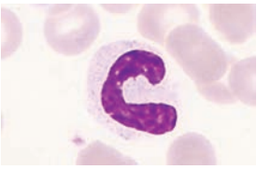 (From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.)	C-shaped nucleus; lavender-gray granules in cytoplasm	0%–5%

of the red blood cells including their size, color, and shape) and determination of size are used to identify each type of blood cell. The leukocyte differential, the red blood cell morphology, and a platelet estimate are reported as part of the results. Examination of the blood smear is necessary when the automated results indicate that there is a need to double-check the differential count or cell morphology of the specimen, or when the method used for the CBC does not allow for an automated white blood cell differential.

Test Your Knowledge 12-6
What characteristics of the white blood cells are used to differentiate the different types? (Outcome 12-7)

Blood smears are stained with a **polychromatic stain,** which consists of a combination of an alkaline and acidic component that allows for cells to appear in a variety of colors. Wright's stain is a popular polychromatic stain used for blood smears. Different structures will absorb more of one color or the other, as they will naturally be attracted to the alkaline or acidic components of the stain. The resulting colors and cell structural appearance are used to differentiate the cells. Nuclei are stained blue by the basophilic (alkaline) part of the stain; other structures are stained red orange by the eosinophilic (acid) stain component. Some structures pick up both stain components.

Manual Leukocyte Differential

For performance of a manual differential, the stained blood smear is placed on the stage of microscope and the immersion oil objective (100X) is used to magnify the blood smear. An area where cells appear in a single layer and are not overlapped is located while looking at the slide. The viewing field is moved from side to side across the width of the smear. Typically 100 consecutive white blood cells are observed and accounted for by type. The size of the cell and the structures of the nucleus and the cytoplasm are used to

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identify each white blood cell type. An electronic or a manual tabulator keeps count. When 100 cells are counted, the percentage of each type is the total number observed.

Test Your Knowledge 12-7
List the five white blood cell types in order from those of the greatest number to those of the least. (Outcome 12-7)

Red Blood Cell Morphology

As well as counting the different types of WBCs on a differential, it is important to observe the RBCs and pay careful attention to their size and shape. As introduced in Chapter 11, normal red blood cells are circular biconcave disks with pale centers. They are 6 to 8 microns in diameter. They are a soft red color and have no nuclei. Red blood cells are smaller than white blood cells and larger than platelets. The red blood cells on the stained slide should all be similar in size, with natural slight differences in the sizes and shapes. These normal red blood cells are called **normocytic** and **normochromic**. The suffix –cytic refers to the size and shape of the red blood cells and the suffix –chromic refers to the color of the cells when viewed under the microscope.

Normocytic red blood cells are the normal size of 6 to 8 microns. Normochromic red blood cells have a center that is paler than the surrounding cell, which means that they contain a sufficient concentration of hemoglobin. In hematological disorders, the red blood cells may vary in the amount of hemoglobin, the size and shape of the cells, the staining characteristics (pale or dark red) and the structures present within the cells.

Test Your Knowledge 12-8
What is the term used to describe a red blood cell visualized on a stained smear that is paler or lighter in color than a normal erythrocyte? (Outcome 12-9)

Red blood cells that have too little hemoglobin will have larger, paler central areas than normal cells. These cells are described as **hypochromic. Spherocytes** are RBCs that assume a spherical shape and are said to be **hyperchromic,** because they have excess hemoglobin concentration and thus no central pallor. **Polychromatic** (a multicolored appearance achieved using a mixture of varied colored stains) red blood cells appear a little more bluish in hue as they contain RNA that attracts the alkaline component of the stain. **Anisocytosis** is a condition in which there is a variety of sizes of red blood cells present. Cells larger than normal size are considered **macrocytes** and those smaller than normal are **microcytes**.

Test Your Knowledge 12-9
What is the term used when the red blood cells on a smear are varied in shape more than usual? (Outcome 12-9)

Poikilocytosis describes red blood cells that are present on the slide in a variety of different shapes. Some types of cells are named for their descriptive shape. Examples of these include teardrops, helmet cells, **sickle cells** (arch-shaped cells that result from low oxygen tension and that contain an abnormal substance known as hemoglobin S, and elliptical-shaped cells known as **ovalocytes.** Cells that have a reduced hemoglobin concentration (known as **target cells)** have so little hemoglobin that there is only a slight ring of color at the edges. These target cells have a spot of trapped hemoglobin in the center (the bull's eye of the target). Figure 12-1 includes examples of normal and abnormal red blood cell morphology.

Immature nucleated red blood cells may be present on the slide when there has been an event that puts an extreme demand on the bone marrow for production of new blood cells. These nucleated red blood cells (NRBCs) will have a blue staining nucleus. NRBCs are not normally present in the circulating blood of an adult but they may be seen in fetal blood or that of young infants. If NRBCs are present, it is important to report this as part of the CBC result, as their presence may be clinically significant.

Platelet Morphology and Estimated Count

Platelets are small, oval-shaped, and purple cellular fragments when visualized on the stained blood smear. A platelet estimate may be calculated by counting the number of platelets on a stained blood smear in fields viewed under the microscope where cells are not overlapped and red blood cell morphology is easily visualized. Ten fields are counted, and the average number of platelets per field is multiplied by 20,000 to achieve a platelet estimate. In a normal platelet count, there are 8 to 20 platelets on an oil immersion field.

Manual Blood Cell Counts

Red blood cells, white blood cells, and platelets may be counted manually by a qualified laboratory professional. This is not a CLIA-waived procedure, so in most circumstances it is not a procedure that will be

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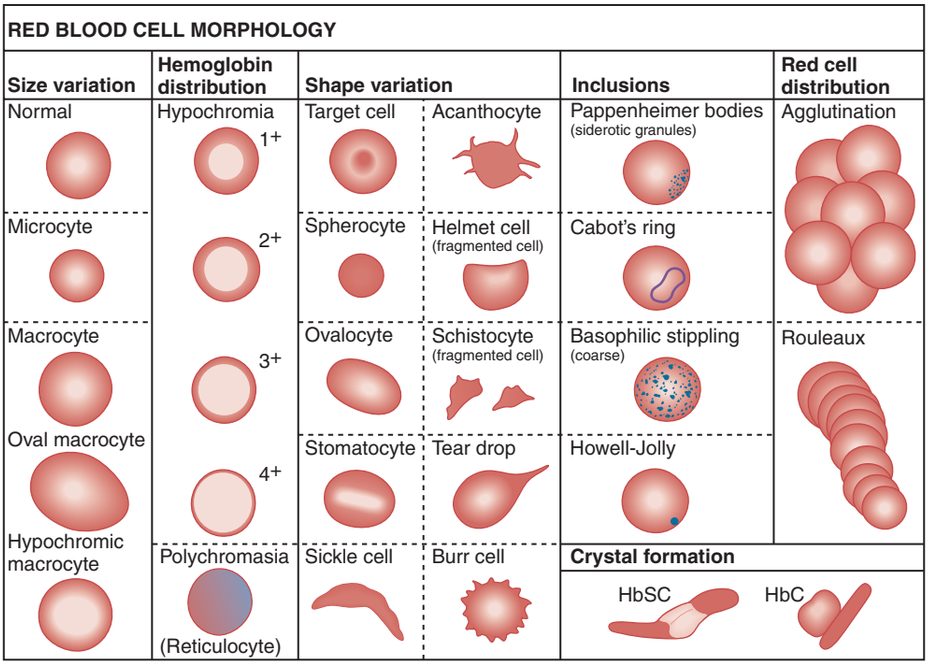

Figure 12-1 Normal and abnormal red blood cell morphology. *From Harmening, DM: Clinical Hematology and Fundamentals of Hemostasis, ed. 5. FA Davis, Philadelphia, 2009, with permission.*

performed by a medical assistant. A manual cell count may be necessary when the automated system is nonfunctional or in situations in which the cell counts are too low to be measured by the instrument commonly used. For a manual count, blood samples are mixed with a specified amount of diluent (Fig. 12-2A) and added to a **hemocytometer.** The hemocytometer is a chamber of specific dimension and depth that has a grid marked for counting the cells under the microscope (Fig. 12-2B). The cells are counted using the magnification of the microscope. Because of the standardized dilution ratio and dimensions of the hemocytometer, a mathematical calculation is used to determine the number of cells in a milliliter of blood.

AUTOMATED ANALYZERS FOR COMPLETE BLOOD COUNT TESTING

Blood cell analyzers have come into use with advances in technology. In hospitals and reference laboratories, these analyzers allow for large volumes of tests to be performed in a short period of time. Automated instruments in the physician office laboratory have added greater accuracy and precision to the results. Most of these test procedures use **electrical impedance** (a process for counting blood cells that depends on their resistance to the flow of an electrical current) and light-scattering principles to count and differentiate blood cells. Beckman-Coulter, Abbott, ABX, and Bayer-Technicon are companies that produce these automated analyzers for large-scale, time-efficient hematology testing.

In electrical impedance analyzers, the cells pass through an opening with an electrical current flowing through it. The changes of electrical resistance due to the formed elements in the sample are monitored and they are counted as voltage pulses. These pulses are proportional in height to the volume of the cells, which allows them to be identified as white blood cells, red blood cells, or platelets.

Some instruments may also use a beam of light to measure the number and size of the cells in the sample, a process called light scattering. A light-sensitive detector measures the light scattered as the sample is introduced into a chamber and the beam of light is interrupted. The size of the pulse detected is proportional to the size of the cellular element. Many of the analyzers use a combination of these two techniques to count the formed elements in the blood sample. A

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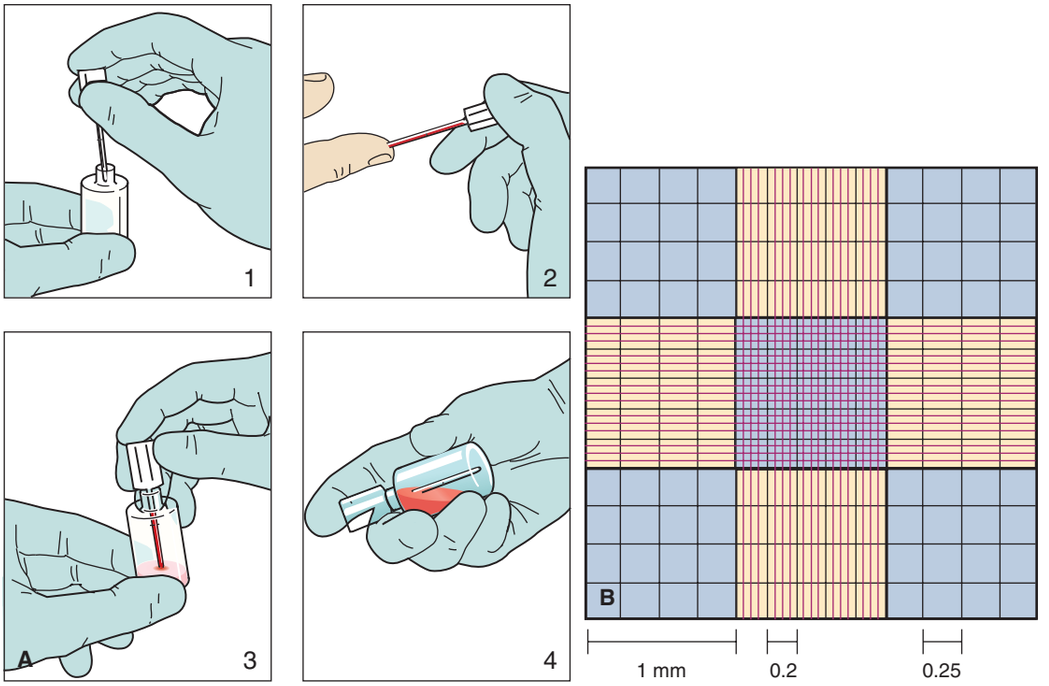

Figure 12-2 (A) Steps involved in using the Unopette system. *From Wedding, ME, and Toenjes, SA: Medical Laboratory Procedures. FA Davis, Philadelphia, 1998, with permission. (B) Hemocytometer counting chamber. From Ciesla, B: Hematology in Practice, ed. 2, FA Davis, Philadelphia, 2012, with permission.*

graph of the distribution of cell sizes made during cell counting on an automated analyzer, known as a **histogram,** may also be reported. An example of the results of an automated CBC is shown in Figure 12-3.

The automated white blood cell differential is performed by a combination of techniques. The information gathered using these techniques is combined to classify the type of white blood cell. The cell volume can be determined by electrical impedance, electromagnetic procedures define nuclear characteristics and granular composition, and light-scattering techniques can analyze cell surface and morphological and granular qualities to determine the type of white blood cell. The automated analyzers work well for the vast majority of specimens, but they do have their limitations. Certain samples with abnormal results must have a manual differential performed for accurate results.

The QBC STAR Centrifugal Hematology System (QBC Diagnostics) is an example of an automated instrument that tests one sample at a time (Fig. 12-4). It may be used in the physician office laboratory where automation is desired, but specimen-testing volumes are not high. The QBC STAR system is a CLIA test of moderate complexity, so those performing the testing will participate in proper training of specified quality assurance procedures. The analysis tube used for testing within the instrument may be filled with EDTA-anticoagulated blood or directly from a capillary puncture. The analysis tube contains a dye and a special "float" that is used for the testing process. The tube is filled with blood and placed directly into the analyzer. The testing process involves centrifugation within the instrument and use of the "float" to measure different parameters of the specimen. This instrument is desirable for some office settings because there are no liquid reagents to work with, and the calibration of the instrument is done internally. The analysis tubes contain all the reagents necessary for the procedure. The QBC Star is capable of measuring most of the components of a typical CBC, with the exception of a red blood cell count and some of the indices.

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ID Number: 00014 Seq#: 4291 Type: 3YR to 4YR
Mode: BLOOD
Patient ID: Date: 02-17-2012
Time: 04:15:00PM
Name: _____ Sex: _____
Address: _____ Age: _____

	PARAMETERS	RESULT		NORMAL	RANGE	ALARMS	DIFFERENTIAL
+	WBC	**15.1**	K/uL	5.0	14.5		
H	LYM#	**6.0**	K/uL	1.5	3.5		
	MID#	1.0	K/uL	0.1	1.0		
+	GRA#	**8.1**	K/uL	1.5	6.6		
	LYM%	39.7	%	25.0	50.0		
	MID%	6.6	%	2.0	10.0		
	GRA%	53.7	%	50.0	80.0		
	RBC	4.47	M/uL	3.50	4.90	R1	
	HGB	11.7	g/dL	10.0	14.0		
	HCT	36.7	%	30.0	42.0		
	MCV	82.0	fl	75.0	96.0		
	MCH	26.2	pg	24.0	32.0		
+	MCHC	**31.9**	g/dL	28.0	30.0		
	RDW	13.1	%	11.7	15.0		
	PLT	381	K/uL	140	440		
	MPV	7.9	fl	6.0	9.5		

PLT Histogram

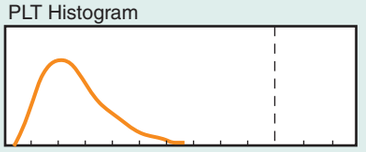

RBC Histogram

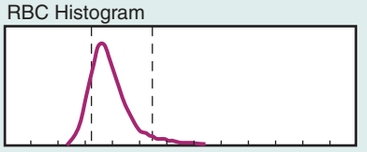

Comments:

WBC Histogram

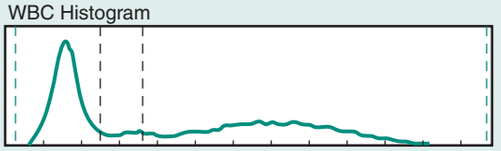

Signature: _____

Figure 12-3 CBC result from an automated hematology analyzer, including histograms.

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Figure 12-4 QBC STAR hematology analyzer. *Courtesy of QBC Diagnostics.*

SUMMARY

The complete blood count (CBC) is a comprehensive hematology test consisting of a white and red blood cell count, hemoglobin and hematocrit determinations, red blood cell indices, a platelet count, and a white blood cell differential. These tests may be performed manually or by use of automated instrumentation. The three red blood cell indices (MCV, MCH, MCHC) are calculations that numerically describe the size of the red blood cells and the amount of hemoglobin that they contain.

There may be times in which examination of a blood smear is necessary to clarify the differential results or view morphology for other cellular elements in a sample. A stained blood smear is viewed with the microscope for a manual white blood cell differential, red blood cell morphology, and platelet estimation. The complete blood count can be used as a tool to diagnose and monitor disease and to follow the course of treatments.

TIME TO REVIEW

1. Choose the correct list of components of a complete blood count. Outcome 12-2
   - **a.** Hemoglobin, hematocrit, red blood cell count, white blood cell count, erythrocyte sedimentation rate, WBC differential
   - **b.** Hemoglobin, hematocrit, red blood cell count, white blood cell count, red blood cell indices, platelet count, WBC differential
   - **c.** Hemoglobin, hematocrit, red blood cell count, platelet count, erythrocyte sedimentation rate, WBC differential
   - **d.** Hemoglobin, hematocrit, red blood cell count, white blood cell count, hemoglobin electrophoresis, WBC differential, platelet count
2. The reference range for an adult white blood cell count is: Outcome 12-3
   - **a.** 4,300 to 10,800/mm^3
   - **b.** 140,000 to 400,000/mm^3
   - **c.** 5.0 to 6.5 million/mm^3
   - **d.** 12 to 14 g/dL
3. A white blood cell count may be decreased because of: Outcome 12-5
   - **a.** A chronic viral infection
   - **b.** Exposure to toxins
   - **c.** Chemotherapy use
   - **d.** All of the above
4. The reference or normal range for the platelet count is: Outcome 12-3
   - **a.** 4,300 to 10,800/mm^3
   - **b.** 150,000 to 450,000/mm^3
   - **c.** 5.0 to 6.5 million/mm^3
   - **d.** 12 to 14 g/dL
5. This type of white blood cell is the most numerous in a healthy adult and makes up about 60% of the white blood cells: Outcome 12-7
   - **a.** Eosinophil
   - **b.** Monocyte
   - **c.** Neutrophil
   - **d.** Lymphocyte
6. This is the term used to describe a variety of sizes of red blood cells on the stained smear: Outcome 12-9
   - **a.** Anisocytosis
   - **b.** Poikilocytosis
   - **c.** Spherocytosis
   - **d.** Hemolysis
7. This type of cell appears as small, purple, circular, or ovoid fragments on the stained blood smear. Outcome 12-10
   - **a.** White blood cell
   - **b.** Red blood cell
   - **c.** Platelet
   - **d.** Band cell

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8. An increased white blood cell count may be evident with which disease? Outcome 12-4
   a. Thrombocythemia
   b. Anemia
   c. Leukopenia
   d. Leukemia

9. Microcytosis is a word used to describe: Outcome 12-9
   a. Large red blood cells
   b. Large white blood cells
   c. Small red blood cells
   d. Small platelets

10. A hemocytometer is used to: Outcome 12-1
   a. Measure a hematocrit level
   b. Perform manual white blood cell counts
   c. Perform staining of peripheral blood smears
   d. Measure hemoglobin concentrations

Case Study 12-1: Clinical significance

Mr. Smith, a 67-year-old patient, presented to the office with symptoms of a cough, a little tightness in his chest, and complaints of a slight fever. The medical assistant took Mr. Smith's vital signs and wrote his results and chief complaint in his chart. When the physician examined the patient, he believed that Mr. Smith was suffering from a respiratory infection. His plan was to prescribe an antibiotic if the infection turned out to be caused by bacteria, so he asked the medical assistant to draw blood for a CBC.

The medical assistant performed a venipuncture on Mr. Smith and processed the sample for pickup by the reference laboratory for testing later that day. She explained to Mr. Smith that the results should be back in the office in the morning and if the CBC results indicate the presence of a bacterial infection, the physician will call in a prescription for an antibiotic to his pharmacy. She told the patient that she would call him in the morning.

The next morning these results were faxed to the office:

CB LABORATORY

ID Number:	09123	Seq#: 43210	Type:
Patient ID:	98789		Mode: Blood
			Date: 10-14-2012
			Time: 10:45 AM
Name:	James Smith		Sex: Male
Address:	3456 Waterview Terrace		Age: 67
	Seattle, WA 98103		

CBC RESULTS

TEST	PATIENT RESULTS	REFERENCE RANGE		
Hemoglobin	14.2 g/dL	13	18	male
		12	16	female
Hematocrit	43%	45	52	male
		37	48	female
Red blood cell count	5.7 x 10^6/mm^3	4.6	6.2	male
		4.2	5.9	female
White blood cell count	12,000/mm^3	4,300	10,800	
Neutrophils	48%	54	65	
Lymphocytes	48%	25	40	
Monocytes	2%	2	8	
Eosinophils	1%	1	4	
Basophils	1%	0	1	
Platelet count	320 x 10^3/mm^3	150	450	

Continued

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The medical assistant highlighted the abnormal results, retrieved James Smith's chart, and took the laboratory report and chart to the physician. The doctor reviewed the results and asked the medical assistant to contact Mr. Smith to let him know that he would not be prescribing antibiotics at this time.

The medical assistant called Mr. Smith and explained that the results were not consistent with a bacterial infection. She told Mr. Smith that no antibiotics would be prescribed at this time, but to check back in a week if the symptoms had not gotten better or if things appeared to be worse.

1. What color tube was used for the blood sample?
2. What out-of-range laboratory results should the medical assistant have highlighted for the physician?
3. Are the abnormal laboratory results consistent with a bacterial infection?

RESOURCES AND SUGGESTED READINGS

"QBS Star"
Provides an overview of the function of the QBC Star hematology analyzer http://www.qbcdiagnostics.com

Chapter 13

Hemoglobin and Hematocrit

Nikki A. Marhefka, EdM, MT(ASCP), CMA (AAMA)

CHAPTER OUTLINE

Hemoglobin
Hemoglobinopathies
Hemoglobin Testing
  CLIA–Waived Hemoglobin Testing
  Potential Errors in Hemoglobin Testing
Hematocrit
  CLIA–Waived Hematocrit Testing
  Potential Errors in Hematocrit Testing
The Relationship of Hemoglobin and Hematocrit Values
Anemia
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

13-1 Define the key terms.

13-2 Describe the structure and function of a hemoglobin molecule.

13-3 State the type of normal adult hemoglobin and list other types present with various hemoglobinopathies.

13-4 Analyze the general principle of and sources of error associated with CLIA-waived testing of hemoglobin.

13-5 Evaluate the concept of the hematocrit.

13-6 Identify the layers into which the blood sample has separated in a spun hematocrit specimen.

13-7 Examine the general principle of and sources of error associated with CLIA-waived hematocrit procedures.

13-8 Recognize the normal reference ranges for hemoglobin and hematocrit.

13-9 Define *anemia* and examine its clinical significance.

13-10 List the various types of anemia and explain how they are classified.

CAAHEP AND ABHES STANDARDS

CAAHEP 2008 Standards

I.C.I. Anatomy and Physiology #6: Identify common pathology as it relates to the interaction of body systems.
I.C.I. Anatomy and Physiology #7: Analyze pathology as it relates to the interaction of body systems.
I.P.I. Anatomy and Physiology #12: Perform hematology testing.

ABHES 2010 Standards

10. Medical Laboratory Procedures, b. CLIA-waived tests, Graduates: 2. Hematology Testing.

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KEY TERMS

Anemia
Anisocytosis
Aplastic anemia
Bilirubin
Cyanmethemoglobin
Erythropoiesis
Hematocrit (hct)
Hb A
Hemoglobin (hgb)
Hemoglobin and hematocrit (H&H)
Hemoglobin electrophoresis
Hemoglobinopathy
Hemolysis
Heterozygous
Homozygous
Hypochromic
Interstitial fluid
Intrinsic factor
Iron-deficiency anemia
Macrocytic
Microcytic
Packed cell volume
Pernicious anemia
Poikilocytosis
Protoporphyrin
Sickle cell anemia
Sickle cell disease
Sickle cell trait
Splenomegaly
Target cell
Thalassemia
Urobilinogen

Two of the most important hematology test procedures are for **hemoglobin (hgb)**, a protein responsible for oxygen transport, and the percentage of the space occupied by red blood cells compared to the entire blood volume known as the **hematocrit (hct).** Measurement of the **hemoglobin and hematocrit** (abbreviated as **H&H**) is commonly performed in all laboratories and physician offices. The results of these two tests may be used to help diagnose or monitor the progress of treatment for **anemia,** a condition in which the oxygen-carrying capacity of the blood is reduced. This chapter presents additional information about the clinical significance of the hemoglobin and hematocrit measurements, and provides details of testing methods for these parameters.

HEMOGLOBIN

As was established in previous chapters, mature red blood cells are filled with fluid as they are released from the bone marrow. The intracellular fluid is primarily made up of hemoglobin. Oxygen attaches to this protein complex for subsequent transport to the tissues of the body, where it is needed for the production of energy. The primary function of hemoglobin (and thus, the red blood cells) is to transport oxygen to the tissues of the body. Hemoglobin is composed of four molecules of heme within a globin protein chain. Each of these heme molecules has one atom of iron, and one molecule of oxygen can attach to each of these iron atoms. Thus, one red blood cell can transport four molecules of oxygen.

Hemoglobin production begins in the erythroid precursor cells of the bone marrow. The heme is synthesized by the mitochondria of the bone marrow cells, and the globin chains are constructed by the ribosomes of the cells as they mature in the bone marrow. Most of the hemoglobin is formed by the early precursor cells, which are nucleated, but the production continues even after these cells have lost their nucleus until they are released into the general circulation (Fig. 13-1).

Test Your Knowledge 13-1
Hemoglobin is made up of one molecule of _____ and four molecules of _____. (Outcome 13-2)

Test Your Knowledge 13-2
What is the function of hemoglobin? (Outcome 13-2)

The hemoglobin molecule becomes oxygenated in the lungs where the oxygen concentration is very high. As the red blood cells leave the pulmonary circulation, the affinity of tissues for the oxygen carried by the hemoglobin molecule will cause the oxygen to diffuse through the red blood cell membrane and across capillary walls to enter the tissues. After the oxygen has left the red blood cells, the cells are capable of transporting carbon dioxide back to the lungs to be expelled. With the delivery of oxygen and transport of

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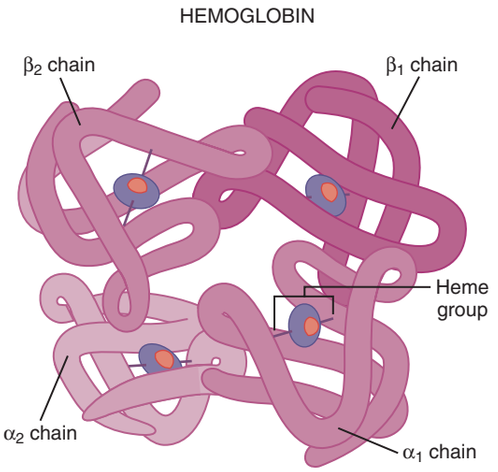

Figure 13-1 A hemoglobin molecule. Note the polypeptide changes with the heme molecules in the center of the complex.

carbon dioxide, the hemoglobin molecules of the red blood cells help the body control the acid-base balance that is necessary for survival.

Mature red blood cells have a life span of approximately 120 days. During their lifetime, they must travel constantly through the cardiovascular system, remaining flexible enough to pass through capillary beds to perform their duties. Eventually, worn-out red blood cells are removed by the tissue macrophage system in the spleen and the hemoglobin is degraded into iron, **protoporphyrin,** and globulin. Protoporphyrin is included in the heme portion of the hemoglobin molecule, and is necessary to make the iron functional and available to attach to the oxygen. The iron released by the breakdown of old red blood cells is removed from the heme, and transported to the bone marrow to be used again. The globulin is degraded into amino acids to be used by the body for creation of protein. Protoporphyrin is converted into **bilirubin,** which combines with albumin for transport to the liver. The liver cells further process the bilirubin and it is excreted as bile, which enters the intestines where bacteria convert it to **urobilinogen** to be excreted in the feces.

HEMOGLOBINOPATHIES

The normal adult hemoglobin is denoted as **Hb A**. Hemoglobin in red blood cells of the fetus and the newborn is Hb F. There are genetic hemoglobin variants present in the population, in which the structure of the globin part of the molecule is altered. The presence of an abnormal hemoglobin is known as a **hemoglobinopathy.** The hemoglobinopathies are a result of genetic changes that may be inherited or caused by mutations. Both the **homozygous** form in which the patient has two identical genes for the same characteristic or the **heterozygous** form that contains two genes for abnormal hemoglobin variants can lead to a mild or severe anemia. If Hb A is present in the cells as well as the abnormal hemoglobin, the abnormality may be masked and no symptoms will be evident. **Sickle cell disease** and **sickle cell trait** are a result of the presence of Hb S. Other hemoglobinopathies may be asymptomatic, whereas others can lead to severe anemia.

POINT OF INTEREST 13-1
Hemoglobinopathies

The hemoglobin molecule must have a very specific structure in order to function optimally. Any change in the structure of the globin chains in the hemoglobin molecule may be classified as a hemoglobinopathy. Many of these abnormalities remain undetected because they are not clinically significant. Others, however, will have a significant effect on the body's ability to transport oxygen.

- **Methemoglobinemia:** For the hemoglobin molecule to function appropriately, it is necessary for the iron molecule to be ferrous. This means that the iron molecule is positively charged with two more protons than electrons present in the molecule. If the iron is present in a state other than this, the hemoglobin molecule has a poor affinity for oxygen. This results in a state of cyanosis for the body, because the red blood cells cannot deliver the oxygen appropriately if they do not pick it up as they should in the lung tissues.
- **Hemoglobinopathies with decreased oxygen affinity:** Certain abnormalities of the hemoglobin molecule may create a situation in which there is a pronounced decrease in the affinity for oxygen. This means that the molecules do not pick up the oxygen as they should in the lungs. This type of hemoglobinopathy is characterized by cyanosis. Hb Seattle and Hb Vancouver are examples of this type of hemoglobinopathy.
- **Increased oxygen affinity:** Erythrocytosis is a common symptom of hemoglobinopathies with increased oxygen affinity. In this situation, the molecule holds on so tightly to the oxygen molecules that they cannot be deposited throughout the

Continued

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body. The kidneys will increase their secretion of erythropoetin because of the reduced oxygen in the tissues of the body. Hb Chesapeake is an example of this type of hemoglobinopathy.

- **Hemolytic hemoglobinopathies:** Hb S and Hb C are abnormalities of the hemoglobin molecule structure that affect the integrity of the red blood cell molecule as well as the hemoglobin molecule. These abnormalities occur because of the way that the globin chains are interconnected. The red blood cell membranes have increased hemolysis because the hemoglobin molecule formation is unstable. This has a profound effect on the life span of the red blood cell. The high levels of hemolysis lead to a constant state of anemia, jaundice, and cholelithiasis.

Hb S (sickle cell) also may cause the vessels of the body to become occluded due to the distinct shape of the red blood cells. The abnormal crescent shape becomes lodged in the small capillaries of the body, with multiorgan effects.

Thalassemias are a group of inherited disorders in which abnormal hemoglobin is present in the red blood cells. In thalassemia, anemia results either from a defective production rate of the alpha or beta globin chains that make up the globin portion of the normal hemoglobin molecule. Without these chains, it is not possible for the red blood cell precursors to build Hb A, the normal hemoglobin present in the adult red blood cell. Those who are homozygous for the defective gene have severe hypochromic, microcytic anemia, and a variety of other issues related to the severe anemia (Table 13-1).

Test Your Knowledge 13-3

List two abnormal types of hemoglobin. (Outcome 13-3)

When a hemoglobinopathy is suspected, identification of the hemoglobin variant present in the red blood cells can be accomplished through **hemoglobin electrophoresis.** In this technique, blood for examination is placed on a cellulose acetate gel support medium that is capable of transmitting an electrical current. An alkaline electrolyte solution is added, and an electrical current is applied to the support medium. Each hemoglobin subtype moves across the support medium at a different rate and creates a distinctive pattern. The bands of hemoglobin are detected by staining and identified by their placement on the medium as they have moved.

TABLE 13-1
Thalassemias

Alpha Thalassemias	Beta Thalassemias
Insufficient alpha globin protein produced	Insufficient beta globin protein
Clinical defect: A gene or genes related to the alpha globin protein of hemoglobin is/are missing or changed	**Clinical defect:** Gene defects affect the production of the beta globin protein of hemoglobin
Frequency: Found in persons of Southeast Asian, Middle Eastern, Chinese, and African descent	**Frequency:** Found in persons of Mediterranean descent, and to a lesser extent in Chinese, other Asians, and African Americans
Subtypes • Major Hydrops fetalis—babies die before or shortly after birth • Hemoglobin H disease, moderate to severe anemia • Minor: Called alpha thalassemia trait, mild anemia. • Alpha thalassemia silent carrier has the abnormal gene, but it is not evident because these genes are heterozygous.	**Subtypes** • Major Cooley's anemia—severe anemia • Intermediate, moderate anemia • Minor: Called beta thalassemia trait

*Thalassemia is a genetic defect in the protein portion of the hemoglobin molecule and affects alpha or beta globin protein production. Both globin proteins are necessary to create healthy hemoglobin.Thalassemia causes the body to make fewer healthy red blood cells because they are hemoglobin deficient and are not as well equipped to transport oxygen as normal hemoglobin.

This is a sophisticated test that is performed in reference or hospital laboratories.

HEMOGLOBIN TESTING

Hemoglobin testing is one of the most frequently performed laboratory procedures. The results can be used to detect anemia and provide information to determine its severity. Hemoglobin testing may also be used to monitor the treatment for anemia. Hemoglobin

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TABLE 13-2
Hemoglobin Reference Ranges (Normal Values)

Age/Gender	Hgb (g/dL)
Adult male	14–18
Adult female	12–16
Newborn	17–23
Two-month-olds	9–14
Child, 1–14 years	11.3–14.4

reference ranges vary by age and gender of the patient (Table 13-2). The normal reference ranges for the adult male are 13 to 18 g/dL, and the reference ranges for the adult female are 12 to 16 g/dL. Women of child-bearing age have a lower normal reference range than do men due to the blood loss experienced as a result of the monthly menstrual cycle. Infant hemoglobin values are significantly lower than those of adults, with an average of 11 to 14 g/dL. Children's hemoglobin values gradually increase from infancy levels to adulthood.

Hemoglobin is usually converted to another compound, called **cyanmethemoglobin,** for measurement. Cyanmethemoglobin is a colored pigment, so the change in color once this conversion has been accomplished can be measured as absorbance by a spectrophotometer, using a wavelength of 540 nm. To release the hemoglobin from the cells to be converted and measured, the red blood cell membranes must be broken or dissolved, a process called **hemolysis.** The cyanmethemoglobin reagents used for hemoglobin testing contain a surfactant that promotes rapid hemolysis and formation of the cyanmethemoglobin moledule. Large complex analyzers used in reference and hospital laboratories as well as CLIA-waived point of care testing methods use this basic procedure.

CLIA-Waived Hemoglobin Testing

The CLIA-waived hemoglobin procedures are performed by handheld, point-of-care instruments. These analyzers have been approved by the U.S. Food and Drug Administration (FDA) for performance of hemoglobin testing. Each instrument determines the hemoglobin values with minimal steps involved in the testing process. The HemoCue Hb instrument (manufactured by HemoCue Inc.), and i-STAT (manufactured by Abbott) are examples of common CLIA-waived hemoglobin analyzers used in physician offices (Fig. 13-2). There are similarities in the testing methods for all the CLIA-waived hemoglobin testing procedures. These include the following:

1. For most of these instruments, blood is collected by capillary puncture and placed on a reaction chamber. The reaction chamber includes the necessary chemicals to lyse the red blood cells and allow the conversion of the hemoglobin to cyanmethemoglobin. For many of these procedures, blood may also be taken from a tube containing anticoagulant.
2. The reaction chamber is placed into the analyzer, and the color intensity is read by a spectrophotometer to determine hemoglobin content.
3. The handheld instruments require very little maintenance or calibration procedures to produce reliable results. However, it is imperative that the operator follow all manufacturer recommendations for calibration and quality control procedures. These results must be logged appropriately, and must all be within an acceptable range before patient testing is performed on the instrument.
4. Test results are available as a digital readout on the instrument. In addition, some of the instruments may be connected to a computer for result storage and printout.
5.
6.

Potential Errors in Hemoglobin Testing

Even though the hemoglobin testing procedure is straightforward, it is still possible to make errors that may have significant impacts on the results. Potential

Figure 13-2 A hemoglobinometer.

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Procedure 13-1: CLIA-Waived Hemoglobin Testing Using the HemoCue Hemoglobin Analyzer

Hemoglobin analysis is one of the most common CLIA-waived tests performed in physician office laboratories and larger, more complex laboratories. For the HemoCue method, capillary, venous, or arterial blood may be used. Hemoglobin results may be used to screen or monitor the progress of the treatment for anemia.

TASK

Accurately perform hemoglobin testing using a HemoCue hemoglobin analyzer.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Lancet for capillary punctures
- Alcohol prep pad
- Gauze pads
- Biohazardous sharps container
- HemoCue hemoglobin analyzer
- HemoCue microcuvettes
- HemoCue calibration cuvette
- HemoCue control solution
- Disinfectant wipes for cleaning work area

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.12. Perform Hematology Testing

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment: 2. Hematology testing

Procedure	Rationale
1. Sanitize hands, allow them to dry completely, and apply gloves.	Gloves must be worn for any procedures in which exposure to blood or other potentially infectious materials is anticipated.
2. Turn on the HemoCue instrument, and wait until the digital printout on the screen indicates that the instrument is ready for testing.	The HemoCue instrument will complete a set of internal verification procedures. Once this has been successfully completed, the digital readout on the screen will indicate that the instrument is ready.
3. Verify the expiration printed on the microcuvette container.	Expired supplies are never to be used for control or patient testing.
4. Open the microcuvette bottle, and remove a microcuvette. Close the bottle securely as soon as the desired microcuvette is removed.	The microcuvette container must stay closed securely. These microcuvettes are very sensitive to moisture exposure.
5. Using the quality control material that is designed for this instrument, verify that the instrument is working correctly. Follow the manufacturer's instructions for use and frequency of testing these materials. Fill the microcuvette with the control material, then insert the cuvette into the holder and push into the instrument for analysis. Note the digital readout when ready, and compare the results to those designated as acceptable for this control material.	The quality control material comes with a set of acceptable result ranges. There are materials available to test at low, medium, and high levels of hemoglobin concentration. Verify that the readout on the digital display indicates a result within the acceptable range for that level of control before performing patient testing. Document the result for this quality control material.

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Procedure	Rationale
6. Perform a capillary puncture, using appropriate technique. Wipe away the first drop of blood.	Appropriate capillary puncture procedure includes disinfection of the draw site, allowing the alcohol to dry, using an appropriate site, performing the puncture perpendicular to the fingerprints on the finger, and wiping away the first drop of blood that forms. This drop of blood is contaminated with interstitial fluid and if used for the analysis, can produce erroneous results.
7. Touch the open end of the HemoCue microcuvette to the drop of blood. The microcuvette will fill by capillary action to the appropriate level.	Don't touch the capillary puncture site with the microcuvette; it should be placed into the drop of blood. The microcuvette will not overfill.
8. Wipe off any excess blood from the bottom and sides of the microcuvette with a gauze pad, then place the microcuvette in the cuvette holder and push the holder into the instrument for analysis.	It is important to wipe away excess blood. However, do not allow the gauze to absorb blood from the interior of the cuvette. The interior of the microcuvette is coated with a chemical that lyses the red blood cells, and converts the hemoglobin present to cyanmethemoglobin to be measured in the instrument.

Continued

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Procedure 13-1: CLIA-Waived Hemoglobin Testing Using the HemoCue Hemoglobin Analyzer—cont'd

Procedure	Rationale
9. The digital display will present a result within 10 to 20 seconds. Document this hemoglobin result.	The result will continue to be displayed until the cuvette holder is pulled out of the instrument. 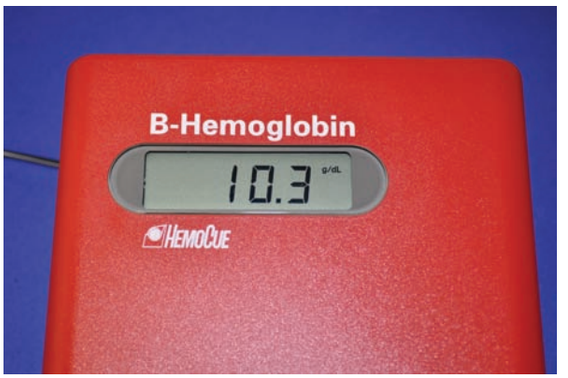
10. After recording the hemoglobin result, pull out the cuvette holder and remove the cuvette. The used cuvette must be discarded as a biohazardous material.	The blood contained in the microcuvette is still considered to be infectious, so it must be disposed of appropriately.
11. Clean and disinfect the work area, then remove gloves and sanitize your hands.	The work area should always be cleaned after use to prepare it for the next user, and hands must always be sanitized afte removing gloves.
12. Document the procedure in the patient's chart if it is available.	In a physician office laboratory, this procedure should be documented in the patient's chart. If the medical assistant is working in a laboratory setting where the chart is not available, this step is not necessary.

Date	
4/2/2012:	*Hemoglobin test performed. QC within range. Hgb 13.3 g/dL*
09:30 a.m.	*Connie Lieseke, CMA (AAMA)*

sources of error to take into consideration include the following:

- Adequate blood flow during the capillary collection is necessary to get a homogeneous (well mixed) sample without clots.
- To avoid diluting the blood sample with **interstitial fluid** (the fluid between cells), there should be no squeezing during capillary sample collection and the first drop or two of blood present after the puncture must be wiped away before the blood is applied to the testing chamber or device. If the sample is diluted by interstitial fluid, the hemoglobin value will be erroneously lowered.
- There should be no air bubbles or spaces in the collecting device.

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- As is the case with all automated instruments, the reagents and supplies must not be expired when used, and storage requirements for all reagents and samples must be followed as directed.
- The test should be performed within the appropriate time limits after specimen collection as indicated on the instructions for the analyzer.
- All instructions for use of the analyzer must be followed exactly as described.
- Internal and external quality control must be performed at the intervals recommended by the manufacturer, and the results must be within the desired ranges before patient results are reported.

Test Your Knowledge 13-4
Are hemoglobin tests performed on intact red blood cells? (Outcome 13-4)

Test Your Knowledge 13-5
List two potential errors in performing hemoglobin testing. (Outcome 13-4)

HEMATOCRIT

The hematocrit is the percentage of space occupied by red blood cells as compared to the entire blood volume in a sample of whole blood. It may also be called the **packed cell volume.** The hematocrit is an indirect test that provides important information about the concentration of red blood cells in the circulating blood. The space occupied by the red blood cells depends on the size of the cells and the total number of cells present. If there is an appropriate amount of red blood cells with a normal hemoglobin concentration in a specimen, the hematocrit will be in the normal reference range. If the red blood cells are small with insufficient hemoglobin or the number of red blood cells is decreased, the hematocrit value will be below the normal reference range.

The normal reference ranges for hematocrit vary with gender and age of the patient (Table 13-3). Newborns have a very high hematocrit value, but it decreases quickly after birth. The reference range for a child is less than that of an adult, but it continues to increase as they approach adulthood. Adult men have a normal range of 45% to 52%, and adult women have a normal range of 37% to 48%. Hematocrit values are decreased with the various forms of anemia, and may be elevated in situations with an overproduction of red blood cells, such as in polycythemia.

TABLE 13-3
Hematocrit reference ranges (normal values)

Age/Gender	hct Value (%)
Adult male	45–52
Adult female	37–48
Newborn	50–62
Two-month-olds	31–39
Child, 1–6 years	30–40

CLIA-waived procedures for hematocrit testing are manual methods requiring centrifugation of the specimen. Hematocrit values may also be derived by using moderately or highly complex automated instruments. These analyzers will use the hemoglobin concentration and the mean corpuscular volume (MCV) to calculate a hematocrit result.

Test Your Knowledge 13-6
Define *hematocrit.* (Outcome 13-5)

CLIA-Waived Hematocrit Testing

In typical hematocrit testing, the red blood cells are forced to the bottom of the tube by centrifugation (Fig. 13-3). This tube may be known as a capillary tube or a microhematocrit tube because the tube is very small and designed to be spun in a small centrifuge. After centrifugation, the tube is compared to a reading device to measure the hematocrit value. The hematocrit is always reported as a percentage, indicating the volume of red blood cells in the sample as compared to the total blood volume.

There are some variables in the testing process, but the following common components are present in all the CLIA-waived manual hematocrit procedures:

- Two hematocrit tubes are always filled from each patient. Both tubes are centrifuged and results are measured from both tubes. The final result reported will be an average of the two tubes, as long as they are within 2% of each other. If the results from the two tubes are more than 2% apart, the sample will need to be recollected and respun.
- The hematocrit tubes must contain anticoagulant (the tube interior is coated with heparin) if they are to be used for capillary samples drawn directly from the

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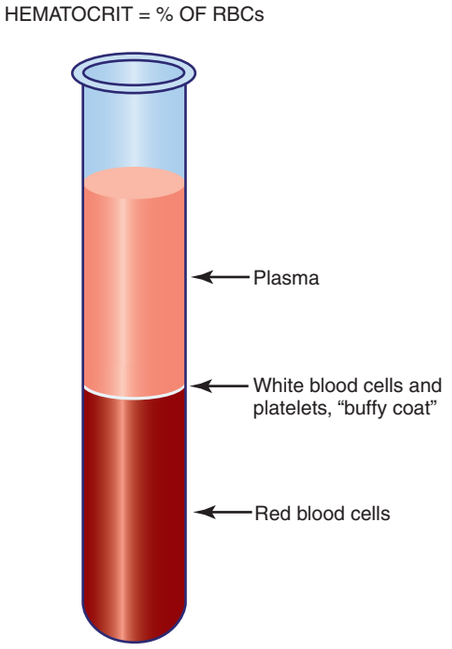

Figure 13-3 Layers of the hematocrit tube. The bottom layer is made up of red blood cells covered with a very thin layer of buffy coat, which represents the white blood cells in the specimen. The uppermost layer is made up of plasma. There is air at the very top of the tube.

patient. If anticoagulant is not used, the blood will clot in the hematocrit tube and the results will be erroneous. It is also possible to use plain tubes (without anticoagulant) if the hematocrit sample is taken from an EDTA lavender top tube.

- Glass tubes should not be used for this process in consideration of employee safety. Safety coated glass tubes are available, which have a glass interior and are covered with a Mylar coating to keep them from breaking. Plastic tubes are also available.
- The sample must be well mixed prior to filling the hematocrit tube (if utilizing an EDTA anticoagulated sample). If a capillary sample is to be used, the site must not be squeezed, as this will add too much interstitial fluid to the sample. The additional fluid may result in a falsely decreased hematocrit result.
- As the tube is filled, air bubbles should be avoided. The addition of bubbles in the specimen can cause the tube to fill insufficiently, in which case it may not be possible to measure the results after centrifugation.
- The end of the hematocrit tube will be plugged with sealing clay to keep the sample from leaving the tube during the centrifugation process.
- Follow the manufacturer's recommendations for the centrifugation times necessary, which may vary with each type of centrifuge.
- Read the results immediately after centrifugation using a built-in reader, or another device designed for hematocrit results. Following centrifugation, the blood in the tube will have been divided into three layers. The hematocrit result is read at the top of the red blood cell column, which is the bottom layer in the tube. There is a thin area called a buffy coat (lighter in color and made of the white blood cells and platelets in the sample) that is visible at the top of the red blood cells, and the plasma makes up the rest of the volume of the sample in the tube (see Fig. 13-3).
- The moderately complex automated procedures available for hematocrit testing are often used in the physician office laboratory. An example of a common instrument is the i-STAT analyzer, made by Abbott Laboratories. The process requires only a few drops of blood. This instrument uses individual cartridges to which the blood sample is added. The hematocrit level is determined by use of an electrical current. As is the case with all CLIA-waived testing procedures, all instructions and quality control procedures recommended by the manufacturer must be followed.

Potential Errors in Hematocrit Testing

The hematocrit testing process may be considered simplistic. However, it is possible to negatively affect the results if not paying close attention to detail. The following are some of the most common errors encountered when using the manual hematocrit procedure:

- If a capillary specimen is used for the procedure, the sample must be collected from free-flowing blood from a skin puncture. If the area is squeezed, interstitial fluid (tissue fluid) may contaminate the sample or the red blood cells can be broken open (hemolysis). The first drop of blood from the skin puncture must be wiped away, as this contains some interstitial fluid as the lancet cut through tissue.
- If the plasma appears pink or reddish, cells may have been hemolyzed during collection. Excessive hemolysis can decrease the value of the hematocrit. Hemolysis may occur during the collection process or as a result of intravascular hemolysis in severe disease states.
- The hematocrit tube must be filled appropriately. If too little blood is added to the tube, it will not be possible to read the result using a reading device after centrifugation. Conversely, the result for a tube that is overfilled cannot be measured using a reading device.

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Procedure 13-2: CLIA–Waived Hematocrit Testing Using the StatSpin CritSpin Microhematocrit Centrifuge and Digital Reader

Hematocrit testing is a common CLIA-waived test that is performed in physician office laboratories and larger, more complex laboratories. Spun hematocrit analysis is relatively inexpensive, requires a small amount of blood, and takes only a few minutes. Although capillary spun microhematocrit testing is the most common method, venous blood may also be used for testing. Hematocrit results may be used to screen for or monitor the progress of the treatment for anemia.

TASK

Accurately perform microhematocrit analysis utilizing the StatSpin CritSpin microhematocrit centrifuge and digital reader. The process must be completed within 15 minutes.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Lancet for capillary punctures
- Alcohol prep pad
- Gauze pads
- Biohazardous sharps container
- StatSpin CritSpin microhematocrit centrifuge and digital reader
- Plastic heparinized microhematocrit tubes
- Sealing clay
- HemoCue control solution
- Disinfectant wipes for cleaning work area

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.12. Perform Hematology Testing

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment: 2. Hematology testing

Procedure	Rationale
1. Sanitize hands, allow them to dry completely, and apply gloves.	Gloves must be worn for any procedures in which exposure to blood or other potentially infectious materials is anticipated.
2. Use the quality control material that is designed for this procedure and this instrument, and verify that the instrument is working correctly. Follow the manufacturer's instructions for use and frequency of testing these quality control materials.	The quality control material comes with a set of acceptable result ranges. There are materials available to test at low, medium, and high levels of hematocrit results. Verify that the result is within the acceptable range for that level of control before performing patient testing. Document the result for this quality control material.
3. Remove two heparinized microhematocrit tubes from the container, and set them on a piece of gauze in the work area.	The tubes need to be within easy reach for the next step of the process. Heparinized tubes must be used for capillary samples because the blood must be anticoagulated to avoid clotting within the tube.

Continued

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Procedure 13-2: CLIA-Waived Hematocrit Testing Using the StatSpin CritSpin Microhematocrit Centrifuge and Digital Reader—cont'd

Procedure	Rationale
4. Perform a capillary puncture, using appropriate technique. Wipe away the first drop of blood.	Appropriate capillary puncture procedure includes disinfection of the draw site, allowing the alcohol to dry, using an appropriate site, performing the puncture perpendicular to the fingerprints on the finger, and wiping away the first drop of blood that forms. This drop of blood is contaminated with interstitial fluid and if used for the analysis, can produce erroneous results.
5. Hold the microhematocrit tube by the end with the color-coded band. Touch the opposite end of the tube to the drop of blood. The blood will enter the tube via capillary action. Fill the tube until the blood reaches the colored band at the opposite end.	For best results, do not allow air bubbles to form in the tube. The tube should be filled to the colored band to allow for accurate reading of the results.
6. Remove the tube from the blood source, and tilt the tube until the blood is halfway between the colored band and the end of the tube.	This step is important to allow for room for the sealing compound at the end of the tube.

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Procedure	Rationale
7. Hold the microhematocrit tube horizontally and push the end of the tube with the color-coded band into the sealing clay. Twist the tube and remove from the sealing clay. Wipe away any excess blood that may have leaked from the opposite end of the tube.	If the microhematocrit tubes are not sealed in this way, the blood will leak out of the tubes during the spinning process.
8. Place the tube with the sealed end toward the outer rim of the rotor.	If the sealed end of the tube is not placed to the outer edge of the rotor, all the blood will leak out of the tube when it is spinning.
9. Repeat steps 5 through 8 with another microhematocrit tube. After it is placed in the rotor, screw the rotor cover in place securely.	There should always be two tubes spun for each result to verify the accuracy of the result.
10. Holding the black knob in the center of the rotor, place it in the rotor holder in the centrifuge.	The rotor must be seated securely in place to avoid malfunction of the centrifuge.
11. Close the cover on the centrifuge and start the centrifuge. The StatSpin CritSpin centrifuge requires 2 minutes to fully pack the cells in the microhematocrit tubes.	The time allowed for the centrifugation will vary by method used.
12. When the rotor stops spinning, remove the rotor and place it in the digital reader.	The digital reader is an optional device. A circular or card reader may also be used to read the results.
13. Line up the pointer on the digital reader with the bottom of the cells in the microhematocrit tube and press the "zero" on the reader. Then line up the pointer with the top of the plasma column and set the "100" status on the reader. The final reading is accomplished at the top of the red blood cell column. The result is displayed on the digital reader.	All three steps must be followed to allow for accurate reading of the hematocrit results. Note: If a digital reader is not available, line up the tube with the bottom of the red blood cell column at the "zero" line on a hematocrit reader card, after which the top of the plasma column is to be aligned at the "100" on the card. Read the hematocrit result at the top of the red blood cell column.

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Procedure 13-2: CLIA-Waived Hematocrit Testing Using the StatSpin CritSpin Microhematocrit Centrifuge and Digital Reader—cont'd

Procedure	Rationale
14. Record this result.	The result must be recorded before removing the rotor from the system, or going on to read the second tube.
15. Following the same procedure, read the hematocrit result on the second tube.	The results must be within 2% of each other for this to be a valid result. If they are not, the process must be repeated. Report the mean (average) of the two tubes read.
16. Remove the microhematocrit tubes from the rotor and dispose of them as biohazardous sharps.	Although these are plastic tubes, they should still be disposed of in a puncture-resistant container.
17. Clean and disinfect the work area, then remove gloves and sanitize your hands.	The work area should always be cleaned after use to prepare it for the next user, and hands must always be sanitized after removing gloves.
18. Document the procedure in the patient's chart if it is available.	In a physician office laboratory, this procedure should be documented in the patient's chart. If the medical assistant is working in a laboratory setting where the chart is not available, this step is not necessary.

Date	
4/2/2012:	*Hematocrit test performed. QC within range. Hct 41%*
09:50 a.m.	*Connie Lieseke, CMA (AAMA)*

The required volume of blood for the hematocrit analysis is determined by following the procedure as written.

- The test may be affected if the timing or the speed of the centrifuge is insufficient. The cells will not pack at the bottom of the tube fully, which may cause the results to be falsely elevated.
- Inaccurate alignment when reading the result will cause errors. The employee must be careful to read only the red blood cell column, and to have the tube placed appropriately against the reading device for accurate results.
- If the sealing clay has not adequately filled the end of the tube, some of the blood will leak out during centrifugation and will affect the result. The end of the tube that is filled with clay is placed to the outside of the centrifuge so that the clay keeps the blood in the tube as the specimen is spun.
- The hematocrit value may be inaccurate immediately after excessive blood loss or following transfusion. Excess plasma may be trapped between the red blood cells in macrocytic, hypochromic, or sickle cell anemias. The cells will not pack as well because of the area occupied by the trapped plasma.

Test Your Knowledge 13-7

What is used to create the layers in the blood sample in manual CLIA-waived hematocrit procedures?

(Outcome 13-6)

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THE RELATIONSHIP OF HEMOGLOBIN AND HEMATOCRIT VALUES

Hemoglobin and hematocrit testing is often ordered together as H&H. To verify the validity of the results, it is important to compare the hematocrit and hemoglobin value of the patient's sample. The hematocrit value is approximately three times that of the hemoglobin value in a normal specimen. The hemoglobin value multiplied times three should be within two of the hematocrit results. In addition, the hemoglobin value is about three times that of the red blood cell count. By checking these relationships each time these tests are performed, the medical assistant can verify that the samples are all from the same patient and that the test procedures were performed correctly. Lipemia, hemolysis, and other clinical conditions can make these comparisons inaccurate. If the sample results don't fall within these parameters, the tests should be repeated.

ANEMIA

Anemia is a disorder characterized by the decreased oxygen-carrying capacity of the blood. The following three clinical scenarios may be evident with anemia:

1. A decreased total red blood cell count
2. A decrease in the hemoglobin content of each cell
3. A dysfunctional abnormal hemoglobin content that is not capable of transporting oxygen as it should

To treat anemia, practitioners will attempt to identify the cause. The problem may be chronic inadequate red blood cell production, red blood cell destruction or loss, or the inability of the bone marrow to react to blood loss adequately. Patients with anemia may exhibit signs of fatigue, pallor (pale skin), tachycardia (rapid heartbeats), or dyspnea (difficult breathing). Difficulty with concentration and memory issues may also be common symptoms. These symptoms are all related to the decreased oxygen-carrying capacity of the blood, which starves the cells of the body.

Test Your Knowledge 13-8

Name the disorder where the oxygen-carrying capacity of the blood is reduced. (Outcome 13-9)

Diagnosis and classification of the type of anemia may be accomplished with physical examination results, patient history, and laboratory tests. Patients with anemia may have decreased red blood cell counts, hemoglobin concentrations, or hematocrit values. Some types of anemia exhibit low values in more than one of these parameters, whereas others may demonstrate only one abnormal result. Anemia is often characterized by red blood cell indices that are outside of the normal range as well as specific red blood cell morphology changes.

Red blood cell morphology is observed on the stained blood smear utilized for the white blood cell differential by a trained laboratory technologist. **Anisocytosis** (red blood cells which appear in various sizes) and **poikilocytosis** (red blood cells which appear in various shapes) may be present. The red blood cells of anemic patients will appear abnormal, and may be **microcytic,** (small) **macrocytic** (large), or **hypochromic** (pale in color).

Impaired red blood cell production may be idiopathic (cause unknown) or due to toxins or infection. Anemia may also occur when there is defective synthesis of the heme of the hemoglobin molecule. Acute or chronic hemorrhage may cause anemia when the body is incapable of making enough cells to make up for the loss. Hemolytic anemia occurs with excessive lysis of the red blood cells intravascularly. This can be the result of red blood cell membrane disorders, hemoglobin disorders, metabolic disease, chemical toxins, extensive burns, malaria, or autoimmune destruction of the erythrocytes. A few specific types of anemia are presented below:

- **Iron-deficiency anemia** occurs when there is insufficient iron available for adequate hemoglobin formation. This is a hypochromic, microcytic anemia, as each cell has a reduced amount of hemoglobin. Iron deficiency may be caused by many situations: the body's supply of iron may be low, the absorption of the iron may be impaired, or the demand may be high. As our body breaks down old red blood cells, most of the available iron present in the system is in the tissue macrophage/reticuloendothelial tissue of the spleen. Dietary iron is absorbed in the small intestines.

  Clinical features of iron deficiency anemia may include sores on or a burning sensation of the tongue, ulcers at the corner of the mouth, "pica" (craving for dirt or ice), or chronic gastritis. "Milk anemia" is often a cause in 6- to 24-month-old children, as their diet may not contain sufficient iron. Other causes may include gastrectomy (total or partial) or prolonged treatment of peptic ulcers or acid reflux. Rapid growth

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during childhood and increased red blood cell production during pregnancy may be causes as well.

- **Aplastic anemias** result from decreased hematopoiesis in the bone marrow that leads to decreased red blood cell production. Only the red blood cells can be affected (**erythropoiesis**) or all blood cell production can be decreased. Radiation, medications, chemicals, or viral infections may be the cause. Chemotherapy agents and radiation treatment for cancer are examples. In most cases, no specific reason for the decreased production of red blood cells is determined. The red blood cell count will be low, and the red blood cell morphology may show anisocytosis and poikilocytosis. If platelet formation is decreased in addition to the low number of red blood cells, bleeding gums and nosebleeds may also be apparent.
- **Pernicious anemia** results from inadequate secretion of **intrinsic factor** by the parietal cells of the stomach lining. Intrinsic factor is necessary for absorption of vitamin B_{12}, which is necessary for red blood cell formation in the bone marrow. The symptoms of pernicious anemia may include pallor, slight jaundice (pale yellow skin), tongue sores, and tingling feelings in the extremities. The red blood cells of the circulating blood are often macrocytic. Autoantibodies to intrinsic factor may be present. The defective absorption of B_{12} may also be associated with celiac disease, malnutrition, or inflammatory disease of the small intestines. Patients with pernicious anemia who lack the intrinsic factor will need to receive B_{12} injections regularly to meet the body's needs.
- **Sickle cell anemia** is caused by a hemoglobinopathy. These patients are homozygous for Hb S; the majority of their hemoglobin is the S variant. The red blood cells of patients with sickle cell anemia are misshapen; they appear crescent or sickle shaped. The red blood cells are destroyed because of their abnormal shape during changes in oxygen tension, The Hb S also causes the cells to be more rigid, which increases their rate of destruction as they try to squeeze through capillaries.

  Sickle cell disease causes **splenomegaly** (an enlarged spleen), as blood pools in the spleen. Patients' hands and feet are sometimes swollen, and patients have increased chance of infection and exhibit joint pain. The abnormally shaped red blood cells become stuck in the blood vessels, causing pain and poor delivery of oxygen to tissues. The red blood cell morphology will include sickle and **target cells** if examined under the microscope.

Test Your Knowledge 13-9

What laboratory tests may be ordered by a physician to verify whether a symptomatic patient may be anemic? (Outcome 13-8)

Test Your Knowledge 13-10

List four examples of specific anemias. (Outcome 13-10)

SUMMARY

Hemoglobin in the erythrocytes is the molecule to which oxygen attaches and travels in the blood to every cell in the body to be available for energy production. The normal hemoglobin of adults is designated as Hb A. The hemoglobin concentration can be measured by analyzers spectrophotometrically, by measuring color change accomplished as the hemoglobin in the red blood cells is changed to cyanmethemoglobin. The type of hemoglobin present in cells can be identified by hemoglobin electrophoresis performed in reference or hospital laboratories.

The hematocrit is the amount of space occupied by red blood cells as compared to the whole sample, expressed as a percentage. Hematocrit values can be calculated by automated analyzers or directly read from a hematocrit tube after spinning in a centrifuge. The hemoglobin and hematocrit tests are the most frequently ordered procedures used to monitor the oxygen-carrying capacities of the body. If these values are below the normal reference range, anemia is suspected, and health-care professionals will use addition information to plan a course of treatment. Anemia is diagnosed by the history and physical examination of the patient, as well as laboratory test results. The results of laboratory tests that describe the volume and other characteristics of erythrocytes are used to classify the type of anemia present and establish a course of treatment.

TIME TO REVIEW

1. A degradation product of hemoglobin is: Outcome 13-1
   - **a.** Anisocytosis
   - **b.** Intrinsic factor
   - **c.** Bilirubin
   - **d.** Polycythemia

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2. _____ from the tissues can contaminate hemoglobin or hematocrit specimens and decrease the result. Outcome 13-1
   a. Anemia
   b. Interstitial fluid
   c. Intrinsic factor
   d. Erythropoiesis

3. Hemoglobin is made of chains of globin and four molecules of: Outcome 13-2
   a. Heme
   b. Sodium
   c. Cyanmethemoglobin
   d. Urobilinogen

4. _____ attaches to the hemoglobin and travels from higher oxygen concentration levels in the lungs to the cells of the body with increased oxygen need. Outcome 13-2
   a. Iron
   b. Vitamin B_{12}
   c. Glucose
   d. Oxygen

5. The type of hemoglobin normally seen in adults is _____. Outcome 13-3
   a. Hb A
   b. Hb C
   c. Hb F
   d. Hb S

6. Hemoglobin analyzers determine hemoglobin concentration by using: Outcome 13-4
   a. Electrophoresis
   b. Spectrophotometry
   c. Centrifugation
   d. Visual examination of the cells

7. Restate the adult reference ranges for hemoglobin and hematocrit testing. Outcome 13-8

8. Packed cell volume is a synonym for _____. Outcome 13-5
   a. Hemoglobin
   b. Hematocrit
   c. Sickle cell trait
   d. Polycythemia

9. List the layers of the blood sample of a spun hematocrit. Outcome 13-6

10. Anemia may be the result of: Outcome 13-9
    a. Excessive blood loss
    b. Inadequate red blood cell production in the bone marrow
    c. Abnormal hemoglobin molecule structures
    d. All of the above

11. Name the anemia caused by an insufficient iron supply in the body. Outcome 13-10
    a. Hemolytic anemia
    b. Iron-deficiency anemia
    c. Pernicious anemia
    d. Sickle cell anemia

12. A substantial decrease in red blood cell production may lead to a(n) _____ anemia. Outcome 13-10
    a. Iron-deficiency
    b. Aplastic
    c. Pernicious
    d. Sickle cell

Case Study 13-1: Why am I so tired?

A 35-year-old male patient came to the medical office with complaints of being weak, lethargic, and unable to focus on tasks. The health-care provider assessed the symptoms and ordered a hemoglobin and hematocrit test to be performed. The results were Hgb 12.3 g/dL and Hct 38%.

Based on the result, the physician ordered another blood draw for iron studies.

1. What disorder was indicated by the results?
2. Why did the physician order the iron studies?

RESOURCES AND SUGGESTED READINGS

Hemoglobal organization; details about thalassemia http://www.hemoglobal.org/whatisthalassemia.html

Mayo Clinic information about anemia http://www.mayoclinic.com/health/anemia/DS00321

Information about the various HemoCue testing instruments http://www.HemoCue.com

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Chapter 14

Erythrocyte Sedimentation Rate

Nikki A. Marhefka, EdM, MT(ASCP), CMA (AAMA)

CHAPTER OUTLINE

Erythrocyte Sedimentation Rate
Plasma Proteins Affecting the Erythrocyte Sedimentation Rate
The Influence of Red Blood Cells on the Erythrocyte Sedimentation Rate
Reference Ranges
Clinical Significance of Erythrocyte Sedimentation Rate Testing
Erythrocyte Sedimentation Rate Determination
  CLIA–Waived Erythrocyte Sedimentation Rate Methods
  Automated Erythrocyte Sedimentation Rate Methods
Potential Sources of Error for the Erythrocyte Sedimentation Rate Procedure
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

14-1 Define the key terms.

14-2 Analyze the effect of plasma proteins on erythrocyte sedimentation rates.

14-3 Describe the effects of abnormally shaped red blood cells in normal and abnormal erythrocyte sedimentation rates.

14-4 Recognize normal reference ranges for erythrocyte sedimentation rates for males and females.

14-5 List the pathological and nonpathological states that may exhibit an increased sedimentation rate.

14-6 Describe the CLIA-waived testing methods for the erythrocyte sedimentation rate.

14-7 Correctly perform an erythrocyte sedimentation rate.

14-8 Highlight procedural errors that can cause erroneous erythrocyte sedimentation rate results.

CAAHEP AND ABHES STANDARDS

CAAHEP 2008 Standards

I.P.I.12: Anatomy and Physiology: Perform Hematology Testing
I.C.I.6: Identify common pathology related to each body system

ABHES 2010 Standards

Medical Laboratory Procedures; Perform selected CLIA-waived tests that assist with diagnosis and treatment; #2: Hematology Testing

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KEY TERMS

Albumin
Aliquot
Erythrocyte sedimentation rate (ESR, sed rate)
Fibrinogen
Globulin
Inflammation
Pipette
Rouleaux
Wintrobe
Westergren

The erythrocyte sedimentation rate is one of the oldest laboratory tests still performed today. The test provides a measurement indicating how far the red blood cells settle in a specimen over a given period of time. The proteins present in the plasma and the specific conditions of the red blood cells in the specimen influence this rate. The erythrocyte sedimentation rate test may be performed using automated methods in hospital and reference laboratories or using CLIA-waived manual methods, which may be performed in any laboratory. The presence of **inflammation** (the protective reaction of the body's tissues to injury or irritation), acute or chronic infection, or neoplasms may be characterized by elevated ESR results. However, normal physiology may also cause the erythrocyte sedimentation rate to be elevated.

ERYTHROCYTE SEDIMENTATION RATE

The erythrocyte sedimentation rate (also known as the **ESR** or **sed rate**) is used (in addition to other more specific laboratory tests and patient history) to screen for inflammatory processes in the body. The results of an ESR are nonspecific; an abnormal result does not provide information about the type or cause of the inflammation, but only that it is present. In most situations, an EDTA (lavender top) anticoagulated venous blood sample is used for the test. (Some test methods require a different type of tube, specified later in the chapter.) A long, hollow, plastic tube (**pipette**) is filled with blood (an **aliquot**) which has been diluted with a citrate or saline solution, and the tube is placed upright on a stable, vibration-free, level surface. Gravity causes the red blood cells to settle out of solution and fall to the bottom of the pipette. After 1 hour, the amount that the red blood cells settled is measured in millimeters. The results of the ESR are reported in millimeters per hour (mm/hr).

Test Your Knowledge 14-1
What is measured by the erythrocyte sedimentation rate? (Outcome 14-1)

PLASMA PROTEINS AFFECTING THE ERYTHROCYTE SEDIMENTATION RATE

Blood plasma normally contains the proteins known as **albumin, globulin,** and **fibrinogen.** Inflammatory processes or infection may cause an increase in the levels of globulin and fibrinogen in the body. When these protein levels are elevated, this will increase the value of the erythrocyte sedimentation rate. Elevated amounts of globulin and fibrinogen decrease the negative charge on the surface of the red blood cells, which means that the cells are not as repelled from one another as they would be normally. This causes the cells to become somewhat "sticky," allowing the red blood cells to stack on top of one another like coins (Fig. 14-1). This configuration is known as **rouleaux** formation. Rouleaux are not uncommon occurrences, but the increase in plasma protein concentrations will cause it to become more pronounced. The increased rouleaux will cause the ESR result to be elevated because these stacked cell formations fall faster than single cells. The plasma proteins influence the settling most when the patient's hematocrit is between 30% and 40%.

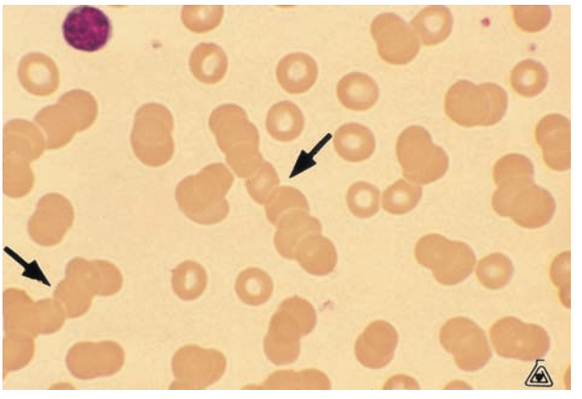

Figure 14-1 Rouleaux formation. Note how the red blood cells "stack" on top of one another, resembling stacks of coins. *From the College of American Pathologists, with permission.*

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Test Your Knowledge 14-2
What happens to the red blood cells in the rouleaux formation? (Outcome 14-1)

Test Your Knowledge 14-3
What plasma proteins contribute to the formation of rouleaux when increased in concentration? (Outcome 14-2)

Test Your Knowledge 14-4
Why do red blood cells in rouleaux formation settle faster than single red blood cells? (Outcome 14-3)

THE INFLUENCE OF THE RED BLOOD CELLS ON THE ERYTHROCYTE SEDIMENTATION RATE

When the ratio of red blood cells to plasma is lower than normal, the potential for rouleaux formation increases and will increase the speed that the red blood cells settle. For example, someone with anemia may have an elevated erythrocyte sedimentation rate, because his sample has fewer red blood cells as compared to the total sample volume than would be present normally. The presence of macrocytes (large cells) in the specimen will also cause the ESR to be greater than normal.

Erythrocyte sedimentation rates below the normal range may be present when the sample has a lot of microcytes (small red blood cells) or spherocytes (small, dense red blood cells) present. Sickle cells will also cause a decrease in the ESR, as the cells do not stack together as they would normally, so they will not settle out as expected. Patients with polycythemia will demonstrate a decreased erythrocyte sedimentation rate because of the excess number of red blood cells. Excessive leukocytosis (as in the case of chronic myelogenous leukemia) will also cause a decreased ESR result.

When the ESR values are out of the normal range because of the sizes or shapes of the red blood cells, the results may not change rapidly with treatment. Red blood cells live for approximately 120 days in the circulation, and the ESR result will not be significantly changed until the red blood cells present in the body have been replaced by healthy cells. It also takes time for the protein levels in the blood to change significantly with treatment. This means that the erythrocyte sedimentation rate is used more often for initial screening for inflammation or infection than it is to monitor the immediate effects of treatment.

REFERENCE RANGES

The normal reference ranges for the ESR vary by gender and by age. This is partly caused by the difference in the normal number of circulating red blood cells for men and women. The reference ranges are also elevated in adults over the age of 50. The normal reference ranges are listed in Table 14-1.

Test Your Knowledge 14-5
List normal ESR values for men and women younger than the age of 50. (Outcome 14-4)

CLINICAL SIGNIFICANCE OF ERYTHROCYTE SEDIMENTATION RATE TESTING

Inflammatory processes and acute infection with tissue breakdown increase the amount of fibrinogen and globulins present in the bloodstream. These proteins will interact with the red blood cells and cause the erythrocyte sedimentation rate to be elevated. The ESR can be used to diagnose a disease or condition, monitor an ongoing disease process or treatment, or assist with a differential diagnosis in certain disorders. For instance, the ESR will be elevated when a patient has recently experienced a myocardial infarction, but will not be elevated with angina pectoris. The ESR is not as sensitive to

TABLE 14-1
Reference ranges for the Westergren erythrocyte sedimentation rate

	Male	Female
Younger than 50 years of age	Less than 15 mm/hr	Less than 20 mm/hr
Older than 50 years of age	Less than 20 mm/hr	Less than 30 mm/hr
Older than 85 years of age	Less than 30 mm/hr	Less then 40 mm/hr

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changes in treatment as some other laboratory tests may be, but it still may be used to monitor treatment over an extended period of time.

It is important to remember that nonpathological issues may also cause the ESR to appear elevated. Pregnancy is a normal physiological process that will exhibit an elevated ESR. By the 12th week of pregnancy, the ESR result will have increased above the normal range, and will remain so through the first month postpartum. Women who are menstruating may also have an elevated erythrocyte sedimentation rate.

The disorders of polymyalgia rheumatica (an inflammatory condition of the muscles) and temporal arteritis (inflammation and damage to the blood vessels that supply the head) are the only two disease conditions for which an elevated ESR is the primary means of diagnosis. The test may also be used (in addition to other clinical information and laboratory tests) to evaluate septic arthritis, pelvic inflammatory disease, and appendicitis. Rheumatoid arthritis, chronic infection, collagen disease (systemic lupus erythematosus [SLE]), and certain neoplasms (especially prostate or kidney cancer) are characterized by increased ESR results. Erythrocyte sedimentation rates may be used to the monitor the efficacy of therapy in osteomyelitis. The ESR results may be misleading in patients with osteoarthritis, as these patients may have ESR results within normal range even with the presence of inflammation in the joints. The ESR results may also offer valuable information to help determine the risk associated with coronary artery disease.

Test Your Knowledge 14-6

If an ESR is elevated, what process is occurring in the body? (Outcome 14-5)

POINT OF INTEREST 14-1
Seditainer procedure

Becton, Dickinson has created the Seditainer system, a unique setup for the erythrocyte sedimentation procedure. It is designed to measure the erythrocyte sedimentation rate without transferring the blood to a separate tube. This eliminates the potential for exposure to blood products while transferring the specimen, as well as the possibility of adding bubbles to the specimen during the ESR setup. In the Seditainer system, the evacuated tubes used for drawing blood during the venipuncture have a black top, and they contain 1.25 mL of a sodium citrate solution. The tube needs to be filled to the point at which the vacuum is exhausted, and the specimen needs to be well mixed. The tube is placed in a special Seditainer stand, and the knob on the stand is used to adjust the top of the blood column to the "0" level. Each spot in the Seditainer stand is marked with a scale used to read the ESR level at the end of 1 hour. The tubes are then discarded without ever being opened.

ERYTHROCYTE SEDIMENTATION RATE DETERMINATION

There are two methods used for performing the ESR. The oldest method is the **Wintrobe** method. To perform the Wintrobe ESR, well-mixed blood from a tube containing EDTA anticoagulant is transferred directly to a Wintrobe tube using a pipette with a long, slim end. The Wintrobe tube is short, with graduated markings up to 100 mm. The ESR result is read after the sample has been allowed to sit undisturbed for 1 hour. It is important that the ESR is not vibrated or disturbed during the time that the test is performed.

The Wintrobe method is not used as widely as is the **Westergren** method. The Westergren method involves the dilution of the EDTA-anticoagulated blood with a sodium citrate solution or saline before the blood is added to the pipette. The Westergren pipette is also smaller in diameter and taller than the Wintrobe tube.

Most offices use a CLIA-waived modified Westergren method that uses a "closed system," allowing the blood to be added to the pipette with a minimal amount of exposure to the specimen for the employee. The test is performed on an EDTA-anticoagulated venous blood sample. A specified amount of room-temperature, well-mixed blood is diluted with a premeasured citrate solution and introduced into a hollow column. The column is marked off into millimeters for ease of reading the results. The top of the sample must be at the "0" mark when the timing is started as a point of reference. The column is placed in a rack so that it is exactly level, and timing begins immediately. The column must not be disturbed during the timing process, and the specimens must be kept out of direct sunlight. At exactly 1 hour, the top of the red blood cell column is noted. The ESR result is documented as the millimeters per hour that the cells have settled. The result is compared to the reference ranges for the patient, based on gender and age.

During the 60 minutes of the testing process, the settling of the red blood cells occurs in three stages. The first

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stage takes place within the first 10 minutes of the testing period. Rouleaux formation (the stacking of red blood cells) is beginning to occur so there is little sedimentation, even in abnormal samples. The second stage occurs in the next 40 minutes, during which there is a constant rate of settling as the rouleaux are set up (if present). The "stacks" of cells fall rapidly during this time because of the increased volume to surface area. The final stage occurs in the last 10 minutes of the testing process. At this time the settling is slowing as the cells are forming the packed cell volume at the bottom of the column.

CLIA-Waived Erythrocyte Sedimentation Rate Methods

There are various modified Westergren ESR systems available for use in the laboratory. Sediplast (manufactured by Polymedco) is one of the most common kits. An EDTA-anticoagulated venous blood sample of 0.8 mL is pipetted into a vial containing 0.2 mL of 3.8% sodium citrate diluting solution. The vial is then gently inverted to mix and placed into the accompanying rack. A 100-mm marked tube is gently pushed into the vial until it sits on the bottom of the small vial containing the blood. The tube is designed for autozeroing, as the blood mixture will reach the "0" mark and any extra will enter into an overflow area. The timing must begin immediately and continue for exactly 60 minutes. The sedimentation rate in mm/hr is read at the top of the red blood cell column. This closed system minimizes potential exposure to the sample while setting up the procedure and also prevents the potential for splashing when disposing of the setup after testing. This process is expanded and detailed in Procedure 14-1.

POINT OF INTEREST 14-2
The C-reactive protein

The erythrocyte sedimentation rate is elevated when inflammation occurs within the body. However, the ESR does not react quickly when inflammation first starts, and the result does not change immediately when treatment begins. The C-reactive protein (CRP) is also elevated with systemic inflammation processes in the body. The CRP is also known as an acute phase protein. The level of the CRP is elevated with infection, cardiovascular disease, and the formation of atherosclerosis. Because the level of CRP is affected immediately with treatment that reduces inflamation, this test may be a better choice than the ESR with which to monitor a course of treatment.

Although the Wintrobe method is not used as often as is the modified Westergren method, the Wintrobe method is still a CLIA-waived procedure carried out some laboratories. The Wintrobe method requires a special pipette to add the specimen to the tube used for the test, and the method is not considered as safe for the employee because it provides an opportunity for more potential exposure to bloodborne pathogens as the blood is added to the tube.

Test Your Knowledge 14-7
List two CLIA-waived ESR procedures. (Outcome 14-6)

Automated Erythrocyte Sedimentation Rate Methods

For laboratories that perform high volumes of testing, there are automated ESR analyzers available. These instruments automatically perform the dilutions (if necessary), set up the ESR tubes, and have internal readers that detect the color change present at the top of the red blood cell column when the designated time has passed. Some determine the ESR in less than the 60 minutes required for the manual methods. Polymedco makes the Sedimat and the Sedten analyzers. The Ves-matic, manufactured by Diesse, uses the EDTA lavender top tube directly to perform the ESR measurement. Many of these analyzers are capable of processing multiple ESR tests at one time.

POTENTIAL SOURCES OF ERROR FOR THE ERYTHROCYTE SEDIMENTATION RATE PROCEDURE

The ESR test must be performed very carefully; procedural errors will directly affect the results. The first consideration is the collection of the blood sample to be used. If the blood is allowed to clot, the ESR will be falsely decreased because the fibrinogen in the sample will be used forming the blood clot. Samples will ideally be used for the ESR within a few hours of the blood draw. Most laboratories state that the sample may be used for the test if it is kept at room temperature (20° to 25°C) for up to 24 hours. Refrigeration may cause irreversible changes in the way the cells interact in the sample, so the process must occur within 12 hours if the sample is refrigerated. The blood must be at room temperature at the time the test is performed.

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Procedure 14-1: Perform CLIA–Waived Sediplast Westergren Erythrocyte Sedimentation Rate

Erythrocyte sedimentation rates are one of the oldest, easiest, and least expensive testing procedures performed in laboratories. The Westergren method is the most common CLIA-waived manual system employed.

TASK

Perform an erythrocyte sedimentation rate using the Sediplast system, and read and record the results correctly.

CONDITIONS

- Hand-washing supplies and/or alcohol-based hand sanitizer
- Disposable gloves
- Sediplast Modified Westergren ESR reservoir tube, pipette, and rack
- Lavender top (EDTA) tube filled with blood
- Biohazardous disposal bag
- Face shield and laboratory coat
- Transfer pipette
- Test tube rack

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

I.P.I.12 Anatomy and Physiology; Perform Hematology Testing

ABHES 2010 Standards

- Medical Laboratory Procedures, b. Perform selected CLIA–waived tests that assist with diagnosis and treatment;
- #2: Perform Hematology Testing

Procedure	Rationale
1. Sanitize hands (allow them to dry), then apply gloves, laboratory coat, and face shield.	Gloves must be worn for any procedures during which exposure to blood or other potentially infectious materials is anticipated. This procedure has an increased risk for exposure to blood products, so a laboratory coat and face shield should also be worn.
2. Gather testing supplies. Check the expiration of the ESR kit components. Verify that the necessary quality control has been performed prior to testing the patient sample.	Expired products must never be used for testing. If the required quality control has not been performed, this needs to be accomplished (and the results verified) before the patient test results are reported.
3. Verify the test ordered and that the sample is appropriately identified.	The test and patient identity should always be verified before any testing procedure is started.
4. Verify that the EDTA tube is at room temperature.	The blood must always be at room temperature for the ESR test result to be valid.
5. Invert the EDTA tube 8 to 10 times to mix the sample.	The specimen must be well mixed or it will provide erroneous test results.
6. Carefully remove the rubber stopper on the top of the EDTA blood tube. Avoid aerosol formation by removing the top slowly. Place the stopper top down on the tabletop, and place the blood tube in a test tube rack.	If the stopper is removed too quickly, a fine "mist" of blood may be released, increasing the potential for exposure.

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Procedure	Rationale
7. Remove the pink cap from the prefilled reservoir vial provided with the test kit. Be careful not to spill any of the solution.	The proper amount of diluent in the tube is vital for the dilution factor to be correct and the results to be valid.
8. Using the transfer pipette, add blood to the reservoir vial until it reaches the fill line. Avoid bubbles or air spaces in the reservoir vial. Recap the EDTA blood tube.	It is important to add the necessary volume of blood to the diluent to allow for the correct dilution ratio and to provide enough specimen for an accurate ESR reading.
9. Replace the pink cap on the reservoir vial and invert fully at least 8 times.	The specimen must be mixed thoroughly with the diluent for the results to be accurate.
10. Place the vial in the rack on a level surface. Insert the marked ESR pipette through the pink cap and push down until it comes to the bottom of the vial. The blood will rise to the "0" mark within the ESR pipette, and any excess blood will enter the overflow reservoir.	The blood must reach the "0" mark or the test will not be valid. This process should be accomplished fairly slowly to make certain that the blood reaches the top of the ESR pipette.
11. Make certain that the rack is in a place where it will not be disturbed and where it is not in direct sunlight. Set a timer for 1 hour.	Vibrations, movement or direct sunlight may affect the ESR results. A timer is necessary for appropriate timing of the procedure.

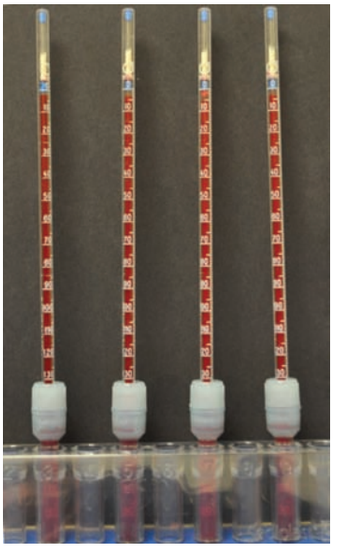

Courtesy of Fisher HealthCare, Inc.

Continued

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Procedure 14-1: Perform CLIA-Waived Sediplast Westergren Erythrocyte Sedimentation Rate—cont'd

Procedure	Rationale
12. After 1 hour, note the number at the top of the red blood cell column. This will be in mm marked on the side of the ESR tube. Note this number as the result in mm/hr, and document the result on the log sheet or the patient's chart.	The marks should be relatively easy to read, and are read from the top of the pipette down. 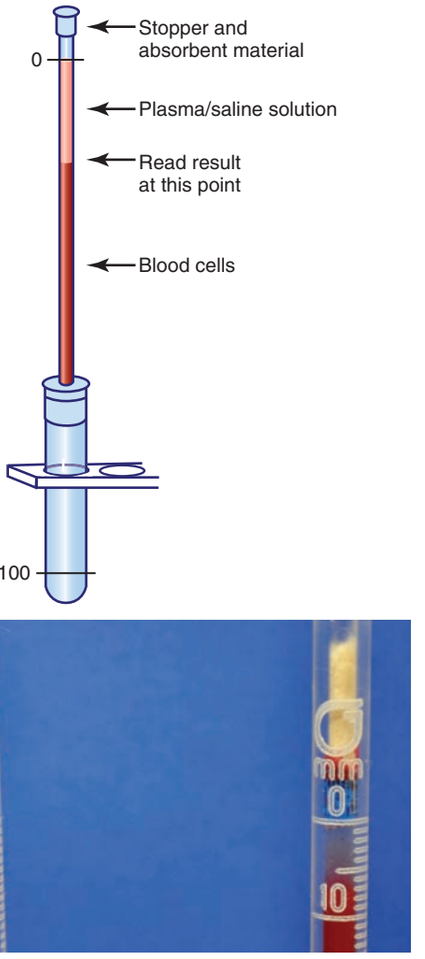
13. Dispose of the ESR setup and the transfer pipette in the biohazardous garbage. Disinfect the work area.	There is blood in the transfer pipette and the ESR setup, so both must be disposed of in the biohazardous garbage.
14. Remove gloves and sanitize hands. Remove face shield.	Hands must always be sanitized after removing gloves. The face shield is not necessary for all procedures, so should be removed until needed again.

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Procedure	Rationale
15. Document the ESR results in the patient's chart if not completed previously. If necessary, also log the lot number and expiration of the kit components on the log sheet.	All procedures must be appropriately documented in the patient's chart.

Date	
1/18/2020:	ESR 22 mm/hr.
1100 a.m.	Connie Lieseke, CMA (AAMA)

The tube of venous blood must be well mixed so that the aliquot removed for the test is representative of the sample. Before removing the blood for the test, the tube is gently inverted at least eight times. After the blood is added to the diluent, adequate mixing is again imperative. When reading the results, if there is not clear definition at the top of the red blood cells in the plasma, the result is to be read at the point when there is a definitive border to the red blood cells in the column.

There can be no bubbles in the column of blood or diluted blood. The tube (column) must be exactly vertical during the testing process, so the holding rack into which it is placed must be level as well. Many of the racks come with leveling devices at the corners so that this can be verified. Movement (such as vibrations) can alter the results, so it is important that this test is not performed on a counter next to a centrifuge or a printer. The timing must be exact for accurate readings, so a timer is usually employed rather than a watch or a clock.

Test Your Knowledge 14-8

List two testing procedure errors that can affect the value of the ESR. (Outcome 14-7)

SUMMARY

The erythrocyte sedimentation rate is a test that screens for the presence of inflammation. The ESR results can be altered as a result of infection, autoimmune disease, or growth of neoplasms in the body. With inflammation, there is a change in the levels of plasma proteins with an increase in fibrinogen and some globulins. This protein change can cause the red blood cells to form excessive rouleaux, which settle out of solution faster than do single red blood cells. The observance of this sedimentation of red blood cells in 60 minutes constitutes the test procedure. The CLIA-waived procedures include manual Westergren and Wintrobe methods. There are also automated testing systems available for laboratories that perform a high volume of testing or desire the results in less than 1 hour. The erythrocyte sedimentation rate is used as a tool to aid in diagnosis, monitor disease process, follow treatment, and assess prognosis of certain disorders.

TIME TO REVIEW

1. Rouleaux formation is: Outcome 14-1
   - **a.** An abnormal collection of proteins in the circulating blood
   - **b.** The test for inflammation
   - **c.** A group of red blood cells stacking together like coins
   - **d.** None of the above
2. Examples of proteins that are increased in the plasma when the sedimentation rate is elevated include: Outcome 14-2
   - **a.** Albumin and fibrinogen
   - **b.** Fibrinogen and globulins
   - **c.** Globulins and albumin
   - **d.** Globulin and tyrosine
3. A 30-year-old male patient has an ESR of 38 mm/hr. The result of this test for this patient is _____ _____. Outcome 14-4
   - **a.** Within the reference range for the patient's gender and age
   - **b.** Elevated for the patient's gender and age
   - **c.** Within range for his age, but not his gender
   - **d.** Below the reference range

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4. An 87-year-old woman has a sedimentation rate of 38 mm/hr. The result for this patient is _____ because of this patient's gender and age. Outcome 14-4
   a. Normal
   b. Elevated
   c. Elevated
   d. Decreased

5. An elevated ESR indicates the presence of: Outcome 14-5
   a. Inflammation
   b. Erythropoiesis
   c. Albumin
   d. Renal disease

6. A/an _____ anticoagulated venous blood sample is used for the erythrocyte sedimentation rate. Outcome 14-6
   a. Citrate
   b. Heparin
   c. EDTA
   d. Fluoride

7. True or False: Westergren and Wintrobe are CLIA-waived erythrocyte sedimentation procedures. Outcome 14-6

8. _____ is measured to determine the ESR value. Outcome 14-7
   a. The ratio of proteins in the blood
   b. The rouleax formation of red blood cells
   c. The settling of the red blood cells
   d. The presence of red blood cells in the bone marrow

9. Examples of potential errors when performing an ESR include: Outcome 14-8
   a. Insufficient sample added to diluent
   b. Insufficient mixing of sample and diluents
   c. Reading result at 50 minutes
   d. All of the above

Case Study 14-1: Cutting corners

Margaret Lindon is a new employee, and she was nervous on her first day alone in the laboratory. One of the first orders she received was to collect a specimen and perform an ESR test. She had been trained on this procedure the week before, and remembered that it was not very difficult. The requisition indicated that a lavender top tube was to be drawn, and Margaret knew where the ESR supplies were kept. As Margaret was collecting the blood sample, the blood flow stopped, and she could not get it to continue. She discontinued the blood draw with a partial lavender top tube filled.

After the patient left, Margaret began to set up the ESR test. She added the blood to the reservoir tube containing the citrate solution, but realized that she did not have quite enough specimen to fill it to the required line. She inserted the ESR pipette, and the blood-citrate solution came almost to the top of the pipette, but was shy by a few millimeters. After 1 hour, Margaret read the results of the ESR, and reported out that it was 28 mm/hr.

1. Was the correct specimen drawn for the ESR order?
2. What were the potential sources of error for this scenario? Was this result of 28 mm/hr a valid result?

RESOURCES AND SUGGESTED READINGS

"Polymedco Products"
Information about the various clinical diagnostic test kits and educational materials provided by Polymedco. http://www.polymedco.com/products-pages-7.php

"Diesse USA Product Line"
Products from Diesse USA including an ESR system. http://www.diesse-usa.com/products.html

Chapter 15

Coagulation Studies

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Purpose of Coagulation Studies
Mechanisms of Blood Clotting
Disorders Diagnosed or Monitored With Laboratory Coagulation Tests
- Thrombosis
- Atrial Fibrillation
- Postsurgical Prophylaxis
- Disseminated Intravascular Coagulation
- Thrombocytopenia
- Antiphospholipid Syndrome
- Hemophilia

Laboratory Tests Used to Diagnose Coagulation Disorders or Monitor Anticoagulant Therapy
- Prothrombin and International Normalized Ratio
- Activated Partial Thromboplastin Time/Partial Thromboplastin Time
- Platelet Count
- Fibrinogen
- Fibrin Degradation Products
- D-dimer
- Bleeding Time Test
- Other Tests Used to Assess Platelet Function

Specimen Requirements for Coagulation Testing
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

15-1 Define the key terms.
15-2 Explain the purpose of coagulation studies.
15-3 Describe the process of coagulation.
15-4 Compare the formation of a thrombus to that of an embolus.
15-5 Compare and contrast the disorders diagnosed or monitored with laboratory coagulation testing.
15-6 Examine how the prothrombin test and INR calculation are used together to monitor coagulation status for a patient.
15-7 Successfully perform a CLIA-waived PT/INR test.
15-8 Explain appropriate use of a PTT test for monitoring coagulation.
15-9 Evaluate the use of platelet counts in coagulation testing.
15-10 Explain why bleeding time tests are not performed as frequently as PT and PTT tests.
15-11 Describe other tests of platelet function.
15-12 List other coagulation tests that may be ordered.
15-13 List the requirements for coagulation specimen collection and potential sources of error for the various tests.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

None

ABHES Standards

None

KEY TERMS

Afibrogenemia
Aggregate
Antiphospholipid syndrome
Atrial fibrillation
Clotting cascade
Clotting factor
Coagulation
Coumadin
D-dimer
Deep vein thrombosis (DVT)
Disseminated intravascular coagulation (DIC)
Dysfibrinogenemia
Embolus
Endothelial cell lining
Extrinsic pathway
Fibrin degradation products (FDPs)
Fibrinogen
Fibrinolysis
Fibrinolytic drugs
Hemophilia
Hemostasis
Heparin
Hypofibrinogenemia
International normalized ratio (INR)
Intrinsic pathway
Occlude
Partial thromboplastin time (PTT)
Pathological thrombosis
Plasmin
Platelet count
Prophylactic
Prothrombin time (PT)
Stroke
Thrombin
Thrombocytes
Thrombocytopenia
Thrombosis
Viscous
Warfarin
von Willebrand's factor

When most of us receive a paper cut or other minor injury, we take for granted that this minor blood vessel injury will stop bleeding and heal within a short period of time. The process of blood clotting, known as **coagulation,** and the breakdown of these clots within the body are monitored by use of various coagulation testing procedures. Platelets, fibrinogen, thrombin, and 13 other clotting factors are all involved in the process of clot formation, which is necessary for repair of blood vessel damage. The blood vessels also play a role. In addition, chemicals are produced by the body to break down the clots when they are no longer needed. This process is known as **fibrinolysis.** Coagulation studies include quantitative and qualitative analysis of the various components, as well as their function.

PURPOSE OF COAGULATION STUDIES

Coagulation studies are performed in the laboratory when the various elements in the clotting process appear to be imbalanced or malfunctioning. These defects can cause excessive bleeding, bruising, or unwanted blood vessel occlusion (blocking of the vessel) with formation of blood clots in the bloodstream. Anticoagulant medication use is also closely monitored with laboratory coagulation testing. Laboratory tests may include quantitative analysis of certain plasma proteins involved in the clotting process, as well as analysis of platelet count and function. Coagulation studies are often performed prior to surgical procedures to verify that the balance between bleeding and clotting in the body is at a desirable level. **Hemostasis** is the word

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used to describe the processes needed to balance clot formation and fibrinolysis in the body.

Test Your Knowledge 15-1
What is one reason that coagulation studies may be performed? (Outcome 15-2)

MECHANISMS OF BLOOD CLOTTING

The balance between blood clotting and excessive bleeding involves numerous factors. These include the blood vessels of the body (including the cells that line those vessels); the platelets **(thrombocytes)** circulating in the bloodstream; and numerous coagulation factors present in the circulation as enzymes, substrates, inhibitors, and plasma proteins. The study of coagulation and hemostasis focuses on two major systems. The primary coagulation system includes the action of the platelets and the vascular response to vessel injury. The actions of the plasma proteins and other chemicals in the circulation make up the secondary coagulation system, and complete the coagulation process.

Test Your Knowledge 15-2
Are platelets solely responsible for coagulation when a vessel is damaged? (Outcome 15-3)

When damage occurs to a blood vessel, the **endothelial cell lining** of that artery, vein, or capillary is disrupted. The first response of the body is to constrict the damaged blood vessel and other vessels in the vicinity, limiting the blood flow to the area so that platelet aggregation can begin. In small arterioles, venules, and capillaries, this may stop the bleeding without moving to the next step. In larger vessels, however, this will not be enough.

When intact, the blood vessel lining does not attract platelets; in fact, the two repel each other. However, when the endothelial cell lining is damaged, the exposed collagen layer underneath the endothelial cells attracts the platelets to **aggregate** and begin the process of coagulation. Fibrinogen and *von Willebrand's factor* assist in the adhesion of the platelets to one another. The following are some of the next steps involved in primary coagulation:

1. The platelets in the area of the damaged vessel change shape and begin to adhere tightly to one another.
2. Platelets are filled with granules in their cytoplasm. As they aggregate and change shape, they release the content of these granules into the plasma. This chemical causes the platelet plug to become more stable and the connections between the platelets to be very tight.
3. The platelets release a compound known as *proaccelerin,* or *labile factor,* that works with vitamin K to start the rest of the changes necessary for a permanent fibrin clot to form.

Test Your Knowledge 15-3
What is the body's first response to vessel injury? (Outcome 15-3)

Secondary coagulation includes a series of events described as the **clotting cascade.** This cascade involves continuous feedback and interaction in which each **clotting factor** affects other clotting factors to achieve the formation of a solid fibrin clot over the area of the damaged vessel. All of the clotting factors are produced in the liver and introduced into the bloodstream. Some of the clotting factors are also produced by endothelial cells in the vessel lining and megakaryocytes in the bone marrow. There are at least 10 clotting factors, and they are designated by Roman numerals. They work in two different pathways, the **intrinsic pathway** and the **extrinsic pathway,** to accomplish the same goal. The intrinsic pathway involves chemicals that are all present in the bloodstream naturally, whereas the extrinsic pathway is initiated by release of chemicals into the bloodstream by the subendothelial cells exposed during the vessel injury. Table 15-1 lists the clotting factors with their Roman numeral numbers, alternative names, and the laboratory tests used to monitor their activity in the body.

Test Your Knowledge 15-4
What does the term *clotting cascade* refer to? (Outcome 15-3)

It is important to keep in mind that the balance of bleeding and clotting in the body must be regulated naturally by clotting processes, as well as by fibrinolysis (the breakdown of the formed clots when they are no longer needed) and inhibitors that keep the system from overreacting to damages to the vessel walls. Any natural or acquired interference in this balance will negatively affect hemostasis.

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TABLE 15-1
Clotting factors with alternative names and common tests used to monitor levels or detect deficiencies*

Clotting Factor	Alternative Name	Laboratory Test
I	Fibrinogen	Fibrinogen level
II	Prothrombin	Prothrombin time (PT)
III	Thromboplastin	PTT
IV	Ionized calcium	Ionized calcium levels
V	Proaccelerin or labile factor	PT and PTT
VII	Proconvertin or stable factor	PT
VIII	Antihemophilic (also linked to von Willebrand's factor)	PTT
IX	Plasma thromboplastin component	PTT
X	Stuart-Prower	PT and PTT
XI	Plasma thromboplastin antecedent	PTT
XII	Hageman factor	PTT
XIII	Fibrin stabilizing factor	PT and PTT

*There is no factor VI.

DISORDERS DIAGNOSED OR MONITORED WITH LABORATORY COAGULATION TESTS

Coagulation testing is used to diagnose or monitor a variety of diseases or disorders. Some of the results provide information that will help the health-care provider to anticipate problems (such as those performed prior to surgical procedures), whereas other laboratory values are used to achieve a diagnosis or monitor the progress of a disease.

Thrombosis

Thrombosis is the clot formation that occurs naturally in the body. However, there may also be times when **pathological thrombosis** occurs. Clots may form in any vessel of the body related to different risk factors and exhibiting different symptoms dependent on the location of clot formation. Arterial thrombosis can be caused by hypertension, atherosclerosis, blood that is too **viscous,** or thick, and by functional platelet abnormalities. Clots in the arteries usually include a small amount of fibrin and more white cells than thromboses formed in the other vessels.

Pathological thrombosis in the venous system is usually made up of red blood cells and large amounts of fibrin. Deep vein thrombosis (DVT) may be caused by impaired (slow) blood flow, especially in those patients who are recovering from surgery and are therefore inactive. Other factors that may contribute to formation of venous thrombi include impaired breakdown of clots (fibrinolytic deficiency) and inadequate levels of clotting inhibitors that keep the body from excessive thrombosis formation. A very serious complication of deep vein thrombosis occurs when pieces of the blood clot dislodge from the vessel of formation and enter the bloodstream. This is called an **embolus,** and if it becomes lodged in the pulmonary tissues, it may be fatal.

Test Your Knowledge 15-5
How is an embolus different from a thrombus?
(Outcome 15-4)

Atrial Fibrillation

Atrial fibrillation is a condition in which there are erratic electrical signals sent through the atria, which are the upper chambers of the heart. Because of these erratic signals, the heart does not beat with the correct rhythm or at the correct speed. This causes turbulence, or a disrupted blood flow through the heart, and an increased risk of blood clot (thrombus) formation within the atria. This is especially common in the left atria. If a thrombus is present, the patient is at a very high risk of embolus formation as well, as the blood travels through the heart and may pick up pieces of the clot. The emboli often travel to the brain, where they **occlude** (block) the small vessels

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and cause a **stroke.** A stroke (also known as a cerebrovascular accident) is the result of a blockage of blood flow to an area of the brain. Patients who have chronic atrial fibrillation are often prescribed **warfarin** as a lifelong treatment option, as warfarin is a drug that interferes with the extrinsic clotting factor system of the body, and decreases the risk of blood clots forming in the atria.

Postsurgical Prophylaxis

Because the opportunity for thrombosis formation is heightened when the blood flow to a specific area of the body is slowed, those who are immobile or recovering from surgery are at high risk of blood clot development in their legs, especially. This is called a **deep vein thrombosis,** or **DVT.** Increased passive exercise (when possible) helps to reduce this risk, and is often started the same day or one day postsurgery with the assistance of a member of the physical therapy team. However, this may not always be enough to keep clots from forming in the deep veins of the legs. Many patients who anticipate extended hospitalization after surgery will be placed on heparin during or immediately after the procedure as a **prophylactic** measure, treatment in anticipation of a potential problem, as opposed to treatment after the blood clot has occurred. Heparin is fast acting, is given via IV or injection, and affects the intrinsic clotting system of the body. Heparin is a very good choice for inpatient treatment, but as patients near discharge, they are usually started on oral warfarin treatment, as this is easier to maintain in the home environment.

Disseminated Intravascular Coagulation

Disseminated intravascular coagulation (DIC) occurs when the blood clotting system is activated throughout the body, rather than just at a site with injury to a blood vessel. Small thrombi form everywhere, including within organs and capillary beds. That patient's coagulation factors are used up after a time, as well as the substances that break down blood clots. This often results in uncontrolled bleeding. DIC can be a process that is slow to develop, and in this situation the individual usually has systemic thrombi develop, but no uncontrolled bleeding. In acute (or rapid-acting) DIC, the patient develops the multiple thrombi, but they also may hemorrhage because of the rapid use of the coagulation factors within their body.

There is *always* an underlying cause for patients who exhibit disseminated intravascular coagulation. Many times (especially in acute cases) if the underlying situation is addressed and resolved, the DIC will also resolve. Potential causes of disseminated intravascular coagulation include the following:

- Systemic infection with bacteria or fungi
- Severe trauma
- Solid tumors or hematological cancers
- Obstetrical complications such as placental abruption or amniotic fluid emboli
- Aortic aneurysms or other vascular disorders
- Systemic inflammatory responses, such as those that occur with transfusion reactions

The first course of treatment for DIC is to resolve the underlying problem, if possible. However, in situations in which the initial disease process cannot easily be resolved, or cannot be resolved quickly enough, the symptoms of disseminated intravascular coagulation may be treated with transfusions of platelets, coagulation factors contained in fresh frozen plasma, and fibrinogen as provided in cryofibrinogen precipitate.

Test Your Knowledge 15-6

How are DIC and DVT similar? (Outcome 15-5)

Thrombocytopenia

In **thrombocytopenia,** the patient does not have enough platelets circulating to coagulate effectively when necessary. Certain medications or other underlying hematology disease states may cause this condition. Because of the low numbers of platelets, the clots that form in response to vascular damage will not be adequate. In addition to thrombocytopenia, patients may exhibit disorders of platelet adhesion, where the platelet count is normal for the patient, but their platelets lack the ability to stick to other platelets and form the aggregate plug that is necessary to stop the bleeding with vascular injuries.

Test Your Knowledge 15-7

How is thrombocytopenia different from the other disorders presented thus far in this chapter? (Outcome 15-5)

Antiphospholipid Syndrome

Antiphospholipid syndrome is a condition in which small systemic blood clots form, presenting potential risk for embolism or organ failure. Because the blood clots can form anywhere, the patient is at a high risk for

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stroke, or total occlusion of blood vessels providing circulation to internal organs.

Hemophilia

Hemophilia is a sex-linked inherited disorder that affects approximately 1 in 5,000 males. There are two types of hemophilia: type A and type B. Those affected with type A hemophilia lack the clotting factor VIII. Those with type B lack the clotting factor IX. Both groups of patients may bleed excessively and experience vascular damage, in addition to internal bleeding in the elbows, knees, and other joints. Not all patients with hemophilia are affected to the same extent; the disorder may express itself with mild to moderate symptoms. It is also possible to develop hemophilia in response to chemotherapy treatment or other disease states. In those situations, the patients actually develop antibodies to the clotting factors, which render them useless when needed within the body. Patients with all types of hemophilia will need to be treated with the missing clotting factors to avoid excessive bleeding. The clotting factors may be derived from human donated plasma, or they may be created in a laboratory without human elements.

LABORATORY TESTS USED TO DIAGNOSE COAGULATION DISORDERS OR MONITOR ANTICOAGULANT THERAPY

As we have learned, certain disease states may cause a patient to be more prone to thrombosis formation, whereas other pathologies may cause excessive bleeding. For those who have disorders causing excessive bleeding, the coagulation tests associated with diagnosis and monitoring of the conditions are usually performed at a hospital or reference laboratory. These tests may include the prothrombin time (PT), the activated partial prothrombin time (PTT), fibrinogen levels, fibrin degradation products (FDPs), and D-dimer. Health-care providers may also request levels of specific clotting factors. Table 15-2 contains information about the tests covered in this chapter, why they are commonly ordered, and the specimen types required. Medical assistants may perform PT/INR tests, and will be involved in the specimen collection process for the tests performed outside the physician office, so they will benefit from the basic knowledge about the specimen requirements and clinical significance of the various test results.

TABLE 15-2

Common coagulation tests, clinical indication or significance, and specimen requirements

Test Name	Abbreviation	Test Use	Specimen Type
Activated partial prothrombin time	PTT or PTT	Screening for coagulation dysfunction; intrinsic system of blood coagulation. Also used to monitor heparin anticoagulant use.	Light blue top tube with citrate anticoagulant; must be filled completely.
Fibrin degradation products	FDP	Monitoring of breakdown products from blood clot dissolution	Special FDP tube for plasma levels; may also use red top tubes for serum levels.
D-dimers	D-dimers	Fibrin breakdown products from blood clot dissolution	Citrated plasma from full light blue top tube. Plasma should be frozen if the test cannot be performed immediately.
Fibrinogen level	Fib	Measures amount of circulating fibrinogen in bloodstream	Plasma from full light blue top citrate tube.
Bleeding time	BT	Platelet function	Test performed on patient
Platelet count	Plt Ct	Assessment of number of platelets available for blood coagulation	Lavender top tube with EDTA anticoagulant. Test performed on whole blood.
Platelet function assay 100	PFA 100	Assessment of platelet function; clotting ability of platelets	Full light blue top citrated tube; whole blood is used for the assay.

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TABLE 15-2

Common coagulation tests, clinical indication or significance, and specimen requirements—cont'd

Test Name	Abbreviation	Test Use	Specimen Type
Prothrombin time	Prothrombin time or PT	Screening for coagulation dysfunction; specifically extrinsic blood clotting cascade. Also used for monitoring oral anticoagulant use.	Full light blue top citrate tube or capillary sample if performed with point-of-care testing.
International normalized ratio	INR	Factor used for monitoring oral anticoagulant use; standardizes results using various reagents and testing methods	Full light blue top citrate tube or capillary sample if test is performed with point-of-care testing instrument

Prothrombin and International Normalized Ratio

The **prothrombin time (PT)** is a test that measures the efficacy of the extrinsic coagulation process. Prothrombin is a clotting factor that is manufactured by the liver, and the change of prothrombin to **thrombin** is one of the last steps to forming a clot when a vessel is damaged. The action of clotting factors I, II, V, VII, and IX may be monitored with the prothrombin time test result. The prothrombin time may be elevated in patients who have insufficient amounts of these clotting factors, as well as those who are deficient in vitamin K. Patients suffering from liver disease may also have an increased prothrombin time result because of the inability of the liver to create the clotting factors as needed.

The PT is reported in seconds, as it is a measurement of the amount of time needed for a clot to form in the specimen after the addition of thromboplastin and calcium to a sample of platelet-poor plasma. PT tests are often performed as part of a coagulation screen before surgical procedures or when a patient shows signs of excessive bleeding or bruising. Prothrombin times may be used to screen for initial coagulation disorders. The PT is also used to help monitor oral anticoagulant use, as the result is elevated when a patient is being treated with these oral anticoagulants.

POINT OF INTEREST 15-1
History of warfarin

As the population in the United States grew dramatically in the early 1900s, so did the demands for farming. The Midwest was farmed extensively, growing crops to feed the U.S. population as well as the food to feed dairy and beef cattle. Once the "natural" feed products of the area were exhausted (such as wheat and grasses native to the region), it was necessary to research other crops that might suffice to feed the animals. Sweet clover was introduced, as the protein content and digestibility was similar to that of alfalfa. However, sweet clover was more prone to spoilage than the other food sources had been because of issues related to its high moisture content.

Soon, there were reports of unexplained hemorrhage and sickness in cattle that had been fed from the sweet clover after harvest. Through analysis, it was found that the spoilage of the clover created dicoumarol. Dicoumarol attached itself to the vitamin K present in the intestines of the cattle. Vitamin K is essential for several blood clotting mechanisms, so these cattle would bleed excessively, as the necessary vitamin was no longer usable.

In 1948, warfarin was created as a derivative of dicoumarol, and in 1952 it was introduced to the world as a type of rat poison. A young navy recruit decided that he wanted to end his life, and ingested a large dose of this warfarin rat poison. Remarkably, he did not die, although his blood clotting processes were definitely affected. This situation prompted more research into how warfarin could be used to treat humans, and in 1954, it was first authorized for human use as an oral anticoagulant. In 1955, President Eisenhower was treated with warfarin after a heart attack.

Warfarin (brand name Coumadin) is the most common drug prescribed worldwide. It is taken by those who have a prior history of blood clots or heart disorders such as atrial fibrillation and heart valve deformities, as well as given to surgical patients. The efficacy of warfarin can be affected by ingestion of foods that are high in vitamin K, such as cabbage, cauliflower, spinach, soybeans, and broccoli.

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A CLIA-waived PT test procedure is used to monitor the anticoagulant effects of medications such as **warfarin** (Coumadin) in the physician office laboratory. These drugs are used by patients who are at a high risk for blood clot formation. Close monitoring of the effects of oral anticoagulants is necessary, as patients who have too much in their bloodstream run the risk of excessive bleeding, whereas those with too little could develop thrombosis.

A calculation called the **international normalized ratio (INR)** is reported with the PT result. The INR is a factor that allows for standardization of prothrombin tests performed with different methodologies and/or reagents. Prothrombin tests performed with different lot numbers of reagents or different methodologies may differ by 10% to 20% from one laboratory to another. This can be problematic when adjusting oral anticoagulant dosages based on PT test results. In 1983 the World Health Organization proposed a calculation (the INR) to standardize the variables that are present when performing prothrombin testing with various instruments and lot numbers for reagents. For an individual who is not on oral anticoagulants, the INR would be approximately 1, and for those who are being treated with warfarin or Coumadin, the INR should be 2 to 3. Decisions to change medication levels are based on the INR result, not the PT result that may be reported with the INR. Reference ranges for the prothrombin time may vary between laboratories, but they are approximately 11 to 13 seconds.

Test Your Knowledge 15-8

True or False: Is the INR used when screening for potential coagulation defects? (Outcome 15-6)

The Coaguchek S, manufactured by Roche Diagnostics, is a CLIA-waived PT/INR testing method often used in the physician office laboratory. This type of analyzer is a point-of-care test (POCT) that allows for immediate results. Performance of this test in the office can benefit the patient by allowing the results to be available to the health-care provider within minutes. This allows the patient to receive any necessary instruction about medication changes warranted by the results while still in the office. The test requires only 10 microliters of blood (approximately one drop), and the sample may be obtained through a capillary puncture or a venipuncture.

In situations in which the PT and INR are ordered as part of a coagulation screen or when the testing is performed at a reference laboratory, a full, well-mixed, light blue top sodium citrate tube is required for the test.

Procedure 15-1: CLIA–Waived Prothrombin Time/INR Testing Using the CoaguChek S Instrument

TASK

Perform PT/INR testing utilizing the CoaguChek S instrument and document the results appropriately. Complete all steps within 10 minutes.

CONDITIONS

- Hand sanitization supplies
- Gloves
- Completed patient requisition form and patient chart
- CoaguChek S instrument
- Test strips
- Quality control material
- Test strip code chip
- Bulb and capillary provided with instrument for application of sample
- Gauze or cotton balls
- Alcohol pad for sanitization
- Lancet device or venipuncture supplies
- Biohazardous disposal container
- Biohazardous sharps container

Note: This test may be performed on a capillary blood sample or a sample obtained through venipuncture. Be certain to have the necessary supplies available for the method used for sample collection, as well as a biohazardous sharps disposal container and gloves.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

None

ABHES 2010 Standards

None

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Procedure	Rationale
1. Verify test ordered on requisition form. Greet and identify patient.	The requisition should always be examined to be certain which test is ordered, and the patient identity must always be verified before proceeding.
2. Sanitize hands, allow them to dry, and apply gloves.	Gloves protect the hands from exposure to potential bloodborne pathogens. Gloves should always be applied in the presence of the patient.
3. Gather necessary supplies. Test strips must be at room temperature for at least 5 minutes prior to use. Compare the number on the code chip (located in a small compartment at the top of the box of test strips) to the last three numbers after the lot symbol on the test strip pouch. If these numbers do not match, this code chip may not be used with these strips.	Supplies must be within reach before starting the process so that the timing of the testing is accurate. The code chip must be the correct number for the reagent strip for the test result to be accurate.
4. Verify whether quality control (QC) testing needs to be performed on the instrument. If so, perform QC testing and verify validity of results before proceeding with patient testing.	The frequency of the QC testing is based on the manufacturer's and individual laboratory recommendations.
5. Determine the method to be used for specimen collection. **a.** If a capillary sample is to be used, prepare the lancet. Roche manufactures a capillary tube and bulb to aid with specimen collection, as well as a lancet specifically designed to be used with the CoaguChek system. Assemble the capillary tube and bulb if desired. The blood may also be applied directly to the test strip without the aid of the capillary tube.	The capillary sample is the most common method of testing used in the physician office laboratory.
b. Blood obtained through venipuncture is acceptable, as long as it is collected into a preservative-free plastic syringe using a 21- to 23-gauge needle. The specimen would need to be applied to the strip immediately after the collection has been completed.	Preservatives and/or anticoagulants are not acceptable for this testing method. The blood cannot be allowed to clot before application on the test strip, or the results will be inaccurate.

Continued

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Procedure 15-1: CLIA-Waived Prothrombin Time/INR Testing Using the CoaguChek S Instrument—cont'd

Procedure	Rationale
6. Insert the code chip into the machine, and place the instrument on a flat, vibration-free surface. Turn on the power, and make certain that the code displayed on the screen matches the numbers printed on the foil wrapper enclosing the test strip.	If the codes do not match, the instrument will not provide a test result.
7. The test strip icon will flash on the CoaguChek S display screen. Open the foil pouch and insert a test strip into the instrument by sliding it (printed side up) into the tray on the front of the instrument in the direction of the arrows. Continue to push the test strip into the instrument until it stops. Test strips must be used within 4 minutes of removal from the foil package.	For most of the testing process, the CoaguChek S display screen will guide your next steps. *Courtesy of Roche Diagnostics.*
8. Prepare the appropriate site for the capillary puncture, or obtain the blood sample via venipuncture.	Once the test strip is placed into the instrument, the time will be limited for the specimen to be collected and applied for the testing process.
9. Monitor the display screen; at this point, a test strip icon should be visible as well as a flashing clock icon. Do not apply the sample until the icon for a blood drop appears on the screen.	If the sample is applied too soon, the instrument will not process the sample and the screen will display an error.

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Procedure	Rationale
10. Once the flashing blood icon appears on the screen, a countdown for 180 seconds begins. The instrument will beep every 30 seconds until an adequate sample has been applied to the test strip. The sample must be applied before the countdown reaches 0.	A countdown of 180 seconds should be adequate time to obtain the capillary sample, or to prepare to apply the venipuncture specimen.
11. Utilizing appropriate capillary or venipuncture procedure, obtain the blood sample. Apply a drop of blood to the test strip directly over the flashing yellow light. This flashing light indicates where the sample is to be applied.	For this procedure, the first drop of blood obtained from a capillary sample is to be used; do not wipe away the first drop of blood as you would customarily do for other types of collections. For samples obtained through venipuncture, the first four drops of blood are to be discarded from the end of the needle, after which the next drop is to be applied to the sample area. Do not allow bubbles to form when applying the sample.
12. After specimen application, the screen will display a clock icon. Do not touch the instrument or the test strip during this time. The result will be available on the screen (and stored in the memory of the instrument) within 1 minute.	The clock icon is displayed during the entire testing procedure.
13. Document the result on the instrument log sheet.	Once the test strip is removed from the machine, the result is no longer displayed on the screen, so it is best to record it immediately.
14. Discard the test strip by pulling it out of the instrument and discarding it into a biohazardous waste container.	The test strip is contaminated with blood and must be disposed of accordingly.
15. Sanitize the work area and put away supplies.	Be sure to refrigerate the test strips right after use.
16. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
17. Document the test results in patient chart.	All results must be documented in the patient's chart.

Date	
04/18/2013:	*PT/INR test performed from capillary puncture. PT result 23.2 seconds, INR 2.1*
	Connie Lieseke, CMA (AAMA)

Activated Partial Thromboplastin Time/ Partial Thromboplastin Time

Activated partial thromboplastin time is abbreviated PTT. The PTT is a measurement of the efficacy of the intrinsic coagulation pathway. This pathway includes the actions of clotting factors VIII, IX, XI, and XII. The PTT is measured in seconds, just as the PT is. Technically it is the amount of time that the blood sample takes to clot when phospholipid and calcium are added to the specimen. The PTT test may be ordered (with the PT) as part of a presurgical screen, when a patient has excessive bleeding or bruising, or to monitor the use of **heparin** therapy. Heparin is a fast-acting anticoagulant that affects the factors in the intrinsic blood-clotting pathway. Heparin is used to treat patients who are at high risk for thrombosis

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and to treat those who have already developed blood clots, especially in postsurgical settings. Heparin is not a medication commonly used in the home setting, because it must be administered IV or by subcutaneous injection multiple times per day. Reference ranges for the PTT are 25 to 31 seconds, and the specimen must be a full light blue top sodium citrate tube.

Test Your Knowledge 15-9

Which medication is monitored by using the PTT?

a. Coumadin
b. warfarin
c. heparin
d. aspirin (Outcome 15-8)

Platelet Count

One of the first steps in the coagulation process is the aggregation of platelets at the site of the vessel injury. For this reason, it is imperative that platelets are present in sufficient numbers and also that they function appropriately in order for the body to repair vessel damage as it should. Platelets are produced by the bone marrow, and when the blood vessels are injured, they adhere to the site of the injury and to other platelets. This primary "plug" helps to protect the body from excess blood loss, and also starts the clotting cascade, which ends with a more permanent fibrin mesh at the site to allow for the damage to heal.

Insufficient platelet amounts (thrombocytopenia) will put the patient at risk for excessive bleeding with vessel injury. A **platelet count** is performed to monitor the number of platelets present in the general circulation. Platelet counts are routinely performed as part of a complete blood count, and may also be ordered as part of a coagulation screen. The specimen required is a lavender top EDTA tube, and the reference range is 150,000 to 450,000 mm^3.

Fibrinogen

Fibrinogen is a "sticky" substance manufactured by the liver that is an essential part of the blood-clotting process. It is naturally dissolved in plasma, and is the precursor to fibrin. Fibrin is necessary for effective blood clot formation. Fibrinogen is also known as clotting factor I. The presence of adequate levels of fibrinogen is essential to platelet aggregation. Levels of fibrinogen may be decreased in the presence of genetic disorders, resulting in a diagnosis of **afibrinogenemia** or **hypofibrinogenemia. Dysfibrinogenemia** is a rare genetic disease that causes abnormal fibrinogen activity; the fibrinogen created in the liver is not able to convert to fibrin correctly to complete blood clot formation. Low levels of fibrinogen may contribute to excessive bleeding, and conversely, levels that are above the normal range may contribute to formation of small intravascular blood clots. Fibrinogen levels may be elevated in any condition that causes inflammation including pregnancy, acute infection, cancer, coronary heart disease, myocardial infarction (MI), and stroke. These increased levels of circulating fibrinogen will make the patient more prone to pathological blood clot formation, so the fibrinogen level test is often performed with the PT, PTT, and platelet count assays to screen for coagulation dysfunction. Reference ranges for fibrinogen are approximately 20 to 400 mg/dL, but may vary with the method used for testing by any individual laboratory. Fibrinogen requires a full light blue top sodium citrate tube.

Test Your Knowledge 15-10

If fibrinogen levels are decreased, what might a potential outcome be for the patient? (Outcome 15-11)

Fibrin Degradation Products

Clot creation and subsequent breakdown must remain in balance for the body to maintain a healthy coagulation response. Once a damaged vessel has healed, **plasmin** (an enzyme designed to dissolve blood clots) and other chemicals in the plasma immediately begin to dissolve the fibrin mesh forming the clot so that it does not become too large. The by-products of fibrinolysis may be measured in the laboratory with an assay that measures **fibrin degradation products (FDPs).** FDPs are essentially fragments that are released as blood clots are dissolved. These fragments are released when fibrinogen (the precursor of fibrin) or fibrin is broken down by plasmin. The amount of fibrin degradation products increase in disseminated intravascular coagulation, pulmonary embolism, and with some obstetrical complications. In most laboratories, the FDP test is performed on plasma collected in a light blue top tube with sodium citrate anticoagulant. If the test is to be performed within 4 hours, the tube is to remain at room temperature. If the sample must be transported elsewhere for testing and the processing takes more than 4 hours, the tube should be spun down and the plasma must be frozen. Serum FDP assays may also be performed, which may require specific tubes that

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contain thrombin to clot the blood and chemicals to prevent fibrinolysis within the tube. Normal reference ranges for FDP are based on the testing procedure, and may vary.

D-Dimer

The FDP test measures all the breakdown products created as blood clots dissolve. One of these by-products is very specific for certain cross-linked components of the fibrin clot, and that can be measured by performing a **D-dimer** test. D-dimers are a specific type of breakdown product that indicates the dissolution of fibrin, rather than just fibrinogen. The D-dimer test is currently replacing the FDP analysis in many laboratories. D-dimers are always present in small amounts in the blood, but elevated levels may be indicative of disseminated intravascular coagulation, pulmonary embolism, or deep vein thrombosis. The body increases the amount of D-dimers produced as soon as a clot begins to form because the clot dissolution process starts almost simultaneously to keep the blood clot from growing larger than necessary. Surgical procedures may elevate D-dimer levels, as well as pregnancy, inflammation, some types of cancer, and liver disease. Use of **fibrinolytic drugs** (also called clot busters) will also increase the amount of FDP and D-dimers in the bloodstream, so these tests may be used to monitor fibrinolytic medication therapy as well. The reference ranges for D-dimers are based on the testing method used for the assay. The D-dimer analysis requires platelet-poor citrated plasma, drawn in a light blue top tube. The specimen must be spun in a typical benchtop centrifuge for at least 10 minutes before separation of the plasma from the cells. In addition, there are specialized centrifuges that are specially equipped to create platelet-poor plasma in less than 10 minutes for tests that require this type of specimen.

Bleeding Time Test

A bleeding time test is performed to evaluate how well platelets function to form a plug in the capillary beds with induced damage. It is not a test performed from a blood sample, but is a measurement performed directly on the patient. Because there are other tests used to monitor the different parts of the coagulation cascade, the bleeding time is generally used to identify platelet function abnormalities, and it may also detect deficiencies of **von Willebrand's factor,** which is part of the factor VIII used for blood clotting. The platelet count and all other clotting factors may be within the normal reference ranges, but if the platelets do not perform as they should, the patient may still have issues with prolonged bleeding. In the past, the bleeding time test was a common presurgical laboratory order, but the true ability of the bleeding time to detect potential surgical hemorrhage has been called into question in recent years.

Bleeding times have been performed using various methods since they were first developed approximately 85 years ago. Many of these procedures were not standardized, so it was difficult to reproduce the results or to establish reliable normal reference ranges. Historically, the procedures all included a "stab" into soft tissues of the body (usually the earlobe) and monitoring the wound until bleeding had stopped. A lancet or surgical blade was used, but there was a lack of uniformity concerning the depth or length of the incisions created.

Test Your Knowledge 15-11

List two reasons that the bleeding time test is not considered to be the test of choice for platelet function analysis as it once was. (Outcome 15-10)

Most modern facilities that perform bleeding times today use a modified Ivy method. This method includes the use of the Surgicutt, a spring-loaded lancet device manufactured by the International Technidyne Corporation. The blade in the lancet device has a depth of 1 mm and a width of 0.5 mm. The device is easy to use, and the blade retracts after use so that there is minimal opportunity for accidental employee exposure to patient fluid. The standardized depth and width of the incision has assisted in the determination of reliable reference ranges and safety for the patients. There are also special lancet devices available for use on infants.

Bleeding times are used to determine how long it will take for a patient to stop bleeding after a superficial puncture or incision is made into the skin. The bleeding time procedure requires an incision device (such as the Surgicutt), a sphygmomanometer (blood pressure cuff), an antiseptic wipe, sterile filter paper provided in circles, and an adhesive bandage. Figure 15-1 shows the supplies necessary to perform a bleeding time test. The performance of a bleeding time is a unique procedure and includes the following concepts:

1. It is essential to ask the patient about aspirin use within the past week. Even one aspirin, or other products that include aspirin, can profoundly affect the results obtained with the bleeding time.

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Figure 15-1 Bleeding time supplies including Surgicutt lancet and filter paper.

The patient should be asked whether he or she is under therapy with heparin or oral blood thinners such as warfarin. If the patient has taken any of these medications, you must check with the physician before performing the test, as the validity of the results may be affected. Long-term use of other NSAIDs (such as ibuprofen) may also increase the bleeding time.

2. The bleeding time is to be performed 2 to 3 inches below the bend of the elbow on the skin of the forearm. Visible veins, moles, tattoos, scars, bruises, shunts, or fistulas and edematous areas should be avoided, as well as areas with excessive hair growth. Clean the site thoroughly with an alcohol antiseptic wipe and allow the alcohol to dry completely before continuing with the procedure.
3. Apply a blood pressure cuff above the elbow to the arm to be used, and inflate the cuff to 40 mm Hg.
4. The bleeding time device (a Surgicutt lancet) is to be applied to the arm in a horizontal manner, and pressure must not be used when making the incision. Start the stopwatch as soon as the incision is made. At 30-second intervals, wick away excess blood with filter paper, taking care not to disturb the actual incision site. Rotate the filter paper as the blood is blotted away each time so that each wicking session is definitive.
5. When no more blood can be blotted away, stop timing the process and release the blood pressure cuff. The time that has elapsed since the incision was made is the bleeding time. Normal results are usually 1 to 9 minutes. If the results are less than 1 minute or more than 9 minutes, some laboratories will require that the test be repeated, as there may be procedural errors that contributed to the result.

Bleeding times are not used as frequently as they once were, and many laboratories no longer offer this test as an option. It has been shown that the correlation of an elevated bleeding time to the risk of excessive surgical bleeding is not always conclusive, and the results for bleeding times are not reproducible. The procedure often causes a scar at the site of the incision, which can be a significant consequence to some patients. In addition, the use of NSAIDs (such as ibuprofen or Advil) may affect the bleeding time, in addition to aspirin or aspirin-containing products. The effect of the drugs on the bleeding time result is not predictable; the bleeding time may be extended, but it is difficult to predict the amount that it will be affected. Other variables may be the result of incorrect technique; if the incision is too deep or too shallow, the results will not be accurate. Also, when blotting away excess blood, if the incision is touched, the bleeding time may be falsely elevated.

It is important to realize that the PTT and PT tests are ordered much more commonly than the bleeding time test. These tests have fewer variables that could cause erroneous results than the bleeding time does, and abnormal results are mapped more specifically to the various coagulation factors. The bleeding time technique also requires specific training, whereas the PT and PTT tests require a more common capillary or venipuncture procedure. In addition, the bleeding time requires 10 to 20 minutes to complete, which may be too time intensive for busy practice or laboratory settings.

Other Tests Used to Assess Platelet Function

Platelet function cannot be measured just by counting the number of cells, and screening for platelet dysfunction is not as precise or easily performed as is a platelet count. The bleeding time test may help to identify gross platelet function abnormalities, but it is not sensitive or specific enough to identify all issues. Many reference and hospital laboratories are now using the Platelet Function Analyzer 100 (PFA-100), manufactured by Siemens Corporation. This machine tries to simulate the bleeding process that occurs in the body by using a tube of blood obtained through a venipuncture. The testing process involves the addition of whole blood into a tube that is coated with additives that promote

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platelet adherence and aggregation in order to mimic these actions within the human body. The machine measures the amount of time that is necessary for a blood clot to form within this treated tube, and this is reported as a closure time (CT).

There are other types of automated platelet function tests available, but they are not used as widely as is the PFA-100. Controversy still exists about whether these new automated tests are as useful for predicting overall platelet function assessment as the bleeding time once was, even though the bleeding time test is no longer performed in many institutions.

SPECIMEN REQUIREMENTS FOR COAGULATION TESTING

With the exception of CLIA-waived point-of-care PT testing, when collecting samples for coagulation testing, a light blue top tube with sodium citrate is used for most coagulation tests ordered. This includes the fibrinogen test, PTT, PT, and sometimes the FDP test. Some laboratories use a special FDP tube that only requires 2 mL of blood in a 5-mL tube.

- Evacuated light blue top vacuum tubes may include different concentrations of citrate (with the same volume of fluid anticoagulant in the tube), so it is important to clarify which type should be drawn for the testing method used in the laboratory where the testing will occur. The light blue top tubes may be available with 3.2% citrate or 3.5% citrate. In all situations, a ratio of one part anticoagulant to nine parts blood must be maintained, or the result will be erroneous because of specimen dilution.
- The citrate tube must be filled until the vacuum has been exhausted; no short samples can be tested. If the evacuated tube is not filled until the vacuum is exhausted, the clotting time (and subsequently the testing results) will be falsely elevated because of the dilution factor with the anticoagulant in the tube.
- Tubes are spun in the centrifuge before the test is performed, and the plasma is tested immediately or separated from the cells. Ideally, the sample will be tested within 1 hour of collection, or within 4 hours if the specimen has been refrigerated.
- For patients who have a hematocrit measuring above 55%, it is necessary to reduce the amount of anticoagulant used in the tube to avoid prolonged clotting times because of the change in the ratio of plasma to anticoagulant. Laboratories will have an established procedure for the performance of this process.
- It is critical that samples used for coagulation testing remain free of IV fluid or other contaminating substances. Many times the samples are drawn as part of the dialysis process, so it is especially critical to clear the line of all other fluids before the specimen is obtained.
- Clotted or hemolyzed samples will also not be acceptable for coagulation testing, as the results will be inaccurate. To avoid microclot formation in the tube, it is very important that the tubes used for coagulation studies are inverted at least eight times as soon as possible after collection.

Test Your Knowledge 15-12

True or False: Light blue top tubes collected for coagulation studies may be partially filled with no negative effects. (Outcome 15-13)

A lavender top tube with EDTA anticoagulant is used for platelet counts. Platelet counts may be performed as part of a complete blood count, or they may be ordered separately when needed. As in the case with the light blue top citrate tube, it is very important that the lavender top tube be mixed thoroughly right after the blood draw to avoid microclot formation. Platelet counts are performed on whole blood, so the specimen is not centrifuged after collection.

SUMMARY

Coagulation and clot dissolution are vital processes to maintain homeostasis in the human body. The repair of damaged blood vessels within the body is a complex process that includes platelets and a variety of chemical reactions to work efficiently. Coagulation studies determine whether there are enough platelets and other chemicals present for the process to be successful, as well as evaluating the efficiency of the clotting process to predict excessive bleeding or unnecessary blood clot formation. Other disease processes may be complicated by formation of small blood clots, so patients may be medicated with anticoagulant drugs to avoid potential problems. This medication use must be monitored closely with the use of coagulation tests on a regular basis. The anticoagulant medications target the various aspects of the clotting cascade and require different testing mechanisms to monitor their levels. Common tests used to monitor coagulation processes in the body and medications that affect the clotting mechanisms include the PT/INR test, platelet counts and platelet function

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tests, and the activated partial thromboplastin time. Other tests may be performed to evaluate the amount of clot dissolution or fibrinolysis occurring in the body. Coagulation testing may be performed in the physician office laboratory as well as in hospital and reference laboratories.

TIME TO REVIEW

1. *Aggregate* is a word used to describe: Outcome 15-1
   a. Platelet adhesion and clumping
   b. Consolidation of clotting factors
   c. Deep vein emboli
   d. Fibrinolysis
2. Which of these terms might be used to define FDP? Outcome 15-1
   a. The factors necessary to form a clot
   b. Products produced as a clot dissolves
   c. Platelet count
   d. Clotting time
3. A substance that is viscous may also be described as: Outcome 15-1
   a. Runny
   b. Thin
   c. Syrupy
   d. Dry
4. Fibrinolysis is an important part of hemostasis because: Outcome 15-3
   a. Fibrinolysis helps to control the number of unwanted blood clots in the body
   b. Fibrinolysis is the first step in coagulation
   c. Fibrinolysis helps to keep the blood viscous
   d. None of the above
5. True or False: A diagnosis of atrial fibrillation increases the risk of unwanted blood clot formation. Outcome 15-5
6. True or False: Postsurgical prophylactic treatment is provided only to patients with hemophilia. Outcome 15-5
7. Platelet counts may be ordered as part of a coagulation workup because: Outcome 15-8
   a. Adequate numbers of platelets are necessary for hemostasis
   b. Platelets play a very important role in the repair process for damaged vessels
   c. Extremely high numbers of platelets can contribute to excessive clot formation
   d. All of the above
8. What are two potential sources of error for the CLIA-waived PT/INR test procedure? Outcome 15-7
9. How are D-dimers and fibrin degradation products similar? Outcome 15-12

Case Study 15-1: Presurgical puzzle

Mr. Hammond will be having a total hip replacement next week. His physician orders a coagulation screen, including a PT, PTT, platelet count, fibrinogen level, and a bleeding time. All results are within the normal range except for the bleeding time, which at 12 minutes is elevated slightly.

1. What may be an explanation for this situation?

Case Study 15-2: Relative values?

Cindy Lou is a new medical assistant who has just started to work in the laboratory. She has experience a high volume of patients this morning, and she feels a bit overwhelmed. Later in the day, the physician office receives a call from the laboratory with abnormal PT and PTT results for one of the patients that Cindy drew that morning. The results for both tests are elevated, but the patient has no signs of excessive bruising or bleeding. These tests were ordered as a screen prior to an elective surgery that the patient was to have done next week.

The physician asks Cindy to contact the laboratory and see if the results for the platelet count are available. Cindy talks to the technician performing the hematology testing, and she is told that the specimen for the platelet count needs to be redrawn because it was clotted.

1. How do you think the specimen condition for the platelet count and the other tube used for the PT/PTT testing might be related?
2. How does this situation with the clotted tube relate to the elevated results for the PT and PTT?

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RESOURCES AND SUGGESTED READINGS

"Atrial Fibrillation and Warfarin"
Excellent explanation of the risks involved with atrial fibrillation as related to blood clots, and the use of warfarin for treatment http://www.patient.co.uk/showdoc/23068883

"D-dimers and Fibrin Degradation Products"
Information about coagulation studies performed at Massachusetts General Hospital; great information about the differences between FDP and D-dimers http://www2.massgeneral.org/pathology/coagbook/CO002700.htm

"Disseminated Intravascular Coagulation (DIC); Consumption Coagulopathy; Defibrination Syndrome"
Details about disseminated intravascular coagulation disease. http://www.merck.com/mmpe/sec11/ch136/ch136c.html

"Hemophilia, Factor VIII Deficiency"
Facts about bleeding and clotting disorders http://www.hemophilia.org/NHFWeb/MainPgs/MainNHF.aspx?menuid=179&contentid=45&rptname=bleeding,

"Warfarin and Chinese Medicine"
Details about the development of warfarin, plus lots of information related to herbs and Chinese medications that affect bleeding tendencies. http://www.itmonline.org/arts/warfarin.htm

"ITC, The Point of Care, Surgicutt Bleeding Time Device"
Detailed information about the Surgicutt device and procedure for bleeding time testing. http://www.itcmed.com/Products/Surgicutt

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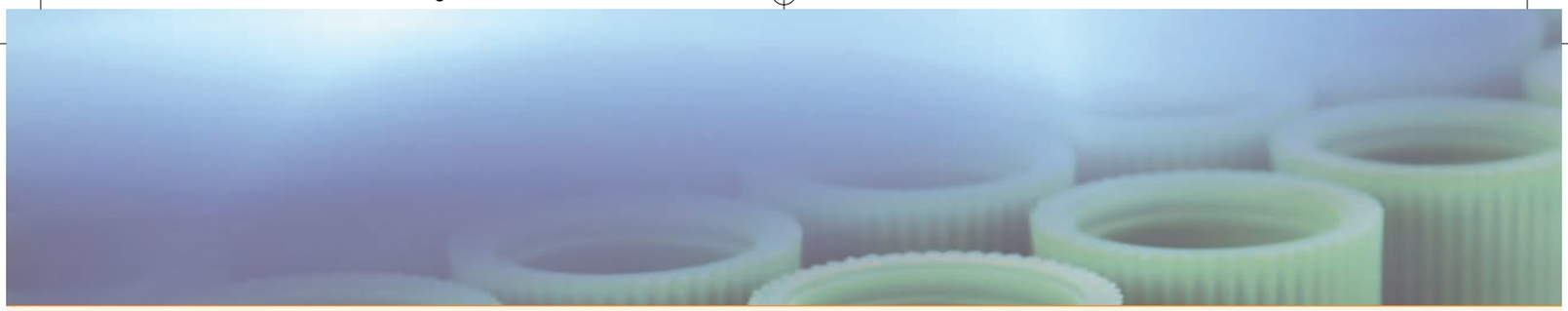

Section III

Hematology and Coagulation

What Does It All Mean?

As you can see, hematology and coagulation testing provides invaluable information to physicians and other primary health-care providers. Now, let us revisit our Case in Point for this section and see what it all means.

Case in Point

At the beginning of this section we met M.J., a 38-year-old male patient who was worked into the doctor's schedule because he felt tired and weak and experienced bleeding gums after brushing his teeth. Patient history revealed that M.J. received a blood transfusion following a tractor accident several weeks prior to this appointment. Upon your encounter with M.J., you noted that he seemed very pale. The doctor ordered a CBC, PT, and PTT to help assess the situation. Upon examination of the results obtained (located on page 258), no wonder M.J. felt so poorly.

M.J. is suffering from a condition known as disseminated intravascular coagulation (DIC). *Disseminated*, in this case, means "widespread over the body." *Intravascular* refers to taking place within blood vessels, and *coagulation* means "the clotting of blood." Under normal conditions, the human body has built-in mechanisms to clot blood when injury occurs and to dissolve clots when appropriate. This balance between clotting and bleeding is known as *hemostasis*. However, when the clotting and bleeding balance is disrupted, individuals experience abnormal bleeding, as noted when M.J. bled while brushing his teeth, and clotting. This imbalance can cause serious injury to the organs of the body. Individuals become anemic, as evidenced by M.J.'s complaints of being tired and weak, as well as the observation of the patient being pale. This anemia results because of the incredible loss of blood, which in turn results in an inability of red blood cells to transport oxygen to the tissues. If the condition is left untreated, death may result. Fortunately, in M.J.'s case, he recognized the abnormal situation taking place in his body and sought help.

Although laboratory results are important in confirming the diagnosis and monitoring of DIC, physicians often make the initial diagnosis based primarily on clinical symptoms. Unfortunately there is no single laboratory test that is diagnostic for DIC; a battery of tests must be performed and the results examined in concert with each other rather than independently. In addition to the tests presented in this case study there are additional laboratory tests that may be performed to provide more information about the clinical situation when DIC is suspected. A further discussion of these additional tests is beyond the scope of this text.

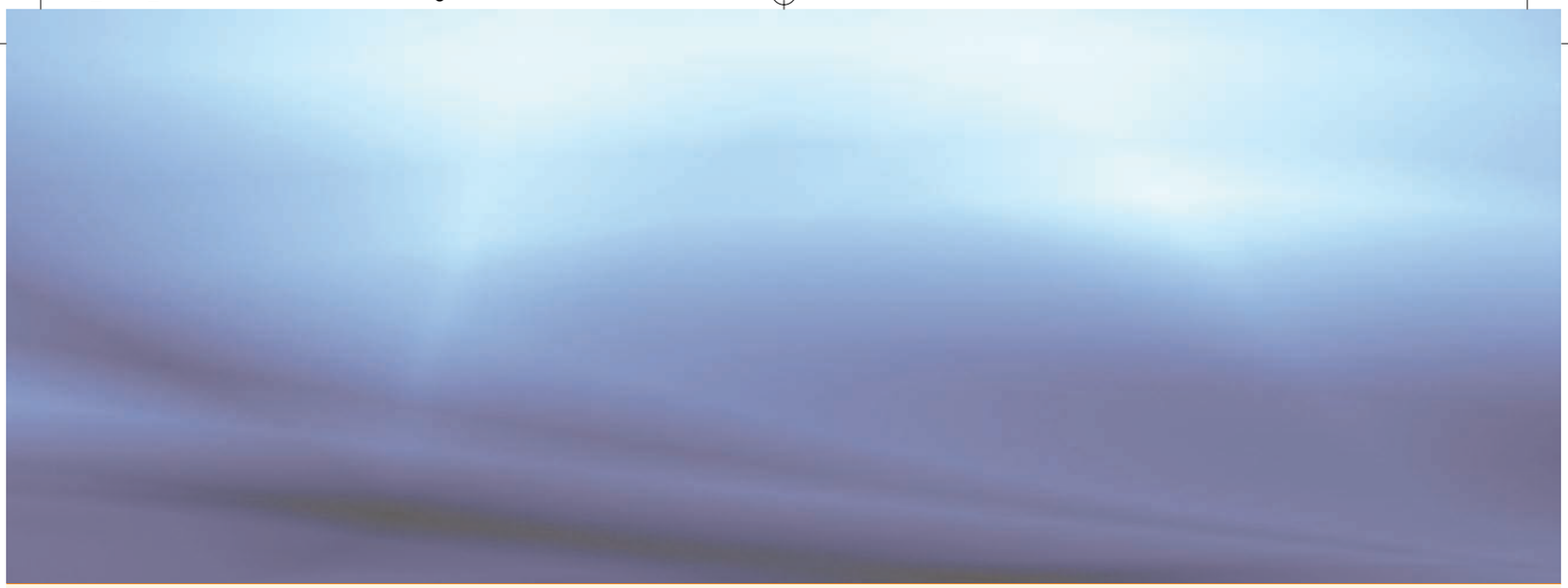

On the Horizon

A wide variety of substances, often referred to as analytes, make up the test menu available in the chemistry section of the clinical laboratory. Likewise, the test methodologies that may be used to determine these analytes are many. Some tests are performed on complex instruments, whereas others are conducted using relatively simple-to-operate equipment. The results obtained from such tests provide healthcare team members with a wealth of knowledge in the diagnosis and monitoring of numerous diseases and conditions.

Relevance for the Medical Assistant

Medical assistants (MAs) typically assume one or both of these roles associated with chemistry laboratory tests: (1) specimen collection and processing and (2) performance of select chemistry tests. In addition to performing CLIA-waived tests, MAs may also perform moderate-complexity tests with appropriate training. Further, MAs may also review patient charts while performing their other duties and in the process may examine laboratory results (from this area as well as all areas of the laboratory). Familiarity of common laboratory tests and their significance allows MAs to take the information obtained from such reviews into account as they work with their patients.

Case in Point

You are working at a health fair being conducted at Acme Innovations, Inc. Part of the health fair consists of collecting blood for a fasting blood glucose level. The following result was obtained on Carrie W., a 34-year-old female Acme employee:

Test	Patient Result	Reference Range
Fasting blood glucose	215 mg/dL	70–100 mg/dL

Questions for Consideration:

- What does the word fasting refer to in this case?
- What is the purpose of the fasting blood glucose test?
- What laboratory test could be ordered to help assess this patient and to monitor Carrie's condition?
- Suppose that Carrie is pregnant and her doctor wishes to assess her for gestational diabetes. What laboratory test could be ordered in this situation?

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Section IV
Clinical Chemistry On the Horizon

The content in this section is limited to three chapters and serves as an overview of the chemistry section of the clinical laboratory:

Chapter 16: Overview of Clinical Chemistry introduces the reader to the scope of the chemistry section of the clinical laboratory, including the identification and brief description of specimens upon which this testing is performed. A brief overview of some of the more common individual chemical analytes, including glucose and cholesterol as well as groups of tests known as profiles, are covered.

Chapter 17: Glucose Testing covers the physiology and pathophysiology associated with blood glucose. The various glucose tests available, including venous blood samples, hemoglobin A1c, glucose tolerance tests, and capillary puncture glucose testing, are described. Suggested procedures and quality control considerations are also covered.

Chapter 18: Other Select Chemistry Tests covers the physiology and pathophysiology associated with the following representative chemistry tests: cholesterol, lipids, and electrolytes. Proper collection and testing technique, reference ranges, quality control issues, sources of error, and test interpretation are included.

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Chapter 16

Overview of Clinical Chemistry

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Clinical Chemistry
Specimen Types Used for Clinical Chemistry Analysis
- Plasma
- Serum
- Other Specimen Types Used for Clinical Chemistry Testing

CLIA–Waived Clinical Chemistry Tests
- Glucose Testing
- Cholesterol and Lipid Testing
  - *Cholesterol*
  - *Triglycerides*
  - *Lipid Panels*
- Electrolytes

Other Common Clinical Chemistry Tests
- Blood Urea Nitrogen
- Creatinine
- Thyroid Panels
- Comprehensive Metabolic Panel and Basic Metabolic Panel
- Cardiac Enzymes
- Hepatic or Liver Profile

Reference Ranges
Potential Sources of Error
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

16-1 Define the key terms.
16-2 Relate how serum differs from plasma.
16-3 Describe common substances dissolved in plasma.
16-4 Examine the reasons that glucose testing is performed in the physician office laboratory.
16-5 Cite the tests included in a lipid panel.
16-6 List common analytes included in an electrolyte panel.
16-7 Differentiate which organ system is evaluated using a blood urea nitrogen test and creatinine test.
16-8 Evaluate the purpose of ordering tests in a panel format rather than individually.
16-9 Describe the tests commonly ordered as cardiac enzymes.
16-10 Explain the rationale for serial cardiac enzyme blood specimen collections.
16-11 Restate the liver profile tests most commonly ordered by physicians.
16-12 Outline the parameters that must be taken into account when considering reference ranges for clinical chemistry tests.
16-13 Examine potential sources of error for chemistry testing procedures.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

None

ABHES Standards

None

KEY TERMS

Analytes
Atherosclerosis
Basic metabolic panel (BMP)
Blood urea nitrogen (BUN)
Brain natriuretic peptide (BNP)
Cholesterol
Clinical chemistry
Comprehensive metabolic panel (CMP)
Creatine kinase (CK)
Creatinine
Diabetes mellitus
Electrolytes
Endogenous cholesterol
Exogenous cholesterol
Gestational diabetes
Glycosylated hemoglobin (Hb A1c)
High-density lipoprotein (HDL)
Hemolysis
Hepatic function panel
Homeostasis
Hyperlipidemia
Hyperthyroidism
Hypothyroidism
Icteric
Ischemia
Jaundice
Lipemia
Lipid
Lipoproteins
Low-density lipoprotein (LDL)
Lytes
Myocardial infarction
Myoglobin
Occlude
Physiology
Plaque
Plasma
Quality not sufficient (QNS) specimen
Qualitative
Quantitative
Serially
Serum
Thyroid-stimulating hormone (TSH)
Thyroxine (T4)
Triiodothyronine (T3)
Troponin
Very low-density lipoprotein (VLDL)

CLINICAL CHEMISTRY

When scientists first began to study the human body, their focus was on anatomy. Science was not able to analyze what could not be seen with the naked eye, so much of the **physiology** (or function) of the body was unknown. Many hypotheses were formed, but it took a very long time before they could be proved or disproved. It was obvious that the human body functioned best when in a state of **homeostasis** (internal balance), and the scientists could recognize some of the more visible means by which this balance was achieved. It was easy to see how the iris in the eye constricted when exposed to bright light or when perspiration was formed on the forehead in hot weather. However, many of the small changes within the human body were not so obvious; they are based on adjustments to the levels of chemicals needed to keep our body functioning appropriately. It was not until the 19th century that scientists began to realize how closely the appropriate balance of these chemicals in the body was linked to overall health.

Clinical chemistry includes the **quantitative** analysis of the various **analytes** (substances being analyzed; in this case, chemicals) dissolved in the fluids of our bodies. Quantitative tests provide an actual number that represents the amount of a substance present in the body.

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Qualitative testing, which indicates the presence or absence of specific chemicals, may also be performed in the clinical chemistry department in the laboratory. Chemical elements are present in our bodies at all times, but increases or decreases in the levels of certain analytes may be indicative of a disease process. Clinical chemistry testing allows the health-care provider to evaluate these changes and use them to diagnose and prescribe treatment. Procedures used to monitor drug levels for some prescription drugs or to identify substances that may be present in the body in the case of environmental or drug poisoning are also performed in the clinical chemistry area of the laboratory.

Test Your Knowledge 16-1

How are qualitative tests different from quantitative tests? (Outcome 16-1)

Reference laboratories may offer hundreds of clinical chemistry tests on various types of specimens. Although all these tests are clinically significant, many of them are only used in the presence of specific disease states. In this chapter, we concentrate on the most commonly performed clinical chemistry tests using blood, urine, and stool specimens.

SPECIMEN TYPES USED FOR CLINICAL CHEMISTRY ANALYSIS

Common specimens in clinical chemistry testing include urine, **serum,** and **plasma.** Many other fluid specimens, including cerebrospinal fluid, synovial fluid taken from the joints of the body, semen, amniotic fluid, and peritoneal fluid from the abdominal cavity, are analyzed for quantitative chemistry. Occasionally chemistry testing may be performed using whole blood. This is usually done in physician office laboratories using CLIA-waived testing methods. In larger laboratories, most clinical chemistry testing is performed on plasma or serum specimens separated from the sample after centrifugation. Serum is obtained from clotted blood and plasma comes from whole blood.

Plasma

As presented in Chapter 8, plasma is the liquid portion of the blood in our body in which the blood cells are suspended. This liquid makes up more than 50% of the total blood volume. We also use the word *plasma* to describe the liquid portion of the blood when collected in a tube containing anticoagulant. Plasma is made up of at least 90% water, in which there are many dissolved substances and gases. There are too many chemical compounds present in plasma to list them all separately, but general categories include the following:

- **Plasma proteins:** Plasma proteins are large molecules that are not excreted as waste products and which are designed to remain in the blood. These include antibodies (immunoglobulins), as well as blood-clotting proteins (fibrinogen and prothrombin) and albumin.
- **Medications:** If an individual must take medication, it is transported throughout the body in the plasma.
- **Electrolytes:** Electrolytes are compounds that have a positive or negative charge when dissolved in water, and are capable of transmitting an electrical impulse within the body.
- **Hormones:** Endocrine glands throughout the body secrete hormones directly into the bloodstream. Hormone tests are commonly ordered to verify the function of the various endocrine glands, such as the pituitary gland and thyroid gland.
- **Lipids:** Fat molecules such as cholesterol are transported through the bloodstream.
- **Enzymes:** Protein-based molecules that catalyze (speed up) chemical reactions are known as enzymes.
- **Food:** When digestion is complete, the food we eat has been broken into components that can be easily used by our body for energy or building blocks for other molecules. These breakdown products are absorbed into our bloodstream and dissolve in the plasma for transportation. Fatty acids, proteins, and simple sugars are carried as food in the plasma. In addition, essential trace elements such as minerals and vitamins are also present.
- **Dissolved gases:** CO_2 is present in plasma as a by-product of metabolism. Other dissolved gases include oxygen (even though it is attached to the red blood cells) and nitrogen.
- **Waste:** Cell metabolism creates waste products that are processed in the liver and removed from the body through the urinary system.

Serum

Serum is the liquid portion of blood that has been collected into a tube that does not contain anticoagulant. Plasma and serum are very similar; however, when a specimen is drawn in a tube without an anticoagulant,

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the proteins and other blood clotting factors are utilized as the blood clot forms. The lack of coagulation factors dissolved in the liquid limits some of the tests that may be performed on a serum specimen.

Test Your Knowledge 16-2

Which of these are present from a centrifuged tube containing no anticoagulant?

a. Serum
b. Plasma
c. Whole blood
d. None of the above (Outcome 16-2)

Other Specimen Types Used for Clinical Chemistry Testing

As mentioned previously in this chapter, clinical chemistry testing may be performed on numerous specimen types. In the physician office laboratory, whole blood may be used for CLIA-waived procedures such as glucose or cholesterol testing, providing a quantitative result.

Urine chemical testing is performed as part of a routine random urinalysis with semiquantitative results reported that indicate a range for the analyte values. In some disease states, it is necessary to obtain results that are more specific, with a specific number reported for the chemical concentration rather than a range. This type of quantitative urine chemistry testing is performed at reference or large hospital laboratories, but not in physician office laboratories. These quantitative urine tests may be used to screen for kidney damage caused by diabetes, hypertension, or other disease processes. Urine may also be analyzed to research the cause of renal calculi (kidney stone) formation. Common quantitative tests performed on urine specimens include microalbumin, total protein, and creatinine. A timed urine specimen (such as a 24-hour urine specimen) is generally used for these tests.

For all clinical chemistry testing, it is important to keep in mind that reference ranges are based on certain specimen types. For instance, serum and plasma look identical once the liquid has been removed from the blood specimen, but the reference ranges for some chemicals are very different in the two specimen types. It is essential to collect the correct type of tube for the analysis when performing a blood collection, and also to label the specimen type if the liquid is removed from the original collection container to avoid any potential problems. Other types of specimens may have a similar appearance if they are transported in an unlabeled specimen container.

CLIA-WAIVED CLINICAL CHEMISTRY TESTS

Glucose Testing

The most common type of CLIA-waived clinical chemistry test performed in the clinic setting is glucose testing. This test may be used to screen for **diabetes mellitus** (type 2 diabetes) or to monitor the glucose levels of patients who have already been diagnosed and are under treatment. **Gestational diabetes** in pregnant women may also be diagnosed with tests performed in the physician office laboratory. It is beneficial to the patient to have these tests performed on site, as the results are available within minutes. Abnormal glucose levels may be reported to the health-care provider immediately, allowing for additional tests to be ordered or for further patient interaction to be initiated if necessary. CLIA-waived glucose testing methods use whole blood specimens, usually obtained from a capillary puncture. The glucose levels may be ordered as fasting, random, or timed specimens.

Test Your Knowledge 16-3

List two reasons that glucose testing might be performed in a physician office laboratory. (Outcome 16-4)

Diabetic patients may also be monitored with a **glycosylated hemoglobin,** or **Hb A1c,** test. Hemoglobin is present in all the red blood cells of the body, and one subunit of this hemoglobin molecule is hemoglobin A. When hemoglobin A is exposed to excessive levels of glucose, it becomes glycosylated, which means that the glucose molecules bind to the hemoglobin A irreversibly. The Hb A1c test can measure the amount of glycosylated hemoglobin present, and because red blood cells live for approximately 3 months in the body, Hb A1c results may be used indirectly as an indication of the overall blood sugar levels for the past few months. Hb A1c may be performed as a CLIA-waived test in the physician office laboratory or automated testing may be performed in a reference laboratory. Whole blood is used for this analysis; capillary samples are used for the CLIA-waived methods, and an EDTA lavender top tube is used for the reference laboratory methods.

Cholesterol and Lipid Testing

Lipids are substances including oils and fats that are insoluble in water and soluble in organic solvents. **Cholesterol** is an example of a lipid, but there are other types of fats in our bodies as well. Our digestive system breaks down ingested fats into fatty acids, which are

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transported through the bloodstream to the liver, where they are used to manufacture lipids. Because lipids do not dissolve in water, the body attaches lipids to a protein molecule for transport to the cells of the body to be used. These complexes are called **lipoproteins.** Lipids are used as an alternative source of energy when glucose is not readily available, and they are also necessary for hormone production, cell wall integrity, utilization of fat-soluble vitamins, hunger satiation, maintenance of appropriate body temperature, and skin health.

In the laboratory, the two types of lipids most commonly analyzed are cholesterol and triglycerides. Total blood cholesterol and total triglyceride counts provide valuable information to health-care providers about cardiovascular health and potential risk factors for the future. However, more information can be gained by breaking down the relative amounts of lipids according to subtype. These categories are **HDL (high-density lipoproteins), LDL (low-density lipoproteins),** and **VLDL (very low-density lipoproteins).** Elevated total cholesterol, triglyceride, and LDL levels may are considered to be risk factors for coronary heart disease. Chapter 18 provides more in-depth information about lipid testing.

Test Your Knowledge 16-4

Which of these tests is included in a lipid panel?

a. LDH
b. LDL
c. VLDL
d. ALT (Outcome 16-5)

Cholesterol

Cholesterol is essential for the human body to function properly. Cholesterol is used for hormone production, absorption of vitamin D, bile production, and cellular membrane structure, and is also used as part of the covering (the myelin sheath) on some of the nerves in the body. The liver creates all the cholesterol that we need to function normally. This is called **endogenous cholesterol** because it is manufactured within the body. **Exogenous cholesterol** comes from our diets. When cholesterol builds up in the body it can lead to **plaque** formation within the blood vessels, a condition known as **atherosclerosis.** Plaque buildup may eventually **occlude** (block) blood vessels, or pieces of plaque may break away from the vessel lining and travel as an embolus, lodging elsewhere in the body and causing a blood clot.

Cholesterol levels ordered individually do not require fasting samples. However, cholesterol levels are often ordered as part of a lipid panel with the triglyceride, HDL, LDL, and VLDL levels. These additional tests do require a fasting sample, so patients should be advised to abstain from eating for 12 hours prior to the blood draw.

Triglycerides

Patients who have a diet that is high in carbohydrates may have elevated triglyceride levels. Most of the fat in our bodies is made up of triglycerides. When a person takes in more calories than are needed for energy, the excess calories are converted into triglycerides and stored as fat for use later as an energy source. Those who have diabetes, hypertension, or excess alcohol intake are especially prone to high triglyceride levels. **Hyperlipidemia** is the word used to describe high levels of lipids (cholesterol and triglycerides) in the plasma. Patients who have elevated triglyceride levels may have plasma or serum that appears "milky" because of all the fat molecules present. The presence of the fat molecules suspended in the blood is called **lipemia.** Because triglyceride levels do rise after ingestion of food, triglyceride testing usually requires a fasting blood draw.

Lipid Panels

A lipid panel commonly includes a total cholesterol level, a triglyceride level, HDL, LDL, VLDL, and a total cholesterol : HDL ratio. These values will provide the health-care provider with valuable information concerning the risk factors for coronary artery disease.

POINT OF INTEREST 16-1
Cholesterol testing

Cholesterol testing is performed to assist the health-care provider in evaluating the patient for potential heart disease. The total cholesterol level consists of high-density lipoproteins (HDL) and low-density lipoproteins (LDL). The HDL is considered to be "good cholesterol" because it actually cleans excess cholesterol from the blood vessels in the body and carries it away in the bloodstream. Ideally, the patient will have a higher concentration of HDL in the bloodstream than LDL. Elevated levels of LDL may lead to heart disease, as the low-density lipoproteins will deposit cholesterol on the walls of the blood vessels.

There is a direct correlation of elevated cholesterol results and/or an imbalance of HDL and LDL results and atherosclerosis. The following individuals are at higher risk than others:

- Smokers
- Those diagnosed with diabetes mellitus

Continued

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- Patients with hypertension
- Men over 45 and women over 55
- Family history of heart disease
- Obesity

Laboratory tests usually place the patient in one of three categories:

High risk: Having a total cholesterol level of 240 mg/dL or above

Borderline high: Having a cholesterol result of 200 to 239 mg/dL. Often the health-care provider will order additional testing to see if the elevated level is the result of the presence of the LDL (bad cholesterol) or HDL (good cholesterol).

Desirable or normal: Having a total cholesterol level less than 200 mg/dL is considered normal, and places the patient at a low risk of heart disease.

Triglyceride testing is often performed with the cholesterol assay in the laboratory as part of a lipid panel. Triglycerides are a form of fat, and are often carried by another lipoprotein, very low-density lipoprotein (VLDL). Elevated levels of triglycerides in the bloodstream may also lead to heart disease. Poor diet and low levels of exercise may lead to elevated triglyceride levels.

Electrolytes

Routine blood screening often includes an order for **electrolytes.** Electrolytes (often abbreviated as **lytes**) include several minerals that are essential for normal body function. They carry an electrical charge (positive or negative charge) when dissolved in water. Sodium, potassium, chloride, and CO_2 are usually included in an electrolyte assay. Additional tests may also be included by some laboratories, such those for as magnesium and calcium. Electrolyte assays may provide information to the health-care provider about the acid-base balance of the body, causes for edema, or additional information about the status of kidney dysfunction. Electrolyte levels may also be altered by certain drugs, dehydration, and overhydration. The tests within the electrolyte panel may be ordered individually, or as a group. CLIA-waived automated procedures are available for electrolyte testing, but these tests may also be performed at hospital laboratories and reference laboratories. More information is available about the specific testing methods for electrolytes and the clinical significance of the analytes in Chapter 18.

Test Your Knowledge 16-5

Which of these analytes is not included in an electrolyte panel?

a. Sodium
b. Potassium
c. Chloride
d. Cadmium (Outcome 16-6)

OTHER COMMON CLINICAL CHEMISTRY TESTS

So far, we have focused on clinical chemistry tests that may be performed in the physician office laboratory as well as reference laboratories. In this section of the chapter, we focus on some of the most commonly ordered clinical chemistry tests that are not usually performed in the physician office laboratory. These tests would all be performed on serum or plasma in a hospital or reference laboratory. Many of these commonly performed tests are ordered as profiles or panels rather than individual tests. The panels are beneficial to the health-care provider because the tests included in a panel may evaluate various aspects of a specific organ system; in the case of the **basic metabolic panel (BMP)** and **comprehensive metabolic panel (CMP),** they evaluate parameters of several organ systems. Obtaining all the results at once can allow for a differential diagnosis, and also may save the patient time and money by not having to return to the laboratory for separate blood draws. Charges for the tests included in a Medicare-approved panel may not legally surpass the costs of ordering the tests individually, so it is cost effective to perform multiple tests at one time.

Test Your Knowledge 16-6

List two advantages of ordering tests as a panel rather than individually. (Outcome 16-8)

Blood Urea Nitrogen

As protein is broken down by the body, it produces urea as a by-product. Nitrogen is part of this urea molecule. Urea should be cleared from the blood by the kidneys, so if the level blood urea nitrogen is elevated, it may be an indication that the patient has impaired renal function. **Blood urea nitrogen (BUN)** is a measurement of the amount of urea in the bloodstream. This test is often ordered in conjunction with a creatinine test.

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Creatinine

Creatinine is a by-product of muscle metabolism. As in the case with the blood urea nitrogen, creatinine should be cleared from the blood by the kidneys. Elevated creatinine levels may indicate impaired kidney function. Creatinine levels may be performed on urine samples to correlate the levels with those obtained from testing the serum or plasma. This provides more in-depth information about potential kidney dysfunction.

Test Your Knowledge 16-7

True or False: BUN and creatinine tests are routinely ordered to evaluate kidney function. (Outcome 16-7)

Thyroid Panels

The thyroid gland secretes several very important hormones directly into the bloodstream. These hormones, **thyroxine (T4)** and **triiodothyronine (T3)** are essential for regulation of cellular metabolism. The thyroid gland also secretes thyrocalcitonin, which helps to stimulate calcium storage in the bones of the body. Many laboratories offer thyroid panels that include the T3 and T4. Another hormone that affects thyroid function is the **TSH** (**thyroid-stimulating hormone),** which is secreted by the pituitary gland. Thyroid-stimulating hormone is necessary for the thyroid to be "stimulated" to produce the T3 and T4. For the thyroid gland to function normally, there must be a source of iodine in the diet. Iodine can be ingested with iodized salt, seafood, or vegetables that were grown in soil with supplementary iodine. **Hypothyroidism** is a condition in which the thyroid gland does not produce enough of the hormones necessary to stimulate cell metabolism at a normal level. Patients may also suffer from **hyperthyroidism,** in which case the thyroid gland is producing hormones at a level that is above normal, resulting in overstimulation of cell metabolism. TSH levels outside of the normal range may cause under- or overstimulation of the thyroid gland, resulting in an imbalance; for this reason, the TSH may also be included in some thyroid panels.

Comprehensive Metabolic Panel and Basic Metabolic Panel

The CMP is a set of 14 tests that screen for problems with the kidneys, glucose metabolism, liver, and acid-base balance of the body. The CMP may be used as a general screening test during a routine office visit, or the panel may be ordered to monitor medication use or changes in a disease process. The tests included in this panel are BUN, creatinine, sodium, potassium, chloride, carbon dioxide, calcium, albumin, total protein, bilirubin, alkaline phosphatase (often abbreviated as ALP), alanine aminotransferase (also called SGPT or ALT), aspartate aminotransferase (which may also be known as SGOT or AST), and glucose. The CMP is a panel that has been approved for payment by the Center for Medicare & Medicaid Services (CMS), so it is acceptable for it to be ordered as a diagnostic test for patients with Medicare coverage.

The BMP includes eight tests that will help to identify problems with electrolytes, kidney function, glucose metabolism, and acid-base balance. The basic metabolic panel may be used as a diagnostic tool, or used to monitor medication use or patient progress with ongoing treatment. The BMP includes glucose, calcium, sodium, potassium, carbon dioxide, BUN, and creatinine levels. The BMP has also been approved for payment as a panel by the CMS, so patients who have Medicare as their primary insurance may have this test ordered knowing that its cost is reimbursable.

Cardiac Enzymes

Cardiac enzymes are ordered in situations in which the health-care provider suspects damage to the heart, as in the case of **ischemia** (a temporary decrease of blood flow to the heart muscle) or in the case of trauma to the heart muscle from a **myocardial infarction** (heart attack). The profile usually includes a total **creatine kinase (CK)** and a CK-MB, in addition to other tests such as **troponin** or **myoglobin.** Creatine kinase is found in muscles other than the heart muscle; therefore, if the total CK level is elevated, additional testing must be performed to identify the source of the abnormal result. CK isoenzymes are subtypes of the creatine kinase analyte. The CK-MB (creatine kinase myocardial band) isoenzyme is a specific marker for heart muscle damage. The CK-MB levels will start to rise in the bloodstream approximately 4 hours after a myocardial infarction, and will peak approximately 18 hours after the event. Troponin levels will be elevated with heart muscle damage, but not with other types of muscle trauma. Troponin I levels are especially sensitive to myocardial damage. Troponin testing may be performed on a STAT basis when a myocardial infarction is suspected because these levels become elevated sooner and remain elevated longer than the CK-MB after a heart attack. This allows for earlier diagnosis and appropriate treatment. It is recommended that the troponin levels are tested every 2 to 4 hours for the first 24 hours after a cardiac event. Myoglobin may also be used as an

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indicator for a myocardial infarction, because it will be elevated in the bloodstream sooner after a cardiac event than troponin will be. Myoglobin is found in cardiac and skeletal muscles, so the levels may be elevated in the bloodstream in situations other than myocardial infarction because it is not specific to the heart muscle.

When a patient has chest pain and a myocardial infarction is suspected, the cardiac enzymes are ordered **serially,** because the levels of the various components will change with time if there was damage to the heart muscle. Specimens are usually collected every few hours, and the health-care provider looks for a pattern in the elevation of the different components to rule out or differentially diagnose damage to the heart muscle as a result of a heart attack. If the specimens are not drawn several times within the first 24 hours, it is not possible to establish whether a heart attack really occurred. The myoglobin is usually the first test to be elevated, but most health-care providers like to have more information before proceeding with a differential diagnosis. It is important to remember that other diagnostic procedures (such as an electrocardiogram) will also assist with the diagnosis as well.

Another common cardiac analysis is the **brain natriuretic peptide (BNP)** test. BNP is synthesized in the ventricles of the heart. The BNP secretion rate is increased under conditions of additional myocardial stretch and abnormal wall tension. The test is used to differentiate whether dyspnea (difficulty breathing) is the result of pulmonary conditions or cardiac dysfunction. An excessively elevated BNP level is indicative of heart failure.

Test Your Knowledge 16-8

Why are cardiac enzymes ordered as a series of blood draws rather than just once? (Outcome 16-10)

Hepatic or Liver Profile

Disorders of hepatic (liver) function may be diagnosed using a **hepatic function panel.** Many of the hepatic enzymes are also found in other tissues of the body. The use of a panel may be helpful to the provider for a differential diagnosis. Patients with elevated liver enzymes often exhibit **jaundice** (yellowing of the skin and eyes), nausea and vomiting, or urine that is dark in color. Specimens obtained from patients with liver disease or damage may have plasma or serum that appears **icteric.** Icteric samples have a dark yellow or greenish tint to the fluid portion of the blood, which often correlates to an elevated total bilirubin level. Hepatic function panels may also be used to monitor liver function when patients are taking medication that is known to cause hepatic damage. This panel usually includes at least seven tests that may be elevated with liver dysfunction: ALT (alanine aminotransferase), alkaline phosphatase, AST (aspartate aminotransferase), bilirubin, total protein, and albumin.

Hepatic function panels may include additional tests in some laboratory settings. However, if there are additional tests added to those listed above, Medicare may not pay for the tests performed.

Test Your Knowledge 16-9

Which of these tests are included in a hepatic function panel?

a. AST
b. Total protein
c. ALT
d. None of the above
e. All of the above (Outcome 16-11)

REFERENCE RANGES

It is important to realize that the reference ranges for clinical chemistry tests are based on the technique used by the laboratory performing the test, the age and gender of the patient, the test preparation, and sometimes even by the time of the day that the specimen was drawn. Occasionally there may be a difference in reference ranges for the plasma versus serum samples as well. It is important always to document the details of the blood draw and patient preparation carefully when collecting the blood sample so that the reference ranges will be accurate. It is also essential that the medical assistant learn how to read the laboratory report so that abnormal results are recognized immediately. The reference ranges for the laboratory tests listed in this chapter are included in Table 16-1 and Table 16-2.

POTENTIAL SOURCES OF ERROR

The most common sources of error for clinical chemistry tests occur in the preanalytical area. These include improper patient preparation, inappropriate specimen collection techniques, and errors in specimen processing. Specific sources of specimen processing errors include the following:

- **Hemolysis:** A sample can be hemolyzed (the red blood cells broken open) during specimen collection or afterward during processing. Examples of procedures that may cause **hemolysis** include a traumatic blood draw, using a needle that is too small for the collection process,

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TABLE 16-1
Reference ranges for glucose testing

	Fasting Plasma Glucose	2-Hour Postprandial Glucose
Normal	70–100 mg/dL	Less than 140 mg/dL
Prediabetes	101–125 mg/dL	141–199 mg/dL
Diabetes	126 mg/dL or above	200 mg/dL or above

Data from American Diabetes Association.

TABLE 16-2
Reference ranges for common chemical analytes (listed alphabetically)

Analyte	Normal Range (Adults)
Albumin (Alb)	3.5–5 g/dL
Alkaline phosphatase (ALP)	42–136 U/L
Alanine aminotransferase (ALT)	10–35 U/L
Aspartate aminotransferase (AST)	0–35 U/L
Bilirubin, total (TBili)	0.3–1 mg/dL
Blood urea nitrogen (BUN)	10–20 mg/dL
Brain natriuretic peptide (BNP)	0–100 ng/L
Calcium (Ca)	8.2–10.5 mg/dL
Carbon dioxide (CO_2)	22–30 mEq/L
Chloride (Cl)	96–106 mEq/L
Cholesterol, total (Chol)	Less than 200 mg/dL
Creatinine (Creat)	0.6–1.2 mg/dL
Creatine kinase (CK) aka Creatine Phosphokinase (CPK)	55–170 U/L
High-density lipoprotein (HDL)	Greater than 50 mg/dL
Lactate dehydrogenase (LD, LDH)	100–190 U/L
Low-density lipoprotein (LDL)	Less than 100 mg/dL
Myoglobin	Less than 90 µg/L
Potassium (K)	3.5–5.0 mEq/L
Sodium (Na)	136–145 mEq/L
Thyroid-stimulating hormone (TSH)	0.4–4.2 µU/mL
Thyroxine (T4)	4.5–11.2 µg/dL
Triglyceride (Trig)	Less than 150 mg/dL
Triiodothyronine (T3)	75–220 ng/dL

shaking a tube after collection rather than using gentle inversion, or subjecting the whole blood sample to extreme heat or cold temperatures. Hemolysis may also result if a tube without anticoagulant is centrifuged before the specimen is allowed to clot adequately. Any activity that causes the red blood cells in the specimen to be agitated unnecessarily may potentially cause the red blood cells to be broken. Hemolysis causes the serum or plasma to take on a red color, which interferes with many testing methods. Figure 16-1 shows a specimen

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Figure 16-1 A centrifuged blood specimen with hemolysis evident in the serum.

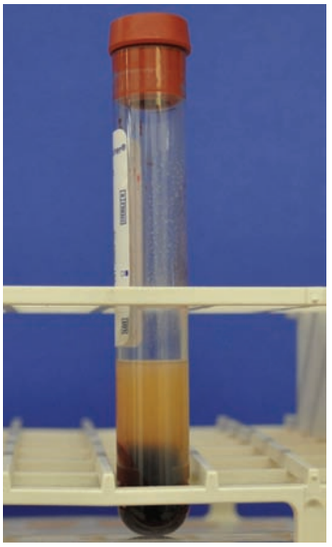

Figure 16-2 A centrifuged blood specimen with lipemia evident in the serum.

with visible hemolysis. Hemolysis may also increase levels of certain analytes in the plasma (potassium or iron, for instance) that are not normally present in high concentrations. The reference ranges for these chemicals are based on nonhemolyzed specimens, so it may appear that the patient needs treatment for an imbalance when the result is erroneous due to hemolysis.

- **Lipemic specimens:** Lipemia is present in a specimen when there are too many lipoproteins in the blood circulation. The excessively high levels of lipoproteins may be caused by hereditary hyperlipidemia or chronic liver disease. Malabsorption disorders may also cause lipemia to be evident. More often, lipemia results when a patient has not followed the instructions for specimen preparation by not fasting as directed before the blood draw. Lipemic specimens have a "milky" appearance that may be visible immediately after collection or after centrifugation. These fatty particles suspended in the specimen will interfere with many clinical chemistry assays. Some testing may be possible if the specimen is "cleared" using a special centrifugation process, but often the laboratory will ask that the specimen be redrawn if the lipemia is severe. Lipemia is evident in the specimen included in Figure 16-2.
- **Specimen collection errors:** The medical assistant who is performing specimen collection needs to keep the difference between plasma and serum samples in mind. If a test calls for a serum sample, a tube without anticoagulant must be used for the collection. In addition, certain test results may also be affected if a tube with serum/plasma separator gel is used for the collection. Specifics about the type of specimens that are acceptable and unacceptable for a particular test would be listed in the laboratory directory, which provides collection specifics for the tests offered by that laboratory. This SST restriction is most common when collecting specimens for medication levels.

Another potential source of error when collecting clinical chemistry specimens is the incorrect timing of the collection. Tests may be ordered as a series of blood draws, as in the case of the cardiac enzymes. Medication levels may also be ordered at specific times as peak and trough draws. It is important to understand the process involved in these timed collections so that the specimens are properly labeled and the reference ranges are matched to the specimen type. In the case of medication levels, it is important to find out if there are restrictions concerning the length of time between the last dose and the specimen collection so that the health-care provider will receive results that allow for proper treatment of the patient.

In addition to the incorrect type of specimen collection and the incorrect timing, another potential source of error is the order in which the tubes are collected. Carryover of anticoagulant from one tube to another may cause changes in the levels of certain analytes when the testing procedures are performed. Potassium levels, for example, may be elevated if the lavender top tube is

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collected before the green top tube and a carryover of anticoagulant results.

- **Quantity not sufficient:** Laboratory directories provide information about the volume needed for testing procedures, and they may also provide a minimum volume accepted for the test. A **QNS specimen** (one that does not have the quantity necessary for testing) will require a re-collection, which delays potential treatment for the patient. These volume requirements must be taken into consideration before the sample is collected; they can affect the choices made concerning which type of collection setup to use and how many tubes to draw. The stated minimum volumes usually allow the test to be performed *only once;* this means that if there are any errors during the analysis or an extremely high or low result, retesting the sample will not be possible. Sometimes it is necessary to retest the sample using dilutions to obtain a true value, but this would also not be possible if only the minimum volume is submitted to the laboratory.
- **Exposure to light:** Some analytes (bilirubin and ferritin, for example) will deteriorate when exposed to light after collection. These samples need to be covered immediately (usually wrapping foil around the tube will suffice) and centrifuged as soon as possible. The plasma or serum to be analyzed should be separated into a tube designed to protect the specimen from light exposure. Figure 16-3 shows an amber plastic transfer tube that is designed to minimize the light exposure for a specimen.
- **Exposure to air:** Once a specimen has been centrifuged, it may be necessary to remove the rubber top of the tube and separate out the plasma or serum. The exposure to air should be minimized, as the concentration for some analytes will change with the exposure. Alcohol analysis is an excellent example of this; the longer the tube is open, the lower the alcohol concentration may become in the specimen. Carbon dioxide is another common analyte that may decrease with continued exposure to air.
- **Specimen processing:** Careful adherence to specimen processing is essential for clinical chemistry tests. Many of the chemical concentrations will change when left at room temperature for extended periods of time, so researching the specimen requirements prior to processing is important. If there is a question about how to handle a specimen, the laboratory directory should be consulted, and if necessary, the testing laboratory should be contacted for clarification *before* the specimen is collected. Plasma or serum may require freezing or refrigeration within a certain amount of time after collection to maintain the integrity of the sample. It is also necessary to prechill specimen collection tubes for some analytes.

Figure 16-3 Amber transfer tubes designed to minimize specimen exposure to light.

- **Delayed processing:** Blood specimens to be used for clinical chemistry should be centrifuged as soon as possible so that the plasma or serum can be removed from the cells in a timely manner. Serum tubes must be allowed to clot completely before centrifuging. Delayed separation of cells from plasma or serum will allow analytes that are in a higher concentration within the cells than outside the cells to "leak" out of the cells and cause erroneous test results. This can result in an inaccurate diagnosis and/or unnecessary treatment for the patient. Conversely, glucose that is present in the plasma or serum will continue to be used by the cells in the specimen as an energy source if the serum or plasma is not removed from the cells in a timely manner. Therefore, the longer that the cells remain in contact with the fluid portion of the blood, the lower the glucose levels will become in the plasma or serum. This can make it appear that the patient has a very low plasma glucose level when the specimen is tested in the laboratory.

Test Your Knowledge16-10

Which of these potential sources of error are related to high levels of lipids in the bloodstream?

a. Lipemia
b. Hemolysis
c. Erroneous low glucose levels
d. QNS specimens (Outcome 16-13)

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SUMMARY

Clinical chemistry is a complex component of laboratory testing. There are hundreds of tests that may fall into this category, and the specimen collection and processing requirements will vary depending on the testing method and laboratory policies. Some clinical chemistry tests may be performed in physician office laboratories; most of these will use whole blood specimens for analysis. Common clinical chemistry tests performed in the physician office laboratory include glucose and cholesterol testing. Clinical chemistry tests performed at reference laboratories are usually performed on plasma or serum specimens rather than whole blood specimens. Many of these tests may be ordered as panels or profiles. There are numerous sources of error in specimen collection and processing for clinical chemistry tests, so the medical assistant has to remain diligent about specific specimen requirements to provide appropriate specimens for meaningful laboratory results.

TIME TO REVIEW

1. Atherosclerosis is: Outcome 16-1
   - **a.** Hardening of the arteries due to age
   - **b.** A buildup of waxy plaque on the lining of blood vessels
   - **c.** A condition related to high glucose levels
   - **d.** The presence of occult blood in the stool
2. Creatinine is present in the blood as a by-product of: Outcome 16-1
   - **a.** Protein metabolism
   - **b.** Heart damage
   - **c.** Muscle metabolism
   - **d.** Glucose metabolism
3. Myoglobin and troponin are examples of: Outcome 16-1
   - **a.** Tests included in a typical hepatic function panel
   - **b.** Tests included in a typical renal function panel
   - **c.** Tests included in the BMP
   - **d.** Tests included in an order for cardiac enzymes
4. True or False: Plasma is the liquid portion of the blood separated after centrifugation from a tube that does not contain anticoagulant. Outcome 16-2
5. True or False: Hemoglobin is a substance that is dissolved in blood plasma. Outcome 16-3
6. Which of these tests are not included in a typical lipid panel? Outcome 16-5
   - **a.** Total cholesterol
   - **b.** Total triglyceride
   - **c.** VLDL
   - **d.** Creatinine
7. An electrolyte panel typically includes which of these tests? Outcome 16-6
   - **a.** BUN
   - **b.** CPK
   - **c.** ALT
   - **d.** Potassium
8. True or False: A panel of laboratory tests costs more for the patient than ordering all the tests in the panel individually. Outcome 16-8
9. Which of these tests are not usually included in a cardiac panel? Outcome 16-9
   - **a.** ALT
   - **b.** CK-MB
   - **c.** CK
   - **d.** Myoglobin
10. Which of these factors may be taken into consideration when evaluating reference ranges for a test? Outcome 16-12
    - **a.** Age and gender of the patient
    - **b.** Testing methodology
    - **c.** Time of day for specimen collection
    - **d.** All of the above
11. True or False: Hemolysis is avoidable when collecting a blood sample. Outcome 16-13

Case Study 16-1: What order?

Mr. Oliver arrived early for his blood draw one Monday morning. The medical assistant was running late that day, and seemed to be a bit distracted as she prepared for the blood draw. Mr. Oliver's physician had ordered a CBC (to be collected in a potassium EDTA tube) and a potassium level (to be collected in a green top heparinized tube). The MA completed the blood draw, and thanked Mr. Oliver for his time.

The next day, the physician's office called Mr. Oliver and asked him to come in to have his potassium level

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rechecked, as it was elevated on the test from the day before. This was not an expected result, as usually Mr. Oliver's potassium level was decreased below the reference range. The specimen was drawn and checked on a STAT basis, and the result was in the low end of the reference range. The physician told Mr. Oliver that the previous result was elevated because of a laboratory error.

1. What are two sources of error that could cause the potassium result to be erroneously elevated in this scenario?

RESOURCES AND SUGGESTED READINGS

"Modern Technology Helps Shed Light on Illness in Artists of the Past"
A summary of an article by Paul L. Wolf, MD, which appeared in the November 2005 edition of the *Archives of Pathology and Laboratory Medicine,* a publication of the College of American Pathologists. Very interesting information concerning the way that illnesses and drugs have influenced the work of many famous artists and composers. http://www.newswise.com/articles/view/516145/

"Cholesterol"
Excellent presentation on cholesterol and the effects that it may have on the cardiovascular system; also includes information about lifestyle changes and symptoms of myocardial infarction and stroke http://www.americanheart.org

"Diseases and Conditions Index, Coronary Artery Disease"
National Heart, Lung and Blood Institute; National Institutes of Health
Excellent information about coronary artery disease including illustrations. http://www.nhlbi.nih.gov/health/dci/Diseases/Cad/CAD_WhatIs.html

"Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)"
National Heart, Lung and Blood Institute: National Institutes of Health
Includes recommendations for lipid testing and desirable ranges and treatment options. http://www.nhlbi.nih.gov/guidelines/cholesterol/index.htm

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Chapter 17

Glucose Testing

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Glucose Utilization and Control Mechanisms
Pathophysiology of Glucose Metabolism
- Prediabetes
- Diabetes
  - *Type 1 Diabetes*
  - *Type 2 Diabetes*
  - *Gestational Diabetes*

Types of Glucose Tests Performed
- Fasting Blood Glucose Test

Random Glucose Test
- Postprandial Glucose Test
- Oral Glucose Tolerance Testing Procedures
- Glycosylated Hemoglobin
- Blood Ketone Testing
- Capillary Sample Testing and Correlation to Plasma Glucose Levels
- Urine Testing for Diabetics

Glucose Testing Methods
- Home Glucose Testing Instruments
  - *Quality Control and Common Errors*
- Laboratory Glucose Testing and Potential Sources of Error

Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

17-1 Define the key terms.

17-2 Explain how insulin and glucagon work together to maintain healthy blood sugar levels.

17-3 List three ways that insulin secretion affects the body.

17-4 Compare and contrast type 1 and type 2 diabetes.

17-5 Describe how gestational diabetes is different from type 1 and type 2 diabetes.

17-6 List potential problems that may develop with uncontrolled diabetes.

17-7 Explain why it is important to diagnose and treat gestational diabetes.

17-8 Examine the differences between the random and fasting glucose testing.

17-9 Explain the procedure for postprandial glucose testing.

17-10 Describe the steps involved in a glucose tolerance test.

17-11 Identify the clinical significance of the Hb A1c test.

17-12 Explain how the results for capillary whole blood glucose testing may compare to those tested on a plasma sample.

17-13 Describe common maintenance and quality control issues that may need to be addressed in home and laboratory glucose testing methods.

17-14 Perform CLIA-waived glucose testing.

17-15 Perform a CLIA-waived Hb A1c test.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.13. Perform chemistry testing

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- Graduates: b. Perform selected CLIA-waived tests that assist with diagnosis and treatment, #3 Chemistry Testing

KEY TERMS

Albumin
Autoantibodies
Autoimmune response
Body mass index (BMI)
Carbohydrates
Diabetes
Diabetes insipidus
Diabetes mellitus
Diabetic ketoacidosis
Diabetic neuropathy
Etiology
Fasting blood sugar (FBS)
Fasting plasma glucose (FPG)
Gestational diabetes
Glucagon
Glucose
Glucose challenge test
Glucosuria
Glycated hemoglobin
Glycemic control
Glycogen
Glycogenolysis
Glycolysis
Glycosylated hemoglobin
Hb A1c
Hyperglycemia
Hypoglycemia
Impaired fasting glucose (IFG)
Impaired glucose tolerance (IGT)
Insulin
Insulin dependent
Insulin resistance
Islets of Langerhans
Ketones
Ketonuria
Macrosomia
Metabolic syndrome
Microalbumin
Microalbuminuria
Oral glucose tolerance test (OGTT)
Polydipsia
Polyphagia
Polyuria
Postprandial
Prediabetes
Type 1 diabetes
Type 2 diabetes

History has provided us with many detailed observations of patients with **diabetes.** The ancient physicians documented the symptoms related to diabetes, such as frequent excessive urination and weight loss; however, they were not able to effectively treat the condition. In the first century AD, a physician in ancient Greece named this malady *diabetes,* based on the Greek word for "siphon," as it seemed to him that the liquid taken in by the body was just "siphoned" through and came directly out as urine. Other ancient civilizations provide examples of urine from ill patients that attracted ants because of the sweetness of the fluid. In the 1700s, physicians discovered that the urine and blood from patients exhibiting diabetic symptoms tasted sweet, like sugar, and this became an accepted means of diagnosing diabetes in symptomatic patients.

The treatment of diabetes remained ineffective because physicians could not determine the cause or source of the dysfunction responsible for the symptoms. Some thought there was a problem with digestion in these

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patients, whereas others thought it must be a disease of the kidneys because there was so much urine produced. It was not until the late 19th century that scientists discovered evidence that the pancreas was involved in the process. In 1889, two physicians who were studying fat digestion and utilization discovered that the removal of the pancreas caused the animals in the experiment to exhibit the symptoms of diabetes. In 1922, Frederick Banting and Charles Best experimented with extracts from the pancreas to isolate **insulin,** an enzyme that is necessary for the proper utilization of glucose by the cells of the body. Insulin became available in the 1920s as injected medication to treat diabetes, with immediate lifesaving results for those afflicted.

In 1935, scientist Roger Himsworth presented evidence that diabetes was actually two separate diseases: "insulin sensitive" (today's type 1 diabetes) and "insulin insensitive" (now known as type 2 diabetes). This discovery provided the opportunity for a deeper understanding of the disease and its treatment, as well as the development of an oral medication for "insulin-insensitive" type of diabetes, which became available in the 1950s.

Even though the cause and types of diabetes are now understood and more treatment options are available, diabetes is still a very serious, widespread, and expensive health problem. According to statistics from the Centers for Disease Control and Prevention (CDC), approximately 8% of the population of the United States has diabetes, and in 2007 it was the sixth leading cause of death. Common complications of diabetes include cardiovascular disease, increased stroke risk, poor healing, hypertension, blindness, kidney disease, nervous system dysfunction, amputations, and dental disease. Diabetes can also contribute to complications of pregnancy and causes increased susceptibility to other illnesses. Because of the severity of this disease and the number of those afflicted, **glucose** testing has become a very common procedure performed in physician office laboratories and reference laboratories. Health-care providers and patients must work closely together to manage the disease and provide appropriate treatment to avoid the onset of life-threatening complications.

GLUCOSE UTILIZATION AND CONTROL MECHANISMS

Glucose is a type of simple sugar that is needed as an energy source by all living things. When **carbohydrates** are digested, glucose enters into the bloodstream as a by-product. As the blood glucose levels rise, the body reacts in several ways:

- Some of the glucose goes directly to the brain tissues, where it is needed for normal function. Cells of the brain do not require insulin to take in glucose for energy.
- The increased levels of glucose in the blood trigger the pancreas to release insulin, which is produced by clusters of specialized beta cells in the pancreatic **islets of Langerhans.** Insulin is required for glucose to enter most of the cells of the body so that it can be used as an energy source. The cells of the body have a receptor that interacts with the insulin molecule. This interaction allows glucose to pass through the cell membrane. Insulin may be considered as a "key" to open the doors on the cells to allow the glucose to enter. The cells accept as much glucose as needed for normal function.
- Because a meal may provide more glucose than is needed immediately, insulin triggers the body to store the excess glucose in the muscles and liver as **glycogen,** which is essentially a long string of glucose molecules. When the demand for glucose increases past what is in the bloodstream, this glycogen is broken down and released for use as glucose. The increased glucose demand may also result in the transmission of a message to the brain encouraging the body to take in food. Additional unneeded glucose may be stored as fat.

Test Your Knowledge 17-1
What is glycogen? (Outcome 17-1)

Once the glucose has entered the cells of the body, the blood glucose levels begin to return to normal. The goal of the body is to keep a consistent level of glucose in the bloodstream at all times while providing the necessary energy to the cells. Glucose continues to be used by the cells constantly, and with increased activity the glucose demands are heightened. The increased demand causes the glucose levels in the bloodstream to decrease below the normal range as the glucose molecules move into the cells. When this occurs, another cell type (alpha cells) in the pancreatic islets of Langerhans secrete a hormone called **glucagon,** which counteracts the effects of insulin. (See Fig. 17-1 for more details about the pancreas and the islets of Langerhans.) Glucagon causes the pancreas to reduce insulin production, and signals the liver, muscles, and adipose tissues of the body to release some of the glucose that is stored there into the bloodstream to increase blood glucose levels. This process of glycogen breakdown is called **glycogenolysis**. Figure 17-2 demonstrates the balance between glucose, insulin, and glucagon.

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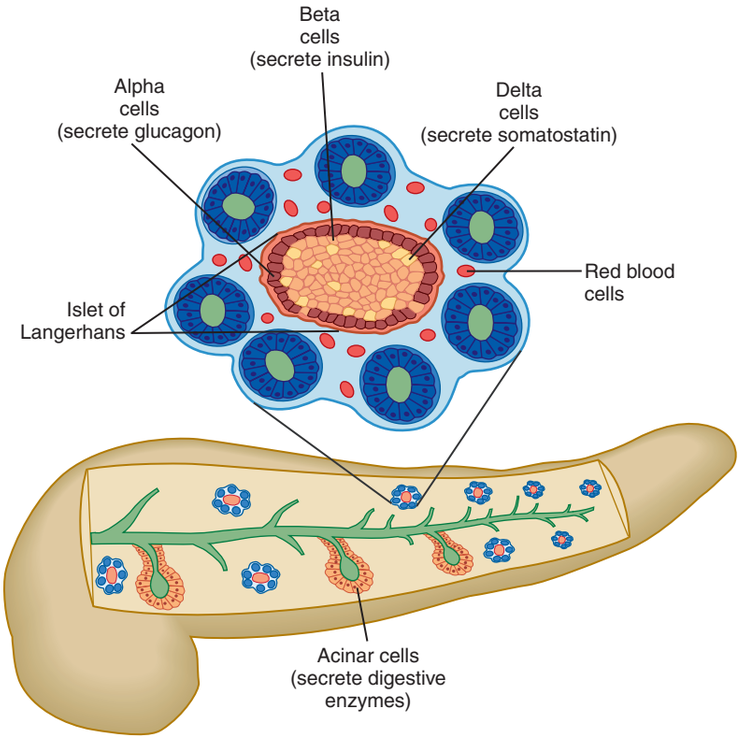

Figure 17-1 Pancreas and islets of Langerhans; note the alpha and beta cells.

The intricate balance of the blood sugar levels, insulin secretion, and glucagon secretion is essential for the body to function normally. Insulin is required for most of the cells in the body to take in glucose to be used for energy, and insulin also triggers the formation of glycogen and triglycerides from the excess blood glucose so that the body has a backup source of energy between meals or during times of increased need. In addition, the secretion of insulin stimulates the liver and muscle cells to absorb amino acids introduced into the bloodstream during digestion and use these to create proteins. Insulin also stimulates the cells to take in fatty acids from the bloodstream so that there is not an excessive buildup.

Test Your Knowledge 17-2

Which of these processes is triggered by the secretion of insulin?

a. Formation of glycogen
b. Increase of blood glucose
c. Formation of glucose
d. Secretion of glucose (Outcome 17-3)

PATHOPHYSIOLOGY OF GLUCOSE METABOLISM

Prediabetes

According to the American Diabetes Association, there are approximately 57 million Americans that have **prediabetes,** which is defined as a condition in which the blood glucose level is elevated, but not high enough to be indicative of a diagnosis for type 1 or type 2 diabetes. Those who have prediabetes may already be experiencing some of the adverse effects of **hyperglycemia** (elevated blood glucose) and are at a greatly increased risk of developing diabetes within the next few years.

Those with prediabetes have some degree of insulin resistance, usually associated with obesity, a sedentary lifestyle, and poor eating habits. Patients with increased abdominal fat and an elevated **body mass index (BMI)** (a measurement of weight in relationship to height) are at an increased risk, as well as those with a history of type 2 diabetes in their immediate family. In addition, diabetes is more common in certain ethnic groups. Latinos,

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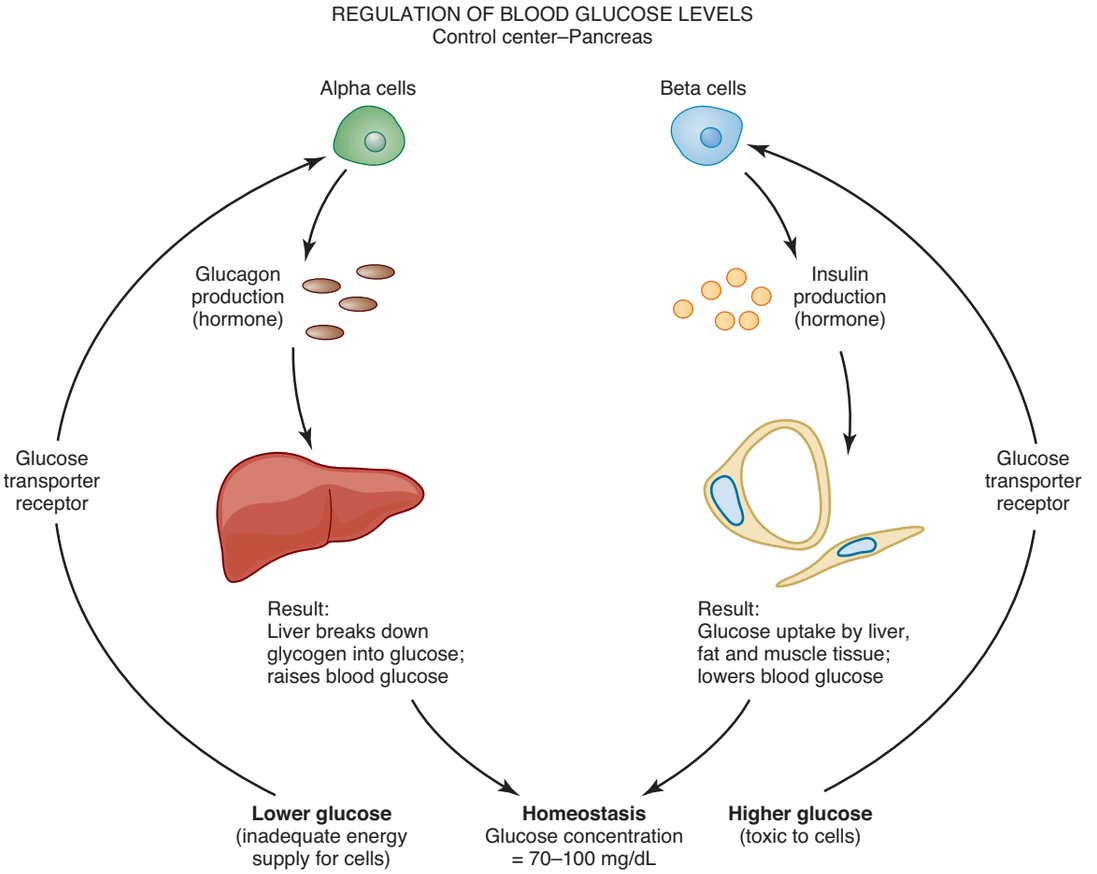

Figure 17-2 Representation of the balance between blood glucose, insulin, and glucagon. When blood glucose is increased, the body produces insulin to allow the glucose to enter the cells. This decreases the blood glucose levels, which triggers glucagon to be released if the level drops too low. The glucagon then decreases the absorption of glucose into the cells, and increases the breakdown of glycogen, if necessary.

African Americans, Native Americans, Asian Americans, and Pacific Islanders have an increased presence of diabetes in their populations. The elderly also have a disproportionate amount of diabetes present. Because these groups have more diabetes in their midst, prediabetes is also more likely.

Prediabetes is detected by testing the blood glucose level. The desirable **fasting plasma glucose (FPG)** result tested after approximately 12 hours of fasting is below 100 mg/dL. Prediabetes is indicated by an FPG of 100 to 125 mg/dL, and patients with diabetes usually demonstrate an FPG of 126 mg/dL or above. Prediabetics with an FPG of 100 to 125 mg/dL are said to have **impaired fasting glucose (IFG).** The prediabetes diagnosis may also be based on an abnormal **oral glucose tolerance test (OGTT)** result. The result at 2 hours during this procedure for prediabetics will be between 140 and 200 mg/dL, and for diabetics it will be over 200 mg/dL. (The OGTT procedure is detailed later in this chapter.) Prediabetics with glucose levels at 2 hours between 140 and 200 mg/dL are said to have **impaired glucose tolerance (IGT).**

Those diagnosed with prediabetes do not always proceed to develop diabetes. Studies have shown that if patients with prediabetes make a concentrated effort to increase physical activity and reduce their weight by 5%

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to 10%, they may not develop diabetes, or at the very least, they may delay the onset of diabetes for a few years. These lifestyle changes will also stop any undesirable effects of the hyperglycemia on the cells of the body. The American Diabetes Association strongly recommends counseling and follow-up for this group to assist with lifestyle changes.

Diabetes

The word *diabetes* is used to refer to a group of disorders that all exhibit **hyperglycemia**, or elevated blood glucose. These may also be known as different types of **diabetes mellitus,** or "sweet" diabetes, because of the glucose content in the urine of those diagnosed. There are actually three different types of diabetes associated with hyperglycemia, which differ by their **etiology** (cause) and by their treatment. These include **type 1 diabetes,** which previously was known as insulin-dependent diabetes or juvenile-onset diabetes. **Type 2 diabetes** was previously known as non-insulin-dependent diabetes. **Gestational diabetes** is a disorder of glucose metabolism that only affects those who are pregnant. A diagnosis of type 1 or type 2 diabetes is usually only assigned to a patient after confirmation of the abnormal blood levels.

Type 1 Diabetes

Patients with type 1 diabetes have a lack of insulin. The beta cells of the islets of Langerhans in the pancreas have been destroyed and are not capable of creating enough insulin to keep the body healthy. Type 1 diabetes is present in approximately 5% to 10% of all diabetic patients, and presents most often in children or adolescents. Adults may also be afflicted, although this is not as common as it is in those under the age of 20. The destruction of the beta cells responsible for insulin production is most commonly associated with an **autoimmune response,** in which the patient's body develops **autoantibodies** that attack the cells in the islets of Langerhans. There seems to be a genetic predisposition to this condition, although it appears that there is usually some sort of "trigger" that brings on the autoantibody production. Viral infections and environmental factors have been linked to the progression of the disease.

Type 1 diabetes may develop over a few weeks; the onset of the disease is often quite rapid as compared to type 2 diabetes, which has a gradual progression. Type 1 diabetes patients commonly exhibit fatigue, increased urination and increased thirst, nausea and vomiting, and weight loss in spite of an increased appetite. During the initial onset of symptoms, the patient may have periods of hyperglycemia as well as **hypoglycemia** (low blood sugar). If the diagnosis and treatment are not established early in the disease process, the body will react to the shortage of insulin by using fatty acids as an energy source instead of depending on glucose. The use of fatty acids may cause a buildup of **ketones** in the bloodstream. Ketones are a by-product of fat metabolism, and because they are acidic in nature, they will change the pH of the body over a period of time. Initial symptoms of **diabetic ketoacidosis** include abdominal pain, nausea, and vomiting. As the condition progresses, the patient may have increased shallow respirations, which is the body's way of attempting to change the acidic blood pH. The patient may have difficulty thinking and communicating clearly, and may eventually become comatose. It is at this point that the diagnosis of type 1 diabetes is often assigned, as the patient is admitted to the emergency room or hospital once he or she becomes critically ill.

Treatment of type 1 diabetes requires frequent insulin injections. Insulin cannot be administered orally, as it is not effective once it has been digested. There are many different types of insulin; some act quickly and stay in the circulation for a short period of time, and others are designed to be longer lasting. Patients who are **insulin dependent** monitor their blood glucose level several times daily and adjust their insulin intake accordingly.

Type 2 Diabetes

Type 2 diabetes is characterized by a lack of insulin activity on the cells of the body. This may be due to **insulin resistance,** in which the cells have a diminished ability to interact with insulin as they should. Because the insulin no longer acts on the cells of the body to allow the glucose to pass through into the cells, the blood glucose levels remain elevated. Type 2 diabetes may also be the result of a decreased production of insulin by the beta cells of the pancreas. In situations in which the patient exhibits insulin resistance, the body will try to produce more insulin to overcome the resistance, but after a period of time the demand is excessive and the production cannot keep up with the needs of the body. Those who have type 2 diabetes often have high levels of insulin in the bloodstream as well as high levels of glucose. In addition to the high levels of blood glucose that result because of ineffective cellular transport, the body also tries to accommodate the imbalance by breaking down additional glycogen in the liver,

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which adds additional glucose to the bloodstream and complicates the situation further.

Type 2 diabetes is the most common form of the disease, affecting approximately 95% of all diabetics. The CDC has declared type 2 diabetes to be at an epidemic level, as the numbers of those diagnosed increase every year. The etiology (cause) of type 2 diabetes is complicated. There is a direct correlation with obesity and individuals who have been diagnosed with **metabolic syndrome** (a group of risk factors that occur together and increase the risk of coronary heart disease, stroke, and type 2 diabetes), as well as a family history of type 2 diabetes and a sedentary lifestyle. Women with a history of polycystic ovary syndrome or gestational diabetes also have an increased chance of developing type 2 diabetes. Those older than age 40 are at a higher risk than those who are younger, although there has been a sharp increase in the number of obese children diagnosed with type 2 diabetes in the past few years. Certain ethnic groups are at a higher risk, such as Native Americans and those of Asian or African descent.

Diagnosis of type 2 diabetes may be delayed for years after the first onset of symptoms as this type of diabetes develops slowly. As with type 1 diabetes, many patients diagnosed with type 2 diabetes demonstrate increased urination and increased thirst. Some other common symptoms include unexplained weight loss or weight gain, flu-like symptoms with fatigue and nausea accompanied by a loss of appetite, changes in vision, and poor healing. Patients may also find that they are more susceptible to other illnesses, such as the common cold. Having frequent urinary or yeast infections may also be an indicator of type 2 diabetes. Another clinical indicator may be a change in oral health, because diabetes may cause inflammation that leads to infection in the gums. In addition, some patients experience tingling or loss of sensation in the fingertips or toes, which is caused by damaged nerve endings from the high levels of glucose in the body.

Type 2 diabetes is first treated with lifestyle changes. Most patients diagnosed with this type of diabetes are overweight, so the first goal is to lose approximately 8% to 10% of the total weight. Diabetics are also encouraged to exercise for at least 150 minutes per week to improve their health. Oral medications that enhance the ability of the body to react to insulin or stimulate the beta cells of the pancreas to produce more insulin may also be used. If these measures are ineffective in accomplishing **glycemic control** (appropriate blood glucose levels), the patient with type 2 diabetes may be treated with insulin injections.

Untreated or uncontrolled type 1 or type 2 diabetes may lead to hypertension and other serious cardiovascular diseases, as well as **diabetic neuropathy**; nervous system damage; eye and kidney tissue damage; poor healing; foot and skin complications; and gastroparesis, a disorder in which the stomach takes too long to empty after eating. Those with diabetes are at an increased risk of developing depression. Patients with type 1 diabetes may also have an increased risk of developing celiac disease (a chronic digestive disorder caused by the inability to metabolize gluten) or a painful musculoskeletal condition known as "frozen shoulder," in which the individual loses movement of the shoulder for a period of time.

Test Your Knowledge 17-3

List one way that type 1 and type 2 diabetes are similar. (Outcome 17-4)

Test Your Knowledge 17-4

List two potential consequences of uncontrolled or untreated diabetes. (Outcome 17-6)

Gestational Diabetes

Gestational diabetes (sometimes abbreviated as GDM) is similar to type 2 diabetes because it is a form of glucose intolerance rather than a reduction in insulin production. Approximately 4% of all pregnant women develop gestational diabetes. It is more frequent among Hispanic Americans, African Americans, Native Americans, Asian Americans, indigenous Australians, and Pacific Islanders. Obesity, previous delivery of an infant weighing more than 9 pounds, and a positive family history of diabetes also increase the risk of developing gestational diabetes. Women who have gestational diabetes will usually demonstrate it in subsequent pregnancies, and are at an increased risk of developing type 2 diabetes later in life.

Although the exact cause of gestational diabetes is not clear, it is thought that the insulin resistance present in gestational diabetes is demonstrated as a result of the additional hormones present in the body during pregnancy. The placenta produces high levels of hormones (such as cortisol and estrogen) to support and sustain the pregnancy. These hormones block or reduce the action of insulin on the cells of the mother's body, which causes her blood glucose levels to become elevated.

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The high levels of hormones are not usually a problem until late in the pregnancy, as the mother's pancreas normally responds to the additional insulin demands early in the pregnancy. As the pregnancy continues, the additional maternal insulin production cannot overcome the effects of the hormones produced by the placenta, and the mother will exhibit sustained elevated blood glucose levels.

Gestational diabetes is a serious health risk because of the additional glucose in the mother's bloodstream. Glucose passes through the placenta to the fetus, causing a condition known as **macrosomia.** *Macrosomia* means "fat baby." In this condition, the additional glucose passed on to the baby from the mother causes the baby's body to produce excessive fat cells in response to the additional unneeded glucose. The baby may become excessively large, which can cause complications during delivery. Many babies born to mothers with gestational diabetes must be delivered using a cesarean delivery, as their excessive size does not allow a vaginal birth. If a vaginal birth is attempted, these babies are at a high risk of shoulder damage during the delivery. Studies have shown that babies born to mothers with gestational diabetes have increased risk of becoming obese as children, as well as an increased risk of developing type 2 diabetes later in life.

In addition to the risks from excessive size, infants born to mothers with gestational diabetes have an increased risk of breathing problems, as well as extreme hypoglycemia (low blood glucose levels) after birth. During the pregnancy, the infant has been producing enough insulin to process the glucose created by his or her own body, as well as the additional glucose supplied by the circulation of the mother. When the additional maternal glucose supply is discontinued at birth, there is too much insulin in the infant's bloodstream, resulting in low levels of blood glucose. Without careful monitoring, this situation can become life threatening. These babies may also be at an increased risk for other chemical imbalances in the first few days of life.

Test Your Knowledge 17-5

Is gestational diabetes more like type 1 or type 2 diabetes? Why? (Outcome 17-5)

Test Your Knowledge 17-6

How is macrosomia related to gestational diabetes? (Outcome 17-7)

POINT OF INTEREST 17-1
Another type of diabetes

There is another disease that shares the name diabetes, but it is not associated with hyperglycemia. **Diabetes insipidus** is an endocrine disease characterized by a lack of the hormone vasopressin, which acts on the kidneys to reduce urinary output and allow for concentration of the urine. Vasopressin is produced by the pituitary gland, and those with this disease either do not produce enough vasopressin, or they have developed a resistance to the actions of vasopressin to concentrate urine. A patient with diabetes insipidus produces excessive amounts of urine each day, and often sees the physician because of symptoms associated with bed-wetting, dehydration, and/or electrolyte imbalances. Diabetes insipidus has very little in common with the other forms of diabetes discussed in this text, except for the initial common symptoms of increased urination and increased thirst.

TYPES OF GLUCOSE TESTS PERFORMED

The role of the laboratory in diabetes care is to assist the health-care provider in the initial diagnosis, differentiation about the type of diabetes present, and monitoring the progress of the treatment once it has started for the patient. There are several types of glucose test procedures performed that provide necessary information to the health-care provider.

Fasting Blood Glucose Test

The glucose level performed in a laboratory on a fasting blood specimen is known as a fasting plasma glucose (FPG). The term **fasting blood sugar (FBS)** may also be used. Most laboratories perform blood glucose levels on plasma or serum, rather than on whole blood. To prepare for this test, the patient needs to fast for 12 hours and should not smoke, drink anything but water, or take medication before the test. (Sometimes the medication is a *must;* this should be cleared with the physician before the specimen is drawn.) The World Health Organization recommends the use of plasma obtained from a venipuncture for this test. If the test cannot be performed within an hour of the blood draw, a gray top tube should be used for the specimen. The additives in the gray top tube reduce **glycolysis** (utilization of the glucose in the specimen by the living cells present) for up to 24 hours at room temperature. The desirable fasting plasma or serum glucose level is 70 to 100 mg/dL

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Patients with FPG of 100 to 125 mg/dL have impaired fasting glucose, and are prediabetic. A result equal to or above 125 mg/dL is indicative of diabetes.

Random Glucose Test

A random blood glucose test is one that is taken at any time of the day without regard for the time of the last meal. A patient who is symptomatic for diabetes, perhaps exhibiting **polyuria,** (excessive urination) **polyphagia,** (excessive hunger), or **polydipsia** (excessive thirst) and unexplained weight loss may have a random glucose test ordered. According to the criteria established by the American Diabetes Association, if the random glucose result for a symptomatic patient is equal to or greater than 200 mg/dL, then the patient is classified as a diabetic.

Test Your Knowledge 17-7

Which of these best describes a random glucose?

a. A glucose level drawn 1 hour after eating
b. A glucose level drawn after 12 hours of fasting
c. A glucose level drawn at any time of the day without any previous preparation
d. A glucose level drawn just before eating

(Outcome 17-8)

Postprandial Glucose Test

Postprandial refers to something done after eating or after mealtime. Glucose testing that is performed postprandial may mean that the blood specimen was collected a specific amount of time after a meal, or it may mean that the specimen was drawn at a certain interval after ingestion of a glucose-rich beverage. Diabetics who are striving to achieve close glycemic control will test their blood glucose levels at home 1 or 2 hours postprandial to see how their body has handled the meal. Most diabetic educational materials provide target ranges for 2-hour postprandial blood glucose levels. Ideally, the blood glucose should not go above 140 mg/dL for nondiabetic patients; for diabetics the level should remain below 180 mg/dL 2 hours after eating.

Initial screening procedures for gestational diabetes may also use postprandial glucose testing. This may be called a **glucose challenge test.** Patients do not need to fast before this procedure. When they arrive at the laboratory or physician office, they are given a drink that contains 50 g of glucose. This drink must be ingested within 5 minutes for the test to be valid. A blood specimen is drawn exactly 1 hour after ingestion of the glucose solution. Patients with gestational diabetes will demonstrate a postprandial blood glucose level at 1 hour that is greater than or equal to 140 mg/dL. If this glucose challenge result is elevated, then the health-care provider will usually order a 3-hour oral glucose tolerance test.

Test Your Knowledge 17-8

True or False: A laboratory postprandial glucose test is drawn at a specific time interval after ingestion of a drink high in glucose or ingestion of a meal.

(Outcome 17-9)

Oral Glucose Tolerance Testing Procedures

According to the National Institutes of Health, the oral glucose tolerance test is more sensitive to the detection of prediabetes than the fasting glucose test level. The OGTT is used primarily for the diagnosis of diabetes mellitus. This test may be performed on a patient with an abnormal FPG, assuming that the result of the FPG was less than 200 mg/dL. If the fasting result was equal to or more than 200 mg/dL, an oral glucose tolerance test is not indicated because the high FPG level is indicative of diabetes. This test may also be ordered for patients who are being evaluated for gestational diabetes, or those who had an abnormal 1-hour postprandial glucose result.

- A patient preparing for an oral glucose tolerance test should have a carbohydrate-rich diet for at least 3 days prior to the scheduled test. Diets that restrict carbohydrate intake may produce erroneous results. The patient must fast for 12 hours prior to the test. During this time, no food or liquid other than water is to be consumed. The patient should also avoid smoking and strenuous exercise.
- Upon arrival at the laboratory or the clinic, the patient will have a fasting plasma glucose specimen drawn. This specimen should be analyzed for glucose content before continuing with the process; if the fasting plasma glucose results are elevated above 126 mg/dL, the test will not continue. Also, some laboratories will collect a urine specimen with each blood draw; this helps to provide more information about the glucose that may be "spilled" into the urine specimen. Usually a blood glucose of 170 mg/dL or greater will cause glucose to be present in the urine specimen, as the body cannot handle these high levels.
- After the fasting specimen has been drawn, the patient will be given a solution with 75 or 100 g of glucose dissolved in water. (For a patient who is not pregnant,

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75 g are used; when testing for gestational diabetes, 100 g are used.)
- Blood specimens (and urine if that is the policy of the laboratory) will be collected at least three more times during the procedure: 1 hour, 2 hours, and 3 hours after the initial dose of glucose drink has been ingested. Some laboratories will also collect a blood specimen half an hour after ingestion to provide more information about how the body is utilizing the glucose in the specimen.
- Occasionally, patients will feel nauseous, tired, cold, and perspire while undergoing this test. It is important that patients are kept calm, and that they stay in an area where they can be monitored while waiting. Sometimes a patient will vomit shortly after ingestion of the glucose solution; if this occurs early in the process (prior to 1 hour after drinking the sweetened drink), then the procedure should be discontinued and rescheduled, as the results may be inaccurate. Also, if a patient loses consciousness or exhibits symptoms of slurred speech and impaired thought processes, the test should be discontinued and the physician or emergency personnel should be notified immediately. These could be signs of hypoglycemia that require immediate treatment.

The interpretation of the test results is different when screening for diabetes mellitus than it is for gestational diabetes. For gestational diabetes screening with a 100-g glucose solution, if there are two abnormal results in the various timed blood draws, the patient is diagnosed with gestational diabetes, whether or not she is symptomatic. According to the American Diabetes Association, these results are considered abnormal for a pregnant woman:

- Fasting plasma glucose: greater than or equal to 95 mg/dL
- 1-hour plasma glucose: greater than or equal to 180 mg/dL
- 2-hour plasma glucose: greater than or equal to 155 mg/dL
- 3-hour plasma glucose: greater than or equal to 140 mg/dL

For suspected diabetes mellitus in patients who are not pregnant, a 75-g glucose solution is used. The American Diabetes Association has established these parameters for a diagnosis of diabetes in nonpregnant individuals:

- Fasting plasma glucose: greater than or equal to 126 mg/dL
- 1-hour plasma glucose: greater than or equal to 200 mg/dL
- 2-hour plasma glucose: greater than or equal to 200 mg/dL
- 3-hour plasma glucose: greater than or equal to 200 mg/dL (the 3-hour sample is not always included in the procedure for non-gestational-diabetes patients)

Test Your Knowledge 17-9

How many times (at a minimum) is the blood drawn for a patient completing a 3-hour glucose tolerance test?

(Outcome 17-10)

Glycosylated Hemoglobin

As presented in Chapter 16, elevated blood glucose levels will eventually change the hemoglobin molecule present in the red cells of the body by irreversibly binding glucose to the hemoglobin A subunit. This compound is known as **glycosylated** or **glycated hemoglobin,** and is abbreviated as **Hb A1c.** The typical red blood cell survives in the body for 90 to 120 days. Because the changes to the hemoglobin molecule are constantly occurring whenever the blood glucose level becomes elevated (whether the patient is aware of the elevation or not) the Hb A1c level is an excellent way to measure glycemic control over a 2- to 3-month period. The Hb A1c test is not recommended as a diagnostic tool for diabetes, but is an excellent tool for monitoring the management of the disease.

The American Diabetes Association has provided guidance regarding the frequency of this test and the interpretation of the results. A nondiabetic patient will have Hb A1c levels below 6%. For diabetic patients, the goal is to remain below 7%, as it is understood that there may be spikes in the blood glucose that are unavoidable. As part of the management of diabetes, those who have unstable blood sugars should have their Hb A1c tested quarterly; those who appear to have good glycemic control should be checked at least two times per year. In addition, the recommendation includes performance of an annual lipid profile and urine **microalbumin** testing to screen for renal damage. Microalbumin testing is discussed in more detail later in this chapter.

Test Your Knowledge 17-10

The Hb A1c test may be used to monitor the overall glycemic control for a patient for which of these time intervals?

a. 1 month
b. 6 weeks
c. 3 months
d. 6 months

(Outcome 17-11)

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TABLE 17-1

Types of diabetes, diagnostic test procedures, and treatment methods

Type of Diabetes	Symptoms	Clinical Presentation	Diagnostic Test Procedures	Treatment
Diabetes insipidus	Excessive amount of urine production; dehydration and electrolyte imbalance as a result of fluid loss	Lack of vasopressin production by pituitary gland or kidney resistance to vasopressin	Medical history, physical examination, urinalysis, magnetic resonance imaging and/or CAT scan of the brain, fluid deprivation testing	Vasopressin (usually a nasal spray) and fluid replacement if necessary
Type 1 diabetes	Hyperglycemia, fatigue, dehydration, nausea, vomiting, weight loss	Autoantibodies destroy pancreatic cells that produce insulin, resulting in reduced or absence of insulin	Medical history, physical examination, abnormal blood glucose levels with verification of fasting plasma glucose above 126 mg/dL or random plasma glucose above 200 mg/dL	Insulin injections
Type 2 diabetes	May be asymptomatic for years; usually develops slowly. Hyperglycemia, fatigue, dehydration, nausea, vomiting, weight loss	Cells of the body develop resistance to insulin; keeps glucose from entering cells so the plasma glucose levels become elevated	Medical history, physical examination, abnormal blood glucose levels with fasting plasma glucose or glucose tolerance test	Lifestyle changes, oral medication; insulin injections may become necessary if oral medications don't accomplish desired glycemic control
Gestational diabetes	Often asymptomatic; may develop symptoms like those of diabetes mellitus	Increased levels of hormones from pregnancy increase cellular resistance to insulin	Abnormal glucose challenge test and/or abnormal glucose tolerance test	Lifestyle changes, oral medications, or insulin injections (if needed for glycemic control) until birth of infant

POINT OF INTEREST 17-2

New Testing procedures for monitoring diabetes

There is a new procedure available for monitoring the glycemic control of diabetes patients. The GlycoMark blood test measures the level of a substance naturally present at a consistent level in the bloodstream. This molecule is known as 1,5-anhydro-D-glucitol (1,5 AG), which is a monosaccharide that is very close in chemical structure to glucose. When the glucose level of a diabetic patient rises above 180 mg/dL, the kidneys are not able to reabsorb the 1,5 AG molecule because the glucose blocks the sites for this molecule to be reabsorbed. Thus, when the glucose level rises (with poor glycemic control) the 1,5 AG concentration decreases below the reference range.

This procedure provides an opportunity to monitor the glycemic control for diabetic patients for the past 1 to 2 weeks. As a comparison, the Hb A1c test provides a measurement of the glycemic control over the past 3 months. Many physicians feel that this new testing method may allow them to treat their newly diagnosed diabetics more efficiently, because the results will be affected by poor glycemic control very quickly.

Blood Ketone Testing

Many home glucose meters are now capable of testing ketones as well as glucose levels in the bloodstream. Elvated levels of ketones in the blood are indicative of fluctuations in the blood glucose levels. Although close attention to diet, exercise, and medication will help to ensure that a diabetic

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patient maintains appropriate glycemic control, there may be situations that stress the body and allow the diabetes to become out of control, such as the following:

- Patients with preexisting diabetes who become pregnant
- Patients who are ill for several days, especially if they are vomiting or have diarrhea
- Situations of unusually high stress
- Blood glucose levels equal to or greater than 300 mg/dL
- Symptoms of hyperglycemia such as nausea, fatigue, and vomiting that are not associated with another disease process

Some ketone testing procedures will provide qualitative results indicating the presence or absence of ketones in the blood. Other testing methods provide quantitative results, indicating the level of ketones present. Patients should discuss their situation with a health-care provider before testing for the presence of blood ketones.

Capillary Sample Testing and Correlation to Plasma Glucose Levels

The World Health Organization recommends that the plasma glucose level (rather than whole blood testing) is used for diagnosis and monitoring of diabetic patients. However, this is not always possible, even in a laboratory or clinic setting. Some rural areas in the United States do not have laboratory facilities that meet these standards. Outside of the United States it can become even more problematic. These rural or underserved areas often have a glucose meter available, which is designed to perform whole blood glucose testing rather than plasma glucose testing.

Plasma glucose levels are 10% to 15% higher than those of whole blood obtained via a capillary procedure. Because the glucose levels for diagnosis of prediabetes and diabetes are very specific, it may be necessary to calculate the plasma glucose level using a whole blood capillary result. Many of the new glucose meters include this calculation in their results when reported; for instance, instead of the number on the screen indicating the glucose level in the whole blood specimen that was just tested, a calculation will have already been included and the number is actually indicative of the plasma glucose level. If the meter in use does not use this calculation, many of the glucose meter manufacturers' websites will provide more information to correlate whole blood glucose to plasma glucose levels.

This discrepancy between plasma and whole blood glucose is not often explained to patients who are self-monitoring their levels at home. It is important to mention that their results may not compare to the laboratory results because the reference ranges and testing methods are different. The health-care provider and any diabetes educators who are working with the patients need to help them develop parameters to use for self-monitoring from the testing instrument that they are using at home.

Glucose may also be tested using serum samples. This is not recommended for diabetes screening because the glucose level in the specimen can change slightly during the time period required for the blood to clot. If the specimen is centrifuged immediately after clotting, with immediate separation of the serum from the cells, then the glucose result will be very similar to that of a plasma specimen. However, if there is a delay in the processing of the specimen, the serum glucose result will be much lower than a plasma result would have been for that patient.

Test Your Knowledge 17-11

If a whole blood glucose and a plasma glucose were collected on the same patient at the same time, which of the results would be expected to be higher?

(Outcome 17-12)

Urine Testing for Diabetics

Urine testing is not used as a diagnosis tool for diabetes or prediabetes. The threshold for each individual for the amount of glucose tolerated in the bloodstream may be different. Usually anyone who has a blood glucose level above 170 mg/dL will have glucose present in the urine as well, a condition known as **glucosuria.**

The urine of diabetic patients may also be monitored for other chemical substances. The presence of ketones in the urine **(ketonuria)** may be an indicator of poor glycemic control. When the glucose in the bloodstream cannot enter the cells of the body to be used for energy, the body will break down fatty acids as an alternative energy source. This process is natural, and occurs in our body during fasting periods and times when our energy needs are accelerated. Ketones are a by-product of fatty acid metabolism, and if they are present in the urine, it may indicate excessive use of fatty acids for energy. This means that there is not enough insulin (or the cells are resisting the insulin that is present) to allow the glucose to be metabolized as it should by the cells of the body.

Glucose molecules are large, and are not designed to be passed into the urine in measurable amounts. When

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a patient has high levels of blood glucose over an extended period of time, these large molecules are forced through the filtration system of the nephron, causing damage because of their large size. The damaged glomerulus will now allow other large molecules present in the blood to enter the urine. The presence of these substances in the urine is considered to be abnormal and indicative of damage to the kidney. One of these large molecules is a plasma protein called **albumin.** Approximately 20% to 40% of all diabetics develop renal disease, and the first sign that the kidneys have been damaged may be the presence of **microalbuminuria.** This means that there are small amounts of albumin present in the urine; the levels are just above normal ranges. When the albumin levels in the urine are still low, it may be possible to eliminate further kidney damage by increasing efforts for glycemic control. If the levels increase to macroalbuminuria (large amounts of albumin in the urine), it is a sign that the renal disease has progressed with more severe damage to the filtration system of the kidneys. It is recommended that all diabetics be tested for urine microalbumin levels at least annually.

GLUCOSE TESTING METHODS

There are many different types of instruments used to perform glucose testing. The equipment varies from machines that analyze hundreds of specimens per hour to those that test one specimen at a time as a CLIA-waived test.

Home Glucose Testing Instruments

Blood glucose monitors are the most common self-testing products sold in the world. They are an essential part of diabetes education and monitoring, and allow diabetic patients a degree of freedom and control of their disease that previously was not possible. Blood glucose meters are all similar in function; a small testing strip is inserted into the instrument, a drop of blood is applied, and a result appears on the screen on the front of the instrument within seconds. However, these instruments may vary in size, complexity, cost of operation, and necessary quality control measures. These are some considerations to take into account when choosing an instrument for home glucose monitoring, including the following:

1. What type of diabetes is being monitored? For those who have type 1 diabetes and use an insulin pump, a continuous glucose monitor may be the most appropriate choice of device. These monitors have a sensor that is placed just under the surface of the skin that samples the blood glucose level 24 hours per day. These results are transmitted to a recording device with a memory, or to an insulin pump. If the continuous glucose monitor is paired with an insulin pump, the amount of insulin injected will be automatically matched to the glucose readings. A health-care provider and/or diabetes educator would be able to help the patient decide if this is the best method for a particular patient.
2. A patient should not take the first testing instrument that is offered and assume that they are all alike. Some instruments require a larger specimen volume than do others, and other machines have a code that must be verified whenever a new bottle of test strips are opened. Some patients prefer instruments that don't need a code to be entered, and some are most interested in a small instrument that can take samples from different areas of the body in addition to the fingertips. If possible, patients should sample several types of instruments when they meet with their health-care provider to discuss the need for blood glucose testing. Diabetes educators are another good resource.
3. Instruments may vary by cost of operation. The blood glucose meters themselves are often quite inexpensive; sometimes they are even free. However, the testing strips can be quite expensive. A typical diabetic patient who is self-monitoring will use at least two or three strips per day. Some insurance plans will help to pay only for specific brands of instruments and strips, so it is best to investigate this early in the process.
4. Patients should be certain that they can read the results displayed on the instrument used. For those with impaired vision, meters are available that display the result in larger numbers. Also, the lighting on the screen may vary, which might make certain models less appealing for some patients with specific vision needs.

Quality Control and Common Errors

Many diabetic patients have been self-monitoring for more than a decade. Unfortunately, they may not have been offered the resources that are now available when they started the process, and their home testing methods may not be providing accurate results. It is important to remember that the glucose meters used by patients at home are an essential tool for their health maintenance. Education about quality control methods

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for the instrument, storage and use of strips, and record-keeping options should be offered.

- Periodically, patients should bring in their home glucose meter and compare plasma glucose levels from the laboratory to those that they obtain at the same time using their own instrument. Although these results may vary as much as 10% to 15% from one another, this process can identify meters that are not testing accurately, or help the clinic staff to identify problems with the way the patient is performing the test on his or her meter while observing the patient.
- Quality control solution may be purchased and tested periodically to assure that the results obtained by the meter are accurate. Desirable ranges for the quality control solution are usually printed on the box or bottle containing the solution, and the patient can immediately verify the accuracy of the result. Explain to patients that if the machine is not testing within these ranges, they need to correct the situation before continuing use of the meter.
- Cleaning and proper storage of the instrument is essential, but often overlooked.
- Reagent strips must be stored as directed by the manufacturer, and need to be discarded if they are discolored or expired. Many patients leave the bottle open between tests, which causes the strips to absorb moisture and provide erroneous results.
- Reviewing the troubleshooting section of the meter instructions with patients can help them to understand error codes and possible courses of action when the instrument is not performing as expected. Much of this information is available online as well.
- Patients who are self-monitoring blood glucose levels must keep careful records in order for their efforts to be meaningful to their care. Educating the patients about different ways to accomplish this goal can be beneficial. Some of the meters available on the market have the capacity to store a great deal of information that may be downloaded to a computer to be printed or transmitted to a health-care provider. Patients may prefer to keep a handwritten log; if so, they should be provided with blank copies for their use.
- Ask patients about the type of lancet they are using, and how they are disposing of the used devices. Many of the newer automatic lancets may be adjusted according to the depth of the puncture, which is beneficial to those who test often. Lancets should never be used more than once, and should not be disposed of in the regular home trash. Some offices allow the patients to bring in their lancets in an appropriate biohazardous sharps container for disposal; others do not. To assist patients with proper disposal methods, find out what the recommendations are in your area for disposal of this type of waste, and provide that information to your diabetic patients.

Test Your Knowledge 17-12

What is one area in which a medical assistant may need to offer education and assistance for diabetics who are performing home monitoring of their glucose levels?

(Outcome 17-13)

Laboratory Glucose Testing and Potential Sources of Error

When glucose testing is performed in a large laboratory on an automated instrument, plasma or serum is tested. There are several different enzymatic methods available for glucose testing with similar reference ranges based on the type of specimen. Fasting samples will have different results from random specimens or those that were drawn as part of a glucose tolerance test.

Glucose testing may also be ordered on cerebrospinal fluid (CSF). The reference range for this test is approximately two-thirds of the blood glucose level for the same patient collected at the same time as the cerebral spinal fluid sample. When the CSF glucose levels are low as compared to the plasma glucose, it may be indicative of meningitis.

Because a specimen drawn for plasma or serum glucose testing in a laboratory must be processed before it is analyzed, there exists opportunities for error in the pre-analytical phase. The following are some considerations that must be addressed to avoid potential problems:

- The timing of the blood draw is critical. For instance, if the specimen is to be drawn fasting, it is imperative that the patient is informed and the preparation is verified before the collection occurs.
- Glucose continues to be metabolized by the cells present in the blood specimen after it is added to the collection tube. If the specimen is not processed by centrifugation and tested within 1 hour of collection, the plasma or serum glucose level may not indicate the actual amount of glucose present in the bloodstream of the patient; instead, it will be indicative of the amount left in the tube after the glucose has been utilized by the cells. If there will be more than a 1-hour delay in testing after collection, a tube with sodium fluoride or potassium oxalate additives should be used for the specimen collection. This slows down the utilization of glucose by the cells, and allows the

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plasma glucose to remain stable for approximately 24 hours at room temperature.
- Reference ranges for glucose levels are generally stated as plasma levels. However, serum may also be drawn for glucose testing, as long as the serum is separated from the cells within 1 hour. The reference ranges are usually the same for plasma and serum glucose.
- CLIA-waived testing for blood glucose is not designed to be performed with plasma samples. It is important to read the directions for the CLIA-waived methods to ensure that the results will be accurate.

Procedure 17-1: Performance of Hb A1c Test Using Bayer's A1c Now+ System

TASK

Correctly perform an Hb A1c test using Bayer's A1c Now+ testing system.

CONDITIONS

- Gloves
- Laboratory coat
- Hand sanitization supplies
- A1c Now *plus* monitor
- Sample dilution kit pouch
- Test cartridge pouch
- Whole blood from capillary puncture or well-mixed heparinized blood sample
- Gauze pad
- Biohazardous waste container
- Quality control materials

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P. Anatomy and Physiology, #13 Perform chemistry testing

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- Graduates: b. Perform selected CLIA-waived tests that assist with diagnosis and treatment, #3 Chemistry Testing

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered, and explain procedure to patient.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. A quick explanation of the procedure for the patient will ensure more cooperation.
3. Verify that all samples, reagents, and monitor are at room temperature.	Test results may not be valid if the sample and/or reagents are not at room temperature.
4. Wash hands and apply gloves.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protective equipment (PPE) for this procedure.
5. Assemble necessary equipment.	Various steps in this procedure require careful adherence to limits in time. Materials that are organized will assist in the process of following the directions properly.

Continued

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Procedure 17-1: Performance of Hb A1c Test Using Bayer's A1c Now+ System—cont'd

Procedure	Rationale
6. Prior to performance of test, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that test *before* the patient's test is performed.	Liquid QC should be used to verify the test results at these times: **a.** With a new shipment **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc. **e.** To ensure that storage conditions are fine, QC should be performed at least once monthly.
7. Verify that all lot numbers match on the monitor, the sample dilution kit pouch, and the test cartridge pouch.	If the lot numbers do not match, the monitor will not provide a valid test result upon completion of the test.
8. Verify that the kit has not expired.	The Bayer's A1c Now+ kit may be kept at room temperature for 4 months, but then any unused materials must be discarded. If kept refrigerated, the supplies may all be used until the printed date of expiration.
9. Open the sample dilution pouch and remove the dilution device.	The dilution device should not be removed until just before the test is performed.
10. Perform the capillary puncture following appropriate procedure, or mix the whole blood sample to prepare for next step.	Whole blood specimen may be obtained from fingerstick capillary puncture, or a green top heparinized sample may be used as long as it has not been at room temperature for more than 8 hours, or refrigerated for more than 14 days. Lithium heparin or sodium heparin are acceptable sample types.
11. Add a 5-µL blood sample to blood collection device.	It is not necessary to measure the blood added to the collection device; however, take care that the sample area on the collection device is filled, but not overfilled. If it appears to be underfilled, add more sample; if overfilled, wipe away excess. Do not allow excess blood to remain on the outside of the collection device.
12. Plug blood collection device into the sampler body. Push firmly so that there is no gap on insertion.	If a gap is present, the sample will not combine with the dilution solution inside the sampler body, and the results will be invalid.

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Procedure	Rationale
13. Shake the device six to eight times to mix the dilution solution with the sample thoroughly.	Solution must be well mixed to break down the blood sample for appropriate testing.
14. Set sample assembly on the tabletop as the test cartridge is prepared.	
15. Tear open the test cartridge pouch and ensure that the code number on the cartridge matches the code number printed on the instrument.	This system is set up so that the monitor has a definitive number of uses available; all the supplies need to be from the same serial number and cartridge code numbers for the results to be valid.
16. Insert the test cartridge into the monitor until it is seated firmly and an audible click is heard.	If the test cartridge is not seated firmly, no test procedure will occur.
17. Verify that the instrument screen display reads WAIT.	The instrument undergoes a series of internal self-checks before the testing process proceeds.
18. When the instrument screen displays SMPL, pick up the sampler device and remove the base piece, exposing the plunger.	The base piece must be removed so that the sample can be added to the testing device. The sample must be added within 2 minutes.
19. Deliver the sample by pressing the plunger gently and firmly into the corresponding sample application area on the cartridge. Remove after 1 second.	The sample application must occur all at once, but excessive force is not necessary. The application device must be removed for the testing process to proceed.
20. The instrument screen will display a countdown from 5 minutes to 0. Do not move the monitor during this time.	The testing process takes 5 minutes to complete. Moving the monitor may cause inaccurate or invalid test results.
21. The results will display as a percentage on the screen. Record results appropriately in computer, on log sheet, and/or in chart if available.	Results must be recorded immediately so that they are reported correctly.
22. Following office protocol, allow the patient to leave the testing area, or consult with the health-care provider.	If results are far outside of the normal range, it may be office policy that the health-care provider speaks with the patient before he or she leaves the office.
23. Dispose of sample dilution cartridge and test cartridge as biohazardous trash, and disinfect work area.	The work area must always be clean and disinfected after each procedure.
24. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
25. Document the test results in patient chart.	All results must be documented in the patient's chart.

Date	
8/30/2014:	Hb A1c 6.9% ~~~~~ Connie Lieseke, CMA (AAMA)
12:45 p.m.	~~~~~

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Procedure 17-2: Performance of Whole Blood Glucose Testing

TASK

Correctly perform a blood glucose test using the HemoCue Glucose 201 Analyzer.

CONDITIONS

- Gloves
- Laboratory coat
- Hand sanitization supplies
- HemoCue Glucose 201 Analyzer
- HemoCue Glucose microcuvettes
- HemoCue Glucose Control Cuvette
- Capillary puncture supplies
- Biohazard sharps container
- Gauze or laboratory wipes
- Biohazardous waste container
- Quality control materials

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P. Anatomy and Physiology, #13 Perform chemistry testing

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- Graduates: b. Perform selected CLIA-waived tests that assist with diagnosis and treatment, #3 Chemistry Testing

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered, and explain procedure to patient.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. A quick explanation of the procedure for the patient will ensure more cooperation.
3. Wash hands and apply gloves.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protective equipment (PPE) for this procedure.
4. Assemble necessary equipment, and verify that all reagents are within the posted expiration dates.	Glucose microcuvettes must be stored refrigerated, as well as the glucose control solution, but they must be removed from the refrigerator and placed within reach before the process begins. Materials that are organized will assist in the process of following the directions properly.
5. Turn on the HemoCue instrument. When the LCD display reads READY, the instrument is ready to be used.	The HemoCue instrument undergoes a series of self-checks when it is turned on.
6. Place the HemoCue Control Cuvette on the cuvette holder and push the holder into the instrument.	The control cuvette is designed to check the function of the instrument and detect any interference with the testing method. It should be used at least once per day.

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Procedure	Rationale
7. Verify that the values displayed on the instrument screen are within the acceptable ranges provided with the Control Cuvette.	The ranges are specific per cuvette and are designed specifically for each instrument. If the results are out of range, try cleaning the cuvette and testing again. If they continue to be out of range, the instrument cannot be used for patient testing and the manufacturer must be notified.
8. Prior to performance of test, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that test *before* the patient's test is performed.	Liquid QC should be tested following laboratory protocol and manufacturer's recommendations. Examples of when QC should be used to verify the test results include the following: **a.** With a new shipment **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc. **e.** To ensure that storage conditions are fine, QC should be performed at least once monthly
9. Perform a capillary puncture, using appropriate technique. Wipe away the first drop of blood.	The first drop of blood should be discarded, as it may be contaminated with interstitial fluids resulting in an erroneous result.
10. Remove a microcuvette from the container. Hold the open end of the microcuvette to the drop of blood obtained from the capillary puncture. Approximately 5 µL of blood will enter the microcuvette.	The blood will enter the microcuvette by capillary action. It is not possible to overfill the microcuvette. Avoid air bubbles as the microvuvette is filled.
11. Wipe away any excess blood on the outside of the microcuvette.	If excess blood is present on the outside of the microcuvette, it may interfere with the testing process and cause erroneous results or an instrument error while processing the specimen.
12. Place the filled microcuvette on the holder and push it into the instrument for processing.	The microcuvette will fit only when placed on the holder in a certain direction.
13. Within a few seconds, the glucose result will appear on the display screen in mg/dL. Record this result appropriately, in the computer, the patient log sheet, and/or the patient's chart.	The result will stay on the screen until the microcuvette holder is pulled from the instrument for the next sample to be added. It is important to record it as soon as it is evident on the screen.
14. Following office protocol, allow the patient to leave the testing area, or consult with the health-care provider.	If results are far outside of the normal range, it may be office policy that the health-care provider speak with the patient before he or she leaves the office.
15. Pull the microcuvette holder back out, remove the microcuvette, and discard in the biohazardous trash.	The microcuvette contains blood, so it must be discarded as a biohazardous substance.

Continued

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Procedure 17-2: Performance of Whole Blood Glucose Testing—cont'd

Procedure	Rationale
16. Turn off the instrument, and disinfect the microcuvette holder.	The microcuvette holder can be completely removed from the instrument for cleaning with alcohol or soap and water.
17. Be sure to dispose of the capillary puncture device in a sharps container and any other equipment that may be contaminated with blood in a biohazardous container.	It is vital to always properly dispose of biohazards.
18. Disinfect the work area.	It is important to keep the work area clean and organized.
19. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
20. Document the test results in the patient's chart.	All results must be documented in the patient's chart.

Date	
8/17/2014: 10:50 a.m.	Fasting blood glucose 85 mg/dL ~~~ Connie Lieseke, CMA (AAMA)

SUMMARY

Diabetes is disease that has reached epidemic proportions. It requires early diagnosis and consistent monitoring for successful treatment. Consequences of untreated diabetes include cardiovascular disease, loss of vision, poor healing, diabetic neuropathy, and permanent renal damage. Prediabetes can now be identified, and early intervention has helped to stop the progression of the disease for those who make appropriate changes to their diet and exercise habits. There are various testing procedures that may be used to diagnose prediabetes and diabetes, and to monitor treatment once it is under way. Type 1 diabetes must be treated with insulin injections, and the dosage is directly related to the amount of glucose present in the body at the time. Type 2 diabetes is managed with lifestyle changes and oral medication. Frequent blood glucose monitoring assists with treatment for this type of diabetes as well. Gestational diabetes is developed by pregnant women and may be identified toward the end of the pregnancy. Gestational diabetes that is untreated may lead to pregnancy complications as well as serious health issues for the unborn child. Several different timed glucose tests allow an opportunity to identify and classify the diabetic patient, including fasting plasma glucose, and postprandial glucose testing. Hb A1c testing is also useful to monitor the progress of the disease. Self-management testing performed at home by diabetic patients helps to achieve glycemic control between visits to the health-care provider.

TIME TO REVIEW

1. Glycogenolysis is: Outcome 17-1

- **a.** The breakdown of glycogen to be used for energy
- **b.** The formation of glycogen as a means of storing energy for later use
- **c.** The breakdown of glucose
- **d.** The breakdown of glucagon

2. What does a BMI tell us about a patient? Outcome 17-1

- **a.** A calculation comparing the height and weight of a patient
- **b.** A calculation used to compare glucose and body weight

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c. A calculation of Hb A1c
d. None of the above

3. When is the term *impaired fasting glucose* used? Outcome 17-1
   a. When the fasting glucose level is over 200 mg/dL
   b. When the fasting glucose level is between 100 to 125 mg/dL
   c. When the fasting glucose level is below 100 mg/dL
   d. When the fasting glucose level is between 100 to 124 mg/dL

4. Does the release of glucagon raise or lower blood glucose levels? Outcome 17-2
   a. Glucagon raises blood glucose levels
   b. Glucagon decreases blood glucose levels

5. True or False: Type 1 diabetes is treated with insulin injections whereas type 2 diabetes is treated with oral medications and lifestyle changes. Outcome 17-4

6. True or False: A patient who is diagnosed with gestational diabetes had diabetes before she became pregnant. Outcome 17-5

7. Which of these body systems may be affected by diabetes? Outcome 17-6
   a. Cardiovascular
   b. Integumentary
   c. Nervous
   d. Eye
   e. All of the above

8. How long should a patient go without food and drink before a fasting plasma glucose is drawn? Outcome 17-8
   a. 8 hours
   b. 16 hours
   c. 12 hours
   d. 10 hours

9. True or False: A postprandial glucose sample is always drawn after drinking a glucose-rich beverage. Outcome 17-9

10. What is the correct number of times that a patient drinks the glucose solution while completing a 3-hour glucose tolerance test procedure? Outcome 17-10
    a. One
    b. Two
    c. Three
    d. Four

11. True or False: The Hb A1c test is used to establish a diagnosis of diabetes. Outcome 17-11

12. How may the serum glucose level be affected if the sample is drawn into a tube with no additive and the tube is allowed to sit for 3 hours before centrifugation and processing? Outcome 17-13
    a. The glucose level may increase
    b. The glucose level may decrease
    c. There will be no effect on the glucose level
    d. It will be impossible to test the glucose level

Case Study 17-1: Use of the Hb A1c

Rose Grace is a patient who has been treated successfully for type 2 diabetes for many years with oral medication and lifestyle changes. The past few months have been especially stressful for her, and she has not been monitoring her diet, exercise, or blood glucose levels consistently during this time. A week before her quarterly appointment with her physician she starts to watch her diet carefully and catch up with some of her glucose monitoring to prepare for the visit. When she sees the physician, she is pleased to have her random glucose at 145 mg/dL, and she does not share all the activities of the past few months with her health-care provider, as it appears that her blood glucose is fine. However, when the Hb A1c result is available, Rose's physician calls her and tells her that she needs to come in for another visit to discuss additional treatment options.

1. What did the Hb A1c result tell the health-care provider that was not apparent with the blood test performed at the initial visit?

RESOURCES AND SUGGESTED READINGS

"National Diabetes Information Clearinghouse"
Provides in-depth information about the various types of diabetes, diagnosis, and management http://www.diabetes.niddk.nih.gov/

"American Diabetes Association website"
Information about risk factors, managing diabetes, and support for those who have diabetes; website provides information for providers, patients, and family members http://www. diabetes.org

"Executive Summary: Standards of Medical Care in Diabetes—2009"
Diabetes Care 32, no. S1 (January 2009): S6–S12, doi: 10.2337/dc09-S006.

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Standards of diabetic medical care developed by worldwide consensus and adopted by the World Health Organization, National Institutes of Health, and the American Diabetes Association. Includes parameters for diagnosis and treatment.

"2007 Diabetes Fact Sheet"
National Center for Chronic Disease Prevention and Health Promotion;
Provides statistics for diabetes morbidity and mortality in 2007
http://www.cdc.gov/diabetes

Chapter 18

Other Select Chemistry Tests

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Lipid Testing
- Cholesterol
  - *Cholesterol Metabolism Within the Body*
  - *Types of Cholesterol*
  - *Risk Factors, Desired Ranges, and Clinical Interpretation of Abnormal Lipid Results*
  - *Triglycerides*
  - *Metabolic Syndrome*
  - *Reference Ranges and Clinical Interpretation of Abnormal Results*
- Lipid Panels

Electrolytes
- Function of Electrolytes and Consequences of Electrolyte Imbalances
  - *Testing Preparation and Common Testing Methods*
- Reference Ranges

Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

18-1 Define the key terms.
18-2 Identify dietary sources of cholesterol.
18-3 Compare and contrast the different types of lipoproteins tested in a lipid panel.
18-4 Provide the desired range for cholesterol levels.
18-5 Describe the effects of elevated cholesterol levels on the body.
18-6 Explain how the body uses triglycerides.
18-7 Describe the appearance of lipemia in a blood specimen.
18-8 Evaluate the potential health issues that are caused by high levels of triglycerides.
18-9 List the components of common lipid panels.
18-10 Explain the patient preparation necessary before a specimen is collected for a lipid analysis.
18-11 Perform a CLIA-waived cholesterol test.
18-12 Describe how electrolytes are used by the body.
18-13 Summarize the consequences of untreated electrolyte imbalances.
18-14 List the common analytes included in an electrolyte panel.
18-15 Perform a CLIA-waived electrolyte test.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

I.P.I.13. Perform Chemistry Testing
I.A.I.2. Use language/verbal skills that enable patients' understanding

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- 10. Medical Laboratory Procedures, b. 3) Chemistry Testing

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KEY TERMS

Acidosis
Alkalosis
Anions
Apolipoproteins
Buffer
Cations
Extracellular
Fibrates
Hyperkalemia
Hypernatremia
Hypokalemia
Hyponatremia
Intracellular
Ions
Lipemia
Lipoproteins
Malabsorption
Metabolic syndrome
Niacin
Statins

Clinical chemistry includes the quantitative chemical analysis of various body fluids, as introduced in Chapters 16 and 17 in this text. Because this area of the laboratory performs so many different testing procedures, it is not possible to cover them all in detail in this book. This chapter provides more details about lipid testing and provides additional information about the role of electrolytes in the body. Cholesterol analysis and some electrolyte testing are commonly performed in physician office laboratories, as well as hospital and reference laboratories.

LIPID TESTING

Lipid testing includes the quantitative analysis of cholesterol levels, differentiation of the different types of lipoproteins that transport cholesterol in the body, and analysis of total triglyceride levels. Heart disease is the most common cause of death in the United States, and because the presence of elevated cholesterol (hypercholesterolemia) or hyperlipidemia is a risk factor for many serious cardiovascular complications, frequent monitoring of lipid levels is very important.

Cholesterol

Cholesterol is a white, soft, waxy substance that is present in all the cells of humans. Although humans use cholesterol to form cell membranes, create hormones, and perform other vital body functions, too much cholesterol is very damaging to the blood vessels within our body. It is recommended by the National Cholesterol Education Program that all adults have their cholesterol levels checked at least once every 5 years. The cholesterol level for any individual is dependent on many factors, including genetics, sex, diet, level of physical activity, social habits, and age.

Cholesterol Metabolism Within the Body

The cholesterol that is needed by our body is manufactured in the liver, but cholesterol is also ingested with animal products, dairy products, and hidden in processed foods. This excess cholesterol is deposited within the blood vessels, causing plaque buildup. The plaque on the interior of the arteries causes them to harden and lose elasticity, a condition known as *atherosclerosis*. The vessels may eventually fill with sticky, hard cholesterol and become occluded (blocked) so that the blood flow is disrupted. The blood that is trapped by the plaque buildup may become clotted. Pieces of the plaque may also break away from the vessel walls and travel to other areas of the body as emboli.

Test Your Knowledge 18-1
The human body produces adequate cholesterol to meet its needs. Additional cholesterol is added as part of our diets. What is one primary source of ingested cholesterol? (Outcome 18-2)

Types of Cholesterol

Cholesterol is a type of lipid that does not dissolve in blood plasma. It must be attached to another molecule for transport throughout the body. The molecules used for cholesterol transport are also created in the liver, and are called **apolipoproteins.** These are special types of protein that are designed to attach to a lipid molecule, becoming a **lipoprotein.** As introduced in Chapter 16,

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there are three types of lipoproteins present to transport cholesterol in the bloodstream:

- **High-density lipoprotein (HDL):** A carrier molecule that is known as the "good cholesterol" because it transports cholesterol through the vascular system without contributing to the buildup on the vessel walls. In fact, HDL has been shown to help remove some of the cholesterol that has accumulated in the vascular system. A high level of HDL appears to protect the body from heart disease, and a low level (below 40 mg/dL for men and 50 mg/dL for women) increases the risk for heart disease and stroke.
- **Low-density lipoprotein (LDL):** The major lipoprotein cholesterol transport molecule present in the bloodstream. This is often referred to as the "bad cholesterol" because the lipoprotein has a higher fat content than does the HDL and actually sticks to the blood vessel walls and adheres to the waxy buildup, leading to vessel occlusion. This waxy buildup (plaque) creates a unique environment in which blood cells may bind to one another and form a blood clot. When a blood clot or an occlusion occurs in one of the coronary vessels that supplies blood to the heart, a heart attack may result. Blocked blood flow to the brain results in a stroke (also known as a cerebrovascular accident [CVA]). According to the American Heart Association, LDL cholesterol levels above 160 mg/dL greatly increase the chance of heart disease.
- **Very Low-Density Lipoprotein (VLDL):** Present in smaller amounts than the other transport molecules. Elevated VLDL levels are directly related to the formation of plaque from sticky cholesterol deposits, which increases the risk of heart disease and stroke.

Test Your Knowledge 18-2
Which classifications of lipoproteins are considered as contributors to plaque buildup? (Outcome 18-3)

Risk Factors, Desired Ranges, and Clinical Interpretation of Abnormal Lipid Results

Total cholesterol screening assists with identification of those who are at high risk for cardiovascular disease. According to the Centers for Disease Control and Prevention (CDC), approximately 17% of the adults in the United States have total cholesterol levels above the desired range. Cholesterol levels may be elevated in certain diseases, such as diabetes, hypothyroidism, and kidney or renal disease. However, more commonly the elevation of total cholesterol is the result of risk factors such as a sedentary lifestyle, poor diet, cigarette smoking, heredity, and obesity. The presence of two or more risk factors for a specific patient may double the risk of a heart attack. Native Americans and African Americans are at an exceptionally high risk because of genetic factors.

HDL levels may be increased in women because of the natural presence of estrogen in their bodies. Testosterone has been shown to lower HDL levels. Cigarette smoking, sedentary lifestyles, and obesity all contribute to lower HDL levels. It is possible to change the relative levels of LDL and HDL in the body through diet and exercise. The goal of treatment is to decrease total cholesterol, increase HDL levels and decrease LDL levels. Increased exercise, smoking cessation, and weight loss can elevate HDL levels and decrease LDL levels. Early detection, immediate lifestyle changes, and oral medications may have a profound effect on these analytes. LDL levels may be decreased with the use of a class of medications called **statins.**

Test Your Knowledge 18-3
True or False: Elevated HDL levels are desirable in a healthy adult. (Outcome 18-4)

Cholesterol reference ranges are based on fasting specimens. According to the CDC, the recommended cholesterol levels are the following:

- Total cholesterol levels below 200 mg/dL
- LDL cholesterol level below 100 mg/dL
- HDL cholesterol at 40 mg/dL or above
- Triglycerides below 150 mg/dL

Test Your Knowledge 18-4
Sally Seashore has her fasting cholesterol test performed as a part of her yearly physical. Her total cholesterol level was 205 mg/dL. Is this within the desirable range? (Outcome 18-4)

It is not only adults who have elevated cholesterol levels. Children who have parents or grandparents who developed heart disease before they were age 55, or those who have other risk factors such as race and obesity should have their cholesterol levels monitored closely, as it is now clear that the development of plaque buildup in the blood vessels may begin very early in life.

Test Your Knowledge 18-5
Why are elevated LDL levels considered to be a health risk? (Outcome 18-5)

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Procedure 18-1: Cholesterol Testing Using the Cholestech LDX System

TASK

Perform CLIA-waived cholesterol testing using the Cholestech LDX System

CONDITIONS

- Gloves
- Laboratory coat
- Hand sanitization supplies
- Cholestech LDX analyzer
- Cholestech thermal label printer
- Liquid controls (level 1 and level 2)
- Test cassettes in foil wrap
- Optics test cassette and holder
- Capillary puncture supplies
- Cholestech capillary tubes and black plungers for collection and application of blood samples
- Biohazardous sharps container
- Gauze or laboratory wipes
- Biohazardous waste container
- Liquid quality control materials (two levels)
- Acrylic safety shield (if using lithium heparin vacuum tubes rather than capillary samples for the testing process)

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #13. Perform Chemistry Testing **I.A.I.** Anatomy and Physiology, #2. Use language/verbal skills that enable patients' understanding

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- 10. Medical Laboratory Procedures, b. 3) Chemistry Testing

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered, and explain procedure to patient. Verify whether patient has prepared properly.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. A quick explanation of the procedure for the patient will ensure more cooperation. Cholesterol testing requires the patient to fast for at least 12 hours prior to the blood draw. It is important that the patient understands the meaning of a 12-hour fast to verify whether he or she has followed the necessary preparation instructions.
3. Wash hands and apply gloves.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protection equipment (PPE) for this procedure, as well as a laboratory coat.
4. Assemble necessary equipment, and verify that all reagents are within the posted expiration dates. Allow all reagents to come to room temperature.	The Cholestech LDX cassettes are stored in the refrigerator, but must come to room temperature before use. It is recommended that they be removed from the refrigerator for at least 10 minutes prior to use. Organization of materials will make it easier to follow the procedure specified by the manufacturer properly.

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Procedure	Rationale
5. Plug in the analyzer and allow it to initialize. Verify that the printer has paper attached to the testing instrument correctly.	The analyzer must be allowed to initialize before use.
6. Perform an optics check using an optics check cassette. When testing the optics test cassette, the following procedures are followed: **a.** Press RUN. The analyzer will then perform a self-test, and display a Self-Test OK message on the screen. The drawer will then automatically open, and a message of Load Cassette and Press Run will appear on the screen. **b.** Use the optics check cassette by inserting the cassette into the open drawer of the instrument. Be careful not to touch the dark areas of the cassette; it should be handled only by the edges and by touching the clear parts of the cassette. **c.** Press RUN again. The drawer will shut and the testing process for the optics check will begin. **d.** A series of numbers will be displayed on the screen. These are the results of the optics check. The results must all fall between 80 and 105, and they must also be within the ranges provided with purchase of the optics check to be a valid test. **e.** Verify that the results are as desired before continuing with the testing process. If the results are not within range, the instrument will display an error code (Optics Test Fail), and it will not be possible to process patient samples until a valid optics check is performed.	The optics check cassette is to be used as directed by the manufacturer and laboratory policy to verify that the four optic channels of the instrument are working correctly. This should be used at least once daily before patient samples or quality control samples are tested. An optics test should also be completed after the machine is moved or cleaned. Acceptable ranges will be provided with the cuvette upon purchase. If the results do not fall within the acceptable range, the instrument may not be used for specimen testing until the cause has been identified and the problem has been identified and solved. Troubleshooting tips will be available in the user manual and/or manufacturer insert.
7. Remove the optics check cuvette from the instrument and place it back in the designated container.	The cuvette must be stored in the designated container to keep it from being damaged. Exposure to moisture or damaging the cuvette may affect the performance.
8. Prior to patient testing, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that process before the patient's test is performed. Patient testing cannot be performed unless the quality control values are within the established ranges.	Liquid QC should be tested following laboratory protocol and manufacturer's recommendations. Examples of when QC may be utilized to verify the test results include the following: **a.** With a new shipment **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc.
9. Tear open the foil package and set the testing cassette on a level nonabsorbent surface.	The cassette needs to be ready for the application of the sample as soon as the blood collection is complete.

Continued

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Procedure 18-1: Cholesterol Testing Using the Cholestech LDX System—cont'd

Procedure	Rationale
10. Perform a capillary puncture, using appropriate technique. Wipe away the first drop of blood.	The first drop of blood should be discarded, as it may be contaminated with interstitial fluids resulting in an erroneous result.
11. Remove a capillary tube and a black plunger from the container. Insert the black plunger into the capillary tube, and then hold the open end of the capillary tube to the drop of blood obtained from the capillary puncture. The capillary tube will fill with sample, and this should be completed within approximately 10 seconds.	The blood will enter the capillary tube without further action if the capillary tube is kept level while the end is immersed in a drop of blood. Avoid air bubbles as the capillary tube is filled.
12. Introduce the blood into the sample well on the cassette. Be careful not to touch the dark areas of the cassette. Use the black plunger to empty the capillary tube into the testing well.	Blood on other areas of the cassette apart from the sample well may interfere with the testing process.
13. Place the filled cassette into the drawer as soon as the sample has been added. If the drawer has closed, press the RUN button again and the drawer will open.	The cassette needs to be processed immediately for accurate results. Do not allow the filled cassette to be moved excessively. It should be kept horizontal as it is placed in the drawer.
14. Within a few seconds, the cholesterol result will appear on the display screen in mg/dL. Record this result on the patient log sheet.	The result will stay on the screen until the RUN button is pushed to open the drawer for the next test sample to be added. It is important to record the result as soon as it is evident on the screen. The result will print if the instrument is attached to a printer.
15. Following office protocol, allow the patient to leave the testing area, or consult with the health-care provider about the test results.	If results are far outside of the normal range, the office policy may be that the health-care provider speaks with the patient before he or she leaves the office.
16. Discard the capillary tube and plunger and contaminated cassette in the biohazardous garbage.	The capillary tube, plunger, and cassette contain blood, so they must be discarded as a biohazardous substance.
17. Turn off the instrument if there are no further tests needed and disinfect the work area. Discard any other waste appropriately.	The work area should always be disinfected after use.
18. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
19. Document the test results in patient chart.	All results must be documented in the patient's chart.

Date	
8/17/2014:	Fasting cholesterol 195 mg/dL
2:15 p.m.	Connie Lieseke, CMA (AAMA)

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Triglycerides

Triglyceride levels are usually included in lipid panels as an additional indicator for evaluating the risk of cardiovascular disease. Triglycerides are the end product of the fats that we ingest. When a person takes in more calories than are needed for energy, some of the excess calories are also turned into triglycerides and stored as fat for use later as an energy source. These are then stored in the liver and the adipose cells of our body, and may also sometimes be stored in the muscle tissue. A patient who often eats more calories than those used by the body may develop elevated blood triglyceride levels.

Test Your Knowledge 18-6

What leads to a buildup of triglycerides in the adipose tissue of the body?

a. Consumption of excess calories
b. Pancreatitis
c. Elevated LDL levels
d. Plaque buildup (Outcome 18-6)

Metabolic Syndrome

Elevated triglyceride levels unaccompanied by other risk factors are not linked as closely to cardiovascular disease as are high cholesterol levels. However, the high triglyceride levels may be part of a group of conditions that are known as **metabolic syndrome.** Metabolic syndrome includes hypertension, hyperglycemia, excessive fat deposits around the waistline, low HDL levels, and high triglyceride levels. Patients who simultaneously exhibit most of these conditions in the metabolic syndrome have an increased risk for cardiovascular disease, as well as a greater potential for developing diabetes. Oral medications may be prescribed to lower triglyceride levels. **Niacin** is commonly used, as is a classification of drugs called **fibrates.** If the triglyceride levels are elevated as well as total cholesterol and LDL levels, a combination of drugs may be used to lower the various lipid levels.

Reference Ranges and Clinical Interpretation of Abnormal Results

Hyperlipidemia is the word used to describe elevated levels of cholesterol and triglycerides in the bloodstream, and as introduced in Chapter 16, patients with hyperlipidemia may have cloudy or "milky" plasma and/or serum apparent after a sample of their blood is spun in a centrifuge. This appearance is known as **lipemia,** and it is caused by suspended fat particles, which can cause interference for many testing procedures. Large reference laboratories may have specialized centrifuges designed to clear the excess fats from the plasma or serum so that testing can continue on these specimens.

Test Your Knowledge 18-7

Lipemia is a suspension of _____ , visualized in the liquid portion of the blood after centrifugation:

a. Hemolyzed red blood cells
b. Excess fat particles
c. Plaque
d. Milk (Outcome 18-7)

According to the CDC, triglyceride levels should be drawn as fasting samples, because the blood levels become elevated with the ingestion of food. Triglyceride levels may be categorized as the following:

- Normal: below 150 mg/dL
- Borderline high: 150 to 199 mg/dL
- High: 200 to 499 mg/dL
- Very high: equal to or greater than 500 mg/dL

Lipid Panels

A lipid panel commonly includes a total cholesterol level; a triglyceride level; the HDL, LDL, VLDL; and a total cholesterol/HDL ratio. These values provide the health-care provider with valuable information to determine whether the cholesterol levels for a patient indicate a risk factor for coronary artery disease. The lipid panel also provides information that is useful for monitoring patients who are taking medication to treat high cholesterol or triglycerides. Current recommendations from the National Institutes of Health's National Cholesterol Education Program include the performance of a screening fasting (at least 12 hours) lipid panel at least once every 5 years. For patients with elevated LDL levels and/or triglyceride or total cholesterol levels that are too high, lifestyle changes and possible drug treatment should be started immediately. The fasting lipid panel should be rechecked once every 6 weeks until the established goals have been met for a patient, and a fasting lipid panel should continue to be performed every 4 to 6 months while completing treatment.

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POINT OF INTEREST 18-1
Types of fats

Fats are essential to homeostasis, but ingestion of too much can be quite harmful. Most Americans take in an excess of fat on a daily basis. According to the Centers for Disease Control and Prevention (CDC), fats should not make up more than 35% of our caloric intake each day. In addition to controlling the amount of fat ingested, we can benefit from monitoring the types of fats we eat, because certain types of fats cause much more harm to our cardiovascular systems than others. Polyunsaturated and monounsaturated fats are healthier for the body than *trans* fats, saturated fats, and cholesterol. The unhealthy fats are "hidden" in many of the processed foods that we eat. To avoid an unhealthy diet, it is important to be educated about the types of fats in our diets:

- ***Trans* fats:** It is required that all products containing *trans* fats have them listed on their nutrition labels. This type of fat actually starts as a liquid; a process called hydrogenation changes the oils into a solid fat. *Trans* fat helps processed foods last longer without spoilage, but the presence of *trans* fats increases LDL cholesterol levels and decreases HDL cholesterol levels. Many processed baked goods (such as pies, cookies, crackers, and cakes) include *trans* fats to extend their shelf life. *Trans* fats may also be present in solid margarine products. Nutritionists recommend soft margarine over solid margarine whenever possible.
- **Saturated fats:** The current recommendation is to restrict our daily caloric intake from saturated fats to less than 10%. This type of fat comes from meat and high-fat dairy products. It is also present in palm and coconut oils, which can be included in a many processed foods. Choosing low-fat products, fat-free milk, and lean meats can help to control the amount of saturated fats ingested. Check labels to reduce the amount of saturated fats (and *trans* fats) whenever possible. Removing the skin from meats before cooking, and skimming off visible fat from soups and stews can also help to reduce dietary intake. Diets that are high in saturated fat are believed to contribute to cardiovascular disease.
- **Cholesterol:** Cholesterol is usually found in the same type of products as those having high levels of saturated fat. Meat, eggs, and dairy products contain high levels of cholesterol. Steps that lower the intake of saturated fat will also help to control cholesterol in the diet because they appear in similar foods. Remember, genetics also plays a role in total blood cholesterol content; many patients will have high levels of cholesterol even with excellent diets and active lifestyles. In this case, patients will usually need to be treated with oral medications to keep their cholesterol level at a reasonable level.
- **Monounsaturated and polyunsaturated fats:** These fats are considered the most "healthy" fats. They come from ingestion of fish, vegetable oils, and nuts. All sources of fat are high in calories, but polyunsaturated and monounsaturated fats do not pose as high a cardiovascular threat as do the other types.

ELECTROLYTES

In Chapter 16, electrolytes are defined as substances that are capable of conducting an electrical charge when dissolved in water. Particles that are positively or negatively charged because of the loss or gain of electrons are called **ions,** and all electrolytes fall within this description**.** Positively charged ions are called **cations,** and those ions with a negative charge are called **anions.** The most common cations in the body are sodium and potassium. Sodium has a high **extracellular** concentration, which means that it has a higher concentration outside the body's cells, in the plasma. Potassium is higher in concentration inside the cells, in the **intracellular** environment**.** The most common anions present in the body are chloride and bicarbonate. Bicarbonate (HCO_3^-) is an ion created when carbon dioxide reacts with water. Most electrolyte panels measure Na^+, K^+, Cl^- and bicarbonate. Figure 18-1 illustrates the distribution of the most common electrolytes inside and outside red blood cells. Bicarbonate may be measured directly or by analysis of total CO_2, as most of the carbon dioxide present in the blood is found as bicarbonate molecules. Additional electrolytes present in the body include magnesium, calcium, phosphate, and sulfate; however, these are not included in most electrolyte panels.

Test Your Knowledge 18-8

True or False: Electrolytes are neutral; they neither exhibit a positive nor negative charge when dissolved in water.

(Outcome 18-1)

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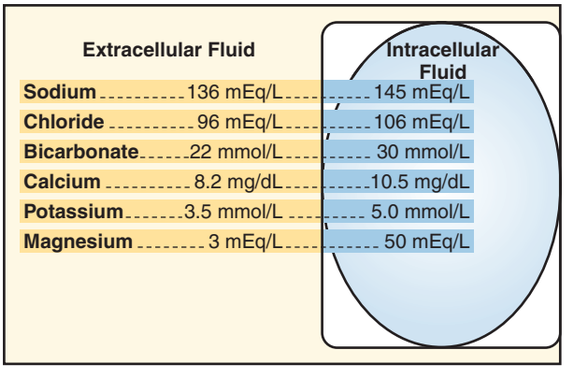

Figure 18-1 Major intracellular and extracellular electrolytes.

Function of Electrolytes and Consequences of Electrolyte Imbalances

Appropriate amounts of the various electrolytes in the body are essential to maintain homeostasis and acid-base balance. The electrolytes are also responsible for transmission of nervous impulses, and they play a major role in contraction and relaxation of the muscle fibers present throughout the body. The presence of the various intracellular and extracellular electrolytes in appropriate concentrations also allows for cells to keep their shape so that they can function properly. More specific electrolyte functions include the following:

- **Sodium (Na^+):** Sodium is the electrolyte found in highest concentration outside the cells of the body. We take in sodium through our diets, and the amount retained by the body is controlled by the kidneys. Sodium loss also occurs through perspiration. Sodium is essential for controlling the amount of fluid retained in the cells of the body. When the sodium levels are too low (a condition known as **hyponatremia)** in relation to the amount of fluid present in the body, the patient may exhibit drowsiness and confusion. If the condition worsens, it can lead to muscle twitches, seizures, coma, and even death. Hyponatremia can occur with various renal disorders, endocrine imbalances that the amount of antidiuretic hormone (ADH) produced, excessive water intake, or retention of fluids from various disease processes. Certain prescription drugs may also contribute to low sodium levels. **Hypernatremia** (elevated sodium levels) results when the concentration of sodium is elevated as compared to the amount of fluid in the body. Essentially, a patient with hypernatremia has too little water in the body for the amount of sodium that is present. This can be the result of severe vomiting and/or diarrhea with fluid loss, or excessive sweating without fluid replacement. Hypernatremia may also occur with severe burns, and is a risk for those with disease states that cause excessive urine to be produced. Sodium levels that are outside the reference range may lead to lethargy, confusion, muscle twitches, seizures, coma, and death if not treated promptly.
- **Potassium (K^+):** Potassium is present in high concentrations within the cells of the body, but normally is quite low in the blood plasma. The kidneys control the amount of potassium excreted from the body, and dietary intake helps to keep the necessary balance for healthy function. The presence of potassium is essential for cardiac function, as well as the transmission of nervous impulses to other muscles of the body. **Hyperkalemia** is the word used to describe elevated levels of potassium in the blood, and **hypokalemia** is the word used to describe diminished levels of potassium. Both conditions may be caused by renal dysfunction or certain hormonal imbalances. Reduced dietary intake may also contribute to hypokalemia, as well as use of prescription medications that contribute to increased urination. Diseases that cause gastrointestinal **malabsorption** (problems with the absorption of nutrients from food ingested) will also cause hypokalemia. Potassium imbalances are not tolerated well by the body, and may result in cardiac arrhythmias or other symptoms of muscle weakness.
- **Chloride (Cl^-):** Chloride is an anion, which means that it has a negative charge when dissolved in water. It is a very important extracellular presence, as chloride contributes to homeostasis by participation in acid-base balance. Chloride moves into and out of the cells of the body in response to the transfer of hydrogen and carbon dioxide through the cellular membrane. When chloride levels become imbalanced, the acid-base neutrality of the body's tissues may be affected, and **acidosis** (increase in acidity of the blood) or **alkalosis** (increase in alkalinity of the blood) may result.
- **Bicarbonate (HCO_3^-):** Bicarbonate is formed when carbon dioxide combines with water present in blood plasma. As is the case with chloride, bicarbonate plays

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an essential role in acid-base balance of the body. It acts as a **buffer,** which means that the presence of bicarbonate helps to keep the body's pH at a neutral level by interacting with substances capable of changing the pH. Most of the bicarbonate in the body is found outside the cells, but there is a small amount present intracellularly. Bicarbonate may be indirectly measured in the laboratory by analyzing the amount of total CO_2 present in the blood. Abnormal amounts of bicarbonate (directly tested or analyzed by measuring total carbon dioxide levels) may contribute to acidosis or alkalosis.

Test Your Knowledge 18-9

A patient who has been treated with diuretics for the past few months develops an arrhythmia and is seen in the ER. When the patient has his blood tested, which electrolyte level may be outside of the reference range? (Outcome 18-13)

Testing Preparation and Common Testing Methods

Specimen collection for electrolyte testing does not require any specific preparation, but it is important to collect the sample using appropriate phlebotomy technique to avoid erroneous results. Electrolyte testing performed in hospital and reference laboratories usually requires plasma or serum samples, which need to be separated from the blood cells in the specimen within an hour of collection. Electrolyte results can easily be affected by poor preanalytical procedures. Because potassium is at such a high concentration within blood cells and exhibits such a low extracellular concentration, any specimen collection or processing errors that contribute to hemolysis will cause the plasma potassium values to be falsely elevated. Excessive hemolysis may also cause the plasma sodium and chloride results to be decreased because of a dilution effect from all the intracellular contents released when the cells are broken. Contamination of the specimen with IV fluids will also alter the plasma electrolyte results; the effects will vary depending on the type of fluids being administered. CLIA-waived electrolyte procedures use whole blood for testing. The samples may be obtained by capillary puncture or by venipuncture, using a lithium heparin (light green top tube) or sodium heparin (dark green top tube). It is not possible to determine whether a sample is hemolyzed at the time of the blood draw by looking at the whole blood specimen; hemolysis does not become apparent until the sample has been spun in a centrifuge or until it has sat long enough for the plasma and/or serum to begin to separate visibly from the cells. This means that it is especially critical to avoid damage to the specimen when it will be used for whole blood testing, because it will not be evident that the cells have been hemolyzed, which could cause erroneous test results for potassium and possibly for the other electrolytes. The phlebotomist must implement appropriate venipuncture technique, including the use of the correct needle size, with complete insertion of the bevel into the interior of the vein. The tourniquet should not be applied for longer than 1 minute, and pumping of the fist should not be encouraged. Also, the blood sample should be gently inverted (not shaken).

There are many instruments that have been approved for CLIA-waived electrolyte testing. These instruments are capable of performing all the tests included in most electrolyte panels, including sodium, potassium, chloride, and bicarbonate. The testing instruments are present in physician office laboratories, but may also be used as a STAT testing method in other environments. These include the Abaxis Piccolo Blood Chemistry Analyzer and the Abbott i-STAT System. (See Fig. 18-2.)

Figure 18-2 Abbott i-STAT analyzer. *Courtesy of Abbott Point of Care, Princeton, NJ.*

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Test Your Knowledge 18-10

Which of these tests is not part of a typical electrolyte panel?

a. Sodium
b. Potassium
c. Nitrogen
d. Chloride (Outcome 18-14)

Reference Ranges

It is important to realize that the reference ranges for any analyte may vary according to the method used for testing. The following are approximate ranges established for adults for plasma samples:

- Sodium: 135 to 145 mmol/L
- Potassium: 3.5 to 5.0 mmol/L
- Chloride: 98 to 108 mmol/L
- Bicarbonate: 22 to 30 mmol/L

Procedure 18-2: Electrolyte Testing Using an Abbott i-STAT Chemistry Analyzer

TASK

Perform CLIA-waived whole blood electrolyte testing using an i-STAT analyzer.

CONDITIONS

- Gloves
- Laboratory coat
- Hand sanitization supplies
- I-STAT chemistry analyzer
- I-STAT analyzer electrolyte (panel or individual test) cartridges
- Capillary puncture supplies or venipuncture supplies and green top tubes
- Biohazardous sharps container
- Gauze or laboratory wipes
- Biohazardous waste container
- Quality control materials

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #13. Perform Chemistry Testing **I.A.I.** Anatomy and Physiology, #2. Use language/verbal skills that enable patients' understanding

ABHES Standards

- 10. Medical Laboratory Procedures, b. CLIA-waived tests
- 10. Medical Laboratory Procedures, b. 3) Chemistry Testing

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered, and explain the testing procedure to the patient.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. A quick explanation of the procedure for the patient will ensure more cooperation.

Continued

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Procedure 18-2: Electrolyte Testing Using an Abbott i-STAT Chemistry Analyzer—cont'd

Procedure	Rationale
3. Assemble necessary equipment, and verify that all reagents are within their expiration dates. For an electrolyte panel to be performed, it may be necessary to use a cartridge that tests for other analytes in addition to those in the electrolyte panel, due to the cartridge packaging.	i-STAT cartridges are to be stored at 2° to 8°C until their printed expiration. Cartridges must be removed from the refrigerator and allowed to be at room temperature for at least 5 minutes before use. A cartridge expires 2 weeks after it is removed from the refrigerator, and it is not to be put back in the refrigerator once it has reached room temperature. Materials that are organized will assist in the process of following the directions properly.
4. Wash hands and apply gloves.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protective equipment (PPE) for this procedure.
5. Turn on the analyzer. If necessary, use the electronic simulator cartridge to verify that the instrument is operating correctly.	An internal electronic simulation occurs after every 8 hours that the instrument is in use. It may also be necessary to use an external electronic simulator cartridge if the internal test is not successful or if the laboratory policy dictates the use of this additional step. This cartridge is stored at room temperature. To use, insert the cartridge into the instrument with the I facing upward. If the test is successful, the LED screen will display a PASS message.
6. Prior to performance of test, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that test before the patient's test is performed. It is recommended that two levels of quality control be tested every time QC is run.	Liquid QC should be tested following laboratory protocol and manufacturer's recommendations. Examples of when QC should be used to verify the test results include the following: **a.** With a new shipment **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc. **e.** To ensure that storage conditions are fine, QC should be performed at least once monthly
7. Remove the cartridge from the foil pouch. Be careful to handle the cartridge only by the edges, and place it on a level, clean surface until use.	If the contact points of the cartridge are scratched or damaged before the test is performed, it may have an adverse effect on the test results. The cartridge should be removed from the pouch before the sample is collected just to save time.
8. Perform a capillary puncture, using appropriate technique. Wipe away the first drop of blood. Use a heparinized capillary tube to collect a blood sample, avoiding the formation of air bubbles in the tube.	The first drop of blood should be discarded, as it may be contaminated with interstitial fluids, resulting in an erroneous result.

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Procedure	Rationale
9. Hold the end of the filled capillary tube to the sample well. The well will fill with blood through capillary action. Fill the well to the indicated fill mark. The sample may also be taken from a sodium heparin– or lithium heparin–evacuated blood tube, or from a sterile syringe without additives.	The blood will enter the cartridge well by capillary action. It is acceptable to slightly overfill the well, but if the well is grossly overfilled or if blood is smeared on the cartridge outside of the well, the instrument will give an ERROR code when the assay is performed. Avoid air bubbles as the sample well is filled. If an evacuated blood tube is used, a plain plastic capillary tube can be used to transfer the specimen to the cartridge. If a sterile syringe is used for the venipuncture, it is important to apply the sample immediately to the cartridge to avoid clots in the specimen.
10. The analyzer will request an operator ID and a specimen/patient identification number. Enter these according to laboratory policy.	These identification methods allow for better documentation and tracking.
11. After the analysis has completed, the result will be displayed on the LED screen for 45 seconds. It may be recorded directly on the patient log sheet and transferred to the patient chart when ready.	The result may be recalled before running the next specimen by pushing DIS (display) on the instrument. Sample results are also kept in the analyzer memory, and some laboratories will have the instrument interfaced with their patient data system for direct documentation in the patient record.
12. Following office protocol, allow the patient to leave testing area, or consult with the health-care provider.	If results are far outside of the normal range, office policy may be that the health-care provider speaks with the patient before he or she leaves the office.
13. Remove the used cartridge from the instrument, and discard it as biohazardous trash.	The cartridge contains blood, so it must be discarded as a biohazardous substance.
14. Turn off the instrument or prepare to run the next specimen.	If numerous specimens are waiting to be assayed, leave the instrument turned on between samples.
15. Dispose of the capillary puncture device or used venipuncture supplies in a sharps container immediately after use. Any other equipment that may be contaminated with blood must be disposed of as a biohazard.	It is vital to always properly dispose of biohazards.
16. Disinfect the work area.	It is important to keep the work area clean and organized. Prompt disinfection helps to stop the cycle of infection.
17. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
18. Document the test results in patient chart.	All results must be documented in the patient's chart.

Date	
8/17/2014:	*Electrolyte test performed: Sodium 140 mmol/L, Potassium 3.7 mmol/L, Chloride 100 mmol/L, TCO2 25 mmol/L*
11:29 a.m.	*Connie Lieseke, CMA (AAMA)*

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SUMMARY

Clinical chemistry is a complex laboratory department where a wide variety of tests may be performed. This chapter focused on some of the clinical chemistry tests that might be performed in a physician office laboratory as well as in larger reference laboratories. These include lipid panels, electrolyte analysis, and fecal occult blood testing. Lipid testing is very important, as elevated levels of total cholesterol, LDL, and triglycerides may be indicative of potential damage to the cardiovascular system and subsequent myocardial infarction or stroke. Electrolytes are responsible for conduction of nerve impulses and maintenance of homeostasis with acid-base balance. Imbalances of sodium, potassium, chloride, and bicarbonate can be life threatening, and may indicate an ongoing disease process elsewhere in the body.

TIME TO REVIEW

1. Hypernatremia is: Outcome 18-1
   - **a.** Elevated sodium concentration in the blood
   - **b.** Elevated potassium concentration in the blood
   - **c.** Decreased sodium concentration in the blood
   - **d.** Decreased potassium concentration in the blood
2. Statins are used to treat: Outcome 18-1
   - **a.** Electrolyte imbalances
   - **b.** Anemia
   - **c.** Elevated triglyceride levels
   - **d.** Elevated cholesterol levels
3. True or False: Cholesterol levels are increased by excessive ingestion of carbohydrates. Outcome 18-2
4. True or False: When evaluating cholesterol levels, the total cholesterol is not the only level considered by the practitioner. Outcome 18-9
5. Which type of lipoprotein is considered to be the "good cholesterol"? Outcome 18-3
   - **a.** HDL
   - **b.** VLDL
   - **c.** Triglyceride
   - **d.** LDL
6. Elevated lipid levels in the bloodstream increase the chance of: Outcome 18-8
   - **a.** Plaque formation on the blood vessel walls
   - **b.** Myocardial infarction
   - **c.** Liver damage
   - **d.** Electrolyte imbalances
7. Which of these are included in the metabolic syndrome? Outcome 18-1
   - **a.** Elevated triglyceride levels
   - **b.** Hypertension
   - **c.** Hyperglycemia
   - **d.** Excessive fat deposits around the waistline
   - **d.** All of the above
8. Which tests are included in a lipid panel? Outcome 18-9
   - **a.** Total cholesterol, HDL, LDL, VLDL, triglyceride
   - **b.** HDL, GLDL, LDL, BUN
   - **c.** Total cholesterol, triglyceride, HDL, anion gap
   - **d.** None of the above
9. How should a patient prepare for a lipid panel specimen collection? Outcome 18-10
   - **a.** No preparation is necessary
   - **b.** The patient must fast for 12 hours
   - **c.** The patient should follow a carbohydrate-restrictive diet for a week prior
   - **d.** The patient should follow a protein-rich diet for a week prior
10. What is a consequence of elevated or decreased bicarbonate levels? Outcome 18-13
    - **a.** Loss of cellular membrane shape
    - **b.** Cardiac arrhythmia
    - **c.** Acidosis or alkalosis
    - **d.** Muscle tremors

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Case Study 18-1: Difficult draw

Kim Babado, CMA (AAMA), is working in the laboratory area of an internal medicine clinic. She has the responsibility of drawing blood on most of the patients in the practice, performing some point-of-care testing, and processing blood and other samples to prepare them for transport to a large reference laboratory across town. The second patient of the morning has an order for an electrolyte panel. When Kim examines the patient's arm, she has a difficult time finding a suitable site for the blood draw. The patient has very small veins that seem to roll away every time Kim touches them. Kim's first attempt is unsuccessful. On her second try, Kim does successfully puncture the vein, but obtains a slow blood flow that fills the tube approximately half full. After the blood specimen is spun in the centrifuge, Kim notes a light pink shade to the plasma.

1. Do you think that the specimen is appropriate for electrolyte testing?

Case Study 18-2: Dietary effects

A patient has a lipid panel drawn on Monday afternoon, and his results include an elevated triglyceride level. The ordering physician asks for the specimen to be redrawn to verify the results before meeting again with the patient.

1. What is a possible explanation for the elevated triglyceride level for this patient?
2. What might be important information to give the patient before the next blood draw?

RESOURCES AND SUGGESTED READINGS

"Colorectal Cancer Screening"
Colorectal cancer screening information and recommendations from the Centers for Disease Control and Prevention http://www.cdc.gov/cancer/colorectal/basic_info/screening/
"Hemoccult's Newest Gold Standard in FOBTs-Hemoccult ICT"
Beckman Coulter Hemoccult ICT test information http://www.hemocultfobt.com/sales/sales_Hemo_ICT.htm
"Hemoccult Fecal Occult Blood Tests"
Provides links to overview for all of Beckman Coulter Hemoccult products http://www.hemoccultfobt.com/
"Tests Granted Waived Status Under CLIA"
List of all CLIA-waived tests, including CPT code for reimbursement http://www.cms.hhs.gov/CLIA/downloads/waivetbl.pdf
"Cholestech"
Detailed information about the Cholestech analyzers available for lipid testing. http://cholestech.com
"Abbott Point of Care"
Detailed information about the Abbott i-STAT analyzer and other point-of-care testing instruments manufactured by Abbott http://abbottpointofcare.com

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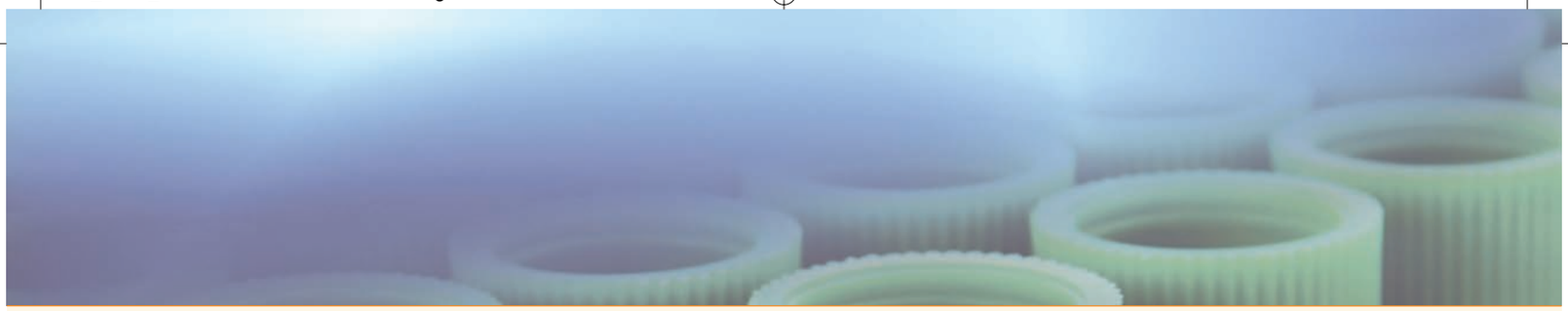

Section IV

Clinical Chemistry

What Does It All Mean?

As the chapters in this section clearly point out, there is a plethora of tests that are typically performed in the clinical chemistry area of the laboratory. These tests may be ordered and performed on an individual basis or may be ordered and tested in groups known as profiles. Physicians and other primary care providers such as nurse practitioners and physician assistants make these important ordering decisions.

Case in Point

At the beginning of this section we met 34-year-old Carrie W. A fasting blood glucose test was performed on her as part of a health fair sponsored by Carrie's employer, Acme Innovations, Inc. Her value was significantly higher than the highest number in the normal range for this test. The fact that this test was done after a period of fasting indicates that her ability to process glucose is likely impaired.

Glucose serves as the body's main source of energy. Under normal circumstances, glucose is metabolized and the resulting products are used by the body for the many functions it performs on a daily basis. An unusually high glucose level suggests that the body is unable to metabolize glucose properly. The most likely condition associated with this scenario is diabetes mellitus. Individuals with diabetes mellitus typically either do not produce the substance insulin that is necessary for glucose metabolism or they produce insulin but its function is impaired. In either event, glucose is not being properly used and eventually builds up in the body, thus causing increased blood glucose levels. Because the body can count on glucose for energy, it resorts to fat. Incomplete fat metabolism ensues. A by-product of incomplete fat metabolism is a substance known as ketone.

Once the body has reached its saturation point of glucose and ketones, excess amounts of both substances are deposited into the urine for disposal from the body. Thus, along with high blood glucose levels, individuals with diabetes mellitus typically also have high levels of glucose and ketones in the urine (urine testing is covered in detail in Chapter 21).

In some instances a change in diet stabilizes the blood glucose levels to the point that the diabetes mellitus can be manageable without taking other steps. However, there are instances when treatment with insulin is indicated.

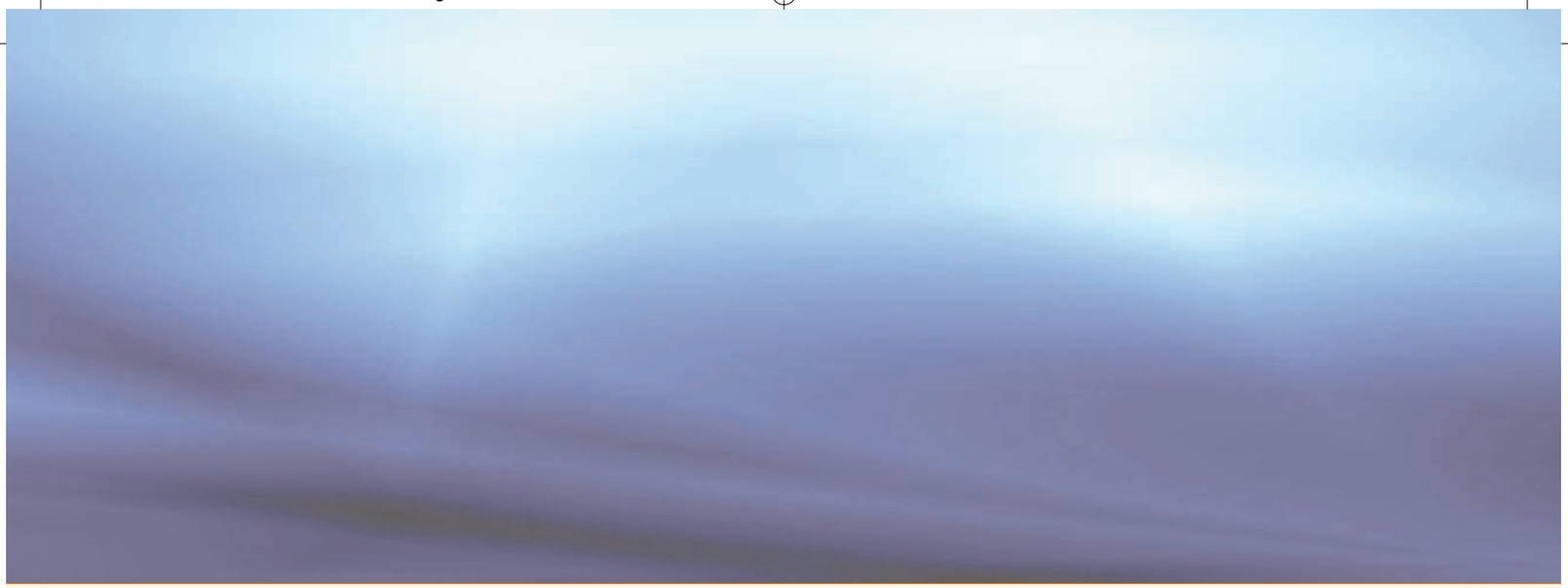

On the Horizon

Perhaps the easiest, most noninvasive specimen type for analysis from humans is urine. In fact, the concept of analyzing urine has been noted in drawings on ancient history walls. Early analyzers determined that if urine from a diabetic individual is spread on the ground, then because of its sweet smell, ants would gravitate to it. At one point, a group of so-called self-taught urine analyzers, known as the "pisse prophets," marketed their services to individuals. Patients who submitted their urine and paid a fee received an analysis of their urine without ever being examined by a physician.

There have been many advances in urine analysis over the years, one of the more notable being the advent of plastic strips impregnated with chemical pads, known as a dipstick. Today, a test that incorporates the dipstick technology, known as a urinalysis, screens for a number of abnormalities. In many instances, such abnormalities may be detected through urinalysis testing, often before the patient experiences any symptoms. This section focuses on the urinalysis test, as it is crucial in the diagnosis and monitoring of disease as well as in the monitoring of select treatment regimens. The occult blood test is also covered in this section.

Relevance for the Medical Assistant (Health-Care Provider)

As with so many other aspects of laboratory testing, medical assistants and other health-care support personnel are often involved in the collection of samples for urinalysis testing by assisting the patient in the process or providing the patient with collection instructions. Furthermore, medical assistants often perform urinalysis and occult blood testing along with appropriate quality control. Medical assistants are also responsible for completing the documentation associated with this testing.

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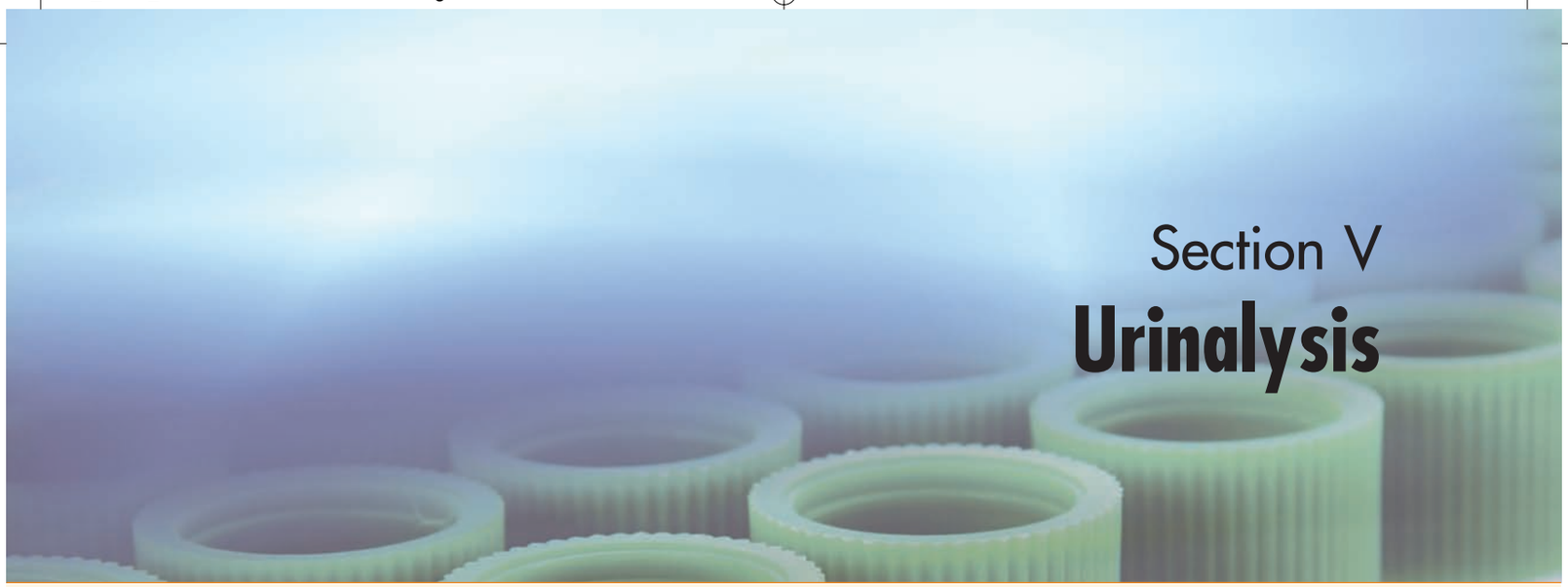

Section V
Urinalysis

On the Horizon

Chapter 19: Urinalysis introduces the reader to key anatomical parts associated with the urinary system. A brief overview of the formation of urine detailing the functions of the anatomical parts of the urinary system is presented. An overview of the routine urinalysis test including quality control is described.

Chapter 20: Physical Characteristics of Urine covers the color, clarity, volume, and odor of urine samples. The measurement of specific gravity and testing for it using a urinometer and refractometer are introduced. Proper technique, normal test reference range, sources of error and interference, and test interpretation are described.

Chapter 21: Chemical Examination of Urine and Feces identifies and describes 10 chemical tests that comprise a typical urine dipstick. The occult blood test is introduced and described. Proper technique, normal test reference range, sources of error and interference, and test interpretation are covered.

Chapter 22: Microscopic Examination of Urine introduces the reader to the most commonly seen microscopic "formed elements" found in urine. Proper technique, normal test reference range, sources of error and interference, and test interpretation are covered.

Continued from page 388.

Case in Point

Three-year-old Johnny is rushed to the doctor's office after he drank antifreeze in the family garage. As the medical assistant on duty at the time, you are asked to give instructions to Johnny's mother so she can help the young boy collect a urine sample. Once the sample is collected, you are asked to conduct the physical and chemical examination portions of a urinalysis test on it. You obtain the following results:

Urinalysis Physical Examination

Component	Result	Reference Range
Color	Amber	Yellow
Clarity	Cloudy	Clear

Urinalysis Chemical Examination (Dipstick)

Component	Result	Reference Range
Glucose	Negative	Negative
Bilirubin	Negative	Negative
Ketone	Negative	Negative
Specific gravity	1.005	1.005–1.030
Blood	Trace	Negative
pH	6.0	4.5–8.0
Protein	100 mg/dL	Negative–trace
Urobilinogen	0.2 mg/dL	0.2–1 mg/dL
Nitrite	Negative	Negative
Leukocyte esterase	Negative	Negative

Questions for Consideration:

- What key points would you make when giving directions to Johnny's mother when she helps Johnny collect a urine sample?
- What is the purpose of the physical examination of urine?
- What is the purpose of the chemical examination of urine?
- What is the third portion of the urinalysis test that has not yet been done?
- What is the purpose of the chemical examination portion of the urinalysis test?

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Chapter 19

Urinalysis

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Historical Perspective of Urinalysis
Anatomy and Physiology of the Urinary System
- The Kidneys
- Ureters
- Bladder
- Urethra

Sequence of Urine Production and Excretion
Clinical Significance of Urine Testing Results
- Physical Examination
- Chemical Examination
- Microscopic Examination

Quality Assurance for Urine Testing Procedures
Standard Precautions Used When Analyzing Urine Specimens
Types of Urine Specimens
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

19-1 Define the key terms.
19-2 Describe the function of the urinary system.
19-3 Differentiate the parts of the urinary system.
19-4 Explain how urine is formed in the kidneys.
19-5 Describe the route followed as urine is excreted from the body.
19-6 Discuss the clinical significance of urinalysis results.
19-7 Compare and contrast the different types of testing involved in routine urinalysis.
19-8 Describe common quality assurance procedures used for the analysis of urine.
19-9 Describe the personal protective equipment necessary to process urine samples.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.C.I.5: Describe the normal function of each body system.

ABHES Standards

None

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KEY TERMS

Afferent arteriole
Aliquot
Anterior
Bladder
Bowman's capsule
Calyx
Distal convoluted tubule
Efferent arteriole
Filtration
Glomerular filtration
Glomerulus
Hilum
Kidneys
Loop of Henle
Macroscopic
Microscopic
Micturition
Nephrons
Peritoneum
Pisse prophets
Proximal convoluted tubule
Reabsorption
Reagent dipstick
Renal cortex
Renal medulla
Renal pelvis
Renal tubule
Retroperitoneal
Rugae
Secretion
Specific gravity
Ureters
Urethra
Urinalysis
Urinary meatus
Urine microscopic
Uroscopy

HISTORICAL PERSPECTIVE OF URINALYSIS

Urine has been used as a primary diagnostic tool by those who practice medicine for thousands of years. The first recorded observation of the characteristics of urine was written over 6,000 years ago. Ancient physicians could only make assumptions utilizing the color, appearance, smell, and sometimes taste of urine because their knowledge of human anatomy and physiology was very limited. Urine observation and analysis was known as **uroscopy.** Some of these early diagnostic theories resulting from uroscopy proved to be quite accurate, whereas others were later shown to be complete fallacies.

Unfortunately, the type and amount of information that could be derived from urine became exaggerated, and examination of urine without the presence of the patient or any other clinical information became popular. The analysis of urine lost medical credibility for a time, as the examination of urine became a tool used by uneducated individuals who pretended to diagnose disease and predict the future using urine specimens. This type of uroscopy was a profitable venture until 1637, when Thomas Brian published a book that labeled these practitioners as **pisse prophets.** The book discredited their practices and led to the demise of this profession.

Today, the analysis of urine is a valuable tool used by health-care practitioners to screen for potential abnormalities or monitor disease processes and the efficacy of treatment. A urinalysis may provide important information to assist with the diagnosis of diabetes or kidney damage, or detect a potential urinary tract infection. Urinalysis is a relatively inexpensive, noninvasive CLIA-waived procedure that is commonly performed in physician offices by medical assistants. The analysis of urine includes observation of the physical characteristics of the urine specimen that may be seen or measured with the naked eye. The physical characteristics of the urine include documentation of the color and appearance of the urine specimen. Urinalysis procedures also include procedures such as the measurement of urine **specific gravity** (a measurement of the density or concentration of the urine specimen), or measurement of the specimen volume when needed for reference. Additional analysis for the presence of various chemical components is another part of the testing process. Analysis of urine may also include a **microscopic** component, which uses a microscope to look for formed elements in the urine specimen. Urine microscopic analysis is not a CLIA-waived test, but medical assistants often prepare and set up the specimen on the microscope for examination by a practitioner or other qualified professional. Additional training may allow for medical assistants to perform microscopic examination of urine specimens as well.

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Test Your Knowledge 19-1
How are procedures used to document the physical characteristics of the urine different from the microscopic procedures? (Outcome 19-7)

It is important to adhere to the proper collection procedure for urinalysis specimens. Ideally, urinalysis is performed on clean-catch midstream urine specimen samples, and if the procedures for this collection are not followed carefully, erroneous results may be reported to the physician. Inadequate cleansing before collection will introduce contaminants into the specimen that can alter the results. In addition, if a culture is added to the specimen after initial testing, it is important that the specimen be collected using the clean-catch midstream method. Ideally, approximately 50 mL of urine will be submitted for urinalysis testing, but according to the Clinical Laboratory and Standards Institute, the minimum volume for accurate results is 12 mL.

ANATOMY AND PHYSIOLOGY OF THE URINARY SYSTEM

The urinary system includes two **kidneys**, two **ureters**, the **bladder,** and the **urethra.** (These structures can be seen in Fig. 19-1.) The functions of the urinary system include filtration of the blood, excretion of excess waste, and the regulation of fluid and acid-base balance within the body. The kidneys also help to regulate blood pressure, and they produce erythropoietin, a hormone that stimulates production of red blood cells.

Test Your Knowledge 19-2
What is the function of the urinary system? (Outcome 19-2)

The Kidneys

The kidneys are considered the most important organs of the urinary system because they are responsible for the formation of urine. They are bean-shaped structures located to the back of the abdominal cavity on either side of the vertebral column. The **peritoneum,** or membrane that lines the abdominal cavity, covers only the **anterior** (front) side of the kidneys, which means that they are **retroperitoneal,** or behind the peritoneum. The left kidney is located a bit higher than the right kidney. A thick renal capsule consisting of connective tissue

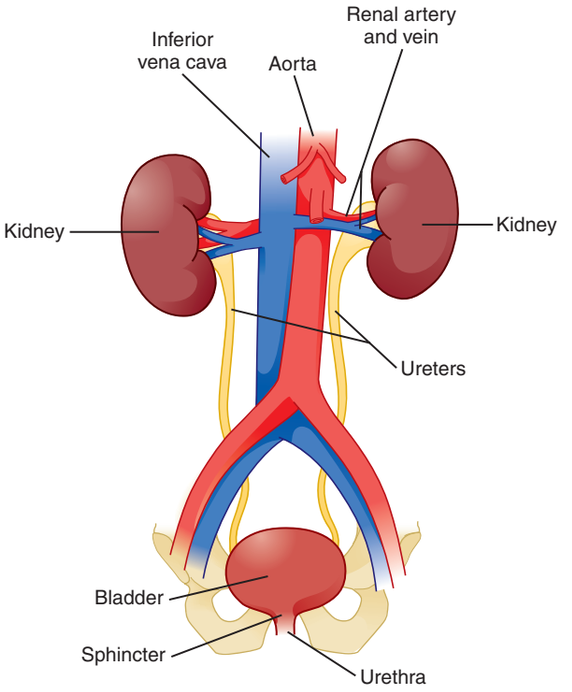

Figure 19-1 The parts of the urinary system, including the kidneys, ureters, urinary bladder, and the urethra.

and fat surrounds and protects each kidney. The indented (concave) portion of the kidney is known as the **hilum,** the region where the renal artery enters the kidney and the renal vein and ureter leave the kidney.

Test Your Knowledge 19-3
Which of these best describes the kidneys?
a. Located in front of the peritoneum
b. Pear-shaped organs
c. Located on either side of the vertebral column with one slightly lower than the other
d. Covered with hilum (Outcome 19-3)

The kidneys are made up of an outer **renal cortex** and an inner **renal medulla.** The renal medulla may be visualized as a series of structures known as *pyramids,* as is evident in Figure 19-2. Each pyramid drains into a **calyx,** which serves as a collection tubule for the urine as it is created. The area of the kidney where the calyces join is called the **renal pelvis,** which is connected to the ureter leaving the kidney.

Each kidney contains approximately 1 million **nephrons.** Nephrons are known as the functional unit of the

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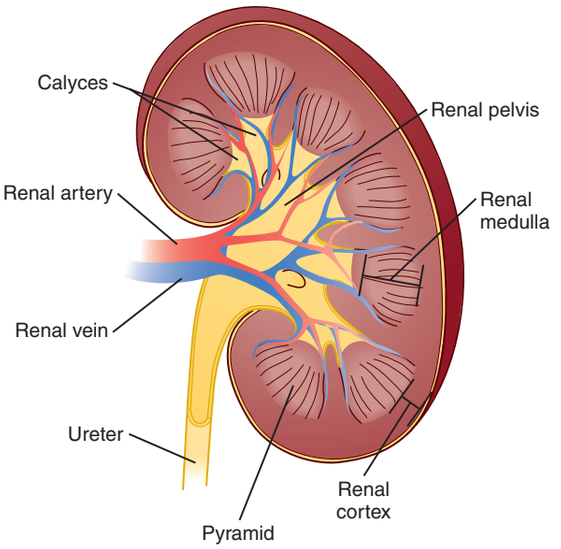

Figure 19-2 A cross section of a kidney, showing the renal vein and artery, ureter, renal pelvis, renal medulla, renal pyramids, and renal cortex.

kidneys, because these microscopic structures filter the blood and create urine utilizing filtration, reabsorption, and secretion, as described later in this chapter. The vast majority of the nephrons in the kidneys are *cortical nephrons,* located in the outer cortex layer of the kidney. All nephrons function to filter blood and create urine, but the cortical nephrons are responsible primarily for removal of waste products and reabsorption of nutrients. *Juxtamedullary nephrons* are longer, and extend deep into the medulla. These nephrons specialize in concentration of the urine.

Test Your Knowledge 19-4

Why are the nephrons called the functional units of the kidneys? (Outcome 19-3)

Almost one-quarter of the body's blood supply is in the kidneys at any given time. The kidneys are incredibly vascular to allow for adequate processing of the blood supply and production of at least 1 liter of urine each day. To understand how this process occurs, it is important to look closely at the anatomy and physiology of the nephrons, as they perform **filtration, reabsorption,** and **secretion** to create urine. A nephron is shown in Figure 19-3.

Blood enters the nephrons through a small vessel called the **afferent arteriole.** The blood continues to flow through a complex tangled tuft of capillaries that makes up the **glomerulus.** The capillaries rejoin, and the blood passes through the **efferent arteriole** as it leaves the glomerulus. The efferent arteriole is much smaller than the afferent arteriole, which causes a great deal of pressure to build up within the glomerulus. This hydrostatic pressure pushes out fluid from the blood as it travels through the tuft of capillaries. The cell lining of these capillaries is different from those in other places in the body, as it contains pores that allow small molecules to pass through and facilitates the passage of fluid at a high rate. This process is called **glomerular filtration.**

The fluid that is forced from the capillaries during glomerular filtration is collected by a tubule that surrounds the tuft of capillaries. This is called the **Bowman's capsule.** The Bowman's capsule is the beginning of the **renal tubule,** a hollow structure that contains the blood filtrate. Not all the fluid forced from the capillaries is excreted from the body as urine; if it were, the body would be depleted of vital electrolytes and fluid very quickly. Approximately 99% of the fluid and electrolytes are reabsorbed by capillaries that surround the renal tubules. Additional substances are also secreted into the filtrate before it leaves the kidneys as urine.

The renal tubules form a V-shaped complex, including the **proximal convoluted tubule,** the **loop of Henle,** and finally the **distal convoluted tubule** on the other side of the V. (See Fig. 19-3.) This complex of tubules is surrounded by capillaries, which allows for essential exchanges to occur between the blood and the filtrate within the tubules. The primary reabsorption of fluid and electrolytes occurs in the proximal convoluted tubule. More water, sodium, and chloride are reabsorbed into the blood from the filtrate in the loop of Henle at the bottom of the V-shaped complex. Most of the final adjustments are accomplished in the distal convoluted tubule to create urine from the glomerular filtrate. Urine that has passed through the renal tubules flows into the collecting duct, which then drains into the calyx area of the kidney. The calyces open up to form the renal pelvis, and the urine leaves the kidneys through the ureter.

Test Your Knowledge 19-5

What processes occur in the renal tubules? (Outcome 19-4)

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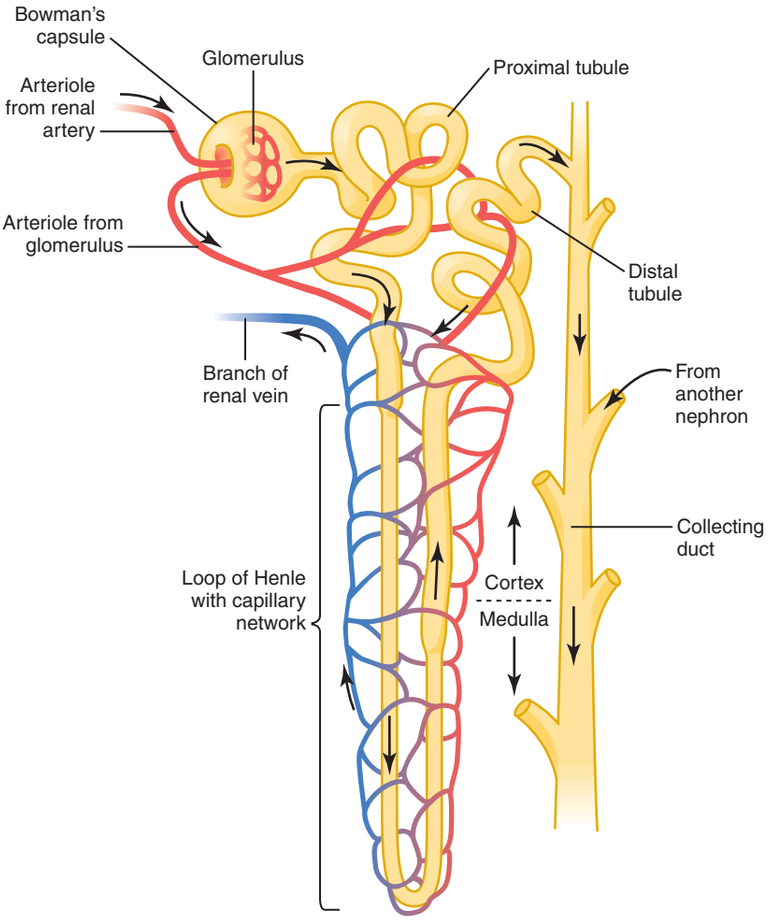

Figure 19-3 The components of the nephron, including the glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henle, and distal convoluted tubule.

Ureters

The ureters are flexible hollow tubes that connect the kidneys to the bladder. Urine flows from each renal pelvis through the ureter by peristaltic waves created by the muscular ureter walls. Each ureter is approximately 12 in. long, which allows enough length for them to pass behind the abdominal cavity before entering the bladder.

Test Your Knowledge 19-6

Are the ureters involved in the production of urine? (Outcome 19-4)

Bladder

The bladder is a hollow muscular sac that is designed to store urine. The size and shape of the bladder differ according to the amount of urine being stored at any time. The interior lining of the empty bladder forms **rugae,** which are folds that allow for the bladder to expand when filled with urine. Typically, the adult bladder can hold about 500 mL of urine, but the urge to urinate can be felt when the bladder contains approximately 150 mL of urine. The release of urine from the bladder **(micturition)** involves the interaction of the micturition reflex center in the sacral region of the spinal cord and the voluntary muscles that surround the urethra.

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Urethra

When the urine leaves the bladder, it travels through a hollow tube called the urethra as it leaves the body. The urethra varies in length according to the patient's gender. The male urethra is approximately 21 cm in length, whereas the female urethra averages only 4 cm. In males the urethra also is used by the reproductive system to transport semen. The opening at the distal (far) end of the urethra where it leaves the body is called the **urinary meatus.**

SEQUENCE OF URINE PRODUCTION AND EXCRETION

Each part of the urinary system plays an important role in the formation and excretion of urine. The process begins as the blood is filtered in the glomerular capillaries and ends as the urine passes through the urinary meatus.

- Blood is forced through the glomerular capillaries with sufficient pressure to force most of the liquid portion of the blood out through the pores in the capillaries to form the glomerular filtrate.
- The glomerular filtrate is collected in the Bowman's capsule that surrounds the glomerulus.
- The glomerular filtrate continues to pass through the renal tubules, including the proximal convoluted tubule, the loop of Henle, and the distal convoluted tubule.
- The refined filtrate (now known as urine) enters the collecting ducts.
- The collecting ducts join to drain into the calyces, which are part of the renal pelvis.
- The urine leaves the renal pelvis through the hilum into the ureter.
- The ureter transports the urine into the urinary bladder.
- Urine leaves the body through the urethra.
- The distal end of the urethra where the urine leaves the body is known as the urinary meatus.

CLINICAL SIGNIFICANCE OF URINE TESTING RESULTS

Urinalysis is one of the most common tests performed in physician offices and laboratories. The test is fast, simple, and relatively inexpensive to perform. Urine testing is considered reliable to detect or monitor the progress of numerous disease states. Disorders of carbohydrate metabolism, urinary tract infections, and abnormal pH changes in the body may all be detected through analysis of urine. The malfunction of the kidneys or liver may also be evident in a urine specimen. Urinalysis is also commonly performed as a screening procedure for asymptomatic disease. The analysis of urine has several parts: physical examination, chemical testing, and a microscopic examination of the urine sediment for detection of formed elements present in the specimen.

Test Your Knowledge 19-7

True or False: Urinalysis is performed only to confirm a clinical diagnosis. (Outcome 19-6)

POINT OF INTEREST 19-1
Bladder cancer testing

Bladder cancer is one of the most prevalent cancers in the United States. It is most common in men over the age of 60. The risk of developing bladder cancer is greatly elevated in those who smoke, and patients who have experienced chemical exposure (such as dry cleaning chemicals) are also at a high risk for bladder cancer. One of the first symptoms of bladder cancer may be the presence of blood in the urine (hematuria), as well as increased urinary frequency, irritability, and pelvic pain. If detected early, bladder cancer is highly treatable.

As of June 2004 the Department of Health and Human Services U.S. Preventive Services Task Force recommends against routine screening for bladder cancer for asymptomatic patients without the presence of risk factors. However, there are various tests for patients who show symptoms of bladder cancer, or for those who have multiple risk factors. One of these is cystoscopy, which is a visual examination of the bladder using a scope. Biopsies that are obtained during a cystoscopy may also provide valuable information.

In addition to these screening procedures, the health-care provider may choose to test the patient's urine specimen for the presence of the *nuclear matrix protein*, which is often elevated in the presence of bladder cancer. The NMP22 Bladder Chek test (manufactured by Matritech Corporation) is the only U.S. Food and Drug Administration–approved, CLIA-waived test for the screening of urine for potential bladder cancer. For patients who have been previously diagnosed with bladder cancer, the BTA Stat test (manufactured by Polymedco) may be used

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to detect bladder cancer cells. The BTA Stat test has not been approved for use as a screening mechanism. A positive result with either of these tests will lead to further investigative procedures to establish the presence of cancer cells and define the severity of the condition.

Physical Examination

The first step taken when analyzing a urine specimen is to perform a direct observation of the urine specimen. The color and appearance of the urine specimen may be noted, depending on the policies and procedures of the laboratory. Some laboratories will also allow for documentation of any unusual specimen odor, because an ammonia-like odor may indicate an old urine specimen that has not been properly preserved. In addition, the physical examination may include the documentation of the urine specific gravity, using a refractometer. The specific gravity measurement provides information about the amount of dissolved substances present in the urine specimen. The physical examination, as well as the rest of the procedures included in a urinalysis, should be performed on fresh urine specimens within 1 hour of collection. If there will be a delay in the testing, the specimen needs to be refrigerated at 4° to 6°C or added to a preservative tube as directed by laboratory policy. If refrigerated, the specimen needs to be brought back to room temperature before testing.

Test Your Knowledge 19-8

What is observed and recorded during the physical examination of a urine specimen? (Outcome 19-7)

Chemical Examination

After the initial physical examination has been performed and recorded, the urine specimen will be tested with a **reagent dipstick,** a thin piece of plastic covered with reagent pads that will change color depending on the concentration of specific chemicals in the urine specimen. Reagent dipsticks are commonly used to test for glucose, ketones, pH, bilirubin, urobilinogen, red blood cells, white blood cells, nitrites, albumin, and protein. Specific gravity may also be measured using this method. Chemical testing may be performed manually with visualization of the color changes on the reagent pads, or an instrument may be used to evaluate the changes in color and assign values. More details about the chemical testing of urine are presented in Chapter 21.

Microscopic Examination

The final test performed as part of a urinalysis is the **urine microscopic** examination. An **aliquot** (small sample) of the urine specimen is centrifuged. At least 12 mL of urine are required to obtain an appropriate specimen for microscopic examination. The sediment formed at the bottom of the tube during centrifugation is placed on a slide and viewed under the microscope. The laboratory professional will document the formed elements present when the specimen is examined. Cells commonly present in the urine specimen include squamous epithelial cells as well as red and white blood cells. Bacteria and fungi may be observed along with many other microscopic structures. Chapter 22 focuses more specifically on the microscopic urine examination and the significance of the results.

Test Your Knowledge 19-9

Which part of the urinalysis procedure uses reagent test strips?

a. Observation of color and clarity
b. Microscopic examination
c. Chemical analysis
d. Culture (Outcome 19-7)

POINT OF INTEREST 19-2
HIV urine testing

According to the Centers for Disease Control and Prevention, every year there are more than 16 million people in the United States who are tested for potential HIV infection. Many of these patients will have a rapid test performed in the physician office, using an oral sample (from the mucosal surface of the mouth) or a capillary blood sample. Most patients are not aware that urine may also be tested for HIV antibodies. Urine HIV testing has not been approved as a rapid test method, but Calypte Biomedical Corporation manufactures a urine screening test that has been approved by the U.S. Food and Drug Administration for HIV testing. It is important to remember that urine is not considered to be an infectious material for HIV; however, antibodies may be present in urine. Urine testing for HIV has been shown to be a little less sensitive and specific for HIV antibodies

Continued

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than the testing performed on blood or oral samples. Any positive results should be rechecked two times, and if the result is positive, the specimen must be sent out for confirmation with a western blot confirmatory test before the patient is to be considered HIV positive.

QUALITY ASSURANCE FOR URINE TESTING PROCEDURES

Urine analysis involves several different processes, some of which may be performed manually or by means of instrumentation. Quality assurance methods for handling and testing urine specimens include the following:

- Appropriate explanation of collection techniques should be provided to patients. A clean-catch midstream urine collection technique is best for urinalysis testing to provide a sample that is contaminant free.
- A sterile collection container with appropriate labeling should be provided to the patient. This allows the specimen to remain contaminant free in case there is a culture added to the specimen after the urinalysis is performed.
- Testing should occur within 1 hour of collection whenever possible. If this is not feasible, refrigeration or preservation of the sample at 4° to 6°C must occur within 1 hour.
- Calibration of and use of quality control specimens on the refractometer if used for specific gravity testing must be implemented.
- Staff training must be ongoing for standardization of terms used to report the physical examination and other results.
- Use of external quality control specimens must occur; a positive and negative quality control specimen should be processed for all parameters reported on patient specimens. The frequency of testing is dependent on the number of urinalysis tests performed, the manufacturer's recommendations, and the adopted laboratory policies.
- Reagent strips must be stored properly; they are to remain in the original container with the dessicant as packaged, and they should remain out of direct light and be protected from humid environments. The cap must stay on the container to keep moisture from affecting the strips, which would result in erroneous results.
- Centrifuges used to spin urine specimens should be calibrated regularly.
- Commercial quality control specimens should be processed by all who perform urine microscopic examination. Slides and pictures used for proficiency testing may also be useful.

STANDARD PRECAUTIONS USED WHEN ANALYZING URINE SPECIMENS

As introduced in Chapte 3, Standard Precautions combine the principles of Universal Precautions with those of Body Substance Isolation. Universal Precautions state that all blood and other potential infectious body fluid specimens should be treated as if they are infectious for HIV, hepatitis B, and other bloodborne pathogens. Body Substance Isolation procedures specify how employees are to be protected from other pathogens that may be present in a specimen. Essentially, when testing urine using the Standard Precautions, it is important for the employee to be shielded from potential exposure to the pathogens that may be present in the urine specimen. This protection may be accomplished by use of gloves when handling the urine specimens and by wearing a laboratory coat to protect against potential splashes or spills. Eye protection should be worn when removing the cover from the tube to protect against aerosols or splashing.

Test Your Knowledge 19-10

Which of these is a type of personal protective equipment (PPE) that should be worn while a medical assistant performs a urinalysis test?

a. Laboratory coat
b. Gloves
c. Respiratory protection
d. a and b
e. a, b, and c (Outcome 19-9)

TYPES OF URINE SPECIMENS

This chapter and the others in this section focus on the collection, processing, and testing of urinalysis samples. A urinalysis should be performed using a clean-catch midstream urine specimen, preferably collected with the first morning void. However, as presented in Chapter 9, urine specimens may be used for other types of testing as well. These samples differ in their collection requirements, analysis procedures, and the clinical significance

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of the results. Examples of alternative urine specimens include the following:

- Timed specimens, such as postprandial specimens or those collected during a glucose tolerance testing procedure
- 24-hour urine specimens used for specific chemical analysis
- Postprostatic massage specimens
- Urine collected for *Chlamydia* testing
- Urine collected for drug testing

SUMMARY

For many years analysis of urine specimens has been an invaluable tool for providing important clinical information. The urinary system is complex, and is responsible for the filtration of toxins from the body, as well as the acid-base and overall fluid balance that is necessary for homeostasis. The technological advances in testing methods are dramatic, and urine may now be used to identify and/or monitor the progress of many disease states. Urinalysis is commonly performed in physician offices as well as large reference laboratories. A typical urinalysis test includes macroscopic, physical, chemical, and microscopic components. Quality control plays a very important role in every part of urine testing procedures.

TIME TO REVIEW

1. The renal calyx is: Outcome 19-1
   - **a.** A cup-like extension of the renal pelvis
   - **b.** Part of the nephron
   - **c.** The membrane that covers the kidney
   - **d.** A vessel in the Bowman's capsule
2. Specific gravity is a ratio that compares: Outcome 19-1
   - **a.** The weight of the urine specimen to a "normal" urine specimen
   - **b.** The weight of the urine specimen to the patient's blood
   - **c.** The weight of the urine specimen to distilled water
   - **d.** None of the above
3. The afferent and efferent arterioles: Outcome 19-2
   - **a.** Enter and exit the bladder
   - **b.** Enter and exit the kidney
   - **c.** Enter and exit the ureters
   - **d.** Enter and exit the glomerulus
4. True or False: The urinary system is very important for maintenance of the body's normal pH. Outcome 19-2
5. The urinary bladder: Outcome 19-3
   - **a.** Helps to concentrate the urine
   - **b.** Serves as a storage receptacle
   - **c.** Can stretch to hold more than 1 L of fluid
   - **d.** Is superior to the kidneys in the body
6. The initial filtration of the blood: Outcome 19-4
   - **a.** Occurs in the distal convoluted tubule
   - **b.** Occurs as the blood enters the kidney
   - **c.** Occurs as the blood passes through the glomerulus
   - **d.** Occurs in the ureters
7. True or False: Microscopic examination of urine specimens is an automated procedure. Outcome 19-7
8. What is the recommendation for the use of quality control materials for the reagent strip testing portion of the urinalysis? Outcome 19-8
   - **a.** Test positive controls only
   - **b.** Test negative controls only
   - **c.** Test positive and negative controls
   - **d.** No quality control materials need to be used for this part of the analysis
9. Why should a laboratory coat be worn when performing urinalysis testing? Outcome 19-9
10. True or False: Because blood is not usually present in urine specimens, it is not necessary to wear gloves when processing urine samples. Outcome 19-9

Case Study 19-1: Reagent storage requirements

When John arrives at work in the office laboratory on Monday morning, he finds that the lid for the urine reagent strips is not on the container. There was no one in the office over the weekend, and John was not the last person in the laboratory at the end of the day on Friday.

1. Should John use these strips for urine testing? Why or why not?

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RESOURCES AND SUGGESTED READINGS

Clinical and Laboratory Standards Institute, Urinalysis: Approved Guideline, ed. 3. CLSI document G16-A3. Wayne, PA, 2009
Approved laboratory standards for collecting, processing, and testing urinalysis samples

Becton, Dickinson, "Best Practice: Tips for Urinalysis." LabNotes, 13, no. 2, 2003
Online newsletter from Becton, Dickinson and Company. Includes details about urine processing for urinalysis and urine cultures, including information about preservative tubes http://www.bd.com/vacutainer/labnotes/2003spring/best_practice.asp

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Chapter 20

Physical Characteristics of Urine

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Physical Characteristics of Urine
- Urine Color
- Urine Clarity
- Specimen Volume
- Urine Odor
- Specific Gravity
  - *Refractometer Measurement Technique*
  - *Urinometer Measurement Technique*
  - *Reagent Strip Methodology*
- Procedure for Recording Physical Characteristics of a Urine Specimen

Potential Sources of Error
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

20-1 Define the key terms.
20-2 Describe the clinical significance of abnormal urine color.
20-3 Explain how urine clarity is interpreted and reported.
20-4 Discuss the clinical significance of urine volume and odor.
20-5 Describe the clinical significance of specific gravity results.
20-6 Compare and contrast the different methods used to perform urine specific gravity testing.
20-7 Provide the units used to report specific gravity results.
20-8 List potential sources of error for urine physical examination procedures.
20-9 Analyze and document the physical characteristics of a urine specimen.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.13. Perform Urinalysis

ABHES Standards

- 10. Medical Laboratory Procedures, b. Perform selected CLIA-waived tests that assist with diagnosis and treatment, #1: Urinalysis

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KEY TERMS

Anuria
Amorphous phosphates
Amorphous urates
Clarity
Enuresis
Glycosuria
Hematuria
Meniscus
Myoglobin
Nocturia
Oliguria
Polyuria
Pyuria
Refractive index
Refractometer
Specific gravity
Urinary frequency
Urinary incontinence
Urinometer
Urochrome

PHYSICAL CHARACTERISTICS OF URINE

There are several steps involved in analyzing a urine specimen. Analysis and documentation of the physical properties of urine make up the first procedural step. This analysis includes observation and documentation of the color, appearance, and specific gravity of the urine specimen. Urine odor may also be noted in some cases, but is not part of the standardized reporting procedure. The physical characteristics of urine may provide information for the health-care provider about kidney function and the status of other body systems. Many times the abnormal color or appearance of a urine specimen is the first sign of a serious disorder.

Urine Color

Normally, urine specimens may appear pale yellow (also known as straw) to amber in color. **Urochrome** is the substance that provides the traditional yellow color observed in urine. Urochrome is a pigment that is released continuously as a product of hemoglobin breakdown and normal metabolism. Because the amount of urochrome is consistent, the intensity of the yellow color in the specimen will vary with the patient's hydration status. Urine specimens that are more concentrated (such as the first morning void specimen) will have a darker yellow color than those that are obtained later in the day, as the patient becomes more hydrated.

Test Your Knowledge 20-1
How is urochrome related to urine color?
(Outcome 20-1)

The terms used to describe the color of urine may vary slightly among laboratories, but it is important that they are standardized within each facility. Simple descriptive terms are best, such as straw, yellow, dark yellow, and amber. Employees should be trained to recognize these colors so that the reporting methods are consistent. It is also important to evaluate urine color on a well-mixed specimen in a clear container, so that the true color can be evaluated. Figure 20-1 shows various colors of urine specimens.

A noticeable change in urine color may be caused by a pathological condition. However, certain foods, vitamins, or medications may also cause an abnormal color. Table 20-1 lists potential causes for various urine colors. The most commonly encountered abnormal colors and their significance are listed here:

- *Dark yellow to amber:* Although these colors are technically within the normal range, sometimes urine will

Figure 20-1 Urine color: *left to right,* straw; yellow; dark yellow; amber.

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TABLE 20-1
Urine Colors and Possible Causes

Urine Color	Possible Causes	More Information
Colorless to pale yellow	Recent fluid intake, diabetes mellitus, polyuria	Pale yellow and/or colorless urine are not necessarily abnormal, but may be present in some disease states
Dark yellow	First morning specimen, recent strenuous exercise	Usually normal; fluorescent, dark yellow urine may be due to ingestion of multivitamins
Yellow/brown/amber	Hepatitis, dehydration	
Green	Presence of *Pseudomonas* bacterial species in urine specimen	The culture reports will confirm the presence of this bacterium type.
Blue or green	Certain types of drugs or dyes used for contrast studies; ingestion of Clorets breath mints	
Pink or red	Red blood cells, myoglobin, ingestion of fresh beets or fresh blackberries	
Brown or black	Hemoglobin in urine that has been standing or melanin	Melanin may be present in patients with melanoma

appear dark yellow or amber when bilirubin is present in the specimen. This may indicate liver dysfunction, such as in hepatitis, or other conditions that lead to increased red blood cell destruction. Recent strenuous exercise may also cause urine to appear dark yellow.

- *Orange:* Urine may also appear orange when bilirubin levels are elevated in the specimen. However, a more common cause of bright orange urine is the presence of Pyridium (phenazopyridine), a medication used to treat recurrent urinary tract infections. This medication produces a potent orange pigment that will interfere with many of the testing procedures included in a urinalysis.
- *Red to brown:* The presence of red blood cells **(hematuria)** in the urine specimen may cause it to appear pink, red, or even brown. Urinary tract infections or renal dysfunction may allow red blood cells to enter the urinary tract. The presence of hemoglobin from increased red blood cell lysis elsewhere in the body also leads to red urine specimens, although the urine is clearer than it is when intact red blood cells are present. **Myoglobin** is a by-product of muscle destruction, and elevated levels may also cause the urine to appear reddish in color. Many medications, fresh beets, and fresh blackberries may also contribute to a red urine specimen.
- *Blue or green:* Urinary tract infections caused by *Pseudomonas* bacterial genus may cause the patient's urine to appear green in color. Various medications may also cause a green or blue hue.
- *Fluorescence:* Multivitamins may cause the urine to "fluoresce," although the urine color may be normal.
- *Brown or black:* Hemoglobin may turn brown in acidic urine that has been left standing for an extended period of time. Brown or black urine may be evident for patients that have melanoma. This is caused by the presence of melanin and melanogen in the specimen.

Test Your Knowledge 20-2

Ms. Jones has had recurrent urinary tract infections for most of the past year. Her physician has prescribed a medication to treat these infections. On Monday morning, Ms. Jones takes her first dose of the medication. Later that afternoon, Ms. Jones goes to the restroom and is alarmed to see that her urine is bright orange.

Is the bright orange color indicative of a serious problem?

What is the probable cause of the abnormal color in her urine? (Outcome 20-2)

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Urine Clarity

The word **clarity** is used to describe the transparency of the urine specimen. A normal urine specimen will be clear when examined in a clear container. The color and the clarity of the specimen are usually evaluated at the same time. As was explained in the section Urine Color, the terms used to describe urine clarity need to be standardized within a laboratory. Common descriptive terms used include clear, hazy, cloudy, or turbid. Figure 20-2 shows the difference in specimen urine clarity. When evaluating urine clarity, it can be helpful to use an object or print behind the specimen; the visibility of the object or print when viewed through the urine specimen will help to determine the clarity that should be reported. Common terms used to describe urine clarity and their clinical significance are listed here:

- *Clear:* A clear specimen has no visible particles and is transparent. Most normal urine specimens appear clear.
- *Hazy:* Hazy specimens may have a few particles floating in the specimen and are not completely transparent. However, it is still relatively easy to see through a hazy specimen. Mucus and other cellular elements may cause the urine to appear hazy.
- *Cloudy:* A cloudy specimen will be difficult to see through because of the particles that are suspended in the specimen. Recently voided specimens may appear cloudy because of **pyuria** (the presence of white blood cells or pus), bacteria, mucus, red blood cells, sperm, yeast, or casts in the specimen. Fat particles suspended in the urine specimen will cause it to be excessively cloudy. Contamination caused by vaginal creams may also cause the urine specimen to appear cloudy. In addition, specimens that have been allowed to stand at room temperature for extended periods of time may develop a cloudy appearance because of the increase in the number of bacteria present in the specimen.

Refrigerated specimens may also become cloudy; this is due to the presence of urates and phosphates in the urine specimen. When the specimen is allowed to cool, these waste products become visible as diffuse (amorphous) particles throughout the specimen, known as **amorphous urates** or **amorphous phosphates.** Amorphous urates are present in acidic urine, and may cause the cloudy urine to appear slightly pink. If there are so many amorphous urates present that the specimen cannot be viewed under the microscope, the urine can be warmed to 60°C to clear the urine. Alkaline urine will result in the formation of amorphous phosphates, with a white, cloudy appearance. The amorphous phosphates can be cleared from the specimen if needed for microscopic examination by adding a drop of acetic acid to the specimen.

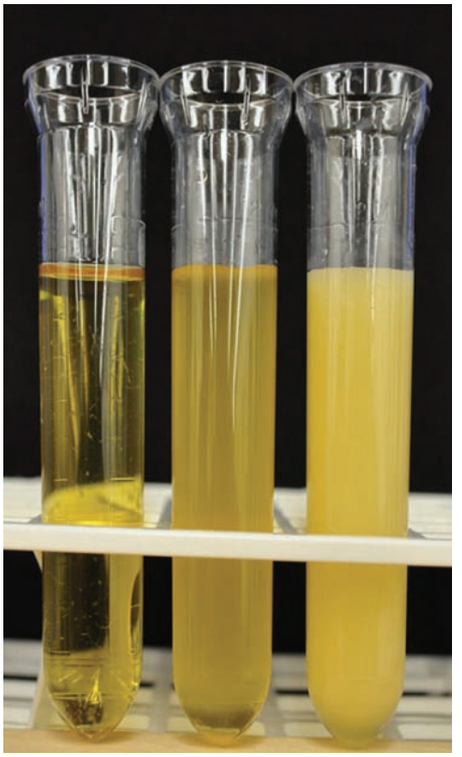

Figure 20-2 Urine clarity: *left to right,* clear; hazy; cloudy.

Urine clarity provides clues concerning the type and number of formed elements present in the specimen. A cloudy specimen has a high concentration of formed elements, whereas a clear specimen usually has a low concentration. The chemical analysis and microscopic examination provide additional information about any chemicals or structures present in the specimen. A clear urine specimen is not always normal, as there may be abnormal chemical constituents present that don't cause the urine to appear abnormally cloudy.

Test Your Knowledge 20-3

Why is it important to place print or something similar behind the urine specimen when evaluating the urine clarity? (Outcome 20-3)

Specimen Volume

The volume of urine produced in a 24-hour period will vary depending on factors such as the hydration status, general renal health, and dietary habits of a patient. The normal adult urine volume for a 24-hour period is

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between 750 and 2,000 mL per day. Terms used to describe abnormalities in urine volume or urinary frequency are listed below:

- **Anuria:** The absence of urine production
- **Urinary frequency:** An increase in the urge to urinate
- **Oliguria:** Diminished urinary output of less than 400 mL per day
- **Polyuria:** Excessive urination
- **Enuresis:** The inability to control the flow of urine. This term is used for patients who have involuntary urination after the age at which bladder control should have been established.
- **Nocturia**: Excessive or frequent urination at night
- **Urinary incontinence**: Involuntary urination

To perform a complete urinalysis, most laboratories prefer a specimen of approximately 50 mL; the minimum acceptable volume is usually 12 mL. Those performing the testing procedures on urine specimens with a volume less than 12 mL will need to be mindful of the limited availability for rechecking the results of the analysis if needed.

Test Your Knowledge 20-4

A patient has been ill with vomiting and diarrhea for several days. His urine volume over 24 hours is likely to be:

a. Increased
b. Decreased (Outcome 20-4)

Urine Odor

Routine urinalysis procedures do not include the documentation of urine odor. A normal, recently voided urine specimen has an aromatic odor that is not unpleasant. Abnormal urine odors are generally not considered to be clinically significant, but they may still be associated with certain conditions or characteristics of the urine specimen. Urine specimens that are left at room temperature for an extended period of time will develop an ammonia odor as the urea present in the specimen degrades. Bacterial infections of the urinary tract will result in a urine specimen with a strong foul-smelling odor. A urine specimen with a fruity, sweet odor may indicate the presence of ketones in the urine in a diabetic patient. Other metabolic disorders may give the urine a characteristic odor. For example, patients with phenylketonuria will excrete urine with a characteristic mousy or musty odor. Ingestion of certain foods (such as asparagus, garlic, or onions) can also cause the urine specimen to have an unusual smell.

Test Your Knowledge 20-5

True or False: A urine specimen with a strong odor is always indicative of a urinary tract infection. (Outcome 20-4)

POINT OF INTEREST 20-1
The odoriferous asparagus

The odor associated with a urine specimen may be attributed to its volume and the concentration of the chemicals present in the urine specimen. For example, within a short period of time after ingesting asparagus, many people have reported that their urine has a "sulfur" smell. It is thought that this distinctive odor is caused by the breakdown of amino acid compounds in the asparagus as it is digested.

However, there is a continuing debate over the production of odoriferous urine because it does not appear to be universal. Some studies have shown that less than half of the population actually excretes sulfurous-smelling urine after asparagus ingestion. It was thought that genetically the two groups differed, and they were labeled as "excretors" and "nonexcretors," based on whether they smelled the sulfur in their urine after asparagus ingestion. This belief is still held by many. However, other scientists believe that all individuals actually excrete the sulfurous odor, but only some individuals are able to detect the odor. Those who cannot detect the smell are not aware of its presence, and may have been misclassified as "nonexcretors" in the original studies. There is not enough scientific evidence available to prove or disprove either hypothesis.

Specific Gravity

Specific gravity measurements are one of the physical examinations performed during a routine urinalysis. Urine specific gravity is defined as the density (or weight) of the urine specimen as compared to the density (weight) of distilled water at the same temperature. The density of the urine specimen is dependent on the amount and size of the dissolved substances present in the urine specimen. These include such substances as glucose, proteins, and electrolytes. The kidneys are responsible for selective reabsorption of essential chemicals and fluid after the blood is filtered. Abnormal specific gravity values may be an early indication of renal dysfunction. Low specific gravity urine is considered to be dilute with very few dissolved substances, whereas

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urine with a high specific gravity indicates that the urine is concentrated with increased amounts of dissolved substances.

Test Your Knowledge 20-6

True or False: Urine specimens with high specific gravity results are always cloudy. (Outcome 20-5)

Because urine specific gravity is measured against distilled water, the results are reported using units that reflect this comparison. Urine specific gravity is reported in units beginning with 1.000 (for distilled water) to amounts above 1.030 (for highly concentrated urine specimens). Urine concentration (as measured by the specific gravity of the urine specimen) may be elevated with congestive heart failure, dehydration, adrenal gland dysfunction, **glycosuria** (the presence of glucose in the urine), high levels of urine protein, or recent use of high molecular weight IV fluids. The urine specific gravity may also be elevated in situations in which the patient has become dehydrated as a result of excessive vomiting or diarrhea. Decreased urine specific gravity may be present in diabetes insipidus, excessive fluid intake, or renal failure. The normal urine specific gravity is 1.005 to 1.030.

Test Your Knowledge 20-7

A urine specific gravity is documented on the patient's chart as 1.25. Is this correct? (Outcome 20-7)

Specific gravity may be measured in several ways, but there are three methods used most often in physician office laboratories. These include the use of a **refractometer**, a **urinometer**, or a reagent dipstick.

Refractometer Measurement Technique

An instrument called a refractometer measures the **refractive index** of a solution. This is a measurement of the velocity of light in air as compared to the velocity of light in a solution. The number of dissolved particles present in the solution affect the velocity and the angle at which the light passes through a urine specimen. Clinical refractometers (see Fig. 20-3) used for urine analysis use a prism to direct one distinct wavelength of light for comparison to a special scale. The concentration of the urine specimen has a direct effect on the angle of the light as it passes through to the prism. The refractive index is not identical to the specific gravity of urine, but refractometers are calibrated to provide specific gravity readings.

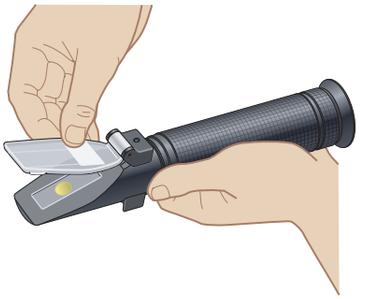

Close the daylight plate gently.

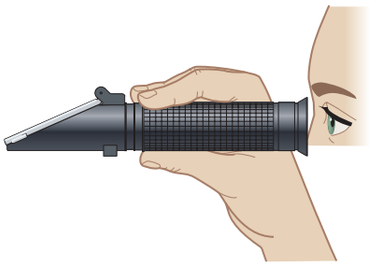

Look at the scale through the eyepiece.

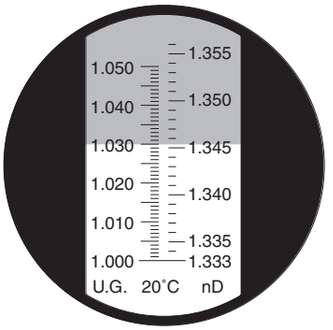

Read the scale where the boundary line intercepts it.

Figure 20-3 Steps to be taken when determining urine specific gravity with a refractometer. *Courtesy of NSG Precision Cells. www.precisioncells.com*

Refractometers are portable, relatively inexpensive, and easily calibrated. This method of measurement uses only a drop of urine, which can be beneficial as compared to other methods. Refractometers must be calibrated regularly with distilled water to achieve a result of 1.000. Five percent NaCl may also be used to check the calibration, and it should read 1.022. Urine quality control samples should also be used to verify that the refractometer is working correctly and that the operator knows how to

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read the results appropriately. Procedure 20-1 provides detailed instructions for the use of a refractometer to measure urine specific gravity.

Urinometer Measurement Technique

A urinometer is a device that uses a weighted float attached to a scale. This weighted float will displace a volume of liquid relative to its weight. When used with distilled water, the weight will sink until the calibrated scale reads exactly 1.000. Because urine has more dissolved substances present than does distilled water, the urinometer float will displace less fluid. This will result in a higher reading on the urinometer scale. Figure 20-4 includes an example of a urinometer.

Urinometers are rarely used for specific gravity testing. The Clinical and Laboratory Standards Institute does not recommend their use for urine specific gravity, but they may still be used in small physician office laboratories. There are several disadvantages to the urinometer method, including the large volume of urine required for the procedure (10 to 15 mL), the fragility of the weighted float/scale, and the need for a specific container that allows for the displacement of the fluid during the process. In addition, the specific gravity is measured at the **meniscus** (the bottom of the curve at the top of the urine column) of the fluid after the float is added to the urine specimen; the reported results may sometimes be inaccurate because of problems with reading the meniscus properly.

Figure 20-4 A urinometer. The result is read at the top of the urine column (at the meniscus) on the measurement scale printed on the urinometer.

Reagent Strip Methodology

Specific gravity measurements performed by using reagent strips are another indirect measurement of the amount of dissolved substances in the urine specimen. Reagent strip reactions are based on the release of ionic solutes in the specimen. These ions are released for measurement when exposed to the reagent pad on the strip as it is dipped into the urine specimen. A color change occurs on the reagent pads, which can be measured in 0.005 intervals from 1.000 to 1.030. Many facilities have adopted this method of measuring specific gravity because it does not involve an additional instrument for the procedure, as the results are read for specific gravity while reading those for other chemical analytes on the reagent strip.

Test Your Knowledge 20-8

What are three advantages of using the refractometer method for specific gravity testing? (Outcome 20-6)

POTENTIAL SOURCES OF ERROR

Numerous preanalytical variables may affect the physical characteristics of urine specimens. The assessment procedures for color, clarity, and specific gravity may also be performed incorrectly. The following are some of the most common sources of error:

- *Incorrect or missing identification on the specimen:* Urine specimens must be labeled with the patient's name, birth date, and specimen number or other unique identifier. The date and time of collection must also be noted on the requisition form and on the specimen.
- *Inappropriate specimen storage:* Urine specimens are to be analyzed within 2 hours of collection. If this is not possible, the specimen must be refrigerated or appropriately preserved within 2 hours of collection. Ideally, the color and clarity of the specimen should be determined, but if they were not, the specimen must be allowed to reach room temperature again before assessment.

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Procedure 20-1: Observation and Documentation of Urine Physical Properties

TASK

The student will perform an assessment of the physical properties of a urine specimen, including the color, appearance, and specific gravity. A handheld refractometer will be used for the specific gravity measurement.

CONDITIONS

- Gloves, laboratory coat, and protective eyewear
- Freshly voided urine specimen
- Transfer tube
- Refractometer
- Graph paper to be used as "print" for urine clarity comparison
- Distilled water
- Transfer pipettes
- Kimwipes
- Permanent fine-tip pen for marking identification on the transfer tube
- Black pen for documentation on the patient's chart
- Patient's chart
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #13. Perform Urinalysis

ABHES Standards

- 10. Medical Laboratory Procedures, b. Perform selected CLIA-waived tests that assist with diagnosis and treatment, #1: Urinalysis

Procedure	Rationale
1. Wash hands	Hand washing breaks the cycle of infection.
2. Put on gloves.	Wearing proper personal protective equipment (PPE) protects employees from potential exposure to pathogens present in the specimen.
3. Verify test order and assemble necessary equipment and specimen.	Verification of test order eliminates potential errors, and organization of supplies saves time.
4. Verify specimen labeling and identification.	Urine specimens need to be labeled with the name of the patient, the birth date, and the account or specimen number. The date and time of the collection must also be documented.
5. Verify that specimen collection was less than 1 hour before testing or that it was refrigerated and/or preserved appropriately after collection.	Specimens that are allowed to stay at room temperature for more than 1 hour after collection without the addition of preservative may yield inaccurate results because of changes in pH, bilirubin or urobilinogen concentration, glucose levels, and bacterial contamination.
6. Allow any refrigerated specimens to come to room temperature before proceeding.	Specimens that are colder than room temperature may exhibit crystallization of amorphous urates or phosphates, which can interfere with measurement of all the physical characteristics of the urine specimen.

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Procedure	Rationale
7. Mix specimen well.	Urine specimens must be mixed well to judge their color and appearance accurately, as well as the specific gravity reading. Without mixing, the formed elements in the specimen will settle to the bottom of the container and may not be considered when determining whether a specimen has an abnormal color or clarity. These substances will also not be reflected in the specific gravity reading.
8. Observe the color of the specimen by visual observation. Report as straw, light yellow, yellow, dark yellow, or amber.	The terms used to describe specimen color need to be standardized throughout the laboratory.
9. Place a printed piece of paper behind the specimen to measure the clarity. Report as clear, hazy, cloudy, or turbid.	Abnormal urine appearance may be linked to a pathological condition. Use of standardized terms is important throughout the laboratory.
10. Pour a small amount of the urine specimen (less than 50 mL) into a transfer tube that has been labeled with the patient's name and/or ID number.	The urine specimen may need to have a culture performed on it; this decision is often not made until the routine urinalysis has been completed. By pouring off specimen into a transfer tube rather than inserting the pipette directly into the urine container, contamination is avoided.
11. Using distilled water, verify the function of the refractometer: **a.** Open the refractometer cover and place one drop of distilled water on the prism under the cover using a clean transfer pipette. **b.** Close the cover, and verify that the sample has spread over the entire prism surface. **c.** Look at the scale through the eyepiece; bright light in the vicinity helps with visualization. **d.** Read the scale where the line intercepts it. This is where the colors change with a sharp line of division. **e.** Wipe the sample away from the face of the prism with a Kimwipe laboratory tissue and water.	The refractometer should read 1.000 when the specific gravity of distilled water is tested. If this is not the reading achieved, follow the manufacturer's directions for calibration of the refractometer before testing the urine specimen. 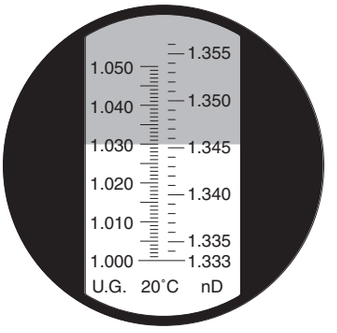 Read the scale where the boundary line intercepts it.

Continued

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Procedure 20-1: Observation and Documentation of Urine Physical Properties—cont'd

Procedure	Rationale
12. Following laboratory protocol, test a quality control specimen using the refractometer. Use the same procedure outlined in step 10. Chart the results on the quality control log.	The frequency of the quality control measurement will be dependent on the number of tests performed in most laboratories. Be certain that the quality control material reading falls within the acceptable range; if the results are outside the acceptable range, do not use the refractometer for testing the specific gravity of the urine specimen until the accuracy of the instrument has been verified.
13. Using a clean transfer pipette, place one to two drops of the urine specimen (from the transfer tube) on the face of the prism. Following the procedure outlined in step 10 above, read the specific gravity of the specimen.	Reference ranges for urine specific gravity are approximately 1.005 to 1.030.
14. Dispose of the urine left in the transfer tube by pouring it down the sink and flushing it with plenty of water. Dispose of the tube and transfer pipette used for the urine in a biohazard disposal bag. If the urine is not to undergo additional testing immediately, refrigerate it or preserve it accordingly.	
15. Clean the instrument using distilled water and a Kimwipe.	Do not allow the urine specimen to dry on the prism. Do not use harsh cleaners or abrasives to clean the prism or it will become scratched and unusable. Refer to the manufacturer's instructions for more cleaning procedures.
16. Remove gloves and sanitize hands.	Gloves should always be removed immediately after a procedure is performed. Hand sanitization is appropriate before and after gloves are worn.
17. Document results for patient specimen on the chart (if available) and testing log sheet. Be certain to use the correct digits for the documentation.	Documentation needs to occur immediately after the specimen testing is complete.

Date	
10/24/2013	Urine color: yellow, Clarity: clear, Specific gravity: 1.015
11:58 a.m.	Connie Lieseke, CMA (AAMA)

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- *Insufficient specimen volume:* There must be a minimum of 12 to 15 mL of urine submitted for a routine urinalysis to be performed.
- *Use of nonstandardized terms for reporting:* Although there may be various terms used to describe the color and/or clarity of the urine specimen, all laboratory personnel must use the same standard terms within their institution. This allows for normal ranges to be established, and is important when reporting results.
- *Lack of personnel training:* Although the assessment of the urine physical properties is a relatively simple process, there must be documented training for those who perform this task.
- *Use of noncalibrated equipment:* Refractometers must be calibrated regularly using distilled water, and quality control materials should be tested to verify that they are working appropriately.

Test Your Knowledge 20-9

A medical assistant performing urinalysis reported the urine clarity for a specimen as partly hazy. If the laboratory where she works uses the same criteria as that noted in this textbook for specimen clarity, is this the correct way to report this test result? (Outcome 20-8)

SUMMARY

The physical examination of urine will provide information about the color, clarity, and specific gravity of the specimen. Occasionally, an unusual odor may also be noted during this part of the urine analysis. Results that are outside the reference range for these physical characteristics may be the result of pathological conditions, or they may be caused by medication use or ingestion of certain foods. Accurate results must begin with a specimen that has been collected properly, identified appropriately, and preserved or refrigerated within 2 hours of collection. When reporting the color and clarity of a specimen, it is important to use terms that have been approved by the facility so that the reporting methods are standardized. Instruments used for specific gravity readings must be calibrated and quality control material must be tested at regular intervals to verify the accuracy of the measurement. Medical assistants must also be aware of potential sources of error when performing an assessment of the physical properties of a urine specimen to avoid inaccurate results.

TIME TO REVIEW

1. Which of the following words is used to describe blood in the urine? Outcome 20-1
   a. Glycosuria
   b. Hematuria
   c. Pyuria
   d. Oliguria
2. Which of the following words is used to describe a slightly cloudy urine specimen? Outcome 20-1
   a. Hazy
   b. Clear
   c. Turbid
   d. Amber
3. Which of the following is an instrument used to measure the specific gravity of a urine specimen? Outcome 20-1
   a. Hemoglobinometer
   b. Urochrome meter
   c. Refractometer
   d. None of the above
4. Which of the following may cause urine specimens to exhibit an abnormal color? Outcome 20-2
   a. Ingestion of rare meat
   b. Ingestion of broccoli
   c. Aspirin use
   d. Ingestion of fresh beets
5. Which of the following is used to describe urine clarity when the specimen has particulate matter suspended in it? Outcome 20-3
   a. Hazy
   b. Cloudy
   c. Turbid
   d. All of the above
6. A urine specimen with an ammonia-like odor may be caused by: Outcome 20-4
   a. Bacteria in the specimen
   b. Asparagus ingestion
   c. Multivitamin use
   d. Dye studies
7. A urine specimen with a specific gravity reading of 1.035 will demonstrate: Outcome 20-5
   a. High levels of dissolved substances
   b. Low levels of dissolved substances
   c. An amber color
   d. A foul odor

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8. Which of the following is not a potential source of error for urine testing? Outcome 20-8
   a. A urine specimen received without a patient name
   b. Observation and documentation of urine color and clarity upon specimen receipt
   c. Observation and documentation of urine color and clarity immediately after taking the specimen from the refrigerator
   d. Use of a container that was not provided by the laboratory for the urine collection

Case Study 20-1: Too much to do

Cindy Collier, CMA (AAMA), is working in the office laboratory for a busy internal medicine clinic. She is about to perform a urinalysis on a specimen that was collected from a patient who is in to see the physician because of blood in her urine. Cindy verifies the identification on the specimen and places it on the counter in the laboratory area. Before she has a chance to do anything else, she is called away to perform a venipuncture and PT/INR on another patient. Approximately 1 hour later, Cindy hurries into the laboratory so that she can start to analyze the urine specimen. She picks up the cup, and documents that the specimen is clear and appears yellow in color. She also notes that there is a red "ring" around the bottom interior of the cup.

1. What did Cindy forget to do before assessing the color and clarity of the specimen?
2. Is her assessment of the specimen's being yellow and clear a correct result for this specimen?

RESOURCES AND SUGGESTED READINGS

Clinical and Laboratory Standards Institute, Urinalysis: Approved Guideline, ed. 3. CLSI document G16-A3. Wayne, PA, 2009
Approved laboratory standards for collecting, processing, and testing urinalysis samples

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Chapter 21

Chemical Examination of Urine and Feces

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Urine Analytes and Their Clinical Significance
- Bilirubin
- Blood
- Glucose
- Ketones
- Leukocytes
- Nitrite
- pH
- Protein
- Urobilinogen
- Specific Gravity

Potential Sources of Error
Safety Precautions
Quality Control Procedures
Urine Testing Methods
Confirmatory Urine Testing
Fecal Occult Blood Testing
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

21-1 Define the key terms.

21-2 Differentiate various disease states related to abnormal urine chemistry results.

21-3 Identify abnormal values for the analytes tested with urine chemistry analysis.

21-4 List potential sources of error for urine chemistry testing, and describe how these errors may be avoided.

21-5 Describe appropriate safety precautions implemented when testing urine.

21-6 Compare the testing methods available for urine chemistry analysis.

21-7 Perform CLIA-waived urine chemistry analysis using a manual and an automated testing method.

21-8 Provide examples of confirmatory tests performed on urine specimens.

21-9 Explain the importance of fecal occult blood testing.

21-10 Detail the necessary patient preparation for fecal occult blood specimen collection.

21-11 Perform a CLIA-waived fecal occult blood test.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P.III.2. Practice Standard Precautions
I.P.I.14. Perform Urinalysis

ABHES Standards

- Apply principles of aseptic techniques and infection control.
- Use standard precautions.
- Perform CLIA-waived tests that assist with diagnosis and treatment, Urinalysis.
- Instruct patients in the collection of a fecal specimen.

KEY TERMS

Acidosis	Hematuria	Microalbuminuria
Alkalosis	Hemoglobinuria	Multiple myeloma
Bence Jones protein	iFOB	Myoglobin
Bilirubin	Intravascular lysis	Myoglobinuria
Conjugated bilirubin	Jaundice	Nitrite
Fecal occult blood testing (FOBT)	Ketones	Proteinuria
Glucosuria	Ketonuria	Semiquantitative
Glycosuria	Leukocyte esterase	Sulfosalicylic acid precipitation test
Guaiac method	Leukocytes	Urobilinogen

The chemical testing of urine specimens is the second component included in a complete urinalysis. There have been numerous changes to chemical urine testing procedures through the years, and the most significant changes occurred with the development of reagent test strips. Since the 1950s it has been possible to test numerous chemical analytes at once with disposable reagent test strips. These strips are made of a plastic with absorbent pads attached. (An example is shown in Fig. 21-1.) The pads are impregnated with various chemicals, and each pad is designed to change color as it reacts with a specific analyte present in the urine specimen. The resulting colors on the pads are interpreted by comparing the individual pad to a chart supplied with the reagent strips. An example of a chart used for comparison is shown in Figure 21-1. By comparing the color changes with the reference chart it is possible to perform a **semiquantitative** measurement, providing an approximate value for each of the chemicals being tested. The results may be reported as the milligrams per deciliter present, or by using a semiquantitative reporting method of trace, 1+, 2+, 3+, or 4+. Some of the results may also be reported as positive or negative, which is an example of a *qualitative* test result.

URINE ANALYTES AND THEIR CLINICAL SIGNIFICANCE

A routine urinalysis usually includes testing for bilirubin, blood, glucose, ketones, leukocytes, nitrites, pH, protein, and urobilinogen. The reagent strips most commonly used include testing for specific gravity as well. Many of these chemical substances are normally present in the urine specimen, but the amount of the individual analyte present may change with certain disease states. Other chemicals are not present in the urine specimen normally, and their detection may

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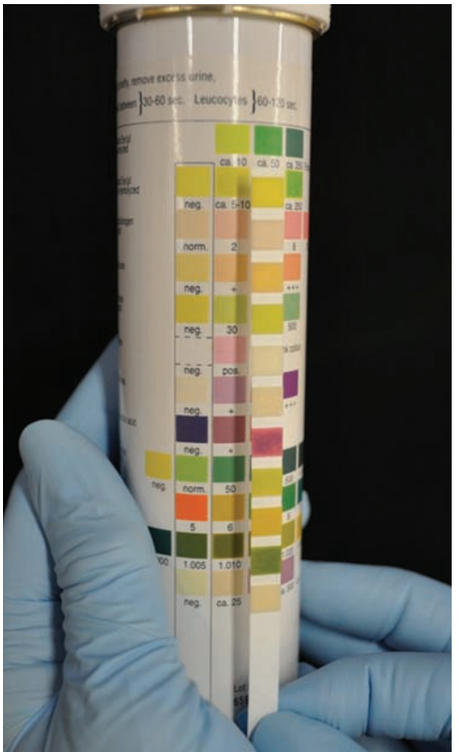

Figure 21-1 Urine chemical reagent testing strip and chart used for comparison when reading urine chemical reagent strip results.

be clinically significant. Chemical analysis of urine specimens may detect dysfunction of carbohydrate metabolism, pH imbalances, red blood cell hemolysis, and liver or kidney problems. The performance of urine chemical testing in the physician office laboratory is beneficial for the patient because abnormalities are quickly detected and appropriate treatment or follow-up testing can be taken care of immediately while the patient is still in the presence of the health-care provider.

There are two primary manufacturers for urine reagent strips. Multistix is manufactured by Siemens Medical Solutions Diagnostics, and Chemstrip is manufactured by Roche Diagnostics. The strips are available with various types of reagent pads, depending on the needs of the health-care provider ordering the urine tests. If testing is performed with an automated system, there may be a recommendation for one brand rather than the other. The manufacturer's insert will include instructions for use and will also include interfering substances for each analyte.

Test Your Knowledge 21-1

True or False: All analytes tested by the urine reagent strips are present in measurable quantities in a normal urine specimen. (Outcome 21-3)

Bilirubin

Normally, **bilirubin** is not present in the urine. The presence of bilirubin in the urine specimen may be an early indication of liver disease or bile obstruction. Bilirubin is a by-product of red blood cell destruction. As red blood cells are broken down at the end of their 120-day life cycle, hemoglobin is released. This decomposition of red blood cells occurs in the spleen and liver. As the hemoglobin molecules released from the red blood cells degrade further, they are split into smaller components. Bilirubin is created from hemoglobin as part of this degradation process. To travel through the bloodstream, bilirubin must be carried by molecules of albumin (a type of protein) because the bilirubin is not water soluble. The bilirubin-albumin molecule is too large to enter the urine within the kidneys. Instead, the bilirubin-albumin complex is returned for processing in the liver, where the bilirubin becomes water soluble and is separated from the albumin. This water-soluble bilirubin is called **conjugated bilirubin.** Conjugated bilirubin is not usually detected in the urine because it is passed from the liver directly into the bile duct to be secreted into the intestines. The intestinal bacteria further alter the bilirubin, changing it into a compound known as **urobilinogen.** Bile obstruction may lead to the presence of conjugated bilirubin in the urine, and liver dysfunction may also cause bilirubin to be detected in the urine specimen.

Bilirubin is has a strong yellow-orange color. When it becomes elevated in the bloodstream, the patient's skin, sclera of the eye, and plasma reflect this intense yellow color, known as **jaundice.** Excessive hemolysis, liver dysfunction, or bile obstruction may cause jaundice. Just as the bilirubin is elevated in the bloodstream with bile obstruction or liver dysfunction, the levels may also be elevated in the urine specimen, allowing for detection with a chemical analysis.

Test Your Knowledge 21-2

What clinical dysfunction will cause a urine specimen to test positive for bilirubin? (Outcome 21-2)

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Blood

There are three reasons that a urine sample may show a positive result for blood. The presence of intact red blood cells, known as **hematuria,** will cause a positive reaction. Hematuria will often present with a cloudy, red urine specimen with large amounts of red blood cells present. Microscopic examination of the urine specimen will detect red blood cells in the urine sediment.

The presence of hemoglobin without the presence of intact red blood cells **(hemoglobinuria)** will also cause a positive result for blood in a urine sample. Hemoglobinuria may be the result of red blood cell lysis that occurs in the urinary tract, or it can be caused by **intravascular lysis,** which is the breakdown of red blood cells within the vessels. Intravascular lysis occurs in hemolytic transfusion reactions. Hemoglobinuria may also be present with severe burns, malaria, hemolytic anemias, or with some spider or snake bites that cause hemolysis within the blood vessels. The presence of blood in the urine specimen is not normal, except in the case of specimen contamination with menstrual blood or trauma caused by catheter insertion.

Finally, the presence of **myoglobin** in the urine, known as **myoglobinuria,** will result in a positive result for blood. Myoglobin is present in muscle tissues, where it serves as an oxygen-storing molecule. When present in urine, it may cause the urine to appear red-brown in color, but the specimen clarity will remain clear. Myoglobin may be present in the urine when there is trauma to the muscles, convulsions, alcoholism, electrocution, or excessive exercise. Myoglobin is actually toxic to the kidneys; therefore, high amounts present in the urine may be an indicator of concurrent kidney damage. There are many testing methods and comparisons between urine and plasma that may differentiate a positive urine blood result due to hemoglobin from one that is due to myoglobin, because there are very few intact red blood cells present in the urine in both cases.

Test Your Knowledge 21-3

Which of the following will result in a positive test for blood in the urine specimen?

a. Intact red blood cells
b. Elevated levels of iron in the blood
c. Pus in the urine
d. None of the above (Outcome 21-3)

Glucose

The presence of glucose in the urine is not a normal result. Blood glucose is normally regulated through hormonal changes and kidney function, including the reabsorption of almost all the glucose filtered out by the glomeruli. However, when the blood glucose concentration becomes excessively elevated (at levels between 160 and 180 mg/dL) the glucose concentration is too high for most of it to be reabsorbed by the tubules, and the glucose "spills" into the urine. **Glycosuria** is a word used to describe the presence of sugar in the urine; **glucosuria** is used when the sugar in the urine is identified as glucose. Glucose is the most common cause of glycosuria, and most reagent strip methods test positive only in the presence of glucose; they do not react with other sugars. However, galactose, lactose, fructose, and pentose are other sugars that may be present in the urine. Point of Interest 21-1 provides more information about additional test procedures that may be performed on the urine specimen to allow for detection of sugars other than glucose. Elevated levels of galactose in the urine of infants may be indicative of a serious condition that needs immediate intervention; therefore, alternative testing methods are often used for urine testing on infants to provide an opportunity to detect galactosuria.

Urine glucose testing can be an invaluable part of diabetes screening. Because the symptoms of diabetes are not clearly defined and do not present themselves in the same way for each individual, there are many patients who are unaware that they are diabetic. For this reason, glucose testing is one of the most common tests performed on urine specimens. Because the blood glucose concentration can fluctuate throughout the day, urine glucose testing done for the purpose of diabetes screening should be performed on fasting specimens. Diabetic patients may also use urine glucose testing to monitor their disease progress; this testing is usually performed on postprandial specimens. Glucosuria may also be present when the reabsorption of the kidney tubules has been compromised, as in the case of renal failure.

Test Your Knowledge 21-4

True or False: All diabetic patients will have a positive urine glucose result at all times. (Outcome 21-2)

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POINT OF INTEREST 21-1
Galactosemia

The glucose test pad on the urine chemical reagent strip is specific for glucose only; other types of sugars that may be present in the urine are not detected by the enzymatic chemical reaction that occurs when this pad is exposed to the urine specimen. However, for infants, this reagent pad test does not provide enough information. Urine specimens that test negative for an infant should have an additional test performed that will detect other types of sugars that may be present in the urine. When an infant ingests lactose (a type of sugar commonly found both in breast milk and formula), the lactose interacts with a naturally occurring enzyme, lactase. Lactase splits the lactose molecule into two smaller sugar molecules, glucose and galactose. Glucose is easily used by the body for energy, but galactose must be metabolized further before the body can make use of it. Hereditary galactosemia is a condition in which the infant is not capable of metabolizing the galactose. The galactose levels in the bloodstream begin to climb, causing initial symptoms of convulsions, irritability, lethargy, poor weight gain, jaundice, and vomiting. If the elevated levels of galactose continue to increase, the liver, brain, kidneys, and eyes may be affected irreversibly. Detection of galactosemia within the first few days of life is critical, as the treatment involves the complete removal of this sugar type from the diet, and these changes must begin immediately.

To ensure that elevated levels of other sugars such as galactose (also known as reducing substances) are detected in urine specimens for infants, an alternate form of testing is used. The Clinitest test manufactured by Bayer Corporation uses a copper reduction testing method, in contrast to the enzymatic method used on test strip reagent pads. The copper reduction test method will detect the presence of all types of sugar, not just glucose. In this test, a few drops of the urine specimen are mixed with a few drops of water, and a reagent tablet is dropped into the tube. A violent reaction ensues, and the resulting color of the mixture in the tube is compared to a chart (provided with the tablets) to interpret the amount of reducing substances present in the specimen. If the test result for the Clinitest is positive, it is assumed that the sugar present is not glucose, as this would have also caused a positive result on the reagent pad reaction.

Care should be taken when performing the Clinitest procedure. Gloves, eye protection, and skin protection need to be worn, as the reaction that occurs within the tube involves boiling the mixture and it is possible to cause damage to the skin, eyes, or mucous membranes. It is important to dispose of the mixture properly as well, as it contains sodium hydroxide and citric acid. The procedure and precautions outlined in the package insert should be followed carefully.

Ketones

Ketones are a product of fat metabolism, and their presence in urine is not considered a normal result. When fat is metabolized, the process usually continues to the point at which the ketones are fully broken down and undetectable. However, if the glucose in the body cannot be readily used for energy, then fat metabolism is increased, and ketones may be present in the blood and in the urine. Uncontrolled diabetes mellitus, malabsorption syndromes, excessive reduction in carbohydrate intake, and vomiting may all lead to the presence of ketones in the urine **(ketonuria)** because these conditions don't allow glucose to be used efficiently as a source of energy.

The word *ketones* is used to describe three different products released into the bloodstream as fat is metabolized: acetone, acetoacetic acid, and beta-hydroxybutyric acid. Reagent strips test specifically for acetoacetic acid. The other two ketone types are actually created by acetoacetic acid, so detection of this compound will provide a clinically significant result, indicating the presence of any type of ketone product.

Urine ketones are often monitored in patients with type 1 diabetes mellitus. When the body does not have enough insulin, the glucose present in the bloodstream cannot be used, and the body will begin to metabolize increasing amounts of fat for energy. If the ketones can be detected early (in the blood and in the urine), the patient may be aware of an impending crisis and the dosage of insulin can be regulated to allow for more efficient glucose metabolism.

Leukocytes

Leukocytes are white blood cells. Their presence in the urine in small amounts is not an abnormal result, but when the number of leukocytes becomes elevated, it is indicative of inflammation or infection of the urinary

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tract. Reagent strips test for the presence of **leukocyte esterase,** a substance present in granulocytic white blood cells (those that have granules in their cytoplasm), such as neutrophils, basophils, and eosinophils. Leukocyte esterase is also present in monocytes. Neutrophils are the white blood cell type that is most commonly elevated in urinary tract infections. Leukocytes may be visualized with microscopic examination of the urine, but because leukocyte esterase is present even with lysed white blood cells, the presence of leukocytes in the urine specimen may be overlooked if only the microscopic results are considered in the patient assessment.

Test Your Knowledge 21-5

True or False: The leukocyte esterase result will always be positive when white blood cells are present in the urine specimen. (Outcome 21-3)

Nitrite

Some types of bacteria are capable of converting nitrate, which is normally present in urine, to **nitrite,** which is not usually detectable. *Escherichia coli*, which is the most common cause of bacterial urinary tract infection, is capable of producing nitrites. Many other gram-negative organisms are also capable of this conversion, such as those of the *Klebsiella, Proteus,* and *Serratia* genera. A positive nitrite result is indicative of the presence of bacteria in the urine. However, there are two factors that must be considered when interpreting this result. First of all, not all bacteria are capable of converting nitrate to nitrite, so a negative result does not necessarily mean that the specimen is bacteria free. Second, the bacteria must be present in the urine specimen long enough to accomplish the conversion, and this usually takes 4 to 6 hours. If a nitrite test is to be used as a screening tool for a potential urinary tract infection, a first morning void specimen should be used for the test, because the urine collected with this type of specimen has been in the bladder all night with the bacteria, allowing for an opportunity for the conversion to occur. Specimens collected at other times of the day may or may not have been in the bladder for a long enough period of time for this result to be a positive one, even if the bacteria present are capable of converting nitrate to nitrite.

pH

The pH of normal freshly voided urine may vary from 4.6 to 8.0. The abbreviation pH stands for "parts hydrogen," and the pH of a substance is the measurement of how acidic or alkaline that substance is, based on the concentration of hydrogen ions present. The lungs and the exchange of ions in the urinary tubules of the kidneys primarily control the pH of the human body. The pH of the blood must be maintained between 7.35 and 7.45.

Urinary pH may be abnormal when the body is in a state of **acidosis** (a blood pH of 7.35 or below) or when the blood pH is elevated above 7.45 (known as **alkalosis).** Metabolic issues not related to kidney function may cause an abnormal urine pH. Kidney dysfunction may also lead to alkaline or acidic urine because the exchange of ions occurs in the renal tubules. Medications or nutritive supplements may be used for patients with chronic urinary tract infections to keep the urine slightly acidic, as this environment is not supportive of bacterial growth. This may cause urine pH results that are outside of the normal range, but will not necessarily be interpreted as abnormal for the patient who is undergoing treatment.

Protein

The presence of protein in the urine **(proteinuria)** is most commonly associated with renal disease. A positive result for protein does not always indicate kidney damage, but there should always be additional testing performed to determine whether the proteinuria is indicative of a pathological condition. Normal urine has very little protein present, as most protein molecules are not allowed to enter the urine through the glomerulus because the molecules are too large to leave the plasma. Any that are filtered out are usually reabsorbed by the renal tubules and are not present in the urine specimen.

Protein may be present in the urine when there is no renal disease or damage. This occurs when the total protein level of the plasma is elevated. This elevation is the result of the increased presence of small protein molecules in the plasma that are capable of passing through the pores in the glomerulus. The kidneys will filter out the excess protein, but when they have reached their capacity for protein reabsorption in the renal tubules, protein will be present in the urine specimen. Muscle trauma, fever, or excessive intravascular hemolysis will elevate the blood protein levels. This is usually a transient result that will not continue once the underlying condition has been resolved.

Patients with **multiple myeloma** (a cancer of the bone marrow) may present elevated amounts of **Bence Jones protein** in their plasma. This specific type of

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protein will be filtered out of the blood, and when the tubular reabsorption capacity has been surpassed, Bence Jones protein will be present in the urine specimen. It is possible to differentiate Bence Jones protein from other types of protein by taking advantage of the different reaction of this specific type of protein when exposed to heat. The Bence Jones protein will coagulate (clump up) when exposed to temperatures between 40°C and 60°C, but it will dissolve back into the solution when exposed to temperatures of 100°C. Other proteins will coagulate at a similar temperature, but will not dissolve at the higher temperatures. The absence of Bence Jones protein in the urine is not a valid means of ruling out multiple myeloma, as many patients with this disease do not excrete levels high enough to be detected in the urine specimen. Protein electrophoresis is a more specific test used for diagnosis.

The most common type of protein present in the urine as a result of damage to the kidneys is albumin. It may be indicative of damage to the glomeruli or to the renal tubules. The presence of albumin may be a transient condition, as in the case of strenuous exercise or dehydration. Patients with hypertension may also present with proteinuria. Positive protein tests in pregnant women (especially in the last trimester of pregnancy) may be indicative of preeclampsia, a serious condition that must be treated immediately. **Microalbuminuria,** or the chronic presence of small amounts of albumin in the urine, is a common occurrence in diabetic patients. It is an indication that the glucose levels in the blood are not stabilized, and the increased workload required of the kidneys to filter out these large molecules has caused the glomeruli to become damaged. The damaged glomerulus allows protein molecules to leak into the urine specimen, presenting as microalbuminuria.

Most reagent strips detect only the presence of albumin. If other types of protein are suspected, it may be necessary to use other testing methods to detect their presence. The **sulfosalicylic acid precipitation test** (SSA test) is a test that will detect all forms of protein in the urine specimen. In this procedure, 3 mL of 3% sulfosalicylic acid is added to an equal volume of centrifuged urine. The specimen is mixed well with the acid, and the degree of turbidity (cloudiness) is measured. The grade or degree of turbidity is correlated to the probable amount of protein present in the specimen. This test may be useful when there is color interference in the urine specimen and a protein test is desired, or when the urine specimen has a very alkaline pH, as this can interfere with the reagent strip results for protein.

Test Your Knowledge 21-6

Which of these are nonpathogenic causes of proteinuria?

a. Fatigue
b. Fever
c. Vomiting
d. Ingestion of red meat (Outcome 21-3)

Urobilinogen

The presence of a small amount of urobilinogen in the urine is normal. However, increased levels may be indicative of liver disease (such as hepatitis or cirrhosis) or hemolytic disorders. Urobilinogen is produced in the intestines by the intestinal bacteria as bilirubin is broken down. Once formed, either it will be reabsorbed into the bloodstream (where it will eventually pass through the kidneys) or it may be excreted in the feces. Some of the urobilinogen in the intestines is further broken down by intestinal bacteria to form urobilin, a pigmented substance that adds color to feces. Urine urobilinogen levels may be elevated because the liver is incapable of processing the urobilinogen in the blood or because there are elevated levels of bilirubin present. In the case of bile duct obstruction, the urine will be positive for bilirubin, but the urobilinogen levels will be normal. Hemolytic diseases may produce a negative bilirubin result with a positive urobilinogen reaction.

Specific Gravity

The clinical significance of the specific gravity test is presented in Chapter 20, as well as several testing methods that are used for specific gravity measurements. Specific gravity tests may be useful in monitoring the hydration status of patients or to measure the ability of the renal tubules to concentrate the urine specimen as needed. The specific gravity pad on the reagent strip takes advantage of the increased amount of ions present in urine specimens having higher concentrations. The greater the number of ions that are present in the urine, the more the color changes when exposed to the specimen. The specific gravity reagent pads are usually sensitive from 1.000 to 1.030 and are semiquantitative. The results may be inaccurate with alkaline urine specimens (falsely decreased results) or when high concentrations of protein are present in the urine specimen (falsely elevated results).

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POINT OF INTEREST 21-2
CLIA-waived drug screening tests

Many employers now require their potential employees to have a urine drug screening test performed prior to an offer of employment. These drug screening collections are becoming a common part of the duties for medical assistants and phlebotomists in many offices. In some cases, the drug screenings may be federally mandated. Other employers have developed a drug screening policy to keep the workplace safer. If a drug screening collection is ordered by an employer, the medical assistant will be involved in the collection process, and a chain of custody will be started to document the transportation of the specimen until it is tested in a reference laboratory that specializes in this type of testing. This process requires specific training and a great deal of attention to detail. The employment status of the client depends on these results.

Urine drug screenings may also be ordered to check for illegal drug use in patients for whom this is suspected as part of their clinical diagnosis. These tests may be performed in the office, using CLIA-waived urine drug screening kits. They are available to test for many different drugs of abuse, such as marijuana, cocaine, amphetamines, opiates, oxycodone, and PCP. These tests are generally performed by applying the urine specimen to a reagent stick that will change color if the metabolite of that specific drug is present. In addition, employers who would like to have immediate results may ask for a quick screening test to be performed in the office using these CLIA-waived kits. This is not always conclusive; sometimes the patient may be taking prescription drugs that will cause the screening tests to be positive, because the urine tests are designed to identify the metabolites (breakdown products) of the drug that was ingested, not the drug itself. If a patient has a positive result, it is imperative to follow the office protocol for sending out the specimen for confirmatory testing.

A urine drug screening test may not always detect the presence of the drugs in the system even if the patient has been exposed recently. Each drug has a different time interval for which it can be detected. This can vary depending on the amount of exposure, the size of the individual, his or her unique metabolic rate, the pH of the urine specimen, and the type of drug. Drugs that are lipid soluble (such as marijuana) are detectable for longer periods of time than are many other drugs that are considered to be more dangerous. The product literature for the CLIA-waived testing kit used in the office should be consulted for more information about the sensitivity of the test. Some facilities now request testing of hair samples, as the retention time for the drug in the hair follicles is much longer than its presence in the urine. There are currently no CLIA-waived procedures for hair testing.

In addition, if the urine specimen is very dilute, it is possible that the test may be falsely negative. Most offices that perform drug screening collections and/or testing will have established policies in which specimens that are too dilute will need to be recollected. This decision is based on the specific gravity value of the specimen.

Another CLIA-waived test that may be requested by employers and/or health-care providers tests for the presence of alcohol by testing a saliva sample. Orasure Technologies manufactures a CLIA-waived quantitative saliva alcohol test. If an employer suspects that an employee has been ingesting alcohol while at work, that employer may request this test be performed as a screening tool. A blood alcohol test would be more sensitive, and may also be requested. This would require testing at a reference or hospital laboratory, as there are no CLIA-waived tests available to screen blood for alcohol.

POTENTIAL SOURCES OF ERROR

Some of the most common errors encountered while performing urine chemical testing are the following:

- *Incorrect specimen labeling:* Urine specimens must have the labels affixed to the specimen container, not to the lid of the container. Lids may be removed from multiple specimen containers at once, allowing for confusion when attempting to identify the correct patient name for each specimen. Labeling errors also include specimens that are mislabeled or not labeled at the time of collection.
- *Improper storage:* The reagent strips must be protected from direct light, moisture, and excessive heat. They should also not be stored in an area near volatile liquids, as the pads on the strip may absorb some of the chemicals present in the environment. Strips should not be removed from the bottle until just before use, and the desiccant provided needs to remain in the bottle of strips until they are all used. If the reagent strips

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are exposed to moisture, they will become discolored and must be discarded. The lid for the bottle must be replaced immediately after removing reagent strips. The bottles are to be stored at room temperature, and care should be taken not to use the strips after the expiration date printed on the bottle. Reagent strips should never be cut in half or altered in any way.

- *Improper technique:* The manufacturer's instructions state that the urine reagent strip is to be dipped completely into a well-mixed specimen and removed immediately. Excess urine is to be removed from the strip by sliding the edge of the strip along the side of the container as it is withdrawn from the specimen. Inaccurate results are produced when the reagent strip is allowed to remain in the urine for an extended period of time, as the chemicals in the reagent pads will erode, contaminating the urine specimen to produce inaccurate color changes. Once the strip is removed from the urine, it is recommended that any excess urine still present be blotted away with an absorbent pad. Also, many formed elements in the urine specimen will settle to the bottom of the container if the specimen is not well mixed, allowing for potential false-negative results when the strip is inserted into the specimen.
- *Incorrect timing of reactions:* Incorrect timing of reactions is probably the most common error in reagent strip analysis. Each brand of test strips will specify how long the urine should remain in contact with the testing strip before the result is to be read by observing the color change on the pad. This time varies among tests, but all test pads should usually be read within 120 seconds. Unfortunately, the person performing the test commonly dips the reagent strip into the urine specimen, but doesn't follow the timing recommendations when reading the results. This results in an inconsistency within the laboratory and may lead to false-positive test results because of increased reaction times, or false-negative test results because of inadequate reaction times.
- *Incorrect result interpretation:* The reagent strips and color charts used to read the reactions are not interchangeable among manufacturers. For manual procedures, it is important to line up the reagent strip appropriately to the color chart used for comparison, and to report the analyte using the units and reporting methods suggested by each manufacturer. Some tests are reported as qualitative results in which the result is either positive or negative, whereas other tests are reported using a scale of 1+, 2+, and so on. Other analytes are reported using units of measurement, such as 20 mg/dL.
- *Test interference:* Because every reagent pad on the test strip is impregnated with a different chemical, each pad may be affected by different types of interfering substances. Urines that are very alkaline may interfere with several of the pads, as will strong colors (such as those with Pyridium [phenazopyridine] use), the presence of detergents or antiseptics, or high specific gravity. High levels of ascorbic acid (vitamin C) may cause false-negative results for blood, glucose, bilirubin, nitrite and leukocyte esterase. The presence of menstrual blood may cause false-positive results for blood that are not clinically significant. Many diagnostic dyes and medications also can cause interference for some of the testing methods. The manufacturer's insert will provide more detailed information about interfering substances for the various tests.
- *Incorrect urine storage or preparation:* Although this is not technically a potential source of error only for reagent strip testing, it is a common problem that can affect all the urinalysis results. Urine samples should be refrigerated, tested, or properly preserved within 1 hour of collection. Urine that is allowed to remain at room temperature for extended periods of time can undergo chemical changes that were not present at the time of collection.
- *Failure to perform maintenance, calibration, or quality control:* Whether the method used in the laboratory is manual or automated, quality control testing should at least be performed at the frequency specified by the manufacturer. In addition, automated instruments have requirements for calibration and maintenance, and these recommendations must be followed and documented appropriately.

Test Your Knowledge 21-7

What are three ways that reagent strips can be handled incorrectly? (Outcome 21-4)

Test Your Knowledge 21-8

Which of these is an example of an improper urine chemistry testing technique that may affect results?

a. Performing the test without wearing gloves
b. Allowing the reagent strip to remain in the urine for 60 seconds before removal
c. Mixing the specimen just prior to testing
d. Allowing the urine specimen to reach room temperature before testing (Outcome 21- 4)

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SAFETY PRECAUTIONS

Urine is not considered to be an infectious agent for HIV and other bloodborne pathogens unless it is visibly contaminated with blood. However, it may still be infectious because it is contaminated with other microorganisms, such as bacteria. Mucous membrane exposure is the route of infection most reasonably anticipated for urine specimens being tested for chemical analytes, because of the potential for splashing the urine into the eyes or mouth as the specimen is handled. Standard precautions should be used when handling urine specimens, and appropriate actions should be taken to avoid splashing, spilling, or formation of aerosols when handling the urine specimen. Application of standard precautions for urine specimens include the following:

- Appropriate hand hygiene procedures before and after application of gloves. Also, if accidental exposure to bare skin does occur, this site should be disinfected as soon as possible.
- Glove use when performing testing procedures. Gloves should be removed when leaving the testing area and approaching a clean area of the laboratory or physician office.
- Wearing of long-sleeved, fluid-resistant laboratory coats that are completely buttoned or snapped.
- Occlusive dressings or bandages used over broken skin.
- Use of eye protection and/or face shield when exposure is anticipated.
- Nail biting, smoking, eating, drinking, or manipulating contact lenses is prohibited when handling urine specimens.
- Covering urine specimens before centrifuging.

Test Your Knowledge 21-9

What is the most common route of accidental exposure to urine specimens? (Outcome 21-5)

QUALITY CONTROL PROCEDURES

The chemical analysis of urine is a CLIA-waived testing procedure. This does not mean, however, that quality control is not an important part of the process. For instance, the package insert for the Bayer Multistix urinalysis test strips suggests that a positive and negative quality control should be tested whenever a new bottle of strips is put into use. This is a minimum frequency suggestion; individual laboratories may require that quality control samples be checked each day or each shift, depending on workload and/or laboratory policy. Most laboratories will require quality control testing daily. The frequency recommendation for automated urine chemistry testing may be different from the advice given for manual urine testing. There may also be unexpected situations (such as the exposure of the strips to extreme heat and/or cold) that will warrant quality control testing before patient specimens can be analyzed.

Commercial quality control materials are available for purchase. Examples of these include Lyphochek Quantitative Urine Control by Bio Rad, and KOVA-Trol (manufactured by Hycor Biomedical, Inc.). It is suggested that the positive control used for urinalysis procedures be a weakly positive specimen, so that the sensitivity of the testing process can be challenged. (Alternatively, three levels of control can be implemented to verify the sensitivity of the testing process.) It is important to note that water should never be used as a negative control because it does not really resemble urine enough to test the procedure. Some laboratories will freeze aliquots of positive and negative urine specimens to be used as quality control specimens; this is appropriate as long as the desired results are verified with multiple testing procedures and acceptable ranges are established for each test. Ideally, each laboratory will also participate in an external quality assessment survey to evaluate its performance as compared to other laboratories utilizing the same testing procedures. This is not a required component for CLIA-waived tests, but the comparison with other laboratories will allow for more confidence in the test results.

It is important to remember that patient testing should be performed only if the urine quality control results are within the acceptable range. If the results are not as expected, then patient results cannot be analyzed until the reason for the discrepancy has been identified. Troubleshooting steps may include using a new bottle of control material or using a new testing strip from a different bottle or lot number.

URINE TESTING METHODS

Urine reagent strip testing is considered one of the easiest laboratory tests performed. However, it is important to follow the instructions provided by the manufacturer precisely the way that they are written to ensure that the patient results are valid. The strips must be stored properly, and must not be exposed to moisture. Reagent strips must be discarded after their

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expiration date, and must be used only once. In addition, it is important to adhere to the instructions for timing the reactions and interpreting the results. The color changes for each test pad must be read individually at different time intervals, ranging from 30 to 120 seconds.

The manufacturer's insert for the reagent strips also provides information about potential causes of interference. An example is ascorbic acid (vitamin C), which can cause false-negative results for glucose, blood, and other substances on some reagent strips. Staff who perform chemical urine analysis need to be familiar with the package insert provided for the reagent strips used by their facility, and a copy should be available for reference at all times.

Reagent strips are also available to test for one or two chemical analytes, rather than the entire spectrum that is usually included in a routine urinalysis. Ketones and glucose are some of the most common analytes included on these limited test strips. These can be beneficial for those with type 1 diabetes or for monitoring pregnant women for potential gestational diabetes. Other test strips may be used to monitor protein and creatinine levels in the urine, which can help to detect kidney dysfunction in high-risk patients, or can be used to monitor the progress of kidney disease for patients who have already been diagnosed. Microalbuminuria may be detected by strips designed to pick up very low levels of protein in the urine. The presence of microalbuminuria is a significant factor in the progression of diabetes.

Test Your Knowledge 21-10

True or False: Urine reagent strips manufactured by different companies may be available with different test capabilities.

The reference values for urine chemical strips are the same whether the test is performed manually or by automation. These results are summarized on Table 21-1. It is important to remember that these reference values are obtained by following the manufacturer's instructions precisely; special attention should be given to the timing intervals for reading the results.

Automated urinalysis instruments are designed to read reagent strip reactions at the appropriate intervals. The results are usually printed out and can also be sent automatically through a computer interface for many instruments. The use of automated urinalysis instruments may help reduce errors by eliminating potential sources of error with the timing of reactions and the interpretation of color changes on the reagent pads. Some of the automated instruments are designed to read one strip at a time, whereas others are capable of processing numerous reagent strips at once. Bayer and Roche Diagnostics both manufacture automated urinalysis instruments, including the Bayer Clinitek models and the Roche Urisys instruments (Fig. 21-2). Various models are available from both of these manufacturers. Calibration and

TABLE 21-1
Reference ranges for urine chemistry results

Chemical Analyte	Normal Finding
pH	4.6–8.0
Protein	2–8 mg/dL (negative to trace)
Specific gravity	1.005–1.030
Leukocyte esterase	Negative
Nitrite	Negative
Glucose	Negative
Ketones	Negative
Leukocytes	Negative
Blood	Negative
Urobilinogen	0.1–1.0 mg/dL

Figure 21-2 Bayer Clinitek urine analyzer with printed results. *From Eagle, S, Brassington, C, Dailey, C, and Goretti, C: The Professional Medical Assistant: An Integrative, Teamwork-Based Approach. FA Davis, Philadelphia, 2009, with permission*

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maintenance are necessary for both of these machines, in addition to the testing of quality control specimens at specified intervals. Results are then recorded on a urinalysis report form (Fig. 21-3).

Test Your Knowledge 21-11

What is an advantage of automated urine chemistry testing procedures over manual testing procedures? (Outcome 21-6)

CONFIRMATORY URINE TESTING

Sometimes the color of a urine specimen may cause color interference with the reagent strip test pads, producing invalid results. It may then be necessary to perform other types of confirmatory tests to provide some reliable information to the practitioner. The following are the most common confirmatory tests performed:

- *Acetest* (Bayer Corporation): The Acetest is used to test for the presence of ketones in the urine specimen. These reagents may be used to test other body fluids if necessary. The Acetest tablet reaction is less affected by the inherent color of the urine specimen, and the color changes are less subtle than they are on the reagent pads on the urine dipsticks. The testing process requires a tablet and an absorbent pad.
- *Ictotest* (Ames Corporation): The Ictotest is used to detect the presence of bilirubin in the urine specimen. This procedure is more sensitive to the presence of bilirubin than the reagent pad test, and is affected less by the strong colors present in some urine specimens. The test involves a tablet and an absorbent pad.

CB LABORATORY

Urinalysis Report Form

Patient Name: _____ **Date:** _____

Patient ID: _____ **Time:** _____

Analyte	Result Observed	Reference Value
Glucose		Negative
Bilirubin		Negative
Ketones		Negative
Blood		Negative
pH		4.6 to 8.0
Protein		Negative to trace
Urobilinogen		0.1 to 1.0 mg/dL
Nitrite		Negative
Leukocyte esterase		Negative
Specific gravity		1.005 to 1.030

Comments: _____

Signature/Initial of Operator: _____

Figure 21-3 Urinalysis report form.

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Procedure 21-1: CLIA-Waived Chemical Examination of Urine Using Manual Reagent Strip Method

TASK

Performance of a CLIA-waived chemical examination of a urine specimen utilizing the manual reagent strip method.

CONDITIONS

- Gloves, laboratory coat, and protective eyewear
- Urine specimen freshly voided or appropriately preserved
- Clear conical plastic transfer tube
- Reagent strips with color comparison chart for reading results
- Normal and abnormal quality control specimens
- Test tube rack
- Kimwipes or paper towels
- Permanent fine-tip pen for marking identification on the transfer tube
- Urinalysis report form
- Black pen for documentation on the patient's chart
- Patient's chart
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P. Psychomotor Skills, III. Applied Microbiology/Infection Control, #2. Practice Standard Precautions
I.P. Psychomotor Skills, I. Anatomy and Physiology, #14. Perform Urinalysis

ABHES Standards

- Apply principles of aseptic techniques and infection control.
- Use standard precautions.
- Perform CLIA-waived tests that assist with diagnosis and treatment, Urinalysis.

Procedure	Rationale
1. Assemble necessary equipment. Put on eye protection, or position plastic shield in a way that the procedure may be performed behind the shield.	Organization of supplies saves time and helps to avoid errors. Eye protection shields employees from potential biohazard exposure.
2. Wash hands.	Hand washing breaks the cycle of infection.
3. Verify test order and specimen labeling and identification.	Verification of test order and specimen identification eliminates potential errors.
4. Verify that specimen collection was less than 1 hour before testing or that it was refrigerated and/or preserved appropriately after collection.	Specimens that are allowed to stay at room temperature for more than 1 hour after collection without the addition of preservative may yield inaccurate results because of changes in pH, bilirubin or urobilinogen concentration, glucose levels, and bacterial contamination.
5. Allow any refrigerated specimens to come to room temperature before proceeding.	Specimens that are colder than room temperature may exhibit crystallization of amorphous urates or phosphates, which can interfere with measurement of all the physical characteristics of the urine specimen, as well as cause potential interference with the chemical analysis.

Continued

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Procedure 21-1: CLIA-Waived Chemical Examination of Urine Using Manual Reagent Strip Method—cont'd

Procedure	Rationale
6. Mix specimen well with a gentle swirling motion.	Urine specimens must be mixed well to provide accurate chemistry results.
7. Pour some of the urine specimen into a labeled clear conical transfer tube. The transfer tube should be at least half full. Place the transfer tube in the tube rack.	Using a transfer tube for the urine to be chemically analyzed eliminates potential contamination of the original specimen by dipping in the reagent strip. If a urine culture is necessary, the original urine specimen will not be contaminated.
8. Prior to performance of patient testing, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that process before the patient's test is performed. Patient testing cannot be performed unless the quality control values are within the established ranges.	Liquid QC should be tested following laboratory protocol and manufacturer's recommendations. Examples of when QC may be used to verify the test results include the following: **a.** With a new shipment of reagent strips **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc.
9. Perform the reagent strip test following these procedures: **a.** Dip the reagent strip into the well-mixed urine in the transfer tube. Make certain that all the reagent pads are moistened. **b.** Remove the reagent strip from the urine immediately, running the straight edge of the reagent strip along the top of the tube to remove excess urine. **c.** Immediately blot the edge of the reagent strip on a paper towel or laboratory wipes. **d.** Begin the timing for the pad development as the reagent strip is removed from the tube. **e.** Observe the color changes on the reagent pad at the appropriate time intervals as directed by the manufacturer. Compare the colors to the provided chart for observation, or to the chart provided on the reagent strip bottle. **f.** Record the results on the urinalysis report form. **g.** Discard the used reagent strip into a biohazard waste container.	Careful adherence to the procedure will allow for accuracy of results.

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Procedure	Rationale
10. Dispose of the urine left in the transfer tube by pouring it down the sink and flushing it with plenty of water. Dispose of the tube and transfer pipette used for the urine in a biohazardous disposal bag. If the urine is not to undergo additional testing immediately, refrigerate it or preserve it accordingly.	
11. Sanitize the work area, remove gloves, and sanitize hands.	Gloves should always be removed immediately after a procedure is performed. Hand sanitization is appropriate before and after gloves are worn.
12. Document results for patient specimen on the chart (if available) and testing log sheet. Be certain to use the correct digits for the documentation.	Results must be recorded immediately after the testing process is complete.

Date	
10/24/2014:	*Chemical Urinalysis: Glucose: negative, Bilirubin: negative, Ketones: negative, Blood: negative, pH: 6.0, Protein: negative, Urobilinogen: 0.1 mg/dL, Nitrite: negative, Leukocyte esterase: negative, Specific gravity: 1.020*
11:58 a.m.	*Connie Lieseke, CMA (AAMA)*

Procedure 21-2: Chemical Examination of Urine Using Automated Reagent Strip Method

TASK

Perform a chemical examination of a urine specimen utilizing an automated urinalysis instrument.

CONDITIONS

- Gloves, laboratory coat, and protective eyewear
- Urine specimen freshly voided or appropriately preserved
- Clear conical plastic transfer tube
- Reagent strips and automated testing instrument with paper for result recording
- Normal and abnormal quality control specimens
- Test tube rack
- Kimwipes or paper towels
- Permanent fine-tip pen for marking identification on the transfer tube
- Urinalysis report form
- Black pen for documentation on the patient's chart
- Patient's chart
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P. Psychomotor Skills, III. Applied Microbiology/Infection Control, #2. Practice Standard Precautions
I.P. Psychomotor Skills, I. Anatomy and Physiology, #14. Perform Urinalysis

ABHES Standards

- Apply principles of aseptic techniques and infection control.
- Use standard precautions
- Perform CLIA-waived tests that assist with diagnosis and treatment, Urinalysis.

Continued

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Procedure 21-2: Chemical Examination of Urine Using Automated Reagent Strip Method—cont'd

Procedure	Rationale
1. Assemble necessary equipment. Put on eye protection or position plastic shield in a way that the procedure may be performed behind the shield.	Organization of supplies saves time and helps to avoid errors. Eye protection protects employees from potential biohazard exposure.
2. Wash hands.	Hand washing breaks the cycle of infection.
3. Verify test order and specimen labeling and identification.	Verification of test order and specimen identification eliminates potential errors.
4. Verify that specimen collection was less than 1 hour before testing or that it was refrigerated and/or preserved appropriately after collection.	Specimens that are allowed to stay at room temperature for more than 1 hour after collection without the addition of preservative may yield inaccurate results because of changes in pH, bilirubin or urobilinogen concentration, glucose levels, and bacterial contamination.
5. Allow any refrigerated specimens to come to room temperature before proceeding.	Specimens that are colder than room temperature may exhibit crystallization of amorphous urates or phosphates, which can interfere with measurement of all the physical characteristics of the urine specimen, as well as cause potential interference with the chemical analysis.
6. Mix specimen well with a gentle swirling motion.	Urine specimens must be mixed well to provide accurate chemistry results.
7. Pour some of the urine specimen into a labeled clear conical transfer tube. The transfer tube should be at least $^1/_2$ full. Place the transfer tube in the tube rack.	Use of a transfer tube for the urine to be chemically analyzed eliminates potential contamination of the original specimen by dipping in the reagent strip. If a urine culture is necessary, the original urine specimen will not be contaminated.
8. Prior to performance of patient testing, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that process before the patient's test is performed. Patient testing cannot be performed unless the quality control values are within the established ranges.	Liquid QC should be tested following laboratory protocol and manufacturer recommendations. Examples of when QC may be used to verify the test results include the following: **a.** With a new shipment of reagent strips **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc.

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Procedure	Rationale
9. Perform the reagent strip test following these procedures: **a.** Dip the reagent strip into the well-mixed urine in the transfer tube. Make certain that all the reagent pads are moistened. **b.** Remove the reagent strip from the urine immediately, running the straight edge of the reagent strip along the top of the tube to remove excess urine. **c.** Immediately blot the edge of the reagent strip on paper towel or laboratory wipes. **d.** Place the reagent test strip onto the appropriate area to be fed into the urinalysis instrument. Input any specimen ID necessary into the instrument, if possible. **e.** Monitor the instrument as the test is completed, watching for possible errors. **f.** Record the results on the urinalysis report form after they are printed. Some models display the results on a screen; if so, it will be necessary for them to be transposed onto the report form. **g.** Discard the used reagent strip into a biohazardous waste container.	Careful adherence to the procedure will allow for accuracy of results.
10. Dispose of the urine left in the transfer tube by pouring it down the sink and flushing it with plenty of water. Dispose of the tube and transfer pipette used for the urine in a biohazardous disposal bag. If the urine is not to undergo additional testing immediately, refrigerate it or preserve it accordingly.	Urine does not need to be disposed of in the biohazardous garbage, but it is important to flush the sink well after disposal.
11. Sanitize the work area, remove gloves, and sanitize hands.	Gloves should always be removed immediately after a procedure is performed. Hand sanitization is appropriate before and after gloves are worn.
12. Document results for patient specimen on the chart (if available) and testing log sheet. Be certain to use the correct digits for the documentation.	Results must be recorded immediately after the testing process is complete.

Date	
10/24/2009:	*Chemical urinalysis using Bayer Clinitek 500; Quality control results within range: Glucose: negative, Bilirubin: negative, Ketones: negative, Blood: negative, pH: 6.0, Protein: negative, Urobilinogen: 0.1 mg/dL, Nitrite: negative, Leukocyte esterase: negative, Specific gravity: 1.020*
11:58 a.m.	*Connie Lieseke, CMA (AAMA)*

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- *Sulfosalicylic acid precipitation test:* This test involves the addition of an acid to the urine specimen and an observation for the amount of turbidity caused when the acid is added. A semiquantitative assessment of the amount of protein present in the urine specimen may result by measuring the turbidity present. The SSA precipitation test is not affected by the color of the specimen, as the measurement involves the turbidity present, not a color change reaction.
- *Clinitest* (Bayer Corporation): This test is used as a confirmatory test for the presence of glucose and other sugars in the urine specimen. It is not affected as much by the original color of the specimen, although some substances (such as ampicillin and vitamin C) can cause inaccurate results.
- *Microscopic examination:* Chapter 22 details the process used for urine microscopic examinations. In situations in which the color of the specimen prohibits valid results for blood, leukocyte esterase, or nitrites, the examination of the urine sediment for these formed elements may provide additional information for the practitioner.

FECAL OCCULT BLOOD TESTING

Fecal occult blood testing (FOBT) detects blood that is "hidden" in or on feces. Blood in the stool may be clinically significant even though there are only small amounts present. It is not unusual for adults to shed a few milliliters each day in their feces as a result of the natural processes occurring in the stomach and intestines. However, increased blood loss may be due to a pathological condition that needs medical attention. Blood may be present in the stool in the following situations:

- Bleeding hemorrhoids
- Ulcers and/or inflammation of the stomach or duodenum
- Presence of polyps, lesions, or tumors in the intestines
- Nosebleeds
- Bleeding gums
- Diverticulitis, colitis, and/or Crohn's disease
- Parasitic infection
- Colorectal cancer

Stool testing for the presence of occult blood is a simple, noninvasive, and relatively inexpensive screening test. The fecal occult blood test is not specific for any disease process, but a positive result will indicate a need for further investigation with a colonoscopy, proctosigmoidoscopy, or a lower gastrointestinal x-ray that uses barium to visualize the digestive tract. Most commonly this test is ordered as a screen for asymptomatic patients, but it may also be used when there is anemia present with no identifiable cause or when the patient exhibits symptoms of other disorders that may result in a positive screen.

According to the Centers for Disease Control and Prevention (CDC), colorectal cancer is the second leading cancer killer in the United States. Early stages of this disease are usually asymptomatic; therefore, colorectal cancer is often overlooked until it has progressed to a point at which treatment options are limited. The CDC and the American Cancer Society recommend that all adults who are 50 to 75 years of age have a yearly fecal occult blood screening test performed. Those past the age of 75 should discuss the necessity of further testing with their physician. Earlier (before the age of 50) or more frequent screening tests may be necessary if a patient has a family history of colorectal cancer or if the patient has inflammatory bowel disease. For patients who are covered by Medicare, yearly fecal occult blood screening is a service that is covered for payment.

Test Your Knowledge 21-12

Why does the American Cancer Society recommend a yearly fecal occult blood screening? (Outcome 21-9)

There are two types of fecal occult blood screening kits available. The **guaiac method**, usually referred to as the **FOBT** (for fecal occult blood test), uses a cardboard specimen holder containing a special guaiac paper inside. This paper is used for application of the specimen and the developer. If there is blood present in the stool, it oxidizes the guaiac, and when the developer (hydrogen peroxide solution) is added, the surrounding test paper turns blue where blood is present (Fig. 21-4). The guaiac reacts with heme present in the blood cells. This method has been available for many years, and is considered reliable if the patient follows the dietary restrictions and collection procedures as instructed. The guaiac method is not as sensitive or specific as the newer methods, but it is inexpensive, so many facilities still use it for their screening. Hemoccult (manufactured by Beckman Coulter) is most commonly used. Seracult (manufactured by Propper) is another screening kit that is available. To perform the collection process properly using guaiac-based kits, keep the following key points in mind:

1. Seven days prior to and during the collection, all NSAIDs (such as naproxen or ibuprofen) must be discontinued. One adult aspirin per day is allowed. Tylenol is also allowed.

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2. Three days before and then during the collection, all vitamin C supplements must be discontinued, as well as citrus fruits or juices. For some test kits, turnips, broccoli, melons, radishes, and fresh fruit should also be discontinued. During this time, ingestion of red meat (beef, lamb, or liver) must be discontinued as well. Anticoagulant use may also cause false-positive test results, but patients must consult their health-care provider before discontinuing these drugs.
3. The stool specimens should be collected from three consecutive bowel movements, preferably on three consecutive days. Follow directions provided concerning the volume of stool to apply, and to which side of the slide to apply it.
4. **Test Your Knowledge 21-13**

   Which of these substances should be avoided for 7 days prior to and then during the collection period for a FOBT?

   a. Red meat
   b. Caffeine
   c. Sodium
   d. NSAIDs (Outcome 21-10)
5. 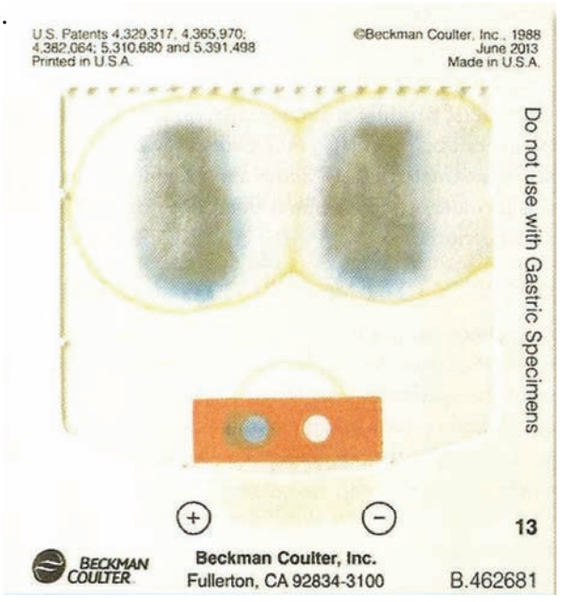

Figure 21-4 Positive fecal occult blood test result using guaiac method. Note the blue area around the specimens, which indicates a positive result and the presence of occult blood in the stool. In addition, there is a positive result on the control area of the slide. *Courtesy of Beckman Coulter.*

The other fecal occult blood testing method, the **iFOB,** which stands for immunochemical fecal occult blood, uses an immunochemical test to detect the presence of globin, part of the hemoglobin molecule. This test reacts only with human blood, and is more sensitive and specific than is the guaiac testing method. The iFOB has been shown to detect a positive result with less blood present in the stool, and to have fewer false-positives due to interfering substances. There are fewer dietary restrictions associated with this testing method; therefore, patient compliance may increase. The iFOB test may be available as a kit containing individual testing cartridges or as slides similar to the other type of fecal occult blood tests. It is still recommended that the sample be collected over three consecutive bowel movements over three days, as polyps and lesions in the GI tract may bleed intermittently, and this method of collection increases the opportunity to detect bleeding if present. Hemoccult ICT (manufactured by Beckman Coulter) is one example of this immunochemical testing method. Other manufacturers, such as Quidel, also produce a CLIA-waived rapid test that provides a qualitative result for the presence of fecal occult blood. The immunochemical tests for occult blood are much more expensive than are the guaiac tests, and are not commonly found in the physician office laboratory.

Regardless of the type of test used, the desired result is a negative one, indicating that no measurable occult blood is present in the stool. However, a positive result does not necessarily indicate colorectal cancer, or even a precancerous condition. The fecal occult blood test procedure is to be used as a screening tool only, and further testing is always necessary to identify the cause of any positive results. The test results for the FOBT and the iFOB are reported as a positive or negative result, indicating the presence or absence of occult blood in the specimen.

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Procedure 21-3: Fecal Occult Blood Testing Using Guaiac Method

TASK

Provide patient instruction for the collection of the sample necessary and perform a test to detect the presence of fecal occult blood using the Hemoccult Sensa test cards and developer.

CONDITIONS

- Gloves
- Laboratory coat
- Hemoccult Sensa test cards
- Hemoccult Sensa developer
- Stool specimens
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P. Psychomotor Skills, III. Applied Microbiology/Infection Control, #2. Practice Standard Precautions

ABHES Standards

- Apply principles of aseptic techniques and infection control.
- Use standard precautions
- Instruct patients in the collection of a fecal specimen

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify test ordered, and explain the specimen collection requirements to the patient.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. A thorough explanation of the collection procedure for the patient will ensure more cooperation. Written literature should also be provided so that the patient knows how to prepare appropriately and collect the specimens correctly. Preparation and collection instructions include the following: • Collect and apply samples from bowel movements from three different days to the slide. This increases the opportunity to detect blood that may be intermittently present from polyps or cancer present in the GI system. • Do not collect a sample if frank (obvious) blood is present in the stool. • For best results, collect the sample before the stool makes contact with the water present in the toilet. Stool specimens that are retrieved from toilet water with chemical additives are unacceptable. • Protect slides from heat, bright lights, and exposure to strong household chemicals such as ammonia. • For 7 days before and during the stool collection period, avoid NSAIDs such as aspirin and ibuprofen. One adult aspirin per day is acceptable. • For 3 days before and during the stool collection period, avoid vitamin C in excess of 250 mg/day and red meats. • Eat a well-balanced diet.

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Procedure	Rationale
3. Provide the patient with a set of three slides, an applicator, collection tissues, and written instructions for collection. Let the patient know how and when to bring the specimens back to the laboratory. Make certain that the slides are correctly identified with the patient's name and account number.	Slides must be returned for testing within 14 days of collection. It is important that the date of each collection is recorded on the outside front of the slide. To apply the specimen to the slide, follow these steps: **1.** Open the front of the slide. Using the applicator provided, place a small amount of stool specimen as a thin smear covering box A. Using the same applicator, choose a different part of the stool specimen and take another small amount to smear on box B. **2.** Dispose of the applicator and close the front of the slide. **3.** Patients must not open the back of the slide. This is for laboratory use only.
4. When the slides arrive back at the laboratory, wash hands and apply gloves before touching the slides.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protective equipment (PPE) for this procedure.
5. Assemble the developer, and verify that all reagents are within the posted expiration dates.	The developer should be stored at room temperature and must be used before the expiration date.
6. Verify the patient identification on the cards.	Always verify that the correct specimen is in hand before completing the testing process.
7. Open the back of the slide. Place two drops of Hemoccult developer directly over the specimens in box A and box B. Results are to be read at 60 seconds after application of the developer. Any blue on or at the edges of the slide is considered to be a positive result for the presence of occult blood.	Guaiac occult blood test results should not be read by those who have color blindness, as they may not recognize the development of the blue color with a positive result.
8. Make a note of the result at 60 seconds.	The result must not be read before allowing 60 seconds for development or after 60 seconds has elapsed.
9. Before the results are considered to be valid, the quality control area of the slide must be developed.	Apply one drop of developer between the positive and negative designation of the QC testing area. Read the results at 10 seconds. • The positive area will turn blue, and no blue will develop in the negative area. • If results are not as expected when performing quality control, the patient results cannot be reported.
10. Repeat the testing process and quality control assessment on the other slides.	The procedure is the same for each slide.

Continued

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Procedure 21-3: Fecal Occult Blood Testing Using Guaiac Method—cont'd

Procedure	Rationale
11. Dispose of the slide in the biohazardous disposal container.	Biohazardous specimens must be disposed of properly.
12. Put away developer, remove gloves, wash hands, and record specimen results.	Hands must always be washed after removing gloves.

Date	
8/19/2014:	Hemoccult slides tested; negative X3
11:50 a.m.	Connie Lieseke, CMA (AAMA)

Procedure 21-4: Fecal Occult Blood Testing Using iFOB Quickvue Method

TASK

Perform a fecal occult blood test using the Quickvue immunoassay method.

CONDITIONS

- Gloves
- Laboratory coat
- Hand sanitization supplies
- Specimen pouch containing
  - QuickVue collection tube (covered with identification label) contained in absorbent sleeve
  - Collection paper with adhesive
  - Patient instructions
  - Return mailer
- QuickVue test cassette
- Absorbent laboratory wipes or gauze pads
- Timer
- Quality control material (if necessary)
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

III.P. Psychomotor Skills, III. Applied Microbiology/Infection Control, #2. Practice Standard Precautions

ABHES Standards

- Apply principles of aseptic techniques and infection control.
- Use standard precautions.
- Instruct patients in the collection of a fecal specimen.

Procedure	Rationale
1. Greet and then identify patient using at least two unique identifiers.	All patients must be identified properly before collecting samples or performing laboratory testing.
2. Verify the test ordered, and explain the collection procedure to the patient. Enter the patient identification information on the collection tube label.	All laboratory test orders should be verified by checking the chart and/or requisition form more than once. The collection process for this procedure is very specific, and must be followed carefully. Patient instructions include the following: • During the collection process, do not allow the fecal specimen to contact the toilet water. The specimen must also be protected from urine.

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Procedure	Rationale
	• When ready to begin the collection, attach the collection paper to the toilet seat by removing the tape cover from the ends of the collection paper and attaching the adhesive material to the toilet seat across the back of the toilet. Attach the paper in such a way that it sags in the middle of the toilet. • Defecate on the collection paper. Do not remove the fecal specimen or the collection paper from the toilet seat at this point. • Unscrew the sampler from the collection tube. • Pierce the fecal specimen (while still on the collection paper) with the grooved end of the sampler device at least five times in different areas of the specimen. • Insert the sampler into the collection tube and close the cap securely. • Shake the tube to mix the buffer provided in the tube with the sample just added to the tube. • Flush the remaining collection paper and the fecal sample down the toilet.
3. Explain to the patient how to return the specimen to the laboratory for testing.	The specimens may be mailed using the provided mailer, or they may be delivered back to the laboratory. Specimens may be kept at room temperature for up to 8 days after collection.
4. When the specimen is returned to the laboratory, verify that the identification is appropriate and that the patient followed the correct collection procedure.	The specimen is invalid if the collection procedure is not followed.
5. Sanitize hands and apply gloves.	Hands should always be washed between patients and before starting any procedures. Gloves are appropriate personal protective equipment (PPE) for this procedure.
6. Assemble necessary equipment, and verify that all reagents are within the posted expiration dates.	The only additional equipment for this test would be the timer and the test cassette.
7. Remove the test cassette from the foil wrapper and place it on a level surface.	The test cassette should not be removed until right before use.
8. Remove the absorbent sleeve from the specimen pouch, and remove the collection tube from the absorbent sleeve.	The absorbent sleeve is provided in case of specimen leakage during transport.
9. Shake the collection tube well to mix the sample and the buffer solution.	The specimen and buffer must be well mixed for valid test results.

Continued

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Procedure 21-4: Fecal Occult Blood Testing Using iFOB Quickvue Method—cont'd

Procedure	Rationale
10. Prior to performance of test, verify whether a quality control (QC) specimen needs to be tested, and if so, complete that test *before* the patient's test is performed.	External QC material should be tested following laboratory protocol and manufacturer's recommendations. Examples of when QC should be used to verify the test results include the following: **a.** With a new shipment of the testing materials **b.** Whenever a new lot number of reagents or QC is put into use **c.** New operator; someone who is being trained on the procedure **d.** Problems with storage, instrument, reagents, etc. **e.** To ensure that storage conditions are fine, QC should be performed at least once monthly
11. Hold the collection tube upright and remove the light blue cap at the top of the tube.	It is important to hold the tube upright for this step.
12. Completely cover the exposed tip of the collection tube with the absorbent pad.	It is important to completely cover the exposed tip to avoid potential exposure to the specimen during the next step.
13. Without twisting, quickly snap off the tip of the collection container.	The tip will not snap off if a twisting motion is used.
14. Turn the collection tube upside down into a vertical position. Dispense six drops into the well of the testing cassette.	The tube should be held vertically to dispense the correct size of drop into the well.
15. Read the results in 5 to 10 minutes.	Some positive results will be evident at 5 minutes, whereas others may take up to 10 minutes to develop as a positive. Negative results should be reported within 10 minutes. Do not read the results after 10 minutes. Results are interpreted as follows: • Maroon lines will appear at the C and T area of the test cassette when the result is positive for the presence of occult blood. • Negative results will only exhibit a line at the C area. • If a line appears only at the T area of the test cassette or if no lines appear, the test results are invalid.
16. Dispose of the testing cassette and sample tube in the biohazardous disposal container.	These should all be disposed of as biohazardous materials because of the potential for the presence of blood or other biological hazards in the specimen.

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Procedure	Rationale
17. Disinfect the work area.	The work area should always be disinfected after potential exposure to biological substances.
18. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
19. Document the test results in patient chart and/or log sheet.	All results must be documented in the patient's chart.

Date	
8/17/2014: 12:50 p.m.	IFOB test negative for occult blood ~~~ Connie Lieseke, CMA (AAMA)

SUMMARY

The comprehensive chemical analysis of urine is a frequently performed procedure as part of a routine urinalysis. Chemical analyses may also be limited to a few analytes, testing for the presence of substances such as glucose, ketones, and microalbumin. Urine reagent test strips contain pads that change color in the presence of various chemicals present in the urine specimen. The amount of color change is observed and recorded, either manually or automatically using an instrument. These color changes provide qualitative or semiquantitative results for the chemical analytes on the strip. Valuable information for the diagnosis and management of various renal diseases and other body system dysfunctions may be obtained by performing chemical urine testing. Fecal occult blood testing is performed as a screening test for the presence of colorectal cancer, allowing for early identification and treatment of that disease.

TIME TO REVIEW

1. What is the difference between glucosuria and glycosuria? Outcome 21-1

2. Jaundice may include : Outcome 21-1
   - **a.** Yellow sclera of the eye
   - **b.** Red, bloody urine
   - **c.** Light-colored feces
   - **d.** Pus in the urine

3. The sulfosalicylic acid precipitation test is used to detect which of these in the urine? Outcome 21-8
   - **a.** Glucose
   - **b.** Ketones
   - **c.** Bilirubin
   - **d.** Protein

4. True or False: A positive blood test on a urine specimen is always indicative of intact red blood cells in the urine. Outcome 21-2

5. The presence of ketones in the urine specimen is indicative of: Outcome 21-2
   - **a.** High blood sugar
   - **b.** Bile obstruction
   - **c.** Increased fat metabolism
   - **d.** Urinary tract infection

6. A positive nitrite result in the urine specimen may be indicative of: Outcome 21-2
   - **a.** Hematuria
   - **b.** White blood cells in the urine specimen
   - **c.** Elevated specific gravity results
   - **d.** Bacteria in the specimen

7. True or False: A urine specimen with a pH of 4.0 is considered to be outside of the reference range. Outcome 21-3

8. True or False: Medication that causes the urine to appear bright orange is likely to cause interference on a urine chemistry test. Outcome 21-4

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9. Which of the following may cause test interference on the urine chemistry tests? Outcome 21-4
   a. Vitamin C ingestion
   b. Dairy products
   c. Cold medication
   d. Excessive caffeine intake
10. List three safety precautions applicable to urine chemistry testing procedures. Outcome 21-5
11. True or False: A positive fecal occult blood test is always indicative of colorectal cancer. Outcome 21-9

Case Study 21-1: Exceptions to the rule?

Sally Steiner is at the physician's office because symptoms that may be indicative of a urinary tract infection. She has been urinating frequently and experiences pain when voiding. When the medical assistant in the laboratory performs the chemical analysis on her urine specimen, the nitrite test is negative.

1. Does this result eliminate the possibility that there may be bacteria present in the urine specimen? Why or why not?

RESOURCES AND SUGGESTED READINGS

Clinical and Laboratory Standards Institute, Urinalysis: Approved Guideline, ed. 3. CLSI document G16-A3. Wayne, PA, 2009
Approved laboratory standards for collecting, processing, and testing urinalysis samples

"Galactosemia"
The U.S. Library of Medicine, Genetic Home Reference, explains how galactosemia is passed genetically and the effect that it may have on the body http://ghr.nlm.nih.gov/condition=galactosemia

"Urinalysis, a Comprehensive Review"
In-depth article from the American Association of Family Practitioners about the causes of urinalysis results, as well as information about false-positives and false-negatives http://www.aafp.org/afp/2005/0315/p1153.html

Chapter 22

Microscopic Examination of Urine

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Reasons for Performing Urine Microscopic Examinations
Common Formed Elements in the Urine and Their Clinical Significance
- Epithelial Cells
- Mucus
- Blood Cells
- Spermatozoa
- Artifacts
- Casts
- Crystals
- Microorganisms

Methods Used for Urine Microscopic Examinations
Reporting Urine Microscopic Results
Role of Medical Assistants in Microscopic Urine Examination Procedures
Quality Control and Quality Assurance Procedures for Urine Microscopic Examinations
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

22-1 Define the key terms.

22-2 Explain why urine microscopic examination procedures are performed.

22-3 List the various formed elements identified in urine specimens.

22-4 Describe the clinical significance of the formed elements in a urine specimen.

22-5 Contrast the standard methods used to prepare a urine specimen for microscopic analysis.

22-6 Describe how to focus the urine sediment specimen appropriately on the microscope for viewing.

22-7 Summarize the procedures for reporting formed elements in urine specimens.

22-8 Describe how a medical assistant may be involved in the performance of a urine microscopic analysis.

22-9 Detail what type of quality assurance and quality control procedures are necessary to perform with urine microscopic analysis.

22-10 Prepare a urine specimen for microscopic analysis.

CAAHEP/ABHES STANDARDS

CAAHEP 2008 Standards

I.P.I.14. Perform Urinalysis
III,P.III.2. Practice Standard Precautions

ABHES Standards

- Medical Office Clinical Procedures: b. Apply principles of aseptic techniques and infection control, i. Use standard precautions
- Perform Urinalysis

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KEY TERMS

Artifacts
Casts
Crystals
Epithelial cell
Fungus
Hematuria
Mucus
Provider performed microscopy (PPM)
Pyuria
Reflexive
Sediment
Spermatozoa
Supernatant

The final step in a complete urinalysis is the microscopic examination of the urine sediment. This procedure is performed to visualize and identify the formed elements that may be present. These microscopic structures may enter the urine while it is in the kidneys or as the urine passes through the lower urinary tract. The microscopic examination can detect infection, trauma, or damage to the urinary system, or provide information used to monitor certain disease states. In addition, some metabolic disorders may be detected because of the presence of pathological crystals in the urine specimen. Because the presence of the formed elements is not always clinically significant when they are present in small amounts, the microscopic examination provides quantitative information about the elements present in addition to the identification of the structures.

REASONS FOR PERFORMING URINE MICROSCOPIC EXAMINATIONS

The Clinical and Laboratory Standards Institute recommends the performance of a urine microscopic examination whenever the chemical or physical testing is abnormal on the urine specimen. Because of this recommendation, some laboratories always perform urine microscopic examinations when the chemical analysis or physical examination of the urine specimen is abnormal. This is known as **reflexive** testing. The decision for adding a urine microscopic examination may also be based on the appearance of the specimen; for example, if the specimen appears cloudy or bloody, then a microscopic examination may be added. In addition, the urine microscopic examination may be ordered by a healthcare practitioner to screen for a disease process or to monitor the progress of treatment. For example, the practitioner may need quantitative information about the amount of bacteria present in a sample in order to prescribe appropriate medication, or it may be necessary to determine if certain types of crystals are present in the specimen for a definitive diagnosis.

Test Your Knowledge 22-1
Provide one reason that a urine microscopic examination may be performed. (Outcome 22-2)

COMMON FORMED ELEMENTS IN THE URINE AND THEIR CLINICAL SIGNIFICANCE

The formed elements that may be present in a urine specimen include epithelial cells, mucus, blood cells, spermatozoa, artifacts, casts, crystals, and various microorganisms. These structures are identified and the approximate amount present in the urine sediment is estimated and reported. Some of the structures are identified using the low-power objective on the microscope (10X), whereas others require the high-power objective (40X) for visualization.

Many normal urine specimens contain a few formed elements. It is important to appropriately report the quantity observed, because the presence of very small amounts of some structures may have clinical significance. The reference ranges and clinical significance of each formed element vary, as explained in the following sections.

Epithelial Cells

A common cell identified in the urine specimen is an **epithelial cell.** These cells are constantly added to the urine as they are shed from the lining of the urinary

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tract. There are three types of epithelial cells that may be present, and they are named according to the area where they originate within the urinary tract:

- *Squamous epithelial cells:* These are the most common epithelial cells present in the urine. Their presence is not considered to be clinically significant, as the cells naturally slough off from the lining of the lower urinary tract in both males and females, and from the vagina in females. Squamous epithelial cells are large, flat, and irregular in shape, with a large nucleus and abundant cytoplasm. Their shape may be described as having a "fried egg" appearance. Squamous epithelial cells are often the first formed element that is visible when focusing the microscope. They are reported using the low-power objective as rare, few, moderate, or many per low-power field. Usually there are at least a few squamous epithelial cells present in any urine sediment (Fig. 22-1).
- *Transitional epithelial cells:* These cells originate from the structures of the kidneys and the ureters, bladder, and upper urethra in males. They line the urinary tract in these locations, and their presence in small numbers in the urine is not considered abnormal. However, if the number of transitional epithelial cells is elevated, it may be indicative of a pathological condition such as a malignancy. Transitional epithelial cells may also appear in increased numbers after urinary catheterization or other invasive urological procedures. These cells are identified using the high-power objective and reported as rare, few, moderate, or many per high-power field. A normal urine sample should not exhibit more than the rare transitional epithelial cell.
- *Renal tubular epithelial cells:* As the name implies, the renal tubular epithelial cells come from the renal tubules in the kidneys. The size and shape of the renal tubular epithelial cells differ, depending on the area of the tubules from which they originate. They are smaller than the other epithelial cells, and their appearance can vary from round to columnar. The presence of renal tubular epithelial cells in the urine specimen is clinically significant, as it may indicate conditions in which damage is occurring to the renal tubules. Examples include glomerulonephritis, viral infections, chronic or acute kidney disease, and other disease states that cause necrosis of the kidney tubules. Renal tubular epithelial cells are identified using the high-power objective, and reported as a number per high-power field. The presence of renal tubular epithelial cells in the urine sediment is always considered to be an abnormal result.

Figure 22-1 Squamous epithelial cells in urine sediment. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

Test Your Knowledge 22-2

Is the presence of epithelial cells in a urine specimen always clinically significant? (Outcome 22-4)

Mucus

The presence of **mucus** in the urine specimen is very common. Mucus appears as thread-like strands made of protein. Figure 22-2 shows an example of mucus. The mucous membranes that line the lower urinary tract and the renal epithelial cells normally produce mucus. The strands may be difficult to visualize when the microscopic light source is at its brightest; it is often necessary to reduce light intensity to see mucus clearly. Mucus is not indicative of a pathological condition in the body, and has no clinical significance. Large amounts of mucus in the specimen may produce a positive protein result on the chemical urine analysis. Mucus is identified using the low-power objective, and is reported as rare, few, moderate, or many per low-power field. Normal urine specimens may include a moderate amount of mucus.

Blood Cells

Red blood cells and white blood cells are often identified as part of the urine microscopic examination. Their clinical significance varies with the number present and the type of blood cell visualized.

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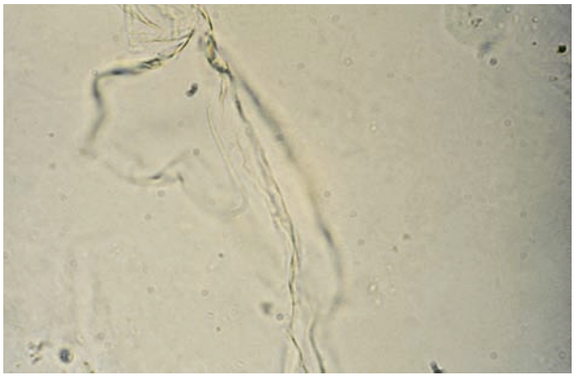

Figure 22-2 Threads of mucus; note the stringy appearance. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

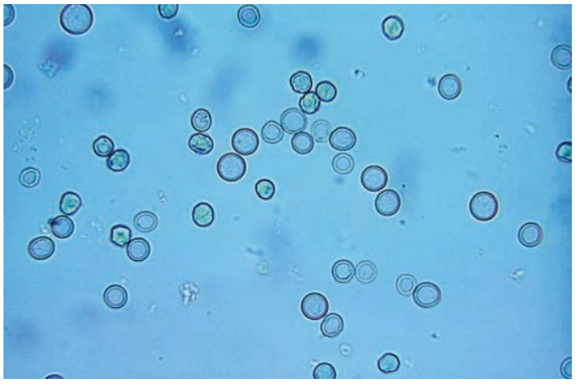

Figure 22-3 Red blood cells (erythrocytes) as they appear in urine sediment. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

- *Red blood cells:* It is not uncommon to see one or two red blood cells when examining urine sediment with a high-power magnification. When the number of red blood cells is elevated, it is indicative of damage to the glomeruli of the kidney or trauma to the vessels surrounding the urinary tract. The presence of red blood cells in the urine is a called **hematuria.** The number of red blood cells present in the specimen is relative to the severity of the damage to the glomerulus or the vessels. Red blood cells may also be present in the urine specimen after strenuous exercise.

Red blood cells may be difficult to identify when viewed in the urine specimen. They are colorless, smooth, and have no nucleus. Red blood cells appear as round biconcave disks that are difficult to distinguish from air bubbles, budding yeast, oil droplets, or artifacts in the specimen. The addition of stain to the specimen may aid in the identification and counting of the red blood cells. Figure 22-3 shows how red blood cells appear in the urine. Red blood cells are identified using the high-power objective, and are reported as the number seen per high-power field.

- **White blood cells:** A few white blood cells may be evident in a normal clean-catch midstream urine specimen when viewed under the microscope. Elevated numbers of white blood cells in the urine is called **pyuria,** which indicates infection or inflammation of the urinary tract. Prostatitis, pyelonephritis, and cystitis may cause elevated white blood cell counts in the urine specimen. Pyuria may also be present when there are tumors in the urinary tract, and other systemic inflammatory conditions.

It is easier to identify white blood cells in the urine specimen than it is to identify red blood cells. The white blood cells are larger, have a granular appearance, and contain a nucleus (Fig. 22-4). Most of those present in the urine specimen are neutrophils, although eosinophils or mononuclear cells may be elevated in certain situations. White blood cells are identified using the high-power objective and reported as the number visualized per high-power field.

Spermatozoa

Occasionally, **spermatozoa** may be present in urine specimens from both males and females after sexual intercourse. The spermatozoa will be identified by their distinctive shape, as they have an oval head that is

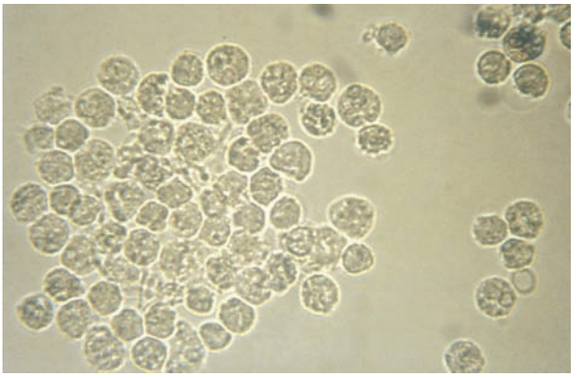

Figure 22-4 White blood cells. Note the presence of the nucleus and the cytoplasmic granules. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

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POINT OF INTEREST 22-1
Clue cells

Occasionally the urine microscopic report for a female patient may include the presence of *clue cells.* This term is used to describe vaginal epithelial cells that are coated with the *Gardnerella vaginalis* bacterium. The clue cells are similar in appearance to the squamous epithelial cells, except that the clue cell borders are ill defined or completely obliterated with a coating of bacteria. The presence of these cells in the urine specimen may be indicative of an infection known as bacterial vaginosis, and they must be noted if viewed in the urine specimen.

There are numerous types of bacteria present as normal flora in the vagina at all times. Bacterial vaginosis is the result of an overgrowth of *G. vaginalis* when the balance of normal flora is disrupted. The use of broad-spectrum antibiotics may destroy healthy bacteria and allow the *G. vaginalis* to increase in number. Douching, retained tampons, use of intrauterine devices for contraception, and use of products that contain nonoxynol-9 may also cause the bacterial balance to shift in the vaginal tissues.

Bacterial vaginosis is the cause of 60% of vulvovaginal infections. It is important to diagnose and treat this condition promptly because it has been linked to an increased risk of pelvic inflammatory disease (PID). Pelvic inflammatory disease is a serious condition that may lead to infertility as well as being a component of many other disease processes.

somewhat teardrop shaped, and a long tail. Urine is toxic to spermatozoa, so it is unusual for these cells to exhibit the same amount of motility as they would in a semen specimen. The clinical significance of spermatozoa in a urine specimen is limited to situations of male infertility and retrograde ejaculation in which the sperm is released into the bladder instead of into the urethra. The presence of spermatozoa should be reported in any situation, whether or not the clinical significance is clear. Elevated amounts of spermatozoa in the urine specimen may cause the urine dipstick to test positive for protein. The presence of spermatozoa is noted with the rest of the microscopic examination results, but the manner in which is it reported is laboratory specific.

Test Your Knowledge 22-3

Is it possible to see spermatozoa in the urine of a female patient? (Outcome 22-3)

Artifacts

Artifacts are contaminants that are visualized in the urine specimen. These may include fecal material, toilet paper, air bubbles, starch or powder, and clothing fibers. Artifacts are not usually reported as part of the urine microscopic examination, because they are not clinically significant. These structures are difficult to identify and may be confused with other formed elements in the urine specimen because of similarities in their shape and size.

Casts

The kidney tubules normally secrete a substance called the Tamm-Horsfall protein. This protein is not clinically significant unless certain conditions exist within the tubules that allow the Tamm-Horsfall protein to "gel" and form a protein-based mold of the tubule. Reduced urine flow, increased amounts of dissolved substances in the glomerular filtrate, and acidic urine conditions contribute to the formation of these **casts.** The casts assume the shape of the tubule or collecting duct in which they were formed. Any structures or substances that were present within the tubule or collecting duct when the cast was formed are trapped within the cast. These trapped substances may include bacteria, cells, or diffuse granules. Eventually, the protein making up the cast breaks away from the lumen of the tubules and flushes out with the urine. These casts can then be identified in the urine sediment when viewed under the microscope.

Casts are cylindrical because of the shape of the structure in which they were originally formed in the nephron tubules. They are classified using the names of the trapped substances within the protein structures. To visualize casts, the intensity of the light source on the microscope must be decreased, and the urine must be examined with the low-power objective. The presence of a few hyaline casts in a urine specimen is not considered abnormal, but the presence of any other type of cast may indicate damage to the kidney tubules. Some common types of casts identified in the urine sediment include the following:

- *Hyaline casts:* Clear, colorless, transparent. Hyaline casts may be difficult to see and to differentiate from threads of mucus. Figure 22-5 shows a hyaline cast. Strenuous exercise, heat exposure, or dehydration may cause an increased number of hyaline casts. Elevated numbers of hyaline casts may also be indicative of pyelonephritis, glomerulonephritis, or chronic renal disease. It is normal to see a few hyaline casts when

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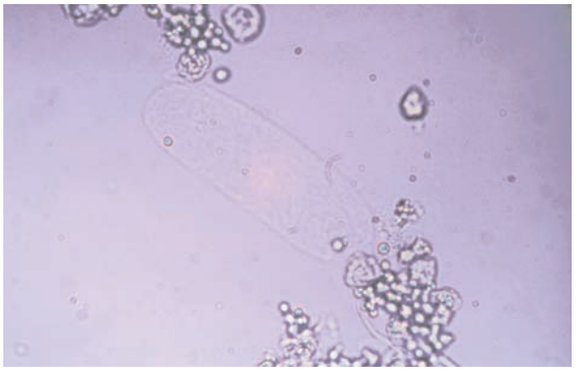

Figure 22-5 Hyaline cast. These casts are "hollow" and have no structures filling their core. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

examining the urine under low magnification. Hyaline casts are reported as the number visualized per low-power field.

- *Granular casts:* Granular casts contain fine or coarse granules. These granules are disintegrated structures that were trapped in the renal tubule at the time that the cast was formed. Granular casts may be present in the urine sediment with stress or strenuous exercise, but they may also be evident with glomerulonephritis or pyelonephritis. Granular casts are identified using the low-power objective and reported as the number visualized per low-power field.
- *Cellular casts:* Cellular casts contain renal epithelial cells, red blood cells, or white blood cells. Renal epithelial cell casts are indicative of damage to the renal tubules and are not present in a normal urine specimen. Red blood cell casts may be seen after strenuous exercise, but their presence may also be indicative of bleeding within the nephron structure as in the case of glomerulonephritis. The red blood cell casts have a distinct orange-red color. White blood cell casts are present when there is inflammation or infection within the nephron. There may also be bacteria present in a white blood cell cast. Pyelonephritis is often characterized by the presence of white blood cell casts in the urine sediment. Cellular casts are identified using the low-power objective and are reported as the number visualized per low-power field.
- *Waxy casts:* Waxy casts appear smooth with an irregular outline. They are very refractive when examined with decreased light under low-power magnification. There are no trapped substances within the cast, but the outline is easier to see than that of a hyaline cast. Waxy casts are indicative of an extreme decrease in the urine flow through the tubules that accompanies renal failure, and are not present in a normal urine specimen. They are identified using the low-power objective and reported as the number visualized per low-power field.

Crystals

The presence of **crystals** in normal urine sediment is common. Although many types of crystals are considered normal, it is important to report them when identified because their presence in increased numbers may be clinically significant. Crystals are formed from the dissolved substances (especially salts) in the urine. The precipitation of these dissolved substances into crystals is affected by the pH of the urine, as well as reduced temperature and increased specific gravity. Urine that has been at room temperature or refrigerated for a period of time will often contain abundant crystals in the urine sediment. In addition, highly concentrated urine (urine with a high specific gravity) with many dissolved substances will crystallize readily. The pH of the urine specimen plays a valuable role when attempting to identify crystals under the microscope, as certain types of crystals are evident in acidic urine, whereas others are present in alkaline urine. Various crystals can be seen in Figure 22-6.

Normal crystals may be present in acidic or alkaline urine specimens. These include the following:

- Amorphous (without a distinct shape) urates are present in acidic urine. The refrigeration of the specimen significantly contributes to the formation of amorphous urates in the specimen. The urine sediment may appear pink, and the amorphous crystals will appear as yellow-brown diffuse granules throughout the specimen when viewed under the microscope. Amorphous urate crystals may return to solution with the application of heat or addition of sodium hydroxide to the specimen.
- Uric acid crystals are evident in acidic urine, and appear with numerous shapes and a yellow-brown color. They may be present in increased numbers with leukemia when the patient is receiving chemotherapy, and occasionally in patients with gout.
- Calcium oxalate crystals are occasionally found in acidic urine or, more commonly, in urine with a neutral pH. They are seldom found in alkaline urine. These crystals appear as "envelopes" and are very refractive when viewed under the microscope.

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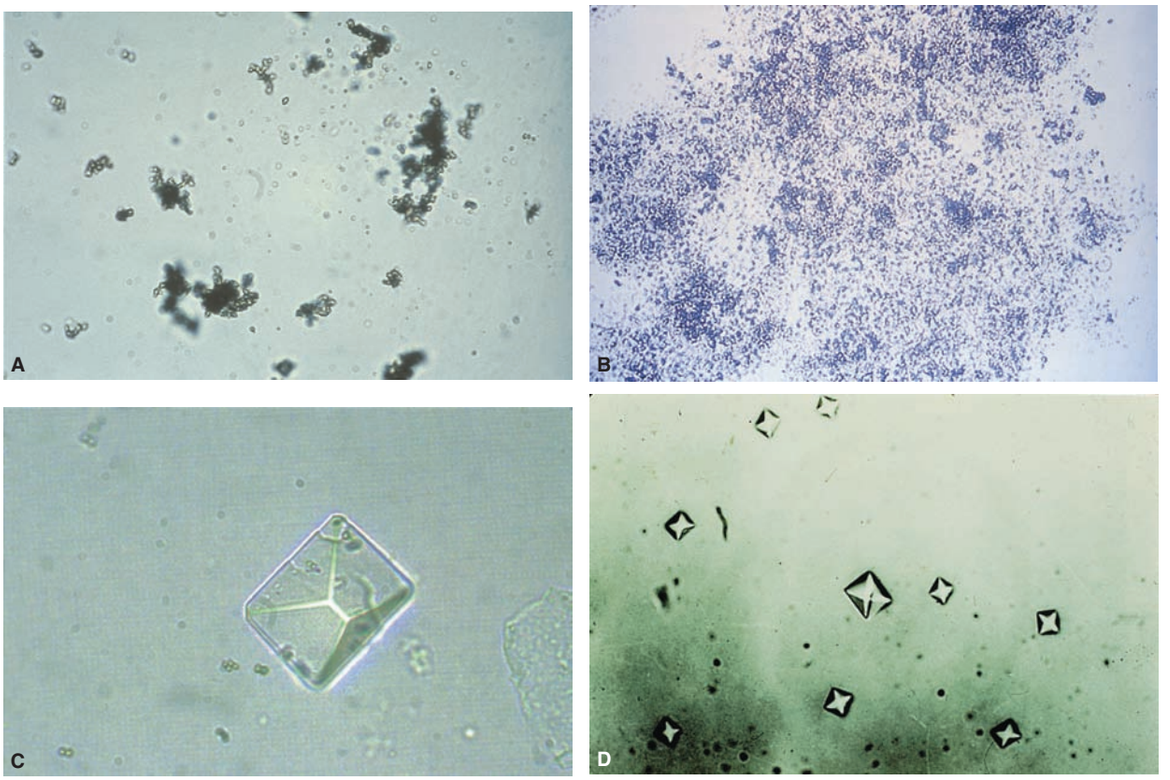

Figure 22-6 Various crystals. A. Amorphous urates. B. Amorphous phosphates. C. Triple phosphate crystals. D. Calcium oxalate crystals. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

- Amorphous phosphates are present in alkaline urine. This crystallization is especially evident after refrigeration of the specimen. The amorphous phosphate crystals appear as diffuse granular particles that may obscure the other structures present in the sediment when viewed under the microscope. The urine specimen may take on a white color if amorphous phosphates are present. Amorphous phosphates dissolve with the addition of 10% acetic acid.
- Triple phosphate crystals are present in neutral or alkaline urine. They are colorless, and very refractive when viewed under the microscope. They are often described as a "coffin lid," shaped like a six-sided prism. Their presence is not clinically significant.

The presence of other crystals considered abnormal in the urine sediment may be indicative of metabolic diseases. Use of certain drugs (such as sulfonamides or ampicillin) may also result in crystal formation. Urine specimens with alkaline or neutral pH values rarely contain abnormal crystals. Fortunately, the abnormal urine crystals all have very characteristic shapes that are easily recognizable. Crystals that are considered abnormal include the following:

- Cystine crystals are present in patients with cystinuria, a metabolic disorder in which individuals are not able to reabsorb cystine in the renal tubules as a normal individual would. Cystine crystals are hexagonal.
- Cholesterol crystals are not usually visualized unless the urine specimen has been refrigerated. When they are present, they appear as flat rectangles with notches out of the corners of the structure. Their presence indicates a disorder that includes lipiduria (the presence of lipids in the urine), such as nephrotic syndrome.
- Tyrosine, leucine, and bilirubin crystals may be present in the urine of patients with liver disorders. Tyrosine needles look like clumps of needles, whereas leucine crystals look like yellow-brown, oily spheres. Bilirubin crystals are also described as lumps of needle structures, but they are yellow (like the color of bilirubin).

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- Sulfonamide crystals have historically been present in urine sediment in patients undergoing sulfa drug treatment. However, the newer sulfonamide drugs are designed to be more soluble, which means that these crystals are rarely present now. If there are sulfonamide crystals present in the urine specimen, it may mean that the patient is not adequately hydrated. These crystals appear as bundles of needles or designs that resemble sheaves of wheat.
- Ampicillin crystals may also be present in urine when patients receive very large doses of the medication without adequate hydration. They also appear as colorless bundles of needles.
- Hippuric acid is increased in the urine when xylene and toluene are metabolized. Xylene and toluene are common industrial chemicals. Hippuric acid crystals may be an indication of increased exposure to these chemicals, as in workplace exposure or in those who abuse chemicals, such as sniffing glue products.

Microorganisms

When viewed with a compound microscope, various microorganisms may be visualized in the urine sediment. These include bacteria, fungi, and parasites. Smaller microorganisms such as viruses are not visible in the urine sediment with this type of magnification.

- *Bacteria:* It is not uncommon to see a few bacteria in urine specimens that are collected using the clean-catch midstream method. (See Fig. 22-7.) The presence of bacteria is usually the result of external contamination, especially in women. These bacterial contaminants multiply quickly after the urine is collected, and may cause the nitrite on the reagent stick to test positive if the urine is allowed to sit for more than an hour. When present in elevated numbers, the presence of bacteria will cause the urine pH to become more alkaline. (A pH above 8 may indicate the presence of excess bacterial contamination.) Bacteria must be visualized by using the high-power microscope objective because of their small size. The methods of reporting bacteria may vary among labs. Most commonly, bacteria is reported as few, moderate, or many, but a quantitative system of 1+, 2+, or 3+ may be used. Urinary tract infections may be caused by bacilli or cocci. When bacteria are present in the urine specimen in high numbers and white blood cells are evident, the urinalysis is generally followed up with a culture for positive identification of the bacteria and an antibiotic sensitivity.
- *Fungi: Candida albicans* is the most common type of fungi (yeast) present in urine. Yeast is commonly present in the urine of diabetic patients or those who are immunocompromised. Women who have the vaginal infection *candidiasis* may also have yeast present in their urine specimen. Yeast may be difficult to differentiate microscopically from red blood cells, as their size and shape are similar. Advanced yeast infections may present with yeast that is "budding" from stocks or branches as it multiplies and matures. The presence of yeast is reported in the same way that the presence of bacteria is reported.
- *Parasites:* The most common parasite present in the urine specimen is *Trichomonas vaginalis*. This is a sexually transmitted pathogenic microorganism that causes vaginal inflammation in females. Infection in males is often asymptomatic. *T. vaginalis* is often motile when viewed under the microscope in the urine sediment, and it may be recognized by the flagella that provides its movement. The motility of the organism is necessary for positive identification of the parasite. The presence of *T. vaginalis* is determined using the high-power objective and is reported as rare, few, moderate, or many per high-power field.

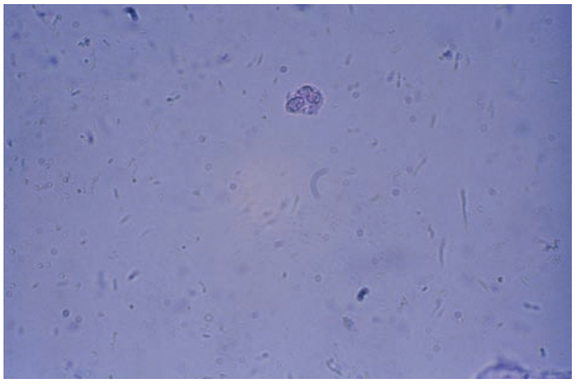

Figure 22-7 Bacteria as they appear in the urine sediment. *From Strasinger, SK, and Di Lorenzo, MS: Urinalysis and Body Fluids, ed. 5. FA Davis, Philadelphia, 2008, with permission.*

Test Your Knowledge 22-4

Which of the following microorganisms is not visualized in a urine sediment specimen using a compound microscope?

a. Viruses
b. Bacteria
c. Fungi
d. Parasites

(Outcome 22-4)

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METHODS USED FOR URINE MICROSCOPIC EXAMINATION

The urine microscopic examination is the part of the routine urinalysis that is the least standardized from one laboratory to another. Each site may vary in the way that the specimen is prepared, in how much urine is used for preparation of the sediment, or by the way that the specimen is visualized during the examination. All procedures include the centrifugation of a specified volume of urine, separation of the **supernatant** (the fluid from the top of the specimen) from the **sediment** (the formed elements that have been compacted to the bottom of the tube), and examination of the urine sediment under a microscope. The formed elements are then examined using the low-power and/or high-power outcomes, and the results are reported.

The results of the microscopic examination may be affected by several factors. The age of the specimen and the conditions under which the specimen was stored can affect the integrity of the structures to be visualized. The volume of specimen centrifuged, the time of centrifugation, and the force of the centrifugation will determine the amount of sediment produced for the microscopic examination. The results may also be affected by the amount of supernatant discarded and the amount of sediment added to the slide for examination. The manner in which the results are reported may also differ according to laboratory protocol. Because of these variables, the Clinical and Laboratory Standards Institute has recommended that the process for preparing and performing urine microscopic examinations be standardized with use of commercial systems that minimize the variables in the process.

The KOVA system (manufactured by Hycor Biomedical, Inc.) is an example of a commercial urinalysis microscopic kit that uses a special pipette to standardize the amount of sediment prepared, has specific instructions concerning the rotations per minute and length of centrifugation to be used, and contains a special slide well used for examination of the sediment that dictates the amount of sediment used for the examination. The KOVA system also includes a stain that enhances the contrast of the formed elements to assist with identification. Procedure 22-1 details the use of the KOVA method for a microscopic examination. There are other commercial systems available, including the Urisystem manufactured by ThermoFisher Scientific and the Count-10 system manufactured by V-Tech, Incorporated.

Test Your Knowledge 22-5

Why might the KOVA system be used to prepare a urine microscopic specimen for examination?

(Outcome 22-5)

Regardless of the system used to process the urine and set up the microscopic examination, it is imperative that a fresh or properly stored urine specimen is used. If the urine specimen is allowed to remain at room temperature for an extended period of time (more than an hour), it may affect the results of the urine microscopic examination, in addition to the chemical analysis of the speicmen. The formed elements present in the specimen will disintegrate and become distorted in specimens that are stored at room temperature for an extended period. The red blood cells, white blood cells, and hyaline casts are most affected. Specimens that are not analyzed within an hour may also exhibit an increase in bacterial growth, accompanied by an increase in pH.

Urine that is refrigerated prior to the performance of a microscopic examination will need to reach room temperature before the procedure is performed. If the urine is still very cold at the time of the examination, the precipitation of crystals will be visualized when viewed under the microscope. The presence of amorphous phosphates and amorphous urates in the refrigerated urine may obscure other clinically significant structures present in the specimen.

Medical assistants are often involved in the preparation of the urine sediment for the microscopic examination. In addition, the medical assistant may be asked to place the slide on the microscope stage and focus it appropriately so that the health-care provider (or another qualified laboratory professional) may perform the examination. To accomplish this, it is important that the medical assistant learn how to focus the microscope so that the formed elements are visible. Procedure 22-2 outlines the important concepts necessary to accomplish this task.

REPORTING URINE MICROSCOPIC RESULTS

As the various formed elements have been presented in this chapter, the reference ranges have been presented as well. It is important to remember that many normal urine specimens will include very few formed elements. If there are structures present in the urine sediment, it is important to report them in a way that is easy to interpret. The exact ranges and terminology used for

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Procedure 22-1: Preparation of Urine Sediment for Microscopic Examination

TASK

Prepare a slide for urine microscopic examination using the KOVA system. Complete all steps within 15 minutes.

CONDITIONS

- Hand sanitization supplies
- Gloves
- Laboratory coat
- Face Shield
- Conical tube
- Freshly voided urine specimen
- KOVA System supplies, including tube cap, KOVA pipette, slide, and stain
- Centrifuge
- Test tube rack
- Microscope
- Biohazardous disposal container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.14. Perform Urinalysis **III,P.III.2.** Practice Standard Precautions

ABHES Standards

- Medical Office Clinical Procedures: b. Apply principles of aseptic techniques and infection control, i. Use standard precautions
- Perform Urinalysis

Procedure	Rationale
1. Sanitize hands, allow them to dry, and apply gloves.	Gloves protect the hands from exposure to potential bloodborne pathogens. Gloves should always be applied in the presence of the patient.
2. Gather necessary supplies. Urine must be at room temperature prior to use.	All supplies must be within reach so that the process can be completed in a timely manner. The urine must be at room temperature to avoid excess crystallization of the specimen.
3. Apply face shield and mix urine well by gently rotating the specimen cup or inverting the cup if necessary. Pour 12 mL of the specimen into the KOVA conical tube.	The application of the face shield protects the eyes and mucous membranes from potential splash and aerosol of the specimen. The urine must be well mixed for the results to be accurate, and the KOVA system instructions require 12 mL of urine to be added to the tube.
4. Apply the supplied cap to the tube, and centrifuge the specimen at 1,500 revolutions per minute for 5 minutes.	Centrifugation is necessary for the solid substances in the specimen to settle to the bottom of the tube so that they can be separated from the liquid at the top of the tube. The protective face shield can be removed at this time until the specimen is taken from the centrifuge, at which point it should be put on again.
5. When the centrifuge has come to a complete stop, remove the conical tube carefully.	Take care not to disturb the sediment in the bottom of the tube when handling the specimen.
6. Remove the cap and carefully insert the "petter" pipette included with the system into the urine specimen. Make sure the hook at the top of the pipette is settled into place over the edge of the conical tube.	The KOVA pipette is designed with a special hook device at the top of the apparatus. When the "petter" pipette is inserted correctly into the specimen, the hook will be firmly seated over the side of the conical tube.

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Procedure	Rationale
7. With the pipette in place, carefully pour off the supernatant by inverting the tube over the sink to allow the liquid to pour out of the tube.	The KOVA pipette is specially designed with a bulb at the bottom of the pipette that holds the urine sediment in place as the supernatant is poured out of the tube. Approximately 1 mL of sediment is left in the bottom of the tube. Courtesy of Fisher HealthCare, Inc.
8. Remove the pipette from the tube, but do not discard it at this time. Insert one drop of KOVA stain into the conical urine tube.	Only one drop of stain should be added so that the sediment is not diluted.
9. Reinsert the pipette into the tube and mix the stain with the sediment by application of gentle pressure on the bulb at the top of the pipette. Squeeze and release the bulb until the specimen is uniformly mixed.	The stain and the sediment must be thoroughly mixed, but excessive formation of air bubbles should be avoided.

Continued

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Procedure 22-1: Preparation of Urine Sediment for Microscopic Examination—cont'd

Procedure	Rationale
10. Use the pipette to add a drop of the stained sediment to the KOVA slide. The slide is created with an opening at the top where the sediment can be added. The slide must not be overfilled or underfilled. At this point in the procedure, the protective face shield can be removed. Discard the pipette into the biohazardous disposal container.	If the slide is overfilled or underfilled, the results of the microscopic examination may be erroneous. When filling the slide, avoid the formation of air bubbles as much as possible. 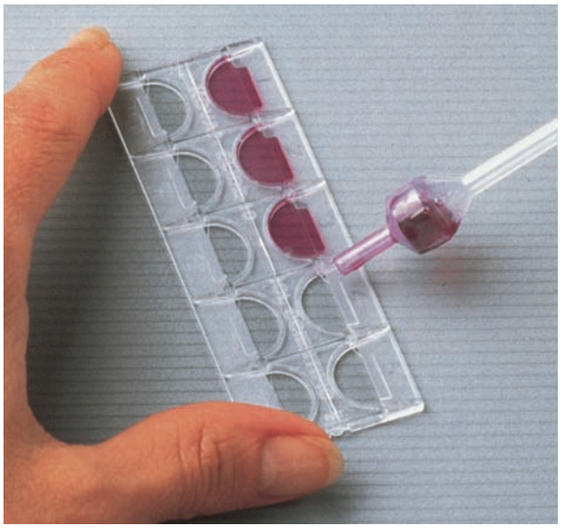 Courtesy of Fisher HealthCare, Inc.
11. Allow the specimen in the slide to settle for at least 1 minute before proceeding to the microscopic examination.	Focusing on the specimen too soon will make it difficult to identify or quantitate the formed elements correctly.
12. Complete the procedure necessary to focus the slide under the microscope.	The medical assistant may be involved in the focusing of the specimen, although he or she will not be performing the actual microscopic examination.

Procedure 22-2: Focusing the Urine Sediment Under the Microscope

TASK

Focus the urine sediment under the microscope to prepare it for identification and quantitation of formed elements. The process should be completed in less than 5 minutes.

CONDITIONS

- Hand sanitization supplies
- Gloves
- Laboratory coat
- KOVA slide with stained sediment added
- Biohazardous disposal container

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.14. Perform Urinalysis **III,P.III.2.** Practice Standard Precautions

ABHES Standards

- Medical Office Clinical Procedures: b. Apply principles of aseptic techniques and infection control, i. Use standard precautions
- Perform Urinalysis

Procedure	Rationale
1. Sanitize hands, allow them to dry, and apply gloves.	Gloves protect the hands from exposure to potential bloodborne pathogens. Gloves should always be applied in the presence of the patient.
2. Move the mechanical stage all the way down, away from the microscope outcomes. Place the filled KOVA slide on the mechanical stage of the microscope. Use the clips on the stage to stabilize the slide.	The stage is moved away from the outcomes so that there is room to place the slide on the stage. All microscopic specimens are placed on the stage for examination. The clips allow the slides to be moved as needed for examination.
3. Move the 10X outcome into place for viewing. Minimize the light by using the adjustment knob at the base of the microscope and/or by closing the aperture opening where the light comes through to the slide.	Reduction of the light using the low-power outcome allows for better focus on the formed elements in the specimen.
4. Use the coarse adjustment knob to bring the stage as close as possible to the outcomes.	This will bring the slide into approximate focus when viewed through the eyepieces.
5. Look through the eyepieces, and use the coarse and fine adjustment knobs as needed to bring the specimen into focus. If necessary, move the slide across the stage to find a formed element to use as reference while focusing. Squamous epithelial cells are often present and easily identifiable.	Some specimens have very few formed elements; therefore, it may be necessary to scan several fields before a point of reference may be identified.
6. Inform the health-care practitioner or technologist that the slide is ready to be viewed. The microscopic examination should be completed within 5 minutes of the initial focus so that the specimen does not become dried out on the slide.	If the specimen dries out, it could lead to erroneous results because the concentration of formed elements on the slide can change with evaporation, and the appearance of the elements may change.
7. When the procedure is completed, discard the slide in the biohazardous disposal container, discard the tube with the rest of the stained sediment in the biohazardous waste container, disinfect the work site and microscope as needed, and remove gloves. Sanitize hands.	It is important to disinfect work areas and appropriately dispose of all laboratory specimens for infection control.

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reporting may vary among laboratories. The differences in reporting methods may be the result of the system used for the examination (for instance, the commercial systems may have a grid that is used for counting and reporting the elements), or the differences may be the result of laboratory preference. Certain structures are reported as the number present per low-power field, whereas others report the number per high-power field. In addition, some of the formed elements are quantitatively reported as rare, few, moderate, and many, whereas others are reported using real numbers, such as 0 to 5, 5 to 10, and so on. Table 22-1 lists common formed elements and the units used for reporting.

Test Your Knowledge 22-6

True or False: All normal urine specimens contain a high number of formed elements. (Outcome 22-7)

ROLE OF THE MEDICAL ASSISTANT IN MICROSCOPIC URINE PROCEDURES

The examination of urine sediment is not a CLIA-waived procedure. Medical assistants who perform this procedure in a physician office or other laboratory setting must possess the appropriate training and education to perform this moderately complex procedure. Urine microscopy examination may also be performed by the health-care provider in a physician office laboratory, as long as that laboratory has been registered appropriately with the Centers for Medicare & Medicaid Services as a site that is performing **provider performed microscopy (PPM).** As part of the PPM process, the medical assistant will centrifuge the urine sample with added stain if necessary, place the sediment on the slide, and focus the specimen to prepare for the provider's microscopic examination. The medical assistant may also perform routine maintenance on the microscope.

Test Your Knowledge 22-7

List one duty that a medical assistant might perform in reference to the urine microscopic examination. (Outcome 22-8)

QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES FOR URINE MICROSCOPIC EXAMINATIONS

Quality assurance is a broad term used to describe the policies and procedures that ensure quality laboratory processes and patient care. For urine microscopic examinations, these parameters include the following components of the preanalytical phase of laboratory testing:

- Providing appropriate patient instructions for the collection of the specimen
- Ensuring adequate specimen volume
- Storing specimens correctly
- Using clean supplies
- Calibrating the centrifuge used to spin the specimen
- Separating the urine supernatant correctly
- Setting up the urine sediment correctly on the slide with the appropriate volume
- Focusing the specimen correctly in preparation for examination by a qualified laboratory professional

TABLE 22-1
Common formed elements and method of reporting

Common Formed Elements	Units Used for Reporting
Squamous epithelial cells	Rare, few, moderate, or many report per low-power field (lpf)
Mucus	Not reported by all laboratories; if reported, use rare, few, moderate, or many per low-power field (lpf)
Red blood cells	Average number visualized after counting 10 high-power fields (hpf). Reported as # per hpf
White blood cells	Average number visualized after counting 10 high-power fields. Reported as # per hpf
Spermatozoa	May or may not be reported according to laboratory protocol
Casts	Average number visualized after counting 10 low-power fields (lpf). Reported as # per lpf
Crystals	Reporting methods vary; usually rare, few, moderate, or many per high-power field
Bacteria	Rare, few, moderate, or many per high-power field
Yeast	Rare, few, moderate, or many per high-power field

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Quality control refers more specifically to policies and procedures directly relating to the testing process. For urine microscopy, most medical assistants will not directly perform the microscopic quality control procedures because they are not qualified to perform examination of urine sediment under the microscope. However, it is important for medical assistants to know that they are still part of the quality control process. The medical assistant needs to verify that all reagents (such as stains) to be used are not expired. The instructions for use of commercial systems must be followed carefully to achieve desired results. Appropriate maintenance of the microscope is also part of quality control, because it is used directly in the testing process.

Medical assistants who have been properly trained to perform the urine microscopic examination may be responsible for quality control procedures that verify their ability to identify and quantitate the formed elements in the urine specimen correctly. These quality control procedures may include examination of commercially prepared specimens that contain known quantities of various formed elements. The laboratory will also participate in proficiency testing procedures in which results from standardized specimens are compared to those of other laboratories across the country to test for competency.

SUMMARY

The microscopic examination of urine specimens provides valuable information to health-care professionals. As the third part of a complete urinalysis, the knowledge gained from urine microscopy enhances the results obtained from the macroscopic and chemical examination of the specimen. The presence of formed elements in the urine such as blood cells, epithelial cells, crystals, and microorganisms provides valuable information to assist in a diagnosis of urinary tract infections, kidney disease or trauma, or metabolic disorders. The standardization of the specimen processing and microscopic examination procedure allows for more reliability in the results. To perform a urine microscopic examination, medical assistants would need appropriate education and training to meet the requirements for performance of a CLIA moderately complex procedure. However, medical assistants who have not received this additional training may still be responsible for preparing a specimen and focusing it under the microscope for reading by a qualified individual.

TIME TO REVIEW

1. The presence of white blood cells in a urine specimen is called: Outcome 22-1
   - **a.** Pyuria
   - **b.** Hematuria
   - **c.** Hemoglobinuria
   - **d.** Cysturia
2. List two types of formed elements that may be identified in a urine microscopic examination. Outcome 22-3
3. Which of the following may be clinically significant if reported as part of a urine microscopic examination? Outcome 22-4
   - **a.** The presence of a rare white blood cell
   - **b.** Many bacteria
   - **c.** The presence of a rare hyaline cast
   - **d.** The presence of a rare squamous epithelial cell
4. Provide the name of one commercial system used to prepare urine specimens for microscopic examinations. Outcome 22-5
5. When focusing the urine sediment under the microscope, which microscope objective is used initially to bring the speciment into approximate focus? Outcome 22-6
   - **a.** 10X
   - **b.** 40X
   - **c.** 100X
   - **d.** None of the above
6. True or False: The presence of red blood cells is reported as few, moderate, or many per lpf. Outcome 22-7
7. Which of the following represents a typical task performed by a medical assistant in preparing for a urine microscopic examination? Outcome 22-8
   - **a.** Counting the number of white blood cells present in 10 fields using the high-power objective
   - **b.** Identifying the types of crystals present in the specimen
   - **c.** Centrifuging the urine specimen
   - **d.** Processing quality control specimens to verify competency with the procedure
8. True or False: Medical assistants are not responsible for any quality control procedures pertaining to the urine microscopic examination. Outcome 22-9

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9. How much supernatant is usually left in the tube with the sediment when preparing the sediment to be placed on a slide for viewing? Outcome 22-10
   a. 5 mL
   b. 3 mL
   c. 0 mL
   d. 1 mL or less

Case Study 22-1: When is a specimen too cold?

Cassie Mason is a medical assistant working in a physician office laboratory at which urinalysis tests are performed. Cassie completed all the initial urinalysis test procedures before leaving for lunch. This included notation of the color and appearance of each specimen, as well as the chemical dipstick testing. She cleaned her work area, put all the specimens in the refrigerator, and left the results for the health-care practitioner to review before lunchtime.

When she returned from lunch an hour later, there was a note from the practitioner asking her to set up urine microscopic slides for two of the urine specimens for the practitioner to examine later that afternoon between appointments. About an hour later, Cassie removed the urine specimens from the refrigerator, centrifuged them, and immediately set up the slides and focused them on the microscope. Immediately thereafter, the practitioner came into the laboratory area and looked at the slide of the first specimen. After a cursory glance, she asked Cassie whether this specimen had been refrigerated. When Cassie acknowledged that it had, she told Cassie that she needed to pour another specimen, allow it to sit for at least a half an hour, then recentrifuge, and set up the slide again for viewing.

1. What did the practitioner see in the specimen that made her ask about the refrigeration?
2. How will it help to have the specimen sit at room temperature for a period of time before setting up another slide to be viewed?

Case Study 22-2: Normal results?

A patient drops off a urine specimen that was collected at home to the laboratory. The time of collection noted on the requisition form was several hours before the specimen was delivered to the laboratory. The medical assistant who is working in the laboratory performed a chemical analysis of the specimen, and notes that the pH of the specimen is 8, and that the nitrite result test produces a positive result.

1. In this scenario, what are the three details that provide a possible explanation for the test results obtained?
2. Should this specimen be used for a complete urinalysis?

RESOURCES AND SUGGESTED READING

University of Iowa Carver College of Medicine, practice tests for the Urine Microscopic Examination
Presentation with questions and answers about the urine microscopic examination process http://www.medicine.uiowa.edu/cme/clia/modules.asp?testID=20

"Origin and composition of renal casts"
Explains the origin and composition of the various types of renal casts http://www.agora.crosemont.qc.ca/urinesediments/doceng/doc_016.html

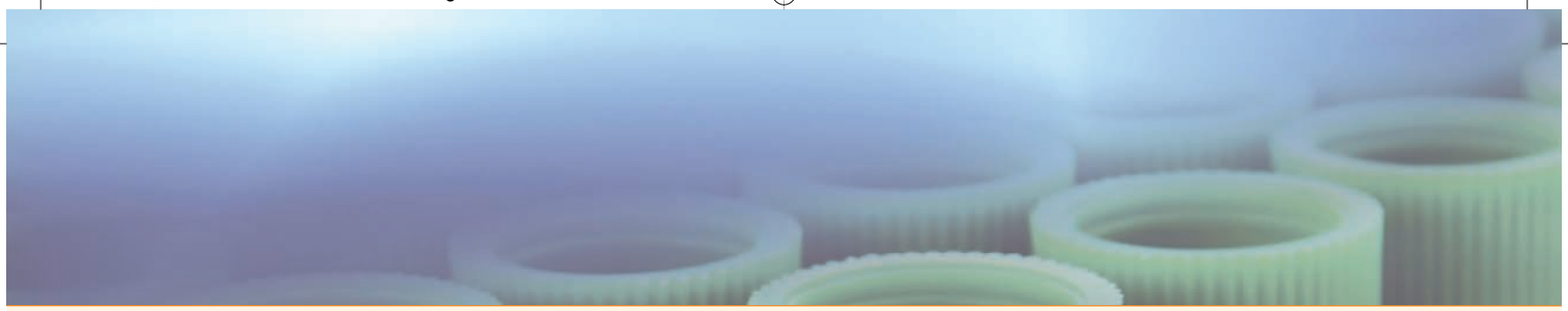

Section V

Urinalysis

What Does It All Mean?

The typical urinalysis test consists of three components: physical examination, chemical examination, and microscopic examination. In many settings only the physical examination and chemical examination are routinely performed. A microscopic examination is only performed when the physical and/or chemical examination results suggest the presence of formed elements. Some situations in which a microscopic examination is typically indicated include the following:

- A sample that is cloudy or turbid
- A sample that is red in color
- A sample that has a large top layer of white or yellow foam
- A sample that has more than trace amounts of protein

It is important to correlate the results obtained in each of the urinalysis components performed. For example, one would expect to detect red blood cells on the dipstick test of a sample noted as being red during physical examination.

Case in Point

Recall Johnny, whom we met at the beginning of this section. He is an active 3-year-old who loves to play in the garage. He was rushed to his doctor's office after drinking antifreeze.

Examination of his urinalysis physical examination results reveals that both the color and clarity of Johnny's sample are abnormal. The fact that his urine is cloudy suggests that formed elements are present and indicate that a microscopic examination should be performed. The most important chemical examination result in this case is protein. Any amount more than a trace is considered abnormal and indicates the need to perform a microscopic examination.

These results are most likely the result of Johnny's ingestion of antifreeze, which is toxic to the kidneys. The kidneys typically respond to such substances by ceasing to produce urine. This stagnate state provides a perfect environment for the development of formed elements known as casts. Casts are cigar-shaped structures that contain a core matrix of a protein known as Tamm-Horsfall. Although this is a different protein from that which the corresponding dipstick test is designed to detect, presence of abnormal amounts of protein suggest that casts may be present. The best next course of action in this case is to perform a microscopic examination on Johnny's urine looking for formed elements, particularly casts.

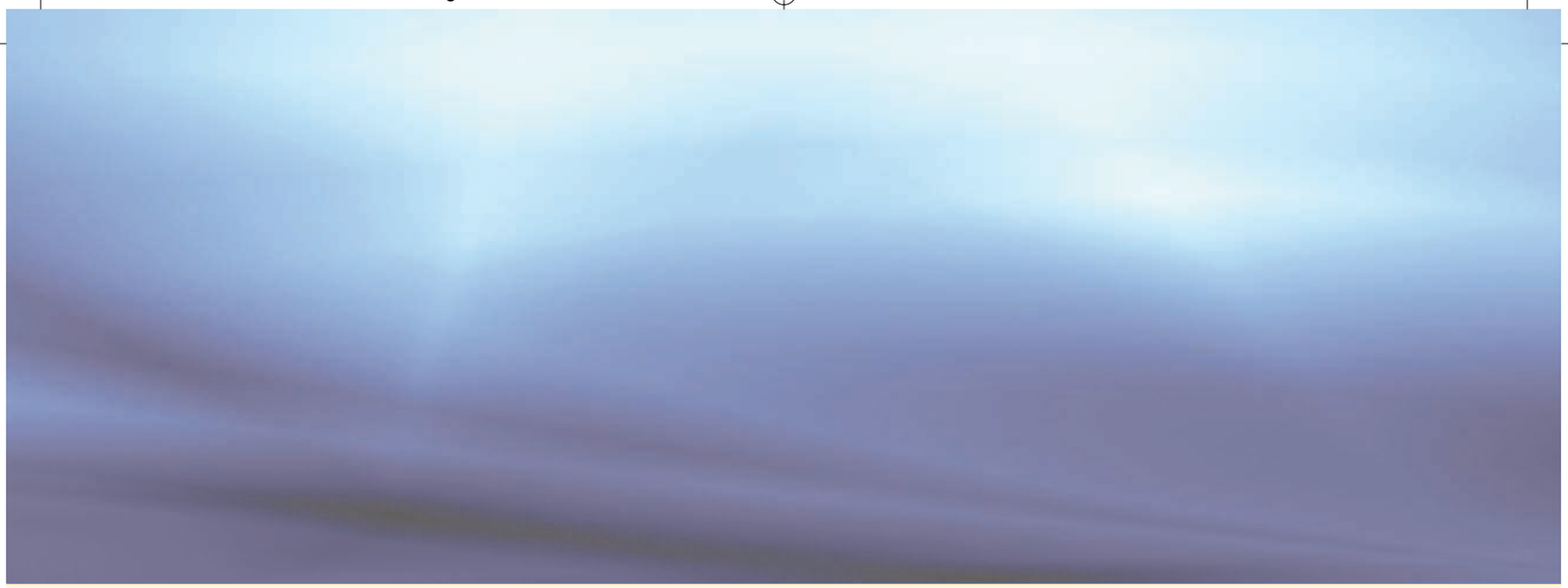

On the Horizon

Advances in our understanding of how the body's immune system works have exploded in recent years. From this work, important discoveries have emerged. One such example is the fact that we now know that diabetes mellitus is associated with the immune system! No one would have even suspected this just a few short years ago. As a result of discoveries such as this, immunology has truly become a laboratory discipline within itself. Likewise, laboratory testing in this area, also known as immunology, has improved and expanded. In fact, there is much crossover of laboratory disciplines associated with immunology tests. Some laboratories have a section dedicated to performing immunology tests. In other settings, immunologic testing is performed throughout the laboratory.

Relevance for the Medical Assistant (Health-Care Provider)

As with so many other aspects of laboratory testing, medical assistants and other health-care support personnel often participate in immunologic testing by being involved in corresponding sample collection and processing. Furthermore, medical assistants often perform select CLIA-waived immunologic tests along with appropriate quality control. Medical assistants are also responsible for completing the documentation associated with this testing.

Case in Point

Four-year-old P.J. presented to the pediatrician's office where you work accompanied by his very worried father. In your initial conversation with P.J.'s father you learn that little P.J. had been battling a fever and sore throat for more than a week and was not showing any signs of improvement. Upon examination of the patient, the physician noted that the child had numerous yellow "spots" on the tonsillar area of his throat. "No wonder this little guy is so uncomfortable," you thought to yourself. The doctor ordered a strep screen test and requested that you perform the test. You obtain the following results: Rapid strip screen—Negative.

Questions for Consideration:

- What is the specimen type of choice for strep screen testing?
- What is the proper collection protocol for this specimen?
- What is the strep screen test designed to detect?
- What accounts for the negative strep screen results obtained?
- What could be done at this juncture to help determine the microbiological agent responsible for PJ's infection?

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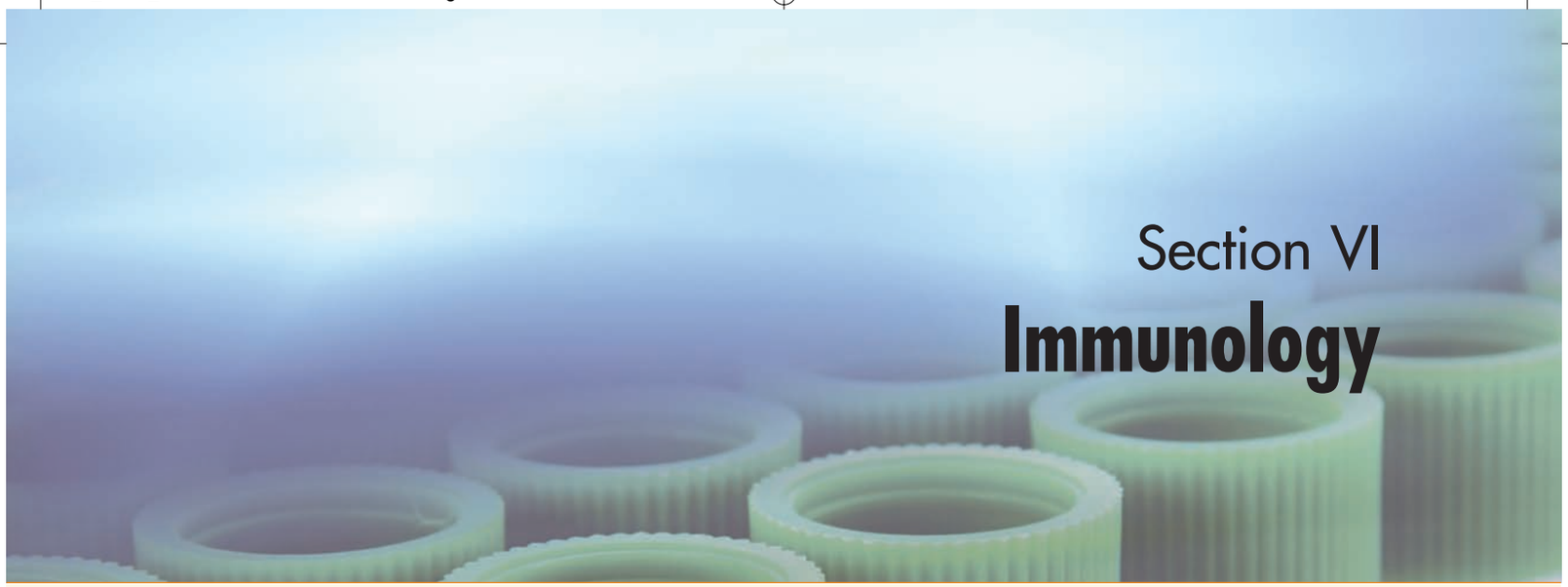

Section VI
Immunology

Chapter 23: Immunology provides the reader with a basic understanding of the immune system. Immunologic principles as they relate to blood typing and hemolytic disease of the newborn are covered. An introduction and overview of common immunology and serology test methods are presented.

Chapter 24: Immunologic-Based Rapid Testing includes a description of the common rapid tests that are routinely performed, including strep screen, infectious mononucleosis testing, pregnancy testing, *Helicobacter pylori* testing, and testing for influenzas A and B and HIV. The nature of each condition associated with these tests is examined. Appropriate follow-up testing is briefly discussed when indicated. Proper technique, normal test reference range, quality control, sources of error and interference, and test interpretation are described.

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Chapter 23

Immunology

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Immunity and Immunology
The Immune Process
- The First Line of Defense: Nonspecific Mechanical and Chemical Barriers
- The Second Line of Defense: Internal Nonspecific Response
- The Third Line of Defense: Acquired or Adaptive Immunity

How Immunity Is Acquired
Failure of Our Immune Systems
Blood Types
Erythroblastosis Fetalis
Immunology Testing Methods
Common Serology Tests Performed in Reference or Hospital Laboratories
CLIA–Waived Tests Commonly Performed in the Physician Office Laboratory
Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

23-1 Define the key terms.

23-2 Explain how serology and immunology are related to immunity.

23-3 Describe the mechanical barriers used by the immune system.

23-4 Explain how the internal defenses at the site of an invasion by foreign substances function.

23-5 Summarize how acquired immunity is activated in the body.

23-6 Distinguish what happens when the immune process malfunctions.

23-7 Examine how vaccinations activate the immune system.

23-8 Demonstrate understanding of the basic ABO and Rh blood typing systems and the role they play in hemolytic disease of the newborn.

23-9 Describe various immunology testing methods and common serology tests performed in hospital and reference laboratories.

23-10 Explain why some serology tests might be performed in physician offices rather than in reference laboratories.

23-11 Explain the clinical significance of the common CLIA-waived serology tests performed in physician offices.

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CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.C.5. Describe the normal function of each body system
I.C.6: Identify common pathology related to each body system
III.C.10: Identify disease processes that are indications for CLIA-waived tests

ABHES Standards

- Identify and apply the knowledge of all body systems; their structure and functions; and their common diseases, symptoms, and etiologies

KEY TERMS

Agglutination
Allergy
Antibody
Antibody-mediated immunity
Antigen
Autoimmune disease
B cells
Cell-mediated immunity
Chemotaxis
Cilia
Complement
ELISA or EIA testing
Erythroblastosis fetalis
Gammaglobulins
Globulin
Hemolytic disease of the newborn (HDN)
Histamine
Immunity
Immunoglobulins
Immunology
Infection
Inflammation
Interferons
In vitro
In vivo
Lateral flow immunoassay
Lysozyme
Macrophage
Mucous membranes
Natural killer (NK) cells
Normal flora
Pathogens
Phagocytes
Phagocytosis
Pus
RhoGam
RIA
Serology
T cells
Vaccine

IMMUNITY AND IMMUNOLOGY

Our bodies are constantly under attack by an army of microorganisms, toxins, allergens and other substances that are recognized as foreign or "nonself." Luckily, our defenses are usually able to protect us from this ongoing attack. The recognition and destruction of these foreign substances by our bodies are known as **immunity**, and the study of this process is called **immunology**.

Immunity includes numerous protective mechanisms within our bodies. In order for these systems to function properly, we must be able to detect what is "self" and what is "nonself." When a foreign (or nonself) invader is detected, the immune process is activated. A foreign substance capable of initiating an immune response is called an **antigen.** The antigen may be a microorganism (such as bacteria or viruses), an allergen (such as pollen or dander), a foreign body (such as a sliver), or even a cancerous cell from within the body.

Antibodies are substances that the body produces in response to certain antigens. The antibody is designed to attach to, or bond with, the specific antigen targeted. Antibodies are made of a type of protein called **globulin,** and because they are part of the immune process, they are known as **immunoglobulins.** The job of immunoglobulins is complex, and includes attachment to

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and destruction of the invader, as well as remembering the unique identity of the antigen so that if this invader comes into the body again, the body is ready to attack and destroy much faster than it was at the first exposure. Antibodies seek out and irreversibly bind to their specific antigen, rendering it ineffective.

A great deal of research has been performed on the immune responses of our bodies. We are now able to test for specific antibodies and antigens in the laboratory, using blood and other body fluids. This area of the laboratory may be known as the Immunology Department, but more commonly it is referred to as the Serology Department. **Serology** is the study of antigen and antibody reactions in serum, and may include methods such as radioactive laboratory testing, agglutination reactions, or simplistic tests such as those used to detect pregnancy.

Test Your Knowledge 23-1
How are antigens and antibodies related to immunity? (Outcome 23-2)

Test Your Knowledge 23-2
Which department in the laboratory provides testing methods to monitor the immune system? (Outcome 23-2)

THE IMMUNE PROCESS

If you've ever watched a movie about the Revolutionary War or Civil War, it is difficult to see the soldiers march forward on the battlefield in straight lines again and again to meet their enemies. Eventually, with a great deal of effort and substantial losses, this method of combat might affect the outcome of the encounter. On the other hand, the battles won with a minimal number of casualties were those that employed *multiple* strategies, or lines of defense.

We wage a similar battle in our bodies every day. The sheer number of foreign substances we encounter is overwhelming. We need more than one line of defense to defeat the invaders with minimal harm to ourselves. A healthy immune system makes use of three basic defense mechanisms (Fig. 23-1). These include mechanical and chemical barriers, internal defenses at the site of the invasion, and acquired or adaptive immunity created by the body in response to a specific antigen. The first two lines of defense are nonspecific, and function in a similar manner with any invader they encounter. These nonspecific mechanisms are protecting us all from birth or very soon afterward. The third defensive mechanism, however, is very specific and is something that we develop throughout our lives.

The First Line of Defense: Nonspecific Mechanical and Chemical Barriers

The first line of defense used by our immune system includes mechanical barriers, chemicals, organisms that are always present in our bodies, and protective reflexes. The goal of these mechanisms is to keep the invaders out of our bodies or prevent them from surviving long enough to cause any further harm.

Intact skin and the **mucous membranes** of our bodies are extremely important because they form a physical or mechanical barrier to many pathogens and other types of invaders. Their secretions also play an important role, by adjusting the pH to deter growth of most pathogens, and by trapping other invaders in a sticky environment where they can be destroyed or immobilized. The **cilia**

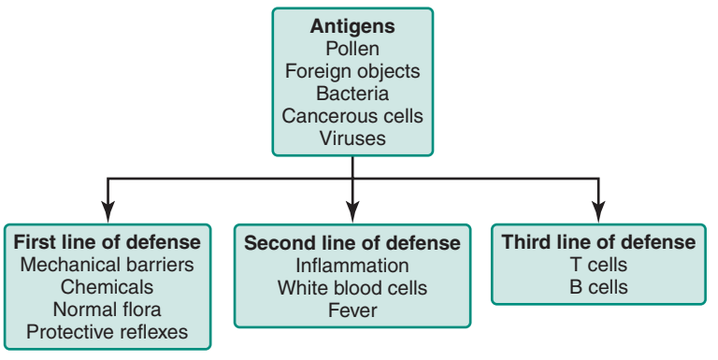

Figure 23-1 Flow chart showing the different kinds of immune responses and their triggers.

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lining the mucous membranes constantly work to sweep out any trapped substances. Reflexes, such as sneezing or coughing, then move these potential **pathogens** out of the body. The acidic environment in our stomach and the enzymes in saliva also assist with this first line of defense. Earwax protects our ears, perspiration helps to flush away unwanted bacteria, and an enzyme in tears called **lysozyme** destroys many potential invaders.

In addition to the protective mechanisms already mentioned, our bodies are populated naturally by numerous types of bacteria. Although this might seem to be a bad thing, it is actually quite beneficial to our immune system. The presence of this **normal flora** creates a competitive environment in which most invading bacteria cannot survive. We have normal flora throughout our bodies, including in and on our skin, in our mouths, and in our intestinal tract.

Test Your Knowledge 23-3

How does a break in the skin trigger the first line of defense to respond? (Outcome 23-3)

Test Your Knowledge 23-4

Are sneezes a good thing? Why or why not? (Outcome 23-3)

The Second Line of Defense: Internal Nonspecific Response

If a foreign substance makes its way past the first line of immune defenses, it will be confronted with a wave of new defense mechanisms within the body. These are all part of the internal nonspecific response, also known as the second line of defense. Included in this arsenal are phagocytosis, inflammation, fever, and natural killer cells. This second line of defense is also known as natural or innate immune response.

When cells are injured, they release a chemical into the bloodstream that signals the second line of defense to activate. This signaling is called **chemotaxis,** and it attracts certain types of white blood cells to the scene of the invasion to act as **phagocytes.** The white blood cells (neutrophils and monocytes) are specially programmed to ingest and destroy the invaders. This process is called **phagocytosis.**

When a foreign substance has entered the body, we often observe the surrounding area become red, hot, and swollen. The internal process that causes this appearance is called **inflammation,** and if it is caused by a pathogen, it may be known as **infection.** Inflammation occurs as a result of injury to or irritation of a cell. When the cells become irritated or injured, they release **histamine.** The histamine causes the blood vessels in the area to dilate, or become larger. The blood flow increases to the irritated area, and this causes the heat and redness we see and feel. Histamine also causes the blood vessel walls to become "leaky," so more fluid leaks out of the bloodstream into the surrounding injured area, causing swelling. Pain is evident because the surrounding nerve receptors are stimulated by all the activity.

As the blood supply is increased, more phagocytes are brought to the area. While doing their job, these cells create a lot of debris. The built-up dead phagocytes, fluid, pathogens, and injured blood cells that accumulate are what we recognize as **pus.**

The next symptom we often note in a pathogenic invasion is fever, which occurs because the phagocytes that respond to the scene of the injury release a chemical that signals the brain to increase the body's temperature. The elevation in temperature helps the second line of defense by decreasing the ability of many pathogens to survive, as well as stimulating even more phagocytosis.

As if all the other activity weren't enough, protective proteins also assist at the scene of the invasion. There are two groups of protective proteins, known as **interferons** and **complement** proteins. Interferons are secreted by cells that have been infected by viruses, and they help other cells resist the spread and replication of the virus. Complement proteins are able to destroy bacteria by covering the surface of the bacterial cells and punching holes in the cell membrane, causing the bacteria to die.

The last component of the second line of defense is the **natural killer (NK) cells,** which are a special type of lymphocyte that responds to the invasion. NK cells can attack and destroy human cells that have been infected by pathogens. In addition, natural killer cells may be beneficial by destroying certain cancer cells before they can spread.

The Third Line of Defense: Acquired or Adaptive Immunity

Acquired or adaptive immunity is a defense mechanism that requires the body to "think" about the invaders. It involves three characteristics that are not present in the first or second line of defense. Recognition of an antigen as nonself must first occur, after which the antigen (invader) is identified very specifically. Then the body

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forms a memory of that antigen, so it will be immediately recognized in case of subsequent exposure. Usually this entire process requires 1 to 2 weeks after the first exposure to a specific antigen.

T cells and **B cells** are specifically programmed lymphocytes. They are both part of this third level of the immune process, but they each perform different functions when exposed to an antigen. T cells are involved in cell-mediated immunity, and B cells are involved in **antibody-mediated immunity,** also known as humoral immunity.

Cell-mediated immunity begins at the site of the invasion (Fig. 23-2). The T cells become "activated" toward a specific antigen when it is presented by a **macrophage.** (A macrophage is a type of phagocyte that leaves the bloodstream and goes into the tissues.) Once activated, this T cell creates four identical copies of itself, which all have specific functions:

- Killer T cells are produced to kill the antigens.
- Helper T cells are designed to stimulate other T cells and help the B cells.
- Suppressor T cells (also known as regulatory T cells) are created to inhibit the activity of the T and B cells when enough have been produced.
- Memory T cells are responsible for remembering the antigen for future encounters, which allows the cell-mediated immunity to occur faster with the next exposure.

Most of the lymphocytes in our circulation are T cells. Although no antibodies are produced by the T cells, they play an important role in many contact sensitivity reactions, as well as viral infections, fungal infections, and destruction of malignant cells.

Antibody-mediated immunity uses the lymphocytic B cells (Fig. 23-3). As with the cell-mediated immunity, the antigen must first be exposed, or introduced, to the B cell by presentation from the macrophage. The helper T cells release a chemical to assist with this recognition process. Once activated, the B cell produces two replicas of itself, which have their own duties:

- Plasma cells are created that secrete antibodies that are specific for a particular antigen. These antibodies

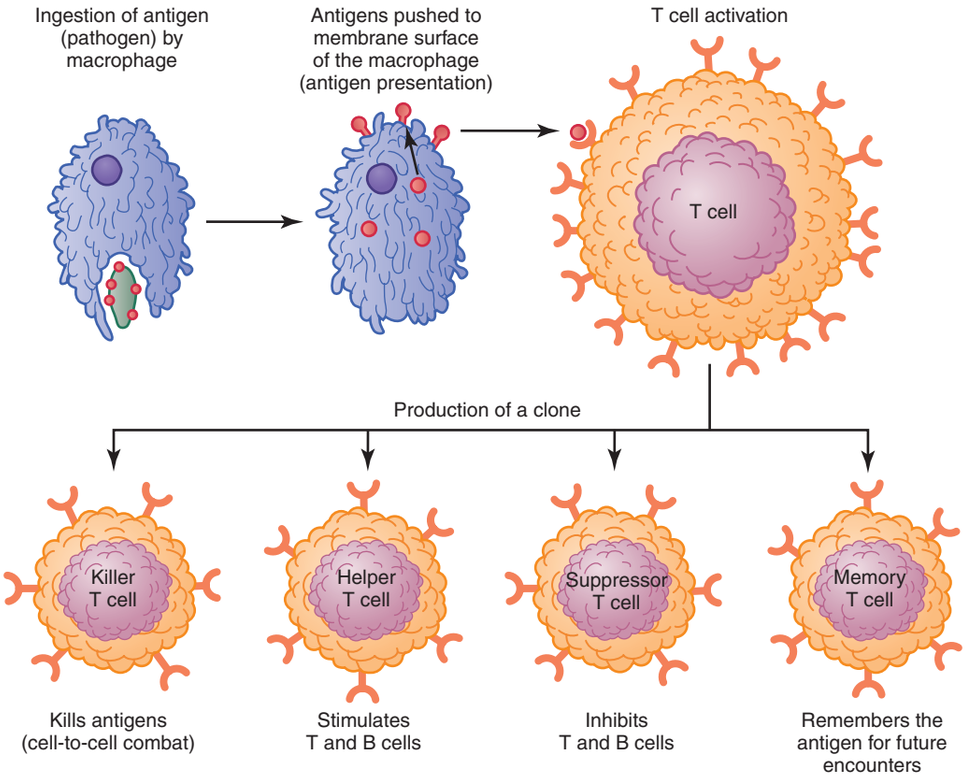

Figure 23-2 Cell-mediated immunity. This drawing represents the T-cell activation and the subsequent steps, creating four subsets of T cells.

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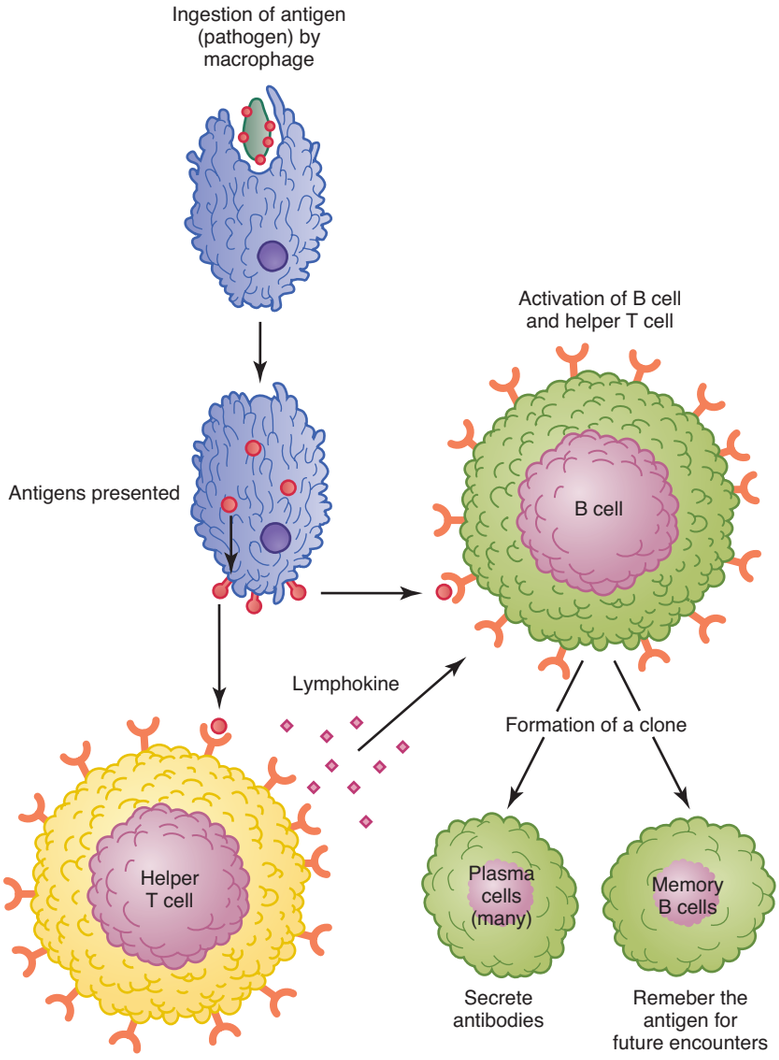

Figure 23-3 Antibody-mediated immunity. B-cell activation leads to antibody creation by plasma cells.

work like a lock and key and cannot be interchanged with other antigens. The antibodies bind to the antigens, blocking their ability to affect the cells of the body.

- Memory B cells form a "picture" of the antigen and remember it for future encounters.

Test Your Knowledge 23-5

True or False: Antigen exposure always triggers all three lines of defense. (Outcome 23-4)

Test Your Knowledge 23-6

Which line of defense is "unique" toward a specific antigen? (Outcome 23-4)

HOW IMMUNITY IS ACQUIRED

There are essentially four ways we can acquire immunity:

- *Natural active immunity acquired from an infection with a pathogen:* This causes the body to produce a memory of the antigen and protects the body on

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subsequent exposures. For instance, natural active immunity is produced when a person is infected with chicken pox. Once the person recovers, he or she is now immune to this pathogen. This is a long-term type of immunity.

- *Artificial active immunity acquired from a* **vaccine:** The typical antibody response of our body after exposure to an antigen is usually too slow to protect us from the initial infection. However, with subsequent exposures, the protection is so fast that we never become ill. Vaccines do this artificially. They contain an antigen that causes the body to develop antibodies as if it were being exposed for the first time. The vaccine may be a killed or weakened pathogen (known as *attenuated)* or it may just be part of a pathogen. Vaccines are available for many diseases, such as hepatitis A and B, measles, and mumps. The protection is long term with this type of immunity.
- *Natural passive immunity, such as the antibodies a mother passes on to an infant through the placenta or through breast milk:* This is a temporary type of immunity and fades as the child grows.
- *Artificial passive immunity:* This usually occurs with the injection of **gammaglobulins** (artificial antibodies). This immunity is short acting, and protects the individual in an emergency situation. For example, a family member has been diagnosed with hepatitis A, but the rest of the family is unvaccinated for that disease. The other family members are then injected with an "artificial antibody" (gammaglobulin) so that they will be protected until the infected individual recovers from the hepatitis A infection.

Test Your Knowledge 23-7

What does it mean when we say that we are "immune" to a certain disease? (Outcome 23-5)

Test Your Knowledge 23-8

How do vaccines "fool" our immune systems? Which line of defense do they target? (Outcome 23-5)

FAILURE OF OUR IMMUNE SYSTEMS

Unfortunately, our immune systems don't always work as they should. Sometimes our body's ability to recognize self and nonself is not fully developed, or is somehow dysfunctional. In this case, our body may attack its own cells, causing damage. This is the theory behind many forms of **autoimmune diseases,** such as rheumatoid arthritis. Also, as we age, our immune systems don't seem to detect the malignant or damaged cells in our bodies and destroy them as they should. This allows the cells to reproduce and cause cancer at a higher rate as we age.

In the case of an **allergy,** our immune system becomes hypersensitive after the initial exposure to an antigen. With subsequent exposures to that antigen, the immune response causes inflammation and organ dysfunction. Allergies may range from those with annoying symptoms (such as hay fever) to those that are truly life threatening, such as reactions to insect stings and certain medications. Table 23-1 provides examples of diseases associated with the immune system.

POINT OF INTEREST 23-1
Vaccines

Vaccines are used to prevent disease by introducing an antigen into the body to induce an immune response. After the vaccine is processed by the body, antibodies are created against that specific antigen. When the patient is exposed again to the disease-causing virus or bacteria, the body immediately produces large amounts of antibody that prevent the disease from developing.

The vaccine antigen may be attenuated, meaning that the antigen it is killed or weakened. Vaccines may also include parts of bacteria or virus particles that are capable of stimulating an immune response but not capable of causing disease. In addition, an inactivated toxin produced by the bacteria (called a toxoid) may be used. The tetanus and diphtheria vaccinations are toxoid vaccines.

BLOOD TYPES

Blood types also involve antigens and antibodies, but in a different way. The antigens that determine blood types are on the surface of all red blood cells. Blood typing also involves natural and acquired antibodies in the plasma. There are several situations that might warrant a test for blood type, including transfusions, testing to prevent hemolytic disease of the newborn, and for investigative or forensic reasons. There are hundreds of different antigens present on the red blood cells of our bodies, all capable of causing transfusion complications. Fortunately, most serious complications from transfusions are due to the ABO and Rh blood groups, so much of our testing is focused on those groups.

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TABLE 23-1
Common immune system disorders

Classification	Examples of Specific Disorders
Hypersensitivity (allergy)	Anaphylactic reactions, dermatitis or eczema, rhinitis, asthma
Autoimmune disorders	Systemic lupus erythematosus, type 1 diabetes, Graves' disease, celiac disease, myasthenia gravis, rheumatoid arthritis, systemic sclerosis
Malignancies of immune cells	Lymphocytic leukemias, lymphoma, multiple myeloma
Congenital immune disorders	Thymic hypoplasia, agammaglobulinemia
Secondary or acquired immunodeficiency	AIDS, transplant anti-rejection medication use, systemic infections, side effect of radiation treatment, overuse of antibiotics

The ABO blood types include A, B, AB, and O, and they represent the antigens present (or absent) on the red blood cells of an individual. If people have a blood type of A, this means they have the A antigens on their cells. If B antigens are present, they are blood type B, and if both are present, the blood type is known as AB. Type O may be thought of as type "zero," as it means neither A or B antigens are present (Fig. 23-4).

The ABO blood typing system is unique, because in the plasma of each person there are natural antibodies to the antigens that are *not* present on their red blood cells. This means a person with a type A blood type has anti-B naturally in his or her plasma, and the plasma of a person with type B blood will contain antibodies to the A antigen. An individual who is type AB has neither anti-A nor anti-B in the plasma, and type O individuals naturally possess both anti-A and anti-B in their plasma. These plasma antibodies are created within the first few months of life as an immune response to dietary antigens and exposure to various environmental factors.

When patients receive blood transfusions, they generally receive a blood product known as packed red blood cells rather than whole blood. To prepare packed red blood cells, the unit of donor blood is centrifuged so that the plasma is separated from the cells, and most of the plasma and the white blood cells are separated from the red blood cells. Removal of the plasma avoids an overload of fluid for the patients needing multiple units to increase their red blood cell and hemoglobin concentration. The absence of white blood cells in the blood product helps to reduce the potential for an immune response.

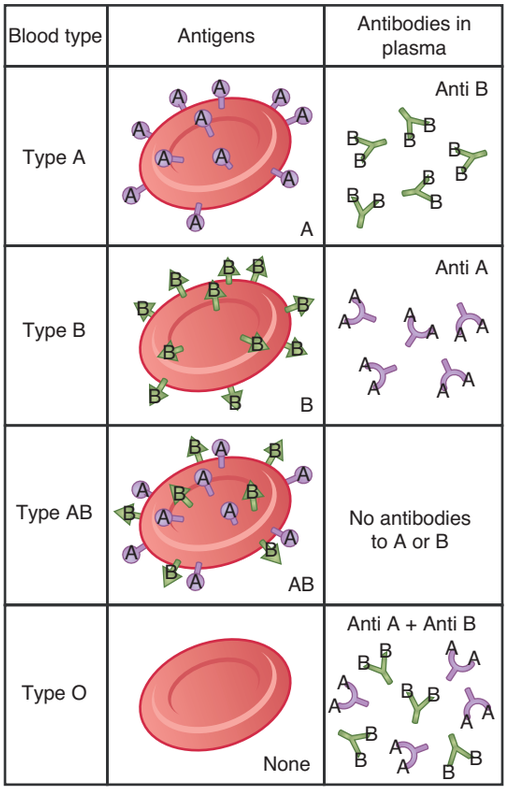

Figure 23-4 Various blood type antigens and antibodies.

It is critical to consider the natural antibodies present in the plasma if a transfusion is needed. Ideally, a person should only be transfused with his or her own blood type. In an emergency situation, a person may be given a different type, but there are only a few alternatives that are safe. If a type B person received type A blood, the natural anti-A antibodies would cause the cells to clump (agglutinate), and eventually hemolyze (rupture). The by-products of this reaction could also clog the capillaries in the kidneys and cause renal failure. Blood type O is known as the universal donor, because there are no ABO antigens on the cells. When type O packed red blood cells are transfused to a patient with any other blood type, they are not rejected by the recipient and the natural anti-A and anti-B that was present in the plasma of the donor are not present in the packed cells to damage the recipient's blood cells. Type AB is known as the universal recipient, because there are no ABO antibodies in the plasma to damage any blood type that is transfused to these recipients. About 40% of the population is type A, 11% is type B, 45% is type O, and 4% is type AB (Table 23-2).

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TABLE 23-2
Percentage of various blood types in the U.S. population

Blood Type	Percentage of U.S. Population
A	40%
B	11%
AB	4%
O	45%

Another very important red blood cell antigen is the Rh or D antigen. It was discovered in 1939 with work on rhesus monkeys, hence the designation Rh. Approximately 85% of the population has the D antigen on their cells, and they are known as Rh positive. Those who don't have the Rh (D) antigen on their cells are known as Rh negative.

Unlike the ABO blood types, Rh-negative individuals do not have naturally occurring Rh antibodies in their plasma. However, they can be sensitized to this foreign Rh antigen if exposed. This exposure may occur with a transfusion error, or it may occur with pregnancy and delivery. There is usually no problem evident with the first Rh exposure because the antibody production takes too much time. However, the antigenic response is *very* swift and strong with subsequent exposures to Rh-positive blood.

ERYTHROBLASTOSIS FETALIS

Erythroblastosis fetalis is a severe hemolytic anemia that affects Rh-positive newborns and occasionally other newborns with ABO incompatibility. This condition may also be known as **hemolytic disease of the newborn (HDN).** The Rh status of the blood cells is only an issue when the baby is Rh positive and the mother is Rh negative. During a first pregnancy, this incompatibility does not usually cause harm to the baby, as the mother's response to the Rh antigen does not happen quickly enough for the antibodies to attack the baby's red blood cells. However, during the first pregnancy, and especially during delivery of the baby and the placenta, there is an exchange of fetal blood with the mother, and the mother will become sensitized, which means that she will develop antibodies to the Rh antigens on the baby's red blood cells. If she becomes pregnant again with an Rh-positive baby, her antibodies to the Rh antigens will destroy the baby's red blood cells and the baby may be born with severe anemia, jaundice, and an enlarged spleen and liver, which may be fatal for the newborn.

An injection of **RhoGam** (anti-Rh gammaglobulin) during the pregnancy and shortly after delivery should be given to all Rh-negative mothers. This will keep the mother from becoming sensitized to the Rh antigen so she does not create the anti-Rh antibodies. When she becomes pregnant again with an Rh-positive baby, her body will react as if this were her first exposure, and the Rh incompatibility will not be a problem.

POINT OF INTEREST 23-2
Kidney transplants for patients with incompatible blood types

Many potential kidney donors are rejected because their blood type is not compatible with that of the patients needing a kidney. There is now a process that allows patients to receive a kidney from a donor with an incompatible blood type.

The natural antibodies present in the plasma of the recipient of a kidney with an incompatible blood type usually cause the kidney to be destroyed. The process for ABO-incompatible kidney transplantation includes a procedure called plasmapheresis. The patient has a unit of blood removed from his or her body, and a portion of the liquid plasma is then removed. After each of the plasmapheresis procedures, the patient will receive replacement antibodies that are necessary to fight off other infections. The procedure may need to be repeated numerous times, until the level of ABO antibody detected in the blood is low enough to be considered safe for the transfusion.

Kidney transplant rejection rates for this procedure are not much different from the rate for patients who receive kidneys of the same ABO blood type. The patient will have more plasmapheresis and artificial antibody treatments after the transplant, depending on the individual needs of the patient. In addition, the recipient may also require a splenectomy, because the spleen is the organ in which the ABO antibodies are produced.

Test Your Knowledge 23-9

What antigens are present on the blood cells of an individual with a blood type of AB positive?

(Outcome 23-8)

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Test Your Knowledge 23-10

A fellow student just found out that she is expecting a baby. Her blood type is A, Rh negative. Will she be likely to receive a RhoGam injection? Why?

(Outcome 23-8)

IMMUNOLOGY TESTING METHODS

Various immunology testing methods are available for use in the medical office as well as hospital and reference laboratories. They can be performed **in vivo** (inside a living organism) as in allergy or tuberculosis testing; an antigen is placed under the skin, and the patient is monitored for a visible reaction. More often, they are performed **in vitro** (within a laboratory testing environment), where we commonly refer to them as serology tests.

Serology tests must be specific to the antigen or antibody being tested, and they must also be sensitive enough to detect even a small amount of the substance in the specimen. Many medications or other concurrent disease states can interfere with the specificity of a certain test, and sometimes can cause false-positive or false-negative results. The sensitivity of a testing method can be affected by high or low temperatures during shipping or storage, and also by minor errors that occur during the testing procedures. Package inserts should be examined carefully for specimen requirements, interfering substances, storage and handling directions, and testing procedures before performing any sort of serology testing.

All immunology tests are performed to determine the presence of a particular antibody or antigen. The specimen tested may be blood, serum, urine, oral fluids, or other body tissues. Various testing methods are used, including the following:

- Enzyme-linked immunosorbent assay tests **(ELISA or EIA)** tests usually involve a testing surface that is coated with an antibody or antigen bound to an enzyme. After the specimen is added, if the matching antibody or antigen is present, a color change will occur that can be read either by the testing personnel directly or by using an instrument to measure the amount of color change.
- An adaptation of the EIA principle, **lateral flow immunoassay** is used in many CLIA-waived tests. The specimen must be absorbed and must "flow" across the testing surface to reach the area imbedded with the antigen or antibody. If the test is positive, the antigen/antibody complex will cause a color change to occur in the testing area. These tests are read directly by the testing personnel, and have a built-in quality control area as well.
- Radioimmunoassays **(RIAs)** use a radioactively labeled protein as the indicator of a positive result. The antigen/antibody complex formed in a specimen that is positive will combine with the radioactive protein rather than an enzyme as in the EIA method. The final result is obtained from the amount of radioactivity present in the sample at the end of the testing process. These assays are complicated, and are performed only by qualified personnel in hospital or reference laboratories.
- Agglutination is the formation of large insoluble aggregates (clumps) of cells that form when an antigen/antibody complex is present. Agglutination may use red blood cells and antibodies, as in the case of ABO and Rh blood typing, or it may use latex beads, as do some of the mononucleosis testing procedures. This reaction is read by the testing personnel directly, as the complex is visible to the naked eye.

COMMON SEROLOGY TESTS PERFORMED IN REFERENCE OR HOSPITAL LABORATORIES

Serology tests may share common methodology, but the complexity of the testing process can vary greatly. The tests mentioned below are usually performed only in reference or hospital settings, as they require additional training and/or credentials for the person performing the test.

- Testing for *ABO/Rh* major blood antigen groups uses agglutination techniques. Screening is also performed for other common red blood cell antigens, and compatibility tests are performed on the donor blood when a transfusion workup is necessary.
- *The antistreptolysin O (ASO)* test is used to detect antistreptolysin O antibodies, which are present in a patient with prior recent infection by group A streptococcus. The identification of those with prior infection is important, as group A streptococcus infection can lead to other complications such as glomerulonephritis, rheumatic fever, and bacterial endocarditis. The ASO antibody may be present for several months after the initial infection.
- *Cold agglutinins* are antibodies present with certain types of infections, pneumonias, cancers, or inflammatory autoimmune disorders. These antibodies can cause the red blood cells of the body to "clump" together when exposed to cold temperatures. This leads to hemolytic anemia and other complications.

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- *The C-reactive protein (CRP)* test verifies the presence of that protein, which is present in the blood with acute systemic inflammation. It may be used as part of the diagnosis for a specific condition related to inflammation, or to monitor the effectiveness of treatment.
- *Hepatitis testing* determines which form of viral hepatitis (A through E) an individual has, and it may also provide more information about where an individual is in the disease process.
- Although a *pregnancy test* can be performed at home or in a physician office laboratory as a CLIA-waived test, it is sometimes necessary to use the more sensitive methods that are available in a larger laboratory. These methods can sometimes detect pregnancy sooner than can the CLIA-waived tests, and they can also quantitate the amount of human chorionic gonadotropin (HCG) present in the specimen. This quantitative analysis can be vital in the case of a suspected ectopic pregnancy, or in the diagnosis and treatment of testicular cancer, in which the hormone is also present in the bloodstream in male patients.
- Rheumatoid arthritis is a crippling and progressive autoimmune disease that affects the joints of the body. Those afflicted will have the *rheumatoid factor* present in their blood, which is a unique antibody used for diagnosis.
- *The most common tests used to detect syphilis* are the rapid plasma reagin (RPR) test and the venereal disease research laboratory (VDRL) test. The tests detect the presence of the microorganism *Treponema pallidum,* the causative agent of syphilis.

Test Your Knowledge 23-11

What do all serology tests have in common? (Outcome 23-9)

Test Your Knowledge 23-12

True or False: The same disease may be detected by more than one serology test. (Outcome 23-9)

CLIA–WAIVED TESTS COMMONLY PERFORMED IN THE PHYSICIAN OFFICE LABORATORY

Tests performed in a physician office laboratory are very important for appropriate diagnosis and treatment of various diseases, as the results are available quickly within the same office where the patient is being examined. This section covers these tests, as well as their testing procedures, in more detail (Table 23-3).

- *Mononucleosis:* Mononucleosis is caused by the Epstein-Barr virus. The test performed for diagnosis identifies the presence of the heterophile antibody produced with this infection,.
- *Pregnancy:* Pregnancy tests determine the presence or absence of human chorionic gonadotropin (HCG) in urine or serum. CLIA-waived tests are qualitative in nature, with a positive or negative result.
- *Helicobacter pylori: H. pylori* is the bacterium responsible for many gastric and duodenal ulcers and gastritis. The test can be performed on serum and other body tissues.

TABLE 23-3

Commonly performed CLIA–waived immunology tests

Disease/Condition	Causative Agent	Test Performed	Required Specimen
Mononucleosis	Epstein-Barr virus	Mononucleosis screen or heterophile test	Blood
Pregnancy	Human chorionic gonadotropin (HCG)	Pregnancy (HCG) test	Serum or urine
H. pylori	*Helicobacter pylori* bacteria	*H. pylori* test	Blood or tissue sample
HIV	Human immunodeficiency virus	HIV test	Blood, oral fluids
Flu	Influenza virus	Influenza test	Nasal or nasopharyngeal swabs
Bladder cancer	Bladder tumor–associated antigen	BTA test	Urine
Strep throat	Group A streptococcus bacteria	Strep screen	Throat swab

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- *HIV:* The human immunodeficiency virus screening test checks for the presence of the antibodies produced with HIV infection. This is designed to be a *screening* test only, and more definitive testing would then be performed on positive samples before the patient would be deemed HIV positive. Various body fluids can be tested for the presence of HIV.
- *Influenza:* The influenza test is performed during the winter months to detect the presence of influenza A or B, which causes a very serious respiratory infection.
- **Bladder tumor–associated antigen:** The screening test for bladder cancer uses a urine specimen.
- *Group A streptococcus infection:* The screening test for active infection with group A streptococcus uses a throat swab. The result is available in minutes after collection, allowing for much faster treatment than was previously available when only a throat culture was used.

Test Your Knowledge 23-13

Why might it be beneficial to perform simple serology tests in the physician office instead of a reference or hospital laboratory? (Outcome 23-10)

Test Your Knowledge 23-14

What is the causative agent of mononucleosis? (Outcome 23-11)

SUMMARY

Our immune systems are complex and protect us in various ways. We have three basic mechanisms that interact to provide this protection. They include various natural barriers, cellular and chemical responses to invaders, and antibody formation. We use vaccinations to protect us by activating our immune systems, and we also have naturally occurring antibodies to ABO blood types that are unlike our own. Blood type antibodies may be protective, but they can also cause serious health issues and must be considered during pregnancy to protect the unborn child.

Laboratory testing for immunity is known as serology. Various tests are performed in the physician office laboratory, as well as in hospital and reference laboratories. These tests may be qualitative or quantitative in nature, and are invaluable to aid in appropriate diagnosis of numerous disease states.

TIME TO REVIEW

1. A substance released in response to antigenic exposure that causes blood vessels to dilate is a(n): (Outcome 23-1)
   a. Lymphocyte
   b. Histamine
   c. Interferon
   d. Chemotaxis

2. A(n) _____ is anything that our body recognizes as nonself. (Outcome 23-1)

3. How are antigens and antibodies related to serology testing? (Outcome 23-2)

4. What role does our stomach play in protecting us from antigens? (Outcome 23-3)
   a. Inflammation destroys the pathogens
   b. The pH of the stomach acid helps to destroy microorganisms that may make their way into our bodies
   c. Antibodies are produced here to destroy the invaders; white blood cells engulf the antigens
   d. The stomach does not play a role in immunity

5. What is phagocytosis? (Outcome 23-1)
   a. The process by which white blood cells engulf and destroy pathogens
   b. The process that occurs when a noncompatible blood type is given to a patient
   c. A term used to describe the first line of immunity
   d. The production of antibodies

6. True or False: Immunity provided by the mother at birth is lifelong for many diseases. (Outcome 23-5)

7. True or False: Acquired immunity occurs only as a consequence of vaccinations. (Outcome 23-6)

8. What is used in vaccinations to activate our immune systems? (Outcome 23-6)
   a. Immunoglobulin
   b. Killed (attenuated) viruses or parts of viruses
   c. Normal flora
   d. B cells

9. Antibodies to blood type antigens A or B: (Outcome 23-8)
   a. Occur after exposure to another blood type
   b. Are naturally occurring and do not require exposure to develop

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c. Do not exist in the bloodstream
d. Are harmless

10. True or False: Serology tests use a variety of testing methods. Outcome 23-9

11. Which of the following are acronyms for tests used to detect syphilis infection? Outcome 23-9

a. VDRL and RPR
b. HCG and IgG
c. HET and RPR
d. CRP and VDRL

12. Doctor Johnson is about to prescribe a medication to treat acne for Carly Lucas. This medication is not advised for those who are pregnant. Which CLIA-waived test might the physician order to be sure this drug is safe for Carly to take? Outcome 23-9

a. RPR
b. *H. pylori*
c. HCG
d. Mononucleosis

13. True or False: All serology tests performed in physician office laboratories require blood samples as the speciment type. Outcome 23-11

Case Study 23-1: Could this be right?

Dr. Johnson has just handed his medical assistant a requisition form for a blood draw for Mr. Daniels, a 22-year-old male. The physician has ordered a β HCG test. The medical assistant is surprised, because she has only seen HCG tests ordered for females in the past. She is sure there is an error, and asks Mr. Daniels to wait a few minutes until she can confirm the order with the physician.

1. Is this test an appropriate one for a 22-year-old male? If so, why might the physician have ordered the test?

RESOURCES AND SUGGESTED READINGS

"How Your Immune System Works"
Another explanation for how the immune system works http://www.health.howstuffworks.com/immune-system16.htm

"Overcoming Sensitivity Limitations of Lateral-Flow Immunoassays With a Novel Labeling Technique"
Information about various medical devices and testing methods http://www.devicelink.com/ivdt/archive/06/05/010.html

"Quidel Rapid Diagnostic Products"
Links to the Quidel point-of-care test kits, including CLIA–waived tests http://www.quidel.com/products/product_list.php?cat=1&by=brand&group=1

"Tests Waived by the FDA From January 2000 to Present"
List of all CLIA–waived tests; updated regularly http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfClia/testswaived.cfm

"What Does It Mean to Be Rh Negative?"
Further information about Rh-negative immunity issues and the use of RhoGam. This site has information for patients and health-care professionals. http://www.rhogam.com/Patient/WhatRhNegativeMeans/Pages/default.aspx

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Chapter 24

Immunological Based Rapid Testing

Constance L. Lieseke, CMA (AAMA), MLT, PBT(ASCP)

CHAPTER OUTLINE

Immunology Methods and Procedures
Rapid Testing
- Advantages of Rapid Testing
- Common Procedural Elements of Rapid Testing
- CLIA–Waived Regulations and Their Application to Immunology -Based Rapid Testing

Common CLIA–Waived Rapid Tests and Their Clinical Significance
- Group A Streptococcal Screening
- Mononucleosis Testing
- Pregnancy Testing
- *Helicobacter pylori* Testing
- Influenzas A and B
- HIV Testing

Summary
Time to Review
Case Study
Resources and Suggested Readings

Learning Outcomes

After reading this chapter, the successful student will be able to:

24-1 Define the key terms.

24-2 Analyze the advantages of rapid immunology testing.

24-3 Restate the common aspects of various rapid testing procedures.

24-4 Describe potential follow-up testing procedures that may be necessary based on rapid testing results.

24-5 Differentiate the clinical significance of strep screens, mononucleosis testing, rapid urine pregnancy tests, *Helicobacter pylori* testing, BTA tests, influenzas A and B, and HIV testing.

24-7 Perform CLIA-waived rapid testing procedures for a strep screen, a urine pregnancy test, and a test for mononucleosis.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I.15. Perform immunology testing
III.P.III.2. Practice Standard Precautions
III.P.III.3. Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations
III.P.III.8. Perform CLIA-waived microbiology testing
I.C.I.6. Identify common pathology related to each body system
III.C.III.10. Identify disease processes that are indications for CLIA-waived tests

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #6: Kit Testing, a. Pregnancy, b. Quick Strep
- Dispose of Biohazard Materials

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KEY TERMS

Agglutination
Chromatographic
Colorimetric
Epstein-Barr virus (EBV)
Helicobacter pylori (H. pylori)
Heterophile antibody
Human chorionic gonadotropin (HCG)
Immunology
Lateral flow immunoassay
Mononucleosis
Qualitative
Quantitative
Quantitative HCG
Rapid flow immunoassay
Sensitivity
Serology
Specificity
Streptococcal pharyngitis

Introduced in Chapter 23, **immunology** is defined as the study of the components of the immune system and their function. This includes numerous areas of specialty, such as autoimmune disorders, infectious disease, blood banking, and even tissue typing and organ transplantation. **Serology** describes the area of the laboratory where antigen-antibody reactions are studied. Serology implies that serum is used for the testing method, but immunology (or serology) testing performed today does not just use serum; urine, tissues, whole blood, and other body fluids may also be used. Immunology or immunoassay testing is performed to detect or identify antibodies or antigens in a specimen. The testing process may be **qualitative**, employing a positive or negative result, or **quantitative**, employing a numerical result, including varied levels of test complexity. Diseases such as mononucleosis, influenza, and hepatitis may be diagnosed using immunology tests.

Test Your Knowledge 24-1
How are immunology and serology similar? (Outcome 24-1)

IMMUNOLOGY METHODS AND PROCEDURES

The majority of the common immunology tests are performed to detect the presence of a specific antigen or antibody in the specimen. The patient's specimen is mixed with the commercial solution that contains the antigen or antibody for that specific disease or condition. If the appropriate counterpart (antigen or antibody) is present in the specimen, a reaction will occur. In CLIA-waived immunology testing methods, a color change is evident when this reaction takes place. The CLIA-waived kits use an absorbent membrane that is treated with a chemical additive. Once the specimen and additional reagents are added to the membrane, a color change will occur, indicating whether the test is positive or negative. Testing methods that include a color change may be called **chromatographic** or **colorimetric** assays.

When choosing a certain test method, laboratories must consider whether the test method demonstrates **specificity** and **sensitivity** for the desired substance. The specificity of a certain method describes the ability to detect only the substance that is being tested for in the specimen. Testing methods that are not very specific will have an increased amount of false-positive test results because substances other than the one desired will also be detected by this method. The sensitivity of a testing method is related to the minimum concentration of the desired substance that will be detected. Ideally, laboratory testing methods will demonstrate a positive result when a very small amount of the substance is present in the specimen so that this presence is not overlooked.

Test Your Knowledge 24-2
If a test reacts positively with the presence of several different antigens, is this described as a lack of specificity or a lack of sensitivity? (Outcome 24-1)

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POINT OF INTEREST 24-1
Bladder tumor–associated antigen

Bladder tumor antigens (BTA) are produced by bladder tumor cells and shed into the urine of those individuals with bladder cancer. There are two CLIA-waived rapid tests that are designed to detect the presence of this antigen in the urine. This test has not been approved as a screening test for bladder cancer because of its low specificity. The BTA test may be positive in the presence of other disorders of the renal system, such as renal stones, nephritis, renal cancer, urinary tract infections, or recent trauma to the bladder or urinary tract. The CLIA-waived rapid screening test is used for monitoring residual or recurring bladder cancer after treatment. Positive results are often followed up with urine cytology, cystoscopy, and examination of biopsy samples.

RAPID TESTING

Rapid testing describes immunology and other laboratory tests that have results available in a very short time. Usually a rapid test can be completed and read within 30 minutes. For rapid immunology testing, the most common rapid testing methods used are **rapid flow immunoassay** procedures and **agglutination** tests. Rapid flow immunoassay procedures are testing methods in which the specimen and any additional reagents must be absorbed and "flow" across the testing surface before they can interact with the antigen or antibody present to display a result. This type of testing may also be known as **lateral flow immunoassay** procedures. These testing methods are usually chromatographic, which means that their results are evident as a color change on the surface of the testing area.

When agglutination testing is performed, the sample and reagents are mixed on a flat surface designed to allow full view of the mixture. The antibodies and antigens present in the specimen will aggregate (agglutinate) if they both are present. Agglutination is visible as clumps on the testing surface.

Test Your Knowledge 24-3

Provide two similarities present in most rapid testing procedures. (Outcome 24-3)

Advantages of Rapid Testing

Many physician office laboratories perform rapid testing so that the health-care provider can obtain as much diagnostic information as possible in a short period of time. This can be especially advantageous when the testing is performed before the patient leaves the office. Testing in the physician office laboratory allows the health-care provider to prescribe medication or other treatment immediately without an additional office visit or phone call. Immediate results can save time and money for the patient, and often lead to better compliance with follow-up care.

Large laboratories may also choose to perform rapid testing rather than automated analysis for certain assays. In some situations, these rapid tests are the most cost-effective way to perform a specific assay. For tests that are not performed often, rapid testing kits may also be used to minimize potential waste of outdated reagents and controls. The CLIA-waived tests may be performed by employees with minimal training, allowing the laboratory professionals to perform tests of higher complexity. Rapid testing allows for the results to be available sooner than they might be if the tests were batched (tested together in large groups) and only performed at certain intervals as they often are in reference or hospital laboratories.

Test Your Knowledge 24-4

List two advantages of rapid testing procedures. (Outcome 24-2)

Common Procedural Elements of Rapid Testing

Rapid testing methods differ by manufacturer and by test. However, there are similarities that are present no matter what type of test or which manufacturer is involved. These include the following:

- Relatively few reagents
- Small sample volume
- Detailed package inserts with images to use for result interpretation
- Qualitative results interpreted as positive or negative
- Lateral flow immunoassay tests have internal validation indicators that change color to indicate whether the device is working and the sample and reagents were added appropriately
- Testing methods that are timed for completion and usually take 10 minutes or less to complete

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- Kits that include all supplies needed for the test, with the exception of personal protective equipment
- Positive and negative controls included with each kit

CLIA-Waived Regulations and Their Application to Immunology-Based Rapid Testing

Many rapid tests are CLIA-waived procedures. The U.S. Food and Drug Administration (FDA) has classified these as simplistic assays with minimal steps and easy-to-interpret test results. However, those rapid methods that require additional specimen preparation or multiple steps in the testing process may be categorized as moderately complex by CLIA standards. For instance, agglutination tests are relatively simple to perform, but reading the results requires subjective interpretation that places agglutination tests in the CLIA moderately complex category. Some rapid lateral flow immunoassay tests may be CLIA waived if whole blood is used for the testing process, but regarded as moderately complex if plasma or serum is used because of the additional steps required to process the specimen for the procedure. If the laboratory where the testing is performed is authorized to perform only CLIA-waived procedures, it is important to verify whether the testing method is appropriate for the qualifications of the personnel performing the test in the facility before it is used. The vendor should be able to verify whether the test is CLIA waived or of higher complexity, and often the CLIA-waived tests are labeled as such in bold letters to avoid confusion.

The instructions provided by the manufacturer must be closely followed for all CLIA-waived testing procedures, as well as those of moderate complexity. These instructions will specify the temperature at which the testing kit should be stored; the conditions for appropriate specimen collection, preparation, and storage; and the frequency at which quality control samples should be tested, in addition to the step-by-step testing procedure instructions. The package insert will also provide necessary information to interpret the test results correctly.

COMMON CLIA-WAIVED RAPID TESTS AND THEIR CLINICAL SIGNIFICANCE

Common immunology-based CLIA-waived rapid tests include strep screens, pregnancy tests, tests for the infectious mononucleosis, and tests for *Helicobacter pylori.* CLIA-waived rapid tests for influenzas A and B and HIV are also available.

Group A Streptococcal Screening

Group A streptococcal infection is a common cause of **streptococcal pharyngitis,** more commonly known as strep throat. Common symptoms of group A strep throat infection include sore throat, fever, white or yellow deposits on the tonsillar area of the throat, swollen glands at the front of the neck, and an absence of cough. It is important to identify patients with streptococcal infections and treat them appropriately with antibiotics so that a more serious secondary disease does not develop. If a patient with pharyngitis has a negative group A strep screen but exhibits additional symptoms, the health-care provider may order a culture specimen to be set up to verify whether group A strep is present. Group A strep infection may cause inflammation of the joints, formation of scar tissue on the heart as a complication of endocarditis, or a dangerous kidney condition called glomerulonephritis.

Test Your Knowledge 24-5

What is a possible complication of untreated streptococcal infection? (Outcome 24-5)

A group A strep screen is an uncomplicated test that can be completed in less than 10 minutes. A sterile throat swab (provided in the kit) is used to collect a specimen from the tonsillar area and back of the throat. Following the instructions included in the package insert, single drops of the kit reagents are added to the swab, after which the reaction is timed for the appropriate interval, usually 5 minutes. The specimen/reagent mixture will travel across the reaction area of the kit, and a positive result will be evident within the time frame indicated in the manufacturer's insert. The result must be read at the specified time after the addition of the reagent to the sample to be valid.

Mononucleosis Testing

Mononucleosis is an infectious disease caused by the **Epstein-Barr virus,** primarily infecting children and adolescents. It is spread through saliva, and is also called the "kissing" disease. Infectious mononucleosis is

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Procedure 24-1: Perform a CLIA–Waived Rapid Strep Screening Procedure

Rapid strep screens are the most common CLIA-waived test performed in physician offices. They may also be performed in hospital or reference laboratories. In addition to patient samples, rapid strep screens may also be used by the microbiology departments in some settings to verify the identity of the growth on a culture specimen.

TASK

Perform a rapid strep screen on an appropriate specimen taken from the throat of a patient.

CONDITIONS

- Hand sanitization equipment
- Gloves
- Rayon collection swab inoculated with throat specimen
- Laboratory coat
- CLIA-waived rapid strep kit
- External quality control materials (if required by manufacturer's recommendations or laboratory policy)
- Timer or watch
- Control log sheet
- Test log sheet
- Manufacturer's insert with reference material for reading results
- Biohazardous waste container

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #15 Perform immunology testing **III.P.III.** Applied Microbiology/Infection Control, #2 Practice Standard Precautions, #3 Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations, #8 Perform CLIA-waived microbiology testing

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #6: Kit Testing, b. Quick Strep
- Dispose of Biohazard Materials

Procedure	Rationale
1. Verify the test ordered on the requisition form and the identification information on the specimen label.	The test and identification on the specimen label should be verified every time to avoid erroneous results.
2. Gather necessary supplies. Verify the expiration date on the kit and the required frequency for the quality control materials. Refer to the manufacturer's insert, if necessary, to verify the quality control (QC) frequency recommended for the kit.	Expired kits may not be used. The manufacturer's insert will provide minimum frequency for external quality control testing, as well as information about any internal quality control testing. Each laboratory may establish a unique schedule for QC testing; however, it may not be less frequent than that recommended by the manufacturer.
3. Wash hands (if they are visibly soiled) or apply hand sanitizer. Allow hands to dry completely.	Clean hands stop the spread of infection. Hands should be completely dry before attempting to apply gloves, or it will be difficult to put the gloves on the wet hands.

Continued

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Procedure 24-1: Perform a CLIA–Waived Rapid Strep Screening Procedure—cont'd

Procedure	Rationale
4. If necessary, perform external quality control testing on the test kit. Log the results. Verify whether the kit is performing correctly before proceeding.	CLIA-waived kits usually come with external quality control testing materials. For those that do not include these materials, they may be purchased separately. Before patient testing may continue, it is important to verify that the positive and negative controls are testing in a valid range. If the controls are out of range, no patient testing can be performed until the problem has been identified and solved.
5. Perform the strep screen test as recommended by the manufacturer.	Test procedures will vary. Some kits use a test tube and dipstick, whereas others use a reagent well that is part of a test cassette. It is imperative that the instructions for the procedure are followed carefully. The number of drops and the timing of the different procedures are very important for accurate results.
6. Read the test result at the appropriate time. Test results are invalid after the time has elapsed, so they must be read immediately. Use the reference material included with the manufacturer's insert to interpret the results correctly. Record the results on the test log sheet and/or in a computer-based reporting system.	The result must be read at the appropriate time for the test to be valid. Reading results too soon or too long after the time interval has elapsed will result in erroneous results. The manufacturer's inserts will provide a chart to be used for reference when interpreting the color development changes for the kit.
7. Dispose of the throat swab and all testing materials in the biohazard disposal container.	All supplies should be disposed of properly for infection control reasons.
8. Remove gloves and wash hands.	Hands must always be washed after gloves are removed.
9. Record the results in the patient's chart, if available.	All results need to be charted immediately for the health-care provider to take appropriate action.

Date	
2/20/2014:	Rapid strep screen performed. Results negative
2:00 p.m.	Connie Lieseke, CMA(AAMA)

most common in those between the ages of 15 and 25. Fatigue, weakness, sore throat, headache, fever, and swollen lymph nodes are common symptoms of this infection. Sometimes the mononucleosis test may be ordered as a **heterophile antibody** test, because of the type of antibody produced by the body when infected with the Epstein-Barr virus. The antigen-antibody tests used to diagnose infectious mononucleosis use erythrocytes from sheep, horse, or cattle cells to interact with the heterophile antibodies.

The CLIA-waived mononucleosis tests demonstrate a positive result when the heterophile antibodies are present rather than reacting specifically with the Epstein-Barr virus. This means that false-positive results are not

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POINT OF INTEREST 24-2
RSV

Respiratory syncytial virus (RSV) is a virus that affects the respiratory system. In most cases, an infected individual will recover from this virus within 2 weeks of infection. However, some populations are severely ill with RSV infection. Some infants, young children, and older adults (over the age of 60) may be at risk for serious infection. In the United States, RSV is the most common cause of the inflammation of the small airways in the lung (also known as viral bronchiolitis) and pneumonia in infants younger than 1 year of age. Recent studies have also linked an increase in cases of severe respiratory illness in the older population to RSV infection.

There are rapid tests available for identification of RSV infection in respiratory specimens. Viral cultures are also commonly performed. RSV is especially sensitive to changes in temperature in the laboratory, which means that it may be expressed as a false-negative result if the specimen is not handled correctly. Older children and adults may need a blood test performed, as they historically have low viral levels present in the respiratory specimens.

uncommon. Patients with lupus or lymphoma may also have heterophile antibodies present in their specimen, even though they do not have infectious mononucleosis. The CLIA-waived tests may result in a false-negative result for young children because they often do not create heterophile antibodies even when infected with the Epstein-Barr virus.

Because the symptoms of infectious mononucleosis are very similar to those of streptococcal pharyngitis, the health-care provider may order a throat swab collection for a group A strep screen to be collected at the same time that the sample is obtained for the mononucleosis test. Procedure 24-2 explains the testing process for a CLIA-waived mononucleosis test.

Pregnancy Testing

CLIA-waived tests for pregnancy are designed to react in the presence of **human chorionic gonadotropin (HCG),** a hormone that is found in urine or blood during pregnancy. The developing placenta secretes HCG, and most rapid test kits can detect the presence in the urine or blood just a few days after conception. CLIA-waived HCG tests provide a qualitative positive or negative result. Procedure 24-3 explains how to perform a CLIA-waived pregnancy test in more detail.

Procedure 24-2: CLIA–Waived Mononucleosis Testing Using an OSOM Mononucleosis Testing Kit

Infectious mononucleosis is diagnosed using laboratory data and clinical symptoms of sore throat, fever, and swollen lymph glands. A positive laboratory test indicates the presence of heterophile antibodies, which are present with the Epstein-Barr virus infection in most patients with acute infectious mononucleosis.

TASK

Perform mononucleosis testing using the CLIA-waived OSOM mononucleosis testing kit, manufactured by Genzyme.

CONDITIONS

- Hand sanitization supplies
- Gloves
- Completed patient requisition form and patient chart
- Appropriate venipuncture supplies if a venous blood sample is to be used. EDTA or heparinized blood samples are acceptable.
- Supplies included in the test kit
  - Test stick
  - Test tube
  - Diluent
  - Positive and negative control material
  - Workstation
  - Capillary tubes and bulb for capillary blood samples
- Timer or watch
- Biohazardous disposal container
- Biohazardous sharps container

Continued

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Procedure 24-2: CLIA–Waived Mononucleosis Testing Using an OSOM Mononucleosis Testing Kit—cont'd

Note: This test may be performed using a capillary blood sample or a sample obtained through venipuncture. Be certain to have the necessary supplies available for the method used for sample collection, as well as a biohazardous sharps disposal container and gloves. Either EDTA or heparin is an appropriate additive for venous samples for the OSOM mononucleosis test.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #15 Perform immunology testing **III.P.III.** Applied Microbiology/Infection Control, #2 Practice Standard Precautions, #3 Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #4 Immunology, #6 Kit Testing
- Dispose of Biohazardous Materials

Procedure	Rationale
1. Verify test ordered on requisition. Greet and then identify patient.	The requisition form should always be examined to be certain which test is ordered, and the patient identity must always be verified before proceeding.
2. Sanitize hands, allow them to dry, and apply gloves.	Gloves protect the hands from exposure to potential bloodborne pathogens. Gloves should always be applied in the presence of the patient.
3. Gather necessary supplies.	Supplies must be within reach before staring the process so that the timing of the testing is accurate.

Courtesy of Genzyme Corporation.

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Procedure	Rationale
4. Verify whether quality control (QC) testing needs to be performed on the kit. If so, perform QC testing and verify validity of results before proceeding with patient testing.	The frequency of the QC testing is based on the manufacturer's and individual laboratory recommendations. Minimum recommendations from the Genzyme Corporation are that the positive and negative QC should be run with each new lot number and each new untrained operator. If the quality control results are not within the established range, patient testing cannot be performed until the problem has been solved.
5. Determine the method to be used for specimen collection. Collect the sample using appropriate techniques. **a.** If a capillary sample is to be tested, use the capillary tube and bulb supplied with the test kit. Follow appropriate procedures to fill the provided capillary tube with blood. **b.** Blood obtained through venipuncture is acceptable, as long as it is collected into a tube containing EDTA or heparin.	Capillary or venous whole blood may be used for this testing procedure. The capillary sample is the most common method of testing used in the physician office laboratory. Always follow appropriate venipuncture collection procedures.
6. Add the sample to the test tube.	For capillary samples, use the bulb provided to add the entire contents of the capillary tube to the test tube. If a venous sample is to be tested, add one drop to the test tube, using the transfer pipettes included in the test kit. Samples must be at room temperature at the time of testing.
7. Add one drop of diluent to the bottom of the test tube. Mix the diluent with the sample by gently moving the tube from side to side.	Slowly add the diluent so that it goes to the bottom of the test tube.
8. Remove a test stick from the container, and immediately recap the container.	The test sticks must not be exposed to moisture. The container must not be left uncapped for an extended period of time.
9. Place the absorbent (testing) end of the test strip into the sample/diluent mixture in the bottom of the tube and leave the strip in place.	One end of the test strip is absorbent, and the other end is designed to be handled during the testing procedure.
10. Set a timer (or note the time on a watch) for 5 minutes.	The test result is to be read at 5 minutes. Positive results may be read earlier, as long as the red control line is present.

Continued

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Procedure 24-2: CLIA–Waived Mononucleosis Testing Using an OSOM Mononucleosis Testing Kit—cont'd

Procedure	Rationale
11. At 5 minutes, observe the test stick for the test results. **a.** If a blue line and the red control line are present, the test result is interpreted as a positive. **b.** If the red control line is present, but no blue line is evident, the test is interpreted as a negative result. **c.** If there is no red control line or if the background in the testing area is not clear (white), the test is considered to be invalid, and must be repeated.	It is important to pay close attention to the test stick to interpret the results appropriately. The red control line must always be visible for the test to be valid. Results are not to be reported as invalid. This is an indication that the test must be repeated with careful attention to the procedure. Quality control material should also be used to verify the performance of the test kit.
12. Make note of the test result.	It is not appropriate to chart the result while still wearing gloves that may be potentially contaminated.
13. Discard the pipette or capillary tube, testing strip, and test tube in the biohazardous disposal container.	Because blood was used in the testing procedure, all contaminated material must be disposed of as biohazardous substances.
14. Sanitize the work area and put away supplies.	The testing kit may be stored at room temperature. Follow laboratory protocol for storage of any unused specimens.
15. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
16. Document the test results in the patient's chart.	All results must be documented in the patient's chart.

Date	
04/18/2013:	Mono test performed from capillary puncture. Results negative
11:33 a.m.	Connie Lieseke, CMA (AAMA)

In some situations, the HCG level in the blood or urine is not elevated enough to be detected by the rapid test procedure. This may be the case very early in pregnancy when the placenta has not had an opportunity to secrete enough of the hormone for the test to be positive. When a woman has an ectopic pregnancy, the hormone levels may never be elevated enough to produce a positive rapid test. In this situation, the healthcare provider may order a **quantitative HCG test,** which provides a number representing the level of hormone present in the blood. If the quantitative HCG result does not increase over time, the pregnancy is usually not viable. In a normal pregnancy, the HCG levels should continue to increase until approximately 3 months of gestation, at which time they will start to decline through the rest of the pregnancy.

Helicobacter pylori Testing

In 1982, it was discovered that most duodenal ulcers and many gastric ulcers were caused by a previously unknown bacteria, ***Helicobacter pylori***. Until then, it was believed that ulcers were caused by stress, lifestyle, and food choices. Medications that reduced the production of stomach acid were often used to heal these ulcers,

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but recurrence was common once the treatment ended. In 1982, pathologist Robin Warren discovered that at least 50% of the biopsies examined from ulcer patients exhibited small, curved bacteria in the area of inflammation. Together with his partner, Barry Marshall, Warren provided evidence that these ulcers were caused by the bacteria he had observed and that the ulcers could be eradicated (without recurrence) with antibiotics and medication to reduce the acidity of the stomach. The bacteria cause inflammation and weaken the stomach lining, allowing stomach acids and bacteria to penetrate the layers and cause a hole or ulcer.

There are now numerous CLIA-waived rapid tests available to detect the presence of *H. pylori*. This bacterium is unique, as it has been isolated only from humans. It is thought that the transmission usually

Procedure 24-3: CLIA–Waived Urine HCG Testing Using the Beckman Coulter Icon 25 Testing Kit

Human chorionic gonadotropin (HCG) is secreted by the placenta shortly after implantation of a fertilized ovum. It may be detected in the urine specimen 7 to 10 days after conception, which may be as early as the first day of a missed menstrual period.

TASK

Perform urine HCG testing using the Beckman Coulter Icon 25 testing kit, and record the results appropriately. Complete all steps within 10 minutes.

CONDITIONS

- Hand sanitization supplies
- Gloves
- Completed patient requisition form and patient chart
- Supplies contained in test kit
- Test devices
- Disposable transfer pipettes
- Commercial quality control material
- Timer or watch
- Urine specimen collected in clean container
- Biohazardous disposal container
- Biohazardous sharps container

Note: The HCG test kit may be used for urine testing or serum testing. The test is only CLIA–waived when performed using urine samples.

CAAHEP/ABHES STANDARDS

CAAHEP Standards

I.P.I. Anatomy and Physiology, #15 Perform immunology testing **III.P.III.** Applied Microbiology/Infection Control, #2 Practice Standard Precautions I#3 Select appropriate barrier/personal protective equipment (PPE) for potentially infectious situations

ABHES Standards

- Perform selected CLIA-waived tests that assist with diagnosis and treatment, #6 Kit Testing, a. Pregnancy
- Dispose of Biohazardous Materials

Procedure	Rationale
1. Verify test ordered on requisition. Greet and then identify patient if present for collection.	The requisition form should always be examined to be certain which test is ordered, and the patient identity must always be verified before proceeding.
2. Sanitize hands, allow them to dry, and apply gloves.	Gloves protect the hands from exposure to potential bloodborne pathogens. Gloves should always be applied in the presence of the patient.

Continued

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Procedure 24-3: CLIA–Waived Urine HCG Testing Using the Beckman Coulter Icon 25 Testing Kit—cont'd

Procedure	Rationale
3. Gather necessary supplies. Supplies and samples must be at room temperature for valid test results.	Supplies must be within reach before staring the process so that the timing of the testing is accurate. 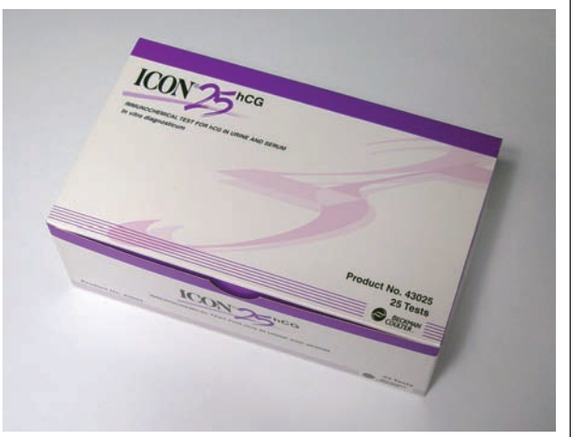 Courtesy of Beckman Coulter.
4. Verify whether quality control (QC) testing needs to be performed. If so, perform QC testing and verify validity of results before proceeding with patient testing.	The frequency of the QC testing is based on the manufacturer's and individual laboratory recommendations. The package insert for this testing procedure does not specify a minimum frequency for quality control testing.
5. Examine the urine specimen. If it appears cloudy, centrifuge the specimen before testing.	Excessive particulate matter needs to be removed from the specimen through centrifugation to ensure valid test results. The specimen should be collected in a clean container.
6. Remove the test device from the wrapper just prior to use.	The test device should not be exposed to room air (and potential exposure to moisture) for an extended period before use, as this may lead to an invalid test result.
7. Place the test device on a flat stable surface. Place three drops of urine in the sample well (marked with an S) using the supplied transfer pipette.	Avoid formation of air bubbles in the specimen during application.
8. Set the timer (or note the time on a watch) to 3 minutes.	The sample results are not valid before 3 minutes have elapsed.

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Procedure	Rationale
9. At 3 minutes, observe the reaction area for the presence of red lines.	The test results need to be read precisely at 3 minutes. A delay in reading the results may allow for slight color development to occur, which may be erroneously interpreted as a positive result. 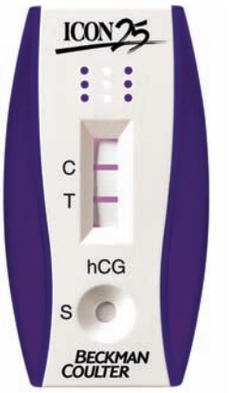 Courtesy of Beckman Coulter.
a. A red line in the Control area in addition to the Test area is to be interpreted as a positive result.	To be a valid test, there must always be a red line in the Control area at three minutes.
b. A red line in the Control area without the presence of a red line in the Test area is to be interpreted as a negative result.	Look carefully at the Test area before reporting a result.
c. If there is no red line in the Control area, the result is not valid, and the test must be repeated.	Invalid tests are not to be reported as such; this is an indication that the test must be repeated with particular attention to procedural details. Quality control material should also be used to verify the performance of the test kit.
10. Make note of the test result.	It is not yet appropriate to chart the result, as the operator is still wearing gloves that may be potentially contaminated.
11. Discard the testing device and transfer pipette into the biohazardous trash.	The testing supplies were exposed to urine.
12. Put away the test kit, and store the specimen according to laboratory protocol.	The test kit may be stored at room temperature.
13. Sanitize the work area.	The work area must always be sanitized before proceeding to other tasks.
14. Remove gloves and sanitize hands.	Hands must always be sanitized after removing gloves.
15. Document the test results in the patient's chart.	All results must be documented in the patient's chart.

Date	
04/23/2013:	*Urine HCG test performed. Results positive. Physician notified.*
1:15 p.m.	*Connie Lieseke, CMA (AAMA)*

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occurs early in life and that the microorganism is probably passed directly from one person to another. The most common specimen used for *H. pylori* testing is whole blood, but there are also CLIA-waived kits available for testing gastric biopsy specimens. Serum, plasma, and stool specimens may also be tested.

Test Your Knowledge 24-6

True or False: The presence of *Helicobacter pylori* in the stomach is linked to an infection of the lungs with the same bacteria. (Outcome 24-5)

Influenzas A and B

The Centers for Disease Control and Prevention (CDC) estimates that every year 5% to 20% of the U.S. population comes down with the seasonal flu. More than 200,000 people are hospitalized with complications of this infection, and it leads to at least 36,000 deaths each year. Influenza flu viruses cause the flu. There are three types of human flu viruses, but only A and B are of clinical significance. Symptoms of the flu include fever, body aches, dry cough, headache, and sore throat. The duration of the symptoms may vary, but for many individuals the recovery time is a week or more. Human influenza C causes mild upper respiratory symptoms and is not vaccinated against. Yearly vaccination is recommended for the majority of the population against influenzas A and B.

Laboratory testing for identification and treatment of the flu virus is not always necessary. Many times the health-care professional will diagnose the patient with seasonal flu based on a clinical examination, and prescribe rest and symptomatic treatment. However, in situations in which the patient has other complicating factors (such as asthma, heart disease, or low immunity) it may be necessary to verify whether the patient is infected with influenza A or influenza B so that antiviral medications may be administered. Laboratory testing may also be indicated if the patient is living in a controlled, confined environment (such as a long-term care facility) so that the spread of the virus can be controlled with isolation of the patient and administration of antiviral medication.

Influenza cultures will provide detailed, specific information about the virus if it is present, but a culture result will usually take 3 to 10 days to be finalized, during which time the patient may be spreading the virus to others. Rapid CLIA-waived tests are a better option for the initial influenza screening, as the results are usually available within 15 minutes after collection. Examples of CLIA-waived tests include Quick Vue and BinaxNOW.

Many times the symptoms of the seasonal flu may mimic those of bacterial infections. Identification of the flu virus through rapid testing methods will also eliminate the use of unneeded antibiotics when bacterial infection is not present. All CLIA-waived testing methods, as well as the rapid tests that have been categorized as moderately complex use nasopharyngeal swabs for influenzas A and B. Nasal swabs, nasal rinses, or nasal aspirates may also be acceptable for some testing methods. Ideally, the specimen will be collected 3 to 4 days after infection is suspected. A viral culture may be indicated when an unexpected negative result is encountered, especially in situations in which the prevalence of the virus in the community is high. Blood testing may also be performed, using a method called reverse transcription polymerase chain reaction. This method is very sensitive and specific to the virus, and may allow for differentiation of variant strains present in the population.

Test Your Knowledge 24-7

When may a viral culture be indicated after a rapid influenza test is performed? (Outcome 24-4)

HIV Testing

Approximately one individual out of every five infected with HIV is unaware of his or her positive status, according to the CDC. It is also estimated that there are approximately 40,000 new individuals infected by HIV annually in the United States. Historically, many of the individuals tested did not return to the health-care provider to receive their HIV results, so they were not treated appropriately, and continued to potentially spread the disease.

In 2004, the FDA approved several rapid testing kits to be used for HIV testing. This development was significant because it facilitated access to early diagnosis and treatment. The patient is now able to visit a health-care provider for pretest counseling and have the test run while waiting for the results. Before leaving the office, the patient will be provided with a result (although positive results are considered to be preliminary). The patient is also given information about appropriate interpretation of their HIV status and instructions before

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they leave. Only patients with a preliminary positive HIV screening test are required to return for their confirmatory results.

Test Your Knowledge 24-8

What is an advantage of rapid HIV testing? (Outcome 24-4)

There are currently four CLIA-waived test procedures available for HIV testing:

1. OraQuick ADVANCED HIV-1/2 Antibody Test, by Orasure Technologies
2. Uni-Gold Recombigen HIV Test, by Trinity BioTech
3. Clearview HIV 1/2 Stat-Pak, by Inverness Professional Diagnostics
4. Clearview Complete HIV 1/2, also by Inverness Professional Diagnostics

All four are CLIA waived for whole blood testing from capillary or venous samples. Several may also be moderately complex if serum or plasma is used for the test procedure. The OraQuick and Clearview methods are capable of detecting two strains of HIV. HIV-1 is the most common strain worldwide, but an additional strain (HIV-2) has been identified, especially in West Africa. It is important to remember that any presumptive positive HIV rapid test result must be confirmed with a western blotting test or a immunofluorescent assay before the patient is considered HIV positive.

The newest CLIA-waived testing procedure for HIV (OraQuick) uses a sample of oral mucosal transudate rather than blood. Oral mucosal transudate is the fluid from the gums and cheek tissue. This method can benefit those patients who are reluctant to have their blood drawn for the test. The sample is obtained by handing the patient a special collection "paddle" and having him or her place it for a few seconds between the cheek and gum, after which it is rubbed over the gum area in the mouth. The end of the paddle that contains the specimen is then placed in a tube that contains the reagent for the test. If HIV antibodies are present in the sample, the reaction indicator on the paddle will demonstrate a positive result after 20 minutes. If the CLIA-waived rapid test is positive, another oral fluid specimen or a blood specimen must be collected for the confirmatory test. Negative test results are interpreted as a negative result for current HIV infection.

Although some of the processes involved in the rapid HIV testing procedures may vary, because a positive HIV test result is clinically significant, all rapid HIV testing procedures include specific federal requirements:

1. All patients must receive an information sheet (included with the testing kit) that explains HIV/AIDS, the testing process, and what the results mean, and provides information about the confirmation of positive results. Patients also sign a consent form before testing.
2. Quality control (QC) testing (positive and negative control samples) must be performed as directed. This includes QC testing whenever a new operator uses the test kit (prior to testing patient samples), whenever a new lot goes into use, and whenever a new shipment is received (even if it is the same lot number). Quality control testing must also be performed if the storage temperature drops below 35°F or rises above 80°F, or if the testing environment drops below 59°F or rises above 99°F. Each laboratory will also specify additional testing intervals for quality control.

SUMMARY

Immunologic-based rapid testing methods are commonly used as diagnostic tools for various diseases. The tests will identify the presence of antigens or antibodies present in whole blood or other body fluids. Many of the rapid testing procedures are CLIA-waived lateral flow immunoassays that indicate a positive result through a color change on the result area of the kit. Some of the rapid tests are used for confirmative diagnostic information so that the patient can be treated appropriately as soon as possible, whereas others may be used as an initial screening test or to follow up after disease treatment. Additional testing procedures are sometimes warranted once the rapid testing procedures are complete. The manufacturer's insert for the CLIA-waived rapid tests must always be followed closely to avoid erroneous results or invalid tests.

TIME TO REVIEW

1. If a test result is reported as positive or negative, the test is _____. Outcome 24-1
   a. Qualitative
   b. Quantitative

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2. How do rapid testing methods save money for patients? Outcome 24-2
   a. Fewer office visits
   b. Inexpensive testing methods
   c. Less expensive antibiotics
   d. a and b

3. If a rapid test for HIV is positive, what is the required follow-up testing procedure? Outcome 24-4
   a. HIV culture
   b. AIDS test
   c. Immunofluorescent assay or western blot test
   d. Neutrophil blood count

4. True or False: A negative urine HCG test always means that the patient is not pregnant. Outcome 24-5

5. When performing a group A strep screen, where should the sample be collected from the patient? Outcome 24-6
   a. Tonsillar area and the back of the throat
   b. Tonsillar area and the tongue
   c. Gum line
   d. Nasopharynx

6. How is an infection of *Helicobacter pylori* treated? Outcome 24-5
   a. Surgical correction
   b. Antiseptic suppositories
   c. Antibiotics and acid reducing medications
   d. None of the above

7. Which of these may be an order for a mononucleosis test? Outcome 24-5
   a. BTA
   b. Influenza A
   c. Heterophile
   d. GAS

Case Study 24-1: CLIA-waived testing procedures

James works as a "float" medical assistant at Briarcreek Medical Center. Today he has been assigned to work in the laboratory area at the busy obstetric/gynecology office of Dr. Stanton. The first patient of the day has a requisition with an FSH and a LH ordered, which both require serum for processing. James draws two tiger top tubes, thanks the patient, and cleans up his work area. Right after the patient leaves, Dr. Stanton tells James that he would also like a STAT pregnancy test to be performed on this patient.

1. Is it possible for James to perform a STAT HCG test on the specimen that he has in the laboratory?
2. What may keep James from performing the test?

RESOURCES AND SUGGESTED READINGS

"Tests Granted Waived Status under CLIA" https://www.cms.gov/CLIA/downloads/waivetbl.pdf

"Helicobacter pylori Fact Sheet for Health Care Providers" Information about *Helicobacter pylori* infection and treatment http://www.cdc.gov/ulcer/files/hpfacts.PDF

"Getting Tested"
San Francisco AIDS Foundation, "HIV Testing" http://www.sfaf.org/aids101/hiv_testing.html#urine

"Evaluation of Rapid Influenza Diagnostic Tests for Detection of Novel Influenza A (H1N1) Virus—United States, 2009" CDC Morbidity and Mortality Weekly Report, August 8, 2009 http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5830a2.htm

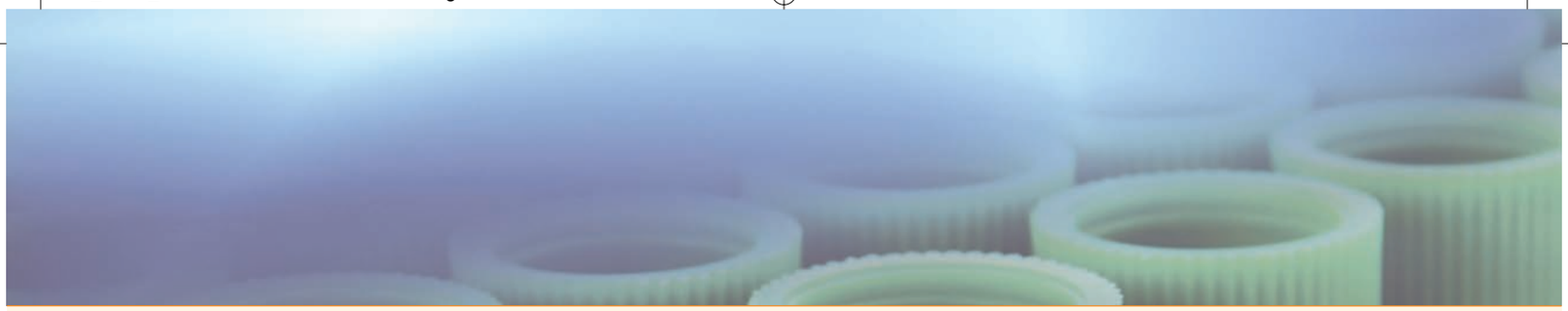

Section VI

Immunology

What Does It All Mean?

As this section clearly points out, immunology is an important aspect of laboratory testing that spans all of the other laboratory disciplines. Immunologic connections are often associated with advances, new discoveries, and findings in the field of medicine. Perhaps the most important concept in immunology testing is antigen-antibody complexes, that is, when antibodies targeted against specific antigens find them and bind together. Visualization of these complexes, as seen in the laboratory, is known as agglutination.

Case in Point

It was noted in the case of little P.J. that his strep screen test was negative, meanng that no agglutination was seen. Most strep screen tests are designed to detect group A streptococci antigens when present. A negative test indicates that the antigens being sought were not present. Because throat infections of this type may be caused by other bacterial or viral agents, the best step to take at this juncture is to submit a new, fresh specimen to the laboratory for microbial culture. Note that, in this case, if the strep screen was submitted to a clinical laboratory, it would likely be performed either in the microbiology area, because the test is looking for a microbiological agent or in a section dedicated to immunologic testing. The location of such tests being performed depends on the organization of the laboratory. Rapid tests such as the strep screen have revolutionized laboratory testing in terms of time and resources. In the case of strep screen results, what used to take 48 hours or more to complete is now available in about 10 minutes. Furthermore, because some of the rapid tests have been deemed CLIA-waived , trained medical assistants and other primary health-care providers can perform these tests in a physician office setting.

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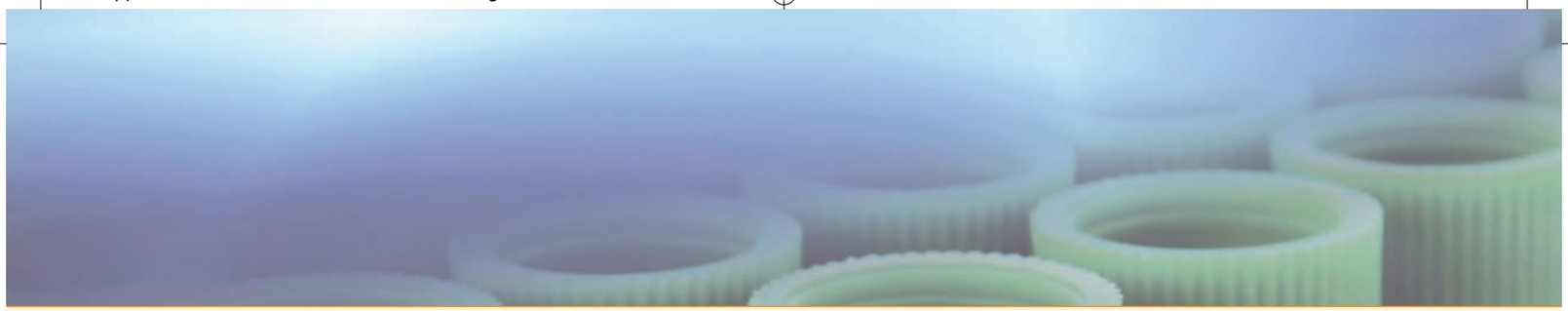

Appendix A
Reference Ranges

Reference Ranges for Glucose Testing Results	
Fasting plasma glucose	70–100 mg/dL
2-hr PP glucose	Less than 140 mg/dL
Glycosylated hemoglobin (HbA1c)	
Nondiabetic	5%
Diabetes, well controlled	2.5%–6%
Diabetes, well controlled	>8%

From the American Diabetes Association.

Reference Ranges of Common Chemical Analytes (listed alphabetically)	
Alanine aminotransferase (ALT)	10–35 U/L
Albumin (Alb)	3.5–5 g/dL
Alkaline phosphatase (ALP)	42–136 U/L
Amylase	30–70 U/L
Aspartate aminotransferase (AST)	0–35 U/L
Bilirubin, total (TBili)	0.3–1 mg/dL
Blood urea nitrogen (BUN)	10–20 mg/dL
Brain natriuretic peptide (BNP)	0–100 ng/L
Calcium (Ca)	8.2–10.5 mg/dL
Carbon dioxide (CO_2)	22–30 mEq/L
Chloride (Cl)	96–106 mEq/L
Cholesterol, total (Chol)	Less than 200 mg/dL
Creatine kinase (CK), aka Creatine Phosphokinase (CPK)	55–170 U/L
Creatinine (Creat)	0.6–1.2 mg/dL
Erythropoietin	5–35 IU/L
Ferritin, adult	10–150 ng/mL
High-density lipoprotein (HDL)	Greater than 50 mg/dL
Iron, serum adult	35–165 mcg/dL
Lactate dehydrogenase (LD, LDH)	100–190 U/L

Reference Ranges of Common Chemical Analytes (listed alphabetically)—cont'd	
Low-density lipoprotein (LDL)	Less than 100 mg/dL
Magnesium	1.6–2.2 mg/dL
Myoglobin	Less than 90 µg/L
Potassium (K)	3.5–5.0 mEq/L
Phosphorus, adult	2.5–4.5 mEq/dL
Phosphorus, child	4.5–6.5 mg/dL
Sodium (Na)	136–145 mEq/L
Thyroid-stimulating hormone (TSH)	0.4–4.2 µU/mL
Thyroxine (T4)	4.5–11.2 µg/dL
Triglyceride (Trig)	Less than 150 mg/dL
Triiodothyronine (T3)	75–220 ng/dL

Reference Ranges for Urine Tests	
Appearance and color	Clear; straw to yellow in color
pH	4.6–8.0
Protein	2–8 mg/dL (negative to trace)
Specific gravity	1.005–1.030
Leukocyte esterase	Negative
Nitrite	Negative
Glucose	Negative
Ketones	Negative
Leukocytes	Negative
Blood	Negative
Urobilinogen	0.1–1.0 mg/dL
White blood cells	3–4/hpf
White blood cell casts	Negative
Red blood cells	1–2/hpf
Red blood cell casts	Negative
Crystals	Few/negative

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Reference Ranges for Hematology	
Red blood cell, male	4.6–6.2 $\times$ 10^6 cells/μL
Red blood cell, female	4.2–5.9 $\times$ 10^6 cells/μL
Hemoglobin, male	13–18 g/dL
Hemoglobin, female	12–16 g/dL
Hematocrit, male	45%–52%
Hematocrit, female	37%–48%
White blood cell count	4,300–10,800 cells/mm^3
Neutrophils	54%–65%
Lymphocytes	25%–40%
Monocytes	2%–8%
Eosinophils	1%–4%
Basophils	0%–1%
Platelets	150,000–450,000/mm^3
Reticulocyte count, adult	0.5%–1.5% of all RBCs
Reticulocyte count, child	0.5%–2.0% of all RBCs
Erythrocyte sedimentation rate	
Adults: males younger than 50 years	<15 mm/hr
Adults: males older than 50 years	<20 mm/hr
Adults: females younger than 50 years	<20 mm/hr
Adults: females older than 50 years	<30 mm/hr
Children: 6 months–12 years	3–13 mm/hr

Reference Ranges for Coagulation	
Fibrinogen	150–400 mg/dL
D-dimers	<250 ng/mL
Prothrombin time	11–13 sec
Activated partial thromboplastin time	25–31 sec
Bleeding time (Ivy method)	1–9 min

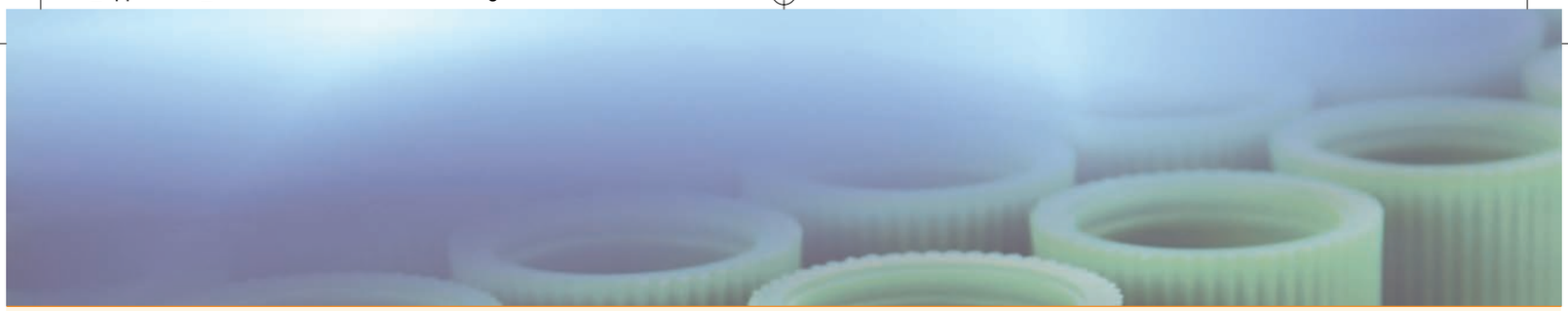

Appendix B
Test Your Knowledge Answers

Chapter 1

1-1. Reference laboratories have the most tests available. (Outcome 1-2)

1-2. The microbiology department would test the patient specimen to identify the microorganisms present in the wound. (Outcome 1-3)

1-3. **b.** The test is being performed to see if the patient is developing diabetes so that the disease can be treated early, or prevented if possible. (Outcome 1-4)

1-4. **False.** Medical assistants may work in specimen processing or as laboratory assistants performing a variety of duties in microbiology, histology, and the like. They may also work as phlebotomists if that laboratory provides this service. Medical assistants may also perform CLIA-waived or moderate-complexity tests with appropriate training. (Outcome 1-5)

1-5. Yes, as long as the training is appropriate and they have been designated as CLIA-waived or moderate-complexity tests. (Outcome 1-5)

1-6. There are various correct answers to this question. One reason is so that the results can be delivered or transmitted to the correct health-care provider upon completion. Another reason may involve reimbursement. Insurance companies require the name of the ordering practitioner for successful payment. (Outcome 1-6)

1-7. The ABN allows patients who have Medicare as their primary insurance to make an informed decision about whether they want to have laboratory tests performed that may not be reimbursed. The form offers an opportunity for the patient to refuse the test, or to accept the fee and have the test performed anyway. (Outcome 1-7)

1-8. To verify specimen requirements, tube stopper colors to be drawn, or any special handling procedures necessary for the test ordered. (Outcome 1-8)

1-9. They both contain important patient information, as well as the name of the ordering practitioner. They are both critical parts of the process, and both must be used for quality patient care. (Outcome 1-9)

1-10. The three phases of laboratory testing include the preanalytical phase, the analytical phase, and the postanalytical phase. (Outcome 1-10)

1-11. The preanalytical phase. This error occurred prior to the performance or reporting of the test results, so it is included with the preanalytical phase of testing. (Outcome 1-11)

Chapter 2

2-1. Yes, a physician assistant may serve as a laboratory director in a physician office laboratory. (Outcome 2-2)

2-2. Yes, this is a role often assumed by a medical technologist. (Outcome 2-3)

2-3. A phlebotomist (in most states) is not required to have specific credentials gained by a national examination or formal education. A phlebotomist is required to have a high school education (or the equivalent) and documented training in phlebotomy. (Outcome 2-4)

2-4. No, they are not limited to drawing blood. They can perform a variety of duties, as long as there is documented training for these expanded duties. (Outcome 2-5)

2-5. CLIA '88 was designed to ensure reliable, accurate, and timely laboratory results. (Outcome 2-6)

2-6. The minimum level of education is as follows:

- **a.** High school graduate (or the equivalent)
- **b.** Same, but additional documented training (on the job is sufficient)
- **c.** At least an associate degree in a laboratory-based curriculum. (Outcome 2-7)

2-7. Assignment of complexity levels takes into account the difficulty of the actual test performance (how many steps involved, etc.) as well as the clinical significance of the test results. (If the test was reported incorrectly, what impact would it have on the patient and his or her treatment?) (Outcome 2-7)

2-8. A clinical laboratory scientist with four years of education could perform any level of testing as designated by CLIA. (Outcome 2-8)

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2-9. The U.S. Food and Drug Administration assigns the categories to the laboratory tests. (Outcome 2-9)

Chapter 3

3-1. Viruses, fungi, and parasites are examples of other types of microorganisms. (Outcome 3-2)
3-2. No. (Outcome 3-3)
3-3. They appear different under the microscope. Staphylococci appear in clusters, and diplococci appear in pairs. (Outcome 3-4)
3-4. Bacilli appear as ovals or rod-shaped organisms. (Outcome 3-4)
3-5. Viruses have a different cellular makeup than bacteria; bacteria have cell walls and membranes, and contain various structures that allow them to survive and reproduce. Viruses have genetic material contained in a protein capsule, and depend on the cells of other living organisms to reproduce. Viruses are much smaller than bacteria. Antibiotics work to destroy bacteria, but not on viruses. (Outcome 3-5)
3-6. No, it is just medically aseptic, with most of the bacteria destroyed, with a special emphasis on pathogens. (Outcome 3-6)
3-7. By washing their hands. (Outcome 3-7)
3-8. She has broken the chain at the point of a susceptible host; she is no longer able to be affected by hepatitis A. (Outcome 3-7)
3-9. Everyone is considered infectious. (Outcome 3-8)
3-10. Hand washing. (Outcome 3-8)
3-11. Alcohol-based hand rubs. (Outcome 3-9)
3-12. Before eating or drinking, after removing gloves, between patients, when visibly contaminated. (Outcome 3-10)
3-13. So that the health-care worker doesn't contaminate his or her hands again by touching the dirty handles. (Outcome 3-10)
3-14. She touched the phone with her gloved hand; her gloves may be contaminated with pathogens and should be removed before she touches the phone or puts her hand near her face. (Outcome 3-9)
3-15. A laboratory coat and gloves. (Outcome 3-9)
3-16. Employees. (Outcome 3-11)
3-17. The laboratory assistant may look at the label on the container; it is required to contain the manufacturer's information. (Outcome 3-13)
3-18. There are nine required components. (Outcome 3-12)
3-19. The NFPA labels provide information about flammability, reactivity, health hazards, and other specific hazards for the chemical. They are color coded and have numeric symbols to indicate the severity of the hazard. (Outcome 3-14)
3-20. The letters are assigned to the fire extinguishers to indicate what type of fire they should be used to extinguish. (Outcome 3-14)
3-21. Other potentially infectious materials include semen, vaginal secretions, cerebrospinal fluid, pericardial fluid, pleural fluid, etc. (Outcome 3-16)
3-22. **False.** It was designed to protect health-care employees. (Outcome 3-15)
3-23. Determination of the employee risk of exposure, education, and implementation of appropriate use of personal protective equipment and other means to reduce the potential exposure of the employees; hepatitis B vaccination; postexposure evaluation procedures; and ongoing communication of hazards. (Outcome 3-17)
3-24. No; this is why it is so important to find out how to use the one that is in place at your worksite. (Outcome 3-18)
3-25. No; much of the waste generated in a laboratory is routine office waste, such as paper. (Outcome 3-19)
3-26. No. Hepatitis, or inflammation of the liver, can be caused by a variety of disease states. Viral hepatitis still has several forms; hepatitis A in particular is not a bloodborne pathogen. (Outcome 3-20)
3-27. They are both bloodborne pathogens, they are both caused by viruses, and they both have long-lasting effects on the body that may be or are fatal. (Outcome 3-20)
3-28. She should immediately rinse them out with water. (Outcome 3-21)
3-29. **True.** (Outcome 3-21)

Chapter 4

4-1. Both include documentation, both affect the quality of the test results, both involve employees, both involve written procedures, and both may involve external quality controls. (Outcome 4-2)
4-2. Incorrect laboratory results may result in improper treatment for the patient. Patients may not receive the necessary treatment, or they may be treated incorrectly based on the inaccurate results, leading to serious consequences. (Outcome 4-3)
4-3. No, they do not. They may provide information about whether the instrument is operating correctly, but they do not let you know whether a test is valid. (Outcome 4-4)
4-4. **d, a,** and **c.** (Outcome 4-4)
4-5. Cindy is following the procedure as she was taught; this means that the manufacturer's instructions may have changed since she was trained. Additional explanations

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may include the use of blood for a kit for which urine is the required specimen, or using an expired kit or one that has been stored incorrectly. This scenario stresses the need to follow the package insert instructions. (Outcome 4-6)

4-6. Without a date, there is really no reason to document the result, as it is not evident when the test was performed and which patient results were dependent on that result as verification that the testing device or instrument was working correctly. (Outcome 4-7)

4-7. No, it is not used to document qualitative results, only quantitative. It would not be possible to use this sort of chart to document positive and negative answers, as it is designed to show an acceptable range of results for a specific test. (Outcome 4-7)

4-8. A calibration sample has a known value, not a known range of acceptable values. Once the calibration specimen is tested, the instrument is adjusted until it reads precisely the known value. A quality control specimen has a known range of values, and it is designed to show that the machine is within calibration. (Outcome 4-8)

4-9. It is not required for all laboratories. Those that perform only CLIA-waived tests are not required to perform proficiency testing, although some sort of outside verification of performance is recommended. (Outcome 4-8)

4-10. The most important step that a medical assistant can take is to follow the manufacturer's instructions specifically. (Outcome 4-8)

Chapter 5

5-1. Enforcement: Laws are enforced by governmental agencies, and those who are noncompliant may be punished financially or even imprisoned. Ethics are not enforced or punished in the same way.

Creation: Laws are created by government agencies; ethics are either created personally by the individual based on morals and values or they are created by a professional organization. (Outcome 5-2)

5-2. **b.** Implied consent. (Outcome 5-3)

5-3. Yes, she has the right to get a copy of her medical record, although she might have to wait for it to be copied. No, it is not all right for her to take the entire original record from the office. (Outcome 5-4 and Outcome 5-5)

5-4. No; assault means the threat of injury, not the actual injury. (Outcome 5-1)

5-5. An intentional tort means that a wrong was committed by one person against another person intentionally, or on purpose. An unintentional tort is a case of accidental wrongdoing. (Outcome 5-6)

5-6. A medical assistant is certainly liable, and it is possible for him or her to be sued for malpractice. (Outcome 5-7)

5-7. No, the scope of practice may change state to state, depending on the laws for a particular state. (Outcome 5-8)

5-8. No, it also includes the portability of health insurance, and the method in which health-care information is transmitted for reimbursement, as well as standardization of health-care information. (Outcome 5-9)

5-9. Several standards are presented in the AAMA code of ethics, including respecting patients, keeping confidential information confidential unless it is required by law, upholding high principles of the profession, being a life-long learner, and being involved in the community. (Outcome 5-10)

5-10. This is most definitely an example of risk management, as appropriate documentation is very important to avoid potential legal issues. (Outcome 5-11)

Chapter 6

6-1. **d.** Compound microscope. (Outcome 6-2)

6-2. The stage is the surface where the slide is placed for observation/examination. (Outcome 6-3)

6-3. The condenser concentrates the light from the light source. (Outcome 6-3)

6-4. **False;** this outcome should be cleaned last. (Outcome 6-4)

6-5. **c.** Lens paper. (Outcome 6-4)

6-6. The coarse adjustment knob should be used first. (Outcome 6-5)

6-7. No, the stage should not be moved once the specimen is in focus with a lower magnification when changing from one outcome to another. (Outcome 6-5)

6-8. **b.** Electron microscope. (Outcome 6-2)

6-9. Generally, medical assistants do not perform microscopic examinations in which they are identifying different formed elements in a specimen. However, with appropriate training, a medical assistant may be able to perform a normal manual differential count, and also to perform urine microscopic examinations. (Outcome 6-6)

6-10. Answers may vary, but they may include cleaning the centrifuge, using a tachometer to monitor the rpms, checking the centrifuge for any cracks or discolorations, and checking the electrical system for wear. All these procedures would, of course, be documented. (Outcome 6-7)

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6-11. Whenever the centrifuge is used, a container of similar size with the same volume of liquid must be placed across from the specimen before turning on the centrifuge. (Outcome 6-7)

6-12. Temperatures should be monitored at least daily. In situations in which the temperature control is critical (as in blood bank facilities), the temperatures must be monitored continuously. In these critical situations, an alarm system is also in place to verify that the temperature stays within the established range for that storage unit. (Outcome 6-8)

6-13. Answers may vary, but could include the following:
- On-site testing allows for a definitive diagnosis to be established as well as a plan of treatment while the patient is still in the office.
- CLIA-waived tests performed in the office may be less expensive.
- Patients are often more compliant because the tests can be performed in the office during an office visit. (Outcome 6-10)

6-14. This method of measurement uses an electrical current. When the specimen is passed through an aperture that runs between the two electrodes for the current, the number, size, and other characteristics of the cells in the specimen can be measured. The amount of disruption (or impedance) to the electrical current provides the information needed for the measurement. (Outcome 6-11)

6-15. **d.** Whole blood. (Outcome 6-13)

6-16. Yes, the results are visible on the screen of the instrument, and often the instrument is capable of printing the results at the time of the test as well. (Outcome 6-13)

6-17. The Cholestech LDX is a common CLIA-waived instrument used for cholesterol testing in the physician office laboratory. (Outcome 6-14)

6-18. No, it is not measured from intact red blood cells. The cells must be broken (or lysed) before the hemoglobin test can be performed. (Outcome 6-15)

6-19. No, the glucometer is an instrument used to test glucose levels in the blood, which is a type of chemistry test, not a hematology test. (Outcome 6-14)

6-20. **d.** Meniscus. (Outcome 6-17)

Chapter 7

7-1. Demographic information, documentation of test ordered, ICD-9 codes, last dose of medication if a drug level is ordered, type of fluid to be tested, wound source, date of testing, name of ordering physician. (Outcome 7-2)

7-2. Both types of panels are designed to assist the healthcare provider with an easier diagnosis by grouping tests that complement one another in a panel. (Outcome 7-3)

7-3. This is not an acceptable order, because standing orders cannot be extended for more than a year. (Outcome 7-4)

7-4. No repeat collections needed, quicker opportunity for diagnosis, faster treatment. (Outcome 7-5)

7-5. No, it should not because there is no way of verifying if it is the armband that belongs to the patient who is in the bed. (Outcome 7-6)

7-6. The medical assistant should ask him if he has had coffee in the past 12 hours before she begins the blood draw. (Outcome 7-8)

7-7. The reference ranges for most laboratory tests are dependent on many factors, including the collection method. Reference ranges for arterial blood are different from those of venous specimens, which are different from capillary specimens. In addition, the reimbursement for the collection may be different for the various types of blood specimen collections. (Outcome 7-10)

7-8. Initials or identification of the person who has collected the specimen, date and time of collection, patient name, and unique identifier (such as patient ID or birth date). (Outcome 7-12)

7-9. The specimen has a special label placed over the top of the container that is tamper evident. Also, the chain of custody form provides documentation of all those who had access to the specimen. The specimen should be kept in a locked area with limited access when it is not in the possession of a laboratory employee. (Outcome 7-13)

Chapter 8

8-1. The heart, arteries, veins, and capillaries. (Outcome 8-1)

8-2. Arteries have a pulse, veins do not. Arteries carry bright red blood that has just been oxygenated, whereas the blood in veins is darker. Veins have valves to help the blood to move in one direction; arteries have blood pulsing through and do not need the valves. Upon palpation, they feel different—the arteries are a bit stiffer; veins are spongier. (Outcome 8-3)

8-3. No. Capillaries are much smaller; they are microscopic in size. (Outcome 8-4)

8-4. The antecubital area. (Outcome 8-5)

8-5. No. They are also performed on the heel when drawing an infant. (Outcome 8-6)

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8-6. Not always; there are times when there is no other choice, so certain precautions have to be taken before drawing the blood near a site at which an IV is running. (Outcome 8-7)

8-7. The edema can add additional fluid to the sample, causing erroneous results. There is an increased chance of infection, and the blood draw may be very difficult. (Outcome 8-7)

8-8. Needle, tubes, sharps biohazardous disposal container, gauze, alcohol pads, tube holder or syringe, gloves. (Outcome 8-8)

8-9. No. The ones used for the evacuated tube system have two ends that are sharp; syringe needles have only one end that is sharp, and they screw onto the syringe. Butterfly systems have needles that are much shorter and attach to a long piece of tubing. (Outcome 8-8)

8-10. Because they have the air removed from the tube to create a vacuum and allow the blood to enter without any additional "pulling" action. (Outcome 8-8)

8-11. The stoppers are color coded to indicate the type (or absence of) additives. (Outcome 8-10)

8-12. To avoid potential crossover contamination from one type of tube to another. This contamination may cause erroneous results. (Outcome 8-11)

8-13. Because the reference ranges are different for each type of blood specimen. The capillary specimens generally have more fluid contamination so the results may be much different. (Outcome 8-13)

8-14. No, it is not. The capillary samples don't have the potential contamination issues from each tube that the venipuncture procedures have, so the order of draw is based more on the tubes that might clot accidentally if they are left unattended too long. (Outcome 8-11)

8-15. Proper patient identification procedure is the most important aspect. (Outcome 8-14)

8-16. The specimens must be drawn into a tube that does not contain anticoagulant. After the draw is complete, the sample must sit for at least half an hour undisturbed at room temperature to allow for a clot to form. After a clot has formed, the sample can be centrifuged for at least 10 minutes so that complete separation can occur. Finally, the serum may be separated using various techniques. (Outcome 8-17)

8-17. Serum does not contain clotting factors, as they are used up in the blood clot. Plasma does contain the clotting factors. Serum is taken from a tube that does not contain anticoagulant. Plasma is taken from a tube that contains anticoagulant. (Outcome 8-18)

8-18. **False.** Tests that require whole blood must be thoroughly mixed prior to testing. (Outcome 8-17)

8-19. **d.** All of the above. (Outcome 8-19)

8-20. **False.** The angle at which the needle is inserted for venipuncture plays a significant role in the success of the procedure and avoidance of the negative outcome. (Outcome 8-20)

Chapter 9

9-1. Diagnosis of urinary tract infections, chemical analysis. (Outcome 9-2)

9-2. Labeling procedures, documentation of medication, documentation of collection times for specimen, communication to the patient for collection procedures. (Outcome 9-2)

9-3. To avoid external contaminants which may lead to a misdiagnosis and incorrect patient treatment. (Outcome 9-2)

9-4. The urine specimen container should be labeled before it is given to the patient. (Outcome 9-6)

9-5. A straight or intermittent catheterization procedure is used to collect a urine specimen for culture, if needed. (Outcome 9-3)

9-6. The patient should be told not to urinate directly into the container. (Outcome 9-7)

9-7. The first morning void specimen is collected immediately after waking up. The 24-hour urine specimen is collected over 24 hours. (Outcome 9-3)

9-8. Because it is not possible to control the urination times of an infant, the device has to be ready to collect the specimen whenever it is generated. (Outcome 9-3)

9-9. Because microscopic pathogens may be present, and OSHA recommends that gloves are worn whenever there is a potential for exposure to body fluids. (Outcome 9-4)

9-10. The bacterial count. (Outcome 9-5)

Chapter 10

10-1. Pathogen. (Outcome 10-1)

10-2. Specimen source, patient name, name or ID for collector, date, and time of collection. (Outcome 10-2)

10-3. Ideally, the sample should be collected before the antibiotic therapy has been initiated. (Outcome 10-2)

10-4. It may differ in the form that it takes (liquid versus solid), the container it is provided in, and by how selective it may be for specific types of samples. (Outcome 10-3)

10-5. Bacterial samples will grow more quickly than the other types listed. (Outcome 10-4)

10-6. No, this will contaminate the specimen with organisms that were not present in the area of specimen collection. (Outcome 10-2)

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10-7. They both use swabs for their collection, and they are both collected from the same area at the back of the throat. Also, the PPE used for both types of collection is the same. (Outcome 10-5)

10-8. No, it is best to collect two swabs, as one is used for the strep screen and one is used for the culture. If one swab is collected and the culture is set up before the strep screen is performed, there is a chance that the strep screen could produce a false negative because of an insufficient sample volume. If the strep screen is performed first, the culture cannot be set up from the swab afterward, as there are chemicals added to the swab that would affect the bacterial growth. (Outcome 10-5)

10-9. No, they are not. Ideally, for both types of collections, the medical assistant will touch areas that appear most inflamed, and if there are any white pustules, those will be areas to target as well. (Outcome 10-5)

10-10. Many of the pathogens present in the sputum of infected patients are spread by droplets while the patient is coughing or sneezing. Collection of the sputum specimen in the waiting area could potentially expose all those who are present and even those who follow, as the droplets may land on surfaces that they touch. Sputum specimens should be collected in a private area; it is recommended that the patients collect them in the privacy of their home. (Outcome 10-6)

10-11. **a.** Specimens taken from indwelling catheters. (Outcome 10-7)

10-12. The bottles include different nutrition sources and additives. One bottle is designed to encourage the growth of aerobic microorganisms, whereas the other is designed for anaerobic microorganism growth. (Outcome 10-8)

10-13. **b.** Two times (Outcome 10-8)

10-14. The CSF tubes must be marked according to their order of collection. This allows the laboratory to process them appropriately when performing chemistry, hematology, and microbiology testing procedures. (Outcome 10-9)

10-15. **c.** Swabs (Outcome 10-10)

10-16. **False.** It is definitely advisable to wash a wound before collecting a culture specimen, so that any extraneous (transient) microorganisms are washed away from the area. (Outcome 10-11)

10-17. It is important because stool specimens include a great deal of normal flora. The media used for this type of specimen encourages the growth of the pathogenic microorganisms that are present in the GI tract, while discouraging the growth of the normal flora to avoid overgrowth. This is more important for stool specimens than it is for any other type of specimen because the normal flora occurs in such high numbers. (Outcome 10-12)

10-18. It reduces the discomfort of using a dry swab in the eye; these patients usually are already in pain from the eye infection. (Outcome 10-13)

10-19. **a.** Otitis externa. This is often linked to swimming or introduction of liquid to the ear canal, as can occur in bathing or showering. (Outcome 10-14)

10-20. No, fungal infections can occur in any area of the body. (Outcome 10-15)

10-21. KOH preps and wet mounts are similar in that they are used for examination of microorganisms in their living state, without preservative or staining. Ideally, the movement of the organisms can be evaluated, as well as the morphology. They are also similar in that both methods may be used to examine samples taken from the same areas of the body. KOH preps are different from wet mounts because the KOH prep is designed specifically to clear away all elements from the sample that are not fungal in nature; the wet mount allows for examination of everything in the specimen. (Outcome 10-16)

10-22. **a.** The O&P collection procedures include containers with preservative solution, but the stool culture samples procedures do not. (Outcome 10-17)

10-23. To collect the sample for detection of pinworms or their ova, clear adhesive tape is pressed against the rectum to pull out the worms or eggs. The adhesive tape is then placed on the slide to be examined under the microscope. (Outcome 10-18)

10-24. The two different types of stains allow for bacteria to be differentiated with the staining procedure. By using two different colors of stains, it is possible to identify bacteria as gram positive (those that absorb the purple stain in their cell walls) or gram negative (those that absorb the pink counterstain in their cell walls). If only one stain were used, it would not allow a chance to examine the bacteria that did not absorb the initial stain, as they would be colorless. (Outcome 10-19)

10-25. **d.** All of the above. (Outcome 10-20)

10-26. Antibiotic discs are used to apply different types of antibiotics to the bacteria so that the microbiologist can determine which antibiotic may be most effective

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to treat the infection. The antibiotics that do not allow the bacteria to grow close to their borders are more effective in treating that specific bacteria than are those antibiotics that allow the growth to continue right up to their borders. (Outcome 10-21)

10-27. C&S means "culture and sensitivity." This is a procedure in which the specimen is cultured and the infection-causing pathogen is identified Then an antibiotic sensitivity is performed to determine which medication is most effective for use. A C&S is not performed for viral or fungal cultures, as antibiotics are not used to treat these infections. (Outcome 10-22)

Chapter 11

11-1. Erythrocytes, leukocytes, and thrombocytes (red cells, white cells, platelets) make up the formed elements in blood. (Outcome 11-3)

11-2. Hematopoiesis is the process of the production of blood cells. (Outcome 11-2)

11-3. *Pluripotent* means "having the ability to differentiate into several types of specialized cells." (Outcome 11-2)

11-4. No, the nucleus is expelled from the red blood cell before it enters the general circulation. Mature red blood cells do not include a nucleus. (Outcome 11-3)

11-5. There may be an increase in the number of reticulocytes following blood loss. (Outcome 11-4)

11-6. The neutrophil is the white blood cell that first fights bacterial infection; therefore, the numbers increase as the cells are employed. (Outcome 11-5)

11-7. The eosinophil count may increase in an allergic reaction. It is a granulocytic white blood cell with a bilobed nucleus and bright red-orange granules in the cytoplasm. (Outcome 11-5)

11-8. The lymphocyte has forms that make antibodies and are active in cell-mediated immunity. (Outcome 11-5)

11-9. Platelets stick together to form the platelet plug to fill the break in the vessel, release serotonin to help the vessel contract, and start the chemical reactions of coagulation to increase the stability of the platelet plug. (Outcome 11-7)

11-10. Three CLIA-waived procedures are hemoglobin, hematocrit, and erythrocyte sedimentation rate testing. (Outcome 11-8)

Chapter 12

12-1. The CBC (complete blood count) tests are the hemoglobin, hematocrit, red blood cell count, white blood cell count, and the differential. The erythrocyte indices and a platelet count are often included. (Outcome 12-2)

12-2. The normal range is 4.2 to 6.2 million red blood cells per cubic millimeter of blood. (Outcome 12-3)

12-3. The white blood cell count is increased in bacterial infection and in leukemia. (Outcome 12-4)

12-4. The red blood cell indices describe the size of red blood cells and the amount of hemoglobin that they contain. (Outcome 12-6)

12-5. The appearance of the white blood cell nuclei and the cytoplasm is used for differentiation. In addition, the colors added by the polychromatic stain aid in the identification process. The nuclei, cytoplasm, and granules all absorb different colors. (Outcome 12-7)

12-6. From greatest in number to least, they are neutrophils, lymphocytes, monocytes, eosinophils, and basophils. (Remember—Never let monkeys eat bananas.) (Outcome 12-7)

12-7. The normal red blood cell is circular, with a pale center. (Outcome 12-9)

12-8. A pale red blood cell that has a decreased amount hemoglobin is hypochromic. (Outcome 12-9)

12-9. *Poikilocytosis* is the word used to describe a variety in the shapes of red blood cells on the blood smear. (Outcome 12-9)

Chapter 13

13-1. Hemoglobin is made up of one molecule of globin and four molecules of heme. (Outcome 13-2)

13-2. Oxygen delivery to the tissues of the body. (Outcome 13-2)

13-3. Answers may vary, but examples of abnormal hemoglobin strains are Hb S, Hb C, Hb D, Hb G, Hb J, and Hb M. (Outcome 13-3)

13-4. No, the cells must be lysed first. (Outcome 13-4)

13-5. Errors may include overfilling or underfilling the tube, sealing inadequately with the clay on the end of the tube, using an incorrect speed for the centrifuge, allowing the specimen to sit for too long before reading the result, contaminating with interstitial fluid, and using an incorrect reading technique. (Outcome 13-5)

13-6. The hematocrit is the amount of space occupied by red blood cells in a sample of whole blood. It is reported as a percentage. (Outcome 13-5)

13-7. The centrifuge is used to create the three layers in performing the hematocrit. (Outcome 13-5)

13-8. Anemia is the disorder in which there is low oxygen-carrying capacity of blood. (Outcome 13-9)

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13-9. The physician could order a hemoglobin and/or hematocrit. The red blood cell count and indices could also give additional information for anemia. (Outcome 13-8)

13-10. Iron deficiency, pernicious, aplastic, and sickle cell anemias are examples. (Outcome 13-10)

Chapter 14

14-1. The sedimentation rate is a laboratory test where the settling of red blood cells is observed. (Outcome 14-1)

14-2. Rouleaux formation is the stacking of red blood cells on top of one another, as in a stack of coins. It occurs when the red cells are no longer repelled from one another. (Outcome 14-1)

14-3. Increased fibrinogen and certain globulin levels in the plasma decrease the negative charge on the red blood cells, and they are not as repelled from each other and will stack more easily into the rouleaux formation. (Outcome 14-2)

14-4. There is less surface area to the volume of the stacked cells so the stack will settle faster in the plasma than single red blood cells. (Outcome 14-3)

14-5. For those younger than 50 years of age, the normal value for men is less than 15 and the normal value for women is less than 20 mm/hr. (Outcome 14-4)

14-6. The inflammatory process causes the shift in proteins that will lead to an increased ESR. (Outcome 14-5)

14-7. The Sediplast Westergren erythrocyte sedimentation system and the Wintrobe ESR system. (Outcome 14-6)

14-8. Any two of the following procedure errors will affect the value of the ESR: using a clotted sample could cause erroneous results; using an EDTA tube that is not well mixed; using a sample that is at refrigerated temperature; leaving air spaces in the column that is filled with the aliquot of blood; not keeping the column vertical during the hour of the procedure; placing the column in direct sunlight or in an area where there is vibration or movement. Also, reading the test at less than 60 minutes would cause an erroneous result. (Outcome 14-7)

Chapter 15

15-1. It may be done to screen for possible coagulation disorders or to monitor medication use. (Outcome 15-2)

15-2. No; there are other factors that are involved in addition to the platelets. (Outcome 15-3)

15-3. The constriction of blood vessels in the immediate and surrounding area is the body's first response to vessel injury. (Outcome 15-3)

15-4. This term refers to a series of events that seal off vessel injury and secondary coagulation steps that follow the formation of the initial platelet plug. (Outcome 15-3)

15-5. A thrombus is a blood clot that is stationary; an embolus is a part of a blood clot or a whole blood clot that has left the point of formation and has traveled through the body. (Outcome 15-4)

15-6. DIC and DVT are similar because they both involve formation of blood clots. DVT is a deep vein thrombosis that is contained in a particular vessel, whereas DIC is intravascular coagulation that is spread throughout the body. (Outcome 15-5)

15-7. Thrombocytopenia is different because it is a disorder specific to the number of platelets; all the other disorders discussed are in reference to other aspects of the clotting process. (Outcome 15-5)

15-8. No, the INR is used when monitoring a patient who is taking warfarin or Coumadin, not for initial screening. It may be reported as part of the initial screening, but the health-care provider will not use the INR to make a decision on potential coagulation defects without the prothrombin time result as well. (Outcome 15-6)

15-9. **c.** Heparin. (Outcome 15-8)

15-10. The patient may exhibit slow or inadequate blood clotting with blood vessel injury, resulting in excessive bruising and/or bleeding. (Outcome 15-11)

15-11. The answers may vary, but should include the following: results are not reproducible; aspirin has a profound effect; other medications and health conditions may affect the result to a high degree; and the bleeding time result does not seem to correlate well to the true risk of bleeding in surgical situations. (Outcome 15-10)

15-12. **False.** It is imperative that these tubes are filled to the point at which the vacuum is exhausted. (Outcome 15-13)

Chapter 16

16-1. Qualitative tests provide a result that indicates whether the specimen is positive or negative for a specific substance. Quantitative tests provide an actual number that indicates the amount of a substance that is present in the specimen. (Outcome 16-1)

16-2. **a.** Serum. (Outcome 16-2)

16-3. Glucose testing may be performed in a physician office laboratory to screen for the presence of diabetes mellitus or gestational diabetes, or to monitor

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the progress of a patient who is being treated for these conditions. (Outcome 16-4)

16-4. **b.** LDL. (Outcome 16-5)

16-5. **d.** Cadmium. (Outcome 16-6)

16-6. Panels allow the health-care provider to have access to a variety of test results, which can often aid in a differential diagnosis.

If the provider orders only one test at a time, the patient may need to return to the office several times to have specimens collected, which would be cumbersome and time consuming.

Some panels also allow the health-care provider to evaluate more than one organ system at once, which can help to establish a diagnosis.

Panels may be less expensive in some situations. (Outcome 16-8)

16-7. **True.** This is the most common reason that these tests are ordered. (Outcome 16-7)

16-8. When damage to the heart muscle occurs, the specific cardiac enzymes become elevated at different rates. To determine whether a myocardial infarction occurred, it is essential to collect a series of specimens to see if the enzymes have become elevated. (Outcome 16-10)

16-9. **a, b,** and **c.** (Outcome 16-11)

16-10. **a.** Lipemia. (Outcome 16-13)

Chapter 17

17-1. Glycogen is the storage form of glucose in the body; it is produced when there is excess glucose present in the bloodstream and stored in the liver and the adipose tissues. (Outcome 17-1)

17-2. **a.** Formation of glycogen. (Outcome 17-3)

17-3. Answers may vary and might include the following: Type 1 and type 2 diabetes both exhibit elevated levels of blood glucose. They both may exhibit similar symptoms. Both type 1 and type 2 diabetes are diagnosed using blood glucose levels, in addition to physical examination and medical history. Both types of diabetes are caused by problems with insulin in the body: a decrease in the amount of glucose, or cellular resistance to glucose. (Outcome 17-4)

17-4. Diabetic neuropathy, damage to the optic nerve, cardiovascular damage, irreversible kidney damage, poor healing. (Outcome 17-6)

17-5. Gestational diabetes is more like type 2 diabetes because in both there is adequate insulin present, but the cells develop a resistance to the action of the insulin. In type 1 diabetes, the patient does not have enough insulin produced. (Outcome 17-5)

17-6. Untreated gestational diabetes may lead to macrosomia (an excessively large fetus). (Outcome 17-7)

17-7. **c.** A glucose level drawn at any time of the day without any previous preparation. (Outcome 17-8)

17-8. **True.** A laboratory postprandial test involves the ingestion of a glucose drink. A postprandial blood glucose test done at home is performed a certain amount of time after a meal. (Outcome 17-9)

17-9. The blood is drawn a minimum of four times if the test is completed entirely. This includes a fasting, 1-hour, 2-hour, and 3-hour draw. (Outcome 17-10)

17-10. **c.** 3 months. (Outcome 17-11)

17-11. The plasma glucose will be higher than the whole blood glucose. (Outcome 17-12)

17-12. Medical assistants may assist with this process in many ways. These include helping the patients understand how their plasma glucose and whole blood levels will be different from one another, showing the patients how to use their blood testing equipment properly, helping patients find an instrument that works well for them, explaining how to document blood glucose levels properly, and assisting with proper use and disposal of lancets. MAs may also assist patients with reimbursement for diabetes testing supplies by researching the policies of their insurance. (Outcome 17-13)

Chapter 18

18-1. Ingested cholesterol comes from animal products (like meat), dairy products, and processed foods. (Outcome 18-2)

18-2. LDL and VLDL. (Outcome 18-3)

18-3. Yes, it is desirable to have high HDL levels and low LDL levels, respectively. (Outcome 18-4)

18-4. No, this result is not within the desirable range. The reference range (or desirable range) is less than 200 mg/dL. (Outcome 18-4)

18-5. Elevated LDL levels are considered a health risk because they directly contribute to plaque buildup by depositing cholesterol on the lining of the blood vessels. (Outcome 18-5)

18-6. **a.** Consumption of excess calories. (Outcome 18-6)

18-7. **b.** Excess fat particles. (Outcome 18-7)

18-8. **False.** Electrolytes exhibit a positive or negative charge when dissolved in water. (Outcome 18-1)

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18-9. The electrolyte most commonly associated with arrhythmia is potassium. (Outcome 18-13)

18-10. **c.** Nitrogen. (Outcome 18-14)

Chapter 19

19-1. The physical examination of the urine specimen includes observations of the urine that can be seen with the naked eye; the microscopic procedures require the use of a microscope for magnification and are generally performed on urine sediment. (Outcome 19-7)

19-2. The function of the urinary system is the filtration of blood, excretion of waste, and the regulation of the body's fluid and acid-base balance. (Outcome 19-2)

19-3. **c.** Located on either side of the vertebral column with one slightly lower than the other. (Outcome 19-3)

19-4. Because urine is formed in the nephron. (Outcome 19-3)

19-5. Reabsorption and secretion. (Outcome 19-4)

19-6. No, ureters are only involved in the transportation of urine, not in the actual formation of urine. (Outcome 19-4)

19-7. **False.** Urinalysis testing is performed for a variety of reasons, including screening of asymptomatic individuals. (Outcome 19-6)

19-8. The physical examination procedures include observation of color, clarity, and sometimes the odor of the urine. (Outcome 19-7)

19-9. **c.** Chemical analysis. (Outcome 19-7)

19-10. **d, a,** and **b.** (Outcome 19-9)

Chapter 20

20-1. Urochrome is the pigment that gives urine its characteristic yellow color. (Outcome 20-1)

20-2. The bright orange color present in the urine is not clinically significant; it is merely a result of the medication she was given, probably pyridium, which is prescribed to those with recurrent urinary tract infections. (Outcome 20-2)

20-3. Using some sort of print or object behind the urine specimen allows the person performing the test to assess the transparency of the urine with more accuracy; it gives a point of reference. (Outcome 20-3)

20-4. **b.** Decreased. (Outcome 20-4)

20-5. No, there are other causes for strong odors in addition to a urinary tract infection. (Outcome 20-4)

20-6. **False.** A high specific gravity means that the specimen has a lot of dissolved substances; this does not necessarily mean that the urine is cloudy. High levels of large molecules such as glucose and protein do not make the urine cloudy. (Outcome 20-5)

20-7. No, this is not correct. Urine specific gravity must always be reported with three spaces to the right of the decimal point, the first of which is a zero, for example, 1.025. (Outcome 20-7)

20-8. Refractometers take only a drop of urine, they are relatively inexpensive, and they may be portable. (Outcome 20-6)

20-9. No, partly hazy is not a valid description of the clarity of the urine specimen. (Outcome 20-8)

Chapter 21

21-1. **False.** The reference range for many of the analytes is actually a negative result; this means that they are not normally present in the specimen. (Outcome 21-3)

21-2. Bile obstruction or liver dysfunction. (Outcome 21-2)

21-3. **a.** Intact red blood cells. (Outcome 21-3)

21-4. No. If the diabetic has too much glucose in the bloodstream at any given time, the urine may be positive for glucose. However, if the blood glucose level is under control (through diet, exercise, medication, or insulin use), then the urine may be negative for glucose. The values can fluctuate quite a bit throughout the day. (Outcome 21-2)

21-5. **False.** The leukocyte esterase result will not always be positive when white blood cells are present in the urine specimen, because not all white blood cells contain this enzyme. However, the only ones that do not secrete this enzyme are the lymphocytes, and they are not usually the type of white blood cell present in an infection. (Outcome 21-3)

21-6. **b.** Fever. (Outcome 21-3)

21-7. The strips can be exposed to moisture by leaving the lid off the container they are kept in or removing the desiccant packaged with the strips. They can also be exposed to direct light, excessive heat, or volatile liquids. They can be used past their expiration date or when discolored. (Outcome 21-4)

21-8. **b.** Allowing the reagent strip to remain in the urine for 60 seconds before removing the strip. (Outcome 21-4)

21-9. The most common route of exposure is through mucous membrane exposure by splashing or aerosol exposure. (Outcome 21-5)

21-10. **True.** Some only test for one or two analytes (e.g., glucose and ketones), and some do or do not provide an opportunity for specific gravity testing even if they are the more comprehensive strips. (Outcome 21-6)

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21-11. Less opportunity for operator error, less time intensive for the person performing the test, and opportunities for multiple testing procedures to occur at once are all advantages of automated urine chemistry testing. (Outcome 21-6)

21-12. Because the FOBT is a means of detecting early, asymptomatic colorectal cancer. (Outcome 21-9)

21-13. **d.** NSAIDs. (Outcome 21-10)

Chapter 22

22-1. It may be added as a reflexive test when the chemical tests are abnormal. The urine microscopic may also be performed when ordered by the practitioner; this may occur if the practitioner suspects the presence of certain formed elements in the urine specimen, such as crystals or casts. (Outcome 22-2)

22-2. No, the presence of squamous epithelial cells is not considered clinically significant. (Outcome 22-4)

22-3. **b** Yes, spermatozoa may be present in the urine of females if they have recently been involved in sexual intercourse. (Outcome 22-3)

22-4. **a.** Viruses. (Outcome 22-4)

22-5. The KOVA system allows for a standardized amount of sediment to be visualized, and it also adds a stain to the sediment before it is placed on the slide for visualization. The stain will allow for more contrast with structures that appear similar, which will aid with identification. (Outcome 22-5)

22-6. **False.** Many normal urine specimens have very few formed elements present in the urine sediment. (Outcome 22-4)

22-7. A medical assistant may be responsible for providing instructions to the patient for specimen collection; accepting and logging in the specimen; pouring off some of the sample into a tube to be centrifuged; centrifuging the urine specimen; processing the centrifuged specimen to place the sediment on a slide; adding stain to the sediment for visualization; focusing the microscope for visualization of the formed elements on the slide. (Outcome 22-8)

Chapter 23

23-1. Antigens stimulate an immune response in our bodies, and antibodies may be produced in response to protect us. (Outcome 23-2)

23-2. It is usually tested in the serology area of the laboratory. (Outcome 23-2)

23-3. The injured cells release a chemical that signals for the internal nonspecific responses to begin. These include histamine production and white blood cell migration. (Outcome 23-3)

23-4. They are good for our immune system. They often occur in response to a foreign object in our nasal passages, and they can expel this before it causes a problem for our body. (Outcome 23-3)

23-5. No. If the first or second line of defense destroys the foreign invader, the subsequent level is never involved in the process. (Outcome 23-4)

23-6. The third line of defense is the one that is very specific toward each antigen. This includes antibody production. (Outcome 23-4)

23-7. It means that we have been exposed (either naturally or artificially) to that disease before, and our body has produced antibodies that will react immediately to protect us in subsequent exposures. (Outcome 23-5)

23-8. Vaccines "fool" our immune system into producing antibodies to a specific antigen without ever becoming ill with that disease. They target the third line of defense. (Outcome 23-5)

23-9. A antigens and B antigens. (Outcome 23-8)

23-10. Yes, she will probably be receiving a RhoGam injection to keep her body from forming anti-Rh that might cause harm to this fetus or those in the future. (Outcome 23-8)

23-11. They involve antigen/antibody reactions as part of the testing procedure. (Outcome 23-9)

23-12. Yes. An example may be the tests for syphilis VDRL and RPR. (Outcome 23-9)

23-13. The results are available quickly so that the physician can take immediate action. They are also usually less expensive than other methods may be for the patient. (Outcome 23-10)

23-14. The Epstein Barr virus. (Outcome 23-11)

Chapter 24

24-1. Immunology is the study of the immune system, including the antigens and antibodies involved in the process. Serology is the study specifically of the antigens and antibodies; therefore, it is part of immunology. They are similar because they both include the study of the reactions of antigens and antibodies. (Outcome 24-1)

24-2. The test is demonstrating a lack of specificity. (Outcome 24-1)

24-3. Most are immunoassays in which the reagents and the sample are mixed and move across the testing surface to produce a chromatographic result indicating a positive or a negative. They are also similar

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because they usually take less than 15 minutes to obtain a result. (Outcome 24-3)

24-4. Answers may vary, but should include the following: The rapid tests allow for faster treatment and better patient compliance because the patients are in the facility when the diagnosis is made and treatment is prescribed; the tests are usually cost effective, especially so for tests that are seldom performed; the results are ready in a short period of time. (Outcome 24-2)

24-5. Complications include glomerulonephritis, inflammation of the joints, and endocarditis. (Outcome 24-5)

24-6. No, it is not present elsewhere. (Outcome 24-5)

24-7. When there is an unexpected negative result with a high prevalence of influenza in the population. (Outcome 24-4)

24-8. The patient doesn't need to return for results, so it allows the health-care provider to provide education and counseling to the patient at the same time that the test specimen is collected. This helps to control the spread of the disease by those at high risk who are unaware of their HIV-positive status. (Outcome 24-4)

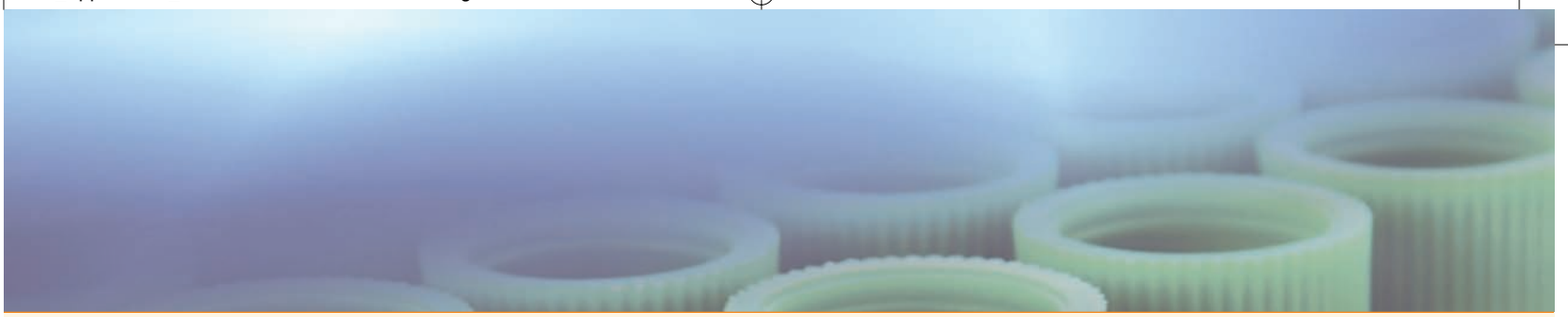

Appendix C

Tube Guide for BD Vacutainer Venous Blood Collection

BD Vacutainer® Venous Blood Collection
Tube Guide

BD Helping all people live healthy lives

For the full array of BD Vacutainer® Blood Collection Tubes, visit www.bd.com/vacutainer. Many are available in a variety of sizes and draw volumes (for pediatric applications). Refer to our website for full descriptions.

BD Vacutainer® Tubes with BD Hemogard™ Closure	BD Vacutainer® Tubes with Conventional Stopper	Additive	Inversions at Blood Collection*	Laboratory Use
Gold	Red/ Gray	• Clot activator and gel for serum separation	5	For serum determinations in chemistry. May be used for routine blood donor screening and diagnostic testing of serum for infectious disease.** Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 30 minutes.
Light Green	Green/ Gray	• Lithium heparin and gel for plasma separation	8	For plasma determinations in chemistry. Tube inversions ensure mixing of anticoagulant (heparin) with blood to prevent clotting.
Red	Red	• Silicone coated (glass) • Clot activator, Silicone coated (plastic)	0 5	For serum determinations in chemistry. May be used for routine blood donor screening and diagnostic testing of serum for infectious disease.**Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 60 minutes.
Orange		• Thrombin-based clot activator with gel for serum separation	5 to 6	For stat serum determinations in chemistry. Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 5 minutes.
Orange		• Thrombin-based clot activator	8	For stat serum determinations in chemistry. Tube inversions ensure mixing of clot activator with blood. Blood clotting time: 5 minutes.
Royal Blue		• Clot activator (plastic serum) • K_2EDTA (plastic)	8 8	For trace-element, toxicology, and nutritional-chemistry determinations. Special stopper formulation provides low levels of trace elements (see package insert). Tube inversions ensure mixing of either clot activator or anticoagulant (EDTA) with blood.
Green	Green	• Sodium heparin • Lithium heparin	8 8	For plasma determinations in chemistry. Tube inversions ensure mixing of anticoagulant (heparin) with blood to prevent clotting.
Gray	Gray	• Potassium oxalate/ sodium fluoride • Sodium fluoride/Na_2 EDTA • Sodium fluoride (serum tube)	8 8 8	For glucose determinations. Oxalate and EDTA anticoagulants will give plasma samples. Sodium fluoride is the antiglycolytic agent. Tube inversions ensure proper mixing of additive with blood.
Tan		• K_2EDTA (plastic)	8	For lead determinations. This tube is certified to contain less than .01 µg/mL(ppm) lead. Tube inversions prevent clotting.

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BD Vacutainer® Tubes with BD Hemogard™ Closure	BD Vacutainer® Tubes with Conventional Stopper	Additive	Inversions at Blood Collection*	Laboratory Use
	Yellow	• Sodium polyanethol sulfonate (SPS) • Acid citrate dextrose additives (ACD): **Solution A -** 22.0 g/L trisodium citrate, 8.0 g/L citric acid, 24.5 g/L dextrose **Solution B -** 13.2 g/L trisodium citrate, 4.8 g/L citric acid, 14.7 g/L dextrose	8 8 8	SPS for blood culture specimen collections in microbiology. ACD for use in blood bank studies, HLA phenotyping, and DNA and paternity testing. Tube inversions ensure mixing of anticoagulant with blood to prevent clotting.
Lavender	Lavender	• Liquid K_3EDTA (glass) • Spray-coated K_2EDTA (plastic)	8 8	K_2EDTA and K_3EDTA for whole blood hematology determinations. K_2EDTA may be used for routine immunohematology testing, and blood donor screening.*** Tube inversions ensure mixing of anticoagulant (EDTA) with blood to prevent clotting.
White		• K_2EDTA and gel for plasma separation	8	For use in molecular diagnostic test methods (such as, but not limited to, polymerase chain reaction [PCR] and/or branched DNA [bDNA] amplification techniques.) Tube inversions ensure mixing of anticoagulant (EDTA) with blood to prevent clotting.
Pink	Pink	• Spray-coated K_2EDTA (plastic)	8	For whole blood hematology determinations. May be used for routine immunohematology testing and blood donor screening.*** Designed with special cross-match label for patient information required by the AABB. Tube inversions prevent clotting.
Light Blue Clear	Light Blue	• Buffered sodium citrate 0.105 M (≈3.2%) glass 0.109 M (3.2%) plastic • Citrate, theophylline, adenosine, dipyridamole (CTAD)	3-4 3-4	For coagulation determinations. CTAD for selected platelet function assays and routine coagulation determination. Tube inversions ensure mixing of anticoagulant (citrate) to prevent clotting.
Clear	New Red/ Light Gray	• None (plastic)	0	For use as a discard tube or secondary specimen tube.

Note: BD Vacutainer® Tubes for pediatric and partial draw applications can be found on our website.

BD Diagnostics
Preanalytical Systems
1 Becton Drive
Franklin Lakes, NJ 07417 USA

BD Global Technical Services: 1.800.631.0174
BD Customer Service: 1.888.237.2762
www.bd.com/vacutainer

* Invert gently, do not shake
** The performance characteristics of these tubes have not been established for infectious disease testing in general; therefore, users must validate the use of these tubes for their specific assay-instrument/reagent system combinations and specimen storage conditions.
*** The performance characteristics of these tubes have not been established for immunohematology testing in general; therefore, users must validate the use of these tubes for their specific assay-instrument/reagent system combinations and specimen storage conditions.

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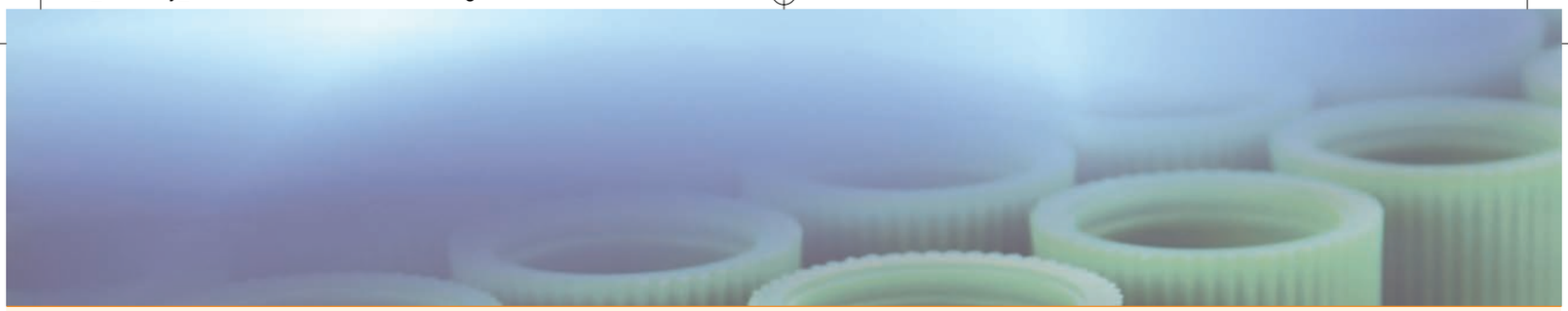

Glossary

1 or 2 hours postprandial (1 hr pp or 2 hr pp) – A specimen drawn 1 or 2 hours after a meal.

24-hour urine collection – A urine specimen collected over a 24-hour period to be used for chemical analysis.

Accuracy – A statistical term representing how close a laboratory result is to the true value.

Acidosis – An increase in the acidity of the blood and body tissues (decrease in pH) because of a buildup of acids in the blood.

Activated partial thromboplastin time (aPTT or PTT) – A test used to measure the time required for a fibrin clot to form after the activation factor, calcium, and a phospholipid mix have been added to the plasma. The results are recorded in seconds.

Advance Beneficiary Notice of Noncoverage (ABN) – A form that must be filled out for Medicare patients when the laboratory test ordered is not likely to be reimbursed.

Aerobes – Bacteria that require oxygen to grow and reproduce.

Aerobic – An organism that requires oxygen to survive and replicate.

Afferent arteriole – The arteriole that transports blood toward the center of the glomerulus of the kidney.

Afibrinogenemia – A condition in which a patient lacks fibrinogen in the bloodstream.

Agar – A solid, jelly-like culture medium usually provided in Petri dishes or tubes.

Agglutination – The clumping of particles (living or nonliving) in fluid. This is often a visible reaction that may be viewed under the microscope.

Aggregate – To come together or cluster in a mass.

Agranular – A classification used to describe white blood cells that do not have granules in their cytoplasm.

AIDS – Acquired immune deficiency syndrome.

Albumin – A plasma protein that functions as a carrier molecule for transporting various chemicals throughout the body. Albumin also functions to prevent plasma from leaking out of the capillaries. Patients with poor glycemic control may have albumin present in their urine, indicating damage to the kidneys.

Aliquot – A small portion of the whole specimen.

Alkalosis – An increase in blood alkalinity resulting from an increased number of alkaline substances or a decrease in the number of acidic substances. The pH will be elevated from the normal range in a state of alkalosis.

Allergy – An immune response to a foreign antigen that results in a hypersensitivity to that antigen. The immune response includes inflammation and dysfunction of body organs or systems.

Ambulatory – Able to walk or transport oneself; not confined to bed.

Ambulatory care – Care provided to patients who are able to ambulate (walk) into the premises. Generally refers to physician offices, urgent care facilities, emergency rooms, and the like.

Amorphous phosphates – A granular diffuse precipitate in alkaline urine that is made up of crystallized calcium and phosphate.

Amorphous urates – A granular diffuse precipitate in acidic urine that is made up of crystallized uric acid.

Anaerobes – Bacteria that do not need oxygen for growth and reproduction.

Anaerobic – An organism that does not need oxygen to survive and replicate. The growth of this type of organism is often actually inhibited by the presence of oxygen in its environment.

Analysis – Assists with differential diagnosis of congestive heart failure or respiratory disease.

Analyte – A chemical substance that is being tested or analyzed.

Anemia – A reduction in the oxygen-carrying capacity of the blood.

Anion – An ion that carries a negative charge. Electrolytes are ions when dissolved in water, and those with a negative charge (such as chloride and bicarbonate) are anions.

Anisocytosis – Condition in which there is inequality in the size of red blood cells.

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Antecubital area – The area of the arm that is directly in front of the elbow. This is the preferred area for venipuncture procedures.

Anterior – Directional term meaning "to the front."

Antibiotic sensitivity testing – Performed to determine how effective antimicrobial therapy is against a certain type of bacteria.

Antibody – A protein substance developed in response to antigenic exposure.

Antibody-mediated immunity – A term used to describe an immune response using antibodies; the third line of defense.

Anticoagulants – Substances added to keep blood from coagulating or clotting.

Antigen – A substance that the body detects as "foreign" or "nonself." This may initiate the formation of antibodies.

Antiphospholipid syndrome – A disorder with increased systemic thrombi formation, in which patients have high levels of antibodies against phospholipids in their system.

Anuria – The absence of urine production.

Aperture – An opening or hole through which a controlled amount of a substance, liquid, or light is admitted.

Aplastic anemia – Anemia caused by deficient red cell production in the bone marrow.

Apolipoproteins – Proteins that combine with and transport cholesterol in the bloodstream.

Arm – Part of a microscope that connects the base of the microscope to the tube where the optical lenses are attached.

Arteries – Blood vessels that carry blood away from the heart.

Arterioles – Small arteries that lead into a capillary at its distal end.

Artifacts – Contaminating substances in the urine specimen that have no clinical significance.

Asepsis – A term that means that a surface is without pathogenic microorganisms.

Aseptic – Free of pathogens.

Assault – A term used to describe a threat to inflict injury, with the apparent means to accomplish the threat.

Asymptomatic – Without symptoms or obvious outward signs of disease.

Atherosclerosis – Sclerosis or hardening of the arteries because of the buildup of a waxy, sticky coating on the inside of the vessel walls.

Atrial fibrillation – A disorder in which there is ineffective ejection of blood into the atria. Those with atrial fibrillation have a rapid and irregular heartbeat.

Autoantibodies – An antibody that is produced by the body against the cells of the same body. Autoantibodies are thought to be the cause of the destruction of the insulin-producing islets of Langerhans, leading to type 1 diabetes.

Autoimmune disease – A disease in which the body does not recognize the antigens on the surface of its own cells; it sees these cells as nonself.

Autoimmune response – The response the body when it no longer recognizes all the cells of the body as "self" and begins to damage these cells.

B cells – A type of lymphocyte that remembers an antigen after exposure to it.

Bacilli – Bacteria that are oval or rod shaped when viewed under the microscope.

Bacteria – Single-cell microorganisms that possess a cell wall in addition to the cell membrane that human cells possess.

Balanced – The practice of placing a tube of equal size and similar volume across from the specimen to be processed in the centrifuge. This allows the centrifuge to operate with symmetry, and not be "pulled" to one side or the other as it spins.

Band cell – An immature, unsegmented neutrophil.

Base – The bottom of a microscope that sits on the bench top.

Basic metabolic panel (BMP) – A group of eight tests that have been approved by the CMS for overall health screening and/or for monitoring certain disease states.

Basilic vein – A vein in the antecubital area that is on the inner side (medial) running over the top of the brachial artery. This vein is the last choice of the major veins in this area for venipuncture procedures.

Basophil – A granulocytic white blood cell essential to the nonspecific immune response in inflammation.

Battery – Touching another without his or her consent.

Beaker – A glass container that may be used in the laboratory to hold, mix, or heat chemicals. Beakers usually have a cylinder shape and a flat bottom.

Bence Jones protein – An immunoglobulin (protein) that is present in the renal tubules and excreted in the urine of patients having multiple myeloma.

Bevel – The slanted area of the needle that creates a sharp point at the tip.

Bilirubin – A product produced from the degradation of hemoglobin; it is yellow or orange in color.

Bilobed – Having two lobes or sections.

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Binocular – A term used to describe a microscope that has two oculars so that both eyes can be used at once to view the specimen.

Biohazard symbol – Symbol used to mark bags or containers that hold items that are biohazardous in nature.

Biohazardous waste – Liquid or semiliquid blood or other potentially infectious materials. This includes contaminated items that would release blood (or OPIM) in a liquid or semiliquid state if compressed. It also includes items that are caked with dried blood (or OPIM) that are capable of releasing these substances while being handled. This classification also includes pathological or microbiological waste that contains blood or other potentially infectious materials. (See also Regulated waste.)

Bladder – The urinary bladder is a muscular "sac" that holds urine until it is expelled from the body.

Blast – Immature stage in cellular development.

Blood urea nitrogen (BUN) – A by-product of protein metabolism that should be cleared from the blood by the kidneys. Elevated amounts in the blood are indicative of renal dysfunction.

Bloodborne pathogens (BBPs) – Pathogenic microorganisms present in human blood that are transmitted by direct contact to blood or mucous membranes of another person.

Bloodborne Pathogens Standard (1910.1030) – A regulation created by the Occupational Safety and Health Administration to educate and protect health-care workers from occupational exposure to blood or other potentially infectious materials. Originally created in 1988; there have been several addendums since that time.

Body mass index (BMI) – A statistical calculation comparing the weight and height of a person. This calculation is used to estimate whether a patient may be overweight or underweight according to his or her weight.

Bowman's capsule – A portion of the renal tubules that collects the initial urinary filtrate when it is forced from the glomerulus.

Brain natriuretic peptide (BNP) – Enzyme secreted by the muscular walls of the ventricles.

Broth – A liquid culture medium.

Buffer – Compound that reacts with strong acids or bases to minimize pH changes in the body.

Butterfly system – A system used for venipuncture that includes a short needle attached to a length of tubing. The tubing is then attached to a syringe or directly to an evacuated tube for blood withdrawal.

C&S – Culture and sensitivity; includes the growth and identification of the bacterial microorganisms present in a specimen as well as the determination of the antibiotics best suited for treatment of the infection.

Calibration – Standardization of an instrument by comparison of the results produced against those of a known value, and appropriate adjustment of the instrument as needed to achieve optimal results.

Calibration verification – The verification of the success of a calibration process by analyzing quality control samples.

Calyx – A cup-like drainage vessel that collects urine as it is formed in the renal pyramids and transports the urine to the renal pelvis to be expelled from the kidneys.

Candle jar – A setup using a jar and a candle that encourages growth of bacteria that prefer less oxygen in their environment. A candle is placed in the jar with the culture plates and then lit. The jar is closed tightly, and the candle uses up the oxygen in the jar, after which it goes out.

Capillaries – The smallest blood vessels. Capillaries are microscopic in size and connect the arterial and venous systems.

Capillary action – A surface tension that attracts liquid to fill a capillary tube or elevates liquid when touched by a solid.

Capillary puncture – A method of blood collection during which an incision is made in through the skin, which passes through the epidermis into the dermal layer.

Capillary tubes – Small, hollow plastic or glass tubes used to perform microhematocrit testing.

Carbohydrate – An organic molecule that is used as an energy source by the body. Carbohydrates are broken down during digestion to provide glucose, which is easily used by the cells of the body.

Carcinogenic – Anything capable of causing cancer.

Cardiovascular – Pertaining to the heart, arteries, veins, and/or capillaries.

Carriers – Someone who is infected (or carrying) a pathogen in the body without symptoms. Sometimes these individuals may have already undergone the complete disease process but keep the causative agent in the blood, and sometimes they have never been symptomatic.

Casts – Protein "shells" formed in the glomerular tubules. Casts may be filled with white cells, red cells, granules, or other substances. All but hyaline casts may be clinically significant.

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Cations – An ion that carries a positive charge. Electrolytes are ions when dissolved in water, and those with a positive charge (such as potassium and sodium) are cations.

CD4 cell – A type of lymphocyte (a white blood cell) that is attacked by HIV.

Cell mediated – A term used to describe all the activities of the T cells during the specific immune response to an antigen.

Centers for Disease Control and Prevention (CDC) – The premier public health agency in the United States. The CDC is part of the Department of Health and Human Services, and it protects the public health through research and implementation of recommendations for education, vaccination, infection control, and proper treatment of disease.

Centers for Medicare & Medicaid Services (CMS) – The organization responsible for enforcement of the CLIA regulations. Its members perform site visits and collect the fees associated with the registration process.

Centrifugal force – An outward force caused by the rotation of an object. The centrifugal force causes the specimen that is being centrifuged to separate into layers based on their relative weight or density.

Centrifuge – An instrument that spins specimens at a high speed to force the contents outward and separate the components as needed.

Cephalic vein – A vein in the antecubital area that is on the outer (lateral) side of this area when the arm is placed in the appropriate position for a venipuncture.

Cerebrospinal fluid (CSF) samples – Used to help diagnose various diseases of the central nervous system.

Chain of Custody – A form used to document all those who have possession of or process a legal specimen through all the steps of collection, testing, and disposal.

Chemotaxis – The process that signals more white blood cells to come to the scene of an invasion by a foreign substance.

Cholesterol – A soft, waxy lipid that is found in various parts of the human body, including the bloodstream.

Chromatographic – Analysis of substances on the basis of color changes that occur during the testing process.

Cilia – Slim, thread-like projections on the inner surface of mucous membranes that sweep away foreign objects such as pollen and dust.

Cirrhosis – A chronic liver disease characterized by scarring and ineffective function.

Clarity – The clearness of appearance. A term used to describe urine transparency.

Clean-catch midstream urine specimen – A procedure to be followed for urine specimen collection in which the potential for contamination with microorganisms from outside the urinary tract is minimized.

CLIA '88 – Clinical Laboratory Improvement Amendment of 1988.

CLIA-waived – Laboratory tests that have been determined by the FDA to fit this category. These tests are very simple to perform, need very little interpretation, and result in minimal clinical significance if they are performed or interpreted incorrectly.

Clinical chemistry – The quantitative or qualitative measurement of clinical compounds in the fluid portions of the body. This includes analysis of blood, urine, CSF, and other fluid specimens from the body.

Clinical significance – Meaningful results or actions affecting the clinical outcome or treatment of a patient.

Clot activators – Substances (such as silicone) that accelerate or aid in the clotting process within an evacuated tube.

Clotting cascade – The clotting process in which each step is dependent on the step prior until the clot has been formed.

Clotting factor – Enzymes and chemicals that interact in the clotting cascade to form a clot.

Coarse adjustment knob – The knob used on a microscope to bring an object into approximate focus.

Cocci – Round bacteria, which can then be classified further by their appearance when examined microscopically.

COLA – An independent company that accredits laboratories.

Colonies – Clusters of microorganisms visible on a culture.

Colorimetric – Analysis of the amount of a substance present in a sample, based on the amount of light absorbed by the substance. True colorimetric analysis often uses an instrument called a colorimeter to read the results. Colorimetric may sometimes be used synonymously with chromatographic.

Competency assessment – A process used to verify whether an employee is performing a testing procedure properly.

Competency testing – See Competency assessment.

Complement – A protein that assists in the second line of defense by destroying pathogens and sending signals to stimulate phagocytosis and inflammation.

Complete blood count (CBC) – A hematology test that includes hemoglobin concentration, hematocrit, red blood cell count, red blood cell indices, white blood cell count, leukocyte differential, and a platelet count.

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Complexity – Level of intricacy, difficulty, or complication.

Compound microscope – A microscope that has two means of magnification that are "compounded" or multiplied for a higher level of magnification.

Comprehensive metabolic panel (CMP) – A group of 14 tests ordered together to provide a comprehensive analysis of overall patient health. This panel has been approved for reimbursement by the CMS.

Condenser – A lens on many microscopes that concentrates the light as it comes through an aperture.

Conjugated bilirubin – Bilirubin that has been changed by the liver to be water soluble. Conjugated bilirubin is also known as direct bilirubin.

Contagious – Anything that is capable of being transmitted from one person to another.

Contaminated sharps – Sharps (needles or other sharp objects such as lancets or glassware) that have been contaminated with blood or other potentially infectious materials. Essentially, any contaminated object that can penetrate the skin.

Contraindications – Any reason that a procedure would be inadvisable or inappropriate.

Coumadin – An anticoagulant medication used to prevent or treat blood clots. Coumadin is taken orally, and monitored with the PT/INR test.

Cover slip – A thin piece of glass or plastic that is placed on top of a liquid specimen when viewed under the microscope.

Creatine kinase (CK) – A by-product of muscle metabolism. May also be known as CPK.

Creatinine – A by-product of muscle metabolism that is cleared from the blood by the kidneys. Elevated levels of creatinine in the blood may be indicative of renal dysfunction.

Credentialed – Formal recognition of competence achieved by an examination. ASCP provides credentialing opportunities to laboratory professionals.

Critical results – Results that are very far outside the expected reference range for a specific test and indicate a critical or crisis condition for the patient. These results are considered to be something that must be acted on immediately by notifying the health-care provider who ordered the test. The critical result ranges are established by the practice (in the case of a physician office laboratory) or the pathologist in a larger laboratory.

Crystals – The precipitation of dissolved substances in the urine. Some of these may be clinically significant.

Culture – The growth of microorganisms in special medium that contains chemicals and/or nutrition to encourage and support their growth.

Current procedural terminology (CPT) codes – These codes are developed and monitored by the American Medical Association and are assigned to individual procedures to be used for reimbursement.

Cyanmethemoglobin – A colored compound used to measure hemoglobin. Hemoglobin is converted to this form so that the color change can be measured and quantitated.

Cylinder – A slim, round glass container used to measure liquids in the laboratory setting.

D-dimer – A breakdown product when clots are dissolved in the bloodstream. D-dimers are specifically formed when fibrin is broken down. It is is used as a diagnostic tool for different types of thrombosis.

Deep vein thrombosis (DVT) – Blood clots formed in the deep veins of the extremities, especially the legs.

Diabetes – A general term used to describe a group of diseases that demonstrate excessive urination. This is most commonly used to describe diabetes mellitus, which is diabetes with hyperglycemia.

Diabetes insipidus – Diabetes characterized by excessive urination resulting from the inability of the kidneys to concentrate urine.

Diabetes mellitus – Diabetes that includes high levels of blood glucose. Diabetes mellitus is caused either by a failure of the pancreas to produce insulin (type 1 diabetes) or by the resistance of the cells of the body to the presence of insulin (type 2 diabetes).

Diabetic ketoacidosis – A condition in which the blood pH is acidic, caused by an accumulation of ketones from an extended state of high blood glucose.

Diabetic neuropathy – Nerve damage caused by vascular and metabolic changes in those with diabetes mellitus. This may cause numbness, tingling, or pain, especially in the extremities. The loss of sensation in the feet may lead to serious damage.

Diapedesis – The movement of white blood cells out of small arterioles, venules, and capillaries as part of the inflammatory process.

Differential – A procedure whereby a blood sample is stained and WBCs are identified and counted by type.

Diluent – A liquid (such as water or saline) used to dilute another ingredient.

Diplococci – Round bacteria that appear in pairs when viewed under the microscope.

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Disclosure – Sharing of the patient's information.

Disinfection – The application of a substance to materials and surfaces to destroy pathogens.

Disk-diffusion method – A procedure in which antibody-impregnated disks are used to test for antibiotic sensitivity on an agar plate.

Dissecting microscope – A microscope used to achieve a low level of magnification of three-dimensional objects, often those that are untreated and/or unstained.

Disseminated intravascular coagulation (DIC) – A disorder in which the coagulation process is stimulated throughout the body instead of in a localized area.

Distal convoluted tubule – A section of the renal tubule that is surrounded by capillaries in the nephron. The distal convoluted tubule is a twisted tubule that is distal to the Bowman's capsule.

Distal urethra – The part of the urethra that is closest to the outside of the body, or furthest from the bladder.

Diurnal variation – The change seen in a urinary or blood chemical at different times during a 24-hour day.

Documentation – Recording of pertinent information. This may be documentation of patient results, quality control results, or maintenance procedures, in a chart or on maintenance charts or logs.

Duress – The use of threats to accomplish a goal.

Dysfibrinogenemia – Any abnormality in the structure or function of the fibrinogen present in the bloodstream.

Ectoparasites – Parasites evident on the outside of their host.

Edema – A condition in which body tissues contain an excessive amount of fluid. An edema an be localized or systemic, and can result from many disease processes.

Efferent arteriole – The arteriole that transports blood away from the center of the glomerulus. The efferent arteriole is smaller in diameter than the afferent arteriole.

Efficacy – The capacity for producing a desired result or effect; a measurement of how effective a mechanism is toward reaching a desired goal.

Electrical impedance – A process for counting blood cells that depends on their resistance to the flow of an electrical current.

Electrolyte – A substance that is capable of conducting electricity when dissolved in water. In the human body, common electrolytes include sodium, potassium, and chloride.

Electron microscope – A specialized microscope that uses electrons to create a visual image with great detail.

Electronic quality control devices – Devices that are used to verify the accuracy of an instrument. These electronic devices should produce results that are within a narrow range every time they are tested on the instrument.

Emancipated – Not constrained or restricted; in the case of emancipated minors, this is a legal procedure that releases a child from the control of the parents, and releases any responsibility that the parents may have for the child.

Embolus – A mass of undissolved material traveling in the bloodstream. An embolus may be a blood clot that has broken away from its point of origin, or other foreign material such as a cluster of bacteria.

Endogenous cholesterol – Cholesterol that is created by the liver for use in the body.

Endoparasites – Parasitic infection within the host.

Endothelial cell lining – Flat epithelial cells that line the interior of the blood vessels.

Engineering controls – Devices that are used to limit or eliminate the potential for exposure to bloodborne pathogens in the workplace.

Enuresis – Inability to control the flow of urine.

Enzyme-linked immunosorbent assay (ELISA) testing – Also called EIA testing, ELISA testing is a common method of identifying the presence or absence of antibodies and/or antigens in a serum or plasma specimen.

Eosinophil – Granulocytic white blood cells with a lobed nucleus and cytoplasmic granules that stain red/orange with Wright's stain. Eosinophils contribute to the destruction of parasites and to allergic reactions by releasing chemical mediators.

Epidemiology – The study of the spread of disease.

Epithelial cells – Cells from the epithelial lining of the urinary tract. These may be squamous, renal tubular epithelial cells, or transitional epithelial cells. They are classified according to their point of origin.

Epstein-Barr virus (EBV) – The virus that causes infectious mononucleosis.

Erythroblastosis fetalis – A severe hemolytic disease of the newborn characterized by anemia and jaundice.

Erythrocyte – Mature red blood cell.

Erythrocyte sedimentation rate (ESR) – A nonspecific laboratory test of the speed at which erythrocytes settle out of anticoagulated blood.

Erythroid – Pertaining to erythrocytes.

Erythropoiesis – The process that results in the formation of red blood cells.

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Erythropoietin – A protein made by the kidneys that stimulates the proliferation of red blood cells.

Ethics – Moral standards and behavioral codes that dictate the behavior of an individual.

Etiology – The cause of a disease.

Eustachian tube – A flexible hollow tube that extends from the middle ear to the nasopharynx.

Evacuated tube system – A system used to draw blood that involves the use of a multipoint needle, a needle holder, and an evacuated tube.

Exogenous cholesterol – Cholesterol that is introduced to the body through ingestion of meat and dairy.

Exposure control plan – A plan that must be created by employers to educate and help protect employees from bloodborne pathogen exposure. This plan includes education, vaccination, safety procedures, and follow-up in case of exposure.

Expressed consent – Consent for a behavior that is expressed fully and personally by the patient; it may be an oral or written expression.

External quality control specimens – Quality control specimens that are purchased from an outside source, or those that are included in a test kit, but are separate from the testing system. These are usually liquid controls.

Extracellular – Outside the cells. Used to describe substances outside the cells of the body, in the plasma or interstitial fluid.

Extrinsic pathway – Part of the blood-clotting cascade that includes chemicals that are secreted into the bloodstream in response to vessel injury.

Exudate – A fluid that is released from the human body. Exudates are classified according to the solid substances present in the drainage, or the level of protein present.

Eyepiece – The part of the microscope for viewing.

Fasting – A period of at least 12 hours during which a patient forgoes food or drink (other than water). Generally done in preparation for a blood specimen to be drawn.

Fasting blood sugar (FBS) – The glucose level performed in a laboratory on a fasting blood specimen.

Fasting plasma glucose (FPG) – The level of glucose tested in the plasma (liquid portion of the blood) after a patient has fasted for at least 8 hours.

Fasting urine specimen – Urine collected during the second morning void. This urine will indicate the state of the body after a prolonged fast.

Fecal occult blood testing (FOBT) – Testing that identifies the presence of occult (hidden) blood in the stool. This test screens for the early stages of colorectal cancer, as well as additional sources of bleeding.

Fecal occult blood – Blood, which cannot be seen, that is present in the feces of an individual.

Fecal-oral route – A method of transmitting infective microorganisms. The pathogen is shed in the feces of the infected individual and then transferred to the skin. It is then spread to food, water, inanimate objects, or other people.

Fibrates – A class of medication used to treat elevated triglyceride levels. Fibrates may also decrease the LDL levels, but to a lesser extent.

Fibrin degradation products (FDPs) – Substances present in the bloodstream when clot dissolution occurs in the body. Fibrin degradation products include the by-products of fibrinogen as well as fibrin that may be involved in the blood clots.

Fibrinogen – A protein that is created in the liver and is present in blood plasma. Fibrinogen is converted into fibrin by the action of ionized calcium.

Fibrinolysis – The breakdown of fibrin in blood clots, allowing them to dissolve. Fibrinolysis occurs spontaneously in the body, and can also be accomplished by use of medications.

Fibrinolytic drugs – Also called clot busters.

Filtration – The process of removing large particles from a solution by allowing the liquid to pass through a semipermeable membrane.

Fine-adjustment knob – The focusing knob used on the microscope to provide fine, detailed focus at higher levels of magnification.

First morning void – A urine specimen collected right after waking from sleep. This specimen usually is more concentrated, and is the recommended collection method for some tests.

Flanges – Flared edges at the bottom of the evacuated tube holder that allow for leverage when inserting or removing a tube.

Flask – A glass container used to mix or store chemicals. Flasks are generally smaller at the top than they are at the bottom.

Fomites – A substance or surface that adheres to and transmits infectious microorganisms.

Formed elements (blood) – The cellular components of blood: erythrocytes, leukocytes, thrombocytes.

Formed elements (urine) – Substances in the urine specimen that may be viewed microscopically, such as cells, bacteria, and fungal elements.

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Fraud – A dishonest or deceitful act that is performed with the intent to hide the truth.

Fungal elements – Fungus microorganisms present in the urine specimen. The most common are yeast.

Fungi – A type of microorganism that causes disease in humans. This type of infection is called a mycotic infection. Examples of fungal infections in humans are yeast infections, athlete's foot, and thrush.

Gammaglobulin (also known as immune globulin) – A fluid that contains active antibodies against a particular antigen that may be given to offer short-term, immediate protection to the recipient.

Gauge – A term used to describe the diameter of the hollow interior portion of a needle. Gauge number is inversely related to the size of the needle.

Gestational diabetes – Hyperglycemia detected during pregnancy in women who did not have diabetes before becoming pregnant.

Glass slides – A piece of finely ground glass that is uniform in shape. Specimens are applied to the glass slide to be viewed under the microscope. Some specimens require staining or some sort of treatment before viewing, whereas others are viewed as they appear naturally.

Globulin – One of the group of plasma proteins that controls colloidal osmotic pressure (oncotic pressure) within the capillaries, participates in the immune response, and binds with substances to transport them in blood.

Glomerular filtration – The filtration process that occurs in the glomerulus. Because the afferent arteriole is much larger in diameter than the efferent arteriole, pressure builds up in the glomerulus, forcing filtrate and small molecules from the capillary bed while retaining large molecules in the bloodstream.

Glomerulus – A group of twisted capillaries encircled by the Bowman's capsule in the nephron of the kidney. The hydrostatic pressure in the glomerulus forces out the initial filtrate from the blood, which eventually becomes urine.

Glucagon – A hormone created by the islets of Langerhans in the pancreas that offsets the effects of insulin on the cells of the body.

Glucose – A type of sugar in the bloodstream that results from digestion of carbohydrates. Glucose is the most commonly used energy source in the body.

Glucose challenge – A process in which a patient is given a glucose drink that contains 50 g of glucose to ingest. The blood is drawn for a glucose test 1 hour after the glucose drink has been ingested.

Glucose tolerance test – A test that screens for diabetes (or occasionally hypoglycemia), which involves serial blood draws following ingestion of a drink containing glucose. Sometimes known as an oral glucose tolerance test, or OGTT.

Glucose tolerance urine specimen – A specimen collected as part of a glucose tolerance test. These are tested specifically for the presence of glucose and sometimes for ketones.

Glucosuria – The presence of glucose in the urine.

Glycated hemoglobin – Hemoglobin that is irreversibly changed with the addition of glucose to the molecule. This occurs when there have been elevated blood glucose levels for an extended period of time.

Glycemic control – A term used to describe the balance or control of blood glucose levels. Good glycemic control means that the patient does not have extremely high or low levels of blood glucose.

Glycogen – A storage form of glucose when there are excessive amounts present in the bloodstream. Glycogen is stored in the liver and some of the cells of the body, to be used for energy when glucose levels are low.

Glycogenolysis – The breakdown of glycogen to allow for the release of glucose when needed. This often occurs during periods of fasting, or when there is an elevated need for energy, such as during exercise.

Glycolysis – The first steps of the use of glucose by the cells of the body; a series of reactions that convert glucose to pyruvic acid and energy.

Glycosuria – The presence of sugar in the urine. This may be glucose, pentose, galactose, or fructose. Further testing is necessary to identify the type of sugar present in the specimen.

Glycosylated hemoglobin (HbgA1c) – Hemoglobin that has been changed by the addition of glucose molecules to the protein. The measurement of the percentage of glycosylated hemoglobin in the blood provides an indication of the glucose levels present in the bloodstream over the past 3 months. A subtype of hemoglobin (Hb A) is glycated when the blood glucose is elevated for an extended period of time, as in the case of uncontrolled diabetes mellitus.

Graduated cylinder – A cylinder that is marked in different quantities for measuring liquids.

Gram stain – A staining method that allows the classification of bacteria dependent on the color of the stain that they absorb. Gram-positive bacteria retain the crystal violet dye used in the process, and appear purple. Gram-negative bacteria do not keep the crystal violet

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dye in their cell membranes, and instead absorb the color from the safranin counterstain. They appear pink when viewed under the microscope.

Granular – A classification used to describe white blood cells that contain granules in their cytoplasm.

Granulocyte – White blood cells that have names ending in –phil (neutrophil, eosinophil, and basophil) and have distinct granules visible in their cytoplasm.

Granulocyte-macrophage colony-stimulating factor (GM-CSF) – A glycoprotein that stimulates the production and functional activity of neutrophils, monocytes, and macrophages.

Guaiac – A type of tree resin used for fecal occult blood testing. Guaiac interacts with the heme in the hemoglobin molecule present in red blood cells. If there is blood present, the interaction makes the guaiac paper turn blue when hydrogen peroxide developer solution is added.

Hanging drop slide – A slide with a depression in the center. This allows a drop of fluid containing the specimen to be suspended from a cover slip over the depression for observation microscopically.

Hazard communication standard – A document created to educate and protect employees from the chemicals in use at their workplace.

Hb A – The normal adult hemoglobin, composed of two alpha and two beta chains.

Hb A1c; HgbA1c – See Glycosylated hemoglobin (HgbA1c).

Health Information Portability and Accountability Act (HIPAA) – A federal law that affects the security, standardization, and confidentiality of health-care information. It also affects the rights of those who have insurance coverage when they change jobs.

Health care–associated infection – An infection contracted by an individual at a health-care facility. Refers specifically to an infection that the individual did not come into contact with in any other way.

Helicobacter pylori (H. pylori) – A type of bacterium that causes gastric and duodenal ulcers.

Hematocrit (Hct) – The volume of erythrocytes packed by centrifugation in a given volume of blood.

Hematology – The study of blood and blood-forming tissues.

Hematoma – A mass of blood caused by damage to a blood vessel.

Hematopoiesis – Production and development of blood cells, normally in the bone marrow.

Hematuria – The presence of blood in a urine specimen.

Hemoconcentration – A condition resulting from a tourniquet that is too tight or is left on too long, causing a relative increase in the cells in the antecubital area and possibly resulting in erroneous test results.

Hemocytometer – A counting chamber for determining the number of cells in a stated volume of blood.

Hemoglobin – The protein in red blood cells that carries oxygen.

Hemoglobin (Hgb) – The iron-containing pigment of red blood cells that carries oxygen from the lungs to the tissues.

Hemoglobin and hematocrit (H&H) – Hemoglobin and hematocrit testing is often ordered together as H&H.

Hemoglobin electrophoresis – The movement of hemoglobin on a medium as a result of changes in electrical potential, used to determine type of hemoglobin present.

Hemoglobinopathies – Any one of a group of genetic diseases caused by or associated with the presence of one or several forms of abnormal hemoglobin in the blood.

Hemoglobinuria – Hemoglobin in the urine.

Hemolysis – The destruction (lysis) of the red blood cell membrane with the release of the fluid contents. A visible reddish tint becomes evident in the plasma if there is marked hemolysis in the specimen.

Hemolytic disease of the newborn (HDN) – A neonatal disease, usually the result of an Rh incompatibility in which the antibodies of the mother cross the placenta and "attack" the neonate. May cause neonatal anemia, jaundice, edema, and enlargement of the liver and spleen.

Hemolytic uremic syndrome – An abnormal reaction to infection with the *E. coli* strain O157:H7. The *E. coli* bacteria secrete a toxin that causes an inflammatory process, resulting in blood clot formation in the capillary vessels of the body. As the red blood cells of the body pass through these clogged capillaries, it causes them to become damaged, which consequently causes damage to the kidneys as they attempt to process these damaged cells. The patient must be treated for the anemia and renal failure immediately.

Hemophilia – Blood-clotting disorders in which the patients have deficiencies of specific clotting factors.

Hemostasis – A stoppage of bleeding or of circulation.

Heparin – A naturally occurring anticoagulant in the human body. Heparin is also provided as a fast-acting anticoagulant, administered via IV or subcutaneously.

Hepatic function panel – A group of tests that are ordered together to monitor liver function.

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Hepatitis – Inflammation of the liver. Hepatitis may be caused by a viral infection or other disease state that causes the liver to be inflamed.

Hepatitis A virus (HAV) – A type of virus that causes inflammation of the liver in infected patients. Hepatitis A is transferred via the fecal-oral route, and usually does not cause permanent liver damage. Vaccinations are available for this disease.

Hepatitis B virus (HBV) – A type of virus that causes inflammation of the liver in infected patients. Hepatitis B is bloodborne, and is transferred through sexual contact, contaminated needles, mucous membrane exposure, or other direct blood-to-blood contact. Hepatitis B infection may lead to permanent liver damage. Hepatitis B is the most common bloodborne pathogen to be transmitted to health-care workers. There are vaccinations available for this disease.

Hepatitis C virus (HCV) – A bloodborne virus that causes inflammation of the liver. Hepatitis C infection usually leads to permanent liver damage, and is often asymptomatic until the liver damage has become quite advanced. There is no vaccination available for this disease.

Hepatitis D – A type of virus that causes liver inflammation. This is considered a genetic mutation or variant of the hepatitis B virus, as it is present only in those who are already infected with hepatitis B. There is no vaccination for this disease.

Heterophile antibody – A nonspecific type of antibody that is present in those with infectious mononucleosis. Heterophile antibodies are also present in other inflammatory situations.

Heterozygous – A genetic term in which the two genes for one characteristic are not the same.

High complexity – Laboratory tests that have been determined by the FDA to be complex enough so that the procedures can be performed only by highly trained laboratory professionals.

High-density lipoprotein (HDL) – A lipid subgroup; this is known as the "good" cholesterol because it helps to reduce the plaque buildup on the interior of the blood vessels.

Hilum – The indented (concave) portion of the kidney.

Histamine – A substance produced by the body in response to antigenic exposure that causes dilation of the blood vessels, increased secretion of acid in the stomach, smooth muscle constriction, mucus production, tissue swelling, and itching (during allergic reactions).

Histogram – A graph of the distribution of cell sizes made during cell counting on an automated analyzer.

Homeostasis – The internal balance of the body that is necessary for good health. Homeostasis includes minor adjusting to outside stimuli.

Homozygous – A genetic term in which the two genes for one characteristic are the same.

Hospital laboratories – Laboratories that are usually housed within a hospital and provide services primarily to patients of that institution. Hospital laboratories may be owned by the hospital or contracted to provide their services.

Human chorionic gonadotropin (HCG) – A hormone that is secreted by the trophoblasts of a fertilized ovum early in pregnancy. This hormone maintains the corpeus luteum so that it will secrete estrogen and progesterone. The presence of HCG in blood and urine is indicative of pregnancy.

Human immunodeficiency virus (HIV) – This is a retrovirus that invades the CD4 cells of humans and causes the failure of their immune systems. Infection leads to the eventual development of AIDS. It is a bloodborne pathogen, and may be transmitted through sexual contact, mucous membrane exposure, or parenteral exposure.

Hyperchromic – Pertaining to excess hemoglobin concentration in the erythrocyte.

Hyperglycemia – Blood glucose levels elevated above acceptable reference ranges.

Hyperkalemia – Elevated levels of potassium in the blood plasma.

Hyperlipidemia – Excessive levels of lipid in the bloodstream.

Hypernatremia – Elevated levels of sodium in the blood plasma.

Hyperthyroidism – A condition in which the thyroid gland is overactive.

Hypochromic – A condition of the blood in which the erythrocytes have a reduced hemoglobin content and appear pale in color.

Hypofibrinogenemia – Low levels of circulating fibrinogen in the bloodstream.

Hypoglycemia – Decreased blood glucose levels below acceptable reference ranges.

Hypokalemia – Decreased levels of potassium in the blood plasma.

Hyponatremia – Decreased levels of sodium in the blood plasma.

Hypothyroidism – A condition in which the thyroid gland is underactive.

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Icteric – A term used to describe the serum or plasma of a patient with hepatic dysfunction. An icteric specimen has a yellowish green color.

iFOB – An acronym used to describe an immunochemical method of testing for fecal occult blood. It uses an antigen-antibody interaction with the globin portion of the hemoglobin molecule and is an alternative testing procedure to the guaiac method for the presence of fecal occult blood.

Immunity – Protection from diseases.

Immunoglobulins – Plasma proteins that play a role in protection from disease. These may occur on the surface of the lymphocytes, or may be secreted in response to antigenic exposure.

Immunology – The study of the components of the immune system and their function.

Impaired fasting glucose (IFG) – A term used to describe prediabetics who exhibit elevated fasting plasma glucose levels.

Impaired glucose tolerance (IGT) – A term used to describe prediabetics who exhibit elevated glucose levels after drinking a glucose solution.

Implied consent – Consent for a procedure that is implied by the actions of the individual.

International Classification of Diseases, 9th ed. (ICD-9) – Codes assigned by the CDC to symptoms or disease states. These codes must be included for reimbursement for laboratory procedures.

In vitro – Latin for "in glass," referring to testing done outside of the body.

In vivo – Latin for "in the living body," referring to something occurring inside the body, such as antigen-antibody reactions within a living subject.

Incubators – A device by which the temperature, and sometimes humidity, of the environment can be controlled. Incubators are often used to help bacterial specimens grow for testing or to assist with the completion of a testing procedure.

Indwelling catheter – A plastic tube that is allowed to remain in the urinary bladder for a period of time to facilitate drainage of urine as it is formed.

Infection – A disease state caused by pathogenic microorganisms, including bacteria, viruses, parasites, or fungi. Infections may be localized or may spread throughout the body. Symptoms often include pain, fever, redness and swelling, and loss of function.

Infection control – Policies and procedures to help minimize the spread of infection and to analyze data in relation to infection within a health-care facility.

Infectious – A term used to describe a subject who is capable of transmitting disease to others. The transmission may occur directly or indirectly.

Inflammation – A immunological defensive mechanism of the body, including increased blood flow, tissue swelling, increased white blood cell presence, and release of chemical toxins.

Informed consent – Approval that is obtained in writing after the patient has been informed about the specifics of the proposed procedure, the risks of the procedure, alternative treatments, and information about what may happen if the patient decides against the procedure.

Inoculation – Addition of a specimen to a culture medium for growth.

Insulin – A hormone produced by the islets of Langerhans of the pancreas. Insulin is necessary for the cells of the body to absorb glucose to be utilized as energy.

Insulin dependent – Diabetes that requires injections of insulin to control blood glucose levels. Patients with type 1 diabetes are usually insulin dependent.

Insulin resistance – A condition in which cells have a diminished ability to interact appropriately with insulin.

Intentional tort – A wrongful act that is committed by one person against another person deliberately.

Interferons – A group of proteins produced in the body having antiviral properties.

Interleukin – A hematopoietic growth factor affecting growth and differentiation of lymphocytes.

Intermittent (straight) catheter – A catheter (hollow, plastic tube) placed directly into the bladder to facilitate drainage. The catheter is removed as soon as the bladder has drained.

Internal quality control – Quality control that is built into the testing kit, provided by the manufacturer.

International normalized ratio (INR) – A mathematical calculation used to standardize treatment based on prothrombin time (PT) results. PT results may vary, depending on lot numbers of reagents and different instruments used for testing. The INR is a calculation that takes these variables into account and provides a tool for monitoring those patients on anticoagulant therapy. Most patients on anticoagulant therapy should have an INR between 2.0 and 3.0.

Interstitial – Between the cells.

Interstitial fluid – The fluid between cells.

Intracellular – Within the cells.

Intravascular lysis – The destruction of red blood cells within the vessels of the body.

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Intrinsic factor – A glycoprotein secreted by the parietal cells of the gastric mucosa, necessary for the absorption of vitamin B_{12}.

Intrinsic pathway – Part of the blood-clotting cascade that uses chemicals that are normally present in the bloodstream.

Ions – An atom or group of atoms that has lost or gained electrons so that it possesses an electrical charge. Electrolytes are substances that become ions when dissolved in water.

Iris diaphragm – A device with a variable diameter that controls the amount of light that is used to view a specimen through a microscope.

Iron-deficiency anemia – Anemia resulting from a greater demand on stored iron than can be supplied.

Ischemia – An insufficient supply of blood to an organ or body part. This term is often used to describe a lack of blood flow to areas of the heart when the patient has atherosclerosis, causing partial blockage of the vessels.

Islets of Langerhans – Specialized groups of pancreatic cells that produce insulin and glucagon. Insulin and glucagon are necessary for controlling the levels of blood glucose in the body.

Jaundice – A yellow staining of body tissues and the fluids of the body as a result of excess bilirubin in the bloodstream in patients with hepatic dysfunction.

Ketones – A chemical that is elevated in the bloodstream with increased fat metabolism. This is usually associated with dysfunctional carbohydrate utilization, as in the case of diabetes mellitus.

Ketonuria – The presence of ketones in the urine.

Kidneys – Organs that create urine.

Kirby-Bauer method – A method used to test specific bacteria for antibiotic sensitivity, utilizing antibody-impregnated disks on special agar plates.

KOH (potassium hydroxide) – A solution used for examination of a sample under the microscope which is performed immediately after collection to search for the presence of fungi.

Labile – Describes a substance or sample that is not fixed, and is easily changeable. These types of specimens generally must be tested immediately to provide accurate results.

Laboratory – Any site where specimens may be collected, processed, or tested.

Laboratory directory – A reference document in which specimen requirements and other useful information might be found. It includes all the tests offered by a particular laboratory.

Laboratory report – A document used to transmit laboratory results and reference ranges.

Laboratory requisition – A form used to order laboratory tests.

Laboratory thermometer – A thermometer used to measure temperatures in a controlled environment, such as a refrigerator, freezer, or incubator.

Lateral flow immunoassay – A test used to determine the presence of an antigen or antibody in a specimen. In this type of test, the sample moves laterally across the testing surface, resulting in a color change if the antibody and/or antigen is present in the specimen. This testing method is used in many CLIA-waived tests.

Laws – Regulations established by a governmental authority that are enforced and punishable for noncompliance.

Leukemia – A class of hematological malignancies in which immortal clones of immature blood cells multiply at the expense of normal blood cells.

Leukocyte – White blood cell.

Leukocyte esterase – An enzyme secreted by granulated white blood cells and monocytes.

Leukocytosis – Abnormal increase in white blood cell (leukocyte) count.

Leukopenia – Abnormal decrease in white blood cell (leukocyte) count.

Liability – Legally responsible for an action.

Libel – A false statement in print.

Light source – The origin of light or illumination for a specimen to be viewed on a microscope. For most compound microscopes, this is a light bulb located in the base of the unit.

Lipemia – The presence of excessive lipids in the blood. This term is used to describe the "milky" appearance of the plasma or serum in specimens with elevated lipid content.

Lipid – A term used to describe fats in the body. Cholesterol and triglycerides are types of lipid molecules.

Lipoproteins – Simple proteins bound to lipids or fats in the bloodstream. Lipoproteins are the method by which cholesterol travels in the bloodstream; they are further differentiated as HDL, LDL. or VLDL.

Lobulated – Having lobes or sections.

Loop of Henle – The middle portion of the renal tubules where exchanges occur as part of the formation of urine from the renal filtrate.

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Low-density lipoprotein (LDL) – A subclass of cholesterol present in the body; this is known as the "bad" cholesterol because it contributes to plaque buildup on the blood vessel walls.

Lumbar puncture – A procedure used to obtain samples of cerebrospinal fluid for examination and testing.

Lumen – The term used to describe the interior hollow portion of the needle. This term may be used to describe the inside of any hollow object, such as a vein or artery.

Lymphocyte – A white blood cell responsible for much of the body's immune protection.

Lymphoid – Pertaining to lymphocytes.

Lysed – The action of cell destruction (lysis) by chemical or mechanical methods, releasing the contents of the cells.

Lysozyme – An enzyme found in various cells and body fluids that damages bacterial cell walls.

Lytes – See Electrolytes.

Macrocyte – Cells larger than normal size.

Macrocytic – Abnormally large erythrocytes exceeding 10 μ in diameter.

Macrophage – Cells that are capable of phagocytosis.

Macroscopic – A description of a structure that is large enough to be seen or examined without magnification.

Macrosomia – An abnormally large baby. An infant who has a birth weight above the 90th percentile of the standardized growth curve exhibits macrosomia. This may be caused by gestational diabetes in the mother.

Malabsorption – Inadequate or incomplete absorption of nutrients from the digestive tract.

Malfeasance – Performance of a wrong and unlawful act.

Malpractice – The negligence of a professional person.

Mastectomy – The removal of breast tissue.

Material Safety Data Sheets (MSDS) – A descriptive sheet required by law to accompany chemicals upon delivery. These sheets contain essential safety information about the chemical, as well as contact information for the manufacturer.

Mean – The mathematical average of a set of results.

Mean corpuscular hemoglobin (MCH) – The average weight of hemoglobin in red blood cells in a sample.

Mean corpuscular hemoglobin concentration (MCHC) – The average weight of hemoglobin in a given volume of packed blood cells.

Mean corpuscular volume (MCV) – The average volume of a red blood cell in a sample.

Media – Plural of *medium;* a term used to describe the substance that supports growth of microorganisms.

Median cubital vein – The middle vein of the antecubital area; this is the first vein of choice for venipuncture procedures.

Medical asepsis – A state of cleanliness and disinfection that has reduced the number of microorganisms and pathogens to a significant degree.

Megakaryocyte – A large bone marrow cell with large or multiple nuclei from which platelets are derived.

Meniscus – A curve in the surface of a liquid in a cylinder caused by surface tension between molecules.

Metabolic syndrome – The presence of four interrelated risk factors for atherosclerosis: insulin resistance (hyperglycemia), hypertension, hyperlipidemia, and obesity.

Methicillin-resistant *Staphylococcus aureus* (MRSA) – *Staphylococcus aureus* organisms that show resistance to the methicillin family of antibiotics. This strain is a growing concern to the health-care profession.

MIC – See Minimum inhibitory concentration.

Microalbumin – Small amounts of albumin.

Microalbuminuria – Small amounts of albumin in the urine. This may be an indication of poor blood glucose control and kidney damage because of high glucose levels.

Microcollection containers – Small blood collection containers designed to be used for small amounts of blood. Often used for capillary draws, or situations in which the venipuncture is very difficult.

Microcytes – A small erythrocyte with a diameter of less than 5 μ.

Microcytic – Small erythrocytes less than 5 μ in diameter.

Micrometer (micron, μ) – One millionth of a meter, or 10^{-6}.

Microorganisms – Living organisms that are too small to be seen without the aid of a microscope.

Microscopic – A description of a structure that cannot be seen or examined without the use of magnification.

Micturition – Urination or the voiding of urine.

Minimum inhibitory concentration (MIC) – A term used to describe the lowest concentration of an antibiotic that will inhibit bacterial growth. This term is used to describe a procedure using a plate of wells that have specific antibiotics at known concentrations.

Misfeasance – Performance of a lawful act in an improper manner.

Moderate complexity – Laboratory tests that have been determined by the FDA to be moderately complex in nature. These tests require more quality control procedures, proficiency testing, and comprehensive documented personnel training than the CLIA-waived tests.

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Monocular – A term used to describe a microscope that has only one ocular for viewing.

Monocyte – A mononuclear phagocytic white blood cell derived from myeloid stem cells.

Mononucleosis – An infectious disease caused by the Epstein-Barr virus.

Morphology – Description of the structure and form; term used to describe the shape of cells in a complete blood count.

Motility – Spontaneous movement; a term often used when describing microorganisms viewed in their natural state without preservation or staining.

MRSA – Acronym for methicillin-resistant *Staphylococcus aureus*. (See also Methicillin-resistant *Staphylococcus aureus*.)

Mucous membranes – Membranes lining body cavities that open to the outside of the body.

Mucus – A viscous fluid secreted by the epithelial cells.

Multiple myeloma – A malignant condition in which the bone marrow is overcome by nonfunctional cancer cells.

Multisample needle – A needle used with the evacuated tube system having a point at both ends.

Mycoses – Fungal infections.

Mycotic – A term used to describe fungal infections.

Myeloid – Pertaining to the precursor cell for granulocytes, monocytes, erythrocytes, and megakaryocytes.

Myocardial infarction – A blockage of the coronary blood vessels, resulting in damage to and death of the heart muscle.

Myoglobin – A protein that stores and uses oxygen in cardiac and skeletal muscle tissue. The blood myoglobin concentration will become elevated with damage to the heart or the skeletal muscle of the body.

Myoglobinuria – The presence of myoglobin in the urine.

Nasopharyngeal collection technique – A sample taken from the portion of the pharynx just above the soft palate. This specimen is obtained by insertion of a collection swab through the nasal cavity to the back of the throat.

Nasopharynx – The portion of the pharynx located directly behind the nose, just above the soft palate.

National Fire Protection Association (NFPA) – A nonprofit organization established in 1896 whose mission is to use education, codes and standards, research, and training to reduce fire and other hazards. This organization is known worldwide for its fire-prevention efforts.

Natural killer cells – Large lymphocytes that bind to invading cells and inject toxins, causing cell lysis.

Negligence – Occurs when a professional does not act with reasonable care.

Nephrons – The functional unit of the kidney where urine is formed.

Neutrophil – A granulocytic white blood cell responsible for much of the body's protection against infection.

Niacin – A B vitamin used to treat elevated triglyceride and cholesterol levels.

Nitrite – Nitrites are important components of the blood because they dilate blood vessels, reduce blood pressure, and perform other functions.

Nocturia – Excessive or frequent urination at night.

Nonintact skin – Skin that is broken. This may be caused by a scratch or puncture, but it may also be caused by irritation, such as develops with use of gloves and frequent hand washing.

Nonfeasance – The failure to perform a necessary medical act.

Normal flora – Resident bacteria normally present in specific areas of the body. This bacterial presence is not pathogenic.

Normal ranges – A range of results that are expected for a specific test within a certain population. Also referred to as reference ranges.

Normochromic – A red blood cell with sufficient hemoglobin.

Normocytic – A red blood cell of normal size, which is of 6 to 8 μ.

Nosocomial infection – An infection contracted in a hospital or other inpatient care facility.

O&P – Ova and parasites.

Objective lenses – The lenses of the microscope that are closest to the specimen. Compound microscopes have various levels of magnification available by using different lenses.

Occlude – To close up or obstruct, such as when a blood vessel has been blocked by a clot or plaque buildup.

Occupational exposure – Exposure that occurs while performing duties in the workplace. Occupational exposure does not always mean that there was an error in the way a task was performed; some types of exposure are inherent to all careers. For laboratory and healthcare personnel, occupational exposure to bloodborne pathogens is commonplace.

Occupational Safety and Health Administration (OSHA) – A governmental agency within the Department of Labor. OSHA's mission is to ensure the health and safety of all American workers.

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Ocular lenses – The lens that is closest to the eyepiece. These lenses provide a low level of magnification that is not adjustable.

Oil immersion lens – The most powerful objective lens (usually 100X magnification) that is used with a drop of oil between the lens and the slide. This allows for the light to be focused fully on the specimen without an opportunity for scatter.

Oliguria – Diminished urinary output of less than 400 mL per day.

Oncologist – A physician who specializes in the field of tumors and/or cancer treatment.

Opportunistic pathogens – Infections that usually do not cause disease in a healthy individual. When the immune system of an individual is compromised, or when there is an imbalance of some sort present, a pathogen may take advantage of the situation and cause an opportunistic infection.

Oral glucose tolerance test (OGTT) – A screening test for diabetes mellitus in which the patient is given a standardized glucose solution to drink, then has blood glucose levels checked at hourly intervals to monitor the response to the ingestion.

Other potentially infectious materials (OPIMs) – This category includes semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva during dental procedures, breast milk, and any body fluids that are visibly contaminated with blood.

Otitis – Inflammation of the ear.

Otitis externa – Inflammation or infection of the outer ear.

Otitis media – Inflammation or infection of the middle ear.

Ova and parasite (O&P) examination – An examination of a stool sample for the presence of parasitic microorganisms or their eggs (ova).

Ovalocyte – An elliptical red blood cell.

Packed cell volume – A synonym for the hematocrit, the volume of erythrocytes packed by centrifugation in a given volume of blood.

Palpation – Process of examination by the application of the hands or fingers; assessing an area of the body by use of touch.

Panels – Groups of laboratory tests that are ordered together. These are often organ or disease specific. Also known as profiles.

Panic results – See Critical results.

Parasites – Any organism that lives on or within another living organism, often at the expense of the host organism.

Parenteral exposure – Exposure that occurred with a piercing of the skin.

Partial thromboplastin time (PTT) – Measurement of the efficacy of the intrinsic coagulation pathway. This pathway includes the actions of clotting factors VIII, IX, XI, and XII. The PTT is measured in seconds.

Pathogen – A microorganism that is capable of causing disease.

Pathological thrombosis – Formation of thrombi unnecessarily or excessively, not only in response to vessel injury.

Patient identifiers – Personal information that may identify a patient seeking care including demographics, Social Security numbers, birth dates, and the like.

Peak collection – A blood specimen drawn at the time when a medication is at its highest level in the bloodstream.

Percutaneous – Through the skin.

Peritoneum – The membrane that lines the abdominal cavity.

Pernicious anemia – A chronic macrocytic anemia in which the stomach secretes insufficient intrinsic factor for B_{12} absorption.

Personal protective equipment (PPE) – Equipment that is worn as protection for the employee, including goggles, masks, respirators, laboratory coats, or face shields.

Petri dish – A small, round dish with a flat bottom and a lid. Agar is often contained in a Petri dish for culture procedures. Petri dishes may be made of glass or plastic.

Phagocytes – A cell that has the ability to ingest and destroy antigens.

Phagocytosis (phagocytic; phagocytize) – A three-stage process by which phagocytes (certain white blood cells) engulf and destroy microorganisms, antigenic substances, and cellular debris.

Phlebotomist – A person who draws blood from a vein, capillary, or artery.

Physician office laboratories (POL) – Laboratories that are located within a physician's office that perform testing on the specimens collected from the patients of that practice.

Physiology – The study of the function of the human body.

Pinworm – Infection caused by the parasite *Enterobius vermicularis,* which is the most common type of worm infection in the United States.

Pipette – A device used in the laboratory to transfer liquid from one place to another.

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Pisse prophets – Nonmedical practitioners who used urine to diagnose and predict disease without scientific basis for the practice.

Plaque – Deposits of cholesterol within blood vessels.

Plasma – The liquid portion of blood within the body. This term is also used to describe the liquid portion of a specimen when it has been drawn into a tube containing anticoagulant.

Plasma separator tubes (PST) – Tubes containing a thixotropic separating gel to form a barrier between the blood cells and the liquid portion of the blood after centrifugation.

Plasmin – An enzyme involved in the breakdown of blood clots.

Platelet – Formed element in the blood that aids in blood clotting.

Platelet count – The quantity of platelets (thrombocytes) present in a blood sample. Adequate numbers are essential for effective coagulation.

Pluripotent – Having the ability to differentiate into several types of specialized cells, a quality that stem cells are said to have.

Poikilocytosis – Variations in the shape of red blood cells.

Point-of-care testing (POCT) – Testing that is performed at the bedside or chairside of a patient, with results available within minutes.

Polychromatic stain – A staining process consisting of both an alkaline stain and an acidic stain that allows for cells to stain a variety of colors.

Polycythemia – Having an excess of red blood cells.

Polydipsia – Excessive thirst.

Polymorphonuclear – Possessing a nucleus consisting of several parts or lobes connected by fine strands.

Polyphagia – Excessive hunger.

Polyuria – Excessive urine production.

Postexposure prophylaxis (PEP) – Protective measures taken immediately after exposure to a chemical or other type of hazard. This may include medication, but may also include other types of precautions taken "just in case" after a chemical or biohazardous exposure.

Postprandial – After eating.

Precision – A statistical term that is used to describe the reproducibility of the results for a test to each other.

Prediabetes – A condition in which a patient shows early evidence of impaired carbohydrate metabolism or impaired secretion of insulin.

Privacy Rule – An expansion of the original HIPAA mandate that applies to confidentiality of health information, and the rights of patients to control access to their own records.

Proficiency testing – A process in which the test results for a specific analyte are compared to those of other laboratories that use the same testing method to verify the accuracy of the test results.

Proficiency testing – A standardized, formal assessment of the quality of test results. These are commonly performed when the laboratory is sent a sample with a known value to see how competent its testing methods are when the specimen is tested.

Profiles – A group of tests often ordered together that test for a specific body system or a specific disease process. Also known as panels.

Prophylactic – A treatment that is used to prevent a disease process or prevent an unwanted outcome.

Prostatitis – Inflammation of the prostate.

Prostatitis specimen – A urine specimen collected to identify a bacterial infection of the prostate.

Prostatitis specimen collection process – A special procedure for collecting urine in which there are three specimens collected in close progression.

Protected health information (PHI) – All information about a patient included in his or her medical record.

Proteinuria – The presence of protein in the urine.

Prothrombin time (PT; protime) – A measurement (in seconds) of the time needed for blood to clot when thromboplastin and calcium are added to a plasma specimen. This test is used to evaluate those who are on oral anticoagulant therapy as well as to screen for potential clotting disorders.

Protime – See Prothrombin time.

Protoporphyrin – A substance included in the heme portion of the hemoglobin molecule. Necessary to make iron functional and available to attach to the oxygen.

Protozoa – Complex single-cell microorganisms, most of which are nonpathogenic.

Provider-performed microscopy (PPM) – Microscopy examinations performed by a health-care provider in the office. To perform these legally, the laboratory will need to be registered with CLIA as a facility that performs PPM.

Provider-performed microscopy procedures (PPMPs) – These are laboratory procedures that are performed by a midlevel provider or a physician using a microscope.

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The examinations are performed on specimens that are unfixed and time sensitive, such as urine sediment microscopic examinations and wet mounts. There are specific quality control requirements that accompany this type of laboratory procedure, including maintenance on the microscope used for the examination.

Proximal convoluted tubule – The proximal part of the renal tubule where the renal filtrate first enters after it leaves the Bowman's capsule.

Plasma separator tubes (PSTs) – PSTs contain a thixotropic gel that separates the blood cells from the liquid when spun in a centrifuge.

Pus – The liquid product of inflammation, including dead cells, fluid, and pathogens.

Pyuria – The presence of white blood cells or "pus" in the urine specimen.

Qualitative – A term used to describe results which indicate whether or not a substance is present in a specimen, rather than the amount of the substance that is present. Qualitative tests provide a positive or negative result.

Qualitative result – A test that determines the presence or absence of a substance, having a yes/no or positive/negative result.

Quality assurance – All the processes used to assure quality in laboratory testing, including all phases of the laboratory experience: before, during, and after the test is performed.

Quality control (QC) – Practices used in the laboratory to ensure that the results for a given test are correct.

Quantitative HCG – A test that provides a numeric result for the presence of human chorionic gonadotropin (HCG) in serum. This test may be necessary if an ectopic pregnancy or fetal demise is suspected.

Quantitative result – A test that determines the amount of a specific substance in a sample. The result is expressed as a number or percentage.

Quantitative test – A test that provides a numeric result, indicating the level of the analyte present in the specimen.

Quantity not sufficient (QNS) specimen – A specimen that is not of sufficient quantity for testing.

RACE – An acronym used to remind employees of the order of action in the event of a fire. R: Rescue those who might be in danger; A: Alarm, activate the alarm system; C: Confine the fire as much as possible by closing doors and windows; E: Extinguish the fire if possible.

Radioimmunoassay (RIA) testing – A testing method in which the antigen or antibody in the specimen binds to a radioactive substance to be measured.

Random – Without plan or purpose or pattern. When used in connection with urine specimen collection, *random* refers to specimens collected at unspecified intervals.

Random collection – A specimen that can be drawn at any time of the day without limitations or special preparation.

Rapid flow immunoassay – A term that may be used interchangeably with lateral flow immunoassay. Rapid flow immunoassay also describes test methods in which the specimen/reagents do not flow laterally across the surface.

Reabsorption – The process by which water and other necessary substances are reabsorbed into the body through the capillaries that surround the renal tubules.

Reagent dipstick – A plastic strip that is imbedded with various reagent pads that test for chemicals in urine specimens.

Reagent strips – Strips of material (usually some type of plastic) that have been covered or treated with chemicals. These are designed to change color or produce certain substances as part of a chemical reaction. Reagent strips are designed to be used one time only, and may be used to detect the presence of a certain substance in a specimen or to measure the amount of a specific substance.

Red blood cell (RBC) – Formed element in the blood; primary function of red blood cells is to transport oxygen.

Red blood cell index – A calculated value that helps to classify RBCs in terms of size and hemoglobin concentration.

Reference laboratory – A reference laboratory is a private commercial laboratory that tests a high volume of specimens, and often performs highly specialized tests that are not available at a physician office laboratory or a hospital laboratory. The reference laboratory receives specimens from other laboratories, and hospital or physician office laboratories, not just from their general community. Specimens may be shipped from all over the country.

Reference ranges – The expected ranges for a specific population for an analyte. These ranges can vary by age, gender, or race. Ranges are established by each laboratory, based on testing method.

Reflexive testing – A policy in which follow-up tests are added automatically to a specimen when abnormal results are found with the initial testing ordered. This often applies to culture and urine specimens.

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Reflexive – The automatic performance of additional laboratory testing in response to abnormal test results. For urine, the urine microscopic examination is often added on as a reflexive test for abnormal urine chemistry results.

Refractive index – A measurement of how much light is deflected from its normal path when it passes through a different media. The amount of deflection may be affected by the concentration of dissolved substances in the medium.

Refractometer – An instrument used to determine the specific gravity of a liquid.

Regulated waste – See Biohazardous waste.

Renal cortex – The outer layer of the kidney.

Renal medulla – The inner layer of the kidney.

Renal pelvis – A basin-shaped hollow structure that collects urine as it is formed before it exits the kidney through the ureters.

Renal tubule – The area of the nephron where reabsorption and secretion occur as urine is formed.

Reportable condition – A condition or disease that has been deemed a threat to the public.

Resident bacteria – Another term used to describe normal flora.

Resistant – A bacterial microorganism that is not affected by the properties of a specific antibiotic.

Reticulocyte – The last immature stage of red blood cells; when stained with a supravital stain, the darkly staining granules are fragments of the endoplasmic reticulum.

Reticulum – A mesh-like microscopic network in a cell.

Retroperitoneal – Behind the peritoneum.

Revolving nosepiece – The part of a microscope where the objectives attach. The revolving nosepiece can be turned as the different objectives are utilized.

RhoGam – A type of immune globulin used to protect neonates who have Rh-negative mothers.

Risk management – Ways of reducing potential risk to patients, employees, and employers.

Rotations per minute (rpm) – Used to measure the speed at which a centrifuge operates.

Rouleaux – A group of red blood cells that are stuck together, resembling a roll of coins.

Rugae – A fold or crease in the cells lining various areas of the body that allows for more stretching and flexibility of these areas.

Sanitization – To remove microorganisms from equipment or surfaces.

Scabies – An infection of the skin with a parasitic mite that causes intense itching.

Scope of practice – The various activities that a professional is qualified to perform. This may be based on education and/or experience and differs by profession.

Secretion – The final process in urine formation within the renal tubules. During secretion, substances are added to the urine filtrate from the capillaries that are wrapped around the renal tubules.

Sediment – Formed elements in the urine specimen that settle to the bottom of the urine specimen when spun in the centrifuge.

Semiquantitative – A type of testing procedure that provides an approximate amount of a substance.

Sensitive – A bacterial microorganism that is killed or kept from multiplying by the use of a specific antibiotic.

Sensitivity – The minimum concentration of the desired substance that will be detected.

Septicemia – Infection of the bloodstream by a pathogenic microorganism.

Sequela – A secondary complication or infection as a result of the primary infection.

Serially – A series at set intervals. This term is used to describe laboratory samples that are to be collected at specific intervals over a period of time.

Serology – The study of the antigen and antibody components in the liquid portion of the blood or other body fluids.

Serotonin – A chemical vasoconstrictor.

Serum – The liquid portion of the blood without the various clotting factors. Serum is taken from a blood specimen that has been allowed to clot before centrifugation.

Serum separator tubes (SST) – Tubes that contain a thixotropic separating gel that is designed to form a barrier between the blood cells and the liquid portion of the blood after it is centrifuged.

Sharp – Any object that has projections, corners, or edges that are capable of piercing the skin. If the object has come into contact with blood or other potentially infectious materials, it is a biohazardous sharp. These must be disposed of in a special, puncture-proof container.

Shift – A sudden change in quality control values. This may be a shift from one side of the mean to another, or a significant jump in values on the same side of the mean.

Short draw – When there has been a loss of vacuum in the evacuated tube, blood will not enter the tube, or it will fill incompletely. Often, this requires that the specimen be redrawn.

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Sickle cell – Red blood cell changed to a crescent shape by low oxygen tension. These cells contain the abnormal hemoglobin, Hb S.

Sickle cell anemia – An inherited autosomal recessive trait in which the individual's red blood cells contain hemoglobin S.

Sickle cell trait – Condition of being heterozygous for Hb S in which each red blood cell has Hb A and Hb S; these cells become sickled under extremely low oxygen tension.

Slander – Untrue statements that are spoken about another person.

Slant – A tube with agar added and allowed to harden in a slanted form to allow for maximum surface area for bacterial growth.

Specific gravity – The weight of a substance as compared to an equal volume of distilled water. The specific gravity of urine provides an indication of the amount of dissolved substances present in the specimen.

Specificity – The ability to detect only the desired substance in the specimen.

Specimens – A piece or part of something that is designed to show the characteristics of the whole.

Spectrophotometer – A machine (or part of a machine) that is used to measure how much light of a certain wavelength has been absorbed by a specimen.

Spectrophotometrically – An estimation of coloring matter in a solution by wavelength of light.

Splenomegaly – An enlarged spleen.

Spermatozoa – A mature male sex cell.

Spherocyte – An erythrocyte that assumes a spheroid shape and has no central pallor.

Spirilla – Bacteria that have a spiral shape when viewed under the microscope.

Spores – A dormant bacterial form that is resistant to heat and moisture. Spores are the form that many bacteria assume when conditions are unfavorable, and this protective form allows them to survive until the conditions become more comfortable for growth and replication.

Sputum – Mucus that is expelled from the lungs and lower respiratory system with a deep cough.

Stage – The portion of a microscope where the glass slide is placed for viewing.

Standard of care – An acceptable level of performance for the employees within a profession.

Standard precautions – Guidelines developed by the CDC to assist with the spread of infectious disease in health-care facilities.

Standing orders – Orders for laboratory tests to be drawn at specific intervals over a period of time.

Staphylococci – Bacteria that are round and appear in grape-like clusters when viewed under a microscope.

STAT – Something that is to be accomplished immediately.

Statins – A classification of drugs used to treat patients with elevated lipid levels. Statins are especially effective for treatment of elevated LDL levels and triglycerides.

Statutes – Laws established by the legislative branch of a government entity.

Stem cells – Precursors of all blood cells that are present in the bone marrow.

Stereomicroscope – A microscope that allows a specimen to be viewed from two different angles to create a three-dimensional image. Also known as a dissecting microscope.

Sterilize – A process by which all microorganisms are destroyed on a surface.

Strep screens – CLIA-waived procedures often performed in a physician office laboratory. These tests employ a throat swab specimen and produce results within minutes. Strep screens test for group A streptococci, and allow for timely treatment of streptococcal throat infections.

Streptococcal pharyngitis – Inflammation and infection of the pharynx and tonsillar area caused by group A streptococcal bacteria.

Streptococci – Bacteria that appear round and in small "chains" when viewed under the microscope.

Stroke – A loss of neurological function that is caused by vessel injury or occlusion in the blood vessels of the brain. Also known as a cerebrovascular accident (CVA).

Sulfosalicylic acid precipitation test – A test that uses turbidity as a measure of the presence of protein in the urine.

Supernatant – The clear part of the urine specimen left at the top of the tube after the sediment has settled out to the bottom of the tube.

Suprapubic aspiration – A procedure used to remove urine from the bladder when traditional catheterization is not an option. Suprapubic aspiration uses a syringe and needle to aspirate urine directly from the bladder. The needle is inserted through the external abdominal wall.

Surgical asepsis – The destruction of all pathogenic organisms before they enter the body. This involves the use of sterile supplies for invasive procedures.

Susceptible – Having very little or no defense from infection by a specific microorganism.

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Syringe system – A method of drawing blood that involves a syringe with a needle attached. This method is used when a patient has veins that may not be able to withstand the evacuated tube method, which applies a lot of reverse pressure all at once, which may collapse the vein.

T cells – Specialized lymphocytic white blood cells that are programmed in the thymus to serve as part of the immune response.

Tachometer – An instrument used to measure rotation speed.

Target cell – An erythrocyte that has a reduced hemoglobin concentration and appears with a little color around the edge of the cell and a dark central area.

Thalassemia – Inherited disorders in which abnormal hemoglobin is produced by either a defective production rate of the alpha or beta globin chains or a decreased synthesis of the beta chain.

Thrombin – An enzyme that converts fibrinogen to fibrin, which is necessary for definitive blood clot formation.

Thrombocytes – Platelets.

Thrombocythemia – Overproduction of platelets by the bone marrow.

Thrombocytopenia – An abnormal decrease in the number of platelets.

Thrombocytosis – An increase in the number of platelets.

Thrombopoietin – A growth factor that acts on the bone marrow to stimulate platelet production as well as the production of other cell lines.

Thrombosis – A blood clot formed in response to vascular injury, or pathological formation of a blood clot.

Thrombus – A blood clot that adheres to the wall of a vessel or organ.

Thyroid-stimulating hormone (TSH) – A hormone produced by the pituitary gland that stimulates the thyroid gland to produce thyroxine, thyrocalcitonin, and triiodothyronine.

Thyroxine (T4) – A hormone produced by the thyroid gland that affects the rate of metabolism of the cells throughout the body.

Tort – Wrongs that are committed that do not involve a contractual agreement.

Tourniquet – A stretchy, rubber-like band that is applied to the arm to facilitate the location of veins to be used for blood draws.

Transient bacteria – Bacteria that are not part of the normal flora of the body. These are the bacteria that are picked up on the hands and skin during daily activities and those that are washed off when washing the hands.

Transmissible – Something that is capable of being passed, or transmitted, to another.

Trends – A slow, steady incline or decline in the quality control values over time.

Trichomoniasis – Infection with a parasite that often lives in the vagina in women or urethra in men. This parasite causes discharge, itching, and burning, and may be transmitted through sexual intercourse.

Triiodothyronine (T3) – A hormone produced by the thyroid gland that affects the rate of metabolism of the cells throughout the body.

Troponin – A muscle protein that is found in skeletal and cardiac muscle, but not smooth muscle. An elevated cardiac troponin level is one of the first indicators of heart trauma.

Troubleshooting – Investigative processes employed when the quality control specimens are not within the expected ranges.

Trough collection – A specimen drawn at the time when a medication is at the lowest level in the bloodstream. This is usually drawn immediately before the next dose is due.

Type 1 diabetes – Diabetes that results from inadequate or absent insulin secretion. Extended periods of hyperglycemia result, and treatment involves insulin injections.

Type 2 diabetes – Diabetes that results from insulin resistance. Type 2 diabetes is usually successfully treated with lifestyle changes and oral medications.

Unintentional tort – A wrongful act that is accidentally committed by one person against another person.

Universal precautions – The concept that all blood products and other potentially infectious materials are to be treated as if they are infected with bloodborne pathogens.

Ureters – The tubes that carry urine from the kidney to the bladder. Most individuals have two ureters, one for each kidney.

Urethra – The tube that extends from the bladder to the outside of the body through which urine travels.

Urinalysis – Analysis of a urine specimen. The urinalysis usually includes a macroscopic examination of the specimen for color and clarity, measurement of the specific gravity of the specimen, testing for various chemicals, and may also include microscopic examination for suspended structures in the specimen.

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Urinary frequency – An increase in the urge to urinate.

Urinary incontinence – Involuntary urination.

Urinary meatus – The external opening of the urethra.

Urine culture – The process by which a urine specimen is added to a medium containing nutrients that nurture the growth of pathogenic microorganisms.

Urine microscopic – The examination of urine sediment under the microscope for detection and quantification of structures suspended in the urine.

Urinometer – A type of hydrometer used to measure specific gravity of urine. A urinometer has a float that will fall to a depth measured at 1.000 when used with distilled water, but will not fall to this depth in urine specimens with an increase in dissolved substances.

Urobilinogen – A derivative of bilirubin; bilirubin is converted to urobilinogen by intestinal bacteria.

Urochrome – A pigment that gives urine its characteristic yellow color.

Uroscopy – The name originally used to describe the analysis of urine specimens. This name is no longer used routinely.

U.S. Department of Health and Human Services (HHS) – An agency that assumes the overall responsibility for laboratory quality assurance as designated in CLIA '88.

U.S. Food and Drug Administration (FDA) – The federal agency responsible for assigning the level of complexity for various laboratory tests.

Vaccine – A substance containing altered antigenic material used to stimulate an immune response to a particular pathogen and provide protection. Vaccines are usually injected.

Vacuum – A space that has all the air removed, creating a "vacuum" when it is opened (or pierced in the case of the vacuum tubes used for venipuncture).

Valid – A term used to describe a test result that can safely be reported. This usually refers to qualitative tests, in which there is an indicator on the testing device to show that the test result is valid. This is independent of whether the result is positive or negative.

Vasodilation – An enlargement of a vein due to the relaxation of the vessel walls.

Vasovagal syncope – Loss of consciousness, usually related to a stressful or upsetting event, such as a blood draw.

Vector – A carrier of pathogenic microorganisms. The vector is usually unaffected by the pathogen that it carries, but it is able to transmit it to a susceptible individual.

Veins – Blood vessels in the body that carry blood from the capillary beds back to the heart.

Venules – The smallest vessels in the venous system. Capillary vessels gradually enlarge and change in structure to become venules. Venules then become veins.

Virus – A microorganism that is too small to be seen without the aid of a microscope with advanced technology. Viruses consist of genetic material wrapped in a protein coating, and they use the genetic information of the host cell to reproduce themselves.

Viscous – Thick, sticky, or syrupy.

Very low-density lipoprotein (VLDL) – A subclass of cholesterol. Elevated VLDL levels are linked to an increased chance of plaque formation in the blood vessels.

von Willebrand's factor – A glycoprotein that is present in plasma. It carries clotting factor VIII, which is necessary for blood hemostasis. von Willebrand's factor also interacts with other processes in the clotting cascade.

Warfarin – An oral anticoagulant.

Water baths – A tank filled with water to be heated to a specific temperature. Test tubes are suspended in the heated water to speed up certain chemical reactions during testing procedures.

Westergren erythrocyte sedimentation rate (ESR) – A test performed in which the anticoagulated blood is mixed with a sodium citrate or saline solution prior to transfer into the pipette for testing.

Wet mount – A method used to observe living organisms microscopically without staining or preserving the specimen. This is especially useful when observing the movement (or motility) of microorganisms. A wet mount is essentially a suspension of the specimen placed on a slide for observation under the microscope.

White blood cell (WBC) – Formed element in the blood; the primary function of white blood cells is to provide immunity for the body.

Window period – The period of HIV infection when the infected individual does not test positive in typical laboratory tests, but is still capable of transmitting the disease. This period can last for several months after infection.

Winged infusion set – A butterfly setup. The winged infusion set consists of a needle (usually a half inch in length) attached to a piece of plastic tubing. The needle has plastic "wings" on both sides where the fingers grip the device while drawing blood.

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Wintrobe erythrocyte sedimentation rate (ESR) – A method of performing the ESR in which the anticoagulated blood is placed directly into a short Wintrobe tube specifically designed to perform the ESR. The tube is graduated in millimeters for reading the results. The tubes are usually made of glass.

Wood's lamp – A lamp used for examination of the skin. The Wood's lamp uses ultraviolet light to detect organisms or areas of the body that fluoresce. Many mycotic infections produce fluorescence.

Work practice controls – Controls that alter the manner in which a task is performed to minimize the risk of exposure to bloodborne pathogens.

Zone of inhibition – The area around a specific antibiotic disk where the growth of the microorganism is absent. The organism on the culture plate is sensitive (susceptible) to the antibiotic that is on the disk.

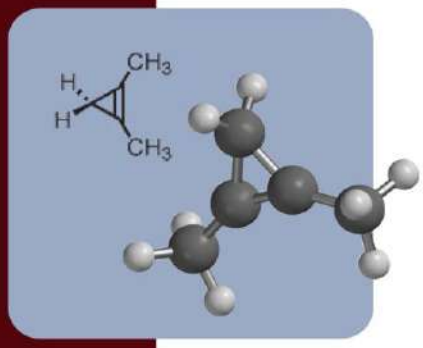

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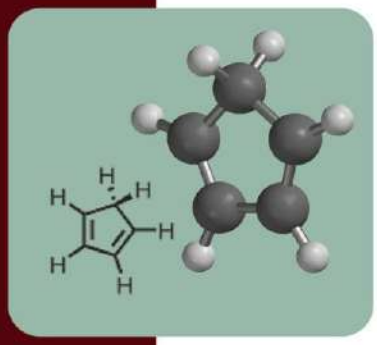

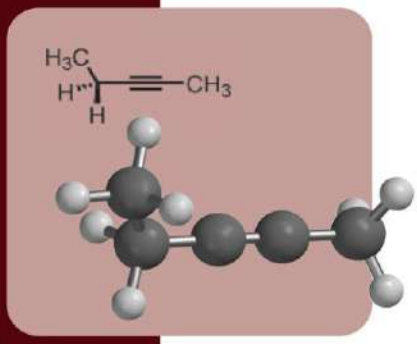

Microscale Organic Laboratory

WITH MULTISTEP AND MULTISCALE SYNTHESES

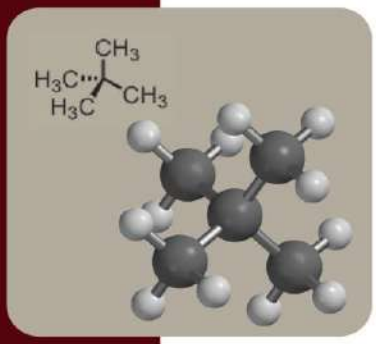

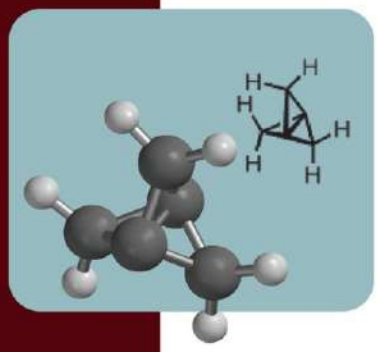

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PREFACE

Twenty-five years ago, in 1985, when *Microscale Organic Laboratory (MOL)* was first published (as paperback Xerox copies of an unproofed manuscript!), it was the only microscale organic laboratory text available. In the February 1999 *Book Buyers Guide Supplement to the Journal of Chemical Education,* however, there were seventeen laboratory manuals (of a total of thirty-nine) containing miniaturized, fully microscale, or a mixture of micro and macro experiments. Fast forward ten years and without any doubt, microscale techniques have solidly established their place in chemical education. The number of lab manuals currently in print reflects the growing number of students being introduced to organic chemistry through microscale techniques. While the conversion may not yet be quite as high as the eighty percent predicted by David Brooks back in 1985, a conservative estimate would be that a solid two-thirds majority of sophomore students now work with miniaturized experiments compared with the amounts of material employed in these laboratories in the late 1970s.

The major changes that were made to *MOL* in the fourth edition were very well received by our readers. Indeed, we are now nearing the fine-tuning stage in the evolution of this laboratory text. Hence, *MOL5* on the surface will look very much like *MOL4*. *MOL5,* however, has undergone further significant internal reorganization and rewriting. Many helpful suggestions have been received from reviewers and from instructors who have used previous editions of this text. As a result, some major changes have been made for this new edition:

- A key change to the 5th edition is the modification of the procedural sections to allow for inquiry-based experimentation. Reaction times have been replaced with guidelines, and options on how to best monitor reactions and gauge product purity are left to the discretion of the student or instructor. Many ideas and new approaches can stem from this change—for example, instructional sections can be split into small groups and each group can approach the monitoring of a reaction differently. Using a completely separate set of experiments, discussions can be pursued which focus on reaction purity and evidence which offers the experimentalist sufficient data about what was prepared. Students can then compare notes at the end of the lab period and discuss the various approaches and end results. We hope that this change will allow the lab to become a more interactive experience between groups of students, should that be the wish of the instructor. The opportunity to monitor a reaction rather than assume reaction completion by simply following a time-based instruction and to allow for students to gather additional evidence of product purity empowers the student and adds an element of excitement to the lab experience. Optional inquiry-based guidelines have been added to experiments 5A, 5B, 7, 19B, 24A, and 32. Experiments 11A, 16, and 28 have been modified in a way which focuses on validation of product purity. References to inquiry-based guidelines [?] and validation experiences [V] are noted in the text.
- The use of microwave heating as a tool in synthetic organic chemistry is fast-growing and is becoming an enabling technology. Optional instructions have been added to experiments to allow for the integration of microwave heating as a tool for performing reactions. Since reaction times are shorter than when conventional heating methods are used,

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students have the opportunity to supplement these activities with traditional techniques and as stated above engage in discussions comparing the two. Optional microwave heating instructions have been added to experiments 7, 8, 15, 22, and 30. References to microwave use are noted in the text by the use of this icon M.

- A rich collection of end of chapter exercises and the addition of pre and post lab questions provides students with the valuable opportunity to test and practice their own understanding of each laboratory experiment.
- Discussion sections that appear at the beginning of each Experiment have been added, revised, and expanded upon. These discussion sections provide chemical context/background for each experiment, and provide more information regarding the chemical principles involved in each experimental procedure.
- **The Refractive Index material, which was formally in chapter 4, has been moved to the book companion web site: http://www.wiley.com/college/mayo.**
- **Chapter 10W, "Advanced Microscale Organic Laboratory Experiments," (formerly chapter 7) has been moved to the book companion web site: http://www.wiley.com/college/mayo.**

Additional Resources

Text web site-http://www.wiley.com/college/mayo

As with the previous edition, a major portion of the background theoretical discussions have been moved to the text web site, without affecting the operational part of the text. Likewise, the web site has allowed us to move a number of more advanced discussions out of the printed text. Wherever the shift of this material has occurred the move is flagged by reference call-outs using an icon www.

These **web reference discussions** include information on the following topics:

- Microscale lab equipment and techniques
- Semimicroscale distillation
- Reduced pressure distillations with microspinning band columns
- Vacuum pumps and pressure regulation
- Crystallization
- Measurement of Specific Rotation
- Introduction to Infrared Spectroscopy—Introduction to Theory
- Group Frequencies of the Hydrocarbons
- Characteristic Frequencies of the Heteroatom Functional Groups
- Instrumentation—the Infrared Interferometer
- Tables of Derivatives

The majority of the background infrared spectra and the associated discussions used to develop the use of group frequencies from these spectra are also found on the web site, while the text still contains the essential tables of characteristic frequencies that are in every day use in the laboratory. The many compound data tables, used primarily in the chapter on qualitative identification, also reside on the web site. The Classification of Experiments Based on Mechanism is also available on the web site.

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CH$_4$apter 1

INTRODUCTION

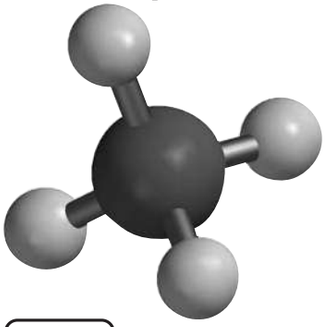

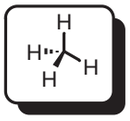

You are about to embark on a challenging adventure—the microscale organic chemistry laboratory!

Your course is going to be quite different from the conventional manner in which this laboratory has been taught in past decades. You will be learning the experimental side of organic chemistry from the microscale level. Although you will be working with very small amounts of materials, you will be able to observe and learn more organic chemistry in one year than many of your predecessors did in nearly two years of laboratory work. You will find this laboratory an exciting and interesting place to be. While we cannot guarantee it for you individually, the majority of students who went through the program during its development found the microscale organic laboratory to be a surprisingly pleasant adventure.

This textbook is centered on helping you develop skills in microscale organic laboratory techniques. Its focus is twofold. For those of you in the academic environment and involved with the introductory organic laboratory, it allows the flexibility of developing your own scaling sequence without being tied to a prescribed set of quantities. For those of you working in a research environment at the advanced undergraduate or graduate level or in the industrial area, this text will provide the foundation from which you can develop a solid expertise in microscale techniques directly applicable to your work. Working at the microscale level is substantially different from using conventional operations in the organic laboratory with multigram quantities of materials.

During the last two decades, the experimental side of organic chemistry has moved ever closer to the microscale level. This conversion started in earnest nearly thirty years ago and has been spurred on by the rapidly accelerating cost of chemical waste disposal. As we have said, you will be working with very small amounts of materials, but the techniques that you will learn and experience you will gain will allow you to accomplish more organic chemistry in the long run than many of your predecessors.

First, we want to acquaint you with the organization and contents of the text. ***With the fifth edition, a continued effort has been made to streamline the basic reference material from the text using our accompanying website (www.wiley.com/college/MOL5). Accordingly, Chapter 10W (formerly Chapter 7 of the fourth edition) in its entirety has been placed online. Throughout this edition, Chapter 10W is identified with a "W" (e.g., Chapter 10W), indicating its location online. Furthermore, an icon will be used in the margin to indicate website material that will be of interest to the user. We hope this treatment of the laboratory will make the more important aspects of the basic text easier to access and will speed your laboratory work along.*** We then give you a few words of advice, which, if they are heeded, will allow you to avoid many of the sand traps you will find as you develop microscale laboratory techniques. Finally, we wax philosophical and attempt to describe what we think you should derive from this experience.

www

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After this brief introduction, the second chapter is concerned with safety in the laboratory. This chapter supplies information that will allow you to estimate

Chapter 1: CH$_4$, Methane
a substance of natural origin, known as Marsh Gas to the alchemists.

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your maximum possible exposure to volatile chemicals used in the microscale laboratory. Chapter 2 also discusses general safety protocol for the laboratory. It is vitally important that you become familiar with the details of the material contained in this chapter; your health and safety depend on this knowledge.

The next three chapters are concerned primarily with the development of experimental techniques. Chapter 3 describes in detail the glassware employed in microscale organic chemistry: the logic behind its construction, tips on its usage, the common arrangements of equipment, and various other laboratory manipulations, including techniques for transferring microquantities of materials. Suggestions for the organization of your laboratory notebook are presented at the end of this chapter.

Chapter 4 deals with equipment and techniques for determining a number of physical properties of microscale samples. Chapter 5 is divided into nine technique sections. Detailed discussions develop the major areas of experimental technique that are used in the microscale organic laboratory.

www Chapters 6, 7, and 10W contain the main experimental sections of this text. Chapter 6 is focused primarily on preparative organic chemistry at the microscale level and consists of 35 experiments. While the number of experiments has not changed with this edition, there have been changes to how the reactions are monitored and conducted. Six experiments (Experiments 5A, 5B, 7, 19B, 24A, and 32) in Chapter 6 have been modified in a way which replaces the posting of a reaction time with the task of monitoring the reaction by TLC until complete. The TLC technique is asked of the experimentalist in three more experiments (Experiments 11A, 16, and 28) in order to provide additional evidence of reaction purity upon recrystallization of the crude reaction mixture. And finally, five experiments (Experiments 7, 8, 15, 22, and 30) in Chapter 6 now have optional exercises which utilize microwave technologies. Additional selections of individual experiments can be drawn from those experiments presented in Chapter 7. Chapter 10W, which is now located online, contains a series of seven experiments of a more sophisticated nature. A number of the experiments contained in Chapters 6 and 10W are of optional scale so that you may also have the opportunity to gain some experience with experimentation at larger scales. Chapter 7 consists of a set of six sequential experiments that are essentially identical to the type of problems tackled by research chemists involved in synthetic organic chemistry. A number of these multistep procedures begin the first step in the experiment with large-scale, multigram quantities of starting material, but require microscale techniques to complete the final step or two. The use of this chapter is most appropriate in the final stages of the course, for example, the latter part of the second semester of a two-semester sequence.

www

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Chapter 8 develops the characterization of organic materials at the microscale level by spectroscopic techniques. The chapter starts with a brief discussion of the interpretation of infrared (IR) group frequencies and is followed by a more detailed treatment of nuclear magnetic resonance (NMR) spectral data, a brief discussion of ultraviolet-visible (UV–vis) spectroscopy, and a brief introduction to the theory, experimental techniques, and applications of mass spectrometry to organic chemistry. A more detailed introduction to the theoretical basis for these spectroscopic techniques is also presented on the accompanying website.

Chapter 9 develops the characterization of organic materials at the microscale level by the use of classical organic reactions to form solid derivatives. Tables of derivative data for use in compound identification by these techniques are discussed and are included on the website as Appendix A.

A list of all the experiments grouped by reaction mechanism is given on the web-site as Appendix B.

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The organization of the experimental procedures given in Chapters 6, 7, and 10W is arranged in the following fashion. A short opening statement describing the reaction to be studied is followed by the reaction scheme. www

Generally, a brief discussion of the reaction follows, including a mechanistic interpretation. In a few cases of particularly important reactions, or where the experiment is likely to precede presentation of the topic in the classroom, a more detailed description is given. The estimated time needed to complete the work, and a table of reactant data come next. For ease in organizing your laboratory time, the experimental section is divided into four subsections: *reagents and equipment, reaction conditions, isolation of product, and purification and characterization.*

We then introduce a series of questions and problems designed to enhance and focus your understanding of the chemistry and the experimental procedures involved in a particular laboratory exercise. Finally, a bibliography offering a list of literature references is given. Although this list comes at the end of the experimental section, we view it as a very important part of the text. The discussion of the chemistry involved in each experiment is necessarily brief. We hope that you will take time to read and expand your knowledge about the particular experiment that you are conducting. You may, in fact, find that some of these references become assigned reading.

A prompt (➡) in the text indicates that experimental apparatus involved with that stage of the experiment are shown in the margin. Important comments are italicized in the text, and **Warnings** and **Cautions** are given in boxes and also indicated in the margins.

In an effort to streamline our treatment of the laboratory we have moved a considerable quantity of material from the previous editions, MOL3 and MOL4, and placed it in easily accessible form on our website (www.wiley.com/college/MOL5). An icon lets you know that supplemental material is available on the website. New to this edition is a detailed listing within the table of contents of all materials available online. We hope this format will make the more important aspects of the basic text easier to access and speed your laboratory work along. www

GENERAL RULES FOR THE MICROSCALE LABORATORY

1. Study the experiment before you come to lab. This rule is a historical plea from all laboratory instructors. In the microscale laboratory it takes on a more important meaning. You will not survive if you do not prepare ahead of time. In microscale experiments, operations happen much more quickly than in the macroscale laboratory. Your laboratory time will be overflowing with many more events. If you are not familiar with the sequences you are to follow, you will be in deep trouble. Although the techniques employed at the microscale level are not particularly difficult to acquire, they do demand a significant amount of attention. For you to reach a successful and happy conclusion, you cannot afford to have the focus of your concentration broken by having to constantly refer to the text during the experiment. Disaster is ever present for the unprepared.

2. ALWAYS work with clean equipment. You must take the time to scrupulously clean your equipment before you start any experiment. Contaminated glass-ware will ultimately cost you additional time, and you will experience the frustration of inconsistent results and lower yields. Dirty equipment is the primary cause of reaction failure at the microscale level.

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3. CAREFULLY measure the quantities of materials to be used in the experiments. A little extra time at the beginning of the laboratory can speed you on your way at the end of the session. A great deal of time has been spent optimizing the conditions employed in these experiments in order to maximize yields. Many organic reactions are very sensitive to the relative quantities of substrate (the material on which the reaction is taking place) and reagent (the reactive substance or substances that bring about the change in the substrate). After equipment contamination, the second-largest cause of failed reactions is attempting to run a reaction with incorrect quantities of the reactants present. Do not be hurried or careless at the balance.

4. Clean means DRY. Water or cleaning solution can be as detrimental to the success of a reaction as dirt or sludge in the system. You often will be working with very small quantities of moisture-sensitive reagents. The glass surface areas with which these reagents come in contact, however, are relatively large. A slightly damp piece of glassware can rapidly deactivate a critical reagent and result in reaction failure. *This rule must be strictly followed.*

5. ALWAYS work on a clean laboratory bench surface, preferably glass!

6. ALWAYS protect the reaction product that you are working with from a disastrous spill by carrying out all solution or solvent transfers over a crystallizing dish.

7. ALWAYS place reaction vials or flasks in a clean beaker when standing them on the laboratory bench. Then, when a spill occurs the material is more likely to be contained in the beaker and less likely to be found on the laboratory bench or floor.

8. NEVER use cork rings to support round-bottom flasks, particularly if they contain liquids. You are inviting disaster to be a guest at your laboratory bench.

9. ALWAYS think through the next step you are going to perform *before* starting it. Once you have added the wrong reagent, it is back to square one.

10. ALWAYS save everything you have generated in an experiment until it is successfully completed. You can retrieve a mislabeled chromatographic fraction from your locker, but not from the waste container!

THE ORGANIC CHEMISTRY LABORATORY

The confidence gained by mastering the microscale techniques described here will pay big dividends as you progress into modern-day experimental chemistry. The organic laboratory has had a reputation of being smelly, long, tedious, and pockmarked with fires and explosions; but present-day organic chemistry is undergoing a revolution at the laboratory bench. New techniques are sweeping away many of the old complaints, as an increasing fraction of industrial and academic research is being carried out at the microscale level.

This book allows the interested participant to rapidly develop the skills needed to slice more deeply into organic chemistry than ever before. The attendant benefits are greater confidence and independence in acquired laboratory techniques. The happy result is that in a microscale-based organic chemistry laboratory, you are more likely to have a satisfying encounter with the experimental side of this fascinating field of knowledge.

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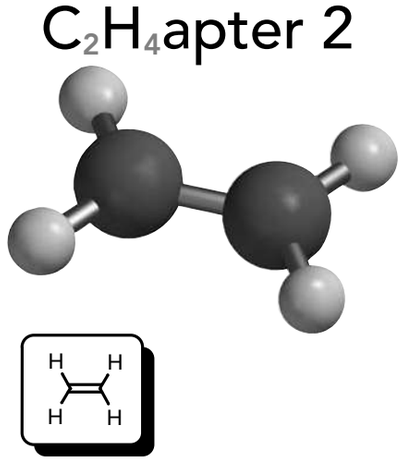

SAFETY

Research laboratories vary widely with respect to facilities and support given to safety. Large laboratories may have several hundred chemists and an extensive network of co-workers, supervisors, safety officers, and hazardous-waste managers. They also, according to government regulations, have an extensive set of safety procedures and detailed practices for the storage and disposal of hazardous wastes. In small laboratories, the individual chemist may have to take care of all these aspects of safety. Some laboratories may routinely deal with very hazardous materials and may run all reactions in hoods. Others may deal mainly with relatively innocuous compounds and have very limited hood facilities.

Our approach is to raise some questions to think about and to suggest places to look for further information. In this chapter, we do not present a large list of safety precautions for use in all situations; rather, we present a list of very basic precautionary measures. A bibliography at the end of the chapter offers a list of selected references. *We urge you to consult these references concerning specific safety regulations.* Many laboratories may have safety guidelines that will supercede this very cursory treatment. This chapter is no more than a starting point.

MAKING THE LABORATORY A SAFER PLACE

Murphy's law states in brief, "If anything can go wrong, it will." Although it is often taken to be a silly law, it is not. Murphy's law means that if sparking switches are present in areas that contain flammable vapors, sooner or later there will be a fire. If the glass container can move to the edge of the shelf as items are moved around or because the building vibrates, at some time it will come crashing to the floor. If the pipet can become contaminated, then the mouth pipetter will eventually ingest a contaminant.

We cannot revoke Murphy's law, but we can do a lot to minimize the damage. We can reduce the incidence of sparks and flames and flammable vapors. We can make sure that if the accident does occur, we have the means to contain the damage and to take care of any injuries that result. All of this means thinking about the laboratory environment. Does your laboratory have or enforce regulations related to important items such as eye, face, and foot protection, safety clothing, respiratory equipment, first aid supplies, fire equipment, spill kits, hoods, and compliance regulations? *Think ahead* about what could go wrong and then *plan* and *prepare* to minimize the chance of an accident and be prepared to respond when one does occur.

NATURE OF HAZARDS

The chemistry laboratory presents a wide assortment of risks. These risks are outlined briefly here so that you can begin to think about the steps necessary to make the laboratory safer:

1. **Physical hazards.** Injuries resulting from flames, explosions, and equipment (cuts from glass, electrical shock from faulty instrumentation, or improper use of instruments).

Chapter 2: C_2H_4, Ethylene
a substance of natural origin, released by ripening fruit.

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2. **External exposure to chemicals.** Injuries to skin and eyes resulting from contact with chemicals that have spilled, splashed, or been left on the bench top or on equipment.
3. **Internal exposure.** Longer term (usually) health effects resulting from breathing hazardous vapors or ingesting chemicals.

REDUCTION OF RISKS

Many things can be done to reduce risks. The rules below may be absolute in some laboratories. In others, the nature of the materials and apparatus used may justify the relaxation of some of these rules or the addition of others.

1. **Stick to the procedures described by your supervisor.** This attention to detail is particularly important for the chemist with limited experience. In other cases, variation of the reagents and techniques may be part of the work.
2. **Wear approved safety goggles.** We can often recover quickly from injuries affecting only a few square millimeters on our bodies, unless that area happens to be in our eyes. Larger industrial laboratories often require that laboratory work clothes and safety shoes be worn. Wear them, if requested.
3. **Do not put anything in your mouth under any circumstances while in the laboratory.** This includes food, drinks, chemicals, and pipets. There are countless ways that surfaces can become contaminated in the laboratory. Since there are substances that must never be pipetted by mouth, one must get into the habit of *never* mouth pipetting anything.
4. **Be cautious with flames and flammable solvents.** Remember that the flame at one end of the bench can ignite the flammable liquid at the other end in the event of a spill or improper disposal. Flames must never be used when certain liquids are present in the laboratory, and flames must always be used with care. Check the *fire diamond* hazard symbol, if available.
5. **Be sure that you have the proper chemicals for your reaction.** Check labels carefully, and return unused chemicals to the proper place for storage. Be sure to replace caps on containers immediately after use. An open container is an invitation for a spill. Furthermore, some reagents are very sensitive to moisture, and may decompose if left open.
6. **Minimize the loss of chemicals to air or water and dispose of waste properly.** Some water-soluble materials may be safely disposed of in the water drains. Other wastes should go into special receptacles. Pay attention to the labels on these receptacles. Recent government regulations have placed stringent rules on industrial and academic laboratories for proper disposal of chemicals. *Severe penalties are levied on those who do not follow proper procedures.* We recommend that you consult general safety references nos. 3 and 4 at the end of the chapter.
7. **Minimize skin contact with any chemicals.** Use impermeable gloves when necessary, and promptly wash any chemical off your body. If you have to wash something off with water, use lots of it. Be sure that you know where the nearest water spray device is located.

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NOTE. Do not use latex gloves. They are permeable to many chemicals and some people are allergic to them. A recommended substitute are the various grades of nitrile gloves.

8. **Do not inhale vapors from volatile materials.** Severe illness or internal injury can result.
9. **Tie back or confine long hair and loose items of clothing.** You do not want them falling into a reagent or getting near flames.
10. **Do not work alone.** Too many things can happen to a person working alone that might leave him or her unable to obtain assistance. As in swimming, the "buddy system" is safest.
11. **Exercise care in assembling glass and electrical apparatus.** All operations with glass, such as separating standard taper glassware, involve the risk that the glass may break and that lacerations or punctures may result. Seek help or advice with glassware, if necessary. Special containers should be provided for the disposal of broken glass. Electrical shock can occur in many ways. When making electrical connections, make sure that your hands, the laboratory bench, and the floor are all dry and that *you* do not complete an electrical path to ground. Be sure that electrical equipment is properly grounded and insulated.
12. **Report any injury or accident to the appropriate person.** Reporting injuries and accidents is important so that medical assistance can be obtained if necessary. It also allows others to be made aware of any safety problems; these problems may be correctable.
13. **Keep things clean.** Put unused apparatus away. Immediately wipe up or care for spills on the bench top or floor. This also pertains to the balance area and to where chemicals are dispensed.
14. **Never heat a closed system.** Always provide a vent to avoid an explosion. Provide a suitable trap for any toxic gases generated in a given reaction.
15. **Learn the correct use of gas cylinders.** Even a small gas cylinder can become a lethal bomb if not properly used.
16. **Attend safety programs.** Many industrial laboratories offer excellent seminars and lectures on a wide variety of safety topics. Pay careful attention to the advice and counsel of the safety officer.
17. **Above all, use your common sense.** Think before you act.

PRECAUTIONARY MEASURES

Know the location and operation of safety equipment in the laboratory. Locate the nearest

- Fire extinguisher
- First aid kit
- Eye wash
- Telephone
- Emergency shower
- Exit
- Fire blanket

Know where to call (have the numbers posted) for

- Fire
- Medical emergency
- Spill or accidental release of corrosive or toxic chemicals.

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Know where to go

- In case of injury
- To evacuate the building

THINKING ABOUT THE RISKS IN USING CHEMICALS

The smaller quantities used in the microscale laboratory carry with them a reduction in hazards caused by fires and explosions; hazards associated with skin contact are also reduced. However, care must be exercised when working with even the small quantities involved.

There is great potential for reducing the exposure to chemical vapors, but these reductions will be realized only if everyone in the laboratory is careful. One characteristic of vapors emitted outside hoods is that they mix rapidly throughout the lab and will quickly reach the person on the other side of the room. In some laboratories, the majority of reactions may be carried out in hoods. When reactions are carried out in the open laboratory, each experimenter becomes a polluter whose emissions affect nearby people the most, but these emissions become added to the laboratory air and to the burden each of us must bear.

The concentration of vapor in the general laboratory air space depends on the vapor pressure of the liquids, the area of the solid or liquid exposed, the nature of air currents near the sources, and the ventilation characteristics of the laboratory. One factor over which each individual has control is evaporation, which can be reduced by the following practices:

- Certain liquids must remain in hoods.
- Reagent bottles must be recapped when not in use.
- Spills must be quickly cleaned up and the waste discarded.

Chemicals must be properly stored when not in use. Some balance must be struck between the convenience of having the compound in the laboratory where you can easily put your hands on it and the safety of having the compound in a properly ventilated and fire-safe storage room. Policies for storing chemicals will vary from place to place. There are limits to the amounts of flammable liquids that should be stored in glass containers, and fire-resistant cabinets must be used for storage of large amounts of flammable liquids. Chemicals that react with one another should not be stored in close proximity. There are plans for sorting chemicals by general reactivity classes in storerooms; for instance, Flinn Scientific Company includes a description of a storage system in their (2009) chemical catalog.

DISPOSAL OF CHEMICALS

Chemicals must also be segregated into categories for disposal. The categories used will depend on the disposal service available and upon federal, state, and local regulations. For example, some organic wastes are readily incinerated, while those containing chlorine may require much more costly treatment. Other wastes may have to be buried. For safety and economic reasons, it is

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important to place waste material in the appropriate container. In today's world, it often costs more to dispose of a chemical than to purchase it in the first place! The economic impact of waste generation and disposal is gigantic. Based upon the toxic release inventory from the EPA for the year of 2005, do you realize that the chemical industry in the United States released more than 4 billion pounds of on-site and off-site chemical waste?[1] Each year hundreds of billions of dollars is spent per year in waste treatment, control, and disposal costs!

It is our obligation as chemists to decrease the impact that hazardous chemicals have on our environment. A movement is currently underway (referred to as"Green Chemistry"or "Benign by Design") to accomplish this goal by focusing on the design, manufacture, and use of chemicals and chemical processes that have little or no pollution potential or environmental risk.

MATERIAL SAFETY DATA SHEETS

Although risks are associated with the use of most chemicals, the magnitudes of these risks vary greatly. A short description of the risks is provided by a Material Safety Data Sheet, commonly referred to as an MSDS. All participants of a laboratory experience are strongly encouraged to educate themselves on the risks, large or small, of the chemicals they are scheduled to work with while in lab. The information contained on these sheets can be obtained from a number of locations. While they are normally provided by the manufacturer or vendor of the chemical, and users are required to keep on file the MSDS of each material stored or used, data sheets can be easily obtained online.

As an example, the 1985 MSDS for acetone is shown here. This sheet was provided by the J. T. Baker Chemical Company. Sheets from other sources, especially those online[2], do provide a very illuminating comparison of what has transpired over 20+ years. Much of the information on these sheets is self-explanatory, but let's review the major sections of the acetone example.

Section I provides identification numbers and codes for the compound and includes a summary of the risks associated with the use of acetone. Because these sheets are available for many thousands of compounds and mixtures, there must be a means of unambiguously identifying the substance. A standard reference number for chemists is the Chemical Abstracts Service Number (CAS No.).

A quick review of the degree of risks is given by the numerical scale under Precautionary Labeling. This particular scale is a proprietary scale that ranges from 0 (very little or nonexistent risk) to 4 (extremely high risk). The National Fire Protection Association (NFPA) uses a similar scale but the risks considered are different. Other systems may use different scales, and there are some that represent low risks by the highest number! Be sure that you understand the scale being used. Perhaps some day one scale will become standard.

Section II covers risks from mixtures. Because a mixture is not considered here, the section is empty. Selected physical data are described in Section III. Section IV contains fire and explosion data, including a description of the toxic gases produced when acetone is exposed to a fire. The MSDSs are routinely made available to fire departments that may be faced with fighting a fire in a building where large amounts of chemicals are stored.

[1]For online access to the EPA Toxic Release Inventory, see: www.epa.gov/tri/
[2]For an online MSDS for acetone, see: www.jtbaker.com/msds/englishhtml/A0446.htm

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J. T. BAKER CHEMICAL CO. 222 RED SCHOOL LANE, PHILLIPSBURG, NJ 08865
M A T E R I A L S A F E T Y D A T A S H E E T
24-HOUR EMERGENCY TELEPHONE — (201) 859-2151
CHEMTREC # (800) 424-9300 — NATIONAL RESPONSE CENTER # (800) 424-8802

A0446 –01 ACETONE PAGE: 1
EFFECTIVE: 10/11/85 ISSUED: 01/23/86

SECTION I – PRODUCT IDENTIFICATION

PRODUCT NAME:	ACETONE
FORMULA:	(CH3)2CO
FORMULA WT:	58.08
CAS NO.:	00067-64-1
NIOSH/RTECS NO.:	AL3150000
COMMON SYNONYMS:	DIMETHYL KETONE; METHYL KETONE; 2-PROPANONE
PRODUCT CODES:	9010,9006,9002,9254,9009,9001,9004,5356,A134,9007,9005,9008

PRECAUTIONARY LABELLING

BAKER SAF-T-DATA(TM) SYSTEM

HEALTH – 1
FLAMMABILITY – 3 (FLAMMABLE)
REACTIVITY – 2
CONTACT – 1

LABORATORY PROTECTIVE EQUIPMENT

SAFETY GLASSES; LAB COAT; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER

PRECAUTIONARY LABEL STATEMENTS

DANGER
EXTREMELY FLAMMABLE
HARMFUL IF SWALLOWED OR INHALED
CAUSES IRRITATION

KEEP AWAY FROM HEAT, SPARKS, FLAME. AVOID CONTACT WITH EYES, SKIN, CLOTHING. AVOID BREATHING VAPOR. KEEP IN TIGHTLY CLOSED CONTAINER. USE WITH ADEQUATE VENTILATION. WASH THOROUGHLY AFTER HANDLING. IN CASE OF FIRE, USE WATER SPRAY, ALCOHOL FOAM, DRY CHEMICAL, OR CARBON DIOXIDE. FLUSH SPILL AREA WITH WATER SPRAY.

SECTION II – HAZARDOUS COMPONENTS

COMPONENT	%	CAS NO.
ACETONE	90-100	67-64-1

SECTION III – PHYSICAL DATA

BOILING POINT:	56 C (133 F)	VAPOR PRESSURE(MM HG):	181
MELTING POINT:	–95 C (–139 F)	VAPOR DENSITY(AIR=1):	2
SPECIFIC GRAVITY: (H2O=1)	0.79	EVAPORATION RATE: (BUTYL ACETATE=1)	5.6

SOLUBILITY(H2O): COMPLETE (IN ALL PROPORTIONS) % VOLATILES BY VOLUME: 100

APPEARANCE & ODOR: CLEAR, COLORLESS LIQUID WITH FRAGRANT SWEET ODOR.

SECTION IV – FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: –18 C (0 F) NFPA 704M RATING: 1-3-0

FLAMMABLE LIMITS: UPPER – 13 % LOWER – 2 %

FIRE EXTINGUISHING MEDIA
USE ALCOHOL FOAM, DRY CHEMICAL OR CARBON DIOXIDE.
(WATER MAY BE INEFFECTIVE.)

SPECIAL FIRE-FIGHTING PROCEDURES
FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED (POSITIVE PRESSURE IF AVAILABLE) BREATHING APPARATUS WITH FULL FACEPIECE.
MOVE EXPOSED CONTAINERS FROM FIRE AREA IF IT CAN BE DONE WITHOUT RISK.
USE WATER TO KEEP FIRE-EXPOSED CONTAINERS COOL.

UNUSUAL FIRE & EXPLOSION HAZARDS
VAPORS MAY FLOW ALONG SURFACES TO DISTANT IGNITION SOURCES AND FLASH BACK.
CLOSED CONTAINERS EXPOSED TO HEAT MAY EXPLODE. CONTACT WITH STRONG OXIDIZERS MAY CAUSE FIRE.

SECTION V – HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE (TLV/TWA): 1780 MG/M3 (750 PPM)

SHORT-TERM EXPOSURE LIMIT (STEL): 2375 MG/M3 (1000 PPM)

TOXICITY: LD50 (ORAL-RAT)(MG/KG) – 9750
LD50 (IPR-MOUSE)(G/KG) – 1297

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EFFECTS OF OVEREXPOSURE

CONTACT WITH SKIN HAS A DEFATTING EFFECT, CAUSING DRYING AND IRRITATION. OVEREXPOSURE TO VAPORS MAY CAUSE IRRITATION OF MUCOUS MEMBRANES, DRYNESS OF MOUTH AND THROAT, HEADACHE, NAUSEA AND DIZZINESS.

EMERGENCY AND FIRST AID PROCEDURES

CALL A PHYSICIAN.
IF SWALLOWED, IF CONSCIOUS, IMMEDIATELY INDUCE VOMITING.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. FLUSH SKIN WITH WATER.

SECTION VI – REACTIVITY DATA

STABILITY: STABLE — HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS TO AVOID: HEAT, FLAME, SOURCES OF IGNITION

INCOMPATIBLES: SULFURIC ACID, NITRIC ACID, STRONG OXIDIZING AGENTS

SECTION VII – SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE

WEAR SUITABLE PROTECTIVE CLOTHING. SHUT OFF IGNITION SOURCES; NO FLARES, SMOKING, OR FLAMES IN AREA. STOP LEAK IF YOU CAN DO SO WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. TAKE UP WITH SAND OR OTHER NON-COMBUSTIBLE ABSORBENT MATERIAL AND PLACE INTO CONTAINER FOR LATER DISPOSAL. FLUSH AREA WITH WATER.

J. T. BAKER SOLUSORB(R) SOLVENT ADSORBENT IS RECOMMENDED FOR SPILLS OF THIS PRODUCT.

DISPOSAL PROCEDURE

DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.

EPA HAZARDOUS WASTE NUMBER: U002 (TOXIC WASTE)

SECTION VIII – PROTECTIVE EQUIPMENT

VENTILATION:	USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS.
RESPIRATORY PROTECTION:	RESPIRATORY PROTECTION REQUIRED IF AIRBORNE CONCENTRATION EXCEEDS TLV AT CONCENTRATIONS UP TO 5000 PPM, A GAS MASK WITH ORGANIC VAPOR CANNISTER IS RECOMMENDED. ABOVE THIS LEVEL, A SELF-CONTAINED BREATHING APPARATUS WITH FULL FACE SHIELD IS ADVISED.
EYE/SKIN PROTECTION:	SAFETY GLASSES WITH SIDESHIELDS, POLYVINYL ACETATE GLOVES ARE RECOMMENDED.

SECTION IX – STORAGE AND HANDLING PRECAUTIONS

SAF-T-DATA(TM) STORAGE COLOR CODE: RED

SPECIAL PRECAUTIONS

BOND AND GROUND CONTAINERS WHEN TRANSFERRING LIQUID. KEEP CONTAINER TIGHTLY CLOSED. STORE IN A COOL, DRY, WELL-VENTILATED, FLAMMABLE LIQUID STORAGE AREA.

SECTION X – TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D.O.T.)

PROPER SHIPPING NAME	ACETONE
HAZARD CLASS	FLAMMABLE LIQUID
UN/NA	UN1090
LABELS	FLAMMABLE LIQUID

INTERNATIONAL (I.M.O.)

PROPER SHIPPING NAME	ACETONE
HAZARD CLASS	3.1
UN/NA	UN1090
LABELS	FLAMMABLE LIQUID

(TM) AND (R) DESIGNATE TRADEMARKS.
N/A = NOT APPLICABLE OR NOT AVAILABLE

THE INFORMATION PUBLISHED IN THIS MATERIAL SAFETY DATA SHEET HAS BEEN COMPILED FROM OUR EXPERIENCE AND DATA PRESENTED IN VARIOUS TECHNICAL PUBLICATIONS. IT IS THE USER'S RESPONSIBILITY TO DETERMINE THE SUITABILITY OF THIS INFORMATION FOR THE ADOPTION OF NECESSARY SAFETY PRECAUTIONS. WE RESERVE THE RIGHT TO REVISE MATERIAL SAFETY DATA SHEETS PERIODICALLY AS NEW INFORMATION BECOMES AVAILABLE.

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Health hazards are described in Section V. The entries of most significance for evaluating risks from vapors are the Threshold Limit Value (or TLV) and the Short-Term Exposure Limit (STEL). The TLV is a term used by the American Conference of Governmental Industrial Hygienists (ACGIH). This organization examines the toxicity literature for a compound and establishes the TLV. This standard is designed to protect the health of workers exposed to the vapor 8 hours a day, five days a week. The Occupational Safety and Health Administration (OSHA) adopts a value to protect the safety of workplaces in the United States. Their value is termed the Time-Weighted Average (TWA) and in many cases is numerically equal to the TLV. The STEL is a value not to be exceeded for even a 15-minute averaging time. TLV, TWA, and STEL values for many chemicals are summarized in a small handbook available from the ACGIH (2000); they are also collected in the *CRC Handbook of Chemistry and Physics.*

The toxicity of acetone is also described in terms of the toxic oral dose. In this case, the LD_{50} is the dose that will cause the death of 50% of the mice or rats given that dose. The dose is expressed as milligrams of chemical per kilogram of body weight of the subject animal. The figures for small animals are often used to estimate the effects on humans. If, for example, we used the mouse figure of 1297 mg/kg and applied it to a 60-kg chemist, a dose of 77,820 mg (~98.5 mL) would kill 50% of the subjects receiving that dose. As a further example, chloroform has an LD_{50} of 80 mg/kg. For our 60-kg chemist, a dose of 4800 mg (~3 mL) would be fatal for 50% of these cases. The effects of exposure of skin to the liquid and vapor are also described.

Section VI describes the reactivity of acetone and the classes of compounds with which it should not come in contact. For example, sodium metal reacts violently with a number of substances (including water) and should not come in contact with them. Strong oxidizing agents (such as nitric acid) should not be mixed with organic compounds (among other things). The final sections (Sections VII–X) are self-explanatory.

ALTERNATE SOURCES OF INFORMATION

Similar information in a more compact form can be found in the *Merck Index* (Merck). This basic reference work provides information on the toxicity of many chemicals. It often refers one to the *NIOSH Pocket Guide to Chemical Hazards* (National Institute for Occupational Safety and Health). The *Merck Index* also supplies interesting information about the common uses of the chemicals listed, particularly related to the medical area. References to the chemical literature are also provided. The *CRC Handbook of Chemistry and Physics,* which is updated each year, contains a wide range of data (located in tables) in the area of health, safety, and environmental protection. It also includes directions for the handling and disposal of laboratory chemicals. Your laboratory should have a copy of this work. Most chemical supply houses now label their containers with data showing not only the usual package size, physical properties, and chemical formula, but also pictures or codes showing hazard information. Some include a pictogram (for example, see the newer Aldrich Chemical labels on their bottles). The J. T. Baker Company uses the Baker SAF-T-DATA System.

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ESTIMATING RISKS FROM VAPORS

Other things (availability, suitability) being equal, one would, of course, choose the least toxic chemical for a given reaction. Some very toxic chemicals play very important roles in synthetic organic chemistry, and the toxicity of the chemicals in common use varies greatly. Bromine and benzene have TLVs of 0.7 and 30 mg/m^3, respectively, and are at the more toxic end of the spectrum of chemicals routinely used. Acetone has a TLV of 1780 mg/m^3. These representative figures do not mean that acetone is harmless or that bromine cannot be used. In general, one should exercise care at all times (make a habit of good laboratory practice) and should take special precautions when working with highly toxic materials.

The TLV provides a simple means to evaluate the relative risk of exposure to the vapor of any substance used in the laboratory. If the quantity of the material evaporated is represented by m (in milligrams/hour) and the TLV is expressed by L (milligrams per cubic meter), a measure of relative risk to the vapor is given by m/L. This quantity represents the volume of clean air required to dilute the emissions to the TLV. As an example, the emission of 1 g of bromine and 10 g of acetone in one hour leads to the values of m/L of 1400 m^3/hour (h) for the bromine and 5.6 m^3/h for acetone. These numbers provide a direct handle on the *relative* risks from these two vapors. It is difficult to assess the absolute risk to these vapors without a lot of information about the ventilation characteristics of the laboratory. If these releases occur within a properly operated hood, the threat to the worker in the laboratory is probably very small. (However, consideration must be given to the hood exhaust.)

Exposure in the general laboratory environment can be assessed if we assume that the emissions are reasonably well mixed before they are inhaled and if we know something about the room ventilation rate. The ventilation rate of the room can be measured by a number of ways.[3] Given the ventilation rate, it might be safe to assume that only 30% of that air is available for diluting the emissions. (This accounts for imperfect mixing in the room.) The effective amount of air available for dilution can then be compared with the amount of air required to dilute the chemical to the TLV.

Let us continue our example. Suppose that the laboratory has a volume of 75 m^3 and an air exchange rate of 2 air changes per hour. This value means that (75 m^3)(2/h)(0.3) = 45 m^3/h are available to dilute the pollutants. There may be enough margin for error to reduce the acetone concentration to a low level (5.6 m^3/h is required to reach the TLV), but use of bromine should be restricted to the hood. An assessment of the accumulative risk of several chemicals is obtained by adding the individual m/L $\left(\frac{\text{mg/h}}{\text{mg/m}^3}\right)$ values.

The m/L figures may also be used to assess the relative risk of performing the experiment outside a hood. Since m/L represents the volume of air for each student, this may be compared with the volume of air actually available for each student. If the ventilation rate for the entire laboratory is Q (in cubic meters per minute) for a section of n students meeting for t minutes, the volume for each student is kQt/n cubic meters. Here k is a mixing factor that allows for the fact that the ventilation air will not be perfectly mixed in the laboratory before it is exhausted. In a reasonable worst-case mixing situation a k value of 0.3 seems reasonable. Laboratories with modest ventilation rates supplied by

[3]Butcher, S. S.; Mayo, D. W.; Hebert, S. M.; Pike, R. M.,"Laboratory Air Quality, Part I"; *J. Chem. Educ.* **1985,** *62*, A238; and"Laboratory Air Quality, Part II"; *J. Chem. Educ.* **1985,** *62*, A261.

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15–20 linear feet of hoods can be expected to provide 30–100 m^3 per student over a 3-h laboratory period if the hoods are working properly. Let us take the figure of 50 m^3 per student as an illustration. If the value of *m/L* for a compound (or a group of compounds in a reaction) is substantially less than 50 m^3, it may be safe to do that series of operations in the open laboratory. If *m/L* is comparable to or greater than 50 m^3, a number of options are available: (1) Steps using that compound may be restricted to a hood. (2) The instructional staff may satisfy themselves that much less than the assumed value is actually evaporated under conditions present in the laboratory. (3) The number of individual repetitions of this experiment may be reduced. The size of the laboratory section can be reduced or the experiment may be done in pairs or trios.

Conducting reactions in a hood does not automatically convey a stamp of safety. Hoods are designed to keep evaporating chemicals from entering the general laboratory space. For hoods to do their job, there must be an adequate flow of air into the hood, and this air flow must not be disturbed by turbulence at the hood face. A frequently used figure of merit for hood operation is the face velocity of 100 ft/min. This is an average velocity of air entering the hood opening. (In the event that your lab does not have monitoring systems already housed within the hoods, instruments for measuring flow rate are available and can be purchased from most major equipment suppliers.) Even with a face velocity of 100 ft/min, vapors can be drawn out of an improperly designed hood simply by people walking by the opening, or by drafts from open windows.

Hood performance should be checked at regular intervals. The face velocity will increase as the front hood opening is decreased. If an adequate face velocity cannot be maintained with a front opening height of 15 cm, use of the hood for carrying out reactions will be limited. A low face velocity may indicate that the fans and ductwork need cleaning, that the exhaust system leaks (if it operates under lower than ambient pressure), or that the supply of makeup air is not adequate. When the hood system is properly maintained, the height of the hood opening required to provide an adequate face velocity is often indicated with a sticker.

Hoods are often used for storage of volatile compounds. A danger in this practice is that the hood space can become quickly cluttered, making work in the hood difficult, and the air flow may be disturbed. Of course, hoods being used for storage must never be turned off.

MICROWAVE SAFETY*

M

Scientific microwave apparatus is designed for preparative chemistry and is built with safety in mind. *Domestic (household) microwave ovens should not be used for preparative chemistry*. When employing microwave heating, all the safety precautions that are taken when performing a reaction using conventional heating should be adhered to, particularly the fact that reaction vessels can be hot and, when sealed, residual pressure needs to be released carefully at the end of the reaction. There are also some safety precautions that are specific to reactions using microwave heating:

- Adherence to the microwave manufacturer's user manual and guidelines is essential.

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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- Before running reactions in sealed vessels, it is prudent to check the reaction vessels for cracks or any other signs of damage prior to use.
- Only fill the reaction vessels to manufacturer's specifications; do not overfill the reaction vessels. An approximate "rule of thumb" is to fill the vessel to no further than half its capacity.
- Only seal a closed reaction vessel with the manufacturer's recommended cap. These caps are designed to vent and reseal in the case of an overpressurization during a reaction.
- If the cap is a twist-on type, be sure to use the appropriate tool to tighten the cap to the manufacturer-specified torque.
- It is important to monitor temperature and pressure profiles during the course of a reaction and to set safety limits before starting. A reaction mixture can be heated gradually to the set temperature or, in some cases, chemists prefer to heat up the contents as rapidly as possible. In the case of the latter, care needs to be taken to ensure that the temperature and pressure do not rise uncontrollably. As a result, it is best to use a low initial microwave power.
- Before performing a reaction at elevated temperatures, chemists should consider carefully the stability of the reagents and solvents they use at these temperatures.
- It is important to ensure efficient stirring, especially when using heterogeneous reaction mixtures and metal catalysts or reagents since localized heating can occur, resulting in some cases in melting of the vessel walls and, if under pressure, failure of the vessel.
- The stir bars used for agitation should not be of exactly 3 cm in length since this equates to ¼ wavelength of a microwave at 2450 MHz and thus acts as an antenna.
- Upon completion of a microwave run, the microwave unit will start a cooling process. In the case of the monomode microwave, the pressure sensor will release when the tube is cool enough to handle (50°C). With multimode microwave units, the apparatus is set to cool for a period of time but, at the end of this, the reaction vessels may still be hot. Check the temperature before removing the reaction vessels.
- When opening sealed vessels at the end of a reaction, be sure to point the vessel away from your face and any other person, preferably doing so in a hood. Any remaining pressure will release as soon as the cap is removed. If the tube is very warm, cool it in an ice bath before removing the cap.

CONCLUDING THOUGHTS

This brief chapter touches only a few of the important points concerning laboratory safety. The risk from vapor exposure is discussed in some detail, but other risks are treated briefly. Applications in some laboratories may involve reactions with a risk from radiation or infection or may involve compounds that are unstable with respect to explosion. The chemist must be aware of the potential risks and must be prepared to go to an appropriate and detailed source of information, as needed. The references cited here represent a small fraction of the safety data, texts, and journals available on this subject. It is highly recommended that the library and/or laboratory at your institution have at least this minimal selection. Of course, the selections should be kept up to date!

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QUESTIONS

2-1. After bookmarking a reputable MSDS URL, locate a chemical of your choice and print out the data. If the information is not available, go to your stock room and request a copy of the MSDS. Underline on the sheet the CAS No., solubility data, fire and explosion data, reactivity data, and what protective equipment is required when using this chemical. Does your laboratory meet the safety regulations required to use this chemical? Why or why not?

2-2. Think and describe what you would do in each of the following situations which could happen in your laboratory.

(a) You are working at your station and the 100-mL round-bottom flask in which you are running a reaction in ether solvent suddenly catches fire.

(b) The person working across the laboratory bench from you allows hydrogen chloride gas to escape from his or her apparatus.

(c) A reagent bottle is dropped, spilling concentrated sulfuric acid.

(d) A hot solution "bumps," splashing your face.

2-3. You are working in the laboratory using 3.0 mL of benzene in an extraction procedure. An alternative to benzene is toluene. However, three times more toluene is required to perform the extraction. The isolation of the desired product from the extraction solution requires evaporation of the solvent (benzene or toluene). This takes 0.5 h to complete. Calculate the relative risks of using these two solvents. Which solvent would you use and why?

2-4. A laboratory has four hoods; each is 39 in. wide. When the hood door is open to a height of 8 in. and the hoods are operating, the average air velocity through the hood face is 170 ft/min.

(a) Evaluate the total ventilation rate for this room, assuming that there are no other exhausts.

(b) The laboratory is designed for use by 30 students. Evaluate the air available per student if the mixing factor is 0.3 and the experiments last for 3 h.

(c) An experiment is considered in which each student would be required to evaporate 7 mL of methylene chloride (CH_2Cl_2). Estimate the average concentration of methylene chloride. Look up the TLV or the TWA for methylene chloride and consider how the evaporation might be performed.

2-5. An experiment is considered in which 1 mL of diethylamine would be used by each student. The ventilation rate for the laboratory is 5 m^3/min. Look up the TLV (or TWA) for diethylamine, $(C_2H_5)_2NH$. What restrictions might be placed on the laboratory to keep the average concentration, over a 3-h period, less than one-third of the TWA? Assume a mixing factor of 0.3.

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15. It is also recommended that one refer to the numerous articles on safety that appear regularly in the *Journal of Chemical Education* (http://jchemed.chem.wisc.edu/) and *The Chemical Educator.*

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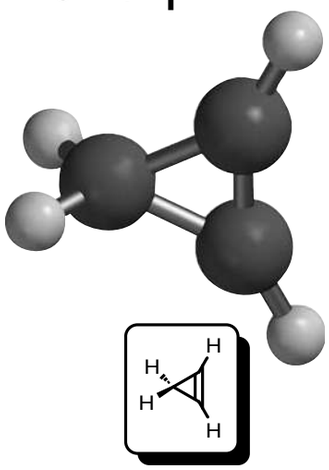

INTRODUCTION TO MICROSCALE ORGANIC LABORATORY EQUIPMENT AND TECHNIQUES

We begin this chapter with a description of the standard pieces of glassware that are generally employed in a microscale laboratory. Modern standard taper glassware is particularly convenient to use and gives the student a sense of the flavor of the research laboratory. It is not essential, however, for the experimental work in an instructional laboratory, and many courses use glassware with alternative connectors. We describe the standard taper glassware as just one example of microscale equipment that is available. The operations carried out in the laboratory will be very similar or identical if, for example, a plastic connector is used to assemble the experimental setup. We next consider a series of standard experimental apparatus setups that use this equipment, and present a short discussion of the role that they play in the laboratory. We end the chapter with a set of laws that govern how one operates in a microscale laboratory (the rules are a bit different than those for a macroscale laboratory) and a set of guidelines for recording your experimental data. The basic individual pieces of equipment are shown in Figures 3.1 to 3.7.

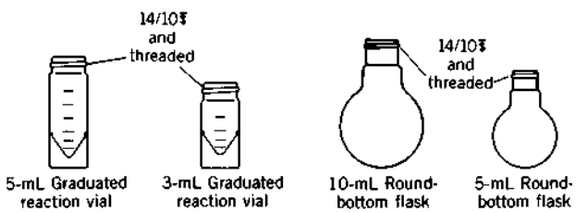

Figure 3.1 Reaction flasks.

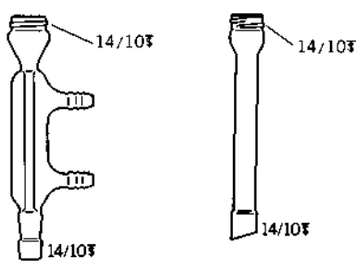

Figure 3.2 Condensers.

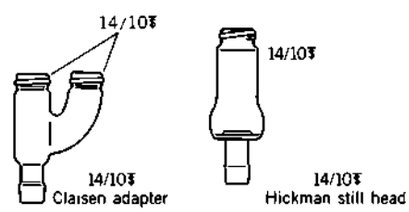

Figure 3.3 Distillation heads.

Chapter 3: C_3H_4, Cyclopropene
Demyanov and Doyarenko (1922).

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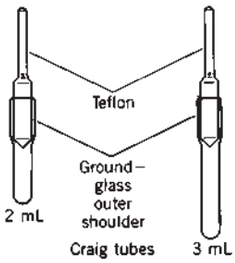

Figure 3.4 Recrystallization tubes.

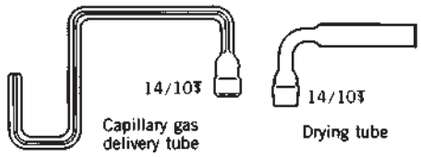

Figure 3.5 Miscellaneous items.

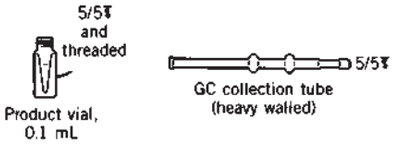

Figure 3.6 Gas chromatographic fraction collection items.

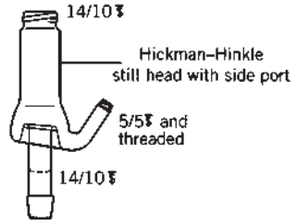

Figure 3.7 Hickman–Hinkle distillation column.

MICROGLASSWARE EQUIPMENT

Standard Taper Joints

Standard taper ground-glass joints are the common mechanism for assembling all conventional research equipment in the organic laboratory. The symbol $ is commonly used to indicate the presence of this type of connector. Normally, $ is either followed or preceded by #/#. The first # refers to the maximum inside diameter of a female (outer) joint or the maximum outside diameter of a male (inner) joint, measured in millimeters. The second number corresponds to the total length of the ground surface of the joint (Fig. 3.8). The advantage of this type of connection is that if the joint surfaces are lightly greased, a vacuum seal is achieved. One of the drawbacks of using these joints is that contamination of the reacting system readily occurs if the solvents present in the reaction vessel dissolve the grease. In small-scale reactions this contamination can be particularly troublesome.

The small joints used in the microscale experimental organic laboratory, however, have the ease of assembly and physical integrity of research-grade, standard taper, ground-glass joints along with a number of important additional features. The joint dimensions are usually $ 14/10. The conical vials in which most microscale reactions are carried out use this type of connecting system. Note that in addition to being ground to a standard taper on the inside surface of the throat of the vial, these vials also have a screw thread on the outside surface (Fig. 3.9).

This arrangement allows a standard taper male joint to be sealed to the reaction flask by a septum-type (open) plastic screw cap. The screw cap applies compression to a silicone rubber retaining O-ring positioned on the shoulder of the male joint (Fig. 3.10). The compression of the O-ring thereby achieves a greaseless gas-tight seal on the joint seam, while at the same time clamping the two pieces of equipment together. The ground joint provides both protection from intimate solvent contact with the O-ring and mechanical stability to the connection. The use of this type of connector leads to a further bonus during construction of an experimental setup. Because the individual sections are small, light, and firmly sealed together, the entire arrangement often can be mounted

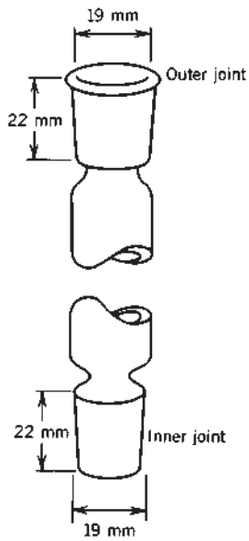

Figure 3.8 Standard taper joints ($). *(From Zubrick, James W.* The Organic Chem Lab Survival Manual, *7th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)*

Figure 3.9 Threaded female joint.

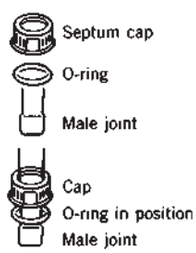

Figure 3.10 Male joint with septum cap and O-ring.

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on the support rack by a single clamp. In conventional systems it is often necessary to use at least two clamps. This can easily lead to strain in the glass components unless considerable care is taken in the assembly process. Clamp strain is one of the major sources of experimental glassware breakage. The ability to single-clamp most microscale setups effectively eliminates this problem.

NOTE. When ground-glass joint surfaces are grease free it is important to disconnect joints soon after use (particularly with basic solutions) or they may become locked or "frozen" together.

Joints of the size employed in these microscale experiments, however, are seldom a problem to separate if given proper care (*keep them clean!*).

Conical Vials

Both the conical vials (3 and 5 mL) and the round-bottom flasks are designed to be connected via an O-ring compression cap installed on the male joint of the adjacent part of the system (see Fig. 3.1).

Condensers

Two types of condensers (air condensers and water-jacketed condensers) are available; in most cases the water-jacketed condenser can work well as an air condenser. Condensers are usually attached to 14/10 $\overline{\$}$-jointed reaction flasks. The upper female joints allow connection of the condenser to the 14/10 $\overline{\$}$ drying tube and the 14/10 $\overline{\$}$ capillary gas delivery tube (see Fig. 3.2).

Distillation Heads

The simple Hickman still is used with an O-ring compression cap to carry out semi-micro simple or crude fractional distillations. The Hickman–Hinkle spinning band still uses a 3-cm fractionating column and routinely develops between five and six theoretical plates. The Hickman–Hinkle still is currently available with 14/10 $\overline{\$}$ joints and can be conveniently operated with the 14/10 $\overline{\$}$ 3- and 5-mL conical vials (see Figs. 3.1, 3.3, and 3.7). The still head is also available with an optional sidearm collection port.

Recrystallization Tubes

Craig tubes are a particularly effective method for recrystallizing small quantities of reaction products. These tubes possess a nonuniform ground joint in the outer section. The substitution of Teflon for glass in the head makes these systems quite durable and much less susceptible to breakage during centrifugation (see Fig. 3.4).

Miscellaneous Items

The Claisen head (see Fig. 3.3) is often used to facilitate the syringe addition of reagents to closed moisture-sensitive systems (such as Grignard reactions) via a septum seal in the vertical upper joint. This joint can also function to position the thermometer (using an adapter) in the well of a Hickman–Hinkle still (see Fig. 3.15). The Claisen adapter is also used to mount the drying tube in a protected position remote from the reaction chamber. The drying tube, in

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turn, is used to protect moisture-sensitive reaction components from atmospheric water vapor, while allowing a reacting system to remain unsealed. The capillary gas delivery tube is employed in transferring gases formed during reactions to storage containers (see Fig. 3.5 and Chapter 3W, Fig. 3.11W). ← www

Gas Chromatographic Fraction Collection Items

For fraction collection the gas chromatographic (GC) collection tube is connected directly to the exit port of the GC detector through a stainless steel standard taper adapter. The collected sample is then transferred to a 0.1-mL conical vial for storage. The system is conveniently employed in the resolution and isolation of two-component mixtures (see Fig. 3.6).

STANDARD EXPERIMENTAL APPARATUS

Heating and Stirring Arrangements

It is important to be able to carry out microscale experiments at accurately determined temperatures. Very often, transformations are successful, in part, because of the ability to maintain precise temperature control. In addition, many reactions require reactants to be intimately mixed to obtain a substantial yield of product. Therefore, the majority of the reactions you perform in this laboratory will be conducted with rapid stirring of the reaction mixture.

Sand Bath Technique—Hot Plate Calibration

A most convenient piece of equipment for heating or stirring or for performing both operations simultaneously on a microscale level is the hot-plate–magnetic stirrer. Heat transfer from the hot surface to the reaction flask is generally accomplished with a crystallizing dish containing a *shallow* layer of sand that can conform to the size and shape of the particular vessel employed. The temperature (external) of the system is monitored by a thermometer embedded in the sand near the reaction vessel.

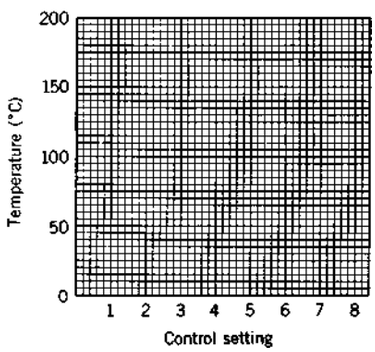

Figure 3.11 Plot your bath and/or vial temperature (°C) versus hot-plate control setting.

A successful procedure for determining the temperature inside the vial relative to the bath temperature is to mount a second thermometer in a vial containing 2 mL of high-boiling silicone oil. The vial temperature is then measured at various sand-bath temperatures and the values are entered on graphs of vial temperatures versus hot-plate settings and bath temperatures versus hot-plate settings (see Fig. 3.11 and Chapter 3W, Fig. 3.5W) for your particular hot-plate ← www system (see also section on Metal Heat-Transfer Devices, p. 22). These data will save considerable time when you bring a reaction system to operating temperature. When you first enter the laboratory, it is advisable to adjust the temperature setting on the hot-plate stirrer with the heating device, or bath, in place. The setting is determined from your control setting–temperature calibration curve. This procedure will allow the heated bath to reach a relatively constant temperature by the time it is required. You will then be able to make small final adjustments more quickly, if necessary.

NOTE. Heavy layers of sand act as an insulator on the hot-plate surface, which can damage the heating element at high temperature settings. When temperatures over 150 °C are required, it is especially important to use the minimum amount of sand.

Recording the weight of sand used and the size of the crystallizing dish will help to make the graph values more reproducible.

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The high sides of the crystallizing dish protect the apparatus from air drafts, and so the dish also operates somewhat as a hot-air bath. Heating can be made even more uniform by covering the crystallizing dish with aluminum foil (see Fig. 3.12 and Chapter 3W, Fig. 3.1W). This procedure works well, but is a bit awkward and is required in only a few instances.

The insulating properties of sand provide a readily available variable heat source because the temperature of the sand is higher deeper in the bath; thus, the depth of sand used in the bath is exceedingly important. **The depth should always be kept to a minimum, in the range of 10–15 mm.** Finally, sand baths offer a significant safety advantage over oil baths. Individual grains of sand are so small that they have little heat capacity and thus are less likely to burn the chemist in the event of a spill.

Metal Heat-Transfer Devices

An alternative to the sand bath is a heat-transfer system that employs copper tube plates or aluminum metal blocks drilled to accommodate the different reaction vials and flasks (Chapter 3W, Fig. 3.3W).

Stirring

Stirring the reaction mixture in a conical vial is carried out with Teflon-coated magnetic spin vanes, and in round-bottom flasks with Teflon-coated magnetic stirring bars (see Fig. 3.12 and Chapter 3W, Fig. 3.1W). It is important to put the reaction flask as close to the center and to the bottom surface of the crystallizing dish as possible when using magnetic stirring. This arrangement is a good practice in general, as it leads to using the minimum amount of sand needed in a sand bath.

If the reaction does not require elevated temperatures, but needs only to be stirred, the system can be assembled without the heat-transfer device (sand bath or metal plate). Some stirred reactions, on the other hand, require cooling.

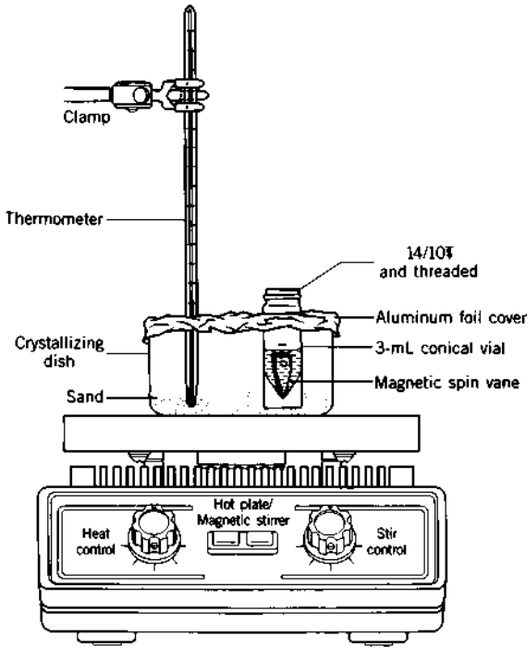

Figure 3.12 Hot-plate–magnetic stirrer with sand bath and reaction vial.

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In these cases a crystallizing dish filled with ice water, or with ice water and salt, if lower temperatures are called for, will provide the correct environment.

Reflux Apparatus

To bring about a successful reaction between two substances, it is often necessary to mix the materials together intimately and to maintain a specific temperature.The mixing operation is conveniently achieved by dissolving the materials in a solvent in which they are mutually soluble. If the reaction is carried out in solution under reflux conditions, the choice of solvent can be used to control the temperature of the reaction. Many organic reactions involve the use of a reflux apparatus in one arrangement or another.

What do we mean by *reflux?* The term means to "return," or "run back." This return is exactly how the reflux apparatus functions. When the temperature of the reaction system is raised to the solvent's boiling point (constant temperature), all vapors are condensed and returned to the reaction flask or vial; this operation is not a distillation and the liquid phase remains at a stable maximum temperature. In microscale reactions, two basic types of reflux condensers are utilized: the air-cooled condenser, or air condenser (Chapter 3W, Fig. 3.6W), and the water-jacketed condenser (see Fig. 3.13 and Chapter 3W, Fig. 3.7W). The air condenser condenses solvent vapors on the cool vertical wall of an extended glass tube that dissipates the heat by contact with the laboratory room air. This arrangement functions quite effectively with liquids boiling above 150 °C. Indeed, a simple test tube can act as a reaction chamber and air condenser all in one unit, and many simple reactions can be most easily carried out in test tubes.

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Air condensers can occasionally be used with lower boiling systems; however, the water-jacketed condenser is more often employed in these situations. The water-jacketed condenser employs flowing cold water to remove heat from the vertical column and thus facilitate vapor condensation. It is highly effective at condensing vapor from low-boiling liquids.

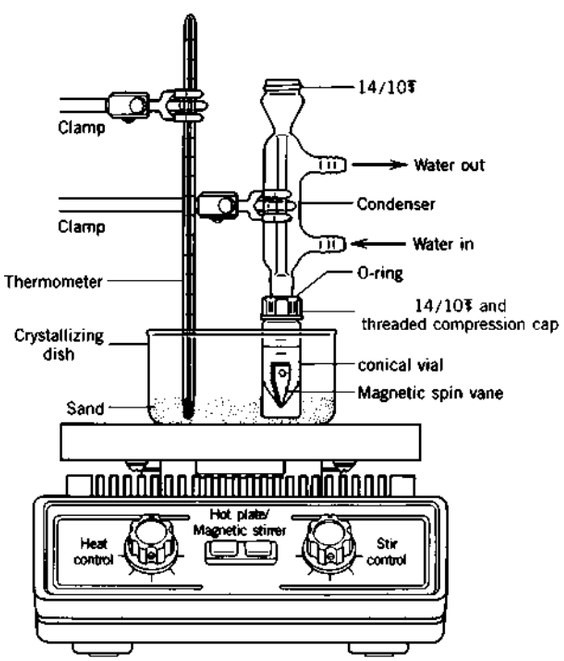

Figure 3.13 Water-jacketed condenser with conical vial, arranged for heating and magnetic stirring.

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Both styles of condensers accommodate various sizes of reaction flasks and are available with 14/10 ⅋ standard taper joints. The tops of both condenser columns have a female 14/10 ⅋ joint.

In refluxing systems that do not require significant mixing or agitation, the stirrer (magnetic spin vane or bar) usually is replaced by a "boiling stone." These sharp-edged stones possess highly fractured surfaces that are very efficient at initiating bubble formation as the reacting medium approaches the boiling point. The boiling stone acts to protect the system from disastrous boilovers and also reduces "bumping." (Boiling stones should be used only once and must **never** be added to a hot solution. In the first case, the vapor cavities become filled with liquid upon cooling, and thus a boiling stone becomes less effective after its first use. In the second case, **adding the boiling stone to the hot solution may suddenly start an uncontrollable boilover**).

Distillation Apparatus

Distillation is a laboratory operation used to separate substances that have different boiling points. The mixture is heated, vaporized, and then condensed; the early fractions of condensate are enriched in the more volatile component. Unlike the reflux operation, in distillations none, or only a portion, of the condensate is returned to the flask where vaporization is taking place. Many distillation apparatus have been designed to carry out this basic operation. They differ mainly in small features that are used to solve particular types of separation problems. In several of the microscale experiments contained in Chapters 6, 7, and 10W *semimicroscale* distillations are required. In carrying out these distillations the choice of still depends to a large degree on the difficulty of the separation required (generally, how close are the boiling points in the mixture to be separated?).

The Hickman still head (Fig. 3.14) is ideally suited for simple distillations. This system has a 14/10 ⅋ male joint for connection to conical vials or round-bottom

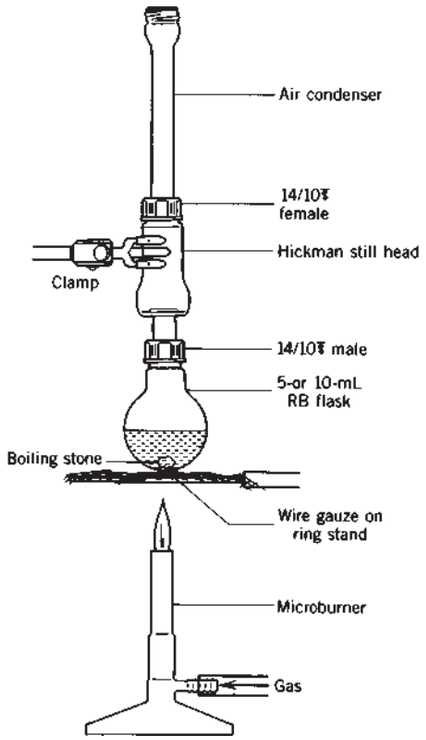

Figure 3.14 Hickman still head and air condenser with 5-mL round-bottom flask, arranged for microburner heating.

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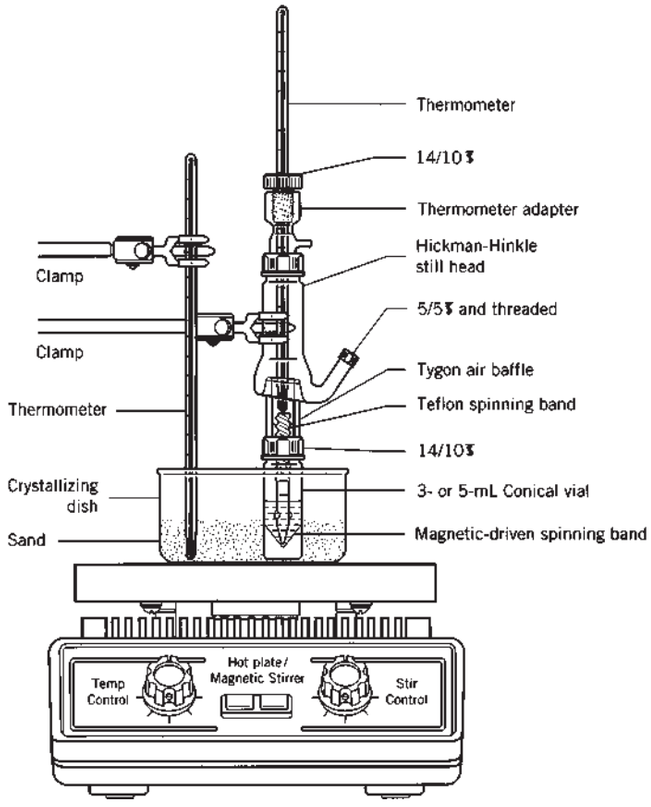

Figure 3.15 Hickman–Hinkle still head with side-port 3- or 5-mL conical vial, Teflon spinning band, and thermometer adapter and arranged for heating and magnetic stirring.

flasks. The still head functions as both an air condenser and a condensate trap. For a detailed discussion of this piece of equipment see Experiments [3A] and [3B]. The simple Hickman still has been modified (see Fig. 3.15) with a spinning band. The still continues to function in much the same way as the simple Hickman still, but a tiny Teflon spinning band is now mounted in a slightly extended section between the male joint and the collection collar. When the band is spun at 1500 rpm by a magnetic-stirring hot plate, this still functions as an effective short-path fractional distillation column (see Distillation, Experiment [3D]). In addition, this modified system has a built-in thermometer well that allows reasonably accurate measurement of vapor temperatures plus a sidearm port for removing distillate.

The most powerful microscale distillation system currently available is the 2.5-in. vacuum-jacketed microscale spinning-band distillation column (see Fig. 3.16 and Experiment [3C] for description and details). This still is designed for conventional downward distillate collection and nonstopcock reflux control. The column is rated at ~10 theoretical plates.

For a discussion of reduced pressure distillations see Distillation. www

Moisture-Protected Reaction Apparatus

Many organic reagents react rapidly and preferentially with water. *The success or failure of many experiments depends to a large degree on how well atmospheric moisture is excluded from the reaction system.* The "drying tube," which is packed with a desiccant such as anhydrous calcium chloride, is a handy way to carry out a reaction in an apparatus that is not totally closed to the atmosphere, but

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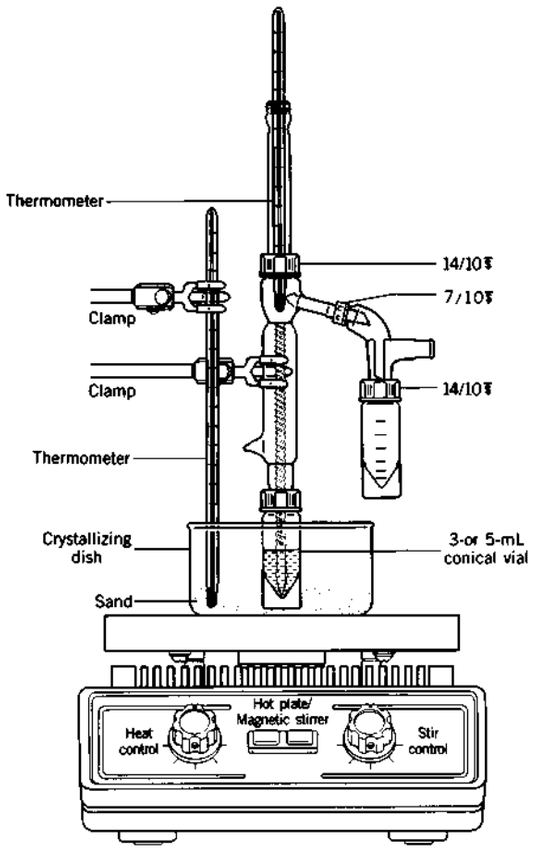

Figure 3.16 Micro spinning band distillation column (2.5 in).

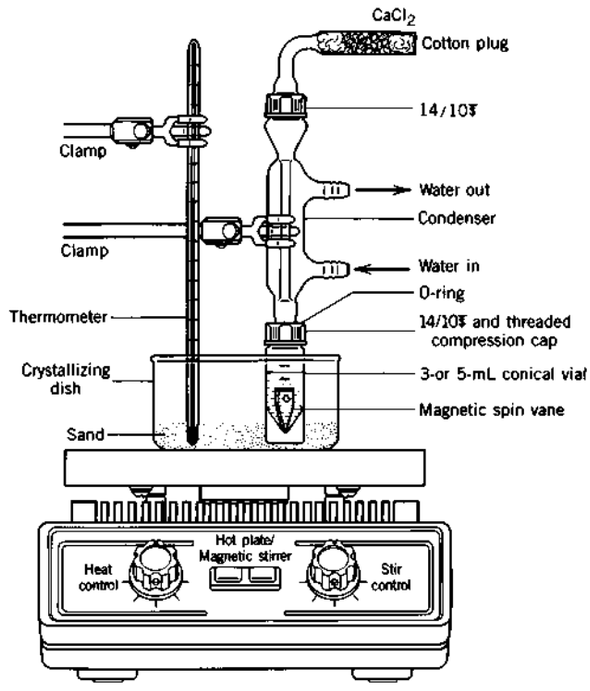

Figure 3.17 Moisture-protected water-jacketed condenser with 3- or 5-mL conical vial, arranged for heating and magnetic stirring.

that is reasonably well protected from water vapor. The microscale apparatus described here are designed to be used with the 14/10 ⅋ drying tube. The reflux condensers discussed earlier are constructed with female 14/10 ⅋ joints at the top of the column, which allows convenient connection of the drying tube if the refluxing system is moisture sensitive (see Fig. 3.17).

Because many reactions are highly sensitive to moisture, successful operation at the microscale level can be rather challenging. If anhydrous reagents are to be added after an apparatus has been dried and assembled, it is important to be able to introduce these reagents without exposing the system to the atmosphere, particularly when operating in a humid atmosphere. In room-temperature reactions that do not need refluxing, adding anhydrous reagents is best accomplished by use of the microscale Claisen head adapter. The adapter has a vertical screw-threaded standard taper joint that will accept a septum cap. The septum seal allows syringe addition of reagents and avoids the necessity of opening the apparatus to the laboratory atmosphere (see Fig. 3.18).

Specialized Pieces of Equipment

Collection of Gaseous Products. Some experiments lead to gaseous products. The collection, or trapping, of gases is conveniently carried out by using the capillary gas delivery tube. This item is designed to be attached directly to a 1- or 3-mL conical vial (see Fig. 3.19), or to the female 14/10 ⅋ joint of a condenser connected to a reaction flask or vial (Chapter 3W, Fig. 3.11W). The tube leads to the collection system, which may be a simple, inverted, graduated cylinder; a blank-threaded septum joint; or an air condenser filled with water

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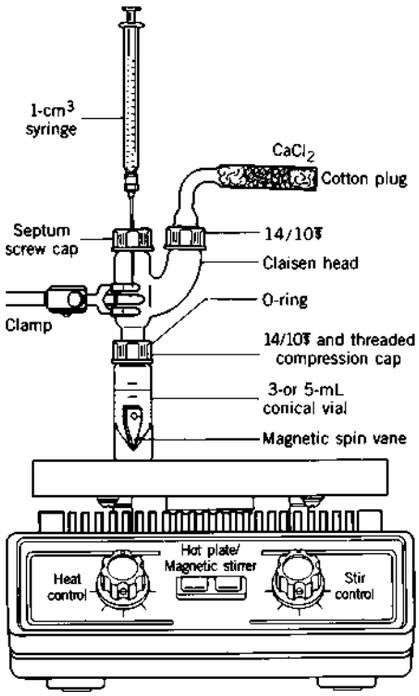

Figure 3.18 Moisture-protected Claisen head with 3- or 5-mL conical vial, arranged for syringe addition and magnetic stirring.

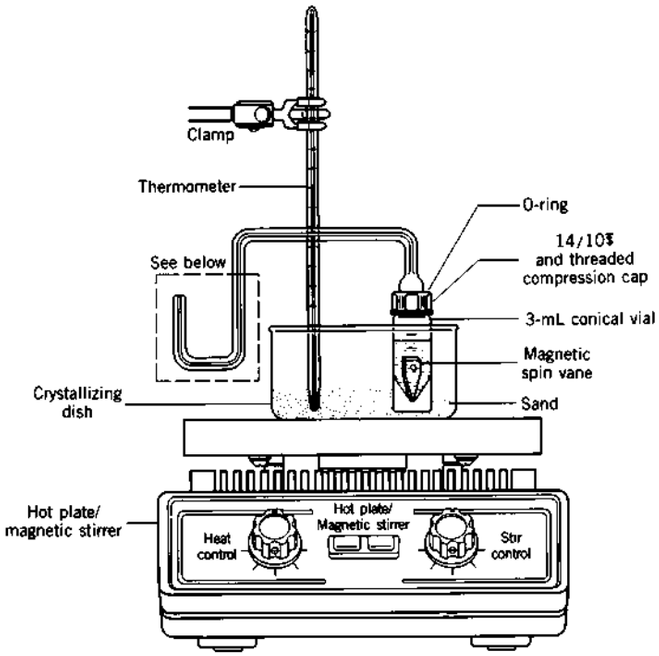

Figure 3.19 Conical vial (3-mL) and capillary gas delivery tube arranged for heating and magnetic stirring.

(if the gaseous products are not water-soluble). The 0.1-mm capillary bore considerably reduces dead volume and increases the efficiency of product transfer.

Collection of Gas Chromatographic Effluents. The trapping and collection of gas chromatographic liquid fractions become particularly important exercises in microscale experiments. When yields of a liquid product are less than 100 μL conventional distillation, even using microscale equipment, is impractical. In this case, preparative gas chromatography replaces conventional distillation as the route of choice to product purification. A number of the reaction products in Chapters 6, 7, and 10W depend on this approach for successful purification and isolation. The ease and efficiency of carrying out this operation is greatly facilitated by employing the 5/5 collection tube and the 0.1-mL 5/5 conical collection vial (Chapter 3W, Fig. 3.12W).

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MICROWAVE HEATING AS A TOOL FOR ORGANIC CHEMISTRY*

Introduction

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An appliance found in almost all homes is a microwave oven. It is possible to heat food much more quickly and easily using a microwave as compared to the stove top. The observation that microwave energy can be used to heat food

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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was first made by Percy Spencer, an employee of the Raytheon Corporation.[1] His company was a manufacturer of radar sets and, while working on one he noticed that the candy bar he had in his pocket had melted. Intrigued by this, the next day he brought in some popcorn from home and found that if he placed this near his radar set, it popped. In 1945, Raytheon filed a patent for the microwave cooking process, and in 1947 they built the first microwave oven called the Radarange.[2] It was almost 6 feet (1.8 m) high and weighed over 750 pounds (340 kg) and cost between $2,000 and $3,000.[3] The first popular home model was launched in 1967, and current estimates suggest that over 200 million microwave ovens are in use throughout the world today.[4]

Just as microwave ovens prove so valuable in the kitchen, it is also possible to use similar technology in preparative chemistry. It was in 1986 that the first reports of microwave heating as a tool for organic chemistry appeared in the scientific literature.[5,6] Two research groups published results they had obtained in their laboratories using kitchen microwave ovens. They said that chemistry that usually takes hours to reach completion using conventional heating could be performed in a matter of minutes in a microwave oven. Since these first reports, the use of microwave heating in organic chemistry has grown rapidly. Today, the technology is used in industry and academic laboratories for performing a wide range of reactions. Microwave heating has opened up a range of new areas in organic chemistry, allowing chemists to perform reactions quickly and easily. As an example, in this book Experiment 7, the Cannizzaro reaction, is performed in *one hour* using conventional heating. In the microwave protocol, the reaction is complete *in just one minute*.

The use of microwave heating addresses a number of the green chemistry principles.[7] Since it is often possible to obtain higher yields using microwave heating as opposed to conventional heating, there will be less waste and unused reagents. Also, since microwave heating is fast, there is often not enough time for products to decompose so this makes the product purification cleaner and easier. Chemists have also used the inherent advantages of microwave heating to their advantage for developing cleaner alternatives to known reactions. Take, for example, the use of water as a solvent instead of organics such as dichloromethane and benzene. Work has shown that water is an excellent solvent for organic chemistry, especially when combined with microwave heating. It is possible to heat water well above its boiling point in a sealed reaction vessel very safely and efficiently using microwaves. At these higher temperatures, water behaves more like an organic solvent. While most organic compounds are not soluble in water at room temperature, they can be in this higher temperature water, or at least partly so. This means that reactions can take place and, when the mixture cools down at the end, the product crystallizes out and is easily removed. As well as allowing for a more environmentally friendly solvent to be used, it also makes purification easy.

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[1] *Reader's Digest*, August 1958, page 114.
[2] Spencer, P. L. 1945. Method of treating foodstuffs. US Patent 2,495,429, filed October 5, 1945, and published January 24, 1950.
[3] Gallawa, J. C. *Complete Microwave Oven Service Handbook: Operation, Maintenance, Troubleshooting, and Repair.* Prentice Hall, 2000.
[4] US Bureau of Labor Statistics.
[5] Gedye, R.; Smith, F.; Westaway, K.; Ali, H.; Baldisera, L.; Laberge, L.; and Rousell, J. "The Use of Microwave Ovens for Rapid Organic Synthesis," *Tetrahedron Lett.* **1986,** *27,* 279.
[6] Giguere, R. J.; Bray, T. L.; Duncan, S. M.; and Majetich, G. "Application of Commercial Microwave Ovens to Organic Sysnthesis," *Tetrahedron Lett.* **1986,** *27,* 4945.
[7] Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*; Oxford University Press, New York, 1998.

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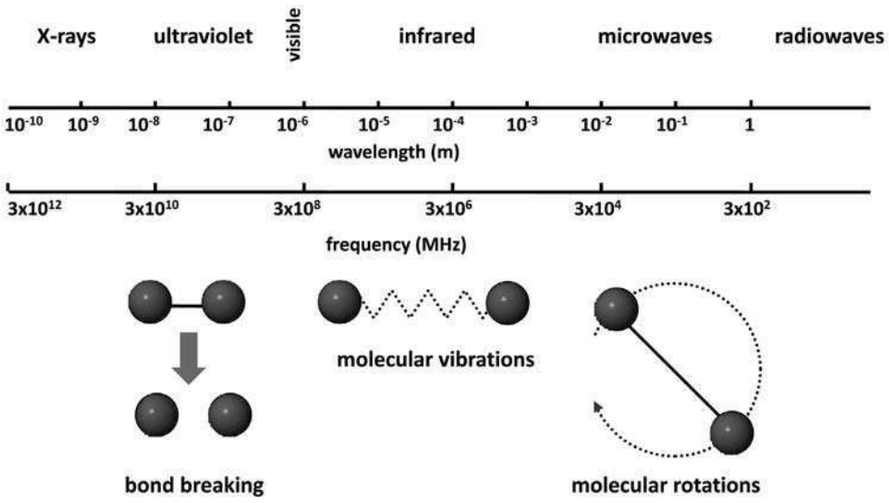

Figure 3.20 The electromagnetic spectrum.

Before looking at applications in organic chemistry, it is important to appreciate some of the physical chemistry concepts behind microwave heating. The microwave region of the electromagnetic spectrum (Fig. 3.20) is classified as that between 300 and 300,000 megahertz (MHz). Compared to ultraviolet, infrared, and visible light, microwave irradiation is of relatively low energy. As a result, microwaves are not high enough in energy to break chemical bonds. Instead they can only make molecules rotate. This is very different from the more energetic ultraviolet radiation which, when it interacts with molecules, can break bonds, giving rise to the area of chemistry known as photochemistry.

Both home and scientific microwave equipment operates at 2,450 MHz. Interestingly, the microwave region of the electromagnetic spectrum is also used for navigation, communication, and remote sensing purposes. This includes technologies such as global positioning systems, wireless Internet, and Bluetooth as well as radar. As a result, the frequency used in microwave ovens has to be different from those used for these other applications and so is strictly regulated.

Microwaves, like all electromagnetic energy, move at the speed of light and comprise oscillating electric and magnetic fields (Fig. 3.21). These components oscillate at right angles to each other and to the direction of propagation.

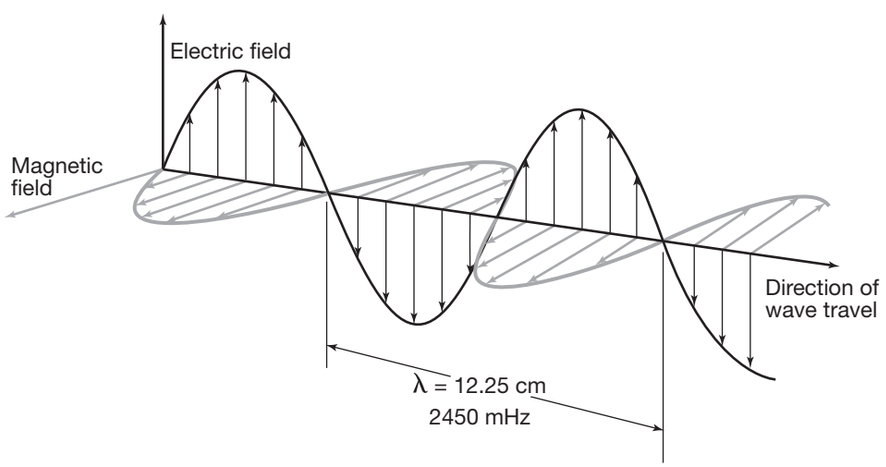

Figure 3.21 Microwave energy comprises electric and magnetic fields.

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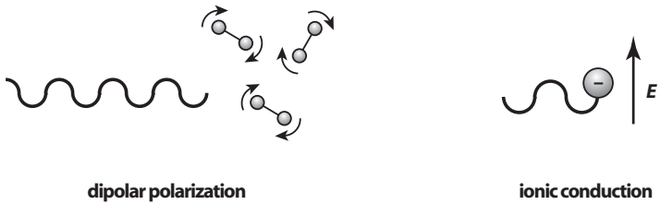

Figure 3.22 The two mechanisms by which microwave energy leads to heating.

There are two ways that microwaves can heat a sample, both involving the interaction of molecules in the sample with the electric field of the microwave irradiation (Fig. 3.22).

If a molecule possesses a dipole moment, then when it is exposed to microwave irradiation, the dipole tries to align with the applied electric field. Since the electric field is oscillating, the dipoles constantly try to realign to follow this. Molecules have time to align with the electric field but not to follow the oscillating field exactly. This continual reorientation of the molecules results in friction and thus heat. This heating method is termed dipolar polarization. If a molecule is ionic, then the electric field component of the microwave irradiation moves the ions back and forth through the sample also colliding them into each other. This movement again generates heat and is termed ionic conduction.

Conventionally, in order to heat reaction mixtures, chemists tend to use a hot plate or sand bath. These can be relatively slow and inefficient ways of transferring heat into a sample because they depend on convection currents and the thermal conductivity of the reaction mixture. Also, the walls of the reaction vessel can be hotter than the contents, thus introducing a thermal gradient. This can mean that reagents or products can be decomposed over time because they sit on the walls of the vessel. When using microwave heating, since the energy interacts with the sample directly, heating can be much more effective. In addition, microwave heating is safer than conventional heating; there are no sand baths or hot plates that can burn the chemist.

Each solvent or reagent in a reaction mixture will interact with microwave energy differently. Although not the only factor in determining the absorbance of microwave energy, the polarity of the solvent is a helpful tool for determining how well it will heat when placed into a microwave field; more polar molecules are affected more and nonpolar less. Solvents can be split into three categories; namely, those that absorb microwaves well, moderately, and poorly (Fig. 3.23). High-absorbing solvents will heat up very fast

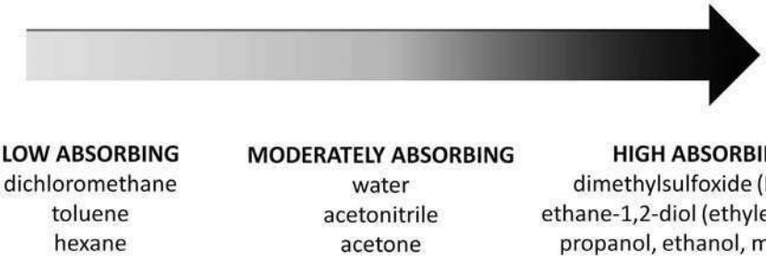

Figure 3.23 The heating characteristics of common solvents.

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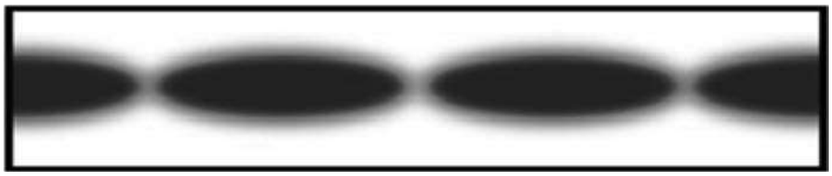

Figure 3.24 Areas of high and low microwave energy are found in the cavity of a multimode microwave unit.

upon microwave irradiation. Lower-absorbing solvents can still be used, but work better if one of the reagents in the reaction mixture is itself a good absorber. Interestingly, water absorbs more weakly than methanol while it is considerably more polar. This can be attributed, at least in part, to that fact that the strong, extensive hydrogen bonding in water goes some way to restricting rotation of molecules when irradiated with microwaves.

Electric power is turned into microwave energy using a magnetron, this in essence being a high-voltage tube in which electrons generated from a heated cathode are affected by magnetic and electric fields in such a way as to produce microwave radiation. As the microwaves come into the cavity (heating chamber) of a home microwave unit, they will move around and bounce off the walls. As they do so, they will generate pockets (called modes) of high energy and low energy as the moving waves either reinforce or cancel out each other (Fig. 3.24). This means that the microwave field in the microwave cavity is not uniform. Instead, there will be hot spots and cold spots; these correspond to the pockets of high and low energy, respectively. Domestic microwave ovens are therefore called "multimode" microwave ovens.

While home microwave ovens are useful for heating food, performing chemical reactions using them presents a number of challenges. They have no accurate temperature measurement device; the microwave field inside the oven is not uniform; and they are not safe for containing hot, flammable, organic solvents. These problems have led to the need for scientific microwave apparatus, specifically designed for performing chemical reactions safely and reliably. Scientific multimode microwave units have been developed for use in preparative chemistry (Fig. 3.26*b*). As well as being built to withstand explosions of reaction vessels inside the microwave cavity, temperature and pressure monitoring has been introduced as is the ability to stir reaction mixtures. It is possible to run a number of reactions at the same time in a multimode microwave oven, the samples being placed into tubes and loaded onto a turntable. As the samples move around, because they are large enough to absorb the microwave energy effectively, heating is fairly uniform.

When performing reactions on a small scale, it is sometimes difficult to heat the small volumes of reagents effectively in a multimode microwave apparatus. This is because, with the hot and cold spots that occur in the cavity of a multimode apparatus, it is hard to get constant microwave energy to irradiate the small sample. To overcome these problems, a smaller, single-mode (often called monomode) microwave apparatus has been developed. The cavity of a monomode microwave apparatus is designed for the length of only one wave (mode) (Fig. 3.25). By placing the sample in the middle of the cavity it can be irradiated constantly with microwave energy. Using a monomode apparatus, it is possible to heat samples of as little as 0.2 mL very effectively. The upper volume limit of the monomode apparatus is determined by the size of the microwave cavity and is in the region of 100 mL (Fig. 3.26*a*).

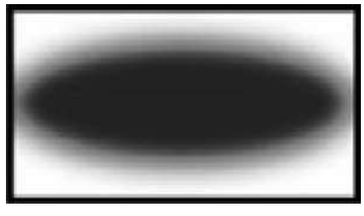

Figure 3.25 The cavity of a monomode microwave unit is designed to fit just one mode.

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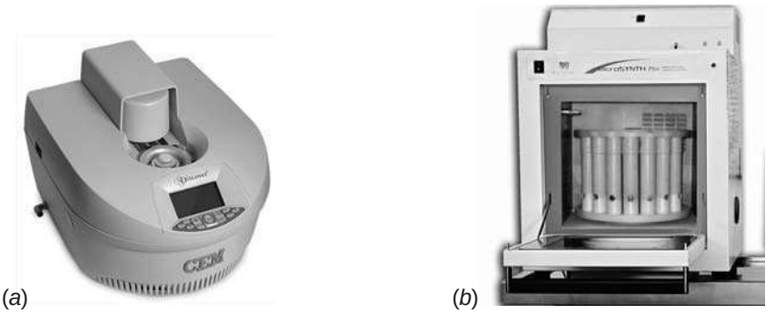

(*a*) (*b*)

Figure 3.26 (a) A monomode microwave unit (reproduced with permission from CEM Corporation) and (b) a multimode microwave unit (reproduced with permission from Milestone srl).

Applications

Many organic reactions require heat in order to proceed. In the lab, this is traditionally done using a hot plate, steam, oil or sand bath or, before that, a Bunsen burner. For those reactions that do require heat, the problem is that these heating sources are inefficient and reactions can often take a long time to reach completion. By using microwave heating, reaction times can be dramatically reduced and product yields can be higher. Shortening the time of known reactions is not the only advantage that microwave heating is having. It is impacting modern organic chemistry by opening up avenues to compounds that were previously not accessible. It is also a cleaner way to do preparative chemistry. Almost any reaction that needs heat can be performed in a microwave (Fig. 3.27). There are a few exceptions, including those that are known to be highly exothermic.

Microwave heating has proven particularly useful in the pharmaceutical industry where compounds need to be made rapidly so they can be screened for activity as drug candidates. In an interesting experiment undertaken by Boehringer Ingelheim Pharmaceuticals, the exact amount of time saved using microwave as opposed to conventional heating was determined.[8] Two

oxidation	*rearrangements*
reduction	*ester and amide synthesis*
substitution	*ring-forming*
addition	*heterocycle synthesis*
cycloadditions	*metal-catalyzed processes*

Figure 3.27 Some classes of organic reaction that can be performed using microwave heating.

[8] "Timesavings associated with microwave-assisted synthesis: A quantitative approach", C. R. Sarko in *Microwave Assisted Organic Synthesis* edited by J. P. Tierney and P. Lidstrom, Blackwell Publishing, Oxford, 2005.

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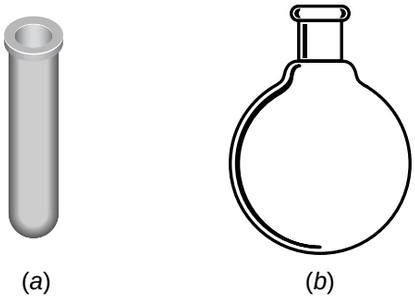

Figure 3.28 Reactions can be performed using either a sealed tube or an open, round-bottom flask.

scientists were told to make a series of compounds. One of them used microwave chemistry and the other used conventional methods. Both scientists were given the same preparative route to the molecules to follow. However, after 37 days the chemist using the conventional heating approach concluded that the molecules could not be generated using that route. The microwave chemist on the other hand optimized reaction conditions and produced the final products in two days.

Many reactions utilizing microwave heating have been performed in sealed vessels (Fig. 3.28*a*). These are tubes of varying sizes that can be sealed with a specially designed stopper. Reaction mixtures can then be heated to temperatures well above the boiling point of the solvent inside. This offers a very safe way to perform chemistry at high temperatures and pressures. It is much more convenient than the steel containers used traditionally for this sort of chemistry. Also, it is possible to monitor the temperature and pressure of reaction mixtures very closely, and this means it is possible to report the exact reaction conditions used so that others can use them.

Another option is to use standard laboratory glassware in a microwave. Reactions can be run in round-bottomed flasks equipped with a reflux condenser (Fig. 3.28*b*). The flask sits inside the microwave cavity, and the reflux condenser comes out through the top of the apparatus. Often, just as good results can be obtained using an open vessel arrangement as compared to a sealed tube.

When using a monomode microwave unit, it is possible to perform reactions using sealed tubes of capacity ranging from 0.2–25 mL and open vessels ranging from 10–100 mL. Reactions are performed one at a time. When using sealed tubes, it is possible to automate the unit using robotics so that when one reaction is complete, the tube can be removed from the microwave and the next one put in. This allows for multiple reactions to be performed without the need for the operator to be present. Up to 60 reaction vessels can be lined up and run one after another.

Multimode microwave units can process multiple reaction vessels at the same time. The sealed vessels all sit in a holder (reaction carousel) that fits into the microwave cavity. Working on a scale of up to a few grams, it is possible to process up to 40 reaction vessels at a time. Up to 92 reactions can be run at a time when using microscale quantities of reagents. Another option possible when working in multimode microwave unit is to use one large reaction vessel. This can either be a larger sealed vessel (up to 1 L in volume) or an open round-bottom flask (up to 5 L in volume). This enables chemists to scale up their reactions to make more of their desired compound.

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Equipment Available

There are a number of commercially available scientific microwave units. The four major microwave manufacturers are listed here:

Anton Paar is an Austrian company that manufactures a multimode microwave unit called the Synthos 3000. There are a number of reaction carousels that are available with the unit, allowing for reactions to be performed from the microliter scale up to 100 mL. On the small scale, reactions are run in specially designed silicon carbide plates with either 24 or 48 wells. Using plates made from this inert, highly microwave-absorbing material allows for equal heating of all the wells. Larger reactions are performed in glass or quartz tubes sealed with a specially designed stopper.

Biotage, a company based in Sweden, manufactures a monomode microwave unit called the Initator. Using this instrument, it is possible to run reactions on scales from 0.2–20 mL in sealed tubes. It is possible to automate the unit with a robotic arm, thus allowing up to 60 reactions to be run sequentially.

CEM Corporation, a company based in North Carolina, manufactures a range of microwave units. Its monomode microwave apparatus is called the Discover platform. A number of variants are available. It is possible to run reactions from 0.5–60 mL in sealed tubes using this unit, as well as open round-bottom flasks up to 125 mL in capacity. It is possible to automate the unit, allowing reactions to be run sequentially. In addition, an accessory is available for loading reaction vessels with reactive gases such as hydrogen and carbon monoxide, opening the door for performing a wide range of reactions otherwise not possible using microwave heating. CEM also manufactures a multimode microwave unit called the MARS. There are a number of reaction carousels accommodating sealed tubes that can be used with the unit. In addition, open round-bottom flasks up to 5 L in capacity can be placed into the microwave cavity and standard reflux glassware attached. This allows for scale-up of reactions using batch processing.

Milestone, a company based in Italy, manufactures a number of microwave units. The MultiSYNTH has the capability to act as both a monomode and a multimode microwave unit. This means that conditions can be optimized in a small sealed tube using the monomode functionality and then a series of up to 12 small or 6 larger reactions can run in parallel in multimode. The unit can also accommodate a round-bottom flask of capacity up to 1 L, allowing a reaction to be performed at atmospheric pressure. The MicroSYNTH platform is a multimode microwave unit. There are a number of reaction carousels that can be used, allowing for reactions to be performed in parallel using either glass, Teflon, or quartz tubes. In addition, open round-bottom flasks can be placed into the microwave cavity and standard reflux glassware attached.

All the modern scientific microwave units have the capability to measure temperature during the course of a reaction. This can be done remotely using an infrared sensor located in the wall or the bottom of the microwave cavity. In many cases it is also possible to record the temperature inside a reaction vessel using a fiber-optic probe or thermocouple. Pressure measurement is also possible in many cases. The contents of a reaction mixture can be stirred by means of a magnetic stir plate located beneath the microwave cavity and a Teflon stir bar in the vessel.

When running a reaction, key parameters such as temperature, pressure, and microwave power can be measured throughout the run and data saved to

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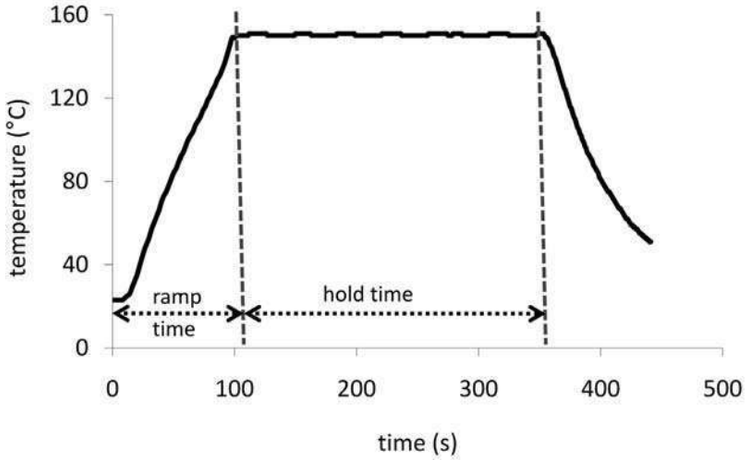

Figure 3.29 Example of a heating profile for a reaction performed using microwave heating.

a computer for use in reports and for reproducing the conditions at a later date (Fig. 3.29). Generally, when programming a protocol into a microwave unit, there are two important stages. The first is entering the ramp time. This is the time that the user wants the microwave to take to reach the target temperature. The second is entering the hold time. This is the time that the user wants the reaction mixture to remain at the target temperature before cooling back to room temperature. The microwave unit will use the requisite microwave power to heat the reaction mixture to temperature and then the power will automatically fluctuate to hold the reaction at the set temperature.

Experimental Protocols

Experimental protocols using microwave heating have been added to Experiments 7, 8, 15, 22, and 30. The experiments in this book can be performed on a range of these commercially available microwave units. The procedures are split into two classes; the first is generally for use with monomode microwave apparatus (Biotage Initiator and CEM Discover) and the second for use with multimode microwave units (Anton Paar Synthos 3000, CEM MARS, and Milestone MicroSYNTH). A modified version of the monomode procedure for use with the Anton Paar Synthos 3000 in conjunction with the silicon carbide plate format for microscale chemistry is added as a footnote in the monomode protocol.

MICROSCALE LAWS

Rules of the Trade for Handling Organic Materials at the Microscale Level

Now that we have briefly looked at the equipment we will be using to carry out microscale organic reactions, let us examine the specific techniques that are used to deal with the small quantities of material involved. Microscale synthetic organic reactions, as defined by Cheronis,[9] start with 15–150 mg of the

[9]Cheronis, N. D. *Semimicro Experimental Organic Chemistry*; Hadrion Press: New York, 1958.

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limiting reagent. These quantities sound small, and they are. Although 150 mg of a light, powdery material will fill half a 1-mL conical vial, you will have a hard time observing 15 mg of a clear liquid in the same container, even with magnification. This volume of liquid, on the other hand, is reasonably easy to observe if it is in a 0.1-mL conical vial. A vital part of the game of working with small amounts of materials is to become familiar with microscale techniques and to practice them as much as possible in the laboratory.

Rules for Working With Liquids at the Microscale Level

1. Liquids are never poured at the microscale level. Liquid substances are transferred by pipet or syringe. As we are working with small, easy-to-hold glass-ware, the best way to transfer liquids is to hold both containers with the fingers of one hand, with the mouths as close together as possible. The free hand is then used to operate the pipet (syringe) to withdraw the liquid and make the transfer. This approach reduces to a minimum the time that the open tip is not in, or over, one vessel or the other. We use three different pipets and two standard syringes to perform most experiments involving liquids. **This equipment can be a prime source of contamination.** Be very careful to thoroughly clean the pipets and syringes after each use.

a. Pasteur pipet (often called a capillary pipet). A simple glass tube with the end drawn to a fine capillary. These pipets can hold several milliliters of liquid (Fig. 3.30*a*) and are filled using a small rubber bulb or one of the very handy, commercially available pipet pumps. Because many transfers are made with Pasteur pipets, it is suggested that several of them be calibrated for approximate delivery of 0.5, 1.0, 1.5, and 2.0 mL of liquid. This calibration is easily done by drawing the measured amount of a liquid from a graduated cylinder and marking the level of the liquid in the pipet. This mark can be made with transparent tape, or by scratching with a file. Indicate the level with a marking pen before trying to tape or file the pipet.

b. Pasteur filter pipet. A very handy adaptation of the Pasteur pipet is a filter pipet. This pipet is constructed by taking a small cotton ball and placing it in the large open end of the standard Pasteur pipet. Hold the pipet vertically and tap it gently to position the cotton ball in the drawn section of the tube (Fig. 3.30*b*). Now form a plug in the capillary section by pushing the cotton ball down the pipet with a piece of copper wire (Fig. 3.30*c*). Finish by seating the plug flush with the end of the capillary (Fig. 3.30*d*). The optimum-size plug will allow easy movement along the capillary while it is being positioned by the copper wire. Compression of the cotton will build enough pressure against the walls of the capillary (once the plug is in position) to prevent the plug from slipping while the pipet is filled with liquid. If the ball is too big, it will wedge in the capillary before the end is reached, and wall pressure will be so great that liquid flow will be shut off. Even some plugs that are loose enough to be positioned at the end of the capillary will still have developed sufficient lateral pressure to make the filling rate unacceptably slow. If the cotton filter, however, is positioned too loosely, it may be easily dislodged from the pipet by the solvent flow. These

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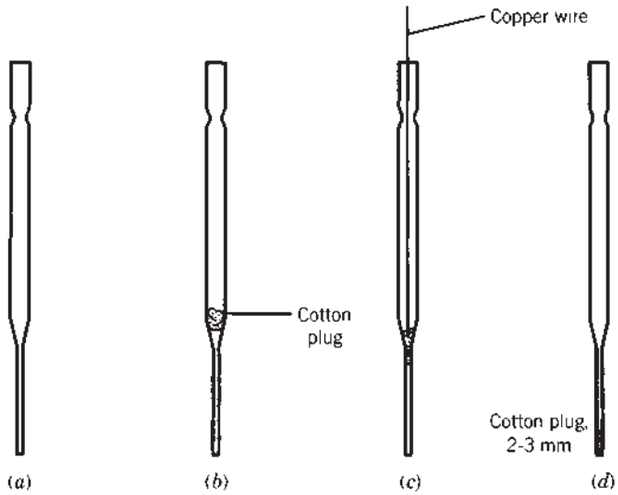

Figure 3.30 Preparation of Pasteur filter pipet.

plugs can be quickly and easily inserted with a little practice. Once in place, the plug is rinsed with 1 mL of methanol and 1 mL of hexane, and dried before use.

There are two reasons for placing the cotton plug in the pipet. First, it solves a particular problem with the transfer of volatile liquids via the standard Pasteur pipet: the rapid buildup of back pressure from solvent vapors in the rubber bulb. This pressure quickly tends to force the liquid back out of the pipet and can cause valuable product to drip on the bench top. The cotton plug tends to resist this back pressure and allows much easier control of the solution once it is in the pipet. The time-delay factor becomes particularly important when the Pasteur filter pipet is employed as a microseparatory funnel (see the discussion on extraction techniques in Technique 4, p. 67).

Second, each time a transfer of material is made, the material is automatically filtered. This process effectively removes dust and lint, which are constant problems when working at the microscale level. A second stage of filtration may be obtained by employing a disposable filter tip on the original Pasteur filter pipet as described by Rothchild.[10]

c. Automatic pipet (considered the Mercedes–Benz of pipets). Automatic pipets quickly, safely, and reproducibly measure and dispense specific volumes of liquids. These pipets are particularly valuable at the microscale level, because they generate the precise and accurate liquid measurements that are absolutely necessary when handling only microliters of a liquid. The automatic pipet adds considerable insurance for the success of an experiment, since any liquid can be efficiently measured, transferred, and delivered to the reaction flask.

The automatic pipet consists of a calibrated piston pipet with a specially designed disposable plastic tip. It is possible to encounter

[10]Rothchild, R. *J. Chem. Educ.* **1990,** *67,* 425.

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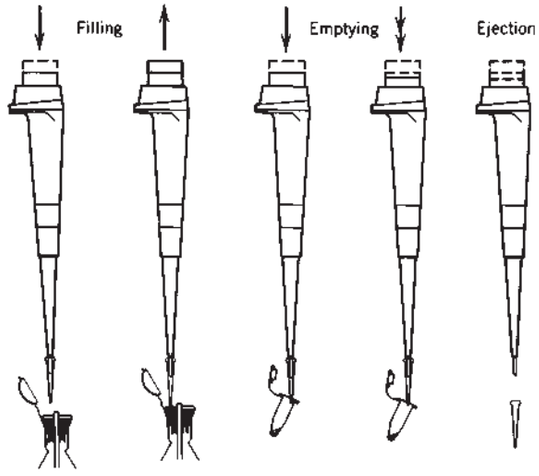

Figure 3.31 Operation of automatic delivery pipet.

any one of three pipet styles: single volume, multirange, or continuously adjustable (see Fig. 3.31). The first type is calibrated to deliver only a single volume. The second type is adjustable to two or three predetermined delivery volumes. The third type is the most versatile; it can be set by the user to deliver any volume within the range of the pipet. Obviously, the price of these valuable laboratory tools goes up with increasing features. Automatic pipets are expensive, and usually must be shared in the laboratory. Treat them with respect!

The automatic pipet is designed so that the liquid comes in contact only with the disposable tip.

- Never load the pipet without the tip in place.
- Never immerse the tip completely in the liquid that is being pipetted.
- Always keep the pipet vertical when the tip is attached.
- If an air bubble forms in the tip during uptake, return the liquid, discard the tip, and repeat the sampling process.

If these three rules are followed, most automatic pipets will give many years of reliable service. A few general rules for improving reproducibility with an automatic pipet should also be followed:

- Try to use the same uptake and delivery motion for all samples. Smooth depression and release of the piston will give the most consistent results. Never allow the piston to snap back.
- *Always* depress the piston to the first stop before inserting the tip into the liquid. If the piston is depressed after submersion, formation of an air bubble in the tip becomes likely, which will result in a filling error.
- *Never* insert the tip more than 5 mm into the liquid. It is good practice not to allow the body of the pipet to contact any surface, or bottle neck, that might be wet with a chemical.
- If an air bubble forms in the tip during uptake, return the fluid, discard the tip, and repeat the sampling process.

d. Syringes. Syringes are particularly helpful for transferring liquid reagents or solutions to sealed reaction systems from sealed reagent or solvent reservoirs. Syringe needles can be inserted through a

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septum, which avoids opening the apparatus to the atmosphere. Syringes are also routinely employed in the determination of ultramicro boiling points (10-μL GC syringe). It is critically important to clean the syringe needle after each use. Effective cleaning of a syringe requires as many as a dozen flushes. For many transfers, the microscale laboratory uses a low-cost glass 1-mL insulin syringe in which the rubber plunger seal is replaced with a Teflon seal (ACE Glass). For preparative GC injections, the standard 50- or 100-μL syringes are preferred (see Technique 1).

2. Liquid volumes may be converted easily to mass measures by the following relationship:

$$\text{Volume (mL)} = \frac{\text{mass (g)}}{\text{density (g/mL)}}$$

3. Work with liquids in conical vials, and work in a vial whose capacity is approximately twice the volume of the material it needs to hold. The trick here is to reduce the surface area of the flask in contact with the sample to an absolute minimum. A conical vial is thus better than the spherical surface of the conventional round-bottom flask.

Liquids may also be weighed directly. A tared container (vial) should be used. After addition of the liquid, the vial should be kept capped throughout the weighing operation. This procedure prevents loss of the liquid by evaporation. If the density of the liquid is known, the approximate volume of the liquid should be transferred to the container using an automatic delivery pipet or a calibrated Pasteur pipet. Use the above expression relating density, mass, and volume to calculate the volume required by the measured mass. Adjustment of the mass to give the desired value can then be made by adding or removing small amounts of liquid from the container by Pasteur pipet.

NOTE. Before you leave the balance area, be sure to replace all caps on reagent bottles and clean up any spills. A balance is a precision instrument that can easily be damaged by contamination.

Rules for Working With Solids at the Microscale Level

1. General considerations. Working with a crystalline solid is much easier than working with the equivalent quantity of a liquid. Unless the solid is in solution, a spill on a clean glass working surface usually can be recovered quickly and efficiently. *Be careful, however, when working with a solution. Treat solutions as you would a pure liquid.*

2. Transfer of solids. Solids are normally transferred with a microspatula, a technique that is not difficult to develop.

3. Weighing solids at the milligram level. Electronic balances can automatically tare an empty vial. Once the vial is tared, the reagent is added in small portions. The weight of each addition is instantly registered; material is added until the desired quantity has been transferred.

Solids are best weighed in glass containers (vials or beakers), in plastic or aluminum weighing trays (“boats”), or on glazed weighing paper. Filter paper or other absorbent materials are not good choices: small quantities of the weighed material will often stick to the fibers of the paper, and vice versa.

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THE LABORATORY NOTEBOOK

Writing is the most important method chemists use to communicate their work. It begins with the record kept in a laboratory notebook. An experiment originally recorded in the laboratory notebook can become the source of information used to prepare scientific papers published in journals or presented at meetings. For the industrial chemist, these written records are critical in obtaining patent coverage for new discoveries.

It is important that you learn to keep a detailed account of your work. A laboratory notebook has several key components. Note how each component is incorporated into the example that follows.

Key Components of a Laboratory Experiment Write-up

1. Date experiment was conducted
2. Title of experiment
3. Purpose for running the reaction
4. Reaction scheme
5. Table of reagents and products
6. Details of procedure used
7. Characteristics of the product(s)
8. References to product or procedure (if any)
9. Analytical and spectral data
10. Signature of person performing the experiment and that of a witness, if required

In reference to point 6, it is the obligation of the person doing the work to list the equipment, the amounts of reagents, the experimental conditions, and the method used to isolate the product. Any color or temperature changes should be carefully noted and recorded.

Several additional points can be made about the proper maintenance of a laboratory record.

11. A hardbound, permanent notebook is essential.
12. Each page of the notebook should be numbered in consecutive order. For convenience, an index at the beginning or end of the book is recommended and pages should be left blank for this purpose.
13. If a page is not completely filled, an "X" should be used to show that no further entry was made.
14. Data are always recorded directly into the notebook, *never* on scrap paper! Always record your data in ink. If a mistake is made, draw a neat line through the word or words so that they remain legible. Do not completely obliterate anything; you might learn from your mistakes, if you can read them later.
15. Make the record clear and unambiguous. Pay attention to grammar and spelling.
16. In industrial research laboratories, your signature, as well as that of a witness, is required, because the notebook may be used as a legal document.

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17. Always write and organize your work so that someone else could come into the laboratory and repeat your directions without confusion or uncertainty. *Completeness* and *legibility* are key factors.

Most of you are newcomers to the organic laboratory, and the reactions you will be performing have probably been worked out and checked in detail. Because of this, your instructor may not require you to keep your notebook in such a meticulous fashion. For example, when you describe the procedure (item 6), it may be acceptable to make a clear reference to the material in the laboratory manual and to note any modifications or deviations from the prescribed procedure. In some cases, it may be more practical to use an outline method. In any event, the following example should be studied carefully. It may be used as a reference when detailed records are important in your work. It is more important to record what you observed and what you actually did, than to record what you were supposed to observe and what you were supposed to do.

NOTE. Because of its length, the example here is typed. Notebooks are usually handwritten. Many chemists, however, now use computers to record their data.

The circled numbers refer to the list on p. 40

EXAMPLE OF A LABORATORY NOTEBOOK ENTRY

① 19 July 2009

② PREPARATION OF DIPHENYL SUCCINATE

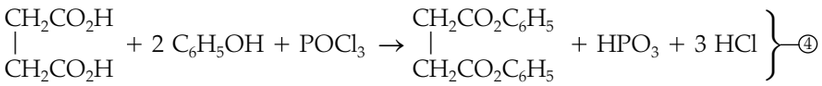

④

Diphenyl succinate is being prepared as one of a series of dicarboxylic acid esters that are to be investigated as growth stimulants for selected fungi species. ③

This procedure was adapted from that reported by Daub, G. H., and Johnson, W. S. *Organic Syntheses,* Wiley: New York, 1963; Collect. Vol. IV, p. 390. ⑧

Physical Properties of Reactants and Products ⑤

Compound	MW[a]	Amounts	mmol	mp (°C)	bp (°C)
Succinic acid	118.09	118 mg	1.0	182	
Phenol	94.4	188 mg	2.0	40–42	182
Phosphorous oxychloride	153.33	84 μL	0.9		105.8
Diphenyl succinate	270.29			121	

[a]MW = molecular weight.

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In a 3.0-mL conical vial containing a magnetic spin vane and equipped with a reflux condenser protected by a calcium chloride drying tube were placed succinic acid (118 mg, 1.0 mmol), phenol (188 mg, 2.0 mmol), and phosphorous oxychloride (84 μL 0.9 mmol). The reaction mixture was heated with stirring at 115 °C in a sand bath in the **hood** for 1.25 h. It was necessary to conduct the reaction in the **hood,** because hydrogen chloride (HCl) gas evolved during the course of the reaction. The drying tube was removed, toluene (0.5 mL) was added through the top of the condenser using a Pasteur pipet, and the drying tube was replaced. The mixture was then heated for an additional 1 hour at 115 °C.

⑥

The hot toluene solution was separated from the red syrupy residue of phosphoric acid using a Pasteur pipet. The toluene extract was filtered by gravity using a fast-grade filter paper and the filtrate was collected in a 10-mL Erlenmeyer flask. The phosphoric acid residue was then extracted with two additional 1.0-mL portions of hot toluene. These extracts were also separated using the Pasteur pipet and filtered, and the filtrate was collected in the same Erlenmeyer flask. The combined toluene solutions were concentrated to a volume of approximately 0.6 mL by warming them in a sand bath under a gentle stream of nitrogen (N_2) gas in the **hood.** The pale yellow liquid residue was then allowed to cool to room temperature; the diphenyl succinate precipitated as colorless crystals. The solid was collected by vacuum filtration using a Hirsch funnel, and the filter cake was washed with three 0.5-mL portions of cold diethyl ether. The product was dried in a vacuum oven at 30°C (3 mm Hg) for 30 min.

⑦ ⑧

The 181 mg (67%) of diphenyl succinate had an mp of 120–121 °C (lit. value 121 °C: *CRC Handbook of Chemistry and Physics,* 89th ed.; CRC Press: Boca Raton, FL, 2008–2009; no. 13559, p. 3–220).

⑨

The IR spectrum exhibits the expected peaks for the compound. [*At this point, the data may be listed, or the spectrum attached to a separate page of the notebook*.]

⑩ Marilyn C. Waris

witnessed by
D. Jeanne d'Arc Mailhiot 19 July 2009

CALCULATING YIELDS

Almost without exception, in each of the experiments presented in this text, you are asked to calculate the percentage yield. For any reaction, it is always important for the chemist to know how much of a product is actually produced (experimental) compared to the theoretical (maximum) amount that could have been formed. The percentage yield is calculated on the basis of the relationship

$$\%\ \text{yield} = \frac{\text{actual yield (experimental)}}{\text{theoretical yield (calculated maximum)}} \times 100$$

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The percentage yield is generally calculated on a weight (gram or milligram) or on a mole basis. In the present text, the calculations are made using milligrams.

Several steps are involved in calculating the percentage yield.

Step 1 Write a *balanced* equation for the reaction. For example, consider Experiment [22], the Williamson synthesis of propyl *p*-tolyl ether.

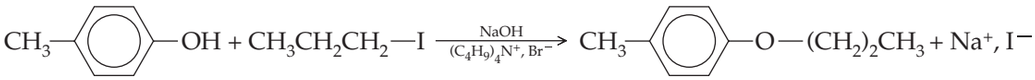

p-Cresol Propyl iodide Propyl *p*-tolyl ether

Physical Properties of Reactants				
Compound	MW (mg/mmol)	Amount	mmol	*d*(mg/μL)
p-Cresol	108.15	160 μL	1.56	1.5312
25% (by weight) NaOH soln	40.0	260 μL	~1.6	
Tetrabutylammonium bromide	322.38	18 mg	0.056	
Propyl iodide	169.99	150 μL	1.54	1.5058

Step 2 Identify the *limiting* reactant. The ratio of reactants is calculated on a millimole (or mole) basis. In the example, 1.56 mmol of *p*-cresol and ca. 1.6 mmol of sodium hydroxide are used, compared to 1.54 mmol of propyl iodide, which is therefore the limiting reagent. The tetrabutylammonium bromide is not considered because it is used as a catalyst—it is neither incorporated into the product nor consumed in the reaction. The calculation of the theoretical yield is thus based on the amount of propyl iodide, 1.54 mmol.

Step 3 Calculate the *theoretical* (maximum) amount of the product that could be obtained for the conversion, based on the limiting reactant. Here, one mole of propyl iodide produces one mole of the propyl *p*-tolyl ether. Therefore, the maximum amount of propyl *p*-tolyl ether (molecular weight = 150.2) that can be produced from 1.54 mmol of propyl iodide is 1.54 mmol, or 231 mg.

Step 4 Determine the *actual* (experimental) yield (milligrams) of product isolated in the reaction. This amount is invariably less than the theoretical quantity, unless the material is impure (one common contaminant is water). For example, student yields for the preparation of propyl *p*-tolyl ether average 140 mg.

Step 5 Calculate the *percentage yield* using the weights determined in steps 3 and 4. The percentage yield is then

$$\%\ \text{yield} = \frac{140\ \text{mg (actual)}}{231\ \text{mg (theoretical)}} \times 100 = 60.6\%$$

As you carry out each reaction in the laboratory, try to obtain as high a percentage yield of product as possible. The reaction conditions in this book's experiments have been carefully developed; if you master the microscale techniques for transferring reagents and isolating products, your yields will be as high as possible.

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QUESTIONS

3-1. Factory A produces the wheels that are used for the frames made in Factory B. Factory C relies exclusively on the materials produced in Factories A and B. Assuming all the necessary parts minus the wheels and frames are housed in Factory C, how many bicycles can be completely assembled when Factories A and B provide 36 wheels and 15 frames, respectively? Explain.

3-2. You are provided a vial that contains 180 mg of material. This material represents a 44 percent isolated yield. Calculate the theoretical amount (theoretical yield) that could have been formed.

3-3. The density of 2-methyl-2-butanol is 0.806 g/mL. How many mgs represent an aliquot of 430 μL? How many mmols represent an aliquot of 0.650 mL (2-methyl-2-butanol, formula weight is 88.15 g/mol)?

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C_4H_6apter 4

DETERMINATION OF PHYSICAL PROPERTIES

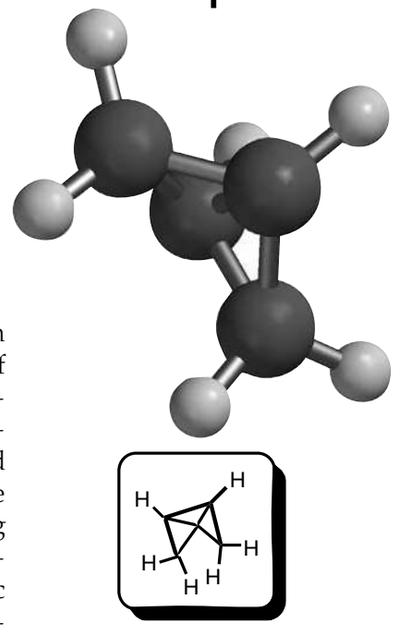

Determination of physical properties is important for substance identification and as an indication of material purity. Historically, the physical constants of prime interest have included boiling point, density, and refractive index in liquids and the melting point in solids. In special cases, optical rotation and molecular weight determinations may be required. Today, with the widespread availability of spectroscopic instrumentation, powerful new techniques may be applied to the direct identification and characterization of materials, including the analysis of individual components of very small quantities of complex mixtures. The sequential measurement of the infrared (IR) and mass spectro-metric (MS) characteristics of a substance resolved "on the fly" by capillary gas chromatography (GC) can be quickly determined and interpreted. This particular combination (GC-IR-MS), which stands out among a number of hyphenated techniques that are now available, is perhaps the most powerful system yet developed for molecular identification. The rapid development of high-field multinuclear magnetic resonance (NMR) spectrometers has added another powerful dimension to identification techniques. NMR sensitivity, however, is still considerably lower than that of either IR or MS. The IR spectrum alone, obtained with one data point per wavenumber can add more than 4000 measurements to the few classically determined properties. *Indeed, even compared to high-resolution MS and pulsed ^1H and ^{13}C NMR, the infrared spectrum of a material remains a powerful set of physical properties (transmission elements) available to the organic chemist for the identification of an unknown compound.*[1]

Simple physical constants are determined mainly to assist in establishing the purity of *known* materials. Because the boiling point or the melting point of a material can be very sensitive to small quantities of impurities, these data can be particularly helpful in determining whether a starting material needs further purification or whether a product has been isolated in acceptable purity. Gas (GC), high-performance liquid (HPLC), and thin-layer (TLC) chromatography, however, now provide more powerful purity information when such data are required. When a new composition of matter has been formed, an elemental (combustion) analysis is normally reported if sufficient material is available for this destructive analysis. For new substances we are, of course, interested in establishing not only the identity, but also the molecular structure of the materials. In this situation other modern techniques (such as ^1H and ^{13}C NMR spectroscopy, high-resolution MS, and single-crystal X-ray diffraction) can provide sensitive and powerful structural information.

When comparisons are made between experimental data and values obtained from the literature, it is essential that the latter information be obtained

Chapter 4: C_4H_6, Bicyclo[1.1.0]butane
Lemal, Menger, and Clark (1963).

[1]Griffiths, P. R.; de Haseth, J. A. *Fourier Transform Infrared Spectrometry,* 2nd ed.; Wiley: New York, 2007.

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from the most reliable sources available. This is especially true when considering the volume of misinformation found online. Certainly, judgment, which improves with experience, must be exercised in accepting any value as a standard. In addition to the wealth of data found online (e.g., SciFinder Scholar), the known classical properties of a large number of compounds can be obtained from the *CRC Handbook of Chemistry and Physics* and the *Merck Index.* The *Aldrich Catalog Handbook of Fine Chemicals* is also a readily available, inexpensive source. These reference works list physical properties for inorganic, organic, and organometallic compounds. The *Aldrich Catalog* also references IR and NMR data for a large number of substances. New editions of the *CRC Handbook* and the *Aldrich Catalog* are published each year.

LIQUIDS

Ultramicro Boiling Point

Upon heating, the vapor pressure of a liquid increases, though in a nonlinear fashion. When the pressure reaches the point where it matches the local pressure, the liquid boils. That is, it spontaneously begins to form vapor bubbles, which rapidly rise to the surface. If heating is continued, both the vapor pressure and the temperature of the liquid will remain constant until the substance has been completely vaporized (Fig. 4.1).

Because microscale preparations generally yield about 30–70 μL of liquid products, using only 5 μL or less of material for boiling point measurements is highly desirable. The modification of the earlier Wiegand ultramicro boiling-point procedure[2] to the ultramicro procedure described here has established that reproducible and reasonably accurate (±1 °C) boiling points can be observed on 3–4 μL of most liquids thermally stable at the required temperatures.

Procedure. Ultramicro boiling points can be conveniently determined in standard (90-mm-length) Pyrex glass capillary melting-point tubes. The melting-point tube replaces the conventional 3- to 4-mm (o.d.) tubing used in the Siwoloboff procedure.[3] The sample (3–4 μL) is loaded into the melting-point capillary via a 10-μL syringe and centrifuged to the bottom if necessary. A small glass bell replaces the conventional melting-point tube as the bubble generator in micro boiling-point determinations. It is formed by heating 3-mm (o.d.) Pyrex tubing with a microburner and drawing it out to a diameter small enough to be readily fit inside the melting-point capillary. A section of the drawn capillary is fused and then cut to yield two small glass bells approximately 5 mm long (Fig. 4.2*a*). It is important that the fused section be reasonably large, because it is more than just a seal. The fused glass must add enough weight to the bell that it will firmly seat itself in the bottom of the melting-point tube.

An alternative technique for preparing the glass bells follows: heat the midsection of an open-ended melting point capillary tube and then draw the glass to form a smaller capillary section. This section is then broken approximately in the middle and each open end is sealed. The appropriate length for the bell is then broken off. Thus, two bells are obtained, one from each section. The sealing

[2]Wiegand, C. *Angew. Chem.* **1955,** *67,* 77. Mayo, D. W.; Pike, R. M.; Butcher, S. S.; Meredith, M. L. *J. Chem. Educ.* **1985,** *62,* 1114.
[3]Siwoloboff, A. *Berichte* **1886,** *19,* 795.

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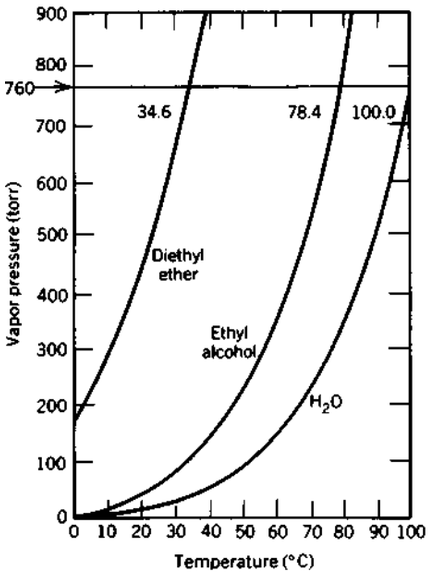

Figure 4.1 Vapor pressure curves. (From Brady, J. E.; Humiston, G. E. *General Chemistry,* 3d ed.; Wiley: New York, 1982. (Reprinted by permission of John Wiley & Sons, New York.)

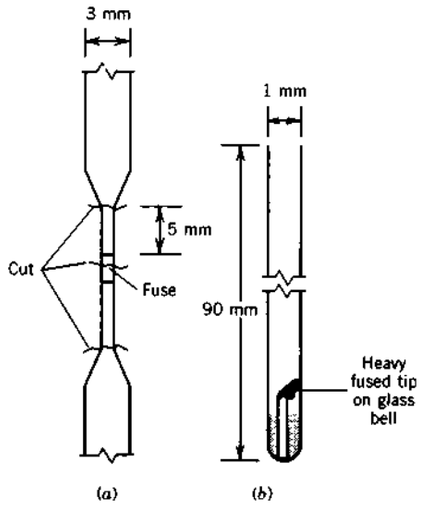

Figure 4.2 (a) Preparation of small glass bell for ultramicro boiling-point determination. (b) Ultramicro boiling-point assembly. (From Mayo, D. W.; Pike, R. M.; Butcher, S. S.; Meredith, M. L. *J. Chem. Educ.* ***1985,*** *62,* 1114.)

process (be sure that a significant section of glass is fused during the tube closure to give the bell enough weight) can be repeated on each remaining glass section and thus a series of bells can be prepared in a relatively short period.

A glass bell is now inserted into the loaded melting-point capillary, open end first (down), and allowed to fall (centrifuged if necessary) to the bottom. The assembled system (Fig. 4.2*b*) is then inserted onto the stage of a Thomas-Hoover Uni-Melt Capillary Melting Point Apparatus (Fig. 4.3)[4] or similar system (such as a Mel-Temp).

The temperature is rapidly raised to 15–20 °C below the expected boiling point (the temperature should be monitored carefully in the case of unknown substances), and then adjusted to a maximum rise rate of 2 °C/min and heated until a *fine stream* of bubbles is emitted from the glass bell. The heat control is then adjusted to drop the temperature. The boiling point is recorded at the point where the last escaping bubble collapses (i.e., when the vapor pressure of the substance equals the atmospheric pressure). The heater is then rapidly adjusted to again raise the temperature at 2 °C/min and induce a second stream of bubbles. This procedure may then be repeated several times. *A precise and sensitive temperature control system is essential to the successful application of this cycling technique, but it is not essential for obtaining satisfactory boiling-point data.*

Utilization of the conventional melting-point capillary as the "boiler" tube has the particular advantage that the boiling point of a liquid can readily be determined using a conventional melting-point apparatus. The illumination and magnification available make the observation of rate changes in the bubble stream easily seen. Inexpensive 10-μL GC injection syringes appear to be the most successful instrument to use for transferring the small quantities of liquids involved. The 3-in. needles normally supplied with the 10-μL barrels

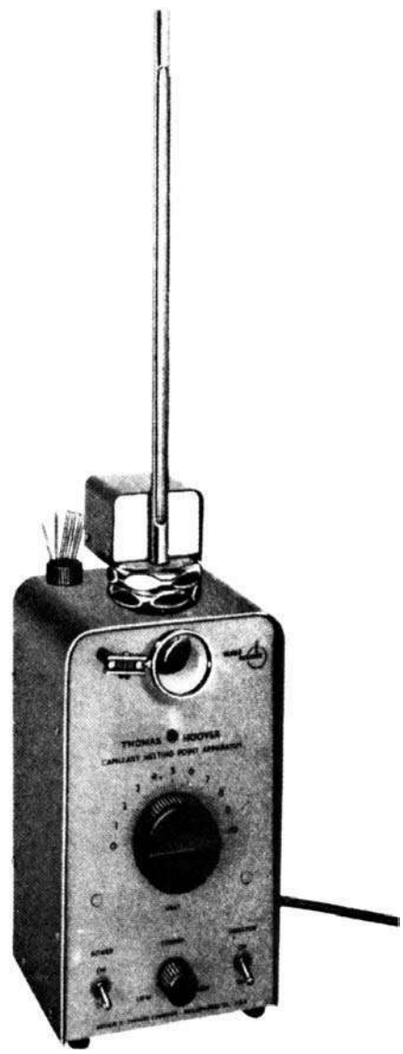

Figure 4.3 Thomas-Hoover melting-point determination device. *(Courtesy of Thomas Scientific, Swedesboro, NJ.)*

[4]Thomas Scientific, P.O. Box 99, Swedesboro, NJ 08085.

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will not reach the bottom of the capillary; liquid samples deposited on the walls of the tube, however, are easily and efficiently moved to the bottom by centrifugation. After the sample is packed in the bottom of the capillary tube, the glass bell is introduced. The glass bell is necessary because a conventional Siwoloboff fused-capillary insert would extend beyond the top of the melting-point tube; thus, capillary action between the "boiler" tube wall and the capillary insert would draw most of the sample from the bottom of the tube up onto the walls. This effect often precludes the formation of the requisite bubble stream.

Little loss of low-boiling liquids occurs (see Table 4.1). Furthermore, if the boiling point is overrun and the sample is suddenly evaporated from the bottom of the "boiler" capillary, it will rapidly condense on the upper (cooler) sections of the tube. These sections extend above the heat-transfer fluid or metal block. The sample can easily be recentrifuged to the bottom of the tube and a new determination of the boiling point begun. Note that if the bell cavity fills completely during the cooling point of a cycle, it is often difficult to reinitiate the bubble stream without first emptying the entire cavity by overrunning the boiling point.

Observed boiling points for a series of compounds, which boil over a wide range of temperatures, are summarized in Table 4.1.

Materials that are thermally stable at their boiling point will give identical values on repeat determinations. Substances that begin to decompose will give values that slowly drift after the first few measurements. The observation of color and/or viscosity changes, together with a variable boiling point, signal the need for caution in making extended repeat measurements.

Comparison of the boiling points obtained experimentally at various atmospheric pressures with reference boiling points at 760 torr is greatly facilitated by the use of pressure–temperature nomographs such as that shown in Figure 4.4. A straight line from the observed boiling point to the observed pressure will pass through the corrected boiling-point value. These values can be of practical importance when carrying out reduced pressure distillations.

Table 4.1 **Observed Boiling Points (°C)**

Compound	Observed	Literature Value	Reference
Methyl iodide	42.5	42–43	*a*
Isopropyl alcohol	82.3	82.3	*b*
2,2-Dimethoxypropane	80.0	83.0	*c*
2-Heptanone	149–159	151.1	*d*
Cumene	151–153	152.4	*e*
Mesitylene	163	164.7	*f*
p-Cymene	175–178	177.1	*g*
Benzyl alcohol	203	205.3	*h*
Diphenylmethane	263–265	265	*i*

Note. (Observed values are uncorrected for changes in atmospheric pressure (corrections all estimated to be less than ±0.5 °C.)

Source. CRC Handbook of Chemistry and Physics, 89th ed.; CRC Press: Boca Raton, FL, 2008–2009: [a]no. 6307, p. 3–306; [b]no. 9167, p. 3–442; [c]no. 3883, p. 3–190; [d]no. 5689; p. 3–274; [e]no. 6478, p. 3–314; [f]no. 10509, p. 3–540; [g]no. 6509, p. 3–316; [h]no. 780, p. 3–42; [i]no. 4498, p. 3–218.

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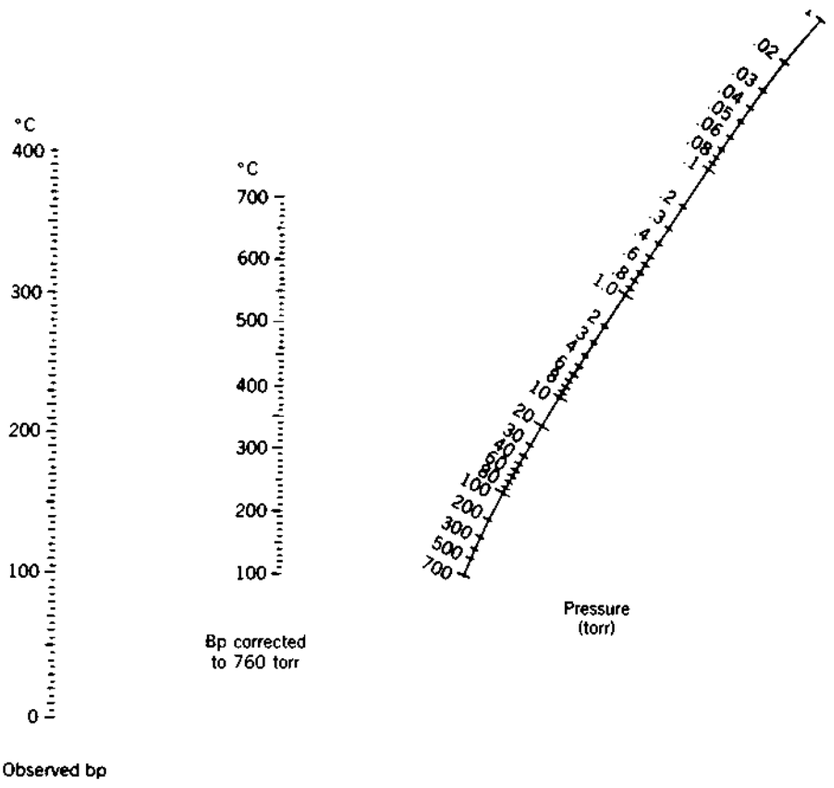

Figure 4.4 Pressure–temperature nomograph.

DENSITY

Density, defined as mass per unit volume, is generally expressed as grams per milli-liter (g/mL) or grams per cubic centimeter (g/cm^3) for liquids. Accurate nondestructive procedures have been developed for the measurement of this physical constant at the microscale level. A micropycnometer (density meter), developed by Clemo and McQuillen requires approximately 2 μL (Fig. 4.5).[5]

This very accurate device gives the density to three significant figures. The system is self-filling, and the fine capillary ends do not need to be capped while temperature equilibrium is reached or during weighing (the measured values tend to degrade for substances boiling under 100 °C and when room temperatures rise much above 20 °C). In addition, the apparatus must first be tared, filled, and then reweighed on an *analytical* balance. A technique that results in less precise densities (good to about two significant figures), but which is far easier to use, is simply to substitute a 50- or 100-μL syringe for the pycnometer. The method simply requires weighing the syringe before and after filling it to a measured volume as in the conventional technique. With the volume and the weight of the liquid known, the density can be calculated. A further advantage of the syringe technique is that the pycnometer is not limited to a fixed volume. Although much larger samples are required, it is not inconvenient to utilize the entire sample obtained in the reaction for this measurement, since the material can be efficiently recovered from the syringe for additional

Figure 4.5 Pycnometer of Clemo and McQuillen. (From Schneider, F. L. Monographien aus dem Gebiete der qualitativen Mikroanalyse, *Qualitative Organic Microanalysis,* Vol. II; Benedetti-Pichler, A. A., Ed.; Springer: Vienna, 1964.)

[5]Clemo, G. R.; McQuillen, A. *J. Chem. Soc.* **1935,** 1220.

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characterization studies. Because density changes with temperature, these measurements should be obtained at a constant temperature.

An alternative to the syringe method is to use *Drummond Disposable Microcaps* as pycnometers. These precision-bore capillary tubes, calibrated to contain the stated volume from end to end (accuracy ±1%), are available from a number of supply houses.[6] These tubes are filled by capillary action or by suction using a vented rubber bulb (provided). The pipets can be obtained in various sizes, but as with the syringe, volumes of 50, 75, or 100 μL are recommended. When using this method, handle the micropipet with forceps and not with your fingers (it's hot). The empty tube is first *tared,* and then filled and weighed again. The difference in these values is the weight of liquid in the pipet. For convenience, the pipet may be placed in a small container (10-mL beaker or Erlenmeyer flask) when the weighing procedure is carried out.

Two inexpensive micropycnometers can also be easily prepared: The first can be made from a Pasteur pipet as reported by Singh et al.[7] The volume of each individual pycnometer can be varied from 20 to 100 μL, or larger if desired. Values to three significant figures are obtained using an *analytical balance,* because evaporation is generally negligible, and if the pycnometer mouth is small.

The second pycnometer, by Pasto and co-workers, is made from a melting-point capillary tube.[8] In both of these techniques, the volume of the pycnometer must be determined. The procedure to determine the density involves the following steps. The empty micropycnometer is tared on an analytical balance, filled with the liquid in question, and reweighed (the difference in weights is the weight of the liquid). The sample is removed and the pycnometer is rinsed with acetone and dried. It is then filled with distilled water and reweighed. From the known[9] density of water at the given temperature the volume of water can be determined and thus the volume of the pycnometer. The volume of the original liquid sample also equals this value. The weight and volume of the sample are used to calculate its density.

SOLIDS

Melting Points

In general, the crystalline lattice forces holding organic solids together are distributed over a relatively narrow energy range. The melting points of organic compounds, therefore, are usually relatively sharp, that is, less than 2 °C. The range and maximum temperature of the melting point, however, are very sensitive to impurities. Small amounts of sample contamination by soluble impurities nearly always will result in melting-point depressions.

The drop in melting point is usually accompanied by an expansion of the melting-point range. Thus, in addition to the melting point acting as a useful

[6]Drummond Disposable Microcaps are available from Thomas Scientific, P.O. Box 99, Swedesboro, NJ 08085; and Sargent-Welch Scientific Co., a VWR company, P.O. Box 1026, Skokie, IL 60097.

[7]Singh, M. M.; Szafran, Z.; Pike, R. M. *J. Chem. Educ.* **1993,** *70,* A36; see also Ellefson-Kuehn, J., and Wilcox, C. J. *J. Chem. Educ.* **1994,** *71,* A150; and Singh, M. M.; Pike, R. M.; Szafran, Z. *Microscale and Selected Macroscale Experiments for General and Advanced General Chemistry;* Wiley: New York, 1995.

[8]Pasto, D.; Johnson, C.; Miller, M. *Experiments and Techniques in Organic Chemistry;* Prentice-Hall: Englewood Cliffs, NJ, 1992.

[9]Values for the density of water at various temperatures can be found in the *CRC Handbook of Chemistry and Physics*.

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guide in identification, it also can be a particularly effective indication of sample purity.

Procedure. In the microscale laboratory, two different types of melting-point determinations are carried out: (1) simple capillary melting points and (2) evacuated melting points.

Simple Capillary Melting Point. Because the microscale laboratory utilizes the Thomas–Hoover Uni-Melt apparatus or a similar system for determining boiling points, melting points are conveniently obtained on the same apparatus. The Uni-Melt system utilizes an electrically heated and stirred silicone oil bath. The temperature readings require no correction in this case because the depth of immersion is held constant. (This assumes, of course, that the thermometer is calibrated to the operational immersion depth.) Melting points are determined in the same capillaries as boiling points. The capillary is loaded by introducing about 1 mg of material into the open end. The sample is then tightly packed (~2 mm) into the closed end by dropping the capillary down a length of glass tubing held vertically to the bench top. The melting-point tube is then ready for mounting on the metal stage, which is immersed in the silicone oil bath of the apparatus. If the melting point of the substance is expected to occur in a certain range, the temperature can be rapidly raised to ~2 °C below the expected value. At that point, the temperature rise should be adjusted to a maximum of 2 °C/min, which is the standard rate of change at which the reference determinations are obtained. The melting-point range is recorded from the temperature at which the first drop of liquid forms (point *e* in Fig. 4.6) to that at which the last crystal melts (point *m* in Fig. 4.6).

Evacuated Melting Points. Many organic compounds begin to decompose at their melting points. This decomposition often begins as the melting point is approached and may adversely affect the values measured. The decomposition can be invariably traced to reaction with oxygen at elevated temperatures. If the melting point is obtained in an evacuated tube, therefore, much more accurate melting points can be obtained. These more reliable values arise not only from increased sample stability, but because several repeat determinations

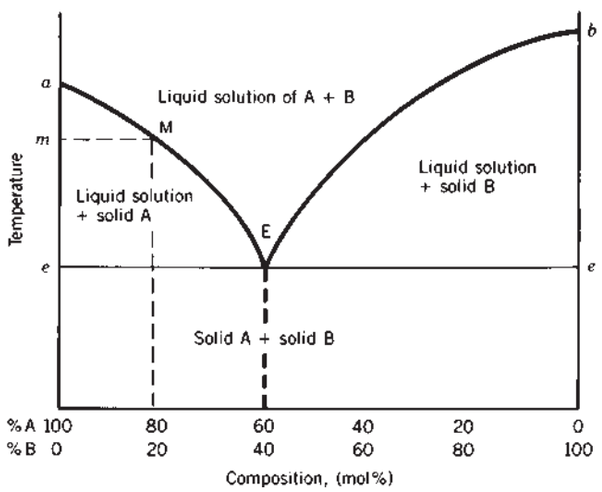

Figure 4.6 Melting point composition diagram for the binary mixture, *A* + *B*. In this diagram, *a* is the melting point of the solid *A*, *b* of solid *B*, *e* of eutectic mixture *E*, and *m* of the 80% *A*:20% *B* mixture, *M*.

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can often be made on the same sample. The multiple measurements then may be averaged to provide more accurate data.

Evacuated melting points are quickly and easily obtained with a little practice. The procedure is as follows: Shorten the capillary portion of a Pasteur pipet to approximately the same length as a normal melting-point tube (Fig. 4.7*a*). Seal the capillary end by rotating in a microburner flame. Touch the pipet only to the very edge of the flame, and keep the large end at an angle below the end being sealed (Fig. 4.7*b*). This technique will prevent water from the flame being carried into the tube, where it will condense in the cooler sections. Then load 1–2 mg of sample into the drawn section of the pipet with a microspatula (Fig. 4.7*c*). Tap the pipet gently to seat the solid powder as far down the capillary as it can be worked (Fig. 4.7*d*). Then push the majority of the sample part way down the capillary with the same diameter copper wire that you used to seat the cotton plug in constructing the Pasteur filter pipet (Fig. 4.7*e*). Next, connect the pipet with a piece of vacuum tubing to a mechanical high-vacuum pump. Turn on the vacuum and evacuate the pipet for 30 s (Fig. 4.7*f*). With a microburner, gently warm the surface of the capillary tubing just below the drawn section. On warming, the remaining fragments of the sample (the majority of which has been forced farther down in the tube) will sublime in either direction away from the hot section. Once the traces of sample have been "chased" away, the heating is increased, and the capillary tube is collapsed, fused, and separated from the shank. The shank remains connected to the vacuum system (Fig. 4.7*g*). The vacuum system is then vented and the shank is discarded. The sample is tightly packed into the initially sealed end of the evacuated capillary by dropping it down a section of glass tubing, as in the case of packing open melting-point samples. After the sample is packed (~2 mm in length, see Fig. 4.7*h*), a section of the evacuated capillary about 10–15 mm above the sample is once more gently heated and collapsed by the microburner flame (Fig. 4.7*i*).

This procedure is required to trap the sample below the surface of the heated silicone oil in the melting-point bath, and thus avoid sublimation up the tube to cooler sections during measurement of the melting point. The operation is a little tricky and should be practiced a few times. It is very important that the tubing completely fuse. Now the sample is ready to be placed in the melting-point apparatus. The procedure beyond this point is the same as in the open capillary case, except that after the sample melts, it can be cooled, allowed to crystallize, and remelted several times, and the average value of the range reported. If these values begin to drift downward, the sample can be considered to be decomposing even under evacuated, deoxygenated conditions. In this case the first value observed should be recorded as the melting point and decomposition noted (mp xx dec, where dec = decompose).

Mixture Melting Point. Additional information can often be extracted from the sensitivity of the melting point to the presence of impurities. Where two different substances possess identical melting points (not uncommon), it would be impossible to identify an unknown sample as either material based on the melting point alone. If reference standards of the two compounds are available, however, then mixtures of the unknown and the two standards can be prepared. It is important to prepare several mixtures of varying concentrations for melting-point comparisons, since the point of maximum depression need not occur on the phase diagram at the 50:50 ratio (see Fig. 4.6). In samples that do not exhibit any decomposition at the melting point, the prepared

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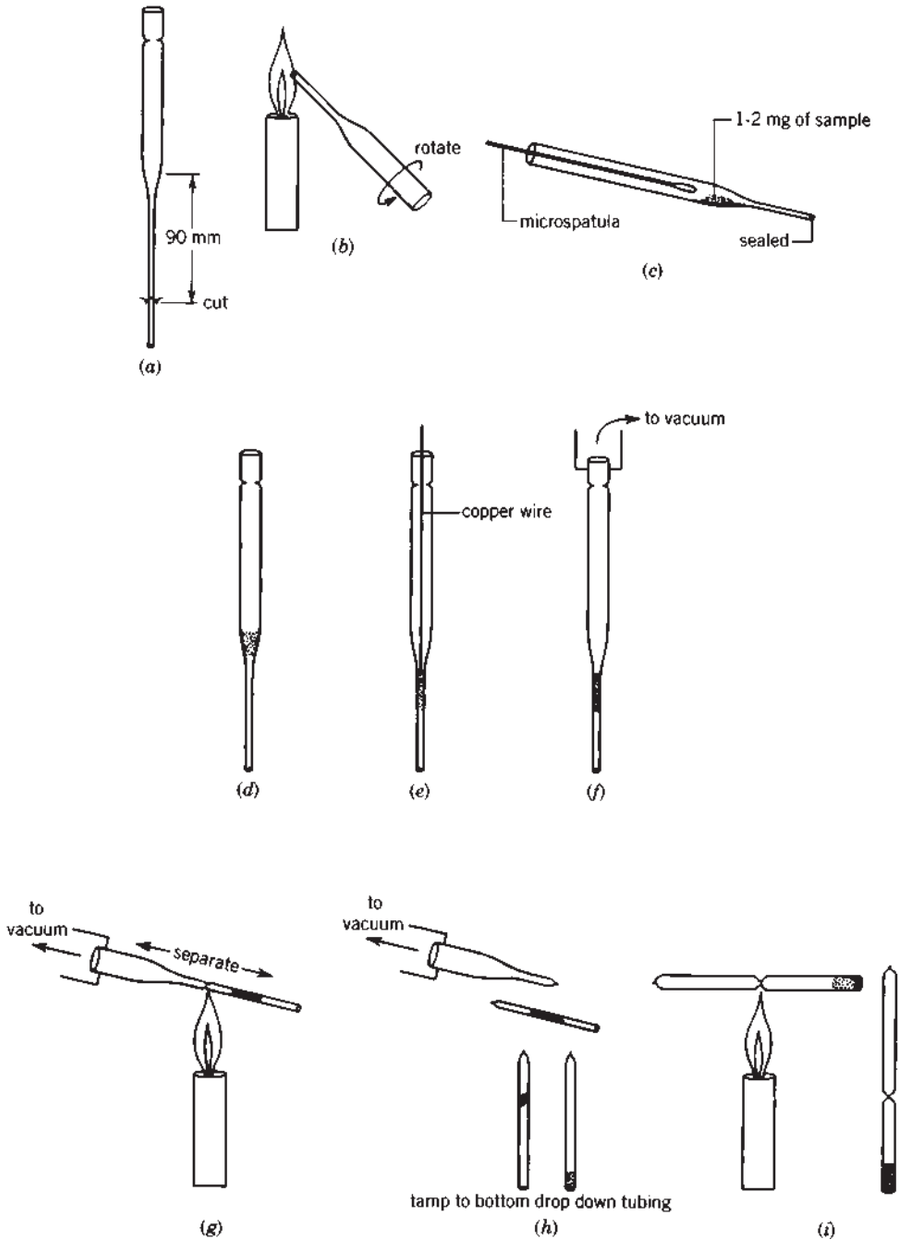

Figure 4.7 Procedure for obtaining evacuated melting-point capillaries.

mixtures should be first heated until a homogeneous melt is obtained. Each is then cooled and ground to a fine powder, and the definitive melting point is obtained on the ground sample. The melting points of the unknown and the mixed samples should be obtained simultaneously (the Uni-Melt stage will accept up to seven capillaries at one time). This is desirable because all the samples will then be heated at the same rate. The unknown sample and the mixture of the unknown with the correct reference will have identical values, but the mixture of the reference with a different substance will give a depressed melting point. This procedure is the classical step to positive identification of crystalline solids.

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Mixtures of two different compounds only rarely fail to exhibit mixture melting-point depression, but it can happen. Some mixtures may not show a depression or show only a very small one, due to eutectic or compound formation. Elevation of the melting point has also been observed. Therefore, if mixture melting-point data are used for identification purposes, comparison of other physical constants or spectroscopic data is advocated to establish identity beyond any reasonable doubt.

QUESTIONS

4-1. Room temperature is recorded when a density determination for a given substance is performed in the laboratory. Why?

4-2. Describe how you would determine the melting point of a substance that sublimes before it melts.

4-3. You are presented with four vials, each containing a white crystalline solid. Two are unlabeled vials containing pure samples of *trans*-cinnamic acid and urea, respectively. The other two are labeled reference standards for each sample. Devise a method for the proper identification of the unlabeled vials, knowing that the literature melting point for both *trans*-cinnamic acid and urea is 132.5–133 °C.

4-4. In the microscale method of determining boiling points, one heats the liquid until a steady stream of bubbles is observed coming out of the bell. The temperature is then lowered and the boiling point is read just as the bubbles stop. Why is this technique preferable to measuring the boiling point when the bubbles first start to appear?

4-5. What would you expect the observed boiling point to be at 10 torr of a liquid which has a boiling point of 300 °C at 760 torr?

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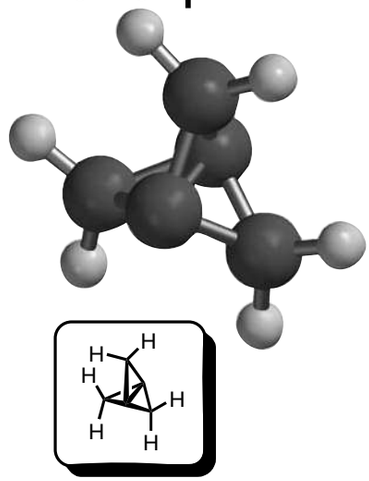

MICROSCALE LABORATORY TECHNIQUES

This chapter introduces the microscale organic laboratory techniques used throughout the experimental sections of the textbook. These must be mastered to be successful when working at this scale. Detailed discussions are given for each individual experimental technique. At the end of each discussion there is a list of the experiments in Chapters 6, 7 and 10W that use the technique. These lists should prove useful to instructors compiling experiments to be covered in the laboratory. The lists will also be handy for students who wish to examine the application of a particular technique to other experiments not covered in their laboratory sequence.

As was the case with the fourth edition, a continued effort has been made to streamline the basic reference material from the text using our accompanying website (www.wiley. com/college/MOL5). The icon at the right is used throughout the text to indicate website material that will be of interest to the user. We hope this treatment of the laboratory will make the more important aspects of the basic text easier to access and will speed your laboratory work along.

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One of the principal hurdles in dealing with experimental chemistry is the isolation of pure materials. Characterization (identification) of a substance almost always requires a pure sample of the material. This is a particularly difficult demand of organic chemistry because most organic reactions generate several products. We are generally satisfied if the desired product is the major component of the mixture obtained. This chapter places a heavy emphasis on separation techniques.

TECHNIQUE 1

Gas Chromatography

Technique 1 begins the discussion of the resolution (separation) of microliter quantities of liquid mixtures via preparative gas chromatography. Techniques 2 and 3 deal with semimicro adaptations of classical distillation routines that focus on the separation of liquid mixtures involving one to several milliliters of material.

Chromatography methods revolutionized experimental organic chemistry. These methods are by far the most powerful of the techniques for separating mixtures and isolating pure substances, either solids or liquids. Chromatography is the resolution (separation) of a multicomponent mixture (several hundred components in some cases) by distribution between two phases, one stationary and one mobile. The various methods of chromatography are categorized by the phases involved: column, thin-layer, and paper (all solid–liquid chromatography); partition (liquid–liquid chromatography); and vapor phase

Chapter 5: C_5H_6, Propellane
Wiberg and Walker (1982).

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(gas–liquid chromatography, or simply gas chromatography). The principal mechanism these separations depend on is differential solubility, or adsorbtivity, of the mixture components in the two phases involved. That is, the components must exhibit different partition coefficients (see also Technique 4 for a detailed discussion of partition coefficients).

Gas chromatography (GC, sometimes called vapor-phase chromatography) is an extraordinarily powerful technique for separating mixtures of organic compounds.The stationary phase in GC is a high-boiling liquid and the mobile phase is a gas (the carrier gas). Gas chromatography can separate mixtures far better than distillation techniques can (see Technique 2 discussion).

Preparative GC separations, which involve perhaps 5–100 μL of material, require relatively simple instrumentation but sacrifice resolution for the ability to separate larger amounts of material.

Analytical GC separations require tiny amounts of material (often 0.1 μL of a very dilute solution), and can separate incredibly complex mixtures. The ability to work with small quantities of materials in analytical GC separations is an advantage at the microscale level. This analytical tool is used to analyze distillation fractions in Experiments [3C] and [3D].

GC Instrumentation

GC instrumentation can range from straightforward and relatively simple systems to systems with complex, highly automated, and relatively expensive components. A diagram of a common and simple GC typically used in an instructional laboratory is shown in Figure 5.1.

Injection Port The analysis begins in a heated injection port. The sample mixture is introduced by syringe through a septum into the high-temperature chamber (injection port) through which the inert carrier gas (the mobile phase) is flowing. Helium and nitrogen are common carrier gases. The solubility of the sample in the carrier gas depends mostly on the vapor pressure of the substances in the sample. Heating the injection port helps to ensure the vaporization of less volatile samples. There are two major constraints on GC:

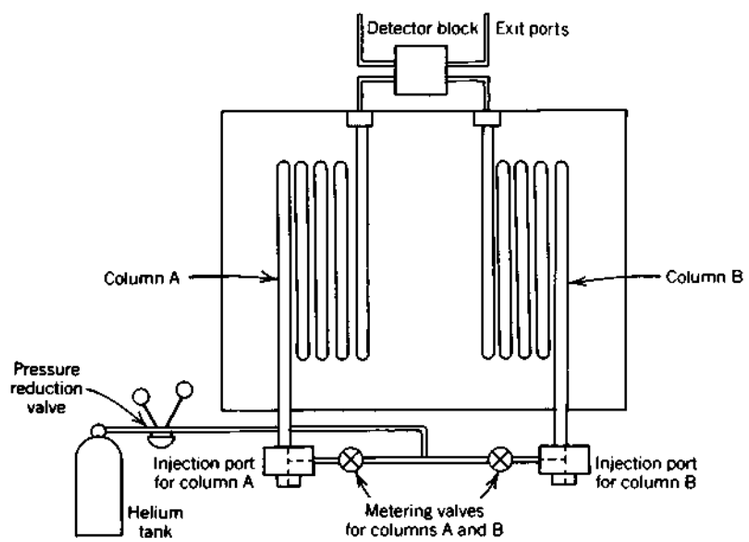

Figure 5.1 Block diagram of a dual-column gas chromatograph showing essential parts. *(Courtesy of GOW-MAC Instrument Co., 277 Brodhead Rd., Bethlehem, PA 18017.)*

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The sample must be stable at the temperature required to cause vaporization, and the sample must have sufficient vapor pressure to be completely soluble in the carrier gas at the column operating temperatures.

NOTE. When injecting a sample, always position your thumb or finger over the syringe plunger. This prevents a blow-back of the sample by the carrier gas pressure in the injection port.

Column The vaporized mixture is swept by the carrier gas from the injection port onto the column. Bringing the sample mixture into intimate contact with the column begins the separation process. The stationary liquid phase in which the sample will partially dissolve is physically and/or chemically bonded to inert packing material (often called the support) in the column. Gas-chromatographic columns are available from manufacturers in a variety of sizes and shapes. In the diagram of the GOW-MAC instrument (Fig. 5.1), two parallel coiled columns are mounted in an oven. Considerable oven space can be saved and better temperature regulation achieved if the columns are coiled. Temperature regulation is particularly important, because column resolution degrades rapidly if the entire column is not at the same temperature. Most liquid mixtures need a column heated above ambient temperatures to achieve the vapor pressure the separation requires.

The mixture is separated as the carrier gas sweeps the sample through the column. Columns are usually made from stainless steel, glass, or fused silica. The diameter and length of the column are critical factors in separating the sample mixture.

Packed Columns. In packed columns the liquid (stationary) phase in contact with the sample contained in the mobile gas phase is maximized by coating a finely divided inert support with the nonvolatile liquid. The coated support is carefully packed into the column so as not to develop empty spaces. Packed columns are usually $\frac{1}{4}$ or $\frac{1}{8}$ inch in diameter and range from 4 to 12 feet in length. These columns are particularly useful in the microscale laboratory, since they can be used for both analytical and preparative GC. Simple mixtures of 20–80 μL of material can often be separated into their pure components and collected at the exit port of the detector. Smaller samples (0.2–2.0 μL range) will exhibit better separation.

Capillary Columns. Capillary columns have no packing; the liquid phase is simply applied directly to the walls of the column. These columns are referred to as wall-coated, open-tubular (WCOT) columns. The reduction in surface area (compared to packed columns) is compensated for by tiny column diameters (perhaps 0.1 mm) and impressive lengths (100 m is not uncommon). Capillary columns are the most powerful columns used for analytical separations. Mixtures of several hundred compounds can be completely resolved on a capillary GC column. These columns require a more sophisticated and expensive chromatography instrument. Capillary columns, because of their tiny diameters, can accommodate only very small samples, perhaps 0.1 μL or less of a dilute solution. Capillary columns cannot be used for preparative separations.

Liquid Phase Once the sample is introduced on the column (in the carrier gas), it will undergo partition into the liquid phase. The choice of the liquid phase is particularly important because it directly affects the relative distribution coefficients.

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In general, the stationary liquid phase controls the partitioning of the sample by two criteria. First, if little or no interaction occurs between the sample components and the stationary phase, the boiling point of the materials will determine the order of elution. Under these conditions, the highest boiling species will be the last to elute. Second, the functional groups of the components may interact directly with the stationary phase to establish different partition coefficients. Elution then depends on the particular binding properties of the sample components.

Some typical materials used as stationary phases are shown below.

Name	Stationary Phase	Maximum Temperature (°C)	Mechanism of Interaction
Silicone oil DC710, etc.	$R_3Si[OSiR_2]_nOSiR_3$	250	According to boiling point
Polyethylene glycol (Carbowax)	$HO[CH_2CH_2O]_nCH_2CH_2OH$	150	Relatively selective toward polar components
Diisodecyl phthalate	*o*-$C_6H_4[CO_2$-isodecyl$]_2$	175	According to boiling point

Oven Temperature The temperature of the column will also affect the separation. In general, the elution time of a sample will decrease as the temperature is increased. That is, retention times are shorter at higher temperatures. Higher boiling components tend to undergo diffusion broadening at low column temperatures because of the increase in retention times. If the oven temperature is too high, however, equilibrium partitioning of the sample with the stationary phase will not be established. Then the components of the mixture may elute together or be incompletely separated. Programmed oven temperature increases can speed up elution of the higher boiling components, but suppress peak broadening and therefore increase resolution. Temperature-programming capabilities require more sophisticated ovens and controllers.

Flow Rate The flow rate of the carrier gas is another important parameter. The rate must be slow enough to allow equilibration between the phases, but fast enough to ensure that diffusion will not defeat the separation of the components.

Column Length As noted, column length is an important factor in separation performance. As in distillations, column efficiency is directly proportional to column height, which determines the number of evaporation–condensation cycles. In a similar manner, increasing the length of a GC column allows more partition cycles to occur. Difficult-to-separate mixtures, such as the xylenes (very similar boiling points: *o*-xylene, 144.4 °C; *m*-xylene, 139.1 °C; and *p*-xylene, 138.3 °C), have a better chance of being separated on longer columns. In fact, both GC and distillation resolution data are described using the same term, *theoretical plates* (see Technique 2 and Experiments [3C] and [3D]).

Detector and Exit Port A successfully separated mixture will elute as its individual components at the instrument's exit port (also temperature controlled). To monitor the exiting vapors, a detector is placed in the gas stream just before the exit port (Fig. 5.1). After passing through the detector, the carrier gas and the separated sample components are then vented.

One widely used detector is the nondestructive, thermal conductivity detector, sometimes called a hot-wire detector. A heated wire in the gas stream changes its electrical resistance when a substance dilutes the carrier gas and thus

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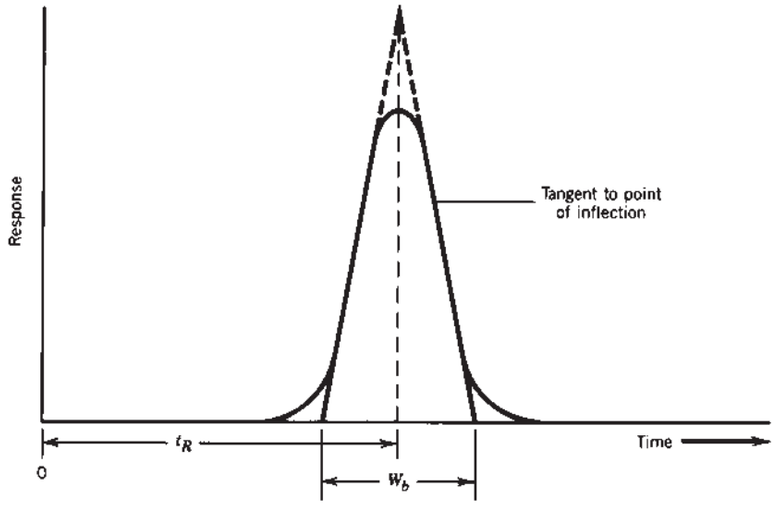

Figure 5.2 Schematic chromatogram.

changes its thermal conductivity. Helium has a higher thermal conductivity than most organic substances. When substances other than helium are present, the conductivity of the gas stream changes, which changes the resistance of the heated wire. The change in resistance is measured by comparing it to a reference detector mounted in a second (parallel) gas stream (Wheatstone bridge). The resulting electrical signal is plotted on a chart recorder, where the horizontal axis is time and the vertical axis is the magnitude of the resistance difference. The plot of resistance difference versus time is referred to as the gas *chromatogram.* The retention time (t_R) is defined as the time from sample injection to the time of maximum peak intensity. The baseline width (W_b) of a peak is defined as the distance between two points where tangents to the points of inflection cross the baseline (Fig. 5.2).

Capillary GC systems, and other GC systems used only for analytical separations, often use a flame-ionization detector (FID). In a flame-ionization detector, the gas eluting from the GC column is mixed with air (or oxygen) and hydrogen, and burned. The conductivity of the resulting flame is measured; it changes with the ionic content of the flame, which is proportional to the amount of carbon (from organic material) in the flame. The advantage of an FID is its high sensitivity; amounts of less than a microgram are easily detected. Its disadvantage is that it destroys (burns) the material it detects.

Theoretical Plates It is possible to estimate the number of theoretical plates (directly related to the number of distribution cycles) present in a column for a particular substance. The parameters are given in the relationship[1]

$$n = 16\left(\frac{t_R}{W_b}\right)^2$$

where the units of retention time (t_R) and baseline width (W_b) are identical (minutes, seconds, or centimeters). As in distillation columns, the larger the number of theoretical plates, n, the higher the resolution of the column and the better the separation.

[1]Berg, E. W. *Physical and Chemical Methods of Separation;* McGraw-Hill: New York, 1963, p. 111.

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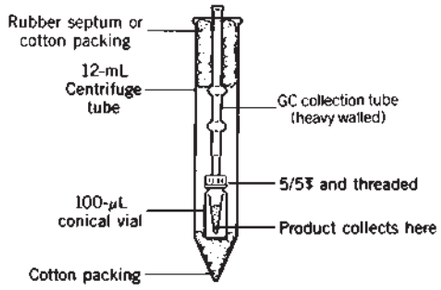

Figure 5.3 Gas chromatographic collection tube and 0.1-mL conical vial.

The efficiency of a system may be expressed as the *height-equivalent theoretical plate* (HETP) in centimeters (or inches) per plate. The HETP is related to the number of theoretical plates n by

$$\text{HEPT} = \frac{L}{n}$$

where L is the length of the column, usually reported in centimeters. The smaller the HETP, the more efficient the column.

www The number of theoretical plates available in fractional distillation columns is limited by column holdup (see Techniques 2, 3, and website discussion of distillation theory). Thus, distillations of less than 500 μL are generally not practical. Gas-chromatographic columns, on the other hand, operate most efficiently at the microscale or submicroscale levels, where 500 μL would be an order of magnitude (even 3–8 orders of magnitude in the case of capillary columns) too large.

Fraction Collection Sequential collection of separated materials can be made by attaching suitable sample condensing tubes to the exit port (see Fig. 3.6).

Procedure for Preparative Collection. The collection tube (oven dried until 5 min before use) is attached to the heated exit port by the metal 5/5 joint. Sample collection is begun 30 s before detection of the expected peak on the recorder (based on previously determined retention values; refer to your local laboratory instructions) and continued until 30 s after the recorder's return to baseline. After the collection tube is detached, the sample can be analyzed directly when collected into a GC NMR collection tube[2] or transferred to the 0.1-mL conical GC collection vial. After the collection tube is joined to the vial (preweighed with cap) by the 5/5 joints, the system is centrifuged to force the sample down into the vial (Fig. 5.3). The collection tube is then removed, and the vial is capped and reweighed.

The efficiency of collection can exceed 90% with most materials, even with relatively low-boiling substances. In the latter case, the collection tube, after attachment to the instrument, is wrapped with a paper tissue. As the (oven-dried) tube is being wrapped, it is also being flushed by the carrier gas, which removes any traces of water condensation. The wrapping is then saturated with liquid nitrogen to cool the collection tube.

Preparative GC in the microscale laboratory often replaces the macroscale purification technique of fractional distillation. Distillation is impractical with less than 500 μL of liquid.

[2]Bressette, A. R. *J. Chem. Educ.* **2001**, *78,* 366.

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Refer to Experiment [2] for specific experimental details on preparative GC applied to the separation of a number of binary (two-component) mixtures. These are designed as practice examples to give you experience with sample collection.

QUESTIONS

5-1. What is the main barrier to separating liquid mixtures of less than 500 μL by distillation?

5-2. A sample mixture of ethyl benzoate (bp 212 °C) and dodecane (bp 216.2 °C) is injected on two GC columns. Column A has DC710 silicone oil as the stationary phase, and column B uses polyethylene glycol as the stationary phase. Which substance would be certain to elute first from column A and would the same material be expected to elute first from column B? Which column, A or B, would be expected to give the better separation of these two substances?

5-3. Question 5-2 refers to separating a mixture of two high boiling liquids by gas chromatography. These materials have similar boiling points. List several GC variables and conditions that would make it easier to separate these substances by gas chromatography.

5-4. Capillary GC columns have better resolution than packed columns even though the enormous surface area provided by the packing material is absent in capillary columns. Why?

5-5. Preparative GC requires packed columns. Why is this technique limited to these lower resolution columns?

NOTE. Gas chromatographic purification of reaction products is suggested in the following experiments: Experiments [2], [3C], [3D], [5A], [5B], [8C], [9], [10], [13], [17], and [32].

TECHNIQUE 2

Simple Distillation

Distillation is the process of heating a liquid to the boiling point, condensing the heated vapor by cooling, and returning either a portion of, or none of, the condensed vapors to the distillation vessel. Distillation differs from reflux (see p. 23) only in that at least some of the condensate is removed from the boiling system. Distillations in which a fraction of the condensed vapors are returned to the boiling system are often referred to as being under "partial reflux." Two types of distillations will be described. Students are encouraged to refer to and study the more detailed discussion of distillation theory. The website also has a detailed discussion of the theory of steam distillation, which is used in Experiments [11C] and [32]. There are times when ordinary distillation may not be feasible for the separation of a liquid from dissolved impurities. The compound of interest may boil at a high temperature that is difficult to control with a simple apparatus, or it may tend to decompose or oxidize at high temperatures. If the compound is only sparingly soluble in water and any small amount of water can be removed with a drying agent, steam distillation may be the technique of choice. Compounds that are immiscible in water have very large positive deviations from Raoult's law. Therefore, the boiling temperature is generally lower than that of water and the compound.

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Simple distillation involves the use of the distillation process to separate a liquid from minor components that are nonvolatile, or that have boiling points at least 30–40 °C above that of the major component. A typical setup for a macroscale distillation of this type is shown in Figure 5.4. At the microscale

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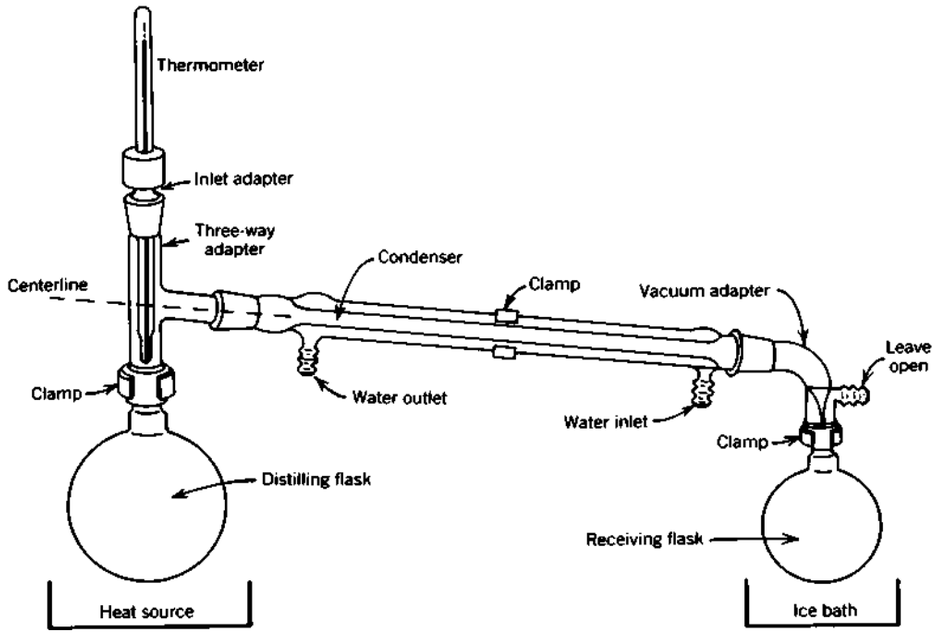

Figure 5.4 A complete simple distillation setup. (From Zubrick, J. W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)

level, working with volumes smaller than 500 μL, GC techniques (see Technique 1) have replaced conventional microdistillation processes.[3] Semimicroscale simple distillation is an effective separation technique for volumes in the range of 0.5–2 mL. Apparatus that achieve effective separation of mixture samples in this range have been developed. One of the most significant of these designs is the classic Hickman still, shown in Figure 5.5. This still is used in several ways in the experiments described in Chapters 6, 7, and 10W for purifying solvents, carrying out reactions, and concentrating solutions. Experiment [3] introduces the use of the Hickman still.

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In a distillation where liquid is to be separated from a nonvolatile solute, the vapor pressure of the liquid is lowered by the presence of the solute, but the vapor phase consists of only one component. Thus, except for the incidental transfer of non-volatile material by splashing, the material condensed should consist only of the volatile component (see Experiment [3A]).

We can understand what is going on in a simple distillation of two volatile components by referring to the phase diagrams shown in Figures 5.6 and 5.7. Figure 5.6 is the phase diagram for hexane and toluene. The boiling points of these liquids are separated by 42 °C. Figure 5.7 is the phase diagram for methylcyclohexane and toluene. Here the boiling points are separated by only 9.7 °C.

Imagine a simple distillation of the hexane–toluene pair in which the liquid in the pot is 50% hexane. In Figure 5.6, when the liquid reaches 80.8 °C it will be in equilibrium with vapor having a composition of 77% hexane. This result is indicated by the line *A–B.* If this vapor is condensed to a liquid of the same composition, as shown by line *B–C,* we will have achieved a significant enrichment of the condensate with respect to hexane. This change in composition is referred to

[3]Schneider, F. L. In *Monographien aus dem Gebiete der qualitätiven Mikroanalyse,* Vol. II: *Qualitative Organic Microanalysis;* Benedetti-Pichler, A. A., Ed.; Springer-Verlag: Vienna, 1964; p. 31.

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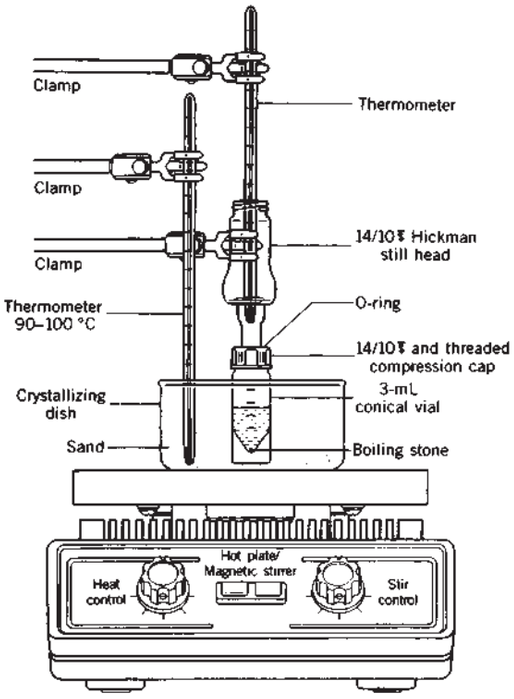

Figure 5.5 Hickman still (14/10 ⅌ with conical vial [3 mL]).

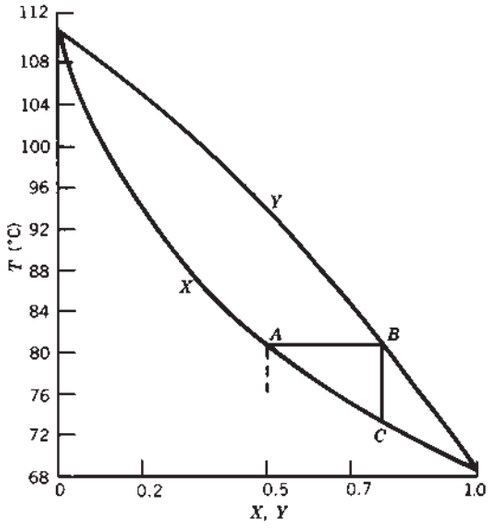

Figure 5.6 Temperature as a function of liquid composition (*X*) and vapor composition (*Y*): hexane and toluene.

as a simple distillation. The process of evaporation and condensation is achieved by the theoretical construct known as a *theoretical plate.* When this distillation is actually done with a Hickman still, some of the mixture will go through one evaporation and condensation cycle, some will go through two of these cycles, and some may be splashed more directly into the collar. A resolution (separation) of between one and two theoretical plates is generally obtained.

Referring to Figure 5.7, if we consider the same process for a 50% mixture of methylcyclohexane and toluene, the methylcyclohexane composition will increase to 58% for a distillation with one theoretical plate. Simple distillation may thus provide adequate enrichment of the MVC (more volatile constituent) if the boiling points of the two liquids are reasonably well separated, as they are for hexane and toluene. If the boiling points are close together, as they are for methylcyclohexane and toluene, the simple distillation will not provide much enrichment.

As we continue the distillation process and remove some of the MVC by condensing it, the residue in the heated flask becomes less rich in the MVC. This means that the next few drops of condensate will be less rich in the MVC. As the distillation is continued, the condensate becomes less and less rich in the MVC.

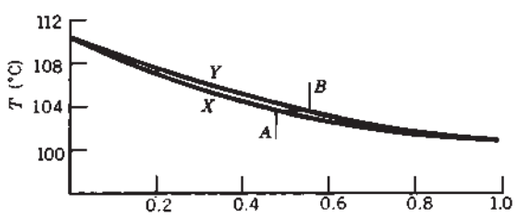

Figure 5.7 Temperature as a function of liquid composition (*X*) and vapor composition (*Y*): methylcyclohexane and toluene.

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We can improve on simple distillation by repeating the process. For example, we could collect the condensate until about one-third is obtained. Then we could collect a second one-third aliquot in a separate container. Our original mixture would then be separated into three fractions. The first third would be richest in the MVC and the final third (the fraction remaining in the distillation pot) would be the richest in the least volatile component. If the MVC were the compound of interest, we could re-distill the first fraction collected (from a clean flask!) and collect the first third of the material condensing in that process. This simplest of all fractional distillation strategies is used in Experiment [3B].

QUESTIONS

5-6. What is the major drawback of trying to distill a 500-μL mixture of liquids, all with boiling points below 200 °C?

5-7. How might you separate the mixture discussed in question 5-6 if distillation were unsuccessful? Explain your choice.

5-8. If starting with an equal mixture of hexane and toluene, approximate the composition of hexane if the vapor at 94 °C is condensed to a liquid using the data presented in Figure 5.6.

5-9. Why do simple distillations require that the components of the mixture to be separated have boiling points that are separated by 40 °C or more?

5-10. Which constituent of an equimolar mixture makes the larger contribution to the vapor pressure of the mixture, the higher or lower boiling component? Explain.

NOTE. The following experiments use Technique 2: Experiments [3A], [3B], [11C], [29], and [32].

www → *[3A$_{adv}$].*

TECHNIQUE 3

Fractional Distillation

Fractional distillation can occur in a distillation system containing more than one theoretical plate. This process must be used when the boiling points of the components differ by less than 30–40 °C and fairly complete separation is desired. A fractionating column is needed to accomplish this separation. As discussed previously, a liquid– vapor composition curve (Fig. 5.8) shows that the lower boiling component of a binary mixture makes a larger contribution to the vapor composition than does the higher boiling component. On condensation, the liquid formed will be richer in the lower boiling component. This condensate will not be pure, however, and, in the case of components with close boiling points, it may be only slightly enriched. If the condensate is vaporized a second time, the vapor in equilibrium with this liquid will show a further enrichment in the lower boiling component. The trick to separating liquids with similar boiling points is to repeat the vaporization–condensation cycle many times. Each cycle is one *theoretical plate.* Several column designs, which achieve varying numbers of theoretical plates, are available for use at the macro level (Fig. 5.9).

Most distillation columns are designed so that fractionation efficiency is achieved by the very large surface area in contact with the vapor phase (and

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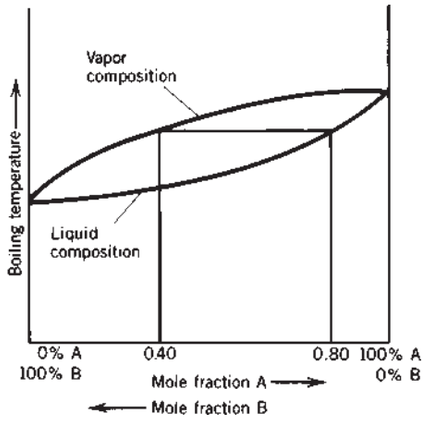

Figure 5.8 Liquid–vapor composition curve.

very similar to the way increased resolution is obtained on a GC column (see Technique 1). This increased surface area can be accomplished by packing the fractionating column with wire gauze or glass beads. Unfortunately, a large volume of liquid must be distributed over the column surface in equilibrium with the vapor. Furthermore, the longer the column the more efficient it becomes (see Technique 1), but longer columns also require additional liquid phase. The amount of liquid phase required to fill the column with a liquid—vapor equilibrium is called *column holdup*. Column holdup is essentially lost from the distillation because this volume can never go past the top of the distillation column; it can only return to the distillation pot upon cooling. Column holdup can be large compared to the total volume of material available for the distillation. With mixtures of less than 2 mL, column holdup precludes the use of the most common fractionation columns. Columns with rapidly spinning bands of metal gauze or Teflon have very low column holdup and have a large number of theoretical plates relative to their height (Fig. 5.10).

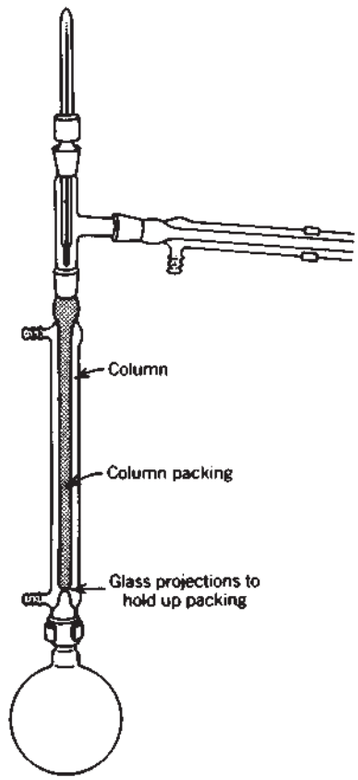

Figure 5.9 A fractional distillation setup. (From Zubrick, J.W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. Reprinted with permission of John Wiley & Sons, Inc., New York.)

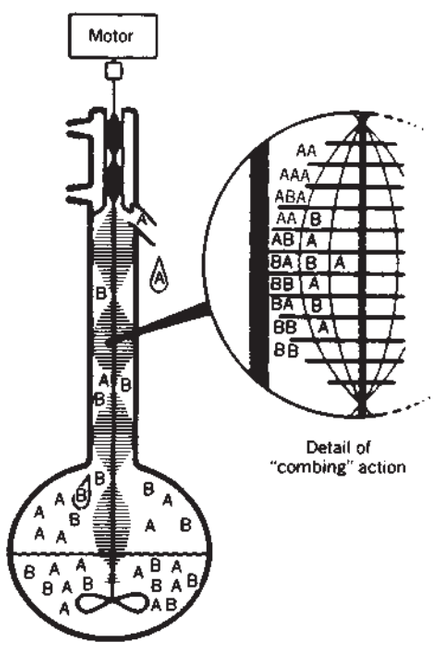

Figure 5.10 Schematic of a metal-mesh, spinning-band still.

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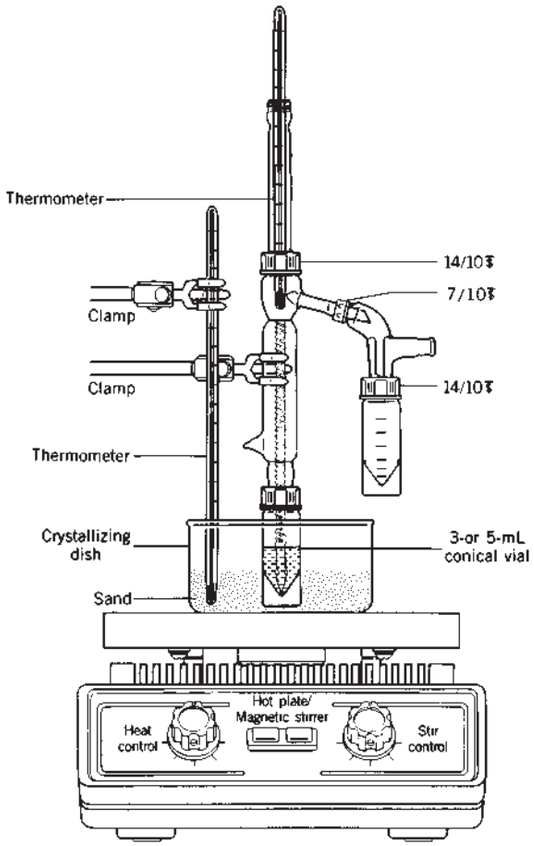

Figure 5.11 Microspinning band distillation column (3 in.).

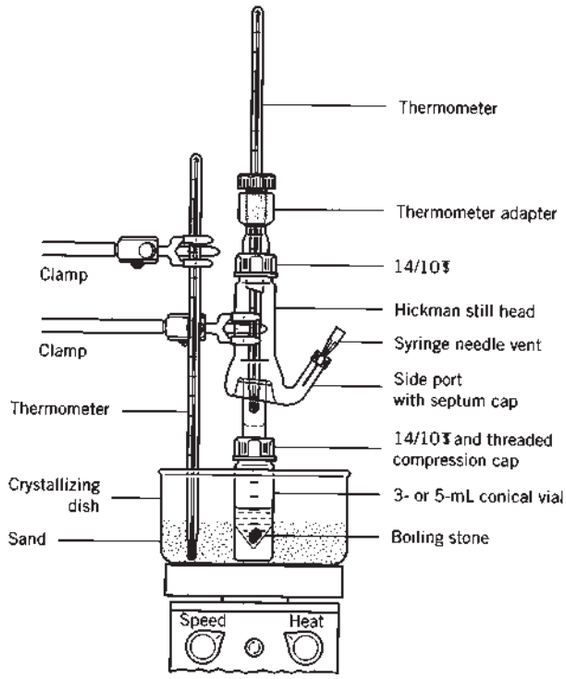

Figure 5.12 Hickman still with thermometer adapter.

Microscale spinning-band distillation apparatus (Fig. 5.11) can achieve nearly 12 theoretical plates and are simple enough to be used in the instructional laboratory. This still has a Teflon band that fits closely inside an insulated glass tube. The Teflon band has spiral grooves which, when the band is spun (1000–1500 rpm), rapidly return condensed vapor to the distillation pot. A powerful extension of this apparatus uses a short spinning band inside a modified Hickman still head (see Fig. 3.15). These stills are called Hickman–Hinkle stills; 4-cm Hickman–Hinkle columns can have more than 10 theoretical plates. The commercially available 2.5-cm version is rated at 6 theoretical plates. Experiments [3C] and [3D] involve fractional distillation with spinning-band columns.

The thermometer is positioned directly down the center of the distillation column, with the bulb just at the bottom of the well. It is very important to position both the still and the thermometer as vertically as possible; the thermometer must not touch the glass walls of the column (Fig. 5.12). Experiment [3B] uses the Hickman still for fractional distillation. A two-theoretical-plate distillation is obtained with this system on a two-component mixture by carrying out two sequential fractional distillations.

www For a more detailed discussion of how spinning bands work, see the discussion of distillation.

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QUESTIONS

5-11. Why is it very important that the hot vapor in microscale distillations climb the column very slowly?

5-12. Why might Teflon be the material of choice for constructing microscale spinning bands?

5-13. The spinning band overcomes two major problems of microscale distillations by wiping the liquid condensate rapidly from the column walls. What are these problems?

5-14. Why are spinning bands so effective at increasing the number of theoretical plates in distillation columns?

5-15. Why is steam distillation often used to isolate and purify naturally occurring plant substances?

NOTE. The following experiments use Technique 3: Experiments [3C] and [3D].

TECHNIQUE 4

Solvent Extraction

Solvent extraction is frequently used in the organic laboratory to separate or isolate a desired compound from a mixture or from impurities. Solvent extraction methods are readily adapted to microscale work because small quantities are easily manipulated in solution. Solvent extraction methods are based on the solubility characteristics of organic substances in the solvents used in a particular separation procedure. Liquid–liquid and solid–liquid extractions are the two major types of extractions used in the organic laboratory.

Intermolecular Properties: Solubility

Substances vary greatly in their solubility in various solvents, but a useful and generally true principle is that a substance tends to dissolve in a solvent that is chemically similar to itself. In other words, *like dissolves like.* The significant exceptions to this general statement are seen when solubilities are determined by acid–base properties.

Thus, to be soluble in water a compound needs to have some of the molecular characteristics of water. Alcohols, for example, have a hydroxyl group (—OH) bonded to a hydrocarbon chain or framework (R—OH). The hydroxyl group can be thought of as effectively half a water (H_2O) molecule; its polarity is similar to that of water. This polarity is due to the charge separation arising from the different electronegativities of the hydrogen and oxygen atoms. The O—H bond, therefore, is considered to have partial ionic character.

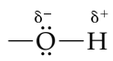

Partial ionic character of the hydroxyl group

This polar, or partial ionic, character leads to relatively strong hydrogen bond formation between molecules with hydroxyl groups. Strong hydrogen bonding (shown here for the ethanol–water system) occurs in molecules that have a hydrogen atom attached to an oxygen, nitrogen, or fluorine atom—all three are quite electronegative atoms.

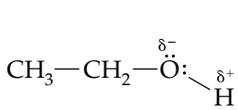

Ethanol

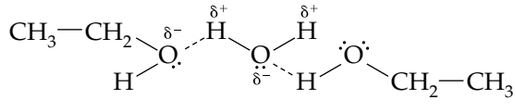

Hydrogen bond formation

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Table 5.1 **Comparison of Boiling Point Data**

Name	Formula	MW	bp (°C)
Ethanol	CH_3CH_2OH	46	78.3
Propane	$CH_3CH_2CH_3$	44	−42.2
Methyl acetate	$CH_3CO_2CH_3$	74	54
Diethyl ether	$(CH_3CH_2)_2O$	74	34.6
Ethene	$CH_2{=}CH_2$	28	−102
Methylamine	CH_3NH_2	31	−6

The hydroxyl end of the ethanol molecule is very similar to water. When ethanol is added to water, therefore, they are miscible in all proportions. That is, ethanol is completely soluble in water and water is completely soluble in ethanol. This degree of solubility occurs because the attractive forces between the two molecules are nearly as strong as those between two water molecules; however, the attraction in the first case is somewhat weakened by the presence of the nonpolar ethyl group, CH_3CH_2—. Hydrocarbon groups attract each other only weakly, as demonstrated by their low melting and boiling points. Three examples of the contrast in boiling points between compounds of different structure, but similar molecular weight, are summarized in Table 5.1. Molecules that attract each other weakly (lower intermolecular forces) have lower boiling points.

Ethanol is completely miscible with water, but the solubility of octanol in water is less than 1%. Why the difference in solubilities between these two alcohols? The dominant structural feature of ethanol is its polar hydroxyl group; the dominant structural feature of octanol is its nonpolar alkyl group:

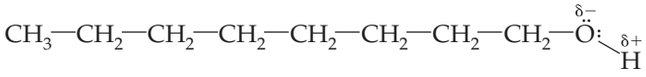

Octanol

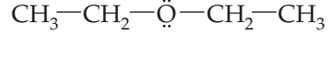

Diethyl ether

As the size of the hydrocarbon section of the alcohol molecule increases, the intermolecular attraction between the polar hydroxyl groups of the alcohol and the water molecules is no longer strong enough to overcome the hydrophobic (lacking attraction to H_2O) nature of the nonpolar hydrocarbon section of the alcohol. On the other hand, octanol has a large nonpolar hydrocarbon group as its dominant structural feature. We might, therefore, expect octanol to be more soluble in less polar solvents, and, in fact, octanol is completely miscible with diethyl ether. Ethers are weakly polar solvents because a C—O bond is much less polar than an O—H bond (carbon is less electronegative than oxygen). Because both octanol and diethyl ether are rather nonpolar, each is completely soluble in the other. For compounds with both polar and nonpolar groups, in general, those compounds with five or more carbon atoms in the hydrocarbon portion of the molecule will be more soluble in nonpolar solvents, such as pentane, diethyl ether, or methylene chloride. Figure 5.13 summarizes the solubilities of a number of straight-chain alcohols, carboxylic acids, and hydrocarbons in water. As expected, most monofunctional compounds with more than five carbon atoms have solubilities similar to the hydrocarbons.

Several additional relationships between solubility and structure have been observed.

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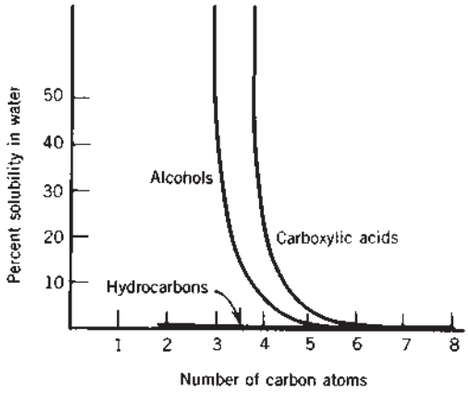

Figure 5.13 Solubility curve of acids, alcohols, and hydrocarbons. (From Kamm, O. *Qualitative Organic Analysis,* 2nd ed.; Wiley: New York, 1932. Reprinted with permission of John Wiley & Sons, New York.)

1. Branched-chain compounds have greater water solubility than their straight-chain counterparts, as illustrated in Table 5.2 with a series of alcohols.

2. The presence of more than one polar group in a compound will increase that compound's solubility in water and decrease its solubility in nonpolar solvents. For example, sugars, such as cellobiose, contain multiple hydroxyl and/or acetal groups and are water soluble and ether insoluble. Cholesterol, which has only a single hydroxyl group on its 27 carbon atoms, is insoluble in water and quite soluble in ether.

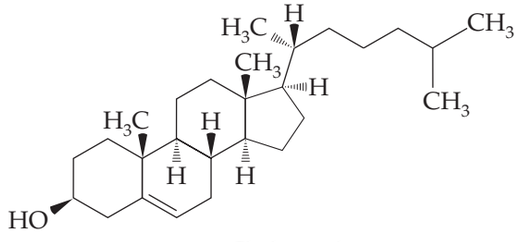

Cholesterol

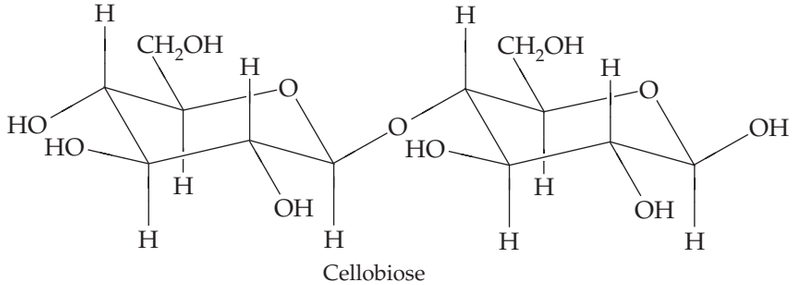

Cellobiose

Table 5.2 Water Solubility of Alcohols		
Name	Structural Formula	Solubility (g/100 g H_2O at 20 °C)
Hexanol	$CH_3(CH_2)_4CH_2OH$	0.6
Pentanol	$CH_3(CH_2)_3CH_2OH$	2.2
2-Pentanol	$CH_3(CH_2)_2CH(OH)CH_3$	4.3
2-Methyl-2-butanol	$(CH_3)_2C(OH)CH_2CH_3$	11.0

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Table 5.3 **Water Solubility of Amines**

Name	Structural Formula	Solubility (g/100 g H_2O at 25 °C)
Ethylamine	$CH_3CH_2NH_2$	∞
Diethylamine	$(CH_3CH_2)_2NH$	∞
Trimethylamine	$(CH_3)_3N$	91
Triethylamine	$(CH_3CH_2)_3N$	14
Aniline	$C_6H_5—NH_2$	3.7
1,4-Diaminobenzene	$H_2N—C_6H_4—NH_2$	3.8

3. The presence of a chlorine atom, even though it lends some partial ionic character to the mostly covalent C—Cl bond, does not normally impart water solubility to a compound. In fact, compounds such as methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), and carbon tetrachloride (CCl_4) have long been used as solvents for extracting aqueous solutions. The latter two solvents are not often used nowadays, unless strict safety precautions are exercised, because they are potentially carcinogenic.

4. Most functional groups capable of forming a hydrogen bond with water increased the water solubility of a substance. For example, smaller alkyl amines have significant water solubility; the water-solubility data for a series of amines are summarized in Table 5.3.

The solubility characteristics of any given compound govern its distribution (*partition*) between the phases of two immiscible solvents (in which the material has been dissolved) when these phases are intimately mixed.

PARTITION (OR DISTRIBUTION) COEFFICIENT

A given substance *X* is partially soluble in each of two immiscible solvents. If *X* is placed in a mixture of these two solvents and shaken, an equilibrium will be established between the two phases. That is, substance *X* will partition (distribute) itself in a manner that is a function of its relative solubility in the two solvents:

$$X_{\text{solvent 1}} \rightleftharpoons X_{\text{solvent 2}}$$

The equilibrium constant, K_p, for this equilibrium expression is known as the *partition* or *distribution coefficient*:

$$K_p = \frac{[X_{\text{solvent 2}}]}{[X_{\text{solvent 1}}]}$$

The equilibrium constant is thus the ratio of the concentrations of the species, *X*, in each solvent for a given system at a given temperature. The partition coefficient can be conveniently estimated as the ratio of the solubility of *X* in solvent 1 vs. solvent 2:

$$K_p = \frac{\text{solubility of } X \text{ in solvent 2}}{\text{solubility of } X \text{ in solvent 1}}$$

When solvent 1 is water and solvent 2 is an organic solvent such as diethyl ether, the basic equation used to express the coefficient K_p is

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$$K_p = \frac{(g/100\ mL)_{organic\ layer}}{(g/100\ mL)_{water\ layer}}$$

This expression uses grams per 100 mL for the concentration units. Note that the partition coefficient is dimensionless, so any concentration units may be used if the units are the same for both phases. For example, grams per liter (g/L), parts per million (ppm), and molarity (M) can all be used. If equal volumes of both solvents are used, the equation reduces to the ratio of the weights ($g_{organic}/g_{water}$) of the given species in the two solvents:

$$K_p = \frac{g_{organic\ layer}}{g_{water\ layer}}$$

Determination of the partition coefficient for a particular compound in various immiscible-solvent combinations often can give valuable information for isolating and purifying the compound by using extraction techniques. Thus, liquid–liquid extraction is a common separation technique used in organic as well as analytical laboratories.

Table 5.4 provides some examples of K_p values determined at room temperature for a number of compounds in the water–methylene chloride system.

Let us now look at a typical calculation for the extraction of an organic compound P from an aqueous solution using diethyl ether. We will assume that the $K_{p\ ether/water}$ value (partition coefficient of P between diethyl ether and water) is 3.5 at 20 °C. If a solution of 100 mg of P in 300 μL of water is extracted at 20 °C with 300 μL of diethyl ether, the following expression holds:

$$K_{p\ ether/water} = \frac{C_e}{C_w} = \frac{W_e/300\ \mu L}{W_w/300\ \mu L}$$

where

W_e = weight of P in the ether layer
W_w = weight of P in the water layer
C_e = concentration of P in the ether layer
C_w = concentration of P in the water layers

Since $W_w = 100 - W_e$, the preceding relationship can be written as

$$K_{p\ ether/water} = \frac{W_e/300\ \mu L}{(100 - W_e)/300\ \mu L} = 3.5$$

If we solve for the value of W_e, we obtain 77.8 mg; the value for W_w is 22.2 mg. Thus, we see that after one extraction with 300 μL of ether, 77.8 mg of P (77.8% of the total) is removed by the ether and 22.2 mg (22.2% of the total) remains in the water layer. Is it preferable to make a single extraction with the total quantity of solvent available, or to make multiple extractions with portions of the solvent? The second method is usually more efficient.

Table 5.4 **Representative K_p Values in CH_2Cl_2—H_2O**

Compound	K_p Value
Nitrobenzene	51.5
Aniline	3.3
1,2-Dihydroxybenzene	0.2

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To illustrate, consider extracting the 100 mg of P in 300 μL of water with *two 150*-μL portions of diethyl ether instead of one 300-μL portion.

For the first 150-μL extraction,

$$\frac{W_e/150\ \mu L}{W_w/300\ \mu L} = \frac{W_e/150\ \mu L}{(100 - W_e)/300\ \mu L}$$

Solving for W_e, we obtain 63.6 mg. The amount of P remaining in the water layer (W_w) is then 36.4 mg. The aqueous solution is now extracted with the second portion of ether (150 μL). We then have

$$\frac{W_e/150\ \mu L}{(36.4 - W_e)/300\ \mu L} = 3.5$$

As before, by solving for W_e, we obtain 23.2 mg for the amount of P in the ether layer; $W_w = 13.2$ mg in the water layer.

The two extractions, each with 150 μL of ether, removed a total of 63.6 mg + 23.2 mg = 86.8 mg of P (86.8% of the total). The P left in the water layer is then 100 − 86.8, or 13.2 mg (13.2% of the total).

It can be seen from these calculations that the multiple-extraction technique is more efficient. The single extraction removed 77.8% of P; the double extraction (with the same total volume of ether) increased this to 86.8%. To extend this relationship, three extractions with one-third the total quantity of ether in each portion would be even more efficient. You might wish to calculate this to prove the point. Of course, there is a practical limit to the number of extractions that can be performed.

The multiple-extraction example shown here illustrates that several extractions with small volumes is more efficient than a single extraction procedure. This is always true *provided* the partition coefficient is neither very large nor very small. If the partition coefficient K_p for a substance between two solvents is very large ($K_p > 100$) or very small ($K_p < 0.01$), multiple extractions (using the same total amount of solvent) do not significantly increase the efficiency of the extraction process.[4]

Extraction

Liquid–Liquid Extraction. The more common type of extraction, liquid–liquid extraction, is used extensively. It is a very powerful method for separating and isolating materials at the microscale level. It is operationally not a simple process, so attention to detail is critical.

There are several important criteria to consider when choosing a solvent for the extraction and isolation of a component from a solution:

- The chosen extraction solvent must be immiscible with the solution solvent.
- The chosen extraction solvent must be favored by the distribution coefficient for the component being extracted.
- The chosen extraction solvent should be readily separated from the desired component after extraction. This usually means that it should have a low boiling point.
- The chosen organic extraction solvent must not react chemically with any component in the aqueous mixture being extracted.

[4]Palleros, D. R. *J. Chem. Educ.* **1995,** *72,* 319.

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NOTE. The aqueous phase may be modified, as in acid–base extractions, but the organic solvent does not react with the components in the aqueous mixture. See Experiments [4B, 4C], pp. 146–150.

Microscale Extraction. A capped conical vial or a stoppered centrifuge tube is the best container for most microscale extractions, but a small test tube may be used. Note that a conical vial and a centrifuge tube have the same inner shape. This shape has the advantage that as the lower phase (layer) is withdrawn by pipet, the interface (boundary) between the two liquid phases becomes narrower and narrower, and thus easier to see, at the bottom of a conical container. This is not the case for a test tube. The centrifuge tube has the added advantage that if a solid precipitate must be separated or an emulsion broken up, it can easily be done using a centrifuge.

A good rule of thumb is that the container to be used for the extraction should be *at least three times the volume of liquid* you wish to extract.

Regardless of the container used, in any liquid–liquid extraction, the two immiscible solvents must be completely mixed to maximize the surface area of the interface between the two and allow partitioning of the solute. This can be accomplished by shaking (carefully to avoid leakage around the cap), using a Vortex mixer, or by adding a magnetic spin vane and then stirring with a magnetic stirrer.

Another important rule in the extraction process is that you should *never discard any layer until the isolation is complete.*

Let us consider a practical example. Benzanilide can be prepared by the in situ rearrangement of benzophenone oxime in acid solution:

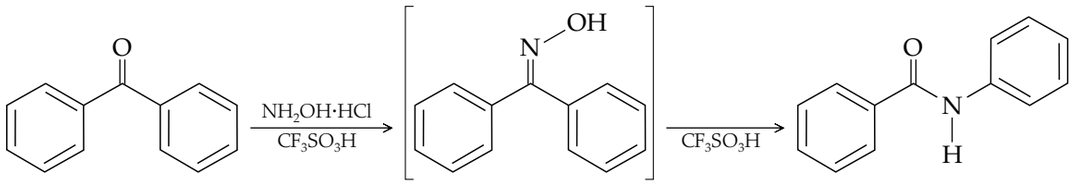

Benzophenone — Benzophenone oxime — Benzanilide

The benzanilide is separated from the reaction mixture by extraction with three 1.0-mL portions of methylene chloride solvent.

NOTE. Saying, for example, "extracted with three 1.0-mL portions of methylene chloride" means that three extractions are performed (one after the other, each using 1.0 mL of methylene chloride) and the three methylene chloride extracts are combined.

A microscale extraction process consists of two parts: (1) mixing the two immiscible solutions, and (2) separating the two layers after the mixing process.

1. Mixing. In the experimental procedure for the isolation of the benzanilide product, methylene chloride (1.0 mL) is added to the aqueous reaction mixture contained in a 5.0-mL conical vial (or centrifuge tube). The extraction procedure is outlined in the following steps:

Step 1. Cap the vial.

Step 2. Shake the vial gently to thoroughly mix the two phases (careful!)

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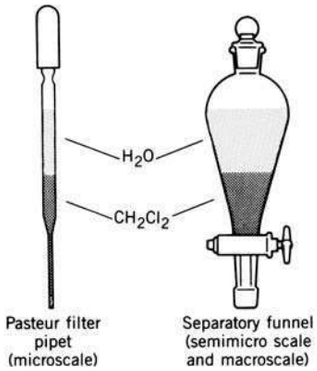

Figure 5.14 Extraction devices.

NOTE. The mixing may be carried out using a Vortex mixer or magnetic stirrer—see previous discussion.

Step 3. Carefully vent the vial by loosening the cap to release any pressure that may have developed.

Step 4. Allow the vial to stand on a level surface to permit the two phases to separate. A sharp phase interface should appear.

NOTE. For safety reasons it is advisable to place the vial in a small beaker to prevent tipping. If a volatile solvent such as ether is used, it is advisable to place the vial or centrifuge tube in a beaker of ice water to prevent loss of solvent during the transfers.

2. Separation. At the microscale level, the two phases are separated with a Pasteur filter pipet (a simple Pasteur pipet can be used in some situations), which acts as a miniature separatory funnel. The separation of the phases is shown in Figure 5.14.

A major difference between macro and micro techniques is that when microscale volumes are used, as just discussed, the mixing and separation are done in two parts. When macroscale volumes are used in a separatory funnel, mixing and separation are both done in the funnel in one step. The separatory funnel is an effective device for extractions with larger volumes, but it is not practical for microscale extractions because of the large surface areas involved.

Benzanilide is more soluble in methylene chloride than in water. Multiple extractions are performed to ensure complete removal of the benzanilide from the aqueous phase. The methylene chloride solution is the lower layer because it is more dense than water. The following list outlines the general method for an organic solvent more dense than water.

NOTE. (a) One technique is to hold the pipet across the palm of the hand and squeeze the bulb with the thumb and index finger. (b) Remember to have an empty tared vial available in which to place the separated phase. (c) A pipet pump (Figure 5.15) may be used to replace the bulb. One advantage with using a pipet pump is the dispensing of liquids in a more controlled fashion.

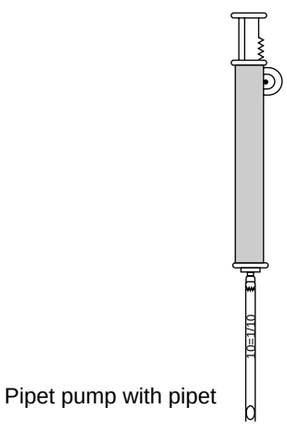

Figure 5.15 Pipet pump with pipet. (Reprinted with permission of John Wiley and Sons, Inc. from Szafran, Z.; Pike, R. M.; Foster, J. C. Microscale *General Chemistry Laboratory,* 2nd ed., p. 36. 2003.)

The recommended procedures are shown in Figures 5.16 and 5.17.

Step 1. Squeeze the pipet bulb to force air from the pipet.

Step 2. Insert the pipet into the vial until it is close to the bottom. Be sure to hold the pipet vertically.

Step 3. Carefully allow the bulb to expand, drawing only the lower methylene chloride layer into the pipet. This should be done in a smooth, steady manner so as not to disturb the interface between the layers. With practice, you can judge the amount that the bulb must be squeezed to just separate the layers. Keep the pipet vertical. *Do not tip the pipet back and allow liquid to enter the bulb! Do not suck liquid into the bulb!*

Step 4. (Step 4 is not shown in the figure.) Holding the pipet vertical, place it over and into the neck of an empty vial (as shown in Fig. 5.16, Step 2), and gently squeeze the bulb to transfer the methylene chloride solution into the vial. A second extraction can now be performed after adding

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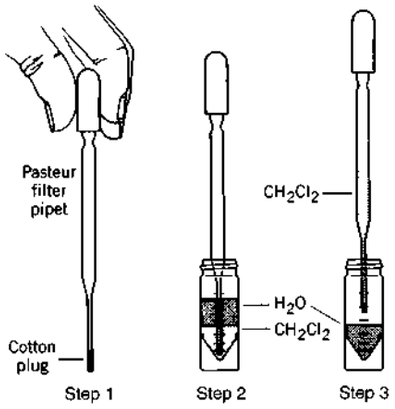

Figure 5.16 Pasteur filter pipet separation of two immiscible liquid phases; the more dense layer contains the product.

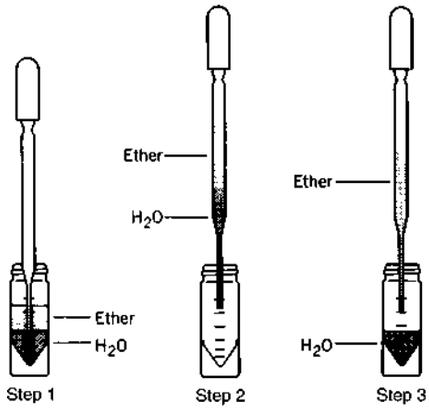

Figure 5.17 Pasteur filter pipet separation of two immiscible liquid phases; the less dense layer contains the product.

another portion of methylene chloride to the original vial. The procedure is repeated. Multiple extractions can be performed in this manner. Each methylene chloride extract is transferred to the same vial—that is, the extracts are combined. The reaction product has now been transferred from the aqueous layer (aqueous phase) to the methylene chloride layer (organic phase), and the phases have been separated.

In a diethyl ether–water extraction, the ether layer is less dense and thus is the upper layer (phase). An organic reaction product generally dissolves in the ether layer and is thus separated from water-soluble byproducts and other impurities. The procedure followed to separate the water–ether phases is identical to that described above for methylene chloride–water systems, except that here the top layer (organic layer) is transferred to the new container. The following list outlines the general method for an organic solvent less dense than water (refer to Fig. 5.17).

Step 1. Squeeze the pipet bulb to force air from the pipet and insert the pipet into the vial until it is close to the bottom. Then, draw **both** phases slowly into the pipet. Keep the pipet vertical. *Do not tip the pipet back and allow liquid to enter the bulb! Do not suck liquid into the bulb!* Try not to allow air to be sucked into the pipet, as this tends to mix the phases in the pipet. If mixing does occur, allow time for the interface to re-form.

Step 2. Return the aqueous layer (bottom layer) to the **original** container by gently squeezing the pipet bulb.

Step 3. Transfer the separated ether layer (top layer) to a new tared vial.

Separatory Funnel—Semimicroscale and Macroscale Extractions. A separatory funnel (Fig. 5.14) is effective for extractions carried out at the semimicroscale and macroscale levels. The mixing and separation are done in the funnel itself in one step. Many of you may be familiar with this device from the general chemistry laboratory. The same precautions as outlined above for microscale extraction should be observed here.

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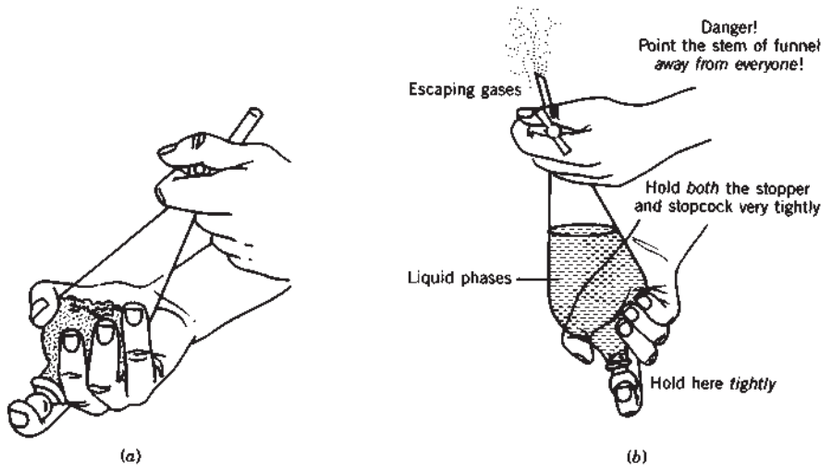

Figure 5.18 (a) Correct position for holding a separatory funnel while shaking. (b) Correct method for venting a separatory funnel.

NOTE. The funnel size should be such that the total volume of solution is less than half the total volume of the funnel. If the funnel has a ground-glass stopcock and/or stopper, the ground-glass surfaces must be lightly greased to prevent sticking, leaking, or freezing. If Teflon stoppers and stopcocks are used, grease is not necessary because these are self-lubricating.

Step 1. Close the stopcock of the separatory funnel.

Step 2. Add the solution to be extracted, after first making sure that the *stopcock is closed.* The funnel should be supported in an iron ring attached to a ring stand or rack on the lab bench.

Step 3. Add the proper amount of extraction solvent (about one-third of the volume of the solution to be extracted is a good rule of thumb) and place the stopper on the funnel.

Step 4. Remove the funnel from the ring stand, keeping the stopper in place with the index finger of one hand, and holding the funnel in the other hand with your fingers positioned so they can operate the stopcock (Fig. 5.18*a*).

Step 5. Carefully invert the funnel (make sure its stem is pointing up, and not pointing at you or anyone else). Slowly open the stopcock to release any built-up pressure (Fig. 5.18*b*). Close the stopcock and then shake the funnel for several seconds. Position the funnel for venting (make sure the stem is pointing up, and not pointing at you or anyone else). Open the stopcock to release built-up pressure. Repeat this process 2–4 times. Then, close the stopcock and return the funnel upright to the iron ring.

Step 6. Allow the layers to separate and then remove the stopper.

Step 7. Place a suitable clean container just below the tip of the funnel. Gradually open the stopcock and drain the bottom layer into the clean container.

Step 8. Remove the upper layer by pouring it from the top of the funnel. This way it will not become contaminated with traces of the lower layer found in the stem of the funnel.

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When aqueous solutions are extracted with a *less dense solvent*, such as ether, the bottom, aqueous layer can be drained *into its original container*. Once the top (organic) layer is removed from the funnel, the aqueous layer can then be returned for further extraction. Losses can be minimized by rinsing the original container with a small portion of the extraction solvent, which is then added to the funnel. When the extraction solvent is denser than the aqueous phase (e.g., methylene chloride), the aqueous phase is the top layer, and therefore is kept in the funnel for subsequent extractions.

Continuous Liquid–Liquid Extraction. Continuous extraction of liquid–liquid systems is also possible and particularly valuable when the component to be separated is only slightly soluble in the extraction solvent. The advantage of using continuous extraction is that it can be carried out with a limited amount of solvent. In batchwise extractions a prohibitive number of individual extractions might have to be performed to accomplish the same overall extraction. Specialized apparatus, however, is required for continuous liquid–liquid extraction.

Two types of continuous extraction apparatus are often used to isolate various species from aqueous solutions using less dense and more dense immiscible solvents (e.g., diethyl ether and methylene chloride) (Fig. 5.19).

The extraction is carried out by allowing the condensate of the extraction solvent, as it forms on the condenser on continuous distillation, to drop through an inner tube (see Fig. 5.19*a* in the case of the less dense solvent) and to percolate up through the solution containing the material to be extracted. This inner tube usually has a sintered glass plug on its end, which generates smaller droplets of the solvent and thus increases the efficiency of the procedure. The extraction solution is then returned to the original distilling flask. Eventually, in this manner, the desired material, extracted in small increments, is collected in the boiling flask and can then be isolated by concentrating the collected solution. This method works on the premise that fresh portions of the less-dense phase are continuously introduced into the system, and it is often used in those instances where the organic material to be isolated has an appreciable solubility in water. In the case of a more dense extraction solvent (see Fig. 5.19*b*) the system functions in much the same fashion, but in this case the inner tube is removed and the condensed vapors percolate directly through the lighter phase (the phase to be extracted) to form the lower layer. This layer can cycle back to the distillation flask through a small-bore tubing connection from the bottom of the receiver flask to the distillation flask. Continuous liquid–liquid extraction is useful for removing extractable components from those having partition ratios that approach zero. Note that this method requires a very long period of time.

Separation of Acids and Bases. The separation of organic acids and bases is another important and extensive use of the extraction method. The distribution coefficients of organic acids and bases are affected by pH when one of the solvents is water. An organic acid that is insoluble in neutral water (pH 7) becomes soluble when the water is made basic with an aqueous sodium hydroxide solution. The acid and the sodium hydroxide quickly react to form a sodium carboxylate salt, RCO_2^-, Na^+. The salt is, of course, ionic and therefore it readily dissolves in the water. Thus, the acid–base reaction reverses the solubility characteristics of a water-insoluble organic acid.

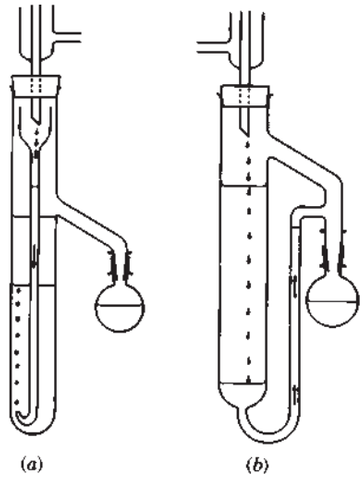

Figure 5.19 Early designs for single-stage extractors: (a) Kutscher–Steudel extractor; (b) Wehrli extractor.

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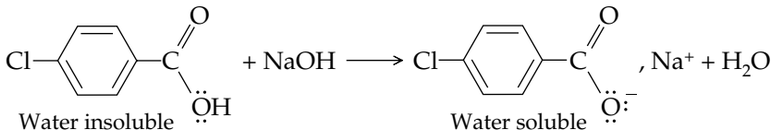

The water phase may then be extracted with an immiscible organic solvent to remove any impurities, leaving the acid salt in the water phase. Neutralizing the water layer with hydrochloric acid (to pH ≤ 7) reprotonates the carboxylate salt to reform the carboxylic acid, and causes the purified water-insoluble organic acid to precipitate (if it's a solid). In a similar fashion, water-insoluble organic bases, such as amines (RNH_2), can be rendered water soluble by treatment with dilute hydrochloric acid to form water-soluble hydrochloride salts (e.g., Experiment [23]).

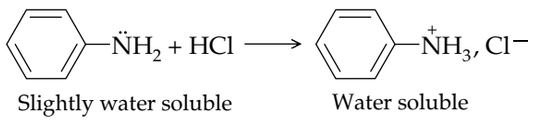

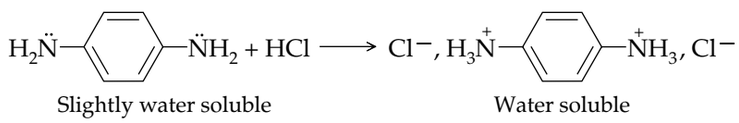

Extraction procedures can be used to separate mixtures of solids. For example, the flow chart below diagrams a sequence used to separate a mixture made up of an aromatic carboxylic acid ($ArCO_2H$), an aromatic base ($ArNH_2$), and a neutral aromatic compound (ArH). Aromatic compounds are discussed here simply because they are likely to be crystalline solids.

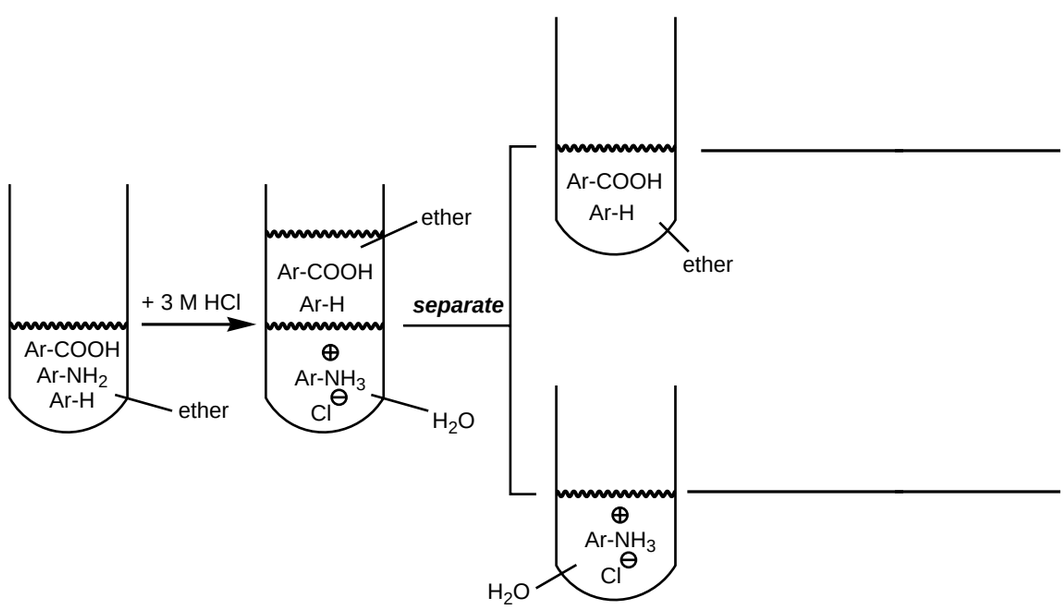

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In this example, we assume that the organic acid and base are solids. If either or both were liquids, an additional extraction of the final acidic aqueous or alkaline solution with ether, followed by drying and concentration, would be required to isolate the acidic or basic component.

Salting Out. Most extractions in the organic laboratory involve water and an organic solvent. Many organic compounds have partial solubility in both solvents. To extract them from water, the partition coefficient (between the organic solvent and water) can be shifted in favor of the organic layer by saturating the water layer with an inorganic salt, such as sodium chloride. Water molecules prefer to solvate the polar ions (in this case sodium and chloride ions), and thus free the neutral organic molecules to migrate into the organic phase. Another way to think of this is to realize that the ionic solution is more polar than pure water, so the less polar organic molecules are less soluble than in pure water. Forcing an organic material out of a water solution by adding an inorganic salt is called *salting out.*

Salting out can also be effectively used for the *preliminary drying* of the wet organic layer that results from an extraction process. (Diethyl ether, in particular, can dissolve a fair amount of water.) Washing this organic layer with a saturated salt solution removes most of the dissolved water into the aqueous phase. This makes further drying of the organic phase with solid drying agents easier and much more effective (see Drying Agents below).

Solid–Liquid Extraction

The simplest form of solid–liquid extraction involves treating a solid with a solvent and then decanting or filtering the solvent extract away from the solid. An example of this technique (see Experiment [11A]) is extracting usnic acid from

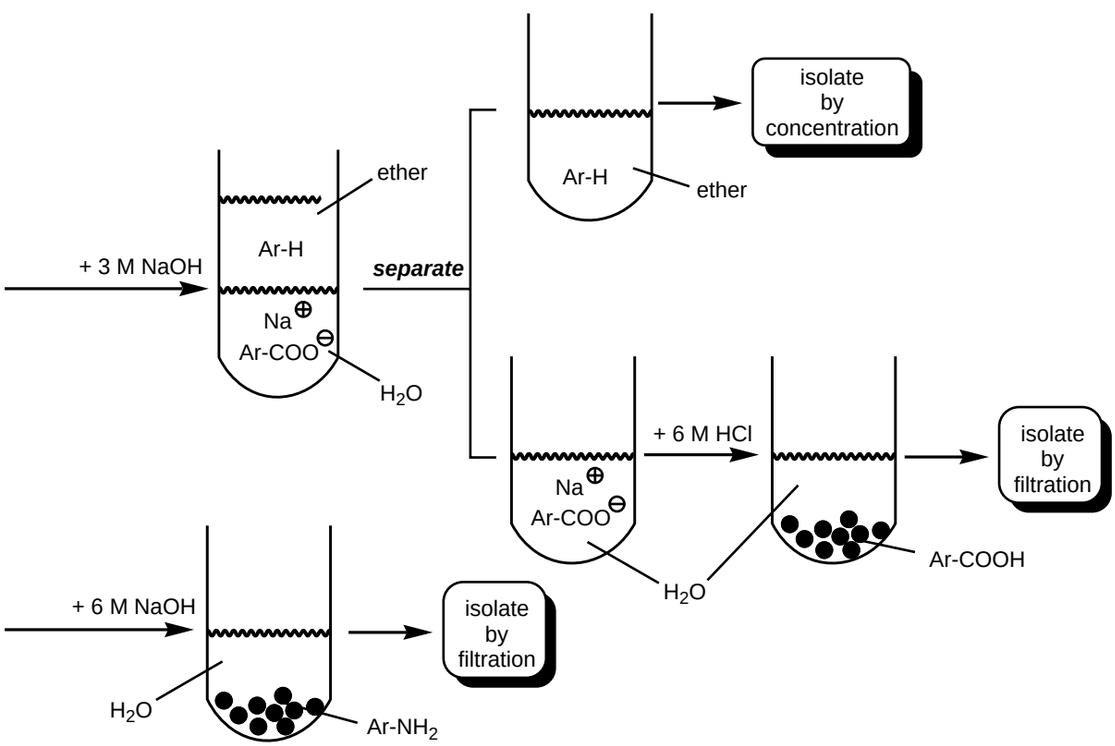

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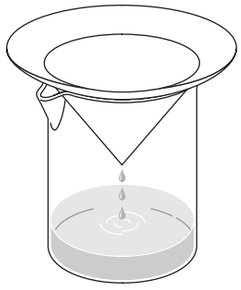

Figure 5.20 A solid–liquid continuous extraction apparatus.

its native lichen with acetone. This type of extraction is most useful when only one main component of the solid phase has appreciable solubility in the solvent. The extraction of caffeine from tea (see Experiment [11B]) is another example of this method; it is accomplished by heating the tea in an aqueous solution of sodium carbonate. This approach works well because the water swells the tea leaves and allows the caffeine to be extracted more readily.

Microscale extractions of trimyristin from nutmeg, and cholesterol from gallstones, have been described.[5] Diethyl ether was used as the solvent in both cases. A packed Pasteur pipet column was used for filtering, drying (nutmeg experiment), and decolorizing (gallstone experiment).

Herrera and Almy described a simple continuous extraction apparatus (Fig. 5.20).[6] The apparatus is constructed from a 50-mL beaker and a paper cone prepared from a 9-cm disk of filter paper (nonfluted), which rests on the lip of the beaker. A small notch is cut in the cone to allow solvent vapor to pass around it. The extraction solvent is placed in the beaker; the solid material to be extracted is placed in the cone. A watch glass containing 2–3 g of ice is placed on top of the assembly to act as the condenser and to hold the paper cone in place. As the ice melts, the water is removed and replaced with fresh ice. The beaker is heated on a hot plate in the hood (some solvent evaporates during the extraction process and may need to be replaced). The concentrated solution collected in the beaker is then cooled and the solid product is isolated by filtration or is recrystallized. This system needs to be attended at all times, but works reasonably well for brief extractions.

Various apparatus have been developed for use when longer extraction periods are required. They all use what is called a *countercurrent process*. The best-known apparatus is the Soxhlet extractor, first described in 1879 (Fig. 5.21).[7] The solid sample is placed in a porous thimble. The extraction-solvent vapor, generated by refluxing the extraction solvent contained in the distilling pot, passes up through the vertical side tube into the condenser. The liquid condensate then drips onto the solid, which is extracted. The extraction solution passes through the pores of the thimble, eventually filling the center section of the Soxhlet. The siphon tube also fills with this extraction solution and when the liquid level reaches the top of the tube, siphoning action returns the thimbleful of extract to the distillation pot. The cycle is automatically repeated many times, concentrating the extract in the distillation pot. The advantage of this arrangement is that the process may be continued automatically and unattended for as long as necessary. The solvent is then removed from the extraction solution collected in the pot, providing the extracted compound(s). Soxhlet extractors are available from many supply houses and can be purchased in various sizes. Of particular interest to us is the microscale variety, which is effective for small amounts of material and is now commercially available.[8]

Drying Agents

Organic extracts separated from aqueous phases usually contain traces of water. Even washing with saturated salt solution (see Salting Out above) cannot

[5]Vestling, M. M. *J. Chem. Educ.* **1990,** *67,* 274.
[6]Herrera, A.; Almy, J. *J. Chem. Educ.* **1998,** *75,* 83.
[7]Soxhlet, F. *Dinglers Polytech. J.* **1879,** *232,* 461.
[8]Microscale Soxhlet equipment is available from ACE Glass, Inc., 1430 Northwest Boulevard, Vineland, NJ 08360.

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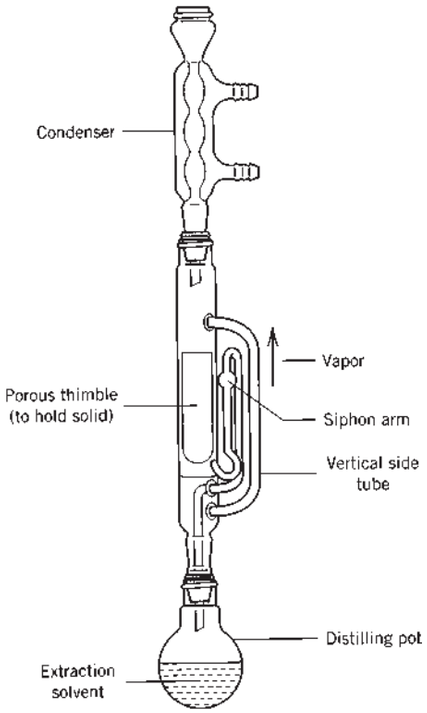

Figure 5.21 Soxhlet extractor.

remove all of the water. Organic extracts must therefore be dried to remove any residual water before the solvent is evaporated or further purification is performed. Organic extracts can be conveniently dried with an anhydrous inorganic salt, such as magnesium sulfate, sodium sulfate, or calcium sulfate. These salts readily absorb water and form insoluble hydrates, thus removing the water from the wet organic phase. The hydrated solid can then be removed from the dried solution by filtration or by decanting (pouring) the solution away from the solid. Although many drying agents are known, not every drying agent can be used in every case. The ideal drying agent should dry the solution quickly, have a high capacity for water, cost little, and not react with the material being dried.[9]

Table 5.5 summarizes the properties of some of the more common drying agents used in the laboratory.

Make sure that the solid drying agent is in its *anhydrous* form. Sodium sulfate is a good general-purpose drying agent and is usually the drying agent of choice at room temperature. Use the granular form, if at all possible.

Magnesium sulfate is supplied as a fine powder (high surface area). It has a high water capacity and is inexpensive; it dries solutions more quickly than does sodium sulfate. The disadvantage of magnesium sulfate is that the desired product (or water molecules) can become trapped on the surface of the fine particles. If it is not thoroughly washed after separation, precious product may

[9]Quantitative studies on the efficiency of drying agents for a wide variety of solvents have been reported. See Burfield, D. R.; Smithers, R. H. *J. Org. Chem.* **1983,** *48,* 2420, and references therein. Other useful information can be found in Armarego, W. L. F.; Chai, C. L. L. *Purification of Laboratory Chemicals,* 5th ed.; Elsevier: New York, 2003, and in Ridduck, J. A.; Bunger, W. B.; Sakano, T. K. *Organic Solvents, Physical Properties and Methods of Purification,* 4th ed.; Wiley: New York, 1986.

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Table 5.5 **Properties of Common Drying Agents**

Drying Agent	Formula of Hydrate	Comments
Sodium sulfate	$Na_2SO_4 \cdot 10H_2O$	Slow to absorb water and inefficient, but inexpensive and has a high capacity. Loses water above 32 °C Granular form available.
Magnesium sulfate	$MgSO_4 \cdot 7H_2O$	One of the best. Can be used with nearly all organic solvents. Usually in powder form.
Calcium chloride	$CaCl_2 \cdot 6H_2o$	Relatively fast drying, but reacts with many oxygen- and nitrogen-containing compounds. Usually in granular form.
Calcium sulfate	$CaSO_4 \cdot \frac{1}{2} H_2O$	Very fast and efficient, but has a low dehydration capacity.
Silica gel	$(SiO_2)_m \cdot nH_2O$	High capacity and efficient. Commercially available t.h.e. SiO_2 drying agent is excellent.[a]
Molecular sieves	$[Na_{12}(Al_{12}Si_{12}O_{48})] \cdot 27H_2O$	High capacity and efficient. Use the 4-Å size.[b]

[a]Available from EMD Chemicals, 10394 Pacific Center Court, San Diego, CA 92121.
[b]Available from Sigma-Aldrich, Inc., 940 West Saint Paul Ave., Milwaukee, WI 53233.

be lost. Furthermore, it is usually more difficult to remove a finely powdered solid agent, which may pass through the filter paper (if used) or clog the pores of a fine porous filter. A smaller surface area translates into less adsorption of product on the surface and easier separation from the dried solution.

Molecular sieves have pores or channels in their structures. A small molecule such as water can diffuse into these channels and become trapped. The sieves are excellent drying agents, have a high capacity, and dry liquids completely. The disadvantages are that they dry slowly and are more expensive than the more common drying agents.

Calcium chloride is very inexpensive and has a high capacity. Use the granular form. Do not use it to dry solutions of alcohols, amines, or carboxylic acids because it can react with these substances.

Calcium sulfate is often sold under the trade name of Drierite. It is a somewhat expensive drying agent. Do not use the blue Drierite (commonly used to dry gases) because the cobalt indicator (blue when dry, pink when wet) may leach into the solvent.

The amount of drying agent needed depends on the amount of water present, on the capacity of the solid desiccant to absorb water, and on its particle size (actually, its surface area). If the solution is wet, the first amount of drying agent will clump (molecular sieves and t.h.e. SiO_2 are exceptions). Add more drying agent until it appears mobile when you swirl the liquid. A solution that is no longer cloudy is a further indication that the solution is dry. Swirling the contents of the container increases the rate of drying; it helps establish the equilibrium for hydration:

$$\underset{\text{Anhydrous solid}}{\text{Drying agent} + nH_2O} \rightleftharpoons \underset{\text{Solid hydrate}}{\text{Drying agent} \cdot nH_2O}$$

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Most drying agents achieve approximately 80% of their drying capacity within 15 min; longer drying times are generally unnecessary. The drying agent may be added directly to the container of the organic extract, or the extract may be passed through a Pasteur filter pipet packed with the drying agent. A funnel fitted with a cotton, glass wool, or polyester plug to hold the drying agent may also be used.

As for the most common question asked with this technique—Is this "dry"?—you should be encouraged to have in your lab a series of flasks which contain a set quantity of solvent and drying agent. The difference with each flask within the series is the percentage of water which allows for a visual comparison of what is and what is not "dry."

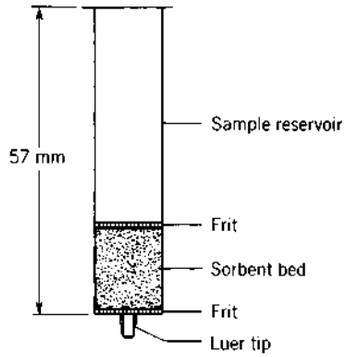

Figure 5.22 Polyethylene solid-phase extraction column.

Solid-Phase Extraction

In the modern research laboratory, the traditional liquid–liquid extraction technique may be replaced by the solid-phase extraction method.[10] The advantages of this newer approach are that it is rapid, it uses only small volumes of solvent, it does not form emulsions, isolated solvent extracts do not require a further drying stage, and it is ideal for working at the microscale level. This technique is finding wide acceptance in the food industry and in the environmental and clinical area, and it is becoming the accepted procedure for the rapid isolation of drugs of abuse and their metabolites from urine. Solid-phase extraction is accomplished using prepackaged, disposable, extraction columns. A typical column is shown in Figure 5.22. The columns are available from several commercial sources.[11]

The polypropylene columns can be obtained packed with 100–1000 mg of 40-μm sorbent sandwiched between two 20-μm polyethylene frits. The columns are typically 5–6 cm long. Sample volumes are generally 1–6 mL.

The adsorbent (stationary phase) used in these columns is a nonpolar adsorbent chemically bonded to silica gel. In fact, they are the same nonpolar adsorbents used in the reversed-phase high-performance liquid chromatography (HPLC). More specifically, the adsorbents are derivatized silica gel where the —OH groups of the silica gel have been replaced with siloxane groups by treating silica gel with the appropriate organochlorosilanes.

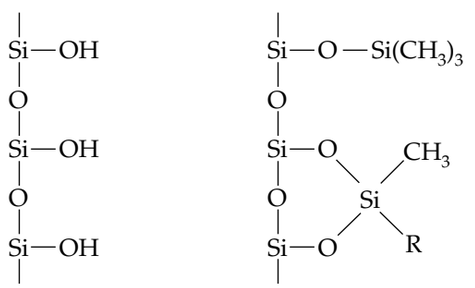

Silica surface — Chemically bonded silica surface

[10]For a description of this method see Zief, M.; Kiser, R. *Am. Lab.* **1990,** *22 70;* Zief, M. *NEACT J.* **1990,** *8,* 38; Hagen, D. F.; Markell, C. G.; Schmitt, G. A.; Blevins, D. D. *Anal. Chim. Acta* **1990,** *236,* 157; Arthur, C. L.; Pawliszyn, J. *Anal. Chem.* **1990,** *62,* 2145; Dorsey, J.; Dill, K. A. *Chem. Rev.* **1989,** *89,* 331; Zubrick, J. W. *The Organic Chem Lab Survival Manual,* 7th ed., Wiley: New York, 2008; Simpson, N. J. K, Ed. *Solid-Phase Extraction: Principles, Techniques and Applications,* Marcel Dekker: New York, 2000; "Solid Phase Extraction." Retrieved March 19, 2009 from www.sigmaaldrich.com/analytical-chromatography/sample-preparation/spe.html.

[11]These columns are available from Analytichem International, J. T. Baker, Inc., Supelco, Inc., Aldrich Chemical, Waters Associates and Biotage (a Division of Dyax Corp).

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Two of the most popular nonpolar packings are those containing R groups consisting of an octadecyl ($C_{18}H_{37}$—)or phenyl (C_6H_5—) group. These packing materials (stationary phases) can adsorb nonpolar (like attracts like) organic material from aqueous solutions. The adsorbed material is then eluted from the column using a solvent strong (nonpolar) enough to displace it, such as methanol, methylene chloride, or hexane. The analyte capacity of bonded silica gels is about 10–20 mg of analyte per gram of packing.

An example of a typical solid-phase extraction is the determination of the amount of caffeine in coffee using a 1-mL column containing 100 mg of octadecyl-bonded silica. This efficient method isolates about 95% of the available caffeine. The column is conditioned by flushing 2 mL of methanol followed by 2 mL of water through the column. One milliliter of a coffee solution (~0.75 mg of caffeine/mL) is then drawn through the column at a flow rate of 1 mL/min. The column is washed with 1 mL of water and air dried (vacuum) for 10 min. The adsorbed caffeine is then eluted with two 500-μL portions of chloroform.

QUESTIONS

5-16. You are presented a two-phase system. The two liquids are immiscible. The top phase is blue and the bottom, orange. One phase is water. Please devise an experiment to **definitively** differentiate which phase is water.

5-17. Which layer (upper or lower) will each of the following organic solvents usually form when being used to extract an aqueous solution?

toluene methylene chloride diethyl ether
hexane acetone

5-18. Construct a flow chart to demonstrate how you could separate a mixture of 1,4-dichlorobenzene, 4-chlorobenzoic acid, and
4-chloroaniline using an extraction procedure.

5-19. A slightly polar organic compound partitions itself between ether and water phases. The K_p (partition coefficient) value is 2.5 in favor of the ether solvent. What simple procedure could you use to increase this K_p value?

5-20. You weight out exactly 1.00 mg of benzoic acid and dissolve it in a mixture of 2.0 mL of diethyl ether and 2.0 mL of water. After mixing and allowing the layers to separate, the ether layer is removed, dried, and concentrated to yield 0.68 mg of benzoic acid. What is the K_p value (ether/water) for this system?

5-21. If asked to separate an equal mixture of benzoic acid [pK_a = 4.2] and 2-naphthol [pK_a = 9.5] using a liquid–liquid extraction technique, explain why an aqueous solution of $NaHCO_3$[pK_a = 6.4] would be far more effective than the stronger aqueous solution of NaOH[pK_a = 15.7].

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For overviews on extraction methods see the following general references:

Dean, J. R. *Extraction Methods for Environmental Analysis;* Wiley: New York, 1998.
Handley, A. J. *Extraction Methods for Organic Analysis;* CRC Press LLC: Boca Raton, FL, 1999.
Kirk–Othmer Encyclopedia of Chemical Technology, 4th ed.; Wiley: New York, 1993; Vol. 10, p. 125.
Schneider, Frank L. *Qualitative Organic Microanalysis*; Vol. II of *Monographien aus dem Gebiete der qualitätiven Mikroanalysis*, A. A. Benedetti-Pichler, Ed.; Springer-Verlag: Vienna, 1964, p. 61.
Shugar, G. J. *Chemical Technicians' Ready Reference Handbook,* 3rd ed.; McGraw-Hill: New York, 1990.
Zubrick J. W. *The Organic Chem Lab Survival Manual: A Student's Guide to Techniques,* 7th ed.; Wiley: New York, 2008.
Zubrick, J. W. *The Organic Chem Lab Survival Manual*, 7th ed. Wiley: New York, 2008.

NOTE The following experiments use Technique 4: Experiments [4A], [4B], [5A], [5B], [7], [8A], [11A], [11B], [11C], [12], [13], [16], [17], [19A], [19B], [19C], [22A], [22B], [23], [27],[30], [32], [34A], [34B], [A1$_b$], [D3], [E3], [F1], [F2], [F3], and [F4].

www *[3A$_{adv}$], [4$_{adv}$], and [6$_{adv}$].*

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TECHNIQUE 5

Crystallization

This discussion introduces the basic technique of purifying solid organic substances by crystallization. The technique of crystallizing an organic compound is fundamental; it must be mastered if you are going to purify solids. *It is not an easy art to acquire.* Organic solids tend not to crystallize as easily as inorganic substances.

Legend has it that an organic chemist resisted an invitation to leave a well-worn laboratory for new quarters because he suspected that the older laboratory (in which many crystallizations had been carried out) harbored seed crystals for a large variety of substances the chemist needed. Carried by dust from the earlier work, these traces of material presumably aided the successful initiation of crystallization of reluctant materials. Further support for this legend comes from the often quoted (but never substantiated) belief that after a material was first crystallized in a particular laboratory, subsequent crystallizations of the material, regardless of its purity or origin, were always easier.

In several areas of chemistry, the success or failure of an investigation can depend on the ability of a chemist to isolate tiny quantities of crystalline substances. Often the compounds of interest must be extracted from enormous amounts of extraneous material. In one of the more spectacular examples, Reed et al. isolated 30 mg of the crystalline coenzyme lipoic acid from 10 tons of beef liver residue.[12]

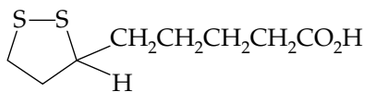

Lipoic acid

General Crystallization Procedure

The following steps are the essentials of crystallization:

Step 1. Select a suitable solvent.

Step 2. Dissolve the material to be purified in the minimum amount of warm solvent. *Remember that most organic solvents are extremely flammable and that many produce very toxic vapor*.

Step 3. Once the solid mixture has fully dissolved, filter the heated solution, and then bring it to the point of saturation by evaporating a portion of the solvent.

Step 4. Cool the warm saturated solution to reduce the solubility of the solute; this usually causes the solid material to precipitate. If the material has a low melting point or is very impure it may come out of solution sometimes as an oil. If so, reheat the solution and allow it to recool slowly.

Step 5. Isolate the solid by filtration, and then remove the last traces of solvent.

The crystallization is successful if the solid is recovered in good yield and is purer than it was before the crystallization. This cycle, from solid state to solution and back to solid state is called *recrystallization* when both the initial and final materials are crystalline.

[12]Reed, L. J.; Gunsalus, I. C.; Schnakenberg, G. H. F.; Soper, Q. F.; Boaz, H. E.; Kem, S. F.; Parke, T. V. *J. Am. Chem. Soc.* **1953,** *75,* 1267.

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Although the technique sounds fairly simple, in reality it is demanding. Successful purification of microscale quantities of solids will require your utmost attention. Choosing a solvent system is critical to a successful crystallization. To achieve high recoveries, the compound to be crystallized should ideally be very soluble in the hot solvent, but nearly insoluble in the cold solvent. To increase the purity of the compound, the impurities should be either *very soluble* in the solvent at all temperatures or *not soluble* at any temperature. The solvent should have as low a boiling point as possible so that traces of solvent can be easily removed (evaporated) from the crystals after filtration. It is best to use a solvent that has a boiling point at least 10 °C lower than the melting point of the compound to be crystallized to prevent the solute from "oiling out" of solution. Thus, the choice of solvent is critical to a good crystallization. Table 5.6 lists common solvents used in the purification of organic solids.

When information about a suitable solvent is not available, the choice of solvent is made on the basis of solubility tests. Craig's rapid and efficient procedure for microscale solubility testing works nicely; it requires only milligrams of material and a nine-well, Pyrex spot plate.[13]

Place 1–2 mg of the solid in each well and pulverize each sample with a stirring rod. Add 3–4 drops of a given solvent to the first well and observe whether the material dissolves at ambient temperature. If not, stir the mixture for 1.5–2 min and observe and record the results. Repeat this process with the chosen set of solvents, using a separate well for each solubility test. *Keep track of which well contains which solvent.* Place your test plate (containing the samples) on a hot plate (set at its lowest setting) in the **hood;** add additional solvent if necessary. Record the solubility characteristics of the sample in each hot solvent. Cool the plate and see if crystallization occurs in any of the wells. On the basis of your observations, choose an appropriate solvent or a solvent pair (see the following paragraph) to recrystallize your material.

Solubility relationships are seldom ideal for crystallization; most often a compromise is made. If there is no suitable single solvent available, it is possible to use a mixture of two solvents, called a *solvent pair*. A solvent is chosen that will

Table 5.6 **Common Solvents**

Solvent	bp (°C)	Polarity
Acetone	56	Polar
Cyclohexane	81	Nonpolar
Diethyl ether	35	Intermediate polarity
Ethanol, 95%	78	Polar
Ethyl acetate	77	Intermediate polarity
Hexane	68	Nonpolar
Ligroin	60–90	Nonpolar
Methanol	65	Polar
Methylene chloride	40	Intermediate polarity
Methyl ethyl ketone	80	Intermediate polarity
Petroleum ether	30–60	Nonpolar
Toluene	111	Nonpolar
Water	100	Polar

[13]Craig, R. E. R. *J. Chem. Educ.* **1989,** *66,* 88.

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readily dissolve the solid. Once the solid is dissolved in the minimum amount of hot solvent, the solution is filtered. A second solvent, miscible with the first, in which the solute has much lower solubility, is then added dropwise to the hot solution to achieve saturation. In general, polar organic molecules have higher solubilities in polar solvents, and nonpolar materials are more soluble in nonpolar solvents (like dissolves like). Table 5.7 lists some common solvent pairs.

It can take a long time to work out an appropriate solvent system for a particular reaction product. In most instances, with known compounds, the optimum solvent system has been established. Most crystallizations are not very efficient because many impurities have solubilities similar to those of the compounds of interest. Recoveries of 50–70% are not uncommon.

Several microscale crystallization techniques are available.

Table 5.7 **Common Solvent Pairs**

Solvent 1 (more polar)	Solvent 2 (less polar)
Acetone	Diethyl ether
Diethyl ether	Hexane
Ethanol	Acetone
Ethyl acetate	Cyclohexane
Methanol	Methylene chloride
Acetone	Water
Water	Ethanol
Toluene	Ligroin

Simple Crystallization

Simple crystallization works well with large quantities of material (100 mg and up), and it is essentially identical to that of the macroscale technique.

Step 1. Place the solid in a small Erlenmeyer flask or test tube. A beaker is not recommended because the rapid and dangerous loss of flammable vapors of hot solvent occurs much more easily from the wide mouth of a beaker than from an Erlenmeyer flask. Furthermore, solid precipitate can rapidly collect on the walls of the beaker as the solution becomes saturated because the atmosphere above the solution is less likely to be saturated with solvent vapor in a beaker than in an Erlenmeyer flask.

Step 2. Add a minimal amount of solvent and heat the mixture to the solvent's boiling point in a sand bath. Stir the mixture by twirling a spatula between the thumb and index finger. A magnetic stir bar may be used if a magnetic stirring hot plate is used.

Step 3. Continue stirring and heating while adding solvent dropwise until all of the material has dissolved.

Step 4. Add a decolorizing agent (powdered charcoal, ~2% by weight; or better, activated-carbon Norit pellets,[14] ~0.1% by weight), to remove colored minor impurities and other resinous byproducts.

Step 5. Filter (by gravity) the hot solution into a second Erlenmeyer flask (pre-heat the funnel with hot solvent). This removes the decolorizing agent and any insoluble material initially present in the sample.

Step 6. Evaporate enough solvent to reach saturation.

Step 7. Cool to allow crystallization (crystal formation will be better if this step takes place slowly). After the system reaches room temperature, cooling it in an ice bath may improve the yield.

Step 8. Collect the crystals by filtration on a Büchner or Hirsch funnel. Save the mother liquor (this is the term used to describe the solution that was separated from the original crystals) until the identity of the product has been established. In some cases, it is possible to recover more product by concentrating and further cooling the mother liquor. The second crop of crystals, however, is usually not as pure as the first.

Step 9. Wash (rinse) the crystals carefully.

Step 10. Dry the crystals.

[14]Available from Sigma-Aldrich Chemical Co., 940 West St. Paul Ave., Milwaukee, WI 53233.

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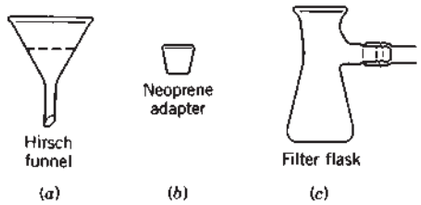

Figure 5.23 Component parts for vacuum filtration.

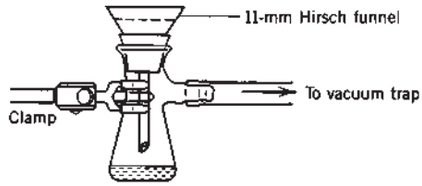

Figure 5.24 Vacuum filtration apparatus.

Filtration Techniques

Use of the Hirsch Funnel. The standard filtration system for collecting products purified by recrystallization in the microscale laboratory is vacuum (suction) filtration with an 11-mm Hirsch funnel. Many reaction products that do not require recrystallization can also be collected directly by vacuum filtration. The Hirsch funnel (Fig.5.23*a*) is composed of a ceramic cone with a circular flat bed perforated with small holes. The diameter of the bed is covered by a flat piece of filter paper of the same diameter. The funnel is sealed into a filter flask with a Neoprene adapter (Fig. 5.23*b*). Plastic and glass varieties of this funnel that have a polyethylene or glass frit are now available. It is still advisable to use the filter paper disk with these funnels to prevent the frit from clogging or becoming discolored. Regardless of the type of filter used, *always wet the filter paper disk with the solvent being used in the crystallization and then apply the vacuum.* This ensures that the filter paper disk is firmly seated on the bed of the filter.

Filter flasks have thick walls, and a side arm to attach a vacuum hose, and are designed to operate under vacuum (see Fig. 5.23*c*). The side arm is connected with *heavy-walled* rubber vacuum tubing to a water aspirator (water pump). The water pump uses a very simple aspirator based on the Venturi effect. Water is forced through a constricted throat in the pump. (See the detailed discussion of the Venturi effect and water pumps in the section on reduced pressure [vacuum] distillations.) When water flows through the aspirator, the resulting partial vacuum sucks air down the vacuum tubing from the filter flask. *Always turn the water on full force.* With the rubber adapter in place, air is pulled through the filter paper, which is held flat on the bed of the Hirsch (or Büchner) funnel by the suction. The mother liquors are rapidly forced into the filter flask, where the pressure is lower, by atmospheric pressure. The crystals retained by the filter are dried by the stream of air passing through them (Fig. 5.24).

When you use a water pump, *it is very important to have a safety trap mounted in the vacuum line leading from the filter flask.* Any drop in water pressure at the pump (easily created by other students on the same water line turning on other aspirators at the same time) can result in a backup of water into the flask. As the flow through the aspirator decreases, the pressure at that point rapidly increases and water is forced up the vacuum tubing toward the filter flask (Fig. 5.24). It is also important to vent the vacuum by opening the vent stopcock or disconnecting the rubber tubing from the filter flask, *before* the water is turned off (see Fig. 5.25).

In some cases, the precipitate collected on the Hirsch funnel is not highly crystalline. The filter cake may be too thick or pasty to dry simply by pulling air through it. A thin, flexible rubber sheet or a piece of plastic food wrap placed over the mouth of the funnel, such that the suction generated from the vacuum pulls the sheeting down onto the filter cake (collected crystals), will place

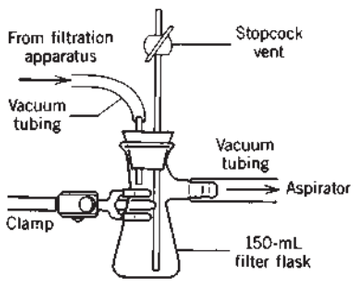

Figure 5.25 Vacuum trap.

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atmospheric pressure on the solid cake. This pressure can force much of the remaining solvent from the collected material, and thus further dry it. Use a piece of sheeting large enough to cover the entire filter cake. Otherwise, a vacuum may not be created and adequate drying may not occur.

In some instances, substances may retain water or other solvents with great tenacity. To dry these materials, a *desiccator* is often used. This is generally a glass or plastic container containing a *desiccant* (a material capable of absorbing water). The substance to be dried, held in a suitable container, is then placed on a support above the desiccant. This technique is often used in quantitative analysis to dry collected precipitates. Vacuum desiccators are available (Fig. 5.26). If this method of drying is still insufficient, a *drying pistol* can be used (Fig. 5.27). The sample, in an open container (vial) is placed in the apparatus, which is then evacuated. The pistol has a pocket in which a strong adsorbing agent, such as P_4O_{10} (for water), NaOH or KOH (for acidic gases), or paraffin wax (for organic solvents), is placed. The pistol is heated by refluxing vapors that surround the barrel. A simple alternative to this method is the use of a side-armed test tube (Fig. 5.28).

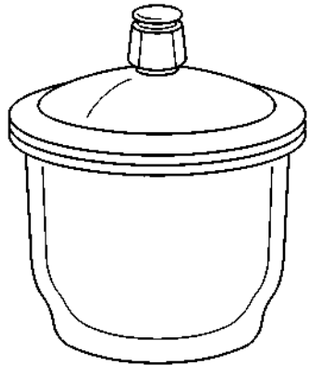

Figure 5.26 Vacuum desiccator.

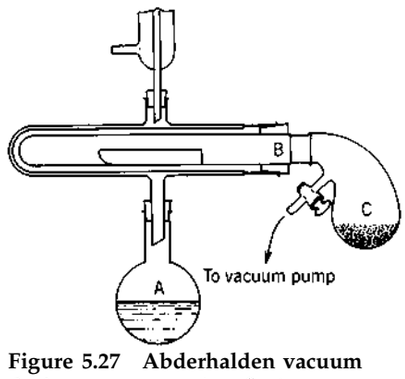

Figure 5.27 Abderhalden vacuum drying apparatus. A, refluxing heating liquid; B, vacuum drying chamber; C, desiccant.

A Hirsch-Funnel Alternative—A Nail-Filter Funnel. A nail-filter funnel is a low-cost substitute for a Hirsch funnel (Fig. 5.29).[15] This apparatus is easily assembled from common laboratory glassware. Obtain a soft-glass rod that fits in the stem of a small glass funnel. Cut the rod to a suitable size and heat the tip of one end over a burner flame. When the tip becomes soft, hold the rod vertically and press the hot tip against a cold metal surface to flatten it to form a flat nail-like head. *The nail head should not be perfectly round or it will block the flow of liquid.* Cut the cooled rod to a suitable length and place the "nail" inside the stem of the funnel so that the flattened head of the nail rests on the top opening of the funnel. Cut a piece of filter paper just slightly larger than the nail head, place it on the nail head, and then place the funnel in a filter flask with a neoprene adapter. Be sure to wet the filter paper before filtering.

Craig Tube Crystallizations. The Craig tube[16] is commonly used for microscale crystallizations in the range of 10–100 mg of material (Fig. 5.30). The process consists of the following steps.

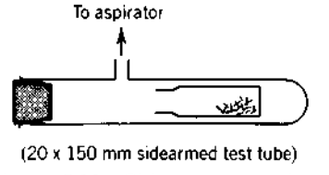

Figure 5.28 Side-arm test tube as a vacuum dryhing apparatus.

Step 1. Place the sample in a small test tube (10 × 75 mm)

Step 2. Add the solvent (0.5–2 mL), and dissolve the sample by heating in the sand bath; add drops of solvent as needed. Rapid stirring with a microspatula (roll the spatula rod between your thumb and index finger) helps dissolve the material and protects against boilover. Add several drops of solvent by Pasteur pipet after the sample has completely dissolved. It will be easy to remove this excess at a later stage, since the volumes involved are very small. The additional solvent ensures that the solute will stay in solution during the hot transfer. Norit charcoal pellets may be added at this stage, if needed to remove colored impurities.

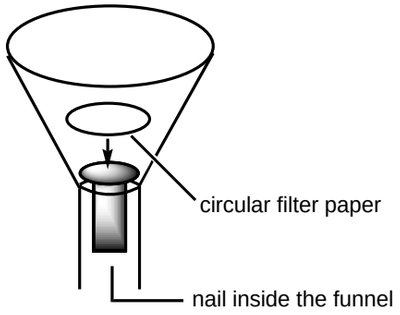

Figure 5.29 Nail-filter funnel.

[15]Singh, M. M.; Pike, R. M.; Szafran, Z. *Microscale & Selected Macroscale Experiments for General & Advanced General Chemistry;* Wiley: New York, NY, 1995, pp. 47, 63; Claret, P. A. *Small Scale Organic Preparations;* Pitman: London, 1961, p. 15.
[16]Craig, L. C.; Post, O. W. *Ind. Eng. Chem., Anal. Ed.* **1944,** *16,* 413.

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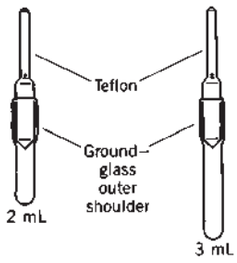

Figure 5.30 Craig tubes.

Step 3. Transfer the heated solution to the Craig tube by Pasteur filter pipet (see Fig. 3.30) that has been preheated with hot solvent. This transfer automatically filters the solution. A second filtration is often necessary if powdered charcoal has been used to decolorize the solution.

Step 4. The hot, filtered solution is then concentrated to saturation by gentle boiling in the sand bath. Constant agitation of the solution with a microspatula during this short period can avoid the use of a boiling stone and prevent boilover. Ready crystallization on the microspatula just above the solvent surface is a good indication that saturation is close at hand.

Step 5. The upper section of the Craig tube (the "head" or stopper) is set in place and the saturated solution is allowed to cool in a safe place. As cooling commences, seed crystals, if necessary, may be added by crushing them against the side of the Craig tube with a microspatula just above the solvent line. A good routine, if time is available, is to place the assembly in a small Erlenmeyer, then place the Erlenmeyer in a beaker, and finally cover the first beaker with a second inverted beaker. This procedure will ensure slow cooling, which will enhance good crystal growth (Fig. 5.31). A Dewar flask may be used when very slow cooling and large crystal growth are required.

Step 6. After the system reaches room temperature, cooling in an ice bath may improve the yield.

Step 7. Remove the solvent by inverting the Craig tube assembly into a centrifuge tube and spinning the mother liquors away from the crystals (Fig. 5.32). *This operation should be carried out with care.* First, fit the head with a thin copper wire (Fig. 5.32), held in place by a loop at the end of the wire that is placed around the narrow part of the neck. Some Teflon heads have a hole in the neck to anchor the wire. The copper wire should not be much longer than the centrifuge tube.

Step 8. Now insert the Craig tube into a centrifuge tube. To do this, hold the Craig tube upright (with the head portion up) and place the centrifuge tube *down over* the Craig tube. Push the Craig tube up with your finger so that the head is against the inverted bottom of the centrifuge tube, and then invert the whole assembly (Fig 5.32).

Step 9. Place the assembly into a centrifuge tube, *balance the centrifuge,* and spin the mother liquors away from the crystals (Fig. 5.32). This

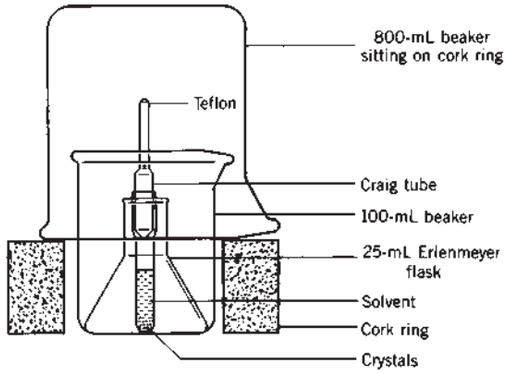

Figure 5.31 Apparatus for slow crystallization.

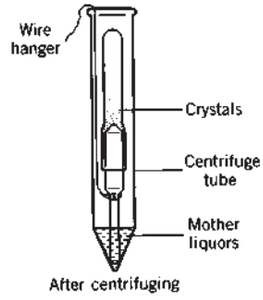

Figure 5.32 Crystal collection with a Craig tube.

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replaces the usual filtration step in simple crystallizations. It avoids another transfer of material and also avoids product contact with filter paper.

Step 10. Remove the apparatus from the centrifuge, and then carefully remove the Craig tube from the centrifuge tube. Gently pull upward on the copper wire while at the same time applying downward pressure with your fingers to the bottom of the inverted Craig tube (this will keep the Craig tube assembly together and not let any of the crystalline product fall back into the centrifuge tube and into the mother liquors). Once the Craig tube assembly is removed from the centrifuge tube, turn it so that the neck of the tube is up, and then disassemble it. At this point scrape any crystalline product clinging to the head into the lower section. If the lower section is tared, it can be left to air dry to constant weight or placed in a warm vacuum oven (use a rubber band or thin wire to wrap a piece of filter paper over the open end to prevent dust from collecting on the product while drying).

The cardinal rule in carrying out the purification of small quantities of solids is *Keep the number of transfers to an absolute minimum!* The Craig tube is very helpful in this regard.

For other recrystallization and filtration methods, see reference material online; Chapter 5W, Crystallization. www

QUESTIONS

5-22. What is the purpose of using activated carbon in a recrystallization procedure?

5-23. List several advantages and disadvantages of using a Craig tube for recrystallization.

5-24. Why is it advisable to use a stemless or a short-stemmed funnel when carrying out a gravity filtration?

5-25. Which of the following solvent pairs could be used in a recrystallization? Why or why not?
(a) Acetone and ethanol
(b) Hexane and water
(c) Hexane and diethyl ether

5-26. You perform a recrystallization on 60 mg of a solid material and isolate 45 mg of purified material. What is the percent recovery? Further concentration of the mother liquor provides an additional 8 mg of material. What is the total percent recovery?

5-27. Describe two techniques that can be used to induce crystallization.

5-28. When would you advise someone to use a solvent pair to carry out a recrystallization?

5-29. You are provided a solid which you suspect is not pure and the accompanying data sheet has very limited information. Two items which are recognizable are that an ethereal solvent has worked well when performing recrystallizations and the literature melting point is 61 °C. When looking at what ethereal solvents you have to choose from, you see two: *t*-butyl methyl ether and diethyl ether. Why would the latter be the far better choice knowing that aside from relative boiling points, the two ethers are very similar when considering their physical properties.

NOTE. The following experiments use Technique 5: Experiments [6], [7], [15], [16], [18], [19A], [19B], [19C], [19D], [20], [23A], [23B], [24A], [24B], [25A], [25B], [26], [28], [29A], [29B], [29C], [29D], [30], [31], [33A], [33B], [34A], [34B], [A1$_a$], [A2$_a$], [A3$_a$], [A1$_b$], [A2$_b$], [A3$_b$], [A4$_{ab}$], [B1], [C2], [D1], [D2], [E1], [E2], [F1], [F2], and [F4].
[2$_{adv}$], [3A$_{adv}$], [3B$_{adv}$], [5$_{adv}$], [6$_{adv}$], and [7$_{adv}$]. www

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TECHNIQUE 6

Technique 6A

Chromatography

Column, Flash, High-Performance Liquid, and Thin-Layer Chromatography

The basic theory of chromatography is introduced in Technique 1 in the discussion of gas-phase separations. The word *chromatography* is derived from the Greek word for color, *chromatos*. Tswett discovered the technique in 1903 while studying ways to separate mixtures of natural plant pigments.[17] The chromatographic zones were detected simply by observing the visual absorption bands. Thus, as originally applied, the name was not an inconsistent use of terminology. Today, however, most mixtures are colorless. The separated zones in these cases are detected by other methods.

Two chromatographic techniques are discussed in this section. Both depend on adsorption and distribution between a stationary solid phase and a moving liquid phase. The first is column chromatography, which is used extensively throughout organic chemistry. It is one of the oldest of the modern chromatographic methods. The second technique, thin-layer chromatography (TLC), is particularly effective in rapid assays of sample purity. It can also be used as a preparative technique for obtaining tiny amounts of high-purity material for analysis.

Column Chromatography

Column chromatography, as its name implies, uses a column packed with a solid stationary phase. A mobile liquid phase flows by gravity (or applied pressure) through the column. Column chromatography uses polarity differences to separate materials. A sample on a chromatographic column is subjected to two opposing forces: (1) the solubility of the sample in the elution solvent system, and (2) the adsorption forces binding the sample to the solid phase. These interactions comprise an equilibrium. Some sample constituents are adsorbed more tightly; other components of the sample dissolve more readily in the liquid phase and are eluted more rapidly. The more rapidly eluting materials, thus, are carried further down the column before becoming readsorbed, and thus exit the column before more tightly bound components. The longer the column, the larger the number of adsorption–dissolution cycles (much like the vaporization–condensation cycles in a distillation column), and the greater the separation of sample components as they elute down the column. A molecule that is strongly adsorbed on the stationary phase will move slowly down the column; a molecule that is weakly adsorbed will move at a faster rate. Thus, a complex mixture can be resolved into separate bands of pure materials. These bands of purified material eventually elute from the column and can be collected.

Many materials have been used as the stationary phase in column chromatography. Finely ground alumina (aluminum oxide, Al_2O_3) and silicic acid (silica gel, SiO_2) are by far the most common adsorbents (stationary phases). Many common organic solvents are used as the liquids (sometimes called *eluents*) that act as the mobile phase and elute (wash) materials through the column. Table 5.8 lists the better known column packing and elution solvents.

[17]Tswett, M. *Ber. Deut. Botan. Ges.* **1906,** *24,* 235.

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Table 5.8 Column Chromatography Materials			
Stationary Phase		**Moving Phase**	
Alumina	*Increasing adsorption of polar materials* ↑	Water	*Increasing solvation of polar materials* ↑
Silicic acid		Methanol	
Magnesium sulfate		Ethanol	
Cellulose paper		Acetone	
		Ethyl acetate	
		Diethyl ether	
		Methylene chloride	
		Cyclohexane	
		Pentane	

Silica gel impregnated with silver nitrate (usually 5–10%) is also a useful adsorbent for some functional groups. The silver cation selectively binds to unsaturated sites via a silver-ion π complex. Traces of alkenes are easily removed from saturated reaction products by chromatography with this system (see Experiment [12]). This adsorbent, however, must be protected from light until used, or it will quickly darken and become ineffective.

Column chromatography is usually carried out according to the procedures discussed in the following five sections.

Packing the Column. The quantity of stationary phase required is determined by the sample size. A common rule of thumb is to use a weight of packing material 30– 100 times the weight of the sample to be separated. Columns are usually built with roughly a 10:1 ratio of height to diameter. In the microscale laboratory, two standard chromatographic columns are used:

1. A Pasteur pipet, modified by shortening the capillary tip, is used to separate smaller mixtures (10–100 mg). Approximately 0.5–2.0 g of packing is used in the pipet column (Fig. 5.33*a*).
2. A 50-mL titration buret (modified by shortening the column to 10 cm above the stopcock) is used for larger (50–200 mg) or difficult-to-separate sample mixtures. A buret column uses approximately 5–20 g of packing (Fig. 5.33*b*).

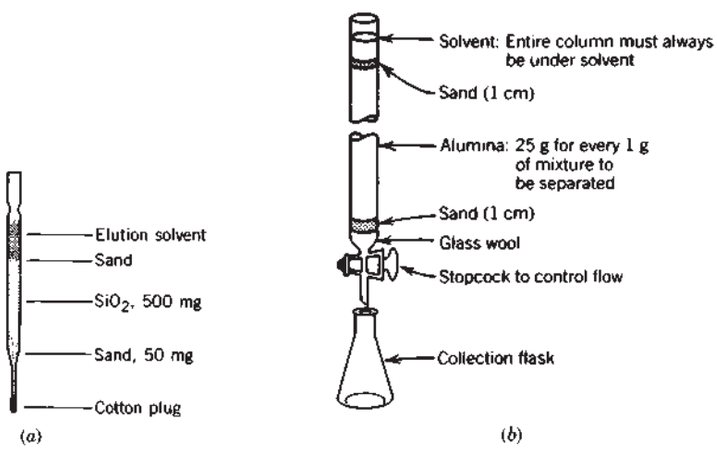

Figure 5.33 Chromatographic columns: (a) a Pasteur pipet column; (b) a buret column. (From Zubrick, James W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)

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Both columns are prepared by first clamping the empty column in a vertical position and then seating a small cotton or glass wool plug at the bottom. For a buret column, cover the cotton with a thin layer of sand. The Pasteur pipets are loaded by adding the dry adsorbent with gentle tapping, "dry packing." The pipet column (*dry column*) is then premoistened just prior to use.

The burets (*wet columns*) are packed by a slurry technique. In this procedure the column is filled part way with solvent; then the stopcock is opened slightly, and as the solvent slowly drains from the column a slurry of the adsorbent–solvent is poured into the top of the column. The column should be gently tapped while the slurry is added. The solvent is then drained to the top of the adsorbent level and held at that level until used. Alternatively, the wet-packed column can be loaded by sedimentation techniques rather than using a slurry. One such routine is to initially fill the column with the least-polar solvent to be used in the intended chromatographic separation. Then the solid phase is slowly added with gentle tapping, which helps to avoid subsequent channeling. As the solid phase is added, the solvent is slowly drained from the buret at the same time. After the adsorbent has been fully loaded, the solvent level is then lowered to the top of the packing as in the slurry technique.

Sample Application. Using a Pasteur pipet, apply the sample in a minimum amount of solvent (usually the least polar solvent in which the material is readily soluble) to the top of the column. *Do not disturb the sand layer!* Rinse the pipet, and add the rinses to the column just as the sample solution drains to the top of the adsorbent layer.

Elution of the Column. The critical step in resolving the sample mixture is eluting the column. Once the sample has been applied to the top of the column, the elution begins (a small layer of sand can be added to the top of the buret column after addition of the first portion of elution solvent).

NOTE: Do not let the column run dry: This can cause channels to form in the column.

In a buret column, the flow is controlled by the stopcock. The flow rate should be set to allow time for equilibrium to be established between the two phases; this will depend on the nature and amount of the sample, the solvent, and how difficult the separation will be. The Pasteur pipet column is *free flowing* (the flow rate is controlled by the size of the capillary tip and its plug); once the sample is on the column, the chromatography will require constant attention.

If necessary, it is possible to ease this restriction somewhat by modifying the pipet. Place a Tygon connector (short sleeve) at the top of the pipet column. Once the sample is on the column, insert a second pipet into this connector with its tip just below the liquid level on the top of the column. Add additional solvent through the second pipet (use a bulb, if necessary, but remove it before the elution begins), which acts as a solvent reservoir. As the solvent level in the column pipet drops below the tip of the top pipet, air is admitted, and additional solvent is automatically delivered to the chromatographic column. Thus, the solvent head on the column is maintained at a constant volume. The top pipet need be filled only at necessary intervals; larger volumes of solvent can thus be added to this reservoir. This arrangement also prevents dislodging of the absorbent as new solvent is added.

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NOTE It is exceedingly important that solvents do not come in contact with the Tygon sleeve holding the second pipet. These sleeves contain plasticizers that will readily dissolve and contaminate the sample.

The choice of solvent is dictated by a number of factors. A balance between the adsorption power of the stationary phase and the solvation power of the elution solvent governs the rate of travel of the material down the column. If the material travels rapidly down the column, then too few adsorption–elution cycles will occur and the materials will not separate. If the sample travels too slowly, diffusion broadening takes over and separation is degraded. Solvent choices and elution rates can strike a balance between these factors and maximize the separation. It can take considerable time to develop a solvent or mixture of solvents that produces a satisfactory separation of a particular mixture.

Fraction Collection. As the solvent elutes from the column, it is collected in a series of "fractions" by using small Erlenmeyer flasks or vials. Under ideal conditions, as the mixture of material travels down the column, it will separate into several individual bands (zones) of pure substances. By careful collection of the fractions, these bands can be separated as they sequentially elute from the column (similar to the collection of GC fractions in the example described in Technique 1). The bands of eluted material can be detected by a number of techniques (weighing fraction residues, colored materials, TLC, etc.).

Column chromatography is a powerful technique for the purification of organic materials. In general, it is significantly more efficient than crystallization procedures. Recrystallization is often best avoided until the last stages of purification, where it will be most efficient. Rely instead on chromatography to do most of the separation.

Column chromatography of a few milligrams of product usually takes no more than 30 min, but chromatographing 10 g of product might easily take several hours, or even all day. Large-scale column chromatography (50–100 g) of a complex mixture could take several days to complete using this type of equipment.

Flash Chromatography

Flash chromatography, first described by Still and co-workers in 1978, is a common method for separating and purifying nonvolatile mixtures of organic compounds.[18] The technique is rapid, easy to perform, relatively inexpensive, and gives good separations. Many laboratories routinely use flash chromatography to separate mixtures ranging from 10 mg to 10 g.

This moderate-resolution, preparative chromatography technique was originally developed using silica gel (40–63 μm). Bonded-phase silica gel of a larger particle size can be used for reversed-phase flash chromatography. Flash chromatography columns are generally packed dry to a height of approximately 6 in. Thin-layer chromatography is a quick way to choose solvents for flash chromatography. A solvent that gives differential retardation factor (DR_f) values (of the two substances requiring seperation) ≥ 0.15 on TLC usually gives effective separation with flash chromatography. Table 5.9 lists typical experimental parameters for various sample sizes, as a guide to separations using flash chromatography. In general, a mixture of organic compounds separable by TLC can be separated preparatively using flash chromatography.

[18]Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978,** *43,* 2923.

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Table 5.9 Typical Experimental Parameters

Column Diameter (mm)	Total Volume of Eluent (mL)[a]	Typical Sample Loading (mg)		Typical Fraction (mL)
		$DR_{f>0.2}$	$DR_{f>0.1}$	
10	100–150	100	40	5
20	200–250	400	160	10
30	400–450	900	360	20
40	500–550	1600	600	30
50	1000–1200	2500	1000	50

Source. Data from Majors, R. E., and Enzweiler, T. *LC, GC* **1998,** *6,* 1046.
[a]Required for both packing and elution.

Flash chromatography apparatus generally consists of a glass column equipped to accept a positive pressure of compressed air or nitrogen applied to the top of the column. A typical commercially available arrangement is shown in Figure 5.34.[19]

Generally, a 20–25% solution of the sample in the elution solvent is recommended, as is a flow rate of about 2 in./min. The column must be conditioned, before the sample is applied, by flushing the column with the elution solvent to drive out air trapped in the stationary phase and to equilibrate the stationary phase and the solvent.

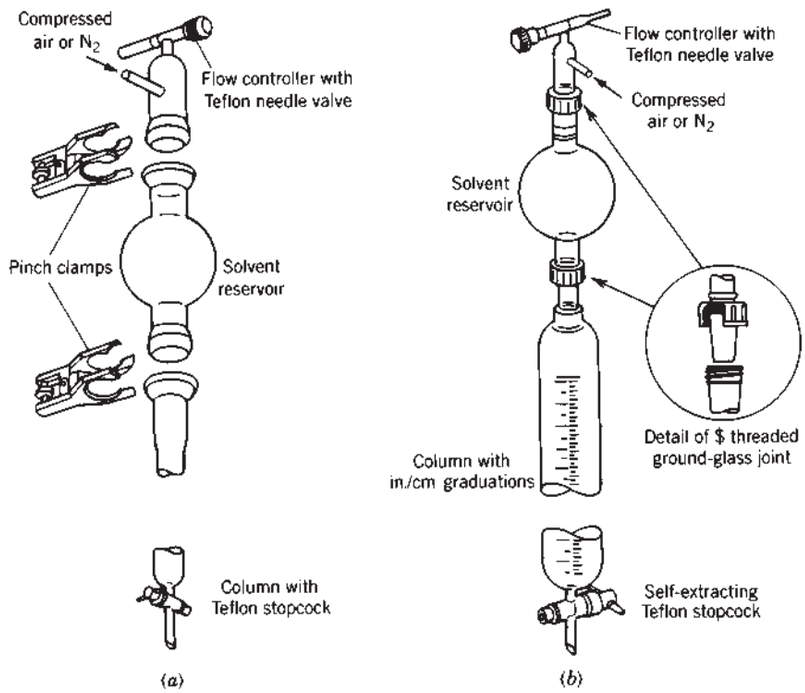

Figure 5.34 (a) Conventional column and (b) screw-threaded column.

[19]A complete line of glass columns, reservoirs, clamps, and packing materials for flash chromatography is offered by Sigma-Adrich Chemical Co., P.O. Box 355, Milwaukee, WI 53201. Silica gels for use in this technique are also available from Amicon, Danvers, MA; J. T. Baker, Phillipsburg, NJ; EM Science/Merck, Gibbstown, NJ.; ICN Biomedicals, Inc., Cleveland, OH.

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Several modifications of the basic arrangement have been reported, especially in regard to the adaptation of the technique to the instructional laboratory. These involve inexpensive pressure control valves, use of an aquarium "vibrator" air pump, and adapting a balloon reservoir to supply the pressurized gas.

At the microscale level, a pipet bulb or pump on the pipet column can be used to supply pressure to the column. If a bulb is used, squeeze it to apply pressure, and *remove the bulb from the pipet before releasing it!* Otherwise, material may be sucked up into the bulb and most likely disturb the column. Reapply the bulb to re-create pressure. If a pump is used, do not back off the pressure once it has been applied.

An improved method, utilizing a capillary Pasteur pipet for introducing the sample onto the chromatographic column approximately doubles the effectiveness (theoretical plates) of the column.[20] Dry-column flash chromatography[21] has been adapted for use in the instructional laboratory.[22] The "column" consists of a dry bed of silica gel in a sintered glass funnel placed in a standard vacuum filtration flask; the solvent is eluted by suction. Small (16 × 150-mm) test tubes inserted into the flask below the stem of the funnel are used to collect the fractions. This technique has been used successfully to separate mixtures ranging from 150 to 1000 mg.

Thin-Layer Chromatography

Thin-layer chromatography (TLC) is closely related to column chromatography, in that the phases used in both techniques are essentially identical. Alumina and silica gel are typical stationary phases, and the usual solvents are the mobile phases. There are, however, some distinct differences between TLC and column chromatography. The mobile (liquid) phase *descends* in column chromatography; the mobile phase *ascends* in TLC. The column of stationary-phase material used in column chromatography is replaced by a thin layer (100 μm) of stationary phase spread over a flat surface. A piece of window glass, a microscope slide, or a sheet of plastic can be used as the support for the thin layer of stationary phase. It is possible to prepare your own glass plates, but plastic-backed thin-layer plates are only commercially available. Plastic-backed plates are particularly attractive because they can easily be cut with scissors into strips of any size. Typical strips measure about 1 × 3 in., but even smaller strips can be satisfactory.

Thin-layer chromatography has some distinct advantages: it needs little time (2– 5 min) and it needs *very* small quantities of material (2–20 μg). The chief disadvantage of this type of chromatography is that it is not very amenable to preparative scale work. Even when large surfaces and thicker layers are used, separations are most often restricted to a few milligrams of material.

NOTE. Do not touch the active surface of the plates with your fingers. Handle them only by the edge.

TLC is performed as follows:

Step 1. Draw a light pencil line parallel to the short side of the plate, 5–10 mm from the edge. Mark one or two points, evenly spaced, on the line.

[20]Pivnitsky, K. K. *Aldrichimica Acta* **1989,** *22,* 30.
[21]Harwood, L. M.; *Aldrichimica Acta* **1985,** *18,* 25; Sharp, J. T.; Gosney I.; Rowley A. G. *Practical Organic Chemistry;* Chapman & Hall: New York, 1989.
[22]Shusterman, A. J.; McDougal, P. G.; Glasfeld, A. *J. Chem. Educ.* **1997,** *74,* 1222.

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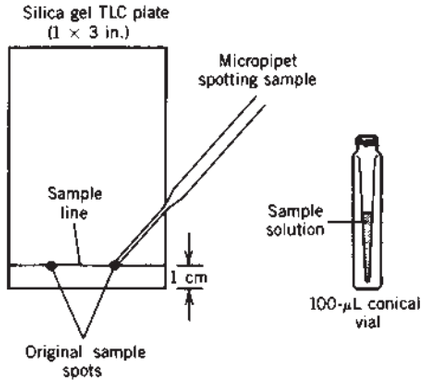

Figure 5.35 Applying a sample to a TLC plate.

Place the sample to be analyzed (1 mg or less) in a 100-μL conical vial and add a few drops of a solvent to dissolve the sample. Use a capillary micropipet to apply a small fraction of the solution from the vial to the plate (Fig. 5.35). (These pipets are prepared by the same technique used for constructing the capillary insert for ultramicro boiling-point determinations, see Chapter 4.) Apply the sample to the adsorbent side of the TLC plate by gently touching the tip of the filled capillary to the plate. Remove the tip from the plate before the dot of solvent grows to much more than a few millimeters in diameter. If it turns out that you need to apply more sample, let the dot of solvent evaporate and then reapply more sample to exactly the same spot.

Step 2. Place the spotted thin-layer plate in a screw-capped, wide-mouth jar, or a beaker with a watch glass cover, containing a small amount of elution solvent (Fig. 5.36). It helps if one side of the jar's (beaker's) interior is covered with a piece of filter paper that wicks the solvent up to increase the surface area of the 100 solvent. The TLC plate must be positioned so that the spot of your sample is *above* the solvent. Cap the jar, or replace the watch glass on the beaker, to maintain an atmosphere saturated with the elution solvent. The elution solvent climbs the plate by capillary action, eluting the sample up the plate. *Do not move the developing chamber after the action has started.* Separation of mixtures into individual spots occurs by exactly the same mechanism as in column chromatography. Stop the elution by removing the plate from the jar or beaker when the solvent front nears the top of the TLC plate. Quickly (before the solvent evaporates) mark the position of the solvent front on the plate.

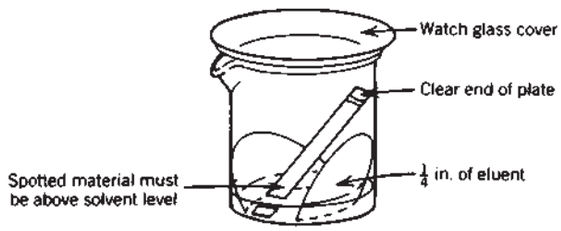

Figure 5.36 Developing a TLC plate. (From Zubrick, J. W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York. 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)

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Step 3. Colorless, separated components of a mixture can often be observed in a developed TLC plate by placing the plate in an iodine-vapor chamber (a sealed jar containing solid I_2) for a minute or two. Iodine forms a reversible complex with most organic substances and dark spots will thus appear in those areas containing sample material. Mark the spots with a pencil soon after removing the TLC plate from the iodine chamber because the spots may fade. Samples that contain a UV-active chromophore (see Chapter 8) can be observed without using iodine. TLC plates are commonly prepared with an UV-activated fluorescent indicator mixed in with the silica gel. Sample spots can be detected with a hand-held UV lamp; the sample quenches the fluorescence induced by the lamp and appears as a dark spot against the fluorescent blue-green background.

Step 4. The TLC properties of a compound are reported as R_f values (retention factors). The R_f value is the distance traveled by the substance divided by the distance traveled by the solvent front (this is why the position of the solvent front should be quickly marked on the plate when the chromatogram is terminated; see Fig. 5.37). TLC R_f values vary with the moisture content of the adsorbent. Thus, the actual R_f of a compound in a given solvent can vary from day to day and from laboratory to laboratory. The best way to determine if two samples have identical R_f values is to elute them together on the same plate.

Thin-layer chromatography is used in a number of applications. The speed of the technique makes it quite useful for monitoring large-scale column chromatography. Analysis of fractions can guide decisions on the solvent–elution sequence. TLC analysis of column-derived fractions can also determine how best to combine collected fractions. Following the progress of a reaction by periodically removing small aliquots for TLC analysis is an extremely useful application of thin-layer chromatography.

Paper Chromatography

The use of cellulose-paper as an adsorbent is referred to as *paper chromatography.* This technique has many of the characteristics of TLC in that sheets or

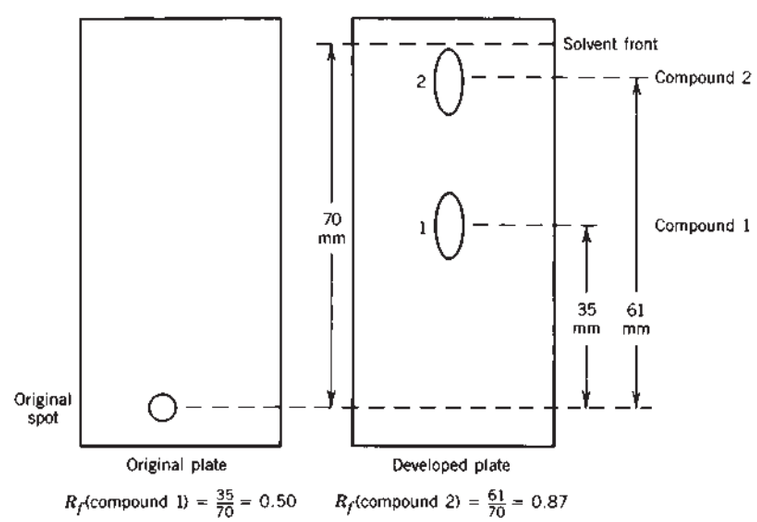

Figure 5.37 Determining R_f values.

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strips of filter paper are used as the stationary phase. In this case, however, the paper is usually positioned to hang down from trays holding the paper and the elution solvent. The solvent front, therefore, descends downward rather than upward as in TLC. Paper chromatography has a distinct advantage: It is very amenable to the use of aqueous mobile phases and very small sample sizes. It is primarily used for the separation of highly polar or polyfunctional species such as sugars and amino acids. It has one major disadvantage: It is very slow. Paper chromatograms can easily take three to four hours or more to elute.

High-Performance Liquid Chromatography

Although gas chromatography is a powerful chromatographic method, it is limited to compounds that have a significant vapor pressure at temperatures up to about 200 °C. Thus, compounds of high molecular weight and/or high polarity cannot be separated by GC. High-performance liquid chromatography (HPLC) does not present this limitation.

GC and HPLC are somewhat similar, in the instrumental sense, in that the analyte is partitioned between a stationary phase and a mobile phase. Whereas the mobile phase in GC is a gas, the mobile phase in HPLC is a liquid. As shown schematically in Figure 5.38, the mobile phase (solvent) is delivered to the system by a pump capable of pressures up to about 6000 psi. The sample is introduced by the injection of a solution into an injection loop. The injection loop is brought in line between the pump and the column (stainless steel) by turning a valve; the sample then flows down the column, is partitioned, and flows out through a detector.

The solid phase in HPLC columns used for organic monomers is usually some form of silica gel. "Normal" HPLC refers to chromatography using a solid phase (usually silica gel) that is more polar than the liquid phase, or solvent, so that the less polar compounds elute more rapidly. Typical solvents include ethyl acetate, hexane, acetone, low molecular weight alcohols, chloroform, and acetonitrile. For extremely polar compounds, such as amino

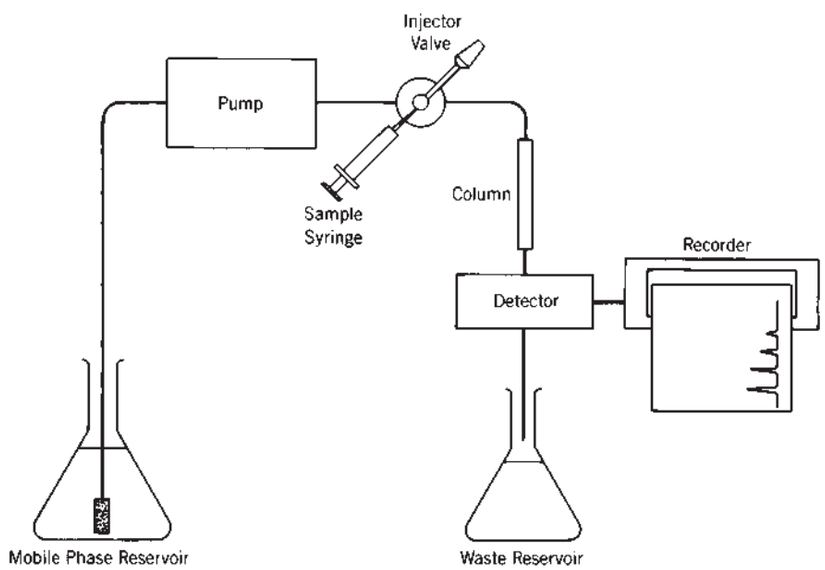

Figure 5.38 High-performance liquid chromatography system block diagram. *(Courtesy of the Perkin-Elmer Corp., Norwalk, CT.)*

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acids, "reversed-phase" HPLC is used. Here, the liquid phase is more polar than the stationary phase, and the more polar compounds elute more rapidly. The mobile phase is usually a mixture of water and a water-miscible organic solvent such as acetonitrile, dioxane, methanol, isopropanol, or acetone. The stationary phase is usually a modified silica gel where the —OH groups of the silica gel have been replaced by —OSiR groups; R is typically a linear C_{18} alkyl chain. These so-called "bonded-phase" columns are not capable of handling as much analyte as normal silica gel columns, and are thus easily overloaded and are less useful for preparative work. (For further discussion see Solid-Phase Extraction, Technique 4, page 83.)

A wide variety of detection systems are available for HPLC. UV detection is common, inexpensive, and sensitive. The solvent flowing off the column is sent through a small cell where the UV absorbance is recorded over time. Many detectors are capable of variable wavelength operation so the detector can be set to the wavelength most suitable to the compound or compounds being analyzed. Photodiode array detectors are available; these can obtain a full UV spectrum in a fraction of a second, so that more information can be obtained on each component of a mixture. For compounds that absorb light in the visible (vis) spectrum, many detectors can be set to visible wavelengths. The principal shortcoming of UV-vis detection is that to be detected, compounds being studied must have a UV chromophore, such as an aromatic ring or other conjugated π system (see Chapter 8).

For compounds that lack a UV-vis chromophore, refractive index (RI) detection is a common substitute. An RI detector measures the difference in refractive index between the eluant and a reference cell filled with the elution solvent. Refractive index detection is significantly less sensitive than UV-vis detection, and the detector is quite sensitive to temperature changes during the chromatographic run.

More sophisticated HPLC instruments offer the ability to mix two or three different solvents and to use solvent gradients by changing the solvent composition as the chromatographic run progresses. This allows the simultaneous analysis of compounds that differ greatly in their polarity. For example, a silica gel column might begin elution with a very nonpolar solvent, such as hexane. The solvent polarity is then continuously increased by blending in more and more ethyl acetate until the elution solvent is pure ethyl acetate. This effect is directly analogous to temperature programming in GC.

For analytical work, typical HPLC columns are about 5 mm in diameter and about 25 cm in length. The maximum amount of analyte for such columns is generally less than 1 mg, and the minimum amount is determined by the detection system. High-performance liquid chromatography can thus be used to obtain small amounts of purified compounds for infrared (IR), nuclear magnetic resonance (NMR) or mass spec-trometric (MS) analysis. Larger "semipreparative" columns that can handle up to about 20 mg without significant overloading are useful for obtaining material for ^{13}C NMR spectroscopy or further synthetic work.

HPLC has the advantage that it is rapid, it uses relatively small amounts of solvent, and it can accomplish very difficult separations.

Concentration of Solutions

Technique 6B

The solvent can be removed from chromatographic fractions (extraction solutions, or solutions in general) by a number of different methods.

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Distillation

Concentration of solvent by distillation is straightforward, and the standard routine is described in Technique 2 (page 61). This approach allows for high recovery of volatile solvents and often can be done outside a hood. The Hickman still head and the 5- or 10-mL round-bottom flask are useful for this purpose. Distillation should be used primarily for concentration of the chromatographic fraction, followed by transfer of the concentrate with a Pasteur filter pipet to a vial for final isolation.

Evaporation with Nitrogen Gas

A very convenient method for removal of final solvent traces is the concentration of the last 0.5 mL of a solution by evaporation with a gentle stream of nitrogen gas while the sample is warmed in a sand bath. This process is usually done at a hood station where several Pasteur pipets can be attached to a manifold leading to a source of dry nitrogen gas. Gas flow to the individual pipets is controlled by needle valves. *Always test the gas flow with a blank vial of solvent.*

Ruekberg described an alternative way to remove solvent from solutions of compounds that are not readily oxidized.[23] The setup includes an aquarium air pump, a pressure safety valve and ballast container, a drying tube, and a manifold. Blunted hypodermic needles are used in place of Pasteur pipets.

The sample vial will cool as the solvent evaporates, and gentle warming and agitation of the vial will thus help remove the last traces of the solvent. This avoids possible moisture condensation on the sample residue, as long as the gas itself is dry. *Do not leave the heated vial in the gas flow after the solvent is removed!* This precaution is particularly important in the isolation of liquids. Tare the vial before filling it with the solution to be concentrated; constant weight over time is the best indication that all solvent has been removed.

Removal of Solvent Under Reduced Pressure

Concentration of solvent under reduced pressure is very efficient. It reduces the time for solvent removal in microscale experiments to a few minutes. In contrast, distillation or evaporation procedures require many minutes for even relatively small volumes. Several methods are available.

Filter Flask Method. This vacuum-concentration technique can be tricky and should be practiced prior to committing hard-won reaction product to this test. The procedure is most useful with fairly large chromatographic fractions (5–10 mL). The sequence of operations is as follows (see also Fig. 5.39):

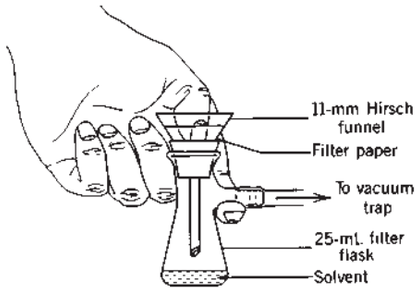

Figure 5.39 Removal of solvent under reduced pressure.

[23]Ruekberg, B. *J. Chem. Educ.* **1995,** *72,* A200.

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Step 1. Transfer the chromatographic fraction to the 25-mL filter flask.

Step 2. Insert the 11-mm Hirsch funnel and rubber adapter into the flask.

Step 3. Turn on the water pump (with trap) and connect the vacuum tubing to the pressure flask side arm while holding the flask in one hand.

Step 4. Place the thumb of the hand holding the filter flask over the Hirsch funnel filter bed to shut off the air flow through the system (see Fig. 5.39). This will result in an immediate drop in pressure. The volatile solvent will rapidly come to a boil at room temperature. Thumb pressure adjusts air leakage through the Hirsch funnel and thereby controls the pressure in the system. It is also good practice to learn to manipulate the pressure so that the liquid does not foam up into the side arm of the filter flask.

The filter flask must be warmed by the sand bath during this operation; rapid evaporation of the solvent will quickly cool the solution. The air leak used to control the pressure results in a stream of moist laboratory air being rapidly drawn over the surface of the solution. If the evaporating liquid becomes cold, water will condense over the interior of the filter flask and contaminate the isolated residue. Warming the flask while evaporating the solvent will avoid this problem and help speed solvent removal. The temperature of the flask should be checked from time to time by touching it with the palm of the free hand. The flask is kept slightly above room temperature by adjusting the heating and evaporation rates. It is best to practice this operation a few times with pure solvent (blanks) to see whether you can avoid boilovers and accumulating water residue in the flask.

Rotary Evaporator Method. In most research laboratories, the most efficient way to concentrate a solution under reduced pressure is to use a **rotary evaporator.** A commercial micro-rotary evaporator is shown in Figure 5.40.

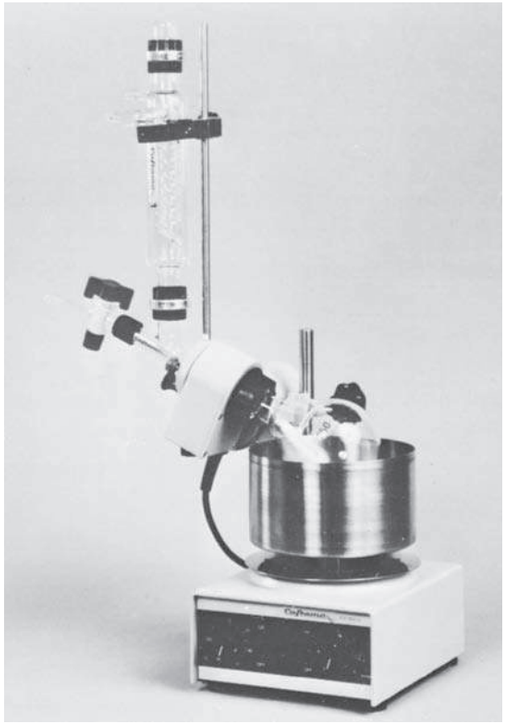

Figure 5.40 Heidolph micro-rotary evaporator. *(Courtesy of Caframo, Ltd., Wiarton, Ontario,Canada.)*

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This equipment makes it possible to recover the solvent removed during the operation.

The rotary evaporator is a motor-driven device that rotates the flask containing the solution to be concentrated under reduced pressure. The rotation continuously exposes a thin film of the solution for evaporation. This process is very rapid, even well below the boiling point of the solvent being removed. Since the walls of the rotating flask are constantly rewetted by the solution, bumping and superheating are minimized. The rotating flask may be warmed in a water bath or other suitable device that controls the rate of evaporation. A suitable adapter (a "bump bulb") should be used on the rotary evaporator to guard against splashing and sudden boiling, which may lead to lost or contaminated products.

In microscale work, never pour a recovered liquid product from the rotary flask. Always use a Pasteur pipet.

Hickman Still–Rotary Evaporation Apparatus. A simple microscale rotary evaporator for use in the instructional laboratory consists of a 10-mL round-bottom flask connected to a capped Hickman still (side-arm type), which in turn is attached to a water aspirator (with trap).[24] The procedure involves transferring the solution to be concentrated to the preweighed 10-mL flask. The flask is then attached to a Hickman still with its top joint sealed with a rubber septum and threaded compression cap. The apparatus is connected by the still side arm to the trap–vacuum source with a vacuum hose. With the aspirator on, one shakes the apparatus while warming the flask in the palm of the hand. In this manner, bumping is avoided and evaporation is expedited. The still acts as a splash guard. Heat transfer is very effective, and once the flask reaches ambient temperature, the vacuum is released by venting through the trap stopcock.

QUESTIONS

5-30. When marking the sample line on a TLC plate, why is it inadvisable to use a ball-point pen?

5-31. A series of dyes is separated by TLC. The data are given below. Calculate the R_f value for each dye.

Material	Distance moved (cm)
Solvent	6.6
Bismarck brown	1.6
Lanacyl violet BF	3.8
Palisade yellow 3G	5.6
Alizarine emerald G	0.2

5-32. Why is it important not to let the level of the elution solvent in a packed chromatographic column drop below the top of the solid-phase adsorbent?

5-33. What are some advantages of using column chromatography to purify reaction products in the microscale laboratory?

5-34. Discuss the similarities and dissimilarities of TLC, paper, and column chromatography.

[24]Maynard, D. F. *J. Chem. Educ.* **1994,** *71,* A272.

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5-35. Discuss the similarities and dissimilarities of HPLC and gas chromatography.

5-36. **(a)** What are the main advantages of using flash chromatography? **(b)** How can TLC be used in connection with flash chromatography?

5-37. Using the information presented on the right, please identify and explain which spot has an R_f value of 0.5.

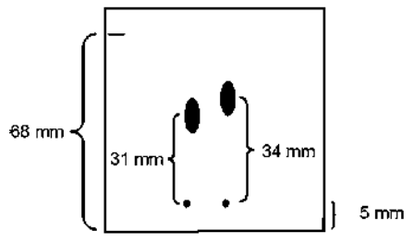

NOTE. The following experiments use Technique 6: Experiments [8A], [8B], [8C], [11C], [12], [13], [16], [17], [19A], [19B], [19C], [19D], [22A], [22B], [27], [29A], [29B], [29C], [29D], [30], [33A], [33B], [35], [A2$_a$], [A1$_b$], [E1], and [E3]. [1A$_{adv}$], [1B$_{adv}$], [4$_{adv}$], and [7$_{adv}$].

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TECHNIQUE 7

Collection or Control of Gaseous Products

Water-Insoluble Gases

Numerous organic reactions lead to the formation of gaseous products. If the gas is insoluble in water, collection is easily accomplished by displacing water from a collection tube. A typical experimental setup for the collection of gases is shown in Figure 5.41.

As illustrated, the glass capillary efficiently transfers the evolved gas to the collection tube. The delivery system need not be glass; small polyethylene or polypropylene tubing may also serve this purpose. In this arrangement, a syringe needle is inserted through a septum to accommodate the plastic tubing as shown in Figure 5.42. An alternative to this connector is a shortened Pasteur pipet inserted through a thermometer adapter (Fig. 5.42). Another alternative to the syringe needle or glass pipet tip is suggested by Jacob.[25] The lower half of the tapered tip of a plastic automatic delivery pipet

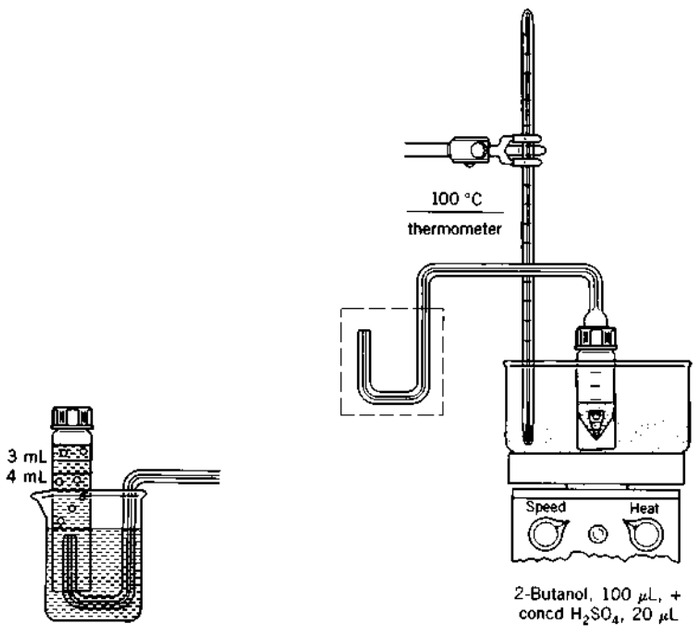

Figure 5.41 Microscale gas collection apparatus.

[25]Jacob, L. A. *J. Chem. Educ.* **1992,** *69,* A313.

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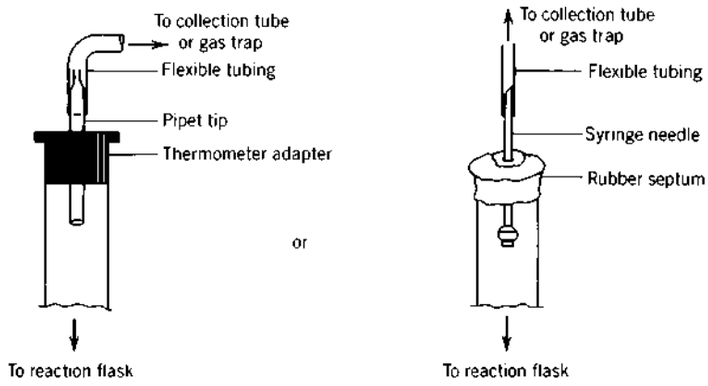

Figure 5.42 Alternative arrangements for controlled gas collection.

tip is cut off to prevent buildup of excess pressure in the reaction vessel. The pipet tip is then inserted through a previously pierced rubber septum or into a thermometer adapter. The narrow end of the tip is then inserted into the plastic tubing.

An example of a reaction leading to gaseous products that can use this collection technique is the acid-catalyzed dehydration of 2-butanol described in Experiment [9]. The products of this reaction are a mixture of alkenes: 1-butene, *trans*-2-butene, and *cis*-2-butene, which boil at −6.3, 0.9, and 3.7 °C respectively and *sec*-butyl ether (2,2′-oxybisbutane) which boils at 123 °C. While all four compounds are formed in the reaction mixture, the setup is designed to collect the gases and thus the three alkenes.

In Figure 5.41 the gas collection tube is capped with a rubber septum. This arrangement allows for convenient removal of the collected gaseous butenes using a gas-tight syringe, as shown in Figure 5.43. In this particular reaction, the mixture of gaseous products is conveniently analyzed at ambient temperature by GC (see Technique 1).

Trapping Byproduct Gases

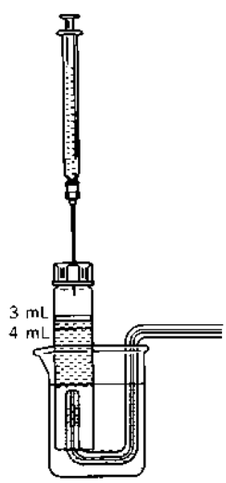

Figure 5.43 Removal of collected gases.

Some organic reactions release poisonous or irritating gases as byproducts. For example, hydrogen chloride, ammonia, and sulfur dioxide are typical byproducts in organic reactions. In these cases, the reaction is generally run in a **hood.** A gas trap may be used to prevent the gases from being released into the laboratory atmosphere. If the evolved gas is water soluble, the trap technique works well at the microscale level. The evolved gas is directed from the reaction vessel to a container of water or other aqueous solution, wherein it dissolves (reacts). For example, a dilute solution of sodium or ammonium hydroxide is suitable for acidic gases (such as HCl); a dilute solution of sulfuric or hydrochloric acid is suitable for basic gases (such as NH_3 or low molecular weight amines). Various designs are available for gas traps. A simple, easily assembled one for a gas that is very soluble in water is shown in Figure 5.44. Note that the funnel is not immersed in the water. If the funnel is held below the surface of the water and a large quantity of gas is absorbed or dissolved, the water easily could be drawn back into the reaction assembly. If the gas to be collected is not very soluble, the funnel may be immersed just below (1–2 mm) the surface of the water.

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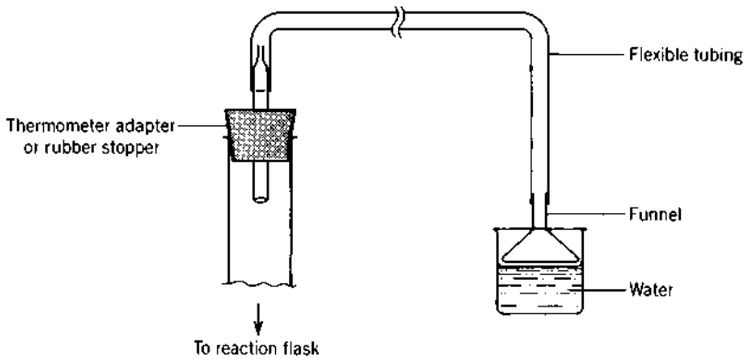

Figure 5.44 Trapping a water-soluble gas.

At the microscale level, small volumes of gases are evolved that may not require the funnel. Three alternatives are available:

a. Fill the beaker (100 mL) in Figure 5.41 with moistened fine glass wool and lead the gas delivery tube directly into the wool.

b. Place moistened glass wool in a drying tube and attach the tube to the reaction apparatus (see Chapter 3W, Fig. 3.10W). However, be careful not to let the added moisture drip into the reaction vessel; place a small section of **dry** glass wool in the tube before the moist section is added.

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c. Use a water aspirator. An inverted funnel can be placed over the apparatus opening where the evolved gas is escaping (usually the top of a condenser) and connected with flexible tubing (through a water trap) to the aspirator. A second arrangement is to use a glass or plastic T-tube (open on one end) inserted in the top of the condenser, by use of a rubber stopper, in place of the funnel.[26] If the reaction must be run under anhydrous conditions, a drying tube is inserted between the condenser and T-tube. This arrangement is very efficient, easy to assemble, and inexpensive. The simplest method is to clamp a Pasteur pipet so that its tip is inserted well into the condenser, and connect it (through a water trap) to the aspirator.

QUESTIONS

5-38. In Figure 5.41 why is a septum, not just a plain cap, used on the top of the gas collection tube?

5-39. An evolved gas is directed from the reaction vessel to a container of water or other aqueous solution, wherein it dissolves (reacts). For example, a dilute solution of sodium or ammonium hydroxide is suitable for acidic gases (such as HCl). What solution would be appropriate to trap thiols and sulfides? (*Hint:* Consult a qualitative analysis text.)

5-40. One way to eliminate emissions is to place moistened glass wool in a drying tube, which is then attached to the reaction apparatus (Fig. 3.10W). What precautions must be taken when using this method?

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5-41. In the collection of water-insoluble gases with the apparatus shown in Figure 5.41, describe how one might measure the rate at which a gas is evolved from a reaction mixture.

NOTE. The following experiments use Technique 7: Experiments [9], [10], [14], [A2$_a$], and [B2].

[26]Horodniak, J. W.; Indicator, N. *J. Chem. Educ.* **1970,** 47, 568.

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TECHNIQUE 8

Measurement of Specific Rotation

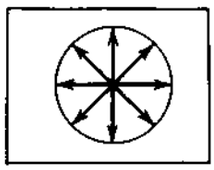

Figure 5.45 Oscillation of the electric field of ordinary light occurs in all possible planes perpendicular to the direction of propagation. (From Solomons, T. W. G. *Organic Chemistry,* 9th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)

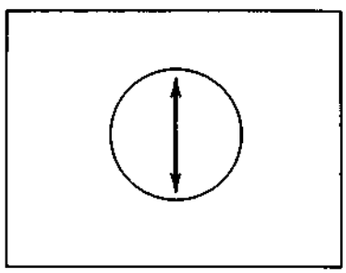

Figure 5.46 The plane of oscillation of the electric field of plane-polarized light. In this example the plane of polarization is vertical. (From Solomons, T. W. G. *Organic Chemistry,* 9th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, Inc., New York.)

Solutions of optically active substances, when placed in the path of a beam of polarized light, may rotate the plane of the polarized light. Enantiomers (two molecules that are nonidentical mirror images) have identical physical properties (melting points, boiling points, infrared and nuclear magnetic resonance spectra, etc.) except for their interaction with plane polarized light, their *optical activity*. Optical rotation data can provide important information concerning the absolute configuration and the enantiomeric purity of a sample.

Optical rotation is measured using a *polarimeter*. This technique is applicable to a wide range of analytical problems, from purity control to the analysis of natural and synthetic compounds. The results obtained from measuring the observed angle of rotation α are generally expressed as the *specific rotation* $[\alpha]$.

Theory

Ordinary light behaves as though it were composed of electromagnetic waves in which the oscillating electric field vectors are distributed among the infinite number of possible orientations around the direction of propagation (see Fig. 5.45).

NOTE. A beam of light behaves as though it is composed of two, mutually perpendicular, oscillating fields: an electric field and a magnetic field. The oscillating magnetic field is not considered in the following discussion.

The planes in which the electrical fields oscillate are perpendicular to the direction of propagation of the light beam. If one separates one particular plane of oscillation from all other planes by passing the beam of light through a polarizer, the resulting radiation is plane-polarized (Fig. 5.46). In the interaction of light with matter, this plane-polarized radiation is represented as the vector sum of two circularly polarized waves. The electric vector of one of the waves moves in a clockwise direction; the other moves in a counterclockwise direction. Both waves have the same amplitude (Fig. 5.47). These two components add vectorially to produce plane-polarized light.

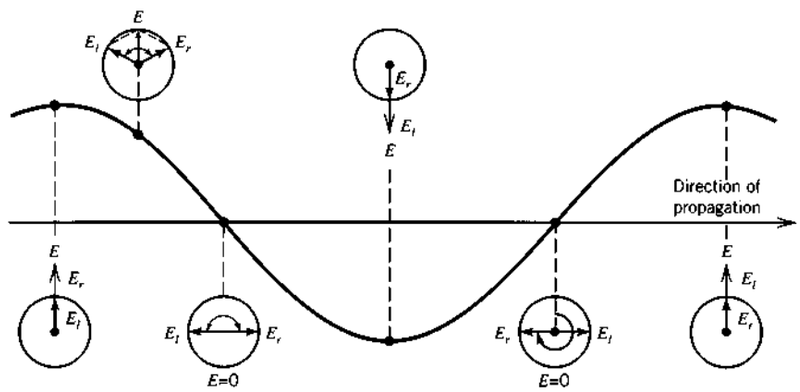

Figure 5.47 A beam of plane-polarized light viewed from the side (sine wave) and along the direction of propagation at specific times (circles) where the resultant vector *E* and the circularly polarized components E_l and E_r are shown. (From Douglas, B., McDaniel, D. H., and Alexander, J. J. *Concepts and Models of Inorganic Chemistry,* 3rd ed. Wiley, New York, 1994. Reprinted by permission of John Wiley & Sons, Inc., New York.)

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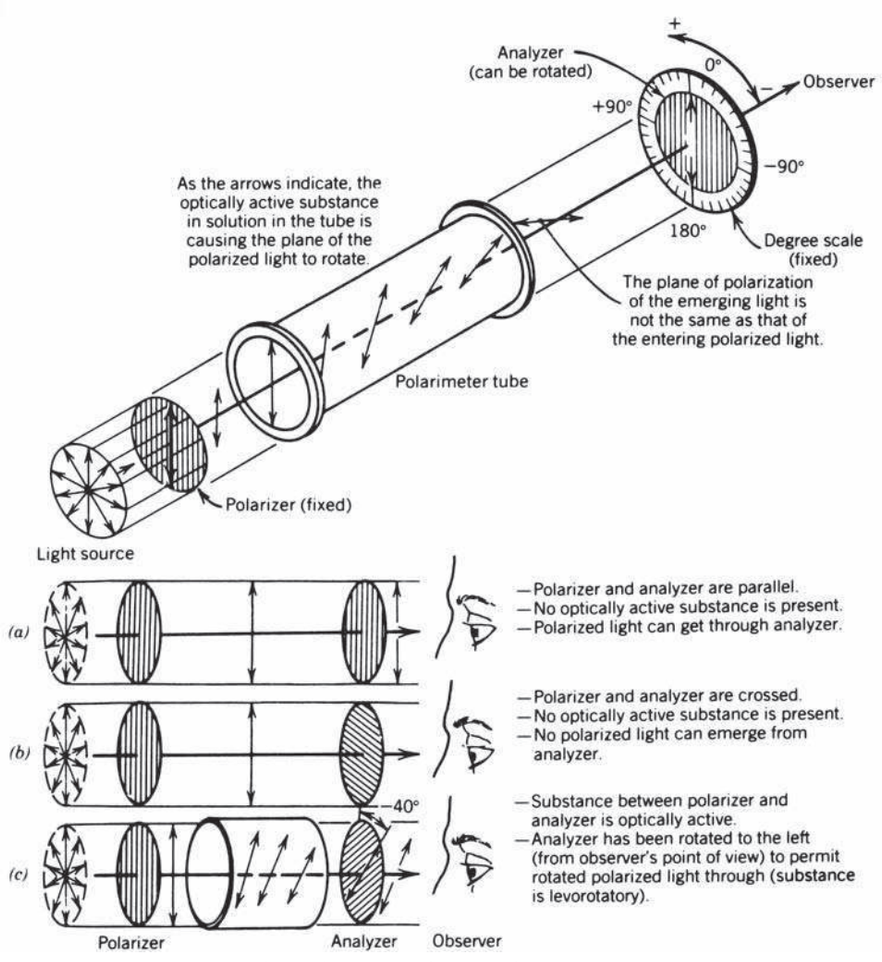

Figure 5.48 Operation of a polarimeter. (From Solomons, T. W. G. *Organic Chemistry,* 9th ed. Wiley, New York, 2008. Reprinted by permission of John Wiley & Sons, Inc. New York.)

If the passage of plane-polarized light through a material reduces the velocity of one of the circularly polarized components more than the other by interaction with bonding and nonbonding electrons, the transmitted beam of radiation has its plane of polarization rotated from its *original* position (Figs. 5.48 and 5.49). A **polarimeter** is used to measure this angle of rotation.

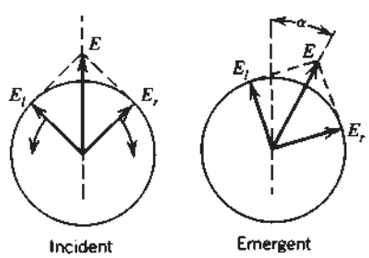

Figure 5.49 Plane-polarized light before entering and after emerging from an optically active substance. (From Douglas, B., McDaniel, D. H., and Alexander, J. J. *Concepts and Models of Inorganic Chemistry,* 3rd ed. Wiley, New York, 1994. (Reprinted by permission of John Wiley & Sons, Inc., New York.)

The Polarimeter

The polarimeter measures the amount of rotation caused by an optically active compound (in solution) placed in the beam of the plane polarized light. The principal parts of the instrument are diagrammed in Figure 5.48. Two Nicol prisms are used in the instrument. The first prism, which polarizes the original light source, is called the polarizer. The second prism, called the analyzer, is used to examine the polarized light after it passes through the solution being analyzed.

When the axes of the analyzer and polarizer prisms are parallel (0°) and no optically active substance is present, the maximum amount of light is transmitted. If the axes of the analyzer and polarizer are at right angles to

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each other (90°), no transmission of light is observed. Placing an optically active solution into the path of the plane-polarized light causes one of the circularly polarized components to be slowed more than the other. The refractive indices are, therefore, different in the two circularly polarized beams. Figure 5.48 represents a case in which the left-hand component has been affected the most.

NOTE. In the simplified drawing, Figure 5.48, the effect on only one of the circularly polarized waves is diagrammed. See Figure 5.49 for a more accurate description (view from behind the figure).

This tilts the plane of polarization. The analyzer prism must be rotated to the left to maximize the transmission of light. If rotation is counterclockwise, the angle of rotation is defined as (−) and the enantiomer that caused the effect is called levorota-tory (*l*). Conversely, clockwise rotation is defined as (+), and the enantiomer is dextrorotatory (*d*). Tilting the plane of polarization is called *optical activity.* Note that if a solution of equal amounts of a *d* and an *l* enantiomeric pair is placed in the beam of the polarimeter, no rotation is observed. Such a solution is *racemic*; it is an equimolar mixture of enantiomers.

The magnitude of optical rotation depends on several factors: (1) the nature of the substance, (2) the path length through which the light passes, (3) the wavelength of light used as a source, (4) the temperature, (5) the concentration of the solution used to make the measurement of optical activity, and (6) the solvent used in making the measurement.

The results obtained from the measurement of the observed angle of rotation, α_{obs}, are generally expressed in terms of *specific rotation* $[\alpha]$. The sign and magnitude of $[\alpha]$ are dependent on the specific molecule and are determined by complex features of molecular structure and conformation; they cannot be easily explained or predicted. The specific rotation is a physical constant characteristic of a substance. The relationship of $[\alpha]$ to α_{obs} is as follows:

$$[\alpha]_{\lambda}^{T} = \frac{\alpha_{obs}}{lc}$$

where

T = temperature of the sample in degrees Celsius (°C),

l = the length of the polarimeter cell in decimeters (1 dm = 0.1 m = 10 cm),

c = concentration of the sample in grams per milliliter (g/mL),

λ = the wavelength of light in nanometers (nm) used in the polarimeter.

These units are traditional, though most are esoteric by contemporary standards. The specific rotation for a given compound depends on both the concentration and the solvent, and thus both the solvent and concentration used must be specified. For example, $[\alpha]_{D}^{25}$ (c = 0.4, $CHCl_3$) = 12.3° implies that the measurement was recorded in a $CHCl_3$ solution of 0.4 g/mL at 25 °C using the sodium D line (589 nm) as the light source.

For increased sensitivity, many simple polarimeters have an optical device that divides the viewed field into three adjacent parts (triple-shadow polarimeter; Fig. 5.50). A very slight rotation of the analyzer will cause one portion to become dimmer and the other lighter (Fig. 5.50*a* and 5.50*c*). The angle of rotation reading (α) is recorded when the field sections all have the same intensity. An accuracy of ± 0.1° can be obtained.

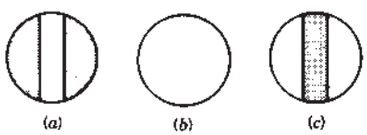

Figure 5.50 View through the eyepiece of the polarimeter. The analyzer should be set so that the intensity in all parts of the field is the same (b). When the analyzer is displaced to one side or the other, the field will appear as in (a) or (c).

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Inaccurate Measurements. Several conditions may lead to inaccurate measurements, including trapped air bubbles in the cell, and solid particles suspended in the solution. Filter the solution, if necessary.

High-Performance Polarimeters and Optical Rotary Dispersion. For details of these two related topics refer to online discussion, Technique 8. www

Applications to Structure Determination in Natural Products. Natural products provide interesting opportunities for measuring optical activity. An excellent example is the lichen metabolite, usnic acid, which can be easily isolated from its native source, "Old Man's Beard" lichens, as golden crystals (see Experiment [11A]).

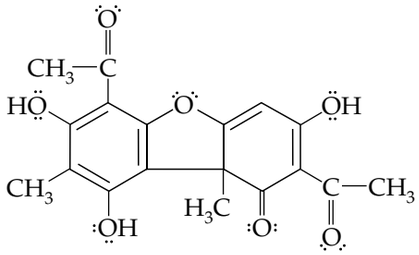

Usnic acid

Usnic acid contains a single stereocenter (stereogenic center, or chiral center) and, therefore, has the possibility of existing as an enantiomeric pair of stereoisomers. Generally, in a given lichen, only one of the stereoisomers (*R* or *S*) is present. Usnic acid has a very high specific rotation (~ ± 460°) which makes it an ideal candidate for optical rotation measurements at the microscale level.

QUESTIONS

5-42. A solution of 300 mg of optically active 2-butanol in 10 mL of water shows an optical rotation of −0.54°. What is the specific rotation of this molecule?

5-43. Draw the structure of usnic acid and locate its stereocenter.

5-44. After drawing all stereoisomers of 3-amino-2-butanol, identify the enantiomeric pairs.

5-45. If a solution of an equimolar mixture of an enantiomeric pair is placed in the beam path of the polarimeter, what would you observe?

5-46. The specific rotation of (+)Q is + 12.80°. At identical concentration, solvent, pathlength, and light wavelength, the observed rotation of a solution containing both enantiomers of Q is 6.40°. What are the relative concentrations of each enantiomer in the solution?

NOTE. The following experiment uses Technique 8: Experiment [11A]

Sublimation

TECHNIQUE 9

Sublimation is especially suitable for purifying solids at the microscale level. It is useful when the impurities present in the sample are nonvolatile under the conditions used. Sublimation is a relatively straightforward method; the impure solid need only be heated.

Sublimation has additional advantages: (1) It can be the technique of choice for purifying heat-sensitive materials—under high vacuum it can be

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effective at low temperatures; (2) solvents are not involved and, indeed, final traces of solvents are effectively removed; (3) impurities most likely to be separated are those with lower vapor pressures than the desired substance and often, therefore, lower solubilities, exactly those materials very likely to be contaminants in a recrystallization; (4) solvated materials tend to desolvate during the process; and (5) in the specific case of water of solvation, it is very effective even with substances that are deliquescent. The main disadvantage of the technique is that it can be less selective than recrystallization when the vapor pressure of the desired material being sublimed is similar to that of an impurity.

Some materials sublime at atmospheric pressure (CO_2, or dry ice, is a well-known example), but most sublime when heated below their melting points under reduced pressure. The lower the pressure, the lower the sublimation temperature. Substances that do not have strong intermolecular attractive forces are excellent candidates for purification by sublimation. Napthalene, ferrocene, and *p*-dichlorobenzene are examples of compounds that are readily sublimed.

Sublimation Theory

Sublimation and distillation are closely related. Crystals of solid substances that sublime, when placed in an evacuated container, will gradually generate molecules in the vapor phase by the process of evaporation (i.e., the solid has a vapor pressure). Occasionally, one of the vapor molecules will strike the crystal surface or the walls of the container and be held by attractive forces. This process, condensation, is the reverse of evaporation.

Sublimation is the complete process of evaporation from the solid phase to condensation from the gas phase to directly form crystals without passing through the liquid phase.

A typical single-component phase diagram is shown in Figure 5.51, which relates the solid, liquid, and vapor phases of a substance to temperature and pressure. Where two of the areas (solid, liquid, or vapor) touch, there is a line, and along each line the two phases exist in *equilibrium*. Line *BO* is the sublimation–vapor pressure curve of the substance in question; only along line *BO* can solid and vapor exist together in equilibrium. At temperatures and pressures along the *BO* curve, the liquid state is thermodynamically unstable. Where the three lines representing pairs of phases intersect, all three phases exist together in equilibrium. This point is called the *triple point*.

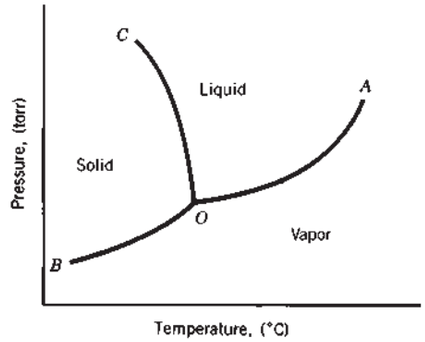

Figure 5.51 Single-component phase diagram.

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Many solid substances have a sufficiently high vapor pressure near their melting point that allows them to be sublimed easily under reduced pressure in the laboratory. Sublimation occurs when the vapor pressure of the solid equals the pressure of the sample's environment.

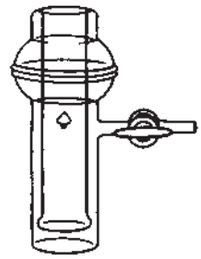

Figure 5.52 Vacuum sublimator. *(Courtesy of ACE Glass Inc., Vineland, NJ.)*

Experimental Setup

Heating the sample with a microburner or a sand bath to just below the melting point of the solid causes sublimation to occur. Vapors condense on the cold-finger surface, whereas any less volatile residue will remain at the bottom of the flask. Apparatus for sublimation of small quantities are now commercially available (Fig. 5.52). Two examples of simple, inexpensive apparatus suitable for sublimation of small quantities of material in the microscale organic laboratory are shown in Figure 5.53.

An example of the purification of a natural product, where the sublimation technique at the microscale level is effective, is the case of the alkaloid caffeine. This substance can be isolated by extraction from tea (see Experiment [11B]).

Precautions

Several precautions should be observed when performing a sublimation:

1. If you use the first setup in Figure 5.53, make sure you attach the hose connections to the cold finger in the proper manner. *The incoming cold water line is attached to the center tube.*
2. If you generate a vacuum using a water aspirator, make sure you place a water trap in the line. *Apply the vacuum to the system before you turn on the cooling water to the condenser.* This will keep moisture in the air in the flask from being condensed on the cold finger. Let the cold finger warm up before releasing the vacuum.
3. After the sublimation is complete, release the vacuum *slowly* so as not to disturb the sublimed material.
4. When using either of the arrangements in Figure 5.53, be careful to avoid loss of purified product as you remove the cold finger from the assembly.
5. The distance between the tip of the cold finger and the bottom of the sublimator should be less than 1 cm in most cases.

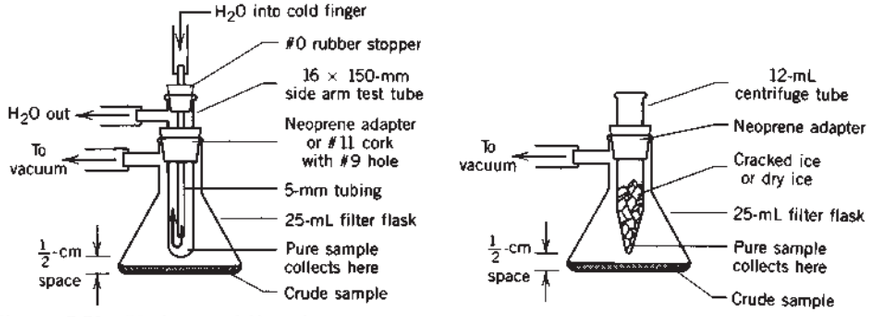

Figure 5.53 Various sublimation apparatus.

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QUESTIONS

5-47. List the advantages and disadvantages of sublimation as a purification technique.

5-48. For a solid compound to evaporate at atmospheric pressure it must have an unusually high vapor pressure. What molecular structural features contribute to this vapor pressure?

5-49. Why apply the vacuum to the sublimation system *before* you turn on the cooling water to the water condenser?

5-50. Why place a water trap in the vacuum line when using an aspirator to obtain the vacuum?

5-51. Why is sublimation particularly useful for purifying deliquescent compounds?

5-52. The 72% recovery after performing a sublimation translates to 32 mg of material. Calculate the amount of crude sample prior to performing the sublimation.

NOTE. The following experiments use Technique 9: Experiments [11B], [25A], and [25B].

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C_6H_6apter 6

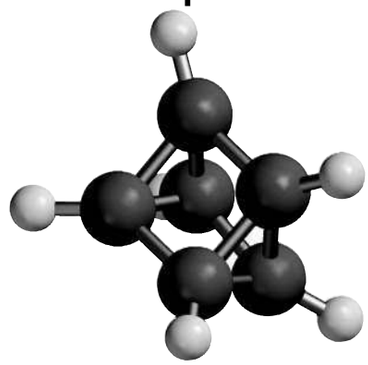

MICROSCALE ORGANIC LABORATORY EXPERIMENTS

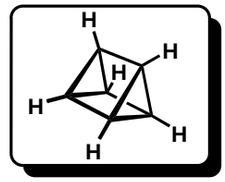

This chapter contains the experimental details of a collection of famous organic reactions that are at the heart of this field of chemistry. One of the great triumphs of the human intellect has been our ability to rationalize the physical transformations of organic materials. The experimental laboratory is the source of information out of which predictive organic theory has been fashioned. The microscale organic laboratory is designed to give you the opportunity to experience, first hand, how organic reactions occur. This program will allow you to see how experimental data are directly related to the development of the structural and mechanistic theory surrounding these transformations. If successful, the microscale organic laboratory should bring the lecture portion of your course to life. What you have been studying in two dimensions in lecture, now becomes alive in three dimensions in the laboratory.

The 35 experiments that make up this chapter focus largely on some of the most important of the fundamental organic reactions that have been discovered over the last two centuries. Because the application of these reactions to synthesis has been extensive, the microscale laboratory program offers a broad and practical introduction to organic chemistry. A significant number of the experiments include optional scale-up procedures to provide laboratory experience at the semimicroscale level, an inquiry-driven format allowing the student to monitor the reaction prior to work-up, validation opportunities to confirm product purity by TLC analysis, and microwave procedures if alternative formats of experimental work are desired. Studying one or two of these modified formats at the beginning of the second semester can be helpful, particularly if some of the multistep syntheses covered in Chapter 7 are planned for study later in that semester. These latter sequences make extensive use of semimicroscale experimentation.

? highlights an inquiry-driven format

V highlights a validation opportunity

M highlights a microwave procedure

The microscale experiments are designed to enhance your ability to master the miniaturized experimental techniques used. A *Prior Reading* section highlights which techniques are to be used in a particular experiment and outlines the pages to refer to in the Techniques section (see Chapter 5). At the beginning of the semester it is important to *review these sections before proceeding* with the assigned experiment (heed the advice in Chapter 1). After examining the written material, it would be particularly helpful if you could see the video we have prepared that is accessible online. It covers the techniques in detail and can be viewed either in your spare time or in a prelab lecture period. As the basic techniques are used repeatedly, you will rapidly gain a firm grasp of the manipulations required and become comfortable working at this scale. You

www

Chapter 6: C_6H_6, Prismane
Katz and Acton (1973).

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should also take advantage of the large number of graphics in the text margin that detail how the experimental apparatus are assembled. There are prompt signs (➡) in the text near the point where the equipment is to be used.

The important role of spectroscopic techniques in the modern organic laboratory is emphasized in the microscale organic laboratory. This information is set aside as a separate chapter, along with additional valuable details on the website, which are reference materials to be used while undertaking the experimental sections in Chapters 6–7. Numerous cases of detailed analyses of the spectra are found in the *Purification and Characterization* sections of the experiments. Because infrared spectroscopy continues to play a major role in the characterization of reaction products in the introductory laboratory, and because this technique is currently given only a cursory treatment in most lecture texts, we have included a fairly detailed qualitative introduction to the theory of the effect and the instrumentation used in obtaining these observations, principally in Chapter 8 and on the website. *While the IR part of the spectroscopic section (including the on line material) may cover more ground than is normally found in many introductory laboratories, we feel it is important to overcome the black-box attitude that students can rapidly develop toward complex chemical instrumentation when they are turned loose on these powerful instruments with very limited knowledge.* Thus, we hope to be able to accomplish this transformation of attitude by offering students the essential details that will allow them to gain a command of the logic and the mechanics of obtaining and interpreting infrared spectral data. As mentioned earlier, *we have also included, in a number of the experiments, illustrative examples of the detailed spectral analysis* that can be used to examine starting materials, follow the progress of the reaction, and finally to assess the character and purity of the products.

A discussion section precedes each experiment. In a number of cases, especially when named reactions are involved, a brief biographical sketch of the individual so honored is included. At this point we also introduce pertinent information concerning the reaction mechanism, often in considerable detail. When appropriate, the relevance of a reaction to the life sciences and the chemical industry is explored.

Note that *Safety* and *Warning* indicators are highlighted or boxed in the experiments. We urge you to *always* adhere strictly to the safety precautions listed.

The nomenclature of organic compounds is often confusing to the beginning student and even occasionally to the experienced research chemist! To ease your introduction to the name game, the common name (sometimes referred to as the *trivial name*) of the compound to be synthesized is also listed at the beginning of each experiment. In addition, the ***Chemical Abstracts*** (CA) number and CA index name are also given.

Good luck! Enjoy your adventure in transforming small quantities of a large number of organic materials.

EXPERIMENT 1

Getting to Know You: Measurement of Physical Properties

Purpose. This experiment will acquaint you with the experimental techniques used to measure certain classic physical properties of organic substances. These properties include the boiling point, density, and refractive index for liquids, and the melting point for solids. The procedures are outlined in Chapter 4.

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A further objective is to study sampling techniques for obtaining the spectral characteristics of organic materials. You will observe that absorption spectra of organic substances contain, without question, the most important collection of physical constants of a material available to the investigator. Spectral information can lead to the elucidation of molecular structure and the rapid identification of unknown substances.

You will also learn how to locate the literature values for these measured properties using various chemical handbooks and online resources.

Prior Reading

Chapter 4: Determination of Physical Properties
- Ultramicro-Boiling Point (pp. 46–48)
- Density (pp. 49–50)
- Refractive Index (online) ← www
- Melting Point (pp. 50–54)
  - Capillary Method (p. 51)
  - Evacuated Technique (pp. 51–52)
  - Mixture Melting Points (pp. 52–54)

Chapter 5, Technique 6: Thin-Layer Chromatography (pp. 97–99)

DISCUSSION

Organic compounds have a number of physical properties that allow their precise characterization. These include the classical physical constants: boiling point, density, and refractive index for liquids and melting point for solids. The rapid development of modern chemical instrumentation, however, has also made easily accessible many of the spectral properties of these materials. Spectroscopy, in particular, provides information that is extremely powerful for establishing the structure of unknown molecular systems and for rapidly identifying known materials.

Not only are physical properties used to characterize a specific organic compound, but they are often used to compare one compound to another. Examples of this approach are illustrated in Chapter 9, Qualitative Identification of Organic Compounds. The route to identification of an unknown organic species has become increasingly dependent on the measurement of the physical properties of the pure substance.

The various classical physical constants of a large number of organic substances appear in the *CRC Handbook of Chemistry and Physics*, *Lange's Handbook*, *Aldrich Catalog Handbook of Fine Chemicals*, and several online resources. The *Aldrich Catalog* also contains references to published infrared (IR) and nuclear magnetic resonance (NMR) spectral data for many of the compounds. Complementing these databases are several online resources, such as SciFinder Scholar, which allow for users to directly and efficiently access published spectral data. The *CRC Atlas of Spectral Data and Physical Constants for Organic Substances* contains IR and ultraviolet (UV) peak positions. Collections of spectra may be located in the Aldrich Libraries of both IR and NMR spectra, and in the Sadtler Library.

A detailed discussion of the spectral properties of organic compounds is given in Chapter 8 and on the website. ← www

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EXPERIMENTAL PROCEDURE

NOTE. Your instructor will select which of the physical properties you are to measure. The length of your laboratory period, the size of your section, and the number of instruments available will all play a role in determining how many of these properties will be suggested.

Melting Point

1. Using the melting point apparatus *(your instructor will provide you with the experimental details concerning the operation of the particular instrument to be used in your laboratory)*, determine the melting point of acetanilide and compare your result with the literature values (Lit. values) reported in the CRC and Aldrich references (see pp. 50–54 for the experimental details on how to proceed with this measurement).

Determined value _____

CRC: Lit. value _____; Ed. _____; Page _____;
Compound No. _____

Aldrich: Lit. value _____; Year _____; Page _____;
Compound No. _____

2. Now determine an ***evacuated*** melting point (see pp. 51–52 for the experimental details on how to proceed with this measurement) of caffeine and compare it to the values in the CRC and Aldrich references. *Your instructor will provide you with the experimental details concerning the operation of the particular instrument to be used in your laboratory.*

First, determine the melting point of caffeine in an unevacuated melting-point tube. After observing the melting point, allow the temperature to drop below the melting point and observe whether the sample crystallizes again. If crystallization occurs, observe a second melting point, and then repeat this procedure a third time. Follow the same routine with an evacuated sample, and compare the results of the two sets of melting points. Do you observe any differences between these data sets?

2nd Determined value

Unevacuated	***Evacuated***
1st Determined value _____	1st Determined value _____
2nd Determined value _____	2nd Determined value _____
3rd Determined value _____	3rd Determined value _____

CRC: Lit. value _____; Ed. _____; Page _____;
Compound No. _____

Aldrich: Lit. value _____; Year _____ ; Page _____;
Compound No. _____

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3. Why is a second seal required on the evacuated melting-point tube?

4. When are evacuated melting points necessary?

5. Next consider the technique of ***mixture melting points*** (see pp. 52–54 for a discussion of the details of this procedure). This technique is the classical approach for establishing a positive identification of a substance when pure reference standards are available in the laboratory. For two examples where this type of measurement is applied in the microscale organic laboratory, see Experiments [6] and [34A].

6. In the present experiment, you have obtained the melting points of acetanilide and caffeine. Using these values as reference standards observe the melting points of two mixtures: (1) caffeine 75%–acetanilide 25% and (2) caffeine 25%–acetanilide 75%. Should these observations be made in evacuated capillaries or not? *(Your instructor will provide you with the experimental details concerning the operation of the particular instrument to be used in your laboratory.)*

(1) caffeine 75%–acetanilide 25% (2) caffeine 25%–acetanilide 75%

Determined value_____ Determined value_____

7. (Optional) Use the following compounds and mixtures: caffeine, acetanilide, caffeine 75%–acetanilide 25%, and caffeine 25%–acetanilide 75%; your instructor will provide no less than one duplicate set of vials. For sections that consist of an odd number of students, triplication of one set will work. While the vials will be labeled, the labels will not offer any direction as to the contents nor its match. Once the vials are distributed, your goal is to determine the melting point of your "unknown" and find your match. Caution should be exercised since depending on how the vials are "duplicated," there may be more than one match! That is, when considering a laboratory section consisting of 18 students, the 18 vials may consist of 10 vials of caffeine and 8 vials of acetanilide. This could as well be presented as 4 vials of caffeine, 4 vials of acetanilide, 4 vials of caffeine 75%–acetanilide 25%, and 6 vials of caffeine 25%–acetanilide 75%. As you can surmise, an even more challenging exercise can be crafted upon the creative mixing of the pairings above. Success will come to those who correctly determine the melting point of their unknown and thus multiple melting point determinations may be needed prior to seeking your match.[1]

8. Is it possible to detect the presence of impurities by melting-point measurements? Why?

9. Would it be possible to establish the composition of an unknown binary mixture of two substances from mixture melting-point data? Explain.

Ultramicro-Boiling Point

1. Make several (5) glass bells (p. 46). Your instructor will demonstrate the procedure, or you can view the procedure on video, if available. Place the bells in a small glass vial and store them in your micro kit.

2. Use the technique for determining ultramicro-boiling points (bp) on a *melting-point apparatus hot stage* (very likely this well be the same apparatus you used in melting-point section of the experiment) as discussed in

[1]This exercise is based upon discussions led by Jerry R. Mohrig and Christina Noring Hammond during an NSF-sponsored CWCS Workshop on Teaching Guided-Inquiry Organic Chemistry Laboratories (Irvine, CA; July **2005**).

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Chapter 4 (p. 47), and complete the following table *(your instructor will provide you with the experimental details concerning the operation of the particular instrument to be used in your laboratory).*

	Propane	Butane	Pentane	Hexane	Heptane
bp (°C)	−42.1	−0.5	36.1	67	?

3. Compare your measured value for heptane to those listed in the *CRC Handbook, Aldrich Catalog,* and online.

Determined value _____; Barometric pressure _____ torr

Corrected value _____

CRC: Lit. value _____; Ed. _____; Page _____;

Compound No. _____

Aldrich: Lit. value _____; Year _____; Page _____;

Compound No. _____

4. Prepare and attach a graph of molecular weight (MW) vs. boiling point (bp) using the above data.

5. Explain the trend in boiling point as the molecular weight increases.

Density

1. Use the syringe method of measuring the density outlined in Chapter 4 (p. 49), and 0.5 mL of liquid, to complete the following table and compare your value to those listed in the CRC and Aldrich references, *(Your instructor will provide you with the experimental details concerning the operation of the particular equipment to be used in this experiment. Pay close attention to the details concerning the operation of the balances.)*

	Methylene Chloride (CH_2Cl_2)	***Octane C_8H_{18}***
Density (g/mL)	1.33	?
Determined value	_____	_____

CRC: Lit. value _____; Ed. _____; Page _____;

Compound No. _____

Aldrich: Lit. value _____; Year _____; Page _____;

Compound No. _____

2. Methylene chloride is often used as a solvent in the laboratory to extract an *organic species* from an aqueous solution. Will the CH_2Cl_2 normally form the top or bottom layer?

3. If octane were used to extract an aqueous phase, would it form the top or bottom layer? How did you arrive at this answer?

Refractive Index

www **1.** Using the lens paper disk technique outlined online determine the refractive index of methanol and compare the value you have obtained to that found in the CRC and Aldrich data collections. *(Your instructor will*

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provide you with the experimental details concerning the operation of the particular instrument used in your laboratory.)

Determined value _____

CRC: Lit. value _____ ; Ed. _____ ; Page _____ ;

Compound No. _____

Aldrich: Lit. value _____ ; Year _____ ; Page _____ ;

Compound No. _____

2. Correct your measured value to 20 °C.

Temperature of your measurement _____ .

Temperature of literature value _____ .

Your measured value corrected to 20 °C _____ .

Calculations:

3. Based on your observations, how does refractive index vary with temperature?

Thin-Layer Chromatography

1. Using the thin-layer chromatography technique outlined in Chapter 5 (Technique 6A, pp. 97–99), determine the R_f values for benzaldehyde, 4-chlorobenzaldehyde, and cyclohexanol using as a solvent system ethyl acetate and hexane (1:4). While a UV lamp will be sufficient for the visualization of benzaldehyde and 4-chlorobenzaldehyde when working with TLC plates with a UV-activated fluorescent indicator mixed in with the silica gel, a staining system of *p*-anisaldehyde will work when wanting to visualize cyclohexanol. *(Your instructor will provide you with the experimental details concerning the operation of staining a TLC plate using* p*-anisaldehyde. Please use for preparation of* p*-anisaldehyde solution: 135 mL EtOH, 5 mL concentrated* H_2SO_4*, 1.5 mL glacial acetic acid, and 3.7 mL* p*-anisaldehyde.)*

2. After recording the R_f values using as a solvent system ethyl acetate and hexane (1:4), determine what solvent system is needed to obtain values between 0.3−0.4 for each of the following systems: benzaldehyde, 4-chlorobenzaldehyde, and cyclohexanol.

3. Using as a solvent system ethyl acetate and hexane (1:4), predict which compound from the following set would have a higher R_f value: (a) cyclohexanol and cyclohexane, (b) benzoic acid and benzaldehyde, and (c) caffeine and naphthalene.

4. (Optional) Three stock solutions labeled solution A, solution B, and solution C, will be provided by your instructor. They will be one of the following systems: benzaldehyde, 4-chlorobenzaldehyde, or cyclohexanol. Select one (or more) and determine its identity using the thin-layer chromatography technique having already established R_f values in several solvent systems.

Infrared Spectroscopy Sampling Procedures

Sampling of Liquids

1. Use the technique for obtaining an IR spectrum of a thin-liquid film as described on page 553 (*your instructor will provide you with the experimental*

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details concerning the operation of the particular instrument to be used in your laboratory and the type of windows on which your sample will be mounted).

2. Obtain the spectra of *n*-octane and 1-octanol (use a single scan with Fourier-transform [FT] instruments). Compare your data with the Aldrich or Sadtler reference collections, or those obtained online using for example SciFinder Scholar, and compare the two spectra to each other.

3. What differences do you observe between the two spectra? Can you associate differences in molecular structure to the differences in the spectra (see Infrared Discussions in Chapter 8 and on the website relating to the IR spectra of *n*-hexane and 1-hexanol).

4. Occasionally, when an IR spectrum is obtained, some of the very strong bands will appear with flattened peaks, as if they were totally absorbing the energy at those wavenumber values. The flat bottom of the band, however, does not correspond to 0% transmission on the scale, but will indicate an energy transmission of 5–10% or even higher. Can you explain the odd shape of the band? Is the energy being totally absorbed or not? Explain your answers.

Sampling of Solids

1. Use the technique for obtaining an IR spectrum of a solid melting above 100 °C as described in Chapter 8 (pp. 553–554) *(your instructor will provide you with the experimental details concerning the operation of the particular instrument to be used in your laboratory and the type of KBr die in which your sample will be pressed if an ATR FTIR is unavailable).*

2. Obtain the IR spectrum of caffeine (use four scans with FT instruments). Compare your data with an authentic spectrum of caffeine and with the data given in Experiment [11B]. Your sample may be saved by taping it to a file card with your name, and stored by your instructor in a desiccator. If, later in the year, you isolate caffeine from its natural source (Experiment [11B]), you will be able to compare the material you have extracted and purified from the plant with your own authentic reference spectrum.

3. Occasionally, the spectral region from 4000 to 2000 cm^{-1} in solid samples is steeply sloping to lower transmission values at higher wavenumber values. Is this drop in transmission an absorption of the radiation? If so, to what process can the absorption be ascribed, and if not, what is the cause of the decreased transmission?

4. Compare the spectra of caffeine obtained in your laboratory section. Are the spectra all identical? Where do they differ? To what effect can you ascribe the differences, if there are any? (This is a good open question for the entire lab section.)

Nuclear Magnetic Resonance Spectroscopy Sampling Procedures: For NMR sampling procedures and examples see Chapter 8 and Experiments [5B], [22A], and [28]

QUESTIONS

6-1. An unknown carboxylic acid has a boiling point of 100 °C at 25 torr. Using the pressure–temperature nomograph on page 49, determine its boiling point at 760 torr. Identify the acid from the list in Appendix A, Table 9W.1.

6-2. Discuss with those in your laboratory section the consequences of incorrect sample loading, variable sample size, and rates of heating and how these factors might lead you to obtain an incorrect value of the melting point for your solid sample.

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6-3. The mass of a certain volume of an unknown liquid at 25 °C is 234 mg. The mass of an equal volume of water at the same temperature is 201 mg. Calculate the density of the unknown liquid at 25 °C.

6-4. The melting point of pure *trans*-cinnamic acid is 133 °C, and that of 2-acetoxybenzoic acid (aspirin) is 135 °C (Appendix A, Table 9W.2). Given pure reference standards of both acids, describe a melting-point procedure by which you could identify whether an unknown sample melting in this range could be assigned to either structure, or to neither one. www

6-5. Why is filter paper a poor choice of surface on which to powder or crush a solid crystalline sample before placing it in a capillary melting-point tube?

6-6. Why is the ultramicro-boiling point determined precisely at the point when the last vapor bubble has escaped and the liquid phase begins to rise in the bell cavity?

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For further information on basic laboratory techniques:

Sharp, J. T.; Gosney, I; Rowley, A. G. *Practical Organic Chemistry: A Student Handbook of Techniques,* Chapman Hall: London, 1989.

Shriner, R. L.; Hermann, C. K. F.; Morrill, T. C.; Curtin, D. Y.; Fuson, R. C. *The Systematic Identification of Organic Compounds,* 8th ed.; Wiley: New York, 2003.

Vogel, A. I. *Vogel's Textbook of Practical Organic Chemistry,* 5th ed.; Furnis, B. S.; et al. Eds.; Wiley: New York, 1989.

Zubrick, J. W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008.

EXPERIMENT 2

The Separation of a 25-μL Mixture of Heptanal (bp 153 °C) and Cyclohexanol (bp 160 °C) by Gas Chromatography

Purpose. This experiment illustrates the separation of a 25-μL mixture, consisting of heptanal and cyclohexanol, into the pure components. The volume of the mixture is approximately that of a single drop, and the materials boil within 7 °C of each other. This mixture would be difficult, if not impossible, to separate by the best distillation techniques available. The purity of the fractions collected from the gas chromatograph (GC) can be assessed by boiling points, refractive indexes, or infrared (IR) spectra.

Prior Reading

Technique 1: Microscale Separation of Liquid Mixtures by Preparative Gas Chromatography (pp. 55–61)

Chapter 4: Determination of Physical Properties
Ultramicro-Boiling Point (pp. 46–48)
Refractive Index (online) www

Experiment [1]: Measurement of Physical Properties
Ultramicro-Boiling Point (p. 119)

Chapter 8: Introduction to Infrared Spectroscopy (pp. 539–561)

DISCUSSION

The efficacy of GC separations is highly dependent on the experimental conditions. For example, two sets of experimental data on the heptanal–cyclohexanol mixture are given below to demonstrate the effects of variations in oven temperature on retention times.

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EQA

In Data Set A, the oven temperature was allowed to rise slowly from 160 to about 170 °C during a series of sample collections. The retention time of heptanal dropped from about 3 min to close to 2 min, whereas the retention time of cyclohexanol was reduced from about 5.5 min to nearly 4 min. The significant decrease in resolution over this series of collections is reflected in the number of theoretical plates calculated, which was over 300 for heptanal and about 500 for cyclohexanol in the first trial, but declined to below 200 for both compounds toward the last run (see Data Set A).

COLLECTION YIELD

Cyclohexanol

Density of cyclohexanol = 0.963 mg/μL.

In 25 μL of 1:1 cyclohexanol–heptanal, we have 12.5 μL of cyclohexanol.

Therefore, 125 μL × 0.963 mg/μL = 12 mg of cyclohexanol injected.

Percent recovered = (8.3 mg/12.0 mg) × 100 = 69% cyclohexanol collected.

Heptanal

Density of heptanal = 0.850 mg/μL.

Therefore, 12.5 μL × 0.85 mg/μL = 10.6 mg of heptanal injected.

Percent recovered = (8.1 mg/10.6 mg) × 100 = 76% heptanal.

In the Data Set B collections, stable oven temperatures and flow rates were maintained, and the data exhibit excellent reproducibility. Oven temperature was held at 155 °C throughout the sampling process. The retention time of heptanal was observed to be slightly longer than 3 min, with a variance of 6 s, whereas the cyclohexanol retention time was found to be slightly longer than 6 min, with a variance of 12 s. The resolution remained essentially constant throughout the series, and the number of theoretical plates

Data Set A

	Heptanal				Cyclohexanol			
Trial No.	Retention Time (min)	Baseline Width (min)	Number of Theoretical Plates	Recovery (mg)	Retention Time (min)	Baseline Width (min)	Number of Theoretical Plates	Recovery (mg)
1	3.1	0.7	314	8.0	5.6	1.0	502	8.0
2	2.9	0.7	275	8.0	5.3	1.0	449	8.0
3	3.0	0.7	294	7.0	5.7	1.0	520	8.0
4	2.8	0.7	256	8.0	5.1	1.1	344	8.0
5	2.5	0.6	278	8.0	4.3	1.1	244	9.0
6	2.7	0.5	467	7.0	4.6	1.0	339	10.0
7	2.5	0.6	278	10.0	4.2	1.0	282	8.0
8	2.2	0.5	310	9.0	3.5	1.0	196	8.0
9	1.8	0.5	207	8.0	3.0	1.0	144	8.0
10	2.3	0.7	173	8.0	3.9	1.0	243	8.0
Av	2.5 ± 0.4	0.6 ± 0.09	285 ± 7	8.1 ± 0.8	4.5 ± 0.9	1.0 ± 0.05	326 ± 129	8.3 ± 0.7

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EQA

Data Set B

	Heptanal				Cyclohexanol			
Trial No.	Retention Time (min)	Baseline Width (min)	Number of Theoretical Plates	Recovery (mg)	Retention Time (min)	Baseline Width (min)	Number of Theoretical Plates	Recovery (mg)
1	3.5	0.7	400	8.0	6.6	1.1	576	8.0
2	3.2	0.7	334	9.0	6.0	1.1	476	7.0
3	3.5	0.7	400	7.0	6.6	1.2	484	10.0
4	3.2	0.7	334	9.0	6.1	1.0	595	9.0
5	3.1	0.6	427	8.0	6.0	1.1	476	8.0
6	3.2	0.7	334	9.0	6.0	1.1	476	9.0
7	3.3	0.8	272	9.0	6.1	1.1	492	8.0
8	3.1	0.7	313	8.0	6.0	1.1	476	10.0
9	3.2	0.7	334	8.0	6.1	1.1	492	8.0
10	3.2	0.7	334	8.0	6.2	1.1	508	8.0
Av	3.2 ± 0.1	0.7 ± 0.05	348 ± 47	8.3 ± 0.7	6.2 ± 0.2	1.1 ± 0.05	505 ± 44	8.5 ± 1.0

calculated was about 350 for heptanal and about 500 for cyclohexanol (see Data Set B).

COLLECTION YIELD

Cyclohexanol

Density of cyclohexanol = 0.963 mg/μL.

In 25 μL of 1:1 cyclohexanol–heptanal, there are 12.5 μL of cyclohexanol.

Therefore, 125 μL × 0.963 mg/μL = 12 mg of cyclohexanol injected.

Percent recovered = (8.5 mg/12.0 mg) × 100 = 71% cyclohexanol collected.

Heptanal

Density of heptanal = 0.850 mg/μL.

Therefore, 12.5 μL × 0.85 mg/μL = 10.6 mg of heptanal injected.

Percent recovered = (8.3 mg/10.6 mg) × 100 = 78% heptanal.

The results just described demonstrate that the resolution of GC peaks may be very sensitive to changes in retention time resulting from instability in oven temperatures. Since the number of theoretical plates is related to resolution values, significant degradation in column plate values can occur with variations in oven temperatures. When you compare the time and effort required to obtain a two-plate fractional distillation on a 2-mL mixture (see Experiment [3B] and Technique 2) with the speed and ease used to obtain a 500 plate separation on 12.5 μL of cyclohexanol in this experiment, it is hard not to be impressed with the enormous power of this technique.

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EQA

COMPONENTS

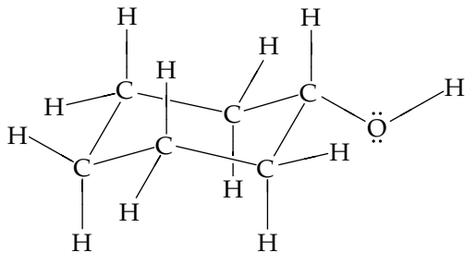

Cyclohexanol

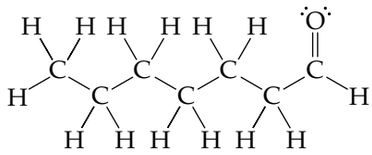

Heptanal

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 2.0 h.

Physical Properties of Components					
Compound	MW	Amount	bp (°C)	Density (*d*)	n_D
Heptanal	114.19	12.5 μL	153	0.85	1.4113
Cyclohexanol	100.16	12.5 μL	160	0.96	1.4641

Reagents and Equipment. The procedure involves injecting a 25-μL mixture of heptanal–cyclohexanol 1:1 (v/v) into a $\frac{1}{4}$-in. × 8-ft stainless-steel column packed with 10% Carbowax 80/100 20M PAW-DMS. Experimental conditions (GOW-MAC series No. 350) are He flow rate, 50 mL/min; chart speed, 1 cm/min; oven temperature, 155 °C.

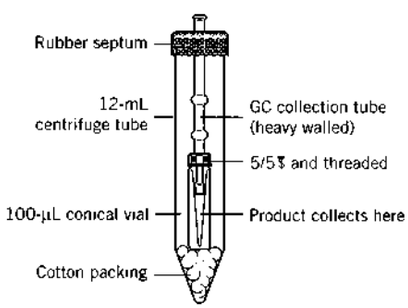

Figure 6.1 Gas chromatographic collection tube and 0.1-mL conical vial.

Procedure for Preparative Collection. The liquid effluents are collected in an uncooled, 4-mm-diameter collection tube (double reservoirs; overall tube length 40–50 mm, see Fig. 6.1)

The collection tube (oven dried until 5 min before use) is attached to the heated exit port by the 5/5 ground joint. Sample collection is initiated 0.5 min prior to detection on the recorder of the expected peak (time based on previously determined retention values)[2] and continued until 0.5 min following return to baseline. After the collection tube is detached, the sample is transferred to the 0.1-mL conical GC collection vial. The transfer is facilitated by the 5/5 ground joint on the conical vial. After the collection tube is joined to the vial (preweighed with stopper), the system is centrifuged (see Fig. 6.1). The collection tube is then removed and the vial is stoppered and reweighed.

Characterization. Calculate the percent recovery. These amounts should range between 7 and 10 mg. Determine the boiling point of each fraction and obtain the refractive index or IR spectrum, if time permits. These latter measurements will require most, if not all, of the sample not used for boiling-point determination.

Assess the purity and efficiency of the separation from your tabulated data and the GC chromatogram.

[2]Refer to your local laboratory instructions.

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EQA

Alternative Mixture Pairs for Preparative Collection

(all mixtures are 1:1 v/v)

Mixture

a. *Separation* of a 40-μL mixture of[3]
(1S)-(−)-α pinene (bp 156 °C, n_D = 1.4650, d = 0.855)
(1S)-(−)-β pinene (bp 165 °C, n_D = 1.4782, d = 0.859)

Components

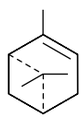

(1*S*)-(−)-α-Pinene

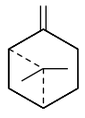

(1*S*)-(−)-β-Pinene

Chromatographic Parameters

A 40-μL injection
Flow rate: 50 mL/min
Column temperature: 120 °C
Column: 20% Carbowax
Elution time
α-Pinene: ~8 min
β-Pinene: ~12 min
Average recovery
α-Pinene: 8.3 μL
β-Pinene: 10.6 μL

Mixture

b. *Separation* of a 40-μL mixture of
2-Heptanone (bp 149–150 °C, n_D = 1.4085, d = 0.820)
Cyclohexanol (bp 160–161 °C, n_D = 1.4641, d = 0.963)

Components

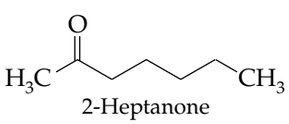

2-Heptanone

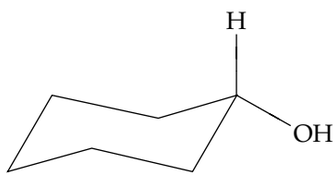

Cyclohexanol

Chromatographic Parameters

A 40-μL injection
Flow rate: 50 mL/min
Column temperature: 145 °C
Column: 20% Carbowax
Elution time
2-Heptanone: ~5.5 min
Cyclohexanol: ~10.0 min

[3]Refractive index at D line of sodium = n_D and density = d.

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EQA

Average recovery
2-Heptanone: 8.1 μL (41%)
Cyclohexanol: 11.4 μL (57%)

Mixture

c. *Separation* of a 40-μL mixture of
d-Limonene (bp 175–176 °C, n_D = 1.4743, d = 0.8402)
Cyclohexanol acetate (bp 173 °C, n_D = 1.4401, d = 0.9698)
Components

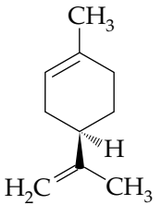

d-Limonene

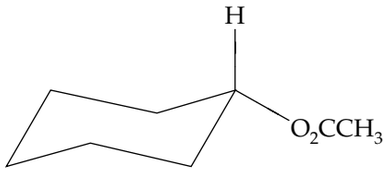

Cyclohexyl acetate

Chromatographic Parameters

A 40-μL injection
Flow rate: 50 mL/min
Column temperature: 170 °C
Column: 20% Carbowax
Elution time
d-Limonene: ~5.5 min
Cyclohexyl acetate: ~7.5 min
Average recovery
d-Limonene: 8.7 μL (44%)
Cyclohexyl acetate: 10.0 μL (50%)

QUESTIONS

6-7. Based on the data presented in the Data Set A chromatographic separation, can you explain why there is such a steep decline in column efficiency with temperature change?

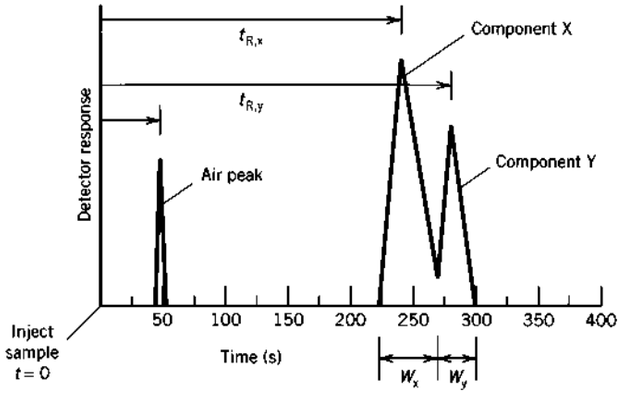

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EQA

6-8. Consider the following gas chromatogram for a mixture of analytes X and Y:
(a) Calculate the number of theoretical plates for the column in reference to the peaks of each component (X and Y).
(b) If the column is 12 m long, calculate the height equivalent theoretical plate (HETP (in plates per cm) for this column.

6-9. The number of theoretical plates a column has is important, but the crucial factor is the ability to separate two or more substances. That is, how well resolved are the peaks? The resolution of two peaks depends not only on how far apart they are (t_R), but also on the peak width (W). Baseline resolution (R) is defined by the following equation:

$$R = \frac{2\Delta t_R}{W_X + W_Y}$$

Because of the tailing of most species on the column, a value of 1.5 is required to give baseline resolution.
(a) Calculate the resolution for the peaks in Question 6–8.
(b) Do you think a quantitative separation of the mixture is possible based on your answer?
(c) Has baseline resolution been achieved?

6-10. Discuss at least two techniques you might use to increase the resolution of the column in Question 6–9 (without changing the column).

6-11. Retention times for several organic compounds separated on a GC column are given below.

Compound	t_R (s)
Air	75
Pentane	190
Heptane	350
2-Pentene	275

(a) Calculate the relative retention of 2-pentene with respect to pentane.
(b) Calculate the relative retention of heptane with respect to pentane.

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Selected references on gas chromatography:

Grob, R. L.; Barry, E. F., Eds.; *Modern Practices of Gas Chromatography;* Wiley: New York, 2004.

Jennings, W.; Mittiefehidt, E.; Stremple, P., Eds.; *Analytical Gas Chromatography;* 2nd ed., Academic Press: New York, 1997.

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Sadek, P. C. *Illustrated Pocket Dictionary of Chromatography;* Wiley: *New York, 2004.*

EXPERIMENT 3

Distillation

In the following set of experiments, we will examine the applications of a variety of distillation techniques to the purification of liquid mixtures. In Experiments [3A] and [3B] you will conduct simple distillations. In Experiment [3A] a volatile liquid component is separated from a nonvolatile solid. Experiment [3B] illustrates the use of the Hickman still in the separation of hexane and toluene, which have boiling points 42 °C apart. The composition of the fractions is analyzed by refractive index and boiling point. Experiments [3C] and [3D] introduce the use of micro spinning-band distillation columns for the separation of cyclohexane (bp 80.7 °C) and 2-methylpentane (bp 60.3 °C). The composition of the distillate fractions are determined by gas chromatography. The number of theoretical plates is determined for the spinning-band column used. In Experiment [3D] you will be introduced to one of the simplest yet most efficient and powerful distillation techniques for the separation of liquid mixtures at the semimicroscale level, the Hickman–Hinkle still.

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EQA

Experiment 3A

Simple Distillation at the Semimicroscale Level: Separation of Ethyl Acetate from *trans*-1,2-Dibenzoylethylene

Purpose. *Simple distillation* is examined using the distillation process to separate a liquid ester from minor components that are nonvolatile or that have boiling points much greater (>100 °C) than that of the major component.

Prior Reading

Techniques 2 and 3: Distillation (pp. 61–67 and online)
Distillation Theory (p. 61 and online)
Simple Distillation at the Semimicroscale Level (pp. 61–64)
Chapter 4: Determination of Physical Properties
Ultramicro-Boiling Point (pp. 46–48)
Density (pp. 49–50)
Refractive Index (online)
Evacuated Melting Point (pp. 51–52)

DISCUSSION

Semimicroscale simple distillation can be an effective separation technique with volumes from 0.5 to 2 mL. Apparatus have been developed that achieve effective separation of mixture samples in this range. One of the most significant of these designs is the classic Hickman still, shown in both Figures 5.5 and 6.2 because of its importance to the associated discussions. In this experiment you will effect the separation of a two-component mixture by the use of this still.

The Hickman still is used in several of the microscale experiments to purify solvents, carry out reactions, and concentrate solutions for recrystallization. An introduction to the use of the Hickman still is given in this experiment.

In a distillation where a liquid is separated from a nonvolatile solute, the vapor pressure of the liquid is lowered by the presence of the solute, but the vapor phase consists only of the pure liquid component. Thus, except for the transfer of nonvolatile material by incidental splashing, the material condensed in the collar of the Hickman still should consist only of the volatile component. In the present experiment this component is ethyl acetate. The temperature of the vial and contents being distilled will rise during the distillation process, since the concentration of the impurity is increasing as the volatile liquid is removed. This effect lowers the vapor pressure of the liquid. However, the boiling point of the liquid remains constant, since only the pure liquid component is being vaporized.

COMPONENTS

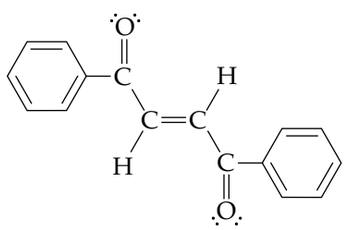

trans-1,2-Dibenzoylethylene

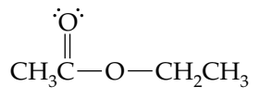

Ethyl acetate

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EQA

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 2.0 h.

Physical Properties of Components						
Compound	MW	Amount	mp (°C)	bp (°C)	d	n_D
Ethyl acetate	88.12	1.0 mL		77	0.90	1.3723
trans-1,2-Dibenzoylethylene	236.27	50 mg	111			

Reagents and Equipment. Transfer 1 mL of the yellow stock solution (*trans*-1,2-dibenzoylethylene/ethyl acetate, 50 mg/mL) to a 3-mL conical vial by automatic delivery pipet (remember to place the vial in a small beaker to prevent tipping during the transfer). Place a boiling stone (or a magnetic spin vane if desirable) into the vial and assemble the Hickman still head. The still assembly is mounted in a sand bath on a hot plate (see Fig. 6.2).

Experimental Conditions. The temperature of the bath is raised to 90–100 °C at a rate of 5 °C/min.

CAUTION: Do not let the temperature of the still rise too rapidly.

Once boiling commences, the rate of heating should be lowered to the point where the temperature increases at 2–3 °C/min. A slow distillation rate is very important in establishing equilibrium between the vapor and liquid components in the mixture. Follow the course of the distillation by the rise of condensate on the sides of the Hickman column. When the condensate reaches the trap, adjust the bath temperature so that liquid is removed from the column slowly (~100 μL/3 min). A smooth, slow distillation will provide a cleaner

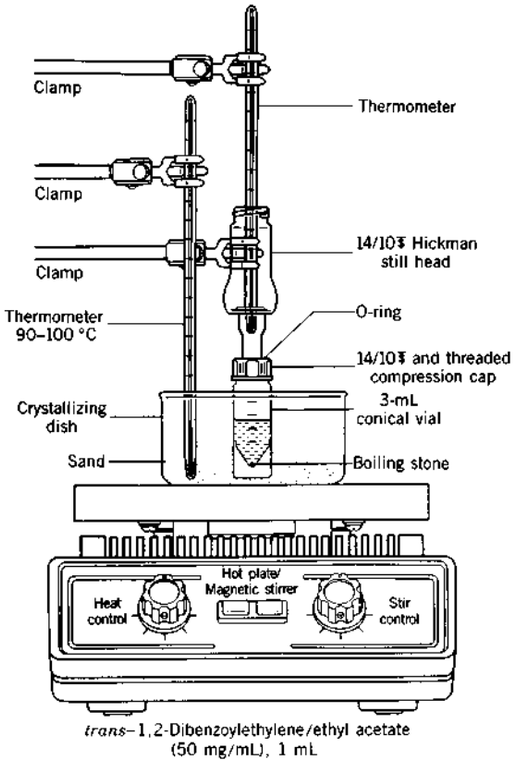

Figure 6.2 Hickman still (14/10 with conical vial [3 mL]).

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EQA

separation of the components, and will also avoid mechanical transfer of nonvolatile components via splattering to the condensate trap (if the condensate appears yellow, contamination has occurred).

Collect approximately 50–150 μL of the ester in the collar of the still (the first fraction collected is often referred to as the forerun; give the temperature range). As the distillation continues, remove the forerun with a Pasteur pipet having a slightly bent tip (bend the tip with a microburner—if you have a Hickman still with a side-arm collection port, the pipet tip will not need to be bent). Place the fraction in a clean, dry, 1-dram, screw-capped vial (use an aluminum foil liner to avoid cap contamination). Label the fraction with a marking pen. Collect a second fraction of ester (400–500 μL, which may require combining two, or even three, collections from the collar; give the temperature range), which should be clear and colorless. Remove and store as before. Discontinue the distillation. Allow the distilling flask to cool slowly by leaving it in the warm sand bath while measuring the physical properties of the distillate fractions.

Characterization. Three physical properties of the ester will be measured to establish the identity and purity of the compound by comparison with known literature values.

www Determine the refractive index of the two fractions collected. Compare the experimental values to those found in the literature for ethyl acetate. If the values are within 0.0010 unit of each other, the fractions can be considered to have the same constitution. Are the values for the two fractions the same? If not, which one deviates the most from the reference data? Attempt to explain the result.

Determine the density (see Chapter 4) of the ester, using material contained in the second fraction. This measurement is nondestructive and the material used may be recovered for use in further tests. Compare your results with those values found in the literature.

Determine the boiling point of the second fraction by the ultramicro-boiling-point procedure (see Chapter 4). Compare your result with the literature value. Does this fraction appear to be pure ethyl acetate?

In the next step, disconnect and cool the 3-mL conical vial in an ice water bath for 10 min. *trans*-1,2-Dibenzoylethylene will crystallize from the concentrated solution. Remove the remaining solvent from the distillation vial with a Pasteur filter pipet and place the crystals on a porous clay plate to air dry. The melting point of the crystalline material is obtained by the evacuated capillary method and compared with the literature value.

Reference values of the physical constants are available online and in the *CRC Handbook of Chemistry and Physics*. Submit a copy of the table prepared in your laboratory notebook to the instructor, after first tabulating the experimentally measured values of the physical properties, in addition to those reported in the literature for ethyl acetate (see *acetic acid, ethyl ester* if necessary).

Experiment 3B

Fractional Semimicroscale Distillation: Separation of Hexane and Toluene

Purpose. This experiment effects the separation of a binary liquid mixture composed of liquids having boiling points that are relatively far apart, greater than 30 °C. It will help you develop the skills to operate a semimicrodistillation apparatus so that purifications required in later experiments can be successfully carried out.

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Prior Reading

Technique 2: Distillation (pp. 61–64)
Distillation Theory (p. 61 and online) www
Simple Distillation at the Semimicroscale Level (pp. 61–64)
Technique 3: Fractional Semimicroscale Distillation (pp. 64–67)
Chapter 4: Determination of Physical Properties
Ultramicro-Boiling Point (pp. 46–48) www
Refractive Index (online)

DISCUSSION

Hexane and toluene are liquid hydrocarbons that have boiling points approximately 40 °C apart. The liquid–vapor composition curve in Figure 5.6 represents this system; it is apparent that a two-plate distillation should yield nearly pure components. The procedure to be outlined consists of two parts. The first deals with the initial distillation (first plate), which separates the liquid mixture into three separate fractions. The second deals with *redistillation* of the first and third fractions (second plate). Exercising careful technique during the first distillation should provide a fraction rich in the lower boiling component, a middle fraction, and a fraction rich in the higher boiling component. Then careful *redistillation* of these fractions can be expected to complete the separation of the two components and to produce fractions of relatively pure hexane and toluene. The Hickman still used in the microscale laboratory is a simple, short-path column, and, therefore, one would not expect complete separation of the hexane and toluene in one cycle.

COMPONENTS

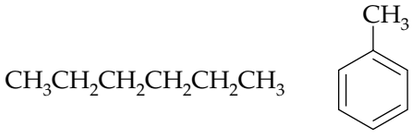

Hexane Toluene

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 2.0 h.

Physical Properties of Components

Compound	MW	Amount	bp (C°)	*d*	n_D
Hexane	86.18	1.0 mL	69	0.66	1.3751
Toluene	92.15	1.0 mL	111	0.87	1.4961

Reagents and Equipment. Use an automatic delivery pipet to place 1.0 mL of hexane and 1.0 mL of toluene in a clean, dry, stoppered 5-mL conical vial.

Place the vial in a small beaker to prevent tipping. Add a boiling stone (or a magnetic spin vane if desirable) assemble the Hickman still with the

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thermometer positioned directly down the center of the column (see previous discussion), and mount the system in a sand bath (see Fig. 6.3).

Experimental Conditions. The temperature of the sand bath is raised to 80–90 °C, at a maximum rate of 5 °C/min (>70 °C at 3 °C/min) using a hot plate.

CAUTION: Do not let the temperature of the still rise too rapidly.

Once gentle boiling begins, the heating rate should be lowered to a maximum of 2 °C/min. It is ***absolutely crucial*** that the distillation rate be kept below 100 μL/3min. to achieve the necessary fraction enrichment that will permit good separation during the second stage of the experiment. The distillate is collected in *three fractions* over the temperature ranges (1) 65–85 °C (bath temperature ~95−110 °C); (2) 85–105 °C (bath temperature ~140 °C) and (3) 105–110 °C (bath temperature ~170 °C) in amounts of approximately 800, 400, and 800 μL, respectively. Remove each fraction from the still with a bent-tip Pasteur pipet. Store the liquid condensate (fractions) in clean, dry, 1-dram, screw-cap vials. *Remember to number the vials in order and use an aluminum foil cap liner.*

Characterization of Crude Fractions. For each of the three fractions, record the refractive index. Fraction 1 has been enriched in one of the two components. Which one? Does the refractive index agree with that found in the literature? Fraction 3 has been enriched in the other component. Does the refractive index of that fraction support your first conclusion? If partial enrichment has been achieved, proceed to the second phase of the distillation.

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Redistillation of Fraction 1 Redistill fraction 1 in a clean Hickman still with a thermometer arranged as before (Fig. 6.3), using a 3-mL conical vial and the procedure just outlined. Collect an initial fraction over the boiling range 68–71 °C (~100−200 μL). Remove it from the collar, using the Pasteur pipet, and place it in a 1-dram screw-cap vial.

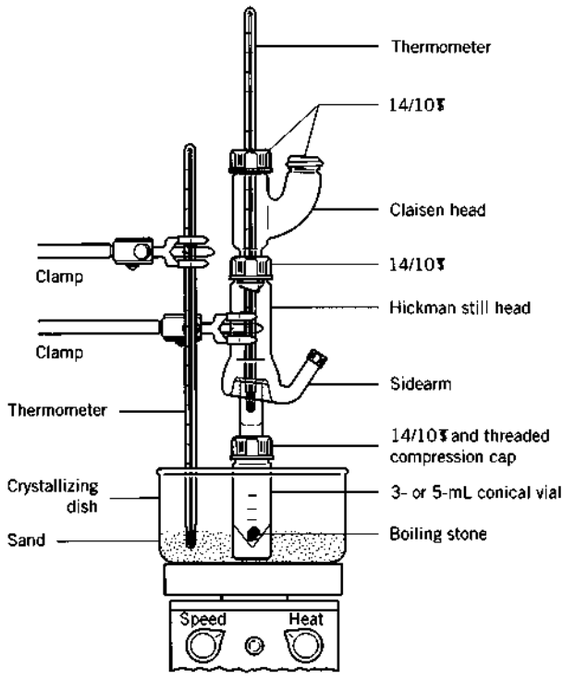

Figure 6.3 Hickman still with Claisen head adapter.

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Characterization of Fraction 1 Determine the ultramicro-boiling point and the refractive index of this lower boiling fraction. Compare the experimental values obtained with those of pure hexane reported in the literature. www

Redistillation of Fraction 3 Fraction 3 is placed in a clean Hickman still, using a thermometer and a 3-mL conical vial (Fig. 6.3), and redistilled using the procedure outlined. Collect an initial fraction over the boiling range 95–108 °C (~500 μL), and transfer this fraction by Pasteur pipet to a screw-cap vial. Collect a final fraction at 108–110 °C (~250 μL), and transfer the material to a second vial. *This second fraction is the highest boiling fraction to be collected in the three distillations and should be the richest in the high-boiling component*.

Characterization of Fraction 3 Determine the refractive index and boiling point of the second fraction and compare your results with those found in the literature for toluene. *Determine the refractive index and boiling point of pure toluene for comparison purposes.* www

Fractional Semimicroscale Distillation: Separation of 2-Methylpentane and Cyclohexane Using a Spinning-Band Column

Experiment 3C

Purpose. The purpose of this experiment is to separate two liquids with boiling points that are relatively similar: less than 20 °C apart, to learn the operation of a high-performance spinning-band distillation column, and to develop the skills for purifying small quantities of liquid mixtures.

Prior Reading

Technique 1: Microscale Separation of Liquid Mixtures by GC (pp. 55–61)
Technique 2: Distillation (pp. 61–64)
Distillation Theory (p. 61 and online) www
Simple Distillation at the Semimicroscale Level (pp. 61–64)
Fractional Semimicroscale Distillation (pp. 64–67)
Chapter 4: Determination of Physical Properties
Ultramicro Boiling Point (pp. 46–48)
Refractive Index (online) www

DISCUSSION

In this experiment, the separation of a 2-mL mixture of 2-methylpentane and cyclohexane using a 2.5-in. spinning-band distillation column is described. The purity of the fractions is determined by gas chromatography and by measurement of the refractive index. Finally, the number of theoretical plates is estimated. You will separate a 50:50 mixture of 2-methylpentane and cyclohexane using the spinning band distillation column shown in Figure 6.4.

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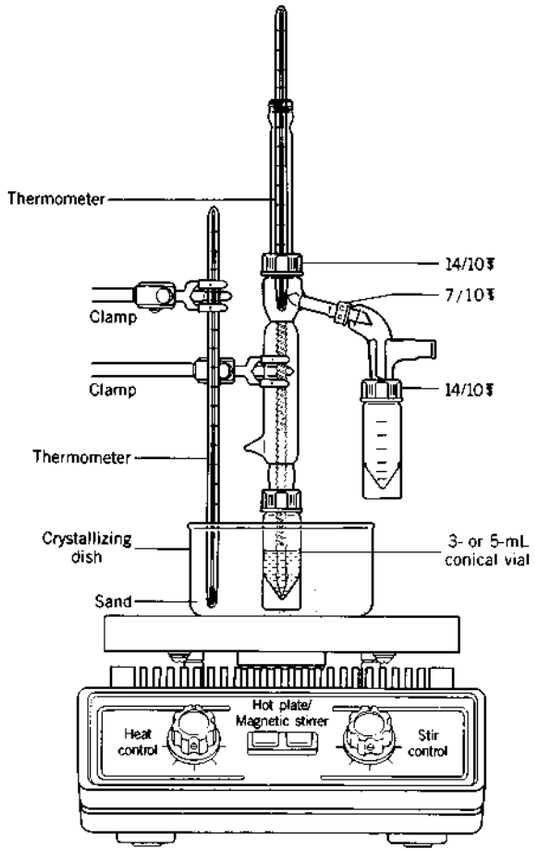

Figure 6.4 Micro spinning-band distillation column (2.5 in.).

COMPONENTS

2-Methylpentane

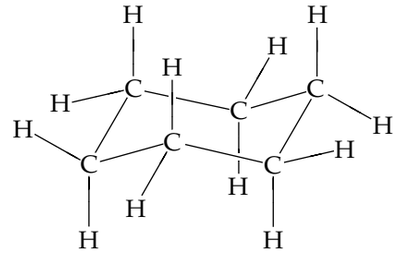

Cyclohexane

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 3.0 h.

Physical Properties of Components				
Compound	MW	Amount	bp (°C)	n_D
2-Methylpentane	86.18	1.0 mL	60.3	1.3715
Cyclohexane	84.16	1.0 mL	80.7	1.4266

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Reagents and Equipment. Assemble the system as shown in Figure 6.4, making sure that the Teflon band is aligned as straight as possible in the column. In particular, the pointed section extending into the vial must be straightened to minimize vibration during spinning of the band.

Place a pipet bulb on the side arm of the collection adapter. This bulb plays an important function in the operation of the column: Attachment of the bulb creates a closed system. Suspension of the thermometer with a septum on the top of the condenser can act to release any buildup of pressure.

CAUTION: The system must be able to vent at the thermometer during operation!

Once the spinning band has been tested and rotates freely, place 1.0 mL of 2-methylpentane and 1.0 mL of cyclohexane in the vial (to be delivered with a Pasteur pipet or an automatic delivery pipet). Reassemble the system and lower the column into the sand bath or copper-tube block. The beveled edge on the air condenser should be rotated 180° from the collection arm.

NOTE. It is important to make an aluminum foil cover for the sand bath; this cover will reflect the heat and hot air away from the collection vial.

Experimental Conditions. Gently heat (copper-tube block, Fig. 3.3W) the vial until boiling occurs. The magnetic stirrer is turned to a low-spin rate when heating commences. When reflux is observed at the base of the column, the magnetic stirrer is adjusted to intermediate spin rate. Once liquid begins to enter the column the spin rate is increased to the maximum (1000–1500 rpm).

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NOTE. It is absolutely critical that the temperature of the vial be adjusted so that vapors in the column rise very slowly. *It is possible for overheated vapors to be forced through the air condenser.*

When the vapors slowly arrive in the unjacketed section of the column head, the condenser joint acts as a vapor shroud to effectively remove vapors from the receiver-cup area. During this total reflux period, maximum separation of the components is achieved. Once vapor reflux occurs in the head of the column, the system is left for 20–30 min to reach thermal equilibrium. During this period of total reflux, the head thermometer should read about 57–60 °C (at least for most of the equilibration time).

Following the equilibration period, collection of the resolved components may begin. Rotate the air condenser 180° so that the beveled edge is over the collection duct. At this point, manipulation of the pipet bulb allows drainage of the condensate from the side arm. (This procedure is repeated occasionally to continue drainage from the side arm.) Collect six drops (~0.30 mL). After removing the collection vial, transfer the contents into a covered vial using a Pasteur pipet. Label all fractions. Collect two 0.6-mL fractions (the pipet bulb may be removed during collection of these latter fractions); then turn off the heat and stirring motor, and remove the vial from the sand bath. Transfer the material remaining in the vial, using a Pasteur pipet, to a fourth covered vial.

Characterization of the Fractions. The composition of each of the fractions may be determined by gas chromatographic analysis and measurement of

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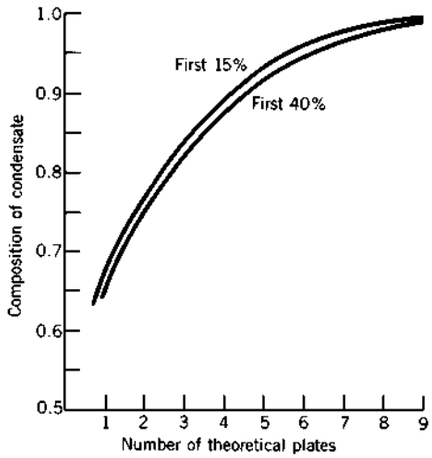

Figure 6.5 Composition of the first 15% and the first 40% of the volume collected in the distillation of a 50% (v/v) mixture of 2-methylpentane and cyclohexane.

the refractive index. A GOW-MAC gas chromatograph should be set up as follows:

Column	DC 710
Injection	10 μL
Temperature	80 °C
Flow rate (He)	55 mL/min
Chart speed	1 cm/min

If we assume that the refractive index is a linear function of the volume fraction, the following relationship gives us the volume fraction of 2-methylpentane in a mixture. The volume fraction is X and the measured refractive index is n_D:

$$X = \frac{1.4266 - n_D}{1.4266 - 1.3715}$$

The curve shown in Figure 6.5 may be used to estimate the number of theoretical plates from the composition (mole fraction) of the *first* 0.30-mL fraction. For example, if the composition of the *first* 0.30 mL is 0.89, we would infer that the system had a resolution equivalent to about four theoretical plates. Note that the number of plates cannot be determined with confidence if the composition is greater than about 0.97. If we really wanted to determine the number of theoretical plates for a system with more than five plates, we could start with a mixture containing only 10 or 20% of the most volatile component (MVC), rather than the 50% used in this example.

Experiment 3D

Fractional Semimicroscale Distillation: The Separation of 2-Methylpentane and Cyclohexane Using a Spinning Band in a Hickman–Hinkle Still

Purpose. In this exercise you will become familiar with a powerful modification of the classic Hickman still: the Hickman-Hinkle spinning band distillation apparatus. This small still is one of the most efficient techniques developed for the purification of small quantities of liquids. You will develop the skills for handling small quantities of liquids and their purification by distillation, and become familiar with these techniques, so that

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they may be used in the purification of reaction products formed in later experiments.

DISCUSSION

This distillation separates the same two compounds used in Experiment [3C]. The distillate can be analyzed to determine the number of theoretical plates. If careful attention is given to the procedure, the spinning Hickman–Hinkle is capable of more than six theoretical plates.

As in Experiment [3C] the separation of a 2-mL mixture of 2-methylpentane and cyclohexane is achieved. The purity of the fractions can be determined by gas chromatography and by measurement of the refractive index. ← www

COMPONENTS

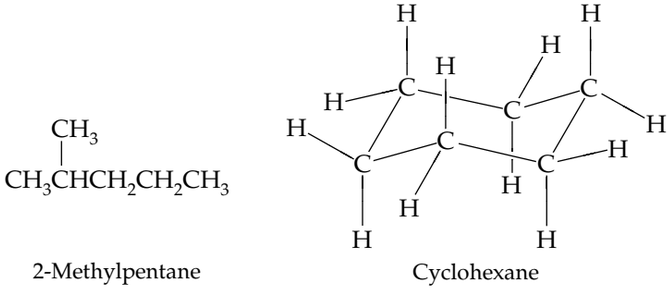

2-Methylpentane Cyclohexane

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 3.0 h.

Physical Properties of Components				
Compound	MW	Amount	bp (°C)	n_D
2-Methylpentane	86.18	1.0 mL	60.3	1.3715
Cyclohexane	84.16	1.0 mL	80.7	1.4266

Reagents and Equipment. The system is assembled as shown in Figure 3.15 on page 25. In the process, make sure that the Teflon band is aligned as straight as possible in the column. In particular, the pointed section extending into the vial must be straightened to minimize vibration during spinning of the band.

Once the spinning band has been tested and rotates freely, place 1.0 mL of 2-methylpentane and 1.0 mL of cyclohexane in the vial (to be delivered with a Pasteur pipet or an automatic delivery pipet). Reassemble the system and lower the column into the sand bath.

Cover the sand bath with aluminum foil during the distillation to prevent the collar of the still from overheating. It is easier to regulate the temperature of the bath when it is covered. However, for distillations, a more efficient heating technique is the recently developed copper-tube block (Fig. 3.3W). ← www

Experimental Conditions. Gently heat the vial until boiling occurs. When heating commences, turn on the magnetic stirrer at a low setting. When reflux commences at the base of the column the magnetic stirrer is raised to

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intermediate settings. Once liquid begins to enter the column, the spin rate is increased to the maximum (1000–1500 rpm).

NOTE. It is extremely important that careful temperature control be exercised at this stage so that the condensing vapors ascend the column very slowly.

Vapor-phase enrichment by the most volatile component is limited mainly to this period, as fraction collection commences immediately on arrival of the vapor column at the annular ring. Once condensation occurs, fractions are collected by the same technique used in Experiment [3B]. Characterization of the fractions, however, follows the procedure given in Experiment [3C].

Characterization of the Fractions. The composition of each of the fractions may be determined by gas chromatography, the refractive index, or both. See Experiment [3C] for details.

An alternative approach to the procedures discussed in Experiment [3C] is to establish the fraction volume by weight. The curves shown in Figure 6.5 may again be used to estimate the number of theoretical plates. The volume of the first fraction can be estimated, or determined more accurately by weighing the fraction in a tared screw-cap vial. The composition of this fraction then may be determined and the fraction of the total represented by this portion calculated. If, for example, the first fraction has a volume of 0.4 mL (20% of the total) and has a composition 0.89 by volume of 2-methylpentane, we would infer that the system had a resolution equivalent to about four theoretical plates.

QUESTIONS

6-12. The boiling point of a liquid is affected by several factors. What effect does each of the following conditions have on the boiling point of a given liquid?
- **(a)** The pressure of the atmosphere
- **(b)** Use of an uncalibrated thermometer
- **(c)** Rate of heating of the liquid in a distillation flask

6-13. Calculate the vapor pressure of a solution containing 30 mol% hexane and 70 mol% octane at 90 °C assuming that Raoult's law is obeyed.

Given: vapor pressure of the pure compounds at 90 °C: hexane = 1390 torr, octane = 253 torr.

6-14. In any distillation for maximum efficiency of the column, the distilling flask should be approximately one-half full of liquid. Comment on this fact in terms of (a) a flask that is too full and (b) a flask that is nearly empty.

6-15. Occasionally during a distillation, a solution will foam rather than boil. A way of avoiding this problem is to add a *surfactant* to the solution.
- **(a)** What is a surfactant?
- **(b)** What is the chemical constitution of a surfactant?
- **(c)** How does a surfactant reduce the foaming problem?

6-16. Explain why packed and spinning-band fractional distillation columns are more efficient at separating two liquids with close boiling points than are unpacked columns.

6-17. Explain what effect each of the following mistakes would have had on the simple distillation carried out in this experiment.
- **(a)** You did not add a boiling stone.
- **(b)** You heated the distillation flask at too rapid a rate.

6-18. In the ultramicro-boiling-point determination, why is the boiling point taken just as bubbles cease emerging from the bell?

6-19. Define each of the following terms, which are related to the distillation process:
- **(a)** Distillate
- **(b)** Normal boiling point
- **(c)** Forerun

6-20. How does the refractive index of a liquid vary with temperature? What corrective factor is often used to determine the value at a specific temperature, for example, 20 °C, if the measurement were made at 25 °C?

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EXPERIMENT 4

Solvent Extraction

Experiment 4A

Determination of a Partition Coefficient for the System Benzoic Acid, Methylene Chloride, and Water

Purpose. This exercise illustrates the general procedures that are used to determine a partition coefficient at the microscale level. Experience in weighing milligram quantities of materials on an electronic balance, the use of automatic delivery pipets for accurately dispensing microliter quantities of liquids, the transfer of microliter volumes of solutions with the Pasteur filter pipet, and the use of a Vortex mixer, are techniques encountered in this experiment.

Prior Reading

Chapter 3: Experimental Apparatus
- Pasteur Filter Pipet (pp. 36–37)
- Automatic Delivery Pipet (pp. 37–38)
- Weighing of Solids in Milligram Quantities (p. 39)

Technique 4: Solvent Extraction
- Liquid–Liquid Extraction (p. 72)
- Partition Coefficient Calculations (pp. 70–72)
- Drying of the Wet Organic Layer (pp. 80–83)
- Separation of Acids and Bases (pp. 77–79)

DISCUSSION

Solubility. Substances vary greatly in their solubility in various solvents, but based on observations, many of which were made in the very early days of chemical experimentation, a useful principle has evolved that allows the chemist to predict rather accurately the solubility of a particular substance. It is generally true that *a substance tends to dissolve in a solvent that is chemically similar to itself. In other words, like dissolves like.*

Thus, for a particular substance to exhibit solubility in water requires that species to possess some of the characteristics of water. For example, an important class of compounds, the organic alcohols, have the hydroxyl group (—OH) bonded to a hydrocarbon chain or framework (R—OH). The hydroxyl group can be viewed as being effectively one-half a water (HOH) molecule, and it has a similar polarity to that of water. This results from a charge separation arising from

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the difference in electronegativity between the hydrogen and oxygen and oxygen atoms. The O—H bond, therefore, is considered to have *partial ionic character:*

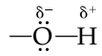

Partial ionic character of the hydroxyl group

This *polar,* or partial ionic, character leads to relatively strong hydrogen bond formation between molecules having this entity. Strong hydrogen bonding is evident in molecules that contain a hydrogen atom attached to an oxygen, nitrogen, or fluorine atom, as shown here for the ethanol–water system. This polar nature of a functional group is present when there are sufficient differences in electronegativity between the atoms making up the group:

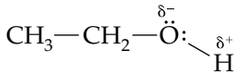

Ethanol

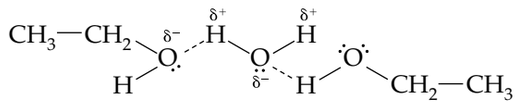

Hydrogen bond formation

In ethanol (CH_3CH_2OH), it is apparent that the hydroxyl end of the molecule is very similar to water (HOH). When ethanol is added to water, therefore, they are miscible in all proportions. That is, ethanol is completely soluble in water and water is completely soluble in ethanol. This solubility results because the attractive forces set up between the two molecules (CH_3CH_2OH and H_2O) are nearly as strong as between two water molecules; however, the attraction in the first case is somewhat weakened by the presence of the nonpolar alkyl ethyl group, CH_3CH_2—. Hydrocarbon groups attract each other only weakly, as evidenced by their low melting and boiling points. Three examples of the contrast in boiling points between compounds of different structure but similar molecular weight are summarized in Table 6.1. Clearly, those molecules that attract each other weakly have lower boiling points.

When we compare the water solubility of ethanol (a two-carbon [C_2] alcohol that, as we have seen, is completely miscible with water) with that of octanol (a straight-chain eight-carbon [C_8] alcohol), we find that the solubility of octanol is less than 2% in water. Why the difference in solubilities between these two alcohols? The answer lies in the fact that the dominant structural feature of octanol has become the non-polar nature of its alkyl group:

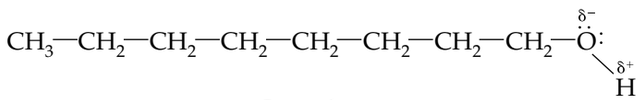

Octanol

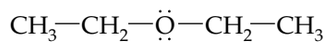

Diethyl ether

As the bulk of the hydrocarbon section of the alcohol molecule increases, the intramolecular attraction between the polar hydroxyl groups of the alcohol and the water molecules is no longer sufficiently strong to overcome the *hydrophobic character* (lack of attraction to water) of the nonpolar hydrocarbon section of the alcohol. On the other hand, octanol has a large nonpolar hydrocarbon group as its dominant structural feature. We might, therefore, expect octanol to exhibit enhanced solubility in less polar solvents. In fact, octanol is found to be completely miscible with diethyl ether. Ethers are solvents of weak polarity. Since the nonpolar characteristics are significant in both molecules, mutual solubility is observed. It has been empirically demonstrated that, in general, if a compound has both polar and nonpolar groups present in its structure, those compounds having five or more carbon atoms in the hydrocarbon portion of the molecule will be more

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Table 6.1 **Comparison of Boiling Point Data**

Name	Formula	MW	bp (°C)
Ethanol	CH_3CH_2OH	46	78.3
Propane	$CH_3CH_2CH_3$	44	−42.2
Methyl acetate	$CH_3CO_2CH_3$	74	54
Diethyl ether	$(CH_3CH_2)_2O$	74	34.6
Ethylene	$CH_2{=}CH_2$	28	−102
Methylamine	CH_3NH_2	31	−6

Table 6.2 **Water Solubility of Alcohols**

Name	Formula	Solubility (g/100 g H_2O)
Pentanol	$CH_3(CH_2)_3CH_2OH$	4.0
2-Pentanol	$CH_3(CH_2)_2CH(OH)CH_3$	4.9
2-Methyl-2-butanol	$(CH_3)_2C(OH)CH_2CH_3$	12.5

Note. Data at 20 °C.

soluble in nonpolar solvents, such as pentane, diethyl ether, or methylene chloride. Figure 5.13, on page 69, summarizes the solubilities of a number of straight-chain alcohols, carboxylic acids, and hydrocarbons in water. As expected, those compounds with more than 5 carbon atoms are shown to possess solubilities similar to those of the hydrocarbons.

Several additional relationships between solubility and structure have been observed and are pertinent to the discussion.

1. Branched-chain compounds have greater water solubility than their straight-chain counterparts, as illustrated in Table 6.2 with a series of alcohols.

2. The presence of more than one polar group in a compound will increase that compound's solubility in water and decrease its solubility in nonpolar solvents. For example, high molecular weight sugars, such as cellobiose, which contain multiple hydroxyl and/or acetal groups, are water soluble and ether insoluble; cholesterol (C_{27}), which possesses only a single hydroxyl group, is water insoluble and ether soluble:

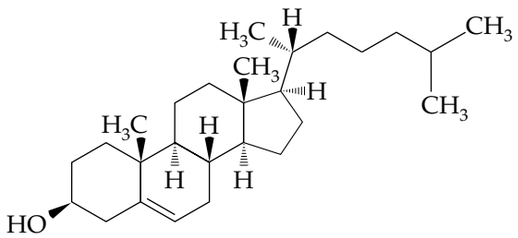

Cholesterol

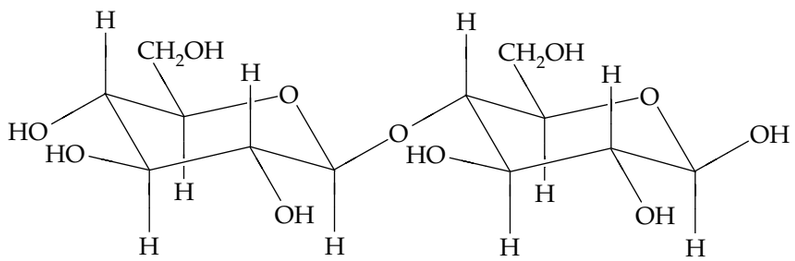

Cellobiose

3. The presence of a chlorine atom, even though it lends some partial ionic character to the covalent C—Cl bond, does not normally impart water solubility to a compound. In fact, such compounds as methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), and carbon tetrachloride (CCl_4) have long been used as solvents for the extraction of aqueous solutions. It should be noted that use of the latter two solvents is no longer recommended, unless strict safety precautions are exercised, because of their potential carcinogenic nature.

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Table 6.3 Water Solubility of Amines		
Name	Formula	Solubility (g/100 g H_2O)
Ethylamine	$CH_3CH_2NH_2$	∞
Diethylamine	$(CH_3CH_2)_2NH$	∞
Trimethylamine	$(CH_3)_3N$	91
Triethylamine	$(CH_3CH_2)_3N$	14
Aniline	$C_6H_5NH_2$	3.7
p-Phenylenediamine	$H_2NC_6H_4NH_2$	3.8
Note. Data at 25 °C.		

4. Most functional groups that are capable of forming a hydrogen bond with water, if it constitutes the dominant structural feature of a molecule, will impart increased water solubility characteristics to a substance (the five-carbon rule obviously applies here in determining just what is a dominant feature). For example, certain alkyl amines (organic relatives of ammonia) might be expected to have significant water solubility. This finding is indeed the case, and the water-solubility data for a series of amines is summarized in Table 6.3.

The solubility characteristics of any given compound will uniquely govern that substance's distribution (*partition*) between the phases of two immiscible solvents (in which the material has been dissolved) when these phases are intimately mixed. In this experiment we determine the partition coefficient (distribution coefficient) of benzoic acid between two immiscible solvents, methylene chloride and water.

COMPONENTS

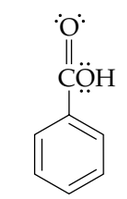

Benzoic acid

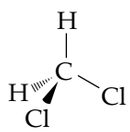

Methylene chloride

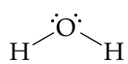

Water

EXPERIMENTAL PROCEDURE

Estimated time of experiment: 1.5 h.

Physical Properties of Components						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Benzoic acid	122.13	50 mg	0.41	122		
Methylene chloride		1.20 mL			40	1.33
Water		600 μL			100	1.00

Equipment Setup and Addition of Reagents. Weigh and add to a 5.0-mL conical vial fitted with a screw cap, 50 mg (0.41 mmol) of benzoic acid. Now add 600 μL of methylene chloride followed by 600 μL of water.

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The solvents are transferred to the vial with automatic delivery pipets (use a different pipet or pipet tip for each solvent). *The methylene chloride addition should be carried out in the* ***hood.*** HOOD

Procedure for Establishing Equilibrium Distribution. Cap the vial and shake (or use a Vortex mixer) until the benzoic acid dissolves and the two phases have been thoroughly mixed. Vent the vial (by releasing the Cap-seal) and then allow the two layers to separate.

Carefully draw the lower methylene chloride layer into a Pasteur filter pipet and transfer it to a 5-mL conical vial containing 100 mg of anhydrous, magnesium sulfate. If the amount of the methylene chloride layer is insufficient to properly transfer into the 5-mL conical vial, carefully add more so that a proper transfer can occur. Once complete, recap the vial.

NOTE. If the volume of the methylene chloride layer is so large that it cannot be transferred completely in one operation, a second transfer may be required. Be careful not to over-fill the pipet to insure that solvent does not come in contact with the rubber bulb. The technique of removing the last traces of water from the methylene chloride solution is often referred to as drying the solution. *It can involve any one of a number of insoluble anhydrous salts, which convert the moisture retained in the organic phase to water of crystallization. In this case, we are using sodium sulfate.*

Isolation of the Benzoic Acid. After drying the methylene chloride solution for 10–15 min, transfer the anhydrous solution to a previously **tared** vial (the term **tare** means to preweigh the empty vial) using a Pasteur filter pipet (the use of the filter pipet is a convenient way of separating the solid hydrated sodium sulfate from the dried solution). Rinse the sodium sulfate with an additional 600 μL of methylene chloride and combine the rinse with the solution in the tared 5.0-mL conical vial. Evaporate the solvent under a gentle stream of nitrogen gas in a warm sand bath in the **hood.** (It is important to warm the solution while evaporating the solvent; otherwise the heat of vaporization will rapidly cool the solution. In this latter case, as the cold, solid acid precipitates from the saturated solution, moisture will condense from the air entrained in the evaporation process, and contaminate the surface of the recovered material.) HOOD

NOTE. If a hot sand bath is used, a boiling stone is placed in the vial before it is tared. The boiling stone will help to avoid explosive, sudden boiling of the solvent when the vial is placed in the sand bath.

Weight Data and Calculations. Weigh the vial and determine the weight of benzoic acid that remains following removal of the methylene chloride. Break up the hard cake of precipitated benzoic acid with a microspatula and *briefly* reheat the vial and contents in a sand bath to remove the last traces of solvent and any water that remains in the system. Cool and reweigh. Repeat this operation until a constant weight is obtained. This weight represents the benzoic acid that dissolved in the *methylene chloride layer*.

The *original weight* of benzoic acid used minus the amount of benzoic acid recovered in the methylene chloride layer equals the weight of the benzoic acid that dissolved and still remains in the *water layer*.

Since equal volumes of both solvents were used, the partition coefficient may be simply determined from the ratio of the weight of benzoic acid in the methylene chloride solvent to the weight of benzoic acid in the water layer.

Calculate the partition coefficient for benzoic acid in the solvent pair used in this exercise.

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Experiment 4B

Solvent Extraction I: The System; Benzoic Acid, Methylene Chloride, and 10% Sodium Bicarbonate Solution; An Example of Acid–Base Extraction Techniques

Purpose. This exercise illustrates an extensively used extraction technique in which a reversible reaction is employed to alter the solubility characteristics of the substance of interest.

Prior Reading

Chapter 3: Experimental Apparatus
- Pasteur Filter Pipet (pp. 36–37)
- Automatic Delivery Pipet (pp. 37–38)
- Weighing of Solids in Milligram Quantities (p. 39)

Technique 4: Solvent Extraction
- Liquid–Liquid Extraction (p. 72)
- Partition Coefficient Calculations (pp. 70–72)
- Drying of the Wet Organic Layer (pp. 80–83)
- Separation of Acids and Bases (pp. 77–79)

REACTION

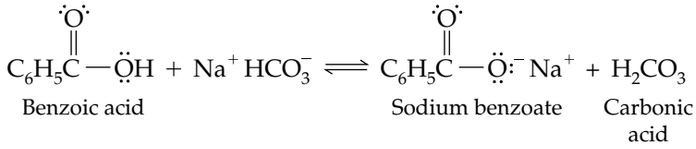

$$H_2CO_3 \rightleftharpoons CO_2 + H_2O$$

DISCUSSION

Benzoic acid reacts readily with sodium bicarbonate to form sodium benzoate, carbon dioxide, and water. The sodium salt of benzoic acid has highly ionic characteristics and thus, unlike the free acid, the salt is very soluble in water and nearly insoluble in methylene chloride. This salt is characterized by a full ionic bond between the carboxylic acid group of the acid and the sodium ion. It is, therefore, a new substance exhibiting many of the solubility properties commonly associated with inorganic ionic salts.

EXPERIMENTAL PROCEDURE

Estimated time of experiment: 1.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Benzoic acid	122.13	50 mg	0.41	122		
Methylene chloride		1.20 mL			40	1.33
Sodium bicarbonate (10% solution)		600 μL				

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Procedure for Establishing Distribution. Repeat the identical procedures carried out in Experiment [4A], but replace the 600 μL of water with 600 μL of 10% sodium bicarbonate solution. A good estimate of the efficiency of the conversion of benzoic acid to the sodium salt of the acid, which because of its ionic character is found almost exclusively in the aqueous phase, can be made by recovering any unreacted acid from the methylene chloride layer and using the distribution coefficient established in Experiment [4A]. Also, be sure to obtain a melting point of any recovered residue (assumed above to be benzoic acid) from the organic phase, since contamination of free acid by the acid salt can be detected by this measurement. Sodium benzoate has a melting point above 300 °C, whereas benzoic acid melts near 122 °C.

Test for a Carboxylic Acid. As illustrated in the above reaction, when a carboxylic acid comes in contact with a solution containing bicarbonate ion, carbon dioxide is generated. Once saturation of the solution by carbon dioxide occurs, bubbles of carbon dioxide gas are observed to form in the liquid phase. This effervescence may be used as a qualitative test for the presence of the carboxylic acid functional group in an unknown substance.

Place 1–2 mL of 10% sodium or potassium bicarbonate on a small watch glass. Add the pure acid, one drop from a Pasteur pipet if the sample is a liquid (~5 mg if it is a solid), to the bicarbonate solution. Evolution of bubbles (CO_2) from the mixture indicate the presence of an acid.

Perform the above test for the presence of carboxyl groups on several organic acids, such as acetic, benzoic, propanoic, or chloroacetic acid.

Solvent Extraction II: A Three-Component Mixture; An Example of the Separation of an Acid, a Base, and a Neutral Substance

Experiment 4C

Purpose. This exercise investigates how solvent extraction techniques can be applied effectively to problems that require the separation of mixtures of organic acids, bases, and neutral compounds in the research or industrial laboratory.

Prior Reading

Chapter 3: Experimental Apparatus
- Pasteur Filter Pipet (pp. 36–37)
- Automatic Delivery Pipet (pp. 37–38)
- Weighing of Solids in Milligram Quantities (p. 39)

Technique 4: Solvent Extraction
- Liquid–Liquid Extraction (p. 72)
- Drying of the Wet Organic Layer (pp. 80–83)
- Separation of Acids and Bases (pp. 77–79)
- Salting Out (p. 79)

DISCUSSION

As implied in the discussions of Experiments [4A] and [4B], the solubility characteristics of organic acids in water can be shown to be highly dependent on the pH of the solution. By extending this extraction approach to include

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organic bases, it has been possible to develop a general procedure for the separation of mixtures of organic acids, bases, and neutral substances.

NOTE. Refer to Technique 4, p. 78–79 for a flowchart outlining the procedure.

The components of the mixture to be separated in this experiment are benzoic acid, ethyl 4-aminobenzoate (a base), and 9-fluorenone (a neutral compound, which may be prepared in Experiment [33A]).

COMPONENTS

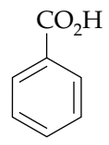

Benzoic acid

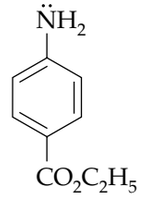

Ethyl 4-aminobenzoate

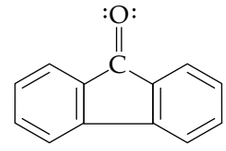

9-Fluorenone

EXPERIMENTAL PROCEDURE

Estimated time of experiment: 2.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Benzoic acid	122.1	50 mg	0.41	122		
Ethyl 4-amino-benzoate	165.19	50 mg	0.31	89		
9-Fluorenone	180.22	50 mg	0.27	84		
Diethyl ether	74.12	4 mL			35	0.7184
3 M HCl		4 mL				
3 M NaOH		4 mL				
6 M HCl						
6 M NaOH						

NOTE. In carrying out the separation, you should keep a record or flowchart of your procedure (as suggested in the prior reading assignment) in your laboratory notebook. You should also be particularly careful to label all flasks.

Reagents and Equipment. Weigh and add to a stoppered or capped 15-mL centrifuge tube the following: 50 mg (0.41 mmol) of benzoic acid, 50 mg (0.31 mmol) of ethyl 4-aminobenzoate, and 50 mg (0.27 mmol) of
HOOD 9-fluorenone. Now, in the **hood,** add 4 mL of diethyl ether using a 10-mL graduated cylinder for the transfer.The solids may be dissolved by either stirring with a glass rod or mixing on a Vortex mixer (capped vial).

Separation of the Basic Component. Cool the solution in an ice bath. Now, using a calibrated Pasteur pipet, add 2 mL of 3 M HCl dropwise to the cooled solution with swirling. Cap and thoroughly mix the resulting two-phase system for several minutes (a Vortex mixer works well). Vent carefully and after

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the layers have separated remove the bottom (aqueous) layer using a Pasteur filter pipet and transfer this phase to a **labeled,** 10-mL Erlenmeyer flask.

Repeat this step with an additional 2 mL of the 3 M acid solution. As before, transfer the aqueous layer to the same labeled Erlenmeyer flask. Stopper or cap this flask. *Save the ether solution.* The aqueous acidic solution is to be used in the next step.

NOTE. A small amount of crystalline material may form at the interface between the layers. A second extraction generally dissolves this material.

Isolation of Ethyl 4-Aminobenzoate: The Basic Component. To the aqueous acidic solution, separated and set aside in the previous step, add 6 M NaOH dropwise until the solution is distinctly alkaline to litmus paper. Cool the flask in an ice bath for about 10–15 min. Collect the solid precipitate that forms in the basic solution by reduced-pressure filtration using a Hirsch funnel. Wash the precipitate with two 1-mL portions of distilled water. Air-dry the washed microcrystals by spreading them on a clay plate, filter paper, or in a vacuum drying oven. Weigh the material and calculate the percent recovery. Obtain the melting point of the dry ethyl 4-aminobenzoate and compare your result to the literature value. This material is used as a topical anesthetic.

Separation of the Acidic Component. Add 2 mL of 3 M NaOH to the ether solution that was set aside earlier in the experiment. At this point, if necessary, add additional ether (~1–2 mL) so that the volume of the organic layer is at least equal to, or somewhat larger than, that of the aqueous phase. This adjustment in volume should allow an efficient distribution to take place when the two phases are mixed. Then carry out the extraction as before, allow the layers to separate, and finally transfer the bottom aqueous basic layer to a **labeled,** 10-mL Erlenmeyer flask.

Repeat this routine and again remove the aqueous layer and transfer it to the same Erlenmeyer flask. Stopper this flask (containing the extracted aqueous basic phase) and set it aside for later use.

Separation of the Neutral Component. Wash (extract) the remaining ether solution contained in the centrifuge tube with two 1-mL portions of water. Separate the lower aqueous layer in each sequence. *Save the aqueous wash layer temporarily; it will be discarded at the very end of the experiment. (It is good practice to never discard any layer until you have recovered or accounted for all of the material.)* Now add about 300 mg of anhydrous granular sodium sulfate to the wet ether (ether saturated with water) solution. Cap the tube and set it aside while working up the alkaline extraction solution. This procedure will allow sufficient time for the traces of moisture to be removed from the ether solution by hydration of the insoluble drying agent. If the sodium sulfate initially forms large clumps, you may add a further quantity of the anhydrous salt.

Isolation of Benzoic Acid: The Acidic Component. Add 6 M HCl dropwise to the aqueous alkaline solution, which was separated and set aside earlier, until the solution becomes distinctly acidic to litmus paper. Then cool the flask in an ice bath for about 10 min. If only a small amount (10–25 mg) of precipitate is obtained on acidification, add a small amount of a saturated aqueous solution of sodium chloride (salting out effect; see Prior Reading assignment) to help promote further precipitation of the benzoic acid. Collect the precipitated benzoic acid by filtration under reduced pressure using a Hirsch funnel. Wash (rinse) the filter cake (precipitated acid) with two 1-mL

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portions of cold distilled water. Dry the solid product using one of the techniques described earlier for ethyl 4-aminobenzoate. Weigh the dry benzoic acid and calculate your percent recovery.

Obtain a melting point of this material and compare your result to the literature value.

Isolation of 9-Fluorenone: The Neutral Component. Use a Pasteur filter pipet to transfer the dried ether solution collected earlier to a tared 10-mL Erlenmeyer flask containing a boiling stone. Rinse the drying agent with an additional 1 mL of ether and combine the ether wash with the anhydrous organic phase.

Concentrate the ether solution on a warm sand bath using a *slow* stream
HOOD of nitrogen gas in the **hood.** Obtain the weight of the residue (9-fluorenone) after removal of the solvent and calculate the percent recovery. Obtain a melting point of the material and compare your result to the literature value.

QUESTIONS

6-21. **(a)** Explain why diethyl ether would be expected to be a satisfactory solvent for the straight-chain hydrocarbons hexane and heptane. **(b)** Explain why *t*-butyl methyl ether would not be expected to be an ideal solvent for the polyhydroxylated carbocycles glucose and fructose.

6-22. The solubility of *p*-dibromobenzene in benzene is 80 μg/100 μL at 25 °C. Would you predict the solubility of this compound to be greater, less, or approximately the same in acetone solvent at this temperature? Explain.

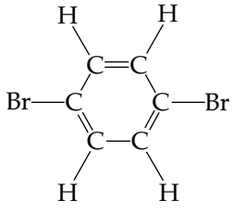

p-Dibromobenzene

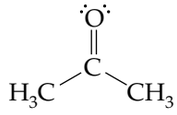

Acetone

6-23. **(a)** Each of the solvents listed below are used in experiments in this text to extract organic compounds from aqueous solutions.

(i) Methylene chloride
(ii) Pentane
(iii) Toluene
(iv) Diethyl ether

Will the organic phase be the upper or lower layer when each of these solvents is mixed with water? Explain your answer for each case. **(b)** If you placed an ice cube in each of the solvents i–iv listed above in (a), would you expect an ice cube placed in each to float or sink? Explain your answer for each case.

6-24. A 36-mg sample of an organic compound (MW = 84) is dissolved in 10 mL of water. This aqueous solution is extracted with 5.0 mL of hexane. Separation and analysis of the aqueous phase shows that it now contains 12 mg of the organic compound. Calculate the partition coefficient for the compound.

6-25. A qualitative method often used to determine whether an organic compound contains oxygen is to test its solubility in concentrated sulfuric acid. Almost all oxygen-containing compounds are soluble in this acid. Explain.

6-26. In the discussion of multiple extractions (p. 71), it was suggested that in the example given you might extend the relationship to the next step by using one-third of the total quantity of the ether solvent in three portions. The reason for increasing the number of extractions was to determine whether this expansion would increase the efficiency of the process even further. To determine if this next step is worth the effort, perform the calculations for the extraction of 100 mg of P in 300 μL of water with three 100-μL portions of ether. Assume the partition coefficient is 3.5 (as before).

(a) Compare the amounts of P extracted from the water layer using one, two, or three extractions.
(b) Do you think that the additional amount of P extracted from the water layer using three extractions is justified? Might it be justified if P were valuable and you were working on the industrial scale of 100 kg of P in 3000 L of water?

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EXPERIMENT 5

Reduction of Ketones Using a Metal Hydride Reagent: Cyclohexanol *and* cis- *and* trans-4-tert-*Butylcyclohexanol*

Common name: cyclohexanol
CA number: [108-95-0]
CA name as indexed: cyclohexanol

Common name: 4-*tert*-butylcyclohexanol
CA number: [98-52-2]
CA name as indexed: cyclohexanol, 4-(1,1-dimethylethyl)-

Purpose. The reduction of a ketone carbonyl to the corresponding alcohol is carried out using sodium borohydride, a commercially available metal-hydride reducing agent. The alcoholic reaction products are isolated by extraction techniques and purified by preparative gas chromatography. Cis and trans diastereomers are formed in the reduction of the 4-*tert*-butylcyclohexanone. These diastereomeric products can be separated during the preparative GC isolation. The stereochemistry of the structures can be deduced, once the mixture is separated into its pure components, using either NMR or IR spectroscopy.

Prior Reading

Technique 1: Gas Chromatography (pp. 55–61)
Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of a Wet Organic Layer (pp. 80–83)
Concentration of Solutions (pp. 101–104)
Technique 6: Thin-Layer Chromatography (pp. 97–99)
Chapter 8: Infrared Spectroscopy (pp. 539–554)
Nuclear Magnetic Resonance Spectroscopy (pp. 561–587)

REACTION (EXPERIMENT [5A])

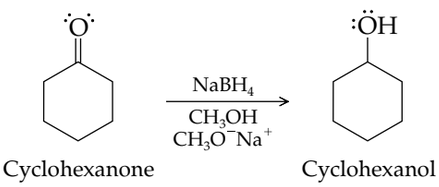

Cyclohexanone Cyclohexanol

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DISCUSSION

An important route for the synthesis of primary and secondary alcohols is the reduction of aldehydes and ketones, respectively. Reduction involves the addition of the equivalent of molecular hydrogen H—H to the carbonyl group (C═O).

A variety of pathways have been discovered to accomplish this conversion, but the most common method used in the research laboratory involves complex metal-hydride reagents. Two reagents that enjoy wide application are lithium aluminum hydride ($LiAlH_4$) and sodium borohydride ($NaBH_4$).

Lithium aluminum hydride is a powerful reducing agent that reacts not only with aldehydes and ketones, but with many other carbonyl containing functional groups as well. Because the first of the four deliverable hydrides available is the most reactive hydride, it will attack esters, lactones, carboxylic acids, anhydrides, and amides. It also reduces noncarbonyl systems, such as, alkyl halides, alkyl azides, alkyl isocyanates, and nitriles. Note that $LiAlH_4$ can be used safely only in aprotic solvents (a solvent that does not contain an ionizable [acidic] proton), such as diethyl ether or tetrahydrofuran (THF). In protic solvents, lithium aluminum hydride reacts *violently* with the acidic hydrogen of the solvent to rapidly generate hydrogen gas:

$$LiAlH_4 + 4\ CH_3OH \rightarrow LiAl(OCH_3)_4 + H_2$$

CAUTION: The hydrogen gas often ignites. This particular hydride reagent should not be used unless specific instructions are made available for its proper use under anhydrous conditions.

Sodium borohydride is a much more selective reducing reagent partly due to the fact that the fourth hydride, not first as is the case with lithium aluminum hydride, is the most reactive, and when used in excess, it is a much milder reagent than $LiAlH_4$. For this reason sodium borohydride is usually used for the reduction of aldehydes and ketones. It does not react with the vast majority of the less reactive organic functional groups, such as C═C, C≡C, nitro, cyano, and even some carbonyl-containing systems, such as, amides and carboxylic acids. Sodium borohydride does react at an appreciable rate with water, but only slowly with aqueous alkaline solution (no available protons), methanol, α, β-unsaturated ketones, and esters. For small-scale reactions an excess of reagent is generally used to compensate for the amount of borohydride that reacts with the protic solvent (methanol). This approach is preferred to that of using a solvent in which the sodium borohydride is less soluble (it is insoluble in ether), because the reaction is driven more rapidly to completion under the former conditions. On the other hand, sodium borohydride can react rapidly with strong acids to generate hydrogen gas. This reaction may be used to advantage as a source of in situ hydrogen for the reduction of C═C bonds (see Experiment [12]). The relatively high cost of the metal hydride reducing agents is offset by their low molecular weight (more moles per gram) and the fact that 1 mol of reducing agent reduces 4 mol of aldehyde or ketone.

The key step in the reduction of a carbonyl group by sodium borohydride is the transfer of a hydride ion ($:H^-$) from boron to the carbon atom of the polarized carbonyl group:

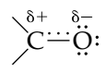

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Table 6.4 Reduction of 4-*tert*-Butylcyclohexanone		
Reagent	Trans (%)	Cis (%)
Sodium borohydride	80	20
Lithium aluminum hydride	92	8
Lithium tri-*sec*-butylborohydride	7	93

In the reaction, the electron-rich hydride ion is acting as a *nucleophile* (nucleus-seeking), which attacks the *electrophilic* (electron-seeking) carbon atom of the carbonyl group:

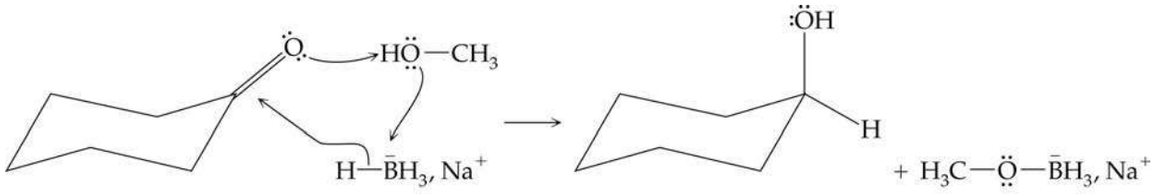

The hydride may make an equatorial (e) or axial (a) attack, depending on steric factors.

The overall reduction process requires two hydrogen atoms, but only one comes directly from the borohydride reagent. The other hydrogen atom is derived from the protic solvent (methanol).

In the 4-*tert*-butylcyclohexanone example, the steric environment is different on either face of the carbonyl group. In this case, the hydride reducing agent attacks more rapidly from the axial direction, and thus the equatorial alcohol (axial H) is the major product. This reaction pathway is preferred with the relatively small sodium borohydride and lithium aluminum hydride reagents. When one stereoisomeric product is preferentially formed, the reaction is called a *stereoselective* reaction.

Sterically large hydride reducing reagents, such as lithium tri-*sec*-butylborohydride, are forced to make an equatorial attack, due to steric factors (these hydride reagents run into the 1,3-diaxial hydrogen atoms), and thus, the cis isomer of 4-*tert*-butylcyclohexanol is the major product. The data are summarized in Table 6.4, which relates the stereochemistry of the reduction to the metal hydride reagent used.

Cyclohexanol

Experiment 5A

The reaction is shown above.

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 1.5 h.
For the GC analysis, 15 min per student.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Cyclohexanone	98.15	100 μL	0.97	156	0.95	1.4507
Methanol	32.04	250 μL	10.3	65	0.79	1.3288
Sodium borohydride reducing solution		300 μL				

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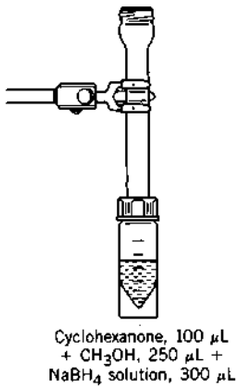

Reagents and Equipment. With the aid of an automatic delivery pipet, place 100 μL (95 mg, 0.97 mmol) of cyclohexanone in an oven-dried and tared (preweighed) 5.0-mL conical vial equipped with an air condenser. Now add 250 μL of methanol and gently stir the contents in the vial using a glass stirring rod (or a magnetic spin vane if desirable) to obtain a homogeneous solution (⬅). In the **hood,** add 300 μL of sodium borohydride reducing solution dropwise, with stirring, to the solution of the ketone.

HOOD

NOTE. The cyclohexanone, methanol, and sodium borohydride solutions are dispensed using automatic delivery pipets. Weigh the cyclohexanone after delivery to get an accurate weight for the yield calculations.

The stock reducing solution should be prepared just prior to conducting the experiment.

INSTRUCTOR PREPARATION. In a 10-mL Erlenmeyer flask place 50 mg of anhydrous sodium methoxide and 2.5 mL of methanol. To this solution add 100 mg of sodium borohydride. Stopper the flask tightly and swirl the contents gently to dissolve the solid phase (100 μL of this solution provides ~2.0 mg of $NaOCH_3$ and 4.0 mg of $NaBH_4$).

NOTE. Test for activity of the reducing solution: Add 1–2 drops of the freshly prepared reducing solution to about 200 μL of concentrated hydrochloric acid. Generation of hydrogen gas bubbles is a positive test.

?

Reaction Conditions. After allowing the resulting solution to stand 10 min at room temperature, begin monitoring the resulting solution by TLC. Use as a solvent system ethyl acetate:hexane (1:4), the R_f of cyclohexanol is 0.4 (R_f of cyclohexanone is 0.6) when stained with a solution of *p*-anisaldehyde (135 mL ethanol, 5 mL H_2SO_4, 1.5 mL glacial acetic acid, and 3.7 mL *p*-anisaldehyde).

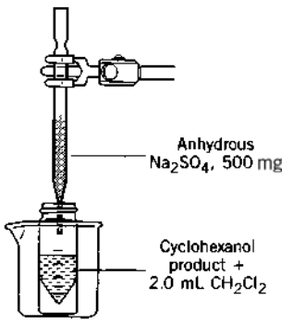

Isolation of Product. When the reaction is complete as judged by TLC, use a calibrated Pasteur pipet to add dropwise 1.0 mL of cold dilute hydrochloric acid (0.1 M HCl). Extract the aqueous mixture with three 0.5-mL portions of methylene chloride. Upon each addition of methylene chloride, cap the vial, shake it gently, and then carefully vent it by loosening the cap (a Vortex mixer may be used if available). After the layers have separated, remove the bottom methylene chloride layer using a Pasteur filter pipet and transfer it to a Pasteur filter pipet containing about 500 mg of anhydrous sodium sulfate.

Collect the dried eluate in a tared 5.0-mL conical vial containing a boiling stone. Use an additional 0.5 mL of methylene chloride to rinse the sodium sulfate and collect the rinse in the same conical vial (⬅).

HOOD

An additional rinse of the sodium sulfate may be made if desired. Remove the methylene chloride solvent by careful evaporation in the **hood** by gentle warming in a sand bath (constantly agitate the surface of the solution with a microspatula to prevent superheating and subsequent boilover). *In this instance, do not use a stream of nitrogen gas to hasten the evaporation. The volatility of the product alcohol is such that a substantial loss of product will occur if this technique is used.*

Purification and Characterization. The crude cyclohexanol reaction product remaining after evaporation of the methylene chloride solvent is usually of sufficient purity for direct characterization.

Determine the weight of the liquid residue and calculate the percent crude yield. Determine the refractive index (3 μL, optional) and boiling

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point (4 μL) of the material. Compare your values with data given in the literature.

Obtain the infrared spectrum of the crude (dry) cyclohexanol product by the capillary film sampling technique. Compare the spectrum of the starting ketone in Figure 6.6 to that of your isolated material. Is there evidence of the unreacted starting material in your product? The spectrum of cyclohexanol crude product is shown in Figure 6.7.

NOTE. Most of the infrared spectra referred to in the experimental analysis sections are derived by Fourier transform and plotted on a slightly different scale than the other spectra presented in the text. These spectra utilize a 12.5-cm^{-1}/division format below 2000 cm^{-1} and undergo a 2:1 compression above 2000 cm^{-1} (25 cm^{-1}/division).

Infrared Analysis: A Comparison Reactant and Product. The key absorption bands to examine in the spectrum of cyclohexanone occur at 3420, 3000–2850, 1715, and 1425 cm^{-1}. The lack of significant absorption between 3100–3000 and 1400–1350 cm^{-1} also should be noted. The sharp weak band at 3420 cm^{-1} is not a fundamental vibration (not O—H or N—H stretching), but arises from the first

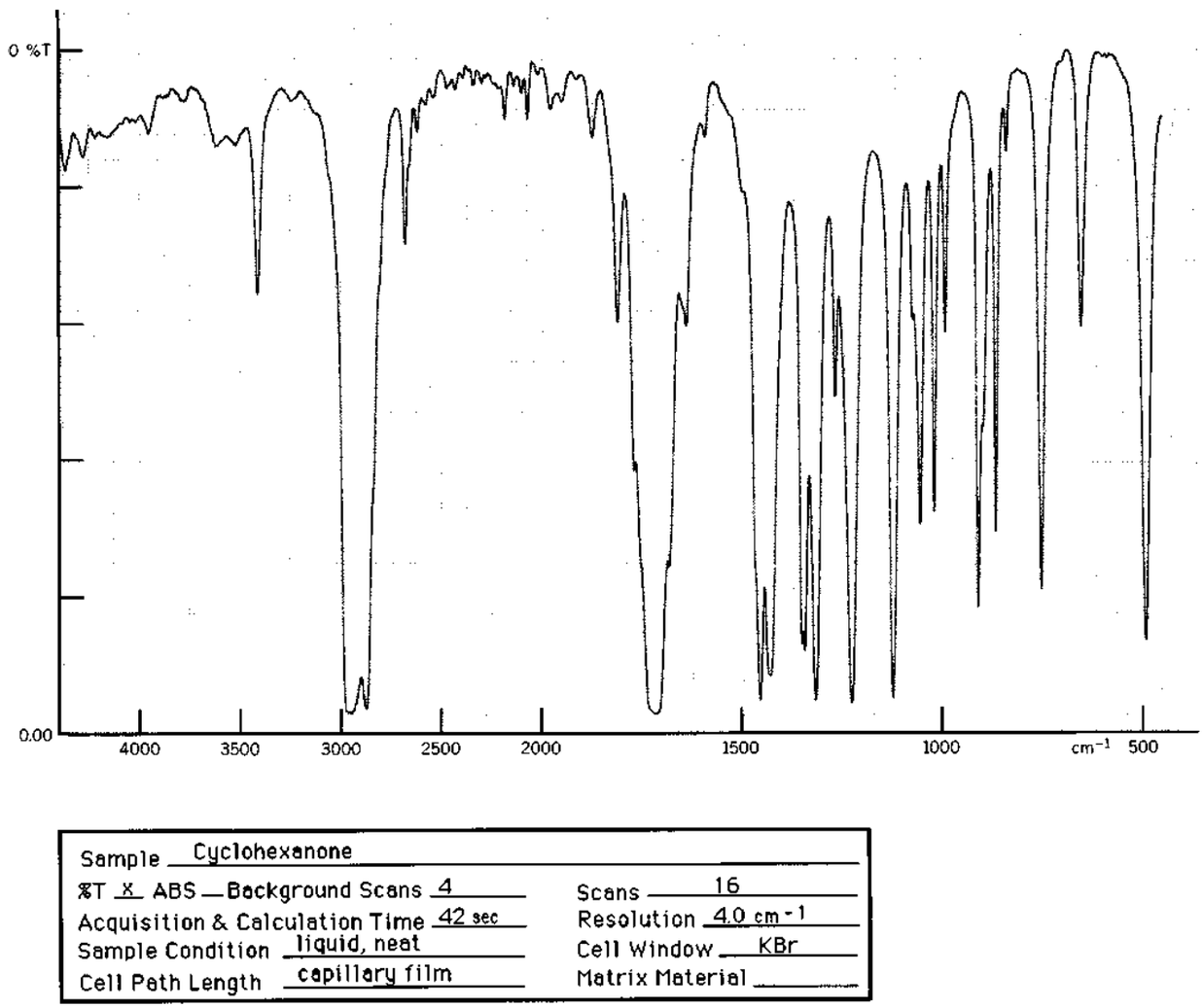

Figure 6.6 IR spectrum: cyclohexanone.

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overtone of the very intense carbonyl stretching mode found at 1715 cm^{-1}. The overtone does not fall exactly at double the frequency of the fundamental, but usually occurs slightly below that value because of anharmonic effects. The lack of absorption in the region near 3100–3000 cm^{-1} and the presence of a series of very strong absorption bands at 3000–2850 cm^{-1} indicates that the only C—H stretching modes present are part of sp^3 systems. Thus, the spectrum is typical of an aliphatic ketone. The occurrence of a 1425-wavenumber band suggests the presence of at least one methylene group adjacent to the carbonyl group, while the 1450-wavenumber band requires other methylene groups more remote to the C═O group. The lack of absorption in the 1400- to 1375-wavenumber region indicates the absence of any methyl groups (a good indication of a simple aliphatic ring system) and further suggests that the absorption at 1450 cm^{-1} must arise entirely from methylene scissoring modes. The value of 1715 cm^{-1} for the C═O stretch supports the presence of a six-membered ring.

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Now examine the spectrum of your reaction product (a typical example is given in Fig. 6.7). The spectrum is rather different from that of the starting material. The major changes are a new very strong broad band occurring between 3500 and 3100 cm^{-1} and the large drop in the intensity of the band found at 1715 cm^{-1}.

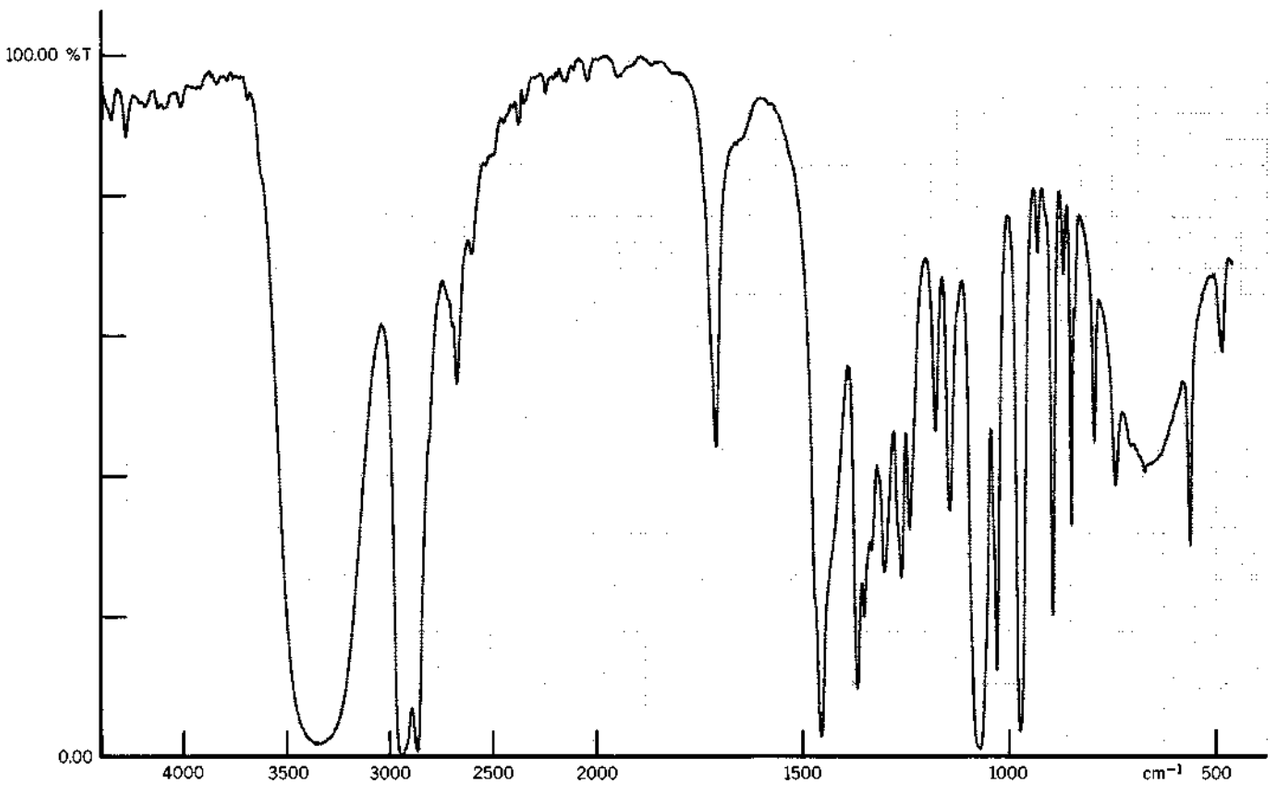

Sample Cyclohexanol (crude product)
%T X ABS Background Scans 4 Scans 16
Acquisition & Calculation Time 42 sec Resolution 4.0 cm-1
Sample Condition liquid, neat Cell Window KBr
Cell Path Length capillary film Matrix Material

Figure 6.7 IR spectrum: cyclohexanol (crude product).

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These changes indicate the reductive formation of an alcohol group from the carbonyl system. The band centered near 3300 cm^{-1} results from the single polarized O—H stretching mode. The drop in intensity of the 1715-wavenumber band indicates the loss of the carbonyl function. The exact amount of cyclohexanone remaining can be determined by carrying out a Beer's law type analysis, but in this case we will use gas chromatographic techniques to determine this value. Other bands of interest in the spectrum of cyclohexanol occur at 1069 and 1031 cm^{-1}. These bands can be assigned, respectively, to the equatorial and axial C—O stretching of the rotational conformers of this alicyclic secondary alcohol. A broad band (width ~300 cm^{-1}) can be found near 670 cm^{-1}. This absorption arises from an O—H bending, out-of-plane mode, of the associated alcohol. This band is generally identified only in neat samples where extensive hydrogen-bonding occurs. Also note that the band at 1425 cm^{-1} has vanished because there are no methylene groups alpha to carbonyl systems in the product.

Separation of Small Quantities of Cyclohexanone from Cyclohexanol

Now proceed with purification of the reaction product by preparative gas chromatography. Use the following conditions and refer to Experiment [2] for the collection technique. If time permits, or perhaps in a later laboratory period, determine the infrared spectrum of the purified product. Describe and explain the changes observed in the new spectrum compared to that of the crude product.

Example

9:1 (v/v) cyclohexanol/cyclohexanone
10% Carbowax 20 M (stationary phase)
Injection volume: 15 μL
Temperature: 130 °C
He flow rate: 50 mL/min
Column: $\frac{1}{4}$-in. × 8-ft stainless steel
Chart speed: 1 cm/min

	Cyclohexanol		Cyclohexanone
Run	Retention Time (min)	Yield (mg)	Retention Time (min)
1	15.3	6.5	11.6
2	17.3	7.3	12.5
3	17.2	8.5	12.6
4	16.0	9.6	12.0
5	14.6	7.3	11.2
6	14.5	8.7	11.2
7	15.5	8.9	11.7
8	15.5	8.9	11.8
9	16.4	8.8	12.3
10	15.4	8.4	12.7
Av	15.8 ± 1	8.3 ± 0.9	12.0 ± 0.6

Cyclohexanol injected = 0.9(15 μL)(0.963 mg/μL) = 13.0 mg
Percent yield = 8.3/13.0 × 100 = 63.8%

NOTE. Collection efficiencies approaching 90% can be obtained by cooling the collection tube. Liquid nitrogen-soaked tissues work best, but methanol-soaked tissues or ice water can give a significant improvement.

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Chemical Tests. Several chemical tests (see Chapter 9) may also be used to establish that an alcohol has been formed by the reduction of a ketone. Perform the ceric nitrate and 2,4-dinitrophenylhydrazine test on both the starting ketone and the alcohol product. Do your results demonstrate that an alcohol was obtained? You may also wish to prepare a phenyl- or α-naphthylurethane derivative of the cyclohexanol. Before the development of chemical instrumentation, the formation of solid derivatives was used extensively to identify reaction products.

Experiment 5B

cis- and *trans*-4-*tert*-Butylcyclohexanol

REACTION

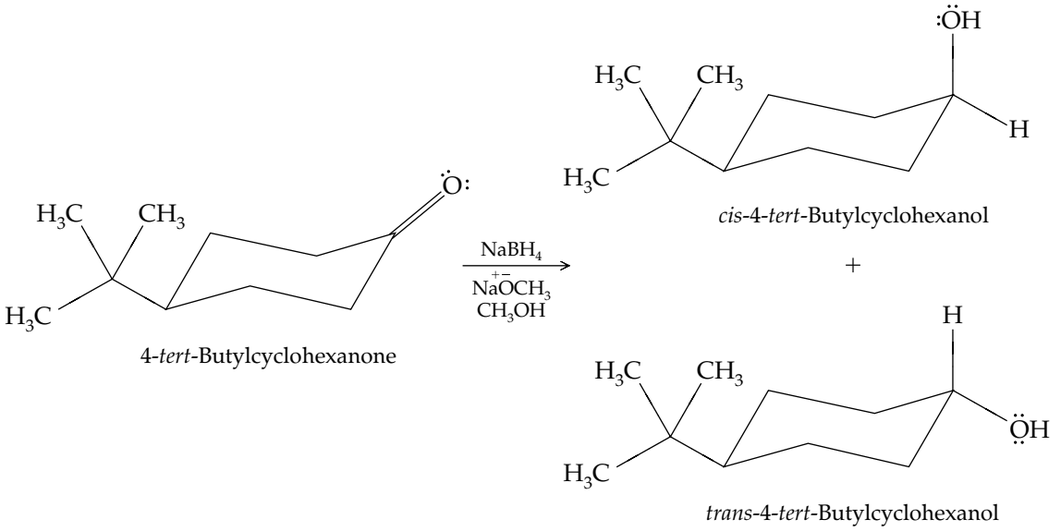

4-*tert*-Butylcyclohexanone

EXPERIMENTAL PROCEDURE

Estimated time of the experiment: 2.0 h.
For the GC analysis, 15 min per student.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
4-*tert*-Butylcyclohexanone	154.25	50 mg	0.33	47–50	
Methanol	32.04	50 μL			65
Sodium borohydride reducing solution		100 μL			

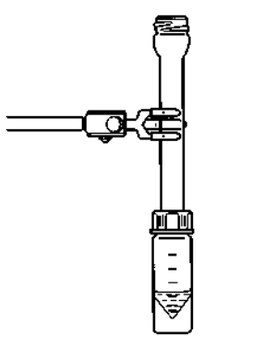

4-*tert*-Butylcyclohexanone, 50 mg + CH_3OH, 50 μL + $NaBH_4$ solution, 100 μL

Reagents and Equipment. In a tared 3.0-mL conical vial equipped with an air condenser weigh and place 50 mg (0.33 mmol) of 4-*tert*-butylcyclohexanone followed by 50 μL of methanol (⬅). Gently stir using a glass stir rod (or a magnetic spin vane if desirable) the contents of the vial to obtain a homogeneous solution.

Now slowly add 100 μL of the sodium borohydride reducing solution while stirring.

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NOTE. The liquid reagents are dispensed by use of automatic delivery pipets. The preparation of the reducing solution is given in Experiment [5A], Reagents and Equipment (p. 154).

Reaction Conditions. After allowing the resulting solution to stand 10 min at room temperature, begin monitoring the resulting solution by TLC. Using as a solvent system of ethyl acetate:hexane (1:4), the R_f of 4-*tert*-butylcyclohexanol is 0.3 (R_f of 4-*tert*-butylcyclohexanone is 0.6) when stained with a solution of *p*-anisaldehyde (135 mL ethanol, 5 mL H_2SO_4, 1.5 mL glacial acetic acid, and 3.7 mL *p*-anisaldehyde).

Isolation of Product. When the reaction is complete as judged by TLC, work up the resulting solution using the procedure described in Experiment [5A], Isolation of Product (p. 154), with the exception that 250 mg of sodium sulfate is placed in the Pasteur filter pipet (➡).

In the **hood,** remove the dried methylene chloride solvent from the final solution by directing a gentle stream of nitrogen gas onto the liquid surface while at the same time externally warming the vial in a sand bath. The use of a heating bath will help to avoid moisture condensation on the residue during solvent evaporation.

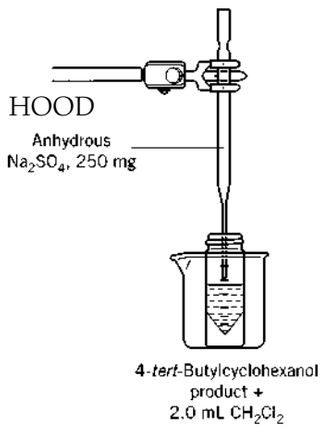

Purification and Characterization. The product mixture remaining after removal of the methylene chloride is normally of sufficient purity for direct characterization. Weigh the solid product and calculate the percent yield. Determine the melting point of your material. 4-*tert*-Butylcyclohexanol (mixed isomers) has a melting point of 62–70 °C.

Obtain the IR and NMR spectra of the crude mixture of isomers. Infrared sampling in this instance is best accomplished by the capillary film-melt (use the heat lamp) technique (see Chapter 8 and online IR discussions).

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Infrared Analysis. Refer to the discussion in Experiment [5A] for an interpretation of the absorption bands found at 3435, 3000–2850, 1717, and 1425 cm^{-1} in the starting material (Fig. 6.8), and at 3250, 3000–2850 (1717 variable relative intensity—may be quite weak, why?), 1069, and 1031 cm^{-1} in the crude alcohol (Fig. 6.9).

In addition, the ketone has bands at 1396 (weak) and 1369 (strong), and the alcohol has bands at 1399 (weak) and 1375 (strong) cm^{-1}. These two pairs of bands establish the presence of the tertiary butyl group in these compounds.

Note that a weak band (3495 cm^{-1}) is present on the high wavenumber side of the 3250-cm^{-1} O—H stretching mode and that even in neat samples of the tertiary butyl derivative, the 670-wavenumber band, clearly evident in cyclohexanol, is difficult to observe.

The mixture of two diastereomeric alcohols that have been synthesized provides an ideal opportunity to introduce you to nuclear magnetic resonance (NMR) spectroscopy. This technique is an extremely powerful tool for the discrimination and characterization of diastereomeric compounds. As you will see, the two diastereomers have quite different NMR spectra. An interpretation of these spectra will allow you to determine the ratio of the two isomers and to make an unambiguous assignment of their relative stereochemistry.

This experiment gives you an opportunity to obtain and interpret NMR data if you have access to NMR equipment. The two diastereomeric alcohols exhibit different splitting patterns for the proton on the carbon bearing the —OH

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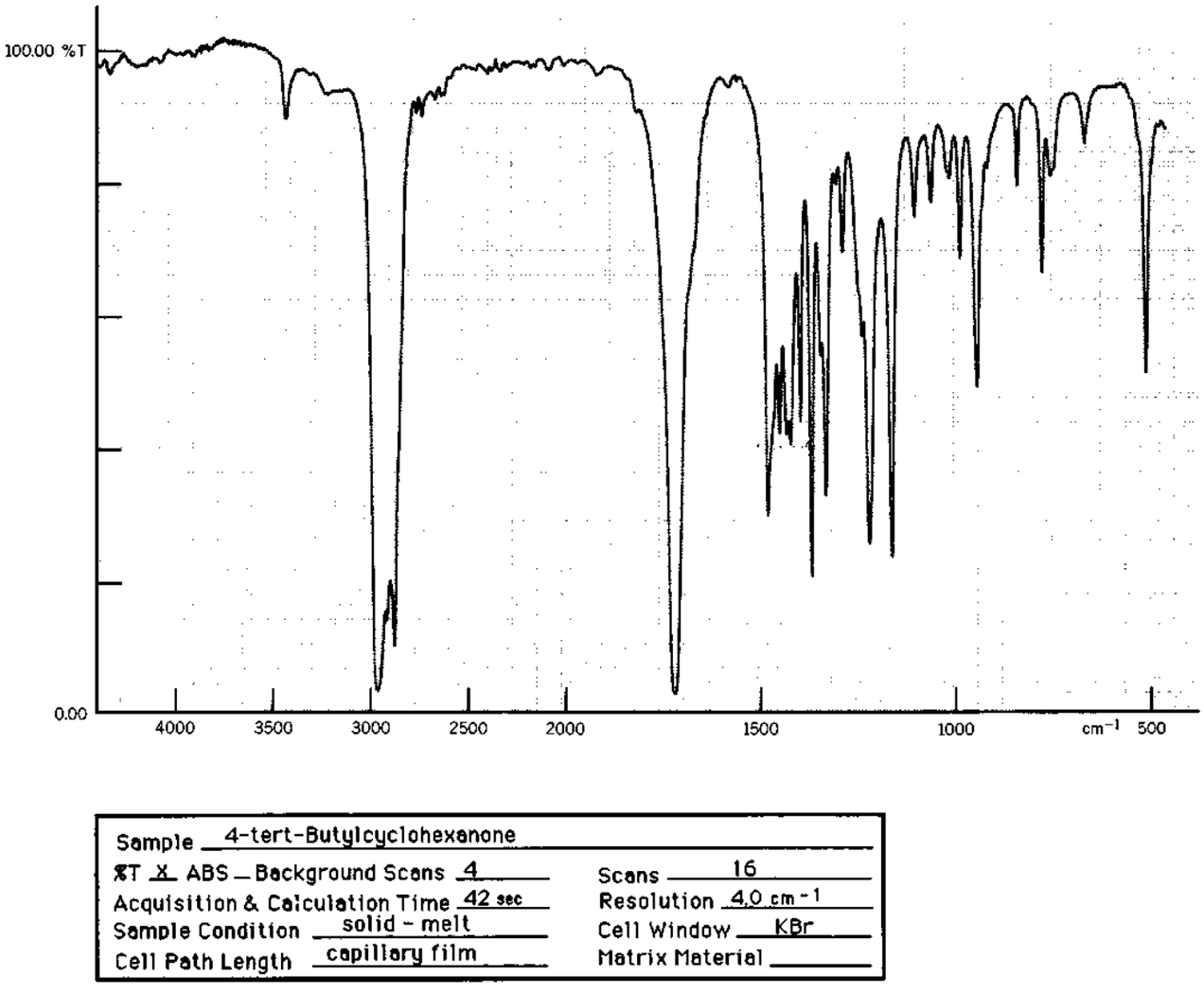

Figure 6.8 IR spectrum: 4-*tert*-butylcyclohexanone.

group. These signals can be integrated to determine the ratio of the diastereomeric alcohols in the sample.

Nuclear Magnetic Resonance Analysis. Refer to the expanded NMR spectrum in Figure 6.10. The signals at about 4.04 and 3.52 ppm correspond to the proton on the carbon bearing the O—H group in the two diastereomers of 4-*tert*-butylcyclohexanol shown. On closer inspection, the downfield signal (4.04 ppm) is a pentet and the upfield signal (3.52 ppm) is a triplet of triplets. The pentet implies that the proton in question is coupled with equal coupling constants (J) to four adjacent protons. The triplet of triplets implies that the proton in question is coupled to two adjacent protons with a large coupling constant and to two other adjacent protons with a smaller coupling constant. Specifically, the proton in the first case must be equatorial and the proton in the second case must be axial, because the dihedral angle between an equatorial proton and each of the four adjacent protons is the same, about 60°, J = 2–3 Hz. When a proton is axial, the dihedral angle to the two adjacent equatorial

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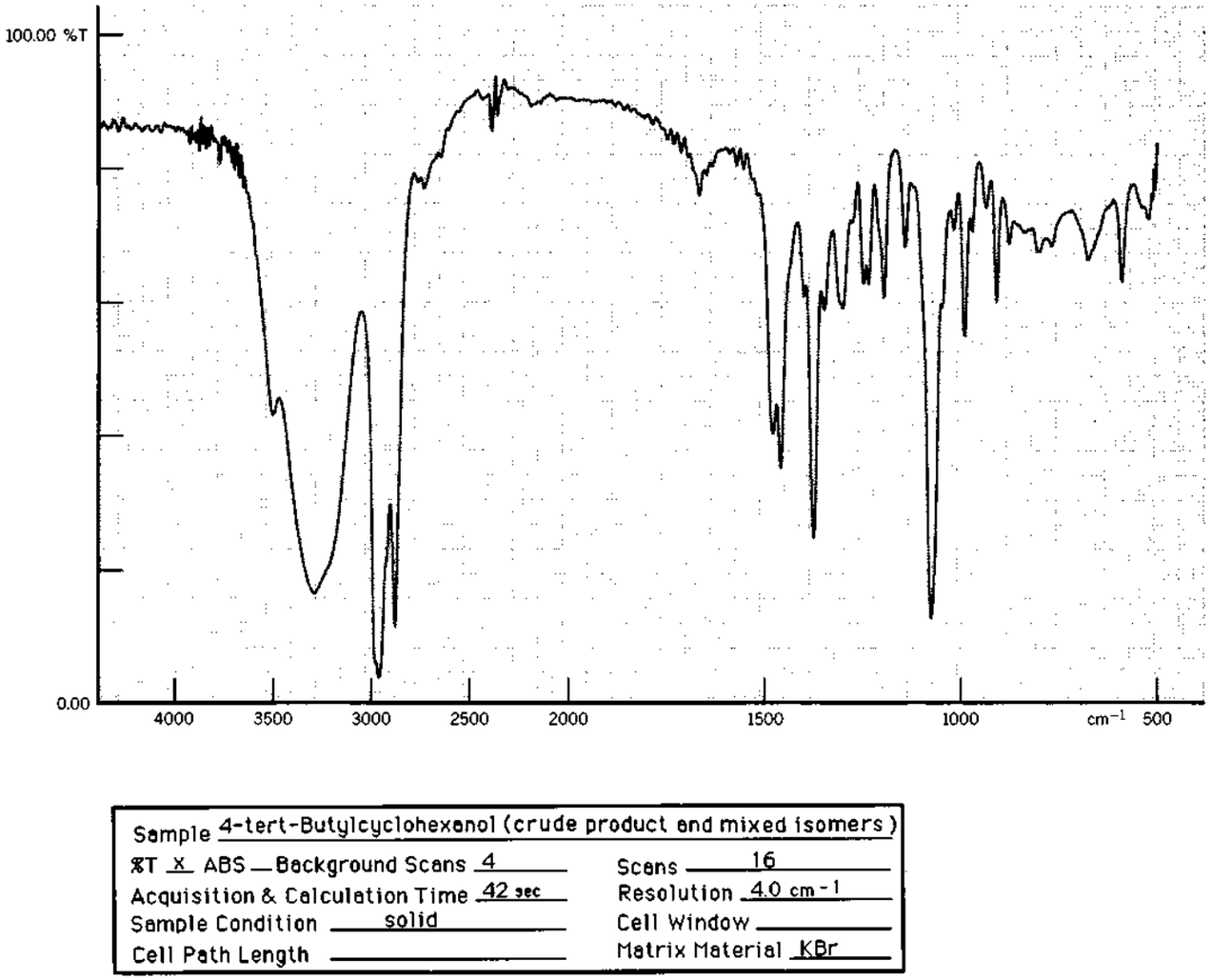

Figure 6.9 IR spectrum: 4-*tert*-butylcyclohexanol (crude product and mixed isomers).

protons is about 60° ($J \approx 3$ Hz) and the dihedral angle to the two adjacent axial protons is about 180° ($J \approx 13$Hz), thus producing a triplet of triplets.

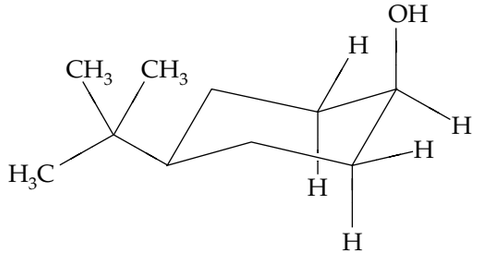

Cis

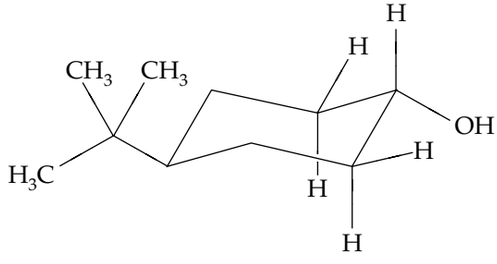

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Gas Chromatographic Analysis. The cis and trans isomers of 4-*tert*-butylcyclohexanol may be separated by gas chromatography using a $\frac{1}{4}$-in. × 8-ft,

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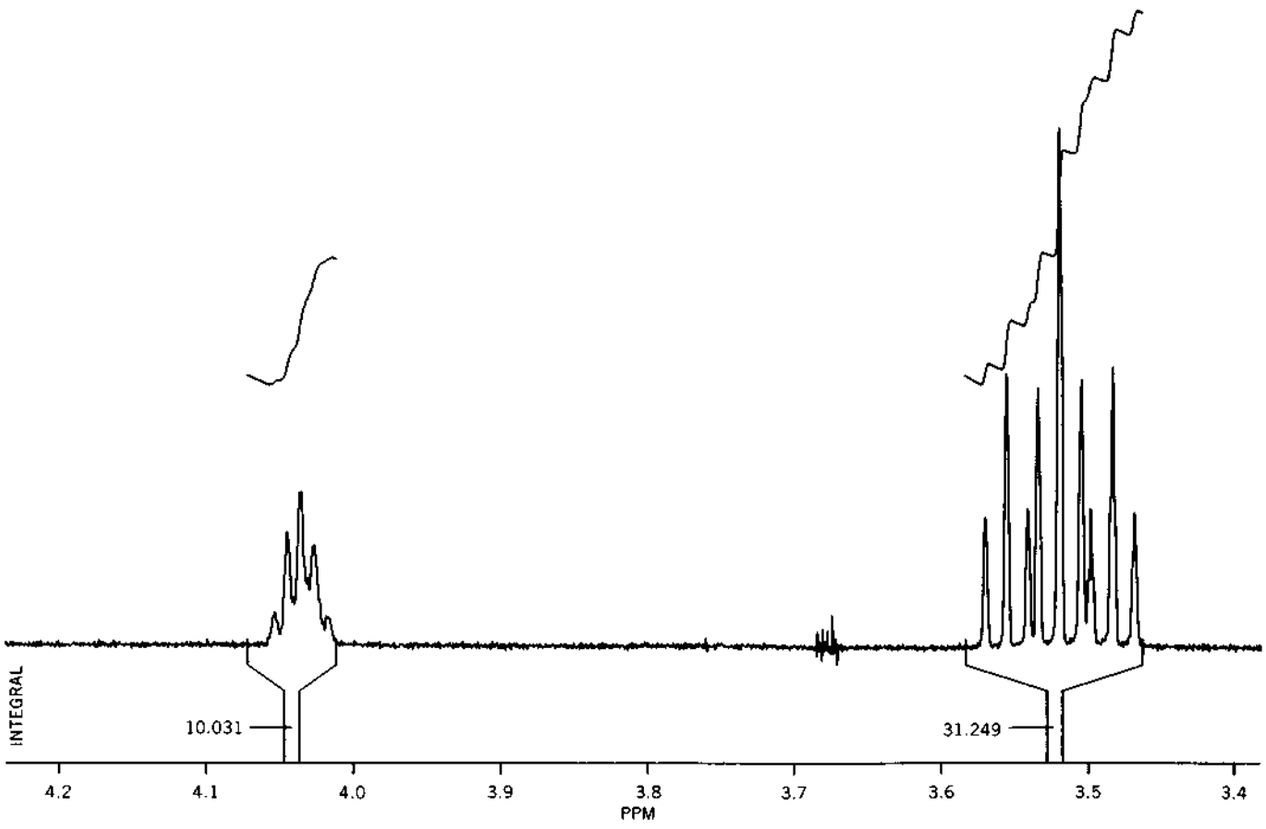

Figure 6.10 NMR spectrum: *cis*- and *trans*-4-*tert*-butylcyclohexanol.

10% FFAP column at 110 °C. Prepare a methylene chloride solution of the alcohol mixture having a concentration of 0.5 mg/μL and inject a 5.0-μL sample into the GC apparatus. At a flow rate of 50 mL/min (He), the retention time of the cis isomer is ~13 min, and the retention time of the trans isomer is ~16 min.

Determine the percentage of each isomer present in the sample by determining the area under each curve.

NOTE. If a Carbowax column (170 °C) is used, the starting ketone has a retention time similar to that of the cis alcohol. Therefore, if the reaction does not go to completion, the apparent cis/trans ratio may not be accurate. It has recently been demonstrated that 10% FFAP columns will resolve all components present in the product mixture. Thus, the starting ketone and the cis isomer concentrations may be effectively established in addition to the trans isomer.

The latter separation scheme was developed by T. J. Dwyer and S. Jones at the University of California, San Diego.

NOTE. Several techniques may be used to calculate the area under a curve (mm^2), but the following method is satisfactory for your needs and gives reproducible results of ±3–4%: Multiply the peak height (mm) by the width at one-half height (mm), measured from the base line of the curve.

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QUESTIONS

6-27. Suggest a chemical test that would allow you to distinguish between *tert*-butyl alcohol and 1-butanol, both of which give a positive ceric nitrate test.

6-28. Which of the isomeric butanols ($C_4H_{10}O$) can be prepared by reduction of a ketone with sodium borohydride?

6-29. Why are there axial and equatorial hydroxyl isomers for 4-*tert*-butylcyclohexanol, but not for cyclohexanol itself?

6-30. What aldehyde or ketone would you reduce to prepare the following alcohols?
(a) Benzyl alcohol **(b)** 3,3-Dimethyl-2-butanol **(c)** 3-Methyl-1-butanol

6-31. The *cis*- and *trans*-4-*tert*-butylcyclohexanol prepared in Experiment [5B] each have a plane of symmetry. Draw this symmetry element for each of the diastereomers.

6-32. In the spectrum of the crude product obtained from the reduction of 4-*tert*-butylcyclohexanone, the fingerprint region appears to possess bandwidths that are slightly broader than those found in cyclohexanol. Explain.

6-33. The reduction of 4-*tert*-butylcyclohexanone is a stereoselective reaction. Which isomer predominates? If you do not have NMR data available, it is still possible to arrive at a rough estimate of the product ratio. How would you go about this measurement? Suggest a value.

6-34. In the spectrum of the crude 4-*tert*-butylcyclohexanols one observes: (a) a weak band (3495 cm^{-1}) located on the high side of the 3250-cm^{-1} O—H stretching mode. (b) Even in neat samples of this alcohol, the 670-cm^{-1} band, clearly evident in cyclohexanol, is difficult to observe. Explain these observations. Is the same effect operating in both cases?

6-35. Sketch the proton NMR spectrum you would expect to observe for the following compounds.
(a) Acetone
(b) 1,1,2-Tribromoethane
(c) Propyl chloride
(d) 2,4-Dimethyl-3-pentanone
(e) 1-Bromo-4-methoxybenzene

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See *Organic Syntheses,* Coll. Vols., for the use of these reagents in specific reductions.

EXPERIMENT 6

Photochemical Isomerization of an Alkene: cis-1,2-Dibenzoylethylene

Common names: *cis*-1,2-dibenzoylethylene
cis-1,4-diphenyl-2-butene-1,4-dione
CA number: [959-27-3]
CA name as indexed: 2-butene-1,4-dione, 1,4-diphenyl-, (Z)-

Purpose. This exercise illustrates the ease of cis–trans isomerization in organic molecules and, specifically in this case, demonstrates the isomerization of a trans alkene to the corresponding cis isomer via photochemical excitation.

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BIOLOGICALLY IMPORTANT PHOTOCHEMICAL REACTIONS

A number of important biochemical reactions are promoted by the adsorption of UV-vis radiation. Vitamin D_3, which regulates calcium deposition in bones, is biosynthesized in just such a photochemical reaction. This vitamin is formed when the provitamin, 7-dehydrocholesterol, is carried through fine blood capillaries just beneath the surface of the skin and exposed to sunlight. The amount of radiation exposure, which is critical for the regulation of the concentration of this vitamin in the blood stream, is controlled by skin pigmentation and geographic latitude. Thus, the color of human skin is an evolutionary response to control the formation of vitamin D_3 via a photochemical reaction.

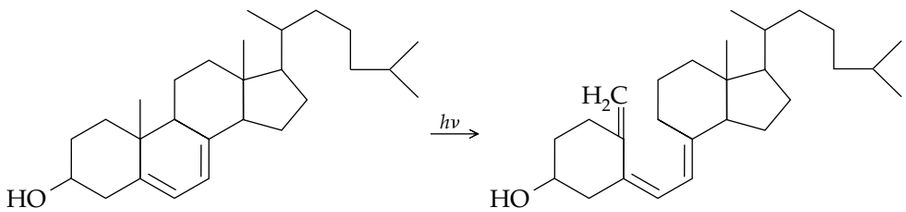

7-Dehydrocholesterol Vitamin D_3

Another set of significant photochemical reactions in human biochemistry is contained in the chemistry of vision. These reactions involve vitamin A_1 (retinol), which is a C_{20} compound belonging to a class of compounds known as diterpenes. These compounds are molecules formally constructed by the biopolymerization of four isoprene, $CH_2{=}C(CH_3){-}CH{=}CH_2$, molecules. Retinol (an all-trans pentaene) is first oxidized via liver enzymes (biological catalysts) to vitamin A aldehyde (*trans*-retinal). The *trans*-retinal, which is present in the light-sensitive cells (the retina) of the eye, undergoes further enzymatic transformation (retinal isomerase) to give *cis*-retinal (a second form of vitamin A aldehyde) in which one of the double bonds of the all-trans compound is isomerized.

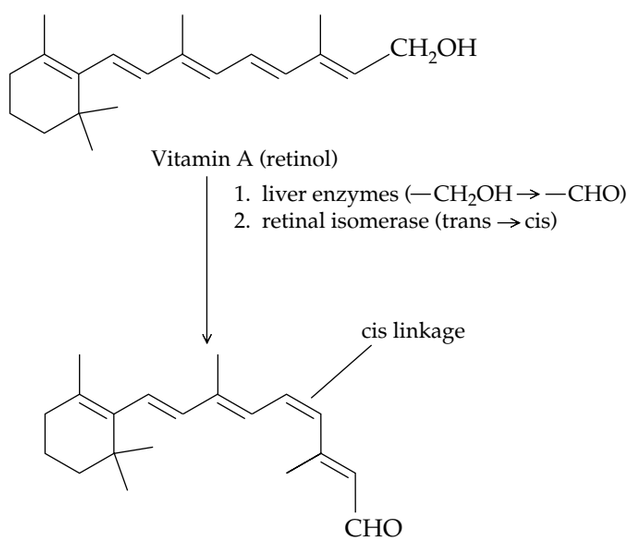

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The cis isomer of vitamin A aldehyde (retinal) possesses exactly the correct dimensions to become coupled to opsin, a large protein molecule (MW ~38,000) (coupling involves a reaction of the retinal aldehyde group, —C(H)═O, with an amine group [—NH_2] of the protein to form an imine linkage [RCH═NR]), to generate a light-sensitive substance, rhodopsin. This material is located in the rodlike structures of the retina. When the protonated form of rhodopsin (—CH═N^+HR), which absorbs in the blue-green region of the visible spectrum near 500 nm, is exposed to radiation of this wavelength, isomerization of the lone cis double bond of the diterpene group occurs and *trans*-rhodopsin is formed:

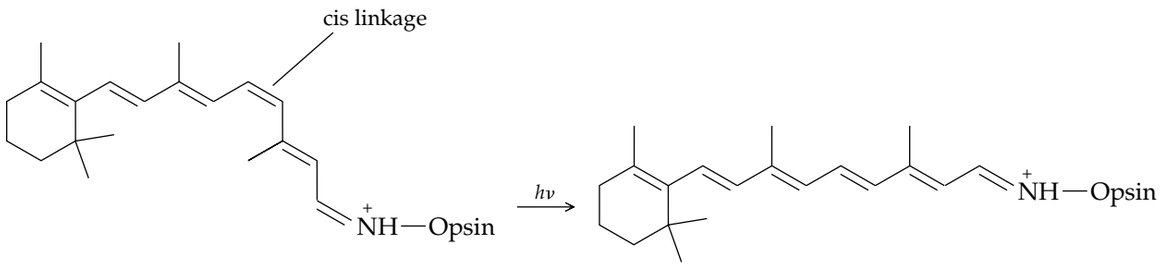

cis-Rhodopsin *trans*-Rhodopsin

This photoreaction (a fast reaction, 10^{-12} s) involves a significant change in the geometry of the diterpene group, which eventually (10^{-9} s) results in both a nerve impulse and the separation of *trans*-retinal from the opsin. The trans isomer is then enzymatically reisomerized back to the cis compound, which then starts the initial step of the visual cycle over again.

There are two interesting facts about this reaction: (1) This reaction is incredibly sensitive. A single photon will cause the visual nerve to fire. (2) All known visual systems use *cis*-retinal, regardless of their evolutionary trail.

The photoreaction that we study next is very similar to the cis–trans double-bond isomerism found in the vitamin A visual pigments. The only difference is that in our case we will be photochemically converting a trans double-bond isomer to the cis isomer.

Prior Reading

Technique 5: Crystallization
Introduction (pp. 85–87)
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)
Recrystallization Pipet

www

Technique 6A: Thin-Layer Chromatography (pp. 97–99)

REACTION

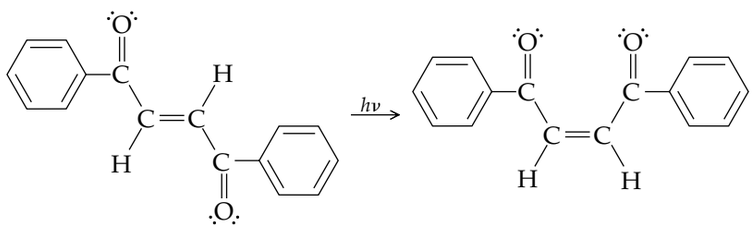

trans-1,2-Dibenzoylethylene *cis*-1,2-Dibenzoylethylene

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DISCUSSION

The π bond of an alkene (C═C) is created by overlap of the sp^2 hybridized carbons' p orbitals. Rotation about the axis of the C═C requires a good deal of energy because it destroys the p orbital overlap, and thus the π bond. Unless the material is irradiated with light of the appropriate wavelength, absorption of the radiation does not take place, and the isomers do not interconvert unless sufficient thermal energy (60–65 kcal/mol, typically >200 °C) is supplied to break the π bond. If one of the electrons in the π bond (π molecular orbital) is photochemically excited into an antibonding, π*, molecular orbital, as occurs in this experiment, the π bond is weakened significantly. Rotation about this bond can then occur rapidly at room temperature.

It is the high-energy barrier to rotation about the C═C that gives rise to the possibility of alkene stereoisomers. The cis and trans isomers of an alkene system are called *diastereoisomer*s, or *diastereomers*. Like all stereoisomers, these isomers differ only in the arrangement of the atoms in space. These isomers have all the same atoms bonded to each other. Diastereomers are not mirror images of each other and, of course, are not superimposable (identical). This particular type of diastereomer often was referred to in the older literature as a "geometric isomer." Diastereomers, therefore, would be expected to possess different physical properties, such as melting points, boiling points, dipole moments, densities, and solubilities, as well as different spectroscopic properties. Because of these differences in physical properties, diastereomers are amenable to separation by chromatography, distillation, crystallization, and other separation techniques. We use both chromatographic and crystallization methods in the present experiment.

The course of the isomerization may be followed using *thin-layer chromatography* (Experiment [6B]) or by spectroscopic techniques using NMR analysis (Experiment [6C]).

The photochemical isomerization of a diazabicyclohexene system is presented in Experiment [F4].

Experiment 6A

Purification of *trans*-1,2-Dibenzoylethylene

EXPERIMENTAL PROCEDURE

Estimated time to complete the purification: 1.5 h of laboratory time.

Physical Properties of Components					
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**
trans-1,2-Dibenzoylethylene	236.27	100 mg	0.42	111	
Ethanol (95%)		6.0 mL			78.5
Methylene chloride		4.0 mL			40

Purification Conditions. Purify the starting alkene by recrystallization.

Weigh and add to a 10-mL Erlenmeyer flask 100 mg (0.42 mmol) of *trans*-1,2-dibenzoylethylene and 3.0 mL of methylene chloride.

NOTE. If the melting point of the alkene was not supplied to you, set aside a small sample (1–2 mg) of the weighed sample so that the evacuated melting point of this initial material can be obtained later.

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Add decolorizing charcoal pellets (10 mg) to this solution and swirl the mixture gently for several minutes. Use a Pasteur filter pipet to transfer the methylene chloride solution to a second 10-mL Erlenmeyer flask containing a boiling stone (remember to hold the necks of the two flasks close together with the fingers of one hand during the transfer).

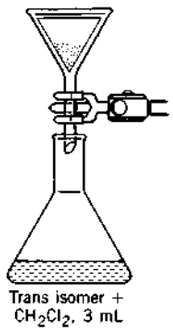

NOTE. If powdered charcoal is used instead of pellets, filter the solution using a Pasteur pipet packed with Celite, sand, and a cotton plug (Technique 6A). Rinse the filter paper with an additional 1 mL of methylene chloride and collect this rinse in the same flask.(➡)

Concentrate the filtered solution to dryness in a warm (50 °C) sand bath under a slow stream of nitrogen gas in the **hood.**

HOOD

Now add 95% ethanol (1–3 mL) to the flask and dissolve the yellow solid residue by warming in a sand bath, adding hot ethanol dropwise, until a homogeneous solution is obtained (➡).

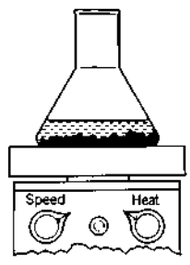

trans-1,2-Dibenzoylethylene, 150 mg + CH_2Cl_2, 3.0 mL, charcoal pellets

Allow the solution to cool slowly to room temperature over a period of 15 min and then place it in an ice bath for an additional 10 min. Collect the yellow needles by vacuum filtration using a Hirsch funnel (➡) and then air-dry them on a porous clay plate or on filter paper.

Weigh the product and calculate the percent recovery. Determine the evacuated melting point and compare your result with both the literature value and that obtained with the material saved prior to recrystallization. If Experiment [3A] has been completed, compare the melting point of that sample of the trans alkene, which was obtained by concentration, via distillation, of an ethyl acetate solution. In the latter experiment, a simple crystallization was performed without the aid of decolorizing charcoal.

Isomerization of an Alkene: Thin-Layer Chromatographic Analysis

Experiment 6B

EXPERIMENTAL PROCEDURE

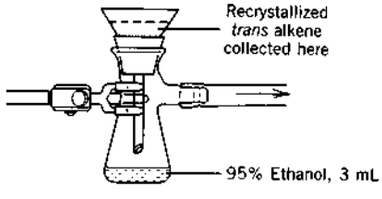

Estimated time to complete the experiment: 2.5 h of laboratory time. The reaction requires approximately 1 h of irradiation; the actual time to completion is quite sensitive to both radiation flux and temperature. These factors are largely determined by the distance the reaction vessel is positioned from the source of radiation.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
trans-1,2-Dibenzoylethylene	236.27	25 mg	0.11	111	
Ethanol (95%)		3.5 mL			78.5

Reagents and Equipment. To a 13 × 100-mm test tube weigh and add 25 mg (0.11 mmol) of recrystallized *trans*-1,2-dibenzoylethylene and 3.0 mL of 95% ethanol.

Reaction Conditions. Use a sand bath to warm the mixture ***gently*** until a homogeneous solution is obtained. Stopper the test tube *loosely,* or cover it with

GENTLY

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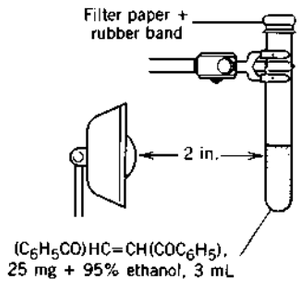

filter paper held in place by a rubber band, and then place it approximately 2–4 in. from a 275-W sun lamp. Irradiate the solution for approximately 1 h (⬅).

NOTE. If a lower wattage lamp is used, longer irradiation times or shorter distances will be necessary. In either case, solvent evaporation can be significantly reduced by directing a flow of cool air (fan) over the reaction tubes. An alternative procedure is to allow the (sealed) tube to stand in sunlight at room temperature for several days.

The progress of the isomerization may be followed by thin-layer chromatography (TLC) analysis.

INFORMATION. The TLC analysis is carried out using Eastman Kodak silica gel–polyethylene terephthalate plates with a fluorescent indicator. ***Activate the plates at an oven temperature of 100 °C for 30 min*** *and then place them in a desiccator to cool until needed. After spotting, elute the plates using methylene chloride as the solvent. Visualize the spots with a UV lamp. The course of the reaction is*

HOT *followed by removing small samples (2–3 drops) of solution from the* ***hot*** *test tube at set time intervals with a Pasteur pipet and placing them in separate $\frac{1}{2}$-dram vials. See Technique 6A for the method of TLC analysis and the determination of R_f values. Approximate R_f values: trans = 0.72; cis = 0.64.*

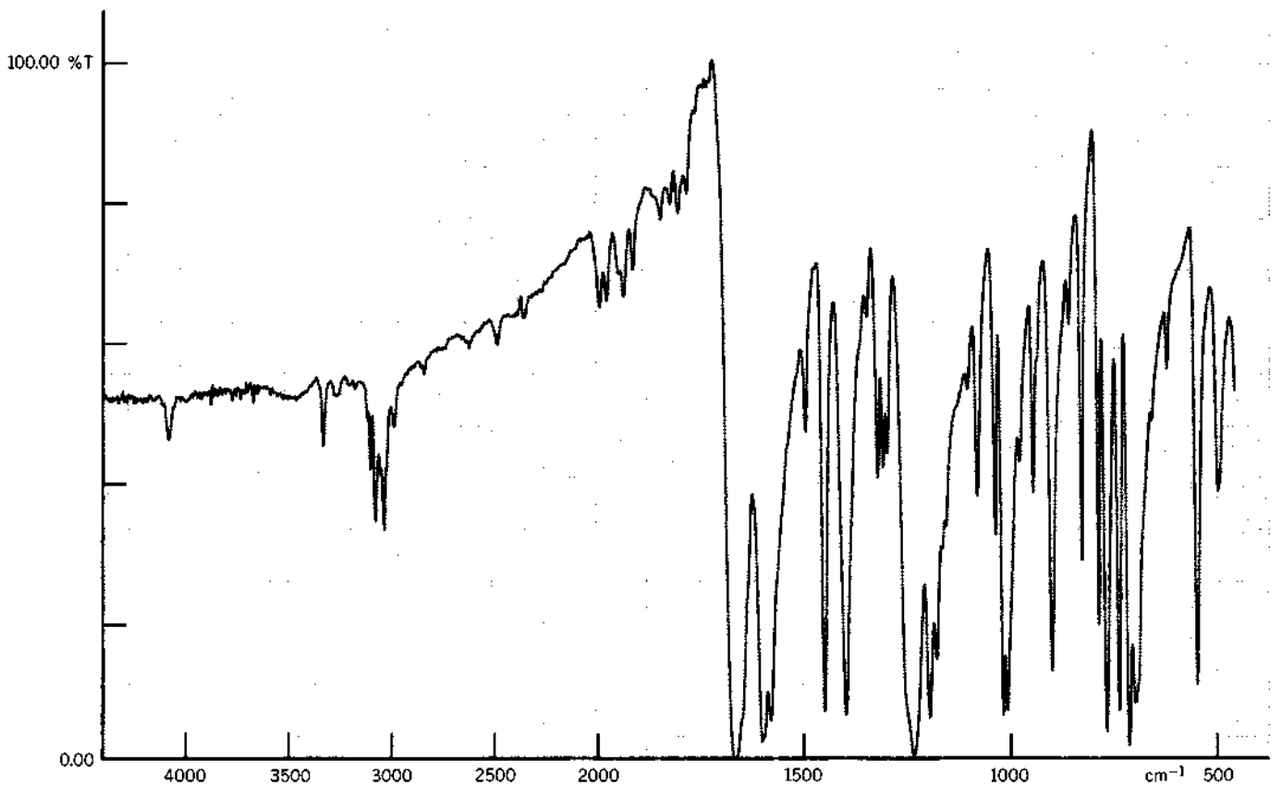

Sample cis-Dibenzoylethylene
%T X ABS Background Scans 4 Scans 16
Acquisition & Calculation Time 42 sec Resolution 4.0 cm-1
Sample Condition solid Cell Window
Cell Path Length Matrix Material KBr

Figure 6.11 IR spectrum: *cis*-dibenzoylethylene.

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Isolation of Product. Remove the **hot** test tube from the light source and allow the solution to cool to room temperature. HOT

Place the resulting mixture in an ice bath to complete crystallization of the *colorless cis*-1,2-dibenzoylethylene product. Collect the crystals by vacuum filtration using a Hirsch funnel, wash them with 0.5 mL of cold 95% ethanol, and then air-dry them on a porous clay plate or on filter paper.

Purification and Characterization. Weigh the dried product and calculate the percent yield. Determine the melting point (evacuated) and compare your result with the literature value. The purity of the crude isolated product may be further determined by TLC analysis (if not used above). Finally, if necessary, further purify a portion of the isolated product by recrystallization from 95% ethanol using a Craig tube.

Obtain IR spectra of the cis and trans isomers and compare them to Figures 6.11 and 6.12. Alternatively, or in addition to the IR analysis, the UV-vis spectra may be observed in methanol solution and the results compared to Figures 6.13 and 6.14.

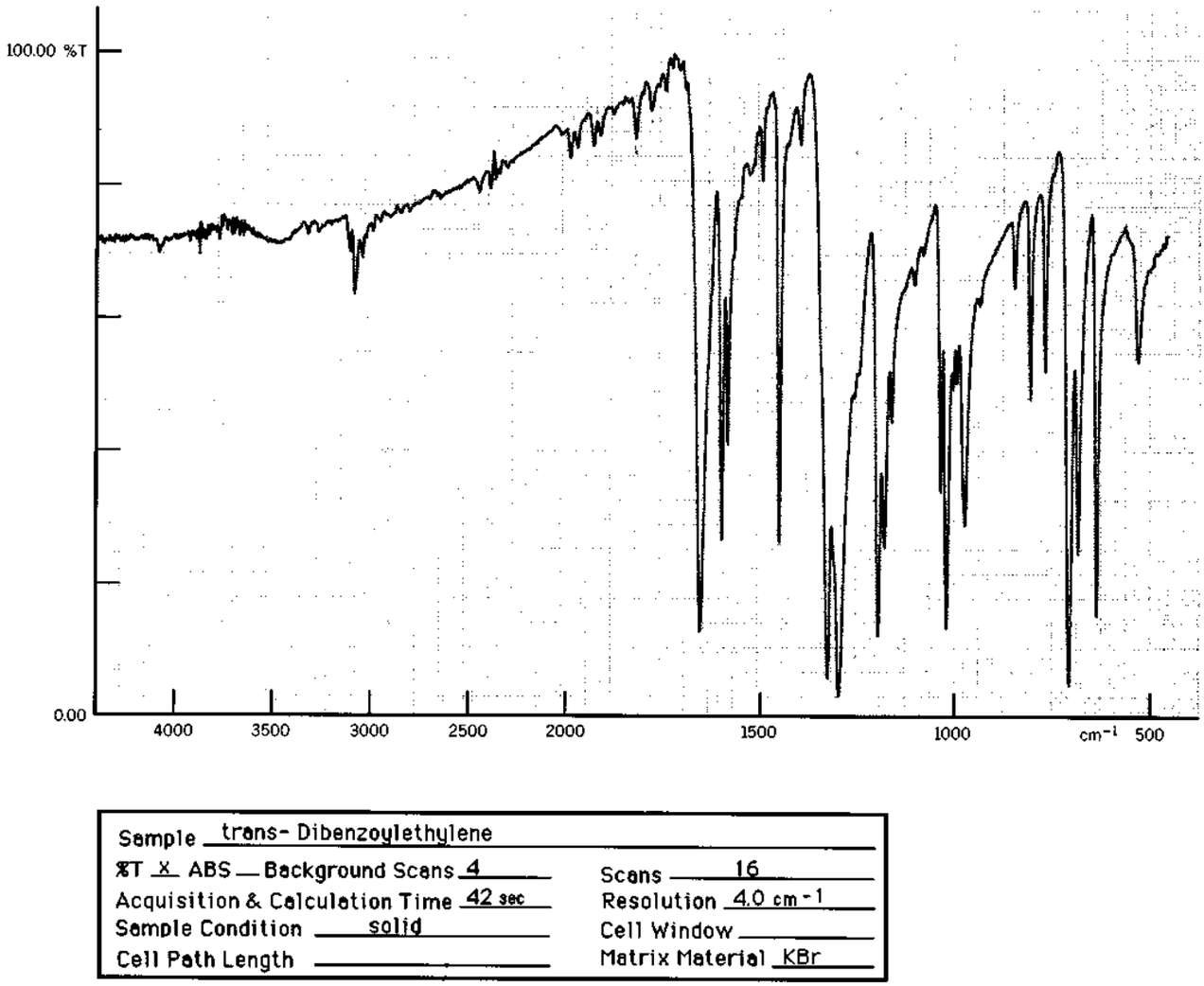

Figure 6.12 IR spectrum: *trans*-dibenzoylethylene.

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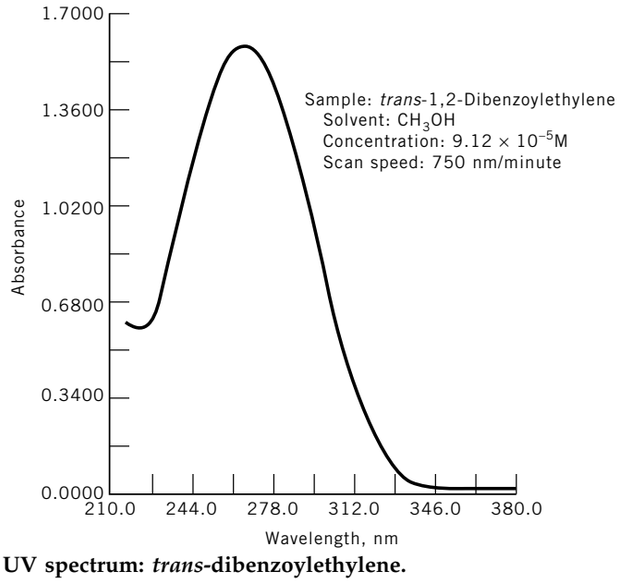

Figure 6.13 UV spectrum: *trans*-dibenzoylethylene.

Ultraviolet-Visible Analysis. The bright yellow color of the *trans*-dibenzoylethylene rapidly fades as the conversion to the colorless cis compound progresses under irradiation. This visual observation may be supported by an examination of the absorption spectra of the isomers in a methanol solution from 225 to 400 nm (see Figs. 6.13 and 6.14). The λ_{max} of the trans isomer drops from 268 to 259 nm in the cis compound. This shift to shorter wavelengths is just enough to move the long-wavelength end of the absorption band in the trans isomer out of the visible region and into the near-ultraviolet (thus, the cis compound does not absorb light to which the eye is sensitive and the compound appears colorless). This observation is consistent with the theory that the spatial contraction of extended π systems moves the

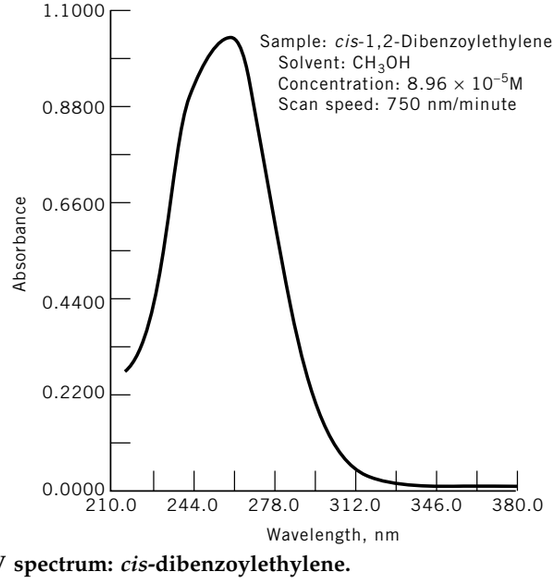

Figure 6.14 UV spectrum: *cis*-dibenzoylethylene.

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EQA

associated electronic transitions to higher energy gaps (higher frequencies or shorter wavelengths), which is exactly what takes place during the trans–cis isomerization.

Infrared Analysis. The infrared spectral changes are consistent with the proposed reaction product. Consider the spectrum of the trans starting material (Fig. 6.12). It contains the following:

1. The macro group frequency train (see Strategies for Interpreting Infrared Spectra, p. 542, for conjugated aromatic ketones is 3080 and 3030 (C—H, aromatic), 1652 (doubly conjugated carbonyl), 1599, and 1581 (ν_{8a}, ν_{8b} degenerate ring stretch, strong intensity of 1581-wavenumber peak confirms ring conjugation), 1495 and 1450 (ν_{19a}, ν_{19b} degenerate ring stretch, ν_{19a} weak) cm^{-1}.

2. The monosubstituted phenyl ring macro group frequency train is 1980(d), 1920(d),[4] 1820, 1780 (mono combination-band pattern), 708 (C—H out-of-plane bend, C═O conjugated), 686 (ring puckering) cm^{-1}.

3. The presence of the trans double bond is indicated by the single medium intensity 970 cm^{-1} band, as the C—H stretching region is overlapped by the aromatic ring C—H stretches.

The spectrum of the cis photoproduct (Fig. 6.11) possesses the same macro group frequencies as the starting material:

1. The conjugated aromatic ketone frequency train is 3335 (overtone of C═O stretch), 3080 and 3040, 1667, 1601, 1581, 1498 (weak), and 1450 cm^{-1}.

2. The monosubstituted phenyl ring macro frequency train is assigned peaks of 1990, 1920, 1830, 1795, 710, and 695 cm^{-1}.

3. The cis double bond is clearly present and utilizes a macro frequency train of 3030 (overlapped by aromatic C—H stretch), 1650 (C═O stretch, shoulder on the low wavenumber side of conjugated carbonyl; resolved in spectra run on thin samples), 1403 (═C—H out-of-phase, in-plane bending mode, strong band not present in trans compound), 970 (trans, in-phase, out-of-plane bend missing), 820 (cis, in-phase out-of-plane bend; band not found in spectrum of trans isomer) cm^{-1}.

Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 6.11 and 6.12).

Optional Isolation of the Thermodynamically Most Stable Reaction Product Under the Conditions Used to Carry Out the Above Reaction. If the photo reaction exposure is continued, the cis isomer, which is formed quickly, slowly undergoes conversion to a more stable, new product, ethyl 4-phenyl-4-phenoxy-3-butenoate. This conversion of the intermediate cis isomer may be followed conveniently by thin-layer chromatography. Maximum yields are obtained over approximately 24 h under the above reaction conditions. The product has R_f = 0.8 in 1:1 hexane/methylene chloride. Evaporation of the solvent yields a yellow oil.

[4]d = double peak.

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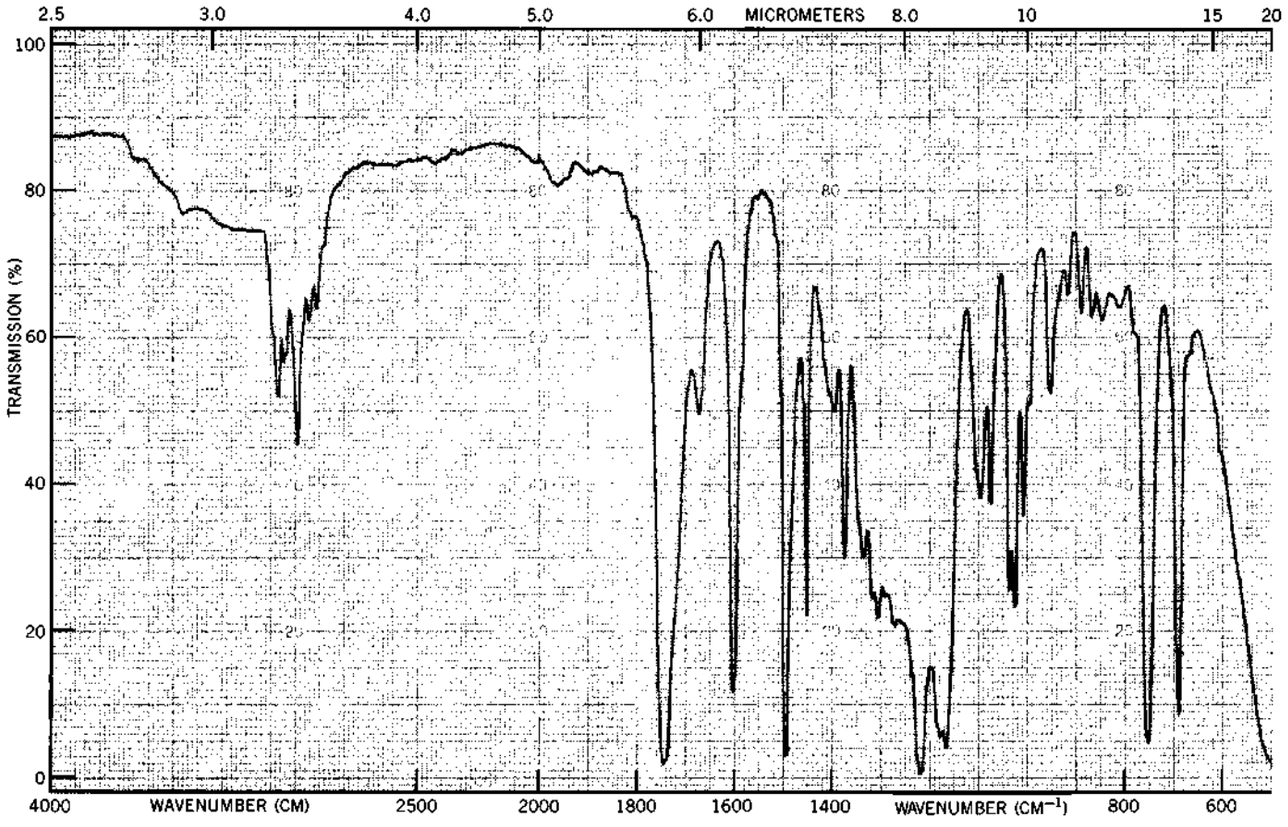

Figure 6.15 IR spectrum: ethyl 4-phenyl-4-phenoxy-3-butenoate.

The infrared spectrum of this new material (Fig. 6.15) indicates that significant changes have occurred in the structure of the material. The proposed structure involves a rather spectacular molecular rearrangement of the cis-unsaturated ketone to yield an ethyl ester containing a phenoxy-substituted double bond. Can you rationalize the data to fit this structure? Suggest possible macro group frequencies that are present in the IR spectrum of the rearranged product.

Mixture Melting-Point Measurements. Observe a series of evacuated mixture melting points (see Chapter 4) with isomer ratios of 75:25, 50:50, and 25:75. These values will allow you to *estimate* the eutectic temperature of this system. This same technique is used in Experiment [29A] to aid in identifying the isolated product, 2,5-dichloronitrobenzene, which has a melting point only 3 °C higher than 1,4-dichlorobenzene, the starting material in this nitration reaction.

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EQA

Isomerization of an Alkene: Nuclear Magnetic Resonance Analysis

Experiment 6C

EXPERIMENTAL PROCEDURE

Estimated time of experiment: 0.5 h.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
trans-1,2-Dibenzoylethyene	236.27	5 mg	0.02	111	
Chloroform-*d*	120.39	500 μL			62

Reagents and Equipment. Prepare a sample of 4–5 mg of recrystallized *trans*-1,2-dibenzoylethylene in about 500 μL of $CDCl_3$ in an NMR tube. Using a fine capillary, spot a silica gel TLC plate (see Experiment [6B]) with a sample of this solution. Use TLC to track the results of the NMR experiment.

Obtain an NMR spectrum of this solution.

Reaction Conditions

NOTE. A 15-min exposure is normally adequate but, as can be seen by TLC analysis, complete isomerization of this alkene may not occur in this short a time.

Clamp the NMR tube 3–4 in. (see comments above, Experiment [6A]) from a 275-W sun lamp for 15–20 min (see Experiment [6B]).

Analysis of the Results. After irradiation, spot the original TLC plate with this irradiated solution and elute the plate with methylene chloride/hexane (1:1) solvent (see Experiment [6B]). Obtain an ^1H NMR spectrum of the irradiated solution.

Does the TLC analysis correlate with the NMR data? Is there evidence that the isomerization did occur?

The data in the following table were taken on a 300-MHz NMR instrument. Which signal in each isomer comes from the hydrogen atoms attached to the C═C group?

^1H Chemical Shift Data	
Trans Isomer (ppm)	Cis Isomer (ppm)
8.06 doublet	7.9 doublet
8.01 singlet	7.55 triplet
7.63 triplet	7.43 triplet
7.52 triplet	7.14 singlet

QUESTIONS

6-36. What properties should an ideal recrystallization solvent have?

6-37. What is meant by the term *solvent pair* when it is used in reference to the recrystallization of solids?

6-38. What is the purpose of adding powdered charcoal to the solvent system during a recrystallization sequence?

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6-39. Why do we obtain larger crystals if a solution of an organic compound is allowed to cool slowly?

6-40. List several advantages of using the Craig tube to purify crystalline products in contrast to using the Hirsch funnel filtration method.

6-41. The stereochemistry of the more highly substituted alkenes is difficult to define using the cis and trans designations. Therefore, a more systematic manner of indicating stereochemistry in these systems has been developed that uses the *E* and *Z* nomenclature system. Draw the structures of the *E* and *Z* stereoisomers of 1,4-diphenyl-2-butene-1,4-dione used in this experiment. In this case, which is cis and which is trans?

6-42. The cis H—C═C—H in-phase out-of-plane bending frequency normally is found in the range 740–680 cm^{-1} and is broad. In addition, this vibrational mode can be quite variable in intensity. On conjugation with C═O groups, the band rises to near 820 cm^{-1}.

(a) Can you explain the underlying cause of this observation? (*Hint:* See the discussion of cis double-bond group frequencies in Chapter 8.)

(b) Can you explain why a broad band near 690 cm^{-1} assigned to this out-of-plane mode is found in the cis product obtained in this reaction?

6-43. In *trans*-1,2-dibenzoylethylene, even though the conjugated C═O group frequency coincides directly with the expected C═C stretching frequency, we would not have expected to observe the latter stretching mode in the infrared spectrum. Why?

6-44. Explain how this photochemical isomerization allows the production of the thermodynamically *less* stable cis isomer. In other words, why is the trans isomer exclusively converted to the cis isomer during short reaction periods and not vice versa? Is it possible, under these conditions, that the trans and cis isomers are in equilibrium with one another?

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The photochemical isomerization was adapted from the following references:

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Reviews on photochemical isomerization reactions may be found in the following references.

Arai, T.; Tokumaru, K. *Chem. Rev.* **1993,** *93,* 23.
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Coyle, J. D. *Introduction to Organic Photochemistry;* Wiley: New York, 1991.
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EXPERIMENT 7

The Cannizzaro Reaction with 4-Chlorobenzaldehyde: 4-Chlorobenzoic Acid and 4-Chlorobenzyl Alcohol[5]

Common name: 4-chlorobenzoic acid
CA number: [74-11-3]
CA name as indexed: 4-chlorobenzoic acid
Common name: 4-chlorobenzyl alcohol
CA number: [873-76-7]
CA name as indexed: benzenemethanol, 4-chloro-

[5]Portions of this experiment were previously published: Mayo D. W.; Butcher, S. S.; Pike R. M.; Foote, C. M.; Hotham, J. R.; Page, D. S. *J. Chem. Educ.* **1985,** *62,* 149.

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Stanislao Cannizzaro (1826–1910): This famous reaction is named for Stanislao Cannizzaro. He was born in Palermo, Italy, where he became interested in chemistry at an early age and studied with Professor Piria at the University of Pisa. He arrived in Paris after participating in the 1847 Sicilian uprising. By 1851 he had moved to Egypt where he became Professor of Chemistry at the National School of Alexandria. It was here that he discovered the reaction that carries his name. In the process he also was the first person to identify benzyl alcohol, which he obtained from the reaction of potash (KOH) with benzaldehyde. It is interesting to note that benzyl alcohol was the first alcohol of the aromatic series to be isolated and characterized. Cannizzaro devoted extensive work to the study of aromatic alcohols and he was the first to propose the term *hydroxyl* for the —OH group. Later he demonstrated the conversion of aromatic alcohols of the benzyl class into their corresponding halides and further to their phenyl acetic acid derivatives. In 1855 he moved to Genoa and in 1861 he moved back to his birthplace to become Professor of Chemistry at Palermo. Finally, 10 years later at the young age of 45, he assumed the chemistry chair at the University of Rome, which he held for 39 years! Upon his move to Rome his old political interests surfaced and he became a member of the Italian Senate that same year. He later carried the honor of serving as vice president of that august body. Cannizzaro was also honored by the Royal Society of London in 1891 when he was awarded the Copley Medal for his investigations of atomic and molecular weights. He was quick to recognize the importance of Avogadro's hypothesis and his studies played a key role in placing this hypothesis on a sound scientific basis, which ultimately was the spark that ushered chemistry into the modern era.[6]

Purpose. This experiment illustrates the simultaneous oxidation and reduction of an aromatic aldehyde to form the corresponding benzoic acid and benzyl alcohol. The experiment further demonstrates the techniques for separation of a carboxylic acid from a neutral alcohol. For a detailed discussion of this extraction procedure, see Experiment [4C].

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Separation of Acids and Bases (pp. 77–79)
Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)
Technique 6A: Thin-Layer Chromatography (pp. 97–99)
Chapter 8: Infrared Spectroscopy (pp. 539–561)

[6]See Newell, L. C. *J. Chem. Educ.* **1926,** *3,* 1361; Parravano, N. *J. Chem. Educ.,* **1927,** *4,* 836; Tilden, W. A. *J. Chem. Soc.* **1912,** 1677; *Dictionary of Scientific Biography;* Gillespie, C. C., Ed.; Scribner's: New York, 1971, Vol. III, p. 45; Surrey, A. R. *Name Reactions in Organic Chemistry;* Academic Press: New York, NY, 1954; p. 27.

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REACTION

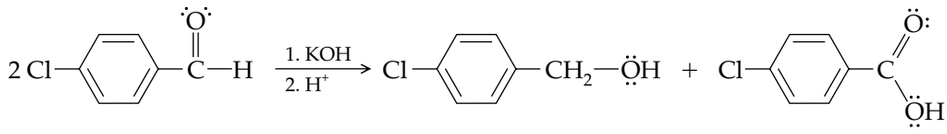

4-Chlorobenzaldehyde 4-Chlorobenzyl alcohol 4-Chlorobenzoic acid

DISCUSSION

The carbonyl group of an aldehyde represents the intermediate stage of oxidation (ox) (or reduction [red]) between an alcohol and a carboxylic acid:

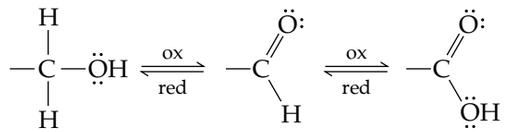

Primary alcohol Aldehyde Carboxylic acid

It is not surprising then, to find a reaction in which a specific type of aldehyde will undergo an oxidation–reduction sequence to form the corresponding alcohol and carboxylic acid. Such a reaction is the **Cannizzaro reaction.** In the presence of hydroxide ion, aldehydes that lack (acidic) *alpha (α)-hydrogen* atoms undergo a self-oxidation–reduction reaction. Thus, under the influence of strong base, one molecule of the aldehyde reduces a second molecule of aldehyde to the primary alcohol, and, in the process, is itself oxidized to the corresponding carboxylate anion. Aldehydes with α-hydrogen atoms, however, do not undergo this reaction because in the presence of base these α-cabon atoms are deprotonated. The resulting enolate generally leads to an aldol reaction (see Experiments [20] and [A3$_a$]).

The first step in the mechanism is the nucleophilic attack of the hydroxide anion on the carbonyl group of the aldehyde. This attack is followed by the key step in the reaction, the transfer of a hydrogen atom with its pair of electrons (a hydride ion) to the carbonyl group of a second molecule of aldehyde:

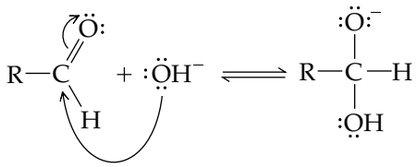

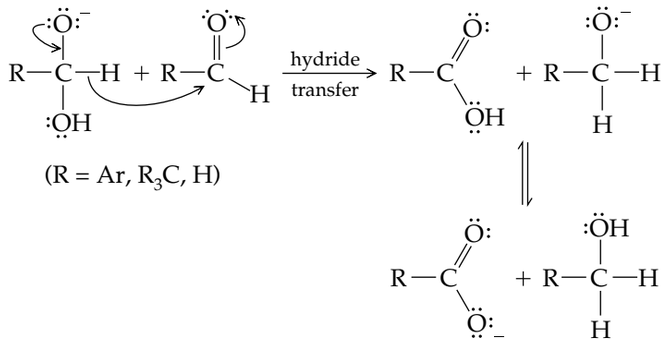

The strong electron-donating character of the negatively charged oxygen atom in the first intermediate anion greatly facilitates the ability of the aldehydic

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hydrogen to be transferred as a hydride ion, that is, *with* its pair of electrons ($:H^-$) to a second molecule of aldehyde. As seen in the preceding diagram, this nucleophilic attack on the carbon of a carbonyl group leads to the formation of a carboxylic acid and an alkoxide anion. The equilibrium established in the final step lies far to the right, and involves a fast acid–base reaction that yields both an alcohol and a carboxylate anion. *Thus, even though the Cannizzaro reaction is an equilibrium reaction, it proceeds nearly to completion.* The proposed mechanism is supported by evidence obtained by carrying out the reaction in D_2O. It was found that under these conditions the product alcohol did not contain any α-deuterium substitution. This result suggests that the transferred hydride ion must come from the aldehyde group and not from the solvent.

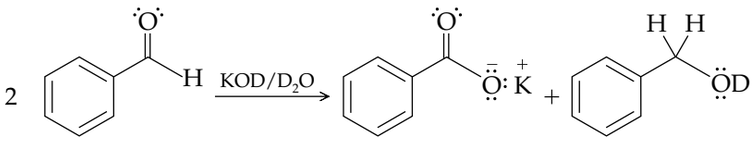

Since few aldehydes lack α-hydrogen atoms, the Cannizzaro reaction is of limited use in modern synthetic sequences, although a variation called the *crossed* Cannizzaro is occasionally used for the reduction of aromatic aldehydes. In this reaction excess formaldehyde is mixed with the aromatic aldehyde and becomes preferentially activated by base since it is present in excess. Thus, the aldehyde present to the lesser extent is reduced to the primary alcohol in high yield. For example,

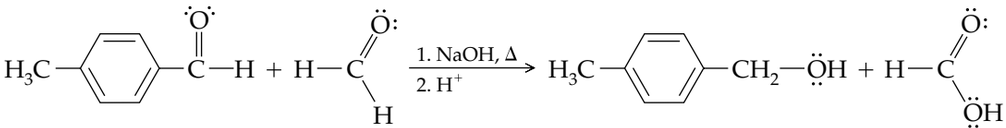

p-Methylbenzaldehyde — Formaldehyde — *p*-Methylbenzyl alcohol (90%) — Formic acid

In addition, it is known that α-ketoaldehydes undergo an internal Cannizzaro reaction to yield α-hydroxy carboxylic acids:

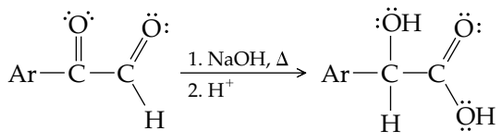

(α-Ketoaldehyde) (α-Hydroxyacid)

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: two laboratory periods.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	n_D
4-Chlorobenzaldehyde	140.57	150 mg	1.1	47.5		
Methanol	32.04	400 μL			65	1.3288
Potassium hydroxide (11 M)	56.11	550 μL	6.05			

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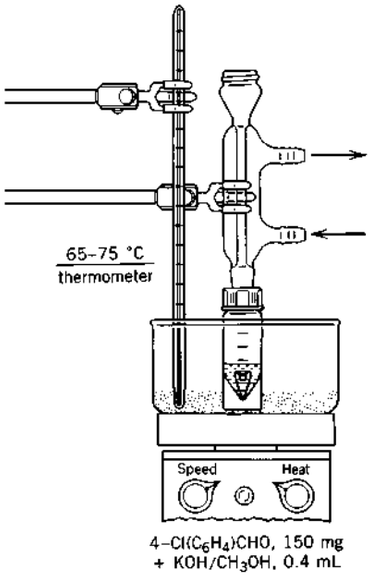

NOTE. This reaction may be carried out in a centrifuge tube containing a boiling stone. The tube should be covered by a piece of filter paper held in place by a rubber band.

Reagents and Equipment. Weigh and add to a 5.0-mL conical vial containing a magnetic spin vane and equipped with a reflux condenser, 150 mg (1.1 mmol) of 4-chlorobenzaldehyde followed by 0.4 mL of methanol (⬅). With gentle swirling, add 0.55 mL of a 11 M aqueous solution of potassium hydroxide.

NOTE. It is convenient to dispense the methanol and KOH solution using automatic delivery pipets. The glass equipment should NOT be rinsed or cleaned with acetone followed by air drying. The residual acetone undergoes an aldol reaction that forms high-boiling contaminants, which interfere with the isolation of the desired products. Also, because ***strong alkali*** *is being used in the reaction, it is important to lightly grease the ground joint of the condenser.*

CAUTION: The concentrated methanolic KOH solution is very caustic. Do not allow it to come into contact with the skin or eyes.

Reaction Conditions. Once the reaction mixture reaches the temperature range of 65–75 °C for a period of 30 min, begin monitoring the reaction progress by TLC. Using a solvent system of ethyl acetate:hexane (1:4) and visualization by a UV lamp, the R_f values of 4-chlorobenzalcohol and 4-chlorobenzoic acid are 0.4 and 0.3 respectively (R_f of 4-chlorobenzaldehyde is 0.6).

NOTE. Initially the mixture is very thick. It will not stir well until the reaction temperature is reached.

Isolation and Purification. When the reaction is complete as judged by TLC, cool the reaction mixture to room temperature and add 2.0 mL of chilled distilled water. Extract the resulting solution with three 0.5-mL portions of methylene chloride, using a Pasteur filter pipet to transfer the extracts to a 3.0-mL conical vial. On each addition of methylene chloride, cap the vial, shake gently, and then carefully vent by loosening the cap. A Vortex mixer, if available, is convenient for this extraction step. After separation of the layers, remove the lower methylene chloride layer using a Pasteur filter pipet.

IMPORTANT. Save both the alkaline and methylene chloride phases for further workup.

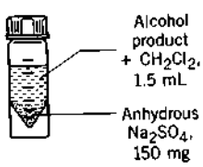

1. 4-Chlorobenzyl alcohol. Wash the combined methylene chloride extracts with two 0.25-mL portions of saturated sodium bicarbonate solution followed by one 0.5-mL portion of distilled water. Remove the aqueous upper phase (Pasteur filter pipet) used in each washing step and save this combined material in a separate 10-mL Erlenmeyer flask. (*This material will be discarded at the end of the experiment [see Rule 10 for the Microscale Laboratory, Chapter 1, p. 4.]*) Dry the methylene chloride layer over 150 mg of granular anhydrous sodium sulfate (⬅).

After drying the solution, transfer it by use of a Pasteur filter pipet to a tared 3.0-mL conical vial. Be particularly careful not to let any granules of the hydrated sodium sulfate adhere to the surface of the pipet and become transferred with the dried organic phase. Rinse the sodium sulfate drying agent with 0.3 mL of fresh methylene chloride, and combine the rinse with the dried organic phase. Evaporate the methylene chloride using a stream of dry nitrogen

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gas in a warm sand bath in the **hood.** If formation of the alcohol took place during the reaction, crude 4-chlorobenzyl alcohol will remain in the vial following removal of the solvent. HOOD

To purify the crude alcohol, recrystallize the residue using a solution of 4% acetone in hexane (0.25 mL). Collect the product under reduced pressure using a Hirsch funnel, and wash the filter cake (*product crystals packed on the funnel are often referred to as filter cake*) with 0.2 mL of ice cold hexane to give the desired 4-chlorobenzyl alcohol. Air-dry the product on a porous clay plate or on filter paper.

Weigh the 4-chlorobenzyl alcohol and calculate the percent yield. Determine the melting point and compare your value with that found in the literature. Obtain the IR spectrum and compare it with that in Figure 6.16.

This point in the procedure is a logical place to divide the experiment into two laboratory sessions, if this seems appropriate. A second melting point may be obtained at the beginning of the next laboratory period after the sample of aromatic

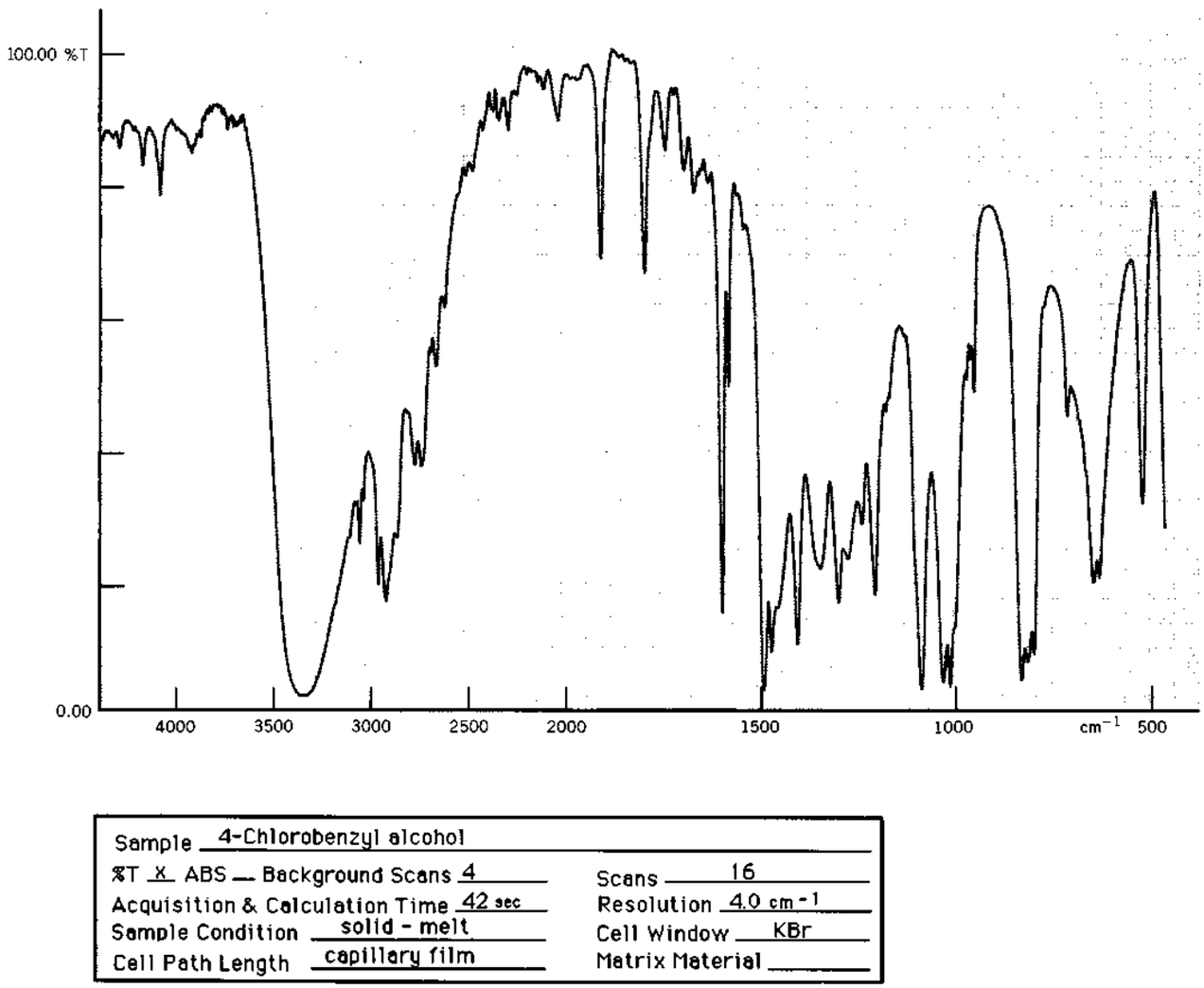

Figure 6.16 IR spectrum: 4-chlorobenzyl alcohol.

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alcohol has had additional time to air dry. A convenient way to let the sample dry for several days is to transfer the crystals from the porous plate and spread them over the bottom of a small Erlenmeyer flask (either 5 or 10 mL). Then, cover the mouth of the flask with filter paper held in place by a rubber band. This procedure will allow the last traces of moisture and solvent to evaporate, and at the same time protect the sample from dirt and dust particles. This is a good technique for drying most crystalline samples. If moisture is a particularly difficult problem, the sample stored in this fashion can be placed in a desiccator in the presence of a hygroscopic material, such as calcium chloride.

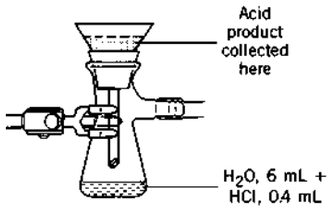

2. 4-Chlorobenzoic acid. Dilute the alkaline phase, obtained and saved during the original extraction procedure, by adding 2.0 mL of water. The dilute aqueous phase is then acidified by the addition of 0.4 mL of concentrated hydrochloric acid. Collect the voluminous white precipitate of the product that forms on addition of the acid, under reduced pressure by use of a Hirsch funnel. Rinse the filter cake with 2.0 mL of distilled water (⬅).

NOTE. It is advisable to check the pH of the solution to insure that it is acidic. Blue litmus or pH paper may be used. Remove a small drop of solution using a glass stirring rod and touch the rod to the paper. ***Never*** *place the paper into the reaction solution.*

Air dry the solid product on a porous clay plate or on filter paper to obtain the crude 4-chlorobenzoic acid product. If a white precipitate is not obtained upon acidification, add a small amount of a saturated sodium chloride solution (salting out technique [see Technique 4, p. 79]) to aid the process.

To purify the crude acid, recrystallize with methanol in a Craig tube. Weigh the dried material and calculate the percent yield. Determine the melting point and compare your value to that found in the literature. Obtain the IR spectrum in a potassium bromide disk and compare your spectrum with that in Figure 6.17.

Infared Analysis. The molecule is 4-chlorobenzaldehyde. The infrared spectrum of this aromatic aldehyde (Fig. 6.18, page 182) is rich and interesting. The aromatic aldehyde macro group frequency train (see Strategies for Interpreting Infrared Spectra) consists of peaks near 3090, 3070, 2830 and 2750, 1706, 1602, 1589, and 1396 cm^{-1}.

a. 3070 cm^{-1}: a C—H stretch on sp^2 carbon

b. 2840 and 2740 cm^{-1}: This pair of bands is a famous example of powerful Fermi coupling (see Chapter 8 and IR discussions). The unperturbed C—H stretching of the aldehyde C—H group would be expected to occur near 2790 cm^{-1} (the C—H stretch on an sp^2 carbon would have been expected to be found at higher values, but the oxygen system in this case significantly lowers the observed values). The in-plane bending mode of this C—H group occurs at 1390 cm^{-1}. Thus, the first harmonic should fall near 2780 cm^{-1}, very close (~10 cm^{-1}) to the stretching frequency of this oscillator. The essential conditions are, therefore, satisfied and strong Fermi coupling occurs and gives rise to the split peaks at 2840 and 2740 cm^{-1}. The latter band is moved well away from the normal sp^3 C—H symmetric stretching modes. Thus, the lower

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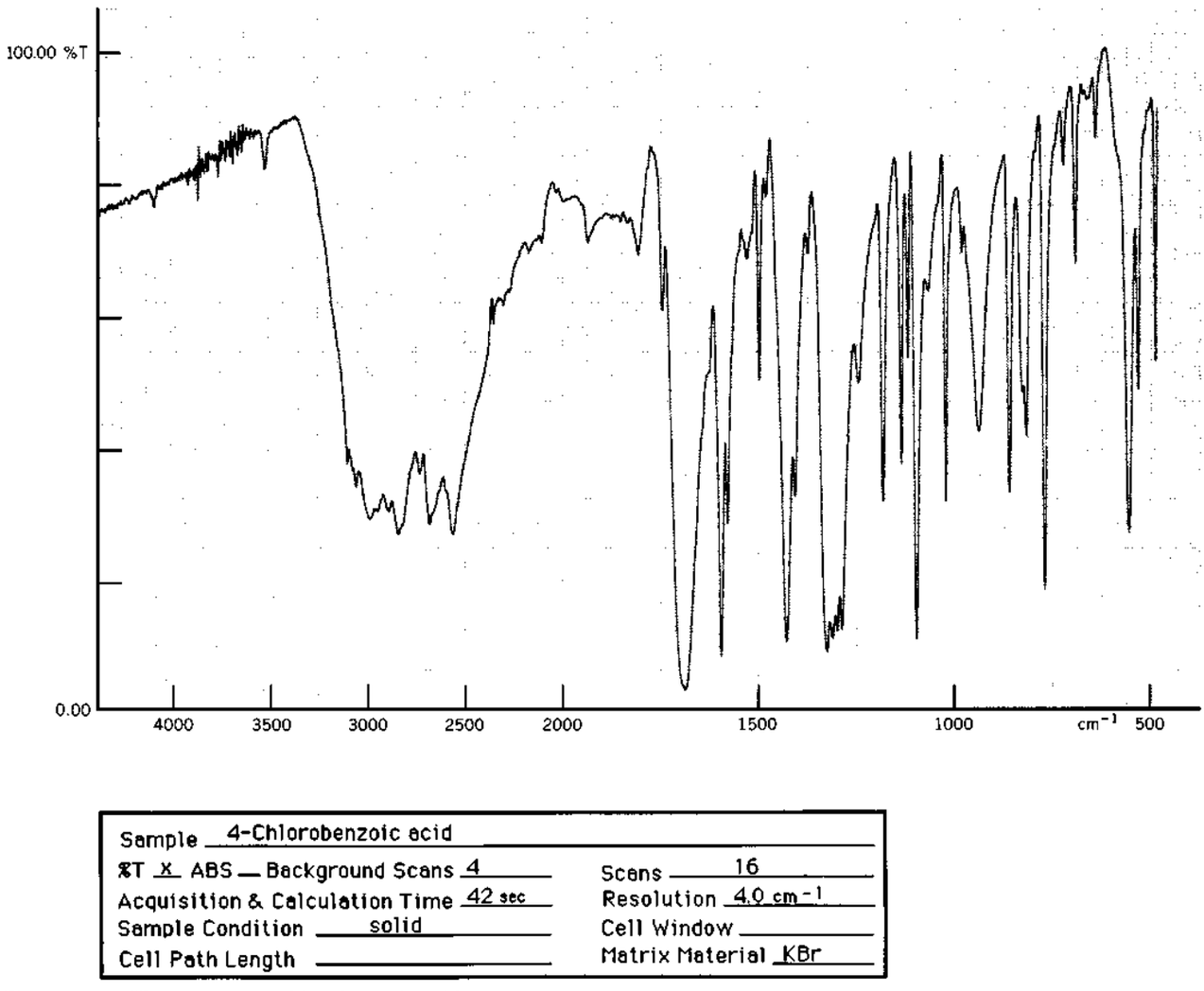

Figure 6.17 IR spectrum: 4-chlorobenzoic acid.

wavenumber component of the Fermi-coupled aldehyde C—H mode leads to easy identification of an aldehyde, even when it represents a very small fraction of an aliphatic system. In the present case where no aliphatic C—H oscillators are present, both components are observed.

c. 1704 cm^{-1}: The carbonyl stretch of the aldehyde group. The frequency observed in aliphatic aldehydes falls in the range 1735–1720 cm^{-1}, but when conjugated, the value drops 15–25 cm^{-1} (see Chapter 8 and online IR discussions) and is found in the range 1720–1700 cm^{-1}.

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d. 1601 and 1578 cm^{-1}: This pair of bands is related to the degenerate ring stretching vibrations v_{8a} and v_{8b} of benzene (see also Infrared discussions in Experiment [$1B_{adv}$]).

e. 1390 cm^{-1}: The aldehyde C—H in-plane bending vibration. The first harmonic of this vibration is Fermi coupled to the aldehyde C—H stretching mode, as discussed earlier.

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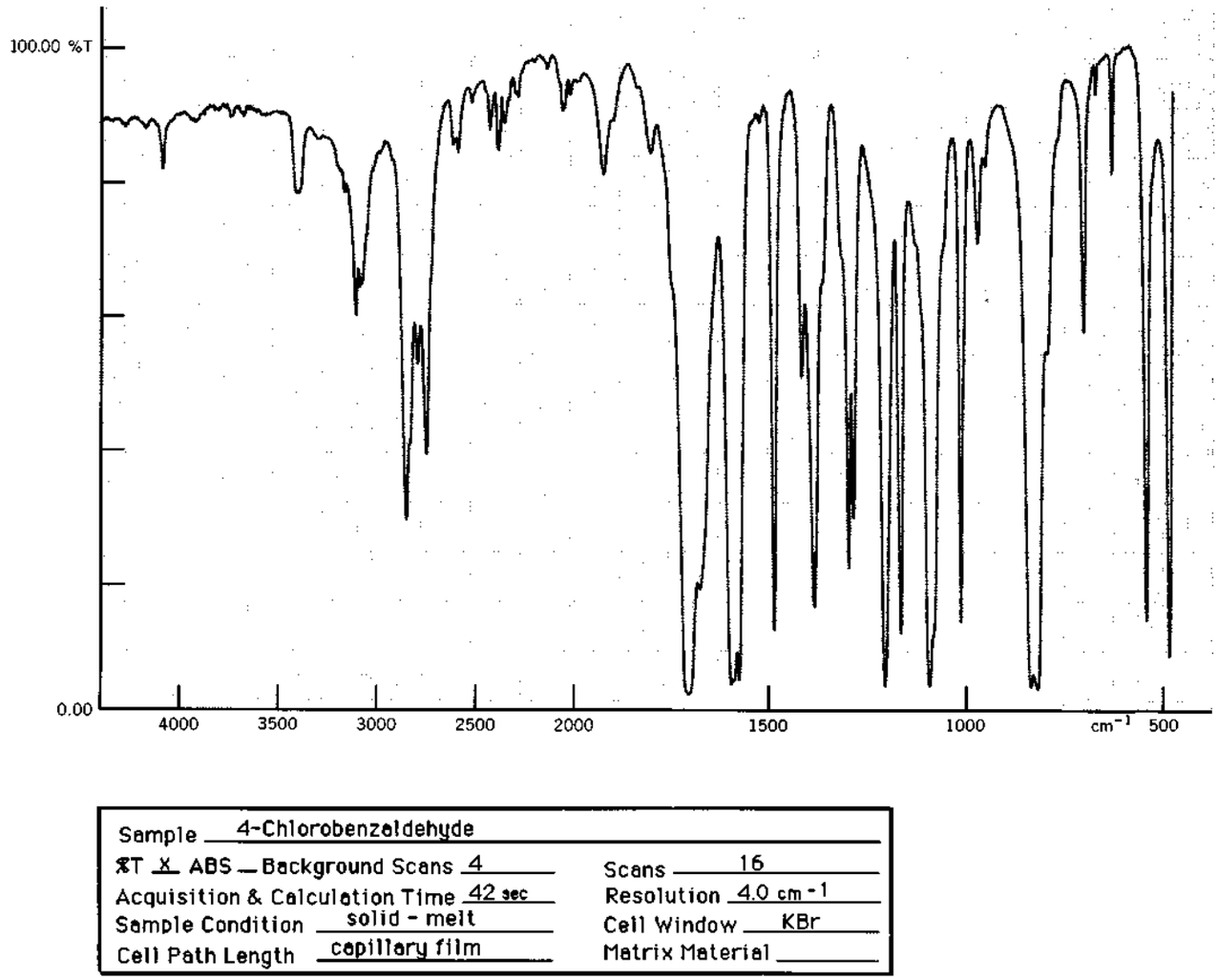

Figure 6.18 IR spectrum: 4-chlorobenzaldehyde.

This compound also possesses a second powerful macro group frequency train that assesses the substitution pattern of the aromatic ring system (see Chapter 8, IR discussions). The para-disubstituted benzene ring macro group frequency train requires peaks in the following regions: 1950, 1880, 1800, 1730, 750, and 690 cm^{-1}.

a. 1905, 1795 cm^{-1}: This pair of weak bands, with the higher wavenumber band more intense than the lower member, arises from combination bands (see Chapter 8, IR discussions) which involve the out-of-plane bending frequencies of the ring C—H bonds (see below). The exact wavenumber positions are not very important, but the overall shape of the pattern can be used to determine the ring substitution pattern (see Chapter 8 and online IR discussions).

b. 832 cm^{-1}: This strong band is very characteristic of para-disubstituted benzene rings. The 832-cm^{-1} peak arises from the in-phase out-of-plane bending vibration of the two pairs of C—H groups on opposite sides of the six-membered ring (see Chapter 8, and online IR discussions).

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The C—Cl stretching mode when substituted on an aromatic ring often becomes heavily coupled with ring vibrations and, as in this case, does not give rise to an identifiable group frequency. The presence of this group must be determined by other methods, such as a Beilstein or sodium fusion test (see Chapter 9, pp. 634–638). The presence of a hidden group (very likely halogen), however, is strongly indicated. Because the system must be para substituted (see above paragraphs), one of the substituents on the ring must exhibit very little identifiable absorption from 4000 to 500 cm^{-1}.

The reaction involves the formation of two products, one neutral and one acidic, both of which incorporate large portions of the substrate molecule. These materials can be characterized by their IR spectra. The neutral product is proposed to be 4-chlorobenzyl alcohol. An examination of the spectrum (Fig. 6.16) supports the presence of two macro group frequency trains. One (a) is the same one found in the starting aldehyde, the para-disubstituted benzene ring frequency train. The other (b) is a primary aliphatic alcohol macro frequency train. Macro (a) has been expanded to include all aromatic ring-specific group frequencies, as the alcoholic side chain is decoupled from the ring and the carbon–chlorine frequencies fall outside the range of the instrumentation normally used in these measurements.

The macro group frequencies for 4-chlorobenzyl alcohol are as follows:

a. 3055 (aromatic C—H stretch), 1906 and 1793 (para combination band pattern), 1596 and 1583 (ring stretch degenerate pair, ν_{8a} and ν_{8b}; 1583 intensity indicates weak conjugation with the ring), 1495 and 1475 (ring stretch degenerate pair, ν_{19a} and ν_{19b}), 834 (C—H, out-of-plane bend) cm^{-1}.

b. 3340 (broad, O—H stretch), 2965–2925 (C—H, aliphatic sp^3), 1450–1300 (broad, O—H bend, associated), 1015 (C—O, stretch, primary alcohol), 630 (broad, weak O—H bend, associated) cm^{-1}.

The acidic product generated in the reaction is assumed to be 4-chlorobenzoic acid. This material also is a para-substituted aromatic compound; thus, the spectrum of this compound (Fig. 6.17) possesses a macro frequency train (a), similar to those of the aldehyde and alcohol. In addition, this benzoic acid derivative exhibits an extended aromatic acid macro group frequency train (b). The macro frequencies are as follows:

a. 1935 and 1795 (para combination band pattern), 852 (ring C—H, in-phase, out-of-plane bend) cm^{-1}.

b. 340–2200 (very broad, very strong, O—H stretch, associated acid), 1683 (C—O, stretch, out-of-phase, associated acid dimer), 1596 and 1578 (degenerate ring stretch), 1500 and 1432 (degenerate ring stretch), 1320–1280 (C—O, stretch), 885 (O—H, out-of-plane, ring dimer bend)cm^{-1}.

The carbon–chlorine stretch is not observed.

Examine the spectra of the reaction products you have obtained, in a potassium bromide matrix. Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 6.16–6.18).

It is a useful exercise to compare the results of organic qualitative analysis reaction tests, which were used historically to classify the preceding compounds, with the data now available from modern spectroscopic instrumentation.

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Chemical Tests. Perform each of the following tests (see Chapter 9). Do the results confirm that you have isolated an aromatic carboxylic acid and an aromatic alcohol?

1. The ignition test.
2. The Beilstein or the sodium fusion test for the presence of halogen.
3. The ceric nitrate and/or the Jones oxidation test for the alcohol.
4. The solubility of the acid in sodium bicarbonate and sodium hydroxide solutions. Is carbon dioxide evolved in the bicarbonate test?

If you were to prepare a derivative for the alcohol and acid products, which one would you choose? See Chapter 9, Preparation of Derivatives.

Experiment 7-1*

4-Chlorobenzoic Acid and 4-Chlorobenzyl Alcohol: Preparation Using a Monomode Microwave Apparatus

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	n_D
4-Chlorobenzaldehyde	140.57	150 mg	1.1	47		
Methanol	32.04	0.4 mL			65	1.3288
Potassium hydroxide (11 M)	56.11	0.4 mL				

Reagents and Equipment. This experiment is designed for use in the CEM Discover and Biotage Initator microwave units.

In a 10.0-mL glass microwave reaction vessel containing a magnetic stir bar, place 150 mg (1.1 mmol) of 4-chlorobenzaldehyde followed by 0.4 mL of methanol. With gentle swirling, add 0.4 mL of an 11 M aqueous solution of potassium hydroxide.

HOOD

CAUTION: Dispense liquid reagents in the **hood** using automatic delivery pipets. Concentrated methanolic potassium hydroxide is *highly caustic*. Since the reaction requires heating reagents to above their boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

Reaction Conditions. Place the reaction vessel in the microwave cavity and, depending on the equipment used, position the pressure device on top. Program the microwave unit to heat the reaction mixture to 120 °C using no more that 50 W of microwave power, and hold at this temperature for 1 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the tube from the microwave unit.

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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Isolation of Product. Add 2.0 mL of cold distilled water to the reaction vessel. Swirl or stir on a stirplate to dissolve the solid material. Transfer the reaction mixture with a Pasteur pipet into a 5.0-mL conical vial. Rinse the microwave reaction vessel with 0.5 mL of dichloromethane and add the washings to the conical vial. Cap the vial, shake gently, and then carefully vent by loosening the cap. After allowing separation of the layers, transfer the bottom (organic) layer to a 3.0-mL conical vial with a Pasteur filter pipet. Extract the aqueous solution in the 5-mL conical vial with two additional 0.5 mL portions of dichloromethane. After each addition carefully cap the vial, shake gently, and vent the solution by loosening the cap. On each occasion, transfer the bottom (organic) layer to the 3.0-mL conical vial with a Pasteur filter pipet. At the end of the extractions, label the 5.0-mL conical vial containing the aqueous alkaline layer "alkaline phase." This phase will be used later in the experiment.

IMPORTANT. Save both the aqueous and dichloromethane layers for further workup.

The remainder of the work-up for the two products is the same as for Experiment 7 (pp. 176–184).

4-Chlorobenzoic Acid and 4-Chlorobenzyl Alcohol: Preparation Using a Multimode Microwave Apparatus

Experiment 7-2*

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	n_D
4-Chlorobenzaldehyde	140.57	465 mg	3.3	47		
Methanol	32.04	2.5 mL			65	1.3288
Potassium hydroxide (11 M)	56.11	2.5 mL				

Reagents and Equipment. This experiment is designed for use in the CEM MARS, Milestone START, and Anton Paar Synthos 3000 microwave units. When using the Anton Paar Synthos 3000 unit with the 24-position silicon carbide plate rotor containing glass vials, the reagent and solvent quantities cited in the monomode procedure should be used in conjunction with the reaction conditions here in the multimode procedure.

In a microwave reaction vessel containing a magnetic stir bar, place 465 mg (3.3 mmol) of *p*-chlorobenzaldehyde and 2.5 mL of methanol. With stirring, slowly add 2.5 mL of an 11 M aqueous solution of potassium hydroxide. Cap the vessel with the microwave pressure cap and adjust the tightness to the manufacturer-specified level. Place the sealed vessel into its outer protective jacket.

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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EQA

HOOD

CAUTION: Dispense liquid reagents in the **hood** using automatic delivery pipets. Concentrated methanolic potassium hydroxide is *highly caustic*. Since the reaction requires heating reagents to above their boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

Reaction Conditions. Insert the loaded vessels into the reaction carousel ensuring they are evenly spaced and then place the carousel into the microwave cavity. If provided by the manufacturer, connect a temperature probe to the control vessel. Program the microwave unit to heat the reaction vessels to 120 °C and hold at this temperature for 1 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the carousel from the microwave unit.

Isolation or Product. Add 5 mL of distilled water to the reaction vessel to dissolve any solids, transfer the solution to a 60-mL separatory funnel, and clamp the funnel to a ring stand. Rinse the microwave reaction vessel with an additional 5 mL of distilled water and add it to the separatory funnel. Extract the alkaline solution with three 3.0-mL portions of dichloromethane. After each addition of dichloromethane carefully cap and invert the funnel. Immediately vent the funnel by opening the stopcock. Close the stopcock, mix the two layers several times by inverting the funnel, repeatedly vent, and then place the funnel back on the ring stand and remove the stopper. Drain the lower (organic) layer into a 25-mL Erlenmeyer flask after each extraction. At the end of the extractions, pipet the alkaline layer into a separate 25-mL Erlenmeyer flask and label it "alkaline phase." (*This phase will be used in part 2.*)

IMPORTANT. Save both the aqueous and organic layers for further workup.

1. 4-chlorobenzyl alcohol. Pipet the organic layer back into the separatory funnel. Wash the combined organic layers with two 5-mL portions of saturated sodium bicarbonate solution. Remove the lower (organic) layer by draining it through the stopcock into a 25-mL Erlenmeyer flask and pipet the remaining aqueous phase into a 25-mL Erlenmeyer flask after each washing. Save the aqueous waste until the experiment is complete and then discard as directed. Return the organic layer to the separatory funnel by pipet. Wash the organic layer once with 5 mL of distilled water. Dry the lower (organic) layer by draining it into a clean 25-mL Erlenmeyer flask containing 200 mg of anhydrous sodium sulfate. Transfer the anhydrous dichloromethane solution, using a Pasteur filter pipet, to a clean tared 10-mL pear-shaped flask. Remove the dichloromethane on a rotary evaporator or

HOOD by evaporation in the **hood** using a gentle stream of nitrogen gas with warming in a sand bath. A white precipitate will remain in the flask. Reweigh the flask plus product and calculate the crude yield.

To further purify the crude alcohol, recrystallize the residue using a solution of 4% acetone in hexane (0.75 mL). Collect the product under reduced pressure using a Hirsch funnel, and wash the filter cake with 0.5 mL of ice cold hexanes. Air-dry the product on a porous clay plate.

Weigh the 4-chlorobenzyl alcohol and calculate the % yield. Determine the melting point of the product and compare it to the literature value. Obtain the IR spectrum and compare it with that in Figure 6.16.

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2. 4-chlorobenzoic acid. Cool the "alkaline phase" in an ice bath and add dropwise 4 mL of 6M aqueous hydrochloric acid. A white precipitate of the product will form. Allow the solution to chill for a further 10 minutes and then collect the product under reduced pressure using a Hirsch funnel. Rinse the filter cake with 2.0 mL of cold distilled water.

Air dry the solid on a porous clay plate or on filter paper to obtain the crude 4-chlorobenzoic acid. If the product is very pasty it may be left to dry overnight. The product can be further purified by recrystallization with methanol. Weigh the dried material and calculate the % yield. Determine the melting point of your product and compare your value to the literature value. Obtain the IR spectrum and compare it to the spectrum given in Figure 6.17.

QUESTIONS

6-45. The discussion mentions that the crossed Cannizzaro reaction can be realized when one of the components is formaldehyde. Predict the product(s) of the reaction below and give a suitable name to the reactants and products.

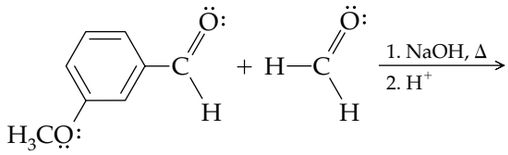

6-46. One group of investigators has suggested that a dianion might be the source of hydride in the Cannizzaro reaction. Explain why this species would be a better source of hydride than the species in the mechanism presented in the discussion.

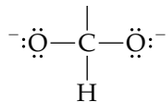

6-47. The Cannizzaro reaction is an oxidation–reduction sequence. What type of reagent is formaldehyde acting as in Question 6.45?

6-48. Propose a mechanism for the internal Cannizzaro reaction depicted below.

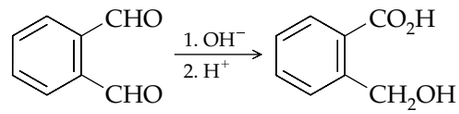

o-Phthalaldehyde — *o*-(Hydroxymethyl) benzoic acid

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Esteb, J. J.; O'Reilly, S.; Richter, J. M. *J. Chem. Educ.* **2004,** *81,* 1794.
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EXPERIMENT 8

The Esterification Reaction: Ethyl Laurate, Isopentyl Acetate, and the Use of Acidic Resins

Common names: ethyl laurate, ethyl dodecanoate
CA number: [106-33-2]
CA name as indexed: dodecanoic acid, ethyl ester

Common names: isopentyl acetate, isoamyl acetate
CA number: [123-92-2]
CA name as indexed: 1-butanol, 3-methyl-, acetate

Common name: butyl acetate
CA number: [123-86-4]
CA name as indexed: acetic acid, butyl ester

Common names: pentyl acetate, amyl acetate
CA number: [628-63-7]
CA name as indexed: acetic acid, pentyl ester

Common name: hexyl acetate
CA number: [142-92-7]
CA name as indexed: acetic acid, hexyl ester

Common name: octyl acetate
CA number: [112-14-1]
CA name as indexed: acetic acid, octyl ester

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)

Technique 6A: Chromatography
Packing the Column (p. 93)
Elution of the Column (p. 94)

Purpose. This exercise explores the classic reactions of carboxylic acids (RCO_2H) with alcohols (R′OH), in the presence of acid catalyst, to yield esters (RCO_2R') plus water (H_2O, a small stable molecule). The physical properties of these esterification products are examined and the techniques of distillation and column chromatography are applied to the purification of these materials.

REACTION

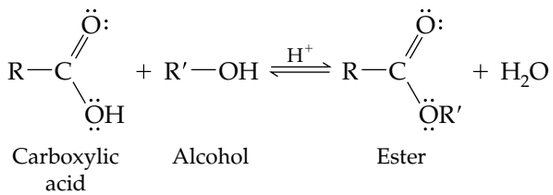

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DISCUSSION

Esters are among the most important of the carboxylic acid (and alcohol) derivatives. Substances possessing this functional group are widely distributed in nature in the form of waxes, essential oils, fatty acid esters, and aromas. The ester functionality plays a significant role in biochemistry, both in primary metabolism and in a variety of substances exhibiting remarkable physiological activity in humans (hormones and neurotransmitters). Esters find extensive use in commercial products from fingernail polish remover and artificial sweeteners, to polymeric fibers, plasticizers, and surfactants.

Biosynthesis of Esters. Fatty acids are naturally occurring, long, straight-chain, C_{12}–C_{40} carboxylic acids; most contain an even number of carbon atoms.Their biosynthesis provides an important and interesting example of a primary metabolic pathway in which a special type of ester is the essential link between the enzyme and the substrate (acetic acid). The enzyme-bound substrate grows by repeated addition of two-carbon (C_2) units and, when eventually released from the enzyme, has undergone an extension of the fatty acid hydrocarbon chain.

The first step in fatty acid biosynthesis involves the formation of a thiol ester, acetyl coenzyme A (acetyl CoA), from acetic acid (present in the primary metabolic pool) and the thiol group (mercapto, or —SH group) of the coenzyme (HSCoA). A thiol ester is an ester in which the single-bonded oxygen (from the alcohol component) is replaced by a sulfur atom,

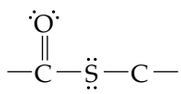

from the coenzyme. Coenzymes are loosely bound, nonprotein factors attached to the enzyme that play an important role in the catalytic function of the enzyme. These coenzymes are distinguished, in an ill-defined manner, from prosthetic groups, which are intimately attached to active sites of enzymes. Part of the role of the CoA is to facilitate the transfer of the substrate (the C_2 unit) to a new thiol group of the enzyme (protein), where the next stage of the biosynthesis takes place:

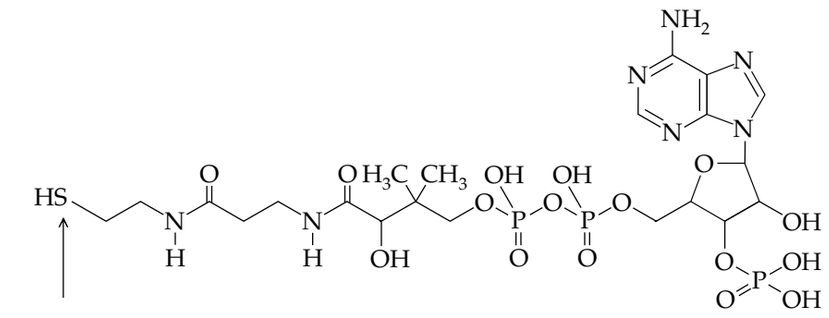

Thiol group

Coenzyme A (HSCoA)

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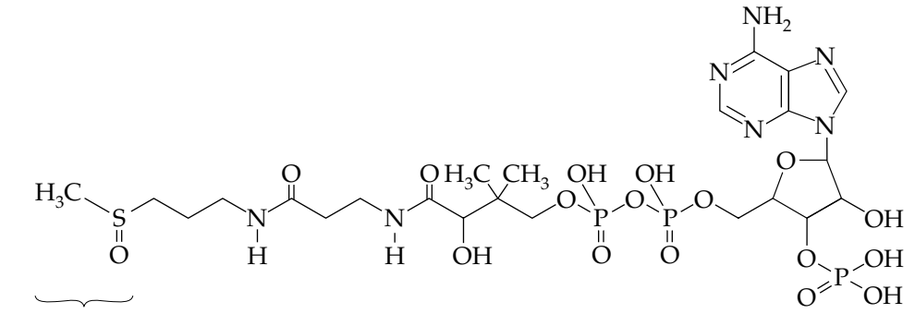

This reactive thiol ester is capable of undergoing aldol-type (see Experiment [20]) condensations under physiological conditions. AcetylCoA is first carboxylated with the help of the enzyme, acetyl CoA-carboxylase, to yield a thiolmalonyl derivative. The resulting intermediate possesses an activated methylene group

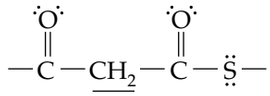

which with further enzymatic support undergoes a Claisen condensation (see Experiment [$3A_{adv}$]) with an acetyl group that has been also transferred via acetyl CoA to an appropriate acyl-carrier protein, fatty acid synthetase. Reduction, dehydration, further reduction, and finally hydrolysis of the thiol ester, yields the fatty acid extended by a C_2 hydrocarbon group.

www

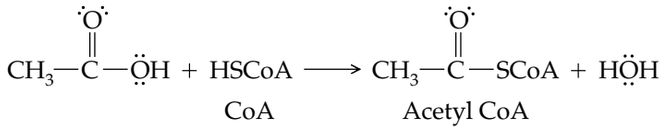

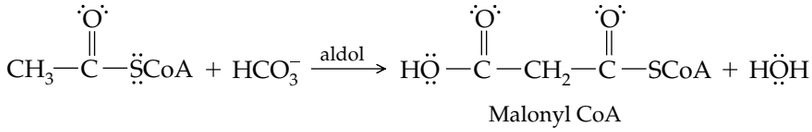

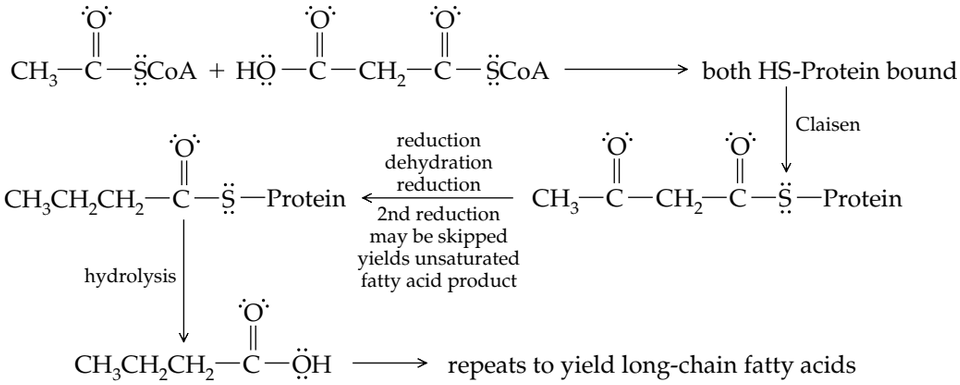

LIPIDS

Oils, Fats, Waxes, and Aromas. Fatty acids derived from primary metabolism play a key role in the formation of naturally occurring oils, fats, and waxes. Fats and oils are esters of these acids with a triol, glycerol ($HOCH_2CHOHCH_2OH$).

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EQA

The common fats and oils are formed from mixtures of C_4–C_{26} saturated fatty acids with the vast majority derived from C_{12}–C_{18} acids. The oils are more likely to include significant contributions from mixtures of unsaturated fatty acids.

Since fats and oils are triesters of glycerol, they are generally called *triglycerides*. In plants and animals, triglycerides function as energy reserves that can be used in primary metabolism when food (energy) is not available to the organism.

Although the fats have high molecular weights, they are generally found to be very low-melting solids, particularly if they contain unsaturated fatty acids. The bent chains, which result from incorporating cis-alkene (C═C) groups into the chain, prevent close packing in a solid and, as a result, such molecules exhibit lower melting points. For example, compare oleic acid ($C_{18}H_{34}O_2$, mp 4 °C) to its saturated analog, stearic acid($C_{18}H_{36}O_2$, mp 69–70 °C). The former melts more than 60 °C lower because of the cis carbon–carbon double bond.

Oleic acid is the simplest of the unsaturated C_{18} fatty acids, because it has a single C═C group located in the middle of the chain. This unsaturated fatty acid is the most widely distributed of all fatty acids. It is the dominant component (76–86%) of the triglycerides in olive oil. Highly saturated fats, on the other hand, are generally solids at room temperature because the straight-chain fatty acids pack together well (see Fig. 6.19 on next page).

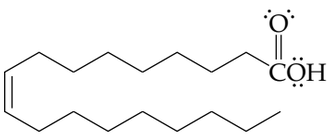

Oleic acid
[(Z)-9-Octadecenoic acid]

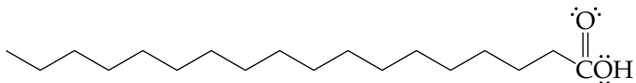

Stearic acid
[Octadecanoic acid]

Many vegetable and fish oils are liquid triglycerides. Because these organisms operate at ambient temperatures, evolution dictated that low-melting fats were required to avoid solidification. In warm-blooded animals, higher melting fats can be tolerated and are used.

The cheap and plentiful unsaturated oils can be converted to solid fats by hydrogenation of the alkene groups, which gives straight-chain alkyl groups. As consumers historically have desired to cook with solid, white, and creamy fats (such as lard) derived from animal triglycerides (low in unsaturation), hydrogenation of vegetable oils, such as peanut, soybean, and cottonseed oils, has been carried out on a large scale (this process is referred to as **hardening** the fat).

Unfortunately, the relationship between saturated fats in the human diet and the formation of cholesterol (a simple lipid, see below) plaque and coronary heart disease has been established. The dietary switch to less saturated fats is currently underway.

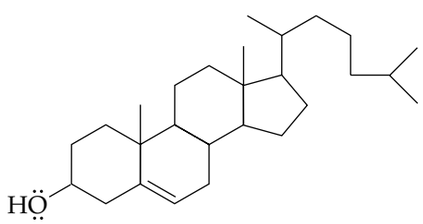

Cholesterol

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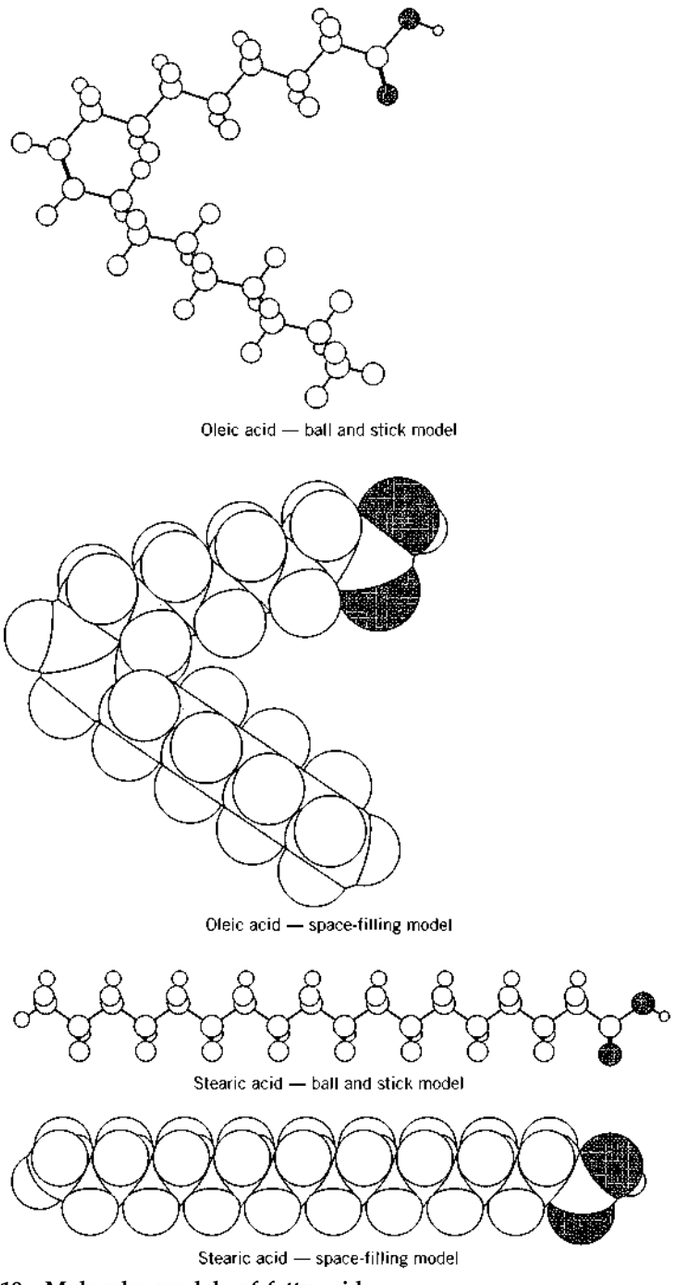

Figure 6.19 Molecular models of fatty acids.

The triglycerides obtained from animal fats have been used for a very long time as a source of soap. When fats are boiled with lye (sodium hydroxide) the ester linkages are cleaved by a process known as *saponification* (the term originates from the Latin word for soap, *sapon*, as does the modern French word for soap, *savon*) to yield the sodium salt of the fatty acid and the esterifying alcohol (glycerol).

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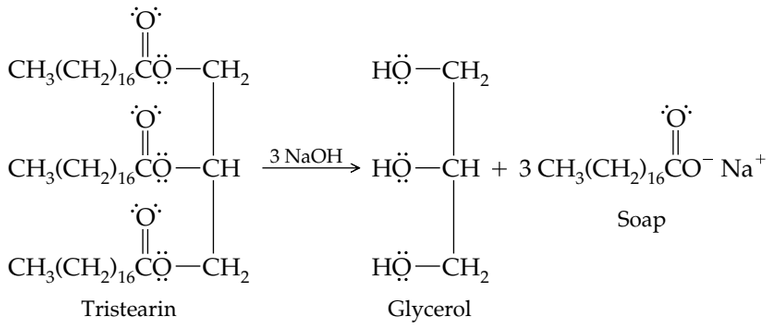

Saponification of a triglyceride found in animal fat

Salts of fatty acids function effectively as soaps because one end of the straight-chain system has the highly polar carboxylate ion and is readily solvated in water. The rest of the fatty acid molecule has all the characteristics of a nonpolar hydrocarbon and readily dissolves in hydrocarbons, such as greases and oils. We refer to the polar end (head) as being hydrophilic (attracted to water) and the hydrocarbon end (tail) as being lipophilic (attracted to oils). When dispersed in an aqueous solution, fatty acids tend to form micelles (spherical clusters of molecules). The lipophilic ends of the fatty acids occupy the interior of the cluster, while the polar ends, which are heavily solvated by water molecules, form the outer surface of the spherical micelle. Micelles absorb the hydrocarbon chains of the triglycerides, and thus soaps break up and help to dissolve the fats and oils that tend to coat skin, clothes, and the surfaces of eating and cooking utensils (see Figs. 6.20 and 6.21).

Waxes are naturally occurring esters of fatty acids (in waxes, chain lengths can reach as high as C_{36}) and a variety of other alcohols that often possess relatively complicated structures (steroid alcohols) and/or long chains. For example, *n*-octacosanol, $CH_3(CH_2)_{26}CH_2OH$, has been isolated from the esters in wheat

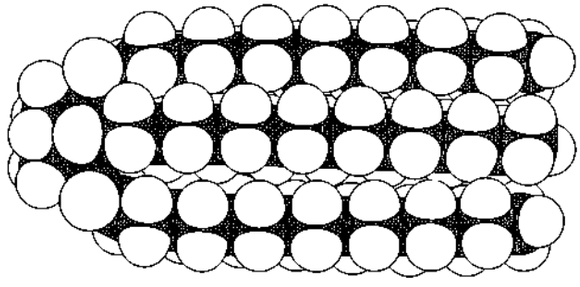

A space-filling model of a saturated triglyceride

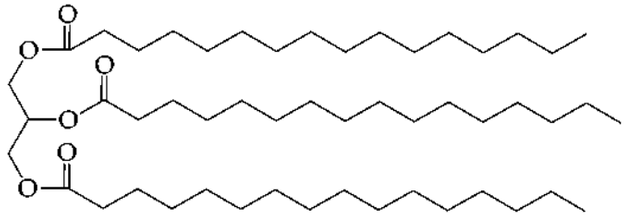

A saturated triglyceride

Figure 6.20 A space-filling model of a saturated triglyceride.

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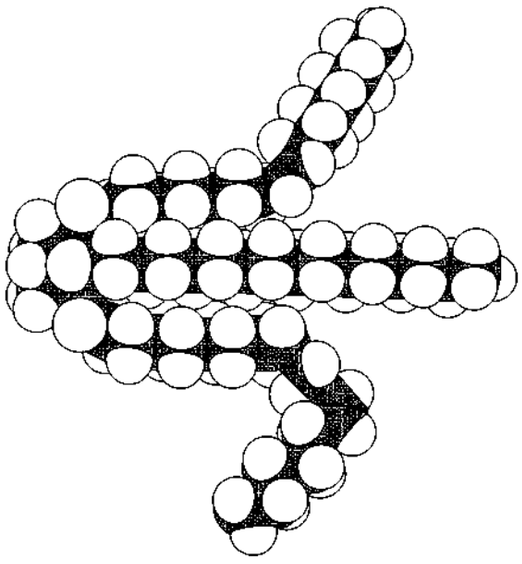

A space-filling model of an unsaturated triglyceride.

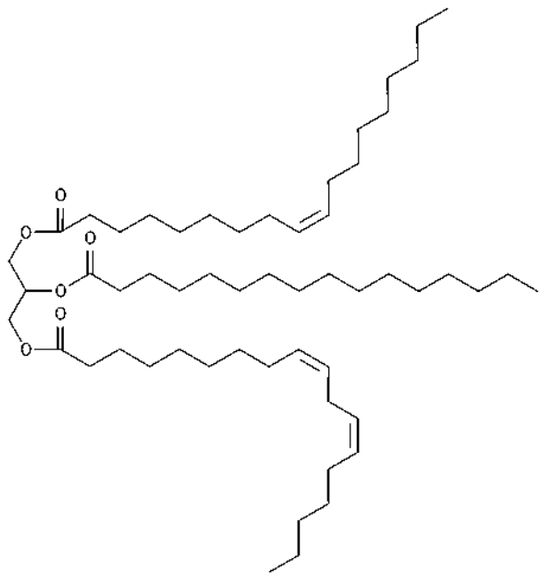

An unsaturated triglyceride

Figure 6.21 A space-filling model of an unsaturated triglyceride.

waxes, and a component of carnauba wax (traditionally an automobile wax) has 62 carbons, $CH_3(CH_2)_{33}CO_2(CH_2)_{26}CH_3$. The biological role of carnauba wax is as a leaf coating involved in the conservation of plant moisture. Animal waxes include cetyl palmitate (spermaceti) found in sperm whales and beeswax (one constituent of which has been identified as $CH_3(CH_2)_{29}CO_2(CH_2)_{29}CH_3$, which is used in the construction of the honeycomb).

Lower molecular weight, naturally occurring esters make major contributions to the pleasant aromas of fruits and flowers. These odors have been shown to be composed generally of complex mixtures of materials that have been separated only since the development of modern chemical instrumentation. Single components, however, may play a dominant role

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in an individual plant or animal. Propyl acetate (pears), ethyl butyrate (pineapples), and 3-methylbutyl acetate (bananas) are examples of simple esters responsible for a particular plant odor. Odors derived from esters are not limited just to esters of straight-chain carboxylic acids, as is demonstrated by oil of wintergreen, methyl salicylate:

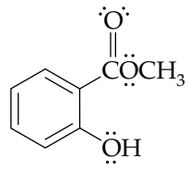

Oil of wintergreen

Phospholipids. *Lipid* is a term applied to those natural substances that are more soluble in nonpolar solvents than in water. In its most general sense, it is a broad definition that includes fats, waxes, hydrocarbons, and so on. In biochemistry, lipids are more narrowly defined as substances that yield fatty acids upon hydrolysis.

Another class of glycerides are those substances in which one of the fatty acid groups has been replaced by a phosphoric acid residue: the phospholipids, or more accurately, the phosphoglycerides. The phosphate group is almost always further esterified, usually with a biological amino alcohol, such as choline (the lecithins) or ethanolamine (the cephalins):

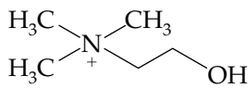

Choline

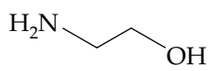

Ethanolamine

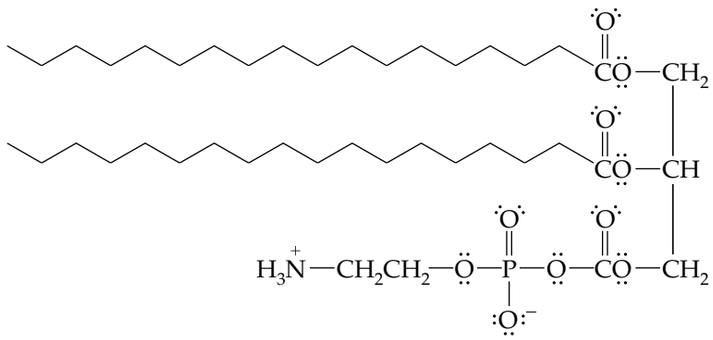

Phosphoglyceride, a cephalin

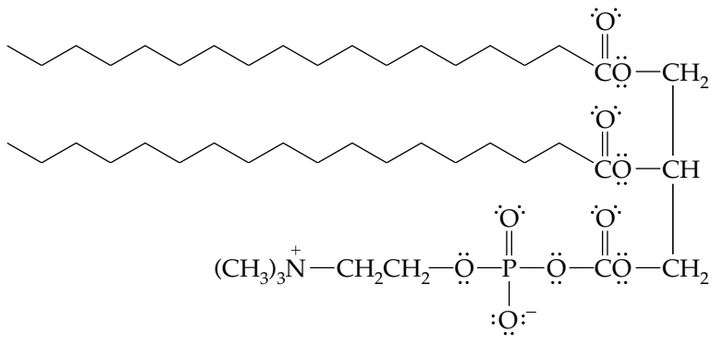

Phosphoglyceride, a lecithin

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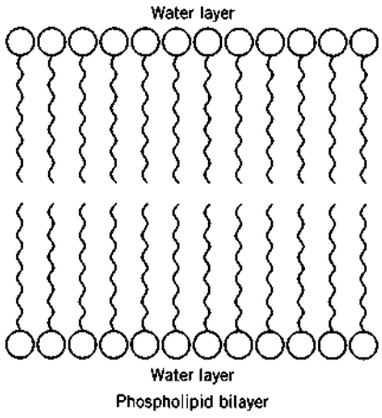

Figure 6.22 Phospholipid bilayer.

These latter groups significantly increase the polarity of the glycerol section of the molecule so that phosphoglycerides undergo strong self-association. In aqueous solutions, this intermolecular attraction can lead to lipid bilayer formation (Fig. 6.22). In a lipid bilayer, the molecules organize themselves to form sheets that contain a double layer of the molecules formed by tail-to-tail association within the interior of the sheet; the outer surface of the lipid bilayer contains the polar heads, which are heavily solvated by water molecules. This association of phosphoglycerides is the key feature in the construction of cell membranes. Thus, esters must have played a vital role at the very earliest stages as cell structures evolved in the development of living systems.

Preparation of Esters. Esters are generally synthesized by one of four fundamental routes:

1. Esterification of a carboxylic acid with an alcohol in the presence of an acid catalyst
2. Alcoholysis of acid chlorides, anhydrides, or nitriles
3. Reaction of a carboxylate salt with an alkyl halide or sulfate
4. Transesterification reactions

The first of these pathways, known as Fischer esterification, is the method used for the preparation of ethyl laurate in Experiment [8A] and of isopentyl acetate in Experiment [8B]. A modern variation of the Fischer esterification is used in Experiment [8C]. The development of this esterification reaction represents just one of a number of major discoveries in organic chemistry by Emil Fischer.

Emil Fischer (1852–1919)[7] In 1874 Fischer obtained his Ph.D. from the University of Strasbourg, studying with Adolf von Baeyer. He later had appointments as Professor of Chemistry at Erlangen, Würzburg, and Berlin universities.

In 1875, at the age of 23, and one year after completing his graduate studies, he synthesized phenyl hydrazine (C_6H_5—$NHNH_2$) for the first time. This highly reactive reagent later played a key role in Fischer's work on elucidating structures of a large majority of the sugars (carbohydrates), an entire class of important and complex organic molecules. Sugars, or carbohydrates, represent the prime pathway for the storage of radiant energy from the sun, through photosynthesis, as chemical energy. In the short period from 1891 to 1894, Fischer established not only the basic structures, but also the configurations of all the known sugars. In addition, he predicted all the theoretically possible isomers and, in the process, developed a method of representing the three-dimensional molecular structures in two-dimensional drawings that became known as Fisher projection formulas. These representations are still in use today, and have been widely applied beyond sugar chemistry. This work by Fischer led directly to proving the existence of the asymmetric carbon atom, a concept proposed by Vant Hoff and LeBel in 1874.

Fischer was also active in the area of protein chemistry. He demonstrated that amino acids are the basic subunits from which proteins are constructed.

[7]See *Chem. Ind.* **1919,** *42,* 269; Darmstaedter, L.; Oester, R. E. *J. Chem. Educ.* **1928,** *5,* 37; Ratman, C.V. *ibid.* **1942,** *38,* 93; Kauffman, G. B.; Priebe, P. M. *ibid.* **1990,** *67,* 93; *Chem. Eng. News* **1992,** June p. 25. Recommended reading, "The Emil Fischer–William Ramsay Friendship: The Tragedy of Scientists in War." *J. Chem. Educ.* **1990,** *67,* 451.

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EQA

Fischer devised methods for the synthesis of many of the known amino acids. Perhaps his most ingenious contribution was the "lock and key"hypothesis of how proteins bind with substrates of complementary shapes. This work ultimately led to our understanding of how enzymes, the catalysts of biochemical reactions, function.

Fischer carried out extensive work on the chemistry of purine and on those compounds containing its nucleus. Purine is one of the two nitrogen base ring systems present in DNA. Fischer synthesized approximately 150 members of this class of heterocyclic compounds (including the first synthesis of the alkaloid caffeine (see Experiment [11B]), uric acid, and the xanthines (also see Experiment [11B]). He developed a general synthesis of another nitrogen heterocycle, indole, which was so effective that it has become one of the classic synthetic methods of organic chemistry and is known today as the "Fischer indole synthesis":

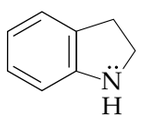

Indole

Fischers work essentially laid the foundation of modern biochemistry. Regarded as the greatest organic chemist of his time, Fischer became the second chemist to receive the Nobel Prize (1902). Depressed by the loss of his young wife at the age of 33, by the loss of two of his three sons (one by suicide, the other in World War I), suffering from the advanced stages of intestinal cancer, and saddened by the socioeconomic conditions of postwar Germany, Fischer committed suicide.

Mechanism of the Fischer Esterification Reaction. The Fischer esterification proceeds by nucleophilic attack of the alcohol on the protonated carbonyl group of the carboxylic acid to form a tetrahedral intermediate. Collapse of the tetrahedral intermediate regenerates the carbonyl group and produces the ester and water. The overall sequence is outlined here:

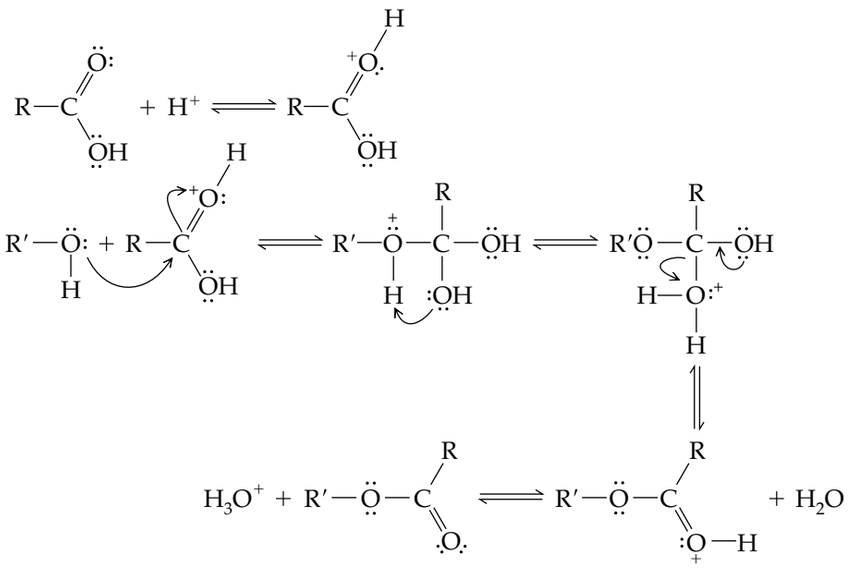

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In the Fischer esterification with primary alcohols, the products are only slightly favored by the equilibrium and, therefore, to obtain substantial yields of the ester, the equilibrium must be shifted toward the products. This result can be accomplished in a number of ways. For example, an excess of the starting alcohol can be used to shift the position of equilibrium toward the products. This technique is used in the preparation of ethyl laurate (Experiment [8A]). An analogous alternative is to use an excess of the carboxylic acid. A third option to drive the reaction is the removal of one or both of the products (the ester or water) as they are formed during the reaction. The preparation of isopentyl acetate, synthesized in Experiment [8B], depends on two of these strategies: (1) the reaction is run in an excess of the carboxylic acid (it doubles as the solvent) and (2) the water generated as one of the products is removed by a drying agent. The acid catalyst used in Fischer esterifications is generally dry hydrogen chloride, concentrated sulfuric acid, or a strong organic acid, such as *p*-toluenesulfonic acid.

When the carboxyl group and hydroxyl group are present in the same molecule, an intramolecular esterification may occur and a cyclic ester (called a lactone) may be formed. Lactonization requires an acceptable conformation: the two groups must be close and spatially positioned to react. Ring closure is especially favorable if lactone formation yields five- or six-membered (stable and rapidly formed) ring systems.

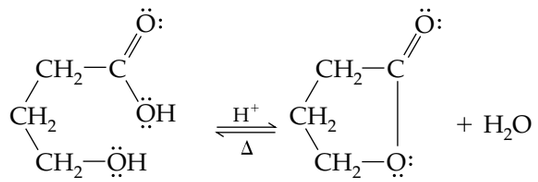

γ-Hydroxybutyric acid γ-Butyrolactone

As noted earlier, Fischer esterification is an equilibrium reaction and is thus reversible. Thus, heating an ester in aqueous solution, in the presence of an acid catalyst, regenerates the corresponding carboxylic acid and alcohol. This latter reaction is called *acid hydrolysis* of an ester. The rate-determining step in both the forward esterification reaction and the reverse reaction, acid hydrolysis, is the formation of the tetrahedral intermediate. It is, therefore, evident that the rate of the reaction will be determined by the ease with which the nucleophile (alcohol on esterification and water on hydrolysis) approaches the carbonyl group. Steric and electronic factors have been shown to have large effects on the rate of esterification. An increase in the number of bulky substituents substituted on the α and β positions of the carbonyl-containing compound decreases the rate (steric effects). Electron-withdrawing groups near the carbonyl group, on the other hand, tend to increase the rate by increasing the electrophilicity (partial positive charge) of the carbonyl carbon (electronic effects). Conversely, electron-donating groups act to retard the rate of esterification (electronic effects).

You are to synthesize the ethyl ester of lauric acid in Experiment [8A]. Lauric acid, $CH_3(CH_2)_{10}CO_2H$ (dodecanoic acid), is one of the four most common fatty acids found in naturally occurring triglycerides. It is named for the laurel botanical family from which it was first isolated in 1842. It is the most abundant of the fatty acids isolated from the vegetable oils of palm kernel oil (52%), the seed fat of *Elaeis guineensis;* of coconut oil (48%), *Cocos nucifera;* and of babassu oil (46%), *Attalea funifera*.

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EQA

In the preparation given for ethyl laurate (Experiment [8A]), acetyl chloride is used to generate the HCl catalyst in situ. Notice that the other product of this step is a molecule of the desired ester:

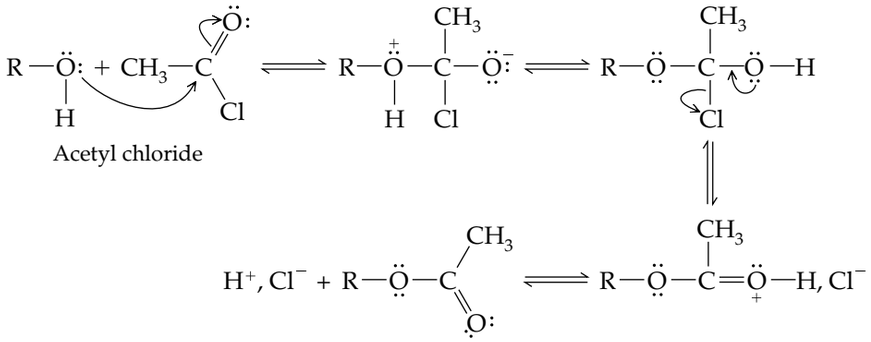

In Experiment [8B] you will be synthesizing the isopentyl alcohol (3-methylbutanol) ester of acetic acid (the basic building block of the fatty acids), isopentyl acetate (isoamyl acetate). This low molecular weight ester has a distinct banana- or pear-like odor, and the liquid product is often referred to as banana oil or pear oil (see above). Isopentyl acetate has a wide variety of uses: as a flavoring agent in mineral waters and syrups; a solvent for oil paints, tannins, nitrocellulose, lacquers, and a number of other commercial products; a perfume ingredient in shoe polish; and in the manufacture of artificial silk, leather, and pearls. You are very likely to find this experiment to be a pleasant olfactory experience!

In Experiment [8C] you will use a polymer-bound acid reagent to catalyze the esterification reaction. Polymer-bound reagents are becoming increasingly useful in organic synthesis; both in the research laboratory and in industrial-scale reactions.

Ethyl Laurate

Experiment 8A

REACTION

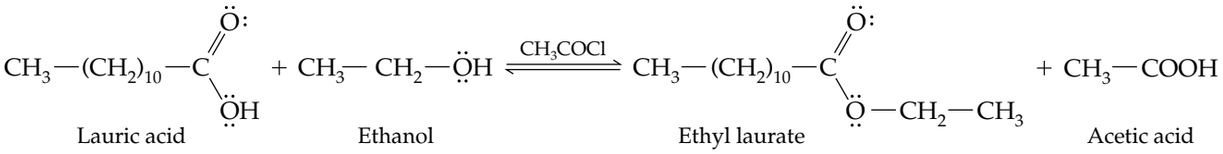

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Lauric acid	200.3	70 mg	0.35	44			
Ethanol	46.07	1.0 mL	17		78.5	0.71	1.3611
Acetyl chloride	78.50	30 μL	0.42		50.9	1.11	1.3898

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EQA

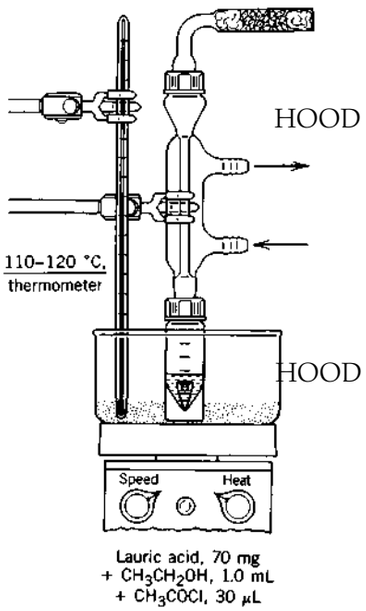

Reagents and Equipment. Weigh and add 70 mg (0.35 mmol) of lauric acid to a 3.0-mL conical vial containing a magnetic spin vane. Then equip the reaction vial with a reflux condenser that is protected by a calcium chloride drying tube (⬅). Use a graduated 1.0-mL pipet to add 1.0 mL of absolute ethanol to the vial. In the **hood,** add 30 μL (0.43 mmol) of acetyl chloride, using an automatic delivery pipet. (Remember not to turn on the cooling water in the condenser until the system is completely assembled. Otherwise, the cold inner surface will condense moisture from the laboratory atmosphere. It takes only a very small amount of water on the condenser walls to completely deactivate your acid chloride catalyst.)

HOOD

CAUTION: Acetyl chloride is an irritant. Dispense this reagent in the ***hood*** using an automatic delivery pipet. (Be sure to quickly reassemble the reaction vial and condenser following addition of the acid chloride, because this reagent will rapidly react with moist laboratory air and lose its activity.)

HOOD

Reaction Conditions. Heat the reaction mixture for 1 h at gentle reflux with stirring, using a sand bath temperature of 110–120 °C. Cool the resulting mixture to room temperature.

Isolation of Product. After removing the reflux condenser and drying tube, remove the spin vane with forceps. Add a boiling stone to the cooled vial and then concentrate the reaction solution to a volume of about 0.25 mL by warming in a sand bath in the **hood.** Remove the vial from the sand bath and allow the vial to cool. Use a 1.0-mL graduated pipet to add 0.5 mL of diethyl ether and 0.25 mL of 5% sodium bicarbonate solution to the concentrated product mixture. Cap the conical vial and shake gently (or mix on a Vortex mixer). Loosen the cap carefully to vent the two-phase mixture. Remove the bottom aqueous layer using a Pasteur filter pipet and set it aside in a labeled Erlenmeyer flask. Extract the ether phase with three additional 0.25-mL portions of 5% sodium bicarbonate solution. Save the aqueous wash after each extraction (you may combine them with the initial aqueous basic phase in the Erlenmeyer) and do not discard them until you have successfully purified and characterized the ethyl laurate.

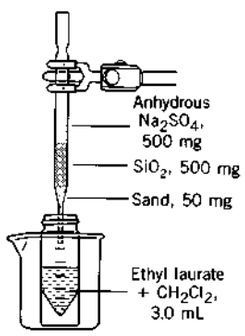

Purification and Characterization. Dry and purify the wet, crude ether solution of ethyl laurate by column chromatography. In a Pasteur filter pipet, place 500 mg of activated silica gel followed by 500 mg of anhydrous sodium sulfate (⬅). Wet the column first with 0.5 mL of methylene chloride and then transfer the crude ether solution of ethyl laurate to the column using a Pasteur filter pipet. Use a **tared** 5-mL conical vial containing a boiling stone as a collection flask for the column eluant. Rinse the reaction vial with methylene chloride (0.5 mL). Transfer the rinse to the column. Repeat both rinse and transfer with a second aliquot of methylene chloride (0.5 mL). Add an additional 1.0 mL of methylene chloride directly to the column to ensure complete elution of the ester.

HOOD

Remove the ether-methylene chloride solvent by evaporation in the **hood** by using a stream of nitrogen gas with gentle warming in a sand bath. Make sure the vial remains warm to your fingers during the evaporation process—a warm vial ensures that condensation of moisture on the liquid product is avoided during solvent concentration.

The recovered ethyl laurate is a clear, viscous, pleasant-smelling ester, and is usually fully characterized without further purification. Weigh the product

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EQA

and calculate the percent yield. Determine the refractive index (optional) and boiling point and compare your data to the literature values. Obtain an IR spectrum of the ester using the capillary film technique and compare it to the spectrum of an authentic sample or to one found in the literature (*Aldrich Library of IR spectra* and/or SciFinder Scholar). www

Chemical Tests. Does this ester give a positive hydroxamate test (see Chapter 9)? Check the solubility of ethyl laurate in water. Would you have predicted the result? Is the ester soluble in 85% phosphoric acid or in concentrated sulfuric acid?

Isopentyl Acetate: Semimicroscale Preparation

Experiment 8B

Isopentyl acetate is prepared by the following procedure.

REACTION

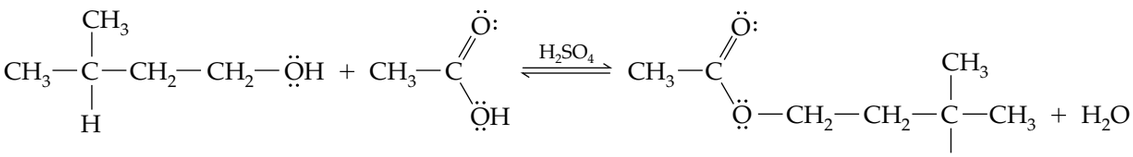

Isopentyl alcohol Acetic acid Isopentyl acetate

EXPERIMENTAL PROCEDURE

Estimated time to complete the experient: 3.0 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Isopentyl alcohol	88.15	800 μL	7.4	132	0.81	1.4053
Acetic acid	60.1	1.5 mL	26.2	116	1.05	1.3720
Sulfuric acid, concd		4 drops				

Reagents and Equipment. In a 5.0-mL conical vial containing a magnetic spin vane and equipped with a reflux condenser protected by a calcium chloride drying tube, place 800 μL (7.4 mmol) of isopentyl alcohol, 1.5 mL (26.2 mmol) of glacial acetic acid, 4 drops (Pasteur pipet) of concentrated sulfuric acid, and approximately 100 mg of silica gel beads (➡).

CAUTION: Cap the vial immediately after addition of each reagent. Dispense the reagents in the ***hood*** using automatic delivery pipets. Concentrated acetic and sulfuric acids are *corrosive*.

NOTE. The silica gel beads (t.h.e. desiccant) are used to absorb the water as it is generated in the reaction.

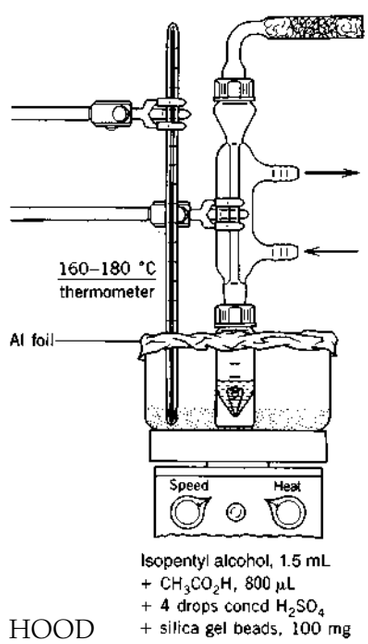

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Reaction Conditions. Heat and stir the reaction mixture using a sand bath temperature of 160–180 °C for 1 h. Cool the resulting mixture to room temperature and remove the spin vane with forceps. Add 0.5 mL of diethyl ether to increase the volume of the organic phase.

Isolation of Product. Extract the crude organic product with three 2-mL portions of 5% sodium bicarbonate solution, followed by 1 mL of water. During each extraction, cap the vial, shake gently, vent carefully, and then allow it to stand so the layers may separate. A Vortex mixer may be used to good advantage in this sequence. Remove the aqueous layer and be sure not to discard it until the final product is purified and characterized.

Following the aqueous extraction, dry the organic phase by adding anhydrous sodium sulfate to the vial. Transfer the anhydrous solution, using a Pasteur filter pipet, to a clean, dry 3-mL conical vial containing a boiling stone. Remove the added ether by evaporation in the **hood** by using a gentle stream of nitrogen gas with gentle warming in a sand bath. Next, attach the vial containing the crude ester residue to a Hickman still equipped with an air condenser and arranged in a sand bath for distillation (⬅). Cover the sand bath with aluminum foil during the procedure.

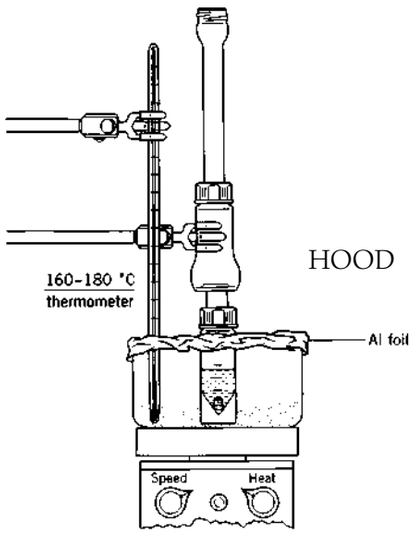

Distillation of reaction products

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Purification and Characterization. Distill the isopentyl acetate product at a sand bath temperature of 160–180 °C. As the material collects in the collar of the still, transfer it by Pasteur pipet (9 in.) to a **tared** $\frac{1}{2}$-*dram* vial.

Weigh the clear, viscous, pleasant-smelling isopentyl acetate, and calculate the percent yield. Determine the refractive index (optional) and boiling point, and compare your values with those found in the literature.

Obtain an IR spectrum of the ester using the capillary film technique and compare it with that shown in Figure 6.23.

Infrared Analysis. The conversion of a branched-chain aliphatic primary alcohol to an acetate ester results in significant changes in the infrared spectrum of the molecule. These changes are similar to those observed in straight-chain systems. The two macro group frequency trains in the present example are

1. Isopentyl alcohol (Fig. 6.24): 3350 (broad), 3000–2850, 1460–1300, 1060, and 660 cm^{-1}
2. Isopentyl acetate (Fig. 6.23): 3490 (weak), 3000–2850, 1746 (strong), 1367 (broad), 1250, and 1040 cm^{-1}

If the macro group frequencies are further constrained to include only those systems in which the chain branching involves the presence of an isopropyl group, two additional bands near 1385 and 1365 cm^{-1} are required. These peaks, which are present in both the alcohol and the ester, arise from the spatially coupled and split symmetric methyl bending vibrations of the aliphatic backbone. In both isopentyl alcohol and isopentyl acetate, this pair of bands are found at identical locations, 1386 and 1367 cm^{-1}.

Chemical Tests. Does the product give a positive hydroxamate test for an ester (Chapter 9)? Check the solubility of this ester in water, ether, and 85% H_3PO_4. In which solubility group (see Chapter 9, pp. 638–639) does isopentyl acetate fall?

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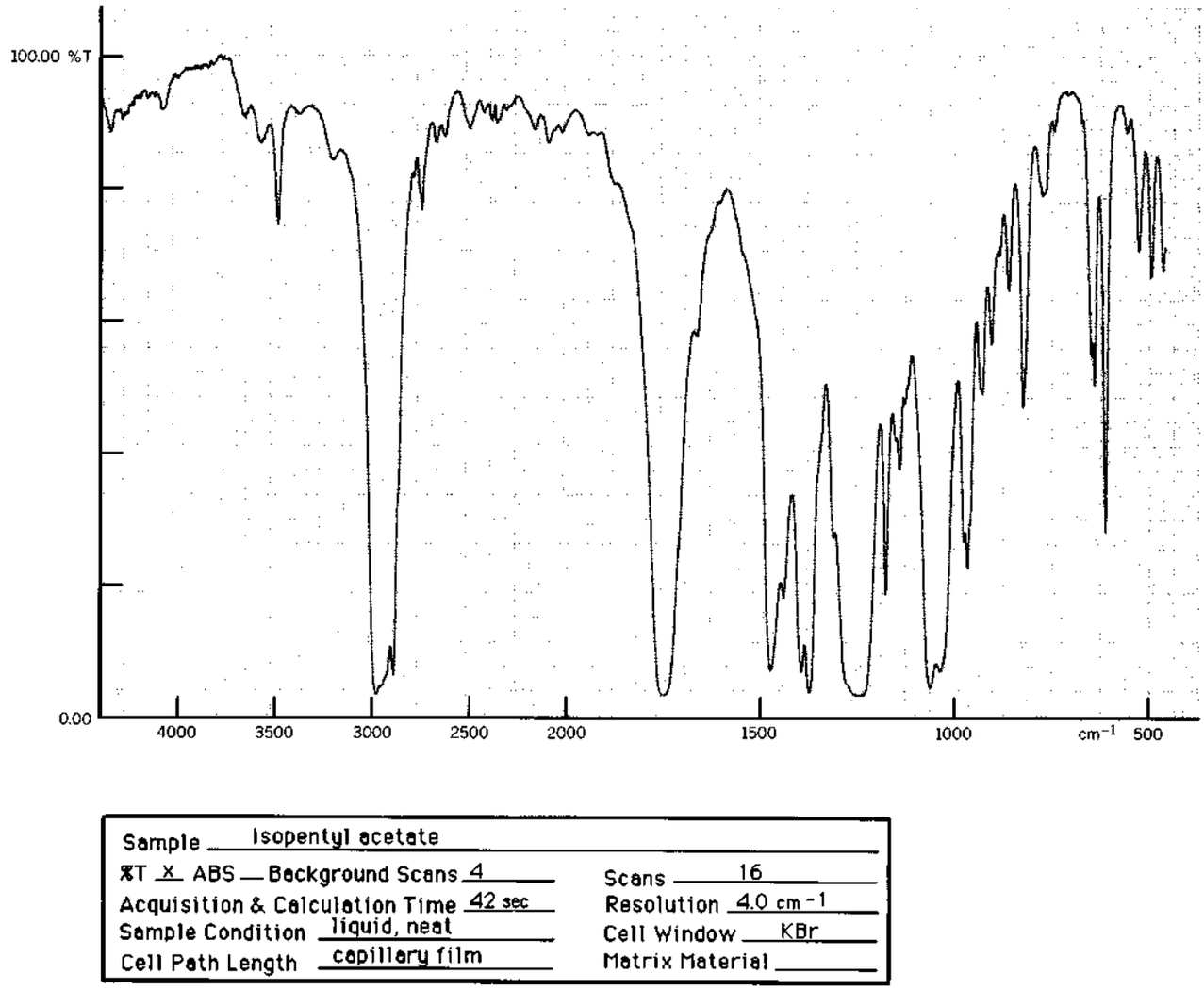

Figure 6.23 IR spectrum: isopentyl acetate.

Isopentyl Acetate: Preparation Using a Monomode Microwave Apparatus

Experiment 8B-1*

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.25 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Isopentyl alcohol	88.15	0.8 mL	7.4	132	0.81	1.4053
Acetic acid	60.1	1.5 mL	26.2	116	1.05	1.3720
Sulfuric acid, conc		4 drops				

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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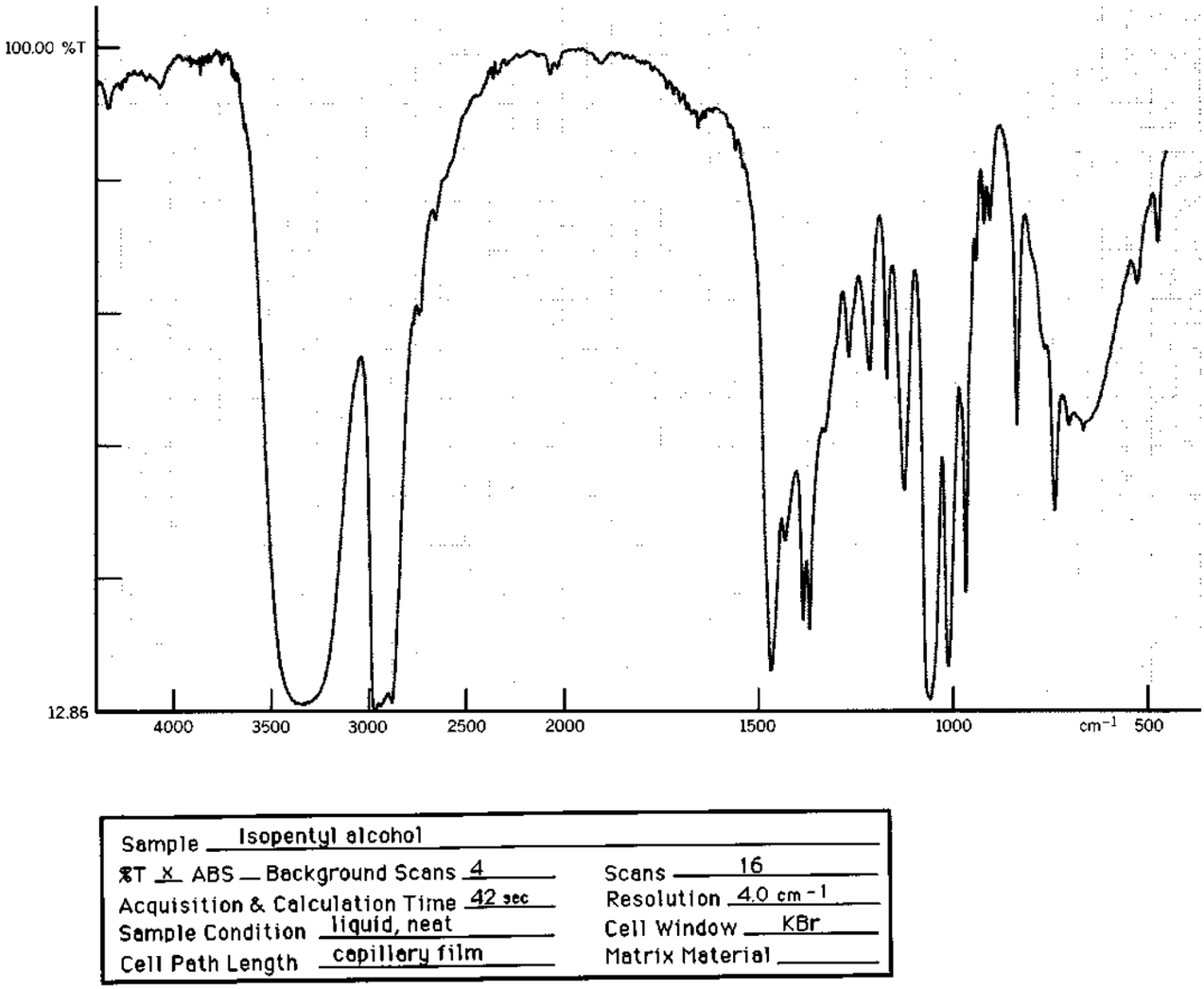

Figure 6.24 IR spectrum: isopentyl alcohol.

Reagents and Equipment. This experiment is designed for use in the CEM Discover and Biotage Initator microwave units.

In a 10.0-mL glass microwave reaction vessel containing a magnetic stir bar, place 0.8 mL (7.4 mmol) of isopentyl alcohol, 1.5 mL (26.2 mmol) of glacial acetic acid, 4 drops (Pasteur pipet) of concentrated sulfuric acid, and approximately 100 mg of silica beads. Immediately cap the vessel with the microwave pressure cap.

HOOD

CAUTION: Dispense reagents in the **hood** using automatic delivery pipets. Concentrated acetic and sulfuric acids are *corrosive*. Since the reaction requires heating reagents to above their boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential.*

Reaction Conditions. Place the reaction vessel in the microwave cavity and, depending on the equipment used, position the pressure device on top. Program the microwave unit to heat the reaction mixture to 130 °C and hold at this temperature for 15 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the tube from the microwave unit. Transfer the reaction mixture with a Pasteur pipet into a 5.0-mL conical vial. Rinse

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EQA

the microwave reaction vessel with 0.5 mL of diethyl ether and add the washings to the conical vial.

Isolation of Product. The remainder of the procedure is identical to experiment 8B (p. 202).

Isopentyl Acetate: Preparation Using a Multimode Microwave Apparatus

Experiment 8B-2*

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.25 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Isopentyl alcohol	88.15	1.6 mL	14.7	132	0.81	1.4053
Acetic acid	60.1	3 mL	52.4	116	1.05	1.3720
Sulfuric acid, conc		8 drops				

Reagents and Equipment. This experiment is designed for use in the CEM MARS, Milestone START, and Anton Paar Synthos 3000 microwave units. When using the Anton Paar Synthos 3000 unit with the 24-position silicon carbide plate rotor containing glass vials, the reagent and solvent quantities cited in the monomode procedure should be used in conjunction with the reaction conditions here in the multimode procedure.

In a microwave reaction vessel containing a magnetic stir bar, place 1.6 mL (14.7 mmol) of isopentyl alcohol, 3.0 mL (52.4 mmol) of glacial acetic acid, 8 drops (Pasteur pipet) of concentrated sulfuric acid, and approximately 200 mg of silica beads. Immediately cap the vessel with the microwave pressure cap and adjust the tightness to the manufacturer-specified level. Place the sealed vessel into its outer protective jacket.

CAUTION: Dispense reagents in the **hood** using automatic delivery pipets. Concentrated acetic and sulfuric acids are *corrosive*. Since the reaction requires heating reagents to above their boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential.*

HOOD

Reaction Conditions. Insert the loaded vessels into the reaction carousel ensuring they are evenly spaced and then place the carousel into the microwave cavity. If provided by the manufacturer, connect a temperature probe to the control vessel. Program the microwave unit to heat the reaction vessels to 120 °C and hold at this temperature for 5 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the carousel from the microwave unit.

Isolation of Product. Place 10 mL of 10% sodium bicarbonate solution in a 30-mL separatory funnel. Clamp the funnel to a ring stand. Pipette the reaction mixture from the microwave reaction vessel to the separatory funnel. An

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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effervescent reaction will occur as the excess acetic acid is neutralized. After the effervescence has subsided, add water to dissolve any solids. Add 5 mL of diethyl ether and carefully cap and invert the funnel. Immediately vent the funnel by opening the stopcock. Close the stopcock, place the funnel back on the ring stand, and remove the stopper. Drain the lower (aqueous) layer into a 50-mL Erlenmeyer flask. Extract the crude organic layer with a further two 5-mL portions of 10% sodium bicarbonate solution, followed by 5 mL of water. During each extraction, cap and invert the funnel several times releasing the pressure by opening the stopcock and then allow the funnel to stand so the layers will separate. Remove the lower (aqueous) layer after each extraction into the 50-mL Erlenmeyer flask. Save the aqueous waste until the experiment is complete and then discard as directed. Dry the organic layer by pipetting it into a clean 25-mL Erlenmeyer flask containing 200 mg of anhydrous sodium sulfate. Transfer the anhydrous solution, using a Pasteur filter pipet, to a clean tared 10-mL pear-shaped flask containing a boiling stone.

HOOD

Remove the ether on a rotary evaporator or by evaporation in the **hood** using a gentle stream of nitrogen gas with warming in a sand bath. Next, attach the flask containing the crude ester residue to a Hickman still equipped with an air condenser and arrange in a sand bath for distillation. Cover the sand bath with aluminum foil during the procedure.

Purification and Characterization. Distill the isopentyl acetate product at a sand bath temperature of 160–180 °C. As the material collects in the collar of the still, transfer it by Pasteur pipet (9 in.) to a **tared** $\frac{1}{2}$-*dram* vial.

Weigh the clear, viscous, pleasant-smelling isopentyl acetate, and calculate the percent yield. Determine the refractive index (optional) and boiling point, and compare your values with those found in the literature.

Obtain an IR spectrum of the ester using the capillary film technique and compare it with that shown in Figure 6.23.

Experiment 8C

Esterification by Use of Acidic Resins: Semimicroscale Preparations

Modern synthetic reactions are making increased use of reagents that are heterogeneous in character. The use of resins as the support material for reactive compounds has become very popular because of their ease of removal and reliability. In this experiment you will utilize one of the recent additions to the arsenal of resin catalysts, Nafion 417. This catalyst is a powerfully acidic resin. It can approach the acidities of 100% sulfuric acid and of trifluoromethanesulfonic acid in trifluoroacetic anhydride solution. The "superacidity" of the sulfonic acid group in Nafion 417 is attributable to the electron-withdrawing ability of the perfluorocarbon backbone of the resin to which it is attached.

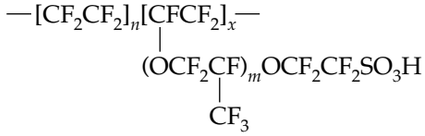

Nafion 417 resin with an equivalent weight of approximately 1200 contains tetrafluoroethylene (the monomer used to make Teflon) and perfluorovinyl ether units in a ratio of 7:1. These resins have been used successfully by Olah, as in this experiment, for the esterification of carboxylic acids.[8]

[8]Olah, G. A.; Keumi, T.; Meidar, D. *Synthesis* **1978,** 929.

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REACTION

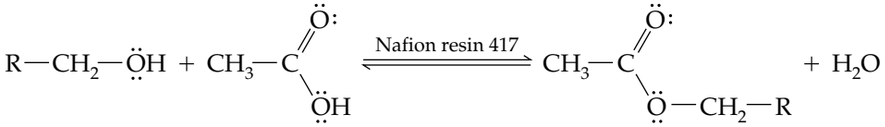

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
1-Butanol	74	365 μL	4.0	118	0.810	1.3990
Isopentyl alcohol	88	500 μL	4.6	132	0.81	1.4053
1-Pentanol	88	500 μL	4.6	138	0.811	1.4090
1-Hexanol	102	570 μL	4.55	156	0.814	1.4180
1-Octanol	130	700 μL	4.45	196	0.827	1.4290
Acetic acid	60	275 μL	4.8	116	1.049	1.3720
Nafion 417 resin	Equivalent weight 1100			1.5 × 0.5-cm strip		

Reagents and Equipment. In a 5.0-mL conical vial containing a magnetic spin vane and equipped with a reflux condenser protected by a calcium chloride drying tube, place the alcohol (*see table for correct molar quantities for your particular alcohol*), 275 μL (4.8 mmol) of glacial acetic acid, and a strip of Nafion 417 resin (1.5 × 0.5 cm). (If the strip of resin is placed so as to encircle the spin vane, mixing of the reaction solution is particularly effective.)

NOTE. The Nafion 417 resin has a significant number of hydrophilic centers that function in exactly the same way as the silica gel does in Experiment [8B]. Thus, Nafion 417, in addition to functioning as an acid catalyst, also acts as a desiccant, which helps to drive the esterification to completion by absorbing water as it is generated in the reaction.

Reaction Conditions. The reaction mixture is heated with stirring at a sand bath temperature of 160–180 °C for 30 min. The mixture is then cooled to room temperature.

Isolation of Product. Remove the Nafion strip and the spin vane (with forceps) from the cool reaction mixture and carefully (to avoid foaming) rinse them with 1 mL of 5% $NaHCO_3$. The rinse is added to the vial (to form a two-phase system) and swirled with the reaction mixture. The bicarbonate wash is then separated and the aqueous phase is transferred to a 10-mL Erlenmeyer flask for temporary storage. The reaction mixture is washed with a further 1-mL portion of 5% $NaHCO_3$, and then by two 1-mL distilled water washes (2 × 1 mL). All the aqueous washes are transferred to the storage Erlenmeyer. Dry the crude and wet reaction product by passing it down a Pasteur pipet containing a cotton plug and 1 g of anhydrous granular sodium sulfate (Na_2SO_4). Collect the product residue from the column in a tared 3-mL conical vial and weigh it to determine the crude yield. Obtain an IR spectrum and measure the refractive index (optional) of the crude material. Does the IR ← www

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spectrum indicate the presence of any unreacted starting material in the crude product? What would be the most likely contaminant?

Purification and Characterization. A 25-μL sample of the crude ester is purified by prep-GC (see GC conditions for each product mixture and Experiment [2] for details on the collection procedure). Following collection of the purified ester, obtain an IR spectrum and boiling point, and compare these with the data obtained on the crude residue. The ester is the first compound to elute from the column. It may be followed by a small amount of a second component. You can calculate the purity of the crude product by measuring the area under the two elution bands. (Only in the case of the butyl acetate synthesis does the workup procedure distort the apparent crude yields: Can you explain why this occurs?) If you want to identify the contaminant (second band) directly, it may be possible to also collect a second fraction from the GC if the contaminant comprises a reasonable fraction of the product mixture (5–10%). It may, however, require a second injection of 30–40 μL.

Gas Chromatographic Conditions	
General	
Stainless steel columns in *8*ft × $\frac{1}{4}$ in. packed with 20% Carbowax Flow rates: 50 mL/min (He); sample size: 25 μL	
Specific	
Ester 1	**Ester 2**
Butyl acetate	*Pentyl acetate*
Column temperature: 120 °C	Column temperature: 130 °C
Retention time Ester: 8.5 min Impurity: 11 min	Retention time Ester: 8.5 min Impurity: 11 min
Ester 3	**Ester 4**
Isopentyl acetate	*Hexyl acetate*
Column temperature: 140 °C	Column temperature: 160 °C
Retention time Ester: 6 min Impurity: 8 min	Retention time Ester: 10 min Impurity: 12 min
Ester 5	
Octyl acetate	
Column temperature: 185 °C	
Retention time Ester: 10 min Impurity: 13 min	

QUESTIONS

6-49. In the preparation of the esters given in this experiment, the reaction product was extracted with 5% sodium bicarbonate solution ($NaHCO_3$) in the isolation step. Why? What gas was evolved during this washing step? Write a balanced equation for the reaction that produced it.

6-50. **(a)** Why is a large excess of acetic acid used in the preparation of isopentyl acetate?
(b) Write a mechanism for the preparation of isopentyl acetate using isopentyl alcohol and acetic acid.

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6-51. Concentrated sulfuric acid is used as a catalyst for the esterification of acetic acid in the preparation of isopentyl acetate. Why is the sulfuric acid needed if another acid, acetic acid, is already present?

6-52. Fatty acids are long-chain carboxylic acids, usually of 12 or more carbon atoms, isolated from saponification of fats and oils (esters of glycerol). Draw the structure of each of the fatty acids named below and also determine its common name:
(a) Hexadecanoic acid *(Z)*-9-octadecenoic acid
(b) Octadecanoic acid *(Z,Z)*-9,12-octadecadienoic acid

6-53. Write a mechanism for the acid-catalyzed transesterification reaction of ethyl acetate with 1-butanol, which gives butyl acetate.

6-54. In the infrared spectra of acetates, two intense bands are usually observed in the 1270- to 1000-wavenumber region. These peaks are related to the stretching vibrations of the two C—O bonds of the ester group. Should we expect to be able to assign the C—O bonds to individual peaks, and if so, which mode is associated with which band? Why? (*Hint:* The peak that occurs at higher wavenumbers is consistently close to 1250 cm^{-1}.)

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For an overall review of esterification see

Euranto, E. K. in *The Chemistry of Carboxylic Acids and Esters;* Patai, S. Ed.; Interscience: New York, 1969, p. 505.

EXPERIMENT 9

The E1 Elimination Reaction: Dehydration of 2-Butanol to Yield 1-Butene, trans*-2-Butene, and* cis*-2-Butene*

Common name: 1-butene
CA number: [06-98-9]
CA name as indexed: 1-butene

Common name: *trans*-2-butene
CA number: [624-64-6]
CA name as indexed: 2-butene, (*E*)-

Common name: *cis*-2-butene
CA number: [590-18-1]
CA name as indexed: 2-butene, (*Z*)-

Purpose. This experiment illustrates the variety of pathways that are available to acid-catalyzed elimination reactions of secondary (2°) alcohols via carbocation intermediates. The dehydration of 2-butanol forms a mixture of gaseous alkene products. The alkenes formed in this reaction are separated and identified by using one of the most powerful instrumental techniques available to the modern research chemist for the separation of complex mixtures: gas chromatography (GC).

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THE DEVELOPMENT OF CARBOCATION THEORY

The dehydration reaction that you are about to study is representative of the large collection of reactions that are classified as E1 elimination reactions. These reactions all form an intermediate in which one of the carbon atoms bears, if not a *full* positive charge, at least a significant fractional positive charge. It is this fleeting, high-energy intermediate, an aliphatic carbocation, that makes these reactions so interesting.

The development of bonding theory in organic chemistry during the late nineteenth and early twentieth centuries did not accept the existence of carbocations, except in a few esoteric instances. This position was reasonable because aliphatic compounds show little ionic character. The first proposal that these nonpolar substances might actually form cations came from Julius Stieglitz (1867–1937), of the University of Chicago, in a paper published in 1899. Eight years later, James F. Norris (1871–1940) at Massachusetts Institute of Technology produced compelling evidence that these substances might be intermediates in reactions of certain *tert*-butyl halides.

These two papers were the origin of the concept that organic carbon cations, which in those days became known as *carbonium ions*, were far more widespread in organic reactions than previously anticipated. Indeed, these early investigations caused more controversy and more experimental work to unambiguously prove the existence of what are now called *carbocations* than any other single problem in American chemistry.

It was, however, the English chemists Arthur Lapworth, Sir Robert Robinson, C. K. Ingold (University of London), and E. D. Hughes who, from 1920 to 1940, undertook a massive effort to develop the experimental and theoretical data to place these early postulates on a solid scientific foundation. Between 1920 and 1922, Hans Meerwein in Bonn, Germany, demonstrated that carbon rearrangements in the camphene series could be best explained by postulating the presence of carbocation intermediates. Perhaps the most important contribution to the entire subject was published in 1932 by Frank C. Whitmore of Pennsylvania State College, where he was Dean of the School of Chemistry and Physics. His paper, "The Common Basis of Intramolecular Rearrangements," brought together a vast array of data in a beautifully consistent interpretation that essentially cemented the carbocation into contemporary organic chemical theory.

A reaction not too distant (in fact, rather close if you overheat your own!) from the one that is to be carried out below, but one that also included a rearrangement along with the dehydration, was studied by Dorothy Bateman and C. S. "Speed" Marvel at the University of Illinois as early as 1927.

Within 2 years of the publication of the Whitmore paper, Robinson proposed the formation of the steroids (including cholesterol) from squalene (a C_{30} polyunsaturated polyisoprene molecule) via an incredible series of intermediates and rearrangements. Later, following the elucidation of the structure of lanosterol, R. B. Woodward and K. Bloch made a brilliant proposal that at once rationalized the biosynthetic origin of both lanosterol and cholesterol and implicated lanosterol as an intermediate in cholesterol biosynthesis. Their mechanism involved the concerted (bonds made and broken simultaneously) cyclization of four rings, as well as four rearrangements

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following the generation of the initial carbocation intermediate, to ultimately yield lanosterol.[9]

The elucidation of these biochemical pathways is further evidence of the major impact that our understanding of carbocation chemistry has had on related fields, such as biochemistry.

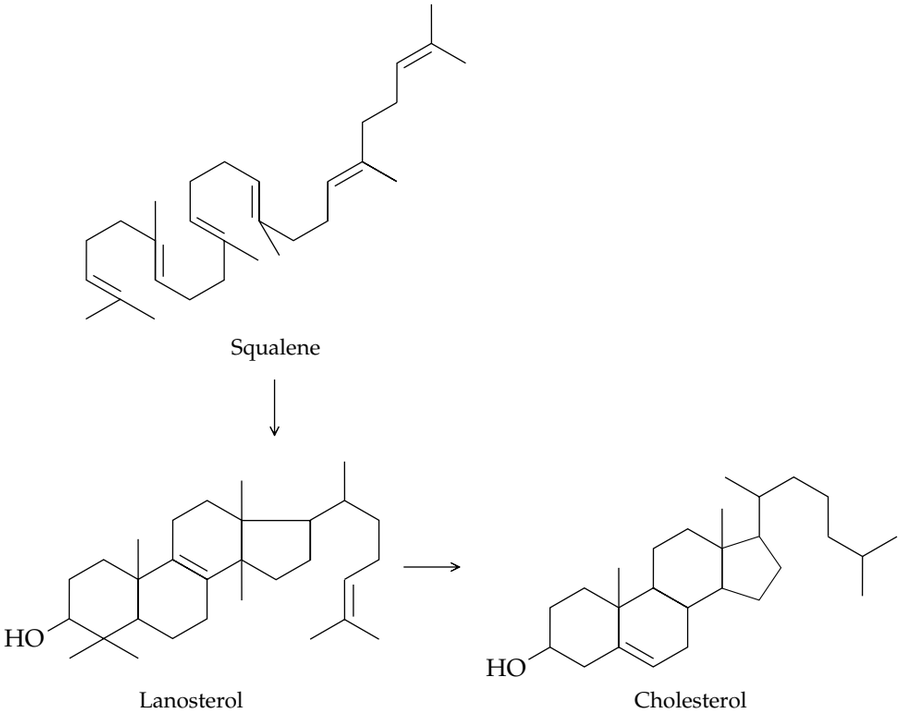

Prior Reading

Technique 1: Gas Chromatography (pp. 55–61)
Technique 7: Collection or Control of Gaseous Products (pp. 105–107)

REACTION

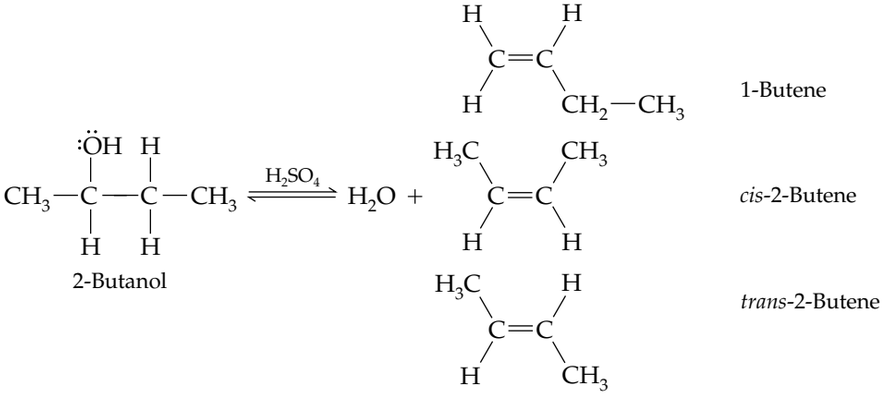

[9]Stieglitz, J. *Am. Chem. J.* **1899,** *21*, 101. Norris, J. F. *Am. Chem. J.* **1907,** *38*, 627. Meerwein, H.; van Emster, K. *Berichte* **1922,** *55*, 2500. Whitmore, F. C. *J. Am. Chem. Soc.* **1932,** *54*, 3274. Bateman, D. E.; Marvel, C. S. *J. Am. Chem. Soc.* **1927,** *49*, 2914. Robinson, R. *Chem. Ind.* **1934,** *53*, 1062. Woodward, R. B.; Bloch, K. *J. Am. Chem. Soc.* **1953,** *75*, 2023. See also: Tarbell, D. S.; Tarbell, T. *The History of Organic Chemistry in the United States, 1875–1955;* Folio: Nashville, TN, 1986.

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DISCUSSION

The formation of an alkene (or alkyne) frequently involves loss of a proton and a leaving group from adjacent carbon atoms. The generalized reaction scheme is shown below.

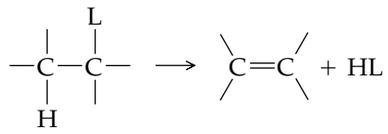

Such a reaction is called an *elimination reaction*, because a small molecule (HL) is *eliminated* from the organic molecule. If the molecule eliminated is water, the reaction may also be referred to as a *dehydration*. One of the common synthetic routes to alkenes is the dehydration of an alcohol.

Dehydration of alcohols is an acid-catalyzed elimination reaction. Experimental evidence shows that alcohols react in the order tertiary (3°) > secondary (2°) > primary (1°); this reactivity relates directly to the stability of the carbocation intermediate formed in the reaction. Generally, sulfuric or phosphoric acid is used as the catalyst in the research laboratory. A Lewis acid, such as aluminum oxide or silica gel, is usually the catalyst of choice at the fairly high temperatures used in industrial scale reactions.

The mechanism for this reaction is classified as E1 (elimination, unimolecular). The elimination, or dehydration reaction, proceeds in several steps:

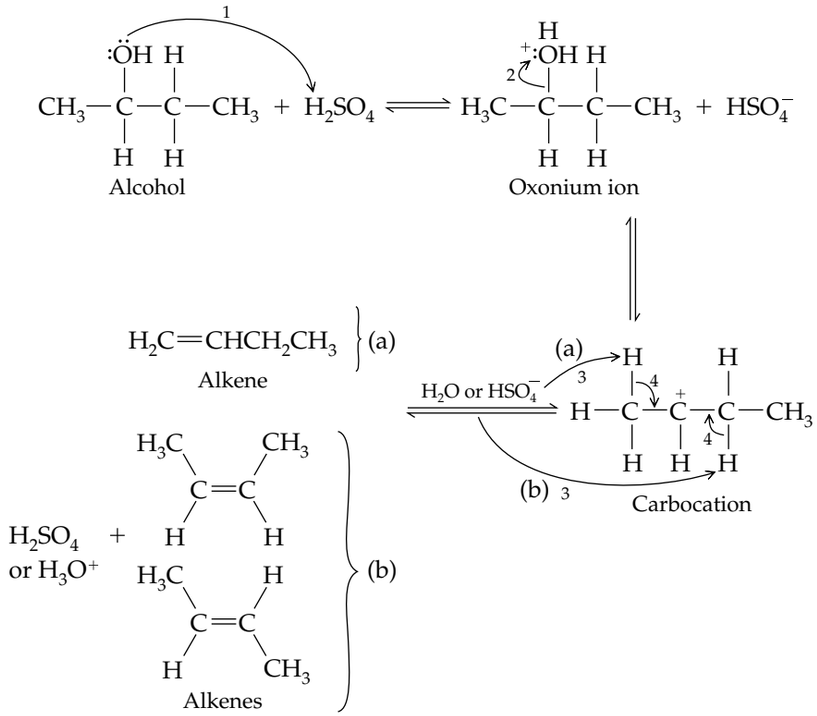

The first step (1) involves the very rapid, though reversible, protonation of the oxygen atom of the alcohol to form an *oxonium ion* (an oxygen cation with a full octet of electrons). This protonation step is important because it produces a good leaving group, water. Without acid, the only available leaving group is hydroxide ion (HO^-) which, as a strong base, is a poor leaving group.

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This finding is the reason why acid plays such an important role in the mechanism of this dehydration. The second step (2) of the reaction is the dissociation of the oxonium ion to form an intermediate *carbocation* and water. This step is the rate-determining (and therefore the slowest) step of the reaction. In the third step (3), the carbocation is deprotonated by a ubiquitous water molecule (or other base, such as bisulfate ion, present in the system) in another rapid equilibration. The carbocation gains stability (lower energy) by releasing a proton (H^+) from a carbon atom adjacent (α) to the carbocation (route (a) or (b) shown) to the attacking base. Thus, in step 4 the catalyst is regenerated as a protonated molecule of water (H_3O^+), and the electron pair, previously comprising the C—H bond adjacent to the carbocation, flows toward the positive charge, generating a stable and neutral alkene. A variety of isomeric products may be formed, since different protons adjacent to the carbocation may be removed, and different conformations of the intermediate carbocation are also possible (see routes (a) and (b) above and further discussion below).

E1 elimination reactions, as we have just seen, involve equilibrium conditions and, thus, to maximize the yield (drive the reaction to completion), the alkene is usually removed from the reaction while it is in progress. A convenient technique for accomplishing this task is distillation, which is often used because alkenes *always* have a lower boiling point than the corresponding alcohol. In the present reaction, the alkenes are gases and, therefore, are easily removed and collected as described in the experimental section.

Many 1° (primary) alcohols also undergo dehydration, but usually by a different route, the E2 (elimination, bimolecular) mechanism. This step is governed mainly by the fact that the 1° carbocation that would be required in an E1 process is a relatively unstable (very high energy) intermediate. In this case, attack by the base occurs directly on the oxonium ion:

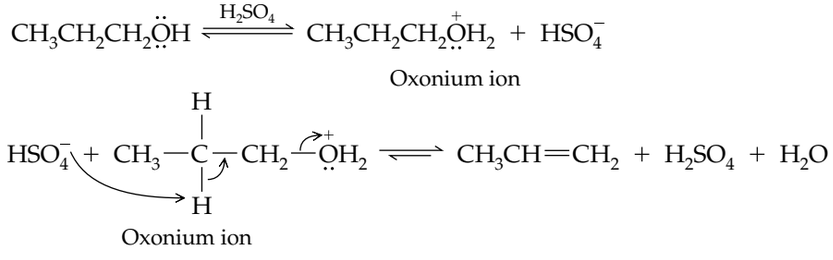

E1 elimination is usually accompanied by a competing S_N1 substitution reaction that involves the *same* carbocation intermediate. Since both reaction mechanisms are reversible in this case, and since the alkene product gases are easily removed from the reaction, the competing substitution reaction (which predominantly regenerates the starting alcohol by attack of water, as a nucleophile, at the carbocation) is not troublesome and the equilibrium eventually leads to gas evolution.

As discussed earlier, many alcohols can dehydrate to yield more than one isomeric alkene. In the present reaction involving the dehydration of 2-butanol, at least three alkenes are usually formed—1-butene, *trans*-2-butene, and *cis*-2-butene:

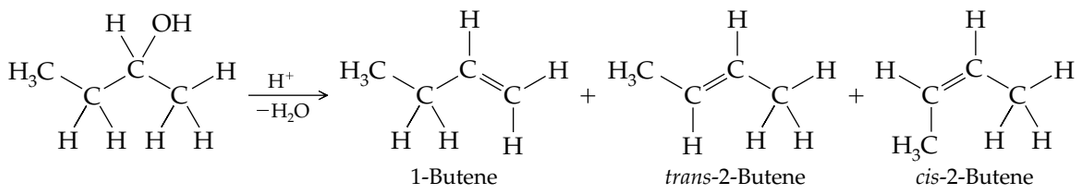

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We would expect the alkene generated in the largest amount to be the one possessing the highest degree of substitution, since it is the most stable product (lowest energy). This is exactly what is observed: more than 90% of the products are isomers of 2-butene. Because trans alkenes are thermodynamically more stable than their cis counterparts, and since the reaction is reversible, one might expect the dominant isomer in the 2-butene mixture to be trans. Indeed, nearly twice as much trans as cis isomer is formed. An empirical rule, originally formulated by the Russian chemist Alexander Zaitsev (or Saytzeff), for base-catalyzed E2 eliminations states that the alkene with the largest number of alkyl substituents on the double bond will be the major product. This rule can also correctly predict the relative ratio of substituted alkenes to be expected from a given E1 elimination reaction, and it obviously applies in the case of 2-butanol.

Rearrangements of alkyl groups (such as methide, $^{-}$:CH_3 and ethide, $^{-}$:CH_2CH_3) and hydrogen (as hydride, :H^{-}) are often observed during the dehydration of alcohols, especially in the presence of very strong acid where carbocations can exist for longer periods of time. For example, when 3,3-dimethyl-2-butanol is treated with sulfuric acid, the elimination reaction yields the mixture of alkenes shown below. Can you predict which alkene is the principal product?

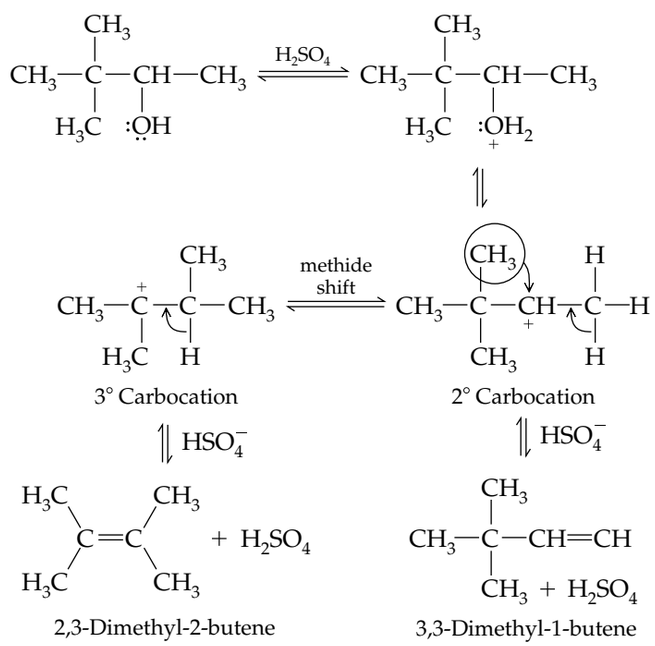

Reactions carried out under these conditions are very susceptible to alkide or hydride shifts if a more stable carbocation intermediate can be formed. In the example above, a 2° carbocation rearranges into the more stable 3° carbocation. This intramolecular rearrangement involves the transfer of an entire alkyl group (in this case a methyl substituent), together with its bonding pair of electrons, to an adjacent carbon atom. This migration, or shift, of the methyl group to an adjacent carbocation is called a *1,2-methide shift*. It commonly occurs in aliphatic systems involving carbocation intermediates that have alkyl substituents adjacent to the cation. Hydride shifts are also frequently observed and actually appear in a wider range of molecules.

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2 h.

NOTE. Staggering the starting times of the reaction will allow more students easier access to the GC instrument when the product gases are analyzed.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
2-Butanol	74.12	100 μL	1.1	99.5	0.81	1.3978
Concd sulfuric acid	98.08	50 μL				

Reagents and Equipment. Assemble the gas collection apparatus shown in the figure *before* the reactants are mixed (➡).

The capacity of the gas collection reservoir is determined by the following procedure. Seal the collection tube with a septum cap and invert it. Then add 3.0 mL of water and mark the 3.0-mL level. Finally, add an additional 1.0 mL, and also mark the 4.0-mL level.

NOTE. Use of a Teflon-lined septum cap on the gas collection reservoir is necessary to prevent loss of the collected butene gases by permeation.

To position the gas collection reservoir, carry out the following steps: (1) fill the reservoir with water; (2) place your finger (index finger is usually used) over the open end of the reservoir; (3) invert it; (4) place it, with the open end down, into a beaker (250 mL) filled with water. When your finger is removed, the column of water should remain in the reservoir.

Place 100 μL (81 mg, 1.1 mmol) of 2-butanol and 50 μL of concentrated sulfuric acid in a **clean,** dry, 1.0-mL conical vial containing a magnetic spin vane.

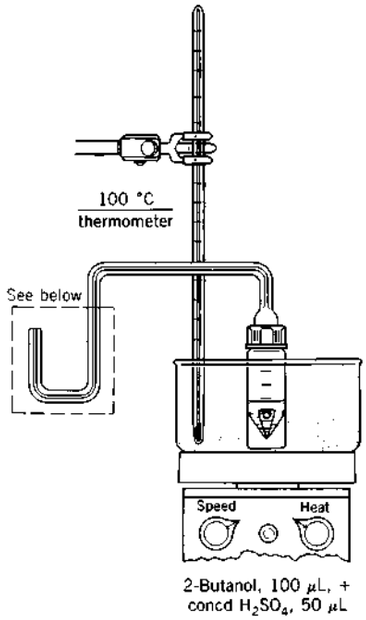

CAUTION: Sulfuric acid is a strong, corrosive material. Contact with the skin or eyes can cause severe burns. It is best to dispense the reactants using automatic delivery pipets.

Cap-seal the 1-mL vial to the gas delivery tube and position the tube under water into the open end of the gas collection reservoir as shown in the figure. Clamp the reservoir in place.

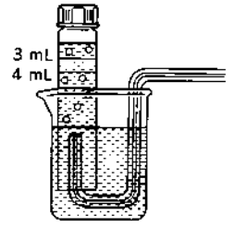

Reaction Conditions. Heat the reaction mixture, with gentle stirring, using a sand bath until the evolution of gas takes place (sand bath temperature ~110–120 °C). The mixture should be warmed slowly through the upper temperature range to prevent foaming.

Isolation of Product. Collect about 3–4 mL of gas in the collection reservoir. Remove the gas delivery tube from the gas collection reservoir, and then from the water bath, before removing the reaction vial from the heat. Use this sequence of steps in shutting down the reaction to prevent water from being sucked back into the hot reaction flask while it is cooling down.

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CAUTION: If water is drawn back into hot concentrated sulfuric acid, a very dangerous situation can occur, particularly if larger quantities of the reagents than recommended above are used in the experiment.

NOTE. Do not remove the gas collection reservoir from the water bath. The beaker containing the reservoir is carried to the gas chromatograph for analysis of the collected gas.

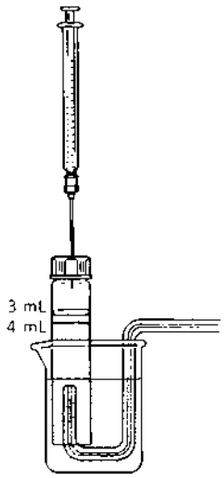

With the aid of a gas-tight syringe, withdraw a 0.5-cm^3 sample through the rubber septum for GC analysis (⬅).

Purification and Characterization. Analyze the collected gas by GC without further purification.

Gas Chromatographic Conditions

Column: 0.25 in. × 8 ft packed with 20% silicone DC 710

Room temperature

Flow rate: 20 mL/min (He gas)

Sample size: 0.5 cm^3 of collected gas

Record the literature values of the physical properties of the products.

The butanes have been determined to elute from the DC 710 column in the following order: 1-butene, *trans*-2-butene, and *cis*-2-butene. *If the reaction mixture is heated above the recommended temperatures, a rearrangement can occur to yield isobutene, which will be detected as an additional isomeric product.*

If we make the assumption that the amount of each substance in the gaseous mixture is proportional to the area under its corresponding GC peak, determining the relative amounts of the three components of the gas sample becomes a straightforward calculation. The accuracy is, of course, dependent on how well the three peaks are resolved in the gas chromatogram.

NOTE. In calculating relative quantities of alkenes formed in the reaction, several techniques may be used to quantitatively determine the composition of the gas mixture if an integrating recorder is not available. Two methods are described here:

1. *Determination of the areas under the peaks gives reproducible results of ±3–4% when these areas are assumed equal to the peak heights (mm) × the peak widths at half-height (mm), measured from the baseline of the curve.*

2. *An other way to determine the areas under the peaks is to cut out the peaks from the chromatogram and weigh them on an analytical balance (sensitivity to 0.1 mg). The weights of the peaks are directly proportional to the relative amount of each compound in the gas sample.*[10]

QUESTIONS

6-55. Gas chromatographic analysis of a mixture of organic compounds gave the following peak areas (cm^2): hexane = 2.7, heptane = 1.6, hexanol = 1.8, and toluene = 0.5.

(a) Calculate the mole percent composition of the mixture. Assume that the response of the detector (area per mole) is the same for each component.

(b) Calculate the weight percent composition of the mixture, using the same assumptions as in (a).

[10]See Pecsok, R. L. *Principles and Practices of Gas Chromatography;* Wiley: New York, 1961; p. 145.

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6-56. At the end of the experiment we note that if the mixture is heated strongly, rearrangement can occur and isobutene (2-methyl-2-propene) is also formed. Suggest a mechanism to account for the formation of this compound.

6-57. When *tert*-pentyl bromide is treated with 80% ethanol, the following amounts of alkene products are detected on analysis:

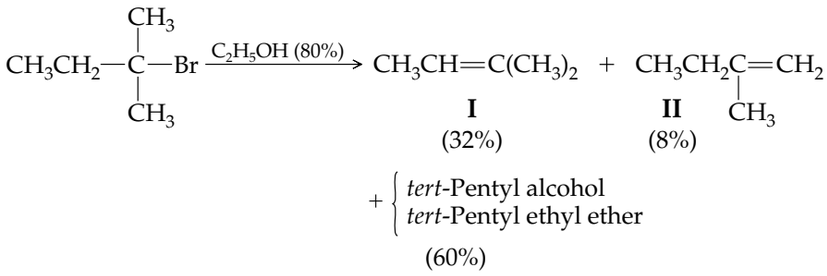

Offer an explanation of why compound **I** is formed in far greater amount than the terminal alkene.

6-58. The —$^{+}SR_2$ group is easily removed in elimination reactions, but the —SR group is not. Explain.

6-59. Why is sulfuric acid, rather than hydrochloric acid, used to catalyze the dehydration of alcohols?

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Several dehydration reactions of secondary alcohols using sulfuric acid as the catalyst are given in *Organic Syntheses:*

Adkins, H.; Zartman, W. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 606.

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Norris J. F. *Organic Syntheses*; Wiley: New York, 1941; Collect. Vol. I, p. 430.

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For an overview of elimination reactions:

March, J. *Advanced Organic Chemistry,* 4th ed.; Wiley: New York, 1992, p. 982.

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed.; Wiley: New York, 2007, Chap 17.

For details on carbonium ion formation:

Olah, G. A.; Schleyer, P. von R., Eds. *Carbonium Ions;* Wiley: New York, Vol. 1, 1968; Vol. II, 1970; Vol. III, 1972.

Olah, G. A.; Prakash, G. K. S. *Carbocation Chemistry;* Wiley: New York, 2004.

Experiment [9] is adapted from the method given by: Helmkamp, G. K.; Johnson, H. W. Jr. *Selected Experiments in Organic Chemistry,* 3rd ed.; W. H. Freeman: New York, 1983; p. 99.

EXPERIMENT 10

The E2 Elimination Reaction: Dehydrohalogenation of 2-Bromobutane to Yield 1-Butene, trans-*2-Butene, and* cis-*2-Butene*

Common name: 1-butene
CA number: [06-98-9]
CA name as indexed: 1-butene

Common name: *trans*-2-butene
CA number: [624-64-6]
CA name as indexed: 2-butene, (*E*)-

Common name: *cis*-2-butene
CA number: [590-18-1]
CA name as indexed: 2-butene, (*Z*)-

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Purpose. This reaction illustrates the base-induced dehydrohalogenation of alkyl halides with strong base and is used extensively for the preparation of alkenes. The stereo- and regiochemical effects of the size of the base is investigated, and the product mixture is analyzed by the use of gas chromatography.

Prior Reading

Technique 1: Gas Chromatography (pp. 55–61)
Technique 7: Collection or Control of Gaseous Products (pp. 105–107)

REACTION

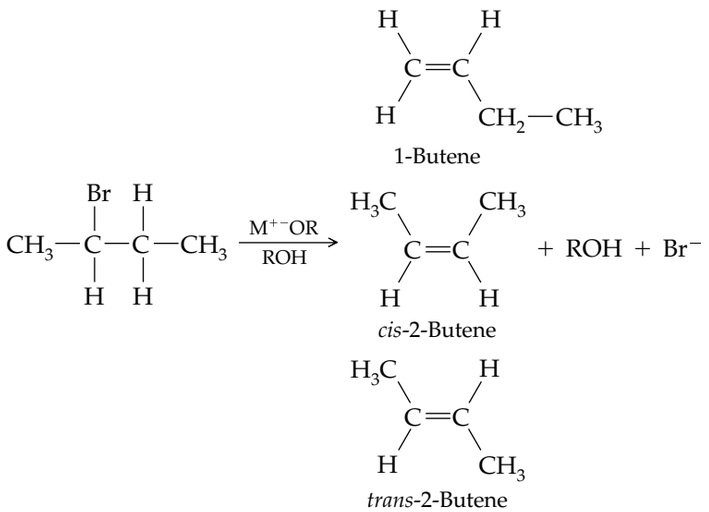

DISCUSSION

Base-induced elimination (dehydrohalogenation) of alkyl halides is a general reaction and is an excellent method for preparing alkenes. This process is often referred to as β *elimination*, since a hydrogen atom is always removed β to the halide (leaving group):

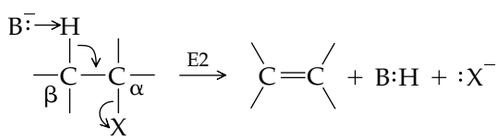

A high concentration of a strong base in a relatively nonpolar solvent is used to carry out the dehydrohalogenation reaction. Such combinations as sodium methoxide in methanol, sodium ethoxide in ethanol, potassium isopropoxide in isopropanol, and potassium *tert*-butoxide in *tert*-butanol or dimethyl sulfoxide (DMSO) are often used.

Elimination reactions almost always yield an isomeric mixture of alkenes, where this is possible. Under the reaction conditions, the elimination is *regioselective* and follows the Zaitsev rule when more than one route is available for the elimination of HX from an unsymmetrical alkyl halide. That is, the reaction

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proceeds in the direction that yields the most highly substituted alkene. For example,

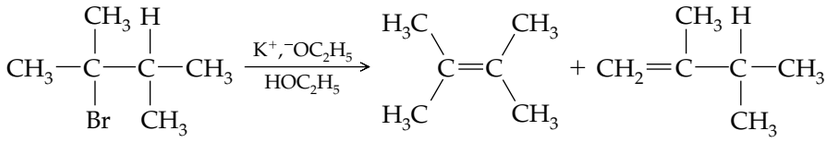

2-Bromo-2,3-dimethylbutane | 2,3-Dimethyl-2-butene (major product) | 2,3-Dimethyl-1-butene (minor product)

In cases where cis or trans alkenes can be formed, the reaction exhibits stereo-selectivity, and the more stable trans isomer is the major product.

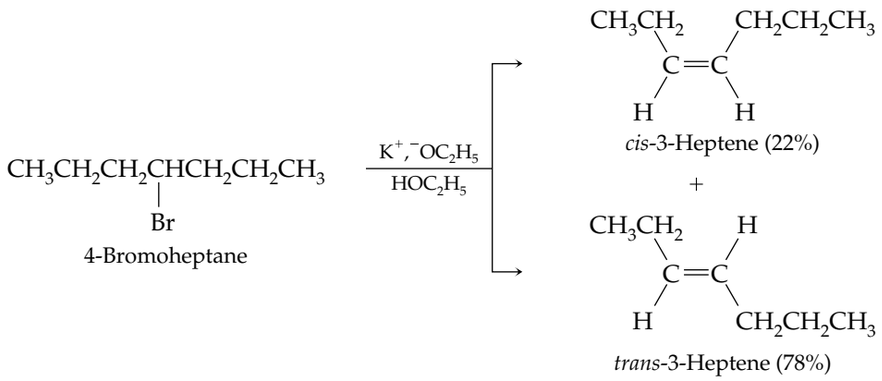

4-Bromoheptane

cis-3-Heptene (22%) + *trans*-3-Heptene (78%)

Experimental evidence indicates that the five atoms involved in the E2 elimination reaction must lie in the same plane; the anti-periplanar conformation is preferred. This conformation is necessary for the orbital overlap that must occur for the π bond to be generated in the alkene. The sp^3-hybridized atomic orbitals on carbon that comprise the C—H and C—X σ bonds broken in the reaction develop into the p orbitals comprising the π bond of the alkene formed:

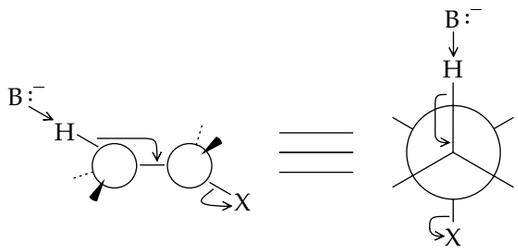

Anti-periplanar conformation

There is a smooth transition between reactant and product. Analogous to the S_N2 reaction, no intermediate has been isolated or detected. Furthermore, no rearrangements occur under E2 conditions. This situation is in marked contrast to E1 elimination reactions, where carbocation intermediates are generated and rearrangements are frequently observed (see Experiment [9]).

The alkyl halide adopts the anti-periplanar conformation in the transition state, and experimental evidence demonstrates that if the size of the base is increased, then it must be difficult for the large base to abstract an internal β-hydrogen atom. In such cases, the base removes a less hindered β-hydrogen

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atom, leading to a predominance of the thermodynamically **less stable (terminal) alkene** in the product mixture. This type of result is often referred to as **anti-Zaitsev** or **Hofmann elimination.** Thus, in the reaction of 2-bromo-2,3-dimethylbutane given above, the 2,3-dimethyl-1-butene would be the major product (anti-Zaitsev) if the conditions used a bulkier base. The anti-periplanar arrangements are illustrated in the Newman projections below.

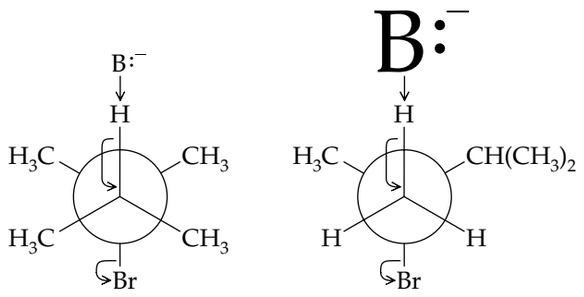

Zaitsev product
internal alkene

Anti-Zaitsev product
terminal alkene

Two anti-periplanar conformations
of 2-bromo-2,3-dimethylbutane

Dehydrohalogenation of alkyl halides in the presence of strong base (E2) is often accompanied by the formation of substitution (S_N2) products. The extent of the competitive substitution reaction depends on the structure of the alkyl halide. Primary alkyl halides give predominantly substitution products (the corresponding ether), secondary alkyl halides give predominantly elimination products, and tertiary alkyl halides give exclusively elimination products. For example, the reaction of 2-bromopropane with sodium ethoxide proceeds as follows:

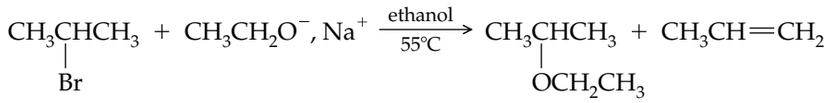

2-Bromopropane | Sodium ethoxide | Ethyl isopropyl ether (21%) | Propene (79%)

In general, for the reaction of alkyl halides with strong base,

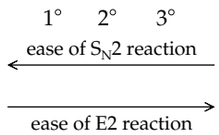

EXPERIMENTAL PROCEDURE

Estimated time of experiment: 2.5 h, if two reactions are run by each student.

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Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
2-Bromobutane	137.03	100 μL	0.92	91.2	1.26	1.4366
Methanol	32.04	3.5 mL		64.9	0.791	1.3288
2-Propanol	60.09	3.5 mL		82.4	0.785	1.3776
2-Methyl-2-propanol (*tert*-butanol)	74.12	3.5 mL		82–83	0.786	1.3838
3-Ethyl-3-pentanol	116.20	3.5 mL		140–142	0.839	1.4266
Sodium	22.98	60 mg	2.6	883	0.97	
Potassium	39.10	60 mg	1.5	760	0.86	

Table 6.5 Reagent Combinations		
Alcohol Solvent	Metal	Alkoxide Base Produced
Methanol	Sodium	Sodium methoxide
2-Propanol	Potassium	Potassium 2-propoxide
2-Methyl-2-propanol (*tert*-butanol)	Potassium	Potassium 2-methyl-2-propoxide (potassium *tert*-butoxide)
3-Ethyl-3-pentanol	Potassium	Potassium 3-ethyl-3-pentoxide

Reagents and Equipment. The combinations of reagents in Table 6.5 may be used to prepare the alkoxide base. Students should compare results to observe a total picture of the effect.

Preparation of the Alkoxide Base. Measure and add to a 5.0-mL conical vial containing a magnetic spin vane 3–3.5 mL of the anhydrous alcohol to be used (see Table 6.5). Add a 60-mg piece of potassium (or sodium) metal and immediately attach the vial to a reflux condenser protected by a calcium chloride drying tube. Place the arrangement in a sand bath and with stirring heat the mixture gently (~50 °C) (⬇).

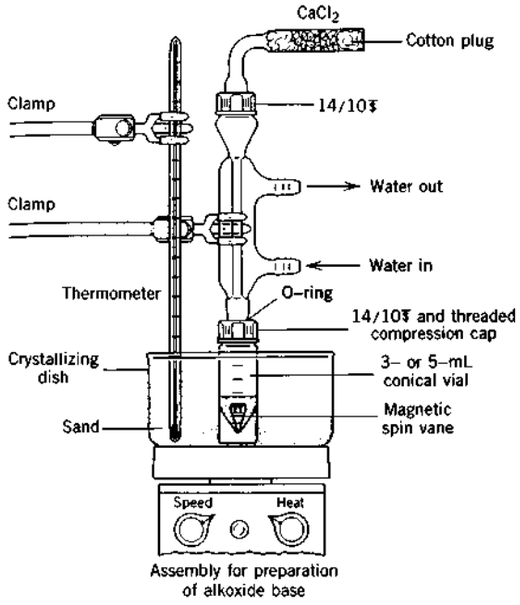

Assembly for preparation of alkoxide base

NOTE. If the sodium/methanol combination is used, it is not necessary to heat the mixture. A fairly vigorous reaction occurs at room temperature. It is recommended that the instructor cut the Na/K metal before commencing the laboratory.

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CAUTION: Handle sodium and potassium with care. These metals react vigorously with moisture and are kept under paraffin oil or xylene. Remove the small piece of the metal from the oil using a pair of forceps or tongs—***never use your fingers!*** Dry the metal quickly by pressing it with filter paper (to soak up the oil), and immediately add it to the alcohol in the reaction vial. Any residual pieces of sodium/potassium should be stored in a bottle marked "sodium/ potassium residues."**Never** throw small pieces of these metals in the sink or in water. To destroy, in the **hood,** add small amounts of the metal to absolute ethanol.

HOOD

When all the metal has reacted, remove the assembly from the sand bath and cool to near room temperature (do not remove the drying tube.).

Table 6.6 **Temperature Conditions**

Base	Temperature (°C)
$NaOCH_3$	100–110
$KOCH(CH_3)_2$	130–140
$KOC(CH_3)_3$	140–150
$KOC(CH_2CH_3)_3$	175–180

Reaction Conditions. Remove the drying tube from the condenser and use a calibrated Pasteur pipet to introduce 100 μL of 2-bromobutane down through the condenser into the vial. Replace the drying tube and place the assembly in the **preheated** sand bath (see Table 6.6). Remove the drying tube and attach the gas delivery tube to the top of the condenser so that the open end of the tube is beneath the water level of the reservoir (⬇). If the connection to the top of the condenser is not made with an O-ring cap seal connection, lightly grease the ground-glass joint to insure a gas-tight seal. After about 10–15 air bubbles emerge, place the water-filled gas collection tube over the open end of the gas delivery tube.

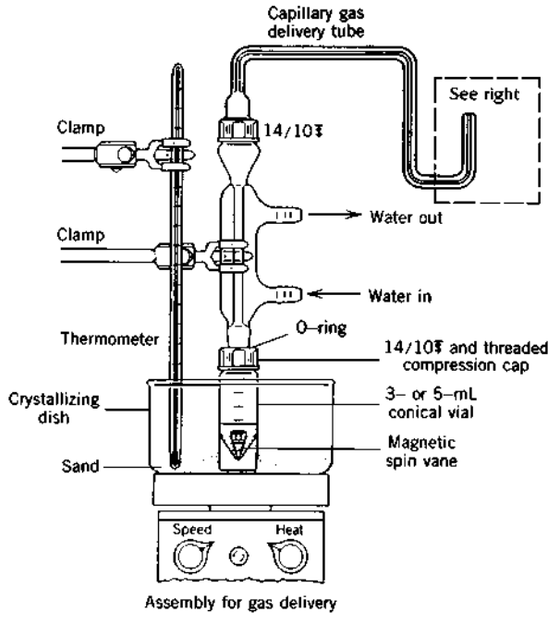

Assembly for gas delivery

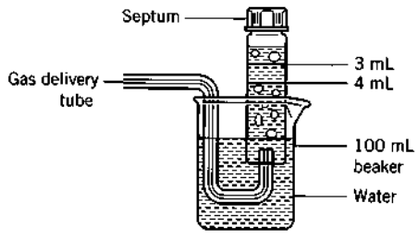

Arrangement for gas collection

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Isolation of Product. Collect about 6–7 mL of gas in the collection reservoir and then use a hypodermic syringe to withdraw a 0.7- to 0.8-mL sample through the rubber septum for GC analysis.

NOTE. Remove the gas delivery tube from the collecting reservoir and then from the water before discontinuing the heat on the reaction vial. This order of events prevents water from being sucked back into the reaction flask.

Purification and Characterization. The collected gas is analyzed by gas chromatography without further purification.

Gas Chromatographic Conditions

Column: $\frac{1}{4}$ in. × 8 ft packed with 20% DC 710

Room temperature

Flow rate (He gas): 30 mL/min

Sample size: 0.7–0.8 mL of collected gas

Chart speed: 1 cm/min

Assuming that the amount of each substance in the gas is proportional to the areas of its corresponding peak, determine the ratio of the three components in the gas sample.

Area Under a Curve. *Several techniques may be used. The following method gives reproducible results of ±3–4%:* Area = peak height (mm) × width at half-height (mm), measured from the baseline of the curve.

The order of elution of the butenes is 1-butene, *trans*-2-butene, and *cis*-2-butene. Record the literature values of their physical properties.

QUESTIONS

6-60. Outline a complete mechanistic sequence for the reaction of 2-bromobutane with potassium 2-methyl-2-propoxide in 2-methyl-2-propanol solvent to form the three alkenes generated in the reaction (1-butene, *trans*-2-butene, and *cis*-2-butene). Include a clear drawing of the anti-periplanar transition state for the formation of each alkene.

6-61. Does the mixture of gases collected in this experiment consist only of alkenes? If not, what other gases might be present?

6-62. Predict the predominant alkene product that would form when 2-bromo-2-methylpentane is treated with sodium methoxide in methanol. If the base were changed to $KOC(CH_2CH_3)_3$ would the same alkene predominate? If not, why? What would be the structure of this alternate product, if it formed?

6-63. Predict the more stable alkene of each of the following pairs:
- **(a)** 1-Hexene or *trans*-3-hexene
- **(b)** *trans*-3-Hexene or *cis*-3-hexene
- **(c)** 2-Methyl-2-hexene or 2,3-dimethyl-2-pentene

6-64. Starting with the appropriate alkyl halide and base–solvent combination, outline a synthesis that would yield each of the following alkenes as the major or only product:
- **(a)** 1-Butene
- **(b)** 3-Methyl-1-butene
- **(c)** 2,3-Dimethyl-1-butene
- **(d)** 4-Methylcyclohexene

6-65. When *cis*-1-bromo-4-*tert*-butylcyclohexane reacts with sodium ethoxide in ethanol, it reacts rapidly to yield 4-*tert*-butylcyclohexene. Under similar conditions, *trans*-1-bromo-4-*tert*-butylcyclohexane reacts very slowly. Using conformational structures, explain the difference in reactivity of these cis–trans isomers.

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McElvain, S. M.; Kundiger, D. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 506.

Paquette, L. A.; Barrett, J. H. *Organic Syntheses*; Wiley: New York, 1973; Collect. Vol. V, p. 467.

Schaefer, J. P.; Endres, L. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 285.

For an overview of elimination reactions:

March, J. *Advanced Organic Chemistry,* 4th ed.; Wiley: New York, 1992, p. 982.

Smith M. B.; March, J. *Advanced Organic Chemistry*, 6th ed.; Wiley: New York, 2007, Chap. 17.

Experiment [10] is adapted from the method given by:

Leone, S. A.; Davis, J. D. *J. Chem. Educ.* **1992,** 69, A175.

EXPERIMENT 11

The Isolation of Natural Products

These experiments are designed to acquaint you with the procedures used to isolate naturally occurring and often biologically active organic compounds. These substances are known as *natural products* because they are produced by living systems. The particular natural products you are going to study come from the plant kingdom. At the end of the nineteenth century more than 80% of all medicines in the Western world were natural substances found in roots, barks, and leaves. There was a widespread belief at that time that in plants there existed cures for all diseases. As Kipling wrote, "Anything green that grew out of the mold/ Was an excellent herb to our fathers of old." Even as the power of synthetic organic chemistry has grown during this century, natural materials still constitute a significant fraction of the drugs used in modern medicine. For example, in the mid-1960s when approximately 300 million new prescriptions were written each year, nearly half were for substances of natural origin. These materials have played a major role in successfully combating the worst of human illnesses, from malaria to high blood pressure; diseases that affect hundreds of millions of people.

Unfortunately, during the latter half of this century a number of very powerful natural products that subtly alter the chemistry of the brain have been used in vast quantities by our society. The ultimate impact on civilization is of grave concern. Evidence clearly demonstrates that these natural substances disrupt the exceedingly complex and delicate balance of biochemical reactions that lead to normal human consciousness. How well the brain is able to repair the damage from repetitive exposure is unknown. We are currently conducting experiments to answer that question.

The natural products that you may isolate in the following experiments include a bright-yellow crystalline antibiotic (Experiment [11A]), a white crystalline alkaloid that acts as a stimulant in humans (Experiment [11B]), and an oily material with a pleasant odor and taste (Experiment [11C]).

Experiment 11A

Isolation and Characterization of an Optically Active Natural Product: Usnic Acid

Common name: usnic acid

CA number: [7562-61-0]

CA name as indexed: 1,3(2*H*,9b*H*)-dibenzofurandione, 2,6-diacetyl-7, 9-dihydroxy-8,9b-dimethyl-

Purpose. In this exercise you will extract the active principle, usnic acid, from one of the lichens that produce it. Usnic acid is a metabolite found in a variety

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of lichens. For this experiment we utilize a local (in Maine) species of lichen, *Usnea hirta* (often referred to as *old-man's beard)*, which is a fruticose lichen (a lichen that possesses erect, hanging, or branched structures). The extraction technique illustrated here is often used to isolate natural products from their native sources (see also Experiment [11B], on page 229, for another extraction strategy). Because usnic acid possesses a single chiral center (stereocenter) and only one of the enantiomers is produced in old-man's beard, this experiment also functions as an introduction to the methods used to measure the specific rotation of optically active substances.

LICHENS AND NATURAL PRODUCTS

Lichens, of which there are estimated to be greater than 15,000 species, are an association between an algae and a fungus that live together in an intimate relationship. This association is often called symbiosis. Symbiosis requires that two different organisms live together in both close structural proximity and interdependent physiological combination. The term ordinarily is applied to situations where the relationship is advantageous, or even required, for one or both, but not harmful to either. In the case of lichens, the algae can be grown independently of the fungi that obtain nutrients from the algae cells. The fungi are, therefore, considered to be parasitic and their contribution to the union has been viewed historically only as an aid in the absorption and retention of water and perhaps to provide a protective structure for the algae. It appears, however, that the fungi may play a far more important role in the life of the lichen than earlier appreciated. The fungi appear to generate a metabolite, usnic acid, which is the most common substance found in these primitive systems. This acid can comprise up to 20% of the dry weight of some lichens! Even more intriguing is the original belief that usnic acid appears to have *no biological function* in these plants. Why would a living system channel huge amounts of its precious energy into making an apparently useless substance? Recently, with our increased understanding of the role of chemical communication substances in ecology, it has been recognized that usnic acid very likely makes a major symbiotic contribution as a *chemical defense agent*. Indeed, in 1945 Burkholder demonstrated that several New England lichens possess antibiotic properties, and usnic acid was subsequently shown to be the active agent against several kinds of bacteria, including staphylococcus. The Finnish company, Lääke Oy Pharmaceutical, has prepared from reindeer lichen a broad-spectrum usnic acid antibiotic for treating tuberculosis and serious skin infections. There is, in fact, evidence that lichens were used in medicine by the ancient Egyptians, and from 1600 to 1800 C.E. these plants were considered an outstanding cure for tuberculosis. Usnic acid has been investigated for use as an antibiotic by the U.S. Public Health Service. It proved to be effective in dilutions between 1 part in 100,000 and 1 part in 1,000,000 against several Gram-positive organisms.

This widespread lichen metabolite is the material isolated in this experiment. Usnic acid was first isolated and identified in 1843 by Rochleder, but a molecule of this complexity was beyond the structural knowledge of organic chemistry in those days. The structure was finally determined in 1941 by Schöpf, and in 1956 it was synthesized in the laboratory by Sir D. H. R. Barton (Nobel Laureate). Barton's route involved a spectacular one-step dimerization of a simple precursor, a synthesis that very closely mimicked the actual biogenetic pathway (see chemistry). The key step was the one-electron (1 e^-) oxidation of methylphloracetophenone, which leads directly to the dimerization. The mechanism of this

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reaction, both in the plant and in the laboratory synthesis, is essentially identical to the oxidative coupling of 2-naphthol to give 1,1′-bi-2-naphthol, which is explored in detail in Experiment [5_{adv}]:

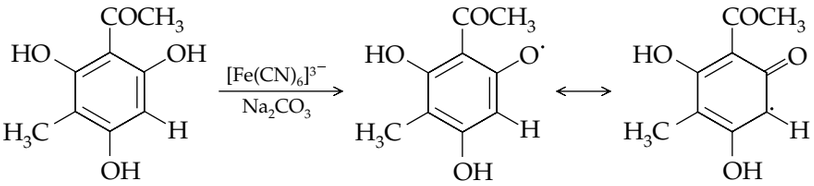

Methylphloracetophenone

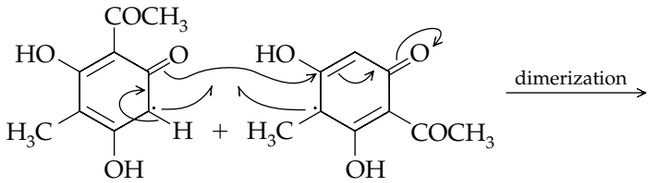

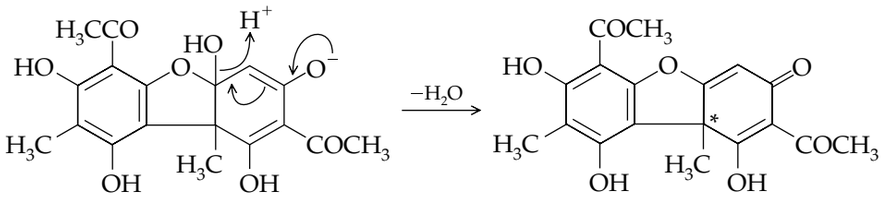

Usnic Acid

The chiral center (stereocenter) (*) is bonded to a highly conjugated aromatic ring system (see structure), which gives rise to a very large specific rotation. This enhanced interaction with polarized radiation makes this compound a particularly interesting molecule to examine for optical activity. The production of a single enantiomer in the natural product, which, as discussed above, is formed by an oxidative coupling process, implies that there must be an intimate association between the substrate and an enzyme (a biological catalyst that itself is optically active) during the crucial coupling process.[11]

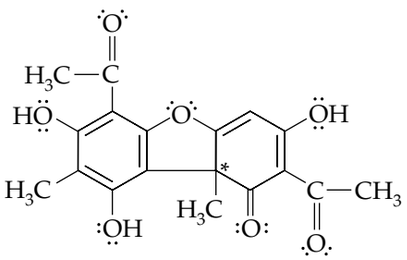

Prior Reading

Technique 6A: Thin-Layer Chromatography (pp. 97–99)
Technique 8: Measurement of Specific Rotation
Optical Rotation Theory (pp. 108–111)

[11]Dean, F. M.; Halewood, P.; Mongkolsuk, S.; Roberston, A.; Whally, W. B. *J. Chem. Soc.* **1953,** 1250. Kreig, M. B. *Green Medicine;* Rand McNally: New York, 1964. Lewis, W. H.; Elvin-Lewis, M. P. F. *Medical Botany;* Wiley: New York, 1977. Hendrickson, J. B. *The Molecules of Nature;* W. A. Benjamin, New York: 1965. Richards, J. H.; Hendrickson, J. B. *The Biosynthesis of Steroids, Terpenes, and Acetogenins;* W. A. Benjamin: New York, 1964. Schöpf, C.; Ross, F. *Annalen* **1941,** *546*, 1 (see further references cited in Experiment [5_{adv}]).

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DISCUSSION

Nonracemic solutions of chiral substances, when placed in the path of a beam of polarized light, may rotate the plane of the polarized light clockwise or counterclockwise and are thus referred to as *optically active*. This angle of optical rotation is measured using a *polarimeter*. This technique is applicable to a wide range of analytical problems varying from purity control to the analysis of natural and synthetic products in the medicinal and biological fields. The results obtained from the measurement of the observed angle of rotation (α_{obs}) are generally expressed in terms of *specific rotation* [α]. The sign and magnitude of [α] are dependent on the specific molecule and are determined by complex features of molecular structure and conformation, and thus cannot be easily explained or predicted. The relationship of [α] to α_{obs} is $[\alpha]_{\lambda}^{T} = \dfrac{\alpha_{obs}}{l \cdot c}$ where T is the temperature of the sample **in degrees Celsius** (°C), l is the length of the polarimeter cell **in decimeters** (1 dm = 0.1 m = 10 cm), c is the concentration of the sample **in grams per milliliter** (g/mL), and λ is the wavelength of the light used in the polarimeter **in nanometers** (nm). These units are traditional, though most are esoteric by contemporary standards. Thus, the specific rotation for a given compound is normally reported in terms of temperature, wavelength, concentration, and the nature of the solvent. For example; $[\alpha]_{D}^{25} = +12.3°$ (c = 0.4, $CHCl_3$) implies that the measurement was recorded in a $CHCl_3$ solution of 0.4 g/mL at 25 °C using the sodium D line (589 nm) as the light source. Unless indicated, the pathlength is assumed to be 1 dm in these observations.

Usnic acid contains a single stereocenter (see structure), and therefore it can exist as a pair of enantiomers. In nature, however, only one of the enantiomers (*R* or *S*) would be expected to be present. Usnic acid has a very high specific rotation, $[\alpha]_{D}^{25} = +488°$ (c = 0.4, $CHCl_3$), which will give a large α_{obs} even at low concentrations, and for this reason it is an ideal candidate to measure rotation in a microscale experiment.

Racemic (equimolar amounts of each enantiomer) usnic acid has been resolved (separated into the individual enantiomers) through preparation and separation of the diastereomeric (−) brucine salts. This procedure was the route followed to obtain an authentic synthetic sample for comparison with the natural material. The separation was required because the dimerization step in the synthesis, which was carried out in the absence of enzymatic, or other chiral, influence, gave a racemic product.

A common method of extracting chemical constituents from natural sources is presented in this experiment. In this case, only one chemical compound, the usnic acid, is significantly soluble in the extraction solvent, acetone. For this reason, the isolation sequence is straightforward.

EXPERIMENTAL PROCEDURE

Isolation of Usnic Acid. Estimated time for completion of the experiment: 2.5 h.

Physical Properties of Components			
Compound	**MW**	**Amount**	**bp (°C)**
Lichen		1.0 g	
Acetone	58.08	15.0 mL	56.2

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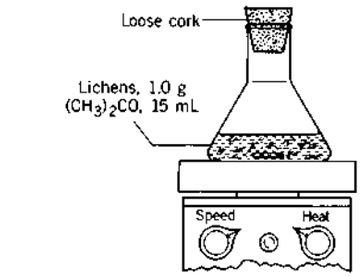

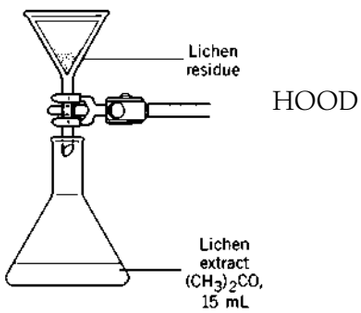

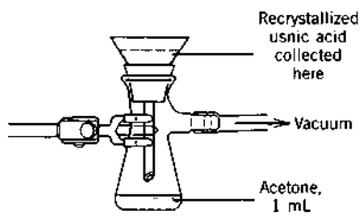

V

Reagents and Equipment. Weigh and place about 1.0 g of oven-dried (40 °C) crushed or cut-up lichens and 15.0 mL of acetone in a 50-mL Erlenmeyer flask containing a magnetic stirrer. Loosely cap the flask with a cork stopper (⬅). The lichens used in this experiment are *Usnea hirta*.

Reaction Conditions. Stir or occasionally swirl the mixture for no less than 30 min at room temperature. If necessary, periodically push the lichens below the surface of the acetone solvent using a glass rod.

Isolation of Product. Prior to filtering the resulting mixture, remove a 0.5 mL aliquot for final analysis. Filter by gravity and collect the filtrate in a 25-mL Erlenmeyer flask (⬅). A Pasteur filter pipet may be used to make this transfer, if desired. In the **hood,** remove the acetone solvent under a slow stream of air or nitrogen on a warm sand bath nearly to dryness. Allow the remainder of the acetone to evaporate at room temperature to obtain the crude bright yellow or orange usnic acid crystals.

Purification and Characterization. Recrystallize all but 5 mg of the crude extract from acetone/95% ethanol (10:1). Dissolve the crystals in the minimum amount of hot acetone, keeping the recrystallization vessel hot, and add the appropriate volume of 95% ethanol. Allow the mixture to cool to room temperature and then place the flask in an ice bath to complete the recrystallization. Collect the golden-yellow crystals by vacuum filtration (⬅) and wash them with *cold* acetone. Dry the crystals on a porous clay plate or on a sheet of filter paper. As an alternative and more efficient procedure, the crude material may be recrystallized using a Craig tube, avoiding the filtration step with the Hirsch funnel.

Weigh the yellow needles of usnic acid and calculate the percentage of the acid extracted from the dry lichen. Determine the melting point (use the evacuated melting point technique) and compare your value to that found in the literature. Using a solvent system of ethyl acetate:hexane (1:4) and a UV lamp for visualization, compare the crude extract with the purified usnic acid by TLC (R_f value for usnic acid is 0.32). Obtain an IR spectrum and compare it with that of an authentic sample or one from the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. Chemical tests can assist in establishing the nature of the functional groups in usnic acid. Perform the 2,4-dinitrophenylhydrazine test and the ferric chloride test (see Chapter 9). Are the results significant?

Determination of the Specific Rotation. Though usnic acid is an optically active compound with a very high specific rotation, a low-volume, long-pathlength cell must be used to successfully determine its specific rotation with microscale quantities.

Dissolve usnic acid (80 mg) in 4.0 mL of tetrahydrofuran (THF) solvent and transfer the solution to the polarimeter cell using a Pasteur pipet.

NOTE. To obtain this quantity (80 mg) of usnic acid will very likely require pooling the recrystallized product of eight or nine students. Spectral grade THF should be used as the solvent. Many of the early specific rotation values on these substances were recorded with chloroform as the solvent, but, because it possesses some toxicity, it is now avoided if possible.

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Place the cell in the polarimeter and measure the angle of rotation. Calculate the specific rotation using the equation given in the discussion section.

QUESTIONS

6-66. Determine the correct *R* or *S* designation for each of the following molecules:

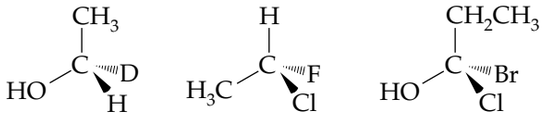

6-67. The structure originally proposed for cordycepic acid, which has [α] = +40.3°, was

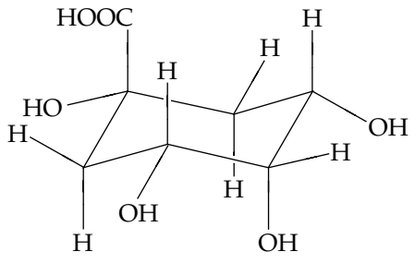

Why is this not a plausible structure?

6-68. A sample of 150 mg of an organic compound is dissolved in 7.5 mL of water. The solution is placed in a 20-cm polarimeter tube and the rotation is measured in a polarimeter. The rotation observed is +2.676°. Distilled water, in the same tube, gave a reading of +0.016°. Calculate the specific rotation for the compound.

6-69. Compound A is optically active and has the molecular formula $C_5H_{10}O$. On catalytic hydrogenation (addition of hydrogen) of A, compound B is obtained. Compound B has the molecular formula $C_5H_{12}O$ and is optically inactive. Give the structure for compounds A and B.

6-70. Which of the following compounds have a meso form?
(a) 2,3-Dibromopentane
(b) 2,4-Dibromopentane
(c) 2,3-Dibromobutane

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Synthesis of usnic acid:

Barton, D. H. R.; DeFlorin, A. M.; Edwards, O. E. *J. Chem. Soc.* **1956,** 530.

Penttila, A., Fales, H. M. *Chem. Commun.* **1966,** 656.

A large-scale method of isolation of usnic acid has been reported:

Stark, J. B.; Walter, E. D.; Owens, H. S. *J. Am. Chem. Soc.* **1950,** *72,* 1819.

Optical, crystallographic and X-ray diffraction data have been reported for usnic acid:

Jones, F. T.; Palmer, K. J. *J. Am. Chem. Soc.* **1950,** *72,* 1820.

Isolation and Characterization of a Natural Product: Caffeine and Caffeine 5-Nitrosalicylate

Experiment 11B

Product

Common names: caffeine, 1,3,7-trimethyl-2,6-dioxopurine

CA number: [58-08-2]

CA name as indexed: 1*H*-purine-2,6-dione, 3,7-dihydro-1,3,7-trimethyl-

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Purpose. To extract the active principle, an alkaloid, caffeine, from a native source, tea leaves. Caffeine is a metabolite (a product of the living system's biochemistry) found in a variety of plants. We will use ordinary tea bags as our source of raw material. This experiment illustrates an extraction technique often used to isolate water-soluble, weakly basic natural products from their biological source (see also Experiment [11A] for another extraction strategy). The isolation of caffeine will also give you the opportunity to use sublimation as a purification technique, since caffeine is a crystalline alkaloid that possesses sufficient vapor pressure to make it a good candidate for this procedure. In addition, the preparation of a derivative of caffeine, its 5-nitrosalicylate salt, will be carried out. This latter conversion takes advantage of the weakly basic character of this natural product.

ALKALOIDS

Caffeine belongs to a rather amorphous class of natural products called alkaloids. This collection of substances is unmatched in its variety of structures, biological response on nonhost organisms, and the biogenetic pathways to their formation.

The history of these fascinating organic substances begins at least 4000 years ago. They were incorporated into poultices, potions, poisons, and medicines, but no attempt was made to isolate and identify the substances responsible for the physiological response until the very early 1800s.

The first alkaloid to be obtained in the pure crystalline state was morphine. Friedrich Wilhelm Sertürner (1783–1841) isolated morphine in 1805. He recognized that the material possessed basic character and he, therefore, classified it as a vegetable alkali (that is, a base with its origin in the plant kingdom). Thus, compounds with similar properties ultimately became known as alkaloids. The term "alkaloid" was introduced for the first time by an apothecary, Meissner, in Halle in 1819.

Sertürner, also a pharmacist, lived in Hamelin, another city in Prussia. He isolated morphine from opium, the dried sap of the poppy. Since the analgesic and narcotic effects of the crude resin had been known for centuries, it is not surprising that, with the emerging understanding of chemistry, the interest of Sertürner became focused on this drug, which is still medicine's major therapy for intolerable pain. He published his studies in detail in 1816 and very quickly two French professors, Pierre Joseph Pelletier (1788–1842) and Joseph Caventou (1795–1877) at the Ecole de Pharmacie in Paris, recognized the enormous importance of Sertürner's work.

In the period from 1817 to 1820, these two men and their students isolated many of the alkaloids, which continue to be of major importance. Included in that avalanche of purified natural products was caffeine, which they obtained from the coffee bean. This substance is the target compound that you will be isolating directly from the raw plant in this experiment. A little more than 75 years later, caffeine was first synthesized by Fischer in 1895 from dimethylurea and malonic acid.

THE CLASSIFICATION OF ALKALOIDS

These compounds are separated into three general classes of materials.

1. **True alkaloids:** These compounds contain nitrogen in a heterocyclic ring; are almost always basic (the lone pair of the nitrogen is responsible for

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this basic character); are derived from amino acids in the biogenesis of the alkaloid; invariably are toxic and possess a broad spectrum of pharmacological activity; are found in a rather limited number of plants (of the 10,000 known genera only 8.7% possess at least one alkaloid); and normally occur in a complex with an organic acid (this helps to make them rather soluble in aqueous media). As we will see, there are numerous exceptions to these rules. For example, there are several very well-known quaternary alkaloids. These are compounds in which the nitrogen has become tetravalent and positively charged (as in the ammonium ion). Thus, they are not actually basic.

2. **Protoalkaloids:** These compounds are simple amines, derived from amino acids, in which the basic nitrogen atom is not incorporated into a ring system; they are often referred to as *biological amines*. An example of a protoalkaloid is mescaline.
3. **Pseudoalkaloids:** These compounds contain nitrogen atoms usually *not* derived from amino acids. There are two main classes into which pseudoalkaloids are divided, the steroidal alkaloids and the *purines*. Caffeine has been assigned to this latter class of alkaloids.

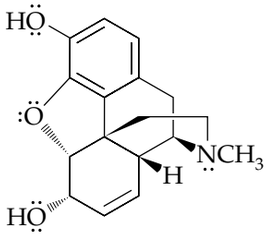

Morphine

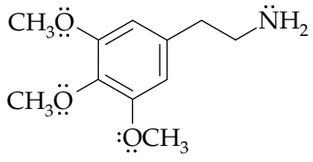

Mescaline

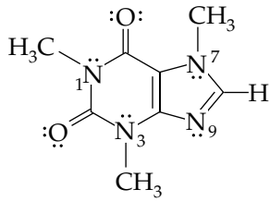

Caffeine

Prior Reading

Technique 4: Solvent Extraction
Solid–Liquid Extraction (p. 79)
Liquid–Liquid Extraction (p. 72)

Technique 9: Sublimation
Sublimation Theory (pp. 112–113)

DISCUSSION

Caffeine (1,3,7-trimethylxanthine) and its close relative theobromine (3,7-dimethyl-xanthine) both possess the oxidized purine skeleton (xanthine). These compounds are often classified as pseudoalkaloids, since only the nitrogen atom at the 7 position can be traced to an amino group originally derived from an amino acid (in this case glycine). This classification emphasizes the rather murky problem of deciding just what naturally occurring nitrogen bases are *true* alkaloids. We will simply treat caffeine as an alkaloid.

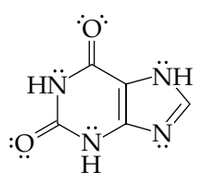

Xanthine

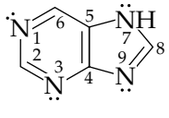

Purine

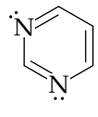

Pyrimidine

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Although the pyrimidine ring (present in caffeine's purine system) is a significant building block of nucleic acids, it is rare elsewhere in nature.

These two methylated xanthines are found in quite a number of plants and have been extracted and widely used for centuries. Indeed, they very likely have been, and remain today, the predominant stimulant consumed by humans. Every time you make a cup of tea or coffee, you perform an aqueous extraction of plant material (tea leaves, *Camellia sinenis*, 1–4%, or coffee beans, *Coffea* spp., 1–2%) to obtain a dose of 25–100 mg of caffeine. Caffeine is also the active substance (~2%) in maté (used in Paraguay as a tea) made from the leaves of *Ilex paraguensis*. In coffee and tea, caffeine is the dominant member of the pair, whereas in *Theobroma cacao*, from which we obtain cocoa, theobromine (1–3%) is the primary source of the biological response. Caffeine acts to stimulate the central nervous system with its main impact on the cerebral cortex, and as it makes one more alert, it is no surprise that it is the chief constituent in No-Doz® pills.

Caffeine is readily soluble in hot water, because the alkaloid is often bound in thermally labile, partially ionic complexes with naturally occurring organic acids, such as with 3-caffeoylquinic acid in the coffee bean. For this reason it is relatively easy to separate caffeine from black tea leaves by aqueous extraction.

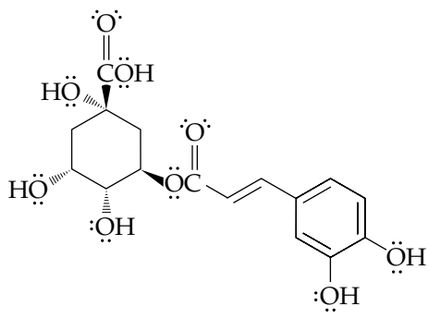

3-Caffeoylquinic acid

Other substances, mainly tannic acids, are also present in the tea leaves and are also water soluble. The addition of sodium carbonate, a base, during the aqueous extraction helps to increase the water solubility of these acidic substances by forming ionic sodium salts and liberating the free base.

Subsequent extraction of the aqueous phase with methylene chloride, in which free caffeine has a moderate solubility, allows the transfer of the caffeine from the aqueous extract to the organic phase. At the same time, methylene chloride extraction leaves the water-soluble sodium salts of the organic acids behind in the aqueous phase.

Extraction of the tea leaves directly with nonpolar solvents (methylene chloride) to remove the caffeine gives very poor results—since, as we have seen, the caffeine is bound in the plant in a partially ionic complex that will not be very soluble in nonpolar solvents. Thus, water is the superior extraction solvent for this alkaloid. The water also swells the tea leaves and allows for easier transport across the solid–liquid interface.

Following extraction and removal of the solvent, sublimation techniques are applied to the crude solid residues to purify the caffeine. This technique is especially suitable for the purification of solid substances at the microscale

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level, if they possess sufficient vapor pressure. Sublimation techniques are particularly advantageous when the impurities present in the sample are nonvolatile under the conditions used.

Sublimation occurs when a substance goes directly from the solid phase to the gas phase upon heating, bypassing the liquid phase. Sublimation is technically a straightforward method for purification in that the materials need only be heated and therefore, mechanical losses can be kept to a minimum (the target substance must, of course, be thermally stable at the required temperatures). Materials sublime only when heated *below* their melting points, and reduced pressure is usually required to achieve acceptable sublimation rates. Obviously, substances that lend themselves best to purification by sublimation are those that do not possess strong intermolecular attractive forces. Caffeine and ferrocene (used as a reactant in Experiment [27]) meet these criteria because they present large flat surfaces occupied predominantly with repulsive π electrons. For other isolation methods, see the discussion of *solid-phase* extraction in Technique 4, where caffeine is extracted from coffee beans (pp. 83–84).

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Constituents				
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**
Tea		1.0 g		
Water		10 mL		
Sodium carbonate	105.99	1.1 g	10	851

Reagents and Equipment. Carefully open a commercial tea bag (2.0–2.5 g of tea leaves) and empty the contents. Weigh out 1.0 g of tea leaves and place them back in the empty tea bag. Close and secure the bag with staples.

Weigh, and add to a 50-mL Erlenmeyer flask, 1.1 g (0.01 mol) of anhydrous sodium carbonate followed by 10 mL of water (➡). Heat the mixture with occasional swirling on a hot plate to dissolve the solid. Now add the 1.0 g of tea leaves (in the tea bag) to the solution. Place the bag in the flask so that it lies flat across the bottom.

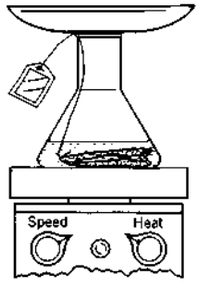

Anhydrous Na_2CO_3, 1.1 g + H_2O, 10 mL + tea bag with tea leaves, 1.0 g

Reaction Conditions. Place a small watch glass over the mouth of the Erlenmeyer flask and then heat the aqueous suspension to **gentle** boiling for 30 min on the hot plate.

GENTLY

Isolation of Product. Cool the flask and contents to room temperature. Transfer the aqueous extract from the Erlenmeyer flask to a 12- or 15-mL centrifuge tube using a Pasteur filter pipet. In addition, gently squeeze the tea bag by pressing it against the side of the Erlenmeyer flask to recover as much of the basic extract as possible. Set aside the tea bag and its contents.

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EQA

Extract the aqueous solution with 2.0 mL of methylene chloride.

NOTE. The tea solution contains some constituents that may cause an emulsion. If you obtain an emulsion during the mixing of the aqueous and organic solvent layers (by shaking or using a Vortex mixer), it can be broken readily by centrifugation.

Separate the lower (methylene chloride) layer (check to make sure that the lower layer is, indeed, the organic layer by testing the solubility of a few drops of it in a test tube with distilled water) using a 9-in. Pasteur pipet. Drain the wet extracts through a filter funnel containing a small plug of cotton that is covered with about 2.0 g of anhydrous sodium sulfate, previously "moistened" with a small amount of methylene chloride (⬅). (The organic phase will be saturated with water following the extraction, therefore it is referred to as "wet." It also may contain a few droplets of the aqueous phase, which become entrained during the phase separation; this can be particularly troublesome if an emulsion forms during the mixing.)

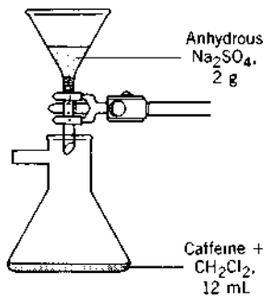

HOOD

Collect the dried filtrate in a 25-mL filter flask. Extract the remaining aqueous phase with four additional 2.0-mL portions of methylene chloride (4×2 mL). Each extraction (an extraction is often referred to as a washing) is separated, dried as above, and transferred to the same filter flask. Finally, rinse the sodium sulfate with an additional 2.0 mL of methylene chloride and combine this wash with the earlier organic extracts.

Add a boiling stone to the flask and concentrate the solution to dryness in the **hood** by warming the flask in a sand bath. The crude caffeine should be obtained as an off-white crystalline solid.

Purification and Characterization. Purify the crude solid caffeine by sublimation.

Assemble a sublimation apparatus as shown in Figure 5.53, on page 113; either arrangement is satisfactory. Using an aspirator, apply a vacuum to the system through the filter flask (remember to install a water-trap bottle between the sidearm flask and the aspirator). After the system is evacuated, run cold water gently through the cold finger or add ice to the centrifuge tube. By cooling the surface of the cold finger *after* the system has been evacuated, you will minimize the condensation of moisture on the area where the sublimed sample will collect.

NOTE. Less caffeine will be lost if the bottom of the cold finger is positioned less than 5 mm from the bottom of the filter flask.

Once the apparatus is evacuated and cooled, begin the sublimation by gently heating the flask with a microburner or sand bath. If you use a gas burner, always keep moving the flame back and forth around the bottom and sides of the flask.

NOTE. Be careful. Do not melt the caffeine. If the sample does begin to melt, remove the flame for a few seconds before heating is resumed. Overheating the crude sample will lead to decomposition and the deposition of impurities on the cold finger. High temperatures are not necessary since the sublimation temperature of caffeine (and of all solids that sublime) is below the melting point. It is generally worthwhile to carry out sublimations as slowly as possible, as the purity of the material collected will be enhanced.

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EQA

When no more caffeine will sublime onto the cold finger, remove the heat, shut off the aspirator and the cooling water to the cold finger, and allow the apparatus to cool to room temperature under reduced pressure. Once cooled, carefully vent the vacuum and return the system to atmospheric pressure. *Carefully* remove the cold finger from the apparatus.

NOTE. If the removal of the cold finger is done carelessly, the sublimed crystals may be dislodged from the sides and bottom of the tube and drop back onto the residue left in the filter flask.

Scrape the caffeine from the cold finger onto weighing paper using a microspatula and a sample brush. Weigh the purified caffeine and calculate its percent by weight in the original tea leaves. Determine the melting point and compare your value to that in the literature.

If your melting point apparatus uses capillary tubes to determine the melting point, an evacuated sealed tube is necessary, since caffeine sublimes; the melting point is above the sublimation temperature (see Chapter 4). The melting point may be obtained using the Fisher–Johns apparatus without this precaution.

Obtain an IR spectrum and compare it with that of an authentic sample.

Chemical Test. Does the soda lime or the sodium fusion test (see Chapter 9) confirm the presence of nitrogen in your caffeine product?

DERIVATIVE: CAFFEINE 5-NITROSALICYLATE

It is not completely surprising to find that caffeine in the coffee bean is bound in a thermally labile complex with acid, since this alkaloid is a weakly basic substance possessing a base strength somewhat greater than that of an aryl amide. Because the purine ring system of caffeine has little reactive functionality, the formation of simple chemical derivatives is limited. The ease of association with high-melting carboxylic acids, however, offers a route to a variety of materials with well-defined melting points.

One such acid is 5-nitrosalicylic acid, which is prepared by nitration of salicylic acid in Experiment [29]. The purified caffeine obtained in this experiment may be further characterized by preparation of the 5-nitrosalicylate complex. This association is similar to the natural one formed with 3-caffeoylquinic acid:

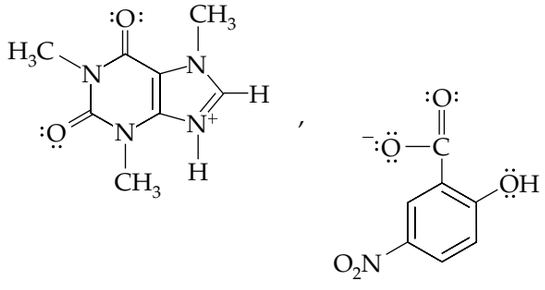

Caffeine 5-nitrosalicylate

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.5 h.

Physical Properties of Reactants and Product					
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**
Caffeine	194.20	11 mg	0.06	238	
5-Nitrosalicylic acid	183.12	10 mg	0.06	229–30	
Petroleum ether (60–80 °C)		0.5 mL			60–80
Ethyl acetate	88.12	0.7 mL			77
Caffeine 5-nitrosalicylate	377.32			180	

Reagents and Equipment. Weigh and add to a 3.0-mL conical vial, containing a magnetic spin vane and equipped with an air condenser, 11 mg (0.06 mmol) of caffeine, 10.0 mg (0.06 mmol) of 5-nitrosalicylic acid, and 0.7 mL of ethyl acetate.

Reaction Conditions. *Gently* warm the mixture on a hot plate, with stirring, to dissolve the solids. Add 0.5 mL of petroleum ether (bp 60–80 °C) to the warm ethyl acetate solution, mix, and warm for several seconds. Remove the spin vane using forceps.

Isolation of Product. Cool the mixture to room temperature and then place it in an ice bath for 10–15 min. Collect the crystals under reduced pressure using a Hirsch funnel, and then wash the filter cake with 0.5 mL of cold ethyl acetate. Dry the product on a porous clay plate or filter paper.

Purification and Characterization. The product normally is sufficiently pure for direct characterization. Weigh the caffeine 5-nitrosalicylate and calculate the percent yield. Determine the melting point and compare your value with that reported above.

Obtain an IR spectrum and compare it with those shown in Figures 6.25 and 6.26. The infrared spectrum reveals some of the details of the derivative formation (see below).

Infrared Analysis. The infrared spectrum of 5-nitrosalicylic acid (Fig. 6.26 on page 238) is characteristic of aromatic carboxylic acids (see discussion in Experiment [7]). Note that (1) the substitution of the ring is revealed by the presence of the 1,2,4-combination band pattern with peaks at 1940, 1860, and 1815 cm^{-1}; (2) the strongest band in the spectrum below 1750 cm^{-1} is assigned to the symmetric stretch of the —NO_2 group found at 1339 cm^{-1}, and (3) the conjugated carboxyl C═O stretch is located at 1675 cm^{-1}.

In the spectrum of the complex (Fig. 6.25) we do not find evidence for ionized carboxylate. This group, if present, would give rise to two very strong *broad* bands at 1600–1550 and 1400–1330 cm^{-1}. What is observed is the carboxylate C═O stretch at 1665 cm^{-1} overlapped with a caffeine band. Evidence for very strong hydrogen bonding, however, is indicated by the series of very broad bands extending from 3550 to 2000 cm^{-1}. The complex association, therefore, very likely does not involve a complete proton transfer as is indicated in the above simplified chemical structures of the complex. The unambiguous formation of the 5-nitrosalicylic acid complex is best ascertained by the identification of the presence of the —NO_2 symmetric stretching vibration from a strong band located at 1345 cm^{-1}. Caffeine does not possess a band in this region.

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EQA

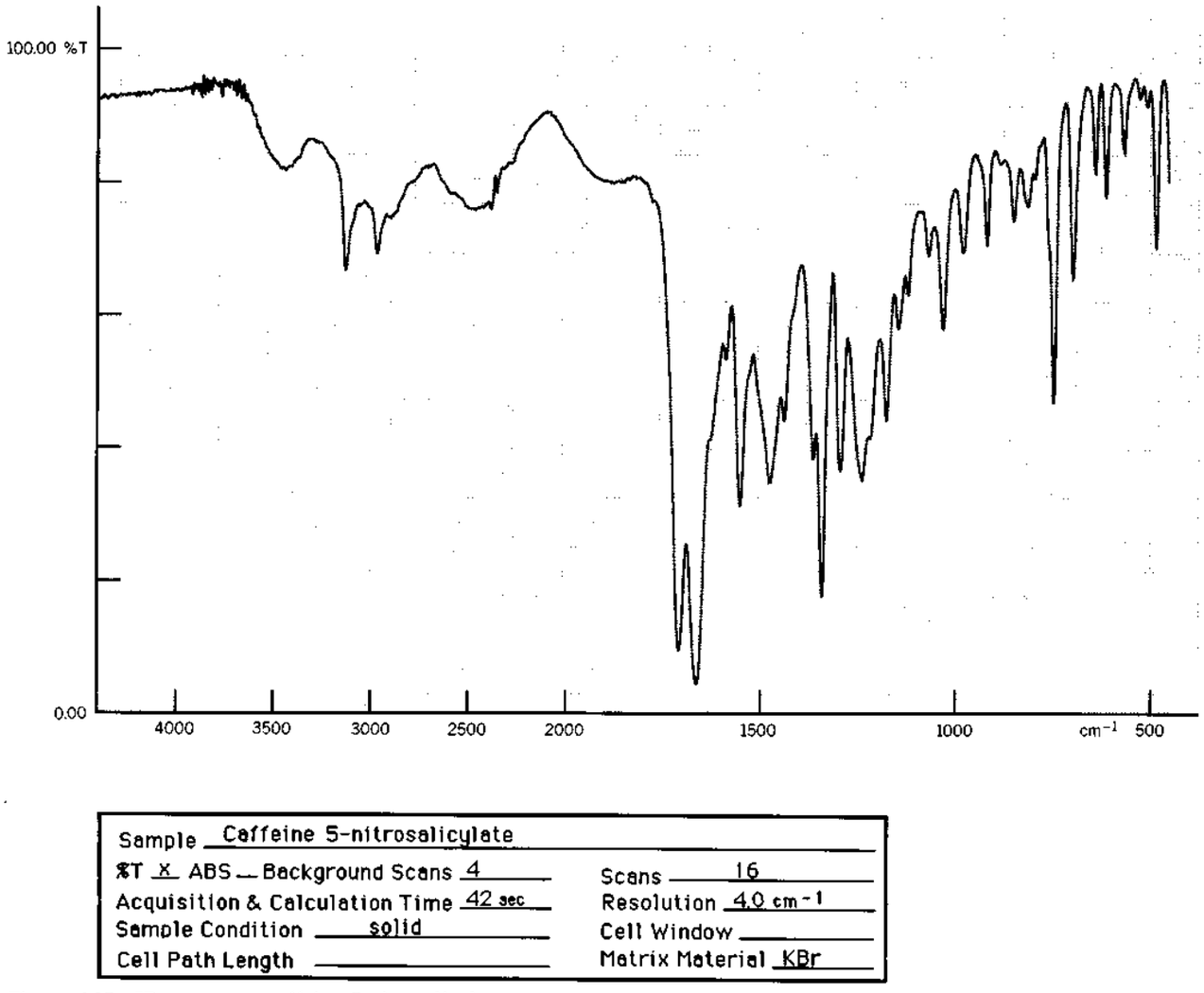

Figure 6.25 IR spectrum: caffeine 5-nitrosalicylate.

QUESTIONS

6-71. Compounds such as naphthalene and 1,4-dichlorobenzene find use as mothballs since they sublime at a slow rate at atmospheric pressure. Explain this behavior in terms of the structure of the molecules.

6-72. **(a)** How many peaks would you expect to find in the NMR spectrum of caffeine? **(b)** What characteristic absorption bands would you expect to find in the infrared spectrum of caffeine? **(c)** Are the NMR spectra (proton and carbon) of caffeine when compared to caffeine 5-nitrosalicylate as characteristic to the comparisons found using IR?

6-73. The vapor pressures of 1,2-diphenylethane, *p*-dichlorobenzene, and 1,3,5-trichlorobenzene are 0.06, 11.2, and 1.4 torr, respectively, at their melting point (52–54 °C). Which compound is likely to be sublimed most rapidly at a reduced pressure of 15 torr and a temperature of 40 °C?

6-74. To color spots on TLC plates for easier visualization after elution with solvent, the plates can be "developed" in a sealed chamber containing solid iodine. Explain how the solid–vapor equilibrium operates in this instance.

6-75. Caffeine is soluble in ethyl acetate. Do you think that the purity of your product could be checked by TLC using ethyl acetate as an elution solvent? Explain.

6-76. The infrared spectrum of 5-nitrosalicylic acid (Fig. 6.26) possesses the typical broad medium band found in *acid dimers* (908 cm^{-1}). In the caffeine 5-nitrosalicylate complex, however, this band is missing. Suggest a reason why the 908-wavenumber peak vanishes.

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EQA

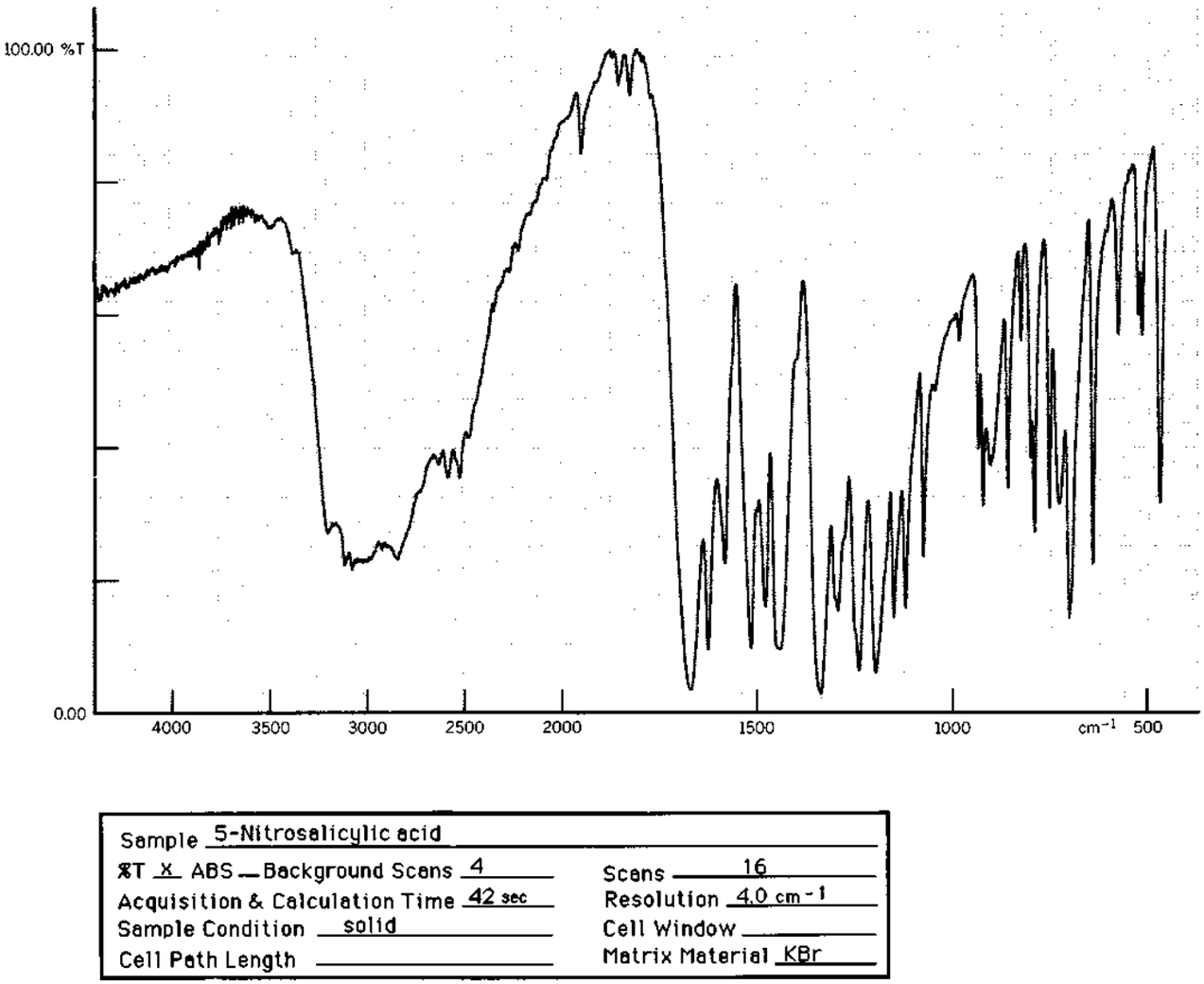

Figure 6.26 IR spectrum: 5-nitrosalicylic acid.

BIBLIOGRAPHY

Several extraction procedures for isolating caffeine from tea, some designed for the introductory organic laboratory, have been reported.

Ault, A.; Kraig, R. *J. Chem. Educ.* **1969,** *46,* 767.
Mitchell, R. H.; Scott, W. A.; West, P. R. *J. Chem. Educ.* **1974,** *51, 69.*
Moyé, A. L. *J. Chem. Educ.* **1972,** *49,* 194.
Murray, S. D.; Hansen, P. J. *J. Chem. Educ.* **1995,** *72,* 851.
Onami, T.; Kanazawa, H. *J. Chem. Educ.* **1996,** *73,* 556.

For additional information on the Fisher-Johns melting point apparatus see

Morhrig, J. R.; Neckers, D. C. *Laboratory Experiments in Organic Chemistry,* 3rd ed.; Van Nostrand: New York, **1979,** p. 92.
Zubrick, J. W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, **2008,** p. 94, Fig. 12.5.

Experiment 11C

Isolation of a Natural Product by Steam Distillation: Cinnamaldehyde from Cinnamon

Common name: cinnamaldehyde

CA number: [14371-10-9]

CA name as indexed: 2-propenal, 3-phenyl-, (*E*)-

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EQA

Purpose. In this exercise you will extract oil of cinnamon from a native plant source, such as *Cinnamomum zeylanicum*, and then purify the principal flavor and odor component of the oil, cinnamaldehyde. The experiment demonstrates the importance of steam distillation techniques (at the semimicro level) to the collection of essential oils. www

Prior Reading

Technique 2: Simple Distillation at the Semimicroscale Level (pp. 61–64)
Technique 3: Steam Distillation www
Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)
Technique 6: Chromatography
Concentration of Solutions with Nitrogen Gas (p. 102)

ESSENTIAL OILS

Let us begin by defining what we mean by the term "metabolite." The metabolism of an organism is composed of the biochemical reactions and pathways in that living system. The products (most of them organic molecules) derived from this array of molecular transformations are the *metabolites*. This vast collection of substances that are generally referred to as *natural products* are, in fact, the metabolites of the natural living world.

Natural products are divided into two large families of compounds. Those metabolites that are *common* to the large majority of all organisms are known as the *primary metabolites*. In general, they have well-defined roles in the biochemistry of the system. For example, the amino acids are the building blocks for protein synthesis in all organisms. The second great category of natural products is known as the *secondary metabolites*. Individual secondary metabolites are far less widely distributed in nature and may be unique to single species (or even limited to a variety of a particular species). While the biochemical role of some of these compounds was established early and easily, the majority of these materials were believed to be of little importance to the functioning of the living system, and their presence was unexplained until very recently. With the development of chemical communication theory over the last few decades, however, the vitally important roles of many of the secondary metabolites in the life cycles of their particular host organisms have been revealed.

You may have had the opportunity to become acquainted with secondary metabolites in Experiments [11A] and [11B]. In Experiment [11A] an acetogenin (this term refers to the biochemical origin of this material from eight acetic acid residues), usnic acid, was isolated from a lichen where it can occur in dramatically high concentrations. Only recently has the role of usnic acid as a defense mechanism come to be fully appreciated.

In Experiment [11B], the alkaloid caffeine was obtained from tea. This compound is a very unusual example of a purine ring system in a secondary metabolite. The ecological significance of the presence of caffeine in both tea and coffee seeds has been established and it has been shown that caffeine acts against both predators and competitors.

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EQA

We will now examine, in Experiment [11C], a third class of secondary metabolites: the *essential oils*. The majority of these materials are high-boiling liquids that can be extracted from plant material via steam distillation techniques. The value of codistilling high-boiling substances was learned early in the days of alchemy. Because these oils often gave pleasant odors and flavors, they were considered to be the "essence" of the original plant material. Eventually, they became known as essential oils.

These materials were used as flavorings, perfumes, and medicines, and as both insect repellents and attractants. By the early 1800s, as it became possible to establish the carbon/hydrogen ratio in organic substances, many of the oils possessing pine-type odors (the oil of turpentine) were shown to have identical C/H ratios. These materials ultimately became known as terpenes. The terpenes all have their origin in mevalonic acid, from which they utilize, as their building block, a branched five-carbon unit as in isoprene. The terpenes of the essential oils occur as C_{10} (monoterpenes), C_{15} (sesquiterpenes), C_{20} (diterpenes), C_{30} (triterpenes), and C_{40} (tetraterpenes) compounds. Today, this collection of substances represents a large fraction of the known secondary metabolites, including the steroids. Terpenes may be polymerized, extending to much higher molecular weights, with between 1000 and 5000 repeating isoprene units (MW = 60,000–350,000) to yield polymers known as the natural rubbers.

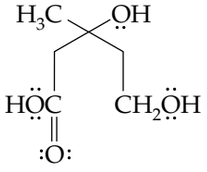

Mevalonic acid

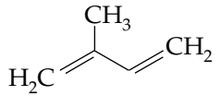

Isoprene

As we have seen, many of the compounds found in the essential oils possess pleasing properties of taste and odor, and we now know that many of these systems contain either ketone or aldehyde functional groups. Our senses of taste and smell, however, possess a wide range of responses to the shape and dimensions of the carbon skeleton supporting the main functionality that triggers the odor signal. Thus, our sense of odor may involve simultaneous multiple stimulations by many different molecular species or, as in a number of cases, the principal response may be to a single component. Since the shape of the odor- or taste-inducing molecule plays a significant role in the effect, it is not surprising that chirality can have a dramatic impact on our perception of a particular odor.

One of the classic examples of this type of response is the case of the cyclic ketone carvone, which contains a single stereocenter (*). The *S* enantiomer is the principal odor and flavor component in caraway seed, whereas the *R* enantiomer gives rise to the odor and flavor of spearmint!

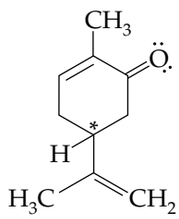

Carvone

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EQA

What we find pleasant may be offensive to others. A constituent of the oil of lemon grass is citronellal, a C_{10} unsaturated aldehyde. While we find this compound to have a pleasant fragrance, it is a potent alarm signal in ants that is shunned by many other insects. Thus, this terpene aldehyde has been used effectively by both ants and humans as an insect repellent.

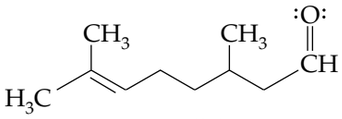

Citronellal

In this experiment we will isolate the principal component of the oil of cinnamon, another naturally occurring aldehyde, cinnamaldehyde. The oil is first extracted from the dried parts of the *Cinnamomum* plant by steam distillation. Although this aromatic aldehyde is a component of an essential oil, it is not formed from mevalonic acid and is not a terpene. Cinnamaldehyde is also not an acetogenin nor is it related to usnic acid. The origin of this fragrant material is shikimic acid, which is part of the plant's *primary metabolism*.

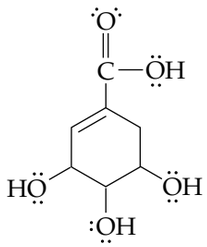

Shikimic acid

Cinnamaldehyde's formation from shikimic acid utilizes one of only two biogenetic routes in nature that lead to the aromatized benzene ring (the other pathway is found in the acetogenins and produces secondary metabolites like usnic acid; see Experiment [11A]). The shikimic acid route contributes to a class of metabolites called the phenylpropanes (Ph—C_3), of which cinnamaldehyde is one of a limited number of simple end products. Another close relative is, for example, eugenol from oil of cloves.

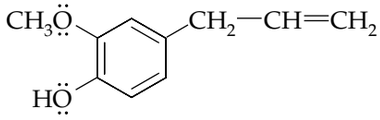

Eugenol

The principal metabolic fate of the phenylpropanes is the formation of lignin polymers that are the fundamental basis of the structural tissue in all plants. Thus, cinnamaldehyde itself is a relatively rare example of a primary metabolite which has been expressed in an *essential oil*.

DISCUSSION

Steam Distillation. The process of steam distillation can be a valuable technique in the laboratory for the separation of thermally labile, high-boiling substances from relatively nonvolatile materials. For steam distillation to be

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successful, however, the material to be isolated must be nearly immiscible with water. (For details of the theory of steam distillation refer to Technique 3 discussions).

Steam distillation is in essence the codistillation (or simultaneous distillation) of two immiscible liquid phases. By definition, one of these liquid phases is water and the other phase is usually a mixture of organic substances that have a low solubility in water. Though steam distillation is widely used as a separation technique for natural products, and occasionally for the isolation and/or purification of synthetic products that decompose at their normal boiling points, it has several limitations. For example, it is not the method of choice when a dry product is required or if the compound to be isolated reacts with water. Obviously, steam distillation is not feasible if the compound to be isolated decomposes upon contact with steam at 100 °C.

Although cinnamaldehyde decomposes at its normal boiling point, it may be extracted from the plant without degradation by boiling water. Steam distillation, therefore, is the method of choice for the isolation of this pleasant smelling and tasting aldehyde.

COMPONENT

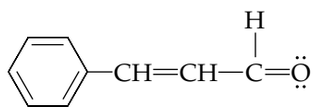

Cinnamaldehyde

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Components		
Compound	MW	Amount
Cinnamon		1 g
Water	18.02	4.0 mL

Components and Equipment. Place 1 g of chopped stick cinnamon (or powder) and 4 mL of water in a 10-mL round-bottom flask containing a boiling stone. Attach the flask to a Hickman still head equipped with an air condenser.

Distillation Conditions. Place the apparatus on a **sand bath maintained at 150–160 °C.** Use an aluminum foil shield or baffle (not shown in drawing) to cover the sand bath. This procedure will prevent the collection collar of the Hickman still from overheating.

NOTE. The mixture tends to foam during the distillation, so care must be taken to prevent contamination of the distillate by cinnamon particles, especially if powdered cinnamon is used. If stick cinnamon is used, first evacuating the flask containing the water and cinnamon for a few minutes and then returning the system to atmospheric pressure will allow water to fill the pores of the bark and greatly aids in reducing the foaming problem (*See* Taber, D. F.; Weiss, A. J. *J. Chem. Educ.* **1998,** *75,* 633).

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Position a thermometer in the throat of the Hickman still to record the distillation temperature, which should be very close to 100 °C. In early Hickman stills (without sidearm access) this thermometer makes pipetting of the condensate difficult. It is suggested that in the latter setup, the thermometer be removed after the initial distillation temperature is established and recorded.(⬇)

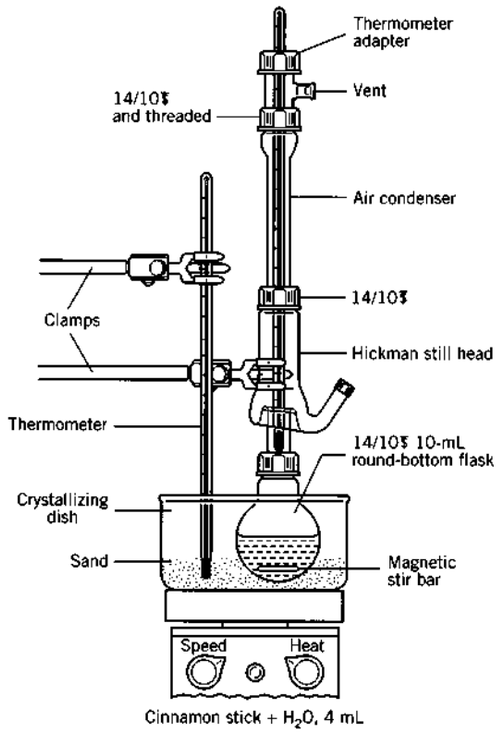

Isolation of Cinnamaldehyde. Remove the milky cinnamaldehyde–water (two-phase) distillate that collects in the collar of the still using a 9-in. Pasteur pipet (or 6-in. in the case of sidearm stills). Transfer this material to a 12- or 15-mL centrifuge tube. Continue the distillation for approximately 1 h or until about 5–6 mL of distillate is collected in the centrifuge tube.

NOTE. Add additional water during the course of the distillation to maintain the original volume in the flask. Add this water using a 9-in. Pasteur pipet inserted down the neck of the Hickman still, after first removing the thermometer if it is still in place (the thermometer need not be replaced in the still following the addition).

Extract the combined distillate fractions, which you collected in the centrifuge tube, with three successive 2-mL portions of methylene chloride (3 × 2 mL). Use the first portion of methylene chloride to rinse the collection collar of the Hickman still. After each extraction, transfer the lower methylene chloride layer (Pasteur filter pipet) to a 25-mL Erlenmeyer flask.

Dry the combined extracts over anhydrous sodium sulfate.

Purification and Characterization. Transfer the dried methylene chloride solution **in at least two portions,** using a Pasteur filter pipet, to a **tared** 5-mL conical vial. Evaporate the solvent in a warm sand bath using a slow stream of nitrogen gas. After all the solution has been transferred and the

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solvent evaporated, rinse the sodium sulfate with an additional two 0.5-mL portions of methylene chloride. Transfer the rinses to the same vial and concentrate as before.

Weigh the flask and calculate the percentage of crude cinnamaldehyde extracted from the original sample of cinnamon.

Record the infrared spectrum and compare it to that reported in the literature (*Aldrich Library of Infrared Spectra* and/or SciFinder Scholar).

To further characterize the aldehyde, prepare its semicarbazone derivative (see Chapter 9, Preparation of Derivatives: Aldehydes and Ketones). The semicarbazone derivative has a melting point of 215 °C.

QUESTIONS

6-77. List several advantages and disadvantages of steam distillation as a method of purification.

6-78. Explain why the distillate collected from the steam distillation of cinnamon is cloudy.

6-79. Calculate the weight of water required to steam distill 500 mg of bromobenzene at 95 °C. The vapor pressure of water at this temperature is 640 torr; that of bromobenzene is 120 torr.

6-80. Steam distillation may be used to separate a mixture of *p*-nitrophenol and *o*-nitrophenol. The ortho isomer distills at 93 °C; the para isomer does not. Explain.

6-81. A mixture of nitrobenzene and water steam distills at 99 °C. The vapor pressure of water at this temperature is 733.2 torr. What weight of water is required to steam distill 300 mg of nitrobenzene?

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Several steam distillation procedures have been reported for isolation of essential oils from native plant sources:

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EXPERIMENT 12

Reductive Catalytic Hydrogenation of an Alkene: Octane

Common name: octane

CA number: [1111-65-9]

CA name as indexed: octane

Purpose. This experiment shows you how to reduce the carbon–carbon double bond of an alkene by addition of molecular hydrogen (H_2). You will gain an understanding of the important role that metal catalysts play in the stereospecific reductions of alkenes (and alkynes), to form the corresponding alkanes, by the activation of molecular hydrogen. You can observe the powerful influence on column chromatography of heavy metal ions, such as silver (Ag^+), which lead to effective separation of mixtures of alkenes from alkanes. Finally, you will appreciate the enormous importance and breadth of application of these reduction reactions in both industrial synthesis and basic biochemistry (for important examples see Experiment [8])

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REACTION

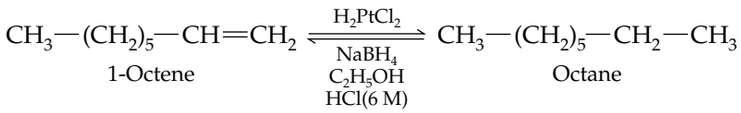

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Concentration of Solutions (pp. 101–104)

DISCUSSION

The addition of hydrogen to an alkene (or to put it another way, the saturation of the double bond of an alkene with hydrogen) to produce an alkane is an important reaction in organic chemistry. Alkanes are also called saturated hydrocarbons, because the carbon skeletons of alkanes contain the greatest possible number of hydrogen atoms permitted by tetravalent carbon atoms; alkenes are thus unsaturated hydrocarbons. Hydrogenation reactions have widespread use in industry. For example, we all consume vegetable fats hardened by partial hydrogenation (see Experiment [8]) of the polyunsaturated oils that contained several carbon–carbon double bonds per molecule as isolated from their original plant sources. Partially hydrogenated fats represented a consumer market of over 2.9 billion pounds in 1992. Since that time major restaurants, fast food chains, and food producers have greatly lowered the amount of trans fats in their produts. Furthermore, batch processes involving hydrogenation reactions are nondiscriminating when considering the geometric isomers cis and trans.

The hydrogenation reaction is exothermic; the energy released is approximately 125 kJ/mol for most alkenes, but on the kinetic side of the ledger, this reductive pathway requires a significant activation energy to reach the transition state.Thus, alkenes can be heated in the presence of hydrogen gas at high temperatures for long periods without any measurable evidence of alkane formation. However, when the reducing reagent (H_2) and the substrate (the alkene) are in intimate contact with each other in the presence of a finely divided metal catalyst, rapid reaction does occur at room temperature. Under these conditions, successful reduction is generally observed at pressures of 1–4 atm. For this reason, this reaction is often referred to as low-pressure catalytic hydrogenation. These reactions are called heterogeneous reactions, since they occur at the boundary between two phases—in this case a solid and a liquid.

The main barrier to the forward progress of the reaction is the very strong H—H bond that must be broken. Molecular hydrogen, however, is adsorbed by a number of metals in substantial quantities; indeed, in some instances the amount of hydrogen contained in the metal lattice can be greater than that in an equivalent volume of pure liquid hydrogen! In this adsorption process the H—H bond is broken or severely weakened. (This adsorption process, which necessarily involves a large exchange of chemical energy between the metal lattice and the adsorbed hydrogen, may in some, as yet unexplained way, be

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related to the "cold fusion" problem in which palladium saturated with a heavy isotope of hydrogen [deuterium] allegedly exhibits apparent excess thermal energies on electrolysis.)

The π system of the alkene is also susceptible to adsorption onto the metal surface and when this occurs the barrier to reaction between the alkene and the activated hydrogen drops dramatically.

Catalytic hydrogenations are also a representative example of a class of organic reactions known as *addition reactions*, which are reactions in which two new substituents are *added* to a molecule (the alkene substrate in this case) across a π system. Usually addition is 1,2, but in extended π systems such as 1,3 dienes, the addition may occur 1,4. In catalytic hydrogenations, formally, one hydrogen atom of a hydrogen molecule adds to each carbon of the alkene linkage, C═C. It is not at all clear that both hydrogen atoms must come from the same original hydrogen molecule even though they are added stereospecifically in syn (cis) fashion while both systems are coordinated with the metal surface. A representation of the stereochemistry of this addition is given below.

The metals most often used as catalysts in low-pressure (1–4 atm) hydrogenations in the laboratory are nickel, platinum, rhodium, ruthenium, and palladium. In industry, high-pressure, large-scale processes are more likely to be found. For example, Germany had little or no access to naturally formed petroleum deposits during World War II, but did possess large coal mines. The Germans mixed powdered coal with heavy tar (from previous production runs) and 5% iron oxide and heated this in the presence of H_2 at a pressure of 3000 lb/in^2, at about 500 °C for 2 h to yield synthetic crude oil. Thirteen German plants operating in 1940 produced 24 million barrels that year, with an average of 1.5–2 tons of coal ultimately converted to about 1 ton of gasoline.

In the present experiment the metal catalyst, platinum, is generated in situ by the reaction of chloroplatinic acid with sodium borohydride. The reduced platinum metal is formed in a colloidal suspension, which provides an enormous surface area, and therefore excellent conditions, for heterogeneous catalysis. The molecular hydrogen necessary for the reduction can also be conveniently generated in situ by the reaction of sodium borohydride with hydrochloric acid:

$$4\,NaBH_4 + 2\,HCl + 7\,H_2O \longrightarrow Na_2B_4O_7 + 2\,NaCl + 16\,H_2$$

This reduction technique does not require equipment capable of safely withstanding high pressures. The use of chloroplatinic acid, therefore, is particularly attractive for saturating easily reducible groups, such as unhindered alkenes or alkynes, in the laboratory. The potential limitation to the use of this reagent is that other reducible functional groups, such as aldehydes and ketones, normally inert to catalytic hydrogenations of alkenes and alkynes, may be reduced by the sodium borohydride. Thus, with chloroplatinic acid and sodium borohydride, we accept, as a compromise, a more limited set of potential reactants (substrates) for the convenience inherent in the reagent.

The platinum catalyst generated in the reaction medium adsorbs both the internally generated molecular hydrogen and the target alkene on its surface. The addition of the hydrogen molecule (H_2) (evidence strongly suggests that it is actually atomic hydrogen that attacks the alkene π system) to the alkene system while they are both adsorbed on the metal surface results in the reduction of the substrate and the formation of an alkane. The addition is, as mentioned

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earlier, syn (or cis), since both hydrogen atoms add to the same face of the alkene plane. The mechanistic sequence is outlined below:

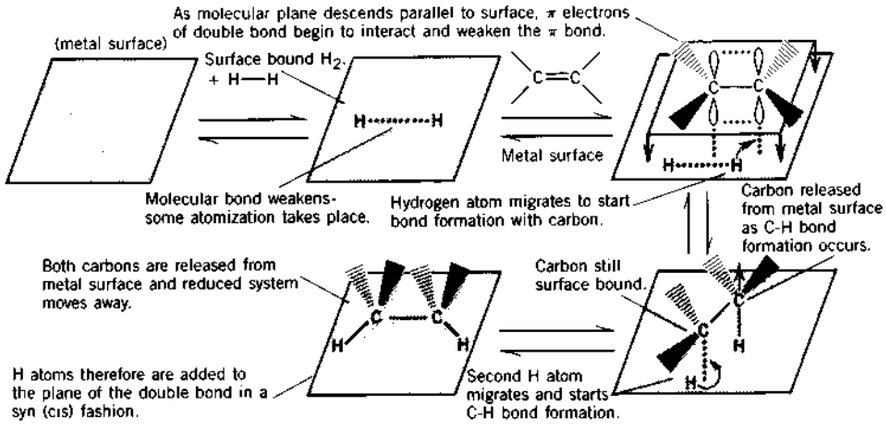

This experiment also provides an opportunity for you to study a powerful aspect of column chromatography in which heavy metal ions have a particularly important role in the purification of the product. Unreacted alkene has the potential to be a problem contaminant during the isolation and purification of the relatively low-boiling saturated reaction product. The successful removal of the remaining 1-octene from the desired *n*-octane in the product mixture is achieved by using column chromatography with silver nitrate/silica gel as the stationary phase. Complex formation between the silver ion (on the silica gel surface) and the π system of the unreacted alkene acts to retard the rate of elution of the alkene relative to that of the alkane.

The ability of alkenes to form coordination complexes with certain metal ions having nearly filled d orbitals was established some time ago. In the case of the silver ion complex with alkenes, the orbital nature of the bonding is believed to involve a σ bond formed by overlap of the filled π orbital of the alkene with the free s orbital of the silver ion plus a π bond formed by overlap of the vacant antibonding π* orbitals of the alkene together with the filled d orbitals of the metal ion.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
1-Octene	112.22	120 μL	0.76	121.3	0.72	1.4087
Ethanol (absolute)	46.07	1.0 mL		78.5		
Chloroplatinic acid (0.2 M)	517.92	50 μL				
Sodium borohydride (1 M)	37.83	125 μL				
Dilute HCl (6 M)		100 μL				

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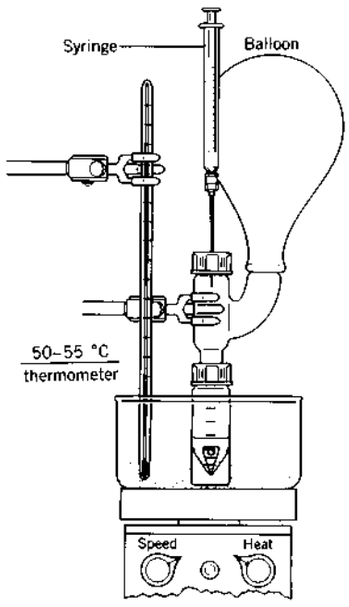

Reagents and Equipment. Equip a 5.0-mL conical vial containing a magnetic spin vane with a Claisen head fitted with a rubber balloon and Teflon-lined rubber septumcap (good *GC septa* work best—this is an important point, because several injections through the septum are required and the seal must remain gas-tight). Mount the assembly in a sand bath on a magnetic stirring hot plate (⬅).

NOTE. 1. No residual acetone (perhaps from cleaning the equipment) can be present since it reacts with the $NaBH_4$. 2. The balloon must make a gas-tight seal to the Claisen head, so be sure to secure it with copper wire or a rubber band.

Remove the 5.0-mL vial from the Claisen head and add the following reagents. *Recap the vial after each addition*.

a. Add 50 μL of a 0.2 M solution of chloroplatinic acid (H_2PtCl_6) (automatic delivery pipet).

b. Add 1.0 mL of absolute ethanol (calibrated Pasteur pipet).

c. Add 125 μL of the sodium borohydride reagent (automatic delivery pipet).

*NOTE. Reattach the vial **immediately** to the Claisen head after the $NaBH_4$ solution is added.*

Stir the mixture vigorously. The solution should turn black immediately as the finely divided platinum catalyst is formed.

INSTRUCTOR PREPARATIONS. 1. The 0.2 M H_2PtCl_6 solution is prepared by adding 41 mg (0.1 mmol) of the acid to 0.5 mL of deionized water. 2. The sodium borohydride reagent is prepared by adding 0.38 g (0.01 mol) of $NaBH_4$ to a solution of 0.5 mL of 2.0 M aqueous NaOH in 9.5 mL of absolute ethanol.

After 1 min, use a syringe to add 100 μL of 6 M HCl solution through the septum cap. In a like manner using a fresh syringe, add *immediately* to the acid solution, a solution of 120 μL (86 mg, 0.76 mmol) of 1-octene dissolved in 250 μL of absolute ethanol. (This solution is conveniently prepared in a 1-mL conical vial; the reagents are best dispensed using automatic delivery pipets.)

Now add dropwise (clean syringe) 1.0 mL of the $NaBH_4$ reagent solution over a 2-min interval.

NOTE. At this point the balloon should inflate and remain inflated for at least 30 min. If it does not, the procedure must be repeated.

Reaction Conditions. Stir the reaction mixture vigorously at a sand bath temperature of 50 °C for 45 min.

Isolation of Product. Cool the reaction to ambient temperature and dropwise add 1 mL of water. Extract the resulting mixture in the reaction vial with three 1.0-mL portions of pentane. Transfer each pentane extract to a stoppered 25-mL Erlenmeyer flask containing 0.5 g of anhydrous sodium sulfate.

The reaction mixture is extracted as follows. Upon addition of each portion of pentane, cap the vial, shake, vent carefully, and then allow the layers to separate. A Vortex mixer may be used if available. The transfers must be made using a Pasteur filter pipet because the pentane solvent is particularly volatile.

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Using a Pasteur filter pipet, transfer the dried solution to a second 25-mL Erlenmeyer flask. Rinse the drying agent with an additional 1.0 mL of pentane (calibrated Pasteur pipet) and add the rinse to this second flask. Add a boiling stone and concentrate the solution to a volume of about 1.0–1.5 mL by warming it gently in a sand bath in the **hood.** HOOD

Purification and Characterization. The saturated product, *n*-octane, is purified by column chromatography. In a Pasteur filter pipet place about 50 mg of sand, 500 mg of 10% silver nitrate on activated silica gel (200 mesh), and then 50 mg of anhydrous sodium sulfate (➨).

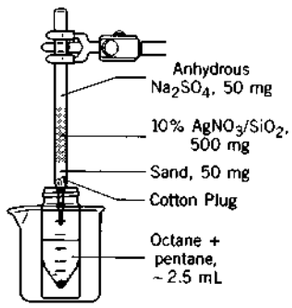

CAUTION: Silver nitrate stains the skin. Protective gloves should be worn during this operation. The ~10% silver nitrate/silica gel used in this separation is commercially available.

Wet the column with 0.5 mL of pentane (calibrated Pasteur pipet) and then transfer the concentrated crude product, as obtained above, to the column by Pasteur filter pipet. Elute the octane from the column using 1.5 mL of pentane and collect the eluate in a tared 5.0-mL conical vial containing a boiling stone.

Fit the vial with an air condenser and then place the assembly in the **hood** in a sand bath maintained at a temperature of 90–100 °C to evaporate the pentane solvent. HOOD

OPTIONAL. The evaporation is continued until a constant weight of product is obtained. This procedure is the best approach, but has to be done very carefully or a considerable amount of product can be lost.

Record the weight of product and calculate the percent yield. Determine the boiling point and refractive index (optional) of your material and compare your results with those reported in the literature for octane. Obtain an IR spectrum. Compare your results with those reported in the literature (*Aldrich Library of IR Spectra* and/or SciFinder Scholar). Also, compare your IR spectrum to that of the 1-octene starting material. Can you establish from the above data if your sample is contaminated by traces of the pentane extraction solvent? If not, how would you go about determining the presence of this potential impurity? ← www

QUESTIONS

6-82. Squalene, first isolated from shark oil and a biological precursor of cholesterol, is a long-chain aliphatic alkene ($C_{30}H_{50}$).The compound undergoes catalytic hydrogenation to yield an alkane of molecular formula $C_{30}H_{62}$. How many double bonds does a molecule of squalene have?

6-83. A chiral carboxylic acid A ($C_5H_6O_2$) reacts with 1 mol of hydrogen gas on catalytic hydrogenation. The product is an achiral carboxylic acid B ($C_5H_8O_2$). What are the structures of compounds A and B?

6-84. Two hydrocarbons, A and B, each contain six carbon atoms and one C═C. Compound A can exist as both *E* and *Z* isomers but compound B cannot. However, both A and B on catalytic hydrogenation give only 3-methylpentane. Draw the structures and give a suitable name for compounds A and B.

6-85. What chemical test would you use to distinguish between the 1-octene starting material and the octane product?

6-86. Give the structure and names of five alkenes having the molecular formula C_6H_{12} that produce hexane on catalytic hydrogenation.

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EXPERIMENT 13

Hydroboration–Oxidation of an Alkene: Octanol

Common name: octanol

CA number: [111-87-5]

CA name as indexed: 1-octanol

Purpose. The oxidation of an alkene to an alcohol is investigated via the in situ formation of the corresponding trialkylborane, followed by the oxidation of the carbon–boron bond with hydrogen peroxide. The conditions required for hydroboration (a reduction) of unsaturated hydrocarbons are explored. Alkylboranes are particularly useful synthetic intermediates for the preparation of alcohols. The example used in this experiment is the conversion of 1-octene to 1-octanol in which an anti-Markovnikov addition to the double bond is required to yield the intermediate, trioctylborane. Since it is this alkyl borane that subsequently undergoes oxidation to the alcohol, hydroboration offers a synthetic pathway for introducing substituents at centers of unsaturation that are not normally available to the anti-Markovnikov addition reactions that are based on radical intermediates.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)

Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Concentration of Solutions (pp. 101–104)

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REACTION

$$3\,CH_3{-}(CH_2)_5{-}CH{=}CH_2 \xrightarrow{THF\cdot BH_3} [CH_3(CH_2)_7]_3B \xrightarrow[OH^-]{H_2O_2} 3\,CH_3{-}(CH_2)_7{-}OH$$

1-Octene — Trioctylborane — 1-Octanol

DISCUSSION

The course of this reaction depends (1) on the *stereospecific* reductive addition of diborane (B_2H_6, introduced as the borane • tetrahydrofuran complex ($BH_3 \cdot THF$)) to an alkene to form an intermediate trialkylborane and (2) on oxidation of the borane with alkaline hydrogen peroxide to yield the corresponding alcohol.

The first step in the reaction sequence is generally called a *hydroboration.*[12] The addition of diborane is a rapid, quantitative, and general reaction for all alkenes (as well as alkynes) when carried out in a solvent that can act as a Lewis base. The ether solvation of the diborane, for example, is the key to the success of this reaction. In the absence of a Lewis base, borane (BH_3) exists as a dimer (B_2H_6), which is much less reactive than the monomer (BH_3). Borane, however, does exist in coordination with ether type solvents. It is the monomer (BH_3) that functions as the active reagent in the reductive addition.

As depicted in the following mechanism, the boron hydride rapidly adds successively to three molecules of the alkene to form a trialkylborane.

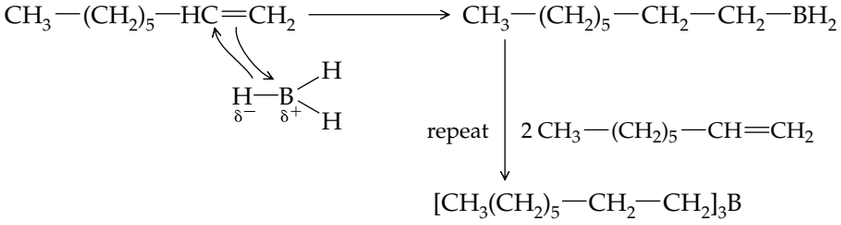

Note that the transition state of this addition reaction is generally considered to be a *four-center* one, and that the 1-octene substrate is oriented such that the boron becomes bonded to the least-substituted carbon atom of the double bond. Thus, the reaction can be classified as *regioselective*, and it will be sensitive to substitution on the carbon–carbon double bond.

In the developing transition state, the alkene π electrons (the least tightly held, and most nucleophilic) flow to the electron-deficient boron atom (the vacant p orbital is the electrophile). The formation of the *transition state* is controlled in large part by the polarization of the alkene π system during the early stages of formation of the transition state. At this point a partial positive charge begins to form on the more highly substituted carbon (the more stable carbocation), and a partial negative charge on the least substituted carbon. The orientation of the polarization, therefore, is to a large extent controlled by the electron-releasing effects of the alkyl substituents on the alkene, which enables the more highly substituted of the sp^2 carbon atoms to better accommodate the positive charge. As the reaction proceeds, the boron acquires a partial negative charge in response to the incoming electron

[12]For references relating to the use of diborane as a hydroboration reagent, see Experiment [1_{adv}].

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density. The ease of hydride ($:H^-$) transfer from the boron to the more highly substituted carbon atom of the alkene, therefore, increases. Thus, hydroboration involves simultaneous hydride release and boron–carbon bond formation, and is a concerted reaction. The reaction can be conveniently considered as passing through a four-centered transition state, wherein the atoms involved undergo simultaneous changes in bonding (i.e., electron redistribution [see below]).

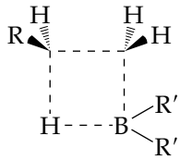

Hydroboration, as we have seen, can be classified as a **concerted addition reaction** in which no intermediate is formed. The mechanism is characteristic of a group of reactions called **pericyclic** (from the Greek, meaning *around the circle*) **reactions,** which involve a cyclic shift of electrons in and around the *transition state*. The mechanism proposed is further supported by the fact that rearrangements are not normally observed in hydroboration reactions, which implies that there are no carbocationic intermediates.

When alkenes with varying degrees of substitution undergo hydroboration, the boron ends up on the least substituted sp^2 carbon atom. While it might appear from the products that the regioselectivity is controlled by steric factors, this assumption is probably too simplistic. Steric and electronic factors both favor, and are both likely responsible for, the observed regioselectivity in hydroboration reactions.

Accumulated evidence demonstrates that the reaction occurs by **syn** addition, which is a consequence of the four-centered transition state. Therefore, the new C—B and C—H bonds are necessarily formed on the same face of the C═C bond, as shown in the following example:

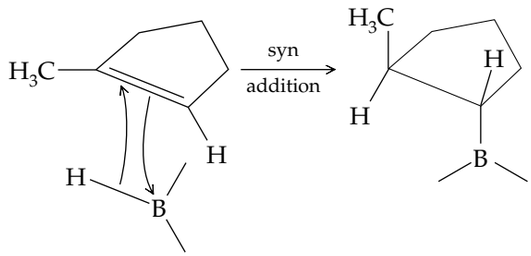

Organoboranes are important in organic synthesis as reactive intermediates. Reactions have been developed by which the boron atom may be replaced by a wide variety of functional groups, such as —H, —OH, —NH_2, —Br, —I, and —COOH. The present experiment demonstrates the conversion of an organoborane to an alcohol by oxidation with alkaline hydrogen peroxide. It is not necessary to isolate the organoborane prior to its oxidation. This simplification is particularly fortuitous in this case, since most alkylboranes, when not in solution, are pyrophoric (spontaneously flammable in air).

With regard to the second stage of the hydroxylation process, there is now conclusive evidence that oxidation of the C—B bond proceeds with retention of configuration at the carbon atom bearing the boron. That is, the hydroxyl group that replaces the boron atom has the identical orientation in the molecule as the boron:

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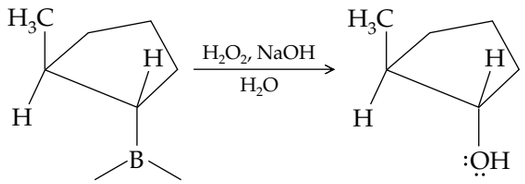

Thus, in unsymmetrical alkenes the hydroboration–oxidation sequence of reactions leads to the addition of the elements of H—OH to the original C═C in an anti-Markovnikov manner.

In the oxidation step a hydroperoxide anion (HOO^-) is generated in the alkaline medium. This species makes a nucleophilic attack on the boron atom to form a boron hydroperoxide. A 1,2 migration of an alkyl group from boron to oxygen occurs to yield a boron monoester (a borate). Hydrolysis of the boron triester, generated by successive rearrangement of all three alkyl groups, produces the desired alcohol. The mechanism of the oxidation sequence is given below.

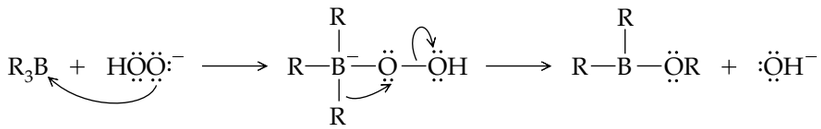

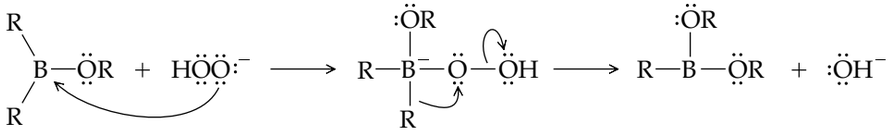

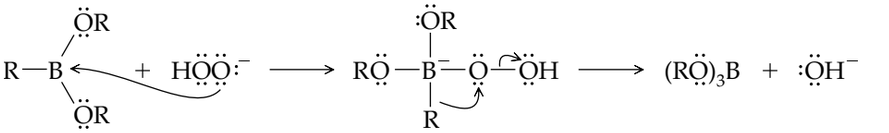

$$B(OR)_3 + OH^- \xrightarrow{H_2O} 3\,ROH + B(OH)_4^-$$

In the final step, alkaline hydrolysis of the trialkyl borate ester yields 3 moles of the alcohol.

The effective use of B_2H_6 in the hydroboration reaction was discovered in 1955 by H. C. Brown, and is just one of the many important hydride reagents developed by Professor Brown and his coworkers at Purdue University.

Herbert Charles Brown (1912) Brown obtained his B.S. in chemistry from the University of Chicago (1936) and his Ph.D. from the same institution in 1938. He later became a Professor of Chemistry at Wayne State and Purdue Universities.

Working with H. I. Schlesinger at the University of Chicago, Brown developed practical routes for the synthesis of diborane (B_2H_6). He discovered that diborane reacted rapidly with LiH to produce lithium borohydride ($LiBH_4$), discovering and opening a synthetic route to the metal borohydrides. These compounds proved to be powerful reducing agents. Later, he developed an effective route to $NaBH_4$, which led to the commercial production of this material. Metal borohydrides, particularly $LiAlH_4$ (developed by Schlesinger and

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Albert Finholt), have revolutionized how organic functional groups are reduced in both the research laboratory and the industrial plant.

In 1955, Brown discovered that alkenes can be converted to organoboranes by reaction with diborane (actually the monomer in ether solution) and with organoboranes containing a B—H bond (the hydroboration reaction). The organoboranes are valuable intermediates in organic synthesis because the boron substituent can be quickly and quantitatively replaced by groups such as —OH, —H, —NH_2, or —X (halogen). Thus, organoboranes have become an attractive pathway for the preparation of alcohols, alkanes, amines, and organohalides.

Brown's investigation of the addition compounds of trimethyl borane, diborane, and boron trifluoride with amines has provided a quantitative estimation for steric strain effects in chemical reactions. He also investigated the role of steric effects in solvolytic, displacement, and in elimination reactions. His results demonstrate that steric effects can assist, as well as hinder, the rate of a chemical reaction.

Brown has published over 700 scientific papers and is the author of several texts. For his extensive work on organoboranes, Brown (with G. Wittig [organophosphorus compounds]) received the Nobel Prize in Chemistry in 1979.[13]

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 4.0 h.

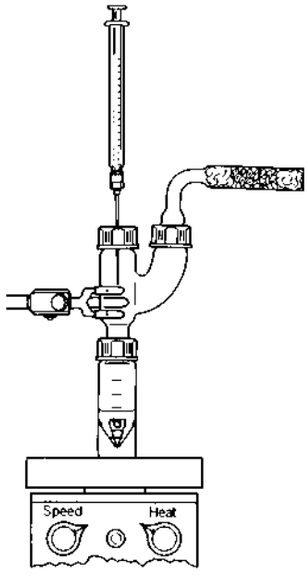

1-Octene, 210 μL
+ 1*M* BH_3•THF, 500 μL

Physical Properties of Reactants						
Compound	**MW**	**Amount**	**mmol**	**bp (°C)**	***d***	n_D
1-Octene	112.22	210 μL	1.34	121	0.72	1.4087
Borane • THF (1M)		500 μL	0.50			
Sodium hydroxide (3 M)	40.00	300 μL				
Hydrogen peroxide (30%)	34.01	300 μL				

Reagents and Equipment. Equip a 5.0-mL conical vial, containing a spin vane, with a Claisen head fitted with a rubber septum and calcium chloride drying tube (⬅). Through the rubber septum add 210 μL (150 mg, 1.34 mmol) of 1-octene (in one portion) with a 1.0-cm^3 syringe.

NOTE. Dry the glassware and syringe in a 100 °C oven for at least 30 min before use. An alternate method is to "flame-out" the glassware with a microburner and a flow of dry nitrogen, and to then add the drying tube and caps.

Cool the reaction vessel in an ice bath and, using the same syringe, add 500 μL (0.5 mmol) of the 1 M borane · THF solution through the septum over a 5-min period.

CAUTION: The BH_3 • THF reagent reacts *violently* with water.

[13]See *McGraw-Hill Modern Scientists and Engineers;* S. P. Parker, Ed.; McGraw-Hill: New York, 1980, Vol. 1, p. 150.

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Reaction Conditions. Allow the reactants to warm to room temperature and then stir for 45 min. Using a Pasteur pipet, carefully add two drops of water to hydrolyze any unreacted borane complex.

NOTE. At this stage of the procedure the vial may be removed from the Claisen head, capped, and allowed to stand until the next laboratory period.

If the experiment is not interrupted, proceed by first removing the reaction vial from the Claisen head. Then use a graduated 1.0-mL pipet to add 300 μL of 3 M NaOH solution, followed by the dropwise addition of 300 μL of 30.0% hydrogen peroxide solution over a 10-min period using another graduated 1.0-mL pipet. Stir the reaction vial gently after each addition.

CAUTION: Hydrogen peroxide blisters the skin. Concentrated solutions of hydrogen peroxide can explode!

Attach the vial to a reflux condenser and warm the reaction mixture with stirring, for 1 h in a sand bath at 40–50 °C (➡).

Cool the resulting two-phase mixture to room temperature and use forceps to remove the spin vane. Add 0.5 mL of diethyl ether to establish a reasonable volume for extraction of the organic phase.

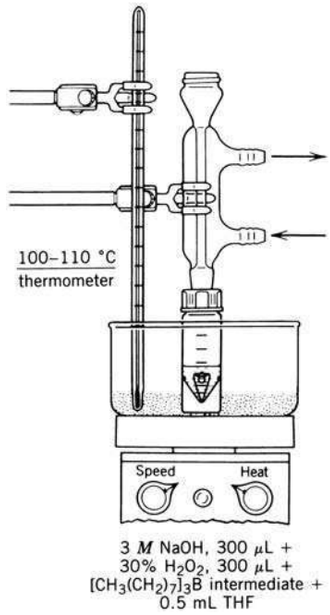

Isolation of Product. Using a Pasteur filter pipet, separate the bottom aqueous layer and transfer it to a 3.0-mL reaction vial. *Save* the organic phase in the 5.0-mL conical vial.

Extract the aqueous phase placed in the 3.0-mL conical vial with two 1.0-mL portions of diethyl ether. Upon the addition of each portion of ether, cap, shake, and carefully vent the vial and allow the layers to separate. The top ether layer is then separated using a Pasteur filter pipet and the ether extracts are combined with the previously saved organic phase in the 5.0-mL conical vial. *If a solid forms during the extraction, add a few drops of 0.1 M HCl.*

Extract the combined organic phases with 750 μL of 0.1 M HCl solution, followed by extraction with several 0.5-mL portions of distilled water or until the aqueous extract is neutral to pH paper. Transfer the neutral organic phase to a 10-mL Erlenmeyer flask. Rinse the conical vial with a further 0.5 mL of ether and combine the rinse with the ether solution in the Erlenmeyer flask. Add granular anhydrous sodium sulfate (Na_2SO_4) (200 mg) to the combined organic phases and let it stand with occasional swirling for 20 min. If large clumps of drying agent form, add an additional 100 mg of Na_2SO_4. The solution should be clear at the end of the drying period. Then transfer the solution to a tared 3.0-mL conical vial in 1-mL aliquots, add a boiling stone to the vial, and concentrate by warming in a sand bath (60–65 °C) in the **hood** to yield the crude product residue.

Weigh the vial and calculate the crude yield.

Gas Chromatographic Analysis. This crude product is easily analyzed by gas chromatography. The procedure involves the injection of 10 μL of the liquid material onto a $\frac{1}{4}$-in. × 8-ft steel column packed with 10% Carbowax 80/100 20M PAW-DMS. Experimental conditions are He flow rate, 50 mL/min; chart speed, 1 cm/min; temperature, 190 °C.

The liquid components elute in the order: unreacted 1-octene, a small amount of 2-octanol, and the major product, 1-octanol. Approximate retention times (conditions above) are 1.3, 3.1, and 4.2 min, respectively.

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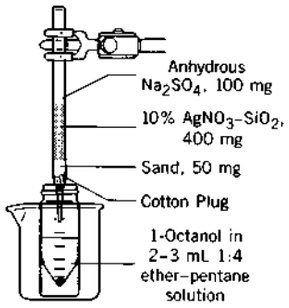

HOOD

Collect the eluted 1-octanol in an uncooled, 4-mm-diameter collection tube. Transfer the collected material to a 0.1-mL conical vial (see Technique 1). This material may then be analyzed by IR spectroscopy and/or used in the procedure described in the following section on Purification and Characterization.

Purification and Characterization. Pack a Pasteur filter pipet with 400 mg of 10% silver nitrate-treated activated silica gel followed by 100 mg of anhydrous sodium sulfate. Dissolve the organic residue isolated above in 500 μL of pentane (spectral or HPLC grade) and then transfer this solution by Pasteur filter pipet to the column (⬅). Elute the material from the column with 3 mL of a 1:4 diethyl ether–pentane solution. Collect the eluate in a tared 5.0-mL conical vial containing a boiling stone.

Concentrate the collected eluate to a constant weight by warming on a sand bath (60–65 °C.) in the **hood.** Weight the octanol product and calculate the percent yield.

This product may again be analyzed by gas chromatography. Follow the procedure and experimental conditions outlined above. The 1-octene impurity should have been removed during the column chromatography step. The small percentage of 2-octanol byproduct, however, more than likely will still be detected. The actual percent composition of the mixture can be calculated by determination of the areas under the chromatographic peaks (see Technique 1).

Obtain an IR spectrum of the alcohol and compare your result to that recorded in the literature (*Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. A positive ceric nitrate test (Chapter 9) should confirm the presence of the alcohol grouping. The ignition test may be used to establish that the material is an aliphatic species. The phenyl or α-naphthylurethane derivative may also be prepared to further characterize the alcohol (Chapter 9).

It might also be of interest to determine the solubility characteristics of this C_8 alcohol in water, ether, concentrated sulfuric acid, and 85% phosphoric acid (Chapter 9). Do your results agree with what you would predict for this alcohol?

What chemical tests would you perform to determine the difference between the starting alkene and the alcohol product?

QUESTIONS

6-87. Using the hydroboration reaction, outline a reaction sequence for each of the following conversions:

(a) 1-Butene to 1-butanol

(b) 1-Methylcyclohexene to *trans*-2-methylcyclohexanol

(c) 2-methylpropene to 2-methyl-1-propanol

6-88. When diborane (B_2H_6) dissociates in ether solvents, such as tetrahydrofuran (THF), a complex between borane (BH_3) and the ether is formed. For example,

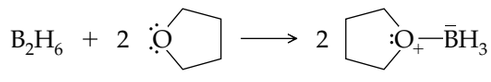

(a) In the Lewis sense, what is the function of BH_3 as it forms the complex? Explain.

(b) Write the Lewis structure for BH_3. Diagram its expected structure indicating the bond angles in the molecule.

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6-89. In reference to question 6-88a:

(a) Explain why borane (BH_3) reacts readily with the π-electron system of an alkene.

(b) Explain why diborane (B_2H_6) reacts only very slowly with C═C groups.

6-90. In an unsymmetrical alkene, the boron atom adds predominantly to the least substituted carbon atom. For example, 2-methyl-2-butene gives the products indicated below:

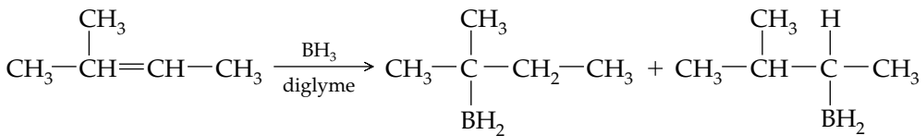

(Diglyme: $CH_3\ddot{O}—CH_2CH_2—\ddot{O}—CH_2CH_2—\ddot{O}CH_3$, diethyleneglycol dimethyl ether)

Offer a reasonable explanation to account for the ratio obtained.

NOTE. The above solvent (diglyme) has been shown to cause a significant increase in the number of miscarriages by workers who come in contact with it.

6-91. An advantage of the hydroboration reaction is that rearrangement of the carbon skeleton does not occur. This lack of migration contrasts with results obtained upon the addition of hydrogen chloride to the double bond. For example,

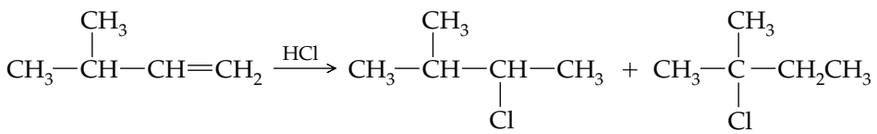

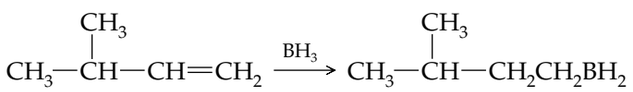

Offer an explanation for the difference in these results.

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Matteson, D. S. in *The Chemistry of the Metal-Carbon Bond,* Hartley, F. R., Ed.; Wiley: New York, 1987, Vol: 4, Chapter 3, p. 307.

Pelter, A.; Smith, K.; Brown, H. C. *Boron Reagents: Best Synthetic Methods;* Academic Press: New York, 1988.

Smith, K. *Organoboron Chemistry in Organometallics in Synthesis —A Manual;* Schlosser, M., Ed.; Wiley: New York, 1994.

Also see

Kabalka, G. W.; Maddox, J. T.; Shoup, T.; Bowers, K. R. *Organic Syntheses* **1996,** *73,* 116.

Experiment [13] was based on the work reported by

Kabalka, G. W. J. *Chem. Educ.* **1975,** *52,* 745; also see Kabalka, G. W; Wadgaonkar, P. P.; Chatla, N. *J. Chem. Educ.* **1990,** *67,* 975.

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley-Interscience: New York, 2007, Chap. 15, p. 1075.

EXPERIMENT 14

Diels–Alder Reaction: 4-Cyclohexene-cis-1,2-dicarboxylic Acid Anhydride

Common name: 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride

CA number: [85-43-8]

CA name as indexed: 1,3-isobenzofurandione, 3a,4,7,7a-tetrahydro-

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EQA

Purpose. This experiment demonstrates the use of the Diels–Alder reaction in the preparation of six-membered carbocyclic rings. The cyclic products are obtained by reaction of a conjugated diene with an alkene. The illustration given here involves the treatment of 1,3-butadiene (generated in situ) with maleic anhydride to form the corresponding Diels–Alder product. These *add*ition prod*uct*s are often called *adducts*.

Prior Reading

Technique 7: Collection or Control of Gaseous Products (pp. 105–107)
Chapter 8: Infrared Spectroscopy (pp. 539–561)
Nuclear Magnetic Resonance Spectroscopy (pp. 561–593)

REACTION

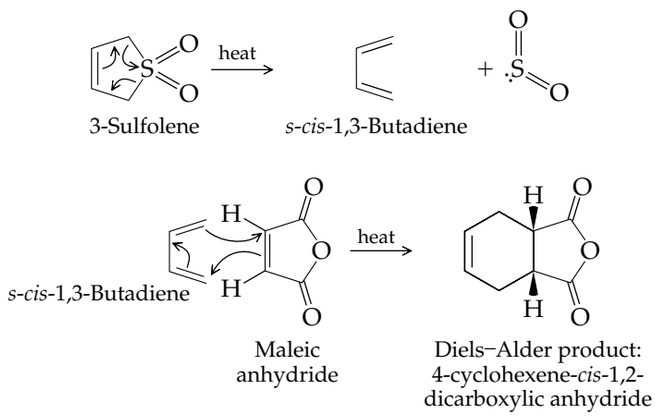

Otto Paul Hermann Diels (1876–1954) Diels obtained his Ph.D. in 1899 while studying with Emil Fischer at the University of Berlin. He later became Associate Professor of Chemistry at the University of Berlin, and in 1916 he moved to the University of Kiel. In 1906 Diels discovered carbon suboxide gas (C_3O_2), obtained from the dehydration of malonic acid. He did extensive studies on saturated fats and fatty acids. Diels also developed the use of selenium as a mild dehydrogenation agent. This latter work led to the commercial production of polyunsaturated oils.

In the same year that he identified carbon suboxide, Diels began to investigate cholesterol with E. Abderhalden. The structure of this lipid had not yet been determined. He was the first to study the products of the selenium dehydrogenation of cholesterol and isolated a hydrocarbon ($C_{18}H_{16}$), which became known as "Diels' hydrocarbon." This substance proved to possess the basic steroidal ring structure; its subsequent synthesis by Diels in 1935 (almost 30 years after he started this work) led to the rapid elucidation of the structures of a vast array of steroidal sex hormones, saponins, cardiac glycosides, bile pigments, and adrenal cortical hormones, such as cortisone.

Diels, however, is best known for his discovery (with his student Kurt Alder) of the reaction that now bears his name (it is now known as the *Diels–Alder cycloaddition reaction*), which was first published in 1928 (see Diels, O.; Alder, K. *Liebigs Ann. Chem.* **1928,** *460,* 98). This reaction involves the 1,4 addition of dienophile reagents to diene substrates to produce six-membered cycloalkenes. The reaction has found extensive application in the synthesis of

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terpenes and other natural products, since six-membered rings abound in the metabolites of living systems, and because for some time it was one of the few methods available for the synthesis of these cyclic structures. Because of the impact of their work in the field of organic synthesis, Diels shared the 1950 Nobel Prize (in chemistry) with Alder. He also was the author of a popular textbook (*Einfuhrung in die organische Chemie*), first published in 1907, which went through 19 editions by 1962.[14]

DISCUSSION

The Diels–Alder reaction is one of the most useful synthetic reactions in organic chemistry because, in a *single* step, it produces two new carbon–carbon bonds and up to four stereocenters. It is an example of a [4 + 2] cycloaddition reaction (4 π electrons + 2 π electrons) between a *conjugated* 1,3-diene and an alkene (dienophile; to have an affinity for dienes, from the Greek *philos,* meaning loving), which leads to the formation of cyclohexenes. Alkynes may also be used as dienophiles, in which case the reaction produces 1,4-cyclohexadienes. The reaction proceeds faster if the dienophile bears electron-withdrawing groups and if the diene bears electron-donating groups. Thus, α,β-unsaturated esters, ketones, nitriles, and so on, make excellent dienophiles, which are often used in the Diels–Alder reaction. By varying the nature of the diene and dienophile, a very large number of compounds can be prepared. Unsubstituted alkenes, such as ethylene, are poor dienophiles and react with 1,3-butadiene only at elevated temperatures and pressures. These high activation energies (slow reactions) pose a particular problem for the Diels–Alder reaction. The Diels–Alder reaction is a reversible, equilibrium reaction that is not very exothermic. Since the equilibrium constant (K_{eq}) is temperature dependent [$K_{eq} = e^{-\Delta G/RT}$], K_{eq} decreases with increasing temperature and eventually can become quite small at the high temperature needed for the reaction of an unactivated dienophile to proceed at a reasonable rate. Elevating the temperature will increase the rate of the reaction, but this will also reduce the amount of product formed, and therefore the lowest possible temperature must often be used.

The reaction is a thermal *cycloaddition* (a ring is formed), which occurs in one step and is thus a *concerted* reaction. Both new C—C single bonds and the new C═C π bond are formed simultaneously, as the three π bonds in the reactants break. The electron flow for the reaction is shown below. The reaction is thus classified as a *pericyclic* reaction (from the Greek meaning "around the circle").

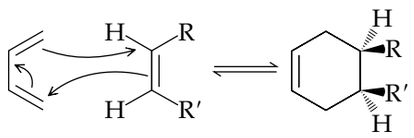

The diene component must be in the *s-cis* (the "*s*" refers to the conformation about a single bond) conformation to yield the cyclic product with the cis C═C required by the six-membered ring. For this reason, cyclic dienes usually

[14]See Newett, L. C. *J. Chem. Educ.* **1931,** *8,* 1493; *Dictionary of Scientific Biography,* C. C. Gillespie, Ed.; Scribner's: New York, 1971, Vol. IV, p. 90; *McGraw-Hill Modern Scientists and Engineers,* S. P. Parker, Ed.; McGraw-Hill: New York, 1980, Vol.1, p. 289.

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react more readily than acyclic species. For example, 1,3-cyclopentadiene, which is locked in the *s-cis* configuration, reacts with maleic anhydride about 1000 times faster than 1,3-butadiene, which prefers an *s-trans* conformation.

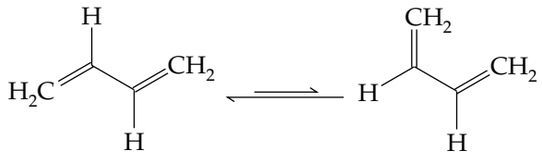

s-trans-1,3-Butadiene *s-cis*-1,3-Butadiene

The reaction is highly stereospecific and the orientation of the groups on the dienophile are *retained* in the product; thus, the addition must be suprafacial–suprafacial. That is, by having the stereochemical information preserved, both new bonds are formed on the same face of the diene and on the same face of the dienophile. Thus, two groups that are cis on the dienophile will be cis in the product (and trans will give a trans product).

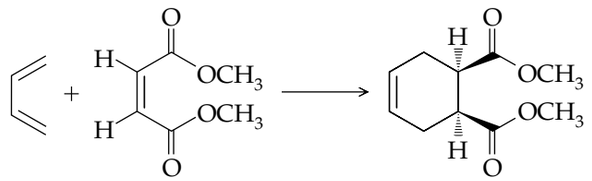

Carbomethoxy groups cis Carbomethoxy groups cis

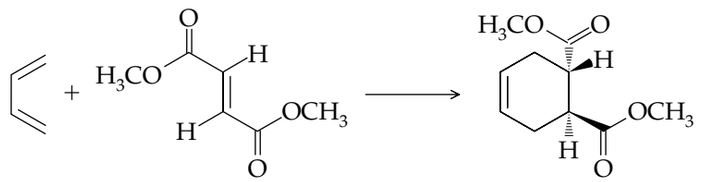

Carbomethoxy groups trans Carbomethoxy groups trans

The reaction of cyclopentadiene with maleic anhydride demonstrates the further stereochemical consequence of the relative orientation of the reactants in Diels–Alder reactions. In this situation, there are two possible ways in which the reactants may bond. This reaction leads to the formation of two products: the endo and exo stereoisomers:

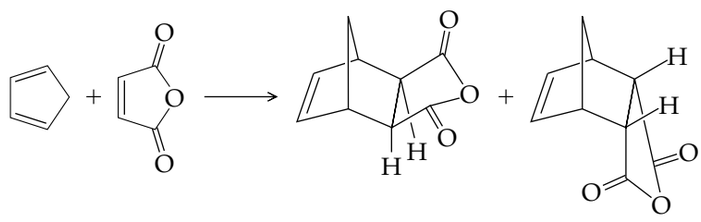

Exo adduct Endo adduct

Generally, the endo form of the product predominates (endo-rule which is a result of secondary orbital overlap between the diene and dienophile), but endo/exo ratios may vary, depending on several steric and electronic factors and with reaction conditions.

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The diene used in this experiment, 1,3-butadiene, is a gas at room temperature (bp −5 °C), which makes it a difficult reagent to measure and handle in the laboratory. Fortunately, 1,3-butadiene can be generated in situ from 3-sulfolene, a solid reagent that is easily handled. In an example of a retro-cycloaddition reaction, 3-sulfolene decomposes at a moderate temperature to yield sulfur dioxide and 1,3-butadiene.

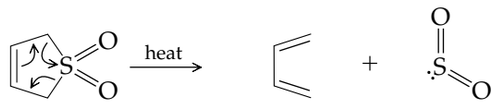

3-Sulfolene *s-cis*-1,3-Butadiene

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

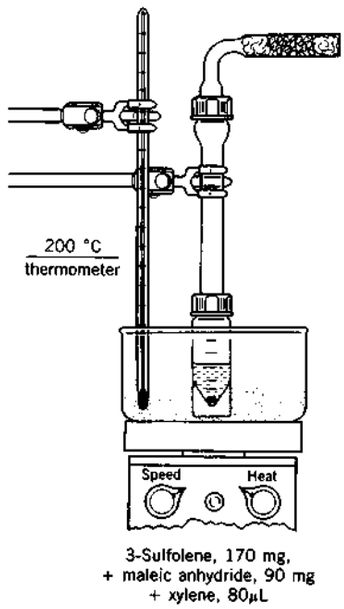

3-Sulfolene, 170 mg,
+ maleic anhydride, 90 mg
+ xylene, 80 μL

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
3-Sulfolene	118.15	170 mg	1.42	66	
Maleic anhydride	98.06	90 mg	0.92	60	
Xylene		80 μL			137–140

Reagents and Equipment. Weigh and place 80 μL of xylene, 90 mg (0.92 mmol) of maleic anhydride, and 170 mg (1.42 mmol) of 3-sulfolene in a 3.0-mL conical vial equipped with an air condenser protected with a calcium chloride drying tube and containing a boiling stone (➡).

NOTE. The maleic anhydride should be finely ground and protected from moisture to prevent hydrolysis to the corresponding acid. A mixture of xylenes in the boiling-point range 137–140 °C will suffice. Use freshly distilled solvent or dry it over molecular sieves before use. Dispense the xylene in the ***hood*** *using an automatic delivery pipet. In large laboratory sections it is recommended that the evolved SO_2 be trapped (see Prior Reading).*

HOOD

Reaction Conditions. Heat the reaction mixture to reflux using a sand bath for 20 min. Avoid overheating.

CAUTION: The reaction is exothermic. Avoid overheating. Sulfur dioxide is evolved in the process and adequate ventilation should be provided.

Carefully remove the **hot** conical vial from the sand bath and allow the contents to cool to room temperature.

HOT

Isolation of Product. Add 0.5 mL of toluene to the cooled solution, and then add petroleum ether (60–80 °C) dropwise until a slight cloudiness persists. Roughly 0.25–0.35 mL of petroleum ether will be needed.

Reheat the solution until it becomes clear and then cool it in an ice bath. *During the recrystallization step, the sides of the vial may have to be scratched with a glass rod to induce crystallization.*

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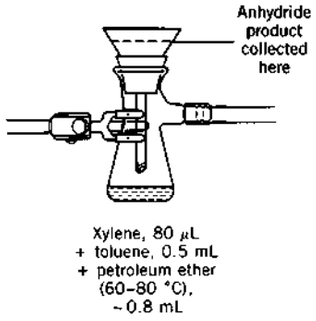

Collect the crystalline product by vacuum filtration and wash the filter cake on the Hirsch funnel with 0.5 mL of *cold* petroleum ether (60–80 °C) (⬅).

NOTE. Do not wash with an excess of the petroleum ether, or a loss of product will result.

Purification and Characterization. The product is of sufficient purity for direct characterization. Weigh the material and calculate the percent yield. Determine the melting point and compare your result with the value found in the literature. Obtain an IR spectrum of the material.

The reaction involves two reactants (butadiene and maleic anhydride), which both contribute functional groups to the product. The infrared spectrum of the isolated material reflects this observation. Compare the infrared spectrum of your product with that of the reference spectrum.

Infrared Analysis. The spectrum of one of the starting materials, 3-sulfolene (Fig. 6.27), is representative of an alkene sulfone. The macro group frequency train for an unconjugated five-membered ring alkene fits the data reasonably

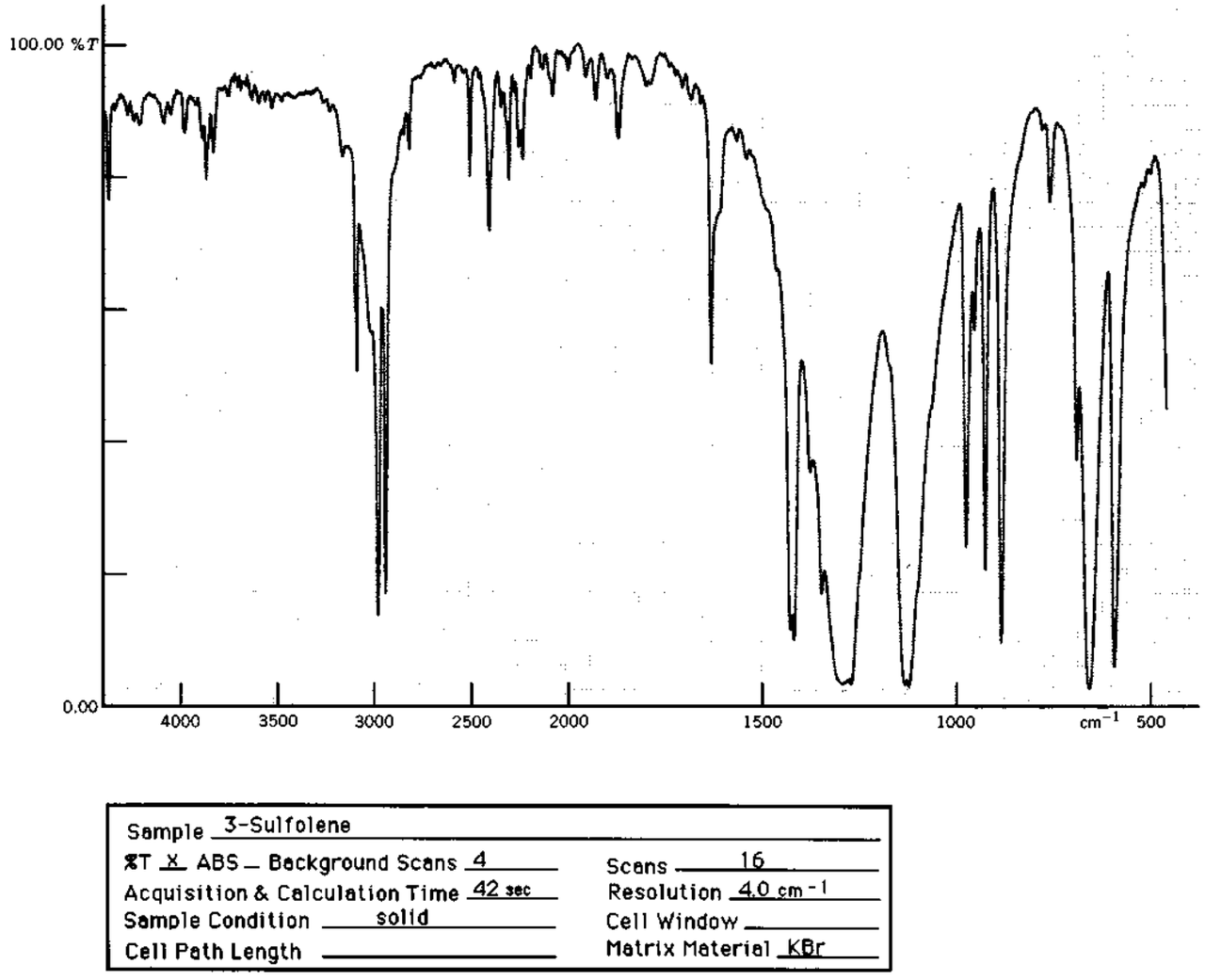

Figure 6.27 IR spectrum: 3-Sulfolene.

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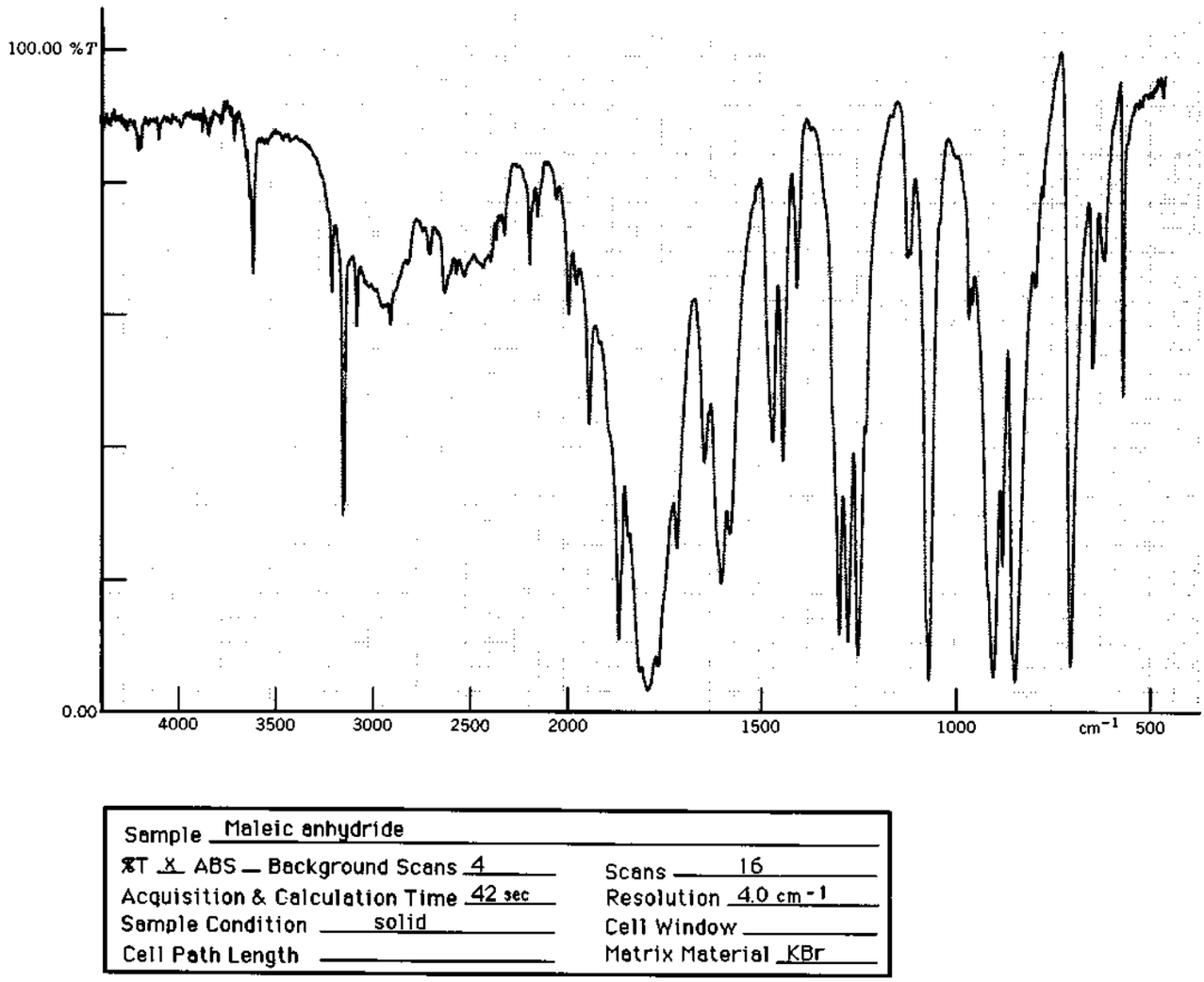

Figure 6.28 IR spectrum: maleic anhydride.

well: 3090 (═C—H, stretch), 1635 C═C, stretch), and 657 (H—C═C—H, cis, out-of-plane bend) cm^{-1}. The presence of the sulfone group is convincingly identified by the very strong bands at 1287 and 1127 cm^{-1}, which are assigned to the coupled in-phase and out-of-phase S—O stretching vibrations. The antisymmetric and symmetric C—H stretching vibrations of the methylene groups are observed at 2975 and 2910 cm^{-1}. Note that the influence of the heterocyclic five-membered ring system has raised all of the C—H stretching modes by 40–50 cm^{-1}.

The spectrum of the other reactant, maleic anhydride (Fig. 6.28), possesses all the peaks representative of a conjugated five-membered ring anhydride: 3110 (═C—H, stretch), 1858 (C═O, in-phase stretch, weak), 1777 (C═O, out-of-phase stretch, strong), 1595 (C═C, stretch, weak), 1060 (C—O, antisymmetric stretch), 899 (C—O, symmetric stretch), 835 (H—C═C—H, out-of-plane bend, normally near 700 cm^{-1}, but raised by conjugation to carbonyls). The in-phase stretch of the anhydride carbonyls is particularly weak as the five-membered ring system forces the two oscillators into nearly opposing positions.

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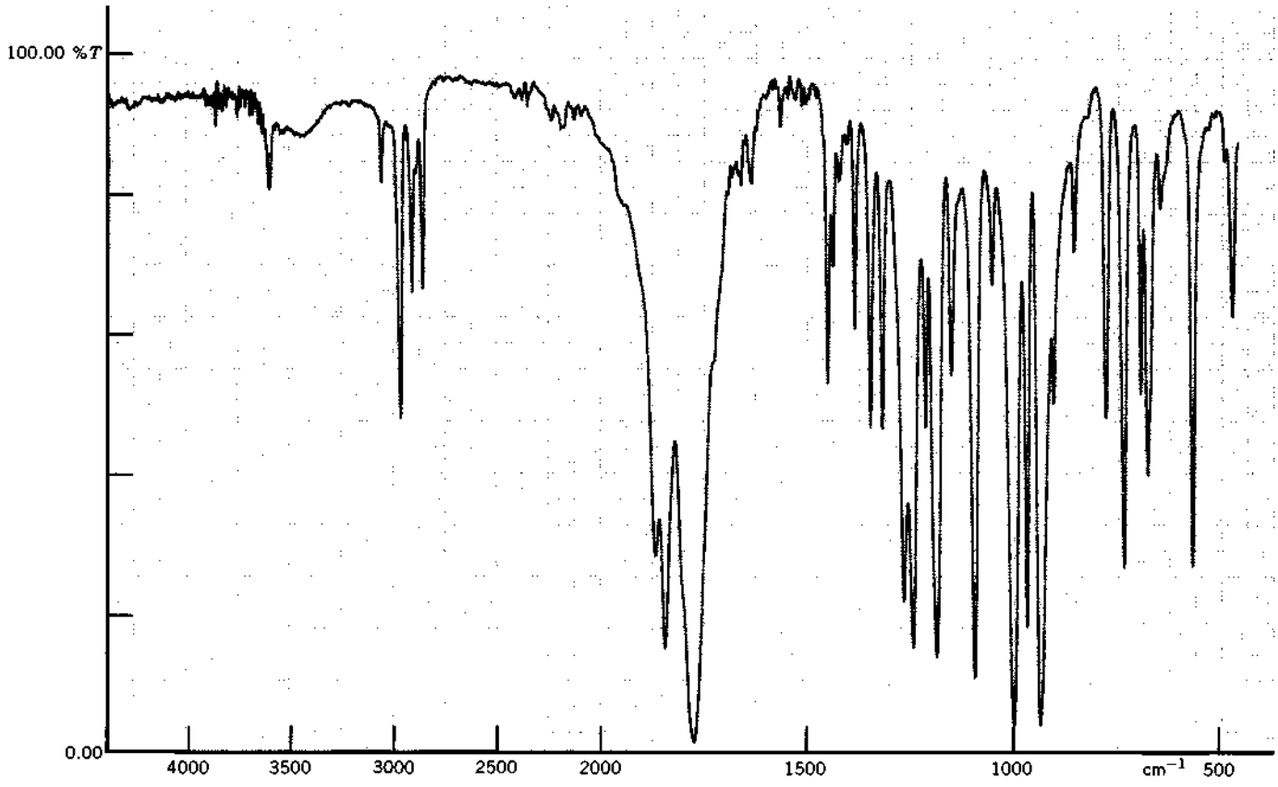

Figure 6.29 IR spectrum: 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride.

The Diels–Alder product exhibits all of the spectral properties of a nonconjugated, alkenyl five-membered anhydride (Fig. 6.29). The macro group frequency train for the anhydride portion of the molecule involves peaks at 1844, 1772, 998, and 935 cm^{-1}:

a. 1844 cm^{-1}: This weak band is similar to the 1858-wavenumber band found in maleic anhydride, and involves the in-phase stretch of the two coupled carbonyl groups. The band is somewhat more intense in the case of this saturated five-membered ring example, because the ring system is more easily distorted from planarity. This band often exhibits some secondary splitting on the high-wavenumber side (see discussion of the 935-wavenumber band below).

b. 1772 cm^{-1}: This band arises from the out-of-phase stretch of the anhydride carbonyls and is the most intense band in the spectrum. The separation, or splitting, between the two carbonyl stretching modes of anhydrides is relatively constant and falls in the range of 60–90 cm^{-1}.

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c. **998 and 935 cm^{-1}:** These two bands are identified with the antisymmetric and symmetric C—O—C stretching modes. It is the overtone of the symmetric stretch that is Fermi coupled (see IR discussions) to the symmetric carbonyl stretch ($935 \times 2 = 1870$ cm^{-1}. The frequency match is variable, with the harmonic generally falling on the high-wavenumber side of the fundamental. ← www

The alkenyl section of the product possesses the following macro group frequency bands: 3065 (═C—H stretch), 1635 (C═C stretch, unsubstituted C═C, 5,6-membered fused ring system), and 685 (H—C═C—H, cis, out-of-plane bend) cm^{-1}.

The saturated C—H section of the cyclohexene ring possesses two identical methylene groups that contain the short macro frequency train of 2972, 2929 and 2860, and 1447 cm^{-1}:

a. **2972 cm^{-1}:** Antisymmetric C—H stretch of the $—CH_2—$ group.
b. **2929 and 2860 cm^{-1}:** Split symmetric C—H stretch of the $—CH_2—$ group. This mode is split by Fermi coupling (see Chapter 8) with the overtone of the symmetric methylene scissoring vibration found at 1447 cm^{-1} ($1447 \times 2 = 2894$). The uncoupled fundamental mode would be expected to occur at or near 2890 cm^{-1}, and thus, falls very close to the predicted location of the overtone. ← www
c. **1447 cm^{-1}:** Symmetric deformation vibration (scissoring motion) of the methylene group present in the cyclohexene system.

Examine the spectrum of your reaction product. Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 6.27–6.29).

Nuclear Magnetic Resonance Analysis. The 4-cyclohexene-*cis*-1, 2-dicarboxylic acid anhydride provides an ideal example of the utility of ^{13}C NMR when only limited information is available from the ^{1}H NMR spectrum. The 300-MHz ^{1}H spectrum is shown in Figure 6.30, page 266. Due in part to the presence of two stereocenters, as well as long-range coupling through the π system of the alkene, the entire ^{1}H spectrum is second order and no information is available from the coupling constants because the spectrum is too complex. Limited assignments to peaks could be made on the basis of chemical shift, but it would be difficult to make any statements regarding the purity of your sample based on the ^{1}H NMR spectrum, since an impurity could well be hidden beneath any of the complex signals.

On the other hand, the fully ^{1}H-decoupled ^{13}C spectrum (Figure 6.31, page 267) of 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride is much less complex. Because of the mirror plane of symmetry in the compound, there are only four unique carbon atoms and thus only four peaks are seen in the ^{13}C NMR spectrum. The 1:1:1 triplet centered at 77 ppm is due to the solvent, $CDCl_3$. Although no ^{1}H–^{13}C coupling is seen as a result of the ^{1}H decoupling, ^{2}H–^{13}C coupling is observed because ^{1}H and ^{2}H (D) resonate at different frequencies.

Sample preparation for ^{13}C NMR is essentially the same as for ^{1}H NMR spectroscopy except that significantly more material is required to obtain a ^{13}C NMR spectrum in a reasonable amount of time. In this case, acceptable signal-to-noise levels can be obtained on 40 mg of material in about 10 min. Although tetramethylsilane (TMS) can be added as a reference, it is often

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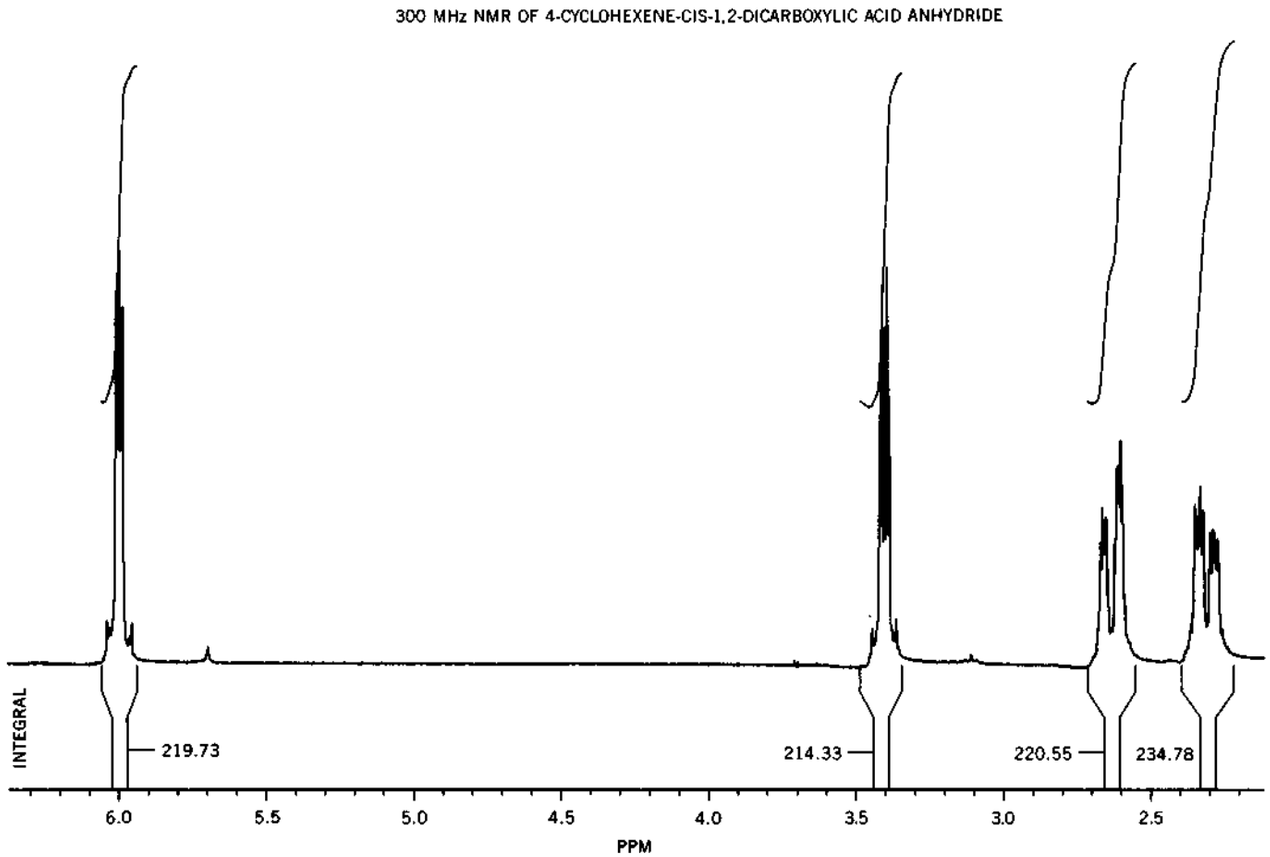

Figure 6.30 ^{1}**H-NMR spectrum: 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride.**

more convenient to reference the spectrum relative to the known chemical shift of the solvent signal. Do not hesitate to use all of your material for the ^{13}C spectrum; it can be easily recovered later by emptying the NMR tube into a small vial, rinsing once with solvent, and evaporating the solvent in a hood under a gentle stream of dry nitrogen.

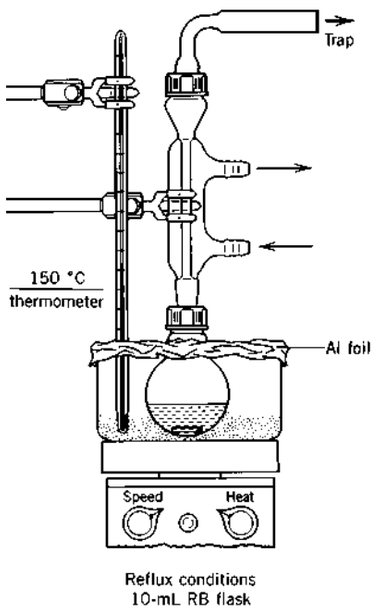

Reflux conditions
10-mL RB flask

Chemical Tests. Selected chemical classification tests can also be used to aid in characterization of this compound. Is the compound soluble in water? If so, does the aqueous solution turn blue litmus paper red? Is the compound soluble in 5% NaOH and 5% $NaHCO_3$? Is there evidence of CO_2 evolution with the bicarbonate solution? If so, what does this test indicate? Give the structure of the product formed when the material is added to the sodium hydroxide solution.

Perform the Baeyer test for unsaturation (Chapter 9). Is there evidence for the presence of a C═C bond?

OPTIONAL SEMIMICROSCALE PREPARATION

The microscale Diels–Alder addition may be scaled up by a factor of 5. The procedure is similar to that outlined above, with the exceptions noted below.

1. Use a 10-mL round-bottom flask containing a magnetic stirrer, equipped with a reflux condenser protected by a calcium chloride drying tube. Place an insulating aluminum foil guard between the bottom of the reflux condenser and the round-bottom flask (⬅).

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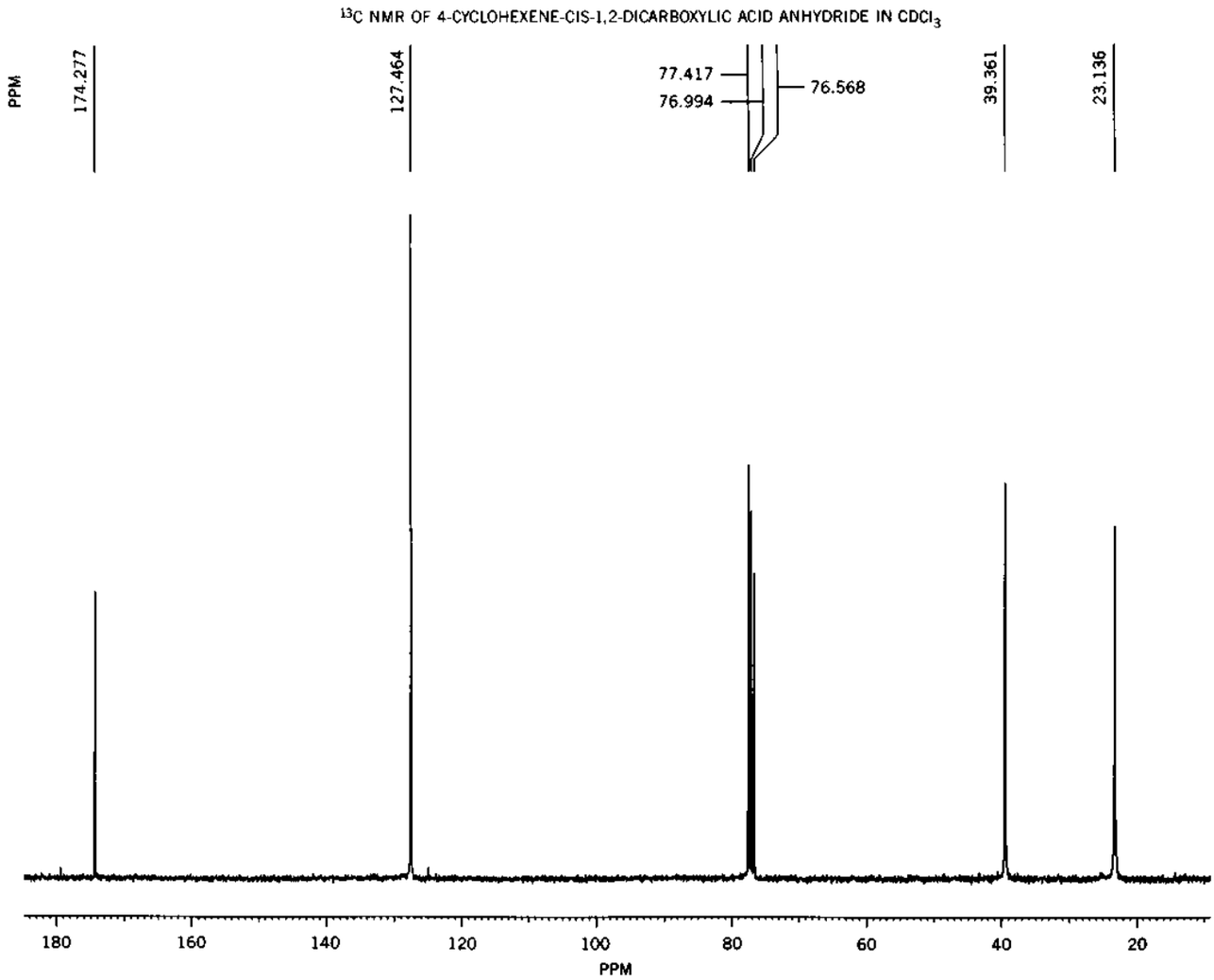

Figure 6.31 **^{13}C-NMR spectrum: 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride.**

CAUTION: At this scale, due to the generation of a considerably larger quantity of sulfur dioxide than at the microscale level, the reaction must be run in the ***hood*** or provisions should be made to trap the evolved gas. HOOD

2. Increase the reagent and solvent amounts about 5-fold:

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
3-Sulfolene	118.15	850 mg	7.2	66	
Maleic anhydride	98.06	450 mg	4.6	60	
Xylene		400 μL			137–140

3. Once in solution, heat the reaction mixture to reflux for 20 min. *Avoid overheating.* Then, cool the reaction to room temperature.

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4. After cooling, add 5 mL of toluene and transfer the resulting clear solution to a 25-mL Erlenmeyer flask. The toluene solution may require heating and stirring to dissolve any crystals that may have formed. Now add petroleum ether (60–80 °C) (2.5–3.5 mL).

5. After isolation by vacuum filtration, wash the product with 5 mL of cold petroleum ether (60–80 °C).

6. Characterize the product as outlined in the microscale procedure (above).

QUESTIONS

6-92. Predict the product in each of the following Diels–Alder reactions.

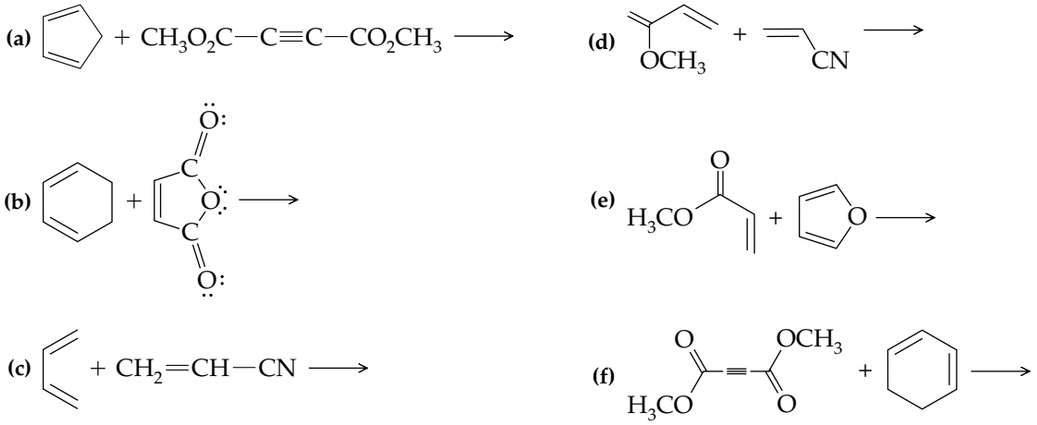

6-93. Cyclopentadiene reacts as a diene in the Diels–Alder reaction a great deal faster than does 1,3-butadiene. Explain.

6-94. Predict the diene and dienophile that would lead to each of the following products.

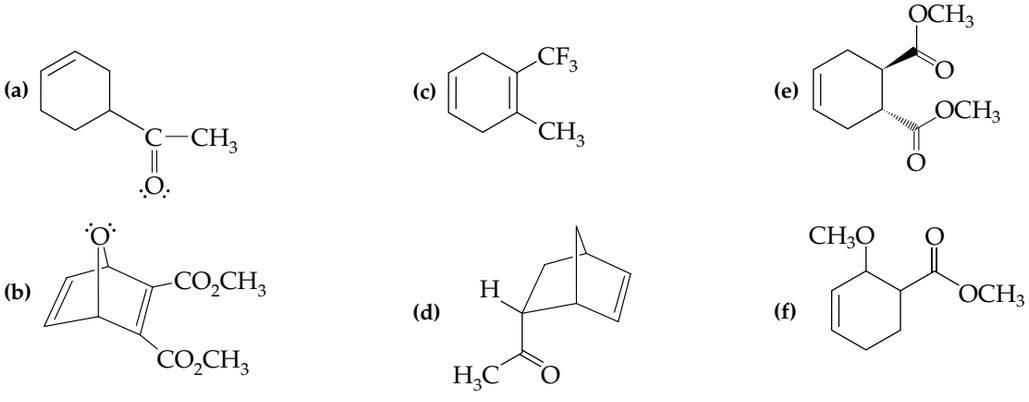

6-95. The decomposition of 3-sulfolene to form 1,3-butadiene generates 1 mol of sulfur dioxide gas per mol of 1,3-butadiene. Substantial quantities of SO_2 would be generated if this decomposition were carried out on a large scale. Suggest a method for trapping the gas to prevent its escape into the environment.

6-96. Two structural isomers are formed when 2-methyl-1,3-butadiene reacts with ethyl acrylate (ethyl 2-propenoate). Draw structures for these isomers.

6-97. In general, on going from the unsaturated fully conjugated anhydrides to the saturated systems, the two C—O stretching modes begin to coalesce, and in many cases only a single band is observed. In maleic anhydride, these modes occur at 1060 and 899 cm^{-1}, while in *cis*-4-cyclohexene-1,2-dicarboxylic acid anhydride they are found at 998 and 935 cm^{-1}. Explain this observation.

6-98. Acyclic anhydrides exhibit a reversal of the intensity relationship of the carbonyl stretching vibrations found in the cyclic anhydrides. That is, the lower wavenumber band is now the weaker member of the pair. Explain why this intensity exchange occurs.

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6-99. If in Experiment [14] you had prepared the other possible diastereomer of the product, 4-cyclohexene-*trans*-1,2-dicarboxylic acid anhydride, how many lines would you expect to see in the ^{13}C NMR spectrum? Note that this isomer does not have a mirror plane of symmetry.

6-100. Does the ^{13}C NMR spectrum unambiguously demonstrate the position of the carbon–carbon double bond? How?

6-101. In ^{1}H spectra, the relative intensities of lines within a triplet are 1:2:1. The signal for $CDCl_3$ is a triplet with relative intensities of 1:1:1. Why?

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Pindur, U.; Lutz, G.; Otto, C. *Chem. Rev.* **1993,** *93,* 741.

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EXPERIMENT 15

Diels–Alder Reaction: 9,10-Dihydroanthracene-9,10-α,β-succinic Acid Anhydride

Common name: 9,10-dihydroanthracene-9,10-α,β-succinic acid anhydride

CA number: [85-43-8]

CA name as indexed: 1,3-isobenzofurandione, 3a,4,7,7a-tetrahydro-

Purpose. The Diels–Alder reaction is investigated. You will explore the role of an aromatic ring system as the diene substrate in this addition reaction. The reaction studied in this experiment is an example of a 1,4 addition by an activated alkene dienophile across the 9,10 positions of anthracene.

Prior Reading

Technique 5: Crystallization

Use of the Hirsch funnel (pp. 88–89)

REACTION

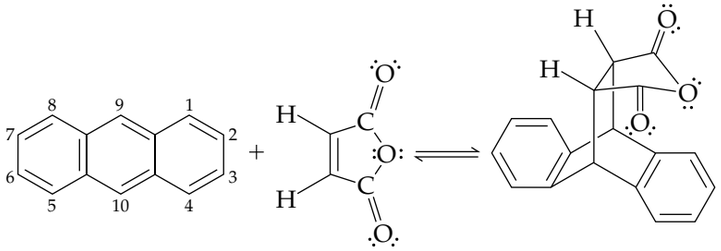

Anthracene | Maleic anhydride | 9,10-Dihydroanthracene-9,10-α,β-succinic acid anhydride

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This famous class of reactions are named for **Otto Paul Hermann Diels** and **Kurt Alder,** who were primarily responsible for its development. Diels and Alder received the Nobel Prize in 1950 for this work. See Experiment [14] for a biography of Diels. A short biography of his student Kurt Alder follows.[15]

Kurt Alder (1902–1958) Alder obtained his Ph.D. in 1926 while studying with Otto Diels at the University of Kiel. His dissertation was titled *Causes of the Azoester Reaction*. He became Professor of Chemistry at the University of Kiel in 1934 and later became head of the Chemical Institute at the University of Cologne (1940). For a few years (1936–1940) he was Research Director of the Baeyer dye works.

Together with Diels, Alder was responsible for the development of what came to be known as the Diels–Alder reaction. This reaction typically involves the reaction of a 1,3-conjugated diene with an activated alkene (dienophile) to form a six-membered cycloalkene. While reactions of this type had been reported as early as 1893, Diels and Alder were the first to recognize their great versatility. Alder continued to focus his academic research in this area following his graduate work with Diels. Over a number of years, Alder carried out a systematic study of the reactivity of a large number of dienes and dienophiles and established the structure and stereochemistry of many new adducts. He also expanded his doctoral research, studying the condensation of azoesters with dienes to yield the corresponding heterocyclic adducts.

Alder demonstrated that successful addition required that the diene double bonds possess an *s*-cis conformation (*s* refers to the single bond connecting the two double bonds). Furthermore, he realized that the bridged ring adducts formed by using cyclic dienes were closely related to natural products, such as camphor, and that this reaction offered a powerful route for the synthesis of a wide variety of naturally occurring compounds, particularly the terpenes. The Diels–Alder reaction also has been invaluable in the industrial synthesis of thousands of new organic materials from insecticides and dyes to lubricating oils and pharmaceuticals.

Alder investigated autooxidation and polymerization processes particularly during his industrial years. For example, he was involved in an extensive study of polymerizations related to the formation of Buna-type synthetic rubbers.[16]

DISCUSSION

This experiment is a further example of the Diels–Alder reaction. *For a discussion of the basic aspects of this reaction see Experiment [14]*. In the present case, the central ring of anthracene is shown to possess the characteristic properties of a diene system. Thus, this aromatic compound reacts to form stable Diels–Alder adducts with many dienophiles at the 9 and 10 positions (the two positions on the central ring where new bonds can be made without destroying the aromaticity of the other two rings). Maleic anhydride, a very reactive dienophile, is used here in the reaction with anthracene. Note, that as this reaction is reversible, it is usually best carried out at the lowest possible temperatures consistent with an acceptable reaction rate (see Experiment [14]).

[15]For references to the Diels–Alder reaction, see Experiment [14].

[16]See Allen, C. F. H. *J. Chem. Educ.* **1933,** *10*, 494; *Dictionary of Scientific Biography,* C. C. Gillespie, Ed.; Scribner's: New York, 1970, Vol. I, p. 105; *McGraw-Hill Modern Scientists and Engineers,* S. P. Parker, Ed., McGraw-Hill: New York, 1980, Vol. 1, p. 8.

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Higher molecular weight polynuclear aromatic hydrocarbons (PAHs) containing the anthracene nucleus have also been found to react with maleic anhydride. These ring systems, however, can differ widely in reaction rates. Typical examples of those systems that undergo the Diels–Alder reaction are 1,2,5,6-dibenzanthracene (a), 2,3,6,7-dibenzanthracene (pentacene) (b), and 9,10-diphenylanthracene (c).

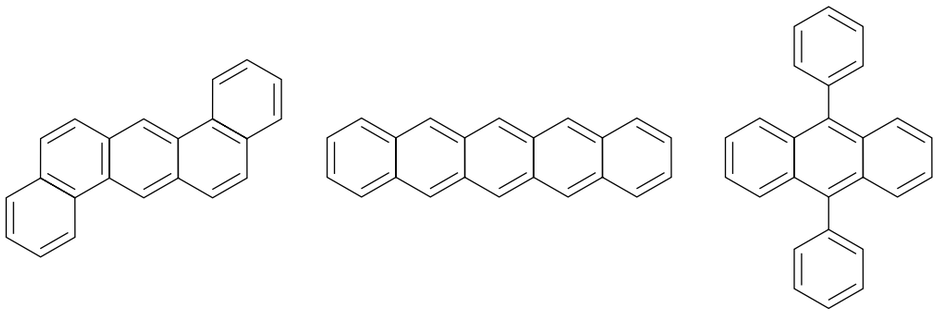

(a) (b) (c)

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Anthracene	178.24	80 mg	0.44	216	
Maleic anhydride	98.06	40 mg	0.40	60	
Xylenes		1.0 mL			137–140
9,10-Dihydroanthracene-9,10-α,β-succinic acid anhydride	276			261–262	

Reagents and Equipment. Weigh and place 80 mg (0.44 mmol) of anthracene and 40 mg (0.40 mmol) of maleic anhydride in a 3.0-mL conical vial containing a boiling stone and equipped with an air condenser protected by a calcium chloride drying tube. Now, while in the **hood,** add 1.0 mL of xylene to the solid mixture using an automatic delivery pipet (➡).

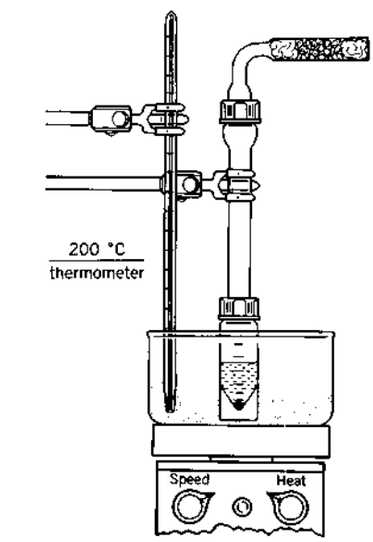

HOOD

Anthracene, 80 mg
+ maleic anhydride, 40 mg
+ xylene, 1.0 mL

NOTE. High-purity grades of anthracene and maleic anhydride are strongly recommended. Anthracene may be recrystallized from 95% ethanol. A mixture of xylenes with a boiling-point range of 137–140 °C is sufficient, but the solvent (xylenes) should be dried over molecular sieves before use.

Reaction Conditions. Heat the reaction mixture at reflux for 30 min in a sand bath at about 200 °C. During this time the initial yellow color of the reaction mixture gradually disappears. (Why?) Allow the resulting bleached solution to cool to room temperature and then place it in an ice bath for 10 min to complete the crystallization of the product.

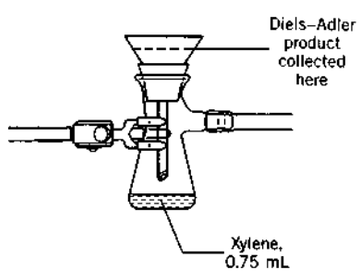

Isolation of Product. Collect the crystals by vacuum filtration using a Hirsch funnel and wash the filter cake with two 300-μL portions of cold ethyl acetate (➡). Partially dry the filter cake under suction using plastic food wrap

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(see Prior Reading). Transfer the filtered, washed, and partially dried product to a porous clay plate or filter paper to complete the drying.

Purification and Characterization. The product is often of sufficient purity for direct characterization at this point. The adduct, however, may be further purified by recrystallization from ethyl acetate using a Craig tube. Weigh the dried Diels–Alder product and calculate the percent yield. Determine the melting point and compare your result with the value listed above.

NOTE. It is suggested that a hot-stage melting point apparatus, such as the Fisher–Johns, be used due to the high melting point of the product.

Chemical Tests. The *ignition test* is often used as a preliminary method to categorize hydrocarbon materials (see Chapter 9). Aromatic compounds give a yellow, sooty flame. Perform this test on anthracene. Based on your results can anthracene be classified as aromatic?

Carry out the ignition test on the following compounds and determine whether they should be classified as aromatic materials.

a. Toluene
b. Octane
c. Isopropyl alcohol
d. Nitrobenzene
e. *trans*-Stilbene

OPTIONAL SEMIMICROSCALE PREPARATIONS

This Diels–Alder reaction may be scaled up by a 5- or 50-fold increase in reactants. The scaled-up procedures are nearly identical in either case to that given for the microscale preparation; changes are noted below.

1. Fivefold Scaleup

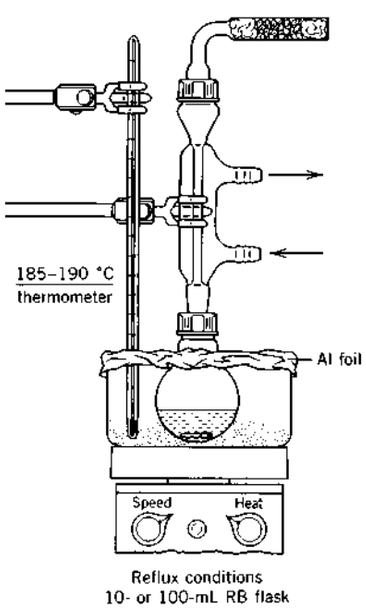

Reflux conditions
10- or 100-mL RB flask

a. In place of the conical vial as the reaction vessel, use a 10-mL round-bottom flask containing a magnetic stirrer connected to the water-jacketed reflux condenser that is protected by a calcium chloride drying tube (⬅).

b. The reagent and solvent quantities are given in the following table:

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Anthracene	178.24	400 g	2.2	216	
Maleic anhydride	98.06	200 g	2.0	60	
Xylene	106.16	5.0 mL			137–140
Ethyl acetate	88.11	3.0 mL			77

c. The reaction flask is **heated at 185–190 °C** bath temperature for 30 min to obtain optimized yields.

2. Fiftyfold Scaleup

a. In place of the conical vial as the reaction vessel, use a 100-mL round-bottom flask connected to a water-cooled reflux condenser that is fitted with a calcium chloride drying tube.

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b. The required reagent and solvent quantities are given in the following table:

Compound	MW	Amount	mol	mp (°C)	bp (°C)
Anthracene	178.24	4.0 g	0.2	216	
Maleic anhydride	98.06	2.0 g	0.2	60	
Xylene	106.16	50 mL			137–140
Ethyl acetate	88.11	30 mL			77

c. Heat the reaction mixture at **vigorous** reflux for **2 h.**

d. Recrystallize the crude product from ethyl acetate.

9,10-Dihydroanthracene-9,10-α,β-succinic Acid Anhydride: Preparation Using a Monomode Microwave Apparatus

Experiment 15-1*

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Anthracene	178.24	178 mg	1.00	216	
Maleic Anhydride	98.06	98 mg	1.00	60	
Toluene		2 mL			111
9,10-Dihydroanthracene-9,10-α,β-succinic Acid Anhydride	276			261–262	

Reagents and Equipment. This experiment is designed for use in the CEM Discover and Biotage Initator microwave units.

In a 10.0-mL glass microwave reaction vessel containing a magnetic stir bar, place 178 mg (1.00 mmol) of anthracene, 98 mg (1.00 mmol) of maleic anhydride, and 2 mL of toluene. Immediately cap the vessel with a microwave pressure cap.

CAUTION: Since the reaction requires heating toluene (solvent for the reaction) to above its boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential.*

Reaction Conditions. Place the reaction vessel in the microwave cavity and, depending on the equipment used, position the pressure device on top. Program the microwave unit to heat the reaction mixture at maximum power to 180 °C and hold at this temperature for 10 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the tube from the microwave unit. Allow the resulting solution to cool to room temperature and then place it in an ice bath for 10 min to complete the crystallization of the product.

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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Isolation of Product. The remainder of the procedure is identical to Experiment 15 (pages 271–272).

Experiment 15-2*

M

9,10-Dihydroanthracene-9,10-α,β-succinic Acid Anhydride: Preparation Using a Multimode Microwave Apparatus

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Anthracene	178.24	214 mg	1.20	216	
Maleic Anhydride	98.06	118 mg	1.20	60	
Toluene		5 mL			111
9,10-Dihydroanthracene-9,10-α,β-succinic Acid Anhydride	276			261–262	

Reagents and Equipment. This experiment is designed for use in the CEM MARS, Milestone START, and Anton Paar Synthos 3000 microwave units. When using the Anton Paar Synthos 3000 unit with the 24-position silicon carbide plate rotor containing glass vials, the reagent and solvent quantities cited in the monomode procedure should be used in conjunction with the reaction conditions here in the multimode procedure.

In a microwave reaction vessel containing a magnetic stir bar, add 214 mg (1.20 mmol) of anthracene, 118 mg (1.20 mmol) of maleic anhydride, and 5 mL of toluene. Immediately cap the vessel with the microwave pressure cap and adjust the tightness to the manufacturer-specified level. Place the sealed vessel into its outer protective jacket.

CAUTION: Since the reaction requires heating toluene (solvent for the reaction) to above its boiling point in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

Reaction Conditions. Insert the loaded vessels into the reaction carousel ensuring they are evenly spaced and then place the carousel into the microwave cavity. If provided by the manufacturer, connect a temperature probe to the control vessel. Program the microwave unit to heat the reaction vessels to 180 °C using maximum power and hold at this temperature for 10 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the carousel from the microwave unit. Allow the resulting solution to cool to room temperature and then place it in an ice bath for 10 min to complete the crystallization of the product.

Isolation of Product. The remainder of the procedure is identical to Experiment 15 (pages 271–272).

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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QUESTIONS

6-102. Given the data tabulated below for the rate of reaction of maleic anhydride with a series of substituted 1,3-butadienes, offer a reasonable explanation to account for the trend in the rates.

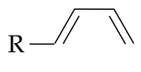

R	*k* (rel) at 25 °C
—H	1
—CH_3	4.2
—$C(CH_3)_3$	<0.05

6-103. Predict the structure of the product formed in the following reactions.

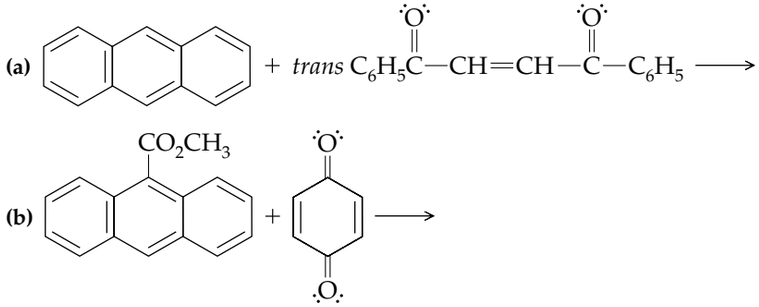

6-104. Offer an explanation of why anthracene preferentially forms a Diels–Alder adduct at the 9,10 positions.

6-105. Experiment [31] demonstrates the monobromination of anthracene to yield one specific monosubstituted product. Other conditions may be used to form other monobrominated anthracenes. Draw the structures of, and name, the possible monobromo-substituted anthracenes that could be prepared in the laboratory.

6-106. There are four reasonable resonance structures for anthracene. Draw them.

6-107. A large number of polycyclic benzenoid aromatic hydrocarbons are known. One of these, benz[*a*]pyrene, is a powerful carcinogen found in tobacco smoke. From the literature, locate and then draw the structure of this hydrocarbon. Can you suggest other sources where this material might be expected to be present?

6-108. Anthracene undergoes a *suprafacial* [$_{\pi}4_s + {}_{\pi}4_s$] cycloaddition reaction at the 9,10 positions when subjected to irradiation to form a cyclic dimer. *Suprafacial* is a term used to describe in detail that the addition of the dienophile to the 1,3-π-system has occurred all from the same side (or face) of this planar structure. It comes from the Latin meaning above, or the dorsal side, and it is symbolized by the subscript "s" in the terminology: [$_{\pi}4_s + {}_{\pi}4_s$]. This is a theoretically forbidden thermal pericyclic reaction, but it can occur under photochemical conditions. Draw the structure of this product.

BIBLIOGRAPHY

For a review of diastereoselectivity in the reaction see Waldmann, H. *Synthesis* **1994,** 535.

Coxon, J. M. et al., *Diastereofacial Selectivity in the Diels–Alder Reaction* in *Advances in Detailed Reaction Mechanisms* **1994,** *3,* 131.

EXPERIMENT 16

Grignard Reaction with a Ketone: Triphenylmethanol

Common name: triphenylmethanol

CA number: [76-84-6]

CA name as indexed: benzenemethanol, α,α-diphenyl-

Purpose. The techniques required to prepare Grignard reagents are developed. The reaction of these reagents with ketones to form *tertiary* alcohols is

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investigated. You will gain experience, first hand, working with these highly air- and moisture-sensitive materials. And you will observe the formation of this famous reagent, in which magnesium metal is transformed (heterogeneous conditions) into organometallic salts of enormous value to the synthetic chemist.

This exercise is the first of a number of experiments in this chapter in which the Grignard reaction is studied at the microscale level. Even if you do not actually do more than one of them, it is well worth the time to read through the other Experiments [17], [21], and [4_{adv}] to get a sense of the breadth of the applications of the reaction.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)
Technique 5: Crystallization
Craig Tube Crystallizations (pp. 89–91)
Technique 6A: Chromatography
Thin-Layer Chromatography (pp. 97–99)

REACTION

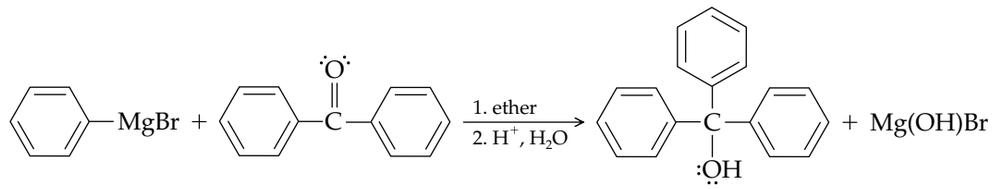

Phenylmagnesium bromide — Benzophenone — Triphenylmethanol

François Auguste Victor Grignard (1871–1935) Born in Cherbourg, Grignard was professor of Chemistry at the Universities of Lyons and Nancy. After studying for one year with Bouveault, Grignard became a graduate student of Phillippe Antoine Barbier, a professor at the University of Lyons. Barbier, who was working in the area of terpene chemistry, had found that magnesium could be used in place of zinc in the reaction of methyl iodide with an unsaturated ketone (methylheptenone) to yield the corresponding tertiary alcohol. This route was much preferred since the zinc reagents were difficult to work with because they were pyrophoric (spontaneously flammable in air). The use of magnesium in the formation of tertiary alcohols was reported in 1899. Barbier suggested to Grignard that it might be interesting to further investigate the reaction of magnesium with alkyl halides. This study was to form the basis of Grignard's doctoral dissertation. Grignard discovered that treatment of alkyl iodides with magnesium in *diethyl ether* produced an alkylmagnesium iodide by a spontaneous reaction at ambient temperatures. His initial results, reported in 1900, were followed by seven papers the following year. His doctoral thesis on organomagnesium compounds and their application to synthetic organic chemistry was presented in 1901, when Grignard was 30 years old.

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Grignard continued this work, having recognized the enormous potential of the alkyl magnesium halides in organic synthesis. These species are now known as *Grignard reagents* and when the reagent is used in synthesis, the reaction is called a *Grignard reaction*. These reagents have found great utility in the preparation of many kinds of organic compounds, including alcohols, ketones, esters, and carboxylic acids. As mentioned above, these reagents contain a carbon–metal bond, and therefore they are classed in a large group of substances called *organometallic* compounds.

For this work, Grignard received the Nobel Prize in 1912. In 1919 Grignard returned to Lyons where he succeeded Barbier as chairman of the Department. By the end of his life, the scientific literature contained over 6000 papers dealing with Grignard reagents and their application.

Grignard also did extensive work in the areas of the terpenes, quantitative ozonolysis of alkenes, aldol reactions, catalytic hydrogenation, and dehydrogenation and cracking of hydrocarbons.[17]

DISCUSSION

Grignard reagents possess significant nucleophilic character because of the highly polarized carbon–metal bond that results in considerable carbanionic character at carbon. Grignard discovered that these reactive materials readily attack the electrophilic carbon of a carbonyl group. It is this direct attack on carbon by a carbon nucleophile, resulting in carbon–carbon bond formation, that makes these such important reactions. Furthermore, as the carbonyl is the most ubiquitous functionality in all of organic chemistry, Grignard reagents have found great utility and widespread use in organic synthesis.

The formation of the organomagnesium halide (Grignard reagent) involves a heterogeneous reaction between magnesium metal and an alkyl, alkenyl, or aryl halide in ether solution. The solvent may be any one of a number of ethers, but diethyl ether and tetrahydrofuran are by far the most popular.

$$\underset{\substack{\text{R = alkyl, alkenyl}\\ \text{and Ar = aryl}}}{\text{R(Ar)—X}} + \text{Mg} \xrightarrow{\text{ether}} \text{R(Ar)—Mg—X}$$

The reaction between an alkyl, alkenyl, or aryl halide and magnesium takes place on the surface of the metal and is an example of a *heterogeneous* (across two phases) reaction. The reactivity of the alkyl halides is in the order Cl < Br < I; fluorides do not generally react. Substituted alkyl halides react in the order 1° > 2° > 3° alkenyl and aromatic halides also form Grignard reagents to varying degrees.

It is important to understand the role of the ether solvent in the formation of the Grignard reagents. The reaction at the surface of the metal is essentially an oxidation–reduction reaction. The metal is partially oxidized to the greater than 1+ state and the organohalide is reduced to a halide ion and a highly polarized

[17]See Gordon, N. E. *J. Chem. Educ.* **1930,** *7,* 1487; Rheineoldt, H. *J. Chem. Educ.* **1950,** *27,* 476; Kauffman, G. B. *J. Chem. Educ.* **1990,** *67,* 569; Gilman H. *J. Am. Chem. Soc.* (Proc.) **1937,** *59,* 17; Gibson, C. S.; Pope, W. J. *J. Chem. Soc.* **1937,** 171; *Dictionary of Scientific Biography,* C. C. Gillespie, Ed., Scribner's: New York, 1972, Vol. V, p. 540.

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carbon–metal bond with the magnesium. The overall reaction can be viewed as forming the species, $R^{\delta-}\!-\!^{\delta+}Mg^{+}X^{-}$ as the Grignard reagent. This highly polarized material is insoluble in most nonpolar organic solvents. The reaction will proceed at the surface of the metal until a layer of the insoluble organometallic reagent has formed. At this point, the surface reaction with the magnesium will immediately cease. If protic solvents are used, they would instantly react with the highly basic Grignard reagent, R—MgX, to form the corresponding hydrocarbon, R—H. Thus, the use of either nonpolar or protic solvents does not lead to successful Grignard reagent formation. Why, then, is ether, a relatively nonpolar solvent, essential to the preparation of Grignard reagents?

The magnesium is essentially divalent, and electron deficient, when it reacts with the halide to form the RMgX species. A full octet around the metal atom requires two additional pairs of electrons. It is the energy gained by filling this octet that drives the coordination of the magnesium with two molecules of the ether solvent. This association in turn dramatically increases the solubility of the Grignard reagent in the relatively nonpolar ether solvent, and thus promotes further Grignard reagent formation.

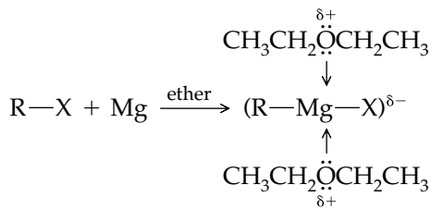

This interaction of RMgX with ether solvent also may be described as a Lewis acid–base interaction in which the coordinating solvent molecules are usually not written. When a Grignard reagent is described, it is important to remember that this vital solvation is always taking place.

The reactions of Grignard reagents with different types of carbonyl groups yield a number of important functional groups. For example, reaction with formaldehyde yields 1° alcohols; with higher aldehydes, 2° alcohols; with ketones, 3° alcohols; with esters, 3° alcohols; with acyl halides, ketones; with *N,N*-dialkylformamides, aldehydes; and with carbon dioxide, carboxylic acids.

In this experiment you will study the addition of the aryl Grignard reagent (phenylmagnesium bromide) to a diaryl ketone (benzophenone) to yield the corresponding tertiary (3°) alcohol. Because it is possible to vary both the structure of the Grignard reagent and the ketone, a wide variety of 3° alcohols may be obtained by this synthetic route.

The mechanism, as discussed above, can be thought of as involving rapid nucleophilic attack by the Grignard reagent at the carbon of the carbonyl group. Hydrolysis of the resulting alkoxide ion intermediate with dilute acid yields the desired alcohol. The reaction sequence is outlined here:

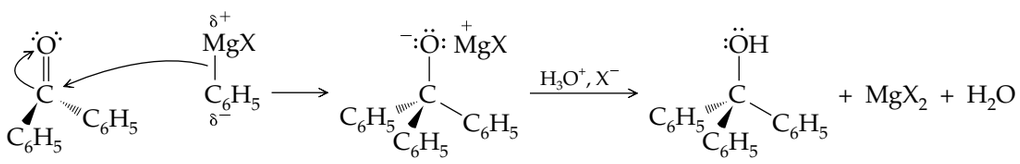

By using Grignard reagents, it is theoretically possible to synthesize a very large number of alcohols. Indeed, there is often more than one synthetic pathway

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open to a desired product. The choice of route is generally dictated by the availability of starting materials and the associated costs of these compounds.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: Two laboratory periods when starting with bromobenzene. If using commercial phenylmagnesium bromide, one laboratory period (experiment starting on p. 280). **(The Benzophenone Reagent)**

CAUTION: Ether is a flammable liquid. All flames must be extinguished during the time of this experiment.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Bromobenzene	157.02	76 μL	0.72		156	1.50	1.5597
Diethyl ether	74.12	1.3 mL			34.5	0.73	
Magnesium	24.3	18 mg	0.74				
Iodine	253.8	1 crystal					
Benzophenone	182.21	105 mg	0.58	48			

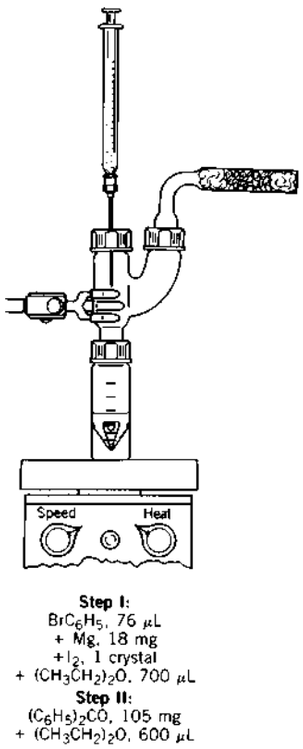

Reagents and Equipment

Preparation of Phenylmagnesium Bromide

NOTE. All the glassware used in the preparation of the Grignard reagent should be cleaned and dried in an oven at 110 °C for at least 30 min. After removal from the drying oven, the hot glassware should be placed in a desiccator and cooled before being assembled. Flame drying of the apparatus with a microburner annealing flame (high gas mixture) is an alternative, if ovens are not available. This latter method preferably should be carried out prior to assembly and, as with the oven-dried equipment, the hot glassware should be placed in a desiccator to cool. Care must be taken when flaming the reaction vial, because thermal shock can easily crack this heavy-walled vessel. If the flame-drying procedure is performed on the assembled apparatus, care also must be taken not to overheat the O-rings and plastic Capseals.

In a 3.0-mL conical vial containing a magnetic spin vane and equipped with a Claisen head fitted with a calcium chloride drying tube and a rubber septum, weigh and place 18 mg (0.74 mmol) of polished magnesium ribbon, a small crystal of iodine, and 100 μL of anhydrous ether (using an automatic delivery pipet in the **hood**)(➡).

HOOD

NOTE. Scrape a 2- to 3-in. piece of magnesium ribbon clean of surface oxide (MgO) coating and then cut it into 1-mm long sections.

Alternate Procedure: Place the (polished) magnesium metal and an iodine crystal in the reaction vial and quickly assemble the apparatus. Warm the mixture (using a microburner or hot plate) **gently** until evidence of purple iodine vapor is observed.

GENTLY

NOTE. If a microburner is used in this step, all flames must be extinguished before proceeding.

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Now add 100 μL of anhydrous ether using a 1.0-mL syringe inserted through the septum.

In a dry, screw-capped vial, prepare a solution of 76 μL (113 mg, 0.72 mmol) of bromobenzene in 400 μL of anhydrous diethyl ether. *Automatic delivery* pipets
HOOD are used to transfer these reagents in the **hood.** Recap the vial until just before injecting its contents into the reaction vial.

Draw the bromobenzene–ether solution into a 1.0-mL syringe and insert the syringe through the rubber septum on the Claisen head. Place an additional 300 μL of anhydrous diethyl ether rinse in the empty vial (which contains traces of bromobenzene), cap it, and set it aside for later use. With slow stirring, add 6–8 drops of the bromobenzene solution to induce the initial formation of Grignard reagent. The evolution of tiny bubbles from the surface of the magnesium (the heat of reaction is vaporizing the low-boiling ether solvent) is evidence of successful reaction initiation.

Once the reaction gives evidence of initiation, add the remainder of the bromobenzene dropwise *slowly* over a 3- to 5-min period. *(In macroscale reactions it is extremely important to make sure that initiation of the reaction has occurred prior to adding large quantities of the organohalide, as Grignard reactions often go through an induction period before starting up. If significant quantities of the halide are present when the reaction commences, the sudden and rapid rate of reaction can produce a very rapid evolution of heat, and the reaction may well erupt out of control.) Warm the reactants gently to maintain gentle reflux.*

After adding the bromobenzene, draw the ether rinse from the capped vial into the syringe and also add it to the reaction vial through the septum in a single portion.

Heat the resulting heterogeneous reaction mixture gently with stirring for 15 minutes.

CAUTION: *Do not overheat!* This overheating will cause loss of ether solvent and promote formation of byproducts. Small fragments of magnesium may remain at the end of the reaction. Maintain no more than a gentle reflux at all times. If solvent volume decreases rapidly, check for leaks around the Capseals and add additional anhydrous ether through the septum to make up for the lost volume of ether.

Cool the gray-brown mixture of the Grignard reagent, phenylmagnesium bromide, to room temperature.

The Benzophenone Reagent. Prepare a solution of 105 mg (0.58 mmol) of benzophenone in 300 μL of anhydrous diethyl ether in a dry vial with a cap.
HOOD *The ether is measured using a graduated 1-mL syringe and is dispensed in the* ***hood.***

Draw the solution immediately into a 1.0-mL syringe, and then insert the syringe needle through the rubber septum on the Claisen head. Place an additional 300 μL of the anhydrous diethyl ether in the empty vial, cap it, and set it aside for later use.

Reaction Conditions. *Carefully*, with stirring, add the benzophenone solution to the Grignard reagent (1.2 equiv) over a period of approximately 30 s or at a rate that maintains the temperature of the ether solvent at a no more than gentle reflux.

Upon completion of this addition, add the rinse from the capped vial, in like manner, in a single portion.

Stir the reaction mixture for 2–3 min and then allow it to cool to room temperature. Remove the reaction vial from the Claisen head and cap it.

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During this cooling period the reaction mixture generally solidifies. *Once the reaction vial is detached from the Claisen head, it is recommended that the vial be placed in a 10-mL beaker to prevent loss of product by accidental tipping.*

NOTE. If the laboratory is done in two periods, you should stop either at this point, or following the hydrolysis sequence described in the next step.

Isolation of Product. Hydrolyze the magnesium alkoxide salt by the *careful*, dropwise addition of 3 M HCl from a Pasteur pipet, while at the same time using a small stirring rod to break up the solid residue. Continue the addition until the aqueous phase tests acidic with litmus paper. A two-layer reaction mixture forms (ether–water) as the solid gradually dissolves.

CAUTION: The addition of the acid may be accompanied by the evolution of heat and some frothing of the reaction mixture. An ice bath should be handy to cool the solution, if necessary. Additional ether may be added, if required, to maintain the volume of the organic phase. Check the acidity of the mixture periodically. The total reaction mixture must be acidic; both insufficient or excess amounts of hydrochloric acid will result in a decreased yield of product during the subsequent workup.

Now remove the magnetic spin vane with forceps and set it aside to be rinsed with an ether wash. Cap the vial tightly, shake, carefully vent, and allow the layers to separate.

Using a Pasteur filter pipet, transfer the lower aqueous layer to a clean 5.0-mL conical vial.

NOTE. Save the ether layer—it should contain your product.

Wash the acidic aqueous layer with three 0.5-mL portions of diethyl ether (calibrated Pasteur pipet). Rinse the spin vane with the first portion of ether as it is added to the vial. Cap the vial, shake (or use a Vortex mixer, if available), vent carefully, and allow the layers to separate. After each extraction, combine the organic phase with the ether solution saved above. The bottom (aqueous) layer is set aside in a 10-mL Erlenmeyer flask until the experiment is completed.

Now extract the combined ether layers with 0.5 mL of cold water to remove any acidic residue. Combine the aqueous rinse with the previously extracted and stored aqueous layers in a 10-mL Erlenmeyer flask. Dry the ether solution (capped) over 250–300 mg of anhydrous granular sodium sulfate for approximately 10 min. Stir the drying agent intermittently with a glass rod or swirl the flask. If large clumps of sodium sulfate begin to develop and the solution remains cloudy, it may be necessary to transfer the ether extracts to another vial for a second treatment with the drying agent, or you may be able to simply add more Na_2SO_4 to the original vial. The ether solution should be *clear* following treatment with the anhydrous sodium sulfate. Make all these transfers with Pasteur filter pipets.

Transfer the dried ether solution to a *previously tared* Craig tube containing a boiling stone. Carry out the transfer in 0.5-mL portions, concentrating each ether aliquot by warming the vial in a sand bath in the **hood** between the transfers. Rinse the vial and drying agent with an additional 0.5 mL of ether, add the rinse to the Craig tube, and, finally, concentrate the solution to dryness to yield the product residue. HOOD

Determine the weight of the crude triphenylmethanol product.

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Purification and Characterization. The major impurity usually present in the triphenylmethanol is biphenyl, which is formed by a coupling reaction,

$$2RX + Mg \xrightarrow{\text{ether}} R{-}R + MgX_2$$

The purity of your crude product may be determined using *thin-layer chromatography.*

TLC CONDITIONS. Use Eastman Kodak fluorescent silica gel sheets (1 × 4 cm). Develop the plates with methylene chloride and visualize the spots by UV light. Reference R_f *values for triphenylmethanol and biphenyl are about 0.6 and 0.9, respectively.*

The coupled byproduct can be separated from the desired alcohol by taking advantage of the difference in solubilities of the hydrocarbon and the alcohol in ligroin. Ligroin, a nonpolar alkyl solvent, readily dissolves the nonpolar biphenyl, whereas the polar tertiary alcohol is much less soluble.

Add 0.5 mL of cold ligroin to the crude product contained in a Craig tube and scrape and agitate the solid material into a suspension with a small stirring rod. Swirl and stir the solid product with the solvent for several minutes.

Recover the solid triphenylmethanol using the Craig tube in the usual manner. *Save* the ligroin solution that will contain any biphenyl by transferring it, using a Pasteur filter pipet, to a tared 10-mL Erlenmeyer flask.

Repeat the above extraction with a second 0.5-mL portion of ligroin, again stirring the solid suspension and combining the recovered ligroin solution with that saved above. Place the Erlenmeyer flask (cover the mouth with filter
HOOD paper held by a rubber band) in the **hood** overnight, or warm it in a sand bath to allow the ligroin to evaporate. Estimate the amount of biphenyl (and any other impurities) produced in the reaction.

Heat the Craig tube containing the solid triphenylmethanol in a 100 °C oven for 5 min, and then place the crystals on a clay plate to complete the drying process. A further check of the product purity should be carried out by TLC, as described above. Comparisons of the two, pure and impure product, will validate that upon trituration followed by recrystallization, TLC analysis offers the experimentalist sufficient evidence of product purity.

Weigh the purified triphenylmethanol product and calculate the percent yield. Determine the melting point of the material and compare your result to that recorded in the literature. If desired, the product may be purified further by recrystallization from isopropanol using the Craig tube.

Characterization of the triphenylmethanol is best done by obtaining the IR and NMR spectra and comparing the spectral data to that of an authentic sample or to the published spectra in *The Aldrich Library of IR Spectra* and *The Aldrich Library of NMR Spectra,* respectively.

Triphenylmethanol (0.1 g/L in methanol) and biphenyl (0.05 g/L in methanol) also have markedly different UV spectra. This electronic absorption data can further help to establish the identity of the products formed in this Grignard reaction.

UV Spectral Data

Triphenylmethanol	λ_{max} 240 nm (log ε_{max} 3.16, dioxane)
	λ_{max} 253 nm (log ε_{max} 3.26, dioxane)
	λ_{max} 260 nm (log ε_{max} 3.28, dioxane)
Biphenyl	λ_{max} 247 nm (log ε_{max} 4.24, ethanol)

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QUESTIONS

6-109. Predict the product formed in each of the following reactions and give each reactant and product a suitable name:

(a) $CH_3CH_2MgBr + CH_2O \xrightarrow[2.\ H^+]{1.\ \text{ether}}$

(b) $p\text{-}CH_3C_6H_4MgBr + CH_3CH_2CHO \xrightarrow[2.\ H^+]{1.\ \text{ether}}$

(c) $C_6H_5MgBr + D_2O \xrightarrow{\text{ether}}$

(d) 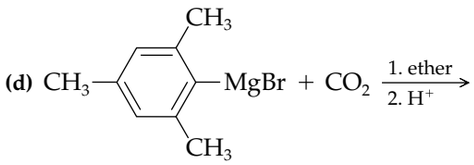

6-110. Using the Grignard reaction, carry out the following transformations. Any necessary organic or inorganic reagents may be used. Name all reactants and products.

(a) 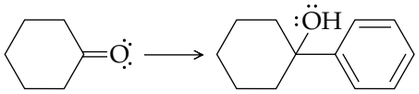

(b) 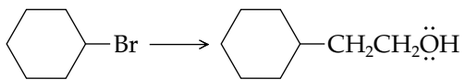

(c) 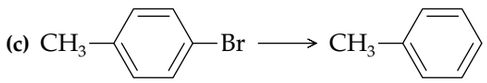

6-111. Outline a synthetic reaction scheme for the preparation of triphenylmethanol from
- **(a)** Methyl benzoate
- **(b)** Diethyl carbonate

6-112. In the experiment, ligroin may be used as a solvent for the separation of the product from biphenyl.
- **(a)** What is ligroin?
- **(b)** Can you suggest an alternative solvent that might be used in this step?

6-113. Give the reaction scheme, showing the products formed (before hydrolysis), when one equivalent of ethylmagnesium bromide is treated with one equivalent of 5-hydroxy-2-pentanone. Does addition of two equivalents of the Grignard reagent to this ketone yield a different product(s)? If so, give the structure(s).

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Moyer, W. W.; Marvel, C. S. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, pp. 602–603. Also see Braun, M; Gräf, S; Herzog, S. *Organic Syntheses* **1995,** *72,* 32.

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EXPERIMENT 17

Grignard Reaction with an Aldehyde: 4-Methyl-3-heptanol

Common name: 4-methyl-3-heptanol
CA number: [14979-39-6]
CA name as indexed: 3-heptanol, 4-methyl-

Purpose. You will carry out a classic method for the synthesis of *secondary* alcohols: the addition of a Grignard reagent to an aldehyde (other than formaldehyde).[18]

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Technique 1: Gas Chromatography (pp. 55–61)

REACTION

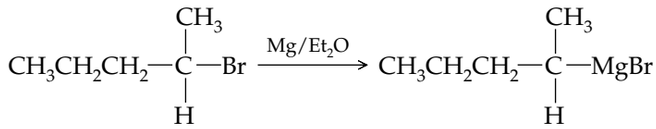

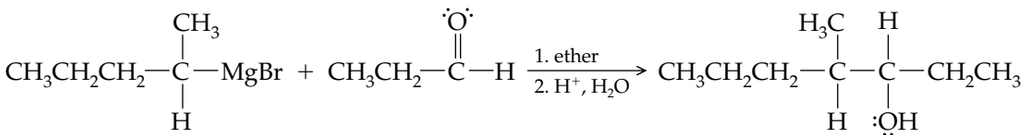

1-Methylbutylmagnesium bromide | Propanal | 4-Methyl-3-heptanol

NOTE. See Experiment [16] for a biography of François Auguste Victor Grignard, Nobel Laureate, who discovered and developed the Grignard reagents. This experiment also contains further details about the mechanism and use of these reagents that have had such a powerful influence on synthetic organic chemistry.

DISCUSSION

In this experiment, the addition of a nucleophilic Grignard reagent (1-methylbutylmagnesium bromide), to the electrophilic carbonyl carbon of an aldehyde (propanal) is described. The product obtained is a 2° alcohol, 4-methyl-3-heptanol. Because it is possible to vary the structure of both the Grignard

[18]For references relating to the preparation of Grignard reagents, see Experiment [16].

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reagent and the aldehyde, a wide variety of 2° alcohols can be prepared by this route. Primary alcohols result when formaldehyde is used as the aldehyde. Secondary alcohols may also be obtained with these reagents when ethyl formate, an ester, acts as the electrophile. This latter reaction, however, requires two molar equivalents of the Grignard reagent. The mechanism for the reaction of an aldehyde with a Grignard reagent follows.

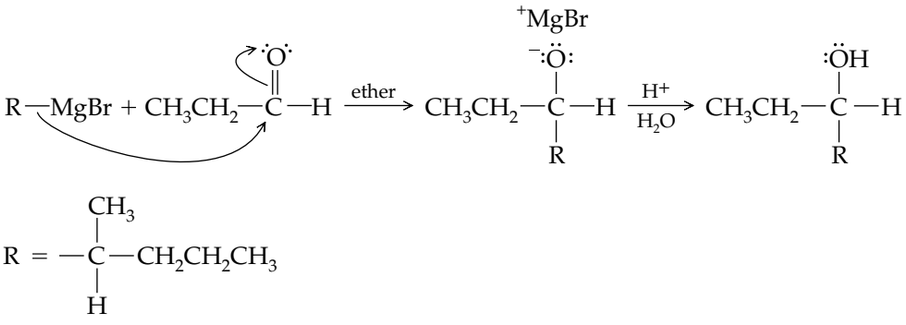

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.0 h. The chromatographic separation requires approximately an additional 15 min per student.

CAUTION: Ether is a flammable liquid. All flames must be extinguished during this experiment.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
2-Bromopentane	151.05	125 μL	1.0	117	1.2	1.4413
Diethyl ether	74.12	700 μL		34.5		
Magnesium	24.31	36 mg	1.48			
Iodine	253.81	1 crystal				
Propanal	58.08	50 μL	0.69	49	0.81	1.3636

Reagents and Equipment

Preparation of 1-Methylbutylmagnesium Bromide

NOTE. All the glassware used in the preparation of the Grignard reagent should be cleaned and dried in an oven at 110 °C for at least 30 min. After removal from the drying oven, the hot glassware should be placed in a desiccator and cooled before being assembled. Flame drying of the apparatus with a microburner annealing flame (high gas mixture) is an alternative, if ovens are not available and if ether is not in use. This latter method preferably should be carried out prior to assembly, and as with the oven-dried equipment, the hot glassware should be placed in a desiccator to cool. Care must be taken when flaming the reaction vial, as thermal shock can easily crack this heavy-walled vessel. If the flame-drying procedure is performed on the assembled apparatus, care also must be taken not to overheat the O-rings and plastic Capseals.

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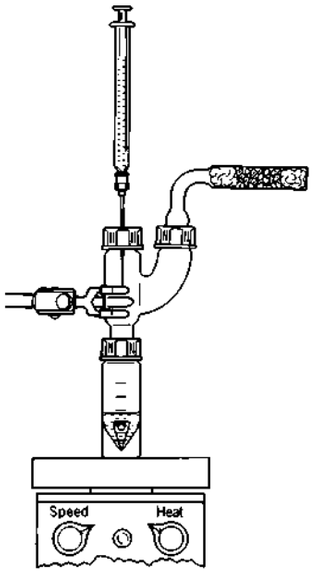

Step I:
Mg, 36 mg + I_2, 1 crystal
+ $(CH_3CH_2)_2O$, 500 μL
+ $CH_3CHBr(CH_2)_2CH_3$, 125 μL
Step II:
CH_3CH_2CHO, 50 μL
+ $(CH_3CH_2)_2O$, 200 μL

NOTE. Scrape a 2- to 3-in. piece of magnesium ribbon clean of oxide coating and cut it into sections 1 mm in length. This freshly cut material should be handled only with forceps.

Prepare a 3.0-mL conical vial containing a magnetic spin vane and equipped with a Claisen head fitted with a calcium chloride drying tube and a rubber septum. Weigh and place 36 mg (1.5 mmol) of magnesium in the vial, and then add a small crystal of iodine, followed by 100 μL of anhydrous ether (⬅).

Alternative Procedure: Place the magnesium metal and the iodine crystal in the vial and assemble the apparatus. *Gently* warm the mixture (microburner or hot plate) until evidence of purple vapor from the iodine is seen.

NOTE. If a microburner is used in this step, all flames must be extinguished before proceeding.

Now add the 100 μL of anhydrous ether, using a 1.0-mL syringe inserted through the septum.

Prepare a solution of 125 μL (153 mg, 1.0 mmol) of 2-bromopentane in 300 μL of anhydrous diethyl ether in a dry, screw-capped vial. *Use an automatic delivery pipet to deliver these reagents.*

After the assembly has cooled to room temperature, draw the 2-bromopentane solution into a 1.0-mL syringe and then insert the syringe needle through the rubber septum on the Claisen head. Place an additional 100 μL of diethyl ether in the empty vial, cap it, and set it aside for later use.

While stirring the heterogeneous mixture, add 6–8 drops of the 2-bromopentane–ether solution to initiate the formation of the Grignard reagent. The evolution of tiny bubbles from the surface of the magnesium is evidence of reaction.

SLOWLY When the reaction has started, **slowly** add the remainder of the 2-bromopentane–ether solution dropwise over a 3- to 5-min period. Warm the reactants slightly. Upon completion of this addition, draw the rinse in the capped vial into the syringe and add it through the septum in a single portion to the reaction vial. Gently warm the resulting solution for 15 min.

CAUTION: *Do not overheat.* Overheating will cause loss of ether solvent. Small fragments of magnesium may remain at the end of the addition of the alkyl halide.

Cool the gray-colored solution of Grignard reagent to room temperature.

The Propanal Reagent. Prepare a solution of the aldehyde by weighing 50 μL (40 mg, 0.7 mmol) of propanal into a tared, oven-dried, capped vial followed by the addition of 100 μL of anhydrous diethyl ether. The propanal is the limiting reagent and therefore an accurate weight should be recorded for the yield calculations. *Dispense the aldehyde and diethyl ether by automatic*

HOOD *delivery pipets in the* **hood.**

Immediately draw the aldehyde solution into a 1.0-mL syringe and insert the syringe needle through the rubber septum on the Claisen head.

Place an additional 100 μL of the anhydrous diethyl ether in the empty vial, cap it, and set it aside for later use.

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Reaction Conditions. Now add the propanal solution *carefully*, with stirring, to the Grignard reagent over a period of about 30 s at such a rate as to keep the ether solvent at a steady reflux.

Following this addition, add the rinse in the capped vial in one portion in a similar manner.

Stir the reaction mixture for 5 min and then allow it to cool to room temperature. Remove the conical vial and cap. It is recommended that the vial be placed in a beaker to prevent tipping and loss of product.

NOTE. If the laboratory is done in two periods, you should stop at this point (recap the vial for storage) or after the hydrolysis sequence in the next step.

Isolation of Product. Hydrolyze the magnesium alkoxide salt by the *careful*, dropwise addition of 2–3 drops of water from a Pasteur pipet. Stir the resulting mixture for 5 min. A two-phase (ether–water) reaction mixture develops as the magnesium salt is hydrolyzed.

CAUTION: The addition of water causes the evolution of heat. An ice bath should be handy to cool the solution if it begins rapid reflux.

Now add 2–3 drops of 3 M HCl. Remove the vial, cap it, and allow it to stand at room temperature for 5 min. Test the aqueous layer with litmus paper. The solution should be slightly acidic. *Too much or too little aqueous HCl will cause problems in the subsequent workup*.

Remove the magnetic spin vane with forceps and set it aside to be rinsed with an ether wash. Cap the vial tightly, shake (or use a Vortex mixer), vent *carefully,* and allow the layers to separate.

Using a Pasteur filter pipet, transfer the aqueous (lower) layer to a clean 5.0-mL conical vial. *Save* the ether layer since it contains the crude reaction product.

Now wash the aqueous layer, previously transferred to the 5.0-mL vial, with three 0.5-mL portions of diethyl ether. Rinse the magnetic spin vane with the first portion as it is added to the vial. Upon addition of each portion of ether (using a calibrated Pasteur pipet), cap the vial, shake (or use a Vortex mixer), vent carefully, and allow the layers to separate. With the aid of a Pasteur filter pipet, remove each ether layer and combine it with the ether solution retained above. After the final extraction, save the aqueous (lower) layer until you have isolated and characterized the final product. Extract the combined ether fractions with 0.5 mL of cold water to remove any acidic material. Save the aqueous rinse until you have isolated and characterized the final product.

Dry the ether solution by transferring it, using a Pasteur filter pipet, to a shortened Pasteur filter pipet containing 500 mg of anhydrous sodium sulfate. Collect the eluate in a tared 10 × 75-mm test tube. In the **hood,** remove the ether solvent from the eluate by warming in a sand bath to concentrate the solution to a weight less than 90 mg.

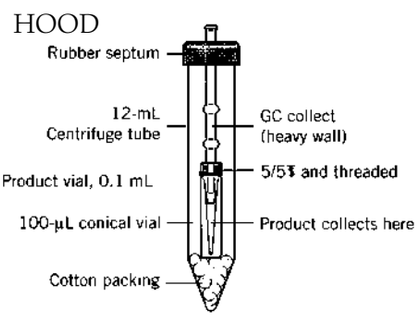

Purification and Characterization. The product, 4-methyl-3-heptanol, is isolated and purified using gas chromatography.

Use a 100-µL syringe to inject the entire sample of crude material obtained above onto the GC column. Collect the components of interest as they elute from the column, using the chromatography technique described in the Prior Reading section (➡).

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EQA

Gas Chromatographic Conditions

GOW-MAC Series-150, Thermal Conductivity Detector

20% Carbowax 20M column, $\frac{1}{4}$ in. × 8 ft

Temperature, 145 °C

Flow rate of 50 mL/min (He gas)

The retention time for 4-methyl-3-heptanol under these conditions is 7–8 min (2 min after any other peak).

Determine the weight of the 4-methyl-3-heptanol collected and calculate the percent yield. Determine the boiling point and refractive index (optional) of the alcohol, and compare these with values in the literature.

Obtain an IR spectrum of the product as a thin film and compare it with that recorded in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). If enough of the hydrocarbon byproduct is collected, also obtain an IR spectrum to aid in its identification.

Chemical Tests. The ignition test should indicate that this compound is an aliphatic species. Does your result confirm this fact? Perform the ceric nitrate test to demonstrate the presence of the —OH group and the Lucas test to demonstrate that a secondary alcohol has been prepared. If you were required to prepare a solid derivative of this alcohol, which one would you select? It may be of interest to determine the solubility of this product in water, ether, concentrated sulfuric, and 85% phosphoric acids. Do your results agree with what you would predict? What test(s) would you perform to establish that one of the starting reagents was an aldehyde?

QUESTIONS

6-114. Show how one could carry out each of the following transformations using the Grignard reaction. Any necessary organic or inorganic reagents may be used. Name each reactant and product.

(a) $CH_3(CH_2)_2CH_2Br \rightarrow (CH_3CH_2CH_2CH_2)_2CHOH$

(b)

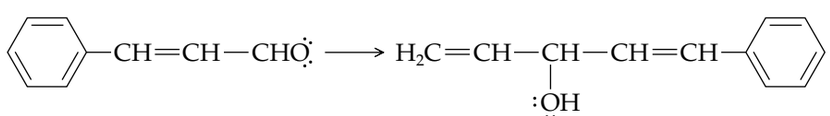

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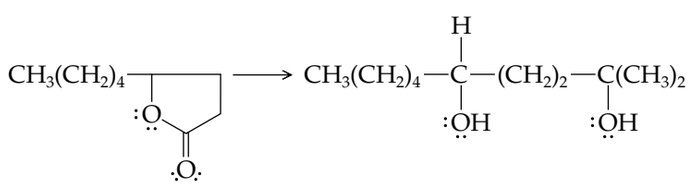

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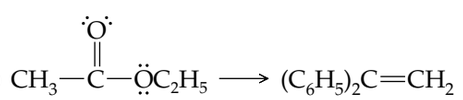

6-115. Explain why Grignard reagents cannot be prepared from an organic halide that also contains a hydroxyl (—OH), a carboxyl ($—CO_2H$), a thiol (—SH) or an amino ($—NH_2$) group.

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EQA

6-116. What would be the final product of the reaction between methyl benzoate and two equivalents of ethylmagnesium bromide?

6-117. Consider the same reaction as in Question 6-116 except that in this case it is carried out with ethyl benzoate. What product would be expected in this case?

6-118. Grignard reagents may be used to prepare other organometallic reagents, for example, ethylmagnesium bromide reacts with cadmium chloride to yield diethylcadmium:

$$2\ CH_3CH_2MgCl + CdCl_2 \rightarrow (CH_3CH_2)_2Cd + 2\ MgCl_2$$

Indicate the products from each of the following reactions and name each organometallic product:

$$4\ CH_3MgCl + SiCl_4 \rightarrow$$

$$2\ C_6H_5MgCl + HgCl_2 \rightarrow$$

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EXPERIMENT 18

The Perkin Reaction: Condensation of Rhodanine with an Aromatic Aldehyde to Yield o-Chlorobenzylidene Rhodanine

Common name: *o*-chlorobenzylidene rhodanine

CA number: [6318-36-1]

CA name as indexed: 4-thiazolidinone, 5-[(2-chlorophenyl)methylene]-2-thioxo-

Purpose. This experiment explores the use of the interesting heterocyclic compound, rhodanine, as the source of an active (acidic) —CH_2— group. (The methylene group contained in the thiazolidinone ring system possesses the capacity to participate in base-catalyzed condensation reactions similar to those of the **aldol reaction.**) You will carry out a base-catalyzed condensation reaction with an aromatic aldehyde. You will examine the properties of this condensation product, which has the capacity to function as an intermediate in a number of synthetic pathways. Indeed, one of these routes yields the important class of aromatic amino acids, the phenylalanines.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

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REACTION

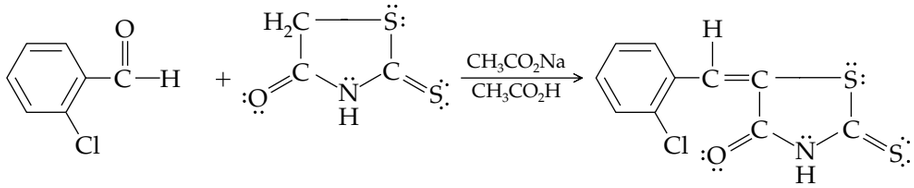

o-Chlorobenzaldehyde Rhodanine *o*-Chlorobenzylidene rhodanine

Sir William Henry Perkin (1838–1907) Perkin came under the influence of the German chemist, A. W. von Hofmann, at the Royal College of Chemistry (London), where Perkin was a student. In his second year at the school, he gained the title of Hofmann's honorary assistant, and following a publication the next year, when he was 17, he was advanced to the rank of assistant. At home, he set up his own laboratory where he worked evenings and on vacations. This laboratory is where he undertook, at Hofmann's suggestion, the synthesis of quinine.

Working with his friend Arthur Church in his home laboratory, he and Church prepared one of the first azo dyes derived from naphthalene (nitrosonaphthlene). This effort resulted in his first patent (with Church). In 1856 at the age of 18, Perkin discovered the first commercially significant synthetic coal-tar dye, *mauve* or *aniline purple*. He also obtained a patent on the synthetic method for preparing this material. The method involved the treatment of an aniline salt with bichromate of potash ($K_2Cr_2O_7$) (this was an outgrowth of his quinine studies). Against Hofmann's wishes, Perkin withdrew from college, designed a factory, and started commercial production of this dye, which was marketed as Perkin's Tyrian Purple. The name *Tyrian Purple* was originally used for a prized purple dye from the Phoenician city of Tyre, which today is part of Lebanon. Tyrian Purple was produced in small quantities from a material isolated from a snail. The production of this dye became a lost art during the Dark Ages, but a species of mollusk containing this very rare pigment was rediscovered in Ireland in 1684. The natural dye is obtained by the air oxidation of a colorless fluid expressed from the glands of the snail. It required the contents of 10,000 snails to obtain a single gram of the fluid.

Perkin's dye synthesis was the beginning of the coal-tar dyestuffs industry. He later developed and manufactured magenta (violet dye) and alizarin (a red dye). The rapid acceptance of these dyes by fabric manufacturers was demonstrated by the fact that annual alizarin production reached 220 tons per year by 1871. At age 37 and a wealthy man, Perkin sold his commercial holdings and devoted the rest of his life to pure chemical research.

Perkin's later years were as productive as his earlier ventures. He developed methods for the preparation of aminoacetic acid. He established the structural relationships between tartaric, fumaric, and maleic acids, and synthesized cinnamic acid. This last endeavor led to the development of what is now known as the *Perkin reaction*. The reaction is widely used to prepare unsaturated acids from aromatic aldehydes. These studies led to his synthesis of coumarin (actually it was the first condensation product he obtained with the classic reaction; see also Experiment [$3A_{adv}$]). Other areas investigated by Perkin dealt with the relationship of physical properties and chemical structure.

Perkin was knighted in 1906 in recognition of his contributions to chemistry and to the practical application of many of his discoveries. In the United

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States, The Society of Chemical Industry awards a Perkin Medal each year to an outstanding industrial chemist.[19]

DISCUSSION

The classic Perkin reaction is the base-catalyzed condensation of an aromatic aldehyde with a carboxylic acid anhydride to yield and an α,β-unsaturated carboxylic acid. The initial stages of the condensation can be viewed as an aldol-type reaction (see Experiments [20], [3A$_{adv}$], [3B$_{adv}$], and [A3a]). www

A variation of the Perkin reaction is the condensation of aromatic aldehydes with rhodanine, which plays a similar role to that of the anhydride in the original reaction. Rhodanine, a derivative of the thiazolidinone ring system was first synthesized in 1935 by Percy Julian (a future president of Howard University) and Bernard Sturgis (an undergraduate at DePauw University at the time). This heterocyclic molecule has an active (acidic) methylene group that can be deprotonated with a relatively mild base (in this case acetate, CH_3COO^- or AcO^-, ion) to generate the nucleophile that attacks the carbonyl group of the aldehyde.

Under the conditions used in the current experiment, dehydration–elimination rapidly follows the initial nucleophilic addition with formation of the benzylidene intermediate. The mechanism is shown here:

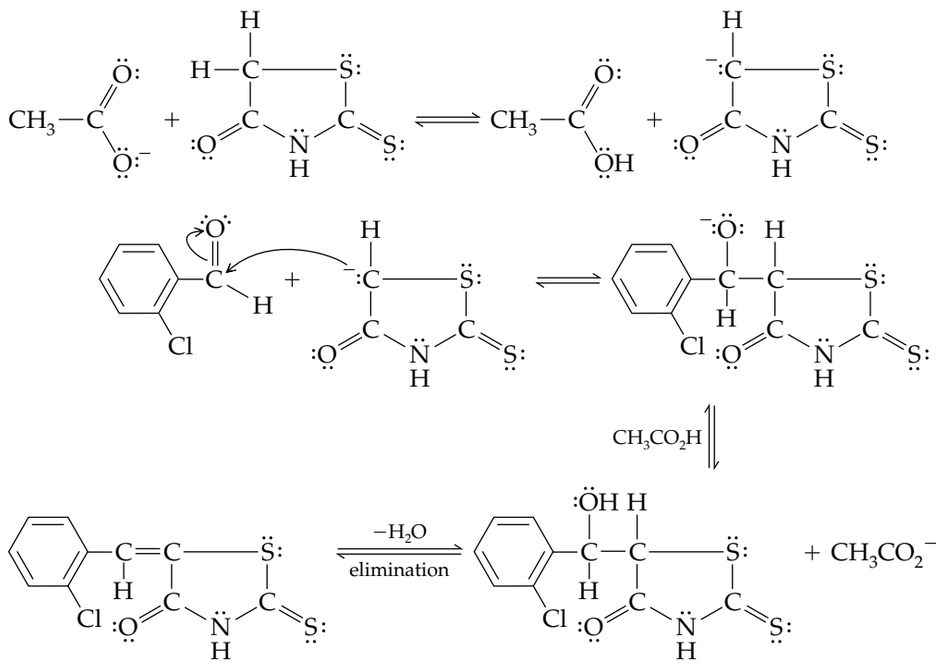

While the resulting rhodanine derivatives have exhibited antibacterial, antitubercular, antimalarial, antifungal, and antiparasitic activity, the principal focus of attention on these interesting compounds has been as reactive synthetic intermediates. For example, these particular compounds can be converted, in

[19]See Edelstein, S. M. *American Dyestuff Reporter* **1956,** *45,* 598; Mendola, R. *J. Chem. Soc.* **1908,** *93,* 2214; Levinstein, H. *Chem. Ind.* **1938,** 1137; Rose, R. E. *Ind. Eng. Chem.* **1938,** *16,* 608; *Dictionary of Scientific Biography,* C. C. Gillespie, Ed., Scribner's: New York, 1974, Vol. X, p. 515.

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high yield, in three steps, to nitriles in which the side chain of the original aldehyde has been extended by an additional carbon atom:

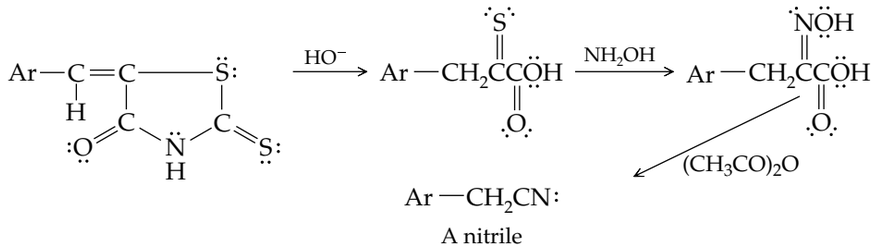

A nitrile

EXPERIMENTAL PROCEDURE

Estimated time of the experiment: 1.5 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Rhodanine	133.19	30 mg	0.23	170			
Sodium acetate	82.03	52 mg	0.63	324			
Acetic acid, glacial	60.05	1.0 mL			118		
o-Chlorobenzaldehyde	140.57	58 mg	0.41		212	1.25	1.5662
o-Chlorobenzylidene rhodanine	259.76			191			

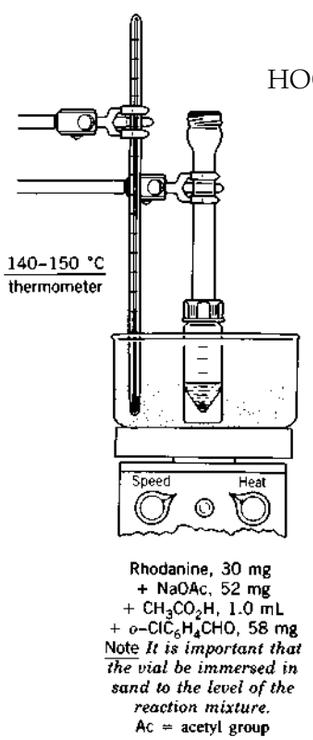

Rhodanine, 30 mg
+ NaOAc, 52 mg
+ CH_3CO_2H, 1.0 mL
+ *o*-ClC_6H_4CHO, 58 mg
Note *It is important that the vial be immersed in sand to the level of the reaction mixture.*
Ac = acetyl group

HOOD

Reagents and Equipment. In a 3.0-mL conical vial containing a boiling stone and equipped with an air condenser, weigh out and place 30 mg (0.23 mmol) of rhodanine and 52 mg (0.63 mmol) of anhydrous sodium acetate. Now, in the **hood,** add 1.0 mL of glacial acetic acid dispensed from a graduated pipet. To this mixture, measure and add 58 mg (0.41 mmol) of *o*-chlorobenzaldehyde (⬅).

NOTE. Dry the sodium acetate in the oven for 1 h before use. The aldehyde ***must*** *be free from the corresponding acid or lower yields of product will result. It is recommended that the purity of the aldehyde be checked by IR analysis. The reaction vial may be weighed before and after the addition of aldehyde to obtain an accurate weight.*

Reaction Conditions. Heat the reaction mixture in a sand bath at 140–150 °C for 30 min.

NOTE. Immerse the vial in the sand up to the level of the top of the reaction mixture.

As the reaction progresses, the mixture becomes homogeneous and turns yellow. At the end of the reaction period the resulting solution is cooled to room temperature. When the conical vial has reached ambient temperature, place it in an ice bath to complete crystallization of the condensation product.

Isolation of Product. Collect the yellow crystals by vacuum filtration using a Hirsch funnel. Rinse the reaction vial with two 1.0-mL portions of cold

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glacial acetic acid transferred by a calibrated Pasteur pipet, and then use each rinse to wash the filter cake on the Hirsch funnel (➡). Complete the removal of the acid solvent by air drying the crystals on a porous clay plate.

Purification and Characterization. Weigh the dried product and calculate the percent yield of the crude material. Recrystallization (Craig tube) of a 5-mg portion of the benzylidene product from 0.5 mL of glacial acetic acid yields fine, bright yellow needles that can be used to complete the characterization of this interesting substance.

Determine the melting point and compare your results with the value given in the table at the beginning of the experiment.

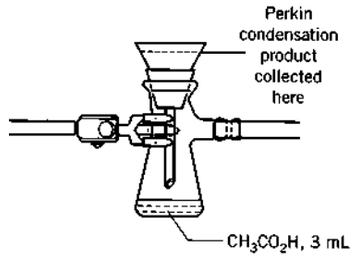

Chemical Tests. This compound is an interesting reaction product because it contains three different types of heteroatoms: chlorine, nitrogen, and sulfur. The sodium fusion test (see Chapter 9) may be used to substantiate the presence of these elements.

It would also be of interest to establish if a positive Beilstein test for chlorine is found when in the presence of sulfur and nitrogen, or whether the soda–lime test for nitrogen is observed with the elements of chlorine and sulfur also located within this molecule (see Chapter 9).

Does ignition of the material (see Chapter 9) indicate that the compound contains an aromatic ring?

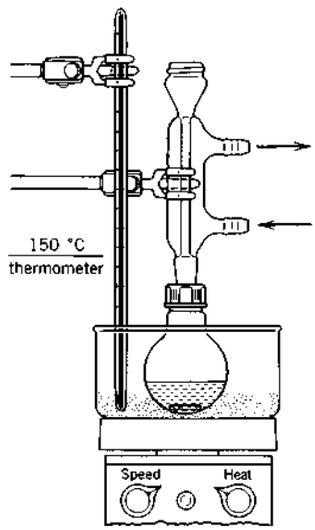

10-mL RB flask

OPTIONAL SEMIMICROSCALE PREPARATION

This experiment may be scaled up and carried out at a level 5 or 10 times greater than the amounts used in the above microscale experiment. The data given below are for the 10-fold procedure. The procedure is identical to that given above in the microscale section, but with the following modifications:

1. A 10-mL round-bottom flask containing a spin bar and fitted with an air cooled condenser is used in place of the conical reaction vial (➡).

2. The reagent and solvent amounts are given in the following table.

Physical Properties of Reactants and Products

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Rhodanine	133.19	300 mg	2.3	170			
Sodium acetate	82.03	520 mg	6.3	324			
Acetic acid, glacial	60.05	5.0 mL		118			
o-Chlorobenzaldehyde	140.57	580 mg	4.1		212	1.25	1.5662
o-Chlorobenzylidene rhodanine	259.76		191				

3. After the product is air dried on a clay plate until no acetic acid (vinegar) odor remains, it is placed in a 100 °C oven to dry overnight. It may also be dried in a vacuum drying oven until no acetic acid (vinegar) odor remains.

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QUESTIONS

6-119. In which of the following two species, (a) or (b), is the underlined hydrogen atom more acidic? Explain.

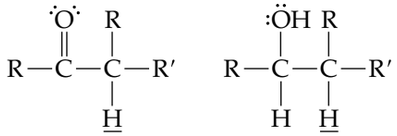

(a) **(b)**

6-120. A number of compounds similar to rhodanine and possessing active methylene groups have been used in the Perkin condensation. Two are shown below:

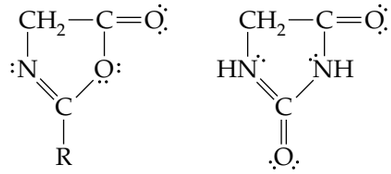

(An azlactone) Hydantoin

Draw the structure of the product that would be formed if each underwent the Perkin condensation with *p*-chlorobenzaldehyde.

6-121. *para*-Nitrobenzaldehyde reacts at a faster rate than benzaldehyde in the Perkin reaction, while *p-N,N*-dimethylaminobenzaldehyde is much less reactive toward the same nucleophile. Explain.

6-122. Explain the fact that the C=O group in 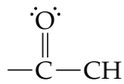 is effective in increasing the acidity of the α-hydrogen atom.

6-123. A large number of condensations that are closely related to the Perkin reaction. Among these are the aldol (Experiments [20], [3B$_{adv}$], and [A3a]), Knoevenagel, Claisen (Experiment [3A$_{adv}$]), and Dieckmann condensations. What general class of compounds can be prepared using each of these well-known reactions?

www

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For a review on the general Perkin reaction see

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Koepp, E.; Vögtle, F. *Synthesis* **1987,** 177
Rosen, T. *Comp. Org. Syn.* **1991,** *2,* 395.

For examples of the general Perkin reaction see

Corson, B. B. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 229.
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Weiss, R. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 61.

For references using rhodanine in the Perkin reaction see

Andreasch, R. *Monatsh. Chem.* **1928,** *49,* 122.
Brown, F. C. *Chem. Rev.* **1961,** *61,* 463.
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Foye, W. O.; Tovivich, P. *J. Pharm. Sci.* **1977,** *66,* 1607.
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EXPERIMENT 19

Alkene Preparation by the Wittig Reaction: (E)-Stilbene; Methylene-4-tert-butylcyclohexane; and trans*-9-(2-Phenylethenyl)anthracene*

Common names: *(E)*-stilbene; *trans*-1,2-diphenylethene
CA number: [103-30-0]
CA name as indexed: benzene, 1,1′-(1,2-ethenediyl)bis-, *(E)*-

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EQA

Common name: 1-methylene-4-*tert*-butylcyclohexane
CA number: [13294-73-0]
CA name as indexed: cyclohexane, 1-(1,1-dimethylethyl)-4-methylene-

Common name: *trans*-9-(2-phenylethenyl)anthracene
CA number: [42196-97-4]
CA name as indexed: anthracene, 9-(2-phenylethenyl)-, *(E)*-

Purpose. The conditions under which the Wittig reaction is carried out are investigated. The Wittig reaction involves the reaction of a *phosphorus ylide* (Experiments [19A] and [19C]) with an aldehyde or ketone, and is used extensively in organic synthesis to synthesize alkenes. The use of the Horner–Wadsworth–Emmons modified Wittig reaction between an aldehyde and a phosphonate ester is investigated (Experiments [19B] and [19D]) using phase-transfer catalysis.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of a Wet Organic Layer (pp. 80–83)
Concentration of Solutions (pp. 101–104)

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

Technique 6: Chromatography
Packing the Column (p. 93)
Elution of the Column (p. 94)
Thin-Layer Chromatography (pp. 97–99)

Georg Friedrich Karl Wittig (1897–1987) Wittig obtained his Ph.D. in 1923 at the University of Marburg under von Auwers. He later became Professor of Chemistry at the Universities of Braunschweig, Freiburg, Tübingen, and Heidelberg. His initial research work was concerned with the concept of ring strain, diradical formation, and valance tautomerism. However, he soon became involved in carbanion chemistry. Wittig discovered halogen–metal exchange reactions and then moved extensively into research involving the chemistry of the ylides. In 1953, he discovered the reactive phosphonium ylides and subsequently their reaction with aldehydes and ketones to give alkenes under very mild conditions; this reaction is now known as the *Wittig reaction*. This discovery allowed the introduction of the C═C linkage at a specific location in the product. In recognition for this work, Wittig received the Nobel Prize in 1979 (with H. C. Brown [organoboron compounds]).

In other work, Wittig postulated the dehydrobenzene intermediate and proved its existence through trapping reactions of the Diels–Alder type. He discovered sodium tetraphenylborate, which is now used in the analytical determination of potassium and ammonium ions. His later work involved the chemistry of metalated Schiff bases. This work subsequently led to the development of the concept of directed aldol condensations.

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Wittig coined a large number of technical terms—valence tautomerism, ylide, onium complexes, halogen–metal exchange, dehydrobenzene, and umpolung (polarity reversal). Wittig died in 1987 at the age of 90.[20]

REACTION

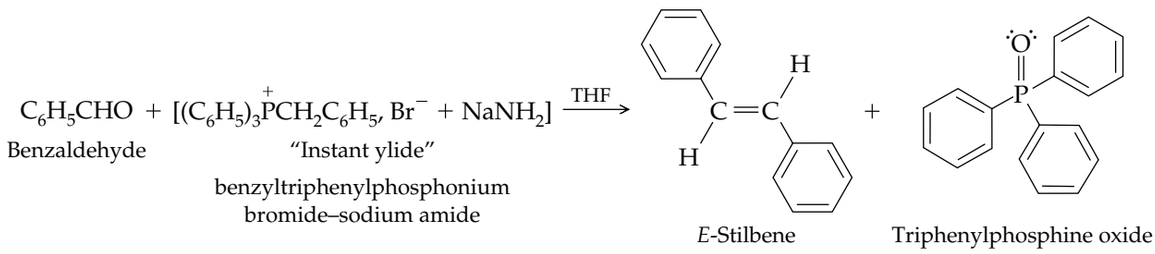

Benzaldehyde

"Instant ylide"

benzyltriphenylphosphonium bromide–sodium amide

E-Stilbene

Triphenylphosphine oxide

DISCUSSION

The Wittig reaction constitutes a valuable method for the preparation of alkenes. The major advantages of this approach are that (1) there is no ambiguity in the location of the C═C generated by the reaction, as there can be in many elimination reactions, and (2), there is no potential for rearrangements, as there can be in E1 elimination reactions.

An *ylide* is a neutral species whose Lewis structure contains opposite charges on adjacent atoms. The atoms involved are carbon and an element from either group 15 (VA) or 16 (VIA) of the periodic table, such as N, P, or S. The Wittig reaction uses phosphorus ylides, which are obtained by deprotonation of a phosphonium salt with a strong base. Phosphorus ylides are relatively stable, but reactive species, for which the following resonance structures may be written; the phosphorus atom can exceed an octet by accommodating electron donation into its 3d orbitals.

$$[R_3\overset{+}{P}—\overset{-}{C}H_2: \longleftrightarrow R_3P{=}CH_2]$$

The phosphonium salts are available through a nucleophilic displacement reaction of triphenylphosphine with various alkyl halides. Triphenylphosphine is a good nucleophile, and thus most phosphonium salts are easily prepared.

$$(C_6H_5)_3P: + RCH_2X \longrightarrow (C_6H_5)_3\overset{+}{P}CH_2R, X^-$$
$$(X = I, Br, Cl)$$

The hydrogen atoms on the carbon attached to the resulting phosphorus cation are somewhat acidic because they are adjacent to a positive charge, a significant electron-withdrawing group. Thus, treatment of the phosphonium salt with a strong base, such as butyllithium in THF or sodium hydride in DMSO, removes one of these protons and produces the ylide.

$$(C_6H_5)_3\overset{+}{P}CH_2R, X^- + C_4H_9Li \xrightarrow{THF} (C_6H_5)_3\overset{+}{P}—\ddot{\ddot{C}}H—R + C_4H_{10} + LiX$$
An ylide

[20]See Parker, S. P. Ed., *McGraw-Hill Modern Scientists and Engineers,* McGraw-Hill: NY, 1980, Vol. 3, p. 341; *The Annual Obituary;* St. James Press: Chicago, 1987, p. 460; Oesper, R. E. *J. Chem. Educ.* **1954,** *31,* 357.

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EQA

The ylides are generally not isolated, but rather generated in situ and reacted directly with the carbonyl compound.

The "instant ylides" are solid-phase mixtures of a phosphonium salt with sodium amide ($NaNH_2$, a strong base and the conjugate base of ammonia) and are now commercially available. In the solid phase, no reaction between the strong base and the phosphonium salt occurs. Thus, to generate the desired ylide, the "instant ylide" mixture need only be placed in a suitable solvent. This process is a marked advantage over the usual methods used to obtain these species. Ylides, because of the significant negative charge density on carbon, are nucleophilic enough to attack electrophiles as reactive as the carbon of a carbonyl group. When the ylide is reacted with an aldehyde or a ketone, an intermediate *oxaphosphetane* (a four-membered ring containing an oxygen and a phosphorus atom) is formed, which decomposes to give the alkene product. The mechanistic sequence is outlined here.

Generation of the Ylide

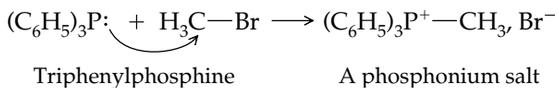

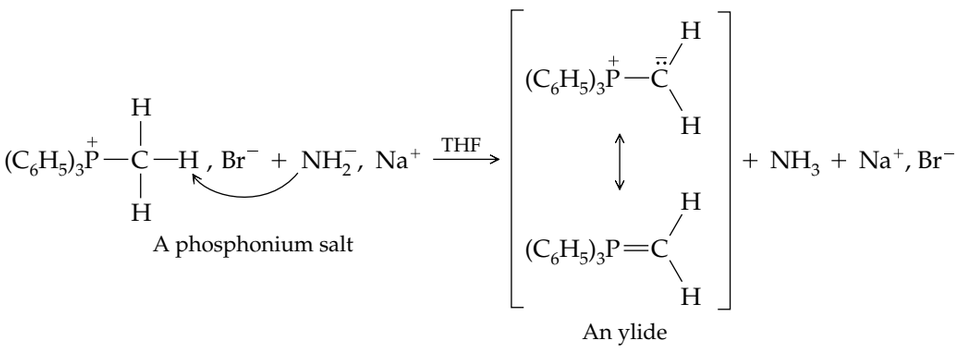

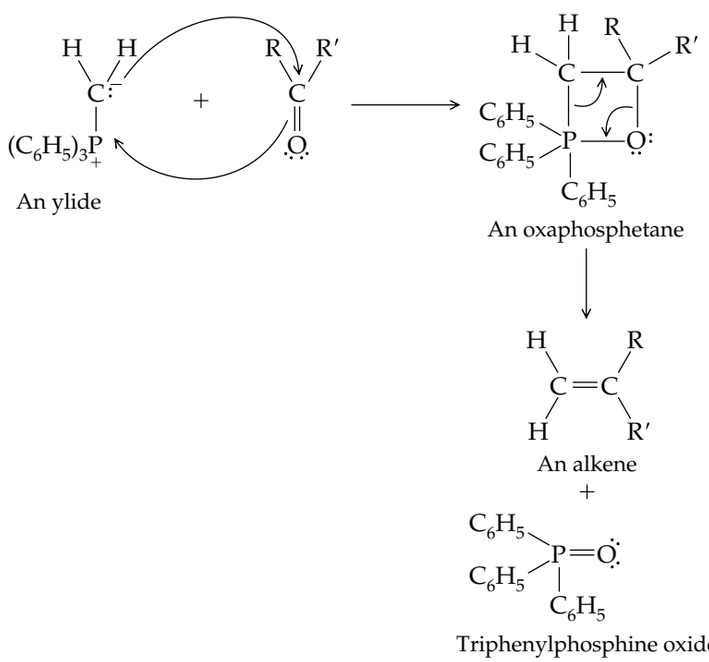

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EQA

The Wittig reaction is very general. The significant limitation is that the carbonyl compound cannot contain acidic hydrogen atoms, such as in an alcohol or carboxyl group, or electrophiles more reactive than the aldehyde or ketone itself. The Wittig reaction can be quite stereoselective for the formation of either *Z* or *E* alkenes, but the factors involved in such stereoselectivity are sometimes difficult to predict and often difficult to explain.

An important modification (often called the Horner–Wadsworth–Emmons reaction) of the Wittig reaction makes use of phosphonate esters, $RPO(OR')_2$. It is highly stereoselective for the formation of *E*-alkenes. The reaction and mechanism are depicted below for the preparation of *(E)*-stilbene. Instead of using a phosphorus cation to stabilize the negative charge, as in the phosphonium ylide above, a phosphonate ester group is used to stabilize an adjacent carbanion.

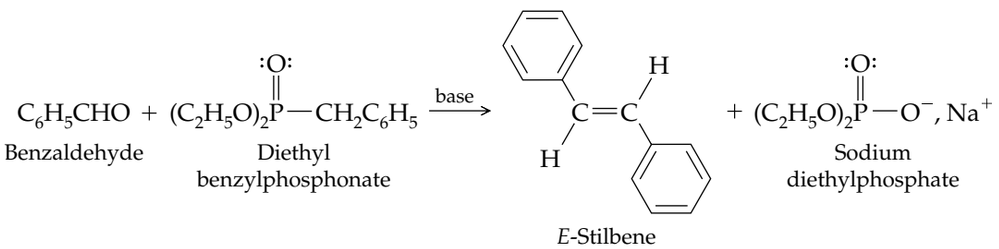

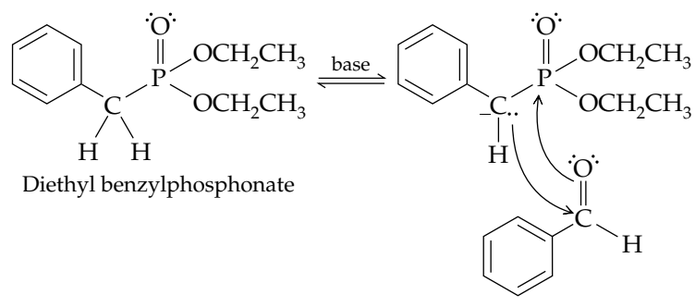

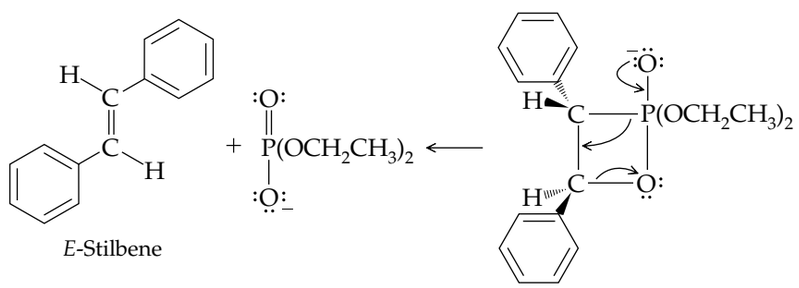

The use of the phosphonate ester (Horner–Wadsworth–Emmons reaction) allows much easier separation of the product alkene, since the sodium phosphate byproduct is water soluble; the byproduct of the Wittig reaction, triphenylphosphine oxide, is not water soluble. In the Horner–Wadsworth–Emmons modification, a conjugated, or electron-withdrawing, substituent (such as a phenyl or carbonyl group) on the nucleophilic carbon is used to assist in the stabilization of the carbanion. This modification (Experiment [19B]) may be used as an alternative to Experiment [19A] for the preparation of *(E)*-stilbene. The "instant-ylide" Wittig reaction yields predominantly the *E* isomer of

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EQA

stilbene (70%). The Horner–Wadsworth–Emmons reaction yields exclusively the *E* isomer. Both procedures are given below. The synthesis described in Experiment [19D] also uses the Horner–Wadsworth–Emmons modification.

Horner–Wadsworth–Emmons reactions lend themselves to the use of *phase-transfer catalysis* in Experiments [19B] and [19D]. Phase-transfer catalysis allows the use of an aqueous base (NaOH in H_2O) with the organic compounds dissolved in an organic solvent (hexane in Experiment [19B], methylcyclohexane in Experiment [19D]) immiscible with water. The reaction system, as the name implies, involves two phases—an aqueous phase and an organic phase. The phase-transfer catalyst plays a very important role: without it, no reaction would occur, since the initial reactants (hydroxide ion and diethyl benzylphosphonate) are dissolved in different, immiscible phases, and NaOH is insoluble in hexane (or methylcyclohexane), and diethyl benzylphosphonate is insoluble in water.

The key features of the phase-transfer catalyst, Aliquat 336, are that it is a quaternary ammonium salt, with long-chain alkyl groups attached to the nitrogen.

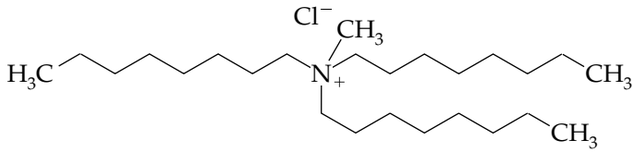

Aliquat 336

The phase-transfer catalyst is soluble in both water and the organic solvent. It is water soluble because it is an ion, and it is hexane soluble because of the three long-chain alkyl groups. Thus, the phase-transfer catalyst distributes itself in both phases, and freely shuttles back and forth through the phase boundary between solvent layers. In aqueous NaOH, the chloride anion exchanges with hydroxide anion, as the counterion to the ammonium cation. When it does this, the catalyst carries the hydroxide ion from the aqueous phase, as an ion-pair, across the phase boundary into the organic phase, where the base then reacts with the diethyl benzylphosphonate. The Horner–Wadsworth–Emmons reaction then occurs, producing the alkene and diethyl phosphate anion. This anion becomes associated with the ammonium cation of the phase-transfer catalyst and is transported to the aqueous layer, where the catalyst picks up another hydroxide ion and repeats the entire process.

(*E*)-Stilbene by the "Instant Ylide" Method

Experiment 19A

CAUTION: Tetrahydrofuran is a flammable liquid. All flames must be extinguished in the laboratory when this solvent is used.

REACTION

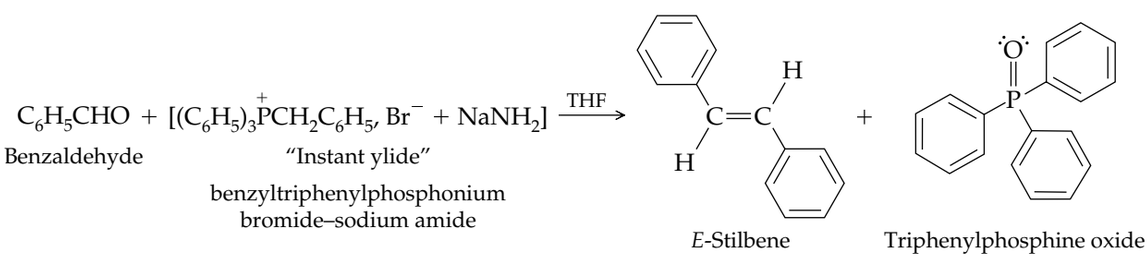

Benzaldehyde

"Instant ylide"
benzyltriphenylphosphonium bromide–sodium amide

E-Stilbene

Triphenylphosphine oxide

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: Two 3-h laboratory periods.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	100 μL	0.95	178	1.04	1.5463
"Instant ylide"benzyltriphenyl phosphonium bromide–sodium amide		600 mg	~1.2			
Tetrahydrofuran	72.12	1.0 mL		67		

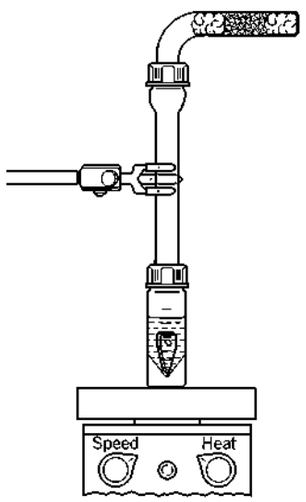

Reagents and Equipment. Weigh and place 600 mg (~1.2 mmol) of benzyltriphenylphosphonium bromide–sodium amide *(instant ylide)* mixture in a dry 5.0-mL conical vial containing a magnetic spin vane. Add *freshly distilled* dry tetrahydrofuran (1.0 mL) using a calibrated Pasteur pipet, and immediately attach the vial to an air condenser protected by a calcium chloride drying tube (⬅). Stir the mixture for 15 min at room temperature. During this time, the mixture turns orange. Following generation of the ylide, remove the air condenser for as short a time as possible and quickly add 100 μL (0.95 mmol) of benzaldehyde *(freshly distilled)* to the reaction flask, using an automatic delivery pipet, and immediately reattach the air condenser.

Reaction Conditions. Stir the resulting heterogeneous mixture at room temperature for an additional 15 min. The system develops a light brown color during this time.

Isolation of Product. Work up the reaction by adding 1.0 mL of a 25% aqueous NaOH solution (calibrated Pasteur pipet), and transfer the resulting mixture to a 15-mL centrifuge tube using a Pasteur pipet. Rinse the reaction vial with three 2.0-mL portions of diethyl ether, each of which is also transferred to the centrifuge tube (Pasteur filter pipet). Partially neutralize the resulting two-phase mixture by careful addition of 3.0 mL of 0.1 N HCl. Transfer the ether layer (top) by Pasteur filter pipet to a short microcolumn prepared from a Pasteur filter pipet containing 1.5 g of anhydrous sodium sulfate (⬅).

Collect the dried eluate in a 25-mL Erlenmeyer flask containing a boiling stone. Extract the remaining aqueous layer with two additional 2.0-mL portions of ether and transfer these ether extracts, as before, to the microcolumn containing anhydrous sodium sulfate. Concentrate the eluate solution (~10 mL) to dryness using a gentle stream of nitrogen, or by warming it in a sand bath in the **hood** to give a white solid.

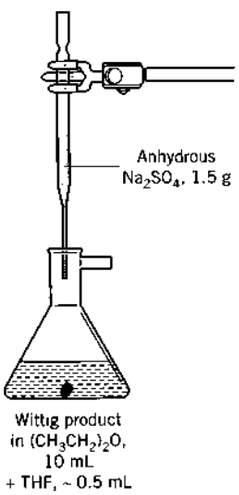

HOOD

Purification and Characterization. Purify the crude product by chromatography, using a silica gel column.

The triphenylphosphine oxide is relatively insoluble in the hexane solvent. First, separate the triphenylphosphine oxide byproduct from the mixture of stilbenes by extracting the solid obtained above with hexane, using the following procedure.

To the 25-mL Erlenmeyer flask containing the crude product, add 2.0 mL of hexane and agitate the solution with swirling. Some breakup of the material with a microspatula may be necessary. Transfer the hexane solution by Pasteur filter pipet to a 10-mL Erlenmeyer flask containing a boiling stone. Extract the remaining crude solid with two additional 2.0-mL portions of hexane, and

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transfer these extracts to the 10-mL Erlenmeyer flask as before. Concentrate the hexane solution (~6 mL) to about 1.5 mL using a gentle stream of nitrogen gas, or by warming on a sand bath in the **hood.**

Pack a short (1 × 10 cm) chromatography column with 2.0 g of activated silica gel, and premoisten the column with ligroin (60–80 °C) (➨). Add the above hexane solution directly to the column. Now elute the column with 15 mL of a 1:1 ligroin (60–80 °C)/methylene chloride solution. Collect the eluate, in a single fraction, in a tared 25-mL **filter flask** containing a boiling stone. Concentrate the solution to dryness under reduced pressure in a warm sand bath to yield the pure product mixture (➨).

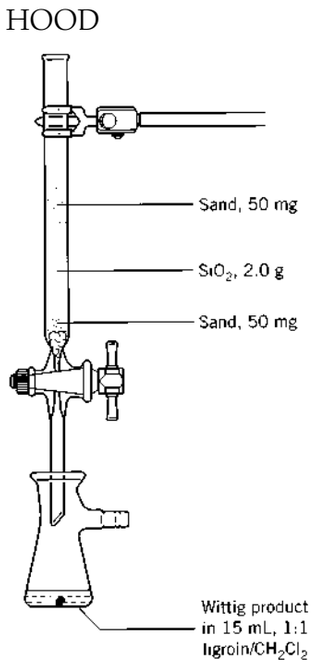

NOTE. A 25-mL sidearm filter flask, equipped with a Hirsch funnel and filter paper disks to control the pressure, is a convenient system for the removal of a small volume (5–20 mL) of solvent. A rotary evaporator, if available, is a nice alternative.

Weigh the crude product residue and calculate the percent yield.

The isolated product mixture may be analyzed by gas chromatography and/or thin-layer chromatography. *This constitutes the second week of laboratory for this experiment.*

Gas Chromatographic Analysis. Dissolve the crude product mixture isolated above in the minimum amount of 1:1 ligroin (60–80 °C)/methylene chloride solution (~0.5–0.75 mL). Inject a 10-μL sample into a gas chromatograph, set up according to the following conditions:

Column: $\frac{1}{4}$-in. × 8-ft, 20% Carbowax 20M on Chromasorb P (80/100 mesh)

Temperature: 220 °C

Flow rate: 30 mL/min (He gas)

Chart speed: 1 cm/min

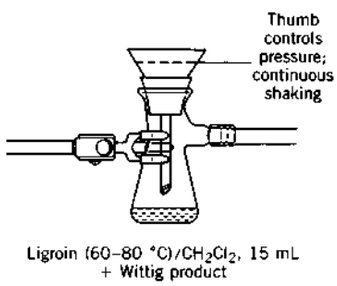

The compounds elute in the following order: *(Z)*-stilbene, followed by *(E)*-stilbene. Measure the ratio of peak heights and calculate the isomeric composition of your mixture.

Thin-Layer Chromatographic Analysis. Spot a TLC plate with a sample from the product solution used for GC analysis, and also with a standard solution.

Use hexane as the elution solvent, silica gel (containing a fluorescent indicator) as the stationary phase, and UV light for visualization.

Typical R_f values are *(E)*-stilbene 0.21; *(Z)*-stilbene, 0.27.

Concentrate the ligroin–methylene chloride product mixture as before. Separate, and purify, the *(E)*-stilbene by recrystallization from a minimum amount of 95% ethanol, using the Craig tube.

Weigh the dried and purified *(E)*-stilbene product and calculate the percent yield. The purity of this material may be determined by TLC, using the conditions outlined above.

Obtain a melting point and IR spectrum of the material and compare your results with those reported in the literature.

(E)- and *(Z)*-Stilbene also exhibit different absorptions in the ultraviolet region. The data are summarized below:

(Z)-Stilbene: (1-mm cell)

λ_{max} 223 nm (ε_{max} = 20,600 methanol, 0.05 g/L)

λ_{max} 276 nm (ε_{max} = 10,900, methanol, 0.1 g/L)

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(E)-*Stilbene: (0.05 g/L, 1 mm cell)*

λ_{max} = 229 nm (ε_{max} = 21,000, methanol)
λ_{max} = 294 nm (ε_{max} = 33,200, methanol)
λ_{max} = 307 nm (ε_{max} = 32,100, methanol)

These ultraviolet absorption data illustrate an interesting example of steric effects on the absorption pattern exhibited by geometrical isomers of an alkene. There is significant steric hindrance between the two phenyl groups in the *Z* isomer, which causes the phenyl groups to twist out of coplanarity with the alkene. Thus, conjugation is diminished. This result is reflected in the lower intensity of the 276-nm band as compared to the 294-nm band in the *E* isomer.

Chemical Tests. Further characterization may be accomplished by performing the Br_2/CH_2Cl_2 test for unsaturation. Note that the dibromo compound is prepared in Experiment [$A2_b$]. It may be used here as a reference sample in the characterization of *(E)*-stilbene. The ignition test (Chapter 9) may be used to confirm the presence of the aromatic portion of the molecule.

Experiment 19B

(*E*)-Stilbene by the Horner–Wadsworth–Emmons Reaction

REACTION

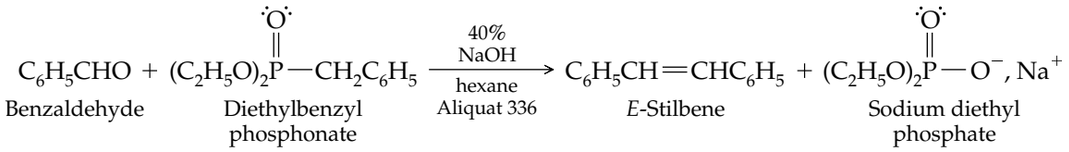

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.12	100 μL	0.98	178	1.04	1.5463
Diethyl benzylphosphonate	228.23	200 μL	0.96	106–108	1.095	
Aliquat 336 (tricaprylmethylammonium chloride)	404.17	88 mg	0.22			
Hexane	86.18	2.0 mL				
40% Sodium hydroxide		2.0 mL				

Reagents and Equipment. Weigh and place 88 mg (100 μL) of tricaprylmethylammonium chloride (Aliquat 336) in a 10-mL round-bottom flask containing a magnetic stirrer. Add 100 μL (0.98 mmol) of benzaldehyde, 200 μL (0.96 mmol) of diethyl benzylphosphonate, 2.0 mL of hexane, and 2 mL of 40% sodium hydroxide solution. Attach the flask to a reflux condenser.

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NOTE. The benzaldehyde, diethyl benzylphosphonate, hexane, and NaOH solution are dispensed in the ***hood*** *using automatic delivery pipets. Aliquat 336 is very viscous and is best measured by weighing. A medicine dropper is used to dispense this material. It is advisable to lightly grease the bottom joint of the condenser since strong base is being used.*

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Reaction Conditions. Warm the two-phase mixture to reflux on a sand bath (temperature ~90–100 °C) for 1 h. Stir the reaction mixture vigorously during this period. Allow the resulting solution to cool to nearly room temperature. Crystals of product may appear as cooling occurs. Confirm by TLC (plates containing a fluorescent indicator) that the reaction is complete using as a solvent system ethyl acetate:hexane (0.1:9.9) and a UV lamp for visualization. The R_f value of benzaldehyde (0.4) is lower than both the R_f values of *E*- and *Z*-stilbene (➡).

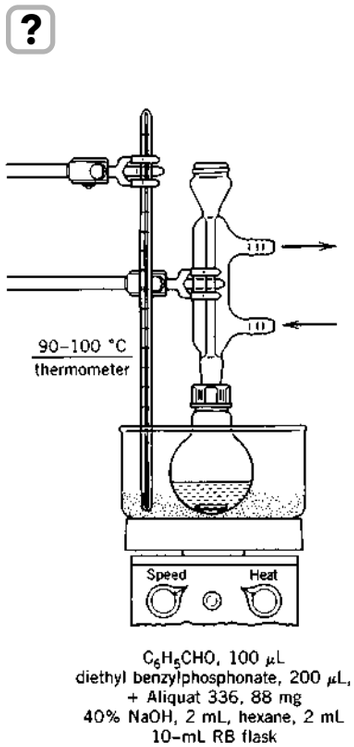

C_6H_5CHO, 100 μL
diethyl benzylphosphonate, 200 μL,
+ Aliquat 336, 88 mg
40% NaOH, 2 mL, hexane, 2 mL
10-mL RB flask

Isolation of Product. Once all the evidence shows that benzaldehyde is no longer present, add methylene chloride (700 μL), which will dissolve any crystalline material that may have formed. Then, using a Pasteur pipet, transfer the contents of the round-bottom flask to a 15-mL centrifuge tube. Rinse the flask with an additional 300 μL of methylene chloride and transfer the rinse to the same centrifuge tube. Remove the aqueous layer carefully, using a Pasteur filter pipet, and save it in a vial until you have successfully isolated and characterized the product.

NOTE: Use care when determining which layer is the "aqueous layer." At room temperature, the density of a 40% sodium hydroxide solution is 1.40 g/mL whereas the density of methylene chloride is 1.33 g/mL.

Wash the organic layer with two 1-mL portions of water. Stir the mixture with a small glass rod after each addition (or a Vortex mixer may be used) and then remove the water layer and add it to the one collected before. Dry the methylene chloride solution by addiing a small amount of anhydrous sodium sulfate. Use a Pasteur filter pipet to transfer the dried solution to a 10-mL Erlenmeyer flask. Wash the sodium sulfate remaining in the centrifuge tube with two 1-mL portions of methylene chloride. Remove these washings, using the Pasteur filter pipet, and transfer them to the same Erlenmeyer flask.

Concentrate the solution, which contains the desired product, to dryness on a warm sand bath under a stream of nitrogen.

Purification and Characterization. The *(E)*-stilbene obtained is, in most cases, sufficiently pure for characterization. However, this should be confirmed by thin-layer chromatography as outlined earlier (see Purification and Characterization, Experiment [19A]). If only a trace of the *Z* isomer is detected, recrystallize the product directly, using absolute ethanol. Collect the recrystallized material by vacuum filtration using a Hirsch funnel. Maintain the vacuum for an additional 10 min to partially dry the crystalline product. Then place it on a clay plate, or on filter paper, and allow it to dry thoroughly. As an alternative, the product may be dried in a vacuum drying oven (or pistol) for 10–15 min at 30 °C (1–2 mm Hg).

Weigh the dried *(E)*-stilbene product and calculate the percent yield. The *(E)*-stilbene may be characterized as outlined in Experiment [19A].

Methylene-4-*tert*-butylcyclohexane

Experiment 19C

REACTION

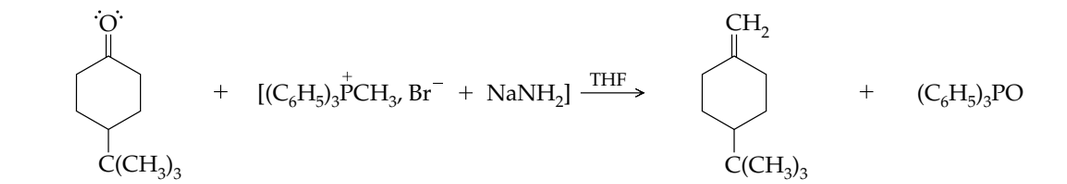

4-*tert*-Butylcyclohexanone | "Instant ylide" methyltriphenylphosphonium bromide–sodium amide | Methylene-4-*tert*-butylcyclohexane | Triphenylphosphine oxide

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 4.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	n_D
4-*tert*-Butylcyclohexanone	154.26	100 mg	0.64	50		
"Instant ylide" (methyltriphenylphosphonium bromide–sodium amide)		320 mg	~0.72			
Tetrahydrofuran		1.0 mL			67	
Methylene-4-*tert*-butylcyclohexane	151.27				185	1.4630

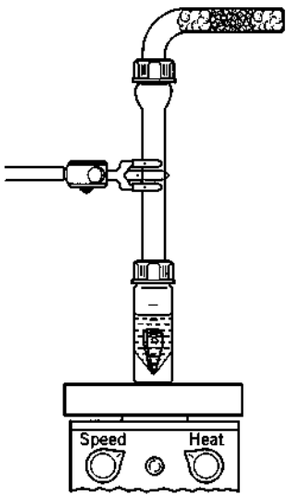

Reagents and Equipment. In a dry 5.0-mL conical vial containing a magnetic spin vane, and equipped with an air condenser protected by a calcium chloride drying tube, weigh and place 320 mg (~0.72 mmol) of methyltriphenylphosphonium bromide–sodium amide (instant ylide) mixture (⬅). Now add *freshly distilled* tetrahydrofuran (1.0 mL), using a calibrated Pasteur pipet, and stir the mixture for 15 min at room temperature. During this period it turns a bright yellow color.

Following generation of the ylide, weigh and add 100 mg (0.64 mmol) of 4-*tert*-butylcyclohexanone to the reaction flask.

Reaction Conditions. Stir the resulting heterogeneous mixture, at room temperature, for an additional 90 min. The mixture develops a light-tan color over this period of time.

Isolation of Product. Work up the reaction by adding 1.0 mL of a 25% aqueous NaOH solution (calibrated Pasteur pipet), and then transfer the resulting mixture to a 12-mL centrifuge tube using a Pasteur filter pipet. Rinse the reaction flask with three 2.0-mL portions of diethyl ether. Transfer each rinse to the same centrifuge tube. Partially neutralize the resulting two-phase system by the careful addition of 2.0 mL of 0.1 N HCl and mix briefly.

Separate the ether layer by Pasteur filter pipet and place it in a 25-mL Erlenmeyer flask. Extract the remaining aqueous layer with three additional 5-mL portions of diethyl ether. Separate these extracts as before and combine them with the original ether layer.

Transfer the combined ether fractions, by Pasteur filter pipet, to a short microcolumn prepared from a Pasteur filter pipet containing 1.5 g of anhydrous sodium sulfate (⬅). Collect the dried eluate in a 25-mL Erlenmeyer flask containing a boiling stone. Concentrate this solution to dryness, using a gentle stream of nitrogen, or by warming on a sand bath in the **hood,** to yield a colorless liquid residue.

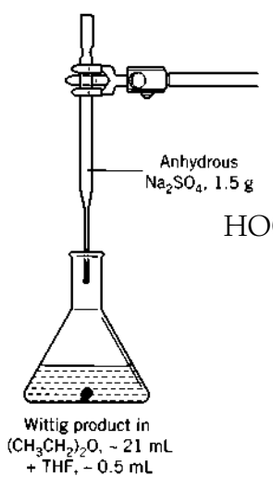

Purification and Characterization. Purify the crude product isolated above by chromatography on an alumina column (see figure on next page).

Pack a short (1 × 10 cm) buret column with 4.0 g of activated basic alumina and premoisten the alumina with ligroin. Dissolve the crude material in 0.5 mL of 9:1 ligroin (60–80 °C)/methylene chloride solvent and transfer the solution to the column using a Pasteur filter pipet. Elute the product in a single fraction using 8.0 mL of 9:1 ligroin (60–80 °C)/methylene chloride. Collect the eluate in a tared 25-mL filter flask containing a boiling stone. Evaporate the solvent in the **hood** under vacuum, with swirling, in a warm sand bath, leaving a liquid residue. Product loss may occur if the concentrated residue is heated excessively (see figure on page 306).

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The product is of sufficient purity for characterization. Weigh the methylene-4-*tert*-butylcyclohexane and calculate the percent yield. Determine the boiling point and compare your result with that listed in the Reactants and Product table.

Obtain an IR spectrum of the alkene product, using the capillary film technique. Compare your result with Figure 6.32.

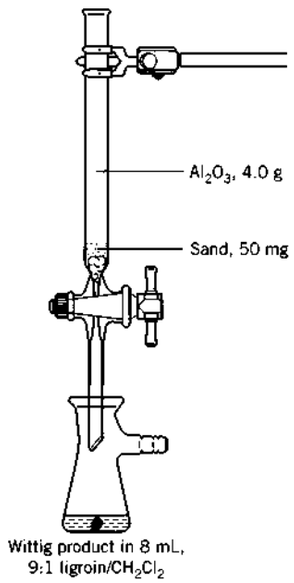

Infrared Analysis. The spectrum (Fig. 6.8 p. 160) of the ketone was discussed in Experiment [5B]. The major change observed in the spectrum of the product (Fig. 6.32), when compared with the starting material, is the loss of the carbonyl absorption band (1717 cm^{-1}), and its replacement by a less-intense new band at 1654 cm^{-1}. This latter absorption is associated with the stretching motion of the C═C system exocyclic to the six-membered ring. The key bands associated with group frequencies present in the reaction product are identified at 3075, 3000–2850, 1783, 1654, 1394, 1368, and 883 cm^{-1}.

The presence of these bands confirms the projected structure of the Wittig reaction product. The data may be interpreted as follows: the bands at 3075 (sharp spike), 1783 (weak), 1654 (sharp–medium), and 883 (strong) cm^{-1} form a frequency train that is defined as a "terminal alkene macrofrequency." The overall interpretation requires the presence of all four bands in the spectrum if the specific assignment of any one of them is to be correct. Thus, these four data

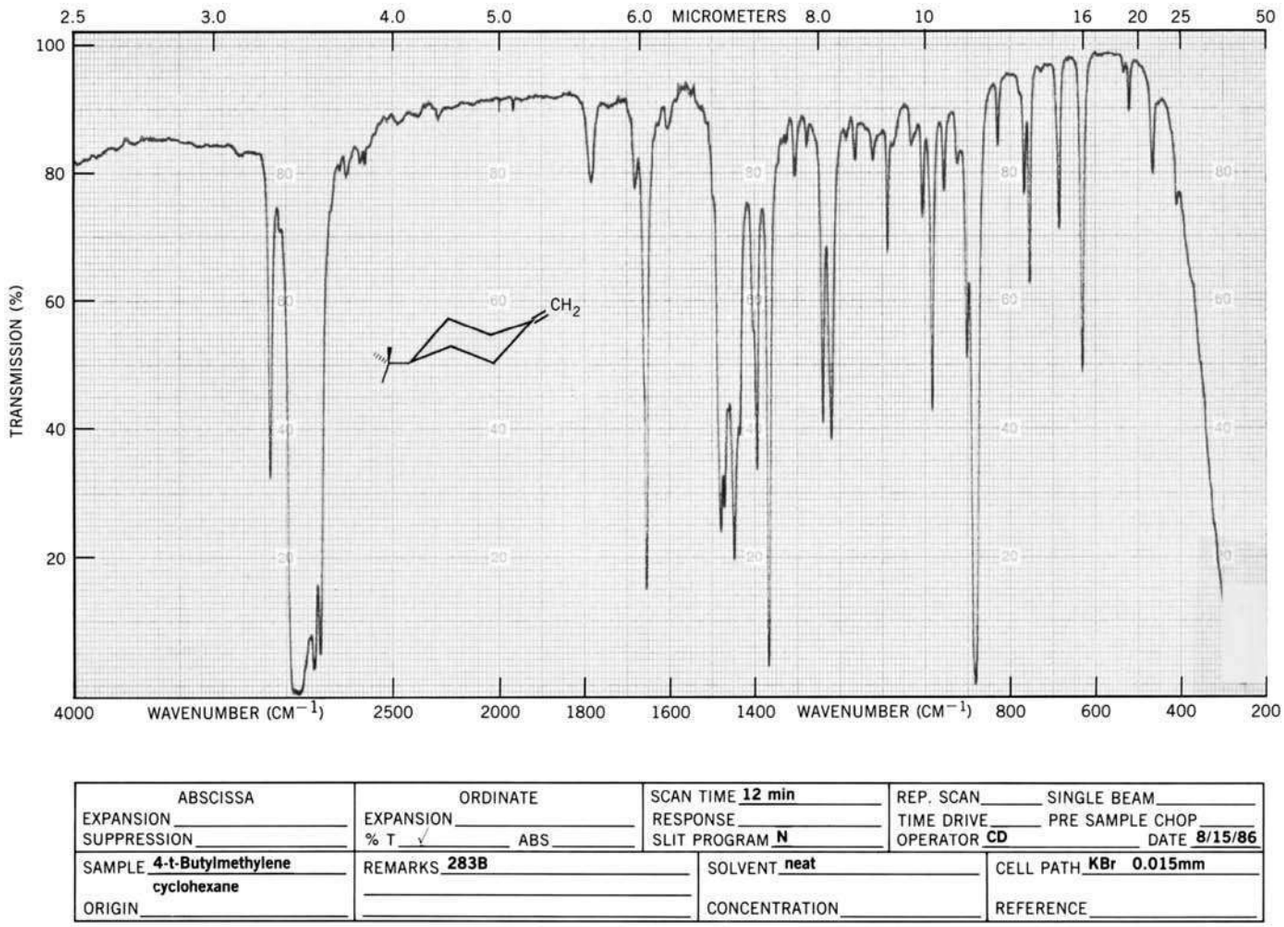

Figure 6.32 IR spectrum: methylene-4-*tert*-butylcyclohexane.

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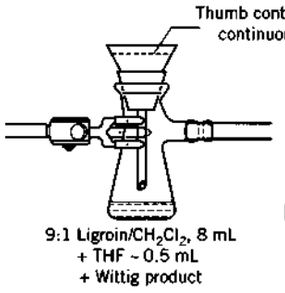

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points lead to a structural interpretation with very high confidence limits. The 3075-wavenumber band arises from the coupled antisymmetric stretch of the two C—H oscillators on the terminal alkenyl methylene group. The weak 1783-wavenumber peak is an overtone of the strong band observed near 883 cm^{-1} ($883 \times 2 = 1766\ cm^{-1}$) and is unusually intense for an isolated harmonic. The fundamental can be assigned as the $=CH_2$ out-of-plane wag (C—H deformation). In this fairly rare example, the observed harmonic occurs at a higher wavenumber value than twice the fundamental frequency. A situation of this type is termed *negative anharmonicity* (see Infrared Discussions). Finally, the C=C stretching mode is assigned to the 1654-wavenumber band, which is consistent with the requirements of this frequency train as it is found below 1660 cm^{-1} (see Infrared Discussions of cis, terminal, or vinyl carbon–carbon double bonds). The bands identified at 1396 and 1368 cm^{-1} indicate that the tertiary butyl group, as expected, has been preserved during the conversion of the ketone to a terminal alkene (see also Discussion, Experiment [5B]).

Experiment 19D

trans-9-(2-Phenylethenyl)anthracene

REACTION

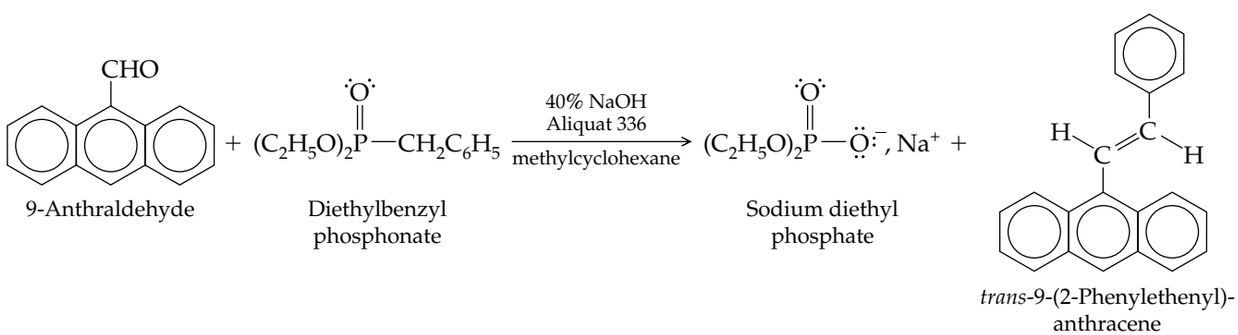

9-Anthraldehyde

Diethylbenzyl phosphonate

Sodium diethyl phosphate

trans-9-(2-Phenylethenyl)-anthracene

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: 2.5 h.

Physical Properties of Reactants and Product							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
9-Anthraldehyde	206.24	106 mg	0.51	104–105			
Diethyl benzylphosphonate	228.23	120 μL	0.58		106–8 @ 1mm	1.095	1.4970
Aliquat 336 (tricaprylmethyl-ammonium chloride)	404.17	2 drops					
Methylcyclohexane	98.2	2.0 mL			101	0.77	1.4215
40% Aqueous sodium hydroxide		2.0 mL					
trans-(2-Phenylethenyl) anthracene	280.4			130–132			

Reagents and Equipment. Weigh and place 106 mg (0.51 mmol) of 9-anthraldehyde in a 10-mL round-bottom flask containing a magnetic stirrer. Add 2 drops of Aliquat 336 (tricaprylmethylammonium chloride), 120 μL (0.58 mmol)

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of diethyl benzylphosphonate, 2.0 mL of methylcyclohexane and 2 mL of 40% sodium hydroxide solution. Attach the vial to a reflux condenser (➡).

NOTE. The diethyl benzylphosphonate, methylcyclohexane, and NaOH solution are dispensed in the ***hood*** *using automatic delivery pipets. The Aliquat 336 is very viscous. A medicine dropper is used to dispense this material. It is advisable to lightly grease the bottom joint of the condenser, since strong base is being used.*

HOOD

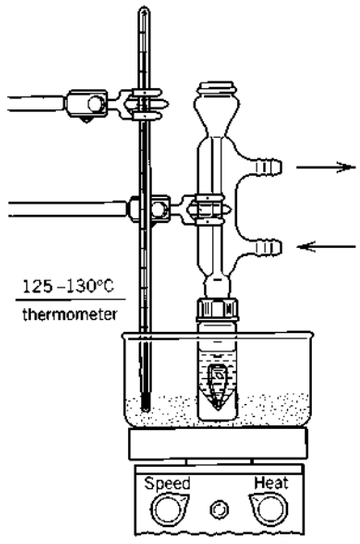

9-Anthraldehyde, 106 mg,
+ diethylbenzyl phosphonate, 120 µL,
+ Aliquat 336, 2 drops, 40% NaOH, 2 mL
+ methylcyclohexane, 2 mL

Reaction Conditions. Heat the two-phase mixture, on a sand bath at a temperature of about 125–130 °C, for 45 min. Stir the reaction mixture vigorously during this period; the upper (organic) layer turns deep red. Allow the mixture to cool to room temperature.

Isolation of Product. Transfer the two-phase solution to a 15-mL glass centrifuge tube using a Pasteur filter pipet. Rinse the flask with 1 mL of methylene chloride and transfer this rinse to the centrifuge tube. Carefully remove the aqueous layer, using a Pasteur filter pipet, and save it in a vial until you have successfully isolated and characterized the product. Wash the organic layer with two 2-mL portions of water. Stir the mixture with a small glass rod after each addition (or a Vortex mixer may be used) and then remove the water layer and save it in the same vial as before. Dry the methylene chloride solution by adding sodium sulfate. Using a Pasteur filter pipet, transfer the dried solution to a tared 10-mL Erlenmeyer flask containing a boiling stone. Wash the sodium sulfate remaining in the centrifuge tube with two 1-mL portions of methylene chloride. Also transfer these washings to the Erlenmeyer flask.

Concentrate the solution, which contains the desired product, almost to dryness on a sand bath under a slow stream of nitrogen gas. Now add approximately 1–2 mL of 2-propanol (isopropanol) to the flask and allow the resulting solution to stand at room temperature for 10–15 min, and then place it in an ice bath to complete the crystallization of the product.

Purification and Characterization. Collect the yellow crystals by vacuum filtration, using a Hirsch funnel, and wash the filter cake with two 1-mL portions of *cold* methanol. Maintain the vacuum for an additional 10 min to partially dry the crystalline product. Then place the material on a clay plate, or on filter paper, and allow it to dry thoroughly. As an alternative, the product may be dried in a vacuum drying oven (or pistol) for 10–15 min at 30 °C (1–2 mm).

The purity of the product may be checked using *thin-layer chromatography* (see Technique 6A). Dissolve a small amount of the starting aldehyde and the product in ethanol and apply a sample to the TLC plate. Use toluene as the elution solvent, silica gel (containing a fluorescent indicator) as the stationary phase, and UV light for visualization. Typical R_f values are 0.92 for *trans*-9-(2-phenylethenyl)anthracene and 0.50 for 9-anthraldehyde.

Weigh the product and calculate the percent yield. A portion of the material may be further purified by recrystallization from 2-propanol using the Craig tube.

Determine the melting point and compare it with the value given in the Reactants and Product table. Obtain the IR spectrum of the alkene product. The material should have a strong absorption band at 962 cm^{-1}, which confirms the presence of a trans double bond.

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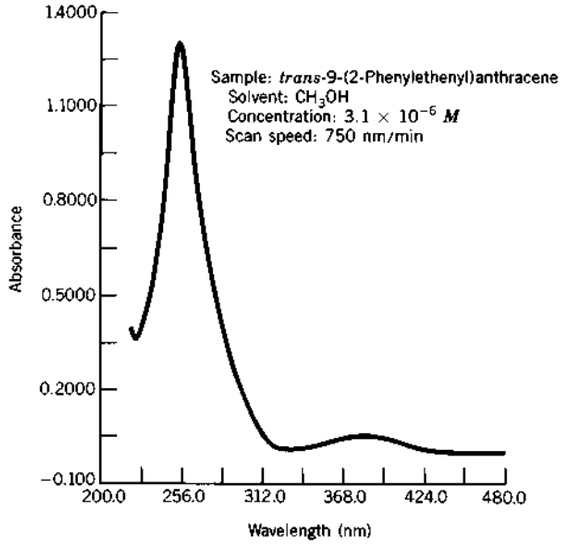

Figure 6.33 UV-visible spectrum: *trans*-9-(2-phenylethenyl)anthracene.

This material has a characteristic UV spectrum in methanol. The following data were obtained at a concentration of 3.1×10^{-6} M (see Fig. 6.33):

λ_{max} 255 nm (ε_{max} = 35,207, methanol)

λ_{max} 383 nm (ε_{max} = 3618, methanol)

QUESTIONS

6-124. Complete each of the following reactions by giving a suitable structure for the species represented by the letters. Give a suitable name for compound B in each reaction.

(a) $(C_6H_5)_3\overset{+}{P}-CH_2C_6H_5, Cl^- \xrightarrow[C_2H_5OH]{NaOC_2H_5} A$

(b) $(C_6H_5)_3\overset{+}{P}-CH_3, Br^- \xrightarrow[DMSO]{NaH} A$

$$A + C_6H_5CH{=}CH{-}\overset{H}{\overset{|}{C}}{=}O \longrightarrow B + (C_6H_5)_3PO$$

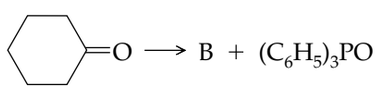

6-125. Why is it important that any aldehyde used in the Wittig reaction be free of carboxylic acid impurities?

6-126. Reaction of triphenylphosphine with benzyl bromide produces the corresponding phosphonium salt. Suggest a suitable mechanism for this reaction.

6-127. Heteroatoms other than P are also capable of stabilizing the negative charge on C to yield ylides. For example, nitrogen is capable of forming such a system:

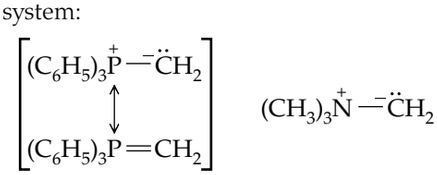

A phosphorus ylide

A nitrogen ylide

Why are resonance structures not drawn for the nitrogen ylide as in the phosphorus system?

6-128. Would you expect that the sulfonium salt, $(C_6H_5)_2CH_3S^+,Br^-$, is capable of forming an ylide when reacted with a strong base? If so, would its structure be best represented in a manner resembling the P or N ylide? Explain.

6-129. Explain why the C═C stretching mode gives rise to a rather weak IR band in 1-methylcyclohexene, while in its isomer, methylenecyclohexene, the band is of medium to strong intensity.

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6-130. Predict the C═C stretching frequencies of the alkenes formed when cyclopentanone, cyclobutanone, and cyclopropanone undergo the Wittig reaction with methyltriphenylphosphonium bromide–sodium amide reagent.

6-131. What concentration of a given compound (mol/L) in methanol, having a molecular weight of 165, would have been used if the solution gave an absorbance of 0.68 with a calculated ε_{max} = 14,800?

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Below are selected examples of the Wittig reaction in *Organic Syntheses:*

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For a historical perspective of the Wittig reaction, see:

Hofmann, R. W. "Wittig and His Accomplishments: Still Relevant Beyond His 100th Birthday." *Angew. Chem. Int. Ed.* **2001,** *40,* 3915.

EXPERIMENT 20

Aldol Reaction: Dibenzalacetone

Common names: dibenzalacetone, dibenzylideneacetone

CA number: [35225-79-7]

CA name as indexed: 1,4-pentadien-3-one, 1,5-diphenyl-, *(E,E)*-

Purpose. The synthetically useful **aldol reaction** is investigated as a method of forming carbon–carbon bonds. It is a general reaction of aldehydes that may also be extended to ketones. The specific case outlined in this experiment is known as the Claisen–Schmidt reaction. Experiments [A3$_a$] and [F1] provide other examples of the aldol condensation.

Prior Reading

Technique 5: Crystallization
Introduction (pp. 85–87)
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

REACTION

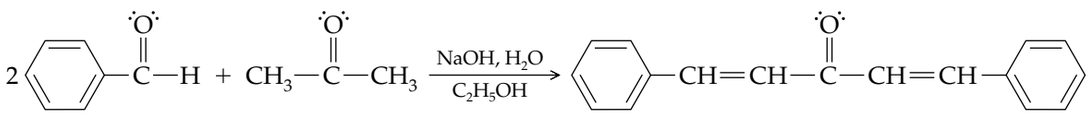

Benzaldehyde Acetone Dibenzalacetone

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DISCUSSION

The aldol reaction (aldol condensation) is one of the fundamental reactions of organic chemistry, since it leads to the formation of a new carbon–carbon bond and is broadly applicable. A condensation reaction is one in which two molecules are joined with the concomitant expulsion of a small stable molecule, usually water or an alcohol. The aldol reaction may be used to condense various combinations of aldehydes and ketones. The mixed aldol condensation of an aldehyde having no α-hydrogen atom with a ketone is specifically known as the Claisen–Schmidt reaction. This variation of the aldol condensation is illustrated here in the synthesis of dibenzalacetone.

The reaction conditions of this aldol condensation favor the formation of the product, dibenzalacetone. This product is insoluble in the aqueous ethanol solvent and precipitates from the reaction as it is formed, whereas the starting materials and the intermediate, benzalacetone, are all soluble in aqueous ethanol. These experimental conditions assist in driving the equilibrium reaction to completion.

The aldol condensation involves generation of an *enolate* by removal of an acidic proton from a carbon to the carbonyl group of an aldehyde or ketone, and subsequent nucleophilic addition of this enolate to the carbonyl carbon of an aldehyde or ketone. The reaction is usually base catalyzed and involves several mechanistic steps.

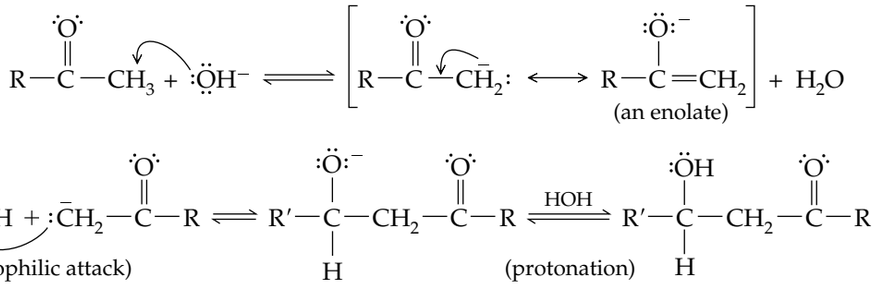

The reaction involves several steps: (1) base-catalyzed generation of an enolate, (2) nucleophilic attack of this anion on a carbonyl carbon, and (3) protonation of the resulting anion to yield the initial aldol product, a β-hydroxy carbonyl compound. Note that each step in the sequence is in equilibrium and the entire reaction is, therefore, reversible. Treatment of the β-hydroxy carbonyl compound with base causes the reverse aldol (**retro-aldol**) reaction to occur.

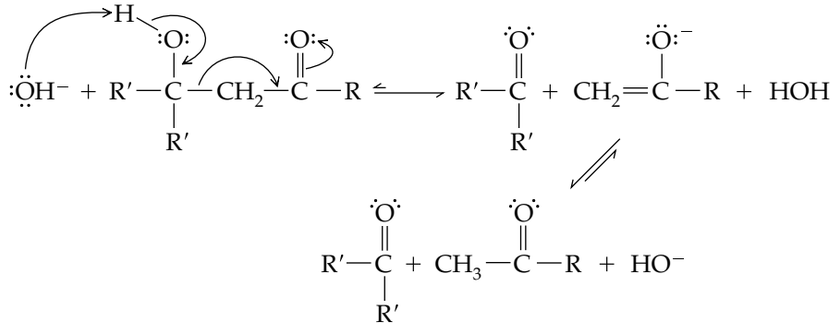

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The β-hydroxy carbonyl product may be isolated in most cases, if desired, as the subsequent dehydration is generally much slower than the addition reaction that precedes it. The final stage, as in the present reaction, is a hydroxide-catalyzed dehydration of this initial product by way of its enolate. Though hydroxide ion (HO^-) is generally not a good leaving group, the hydrogen α to the ketone is quite acidic, the elimination produces a rather stable and conjugated α,β-unsaturated ketone, and under strongly basic conditions the hydroxide ion is an adequate leaving group.

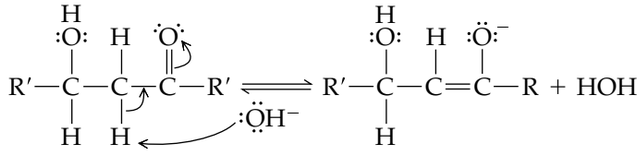

Enolate anion

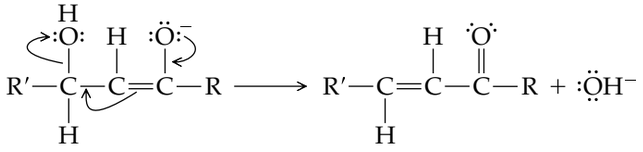

In the present reaction, a double aldol condensation occurs, which yields the dibenzalacetone product. An additional example of the aldol reaction is shown in Experiment [$A3_a$], where tetraphenylcyclopentadienone is prepared.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	80 μL	0.79	178	1.04	1.5463
Acetone	58.08	29 μL	0.40	56	0.79	1.3588
NaOH catalyst solution		1 mL				

NOTE. It is recommended that the purity of the benzaldehyde be checked by IR. The presence of benzoic acid in the benzaldehyde can substantially lower the yield of product. The benzaldehyde may be purified by distillation under reduced pressure (bp 178–179 °C; 57–59 °C @ 8 torr).

The benzaldehyde may be added to the vial by weight, or by volume (using an automatic delivery pipet). To prevent loss of acetone by evaporation, fit the reaction vial with a septum cap and cool it in an ice bath. Add the acetone (by volume) through the septum using a GC syringe.

Stoichiometric quantities of the reagents are used. An excess of benzaldehyde results in a more intractable product; excess acetone favors the formation of benzalacetone.

NOTE. This reaction may be carried out in a 10 × 75-mm test tube. However, the reagents must be stirred efficiently with a glass rod at frequent intervals. If a larger test tube is used, a small magnetic stirring bar or vane is more efficient as an agitator.

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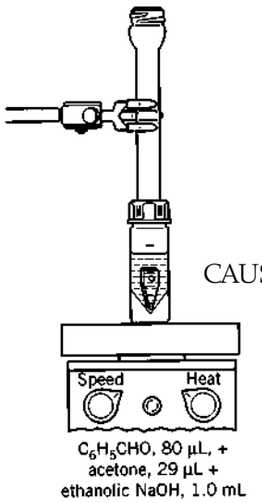

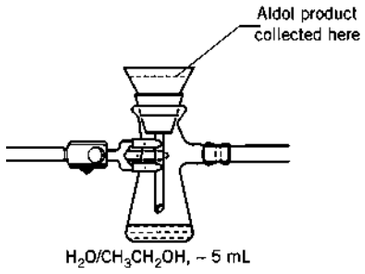

Reagents and Equipment. In a 3.0-mL conical vial containing a magnetic spin vane and equipped with an air condenser place 80 µL (84 mg, 0.79 mmol) of benzaldehyde and 29.0 µL (23 mg, 0.40 mmol) of acetone (⬅).

Now add to this reaction mixture 1.0 mL of the aqueous, ethanolic sodium hydroxide catalyst solution, delivered from a calibrated Pasteur pipet.

INSTRUCTOR PREPARATION. The catalyst solution is prepared by dissolving 0.4 g of sodium hydroxide (which is ***caustic****) in 4.0 mL of water. To this solution add 3.0 mL of 95% ethanol.*

Reaction Conditions. Stir the reaction mixture at room temperature for 30 min. During this time the solid yellow product precipitates from solution.

Isolation of Product. Collect the crude yellow dibenzalacetone by vacuum filtration using a Hirsch funnel (⬅). Remove the magnetic spin vane from the reaction vial with forceps. *Some of the product adheres to the magnetic spin vane. This material should be removed by carefully scraping the vane with a microspatula. The material is added to the product collected by filtration.*

Wash the filter cake with three 1.0-mL portions of water. The filtrate should be nearly neutral, as indicated by pH test paper. If not, repeat the washing until the test indicates that the filtrate is neutral.

NOTE. It is essential to remove the NaOH completely. If it is not removed, the recrystallization step will be difficult.

Air-dry the product by maintaining the suction on the Hirsch funnel for approximately 10 min. During this operation a piece of plastic food wrap may be placed over the mouth of the Hirsch funnel to aid in the drying process (see Prior Reading).

NOTE. An alternative procedure may be used to isolate and purify the dibenzalacetone. Transfer the reaction product directly to a large Craig tube. The washings and the ethanol recrystallization step (see Purification and Characterization section) may then be carried out with no transfer of the material. In this way, loss of product is minimized.

Purification and Characterization. The crude dibenzalacetone may be purified by recrystallization from 95% ethanol, using a Craig tube.

Weigh the dried product and calculate the percent yield. Determine the melting point and compare your result with those in the literature.

Obtain an infrared spectrum of the material and compare your spectrum with that shown in Figure 6.34.

A comparison of the infrared spectra of the starting reagents with that of the product is given below.

Infrared Analysis

Acetone: This simple aliphatic ketone possesses the short macro group frequency train: 3415 (overtone of C═O stretch, $2 \times 1712 = 3424$ cm^{-1}), 3000–2850 (sp^3 C—H stretch), 1712 (C═O stretch), and 1360 cm^{-1} (symmetric

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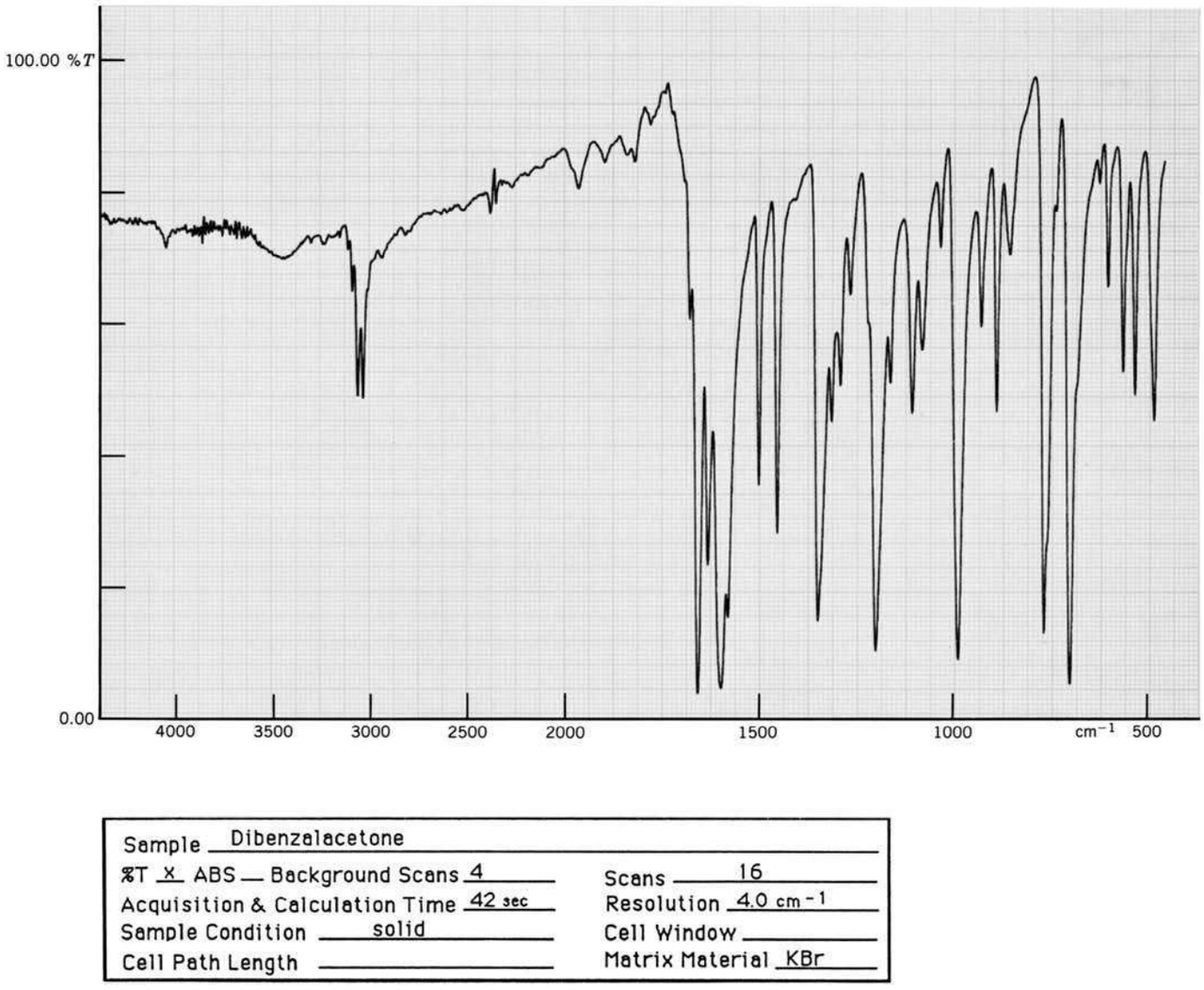

Figure 6.34 IR spectrum: dibenzalacetone.

methyl bend α to a carbonyl. See discussion of methyl bends in acetates in Experiment [8B]).

Benzaldehyde: The infrared spectrum of this aromatic aldehyde (Fig. 6.35) is rich and interesting. The aromatic aldehyde macro group frequency consists of the following peaks: 3070, 2830 and 2750, 1706, 1602, 1589, and 1396 cm^{-1}.

a. 3070 cm^{-1}: C—H stretch on sp^2 carbon.

b. 2830 and 2750 cm^{-1}: This pair of bands is another example of Fermi coupling (see discussion in Experiment [7] and Infrared Discussions). ← www

c. 1706 cm^{-1}: The carbonyl stretch of the aldehyde group. The frequency observed in aliphatic aldehydes falls in the range 1735–1720 cm^{-1}, but when conjugated, the value drops (see Infrared Discussions) and is found in the range 1720–1700 cm^{-1}. ← www

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d. 1602 and 1589 cm^{-1}: This pair of bands is related to the degenerate ring stretching vibrations ν_{8a} and ν_{8b} of benzene (see infrared discussions in Chapter 10W, Experiment [$1B_{adv}$] and Infrared Discussions).

e. 1396 cm^{-1}: The aldehyde C—H in-plane bending vibration. The first harmonic of this vibration is Fermi coupled to the aldehyde C—H stretching mode.

Benzaldehyde also possesses a second powerful macro group frequency train that reflects the substitution pattern of the aromatic ring system (see Infrared Discussions). The monosubstituted benzene ring macro group frequency train contains peaks in the following regions: 1950, 1880, 1800, 1730, 750, and 690 cm^{-1}.

a. 1990, 1920, 1830, and 1770 cm^{-1}: this series of four weak bands with generally decreasing intensity from high-to-low wavenumber values (the third peak near 1800 cm^{-1} may be intensified if the ring is conjugated as in this case) arise from combination bands (see Infrared Discussions), which involve the out-of-plane bending frequencies of the ring C—H bonds (see below). The exact wavenumber positions are not very important, but the overall shape of the pattern can be used to determine the ring substitution pattern (see Infrared Discussions).

b. 750 and 690 cm^{-1}: this pair of bands is very characteristic of monosubstituted phenyl groups. The 750-wavenumber peak arises from the all-in-phase out-of-plane bending vibration of the five C—H groups adjacent to each other on the ring (see Infrared Discussions). The 690 cm^{-1} companion band involves an out-of-plane displacement of the ring carbon atoms (see Infrared Discussions).

Dibenzalacetone: The infrared spectrum of the product (Fig. 6.35) contains many features of the starting materials, plus new and shifted bands unique to the newly formed structure.

a. The monosubstituted aromatic macro group frequency remains: 1960, 1890, 1815, 1770, 760, and 690 cm^{-1}. In addition, the two pairs of degenerate ring stretching bands are present: 1598, 1580 and 1500, 1450 cm^{-1}. The 1500-wavenumber band is rather weak in benzaldehyde, but intensifies in the product.

b. The ketone carbonyl remains the most intense band in the spectrum but is shifted to 1653 cm^{-1} because of the carbonyl's conjugation to two aromatic rings. The aldehyde's carbonyl stretching mode at 1706 cm^{-1} has vanished.

c. The methyl C—H stretching bands between 3000 and 2850 cm^{-1}, and the coupled aldehyde C—H stretching peaks at 2830 and 2750 have disappeared.

d. New bands appear at 3058 and 3035 cm^{-1} (alkene C—H, stretch) which are overlapped with the aromatic ring C—H stretching) peaks (3075 cm^{-1}). In addition, bands appear at 1627 (conjugated C=C) and 985 cm^{-1} (trans-substituted C=C, C—H in-phase out-of-plane bend).The latter band occurs slightly above its usual location near 965 cm^{-1}. This rise in frequency is the result of conjugation of the double bond to the carbonyl group. For an example of a much more dramatic rise in frequency, refer to the discussion of the cis C—H bending modes in the spectrum of maleic anhydride (Experiment [14]).

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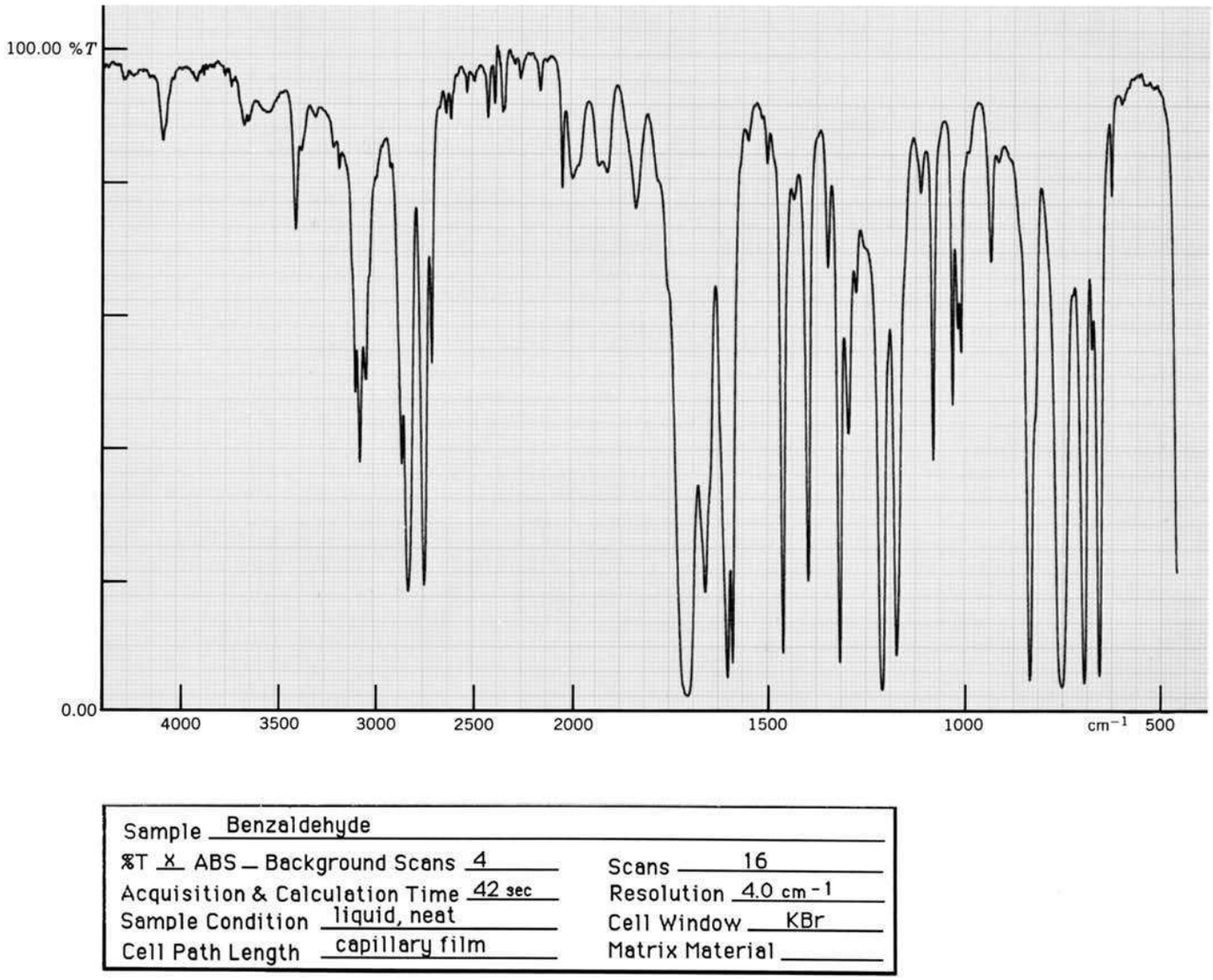

Figure 6.35 IR spectrum: benzaldehyde.

If performed in a potassium bromide matrix, examine the spectrum of your product. Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 6.34 and 6.35).

Dibenzalacetone is a compound that can be characterized by classical chemical tests.

Chemical Tests. An ignition test (See Table 9.1, p. 633) should indicate that dibenzalacentone contains an aromatic ring system. Perform the test to confirm this.

Several classification tests might also be of assistance in classifying this compound. Does the 2,4-dinitrophenylhydrazine test for an aldehyde or ketone give a positive result? Isolate the 2,4-dinitrophenylhydrazone derivative and determine its melting point. Does it correspond to the literature value of 180 °C? What further test could be run to determine whether the carbonyl is present as an aldehyde or ketone?

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EQA

A test for unsaturation should be enlightening. Would you perform the bromine–methylene chloride or the Baeyer test (Chapter 9, Classification Tests). Did the correct test give a positive result?

OPTIONAL SEMIMICROSCALE PREPARATION

This experiment may be scaled up to be carried out at 5 or 10 times the amounts used in the above micro preparation. The data summarized below are for the 10–fold procedure.

The procedure is identical to the above with the following exceptions.

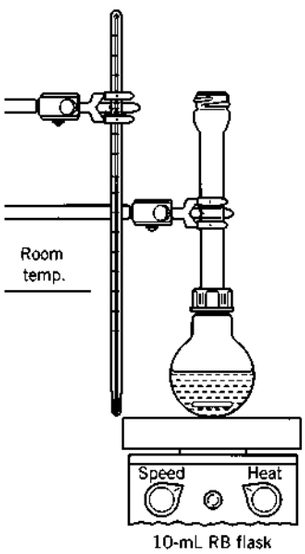

1. Use a 10-mL round-bottom flask fitted with an air condenser (⬅).
2. Increase the reagent and solvent amounts.

Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	800 μL	7.9	178	1.04	1.5463
Acetone	58.08	300 μL	4.0	56	0.79	1.3588
NaOH catalyst solution		5 mL				

3. The collected filter cake is transferred to a 10-mL beaker, stirred with 5.0 mL of water, and then recollected by vacuum filtration. Repeat this process, usually about three times, until the filtrate is neutral to litmus paper.

QUESTIONS

6-132. A key step in the total synthesis of the hydrocarbon azulene follows. Outline a suitable mechanism to account for the reaction.

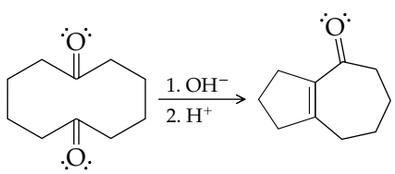

6-133. The aldol reaction has been utilized extensively for the generation of five- and six-membered rings. Suggest a suitable mechanism for the cyclization reactions shown below.

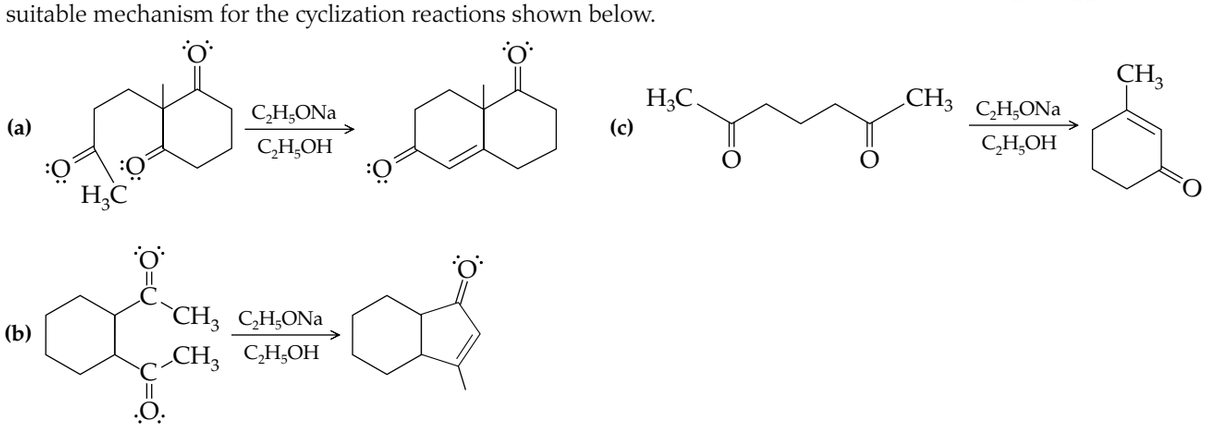

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EQA

6-134. Predict the major organic product formed in each of the following reactions.

(a) $CH_3CH_2NO_2 + CH_2O \xrightarrow{NaOH}$

(b) $C_6H_5{-}CH{=}CH{-}CHO + CH_3{-}\overset{\overset{\cdot\cdot}{O}\cdot\cdot}{\overset{\|}{C}}{-}C_6H_5 \xrightarrow[C_2H_5OH]{C_2H_5ONa}$

(c) $C_6H_5CHO + C_6H_5CH_2CN \xrightarrow[C_2H_5OH]{C_2H_5ONa}$

6-135. "Crossed" or "mixed" aldol condensations are practical for synthesis, if one of the aldehydes (or ketones) has no α-hydrogen atoms. Explain.

6-136. Give several examples of aldehydes or ketones that could be used in a "crossed" aldol condensation with propanal. Assign structures and names to the products that could be formed and point out any side reactions that might occur.

6-137. In the aldol condensation using the conditions of this experiment, why might it be essential that the benzaldehyde contain no benzoic acid?

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Leuck, G. J.; Cejka, L. *Organic Syntheses*; Wiley: New York, 1941; Collect. Vol. I, p. 283.
Russell, A.; Kenyon, R. L. *Organic Syntheses*; Wiley: New York, 1955; Collect. Vol. III, p. 747.
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EXPERIMENT 21

Quantitative Analysis of Grignard Reagents: 1-Methylbutylmagnesium Bromide and Phenylmagnesium Bromide

Common names: 1-methylbutylmagnesium bromide, 2-pentylmagnesium bromide
CA number: [57325-22-1]
CA name as indexed: magnesium, bromo(1-methylbutyl)-

Common name: phenylmagnesium bromide
CA number: [100-58-3]
CA name as indexed: magnesium, bromophenyl-

Purpose. In this experiment you will generate a Grignard reagent, a common and synthetically useful source of a nucleophilic carbanion, and use an aqueous titration method to determine the amount prepared.

Prior Reading

Moisture-Protected Reaction Apparatus (pp. 25–26)

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REACTION

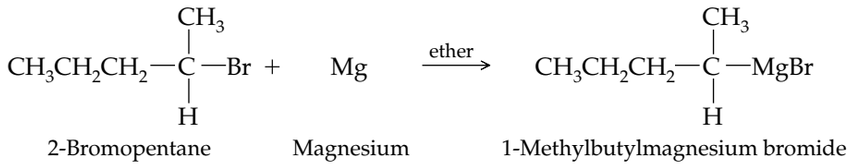

2-Bromopentane Magnesium 1-Methylbutylmagnesium bromide

or

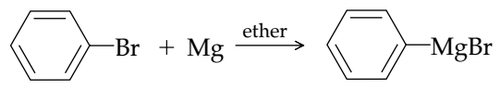

Bromobenzene Phenylmagnesium bromide

then

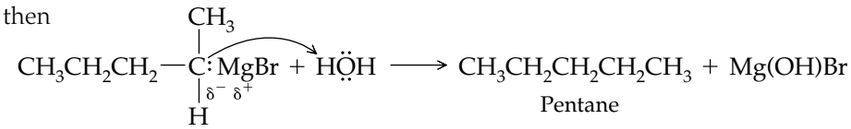

1-Methylbutylmagnesium bromide Pentane

or

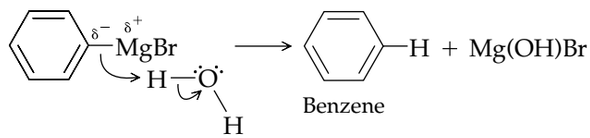

Benzene

DISCUSSION

This experiment demonstrates the formation of a Grignard reagent (1-methylbutylmagnesium bromide or phenylmagnesium bromide) and a titration method by which the amount of the reagent prepared can be analyzed.

The discovery by Victor Grignard in 1900 that organic halides react with magnesium metal to give organomagnesium compounds was a landmark in organic chemistry. Grignard reagents are among the most useful and versatile reagents in organic synthesis.

The reaction of the Grignard reagent with water is the basis of the analytical method used in this experiment.

$$RMgX + HOH \longrightarrow RH + Mg(OH)X$$

In the Grignard reagent, the carbon atom bound to the electropositive magnesium atom has a high negative charge density, which is responsible for the strong nucleophilic and basic character exhibited by this organometallic reagent. The carbon, acting as a base, can abstract even a weakly acidic proton from protic reagents, such as water, carboxylic acids, alcohols, and so on. In this process, the corresponding hydrocarbon (the conjugate acid of the R group carbanion) and the basic magnesium halide species are produced. This reaction sequence can be used in the laboratory as a synthetic method to convert organohalides to hydrocarbons. In the examples given in this experiment, 1-methylbutylmagnesium bromide would yield pentane, while phenylmagnesium bromide gives benzene upon protonation.

Titration of the Mg(OH)X species with standardized acid solution makes it possible to determine the amount of Grignard reagent originally formed in the solution.

$$2\,Mg(OH)X + H_2SO_4 \longrightarrow \ + 2\,HOH + MgSO_4 + MgX_2$$

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An excess of the sulfuric acid is generally added to ensure that the Mg(OH)X is completely reacted. The excess acid is then neutralized with standard sodium hydroxide solution. The difference between the total amount of sulfuric acid used and the amount of sodium hydroxide required corresponds to the number of equivalents of the acid actually used to neutralize the Mg(OH)X species. This value is then directly related to the equivalents of Grignard reagent by the reactions given above.

Preparation of the Grignard Reagent[21]

CAUTION: Ether is a flammable liquid. Extinguish all flames during this experiment.

NOTE. All the glassware used in the experiment should be cleaned, dried in an oven at 110 °C for at least 30 min, and then cooled in a desiccator before use.

EXPERIMENTAL PROCEDURE

Estimated time for the experiment: 1.5 h.

Part 1 1-Methylbutylmagnesium Bromide

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
2-Bromopentane	151.05	125 μL	1.0	117	1.21	1.4413
Magnesium	24.31	36 mg	1.5			
Iodine	253.81	1 crystal				
Diethyl ether	74.12	400 μL		34.5		

Prepare the Grignard reagent exactly as described in Experiment [16]. The reagents, amounts of reagents, order of addition, workup manipulations, and precautions are the same. The equipment is also identical (➡).

Cool the gray-colored Grignard reagent mixture to room temperature, and then assay it by the titration method outlined in Part 2.

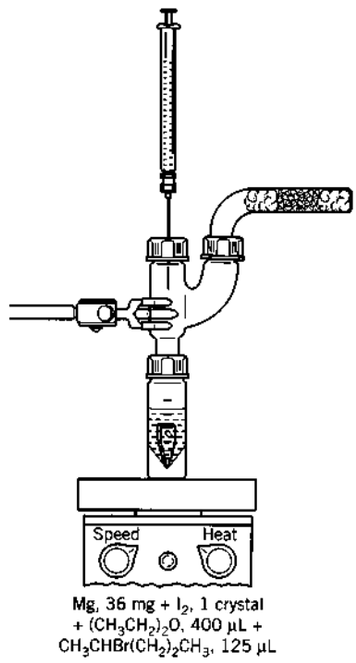

Part 2 Phenylmagnesium Bromide[22]

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Bromobenzene	157.02	76 μL	0.72	156	1.50	1.5597
Diethyl ether	74.12	1.3 mL		34.5	0.73	
Magnesium	24.3	17.5 mg	0.73			
Iodine		1 crystal				

[21]For references relating to the preparation of Grignard reagents, see Experiment [16].
[22]This Grignard reagent is prepared exactly as described in Experiment [16]. The reagents, amount of reagents, order of addition, workup manipulations, and precautions are the same. The equipment is also identical.

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NOTE. If not used for analysis, the solution of Grignard reagent may be treated with various reagents to prepare a wide variety of compounds. For example, see Experiments [16], [17], and [4_{adv}].

Analysis of the Grignard Reagent: Place 10 mL of freshly boiled distilled water and one drop of phenolphthalein indicator in a 50-mL Erlenmeyer flask. Using a syringe, transfer the cool Grignard reagent solution to the Erlenmeyer flask. Rinse the reaction vial with 0.5 mL of diethyl ether and add the rinse to the Erlenmeyer flask.

NOTE. The addition of water to the Grignard reagent results in the hydrolysis of this reagent to form the corresponding hydrocarbon and a basic magnesium halide, Mg(OH)X. The water is initially boiled to remove any dissolved carbon dioxide that might interfere with the titration.

Make sure that in the transfer of the Grignard reagent solution all small pieces of unreacted magnesium are excluded.

Analysis by Titration: Add, from a 10-mL buret, 5 or 6 mL of standard 0.2 N H_2SO_4 solution to the ethereal Grignard solution. *The resulting solution should be acidic and colorless. If not, add an additional portion of the acid.*

Add a boiling stone to the flask and heat the mixture at a sand bath temperature of 90–95 °C in the **hood** for 5 min.

HOOD

While the solution is still warm, add a drop of phenolphthalein indicator solution and neutralize the excess acid by back titration with 0.1 M NaOH solution. Back titration produces a very light-colored, pink end point. *It may be necessary to add an additional drop of acid, and then more base, to get the best possible end point.*

Data and Calculations: The difference between the initial and final buret readings is the volume of standard acid and base used in the titration of the Grignard reagent.

From the data, calculate the equivalents of Grignard reagent formed. Also, as a percentage, determine the amount of Grignard reagent analyzed compared to its theoretical yield of formation.

QUESTIONS

6-138. Technical grade ether often contains ethanol. Would you recommend this material as a suitable solvent for the preparation of Grignard reagents? If not, why not?

6-139. It is likely that the amount of Grignard reagent your analysis indicates was formed is greater than the amount of Grignard reagent actually present just before you added water. Explain.

6-140. What hydrocarbon would you expect to obtain by the action of water on each of the Grignard reagents listed below?

(a) Butylmagnesium bromide
(b) *sec*-Butylmagnesium bromide
(c) Isobutylmagnesium bromide
(d) *tert*-Butylmagnesium bromide

6-141. What product would each of the Grignard reagents in question 6-140 yield when treated with D_2O?

6-142. **(a)** What product would each of the Grignard reagents listed in Question 6–140 yield when treated with ethanol?
(b) With isopropyl alcohol?
(c) Explain why 4-hydroxycyclohexanone is not a viable candidate when considering Grignard reagents?

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6-143. The solubility of Grignard reagents in ether plays a crucial role in their formation. The reagents are soluble because the magnesium is coordinated to the ether oxygen in a Lewis acid–base interaction. Each ether molecule donates an electron pair to the magnesium to complete an octet.

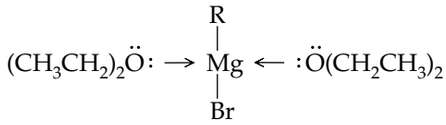

Grignard reagents are normally insoluble in hydrocarbon solvents. However, they can be rendered soluble by the addition of a tertiary amine to the hydrocarbon–Grignard reagent mixture. Explain.

BIBLIOGRAPHY

For the many references related to the preparation and use of the Grignard reagent cited in *Organic Syntheses,* see the Reaction Indexes in Collected Volumes I–X under Grignard Reactions.

EXPERIMENT 22

Williamson Synthesis of Ethers

Common names: propyl *p*-tolyl ether, 4-propoxytoluene
CA number: [5349-18-8]
CA name as indexed: benzene, 1-methyl-4-propoxy-

Common names: methyl *p*-ethylphenyl ether, *p*-ethylanisole
CA number: [1515-95-3]
CA name as indexed: benzene, 1-ethyl-4-methoxy-

Common names: butyl *p*-nitrophenyl ether
CA number: [7244-78-2]
CA name as indexed: benzene, 1-butoxy-4-nitro-

Purpose. The conditions under which ethers are prepared are explored by the well-known Williamson ether synthesis. You will prepare alkyl aryl ethers by S_N2 reactions of alkyl halides with substituted phenoxide anions. The use of phase-transfer catalysis is demonstrated.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
For Optional Scaleup: Separatory Funnel Extraction (pp. 75–77)

REACTION

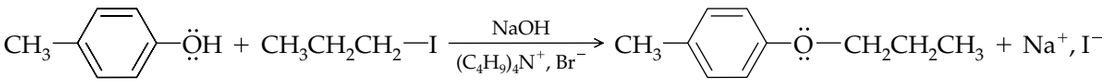

p-Cresol Propyl iodide Propyl *p*-tolyl ether

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EQA

DISCUSSION

The compounds whose preparations are described in Experiments [22A], [22B], [22C], and [22D] are alkyl aryl ethers. The general method of preparation is the Williamson synthesis, an S_N2 reaction specifically between a phenoxide ion (ArO^-) nucleophile and an alkyl halide. This reaction is often used for the synthesis of symmetrical and unsymmetrical ethers where at least one of the ether carbon atoms is primary or methyl, and thus amenable to an S_N2 reaction. Elimination (E2) is generally observed if secondary or tertiary halides are used, since phenoxide ions are also bases.

The conditions under which these reactions are conducted lend themselves to the use of phase-transfer catalysis.The reaction system involves two phases: the aqueous phase and the organic phase. In the present case, the alkyl halide reactant acts as the organic solvent, as does the product formed. The phase-transfer catalyst plays a very important role. In effect, it carries the phenoxide ion, as an ion-pair, from the aqueous phase, across the phase boundary into the organic phase, where the S_N2 reaction then occurs. The ether product and the corresponding halide salt of the catalyst are produced in this reaction. The halide salt then migrates back into the aqueous phase, where the halide ion is exchanged for another phenoxide ion, and the process repeats itself. The catalyst can play this role, since the large organic groups (the four butyl groups) allow the solubility of the ion-pair in the organic phase, while the charged ionic center of the salt renders it soluble in the aqueous phase. For further discussions of phase-transfer catalysis, see Experiments [19B] and [19D].

In the reactions described below, the mechanism is a classic S_N2 process, and involves a backside nucleophilic attack of the phenoxide anion on the alkyl halide.

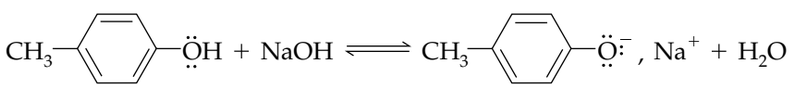

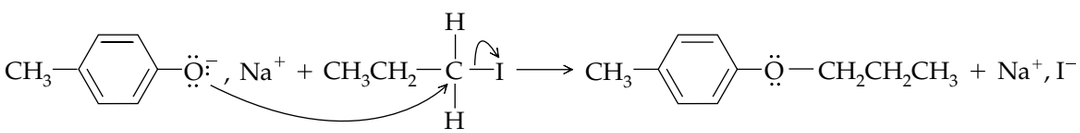

It is of interest to contrast the acidity of phenols with that of simple alcohols. A phenol is more acidic than an alcohol. In a typical aliphatic alcohol (e.g., ethanol) loss of the proton forms a strong anionic base, alkoxide ion (ethoxide ion).

$$R-CH_2-OH \rightleftharpoons H^+ + R-CH_2-O^-$$

Alkoxide ion

The strongly basic characteristics of the alkoxide species are due to the fact that the negative charge is localized on the oxygen atom. Ethanol has a $pK_a = 16$. In contrast, the conjugate base of a phenol can delocalize its negative charge.

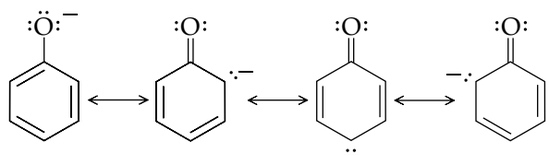

Phenoxide ion

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The phenoxide ion is stabilized by this resonance delocalization; therefore, it is a weaker base than the alkoxide ion. Conversely, the phenol is a stronger acid than a typical aliphatic alcohol. Phenol has a $pK_a = 10$ and is thus 1 million times more acidic than ethanol.

Propyl *p*-Tolyl Ether

Experiment 22A

The reaction for Experiment [22A] is shown above.

EXPERIMENTAL PROCEDURE

Estimated time of the experiment: 2.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
p-Cresol	108.15	160 μL	1.56	32–34	202	1.02	1.5312
25% NaOH solution		260 μL					
Tetrabutylammonium bromide	322.38	18 mg	0.056	103–104			
Propyl iodide	169.99	150 μL	1.54		102	1.75	1.5058

Reagents and Equipment. Weigh and place 160 μL (168 mg, 1.56 mmol) of *p*-cresol in a 5.0-mL conical vial containing a magnetic spin vane. Now add 260 μL of 25% aqueous sodium hydroxide and thoroughly mix the resulting solution (➡). To this solution weigh and add the tetrabutylammonium bromide ($Bu_4N^+Br^-$) catalyst (18 mg), followed by 150 μL (262 mg, 1.54 mmol) of propyl iodide. Immediately attach the vial to a reflux condenser.

NOTE. Warm the cresol in a hot water bath to melt it. Dispense this reagent and the propyl iodide in the **hood** *using an automatic delivery pipet.*

HOOD

CAUTION: Propyl iodide is a cancer suspect agent.

Reaction Conditions. Place the reaction vessel in a sand bath and stir vigorously at 110–115 °C for 45–60 min.

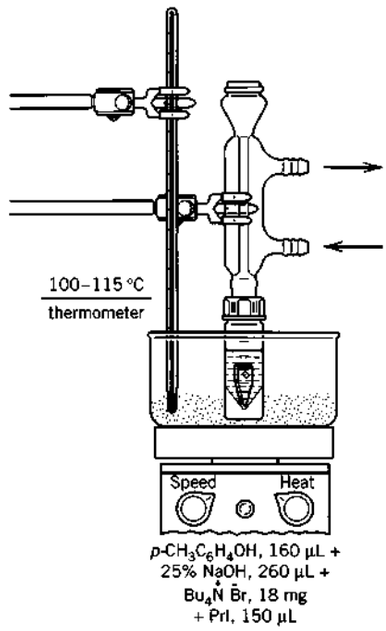

Isolation of Product. Cool the resulting two-phase mixture to room temperature, and remove the spin vane with forceps. Rinse the spin vane with 1.0 mL of diethyl ether, adding the rinse to the two-phase mixture. Cap the vial, agitate, vent, and transfer the bottom aqueous layer, using a Pasteur filter pipet, to a 3.0-mL conical vial. A Vortex mixer, if available, can be used to good advantage in this extraction step. Wash this aqueous fraction with 1.0 mL of diethyl ether. Save this and all subsequent aqueous fractions together in a small Erlenmeyer flask until your final product has been isolated and characterized. Now transfer this diethyl ether wash to the 5-mL conical vial containing the ether solution of the product. Extract the resulting ether solution with a 400-μL portion of 5% aqueous sodium hydroxide solution. Cap the vial, agitate, vent, and remove and save the bottom aqueous layer, using a Pasteur filter pipet. Wash the product–ether solution with 200 μL of water. Remove, and save, the aqueous phase to obtain the crude, wet ether solution of the product. Add a boiling stone to the vial and concentrate the solution in a warm sand bath under a gentle stream of nitrogen to isolate the crude product.

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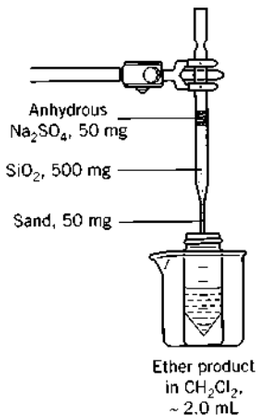

Purification and Characterization. The crude product is purified by chromatography on silica gel. Prepare a microchromatographic column by placing 500 mg of activated silica gel in a Pasteur filter pipet, followed by 50 mg of anhydrous sodium sulfate (⬅). Dissolve the crude product in 250 μL of methylene chloride and transfer the resulting solution to the dry column by use of a Pasteur pipet. Elute the material with 2.0 mL of methylene chloride and collect the eluate in a tared 3.0-mL conical vial containing a boiling stone. Evaporate the solvent by placing the vial in a sand bath maintained at a temperature of 60–65 °C.

Weigh the pure propyl *p*-tolyl ether and calculate the percent yield. Determine the boiling point and density (optional) and compare the experimental values with those in the literature.

Obtain an IR spectrum of the compound and compare it to that shown in Figure 6.36 for 4-propoxytoluene (propyl *p*-tolyl ether).

Nuclear Magnetic Resonance Analysis. If facilities permit, you can obtain both ^1H and ^{13}C NMR spectra of your propyl *p*-tolyl ether in $CDCl_3$ and compare your spectra with those in Figures 6.37 and 6.38. There are two extraneous peaks in the ^1H spectrum: the small singlet at 7.24 ppm is due to residual $CHCl_3$ in the $CDCl_3$, and the small singlet at 1.55 ppm is probably due to a trace amount of H_2O in either the sample or the NMR solvent. The 1:1:1 triplet at 77 ppm in the ^{13}C spectrum is from the $CDCl_3$ solvent.

Since the ^1H spectrum is entirely first order, it can be readily interpreted. You should be able to use the splitting patterns to assign peaks to each of the different groups of protons in the molecule. The integration can assist you.

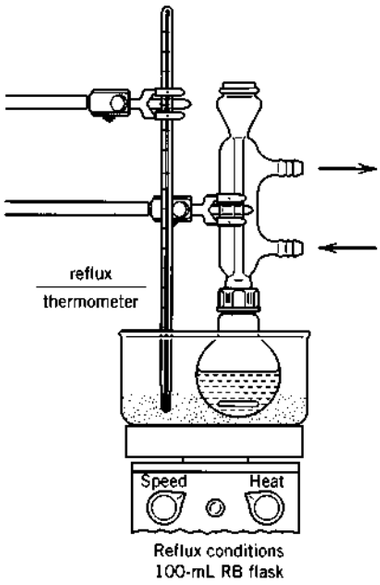

Chemical Tests. Qualitative chemical tests can also be used to assist in characterizing this compound as an ether. Perform the ignition test (Table 9.1) to determine whether the material contains an aromatic ring.

A key factor to investigate is the solubility characteristics of this material (see Chapter 9). Determine its solubility in water, 5% sodium hydroxide, 5% hydrochloric acid, concentrated sulfuric acid, and 85% phosphoric acid. Do the results place this compound in the solubility class of an ether containing less than 8, or more than 8, carbon atoms? Does the ferrox test (Chapter 9) confirm the presence of oxygen in the compound?

OPTIONAL MACROSCALE PREPARATION

This ether may be prepared on a larger scale (~100-fold increase) using a procedure similar to that just outlined, with the following modifications.

1. Use a 100-mL round-bottom flask containing a magnetic stirrer and equipped with a reflux condenser (⬅).

2. The reagent and solvent amounts are summarized in the following table. Note that propyl bromide is used in place of propyl iodide at this scale.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
p-Cresol	108.15	16.3 g	0.15	32–34	202	1.02	1.5312
NaOH	40.0	6.05 g	0.15				
Tetrabutyl ammonium bromide	322.38	0.41 g	0.0012	103–104			
Propyl bromide	122.99	12.71 g	0.1		71	1.35	1.4341
Water		25 mL					

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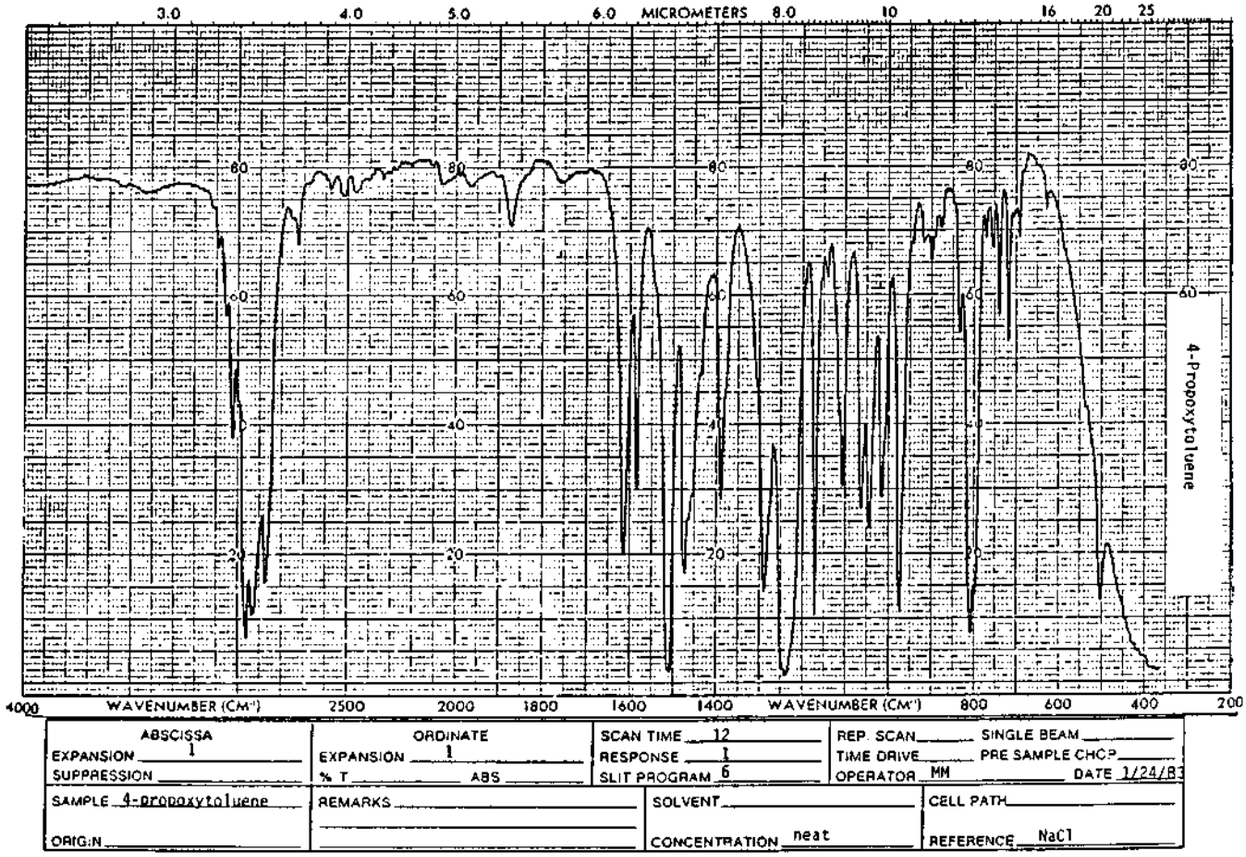

Figure 6.36 IR spectrum: propyl *p*-tolyl ether.

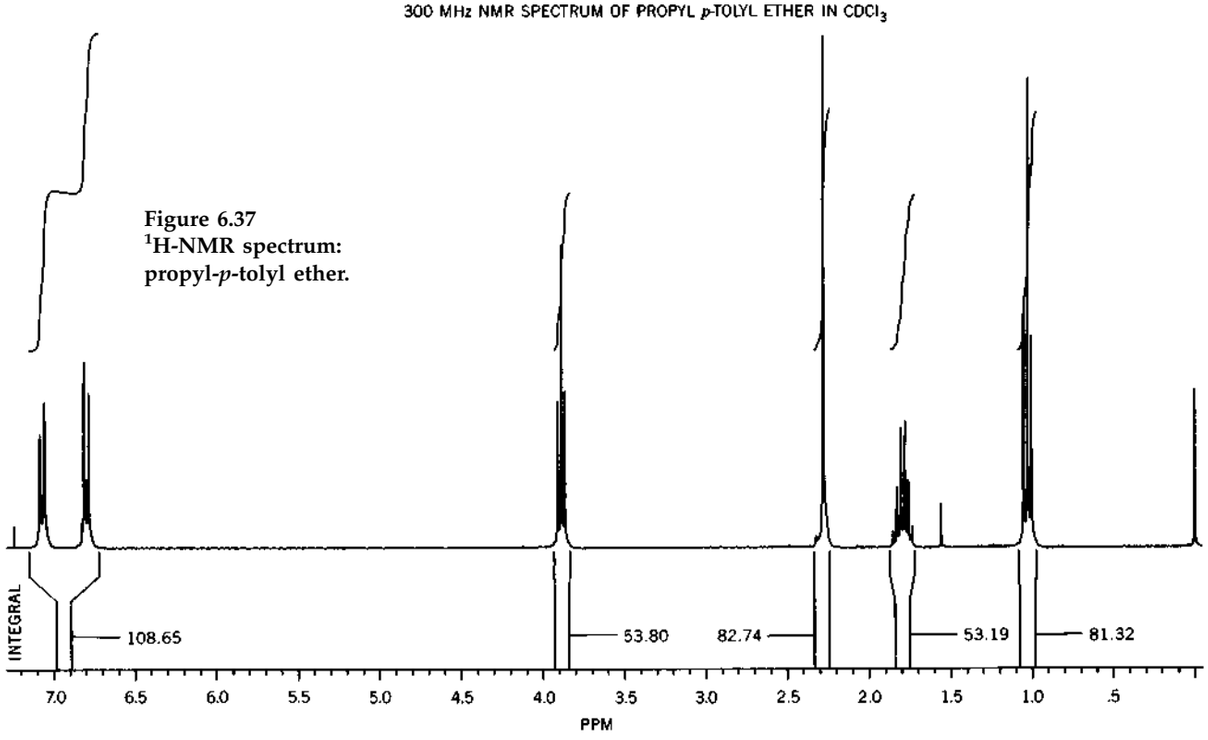

Figure 6.37
^{1}H-NMR spectrum: propyl-*p*-tolyl ether.

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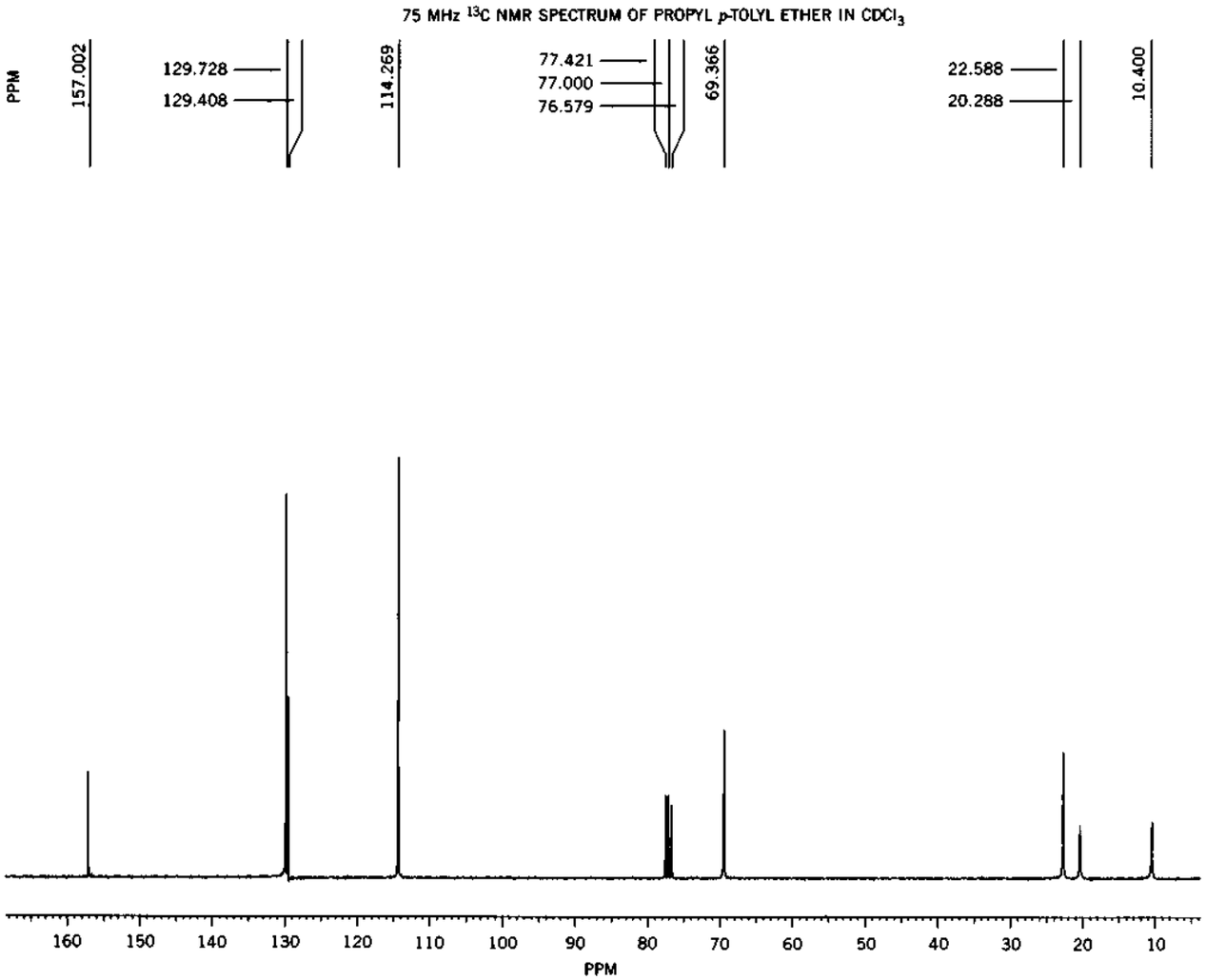

Figure 6.38 **^{13}C-NMR spectrum: propyl *p*-tolyl ether.**

3. Stir the reaction mixture at reflux temperature for 90 min.

Isolation of Product. Allow the solution to cool to room temperature, transfer it to a 125-mL separatory funnel, and remove the aqueous layer. Store the aqueous layer in a 125-mL Erlenmeyer flask. Wash the organic layer successively with 5% NaOH solution (20 mL) and distilled H_2O (20 mL). After each washing, remove the aqueous phase and add it to the 125-mL Erlenmeyer flask, which should be kept until the final product has been purified and characterized. Collect the remaining deep-red organic layer in a 125-mL Erlenmeyer flask, and dry it over anhydrous sodium sulfate.

Remove the drying agent by filtration through a glass wool plug and collect the product ether in a tared container. Weigh, calculate the percent yield, and then purify and characterize a small amount of the material as described in the microscale procedure.

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EQA

Methyl *p*-Ethylphenyl Ether

Experiment 22B

REACTION

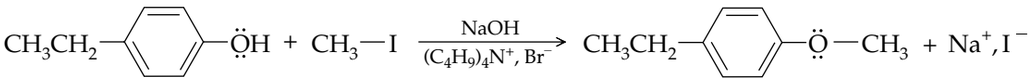

4-Ethylphenol Methyl iodide Methyl *p*-ethylphenyl ether

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
4-Ethylphenol	122.17	150 mg	1.2	42–45			
25% NaOH solution		250 μL					
Tetrabutylammonium bromide	322.38	15 mg	0.047	103–104			
Methyl iodide	141.94	90 μL	1.45		41–43	2.28	1.5304

Reagents and Equipment. Use the same apparatus as in Experiment [22A] for this synthesis. Weigh and add 150 mg (1.2 mmol) of 4-ethylphenol to the reaction vial followed by 250 μL of 25% aqueous sodium hydroxide solution (➡). Stir the mixture at room temperature until dissolution occurs. The phase-transfer catalyst (tetrabutylammonium bromide ($Bu_4N^+Br^-$), 15 mg, 0.05 mmol) is now added, followed by 90 μL (205 mg, 1.45 mmol) of methyl iodide.

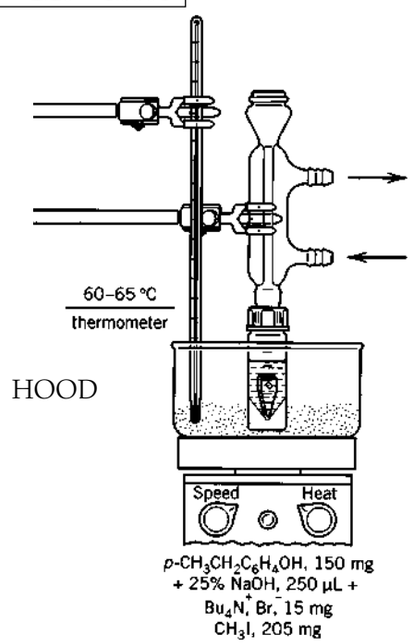

NOTE. Methyl iodide is toxic and must be dispensed in the ***hood.*** *Dispense both the alkaline solution and the methyl iodide using an automatic delivery pipet. Because of its volatility, methyl iodide is used in slight excess.*

Reaction Conditions. Place the reaction assembly in a sand bath maintained at 60–65 °C and stir the mixture for 1 h.

Isolation of Product. Work up the resulting product mixture as described in Experiment [22A].

Purification and Characterization. Purify the crude product by chromatography on silica gel as described in Experiment [22A], Purification and Characterization (➡).

Weigh the pure methyl *p*-ethylphenyl ether and calculate the percent yield. Determine the boiling point and density (optional). Compare your results with the values reported in the literature.

Obtain the IR spectrum of the compound and compare it with that in Figure 6.39.

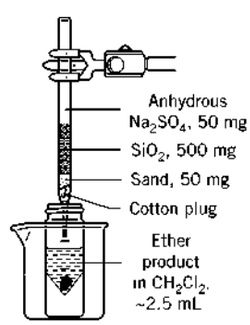

Nuclear Magnetic Resonance Analysis. If facilities permit, you can obtain both ^1H and ^{13}C NMR spectra of your methyl *p*-ethylphenyl ether in

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EQA

$CDCl_3$, and compare your spectra with those in Figures 6.40 and 6.41. There are two extraneous peaks in the ^1H spectrum: The small singlet at 7.24 ppm is due to residual $CHCl_3$ in the $CDCl_3$ and the small singlet at 1.55 ppm is probably due to a trace amount of water in either the sample or the NMR solvent. The 1:1:1 triplet at 77 ppm in the ^{13}C spectrum is from the $CDCl_3$ solvent.

Since the ^1H spectrum is entirely first order, it can be readily interpreted. You should be able to use the splitting patterns to assign peaks to each of the different groups of protons in the molecule. The integration can assist you.

Chemical Tests. Qualitative chemical tests can also be used to assist in characterizing this compound as an ether. Perform the ignition test (Table 9.1) to determine whether the material contains an aromatic ring.

A key factor to investigate is the solubility characteristics of this material (see Chapter 9). Determine its solubility in water, 5% sodium hydroxide, 5% hydrochloric acid, concentrated sulfuric acid, and 85% phosphoric acid. Do the results place this compound in the solubility class of an ether containing fewer than 8, or more than 8, carbon atoms?

Does the ferrox test (Chapter 9) confirm the presence of oxygen in the compound?

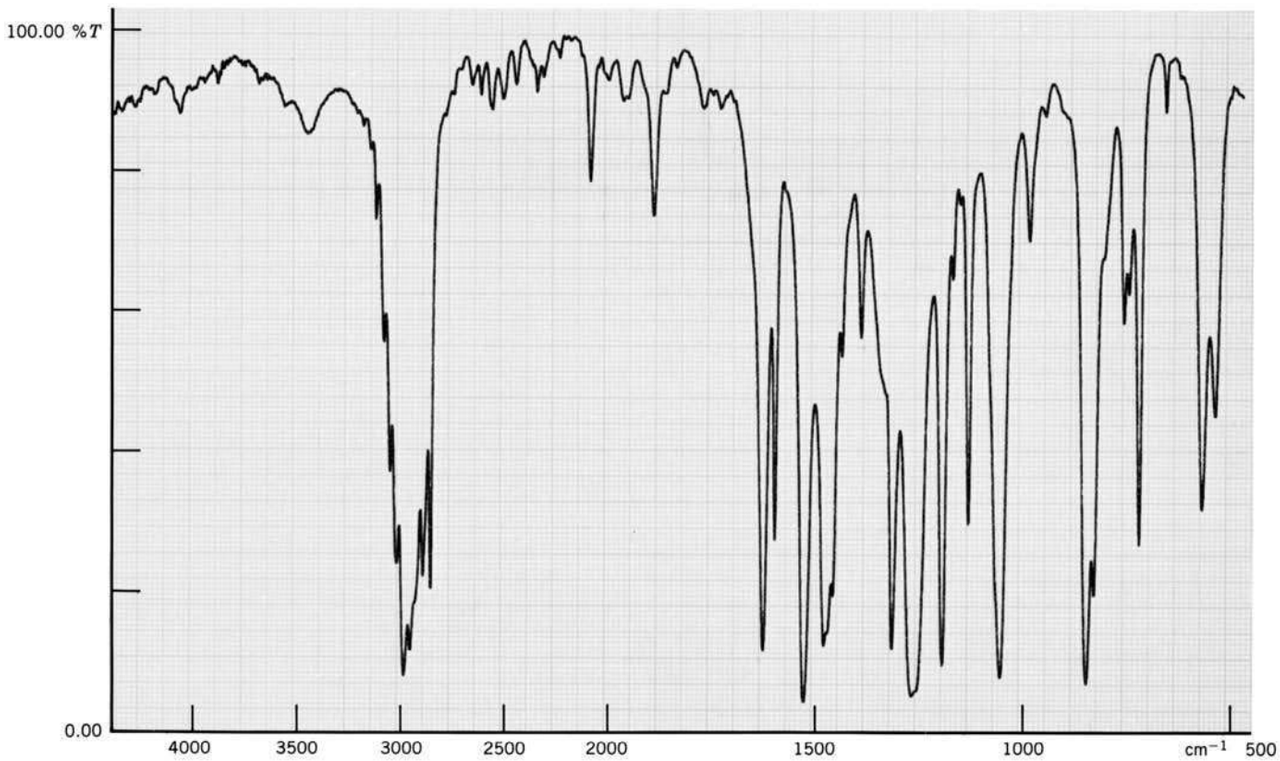

Figure 6.39 IR spectrum: methyl *p*-ethylphenyl ether.

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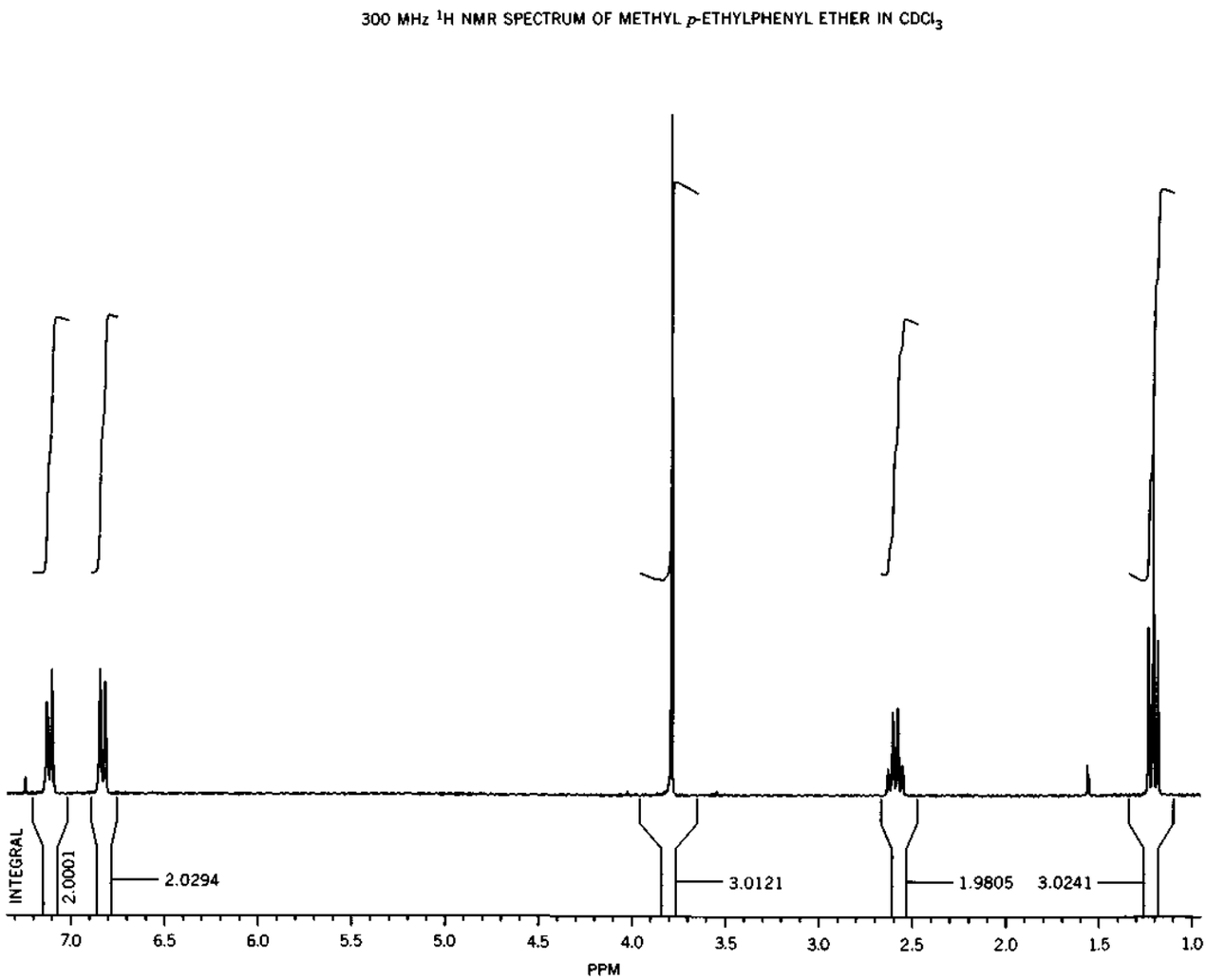

Figure 6.40 ^{1}H-NMR spectrum: methyl *p*-ethylphenyl ether.

OPTIONAL SEMIMICROSCALE AND MACROSCALE PREPARATIONS

If desired, this experiment can be scaled up by a factor of 10 or more.

Tenfold Scaleup. The reagent and solvent amounts are given in the following table.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
4-Ethylphenol	122.17	1.5 g	12.3	42–45			
NaOH	40.0	625 mg	15.6				
Tetrabutylammonium bromide	322.38	150 mg	0.47	103–104			
Methyl iodide	141.94	2.05 g	14.5		41–43	2.28	1.5304
Water		2.5 mL					

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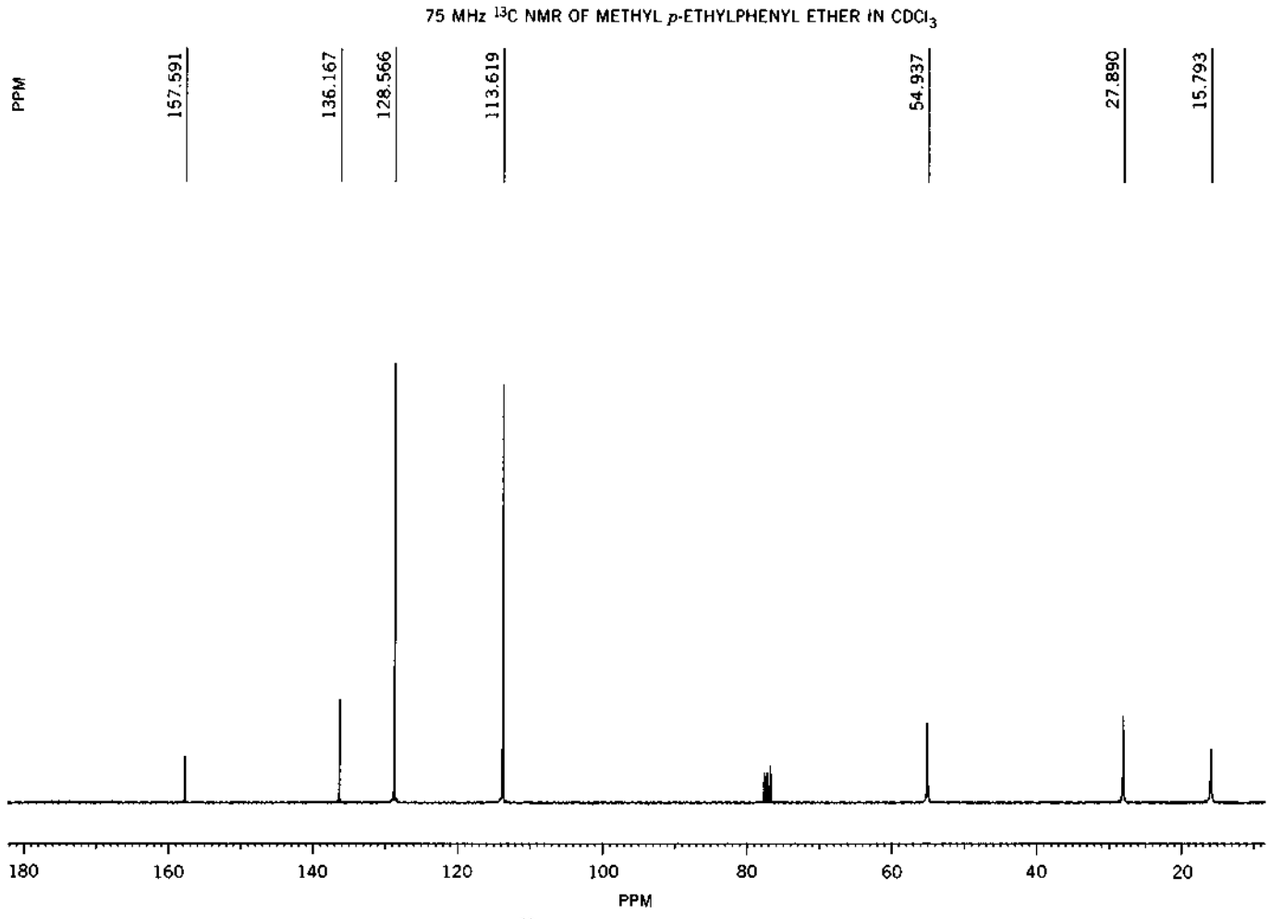

Figure 6.41 **^{13}C-NMR spectrum: methyl *p*-ethylphenyl ether.**

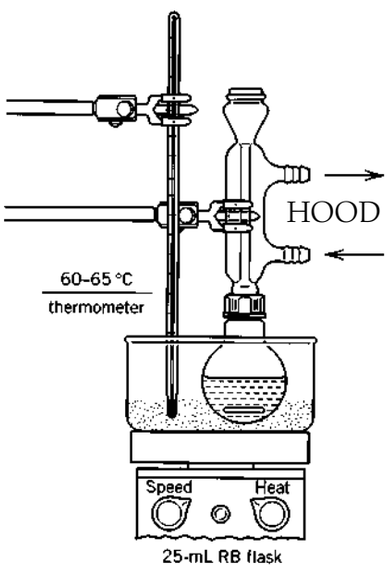

Reagents and Equipment. In a 25-mL round-bottom flask equipped with a stirring bar and a reflux condenser, place 2.5 mL of water and 1.5 g (12 mmol) of *p*-ethylphenol (the phenol will not be water soluble). Cool the mixture by immersing the flask in a beaker of cold water, and then, with stirring, **cautiously** add 625 mg of sodium hydroxide.

After dissolution of the sodium hydroxide, weigh and add 150 mg of the phase-transfer catalyst, tetrabutylammonium bromide, followed by 2.05 g (900 μL) of methyl iodide (in the **hood**) using an automatic delivery pipet (⬅).

Reaction Conditions. Place the reaction vessel in a sand bath, and heat the reaction mixture, with stirring, at 60–65 °C for 1 h.

Isolation of Products. Cool the resulting two-phase mixture to room temperature and then transfer it by Pasteur pipet to a 15-mL centrifuge tube. Wash the reaction flask with three 1-mL portions of diethyl ether and transfer the washings to the centrifuge tube. Cap the tube, shake, and vent (this operation may be done using a Vortex mixer if available), and allow the layers to separate. Remove the lower aqueous layer using a Pasteur filter pipet,

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and save it in a 10-mL Erlenmeyer flask until the final product has been purified and characterized.

NOTE. Do not remove any precipitated material that settles between the two layers.

Extract the ether layer with one 2-mL portion of 5% sodium hydroxide solution and then with 1 mL of water. Add these washings to the 10-mL Erlenmeyer flask.

Purify the crude product by chromatography on silica gel. Prepare a column by placing 5 g of activated silica gel in a 25-mL buret, followed by 0.5 g of anhydrous sodium sulfate. Dissolve the wet ether extract obtained above in 2.5 mL of methylene chloride and transfer the resulting solution by Pasteur pipet to the dry column. Elute the sample with an additional 20 mL of methylene chloride. Collect the eluate in a tared 50-mL Erlenmeyer flask containing a boiling stone. Evaporate the solvent by placing the flask in a sand bath maintained at 60–65 °C in the **hood.** Use a gentle stream of nitrogen or dry air to hasten the process. HOOD

Weigh the resulting product and calculate the percent yield. Characterize the product as outlined above in the microscale procedure.

Eightyfold Scaleup. The reagent and solvent amounts are given in the following table.

Physical Properties of Reactants

Compound	MW	Amount	mol	mp (°C)	bp (°C)	*d*	n_D
4-Ethylphenol	122.17	12.5 g	0.102	42–45			
NaOH	40.0	4.0 g	0.10				
Tetrabutylammonium bromide	322.38	0.40 g	0.0012	103–104			
Methyl iodide	141.94	14.5 g	0.102		41–43	2.28	1.5304
Water		25 mL					

Reagents and Equipment. Use a 100-mL round-bottom flask containing a magnetic stirring bar and equipped with a reflux condenser (➡).

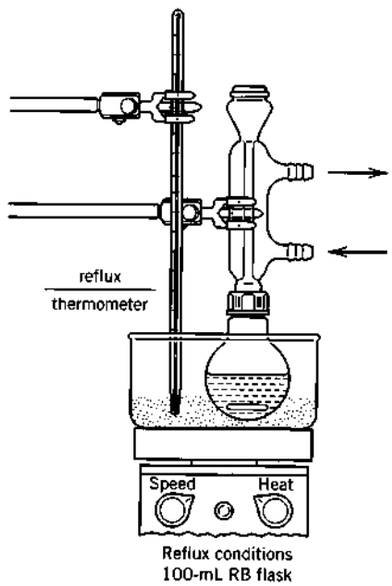

Reflux conditions
100-mL RB flask

Reaction Conditions. Heat the reaction mixture at reflux, with stirring, for 90 min.

Isolation of Product. Allow the two-phase mixture to cool to room temperature. Transfer this mixture to a 125-mL separatory funnel and remove the aqueous layer. Store this in a 125-mL Erlenmeyer flask until the final product has been purified and characterized. Wash the organic layer successively with 5% sodium hydroxide solution (20 mL) and distilled water (20 mL). After each washing remove the aqueous layer and add it to the 125-mL Erlenmeyer flask. Finally, collect the reddish-brown organic layer in another 125-mL Erlenmeyer flask and dry it over anhydrous sodium sulfate.

Remove the drying agent by filtration through a glass wool plug and collect the product ether in a tared container. Weigh, calculate the percent yield, and then characterize the material as described in the microscale procedure.

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EQA

Experiment 22C* Butyl *p*-Nitrophenyl Ether: Preparation Using a Monomode Microwave Apparatus

M

REACTION

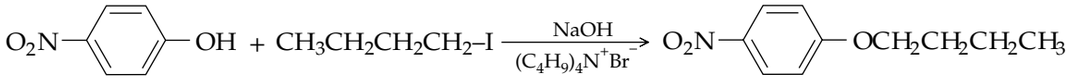

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
p-nitrophenol	139	215 mg	1.55	110–115			
1-iodobutane	184	0.17 mL	1.49		130–131	1.617	1.498
Tetrabutylammonium bromide	322	20 mg	0.06	103–104			
15% NaOH solution		2 mL					

Reagents and Equipment. This experiment is designed for use in the CEM Discover and Biotage Initator microwave units.

In a 10.0-mL glass microwave reaction vessel containing a magnetic stir bar, place 215 mg (1.55 mmol) of *p*-nitrophenol, 20 mg (0.06 mmol) of tetrabutylammonium bromide, 2 mL of 15% sodium hydroxide solution, and 0.17 mL (1.49 mmol) of 1-iodobutane. Immediately cap the vessel with the microwave pressure cap.

HOOD

CAUTION: 1-iodobutane is toxic and must be dispensed in the **hood.** Dispense both the 1-iodobutane and alkaline solution using an automatic delivery pipet. Since the reaction requires heating the reaction mixture to above the boiling point of some components in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

Reaction Conditions. Place the reaction vessel in the microwave cavity and, depending on the equipment used, position the pressure device on top. Program the microwave unit to heat the reaction mixture to 150 °C using no more that 50 W of microwave power, and hold at this temperature for 5 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the tube from the microwave unit.

Isolation of Product. Transfer the reaction mixture with a Pasteur pipet into a 30-mL separatory funnel. Clamp the funnel to a ring stand. Rinse the microwave reaction vessel with 2.0 mL of diethyl ether and add the washings to the separatory funnel. Carefully cap and invert the funnel. Immediately vent the funnel by opening the stopcock. Close the stopcock, place the funnel back on the ring stand and remove the stopper. Drain the lower (aqueous) layer into a 50-mL Erlenmeyer flask. Extract the crude organic layer with an additional two 5-mL portions of 5% sodium hydroxide solution, followed by 5 mL of water. During each extraction, cap and invert the funnel several times and each time release the pressure by opening the stopcock and then allow the funnel to stand so the layers will separate. Remove the lower

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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(aqueous) layer after each extraction into the 50-mL Erlenmeyer flask. Save the aqueous waste until the experiment is complete and then discard as directed. Dry the organic layer by pipetting it into a clean 25-mL Erlenmeyer flask containing 200 mg of anhydrous sodium sulfate. Transfer the anhydrous solution, using a Pasteur filter pipet, to a clean tared 10-mL pear-shaped flask. Remove the ether on a rotary evaporator or by evaporation in the **hood** using a gentle stream of nitrogen gas with warming in a sand bath to isolate the crude product. Reweigh the flask and calculate the crude yield.

HOOD

Purification and Characterization. The crude product can be further purified by recrystallization from 95% ethanol using a Craig tube.

Weigh the pure butyl *p*-nitrophenyl ether and calculate the percent yield. Determine the melting point and compare the experimental values with those in the literature.

Obtain an IR spectrum of the compound and compare it to that shown in Figure 6.42 for 4-butoxy nitrobenzene (butyl *p*-nitrophenyl ether).

Nuclear Magnetic Resonance Analysis. If facilities permit, you can obtain both ^{1}H and ^{13}C NMR spectra of your butyl *p*-nitrophenyl ether in $CDCl_3$, and compare your spectra with those in Figures 6.43 and 6.44.

^{13}C NMR ($CDCl_3$): δ 164.3, 141.4, 125.8, 114.5, 68.6, 31.1, 19.2, 13.8

^{1}H NMR ($CDCl_3$): δ 8.2 (d, J = 9.1, 2H), 7.93 (d, J = 9.2, 2H), 4.05 (t, J = 6.5, 2H), 1.8 (m, J = 8.0, J = 6.5, 2H), 1.6 (m, J = 8.0, J = 7.4, 2H), 1.0 (t, J = 7.4, 3H)

IR (neat, HATR) 3114, 2955, 2873, 1594, 1509, 1261, 1175, 1109, 846 cm^{-1}

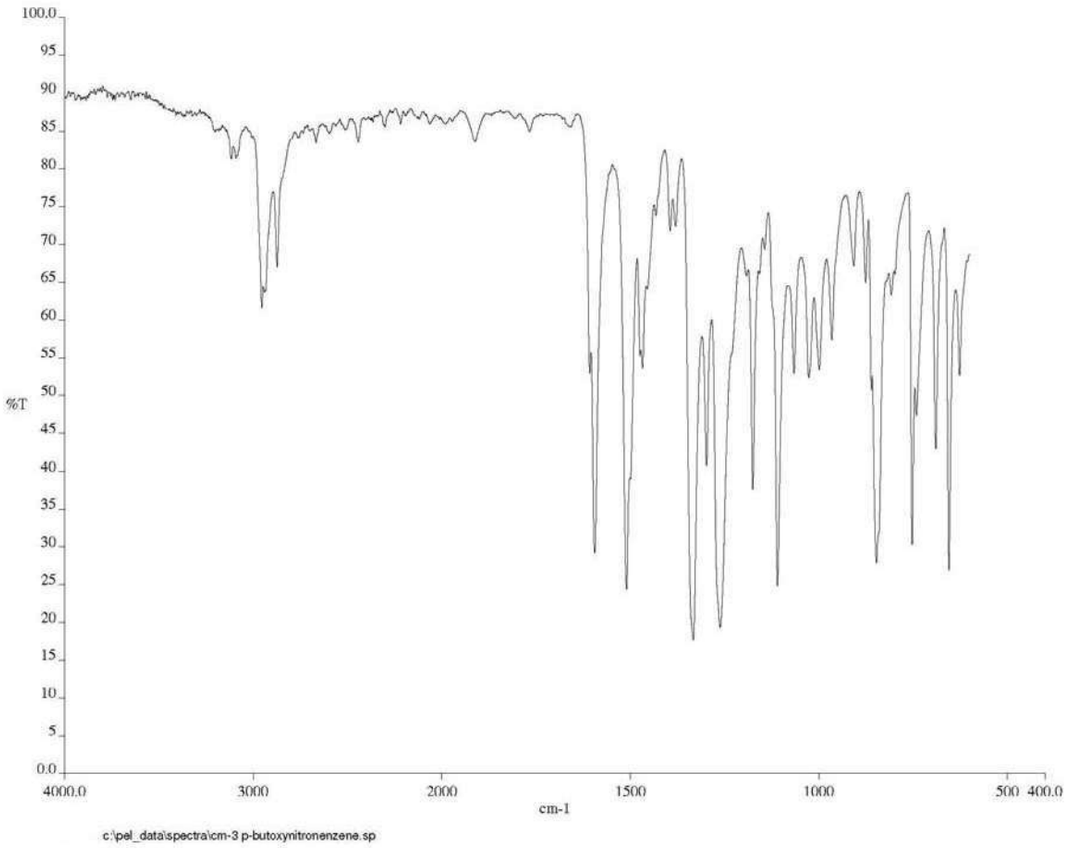

Figure 6.42 HATR-IR spectrum: butyl *p*-nitrophenyl ether.

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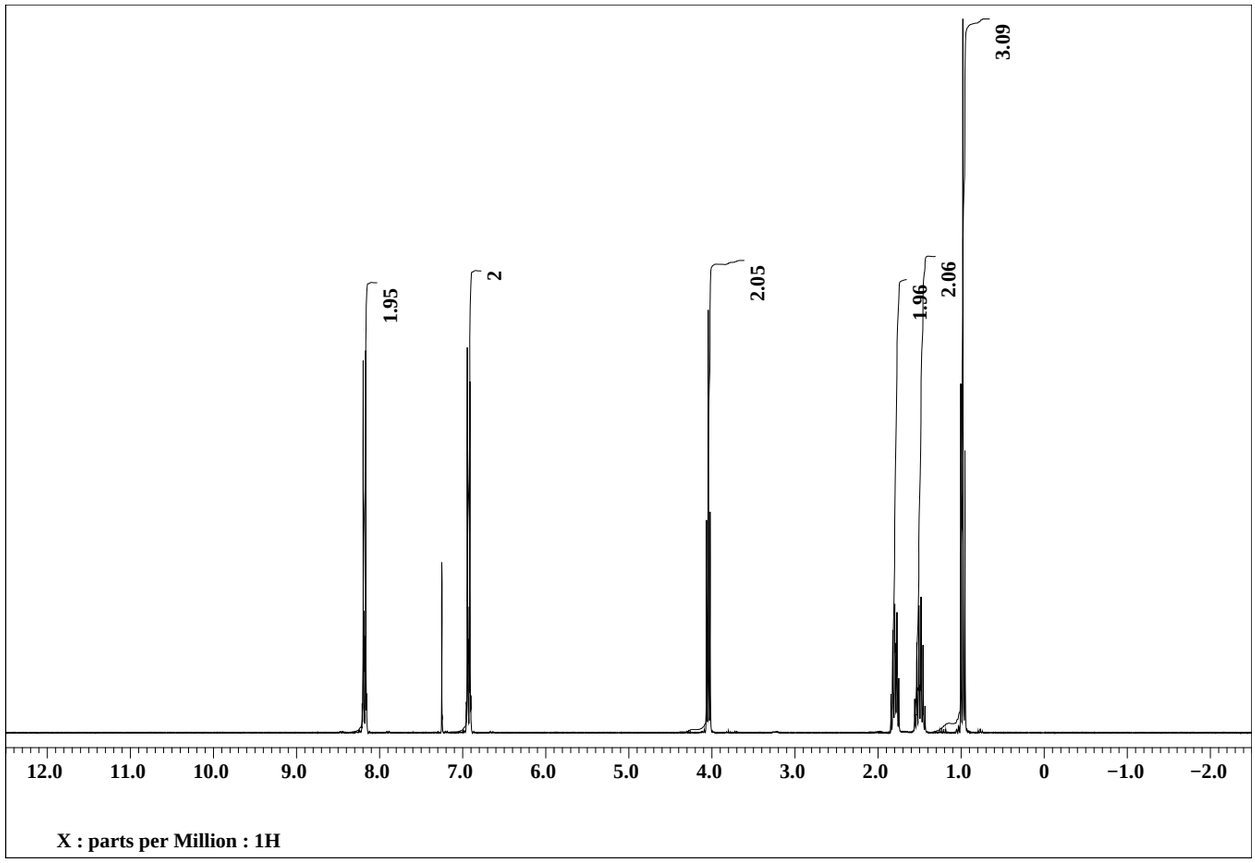

Figure 6.43 ^{1}H-NMR spectrum: butyl *p*-nitrophenyl ether in $CDCl_3$.

Experiment 22D*

Butyl *p*-Nitrophenyl Ether: Preparation Using a Multimode Microwave Apparatus

M

REACTION

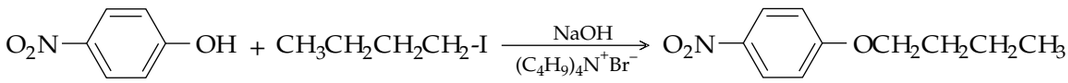

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
p-nitrophenol	139	215 mg	1.55	110–115			
1-iodobutane	184	0.17 mL	1.49		130–131	1.617	1.498
Tetrabutylammonium bromide	322	20 mg	0.06	103–104			
15% NaOH solution		5 mL					

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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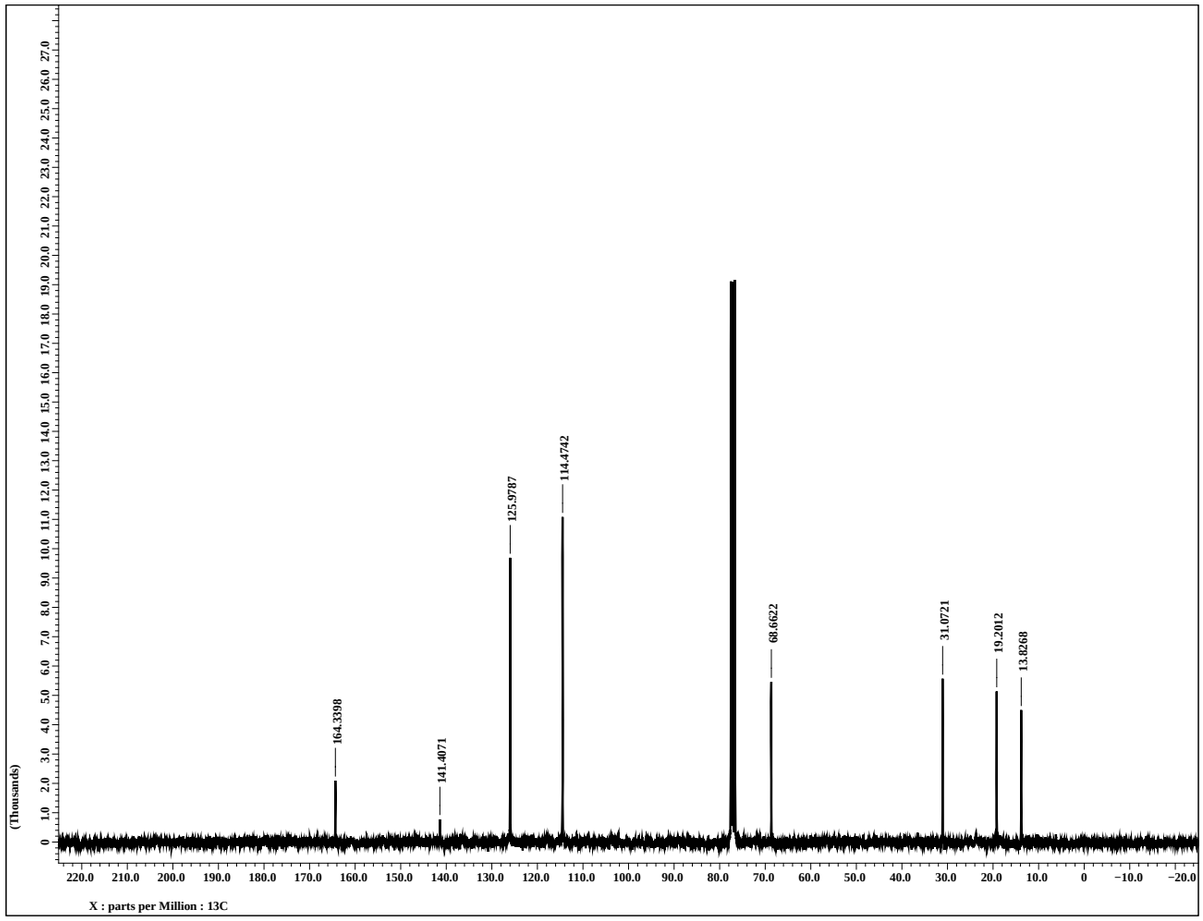

Figure 6.44 **^{13}C-NMR spectrum: butyl *p*-nitrophenyl ether in $CDCl_3$.**

Reagents and Equipment. This experiment is designed for use in the CEM MARS, Milestone START, and Anton Paar Synthos 3000 microwave units. When using the Anton Paar Synthos 3000 unit with the 24-position silicon carbide plate rotor containing glass vials, the reagent and solvent quantities cited in the monomode procedure should be used in conjunction with the reaction conditions here in the multimode procedure.

In a microwave reaction vessel containing a magnetic stir bar, place 215 mg (1.55 mmol) of *p*-nitrophenol, 20 mg (0.06 mmol) of tetrabutylammonium bromide, 5 mL of a 15% sodium hydroxide solution, and 0.17 mL (1.49 mmol) of 1-iodobutane. Immediately cap the vessel with the microwave pressure cap and adjust the tightness to the manufacturer-specified level. Place the sealed vessel into its outer protective jacket.

CAUTION: 1-iodobutane is toxic and must be dispensed in the **hood.** Dispense both the 1-iodobutane and alkaline solution using an automatic delivery pipet. Since the reaction requires heating the reaction mixture to above the boiling point of some components in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential.* HOOD

Reaction Conditions. Insert the loaded vessels into the reaction carousel ensuring they are evenly spaced and then place the carousel into the microwave

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cavity. If provided by the manufacturer, connect a temperature probe to the control vessel. Program the microwave unit to heat the reaction vessels to 150 °C and hold at this temperature for 5 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the carousel from the microwave unit.

Isolation of Product. Transfer the reaction mixture with a Pasteur pipet into a 30-mL separatory funnel. Clamp the funnel to a ring stand. Rinse the microwave reaction vessel with 2.0 mL of diethyl ether and add the washings to the separatory funnel. Carefully cap and invert the funnel. Immediately vent the funnel by opening the stopcock. Close the stopcock, place the funnel back on the ring stand and remove the stopper. Drain the lower (aqueous) layer into a 50-mL Erlenmeyer flask. Extract the crude organic layer with an additional two 5-mL portions of 5% sodium hydroxide solution, followed by 5 mL of water. During each extraction, cap and invert the funnel several times and each time release the pressure by opening the stopcock and then allow the funnel to stand so the layers will separate. Remove the lower (aqueous) layer after each extraction into the 50-mL Erlenmeyer flask. Save the aqueous waste until the experiment is complete and then discard as directed. Dry the organic layer by pipetting it into a clean 25-mL Erlenmeyer flask containing 200 mg of anhydrous sodium sulfate. Transfer the anhydrous solution, using a Pasteur filter pipet, to a clean tared 10-mL pear-shaped flask. Remove the ether on a rotary evaporator or by evaporation in the **hood** using a gentle stream of nitrogen gas with warming in a sand bath to isolate the crude product. Reweigh the flask and calculate the crude yield.

HOOD

Purification and Characterization. The crude product can be further purified by recrystallization from 95% ethanol using a Craig tube.

Weigh the pure butyl *p*-nitrophenyl ether and calculate the percent yield. Determine the melting point and compare the experimental values with those in the literature.

Obtain an IR spectrum of the compound and compare it to that shown in Figure 6.42 for 4-butoxy nitrobenzene (butyl *p*-nitrophenyl ether).

Nuclear Magnetic Resonance Analysis. If facilities permit, you can obtain both ^{1}H and ^{13}C NMR spectra of your butyl *p*-nitrophenyl ether in $CDCl_3$, and compare your spectra with those in Figures 6.43 and 6.44.

^{13}C NMR ($CDCl_3$): δ 164.3, 141.4, 125.8, 114.5, 68.6, 31.1, 19.2, 13.8

^{1}H NMR ($CDCl_3$): δ 8.2 (d, J = 9.1, 2H), 7.93 (d, J = 9.2, 2H), 4.05 (t, J = 6.5, 2H), 1.8 (m, J = 8.0, J = 6.5, 2H), 1.6 (m, J = 8.0, J = 7.4, 2H), 1.0 (t, J = 7.4, 3H)

IR (neat, HATR) 3114, 2955, 2873, 1594, 1509, 1261, 1175, 1109, 846 cm^{-1}

QUESTIONS

6-144. Sulfides are often prepared using an S_N2 reaction. For example,

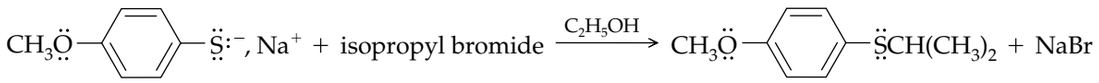

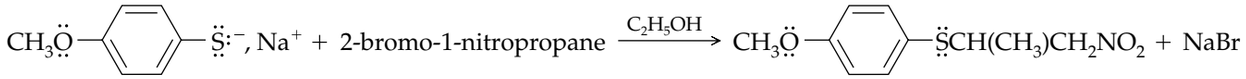

The reaction with isopropyl bromide is 16 times faster than the reaction with 2-bromo-1-nitropropane. Explain.

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6-145. If 3-bromo-1-propanol is treated with NaOH, a compound of molecular formula C_3H_6O is formed. Suggest a structure for this product.

6-146. Arrange the substituted phenols given below in order of increasing reactivity toward ethyl iodide in the Williamson reaction. After arranging and explaining your order, does this order match that of rates of deprotonation?

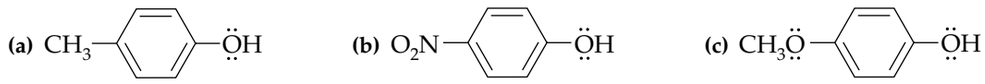

6-147. *trans*-2-Chlorocyclohexanol reacts readily with NaOH to form cyclohexene oxide, but the cis isomer will not undergo this reaction. Explain.

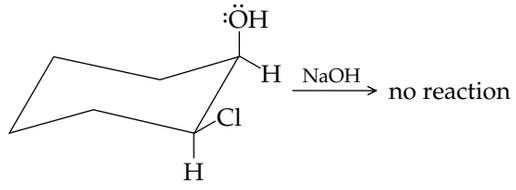

cis-2-Chlorocyclohexanol

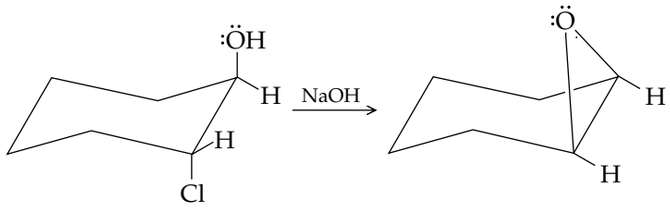

trans-2-Chlorocyclohexanol Cyclohexene oxide

6-148. *tert*-Butyl ethyl ether might be prepared two ways using different starting materials.

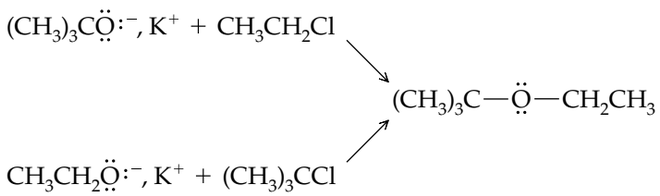

Which route would you choose to prepare the above ether, and why?

6-149. What product(s) would you expect to form when tetrahydrofuran is treated with excess hydroiodic acid (HI)?

6-150. Write a suitable mechanism for the cleavage of butyl isopropyl ether with HI at 100 °C to form exclusively isopropyl alcohol and 1-iodobutane. Explain why butyl alcohol and isopropyl iodide are not formed in the reaction.

6.151. There are only four lines in the aromatic region of the fully ^1H decoupled ^{13}C NMR spectrum of propyl *p*-tolyl ether (110–160 ppm), yet there are six aromatic carbon atoms. Explain.

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Gokel, G. W.; Weber, W. P. *J. Chem. Educ.* **1978,** *55,* 350; *ibid.,* 429.
Smith, M. B.; March. J. *Advanced Organic Chemistry*, 6th ed.; Wiley-Interscience: New York, 2007, Chap. 10, p. 508.

The procedures used in these experiments for the preparation of the ethers were adapted from the work of

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Rowe, J. E. *J. Chem. Educ.* **1980,** *57,* 162.

EXPERIMENT 23

Amide Synthesis: Acetanilide and N,N′*-Diacetyl-1,4-phenylenediamine*

Common name: acetanilide
CA number: [103-84-4]
CA name as indexed: acetamide, *N*-phenyl-
Common name: *N,N′*-diacetyl-1,4-phenylenediamine
CA number: [140-50-1]
CA name as indexed: acetamide, *N,N′*–1,4-phenylenebis-

Purpose. You will carry out one of the major synthetic routes used in the preparation of amides; the method involves the reaction of ammonia, or a primary or secondary amine, with an active acylating reagent. You will also explore the use of acetic anhydride as an acylating agent. The acetanilide product (Experiment [23A]) may be used in Experiment [28].

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)

REACTION

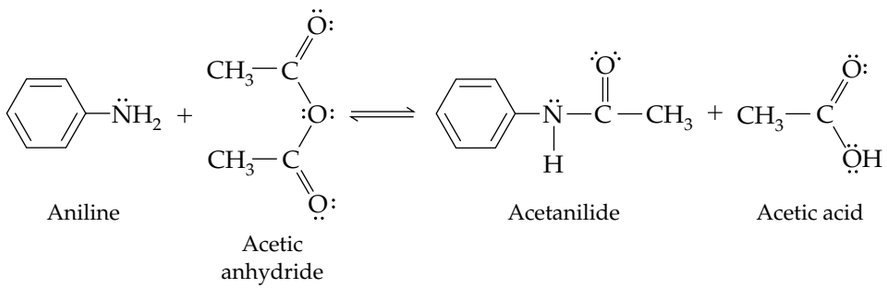

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DISCUSSION

A number of important chemical and biochemical synthetic sequences are initiated by the addition of a nitrogen nucleophile to a carbonyl carbon atom to yield **carboxylic amides.** Amides are classified as **primary (1°), secondary (2°)** or **tertiary (3°)** based on the number of carbon atoms attached to the nitrogen.

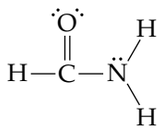

1° Amide
Methanamide
(formamide)

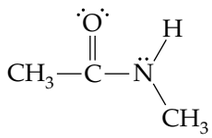

2° Amide
N-Methylethanamide
(*N*-methylacetamide)

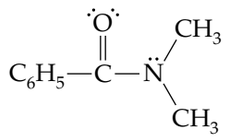

3° Amide
N,N-Dimethylbenzamide

Cyclic amides are called **lactams** and are classified by ring size. Imides contain a nitrogen bonded to two carbonyl groups and are nitrogen analogues of anhydrides.

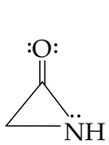

An α-lactam

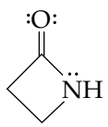

A β-lactam

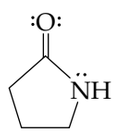

A γ-lactam

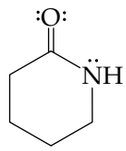

A δ-lactam

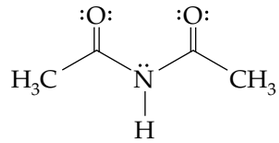

An imide

Amides appear in such diverse compounds as penicillin V (a β-lactam and an amide) and polypeptides (α-amino acids linked by amide bonds); and an imide, 1,2-benzenecarboxylic imide, is used in the Gabriel synthesis of amines. An imide is prepared in Experiment [24] and anhydrides are prepared in Experiments [25A] and [25B]. The polyamide polymer, nylon, is prepared in Chapter 7, Sequence B.

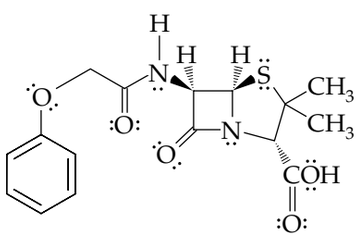

Penicillin V

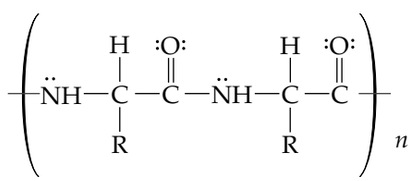

A polypeptide

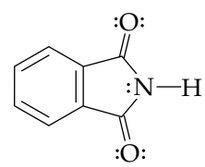

1,2-Benzenecarboxylic imide

The experiments outlined here illustrate the preparation of 2° amides. The process involves the attack of a primary amine on the acetyl group of acetic anhydride. Ammonia or secondary amines also react readily with this reagent to yield 1° and 3° amides, respectively. The mechanism shown here

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EQA

is an example of the attack of a nucleophilic reagent on a carbonyl carbon of the anhydride:

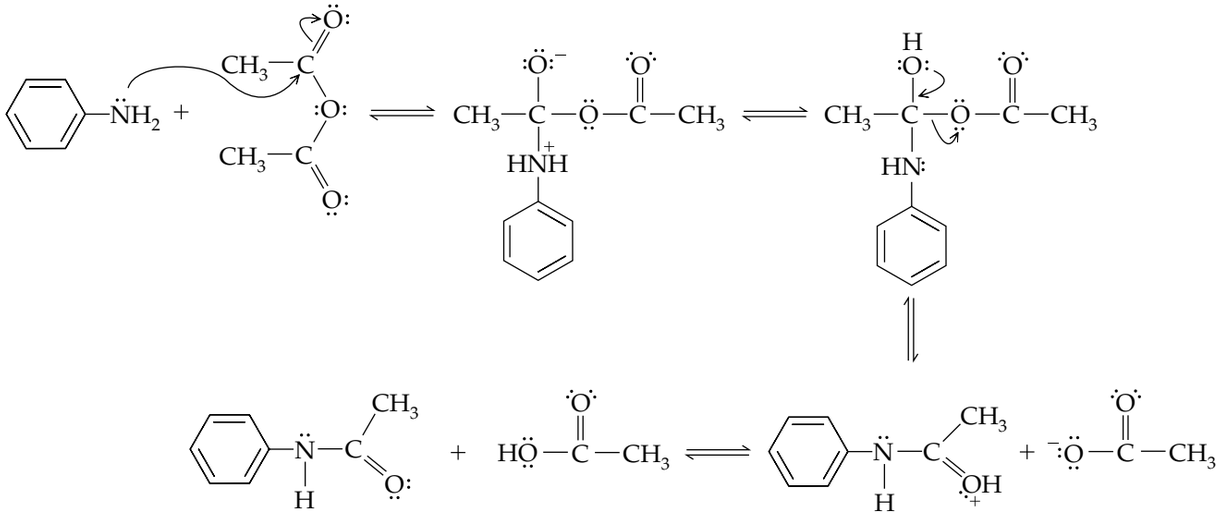

In the preparations given below, the amine reagents (aniline and *p*-phenylenediamine) are purified as their hydrochloride salts. Arylamines are relatively weak bases (K_b values in the order of 10^{-10}) but when treated with a strong acid, such as HCl, they are completely protonated, yielding the corresponding water-soluble hydrochloride salt:

$$\underset{\text{Aniline}}{C_6H_5{-}NH_2} + HCl \rightarrow \underset{\substack{\text{Anilinium hydrochloride salt} \\ \text{(water soluble)}}}{C_6H_5{-}NH_3^+, Cl^-}$$

As directed in the experiment, decolorizing charcoal is added to the aqueous solution of the arylamine salt. The charcoal absorbs impurities and subsequent filtration of the mixture, which removes the charcoal, yields an aqueous solution of the purified arylamine salt.

The second stage of the reaction sequence requires that a solution of sodium acetate be added to the reaction mixture after initial addition of acetic anhydride to the purified anilinium hydrochloride salt solution:

$$C_6H_5{-}NH_3^+, Cl^- + CH_3COO^-, Na^+ \rightleftharpoons C_6H_5{-}NH_2 + CH_3COOH + Na^+, Cl^-$$

Addition of the sodium acetate solution serves to liberate the arylamine so that the desired nucleophilic substitution reaction may occur; ammonium cations are not nucleophilic, since they are positively charged and do not even possess a lone pair of electrons.

Sodium acetate is the conjugate base of acetic acid, which is a weak acid. Furthermore, the anilinium ion ($pK_a = 4.6$) is a slightly stronger acid than acetic acid ($pK_a = 4.8$). Thus, the equilibrium reaction is shifted to the right, producing the arylamine.

In Experiment [23B], the *p*-phenylenediamine forms the corresponding dihydrochloride salt, $Cl^- \cdot H_3N^{\pm}{-}C_6H_4{-}^{\pm}NH_3 \cdot Cl^-$. As in Experiment [23A], the

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EQA

aqueous solution of the salt is purified with charcoal, and upon addition of the sodium acetate solution, the free amine is regenerated.

This overall process illustrates an important transformation for most amines. These amines can be converted to water-soluble ionic salts by reaction with acids and can be recovered from these acid salts by treatment with base. This technique was used in Experiment [4C] to extract ethyl 4-aminobenzoate, as its water-soluble salt, from a mixture.

Acetanilide

Experiment 23A

The reaction is shown above.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Aniline	93.13	100 μL	1.09		184	1.02	1.5863
Concd HCl		3 drops					
Sodium acetate trihydrate	136.08	150 mg	1.10	58			
Acetic anhydride	102.09	150 μL	1.59		140	1.08	1.3901

Reagents and Equipment. In the **hood,** place 100 μL of aniline in a tared 10 × 75-mm test tube (standing in a small beaker or Erlenmeyer flask). Fit the tube with a cork stopper.

HOOD

CAUTION: Aniline is a toxic material and a cancer suspect agent.

NOTE. Dispense the aniline using an automatic delivery pipet. Again weigh the test tube and container to determine the exact amount of aniline delivered.

Now using a 1.0-mL graduated pipet add, with swirling, 0.5 mL of water; then, in the **hood,** add 3 drops of concentrated hydrochloric acid using a Pasteur pipet. Add 10 mg of powdered decolorizing charcoal, or the pelletized form (Norit), to the resulting solution.

HOOD

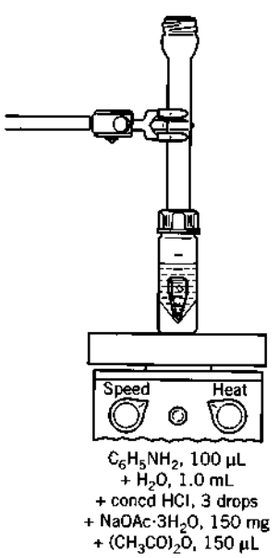

Using a Pasteur pipet, transfer the well-mixed suspension to a 25-mm funnel fitted with fast-grade filter paper to remove the charcoal by gravity filtration. *Wet the filter paper in advance with distilled water and blot the excess water from the stem of the funnel.*

Collect the filtrate in a 3.0-mL conical vial. Use an additional 0.5 mL of water to rinse the test tube and the collected charcoal. Combine the rinse with the original filtrate. Place a magnetic spin vane in the vial and attach it to an air condenser (➨).

NOTE. If the pelletized form of charcoal is used, transfer through a Pasteur filter pipet directly to the 3.0-mL conical vial should be sufficient.

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EQA

NOTE. Tap all of the filtrate from the funnel stem into the collecting vial. As a result of this purification step, a clear, colorless solution of aniline hydrochloride should be obtained.

Dissolve 150 mg (1.10 mmol) of sodium acetate trihydrate in 0.5 mL of distilled water in a 10 × 75-mm test tube. Cap the tube and set the solution aside for use in the next step.

Remove the air condenser, and then use an automatic delivery pipet in HOOD the **hood** to add, with stirring, 150 μL of acetic anhydride to the solution of aniline hydrochloride, followed quickly by addition (Pasteur pipet) of the previously prepared solution of sodium acetate. Reattach the air condenser.

Reaction Conditions. The reaction is very rapid and the product begins to precipitate immediately upon mixing of the reagents. Stir to thoroughly mix the reagents. Allow the reaction mixture to stand at room temperature for approximately 5 min and then place it in an ice bath for an additional 5–10 min to complete the crystallization process.

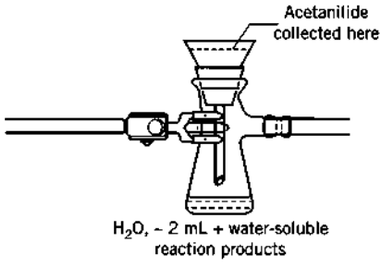

Isolation of Product. Collect the acetanilide product by filtration under reduced pressure using a Hirsch funnel (⬅). Rinse the conical vial with two 0.5-mL portions of water (using calibrated Pasteur pipet) and use the rinse to wash the collected filter cake. Place a piece of plastic food wrap over the mouth of the funnel and continue the suction for 5–8 min (see Prior Reading). The snow-white crystals are further dried on a porous clay plate or on filter paper in a desiccator.

Purification and Characterization. Further purification of the product is generally not required. However, the acetanilide may be recrystallized from hot water or from ethanol–water using the Craig tube.

NOTE. Acetanilide (150 mg) can be recrystallized from approximately 3 mL of water, or from 2 mL of ethanol–water (1:10 v/v), with better than 80% recovery.

Weigh the dried crystals and calculate the percent yield. Determine the melting point of the material and compare your result to that reported in the literature.

Obtain an IR and/or NMR spectrum of the product and compare it with that of an authentic sample or to that recorded in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or SciFinder Scholar).

Chemical Tests. Characterization of the product may be enhanced by performing several chemical tests given in Chapter 9.

Check the solubility of acetanilide in water. Is the aqueous solution acidic, basic, or does it remain neutral as indicated by pH paper? Does the ignition test indicate that an aromatic group is present? Does the soda lime or sodium fusion test indicate the presence of nitrogen? Does the hydroxamate test for amides give a positive result?

OPTIONAL SEMIMICROSCALE PREPARATION

This experiment can be scaled up to be run at five times the amounts used in the above microscale preparation.

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EQA

The procedure is identical to the above with the following exceptions.

1. Use two 15 × 100-mm test tubes.

2. Carry out the reaction in a 10-mL round-bottom flask containing a magnetic spin bar and fitted with an air condenser (➡).

3. Increase the amounts of all reagents and the solvent by a factor of 5.

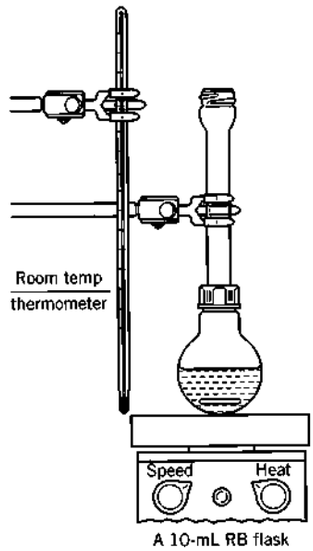

A 10-mL RB flask

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Aniline	93.13	500 μL	5.45		184	1.02	1.5863
Concd HCl		0.75 mL					
Sodium acetate trihydrate	136.08	750 mg	5.50	58			
Acetic anhydride	102.09	750 μL	7.93		140	1.08	1.3901

N,N′-Diacetyl-1,4-phenylenediamine

Experiment 23B

REACTION

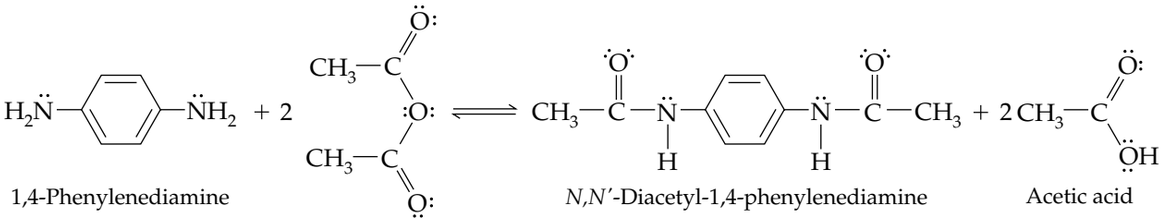

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
1,4-Phenylenediamine	108.14	117 mg	1.08	138			
Concd HCl		6 drops					
Sodium acetate trihydrate	136.08	300 mg	2.20	58			
Acetic anhydride	102.09	350 μL	3.71		140	1.08	1.3901

Reagents and Equipment. Weigh and place 117 mg (1.08 mmol) of 1,4-phenylenediamine in a 10 × 75-mm test tube (standing in a small beaker or Erlenmeyer flask).

CAUTION: This reagent is toxic and a cancer suspect agent.

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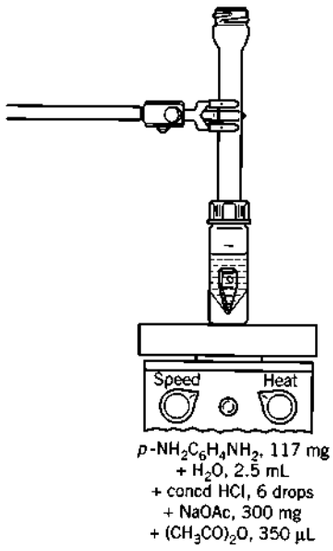

With gentle swirling, add 1.0 mL of distilled water and, using a Pasteur pipet, 6 drops of concentrated hydrochloric acid. After dissolution, add 30 mg of either powdered decolorizing charcoal (Norit) or the pelletized form. Transfer the well-mixed suspension, by use of a Pasteur pipet, to a 25-mm funnel fitted with fast-grade filter paper previously wet with water. The charcoal is removed by gravity filtration. Collect the filtrate, which is clear to slightly yellow, in a 5-mL conical vial containing a magnetic spin vane. Use three 0.5-mL portions of water (calibrated Pasteur pipet) to rinse the test tube, and in turn use the rinse to wash the collected charcoal. The rinse is combined with the original filtrate. *Blot the excess water from the stem of the funnel*. Attach the vial to an air condenser (⬅).

NOTE. If the pelletized form of charcoal is used, transfer through a Pasteur filter pipet directly to the 5.0-mL conical vial should be sufficient.

Dissolve 300 mg (2.20 mmol) of sodium acetate trihydrate in 0.5 mL of distilled water in a 10 × 75-mm test tube. Stir the mixture with a spatula to aid the dissolution process. Cap the tube and set it aside for use in the next step.

Reaction Conditions. Remove the air condenser, and use an automatic delivery pipet to add 350 µL of acetic anhydride to the solution of 1,4-phenylenediamine dihydrochloride, and stir the mixture briefly using a magnetic stirrer.

HOOD *NOTE. Dispense the acetic anhydride in the* **hood** *using an automatic delivery pipet. A slight amount of white precipitate may be observed at this stage.*

Now add the previously prepared sodium acetate solution by Pasteur pipet to the reaction mixture with stirring. Reattach the air condenser.

Isolation of Product. The reaction is very rapid and the desired product begins to precipitate almost immediately. After stirring briefly, allow the mixture to stand at room temperature for a few minutes and then place it in an ice bath for an additional 5–10 min.

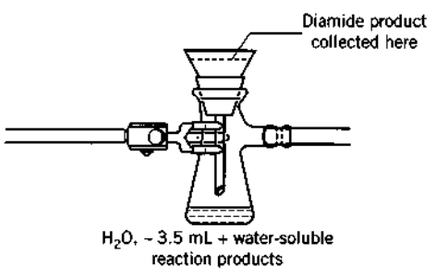

Purification and Characterization. Collect the crude *N,N′*-diacetyl-1,4-phenylenediamine by vacuum filtration using a Hirsch funnel (⬅). Rinse the vial with two 0.5-mL portions of water and use the rinse to wash the filter cake. Place a piece of plastic food wrap over the mouth of the funnel and continue the suction for an additional 5–8 min. Place the collected material on a porous clay plate or filter paper to dry further.

NOTE. If this material is to be used in Experiment [29B], recrystallization from methanol is suggested.

Weigh the dried crystals and calculate the percent yield. Determine the melting point and compare it with the value in the literature. Obtain an IR and/or the NMR spectrum of the product. The infrared spectrum is shown in Figure 6.45.

Chemical characterization tests might also be run as outlined in Experiment [23A].

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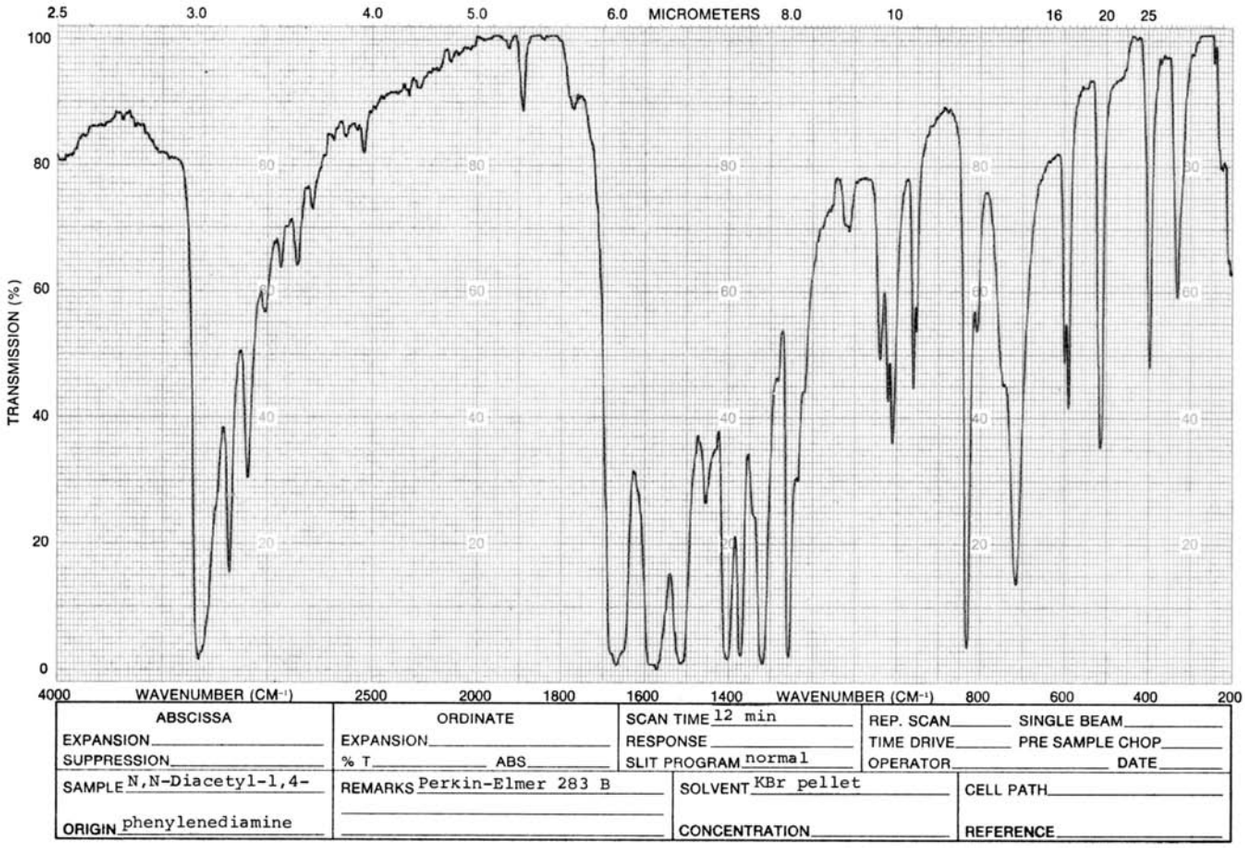

Figure 6.45 IR spectrum: *N,N′*-diacetyl-1,4-diphenylenediamine.

QUESTIONS

6-152. What is the function of the sodium acetate in the reactions outlined in this experiment?

6-153. Which is the stronger base: aniline or cyclohexylamine? Explain.

6-154. Arrange the following substituted anilines in increasing order of reactivity toward acetic anhydride:

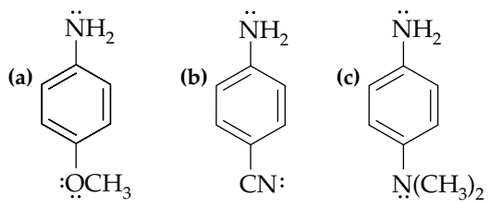

6-155. Suggest a mechanism for the preparation of acetic anhydride from acetic acid and acetyl chloride in the presence of pyridine (an amine base).

6-156. Anhydrides generally react more slowly with an amine than acid chlorides, though both reactions produce amides. Explain this observation.

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EQA

6-157.

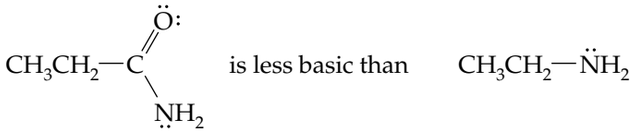

Explain.

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EXPERIMENT 24

Imide Synthesis: N-*Phenylmaleimide*

Common name: *N*-phenylmaleimide

CA number: [941-69-5]

CA name as indexed: 1*H*-pyrrole-2,5-dione, 1-phenyl-

Purpose. To extend the amide synthesis (Experiment [23]) to the preparation of imides. In this experiment, the condensation of a cyclic anhydride with aniline to form an imide is described. The initial reaction to give the carboxylic amide is followed by an intramolecular condensation to produce the desired imide derivative.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)

Technique 6A: Thin-Layer Chromatography (pp. 97–99)

REACTION

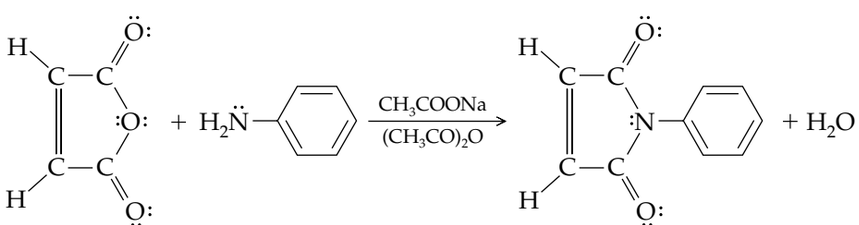

Maleic anhydride | Aniline | *N*-Phenylmaleimide

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EQA

DISCUSSION

Imides are diacyl derivatives of ammonia or primary amines. The reaction is similar in its scope and mechanism to the acetylation of aniline or 1,4-phenylenediamine presented in Experiments [23A] and [23B]. As illustrated in the present experiment, cyclic anhydrides produce cyclic imides. Cyclic anhydrides are prepared in Experiments [25A] and [25B]. Derivatives of imides have been suggested for use in the treatment of arthritis, tuberculosis, and epilepsy. Several also have been found to be growth stimulants. Imide-based polymers are used in many applications, including fire-resistant woven fabrics. The *N*-phenylmaleimide prepared in this experiment is also a good dienophile in the Diels–Alder reaction (see Experiments [14] and [15]), and in fact has been used as a reagent to characterize 1,3 dienes.

The first step in the reaction between the primary amine and the cyclic anhydride is an addition–elimination reaction, which involves a nucleophilic attack by the amine on a carbonyl carbon of the maleic anhydride. This results in the formation of an amide and a carboxylic acid, which are linked together to constitute maleanilic acid. Since anhydrides are considerably more reactive toward nucleophiles, to promote ring closure to the imide, the carboxylic acid is then converted to another (mixed) anhydride by reaction with acetic anhydride. This anhydride then undergoes an intramolecular nucleophilic addition–elimination by the amide nitrogen, which gives the desired imide, *N*-phenylmaleimide. The second acylation of a nitrogen nucleophile is much slower than the first. That is, attack of an amide nitrogen on the carbonyl carbon of the anhydride is slower than the attack of the amine nucleophile on the anhydride carbonyl carbon. The mechanistic sequence is given below (R = phenyl):

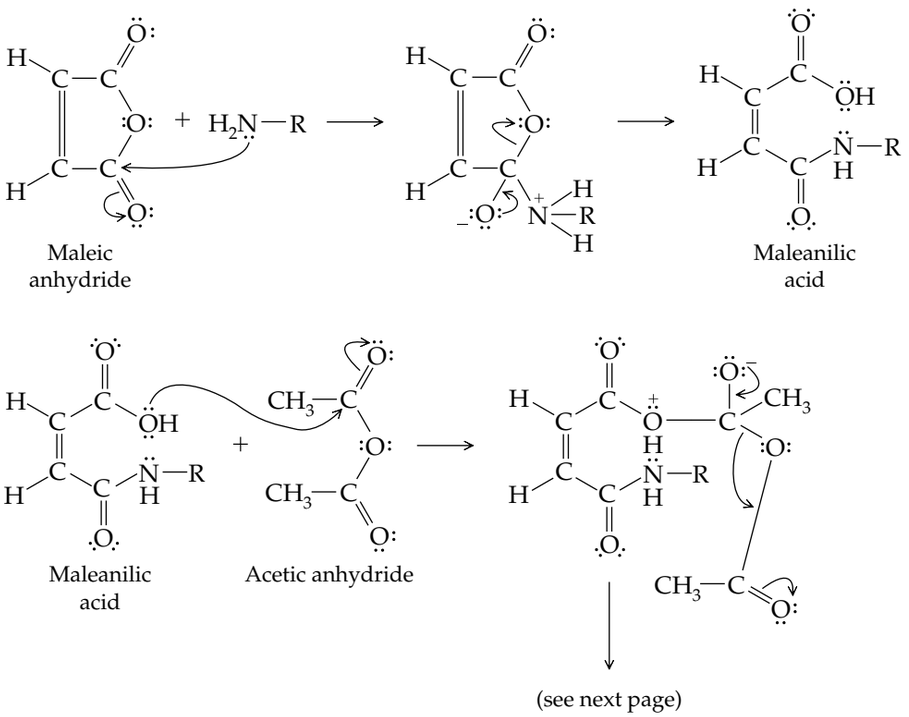

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EQA

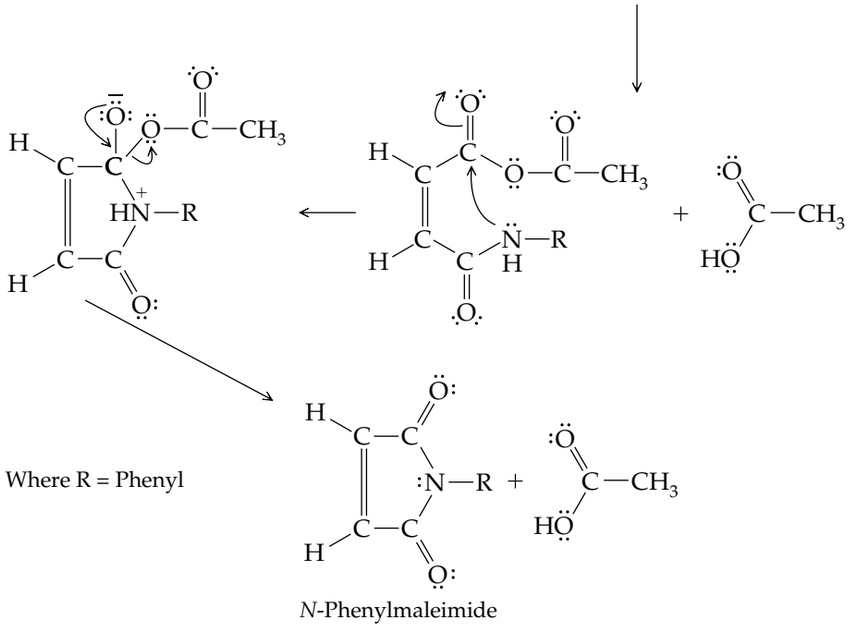

Experiment 24A

Maleanilic Acid

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

REACTION

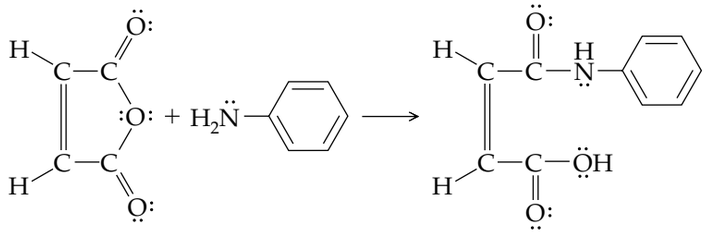

NOTE. It is recommended that the purity of the maleic anhydride be checked by mp. The presence of maleic acid can substantially lower the yield of product.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Maleic anhydride	98.06	60 mg	0.61	60			
Acetonitrile	41.05	1.2 mL			81		
Aniline	93.13	56 μL	0.62		184	1.02	1.5863

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EQA

Reagents and Equipment. In a 3.0-mL conical vial containing a magnetic spin vane, and equipped with an air condenser protected with a drying tube, place 60 mg (0.61 mmol) of maleic anhydride and 1.0 mL of anhydrous acetonitrile (➡). Stir the mixture at room temperature until all the maleic anhydride has dissolved.

HOOD

CAUTION: Dispense this reagent in the **hood** using a calibrated Pasteur pipet.

In a separate, dry $\frac{1}{2}$-*dram* vial prepare a solution of 56 μL (57 mg, 0.62 mmol) of aniline in 100 μL of anhydrous acetonitrile.

HOOD

CAUTION: Dispense these reagents in the **hood** using a calibrated Pasteur pipet. Aniline is highly toxic and is a cancer suspect agent.

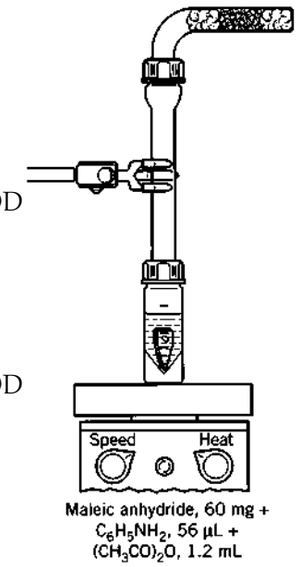

Using a Pasteur pipet, add the aniline–acetonitrile solution in one portion to the stirred maleic anhydride–acetonitrile solution. Rinse the $\frac{1}{2}$-*dram* vial with 100 μL of anhydrous acetonitrile and also transfer this rinse to the reaction solution.

Reaction Conditions. After stirring the reaction mixture at room temperature for 15 min, begin monitoring the system by TLC (plates with fluorescent indicator). Using as a solvent system ethyl acetate:hexane (3:2) and a UV lamp for visualization, the R_f value for maleanilic acid is 0.2. The R_f values for aniline and maleic anydride are 0.73 and 0.67, respectively. Once complete as judged by TLC, cool the reaction mixture in an ice bath for 5–10 min.

?

Isolation of Product. Collect the deposit of fine, cream-colored powder by vacuum filtration using a Hirsch funnel (➡). Wash the maleanilic acid crystals with 0.5 mL of cold diethyl ether (calibrated Pasteur pipet), and air-dry them in the funnel for 5 min while maintaining the suction.

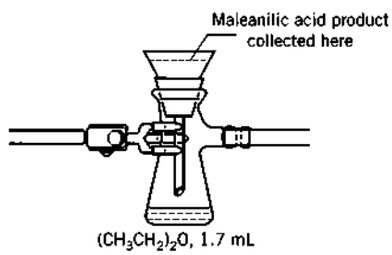

Purification and Characterization. Weigh the maleanilic acid and calculate the percent yield. Determine the melting point and compare your value to that given in Cava et al. (Bibliography section). Obtain an IR spectrum using the KBr pellet technique and compare it with an authentic sample. The air-dried product is suitable for use in the next step without further purification.

N-Phenylmaleimide

Experiment 24B

REACTION

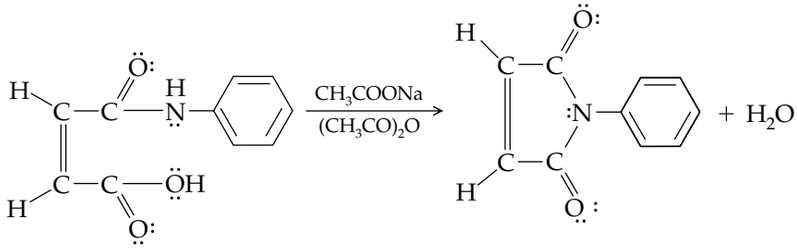

Maleanilic acid *N*-Phenylmaleimide

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EQA

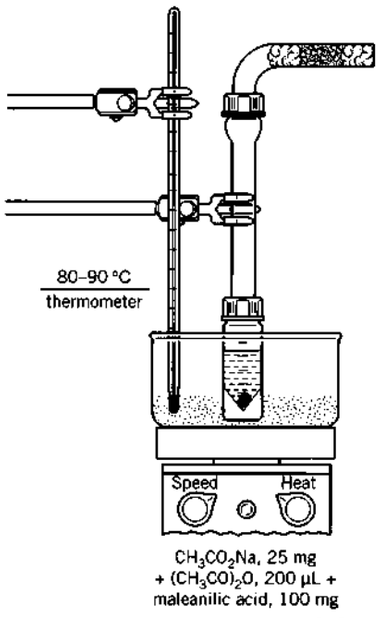

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Maleanilic acid	191.18	100 mg	0.52	201–202			
Sodium acetate	82.03	25 mg	0.30	324			
Acetic anhydride	102.09	200 μL	2.12		140	1.08	1.3901

Reagents and Equipment. In a 3.0-mL conical vial containing a magnetic spin vane, and equipped with an air condenser protected by a drying tube, place 25 mg (0.30 mmol) of anhydrous sodium acetate and 200 μL (216 mg, 2.12 mmol) of acetic anhydride (⬅).

CAUTION: Acetic anhydride is corrosive and a lachrymator. It should be dispensed in the **hood** by use of an automatic delivery pipet.

Now add 100 mg (0.52 mmol) of maleanilic acid (prepared in Experiment [24A]) to the reaction vial.

Reaction Conditions. Heat the reaction mixture, with stirring, at a sand bath temperature of 80–90 °C for 30 min. Then cool the resulting mixture to room temperature, add 1.0 mL of cold water (calibrated Pasteur pipet), stir for a few minutes, and then place the vial in an ice bath for 5–10 min to complete crystallization.

Isolation of Product. Collect the solid product by vacuum filtration using a Hirsch funnel and then wash the filter cake with three 0.5-mL portions of cold water (calibrated Pasteur pipet) (⬅). Cover the mouth of the funnel with plastic food wrap and continue the suction for an additional 5–10 min.

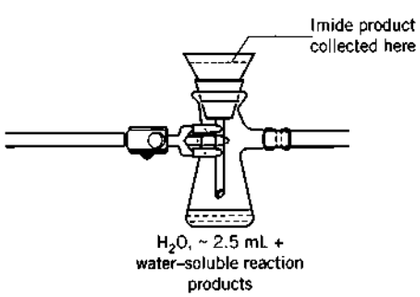

Purification and Characterization. Recrystallize the crude *N*-phenylmaleimide from cyclohexane using the Craig tube, to yield canary-yellow needles. After drying the product on filter paper, or on a porous clay plate, weigh the crystals and calculate the percent yield. Determine the melting point and compare your result with the value given by Cava et al. (Bibliography section). Obtain an IR spectrum and compare it with that of an authentic sample or with that shown in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

QUESTIONS

6-158. As stated in the discussion section, the second step in the reaction to form the imide is much slower than that of the first stage (formation of the acid amide). Explain.

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EQA

6-159. Phthalimide has a $K_a = 5 \times 10^{-9}$. Write an equation for the reaction of phthalimide with potassium amide (a strong base) in *N,N*-dimethylformamide (DMF) solvent. Name the product.

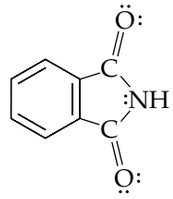

6-160. Predict which of the following species is the most acidic. Explain.

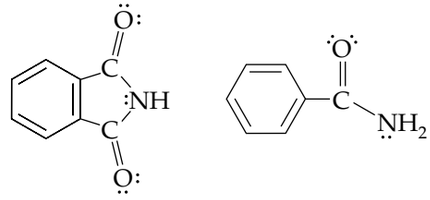

Phthalimide Benzamide

6-161. The phthalimide anion is a strong nucleophile. It can react easily with primary alkyl halides to form substituted phthalimides. One advantage when working with substituted phthalimides is that when treated with hydrazine, primary amines are furnished through this alkylation protocol (Gabriel synthesis). For both synthetic pathways (a) and (b), suggest a suitable mechanism.

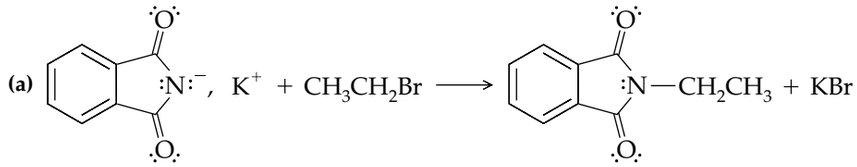

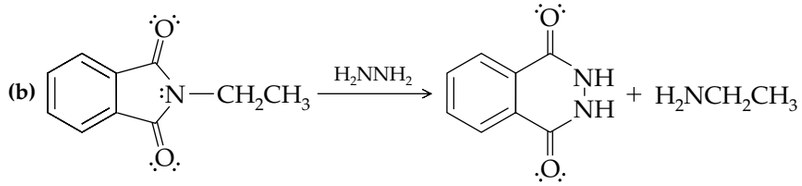

6-162. *N*-Phenylmaleimide, the product prepared in Experiment [24B], can act as a dienophile in the Diels–Alder reaction (see Experiments [14] and [15]). Draw the structure of the product that would be formed by the treatment of *N*-phenylmaleimide with (a) 3-sulfolene under the conditions given in Experiment [14] and (b) furan.

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Review articles on cyclic imides:

Benjamin, E.; Hijji, Y. *Molecules* **2008,** *13,* 157.

Hargreaves, M. K.; Pritchard, J. G.; Dave, H. R. *Chem. Rev.* **1970,** *70,* 439.

Naik, S.; Bhattacharjya, G.; Talukdar, R.; Patel, B. K. *J. Org. Chem.* **2004,** *69,* 1254.

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, 2007, Chap. 16, p. 1429.

Wheeler, O. H.; Rosado, O. In *The Chemistry of the Amides;* Zabicky, J., Ed.; Wiley: New York, 1970, p. 335.

Selected imide preparations in *Organic Syntheses* include

Cava, M. P.; Deana, A. A.; Muth, K.; Mitchell, M. J. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 944.

Noyes, W. A.; Porter, P. K. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 457.

Smith, L. I.; Emerson, O. H. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 151.

Soine, T. O.; Buchdahl, M. R. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 106.

For the preparation of maleanilic acid also see

Ram, R. N.; Varsha, K. *J. Chem. Educ.* **1990,** *67,* 985.

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EQA

EXPERIMENT 25

Synthesis of Cyclic Carboxylic Acid Anhydrides: Succinic Anhydride and Phthalic Anhydride

Common name: succinic anhydride
CA number: [108-30-5]
CA name as indexed: 2,5-furandione, dihydro-

Common names: phthalic anhydride, benzene-1,2-dicarboxylic anhydride
CA number: [85-44-9]
CA name as indexed: 1,3-isobenzofurandione

Purpose. One of the important methods for preparing cyclic carboxylic acid anhydrides is carried out. The reaction demonstrates the use of acetic anhydride, an important industrial and research chemical, as a dehydrating agent.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)
Technique 9: Sublimation (pp. 111–114)

REACTION

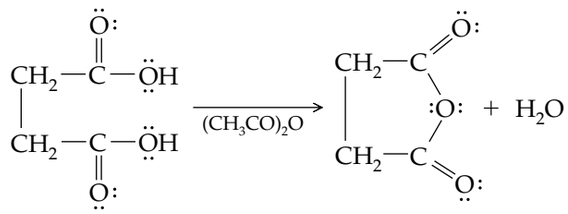

Succinic acid Succinic anhydride

DISCUSSION

Five- and six-membered cyclic anhydrides can be easily formed when the corresponding dicarboxylic acid is heated in the presence of a dehydrating agent. One of the most commonly used dehydrating agents is acetic anhydride. The formation of an anhydride from its corresponding acid by reaction with another anhydride is referred to as *anhydride exchange*.

The similarity of this reaction for the preparation of anhydrides to that for the synthesis of imides (Experiment [24]) should be noted. The ring closure to form the imide is mechanistically related to that of anhydride formation: in

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EQA

one case an amide nitrogen makes a nucleophilic attack on a carbonyl, while in the other, an acid oxygen acts as the nucleophile.

The mechanistic sequence for anhydride exchange is

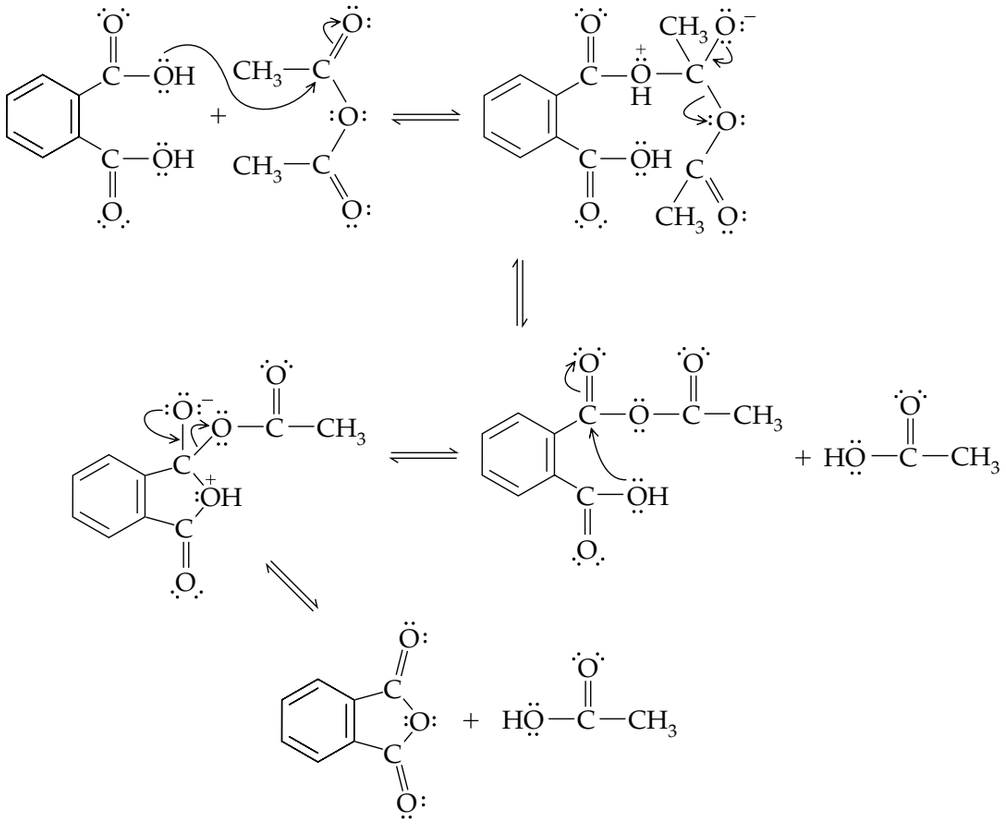

Phthalic anhydride

It is possible to prepare five- and six-membered cyclic anhydrides in the absence of acetic anhydride by direct dehydration at elevated temperatures. Maleic anhydride, for example, is easily obtained by this method in greater than 85% yield. Heating of succinic acid at 300 °C yields succinic anhydride in 95% yield.

This equilibrium is driven toward the products since formation of three molecules (two molecules of acetic acid and one molecule of anhydride) is entropically favored over the two molecules of reactants. The equilibrium could be further driven toward the products by distilling off the more volatile acetic acid as it is formed.

Acetic anhydride is an important industrial reagent. Over one-half its annual production of approximately 750,000 tons is used for the manufacture of cellulose acetate. Cellulose acetate is a widely used textile fiber and is the chief component of cigarette filters. Acetic anhydride is the acetylation reagent used for the production of aspirin (acetylsalicylic acid). Succinic anhydride finds use in the succinylation of gelatin used as a blood plasma substitute, as a food preservative in chicken against *Salmonella,* and as a dog food preservative.

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EQA

Phthalic anhydride finds extensive use in plasticizer formulations for many resins, and in the manufacture of dyes.

Experiment 25A

Succinic Anhydride

The reaction is shown on p. 352.

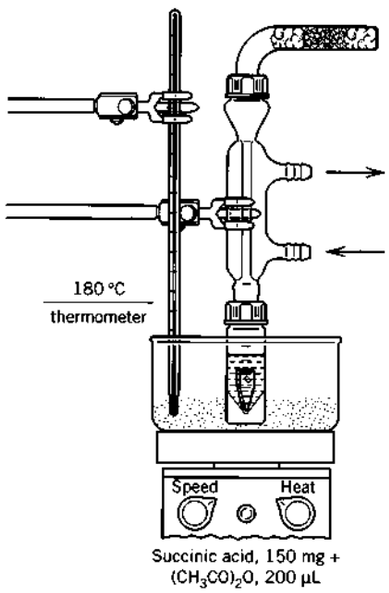

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Succinic acid	118.09	150 mg	1.27	188			
Acetic anhydride	102.09	200 μL	2.12		140	1.08	1.3901

Reagents and Equipment

NOTE. All equipment must be dried in an oven (110 °C) for 30 min before use.

Weigh and place 150 mg (1.3 mmol) of succinic acid in a 1.0-mL conical vial containing a magnetic spin vane. Add 200 μL (2.12 mmol) of acetic anhydride and then attach the vial to a reflux condenser protected by a calcium chloride drying tube (⬅).

HOOD

CAUTION: Acetic anhydride is moisture sensitive and an irritant. Dispense it in the **hood** using an automatic delivery pipet.

Reaction Conditions. Heat the reaction mixture, with stirring, in a sand bath at a temperature of 180 °C for 45 min, timing the reaction from the point at which the succinic acid is completely dissolved.

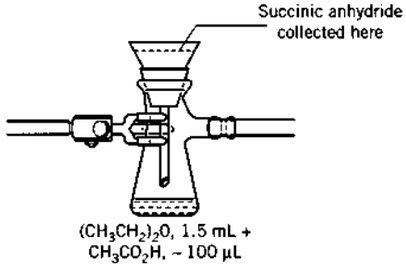

Isolation of Product. Cool the mixture to room temperature. A voluminous precipitate of succinic anhydride deposits. Further cool the vial in an ice bath for 5 min, and collect the solid material by vacuum filtration using a Hirsch funnel (⬅). Wash the white needles with three 0.5-mL portions of diethyl ether (calibrated Pasteur filter pipet) and then place them on a porous clay plate or filter paper to dry.

Purification and Characterization. The succinic anhydride crystals should be sufficiently pure for characterization. These crystals may, however, be recrystallized from absolute ethanol using a Craig tube.

Weigh the product and calculate the percent yield. Determine the melting point and obtain an infrared spectrum. Compare your results to those listed in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). What characteristic absorptions do you observe for the anhydride group in the carbonyl region of the spectrum?

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EQA

Phthalic Anhydride

Experiment 25B

REACTION

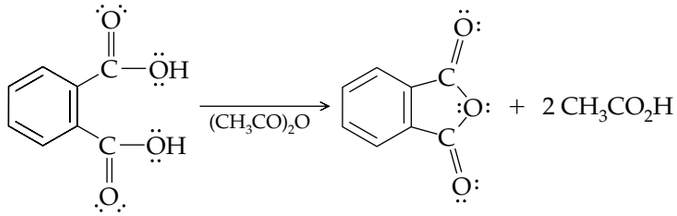

Phthalic acid Phthalic anhydride

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Phthalic acid	166.14	100 mg	0.60	210			
Acetic anhydride	102.09	200 μL	2.12		140	1.08	1.3901

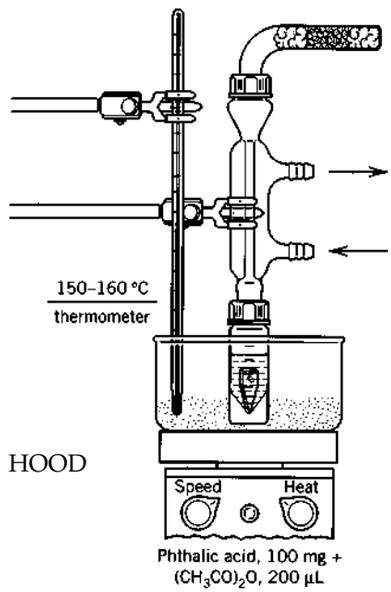

Reagents and Equipment. Weigh and add 100 mg (0.60 mmol) of phthalic acid to a 3.0-mL conical vial containing a magnetic spin vane. Add 200 μL (2.1 mmol) of acetic anhydride and then attach the vial to a reflux condenser protected by a calcium drying tube (➡).

CAUTION: Acetic anhydride is moisture sensitive and an irritant. Dispense it in the **hood** using an automatic delivery pipet.

Reaction Conditions. Heat the reaction solution, with stirring, at a sand bath temperature of 150–160 °C for 30 min.

NOTE. Position the vial firmly on the bottom of the sand bath vessel to maintain this reaction temperature.

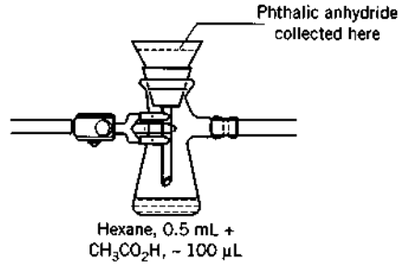

Isolation of Product. Cool the mixture to room temperature, whereupon the product crystallizes from solution. Cool the vial and contents in an ice bath for 10 min and collect the solid by vacuum filtration using a Hirsch funnel (➡). Rinse the filter cake carefully by dropwise addition of 0.5 mL of cold hexane (Pasteur pipet) and continue the suction for several minutes. Complete the drying of the solid product by placing the crystals on a porous clay plate or on filter paper.

Purification and Characterization. The phthalic anhydride should be sufficiently pure for characterization. It may be purified further by sublimation or by recrystallization from absolute ethanol using the Craig tube.

Weigh the product and calculate the percent yield. Determine the melting point and obtain an infrared spectrum. Compare your results with those

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EQA

reported in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). What characteristic absorptions do you observe for the anhydride group in the carbonyl region of the spectrum?

QUESTIONS

6-163. As stated in the discussion, direct dehydration can be used as a method for the preparation of five- and six-membered cyclic anhydrides. Propose a suitable mechanism for the reaction below:

$$\text{maleic acid} \xrightarrow{\Delta} \text{maleic anhydride} + H_2O$$

6-164. Propose a suitable mechanism for the formation of the mixed anhydride obtained in the following reaction:

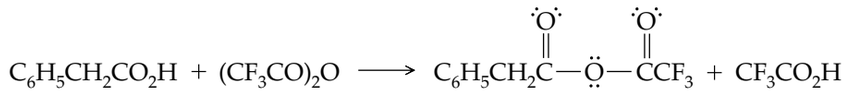

6-165. There are two stereoisomeric 1,3-cyclobutane dicarboxylic acids. One can form a cyclic anhydride, the other cannot. Draw the structures of these compounds and indicate which one can be converted to a cyclic anhydride. Explain.

6-166. When maleic acid is heated to about 100 °C it forms maleic anhydride. However, fumaric acid requires a much higher temperature (250–300°C) before it dehydrates. In addition, it forms only maleic anhydride. Explain.

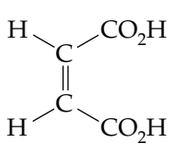

Maleic acid

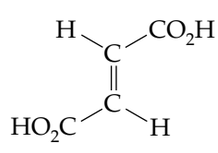

Fumaric acid

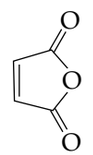

Maleic anhydride

6-167. What product would you expect to obtain from reaction of one equivalent of propanol with phthalic anhydride?

BIBLIOGRAPHY

Selected references from *Organic Syntheses* in which anhydrides are prepared, using acetic anhydride as the dehydrating agent, include

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Fieser, L. F.; Martin, E. L. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 560.

EXPERIMENT 26

Diazonium Coupling Reaction: Methyl Red

Common names: methyl red

CA number: [493-52-7]

CA name as indexed: benzoic acid, 2-[[4-(dimethylamino)phenyl]azo]-

Purpose. In this experiment you will learn the process of generating arenediazonium salts in solution. The arenediazonium salt generated will be used

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in an electrophilic aromatic substitution reaction (diazo coupling) to prepare an azobenzene derivative. Many azobenzene derivatives, including the one prepared here, have extensively conjugated π-electron systems. Because these are highly colored compounds, they are generally referred to as azo dyes.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

REACTION

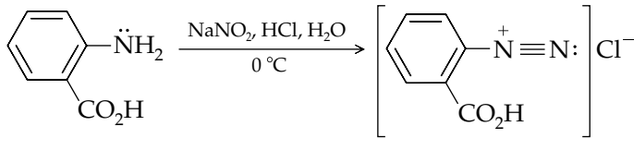

Anthranilic acid — Anthranyl diazonium chloride

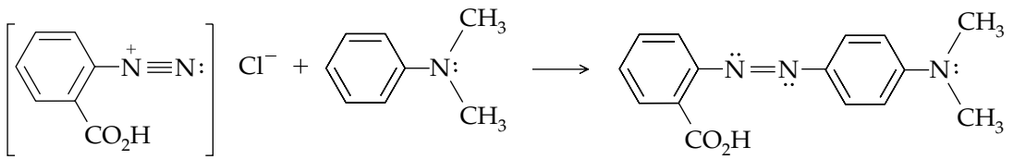

Anthranyl diazonium chloride — *N*,*N*-Dimethylaniline — Methyl red

DISCUSSION

The coupling of a diazonium salt to a suitable aromatic substrate is an example of an aromatic electrophilic substitution reaction. When primary aromatic (and also aliphatic) amines ($ArNH_2$) are treated with nitrous acid ($NaNO_2 + HCl \rightarrow HONO$), they are converted into diazonium cations, ArN_2^+. In solution, nitrous acid (HONO) is in equilibrium with its anhydride, dinitrogen trioxide (N_2O_3), which is the actual diazotizing agent. The primary amine reacts with the dinitrogen trioxide to form a nitrosamine:

$$Ar{-}NH_2 + N_2O_3 \longrightarrow \underset{\text{(a nitrosamine)}}{Ar{-}NH{-}N{=}O} + HONO$$

The nitrosamine is in equilibrium with its tautomer, a diazoic acid. The diazoic acid then undergoes dehydration to form the diazonium salt. Diazonium salts are explosive when dry, and therefore are generally not isolated.

$$\underset{\text{(a nitrosamine)}}{Ar{-}NH{-}N{=}O} + H_3O^+ \rightleftharpoons \underset{\text{(a diazoic acid)}}{Ar{-}N{=}N{-}OH} + H_3O^+$$

$$Ar{-}N{=}N{-}OH + H_3O^+ \longrightarrow \underset{\text{Diazonium ion}}{Ar{-}N^+{\equiv}N} + 2\,H_2O$$

Reaction of the diazonium salt with various aromatic compounds leads to the formation of azo derivatives by what is generally called a "coupling

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reaction," but is mechanistically simply an ordinary electrophilic aromatic substitution reaction. The mechanism of the reaction is given here:

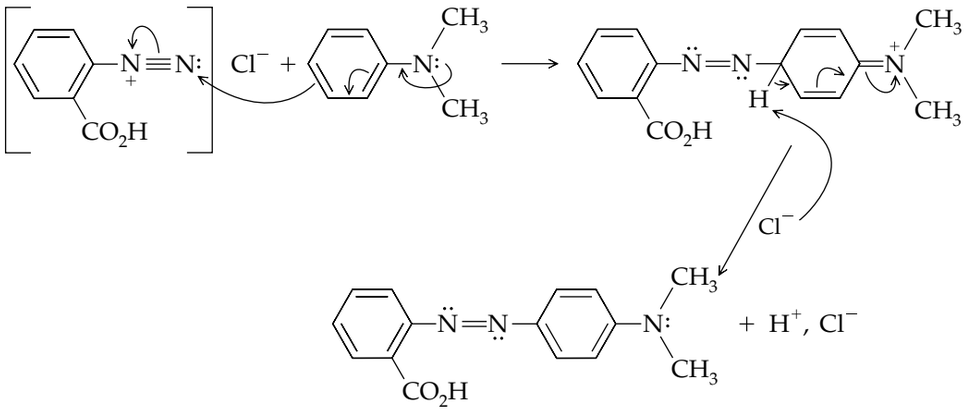

Azo dyes find use as acid–base indicators. For example, Methyl Red prepared in this experiment, Methyl Orange, and Congo Red are well-known acid–base indicators. Azo dyes are commonly used in the textile, food, and cosmetic industries; FD&C Yellow No. 6, a yellow azo dye is used to color candy, ice cream, beverages, and so on. Several azo dyes (including Butter Yellow and FD&C Red No. 2) have been banned by the FDA from use in foods, drugs, and cosmetics in the United States because of suspected carcinogenic properties.

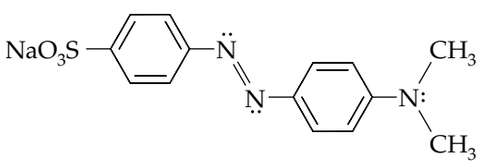

Methyl Orange

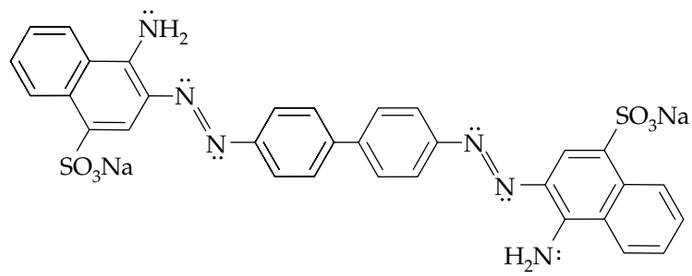

Congo Red

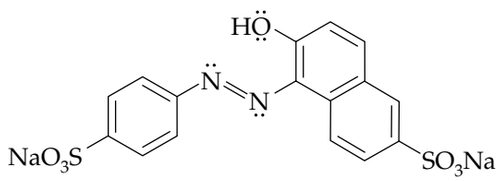

FD&C Yellow No. 6

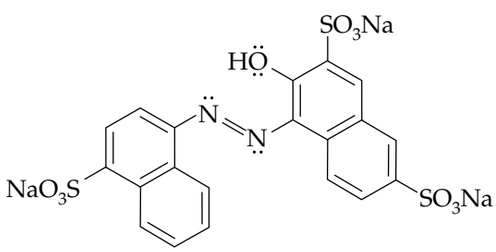

FD&C Red No. 2

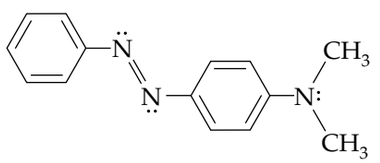

Butter Yellow

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EXPERIMENTAL PROCEDURE

Estimated time for the completion of the experiment: 3.0 h.
The reaction is shown on p. 357.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Anthranilic acid	137.14	65 mg	0.47	146–147			
Concd HCl		150 μL					
Water		800 μL					
Sodium nitrite	69.0	36 mg	0.52	271			
N,N-Dimethylaniline	121.18	89 μL	0.71		194	0.96	1.5582
Sodium acetate	82.03	68 mg	0.83	324			
10% aq. NaOH		100 μL					

CAUTION: When dry, benzenediazonium 2-carboxylate detonates violently upon being scraped or heated. It must, therefore, be kept in solution at all times.

Reagents and Equipment. Equip a 3.0-mL conical vial with a magnetic spin vane and an air condenser (➡). Weigh and add 65 mg (0.48 mmol) of anthranilic acid to the vial. Now add a solution of 150 μL of concentrated hydrochloric acid dissolved in 400 μL of water to the vial, using a Pasteur pipet.

CAUTION: When preparing the acid solution, the acid must be added *to* the water. Dispense these reagents using automatic delivery pipets.

If necessary, warm the mixture, with stirring, on a hot plate magnetic stirrer to obtain a homogeneous solution. Cool the solution in an ice bath, with stirring, for 10 min.

In a 10 × 75-mm test tube, or a small vial, prepare a solution of 36 mg (0.52 mmol) of sodium nitrite dissolved in 200 μL of water. Cool this solution in an ice bath.

Reaction Conditions. When both solutions in the ice bath are cooled to a temperature below 5 °C slowly add (dropwise) the nitrite solution to the stirred anthranilic acid solution, while maintaining the temperature below 5 °C. This transfer is accomplished using a Pasteur pipet. *The solution must be kept cool so that the diazonium salt will not hydrolyze to the corresponding phenol.*

After a period of 4–5 min, check the clear solution of anthranyldiazonium chloride for the presence of excess nitrous acid by placing a drop of the solution on a piece of potassium iodide–starch test paper. If an excess is present, the test paper gives an immediate blue color. If no color is obtained, prepare additional nitrite solution and add as before until a positive test is observed.

Remove the air condenser from the reaction vial containing the solution of anthranyldiazonium chloride. Fairly rapidly, add 89 μL (85 mg, 0.71 mmol) of *N,N*-dimethylaniline (automatic delivery pipet). Reattach the air condenser.

CAUTION: This aniline derivative is toxic and should be dispensed in the **hood.**

HOOD

Stir the solution for an additional 15 min, keeping the temperature below 5 °C.

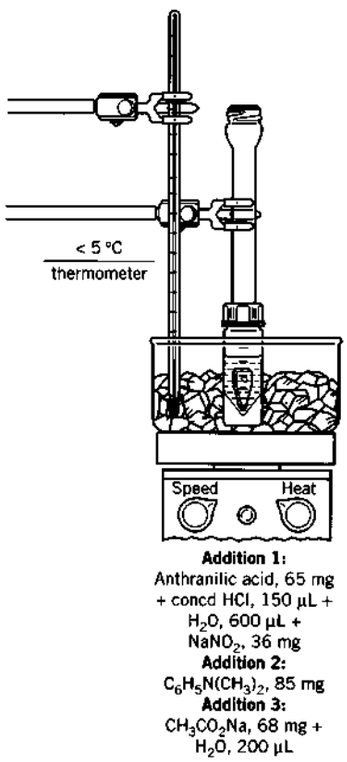

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Prepare a solution of 68 mg (0.83 mmol) of sodium acetate dissolved in 200 μL of water in a 10 × 75-mm test tube. Transfer this solution (Pasteur pipet) to the reaction mixture. Make this addition *without* removing the air condenser. Maintain the resulting solution at 5 °C with stirring, for an additional 20 min.

Remove the reaction vial from the ice bath and allow it to stand for 15 min in order to warm to ambient temperature.

Now add 100 μL of 10% aqueous NaOH solution (automatic delivery pipet) to the solution. Allow the reaction mixture to stand at room temperature for about 30 min. *The formation of the azo compound is a very slow reaction, but the rate of formation is increased by raising the pH of the solution.*

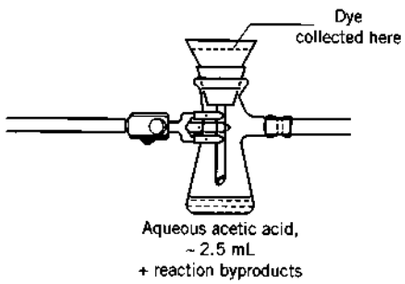

Isolation of Product. Collect the precipitate of crude Methyl Red dye by vacuum filtration using a Hirsch funnel (⬅). Rinse the reaction flask with 0.5 mL of water and use this rinse to wash the crystals. Then wash the crystals with 0.5 mL of 3 M acetic acid, to remove unreacted *N,N*-dimethylaniline from the product, followed by another wash with 0.5 mL of water. *This last wash is usually pale pink in color.*

NOTE. Dispense the small amounts of water and acetic acid using a calibrated Pasteur pipet.

Purification and Characterization. Dissolve the crude product in 500 μL of methanol. If necessary, warm the mixture in a beaker of hot water to aid in the dissolution. Cool the solution in an ice bath and collect the resulting crystals of Methyl Red by vacuum filtration using a Hirsch funnel. Dry the material on filter paper or under vacuum at room temperature.

Weigh the product and calculate the percent yield. Determine the melting point and compare it to the value given in the literature. If further purification is desired, recrystallize the material from toluene using a Craig tube.

QUESTIONS

6-168. In the experiment, a point is made that the formation of the azo compound is a slow reaction, but that the rate is increased by raising the pH of the solution. Why is this necessary? In other words, how does the pH of the solution affect the reactivity of the *N,N*-dimethylaniline reagent?

6-169. In relation to Question 6-168, diazonium salts couple with phenols in slightly alkaline solution. What effect does the pH of the solution have on the reactivity of the phenol?

6-170. Starting with the appropriate aromatic amine and using any other organic or inorganic reagent, outline a synthetic sequence for the preparation of the following azo dyes:

(a)

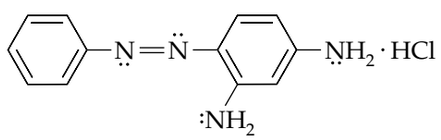

Chrysoidine

(b)

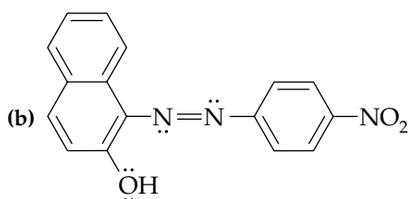

Para Red

(c)

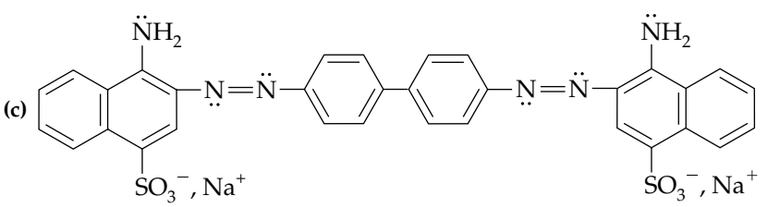

Congo Red

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6-171. What is the main structural feature of the azo dyes that causes them to be colored compounds?

6-172. Methyl Orange is an acid–base indicator. In dilute solution at pH > 4.4, it is yellow.

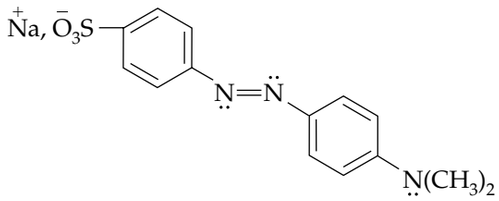

At pH = 3.2 the solution appears red. Draw a structure of the species that is formed at the lower pH if the acid proton adds to the azo nitrogen atom adjacent to the aromatic ring containing $-SO_3^-$ group. Why does the proton add to this particular nitrogen when two other nitrogen atoms are available in the molecule?

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Smith, M. B.; March. J. *Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, 2007, Chap. 11, p. 691.

Zollinger, H. *Color Chemistry;* VCH: New York, 1987, p. 85.

Zollinger, H. *Diazo Chemistry I;* VCH: New York, 1994.

Selected coupling reactions with diazonium salts from *Organic Syntheses:*

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Hartwell, J. L.; Fieser, L. F. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 145.

Santurri, P.; Robbins, F.; Stubbins, R. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 341.

The synthesis of Methyl Red is also given in *Organic Syntheses*:

Clarke, H. T.; Kirner, W. R. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 374.

The present experiment is an adaptation of that given in

Vogel, A. I. *A Textbook of Practical Organic Chemistry,* 5th ed.; Furnis, B. S., *et al.* Eds.; Wiley: New York, 1989.

EXPERIMENT 27

Friedel–Crafts Acylation: Acetylferrocene and Diacetylferrocene

Common name: acetylferrocene

CA number: [1271-55-2]

CA name as indexed: ferrocene, acetyl-

Common names: diacetylferrocene, 1,1′-diacetylferrocene

CA number: [1273-94-5]

CA name as indexed: ferrocene, 1,1′-diacetyl-

Purpose. To investigate the conditions under which the synthetically important Friedel–Crafts acylation (alkanoylation) reaction is carried out. The reaction described here illustrates electrophilic aromatic substitution on an aromatic ring

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contained in an organometallic compound. The highly colored products are easily separated by both thin-layer and dry-column chromatography.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)

Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Thin-Layer Chromatography (pp. 97–99)
Concentration of Solutions (pp. 101–104)

REACTION

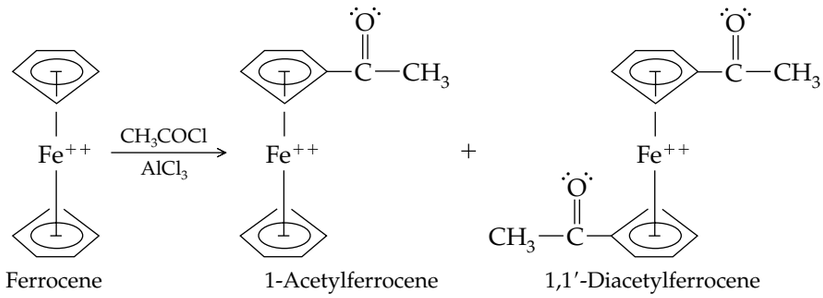

DISCUSSION

The generation of the appropriate electrophile (carbocation, carbocation complex, or acylium ion) in the presence of an aromatic ring system (nucleophile) can lead to alkylation or acylation of the aromatic ring. This set of reactions, discovered by Charles Friedel and James Crafts in 1877, originally used aluminum chloride as the catalyst. The reaction is now known to be catalyzed by a wide range of Lewis acids, including ferric chloride, zinc chloride, boron trifluoride, and strong acids, such as sulfuric, phosphoric, and hydrofluoric acids.

Alkylation is accomplished by use of haloalkanes, alcohols, or alkenes; any species that can function as a carbocation precursor. The alkylation reaction is accompanied by two significant and limiting side reactions: polyalkylation, due to ring activation by the added alkyl groups, and rearrangement of the intermediate carbocation. These lead to diminished yields, and mixtures of products that can be difficult to separate as shown here:

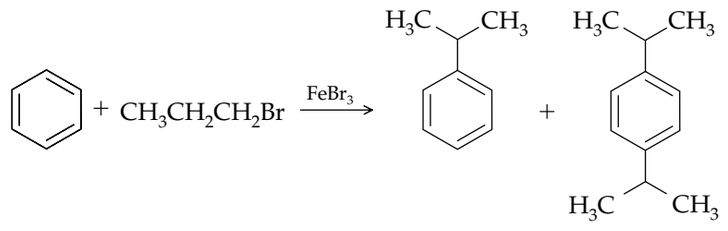

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Acylation reactions generally do not suffer from these limitations, and can be conducted using acid chlorides or anhydrides as the electrophilic reagents. Since the introduction of a carbonyl group onto the aromatic ring in an acylation reaction deactivates the ring, the problem of multiple substitution is avoided. The acylium cation, since it is resonance stabilized, is unlikely to rearrange.

The mechanism involves three steps: (1) formation of a cationic electrophile, (2) nucleophilic attack on this electrophile by an aromatic ring, and (3) loss of a proton from the resulting cation to regenerate the aromatic ring system. The mechanism shown here represents the $AlCl_3$ catalyzed generation of the acylium ion electrophile from acetyl chloride (ethanoyl chloride), followed by subsequent nucleophilic attack by the ferrocene ring system:

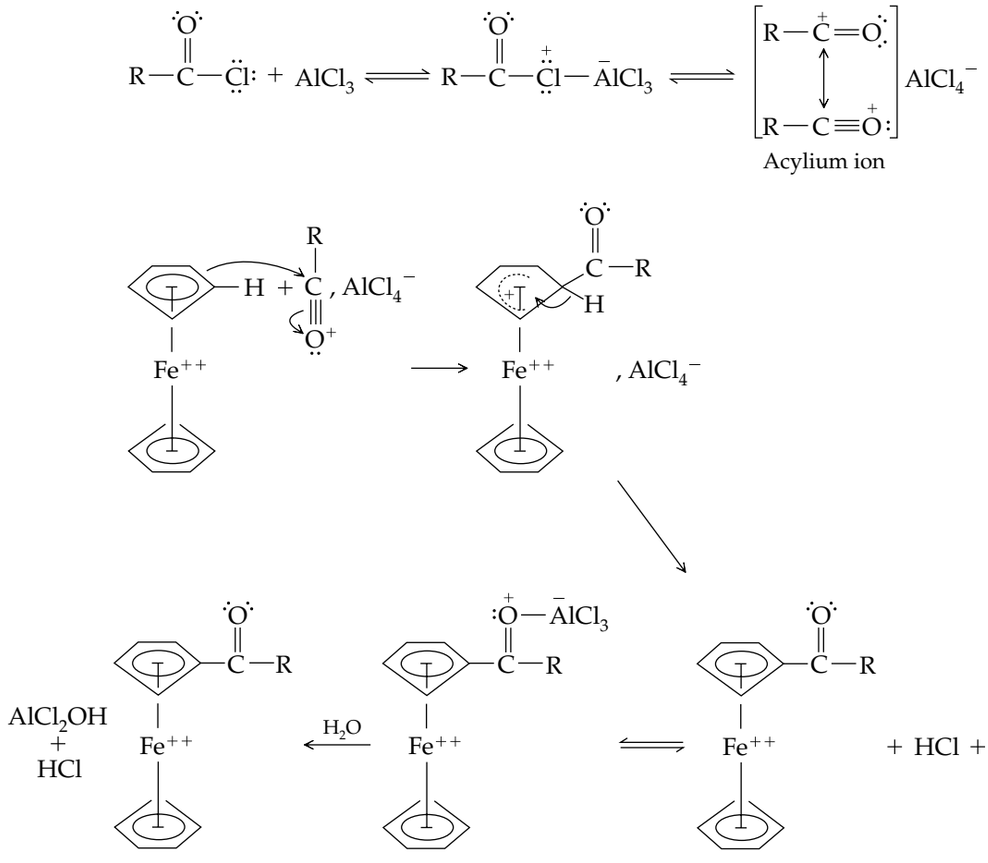

The present experiment also demonstrates the practical value of monitoring reaction progress by TLC analysis.

Charles Friedel (1832–1899) Friedel was Professor of Chemistry at the Sorbonne. He did extensive work on ketones, lactic acid, and glycerol and he discovered isopropyl alcohol. He is best known for his studies of the use of aluminum chloride in the synthesis of aromatic products (**Friedel–Crafts reaction,** 1877). Friedel prepared a series of esters of silicic acid and demonstrated the analogy between the compounds of carbon and silicon, meanwhile confirming the atomic weight of silicon. He determined the

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vapor densities and molecular weights of the chlorides of aluminum, iron, and gallium.[23]

James Mason Crafts (1839–1917) Crafts was Professor of Chemistry at Cornell University and later at Massachusetts Institute of Technology, where he eventually became President. Crafts studied with Bunsen (Germany) and Wurtz (France) and also worked on the organic compounds of silicon. Crafts was, of course, the codiscoverer of the **Friedel–Crafts reaction.** He also carried out investigations in the area of thermochemistry, catalytic effects in concentrated solutions, and determination of the densities of the halogens at high temperatures.[24]

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: two 3.0-h laboratory periods.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	d	n_D
Aluminum chloride	133.34	150 mg	1.12	190			
Acetyl chloride	78.50	80 μL	1.12		51	1.11	1.3898
Ferrocene	186.04	100 mg	0.54	173			
Methylene chloride		4.0 mL			40		

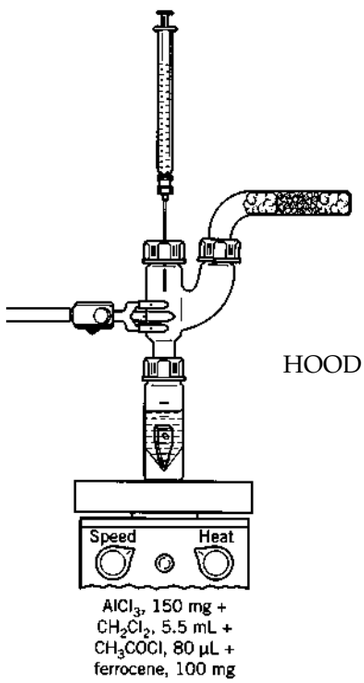

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Reagents and Equipment

NOTE. Dry the glassware in an oven at 110 °C for 30 min and allow it to cool in a desiccator before starting the experiment.

Equip a tared 5.0-mL conical vial containing a magnetic spin vane with a Claisen head protected by a calcium chloride drying tube and a septum cap. Weigh and add 150 mg (1.12 mmol) of fresh, anhydrous aluminum chloride (⬅).

Using a calibrated Pasteur pipet, add 2.5 mL of methylene chloride to the reaction vial. In the **hood,** with swirling, add 80 μL (1.12 mmol) of acetyl chloride from an automatic delivery pipet. Use a syringe to add a solution of 100 mg (0.54 mmol) of ferrocene dissolved in 1.5 mL of methylene chloride to the resulting mixture.

NOTE. Use a capped vial and recap it between the addition of each reagent. After addition of the acetyl chloride, attach the vial to the Claisen head and add the ferrocene solution through the septum as shown in the figure. Do this in one or two portions, depending on whether a 1- or 2-mL syringe is used.

[23]See *Berichte* **1899,** *32,* 372; Crafts, J. M. *J. Chem. Soc.* **1900,** *77,* 993; *Bull. Soc. Chim. Fr.* **1900,** *23,* 1; Béhal, A. *ibid.,* **1932,** *51,* 1423; Willemart, A. *J. Chem. Educ.* **1949,** *26,* 3.
[24]Ashdown, A. A. *J. Chem. Educ.* **1928,** *5,* 911; Talbot, H. P. *J. Am. Chem. Soc.* **1917,** *39,* 171; Richards, T. W. *Proc. Am. Acad.* **1917–1919,** *53,* 801; Cross, C. R. *J. Natl. Acad. Sci.* **1914,** *9,* 159.

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At this stage, the reaction mixture turns a deep-violet color.

CAUTION: It is important to minimize the exposure to moist air during these transfers. Both the aluminum chloride and the acetyl chloride are highly moisture sensitive so that rapid, yet accurate, manipulations are necessary to minimize deactivation of these reagents, which leads to poor results. In addition, both chemicals are irritants. Avoid breathing the vapors or allowing the reagents to come in contact with skin. These reagents must be dispensed in the **hood.** HOOD

TLC Sample Instructions. Obtain an aliquot for TLC analysis by removing a small amount of the reaction mixture by touching the open end of a Pasteur pipet to the surface of the solution. First, remove the cap from the straight neck of the Claisen head, and then insert the pipet down the neck so as to touch the surface of the solution. Dissolve this aliquot in about 10 drops of cold methylene chloride in a small capped vial. Mark the vial and *save* it for TLC analysis.

Reaction Conditions. Following the addition of the ferrocene solution, note the time, and begin stirring. Allow the reaction to proceed at room temperature for 15 min.

Isolation of Product. Quench the reaction by transferring the mixture by Pasteur pipet to a 15-mL capped centrifuge tube (or a 15-mL screw-capped vial) containing 5.0 mL of ice water. Cool the tube in an ice bath and neutralize the resulting solution by dropwise addition (calibrated Pasteur pipet) of about 0.5 mL of 25% aqueous sodium hydroxide.

NOTE. Avoid an excess of base. Use litmus or pH paper to confirm the neutralization.

Now extract the mixture with three 3-mL portions of methylene chloride. Cap the tube, shake, vent, and allow the layers to separate (a Vortex mixer may be used in this step). Remove the lower (methylene chloride) layer using a Pasteur filter pipet. Combine the methylene chloride extracts in a 25-mL Erlenmeyer flask, and dry the wet solution over about 200 mg of granular anhydrous sodium sulfate for 20 min. Transfer the dried solution to a tared 10-mL Erlenmeyer flask, using a Pasteur filter pipet, in aliquots of 4 mL each. After each transfer, concentrate the solution, in the **hood,** under a stream of dry nitrogen gas in a warm sand HOOD
bath to a volume of about 0.5 mL. Rinse the drying agent with an additional 2.0 mL of methylene chloride and combine this rinse with the concentrate. Remove several drops of this solution by Pasteur pipet and place them in a capped vial containing 10 drops of *cold* methylene chloride. Mark the vial and *save* it for TLC analysis. Remove the remaining solvent by warming in a sand bath in the **hood** to yield the crude, solid product (~130 mg). Weigh the residue. HOOD

OPTION. As an option, the combined extracts and washes may be left to evaporate in the ***hood*** *in a 25-mL Erlenmeyer flask, with the mouth covered by filter* HOOD
paper, until the following week.

If the reaction is performed over a 2-week period, this is a convenient point at which to stop. However, if time permits, perform the TLC analysis now.

Thin-Layer Chromatographic Analysis. Use TLC to analyze the two samples saved above. Also analyze a standard mixture of the substituted ferrocenes (supplied by the instructor) at the same time. Use the developed TLC

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plates as a guide to determine the product mixture obtained in the reaction and as an aid in determining the appropriate elution solvent required for separation of the mixture by dry-column chromatography.

INFORMATION. Good results have been achieved by conducting the TLC analysis with Eastman Kodak silica gel–polyethylene terephthalate plates (#13179). Activate the plates at an oven temperature of 100 °C for 30 min. Place them in a desiccator for cooling and storing until used. Elute the plates using pure methylene chloride as the elution solvent. Visualization of unreacted ferrocene can be enhanced with iodine vapor. See Prior Reading for methods of TLC analysis and determination of R_f *values.*

Purification and Characterization. Now purify the reaction products formed in the reaction by dry-column chromatography. The term *dry-column chromatography* refers to the fact that the column is packed with dry alumina, rather than with a slurry (see Prior Reading). Dissolve the solid product residue isolated above in 0.5 mL (calibrated Pasteur pipet) of methylene chloride in a small vial. Mix this solution with 300 mg of alumina (activity III, see Glossary) in a tared vial, and evaporate the solvent under a stream of dry nitrogen in the **hood** to give a product–alumina mixture. Assemble a chromatographic buret column in the following order (bottom to top): prewashed cotton plug, 5 mm of sand, 60–80 mm of alumina (~5.0 g, activity III), *one-half* of the product–alumina mixture, and 10 mm of alumina (⬅).

HOOD

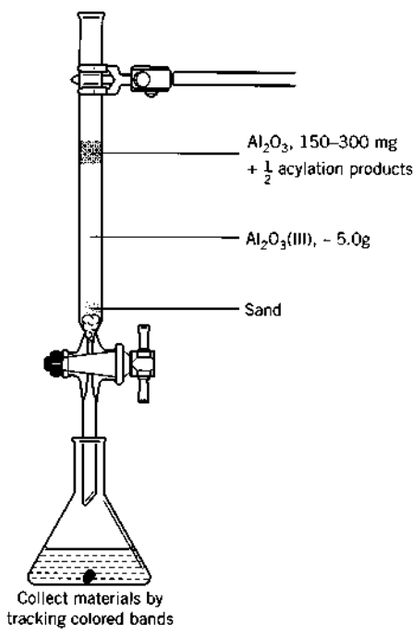

NOTE. This procedure prevents overloading of the chromatographic column during the separation of the reaction products. If the yield of crude reaction products exceeds 75 mg (the usual case), introduce one-half of the alumina–product mixture to the column. If the crude products, however, are obtained in quantities of less than 75 mg, add the entire alumina–product mixture to the top of the column. If only one-half of the alumina–crude ferrocene acylation product mixture is placed on the column, it is important to reweigh the tared vial to establish a reasonably accurate estimate of the overall yields obtained in the reaction.

Given the polar nature of the alumina, the products will elute in order of increasing polarity: ferrocene followed by acetylferrocene, followed by diacetylferrocene. Begin elution of the column with pure hexane if TLC analysis indicates that unreacted ferrocene is present in the product mixture. Be sure to add the initial solvent down the side of the column so as not to disturb the alumina bed. During elution, the ferrocenes will separate into two or three bands of different colors on the column. The volume of each eluted fraction should be in the range of 2–5 mL if the band is carefully tracked down the column. Once the ferrocene band has been collected, continue the elution with a 1:1 mixture of CH_2Cl_2/hexane to obtain the monosubstituted product. Further elution with a 9:1 mixture of CH_2Cl_2/CH_3OH will elute the disubstituted material. Collect and save each chromatographic band separately. Store the solvent that elutes without color in an Erlenmeyer flask or beaker until you have isolated all your product. In the **hood,** remove the solvent under a stream of dry nitrogen gas, using a warm sand bath. During concentration of the solvent, spot each fraction on a TLC plate to verify the separation and purity of its contents.

HOOD

Determine the melting point of each of the isolated products and compare your results to those reported in the literature.

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Obtain an IR spectrum of each material and compare the results with an authentic sample or spectra found in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). Interpretation of the spectra allows an unambiguous determination of substitution based on the presence or absence of absorption in the 1100- to 900-wavenumber region of the spectrum.

Characterization of the Fractions (Total Sample) Isolated From the Reaction Workup

Acetylferrocene: mp _____ °C; _____ mg, _____ mmol

Diacetylferrocene: mp _____ °C; _____ mg, _____ mmol

Total: _____ mmol, _____ % yield

QUESTIONS

6-173. In the formation of diacetylferrocene, the product is always the one in which each ring is monoacetylated. Why is no diacetylferrocene produced in which both acetyl groups are on the same aromatic ring?

6-174. Ferrocene cannot be nitrated using the conventional HNO_3–H_2SO_4 mixed acid conditions, even though nitration is an electrophilic aromatic substitution reaction. Explain.

6-175. In contrast to nitration (Question 6-174), ferrocene undergoes the acetylation and sulfonation reaction. Explain.

6-176. The bonding in ferrocene involves sharing of the 6 electrons from each cyclopentadienyl ring with the iron atom. Based on the electronic configuration of the iron species in the compound, show that a favorable 18-electron inert gas configuration is established at the iron atom.

6-177. In a manner similar to that in Question 6-176, predict whether ruthenocene and osmocene (the ferrocene analogues of ruthenium and osmium) would be stable compounds? Explain.

6-178. Would you predict that bis(benzene)chromium (0) would be a stable compound? Explain.

6-179. Predict the major product(s) in each of the following Friedel–Crafts reactions. Name each product. If the reaction does not occur, offer a reasonable explanation for that fact.

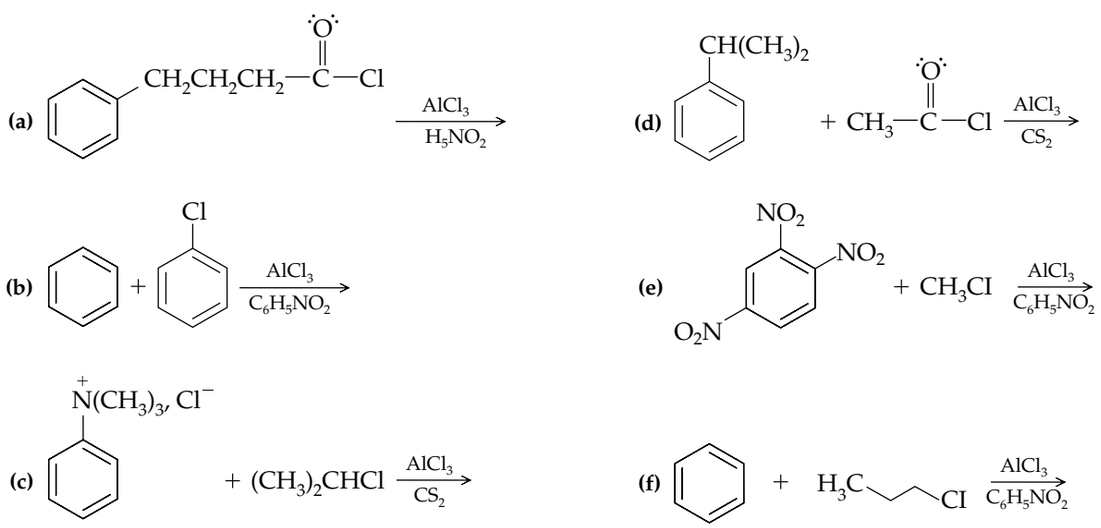

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Several reviews on the Friedel–Crafts reaction, selected from many cited in the literature:

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Harada, T; Ohno, T.; Kobayashi, S.; Mukaiyama, T. *Synthesis* **1991,** 1216.

Heaney, H. *Comp. Org. Syn.* **1991,** *2,* 733.

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Several of the large number of Friedel–Crafts acetylation reactions given in *Organic Syntheses:*

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Marvel, C. S.; Sperry, W. M. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 95.

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EXPERIMENT 28

Halogenation: Electrophilic Aromatic Substitution to Yield 4-Bromoacetanilide

Common names: 4-bromoacetanilide, *p*-bromoacetanilide

CA number: [103-88-8]

CA name as indexed: acetamide, *N*-(4-bromophenyl)-

Purpose. This experiment extends our understanding of the experimental conditions under which electrophilic aromatic substitution reactions are carried out (also see Experiments [27] and [29A]–[29D]). It deals with electrophilic aromatic halogenation. The directive influence of the acetamido, —$NHCOCH_3$, group on the bromination of acetanilide is explored.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

Technique 6A: Thin-Layer Chromatography (pp. 97–99)

REACTION

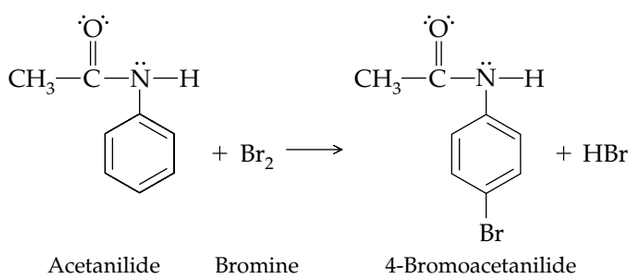

Acetanilide Bromine 4-Bromoacetanilide

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DISCUSSION

Aromatic compounds may be brominated by treatment with bromine in the presence of a Lewis acid catalyst, such as ferric chloride. For very electron-rich aromatic rings, such as arylamines, the reaction may proceed in the absence of a catalyst. With amines or phenols, in many cases, it is difficult to stop the bromination at monosubstitution, and all open ortho and para positions are brominated. For this reason, primary aromatic amines are often converted to a corresponding amide derivative, if a monobrominated product is desired. This strategy is demonstrated in the present experiment. The —$NHCOCH_3$ group is a less powerful *o*,*p*-directing group than —NH_2 due to the presence of the electron-withdrawing carbonyl group, which renders the ring less nucleophilic. Electrophilic substitution by bromine is still, however, effectively directed electronically to the ortho and para positions on the ring. The acetamido group, —$NHCOCH_3$, effectively blocks the ortho positions by steric hindrance. For these reasons, only para substitution is observed. The acetanilide used in this experiment may be prepared using the procedure described in Experiment [23A].

The mechanism of the bromination reaction is a classic illustration of an electrophilic substitution on an aromatic ring. The mechanism shown below is presented as proceeding without the aid of a catalyst:

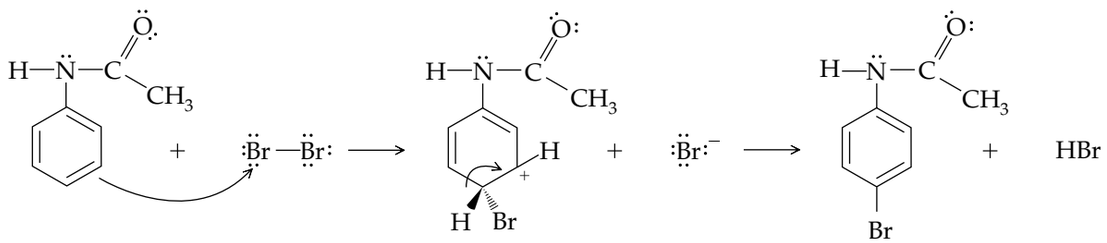

EXPERIMENTAL PROCEDURE

Estimated time for completion of the experiment: 1.5 h.

INSTRUCTOR PREPARATION. For the bromine/AcOH solution. Prepare the bromine–acetic acid reagent by mixing 2.5 mL of bromine with 5.0 mL of glacial acetic acid in the ***hood.*** HOOD

Physical Properties of Reactants					
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**
Acetanilide	135.17	25 mg	0.19	114	
Glacial acetic acid	60.05	4 drops			118
Bromine–acetic acid solution		3 drops			

Reagents and Equipment. Weigh and place 25 mg (0.19 mmol) of acetanilide in a 3.0-mL conical vial fitted with a cap. Add between 8–10 drops of glacial acetic acid using a medicine dropper. Stir with a glass rod to help

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dissolve the acetanilide. Once in solution, add a magnetic spin. Now, in the HOOD **hood,** add to the clear solution three drops of the bromine–acetic acid solution. Cap the vial immediately.

CAUTION: Bromine is a severe irritant. Bromine burns can be severe and require a long time to heal. Always wear plastic gloves and dispense the bromine solution in the **hood.** HOOD

Reaction Conditions. Allow the reddish-brown solution to stand at room temperature for 10 min. During this period, yellow-orange colored crystals precipitate from the solution.

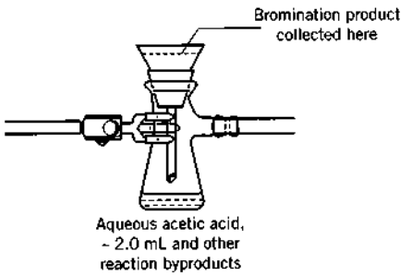

Isolation of Product. Using a calibrated Pasteur pipet add 0.5 mL of water to the reaction mixture with swirling, followed by 5 drops of aqueous sodium bisulfite solution (33%). This treatment destroys the unreacted bromine (and its residual color) and results in white crystals. Cool the reaction mixture in an ice bath for 10 min to maximize the yield of product.

Collect the crude reaction mixture by vacuum filtration using a Hirsch funnel (⬅). Once collected, add 0.25 mL of cold water (using a calibrated Pasteur pipet) to the 3.0-mL conical vial. Transfer this rinse to the filter cake and repeat two more times (rinse followed by washing of the filter cake with 0.25-mL portions of cold water). Once complete, partially dry the filter cake by drawing air through the crystals under reduced pressure for approximately 5 min. A sheet of plastic food wrap over the funnel mouth aids this process (see Prior Reading).

Purification and Characterization. Purify all but 10 mg of the crude 4-bromoacetanilide by recrystallization from 95% ethanol using the Craig tube. Weigh the dried product and calculate the percent yield. Determine the melting point, compare both the crude and recrystallized materials by TLC analysis (plates with fluorescent indicator, R_f value for 4-bromoacetanilide is 0.32 using as solvent system ethyl acetate:hexane (2:3), and a UV lamp for visualization purposes), and compare your observed melting point to the value given in the literature. V

Obtain an IR spectrum of the material and compare it with one found in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). If possible, obtain ^{1}H and/or ^{13}C NMR spectra of your material in DMSO-d_6.

Nuclear Magnetic Resonance Analysis. Figures 6.46 and 6.47 are, respectively, the ^{1}H and ^{13}C NMR spectra of *p*-bromoacetanilide in DMSO-d_6. These can be used to compare with the NMR spectra you may obtain of your product.

In the ^{13}C NMR spectrum, the DMSO-d_6 appears as a septet at 39.7 ppm. The resonance from the methyl group of the *p*-bromoacetanilide occurs at 24 ppm and the amide carbonyl carbon resonates at 169 ppm. The carbon atoms of the benzene ring are observed between 110 and 140 ppm.

In the ^{1}H spectrum, the peak from trace amounts of DMSO-d_5 is seen at about 2.6 ppm. The peak at 3.4 ppm is probably due to water or another impurity in the sample. Note the two small peaks located equidistant to the tall singlet near 2.0 ppm. The small "satellite" peaks are the result of the 1.1% of the methyl groups that have ^{13}C instead of ^{12}C, and thus here coupling between the carbon and the protons is observed. The two doublets for the aromatic protons are observed near 7.5 ppm. The amide NH proton, which is probably hydrogen bonded to the basic (Lewis) sulfoxide functional group in DMSO-d_6,

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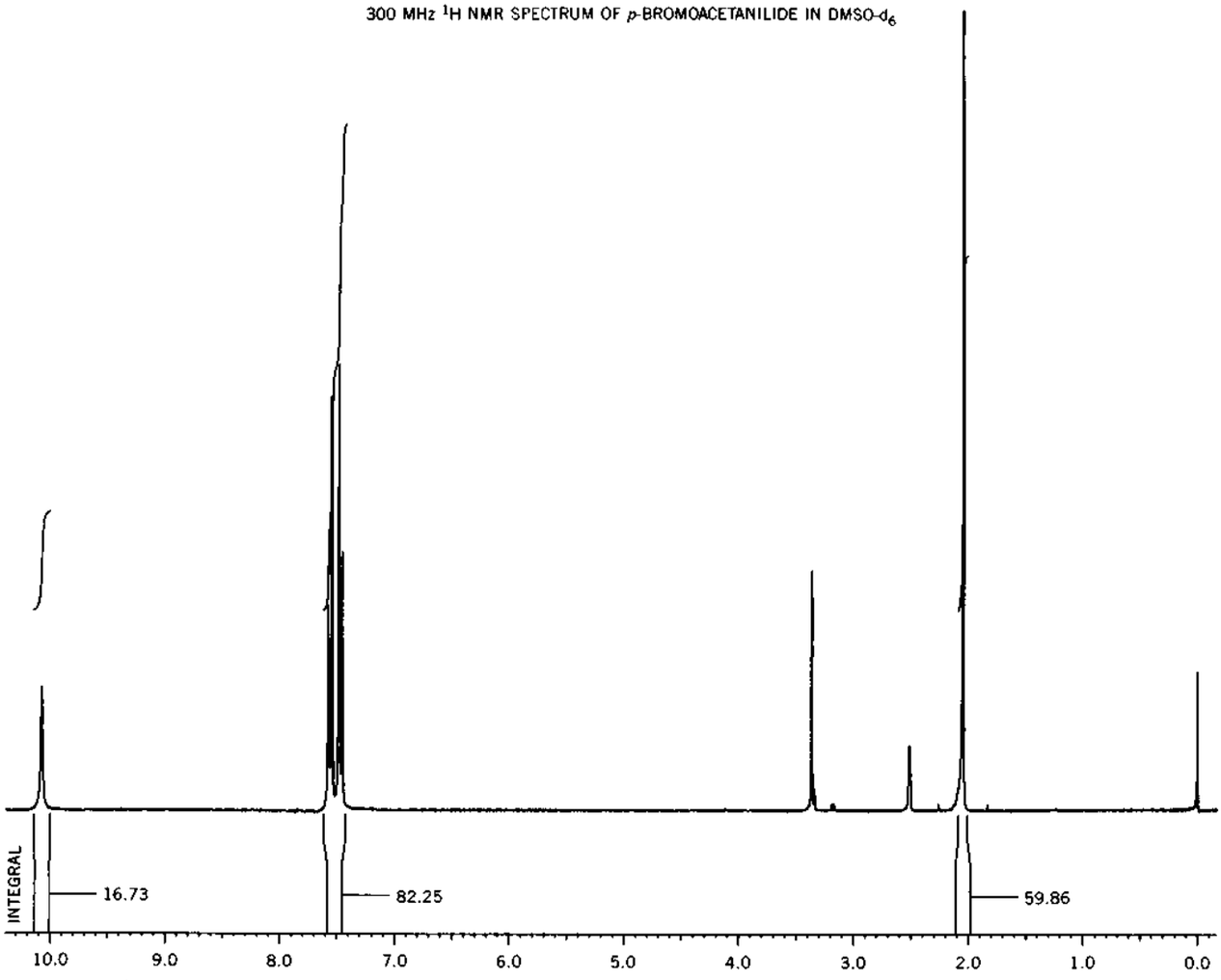

Figure 6.46 **^{1}H-NMR spectrum: *p*-bromoacetanilide.**

occurs rather downfield, near 10.1 ppm.This chemical shift may vary in your sample due to subtle differences in concentration, temperature, and moisture content of your DMSO-d_6.

Chemical Tests. Chemical classification tests may also be performed on the amide product. The ignition and the Beilstein test (Chapter 9) are used to confirm the presence of the aromatic ring and the halogen group, respectively. Does the hydroxamate test for amides (Chapter 9) give a positive result?

QUESTIONS

6-180. Use resonance structures to show why the group shown is a less powerful ortho–para directing group than the $-NH_2$ group:

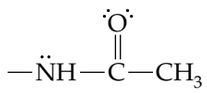

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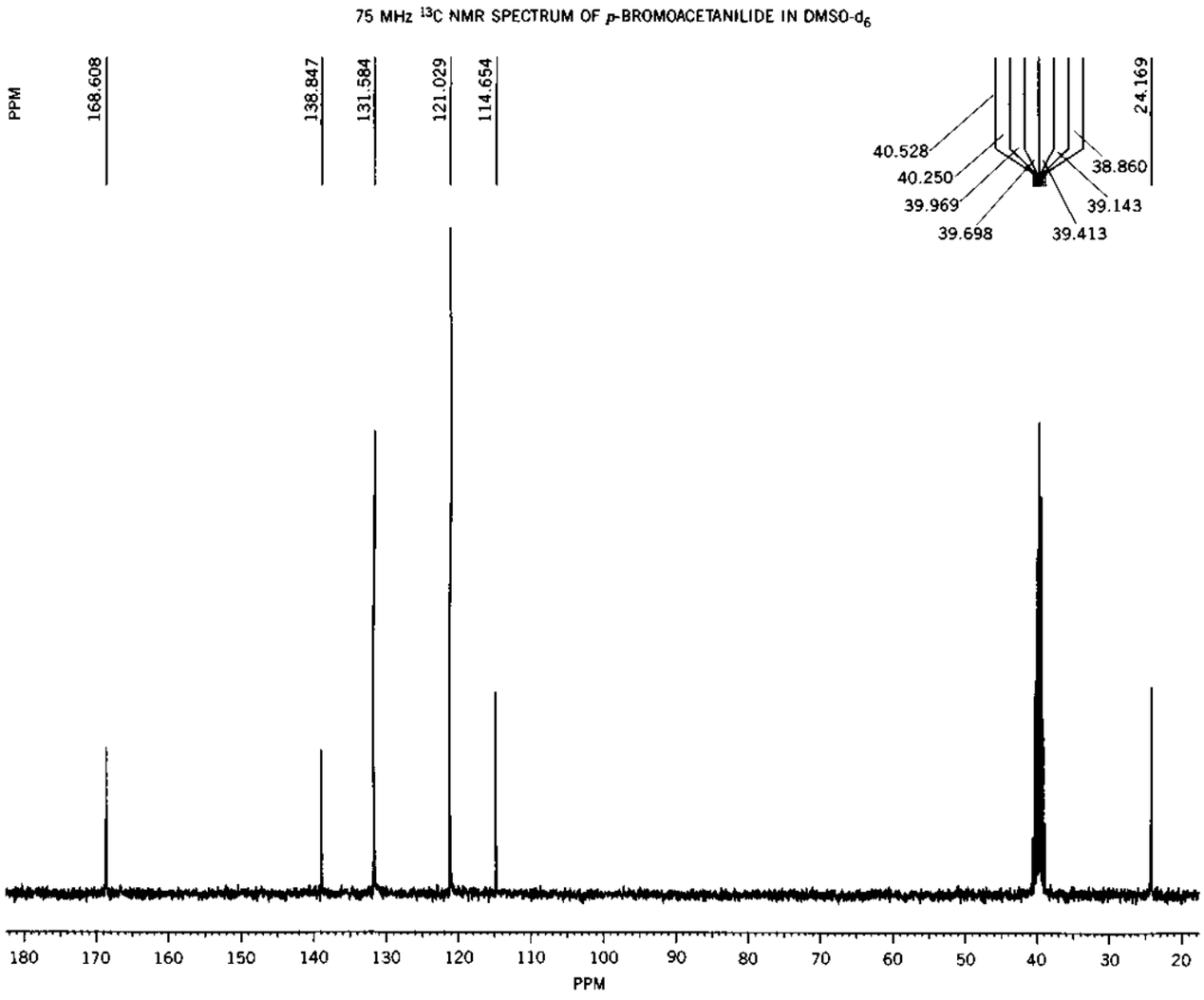

Figure 6.47 **^{13}C-NMR spectrum: *p*-bromoacetanilide.**

6-181. Benzene is brominated in the presence of $FeBr_3$ catalyst:

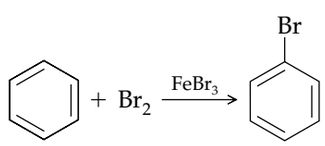

Suggest an appropriate mechanism for this reaction.

6-182. Draw the structure of the major monobrominated product(s) formed when each of the following compounds is reacted with Br_2 in the presence of $FeBr_3$:

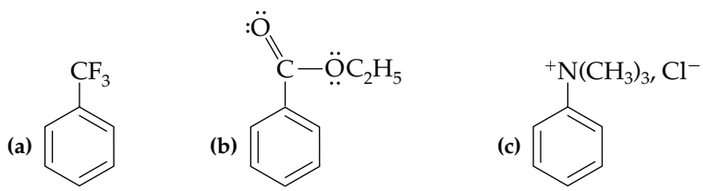

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6-183. Arrange the following compounds in order of increasing reactivity toward electrophilic aromatic substitution. Explain the reason(s) for your decisions.

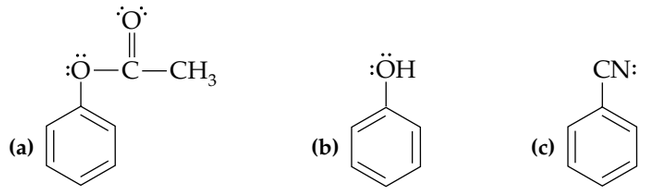

6-184. In the experiment, sodium bisulfite solution is added at the end to destroy the unreacted bromine. What reaction is occurring here? Is HSO_3^- acting as an oxidizing or reducing agent? Write a balanced equation as part of your answer.

6-185. Both the ^1H and ^{13}C NMR spectra (Figs. 6.46 and 6.47) provide unambiguous evidence that the bromination of acetanilide gave exclusively para substitution. Explain.

BIBLIOGRAPHY

For a general review of bromination see

Smith, M. B.; March. J. *Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, 2007, Chap. 11, p. 698.

For use of an alternate reagent for the bromination of acetanilide see

Schatz, P. F. *J. Chem. Educ.* **1996,** *73,* 267.

The following references are selected from a large number of examples given in *Organic Syntheses* that illustrate electrophilic aromatic substitution using bromine:

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EXPERIMENT 29

Nitration: 2,5-Dichloronitrobenzene; N,N′-Diacetyl-2,3-dinitro-1, 4-phenylenediamine; 5-Nitrosalicylic Acid; and 2- and 4-Nitrophenol

Common name: 2,5-dichloronitrobenzene

CA number: [89-61-2]

CA name as indexed: benzene, 1,4-dichloro-2-nitro-

Common name: *N,N′*-diacetyl-2,3-dinitro-1,4-phenylenediamine

CA number: [7756-00-5]

CA name as indexed: acetamide, *N,N′*-(2,3-dinitro-1,4-phenylene)bis-

Common names: 5-nitrosalicylic acid, anilotic acid

CA number: [96-97-9]

CA name as indexed: benzoic acid, 2-hydroxy-5-nitro-

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Common names: 2-nitrophenol, *o*-nitrophenol
CA number: [88-75-5]
CA name as indexed: phenol, 2-nitro-

Common names: 4-nitrophenol, *p*-nitrophenol
CA number: [100-02-7]
CA name as indexed: phenol, 4-nitro-

Purpose. Aromatic nitration is an important synthetic reaction. This experiment explores two methods used for placing a nitro group on an aromatic ring system via an electrophilic aromatic substitution reaction. In Experiments [29A], [29B], and [29C] anhydrous nitric acid is used as the nitrating agent. In Experiment [29D], nitration is accomplished using a $SiO_2 \cdot HNO_3$ reagent.

Prior Reading

Technique 2: Simple Distillation at the Semimicroscale Level (pp. 61–64)
Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Thin-Layer Chromatography (pp. 97–99)
Concentration of Solutions (pp. 101–104)
Chapter 4: Mixture Melting Points (pp. 52–54)

GENERAL REACTION

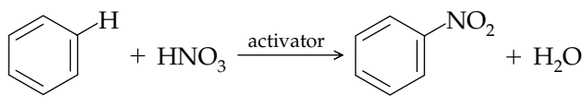

DISCUSSION

The nitration reactions described in this experiment all demonstrate one of the classic electrophilic aromatic substitution reactions. Nitration has been used extensively in organic synthesis since a nitro group on an aromatic ring may be readily reduced to an amino group.

Once introduced onto the aromatic ring, the electron-withdrawing nitro group deactivates the ring toward further reactions with electrophiles. For example, bromination of nitrobenzene leads only to *m*-nitrobromobenzene; no dibromonitrobenzene is readily formed. However, when activating groups (π-electron donors) are present on the ring, it is possible to nitrate the ring twice. This phenomenon can be illustrated by comparing the results of the nitration of 1,4-dichlorobenzene (Experiment [29A]) with that of *N,N′*-diacetyl-1,4-phenylenediamine (Experiment [29B]). Because of the presence of the activating acetamido (CH_3CONH—) groups, the dinitro derivative forms readily.

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In Experiment [29C] (the preparation of 5-nitrosalicylic acid), the directing influences of the 1-CO_2H and 2-OH substituents on the entering —NO_2 group are illustrated. In this example, these two groups compliment each other since they both direct the entering nitro group to the 5 position. The 5 position and the 3 position are both electronically favored since the —CO_2H group is meta directing; the —OH group is ortho–para directing. The nitro group ends up at the 5 position, and not at the 3 position, due to steric effects.

The use of a silica gel-based reagent to accomplish nitration under fairly mild conditions is illustrated in Experiment [29D]. The nitrating reagent, $SiO_2 \cdot HNO_3$ is prepared by treatment of silica gel with nitric acid. In the experiment, phenol is nitrated to produce a mixture of products. *Thin-layer chromatography* is used to analyze the mixture, and the ortho and para nitrated phenols are separated by *column chromatography* using a silica gel column. If unreacted phenol is detected in the TLC analysis, an extraction technique is used to separate it from the para isomer. This separation technique is based on the fact that a nitrated phenol is more acidic than phenol itself.

It is generally accepted that the nitronium ion (NO_2^+) is the electrophile that adds to the aromatic ring. The overall mechanism for nitration follows:

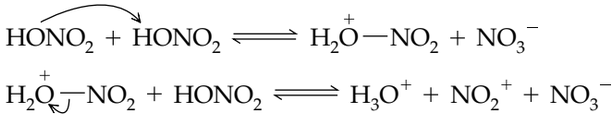

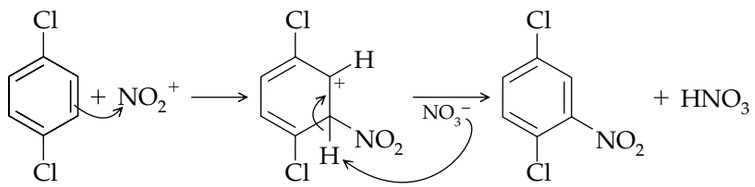

This mechanism illustrates two HNO_3 molecules reacting to generate the nitronium ion as when using the anhydrous nitric acid reagent. Sulfuric acid is often used to enhance the production of NO_2^+ as shown here:

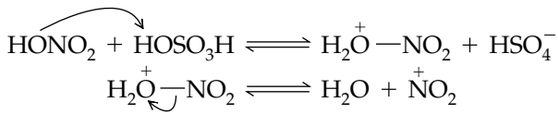

Thus a commonly used nitrating reagent is a mixture of concentrated sulfuric and nitric acids.

SEMIMICROSCALE PREPARATION OF ANHYDROUS NITRIC ACID

Anhydrous nitric acid (HNO_3) is prepared by the following procedure.

CAUTION: The reagents and the product of this preparation are highly corrosive. The distillation must be conducted in a **hood.** Appropriate gloves are strongly suggested. Prevent contact with eyes, skin, and clothing. Any spill should be neutralized using solid sodium carbonate or bicarbonate. HOOD

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EQA

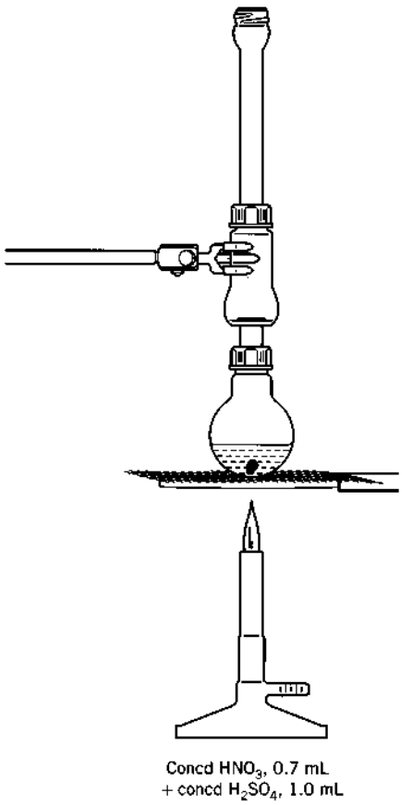

EXPERIMENTAL PROCEDURE

Estimated time of preparation: 0.5 h.

NOTE. Use this anhydrous nitric acid immediately for the nitration experiments given below. The amount obtained at the scale used here is sufficient for the preparation of two of the nitro compounds described in this experiment.

Physical Properties of Reactants and Product				
Compound	MW	Amount	bp (°C)	*d*
Concd nitric acid (68%)		0.7 mL	120.5	1.41
Concd sulfuric acid (96–98%)		1.0 mL	338	1.84
Anhydrous nitric acid	63.01		83	1.40

Reagents and Equipment. Using two clean, dry 1.0-mL graduated pipets, add 0.7 mL of concentrated nitric acid, followed by 1.0 mL of concentrated sulfuric acid, to a 10-mL round-bottom flask containing a boiling stone. Swirl the flask gently to mix the reagents. Attach the flask to a Hickman still fitted with an air condenser (⬅).

NOTE: It is useful to invert a 10-mL beaker over the air condenser to help contain the acid vapors.

CAUTION: Sulfuric acid can cause severe burns. Nitric acid is a strong oxidizing agent. Prevent contact with eyes, skin, and clothing. A spill can be neutralized using sodium carbonate or bicarbonate.

Reaction Conditions. Heat the acid solution very gently with a microburner, keeping the microburner in constant motion, until approximately 0.2 mL of anhydrous nitric acid has been collected as distillate in the collar of the still.

Purification and Characterization. Use the anhydrous nitric acid as collected. No further purification is required.

NOTE. Anhydrous nitric acid (white fuming nitric acid) is a colorless liquid, bp 83°C It is estimated that the nitric acid obtained in this preparation is at least 99.5–100% pure. If it is necessary to store the distillate, remove the acid from the collar of the still (Pasteur pipet) and place it in a 1.0-mL conical vial fitted with a glass stopper. It may be necessary to slightly bend the end of the pipet in a flame so that it can reach the collar of a still that does not have a side port. The anhydrous nitric acid is colorless or faintly yellow.

Experiment 29A

2,5-Dichloronitrobenzene

REACTION

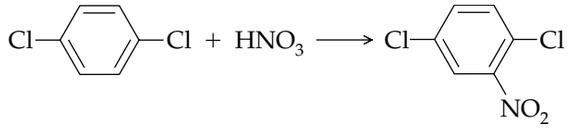

1,4-Dichlorobenzene 2,5-Dichloronitrobenzene

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.5 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
1,4-Dichlorobenzene	147.01	38 mg	0.26	53		
Anhydrous nitric acid	63.01	100 μL	2.4		83	1.50

Reagents and Equipment. Equip a 3.0-mL conical vial with an air condenser (➡). Weigh and add 38 mg (0.26 mmol) of 1,4-dichlorobenzene, followed by 100 μL of anhydrous nitric acid delivered from a calibrated Pasteur pipet (9 in.).

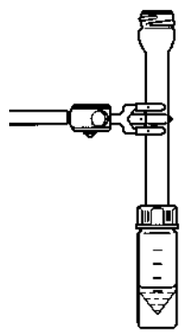

1,4-$Cl_2C_6H_4$, 38 mg + anhydrous HNO_3, 100 μL

CAUTION: The nitric acid reagent is highly corrosive. Prevent contact with eyes, skin, and clothing. A spill is neutralized using solid sodium carbonate or bicarbonate.

Reaction Conditions. Allow the resulting solution to stand at room temperature for a period of 15 min. Next add 1.0 mL of water (calibrated Pasteur pipet) dropwise, while stirring with a thin glass rod, and then place the vial in an ice bath to cool.

Isolation of Product. Collect the crystalline precipitate by vacuum filtration using a Hirsch funnel (➡). Wash the filter cake with four 1.0-mL portions of water (calibrated Pasteur pipet) and then place it on a porous clay plate or on filter paper to dry.

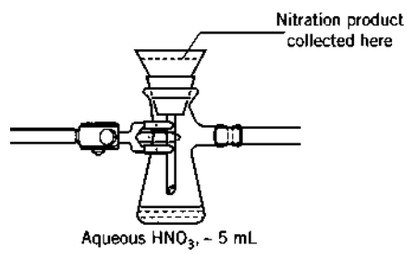

Purification and Characterization. The product, consisting of fine, white needles, is sufficiently pure for characterization. It may be recrystallized from ethanol–water, using a Craig tube, if desired.

Weigh the 2,5-dichloronitrobenzene and calculate the percent yield. Determine the melting point and compare your result to that reported in the literature. Notice that the starting material and the nitrated product have very close melting points. It is recommended that a mixed melting point be carried out to establish that the desired product has been isolated (see Prior Reading).

A further or alternative check on the purity of the material may be made using thin-layer chromatography (TLC).

INFORMATION. Carry out the TLC analysis with Eastman Kodak silica gel–polyethylene terephthalate plates (#13179). Activate the plates at an oven temperature of 100 °C for 30 min. Place them in a desiccator for cooling and storing until used. Elute the plates using hexane solvent. Visualization is accomplished with UV light. See Prior Reading for the methods of TLC analysis and determination of R_f *values.*

Chemical Tests. Additional chemical tests (Chapter 9) may also be performed to further characterize the product. Does the ignition test confirm the presence of the aromatic ring? Does the Beilstein test detect the presence of chlorine? Can the sodium fusion test detect the presence of nitrogen? Can the specific presence of the nitro group be detected by reaction with ferrous hydroxide solution?

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EQA

Experiment 29B

N,N′-Diacetyl-2,3-dinitro-1,4-phenylenediamine

REACTION

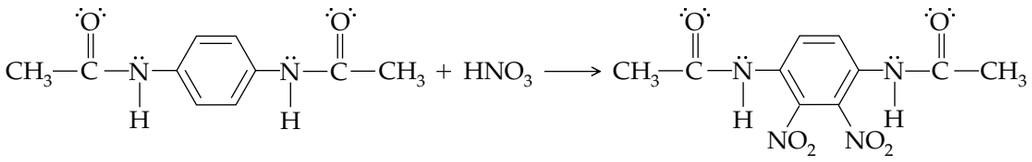

N,N′-Diacetyl-1,4-phenylenediamine *N,N′*-Diacetyl-2,3-dinitro-1,4-phenylenediamine

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.5 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
N,N′-Diacetyl-1,4-phenylenediamine	192	48 mg	0.25	312–315		
Anhydrous nitric acid	63.01	100 μL	2.4		83	1.50
N,N′-Diacetyl-2,3-dinitro-1,4-phenylenediamine	282			257		

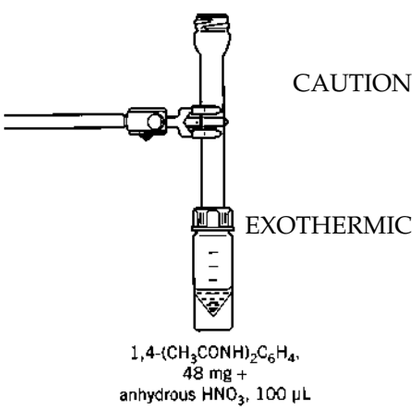

Reagents and Equipment. To a 3.0-mL conical vial equipped with an air condenser, weigh and add 48 mg (0.25 mmol) of *N,N′*-diacetyl-1,4-phenylenediamine. Now, using **caution,** add dropwise 100 μL of anhydrous nitric acid delivered from a calibrated Pasteur pipet (9 in.) (⬅). *The N,N′-diacetyl-1,4-phenylenediamine is prepared by the procedure outlined in Experiment [23B].*

CAUTION: The reaction is highly ***exothermic.*** A vigorous reaction occurs if the acid is added too rapidly. The nitric acid reagent is highly corrosive; prevent contact with eyes, skin, and clothing. A spill is neutralized using sodium carbonate or bicarbonate.

Reaction Conditions. Allow the resulting solution to stand at room temperature for a period of 10 min. Add 1.0 mL of water from a calibrated Pasteur pipet dropwise and then place the vial in an ice bath to cool.

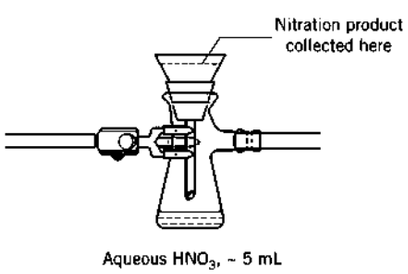

Isolation of Product. Collect the resulting yellow precipitate by vacuum filtration using a Hirsch funnel (⬅). Wash the filter cake with four 1.0-mL portions of water from a calibrated Pasteur pipet. Maintain suction to aid in drying of the product. A piece of plastic food wrap over the mouth of the funnel can aid this process (see Prior Reading). Dry the material further on a porous clay plate, on filter paper, or under vacuum at room temperature.

Purification and Characterization. The product needs no further purification. Weigh the dried material and calculate the percent yield.

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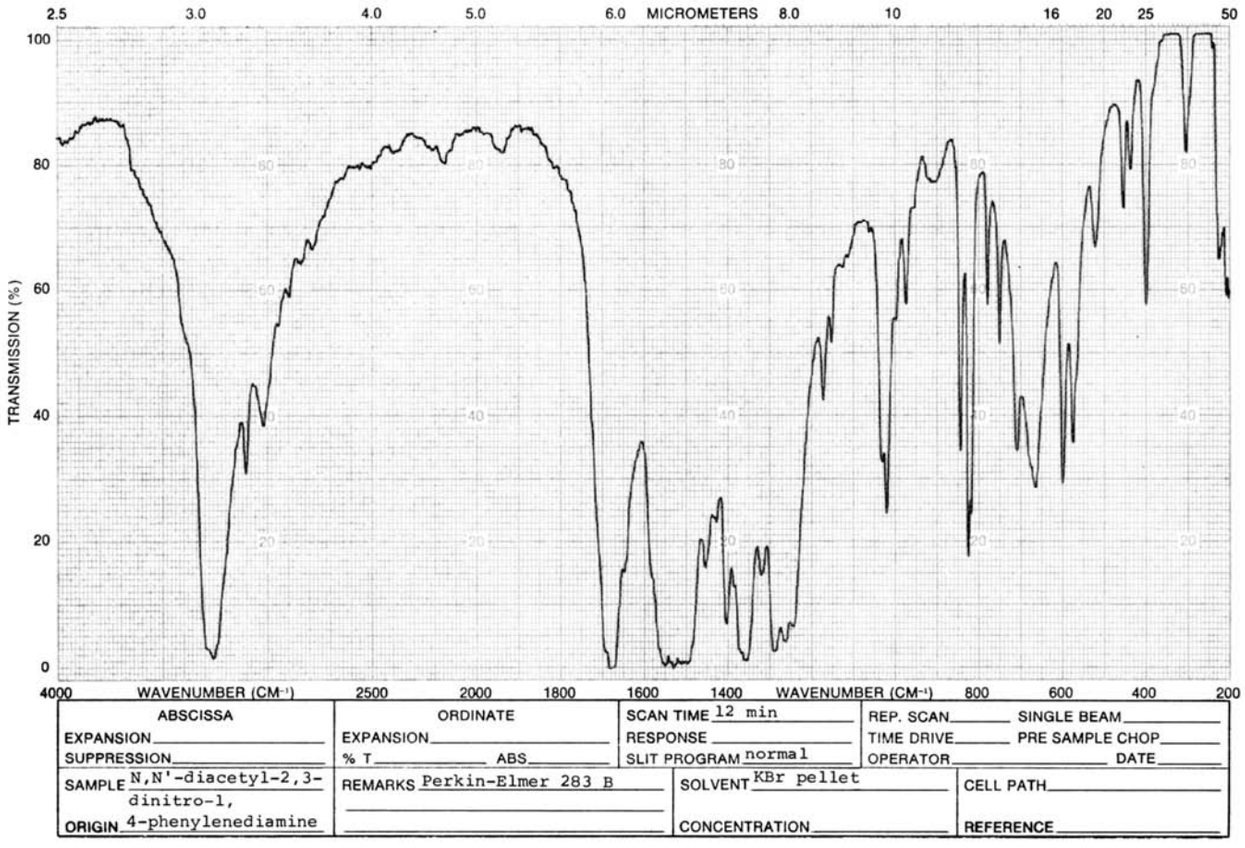

Figure 6.48 IR spectrum: *N,N′*-diacetyl-2,3-dinitro-1,4-phenylenediamine.

Determine the melting point and compare your result with the melting point listed in the above Reactant Product table. Obtain an IR spectrum of your product and compare it with that shown in Figure 6.48.

5-Nitrosalicylic Acid

Experiment 29C

This material may be used to prepare the caffeine 5-nitrosalicylate derivative (see Experiment [11B]).

REACTION

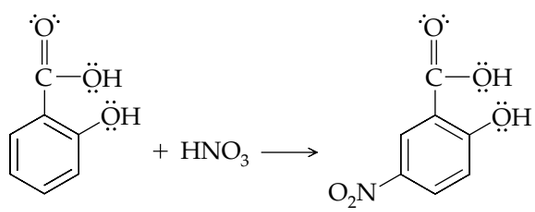

Salicylic acid 5-Nitrosalicylic acid

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.5 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Salicylic acid	138.12	50 mg	0.36	159		
Anhydrous nitric acid	63.01	100 μL	2.4		83	1.50

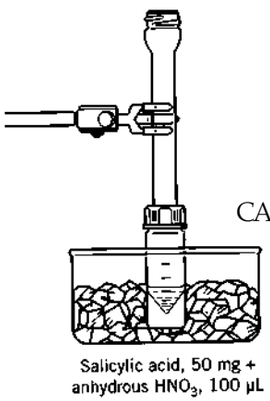

HOOD

CAUTION: This reaction should be conducted in a **hood.**

Reagents and Equipment. Weigh and add 50 mg (0.36 mmol) of salicylic acid to a 3.0-mL conical vial equipped with an air condenser. Place the vial in an ice bath to cool. Also place a stoppered conical vial containing 100 μL of freshly prepared **ANHYDROUS** nitric acid (use **caution**) from a Pasteur pipet in the ice bath (⬅).

CAUTION

CAUTION: The nitric acid reagent is highly corrosive; prevent contact with eyes, skin, and clothing. A spill is neutralized using solid sodium carbonate or bicarbonate.

Reaction Conditions. **Carefully** add the cold nitric acid dropwise from a calibrated Pasteur pipet (9 in.) to the salicylic acid. Keep the vial containing the salicylic acid in the ice bath during the addition. The evolution of a red-brown gas (NO_2, which is **toxic**) is observed during the addition, if the acid is not pure.

TOXIC

EXOTHERMIC

CAUTION: The reaction is highly **exothermic.** A very vigorous reaction occurs if the acid is added too rapidly.

Allow the vial to stand in the ice bath for an additional 20 min and then add 1.0 mL of distilled water dropwise from a calibrated Pasteur pipet to the reaction mixture.

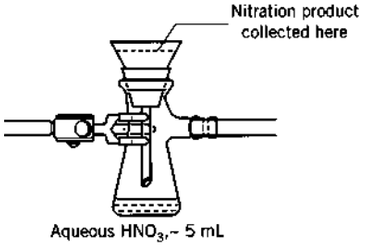

Isolation of Product. Collect the orange-pink solid by vacuum filtration using a Hirsch funnel (⬅). Wash the filter cake with four 1.0-mL portions of cold water from a calibrated Pasteur pipet. Maintain suction to aid in drying of the product. A piece of plastic food wrap over the mouth of the funnel can aid this process (see Prior Reading). Dry the material further on a porous clay plate, on filter paper, or under vacuum at room temperature.

Purification and Characterization. Recrystallize the product using a Craig tube by dissolving the material in the *minimum* amount of absolute ethanol, followed by the dropwise addition of water until precipitation occurs. Cool the mixture in an ice bath and separate the light-yellow crystals. Dry them on a porous clay plate or under vacuum as noted above.

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EQA

Weigh the crystals and calculate the percent yield. Determine the melting point and compare your value to that listed in the literature. Obtain an IR spectrum of the material and compare it with that recorded in the literature.

2- and 4-Nitrophenol

Experiment 29D

INSTRUCTOR PREPARATION. In a 250-mL Erlenmeyer flask containing a magnetic stirring bar, weigh and place 20.0 g of silica gel (70–230 mesh; the removal of fines is not necessary). Now add 50 mL of 7.5 M nitric acid and stir the mixture for 3 h at room temperature. Remove the nitrated silica gel by gravity filtration (do not rinse), place it on a clay plate, and allow it to air dry in a ***hood*** HOOD *overnight. Store the product in an airtight container.*

Determine the nitric acid content of the silica gel by titration of a water suspension of the gel with a 0.1 M NaOH solution. The acid content of the gel should be in the range of 16–20% by weight.

Nitration of Phenol

REACTION

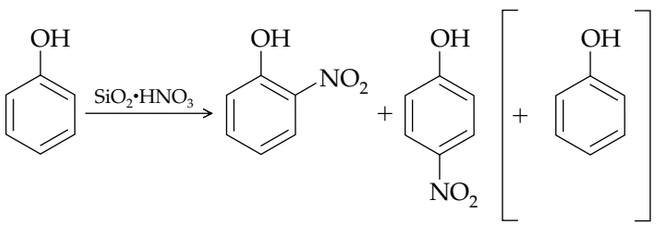

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Phenol	94.11	240 mg	2.55	40.5–41.5	182
$SiO_2 \cdot HNO_3$		1.0 g			
Methylene chloride		5 mL			40

Reagents and Equipment. Weigh and add 240 mg (2.55 mmol) of phenol to a 10-mL round-bottom flask containing a stir bar. Now add 5 mL of methylene chloride. To this solution, weigh and add 1.0 g of nitrated silica gel (~16% HNO_3). Attach the flask to an air condenser (➡).

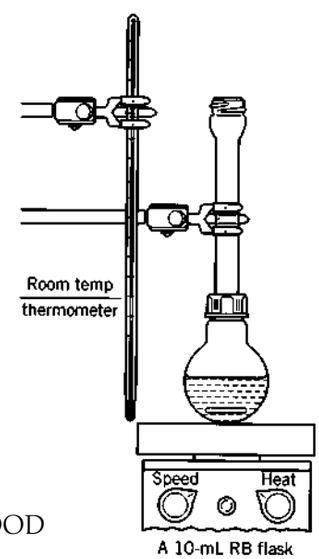

CAUTION: Phenol is highly toxic and corrosive. Prevent contact with eyes and skin. It is best dispensed by warming the container of phenol in a warm water bath and then using an automatic delivery pipet. This should be done in the **hood.** HOOD

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EQA

Reaction Conditions. Stir the resulting mixture at room temperature for 5 min.

Isolation of Product. Separate the silica gel from the reaction mixture by gravity filtration through a filter funnel containing a small plug of glass wool. Collect the filtrate in a 10-mL Erlenmeyer flask containing a boiling stone. Wash the collected silica gel with two 0.5-mL portions of methylene chloride, and collect these washings in the same Erlenmeyer flask.

Concentrate the filtrate to a volume of about 1.0 mL using a warm sand bath under a slow stream of nitrogen in the **hood.**

HOOD

Use thin-layer chromatography to obtain an analysis of the product mixture (see Prior Reading). Use methylene chloride as the elution solvent, silica gel (with a fluorescent indicator) as the stationary phase, and UV light for visualization. Typical R_f values are 0.04 for 4-nitrophenol, 0.15 for phenol, and 0.58 for 2-nitrophenol.

NOTE. 2,4-Dinitrophenol has a typical R_f *value of 0.33 under the chromatography conditions above; it is not usually formed under these reaction conditions.*

Characterization and Purification. Column chromatography is now used to separate the mixture of products. Pack (dry) a 1.0-cm-diameter buret column with 7.5 g of activated silica gel. Place the above product solution on the column using a Pasteur pipet and then elute the column with 25 mL of 60:40 methylene chloride/pentane solvent. Collect the first 20 mL of eluate in a tared 25-mL Erlenmeyer flask. Concentrate this fraction to dryness in a warm sand bath under a slow steam of nitrogen to isolate the 2-nitrophenol. Weigh the product.

Now elute the column with about 30 mL of 1:1 ethyl acetate/methylene chloride solvent. Collect the first 20 mL of eluate in a tared 25-mL Erlenmeyer flask containing a boiling stone. Concentrate this fraction as above to a volume of about 2 mL. Use thin-layer chromatography to determine the purity of the product (see conditions outlined above). The main constituent of this fraction is 4-nitrophenol. However, the presence of unreacted phenol or possibly quinone is often detected. Now concentrate the product solution to dryness and weigh the 4-nitrophenol isolated.

If the TLC analysis indicates impurity, 4-nitrophenol may be purified as follows. Dissolve the solid residue in 7 mL of saturated sodium bicarbonate solution and transfer the resulting solution to a 15-mL centrifuge tube. Extract this solution twice with 2-mL portions of methylene chloride (a Vortex mixer may be used to good advantage here). Remove the methylene chloride layers using a Pasteur pipet and save them (together) in a small Erlenmeyer flask until you have isolated and characterized the product.

Cool the resulting aqueous solution in an ice bath and add 6 M HCl dropwise, with mixing (glass rod or Vortex mixer), until it becomes neutral or slightly acidic toward litmus or pH paper. *Do this step carefully. Too vigorous a reaction may result in loss of product.* Now extract the resulting solution with three 2-mL portions of methylene chloride. Following each extraction, remove the methylene chloride using a Pasteur filter pipet and transfer it to a 10-mL Erlenmeyer flask. Dry the wet solution over anhydrous sodium sulfate and then transfer it by Pasteur filter pipet to a tared 10-mL Erlenmeyer flask containing a boiling stone. Concentrate this solution using a warm sand bath under a slow stream of nitrogen gas to yield the 4-nitrophenol product. Weigh the product. The purity of the material may be checked again, using

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TLC as outlined above. It may also be recrystallized from water using the Craig tube, if necessary.

To characterize the 2- and 4-nitrophenols, determine their melting points and obtain their infrared spectra. Compare your results to those reported in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. Chemical classification tests (see Chapter 9) are also of value to establish the identity of these compounds. Perform the ferric chloride test for phenols. Is a positive result obtained for each compound? Does the sodium fusion test detect the presence of nitrogen? The test for nitro groups might also be performed. The phenyl- or α-naphthylurethane derivatives of the phenols may be prepared to further establish their identity (see Chapter 9, Preparation of Derivatives).

QUESTIONS

6-186. Predict the most likely mononitration product from each of the following compounds. Explain the reasons for your choice.

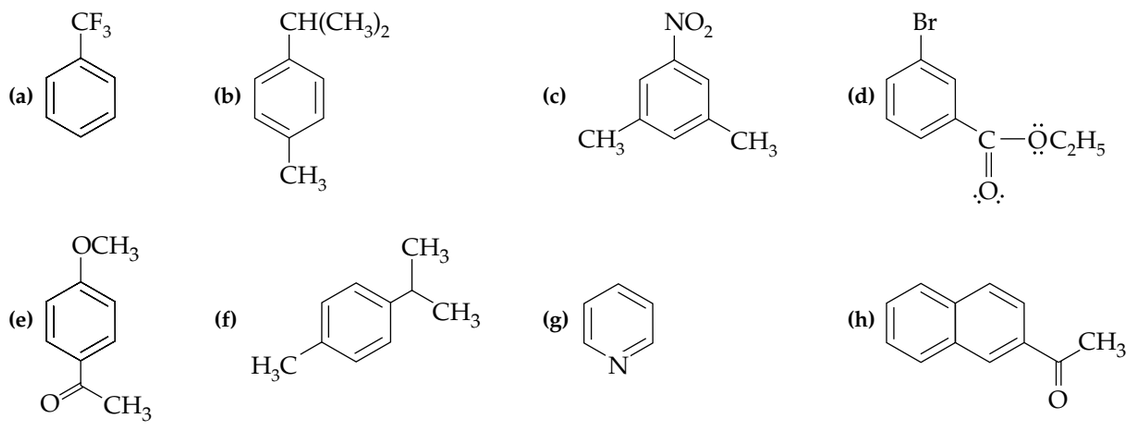

6-187. Write equations to show how nitronium ions might be formed using a mixture of nitric and sulfuric acids.

6-188. Which ring of phenyl benzoate would you expect to undergo nitration more readily? Explain.

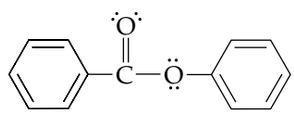

Phenyl benzoate

6-189. Arrange the following compounds in order of increasing reactivity toward nitration. Explain.
- **(a)** Acetanilide
- **(b)** Acetophenone
- **(c)** Bromobenzene
- **(d)** Toluene

6-190. Offer a reasonable explanation of why nitration of 1,4-dichlorobenzene yields the mononitro derivative while *N,N′*-diacetyl-1,4-phenylenediamine forms the dinitro compound.

6-191. Explain why *p*-nitrophenol is a stronger acid than phenol itself. Would *p*-methoxyphenol be a stronger or weaker acid than phenol? Explain.

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EQA

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Stern, S. A.; Mullhaupt, J. T.; Kay, W. B. *Chem. Rev.* **1960,** *60,* 185.

The preparation used in this experiment is an adaptation of that reported by

Cheronis, N. D.; Entrikin, J. B. *Semimicro Qualitative Organic Analysis;* Crowell: New York, 1947, p. 258.

The preparation of the nitrated silica gel was adapted from that reported by

Tapia, R.; Torres, G.; Valderrama, J. A. *Synth. Commun.* **1986,** *16,* 681.

For a general review of nitration of aromatic species see

Olah, G. A.; Malhotra, R.; Narang, S. C. *Nitration: Methods and Mechanism;* VCH: New York, 1989.

Schefield, K. *Aromatic Nitration;* Cambridge Univ. Press: New York, 1980.

Smith, M. B.; March. *J. Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, 2007, Chap. 11, p. 685.

These references are selected from a large number of examples of nitration given in *Organic Syntheses*. None of these examples uses anhydrous nitric acid or the nitrated silica gel as the nitrating agent.

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Mendenhall, G. D.; Smith, P. A. S. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 829.

Newman, M. S.; Boden, H. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 1029.

EXPERIMENT 30

Nucleophilic Aromatic Substitution: 2,4-Dinitrophenylthiocyanate

Common name: 2,4-dinitrophenylthiocyanate

CA number: [1594-56-5]

CA name as indexed: thiocyanic acid, 2,4-dinitrophenyl ester

Purpose. The conditions under which a specific type of **nucleophilic aromatic substitution reaction** can occur are investigated. You will carry out the conversion in a two-phase solvent system through the use of a phase-transfer catalyst. The experiment is an example of nucleophilic aromatic substitution on an aromatic ring having two strongly electron-withdrawing substituents. In this experiment, a bromine substituent (leaving group) is replaced by a thiocyanate, —S—C≡N, group (nucleophile).

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)

Technique 5: Crystallization
Craig Tube Crystallization (pp. 89–91)

Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Concentration of Solutions (pp. 101–104)

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REACTION

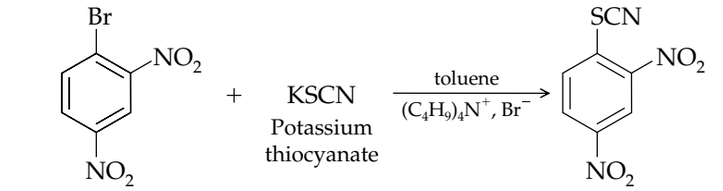

2,4-Dinitrobromobenzene

2,4-Dinitrophenyl thiocyanate

DISCUSSION

Nucleophilic aromatic substitution reactions generally take place only if activating groups are present at the positions ortho and/or para to a good leaving group. Activating groups, in this case, are groups that are electron withdrawing and render the aromatic ring more electron-deficient, and thus more susceptible to nucleophilic attack. On the other hand, π-electron donating groups hinder the reaction. Groups such as $-NO_2$, $-SO_2CH_3$, $-{}^+N(CH_3)_3$, $-CF_3$, $-CN$, $-SO_3{}^-$, $-Br$, $-Cl$, $-I$, $-CO_2{}^-$, especially if one $-NO_2$ group is already present, are strongly activating. These groups not only make the ring more susceptible to nucleophilic attack, they assist in the resonance stabilization of the intermediate cyclohexadienyl anion. In the reaction illustrated in this experiment, two nitro groups are present on the ring, both ortho and para to the departing bromine substituent. While functional groups containing a carbonyl group do, in principle, activate the aromatic ring toward nucleophilic attack, the carbonyl groups themselves are usually more likely to react with a nucleophile than is the aromatic ring.

The conditions under which this reaction is conducted lend themselves to the use of phase-transfer catalysis. The system involves two phases: the aqueous phase and the organic phase (toluene). The phase-transfer catalyst plays a very important role. As an ammonium cation, it carries the SCN^- ion from the aqueous phase into the organic phase where the substitution reaction then occurs. The product and the corresponding bromide salt of the phase-transfer catalyst are produced in this conversion. The bromide salt of the phase-transfer catalyst then migrates back into the aqueous phase, and the process repeats itself. The catalyst can play this role since the large organic groups (the four butyl groups) increase the solubility of the phase-transfer catalyst in the organic phase, while the charged ionic center of the catalyst renders it water soluble. Phase-transfer catalysts can also be used in many other reactions, including the preparation of ethers by the Williamson method (see Experiments [22A] and [22B]), and the Horner–Wadsworth–Emmons modification of the Wittig reaction (see Experiments [19B] and [19D]).

The reaction in this experiment proceeds by an *addition–elimination two-step* sequence, of which the first step is generally rate determining. A tetrahedral intermediate (cyclohexadienyl anion) is formed by the attack of the nucleophile on the carbon atom to which the leaving group is attached. In the subsequent step, the leaving group then departs with its bonding electrons, regenerating the aromatic system. It is important to note that, in contrast to nucleophilic substitution reactions on alkyl carbon atoms, the reaction does not

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proceed by an S_N2 mechanism, as in this case an intermediate is formed. The mechanism is outlined on the next page.

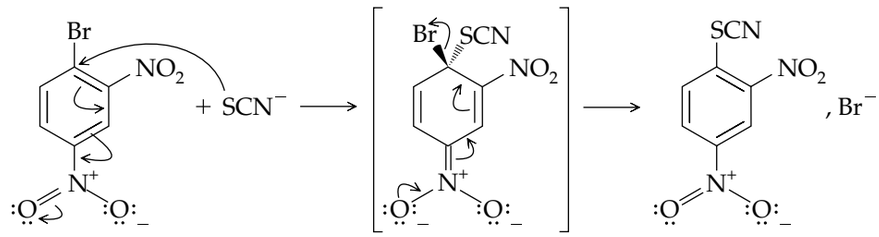

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: 2.0 h.

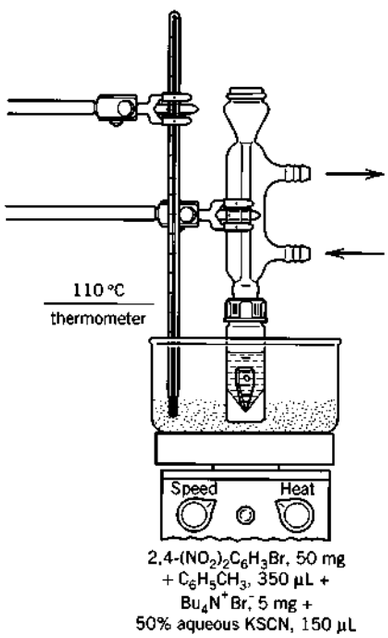

HOOD

Physical Properties of Reactants and Product					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
2,4-Dinitrobromobenzene	247.01	50 mg	0.20	75	
Tetrabutylammonium bromide	322.38	5 mg	0.02	103–104	
Aqueous potassium thiocyanate (50%)		150 µL			
Toluene	92.15	350 µL			111
2,4-Dinitrophenyl-thiocyanate	244			138–139	

Reagents and Equipment. Assemble a 3.0-mL conical vial containing a magnetic spin vane and equipped with a reflux condenser. Weigh and place in the vial 50 mg (0.20 mmol) of 2,4-dinitrobromobenzene followed by 350 µL of toluene (⬅). To this solution add 5.0 mg (0.02 mmol) of tetrabutylammonium bromide and 150 µL of a 50% aqueous potassium thiocyanate (wt/wt) solution.

CAUTION: Tetrabutylammonium bromide is an irritant. ***Handle with care!*** It is also hygroscopic and should be protected from moisture prior to its use. Dispense the toluene and the thiocyanate solution in the **hood** using automatic delivery pipets.

Reaction Conditions. Heat the resulting mixture at a sand bath temperature of 100 °C with stirring for 1 h. Allow the solution to cool to room temperature.

Isolation of Product. Use a Pasteur filter pipe to separate the toluene layer from the aqueous layer (**saving** both layers) and place the toluene layer in a 3.0-mL capped vial. Extract the toluene layer with two 1.0-mL portions of water and combine the water extracts with the original water layer you saved. Now extract the combined aqueous layers with two 0.5-mL portions of toluene, and combine these toluene extracts with the original toluene layer.

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NOTE. The volumes of liquid used in the extraction are measured using calibrated Pasteur pipets. For each extraction, shake the vial, vent it carefully, and allow the layers to separate. The transfers are made using Pasteur filter pipets.

Transfer the toluene solution by Pasteur pipet to a Pasteur filter pipet microcolumn containing 700 mg of anhydrous sodium sulfate previously wetted with toluene (➡). Allow the solution to elute through the column, and collect the dried toluene eluate in a 10-mL Erlenmeyer flask containing a boiling stone. Concentrate this solution by warming in a sand bath under a gentle stream of nitrogen gas in the **hood.** A yellow, solid product is obtained.

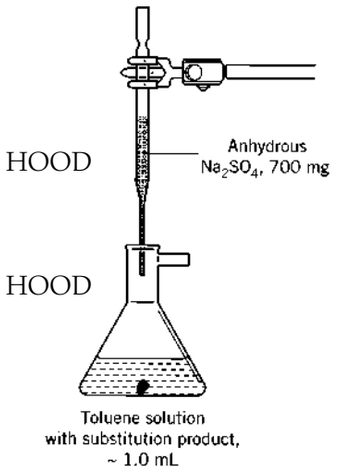

Purification and Characterization. The product is generally nearly pure. Re-crystallize the material from chloroform, using a Craig tube, if desired.

CAUTION: Chloroform is toxic! Dispense and use only in the **hood.** Do not breathe the vapors.

Weigh the dried product and calculate the percent yield. Determine the melting point and compare it with that listed in the Reagent and Product table. Obtain an IR spectrum and compare your result to that of an authentic sample, or to one in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar)

2,4-Dinitrophenylthiocyanate: Preparation Using a Monomode Microwave Apparatus

Experiment 30-1*

M

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
1-Bromo-2,4-dinitrobenzene	247.01	67 mg	0.27	71–73	
Aqueous potassium thiocyanate (50%)		0.2 mL			
Ethanol	276	0.8 mL			78
2,4-Dinitrophenylthiocyanate	244			138–139	

Reagents and Equipment. This experiment is designed for use in the CEM Discover and Biotage Initator microwave units.

In a 10.0-mL glass microwave reaction vessel containing a magnetic stir bar, add 67 mg (0.27 mmol) of 2,4-dinitrobromobenzene, 0.2 mL of 50% aqueous potassium thiocyanate (wt/wt) solution, and 0.8 mL of ethanol. Immediately cap the vessel with the microwave pressure cap.

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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HOOD

CAUTION: Dispense the potassium thiocyanate solution in the **hood** using an automatic delivery pipet. Since the reaction requires heating the reaction mixture to above the boiling point of some components in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

Reaction Conditions. Place the reaction vessel in the microwave cavity and, depending on the equipment used, position the pressure device on top. Program the microwave unit to heat the reaction mixture to 125 °C and hold at this temperature for 5 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the tube from the microwave unit. Allow the resulting solution to cool to room temperature and then place it in an ice bath for a 10-min period to complete the crystallization of the product.

Isolation of Product. Collect the yellow crystals by vacuum filtration using a Hirsch funnel and wash the filter cake with cold 95% ethanol (1–2 mL). Partially dry the filter cake under suction. Transfer the filtered, washed, and partially dried product to a porous clay plate or filter paper to complete drying.

Characterization. Weigh the dried product and calculate the percent yield. Determine the melting point and compare it with the list in the Reagent and Product table. Obtain an IR spectrum of your product, and compare it to that of an authentic sample, or to the spectrum shown in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Experiment 30-2*

M

2,4-Dinitrophenylthiocyanate: Preparation Using a Multimode Microwave Apparatus

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1 h.

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
1-Bromo-2,4-dinitrobenzene	247.01	296 mg	1.20	71–73	
Aqueous potassium thiocyanate (50%)		1.0 mL			
Ethanol	276	4 mL			78
2,4-Dinitrophenylthiocyanate	244			138–139	

Reagents and Equipment. This experiment is designed for use in the CEM MARS, Milestone START, and Anton Paar Synthos 3000 microwave units. When using the Anton Paar Synthos 3000 unit with the 24-position silicon carbide plate rotor containing glass vials, the reagent and solvent quantities cited in the monomode procedure should be used in conjunction with the reaction conditions here in the multimode procedure.

In a microwave reaction vessel containing a magnetic stir bar, add 296 mg (1.2 mmol) of 2,4-dinitrobromobenzene, 1.0 mL of 50% aqueous potassium

*This section has been written by Dr. Nicholas E. Leadbeater from the Department of Chemistry at the University of Connecticut, and Dr. Cynthia B. McGowan from the Department of Chemistry at Merrimack College, MA.

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thiocyanate (wt/wt) solution, and 4.0 mL of ethanol. Immediately cap the vessel with the microwave pressure cap and adjust the tightness to the manufacturer-specified level. Place the sealed vessel into its outer protective jacket.

CAUTION: Dispense the potassium thiocyanate solution in the **hood** using an automatic delivery pipet. Since the reaction requires heating the reaction mixture to above the boiling point of some components in sealed vessels, *adherence to the microwave manufacturer's guidelines is essential*.

HOOD

Reaction Conditions. Insert the loaded vessels into the reaction carousel ensuring they are evenly spaced and then place the carousel into the microwave cavity. If provided by the manufacturer, connect a temperature probe to the control vessel. Program the microwave unit to heat the reaction vessels to 125 °C and hold at this temperature for 5 min. After heating, allow the reaction mixture to cool to 50 °C or below before removing the carousel from the microwave unit. Allow the resulting solution to cool to room temperature and then place it in an ice bath for 10 min to complete the crystallization of the product.

Isolation of Product. Collect the yellow crystals by vacuum filtration using a Hirsch funnel and wash the filter cake with cold 95% ethanol (3–5 mL). Partially dry the filter cake under suction. Transfer the filtered, washed and partially dried product to a porous clay plate or filter paper to complete drying.

Characterization. Weigh the dried product and calculate the percent yield. Determine the melting point and compare it with the list in the Reagent and Product table. Obtain an IR spectrum of your product, and compare it to that of an authentic sample, or to the spectrum shown in the literature *(The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

QUESTIONS

6-192. Explain why the first reaction below requires substantially more vigorous reaction conditions than the second reaction:

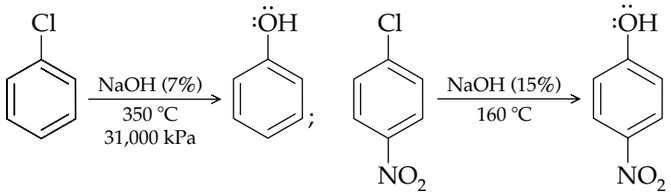

6-193. Explain why the intermediate cyclohexadienyl anion in the nucleophilic aromatic substitution reaction (see Discussion section) is not aromatic, even though it has the same number of π electrons (6) as the starting benzene derivative.

6-194. Complete each of the following reactions and name the expected product of each:

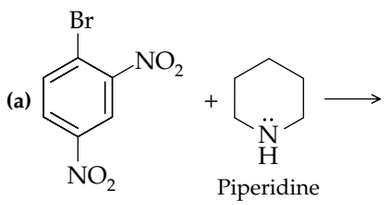

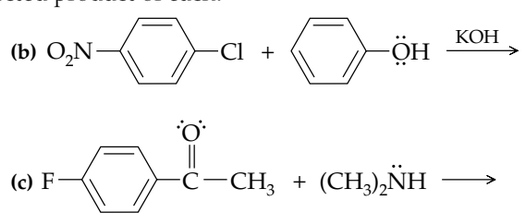

6-195. Compare the potential energy diagram of an S_N2 substitution reaction on an aliphatic halide to that of the nucleophilic substitution reaction carried out in this experiment. Discuss the main differences in the diagrams in terms of the mechanisms.

6-196. Would you expect the rate of the reaction in this experiment to depend on the concentrations of *both* the thiocyanate ion *and* 2,4-dinitrobromobenzene? Explain.

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6-197. Show the intermediates, including all the resonance hybrid structures for the cyclohexadienyl anion, that are formed in the following aromatic nucleophilic substitution reactions:

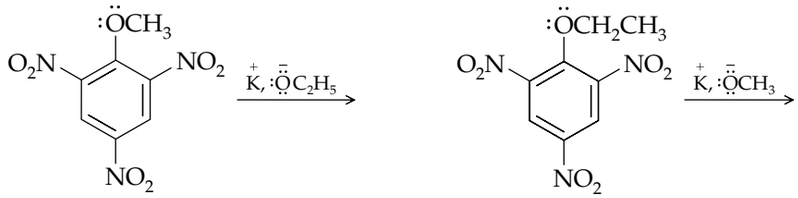

6-198. On workup of each of the reactions given in Question 6-197, what product(s) would you expect to form? If more than one, indicate their relative amounts.

BIBLIOGRAPHY

Selected examples of nucleophilic aromatic substitution reactions in *Organic Syntheses* include

Brewster, R. Q.; Groening, T. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 445.

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Reverdin, F. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 219.

Sahyun, M. R. V.; Cram, D. J. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 926.

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Smith M. B.; March. J. *Advanced Organic Chemistry*, 6th ed.; Wiley-Interscience: New York, 2007, Chap. 13, p. 870.

EXPERIMENT 31

Halogenation Using N*-Bromosuccinimide: 9-Bromoanthracene*

Common name: 9-bromoanthracene

CA number: [1564-64-3]

CA name as indexed: anthracene, 9-bromo-

Purpose. A free radical halogenation reaction is run using *N*-bromosuccinimide (NBS), a highly specific brominating agent. This material has the advantage that it is a solid and is therefore easier to handle than bromine, which is a toxic liquid.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

REACTION

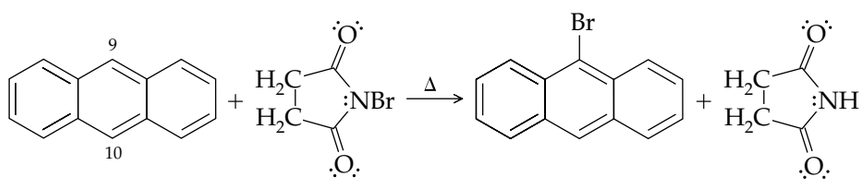

Anthracene *N*-Bromosuccinimide 9-Bromoanthracene Succinimide

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DISCUSSION

N-Bromosuccinimide (NBS) is a highly specific brominating agent. When this reagent is used, anthracene is brominated in the 9-position. *N*-Bromosuccinimide may also be used to brominate positions α to (1) a carbonyl group, (2) a triple bond, (3) an alkene (allylic position), and (4) aromatic rings (benzylic position). Other polynuclear hydrocarbons that have been brominated using NBS include naphthalene, phenanthrene, and acenaphthene.

In the preparation of 9-bromoanthracene, the reaction progress is easily followed, since NBS (a reactant) and succinimide (a product) are both nearly insoluble in carbon tetrachloride. The NBS is more dense than the carbon tetrachloride solvent, and as the reaction proceeds this solid disappears from the bottom of the reaction flask and the less dense succinimide forms and floats on the surface of the reaction solution.

Free radicals have been identified in the mechanism of bromination using *N*-bromosuccinimide. In fact, the reaction proceeds only under conditions likely to produce radicals: photochemical conditions, by heating, or in the presence of a free radical initiator. The NBS reagent provides a steady source of small amounts of Br_2 via the rapid reaction of NBS with traces of hydrogen bromide.

The initiation step in bromination with NBS is the formation of a bromine radical by the homolytic dissociation of the Br_2 molecule.

Initiation Step

$$Br_2 \xrightarrow[\text{free radical initiators}]{h\nu \text{ or}} 2\ Br\cdot$$

The bromine radical then abstracts a hydrogen atom from the 9-position of the anthracene.

Propagation Step

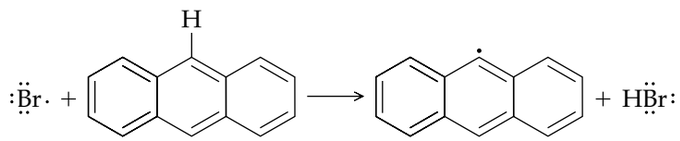

The HBr so formed then reacts with NBS to produce a bromine molecule and succinimide:

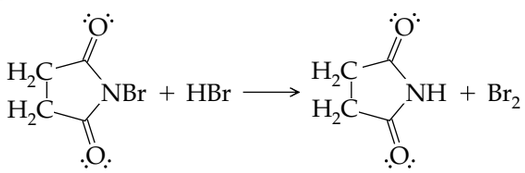

The Br_2 molecule then reacts with the anthracenyl radical formed above to yield the product and a bromine radical:

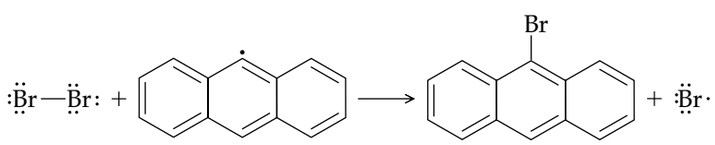

This bromine radical starts the sequence over again. That is, a chain reaction is initiated. In the present reaction, a trace amount of an iodine–carbon tetrachloride solution is added to the reaction mixture. The iodine acts as a moderator or a

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retarder in the reaction (see Dauben et al. in the Bibliography section), and thus only the monobrominated product is formed; 9,10-dibromoanthracene is not generated under these conditions.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants					
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**
Anthracene	178.24	50 mg	0.28	216	
N-Bromosuccinimide	177.99	50 mg	0.28	180–183	
Carbon tetrachloride	153.82	0.4 mL			77
Iodine–CCl_4 solution		1 drop			

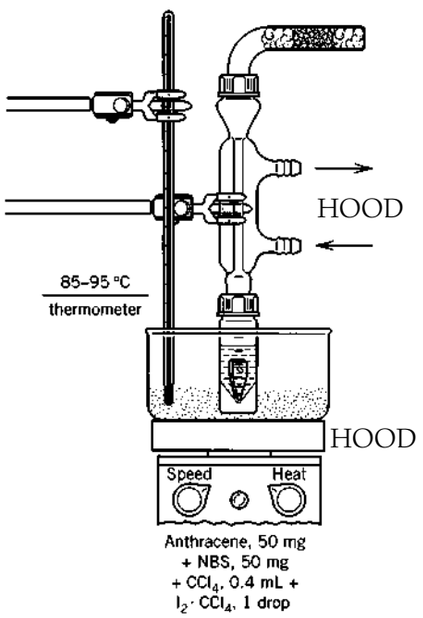

Reagents and Equipment. Weigh and add 50.0 mg (0.28 mmol) of anthracene and 50 mg (0.28 mmol) of *N*-bromosuccinimide to a 3.0-mL conical vial containing a magnetic spin vane. To this mixture add 0.4 mL of carbon tetrachloride followed by one drop of I_2–CCl_4 solution delivered from a Pasteur pipet.

CAUTION: Carbon tetrachloride is a cancer suspect agent. Dispense it in the **hood** using an automatic delivery pipet.

Attach the vial to a reflux condenser fitted with a calcium chloride drying tube (⬅).

INSTRUCTOR PREPARATION I_2–CCL_4 SOLUTION. Iodine (0.2 g, 0.01 mol) is dissolved in 10 mL of carbon tetrachloride. Place the solution in a **hood** *for student use.*

Reaction Conditions. Heat the reaction mixture, with stirring, to reflux in a sand bath at 85–95 °C for 1 h. During this time the solution turns brown and crystals of succinimide appear at the surface of the reaction solution.

Isolation of Product. Collect the succinimide product by vacuum filtration of the warm solution using a Hirsch funnel (⬅). Wash the filter cake of succinimide with three or four 0.5-mL portions of cyclohexane from a calibrated Pasteur pipet. Combine the washings with the original filtrate.

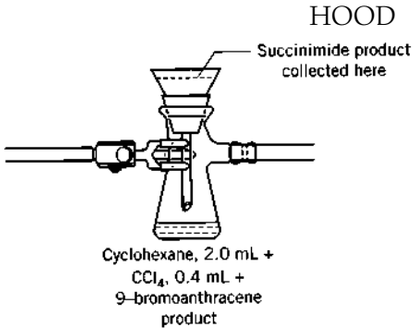

Concentrate the filtrate to dryness in a **hood** under reduced pressure to obtain yellow-green crystals of 9-bromoanthracene. *Accelerate evaporation of the solvent by immersing the flask in warm water.*

Purification and Characterization. Weigh the air-dried succinimide and calculate the percent yield. Determine the melting point and compare your value to that in the literature. Obtain an IR spectrum and compare your spectrum with that shown in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

The crude 9-bromoanthracene is purified by recrystallization from 95% ethanol using the Craig tube. Weigh the dried product and calculate the percent

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yield. Determine the melting point and compare your result with that listed in the literature.

Chemical Tests. The ignition test should establish the presence of the aromatic nature of the substituted anthracene compound. Does the Beilstein test indicate the presence of a halogen?

QUESTIONS

6-199. Predict and give a suitable name for the product(s) formed in the following reactions with NBS:

(a) 1-Propene + NBS $\xrightarrow[h\nu]{CCl_4}$

(b) + NBS $\xrightarrow[h\nu]{CCl_4}$

(c) $CH_3CH_2CH_2{-}CH{=}CH{-}CH_3$ + NBS $\xrightarrow[h\nu]{CCl_4}$

(d) 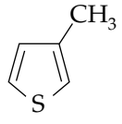 + NBS $\xrightarrow[h\nu]{CCl_4}$

(e) 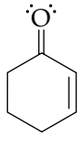 + NBS $\xrightarrow[h\nu]{CCl_4}$

6-200. When 1-octene is treated with NBS, three monobromo straight-chain alkenes with the molecular formula $C_8H_{15}Br$ are isolated from the reaction mixture. Identify these compounds and give each a suitable name.

6-201. Benzyl bromide ($C_6H_5CH_2Br$) can be prepared by treating toluene with NBS in the presence of a peroxide initiator. Suggest a suitable mechanism to account for this reaction.

6-202. The benzyl radical has unusual stability. Account for this fact by drawing appropriate resonance structures.

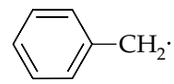

6-203. Suggest a suitable mechanism for the following reaction:

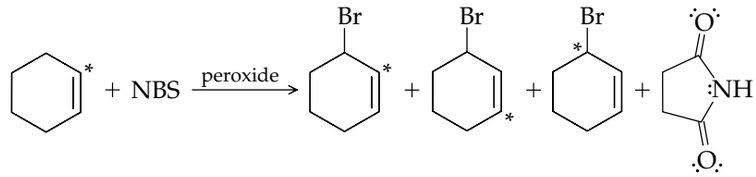

* = ^{13}C label 50% 25% 25%

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Dauben, H. J. Jr.; McCoy, L. L. *J. Am. Chem. Soc.* **1959,** *81,* 4863.
Djerassi, C. *Chem. Rev.* **1948,** *43,* 271.
Horner, L.; Winkelmann, E. H. *Angew. Chem.* **1959,** *71,* 349.
Horner, L.; Winkelmann, E. H. *Newer Methods Prep. Org. Chem.* **1964,** *3,* 151.

For an overview of the scope of the reaction see

Smith, M. B.; March. *J. Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, **2007,** Chap. 11, p. 699.
Also see Mauthen, H. A. *J. Org. Chem.* **1992,** *57,* 2740 for alternative brominating agents.

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EQA

Brominations in *Organic Syntheses* using NBS:

Amat, M.; Hadida, S.; Sathyanarayana, S.; Bosch, J. *Organic Syntheses* **1997,** *74,* 248.
Campaigne, E.; Tullar, B. F. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 921.
Corbin, T. F.; Hahn, R. C.; Schechter, H. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 328.
Greenwood, F. L.; Kellert, M. D.; Sedlak, J. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 108.
Kalir, A. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 825.
Nakagawa, N.; Saegusa, J.; Tomozuka, M.; Ohi, M.; Kiuchi, M.; Hino, T.; Ban, Y. *Organic Syntheses;* Wiley: New York, 1988; Collect. Vol. VI, p. 462.

EXPERIMENT 32

Hypochlorite Oxidation of an Alcohol: Cyclohexanone

Common name: cyclohexanone
CA number: [108-94-1]
CA name as indexed: cyclohexanone

Purpose. The oxidation of a secondary alcohol to a ketone is explored using the hypochlorite reagent. Steam distillation is used to separate the product from the reaction mixture and chromatographic techniques are used to purify and isolate the cyclohexanone product.

Prior Reading

Technique 1: Gas Chromatography (pp. 55–61)
Technique 2: Simple Distillation (pp. 61–64)
Steam Distillation
Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–83)
Salting Out (p. 79)
Technique 6A: Thin-Layer Chromatography (pp. 97–99)

REACTION

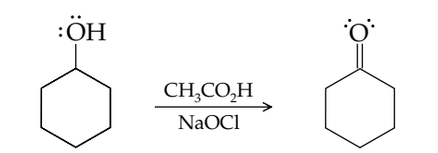

Cyclohexanol Cyclohexanone

DISCUSSION

Sodium hypochlorite solutions (1.8–2.0 M) sold as liquid bleach are often described as having 11.5–12.5% available chlorine. The term "available chlorine" compares the oxidizing capacity of the solution relative to that of the same weight of chlorine, Cl_2.

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EQA

Sodium hypochlorite solutions are used extensively in swimming pool sanitation and as a bleach in the pulp and textile industries. A less-concentrated product (5% available chlorine) is used in laundries and as household bleach. Consumption statistics for 1982 indicate that 210×10^3 tons of sodium hypochlorite were consumed in the United States alone. World consumption of sodium hypochlorite for household use is estimated to be 426×10^3 metric tons annually in 2005. The reaction described in this experiment illustrates the use of liquid bleach (11.5–12.5% available chlorine) as an oxidizing agent in the organic laboratory.

Sodium hypochlorite is prepared commercially by passing chlorine gas through a solution of aqueous sodium hydroxide:

$$Cl_2 + NaOH \rightleftharpoons NaOCl + NaCl$$

The actual oxidizing agent in the present experiment is the chloronium ion (Cl^+), which is reduced in the reaction to chloride ion (Cl^-). The cyclohexanol acts as a reducing agent, and thus becomes oxidized to cyclohexanone:

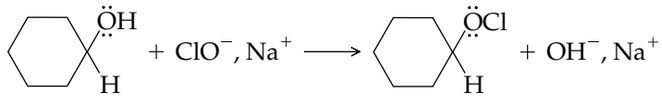

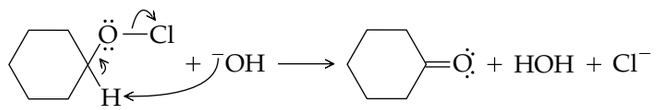

Chromium-based oxidants are commonly used to accomplish these transformations in the research laboratory (see Experiments [33A] and [E1]); the hypochlorite oxidation presents an opportunity to perform an oxidation using the much less costly and much less toxic hypochlorite solution as the oxidant.

In this experiment, a Hickman still is used to isolate the crude cyclohexanone product from the reaction mixture in an example of the steam distillation technique (see Prior Reading). The crude mixture collected in the collar of the still consists of cyclohexanone, water, and acetic acid. If any unreacted cyclohexanol is present in this mixture, it is removed in the subsequent chromatographic purification sequence using alumina. Gas chromatographic analysis may be used to determine the purity of the cyclohexanone product.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Cyclohexanol	100.16	100 mg	1.0	161	0.96	1.4641
Glacial acetic acid	60.05	250 μL		118		
Sodium hypochlorite soln (~12.5% available chlorine)		2 mL				

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EQA

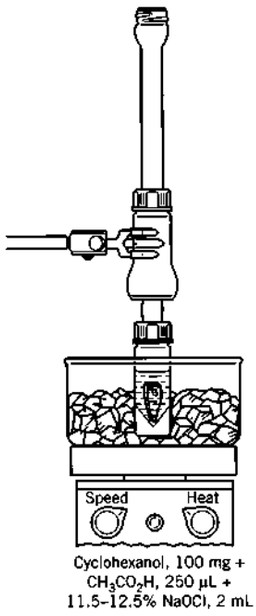

Reagents and Equipment. Weigh and place 100 mg (1.0 mmol) of cyclohexanol in a 5.0-mL conical vial containing a magnetic spin vane. Add 250 µL of glacial acetic acid and then attach the vial to a Hickman still (⬅). *Dispense the glacial acetic acid in the* ***hood*** *by use of an automatic delivery pipet.*

Cool the resulting solution in an ice bath and add dropwise, with stirring, 2.0 mL of aqueous sodium hypochlorite (NaOCl) solution (~12.5% available chlorine, 1.8–2.0 M) by use of a graduated pipet. Remove the ice bath following the addition. *Add the NaOCl solution by inserting the pipet down the neck of the still just into the throat of the vial.*

NOTE. Solid calcium hypochlorite (65% available chlorine) may be used as a source of oxidant in place of the sodium hypochlorite solution.

Reaction Condition. After 30 min, begin monitoring the reaction mixture by TLC. Using as a solvent system ethyl acetate:hexane (1:4), the R_f value of cyclohexanone is 0.6 (R_f value of cyclohexanol is 0.4) when stained with a solution of *p*-anisaldehyde (135 mL ethanol : 5 mL H_2SO_4 : 1.5 mL glacial acetic acid : 3.7 mL *p*-anisaldehyde). *If incomplete as judged by TLC, maintain an excess of hypochlorite oxidizing agent for an additional 30 min and check for the disappearance of starting material by TLC. Overoxidation is not likely. Monitor the aqueous layer periodically using KI–starch paper. If a positive test is not obtained (the paper should turn blue if an oxidant is present), add additional sodium hypochlorite solution (1–3 drops) to ensure that an excess of the oxidizing agent is present. Use a Pasteur pipet inserted down the neck of the still to add the reagent and a clean pipet to remove a drop of solution for testing with KI–starch paper.*

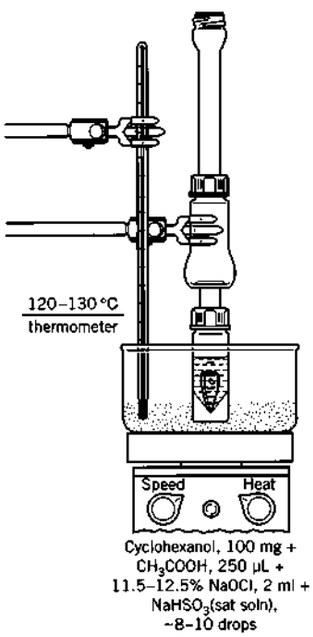

Isolation of Product. Using a Pasteur pipet, add a saturated, aqueous sodium bisulfite solution dropwise to the reaction mixture until the solution gives a negative KI–starch test.

Separate the crude product from the reaction mixture by steam distillation. With stirring, heat the mixture in a sand bath at a temperature of 120–130 °C (⬅). Collect the first 0.5–1.0 mL of distillate in the ring collar of the condenser. Using a Pasteur pipet, transfer this material to a 3.0-mL conical vial containing a spin vane and remove the heat from the still pot. After the distillation apparatus has cooled, rinse the condenser collar with 0.5 mL of diethyl ether and also transfer this rinse to the conical vial.

NOTE. The distillate collected in the condenser collar consists of cyclohexanone, water, and acetic acid.

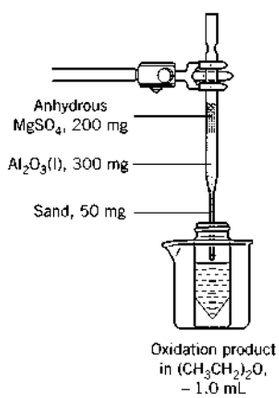

To neutralize the acetic acid present in the separated product mixture, add anhydrous sodium carbonate (~100 mg) in small portions, with stirring, to the solution until evolution of CO_2 gas ceases. Now add 50 mg of NaCl to the mixture. The resulting two-phase system is stirred until all the solid material dissolves.

Use a Pasteur filter pipet to separate the ether layer containing the cyclohexanone product from the aqueous phase and transfer it to a microscale drying and chromatography column. Assemble the column using a Pasteur filter pipet packed first with about 50 mg of sand, then with 300 mg of alumina (Activity I, see Glossary), followed by 200 mg of anhydrous magnesium sulfate (⬅). Wet the column with diethyl ether before the transfer.

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EQA

Collect the eluate in a tared 3.0-mL conical vial containing a boiling stone. Extract the aqueous layer remaining in the conical vial with three 0.5-mL portions of ether, and also pass each extract through the column and combine these fractions with the original eluate.

Fit the 3.0-mL conical vial with an air condenser and remove the ether by gentle warming on a sand bath in the **hood.** HOOD

Purification and Characterization. The liquid residue of cyclohexanone isolated upon evaporation of the ether solvent is sufficiently pure for characterization. It may be further purified by prep-GC (see below). Weigh the product and calculate the percent yield.

The purity of the cyclohexanone product may be determined using *gas chromatographic analysis (see Prior Reading and Experiment [5A] to review this technique and the experimental conditions for its use*). Determine the boiling point and density of your product; compare your results to those given in the literature.

Obtain the IR spectrum of your product and compare it with one in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. Chemical classification tests may also be run to assist in the characterization of this material. The 2,4-dinitrophenylhydrazine test (Chapter 9) should give a positive result. Isolation of this derivative and the determination of its melting point would further establish the identity of the product as cyclohexanone.

QUESTIONS

6-204. In the experiment, why is a solution of sodium bisulfite added to the reaction product mixture (see Isolation of Product)? Write a reaction to account for what is happening. Is the bisulfite ion acting as an oxidizing or reducing agent?

6-205. In the isolation of the cyclohexanone product, 50 mg of sodium chloride is added to the water–cyclohexanone–diethyl ether mixture. Explain how the addition of sodium chloride aids in isolation of the cyclohexanone product.

6-206. Predict the product(s) for each of the following oxidation reactions. Give a suitable name for each reactant and product.

(a)

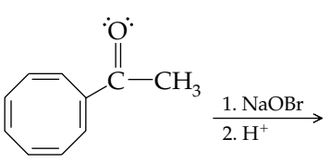

(b) $CH_3CH_2\ddot{O}H \xrightarrow[2.\ H^+]{1.\ NaOI}$

(c)

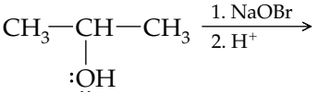

6-207. 2,3-Dimethyl-2,3-butanediol (*pinacol*), upon heating in aqueous acid, rearranges to form 3,3-dimethyl-2-butanone (*pinacolone*). Suggest a mechanism for this reaction.

6-208. What chemical tests might be used to distinguish between pentanal and 2-pentanone? Between benzyl alcohol and diphenylmethanol?

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EQA

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As a general reference for the use of sodium hypochlorite as an oxidant, see

Fieser, L. F; Fieser, M. *Reagents for Organic Synthesis;* Wiley: New York, 1967; Vol. I, p. 1084.

Nohrig, J. R.; Nienhuis, D. M.; Linck, C. F.; Van Zoeren, C.; Fox, B. G. *J. Chem. Educ.* **1985,** *62,* 519.

Experiment [32] is based on work reported by

Stevens, R.V.; Chapman, K.T.; Weller, H. N. *J. Org. Chem.* **1980,** *45,* 2030.

See also Zuczek, N. M.; Furth, P. S. *J. Chem. Educ.* **1981,** *58,* 824.

EXPERIMENT 33

Chromium Trioxide–Resin or Hypochlorite Oxidation of an Alcohol: 9-Fluorenone

Common name: 9-fluorenone

CA number: [486-25-9]

CA name as indexed: 9*H*-fluoren-9-one

Purpose. The experiment investigates the use of a polymer-bound chromium trioxide oxidizing agent in the oxidation of a secondary (2°) alcohol to a ketone. An alternative oxidizing agent, sodium hypochlorite, may be used instead. The progress of the reaction is monitored by thin-layer chromatography (TLC). The product ketone can be characterized by formation of its 2,4-dinitrophenylhydrazone (2,4-DNP) derivative.

Prior Reading

Technique 5: Crystallization
- Use of the Hirsch Funnel (pp. 88–89)
- Craig Tube Crystallizations (pp. 89–91)

Technique 6: Chromatography
- Thin-Layer Chromatography (pp. 97–99)
- High-Performance Liquid Chromatography (pp. 100–101)
- Concentration of Solutions (pp. 101–104)

Experiment 33A

9-Fluorenone: CrO_3 Oxidation of 9-Fluorenol

REACTION

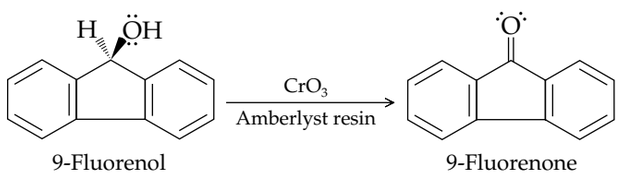

9-Fluorenol 9-Fluorenone

DISCUSSION

This experiment illustrates the oxidation of a 2° alcohol to a ketone. The oxidizing agents commonly used for this purpose are sodium dichromate or chromic oxide in sulfuric acid. In the present case, a convenient and advantageous polymer-

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EQA

bound chromium trioxide reagent is used. It is not only easy to prepare, but is also easy to separate from the product mixture and can be recycled. Today, the use of polymer-bound reagents in organic synthesis is developing at a rapid pace. The mechanism of the oxidation is outlined here:

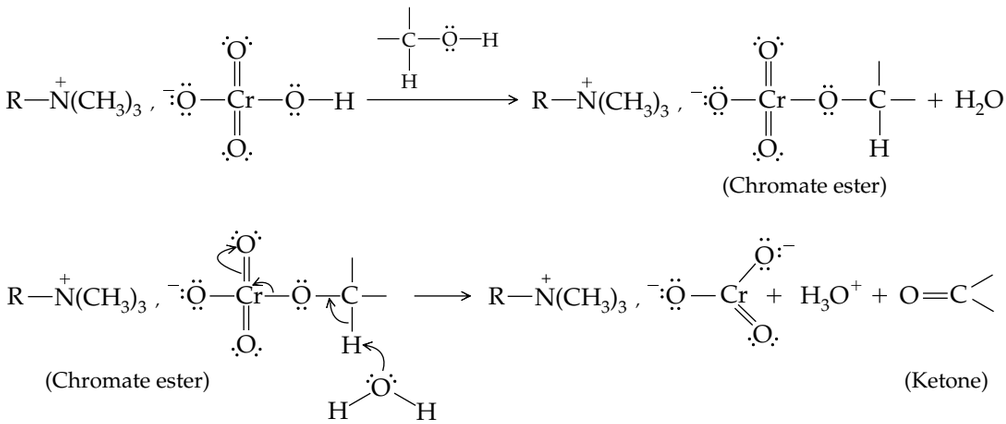

As seen, the oxidation proceeds through the formation of a chromate ester. Note that the oxidation state of chromium, Cr(VI), at this stage remains the same as in the starting reagent. The second stage is equivalent to an E2 elimination reaction, with the water molecule acting as a base. The donation of an electron pair to the metal atom changes its oxidation state to Cr(IV).

Note that a solution of chromic oxide in aqueous sulfuric acid (the Jones reagent) is used as a test reagent for 1° and 2° alcohols. A positive test is observed when the clear orange test reagent gives a greenish opaque solution upon addition of the alcohol (see Chapter 9).

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3–4 h.

INSTRUCTOR PREPARATION. Prepare the CrO_3 resin by adding 35 g of Amberlyst A-26 resin to a solution of 15 g of CrO_3 in 100 mL of water. Stir the mixture for 30 min at room temperature. Then collect the resin by vacuum filtration using a Büchner funnel and successively rinse it with water and acetone. Partially dry the material on the Büchner funnel by drawing air through the resin under vacuum for 1 h. Allow it to air-dry overnight.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
9-Fluorenol	182.23	100 mg	0.55	154	
Chromic oxide–resin		500 mg			
Toluene	92.15	3.5 mL			111

NOTE. CrO_3 has been listed as a known carcinogen (see The Merck Index, *12th ed.; 1996; p. 375, no. 2293).*

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EQA

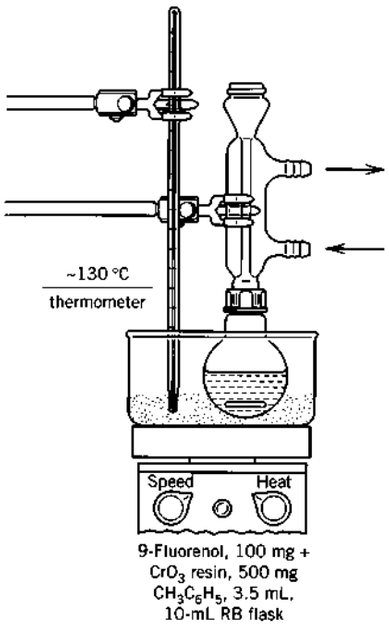

Reagents and Equipment. Weigh and add 100 mg (0.55 mmol) of 9-fluorenol to a 10-mL round-bottom flask containing a magnetic stirring bar. Add 3.5 mL of toluene, and sample the resulting solution for TLC analysis (see Prior Reading). Now add 500 mg of the oxidizing resin and attach the flask to a reflux condenser (⬅). If the longest Pasteur pipet available to you will not reach down the condenser and allow you to sample the solution, consider placing a Claisen head between the condenser and the flask (using the neck above the bend to connect the condenser. If you do this, be sure to cap the other neck of the Claisen head, and be sure to open it for the minimum possible amount of time when sampling—otherwise toluene vapors will escape into the air you breathe.

Reaction Conditions. Heat the contents of the flask to reflux, with stirring, using a sand bath temperature of approximately 130 °C.

Sample the solution for TLC analysis after a period of 5 min and every 15–20 min thereafter. In this manner, the progress of the reaction may be monitored until the conversion is complete (~35–40 min). This point is reached when the TLC analysis shows that the 9-fluorenol has been completely consumed.

SUGGESTED TLC CONDITIONS. Use Eastman Kodak fluorescent silica gel sheets (1 × 6 cm). Elute them with methylene chloride solvent and visualize the spots by UV light. Determine reference R_f values for 9-fluorenol and 9-fluorenone using known reference samples under the same conditions.

Isolation of Product. Cool the reaction mixture and remove the resin by gravity filtration through a cotton plug placed in a small funnel. Transfer the solution to the filter funnel using a Pasteur pipet, and collect the filtrate in a tared 10-mL Erlenmeyer flask containing a boiling stone. Rinse the reaction flask and resin with two 1.0-mL portions of methylene chloride using a calibrated Pasteur pipet. Combine the rinse with the original filtrate.

HOOD In the **hood** remove the solvent from the filtrate under a stream of nitrogen by warming in a sand bath to yield a yellow colored residue of crude 9-fluorenone product.

Purification and Characterization. Obtain the weight of the crude product and calculate the percent yield.

Recrystallize a 30- to 50-mg portion of the 9-fluorenone from hexane (~1.0 mL of hexane/50 mg of ketone) using a Craig tube. Determine the melting point of this purified material and compare your data to those reported in the literature. Calculate the percent recovery on recrystallization.

NOTE. High-performance liquid chromatography (see Prior Reading) is effective in separating the pure ketone. Use a C_{18} reversed-phase column and methanol–water as the elution solvent.

Chemical Tests. The 2,4-dinitrophenylhydrazine test for aldehydes and ketones (see Chapter 9) may be done to confirm the presence of the carbonyl group. The isolation of this derivative and the determination of its melting point (Lit. value = 283 °C) would aid in establishing the identity of the product.

Does the ignition test indicate that this compound is aromatic?

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EQA

9-Fluorenone has a characteristic UV spectrum. The following data were obtained at a concentration of 8.66×10^{-6} M (see Chapter 8, Ultraviolet–Visible Discussions):

λ_{max}248 nm($\varepsilon_{max} = 5.27 \times 10^4$, methanol)
λ_{max}255 nm($\varepsilon_{max} = 7.83 \times 10^4$, methanol)
λ_{max}290 nm($\varepsilon_{max} = 3.93 \times 10^3$, methanol)

9-Fluorenone: NaOCl Oxidation of 9-Fluorenol

Experiment 33B

REACTION

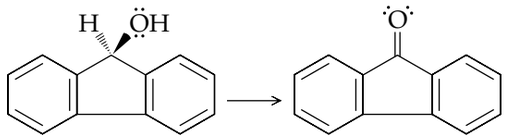

DISCUSSION

This experiment is a further illustration of the oxidation of a 2° alcohol to a ketone. The reagent used is sodium hypochlorite solution. This reagent is also used in oxidation reactions described in Experiments [32] and [34A, B]. The chemistry of the reagent, sodium hypochlorite, is discussed in Experiment [32]. This alternative reagent for the oxidation of 9-fluorenone offers a material that is cheap (Clorox, a household bleach), easy to handle, and environmentally safe.

As in experiment [33A], the progress of the reaction is followed using TLC.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3 h.

Physical Properties of Reactants					
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**
9-Fluorenol	182.23	50 mg	0.27	154	
Acetone	58.08	3 mL			56.5
Acetic acid, glacial	60.05	120 μL		16.7	118
Sodium hypochlorite (5.25%)	74.44	~1.3 mL			

Reagents and Equipment. Weigh and add 50 mg (0.27 mmol) of 9-fluorenol to a 10-mL round-bottom flask containing a magnetic stir bar. Add 3 mL of acetone and *sample the resulting solution (2–4 μL) for TLC analysis* (see Prior Reading). Add 120 μL of glacial acetic acid and then attach the flask to an air condenser (➨).

CAUTION: Dispense the glacial acetic acid in the **hood** by use of an automatic delivery pipet. This acid burns skin!

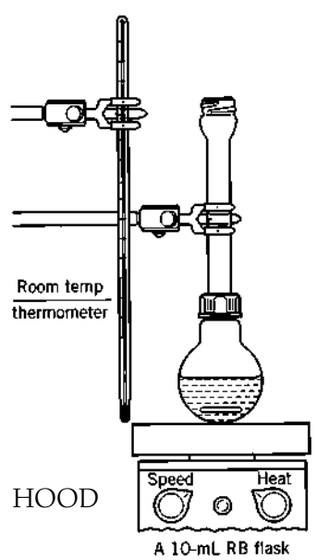

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EQA

Use a graduated 1-mL pipet to slowly add, with gentle stirring, 0.4 mL of aqueous sodium hypochlorite solution (5.25%—commercial bleach). Add the NaOCl solution by inserting the pipet down the neck of the condenser just to the throat of the flask.

? ***Reaction Conditions.*** Gently stir the reaction mixture at room temperature. After a period of 5 min, sample the solution (2–5 μL) for TLC analysis. *Sample the reaction solution by inserting a 9-in. Pasteur pipet down the air condenser to obtain a drop of solution by capillary action.* If starting material is present as shown by TLC analysis, add an additional 0.4 mL of the hypochlorite solution as before. Stir for 5 min and sample again. Continue this process until TLC analysis shows that the 9-fluorenol has been completely consumed. Approximately 1.2–1.4 mL of hypochlorite solution should be sufficient, if the reagent is fresh.

SUGGESTED TLC CONDITIONS. Use Eastman Kodak Fluorescent silica gel sheets (1.0 cm × 6 cm). Elute the plates with 30% acetone/70% hexane solvent, and visualize the spots by UV light. R_f *values are 0.56 for 9-fluorenol and 0.80 for 9-fluorenone.*

Isolation of Product. Using a Pasteur pipet, transfer the reaction solution to a stoppered 15-mL centrifuge tube. Rinse the flask with 300 μL of acetone and transfer the rinse to the same centrifuge tube. Extract the solution with two 2-mL portions of hexane. Transfer the hexane extracts (upper layer) to a second centrifuge tube. Wash the combined hexane extracts with one 1-mL portion of 5% sodium bicarbonate solution followed by one 2-mL portion of water. Dry the hexane solution by addition of a small amount of anhydrous sodium sulfate. Use a Pasteur filter pipet to transfer approximately 3.0 mL of the dried solution to a tared 5-mL conical vial. Concentrate the solution, which contains a portion of the desired product, to dryness on a warm sand bath under a stream of nitrogen or dry air in the **hood.** Transfer the remaining hexane solution to the same vial. Rinse the sodium sulfate with an additional 1 mL of hexane and transfer this rinse to the same vial. Concentrate the solution as before.

HOOD

Purification and Characterization. See this section in Experiment [33A].

QUESTIONS

6-209. Suggest a suitable mechanism for the reaction of 9-fluorenone with 2,4-dinitrophenylhydrazine to form the corresponding 2,4-dinitrophenylhydrazone.

6-210. It is also possible to characterize 9-fluorenone by preparation of an oxime or semicarbazone. Formulate equations showing clearly the formation of these two derivatives and name each reagent used in the preparation.

6-211. As indicated in the Discussion, a solution of chromic oxide in aqueous sulfuric acid is used as a test reagent for 1° and 2° alcohols.
- **(a)** What is this test (consult Chapter 9)?
- **(b)** Predict which of the following alcohols will give a positive test with the chromic oxide reagent. Give the structure for each of the alcohols: 1-heptanol, 2,2,3-trimethyl-3-pentanol, cholesterol, 3-methyl-2-butanol, and 4-*tert*-butylcyclohexanol.

6-212. There are actually **two** isomeric 2,4-dinitrophenylhydrazones of 2-pentanone. Draw the structures of these isomers.

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6-213. 2-Pentanone, in reference to Question 6-212, also forms a derivative on treatment with semicarbazide:

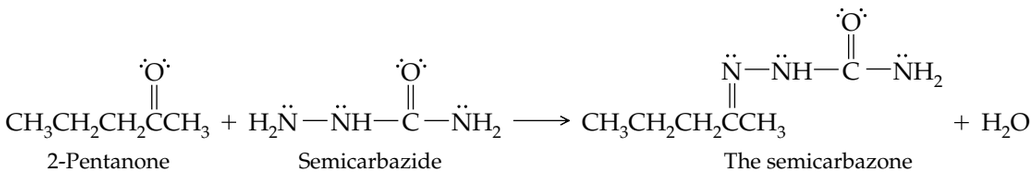

Note that semicarbazide has **two** —NH_2 groups that might react with the carbonyl of the ketone to form the semicarbazone. Explain why it reacts as depicted above.

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EXPERIMENT 34

Hypochlorite Oxidation of Methyl Ketones by the Haloform Reaction: Benzoic Acid and p*-Methoxybenzoic Acid*

Common name: benzoic acid

CA number: [65-86-0]

CA name as indexed: benzoic acid

Common names: *p*-methoxybenzoic acid, 4-methoxybenzoic acid, *p*-anisic acid

CA number: [100-09-4]

CA name as indexed: benzoic acid, 4-methoxy-

Purpose. The well-known haloform reaction is explored as a synthetic route to the preparation of organic acids. You will investigate the use of a basic aqueous solution of hypochlorite ion as a source of molecular chlorine (Cl_2).

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Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Separatory Funnel Extraction (Scaleup) (pp. 75–77)

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)

REACTION

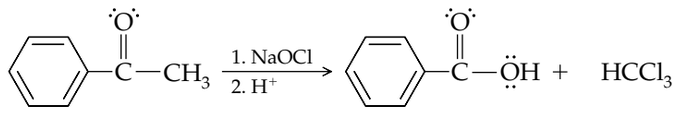

Acetophenone Benzoic acid Chloroform

DISCUSSION

The reaction of methyl ketones with a halogen in an alkaline medium is known as the haloform reaction. In this experiment, halogen and base are present because of the equilibrium reaction shown here:

$$H_2O + NaOCl + NaCl \rightleftharpoons 2\,NaOH + Cl_2$$

In the haloform reaction, two products are formed: (1) a haloform ($CHCl_3$, $CHBr_3$, or CHI_3, depending on the halogen used); and (2) the carboxylic acid having one less carbon atom than the starting ketone. It is the formation of the carboxylic acid that gives the reaction its synthetic utility. An advantage of this oxidation is that it does not affect carbon–carbon double bonds, as illustrated here:

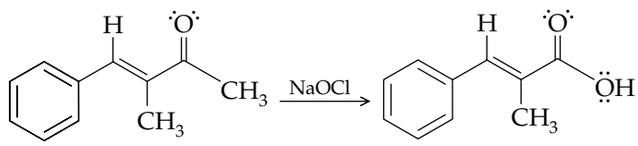

If I_2 in a basic solution is used, iodoform (CHI_3) is generated in the reaction. This compound is a yellow solid that precipitates from the reaction medium. This observation has been used extensively as a chemical test **(iodoform test)** for methyl ketones and the $RCH(OH)CH_3$ structural group (see Chapter 9).

In the present experiment, a solution of sodium hypochlorite (NaOCl) is used as the source of the chlorine. Sodium hypochlorite solutions are marketed with the hypochlorite concentration described in terms of the "available chlorine"content, which is a term comparing the oxidizing potential of the solution with that of the equivalent mass of chlorine. For the purposes of this experiment, a solution of NaOCl that has 5% available chlorine is needed, and common household bleach will suffice. For another example of an oxidation with an aqueous hypochlorite solution, see Experiment [32].

The reaction takes place in two stages. In the first stage, the methyl group is trihalogenated in a stepwise fashion. In the second stage, hydroxide ion attacks the carbonyl carbon of the trihaloketone to generate the haloform along

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with the alkali metal salt of the acid; acidification yields the carboxylic acid. The mechanistic sequence follows:

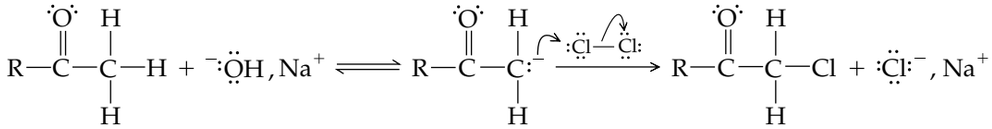

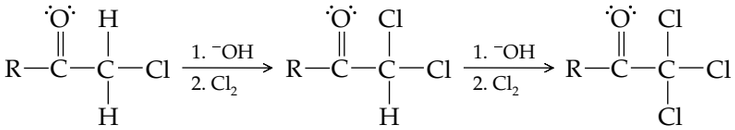

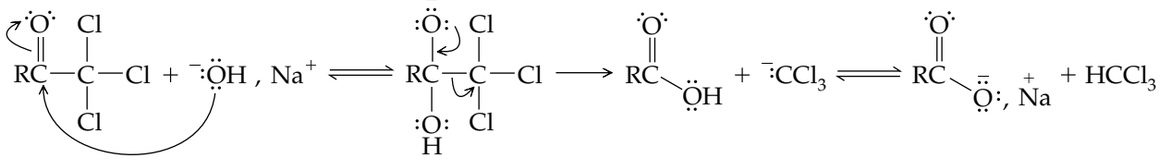

Benzoic Acid

Experiment 34A

The reaction is shown above.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants							
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Acetophenone	120.16	60 μL	51	20.7	202.6	1.03	1.5372
Aqueous NaOCl (household bleach, 5% available chlorine)		2.1 mL					
Sodium sulfite	120.6	15 mg					

Reagents and Equipment. To a 5-mL conical vial containing a magnetic spin vane and equipped with an air condenser, add 6 μL (63 mg, 51 mmol) of acetophenone and 2.1 mL of household bleach (NaOCl, 5% available chlorine) (➡).

CAUTION: Both reagents are irritants and should be dispensed in the **hood** using automatic delivery pipets.

HOOD

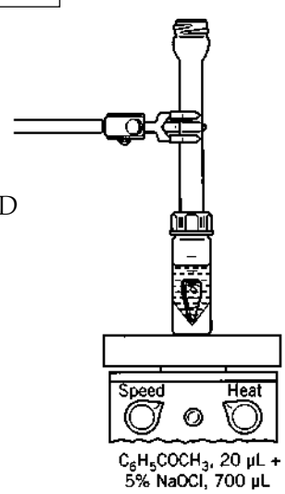

Reaction Conditions. Stir the mixture at room temperature for 30 min.

Isolation of Product. Add approximately 15 mg of sodium sulfite to destroy any unreacted bleach, and stir the reaction mixture briefly. Extract the resulting mixture with two 0.5-mL portions of ether (calibrated Pasteur filter pipet). Separate each portion of ether extract using a Pasteur filter pipet.

NOTE. The ether layer is the top layer; the lower, alkaline, layer contains the acid product. The ether extraction removes the chloroform generated in the reaction and any unreacted acetophenone. Save the ether extracts in a small vial until you have successfully isolated and characterized the final product.

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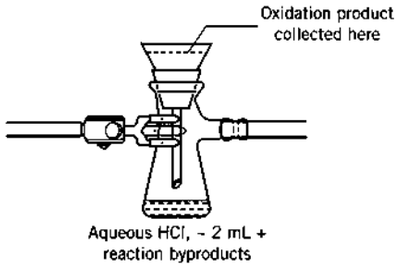

Acidify the aqueous layer (check with pH paper) by adding dropwise 3 M HCl from a Pasteur pipet. A thick, white precipitate of benzoic acid then appears. Collect the solid by vacuum filtration using a Hirsch funnel, and wash the filter cake with three 0.5-mL portions of water (calibrated Pasteur pipet) (⬅). Maintain the vacuum for approximately 5 min by covering the funnel with plastic food wrap (see Prior Reading) to partially dry the product. Transfer the material to a porous clay plate or filter paper to complete the drying process.

Purification and Characterization. The product is of sufficient purity for characterization. Weigh the material and calculate the percent yield.

Determine the melting point and compare your result with the value listed in the literature. If desired, obtain an IR spectrum and compare it with an authentic sample of benzoic acid, or with that given in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. Chemical classification tests may also be used to assist in product analysis. You might wish to perform the following:

1. The ignition test should indicate the presence of the aromatic ring (Chapter 9).

2. The solubility of the compound in water, 5% NaOH, and 5% $NaHCO_3$ should be checked (see Chapter 9). Does the water solution turn blue litmus paper red? Is there evidence of CO_2 evolution when the benzoic acid is added to the bicarbonate solution? If positive results are obtained in these tests, how do they confirm that a carboxylic acid is present?

3. The preparation of an amide derivative (see Chapter 9) would also aid in establishing the identity of the acid product.

Experiment 34B

p-Methoxybenzoic Acid

REACTION

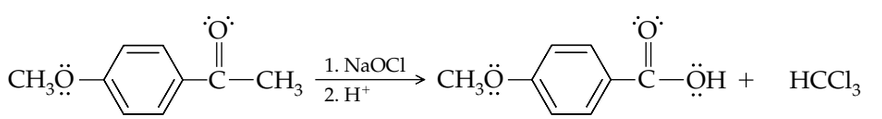

p-Methoxyacetophenone — *p*-Methoxybenzoic acid — Chloroform

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
p-Methoxyacetophenone	150.8	29 mg	0.19	38–39	258
Aqueous NaOCl (household bleach, 5% available chlorine)		700 μL			
Sodium sulfite	120.6	5 mg			

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Reagents and Equipment. Weigh and add 29 mg (0.19 mmol) of *p*-methoxyacetophenone to a 3.0-mL conical vial containing a magnetic spin vane. Now add 700 μLof household bleach (5% available chlorine), and then attach the vial to an air condenser (➡).

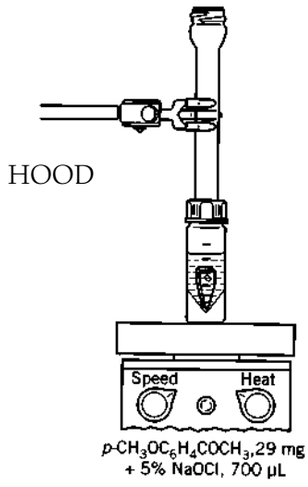

CAUTION: The bleach is an irritant to skin and eyes. It should be dispensed using an automatic delivery pipet in the **hood.**

Reaction Conditions. Stir the mixture for 30 min with very gentle heating. *Use the lowest possible setting on a hot plate magnetic stirrer.*

Isolation of Product. Weigh and add approximately 5 mg of sodium sulfite. Stir the reaction medium briefly and then cool it to room temperature. Extract the resulting mixture with two 0.5-mL portions of ether (calibrated Pasteur pipet). Separate each portion of ether extract using a Pasteur filter pipet.

NOTE. The ether layer is the top layer; the bottom aqueous layer contains the product. The ether extraction removes the chloroform generated in the reaction and any unreacted p*-methoxyacetophenone. Save the ether extracts in a small vial until you have successfully isolated and characterized the final product.*

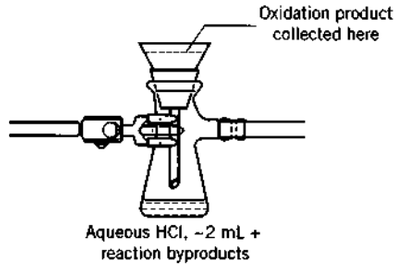

Acidify the aqueous layer by the dropwise addition (check with pH paper) of 3 M HCl from a Pasteur pipet until a thick, white precipitate of *p*-methoxybenzoic acid is formed. Cool the mixture in an ice bath for 5 min and collect the solid by vacuum filtration using a Hirsch funnel (➡). Wash the filter cake with three 0.5-mL portions of cold water (calibrated Pasteur pipet). Maintain the vacuum for approximately 5 min and cover the funnel with plastic food wrap (see Prior Reading) to partially dry the product. Transfer the material to a porous clay plate or filter paper to complete the drying process.

Purification and Characterization. The product is reasonably pure but may be recrystallized from ethanol–water, if desired, using a Craig tube. Weigh the product and calculate the percent yield. Determine the melting point and obtain an IR spectrum. Compare your results with those reported in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). Chemical characterization tests can be used to assist in the classification of this product, as outlined in Experiment [34A].

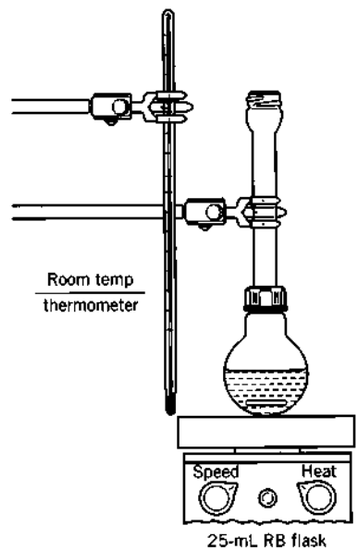

OPTIONAL SEMIMICROSCALE PREPARATION

This preparation may be scaled up by a 15-fold increase in reagent amounts. The procedure is similar to that given above for the micropreparation with the exceptions noted below. *A major difference is that a separatory funnel is used in the extraction step.*

1. Use a 25-mL round-bottom (RB) flask containing a magnetic stirring bar and equipped with an air condenser. The reaction conditions are as given in the microscale experiment (➡).

2. The reagent and solvent amounts are increased 15-fold.

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EQA

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
p-Methoxyacetophenone	150.8	435 mg	2.88	38–39	258
Aqueous NaOCl (household bleach, 5% available chlorine)		10.5 mL			
Sodium sulfite	120.6	75 mg			

3. Add the sodium sulfite, stir, cool, and then transfer the product mixture to a 125-mL separatory funnel. Extract this mixture with two 7.5-mL portions of diethyl ether. Save the ether extracts in a small Erlenmeyer flask until you have successfully isolated and characterized the final product. The product is in the aqueous layer.

NOTE. Carry out the extraction by first returning the lower aqueous layer to the reaction flask and then removing the ether layer. Then return the aqueous layer to the separatory funnel and rinse the reaction flask with the second portion of ether. This ether rinse is then added to the separatory funnel to complete the extraction.

4. Collect the product by vacuum filtration, then wash the filter cake with three 7-mL portions of cold water.

5. The pale-yellow product is characterized as described in the microscale procedure.

QUESTIONS

6-214. In the haloform reaction, once the first α-hydrogen atom is replaced by a halogen atom, each successive hydrogen is more easily substituted until the trihalo species is obtained. Explain.

6-215. The haloform reaction using I_2 and NaOH is referred to as the "iodoform" test for methyl ketones (see Chapter 9). The test also gives positive results for compounds containing the —$CH(OH)CH_3$ group. This results from the oxidation of the alcohol to the methyl ketone in the first stage. Write a balanced equation for the conversion of $C_6H_5CHOHCH_3$ to the methyl ketone in the presence of I_2 and NaOH. Identify which species is being oxidized and which is being reduced.

6-216. If you were carrying out an industrial scale synthesis in which one step involved a haloform reaction to convert a methyl ketone into the corresponding acid having one less carbon atom, would you use NaOH and Cl_2, NaOH and Br_2, or NaOH and I_2 as the reagent? Give reasons for your choice.

6-217. Can you explain the fact that even though dibenzoylmethane ($C_6H_5COCH_2COC_6H_5$) is not a methyl ketone, it gives a positive iodoform test when treated with the NaOH and I_2.

6-218. Do you think that acetaldehyde would give a positive iodoform test? Explain your reasoning.

6-219. A water-soluble phenol is also acidic toward litmus paper as is a water-soluble carboxylic acid. How would you distinguish the difference between an aromatic acid and a phenol using a chemical test?

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For a review of oxidation see

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Smith, M. B.; March. J. *Advanced Organic Chemistry,* 6th ed.; Wiley-Interscience: New York, 2007, Chap. 12, p. 842.
Wiberg, K. B. In *Oxidation in Organic Chemistry;* Trahanovsky, W. S., Ed.; Academic Press: New York, 1978, Vol. 5, Part A, Chapter 2.

EXPERIMENT 35

Conversion of Cyclohexyl Bromide to Cyclohexene–An E2 Elimination Reaction: Factors Affecting the Rate of a Chemical Reaction

Common name: cyclohexene
CA number: [110-83-8]
CA name as indexed: cyclohexene

Purpose. A dehydrohalogenation reaction is designed and carried out for conversion of cyclohexyl bromide (bromocyclohexane) to cyclohexene using a strong base. The relative rate of this reaction is followed with gas chromatography. You will explore the effect of varying several parameters that alter the rate of the reaction such as temperature, concentration of the base, and the nature of the leaving group.

Prior Reading

Technique 1: Gas Chromatography (pp. 55–61)
Technique 4: Solvent Extraction (p. 67)
Chapter 3: Reflux and reflux apparatus (pp. 23–24)
Automatic delivery pipets: (pp. 37–38)
Theoretical yield calculations: (p. 42)
Chapter 6: Experiment [10]: (pp. 217–224)
Lecture text on kinetic theory and mechanisms of E2 reactions

REACTION

Cyclohexyl bromide Sodium ethoxide Cyclohexene

DISCUSSION

The rates of chemical reactions and the factors that affect them are of great importance in chemistry. This area of chemistry is termed *kinetics*. Most of the ionic reactions observed in inorganic chemistry take place so fast that their rates cannot be easily measured, but in many organic reactions the study of chemical kinetics is particularly important. This is because measurement of reaction rates is a powerful guide for probing reaction mechanisms.

These rates can vary greatly. Five factors are involved in establishing the rate at which a reaction may proceed: (1) the nature of the reacting substances, (2) the states of the reactants, (3) the temperature of the reactants, (4) the

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concentration of the reactants, and (5) the presence of a catalyst. The rate of a chemical reaction is measured by the decrease in concentration of a reactant or the increase in concentration of a product in a unit period of time.

The relationship between the rate of a chemical reaction and the change in concentration of the reactants can be described quantitatively based on experimental measurements. Each reaction has its own *rate equation*. In general, a rate equation has the form

$$\text{rate} = k[\text{A}]^a[\text{B}]^b[\text{C}]^c \qquad 6\text{–}1$$

in which [A], [B], and [C] represent molar concentrations of reactants (or products or other substances), k is the rate constant for a certain reaction at a particular temperature, and the exponents *a, b,* and *c* are positive and usually integers. Both k and the exponents must be determined experimentally by observing the variation in the rate of the reaction as the concentrations of the reactants are varied. It is important to recognize that the rate equation depends on the mechanism of the reaction and on the individual steps therein.

In the general rate equation, the exponent a is called the order of the reaction with respect to the reactant A. Likewise, the exponent b is the order of the reaction with respect to B, and so on. The sum of the exponents is the overall order of the reaction. In the E2 reaction, investigated in the present experiment, we have (see above) a dehydrohalogenation following this mechanism.

Experimentation shows us that if the concentration of the reactant (cyclohexyl bromide) is doubled, the reaction rate doubles. The rate is also doubled if the concentration of the reagent, sodium ethoxide ($NaOC_2H_5$), is doubled. Thus, the concentration of both species present affects the rate of the reaction. The rate expression for this type of reaction (E2) can be quantitatively expressed as

$$\text{rate} = k[C_6H_{11}Br]^1[NaOC_2H_5]^1 \qquad 6\text{–}2$$

This expression indicates that the rate equation is *first order* in both the substrate (cyclohexyl bromide) and the basic reagent (sodium ethoxide). The overall rate expression is *second order* (the sum of 1 + 1 = 2).

NOTE. The powers of 1 are not usually expressed, but they are shown here for clarity.

Kinetics and Thermodynamics. Chemical reactions are governed by two basic relationships.

1. Chemical Thermodynamics: These phenomena deal with the changes in energy that occur when molecules react. Thus, thermodynamics ultimately controls the *extent* to which a reaction will go to completion.

2. Chemical Kinetics: As outlined above, kinetics concern the *speed* at which a reaction will go to completion.

All chemical reactions are reversible. When the reactants and products reach the stage where changes in concentration can no longer be measured, the reaction is considered to be in a **state of equilibrium.** If the equilibrium lies far to the side of product formation, the reaction is said to have essentially *gone to completion*. Thus, when the equilibrium constant, K, is large, the reaction is said to have a large *driving force.* When a reaction satisfies this latter condition, a certain amount of *energy* is necessarily released when equilibrium is reached.

In terms of thermodynamics, for a reaction to take place spontaneously, the *free energy*, ΔG, of the products must be lower than the free energy of the reactants; that is, ΔG must be negative. Free energy is made up of two

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components: enthalpy H (the difference in bond energies between reactants and products) and entropy S (energy related to the randomness of the system). These quantities are related by the expression

$$\Delta G = \Delta H - T\Delta S \qquad 6\text{–}3$$

In many reactions, however, it is the enthalpy that mainly determines whether the reaction can take place spontaneously.

A negative ΔG value it does not necessarily mean that the reaction will take place in a reasonable length of time (that is reach equilibrium). A negative ΔG value is necessary, but not sufficient, to guarantee a spontaneous reaction. The *free energy of activation,* $\Delta G^{\ddagger}$, must also be considered. This condition is illustrated in the potential energy diagram (Fig. 6.49) for a one-step reaction of molecule A with molecule B to form molecules C and D (with no reaction intermediate assumed). This energy profile is typical of the base-catalyzed dehydrohalogenation reaction being studied in the current experiment, the E2 elimination reaction.

The generalized reaction profile is as shown in Figure 6.49

$$A + B \rightleftharpoons C + D \qquad 6\text{–}4$$

In the diagram the horizontal axis, called the reaction coordinate, indicates the progression of the reaction. $\Delta G^{\ddagger}$, is the free energy of activation for the forward reaction. The point at the top of the curve is called the *transition state*. Bond breaking and bond formation are involved over the range of this transition. Energy must be supplied through collision of molecules A and B (this involves both velocity and orientation in the collision) to move the system into and through the transition state and allow the products to form. As the products form, the activation energy is recovered plus additional energy (mainly from bond formation) so that the total energy evolved, $\Delta G_r^{\ddagger}$; is lower than that of the initial mixture.

The interpretation of the rate constant in terms of experimentally derived energy data is facilitated by the relationship known as the **Arrhenius equation** which rather successfully predicts the temperature dependence of the rate constants:

$$k = A \exp\left(-\frac{E_a}{RT}\right) \qquad 6\text{–}5$$

where

R is the gas constant with the value 8.314 J mol^{-1} K^{-1}

T is the temperature on the Kelvin scale

E_a is the Arrhenius activation energy in joules/mole

A is a constant (for a given reaction) called the *frequency factor*

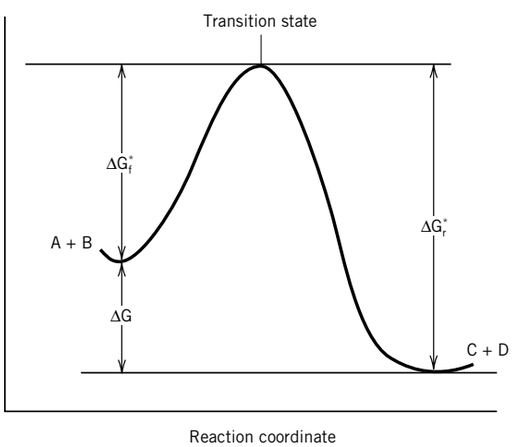

Figure 6.49 Activation energy.

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The *frequency factor* is related to the frequency of collisions and the orientation of the reacting molecules. A indicates how many collisions have the correct orientation to lead to products. The rest of the equation, $e^{-E_a/RT}$, gives the fraction of collisions in which the energy of the reacting species is greater than the activation energy for the reaction.

Also note that we can rewrite equation 6–5 as $-E_a = RT \ln(k/A)$, which closely resembles the expression between the equilibrium constant and the Gibbs free energy change, $-\Delta G° = RT \ln k$, and underlines the treatment of E_a as an energy term.

Thus, the Arrhenius equation describes quantitatively the discussion given here. For two reactions *at the same temperature,* the reaction with the higher activation energy has the lower rate constant and thus the slower rate. In other words, there is a smaller fraction of molecules possessing sufficient energy to react. An *increase in temperature* results in more molecules having enough energy to react and thus a faster rate. A change in conditions in which the frequency factor A is increased (by an increase in collisions in which the orientation of the molecules is right for reaction) also results in an increase in rate.

In the present experiment, the temperature is held relatively constant at the boiling point of the reaction mixture. Remember that a boiling solvent has a constant temperature at its boiling point. This is critical in reaction rate investigations for, as noted above, temperature change can exhibit a profound effect on rate. This phenomenon will be investigated in the second half of the experiment.

Geometrical Considerations in the E2 Elimination Reaction. Base-induced elimination of alkyl halides (dehydrohalogenation) is a general reaction and is an excellent method for preparing alkenes. This process is often referred to as β-*elimination,* since a hydrogen atom is always removed β to the halide (leaving group):

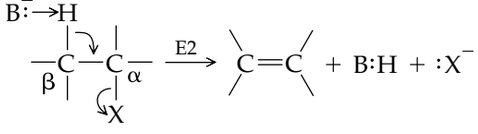

A high concentration of a strong base in a relatively nonpolar solvent is used to carry out the dehydrohalogenation reaction (see Experiment [10] for further examples).

Experimental evidence indicates that the five atoms involved in the E2 elimination reaction must lie in the same plane; the *antiperiplanar* conformation is preferred. This conformation is necessary for the orbital overlap that must occur for the π bond to be generated in the alkene. The sp^3-hybridized atomic orbitals on carbon that comprise the C—H and C—X σ bonds broken in the reaction develop into the p orbitals comprising the π bond of the alkene being formed. The reaction is termed *stereospecific.*

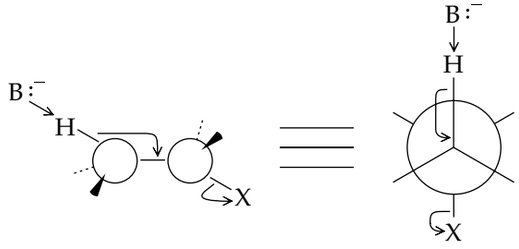

Anti-periplanar conformation

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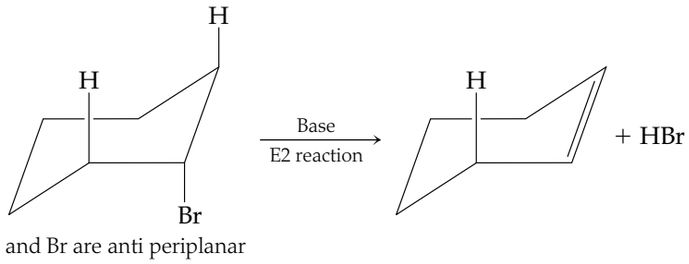

Figure 6.50 Geometric requirements for E2 elimination reaction in cyclohexanes.

The *antiperiplanar* conformation is particularly important in cyclohexane rings. This configuration can be met only if the hydrogen and the halide groups are *trans diaxial* to one another (see Fig 6.50). If either the hydrogen or halide group is *equatorial* the reaction does not occur. Furthermore, while there are exceptions to the relative disposition of the β-hydrogen and leaving group (Cope Elimination, for example), the number of systems which do not rely upon an antiperiplanar conformation are few and far between.

There is a smooth transition between reactant and product. Analogous to the S_N2 reaction, *no intermediate has been isolated or detected*. The reaction takes place in a single step through a high-energy *transition state* in which the double bond begins to form at the same time the hydrogen and halide groups leave. Figure 6.49 illustrates the energy profile for the reaction.

Evidence in support this mechanism is obtained from the measurement of the reaction kinetics of these reactions. Since both the alkyl halide and base concentrations appear to enter into the rate determining step, E2 reactions follow the second-order rate law:

$$\text{Rate} = k[\text{RX}]\,[\text{Base}] \qquad 6\text{–}6$$

As discussed above, a change in concentration of the base or of the alkyl halide should, therefore, affect the overall rate of the reaction. This dependence on concentration can be demonstrated by changing the base concentration. The current reaction, as it proceeds, will be sampled at 30-min intervals to track the generation of the alkene product, cyclohexene. Monitoring the formation of the product is carried out by removing a small aliquot sample from the reaction vessel and immediately quenching (stopping) the reaction with 1 M HCl. Rapid neutralization of the reacting medium (in the aliquot) with acid blocks the reaction. Each quenched sample is then extracted with methylene chloride to isolate the product and any unreacted starting material (cyclohexyl bromide). The rapid analysis of the small quantities of isolated reactants and products is accomplished by GC. Methylene chloride is effective as the extracting solvent, since it elutes from the GC column well before the compounds of interest (cyclohexene and cyclohexyl halide). From the chromatographic data obtained it is possible to determine if the amount of cyclohexyl halide has decreased and if the amount of cyclohexene has begun to increase. The results are reported as the percent cyclohexyl halide reacted.

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EXPERIMENTAL PROCEDURE

Estimated time of experiment: two laboratory periods.

NOTE. It is recommended that the experiment be done in two parts. Use the first period to work out the procedure (equipment setup, sampling, GC analysis, etc.) and the second period to study the effect of several parameters on the rate of the reaction.

All drops are measured using a Pasteur pipet.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Cyclohexyl bromide	163.06	0.6 mL	4.87	166.2	1.3359	1.4957
Sodium ethoxide (21% in ethanol)		2 mL				

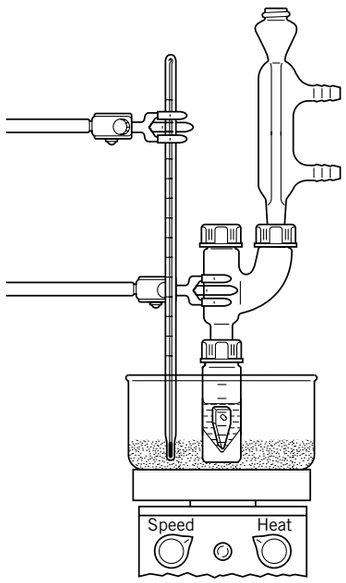

Cyclohexyl bromide, 0.6 mL Sodium ethoxide (21% in EtOH), 2.0 mL

Reagents and Equipment. Using a 10-mL graduated cylinder, measure 2 mL of a 21 wt% solution of sodium ethoxide in ethanol and add it to a 5-mL conical vial containing a magnetic spin vane (use a precalibrated Pasteur pipet for the transfer). Then equip the reaction vial with a Claisen head to which is connected a reflux condenser (⬅).

Reaction Conditions. Heat the reagent, with stirring, to reflux using a sand bath temperature of approximately 100 °C. Remove the cap from the Claisen head and use an automatic delivery pipet to add, in one portion, 0.6 mL (4.87 mmol) of cyclohexyl bromide. *Note the time of addition in your laboratory notebook.* Allow a few seconds for intimate mixing of the reactants to take place and then **immediately** remove 10 drops (about 0.4–0.5 mL) of the reaction solution using a Pasteur pipet, *recap the Claisen head*, and place the aliquot in a small sample vial containing 4–5 drops of 1 M HCl.

NOTE. You should notice that after a short time solid NaBr begins to form in the reaction vial.

To the sample vial containing the initial aliquot, add 10 drops of methylene chloride. Cap the vial and shake gently (or mix on a Vortex mixer). Loosen the cap carefully to vent the two-phase mixture. Remove the bottom, brown organic layer using a Pasteur filter pipet and transfer it to a second vial containing a small amount of anhydrous sodium sulfate. Cap the vial and label it as the *time-zero* sample.

NOTE. For separation of the layers, it is recommended that ***both*** *layers be drawn into the pipet. The bottom layer is then transferred to the second vial.*

Sampling Procedure. Two further samples for analysis are removed, *as outlined above*, one at 30 min into the reaction and the second after 1 h.

Each time the aliquot is treated

1. Remove 10 drops (0.4–0.5 mL) of reaction solution (recap the Claisen head).
2. Quench the reaction with acid (4–5 drops of 1 M HCl).
3. Extract the product and unreacted cyclohexyl bromide with methylene chloride, followed by drying the methylene chloride solution over anhydrous sodium sulfate.

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NOTE. Having the 5 drops of 1 M HCl in each of three sample vials and sodium sulfate in each of three second sample vials (a total of six vials) before you add the cyclohexyl bromide to initiate the reaction will help you facilitate this sampling procedure. Carefully label all the vials!

At the end of the sampling period you should have three samples for analysis by GC: time-zero, 30 min, and 60 min.

Gas Chromatographic Analysis. The composition of the aliquot samples may be determined by gas chromatographic analysis.

Parameters for the GOW-MAC 350 Column

Packed Column: DC 710 ($\frac{1}{4}$ *inch* $\times$ 8 *ft*).
Injection: 10 μL
Temperature: 132 °C
Flow rate (He): 50 mL/min
Chart speed: 1 cm/min

Gas chromatograph data may be used to determine the change in concentrations of cyclohexene and cyclohexyl bromide in the reacting medium during the 1-h reaction period. The samples can be injected after the extracted solution has had a 15- to 20-min period to dry over anhydrous sodium sulfate. *Each sample must elute from the GC before another sample is injected.* Each sample takes approximately 20 min to elute from the column, so start sample injections as soon as possible. For a typical chromatogram see Figure. 6.51.

INSTRUCTOR PREPARATION. For each chromatograph used, a mixture of cyclohexene and cyclohexyl bromide (approximately 80:30 by volume) should be injected once the parameters of the column are set. This is to establish the retention times of the components in the mixture.

NOTE. If the laboratory is done in two parts, it is advisable to stop at this point.

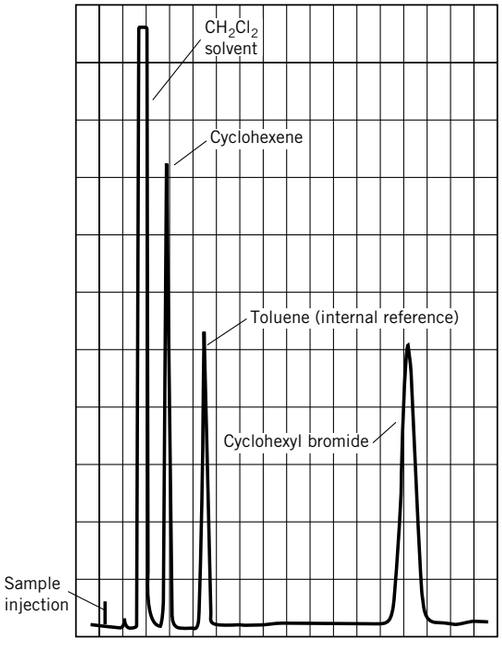

Figure 6.51 Example cyclohexene–cyclohexyl bromide GC.

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DATA ANALYSIS

The percentage of each component (cyclohexene and cyclohexyl bromide) in the sample can be determined by measuring the area under the curves. How would you expect the areas under the cyclohexene peak and the cyclohexyl bromide peak to vary with time?

The boiling point of cyclohexene (82.9 °C) is close to that of the refluxing ethanol (78.2 °C). Therefore, when samples are removed from the reaction mixture some of the cyclohexene may be lost, since some of it will be in the vapor phase in the reaction vial. How would this loss affect the observed concentrations over the reaction period?

The *time-zero* fraction should be analyzed, since the reaction starts immediately upon addition of the cyclohexyl bromide to the basic solution.

NOTE. Several alternative techniques may be used to quantitatively determine the composition of the sample mixture from the GC data, if an integrating recorder is not available.

Two methods are described here:

1. Determination of the areas under the peaks gives reproducible results of $\pm 3-4\%$ when these areas are assumed equal to the peak heights (mm) $\times$ the peak widths at half-height (mm), measured from the baseline of the curve.

2. An alternative method for determinating these areas is to cut out the peaks from the chromatogram and weigh them on an analytical balance (sensitivity to 0.1 mg). The weights of the peaks are directly proportional to the relative amount of each compound in the sample (assuming that the detector is similar sensitivity to the two components).

The percentage of the individual components is then calculated by dividing each area by the total sum of the two areas and multiplying by 100.

Attach a copy of your chromatogram to your Data Analysis Sheet. Label the cyclohexene and cyclohexyl bromide peaks. Show the area measurements on the chromatogram and all the calculations in your report. What conclusions can you draw based on your results? Include an explanation of the conclusions drawn.

VARIATION OF PARAMETERS

The effect of varying several parameters that influence the *rate* of the reaction can also be investigated. Of particular interest for study are the effect of changes in the concentration of the base, the reaction temperature, and the nature of the leaving group.

INSTRUCTOR NOTE. It is suggested that the class be divided into groups, with each group assigned to investigate a different parameter. The results of each group are then shared by the entire class and each student then submits a report.

The parameters to be investigated are

1. A control (see conditions below).
2. Halving the base concentration.
3. Room temperature reaction.

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4. Replacing cyclohexyl bromide with cyclohexyl chloride.
5. Replacing cyclohexyl bromide with cyclohexyl iodide.

Determine the percentage of unreacted cyclohexyl bromide in the sample mixture from the chromatogram for parameters 1, 2, and 3. Determine the percentage of cyclohexyl chloride and iodide in parameters 4 and 5, respectively. A comparison of unreacted starting halide with the control reaction shows the effect on the relative rate of dehydrohalogenation of changing the conditions under which the reaction is carried out. Tabulate your results.

In this set of experiments track only the disappearance of cyclohexyl bromide, and not the appearance of cyclohexene. As mentioned previously, the amount of cyclohexene observed in successive aliquots tends to drop below the predicted values because of the sampling techniques employed. As the reaction progresses, however, the amount of cyclohexyl bromide continues to decrease at the predicted rate (see below).

Use of an Internal Standard. How can we quantitatively track the disappearance of cyclohexyl bromide? As we have seen, the ratio of cyclohexyl bromide to cyclohexene cannot be determined accurately because of the inaccuracies in measuring the cyclohexene formed in the reaction. Also, there are small inaccuracies in the amount of the reaction mixture removed from the system for any given sample. These problems are solved by *standardizing* the samples. An *internal standard* is added to the reaction mixture. Ideally, this standard should not interfere with the reaction being studied and the substance must be easy to track by GC. In these experiments we will use *toluene*. Toluene is not very volatile (bp 110.6 °C) and has a retention time on the GC that does not interfere with the resolution of any other peaks on the chromatogram. It will be added *in a known amount* to the reaction mixture before you begin. For each gas chromatogram we can then measure *the area of the standard's peak* and use it to determine the amount of cyclohexyl bromide in the reaction mixture at that point.

Experimental Conditions

NOTE. Use the same experimental setup and workup procedure as in the previous experiment. A sample for analysis will be taken only at the 30-min mark. You may wish to take two samples so as to determine whether you can duplicate your results. The GC is setup at the same operating conditions. Drops are measured using a Pasteur pipet.

1. **Control**

Reaction conditions

2 mL of 21 wt% solution of sodium ethoxide in ethanol
300 μL toluene
Heat to reflux and stir.
Add 0.6 mL cyclohexyl bromide.

Time the reaction

At the 30-min mark, remove 20 drops of reaction solution and add it to 10 drops of 1 M HCl. Extract the mixture with 20 drops of methylene chloride and dry the methylene chloride layer over anhydrous sodium sulfate (15 min). Analyze the sample by GC.

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2. Room Temperature Conditions

Reaction conditions

2 mL of 21 wt% solution of sodium ethoxide in ethanol
300 μL of toluene
Stir at room temperature **(do not heat the hot plate).**
Add 0.6 mL of cyclohexyl bromide.

Time the reaction

At the 30-min mark, remove 20 drops of reaction solution and add it to 10 drops of 1 M HCl. Extract the mixture with 20 drops of methylene chloride and dry the methylene chloride layer over anhydrous sodium sulfate (15 min). Analyze the sample by GC.

3. Variation of the Concentration of Base

Reaction conditions

1 mL of 21 wt% solution of sodium ethoxide in ethanol
1 mL of absolute (anhydrous) ethanol
300 μL of toluene
Heat to reflux and stir.
Add 0.6 mL cyclohexyl bromide.

Time the reaction

At the 30-min mark, remove 20 drops of reaction solution and add it to 10 drops of 1 M HCl. Extract the mixture with 20 drops of methylene chloride and dry the methylene chloride layer over anhydrous sodium sulfate (15 min). Analyze the sample by GC.

4. Variation of Substrate—Cyclohexyl Chloride

Reaction conditions

2 mL of 21 wt% solution of sodium ethoxide in ethanol
300 μL of toluene
Heat to reflux and stir.
Add 0.58 mL cyclohexyl chloride.

Time the reaction

At the 30-min mark, remove 20 drops of reaction solution and add it to 10 drops of 1 M HCl. Extract the mixture with 20 drops of methylene chloride and dry the methylene chloride layer over anhydrous sodium sulfate (15 min). Analyze the sample by GC.

5. Variation of Substrate—Cyclohexyl Iodide

Reaction conditions

2 mL of 21 wt% solution of sodium ethoxide in ethanol
300 μL of toluene
Heat to reflux and stir.
Add 0.63 mL of cyclohexyl iodide.

Time the reaction

At the 30-min mark, remove 20 drops of reaction solution and add it to 10 drops of 1 M HCl. Extract the mixture with 20 drops of methylene chloride

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and dry the methylene chloride layer over anhydrous sodium sulfate. Analyze the sample by GC.

Data Analysis

To calculate the % of cyclohexyl bromine (chloride or iodide) reacted, follow the outline given here.

Given:

a. The amount of toluene added as the internal standard:

259 mg

Calculation (show here):

$$\underline{\text{Volume of toluene used}} \times \underline{\text{its density}}$$

b. The amount of cyclohexyl bromide used in the reaction:

794 mg

Calculation (show here):

$$\underline{\text{Volume of cyclohexyl bromide used}} \times \underline{\text{its density}}$$

If cyclohexyl chloride or iodide is used in place of the bromide:

Chloride: 581 mg
Iodide: 1029 mg

NOTE. The amount of cyclohexyl chloride and iodide used is the same molar amount as the cyclohexyl bromide.

The Calculations Using an Internal Standard. The calculations allow us to compare the amount (%) of cyclohexyl bromide (or chloride or iodide) reacted at the 30-min time point for each of the different reaction parameters.

Step 1. The amount of cyclohexyl bromide (chloride or iodide) **left** (unreacted) at the 30-min mark:

$$\frac{\text{Area of } C_6H_5\text{—Br, —Cl, or —I peaks}}{\text{Area of toluene peak}} \times [259 \text{ mg of toluene standard}] = ____ \text{ mg unreacted}$$

Step 2. The amount of cyclohexyl bromide (chloride or iodide) **reacted** at the 30-min mark:

[Amount of C_6H_5— Br, —Cl, or —I used in the reaction (in mg)] − [the amount left after 30 minutes (in mg), see step 1] =____ mg reacted

Step 3. The percent of cyclohexyl bromide (chloride or iodide) **reacted** at the 30-min mark:

$$\frac{\text{Amount reacted (in mg)}}{\text{Amount used (in mg)}} \times 100 = _____ \% \text{ reacted}$$

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Attach a copy of your chromatogram to your Data Analysis Sheet. Indicate which parameter you worked on. Label the toluene and cyclohexyl bromide, chloride, or iodide peaks. Show the area measurements on the chromatogram. Show all the above calculations in your report. Draw conclusions as to the effect on the rate of the reaction for each of the parameters investigated in the laboratory. Include an explanation of the conclusions drawn.

QUESTIONS

6-220. What reaction occurs between $NaOCH_2CH_3$ and HCl that stops the dehydrohalogenation reaction?

$$NaOCH_2CH_3 + HCl \rightarrow$$

6-221. Would you expect the replacement of cyclohexyl bromide with cyclohexyl iodide to result in a decrease, increase, or no change in the rate of the reaction? Explain.

6-222. In the second part of the experiment, why was it necessary to use toluene as an internal standard? What are the requirements for an internal standard? How would the loss of some toluene in the sampling procedure (from over heating the reaction system) affect the data?

6-223. A negative ΔG value does not necessarily mean that a reaction will take place in a reasonable length of time. A negative ΔG value is necessary, but not sufficient to guarantee a spontaneous reaction. The *free energy of activation*, $\Delta G^{\ddagger}$, must be considered. Explain this statement.

6-224. In E2 elimination reactions involving cyclohexane rings, why is it critical that the β-hydrogen and the leaving group be *trans diaxial* to one another?

6-225 Please explain why *trans*-1-bromo-4-methycyclohexane is more likely to undergo an E2 reaction when compared to *trans*-1-bromo-4-*tert*-butylcyclohexane even when working with warm toluene.

6-226. What effect on the rate of reaction would be observed if some of the ethanol solvent escaped from the reaction flask (as volatile vapor) while samples are being removed? Explain.

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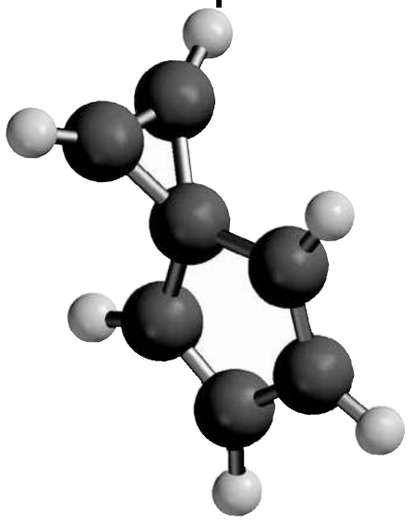

SEQUENTIAL SYNTHESES: THE TRANSITION FROM MACRO TO MICRO

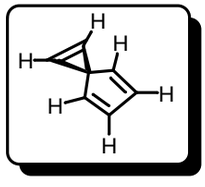

The synthesis of a vast array—now numbering in the millions—of new organic molecules in academic and industrial laboratories over the past 100 years is one of the great achievements of modern science. Many of these new compounds have had profound effects on our way of life, both good and bad. A great challenge in the next century will be how society applies these powerful materials, and the new molecules yet to be born, to the common good.

Our ability to synthesize highly complex organic substances has taken a number of dramatic jumps during this century, and has resulted in a bewildering collection of substances that have been devised, synthesized, and applied to practically every facet of our lives. Many of these materials are now vital to our daily life (consider penicillin) and we all too often take them for granted. In just the last 30–40 years, new advances in pharmaceutical compounds have saved, extended, and made more comfortable the lives of hundreds of millions of people. The list could go on and on, including textiles, surfactants, plastics, and synthetic oils, to name only a few.

Historically, the synthesis of complex organic substances was primarily driven by the need to obtain large quantities of biologically active material that occurred as the product of plant or animal metabolism, but that could be obtained only in very small quantities from nature. For example, the synthesis of the adrenal cortex hormone, cortisone, was a major breakthrough for hormone therapy. The synthesis of this material initially required 33 steps. That is, the research chemist carried out a sequence of 33 reactions in which stable isolable intermediates were formed sequentially, leading ultimately to the desired cortisone molecule. Industrial sequences of this length are now rare, but those requiring three to six steps are common.

The strategy of the synthetic chemist is to devise a route whereby the desired compound can be prepared efficiently, using inexpensive, readily available starting materials in the fewest steps, and have a minimal impact on the environment when considering the waste(s) generated. For each individual step, the yield of intermediate should be as high as possible with a minimum of side reactions. In industry the overall cost of the proposed synthetic sequence must be considered, including the time involved, type of equipment required, and safety factors. Today, with the worldwide demand for organic materials in vast quantities (e.g., petroleum products) it is becoming increasingly important to assess the impact on our environment of these synthetic materials prior to large-scale production.

Chapter 7: C_7H_6, [1,2]Spirene
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Because organic transformations almost always take place with some loss of material (similar bond energies lead to alternative reaction pathways and easy byproduct formation), the yield of intermediate from each individual step can have a significant impact on the overall yield of the final product. *In a multistep synthesis, the overall yield is the mathematical product of the yields of the individual steps.* For example, if we assume that in a five-step sequence for the preparation of a new dye, each step takes place in 85% yield, the overall yield would be $(0.85)^5 \times 100$ or 44% (in a 33-step synthesis with an 85% yield for every step, the overall yield would be ~0.5%). This property of organic synthesis emphasizes why a synthetic route devised to produce a particular molecular structure must be carefully planned to minimize losses at each stage of the chosen pathway. This problem also illustrates why the initial steps of a sequence usually use larger quantities of reactants (macro or semimicro quantities), and why in the last stages, experience at running reactions at the microscale level can be invaluable.

In this chapter we describe a set of six sequential experiments. These experiments vary in the number of intermediates that are required from seven to three, and they vary in the complexity of the chemistry, from straightforward extensions of Chapter 6 to relatively demanding experimentation similar to that described in Chapter 10W.

The target molecules include

- The drug **sulfanilamide** (the first of the antibiotics), which is obtained in a novel three-step sequence not usually found in the introductory laboratory:

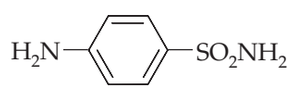

p-Aminobenzenesulfonamide
(sulfanilamide)

- The industrially important polymer, **nylon-6,6** (the first of the commercial synthetic textile fibers), formed in three steps closely paralleling the original synthesis:

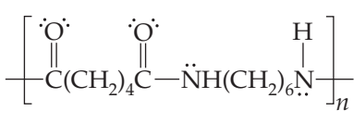

Nylon-6,6

- The synthesis of **2′-bromostyrene,** which requires three steps. This compound is an interesting substance because of its commercial use as a fragrance in soap products:

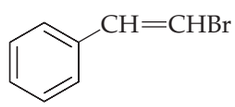

2′-Bromostyrene

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EQA

- The synthesis of **piperonylonitrile** is an example of a novel conversion, in three steps, of an aromatic aldehyde to an aromatic nitrile:

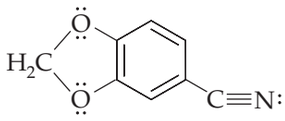

Piperonylonitrile

- The synthesis of **hexaphenylbenzene** requires two parallel three-step sequences to obtain two intermediates that then react with each other to give the target compound after a seven-step synthesis. The final product is a most unusual organic material with one of the highest melting points observed for an organic substance:

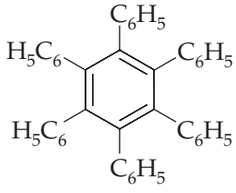

Hexaphenylbenzene

- The synthesis of a **photochromic imine** in four steps yields perhaps the most intriguing substance in the entire chapter. The ability of this material to turn a deep-blue color when exposed to light, and then to lose its color when placed back in the dark makes this structure one of the most interesting of the sequential products. It also involves the most challenging chemistry of the multistep syntheses:

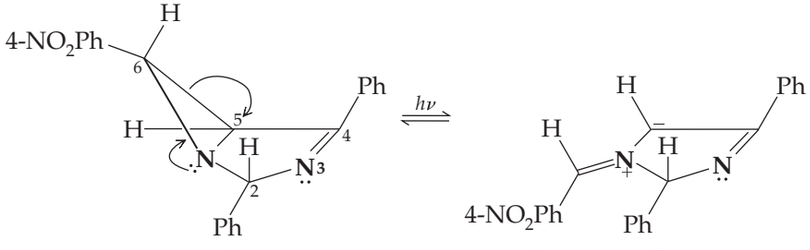

2-*exo*-6-*exo*-2,4-Diphenyl-
6-(4-nitrophenyl)-
1,3-diazabicyclo[3.1.0]hex-3-ene

Blue azomethine ylide
(syn configuration)

In a number of the sequences, the stereochemistry of the reactions is vitally important and controlled by the mechanisms that are operating under the prescribed conditions. This aspect of the transformations is discussed in detail. By performing one or all six of these multistep sequences you will have a chance to challenge your experimental technique under conditions essentially identical to those found in the modern synthetic organic research laboratory. You will quickly recognize the reason why laboratory technique is so vital to the success of multistep syntheses.

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SEQUENCE A

The Synthesis of Hexaphenylbenzene

The molecule to be prepared in the Sequence A synthesis is hexaphenylbenzene (**I**):

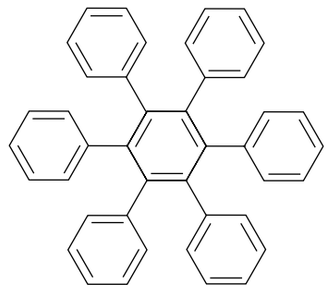

I
Hexaphenylbenzene

This system, which contains seven aromatic rings, was first made by Dilthey at the University of Bonn in 1933 by using a classic Diels–Alder reaction with exactly the same two reactants as you will generate in Sequence A. The Bonn group showed that an earlier claim, by Durand, to have prepared this compound via a massive Grignard attack by phenylmagnesium bromide on hexachlorobenzene, had not actually yielded hexaphenylbenzene. The compound isolated by Durand melted at 266 °C while Dilthey's material melted at 421–422 °C. Hexaphenylbenzene was later synthesized photochemically by Büchi at the Massachusetts Institute of Technology (MIT) in 1962. The MIT group improved the purity of the isolated material, and reported a melting point of 439–441 °C. Fieser, at Harvard University, refined Dilthey's synthetic route, and published the definitive preparation in *Organic Syntheses* in 1966. Fieser obtained melting points *without decomposition* in evacuated melting point capillaries (see Chapter 4) in the range 454–456 °C.

This hydrocarbon system possesses a number of interesting structural and physical properties. First, we should note that it has a relatively high molecular weight, near 534, and a molecular formula of $C_{42}H_{30}$. Hexaphenylbenzene exhibits an extremely high melting point for a nonionic organic material. For example, of the 15,000 plus substances listed in the Table of Physical Constants for Organic Compounds in the *CRC Handbook of Physics and Chemistry,* only two materials melt above 450 °C (and both of these compounds decompose at their melting point), and only 10 melt above 400 °C. Indeed, hexaphenylbenzene melts above hexabenzobenzene (**II**), the completely delocalized seven-ring fused system, mp = 438–440 °C.

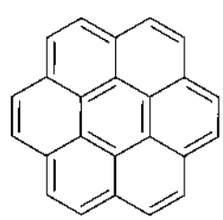

II
Hexabenzobenzene
(coronene)

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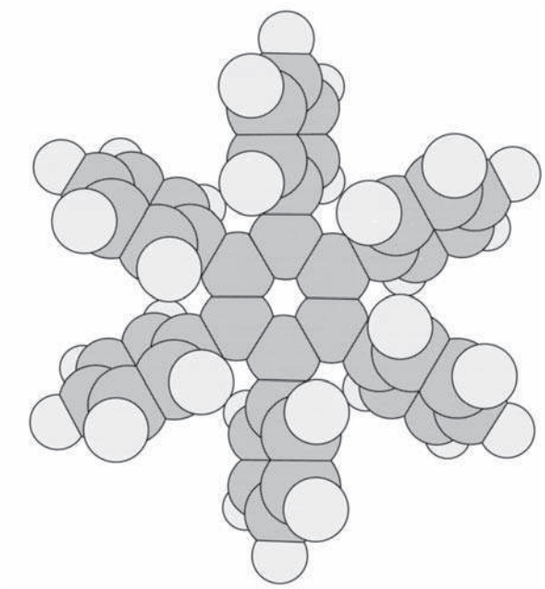

Figure 7.1 Molecular model of one of the chiral rotamers of hexaphenylbenzene.

From molecular modeling studies of hexaphenylbenzene, it appears that the six substituent rings surrounding the central system will be sterically restricted from lying in the plane of that ring by ortho-position interaction (**III**) and Figure 7.1 shows a molecular model of one of the chiral rotamers of hexaphenylbenzene.

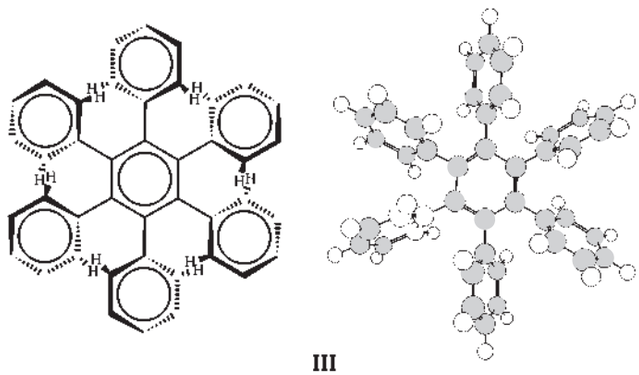

III
Hexaphenylbenzene with steric interactions between ortho positions

The twisted structure presents a particularly interesting problem in stereoisomerism. It is clear that when all the rings are coplanar (dihedral angle of 0°) we have maximum overlap of the π system and delocalization energy, but we also have a maximum of steric repulsion energies. On the other hand, when the dihedral angle approaches 90°, all delocalization is blocked, though steric repulsion between rings is at a minimum. It would seen reasonable to expect the system to reach some energetic compromise between these two extreme orientations. If this is the case, is it possible to establish the angle at which the external rings are positioned? An X-ray crystallographic study carried out by Bart in 1968 on solid crystalline hexaphenyl-benzene did, in fact, show that in the crystal lattice the phenyl groups are twisted 65° out of the plane of the central ring. In the crystal lattice, the molecule adopts a conformation, similar to a six-bladed propeller, which is chiral. That is, in the solid state hexaphenylbenzene can exist in two enantiomeric forms. Indeed, if this molecule happened to undergo resolution of the optical isomers during crystallization, in much the same fashion as Pasteur's tartaric acid salts, it should be

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possible to mechanically separate the racemate into crystals in which all the rings are tilted only in one possible conformation or in the other. These enantiomers, however, should possess a relatively low barrier to rotation, so that when dissolved in solution rapid racemization, via rotation of the rings (propeller blades) to the opposite pitch, would be expected.

This does seem to be the case. In 1977, Gust at Arizona State University showed that if a derivative of hexaphenylbenzene were synthesized in which two different groups were substituted on adjacent rings in the ortho positions (e.g., a methyl group and a methoxy group, **IV**), two possible sets of diastereomers would result:

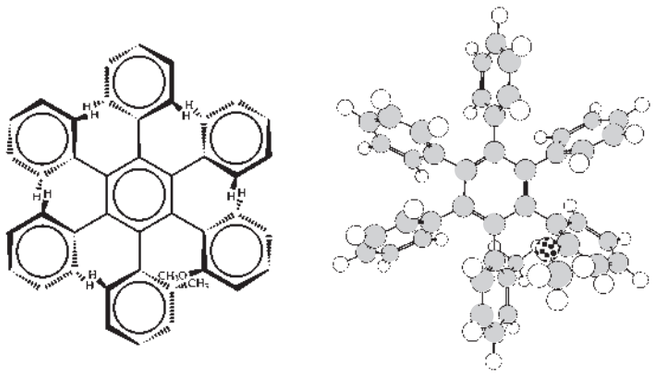

IV
Substituted hexaphenylbenzene with steric interactions between ortho position

It is presumed that it would be impossible for the rings to rotate the two ortho substituents past one another, but that other rotations may or may not be facile. If a large rotational barrier were present, the external rings would remain tilted at 65° with the same pitch. If this were the case, we would expect four diastereomers, and thus four different C—CH_3 resonances in the ^{1}H NMR spectrum. If rapid interconversion of the tilted conformers occurred, we would expect that the two bulky ortho groups would restrict full rotation of those two rings, even though the barrier to pitch inversion is low. Thus, in this latter case we would expect two diastereomeric pairs of enantiomers (one with the two ortho groups up and one with one up and one down), and two different C—CH_3 resonances in the NMR. When the compound was synthesized, and its ^{1}H NMR spectrum obtained, two resonances for methyl groups attached to aromatic rings and two O—CH_3 resonances were observed. These two diastereomers, **V**, were separated by column chromatography, and it was found that they slowly interconverted upon being heated to 215 °C. Thus, on the NMR time scale, it would appear that in hexaphenylbenzene, a reasonably rapid inter-conversion of the propeller conformations is taking place in solution at room temperature:

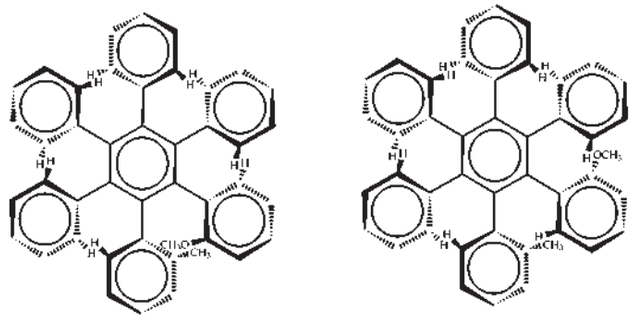

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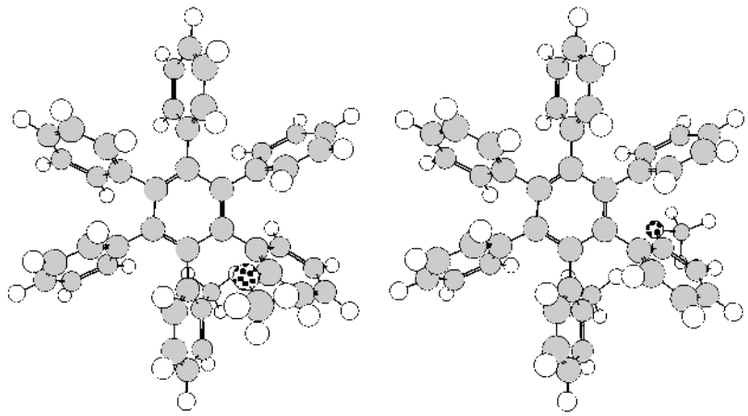

V
ortho-Disubstituted hexaphenylbenzene exists as two diastereomers

The Synthesis of Hexaphenylbenzene from Benzaldehyde:

EXPERIMENTS A1$_a$, A2$_a$, A3$_a$, A1$_b$, A2$_b$, A3$_b$, and A4$_{ab}$

As shown on the flow charts below and on page 428, the total synthesis of hexaphenylbenzene involves two parallel sets of three reactions each, the **a** series and the **b** series. The two series culminate in synthesizing tetraphenylcyclopentadienone (**a** series) and diphenylacetylene (**b** series), which are then reacted together (Experiment [A4$_{ab}$]) to produce the final product, hexaphenylbenzene.

The **a** series uses benzaldehyde as a starting material, which is first converted to the α-hydroxyketone benzoin in Experiment [A1$_a$]. Benzoin is then oxidized to benzil (Experiment [A2$_a$]). Benzil (along with diphenylacetone) is used in the construction of tetraphenylcyclopentadienone in Experiment [A3$_a$], the third and last of the Sequence A$_a$ intermediates.

The **b** series of synthetic experiments also begins with benzaldehyde, which is converted in Experiment [A1$_b$] into (*E*)-stilbene. (*E*)-Stilbene is the precursor to *meso*-1,2-dibromo-1,2-diphenylethane (*meso*-stilbene dibromide) prepared in Experiment [A2$_b$]. This dibromide is in turn converted

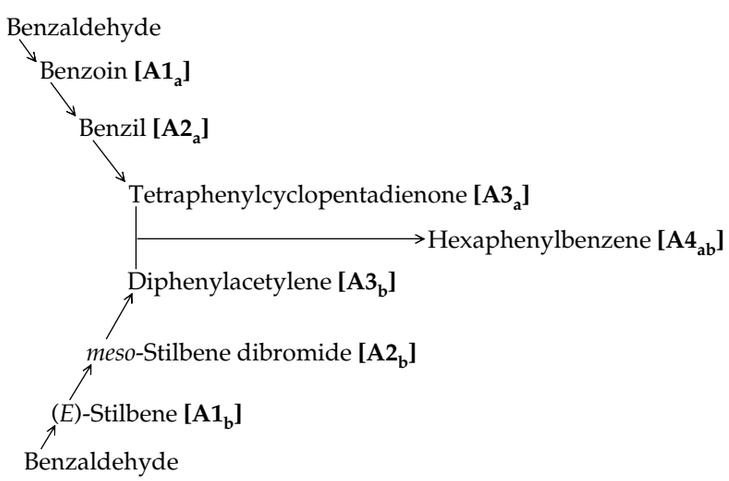

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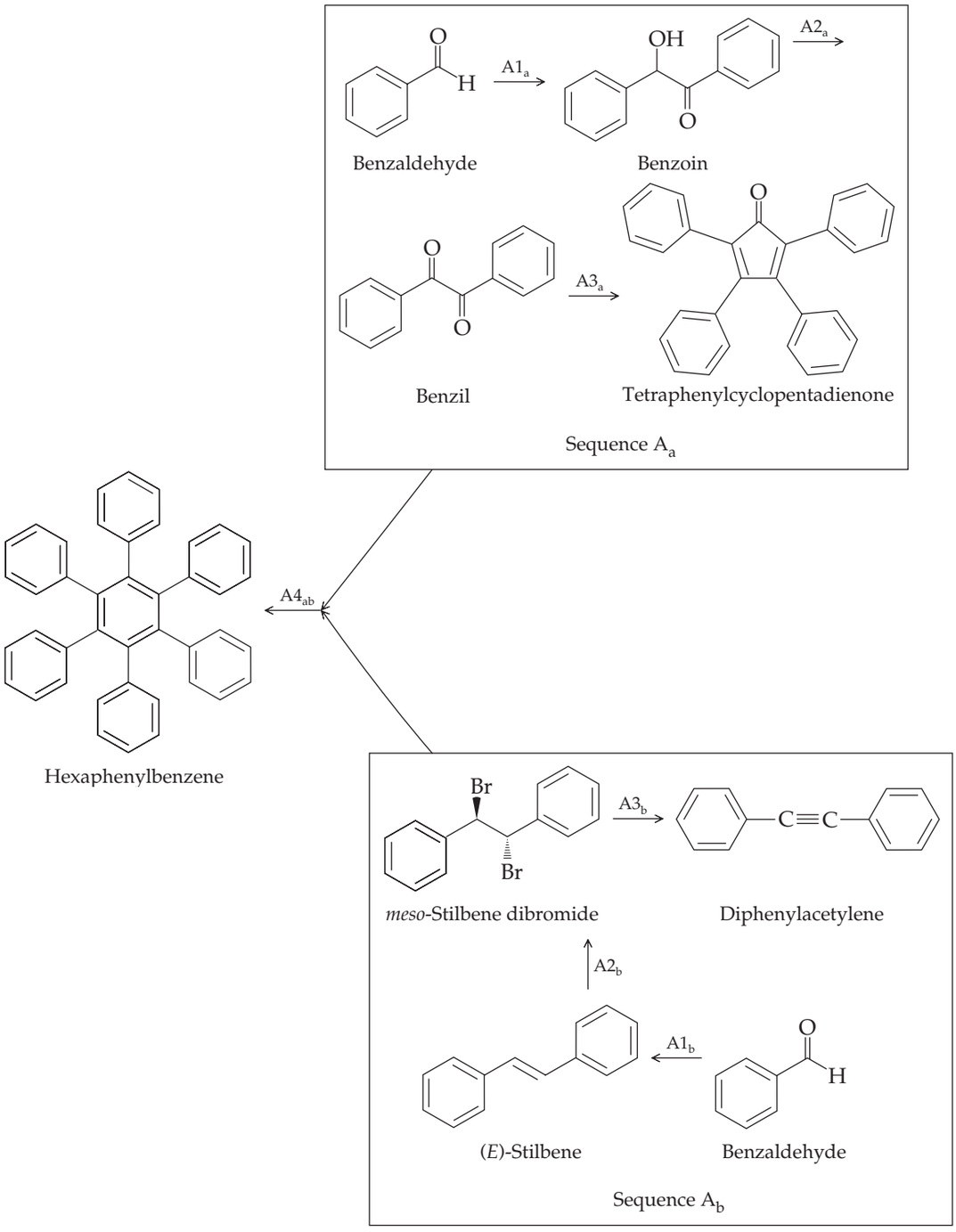

by the double dehydrohalogenation reaction in Experiment [$A3_b$] into diphenylacetylene.

The diphenylacetylene is then reacted with the tetraphenylcyclopentadiene, synthesized in the last step of the **a** series, in a Diels–Alder reaction to produce the final product of the sequences, hexaphenylbenzene, in Experiment [$A4_{ab}$].

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EQA

This preparation of hexaphenylbenzene demonstrates the manner in which a variety of basic organic reactions can be integrated to prepare a desired end product.

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Gust, D. *J. Am. Chem. Soc.* **1977,** *99,* 6980.

The Benzoin Condensation of Benzaldehyde: Benzoin

Experiment A1$_a$

Common name: benzoin

CA number: [579-44-2]

CA name as indexed: ethanone, 2-hydroxy-1,2-diphenyl-

Purpose. One of the classic reactions of organic chemistry, the *benzoin condensation,* is carried out. You will examine the properties of the α-hydroxyketone product of this well-known reaction. The particular α-hydroxyketone generated in this experiment is the compound from which the reaction gains its name, *benzoin*.

This reaction provides quantities of benzoin for use in the multistep synthesis of hexaphenylbenzene (see Experiment [A4$_{ab}$]). Benzoin is synthesized in this first step of the **a** series of the Sequential Experiments. In this sequence of reactions, benzoin is converted by oxidation (Experiment [A2$_a$]) to benzil and then to tetraphenylcyclopentadienone (Experiment [A3$_a$]). The latter compound undergoes a Diels–Alder addition with diphenylacetylene (Experiment [A3$_b$]) to give hexaphenylbenzene (Experiment [A4$_{ab}$]).

NOTE. If the benzoin product is to be used in the reaction sequence, it is recommended that one of the semimicro procedures be followed so that sufficient material will be available for the subsequent steps. The conditions for a one-step microscale experiment are listed following the two semimicroscale procedures.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)

REACTION

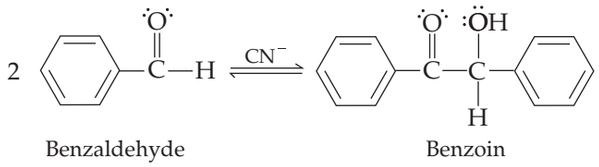

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DISCUSSION

Aromatic aldehydes, in the presence of catalytic cyanide ion, dimerize to form the corresponding α-hydroxyketone (acyloin). This reaction, which is reversible, is known as the benzoin condensation, even though we now know that it is not actually a condensation reaction, because no water or alcohol is produced. Cyanide ion is a specific catalyst for the reaction with aromatic aldehydes, and can function in this capacity because it is a good nucleophile, it stabilizes the intermediate carbanion, and it is a good leaving group. In the mechanism outlined below, the nucleophilic cyanide ion attacks a molecule of the aromatic aldehyde to form the conjugate base of a cyanohydrin. The effect of the —CN group is to increase the acidity of the α-hydrogen atom, thus allowing the formation of the anion (**I**):

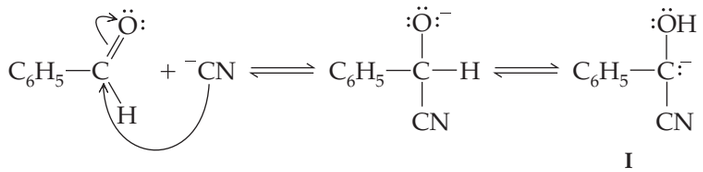

(1)

I

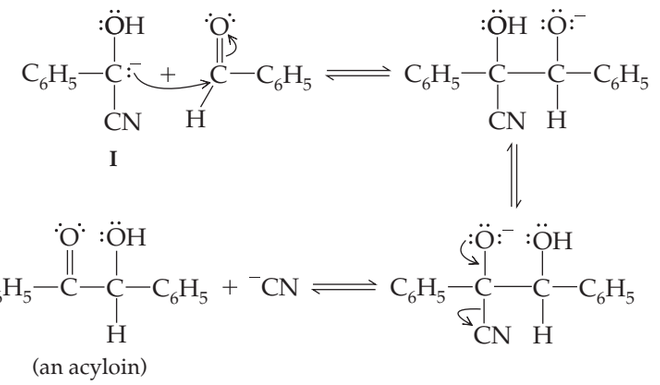

(2)

(an acyloin)

Once generated, the nucleophilic carbanion (**I**) attacks a second molecule of the aromatic aldehyde to yield a substituted cyanohydrin. This species can then be stabilized by loss of cyanide ion to form the α-hydroxyketone product.

The electronic effects of various substituents on the aromatic ring have been investigated. Because, in this reaction, the same aldehyde functions as both the nucleophile and the electrophile, electronic effects that enhance one of these functions are likely to inhibit the other. If a strongly electron-donating group is in the para position of the ring, the reaction fails due to the increase in electron density at the carbonyl carbon, brought about by the presence of the electron donor, which renders the carbonyl carbon less electrophilic. The benzoin condensation is also hindered by strong electron-withdrawing groups on the ring. The presence of a para-nitro group decreases the electron density on the carbonyl carbon atom in the cyanohydrin anion, making its carbanion less nucleophilic, which drastically retards the rate of addition of the anion to the second molecule of aldehyde.

The cyanide-ion catalysis works only for aromatic aldehydes. Aliphatic aldehydes can, however, be condensed to α-hydroxyketone in the presence of thiazolium salts, such as *N*-dodecylthiazolium bromide:

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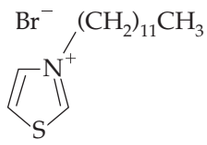

N-Dodecylthiazolium bromide

SEMIMICROSCALE EXPERIMENTAL PROCEDURE

(The microscale reaction quantities are increased by a factor of 2.)

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	400 μL	3.92	178	1.04	1.5450
Sodium cyanide (0.54 M) in ethanol (95%)		2 mL				

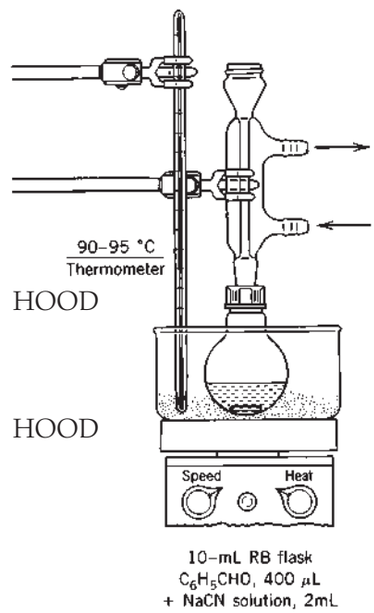

Reagents and Equipment. Using an automatic delivery pipet in the **hood,** place 400 μL (416 mg, 3.92 mmol) of fresh, acid-free, benzaldehyde in a weighed 10-mL round-bottom flask containing a magnetic spin bar. Reweigh the flask and record the weight. Now add 2 mL of a 0.54 M solution of sodium cyanide in ethanol (in the **hood**). Remember to use a fresh tip on the automatic delivery pipet.

NOTE. The 0.54 M NaCN solution should be prepared by the instructor.

CAUTION: Sodium cyanide (NaCN) is extremely toxic.

Attach the flask to a reflux condenser and mount the assembly in a sand bath on a magnetic stirring hot plate (➡).

Reaction Conditions. Heat the mixture with stirring in a sand bath at 90–95 °C. Maintain this temperature for 30 min. The reaction solution turns yellow, and may then become cloudy within approximately 5 min.

NOTE. Do not overheat the reaction mixture. If the solution begins to darken, immediately remove the vial from the sand bath.

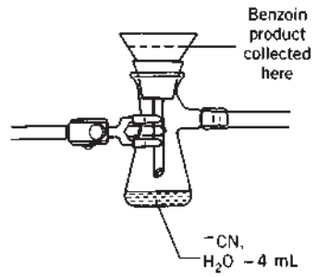

Isolation of Product. At the end of the reflux period, cool the solution to room temperature and then place it in an ice bath for 10 min. Collect the benzoin product by filtration under reduced pressure using a Hirsch funnel (➡). Wash the filter cake on the Hirsch filter bed with two 1-mL portions of cold water, and air-dry the material under suction using plastic food wrap (see Prior Reading) for 5 min. The crude material is further dried on a porous clay plate or on filter paper.

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Purification and Characterization. This crude material may be purified by recrystallization from methanol or ethanol (95%) in a Craig tube.

Weigh the benzoin product and calculate the percent yield. Determine the melting point and compare your value to that found in the literature.

Obtain the IR spectrum of the compound. Compare your spectrum to that recorded in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

This compound also has a characteristic ultraviolet spectrum showing a peak of maximum absorption (λ_{max}) at 247 nm (ε_{max} = 13,200, at a concentration of 6.0×10^{-5} M in ethanol) characteristic of the benzoyl group, $C_6H_5C{=}O$.

Chemical Tests. Benzoin contains an aromatic ring. Confirm this fact by performing the ignition test (Chapter 9). To confirm the presence of the alcohol and ketone functions in benzoin carry out the chromic anhydride test for the —OH group and the 2,4-dinitrophenylhydrazine test for the C=O group. Isolate the solid 2,4-dinitrophenylhydrazone derivative and compare its melting point to the literature value.

There is a specific test for the presence of benzoin. Place a few crystals of your material in 800 μL of 95% ethanol. The addition of a few drops of 10% sodium hydroxide solution produces a purple coloration. The color fades when the solution is shaken in air but reappears if the solution is allowed to stand.

OPTIONAL SCALES

These procedures are identical to that given above with the following exceptions:

Fivefold Scaleup

1. Increase the scale of the reaction by a factor of 5 compared to the microscale procedure.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	1.0 mL	9.8	178	1.04	1.5450
Sodium cyanide (0.54 M) in ethanol (95%)		5.0 mL				

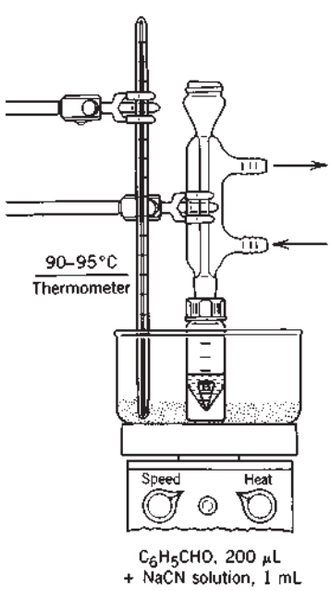

2. Use a 10-mL round-bottom flask.

3. The product is washed with two 2-mL portions of cold water.

MICROSCALE REACTION PROCEDURE

Physical Properties of Reactants						
Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Benzaldehyde	106.13	200 μL	1.96	178	1.04	1.5450
Sodium cyanide (0.54 M) in ethanol (95%)		1.0 mL				

1. The product is washed with two 0.5-mL portions of cold water.

2. Use a 5-mL conical vial (⬅).

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EQA

QUESTIONS

7-1. The benzoin produced in this experiment contains a chiral carbon atom (a stereocenter), but the product itself is not optically active. Explain.

7-2. The cyanide ion is a highly specific catalyst for the benzoin condensation. Can you list three functions this ion performs in this catalytic role?

7-3. Can you suggest a reason why *p*-cyanobenzaldehyde does not undergo the benzoin condensation to yield a symmetrical benzoin product?

7-4. Tollens' reagent is used as a qualitative test for the presence of the aldehyde functional group (see Chapter 9, Classification Tests). However, benzoin, which does not contain an aldehyde, gives a positive test with this reagent. Explain.

7-5. Show how one might accomplish the conversion of *p*-methylbenzaldehyde to each of the following compounds.

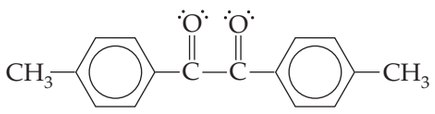

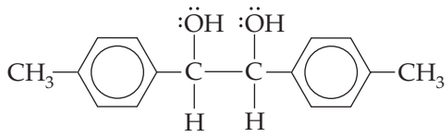

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Ide, W. S.; Buck, J. S. *Org. React.* **1948,** *4,* 269.

Kuebrich, I. P.; Schowen, R. L.; Wang, M.; Lupes, M. E. *J. Am. Chem. Soc.* **1971,** *93,* 1214.

Stetter, H.; Kuhlmann, H. *Organic Syntheses;* Wiley: New York, 1990; Collect. Vol. VII, p. 95.

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 16, p. 1396 and references therein.

For the use of thiamine hydrochloride as a catalyst in the reaction see

Pasto, D. J.; Johnson, C. R.; Miller, M. J. *Experiments and Techniques in Organic Chemistry;* Prentice-Hall: New Jersey, 1992, p. 500.

Copper(II) Ion Oxidation of Benzoin: Benzil

Experiment A2$_a$

Common name: benzil

CA number: [134-81-6]

CA name as indexed: ethanedione, diphenyl-

Purpose. Benzil is the second of three synthetic intermediates in the **a** series of Sequential Reactions, which lead to the synthesis of hexaphenylbenzene. Benzoin, the starting material for this step, is prepared in Experiment [A1$_a$]. Benzil, the product formed in the present reaction, is used in the synthesis of tetraphenylcyclopentadienone in Experiment [A3$_a$]. Tetraphenylcyclopentadienone is then converted to hexaphenylbenzene in Experiment [A4$_{ab}$].

This experiment also affords an excellent opportunity for you to investigate the use of a soluble, metal–ion catalyst as an oxidizing agent. In this case, a secondary alcohol is oxidized to a ketone. Because nitrogen gas is formed as a byproduct, the progress and rate of the reaction can be followed by measuring the evolution of nitrogen.

NOTE. If you plan to continue the synthetic sequence to hexaphenylbenzene, the semimicroscale procedure described below should be used. If you wish to study this reaction as an individual microscale experiment, those conditions follow the semimicro discussion.

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Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Thin-Layer Chromatography (pp. 97–99)
Concentration of Solutions (pp. 101–104)
Technique 7: Collection or Control of Gaseous Products (pp. 105–107)

REACTION

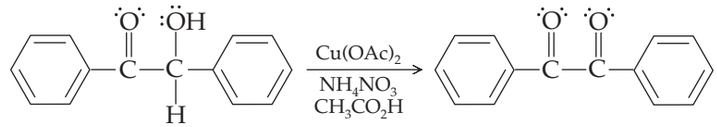

Benzoin Benzil

DISCUSSION

Benzil, a diketone, is obtained by the catalytic oxidation of benzoin using Cu^{2+} ion as the catalytic oxidant. The reaction is general for α-hydroxyketones, and is the basis of Fehling's qualitative test for certain sugars. The mechanism of the oxidation shows the catalytic effect of the Cu^{2+} ion as it is continuously reduced and reoxidized in the sequence outlined below. A key ingredient is the nitrate ion, which oxidizes the Cu^{+} to the Cu^{2+} oxidation state, and is in turn reduced to nitrite ion. The nitrite ion in the presence of acid and ammonium ion, decomposes to yield nitrogen gas and water.

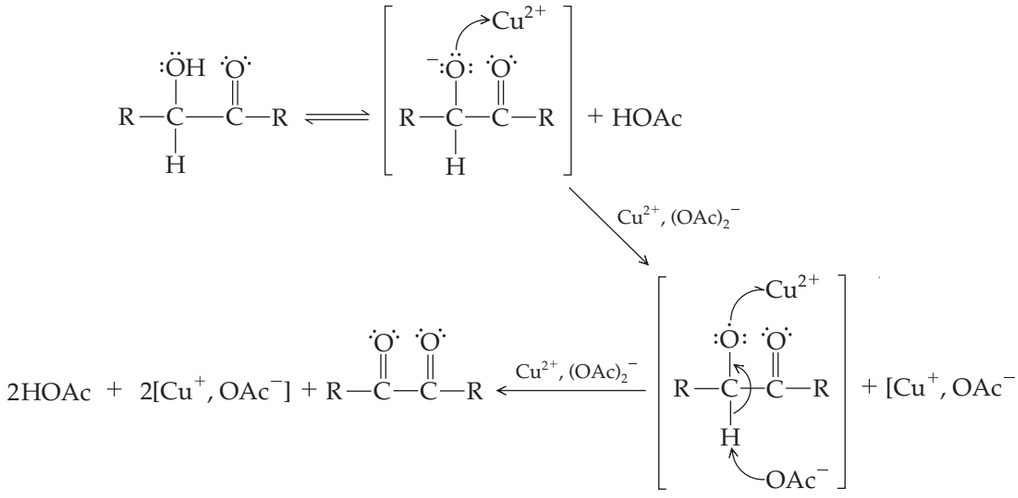

and

$$2\,Cu^{+} + 2\,H^{+} + NO_3^{-} \rightarrow 2\,Cu^{2+} + NO_2^{-} + H_2O$$

$$NH_4NO_2 \xrightarrow{H^{+}} N_2 + 2\,H_2O$$

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SEMIMICROSCALE EXPERIMENTAL PROCEDURE

(The microscale reaction is increased fourfold.)

Estimated time of the experiment: 2.5 h.

Physical Properties of Reactants				
Compound	MW	Amount	mmol	mp (°C)
Benzoin	212.25	400 mg	1.88	137
Cupric acetate solution		1.4 mL		

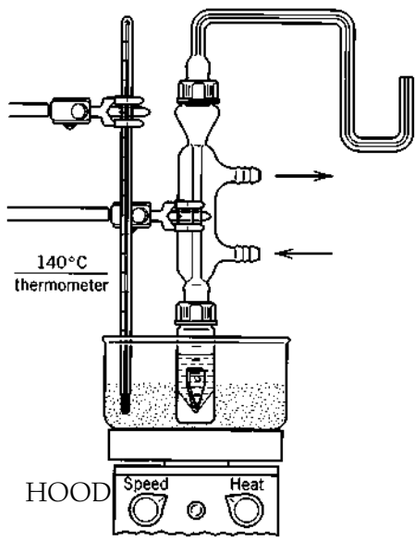

Benzoin, 400 mg
+ cupric acetate catalyst, 1.4 mL,
5–mL conical vial

INSTRUCTOR PREPARATION. Prepare the catalyst solution by dissolving 0.1 g of cupric acetate and 5 g of ammonium nitrate in 7.0 mL of deionized water (may require warming), followed by addition of 28 mL of glacial acetic acid. Place the container in the ***hood*** *and dispense the solution by use of an automatic delivery pipet.*

Reagents and Equipment. Equip a 5.0-mL conical vial, containing a magnetic spin vane, with a reflux condenser, to which is attached a gas exit delivery tube(➡). Weigh and add to the vial 400 mg (1.88 mmol) of benzoin, followed by 1.4 mL of cupric acetate catalyst solution (using a calibrated Pasteur pipet).

Arrange the gas delivery tube so that it fits into an inverted 100-mL graduated cylinder that is filled with, and immersed in, a beaker of water (➡). This arrangement facilitates the measurement of the nitrogen gas evolved during the course of the reaction.

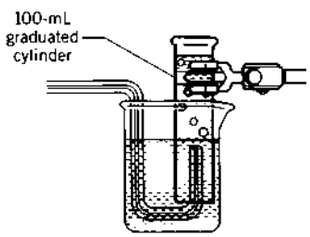

NOTE. It is absolutely necessary that all connections be tight to prevent leakage of the gas evolved. Lightly grease the ground-glass joint on the gas delivery tube.

Reaction Conditions. Heat the reaction mixture with stirring at a sand bath temperature of 140–145 °C for about 1 h or until the collected gas volume remains constant. *As the benzoin dissolves, the reaction mixture turns green and evolution of nitrogen gas commences. The theoretical volume of gas from the oxidation of 400 mg of benzoin is 42.4 mL at standard temperature and pressure (STP).*

Isolation of Product. If the gas delivery tube is used, *disconnect* it from the top of the condenser *before* removing the reaction vial from the heat source.

Cool the reaction mixture to room temperature, add 2 mL of cold water (using a calibrated Pasteur pipet), and then place the reaction vial in an ice bath for 10 min. Collect the yellow crystals of benzil by vacuum filtration using a Hirsch funnel (➡). Rinse the reaction vial and crystals with two additional 2-mL portions of cold water.

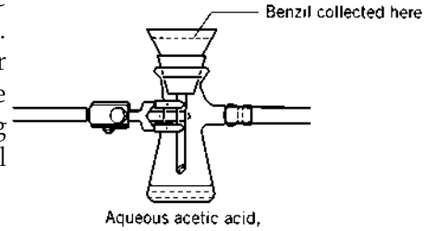

Aqueous acetic acid,
~7.5 mL and other
reaction by-products

Purification and Characterization. Purify the crude product by recrystallization from methanol, or from 95% ethanol. Dry the recrystallized yellow benzil on a porous clay plate, or on filter paper. *The benzil obtained after recrystallization often contains a small amount of benzoin impurity. It may*

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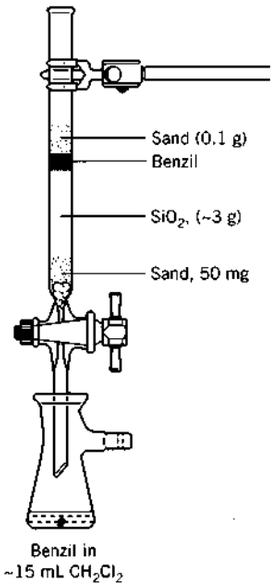

V *be purified by chromatography on silica gel using the procedure outlined below.* Before carrying out the column chromatography purification of benzil, the purity of the initial product may be assessed using thin-layer chromatography (see Prior Reading). Use methylene chloride as the elution solvent, silica gel as the stationary phase, and UV light for visualization. Typical R_f values are benzil, 0.62; benzoin, 0.33.

Pack a 1.0-cm-diameter column to a height of 5 cm with a slurry of activated silica gel in methylene chloride (⬅). Introduce the sample of benzil to the column, followed by 100 mg of sand. Use approximately 10–15 mL of methylene chloride to elute the benzil, which is easily identified on the column because of its yellow color. Concentrate the eluate collected in a 25-mL filter flask to obtain the pure benzil (see Prior Reading). A rotary evaporator is an effective alternative.

Weigh the dried product and calculate the percent yield. Determine the melting point and compare your value to that reported in the literature.

Obtain an IR spectrum of the product and compare it with that of the starting material and to that reported in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Benzil also has a characteristic UV spectrum (see Fig. 7.2). It exhibits a wavelength maximum (λ_{max}) at 259 nm (ε_{max} = 16,329 methanol). It is of interest to compare this absorption spectrum of benzil with that of benzoin (Experiment [$A1_a$]). If the melting point and infrared spectrum compare reasonably closely to the literature values, this material may be used in the synthesis of tetraphenylcyclopentadienone (Experiment [$A3_a$]). If the melting point is low, check the product's purity by thin-layer chromatography.

Chemical Tests. Ketones and aldehydes are often characterized by the preparation of a solid derivative. To assist in the characterization of benzil, prepare its 2,4-dinitrophenylhydrazone or semicarbazone (Chapter 9). The melting points of these derivatives are listed in Appendix A, Table A.5.

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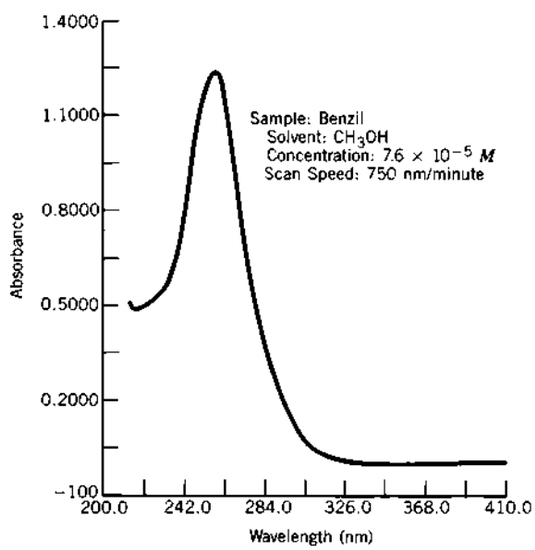

Figure 7.2 UV-visible spectrum: benzil.

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OPTIONAL MICROSCALE PREPARATION

The microscale procedure is similar to that outlined above for the semimicroscale preparation, with the following exceptions:

1. Use a 3.0-mL conical vial containing a magnetic spin vane fitted with a reflux condenser to which is attached a gas delivery tube (➡).
2. Collect the gas in an inverted calibrated collection tube (➡).
3. Decrease the amount of the reagents and solvents fourfold.

Physical Properties of Reactants				
Compound	MW	Amount	mmol	mp (°C)
Benzoin	212.25	100 mg	0.47	137
Cupric acetate solution		350 μL		

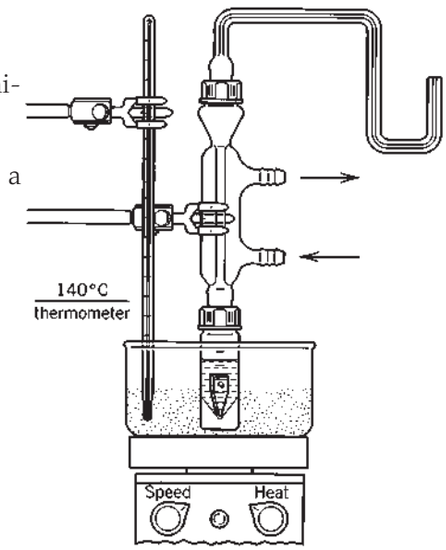

Benzoin, 100 mg + oxidation catalyst, 350 μL, 3-mL conical vial

4. Heat the reaction mixture at about 140 °C until the evolution of gas has ceased.
5. Add 0.5 mL of cold water to the cooled reaction product and, after filtration, wash the material with two 0.5-mL portions of cold water.
6. Purify and characterize the benzil product as described in the semimicroscale procedure, but using a Craig tube for the recrystallization.

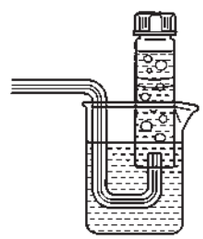

QUESTIONS

7-6. In the directions given for the experiment, it is emphasized that the gas delivery tube must be disconnected from the top of the condenser before removing the reaction vial from the heat source. Why is this necessary?

7-7. What qualitative chemical tests would you perform to distinguish between benzoin and benzil? (See Chapter 9.)

7-8. 1,2-Dicarbonyl compounds, such as benzil, can be characterized by reaction with *o*-phenylenediamine to form a substituted quinoxaline:

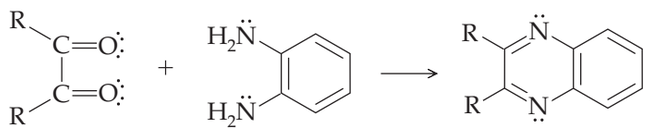

o-Phenylenediamine (a quinoxaline)

(a) Write the structure for the quinoxaline derivative obtained when benzil is the reactant. Do you think this compound would be colored? If so, why?

(b) Suggest a suitable mechanism for the formation of the quinoxaline compounds based on the reaction scheme shown above.

(c) What reagent would you react with *o*-phenylenediamine to prepare the unsubstituted compound quinoxaline? Show a reaction scheme giving the structure of reactants and products.

7-9. Make a sketch of the ^{1}H NMR spectrum that would be observed for benzil.

7-10. Suggest a method for the synthesis of $C_6H_5CH(OH)CH(OH)C_6H_5$ from benzil. Discuss the stereochemical aspects of this 1,2 diol.

7-11. Based on the ultraviolet data given for benzil in the Purification and Characterization section of this experiment, what concentration of the benzil must have been used if a 1-cm cell was used, and a maximum absorption of 0.5 was observed?

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Clarke, H. T.; Dreger, E. E. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 87.

For further information on the oxidation see

Depreux, P.; Bethegines, G.; Marcinal-Lefebure, A. *J. Chem. Educ.* **1988,** *65,* 553.

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Weiss, M.; Appel, M. *J. Am. Chem. Soc.* **1948,** *70,* 3666.

Experiment A3$_a$

Tetraphenylcyclopentadienone

Common name: tetraphenylcyclopentadienone

CA number: [479-33-4]

CA name as indexed: 2,4-cyclopentadien-1-one, 2,3,4,5-tetraphenyl-

Purpose. The cyclic dienone product of this aldol condensation is the *third* intermediate in the **a** series of Sequential Reactions, which lead to the target molecule, hexaphenylbenzene. It is the last intermediate in the **a** series, and when reacted with the *last* intermediate in the **b** series (Experiment [A4$_{ab}$]) will give the target molecule.

In addition to supplying a key intermediate in the **a** series synthetic sequence, the experiment illustrates the use of the aldol condensation for the synthesis of a five-membered carbocyclic ring. The product also is a good demonstration of the impact of extended conjugation on the absorption of visible light. Starting with bright-yellow benzil, we form an even more extended π system in this experiment, and as a result, the tetraphenyldienone product absorbs strongly over a significant portion of visible spectrum and is thus deeply colored.

NOTE. If you plan to continue the synthetic sequence to hexaphenylbenzene, the first microscale procedure described on page 439 should be used. If you wish to study this reaction as an individual microscale experiment, follow the second set of conditions.

Prior Reading

Experiment [20] (pp. 309–317)

Technique 5: Crystallization

Use of the Hirsch Funnel (pp. 88–89)

Craig Tube Crystallizations (pp. 89–91)

REACTION

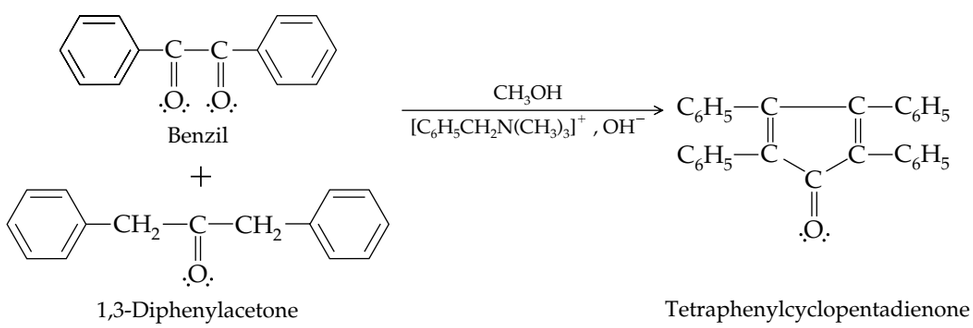

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DISCUSSION

This experiment is a further example of the aldol condensation reaction (see Experiment [20] for discussion and Experiment [F1] for another example).[1] The reaction carried out here differs from the earlier example in that in this case two ketones, one of which has no α-hydrogen atoms, are the reactants. It is also different because the reagents selected lead to the formation of a carbocyclic ring system. The initially formed aldol product undergoes an elimination reaction to yield a material that has a highly conjugated system of double bonds. In general, the more extended the conjugation in a molecule, the less energy is required to promote the π electrons to a higher energy level. In this case, energy in the visible region of the spectrum is absorbed, which results in a product possessing a deep purple color.

The mechanism involves a sequence of two aldol condensations. The first is intermolecular; the second is intramolecular. The mechanism is similar to that outlined in Experiment [20].

The product of this reaction is the dienone intermediate used in the final step of the synthesis of hexaphenylbenzene (see Experiment [A4$_{ab}$]).

MICROSCALE REACTION PROCEDURE (1)

(The first microscale reaction is increased by a factor of 2.)

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
1,3-Diphenylacetone	210.28	100 mg	0.48	35	
Benzil	210.23	100 mg	0.48	95	
Triethylene glycol	150.18	0.5 mL			278
Benzyltrimethylammonium hydroxide (40% solution in MeOH)		100 μL			

Reagents and Equipment. Measure and place 100 mg (0.48 mmol) of 1,3-diphenylacetone and 100 mg (0.48 mmol) of benzil, followed by 0.5 mL of triethylene glycol, in a 3.0-mL conical vial containing a magnetic spin vane. Equip the vial with an air condenser (➡).

NOTE. The benzil used in this reaction must be free of benzoin impurity. If benzil is prepared according to Experiment [A2$_a$], it should be purified by the chromatographic procedure cited therein if benzoin is detected by thin-layer chromatography.

Reaction Conditions. Heat the mixture with stirring in a sand bath at 150–160 °C for 5–10 min. The benzil should dissolve during this time.

Next, remove the apparatus containing the homogeneous reaction solution from the heat source, and immediately add 100 μL of a 40% benzyltrimethylammonium hydroxide–methanol solution to the hot reactants, with gentle shaking. As cooling occurs, dark purple crystals of tetraphenylcyclopentadienone appear. *Cooling may be accelerated by placing the vial under a stream of cold water.*

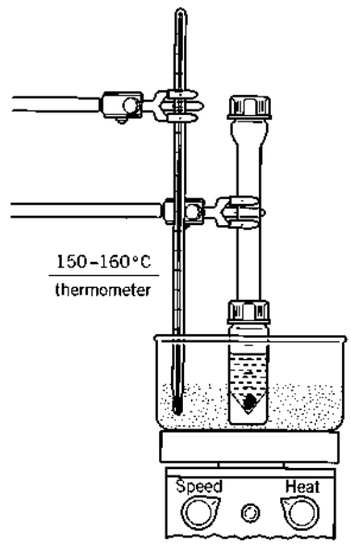

Benzil, 100 mg + 1,3-diphenylacetone, 100 mg + triethylene glycol, 0.5 mL + [Immediately upon removal from the sand bath 100 μL of 40% benzyltrimethylammonium hydroxide in methanol is added.]

[1]For references to the aldol condensation reaction, refer to Experiment [20].

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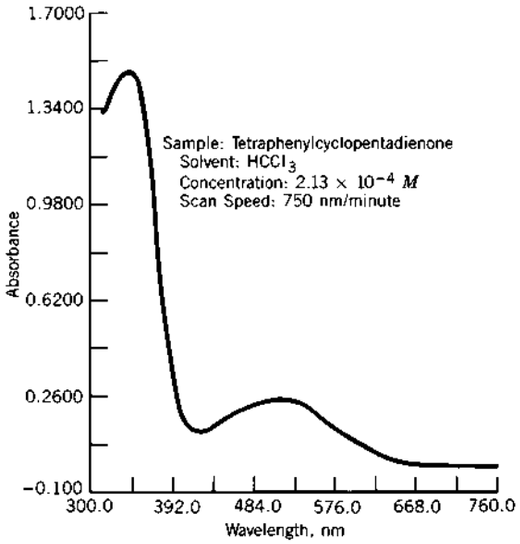

Figure 7.3 UV-visible spectrum: tetraphenylcyclopentadienone.

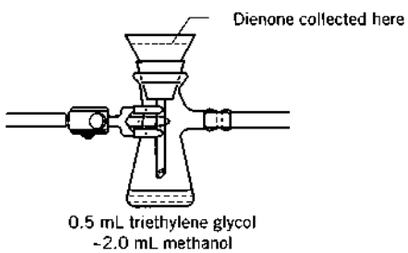

Isolation of Product. Add 1.4 mL of cold methanol with stirring (glass rod), and then cool the mixture in an ice bath for 5–10 min. Collect the dark crystals by filtration under reduced pressure using a Hirsch funnel. Rinse the reaction vial and crystals with a few drops of cold methanol. Continue dropwise addition of cold methanol to the crystals on the filter bed until the product appears purple and is no longer brownish in color. Finally, allow the crystalline product to air-dry on a porous clay plate (or in an oven at about 80 °C for 1 h) (⬅).

Purification and Characterization. The product is often of sufficient purity for direct use in the preparation of hexaphenylbenzene (Experiment [$A4_{ab}$]). If further purification is required, the intermediate dienone may be recrystallized from triethylene glycol using a Craig tube.

Weigh the tetraphenylcyclopentadienone product and calculate the percent yield. Determine the evacuated melting point and compare it with the literature value. Obtain an IR spectrum of the material and compare it with that of an authentic sample.

The comparison of the UV-visible spectra of benzil (see data given in Experiment [$A2_a$]) and the product may be used to demonstrate the shift of absorption bands with increased conjugation in the molecule.

The UV-visible data for tetraphenylcyclopentadienone are summarized as follows and as shown in Figure 7.3 (see Chapter 8).

λ_{max} 510 nm (ε_{max} = 1080, chloroform)

λ_{max} 345 nm (ε_{max} = 6380, chloroform)

NOTE. If you have synthesized the tetraphenylcyclopentadienone from benzaldehyde, calculate the overall yield to this point in the synthesis of hexaphenylbenzene. Base these calculations on the amount of benzaldehyde you started with.

MICROSCALE REACTION PROCEDURE (2)

When the microscale procedure is used as a single-step experiment, and not as part of the synthesis of hexaphenylbenzene, the scale is conveniently reduced to one-half that outlined above, with the following experimental modifications.

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EQA

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
1,3-Diphenylacetone	210.28	50 mg	0.24	35		
Benzil	210.23	50 mg	0.24	95		
Triethylene glycol	150.18	0.25 mL			278	1.124
Benzyltrimethylammonium hydroxide (40% solution in MeOH)		50 μL				

1. The reaction is carried out in a 3-mL conical vial.
2. The reaction mixture is maintained at 155–165 °C for 10 min.
3. Following addition of the base, the vial is reheated to 150–160 °C (2–3 min) and then allowed to cool.

QUESTIONS

7-12. The above reaction carried out to construct the intermediate dienone parallels an earlier example of an aldol condensation in Experiment [20] in which another dienone was synthesized. In both cases all the reactants possessed carbonyl groups. What further structural similarities between the key reactants were required so that both pathways would lead to aldol condensations?

7-13. Outline a complete mechanistic sequence to account for the formation of the tetraphenylcyclopentadienone compound.

7-14. Cyclopentadienone is unstable and rapidly undergoes the Diels–Alder reaction with itself. Write the structure for this Diels–Alder addition product.

7-15. The Diels–Alder addition product of Question 7-14 undergoes a fragmentation reaction on heating to produce a bicyclotrienone compound plus carbon monoxide. Suggest a structure for this product.

7-16. Using the Hückel [4*n* + 2] rule for aromaticity, predict which of the following species might be expected to show aromatic properties:

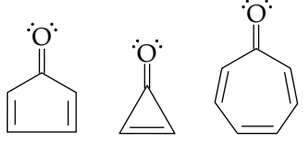

7-17. Based on Questions 7-14 and 7-15, why is tetraphenylcyclopentadienone such a stable compound?

BIBLIOGRAPHY

An *Organic Syntheses* preparation of tetraphenylcyclopentadienone is available:

Johnson, J. R.; Grummitt, O. *Organic Syntheses;* Wiley, New York, 1955; Collect. Vol. III, p. 80.

For preparing this material under microwave conditions see

Elder, J. W. *J. Chem. Educ.* **1994,** *71,* A142.

(*E*)-Stilbene

Experiment A1$_b$

Common names: (*E*)-stilbene; *trans*-1,2-diphenylethene

CA number: [103-30-0]

CA name as indexed: benzene, 1,1′-(1,2-ethenediyl)bis-, (*E*)-

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EQA

Purpose. The purpose of this experiment is to prepare a sufficient quantity of (*E*)-stilbene to complete a multistep sequence of synthetic reactions to obtain the target compound, hexaphenylbenzene (Experiment [$A4_{ab}$]).

A further purpose of experiment [$A1_b$] is to investigate the use of the Horner–Wadsworth–Emmons modified Wittig reaction to complete the synthetic objective. You will also study a reaction that involves the condensation of an aldehyde and a phosphonate ester, using a highly effective *phase-transfer catalyst*.

NOTE. (E)-*stilbene is the first intermediate to be synthesized in the* ***b*** *series of Sequential Reactions en route to hexaphenylbenzene. If you plan to carry out the entire sequence to hexaphenylbenzene, the semimicroscale procedure presented here should be used. Conditions to run the reaction as an individual microscale experiment are given in detail in Experiment [19B].*

Prior Reading

Technique 4: Solvent Extraction
- Liquid–Liquid Extraction (pp. 72–75)
- Drying of a Wet Organic Layer (pp. 80–83)

Technique 5: Crystallization
- Use of the Hirsch Funnel (pp. 88–89)
- Craig Tube Crystallization (pp. 89–91)

Technique 6: Chromatography
- Packing the Column (pp. 93–94)
- Elution of the Column (pp. 94–95)
- Thin-Layer Chromatography (pp. 97–99)
- Concentration of Solutions (pp. 101–104)

REACTION

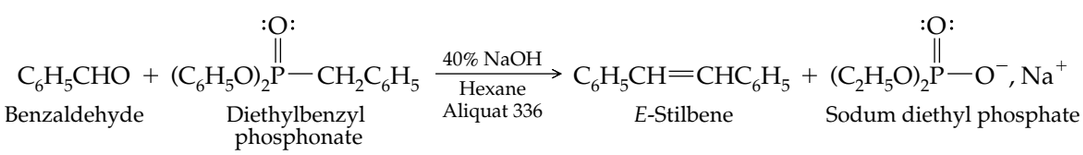

DISCUSSION

For a discussion of the Wittig reaction and a list of references, including the mechanism and modifications, see Experiment [19]. The role of the phase-transfer catalyst in the Horner–Wadsworth–Emmons modification of the Wittig reaction is also discussed in some detail in that experiment.

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	d	n_D
Benzaldehyde	106.12	600 μL	5.88	178	1.04	1.5463
Diethyl benzylphosphonate	228.23	1.20 mL	5.57	106–108 (@1 mm)	1.095	1.4970
Aliquat 336 (tricaprylmethylammonium chloride)	404.17	528 mg	1.30			
Hexane	86.18	12.0 mL				
40% Sodium hydroxide		12.0 mL				

Reagents and Equipment. Weigh and place 528 mg (600 μL of tricaprylmethylammonium chloride (Aliquat 336) in a 50-mL round-bottom flask containing a magnetic stirrer. Add 600 μL (5.88 mmol) of *freshly distilled* benzaldehyde, 1.20 mL (5.57 mmol) of diethyl benzylphosphonate, 12.0 mL of hexane, and 12 mL of 40% sodium hydroxide solution. Attach the flask to a reflux condenser (➡).

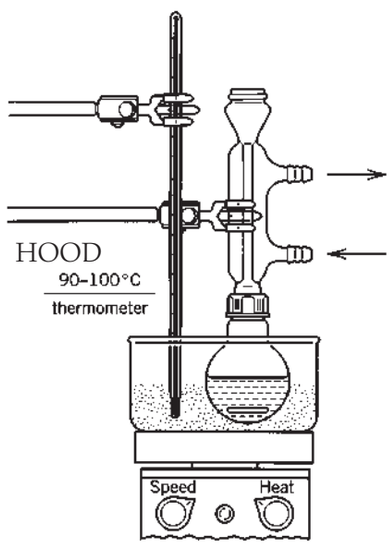

C_6H_5CHO, 600 μL + diethyl benzylphosphonate, 1.2 mL + Aliquat 336, 528 mg + 40% NaOH, 12 mL, hexane, 12 mL, 50-mL RB flask

NOTE. The benzaldehyde, (automatic delivery pipet), diethyl benzylphosphonate (2-mL glass pipet), hexane, and NaOH solution are dispensed in the ***hood.***

Aliquat 336 is very viscous and is best measured by weighing. A medicine dropper is used to dispense this material.

It is advisable to lightly grease the bottom joint of the condenser because strong base is being used in the reacting medium. At the end of the reaction, it is also important to loosen the Cap-seal and twist the joint to make sure it is free to rotate as the apparatus is cooling.

Reaction Conditions. Heat the two-phase mixture at reflux on a sand bath at about 90–100 °C for 1 h. Stir the reaction mixture vigorously during this period. Allow the resulting orange solution to cool to nearly room temperature. Crystals of product may appear as cooling occurs.

Isolation of Product. Add 4.0 mL of methylene chloride, which will dissolve any crystalline material that may have formed. Now transfer the contents of the round-bottom flask to a 125-mL separatory funnel. Rinse the flask with an additional 2.0–3.0 mL of methylene chloride, and transfer this rinse to the separatory funnel using a Pasteur filter pipet. Remove the aqueous layer carefully (*because the densities of the aqueous and organic layers are rather close, it is wise to test the solubility of a few drops of the bottom layer in water to ascertain which phase is the aqueous one in the separatory funnel*), and then wash the remaining organic layer with two 6.0-mL portions of water. Save the combined aqueous extracts in a 50-mL Erlenmeyer flask until you have successfully isolated and characterized the product. Now transfer the remaining wet methylene chloride solution to a 50-mL Erlenmeyer flask. Dry the solution by addition of anhydrous sodium sulfate (~1–2 g). Use a 50-mL glass pipet to transfer the dried solution to a second 50-mL Erlenmeyer flask. Wash the sodium sulfate remaining in the first Erlenmeyer

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flask with two 3-mL portions of methylene chloride. Remove these washings, using a Pasteur filter pipet, and transfer them to the same Erlenmeyer flask.

You may concentrate the solution, which contains the desired product, to dryness on a warm sand bath under a gentle stream of nitrogen gas, but a more efficient and rapid procedure is to remove the solvent by rotary evaporation (see Concentration of Solutions, Technique 6B).

Purification and Characterization. Recrystallize the crude (*E*)-stilbene from 95% ethanol in a small Erlenmeyer flask or a test tube. Collect the recrystallized material by vacuum filtration using a Hirsch funnel. Maintain the vacuum for an additional 10 min to partially dry the crystalline product. Now place the material on a clay plate, or on filter paper, and allow it to air-dry thoroughly. As an alternative procedure, the final traces of water may be removed by placing the sample (use an open test tube with the mouth covered by filter paper retained by a rubber band) in a vacuum drying oven (or pistol) for 10–15 min at 30 °C (1–2 mm).

The recrystallized compound, generally, is sufficiently pure to use in the next step of the **b** series of Sequential Reactions, Experiment [$A2_b$].

Weigh the (*E*)-stilbene and calculate the percent yield. Obtain a melting point and IR spectrum of the material, and compare your results with those reported in the literature.

Further characterization of the (*E*)-stilbene, including thin-layer chromatography, gas chromatography, and ultraviolet–visible spectroscopy may be carried out as outlined in Experiment [19A].

Chemical Tests. Further characterization may be accomplished by performing the Br_2/CH_2Cl_2 test for unsaturation. Note that the dibromo compound is prepared in Experiment [$A2_b$]. It may be used here as a derivative to characterize the (*E*)-stilbene. The ignition test (see Chapter 9) may be used to confirm the presence of the aromatic portion of the molecule.

QUESTIONS

7-18. Give the structure of the phosphorus ylide and carbonyl compound you might use to prepare the following alkenes:
(a) Methylenecyclohexane **(b)** 2-Methyl-2-hexene **(c)** $C_6H_5CH{=}C(CH_3)_2$

7-19. Trimethylphosphine is less expensive than triphenylphosphine. However, it cannot be used in the preparation of most phosphorus ylides. Explain.

7-20. How, starting from triphenylphosphine, $(C_6H_5)_3P{:}$, can you prepare the following ylide:
$(C_6H_5)_3P{=}C(CH_3)CH_2CH_2CH_3$

7-21. Consult *The Aldrich Library of IR Spectra* (and/or SciFinder Scholar) for IR spectra of (*E*)- and (*Z*)-stilbene. Which absorption bands are most useful in determining the difference between the two compounds?

7-22. Compare the mechanisms of the aldol condensation (Experiment [20]) with that of the Wittig reaction. Point out any similarities and/or differences.

Experiment $A2_b$

Bromination of (*E*)-Stilbene: *meso*-Stilbene Dibromide

Common names: *meso*-stilbene dibromide, *meso*-1,2-dibromo-1,2-diphenylethane

CA number: [13440-24-9]

CA name as indexed: benzene, 1,1′-(1,2-dibromo-1,2-ethanediyl)bis-, (*R**,*S**)-

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Purpose. You will synthesize the *second* intermediate in the **b** series of Sequential Reactions by carrying out the bromination of (*E*)-stilbene to obtain *meso*-stilbene dibromide. This product is the precursor to diphenylacetylene, the next synthetic intermediate in the **b** series. A further purpose of this experiment is to demonstrate the *stereospecific* addition of bromine to alkenes.

NOTE. If you plan to continue the synthetic sequence to hexaphenylbenzene, the semimicroscale procedure described below should be used. If you wish to study this reaction as an individual microscale experiment, those conditions and other scaleup options follow the semi-micro discussion.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

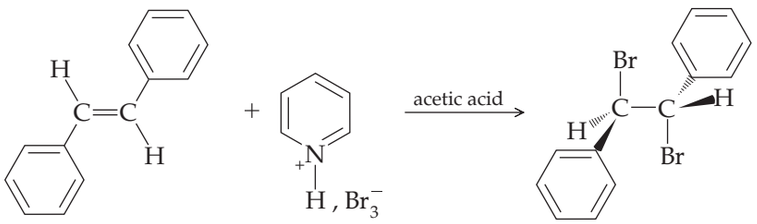

(*E*)-Stilbene | Pyridinium bromide perbromide | *meso*-Stilbene dibromide

DISCUSSION

The bromination of alkenes is an example of an electrophilic addition reaction (also see Experiments [D2] and [F2]).

In the present reaction, bromination of (*E*)-stilbene yields *meso*-stilbene dibromide. Thus, this reaction is classed as *stereospecific* because the other possible diastereomers are not formed.

The reaction proceeds in two stages. The first step involves the formation of an intermediate cyclic *bromonium ion*. The concept of a three-membered cyclic intermediate was first proposed as early as 1937. Subsequent studies have provided solid evidence that cyclic halonium ions do, indeed, exist. For example, stable solutions of cyclic bromonium ions in liquid SO_2 (−60 °C) have been prepared as SbF_6^- salts. Two examples are given here:

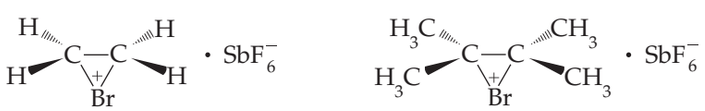

Ethylene bromonium ion salt | Tetramethylethylene bromonium ion salt

Nuclear magnetic resonance spectroscopic measurements have provided powerful evidence that these and other selected alkenes form stable *bridged* bromonium ion salts. A solid bromonium ion tribromide salt of adamantylidene

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adamantane has been isolated, and its structure determined by X-ray crystallography:

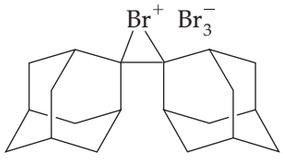

Tribromide salt of adamantylidene adamantane

The bromine molecule (Br_2) is normally symmetrical. However, as it approaches the nucleophilic and electron-rich π bond of the alkene, it becomes polarized by induction and can then function as the electrophile in an addition reaction. The result is the generation of a cyclic bromonium ion:

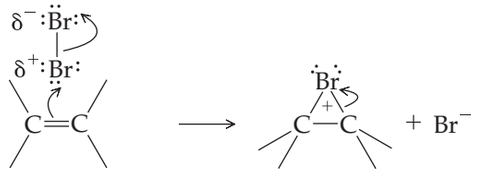

Induced polarization of Br_2 as it approaches the alkene

Bromonium ion

In the present reaction, both the bromine and the *(E)*-stilbene are achiral. However, the bromonium ion that is produced is chiral. In this ion, the bromine atom bridges both carbon atoms of the original carbon–carbon double bond to form a three-membered ring intermediate. The generation of a cyclic species has a profound effect on the *stereochemistry* of the second step of the bromine addition.

The second stage of the bromination involves nucleophilic attack by bromide ion on the intermediate bromonium ion. Since the nucleophile must approach from the face opposite the leaving group, bond formation involves inversion of configuration at the carbon center under attack in the second stage of the bromination reaction.

Note that *either* carbon can be approached by the nucleophile (one attack is shown). This second step is a classic backside S_N2 sequence. The bromination of cyclic alkenes provides further evidence that this type of halogenation is an anti addition, with the bromine atoms introduced trans to one another:

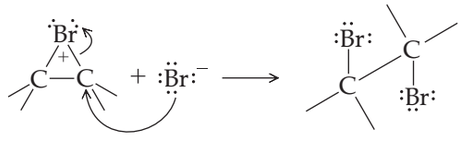

Bromonium ion Dibromo product

It is important to realize that if two different groups are present on one or both of the sp^2 carbon atoms of the alkene linkage, chiral carbon centers are generated when bromine is added, though if a chiral product were formed from achiral reagents, one would expect it to be racemic. In the case of *(E)*-stilbene, two chiral centers are generated. However, due to the symmetry of the reactants and the stereoselectivity of the reaction, only the meso diastereomer is formed:

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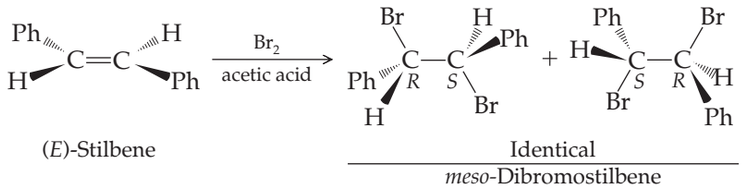

Refer to the Discussion section of Experiment [D2] for further information on the stereochemistry of bromination reactions.

Bromination of alkenes using a Br_2–CCl_4 solution (a red-brown color) is frequently used as a qualitative test for the presence of unsaturation in a compound. Rapid loss of color from the reagent solution is a positive test (see Chapter 9). Pyridinium bromide perbromide, a solid brominating agent, is used as a source of bromine in this experiment. The material is more convenient to handle than liquid bromine (see Experiment [D2]).

SEMIMICROSCALE EXPERIMENTAL PROCEDURE

(The microscale reaction is increased by a factor of 2.6.)

Estimated time to complete the reaction: 1.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
(*E*)-Stilbene	180.25	600 mg	3.3	122–124		
Glacial acetic acid		12 mL			118	1.049
Pyridinium bromide perbromide	319.83	1.2 g	3.7	205		

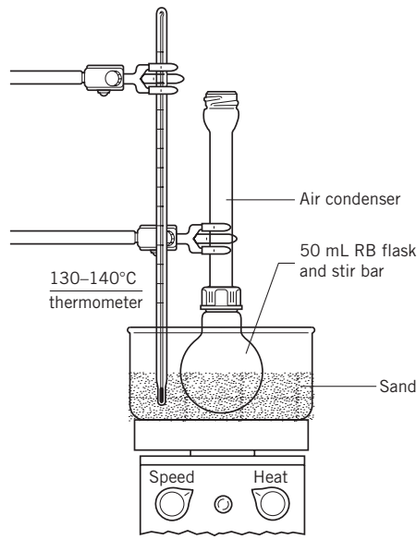

(*E*)-Stilbene, 600 mg + glacial acetic acid, 12 mL + pyridinium bromide perbromide, 1.2 g

Reagents and Equipment. In a 50.0-mL round-bottom flask containing a magnetic spin bar and equipped with an air condenser, weigh and place 600 mg (3.3 mmol) of *(E)*-stilbene. Next add 6 mL of glacial acetic acid (using a graduated cylinder), and warm the resulting mixture in a sand bath at 130–140 °C with stirring until the solid dissolves (~5 min) (➡).

CAUTION: Glacial acetic acid is corrosive and toxic. It is dispensed in the ***hood*** using an automatic delivery pipet. HOOD

Remove the condenser from the flask, and to the warm solution, in the **hood,** add 1.2 g (3.7 mmol) of pyridinium bromide perbromide in one portion. HOOD Wash down any perbromide adhering to the sides of the flask with an additional 6 mL of acetic acid using a Pasteur pipet. Reattach the air condenser.

CAUTION: The brominating agent is a mild lachrymator. It should be dispensed in the ***hood.*** An alternative solid brominating agent is tetra-*N*-butylammonium tribromide. HOOD

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EQA

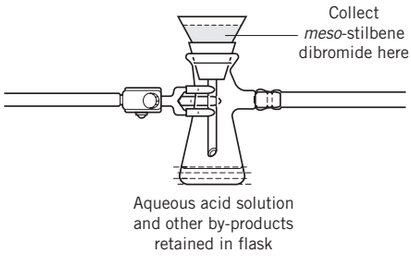

Reaction Conditions. With stirring, heat the reaction mixture at a sand bath temperature of 130–140 °C for an additional 5–6 min. (The product often begins to precipitate during this period.)

Isolation of Product. Remove the reaction flask from the heat source and allow it to cool to approximately 40–50 °C (water bath). Add 12 mL of water, with swirling, and then place the flask in an ice bath for 5–8 min. Collect the crystalline solid by vacuum filtration using a Hirsch funnel (⬅).

Purification and Characterization. Wash the material with three 2-mL portions of cold water to obtain white crystals, and then with two 2-mL portions of acetone. Air-dry the product on a clay plate or on filter paper.

Weigh the *meso*-stilbene dibromide and calculate the percent yield. Determine the evacuated melting point, and compare your result with the literature value. Obtain IR and NMR spectra and compare them with those reported in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

Generally, the material is sufficiently pure to be used in the next stage of the **b** series of Sequential Reactions, the preparation of diphenylacetylene. If desired, a small portion (~10–20 mg) may be recrystallized from hot xylene using the Craig tube.

Chemical Tests. You may wish to perform several classification tests on the product (see Chapter 9). Carry out the ignition test to confirm the presence of an aromatic group. The Beilstein test can be used to detect the presence of bromine. The silver nitrate test for alkyl halides should also give a positive result.

Optional Macroscale and Microscale Preparations

Macroscale Reaction Procedure. The procedure is similar to that for the 2.6-fold scaleup preparation with the following exceptions:

1. The reagent and solvent amounts are increased approximately 4.3-fold over the microscale preparation.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
(*E*)-Stilbene	180.25	1.0 g	5.5	122–124		
Glacial acetic acid		12 mL			118	1.049
Pyridinium bromide perbromide	319.83	2.0 g	6.2	205		

2. After cooling the reaction mixture, add 20 mL of water to assist in precipitating the product. Wash the collected crystals with three 3-mL portions of cold water followed by two 3-mL portions of acetone.

Microscale Reaction Procedure. The procedure is similar to that for the 2.6-fold scaleup preparation with the following modifications:

1. Use a 10-mL round-bottom flask

2. The reagent and solvent amounts are *decreased* by a factor of approximately 2.6.

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Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
(*E*)-Stilbene	180.25	230 mg	1.28	122–124		
Glacial acetic acid		4.2 mL			118	1.049
Pyridinium bromide perbromide	319.83	450 mg	1.4	205		

3. Add 2.2 mL of glacial acetic acid at the same time as the addition of the (*E*)-stilbene.

4. An additional 2 mL of glacial acetic acid is added with the brominating reagent.

5. The reaction mixture is diluted with 4.5 mL of water, swirled, and placed in an ice bath for 5–8 min.

6. The filter cake is washed with three 2-mL portions of cold water, followed by two 2-mL portions of acetone.

QUESTIONS

7-23. Using suitable structures, draw the sequence for the addition of bromine to (*Z*)-stilbene.

7-24. Are the results different for the answer in Question 7-23 than for the result in this experiment? If so, how? What is the stereochemical relationship between the products formed in the two reactions?

7-25. Bromine undergoes addition to ethylene in the presence of a high concentration of Cl^- ion to give 1-bromo-2-chloroethane, as well as 1,2-dibromoethane. Chloride ion does not add to the C═C unless bromine is present. Suggest a suitable mechanism to explain these results. Is the rate of bromination significantly affected by the presence of the Cl^- ion?

7-26. Offer an explanation for the fact that bromine adds to 2,3-dimethyl-2-butene 920,000 times faster than to ethylene, to produce the respective dibromides.

7-27. A student adds a few drops of Br_2–CCl_4 solution to an unknown organic compound. The color of the bromine solution disappears. The student reports that the unknown contains a C═C. Would you arrive at the same conclusion? If not, why not?

BIBLIOGRAPHY

A large number of examples of the bromination of alkenes appear in *Organic Syntheses*. Selected references are given below:

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Cromwell, N. H.; Benson, R. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 105.

Fieser, L. F. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 195.

Khan, N. A. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 969.

McElvain, S. M.; Kundiger, D. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 123.

Paquette, L. A.; Barrett, J. H. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 467.

Rhinesmith, H. S. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 177.

Snyder, H. R.; Brooks, L. A. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 171.

Also see

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 15, p. 999 and references therein.

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EQA

Experiment A3$_b$

Dehydrohalogenation of *meso*-Stilbene Dibromide: Diphenylacetylene

Common names: diphenylacetylene, diphenylethyne
CA number: [501-65-5]
CA name as indexed: benzene, 1,1′-(1,2-ethynediyl)bis-

Purpose. The product formed in this multiple elimination reaction is the third intermediate in the **b** series of Sequence A, and is one of the immediate precursors to our target molecule, hexaphenylbenzene.You will investigate the synthesis and properties of alkynes and become familiar with E2 elimination reactions.

NOTE. If you plan to continue the synthetic sequence to hexaphenylbenzene, the semimicroscale procedure described below should be used. If you wish to study this reaction as an individual microscale experiment, those conditions and other scaleup options follow the semi-micro discussion.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

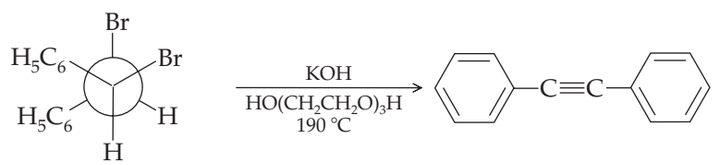

meso-Stilbene didromide Diphenylacetylene

DISCUSSION

This reaction illustrates the double dehydrohalogenation of a *vicinal* dibromo compound to form an alkyne. It is a useful reaction for the synthesis of alkynes, because the starting dibromides are readily available from alkenes (see, e.g., Experiment [A2$_b$]).

The double dehydrohalogenation reaction is usually run in the presence of a strong base, such as KOH or $NaNH_2$, and proceeds in two stages. In the first, an intermediate bromoalkene is formed, which can be isolated under more mildly basic conditions. In fact, this reaction is a valuable route to vinyl halides. The mechanism of elimination involves the abstraction of the proton on the carbon atom β to the halogen. The E2 mechanism, which operates under these strongly basic conditions, is fastest when it involves removal of a proton, H^+, antiperiplanar to the leaving group, Br^-. The E2 sequence of bond breakage and formation involves a smooth transition from reactant to product without the formation of an intermediate (concerted mechanism). The general mechanism is shown here:

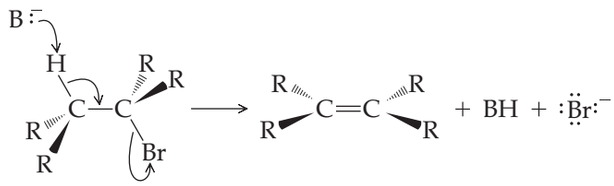

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This type of elimination reaction is stereospecific because the geometry of the transition state requires that the H, both Cs, and the Br all lie in the same plane.

If *meso*-stilbene dibromide is treated with KOH in ethanol solvent, it is possible to isolate the monodehydrohalogenation product, the bromoalkene.

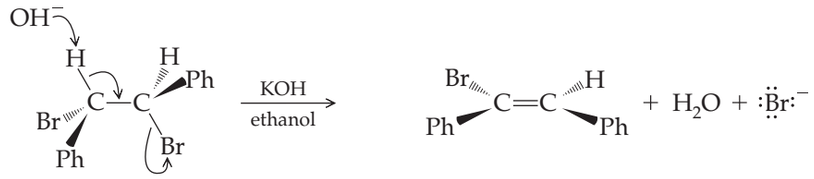

meso-Stilbene dibromide (*E*)-1-Bromo-1,2-diphenylethylene

The second stage of the reaction involves a higher activation energy, and therefore it requires higher temperatures to proceed. In the presence of a strong base near 200 °C, the bromoalkene undergoes an E2 elimination to form the triple bond. Part of the reluctance to eliminate, in this particular case, results from the fact that the elimination proceeds by a syn pathway:

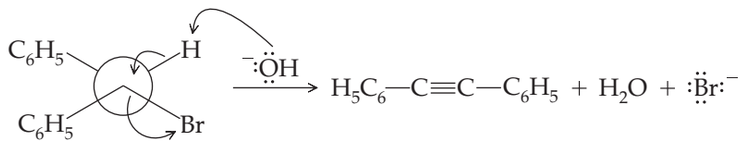

Thus, the stereochemistry of the reactant used necessitates somewhat higher temperatures for the second elimination reaction.

SEMIMICROSCALE EXPERIMENTAL PROCEDURE

(The microscale reaction is increased by a factor of 5.)

Estimated time to complete the reaction: 1.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
meso-Stilbene dibromide	340.07	400 mg	1.2	241 dec		
Potassium hydroxide	56.11	387 mg	6.9	360		
Triethylene glycol	150.18	2 mL			278	1.124

Reagents and Equipment. Weigh and place 400 mg (1.2 mmol) of *meso*-stilbene dibromide and 387 mg (6.9 mmol) of KOH flakes in a 10-mL Erlenmeyer flask containing a magnetic stir bar. Using a graduated cylinder, measure and add 2 mL of triethylene glycol to the flask.

Reaction Conditions. Place the reaction flask in a ***preheated*** sand bath set at a temperature of 190–195 °C, and stir the reaction for 7–8 min.

Isolation of Product. Allow the resulting dark-colored reaction mixture to cool to approximately 40–50 °C (water bath), and then add 5.0 mL of water. Now place the flask in an ice bath for 15 min. Collect the solid product by filtration under reduced pressure using a Hirsch funnel (➡).

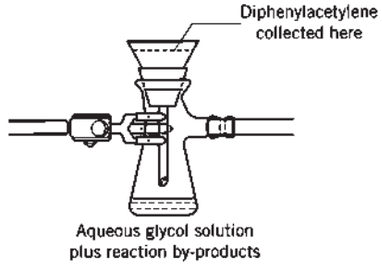

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Purification and Characterization. Rinse the product crystals with two 1-mL portions of cold 70% ethanol and air-dry them on a porous clay plate or on filter paper. These crystals can be recrystallized from 95% ethanol (~2.0 mL). If desired, the product can be further purified by a second crystallization from 95% ethanol using the Craig tube.

Weigh the recrystallized product and calculate the percent yield. Determine the melting point and compare your result with the literature value. Obtain IR and NMR spectra of the material and compare them with those recorded in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

NOTE. If you have synthesized the diphenylacetylene from benzaldehyde, calculate the overall yield to this point in the synthesis of hexaphenylbenzene. Base these calculations on the starting amount of benzaldehyde.

Chemical Test. The ignition test for aromatic groups indicates the presence of the phenyl groups. Decolorization of a Br_2–CH_2Cl_2 solution should give a positive test for unsaturation (see Chapter 9).

OPTIONAL MACROSCALE AND MICROSCALE PREPARATIONS

Macroscale Reaction Procedure. (This reaction is scaled up by a factor of 10 over the microscale procedure.)

The procedure is similar to that outlined above with the following exceptions:

1. Carry out the reaction in a 25-mL Erlenmeyer flask containing a boiling stone. Run the reaction in the **hood.** HOOD

2. Increase the reagent and solvent amounts approximately twofold over the semimicroscale procedure, as indicated here.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
meso-Stilbene dibromide	340.07	800 mg	2.4	241 dec		
Potassium hydroxide	56.11	756 mg	13	360		
Triethylene glycol	150.18	4 mL			278	1.124

3. After cooling the reaction mixture, add 10 mL of water.

4. Rinse the product crystals with two 1-mL portions of cold 70% ethanol. They can be recrystallized from 95% ethanol (~5.0 mL).

Microscale Reaction Procedure. The procedure is similar to that outlined above with the following exceptions:

1. Carry out the reaction in a 3-mL conical vial containing a boiling stone.

2. The reaction is heated in a sand bath at 190 °C for 5 min.

3. Decrease the amounts of reagents and solvents as given here.

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Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
meso-Stilbene dibromide	340.07	80 mg	0.24	241 dec		
Potassium hydroxide	56.11	75 mg	1.3	360		
Triethylene glycol	150.18	0.4 mL			278	1.124

4. After cooling of the reaction mixture to 40–50 °C (in a water bath), add 1.0 mL of water, and place the reaction vessel in an ice bath for 15 min.

5. Rinse the product crystals with one 0.25-mL portion of cold 70% ethanol. The alkyne can be recrystallized from 95% ethanol (~0.5 mL).

QUESTIONS

7-28. Both (*E*)- and (*Z*)-2-chlorobutenedioic acids dehydrochlorinate to give acetylene dicarboxylic acid:

$$HO_2C-C(Cl)=CH-CO_2H \rightarrow HO_2C-C\equiv C-CO_2H$$

The *Z* acid reacts about 50 times faster than the *E* acid. Explain.

7-29. Compounds containing a carbon–carbon triple bond undergo the Diels–Alder reaction. Formulate the product formed by the reaction of (*E,E*)-1,4-diphenyl-1,3-butadiene with diethyl acetylenedicarboxylate.

7-30. Alkynes can be hydrated in the presence of acid and $HgSO_4$ by electrophilic addition of a molecule of water to the triple bond. The reaction proceeds by way of a carbocation intermediate. Hydration of acetylene (ethyne) produces acetaldehyde (ethanal). Outline the steps that occur in this transformation.

7-31. Use the IR tables to locate the absorption bands of the stretching frequencies of the alkyne C—H bond, the alkyne C≡C bond, and the alkene C—H bond. Using these data, explain how you would distinguish between 1-butyne, 2-butyne, and 2-butene.

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For a review on the preparation of alkynes see

Jacobs, T. L. *Org. React.*, **1949,** *5,* 1.

Stang, P. J.; Diederich, F., Eds. *Modern Acetylene Chemistry;* VCH: New York, 1995.

A large number of elimination reactions leading to the formation of acetylenes appear in *Organic Syntheses*. Selected references are given below:

Abbott, W. T. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 515.

Campbell, K. N.; Campbell, B. K. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 763.

Guha, P. C.; Sankaren, D.K. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 623.

Hessler, J. C. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 438.

Khan, N. A. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 967.

Le Coq, A.; Gorgues, A. *Organic Syntheses* **1980,** *59,* 10.

The synthesis of diphenylacetylene has been reported:

Smith, L. I.; Falkof, M. M. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 350.

Hexaphenylbenzene

Experiment A4$_{ab}$

Common name: hexaphenylbenzene

CA number: [992-04-1]

CA name as indexed: 1,1′:2′,1″-terphenyl, 3′,4′,5′,6′-tetraphenyl-

Purpose. This reaction completes the Sequence A experiments. The Diels–Alder reaction is used to form six-membered aromatic rings. You will carry out the decarbonylation and aromatization of an intermediate bicyclic Diels–Alder adduct. You will examine the properties of our synthetic target molecule, hexaphenylbenzene.

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NOTE. If you plan to continue the synthetic sequence to hexaphenylbenzene, you should have enough of the two starting reactants to carry out the first true microscale reaction used in Sequence A. The details of this interesting Diels–Alder addition, first carried out in 1933, are described below. You may, of course, wish to study this reaction as an individual microscale experiment, in which case use the same conditions given here.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–91)
Experiment [14]: (pp. 257–269)
Experiment [15]: (pp. 269–275)

REACTION

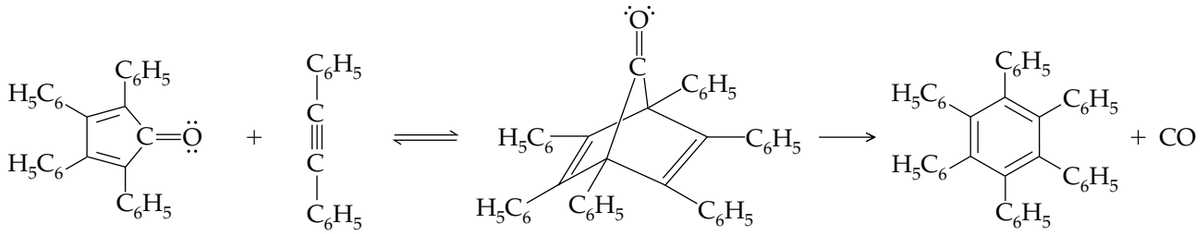

Tetraphenylcyclopentadienone Diphenylacetylene Hexaphenylbenzene

DISCUSSION

This experiment (Experiment [$A4_{ab}$]) completes the Sequence A set of seven experiments that lead to the synthesis of hexaphenylbenzene. As we have noted earlier (see introduction to Sequence A), this compound is a rather unique and interesting organic system possessing a number of unusual properties. For example, it has one of the highest known melting points for a nonionic organic molecule, 465 °C, and it is perhaps even more intriguing that it melts without decomposition. Indeed, its melting point exceeds that of all 15,000 organic compounds listed in the *CRC Handbook* for 1991–1992. Hexaphenylbenzene also contains particularly novel stereochemistry as discussed in the introduction.

The Diels–Alder reaction is one of the most useful synthetic tools in organic chemistry. It is an example of a cycloaddition reaction between a conjugated diene and a dienophile, which leads to the formation of six-membered rings. Here, the initial bicyclic Diels–Alder adduct can undergo a reaction that is the reverse of a concerted cycloaddition reaction between a benzene ring and the lone electron pair on the carbon of carbon monoxide. This retro cycloaddition is thermodynamically favored here because the retro reaction generates an aromatic system, along with the quite stable carbon monoxide molecule. Under the high-temperature conditions used in this experiment, the initial bicyclic Diels–Alder adduct is quickly decarbonylated to yield hexaphenylbenzene and is not itself isolated.

By varying the nature of the diene and dienophile, a very large number of structures can be prepared using the Diels–Alder reaction. In the majority of cases, carbocyclic rings are generated, but ring closure can also occur with

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reactants containing heteroatoms. This leads to the synthesis of compounds containing heterocyclic rings. For further and more detailed discussion of the Diels–Alder reaction see Experiments [14] and [15].

In the present reaction, an excess of diphenylacetylene is used to ensure that all the tetraphenylcyclopentadienone is consumed in the reaction, since diphenylacetylene is far easier to separate from hexaphenylbenzene in the purification steps.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)
Tetraphenylcyclopentadienone	384.48	100 mg	0.26	220–221
Diphenylacetylene	178.23	100 mg	0.56	61
Hexaphenylbenzene	534.66			465

Reagents and Equipment. In a 13 × 100-mm Pyrex test tube, place 100 mg (0.26 mmol) of tetraphenylcyclopentadienone and 100 mg (0.56 mmol) of diphenylacetylene. Then transfer to the test tube about 1 mL of high-boiling silicone oil (calibrated Pasteur pipet). Clamp the test tube at a slight angle, facing it away from both yourself and your laboratory neighbors.

Reaction Conditions. Bring the mixture gently to a boil over a 3- to 5-min period by heating the test tube with the moving flame of a microburner. On melting, the reagents dissolve in the hot silicone oil to yield a dark red-purple solution. Continue to gently boil the solution for an additional 10 min. During this latter period, the deeply colored solution fades and hexaphenylbenzene begins to separate from solution as tan crystals.

Isolation of Product. After heating for 15 min, cool the test tube to room temperature and add 4 mL of hexane, with stirring, to dilute the silicone oil and any unreacted starting material. The crude, precipitated hexaphenylbenzene is then collected by filtration on a Hirsch funnel (➨).

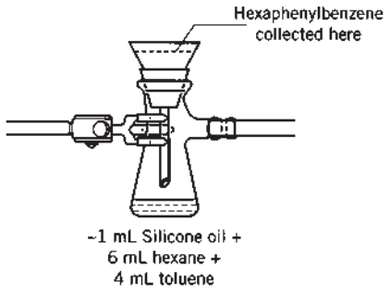

Purification and Characterization. Wash the filter cake with 2 mL of hexane to yield tan crystals of the addition product. Then wash it twice with 2-mL portions of cold toluene to yield white crystalline hexaphenylbenzene. Air-dry the product on filter paper or a porous clay plate. Weigh the Diels–Alder adduct and calculate the percent yield. Obtain an IR spectrum and compare it to that of an authentic sample. The melting point of this material is well over 400 °C, therefore, melting point determinations with apparatus that use oil baths should **not** be attempted.The best approach, if a melting point is required, is to carry out an evacuated melting point determination with one of the metal heating block systems that accept the normal capillaries, *but remember to first check the maximum temperature reading on the thermometer used in the apparatus* (see evacuated melting points, Chapter 4, pp. 51–52).

CAUTION

CAUTION

If necessary, the product can be recrystallized in a Craig tube from diphenyl ether (5–10 mg maximum, since this very high-melting material is very insoluble even in this high-boiling aromatic ether; recrystallization is rather difficult).

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This experiment completes the seven-step Sequence A synthesis of hexaphenylbenzene from benzaldehyde. Calculate the overall yield based on both the earlier calculations for each pathway (for the diene and the dienophile used in the final Diels–Alder reaction), see Experiments [$A3_a$] and [$A3_b$], and the actual yield for this step in the synthesis.

QUESTIONS

7-32. What starting materials would you use to prepare each of the following compounds by the Diels–Alder reaction?

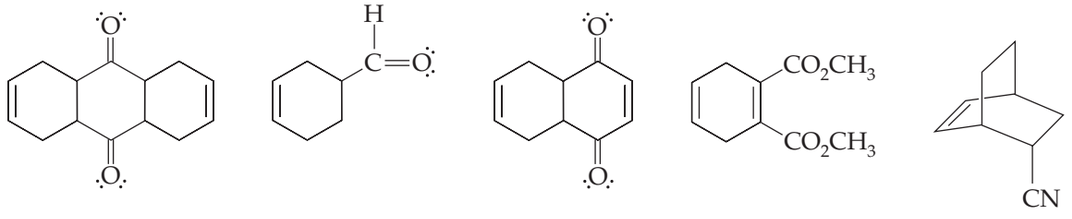

7-33. Diels–Alder reactions with benzene are rare, and require a very reactive (electron-deficient) dienophile, because benzene is a rather unreactive diene. Two are shown below. Give the structures of the product produced in each reaction.

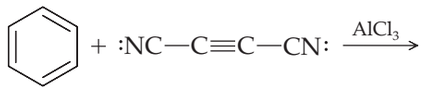

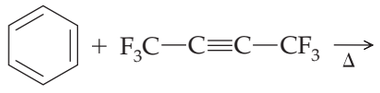

7-34. Shown below are two heteroatom compounds that undergo the Diels–Alder reaction. Formulate the product obtained in each reaction.

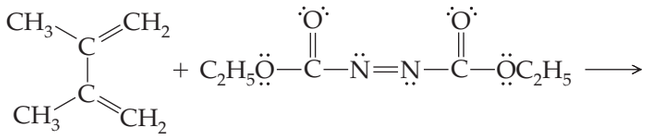

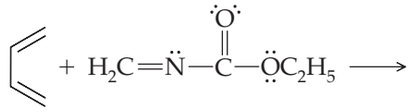

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Holm, H. L. *Org. React.* **1948,** *4,* 60.

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Norton, J. A. *Chem. Rev.* **1942,** *31,* 319.

Sauer, J. *Angew. Chem. Int. Ed. Engl.* **1966,** *5,* 211; *Ibid.,* **1967,** *6,* 16.

Stang, P. J.; Diederich, F., Eds. *Modern Acetylene Chemistry;* VCH: New York, 1995.

An *Organic Syntheses* preparation using tetraphenylcyclopentadienone in a Diels–Alder reaction to obtain tetraphenylphthalic anhydride has been recorded:

Grummitt, O. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 807.

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EQA

SEQUENCE B

The Stepwise Synthesis of Nylon-6,6

Purpose. The important industrial polymer, nylon-6,6, is prepared by the technique of step-growth polymerization. The physical properties of the polymer are examined. The two monomers used in the polymerization are synthesized.

Background of an Industrial Polymer. The type of polymerization used in the nylon preparation described in this series of experiments is called "step-growth" polymerization. The technique uses two different difunctional monomers that undergo ordinary organic reactions. In the present case an acid chloride is treated with an amine to produce an amide linkage.

Nylon is a polyamide. In industry it is produced by reaction of two difunctional monomers (or comonomers): a dicarboxylic acid and a diamine. The polymer that you are going to study is of great historical significance in polymer chemistry, because it was the first of the polyamides to be recognized as possessing excellent physical properties for forming very strong fibers. Nylon-6,6 was, in fact, the first commercially produced synthetic polyamide. The "6,6" nomenclature refers to the number of carbon atoms in each of the two comonomers. Industrially, nylon-6,6 is prepared from 1,6-hexanediamine (hexamethylenediamine) and hexanedioic acid (adipic acid):

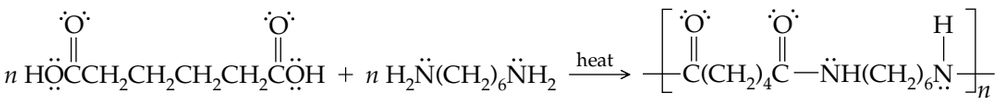

Adipic acid 1,6-Hexanediamine Nylon-6,6

In the industrial process, the diacid and diamine are mixed to form the corresponding amine salt (hexamethylene diammonium adipate), which is then heated under steam pressure (250 psig) at 275 °C to form the amide bonds. The resulting polymer has an average molecular weight of about 10,000, with an average of over 400 repeating monomer units in each molecule of polymer and a melting point of about 150 °C. Fibers can be drawn from the melted polymer by a "cold-drawing" technique. This method of drawing fibers physically orients the polymer molecules into linear chains that are stabilized by the presence of hydrogen bonds between C═O and the N—H groups of adjacent chains, and the strength of the fiber is thereby increased. The synthetic polyamide linkages in the various forms of nylon are very similar (identical in some cases) to those found in proteins. For example, silk fibers gain their great strength from this type of interaction.

Numerous combinations of diacids and diamines have been evaluated as fiber materials. However, only a few have reached commercial production, which depends on low-cost, easy-to-access intermediates, and satisfactory general and physical properties of the polymer. One such group of materials are the "Aramid" class of fibers, which are prepared from aromatic monomers (see Experiment [B3], Question 7-47). One trade name for a material prepared from these type of fibers is Nomex. It has a high degree of heat and flame resistance. Race car driving suits are made from it, and it is also used as an insulator in the space shuttles.

Nylon-6,6 was first synthesized in 1899 by Gabriel and Maas in Germany. It was not until 1929, however, that the substance was shown to possess practical commercial properties. It was Carother's research program on polyamides

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at DuPont that made the major discoveries that initiated the world's polymer industry. DuPont began production of nylon in October 1939, and the first nylon stockings were manufactured in May 1940. By 1950, 14 chemical plants in 10 countries produced 55,000 metric tons of polyamide fiber. By 1980 worldwide production had expanded to 3.05×10^6 tons, with about one-third of the polymer synthesized in the United States.

Thus, you should appreciate that the chemical industry carries out organic reactions on massive quantities of material for use in today's highly technological society. The discovery and characterization of these materials all starts in the research laboratory, with many of them initially prepared in microscale quantities. One of the great triumphs of our technology has been the successful scaleup of synthetic organic reactions, but that is a story for another day.

Experiment B1

Oxidation of Cyclohexanol: Adipic Acid

Common name: adipic acid
CA number: [124-04-9]
CA name as indexed: hexanedioic acid

Purpose. You will carry out the nitric acid oxidation of cyclohexanol to obtain adipic acid, an intermediate in the route to prepare nylon, a polyamide.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Standard Experimental Apparatus: Reflux Apparatus (pp. 23–24)

REACTION

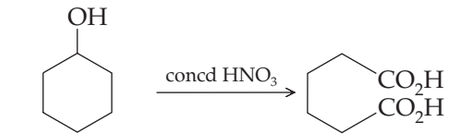

Cyclohexanol Adipic acid

DISCUSSION

Industrially, the production of adipic acid is a two-step sequence. The main route involves the oxidation of cyclohexane with air to form a mixture of cyclohexanol and cyclohexanone. This mixture is then further oxidized using nitric acid, oxygen, and a Cu–V catalyst to yield the acid.

Ninety percent of all the synthetically produced adipic acid is used in the manufacture of nylon-6,6. In the United States, 1.9×10^6 tons/year of adipic acid were manufactured in 1992. In 2004, DuPont alone, produced 1.1×10^6 tons of adipic acid accounting for 38% of the world's total. In the early years of nylon production, adipic acid was also used to prepare the 1,6-hexanediamine (more commonly known as hexamethylenediamine) comonomer. Treatment of the adipic acid with ammonia gave hexanedinitrile, which, on catalytic hydrogenation, produced the diamine. This monomer is now generally obtained

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from 1,3-butadiene. A recent DuPont industrial process involves direct *regioselective* addition of two molecules of HCN to the diene, in the presence of a transition metal catalyst, to produce the dinitrile intermediate.

The oxidation of cyclohexanol by concentrated nitric acid is mechanistically complex. A reasonable mechanistic route to the dicarboxylic acid is given here. The first stage of the oxidation is considered to proceed by a mechanism similar to that found in chromic acid oxidations of alcohols (see Experiment [33]). The reaction here involves the initial formation of a nitrate ester intermediate, which, under the reaction conditions, cleaves by proton abstraction to form the ketone. This reaction is accompanied by reduction of the nitrate to nitrite. The proton transfer may involve a cyclic intramolecular rearrangement during the oxidation–reduction cleavage step. A likely mechanism is outlined below:

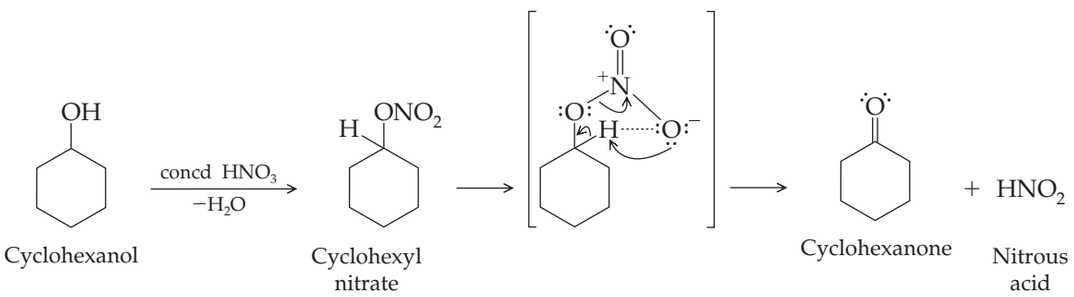

The next stage of the reaction can be viewed as a further oxidation to yield a diketone. This stage is initiated by nucleophilic attack on a nitronium ion (NO^+) derived from either the nitric or nitrous acid. The nucleophile is the enol tautomer of the ketone, and the reaction forms an α-nitrosoketone, which is in tautomeric equilibrium with a mono-oxime. This species rapidly hydrolyzes under acidic conditions to yield an α-diketone intermediate. This sequence is shown here:

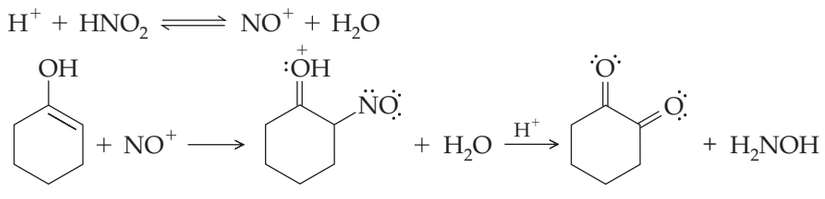

Under strongly acidic conditions, the diketone (these highly electrophilic systems are reactive toward weak nucleophiles) likely undergoes nitrate addition, which is followed by attack of water, ring opening, and reduction of nitrate to nitrite. All this activity ultimately leads to the formation of the desired compound, the open-chain dicarboxylic acid, adipic acid:

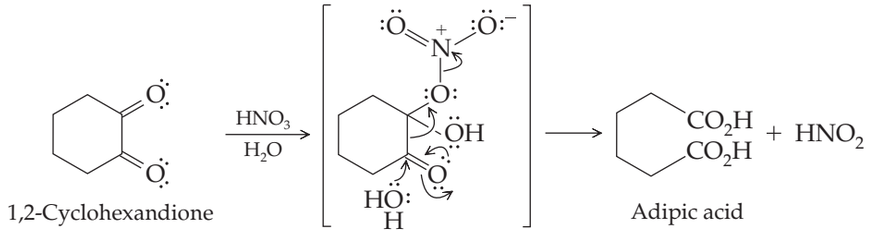

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Cyclohexanol	100.16	1.0 mL	9.6	25.1	161.1	0.96
Concd HNO_3	31	2.0 mL				

Reagents and Equipment. Using a graduated glass pipet, measure and add 2.0 mL of concentrated nitric acid to a 10-mL round-bottom flask containing a boiling stone.

CAUTION: Nitric acid is very corrosive. Dispense the material in the ***hood.***

HOOD

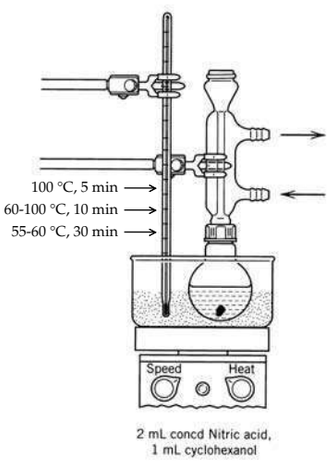

Attach the flask to a water-cooled reflux condenser, place the assembly in a sand bath, and heat the acid solution to 55–60 °C. Now add dropwise, using a calibrated 9-in. Pasteur pipet inserted down the throat of the reflux condenser, 1.0 mL of cyclohexanol at a rate of one drop every 30 s. *(Gently swirl the reaction mixture in the bath after each addition.)* The slow addition is necessary to control the reaction temperature (⬅).

Reaction Conditions. Maintain the sand bath temperature at 55–60 °C for 30 min after the addition of cyclohexanol is complete. Now gradually raise the sand bath temperature to 100 °C over 10 min, and then maintain this temperature for an additional 5 min.

Isolation of Product. Remove the assembly from the hot sand bath and allow the solution to cool to room temperature. Detach the round-bottom flask, and clamp it in an ice bath for 5–10 min. Collect the light yellow crystals by vacuum filtration using a Hirsch funnel.

CAUTION: This solution is still strongly acidic.

Wash the product crystals with 200 μL portions of *ice-cold* water until the crystals turn white.

Purification and Characterization. Dry the adipic acid crystals in an oven at 110–125 °C for 10 min. Weigh the product and calculate the percent yield. Determine the melting point and obtain an IR spectrum. Compare your results to those recorded in the literature.

Chemical Test. Add several crystals (~5 mg) of the adipic acid to 1 mL of a 10% aqueous solution of sodium bicarbonate. Does evolution of CO_2 indicate the presence of a carboxylic acid?

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EQA

QUESTIONS

7-35. Which of the following compounds is the stronger acid: $CF_3CH_2CO_2H$ or $CH_3CH_2CO_2H$? Explain.

7-36. What spectroscopic method would you use to unambiguously distinguish between the following isomeric acids? Give an explanation of how the spectra are interpreted to give you an assignment for each compound.

(a) $CH_3(CH_2)_3CO_2H$
(b) $(CH_3)_2CHCH_2CO_2H$
(c) $(CH_3)_3CCO_2H$

7-37. Indicate how you would use both ^1H and ^{13}C NMR spectroscopy to tell the difference between the following isomeric carboxylic acids:

(a) $HO_2CCH_2CH_2CO_2H$
(b) $CH_3CH(CO_2H)_2$

7-38. The two carboxyl groups in 3-chlorohexanedioic acid are not equivalent and thus have different dissociation constants. Which carboxylic group is more acidic? Explain.

7-39. Write an equation for the formation of the salt that could be formed by reaction of one molecule of adipic acid with two molecules of ethylamine.

BIBLIOGRAPHY

For detailed information on the production and use of adipic acid see

Kirk-Othmer Encylopedia of Chemical Technology, 5th ed., Vol. 1, Willey-VCH: New York, 2004.

For oxidation methods in organic chemistry see

Haines, A. H. *Methods for the Oxidation of Organic Compounds;* Academic Press: New York, Vol. 1, 1985, Vol. 2., 1988.

Hudlicky, M. *Oxidations in Organic Chemistry;* American Chemical Society: Washington, DC, 1990.

Mijs, W. J.; de Jonge, C. R. H. I. *Organic Synthesis by Oxidation with Metal Compounds;* Plenum: New York, 1987.

Taber, D.F. *Organic Synthesis: State of the Art 2003–2005;* Wiley: New York, 2006.

———.*Organic Synthesis: State of the Art 2006–2007;* Wiley: New York 2008.

The synthesis of adipic acid is given in *Organic Syntheses:*

Ellis, B. A. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 18.

Preparation of an Acid Chloride: Adipoyl Chloride

Experiment B2

Common name: adipoyl chloride
CA number: [111-50-2]
CA name as indexed: hexanedioyl dichloride

Purpose. Adipic acid is converted to its corresponding acid chloride by reaction with thionyl chloride. The experiment will help you further understand the nucleophilic substitution reaction pathway by which carbonyl-containing compounds undergo reaction.

Prior Reading

Standard Experimental Apparatus: Reflux Apparatus (pp. 23–24)
Collection or Control of Gaseous Products: (pp. 105–107)

REACTION

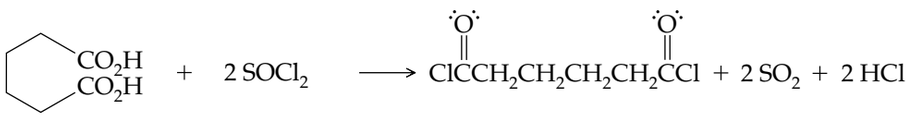

Adipic acid Thionyl chloride Adipoyl chloride

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EQA

DISCUSSION

Carboxylic acids react with thionyl chloride ($SOCl_2$) to produce the corresponding acid chlorides, as shown in the above reaction.Thionyl chloride is an attractive reagent due to its low cost, and the fact that both byproducts produced in the reaction are gases. Thus, the reaction is driven to completion by the evolution of HCl and SO_2, and a nearly pure acid chloride is obtained. The major drawback to the reaction is that it produces a strong acid (HCl) and thus cannot be used with compounds that are acid sensitive. Oxalyl chloride is often used as an alternative reagent.

The reaction proceeds by a nucleophilic acyl substitution pathway. With thionyl chloride, a chlorosulfite intermediate is generated. Thus, the —OH group is converted into a relatively good leaving group. The chlorosulfite intermediate then undergoes attack by the chloride ion at the carbonyl carbon to yield the final product. The sequence is shown here:

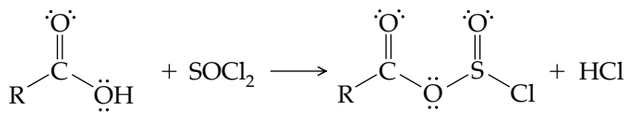

Carboxylic acid — A chlorosulfite

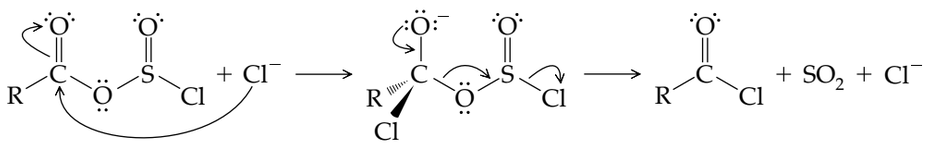

Acid chloride

Acid halides are important intermediates and they are used extensively for the conversion of carboxylic acids into other derivatives. For example, acid halides can be used to prepare (in addition to amides): anhydrides, esters, aldehydes, and ketones. Acid halides readily undergo reaction with water (hydrolysis) to form the corresponding carboxylic acid. For this reason the reaction system must be protected from atmospheric moisture when acid halides are formed and/or used.

In the present sequence leading to the formation of nylon, the adipoyl chloride provides a reactive species, which, when treated with a diamine, forms the desired amide linkage inherent to nylon.

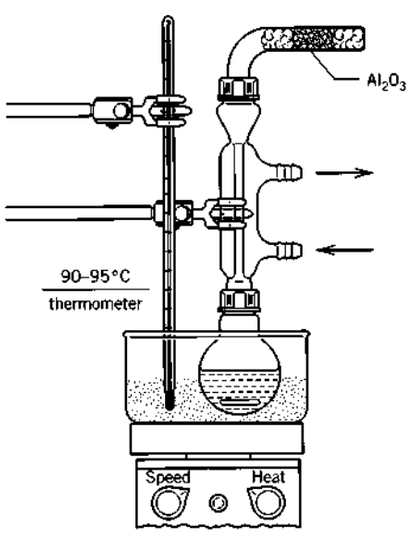

Adipic acid, 500 mg + thionyl chloride, 0.75 mL reflux conditions, 10-mL RB flask

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Adipic acid	146.14	500 mg	3.4	153	265	1.35
Thionyl chloride	118.97	0.75 mL	10.4	−105	78.8	1.66

Reagents and Equipment. Place and dry in an oven at about 125 °C for 30 min, a 10-mL round-bottom flask, a water-cooled reflux condenser, and a drying tube packed with glass wool and alumina. After removing them from the oven, place these items in a desiccator and allow them to cool to room temperature. Measure and place 500 mg (3.4 mmol) of adipic acid and 0.75 mL (10.4 mmol) of thionyl chloride into the 10-mL flask (⬅).

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EQA

*NOTE. Store the dry adipic acid and the container of thionyl chloride in a desiccator. Dispense the thionyl chloride in the **hood** using an automatic delivery pipet.* HOOD

CAUTION: Thionyl chloride is both corrosive and a lachrymator.

Add a magnetic stir bar to the flask, quickly attach the flask to the reflux condenser protected by the drying tube, and mount the assembly in a sand bath.

*NOTE. If a larger scale reaction is to be run outside of the **hood,** it will be necessary to construct a gas trap to control the evolution of the SO_2 and HCl gases (see Prior Reading).* HOOD

Reaction Conditions. With stirring, heat the reaction mixture to 90–95 °C within 5 min. Continue to heat the system within this temperature range for an additional 1 h.

NOTE. Heating the solution above 95 °C causes decomposition of the product. The presence of unreacted adipic acid in the flask indicates incomplete reaction.

Isolation and Characterization. The progress of the reaction may be followed by IR analysis. With a glass capillary, remove a small sample from the flask and obtain the spectrum of the material using the capillary film technique. Remove the sample from the instrument sampling compartment immediately following the spectral scan to prevent the HCl gas buildup from damaging the instrument. The reaction is considered incomplete if the IR spectrum displays a weak band on the low-wavenumber side of the acid halide carbonyl peak.

If the reaction is determined to be incomplete after 1 h, add an additional 200 μL of $SOCl_2$ and continue to heat the mixture until IR analysis (the disappearance of the weak side band) indicates that completion has occurred. The adipoyl chloride is quite labile, and therefore, it is not purified further, but it is used directly in the preparation of nylon as described in Experiment [B3].

QUESTIONS

7-40. Diagram a complete mechanistic sequence showing the hydrolysis reaction of ethanoyl chloride with water to form ethanoic acid.

7-41. Give an explanation of why acid chlorides are more reactive toward nucleophilic substitution than are the corresponding ethyl esters. *Hint:* Consider the nature of the leaving group and the rate-determining step in an addition–elimination sequence.

7-42. What major organic product would you expect to be formed when acetyl chloride reacts with each of the following reagents?

(a) H_2O
(b) NH_3 (excess)
(c) 1-Butanol and pyridine
(d) CH_3COOH^-, Na^+

7-43. Acid chlorides are used extensively as electrophiles in the Friedel–Crafts reaction to prepare aromatic ketones. The reaction involves the treatment of an aromatic hydrocarbon with an acyl chloride in the presence of a Lewis acid, such as aluminum chloride (see Experiment [27]). Using this reaction, outline the reaction sequence you would use to prepare

(a) Ethyl phenyl ketone
(b) Benzophenone

7-44. Formulate a suitable mechanism to account for the reaction of thionyl chloride with carboxylic acids to yield the corresponding chlorosulfite (see the reaction diagrammed in the discussion section). *Hint:* The first step is the nucleophilic attack of the oxygen of the —OH group of the acid on the sulfur atom of the S═O group of the thionyl chloride.

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BIBLIOGRAPHY

Adipoyl chloride is prepared as an intermediate in several preparations reported in *Organic Syntheses:*

Fuson, R. C.; Walker, J. T. *Organic Syntheses*; Wiley: New York, 1943; Collect. Vol. II, p. 169.

Guha, P. C.; Sankaran, O. K. *Organic Syntheses*; Wiley: New York, 1955; Collect. Vol. III, p. 623.

See your organic textbook for an introduction to this reaction and its scope in synthesis. For example,

Solomons, T. W. G.; Fryhle, C. B. *Organic Chemistry*, 9th ed., Wiley: New York, 2008, p. 794.

For a review on the preparation and reactions of acyl halides see

Ansell, M. F. in *The Chemistry of Acyl Halides;* Patai, S., Ed.; Wiley: New York, 1972, p. 35.

Experiment B3

Preparation of a Polyamide: Nylon-6,6

Common names: nylon-6,6, polyhexamethylene adipamide

CA number: [32131-17-2]

CA name as indexed: poly[imino(1,6-dioxo-1,6-hexanediyl)imino-1, 6-hexanediyl]

Purpose. The polyamide, nylon, is prepared by the step-growth condensation polymerization of adipoyl chloride with 1,6-hexanediamine. An interfacial (emulsion) polymerization technique is used to generate nylon fibers.

REACTION

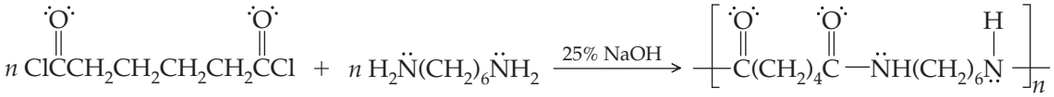

Adipoyl chloride 1,6-Hexanediamine Nylon-6,6

DISCUSSION

The preparation of nylon outlined in this experiment is not the industrial method (see initial discussion). The use of the reactive diacid chloride reagent allows one to carry out the step-growth polymerization reaction under very mild conditions more convenient to the instructional laboratory. The interfacial (emulsion) polymerization technique used consists of dissolving the adipoyl chloride reagent in a water-immiscible solvent (cyclohexane) and bringing this solution into contact with an aqueous solution of the diamine. A thin film forms at the *interface* of the two solvents as the condensation reaction proceeds. A "rope" of nylon polymer can be pulled from the interface of the two solvents because the film is continuously generated as the reaction occurs. This polymer has an average molecular weight of ~10,000! In this particular experiment, about 5–7 meter lengths of nylon polymer can be obtained. This particular synthesis of nylon is often used in lecture demonstrations and chemical magic shows.

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.5 h.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	*d*
Adipoyl chloride	183.05	~622 mg	3.4		
1,6-Hexanediamine (5% aq)	116.21	8 mL		41–42	1.259
Cyclohexane	84.16	8 mL			

Reagents and Equipment. Transfer the clear solution of adipoyl chloride prepared in Experiment [B2] to a 50-mL beaker using a Pasteur pipet. Rinse the flask with 2 mL of cyclohexane and transfer this rinse to the same beaker. Add an additional 8.0 mL of cyclohexane. Now slowly add 8.0 mL of a 5% aqueous solution of 1,6-hexanediamine containing eight drops of 25% NaOH solution.

NOTE. Add the solution using a Pasteur pipet, taking care to run it down the side of the beaker.

Isolation and Characterization. Using a copper wire bent into a small hook, hook the film in the center of the beaker and draw up the nylon fiber from the solution interface. A slow, steady pull will result in long strands of the polymer. Wash the fibers in a beaker of water before handling them.

QUESTIONS

7-45. Explain why the 25% NaOH solution is added to the reaction mixture.

7-46. Draw a structure to illustrate the hydrogen bonding that may occur when two polymer molecules of this polyamide are cold-drawn together.

7-47. Predict the structure of the polymer that would result in the condensation of the following reactants. These monomers are used to produce the polyamide Nomex, a high-melting material used as an insulator in space shuttles and as the fire-resistant fabric in clothing worn in race cars.

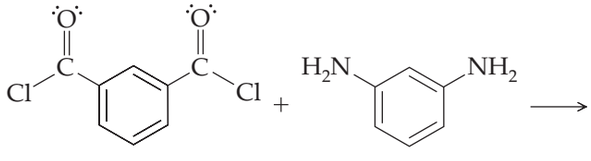

7-48. Amides undergo hydrolysis to carboxylic acids on treatment with alkali. Diagram a suitable mechanism for the conversion of benzamide to benzoic acid using sodium hydroxide as the base.

BIBLIOGRAPHY

For detailed information on the production and use of nylon see

Heckert, W. W. *J. Chem. Educ.* **1953,** *30,* 166.

Kirk–Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. 19, Wiley: New York, 1996, pp. 454, 470, 485.

For information on the interfacial polymerization technique see

Sprague, B. S.; Singleton, R. W. *Text. Res. J.* **1965,** *35,* 999.

Morgan, P. W.; Kwolek, S. L. *J. Chem. Educ.* **1959,** *35,* 182.

Nikonov, V. Z.; Savinov, V. M. In *Interfacial Synthesis;* Millich, F.; Carraher, C. E., Jr., Eds.; Marcel Dekker: New York, 1977, Vol. II, Chap. 15.

Odian, G. *Principles of Polymerization,* 4th ed.; Wiley-Interscience: New York, 2004.

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EQA

SEQUENCE C

The Synthesis of Sulfanilamide

Purpose. You will carry out the multistep synthesis of the epoch-making antibacterial drug, sulfanilamide. You will learn the techniques for handling moisture sensitive materials and investigate the strategies involved in solving a synthetic organic problem.

THE SULFA DRUGS

The sulfanilamides were the first effective systemic bactericides. The discovery, in the early 1930s, of these substances transformed medical care. Indeed, a major fraction of the world's population is alive today as a result of these compounds and their microbiological successors. Early recognition of the importance of these materials was underlined when their discoverer was honored by receiving the 1938 Nobel Prize in Medicine. Even 60 years later, "sulfa" drugs are still some of the most effective antibacterial substances available to physicians today.

These compounds, to which human existence owes a considerable debt of gratitude, are all derivatives of the parent material, *p*-aminobenzenesulfonamide (sulfanilamide):

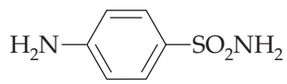

p-Aminobenzenesulfonamide
(sulfanilamide)

This weakly basic compound contains two —NH_2 groups located in quite different environments, so that each one possesses quite different chemical properties and reactivities. One is substituted directly on the aromatic ring; the other is contained in a sulfonamide group. A wide variety of these derivatives can be prepared by introducing different substituents on the nitrogen atom of the sulfonamide functional group. Any attempt at modifying the ring —NH_2 group, however, was found to completely destroy the biological activity.

Prontosil, *p*-[(2,4-diaminophenyl)azo]benzenesulfonamide, was first synthesized in Germany in 1932 as a product of azo-dye research at I. G. Farbenindustrie. It was soon tested for chemotherapeutic activity, because it bound very strongly to protein fibers. In 1933, it became the first drug to effectively cure blood stream infections. The early investigations of the biological activity of Prontosil required direct testing on animal infections, since the drug appeared to be inactive in vitro.

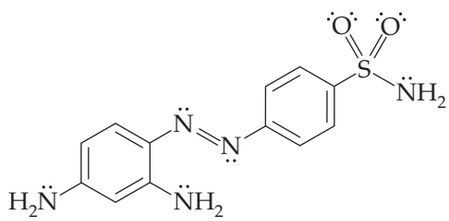

Prontosil

In 1935, Trefouels (Pasteur Institute) established that Prontosil breaks down in the body to yield, as one of the metabolites, sulfanilamide. It was

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shown later that year, by Fourneau, that the biological activity of Prontosil was entirely contained in the sulfanilamide section of the molecule, and that no biological activity was lost during the cleavage. This later discovery, and the fact that sulfanilamide itself had been earlier synthesized by Gelmo in 1908 (unfortunately by not exploring the biological activity of the substance, he missed the opportunity at a Nobel Prize), voided any patent protection, and led to a worldwide effort to synthesize a wide variety of these materials. By 1944 over 5000 sulfanilamide derivatives had been prepared and tested.

Currently the sulfa drugs are still very important therapeutic agents, but have to a large extent been replaced by antibiotics, such as the penicillins. Their low cost and general effectiveness for urinary tract infections, however, still make sulfanilamide derivatives attractive alternatives. These compounds have also found a valuable role in veterinary medicine.

Production of sulfanilamide reached a peak of 9000 metric tons/year in 1943; present production is about one-half that amount.

The following experiments in this sequence outline a novel and efficient procedure for the preparation of this important substance. The chemistry involves the trifluoroacetylation of aniline (Experiment [C1]), the chlorosulfonation of the resulting acetanilide (Experiment [C2]), which is followed by concomitant aminolysis and hydrolysis of the sulfonyl chloride intermediate (Experiment [C3]) to produce the final product, sulfanilamide:

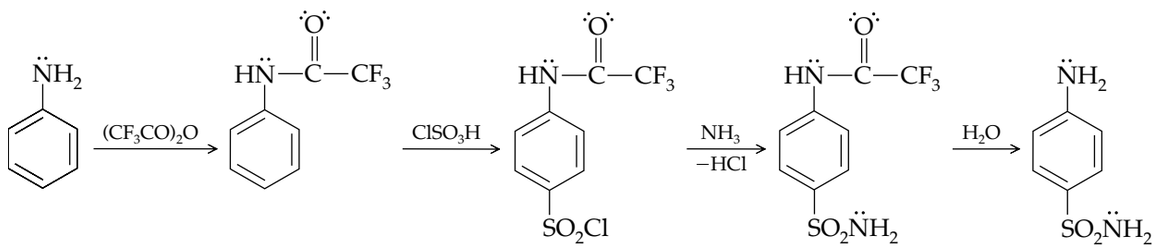

Acetylation of Aniline: 2,2,2-Trifluoroacetanilide

Experiment C1

Common name: 2,2,2-trifluoroacetanilide

CA number: [404-24-0]

CA name as indexed: acetamide, 2,2,2-trifluoro-*N*-phenyl-

Purpose. The goal of this experiment is to protect the easily oxidized amine group of aniline from electrophilic attack during the sulfonation of the benzene ring in the next step of the synthesis. This deactivation is accomplished by reducing the electron density on the amine nitrogen (and thus its nucleophilicity) by acetylating aniline with the strongly electron-withdrawing trifluoroacetyl group.You will become familiar with techniques for handling moisture-sensitive materials.

Prior Reading

Standard Experimental Apparatus: Moisture-protected Claisen head with 3- or 5-mL conical vial, arranged for syringe addition (pp. 25–26)

Technique 6B: Concentration of Solutions:
Evaporation with Nitrogen Gas (p. 102)

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REACTION

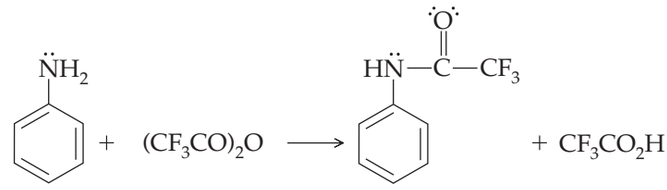

Aniline — Trifluoroacetic anhydride

DISCUSSION

Acid anhydrides react with amines, or ammonia, to yield amides. The reaction of anhydrides is similar to that of acid chlorides (see Experiment [B3]), although the anhydrides normally react at slower rate.

Acetic anhydride, $CH_3C(O)OC(O)CH_3$, is an important industrial reagent used to prepare acetamides, $CH_3C(O)NR_2$, from a variety of amines. For example, acetaminophen, an over-the-counter analgesic, is synthesized by the reaction of *p*-hydroxy-aniline with acetic anhydride:

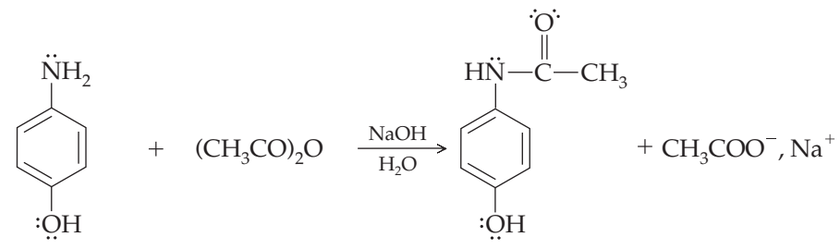

p-Hydroxyaniline — Acetic anhydride — Acetaminophen

In the present reaction, *trifluoro*acetic anhydride is used in place of acetic anhydride. The halogenated anhydride is considerably more reactive because of the presence of the three fluorine atoms on the α-carbon atom of the anhydride. The electron-withdrawing power of the fluorine substituents helps to enhance nucleophilic attack on the anhydride by the weak aromatic nucleophile. Once the amide is formed, the trifluoromethyl group makes the amide a better protecting group than the acetyl group, as the trifluoroacetyl group renders the amine lone electron pair less nucleophilic. Furthermore, the byproduct of the reaction, trifluoroacetic acid, is fairly volatile (bp 72 °C) and is therefore easily removed from the reaction mixture by evaporation. This enhanced reactivity helps avoid the use of an added base, as is required in the preparation of acetaminophen. Chemically, the procedure is simplified and the intermediate trifluoroacetanilide is usually obtained in a relatively pure condition. *This highly reactive anhydride, however, requires considerable care in its use.*

CAUTION: No moisture can remain on the surface of the clean glassware or hydrolysis may occur with explosive force!

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.75 h.

Physical Properties of Reactants							
Compound	MW	Mass	Volume	mmol	mp (°C)	bp (°C)	*d*
Aniline	93.13	235 mg	230 μL	2.5	−6.2	184.3	1.02
Trifluoroacetic anhydride	201.04	744 mg	500 μL	3.54	−6.5	39.5	1.49
Methylene chloride	84.93		500 μL			40	1.33

Reagents and Equipment. Place and dry in an oven at about 125 °C for 30 min, a 5-mL conical vial, a Claisen head, a drying tube packed with glass wool and calcium chloride, a 1-mL glass syringe, and a $\frac{1}{2}$-dram screw-cap vial. After removal from the oven, place these items in a desiccator and allow them to cool to room temperature. Measure and place 230 μL (2.5 mmol) of aniline and 500 μL of methylene chloride in the 5-mL conical vial. Immediately attach the vial to the Claisen head equipped with a septum cap and protected by the drying tube (see Prior Reading). Cool the vial in a cold water bath.

*NOTE. Dispense the aniline and methylene chloride in the **hood** using automatic delivery pipets.* HOOD

CAUTION: Aniline is a highly toxic substance and a cancer suspect agent.

In the **hood,** place 500 μL of trifluoroacetic anhydride and 500 μL of methylene chloride in the dried $\frac{1}{2}$-dram vial. HOOD

NOTE. The anhydride hydrolyzes rapidly in moist air, so make the transfer quickly.

Now draw this solution into the dried syringe, and insert the needle through the septum cap of the Claisen head. Dropwise, **slowly** add this solution to the cold aniline–methylene chloride solution. SLOWLY

NOTE. Heat is produced in the reaction. If the addition is too rapid, the methylene chloride starts to reflux and fumes are emitted through the drying tube.

Reaction Conditions. After the addition is complete, allow the reaction mixture to stand at room temperature for 10 min.

Isolation of Product. Remove the reaction vial and, in the **hood,** concentrate the solution on a warm sand bath under a slow stream of nitrogen gas. The crude 2,2,2-trifluoroacetanilide intermediate is obtained as a white powder. Cap the vial. HOOD

Purification and Characterization. The crude material is not purified further, but rather used directly in the next reaction of the sequence without further characterization.

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EQA

QUESTIONS

7-49. Outline a complete mechanistic sequence for the reaction to prepare acetaminophen as presented in the discussion section of this experiment.

7-50. In the preparation of amides, acid chlorides or anhydrides may be used to react with the selected amine. It is known that acid chlorides are more reactive than the corresponding anhydrides in this type of nucleophilic acyl substitution reaction. Offer a reasonable explanation for this observation.

7-51. Offer an explanation of why 2,2,2-trifluoroacetic anhydride is more reactive toward aniline than acetic anhydride in the nucleophilic acyl substitution reaction presented in this experiment.

7-52. Offer a reasonable explanation of why acetamide has a higher melting and boiling point then *N,N*-dimethylacetamide even though it has a lower molecular weight:

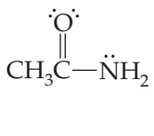

Acetamide
mp 82 °C
bp 221 °C

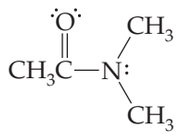

N,N-Dimethylacetamide
mp −20 °C
bp 166 °C

7-53. Outline a simple chemical test that would distinguish between ethyl benzoate and benzamide (*Hint:* See Chapter 9).

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Noyes, W. A.; Porter, P. K. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 457.

Wiley, R. H.; Borum, O. H. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 5.

The use of the perfluoroacetic anhydride reagent in this synthesis is reported in

Hurdis, E. C.; Yang, J. W. *J. Chem. Educ.* **1969,** *46,* 697.

Experiment C2

Chlorosulfonation of 2,2,2-Trifluoroacetanilide: *p*-(Trifluoroacetamido)benzenesulfonyl Chloride

Common name: *p*-(trifluoroacetamido)benzenesulfonyl chloride

CA number: [31143-71-2]

CA name as indexed: benzenesulfonyl chloride, 4-[(trifluoroacetyl)amino]-

Purpose. The substitution of the aniline ring is carried out by introduction of the sulfonyl group. This substitution reaction is the second stage on the route to preparing sulfanilamide. *p*-(Trifluoroacetamido)benzenesulfonyl chloride is prepared by treatment of the intermediate, 2,2,2-trifluoroacetanilide, with chlorosulfonic acid. You will gain experience at handling highly reactive moisture-sensitive reagents.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

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EQA

REACTION

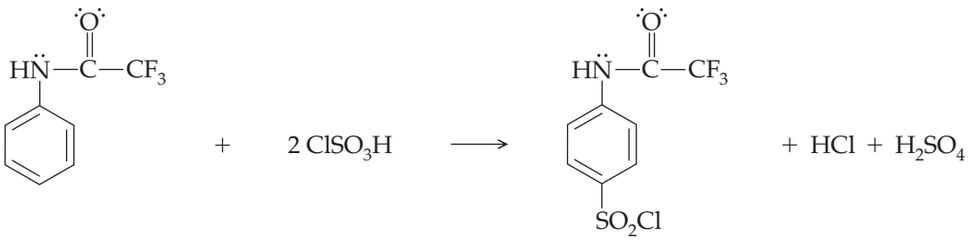

2,2,2-Trifluoroacetanilide Chlorosulfonic acid *p*-(Trifluoroacetamido)-benzenesulfonyl chloride

DISCUSSION

As shown here, the sulfonyl chloride group (—SO_2Cl) can be conveniently introduced to an aromatic ring via an electrophilic aromatic substitution reaction using chlorosulfonic acid. The reaction is usually referred to as *chlorosulfonation*. It has been determined that two equivalents of the acid are required per equivalent of the aromatic compound. In the initial attack the system first forms the corresponding sulfonic acid, which in turn is converted to the sulfonyl chloride. It is believed that the initial stage of the reaction involves SO_3 as the electrophile. It is likely that this reagent results from the establishment of the equilibrium reaction shown here:

$$ClSO_3H \rightleftharpoons SO_3 + HCl$$

The intermediate sulfonic acid is converted to its sulfonyl chloride derivative by reaction with a second equivalent of the chlorosulfonic acid:

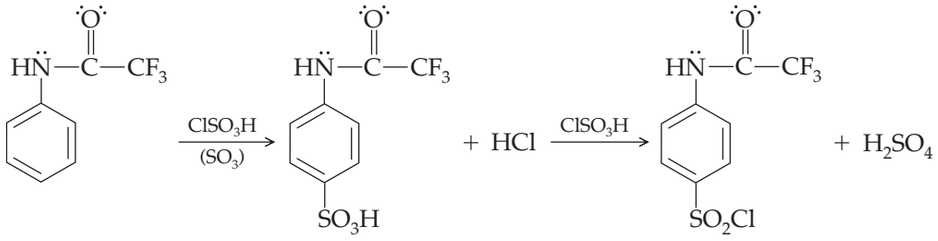

Product isolation is achieved by transferring the solution of the sulfonyl chloride onto crushed ice to precipitate the insoluble acid chloride. This isolation procedure can be used because sulfonyl chlorides are much less susceptible to hydrolysis than their carboxylic acid chloride counterparts (see Experiment [B2]). Sulfonyl chlorides *do* undergo this hydrolysis reaction, albeit rather slowly, resulting in the formation of the corresponding sulfonic acid.

Notice that the para-substituted product is formed in the reaction. Why is this observed given that two other isomers are possible (the meta- and/or ortho-products)? (See Question 7-57.)

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EQA

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.75 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
2,2,2-Trifluoroacetanilide	189.06	478 mg (theoretical value)	2.5	87.6		
Chlorosulfonic acid	116.52	900 μL	13.7	−80	158	1.77

HOOD *NOTE. All reagent transfers must be made and the reaction must be conducted in the **hood.***

Reagents and Equipment. Place and dry in an oven at about 125 °C for 30 min, an air condenser and a 9-in. Pasteur pipet calibrated to deliver 0.9 mL. After removal from the oven, place these items in a desiccator and allow them to cool to room temperature.

Attach the vial containing the 2,2,2-trifluoroacetanilide (prepared in Experiment [C1]) to the *dry* air condenser. Measure, using the 9-in. Pasteur pipet, SLOWLY 0.9 mL of chlorosulfonic acid, and **slowly** add this reagent to the flask by inserting the pipet down the neck of the air condenser.

HOOD CAUTION: Chlorosulfonic acid is a very corrosive substance. It reacts violently with water and causes serious burns on contact with the skin. Dispense the reagent in the ***hood.*** Leave all equipment used to transfer this material in the *hood* until it is obvious that the residual reagent has reacted with the moist air (white fumes subside), and leave these materials in contact only with *glass* surfaces.

NOTE. An alternative procedure for making the transfer is to measure the amount of this reagent using an oven-dried 1-mL glass pipet and then transfer it to an oven-dried screw-cap vial. The material is then transferred to the reaction vial as described above, using the dry 9-in. pipet.

Reaction Conditions. Place the reaction assembly on a sand bath in the HOOD **hood** and heat the mixture at 60–70 °C for 10 min.

Isolation and Characterization. Allow the reaction mixture to cool to room temperature, and then place the flask in an ice bath. Using a second, SLOWLY dry 9-in. Pasteur pipet, transfer the cold reaction solution **slowly** to a 10-mL HOOD beaker containing ice (~$\frac{1}{2}$ full) in the **hood.**

CAUTION CAUTION: This is a very vigorous reaction. Use ***caution.*** Leave all HOOD equipment in the ***hood*** until it is obvious the residual reagent has reacted with the moist air (white fumes subside). Make sure that only glass surfaces are in contact with the reagent residues.

A precipitate of the product, *p*-(trifluoroacetamido)benzenesulfonyl chloride, forms at this stage. Collect the tannish-white precipitate by vacuum filtration and wash the filter cake with three 1-mL portions of ice cold water.

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EQA

Allow the material to air-dry. Determine the weight of the crude product, and calculate the percent yield from aniline. Determine its melting point, and compare it to the reported value of 142–145 °C.

Chemical Test. Carry out a sodium fusion test to confirm the presence of nitrogen, sulfur, and chlorine in the product (see Chapter 9).

QUESTIONS

7-54. Outline a suitable mechanism to illustrate the reaction of benzenesulfonyl chloride with excess ethylamine to form the corresponding sulfonamide.

7-55. In reference to Question 7-54, why is an excess of ethylamine used?

7-56. Account for the fact that the amide group (—$NHCOCF_3$) is ortho and para directing. Use resonance structures to illustrate your written explanation.

7-57. As mentioned in the discussion, offer an explanation of why only the para isomer is obtained in the chlorosulfonation reaction carried out in this experiment.

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For a summary of electrophilic aromatic substitution reactions see

Hapworth, J. D.; Waring, D. R.; Waring, M. J. *Aromatic Chemistry* Wiley: New York, 2003, Chap. 2.

For the use of chlorosulfonic acid in aromatic substitution reactions see

Gilbert, E. E. *Sulfonation and Related Reactions;* Wiley: New York, 1965, p. 84.

Rathke, M. E.; Millard, A. A. *Organic Syntheses* **1978,** *58,* 32.

Reid, J. R.; Dufresne, R. F.; Chapman, J. J. *Organic Syntheses* **1997,** *74,* 217.

Scheifele, H. J., Jr.; De Tar, D. F. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 34.

Smiles, S.; Stewart, J. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 8.

Webb, C. N. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 85.

Also see

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 14, p. 974 and references therein.

Preparation of an Arene Sulfonamide: Sulfanilamide

Experiment C3

Common names: sulfanilamide, *p*-aminobenzenesulfonamide

CA number: [63-74-1]

CA name as indexed: benzenesulfonamide, 4-amino-

Purpose. The sequential synthesis is completed and the sulfa drug, *sulfanilamide*, is obtained by treatment of the sulfonyl chloride intermediate prepared in Experiment [C2], with an aqueous ammonia solution.[2] This interesting product is fully characterized.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallization (pp. 89–91)

[2]This experiment is adapted from the work of S. Danishefsky, Yale University (personal communication).

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EQA

DISCUSSION

The final step in the synthesis of the target molecule, sulfanilamide, is the conversion of the sulfonyl chloride intermediate to a sulfonamide and the removal of the 2,2,2-trifluoroacetyl protecting group. These transformations are accomplished in one step because both reactions take place upon heating the protected sulfonyl chloride with aqueous ammonia. The reaction sequence is shown here:

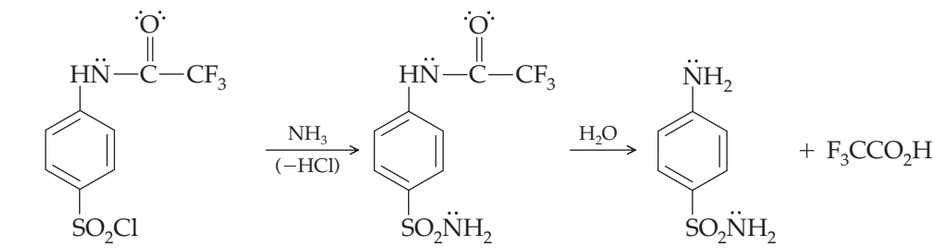

p-(Trifluoroacetamido)-benzenesulfonyl chloride

Sulfanilamide

We can now see several reasons for first protecting the reactive amino group on the aniline molecule. First, to attempt the introduction of the sulfonyl group directly on aniline would very likely lead to a species (*p*-aminobenzenesulfonyl chloride) that would react with itself (act as a difunctional monomer) to produce a sulfonamide polymer:

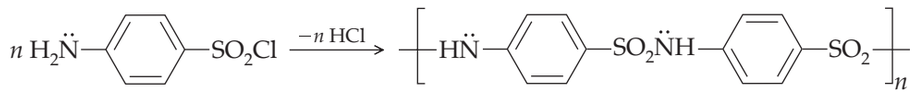

Second, because the sulfonyl group is introduced using chlorosulfonic acid, an acidic medium is present. Under these conditions, because free HCl is available (see discussion in Experiment [C2]), the amino group would be protonated and become a meta directing group. This situation would lead to the formation of the wrong isomer or, at best, a mixture of isomers.

Third, as mentioned above, the amino group is highly prone to oxidation and the unavoidable presence of traces of the strong oxidant, SO_3, would be expected to lead to considerable oxidation of the aromatic amine.

The 2,2,2-trifluoroacetyl group meets all the requirements of a good protecting group. First, the acetylation reaction goes rapidly in nonaqueous media to give a clean, dry product. Second, the protecting group is easily and rapidly removed in the final stage without disturbing the other functional groups in the molecule.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 0.75 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)
(2,2,2-Trifluoroacetamido)-benzenesulfonyl chloride	287	400 mg	1.39	142–145
Aqueous ammonia		600 μL		

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EQA

CAUTION: All reagent transfers and the *reaction* must be conducted in the ***hood.*** HOOD

Reagents and Equipment. Weigh and place in a 10-mL Erlenmeyer flask 400 mg (1.39 mmol) of the *p*-(2,2,2-trifluoroacetamido)benzenesulfonyl chloride, which was prepared in Experiment [C2]. In a 10 × 75-mm test tube, prepare a solution of 0.6 mL of fresh, concentrated aqueous ammonia (ammonium hydroxide) and 0.4 mL of deionized water. Add this solution to the solid sulfonyl chloride in the Erlenmeyer flask. Now add a boiling stone. Use a glass rod to break up any lumps of the solid that may form.

CAUTION: Dispense the ammonia solution in the ***hood.*** HOOD

CAUTION: If the sulfonyl chloride reagent contains acidic impurities, a vigorous reaction may occur when the reagents are mixed.

Reaction Conditions. Place the Erlenmeyer flask on a hot (100–110 °C) sand bath in the **hood** and heat the mixture until the solid material dissolves. HOOD Agitate with a glass rod, if necessary, to assist the dissolution process. Now heat the solution to boiling for an additional minute.

Isolation and Characterization. Remove the flask from the sand bath and allow the reaction mixture to cool to room temperature. Place the flask in an ice bath for 15–20 min. During this time light-yellow crystals of product precipitate.

Collect the crystalline product by vacuum filtration, and wash the crystals with three 0.5-mL portions of ice-cold water. Air-dry the sulfanilamide, weigh, and calculate a crude yield, both for this step and for the overall sequence based on the amount of aniline used in the first step. Determine the melting point of this material.

Recrystallize the crude material from water using the Craig tube. Air-dry the white crystals overnight, or in an oven (110 °C) for 10–15 min. Determine the melting point and compare your value to that reported in the literature. To further characterize the material obtain an IR and NMR spectrum and compare them to those found in the literature (*The Aldrich Library of Infrared Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

Chemical Test. Carry out a sodium fusion test to confirm the presence of nitrogen and sulfur in the product (see Chapter 9).

QUESTIONS

7-58. Based on the results of this experiment, which is more nucleophilic: hydroxide ion (HO^-) or ammonia (NH_3)? Explain.

7-59. Outline a suitable mechanism to account for the conversion of the sulfonyl chloride group to the sulfonamide group by reaction with ammonia.

7-60. Outline a synthesis for the sulfa drug, sulfathiazole, starting from benzene. The primary aminothiazole ring system is available:

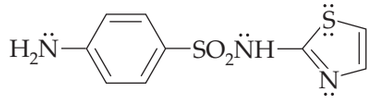

Sulfathiazole

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EQA

7-61. Sulfonyl chlorides also react readily with alcohols to yield sulfonate esters:

$$ArSO_2Cl + HOR \xrightarrow[\text{or}\ 3^\circ\ \text{amine}]{\text{pyridine}} ArSO_2OR + HCl$$

Propose a suitable mechanism to account for this reaction.

7-62. In reference to the Hinsberg test used to distinguish between primary, secondary, and tertiary amines (see Chapter 9), primary amines yield a sulfonamide that is soluble in aqueous sodium hydroxide, whereas secondary amines give a sulfonamide that is not soluble in this reagent. Offer an explanation for this observation.

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For an overall view of the sulfa drug story see

Kirk–Othmer Encyclopedia of Chemical Technology, 4th ed., Wiley: New York, 1992, Vol. 2, p. 876.

Examples of treatment of sulfonyl chlorides with amines:

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Reid, J. R.; Dufresne, R. F.; Chapman, J. J. *Organic Syntheses* **1997,** *74,* 217.

Scheifele, H. J., Jr.; De Tar, D. F. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 34.

The use of the perfluoroacetic anhydride reagent in this synthesis is reported in

Hurdis, E. C.; Yang, J. W. *J. Chem. Educ.* **1969,** *46,* 697.

SEQUENCE D

The Synthesis of 2′-Bromostyrene

Purpose. A three-step synthesis of 2′-bromostyrene is carried out starting with benzaldehyde. You will gain experience working with semimicroscale quantities of organic materials. (See Sequence A, where benzaldehyde is also used as the starting material, in that case for the formation of two different intermediates in the seven-step synthesis of hexaphenylbenzene.) You will become familiar with the stereo-chemistry involved in the addition of molecular halogen to an alkene (see also Experiment [$A2_b$]). You will observe the elimination of a hydrogen halide promoted by a concerted decarboxylation reaction (see also Experiment [$A3_b$]). As an option, ^{1}H NMR spectroscopy will be used to determine the cis/trans ratio of isomers in the product (see also Experiment [5B]).

THE SYNTHESIS OF A FRAGRANCE

Numerous classes of organic compounds have characteristic odors. For example, volatile esters have pleasant odors (see Experiment [8B]) and are often used in perfumes and artificial flavorings where they contribute to the fragrance of the material; acid chlorides have sharp penetrating odors (see Experiment [B2]); the alkyl amines have a "fishy" smell (see Experiment [B3]); benzaldehyde has the odor of bitter almond oil (see Experiment [20]); and cinnamaldehyde, the odor of cinnamon (see Experiment [11C]). Experiment [11C] also contains an expanded discussion of naturally occurring fragrant materials, called *essential oils*. As chain length increases, the odors of the short-chain alkyl carboxylic acids progress from the sharp, irritating odors of formic and acetic acids to the very rank, disagreeable odors of butyric (rancid butter), valeric, and caproic (dirty socks and goats) acids. Low molecular weight thiols (mercaptans), sulfides, and disulfides have

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EQA

intensely disagreeable odors. Examples of these materials are the active principals in the chemical defense spray used by the skunk. Via evolution, this animal has developed a highly effective mixture of 3-methylbutane-1-thiol, *trans*-2-butene-1-thiol, and *trans*-2-buten-1-yl methyl disulfide, which is able to deter most skunk predators, not just humans. Our sense of smell can detect one part of ethanethiol in 50 billion parts of air. This sounds spectacular, but humans have developed other highly sensitive detectors (the retinas of our eyes) to a band of electromagnetic radiation in the region 400–750 nm (the visible region of the spectrum). We have, as a consequence, become less dependent on our sense of chemical communication (our sense of smell). When we compare our detection limit of mercaptans to the male silkworm's detection of the female sex *pheromone*, we find that the *Bombyx mori* respond to threshold levels close to 1 million times lower (in the concentration range of 100 molecules per milliliter)!

Clearly, chemical communication (odor) plays a critical role in mediating animal and plant behavior within and between species. These metabolites are often stored and released when the animal (or plant) responds to certain stimuli. Historically, these substances served as the major communication link between living systems during the evolutionary development of single cell organisms. Thus, they predated hormones, which function in a similar fashion, but within a host collection of cells. While these substances may be used by a given insect species as a sex attractant, pheromones can also mediate other intraspecies functions, such as acting as trail guides and alarm signals. Thus, pheromones are substances that are used to communicate information between individuals of the same species to their adaptive advantage. The activity of a pheromone frequently depends on the configuration around a double bond (*E* or *Z*) as well as the absolute configuration around an *R* or *S* chiral center, just as humans select for these structural features (see discussion in Experiment [11D]). In a number of cases, the response has been shown to depend on the ratio of the isomers. There are several other classes of chemical communication substances used by plants and animals. The *allomones* are interspecies materials, which, on release, are used to the adaptive advantage of the host but to the disadvantage of the receiver. A typical function of an allomone is as a chemical defense agent; the thiols and disulfides used by the skunk are excellent examples. Three typical chemical communication substances are shown here:

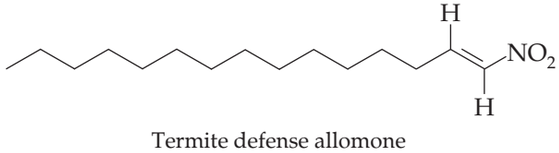

Termite defense allomone

and

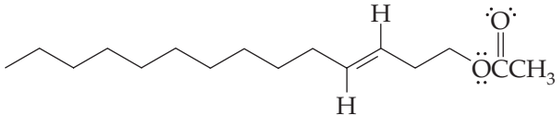

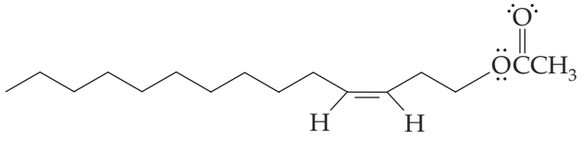

Sex pheromones of the European corn borer (a mixture of cis + trans acetates)

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EQA

The synthetic route undertaken in the Sequence D experiments leads ultimately to a mixture of the diastereomeric cis–trans isomers of 2′-bromostyrene:

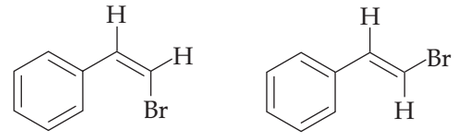

cis-2′-Bromostyrene *trans*-2′-Bromostyrene

This material is often used as an additive to impart a pleasant fragrance to soaps, since it has a very pleasant aroma, similar to that of hyacinth. It is not, however, a naturally occurring material. As a nice illustration of the fact that stereoisomeric compounds can have markedly different physiological effects, it has been demonstrated that a single diastereomer, *trans*-2′-bromostyrene, is responsible for the hyacinth-like odor.

The chemistry involved in this particular synthesis of 2′-bromostyrene contains a number of fundamental organic reactions and is rather interesting to study. The first stage (Experiment [D1]) involves the condensation of benzaldehyde with malonic acid to produce the intermediate, *trans*-cinnamic acid. This reaction is mechanistically similar to the well-known *aldol* reaction, and is often referred to as the *Knoevenagel* condensation:

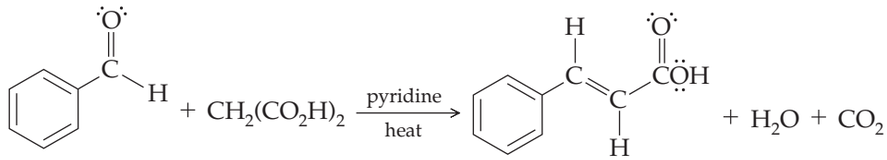

Benzaldehyde Malonic acid *trans*-Cinnamic acid

The second stage (Experiment [D2]) involves the addition of bromine to the intermediate formed in the first step, *trans*-cinnamic acid. The product of this halogenation is *erythro*-2,3-dibromo-3-phenylpropanoic acid. The stereochemistry involved in the formation of this second intermediate is a result of the nature of the anti addition of molecular bromine to a trans alkene. The details are given in the discussion in Experiment [D2].

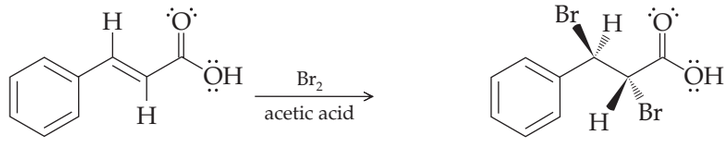

trans-Cinnamic acid *erythro*-2,3-Dibromo-3-phenylpropanoic acid

In Experiment [D3], the third step in Sequence D, the target molecule, 2′-bromostyrene, is generated by a novel elimination reaction that involves the loss of both CO_2 and HBr from the dibromophenylpropanoic acid. This stage of the synthesis offers an excellent opportunity to study the effect of solvent on the stereochemical course of a reaction by spectral analysis. In this

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case NMR (or infrared) data can be used to establish whether a cis–trans mixture is obtained, or just one pure isomer (cis):

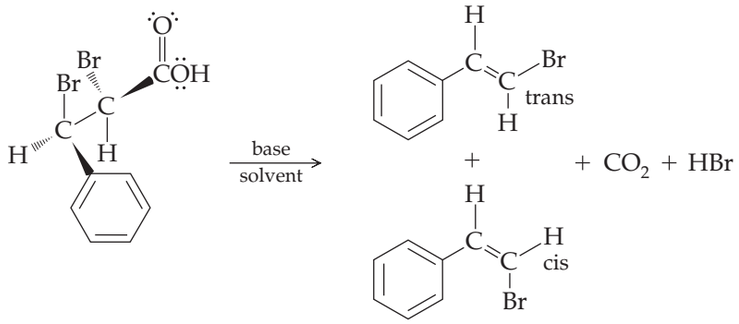

erythro-2,3-Dibromo-3-phenylpropanoic acid

cis- + *trans*-2′-Bromostyrene

The Verley–Doebner Modification of the Knoevenagel Reaction: *trans*-Cinnamic Acid

Experiment D1

Common name: *trans*-cinnamic acid

CA number: [140-10-3]

CA name as indexed: 2-propenoic acid, 3-phenyl-, (*E*)-

Purpose. *trans*-Cinnamic acid is prepared as the first intermediate in the Sequence D set of reactions that ultimately lead to 2′-bromostyrene. You will review the chemistry associated with an important variety of aldol-type condensation, the modified Knoevenagel reaction.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

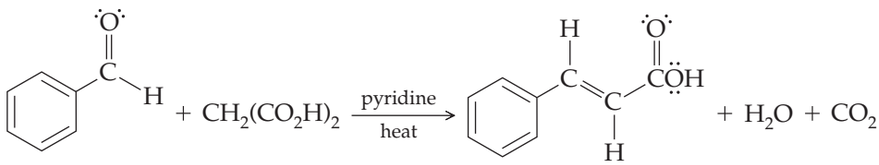

Benzaldehyde Malonic acid *trans*-Cinnamic acid

DISCUSSION

Those reactions that are called aldols derive their name from the early nineteenth-century organic literature. The term was first applied to a self-addition product of acetaldehyde that forms under basic conditions. The product, 3-hydroxybutanal, can form in yields as high as 50% in the presence of sodium hydroxide. This substance eventually became referred to as *aldol,* because it was both an aldehyde and an alcohol.

The aldol reaction can be defined in the broad sense as a reaction in which a nucleophile-generated alpha to an electron-withdrawing functional group (in the large majority of cases, carbonyl groups are responsible for the α-hydrogen

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acidity, although they are not required) adds to a carbonyl group (it may be self-condensation, as in the example of acetaldehyde, but it may also involve attack on another carbonyl-containing species, if it is present). Several experiments in this text illustrate this type of reactivity. Experiments [20] and [$A3_a$] are classic aldol reactions in which conditions are vigorous enough to result in elimination of the β-hydroxyl group to yield α,β-unsaturated ketones as products. In the first step of Sequence D, we now add the Knoevenagel reaction as another condensation possessing a mechanism similar to that of the aldol.

Emil Knoevenagel (1865–1921) Knoevenagel was born in Hanover, Germany. He was the son of a chemist and started his studies at the Technical Institute at Hanover. Later he studied with both Victor Meyer and Gattermann at Göttingen where he received a Ph.D. in 1889. When Victor Meyer moved to Heidelberg, Knoevenagel accompanied him. In 1896 he was appointed assistant professor of organic chemistry at Heidelberg and, in the same year, published his studies on the reaction that now bears his name. He eventually became professor of organic chemistry in 1900.

Knoevenagel had a variety of interests, including stereoisomerism. He worked extensively with aldol-type reactions, and pioneered the use of amine bases to promote these condensations. He was particularly interested in pyridine chemistry, and was the first to synthesize the pyridine ring by heating hydroxylamine with 1,5-diketones.

Following World War I, in which he saw active service, he continued his studies, only to die suddenly, at the age of 56, during an appendectomy.

Interestingly, although Knoevenagel demonstrated the effectiveness of amine bases in promoting aldol-type reactions and though, as noted above, he was particularly interested in pyridine, he overlooked this material's potential application to aldol condensations. It was left to Verley (1899) and Doebner (1900) to introduce successful modifications of the condensation in which pyridine appears to play a number of roles: as a solvent, as a base, and assisting in the decarboxylation.

The Knoevenagel reaction in its simplest form is the condensation of malonic esters (or their analogues) with aldehydes or ketones in the presence of an amine base catalyst plus a small amount of a carboxylic acid (or amino acid) cocatalyst. The condensation products are often α,β-unsaturated carbonyl compounds. For example,

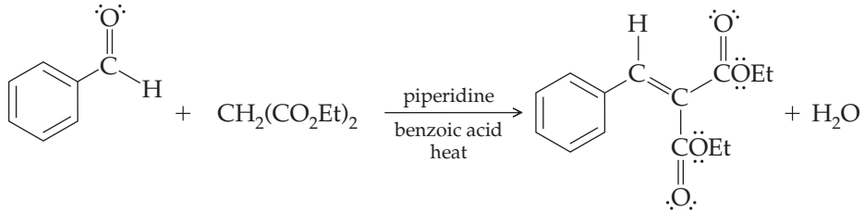

Benzaldehyde Diethyl malonate Diethyl benzalmalonate

Other substances possessing an acidic methylene group have been incorporated in aldol-type reactions. These materials include ethyl cyanoacetate and ethyl acetoacetate, as well as phenylacetonitrile, benzyl ketones, and aliphatic nitro compounds. The reaction is often run in benzene or toluene solvent, so that the water formed can be continuously removed. Other cocatalysts, besides carboxylic acids, are various ammonium salts, such as ammonium

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acetate and piperidinium acetate. The Knoevenagel reaction gives highest yields when aldehydes are used as the electrophile, although selected ketones can sometimes give acceptable yields. One of the more important properties of these reactions from a synthetic perspective is that they offer a route to the formation of C—C bonds.

In the formation of the first synthetic intermediate in Sequence D, the very effective Verley–Doebner modification of the fundamental Knoevenagel condensation is used. This modification uses malonic acid in place of the conventional ester to promote enolization. In addition, the heterocyclic amine, pyridine, functions as both the base catalyst and the solvent. A cocatalyst, β-alanine (an amino acid), is also introduced. Mechanistically, the reaction closely resembles the aldol condensation in that in both cases a carbanion is generated by abstraction, by base, of a proton *alpha* to a carbonyl group. The resulting carbanion is stabilized as an enolate anion (see below).

The enolate anion then acts as a nucleophile and attacks the carbonyl carbon of a second carbonyl-containing molecule in the reaction. (An example would be the aldol reaction in Experiment [20].) The intermediate aldol product, the β-hydroxyacid, undergoes rapid dehydration under these reaction conditions, to give the α,β-unsaturated diacid shown here:

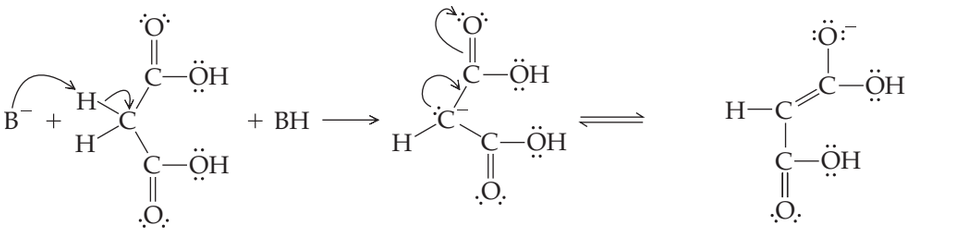

(acidic hydrogen) (carbanion) (enolate anion)
(one resonance structure shown)

Conjugate addition (1,4 addition) of pyridine and ionization of a carboxylic acid are followed by decarboxylation and concomitant elimination of pyridine to yield the α,β-unsaturated carboxylic acid as shown here.

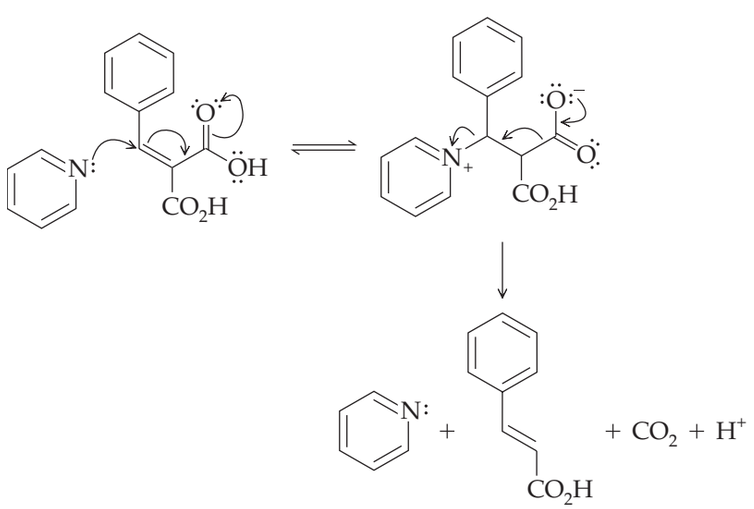

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Benzaldehyde	106.12	580 μL (603 mg)	5.7	−26	179	1.04
Malonic acid	104.06	1.5 g	14.4	135 dec		
Pyridine	79.10	3 mL			115	0.978
β-Alanine	89.09	120 mg	1.35	205 dec		

Reagents and Equipment. In a 10-mL round-bottom flask containing a magnetic stir bar, weigh and place 1.5 g (14.4 mmol) of malonic acid followed by
HOOD 120 mg of β-alanine. Now, in the **hood,** add 3 mL of pyridine and 580 μL of freshly distilled benzaldehyde.

NOTE. Dispense the benzaldehyde using an automatic delivery pipet. Measure the pyridine using a 10-mL graduated cylinder.

CAUTION: Pyridine is a toxic amine with a strong unpleasant odor.
HOOD Both reagents should be stored and dispensed in the **hood.**

Attach the flask to a water-jacketed reflux condenser, and place the assembly in a sand bath on a magnetic stirring hot plate.

Reaction Conditions. Heat the mixture with stirring at a sand bath temperature of about 130 °C for 1.5 h.

Isolation of Product. Allow the reaction mixture to cool to room temperature and, in the **hood,** remove the flask. Transfer the reaction solution using a Pasteur pipet to a 50-mL Erlenmeyer flask containing 12 mL of ice-cold water. Rinse the round-bottom flask with an additional 3 mL of ice-cold water, and transfer the rinse to the same Erlenmeyer flask in like manner. Now add, in small portions, 6 M HCl (~8 mL) until a white precipitate forms and the solution tests weakly acidic to pH paper. Collect the precipitate of *trans*-cinnamic acid by vacuum filtration using a Hirsch funnel. Wash the white crystals with three 2-mL portions of cold water. To partially dry the material, continue the suction for an additional 15 min (remember to cover the Hirsch funnel with filter paper to protect the filter cake from contamination with dust from the laboratory atmosphere during the extended air-drying period).

Purification and Characterization. Oven-dry the partially dried product at 100 °C overnight. Weigh the crude acid and calculate the percent yield. Determine the melting point. Compare your result with the literature value. This material is likely to be of sufficient purity to be used in the next step of Sequence [D], Experiment [D2]. If your material melts below the literature value, for characterization recrystallize approximately 30 mg from hot water using the Craig tube. Dry as before and redetermine the melting point. To further characterize the material, obtain IR and ^{1}H NMR spectra. Compare your spectra with those recorded in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

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NOTE. Approximately 500 mg of purified product with a melting point within 2–3 °C of the literature value is suggested for continuing the sequence on to Experiment [D2].

Chemical Tests. Add several crystals (~5 mg) of the *trans*-cinnamic acid to 1 mL of 5% sodium bicarbonate on a watch glass. Does evolution of CO_2 indicate the presence of a carboxylic acid? Does the material give a positive bromine test for unsaturation (see Chapter 9).

QUESTIONS

7-63. Write a complete mechanism for the addition of diethyl malonate to ethanal in the presence of base to form a β-hydroxy ester.

7-64. Outline a synthesis that forms at least one C—C bond for each of the following compounds:

(a) $CH_3CH_2CH_2CH_2CH_2CH{=}CHCO_2H$

(b) $CH_3CH_2CH_2CH{=}C(CN)(CO_2CH_2CH_3)$

7-65. As mentioned in the discussion, ketones generally give poor yields in the Knoevenagel reaction with diethyl malonate. However, the reaction with ketones gives good yields with ethyl cyanoacetate and malononitrile. Explain.

7-66. Give the structure of the products of the Knoevenagel reaction for the following pairs of reactants:

(a) Cyclopentanone + malononitrile (dicyanomethane)

(b) Benzaldehyde + ethyl acetoacetate

(c) Propanal + nitromethane

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McElvain, S. M.; Clemens, D. H. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 463.

This step in the sequence was adapted from the work of

Kolb, K. E.; Field, K. W.; Schatz, P. F. *J. Chem. Educ.* **1990,** *67,* A304.

Bromination of *trans*-Cinnamic Acid: *erythro*-2,3-Dibromo-3-phenylpropanoic Acid

Experiment D2

Common name: *erythro*-2,3-dibromo-3-phenylpropanoic acid

CA number: [31357-31-0]

CA name as indexed: Benzenepropanoic acid, α,β-dibromo-, (*R**,*S**)-

Purpose. The bromination of *trans*-cinnamic acid is carried out to obtain *erythro*-2,3-dibromo-3-phenylpropanoic acid, the direct precursor to 2′-bromostyrene, which is the synthetic target of Sequence D. You will review the stereospecificity of the addition of molecular bromine to an alkene.

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Prior Reading

Technique 5: Crystallization

Use of the Hirsch Funnel (pp. 88–89)

REACTION

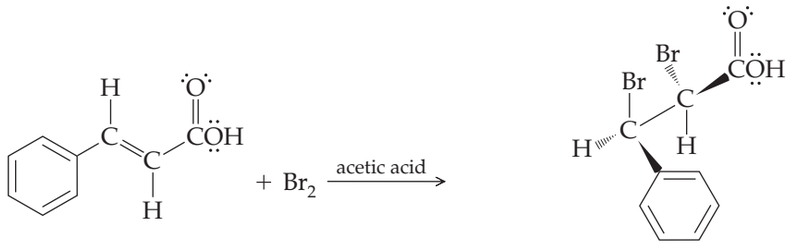

trans-Cinnamic acid

erythro-2,3-Dibromo-3-phenylpropanoic acid

DISCUSSION

The bromination of alkenes is known to be a **stereospecific** reaction. An example and detailed discussion of this addition to *trans*-stilbene is given in Experiment [$A2_b$], and another example is illustrated in Experiment [F2]. In the present case, bromine undergoes a similar addition, and the halogenated product obtained is the erythro diastereomer of 2,3-dibromo-3-phenylpropanoic acid, which is produced as a racemic mixture of the two enantiomers.

The term *erythro* is derived from carbohydrate chemistry, and is used to describe the *relative* configurations of the two adjacent chiral centers (stereocenters). Specifically, the term erythro describes structures whose Fischer projections place identical substituents (on adjacent carbon atoms) on the *same side* of the (otherwise identical) Fischer projection. The opposite of erythro is *threo*, which would describe structures with identical substituents (on adjacent carbons) on opposite sides of the (otherwise identical) Fischer projection. Because erythro and threo describe only the relative configurations of the two chiral centers with respect to one another, there are two enantiomers of each erythro diastereomer, and of each threo diastereomer, as shown here both in Fischer projections and more familiar illustrations:

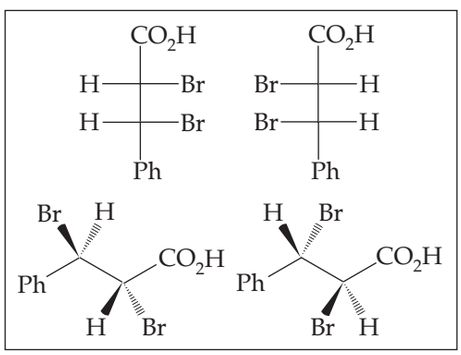

Enantiomers of the erythro diastereomer of 2,3-dibromo-3-phenylpropanoic acid

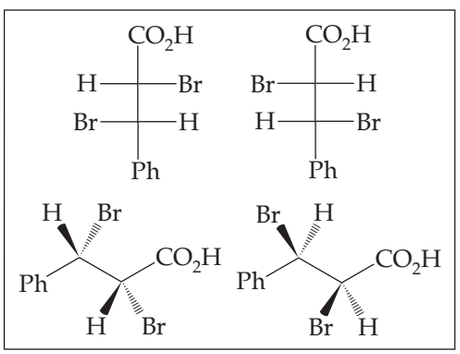

Enantiomers of the threo diastereomer of 2,3-dibromo-3-phenylpropanoic acid

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The result of the halogenation of *trans*-cinnamic acid, as in the case of (*E*)-stilbene in Experiment [$A2_b$], is an anti addition of molecular bromine. The enantiomeric products are shown here:

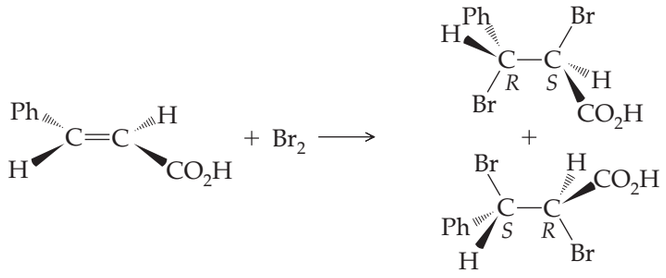

trans-Cinnamic acid

erythro-(2*R*,3*S*- and 2*S*,3*R*)-2,3-dibromo-3-phenylpropanoic acid

What mechanism best explains this observed stereochemistry? The starting un-saturated acid and bromine are both *achiral*, and thus the product, if a chiral molecule, must be racemic. The outer-shell electrons of molecular bromine, however, are highly polarizable and molecular bromine reacts as an electrophile with the nucleophilic π electrons of the alkene group of cinnamic acid, in a reaction that is effectively a nucleophilic substitution reaction on a bromine atom. The product is a carbocation, which is, however, stabilized by the ability of the bromine atom to donate a lone pair to the carbocation. This interaction results in the formation of a *chiral*, cyclic *bromonium ion* intermediate. This intermediate ion is a rigid structure in which the ring section is only open to further attack by a nucleophile (S_N2 attack by the Br^- ion generated in the first stage) from the side opposite the bromine atom.

Because both cinnamic acid and molecular bromine are achiral, two enantiomeric bromonium ions are formed at equal rates. Ring opening of each bromonium ion may preferentially occur as shown here at the carbon bearing the phenyl group, since this carbon bears more fractional positive charge than the carbon adjacent to the carboxyl group. Because the two reaction pathways shown here are enantiomeric, they proceed at equal rates to produce racemic *erythro*-2,3-dibromo-3-phenylpropanoic acid:

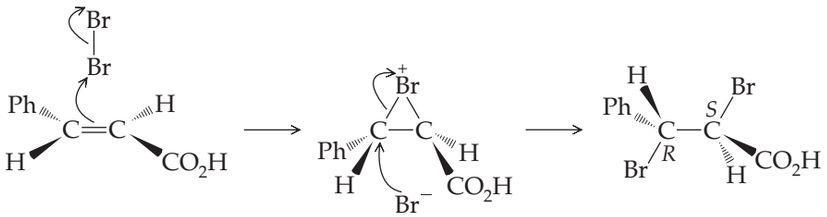

trans-Cinnamic acid

erythro-2,3-Dibromo-3-phenylpropanoic acid

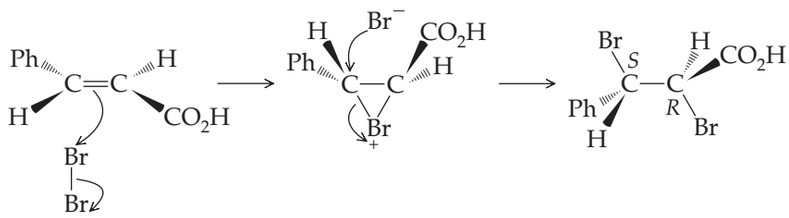

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Recent investigations have shed further light on the nature of the cyclic intermediate. Stable solutions of cyclic bromonium ions in liquid SO_2 have been prepared as SbF_6^- salts. For example,

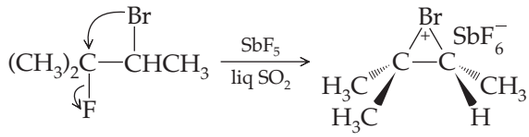

See the discussion in Experiment [$A2_b$] for further evidence relating to these intermediate species.

The *erythro*-2,3-dibromo-3-phenylpropanoic acid product prepared in this experiment has a melting point of 203–204 °C. The corresponding threo diastereomer has been synthesized and its racemate melts at 91–93 °C. Thus, the experimental results support the stereospecific nature of the bromine addition that is rationalized by the proposed mechanism.

NOTE. Pyridinium bromide perbromide, a solid reagent, is used as a source of bromine in this experiment. This material is much easier to handle than liquid bromine (also see Experiment [$A2_b$]).

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
trans-Cinnamic acid	148.2	500 mg	3.37	133		
Pyridinium bromide perbromide (tech)	319.84	1.2 g				
Acetic acid	60.05	12 mL	16.2		116–118	1.05
erythro-2,3-Dibromo-3-phenylpropanoic acid	308.0			203–204		

Reagents and Equipment. Weigh and place 500 mg (3.37 mmol) of *trans*-cinnamic acid in a 25-mL round-bottom flask containing a magnetic stir bar.

HOOD Now weigh and place (in the **hood**) 1.2 g of pyridinium bromide perbromide in the same flask.

CAUTION: Pyridinium bromide perbromide is a corrosive reagent

HOOD and a lachrymator. Dispense this material in the ***hood.***

Using a graduated cylinder, measure 12 mL of glacial acetic acid and add this to the solid reagents. Attach the flask to a water-cooled reflux condenser and place the assembly in a sand bath.

Reaction Conditions. Heat the mixture with stirring in a sand bath at 120–125 °C for 45 min.

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Isolation of Product. Cool the orange solution to room temperature. With a Pasteur pipet, transfer the solution in small portions to a 50-mL Erlenmeyer flask. Rinse the reaction flask with an additional 2 mL of acetic acid, and transfer this rinse to the same Erlenmeyer flask.

Cool the solution in an ice bath for 5 min, and then slowly add 15 mL of cold water in three 5-mL portions. Swirl the contents of the flask between additions. A pale yellow precipitate should form. Collect the crude product by vacuum filtration using a Hirsch funnel. Wash the filter cake with three 2-mL portions of cold water, during which time the solid product should become white.

Purification and Characterization. Dry the product in an oven at 110 °C overnight. Weigh the product and calculate the crude yield. Determine the melting point and compare it to that listed in the Reactant and Product table.

A 20- to 30-mg sample of the *erythro*-2,3-dibromo-3-phenylpropanoic acid may be recrystallized (Craig tube) from chloroform (in the **hood**), if desired. HOOD

Chemical Test. Perform the Beilstein test to detect the presence of a halogen (see Chapter 9).

NOTE. Approximately 300 mg of purified (washed) product, with a melting point within 3–5 °C of the literature value, is suggested for continuing the sequence on to Experiment [D3].

QUESTIONS

7-67. The product prepared in this experiment has 2 chiral centers (stereocenters), which give rise to 4 stereoisomers. Draw each of these stereoisomers, and indicate the relationships between each of the stereoisomers.

7-68. The addition of bromine to ethylene in the presence of high concentrations of chloride ion in an inert solvent results in the formation of 1,2-dibromoethane and 1-bromo-2-chloroethane. No 1,2-dichloroethane is obtained. Account for these results using a suitable mechanistic sequence.

7-69. 2,3-Dibromobutane contains 2 chiral centers. Therefore, the possibility of 4 stereoisomers exists. However, the addition of bromine to an equimolar mixture of *cis*- and *trans*-2-butene generates only three stereoisomers. Explain.

7-70. Cyclohexene undergoes bromination in methanol solvent to give *trans*–1-bromo-2-methoxycyclohexane. Draw a suitable mechanism to account for this.

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Also see

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Experiment D3

An Elimination Reaction with *erythro*-2,3-Dibromo-3-phenylpropanoic Acid: 2′-Bromostyrene

Common names: (*Z*)-β-Bromostyrene, *cis*-2′-bromostyrene
CA number: [588-73-8]
CA name as indexed: benzene, (2-bromoethenyl)-, (*Z*)-
Common names: (*E*)-β-bromostyrene, *trans*-2′-bromostyrene
CA number: [588-72-7]
CA name as indexed: benzene, (2-bromoethenyl)-, (*E*)-

Purpose. An elimination reaction is carried out using *erythro*-2,3-dibromo-3-phenylpropanoic acid, the direct precursor to 2′-bromostyrene. The influence of solvents and base on the course of the elimination reaction is illustrated. You will consider factors that control the stereospecificity of a reaction. You will explore the option of using NMR spectroscopy to establish the cis/trans isomer ratio in the 2′-bromostyrene product.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 6B: Concentration of Solutions (pp. 101–104)

REACTION

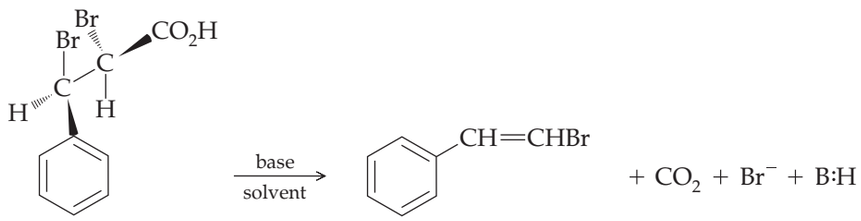

erythro-2,3-Dibromo-3-phenylpropanoic acid

cis- + *trans*-2′-Bromostyrene

DISCUSSION

The course of the elimination depicted in the above reaction is both base and solvent dependent. In this experiment you will have the opportunity to investigate this solvent dependence. In Part A, you will study the effect of carbonate base in aqueous solvent. Under these conditions, the reaction sequence proceeds via an E1 mechanism in which the first step involves the ionization of one of the C—Br bonds. Clearly, of the two possibilities, halide formation that results in a resonance stabilized benzylic carbocation will be highly favored over development of a positive charge on a carbon alpha to a carboxyl group (see Question 7-71). Formation of the carbocation intermediate is then rapidly followed by decarboxylation. Although the conjugated section of the positively charged intermediate is planar, free rotation or partially hindered rotation remains possible about the C—C bond, leading to the remaining tetrahedral carbon. Thus, both *cis*- and *trans*-2′-bromostyrene may be obtained

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during the subsequent decarboxylation. The proposed sequence is shown here:

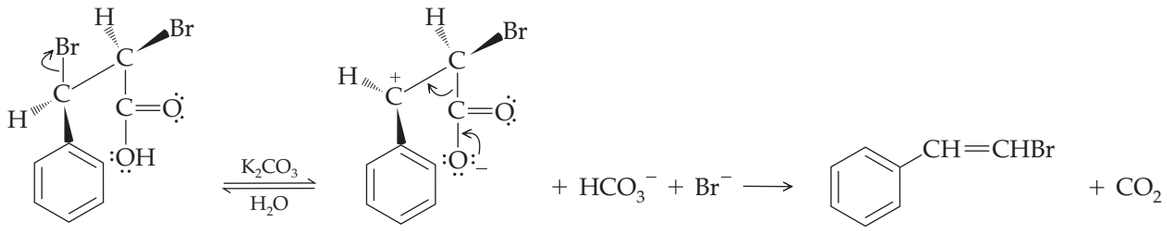

erythro-2,3-Dibromo-3-phenylpropanoic acid

(benzylic carbocation)

cis- + *trans*-2′-Bromostyrene

In Part B of the experiment, the solvent is changed from water (used in Part A) to a much less polar solvent, acetone. Under these nonaqueous conditions, elimination also occurs, but in this case the experimental data demand a different mechanism, one involving a smooth concerted electron flow without short-lived intermediate formation. Furthermore, when carried out in acetone, the reaction yields exclusively *cis*-2′-bromostyrene. Details of the mechanism follow:

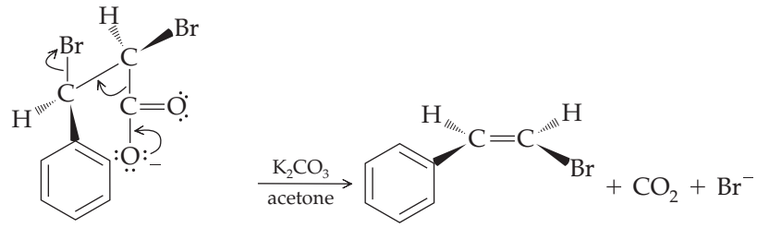

erythro-2,3-Dibromo-3-phenylpropanoic acid anion

cis-2′-Bromostyrene

Under these conditions, therefore, the reaction becomes stereospecific. The mechanism is classified as an E2 elimination. Note that when the two leaving groups are anti to one another, as is thermodynamically preferred, elimination yields the cis alkene.

In the two sets of reaction conditions to be studied in Parts A and B of this experiment, potassium carbonate is used as the base in both cases and it is the solvent that is varied, as mentioned above. In another experimental procedure, sodium azide is used as the base and *N,N*-dimethylformamide (DMF) is used as the solvent, and higher selectivity for the formation of the cis isomer is reported (see Bibliography, Corvari et al.).

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: 1.5 h, Part A; 2.0 h, Part B.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)
erythro-2,3-Dibromo-3-phenylpropanoic acid	308.0	300 mg	0.97	203–204
Potassium carbonate	38.21	300 mg	2.1	891

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PART A Conditions: Water Solvent

Reagents and Equipment. Weigh and place 300 mg (0.97 mmol) of *erythro*-2,3-dibromo-3-phenylpropanoic acid (prepared in Experiment [D2]) and 300 mg (2.1 mmol) of potassium carbonate in a 25-mL Erlenmeyer flask. Add 5 mL of distilled water.

Reaction Conditions. Warm the mixture in a 120 °C sand bath until the solids dissolve (5–10 min) and then heat for an additional 10 min. A yellow oil should separate from the aqueous phase during this period.

Isolation of Product. Cool the two-phase system to room temperature and, using a Pasteur pipet, transfer the contents of the flask to a 12-mL centrifuge tube. Rinse the Erlenmeyer flask with a 2-mL portion of methylene chloride, which is then transferred to the centrifuge tube. Extract the aqueous phase with the CH_2Cl_2 rinse and follow this extraction with two more extractions of the aqueous phase with 2-mL portions of methylene chloride. Transfer the methylene chloride extracts (the organic phase should be the lower phase, but check solubility in water to be sure) to a 25-mL Erlenmeyer flask containing enough anhydrous sodium sulfate to dry the solution. Allow the extracts to dry for about 10 min.

Transfer a portion of the dried solution, using a Pasteur filter pipet, to a *tared* 5-mL conical vial containing a boiling stone. Concentrate this portion on a warm sand bath under a gentle stream of nitrogen gas in the **hood.**

HOOD

Now transfer the remaining dried solution to the same tared vial and concentrate as before. Finally, rinse the sodium sulfate drying agent with an additional 1-mL portion of methylene chloride, transfer it to the vial and concentrate again to yield the *cis/trans*-2′-bromostyrene as a yellow oil.

NOTE. Exercise care during the concentration steps. Product yield will be greatly reduced by overheating or leaving the solution on the sand bath for too long a period.

Purification and Characterization. No further purification of the product is usually necessary. Note the hyacinth-like odor of the liquid. Determine the refractive index and compare it to the literature value (lit. value = 1.6070 at 20 °C, 78% trans isomer). Obtain IR and ^{1}H NMR spectra of the oil. In the infrared, the cis isomer shows a phenyl C—H bend at 770 cm^{-1}, while the trans isomer shows this bending mode at 731 and the alkene C—H out-of-plane mode is found at 941 cm^{-1} (see Bibliography, Strom et al.). Compare your results with the spectrum recorded in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

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NMR Analysis. The ^{1}H NMR spectrum of a mixture of *cis*- and *trans*-2′-bromostyrene is shown in Figure 7.4. The doublets corresponding to the two olefinic protons of the major isomer can be clearly seen, centered at 6.75 and 7.1 ppm. One of the corresponding doublets from the minor isomer is evident at 6.42 ppm. This doublet has a coupling constant of 8.0 Hz. The two larger doublets from the major isomer have a coupling constant of 14.0 Hz, and thus, in this sample, the major isomer must be *trans*-2′-bromostyrene.

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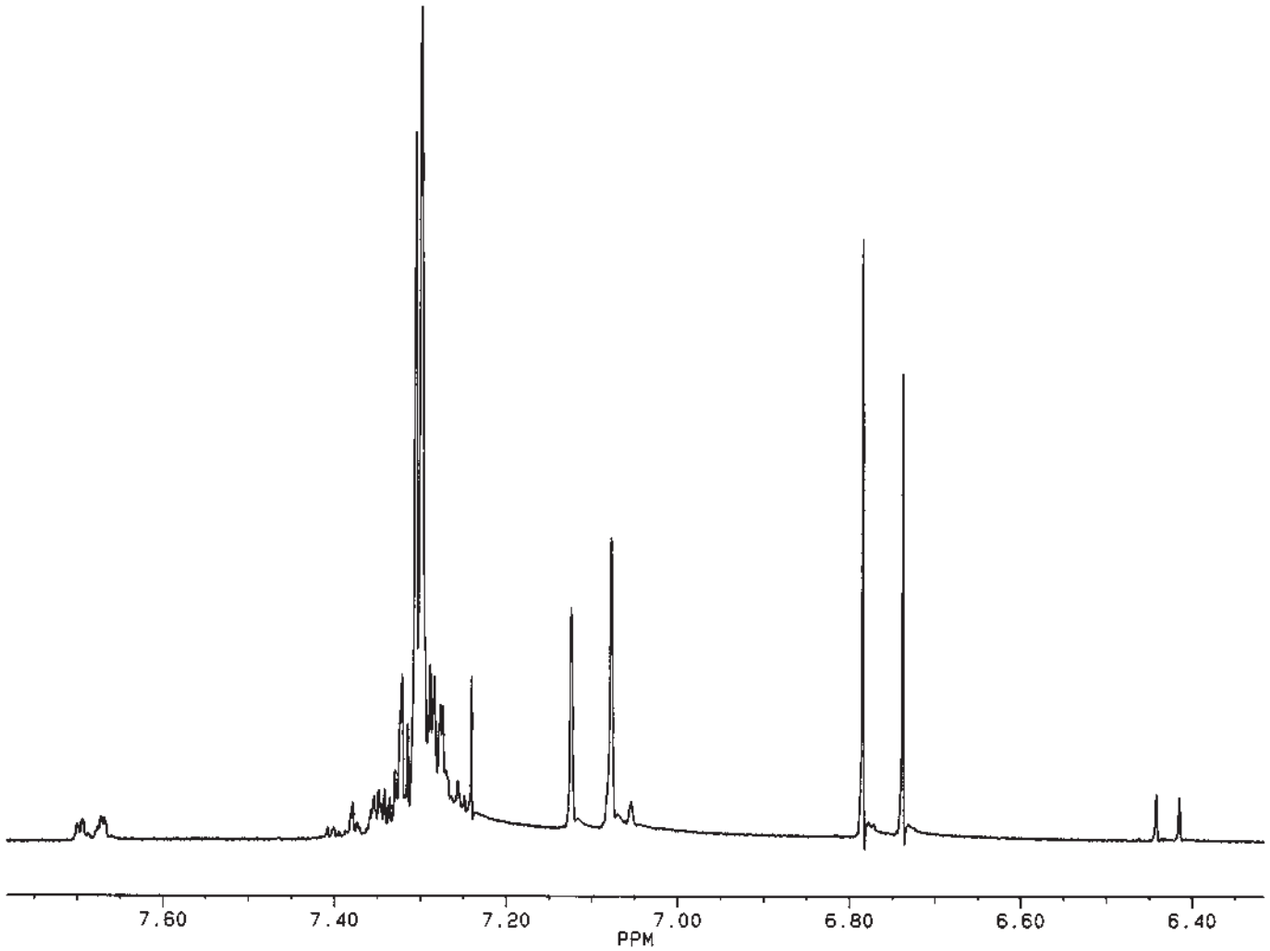

Figure 7.4 ^{1}H NMR spectrum: Mixture of *cis*- and *trans*-2′-bromostyrene.

We can readily locate the second doublet from the minor, cis isomer by examining the ^{1}H–^{1}H COSY two-dimensional NMR spectrum (see Chapter 8, NMR discussions and Figure 7.5). The spectrum here is shown at a large vertical scale in order to discern the minor (cis) isomer. By looking below the doublet at 6.42 ppm, a cross-peak can be seen at about 7.1 ppm. Careful inspection reveals that these signals must be slightly upfield from the doublet at 7.1 ppm from the major (trans) isomer. Referring back to the ^{1}H NMR spectrum (Figure 7.4) one can see one peak of the hidden doublet just emerging from the upfield end of the doublet from the major isomer. Thus, the second doublet from the minor (cis) isomer must coincidentally be obscured by the NMR signal from the major isomer.

PART B Conditions: Acetone Solvent

Reagents and Equipment. Weigh and place 300 mg (0.97 mmol) of *erythro*-2,3-dibromo-3-phenylpropanoic acid (prepared in Experiment [D2]) and 300 mg (2.1 mmol) of potassium carbonate in a 10-mL round-bottom flask containing a magnetic stir bar. Add 5 mL of acetone that has been dried over sodium sulfate. Attach the flask to a reflux condenser and assemble the apparatus on an 80 °C sand bath.

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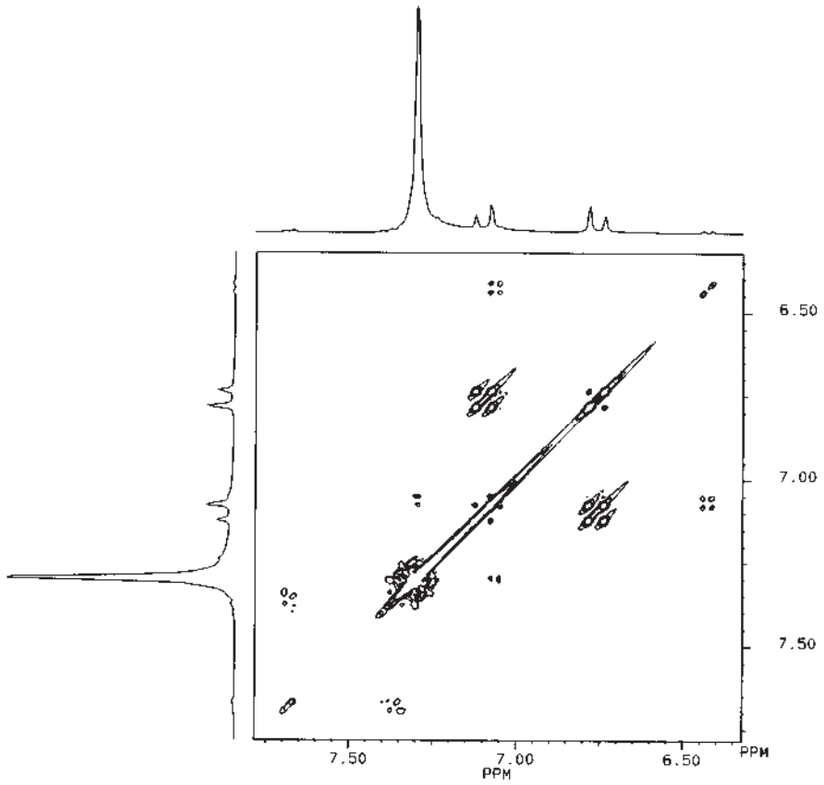

Figure 7.5 **^{1}H–^{1}H COSY NMR spectrum: Mixture of *cis*- and *trans*-2′-bromostyrene.**

Reaction Conditions. Heat (bath temperature ~80 °C) the mixture, with stirring, at reflux for 1 h.

Isolation of Product. Allow the solution to cool to room temperature and HOOD then concentrate it to dryness in the **hood** on a warm sand bath under a gentle stream of nitrogen gas. **Do not overheat!**

Now add 5 mL of distilled water to dissolve the solid cake. A yellow oil appears at this point, forming a two-phase system. Using a Pasteur pipet, transfer this aqueous–oily mixture to a 12-mL centrifuge tube. Rinse the round-bottom flask with a 2-mL portion of methylene chloride, which is then transferred to the centrifuge tube. Extract the aqueous phase with the CH_2Cl_2 rinse and follow this extraction with two more extractions of the aqueous phase with 2-mL portions of methylene chlo-ride. Transfer the organic extracts to a second 25-mL Erlenmeyer flask using a Pasteur filter pipet and dry the combined extracts over anhydrous sodium sulfate for at least 10 min.

Transfer the dried solution in 2- to 3-mL portions to a *tared* 5-mL coni- HOOD cal vial containing a boiling stone. Concentrate the solution in the **hood** on a *warm* sand bath under a gentle stream of nitrogen gas. Rinse the sodium sulfate with an additional 1 mL of methylene chloride and combine this rinse with the dried solution. Concentrate to yield a yellow oil, *cis*-2′-bromostyrene.

NOTE. Exercise care during the concentration steps. Product yield will be greatly reduced by overheating or leaving the solution on the sand bath for too long a period.

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Purification and Characterization. No further purification of the product is usually necessary. Weigh the product and calculate the crude percent yield. Obtain IR and ^{1}H NMR spectra of the oil. In the NMR, the peaks due to both isomers, if present, can be discerned (see Discussion, Part A). Compare your IR and NMR results with the spectra obtained for the cis–trans mixture formed in Part A and to those recorded in the Corvari et al. reference (see Bibliography) for pure *cis*-2′-bromostyrene. This reference also gives conditions under which the purity of the material may be more carefully determined by gas chromatography.

Chemical Tests. Several tests can be run to determine the presence of unsaturation, aromatic character, and the presence of bromine. Select the appropriate tests from Chapter 9. Do your results confirm the presence of these groups?

QUESTIONS

7-71. 1-Chloro-1-phenylethane ionizes easily under E1 conditions to form a benzylic carbocation intermediate. The ion is stabilized due to the delocalization of the positive charge to the aromatic ring. Draw resonance structures that indicate the stability of this ion.

7-72. Comment on the fact that *erythro*-2,3-dibromo-3-phenylpropanoic acid undergoes elimination by an E1 pathway in water solvent (Part A conditions), but by an E2 pathway (Part B conditions) when acetone is used as the solvent.

7-73. Explain in terms of the mechanism why conditions in Part A lead to a mixture of cis–trans isomers but that those used in Part B give only the cis isomer.

7-74. A benzylic carbocation is generated under the conditions of Part A. Would the presence of a para CH_3O— group on the benzene ring increase or decrease the stability of the benzylic carbocation? Explain.

7-75. Consider the stereochemistry of the carbocation intermediate formed under the conditions of Part A. Because the starting material used in this experiment, *erythro*-2,3-dibromo-3-phenylpropanoic acid, is racemic, the enantiomer of the carbocation shown must also be generated. Does the other enantiomer lead to the same diastereomer (cis) of the product or does it lead to the trans diastereomer?

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The synthesis of 2′-bromostyrene has been reported:

Corvari, L.; McKee, J. R.; Zanger, M. *J. Chem. Educ.* **1991,** *68,* 161.
Cristol, S. J.; Norris, W. P. *J. Am. Chem. Soc.* **1953,** *75,* 2645.
Grovenstein, E., Jr.; Lee, D. E. *J. Am. Chem. Soc.* **1953,** *75,* 2639.
L'abbé, G.; Miller, M. J.; Hassner, A. *Chem. Ind. (London)* **1970,** 1321.
Mestdagh, H.; Puechberty, A. *J. Chem. Educ.* **1991,** *68,* 515.
Murahashi, S.; Naota, T.; Tanigawa, Y. *Organic Syntheses;* Wiley: New York, 1990; Collect.Vol.VII, p. 172.
Strom, L. A.; Anderson, J. R.; Gandler, J. R. *J. Chem. Educ.* **1992,** *69,* 588.

For an overview of elimination reactions see

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 17, p. 1477 and references therein.

SEQUENCE E

The Synthesis of Piperonylonitrile from Piperonyl Alcohol

Purpose. The aromatic nitrile, piperonylonitrile, is obtained via a multistep synthesis that does not depend on potentially dangerous diazonium intermediates. The selective oxidation of a primary alcohol to an aldehyde is investigated. You will explore, at the same time, the use of resin-bound reagents that simplify the isolation of products. You will carry out a novel elimination reaction using an oxime to obtain the target nitrile.

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Synthetic Perfumes

The first step in this sequence of reactions is the oxidation of piperonyl alcohol to obtain piperonal, an aromatic aldehyde. The reaction is selective and only the aldehyde is obtained; no oxidation to the carboxylic acid is observed:

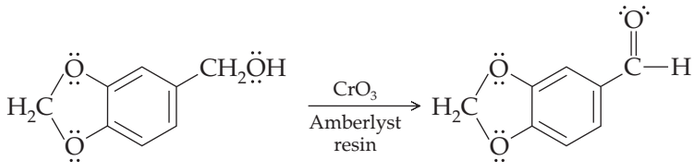

Piperonyl alcohol Piperonal

Piperonal has an agreeable odor and is marketed to the perfume industry as *heliotropine*. This commercial term comes from *heliotrope*, which was a name given by early herbalists to any plant that turned to the sun (from the Greek *helios,* the sun, and *trepein,* to turn), such as the sunflower. The name now is more narrowly defined as applying to those plants of the genus *Heliotropium* and specifically to *H. peruvianum*, a common species that is widely cultivated. The fragrance of this particular species also is referred to as *heliotrope.* Since piperonal possesses a very similar fragrance, the origin of the commercial terminology is clear. The commercial source of piperonal, however, is safrole, the formaldehyde ketal (acetal) of 3,4-dihydroxyallylbenzene. Safrole is the chief constituent of the oil of sassafras and is itself obtained commercially from oil of camphor. When safrole is heated in the presence of a strong base, isomerization of the side-chain double bond yields isosafrole. Subsequent oxidation of the isomerized double bond yields piperonal. For more detailed discussions of odor–fragrance molecules and their role in living systems see Sequence D and Experiment [11C].

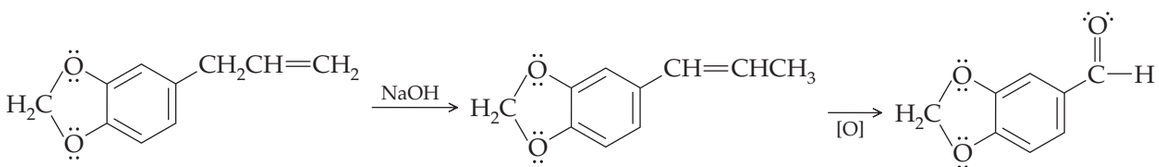

Safrole Isosafrole (cis and trans) Piperonal

The second step of the sequence is the conversion of the intermediate aldehyde to a substituted oxime. By design, the oxime intermediate is constructed with a good leaving group as the oxygen substituent on the nitrogen atom. The second stage, therefore, creates a molecular system prone to undergo the subsequent desired elimination reaction:

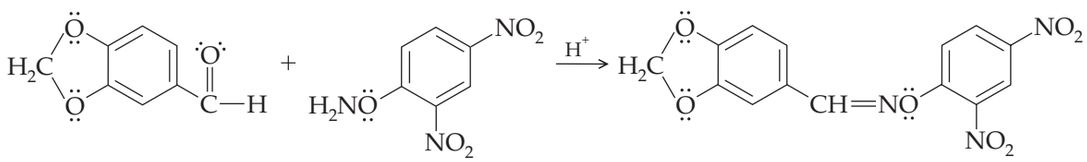

Piperonal *O*-(2,4-Dinitrophenyl)-hydroxylamine Piperonal *O*-(2,4-dinitrophenyl)oxime (an aldoxime)

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Treatment of the oxime intermediate with alcoholic KOH causes an elimination reaction that yields the target nitrile product, piperonylonitrile:

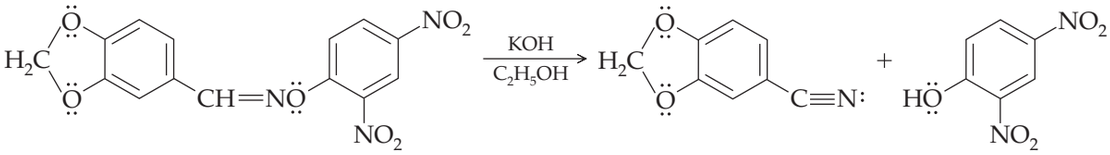

Piperonal *O*-(2,4-dinitrophenyl)oxime (an aldoxime) | Piperonylonitrile | 2,4-Dinitrophenol

The present synthetic sequence offers an alternative approach to the preparation of aromatic nitriles. The classic route to this class of compounds is to use the Sandmeyer reaction. The key steps in this latter pathway involve the diazotization of an aromatic amine followed by reaction of the diazonium salt, which is not isolated (it is explosive!), with CuCN to give the aromatic nitrile directly. Aromatic halides (Br or Cl) may also be prepared in this manner using the corresponding copper(I) halides, as shown here:

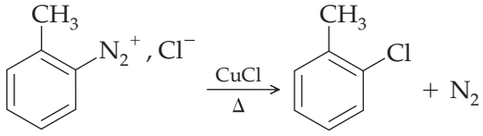

Piperonal

Experiment E1

Common names: piperonal, 3,4-(methylenedioxy)benzaldehyde
CA number: [120-57-0]
CA name as indexed: 1,3-benzodioxole-5-carboxaldehyde

Purpose. The selective oxidation of a primary (1°) alcohol to an aldehyde is investigated. The use of polymer-bound chromium trioxide as an oxidizing agent is explored. You will prepare the intermediate aldehyde, piperonal, as the first step in the sequence to synthesize piperonylonitrile.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Concentration of Solutions (pp. 101–104)

REACTION

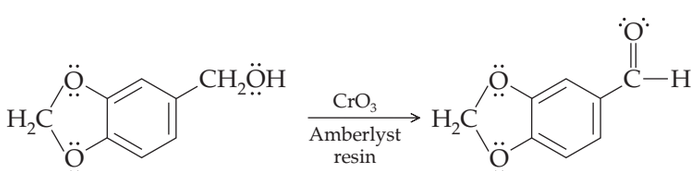

Piperonyl alcohol | Piperonal

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DISCUSSION

Many of the preferred reagents for the oxidation of primary alcohols to aldehydes (secondary alcohols to ketones) contain the transition metal chromium in its highest oxidation state, VI. Upon reaction with an alcohol, the yellow-orange chromium(VI) species is reduced to the blue-green chromium(III) state. Normally the reaction is carried out in aqueous acid solution using the sodium dichromate salt, $Na_2Cr_2O_7$, or the oxide, CrO_3. A typical reaction is shown here:

$$3\ CH_3CH_2CH_2OH + 4\ H_2SO_4 + Na_2Cr_2O_7 \longrightarrow 3\ CH_3CH_2CHO + Cr_2(SO_4)_3 + Na_2SO_4 + 7\ H_2O$$

In this case, the aldehyde, propanal, can be isolated in moderate yield because it is relatively volatile and can be removed from the reaction mixture by distillation as it is formed. If not removed, the aldehyde, which is in equilibrium with the corresponding hydrate (geminal diol), is oxidized further to the carboxylic acid:

$$\underset{\text{1-Propanol}}{CH_3CH_2CH_2OH} \xrightarrow[H_2SO_4]{Na_2Cr_2O_7} \underset{\text{Propanal}}{CH_3CH_2CHO} \overset{H_2O}{\rightleftharpoons} \underset{\text{1,1-Dihydroxypropane}}{CH_3CH_2CH(OH)_2} \xrightarrow[H_2SO_4]{Na_2Cr_2O_7} \underset{\text{Propanoic acid}}{CH_3CH_2COOH}$$

Because the hydrate is the species oxidized to the acid, oxidation of the aldehyde can largely be prevented by running the oxidation in a nonaqueous medium.

A number of selective oxidizing agents, such as pyridinium chlorochromate, are frequently used for this purpose. With this reagent, the oxidation stops at the aldehyde stage, because the oxidation, as pointed out earlier, is conducted in a nonaqueous solution. Thus, decanal can be obtained from 1-decanol using this reagent (methylene chloride solvent) in 92% yield. Pyridinium chlorochromate (PCC) is a solid, yellow salt prepared from chromium trioxide as shown here:

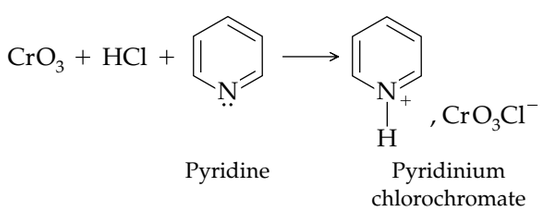

An alternate reagent is the chromium trioxide(pyridine)$_2$ complex, $CrO_3 \cdot (py)_2$ (where py = pyridine), often referred to as the Collins reagent:

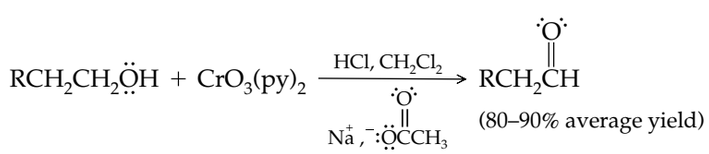

The chief difficulty with this reagent is that the complex is highly hygroscopic. However, it can be prepared in situ, thus avoiding this major drawback. Pyridinium dichromate and chromium trioxide · 3,5-dimethylpyrazole are also effective as selective oxidizing agents for these reactions.

In the present experiment, the selective oxidation of a 1° alcohol to an aldehyde is carried out using a chromium trioxide polymer-bound oxidizing agent. This reagent is also used in Experiment [33A] to oxidize a 2° alcohol to a ketone. As noted there, the reagent is easy to prepare and has the advantage

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that the toxic reduced chromium species is bound to a polymer resin and can thus be easily separated from the reaction mixture by simple filtration.

As shown here, the oxidation proceeds through the formation of a chromate ester. Note that the oxidation state of chromium, Cr(VI), at this stage remains the same as in the starting reagent. The second stage is equivalent to an E2 elimination reaction, with the water molecule acting as a base. The donation of an electron pair to the metal atom changes its oxidation state to Cr(IV):

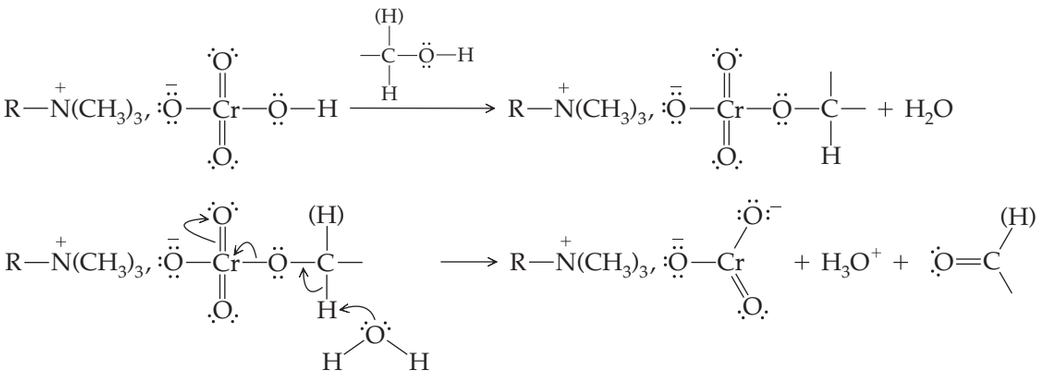

(chromate ester)

(ketone or aldehyde)

NOTE. If you plan to carry out the total sequence of reactions, the scaled-up procedure should be followed. If an individual oxidation reaction is to be studied, the microscale procedure may be used.

EXPERIMENTAL PROCEDURE

Semimicroscale Preparation. (This procedure is scaled up to 10 times the amounts of the microscale preparation.)

Estimated time to complete the experiment: 3.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Piperonyl alcohol	152.16	1.0 g	6.57	58		
Chromic oxide resin		7.5 g				
Dioxane	88.12	10 mL			101	1.034

Reagents and Equipment. Weigh and place 1.0 g (6.57 mmol) of piperonyl alcohol and 7.5 g of freshly prepared chromic oxide resin in a 25-mL round-bottom flask containing a magnetic stirring bar. Using a graduated cylinder in the **hood,** measure and add to the flask 10 mL of dioxane. Attach the flask to a reflux condenser (➡).

CAUTION: Dioxane is a cancer suspect agent. It should be dispensed and handled in the **hood.** That is, the entire experiment should be set up and run in the **hood,** at least until the solvent is removed.

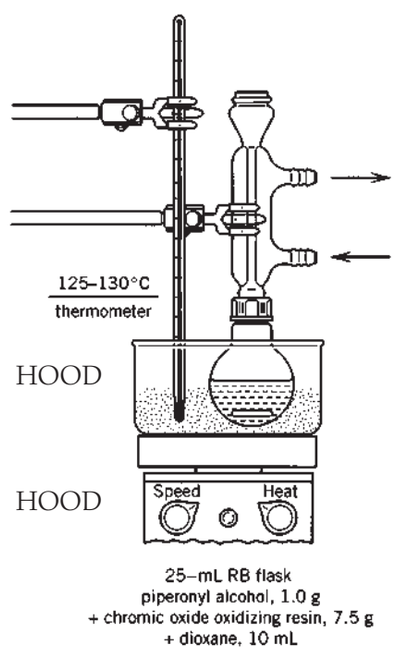

25–mL RB flask
piperonyl alcohol, 1.0 g
+ chromic oxide oxidizing resin, 7.5 g
+ dioxane, 10 mL

INSTRUCTOR PREPARATION. The CrO_3 resin is prepared by adding 35 g of Amberlyst A-26 resin to a solution of 15 g of CrO_3 in 100 mL of water. Stir the mixture

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for 30 min at room temperature. Collect the resin by filtration under reduced pressure and successively rinse the material with water and acetone. Partially dry the resin on a Büchner funnel by drawing air through it for 1 h, then air-dry the material overnight.

Reaction Conditions. With stirring, heat the reaction mixture at reflux in the **hood** for a period of 1.0 h using a sand bath temperature of 125–130 °C.

HOOD

Isolation of Product. Cool the reaction product to room temperature. Transfer the solution by Pasteur filter pipet to a funnel fitted with fast-grade filter paper. Collect the filtrate in a 25-mL Erlenmeyer flask containing approximately 1 g of anhydrous sodium sulfate. Rinse the reaction flask and resin (include the walls of the condenser) with three 1.0-mL portions of methylene chloride solvent (calibrated Pasteur pipet). Transfer each rinse by Pasteur filter pipet to the funnel. Combine each rinse filtrate with the original filtrate.

Now transfer the solution in three portions by Pasteur filter pipet to a 10-mL round-bottom flask and concentrate the solution following each addition using a rotary evaporator. If a rotary evaporator is not available, transfer the solution to a 25-mL Erlenmeyer flask containing a boiling stone and remove the solvent in the **hood** by warming the flask on a sand bath at 125 °C. A gentle stream of nitrogen aids this concentration process.

HOOD

The crude piperonal is obtained as an oil and is purified by column chromatography.

Purification and Characterization. Preweigh (and number 1–10) ten 25-mL Erlenmeyer flasks containing a boiling stone. Wet-pack a 25-mL buret using hexane and silica gel in the following manner. Place a cotton plug in the buret followed by a 1-in. layer of sand. Add 15 mL of hexane to the column, and then slowly add 8 g of silica gel while tapping the sides of the buret to release any air bubbles. Finally, add an additional 1 in. of sand to the top of the column.

Allow the hexane to drain from the buret until it reaches the top of the sand level in the column. Collect the eluted hexane in a waste container.

Dilute the crude piperonal oil with 5 drops of methylene chloride and then, using a Pasteur filter pipet, add this solution to the top of the column. Again, drain a portion of the elution solvent until the solvent head is level with the sand at the top of the column. Rinse the sides of the column with 0.5 mL of 4:1 methylene chloride/hexane solution, and again drain the column to the same sand level.

Now add, in order, the following amounts of elution solvents: three 10-mL portions of 4:1 methylene chloride/hexane; three 10-mL portions of methylene chloride; and three 10-mL portions of 9:1 methylene chloride/ethyl acetate.

Collect 10-mL fractions in each of the preweighed Erlenmeyer flasks. After collecting fraction No. 9, use flask No. 10 to collect a final fraction as the column completely drains. (Fraction No. 1 can be added directly to the waste container.)

Concentrate each of the collected fractions to dryness on a warm sand bath under a gentle stream of nitrogen gas in the **hood.** Weigh the flasks to determine the total amount of piperonal product. Now preweigh an additional 25-mL Erlenmeyer flask containing a boiling stone. To each of the flasks containing white or light yellow fanlike crystals, add sufficient methylene chloride to just dissolve them and then transfer the resulting solutions to the tared Erlenmeyer flask using a Pasteur filter pipet. Concentrate this final solution as before, and weigh the flask to obtain the total amount of piperonal isolated.

HOOD

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NOTE. If a rotary evaporator is available, the eluate can be concentrated in a 10-mL round-bottom flask. Transfer of each fraction to a single evaporation flask shortens the above procedure.

Determine the melting point of your product and compare your value to that found in the literature. Obtain IR and/or ^{1}H NMR spectra and compare your results to those reported in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

Chemical Tests. Chemical classification data may also be useful. The ignition test, the Tollens test, and the 2,4-dinitrophenylhydrazine test should all give a positive result for the piperonal compound.

NOTE. Approximately 300 mg of purified product with a melting point within 2–4 °C of the literature value is suggested for continuing the sequence on to Experiment [E2].

OPTIONAL MICROSCALE PREPARATION

The microscale preparation is similar to that of the scaled-up synthesis outlined above, with the following exceptions.

*NOTE. Even in the case of the microscale preparation this reaction should be **entirely** carried out in the **hood** at all times until the dioxane solvent has been removed.* HOOD

1. The reagent and solvent amounts are one-tenth of those used above.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)
Piperonyl alcohol	152.16	100 mg	0.66	58	
Chromic oxide resin		750 mg			
Dioxane	88.12	1.0 mL			101

2. A 5-mL round-bottom flask is used.

3. The reaction mixture is heated for 1 h.

4. After the reaction product is cooled to room temperature, transfer the solution by Pasteur filter pipet to a funnel containing a loose cotton plug covered with 500 mg of anhydrous sodium sulfate. Collect the filtrate in a 10-mL Erlenmeyer flask. Rinse the reaction flask and resin (include the walls of the condenser) with three 0.5-mL portions of methylene chloride solvent (calibrated Pasteur pipet). Transfer each rinse by Pasteur filter pipet to the funnel and, finally, rinse the sodium sulfate with an additional 0.1 mL of methylene chloride. Combine each rinse filtrate with the original filtrate. Concentrate the solution as described.

5. Purify the crude oil using chromatography as follows:

(a) Pack a short buret column with approximately 1.75 g of silica gel, and transfer the crude product by Pasteur filter pipet to the column. Rinse

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the flask with 1.0 mL of methylene chloride (calibrated Pasteur pipet) and also transfer the rinse to the column.

(b) Now add methylene chloride to the column, 2.0 mL at a time (calibrated Pasteur pipet), and collect the eluate in three tared 10-mL Erlenmeyer flasks. Set aside the first 4.0 mL of eluate collected in the first flask. Collect the next 6.0 mL in one flask; this fraction contains the bulk of the product. Also collect one additional fraction of 3.0 mL in the third flask.

HOOD **(c)** Concentrate the second fraction (6.0 mL) in the **hood** using a warm sand bath with a slow stream of nitrogen to assist solvent removal. *Do not forget to add a boiling stone to the flask.*

(d) Weigh the flask and contents. Reheat for 1 min, cool, and weigh again. If the two weights are within 2.0 mg, the product is quite pure. If not, repeat the evaporation process until a constant weight is obtained.

(e) Cool the product. If it does not solidify, place it in an ice bath and scratch the sides and bottom with a glass rod to induce crystallization.

A small amount of additional product can be isolated from the third fraction in a like manner.

QUESTIONS

7-76. Primary alcohols can be oxidized to aldehydes and carboxylic acids. Often it is difficult to stop at the aldehyde oxidation state. One method frequently used to accomplish this, for those that boil below about 100 °C is to remove the product from the reaction mixture as it is formed. This method is based on the fact that aldehydes have a lower boiling point than their corresponding alcohols. Explain this difference in boiling point.

7-77. A specific oxidizing agent for the conversion of primary alcohols to aldehydes is pyridinium chlorochromate, abbreviated as $^{+}\text{py} \cdot \text{CrO}_3\text{Cl}^{-}$. Generally, the oxidation is run in methylene chloride solvent. For example,

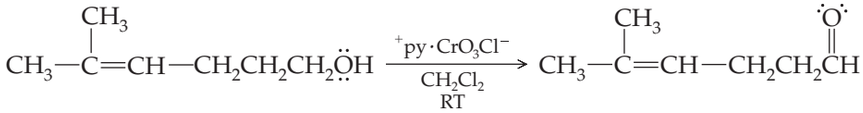

Oxidation of this alcohol with the conventional $Na_2Cr_2O_7$–H_2SO_4–water system produces the carboxylic acid. Offer an explanation for the difference in these results.

7-78. In reference to Question 7-77, can you see another advantage of the pyridine chlorochro-mate reagent over that of the conventional conditions?

7-79. An excellent way to identify the presence of an aldehyde group is by ^{1}H NMR. The chemical shift of the aldehydic proton occurs in the 9- to 10-ppm region, where few other proton signals occur. Why is this chemical shift so far downfield?

7-80. A series of compounds with increasing boiling point is listed below. Offer an explanation for this trend.

(a) Butane (8 °C)
(b) Propanal (56 °C)
(c) 1-Propanol (97 °C)

BIBLIOGRAPHY

The present procedure is based on the work reported by

Cainelli, G.; Cardillo, G.; Orena, M.; Sandri, S. *J. Am. Chem. Soc.* **1978,** *98,* 6737.

Several preparations involving the oxidation of a 1° alcohol to an aldehyde are given in *Organic Syntheses:*

Collins, J. C.; Hess, W. W. *Organic Syntheses;* Wiley: New York, 1988; Collect. Vol. VI, p. 644.

Hurd, C. D.; Meinert, R. N. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 541.

Ratcliffe, R. W. *Organic Syntheses;* Wiley: New York, 1988; Collect. Vol. VI, p. 373.

Also see

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 19, p. 1750 and references therein.

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EQA

Piperonal *O*-(2,4-Dinitrophenyl)oxime

Experiment E2

Common name: piperonal *O*-(2,4-dinitrophenyl)oxime

CA number: [17188-61-3]

CA name as indexed: 1,3-benzodioxole-5-carboxaldehyde, *O*-(2,4-dinitrophenyl)oxime

Purpose. You will carry out the second step in the sequence of synthetic reactions leading to an aromatic nitrile, piperonylonitrile.You will prepare a specific oxime derivative of the aldehyde obtained in Experiment [E1]. This oxime derivative is derivatized on oxygen so as to allow the oxygen to function as a good leaving group, which will allow an elimination reaction to form a nitrile in the final step of the synthetic sequence leading to piperonylonitrile.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

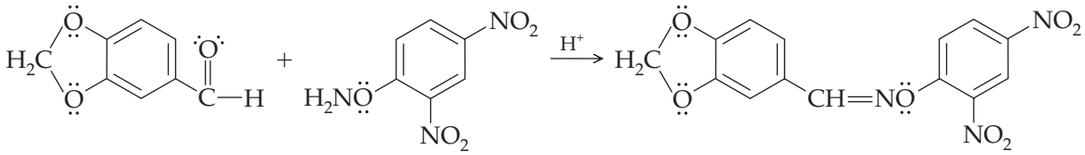

Piperonal | *O*-(2,4-Dinitrophenyl)-hydroxylamine | Piperonal *O*-(2,4-dinitrophenyl)oxime

DISCUSSION

The preparation of this oxime is the second step in this sequence to obtain the aromatic nitrile target molecule. In Experiment [E2] you are going to convert the aromatic aldehyde formed in Experiment [E1] into an *O-phenylated oxime,* which on treatment with base in Experiment [E3] yields the desired nitrile via an elimination reaction. Oxime formation is also involved in the well-known Beckmann rearrangement (see Experiment [6_{adv}]), which is used for the synthesis of amides. ← www

The generation of the oxime intermediate involves a nucleophilic addition of the amine group of the hydroxylamine to the carbonyl carbon, followed by a dehydration to form the carbon–nitrogen double bond (and the oxime group). A general mechanism for the reaction is given here.

The first step is a nucleophilic addition to the carbonyl group. Rapid proton transfer gives an intermediate that generally is not isolated:

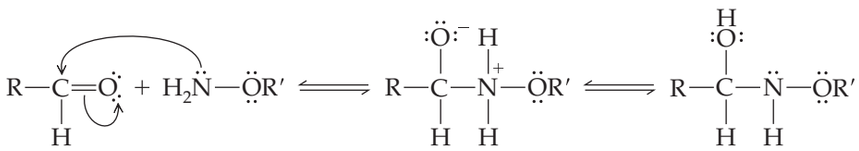

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The next stage is an acid-catalyzed dehydration reaction in which water is eliminated to produce the oxime. This stage has been shown to be the rate-determining step in oxime formation.

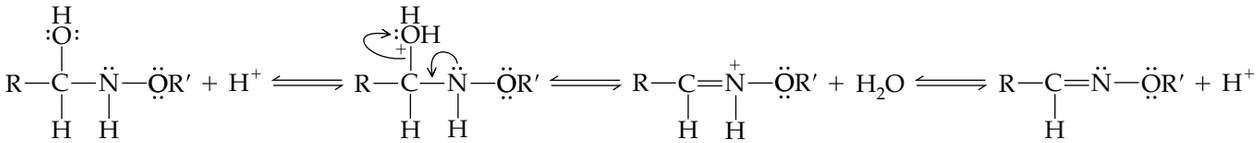

Oxime
(an aldoxime)

NOTE. If you are conducting the total sequence of reactions to obtain piperonylonitrile, follow the scaled-up procedure. If the individual reaction is to be studied, follow the microscale procedure.

EXPERIMENTAL PROCEDURE

Semimicroscale Preparation. (This procedure is scaled up to 10 times the amounts of the microscale preparation.)

Estimated time to complete the experiment: 1 h.

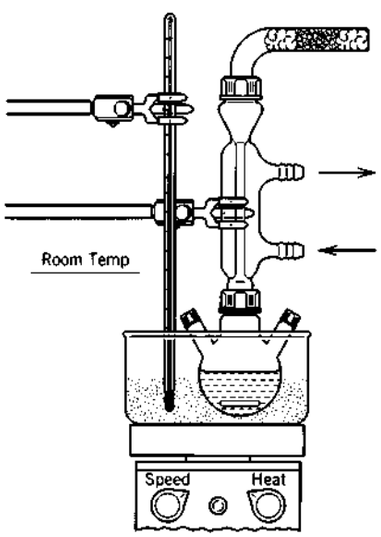

100-mL RB three necked flask containing *O*-(2,4-dinitrophenyl)hydroxylamine, 400 mg + absolute ethanol, 30 mL + piperonal, 300 mg + 12 *M* HCl, 20 mL

Physical Properties of Reactants and Product						
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**	**bp (°C)**	***d***
Piperonal	150.14	300 mg	2.0	37	263	
O-(2,4-Dinitrophenyl) hydroxylamine	199.12	400 mg	2.0	111–112		
Ethanol	46.07	30 mL			78	0.789
HCl (12 M)		2 mL				
Piperonal *O*-(2,4-dinitrophenyl)oxime	330.24			194–195		

Reagents and Equipment. To a 100-mL three-necked round-bottom flask containing a magnetic stir bar and equipped with a reflux condenser protected by a calcium chloride drying tube and two caps or glass stoppers, weigh and place 400 mg (2.0 mmol) of *O*-(2,4-dinitrophenyl)hydroxylamine, followed by 30 mL of absolute ethanol (⬅).

NOTE. The three-necked flask may be replaced with a conventional round-bottom 100-mL flask. In this case, addition of reagents can be carried out in the first instance by removing the condenser and in the second case by addition directly down the condenser with a 9-in. Pasteur pipet.

www → *NOTE. The preparation of O-(2,4-dinitrophenyl)hydroxylamine is described in the Instructor's Manual, which is available from the publisher.*

Attach the flask to the condenser and warm (60–65 °C) the contents, with stirring, in a sand bath until a homogeneous solution is obtained. Now add 300 mg (0.2 mmol) of piperonal via one of the unused flask necks. After the aldehyde has dissolved, add slowly, with stirring, 2 mL of 12 M HCl through

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an unused flask neck using a Pasteur pipet. Stir the reaction mixture for an additional 1 min after the addition is complete.

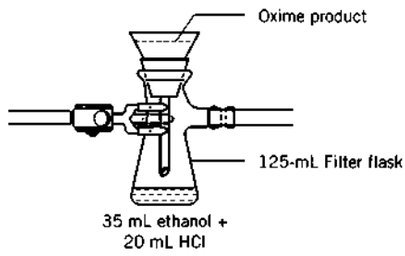

Reaction Conditions. The oxime forms immediately. Complete the precipitation of the product by cooling the reaction flask in an ice bath for 10 min.

Isolation of Product. Collect the solid product by filtration under reduced pressure using a Hirsch funnel. Rinse the flask with two 3-mL portions of cold absolute ethanol, using the rinse to wash the crystals on the filter funnel. Now rinse the crystals with three additional 3-mL portions of cold absolute ethanol (➡).

NOTE. Approximately 50–70 mg of purified product with a melting point within 2–4 °C of the literature value is the minimum quantity and quality suggested for continuing the sequence in Experiment [E3].

Air-dry the product on a clay plate or on filter paper. Collect and refrigerate the filtrate for at least 24 h. This procedure generally produces another crop of oxime crystals. This second crop, collected by the same technique, may be combined with the initial product, if its melting point is above 180 °C.

Purification and Characterization. Determine the melting point of the oxime. It is of sufficient purity to proceed with the next step of the sequence if its mp is 187 °C or greater. If necessary, recrystallize the material from acetic acid or hot acetone.

Obtain an IR spectrum of the oxime and compare it with that of the reference standard shown in Figure 7.6.

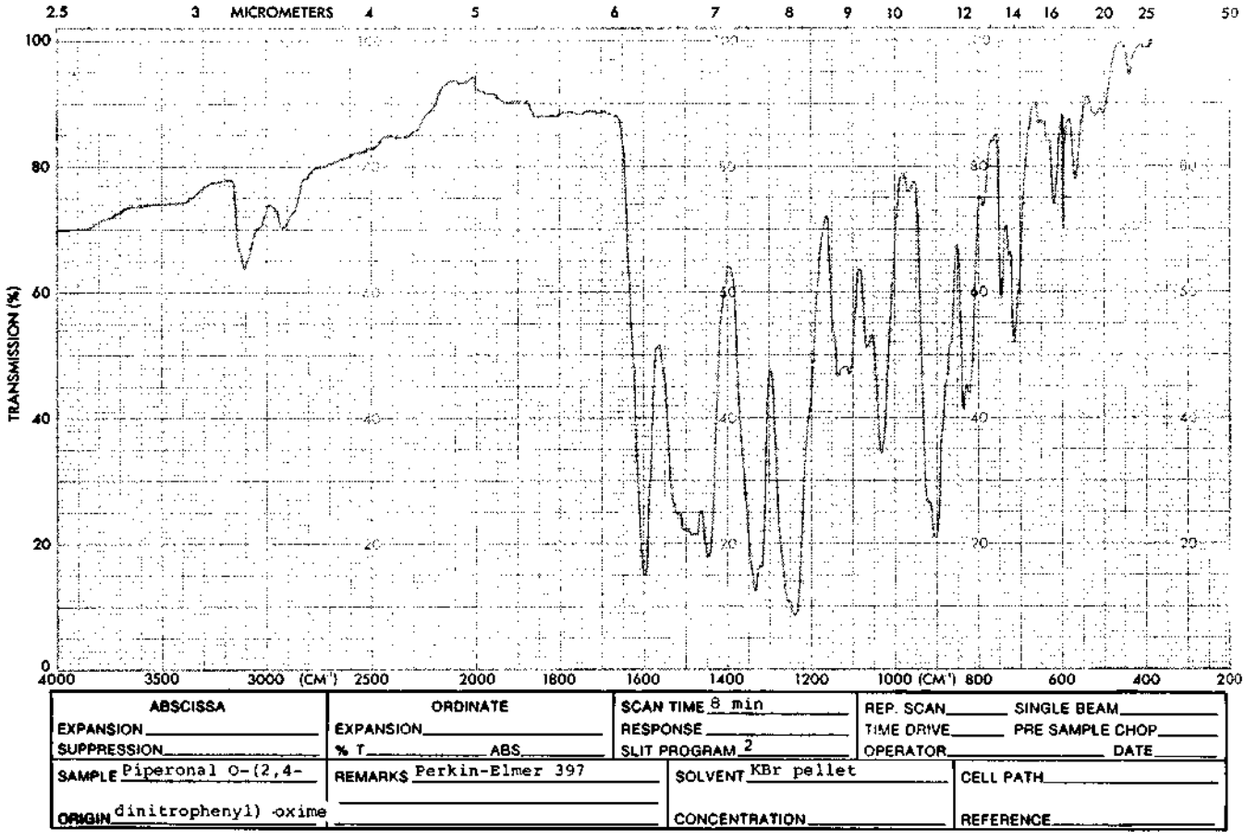

Figure 7.6 IR spectrum: piperonal *O*-(2,4-dinitrophenyl)oxime.

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OPTIONAL MICROSCALE PREPARATION

The microscale preparation is similar to that of the scaled-up synthesis outlined above, with the following exceptions:

1. The reagent and solvent amounts are one-tenth of those used above.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Piperonal	150.14	30 mg	0.2	37	263	
O-(2,4-Dinitrophenyl)hydroxylamine	199.12	40 mg	0.2	111–112		
Ethanol	46.07	3.0 mL			78	0.789
HCl (12 M)		2 drops				
Piperonal *O*-(2,4-dinitrophenyl)oxime	330.24			194–195		

2. A 5-mL conical vial is used.

3. The hydrochloric acid is added dropwise through the top of the condenser using a 9-in. Pasteur pipet, after removing the drying tube. As the acid is delivered, the tip of the pipet should be held just above the surface of the solution. The drying tube is then reattached, and the contents are mixed by swirling the flask.

QUESTIONS

7-81. Referring to the first step in the mechanism of oxime formation outlined in the discussion section, offer an explanation of why a high acid concentration would hinder the formation of the intermediate generated in this first stage.

7-82. Oximes prepared from aldehydes or ketones by reaction with hydroxylamine can be reduced to primary amines in high yields. One can use various reagents for the reduction step, including Ni–H_2 in methanol or $LiAlH_4$ in ether. Using a reduction reaction, carry out the following transformations:

(a) 3-Pentanone to 3-aminopentane

(b) Propanal to 1-aminopropane

(c) Benzaldehyde to benzylamine

7-83. Oximes prepared from unsymmetrical ketones are likely to exist as mixtures of geometrical isomers. For example,

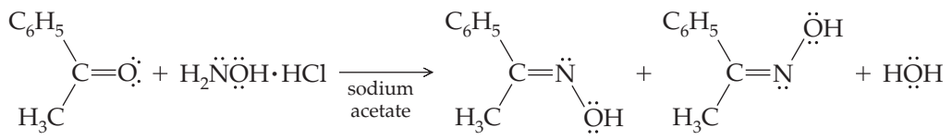

(*E*)- and (*Z*)-isomeric oximes

Which isomer is designated as *E*? How do you account for both of these isomers being formed?

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For the preparation of oximes using hydroxylamine hydrochloride as the reagent see

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Hach, C. C.; Banks, C.V.; Diehl, H. *Organic Syntheses;* Wiley: New York, 1963, Collect. Vol. IV, p. 229.

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Semon, W. W.; Damerell, V. R. *Organic Syntheses;* Wiley: New York, 1943, Collect. Vol. II, p. 204.

Smith, M. B.; March, J. *Advanced Organic Chemistry*, 6th ed., Wiley: New York, 2007, Chap. 16, p. 1286 and references therein.

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EQA

Piperonylonitrile

Experiment E3

Common names: piperonylonitrile, 3,4-methylenedioxybenzonitrile
CA number: [4421-09-4]
CA name as indexed: 1,3-benzodioxole-5-carbonitrile

Purpose. The piperonal *O*-(2,4-dinitrophenyl)oxime intermediate, prepared in the previous experiment (Experiment [E2]), is converted into the target molecule, piperonylonitrile. This completes the set of Sequence E reactions for the conversion of a substituted benzyl alcohol into an aromatic nitrile. You will investigate the use of a novel elimination reaction to convert an oxime derivative to a nitrile.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 6: Chromatography
Column Chromatography (pp. 92–95)
Concentration of Solutions (pp. 101–104)

REACTION

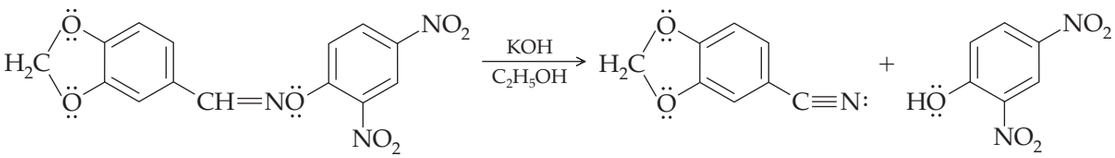

Piperonal *O*-(2,4-dinitrophenyl)oxime — Piperonylonitrile — 2,4-Dinitrophenol

DISCUSSION

The Sequence E reactions illustrate the oxidation of a benzylic alcohol to its corresponding aldehyde and the subsequent two-step conversion of this aldehyde via an intermediate aldoxime to an aromatic nitrile. This synthetic route is an attractive alternative to the preparation of aromatic nitriles via the Sandmeyer reaction.

Aromatic nitriles are usually prepared by the diazotization of the corresponding aromatic amine followed by treatment of the diazonium salt with copper(I) cyanide. This sequence is an example of the Sandmeyer reaction, a specific example of which is shown here:

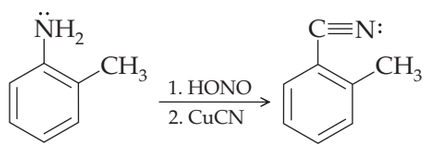

(64–70%)

This particular variation of the Sandmeyer reaction is useful because it allows the conversion of an aromatic amine, readily available by reduction of the corresponding nitro compound, to a reactive carbon substituent. This substitution involves replacement of the C—N bond with a C—C bond.

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In the present reaction, treatment of an *O*-phenylated oxime with base yields the nitrile by an elimination reaction. The role of the dinitrophenyl group is to enhance the oxime oxygen to function as a good leaving group. Thus, the phenoxy system departs as the conjugate base of the relatively acidic 2,4-dinitrophenol. The mechanistic sequence is outlined below:

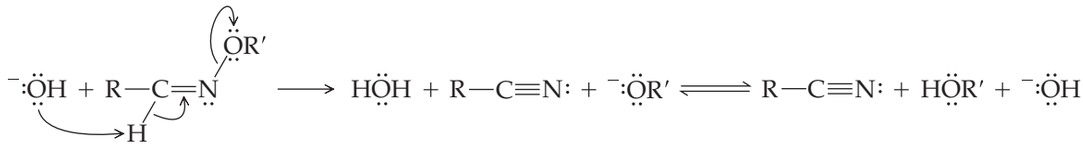

Oximes derived from aldehydes (aldoximes) can be dehydrated to nitriles by many different dehydrating reagents; acetic anhydride is one of the most common reagents used:

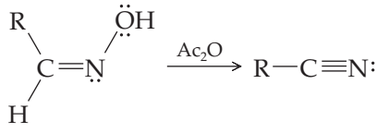

The reaction proceeds more rapidly when the hydrogen and the hydroxyl group are trans to one another (see also Experiments [10], [D3], and [$A3_b$]). Various derivatives of the hydroxylamine other than the ethers, RCH═NOR, illustrated in the present reaction, also undergo the conversion to nitriles. Among these are the RCH═NOCOR and RCH═$NOSO_2Ar$ compounds. In some cases it is also possible to convert aldehydes to nitriles in one step by refluxing the reagents in concentrated hydrochloric acid (or by reaction with sodium formate in formic acid or sodium acetate in acetic acid) as follows:

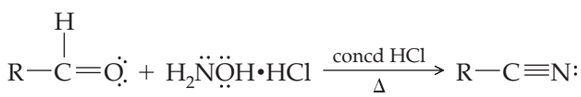

When oximes are treated with strong acid they are converted to amides by a rearrangement sequence known as the Beckmann rearrangement. This reaction is illustrated in Experiment [6_{adv}].

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Nitriles are synthetically versatile functional groups because they are readily converted to carboxylic acids by hydrolysis under acidic or basic conditions, reduced with $LiAlH_4$ to form primary amines, and reaction with Grignard reagents leads to the formation of ketones. These reactions are illustrated here:

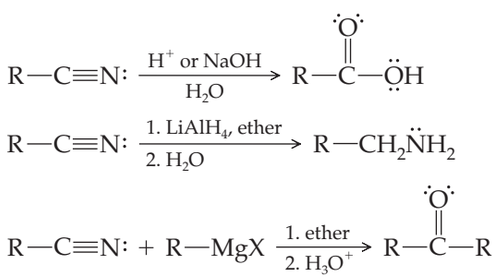

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants and Product						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Piperonal *O*-(2,4-dinitrophenyl)oxime	330.24	50 mg	0.15	194–195		
Ethanol		5 mL			78.5	0.789
Potassium hydroxide (0.2 M)		2 mL				
Piperonylonitrile	147.13			92–93		

Reagents and Equipment. Weigh and place 50 mg (0.15 mmol) of piperonal *O*-(2,4-dinitrophenyl)oxime in a 10-mL round-bottom flask containing a magnetic stir bar. Now add 5.0 mL of 95% ethanol and 2.0 mL of 0.2 M ethanolic KOH. Attach the flask to a reflux condenser (➨).

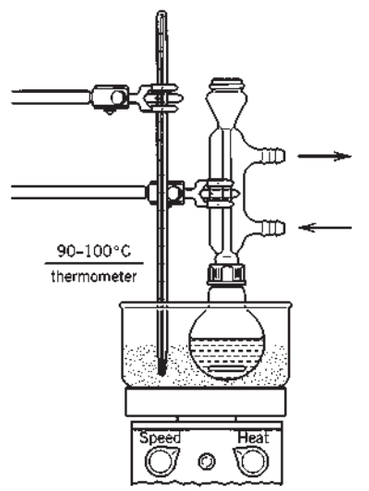

Piperonal *O*-(2,4-dinitrophenyl)oxime, 50 mg + 95% ethanol, 5.0 mL + 0.2 *N* ethanolic KOH, 2.0 mL 10 mL RB flask

NOTE. The oxime is prepared in Experiment [E2]. The 0.2 M ethanolic KOH is prepared using 95% ethanol.

Reaction Conditions. Slowly heat the reaction mixture, while stirring, to reflux by use of a sand bath (100–110 °C) and maintain the mixture at this temperature (gentle reflux) for 1 h. During the initial warming period, the solution turns a deep yellow.

NOTE. If the laboratory time is not sufficient to continue the isolation and purification of the product after the heating is terminated, cool the solution and remove the reaction vial. Cap the vial and store it until the next laboratory period.

Isolation of Product. Remove the reaction flask and concentrate the reaction mixture to a volume of 0.5 mL or less with a gentle stream of nitrogen gas and/or warming in a sand bath in the **hood.** *This concentration process takes a considerable length of time.* HOOD

Now prepare an alkaline solution by diluting 1 mL of 5% aqueous NaOH with 5 mL of distilled water. Use this solution to transfer the concentrated reaction mixture to a 12-mL centrifuge tube in the following manner.

Add a 2-mL portion of the alkaline solution to the reaction flask, mix by swirling, and then transfer the resulting suspension to the centrifuge tube using a Pasteur pipet. Repeat this operation twice, using 2 mL of the alkaline solution each time.

Extract the resulting suspension with four 2-mL portions of methylene chloride (calibrated Pasteur pipet). Remove the methylene chloride extract (bottom layer) using a Pasteur filter pipet, and place the combined fractions in a 25-mL Erlenmeyer flask. Dry the solution over granular anhydrous sodium sulfate (0.5 g).

By use of a Pasteur filter pipet, transfer the dried solution to a second 25-mL Erlenmeyer flask containing a boiling stone. Rinse the drying agent with two 1-mL portions of methylene chloride. Combine the rinses with the original solution. Remove the solvent in the **hood** under a gentle stream of nitrogen and/or by warming in a sand bath to obtain the crude piperonylonitrile. HOOD

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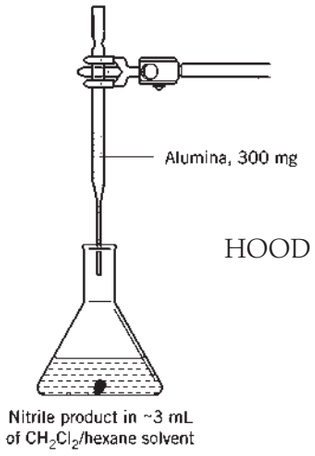

Purification and Characterization. Purify the crude product by column chromatography using a Pasteur filter pipet filled with 300 mg of alumina (neutral, activity 1, see Glossary). Wet the column with 1.0 mL of 1:1 methylene chloride/hexane solution.

Dissolve the residue of crude nitrile in a minimum amount of 1:1 methylene chloride/hexane solvent, and transfer the resulting solution by Pasteur pipet to the column. Elute the nitrile from the column with 2.0 mL of the 1:1 CH_2Cl_2/hexane solvent and collect the eluate in a 10-mL Erlenmeyer flask containing a boiling stone (⬅).

Evaporate the solvent under a gentle stream of nitrogen while warming in a sand bath in the **hood.** Dry the white needles of piperonylonitrile on a porous clay plate or on filter paper.

Weigh the product and calculate the percent yield. Determine the melting point and compare it with the literature value.

Obtain an IR spectrum and ^{1}H NMR spectra of the sample and compare your results with those in the literature (*The Aldrich Library of IR Spectra, The Aldrich Library of NMR Spectra,* and/or the corresponding spectral data available online (e.g., SciFinder Scholar)).

QUESTIONS

7-84. The Sandmeyer reaction is based on the replacement of the diazonium group in aryldiazonium salts by chloro, bromo, or cyano groups. Copper salt reagents are used:

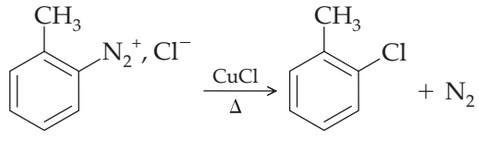

Show how one could carry out the following transformations using the Sandmeyer reaction:

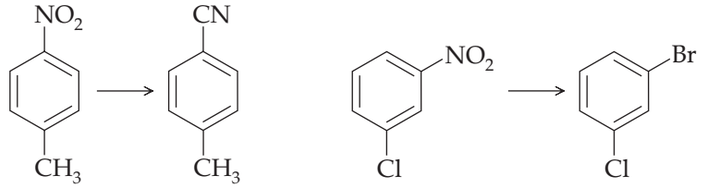

7-85. When CuCN is used in the Sandmeyer reaction, the preparation is generally carried out in a neutral medium. Can you offer an explanation of why this is done?

7-86. Outline a synthetic route for the preparation of nitriles using a carboxylic acid as the starting material.

7-87. A yellow azo dye once used to color margarine has been outlawed because it is carcinogenic. Outline a synthesis of this dye, butter yellow, starting from benzene and *N,N*-dimethylaniline:

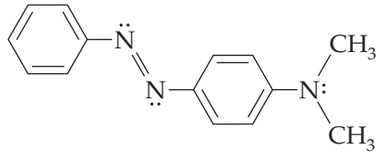

Butter Yellow

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The procedure outlined above for the preparation of piperonylonitrile is based on the work of

Miller, M. J.; Loudon, G. M. *J. Org. Chem.* **1975,** *40*, 126.

Several examples of the conversion of an aromatic aldehyde to the corresponding nitrile are given in *Organic Syntheses:*

Back, J. S.; Ide, W. S. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 622.

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Clarke, H. T.; Nagy, S. M. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 690.

For a one-step conversion of aromatic aldehydes to the corresponding nitrile see

DeMott, J. M. Jr.; Kelley, C. J. *J. Chem. Educ*. **2001,** *78*, 780. This procedure works for the conversion of the present experiment as verified by DeMott, J. M., Jr. (Massachusetts College of Pharmacy and Allied Health, Boston), private communication.

There are numerous references to the use of the Sandmeyer reaction in *Organic Syntheses*. Several are cited here:

Bigelow, L. A. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, pp. 135, 136.

Cleland, G. H. *Organic Syntheses;* Wiley: New York, 1988; Collect. Vol. VI, p. 21.

Grundstone, F. D.; Tucker, S. H. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 160.

Hartwell, J. L. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 185.

Marvel, C. S. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 170.

Rutherford, K. G.; Redmond, W. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 133.

Smith, M. B.; March, J. *Advanced Organic Chemistry*, 6th ed., Wiley: New York, 2007, Chap. 14, p. 984 and references therein.

SEQUENCE F

Introduction to Photochromism: The Synthesis of a Photochromic Imine

The photochromic effect is a property of relative rarity in both organic and inorganic molecular structures. When it is present, a material is found to exhibit reversible color change upon exposure to radiation:

$$\text{Photochromic Substance A} \underset{\Delta \text{ or } h\nu_B}{\overset{h\nu_A}{\rightleftharpoons}} \text{Photochromic Substance B}$$

The photoproduct generally reverts to the initial system via thermal pathways, but there are examples where the reverse reaction is induced by radiation of a different wavelength from that driving the forward reaction, or by both thermal and photochemical processes. Generally, sensitivity to thermal effects controls the concentrations obtained from the forward reactions and, therefore, their effectiveness in producing the product.

CLASSES OF PHOTOCHROMIC REACTIONS

Cis–Trans Isomerizations. Experiment [6] studies the photochromic properties of *trans*-dibenzoylethylene. In this case, the highly conjugated bright-yellow trans diastereomer is rapidly isomerized under intense sunlamp visible radiation, via excited electronic states, to the colorless cis alkene. A π electron is promoted to an anti-bonding π^* molecular orbital, which destroys the π bond, and thus permits facile rotation about the remaining σ bond and formation of the cis alkene:

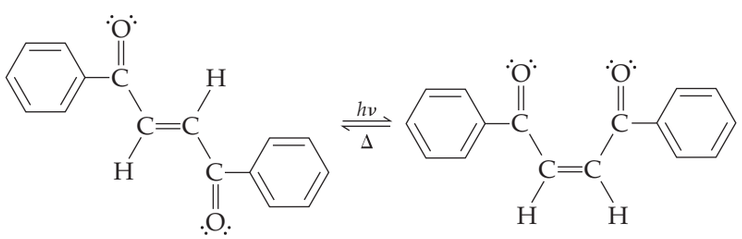

trans-1,2-Dibenzoylethylene (bright yellow)

cis-1,2-Dibenzoylethylene (colorless)

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This is an endothermic reaction that does not reach equilibrium, but goes to completion because the cis isomer's electronic transitions are shifted to the ultraviolet and do not absorb visible radiation. The cis alkene is a structurally shorter chromophore than its trans isomer, and it is also likely to experience steric crowding with resultant distortion of the π system. The cis isomer, therefore, absorbs at shorter wavelengths (higher energies) and has a lower molecular extinction coefficient (weaker) than the trans isomer. Thus, once formed, the cis isomer is trapped. Upon heating, however, the cis isomer undergoes exothermic isomerization back to the original, more stable, trans alkene under equilibrium conditions.

A good example of photochromic behavior is the highly colored *cis*- and *trans*-azobenzene. In this case the $\pi \rightarrow \pi^*$ transition is promoted by ultraviolet light so that nonequilibrium isomerization to the cis isomer requires UV irradiation. The cis isomer is considerably less stable, however, and it undergoes relatively easy reversion back to the trans isomer by other mechanisms (the thermal conversion of visible radiation absorbed by the colored cis compound is an additional isomerization route apparently open to the cis isomer):

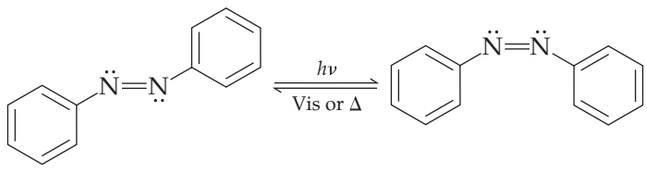

trans-Azobenzene *cis*-Azobenzene

Tautomerism. A number of proton and valence tautomers are subject to photo-chemical induction. One example is 2-methylbenzophenone (**I**), a colorless compound that can be photochemically induced to tautomerize to a system with extended conjugation. The tautomer (**II**) is a yellow material that will revert to the colorless form under thermal conditions:

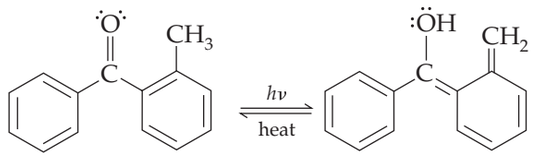

I
2-Methylbenzophenone
(colorless)

II
(enol, yellow)

Homolysis and Heterolysis of Bonds. Photochromic homolysis has been observed with materials such as 2,3,4,4-tetrachloro-1-(4*H*)-naphthalenone (**III**):

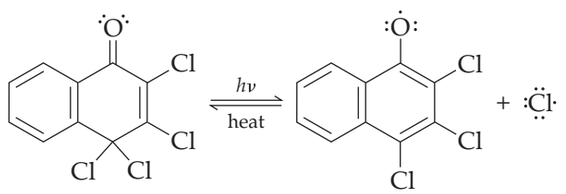

III
(colorless)

(violet)

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Excitation leading to heterolysis and zwitterion formation has been observed in numerous spiropyrans, as shown here for **IV**. These compounds undergo ring opening to yield a zwitterion (**V**):

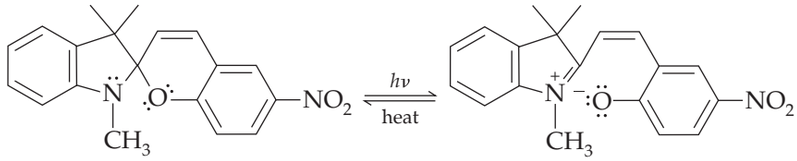

IV
(colorless)

V
(violet)

The spiropyran example in which the photochromism develops following the transformation of a colorless isomer to a violet system is closely related to the structural isomerism observed in the target photochromic substance, a diazabicyclo[3.1.0]hex-3-ene (**VI**) synthesized in Sequence F. In both instances, the photoisomerization involves heterocyclic ring opening with formation of zwitterion **VII**:

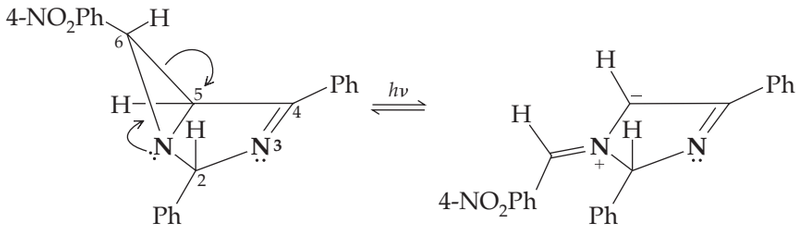

VI
2-*exo*-6-*exo*-2,4-Diphenyl-
6-(4-nitrophenyl)-
1,3-diazabicyclo[3.1.0]hex-3-ene

VII
Blue azomethine–ylide
(syn configuration)

The diazabicyclo[3.1.0]hexenes form a series of compounds of which many exhibit photochromic properties.

APPLICATIONS OF PHOTOCHROMISM

One successful application of inorganic photochromic systems has been in the manufacture of sunglasses. When a particular silver salt is incorporated in the lenses, the glass will darken on exposure to sunlight in order to protect the eyes, but then bleach quickly when the light intensity drops, so that the same glasses can be used at night or indoors.

The cis–trans isomerism of azobenzene has been incorporated in a novel chemical method for information storage at ultrahigh densities with nondestructive readout. A device based on this chemical information storage system would have, it is estimated, the capacity of 100 million bits per square centimeter.

There also have been some investigations by the military directed toward developing camouflage "photochromic paints."

In most applications the ability of the system to undergo essentially endless recycling is an important factor. Thus, the degradation response time impacts heavily on the effectiveness of the system. In this regard, the valence bond tautomeric isomerizations would appear to possess the most promising properties, while those mechanisms that involve fragmentation open the

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system up to the possibility of irreversible byproduct formation. The heterolytic processes described in the photochromism of the target compound (internal ring opening) would appear to fall in between the two boundaries.

THE REACTIONS OF SEQUENCE F[3]

The synthesis begins with an aldol reaction between 4-nitrobenzaldehyde and acetophenone in Experiment [F1] to yield 4-nitrochalcone:

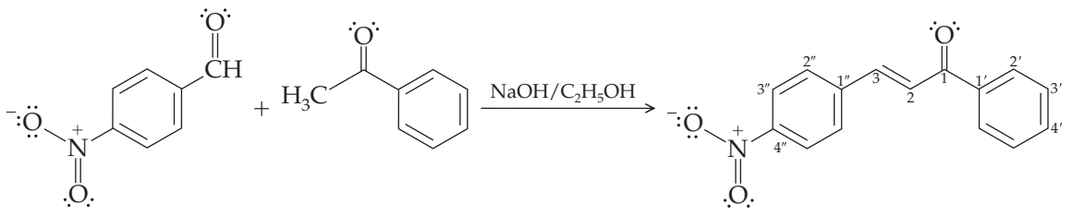

p-Nitrobenzaldehyde Acetophenone *trans*-4-Nitrochalcone

The chalcone is brominated in the second step (Experiment [F2]) to yield *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone:

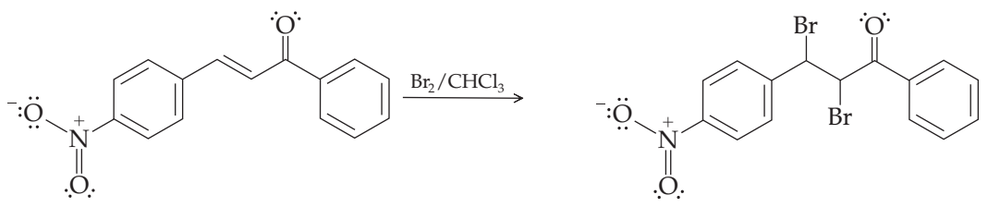

trans-4-Nitrochalcone *erythro*-2,3-Dibromo-3-(4-nitrophenyl)propiophenone

When this halogenated compound is treated with ethanolic ammonium hydroxide for several days, as in Experiment [F3], the system undergoes several reactions (dehydrohalogenation, amination, and ring closure) to ultimately yield a trans-substituted aziridine product:

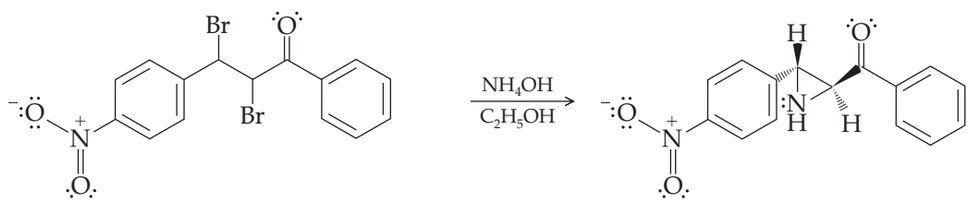

erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone *trans*-2-(4-Nitrophenyl)-3-benzoylaziridine

The photochromic substance, a diazabicyclo[3.1.0]hex-3-ene, is obtained in the fourth step (Experiment [F4]) when the aziridine is treated with benzaldehyde, anhydrous ammonia, and ammonium bromide. The reaction requires several days to go to completion.

[3]This synthetic sequence is based on a set of experiments first developed for the undergraduate instructional laboratory by Professor R. Marshall Wilson and Laboratory Director D. L. Lieberman of the University of Cincinnati. We are grateful to Paulette Messier of Bowdoin College and Dr. Joanne M. Holland of Sepracor, Inc. for further development and optimization work.

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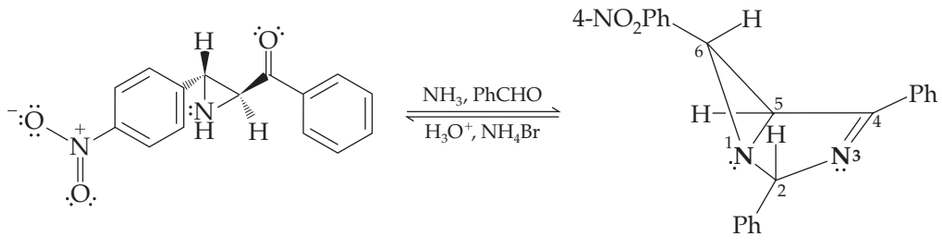

trans-2-(4-Nitrophenyl)-3-benzoylaziridine

2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]-hex-3-ene

The product is a colorless crystalline substance that possesses the property of turning a deep blue when exposed to indoor light:

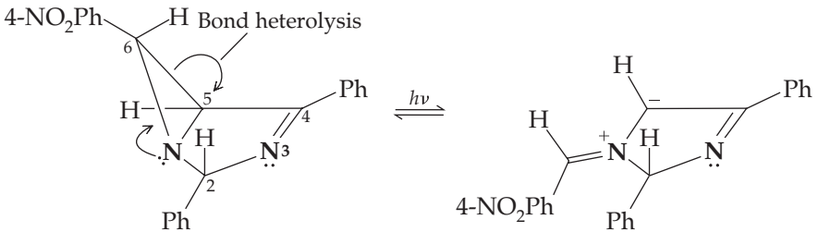

2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0.]hex-3-ene

syn-Azomethine-ylide

The mechanism involved in the photochromic isomerization reaction is relatively rare, which makes these substances all the more interesting to study.

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de la Mare, P. D. H.; Suzuki, H. *J. Chem. Soc.* **1968,** 648.

Coxon, J. M.; Halton, B. *Organic Photochemistry;* 2nd ed., Cambridge University Press: New York, 1987.

Kopecky, J. *Organic Photochemistry;* VCH: New York, 1992.

Also see

Horspool, W. M.; Lenci, F., Eds., *CRC Handbook of Photochemistry and Photobiology,* 2nd ed., Vols. 1, 2, CRC Press: Boca Raton, FL, 2003.

Smith, M. B.; March, J. *Advanced Organic Chemistry*, 6th ed., Wiley: New York, 2007, Chap. 7, p. 328 and references therein.

An Aldol Reaction: *trans*-4-Nitrochalcone

Experiment F1

Common name: 4-nitrochalcone

CA number: [2960-55-6]

CA name as indexed: 2-propen-1-one, 3-(4-nitrophenyl)-1-phenyl-, (*E*)-

Purpose. We prepare the first of three intermediates on the synthetic pathway to our target molecule, a photochromic imine. A base-catalyzed aldol reaction is carried out in which an aromatic aldehyde is condensed with an aryl alkyl ketone. This addition reaction is followed by dehydration to form an α,β-unsaturated ketone; this particular product is commonly called a chalcone. This intermediate is isolated and purified for use as the starting material in the next stage of the synthesis. You will carry out a semimicroscale reaction to gain experience at conducting larger-scale organic reactions.

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Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

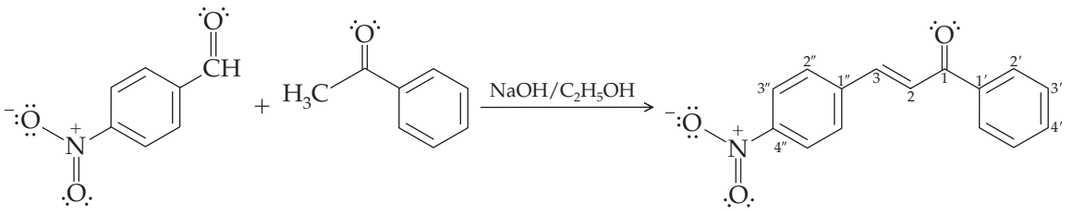

4-Nitrobenzaldehyde Acetophenone *trans*-4-Nitrochalcone

DISCUSSION

The aldol reaction (aldol condensation) is one of the fundamental reactions of organic chemistry because it leads to the formation of a new carbon–carbon bond (see Experiment [20] for a very similar example of the Claisen–Schmidt type of aldol reaction). In this version, the condensation of 4-nitrobenzaldehyde (an aldehyde without an α-hydrogen atom) with acetophenone (a ketone) gives *trans*-4-nitrochalcone. The aldol condensation of the unsubstituted aromatic aldehyde, benzaldehyde with acetophenone, yields *trans*-1,3-diphenyl-2-propenone (PhCH═CHCOPh), which has the common name, chalcone. Thus, the substituted derivatives of this system are known collectively as chalcones.

The extended conjugation in the product favors the formation of the chalcone product. Furthermore, this product is insoluble in the aqueous ethanol solvent and rapidly precipitates from the reaction medium as it is formed, whereas the starting materials are all soluble in aqueous ethanol. Thus, the experimental conditions assist in driving this equilibrium reaction to completion.

The classic aldol condensation involves generation of an *enolate* by removal of an acidic proton from a carbon alpha to the carbonyl group of an aldehyde or ketone, and subsequent nucleophilic addition of this enolate to the carbonyl carbon of an aldehyde or ketone. This reaction is base catalyzed and involves the following mechanistic steps:

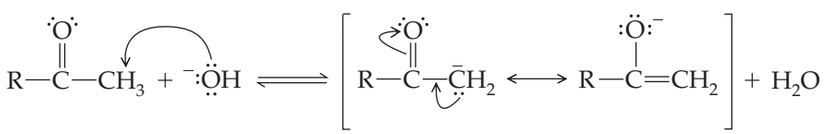

An enolate

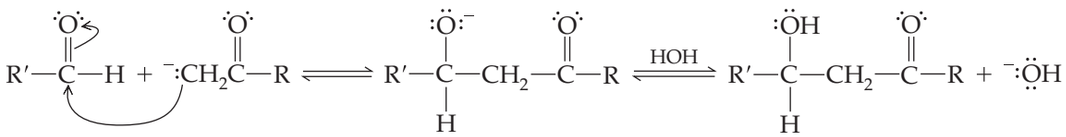

Nucleophilic attack Protonation

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The reaction involves (a) base-catalyzed generation of the enolate, (b) nucleophilic attack of this anion on a carbonyl carbon, and (c) proton transfer to the resulting anion to yield the initial aldol product, a β-hydroxycarbonyl compound. The β-hydroxycarbonyl product may be isolated in many cases, if desired, since the subsequent dehydration is generally much slower than the addition reaction that precedes it. The final stage of the aldol reaction, as in the present reaction, is a hydroxide-catalyzed dehydration of the initial product by way of the enolate. Though hydroxide ion (HO^-) is generally not a good leaving group, the H alpha to the carbonyl in the β-hydroxyketone is quite acidic. In addition, the elimination produces a highly conjugated α,β-unsaturated ketone. Under these strongly basic conditions, the hydroxide ion becomes an adequate leaving group. In these systems, both during the loss of the proton in the formation of the enolate anion and during the loss of hydroxide to yield the α,β-unsaturated ketone, the molecular conformations involved favor development of the more-stable trans product:

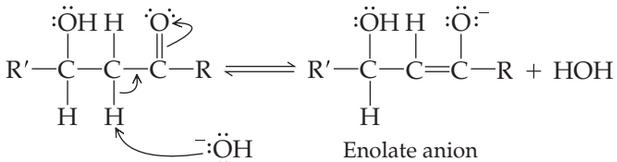

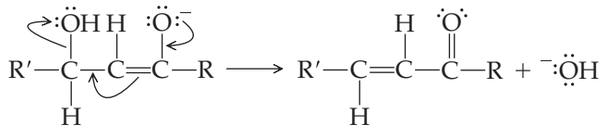

In the present experiment an aldol condensation yields a benzalacetophenone (chalcone) product. In Experiment [20], a nearly identical double aldol reaction yields dibenzalacetone. A further example of a double aldol reaction is found in Experiment [$A3_a$], where tetraphenylcyclopentadienone is the product of the reaction of benzil and 1,3-diphenylacetone.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
Acetophenone	120.16	488 μL	4.16	20.5	202.6	
Ethanol (95%)		20 mL			78.5	0.789
4-Nitrobenzaldehyde	151.12	500 mg	3.31	106		
Sodium hydroxide (aq, 10%)		2 mL				

Reagents and Equipment. Weigh and place 500 mg (3.31 mmol) of 4-nitrobenzaldehyde in a 50-mL Erlenmeyer flask containing a magnetic stir bar. Now add 20 mL of 95% ethanol and 488 μL of acetophenone.

Reaction Conditions. Warm the reaction mixture, while stirring in a sand bath at 65–70 °C, until the aldehyde dissolves to yield a clear light yellow solution.

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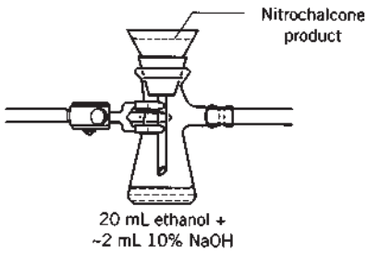

At this point, cool the Erlenmeyer flask in an ice bath for at least 5 min and then, while continuing to cool the system, *carefully* add dropwise with stirring, 2 mL of 10% (aq) sodium hydroxide over a second 5-min period. During this time, the reaction mixture often turns a dark orange color and considerable precipitation may occur. Cool the Erlenmeyer flask for an additional 15 min following the last addition of base.

Isolation of Product. Collect the solid tan precipitate, which formed during the reaction, on the filter bed of a Hirsch funnel under reduced pressure (⬅).

If solid continues to form in the filtrate, refilter the reaction solution and combine the second collection of crystals with the first batch. You want to maximize your total yield of the aldol product, because this is the first step of a four-step synthesis. Thus, you will need efficient recovery of product at each intermediate stage of the synthesis to successfully obtain a reasonable quantity of the photochromic target molecule. Rinse the Erlenmeyer flask once or twice with ice-cold water to effect as closely as possible a quantitative transfer of the chalcone to the Hirsch funnel.

Purification and Characterization. Wash the tan filter cake containing the reaction product, dropwise with an ice-cold 80:20 ethanol/water solution until the product appears as pale yellow crystals. The wash dissolves and removes a red-brown amorphous material that contaminates the crude product in many instances. Transfer the purified and partially dried chalcone to a watch glass, and then place it in a desiccator for final drying. Characterize the anhydrous intermediate accurately by an evacuated melting point and infrared spectrum; the latter can be compared to that recorded in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar). The chalcone normally is of sufficient purity to be carried directly on to Experiment [F2].

NOTE. Approximately 400 mg of purified product with a melting point within 2–4 °C of the literature value is the minimum quantity of intermediate suggested for continuing the sequence on to Experiment [F2].

QUESTIONS

7-88. In a number of cases it is possible to successfully isolate the β-hydroxyketone intermediate prior to the dehydration that forms the α,β-unsaturated ketone.

- **(a)** Does the isolation of the β-hydroxyketone suggest which step in the aldol condensation is the rate-determining step in this case?
- **(b)** If so, which one *is* the rate-determining step?
- **(c)** Suggest what reaction conditions may have a significant impact on determining which step becomes rate determining.
- **(d)** What structural changes might lead to a change in the rate-determining step?

7-89. Ketones also undergo the aldol condensation, although a successful reaction often requires "enhanced" conditions, since the addition involves an unfavorable equilibrium constant. This is the situation in the reaction in which 4-nitrochalcone is synthesized. With the odds against it, why is the reaction successful in this case?

7-90. If you had obtained both the *cis*- and *trans*-chalcone products, and had purified them by recrystallization, how could you instantly know which one was cis and which one was trans without any further characterization?

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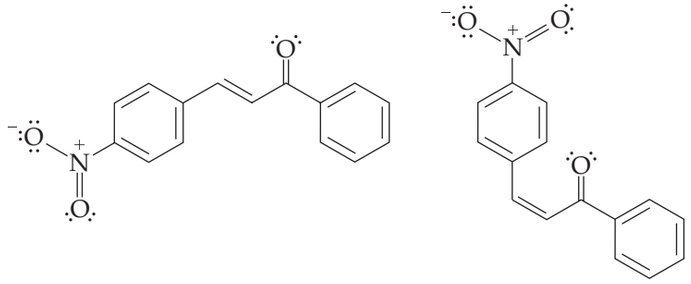

Trans Cis

7-91. The mixed aldol reaction between propionaldehyde and acetone gives an 85% yield of 4-hydroxy-2-hexanone when run in THF at −78 °C with lithium diisopropylamide (LDA, a powerful base). The reaction is carried out by first adding the ketone to the base, cooling the solution, and then adding the aldehyde.

(a) Why does this mixed system give essentially a single product?

(b) Why is there no self-condensation of the acetone?

(c) Why does the system not rapidly go on to dehydrate?

(d) Why is the ketone added to the base rather than vice versa?

7-92. Give the aldol product or products from the following reaction:

$$CH_3CH_2CH_2CH_2CH_2CHO + CH_3CH_2CH_2CH_2CHO \xrightarrow{\text{base}}$$

7-93. The chalcone structure is particularly interesting. It was known in nature long before it was synthesized in the laboratory. This structure is incorporated biosynthetically into a large class of over 300 natural pigments called flavonoids. These substances heavily contribute to the spectacular New England autumn colors and many flower pigments. Flavonoids arise from chain extension of shikimic acid–derived cinnamic acids (see Experiment [10C] for a more detailed discussion of biological origin of these materials). A typical example of a flavone would be luteolin (5,7,3′,4′-tetrahydroxyflavone, **I**), the orange-yellow pigment of the snapdragon:

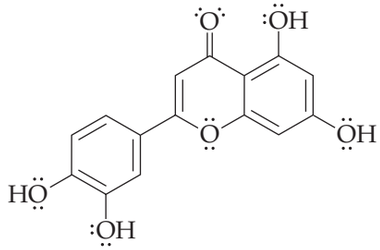

I
Luteolin

Flavonoids may be synthesized by using reactions similar to those used in the chalcone synthesis. For example, the basic flavone structure (**II**) can be simply derived from a Claisen condensation between ethyl benzoate and 2-methoxyacetophenone, followed by treatment with HI:

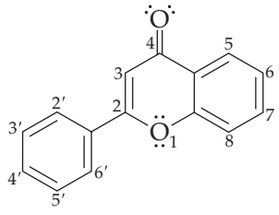

II
Flavone (skeleton)

Show the mechanistic route leading to this flavone from the ester and the ketone.

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Selected examples of the Claisen–Schmidt reaction from *Organic Syntheses* are given here:

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Also see

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Experiment F2

erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone

Common name: *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone

CA number: [24213-17-0]

CA name as indexed: 1-propanone, 2,3-dibromo-3-(4-nitrophenyl)-1-phenyl-, (*R**,*S**)-

Purpose. You will prepare the appropriate dibromide, an intermediate in your synthetic sequence, to act as the precursor to the aziridine ring system. You will carry out a semimicroscale halogenation with bromine as the active reagent. A further purpose of this experiment is to demonstrate the stereospecific addition of bromine to alkenes.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Concentration of Solutions (pp. 101–104)

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)

REACTION

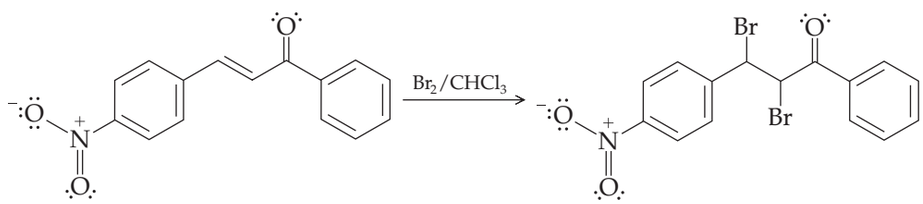

trans-4-Nitrochalcone

erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone

DISCUSSION

The bromination of alkenes is an example of an electrophilic addition reaction. (See Experiments [$A2_b$] and [D2] for detailed discussions of the mechanism involved in this reaction. In particular, refer to Experiment [D2], which very closely resembles this reaction, for a discussion of the erythro and threo nomenclature used in this experiment.) In the present reaction, bromination of 4-nitrochalcone yields *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone.

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This reaction is *stereospecific* because the other possible diastereomer [threo or (*R*, R**)] is not formed:

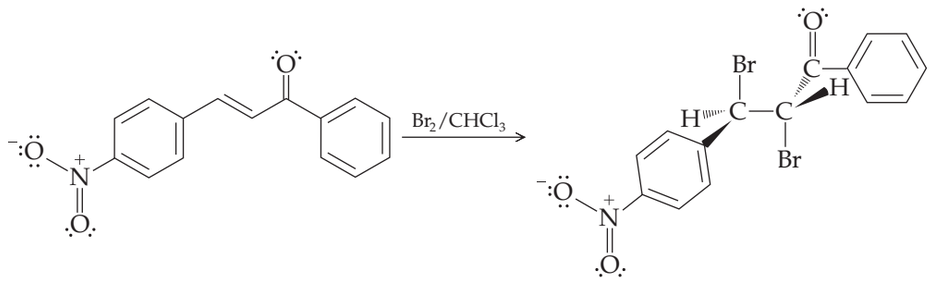

trans-4-Nitrochalcone

erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone

The reaction proceeds in two steps. The first involves the formation (from either side of the plane of the double bond; attack from below is shown here) of an intermediate cyclic *bromonium ion*:

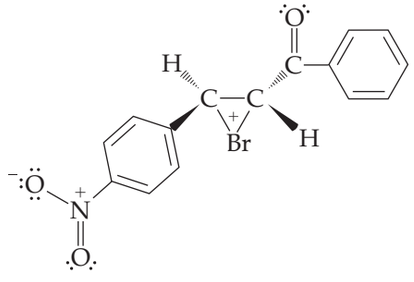

The bromine molecule (Br_2) is normally symmetrical. However, as it approaches the electron-rich, and nucleophilic, π bond of the alkene, it becomes polarized by induction and then functions as the electrophile in an addition reaction. The result is the generation of a cyclic bromonium ion:

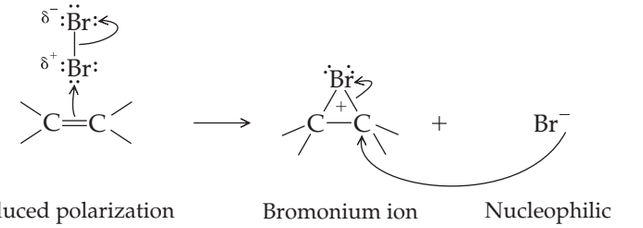

Induced polarization of Br_2 as it approaches the alkene

Bromonium ion

Nucleophilic attack by bromide

In the present reaction, both the bromine and the 4-nitrochalcone are achiral, though the bromonium ion that is produced is chiral. Because it results from the reaction of achiral molecules in an achiral environment, the bromonium ion must be racemic. In this ion, the bromine atom bridges both carbon atoms of the original carbon–carbon double bond to form a three-membered ring intermediate. The generation of this high-energy cyclic species has a profound effect on the *stereochemistry* of the second step of the bromine addition: the ring restricts rotation about the C—C single bond in the carbocation.

The second stage of the bromination involves nucleophilic attack by bromide ion on the intermediate bromonium ion. Since the nucleophile must

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approach from the face opposite the leaving group, bond formation involves inversion of configuration at the carbon center under attack in the second stage of the bromination reaction.

Note that *either* carbon can be approached by the nucleophile (one attack is shown). This second step is a classic backside S_N2 type displacement:

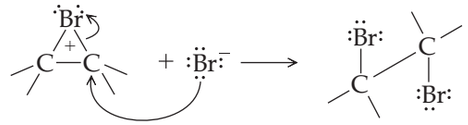

Bromonium ion Dibromo product

In the case with 4-nitrochalcone, two chiral centers are generated in the bromonium ion and we might, therefore, expect that two diastereomeric pairs would be formed. However, due to the stereoselectivity of the reaction, only a single diastereomer is generated, as a racemic pair of enantiomers (refer to Experiment [D2] for a further discussion of the stereochemistry of this halogenation).

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
trans-4-Nitrochalcone	253	400 mg	1.58	161–164		
Chloroform		~8 mL			61.7	1.492
Bromine/chloroform (2.5%)	179.8	(200 μL Br_2)	3.91		58.8	
erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone	413			151–153		

Reagents and Equipment. Weigh and place 400 mg (1.58 mmol) of 4-nitrochalcone in a tared 50-mL round-bottom flask containing a magnetic stir bar. Now add about 8 mL of chloroform (dispensed in the **hood**). Connect the flask to a water-jacketed reflux condenser fitted with a drying tube.

HOOD

*INSTRUCTOR PREPARATION. The active brominating reagent in this reaction is liquid Br_2 dissolved in chloroform. Prepare a solution of 200 μL (624 mg) of bromine dissolved in 8 mL of chloroform multiplied by the number of students carrying out the experiment. The reagent should be prepared, dispensed, and added to the reaction in the **hood.***

HOOD

CAUTION: Bromine is a highly reactive substance. Even in chloroform solution you must handle it with care. Be very careful not to get this reagent on your skin. All transfers of the reagent should be made in the ***hood.***

HOOD

Chloroform itself is highly toxic and a cancer suspect agent. Handle it with respect.

Reaction Conditions. Warm the round-bottom flask in a sand bath between 60 and 70 °C, with stirring, until the 4-nitrochalcone dissolves to yield a clear light yellow solution. Once dissolution has occurred, continue to maintain the bath temperature at 60–70 °C and add the bromine reagent. The addition is

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carried out dropwise using a 9-in. Pasteur pipet inserted down the condenser (briefly remove the drying tube during this operation), with stirring, over a 10-min period. By the end of the Br_2 addition the solution turns a dark orange. Continue to heat the stirred reaction mixture for an additional 20 min (➡).

After cooling the reaction mixture to room temperature, remove a small aliquot and spot it on a silica gel TLC plate next to a reference spot of the 4-nitrochalcone starting material. Elute the plate with 50:50 methylene chloride/hexane and visualize the spots by UV. (A number of unidentified byproducts are formed in small quantities during the reaction that are often observed on the TLC plates.) There also will probably be a trace of unreacted 4-nitrochalcone left in the reaction solution. The major (and highest R_f) spot ($R_f = 0.3$) is the brominated product. Because an excess of bromine was used in the reaction, however, only small quantities of 4-nitrochalcone are normally detected at this stage. If significant unreacted substrate remains (i.e., more than a faint or weak spot on TLC), add an additional small amount of the bromine reagent and then reanalyze the reaction mixture again by TLC.

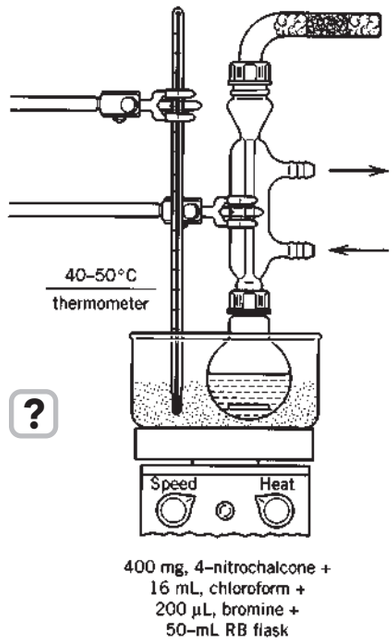

Isolation of Product. Once it is established that the reaction is largely complete, remove the solvent and excess reagent from the reaction mixture by rotary evaporation. Weigh the crude residue.

NOTE. At this point the crystalline residue that remains following rotary evaporation may be stored until the next laboratory period by first flushing the round-bottom flask with dry nitrogen (or argon) and then quickly sealing the flask with a ground-glass standard-taper stopper that is sealed with Parafilm. The flask should be labeled and given to your instructor for storage in the freezer. While it is possible to safely interrupt the workup at this stage, most organic materials are much more stable when they are stored in as pure a state as possible. ***If time permits, you are urged to finish the workup of the bromination.***

Purification and Characterization. The crude material, a yellow-orange solid is now partially purified by column chromatography.

The chromatographic column (short buret) is packed with silica gel (10 g) after first positioning a plug of cotton and about 1 cm of sand at the bottom. Then a portion of 50:50 methylene chloride/hexane is added to the column (~15 mL), followed by 10 g of silica gel. The solid substrate is slowly added while the column is tapped to promote even settling of the packing material. During this process the column stopcock is slightly opened to create a slow drip rate of the packing solvent out of the column. As a result of this drainage more solvent may be required to keep the solvent level above that of the silica gel during the settling operation. Finally, carefully drain any excess solvent to the top of the column and close the stopcock after the packing procedure is complete.

The crude *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone is then dissolved in a minimum amount of methylene chloride (~10 mL) and applied to the top of the column by slowly pipetting the solution down the side of the column without disturbing the silica gel (as this solution is added it is also slowly drained onto the column by cracking open the stopcock). As the final quantity of crude product drains to the top of the column, elution is started with 50:50 methylene chloride/hexane solution (again by careful addition so as not to disturb the upper layers of silica gel containing the adsorbed reaction products). Collect 3 × 30-mL fractions in 50-mL Erlenmeyer flasks (labeling each flask with the fraction number). You may observe some yellow zones of material slowly moving down the column during the elution. This colored material usually does not begin to elute with this chromatographic scheme. Once

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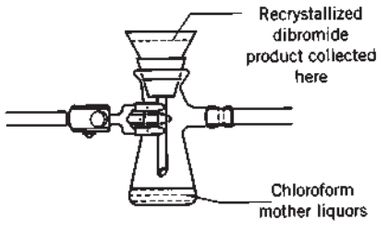

the fractions have been collected, use TLC analysis (silica gel plates, 50:50 methylene chloride/hexane) to determine the composition of the fractions. The purest fractions are combined to give sufficient material to continue on to the next step (Experiment [F3]) in the sequence. Separate and remove the solvent (N_2 and warm sand bath). Determine the weight and melting point (evacuated) of your brominated product. The *erythro*-2,3-dibromo-3-(4-nitrophenyl)-propiophenone should appear as white to light yellow needles. It may be further recrystallized from 95% ethanol if desired.

If the melting point is only a few degrees low (~142–147 °C), increased purity often is quickly obtained by simply adding a few milliliters of ice cold chloroform to the product residue that is cooled in an ice bath. Triturate the residue for a few seconds with the cold solvent. Withdraw the solvent by Pasteur filter pipet leaving the washed crystals behind (this treatment may be repeated if necessary). Remove traces of the solvent remaining on the residue by a short rotary evaporation. Recheck the melting point (evacuated) to determine if product purity is improved enough to continue on to the third step (⬅).

Weigh your purified *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone intermediate and calculate the percent yield based on both the starting 4-nitrochalcone and the 4-nitrobenzaldehyde (the starting material used in Experiment [F1]). Compare your spectrum to that of a reference standard shown in Figure 7.7.

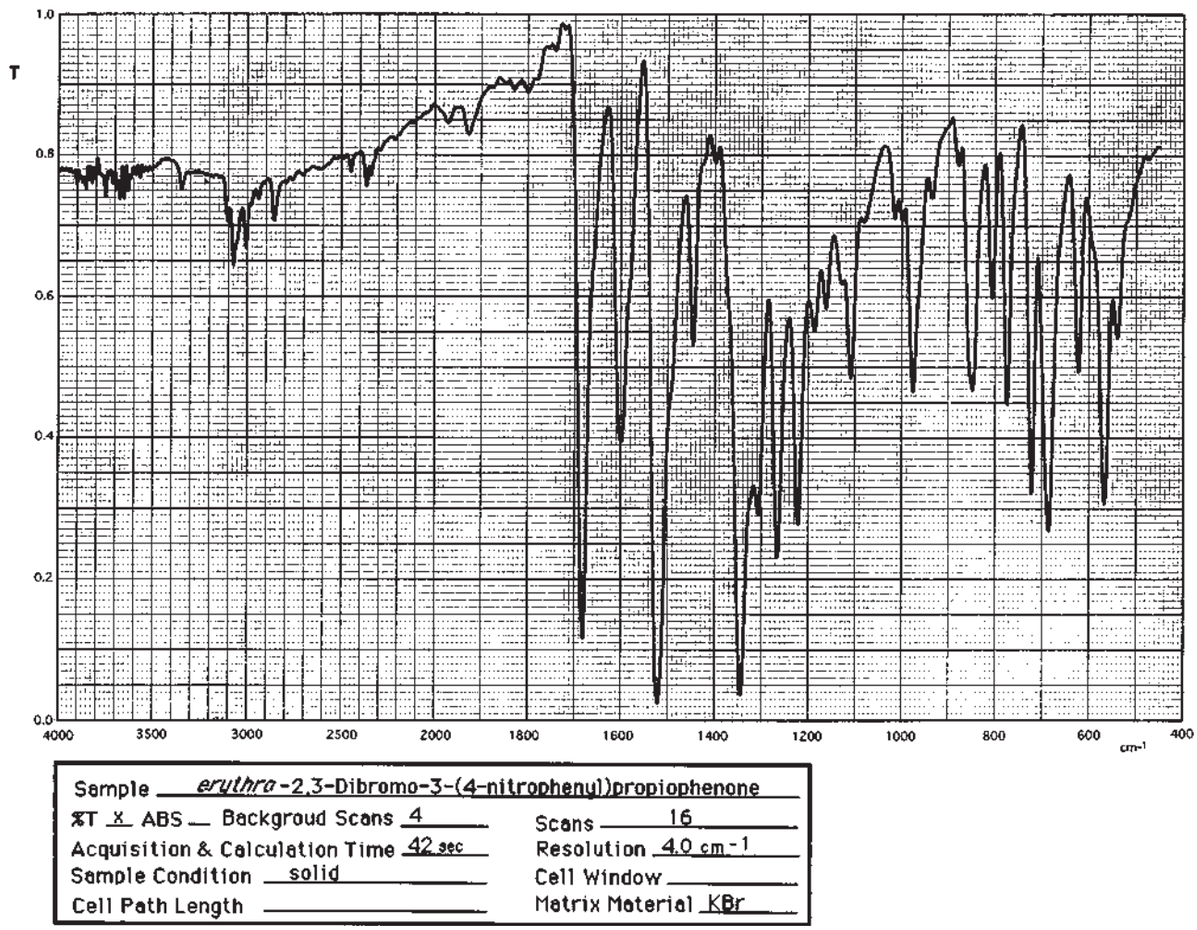

Figure 7.7 IR spectrum: *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone.

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OPTIONAL. Obtain the ^1H NMR spectrum of the product in $CDCl_3$. Identify the resonances for the two protons attached to the halogenated carbon atoms, and ascertain that the product is a single diastereomer. This information will be useful in Experiment [F3].

NOTE. The erythro-2,3-dibromo-3-(4-nitrophenyl)propiophenone is a particularly sensitive substance and will decompose in contact with air at room temperature over several days. If you do not have time to continue on to Experiment [F3] during this laboratory period you should store your purified material as described above for the crude product.

If you have time to start the reaction, you are urged to continue on to the next step. *Once you have the pure dibromide in hand, it takes only a relatively short time to set up and get the next reaction running. Since this latter reaction will be left to run for a week, you have a lot to gain by getting the third step started during the period when the second intermediate is worked up.*

NOTE. Approximately 450 mg of purified product with a melting point within 2–4 °C of the literature value is the minimum quantity of intermediate suggested for continuing the sequence on to Experiment [F3].

QUESTIONS

7-94. A considerable excess of Br_2 in chloroform is required to successfully drive the halogenation of 4-nitrochalcone to completion. Offer a suggestion as to the role of the excess reagent.

7-95. What product(s) would you expect to obtain from the bromination (Br_2 in CCl_4) of cyclobutene?

7-96. In the bromination of 4-nitrochalcone a racemic dibromide is formed. A second diastereomeric dibromide is structurally possible, but it is not formed in the reaction.
- **(a)** Give stereochemically detailed drawings of the stereoisomer(s) isolated from the reaction mixture.
- **(b)** Give stereochemically detailed drawings of the stereoisomer(s) that is/are not formed.
- **(c)** Why is this reaction stereoselective?
- **(d)** How could the second diastereomer be synthesized if its preparation was required?
- **(e)** Assign, by the *R* and *S* convention, the stereocenters in each of the diastereomers.

7-97. Show the stereoisomer(s) generated by bromination of each of the enantiomers of *cis*- and *trans*-4-bromo-2-pentene. Show the relationship (enantiomer, diastereomer, etc.) and assign *R* and *S* centers in all product(s) and starting materials.

7-98. Show, with the correct absolute configuration, the stereoisomer(s) formed on bromination of *(S)*–4-*tert*-butyl-1-cyclohexene. Would you expect them to be formed in equal amounts?

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A large number of examples of the bromination of alkenes appear in *Organic Syntheses*. Selected references are given below:

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Snyder, H. R.; Brooks, L. A. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 171.

Also see

Smith, M. B.; March, J. *Advanced Organic Chemistry*, 6th ed., Wiley: New York, 2007, Chap. 15, p. 999 and references therein.

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Experiment F3

trans-2-(4-Nitrophenyl)-3-benzoylaziridine

Common names: *trans*-2-(4-nitrophenyl)-3-benzoylaziridine
CA number: [76336-95-3]
CA name as indexed: methanone, [3-(4-nitrophenyl)-2-aziridinyl]phenyl-, *trans*-

Purpose. The third intermediate on the pathway to the target photochromic imine is synthesized. A heterocyclic three-membered ring, an aziridine derivative, is formed. This is the first ring of the diazabicyclohexene system that you will ultimately convert into the photochromic imine. You will study a process that involves three reactions and the formation of two intermediates en route to the final product. You will study a number of interesting stereoselective reactions. You will work with organic reactions that require several days to come to completion.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)

REACTION

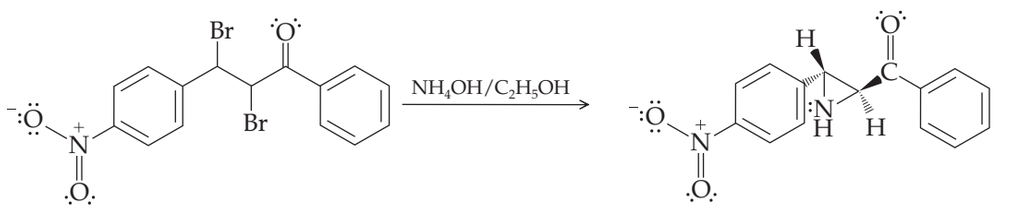

erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone

trans-2-(4-Nitrophenyl)-3-benzoylaziridine

DISCUSSION

The conversion of *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone to a substituted aziridine involves a number of interesting steps and intermediates. The *first stage* of the reaction involves attack on the halogenated intermediate by base (concd ammonium hydroxide, $NH_4OH \rightleftharpoons NH_3 + H_2O$). Under the highly polar conditions, the reaction likely proceeds via an E1cb mechanism involving the initial attack by ammonia, acting as a base, on the **2** proton to yield the resonance stabilized anion:

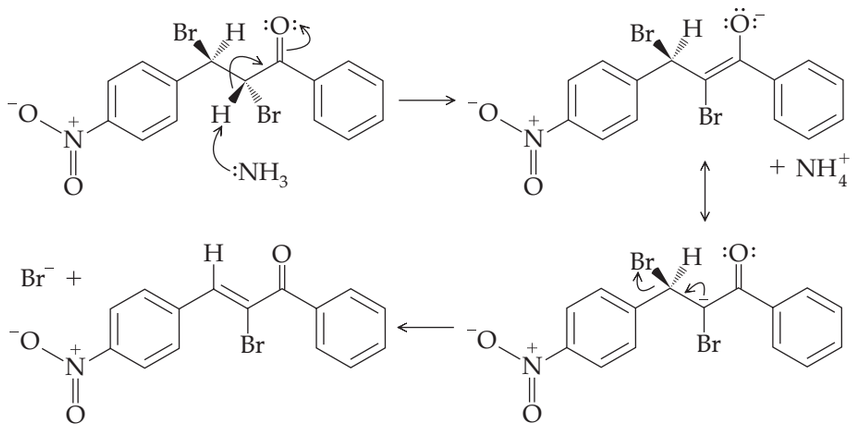

(*Z*)-2-Bromo-4′-nitrochalcone

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You should refer to the detailed discussions in Experiments [9] and [10], which describe in detail the chemistry associated with the E1 and E2 elimination mechanisms. The E1cb mechanism, like the E1 mechanism, involves a two-step process, but in this case the order of charge development is the reverse of the E1 mechanism. Here proton abstraction precedes loss of the leaving group. A generalized scheme is shown here:

E1cb Mechanism

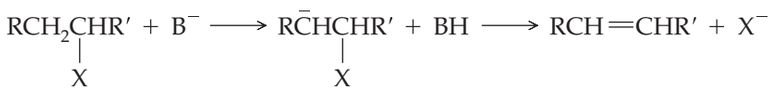

The mechanisms of a large majority of elimination reactions can be explained by invoking various positions along the continuum between the three elimination mechanisms mentioned here; E1cb and E1 are at the extremes of the continuum, and the E2 mechanism lies exactly halfway between the two.

In the present case, carbanion (or near-carbanion) formation following α-proton abstraction appears to be favored, and formation of the anionic intermediate has the attractive feature that it then allows rotation about the incipient π bond. Stereoelectronic requirements of the elimination mechanism require the carbon–bromine bond to be parallel to the p orbital of the adjacent enolate (or α-keto carbanion, depending on which resonance structure is being discussed), just as the proton being removed and the leaving group prefer to be anti in an E2 elimination. Two possible conformations (or rotamers) meet this requirement. The most stable one will be that with the carbonyl and nitrophenyl groups anti to one another, and elimination of bromide ion from this conformation leads to the alkene with the carbonyl and nitrophenyl groups trans, which is the *Z* alkene, as illustrated here:

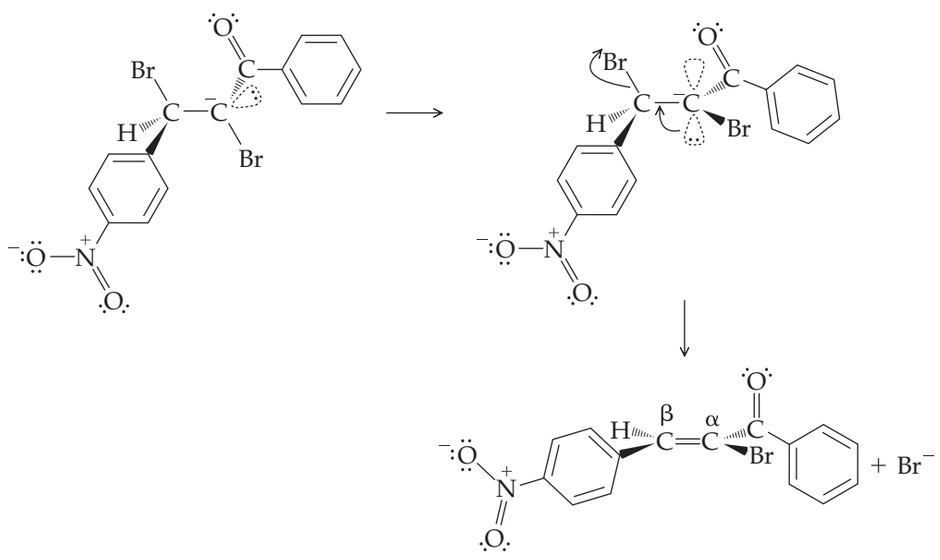

(Z)-2-Bromo-4′-nitrochalcone

Thus, the first stage of the reaction primarily leads to formation of an α-bromo-α,β-unsaturated ketone, (Z)-2-bromo-4′-nitrochalcone. This alkene could be easily isolated from the reaction medium, if required, since the second step in the reaction occurs at a considerably slower rate than the first step. Thus, appreciable concentrations of this unsaturated intermediate are obtained.

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The *second stage* of the reaction involves 1,4 addition of the amine (in this case ammonia in equilibrium with the ammonium hydroxide) to the unsaturated ketone.

There are many examples of nucleophilic reagents that add to α,β-unsaturated aldehydes and ketones in a manner in which the addition is formally 1,4. This result is called conjugate addition. Under basic conditions, these transformations involve initial attack by the nucleophile to the β-carbon atom, followed by electrophilic addition (normally of a proton) on the carbonyl oxygen; the nucleophile and electrophile add at the 1 and 4 positions relative to one another. The enolate formed in the early stages of the reaction is generally quickly protonated to give an enol. The enol will subsequently tautomerize to the ketone. A general mechanistic scheme is shown below for the 1,4 addition of water to an α,β-unsaturated carbonyl system.

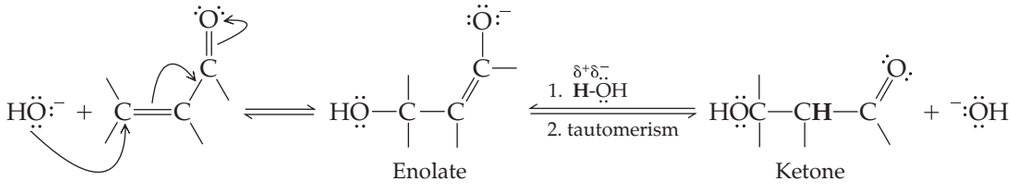

In the present case, conjugate addition has the potential to result in two diastereomers. As in the case of the starting dibromide, these stereoisomers can be either erythro or threo. The distribution between these two products is important because it ultimately determines the ratio of products in the next step (third) of the reaction.

From the geometry of the aziridine final product, and the fact that the internal nucleophilic substitution reaction will proceed with inversion of configuration, we can reliably postulate that conjugate addition must eventually result in the erythro diastereomer. In the conjugate addition of ammonia to 2-bromo-4′-nitrochalcone, the stereochemistry of the product is determined by which face of the resulting enolate receives the proton. The proton source may be the $—NH_3^+$ group resulting from the initial step of the conjugate addition reaction (as shown here), or it may be an ammonium ion or a molecule of ethanol or water hydrogen bonded to the amino group. A further consideration may be the geometry of the resulting enolate, since there is the potential to generate either the *Z* or the *E* enolate; the *E* enolate is illustrated here because it would appear to be the least hindered of the two diastereomeric enolates:

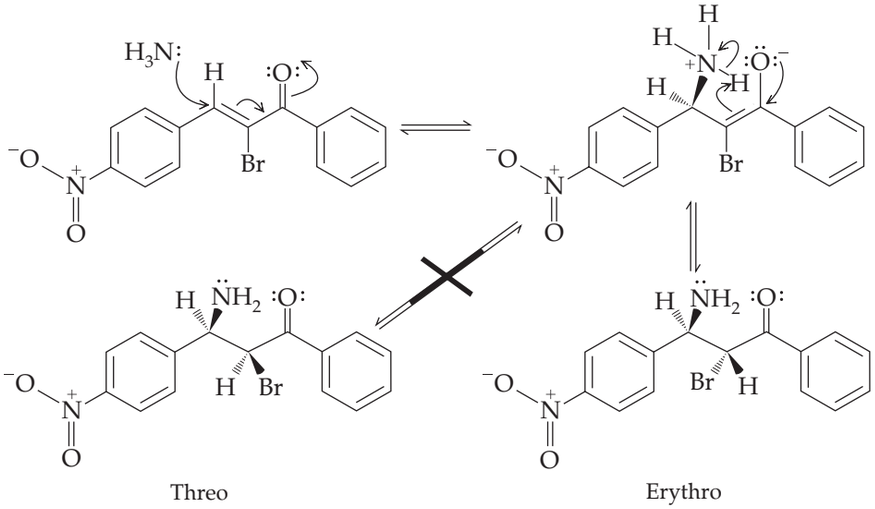

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It is also possible that both the threo and erythro diastereomers are produced at comparable rates and that the erythro is thermodynamically preferred by an equilibrium process between the two.

A comparison of the most-favored conformations, based on relative group sizes, for the erythro and threo diastereomers, indicates that the conformation **A** for the erythro isomer would be less sterically crowded than conformation **B** for the threo isomer, as shown here.

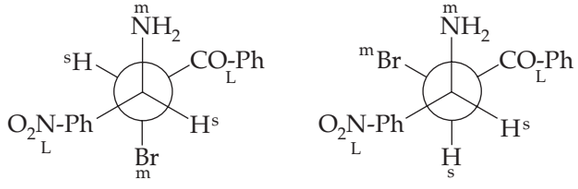

L = large, m = medium, s = small
Ph = phenyl

The *final stage* on the route to the aziridine product involves an internal S_N2 ring closure in which the primary amine group attacks the α-carbon atom holding the remaining bromine from the backside to close an aziridine ring and displace bromide with inversion of configuration at the αcarbon. This displacement has been shown to go exclusively by this mechanism in the case of the β-amino-α-bromoketones; an S_N1 reaction is less likely because of the instability of an α-keto carbocation. For a detailed discussion of the mechanism of the classic S_N2 substitution reaction, refer to Experiment [22].

The stereochemistry of aziridine ring substitution, as pointed out above, is controlled by the product distribution in the β-amino-α-bromoketone intermediate, which in this case favors the erythro configuration. Thus, inversion of configuration during ring formation leads to the trans-substituted aziridine ring in the present example:

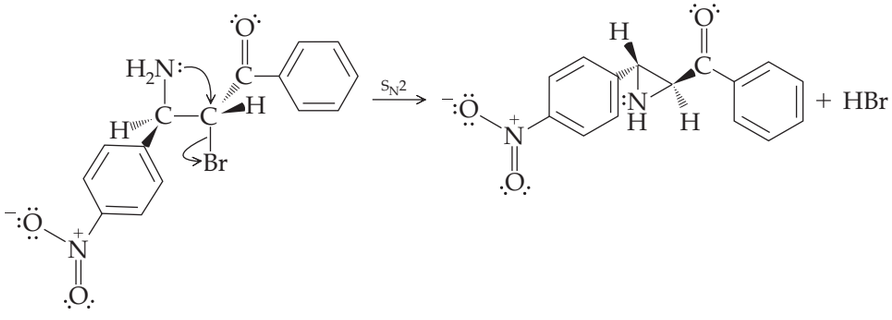

erythro-3-Amino-2-bromo-3-(4-nitrophenyl)propiophenone

trans-2-(4-Nitrophenyl)-3-benzoylaziridine

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.5 h.

Estimated time to complete Part A of the experiment: 1.5 h.

Estimated time to complete Part B of the experiment: 2.0 h.

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Physical Properties of Reactants and Product						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
erythro-2,3-Dibromo-3-(4-nitrophenyl)propiophenone	411	450 mg	1.10	151–153		
Ethanol (95%)		4.4 mL			78.5	0.789
Ammonium hydroxide (concd)		1.3 mL				
trans-2-(4-Nitrophenyl)-3-benzoylaziridine	268.3			142–143		

PART A

Reagents and Equipment. Weigh and place 450 mg (1.10 mmol) of the *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone intermediate synthesized in Experiment [F2] in a labeled 25-mL round-bottom flask containing a magnetic stir bar. In the **hood,** add 4.4 mL (9.8 mL/g of chalcone) of 95% ethanol (graduated cylinder) and 1.3 mL (2.8 mL/g of chalcone) of concd ammonium hydroxide (automatic delivery pipet or 2-mL glass pipet) to the flask. Stopper the flask, swirl to mix the contents, and then seal it with Parafilm. (A polypropylene standard taper stopper is preferred for sealing the vessel for long periods in the presence of base.)

HOOD

CAUTION: Concentrated ammonium hydroxide is a strongly caustic reagent. You must handle it with care. Be particularly alert not to get this reagent on your skin or breathe the vapors. All transfers of the reagent should be made in the ***hood.***

HOOD

Reaction Conditions. Stir the reaction mixture for 15 min. Then wrap the flask with aluminum foil and continue to stir the system for 24 h. The reaction may be worked up at this point or stored in the dark for 1 week if necessary. Do not expect the chalcone to immediately dissolve in the reaction medium; it will do so over the course of several hours as the aziridine product begins to precipitate. If you wish, you can occasionally magnetically stir the reaction mixture for 15–20 min during this intervening period.

This completes Part A of the experiment.

PART B

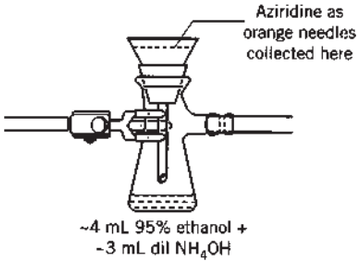

Isolation of Product. Add 15 mL of ice-cold water to the reaction mixture and swirl for 5 min. Collect the solid residue formed in the reaction by vacuum filtration on a Hirsch funnel. The product will appear as pale orange, very fine needles. There may also be a small amount of a more powdery yellow material that should dissolve in three 1.0-mL washes with ice-cold water. Use the first wash to rinse the Erlenmeyer flask and transfer the rinse to the Hirsch funnel. Fine orange needles of the aziridine product will be deposited on the filter bed (⬅).

Purification and Characterization. Collect the orange needles, dry them to constant weight (under reduced pressure), and determine an evacuated melting point. Recrystallize the crude product from hot methanol (~10–20 mL). After crystallization has begun, cool the system further in an ice bath for

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10–15 min to complete the collection. The purified aziridine is obtained as long, shiny, pale orange needles via Hirsch filtration.

Weigh the *trans*-2-(4-nitrophenyl)-3-benzoylaziridine and calculate the percentage yield based on both the starting materials: *erythro*-2,3-dibromo-3-(4-nitrophenyl)propiophenone (Experiment [F3]), 4-nitrochalcone (Experiment [F2]), and 4-nitrobenzaldehyde (Experiment [F1]). Recheck the evacuated melting point, to see if further purification is required, and obtain an IR spectrum. Compare the spectrum to that of a reference standard shown in Figure 7.8.

OPTIONAL. Obtain the ^{1}H NMR spectrum of the aziridine. Establish from this spectrum and the NMR data obtained in Experiment [F2] if any unreacted dibromochalcone still contaminates the aziridine sample that has been purified for use in the preparation of the photochromic target molecule. Determine the diastereomeric purity of your product, and determine that the aziridine product is indeed trans substituted.

NOTE. Approximately 50 mg of purified product with a melting point within 2–4 °C of the literature value is the minimum quantity of intermediate suggested for continuing the sequence on to Experiment [F4].

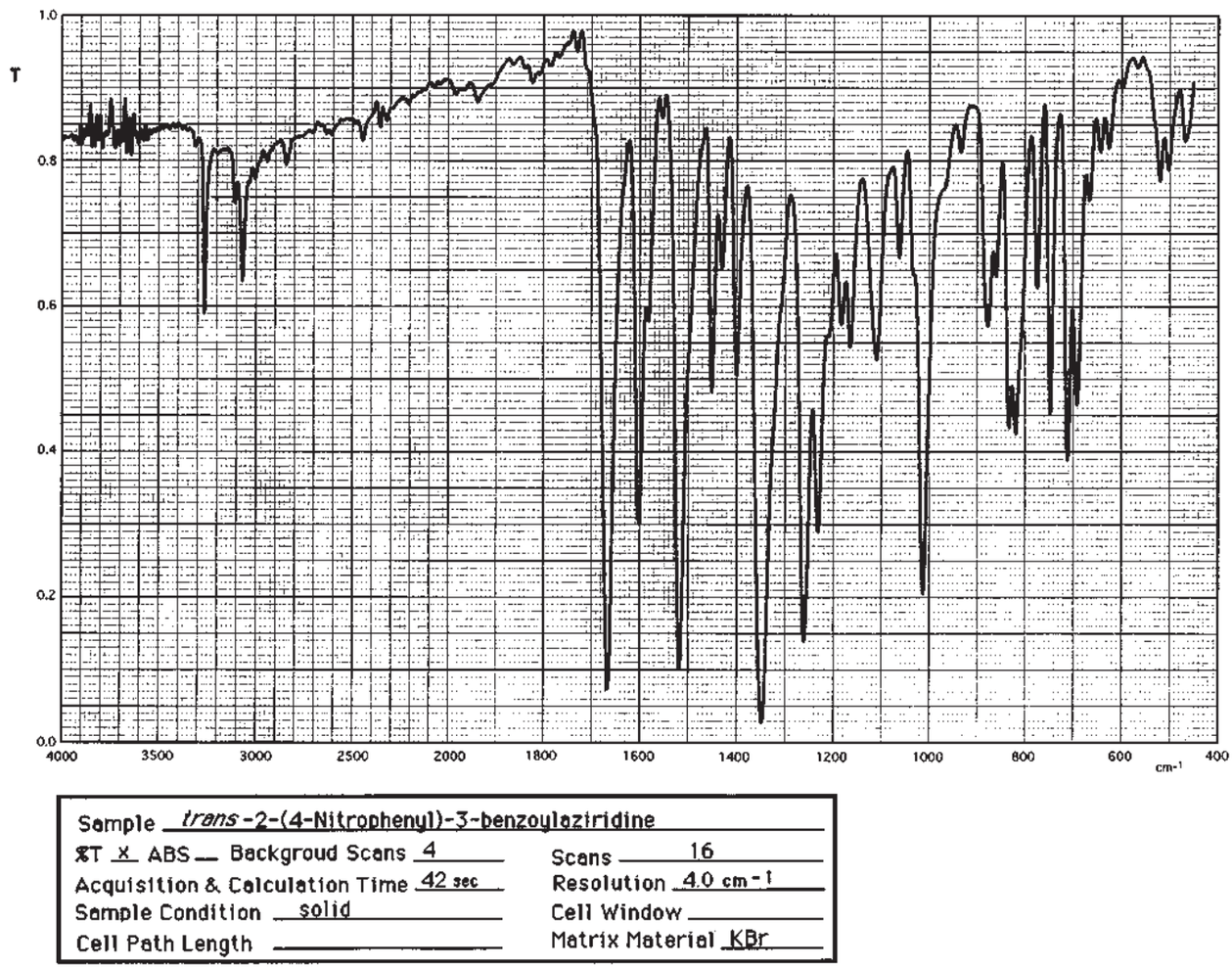

Figure 7.8 IR spectrum: *trans*-2-(4-nitrophenyl)-3-benzoylaziridine.

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QUESTIONS

7-99. The synthesis of 1-cyclohexyl-2-phenyl-3-(4-phenylbenzoyl)aziridine from cyclohexylamine and 4′-phenylchalcone dibromide, gives a mixture of 47% of the cis isomer and 44% of the trans isomer. Chromatography on activated alumina yielded, in the first eluates, a crystalline material, mp = 118–119 °C while the final eluates produced a higher melting material, mp = 144–146 °C. The lower melting substance exhibited a $\tilde{\nu}_{C=O} = 1656\ cm^{-1}$ while the higher melting compound had $\tilde{\nu}_{C=O} = 1686\ cm^{-1}$. Which product is the trans-substituted aziridine and which is the cis compound?

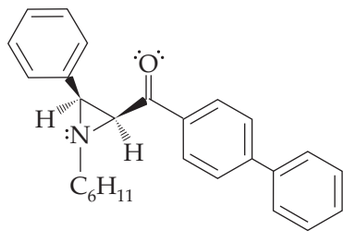

Cis

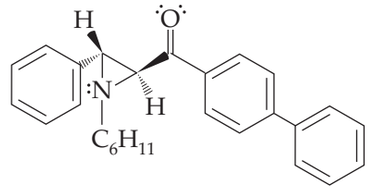

Trans

7-100. *N*-Haloaziridines have been found to possess an extremely high nitrogen inversion barrier. The isolation of the cis (**I**) and trans (**II**) isomers of 1-chloro-2-methylaziridine has been accomplished and they represent the first isolated inversion isomers of trivalent nitrogen. These inversion isomers appear to have remarkable stability. For example, 1-chloro-2,2-dimethylaziridine (**III**) retains configurational stability at temperatures as high as about 135 °C! Make a list of the potential stereoisomerism available to structures **I**, **II**, and **III**. Use perspective drawings to illustrate each isomer and label the stereocenters by the *R* and *S* convention:

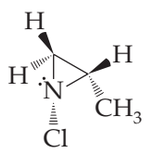

I

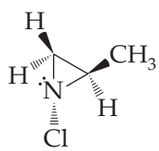

II

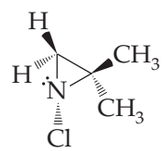

III

7-101. Another route to the effective synthesis of aziridines (**III**) is through the ring closure of the β-amino alcohol (**I**). The alcohol must first be converted to the β-amino hydrogen sulfate (**II**), which is the actual species that undergoes cyclization with strong base. Why is it necessary to convert the hydroxyl group into a hydrogen sulfate group prior to base treatment?

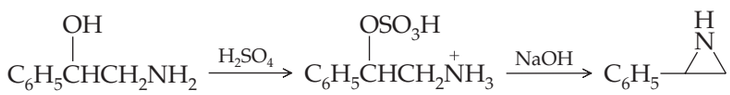

I **II** **III**

7-102. Aziridines are relatively reactive systems and undergo nucleophilic ring opening with the accompanying release of ring strain. Give a Fischer projection drawing of the expected product(s) of the reaction of *N*-ethyl-(2*S*,3*S*)-*trans*-2,3-dimethylaziridine (**I**) in aqueous ethyl amine:

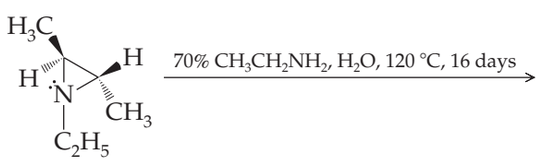

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Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed., Wiley: New York, 2007, Chap. 10, p. 557 and references therein.

A Photochromic Imine: 2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]hex-3-ene

Experiment F4

Common name: *exo*-2,4-diphenyl-6-(*trans*-4-nitrophenyl)-1,3-diazabicyclo[3.1.0]hex-3-ene

CA number: [36799-57-2]

CA name as indexed: 1,3-diazabicyclo[3.1.0]hex-3-ene, 6-(4-nitrophenyl)-2,4-diphenyl-, (2α,5β,6β)-

Purpose. This experiment completes the synthesis of the photochromic imine, which is incorporated into the diazabicyclo[3.1.0]hex-3-ene skeleton. A rare molecular system is obtained in which an aziridine ring is fused to another heterocyclic ring. You will explore the exceedingly interesting photochromic properties of the target molecule. Microscale techniques are used during the conversion and isolation of this light-sensitive material.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 5: Crystallization
Craig Tube Crystallization (pp. 89–91)

REACTIONS

The Photosensitive Compound

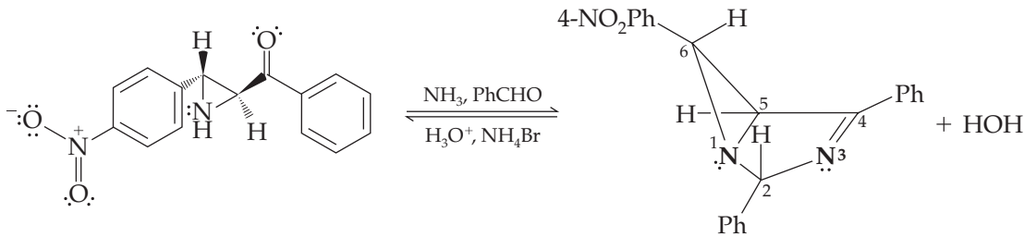

trans-2-(4-Nitrophenyl)-3-benzoylaziridine

2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]-hex-3-ene

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Photoproduct

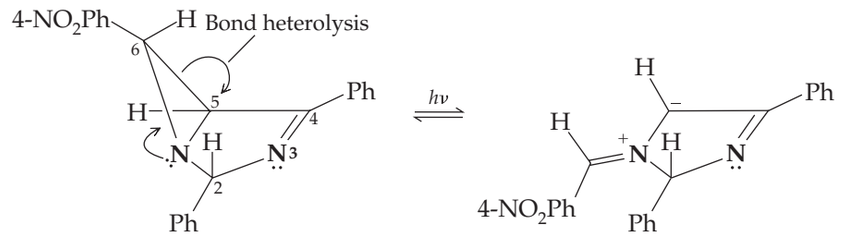

2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]hex-3-ene

syn-Azomethine-ylide

DISCUSSION

This reaction completes the synthesis of the photochromic target molecule, which possesses the 1,3-diazabicyclo[3.1.0]hex-3-ene ring system. The substituted aziridine ring system formed in Experiment [F3] is condensed with benzaldehyde and ammonia to yield this bicyclic system. The reaction may be viewed as proceeding under anhydrous conditions via an initial reaction between the aromatic aldehyde and the base, aided by the ammonium bromide catalyst, to generate an imine as indicated in the following scheme:

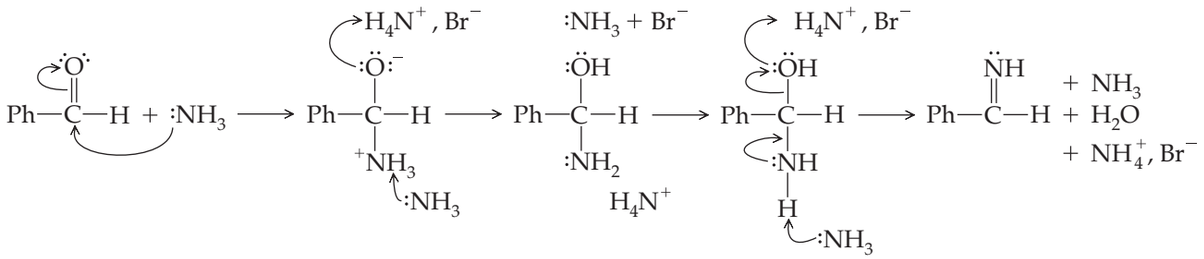

Aldehyde Hemiaminal Imine

The imine is subsequently attacked by the aziridine nucleophile to yield an aminal, again catalyzed by the ammonium bromide as shown in the following scheme:

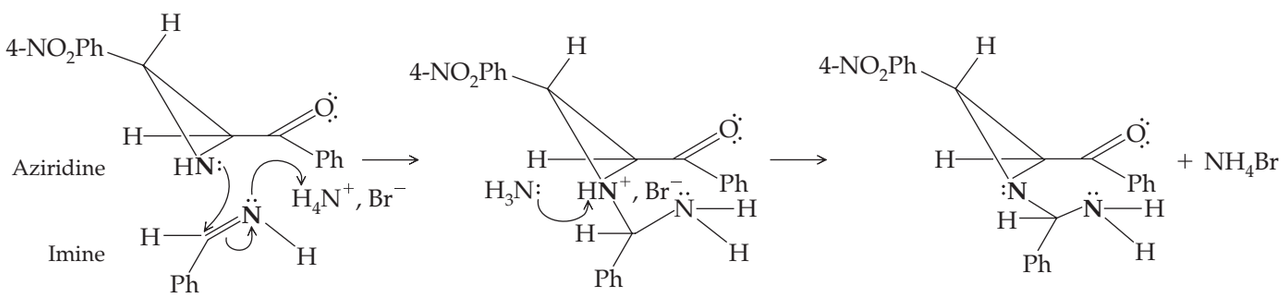

Aminal

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Finally, the aminal undergoes an internal condensation involving ring closure by nucleophilic attack of the primary amine group on the carbon of the carbonyl followed by dehydration of the hemiaminal to yield the diazabicyclo[3.1.0]hex-3-ene ring system, again catalyzed by ammonium bromide. A reasonable scheme is shown below:

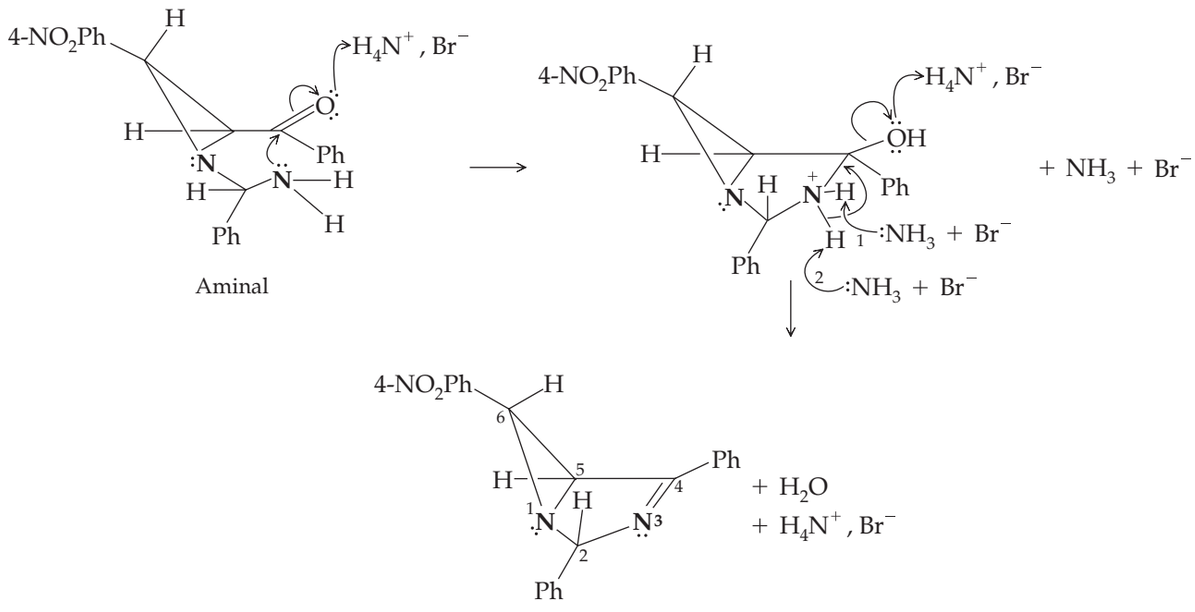

2-*exo*-6-*exo*-2,4-Diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo[3.1.0]-hex-3-ene

The photochromic compound appears to interconvert in the solid state to a bright blue azomethine–ylide (**I**) by an electrocyclic ring cleavage. An *ylide* is a neutral species whose Lewis structure contains opposite charges on adjacent atoms. The atoms involved are carbon, and an element from either group 5A or 6A of the periodic table, such as N, P, or S. Of considerable interest is the fact that the photochemical process has been shown to give exclusively the syn isomer.

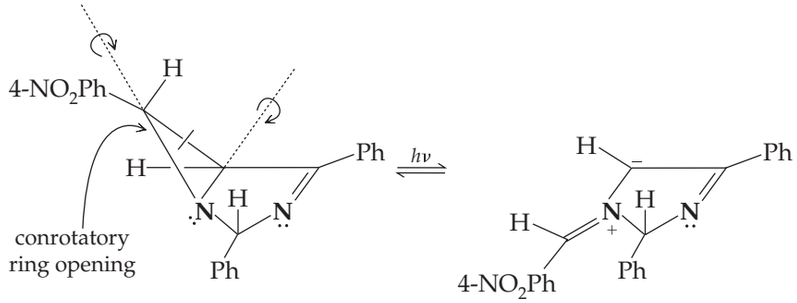

I
Blue azomethine-ylide
(syn configuration)

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This result is consistent with a *conrotatory ring opening* involving a symmetry-allowed concerted transformation in the *ground state*. Since orbital symmetry requires a *disrotatory ring opening* from an *excited state* in these aziridines, the photochemically induced formation of the *syn*-azomethine–ylide (which is isoelectronic with the allyl anion) has been proposed to proceed via a dark reaction in which *electronically excited* states internally convert to *vibrationally excited* ground states. Indeed, evidence supporting this mechanism comes from the thermochromic behavior (a *ground-state* process) of the close relative 6-*exo*-2-dimethyl-4-diphenyl-6-(4-nitrophenyl)-1,3-diazabicyclo [3.1.0]-hex-3-ene (**II**), which when heated to 150 °C turns the same bright blue color (**III**).

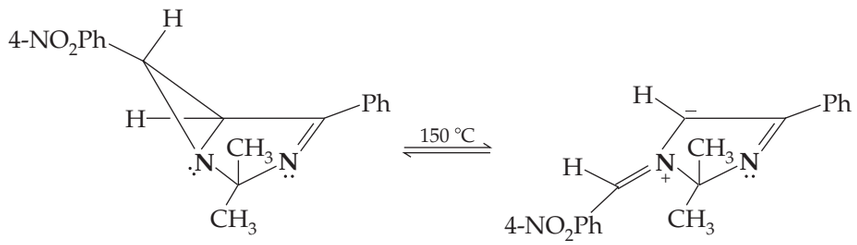

II **III**
Blue azomethine-ylide
(syn configuration)

Exposure to light from tungsten lamps will not photochemically induce the ring-opening step. Most laboratories, however, are illuminated by fluorescent lights that emit small amounts of short wavelength radiation at the edge of the ultraviolet region (a wavelength long enough to not be absorbed by Pyrex glass), which will initiate the photochemical reaction. It is important to recognize that the azomethine-ylide photoproduct is a highly reactive species. Thus, if it is formed in solution where it can easily interact with other species, it rapidly decays to various byproducts, generally turning the solution yellow (not blue). It appears that if the ylide is produced in an environment that isolates it from other molecules, the system is stable and, given enough time, it will slowly revert to the diazabicyclic starting material.

The crystalline state is the ideal solution to this problem. Thus, when the nearly colorless, solid imine is irradiated, it turns bright blue. The neighbors to any ylide in the crystal can be either the ylide itself or the diazabicyclo starting material. If colored material is then placed in the dark it will slowly revert to the colorless form once again. These molecular systems have been successfully cycled between the colorless and colored states many hundreds of times with little degradation of the crystalline material. Obviously, it is exceedingly important that (a) you do not expose the imine to light when it is in solution during recrystallization (or at least that contact with light is kept to a minimum; working in a red-light darkroom would be ideal), and (b) recrystallizations should be carried out as quickly as possible, but obviously with care. Remember, you have a lot of time invested in this product, so work as quickly as is consistent with avoiding a costly spill.

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EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants						
Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*
trans-2-(4-Nitrophenyl)-3-benzoylaziridine	268.3	40 mg	0.15	142–143		
Ethanol, absolute		800 μL			78.5	0.789
Benzaldehyde	106.13	140 μL	1.37		178	1.045
Ammonium bromide	97.95	14 mg	0.14	452 sub		
Ammonia	17.03	Excess			−33	

Reagents and Equipment. Weigh and place 40 mg (0.15 mmol) of the *trans*-2-(4-nitrophenyl)-3-benzoylaziridine synthesized in Experiment [F3] in a 15-mL screwcapped centrifuge tube containing a magnetic spin vane. Dissolve the aziridine (20 μL of EtOH/mg of aziridine) and benzaldehyde (140 μL, 1.37 mmol) in 800 μL of absolute ethanol. To this solution add 14 mg (0.14 mmol) of ammonium bromide (0.35 mg of NH_4Br/mg of aziridine). Stir this mixture for 1 min and saturate the system with anhydrous ammonia (NH_3) in the **hood** (see your instructor for directions on this addition). HOOD

CAUTION: Anhydrous ammonia is a dangerous substance, particularly under pressure. The addition of this material to the reaction must be carried out in the ***hood*** under the *direct* supervision of the laboratory instructor. HOOD

Reaction Conditions. Gently bubble the ammonia gas through the reaction mixture until the system is saturated (until the reaction mixture cools off, ~5 min). Tightly cap the tube (Teflon liner), wrap it in aluminum foil, and stir the mixture for a minimum of 24 h. As in Experiment [F3], the reaction takes place at room temperature over a period of several hours. You can safely store the sealed reaction tube in your locker, protected from light with aluminum foil, for up to 1 week if necessary.

Isolation of Product. After the 24-h period, remove the supernatant liquid by centrifuging the tube and then transferring the liquid by means of a 9-in. Pasteur filter pipet to a Craig tube. Dry the remaining crystals in a stream of nitrogen gas. Remove a small sample of the solid material from the centrifuge tube on a glass rod or spatula and expose this material to direct sunlight or fluorescent light. If the solid material slowly turns blue, you have successfully synthesized the photochromic product. Concentration of the solution in the Craig tube may yield further quantities of the azomethine product. Weigh the tube and determine your percentage crude yield.

Purification and Characterization. Recrystallize the crude product in the dark or red light (best) or with the laboratory lights off from hot 95% ethanol. Dissolution may require as much as 10 mL of solvent and is best carried out in the centrifuge tube. After cooling the centrifuge tube in ice and scratching the sides with a glass rod to induce crystallization, centrifuge the system, and remove the mother liquors with a Pasteur filter pipet. Dry the white (or near

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white) crystals using a stream of nitrogen gas (crystals should be white if the recrystallization is done without fluorescent lights or sunlight).

NOTE. The photoproduct is an azomethine–ylide that is highly reactive. It is wise, therefore, to reduce the time that the material is in solution to a minimum, and to protect, while in solution, the contents of the capped centrifuge tube from light as much as possible. Once in the crystalline state, the large majority of the photochromic reactions take place in an environment in which the azomethine–ylide is protected from further reaction and thus, given the opportunity (in the dark), the ylide will slowly recycle back to the diazabicyclic precursor with little loss.

After removing the mother liquors and drying the purified photochromic product, determine an evacuated melting point. (The diazabicyclic intermediate substance is oxidatively sensitive and will decompose during atmospheric melting point measurements.) Be alert to color changes during the melting point determination.

Compare your results with the literature value of 169–172 °C. Obtain an infrared spectrum (if using a KBr disk, prepare in the dark or red light) of the white form of the product. Compare your spectral data to that of the reference standard shown in Figure 7.9. Then expose the disk to a bright fluorescent

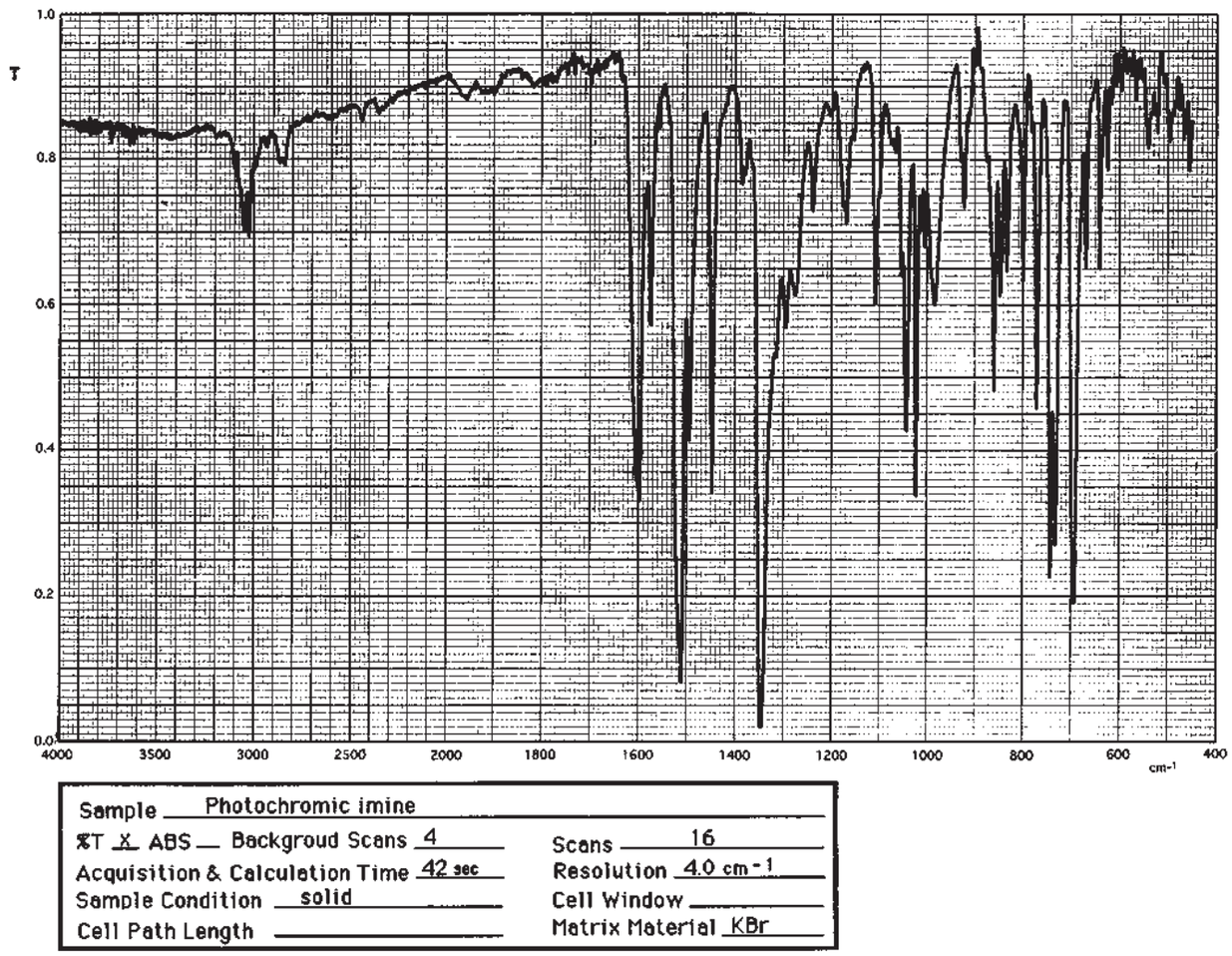

Figure 7.9 IR spectrum: photochromic imine.

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light for 1 min and redetermine the infrared spectrum. What does a comparison of the two experimentally derived spectra tell you about this photochemically induced reaction?

Store the remainder of your azomethine–ylide in a clean, sealed vial, flushed with N_2, and protected from light. By your next laboratory period this material should be colorless.

QUESTIONS

7-103. The heavily halogenated napthalenones were synthesized well over 100 years ago, but the structural details were sorted out less than 20 years ago. The compound, 2,3,4,4-tetrachloro-1-(4*H*)-naphthalenone (**I**), was discussed in the introduction to this sequence as an example of a substance that gains its photochromic activity by *bond homolysis.* In the synthesis of **I** two tetrachloro isomers were originally isolated. Compound **I** has photochromic activity while the second isomer (**II**) is simply a yellow-colored material. The structure of **II** has been determined to be 2,2,3,4-tetrachloro-1-(2*H*)-naphthalenone. A key piece of physical evidence that allowed the assignment of the structures was the infrared frequencies of the carbonyl groups. These frequencies were found to be 1701 and 1675 cm^{-1}. Which wavenumber value belongs with which structure?

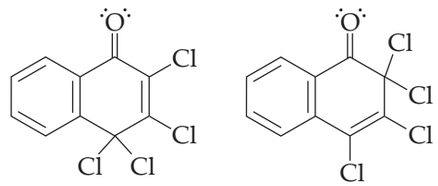

I **II**

Explain your reasoning.

7-104. Explain why the neutral aziridine ring system is isoelectronic with the cyclopropyl carbanion.

7-105. As shown in Question 7-104, the aziridine ring system is isoelectronic with the cyclopropyl anion. Based on the theory of electrocyclic reactions these *even-number* π-electron-pair systems would be expected to undergo photochemical ring-cleavage in *disrotatory* fashion. Huisgen et al. have shown that in dimethyl 1-(4-methoxy-phenyl)aziridine-*trans*-2,3-dicarboxylate (**I**), upon photochemical excitation the ring opens to a 1,3-dipolar azomethine–ylide in a *disrotatory* cleavage that can be trapped by the addition of dimethyl acetylenedicarboxylate, which acts as a dipolarophile:

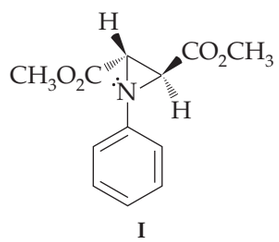

I

(a) Give a perspective drawing of the expected adduct.

(b) Give a perspective drawing of the expected adduct that would be formed from the blue azomethine ylide formed from our photochromic imine.

(c) Is the relative stereochemistry the same in the two adducts in *a* and *b*? Explain.

7-106. The dramatic change in color that occurs when the diazabicyclo[3.1.0]hex-3-ene ring system isomerizes on exposure to long wavelength UV radiation is related to what structural or electronic changes (or both) in the photochemically induced system?

7-107. Discuss the following:

(a) What role does ammonium bromide play in the conversion of the trans-substituted aziridine to the diazabicyclo[3.1.0]hex-3-ene derivative?

(b) Why is this particular bromide salt used?

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For an overview of photochemistry see

Smith, M. B.; March, J. *Advanced Organic Chemistry*, 6th ed., Wiley: New York, 2007, Chap, 7, p. 329 and references therein.

Also see references cited in Experiment [6].

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C_8H_8apter 8

SPECTROSCOPIC IDENTIFICATION OF ORGANIC COMPOUNDS

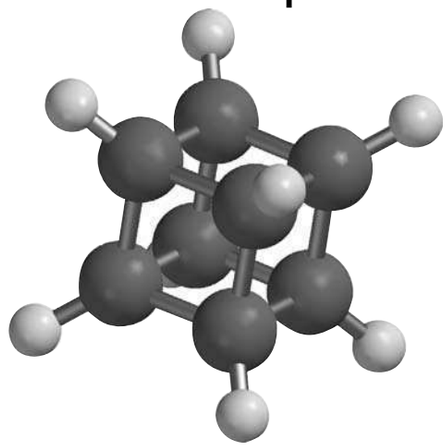

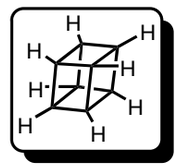

INFRARED SPECTROSCOPY

The wavelike character of electromagnetic radiation can be expressed in terms of velocity v, frequency ν, and wavelength λ of sinusoidally oscillating electric and magnetic vectors traveling through space (Fig. 8.1). Frequency is defined as the number of waves passing a reference point per unit time, usually expressed as cycles per second (s^{-1}) or hertz (Hz). The velocity of the wave, therefore, equals the product of frequency and wavelength:

$$v = \nu\lambda$$

If the wavelength (the distance between the wave maxima or alternate nodes) is measured in centimeters, v is expressed in centimeters per second (cm/s). For radiation traveling in a vacuum, v becomes a constant, c ($c \sim 3 \times 10^{10}$ cm/s), for all wavelengths. When electromagnetic radiation traverses other media, however, the velocity changes. The ratio of the speed in a vacuum, c, to the matrix velocity, v, is termed the *refractive index, n*, of the material:

$$n = \frac{c}{v}$$

Since n is frequency dependent, the frequency at which the refractive index is measured must be specified. Frequency, however, has been shown to be independent of the medium and, therefore, remains constant. Wavelength thus varies inversely with n.

$$\lambda = \frac{c}{n\nu}$$

Since the velocity of electromagnetic radiation in a vacuum is normally greater than that in any other medium, n will generally be greater than 1 at all frequencies. Thus, the wavelength must become shorter for a particular frequency when measured in any matrix.

Frequency can be considered to be a more fundamental property of radiation because it is independent of the medium. This property also requires that the energy E associated with the radiation be matrix independent because E is directly proportional to frequency by

$$E = h\nu$$

Chapter 8: C_8H_8, Cubane
Eaton and Cole (1964).

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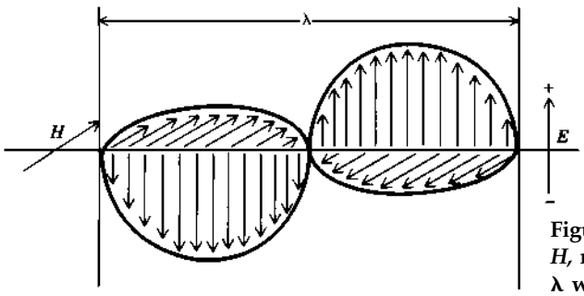

Figure 8.1 Electromagnetic wave. *H*, magnetic field; *E*, electric field; λ wavelength.

where E equals the energy of a photon, which is related to frequency ν by Planck's constant (h) (6.6×10^{-27} erg s or 6.6×10^{-34} J s).

The vibrational states present in molecules can be excited by absorption of photons. The nuclear masses and bond force constants determine the separation of these states and, therefore, the energies of the photons involved in the absorption process. The corresponding radiation frequencies fall predominantly in the IR region (10^{14}–10^{12} Hz) of the electromagnetic spectrum.

The IR spectrum is currently measured in *wavenumbers*, $\tilde{\nu}$, which are units proportional to frequency and energy. The wavenumber is defined as

$$\tilde{\nu} = \frac{\nu}{c} = \frac{E}{hc}$$

and as

$$\nu = \frac{c}{n\lambda} \qquad \text{then in air} \qquad \tilde{\nu} = \frac{\sim 1}{\lambda}$$

The wavenumber, as expressed in units of reciprocal centimeters (cm^{-1}) (the number of waves per centimeter), offers several advantages:

1. Wavenumbers are directly proportional to frequency and are expressed in much more convenient numbers (in this region of the spectrum), 5000–500 cm^{-1}.

2. As shown above, wavenumbers are easily converted to wavelength values. The reciprocal of $\tilde{\nu}$ and conversion of centimeters to wavelength units are all that is required (this is particularly handy because much early IR data were recorded linearly in wavelength). The wavelength unit employed in most of these spectra was the micron, μ (1×10^{-4} cm). The micron has been replaced by a unit expressed in meters, the micrometer, μm ($1\ \mu m = 1 \times 10^{-6}$ m).

3. Because the wavenumber is directly proportional to frequency and energy, the use of wavenumbers allows spectra to be displayed linearly in energy, which is a distinct aid in sorting out related vibrational transitions. For an introductory discussion of vibational energy see Chapter 8W, IR section, Part I.

INTRODUCTION TO GROUP FREQUENCIES: INTERPRETATION OF INFRARED SPECTRA

Studies of the vibrational spectra of thousands of molecules have revealed that many of the normal modes associated with particular atomic arrangements may be transferred from one molecule to another. A *normal mode* of vibration is one of the residue *fundamental* vibrations of a molecular system in which the

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atomic displacements are all related by simple harmonic motion to the overall total vibrational motion (or vibrational energy) of the molecule. There are $3N - 6$ (where N = the number of atoms) *normal modes* (or fundamental vibrations or vibrational degrees of freedom—all these terms are essentially synonymous) present in all nonlinear molecules. Linear molecules have only $3N - 5$ normal modes—in this case there is one more normal mode of vibrational energy present because a rotational degree of freedom has been lost. Rotation around the molecular axis involves no energy because the atomic nuclei are assumed to be point sources of matter. (For an introductory discussion of vibrational energy see Chapter 8W, IR section, Part I B.) www

Operating under selection rules these normal modes of vibration give rise to absorption bands in the infrared region of the spectrum (see, for example, the infrared spectrum of *n*-hexane, Fig. 8.2, p. 544). In the analysis these modes are often assigned numbers. For example, the 30 modes of benzene (where $N = 12$ in the $3N - 6$ expression) can be assigned 1 through 30 or the numbering can be done using any one of a number of different criteria. Subscripts *a* and *b* are often used to indicate doubly degenerate modes, that is, modes that have identical energies (and thus required to have the same frequency. One of the numbering systems for the benzene ring is used here when the aromatic ring stretching vibrations are identified (see Table 8.6 and Chapter 8W, IR section, Part II D, for a more detailed discussion of normal modes). www

Many of these vibrational frequencies are associated with small groups of atoms that are essentially uncoupled from the rest of the molecule. The absorption bands that result from these modes, therefore, are characteristic of the small group of atoms regardless of the composition of other parts of the molecule. These vibrations are known as the *group frequencies.* Interpretation of infrared spectra of complex molecules based on group frequency assignments is an extremely powerful aid in the elucidation of molecular structure.

The following four factors make significant contributions to the development of a good group frequency from a molecular vibration:

1. The group has a large dipole-moment change during vibrational displacement. This change in moment is formally related to the efficiency of absorption of radiation during the molecular displacement by the expression $I\alpha(\delta\mu/\delta Q)^2$ (where I = intensity, μ = electric dipole moment, and Q = the normal coordinate [a mathematical description of the vibration]). Thus, if $\delta\mu/\delta Q$ is large, there is a large absorption of infrared radiation which gives rise to very intense bands (the intensity is dependent on the square of the moment change at that vibrational frequency).

2. The presence of a large force constant, so that for many of these groups the stretching frequency occurs at high values above the fingerprint region.

3. The fundamental mode occurs in a frequency range that is reasonably narrow (little coupling), but sensitive enough to the local environment to allow for considerable interpretation of the surrounding structure.

4. The range of frequencies is determined by a number of factors that are now well understood in terms of the mass, geometric, electronic, intramolecular, and intermolecular effects (for an introductory discussion of these effects see Chapter 8W, IR section, Part III A). www

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Strategies for Interpreting Infrared Spectra

1. Divide the spectrum into two parts at 1350 cm^{-1}.

2. Above 1350 cm^{-1}, absorption bands have a high probability of being good group frequencies. The interpretation is usually reliable and free from ambiguities. We can be much more confident of our assignments in this region even with rather weak bands.

3. Because of the reliability of the high-wavenumber region, we always begin the interpretation of a spectrum at this end.

4. Bands below 1350 cm^{-1} may be either group frequencies or fingerprint frequencies.

5. Below 1350 cm^{-1}, group frequencies are less easily assigned. In addition, even if a reliable group frequency occurs in this region, absorption at that frequency is not necessarily a result of that mode. That is, fingerprint bands can also randomly occur in the same location as reliable group frequency bands and the observer cannot usually distinguish which type of band is present.

6. To make more confident assignments below 1350 cm^{-1}, it is helpful to be able to associate a secondary property, such as band shape, with the particular mode. For example, it helps to know whether the band is very intense, broad, sharp, occurs as a characteristic doublet, gives the correct frequency shift on isotopic substitution, or the like.

7. A good rule to remember is that in the fingerprint region the **absence** of a band is more important than the presence of a band. If a band is absent, you can conclude with confidence that a reliable group frequency assigned to this region is absent and therefore the group must be absent from the sample. At the same time you also know that no interfering fingerprint bands occur in the region.

8. Before beginning the interpretation, note the sampling conditions and determine as much other information about the sample as possible—such as molecular weight, melting point, boiling point, color, odor, elemental analysis, solubility, and refractive index.

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9. In the interpretation try to assign the most intense bands first. These bands very often will be associated with a polar functional group.

10. Do not try to assign all the bands in the spectrum. Fingerprint bands are unique to a particular system. Occasionally, intense bands will be fingerprint-type absorptions; these bands, generally, will be ignored in the interpretation. Fingerprint bands do, however, play an important role when infrared data are employed for identification purposes.

11. The correlation chart (back endpaper) can act as a helpful quick aid for checking potential assignments. It is not a substitute for understanding the theory and operation of group frequency logic. *The use of the correlation chart without a good knowledge of group frequencies is the shortest path to disaster!*[1]

12. Try to utilize the so-called *macro group frequency* approach. That is, if the functionality or molecular structural group requires the presence of more than a single group frequency vibrational mode, make sure that all modes are correctly represented. The *macro frequency train* represents a very powerful approach to the interpretation of relatively complex spectral data. This

[1]Bellamy, L. J. *The Infrared Spectra of Complex Molecules,* 3rd ed.; Chapman & Hall: London, 1975, p. 3.

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technique is at the core of current work on the automatic computer interpretation of infrared spectra. Contained in the product characterization section of the experiments given in Chapters 6 and 10W (online) are 12 detailed discussions (in Chapter 6, Experiments [5A], [5B], [6], [7], [8], [11], [14], [19], and [20]; in Chapter 10W (online), Experiments [1_{adv}], [4_{adv}] and [6_{adv}]) that demonstrate the operational use of the *macros.* Careful reference to these discussions will be very helpful in the initial stages of learning these interpretation techniques. It should become relatively easy to extend this interpretive approach to other reactions by reference to common infrared library files. Practice using *macro group frequencies* will pay big dividends in the laboratory. This last suggestion is perhaps the most important strategy to master in learning to interpret infrared spectra.

A SURVEY OF GROUP FREQUENCIES IDENTIFIED IN ORGANIC MOLECULES

The useful group frequencies are listed in the following sets of tables.

NOTE: A detailed description of the associated fundamental vibrational modes, diagrams of the actual displacements of the atoms, along with associated spectra, may be found at Chapter 8W, IR section, Part II. It is highly advisable to study this material.

In the following tables the vibration motion of the localized sections of the molecules assigned to a particular group's frequencies is often described using the following terms:

1. *Symmetric stretch* or *symmetric bend (deformation):* Here the local group retains its symmetry during displacement. The symmetric bend of the methylene group, CH_2, is often termed the *scissoring* bend, while the symmetric bend of a methyl group, CH_3, is termed an *umbrella* mode—both descriptions imply the type of displacements that are taking place in the vibration.
2. *Antisymmetric stretch* or *bend* (deformation): Here the vibrating system loses its symmetry during the vibration. The displacements involve a reflective (mirror image) displacement during the opposite phase of the simple harmonic vibration and the motion is termed antisymmetric rather than asymmetric. Antisymmetric bends (deformations) are often classified as *twisting, rocking,* and *wagging* vibrations.
3. Some vibrations involving planar sections of the molecules are referred to as *in-plane* or *out-of-plane.* They can be either symmetric or antisymmetric in nature and if they involve the bending of all the displaced bonds of a set of atoms moving together in the same direction they will be termed *all-in-phase.*
4. *Degenerate* vibrations are defined as the case where two or more molecular vibrations are required to occur at the same frequency (see Chapter 8W, IR sections, Part I B and Part I D3 for more details).

5. *Overtones* (integral multiples of the fundamental mode frequency) and *sum tones* (the sum of two different fundamental modes) are forbidden bands that are almost always very weak. Occasionally these bands are good group frequencies.

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Group Frequencies of the Hydrocarbons

Alkanes Alkynes
Alkenes Arenes

Alkanes. The C—H vibrational modes of the alkanes (or mixed compounds containing alkyl groups) that are characteristic and reliable group frequencies are summarized in Table 8.1 (also see Chapter 8W, IR section, Part II A).

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These modes give rise to characteristic bands found in the infrared spectrum of alkanes, such as in the spectrum of *n*-hexane shown in Figure 8.2.

Alkenes C═C Stretching. It is possible to classify open-chain unsaturated systems into two groups, those with C═C stretching modes falling above 1660 cm^{-1} and those with modes falling below 1660 cm^{-1} as shown in Table 8.2 (see also Chapter 8W, IR section, Part II B1).

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Alkenes C—H. Several fundamental modes associated with the alkene C—H groups are group frequencies and are summarized in Table 8.3.

Alkynes. The group frequencies of the alkynes are summarized in Table 8.4 (see also Chapter 8W, IR section, Part II C).

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Table 8.1 **Alkane Vibrational Normal Modes**

C—H Vibrational Modes	$\tilde{\nu} \pm 10$ (cm^{-1})
Methyl groups	
Antisymmetric (degenerate) stretch	2960
Symmetric stretch	2870
Antisymmetric (degenerate) deformation	1460
Symmetric (umbrella) deformation	1375
Methylene groups	
Antisymmetric stretch	2925
Symmetric stretch	2850
Symmetric deformation (scissors)	1450
Rocking mode (all-in-phase)	720

Table 8.2 **Substitution Classification of C═C Stretching Frequencies**

C═C Normal Modes	$\tilde{\nu}$ (cm^{-1})
Trans-, tri-, tetrasubstituted	1680–1665
Cis-, vinylidene- (terminal 1,1-disubstituted), vinyl-substituted	1660–1620

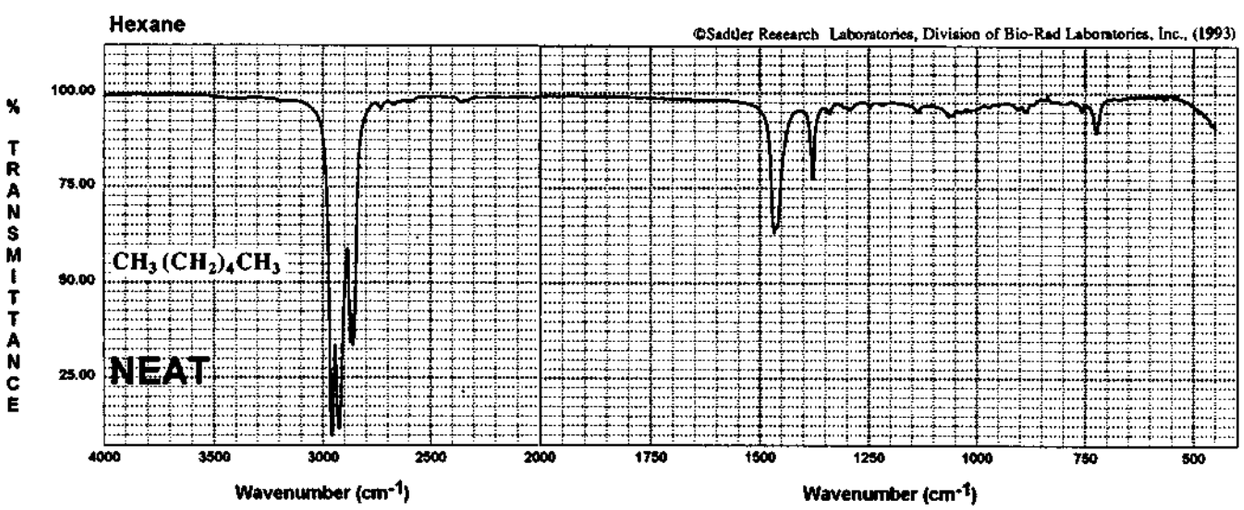

Figure 8.2 IR spectrum: *n*-hexane.

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Table 8.3 Alkene Vibrational Normal Modes	
C—H Vibrational Modes	$\tilde{\nu} \pm 10\ (cm^{-1})$
Stretching modes	
Antisymmetric stretch (═CH_2)	3080
Symmetric stretch (═CH_2)	3020
Uncoupled stretch (═CH_2)	3030
Out-of-plane bending modes	
Vinyl group	
Trans hydrogen atoms (in-phase)	990
Terminal hydrogen atoms (wag)	910
Vinylidene group (═CH_2)	
Terminal (wag)	890
Trans alkene	
Trans hydrogen atoms (in-phase)	965
Cis alkene	
Cis hydrogen atoms (in-phase)	~700
Trisubstituted alkene	
Uncoupled hydrogen atom	820
Tetrasubstituted alkene: no vibrational modes seen in IR	

Table 8.4 Alkyne Vibrational Normal Modes	
C≡C, C—H Vibrational Modes	$\tilde{\nu} \pm 10\ (cm^{-1})$
Triple-bond stretch (monosubstituted)	2120
Triple-bond stretch (disubstituted)	2225
R—C≡C—H bond stretch (monosubstituted)	3300

Arenes. The group frequencies of the *phenyl* group can be classified as carbon–hydrogen vibrations consisting of stretching and out-of-plane bending modes, plus carbon–carbon ring stretching and out-of-plane bending modes. The in-plane bending modes in both cases are not effective group frequencies.

The wavenumber values for the all-in-phase C—H bending vibrations are presented in Table 8.5.

The generalized group frequencies of the arenes are summarized in Table 8.6 (see also Chapter 8W, IR section, Part II D). ← www

Group Frequencies of Carbonyl Groups: C═O

The carbonyl group is perhaps the single most important functional group in organic chemistry. It is certainly the most commonly occurring functionality. Infrared spectroscopy can play a powerful role in the characterization of the carbonyl because this group possesses all of the properties that give rise to an excellent group frequency. (Table 8.7; for an in depth discussion see Chapter 8W, IR section, Part III A.) ← www

Table 8.5 Arene Out-of-Ring-Plane C—H Deformation Modes	
Arene Fundamentals (C—H bend) (Number of C—H groups directly adjacent)	$\tilde{\nu}$ Range (cm^{-1})
5	770–730
4	770–735
3	810–750
2	860–800
1	900–845

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Table 8.6 Arene Group Frequencies	
Arene Fundamentals	**$\tilde{\nu}$ Range (cm^{-1})**
C—H stretch	3100–3000
C═C ring stretch (ν_{8a})	1600 ± 10
C═C ring stretch (ν_{8b})	1580 ± 10
C═C ring stretch (ν_{19a})	1500 ± 10
C═C ring stretch (ν_{19b})	1450 ± 10
C—H out-of-plane bend (1H)	900–860
C—H out-of-plane bend (2H)	860–800
C—H out-of-plane bend (3H)	810–750
C—H out-of-plane bend (4H)	770–735
C—H out-of-plane bend (5H)	770–730
C—C ring out-of-plane bend (1; 1,3; 1,3,5-substituted)	690 ± 10
C—H out-of-plane bend sum tones	2000–1650

The major factors perturbing carbonyl frequencies can be summarized as follows:

Factors That Raise the C═O Frequency

1. Substitution with electronegative atoms
2. Decrease in C—CO—C internal bond angle

Factors That Lower the C═O Frequency

1. Conjugation
2. Hydrogen bonding

Several of these factors may be operating simultaneously, so careful judgment as to the contribution of each individual effect must be exercised in

Table 8.7 Carbonyl Group Vibrational Frequencies	
Compound	**$\tilde{\nu}$ (cm^{-1})**
Ketones, aliphatic, open-chain (R_2CO)	1725–1700
Ketones, conjugated	1700–1675
Ketones, cyclic	*a*
Acyl halides	>1800
Esters, aliphatic	1755–1735
Esters, conjugated	1735–1720
Esters (conjugated to oxygen)	1780–1760
Lactones	*a*
Anhydrides: aliphatic, open-chain	1840–1810 and 1770–1740
Carboxylic acids, aliphatic	1725–1710
Amides	(see Tables 8.22–8.24)
Lactams	*a*
Aldehydes	1735–1720
[a]See Chapter 8W, IR section, Part III A.	

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Table 8.8 Vibrational Normal Modes of the Hydroxyl Group		
$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3500–3200	Very strong	O—H stretch (only strong when hydrogen bonded
1500–1300	Medium strong	O—H in-plane bend (overlap CH_2, CH_3 bend)
1260–1000	Strong	C—C—O antisymmetric stretch
650	Medium	O—H out-of-plane bend

Table 8.9 Substitution Effects on C—O Stretch of Aliphatic Alcohols	
Type of Alcohol	$\tilde{\nu}_{c—o}$ (cm^{-1})
RCH_2—OH (primary)	1075–1000
R_2CH—OH (secondary)	1150–1075
R_3C—OH (tertiary)	1200–1100
C_6H_5—OH (phenol)	1260–1180

predicting carbonyl frequencies. This judgment develops rapidly with practice at interpretation.

Group Frequencies of the Heteroatom Functional Groups

(Alkanes)			
Alcohols	Aldehydes	Ketones	Esters
Acyl halides	Carboxylic acids	Anhydrides	Ethers
Amines, primary	Nitriles	Amides, primary	Amides, secondary
Isocyanates	Thiols	Halogens	Phenyl

Hexane. Refer to Table 8.1 (see also Chapter 8W, IR section, Part II A, and Fig. 8.2). www

Alcohols. A very intense band appears at ~3350 cm^{-1}, which is assigned to the stretching mode of the O—H group (Table 8.8; also see Chapter 8W, IR section, Fig. W8.24). www

Of particular importance is a strong band in the spectrum of aliphatic alcohols usually located near 1060 cm^{-1}. This absorption has been identified as the C—O stretching mode. The vibrational displacements of this fundamental are similar to the antisymmetric stretch of water (see Chapter 8W for a detailed discussion of the vibrational modes of the water molecule). Since the vibration involves significant displacement of the adjacent C—C oscillator, the vibration will be substitution sensitive. These latter shifts can be of value in determining the nature of the alcohol (primary, secondary, or tertiary, see Table 8.9). www

Aldehydes. The aldehyde functional groups gives rise to several good group frequencies (Table 8.10; also see Chapter 8W, IR section, Fig. W8.25). www

Ketones. The only group frequency mode associated directly with aliphatic ketones is the stretching frequency ($\tilde{\nu}_{c=o}$~1720 cm^{-1}), which occurs within the expected region as discussed above. There are, however, several other related bands (Table 8.11; also see Chapter 8W, IR section, Fig. W8.26). www

Table 8.10 Vibrational Normal Modes of the Aliphatic Aldehyde Group		
$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
2750–2720	Weak to medium	C(O)—H stretch (see also online Chapter 8W, IR section)
1735–1720	Very strong	C═O stretch
1420–1405	Medium	CH_2 symmetric bend, —CH_2—α to —CHO
1405–1385	Medium	C—H in-plane bend

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Table 8.11 Normal Vibrational Modes of Aliphatic Ketones		
$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3430–3410	Very weak	Overtone of carbonyl stretch
1725–1700	Very strong	C═O
1430–1415	Medium	—CH_2— symmetric bend, —CH_2—α to ketone C═O

Table 8.12 Vibrational Normal Modes of the Aliphatic Ester Group		
$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
1755–1735	Very strong	C═O stretch
1370–1360	Medium	CH_3 symmetric bend α to ester C═O
1260–1230	Very strong	C—CO—O antisymmetric stretch —acetates
1220–1160	Very strong	C—CO—O antisymmetric stretch —higher esters
1060–1030	Very strong	O—CH_2—C antisymmetric stretch —1° acetates
1100–980	Very strong	O—CH_2—C antisymmetric stretch —higher esters (may overlap with upper band)

Table 8.13 Vibrational Normal Modes of the Acyl Halide Group		
$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
1810–1800	Very strong	C═O stretch, acyl chlorides
1415–1405	Strong	—CH_2—symmetric bend, α to —COCl carbonyl

Esters

The very strong band found at ~1745 cm^{-1} is typical of the carbonyl frequency of an aliphatic ester, particularly aliphatic acetate esters (Table 8.12; also see Chapter 8W, IR section, Fig. W8.27).

Acyl Halides. The carbonyl stretching mode dominates the spectrum in aliphatic acyl halides. In acyl chlorides it is an extremely intense band occurring near 1800 cm^{-1} (Table 8.13; also see Chapter 8W, IR section, Fig. W8.28).

Carboxylic Acids. Acids, observed in the solid or pure liquid states, often possess a very intense band with a width at one-half peak height of about 1000 cm^{-1}, which covers the region 3500–2200 cm^{-1}. This absorption is characteristic of very strongly hydrogen-bonded carboxylic acid groups (Table 8.14; also see Chapter 8W, IR section, Fig. W8.29).

Anhydrides. The coupling of the anhydride carbonyls through the ether oxygen splits the carbonyls (in the aliphatic case $\tilde{\nu}_{c=o}$ = ~1830, 1760 cm^{-1}) by about 70 cm^{-1} (Table 8.15; also see Chapter 8W, IR section, Fig. W8.30).

Ethers. The large intensity associated with antisymmetric C—O—C stretching mode relative to the other bands occurring in this part of the fingerprint region, particularly in aliphatic compounds, makes it possible, in most cases, to assign

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Table 8.14 Vibrational Normal Modes of the Carboxylic Acid Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3500–2500	Very very strong	O—H stretch intensified by hydrogen bonding
2800–2200	Very weak	Overtone and sum tones
1725–1710	Very strong	C═O antisymmetric hydrogen-bonded dimer stretch
1450–1400	Strong	CH_2—CO—O antisymmetric stretch mixed with O—H bend
1300–1200	Strong	CH_2—CO—O antisymmetric stretch mixed with O—H bend
950–920	Medium	Out-of-plane O—H bend, acid dimer

Table 8.15 Vibrational Normal Modes of the Anhydride Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
1840–1810	Very strong	C═O in-phase stretch
1770–1740	Very strong	C═O out-of-phase stretch
1420–1410	Strong	—CH_2— symmetric bend α to C═O
1100–1000	Very strong	C—O stretch, mixed modes

Table 8.16 Vibrational Normal Modes of the Ether Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
1150–1050	Strong	C—O—C antisymmetric stretch, mixed mode

with confidence the observed strong band (Table 8.16; also see Chapter 8W, IR section, Fig. W8.31). www

Primary Amines. The spectra of these bases usually possess two bands ($\tilde{\nu}_{N—H}$ = ~3380, ~3300 cm^{-1}) of medium-to-weak intensity. These bands are assigned to the antisymmetric and symmetric N—H stretching modes, respectively, of the primary amino group (Table 8.17; also see Chapter 8W, IR section, Fig. W8.32). www

Nitriles. The very strong triple bond present in the nitrile group (as in the case of the alkynes) contributes to an unusually high stretching frequency, and the polar character of the group gives rise to very intense bands (Table 8.18; also see Chapter 8W, IR section, Fig. W8.33). www

Primary Amides. The highly polar amide group leads to very strong hydrogen bonding, which in turn leads to greatly intensified N—H antisymmetric and symmetric stretching modes ($\tilde{\nu}_{N—H}$ = ~3375, ~3200 cm^{-1}; see Table 8.19; also see Chapter 8W, IR section, Fig. W8.34). www

Secondary Amides. The single N—H group present in secondary amides gives rise to a very strong band near about 3300 cm^{-1}, which is indicative of strong hydrogen bonding. The drop in frequency from that of the primary —NH_2 scissoring mode near 1600 cm^{-1} allows for confident assignment of substitution on secondary amide groups (Table 8.20; also see Chapter 8W, IR section, Fig. W8.35). www

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Table 8.17 Vibrational Normal Modes of the Primary Amine Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3400–3200	Weak to medium	NH_2 stretch doublet, (antisymmetric and symmetric modes)
1630–1600	Medium	NH_2 symmetric bend
820–780	Medium	NH_2 wag

Table 8.18 Vibrational Normal Modes of the Nitrile Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
2260–2240	Strong	C≡N stretch, aliphatic
2240–2210	Strong	C≡N stretch, conjugated

Table 8.19 Vibrational Normal Modes of the Primary Amide Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3400–3150	Very strong	—NH_2 antisymmetric and symmetric stretching modes, hydrogen bonded
1680–1650	Very strong	C═O stretch, hydrogen bonded
1660–1620	Strong	—NH_2 symmetric bend (overlap with C═O stretch)
1430–1410	Strong	—CH_2—symmetric bend α to amide carbonyl
750–650	Medium	—NH_2 wag

Table 8.20 Vibrational Normal Modes of the Secondary Amide Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
3350–3250	Strong	—NH stretch, intensified by hydrogen bonding
3125–3075	Medium	Overtone N—H bend (see also)
1670–1645	Very strong	C═O stretch, hydrogen bonded
1580–1550	Strong	N—H in-plane bend (see also)
1415–1405	Strong	—CH_2— symmetric bend α to amide C═O
1325–1275	Medium	C—N stretch mixed with N—H in-plane bend
725–680	Medium	N—H out-of-plane bend

Table 8.21 Vibrational Normal Modes of the Amide Carbonyl: Solution and Solid-Phase Data

Amide	Dilute Solution (cm^{-1})	Solid (cm^{-1})
R—CO—NH_2 (primary)	~1730	~1690–1650
R—CO—NHR (secondary)	~1700	~1670–1630
R—CO—NR_2 (tertiary)	~1650	~1650

Studies of amide carbonyl frequencies in dilute nonpolar solution indicate that hydrogen-bonding effects are largely responsible for the low frequencies observed with primary and secondary amides, but play no role in tertiary amides (see Table 8.21).

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Table 8.22 Vibrational Normal Mode of the Isocyanate Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
2280–2260	Very strong	—N═C═O antisymmetric stretch

Table 8.23 Vibrational Normal Mode of the Thiol Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
2580–2560	Weak	S—H stretch

Table 8.24 Vibrational Normal Mode of the Alkyl Chloro Group

$\tilde{\nu}$ (cm^{-1})	Intensity	Mode Description
750–650	Strong	C—Cl stretch (see also)

Table 8.25 Vibrational Normal Modes of the Aryl Chloro Group

$\tilde{\nu}$ (cm^{1})	Intensity	Mode Description
3080	Medium	C—H stretch, bonded to ring carbon
1585	Strong	ν_{8a} ring stretching
1575	Weak	ν_{8b} ring stretching
1475	Strong	ν_{19a} ring stretching
1450	Strong	ν_{19b} ring stretching
747	Strong	C—H all-in-phase, out-of-plane bend
700	Strong	C—Cl stretch
688	Strong	Ring deformation
1945, 1865, 1788, 1733	All weak	Sum tones, out-of-plane C—H bends, pattern matches monosubstitution of ring

Isocyanates. The range of stretching frequencies observed for alkyl-substituted isocyanates is very narrow, $\tilde{\nu} = 2280 - 2260\,cm^{-1}$, which implies little coupling to the rest of the system (Table 8.22; also see Chapter 8W, IR section, Fig. W8.36).

Thiols. Although weak absorption is associated with the S—H stretching fundamental the band is generally found in a very open region of the infrared spectrum (Table 8.23; also see: Chapter 8W, IR section, Fig. W8.37).

Alkyl Halides. The massive halogen atom is connected to the alkyl section by a fairly weak but highly polarized bond, which dictates that the C—X stretching frequency appears as an intense band at low frequencies (Table 8.24; also see Chapter 8W, IR section, Fig. W8.38).

Aryl Halides (Chlorobenzene). The final system to be considered in this section is the aryl halide, chlorobenzene. Based on the above assignments the group frequencies of the complete hydrocarbon portion and the heteroatom functional group can be assigned as in Table 8.25 (also see Chapter 8W, IR section, Fig. W8.39).

INFRARED SPECTROSCOPY INSTRUMENTATION AND SAMPLE HANDLING

Instrumentation

The workhorse infrared instrument used for routine characterization of materials in the undergraduate organic laboratory is the optical-null double-beam grating spectrometer (Fig. 8.3*a*). For a discussion of double-beam spectrometers, see the UV-vis instrumentation discussion (p. 604). Although many

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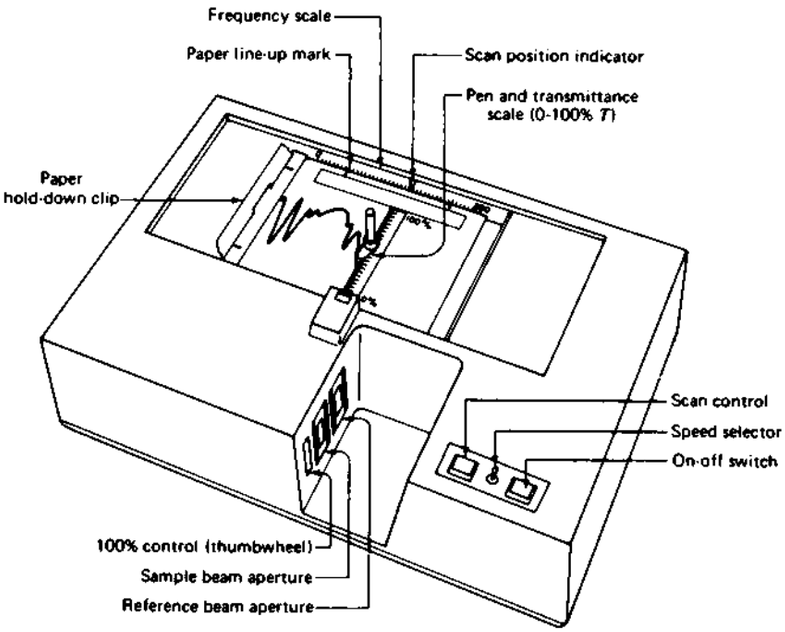

Figure 8.3*a* The Perkin–Elmer model 710B IR spectrometer. From Zubric, James W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. (Reprinted by permission of John Wiley & Sons, Inc., New York.)

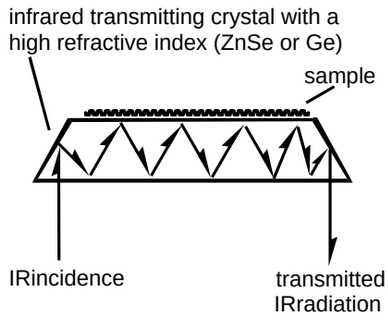

Figure 8.3*b* Attenuated Total Reflectance (ATR).

undergraduate instructional laboratories still utilize this type of instrumentation, the winds of change are blowing. ATR (attenuated total reflectance) FT-IRs and lower-cost FT-IR spectrometers, which both depend on computer manipulation of the spectral data, are becoming the infrared instructional instrumentation of choice. Two of the many benefits when using the more expensive ATR FT-IR spectrometer are faster sampling and spectral reproducibility. Even though ATR plates are prone to contamination, one key advantage when working with an ATR crystal (Fig. 8.3*b*) is that no sample preparation is required. This avoids the need to use KBr or mineral oil (Nujol) when working with solids! Many of the spectra utilized in the interpretive discussions (Chapter 8W, IR section) were generated on a prototype of this kind of infrared instrumentation, the Perkin–Elmer model 1600.

This instrument can acquire 16 scans and carry out the required calculations in 42 s. While the spectrum is being printed out(~40 s) the data on a second sample can be acquired. The 42-s acquisition data are significantly superior to those recorded by dispersive instruments that take from 5 to 8 min to scan a sample from 4000 to 600 cm^{-1}.

A short description of FT-IR spectrometers is included in the discussion of instrumentation on the website (Chapter 8W, IR section, Part IV).

Sample Handling in the Infrared

If not working with an ATR FT-IR, the standard techniques of sample preparation employed to obtain infrared spectra of microscale laboratory products are the use of capillary films with liquids on NaCl (or AgCl) plates and the use of KBr disks and melts in solids. This, of course, assumes that for a spectrum to be obtained in the infrared region, the sample must be mounted in a cell that is transparent to the radiation. With an ATR FT-IR spectrometer, liquids and solids are placed in direct contact with the ATR crystal. Since glass and quartz absorb in this spectral region, cells constructed of these materials cannot be

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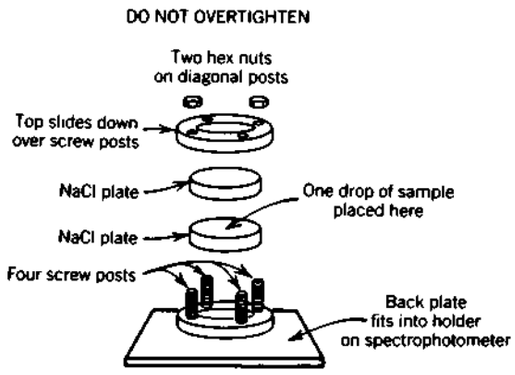

Figure 8.4 IR salt plates and holder. From Zubric, James W. *The Organic Chem Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. (Reprinted by permission of John Wiley & Sons, Inc., New York.)

used when working with spectrometers not utilizing ATR technology. Accordingly, alkali metal halides have large spectral regions of transmission in the infrared, as do silver halides. Sodium chloride is the most commonly used material in cell windows in infrared sampling.

Liquid Samples. For materials boiling above 100 °C, the procedure is very simple. Using a syringe or Pasteur pipet, place 3–5 μL of sample on a polished plate of sodium chloride or silver chloride or directly on the ATR crystal. If working with a NaCl or AgCl plate, cover it with a second plate of the same material and clamp it in a holder that can be mounted vertically in the instrument. Be sure that the plates are clean when you start and when you are through! Obviously, the sodium chloride plates cannot be cleaned with water. Silver chloride is very soft and scratches easily; it also must be kept in the dark when not in use because it darkens quickly in direct light. Spectra obtained in this fashion are referred to as *capillary film spectra* (Fig. 8.4).

Solution Spectra and the Spectra of Materials Boiling Below 100 °C. These samples generally require a sealed cell constructed of either sodium chloride or potassium bromide windows. Such cells are expensive and need careful handling and maintenance. They are assembled as shown in Figure 8.5.

Solid Samples using non-ATR Spectrometers. Solid powders could be mounted on horizontal sodium chloride plates, and the beam diverted

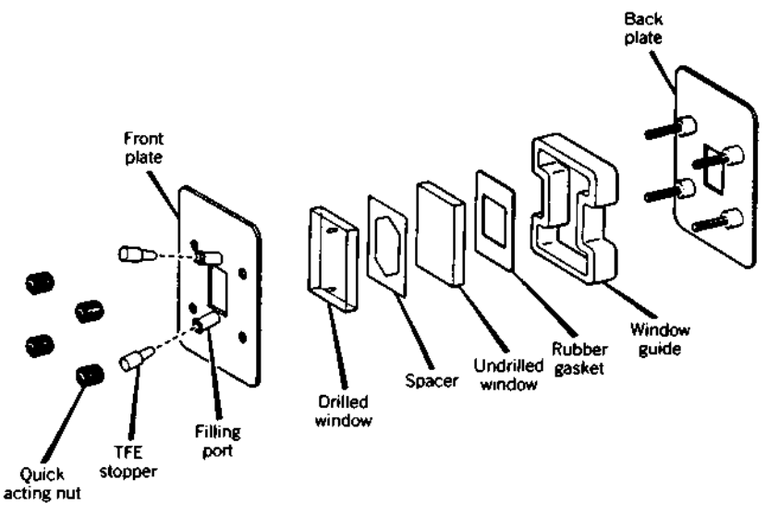

Figure 8.5 Sealed demountable cell or demountable cell with ports. (Courtesy of the Perkin-Elmer Corp., Norwalk, CT.)

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through the sample by mirrors. This procedure would make sample preparation very easy for solids. Unfortunately, powders tend to scatter the entering radiation very efficiently by reflection, refraction, and molecular scattering. Some of these effects become rapidly magnified at higher frequencies, since they vary with the fourth power of the frequency. Thus, in solid-sample scattering a lot of energy is scattered away from the sample beam. This results in poor absorption spectra, as the instrument is forced to operate at very low energies. The detector cannot differentiate between a drop in energy from absorption or one derived from scattering.

For materials melting below 80 °C the simplest technique is to mount the sample between two salt plates and **gently** warm with a heat lamp until melting occurs. With the fast acquisition times of interferometers, the melting point range is now as high as 100 °C and the spectrum can be obtained so rapidly that the sample does not have time to cool and crystallize. (Heated cells are used in research laboratories, but they are rather expensive and difficult to maintain.) For substances melting above 100 °C, the sampling routine most often employed to avoid scattering problems is the potassium bromide (KBr) disk. Potassium bromide is transparent to infrared radiation in the region of interest. Most important, however, the KBr makes a much better match of the refractive indexes between the sample and its matrix than does air. Thus, reflection and refraction effects at the crystal faces of the sample are greatly suppressed.

In the KBr method the sample (2–3 mg) is finely ground in a mortar, the finer the better for lower reflection or refraction losses. Then, 150 mg of previously ground and dried KBr is added to the mortar and quickly mixed by stirring, not grinding, it with the sample. (Potassium bromide is very hygroscopic and will rapidly pick up water while being ground in an open mortar.) When mixing is complete the mixture is transferred to a die and pressed into a solid disk. Potassium bromide will flow under high pressure and seal the solid sample in a glasslike matrix. Several styles of dies are commercially available. For routine use a die consisting of two stainless steel bolts and a barrel is the simplest to operate (see Fig. 8.6). The ends of the bolts are polished flat to form the die faces. The first bolt is seated to within a turn or two of the head. Then the sample mixture is added (avoid breathing over the die while adding the sample). The second bolt is firmly seated in the barrel, and then the clamped assembly is tightened by a torque wrench to 240 in./lb. After standing for 1.5 min, the two bolts are removed, leaving the KBr disk mounted in the center of the barrel, which can then be mounted in the instrument. After the spectrum of the sample is run, the disk can be retrieved and the sample recovered if necessary (Fig. 8.6). *Always clean the die immediately after use. KBr is highly corrosive to steel.*

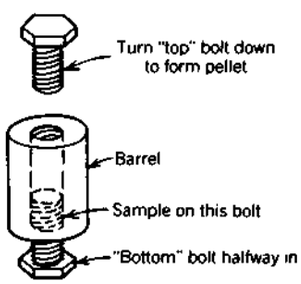

Figure 8.6 The KBr pellet mini-press. From Zubric, James W. *The Organic Chem Lab Survival Manual,* 7th ed.: Wiley: New York, 2008. (Reprinted by permission of John Wiley & Sons, Inc., New York.)

When infrared spectra are obtained, it is important to establish that the wavenumber values have been accurately recorded. Successful interpretation of the data often depends on very small shifts in these values. Calibration of the frequency scale is usually accomplished by obtaining the spectrum of a reference compound, such as polystyrene film. To save time, record absorption peaks only in the region of particular interest (this applies only to dispersive instrument derived data).

NOTE. Most of the infrared spectra found in the experimental sections of the text, which are Fourier-transform derived (Perkin–Elmer 1600), have been plotted on a slightly different scale than the other spectra presented in the text and on the website. The former spectra utilize a 12.5-cm^{-1}/mm format below 2000 cm^{-1} and undergo a 2:1 compression above 2000 cm^{-1} (25 cm^{-1}/mm).

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QUESTIONS

NOTE. Some of the following questions assume that the student is familiar with the infrared material contained on the website available to refer to if needed.

8-1. The form of the C—H out-of-plane bending vibrations of the vinyl group are shown below:

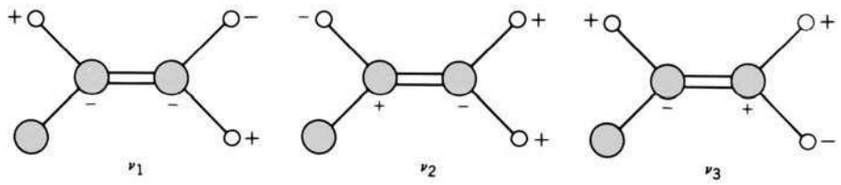

The first two vibrational modes give rise to excellent group frequencies, while the third fundamental does not lend itself to these correlations.

(a) Explain the factors that lead to the third vibrational mode being such a poor group frequency.

(b) Predict the location in the spectrum of the third fundamental vibration.

8-2. In the figure below, the mass of the terminal hydrogen atoms on the acetylene is hypothetically varied from zero to infinity. The response of the C—H symmetric stretching (3374 cm^{-1}) and triple-bond stretching (1974 cm^{-1}) modes to the change in mass is shown.

(a) Calculate the expected deuterium isotope shift for the C—H symmetric stretching mode. Is the hypothetical value close to the calculated value? Explain.

(b) Explain why the triple-bond stretching frequency is approximately 100 cm^{-1} higher for high-mass terminal isotopes (>100) than for the low-mass terminal isotopes (<3).

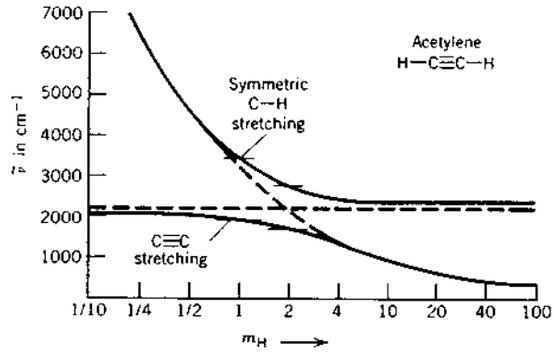

8-3. Acetylene has two C—H groups. It will have two C—H stretching frequencies, the in-phase and out-of-phase stretching modes. The in-phase (symmetric) stretch occurs at 3374 cm^{-1} and the out-of-phase stretch at 3333 cm^{-1}. Explain why the in-phase vibration is located at a higher frequency than the out-of-phase stretch.

8-4. The carbonyl stretching frequencies of a series of benzoyl derivatives are listed below:

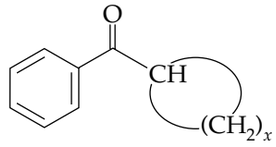

x	$\tilde{\nu}_{C=O}$ (CCl_4)
2	1677
3	1686
4	1687
5	1686

Consider the $\tilde{\nu}_{C=O}$ of acetone at 1715 cm^{-1} as a reference frequency and identify the factors affecting $\tilde{\nu}_{C=O}$ in the series of compounds listed.

8-5. Explain how mass effects act to lower the carbonyl frequency, as well as how inductive and hyperconjugation effects act to raise the carbonyl frequency of aldehydes relative to ketones.

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8-6. The carbonyl stretching frequency of aliphatic carboxylic acids in dilute solution is located near 1770 cm^{-1}. This frequency is much higher than the carbonyl frequency of these substances when measured neat (~1720 cm^{-1}). Also, it is considerably higher than the corresponding simple aliphatic ester value (1745 cm^{-1}). Explain.

8-7. In a number of cases, dipolar interactions control the frequency shifts found in carbonyl stretching vibrations. The table lists wavenumber shifts in going from neat to dilute nonpolar solutions. Explain the observed values.

Carbonyl Dipolar Interactions[a]

Compound	$\Delta\tilde{\nu}$ (cm^{-1})
Acetyl chloride	15
Phosgene	13
Acetone	21
Acetaldehyde	23
N,N-Dimethylformamide	50

[a]Shift measured between dilute nonpolar solution and neat sample.

8-8. The antisymmetric —CH_2—CO—O—stretching vibration in carboxylic acids is heavily mixed with the in-plane bending mode of the O—H group. In alcohols these two vibrations seldom show evidence of mechanical coupling. Explain.

8-9. Conjugation of the functional group in alkyl isocyanates has little impact on the antisymmetric —N═C—O stretching vibration located near 2770 cm^{-1} Explain.

8-10. In the infrared spectrum of 2-aminoanthraquinone (**I**) two carbonyl stretching frequencies are observed at 1673.5 and 1625 cm^{-1}:

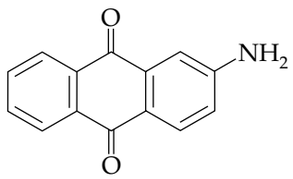

2-Aminoanthraquinone
I

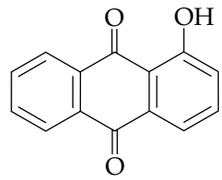

1-Hydroxyanthraquinone
II

(a) Assign carbonyl bands in the infrared spectrum to the carbonyl groups in structure **I** and explain your reasoning.

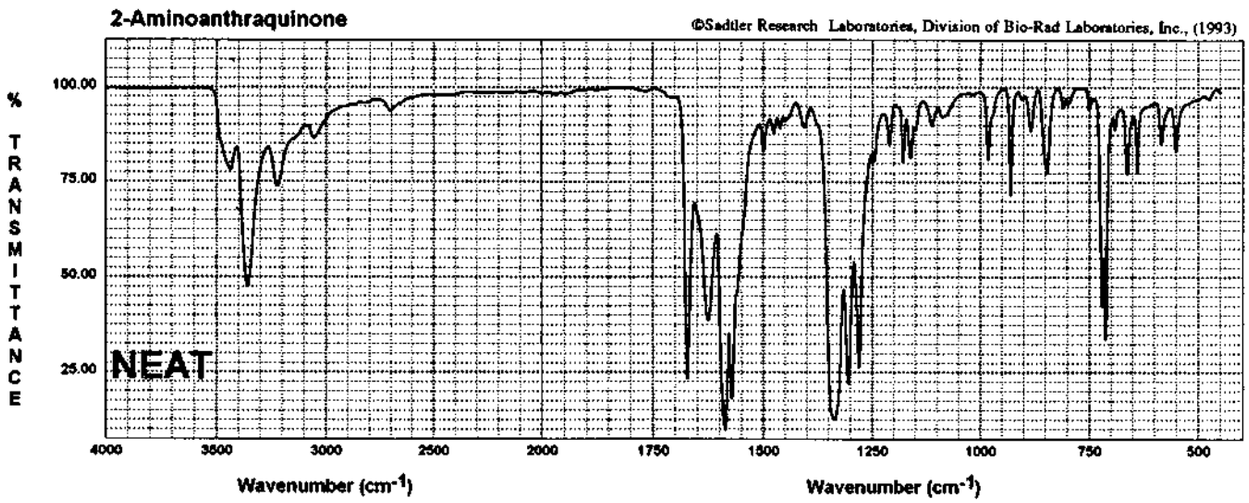

IR spectrum: 2-Aminoanthraquinone.

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(b) The infrared spectrum of 1-hydroxyanthraquinone (**II**) also exhibits two carbonyl frequencies, which are located at 1675 and 1637 cm^{-1}. Assign the carbonyl groups to the related absorption bands. Explain your reasoning.

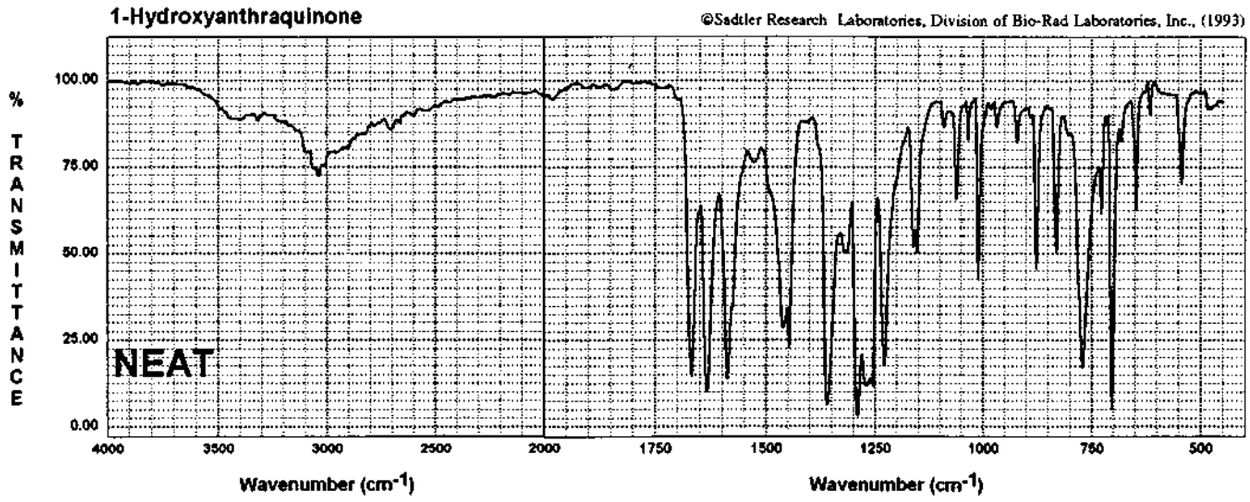

IR spectrum: 1-Hydroxyanthraquinone.

(c) The spectrum of 2-hydroxyanthraquinone exhibits a single carbonyl stretching frequency near 1673 cm^{-1}. Explain why a single carbonyl band would be expected in the system and why this vibration is located at 1673 cm^{-1}.

8-11. Suggest a possible structure for the hydrocarbon C_6H_{14}, which has the infrared spectrum shown here: Is there more than one correct structure?

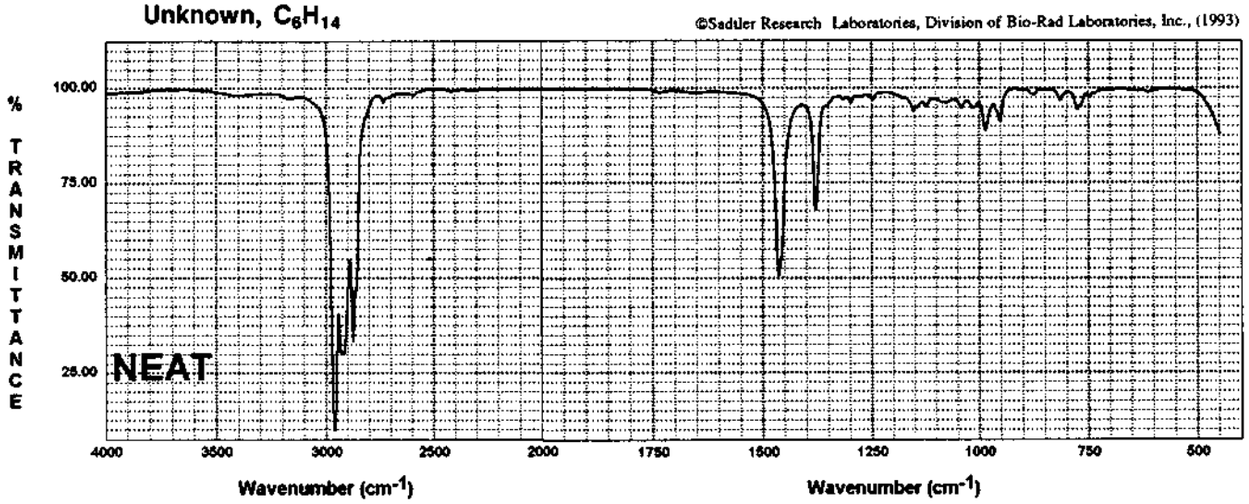

IR unknown spectrum: C_6H_{14}.

8-12. The hydroxylamine **I** can be oxidized by MnO_2 to the amide oxohaemanthidine (**II**). In dilute solution the carbonyl absorption band of **II** occurs at 1702 cm^{-1}. Explain this observation.

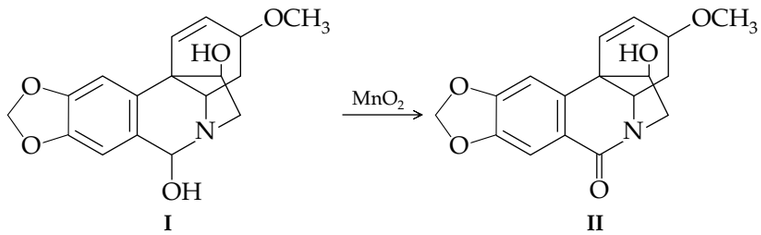

I **II**

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8-13. Identify the following alkenes. All samples were obtained from distillation cuts in the C_6 boiling range.

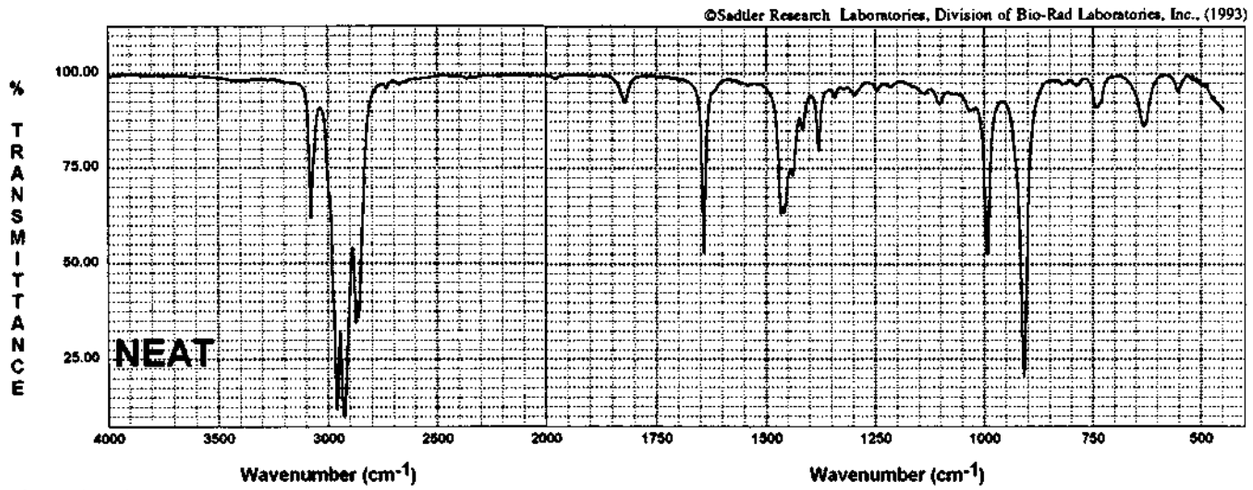

Infrared unknown spectrum *a*.

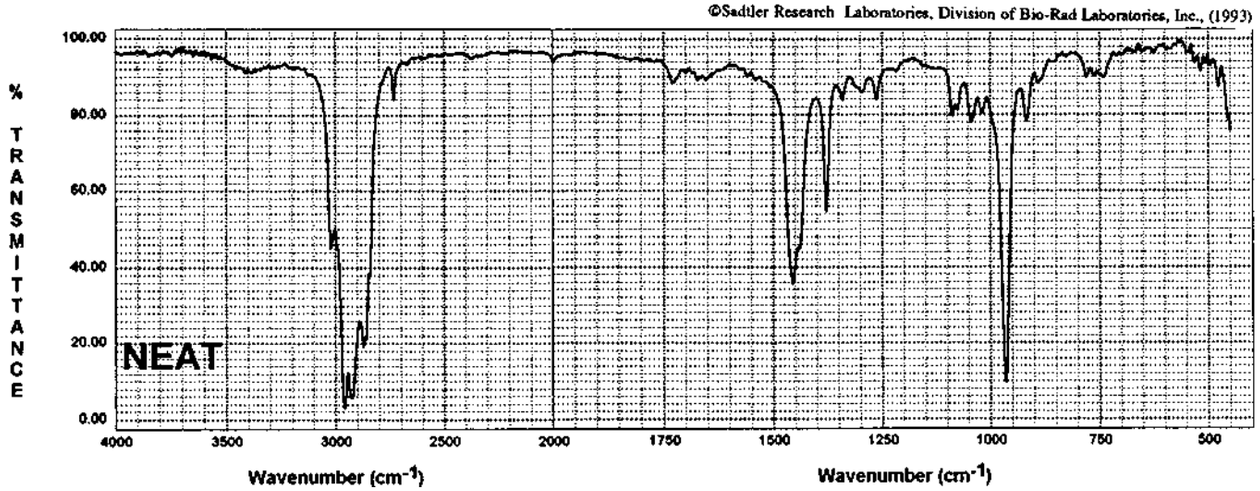

Infrared unknown spectrum *b*.

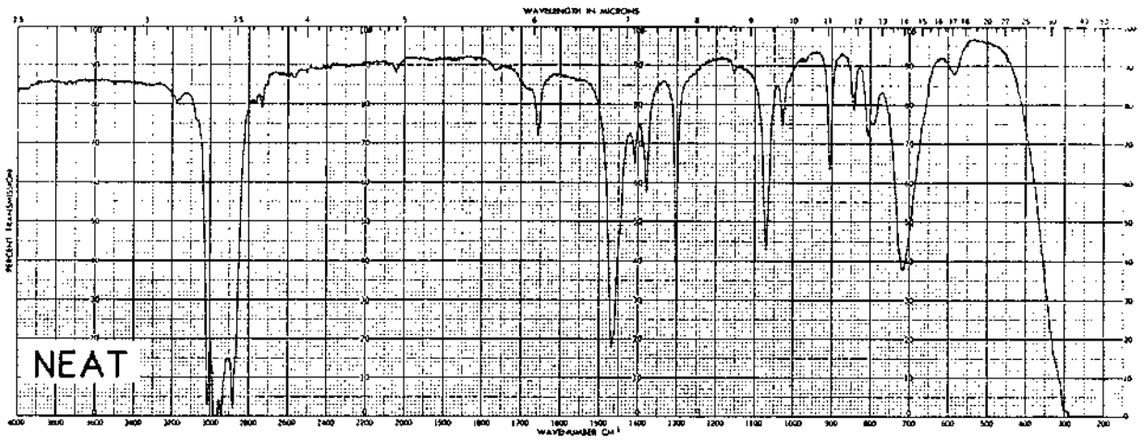

Infrared unknown spectrum *c*. *(Courtesy of Bowdoin College.)*

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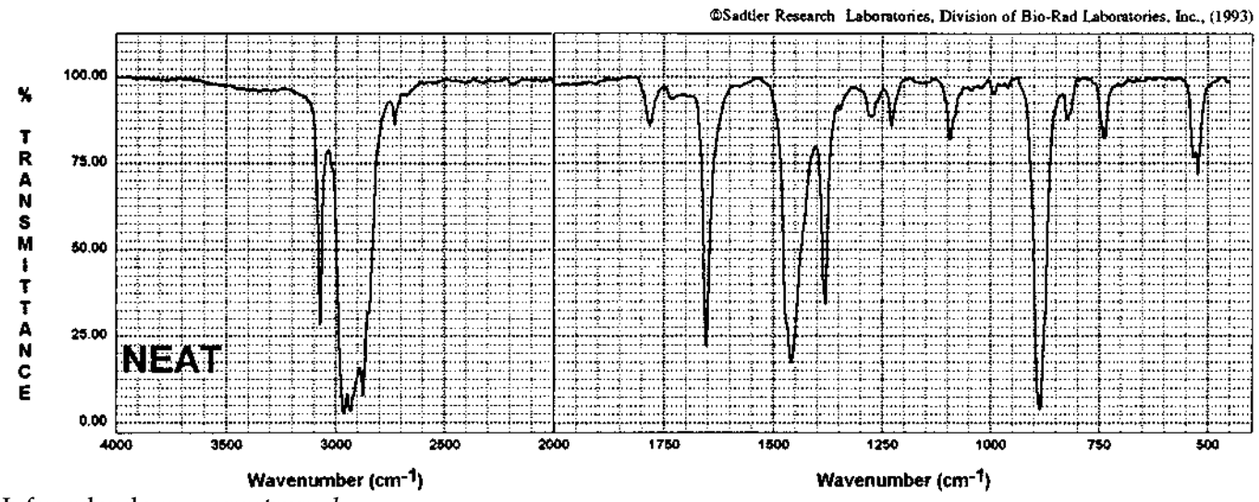

Infrared unknown spectrum *d*.

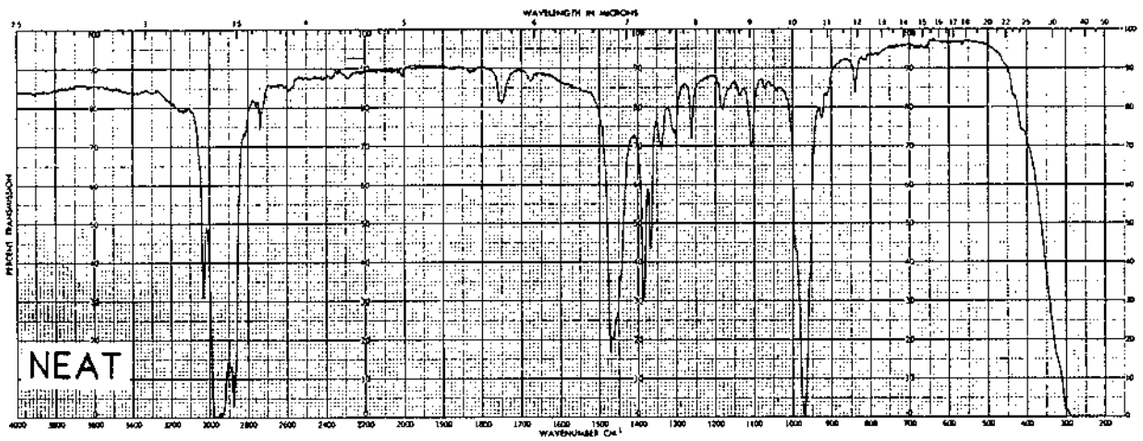

Infrared unknown spectrum *e*. *(Courtesy of Bowdoin College.)*

8-14. The infrared spectra of the three xylene (dimethylbenzene) isomers, and an additional aromatic hydrocarbon, are given below. Assign the spectra to the isomers and suggest a potential structure for the remaining unknown substance.

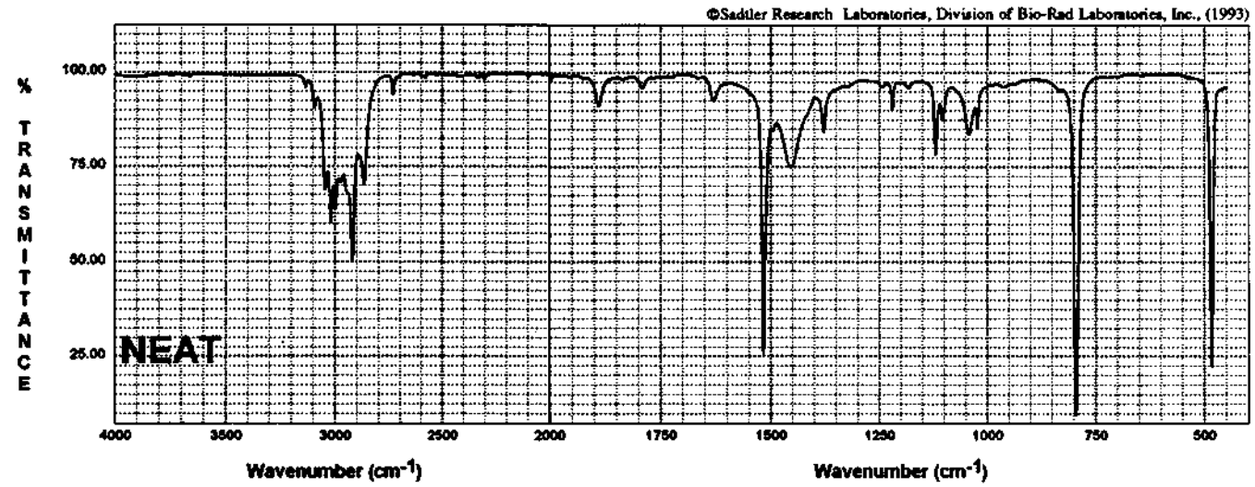

Infrared unknown spectrum *a*.

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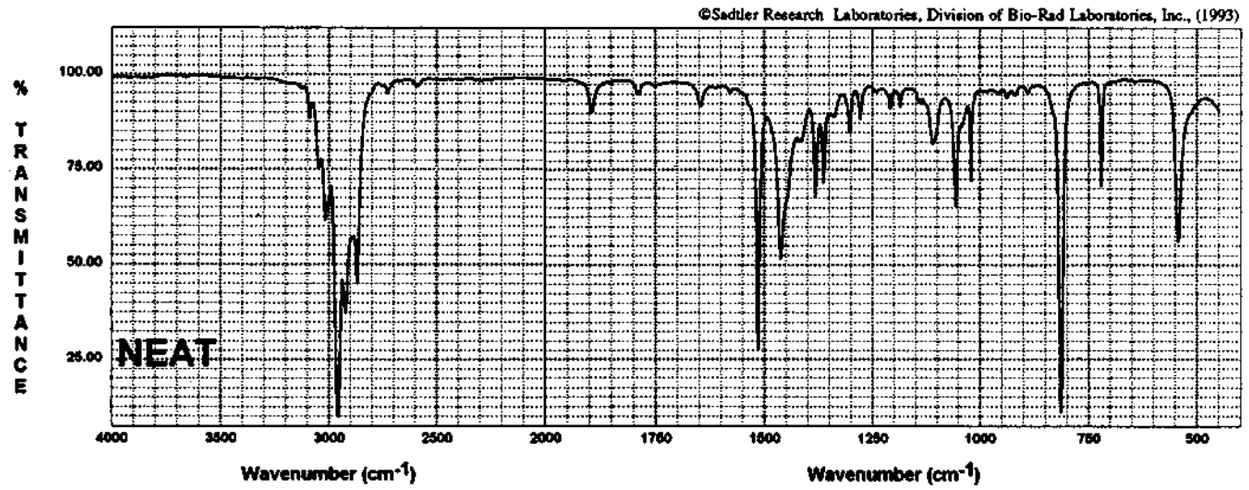

Infrared unknown spectrum *b*.

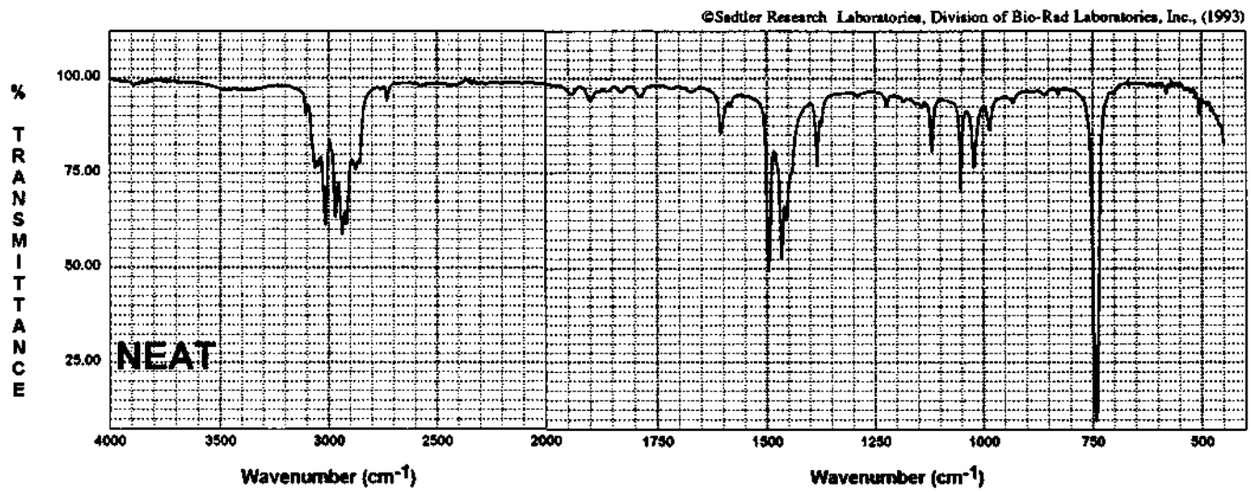

Infrared unknown spectrum *c*.

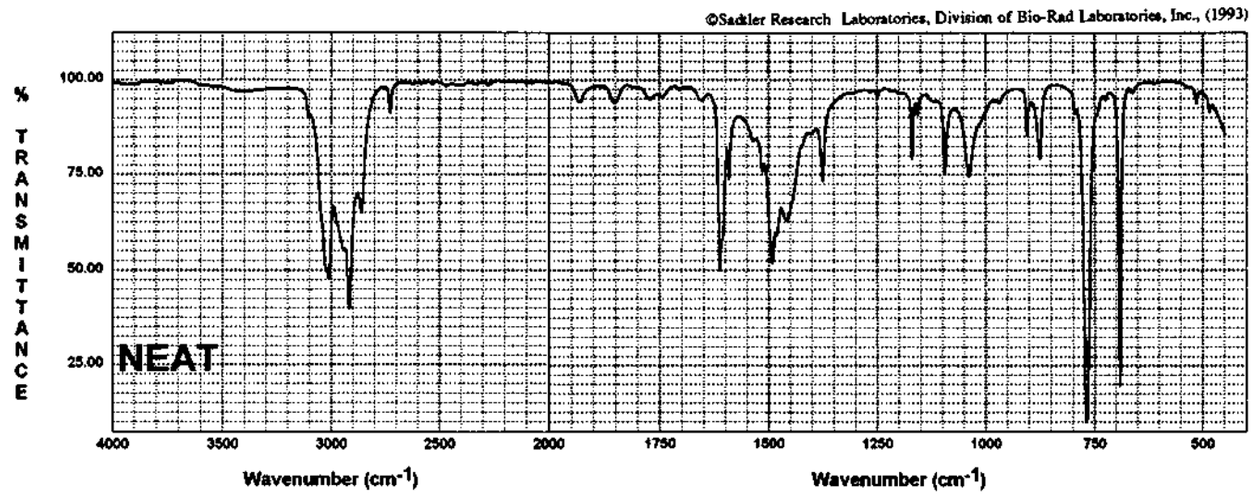

Infrared unknown spectrum *d*.

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8-15. The C—H stretching mode of chloroform ($CHCl_3$), which occurs at 3022 cm^{-1}, is one of the rare exceptions to the 3000-cm^{-1} rule. What is the rule? Suggest an explanation for this exception.

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NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

Nuclear spin

Nuclear spin is an energy property intrinsic to a nucleus and analogous to the electron spin that plays such an important role in determining electron configurations. Nuclear spin values are quantized, as are electron spins, and are represented by I, the nuclear spin quantum number. Nuclear spin quantum numbers range from 0 through $\frac{7}{2}$ in increments of $\frac{1}{2}$. The nuclei of greatest interest to organic chemists, the ^{1}H, ^{13}C, ^{19}F, and ^{31}P nuclei, have spins of $\frac{1}{2}$; the ^{12}C, ^{16}O, and ^{32}S nuclei have spins of 0 (and thus cannot be observed by nuclear magnetic resonance spectroscopy, NMR); the ^{2}H (deuterium, D) and ^{14}N nuclei have spins of 1. Since any spinning charged particle (or body) produces a magnetic moment, a nucleus with a nonzero spin quantum number has a magnetic moment, μ.

Nuclear spin values are quantized because the nuclear angular momentum, and thus the nuclear magnetic moment, is quantized. When placed in an external magnetic field, nuclei orient their magnetic moments in certain ways with respect to the magnetic field, which is assumed to be aligned with the z axis of a Cartesian coordinate system. These orientations are referred to as the z components of the nuclear magnetic moment, μ_z. For a nucleus with a spin of $\frac{1}{2}$, μ_z may be $+\frac{1}{2}$ or $-\frac{1}{2}$. In general, for a nucleus of spin I, the μ_z takes quantized values from $[-I, -I+1, \ldots, I-1, I]$; or $(2I + 1)$ different values in all. For this discussion we will limit ourselves to nuclei with spin $\frac{1}{2}$, since this is easier to describe, and since most nuclei of interest in organic chemistry are of spin $\frac{1}{2}$.

When placed in a static magnetic field of strength H_0, the magnetic moment, μ_z, of the spinning nucleus precesses about the magnetic field at a

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frequency, ν, such that $\nu = \gamma H_0/2\pi$, where H_0 is the strength of the applied magnetic field, and γ is a characteristic property of the nucleus known as the gyromagnetic ratio. When a nucleus of spin $\frac{1}{2}$ is placed in a magnetic field, the energies of the $\mu_z = +\frac{1}{2}$ and $-\frac{1}{2}$ states are separated, since in one spin state the nuclear magnetic moment is aligned with the applied magnetic field, and in the other spin state the nuclear magnetic moment is opposed to the applied magnetic field.

The amount of separation of the two energy states, ΔE, is proportional to the magnetic field, and is given by the following expression:

$$\Delta E = \frac{h\gamma H_0}{2\pi} = h\nu$$

When nuclei in the magnetic field are exposed to radiation of the proper frequency, transitions between the two energy states are stimulated, and the nucleus is said to be in *resonance,* or to *resonate.* This transition occurs when the frequency and the energy difference are related by the Planck relation, $\Delta E = h\nu$, and thus the sample will absorb energy of frequency ν. The study of these energy changes is known as nuclear magnetic resonance, or NMR, spectroscopy.

INSTRUMENTATION

In an NMR spectrometer, the magnetic field is provided by a large permanent magnet, electromagnet, or superconducting electromagnet. Commercially available NMR spectrometers have magnets with field strengths that range from 1.4 to 16.3 tesla (the earth's magnetic field at its surface is roughly 5×10^{-5} tesla), and thus operate at frequencies from 60 to 700 MHz for protons. In general, most spectrometers with an operating frequency above 100 MHz use a superconducting electromagnet.

Traditionally, NMR spectra were acquired either by holding the applied magnetic field constant and sweeping the radio frequency (rf), or by holding the rf constant and sweeping the applied magnetic field. Energy absorption by the sample was detected, and the result was the NMR spectrum, a plot of intensity (of energy absorption) versus frequency (or field). This instrumental technique is referred to as continuous wave, or CW, spectroscopy (Fig. 8.7). Over the last 20 years, however, it has been commonly replaced by pulsed, or Fourier transform (FT), NMR spectroscopy. Among many other benefits, FT-NMR spectroscopy allows very rapid acquisition of spectral data, which permits analysis of small samples and rare nuclei, such as ^{13}C.

The basic principles of FT-NMR spectroscopy can be qualitatively explained as follows. Take, for example, an NMR spectrum that contains a single peak at a given frequency. The graph of this spectrum (Fig. 8.8) is a plot of intensity versus frequency. The same information can be conveyed by a plot of intensity versus time that shows a cosine wave at the frequency described by the graph of the usual NMR spectrum. This is shown in Figure 8.9, and for a spectrum with a single frequency, this plot of intensity versus time is almost as easy to interpret as the usual NMR spectrum shown in Figure 8.8.

Of course, it would be very difficult to determine the frequencies of many superimposed cosine waves from this kind of plot, and it would be at best awkward to interpret a complex NMR spectrum presented in such a fashion (Fig. 8.10). The use of the Fourier transform allows us mathematically to

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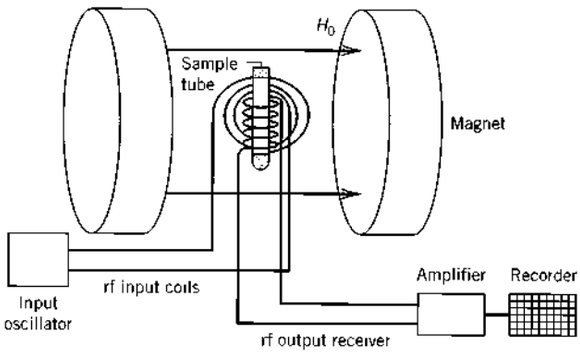

Figure 8.7 Schematic of NMR spectrometer. (Reprinted with permission of John Wiley & Sons, New York.)

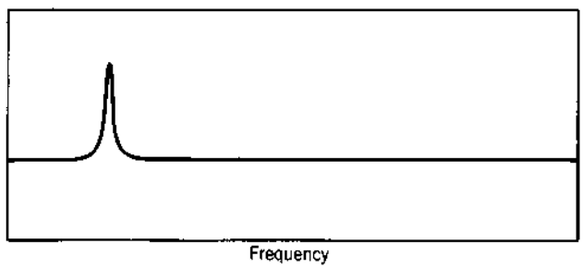

Figure 8.8 Intensity versus frequency (usual NMR spectrum).

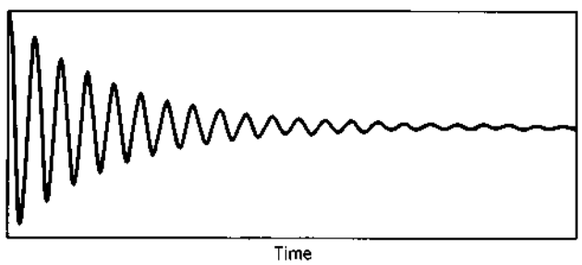

Figure 8.9 Intensity versus time.

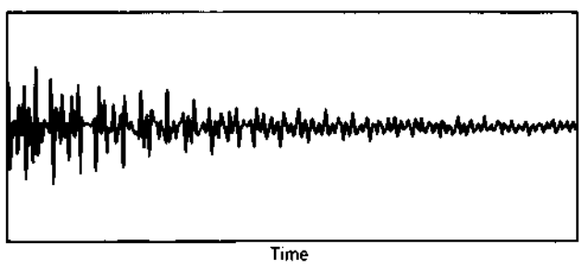

Figure 8.10 Three-signal NMR spectrum: intensity versus time.

interconvert these time domain (Fig. 8.10) and frequency domain spectra (Fig. 8.11). Fourier transform of the apparently complex spectrum in Figure 8.10 gives the spectrum in Figure 8.11. It is then easy to see that there are actually only three different resonance signals contained in the time domain of the data of Figure 8.10.

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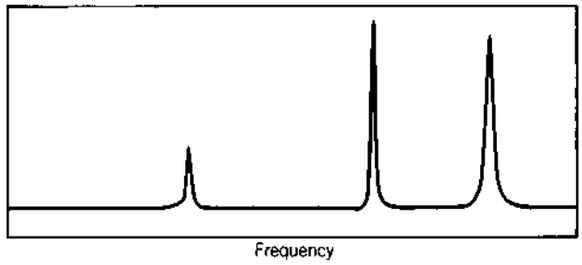

Figure 8.11 Three-signal NMR spectrum: intensity versus frequency.

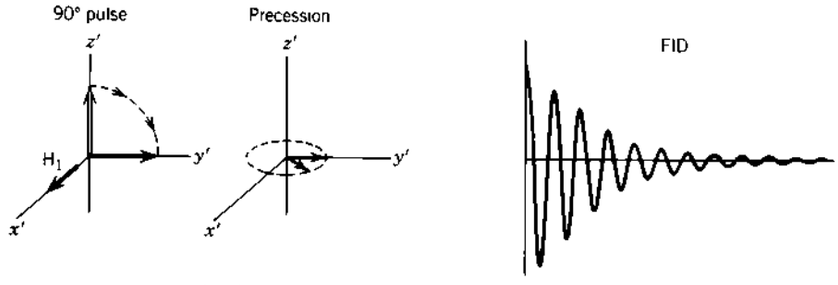

Figure 8.12 Basic pulsed NMR experiment.

Fourier transform NMR spectra are obtained by applying a short (~1−10 ms), high-powered pulse of rf energy to the sample (Fig. 8.12). This pulse affects all the nuclei to be observed. Before the pulse is applied, the equilibrium net nuclear magnetization is aligned with the applied magnetic field, along the *z* axis. The coordinate system is presumed to be rotating about the *z* axis at the frequency of the rf pulse. The pulse, applied down the *x* axis, applies a torque to the nuclear magnetic moments and rotates them into the *xy* plane. At this point the pulse is turned off and the nuclear magnetic moments return to their equilibrium alignments. In the process, they precess about the *z* axis (applied magnetic field) in the *xy* plane and induce a current in a detector coil, which can be thought of as being aligned with the *y* axis. This current varies in a sinusoidal manner, and the observed frequency will be the difference between the resonance frequency of the nuclei and the frequency of the rf pulse.

The detected signal, which is called the free induction decay (FID), is digitized and stored. For small organic molecules in a nonviscous solution, the FID will disappear after a few seconds, which corresponds to the time it takes the nuclei to regain equilibrium alignments after the rf pulse. Thus, an entire ^{1}H NMR spectrum can be obtained in approximately 2 s, in contrast to the 10–15 min usually needed to obtain a CW spectrum. A major advantage of FT-NMR is that many spectra of a sample can be rapidly obtained and added together to increase the signal-to-noise (*S/N*) ratio. Noise is presumably random about some zero level, so when many spectra are added together, the noise level is reduced, while real signals are reinforced when added. The *S/N* ratio is proportional to the square root of the number of spectra added together. Thus, one can obtain the ^{1}H spectrum of a 10-μmol sample in a minute or two. With FT-NMR it is possible to obtain spectra of isotopes that are insensitive and/or of low natural abundance, as well as spectra of large biological molecules in dilute solution. By adding a few hundred spectra together, an adequate ^{13}C NMR spectrum of a 100-μmol sample can be obtained in about 20–30 min.

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CHEMICAL SHIFT

In a molecule, the magnetic field at a nucleus depends not only on H_0, the field generated by the instrument (the external field), but also on the magnetic fields associated with the electron density near the nucleus. Electrons are influenced by the external field in such a way that their motion generates a small magnetic field that opposes the applied field, and reduces the actual field experienced at the nucleus. This reduction is very small (relative to the external field) and is on the order of 0.001%, 10 ppm, for most protons, and about 200 ppm for ^{13}C nuclei. Reduction of the external field is known as *shielding*, and it gives rise to differences in the energy separation for nuclei in different electronic environments in a molecule. The differences in the energy separation are known as *chemical* shifts.

The magnitude of the chemical shift depends on the nature of the valence and inner electrons of the nucleus and even on electrons that are not directly associated with the nucleus. Chemical shifts are influenced by inductive effects, which reduce the electron density near the nucleus and reduce the shielding. The orientation of the nucleus relative to π electrons also plays an important role in determining the chemical shift. A proton located immediately outside a π-electron system (as in the case of the protons on benzene rings) will be significantly deshielded. In most molecules the chemical shift is determined by a combination of these factors. Chemical shifts are difficult to predict using theoretical principles, but have been well studied and can usually be easily predicted empirically upon comparison to reference data.

In an NMR spectrum, the absorption of rf energy is detected, as in Figure 8.13, where the energy absorption is shown for increasing frequency. In this example we illustrate the case with two different nuclei, A and X. Since A and X are different, they absorb energy at different frequencies while in the same applied magnetic field.

The spectrum would be displayed as in Figure 8.14. The difference in the resonances is known as a *chemical shift* and is expressed in parts per million (ppm). The use of frequency units is cumbersome and is complicated because

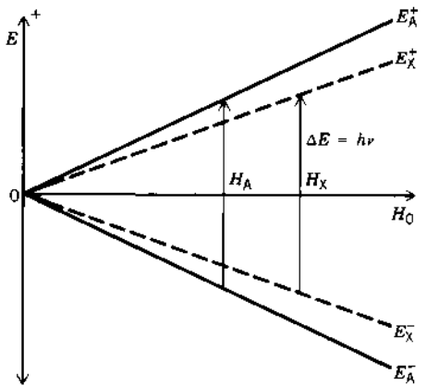

Figure 8.13 The energy splitting for two chemically different protons. The differences between the *A* energy levels (solid lines) and the *X* levels (dashed lines) have been amplified for illustrative purposes. At 60 MHz, nucleus *A* absorbs energy at field H_A and nucleus *X* absorbs energy at field H_X. Nucleus *X* is said to be more strongly shielded than *A*. The resonance for *X* is said to occur upfield of that for *A*.

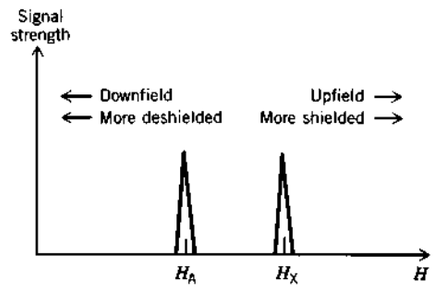

Figure 8.14 The spectrum for the system in Figure 8.13 as it would be displayed. It is conventional to display the spectrum with magnetic field strength increasing to the right so that upfield (and more strongly shielded) is toward the right and downfield (and deshielded) is toward the left.

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NMR spectrometers of different magnetic field strengths (and thus operating frequencies) are used. The use of ppm units allows direct comparisons of spectroscopic data obtained on different instruments, when chemical shifts are referenced relative to a reference compound whose chemical shift is arbitrarily defined as 0 ppm. The accepted reference standard for ^{1}H and ^{13}C NMR in organic solutions is tetramethylsilane (TMS), $(CH_3)_4Si$. The chemical shift relative to TMS is symbolized by δ.

Tetramethylsilane is used as a reference substance for a number of reasons. It is more strongly shielded (Si is more electropositive than C) than most other protons and carbon atoms, and its resonance is thus well removed from other areas of interest in the NMR spectrum. Tetramethylsilane is inert and thus unlikely to react with the compound being analyzed, it is volatile (bp 26 °C) and thus easily removed after a sample has been analyzed, and its 12 identical protons per molecule provide a strong signal per molecule of TMS.

SPIN–SPIN COUPLING

In a molecule with several protons, the exact frequency at which a proton resonates depends not only on the chemical shift of that proton, but also on the spin states of nearby protons. This occurs because the magnetic moments of the nearby protons can either shield or deshield the proton in question from the applied magnetic field, depending on the orientation of the nearby magnetic moments relative to the applied magnetic field. The extent of this perturbation is independent of the applied magnetic field strength. The effect of the spin state of one nucleus on the resonance of another is known as *coupling* or *splitting.*

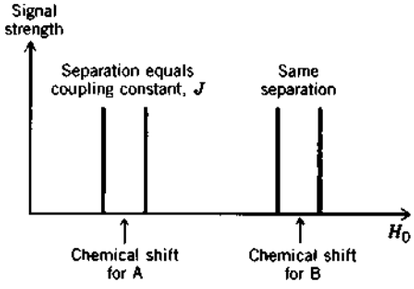

Figure 8.15 Spectrum of two chemically different protons that are coupled.

The spectra resulting from spin–spin coupling depend on the types of nuclei, the distance and geometry between the nuclei, the nature of the bonding, the electronic environment, and the total number of spin states possible. The latter may be illustrated by looking at the spectrum of an imaginary compound that has protons H_A and H_X on adjacent carbons, connected by three bonds: $H_A—C—C—H_X$ (Fig. 8.15). In the first approximation we would expect one resonance for H_A and one resonance for H_X, and the spectrum would resemble that shown in Figure 8.14. In the presence of coupling, the resonance for H_A splits into two signals, one of which corresponds to H_X, having $\mu_z = +\frac{1}{2}$ and the other to $\mu_z = -\frac{1}{2}$. The coupling effect is symmetric in that the H_X resonance also splits into two resonances, one for each spin state of H_A. The magnitude of the separation of the H_A pair (a doublet) or the H_X pair (also a doublet) is known as the coupling constant, or *J.* It is usually expressed in frequency units (Hz), since *J* is independent of the magnetic field strength.

A simple way to explain this is to consider the effect the two possible spin states of H_X have on the resonance frequency of H_A. The equilibrium population distribution of the two spin states in H_X is very close to 1:1, since ΔE is only about 10^{-3} cal/mol. Since H_X has a magnetic moment, there are then two slightly different magnetic fields at H_A. We thus see two signals for H_A, one for those H_A nuclei adjacent to H_X nuclei with μ_z aligned with the applied magnetic field, and one signal for those H_A nuclei adjacent to H_X nuclei with μ_z aligned opposed to the applied field. Coupling between protons connected by more than three bonds does occur, but its magnitude, *J*, is usually small and often not directly observed in a usual NMR spectrum.

The splitting becomes more interesting when there are several nuclei of one type. 1,1-Dibromoethane (CH_3CHBr_2) has three equivalent protons in the

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Individual μ_z	SUM
(+)(+)(+)	$+\frac{3}{2}$
(+)(+)(−) or (+)(−)(+) or (−)(+)(+)	$+\frac{1}{2}$
(+)(−)(−) or (−)(+)(−) or (−)(−)(+)	$-\frac{1}{2}$
(−)(−)(−)	$-\frac{3}{2}$

Figure 8.16 Possible combinations of spin states for a methyl group.

methyl group and one proton on the C-1 atom. The methyl group exhibits rapid internal rotation so that its three protons are equivalent. The chemical shift for the C-1 proton is 5.86 ppm and that for the methyl protons is 2.47 ppm. Here we can see an example of decreased shielding resulting from the presence of electronegative substituents. Equivalent protons do not couple with one another (this is an important rule in interpreting spectra), but the methyl protons will affect the proton on C-1, and vice versa.

To analyze the splitting pattern, we need to consider the orientations of the nuclear magnetic moments, with respect to the applied magnetic field, for all three methyl protons. Since each of the three protons may have two spin states that are of nearly equal probability, there are $2^3 = 8$ possible combinations of spin states in all for the methyl protons. The net sums of these may have only four different values, as shown in Figure 8.16. The symbol (+) is used to represent $\mu_z = +\frac{1}{2}$ for a single proton and (−) is used to represent $\mu_z = -\frac{1}{2}$. Thus (+)(+)(−) means that protons 1 and 2 have $\mu_z = +\frac{1}{2}$, while proton 3 has $\mu_z = -\frac{1}{2}$.

The number of different μ_z states is $(2N + 1)$, where N is the number of equivalent nuclei (of spin $\frac{1}{2}$) Thus the three methyl protons can generate four slightly different magnetic fields, and the proton on the C-1 of CH_3CHBr_2 sees (in different molecules) four different magnetic fields. Since these different magnetic fields are not of equal probability, but rather are populated in a ratio of 1:3:3:1, the four signals we see for the proton on C-1 when coupled to the methyl group are of intensities 1:3:3:1, and are referred to as a *quartet.* This is shown schematically in Figure 8.17.

Since the proton on C-1 has two possible spin states of nearly equal probability, the protons of the methyl group experience two slightly different magnetic fields and are observed in the spectrum as two slightly separated signals of equal intensity, or a *doublet.* The separation between each of the C-1 proton signals is the coupling constant, *J*, and will equal the *J* of the methyl signal. The proposed spectrum is shown in Figure 8.17*b.* The coupling constant in this case is about 7 Hz. The 60-MHz NMR spectrum of 1,1-dibromoethane is shown in Figure 8.17*c*.

NOTE. The net effect of spin–spin coupling is that a proton (or group of equivalent protons) adjacent to N *other protons will be observed as a multiplet with* (N + *1) lines.*

A proton, or group of equivalent protons, may be coupled to more than one group of nuclei. The spectrum of 1-nitropropane ($CH_3CH_2CH_2NO_2$) is

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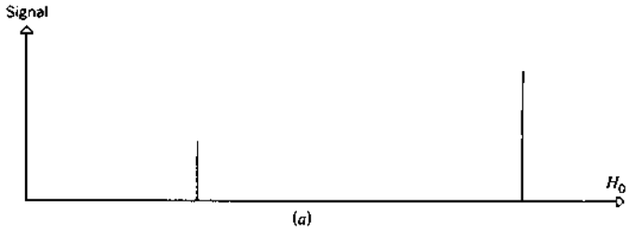

Figure 8.17*a* **The spectrum without any spin–spin coupling.**

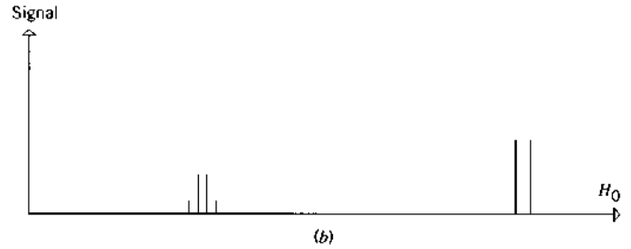

Figure 8.17*b* **A "stick figure" spectrum indicating the expected intensities.**

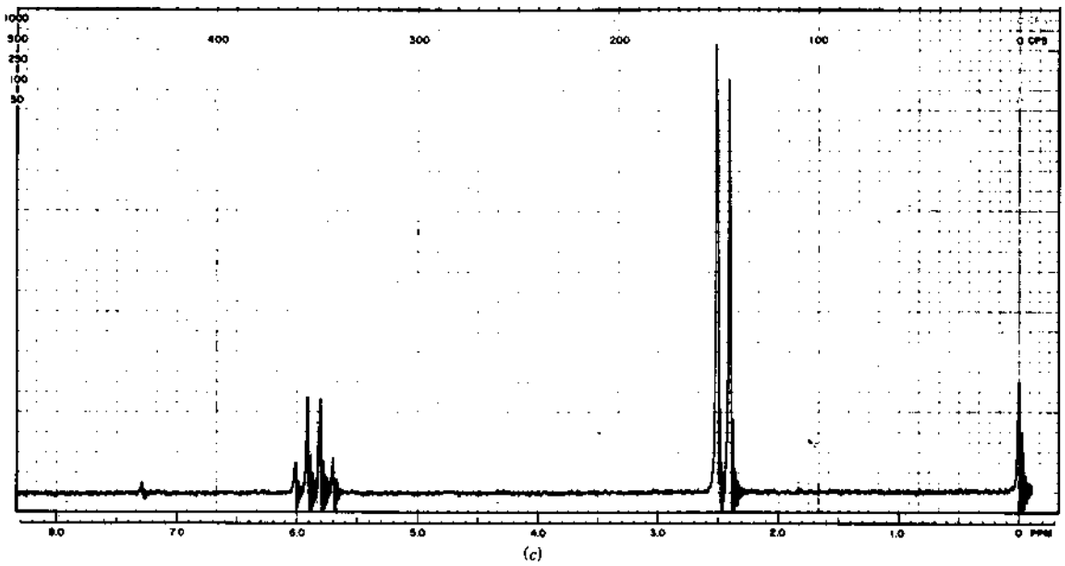

Figure 8.17*c* **The actual 60-MHz spectrum of 1,1-dibromoethane. The TMS signal at 0 ppm is seen as well as a weak signal at 7.3 ppm, which is not from this molecule.**

shown in Figure 8.18. The signal from the central methylene (CH_2) group is seen at about 2.0 ppm. Because the methylene group is adjacent to (and thus coupled to) five protons, its signal is a (5 + 1) or six-line multiplet—a *sextet.*

Nuclei with spins of 1 or greater exhibit more complex spin–spin coupling, since they can exist in more than two different spin states. For a nucleus coupled to N nuclei of spin I, a multiplet of $2IN$ lines will be observed. Nuclei of spin zero do not couple.

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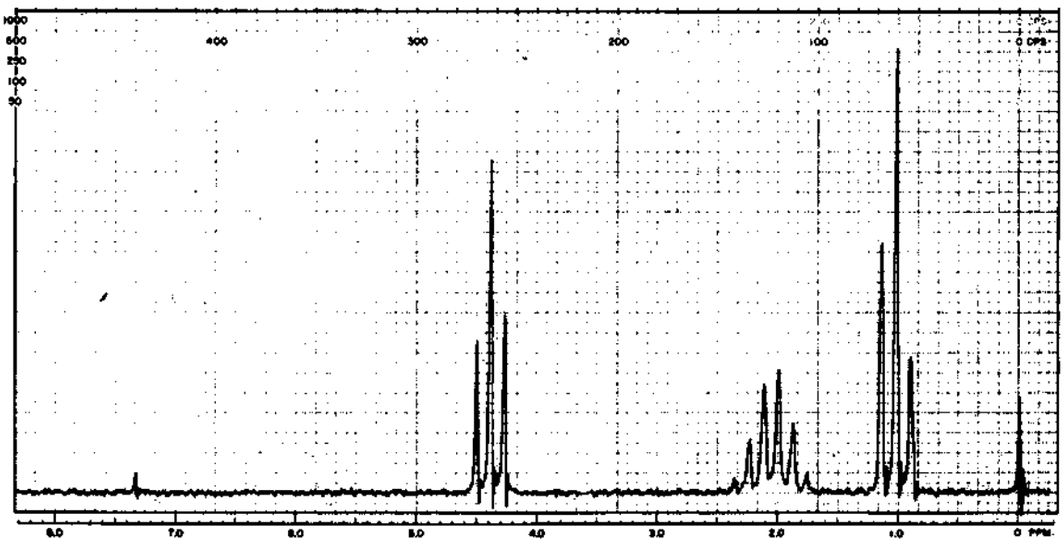

Figure 8.18 The 60-MHz spectrum of 1-nitropropane. (Courtesy of Varian Associates, Palo Alto, CA.) **Starting from the right, the TMS signal at 0 ppm is seen. Next is a 1:2:1 triplet at 1.03 ppm. This triplet results from the protons on C-3 and their coupling with the two protons on C-2. Next is the sextet centered at 2.07 ppm. This multiplet is from the protons on C-2 and their coupling with the protons on C-1 and C-3. Finally, we have the signal from the protons closest to the nitro group centered at 4.38 ppm. These protons appear as a 1:2:1 triplet due to their coupling with the protons on C-2.**

INTENSITIES

The area under an NMR peak is proportional to the number of nuclei giving rise to that signal. The intensity of a resonance is thus best determined by the *integral* of the NMR spectrum over a resonance, or group of resonances. Nuclear magnetic resonance spectrometers can measure the integral, though integration data from an FT spectrometer are less reliable than those from a CW spectrometer. In more complex spectra the intensities are useful as a measure of the number of protons of a given type. For instance, in the above case the integral over both peaks of the methyl group doublet will be three times the integral over the quartet of the proton on C-1. Integration can thus often provide useful information for determining the identity of a compound.

SECOND-ORDER EFFECTS

So far, all of our examples have consisted of first-order spectra. First-order spectra are those multiplets interpretable through elementary coupling analysis, such as that above; second-order spectra are those that are not interpretable in this manner. These highly symmetric and fairly simple first-order spectra are generally observed when the chemical-shift differences (expressed as a frequency) are much greater than the coupling constant. Second-order effects occur when the coupling constants become comparable to or greater than the chemical-shift differences. Thus, spectra obtained on instruments with higher magnetic fields are more likely to be first order, since the frequency differences between given signals increase with increasing magnetic fields. However, the chemical-shift differences (in ppm) remain the same regardless of magnetic field strength.

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Second-order effects may be understood in qualitative terms by considering the limiting cases. Let us consider the hypothetical disubstituted ethylene shown in Figure 8.19, where R and M are substituents that might be identical or may have very different effects on the alkenyl protons. In Figure 8.19*a* the spectrum is shown for the situation in which R and M have very different effects. In this case we will observe a first-order spectrum consisting of two doublets. The coupling constant is the separation in the doublets, and the chemical shift of each nucleus is the geometric midpoint of each doublet.

In Figure 8.19*b*, groups R and M are identical. H_A and H_B are identical in this case and only a single resonance is observed (coupling between equivalent nuclei is not observed).

In Figure 8.19*c* the difference in the chemical environment of H_A and H_B is very slight. The spectrum shown may be seen as intermediate between the limiting cases in Figure 8.19*a* and Figure 8.19*b*. Note that there is a "leaning in" of the doublets as the central members increase in intensity at the expense of the outer members. A full continuum of behavior may be expected with cases observed in which the outer members are lost in the noise and the central members take the appearance of a doublet. This would be one example of a class of spectra known as "deceptively simple spectra."

The second-order spectra of systems with more than two protons are difficult to describe even in qualitative terms. Second-order spectra may well display more lines than one would predict from simple coupling theory. Also, in second-order spectra, the coupling constants and the chemical-shift differences may not be obtainable as simple differences in the positions of spectral lines. Thus, spectra obtained at high frequencies (and magnetic fields) are often more useful. As the operating frequency of the instrument is increased, the chemical-shift differences (in frequency terms) increase while the spin–spin coupling remains constant. Thus, the complicating second-order effects are likely to be less noticeable in high-field spectra. The reader is referred to more extensive treatments of NMR for a discussion of second-order cases.

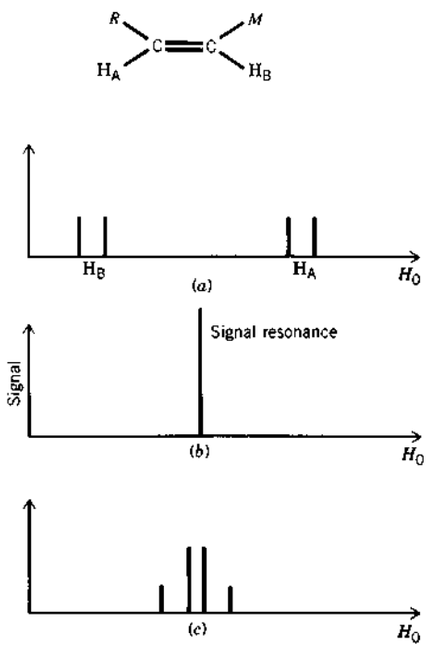

Figure 8.19 Second-order effects. (a) The chemical-shift difference is much larger than the coupling constant and a first-order spectrum is observed. (b) Protons A and B are equivalent and a single resonance is observed. (c) The chemical-shift difference is of the same order of magnitude or less than the coupling constant. Note the "leaning in" of the peak intensities in this spectrum relative to that in part *a*.

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INTERPRETATION OF ^{1}H NMR SPECTRA

The first issues that must be addressed are molecular symmetry and the magnetic equivalence or nonequivalence of protons or other functional groups. Even if two protons, or groups, are chemically equivalent, they may or may not be magnetically equivalent. Although molecular symmetry can often simplify NMR spectra, one must be able to discern which protons or groups are equivalent by symmetry. The two most useful symmetry properties (or symmetry operators) are the plane of symmetry and the axis of symmetry.

A plane of symmetry is simply a mirror plane such that one half of the molecule is the mirror image of the other half, as in *meso*-pentane-2,4-diol:

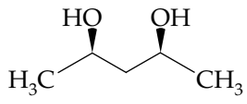

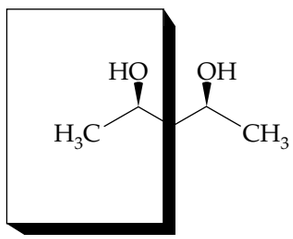

meso-Pentane-2,4-diol

The methyl groups are identical by symmetry, and one would expect this stereoisomer to show one methyl doublet in its ^{1}H NMR spectrum and one signal for a methyl group in its ^{13}C spectrum.

Consider the other diastereomer of pentane-2,4-diol, the chiral *d,l* isomer. This isomer has an axis of symmetry. If the molecule is rotated 180° about an axis in the plane of the paper passing through the central carbon, the molecule can be converted into itself:

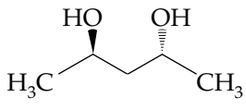

d,l-Pentane-2,4-diol

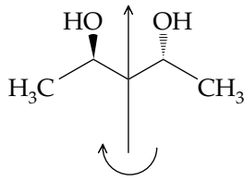

Here, too, the methyl groups are identical by symmetry, and one would expect this stereoisomer to show one methyl doublet in its ^{1}H NMR spectrum and one signal for a methyl group in its ^{13}C spectrum.

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It is, however, relatively simple to use NMR spectroscopy to distinguish between these stereoisomers. To do this, look at the two methylene protons on the central carbon, C-3, of each isomer:

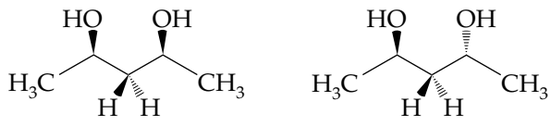

The plane of symmetry in the meso isomer bisects each of the two protons. In the *d,l* isomer, the axis of symmetry interconverts the two protons. Thus, in the *d,l* isomer, the two methylene protons are equivalent by symmetry, but they are not equivalent in the meso isomer. This can also be seen by inspecting the molecule. On the left, one H is syn to both —OH groups and the other is anti to both —OH groups. On the right, each H atom is syn to one —OH group and anti to the other.

The more rigorous way to determine equivalence or nonequivalence is to determine whether the two protons (or groups) are homotopic (identical), diastereotopic, or enantiotopic. To compare two protons, we use the usual Cahn–Ingold–Prelog system for the nomenclature of stereoisomers. We artificially distinguish the relative priority of two protons by a method such as drawing them in different colors or pretending that one is deuterium (as long as the molecule does not contain D). We draw the two possibilities (i.e., the first H as D and then the second H as D) and then determine the stereochemical relationship between the two:

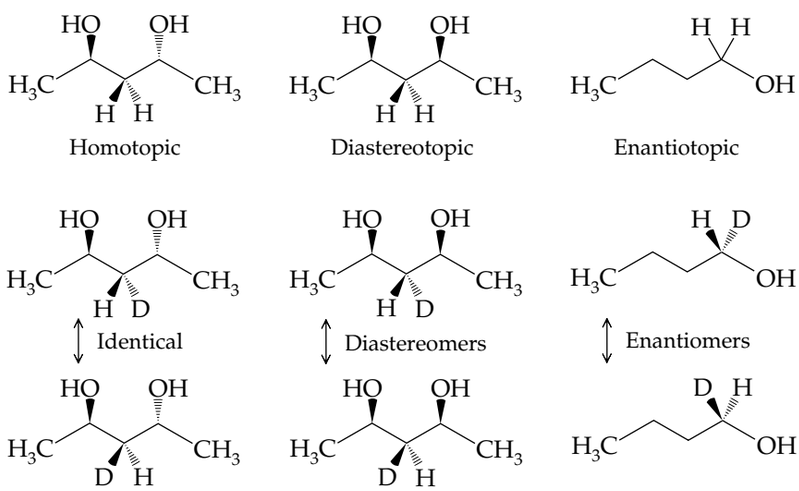

If the two are identical, the two protons are identical, or *homotopic*. If the two structures are diastereomers, the two protons are *diastereotopic,* and if the two structures are enantiomers, the two protons are *enantiotopic.* Diastereotopic protons, or groups, will be magnetically nonequivalent. Enantiotopic protons, or groups, will be magnetically equivalent only in an achiral environment and may appear nonequivalent in a chiral environment, such as a chiral solvent or in a biological sample. Homotopic protons may or may not be magnetically equivalent. Of course, it is possible for magnetically nonequivalent signals to be so close to one another in the NMR spectrum as to overlap (accidentally degenerate).

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Homotopic protons may be magnetically nonequivalent if the two protons have different coupling constants to the same third proton. The most common example of this occurs in para-substituted benzenes:

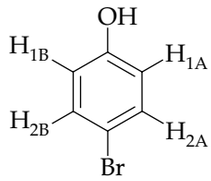

By symmetry, H_{1A} and H_{1B} are equivalent. These protons are not, however, magnetically equivalent because H_{1A} and H_{1B} have different coupling constants to, for example, H_{2A}, and the spectrum of this molecule may well be more complex than one would at first expect.

The equivalence or nonequivalence of functional groups, as well as protons, can easily be determined. The ^{1}H NMR spectrum of menthol shows three methyl doublets, since the two methyls in the isopropyl group are diastereotopic. The ^{13}C spectrum of menthol shows three distinct resonances for the three different methyl groups:

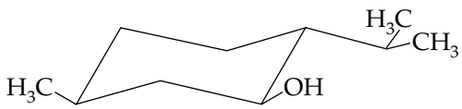

Menthol

^{1}H CHEMICAL SHIFTS

Figure 8.20 summarizes the chemical shifts of protons in a large range of chemical environments. It is, however, a bit dangerous to use figures such as

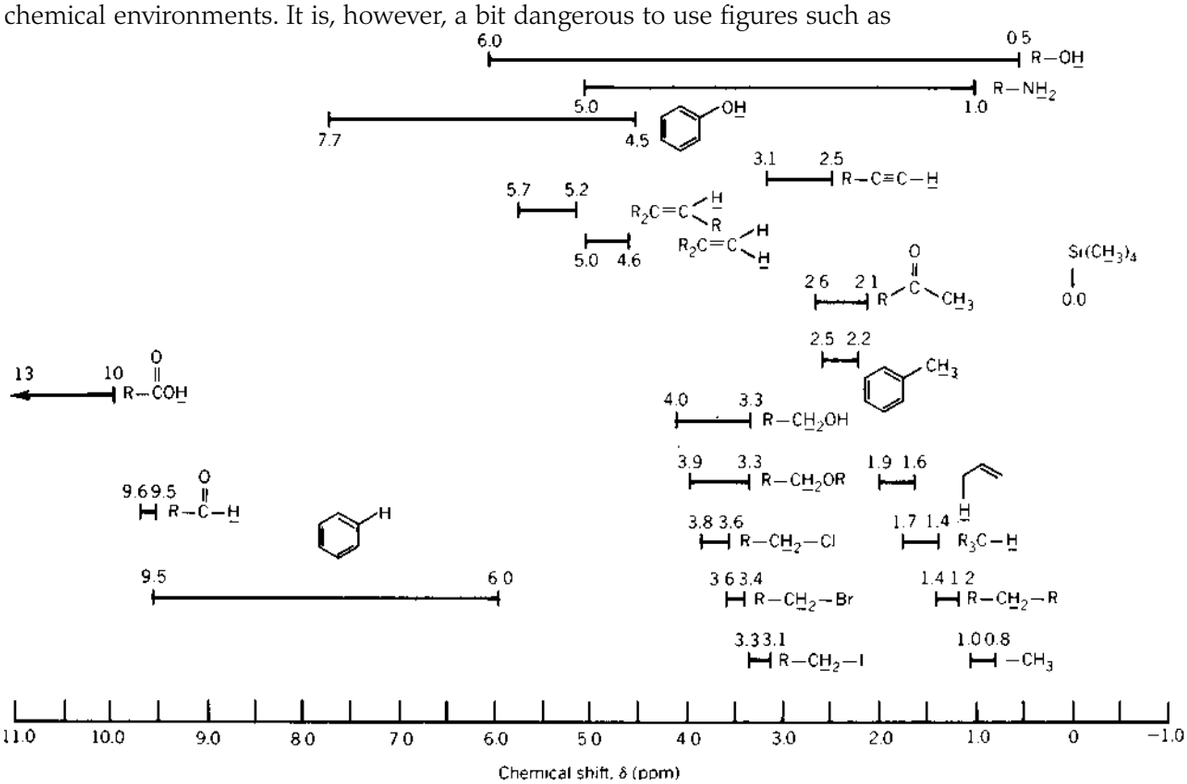

Figure 8.20 NMR ^{1}H chemical shifts. (From Zubrick, J. W. *The Organic Lab Survival Manual,* 7th ed.; Wiley: New York, 2008. Reprinted by permission of John Wiley & Sons, New York.)

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this one without understanding some of the factors that underlie shielding and the chemical shift. To give some flavor of the factors that determine chemical shifts and the range of values observed, we will briefly examine chemical shifts in methyl groups and chemical shifts for protons on sp^2 carbon atoms.

Methyl groups bonded to an sp^3 carbon generally have chemical shifts in the range 0.8–2.1 ppm as long as there is no more than one electron-withdrawing group attached to the carbon. The shifts generally increase as the strength of the electron withdrawing group increases, or as more electron-withdrawing groups are added. Groups that inductively withdraw electrons reduce the electron density near the methyl group protons. This results in less shielding and a downfield shift of the methyl resonance. This effect is clearly seen in the spectra of 1-nitropropane and 1,1-dibromoethane (Figure 8.17*c* and Figure 8.18), respectively. The chemical shifts for methyl groups bonded to sp^2 carbon atoms fall in the range 1.6–2.7 ppm.

In the case of a proton bonded to an sp^2 carbon, the location of the proton relative to the π cloud plays an important role in determining the chemical shift. In unconjugated alkenes the chemical shifts fall in the range 5–6 ppm. Where more than one proton is bonded to an alkene, complex second-order spectra can be expected at low operating frequencies since the coupling constants are usually fairly large relative to the difference in resonance frequencies. In aldehydes, RC**H**O, the increased electronegativity of the oxygen increases the deshielding and the chemical shift falls in the range 9–10.5 ppm.

The chemical shift in an aromatic system is generally greater than that for alkenes. For example, the chemical shift of benzene is 7.37 ppm, which is substantially greater than the 5.6 ppm for the alkenyl protons of cyclohexene. Much of this difference results from the "ring current" effect and the orientation of the proton relative to the aromatic π electrons. If the ring substituents are not strongly electron withdrawing or electron donating, such as alkyl groups, the chemical shift for ring protons will not be shifted greatly from that of benzene itself. Furthermore, these substituents generate only small chemical-shift differences among the ring protons. Thus, the 60-MHz spectra for toluene (methylbenzene) appears to have a single resonance in the aromatic region at about 7.1 ppm. If, on the other hand, the substituents are electron withdrawing, the ortho and para ring protons will be somewhat deshielded relative to benzene. Pi-electron-donating substituents, such as a methoxy group, will increase the shielding of groups ortho and para to it.

SPIN–SPIN COUPLING

Coupling information is the primary reason that ^{1}H NMR is such a powerful tool for organic structure determination. Since coupling information is transmitted through bonds, coupling provides information about nearby protons and can often be used to deduce stereochemistry.

The sign of the coupling constant (usually symbolized as J) may be positive or negative. However, first-order spectra are not sensitive to the sign of the coupling constant. In second-order cases, the sign of J may be determined by a detailed analysis of the spectrum, though the sign of J is generally of little value for organic structure determination.

Geminal Coupling

Nonequivalent protons attached to the same carbon (geminal protons) will couple with one another. These coupling constants tend to be large (>10 Hz) for sp^3 carbon atoms and small (<4 Hz) for sp^2 carbon atoms. Geminal coupling constants tend to decrease with decreasing ring size, because of hybridization

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changes at carbon, and with the increasing electronegativity of the substituents on a given methylene group.

Vicinal Coupling

Vicinal coupling describes the coupling over three bonds observed between protons attached to two bonded carbon atoms, H—C—C—H. Vicinal coupling constants (J values) can range from near 0 to greater than 15 Hz, depending on the stereochemical relationship (dihedral angle) between the coupled protons, the hybridization of the carbon atoms, and the electronegativity of other substituents. For vicinal protons on sp^3 carbon atoms, the coupling constant is related to the dihedral angle and is expressed graphically by the Karplus curve (Fig. 8.21).

Though the magnitude of vicinal coupling is very sensitive to the angle of rotation about the central bond, in many simple cases nearly all coupling constants are equal. This situation is often the case if internal rotation about a C—C single bond can occur on a time scale that is very short relative to the NMR time scale, such as in acyclic systems. In these cases, the effect of internal rotation is completely blurred as far as NMR is concerned, and only an average coupling constant is observed. Vicinal coupling constants in freely rotating alkyl groups are usually observed in the 6.5- to 8-Hz range.

When the central C—C bond between two coupled protons is a double bond, rotation is restricted and separate coupling constants for cis and trans protons may be observed. Cis coupling constants fall in the range 5–12 Hz, whereas trans coupling constants range from 12 to 20 Hz. As a result of these large coupling constants, second-order effects are often observed in substituted alkenes in instruments of lower field strengths.

When rotation about carbon–carbon single bonds is restricted, or when stereochemistry dictates significant conformational preferences, nonaveraged coupling constants may be observed that can complicate the appearance of the NMR spectrum. For example, two diastereotopic protons of a methylene (CH_2) group may well each couple to a given third proton with different coupling constants. The familiar coupling explained at the elementary level suggests that if one proton is adjacent to, for example, two others, the NMR signal of the first proton will be a triplet. This simplification will be true only if the two coupling constants are identical. A triplet is merely a doublet of doublets with equal coupling constants, which gives rise to the familiar triplet with intensities of 1:2:1 (Fig. 8.22*a*). A doublet of doublets, on the other hand, gives rise to a four-line multiplet with peaks of roughly equal intensity (Figure 8.22*b*).

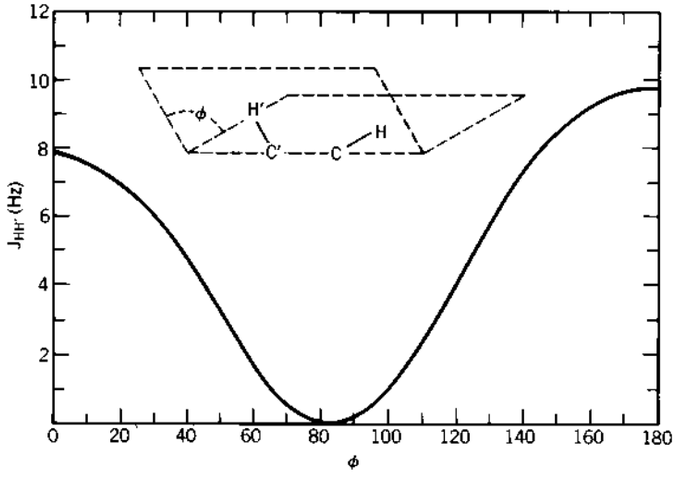

Figure 8.21 The vicinal Karplus correlation showing the relationship between dihedral angle and coupling constants for vicinal protons.

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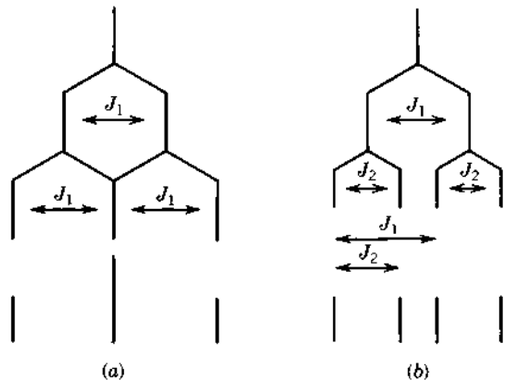

Figure 8.22 (a) Triplet equals doublet of doublets with equal *J* values; (b) doublet of doublets.

Long-Range Coupling

Longer range coupling involving four or more bonds is common in allylic systems and in aromatic rings and other conjugated π systems. These coupling constants are generally smaller than the values considered above (i.e., $<$3 Hz).

EXAMPLES OF COMPLEX, YET FIRST-ORDER, COUPLING

Ethyl Vinyl Ether

The coupling constants of even a seemingly complex multiplet can be discerned in a relatively simple manner. First, the total width (outside peak to outside peak) of a first-order multiplet is equal to the sum of all the coupling constants, keeping in mind that, for example, a triplet of $J = 7$ Hz is really a doublet of doublets with both *J* values equal to 7 Hz. The expansion of the proton spectrum of ethyl vinyl ether is presented as an example in Figure 8.23. Integration data are displayed between the spectrum and the horizontal axis in Figure 8.23*a*.

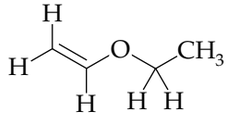

Ethyl vinyl ether

Consider the multiplet centered at 6.45 ppm (Fig. 8.23*b*). By measuring the distance (in Hz) from either outside line to the next inner line, which is 6.8 Hz, the first coupling constant is determined. Then, by measuring from the outside line to the second line in, the second coupling constant is found to be 14.4 Hz. We know that this is the last coupling constant to be found for several reasons. First, if we measure from the outside line to the third line in, we get a value, 21.2 Hz, which is equal to the sum of the previously determined coupling constants. Second, the width of the multiplet (the same measurement in this simple case) is equal to our two coupling constants. Thus, the NMR signal at 6.45 ppm is a doublet of doublets with $J = 14.4$ and 6.8 Hz.

The two doublets of doublets at 4.15 and 3.96 ppm (Fig. 8.23*c*) must be coupled to one another because they both have the coupling constant of 1.9 Hz in common. This geminal coupling constant is typical of the terminal methylene of an alkene.

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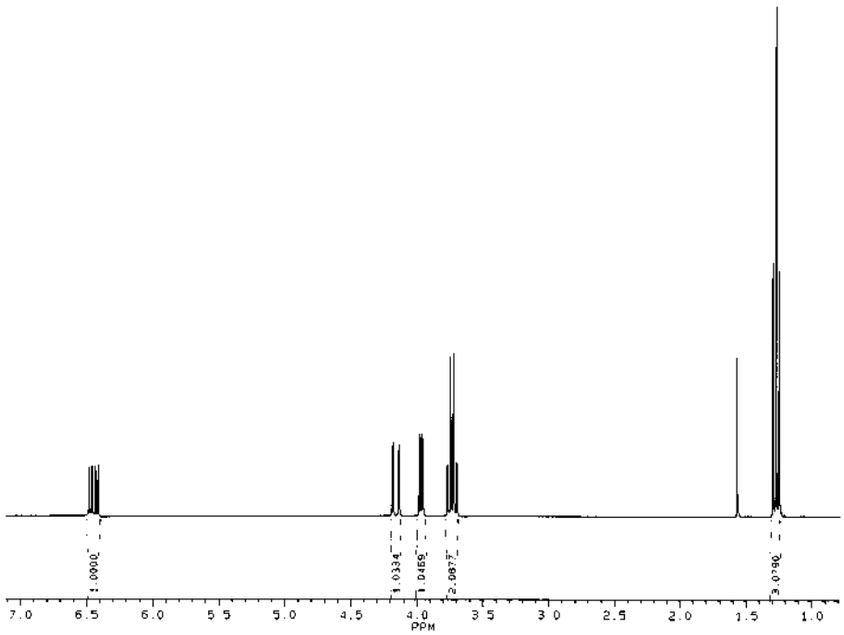

Figure 8.23*a* **Ethyl vinyl ether in $CDCl_3$.**

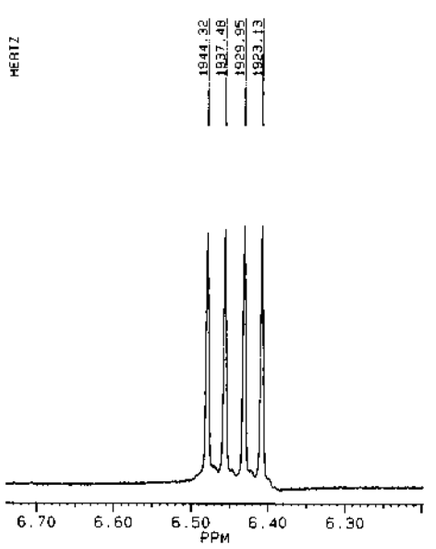

Figure 8.23*b* **Ethyl vinyl ether in $CDCl_3$ (expansion).**

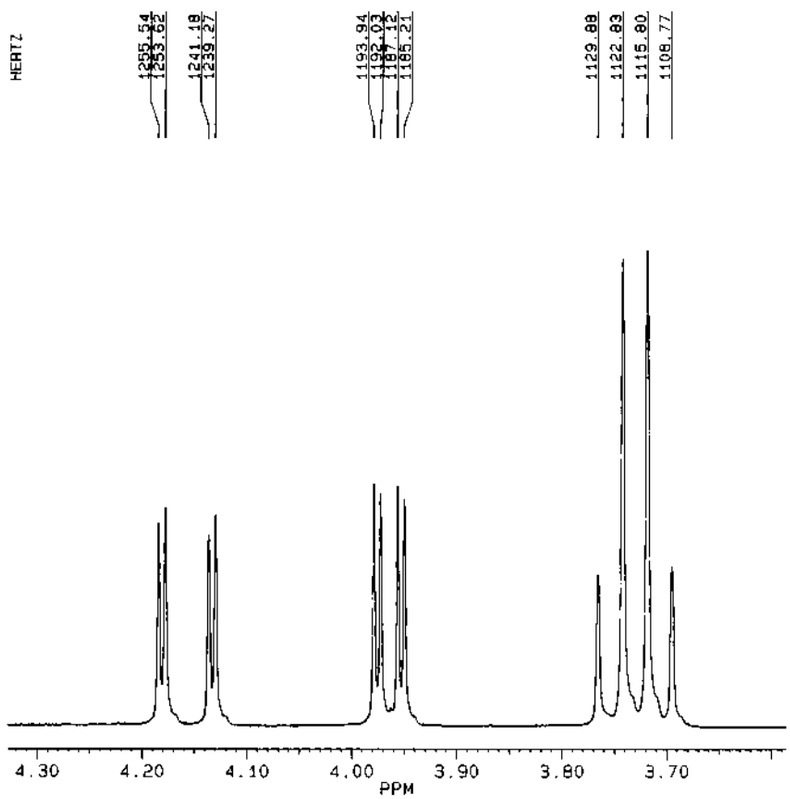

Figure 8.23*c* **Ethyl vinyl ether in $CDCl_3$ (expansion).**

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Since the proton at 3.96 is coupled to the proton at 6.45 ppm by $J = 6.8$ Hz, and the proton at 4.15 ppm is coupled to the one at 6.45 ppm by $J = 14.4$ Hz, the proton at 3.96 ppm must be cis, and the proton at 4.15 ppm must be trans, to the alkene proton at 6.45 ppm.

The simple coupling observed for the ethyl group in ethyl vinyl ether can be readily assigned. The triplet at about 1.25 ppm, which integrates for three protons, is due to the methyl group; it is a triplet because the equivalent protons of the methyl group are coupled to the two protons on the adjacent carbon with equal coupling constants. The O—C**H**$_2$ protons are observed in the NMR spectrum as the quartet at about 3.75 ppm; they are a quartet because they are coupled equally to the three equivalent protons of the methyl group:

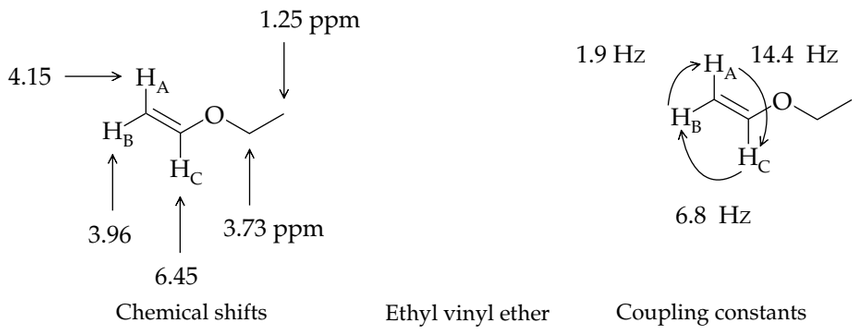

Allyl Acetate

For a more complex example, refer to the ^{1}H NMR spectrum of allyl acetate (the NMR signal for the methyl group has been omitted) in Figure 8.24*a*.

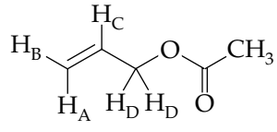

Protons A, B, and C are all chemically distinct, and the two protons labeled D are equivalent to one another by symmetry (the plane of the paper). The multiplet at 4.58 ppm (Fig. 8.24*d*) corresponds to H_D and is a doublet of triplets. The coupling constant for the triplet is 1.4 Hz and the coupling

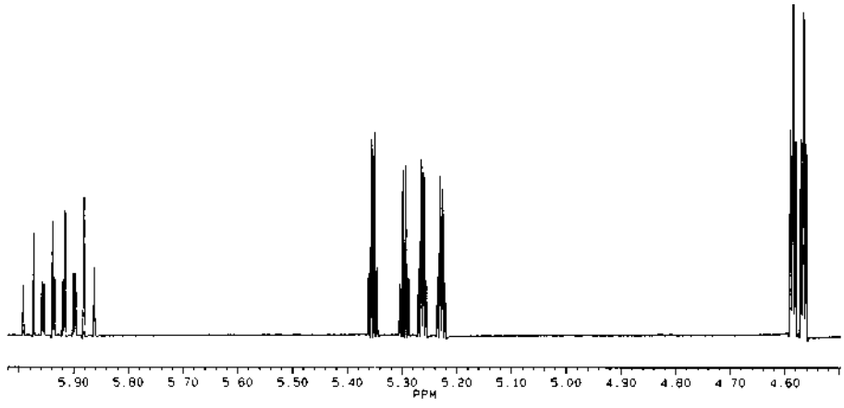

Figure 8.24*a* Allyl acetate in $CDCl_3$.

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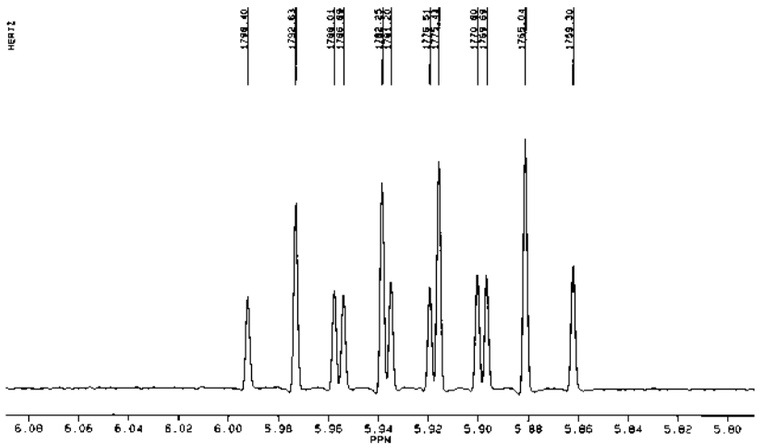

Figure 8.24*b* **Allyl acetate in $CDCl_3$ (expansion).**

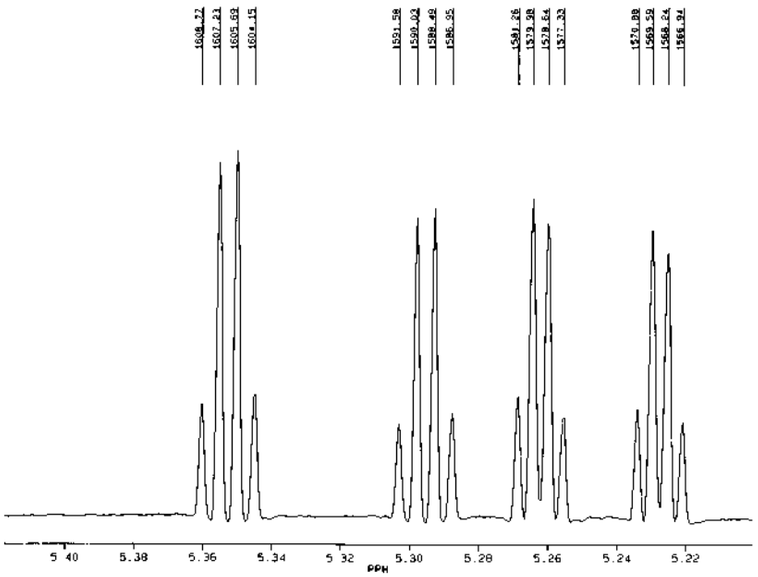

Figure 8.24*c* **Allyl acetate in $CDCl_3$ (expansion).**

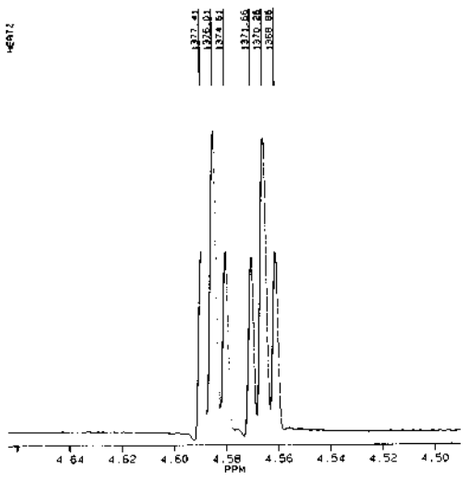

Figure 8.24*d* **Allyl acetate in $CDCl_3$ (expansion).**

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constant for the doublet is 5.8 Hz, which can be measured between any two corresponding peaks in the two triplets.

The four quartets around 5.3 ppm (Fig. 8.24*c*) are actually two doublets of quartets at 5.32 and 5.24 ppm and correspond to H_A and H_B in the structure above. At 5.32 ppm, the multiplet is a doublet of quartets, $J = 17.2$, 1.5 Hz. At 5.24 ppm, we have another doublet of quartets, $J = 10.4$, 1.3 Hz. We see quartets because the long-range allylic coupling to the two H_D signals gives a triplet that has a coupling constant J that is approximately equal to the geminal coupling constant (~1.4 Hz) between H_A and H_B. Since NMR line widths are naturally several tenths of a hertz, it is not possible to distinguish between coupling constants such as these that differ only by 0.2 Hz. We can unambiguously distinguish H_A and H_B by the magnitudes of their coupling constants to H_C, which are 17.2 and 10.4 Hz. Since trans coupling constants are larger than cis coupling constants, H_A must have the 17.2-Hz coupling constant to H_C and is thus assigned to the signal centered at 5.32 ppm. Since H_B is coupled to H_C by $J = 10.4$ Hz it is assigned to the signal centered at 5.24 ppm.

Finally, we already know what the multiplet for H_C should look like, since we know all of its coupling constants. It is coupled to the two H_D protons with a coupling constant of 5.8 Hz, to H_A with $J = 17.2$, Hz, and to H_B with $J = 10.4$ Hz. The multiplet for H_C at 5.93 ppm should be, therefore, a doublet of doublets of triplets with $J = 17.2$, 10.4, and 5.8 Hz, respectively. There should be $2 \times 2 \times 3 = 12$ lines and the width should be $17.2 + 10.4 + (2 \times 5.8) = 39.2$ Hz. There are indeed 12 lines (Fig. 8.24*b*) and the distance between the outside peaks is 39.1 Hz, which is a perfectly reasonable deviation from the ideal:

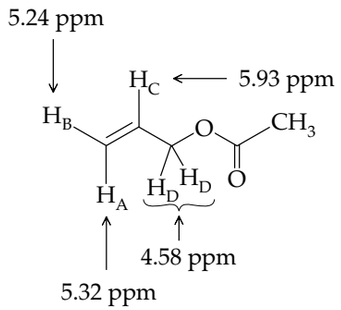

Allyl acetate, chemical shift assignments

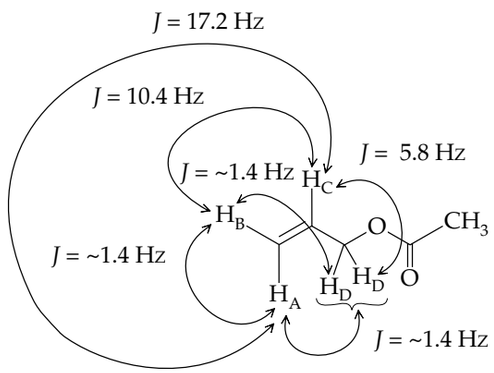

Allyl acetate, proton-proton coupling constants

Since cyclohexane rings are often held in at most two potential conformations (both chairs), coupling constants may allow the determination of relative stereochemistry. On cyclohexane rings in chair conformations, the axial–axial coupling constants for vicinal protons (180° dihedral angle) are on the order of 9–12 Hz.

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Equatorial–equatorial and equatorial–axial coupling constants (60° dihedral angles) are on the order of 2–4 Hz. Thus it is often a relatively simple matter to determine stereochemical relationships on a six-membered ring using NMR spectroscopy.

Take, for example, the two diastereomers of 4-*tert*-butylcyclohexanol:

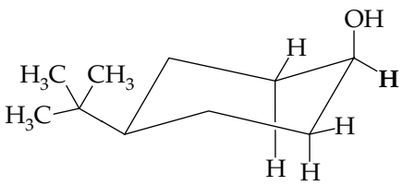

Cis

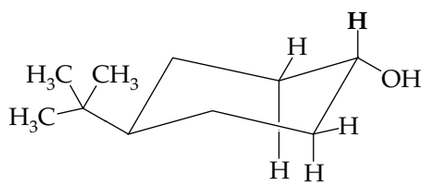

Trans

We know that the very large *tert*-butyl group will effectively always be equatorial. By examining the coupling to the methine proton of the alcohol, it is simple to determine whether that proton is axial or equatorial. It is also possible to distinguish between these stereoisomers by using chemical-shift information (in one isomer the alcohol methine is seen at ~3.52 ppm and in the other at ~4.04 ppm), but use of coupling information provides a far more definitive and unambiguous determination of stereochemistry.

The alcohol methine proton in the cis isomer is equatorial and thus has a 60° dihedral angle to all four adjacent protons that give rise to a pentet (which is really a doublet of doublets of doublets of doublets with equal coupling constants) with a coupling constant J = ~3 Hz, which is seen in Figure 8.25.

The alcohol methine in the trans isomer is axial and thus has a 180° dihedral angle to each of the two adjacent axial protons and a 60° dihedral angle to each of the two adjacent equatorial protons. This arrangement gives rise to a triplet of triplets with J = ~13 and 3 Hz, which is shown in Figure 8.26.

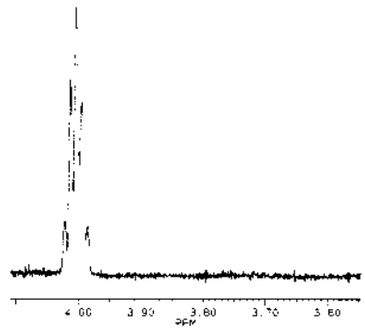

Figure 8.25 ***cis*-4-*tert*-Butylcyclohexanol.**

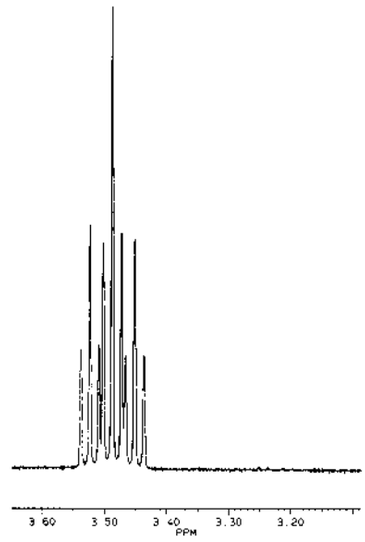

Figure 8.26 ***trans*-4-*tert*-Butylcyclohexanol.**

^{13}C NMR SPECTROSCOPY

With the advent of Fourier transform (FT) NMR spectrometers, ^{13}C NMR spectroscopy is now available as a simple and routine tool for the structure determination of organic molecules. Since ^{13}C is of low natural abundance (1.1%), addition of many spectra is required to obtain acceptable signal-to-noise (*S/N*) levels. With modern spectrometers, ^{13}C spectra can often be acquired simply by issuing software commands; in some instruments a different probe is inserted into the magnet. Since ^{13}C resonates at roughly 25% of the proton operating frequency of a spectrometer system, an instrument that acquires ^{1}H spectra at 300 MHz will be reset to about 75 MHz for ^{13}C work.

Generally, ^{13}C NMR spectra are acquired while the entire ^{1}H frequency range is irradiated by a second rf coil inside the probe assembly. These spectra are referred to as broadband-decoupled ^{13}C spectra and they do not show the effect of spin–spin coupling to ^{1}H nuclei. Such decoupling is done because ^{1}H–^{13}C coupling constants can be quite large (a few hundred Hz) relative to chemical-shift differences, which leads to multiplets split over a large portion of the spectrum and subsequent confusion (Fig. 8.27). It is often simpler to see a single line for each distinct carbon atom in a molecule. Furthermore, irradiation of the ^{1}H spectrum results in signal enhancement of the ^{13}C signals of the attached carbon atoms. This enhancement is the nuclear Overhauser effect (NOE).

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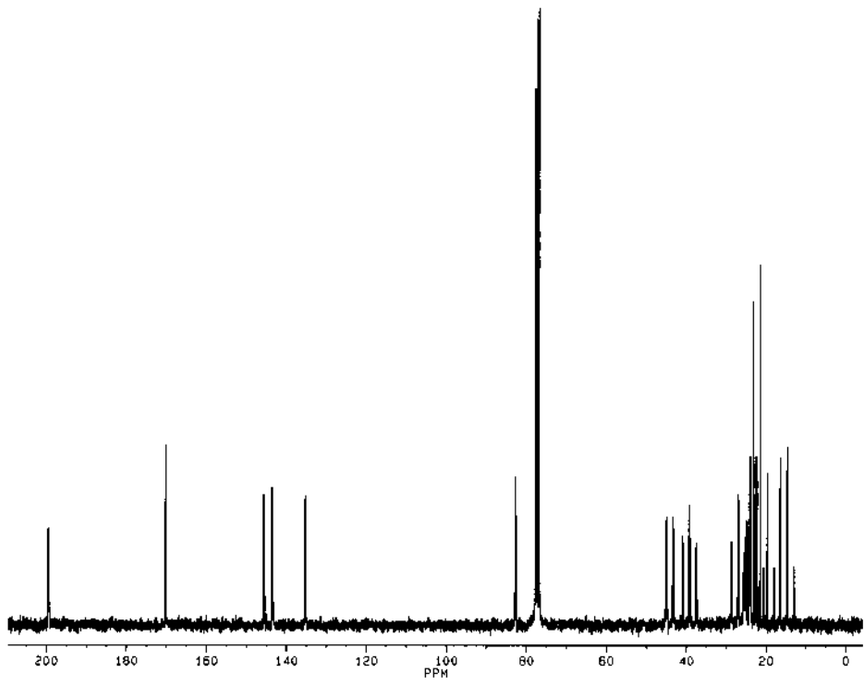

Figure 8.27 Fully ^{1}H-coupled ^{13}C NMR spectrum of 5-(1-acetoxy-1-methylethyl)-2-methyl-2-cyclohexenone in $CDCl_3$.

The ^{13}C NMR chemical shifts follow the same rough trends as seen in ^{1}H chemical shifts. ^{13}C chemical shifts, however, are not nearly as amenable to prediction based on the electronegativity of substituents as are ^{1}H chemical shifts. The ^{13}C chemical shifts are, in general, less sensitive to substituent electronegativities, and are far more sensitive to steric effects than are ^{1}H chemical shifts. A brief listing of approximate ^{13}C chemical shifts is provided in Table 8.26; a more extensive and thorough listing is available in the Silverstein et al. reference (Bibliography). As in ^{1}H NMR spectroscopy, TMS ($Si(CH_3)_4$) is used as the internal reference and the chemical shift of TMS is defined as zero. Except for functional groups such as acetals and ketals, sp^3-hybridized carbon atoms appear upfield (to the right) of 100 ppm, and sp^2-hybridized carbon atoms appear downfield of 100 ppm. Common carbonyl-containing functional groups appear downfield of 160 ppm. Aldehydes and ketones appear at 195–220 ppm; esters, amides, anhydrides, and carboxylic acids appear at 165–180 ppm.

Typical ^{13}C NMR spectroscopy provides an NMR spectrum that is not amenable to integration because of the NOE and insufficient relaxation delays. Therefore, the number of carbon atoms giving rise to a given signal cannot generally be determined by these techniques. It is possible to obtain ^{13}C NMR spectra that can be accurately integrated (inverse-gated decoupling), but this experiment requires a great deal of acquisition time to achieve adequate signal-to-noise levels.

Information about C—H coupling can be readily obtained, however. Fully coupled ^{13}C NMR spectra are not very useful for structure determination because C—H couplings are large (~120–270 Hz, depending mainly on the hybridization at carbon) and multiplets tend to overlap. Furthermore, when the hydrogen atoms are not irradiated, there is no NOE, and the signal-to-noise ratio suffers significantly. The most common use for coupling information is to

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Table 8.26 **Approximate ^{13}C NMR Chemical Shifts**

Functional Group	Carbon[a]	Chemical Shift/ δ (ppm)
Alkyl carbon atoms		~5–45
	1° R—**C**H_3	~5–30
	2° R—**C**H_2—R′	~15–35
	3° R—**C**HR′R″	~20–40
	4° R**C**R′R″R‴	~25–45
Alkenyl carbon atoms		~110–150
	H_2**C**=C	~100–125
	HR**C**=C	~125–145
	RR′**C**=C	~130–150
Aromatic carbon atoms		~120–160
Alkynyl carbon atoms	**C**≡C	~65–90
Nitriles	R—**C**≡N	~115–125
Alcohols and ethers	**C**—OH(R)	~50–75
	C—O (epoxides)	~35–55
Amines	**C**—N	~30–55
Alkyl halides	**C**—X	~0–75
Carbonyl groups	**C**=O	~165–220
Ketones, aldehydes	R**C**OR′, R**C**HO	195–220
Carboxylic acids, esters	R**C**O_2H, R**C**O_2R′	165–180
Amides, anhydrides	R**C**ON, R**C**O_2OCR′	160–175

[a]R = alkyl group.

determine the number of protons attached to a given carbon atom. This can be done in a variety of ways, some of which do not actually display the carbon signals as multiplets due to coupling to attached protons.

Single-frequency off-resonance decoupling (SFORD) is a useful technique for determining the number of hydrogen atoms attached to a given carbon. The decoupler is tuned off to one side of the proton spectrum and the sample is irradiated at a single frequency giving rise to ^{13}C spectra that show C—H couplings as a fraction of their actual values and that show a partial NOE. The apparent C—H coupling is dependent on both the actual coupling constant and the difference between the decoupler frequency and the resonance frequency of the hydrogen in question. The major disadvantage of SFORD is its low signal-to-noise ratio, which is due to two factors. First, there is only a partial NOE. Second, when NMR signals are split into multiplets, the signal intensity becomes distributed among several peaks. Thus, SFORD spectra require significantly more spectral acquisitions than do fully decoupled ^{13}C NMR spectra, and to some extent have been replaced with distortionless enhancement by polarization transfer (DEPT) spectra.

DEPT ^{13}C NMR spectroscopy provides a rapid way of determining the number of hydrogen atoms attached to a given carbon atom. DEPT spectra result from a multiple-pulse sequence that terminates in a "read pulse," which can be varied according to the spectrum desired. In DEPT spectra, all peaks are singlets; quaternary carbon atoms (without attached hydrogen atoms) are not seen in any DEPT spectra. In DEPT-135° spectra, CH and CH_3 groups appear as singlets of positive intensity, and CH_2 groups appear as negative peaks. The

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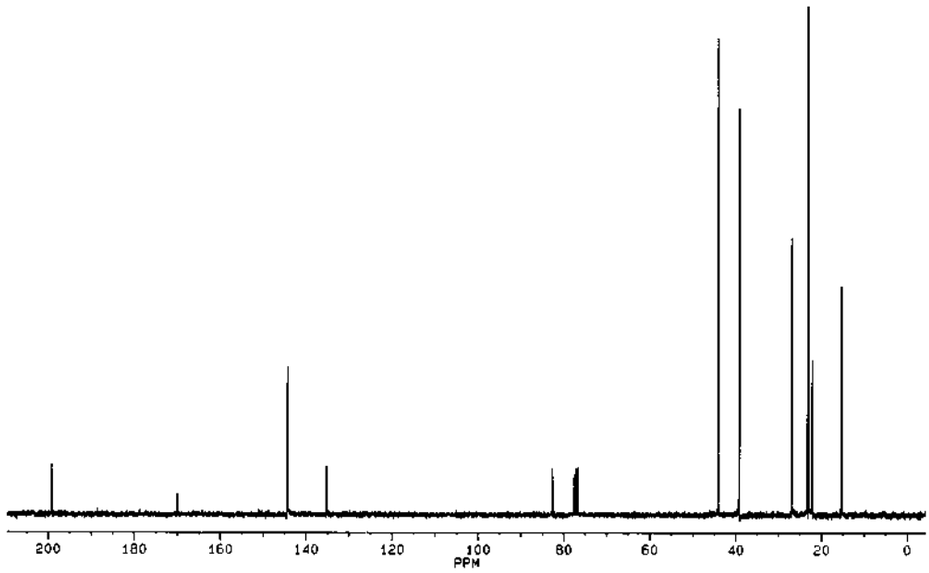

Figure 8.28 Broadband ^{1}H-decoupled ^{13}C NMR spectrum of 5-(1-acetoxy-1-methylethyl)-2-methyl-2-cyclohexenone in $CDCl_3$.

DEPT-90° spectra show only CH groups, and thus allow CH_3 and CH groups to be distinguished. In combination with a routine fully decoupled spectrum, DEPT spectra allow unambiguous assignment of the number of hydrogen atoms attached to each carbon. In practice, such spectral editing techniques are not perfect, and small residual peaks are often seen where, in principle, there should be none; these are usually small enough to be readily distinguished from the "real" peaks.

The fully coupled ^{13}C NMR spectrum of the acetoxy-enone (**I**) is shown in Figure 8.27, the broadband decoupled spectrum in Figure 8.28, and the SFORD spectrum in Figure 8.29. The DEPT-135° spectrum is shown in Figure 8.30, and the DEPT-90° spectrum in Figure 8.31. The 1:1:1 triplet centered at 77 ppm is due to the solvent, $CDCl_3$.

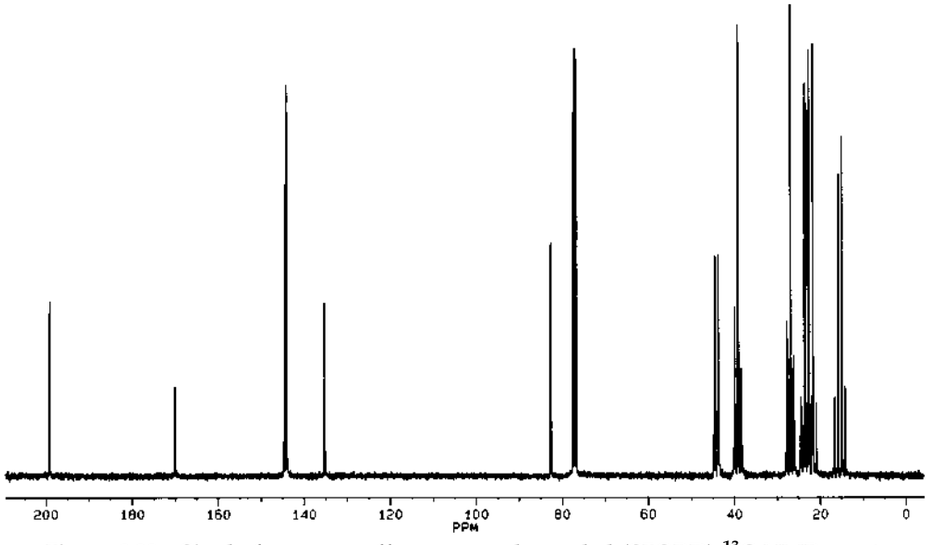

Figure 8.29 Single-frequency off-resonance decoupled (SFORD) ^{13}C NMR spectrum of 5-(1-acetoxy-1-methylethyl)-2-methyl-2-cyclohexenone in $CDCl_3$.

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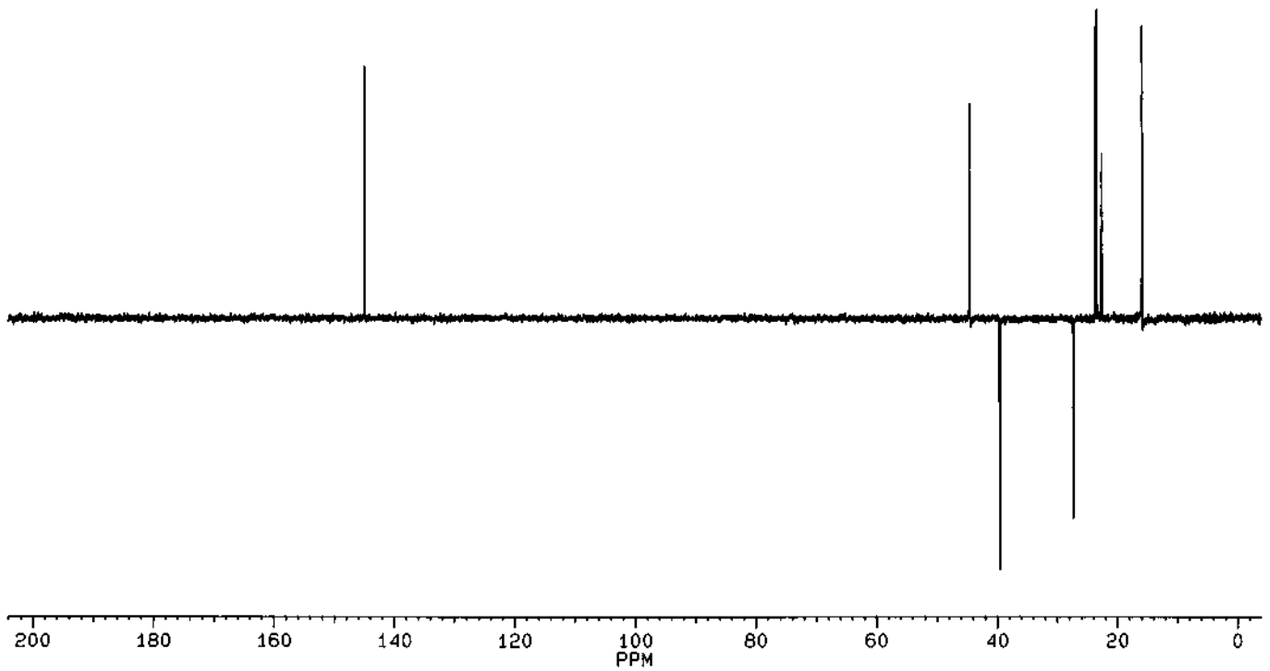

Figure 8.30 The DEPT-135° spectrum of 5-(1-acetoxy-1-methylethyl)-2-methyl-2-cyclohexenone in $CDCl_3$.

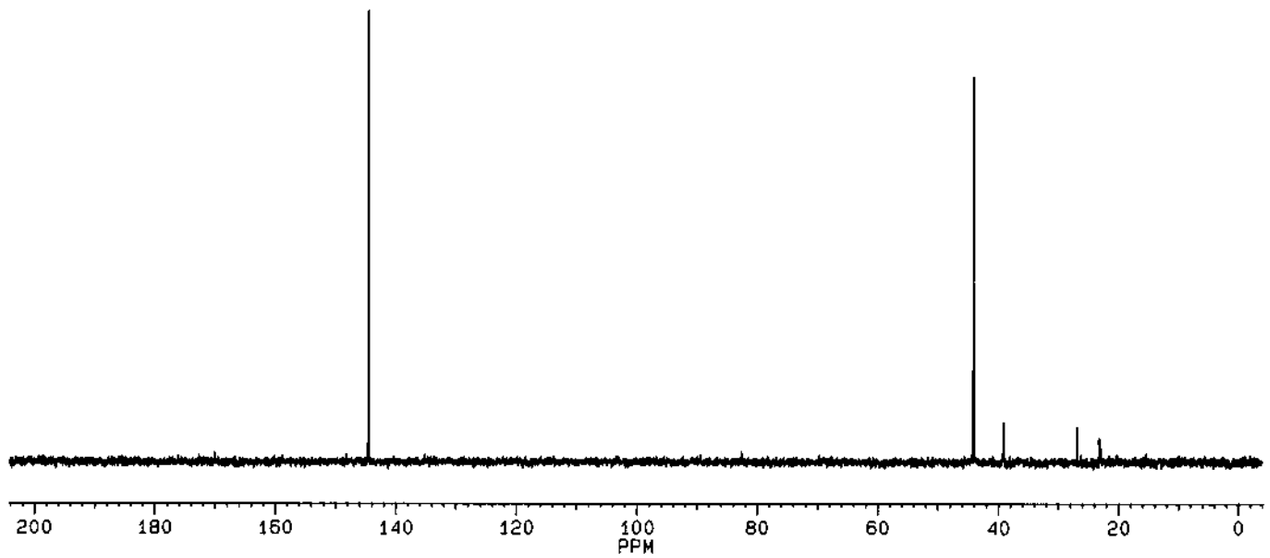

Figure 8.31 The DEPT-90° spectrum of 5-(1-acetoxy-1-methylethyl)-2-methyl-2-cyclohexenone in $CDCl_3$.

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Interpretation and assignment of the ^{13}C NMR spectrum are much easier when we unambiguously know how many protons are attached to each carbon.

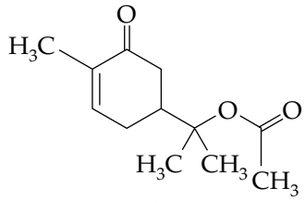

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The ^{13}C NMR is often better than ^{1}H NMR for distinguishing functional groups because typical ^{13}C chemical shifts are in the range 0–200 ppm relative to TMS, as compared to 0–10 ppm for proton chemical shifts. Coupling between adjacent ^{13}C nuclei is not observed (except in isotopically enriched samples) because the probability of having two rare isotopes adjacent to one another is very small. Because of the absence of decoupling, ^{13}C spectra are less complex than ^{1}H spectra, and ^{13}C spectra are often better suited for the detection and identification of isomeric or other impurities in a sample; it is easy for small peaks to be concealed underneath a complex second-order multiplet in the ^{1}H NMR spectrum.

The 300-MHz ^{1}H spectrum of 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride is shown in Figure 8.32. Owing in part to the presence of two stereocenters, as well as to long-range coupling through the π system of the alkene, the entire ^{1}H spectrum is second order at this field strength, and no information is available from the coupling constants because the spectrum is too complex. Limited assignments to peaks could be made on the basis of chemical shift, but it would be difficult to make any statements regarding purity of our sample based on the ^{1}H NMR spectrum, because an impurity could easily be hidden underneath any of the complex signals.

The ^{13}C spectrum of 4-cyclohexene-*cis*-1,2-dicarboxylic acid anhydride (Figure 8.33) is much less complex. Because of the mirror plane of symmetry in the compound, there are only four different carbon atoms and thus only four lines are seen in the fully decoupled ^{13}C NMR spectrum. This simplicity makes it easy to detect isomeric or other impurities in this sample. These impurities were not as easy to detect in the ^{1}H NMR spectrum. The 1:1:1 triplet centered at 77 ppm is due to the solvent, $CDCl_3$. Although no ^{1}H–^{13}C

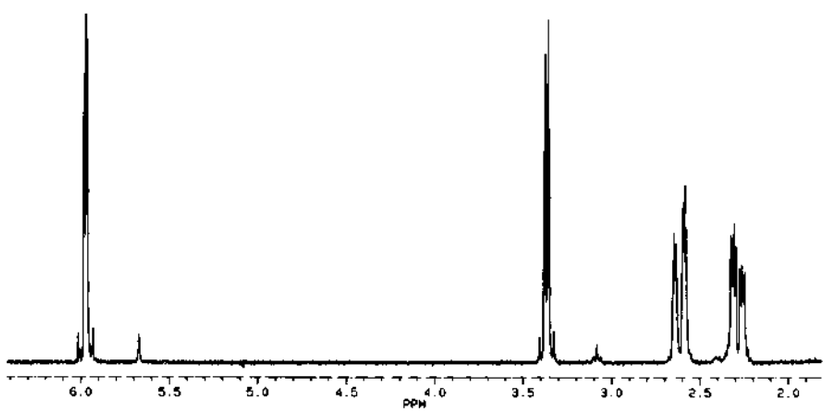

Figure 8.32 The ^{1}H NMR spectrum of 4-cyclohexene-cis-1,2-dicarboxylic acid anhydride in $CDCl_3$.

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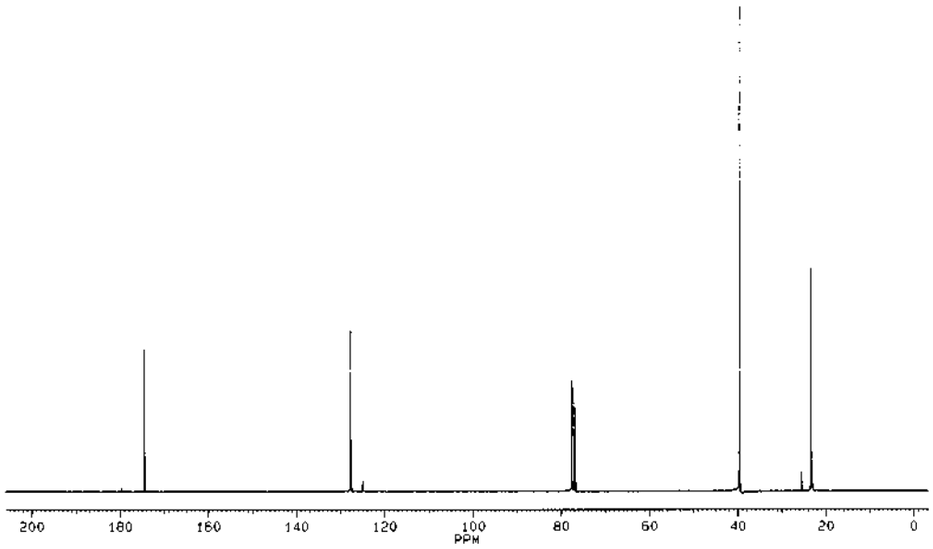

Figure 8.33 Broadband ^{1}H-decoupled ^{13}C NMR spectrum of 4-cyclohexene-cis-1,2-dicarboxylic acid anhydride in $CDCl_3$.

coupling is observed because of the ^{1}H broadband decoupling, ^{2}H–^{13}C coupling is observed because ^{1}H and ^{2}H resonate at different frequencies.

TWO-DIMENSIONAL NMR SPECTROSCOPY

Two significant developments in NMR spectroscopy are the use of Fourier transform techniques, and the development of two-dimensional (2D) NMR spectroscopy. Two-dimensional spectra are obtained using a sequence of rf pulses that includes a variable delay or delays. A set of FIDs is acquired and stored. The variable delay is incremented by a small amount of time and a new set of FIDs are obtained and stored, and so on. At the end, the resulting matrix of FID data is Fourier transformed twice: once with respect to the acquisition time (as in normal FT-NMR) and second with respect to the time of the variable delay in the pulse sequence. The resulting data represent a surface and are presented as a contour plot of that surface.

The most useful 2D spectra for organic compound identification are called correlation spectra. Correlation Spectroscopy (COSY) spectra are presented as a contour plot with routine proton spectra along both of the axes, as shown in the COSY spectrum of ethyl vinyl ether in Figure 8.34. The spectra along the axes are low-digital-resolution spectra and appear to be a bit different from those generated as usual NMR spectra. Note that the 2D spectrum is symmetric about the diagonal that runs from the lower left corner to the upper right corner. Every peak is represented by a peak along the diagonal and, in fact, the diagonal *is* the normal proton spectrum. Where the contour plot indicates a peak other than on the diagonal, the interpretation is that the corresponding peaks on the two axes represent protons coupled to one another.

For example, draw a line down from the signal at 1.2 ppm on the horizontal axis. This line encounters the diagonal at 1.2 ppm and then there is a peak at 3.7 ppm. By drawing a horizontal line over to the spectrum on the vertical axis, we can see that the peaks at 1.2 and 3.7 ppm are coupled to one another; these are the signals from the methyl triplet and methylene quartet of the ethyl group.

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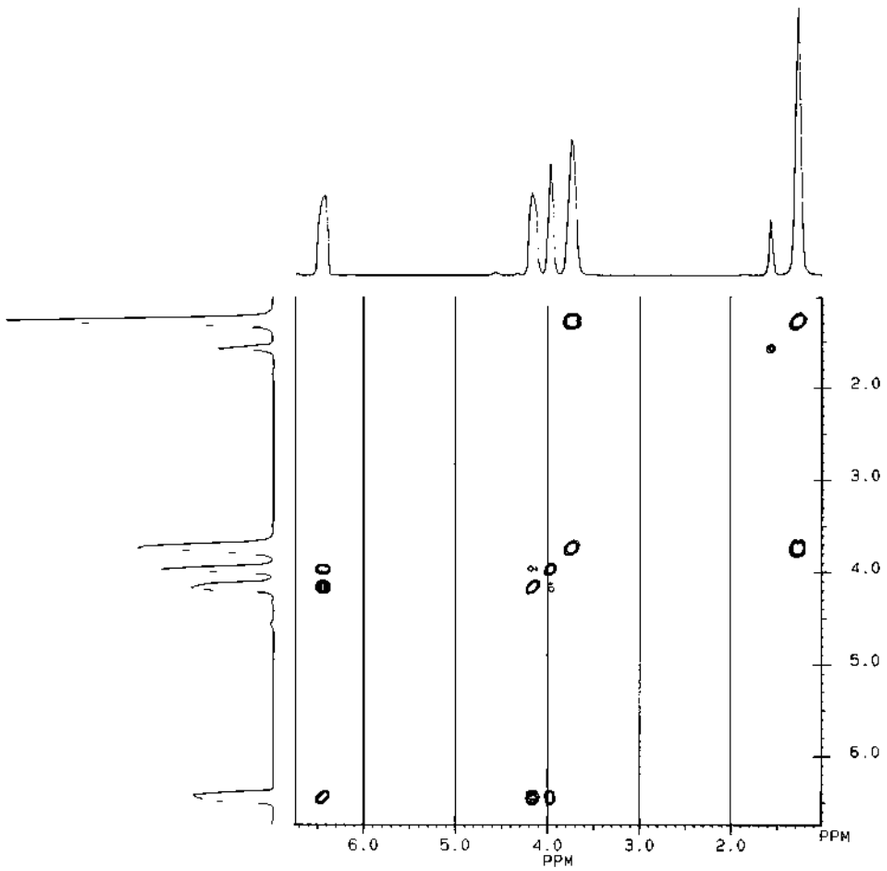

Figure 8.34 The COSY NMR spectrum of ethyl vinyl ether.

We can also see that neither of these is coupled to the remainder of the spectrum, which of course is the vinyl group. Each proton in the vinyl group is coupled to each of the others, as we can see in the COSY spectrum. For example, the signal at 4.2 ppm is coupled to both the signal at 4.0 ppm and the one at 6.4 ppm.

It is possible to obtain 2D spectra that correlate the spectra of different nuclei, such as ^{1}H and ^{13}C. The heteronuclear correlation spectrum of ethyl vinyl ether is shown in Figure 8.35. The ^{13}C spectrum is along the horizontal axis and the ^{1}H spectrum is along the vertical axis. The peaks of the 2D spectrum indicate that the corresponding peaks on the axes represent a carbon and a proton (or protons) that are directly bonded. By using this spectrum we can easily verify the ^{13}C and ^{1}H chemical-shift assignments below:

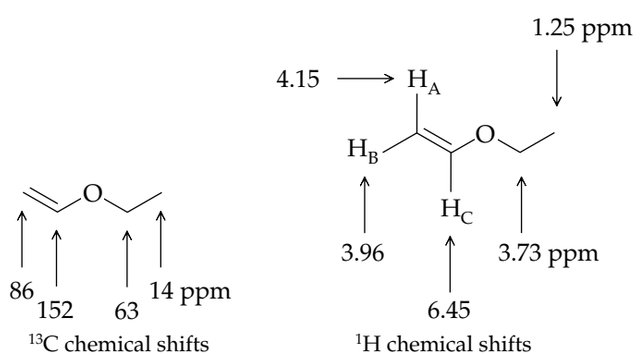

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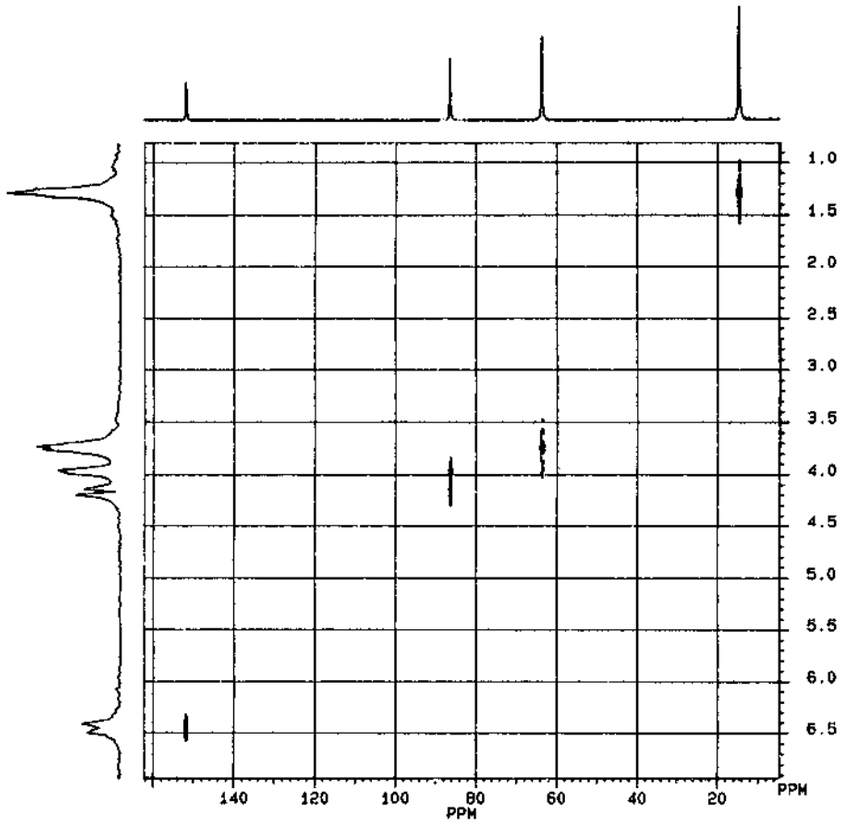

Figure 8.35 Ethyl vinyl ether ^{1}H–^{13}C correlation spectrum.

There are many other powerful 2D NMR spectroscopic techniques that can provide a wealth of information about molecular structure, even in organic molecules as large as proteins and nucleic acids. A few of the good texts that provide further information about these powerful tools are listed in the Bibliography.

NUCLEAR MAGNETIC RESONANCE SAMPLING

It is usually simple to prepare a sample of a small organic molecule (MW 500) for NMR analysis. For ^{1}H NMR spectroscopy, the sample size compatible with CW spectrometers is in the range 30–50 mg dissolved in about 0.5 mL of solvent. Fourier transform spectrometers require only 2–3 mg of sample in the same volume of solvent. Most samples are measured in solution in thin-walled tubes 5 mm in diameter and 18–20 cm long. NMR sample tubes are expensive and delicate; they must be as perfectly straight, and have as perfectly concentric walls, as possible. The sample tube is filled to a depth of about 3 cm. Filling the tube to this depth maximizes sample concentration in the active part of the NMR probe, and thus the strength of the signal. Adding more solvent just wastes sample by dilution. The sample tube is spun about its axis in the instrument to average out small changes in

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the tube walls and in the magnetic field strength over the sample volume. There must be enough solvent in the tube to ensure that the vortex, or whirlpool, created when the tube is spun, does not extend down into the portion of the tube where the rf coils in the NMR probe are active. Many instruments use a depth gauge that shows exactly where this area is. Glass microcells are now commercially available. An inexpensive microcell technique for CW-NMR spectrometers using ordinary 5-mm NMR tubes has been described.[2]

The most practical NMR solvent is deuterochloroform ($CDCl_3$); it is relatively cheap and dissolves many different compounds. Handle this solvent
HOOD with care, in the **hood,** because it is **toxic!** Many other deuterated solvents are commercially available, including acetone, methanol, and water. The universally accepted internal reference compound employed in making these measurements is tetramethylsilane, $Si(CH_3)_4$ (TMS). The most convenient source of TMS is commercially available $CDCl_3$, which contains about 1% TMS for use with CW spectrometers (commercially available 0.03% solutions are more appropriate for FT spectrometers).

The most significant problem in sample preparation is the exclusion of small pieces of dust and dirt, because they may contain magnetic material, which will result in poor spectra. Scrupulously clean samples of liquids can often simply be added to the NMR tube, followed by the solvent. Liquids containing visible impurities, and solids, are best prepared by dissolving the sample in about 0.3–0.4 mL of solvent in a small vial. The solution can then be filtered into the NMR tube through a Pasteur pipet plugged with a small piece of cotton, and the pipet can be rinsed with the NMR solvent to achieve the appropriate volume in the NMR tube. Since TMS is volatile (bp = 26.5 °C), the tube should be capped following addition, or the TMS will evaporate. If several people in a laboratory section are going to be obtaining NMR spectra, you will find that the spectrometer will be easier to tune with each new sample if all the sample tubes are filled to exactly the same level.

At this point, all specific instructions are dependent on the NMR spectrometer available to you. In general, the sample is inserted into the magnet and the magnetic field is adjusted very slightly (called shimming or tuning) to obtain a magnetic field that is as homogeneous as possible throughout the sample volume observed by the spectrometer. These adjustments are accomplished by energizing a collection of small electromagnetic coils around the sample, a process that is often done by the spectrometer's computer. Symptoms of a poorly shimmed spectrometer include broad and/or asymmetric peaks. The best place to check for this is on the TMS peak because it is the one peak in the spectrum you *know* should be narrow and symmetric. Once the spectrometer is tuned, the spectrum is obtained and plotted, and the sample is removed from the magnet.

Your NMR sample can be easily recovered by emptying the NMR tube into a small vial, rinsing the tube once or twice with (a nondeuterated) sol-
HOOD vent, and then evaporating the solvent in a **hood** under a gentle stream of dry nitrogen.

[2]Yu, S. J. *J. Chem. Educ.* **1987,** *64,* 812.

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QUESTIONS

Several 60-MHz ^{1}H NMR spectra are given below (Figs. 8.36–8.40) along with the molecular formula of the compound.[3] You should be able to account for at least one acceptable structure and for all of the observed resonances.

8-16. C_4H_8O. Spectrum *a:*

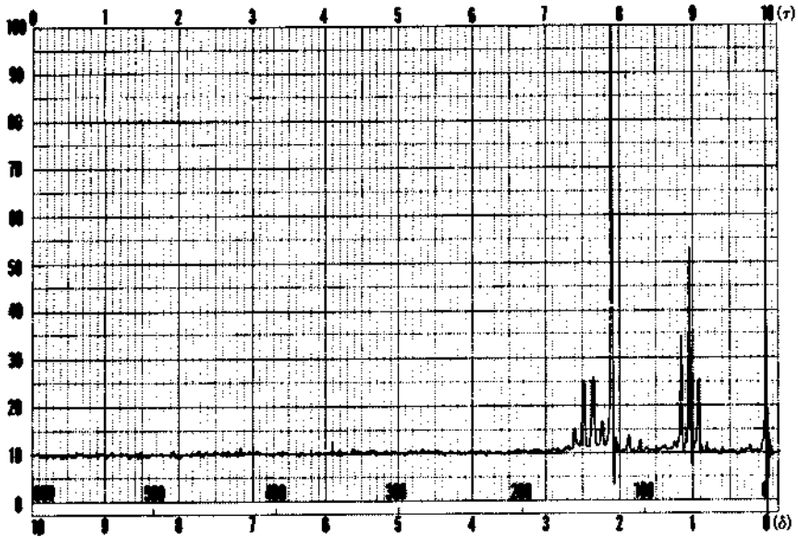

Figure 8.36 NMR unknown spectrum *a*.

8-17. $C_3H_6O_2$. Spectra *b* and *c.* Two compounds with the same empirical formula:

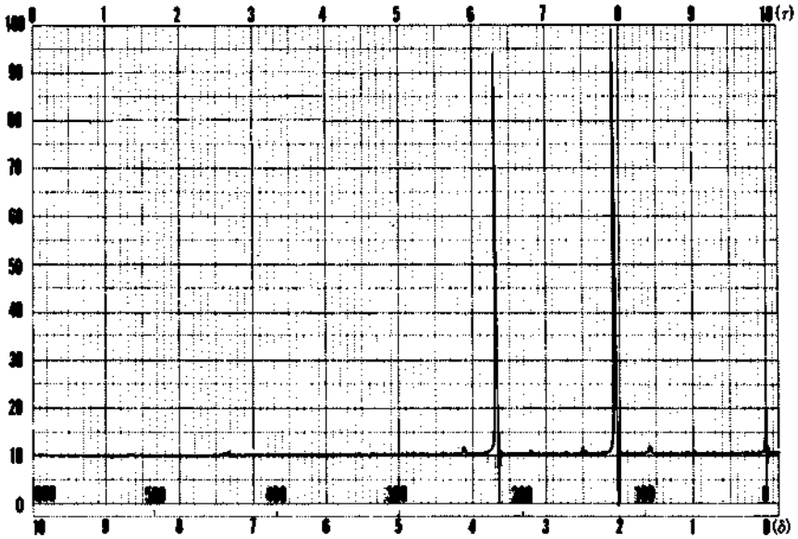

Figure 8.37*a* NMR unknown spectrum *b*.

[3]From Pouchert, C. J. *The Aldrich Library of NMR Spectra,* 2nd ed.; Aldrich Chemical Co.: Milwaukee, WI, 1983.

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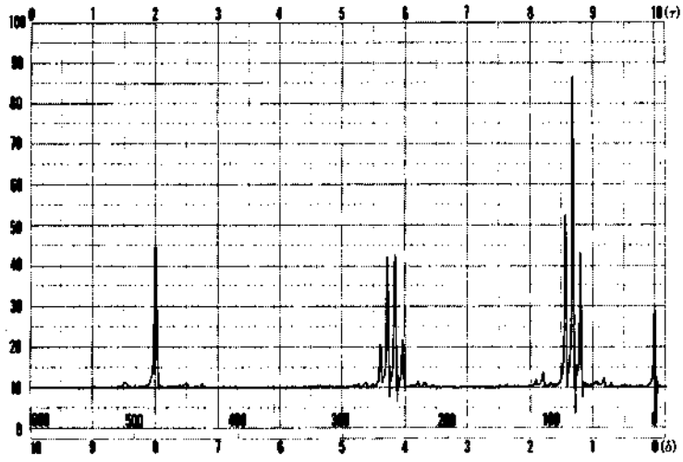

Figure 8.37*b* NMR unknown spectrum *c*.

8.18 C_4H_8O. Spectrum *d*. Also give some thought to the weak resonances at 0.5 and 1.8 ppm:

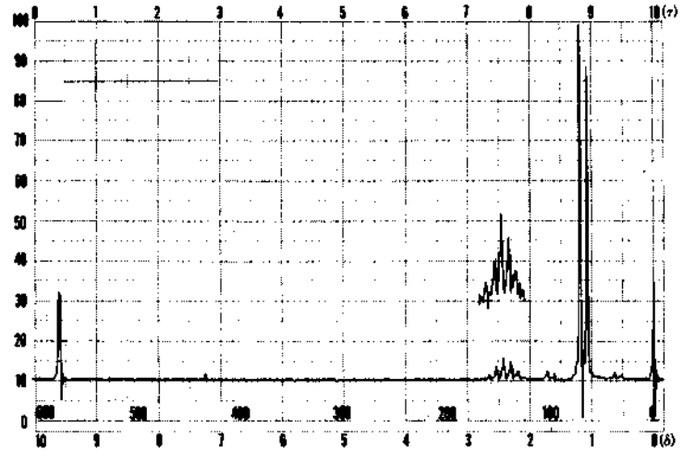

Figure 8.38 NMR unknown spectrum *d*.

8-19 C_7H_7Cl. Spectrum *e:*

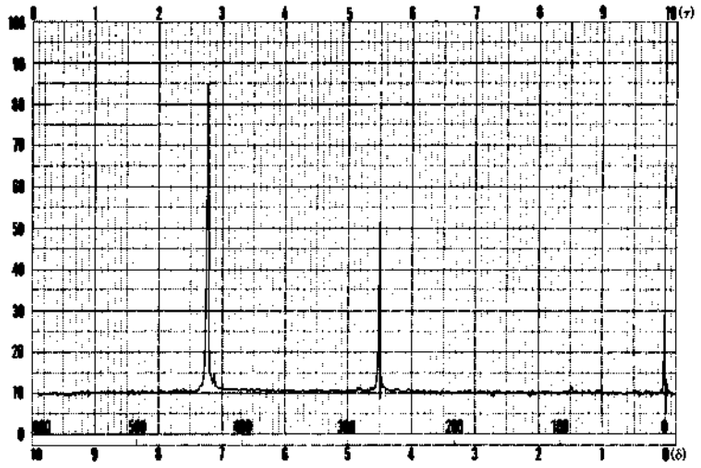

Figure 8.39 NMR unknown spectrum *e*.

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8-20. $C_8H_{10}O$. Spectrum *f:*

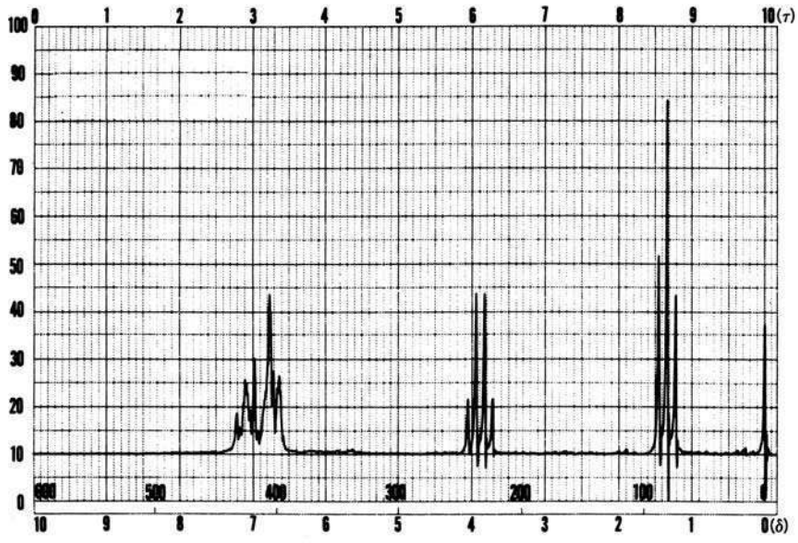

Figure 8.40 NMR unknown spectrum *f*.

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Pouchert, C. J.; Behnke, J. *The Aldrich Library of ^{13}C and ^{1}H FT-NMR Spectra;* Aldrich Chemical Co.: Milwaukee, WI, 1992.

Online libraries of NMR spectra:

Online Resource Guide (NMR and Other Spectra (http://www.library.illinois.edu/chx/onlineresources/nmr.html))

SciFinder Scholar (https://scifinder.cas.org/)

ULTRAVIOLET–VISIBLE SPECTROSCOPY: INTRODUCTION TO ABSORPTION SPECTROSCOPY

In an atom, molecule, or ion, a limited number of electronic energy states are available to the system because of the quantized nature of the energies involved. The absorption of a photon by the system can be interpreted as corresponding

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to the occupation of a new energy state by an electron. The difference in energy between these two states may be expressed as ΔE:

——— Upper state (excited electronic state, E_1)
$\updownarrow$ ΔE
——— Lower state (ground electronic state, E_0)

where the energy of the photon, E, is related to the frequency of the radiation by the Planck equation,

$$E = h\nu_i$$

where h is Planck's constant, 6.626×10^{-34} J s, and ν_i is the frequency in hertz. In the case above, $\Delta E = E_1 - E_0 = h(\nu_1 - \nu_0) = h\nu_i$.

Thus, when a frequency match between the radiation and an energy gap (ΔE) in the substance occurs, a transition between the two states involved may be induced. The system can either absorb or emit a photon corresponding to ΔE, depending on the state currently occupied (emission would occur if the system relaxed from an upper-level excited state to a lower state). All organic molecules absorb photons with energies corresponding to the visible or ultraviolet regions of the electromagnetic spectrum, but to be absorbed, the incident energy in this frequency range must correspond to an available energy gap between an electronic ground state and an upper-level electronic excited state. The electronic transitions of principal interest to the organic chemist are those that correspond to the excitation of a single electron from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO). As we will see, this will be the molecule's absorption occurring at the longest wavelength in the electronic absorption spectrum; it is, therefore, the most easily observed.

Electromagnetic radiation can be defined in terms of a frequency ν, which is inversely proportional to a wavelength λ times a velocity c ($\nu = c/\lambda$, where c is the velocity of light in a vacuum, 2.998×10^8 m/s, and $c = \nu\lambda$ is the wave velocity). Thus,

$$\Delta E = h\nu = \frac{hc}{\lambda} = hc\tilde{\nu}$$

where $\tilde{\nu}$ is the wavenumber, defined as the reciprocal of the wavelength ($1/\lambda$)$\times$ the velocity of light.

Most ultraviolet and visible (UV and vis) spectra are recorded linearly in wavelength, rather than linearly in frequency or in units proportional to frequency (the wavenumber) or in energy values. Wavelength in this spectral region is currently expressed in nanometers (nm, where 1 nm $= 10^{-9}$ m) or angstrom units (Å, where 1 Å $= 10^{-10}$ m). The older literature is full of UV–vis spectra in which wavelength is plotted in millimicrons (mμ), which are also equivalent to 10^{-9} m. For a further discussion of the relationship between frequency, wavelength, wavenumber, and refractive index, see the discussion on infrared spectroscopy.

It is unfortunate that because of instrumentation advantages this region of the spectrum is most often plotted in units that are nonlinear in energy (note the inverse relationship of E to λ) A convenient formula for expressing the relationship of wavelength and energy in useful values is

$$E = 28{,}635/\lambda \text{ kcal/mol} \qquad (\lambda \text{ in nm})$$

or in terms of wavenumbers

$$E = (28.635 \times 10^{-4})\tilde{\nu} \qquad (\tilde{\nu} \text{ in cm}^{-1})$$

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Table 8.27 Spectroscopic Wavelength Ranges			
Region	**Wavelength (m)**	**Energy (kJ/mol)**	**Change Excited**
Gamma ray	Less than10^{-10}	$> 10^6$	Nuclear transformation
X-ray	10^{-8}–10^{-10}	10^4–10^6	Inner shell electron transitions
Ultraviolet (UV)	4×10^{-7}–1×10^{-8}	10^3–10^4	Valence shell electrons
Visible (vis)	8×10^{-7}–4×10^{-7}	10^2–10^3	Electronic transitions
Infrared (IR)	10^{-4}–2.5×10^{-6}	1–50	Bond vibrations
Microwave	10^{-2}–10^{-4}	10–1000	Molecular rotations
ESR	10^{-2}	10	Electron spin transitions
NMR	0.5–5	0.02–0.2	Nuclear spin transitions

The electromagnetic spectrum and the wavelength ranges corresponding to a variety of energy-state transitions are listed in Table 8.27. Infrared, UV–vis, and rf are of particular interest to the organic chemist because the excitation of organic substances by radiation from these regions of the spectrum can yield significant structural information about the molecular system being studied.

The absorption of rf energy by organic molecules immersed in strong magnetic fields involves exceedingly small energy transitions (~0.05 cal/mol), which correspond to nuclear spin excitations and result in NMR spectra. When a molecule absorbs microwave radiation, the energy states available for excitation correspond to molecular rotations and involve energies of roughly 1 cal/mol. With relatively simple molecules (in the gas phase) possessing a dipole moment (required for the absorption process) the analysis of the microwave spectrum can yield highly precise measurements of the molecular dimensions (bond lengths and angles). Unfortunately, relatively few organic systems exhibit pure rotational spectra that can be rigorously interpreted.

Absorption of radiation in the infrared region of the spectrum involves the excitation of vibrational energy levels and corresponds to energies in the range of about 1–12 kcal/mol. The excitation of electronic states requires considerably higher energies, from a little below 40 to nearly 300 kcal/mol. The corresponding radiation wavelengths would fall across the visible (400–800 nm), the near-UV (200–400 nm), and the far- (or vacuum) UV (100–200 nm) regions.The long-wavelength visible and near-UV regions of the spectrum hold information of particular value to the organic chemist. Here the energies correspond to the excitation of loosely held bonding (π) or lone-pair electrons. The far-UV region, however, involves high-energy transitions associated with the inner-shell and σ-bond electronic energy transitions. This region is difficult to access because atmospheric oxygen begins to absorb UV radiation below 190 nm, which requires working in evacuated or purged instruments (which is why this region is often referred to as the vacuum UV).

UV–VIS SPECTROSCOPY

As we have seen, the application of electronic absorption spectroscopy in organic chemistry is restricted largely to excitation of ground-state electronic levels in the near-UV and vis regions. When photons of these energies are absorbed, the excited electronic states that result have bond strengths appreciably less than their ground-state values, and the internuclear distances and bond angles will be altered within the region of the molecules where the electronic

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excitation occurs (see Figure 8.41). It is normally reasonable to assume that nearly all of the molecules are present in the ground vibrational state within the ground electronic state. The upper electronic state also contains a set of vibrational levels and any of these may be open to occupation by the excited electron (see Figure 8.41). Thus, an electronic transition from a particular ground-state level can be to any number of upper-level vibrational states on the excited electronic state.

The shape of an electronic absorption band will be determined to a large extent by the spacing of the vibrational levels and the distribution of band intensity over the vibrational sublevels. In most cases these effects lead to broad absorption bands in the UV–vis region.

The wavelength maximum at which an absorption band occurs in the UV–vis region is generally referred to as the λ_{max} of the sample (where wavelength is determined by the band maximum).

The quantitative relationship of absorbance (the intensity of a band) to concentration is expressed by the Beer–Lambert equation:

$$A = \log\frac{I_0}{I} = \varepsilon c I$$

where

A = absorbance, expressed as I_0/I

I_0 = the intensity of the incident light

I = the intensity of the light transmitted through the sample

ε = molar absorbtivity, or the extinction coefficient (a constant characteristic of the specific molecule being observed); values for conjugated dienes typically range from 10,000 to 25,000

c = concentration (mol/L)

λ = length of sample path (cm)

The calculated extinction coefficient and solvent are usually listed with the wavelength at the band maximum. For example, data for methyl vinyl ketone (3-buten-2-one) would be reported as follows:

λ_{max} 219 nm (ε = 3600, ethanol)
λ_{max} 324 nm (ε = 24, ethanol)

Typical UV–vis spectra are shown in Experiments [6], [19D], [A2$_a$], and [A3$_a$]. As part of the characterization data, UV–vis information is also given in Experiments[16], [A1$_a$], [19A], and [33A].

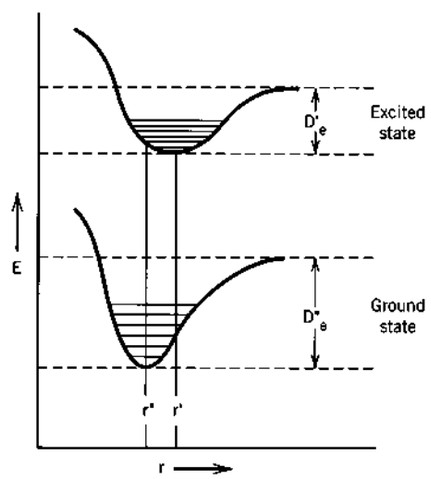

Figure 8.41 Two electronic energy levels in a diatomic molecule.

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APPLICATION TO ORGANIC MOLECULES

In organic compounds containing *conjugated* systems of π electrons, a particular *chromophore* present can often be identified by the use of UV–vis spectroscopy. A *chromophore* is, in this case, a group of atoms able to absorb light in the UV–vis region of the spectrum. Since the electronic transitions involved are limited primarily to π-electron (and lone-pair) systems, this type of spectroscopy is less commonly used than the other modern spectroscopic techniques—which, in fact, it predates by several decades. Ultraviolet–visible spectroscopy, however, can play a valuable role in certain situations. For example, if a research problem involves synthesizing a series of derivatives of a complex organic molecule that possesses a strong chromophore, the UV–vis spectrum will be highly sensitive to structural changes involving the arrangement of the π-electron system (see, e.g., Experiment [6]).

In a conjugated alkene, such as 1,3-butadiene, the long-wavelength photon absorbed corresponds to the energy required for the excitation of a π electron from the HOMO, π_2 to the LUMO, π^*_3. For these alkenes, this transition is represented as $\pi \rightarrow \pi^*$; that is, an electron is promoted from a π (bonding) molecular orbital to a π* (antibonding) orbital. This type of excitation is depicted below for both ethylene and 1,3-butadiene. Note that as a consequence of extending the chromophore and raising the energy of the highest occupied level in butadiene, the energy gap between the HOMO and LUMO levels of ethylene is larger than that in the conjugated system. Thus, the photon required for excitation of ethylene has a higher energy (higher frequency = shorter wavelength, λ_{max} = 171 nm) than the photon absorbed by 1,3-butadiene(λ_{max} = 217 nm):

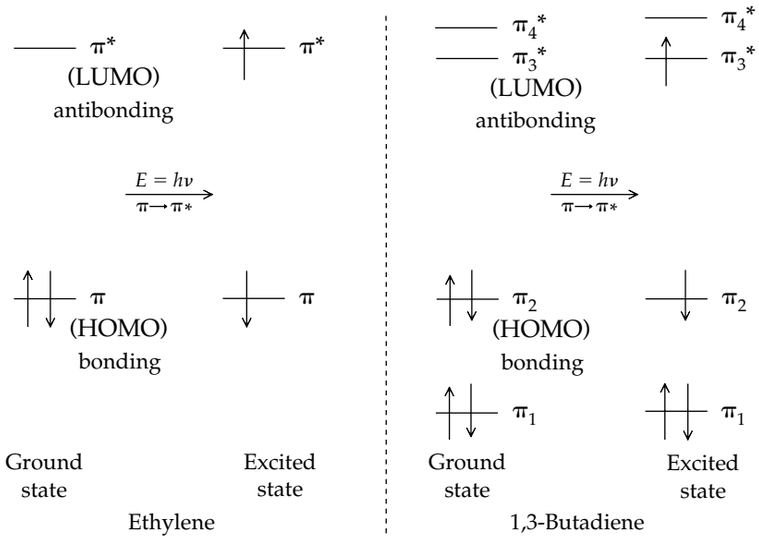

If we continue to extend the chromophore, the decrease of the energy gap between the HOMO and LUMO levels also continues. This drop in ΔE is then reflected in a drop in energy of the photon required to excite the $\pi \rightarrow \pi^*$ transition. This effect is illustrated in Table 8.28.

As the extension of the chromophore continues, the λ_{max} of the $\pi \rightarrow \pi^*$ transition will eventually shift into the visible region. At this point the substance exhibits color. Because the absorbed wavelength is coming from the blue end of the visible spectrum, these compounds will appear yellow. The color will deepen and become red as the energy of the photon required for

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Table 8.28 Absorption Maxima of Conjugated Alkene		
Name	**Structure**	**λ_{max} (nm)**
Ethylene	$CH_2{=}CH_2$	165
1,3-Butadiene	$CH_2{=}CH{-}CH{=}CH_2$	217
1,3,5-Hexatriene	$CH_2{=}CH{-}CH{=}CH{-}CH{=}CH_2$	268
1,3,5,7-Octatetraene	$CH_2{=}CH{-}CH{=}CH{-}CH{=}CH{-}CH{=}CH_2$	290

electronic excitation continues to drop. For example, tetraphenylcyclopentadienone is purple (Experiment [A3$_a$]); the dye, methyl red, is deep red (Experiment [26]); and *trans*-9-(2-phenylethenyl)anthracene is golden yellow (Experiment [19D]).

Compounds that contain a carbonyl chromophore $\rangle C{=}\ddot{O}:$ also absorb radiation in the UV region. A π electron in this unsaturated system undergoes a $\pi \rightarrow \pi^*$ transition. However, unless the carbonyl is part of a more extended chromophore, such as an α,β-unsaturated ketone system, the $\pi \rightarrow \pi^*$ transition requires a fairly high-energy photon for excitation, usually below 190 nm in the far-UV and similar to the energy required for excitation of a carbon–carbon double bond. The edge of the $\pi \rightarrow \pi^*$ absorption band may just barely be observed on instrumentation designed for near-UV studies. This partially observed absorption band is generally referred to as *end absorption.* In the case of carbonyls, however, the heteroatom also loosely holds two pairs of nonbonding electrons that are often termed *lone-pair* electrons. These nonbonding electrons reside in orbitals (n) that are higher in energy than the bonding π orbital, but lower in energy than the antibonding π^* orbital. Thus, while a transition from an n level to a π^* level is formally forbidden, in fact, weak bands are observed at λ_{max} in the near-UV that have their origin in the excitation of a lone-pair electron by an $n \rightarrow \pi^*$ transition. An energy diagram of a typical carbonyl system follows:

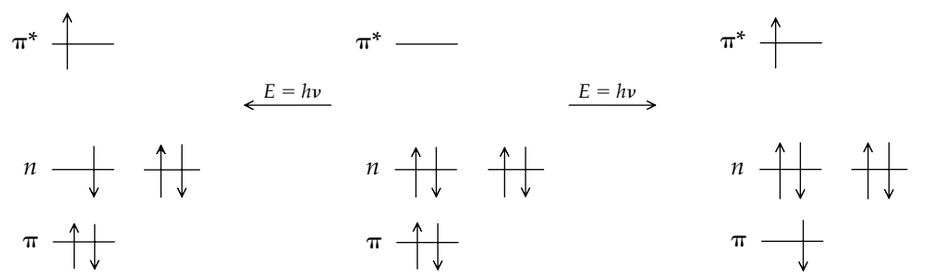

Excited state resulting from promotion of a nonbonding electron to the antibonding π^* orbital

Ground state

Excited state resulting from promotion of a π electron to the antibonding π^* orbital

Thus, those substances that contain the carbonyl chromophore absorb radiation of wavelengths that corresponds to both the $n \rightarrow \pi^*$ and the $\pi \rightarrow \pi^*$ transitions. For a simple ketone, such as acetone (CH_3COCH_3), the $\pi \rightarrow \pi^*$ transition is found in the far-UV and the $n \rightarrow \pi^*$ in the near-UV. When the carbonyl becomes part of an extended chromophore, such as in methyl vinyl ketone (3-buten-2-one), the spectra reveal that these two transitions have shifted to longer wavelengths—a bathochromic shift (see Fig. 8.42 for the

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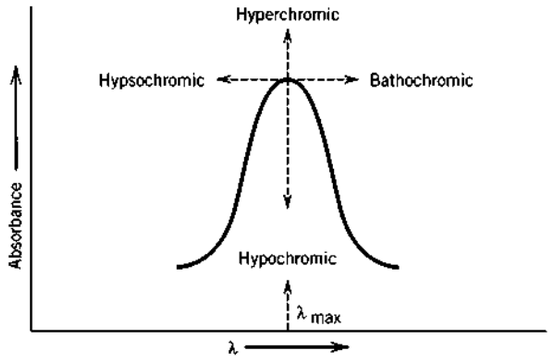

Figure 8.42 Terms describing direction of wavelengths and intensity shifts.

definition of terms used in UV–vis spectra to indicate the direction of wavelength and intensity shifts):

$n \Longrightarrow \pi^*$	λ_{max} 270 nm	ε_{max} 16	λ_{max} 324 nm	ε_{max} 24
$\pi \Longrightarrow \pi^*$	λ_{max} 187 nm	ε_{max} 900	λ_{max} 219 nm	ε_{max} 3600

Saturated systems containing heteroatoms with nonbonded electrons also exhibit weak absorption bands, often as end absorptions, which have their origin in forbidden $n \rightarrow \sigma^*$ transitions. When these heteroatomic groups are attached to chromophores, both the wavelength and the intensity of the absorption can be altered. These are often referred to as *auxochromes* and *auxochromic shifts.*

Often, model compounds containing a chromophore of interest are referred to as an aid in the interpretation of the UV–vis spectrum of a new structure. Substantial collections of data have been developed for a wide variety of chromophores as an aid to this type of correlation. A number of empirical correlations, such as the Woodward–Fieser rules, of substituent effects on λ_{max} values are available. The Woodward–Fieser rules are a set of empirical correlations derived from studies of UV–vis spectral data. Using these rules it is possible to predict with reasonable accuracy the λ_{max} for *new* systems containing various substituents on *known* chromophores. The rules are summarized in Table 8.29.

Examples of homoannular and heteroannular dienes are shown below:

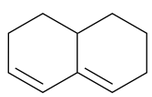

A heteroannular diene

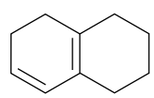

A homoannular diene

An example illustrating the use of these rules follows. Calculate the wavelength at which the following steroidal methyl sulfide will absorb:

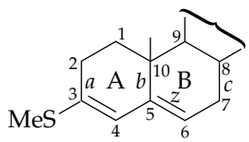

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Table 8.29 Woodward–Fieser Rules for Conjugated Dienes	
Functionality	**Increment (nm)**
Base value for homoannular diene	253
Base value for heteroannular diene	214
Add:	
For each double bond extending conjugation	+30
For double bond outside of ring (exocyclic)	+5
For alkoxy groups	+6
For *S*-alkyl groups	+30
For Cl, Br groups	+5
For dialkylamino groups	+60
For parts of rings attached to butadiene fragment	+5

The base value for the diene is 214 nm, because the system is heteroannular (if a homoannular diene were present it would take precedence over the heteroannular diene; see the following example). There are three ring residues (or alkyl substituents) attached to the chromophore. Through hyperconjugation, the π system is slightly extended by this type of substitution. The residues are labeled *a, b,* and *c.* Each of these substituents is assumed to add 5 nm to the λ_{max} of the parent heteroannular diene, for a total of 15 nm. The 5,6-double bond in the B ring marked *z* is exocyclic to the A ring, so empirically we add an additional 5 nm. Finally, for the thiomethyl substituent at the 3 position we add 30 nm. The total is 214 + 15 + 5 + 30 = 264 nm.

Thus we have

Predicted value λ_{max} (calcd) = 264 nm
Observed value λ_{max} (obsd) = 268 nm (ε = 22,600)

As another example, consider ergosta-3,5,7,9-tetraene-3-acetate (**I**):

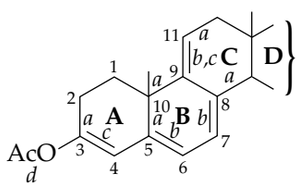

I

Prediction of λ_{max} for a homoannular diene

Parent homoannular diene in ring **B**		253 nm
Increments for		
Double bond extending conjugation	*c* [2 × 30]	60
Alkyl substituent or ring residue	*a* [5 × 5]	25
Exocyclic double bond	*b* [3 × 5]	15
Polar substituents	*d* [0]	0
	λ_{calcd}	353

Predicted value λ_{max} (calcd) = 353 nm
Observed value λ_{max} (obsd) = 355 nm (ε = 19,700)

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Table 8.30 **Conjugated Carbonyl Systems**

α,β-Unsaturated Functionality	Base Value (nm)
Acyclic or six-membered or higher cyclic ketone	215
Five-membered ring ketone	202
Aldehydes	210
Carboxylic acids and esters	195
	Increment (nm)
Extended conjugation	+30
Homoannular diene	+39
Exocyclic double bond	+5

	Substituent Increment (nm)		
Substituent	α	β	δ
Alkyl	+10	+12	+18 (γ and higher)
Hydroxyl	+35	+30	+50
Alkoxy	+35	+30	+31 (γ + 17)
Acetoxy	+6	+6	+6
Dialkylamino		+95	
Chloro	+15	+12	
Bromo	+25	+30	
Alkylthio		+85	

Solvent	Solvent Increment (nm)
Water	−8
Ethanol	0
Methanol	0
Chloroform	+1
Dioxane	+5
Ether	+7
Hexane	+11
Cyclohexane	+11

There are additional rules for carbonyl-containing compounds, such as ketones, aldehydes, carboxylic acids, and so on, and for aromatic compounds. Table 8.30 lists the parameters for conjugated carbonyl systems. Note that in contrast to the conjugated diene compounds, in which we are observing $\pi \rightarrow \pi^*$ transitions, the $n \rightarrow \pi^*$ transitions of the carbonyl λ_{max} chromophore are often solvent dependent. Thus, solvent effects will have to be considered when predicting λ_{max} values in these systems.

An example of λ_{max} (ethanol) calculation for a carbonyl system is presented here:

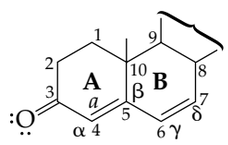

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The base value for the α,β-unsaturated six-membered ring ketone system is 215 nm. Extended conjugation adds an additional 30 nm. The presence of an exocyclic double bond, marked *a*, extends the λ_{max} another +5 nm. There is asubstituent on the β-carbon atom (+12 nm) and on the δ-carbon atom (+18 nm). There is no solvent effect because the spectrum was obtained in ethanol (0 shift). The total is 215 + 30 + 5 + 12 + 18 = 280 nm:

Predicted value	λ_{lmax} (calcd) = 280 nm
Observed value	λ_{lmax} (obsd) = 284 nm

The Woodward–Fieser rules work well for systems with four or fewer double bonds. For more extensively conjugated systems, λ_{max} values are more accurately predicted using the Fieser–Kuhn equation:

$$\text{Wavelength} = 114 + 5\,M + n(48.0 - 1.7n) - 16.5\,R_{endo} - 10R_{exo}$$

where

n = number of conjugated double bonds
M = number of alkyl substituents in the conjugated system
R_{endo} = number of rings with endocyclic double bonds in the system
R_{exo} = number of rings with exocyclic double bonds in the system

Sample calculation: Find the UV λ_{max} of β-carotene:

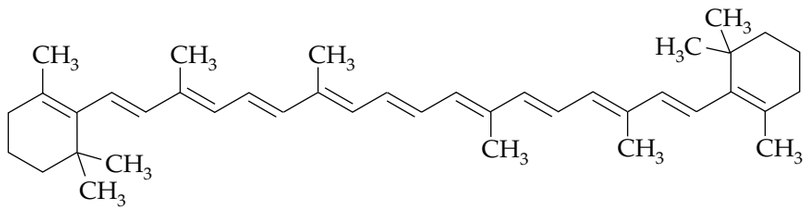

β-Carotene

In the structure there are 11 conjugated double bonds, $n = 11$. There are 6 alkyl groups and 4 ring residues on the conjugated system, $M = 10$. Both rings have an endocyclic double bond, $R_{endo} = 2$ Neither ring has any exocyclic double bonds, therefore $R_{exo} = 0$. Substituting in the equation gives

$$\text{Wavelength} = 114 + 5(10) + 11[48 - 1.7(11)] - 16.5(2) - 10(0)$$
$$= 114 + 50 + 322.3 - 33 - 0 = 453 \text{ nm}$$

Predicted value	λ_{lmax} (calcd) = 453 nm
Observed value	λ_{max} (obsd) = 455 nm

Two examples of this correlation scheme (see Table 8.31) are

1. 6-Methoxytetralone

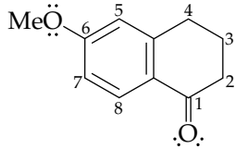

Predicted λ_{max} is calculated by taking

Parent value, 246 nm + one *o*-ring residue, 3 + one *p*-OMe, 25 = 274 nm

Predicted value	λ_{max} (calcd) = 274 nm
Observed value	λ_{max} (obsd) = 276 nm (ε = 16,500)

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Table 8.31 The Benzoyl Chromophore			
Parent Chromophore C_6H_5—CO—R			
Function			**Wavelength (nm)**
R = alkyl or ring residue			246
R = H			250
R = OH, *O*-alkyl			230
	Substituent Increment (nm)		
Substituent	*o*-	*m*-	*p*-
Alkyl or ring residue	3	3	10
—OH, —OCH_3, —*O*-alkyl	7	7	25
—O^- (*p*-sensitive to steric effects)	11	20	78
—Cl	0	0	10
—Br	2	2	15
—NH_2	13	13	58
—NHAc	20	20	45
—$NHCH_3$			73
—$N(CH_3)_2$	20	20	85
Note. Spectra obtained in alcohol solvents.			

2. 3-Carboethoxy-4-methyl-5-chloro-8-hydroxytetralone

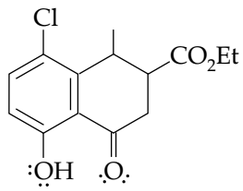

Parent value, 246 nm + one *o*-ring residue, 3 + one *o*-OH, 7 + 0 *m*-Cl = 256 nm

Predicted value λ_{max} (calcd) = 256 nm
Observed value λ_{max} (obsd) = 257 nm (ε = 8000)

In summary, UV–vis spectra can make substantial contributions to understanding the molecular structure of organic substances that possess *chromophores:*

1. Interpretation of ultraviolet–visible spectra often can be a powerful approach for identifying the molecular structure of that section of a new substance that contains the chromophore.

2. The λ_{max} increases within a series of compounds that contain a common chromophore that is lengthened (increased conjugation) over the series. The intensity of the absorption (ε_{max}) also generally becomes greater as conjugation increases, but can be very sensitive to steric effects (see Experiment [6]).

3. The λ_{max} is sensitive to hyperconjugation by alkyl substituents, conformational changes that restrict π-system overlap, configurational, or geometric isomerization in which π systems are perturbed, and structural changes, such as the isomerization of a double bond from an *exocyclic* to an *endocyclic* position and changes in ring size.

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Table 8.32 **Absorption Maxima of Several Unsaturated Molecules**

Compound	Structure	λ_{max} (nm)	ε_{max}
Ethylene	$CH_2{=}CH_2$	171	15,530
1,3-Butadiene	$CH_2{=}CH{-}CH{=}CH_2$	217	21,000
Cyclopentadiene		239	3,400
1-Octene	$CH_3(CH_2)_5CH{=}CH_2$	177	12,600
trans-Stilbene	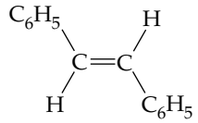	295	27,000
cis-Stilbene	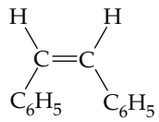	280	13,500
Toluene	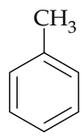	189 208 262	55,000 7,900 260
4-Nitrophenol	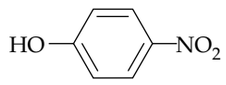	320	9,000
3-Penten-2-one	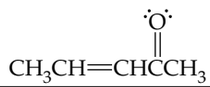	220 311	13,000 35

4. In many instances, accurate prediction of the λ_{max} of a new molecular system can be made based on empirical correlations of the parent chromophore giving rise to the absorption.

Table 8.32 lists the λ_{max} values of a number of common organic molecules.

INSTRUMENTATION

The acquisition of UV–vis absorption spectra for use in the elucidation of organic molecular structure is now carried out with instrumentation that is typically an automatic-recording photoelectric spectrophotometer. The optical components of one of the classic spectrophotometers is given in Figure 8.43. This system is typical of a high-quality double-beam double-monochromator instrument. The instrument consists of a number of components: the radiation source, monochromator, sample compartment, detector, amplifier, and recorder.

The Source of Radiation

Radiant energy may be generated by either a deuterium discharge lamp or a tungsten– halogen lamp depending on the spectral region to be observed. Deuterium is generally preferred over hydrogen since the intense radiating ball of plasma is slightly larger in the case of deuterium, and therefore source

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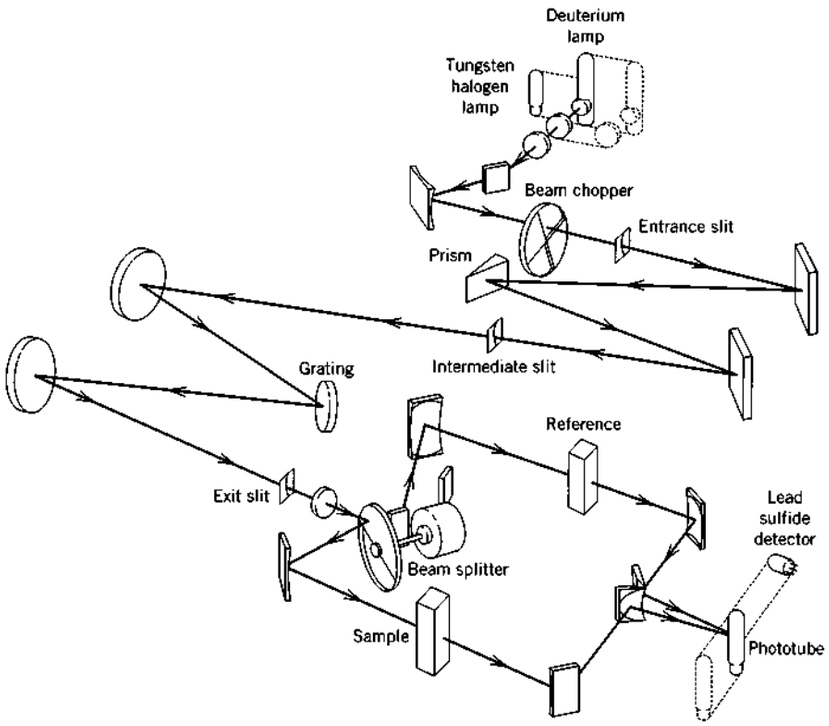

Figure 8.43 Schematic optical diagram of a double beam-in-time spectrophotometer with double monochromation (Cary Model 17D). (Courtesy of Varian Associates, Inc.)

brightness is enhanced by a factor of about 4. Below 360 nm, deuterium gas emits an intense continuum band that covers a major portion of the UV region. With special windows the short wavelength cutoff can be extended down to about 160 nm well out into the vacuum-UV. Emission line spectra limit the long wavelength use of these lamps to about 380 nm. The lamps of choice for the region above 350 nm (the visible) are incandescent filament lamps, because they emit a broad band of radiation from 350 nm on the short wavelength end all the way to about 2.5 μm (the near-IR) on the long wavelength side. Most of the radiation emitted falls outside the visible, peaking at about 1 μm in the near-IR. Nevertheless, tungsten lamps are *the* choice for measurements in the visible region, because they are extremely stable light sources.

Thus, radiation sources must possess two basic characteristics: (1) they must emit a sufficient level of radiant energy over the region to be studied so that the instrument detection system can function, and (2) they must maintain constant power during the measurement period. Source power fluctuations can result in spectral distortion.

The Monochromator

As the name implies, a monochromator (making a single color or hue) functions to isolate a single frequency from the source band of radiation. In practice we settle for isolating a small collection of overlapping frequencies surrounding the monochrome radiation we wish to observe. Thus, the monochromator section of the instrument takes all the source radiation in at one end and releases a very narrow set of bands of radiation at the other end. This function is accomplished, as shown in Figure 8.43, by focusing the entering radiation on

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an entrance slit that forms a narrow image of the source. After passing through the entrance slit, the spreading radiation is collimated by being reflected off a parabolic mirror, and is converted into parallel light rays (just as in a search light). The collimated radiation is then directed to the dispersing agent, which is usually a quartz prism (quartz is transparent to UV, glass is not) or diffraction grating. The dispersing device spreads the different wavelengths of collimated light out in space. After emerging from the prism the dispersed radiation is redirected to either the same or a new collimator mirror and refocused as an image of the source on the exit slit of the monochromator. The exit slit has only a small fraction of the original radiation focused on it, and allows it to pass through in the image of the source. The remaining frequencies lie at different angles on either side of the exit slit. By mechanically turning the prism or grating, and thus changing the angle of the dispersing device with respect to the exit slit, all of the narrowly dispersed bands of radiation can be passed out of the monochromator in sequential fashion.

Instruments that are designed to reduce unwanted radiation to an absolute minimum will place two monochromators in tandem with an intermediate slit connecting the dispersing systems. In the case illustrated in Figure 8.43 the first monochromator uses a prism, while the second uses a grating. The two monochromators, however, must be in perfect synchronization or no light at all will be transmitted.

Sample Compartment

After leaving the monochromator the radiation is directed to the sample compartment by a rotating sector mirror, where it is alternately focused on the substance to be examined (which is contained in a cell with quartz windows) and a reference cell (which holds the pure solvent used to dissolve the sample). The system now has two beams, hence the name *double-beam spectrophotometer.* After passing through the sample where the absorption of radiation may occur, the beams are recombined.

The sampling position could be placed either before or after the monochromator. In infrared instruments (such as the PE Model 710B, Fig. 8.3*a*) it was generally found before the monochromator until the introduction of interferometers. In UV systems, the sampling area is most often placed after the monochromator, and for good reasons. If the sample were placed before the monochromator, it would be exposed to the entire band of high-energy UV radiation being emitted by the source over the entire sampling period. By positioning the sample after the monochromator, at any one time the sample sees only the very small fraction of the dispersed radiation passed by the exit slit. Thus, sample stability is greatly protected by this arrangement. Remember that near-UV radiation carries photons with energies that approach those of the bond energies of organic molecules.

The Detector

The recombined beams are then focused on the detector. Detectors function as transducers because they convert electromagnetic radiation into electrical current. There are a number of radiation-sensitive transducers available as detectors for these instruments. One is the photomultiplier tube. These detectors operate with photocathodes that emit electrons in direct proportion to the number of photons striking the photosensitive surface and possess very large

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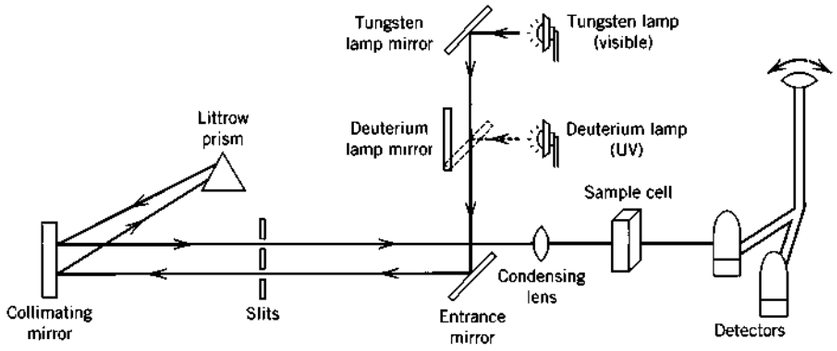

Figure 8.44 UV–visible single-beam spectrometer.

internal amplification. Thus, they operate at low power levels. One particular advantage of the photomultiplier is that you can adjust their sensitivity over a wide range simply by adjusting the supply voltage.

The Electronics: The Amplifier and Recorder

In double-beam instruments, the two signals generated by the sample and reference beams (each referenced against a dark current) in the detector are amplified and the ratio of the sample signal to the reference signal is plotted on a recorder. The simplest of the absorption spectrometers are the single-beam instruments (see Fig. 8.44). These spectrometers are generally employed for problems involving simple one-component analyses. The photometric accuracy of scanned spectra should not be of paramount importance with these systems. Single-beam spectrometers require extremely stable sources and detectors.

SAMPLE PREPARATION

Ultraviolet spectra are usually obtained on samples in solution using quartz cells. Quartz is used because it is transparent to both UV and visible light. For spectra restricted to the visible region, Pyrex cells are satisfactory (and a good deal less expensive), but because Pyrex absorbs UV radiation, these cells cannot be employed for measurements in this region.

Solution cells usually have a horizontal cross section of 1 cm^2 and require about 3 mL of sample solution. Cells must be absolutely clean, and it is advisable to rinse the cell several times with the solvent used to dissolve the sample. A background spectrum of the solvent-filled cell (*without* a reference sample) can easily be obtained at this time and used as a check against contamination of either the cell or the solvent or both.

Because the intensities of electronic transitions vary over a very wide range, the preparation of samples for UV–vis spectra determination is highly concentration dependent. Intense absorption can result from the high molecular extinction coefficients found in many organic chromophores. The sampling of these materials requires very dilute solutions (on the order of 10^{-6}–10^{-4} M). These solutions can be conveniently obtained by the technique of *serial dilution.* In this method a sample of the material to be analyzed is accurately weighed, dissolved in the chosen solvent, and

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Table 8.33 **Solvents Used in the Near-UV**

Solvent	Cutoff Wavelength (nm)
Acetonitrile	190
Chloroform	245
(toxic, substitute CH_2Cl_2)	235
Cyclohexane	205
1,4-Dioxane	215
(toxic, substitute EtOEt)	218
95% Ethanol	205
n-Hexane	195
Methanol	205
Isooctane	195
Water	190

Note. Since these solvents have no color, they are transparent in the visible.

diluted to volume in a volumetric flask. Sample weights of 4–5 mg in 10-mL volumetric flasks are typical. An aliquot is then taken from this original solution, transferred to a second volumetric flask, and diluted as before. This sequence is repeated until the desired concentration is obtained.

Numerous choices of solvent are available (a list is given in Table 8.33) and most of them are available in "spectral grade." The most commonly used solvents are water, 95% ethanol, methanol, and cyclohexane.

Criteria for Choosing a Solvent

- The most important factor is solubility of the sample. UV–vis spectra can be very intense, so even low solubility may be quite acceptable in sample preparation.
- The wavelength cutoff for the solvent may be important if the sample absorbs below about 250 nm.
- Sample–solvent molecular interactions must be considered. An example of these effects would be hydrogen bonding of protic solvents with carbonyl systems. Hydrocarbon chromophores are less influenced by solvent character than are the more polar chromophores.

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MASS SPECTROMETRY*

In comparison with other forms of spectroscopy, such as NMR, IR, or UV–vis, mass spectrometry is unique in terms of how we generate and interpret the spectrum. Instead of monitoring the absorption of electromagnetic radiation in terms of frequency or wavelength, a mass spectrum can be thought of as a snapshot of a rather unconventional organic reaction involving one energetic reactant that decomposes to give a variety of reaction products. By characterizing the composition of this "reaction mixture" we are able to learn the identity of the starting reactant.

The reaction gets started when a molecule in the gas phase is converted to a radical cation by an energetic collision with an electron, as shown below for N_2O:

$$N_2O_{(g)} + e^- \longrightarrow N_2O^{+\cdot} + 2e^-$$

The fact that we have formed a positive ion (cation) with an unpaired electron (radical) becomes important for understanding the decomposition reactions. The process of forming the radical cation yields a collection of energized *molecular ions* that contain a range of internal energies. The molecular ion is produced in a low-pressure environment where it is unable to bump into other molecules. Fragmentation (bond breaking) results in the formation of charged and neutral products. Ideally, intramolecular rearrangements, which could complicate determination of the molecules original structure, do not occur. Depending on characteristics of the molecule and the amount of energy deposited, a variety of fragmentation reactions can take place. For example, the molecular ion ($N_2O^{+\cdot}$) may fragment to give the following products through one- or two-step reactions:

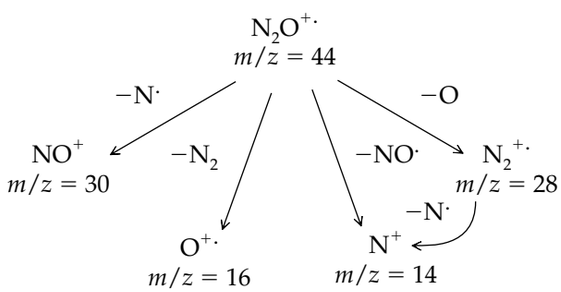

*This section has been written by Elizabeth A. Stemmler, Professor of Chemistry, Bowdoin College.

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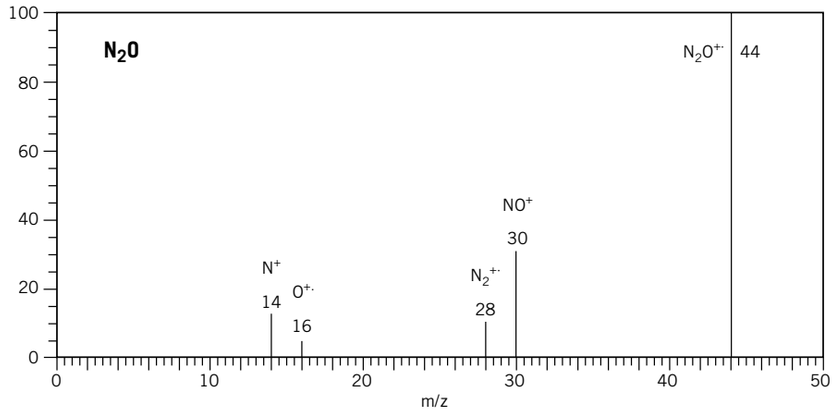

Figure 8.45 Electron ionization mass spectrum of nitrous oxide, N_2O.

Mass spectrometry derives its name from its ability to distinguish the molecular ion and the different charged reaction products based on the ratio of the ion mass to its charge (*m/z* ratio). In most cases, the charge, *z*, is equal to 1 and we can easily tell the difference between the molecular ion (*m/z* = 44) and products, such as N_2^+ (*m/z* 28). In addition, a mass spectrometer can be used to determine the relative amounts of molecular ions and fragment ions present after the reaction has had a little (very little!) time to proceed. A mass spectrum, typically shown in a bar-graph format, is a display of the relative number of each type of ion plotted as a function of the *m/z* ratio (see Fig. 8.45). Instead of reporting the actual number of each type of ion, we normalize the data and give the most abundant ion a value of 100%. Note that only charged species are detected by a mass spectrometer. The neutral products are not observed and their identity must be inferred.

Mass spectrometry is useful to organic chemists because of the information it provides about molecular structure. For example, if the molecular ion is present, that peak can be used to determine the molecular weight (MW) of the neutral molecule. With precise measurement of the *m/z* ratio (to ± 0.0001,for example), the elemental formula of the molecular ion can be determined. For example, N_2O and CO_2 both have a molecular weight of 44; however, measurement of their exact masses (44.0011 and 43.9898, respectively) can be used to assign their elemental formula. Mass spectrometry was used to originally determine the exact mass of each element (see Table 8.34), and these exact masses, *not* the atomic weights, are used to calculate mass.

Even when precise mass measurements are not available, the products in the mass spectrum may provide enough information to determine the structure of the neutral molecule. Interpretation of a mass spectrum involves working backward from the observed charged fragments to a proposed molecular structure. For example, CO_2 or N_2O (same MW) could be distinguished by an examination of the mass spectrum. The fragment ions at *m/z* 14 and 30 in Figure 8.45 clearly eliminate CO_2 as a possible structure. There are no combinations of carbon (mass = 12) and oxygen (mass = 16) that could produce these ions. In addition, the mass spectrum allows us to distinguish between the isomers NNO and NON. What would the mass spectrum of NON show? We would expect to see only a peak at *m/z* 30 (NO^+) and no signal at *m/z* 28 (N_2^+). The mass spectrum would thus support your chemical intuition that NON is an unlikely and unstable molecular structure.

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Table 8.34 Exact Masses and the Atomic Weights for Isotopes of Some Common Elements

Element	Nuclide	Mass	Atomic Weight[a]
Hydrogen	^{1}H	1.0078	1.0079
	D(^{2}H)	2.0141	
Carbon	^{12}C	12.00000 (std)	12.011
	^{13}C	13.0034	
Nitrogen	^{14}N	14.0031	14.0067
	^{15}N	15.0001	
Oxygen	^{16}O	15.9949	15.9994
	^{17}O	16.9991	
	^{18}O	17.9992	
Fluorine	^{19}F	18.9984	18.9984
Silicon	^{28}Si	27.9769	28.0855
	^{29}Si	28.9765	
	^{30}Si	29.9738	
Phosphorus	^{31}P	30.9738	30.9738
Sulfur	^{32}S	31.9721	32.066
	^{33}S	32.9715	
	^{34}S	33.9679	
Chlorine	^{35}Cl	34.9689	35.4527
	$^{37}C1$	36.9659	
Bromine	^{79}Br	78.9183	79.904
	^{81}Br	80.9163	
Iodine	^{127}I	126.9045	126.904

[a]Average mass of the naturally occurring isotopes of the element; *not* used for mass calculations in mass spectrometry.

As you will see below, mass spectral interpretation is not always as straightforward as the case given above. Like the outcome of an organic reaction, a mass spectrum will reflect the outcome of competing sequential and simultaneous reaction pathways. For some molecules, very little fragmentation will take place and only the molecular ion is observed. For other less stable molecules, we may have complete conversion of the molecular ion to products, although, because of the high energy required for their formation, we will rarely see complete fragmentation down to products at the atomic level. The interpretation of a mass spectrum requires developing an understanding of important, characteristic reaction pathways and an appreciation of factors influencing ion stability. In many ways, the interpretation of mass spectra provides a place to apply principles of organic chemistry to a unique kind of chemical reaction.

INSTRUMENTATION

All mass spectrometric instruments contain regions where ionization, mass analysis, and ion detection take place. Mass spectrometry takes place at low pressure; all of the mass spectrometric components are contained in a vacuum

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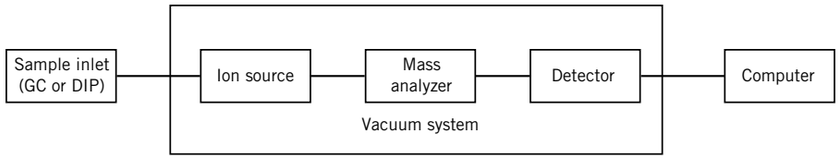

Figure 8.46 Block diagram of components of a mass spectrometer.

system at pressures of 10^{-7} to 10^{-5} torr. Because the instrument must be sealed from the atmosphere to maintain the low pressure, and because samples must be converted to the gas phase prior to ionization, all mass spectrometers have a region devoted to sample introduction. In this region the sample—in the form of a solid, liquid, or gas—is transferred to the low pressure of the mass spectrometer, while preventing the introduction of air. A block diagram of a basic mass spectrometer is shown in Figure 8.46. Ions are generated and fragment in the ion source; the molecular ion and fragments are separated, based upon *m/z* ratios, in the mass analyzer; and the ion signals are converted by the detector into a signal that may be input to a computer.

Ion Source

The ion source is the region where ions are generated. Mass spectrometrists have many ways of creating ions from different types of samples, including biological materials or the surface of a particle. In our discussions, we will focus only on the most common ionization method, electron ionization (EI). In an EI ion source (Fig. 8.47), we send current through a wire, called a filament. As the filament gets hot, electrons are emitted from the surface. The electrons are produced in an electric field, which results in electron acceleration through

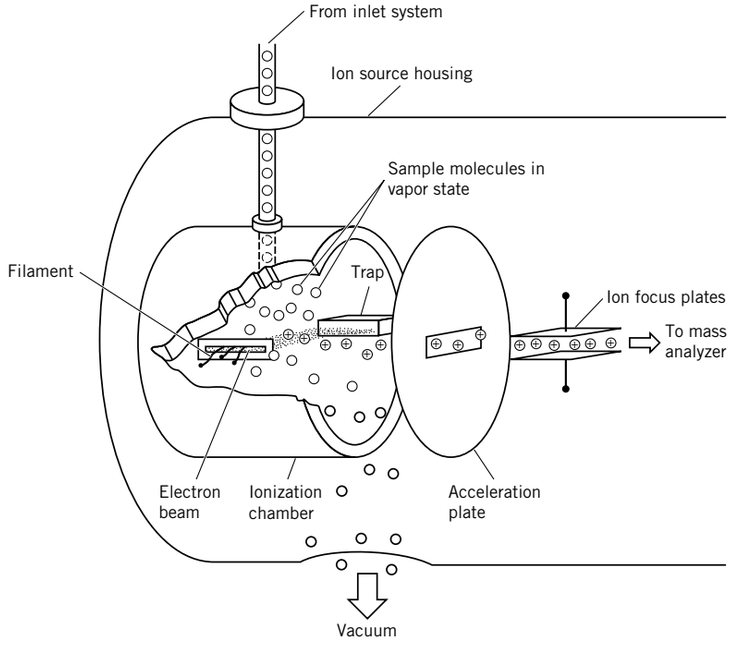

Figure 8.47 Schematic diagram of an electron ionization source. (From Watson, J.T. *Introduction to Mass Spectrometry,* 3rd ed.; Lippincott-Raven Publishers: Philadelphia, 1997, p. 140.)

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the ion source region where the sample vapor is found. If you work with an electron energy that is too low (below the ionization potential for the molecule), no ions will be produced. As the electron energy increases, the molecular ion ($M^{+\cdot}$) will appear. With further increases in electron energy, fragment ions are observed. Formation of doubly charged ions ($M^{2+\cdot}$) occurs, but the ion intensities are very low:

$$M + e^-(70\ eV) \longrightarrow \begin{cases} M^{+\cdot} + 2e^- \\ M^{2+} + 3e^- \quad \text{(rare)} \\ M^{-\cdot} \quad \text{(not observed)} \end{cases}$$

Mass spectra, by convention, are measured with 70-eV electrons. At this energy, the ion intensity is high and the distribution of products remains relatively constant with small changes in electron energy. Formation of negative molecular ions with 70-eV electrons does not occur.

Another important role for the ion source is directing the ions toward the mass analyzer. The ions are pushed and pulled as they pass through one or more metal plates that have a hole in the center for ion transmission. These plates accelerate the ions and keep them directed at the mass analyzer. Depending on the mass analyzer in use, the ions are accelerated toward the analyzer with high or low energy.

Mass Analyzer

Ion formation and fragmentation in the source is followed by mass analysis. Mass analyzers are used to separate ions based on their mass-to-charge ratios. Organic chemists commonly use two types of mass analyzers: magnetic sector instruments (low- and high-resolution) and quadrupole instruments. Magnetic sectors separate ions based on dispersion of the ions into beams with different *m/z* ratios; quadrupoles are mass filtering devices.

In a magnetic sector instrument, ions are accelerated out of the ion source into a magnetic field with high (kilovolt) kinetic energies. The magnet field, applied perpendicular to the path of the ions, exerts a force that causes the ions to follow a curved path through the magnet (Fig. 8.48). The extent to which the path is bent depends on the mass-to-charge ratio (more specifically, the momentum) of the ions. Light ions are bent more than heavier ions. If the path that the ions must travel is fixed, ions that are too light or too heavy will run into the walls of the mass analyzer, where they are neutralized, and will then be pumped away by the vacuum system. Only the ions with the correct radius (correct *m/z* ratio) will make it to the detector. To measure a complete mass spectrum, the magnetic field strength is varied to bring ions of different *m/z* ratio to focus on the detector.

High-resolution magnetic sector instruments incorporate an additional energy analyzer prior to mass analysis by the magnetic sector. This more precisely defines the kinetic energies of ions entering the magnetic sector, which improves the mass resolution. High-resolution instruments require more expertise to operate and are less common because of their expense, but they can provide the precise and accurate mass measurements needed to determine elemental composition.

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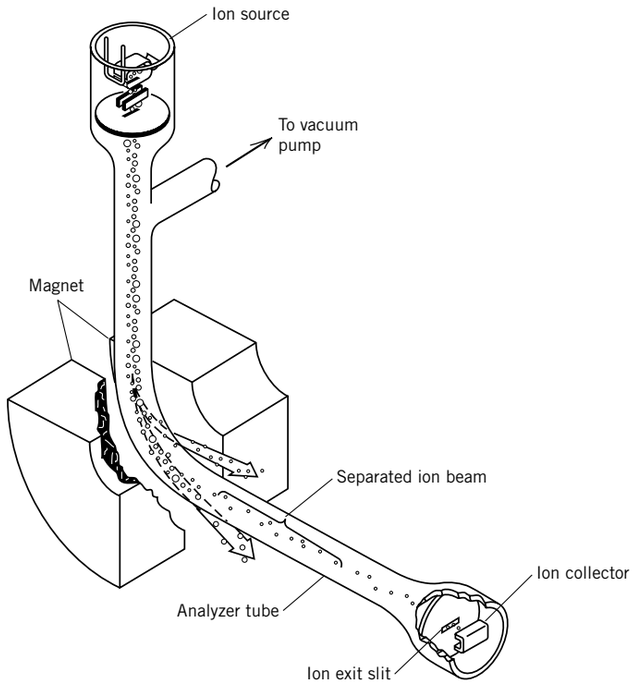

Figure 8.48 Schematic diagram of a magnetic sector mass analyzer. (From McLafferty, F.W.; Turevek, F. *Interpretation of Mass Spectra,* 4th ed.; University Science Books: Sausalito, CA, 1993, p. 8.)

A quadrupole is composed of a set of four rods to which (electric) potentials are applied (Fig. 8.49). To allow ions of a particular *m/z* ratio through the rods, a constant positive potential is applied to two opposing rods (the x-rods), while the remaining two rods experience a constant negative potential (the y-rods). In addition, each set of rods experiences a time-varying potential that causes the rod potentials to vary between positive and negative potentials, with the signals 180° out-of-phase. When the x-rods are positive, the y-rods

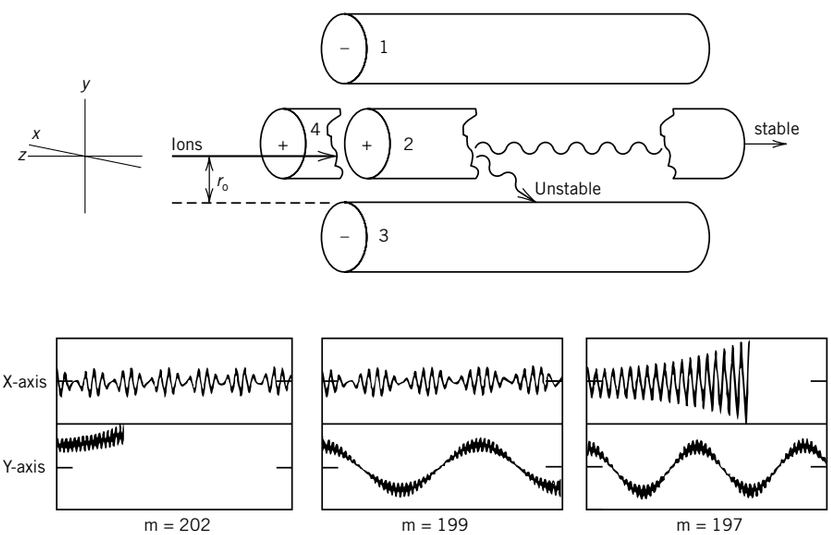

Figure 8.49 Schematic diagram of a quadrupole mass analyzer. *X* and *Y* axis trajectories for m/z 202, 199, and 197. (From Steel, C.; Henchman, M. *J. Chem. Educ.* **1998,** *75,* 1049–1054.)

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are negative. Mass filtering occurs when a group of ions enters the analyzer. Ions that have *m/z* ratios that are too low or too high will experience unstable trajectories through the rods and will strike a rod, become neutralized, and be pumped out of the system. Only ions with an appropriate *m/z* ratio will have a stable trajectory and will make it through the rods to the detector. Figure 8.49 shows the trajectories of three ions with respect to the x- and y-rods. Only the ion with $m/z = 199$ makes it through the quadrupole. To change the *m/z* ratio of the ions that are transmitted, the magnitude of the constant and time-varying potentials are changed. Mass spectrometers that fit on a laboratory benchtop have a mass range of $m/z = 10$ to 650. With the quadrupole mass analyzer a mass spectrum can be measured rapidly (roughly 1 scan per second), which is important when capillary GC columns are used for sample introduction.

Detector

Ions can be detected directly through the current produced when they strike a plate; however, we usually make this signal larger through the use of electron multiplier detectors.

Tuning the Mass Spectrometer

Before the mass spectrometer can be used to collect mass spectra, the instrument must be tuned and calibrated. The tuning procedure involves setting voltages associated with the ion source, lenses, and detector (to optimize sensitivity), and selecting values for potentials applied to the quadrupole (to set the instrument resolution). These tasks are accomplished while a calibration standard is continuously added to the instrument. A common calibration standard is perfluorotributylamine (PFTBA), $(CF_3CF_2CF_2CF_2)_3N$. Usually ions at *m/z* 69, 219, and 502 are monitored (Fig. 8.50).

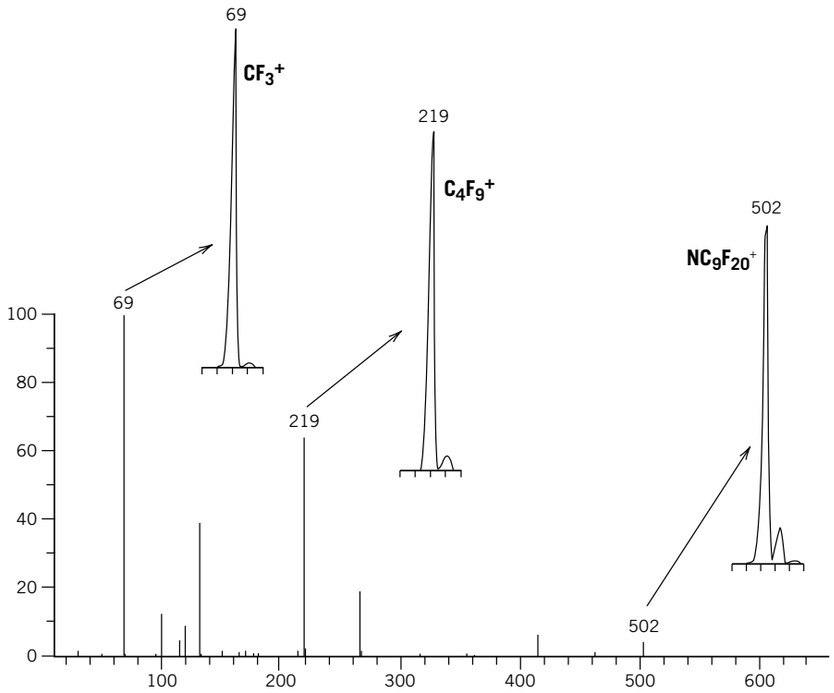

Figure 8.50 Electron ionization mass spectrum of perfluorotributylamine (PFTBA). Inserts show the peak profiles for *m/z* 69, 219, and 502.

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Sample Introduction

Samples analyzed by EI mass spectrometry must be converted to gas phase. For pure gases or volatile liquids the samples may be introduced directly through a small orifice that allows an appropriate amount of material into the vacuum chamber. A small amount of a solid sample can be placed in a melting point capillary tube and inserted into the mass spectrometer at the end of a metal rod, called a *direct insertion probe* (DIP). The temperature at the tip of the probe can be varied to promote sublimation of the sample. Another common method of sample introduction is gas chromatography, which is the ideal choice for samples that are impure.

Gas Chromatography/Mass Spectrometry (GC/MS)

While the goal of a synthetic organic reaction is the production of one pure product in high yield, organic reactions often produce a mixture of reaction products. Chromatographic separation of those products is a useful complement to the mass spectral analysis. The components of the mixture elute from the chromatographic column, ideally, as pure peaks. The mass spectrometer, which is scanning rapidly, is then able to collect a few spectra for each eluting peak. Both the chromatographic retention time and the mass spectrum can be used to help identify components of the mixture. Because the compounds are detected with little bias for one type of compound over another, GC/MS has provided organic chemists with a powerful tool to characterize reaction mixtures and assess product purity.

Sensitivity is another distinguishing feature of mass spectrometry. This sensitivity has allowed mass spectrometers to act as detectors for capillary columns, which can separate mixture containing hundreds of compounds, when less than a nanogram(10^{-9} g) of each compound is injected.

Capillary Columns

Most GC/MS instruments use capillary columns for chromatographic separation. Capillary columns are very long (15- to 30-m), open tubes of fused silica that are coated with a thin coating of the stationary phase (Fig. 8.51). A carrier gas, typically helium, is used as the mobile phase. Capillary column diameters are commonly in the range of 0.25 to 0.53 mm, and the coating of the stationary phase is in the range of 0.25 to 1 μm Thicker coatings are used for the separation of low-boiling compounds.

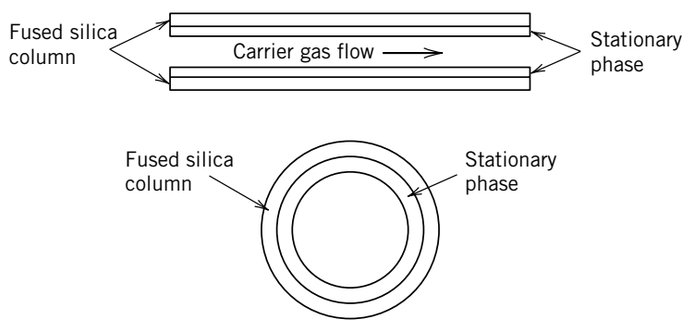

Figure 8.51 Longitudinal and radial cross sections of a capillary column.

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Chromatographic resolution increases as a function of the square root of the column length, and the extraordinary length of capillary columns means that most simple mixtures are easily resolved on just a few types of stationary phases. One common nonpolar stationary phase is poly(dimethylsiloxane) (R = CH_3) which can be made slightly more polar by the incorporation of phenyl groups (typically 5% phenyl) in place of methyl groups:

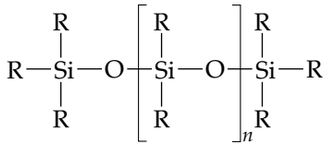

These two stationary phases interact with solutes primarily through dispersion interactions, and compounds elute as a function of boiling point. More polar stationary phases are also available. Because capillary columns are used to separate compounds with a wide range of boiling points, we often make use of a technique called *temperature programming*. This techniques allows you to start with a low oven temperature, to optimize the elution of low boiling components, and then increase the oven temperature at a controlled rate, to decrease stationary phase interactions for high-boiling compounds. The increase in temperature decreases retention times and produces narrower peaks for compounds that would otherwise require a long time to elute as a very broad peak.

While samples may be directly injected onto a packed column, the small diameter of the capillary column presents a problem. In addition, it is easy to overload the capillary column with sample (Table 8.35). Two techniques for getting the sample into the column are split and split/splitless injection.

Split Injection

In the split injector the sample is injected into the heated injection port and the evaporated sample is mixed with the carrier gas. The sample/carrier gas mixture is then split between the column and a vent, and a fraction of the sample (determined from the column and vent flow) is introduced to the column (Fig. 8.52*a*). This technique is used to introduce concentrated samples.

Split/Splitless Injection

Splitless injections are used to introduce dilute solutions. The sample is injected into the heated injection port, which is in the "purge off" mode. In this

Table 8.35 **Sample Capacity as a Function of Column Diameter and Stationary Phase Thickness**

Column Diameter (mm)	Stationary Phase Thickness (μm)	Approximate Capacity (ng/component)
0.25	0.10 (thin)	25
	0.25 (most common)	80
	1.0 (thick)	250
0.53	0.10 (thin)	53
	1.0 (most common)	530
	5.0 (thick)	2600

Source: Alltech Capillary Instruction Manual, Bulletin No. 242; Alltech Associates, Inc.: Deerfield, IL, 1991, p. 9.

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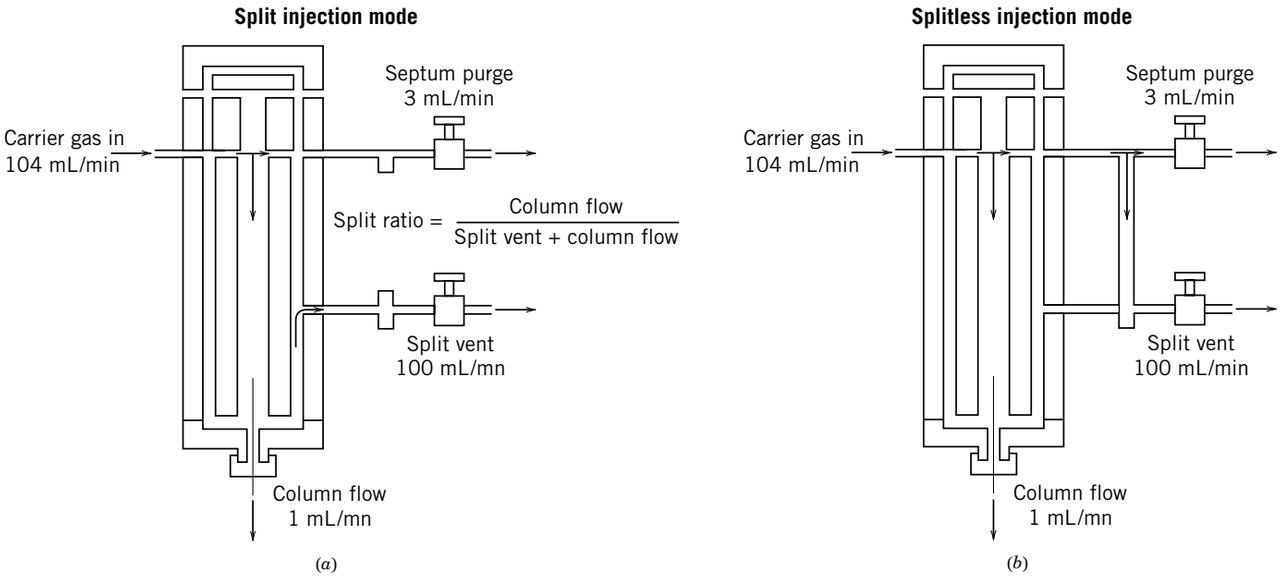

Figure 8.52 Schematic diagram showing the operation of a split/splitless injection port.

mode, carrier gas flows through the injector directly to the column (Fig. 8.52*b*). This flow rate is very low (0.5–3 mL/min). Of critical importance to splitless injection is the "solvent effect." The oven temperature is maintained below the solvent boiling point, and the vaporized solvent condenses in the column inlet. This condensed solvent acts like a thick layer of stationary phase and traps sample components. After this concentration period (typically 1 min), the injector is changed to the "purge on" mode. This purge sweeps excess solvent (and other volatile components) out of the injector. Purging too early risks venting volatile components, while purging too late increases interference from the solvent tail.

FEATURES OF THE MASS SPECTRUM

A low-resolution mass spectrum can provide many pieces of information that help an organic chemist determine the structure of a molecule. One of the most useful pieces of information is the compound's nominal molecular weight, MW, as determined by identification of the molecular ion, $M^{+\cdot}$. In addition, by careful examination of the region around the molecular ion for the presence of isotopes, we can learn more about the elemental formula for the molecule. The mass spectrum also reveals information about the molecular structure through the appearance of groups of ions characteristic of certain compound types. With more experience and an understanding of mass spectral fragmentation pathways, a molecular structure can be proposed by gathering all information from the spectrum and determining if a proposed structure is consistent with the observed ions. Here we will provide a limited introduction to this process with an emphasis on identification of the molecular ion. We will present one case study to show how mass spectrometry, coupled with gas chromatography, can be used to characterize the products of a synthetic organic reaction.

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Terms

The *molecular ion*, represented by $M^{+\cdot}$, is the intact molecule with one electron missing. This should be the peak in the spectrum with the largest mass, but it is not always observed. All spectra have an ion that we call the *base peak*. This is the most abundant peak in the spectrum (*m/z* 44 in the spectrum of N_2O or *m/z* 69 in the spectrum of PFTBA). In the next section you will find that more than one peak may correspond to the $M^{+\cdot}$ or fragment ion when that ion contains elements with different isotopes. We use the term *nominal mass* to describe the mass of the molecule in terms of the most abundant (and, generally, the lightest) isotopes of the element. Relative isotopic abundances for common elements are summarized in Table 8.36.

Isotope Peaks

The mass spectrum for $N(C_4F_9)_3$ (PFTBA; MW = 671) is shown in Figure 8.50. The peaks at *m/z* 69, 219, and 502 are shown above the spectrum as they were measured by the instrument; the spectrum shows their bar-graph representation. These peaks correspond to CF_3^+, $C_4F_9^+$, and $NC_9F_{20}^+$. If you look carefully at the enlarged peaks, you will notice smaller peaks that appear one mass unit above that of the ion. We call these $[A + 1]^+$ peaks. Where do these peaks come from and why does the abundance increase with the mass of the fragment?

If you look at Table 8.36, you will find that fluorine is an isotopically pure element; however, 1.1% of carbon is the ^{13}C isotope. You may recall that it is this low abundance of ^{13}C that you measure with ^{13}C NMR. For nitrogen there is a small amount of ^{15}N. When a molecule contains more than one atom of an isotopically impure element, you increase the chance of finding the higher mass isotope in the molecule. For example, the ^{13}C peaks for *m/z* 69, 219, and 502 of PFTBA (Fig. 8.50) are 1.1, 4.4, and 10.3% of the ^{12}C peaks. The relative intensity increases because there is a higher statistical probability of finding one ^{13}C when the ion has nine vs. one carbon atom. The $[A + 1]^+$ peak intensity from ^{13}C is equal to *n* times 1.1% the height of the peak A^+, where *n* is the number of carbon atoms. In addition, we need to add contributions from other A + 1 elements, like nitrogen (0.4%). With precise ion intensity measurements, the relative abundance of the [A + 1] peak can be used to determine the number of carbons present in an organic molecule.

Table 8.36 **Relative Isotope Abundances of Common Elements**

Element	Mass	%	Mass	%	Mass	%
Carbon	12	100	13	1.1		
Hydrogen	1	100	2	0.015		
Nitrogen	14	100	15	0.37		
Oxygen	16	100	17	0.04	18	0.2
Fluorine	19	100				
Silicon	28	100	29	5.10	30	3.4
Phosphorus	31	100				
Sulfur	32	100	33	0.79	34	4.4
Chlorine	35	100			37	32.0
Bromine	79	100			81	97.3
Iodine	127	100				

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Mass spectra get very interesting when chlorine or bromine is present. Both elements exist as mixtures of the A and A + 2 isotopes (Table 8.36). The characteristic isotope distribution for bromine, with nearly equal abundances for ^{79}Br and ^{81}Br, is apparent in the spectrum of bromobenzene (Fig. 8.53*a*). The $M^{+\cdot}$ is observed as a cluster of peaks, with *m/z* 156 containing the lightest isotopes (^{12}C and ^{79}Br). Note that the fragment at *m/z* 77 results from loss of Br, and consequently no Br isotope peaks are observed. When more atoms of A + 2 elements are present, characteristic peak distributions are produced (Fig. 8.54). For example, an ion that contains two chlorine atoms will show three peaks, A, [A + 2], and [A + 4], with a 100:65:10.6 intensity distribution. Working from Figure 8.54, you can use a pattern recognition approach to determine the number of chlorine or bromine atoms present in an ion. For example, the spectrum in Figure 8.53*b* shows two ion clusters that suggest the presence of chlorine. A close examination of the distributions indicates that two chlorines are found in the *m/z* 84 cluster, while the *m/z* 49 cluster contains one chlorine. When looking at the mass difference between these ions we work with the *nominal* mass (mass of the ion that has the lightest isotopes). The mass difference, defined by the nominal mass of each cluster, is 35, which corresponds to the mass of one ^{35}Cl (Fig. 8.53*b*).

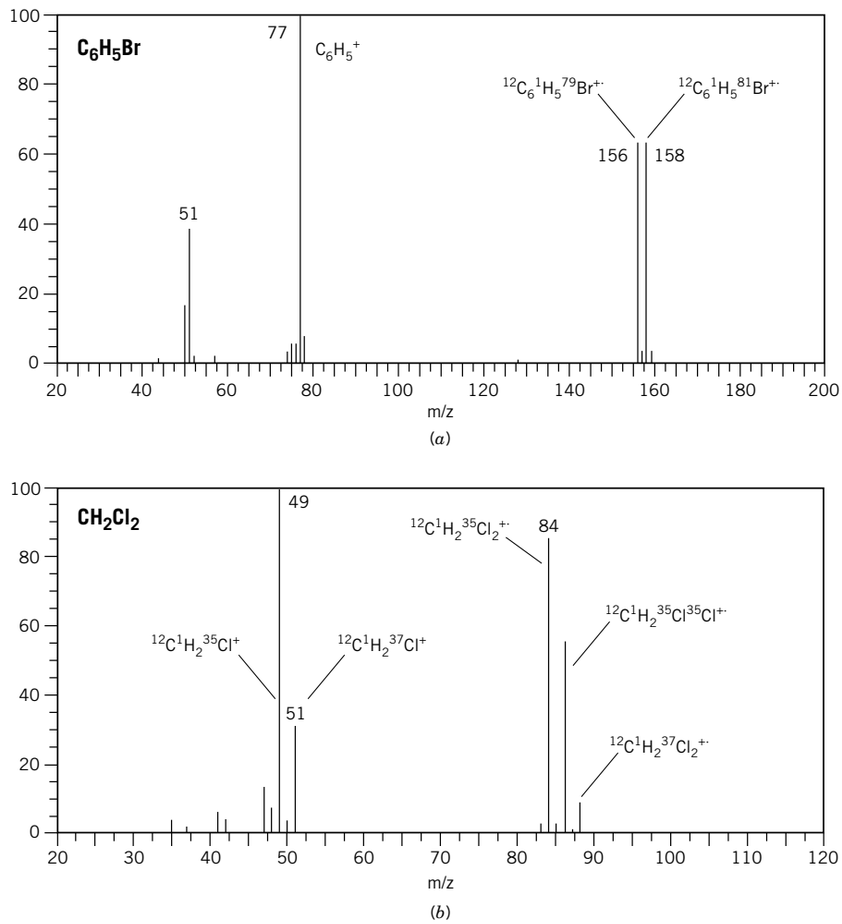

Figure 8.53 Electron ionization mass spectrum of (a) bromobenzene and (b) dichloromethane.

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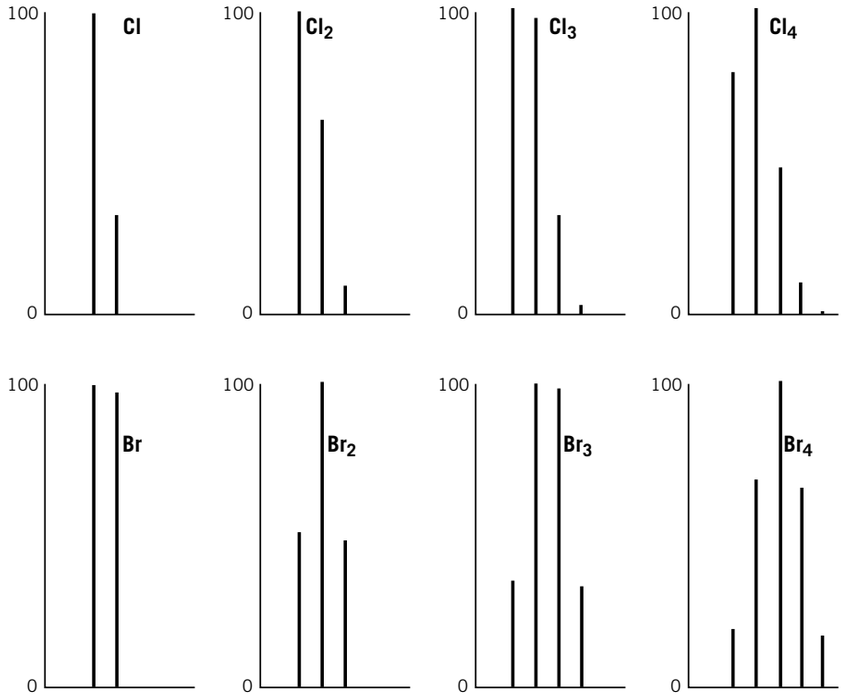

Figure 8.54 Isotope peak distributions for ions containing chlorine and bromine atoms.

Recognizing the Molecular Ion

Compound molecular weight is a valuable piece of information that is not always available from the NMR or IR spectrum. In this section we discuss some things to consider as you examine a mass spectrum and attempt to identify the $M^{+\cdot}$ ion. If you look back at the mass spectra that have appeared above, you will find examples of spectra where the molecular ion is the base peak in the spectrum. In some other cases the molecular ion may be weak or not observed at all! For example, PFTBA fragments extensively and the molecular ion does not appear in the spectrum. The following are some things to consider as you attempt to identify the molecular ion.

The molecular ion should be the highest mass peak in the spectrum. When you have tentatively identified a peak as the molecular ion, you should then determine the masses lost from the molecular ion to give high-mass fragments. For example, in Figure 8.53*b* we found a mass difference of 35 between $M^{+\cdot}$ and the first fragment. A listing of common losses from $M^{+\cdot}$ can be found in Table 8.37. If an observed fragment corresponds to an unreasonable loss, such as M − 12, this strongly suggests that your tentative identification of the molecular ion is incorrect. Remember that it is always possible that no molecular ion is present.

Another useful feature to consider is the *nitrogen rule*. For most elements found in organic molecules, the compound molecular weight will be *even* if the compound has an even number of nitrogen atoms (remember, zero is an even number). In contrast, the mass will be *odd* if the compound contains an odd number of nitrogen atoms. If you are sure that your product could not contain nitrogen, then an odd mass ion could not correspond to the molecular ion.

Mass spectrometrists also use "softer" ionization techniques to obtain MW information. These techniques included measuring EI mass spectra at lower

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Table 8.37 Some Reasonable[a] Losses From $M^{+\cdot}$

Fragment[b]	Radical Lost	Neutral Loss
M-1	H	
M-2		H_2
M-15	CH_3	
M-18		H_2O
M-28		CO or C_2H_4
M-29	C_2H_5	
M-31	OCH_3	
M-32		CH_3OH
M-43	C_3H_7	

[a]Unreasonable losses include [M-4] to [M-14]; [M-21] to [M-25].
[b]For a more complete listing see McLafferty and Turecek (1993).

ionization energies and using a higher pressure ionization technique called *chemical ionization*.

Mass Spectral Interpretation

The following list contains some factors to consider when interpreting mass spectra. To make best use of this summary, the interested reader should consult the text by McLafferty and Turecek, which is considered by many to be the best resource to learn mass spectral interpretation.

1. Using the considerations described above, identify the molecular ion.
2. If possible, determine the elemental composition for $M^{+\cdot}$ and other important peaks using isotopic abundances. In particular, look for isotope peaks from "M + 2" elements like Cl, Br, S, and Si (Table 8.36 and Fig. 8.54). If you are able to establish a molecular formula, calculate "rings + π bonds":

$$\text{For } C_XH_YN_ZO_N \text{ (rings + } \pi \text{ bonds)} = X - \frac{Y}{2} + \frac{Z}{2} + 1$$

NOTE. An even-electron ion, with no unpaired electrons, will have a fractional value. If halogens are present, they are counted as hydrogens.

3. Is the molecular weight odd? If so, this indicates an odd number of nitrogen atoms (for organic molecules).
4. Consider the general appearance of the EI mass spectrum: Is it "aliphatic" (lots of fragmentation) or "aromatic" character (minimal fragmentation)?
5. Look for important low-mass ions (Table 8.38).
6. In the region near M^+, identify fragments lost from the molecular ion (neutral losses) (Table 8.37). Look for intense high-mass ions that may indicate a characteristic, stable fragment ion.
7. Postulate a structure by assembling the various mass fragments/neutral losses. Do the observed fragment ions make sense in terms of fragment/neutral loss stability considerations? Does the structure make sense in

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Table 8.38 Some Common Ion Series	
Ion Series	**Compound Type**
m/z 15, 29, 43, 57, 73	Aliphatic hydrocarbons
m/z 38, 39, 50–52, 63–65, 75–78	Aromatic hydrocarbons (not all peaks in ranges will be observed)
m/z 30, 44, 58	Amines
m/z 31, 45, 59	Alcohols
Note. For a more complete listing see McLafferty and Turecek (1993).	

terms of other information, such as the reaction conditions, NMR or IR spectra?

8. Verify a postulated structure by comparing the spectrum with a reference spectrum. The reference spectrum may be found in the literature or it may be measured by purchasing or synthesizing a standard of the postulated structure.

CASE STUDY: SYNTHESIS OF METHYL BENZOATE*

To illustrate how gas chromatography and mass spectrometry can be used to characterize the products of an organic reaction, we consider the synthesis of methyl benzoate using a base-catalyzed esterification of benzoic acid. The reaction proposed for this synthesis involved deprotonation of benzoic acid by *n*-butyllithium in dry tetrahydrofuran (THF), followed by the addition of methyl iodide, with dimethylformamide (DMF) added to promote the S_N2 displacement of iodide by the benzoate anion:

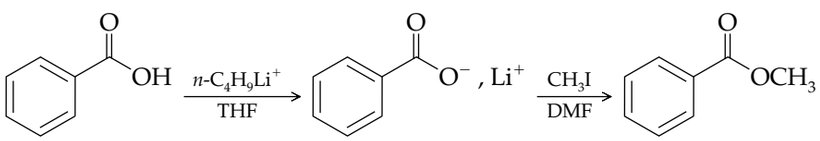

We isolated the reaction products from the reaction mixture by quenching the reaction with water, adding saturated $NaHCO_3$, and extracting the neutral products with diethyl ether. The ethereal solution containing the reaction products was then analyzed by capillary column GC/MS, and the chromatogram shown in Figure 8.55 was produced. The chromatogram displays total ionization as a function of time. The total ionization is a summation of all the ions detected in one scan of the mass spectrometer (one spectrum) plotted as a point as a function of time. The display is often called the TIC (total ionization chromatogram), and the peak areas should reflect the relative amounts of each compound detected by the mass spectrometer.

The chromatogram shown in Figure 8.55 is not quite what we would hope to see. Instead of detecting a single chromatographic peak for our product, we see three peaks. To determine if we made *any* methyl benzoate, and to determine what other components are present in our mixture, we examine the mass

*The synthetic work presented below was carried out by Joshua Pacheco, Bowdoin College Class of 1999.

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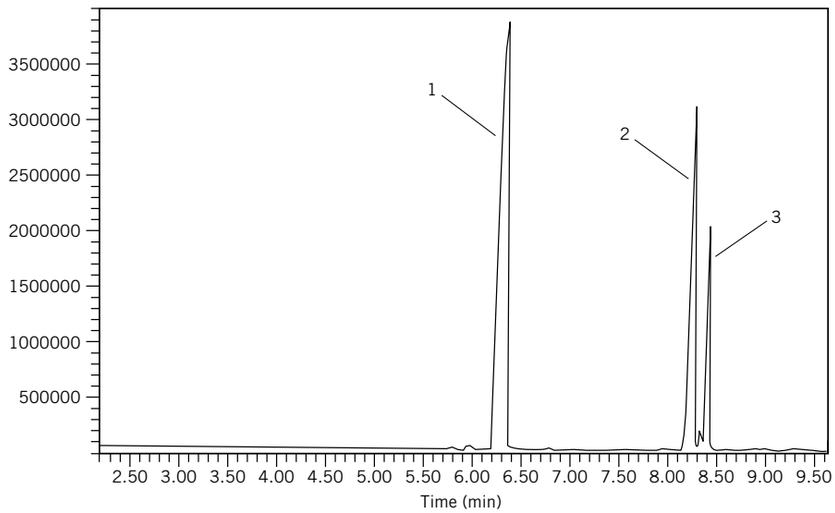

Figure 8.55 Total ionization chromatogram of a reaction mixture.

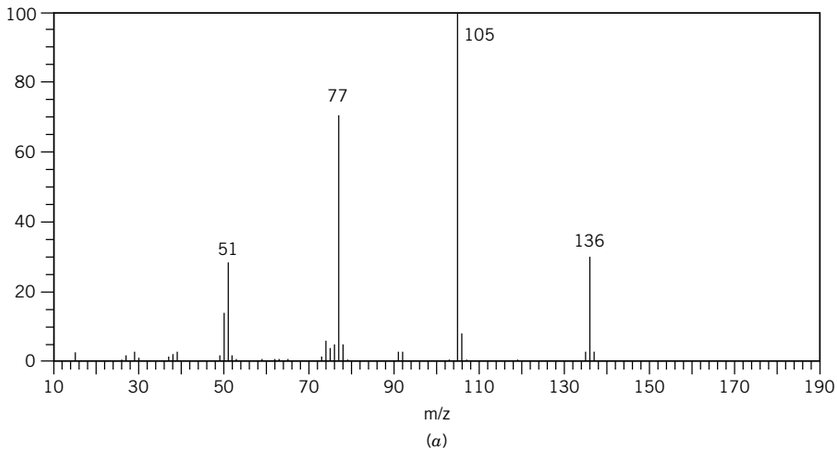

Figure 8.56*a* Electron ionization mass spectrum of (*a*) peak 1.

spectrum for each peak. Because we are eager to determine if we made any methyl benzoate, we start by trying to locate a chromatographic peak that has a mass spectrum that corresponds to methyl benzoate. Even if we are not sure what the mass spectrum will look like, we can try to find a spectrum that shows a molecular ion, $M^{+\cdot}$, that corresponds to the molecular weight of methyl benzoate ($C_8H_8O_2$, MW = 136). The mass spectrum for peak **1** (Fig. 8.56*a*) shows an ion at *m/z* 136 that appears as the highest mass peak in the spectrum. Let's now take a closer look at the mass spectrum to see if the fragment ions are consistent with the structure of methyl benzoate.

The base peak in the spectrum appears at *m/z* 105. This intense peak results from a loss of 31 from the molecular ion, which corresponds to loss of OCH_3. This is a predicted loss. Upon ionization, we expect one of the nonbonding electrons on the carbonyl oxygen to be lost, and can consider the charge and unpaired electron to be localized on that oxygen. The unpaired electron initiates a cleavage that results in loss of OCH_3 radical. The ions at *m/z* 77 and 51, which are characteristic of aromatic rings, may form by cleavage on the other side of the carbonyl group. The ions at *m/z* 105 and 77 may

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undergo another fragmentation, but the loss of another radical species is not generally observed from ions of this type, where all electrons are now paired up. Instead, even-electron neutrals, such as CO or C_2H_2, are lost to give fragments *m/z* 77 and 51, respectively:

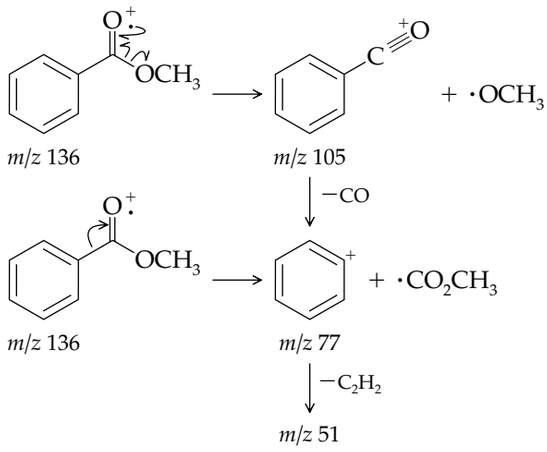

Thus, the mass spectrum for peak **1** is consistent with the structure of methyl benzoate. We could further confirm our identification by consulting a library of mass spectra. If we had any pure methyl benzoate around, we could also prepare a standard and use both the GC retention time and the mass spectrum of the standard as a means of confirming the compound identification.

We can now move on to some other peaks in the chromatogram. The mass spectra for peaks **2** and **3** (Fig. 8.56*b, c*) have many similar features to those of methyl benzoate. Both **2** and **3** show ions at *m/z* 51, 77, and 105. We can conclude that both compounds have a carbonyl group attached to an aromatic ring. We can next consider identification of the molecular ion. For peak **2**, the highest mass ion is *m/z* 162. To determine if this is a reasonable assignment for M^+, we determine losses from *m/z* 162. The ions at *m/z* 133, 120, and 105 could result from losses of 29, 42, and 57, respectively. None of these losses are unreasonable. We next want to consider two important pieces of information. First, if we assume that the MW is 162, we must add

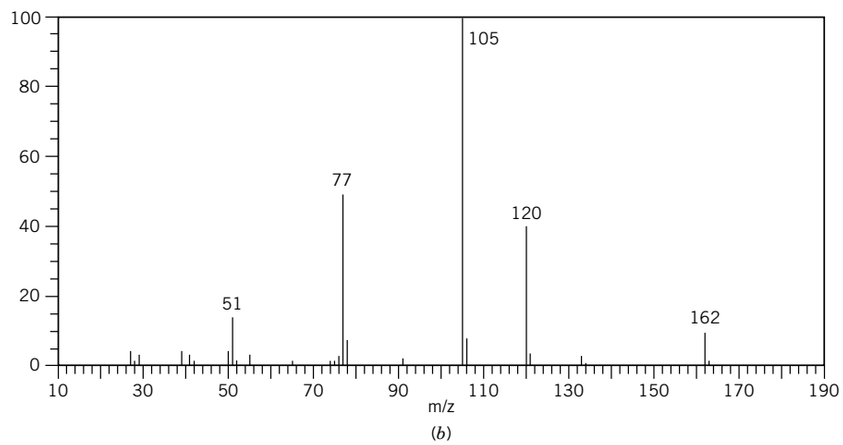

Figure 8.56*b* **Electron ionization mass spectrum of peak 2, and (c).**

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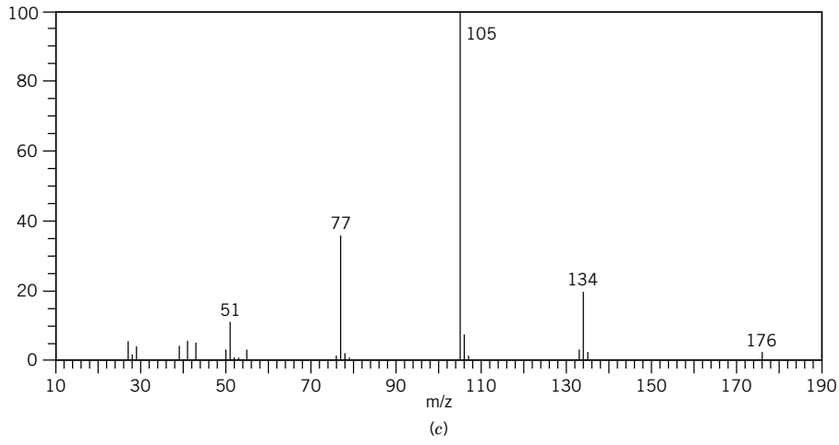

Figure 8.56*c* **Electron ionization mass spectrum of peak 3.**

57 to the carbonyl substituted aromatic ring to make our molecule. Addition of a butyl group is a logical choice:

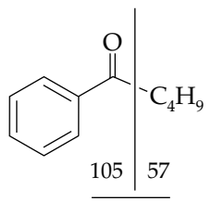

MW = 162

Next we take note of the peak at *m/z* 120. The even mass of this ion, resulting from an even mass molecular ion, indicates that it is a special ion! Even-mass fragments generally result from rearrangement reactions, and rearrangements involving hydrogen transfers to carbonyl groups can produce particularly informative product ions. If a butyl group is attached to the carbonyl, the following fragmentation pathway will occur, which nicely explains the *m/z* 120 peak:

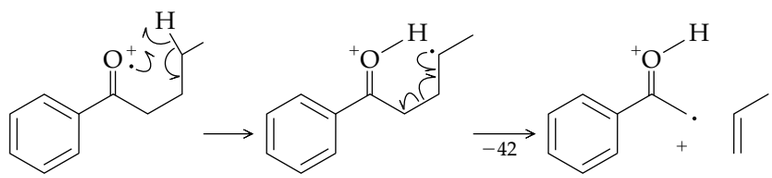

m/z 162 *m/z* 120

To determine if this assignment makes sense, we go back to consideration of our reaction. How could this product be generated? If we assume that there is some unreacted *n*-butyllithium around after the methyl benzoate has been formed, then the following reaction is possible. Thus, we can feel quite confident in our assignment for peak **2**:

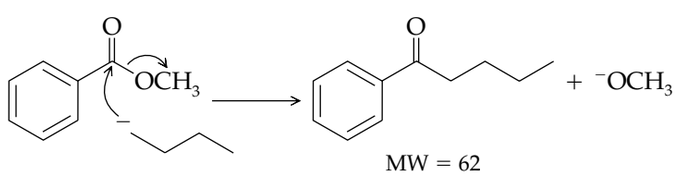

MW = 62

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Moving on to peak **3**, we detect an ion at *m/z* 134. Let's start by assuming that this is our molecular ion. The *m/z* 105 peak would result from a loss of 29 (C_2H_5) from *m/z* 134, which is a reasonable loss from $M^{+\cdot}$. This *suggests*, erroneously, that ethyl benzoate is our product:

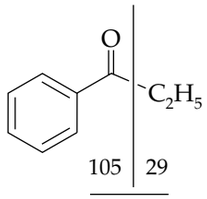

MW = 134

Why is this identification incorrect? If we look back at the chromatogram in Figure 8.55 the chromatographic retention times tell us that something is amiss. Remember that compounds elute from the column in approximate order of increasing boiling point. We would expect that the butyl phenyl ketone would elute *after*, not before, the ethyl phenyl ketone! In addition, you would be hard pressed to propose a mechanism for formation of ethyl benzoate in the context of this reaction. Let's go back and take another look at the mass spectrum. A careful examination shows a small peak at *m/z* 176. We may have incorrectly identified the molecular ion! If $M^{+\cdot}$ is *m/z* 176, this gives losses of 42 and 71 to form *m/z* 134 and 105, respectively. Now it looks like we have a pentyl group attached to the carbonyl, which agrees nicely with the chromatographic retention times. The *m/z* 134 ion becomes one of our special, even mass ions. What does this ion reveal about the pentyl group? The fact that the ion results from loss of 42, and not 58, clearly indicates that this is not an *n*-pentyl group. What makes the most sense is the branching shown below:

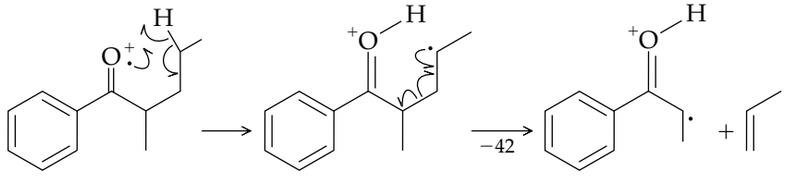

m/z 176 *m/z* 134

In terms of the chemistry of the reaction, this product also makes sense if deprotonation by *n*-butyllithium occurs α to the carbonyl, followed by reaction with methyl iodide:

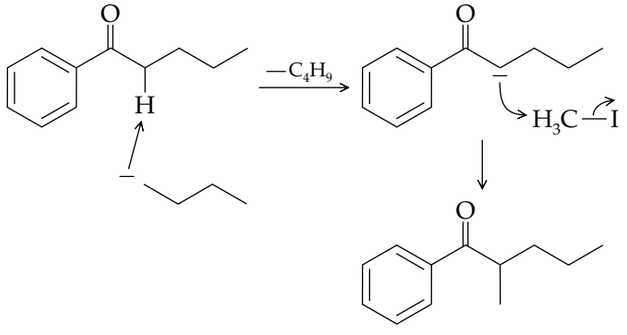

MW = 176

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NIST/EPA/MSDC Mass Spectral Library; National Institute of Standards and Technology. You may also access some mass spectral data through the internet: *WebBook.nist.gov*

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C_9H_{12}apter 9

QUALITATIVE IDENTIFICATION OF ORGANIC COMPOUNDS

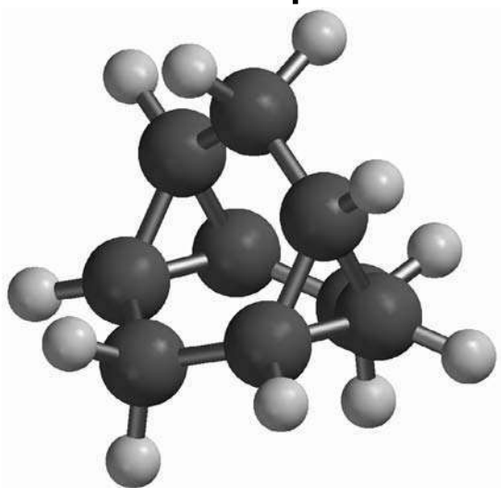

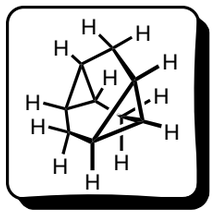

ORGANIC QUALITATIVE ANALYSIS

One of the exciting challenges that a chemist faces on a regular basis is identifying organic compounds. This challenge is an excellent way for a student to be initiated into the arena of chemical research. Millions of organic compounds are recorded in the chemical literature. At first glance it may seem a bewildering task to attempt to identify one certain compound from this vast array, but most of these substances can be grouped, generally by functional groups, into a comparatively small number of classes. In addition, chemists have an enormous database of chemical and spectroscopic information, which has been correlated and organized over the years, at their disposal. Determination of the physical properties of a molecule, the functional groups present, and the reactions the molecule undergoes has allowed the chemist to establish a systematic, logical identification scheme.

Forensic chemistry, the detection of species causing environmental pollution, the development of new pharmaceuticals, progress in industrial research, and development of polymers all depend to a large extent on the ability of the chemist to isolate, purify, and identify specific chemicals. The objective of organic qualitative analysis is to place a given compound, through screening tests, into one of a number of specific classes, which in turn greatly simplifies the *identification* of the compound. This screening is usually done by using a series of preliminary observations and chemical tests, in conjunction with the instrumental data that developments in spectroscopy have made available to the analyst. The advent of infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry (MS) have had a profound effect on the approach taken to identify a specific organic compound. Ultraviolet (UV) spectra may also be utilized to advantage with certain classes of materials.

The systematic approach taken in this text for the identification of an unknown organic compound is as follows:

1. Preliminary tests are performed to determine the physical nature of the compound.

2. The solubility characteristics of the unknown species are determined. This identification can often lead to valuable information related to the structural composition of an unknown organic compound.

Chapter 9: C_9H_{12}, Triasterene (*L. aster,* star)
Musso and Biethan (1964)

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3. Chemical tests, mainly to assist in identifying elements other than C, H, or O, may also be performed.

4. Classification tests are carried out to detect *common functional groups* present in the molecule. Most of these tests may be done using a few drops of a liquid or a few milligrams of a solid. An added benefit to the student, especially in relation to the chemical detection of functional groups, is that a vast amount of chemistry can be *observed* and *learned* in performing these tests. The successful application of these tests requires that you develop the ability to think in a logical manner and to interpret the significance of each result based on your observation. Later, as the *spectroscopic techniques* are introduced, *the number of chemical tests performed are usually curtailed.*

5. The spectroscopic method of analysis is utilized. As your knowledge of chemistry develops, you will appreciate more and more the revolution that has taken place in chemical analysis over the past 25–30 years and the powerful tools now at your disposal for the identification of organic compounds. In the introductory laboratory, the techniques of IR, NMR, and UV–vis spectroscopy, and mass spectrometry are generally explored.

It is important to realize that *negative* findings are often as important as *positive* results in identifying a given compound. Cultivate the habit of following a *systematic pathway or sequence* so that no clue or bit of information is lost or overlooked along the way. It is important also to develop the *attitude* and *habit* of planning ahead. Outline a logical plan of attack, depending on the nature of the unknown, and follow it. As you gain more experience in this type of investigative endeavor, the planning stage will become easier.

At the *initial* phase of your training, the unknowns to be identified will be relatively pure materials and will all be known compounds. The properties of these materials are recorded in the literature, and/or in the tables on the website; see Chapter 9W. Later, perhaps, mixtures of compounds or samples of commercial products will be assigned for separation, analysis, and identification of the component compounds.

Record all observations and results of the tests in your laboratory notebook. Review these data as you execute the sequential phases of your plan. This method serves to keep you on the path to success.

A large number of texts have been published on organic qualitative analysis. Several references are cited here.

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PRELIMINARY TESTS

Preliminary tests help you select a route to follow to ultimately identify the unknown material at hand. These tests frequently consume material, so, given the amounts of material generally available at the micro- or semimicroscale level, judicious selection of the tests to perform must be made (in some tests, the material analyzed may be recovered). Each preliminary test that can be conducted with *little expenditure of time and material* can offer valuable clues as to which class a given compound belongs.

Nonchemical Tests

Physical State. If the material is a *solid*, a few milligrams of the sample may be viewed under a magnifying glass or microscope, which may give some indication as to the homogeneity of the material. Crystalline shape is often an aid in classifying the compound.

Determine the melting point, using a small amount of the solid material. A narrow melting point range (1–2 °C is a good indication that the material is quite pure. If a broad range is observed, the compound must be recrystallized from a suitable solvent before proceeding. If the material undergoes decomposition on heating, try an evacuated (sealed-tube) melting point. If any evidence indicates that sublimation is occurring, an evacuated melting point should be run. Furthermore, this result indicates that sublimation might be used to purify the compound, if necessary.

If the material is a *liquid*, the boiling point is determined by the ultramicro method. If sufficient material is on hand and the boiling point reveals that the material is relatively pure (narrow boiling point range), the *density* and the *refractive index* can provide valuable information for identification purposes.

www

Color. Since the majority of organic compounds are colorless, examination of the color can occasionally provide a clue as to the nature of the sample. Use caution, however, since tiny amounts of some impurities can color a substance. Aniline is a classic example. When freshly distilled it is colorless, but on standing a small fraction oxidizes and turns the entire sample a reddish-brown color.

Colored organic compounds contain a *chromophore*, usually extended conjugation in the molecule. For example, 1,2-dibenzoylethylene (Experiments [3A] and [6]) is yellow; 5-nitrosalicylic acid (Experiment [29C]) is light yellow; tetraphenylcyclopentadienone (Experiment [$A3_a$]) is purple.

Can you identify the chromophores that cause these compounds to be colored? Note that a colorless liquid or white solid would not contain these units. Thus, compounds containing these groupings would be excluded from consideration as possible candidates in identification of a given substance.

Odor. Detection of a compound's odor can occasionally be of assistance, since the vast majority of organic compounds have no definitive odor. You should become familiar with the odors of the common compounds or classes. For example, aliphatic amines have a fishy smell; benzaldehyde (like nitrobenzene and benzonitrile) has an almond odor; esters have fruity odors (Experiments [8A–C]). Common solvents, such as acetone, diethyl ether, and toluene, all have distinctive odors. Butyric and caproic acids have rancid odors. Low molecular weight mercaptans (—SH) have an intense smell of rotten eggs. In many cases, extremely small quantities of certain relatively high molecular weight compounds

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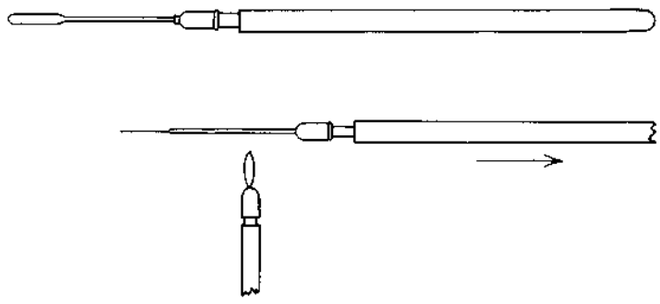

Figure 9.1 Heating on the microspatula. *(Courtesy of Springer-Verlag, Vienna.)*

can be detected by their odor. For example, a C_{16} unsaturated alcohol released by the female silk worm moth elicits a response from male moths of the same species at concentrations of 100 molecules/cm^3. Odors are an important facet of chemical communication between plants and animals and often result in a spectacular behavioral response (see also Experiment [8]).

Odor detection in humans involves your olfactory capabilities and thus can be a helpful lead, *but very rarely can this property be used to strictly classify or identify a substance.* As mentioned above, contamination by a small amount of an odorous substance is always a possibility.

CAUTION

CAUTION: You should be very cautious when detecting odors. Any odor of significance can be detected several inches from the nose. Do not place the container closer than this to your eyes, nose, or mouth. Open the container of the sample and gently waft the vapors toward you.

Ignition Test

CAUTION

CAUTION: Make sure you are wearing safety glasses.

Valuable information can be obtained by carefully noting the manner in which a given compound burns. The ignition test[1] is carried out by placing 1–2 mg of the sample on a spatula, followed by heating and ignition with a microburner flame. Do not hold the sample directly in the flame; heat the spatula about 1 cm from the flat end and move the sample slowly into the flame (see Fig. 9.1).

Important observations to be made concerning the ignition test are summarized in Table 9.1.

As the sample is heated, you should make the following observations:

1. Any melting or evidence of sublimation: This observation gives an approximate idea of the melting point by the temperature necessary to cause melting.

2. Color of the flame as the substance begins to burn (see Table 9.1).

3. Nature of the combustion (flash, quiet, or an explosion). Rapid, almost instantaneous combustion indicates high hydrogen content. Explosion indicates

[1]For an extensive discussion on examination of ignition residues see Feigl, F.; Anger, V. *Spot Tests in Organic Analysis,* 7th ed.; Elsevier: New York; 1966, p. 51.

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Table 9.1 **Ignition Test Observations**

Type of Compound	Example	Observation
Aromatic compounds, unsaturated, or higher aliphatic compounds	Toluene	Yellow, sooty flame
Lower aliphatic compounds	Hexane	Yellow, almost nonsmoky flame
Compounds containing oxygen	Ethanol	Clear bluish flame
Polyhalogen compounds	Chloroform	Generally do not ignite until burner flame applied directly to the substance
Sugars and proteins	Sucrose	Characteristic odor
Acid salts or organometallic compounds	Ferrocene	Residue

Source. Cheronis, N. D.; Entrikin, J. B. *Semimicro Qualitative Analysis;* Interscience: New York, 1947, p. 85.

the presence of nitrogen- or nitrogen–oxygen-containing groups, for example, nitro groups (Experiment [29]).

4. Nature of the residue, if present, after ignition.

a. If a black residue remains and disappears on further heating at higher temperature, the residue is carbon.

b. If the residue undergoes swelling during formation, the presence of a carbohydrate or similar compound is indicated.

c. If the residue is black initially but still remains after heating, an oxide of a heavy metal is indicated.

d. If the residue is white, the presence of an alkali or alkaline earth carbonate or SiO_2 from a silane or silicone is indicated.

SEPARATION OF IMPURITIES

If the preliminary tests outlined above indicate that the unknown in question contains impurities, it may be necessary to carry out one of several purification steps. These techniques are discussed in earlier chapters and are summarized below for correlation purposes:

1. For a liquid, distillation is generally used (see Techniques 2 and 3).
2. For a solid, recrystallization is generally used (see Technique 5).
3. Extraction is used if the impurity is insoluble in a solvent in which the compound itself is soluble (see Technique 4).
4. Sublimation is a very efficient technique if the compound sublimes (see Technique 9).
5. Chromatography (gas, column, and thin-layer) is often used (see Techniques 1 and 6A).

These techniques may be applied to the separation of mixtures as well.

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DETECTION OF ELEMENTS OTHER THAN CARBON, HYDROGEN, OR OXYGEN

Other than C, H, and O, the elements that are most often present in organic compounds are nitrogen, sulfur, and the halogens (F, Cl, Br, or I). To detect the presence of these elements, the organic compound is generally fused with metallic sodium. This reaction converts these heteroatoms to the water-soluble inorganic compounds, NaCN, Na_2S, and NaX. Inorganic qualitative analysis tests enable the investigator to determine the presence of the corresponding anions:

$$\text{Organic compound containing} \begin{Bmatrix} \text{C} \\ \text{H} \\ \text{O} \\ \text{N} \\ \text{S} \\ \text{X} \end{Bmatrix} \xrightarrow[\Delta]{\text{Na}} \begin{Bmatrix} \text{NaCN} \\ \text{Na}_2\text{S} \\ \text{NaX} \end{Bmatrix}$$

Sodium Fusion[2]

HOOD *NOTE. The fusion reaction is carried out in the* ***hood.*** *Make sure you are wearing safety glasses. All reagents must be of analytical grade, and deionized water must be used.*

CAUTION CAUTION: Sodium metal can cause serious burns and it reacts violently with water.

In a small (10 × 75-mm) test tube (soft glass preferred), supported in a transite board (see Fig. 9.2), place about 25–30 mg of clean sodium metal (about one-half the size of a pea).

CAUTION CAUTION: Use forceps to make this transfer; never touch sodium metal with your fingers.

Heat the tube with a flame until the sodium melts and sodium vapor is observed rising in the tube (see Fig. 9.2).

Mix a small sample of your unknown compound (1–2 drops of a liquid; 6–10 mg if a solid) with about 15–25 mg of *powdered* sucrose.[3] Gentle mixing of solids may be done on filter paper or glassine weighing paper; liquids can be mixed on a watch glass. Add this mixture to the tube, being careful not to get any material on the sides of the test tube.

NOTE. The addition of sucrose to the sample helps reduce various nitrogen or sulfur compounds. It also absorbs volatile materials so that they may undergo the desired reaction before significant vaporization can occur.

Now heat the tube gently to initiate the reaction with sodium. Remove the flame until the reaction subsides, and then heat to redness for 1–2 min. Allow the

[2]See Campbell, K. N.; Campbell, B. K. *J. Chem. Educ.* **1950,** *27,* 261 for a discussion of the procedure.
[3]Ordinary confectioner's sugar purchased at the supermarket can be used.

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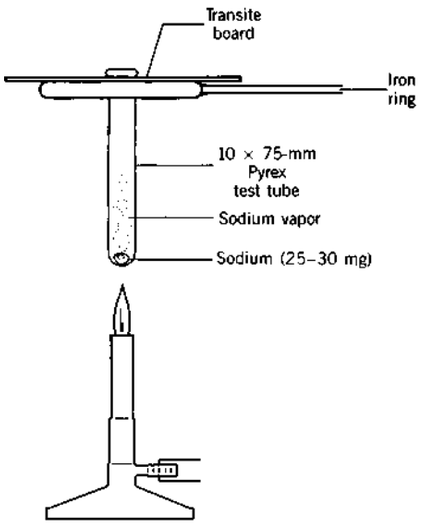

Figure 9.2 Apparatus for sodium fusion.

tube and contents to cool to room temperature. Then, *and only then*, **cautiously** add several drops of methanol (using a Pasteur pipet) to decompose any unreacted metallic sodium. Gently warm the mixture to drive off the excess methanol.

Reheat the tube to a bright red. While the tube is still red hot, lift the transite board and test tube from the iron ring and place the tube in a small beaker (30 mL) containing about 15 mL of deionized water (the transite board acts as a cover on the beaker).

CAUTION: The soft-glass tube usually cracks and breaks during this operation. CAUTION

Break up the tube with a glass rod, heat the solution to boiling and filter it by gravity into a clean 50-mL Erlenmeyer flask. Wash the filter paper with an additional 2.0 mL of distilled water and combine this wash with the original filtrate.

NOTE. If a Pyrex test tube is used, after the unreacted sodium metal is completely destroyed by adding methanol, add 2 mL of deionized water directly to the tube and contents. Place a glass stirring rod in the tube and heat the solution to boiling with stirring and then filter as described above. Dilute the filtrate with deionized water to about 5 mL.

Using the Fusion Solution. The clear, colorless fusion solution is used to test for the presence of CN^- (nitrogen), S^{2-} (sulfur), and X^- (halogens, except F^-) as described in the following sections.

Sulfur

1. Place 2–3 drops (Pasteur pipet) of the fusion solution on a white spot plate, followed by 2 drops of water. Now add 1 drop of dilute (2%) aqueous sodium nitroprusside solution. The formation of a deep blue-violet color is a positive test for sulfur:

$$\underset{}{Na_2S} + \underset{\text{Sodium nitroprusside}}{Na_2Fe(CN)_5NO} \longrightarrow \underset{\text{Blue-violet complex}}{Na_4[Fe(CN)_5NOS]}$$

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2. Place 3–4 drops (Pasteur pipet) of the fusion solution on a white spot plate followed by 1–2 drops of acetic acid. Now add 1 drop of 1% lead(II) acetate solution. The formation of a black precipitate (lead sulfide) indicates the presence of sulfur.

Nitrogen[4]

Reagents

1. A 1.5% solution of *p*-nitrobenzaldehyde in 2-methoxyethanol
2. A 1.7% solution of *o*-dinitrobenzene in 2-methoxyethanol
3. A 2.0% solution of NaOH in distilled water

NOTE. All reagent drops are dispensed using Pasteur pipets.

On a white spot plate, place together: 5 drops of reagent **1,** 5 drops of reagent **2,** and 2 drops of reagent **3.** Stir this mixture gently with a glass rod.

Now add 1 drop of the fusion solution. The formation of a deep-purple color is a positive test for the presence of CN^- ion; a yellow or tan coloration is negative. If a positive result is obtained, nitrogen is present in the sample.

The test is valid in the presence of halogens (NaX) or sulfur (Na_2S). It is much more sensitive than the traditional Prussian Blue test.[5]

The Soda Lime Test. In a 10 × 75-mm test tube, mix about 50 mg of soda lime and 50 mg of MnO_2. Add 1 drop of a liquid unknown or about 10 mg of a solid unknown. Place over the mouth of the tube a moist strip of Brilliant Yellow paper (moist, red litmus paper is an alternative). Using a test tube holder, hold the tube at an incline (*pointing away from you and others*) and heat the contents gently at first and then quite strongly. Nitrogen-containing compounds will usually evolve ammonia.

A positive test for nitrogen is the deep red coloration of the Brilliant Yellow paper (or blue color of the litmus paper).

The Halogens (Except Fluorine)

Using the Fusion Solution. In a 10 × 75-mm test tube containing a boiling stone, place 0.5 mL (calibrated Pasteur pipet) of the fusion solution. Carefully acidify this solution by the dropwise addition of dilute HNO_3 (nitric acid), delivered from a Pasteur pipet (test acidity with litmus paper). If a positive test for nitrogen or sulfur was obtained, heat the resulting solution to a gentle boil (stir with a microspatula to prevent boilover) for 1 min over a microburner in the **hood** to expel any HCN or H_2S that might be present. Then cool the tube to room temperature.

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To the resulting cooled solution, add 2 drops (Pasteur pipet) of aqueous 0.1 M $AgNO_3$ solution.

[4]Adapted from Guilbault, G. G.; Kramer, D. N. *Anal. Chem.* **1966,** *39,* 834. *Idem. J. Org. Chem.* **1966,** *31,* 1103. See also Shriner, R. L.; Fuson, R. C.; Morrill, T. C. *The Systematic Identification of Organic Compounds,* 6th ed.; Wiley: New York, 1980, p. 80.

[5]See Vogel, A. I. *Elementary Practical Organic Chemistry,* Part 2, 2nd ed.; Wiley: New York, 1966, p. 37.

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A heavy curdy-type precipitate is a positive test for the presence of Cl^-, Br^-, or I^- ion. A faint turbidity is a negative test.

AgCl precipitate is white.

AgBr precipitate is pale yellow.

AgI precipitate is yellow.

AgF is not detected by this test since it is relatively soluble in water.

The silver halides have different solubilities in dilute ammonium hydroxide solution.

Centrifuge the test tube and contents and remove the supernatant liquid using a Pasteur filter pipet. Add 0.5 mL (calibrated Pasteur pipet) of dilute ammonium hydroxide solution to the precipitate and stir with a glass rod to determine whether the solid is soluble.

AgCl is soluble in ammonium hydroxide due to the formation of the complex ion, $[Ag(NH_3)_2]^+$.

AgBr is slightly soluble in this solution.

AgI is insoluble in this solution.

A Further Test. Once the presence of a halide ion has been established, a further test is available to help you distinguish between Cl^-, Br^-, and I^- ions.[6]

As described above, acidify 0.5 mL of the fusion solution with dilute HNO_3. To this solution, add 5 drops (Pasteur pipet) of a 1.0% aqueous $KMnO_4$ solution and shake the test tube for about 1 min.

Now add 10–15 mg of oxalic acid, enough to decolorize the excess purple permanganate, followed by 0.5 mL of methylene chloride solvent. Stopper, shake, and vent the test tube and allow the layers to separate. Observe the color of the CH_2Cl_2 (lower) layer.

A clear methylene chloride layer indicates Cl^- ion.

A brown methylene chloride layer indicates Br^- ion.

A purple methylene chloride layer indicates I^- ion.

The colors may be faint and should be observed against a white background.

The Beilstein Test[7]. In the Beilstein test organic compounds that contain chlorine, bromine, or iodine, and hydrogen decompose on ignition in the presence of copper oxide, to yield the corresponding hydrogen halides. These hydrogen halides react to form the volatile cupric halides that impart a green or blue-green color to a nonluminous flame. It is a very sensitive test, but some nitrogen-containing compounds and some carboxylic acids also give positive results.

Pound one end of a 4-in. long copper wire to form a flat surface that can act as a spatula. The other end of the wire is stuck in a cork stopper to serve as an insulated handle.

Heat the flat tip of the wire in a flame until coloration of the flame is negligible.

[6]For a further test to distinguish between the three halide ions see Shriner, R. L.; Fuson, R. C.; Morrill, T. C. *The Systematic Identification of Organic Compounds,* 6th ed.; Wiley: New York, 1980, p. 81. Also see this reference (p. 85) for a specific test for the F^- ion.

[7]Beilstein, F. *Berichte* **1872,** *5,* 620.

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On the **cooled** flat surface of the wire, place a drop (Pasteur pipet) of liquid unknown or a few milligrams of solid unknown. Gently heat the material in the flame. The carbon present in the compound will burn first, so the flame will be luminous, but then the characteristic green or blue-green color may be evident. It may be fleeting, so watch carefully.

It is recommended that a known compound containing a halogen be tested so that you become familiar with the appearance of the expected color.

Fluoride ion is not detected by this test, since copper fluoride is not volatile.

SOLUBILITY CHARACTERISTICS

Determination of the solubility characteristics of an organic compound can often give valuable information as to its structural composition. It is especially useful when correlated with spectral analysis. Several schemes have been proposed that place a substance in a definite group according to its solubility in various solvents. The scheme presented below is similar to that outlined in Shriner et al.[8]

There is no sharp dividing line between soluble and insoluble, and an arbitrary ratio of solute to solvent must be selected. We suggest that a compound be classified as soluble if its solubility is greater than 15 mg/500 μL of solvent.

Carry out the solubility determinations, at ambient temperature, in 10 × 75-mm test tubes. Place the sample (~15 mg) in the test tube and add a total of 0.5 mL of solvent in three portions from a graduated or calibrated Pasteur pipet. Between addition of each portion, stir the sample vigorously with a glass stirring rod for 1.5–2 min. If the sample is water soluble, test the solution with litmus paper to assist in classification according to the solubility scheme that follows.

NOTE. To test with litmus paper, dip the end of a small glass rod into the solution and then gently touch the litmus paper with the rod. ***Do not dip the litmus paper into the test solution.***

In doing the solubility tests follow the scheme in the order given. *Keep a record of your observations.*

Step I Test for water solubility. If soluble, test the solution with litmus paper.

Step II If water soluble, determine the solubility in diethyl ether. This test further classifies water-soluble materials.

Step III Water-insoluble compounds are tested for solubility in a 5% aqueous NaOH solution. If soluble, determine the solubility in 5% aqueous $NaHCO_3$. The use of the $NaHCO_3$ solution aids in distinguishing between strong (soluble) and weak (insoluble) acids.

Step IV Compounds insoluble in 5% aqueous NaOH are tested for solubility in a 5% HCl solution.

[8]Shriner, R. L.; Fuson, R. C.; Morrill, T. C. *The Systematic Identification of Organic Compounds,* 6th ed.; Wiley: New York, 1980.

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Step V Compounds insoluble in 5% aqueous HCl are tested with concentrated H_2SO_4. If soluble, further differentiation is made using 85% H_3PO_4, as shown in the scheme.

Step VI Miscellaneous neutral compounds containing oxygen, sulfur, or nitrogen are normally soluble in strong acid solution:

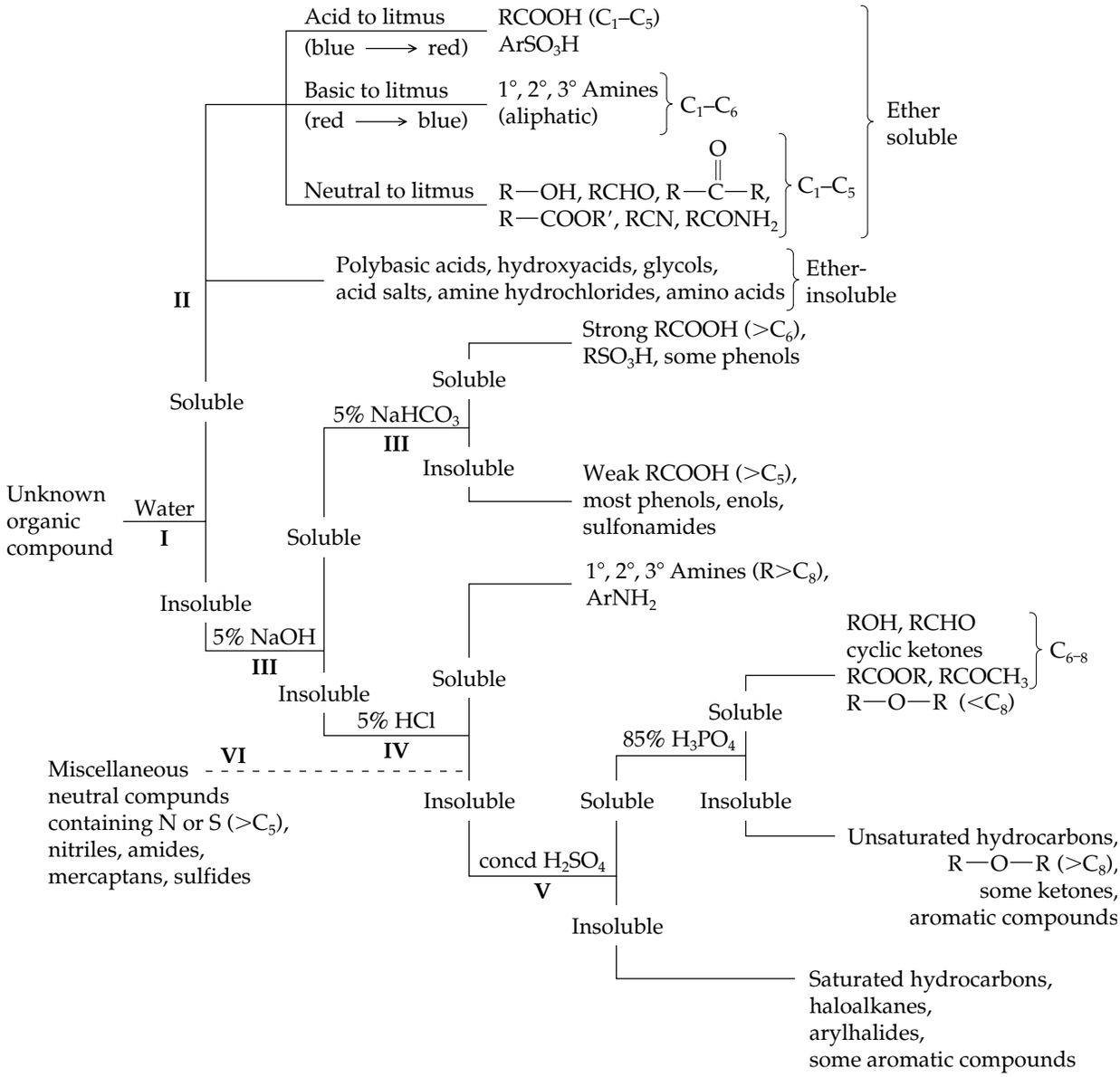

To classify a given compound, it may not be necessary to test its solubility in every solvent. *Do only those tests that are required to place the compound in one of the solubility groups.* Make your observations with care, and proceed in a logical sequence as you make the tests.

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THE CLASSIFICATION TESTS[9]

NOTE. For all tests given in this section, drops of reagents are measured out using Pasteur pipets.

Alcohols

Ceric Nitrate Test

INSTRUCTOR PREPARATION. The reagent is prepared by dissolving 4.0 g of ceric ammonium nitrate [$(NH_4)_2Ce(NO_3)_6$] in 10 mL of 2 M HNO_3. Warming may be necessary.

Primary, secondary, and tertiary alcohols with fewer than 10 carbon atoms give a positive test as indicated by a change in color from *yellow* to *red*:

$$\underset{\text{Yellow}}{(NH_4)_2Ce(NO_3)_6} + RCH_2OH \longrightarrow \underset{\text{(Red complex)}}{[\text{alcohol} + \text{reagent}]}$$

Place 5 drops of test reagent on a white spot plate. Add 1–2 drops of the unknown sample (5 mg if a solid). Stir with a thin glass rod to mix the components and observe any color change.

1. If the alcohol is water insoluble, 3–5 drops of dioxane may be added, but run a blank to make sure the dioxane is pure. Efficient stirring gives positive results with most alcohols.

2. Phenols, if present, give a brown color or precipitate.

Chromic Anhydride Test: The Jones Oxidation

INSTRUCTOR PREPARATION. The reagent is prepared by slowly adding a suspension of 1.0 g of CrO_3 in 1.0 mL of concentrated H_2SO_4 to 3 mL of water. Allow the solution to cool to room temperature before using.

The Jones oxidation test is a rapid method to distinguish primary and secondary alcohols from tertiary alcohols. A positive test is indicated by a color change from *orange* (the oxidizing agent, Cr^{6+}) while the oxidizing agent is itself reduced to the *blue green* (Cr^{3+}):

$$\left.\begin{matrix} RCH_2OH \\ \text{or} \\ R_2CHOH \end{matrix}\right\} + \underset{\text{Orange}}{H_2Cr_2O_7} \xrightarrow{H_2SO_4} \underset{\text{Green}}{Cr_2(SO_4)_3} + \begin{matrix} RCO_2H \\ \text{or} \\ R_2C{=}O \end{matrix}$$

The test is based on oxidation of a primary alcohol to an aldehyde or acid, and of a secondary alcohol to a ketone.

On a white spot plate, place 1 drop of the liquid unknown (10 mg if a solid). Add 10 drops of acetone and stir the mixture with a thin glass rod. Add

[9]For a detailed discussion of classification tests see (a) Shriner, R. L.; Fuson, R. C.; Morrill, T. C. *The Systematic Identification of Organic Compounds,* 6th ed.; Wiley: New York, 1980, p. 138; (b) Pasto, D. J.; Johnson, C. R.; Miller, M. J. *Experiments and Techniques in Organic Chemistry;* Prentice Hall: Englewood Cliffs, NJ, 1992.

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1 drop of the test reagent to the resulting solution. Stir and observe any color change within a 2-second time period.

1. Run a blank to make sure the acetone is pure.

2. Tertiary alcohols, unsaturated hydrocarbons, amines, ethers, and ketones give a negative test within the 2-s time frame for observing the color change. Aldehydes, however, give a positive test, since they are oxidized to the corresponding carboxylic acids.

The HCl/$ZnCl_2$ Test: The Lucas Test

INSTRUCTOR PREPARATION. The Lucas reagent is prepared by dissolving 16 g of anhydrous $ZnCl_2$ in 10 mL of concd HCl while it is cooling in an ice bath.

The Lucas test is used to distinguish between primary, secondary, and tertiary monofunctional alcohols having fewer than six carbon atoms:

$$\underset{\text{Soluble}}{R{-}OH} + H^+ \xrightarrow{ZnCl_2} R^+ + H_2O$$

$$R^+ \xrightarrow{Cl^-} \underset{\text{Insoluble}}{RCl}$$

The test requires that the alcohol initially be soluble in the Lucas test reagent solution. As the reaction proceeds, the corresponding alkyl chloride is formed, which is insoluble in the reaction mixture. As a result, the solution becomes cloudy. In some cases a separate layer may be observed.

1. Tertiary, allyl, and benzyl alcohols react to give an immediate cloudiness to the solution. You may be able to see a separate layer of the alkyl chloride after a short time.

2. Secondary alcohols generally produce a cloudiness within 3–10 min. The solution may have to be heated to obtain a positive test.

3. Primary alcohols having less than six carbon atoms dissolve in the reagent but react very, very slowly. Those having more than six carbon atoms do not dissolve to any significant extent, no reaction occurs, and the aqueous phase remains clear.

4. A further test to aid in distinguishing between tertiary and secondary alcohols is to run the test using concentrated hydrochloric acid. Tertiary alcohols react immediately to give the corresponding alkyl halide, whereas secondary alcohols do not react under these conditions.

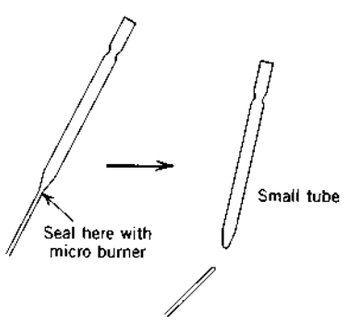

In a small test tube prepared by sealing a Pasteur pipet off at the shoulder (➡), place 2 drops of the unknown (10 mg if a solid) followed by 10 drops of the Lucas reagent.

Shake or stir the mixture with a thin glass rod and allow the solution to stand. Observe the results. Based on the times given above, classify the alcohol.

Additional points to consider:

1. Certain polyfunctional alcohols also give a positive test.

2. If an alcohol having three or fewer carbons is expected, a 1-mL conical vial equipped with an air condenser should be used to prevent low molecular weight alkyl chlorides (volatile) from escaping and thus remaining undetected.

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EQA

The Iodoform Test. This test is positive for compounds that on oxidation generate methyl ketones (or acetaldehyde) under the reaction conditions. For example, methyl carbinols (secondary alcohols having at least one methyl group attached to the carbon atom to which the —OH is attached), acetaldehyde, and ethanol give positive results.

For the test see Methyl Ketones and Methyl Carbinols (p. 651).

Periodic Acid: Vicinal Diols

INSTRUCTOR PREPARATION. This reagent solution is prepared by dissolving 250 mg of periodic acid (H_5IO_6) in 50 mL of deionized water.

Vicinal diols (1,2 diols) are differentiated from the simple alcohols by the characteristic reaction below. Metaperiodic acid (HIO_4) selectively oxidizes 1,2-diols to give carbonyl compounds:

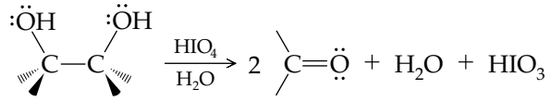

1,2-Diol

The test is based on the *instantaneous* formation of a white precipitate of silver iodate ($AgIO_3$) following addition of silver nitrate:

$$HIO_3 + AgNO_3 \longrightarrow HNO_3 + AgIO_3\downarrow$$

Place 2 mL of the periodic acid reagent solution in a small test tube.

Add 2 drops of concentrated nitric acid and mix the solution thoroughly. Add 2 drops of a liquid unknown (~2–5 mg of a solid) and mix again. Now add 2–3 drops of 5% aqueous silver nitrate solution. An *instantaneous white precipitate* constitutes a positive test.

α-Hydroxyaldehydes, α-hydroxyketones, α-hydroxyacids, 1,2-diketones, and α-aminoalcohols also give a positive test.

Aldehydes and Ketones

The 2,4-Dinitrophenylhydrazine Test

INSTRUCTOR PREPARATION. The reagent solution is prepared by dissolving 1.0 g of 2,4-dinitrophenylhydrazine in 5.0 mL of concentrated sulfuric acid. This solution is slowly added, with stirring, to a mixture of 10 mL of water and 35 mL of 95% ethanol. After mixing, filter the solution.

Aldehydes and ketones react rapidly with 2,4-dinitrophenylhydrazine to form 2,4-dinitrophenylhydrazones. These derivatives range in color from *yellow* to *red*, depending on the degree of conjugation in the carbonyl compound:

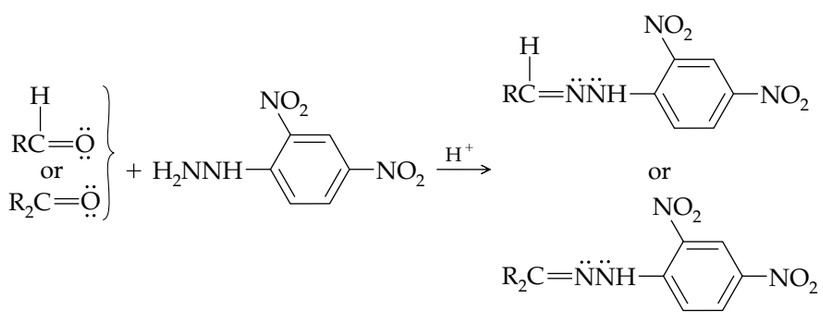

2,4-Dinitrophenylhydrazine

Yellow-to-red precipitate

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EQA

On a white spot plate place 7–8 drops of 2,4-dinitrophenylhydrazine reagent solution.

Then add 1 drop of a liquid unknown. If the unknown is a solid, add 1 drop of a solution prepared by dissolving 10 mg of the material in 10 drops of ethanol. The mixture is stirred with a thin glass rod. The formation of a red-to-yellow precipitate is a positive test.

NOTE. The reagent, 2,4-dinitrophenylhydrazine, is orange-red and melts at 198 °C (dec). Do not mistake it for a derivative!

Reactive esters or anhydrides react with the reagent to give a positive test. Allylic or benzylic alcohols may be oxidized to aldehydes or ketones, which in turn give a positive result. Amides do not interfere with the test. Be sure that your unknown is pure and does not contain aldehyde or ketone impurities.

Phenylhydrazine and *p*-nitrophenylhydrazine are often used to prepare the corresponding hydrazones. These reagents also yield solid derivatives of aldehydes and ketones.

Silver Mirror Test for Aldehydes: Tollens Reagent. This reaction involves the oxidation of aldehydes to the corresponding carboxylic acid, using an alcoholic solution of silver ammonium hydroxide. A positive test is the formation of a *silver* mirror, or a black precipitate of finely divided silver:

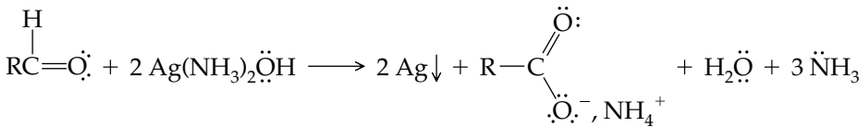

The test should be run only after the presence of an aldehyde or ketone has been established.

In a small test tube prepared from a Pasteur pipet (see the Lucas test) place 1.0 mL of a 5% aqueous solution of $AgNO_3$, followed by 1 drop of aqueous 10% NaOH solution. Now add concentrated aqueous ammonia, drop by drop (2–4 drops) with shaking, until the precipitate of silver oxide just dissolves. Add 1 drop of the unknown (10 mg if a solid), with shaking, and allow the reaction mixture to stand for 10 min at room temperature. If no reaction has occurred, place the test tube in a sand bath at 40 °C for 5 min. Observe the result.

Additional points to consider:

1. Avoid a large excess of ammonia.

2. Reagents must be well mixed. Stirring with a thin glass rod is recommended.

CAUTION

3. *This reagent is freshly prepared for each test. It should not be stored since decomposition occurs with the formation of AgN_3, which is explosive.*

4. This oxidizing agent is very mild and thus alcohols are not oxidized under these conditions. Ketones do not react. Some sugars, acyloins, hydroxylamines, and substituted phenols do give a positive test.

Chromic Acid Test

INSTRUCTOR PREPARATION. The reagent is prepared by dissolving 1 g of chromium trioxide in 1 mL of concd H_2SO_4, followed by 3 mL of H_2O.

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EQA

Chromic acid in acetone rapidly oxidizes aldehydes to carboxylic acids. Ketones react very slowly, or not at all.

In a 3-mL vial or small test tube, place 2 drops of a liquid unknown (~10 mg if a solid) and 1 mL of spectral-grade acetone. Now add several drops of the chromic acid reagent.

A green precipitate of chromous salts is a positive test. Aliphatic aldehydes give a precipitate within 30 s; aromatic aldehydes take 30–90 s.

The reagent also reacts with primary and secondary alcohols (see Chromic Anhydride Test: Jones Oxidation, p. 640).

Bisulfite Addition Complexes

INSTRUCTOR PREPARATION. The reagent is prepared by mixing 1.5 mL of ethanol and 6 mL of a 40% aqueous solution of sodium bisulfite. Filter the reagent before use, if a small amount of the salt does not dissolve.

Most aldehydes react with a saturated sodium bisulfite solution to yield a crystalline bisulfite addition complex:

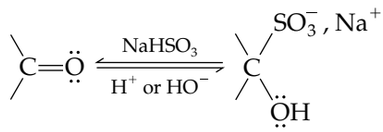

The reaction is reversible and thus the carbonyl compound can be recovered by treatment of the complex with aqueous 10% $NaHCO_3$ or dilute HCl solution.

Place 50–75 μL of the liquid unknown in a small test tube and add 150 μL of the sulfite reagent and mix thoroughly.

A crystalline precipitate is a positive test.

Alkyl methyl ketones and unhindered cyclic ketones also give a positive test.

Alkanes and Cycloalkanes: Saturated Hydrocarbons

Iodine Charge-Transfer Complex. Alkanes exhibit a *negative* iodine charge-transfer complex test. Species containing π electrons or nonbonded electron pairs produce a brown solution. This color formation is due to the charge-transfer complex between iodine and the available electrons:

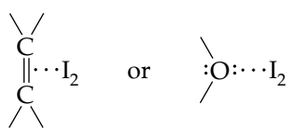

Solutions of iodine and nonparticipating compounds are violet in color.

On a white spot plate, place a small crystal of iodine. Now add 2–3 drops of a liquid unknown. Alkanes give a *negative* test (violet color).

The test is run only on liquid unknowns. Saturated hydrocarbons, fluorinated and chlorinated saturated hydrocarbons, and aromatic hydrocarbons and their halogenated derivatives all give violet solutions. All other species give a positive test (brown solution).

Concentrated Sulfuric Acid. Saturated hydrocarbons, halogenated saturated hydrocarbons, simple aromatic hydrocarbons, and their halogenated derivatives are insoluble in *cold* concentrated sulfuric acid.

CAUTION In a small test tube, using **caution,** place 100 μL of *cold* concentrated sulfuric acid. Now add 50 μL of an unknown. A resulting heterogeneous solution (the unknown does *not* dissolve) is a positive test for a saturated hydrocarbon.

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EQA

Alkenes, and compounds having a functional group containing a nitrogen or oxygen atom, are soluble in cold, concentrated acid.

Alkenes and Alkynes: Unsaturated Hydrocarbons

Bromine in Methylene Chloride. Unsaturated hydrocarbons readily add bromine (Br_2). An example of this reaction is given in Experiment [F2]:

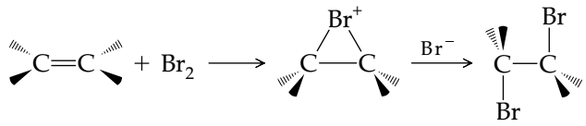

The test is based on the decolorization of a red-brown bromine–methylene chloride solution.

CAUTION: Bromine is highly toxic and can cause burns. CAUTION

In a 10 × 75-mm test tube, or in a small tube prepared from a Pasteur pipet (see Lucas test), place 2 drops of a liquid unknown (~15 mg if a solid) followed by 0.5 mL of methylene chloride. Add dropwise, in the **hood** with shaking, a 2% solution of bromine in methylene chloride solvent. The presence of an unsaturated hydrocarbon will require 2–3 drops of the reagent before the reddish-brown color of bromine persists in the solution. HOOD

Additional points to consider:

1. Methylene chloride is used in place of the usual carbon tetrachloride (CCl_4) because it is less toxic.

2. Phenols, enols, amines, aldehydes, and ketones interfere with this test.

Permanganate Test: Baeyer Test for Unsaturation. Unsaturation in an organic compound can be detected by the decolorization of permanganate solution. The reaction involves the cis hydroxylation of the alkene to give a 1,2 diol (glycol):

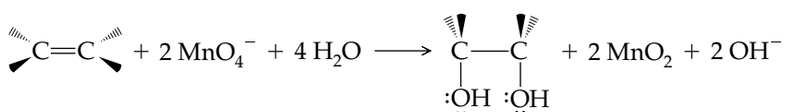

On a white spot plate, place 0.5 mL of *alcohol-free* acetone, followed by 2 drops of the unknown compound (~15 mg if a solid). Now add dropwise (2–3 drops), with stirring, a 1% aqueous solution of potassium permanganate ($KMnO_4$). A positive test for unsaturation is the discharge of purple permanganate color from the reagent and the precipitation of brown manganese oxides.

Any functional group that undergoes oxidation with permanganate interferes with the test (phenols, aryl amines, most aldehydes, primary and secondary alcohols, etc.).

Alkyl Halides

Silver Nitrate Test. Alkyl halides that undergo the S_N1 substitution reaction react with alcoholic silver nitrate ($AgNO_3$) to form a precipitate of the corresponding silver halide.

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EQA

Secondary and primary halides react slowly or not at all at room temperature. However, they do react at elevated temperatures. Tertiary halides react immediately at room temperature.

In a 1.0-mL conical vial place 0.5 mL of 2% ethanolic $AgNO_3$ solution and 1 drop of unknown (~10 mg if a solid). A positive test is indicated by the appearance of a precipitate within 5 min. If no reaction occurs, add a boiling stone and equip the vial with an air condenser. Heat the solution at *gentle* reflux for an additional 5 min using a sand bath. Cool the solution.

If a precipitate is formed, add 2 drops of dilute HNO_3. Silver halides will not dissolve in nitric acid solution.

Additional points to consider:

1. The order of reactivity for R groups is allyl ≅ benzyl > tertiary > secondary > > > primary. For the halide leaving groups the order is I > Br > Cl.

2. Acid halides, α-haloethers, and 1,2-dibromo compounds also give a positive test at room temperature. Only activated aryl halides give a positive test at elevated temperatures.

Sodium Iodide in Acetone

INSTRUCTOR PREPARATION. The reagent is prepared by dissolving 3 g of sodium iodide (NaI) in 25 mL of acetone. Store in a dark bottle.

Primary alkyl chlorides and bromides can be distinguished from aryl and alkenyl halides by reaction with sodium iodide in acetone (Finkelstein reaction):

$$\underset{X = Cl, Br}{R{-}X} + NaI \xrightarrow{\text{acetone}} R{-}I + NaX\downarrow$$

Primary alkyl bromides undergo an S_N2 displacement reaction within 5 min at room temperature, and primary alkyl chlorides only at 50 °C.

In a 1.0-mL conical vial, place 1 drop of a liquid unknown (~10 mg if a solid) and 3 drops of acetone. To this solution add 0.5 mL of sodium iodide–acetone reagent.

A positive test is the appearance of a precipitate of NaX within 5 min. If no precipitate is observed, add a boiling stone and equip the vial with an air condenser. Warm the reaction mixture in a sand bath at about 50 °C for 5 min. Cool to room temperature and determine whether a reaction has occurred.

Additional points to consider:

1. Benzylic and allylic chlorides and bromides, acid chlorides and bromides, and α-haloketones, α-haloesters, α-haloamides, and α-halonitriles also give a positive test at room temperature.

2. Primary and secondary alkyl chlorides, and secondary and tertiary alkyl bromides, react at 50 °C under these conditions.

3. If the solution turns red brown in color, iodine is being liberated.

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EQA

Amides, Ammonium Salts, and Nitriles

Hydroxamate Test for Amides. Unsubstituted (on nitrogen) amides, and the majority of substituted amides, will give a positive hydroxamate test:

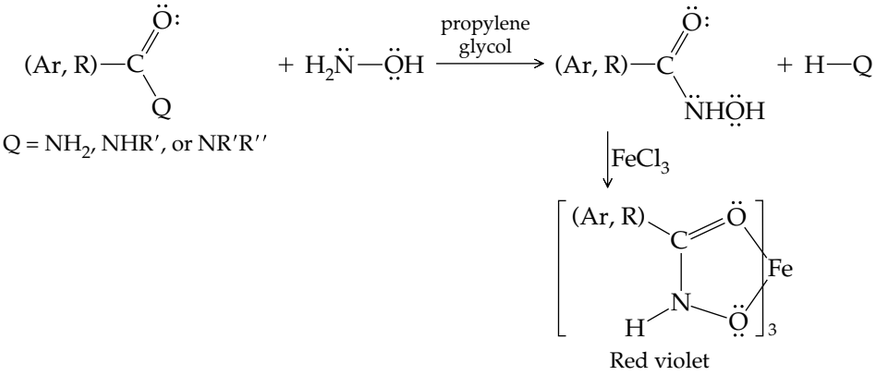

The hydroxamic acid is identified by formation of a red-to-purple color in the presence Fe^{3+} of ion, as for the test with esters (see page 650).

In a 3.0-mL conical vial containing a boiling stone and equipped with an air condenser place 1 drop of a liquid unknown (~10 mg if a solid), followed by 0.5 mL of 1 M hydroxylamine hydrochloride–propylene glycol solution. Heat the resulting mixture to reflux temperature (~190 °C) using a sand bath, and reflux for 3–5 min. Cool the solution to room temperature, and add 2 drops of 5% aqueous $FeCl_3$ solution. The formation of a red-to-purple color is a positive test.

Alkaline Hydrolysis. Ammonium salts, amides, and nitriles undergo hydrolysis in alkaline solution to form ammonia gas, or an amine:

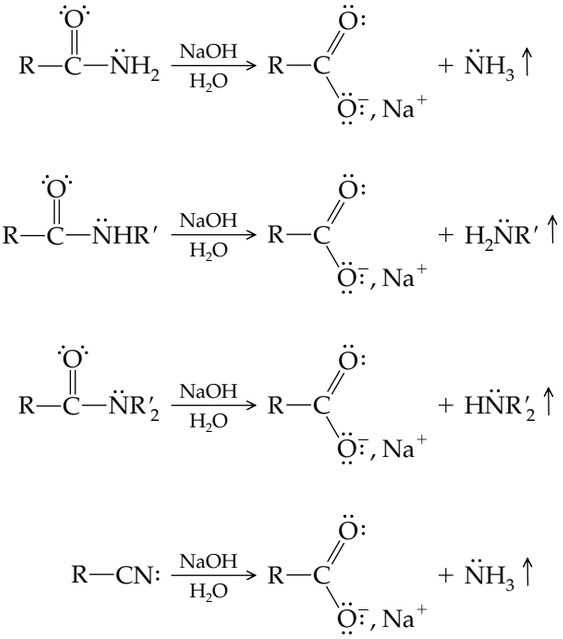

Detection of ammonia from ammonium salts, primary amides, and nitriles, by use of a color test using copper sulfate solution, constitutes a positive test for these functional groups. The same test may also be used for secondary

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EQA

and tertiary amides that can generate low molecular weight (volatile) amines upon hydrolysis.

In a 1.0-mL conical vial containing a boiling stone, and equipped with an air condenser, place 1–2 drops of the unknown liquid (~10 mg if a solid) and 0.5 mL of 20% aqueous NaOH solution. Heat this mixture to *gentle* reflux on a sand bath. Moisten a strip of filter paper with 2 drops of 10% aqueous copper sulfate solution and place it over the top of the condenser. Formation of a *blue* color (copper ammonia [or amine] complex) is a positive test.

The filter paper may be held in place using a small test tube holder or other suitable device.

Amines

Copper Ion Test. Amines will give a blue-green coloration or precipitate when added to a copper sulfate solution. In a small test tube, place 0.5 mL of a 10% copper sulfate solution. Now add 1 drop of an unknown (~10 mg if a solid). The blue-green coloration or precipitate is a positive test. Ammonia will also give a positive test.

Hinsberg Test. The Hinsberg test is useful for distinguishing between primary, secondary, and tertiary amines. The reagent used is *p*-toluenesulfonyl chloride in alkaline solution.

Primary amines with fewer than seven carbon atoms form a sulfonamide that is soluble in the alkaline solution. Acidification of the solution results in the precipitation of the insoluble sulfonamide:

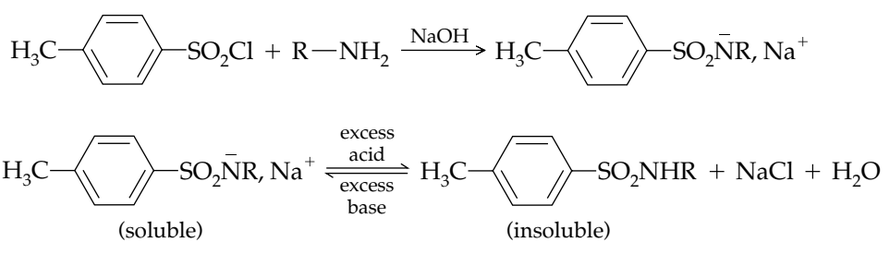

Secondary amines form an insoluble sulfonamide in the alkaline solution:

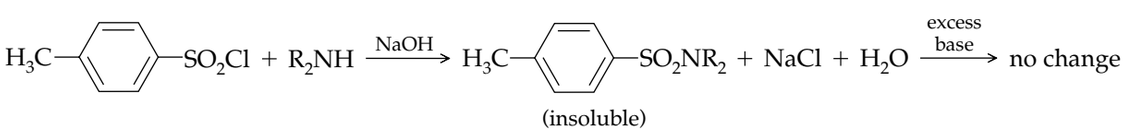

Tertiary amines normally give no reaction under these conditions:

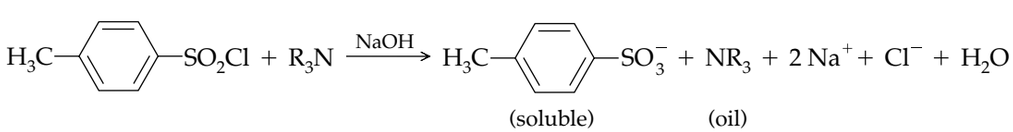

HOOD

In a 1.0-mL conical vial containing a boiling stone, and equipped with an air condenser, place 0.5 mL of 10% aqueous sodium hydroxide solution, 1 drop of the sample unknown (~10 mg if a solid), followed by 30 mg of *p*-toluenesulfonyl chloride (in the **hood**). Heat the mixture to reflux for 2–3 min

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EQA

on a sand bath, and then cool it in an ice bath. Test the alkalinity of the solution using litmus paper. If it is not alkaline, add additional 10% aqueous sodium hydroxide dropwise.

Using a Pasteur filter pipet, separate the solution from any solid that may be present. Transfer the solution to a clean 1.0-mL conical vial and **save.** SAVE

NOTE. If an oily upper layer is obtained at this stage, remove the lower alkaline phase using a Pasteur filter pipe and ***save.*** *To the remaining oil add 0.5 mL of cold water and stir vigorously to obtain a solid material.* SAVE

If a solid is obtained, it may be (1) the sulfonamide of a secondary amine; (2) recovered tertiary amine, if the original amine was a solid; or (3) the insoluble salt of a primary sulfonamide derivative, if the original amine had more than six carbon atoms.

Additional points to consider:

1. If the solid is a tertiary amine, it is soluble in aqueous 10% HCl.
2. If the solid is a secondary sulfonamide, it is insoluble in aqueous 10% NaOH.
3. If no solid is present, acidify the alkaline solution by addition of 10% aqueous HCl. If the unknown amine is primary, the sulfonamide will precipitate.

Bromine Water. Aromatic amines, since they possess an electron-rich aromatic ring, can undergo electrophilic aromatic substitution with bromine, to yield the corresponding arylamino halide(s). Therefore, if elemental tests indicate that an aromatic group is present in an amine, treatment with the bromine water reagent may indicate that the amine is attached to an aromatic ring.

For the test, see Phenols and Enols (p. 653).

Aromatic Hydrocarbons with NO Functional Groups

Fuming Sulfuric Acid. Simple aromatic hydrocarbons are insoluble in sulfuric acid (H_2SO_4) but are soluble in fuming sulfuric acid. If these hydrocarbons contain more than two alkyl substituents, they may be sulfonated under these conditions.

In a small test tube place 100 μL of fuming sulfuric acid, using **caution.** CAUTION Now add 50 μL of the unknown suspected to be aromatic. A resulting homogeneous solution is a positive test.

Azoxybenzene and Aluminum Chloride. This color test is run only on those aromatic compounds that are insoluble in sulfuric acid (see previous test). The color produced in this test results from the formation of a complex of $AlCl_3$ and a *p*-arylazobenzene derivative:

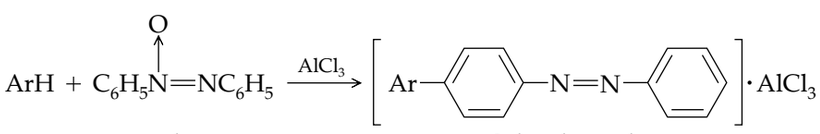

Azoxybenzene — Colored complex

In a small dry test tube, place 250 μL of the aromatic unknown. Add a small crystal of azoxybenzene and about 12 mg of anhydrous aluminum chloride. If a color is not produced immediately, warm the mixture for a few minutes.

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EQA

Aryl halides and other simple aromatic hydrocarbons give a deep-orange to dark-red color or precipitate. Polynuclear aromatic hydrocarbons, such as naphthalenes and anthracenes, give brown colors. Aliphatic hydrocarbons give no color, or at most a light yellow tint.

Carboxylic Acids

The presence of a carboxylic acid is detected by its solubility behavior. An aqueous solution of the acid will be acidic to litmus paper (or pH paper may be used). Since a sulfonic acid would also give a positive test, the test for sulfur (sodium fusion) is used to distinguish between the two types of acids. A water-soluble phenol is acidic toward litmus paper but also would give a positive ferric chloride test.

Carboxylic acids also react with a 5% solution of sodium bicarbonate (see Experiment [4B]).

Place 1–2 mL of the bicarbonate solution on a watch glass and add 1–2 drops of the acid (~10 mg if a solid). Gas bubbles of CO_2 constitute a positive test.

Esters

Hydroxamate Test. Carboxylic esters can be identified by conversion to hydroxamic acid salts. Acidification of this salt produces the corresponding hydroxamic acid (RCONHOH), which is identified by formation of a red-to-purple color in the presence of Fe^{3+} ion:

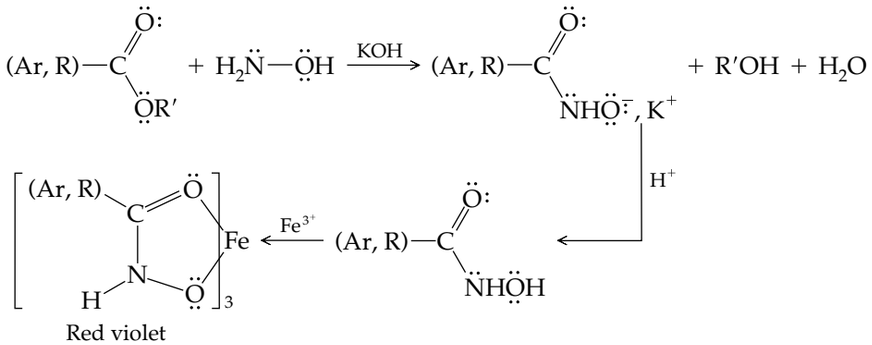

Red violet

In a 3.0-mL conical vial containing a boiling stone, and equipped with an air condenser, place 1 drop of the liquid unknown (~10 mg if a solid) followed by 0.5 mL of 1.0 M ethanolic hydroxylamine hydrochloride solution. Add 10% methanolic KOH to this solution (dropwise) until the resulting solution has pH ~10 (pH paper). Heat this mixture to reflux temperature using a sand bath for 5 min, cool to room temperature, and acidify to pH = 3–4 by dropwise addition of 5% aqueous HCl solution. Now add 2 drops of 5% aqueous $FeCl_3$ solution. The formation of a red-to-purple color is a positive test.

Additional points to consider:

1. It is suggested that a blank be run for comparison purposes.
2. Acid chlorides, anhydrides, lactones, and imides also give a positive test.

Saponification. This well-known reaction of esters can often be used to classify these compounds. It also may lead to a useful derivative if the corresponding carboxylic acid is isolated.

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In a 3.0-mL conical vial containing a magnetic spin vane, place 100 μL of the liquid unknown (~150 mg if a solid) and add 1 mL of 6 M NaOH solution. Attach the vial to a reflux condenser. Now place the vial in a sand bath on a magnetic stirring hot plate and, with stirring, heat the mixture at reflux for 0.5 h, or until the solution becomes homogeneous.

A positive test is the disappearance of the organic layer (if the original unknown was water insoluble) or the lack of the usually pleasant aroma of the unknown ester.

High-boiling esters (bp > 200 °C) are usually not saponified under these conditions due to their low solubility in the aqueous solvent.

Ethers

CAUTION: Upon standing, ethers may form peroxides. Peroxides are very explosive. To test for the presence of these substances, use starch–iodide paper that has been moistened with 6 M HCl. Peroxides cause the paper to turn blue. To remove peroxides from ethers, pass the material through a short column of highly activated alumina (Woelm basic alumina, activity grade 1).[10] Always retest for peroxides before using the ether.

Ferrox Test. The ferrox test is a color test sensitive to oxygen, which may be used to distinguish ethers from hydrocarbons that, like most ethers, are soluble in sulfuric acid.

In a dry 10 × 75-mm test tube using a glass stirring rod, grind a crystal of ferric ammonium sulfate and a crystal of potassium thiocyanate. The ferric hexathiocyanatoferrate that is formed adheres to the rod.

In a second clean 10 × 75-mm test tube, place 2–3 drops of a liquid unknown. If dealing with a solid, use about 10 mg and add toluene until a saturated solution is obtained. Now, using the rod with the ferric hexathiocyanatoferrate attached, stir the unknown. *If the unknown contains oxygen, the ferrate compound dissolves and a reddish-purple color is observed.*

Some high-molecular-weight ethers do not give a positive test.

Bromine Water. Since the aromatic ring is electron rich, aromatic ethers can undergo electrophilic aromatic substitution with bromine to yield the corresponding aryl ether–halide(s). Therefore, if elemental tests indicate that an aromatic group is present in an ether, treatment with the bromine water reagent may substantiate the presence of an aryl ether.

For the test see Phenols and Enols (p. 653).

Methyl Ketones and Methyl Carbinols

Iodoform Test

INSTRUCTOR PREPARATION. Dissolve 3 g of KI and 1 g I_2 in 20 mL of water.

[10]Pasto, D. J.; Johnson, C. R.; Miller, M. J. *Experiments and Techniques in Organic Chemistry;* Prentice Hall: Englewood Cliffs, NJ, 1992, p. 33.

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The iodoform test involves hydrolysis and cleavage of methyl ketones to form a yellow precipitate of iodoform (CHI_3):

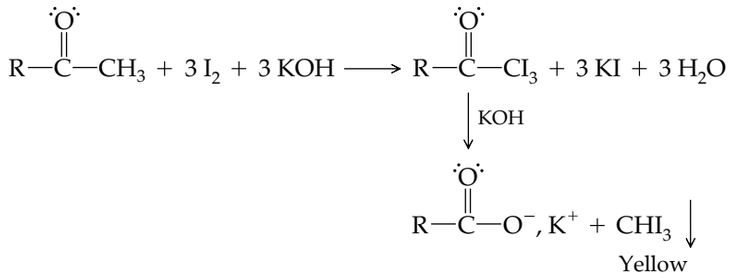

It is also a positive test for compounds that, upon oxidation, generate methyl ketones (or acetaldehyde) under these reaction conditions. For example, methyl carbinols (secondary alcohols having at least one methyl group attached to the carbon atom to which the —OH unit is linked), acetaldehyde, and ethanol give positive results.

In a 3.0-mL conical vial equipped with an air condenser, place 2 drops of the unknown liquid (10 mg if a solid), followed by 5 drops of 10% aqueous KOH solution.

HOOD *NOTE. If the sample is insoluble in the aqueous phase, either mix vigorously or add dioxane (in the* ***hood****) or bis(2-methoxyethyl) ether to obtain a homogeneous solution.*

Warm the mixture on a sand bath to 50–60 °C and add the KI–I_2 reagent dropwise until the solution becomes dark brown in color (~1.0 mL). Additional 10% aqueous KOH is now added (dropwise) until the solution is again colorless.

CAUTION CAUTION: Iodine is highly toxic and can cause burns.

After warming for 2 min, cool the solution and determine whether a yellow precipitate (CHI_3, iodoform) has formed. If a precipitate is not observed, reheat as before for another 2 min. Cool and check again for the appearance of iodoform.

Additional points to consider:

1. The iodoform test is reviewed elsewhere.[11]
2. An example of the general haloform reaction, using bleach to oxidize a methyl ketone, is given in Experiment [34].

Nitro Compounds

Ferrous Hydroxide Test. Many nitro compounds give a positive test based on the following reaction:

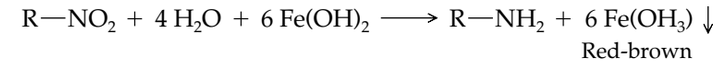

The nitro derivative oxidizes the iron(II) hydroxide to iron(III) hydroxide; the latter is a red-brown solid.

In a 1.0-mL conical vial place 5–10 mg of the unknown compound, followed by 0.4 mL of freshly prepared 5% aqueous ferrous ammonium sulfate

[11]Fuson, R. C.; Bull, B. A. *Chem. Rev.* **1934,** *15,* 275.

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solution. After mixing, add 1 drop of 3 M sulfuric acid followed by 10 drops of 2 M methanolic KOH. Cap the vial, shake vigorously, vent, and then allow it to stand over a 5-min period. The formation of a red-brown precipitate, usually within 1 min, is a positive test for a nitro group.

Sodium Hydroxide Color Test. Treatment of an aromatic nitro compound with 10% sodium hydroxide solution may often be used to determine the number of nitro groups present on the aromatic ring system.

Mononitro compounds produce no color (a light yellow may be observed).

Dinitro compounds produce a bluish-purple color.

Trinitro compounds produce a blood-red color.

The color formation is due to formation of Meisenheimer complexes (for a discussion, see Pasto et al.[12]).

To run the test, dissolve 10 mg of the unknown (1–2 drops if a liquid) in 1 mL of acetone in a small test tube. Now add about 200 μL of 10% NaOH solution and shake. Observe any color formation.

If amino, substituted amino, or hydroxyl groups are present in the molecule, a positive color test is not obtained.

Phenols and Enols

Ferric Ion Test. Most phenols and enols form colored complexes in the presence of ferric ion, Fe^{3+}:

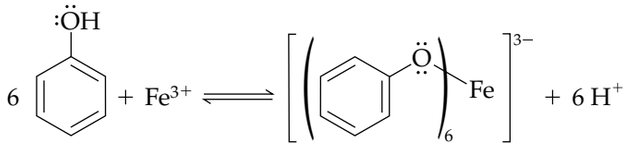

Phenols give red, blue, purple, or green colors. Sterically hindered phenols may give a negative test. Enols generally give a tan, red, or red-violet color.

On a white spot plate place 2 drops of water, or 1 drop of water plus 1 drop of ethanol, or 2 drops of ethanol, depending on the solubility characteristics of the unknown. To this solvent system add 1 drop (10 mg if a solid) of the substance to be tested. Stir the mixture with a thin glass rod to complete dissolution. Add 1 drop of 2.5% aqueous ferric chloride ($FeCl_3$) solution (light yellow in color). Stir and observe any color formation. If necessary, a second drop of the $FeCl_3$ solution may be added.

Additional points to consider:

1. The color developed may be fleeting or it may last for many hours. A slight excess of the ferric chloride solution may or may not destroy the color.
2. An alternative procedure using $FeCl_3$–CCl_4 solution in the presence of pyridine is available.[13]

[12]Pasto, D. J.; Johnson, C. R.; Miller, M. J. *Experiments and Techniques in Organic Chemistry;* Prentice Hall: Englewood Cliffs, NJ, 1992, p. 321.
[13]Soloway, S.; Wilen, S. H. *Anal. Chem.* **1952,** *4,* 979.

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Bromine Water. Phenols, substituted phenols, aromatic ethers, and aromatic amines, since the aromatic rings are electron rich, undergo aromatic electrophilic substitution with bromine to yield substituted aryl halides. For example,

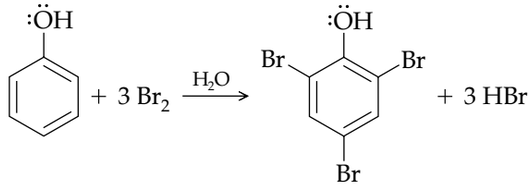

HOOD CAUTION: The test should be run in the **hood.**

In a small test tube, place 1–2 drops of the unknown (~20 mg if a solid) and add 1–2 mL of water. Check the pH of the solution with pH paper. In the HOOD **hood,** add saturated bromine water dropwise until the bromine color persists. A precipitate generally forms.

A positive test is the decolorization of the bromine solution, and often the formation of an off-white precipitate. If the unknown is a phenol, this should cause the pH of the original solution to be less than 7.

PREPARATION OF DERIVATIVES

Based on the preliminary and classification tests carried out to this point, you should have established the type of functional group (or groups) present (or lack of one) in the unknown organic sample. The next step in qualitative organic analysis is to consult a set of tables containing a listing of known organic compounds sorted by functional group and/or by physical properties or by both. Using the physical properties data for your compound, you can select a few possible candidates that appear to "fit" the data you have collected. On a chemical basis, the final step in the qualitative identification sequence is to prepare one or two *crystalline derivatives* of your compound. Selection of the specific compound, and thus final confirmation of its identity, can then be made from the extensive derivative tables that have been accumulated. With the advent of spectral analysis, the preparation of derivatives is often not necessary, but the wealth of chemistry that can be learned by the beginning student in carrying out these procedures is extensive and important. The preparation of selected derivatives for the most common functional groups are given below. Condensed tables of compounds and their derivatives are summarized www on the website, in Chapter 9W. For extensive tables and alternative derivatives that can be utilized, see the following Bibliography.

BIBLIOGRAPHY

Pasto, D. J.; Johnson, C. R.; Miller, M. J. *Experiments and Techniques in Organic Chemistry*; Prentice Hall: Englewood Cliffs, NJ, 1992.

Rappoport, Z. *Handbook of Tables for Organic Compound Identification,* 3rd ed.; CRC Press: Boca Raton, FL, 1967.

Shriner, R. L.; Hermann, C. K. F.; Morrill, T. C.; Fuson, R. C. *The Systematic Identification of Organic Compounds,* 8th ed.; Wiley: New York, 2003.

NOTE. In each of the procedures outlined below, drops of reagents are measured using Pasteur pipets.

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EQA

CARBOXYLIC ACIDS[14]

Preparation of Acid Chlorides

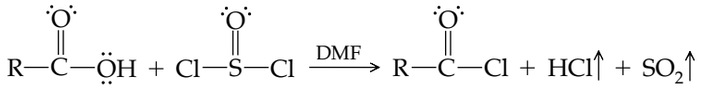

Weigh and place 20 mg of the unknown acid in a dry 3.0-mL conical vial containing a boiling stone and fitted with a cap. Now, in the **hood,** add 4 drops of HOOD
thionyl chloride and 1 drop of *N,N*-dimethylformamide (DMF). Immediately attach the vial to a reflux condenser that is protected by a calcium chloride drying tube.

CAUTION: This reaction is run in the **hood** since hydrogen chloride HOOD
and sulfur dioxide are evolved. Thionyl chloride is an irritant and is harmful to breathe. Immediately recap the vial after each addition until the vial is attached to the reflux condenser.

Allow the mixture to stand at room temperature for 10 min, heat it at gentle reflux on a sand bath for 15 min, and then cool it to room temperature. Dilute the reaction mixture with 5 drops of methylene chloride solvent.

The acid chloride is not isolated but is used directly in the preparations that follow.

Amides

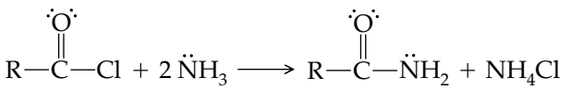

Cool the vial in an ice bath and add 10 drops of concentrated aqueous ammonia, in the **hood** via Pasteur pipet, *dropwise*, with stirring. *It is convenient to* HOOD
make this addition down the neck of the air condenser. The amide may precipitate during this operation. After the addition is complete, remove the ice bath and stir the mixture for an additional 5 min. Now add methylene chloride (10 drops) and stir the resulting mixture to dissolve any precipitate. Separate the methylene chloride layer from the aqueous layer using a Pasteur filter pipet and transfer it to another Pasteur filter pipet containing 200 mg of anhydrous sodium sulfate. Collect the eluate in a Craig tube containing a boiling stone. Extract the aqueous phase with an additional 0.5 mL of methylene chloride. Separate the methylene chloride layer as before and transfer it to the same column. Collect this eluate in the same Craig tube. Evaporate the methylene chloride solution using a warm sand bath in the **hood** under a gentle stream of nitrogen gas. HOOD
Recrystallize the solid amide product using the Craig tube. Dissolve the material in about 0.5 mL of ethanol, add water (dropwise) until the solution becomes cloudy, cool the Craig tube in an ice bath, and collect the crystals in the usual manner. Dry the crystalline amide on a porous clay plate and determine the melting point.

[14]See Tables 9W.1 and 9W.2.

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Anilides

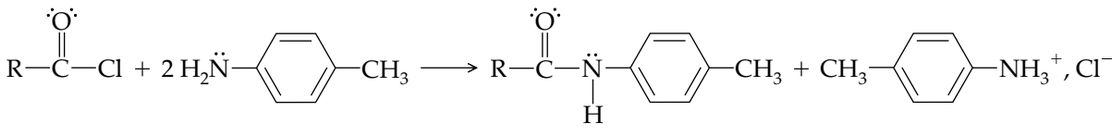

In a 3.0-mL conical vial containing a magnetic spin vane, and equipped with an air condenser, place 5 drops of aniline and 10 drops of methylene chloride. Cool the solution in an ice bath and transfer the acid chloride solution (prepared above) via Pasteur pipet, *dropwise*, with stirring, to the aniline solution in the **hood.** *It is convenient to make this addition down the neck of the condenser.* After the addition is complete, remove the ice bath and stir the mixture for an additional 10 min.

HOOD

Transfer the methylene chloride layer to a 10 × 75-mm test tube, and wash it with 0.5 mL of H_2O, 0.5 mL of 5% aqueous HCl, 0.5 mL of 5% aqueous NaOH, and, finally, 0.5 mL of H_2O. For each washing, shake the test tube and remove the top aqueous layer by Pasteur filter pipet. Transfer the resulting wet methylene chloride layer to a Pasteur filter pipet containing 200 mg of anhydrous sodium sulfate. Collect the eluate in a Craig tube containing a boiling stone. Rinse the original test tube with an additional 10 drops of methylene chloride. Collect this rinse and pass it through the same column. Both eluates are combined.

HOOD

Evaporate the methylene chloride solvent on a warm sand bath under a gentle stream of nitrogen gas in the **hood.** Recrystallize the crude anilide from an ethanol–water mixture using the Craig tube. Dissolve the material in about 0.5 mL of ethanol, add water (dropwise) to the cloud point, cool in an ice bath, and collect the crystals in the usual manner. Dry the purified derivative product on a porous clay plate, and determine its melting point.

Toluidides

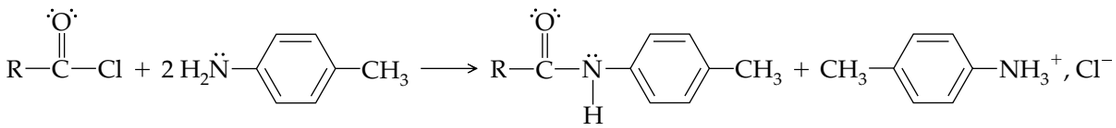

The same procedure described for the preparation of anilides is used, except that *p*-toluidine replaces the aniline.

ALCOHOLS[15]

Phenyl- and α-Naphthylurethanes (Phenyl- and α-Naphthylcarbamates)

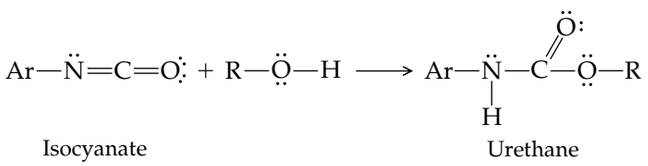

Isocyanate Urethane

www [15]See Table 9W.3.

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NOTE. For the preparation of these derivatives, the alcohols must be anhydrous. Water hydrolyzes the isocyanates to produce arylamines that react with the isocyanate reagent to produce high-melting, disubstituted ureas.

In a 3.0-mL conical vial containing a boiling stone and equipped with an air condenser protected by a calcium chloride drying tube place 15 mg of an anhydrous alcohol or phenol. Remove the air condenser from the vial and add 2 drops of phenyl isocyanate or α-naphthyl isocyanate. Replace the air condenser immediately. If the unknown is a phenol, add 1 drop of pyridine in a similar manner.

CAUTION: This addition must be done in the **hood.** The isocyanates are lachrymators! Pyridine has the characteristic strong odor of an amine.

If a spontaneous reaction does not take place, heat the vial at about 80–90 °C using a sand bath, for a period of 5 min. Then cool the reaction mixture in an ice bath. It may be necessary to scratch the sides of the vial to induce crystallization. Collect the solid product by vacuum filtration, using a Hirsch funnel, and purify it by recrystallization from ligroin. For this procedure, place the solid in a 10 × 75-mm test tube and dissolve it in 1.0 mL of warm (60–80 °C) ligroin. If diphenyl (or dinaphthyl) urea is present (formed by reaction of the isocyanate with water), it is insoluble in this solvent. Transfer the warm ligroin solution to a Craig tube using a Pasteur filter pipet. Cool the solution in an ice bath and collect the resulting crystals in the usual manner. After drying the product on a porous clay plate, determine the melting point.

3,5-Dinitrobenzoates

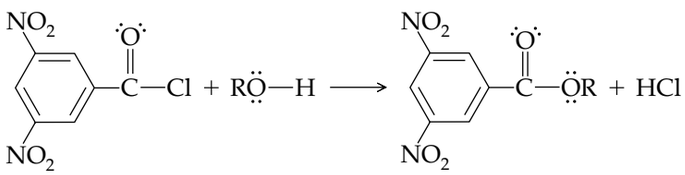

3,5-Dinitrobenzoyl chloride

NOTE. The dinitrobenzoyl chloride reagent tends to hydrolyze on storage to form the corresponding carboxylic acid. Check its melting point before use (3,5-dinitrobenzoyl chloride, mp = 74 °C; 3,5-dinitrobenzoic acid, mp = 202 °C)

In a 3.0-mL conical vial containing a boiling stone, and equipped with an air condenser protected by a calcium chloride drying tube, place 25 mg of pure 3,5-dinitrobenzoyl chloride and two drops of the unknown alcohol. Heat the mixture to about 10 °C below the boiling point of the alcohol (but not over 100 °C) on a sand bath for a period of 5 min. Cool the reaction mixture, add 0.3 mL of water, and then place the vial in an ice bath to cool. Collect the solid ester by vacuum filtration, using a Hirsch funnel, and wash the filter cake with three 0.5-mL portions of 2% aqueous sodium carbonate (Na_2CO_3) solution, followed by 0.5 mL of water. Recrystallize the solid product from an ethanol–water mixture using a Craig tube. Dissolve the material in about 0.5 mL of ethanol, add water (dropwise) until the solution is just cloudy, cool in an ice bath, and collect the crystals in the usual manner. After drying the product on a porous clay plate, determine the melting point.

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EQA

ALDEHYDES AND KETONES[16]

2,4-Dinitrophenylhydrazones

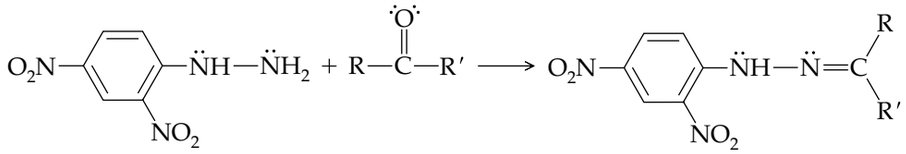

2,4-Dinitrophenylhydrazine — A 2,4-dinitrophenylhydrazone

The procedure outlined in the Classification Test Section for aldehydes and ketones (p. 642) is used. Since the derivative to be isolated is a solid, it may be convenient to run the reaction in a 3-mL vial or in a small test tube. Double the amount of the reagents used. If necessary, the derivative can be recrystallized from 95% ethanol.

The procedure is generally suitable for the preparation of phenylhydrazone and *p*-nitrophenylhydrazone derivatives of aldehydes and ketones.

Semicarbazones

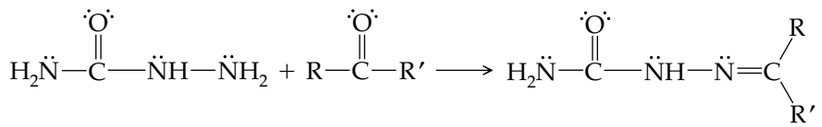

Semicarbazide — A semicarbazone

In a 3.0-mL conical vial place 12 mg of semicarbazide hydrochloride, 20 mg of sodium acetate, 10 drops of water, and 12 mg of the unknown carbonyl compound. Cap the vial, shake vigorously, vent, and allow the vial to stand at room temperature until crystallization is complete (varies from a few minutes to several hours). Cool the vial in an ice bath if necessary. Collect the crystals by vacuum filtration, using a Hirsch funnel, and wash the filter cake with 0.2 mL of cold water. Dry the crystals on a porous clay plate. Determine the melting point.

AMINES[17]

Primary and Secondary Amines: Acetamides

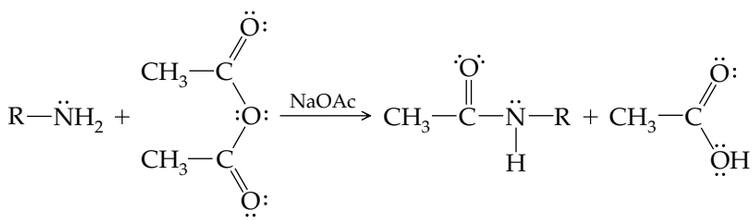

In a 3.0-mL conical vial equipped with an air condenser, place 20 mg of the unknown amine, 5 drops of water, and 1 drop of concentrated hydrochloric acid.

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www [16]See Tables 9W.4 and 9W.5.

www [17]See Tables 9W.6 and 9W.7.

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In a small test tube, prepare a solution of 40 mg of sodium acetate trihydrate dissolved in 5 drops of water. Stopper the solution and set it aside for use in the next step.

Warm the solution of amine hydrochloride to about 50 °C on a sand bath. Then cool it, and add 40 μL of acetic anhydride in one portion (in the **hood**) through the condenser by aid of a 9-in. Pasteur pipet. In like manner, *immediately* add the sodium acetate solution (prepared previously). Swirl the contents of the vial to ensure complete mixing. HOOD

Allow the reaction mixture to stand at room temperature for about 5 min, and then place it in an ice bath for an additional 5–10 min. Collect the white crystals by vacuum filtration, using a Hirsch funnel, and wash the filter cake with two 0.1-mL portions of water. The product may be recrystallized from ethanol–water using the Craig tube, if desired. Dry the crystals on a porous clay plate and determine the melting point.

Primary and Secondary Amines: Benzamides

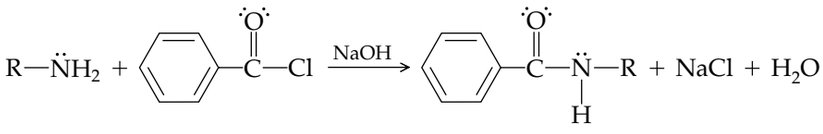

In a 3.0-mL conical vial in the **hood** place 0.4 mL of 10% aqueous NaOH solution, 25 mg of the amine, and 2–3 drops of benzoyl chloride. Cap and shake the vial over a period of about 10 min. Vent the vial periodically to release any pressure buildup. HOOD

Collect the crystalline precipitate by vacuum filtration, using a Hirsch funnel, and wash the filter cake with 0.1 mL of dilute HCl followed by 0.1 mL of water. It is generally necessary to recrystallize the material from methanol or aqueous ethanol using the Craig tube. Dry the product on a porous clay plate and determine the melting point.

Primary, Secondary, and Tertiary Amines: Picrates

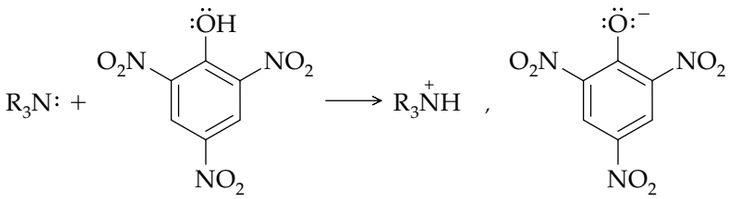

Picric acid Picrate salt

In a 3.0-mL conical vial containing a boiling stone and equipped with an air condenser, place 15 mg of the unknown amine and 0.3 mL of 95% ethanol.

NOTE. If the amine is not soluble in the ethanol, shake the mixture to obtain a saturated solution and then transfer this solution, using a Pasteur filter pipet, to another vial.

Now add 0.3 mL of a saturated solution of picric acid in 95% ethanol.

CAUTION: Picric acid explodes by percussion or when rapidly heated. CAUTION

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EQA

Heat the mixture at reflux, using a sand bath, for about 1 min and then allow it to cool slowly to room temperature. Collect the yellow crystals of the picrate by vacuum filtration, using a Hirsch funnel. Dry the material on a porous clay plate and determine the melting point.

ACID CHLORIDES AND ANHYDRIDES[18]

Amides

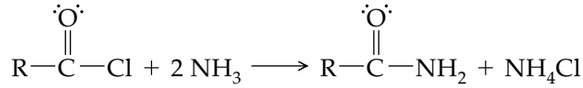

In a 10 × 75-mm test tube, place 0.4 mL of ice cold, concentrated ammonium hydroxide solution. To this solution, in the **hood,** slowly add, with shaking, about 15 mg of the unknown acid chloride or anhydride. Stopper the test tube and allow the reaction mixture to stand at room temperature for about 5 min. Collect the crystals by vacuum filtration, using a Hirsch funnel, and wash the filter cake with 0.2 mL of ice-cold water. Recrystallize the material, using a Craig tube, from water or an ethanol–water mixture. Dry the purified crystals on a porous clay plate and determine the melting point.

HOOD

AROMATIC HYDROCARBONS[19]

Picrates

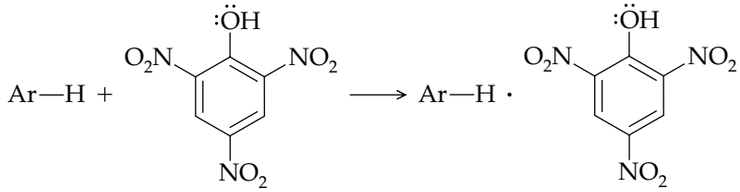

Picric acid Picrate complex

The procedure outlined on page 659 is used to prepare these derivatives.

NITRILES[20]

Hydrolysis to Amides

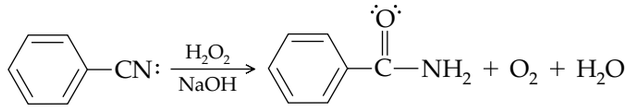

Conversion of nitriles to water-insoluble amides, by hydrolysis with alkaline hydrogen peroxide, is a possible method of characterization for these compounds. It is especially useful for aromatic nitriles.

www [18]See Table 9W.8.
www [19]See Table 9W.9.
www [20]See Table 9W.13.

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In a 5-mL conical vial containing a magnetic spin vane, weigh and place about 50 mg of the nitrile and 500 μL of a 1 M NaOH solution. Cool the mixture in a water bath and, with stirring, add dropwise 500 μL of 12% H_2O_2 solution. Attach the vial to an air condenser and warm the solution on a sand bath while stirring at 50–60 °C for approximately 45 min. To the cooled reaction mixture add 1–2 mL of cold water, and then collect the solid amide by vacuum filtration. Wash the product with two 1-mL portions of cold water, and recrystallize the amide from aqueous ethanol using the Craig tube. Dry the solid and determine the melting point.

PHENOLS[21]

α-Naphthylurethanes (α-Naphthylcarbamates)

The procedure outlined under Alcohols: Phenyl-, and α-Naphthylurethanes is used to prepare these derivatives (p. 656).

Bromo Derivatives

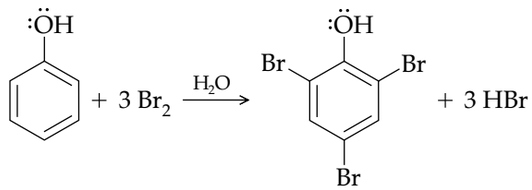

*INSTRUCTOR PREPARATION. The brominating reagent is prepared by adding 1.0 mL (3 g) of bromine in the **hood** to a solution of 4.0 g of KBr in 25 mL of water.* HOOD

In a 1.0-mL conical vial, place 10 mg of the unknown phenol followed by 2 drops of methanol and 2 drops of water. To this solution, in the **hood,** add 3 drops of brominating agent from a Pasteur pipet. HOOD

Continue the addition (dropwise) until the reddish-brown color of bromine persists. Now add water (4 drops), cap the vial, shake, vent, and then allow it to stand at room temperature for 10 min. Collect the crystalline precipitate by vacuum filtration using a Hirsch funnel and wash the filter cake with 0.5 mL of 5% aqueous sodium bisulfite solution. Recrystallize the solid derivative from ethanol, or from an ethanol–water mixture, using a Craig tube. Dissolve the material in about 0.5 mL of ethanol, add water until it becomes cloudy, cool in an ice bath, and collect the crystals in the usual manner. Dry the purified product on a porous clay plate and determine the melting point.

[21]See Table 9W.10.

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EQA

ALIPHATIC HYDROCARBONS, HALOGENATED HYDROCARBONS, AMIDES, NITRO COMPOUNDS, ETHERS, AND ESTERS[22]

These compounds do not give derivatives directly, but are usually converted into another material that can then be derivatized. The procedures are, for the most part, lengthy, and frequently give mixtures of products. It is recommended that compounds belonging to these classes be primarily identified using spectroscopic methods. Measurement of their physical properties is also of utmost importance.

QUESTIONS

9-1. The following six substances have approximately the same boiling point and are all colorless liquids. Suppose you were given six unlabeled bottles, each of which contained one of these compounds.

Explain how you would use simple chemical tests to determine which bottle contained which compound.

Ethanoic acid	Toluene
Propyl butanoate	Diisobutylamine
1-Butanol	Styrene

9-2. A colorless liquid (C_4H_6O) with a boiling point of 81 °C was found to be soluble in water and also in ether. It gave a negative test for the presence of halogens, sulfur, and nitrogen. It did, however, give a positive test with the Baeyer reagent and also gave a positive test with the 2,4-dinitrophenylhydrazine reagent. It gave negative results when treated with ceric nitrate solution and with Tollens reagent. Treatment with ozone followed by hydrolysis in the presence of zinc gave formaldehyde as one of the products.

What is the structure and name of the colorless liquid?

9-3. A colorless liquid, compound A (C_3H_6O), was soluble in water and ether, and had a boiling point of 94–96 °C. It decolorized a Br_2–CH_2Cl_2 solution and gave a positive ceric nitrate test. On catalytic hydrogenation it formed compound B (C_3H_8O), which did not decolorize the above bromine solution, but did give a positive ceric nitrate test. Treatment of compound A with ozone, followed by hydrolysis in the presence of zinc, gave formaldehyde as one of the products. Compound A formed an α-napthylurethane with a melting point of 109 °C.

What are the names and structures of compounds A and B?

9-4. A compound of formula $C_{14}H_{12}$ gave a positive Baeyer test and burned with a yellow, sooty flame. Treatment with ozone followed by hydrolysis in the presence of zinc gave formaldehyde as one of the products. Also isolated from the ozonolysis reaction was a second compound, $C_{13}H_{10}O$, which burned with a yellow, sooty flame, and readily formed a semicarbazone with a melting point of 164 °C. The ^{1}H NMR spectrum of this compound ($C_{13}H_{10}O$) showed only complex multiplets that were near 7.5 ppm; the fully ^{1}H-decoupled ^{13}C NMR spectrum showed only 5 peaks.

What are the structures and names of the two compounds?

9-5. Compound A ($C_7H_{14}O$) burned with a yellow, nonsooty flame and did not decolorize a bromine–methylene chloride solution. It did give a positive 2,4-dinitrophenylhydrazine test, but a negative Tollens test. Treatment of the compound with lithium aluminum hydride followed by neutralization with acid, produced compound B, which gave a positive Lucas test in about 5 min. Compound B also gave a positive ceric nitrate test. The ^{1}H NMR spectrum for compound A gave the following data:

1.02 ppm	9H, singlet
2.11 ppm	3H, singlet
2.31 ppm	2H, singlet

Give suitable structures for compounds A and B.

www → [22]See Tables 9W.11, 9W.12, and 9W.14–9W.17.

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EQA

9-6. A friend of yours, who is a graduate student attempting to establish the structure of a chemical species from field clover, isolated an alcohol that was found to have an optical rotation of +49.5°. Chemical analysis gave a molecular formula of $C_5H_{10}O$. It was also observed that this alcohol readily decolorized Br_2–CH_2Cl_2 solution. On this basis, the alcohol was subjected to catalytic hydrogenation and it was found to absorb 1 mol equivalent of hydrogen gas. The product of the reduction gave a positive ceric nitrate test, indicating that it, too, was an alcohol. However, the reduced compound was optically inactive.

Your friend has come to you for assistance in determining the structures of the two alcohols. What do you believe the structures are?

9-7. An unknown compound burned with a yellow, nonsmoky flame and was found to be insoluble in 5% sodium hydroxide solution but soluble in concentrated sulfuric acid. Measurement of its boiling point gave a range of 130–131 °C. Combustion analysis gave a molecular formula of C_5H_8O. It was found to give a semicarbazone with a melting point of 204–206 °C. However, it gave a negative result when treated with Tollens reagent and it did not decolorize the Baeyer reagent. It also gave a negative iodoform test.

Identify the unknown compound.

9-8. An unknown organic carboxylic acid, mp = 139–141 °C, burned with a yellow, sooty flame. The sodium fusion test showed that nitrogen was present. It did not react with *p*-toluenesulfonyl chloride, but did give a positive test when treated with 5% aqueous ferrous ammonium sulfate solution, acidified with 3 M H_2SO_4, and then followed by methanolic KOH solution. A 200-mg sample of the acid neutralized 12.4 mL of 0.098 M sodium hydroxide solution.

Identify the acid.

Does your structure agree with the calculated equivalent weight?

9-9. An unknown organic liquid, compound A, was found to burn with a yellow, sooty flame and give a positive Lucas test (~5 min). Upon treatment with sodium dichromate–sulfuric acid solution it produced compound B, which also burned with a yellow, sooty flame. Compound B gave a positive 2,4-dinitrophenylhydrazine test, but a negative result when treated with the Tollens reagent. However, compound B did give a positive iodoform test.

The 1H NMR spectrum for compound A showed the following:

1.4 ppm	3H (doublet)	4.8 ppm	1H (quartet)
1.9 ppm	1H (singlet)	7.2 ppm	5H (complex multiplet)

Give the structures and suitable names for compounds A and B.

9-10. A hydrocarbon, compound A (C_6H_{10}), burned with a yellow, almost nonsmoky flame. On catalytic hydrogenation over platinum catalyst it absorbed 1 mol of hydrogen to form compound B. It also decolorized a Br_2–CH_2Cl_2 solution to yield a dibromo derivative, compound C. Ozonolysis of the hydrocarbon gave only one compound, D. Compound D gave a positive iodoform test when treated with iodine–sodium hydroxide solution. On treatment of compound D with an alcoholic solution of silver ammonium hydroxide, a silver mirror was formed within a few minutes.

Identify the hydrocarbon A and compounds B–D.

9-11. A high-boiling liquid, bp = 202–204 °C burns with a yellow, sooty flame. Sodium fusion indicates that halogens, nitrogen, and sulfur are not present. The compound is not soluble in water, dilute sodium bicarbonate solution, or dilute hydrochloric acid. However, it proved to be soluble in 5% aqueous sodium hydroxide solution. The compound gives a purple color with ferric chloride solution and a precipitate when reacted with bromine–water. Treatment with hydroxylamine reagent did not give a reaction, but a white precipitate was obtained when the compound was treated with α-napthylisocyanate. On drying, this white, solid derivative had an mp = 127–129 °C. Identify the original liquid and write a structure for the solid derivative.

After identifying the unknown liquid, can you indicate what the structure of the precipitate obtained on reaction with bromine might be?

9-12. A colorless liquid, bp = 199–201 °C, burns with a yellow, sooty flame. The sodium fusion test proved negative for the presence of halogens, nitrogen, and sulfur. The compound was not soluble in water, 5% aqueous sodium hydroxide, or 5% hydrochloric acid. However, it dissolved in sulfuric acid with evolution of heat. It did not give a precipitate with 2,4-dinitrophenylhydrazine solution, and it did not decolorize bromine–methylene chloride solution. The unknown liquid did give a positive hydroxamate test and was found to have a saponification equivalent of 136.

Identify the unknown liquid.

9-13. Your friend of Question 9-6 still needs your help. A week later a low-melting solid, compound A, was isolated, which combustion analysis showed had composition $C_9H_{10}O$. The substance gave a precipitate when treated with 2,4-dinitrophenylhydrazine solution. Furthermore, when reacted with iodoform reagent, a yellow precipitate

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EQA

of CHI_3 was observed. Acidification of the alkaline solution from the iodoform test produced a solid material, compound B.

Reduction of compound A with $LiAlH_4$ gave compound C ($C_9H_{12}O$). Compound C also gave compound B when treated with iodoform reagent. Vigorous oxidation of compound A, B, or C with sodium dichromate–sulfuric acid solution gave an acid having an mp = 121–122 °C.

Your friend needs your assistance in determining the structures for compounds A, B, and C. Can you identify the three compounds?

9-14. An organic compound ($C_9H_{10}O$) showed strong absorption in the IR spectrum at 1735 cm^{-1} and gave a semicarbazone having a melting point of 198 °C. It burned with a yellow, sooty flame and also gave a positive iodoform test. The ^1H NMR spectrum of the compound provided the following information:

2.11 ppm	3H (singlet)
3.65 ppm	2H (singlet)
7.20 ppm	5H (complex multiplet)

Identify the unknown organic compound.

9-15. An unknown compound (A) was soluble in ether but only slightly soluble in water. It burned with a clear blue flame and combustion analysis showed it to have the molecular formula of $C_5H_{12}O$. It gave a positive test with the Jones reagent producing a new compound (B) with a formula of $C_5H_{10}O$. Compound B gave a positive iodoform test and formed a semicarbazone. Compound A on treatment with sulfuric acid produced a hydrocarbon (C) of formula C_5H_{10}. Hydrocarbon C readily decolorized a Br_2–CH_2Cl_2 solution, and on ozonolysis, produced acetone as one of the products.

Identify the structure of each of the lettered compounds.

9-16. Compound A (C_7H_{14}) decolorized a Br_2–CH_2Cl_2 chloride solution. It reacted with $18H_3 \cdot THF$ reagent, followed by alkaline peroxide solution, to produce compound B. Compound B, on treatment with chromic acid–sulfuric acid solution, gave carboxylic acid C, which could be separated into two enantiomers. Compound A, on treatment with ozone, followed by addition of hydrogen peroxide, produced compound D. Compound D was identical to that material isolated from the oxidation of 3-hexanol with chromic acid–sulfuric acid reagent.

Identify the structures of compounds A, B, C, and D.

9-17. Compound A (C_8H_{16}) decolorized a bromine–methylene chloride solution. Ozonolysis produced two compounds, B and C, which could be separated easily by gas chromatography. Both B and C gave a positive 2,4 dinitrophenylhydrazine test. Carbon–hydrogen analysis and molecular weight determination of B gave a molecular formula of $C_5H_{10}O$. The ^1H NMR spectrum revealed the following information for B:

0.92 ppm	3H, triplet	2.17 ppm	3H, singlet
1.6 ppm	2H, pentet	2.45 ppm	2H, triplet

Compound C was a low-boiling liquid (bp 56°C) The ^1H NMR of this material showed only one singlet.

Identify compounds A, B, and C.

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ADVANCED MICROSCALE ORGANIC LABORATORY EXPERIMENTS

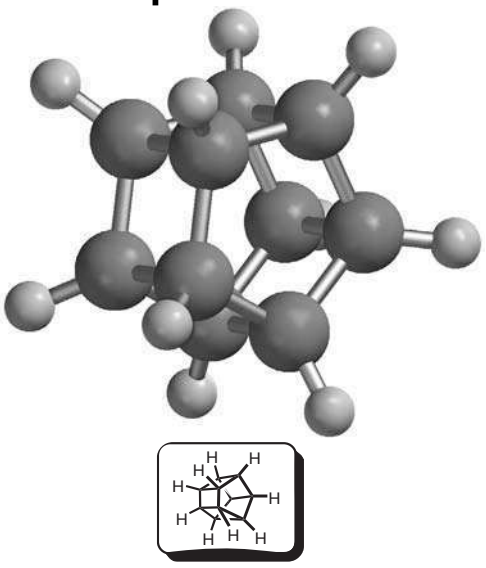

From a theoretical perspective, the chemistry described in this chapter is more demanding of the student–investigator than that described in Chapter 6.

1. The organic reactions performed are less familiar and are not as likely to be found in most introductory texts.
2. The mechanisms proposed for these systems are more involved and not generally developed at the introductory level.
3. Many of the reagents used are rarely used in the introductory organic laboratory.

Thus, the experiments contained in Chapter 10W are specifically tailored to challenge the more advanced undergraduate students, those who are already able to access the chemical literature. This chapter can also offer a special laboratory experience for those few beginning students who are particularly interested in the subject and wish to spend extra preparation time. The techniques involved are not, in most instances, any different from those used in the introductory microscale laboratory reactions described in Chapter 6, and therefore the manipulations involved should not be considered a barrier to undertaking any of the advanced experiments. The reaction conditions, however, are less forgiving to slight deviations from the suggested ones and the ultimate success of the transformations is less secure.

Thus, the experimentation contained in Chapter 10W can be adapted to several levels of undergraduate laboratory programs. For example, the study of these reactions can potentially make significant contributions to advanced undergraduate programs where microscale techniques are being introduced to research-oriented students for the first time.

The formats for the discussions and experimental procedures are similar to those used in Chapter 6. The reactions selected for study in this chapter include

- An unusual borane reduction of a carbonyl directly to a methylene group.
- The trapping of an α,β-unsaturated ketone as its enol acetate, by acylium ion formation with chlorotrimethylsilane and acetic anhydride.

Chapter 10W: $C_{10}H_{10}$, Housane
Eaton, Or, Branca and Shankar (1968).

- The synthesis of a heterocyclic ring using diethyl carbonate and sodium hydride. The discovery of the medicinal properties of this class of heterocycles led directly to modern anticoagulation therapy.
- The synthesis of an isotopically labeled molecule through the use of a unique Grignard cross-coupling reaction in the presence of dichloro[1,3-bis(diphenylphosphino)propane]nickel(II).
- An oxidative coupling of a naphthol by ferric chloride in a reaction that mimics nature's method of coupling phenolic substances into important pigments, such as hypericin (**I**):

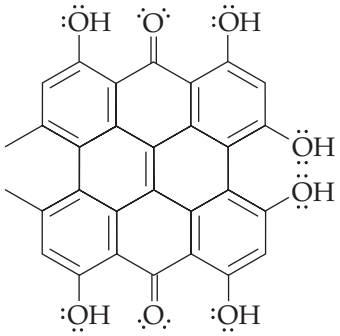

I

- An important molecular rearrangement of oximes to amides discovered by Ernst Otto Beckmann in 1886 and so named in his honor. The modern version uses one of the most powerful acid reagents used in organic chemistry, triflic acid.

The study of the reactions outlined in Chapter 10W should help to facilitate the student's smooth transition into the organic research laboratory. We hope you find the collection as exciting as we did.

EXPERIMENT [1 adv]

Diborane Reductions: Thioxanthene and Xanthene

Common name: thioxanthene
CA number: [261-31-4]
CA name as indexed: 9*H*-thioxanthene
Common name: xanthene
CA number: [92-83-1]
CA name as indexed: 9*H*-xanthene

Purpose. This experiment investigates an unusual example of a hydroboration in which a carbonyl group is directly and fully reduced to a methylene group by borane (BH_3). This example is an atypical reduction of an aldehyde or ketone, since the use of this reagent usually leads to the formation of the corresponding alcohol. You will explore the mechanistic rationale for this unexpected product.

Prior Reading

Standard Experimental Apparatus: Moisture Protected Reaction Apparatus (pp. 23–24)

Technique 6: Chromatography
Packing the Column (p. 93)
Elution of the Column (p. 94)

Technique 6B: Concentration of Solutions
Removal of Solvent Under Reduced Pressure (pp. 102-104)

NOTE. See Experiment [13] for a biography of Herbert C. Brown, Nobel Laureate, who discovered and developed the boron hydride reagents. This experiment also contains further details about the use of these powerful reagents, which have revolutionized reduction reactions in organic chemistry.

DISCUSSION

Borane is a useful and selective reducing agent. It is prepared by the reaction of boron trifluoride etherate with sodium borohydride. The borane produced, as the etherate, may be distilled as the dimer, which is a colorless, toxic gas (B_2H_6). Collection of the dimer distillate in tetrahydrofuran (THF) again forms the monomer, in this case as the $BH_3 \cdot$ THF complex. The latter is commercially available as a 1.0 M solution.

$$3\ NaBH_4 + 4\ BF_3 \cdot O(CH_2CH_3)_2 \longrightarrow 3\ NaBF_4 + 2\ B_2H_6\uparrow(gas)$$

Borane complexes can also be formed with other ethers, such as diethyl ether (as just discussed) or diglyme (diethylene glycol dimethyl ether). These complexes form readily because the ether, acting as a Lewis base (electron donor), can satisfy the electron-deficient boron atom, which acts as a Lewis acid (electron acceptor). Borane reacts rapidly with water, and therefore procedures using the $BH_3 \cdot$ THF complex must be conducted under anhydrous conditions.

Borane is a Lewis acid that is attacked by electron-rich centers. Thus, when aldehydes or ketones are treated with the $BH_3 \cdot$ THF complex, the borate ester (H_2B-OR) is rapidly formed, which, upon hydrolysis, gives the corresponding alcohol. The reduction of the carbonyl group is believed to take place by addition of the oxygen atom to the electron-deficient boron atom, followed by irreversible transfer of hydride ion from the now anionic boron to the carbon atom of the (former) carbonyl:

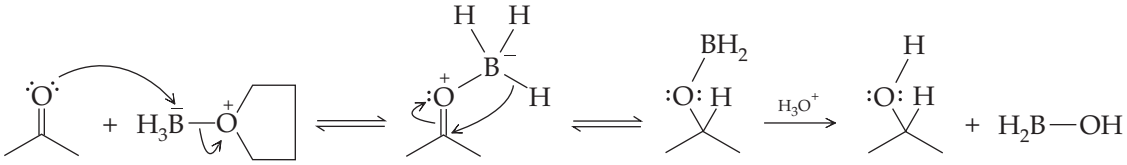

In the case of the xanthone and thioxanthone ring systems, the corresponding alcohol is not formed. The intermediate borate ester undergoes an elimination reaction, forming a borate anion and a resonance-stabilized carbocation. The second stage of the reaction is initiated by displacement of THF from

a second $BH_3 \cdot THF$ complex by a lone pair from either the oxygen atom of the xanthene carbocation or the sulfur atom of the thioxanthene carbocation. This *new complex* then undergoes an internal hydride ($:H^-$) transfer from boron to the C-9 ring position (this is the second hydride attack on this position in the overall reaction) to form a stable oxonium (or sulfonium) ion intermediate. On aqueous–alcohol workup of the reaction mixture the oxonium (sulfonium) product is quickly hydrolyzed to yield xanthene (or thioxanthene) possessing a fully reduced methylene group, $—CH_2—$, at the 9 position.

Conventional methods for the reduction of a carbonyl to a methylene group that do not require the conjugative assistance of a heteroatom are the well-known Clemmensen (Zn(Hg), HCl), and Wolff–Kishner (H_2NNH_2/KOH) reductions, and the desulfurization of the corresponding thioacetal with Raney nickel.

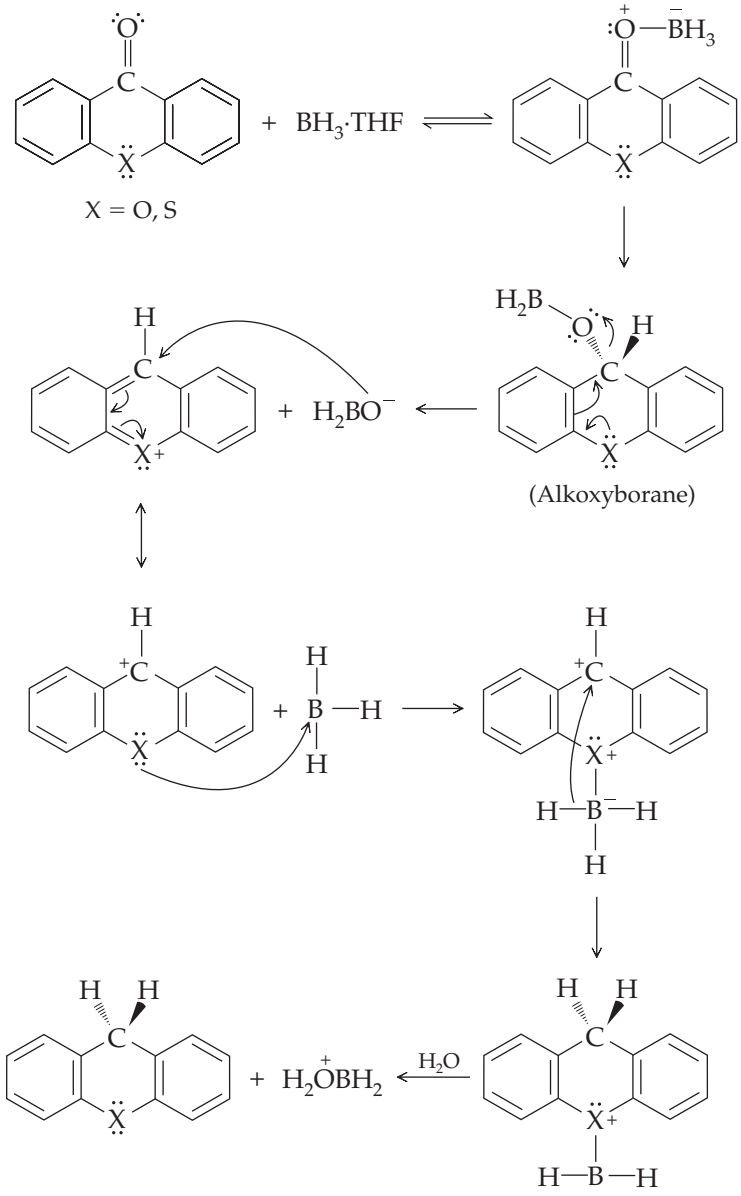

Thioxanthene

Experiment [1A$_{adv}$]

REACTION

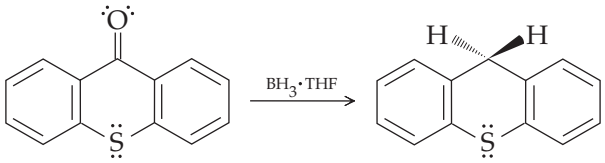

Thioxanthone Thioxanthene

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 1.5 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Thioxanthone	212.28	50 mg	0.24	209			
Tetrahydrofuran	72.12	1.7 mL			67	0.889	1.407
Borane · THF, 1 M		1.0 mL	1.0				

Reagents and Equipment. Attach a 5.0-mL conical vial containing a magnetic spin vane to a Claisen head. Then fit the Claisen head with a nitrogen inlet tube (prepared from a syringe) and a rubber septum. Weigh and add 50 mg (0.24 mmol) of thioxanthone to the conical vial.

Flush the reaction vial with a gentle stream of nitrogen gas for several minutes, add 1.7 mL of *dry* (see Note) tetrahydrofuran (THF) through the septum (syringe), and then place a small balloon over the Claisen-head outlet so as to maintain a dry atmosphere in the system (➨).

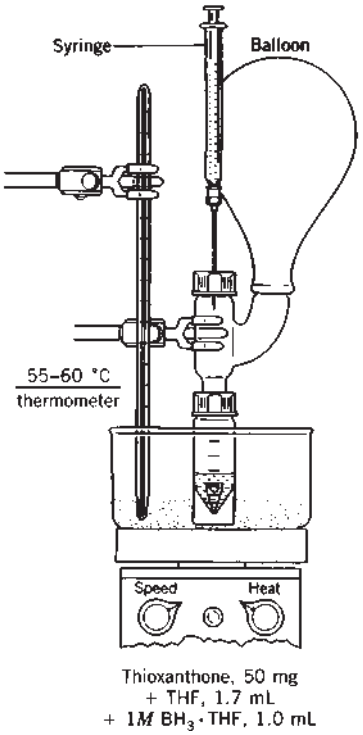

Thioxanthone, 50 mg
+ THF, 1.7 mL
+ 1*M* BH_3·THF, 1.0 mL

INSTRUCTOR'S NOTE. The THF must be ***absolutely*** *dry. It is recommended that HPLC grade reagent be used. If you do not have a fresh bottle, distill it once from calcium hydride (or sodium benzophenone ketyl) and store it over molecular sieves. It may be stored and used safely for up to a week without adversely affecting the yield of product.*

Heat the mixture with stirring in a sand bath at 55–60 °C until the thioxanthone dissolves, yielding a yellow solution. Then, with continued stirring, add 1.0 mL of a 1.0 M solution of BH_3 · THF in one portion through the rubber septum with a 1.0-mL syringe.

CAUTION: The BH_3 · THF solution reacts *violently* with water.

Reaction Conditions. Heat the solution with stirring in a sand bath at 55–60 °C for 5 min. The solution should become colorless during this time.

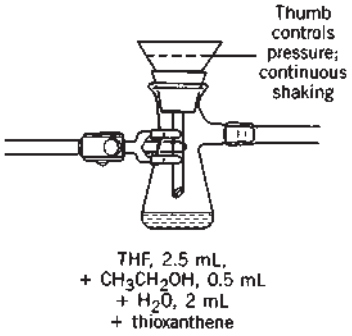

Isolation of Product. Quench the reaction by *carefully* adding dropwise approximately 10 drops of 95% ethanol (Pasteur pipet), with stirring, or until the observed foaming subsides. *The aqueous alcohol is added to decompose any unreacted $BH_3 \cdot THF$ reagent and to hydrolyze the sulfonium ion intermediate.*

After the solution has cooled to room temperature, transfer the mixture by Pasteur pipet to a 25-mL filter flask containing a boiling stone. Carefully remove roughly one-half of the tetrahydrofuran solvent under reduced pressure with continuous swirling of the flask (see Prior Reading) (⬅). Then, use a calibrated Pasteur pipet to add two 1.0-mL portions of water to the reaction mixture. Carefully remove the remaining tetrahydrofuran and ethanol solvent under reduced pressure with continuous swirling of the flask. As the tetrahydrofuran and ethanol evaporate, white crystals of thioxanthene appear, and a slurry of these crystals in water will remain in the flask after the tetrahydrofuran and ethanol are removed. Collect the product crystals under reduced pressure by use of a Hirsch funnel, and wash the filter cake on the Hirsch filter bed with two 1.0-mL portions of water. Dry the crystals in air on a porous clay plate or on filter paper.

Purification and Characterization. The thioxanthene product is essentially pure as isolated. It may be recrystallized from an ethanol–chloroform mixture, if necessary. Weigh the product and calculate the percent yield. Determine the melting point of the material and compare it with the value reported in the literature. Obtain IR spectra of thioxanthone and thioxanthene and compare them to each other as well as to those given in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Experiment [$1B_{adv}$]

Xanthene

REACTION

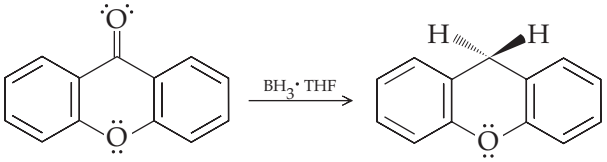

Xanthone Xanthene

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 3.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Xanthone	196.22	50 mg	0.26	174			
Tetrahydrofuran	72.12	0.7 mL			67	0.889	1.407
Borane • THF, 1 M		0.75 mL	0.75				

Reagents and Equipment. Using the experimental apparatus described in Experiment [$1A_{adv}$], weigh and place in the reaction flask 50 mg (0.26 mmol) of xanthone followed by 0.7 mL of dry THF (see Experiment [$1A_{adv}$], Reagents and Equipment). Maintain a dry nitrogen atmosphere in the system by the same procedure as used in Experiment [$1A_{adv}$]. Heat the reaction mixture, with stirring, to 55–60 °C using a sand bath. After the xanthone dissolves, use a 1.0-mL syringe to add, in one portion, 0.75 mL of a 1.0 M solution of $BH_3 \cdot$ THF through the rubber septum on the screw-cap port of the Claisen head.

CAUTION: The $BH_3 \cdot$ THF solution reacts *violently* with water.

Reaction Conditions. Stir the reaction solution in a sand bath at 55–60 °C for a period of 1 h.

Isolation of Product. While stirring the warm reaction mixture, quench the reaction by carefully adding (with a Pasteur pipet) 95% ethanol—approximately 10 drops of or until the observed foaming subsides. *The alcohol is added to decompose any unreacted $BH_3 \cdot$ THF reagent and to hydrolyze the oxonium ion intermediate.*

Transfer the solution by Pasteur pipet to a 25-mL filter flask containing a boiling stone. Remove roughly one-half of the tetrahydrofuran solvent under reduced pressure with continuous swirling of the flask (➡). Now add two 1.0-mL portions of water (calibrated Pasteur pipet) to the solution. Carefully remove the **remaining** tetrahydrofuran–ethanol solvent under reduced pressure with continuous swirling of the flask. As the tetrahydrofuran and ethanol are removed and the solution becomes more concentrated, white crystals of xanthene appear as a slurry in the remaining water. Collect the crystals under reduced pressure using a Hirsch funnel.

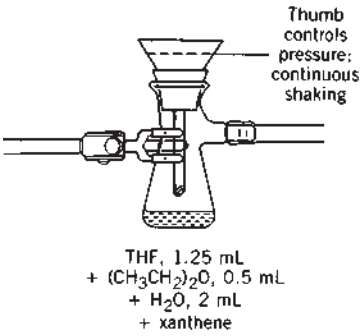

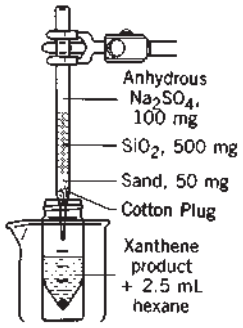

HOOD

Purification and Characterization. Purify the crude xanthene by column chromatography. Place 0.5 g of activated silica gel followed by 0.1 g of anhydrous sodium sulfate in a Pasteur filter pipet (➡).

Wet the column with a small amount of hexane, and then place a solution of the crude xanthene, dissolved in 0.25 mL of methylene chloride, on the column using a Pasteur filter pipet. Elute the xanthene by adding additional hexane (~2.5 mL). Collect the eluate in a tared 5-mL conical vial containing a boiling stone. Remove the hexane solvent by evaporation in the **hood** while warming in a sand bath to yield pure xanthene. This compound may be recrystallized from ethanol if further purification is found to be necessary after characterization of the product.

After air-drying, weigh the solid and calculate the percent yield of xanthene. Determine the melting point and compare it with the value found in the literature.

Obtain an IR spectrum of your xanthene, and compare the spectrum to that shown in Figure 10.1W.

In this experiment, the carbonyl group of an aromatic ketone was reduced to a methylene group. Examine the infrared spectra of the starting material and of the reduction product to see what evidence is present to indicate that the desired reaction has occurred.

Infrared Analysis. We will first consider the spectrum of xanthone (Fig. 10.2W). The macro group frequency associated with six-membered carbocyclic aromatic ring systems applies in this instance (peaks at 3100–3000, 1600, 1585, 1500, and 1450 cm^{-1}). This frequency train involves the bands located at

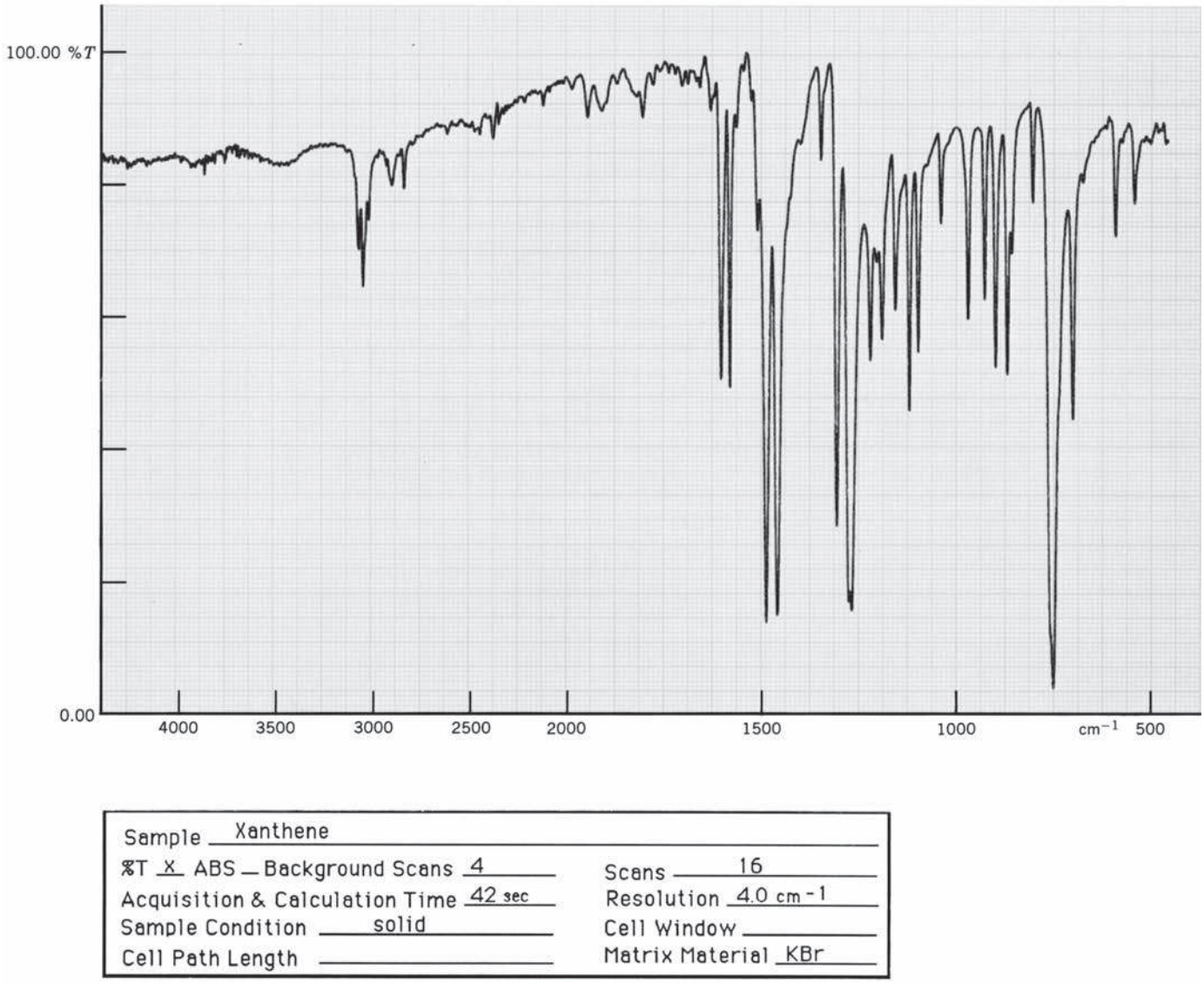

Figure 10.1W IR spectrum: xanthene.

3085–3020, 1610–1570, 1484, and 1460 cm^{-1}. These peaks are assigned as follows:

a. 3085–3020 cm^{-1}: C—H stretch on sp^2-hybridized carbon. The breadth and complexity of this set of absorption bands indicates the presence of a fairly complex aromatic system.

b. 1610–1570 cm^{-1}: The peaks observed in this region are related to the two degenerate fundamental stretching motions, ν_{8a} and ν_{8b}, of the simple aromatic ring system. Normally, ν_{8a} is found near 1600 cm^{-1} and is considerably more intense than $\nu_{8b,}$ which is located near 1580 cm^{-1}. In xanthone the situation is more complicated, because the central γ-pyrone ring introduces a pseudoaromatic six-membered ring system. Thus, this ring system might be expected to possess somewhat shifted fundamental frequencies for the carbon rings. It is not unexpected, then, that we observe a band system of four major components in this region.

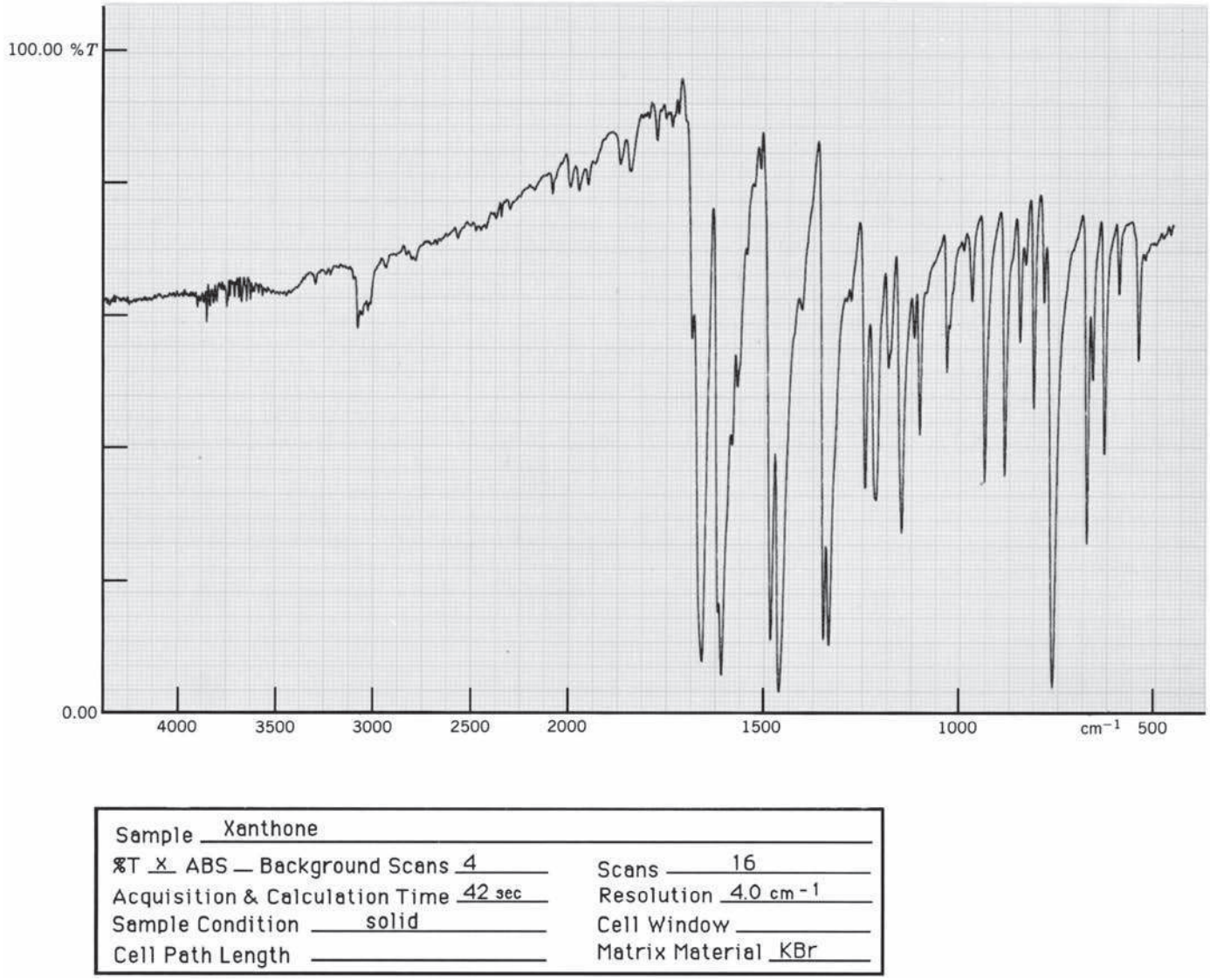

Figure 10.2W IR spectrum: xanthone.

c. 1484 and 1460 cm^{-1}: Aromatic ring stretch related to ν_{19a} and ν_{19b}. These frequencies are less disturbed by the presence of the pyrone system and occur near their expected locations of 1500 and 1450 cm^{-1}.

The very strong band at 756 cm^{-1}, in the absence of strong absorption near 700 cm^{-1}, is supporting evidence for the presence of four adjacent ring C—H groups, which implies ortho substitution.

The intense band observed at 1656 cm^{-1} is strong evidence for the presence of a highly conjugated carbonyl group, which, of course, is consistent with the structure of the starting material.

The IR spectrum of the product (Fig. 10.1W) supports the complete reduction to the methylene system. The macro group frequency train defined for six-membered carbocyclic aromatic systems still applies. The expected frequencies are very close to the observed values:

a. 3075–3025, 1603, 1589, 1490, and 1457 cm^{-1}.

b. The carbonyl band has vanished, and in its place two weak bands have arisen near 2902 and 2840 cm^{-1}. These latter peaks are assigned to the

antisymmetric and symmetric stretching modes of the newly formed methylene group.

c. The most intense band in the spectrum occurs at 750 cm^{-1} (four in a row, C—H all-in-phase, out-of-plane bend) and indicates that the basic substitution pattern has not changed on the ring system during the reaction.

QUESTIONS

10W-1. In the reaction performed in this experiment, assume that the first stage of the reaction is the rate-determining step. Would you then predict that the relative rate of reduction of the carbonyl group in compound A to the methylene group to be faster or slower than that of xanthone under the conditions of this experiment? Explain.

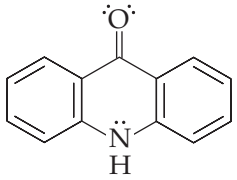

Compound A

10W-2. The reduction of aldehydes or ketones to the methylene group occurs with hydride reagents only when some special feature of the substrate promotes cleavage of the C—OH linkage. Suggest a suitable mechanism by which the reductions given below might occur.

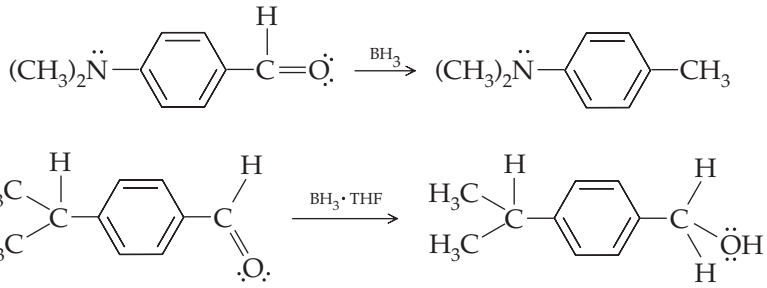

10W-3. Borane also forms complexes with sulfides and amines. Draw a suitable structure to represent the complex formed between BH_3 and dimethyl sulfide, and also that formed between BH_3 and triethylamine.

10W-4. Using your lecture textbook as a reference, find three different methods for the conversion of 4-methylcyclohexanone to methylcyclohexane.

10W-5. The infrared spectrum of the xanthene reduction product contains evidence that demonstrates that conjugation of the rings is still maintained following removal of the carbonyl group. What is this evidence?

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EXPERIMENT [2adv]

Heterocyclic Ring Synthesis: Benzimidazole

Common name: benzimidazole
CA number: [51-17-2]
CA name as indexed: 1*H*-benzimidazole

Purpose. This experiment investigates conditions under which one of the important heterocyclic ring systems, the benzimidazole ring, may be formed. The method used involves the condensation of a 1,2-diaminobenzene with formic acid. The simplest possible benzimidazole ring system, benzimidazole itself, is prepared.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–90)

REACTION

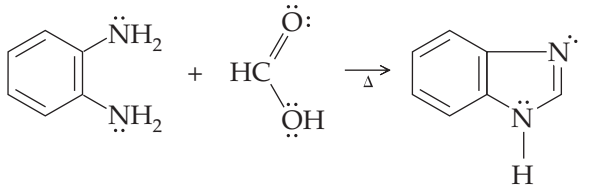

o-Phenylenediamine Formic acid 1-*H*-Benzimidazole

DISCUSSION

This experiment illustrates the classic method of forming the benzimidazole ring system. This heterocycle is generally prepared from 1,2-diaminobenzene (*o*-phenylenediamine) derivatives by reaction with carboxylic acids, or their derivatives, under acidic conditions. The ring system is aromatic; thus it is difficult to oxidize or reduce, and it is stable to both acids and bases. It is an important heterocyclic ring system that occurs in vitamin B_{12} and in many other biologically important compounds. Benzimidazole itself inhibits the growth of certain yeasts and bacteria.

The parent compound of this class of heterocyclic compounds is imidazole. This ring system exhibits basic properties and is protonated to give a conjugate acid with $pK_a = 6.95$. Once the imidazole ring is protonated, the two nitrogen atoms are indistinguishable, because the resonance forms of the protonated species are equivalent. As a resonance stabilized intermediate, the imidazole scaffold offers the synthetic organic chemist a multitude of opportunities when considering its role as part of an ionic liquid. As the term implies, an ionic liquid is a salt. However, when the salt is appropriately modified, it can exist as a

liquid at room temperature. As a salt, the system exhibits a significantly lower vapor pressure when compared to standard organic solvents, and thus it can serve the role of a solvent for many synthetic transformations. Over the past decade, ionic liquid technologies have witnessed an unprecedented surge in interest, especially among industrial applications.

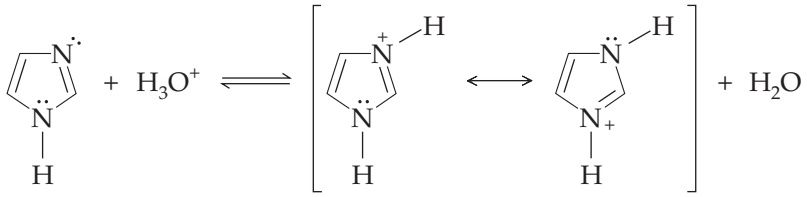

The reaction to form the ring system used in this experiment proceeds in two stages. The first involves the in situ formation of an *N*-substituted formamide, via the usual nucleophilic addition–elimination reaction. The second involves an intramolecular nucleophilic addition to a carbonyl group and subsequent elimination of water to form the unsaturated heterocyclic ring. The sequence is outlined below:

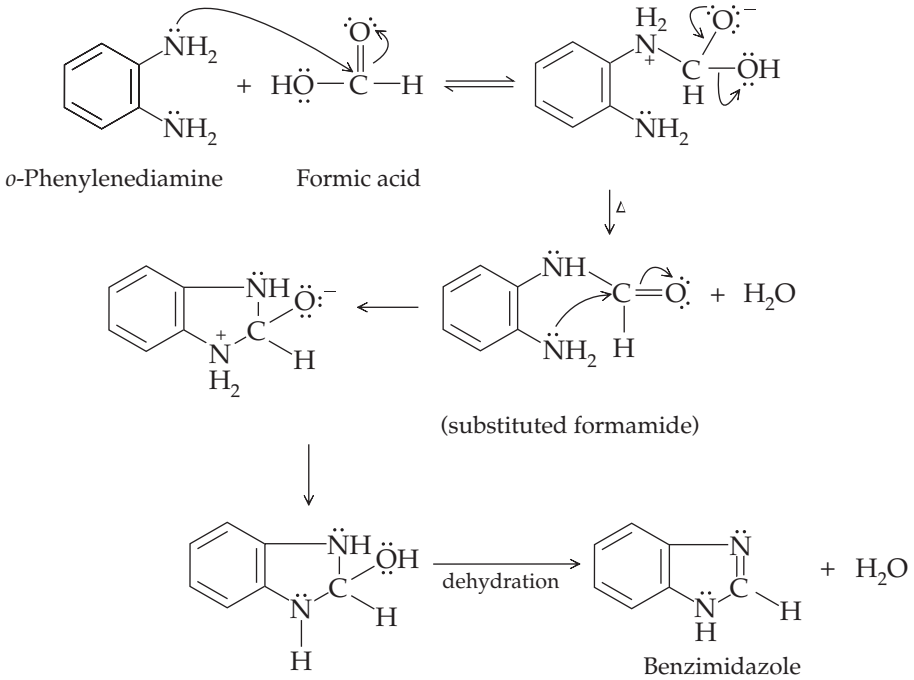

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
o-Phenylenediamine	108.1	108 mg	1.0	102			
90% Formic acid	46.03	64 μL	1.7		101	1.22	1.3714

Reagents and Equipment. Weigh and add 108 mg (1.0 mmol) of *o*-phenylenediamine to a 3.0-mL conical vial containing a magnetic spin vane. Now add 64 μL (79 mg, 1.7 mmol) of 90% formic acid, and attach the vial to a reflux condenser protected by a calcium chloride drying tube (➡).

CAUTION: *o*-Phenylenediamine is toxic and is a cancer suspect agent. Formic acid is very corrosive to the skin and should be dispensed in the **hood** using an automatic delivery pipet.

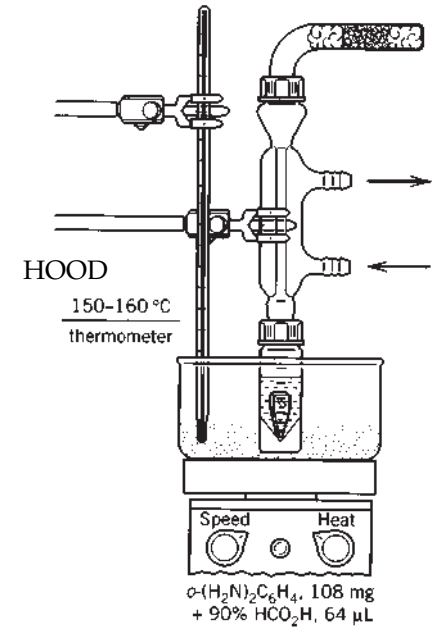

Reaction Conditions. Heat the reaction mixture, with stirring, at a sand bath temperature of 150–160 °C for 1 h.

Isolation of Product. Allow the reaction mixture to cool to room temperature. Add 630 μL of 10% aqueous sodium hydroxide solution (automatic delivery pipet). Crude benzimidazole precipitates at this point. Collect the product by vacuum filtration using a Hirsch funnel and wash the filter cake with three 0.5-mL portions of cold water (calibrated Pasteur pipet) (➡).

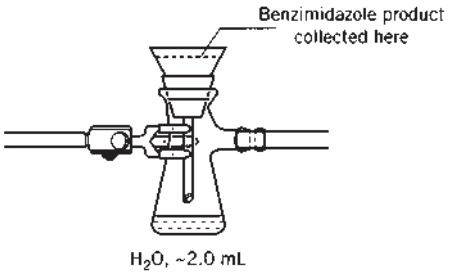

Purification and Characterization. Recrystallize the crude material from water, using a Craig tube. Dry the product in a desiccator or in a vacuum drying apparatus (see Prior Reading). Weigh the crystals and calculate the percent yield. Determine the melting point and compare your result with that listed in the literature.

The UV spectrum of benzimidazole in 95% ethanol has been reported.[1]

Chemical Tests. Several tests may be run to assist in the identification of this material. Does the ignition test confirm the presence of the aromatic ring system? Does the soda lime or sodium fusion test indicate that nitrogen is present? Is the material soluble in 10% hydrochloric solution?

QUESTIONS

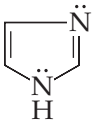

I

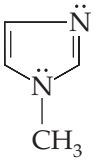

II

10W-6. The parent compound of the imidazole series, imidazole (**I**) itself, was first prepared in 1858: Can you account for the fact that it has a very high boiling point (256 °C), whereas 1-methyl imidazole (**II**) has the somewhat lower boiling point of 199 °C?

10W-7. The imidazole ring system has a great deal of aromatic character. Can you formulate two resonance structures that account for this characteristic?

10W-8. Imidazole is a weak acid, and thus reacts with strong bases to form the corresponding anion. Show this reaction, and draw resonance structures that account for the stability of the conjugate base.

10W-9. Suggest a mechanism for the dehydration involved in the last step in the synthesis of benzimidazole.

10W-10. Imidazole, acting as a nucleophile, catalyzes the hydrolysis of phenyl acetate by attack on the carbonyl carbon atom of the ester. The imidazole displaces the phenoxide anion and forms acetyl imidazole. In turn, the acetyl imidazole is quite unstable in water and hydrolyzes to form acetic acid, and regenerates the imidazole molecule. Write a suitable mechanism outlining these steps.

[1]Steck, E. A.; Nackod, F. C.; Ewing, G. W.; Gorman, N. H. *J. Am. Chem. Soc.* **1948,** *70,* 2406.

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The conditions of this reaction were adapted from those reported by

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EXPERIMENT [3adv]

Heterocyclic Ring Synthesis: 4-Hydroxycoumarin and Dicoumarol

Common name: 4-hydroxycoumarin

CA number: [1076-38-6]

CA name as indexed: 2*H*-1-benzopyran-2-one, 4-hydroxy-

Common names: dicoumarol, dicoumarin

CA number: [66-76-2]

CA name as indexed: 2*H*-1-benzopyran-2-one, 3,3′-methylenebis[4-hydroxy]-

Purpose. You will synthesize a material, dicoumarol, that was the prototype for the oral anticoagulants widely used in medicine to lower blood coagulation rates. A carbon nucleophile is added to a carbonyl carbon to form a C—C bond. You will utilize a Claisen condensation reaction to prepare a β-ketoester, which, upon cyclization, forms a lactone, 4-hydroxycoumarin. Further condensation of two mole equivalents of 4-hydroxycoumarin with formaldehyde yields dicoumarol.

Prior Reading

Technique 2: Simple Distillation at the Semimicroscale Level (pp. 61–64)
Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–90)

REACTION

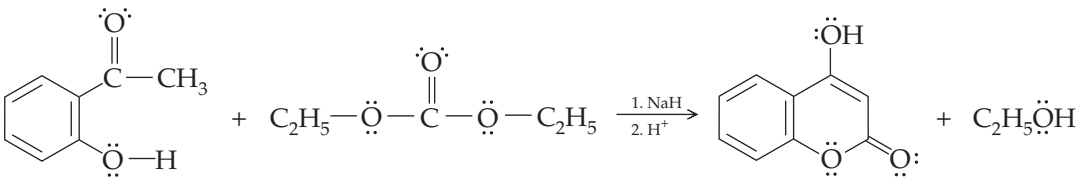

o-Hydroxyacetophenone Diethyl carbonate 4-Hydroxycoumarin Ethanol

DISCUSSION

This reaction sequence illustrates the well-known Claisen condensation, which is widely used to form C—C bonds. The bond formation is brought about by the nucleophilic attack of an enolate anion on the carbonyl carbon of an ester. The enolate is generated by removal of a slightly acidic hydrogen from the α-carbon atom of a ketone, nitrile, or ester, using a relatively strong base. The reaction mechanism is shown here. The methyl ketone is deprotonated by the base, sodium hydride. Sodium hydride (NaH) provides a basic and nonnucleophilic source of hydride ion (H^-). The resulting enolate then attacks the ester, diethyl carbonate. The β-ketoester product thus formed is esterified in an *intramolecular* reaction with the phenolic —OH group to form the lactone product (**I**). Note that the methylene hydrogen atoms in this lactone (**I**) are quite acidic because they are adjacent to two carbonyl groups. In the basic medium of this reaction, the sodium enolate of the lactone (**II**) will be formed. This enolate is water soluble, because it is a salt, which explains why the aqueous solution must be acidified to precipitate the neutral 4-hydroxycoumarin when isolating the product.

1. 4-Hydroxycoumarin

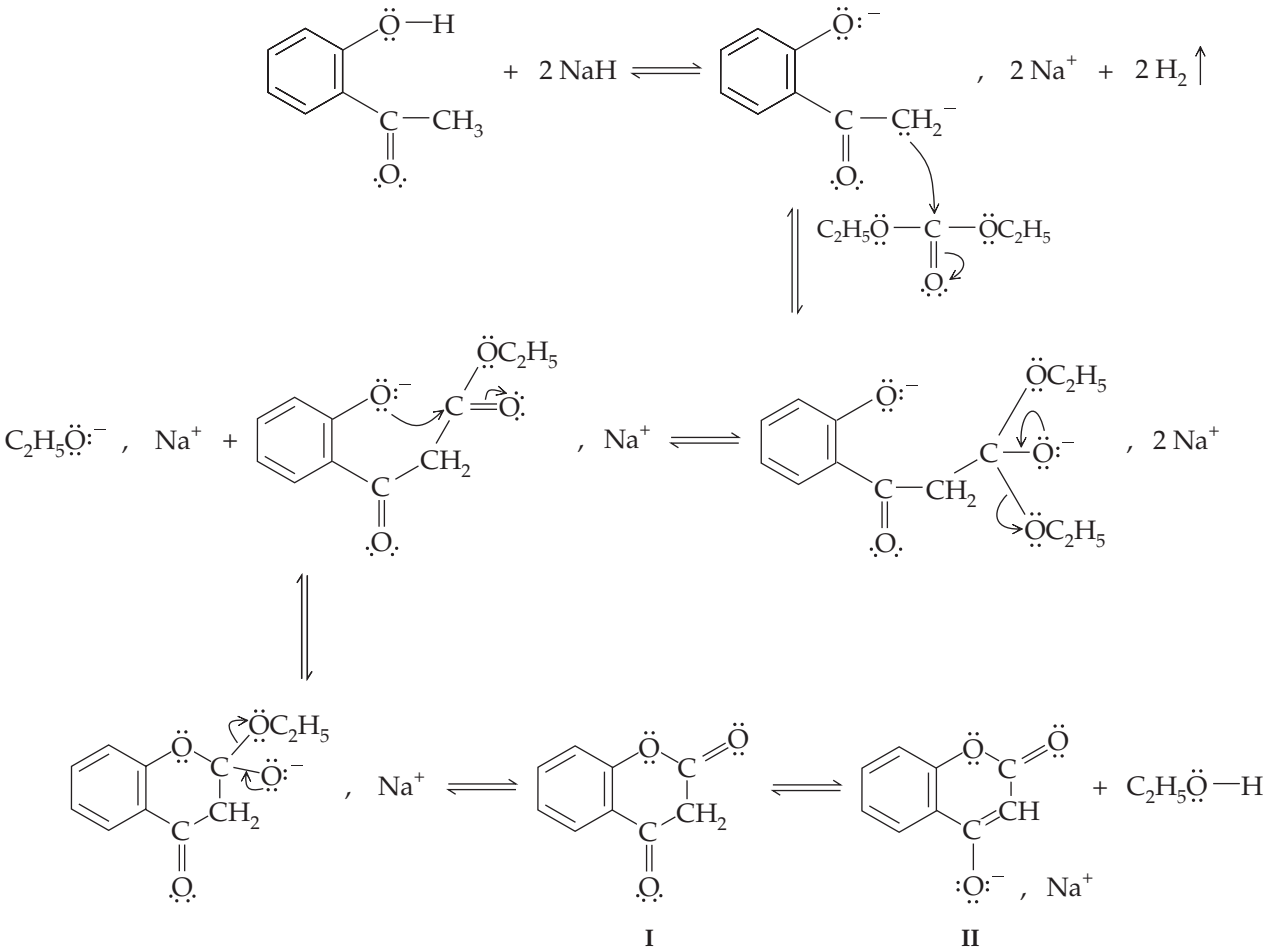

I **II**

2. Dicoumarol

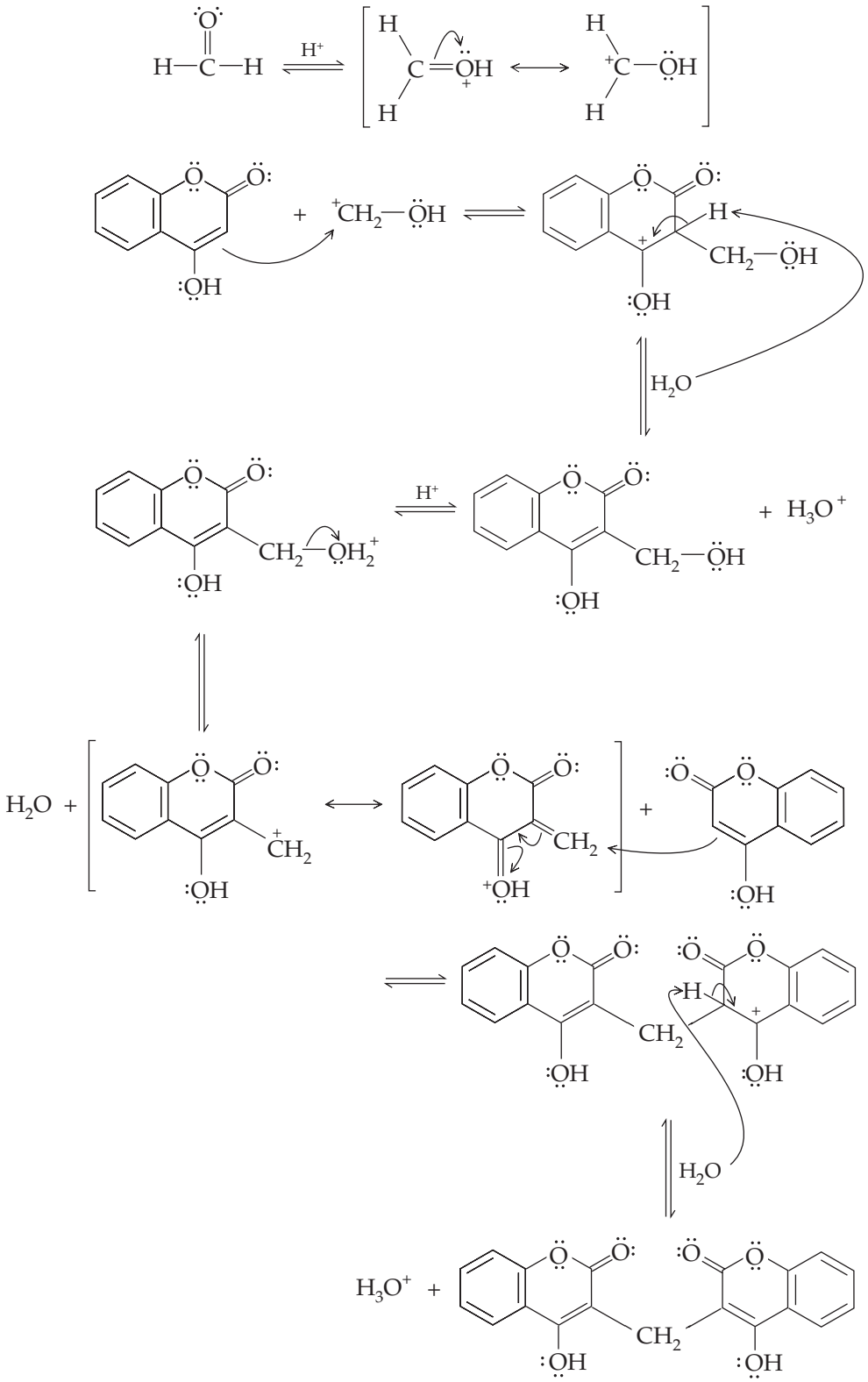

The aldol condensation of 4-hydroxycoumarin with formaldehyde provides an α,β-unsaturated carbonyl compound, which then undergoes a conjugate (1,4-) addition of a second molecule of 4-hydroxycoumarin. This reaction could be catalyzed by either trace base or trace acid; the acid-catalyzed reaction is shown and discussed here. The enol portion of 4-hydroxycoumarin is the nucleophile in an aldol reaction with protonated formaldehyde. The resulting product dehydrates to provide the α,β-unsaturated carbonyl compound, which, after protonation renders it a more reactive electrophile, then reacts with another nucleophilic molecule of 4-hydroxycoumarin in a conjugate addition reaction. This product, upon loss of a proton to the aqueous solvent, leads to dicoumarol. This substance is present in moldy sweet clover. It is a blood anticoagulant and its ingestion leads to the hemorrhagic sweet clover disease that kills cattle.

4-Hydroxycoumarin

Experiment [3A$_{adv}$]

The reaction is shown on pages 679–680.

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: 4.0 h.

Physical Properties of Reactants

Compound	MW	Amount	mmol	bp (°C)	*d*	n_D
Sodium hydride (60% in oil dispersion)	24.0	85 mg	2.13			
Toluene	92.15	6.0 mL		111	0.86	1.4960
o-Hydroxyacetophenone	136.16	133 μL	1.1	218	1.13	1.5584
Diethyl carbonate	118.13	333 μL	2.75	126	0.96	1.3845

Reagents and Equipment.

NOTE. All equipment used in this reaction must be thoroughly dried in an oven at 110 °C for 30 min just prior to use. Upon removal from the drying oven, it should be allowed to cool to ambient temperature in a desiccator.

Weigh and place 85 mg (2.13 mmol) of sodium hydride (60% dispersion in oil) in a 10-mL round-bottom flask containing a magnetic stirring bar. Now add 3.0 mL of dry toluene. Attach the flask to a Hickman still fitted with an air condenser protected by a calcium chloride drying tube. Wrap the Hickman still 14/10 TS male joint with Teflon tape to prevent joint freeze-up (➨).

CAUTION: Sodium hydride (NaH) is a flammable solid. Dispense in the **hood.** Toluene is distilled and stored over molecular sieves. Also dispense this solvent in the **hood.**

In rapid order, place 133 μL (150 mg, 1.1 mmol) of *o*-hydroxyacetophenone, 3.0 mL of dry toluene, and 333 μL (324 mg, 2.75 mmol) of diethyl carbonate in a stoppered 10-mL Erlenmeyer flask.

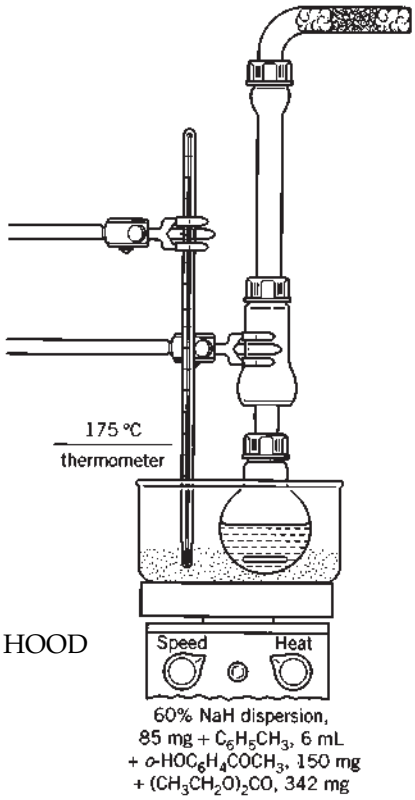

NOTE. Dispense the small volumes of the liquid reagents using an automatic delivery pipet. Be sure to dry the removable plastic tips in the oven before use. Use a 10-mL graduated cylinder to measure the toluene.

Remove the air condenser from the distilling head and add the *o*-hydroxyacetophenone solution, with stirring, to the reaction flask as rapidly as possible using a Pasteur pipet. The resulting solution turns yellow. Immediately reattach the air condenser.

Reaction Conditions. Place the reassembled apparatus in a sand bath and rapidly raise the temperature of the bath to about 175 °C.

CAUTION: To avoid excessively high temperatures, calibrate the hot plate temperature control before conducting the experiment.

Collect the ethanol and toluene distillate (1.0 mL in 2–3 fractions) in the collar of the still, and then remove the apparatus from the heat source. Allow the reaction solution to cool to room temperature, and then add 3.0 mL of water with stirring.

Isolation of Product. Transfer the resulting two-phase solution, using a Pasteur pipet, to a 15-mL centrifuge tube. Rinse the reaction flask with an additional 2.0 mL of water and add this to the centrifuge tube. Separate the toluene layer using a Pasteur filter pipet and transfer it to a second 15-mL centrifuge tube. Then extract this organic phase with 3.0 mL of water, and add the water extract to the original water phase. *This aqueous solution contains the water-soluble sodium enolate* (**II**). Cool the combined aqueous layers in an ice bath and acidify them by drop-wise addition of concentrated hydrochloric acid delivered from a Pasteur pipet. The solid product precipitates from the aqueous phase. Add acid until the yellow color of the solution disappears (~10 drops). Collect the product by vacuum filtration using a Hirsch funnel (⬅).

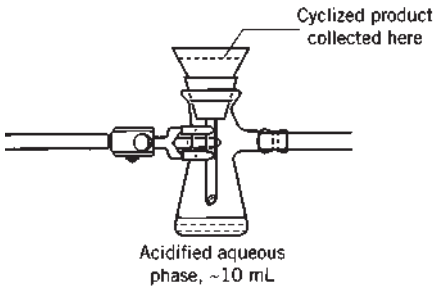

Purification and Characterization. Recrystallize the crude 4-hydroxycoumarin from 50% ethanol using a Craig tube. Dry the material on a porous clay plate or in a vacuum apparatus (see Prior Reading).

Weigh the product and calculate the percent yield. Determine the melting point and obtain an IR spectrum. Compare your results with those reported in the literature.

Chemical Tests. You may wish to perform the ignition test to establish that the compound is aromatic. Does the ferric chloride test (Chapter 9) for phenols give a positive result?

Experiment [3B$_{adv}$]

Dicoumarol

REACTION

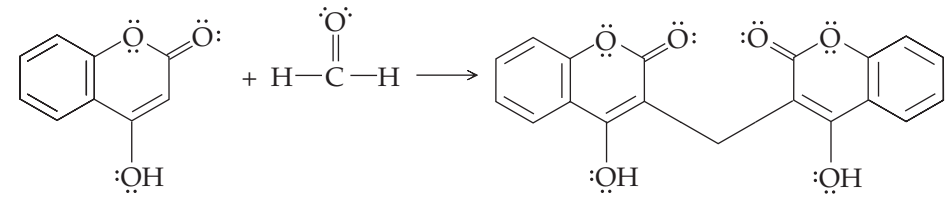

4-Hydroxycoumarin Formaldehyde Dicoumarol

EXPERIMENTAL PROCEDURE

Estimated time to complete the reaction: 0.5 h.

Physical Properties of Reactants					
Compound	MW	Amount	mmol	mp (°C)	bp (°C)
4-Hydroxycoumarin	162.15	50 mg	0.31	213–214	
Water		15 mL			100
Formaldehyde (37% in H_2O)		0.5 mL	6		

Reagents and Equipment. Weigh and place 50 mg (0.31 mmol) of 4-hydroxycoumarin, followed by 15 mL of water, in a 50-mL Erlenmeyer flask containing a boiling stone. Heat the mixture to boiling on a hot plate. Now add 0.5 mL (~500 mg, ~6 mmol) of formaldehyde (37% aqueous solution) to the resulting solution.

CAUTION: Formaldehyde is a cancer suspect agent. Dispense in the **hood.**

HOOD

Reaction Conditions. White crystals of the product form immediately on addition of the formaldehyde solution. Cool the flask in an ice bath.

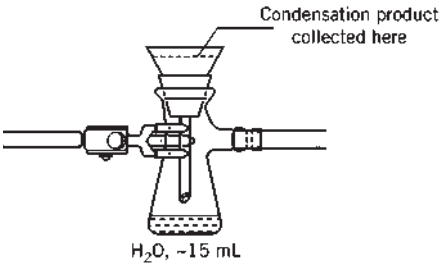

Isolation of Product. Collect the solid product by vacuum filtration using a Hirsch funnel (➡). Wash the filter cake with three 1-mL portions of ice water. Remove the crystals and dry them on filter paper or on a porous clay plate.

Purification and Characterization. Recrystallize the material from a mixture of toluene/cyclohexanone (~2:1) using a Craig tube. After drying the isolated material, determine its melting point and compare your value with that in the literature. Obtain an IR spectrum and compare your spectrum with that in the literature (*The Aldrich Library of IR Spectra* and/or Sci Finder Scholar).

QUESTIONS

10W-11. Why must water be excluded from the reaction that generates 4-hydroxycoumarol?

10W-12. In the first step of the above reaction, formation of 4-hydroxycoumarin, what is the purpose of removing the ethanol generated in the reaction?

10W-13. The Dieckmann condensation is simply an intramolecular Claisen condensation. For example,

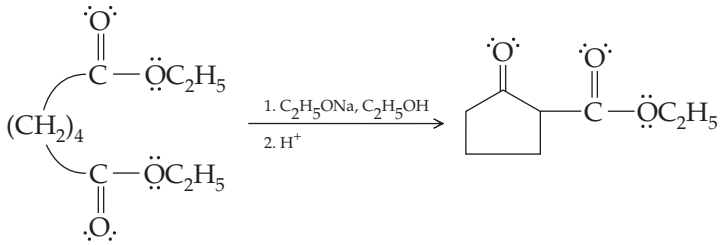

Suggest a suitable mechanism to account for the formation of the cyclic β-ketoester.

10W-14. Predict the product formed in each of the following reactions:

(a) Acetophenone + diethyl carbonate $\xrightarrow[2.\ H^+]{1.\ NaH,\ toluene}$

(b) Acetophenone + ethyl formate $\xrightarrow[2.\ H^+]{1.\ C_2H_5ONa,\ ethanol}$

10W-15. Suggest a synthesis for each of the following compounds using the Claisen condensation. Any necessary organic or inorganic reagents may be used.

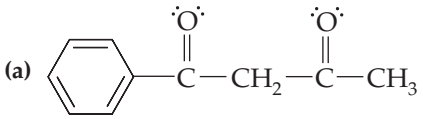

(a)

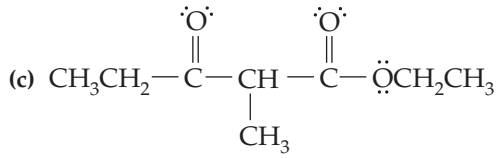

(c)

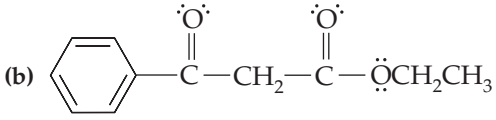

(b)

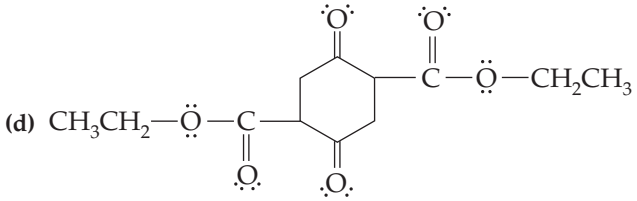

(d)

10W-16. Draw structures for the two possible mono enols of 1,3-cyclohexanedione. Explain which one is more stable.

BIBLIOGRAPHY

A review of the Claisen condensation is given in

Davis, B. R.; Garratt, P. *J. Comp. Org. Syn.* **1991,** *2,* 795.
Garst, J. F. J. *Chem. Educ.* **1979,** *56,* 721.
Hauser, C. R.; Swamer, F. W.; Adams, J. T. *Org. React.* **1954,** *8,* 59.

See your organic textbook for an introduction to this reaction and its scope in synthesis. For example,

Smith, M. B.; March, J. *Advanced Organic Chemistry,* 6th ed.; Wiley: New York, 2007, Chap. 16, p. 1452.
Solomons, T. W. G.; Fryhle, C. B. *Organic Chemistry,* 9th ed.; Wiley: New York, 2008, p. 842.

Selected references of Claisen condensations from *Organic Syntheses* include

Ainsworth, C. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 536.
Floyd, D. E.; Miller. S. E. *Organic Syntheses;* Wiley: New York, 1963; Collect. Vol. IV, p. 141.
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Magnani, A.; McElvain, S. M. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 251.
Riegel, E. R.; Zwilgmeyer, F. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 126.
Snyder, H. R.; Brooks, L. A.; Shapiro, S. H. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 531.

For the synthesis of coumarin see:

Sethna, S.; Phadke, R. *Org. React.* **1953,** *7,* 1.

It may be of interest in a broad aspect to review

Corey, E. J.; Czakó, B; Kürti, L. *Molecules and Medicine,* Wiley: New York, 2007.

EXPERIMENT [4 adv]

Grignard and Aryl Halide Cross-Coupling Reaction: 1-Methyl-2-(methyl-d_3)-benzene

Common names: 1-methyl-2-(methyl-d_3)-benzene, α,α,α-d_3-o-xylene
CA number: [25319-53-3]
CA name as indexed: benzene, 1-methyl-2-(methyl-d_3)-

Purpose. This experiment illustrates a selective cross-coupling reaction between an alkyl Grignard reagent[2] and an aryl halide in the presence of a nickel phosphine catalyst to form a C—C bond. The reaction is also used to demonstrate the technique of "labeling" specific hydrogen atoms with an isotope for identification purposes.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Drying of the Wet Organic Layer (pp. 80–82)
Technique 6: Chromatography
Column Chromatography (pp. 92–93)
Concentration of Solutions (pp. 101–104)

REACTIONS

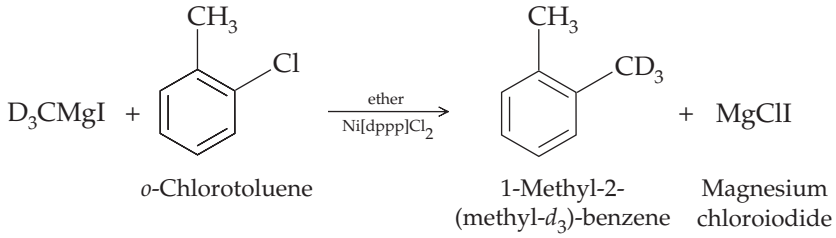

Alternatively, the use of methyl iodide in the formation of the Grignard reagent produces *o*-xylene in step 2.

DISCUSSION

Before the discovery of the nickel-phosphine catalyst, the cross-coupling of Grignard reagents with organic halides was seldom used in synthetic practice. This fact was mainly due to the formation of homocoupling products along with significant elimination side reactions. With the use of this new catalyst, the reaction now has wide application in the synthesis of unsymmetrical alkanes and alkenes.

In this experiment we will synthesize an isotopically labeled *o*-xylene. The *o*-xylene product will be labeled with a trideuteromethyl group. Deuterium, one of the hydrogen **isotopes,** can be used as a **label** in organic compounds. Its incorporation into a molecule can be detected by IR, NMR, or MS. Deuterium labeling is a particularly powerful way of investigating infrared spectra because the resultant frequency shifts (which are inversely proportional to the square root of the mass ratio; see Infrared Discussions, Chapter 8) are the largest obtainable with stable isotopes. Isotopic labeling is often used to follow hydrogen-deuterium exchange reactions, such as enolizations, to study biological reactions, and for gaining insight into organic reaction mechanisms. The nickel catalyst

[2]For general references on Grignard reagents refer to Experiment [16].

used in this experiment is [1,3-bis(diphenylphosphino)propane]nickel(II) chloride, mercifully abbreviated as Ni[dppp]Cl_2.

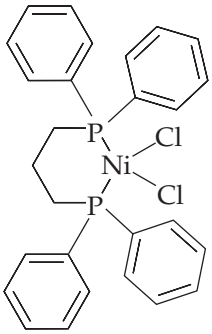

[1,3-Bis(diphenylphosphino)propane]nickel(II) chloride
(Ni[dppp]Cl_2)

It has been proposed that the catalytic ability of the dihalodiphosphinenickel reagent stems from its ability to react with a Grignard reagent to form a diorgano-nickel complex (A).[3] This complex is then converted to the haloorganonickel complex B, by reacting it with an *organic halide:*

$$L_2NiX_2 + 2\,RMgX' \rightarrow L_2Ni(R)(R) + 2\,MgXX'$$

A

$$L_2Ni(R)(R) + R'—X'' \rightarrow L_2Ni(X'')(R') + R—R$$

A **B**

(where L_2 = organodiphosphine ligand;
R = alkyl or aryl; R′aryl or vinyl;
X, X′ and X″ = halo

Reaction of complex B with the Grignard reagent forms a new diorganonickel complex C, from which the cross-coupling product is formed by attack of the organic halide. In the reaction, complex B is regenerated and thus the catalytic cycle is completed:

$$L_2Ni(X'')(R') + RMgX' \rightleftharpoons L_2Ni(R)(R') + MgX'X''$$

B **C**

$$L_2Ni(R)(R') + R'—X'' \rightleftharpoons L_2Ni(X'')(R') + R—R'$$

C **B** Cross-coupling product

[3]Tamao, K.; Sumitani, K.; Kumada, M. *J. Am. Chem. Soc.* **1972,** *94,* 4374.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 5.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	d	n_D
Magnesium	24.31	65 mg	2.7	649			
Diethyl ether	74.12	700 μL			34.5	0.71	1.3526
Methyl-d_3-iodide	144.96	250 μL	3.93		42	2.28	1.5262
Ni[dppp]Cl_2	542.1	10 mg	0.02				
o-Chlorotoluene	126.59	150 μL	1.28		159	1.08	1.5268
1-Methyl-2-(methyl-d_3)-benzene	109.17				144		1.5055

NOTE. All the glassware used in the experiment should be cleaned, dried in an oven at 110 °C for at least 30 min, and then cooled in a desiccator before use.

Reagents and Equipment. Equip a 5.0-mL conical vial containing a magnetic spin vane with a reflux condenser protected by a calcium chloride drying tube.

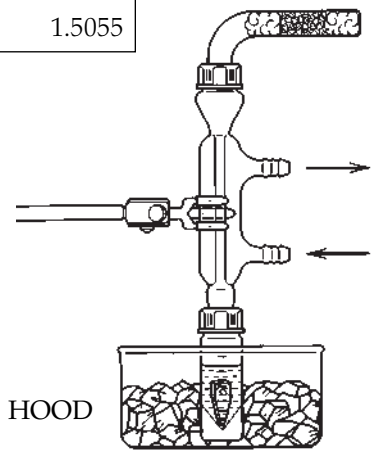

Step 1. Scrape a 4- to 5-in. piece of magnesium ribbon to remove the oxide coating. Then cut it into 1-mm-long sections. *Using forceps*, weigh and add 65 mg (2.7 mmol) of the magnesium sections to the conical vial. In the **hood,** use an automatic delivery pipet to dispense 300 μL of anhydrous diethyl ether into the conical vial containing the magnesium. Reassemble the apparatus.

Using automatic delivery pipets, prepare a solution of 250 μL of methyl-d_3 iodide in 200 μL of anhydrous diethyl ether in a capped vial.

CAUTION: Methyl-d_3 iodide is a suspected carcinogen.

Draw this solution into a Pasteur filter pipet. Remove the drying tube and insert the pipet down the length of the condenser, allowing the pipet bulb to rest on the condenser lip.

Reaction Conditions. Place the reaction vial in an ice bath and add the methyl-d_3 iodide dropwise with stirring. Withdraw the pipet, reinstall the drying tube, and stir the mixture for 20 min (➡).

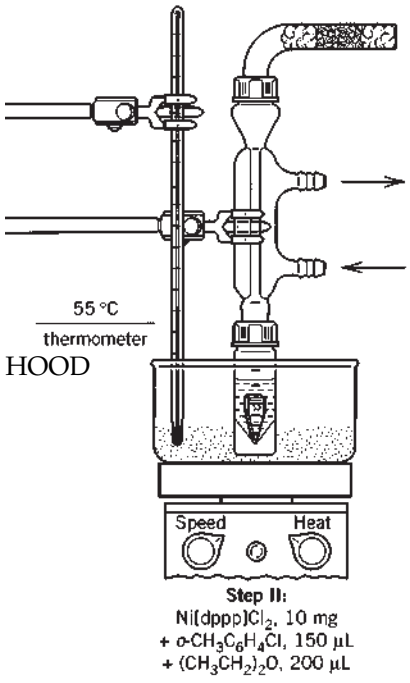

Step 2. In this step, all liquids must be dispensed in the **hood** using automatic delivery pipets. Weigh and add to a capped 0.5-dram vial, 10 mg (0.02 mmol) of Ni[dppp]Cl_2.

CAUTION: Ni[dppp]Cl_2 is a cancer suspect agent.

Now add 150 μL of *o*-chlorotoluene and 200 μL of anhydrous diethyl ether. Draw this solution into a Pasteur filter pipet and, in one portion, add it to the reaction vial through the condenser as described above. Reinsert the drying tube. Place this mixture in a preheated sand bath at a temperature of 55 °C. Heat with stirring for 2 h (➡).

On addition of the catalyst, the solution turns green. After approximately 30 min of heating, the mixture becomes dark brown.

Isolation of Product. Cool the reaction mixture in an ice bath and quench the reaction by the dropwise addition (calibrated Pasteur pipet) of 1.5 mL of 1.0 M HCl solution. *The acid should be added slowly because frothing occurs.*

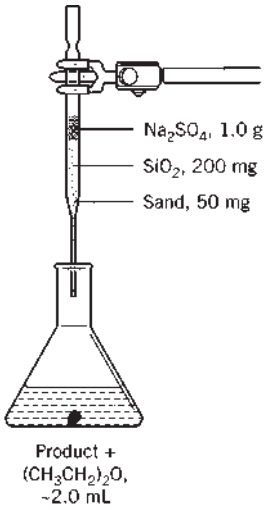

NOTE. The following extracting solutions are measured using calibrated Pasteur pipets. For each extraction operation, the vial is capped, shaken, and vented, and the layers are allowed to separate. The aqueous (lower) phase is then removed.

Add 1.0 mL of ether to the solution. Using a Pasteur filter pipet, remove the aqueous layer. Extract the remaining ether phase with 1.0 mL of water followed by 1.0 mL of saturated sodium bicarbonate solution and then 1.0 mL of deionized water. Then extract with two 1.0-mL portions of 1.0 N sodium thiosulfate (Na_2SO_3) solution and then with 1.0 mL of water.

Purification and Characterization. Isolate and purify the reaction product using column chromatography. In a modified Pasteur filter pipet, place 200 mg of activated silica gel (100 mesh) followed by 1.0 g of anhydrous sodium sulfate. Wet the column with 0.5 mL of ether using a calibrated Pasteur pipet (⬅).

Transfer the ether solution of product to the column by Pasteur pipet, and elute the material from the column with two 0.5-mL portions of ether. Collect the eluate in a tared 10-mL Erlenmeyer flask and then transfer the eluate to a 5-mL conical vial for concentration. Evaporate the solvent by warming the vial in a sand bath in the **hood** to yield the "labeled" *o*-xylene.

HOOD

Weigh the product and calculate the percent yield. Determine the boiling point, density, and refractive index (optional) and compare your values with those listed for *o*-xylene in the literature. Obtain an IR spectrum of the crude (dry) reaction product using the capillary film sampling technique and analyze it following the analysis given below.

Infrared Analysis. The spectrum of *o*-chlorotoluene (Fig. 10.3W) nicely mimics the large macro group frequency train for an ortho-substituted dialkylbenzene system, which has the following frequency train: 3100–3000, 3000–2850, 1950, 1920, 1880, 1840, 1790, 1690, 1600, 1580, 1500, 1450, 1380, and 750 cm^{-1}.

a. **3072 and 3026 cm^{-1}:** C—H stretch on aromatic ring.
b. **3000–2850 cm^{-1}:** C—H stretch on alkyl substituents.
c. **1955, 1915, 1880, 1835, 1795, and 1690 cm^{-1}:** Combination band pattern for ortho-disubstituted rings. The fit in this case is extremely good.
d. **1596 and 1577, 1475 and 1450 cm^{-1}:** Two degenerate pairs of ring stretching modes. The 1450 wavenumber band is overlapped by the antisymmetric methyl deformation vibrations.
e. **1382 cm^{-1}:** Symmetric methyl deformation mode.
f. **749 cm^{-1}:** All in-phase out-of-plane bend of four adjacent C—H groups on the aromatic ring.

The C—Cl stretch falls below the region of measurement in these aromatic systems.

The IR spectrum of 1-methyl-2-(methyl-d_3)-benzene is shown in Figure 10.4W. The reaction has replaced the —Cl group with a —CD_3 group. Thus, the only spectral changes expected to be observed will involve the vibrations of the

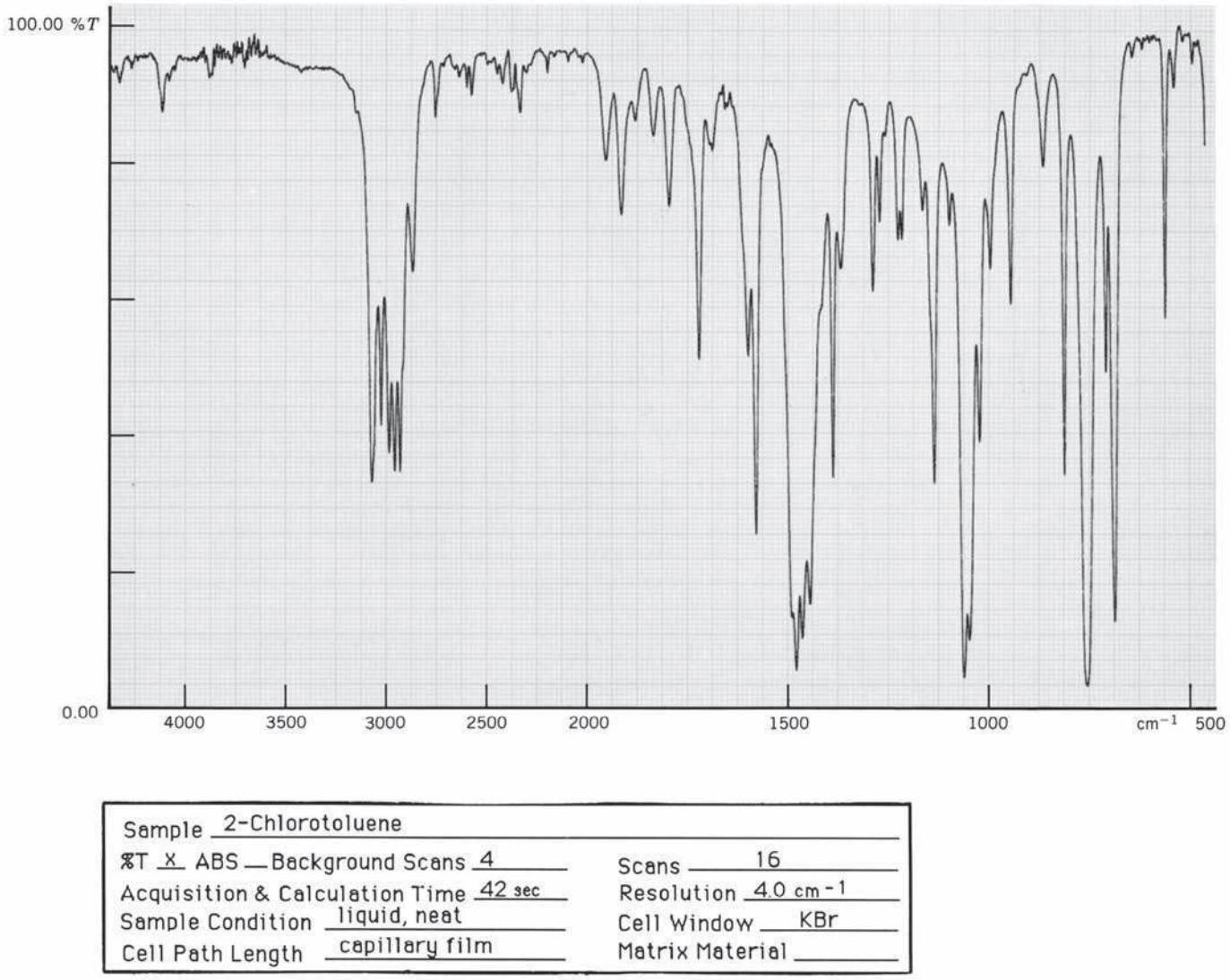

Figure 10.3W IR spectrum: 2-chlorotoluene.

labeled group. To a first approximation, the frequency should shift by a factor of $1/\sqrt{2} = 0.707$, but in practice the full shift is not observed because most vibrations are not pure modes. A factor of 0.75–0.72 is generally observed. In 1-methyl-2-(methyl-d_3)-benzene, we have two sets of doublets, with the doublet centers at 2220 and 2090 cm^{-1}. Because we would expect the C—D stretching modes to give rise to only two band systems, coupling with overtones of lower lying fundamental vibrations is likely occurring. The corresponding C—H stretching modes also evidence some coupling. If we use the major band centers observed at 2965 and 2870 cm^{-1}, however, as the C—H stretching values, the observed ratios are 2220/2965 = 0.749 and 2090/2870 = 0.728, results that are quite reasonable to expect for this type of isotopic shift. The bending modes are moved into the cluttered fingerprint region and do not easily lend themselves to analysis.

Examine the spectrum of the reaction product you have obtained as a capillary film. Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 10.3W and 10.4W).

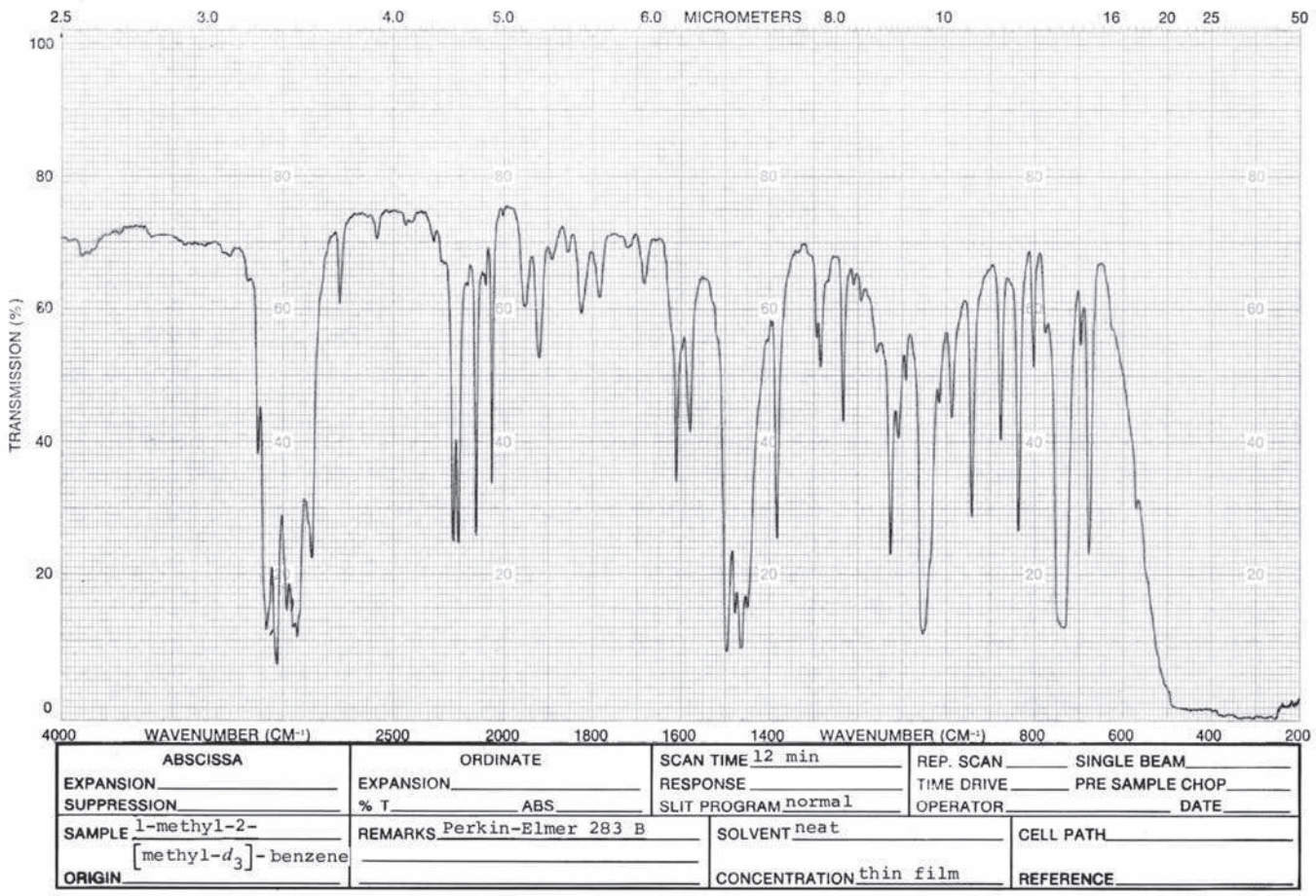

Figure 10.4W IR spectrum: 1-methyl-2-(methyl-d_3)-benzene.

QUESTIONS

10W-17. Predict the reagents that could be used to prepare each of the compounds by the Grignard coupling reaction. Give a suitable name to each reactant.

(a) 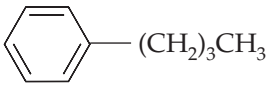

(c) 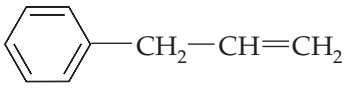

(b) 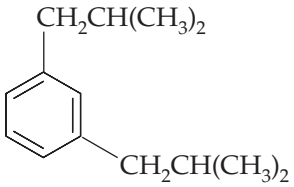

(d) 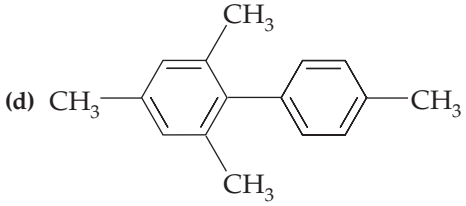

10W-18. The Wurtz coupling reaction involves the treatment of haloalkanes with an active metal, such as sodium.
(a) Butyl bromide + Na
(b) 1-Bromo-3-chorocyclobutane + Na
What products would be formed in the above reactions? Name the products.

10W-19. In reference to Question 10W-18, explain why the coupling reaction of *n*-butyl bromide and *n*-propyl bromide under conditions of the Wurtz reaction is synthetically inefficient for the preparation of heptane.

10W-20. Describe what you would expect to see in the ^{1}H and ^{13}C NMR spectra of 1-methyl-2-(methyl-d_3)-benzene.

10W-21. The spectrum of *o*-chlorotoluene given in Figure 7.3 has two additional peaks that are not present in the library reference standard spectrum. Both these bands are weak. One occurs near 1714 cm^{-1} and the other at 1362 cm^{-1}. Can you offer an explanation for the presence of the extra absorption bands? How successful do you think the coupling reaction would be if carried out using this sample as the starting material?

10W-22. In the spectrum of *o*-chlorotoluene, the lower wavenumber band of the 1596, 1577 pair is the more intense member. In the labeled product, the 1610, 1580 pair has the higher wavenumber peak more intense. Explain this reversal of intensities.

BIBLIOGRAPHY

The present coupling reaction is based on the work reported by

Kumada, M.; Tamao, K.; Sumitani, K. *Organic Syntheses;* Wiley: New York, 1988; Collect. Vol. VI, p. 407, and references cited therein.

Selected Grignard coupling reactions presented in *Organic Syntheses*:

Gilman, H.; Catlin, W. E. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 471.

Gilman, H.; Robinson, J. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 47.

Lespieau, R.; Bourguel, M. *Organic Syntheses;* Wiley: New York, 1941; Collect. Vol. I, p. 186.

Smith, L. I. *Organic Syntheses;* Wiley: New York, 1943; Collect. Vol. II, p. 360.

Turk, A.; Chanan, H. *Organic Syntheses;* Wiley: New York, 1955; Collect. Vol. III, p. 121.

The reaction was first described by

Mayo, D. W.; Bellamy, L. J.; Merklin, G. T.; Hannah, R. W. *Spectrochim. Acta* **1985,** *41A,* 355.

Oxidative Coupling of 2-Naphthol: 1,1′-Bi-2-Naphthol

EXPERIMENT [5 ADV]

Common name: 1,1′-bi-2-naphthol

CA number: [602-0-5]

CA name as indexed: [1,1′-binaphthalene]-2,2′-diol

Purpose. The coupling reaction that aromatic phenols undergo in the presence of transition metal oxidants is investigated. This reaction mimics the biogenetic process that occurs in nature.

Prior Reading

Technique 5: Crystallization
Use of the Hirsch Funnel (pp. 88–89)
Craig Tube Crystallizations (pp. 89–90)

REACTION

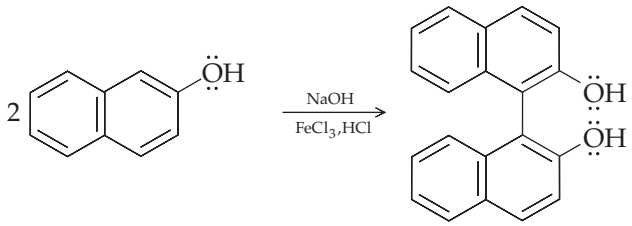

2-Naphthol 1,1'-Bi-2-naphthol

DISCUSSION

This reaction illustrates oxidative coupling of phenols, which is an important biogenetic pathway in nature, leading to the formation of many different natural products.

The coupling reaction involves oxidation of 2-naphthol by electron transfer to give an aryloxy radical, which then dimerizes to yield the product. The mechanism is shown here:

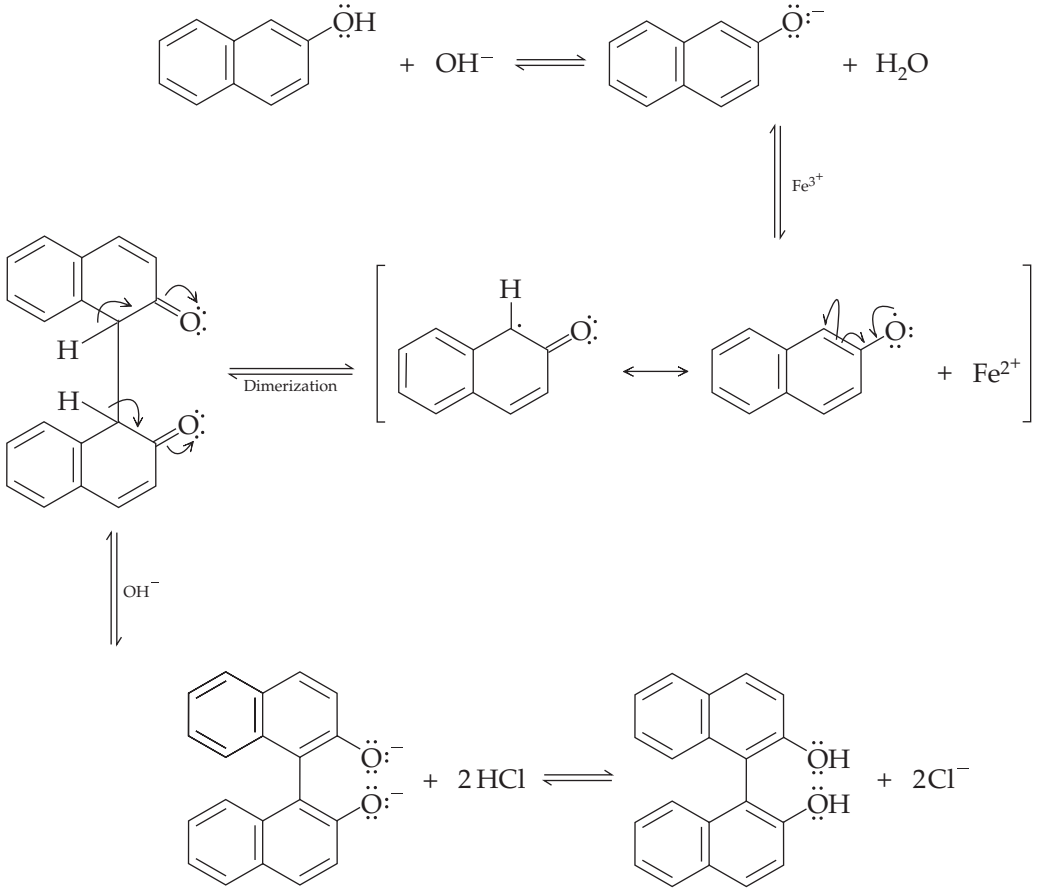

This binaphthol compound, by virtue of restricted rotation about the single bond joining the two naphthalene groups, is a chiral compound. That is, the molecule cannot readily exist in a planar form because of the steric interference of the bulky —OH substituents, and, in fact, the two enantiomers have been separated. Such enantiomeric compounds contain no stereocenter, but rather have an axis of chirality, or a *chiral axis*, which in this case contains the bond joining the two napthalene rings (see Fig. 10.5W)[4]:

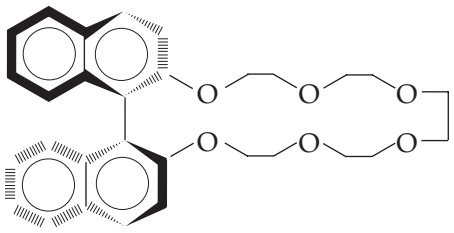

[4]Donald J. Cram (Nobel Laureate, 1987) and coworkers have incorporated this binaphthyl group into cyclic crown ethers.

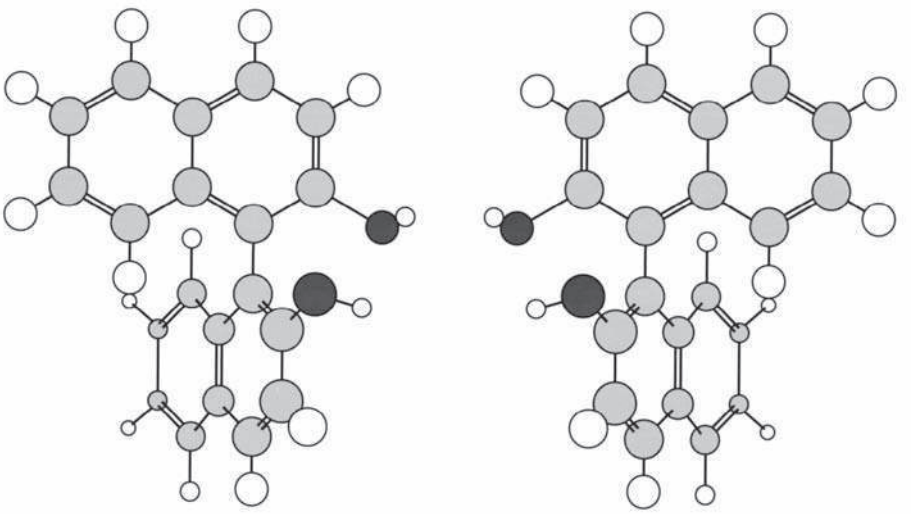

Figure 10.5W Enantiomers of 1,1′-bi-2-naphthol.

An investigation of the complexation of this class of molecules with various ionic species may lead to important insights into the catalytic nature of enzymes. For example, the crown ether similar to that above containing *two* 2,2′-substituted 1,1′-binaphthyl groups as chiral barriers complexes preferentially with one enantiomer of some primary amine salts:

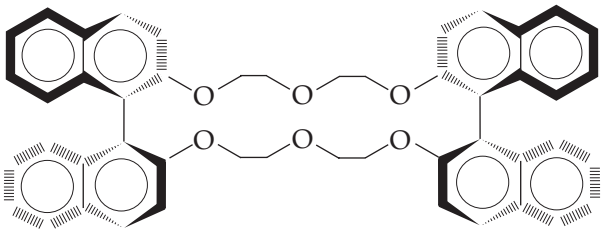

Complexation of enantiomerically pure binaphthols with metal hydride reducing agents allow enantiospecific reductions of some carbonyl compounds.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.0. h.

Physical Properties of Reactants				
Compound	MW	Amount	mmol	mp (°C)
2-Naphthol	144.19	100 mg	0.69	123–124
Sodium hydroxide	40.00	30 mg	0.75	318.4
Ferric chloride·$6H_2O$	270.30	297 mg	1.1	37
HCl (concd)	36.46	100 μL		
Water	18.06	3 mL		

Reagents and Equipment. Weigh and add 100 mg (0.69 mmol) of 2-naphthol and 30 mg (0.75 mmol) of sodium hydroxide to a 10-mL round-bottom flask containing a stirring bar.

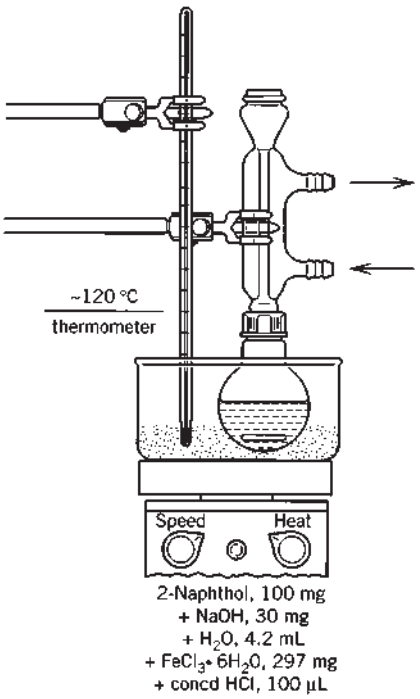

CAUTION: Sodium hydroxide is a corrosive and toxic chemical. Do not allow it to touch your skin or to come in contact with your eyes.

Add 3.0 mL of water. Attach the flask to a reflux condenser and place the assembly in a sand bath on a magnetic stirring hot plate (⬅).

Heat the reaction mixture to reflux, with stirring, using a sand bath temperature of 120 °C.

In a 10-mL Erlenmeyer flask prepare a solution of 180 mg (1.1 mmol) of *anhydrous* ferric chloride (MW 162) *or* 297 mg (1.1 mmol) of ferric chloride *hexahydrate* (MW 270), 1.0 mL of water (calibrated Pasteur pipet), and 100 μL of concentrated hydrochloric acid.

CAUTION: Be careful when mixing acid with water. ***Add the acid to the water.*** Avoid contact with the skin. Dispense the acid with an automatic delivery pipet.

Using a Pasteur pipet, transfer the ferric chloride solution, through the top of the condenser, to the reaction flask. Rinse the Erlenmeyer flask with 200 μL of water, and add this rinse to the reaction flask as before.

Reaction Conditions. Heat the resulting mixture at reflux, with stirring, for 45–60 min using a sand bath temperature of 120 °C. Allow the mixture to cool to room temperature, and then place the flask in an ice bath to complete crystallization of the product.

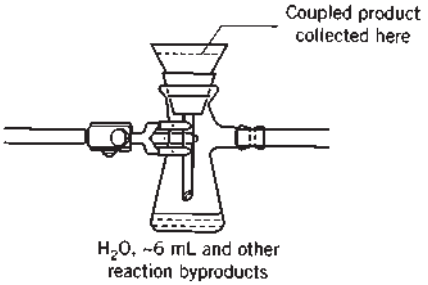

Isolation of Product. Collect the solid product by vacuum filtration using a Hirsch funnel, and wash the filter cake with two 1.0-mL portions of cold water (calibrated Pasteur pipet) (⬅).

Purification and Characterization. Recrystallize the crude product from 95% ethanol using a Craig tube, and dry the resulting crystals on a porous clay plate or on filter paper.

Weigh the crystals and calculate the percent yield. Determine the melting point and compare it with the literature value. Obtain the IR spectrum and compare it to that shown in the literature (*The Aldrich Library of IR Spectra* and/or SciFinder Scholar).

Chemical Tests. Chemical classification tests (Chapter 9) may be used to assist in characterization of this material. Perform the ignition test and the ferric chloride test.

QUESTIONS

10W-23. In the oxidative coupling reaction of 1-naphthol, it is *possible* to obtain three products:

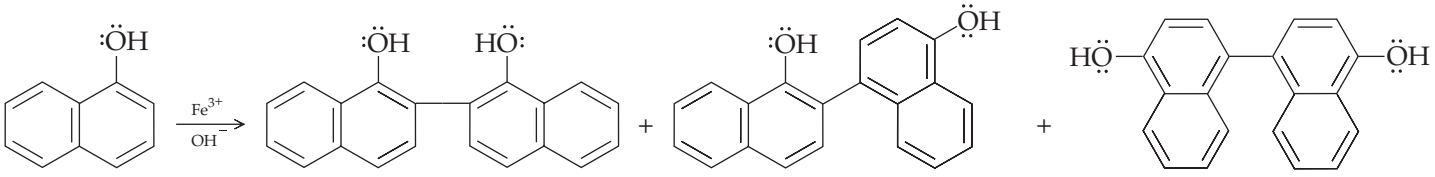

Account for the formation of this mixture by suggesting a mechanistic sequence similar to that presented in the discussion section of this experiment.

10W-24. Predict the structure of the diphenylquinone product, $C_{28}H_{40}O_2$, formed by the oxidative coupling of 2,6-di-*tert*-butylphenol with oxygen in the presence of base.

10W-25. Substituted phenols, such as BHT, are used as antioxidants in processed foods:

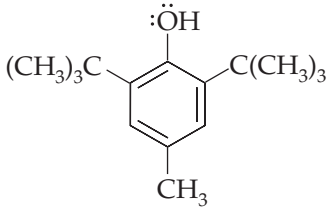

BHT

The role of the antioxidant is to stop spoilage caused by the free radical reactions brought about by reaction of oxygen with compounds containing C═C bonds.

(a) Give a suitable chemical name for BHT.

(b) Can you suggest why this compound is an effective antioxidant?

10W-26. Naphthalene is the simplest of the polycyclic aromatic hydrocarbons and can be represented by three resonance structures. Draw them. Indicate which of the structures are equivalent.

10W-27. Some relatively simple chiral compounds contain a chiral axis. Use molecular models to convince yourself that the two molecules below are enantiomers, even though they contain no stereocenters:

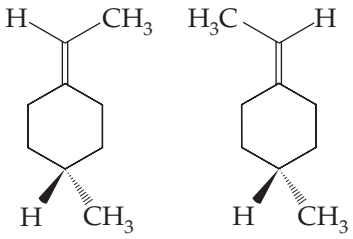

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For references related to the oxidative coupling of phenolic derivatives, see

Dewar, M. J. S.; Nakaya, T. J. *Am. Chem. Soc.* **1968,** 90, 7134.
Scott, A. I. Q. *Rev*. **1965,** *19,* 1.

For an overview of Cram's work on the binaphthyl crown ethers, see

Cram, D. J.; Cram, J. M. *Science* **1974,** 183, 803.

For the resolution of 1,1′-bi-2-naphtol, see

Dongwei, C; Hughes, D. L; Verhoeven, T. R.; Reider, P. J. *Organic Synthesis,* Collect. Vol 10, p. 93. Also see Kazlauskas, P. J. *Organic Synthesis,* Collect. Vol 9, p. 77.

For the use of 1,1′-bi-2-naphthol as a chiral element for asymmetric catalysts, see

Chem. Eng. News: **1995,** 9 Oct, p. 74.
Noyori, R.; Takaya, H. *Acc. Chem. Res.* **1990,** *23,* 345.

Beckmann Rearrangement: Benzanilide

EXPERIMENT [6 adv]

Common name: benzanilide
CA number: [93-98-1]
CA name as indexed: benzamide, *N*-phenyl-

Purpose. You will carry out the *Beckmann rearrangement* in which a ketone is converted, via an oxime, to an amide. The reaction is an example of a group of reactions in which migration to an electron-deficient nitrogen occurs.

Prior Reading

Technique 4: Solvent Extraction
Liquid–Liquid Extraction (p. 72)
Technique 5: Crystallization
Craig Tube Crystallizations (pp. 89–90)

REACTION

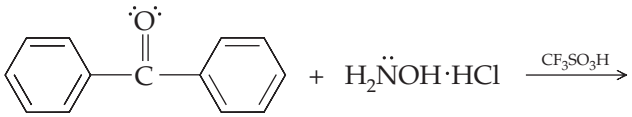

Benzophenone — Hydroxylamine hydrochloride

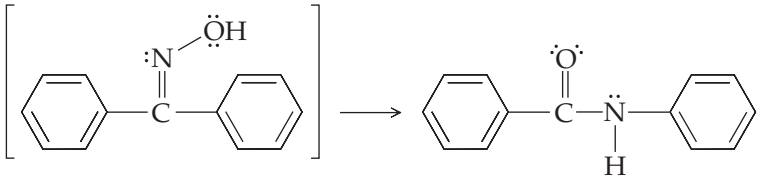

Benzophenone oxime — Benzanilide

DISCUSSION

The Beckmann rearrangement was discovered in 1886 by E. Beckmann and is the reaction of an oxime of a ketone, in the presence of acid, to yield the corresponding amide or amides. It is a very general reaction and a wide variety of reagents have been used to cause the rearrangement to take place. These include sulfuric, hydrochloric, and polyphosphoric acids, phosphorus pentachloride, and aromatic sulfonyl chlorides. The Beckmann rearrangement is the nitrogen analogue, both functionally and mechanistically, of the Baeyer–Villiger oxidation, which converts a ketone to an ester.

In the present case, only one amide is formed, because benzophenone is a symmetrical ketone. Because the oximes are prepared from ketones, the reaction was often used, before the advent of modern spectroscopic techniques, to determine the structure of the starting ketone. This structure determination was accomplished by the subsequent identification of the acid and amine obtained upon hydrolysis of the amide product of the rearrangement.

As depicted in the following mechanism, the acid catalyst converts the oxime's hydroxyl group to a good leaving group (water, a small neutral molecule). The acid used in this experiment is a very strong acid, trifluoromethanesulfonic acid, usually called *triflic acid*. The first part of the overall reaction in this experiment constitutes the formation of the oxime, which is followed by the actual migration of an aryl (or alkyl) group from the former carbonyl carbon to the nitrogen atom, the Beckmann rearrangement:

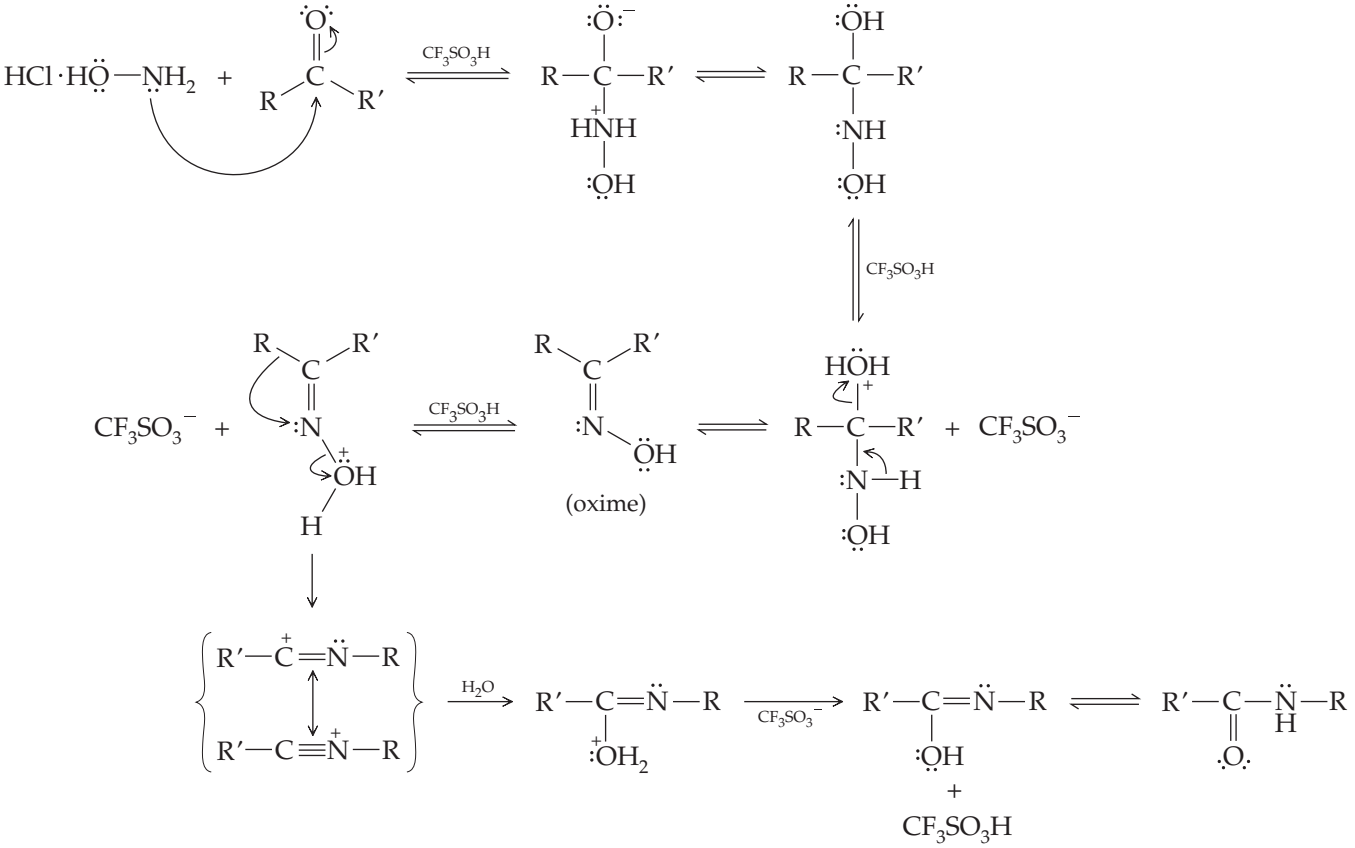

There are two significant points concerning the stereo- and regiochemistry of the reaction: (1) the group that migrates is the one *anti* to the hydroxyl group on the C═N bond and (2), the stereochemistry, if any, of the migrating group is retained.

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 2.5 h.

Physical Properties of Reactants				
Compound	**MW**	**Amount**	**mmol**	**mp (°C)**
Benzophenone	182.21	100 mg	0.55	48.1
Hydroxylamine hydrochloride	69.49	51 mg	0.73	155–57
Triflic acid–formic acid solution		500 μL		

Reagents and Equipment. Weigh and place 100 mg (0.55 mmol) of benzophenone and 51 mg (0.73 mmol) of hydroxylamine hydrochloride in a 5.0-mL conical vial containing a magnetic spin vane. Using an automatic delivery pipet in the **hood,** now add 500 μL of triflic acid–formic acid solution to this mixture. Attach the vial to a re-flux condenser and mount the assembly in a sand bath on a magnetic stirring hot plate (➨).

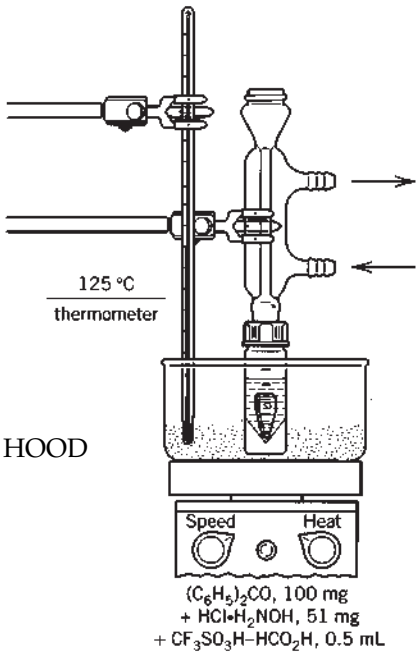

CAUTION: Triflic acid (trifluoromethanesulfonic acid) is one of the strongest acids known. It is very corrosive and toxic!

INSTRUCTOR PREPARATION. The acid solution is prepared by adding 2 drops of triflic acid to 5.0 mL of 90% formic acid.

Reaction Conditions. With stirring, heat the reaction mixture at reflux for 1 h in a sand bath at 125 °C. Then cool the resulting solution to room temperature.

Isolation of Product. To the cooled reaction solution add 1.0 mL of water (using a calibrated Pasteur pipet), and extract the resulting mixture with three 1.0-mL portions of methylene chloride. Separate the organic phase using a Pasteur filter pipet and transfer it to a 10-mL Erlenmeyer flask. For each extraction, after addition of the methylene chloride, cap the vial, shake, vent, and then allow the layers to separate.

Dry the combined methylene chloride extracts over granular, anhydrous sodium sulfate. Using a Pasteur filter pipet, transfer the dried solution to a clean, dry 10-mL Erlenmeyer flask containing a boiling stone. Evaporate the
HOOD solvent in the **hood** under a gentle stream of nitrogen on a warm sand bath to yield the crude reaction product.

Characterization and Purification. Transfer the crude benzanilide from the Erlenmeyer flask to a Craig tube, and recrystallize the material from 95% ethanol.

Weigh the product and calculate the percent yield. Determine the melting point and compare your result to that listed in the *CRC Handbook* or found using SciFinder Scholar. Obtain an infrared spectrum.

Infrared Analysis. In this experiment, an aromatic ketone has been rearranged to a secondary amide. By examining the infrared spectra of starting material and product, we can confirm this molecular transformation.

The spectrum of benzophenone (Fig. 10.6W) possesses two macro group frequency trains:

1. Conjugated aromatic ketone: This ketone is defined by the bands at 3325 (overtone of ketone carbonyl stretch), 1663 (C═O stretch, doubly conjugated), 1601 and 1580 (ν_{8a} and ν_{8b} degenerate ring stretch), 1492 and 1450 cm^{-1} (ν_{19a} and ν_{19b} degenerate ring stretch). The intensification of the 1580-wavenumber peak confirms the conjugation of the carbonyl to the ring. The 1500-wavenumber ring stretch, which is generally a bit variable in intensity, is quite weak in this case (2 different benzene rings).

2. Monosubstituted phenyl group: This group is defined by weak bands located at 1969, 1913, 1823, 1724 cm^{-1}, and strong bands recorded at 701 and 640 cm^{-1}. For discussions of these modes see Chapter 8, and Experiment [20]. In the case of phenyl rings conjugated to carbonyl groups, the 750- and 690-wavenumber bands often appear on the low side of their usual range and can be down as much as 40–50 cm^{-1}, as occurs here.

The rearrangement product has incorporated a heteroatom into its structure, but the carbonyl group and the ring systems have survived. The infrared spectrum of benzanilide (Fig 10.7W) must be consistent with the formation of a secondary amide. We expect to observe a macro group frequency for the presence of monosubstituted phenyl groups, plus a second macro group frequency for a secondary aromatic amide.

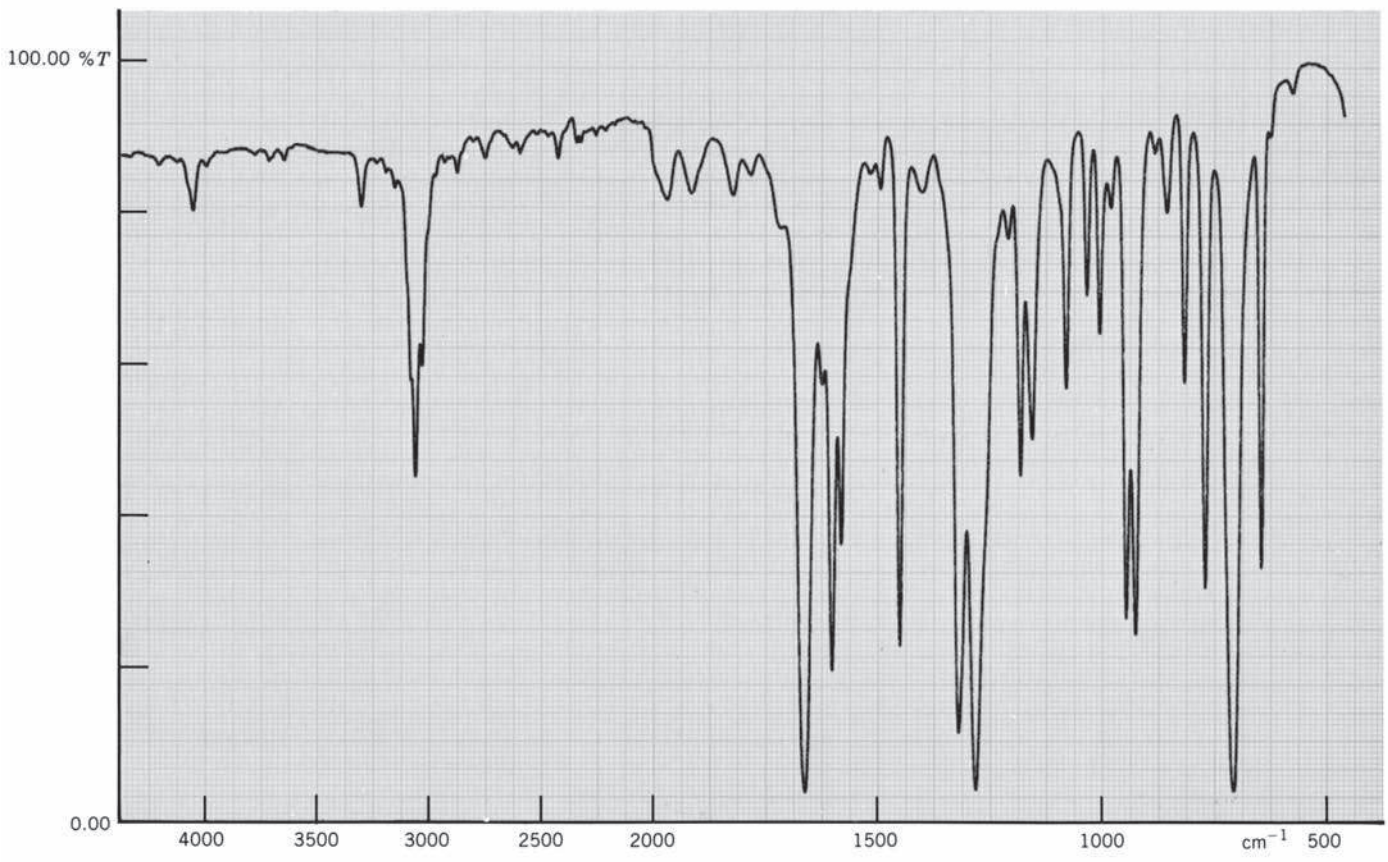

Figure 10.6W IR spectrum: benzophenone.

The first macro group frequency is similar to that of the starting material with bands occurring at

a. **1950, 1912, 1840, and 1725 cm^{-1}:** All four combination bands are doubled in this case. The values given are for the centers of the doublets.
b. **752 and 718 cm^{-1}:** C—H out-of-plane bend. The lower value likely corresponds to the ring conjugated directly with the carbonyl group.
c. **693 cm^{-1}:** Ring out-of-plane bend (puckering) vibration.

The second macro group frequency for the aromatic secondary amide uses the following bands: 3350, 3060, 1659, 1602, 1587, 1539, 1322, and 680 (broad) cm^{-1}.

a. **3350 cm^{-1}:** This strong band corresponds to the highly hydrogen-bonded amide N—H stretch.
b. **3060 cm^{-1}:** C—H stretch on sp^2 carbon, aromatic C—H.

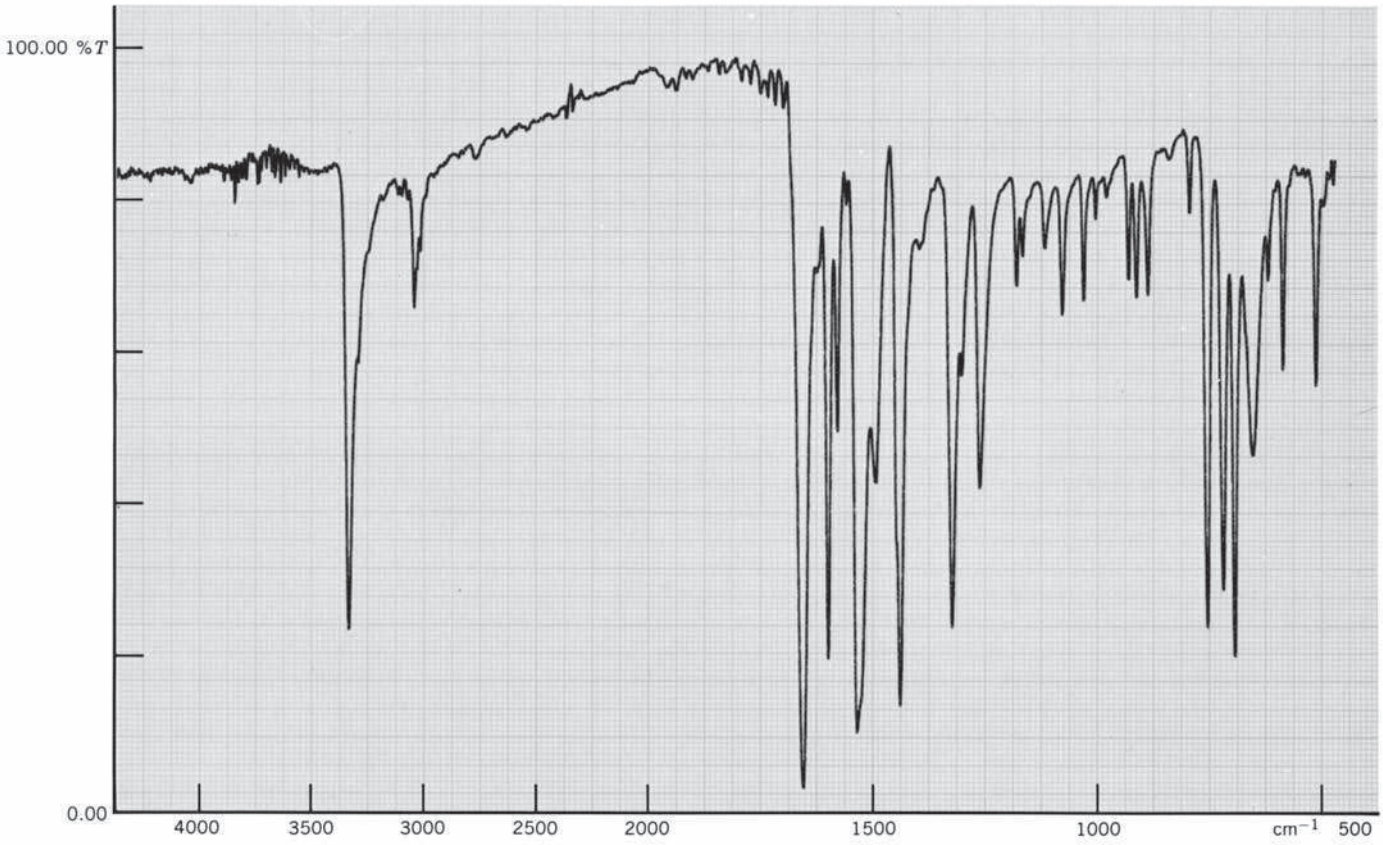

Figure 10.7W IR spectrum: benzanilide.

c. 1659 cm^{-1}: C═O stretch of a conjugated and hydrogen-bonded amide. It is the most intense band in the spectrum.

d. 1602 and 1587 cm^{-1}: Ring stretch degenerate pair, ν_{8a} and ν_{8b}.

e. 1539 and 1322 cm^{-1}: These two bands involve both N—H bending (in-plane) and C—N stretch. The two fundamentals fall somewhere between 1450–1400 cm^{-1}. Thus, they can mechanically interact and split apart with one component falling at 1539 cm^{-1} and the other near 1322 cm^{-1}. Since the fundamental frequencies will vary somewhat from molecule to molecule, the interaction term that is sensitive to the frequency match (see Infrared discussions, Chapter 8) will also vary in magnitude, and thus the wavenumber separation will be affected.

f. 680 cm^{-1}: Broad and weak. This ill-defined band arises from the out-of-plane bend of the N—H group. It is similar to the O—H bend found in alcohols in this spectral region (see infrared discussion in Experiments [5A], [5B], and [8B]).

Examine the IR spectrum of your reaction product. Discuss the similarities and differences of the experimentally derived spectral data to the reference spectra (Figs. 10.6W and 10.7W).

Chemical Tests. Chemical classification tests (Chapter 9), such as the ignition test and the soda lime test (or sodium fusion test), may also be conducted to further establish the identity of the product. The hydroxamate test may be used to establish the presence of the amide functional group.

QUESTIONS

10W-28. Draw the structure of the product expected in each of the Beckmann rearrangements presented below. Give a suitable name for each product.

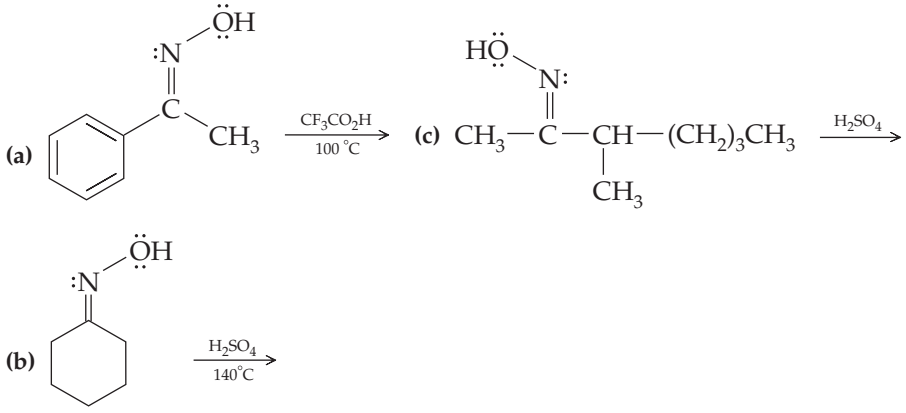

10W-29. The picryl iminoethers (an iminoether is C═N—O—C) of oximes undergo the Beckmann rearrangement without an acid catalyst:

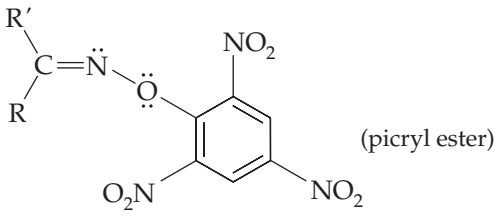

Explain why a catalyst is not required in this rearrangement.

10W-30. Compounds A and B undergo the Beckmann rearrangement upon gentle heating of the solid compounds:

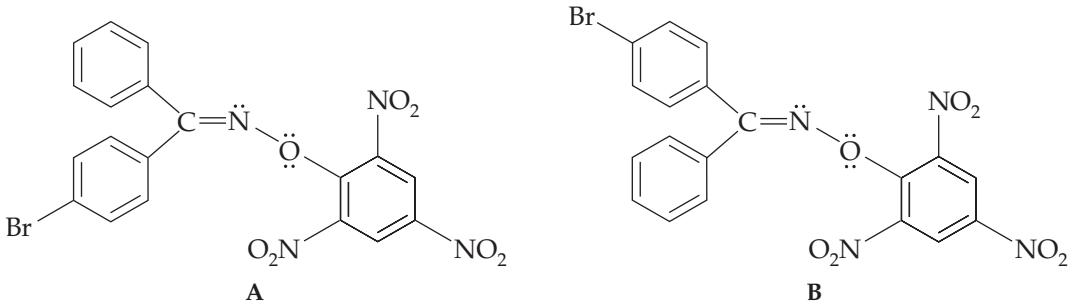

A **B**

(a) Write the structure of the products expected.

(b) If a mixture of the two iminoethers, A and B, are heated in the same reaction flask, what products would be formed? Explain.

10W-31. When acetophenone oxime was allowed to rearrange in ^{18}O-enriched solvent, the amide product contained the same percentage of ^{18}O as the solvent. Explain this observation.

10W-32. Oximes are usually crystalline materials and have been prepared as a means of identifying liquid ketones or aldehydes. It has been found in the preparation of these derivatives that if the acid concentration is too high (low pH), then the oxime does not form. Explain.

10W-33. The mechanical coupling between the N—H bending vibration and the C—N stretching vibration depends on a close frequency match. Normally the C—C, C—N, and C—O stretching vibrations are found in the 1200- to 800-wavenumber region. Why, in the case of the amides, do we find the C—N stretch approaching 1400 cm^{-1}?

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Reviews on the Beckmann rearrangement:

Donaruma, L. G.; Heldt, W. Z. *Org. React.* **1960,** *11,* 1.
Gawley, R. E. *Org. React.* **1988,** *35,* 1.
Jochims, J. C.; Hehl, S.; Herzberger, S. *Synthesis* **1990,** 1128, and references therein.
McCarthy, C. G. in *The Chemistry of the Carbon–Nitrogen Double Bond;* Patai, S., Ed.; Interscience: New York, 1970; p. 408.
Yamabe, S.; Tauchida, N.; Yamazaki, H. *J. Org. Chem.* **2005,** *70,* 10638.

An example of the Beckmann rearrangement using different reagents is given in

Deluca, L.; Giacomelli. G.; Porcheddu, A. *J. Org. Chem.* **2002,** *67,* 6072.
Furuya, Y.; Ishihara, K.; Yanamoto, H. *J. Am. Chem. Soc.* **2005,** *127,* 11240.
Harada, T.; Ohno, T.; Kobayashi, S.; Mukaiyama, T. *Synthesis* **1991,** 1216.
Ohno, M.; Naruse, N.; Terasawa, I. *Organic Syntheses;* Wiley: New York, 1973; Collect. Vol. V, p. 266.

The present reaction was adapted from the work of

Ganboa, I.; Palomo, C. *Synth. Commun.* **1983,** *13,* 941.

EXPERIMENT [7 adv]

Preparation of an Enol Acetate: Cholesta-3,5-dien-3-ol Acetate

Common name: cholesta-3,5-dien-3-ol acetate
CA number: [2309-32-2]
CA name as indexed: cholesta-3,5-dien-3-ol, acetate

Purpose. This experiment investigates the conditions under which the enol acetate of an α,β-unsaturated ketone is prepared. The combined use of acetic anhydride with chlorotrimethylsilane is an illustration of a technique for the generation of *acylium ions*, a reactive electrophile for acylation reactions.

Prior Reading

Technique 5: Crystallization
Craig Tube Crystallizations (pp. 89–90)
Technique 6: Chromatography
Column Chromatography (pp. 92)
Thin-Layer Chromatography (pp. 97–99)
Removal of Solvent Under Reduced Pressure (pp. 102–104)

REACTION

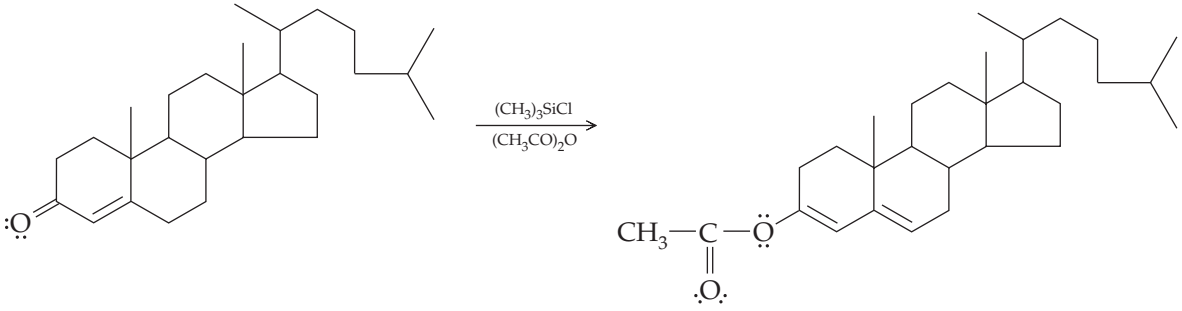

Cholesta-4-en-3-one

Cholesta-3,5-dien-3-ol acetate

DISCUSSION

Acylium ions are useful reactive intermediates in organic synthesis because their high reactivity allows reactions with relatively weak nucleophiles, in this case the carbonyl oxygen of an α,β-unsaturated enone. The product in this experiment, a dienol acetate of a cholesterol derivative, is itself a useful intermediate in the synthesis of steroids such as cortisone.

Acetic anhydride and chlorotrimethylsilane react, as shown here, to generate a small equilibrium concentration of acylium ion ($CH_3C{\equiv}O^+$)along with trimethylsilyl acetate, $CH_3CO_2Si(CH_3)_3$. The acylium ion is a much more reactive electro philic acyl group than neutral sources of an electrophilic acyl group, such as acetic anhydride or acetyl chloride, CH_3COCl.

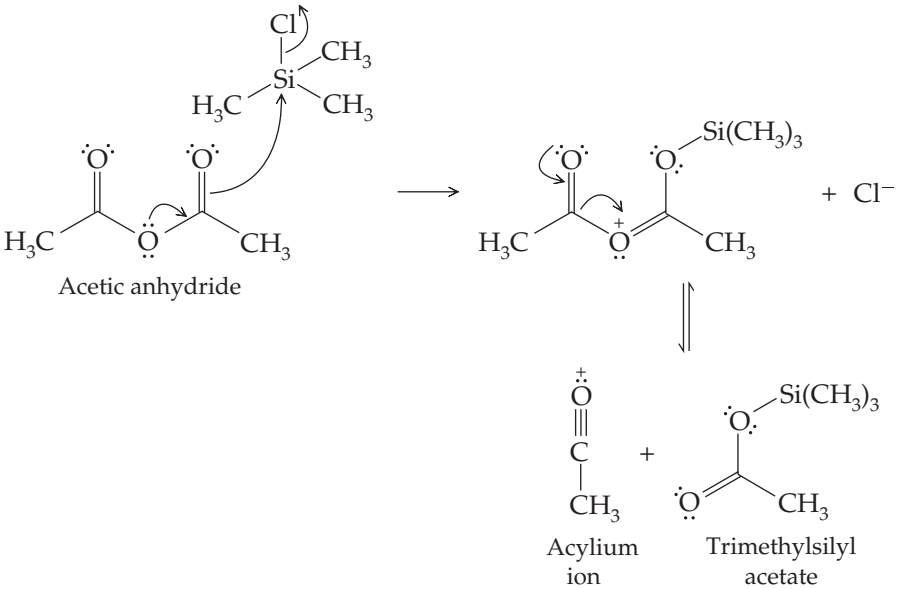

Acetic anhydride

Acylium ion

Trimethylsilyl acetate

The acylium ion thus generated is a very reactive electrophile, capable of reacting with the relatively weakly nucleophilic lone pairs on the carbonyl oxygen of the cholesta-4-en-3-one. The resulting oxonium ion renders the γ-protons of the enone quite acidic, and thus they are readily removed by a very weak base, such as chloride ion, to generate the product,

cholesta-3,5-dien-3-ol acetate. The proposed mechanism for this transformation is shown here:

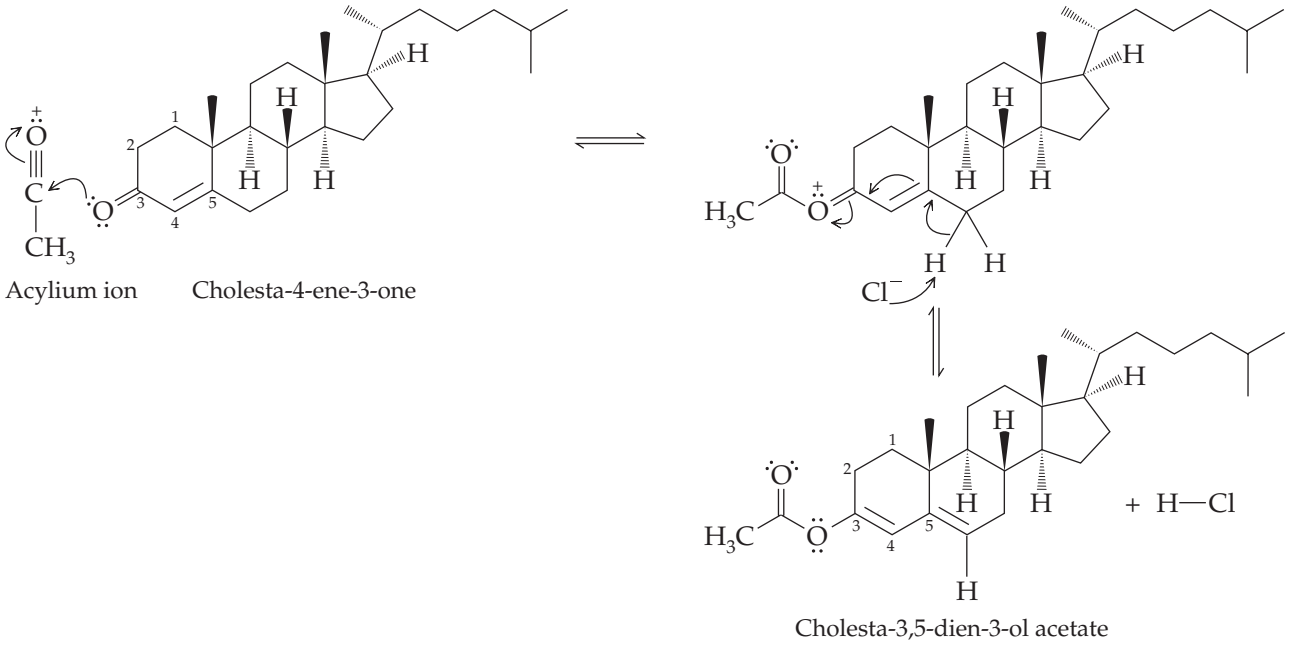

Acylium ion Cholesta-4-ene-3-one

Cholesta-3,5-dien-3-ol acetate

EXPERIMENTAL PROCEDURE

Estimated time to complete the experiment: 4.0 h.

Physical Properties of Reactants and Product

Compound	MW	Amount	mmol	mp (°C)	bp (°C)	*d*	n_D
Cholesta-4-en-3-one	384.65	96 mg	0.25	81–82			
Acetic anhydride	102.09	1.0 mL	10.6		140	1.08	1.3901
Chlorotrimethylsilane	108.64	200 μL	1.58		57	0.86	
Cholesta-3,5-dien-3-ol acetate	425.68			79–80			

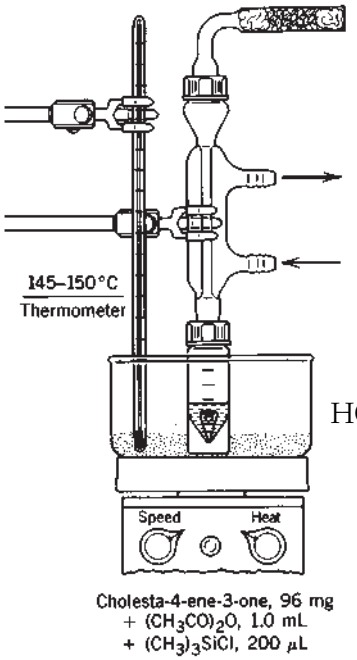

Cholesta-4-ene-3-one, 96 mg
+ $(CH_3CO)_2O$, 1.0 mL
+ $(CH_3)_3SiCl$, 200 μL

HOOD

NOTE. The glass equipment should be dried in an oven (110 °C) and cooled to room temperature in a desiccator before use.

Reagents and Equipment. Weigh and place 96 mg (0.25 mmol) of cholesta-4-en-3-one in a dry 5.0-mL conical vial containing a magnetic spin vane. Now, in the **hood,** add 1.0 mL of acetic anhydride and 200 μL of chlorotrimethylsilane. Immediately attach the vial to a reflux condenser protected by a calcium chloride drying tube (⬅).

HOOD

NOTE. The quality of the acetic anhydride has a significant influence on the reaction. For best results, the anhydride should be distilled and stored over molecular sieves before use. It is convenient to dispense the anhydride and the chlorotrimethylsilane (which hydrolyzes rapidly in moist air) using automatic delivery pipets (in the **hood***). An alternative is to place each reagent in a small bottle sealed with a septum cap. The reagents are then removed through the septum using a 1-mL*

syringe with a Teflon-tipped plunger while the bottle is connected to another needle providing dry nitrogen. The chlorotrimethylsilane (bp 57 °C) may also be purified by distillation in the **hood.**

HOOD

Reaction Conditions. Heat the reaction mixture with stirring at reflux for 1–2 h in a sand bath (145–150 °C). Follow the course of the reaction using TLC.

?

TLC DIRECTIONS. Use activated silica gel plates with 1:1 methylene chloride/hexane as the elution solvent. Visualization of the separated components is achieved by placing the plate in a closed jar containing a few crystals of iodine (see Prior Reading for further details).

Isolation of Product. Allow the reaction mixture to cool to room temperature and then place it in an ice bath for 15–30 min. A solid product forms during this time. Collect this solid by vacuum filtration using a Hirsch funnel, and wash the filter cake with 15 mL of 5% aqueous sodium bicarbonate, followed by 5 mL of cold water (➡).

Purification and Characterization. Purify the crude product by column chromatography. In a 1 × 10-cm buret, place 2.0 g of activated silica gel (100 mesh) packed wet (slurry) with methylene chloride (➡). Dissolve the product in about 1.0 mL of hexane and transfer the solution by Pasteur pipet to the column. Elute the material from the column using approximately 10 mL of 1:1 methylene chloride/hexane solvent. Collect the eluate in a tared 25-mL filter flask.

Remove the solvent by warming in a sand bath under reduced pressure to give the solid product, cholesta-3,5-dien-3-ol acetate (⬇). A rotary evaporator, if available, is a more rapid alternative. Recrystallize this material from methanol using a Craig tube, and dry the resulting crystals on a clay plate. Weigh the product and calculate the percent yield. Determine the melting point and compare it with the literature value shown in the Reactant and Product table. Obtain an IR spectrum of the material and compare it with that of an authentic sample, as well as with the spectrum of the starting material.

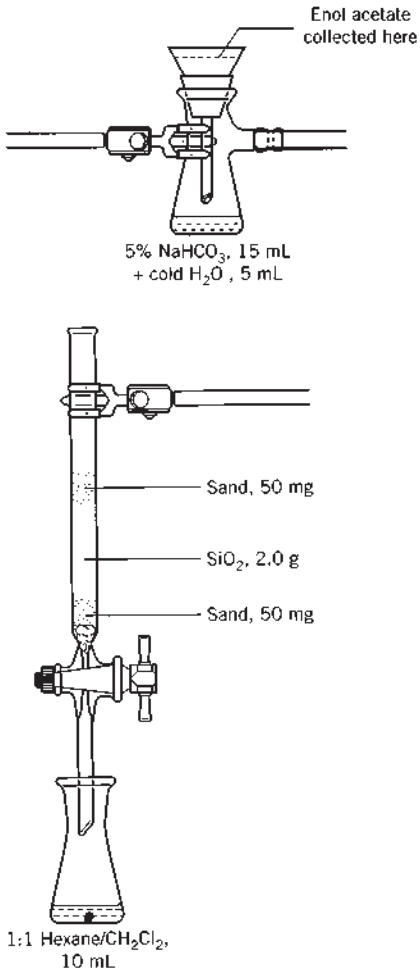

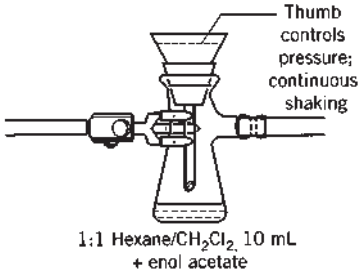

QUESTIONS

10W-34. Reaction of $(CH_3)_3SiCl$ with alcohols produces a trimethylsilyl ether. For example,

$$CH_3CH_2CH_2\ddot{O}H + (CH_3)_3SiCl \xrightarrow[\text{ether}]{(C_2H_5)_3N:} CH_3CH_2CH_2\ddot{O}Si(CH_3)_3 + (C_2H_5)_3\overset{+}{N}H,\ Cl^-$$

The trimethylsilyl ether is more volatile than the corresponding alcohol, and is often used to facilitate GC analysis. Explain.

10W-35. Chlorotrimethylsilane reacts with enolate anions to form stable silyl enol ethers. For example,

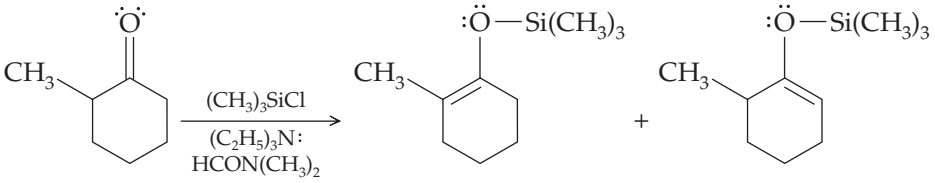

Assuming that the reaction is run under equilibrium conditions, predict which of the above silyl enol ethers is formed in the largest amount and why.

10W-36. In this experiment, the protons at *both* the γ and α′ positions relative to the intermediate oxonium ion are quite acidic. Removal of a proton from the γ position results in the formation (pathway *a* below) of the actual product, cholesta-3,5-dien-3-ol acetate (see Discussion section). Removal of a proton from the α′ position would result in the formation (pathway *b* below) of an isomeric product, cholesta-2,4-dien-3-ol acetate. Because the reaction is conducted under equilibrium conditions, the product obtained must be the thermodynamically more stable of the two possibilities. Why is cholesta-2,4-dien-3-ol acetate less stable than cholesta-3,5-dien-3-ol acetate?

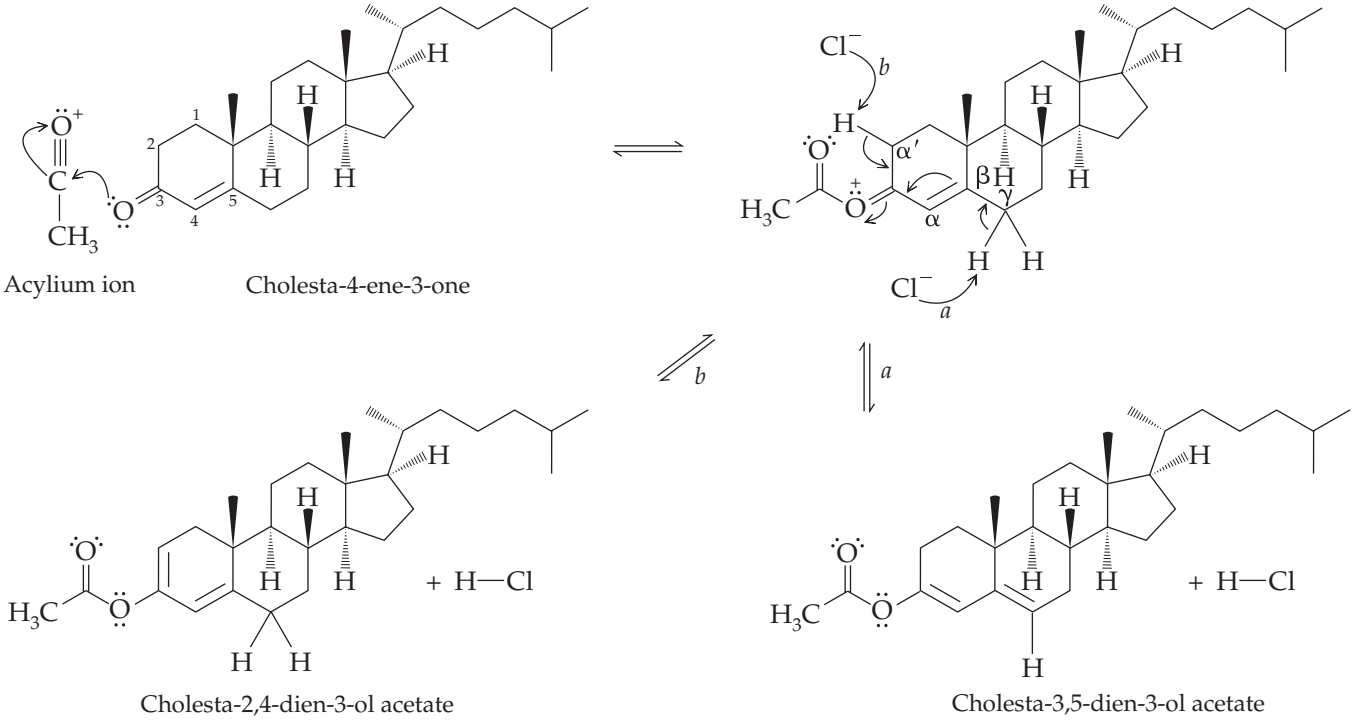

10W-37. There are two reasons why the enols of β-dicarbonyl compounds, such as pentane-2,4-dione are relatively stable. One is that they are conjugated and the π-electron overlap due to the conjugation provides additional stability. What is the other reason that these species are relatively stable? Would you expect the enol of cyclohexane-1,3-dione to be as stable as the enol of pentane-2,4-dione?

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The present experiment is adapted from the work reported by

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For information on the formation and reactivity of enols, see

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Rappoport, Z., Ed.; *The Chemistry of the Enols;* Wiley: New York, 1990.

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GLOSSARY

Absorb To take up matter (to dissolve), or to take up radiant energy.

Activated complex An unstable combination of reacting molecules that is intermediate between reactants and products.

Activation energy The minimum energy, $\Delta G^{\ddagger}$, necessary to form an activated complex in a reaction. Or the difference in energy levels between the ground state and transition state.

Active methylene A methylene group with hydrogen atoms rendered acidic due to the presence of an adjacent (α) electron withdrawing group, such as a carbonyl group.

Activity (of alumina) A measure of the degree to which alumina adsorbs polar molecules.The activity (adsorbtivity) of alumina may be reduced by the addition of small amounts of water. Thus, the amount of water present in a sample of alumina determines the activity grade. Alumina of a specific activity can be prepared by dehydrating alumina at 360 °C for about 5–6 h and then allowing the dehydrated alumina to absorb a suitable amount of water. The Brockmann scale of alumina activity is based on the amount of water (weight percent) that the alumina contains: grade I = 0%, grade II = 3%, grade III = 6%, grade IV = 10%, and grade V = 15%. For further information, see Brockmann, H.; Schodder, H. *Chem Ber.* **1941,** *74,* 73.

Adsorb The process by which molecules or atoms (either gas or liquid) adhere to the surface of a solid.

Aliphatic Term used to refer to nonaromatic species, such as alkanes, alkenes, alkynes.

Aliquot A portion.

Alkaloid A naturally occurring compound that contains a basic amine functional group. They are found particularly in plants.

Anilide A compound that contains a C_6H_5NHCO group. An amide formed by acylation of aniline (aminobenzene).

Bimolecular reaction The collision and combination of two reactants to give an activated complex in a reaction.

Capillary action The action by which the surface of a liquid,where it contacts a solid, is elevated or depressed because of the relative attractions of the molecules of the liquid for each other and for the solid. It is particularly observable in capillary tubes, where it determines the ascent (descent) of the liquid above (below) the level of the liquid in which the capillary tube is immersed.

Catalyst A substance that changes the speed of a chemical reaction without affecting the yield or undergoing permanent chemical change itself.

Characterize To conclusively identify a compound by the measurement of its physical, spectroscopic, and other properties.

Condensation reaction A condensation reaction is an addition reaction that produces water (or another small neutral molecule such as CH_3OH or NH_3) as a byproduct.

Dehydrohalogenation A reaction that involves loss of HX from a halide by treatment with strong base.

Deliquescent Liquefying by the absorption of water from the surrounding atmosphere.

Dihedral angle The angle between two intersecting planes. In organic chemistry the term dihedral angle (or torsional angle) is used to describe the angle between two atoms (or groups) bonded to two adjacent atoms, such as H—C—C—H, and

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can be determined from a molecular model by looking down the axis of the bond between the two central atoms.

Dipole The separation of charge in a bond or in a molecule with a positively and negatively charged end.

Eluant A mobile phase in chromatography.

Eluate The solution that is eluted from a chromatographic system.

Elute To cause elution.

Elution The flow, in chromatography, of the mobile phase through the stationary phase.

Emulsion A suspension composed of immiscible drops of one liquid in another liquid (e.g., oil and vinegar in salad dressing).

Enol A functional group composed of a hydroxyl group bonded to an alkene.

Enolate The conjugate base of a enol, that is, a negatively charged oxygen atom bonded to an alkene. An enolate results from deprotonation α to a carbonyl group.

Enthalpy change (ΔH) The heat lost or absorbed by a system under constant pressure during a reaction.

Entropy (*S*) The randomness, or amount of disorder of a system.

Entropy change (ΔS) The change in the amount of disorder.

Filter cake The material that is separated from a liquid, and remains on the filter paper, after a filtration.

Free energy change (ΔG) A predictor of the spontaneity of a chemical reaction at constant temperature. $\Delta G = \Delta H - T\,\Delta S$

Glacial acetic acid Pure acetic acid containing less than 1% water.

Heterocycle A cyclic molecule whose ring contains more than one kind of atom.

Heterolysis Cleavage of a covalent bond in a manner such that both the bond's electrons end up on one of the formerly bonded atoms.

Homogeneous Consisting of a single phase.

Homolysis Cleavage of a covalent bond in a manner such that the bond's electrons are evenly distributed to the formerly bonded atoms.

Hydroboration Addition of borane (BH_3) or an alkyl borane to a multiple bond.

Hydrogenation Addition of hydrogen to a multiple bond.

Hygroscopic Absorbs moisture.

In situ In chemistry, the term usually refers to a reagent or other material generated directly in a reaction vessel and not isolated.

Kinetics Referring to the rate of a reaction.

Lachrymator A material that causes the flow of tears.

Ligroin A solvent composed of a mixture of alkanes.

Mechanism A complete description of how a reaction occurs.

Metabolism The chemical processes performed by a living cellular organism.

Metabolites The compounds consumed and produced by metabolism.

Methine A CH group (with no other hydrogen atoms attached to the carbon atom).

Methylene A CH_2 group (with no other hydrogen atoms attached to the carbon atom).

Mother liquor The residual, and often impure, solution remaining from a crystallization.

Olefin An older term for an alkene.

Optical isomers Enantiomers. Isomers that have a mirror-image relationship.

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Order of reaction With respect to one of the reactants, the order of a reaction is equal to the power to which the concentration of that reactant is raised in the rate equation.

Oxonium ion A trivalent oxygen cation with a full octet of electrons (e.g., H_3O^+).

Paraffins An older name for alkanes.

Phase transfer catalysts Agents that cause the transfer of ionic reagents between phases, thus catalyzing reactions.

Plasticizer A substance added to a polymer to make it more flexible or to prevent embrittlement.

Polymer A compound of high molecular mass that is built up of a large number of repeating simple molecules, or monomers.

Racemic Consisting of an equimolar mixture of two enantiomers.

Rate equations Equations giving the relationship between reaction rate and the concentrations of the reactants.

Reaction mechanism The stepwise sequence of elementary reactions in an overall reaction.

Reagent A chemical or solution used in the laboratory to detect, measure, react with, or otherwise examine other chemicals, solutions, or substances.

Reflux The process by which all vapor evaporated or boiled from a vessel is condensed and returned to that vessel.

Rotamers Conformational isomers that can be interconverted by rotation about one or more single bonds (e.g., *gauche* and *anti* butane).

Spontaneous process A physical or chemical change that occurs without the net addition of energy. $\Delta G < 0$ for a spontaneous process.

Sublimation The passing of a solid directly into vapor state without first melting.

Tare A tared container is one whose weight has been measured. The term may also refer to the process of zeroing a balance after a container has been placed on the weighing platform.

Thermodynamics The chemical science that deals with the energy transfers and transformations that accompany chemical and physical changes.

Transition state A combination of reacting molecules that is intermediate between reactants and products.

Triturate To grind to a fine powder. (Or, washing solid organic products in a solvent in which the desired product has little solubility.)

Vapor pressure The pressure exerted by a vapor in equilibrium with a liquid or solid at a given temperature.

Ylide A neutral dipolar molecule in which negative and positive charges are on adjacent atoms.

Zwitterion A neutral molecule containing separated opposite formal charges.

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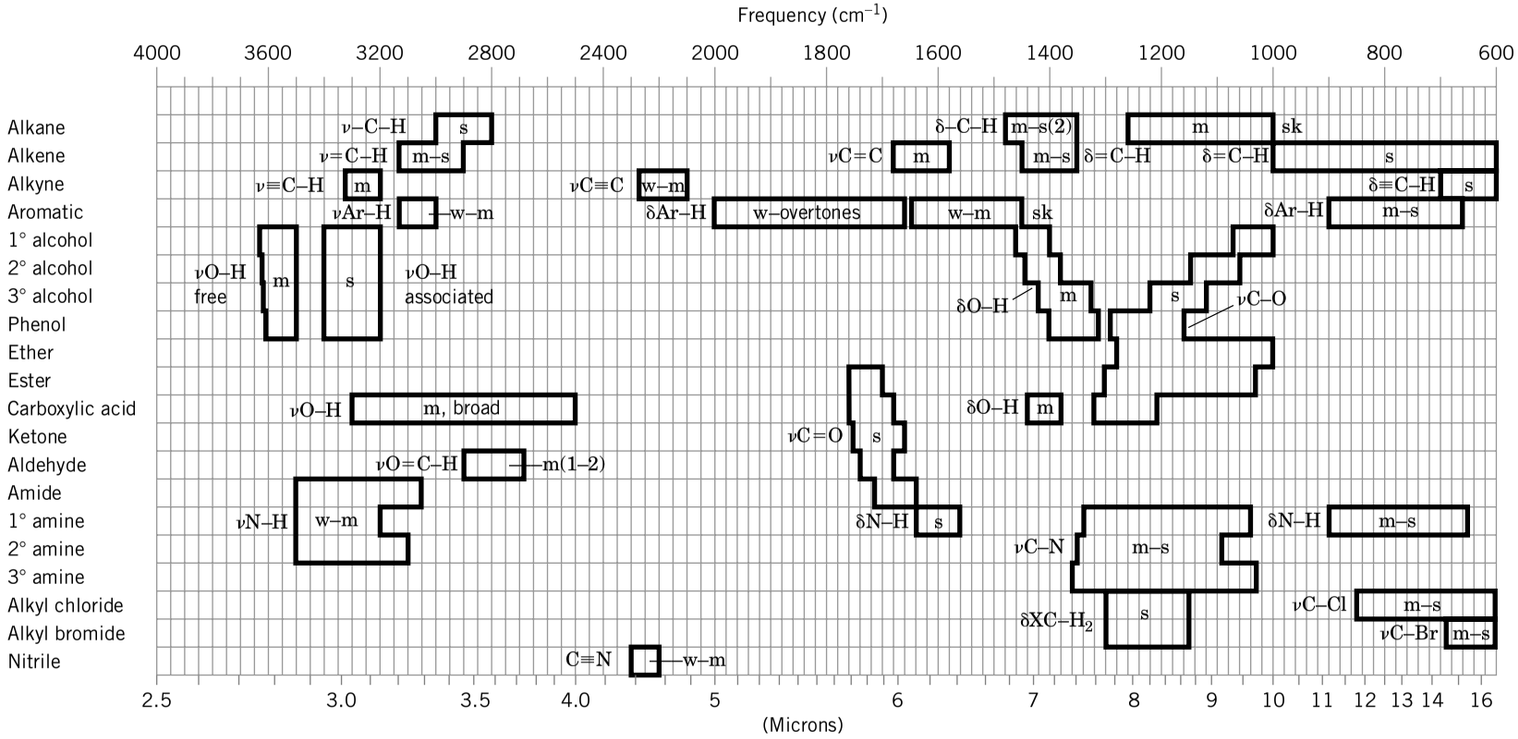

Typical IR absorption frequencies for common functional groups.
Absorptions are as follows: ν = stretching; δ = bending; w = weak; m = medium; s = strong; sk = skeletal
From *Multiscale Organic Chemistry: A Problem-Solving Approach* by John W. Lehman © 2002.
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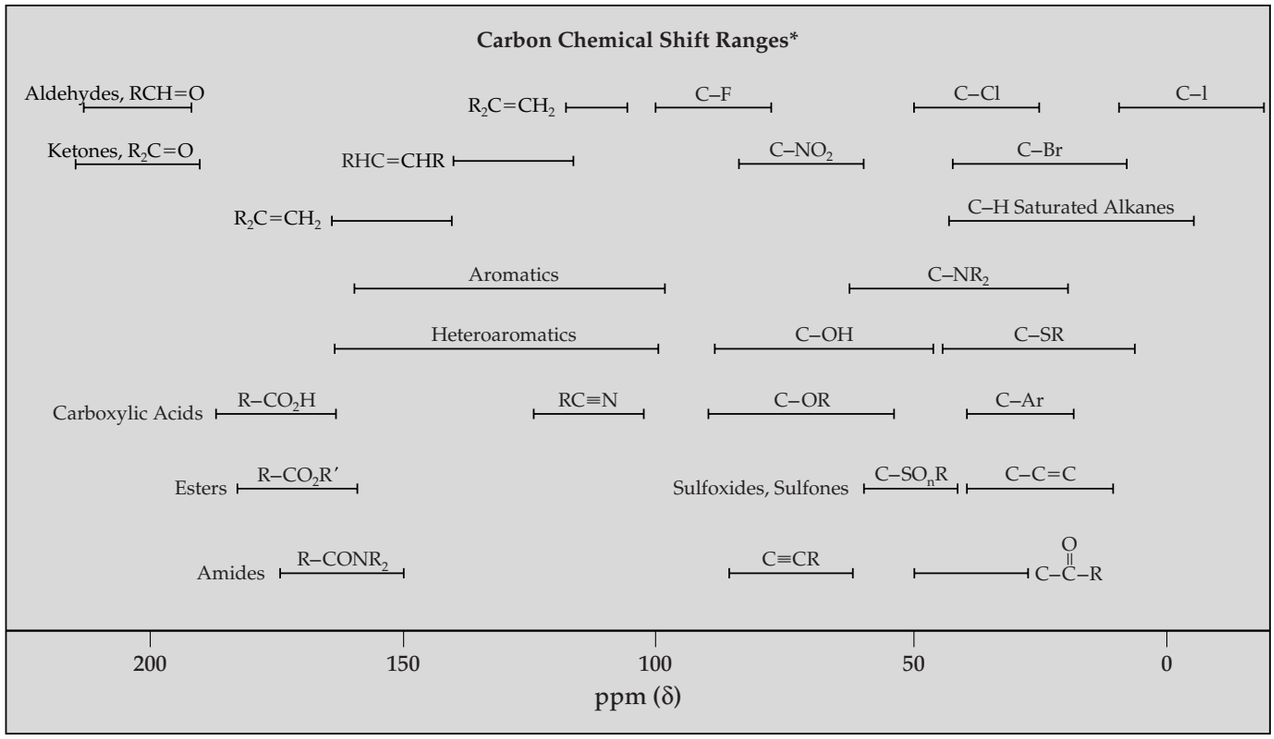

*For samples in $CDCl_3$ solution. The δ scale is relative to TMS at δ=0. Organic Chemistry Michigan State University Source, Dept. of Chemistry, Michigan State University.

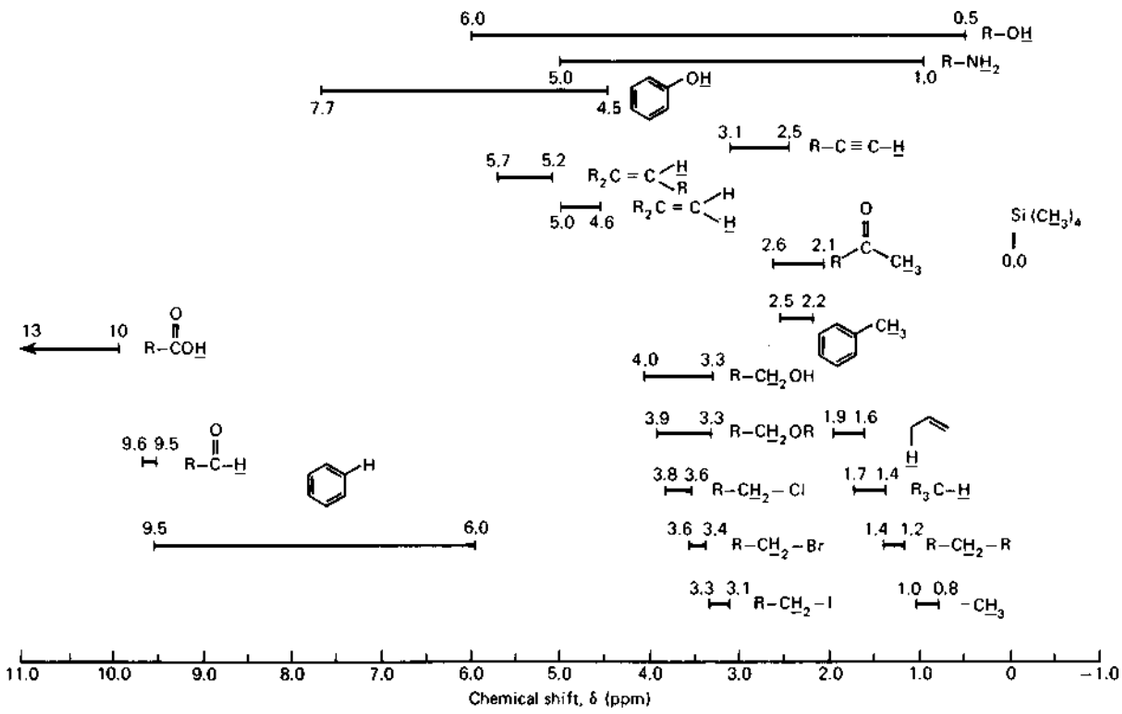

^{1}H NMR Chemical Shift Ranges

Periodic Table of the Elements

Atomic number → 6
Symbol → C
Name (IUPAC) → Carbon
Atomic mass → 12.011

IUPAC recommendations →
Chemical Abstracts Service group notation →

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.0079																	2 He Helium 4.0026
3 Ll Lithium 6.941	4 Be Berylium 9.0122											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22,990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xeno 131.29
55 Cs Caesium 132.91	56 Ba Barium 137.33	57 *La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 #Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Uun (281)	111 Uuu (272)	112 Uub (285)		114 Uuq (289)				

*Lanthanide Series	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
# Actinide Series	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

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Common Organic Solvents: Table of Properties

Solvent	formula	MW	boiling point (°C)	melting point (°C)	density (g/mL)	solubility in water (g/100g)	Dielectric Constant	flash point (°C)
acetic acid	$C_2H_4O_2$	60.05	118	16.6	1.049	Miscible	6.15	39
acetone	C_3H_6O	58.08	56.2	−94.3	0.786	Miscible	20.7(25)	−18
acetonitrile	C_2H_3N	41.05	81.6	−46	0.786	Miscible	37.5	6
benzene	C_6H_6	78.11	80.1	5.5	0.879	0.18	2.28	−11
1-butanol	$C_4H_{10}O$	74.12	117.6	−89.5	0.81	6.3	17.8	35
2-butanol	$C_4H_{10}O$	74.12	98	−115	0.808	15	15.8(25)	26
2-butanone	C_4H_8O	72.11	79.6	−86.3	0.805	25.6	18.5	−7
t-butyl alcohol	$C_4H_{10}O$	74.12	82.2	25.5	0.786	Miscible	12.5	11
carbon tetrachloride	CCl_4	153.82	76.7	−22.4	1.594	0.08	2.24	—
chlorobenzene	C_6H_5Cl	112.56	131.7	−45.6	1.1066	0.05	5.69	29
chloroform	$CHCl_3$	119.38	61.7	−63.7	1.498	0.795	4.81	—
cyclohexane	C_6H_{12}	84.16	80.7	6.6	0.779	<0.1	2.02	−20
1,2-dichloroethane	$C_2H_4Cl_2$	98.96	83.5	−35.3	1.245	0.861	10.42	13
diethyl ether	$C_4H_{10}O$	74.12	34.6	−116.3	0.713	7.5	4.34	−45
diethylene glycol	$C_4H_{10}O_3$	106.12	245	−10	1.118	10	31.7	143
diglyme (diethylene glycol dimethyl ether)	$C_6H_{14}O_3$	134.17	162	−68	0.943	Miscible	7.23	67
1,2-dimethoxy-ethane (glyme, DME)	$C_4H_{10}O_2$	90.12	85	−58	0.868	Miscible	7.2	−6
dimethylether	C_2H_6O	46.07	−22	−138.5	NA	NA	NA	−41
dimethyl-formamide (DMF)	C_3H_7NO	73.09	153	−61	0.944	Miscible	36.7	58
dimethyl sulfoxide (DMSO)	C_2H_6OS	78.13	189	18.4	1.092	25.3	47	95
dioxane	$C_4H_8O_2$	88.11	101.1	11.8	1.033	Miscible	2.21(25)	12
ethanol	C_2H_6O	46.07	78.5	−114.1	0.789	Miscible	24.6	13
ethyl acetate	$C_4H_8O_2$	88.11	77	−83.6	0.895	8.7	6(25)	−4
ethylene glycol	$C_2H_6O_2$	62.07	195	−13	1.115	Miscible	37.7	111
glycerin	$C_3H_8O_3$	92.09	290	17.8	1.261	Miscible	42.5	160
heptane	C_7H_{16}	100.20	98	−90.6	0.684	0.01	1.92	−4
Hexamethylphosphoramide (HMPA)	$C_6H_{18}N_3OP$	179.20	232.5	7.2	1.03	Miscible	31.3	105
Hexamethylphosphorous triamide (HMPT)	$C_6H_{18}N_3P$	163.20	150	−44	0.898	Miscible	??	26
hexane	C_6H_{14}	86.18	69	−95	0.659	0.014	1.89	−22
methanol	CH_4O	32.04	64.6	−98	0.791	Miscible	32.6(25)	12
methyl *t*-butyl ether (MTBE)	$C_5H_{12}O$	88.15	55.2	−109	0.741	5.1	??	−28
methylene chloride	CH_2Cl_2	84.93	39.8	−96.7	1.326	1.32	9.08	1.6
N-methyl-2-pyrrolidinone (NMP)	CH_5H_9NO	99.13	202	−24	1.033	10	32	91
nitromethane	CH_3NO_2	61.04	101.2	−29	1.382	9.50	35.9	35
pentane	C_5H_{12}	72.15	36.1	−129.7	0.626	0.04	1.84	−49
Petroleum ether (ligroine)	—	—	30–60	−40	0.656	—	—	−30
1-propanol	C_3H_8O	88.15	97	−126	0.803	Miscible	20.1(25)	15
2-propanol	C_3H_8O	88.15	82.4	−88.5	0.785	Miscible	18.3(25)	12
pyridine	C_5H_5N	79.10	115.2	−41.6	0.982	Miscible	12.3(25)	17
tetrahydrofuran (THF)	C_4H_8O	72.11	66	−108.4	0.886	30	7.6	−21
toluene	C_7H_8	92.14	110.6	−93	0.867	0.05	2.38(25)	4
triethyl amine	$C_6H_{15}N$	101.19	88.9	−114.7	0.728	0.02	2.4	−11
water	H_2O	18.02	100.00	0.00	0.998	—	78.54	—
water, heavy	D_2O	20.03	101.3	4	1.107	Miscible	??	—
o-xylene	C_8H_{10}	106.17	144	−25.2	0.897	Insoluble	2.57	32
m-xylene	C_8H_{10}	106.17	139.1	−47.8	0.868	Insoluble	2.37	27
p-xylene	C_8H_{10}	106.17	138.4	13.3	0.861	Insoluble	2.27	27

T = 20 °C unless specified otherwise.
Source: http://virtual.yosemite.cc.ca.us/smurov/orgsoltab.htm

CONFIRMING PAGES aptara

SECOND EDITION

BIOCHEMISTRY LABORATORY

MODERN THEORY AND TECHNIQUES

RODNEY BOYER

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CHAPTER

1 INTRODUCTION TO THE BIOCHEMISTRY LABORATORY

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Welcome to the biochemistry laboratory! You are reading this book for one of the following reasons: (1) you are enrolled in a formal biochemistry lab course at a college or university and you will use the book as a guide to procedures; or (2) you have started a research project in biochemistry and desire an understanding of the theories and techniques you will use in the lab; or (3) you have started a job in a biochemistry lab and wish to review theory and techniques. Whether you are a novice or experienced in biochemistry, I believe you will find the subject matter and lab work to be exciting and dynamic. Most of the experimental techniques and skills that you have acquired and mastered in other laboratory courses will be of great value in your work. However, you will be introduced to many new concepts, procedures, and instruments that you have not used in chemistry or biology labs. Your success in biochemistry lab activities will depend on your mastery of these specialized techniques, use of equipment, and understanding of chemical/ biochemical principles.

For many students, the primary reason to enroll in a formal biochemistry lab course is to learn how to do **research** in the discipline. Most students have observed graduate and undergraduate students participating in research activities at their institutions, but observers

may not be entirely familiar with the step-by-step process. The questions "What is research?" and "How is it done in biochemistry?" will be answered in Chapter 2, Section A, p. 35. For now, we will define research simply as "hunting for the truth."

As you proceed through this text, you will no doubt compare your activities with previous laboratory experiences. In organic lab, you ran reactions, isolated and purified several hundred milligrams or a few grams of solid or liquid products, and characterized the materials by infrared spectroscopy, gas chromatography, nuclear magnetic resonance spectroscopy, mass spectrometry, and other techniques. In biochemistry lab, you will work with milligram or even microgram quantities, and in most cases the biomolecules will be extracted from biological sources and dissolved in solution, so you will never really "see" the materials under study. But you will observe the dynamic chemical and biological changes brought about by biomolecules. The procedures and instruments introduced in the lab will be your "eyes" and will monitor the occurrence of biochemical events.

This chapter is an introduction to procedures that are of utmost importance for the safe and successful completion of a biochemical project. It is recommended that you become familiar with the following sections before you begin laboratory work.

A. SAFETY IN THE LABORATORY

Safety First

The concern for laboratory safety can never be overemphasized. Most students who are involved in biochemistry laboratory activities have progressed through several years of college lab work without even a minor accident. This record is, indeed, something to be proud of; however, it should not lead to overconfidence. You must always be aware that chemicals used in the laboratory are potentially toxic, irritating, and flammable. However, such chemicals are a hazard only when they are mishandled or improperly disposed of. It is my experience as a lab instructor for 30 years that accidents happen least often to those who come to each lab session mentally prepared and with a complete understanding of the experimental procedures to be followed. Because dangerous situations can develop unexpectedly, though, you must be familiar with general safety practices, facilities, and emergency actions. When we work in the lab, we must also have a special concern for the safety of lab mates. Carelessness on the part of one person can often cause injury to others.

Material Safety Data Sheets

The procedures in this book are designed and described with an emphasis on safety. However, no amount of planning or pretesting of procedures substitutes for awareness and common sense on the part of the student. All chemicals used in the procedures outlined here must be handled with care and respect. The use of chemicals in all U.S. workplaces, including academic research and teaching labs, is regulated by the Federal Hazard Communication Standard, a document

written by the Occupational Safety and Health Administration (OSHA).[1] Specifically, the OSHA standard requires all workplaces where chemicals are used to do the following: (1) develop a written hazard communication program; (2) maintain files of **Material Safety Data Sheets (MSDS)** on all chemicals used in that workplace (an MSDS is a detailed description of the properties of a chemical substance, the potential health hazards, and the safety precautions that must be taken when handling it); (3) label all chemicals with information regarding hazardous properties and procedures for handling; and (4) train employees in the proper use of these chemicals. Several states have passed "right-to-know" legislation that amends and expands the federal OSHA standard. If you have an interest in or concern about any chemical used in the laboratory, the MSDS may be obtained from your instructor or laboratory director or from the Internet (www.sigma-aldrich.com, for example). The actual form of an MSDS for a chemical may vary, but certain specific information must be present. Figure 1.1 is a partial copy of the MSDS for glacial acetic acid, a reagent often used in biochemical research. All chemical reagent bottles in a workplace, lab, or stockroom must be labeled to identify potential hazardous materials and to specify personal protection necessary for handling. One standard hazard communication system used for this purpose is the Hazardous Materials Identification System (HMIS® III Wall Chart containing an HMIS® III Label in the lower left-hand corner is shown in Figure 1.2). The health, flammability, physical hazard, and personal protection codes for the chemical reagent are summarized on the bottle label for quick identification.

Safe Practices in the Biochemistry Laboratory

It is easy to overlook some of the potential hazards of working in a biochemistry laboratory. Students often have the impression that they are working less with chemicals and more with natural biomolecules; therefore, there is less need for caution. However, this is not true; many reagents used are flammable and toxic. In addition, materials such as fragile glass (disposable pipets), sharp objects (needles, razor blades, etc.), and potentially infectious biological materials (blood, bacteria, viruses) must be used and disposed of with caution. The extensive use of electrical equipment, including hot plates, stirring motors, and high-voltage power supplies for electrophoresis, presents special hazards.

Proper disposal of all waste chemicals, sharp objects, and infectious agents is essential not only to maintain safe laboratory working conditions, but also to protect the general public and your local environment. Some of the liquid chemical reagents and reaction mixtures from experiments are relatively safe and may be disposed of in the laboratory drainage system without causing environmental damage. However, special procedures must be followed for the use and disposal of most reagents and materials. Often this means that your instructor will provide detailed information on proper use procedures. In some cases, proper

[1] *Federal Register,* Vol. 48, Nov. 25, 1983, p. 53280; Vol. 50, Nov. 27, 1985, p. 48758.

Section 2–Composition/Information on Ingredient

Substance Name	CAS #	SARA 313
ACETIC ACID	64-19-7	No

Formula C2H4O2

Synonyms Acetic acid (ACGIH:OSHA), Acetic acid, glacial, Acide acetique (French), Acido acetico (Italian), Azijnzuur (Dutch), Essigsaeure (German), Ethanoic acid, Ethylic acid, Glacial acetic acid, Kyselina octova (Czech), Methanecarboxylic acid, Octowy kwas (Polish), Vinegar acid

---

Section 4–First Aid Measures

Oral Exposure

If swallowed, wash out mouth with water provided person is conscious. Call a physician immediately.

Inhalation Exposure

If inhaled, remove to fresh air. If not breathing give artificial respiration. If breathing is difficult, give oxygen.

Dermal Exposure

In case of skin contact, flush with copious amounts of water for at least 15 minutes. Remove contaminated clothing and shoes. Call a physician.

Eye Exposure

In case of contact with eyes, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician.

Section 7–Handling and Storage

Handling

User Exposure

Do not breathe vapor. Do not get in eyes, on skin, on clothing. Avoid prolonged or repeated exposure.

Storage

Suitable

Keep tightly closed. Store in a cool dry place.

Section 9–Physical/Chemical Properties

Appearance	Color	Form
	Colorless	Clear liquid

Molecular Weight: 60.05 AMU

Property	Value	At Temperature or Pressure
pH	N/A	
BP/BP Range	117-118C	760 mmHg
MP/MP Range	4C	
Freezing Point	N/A	
Vapor Pressure	11.4 mmHg	20C
Vapor Density	2.07 g/f	
Saturated Vapor Conc.	N/A	
SG/Density	1.06 g/cm3	

Section 11–Toxicological Information

Route of Exposure

Skin Contact

Causes burns.

Skin Absorption

Harmful if absorbed through skin.

Eye Contact

Causes burns.

Inhalation

May be harmful if inhaled.

Ingestion

May be harmful if swallowed.

Target Organ(s) or System(s)

Teeth. Kidneys.

Signs and Symptoms of Exposure

Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract, eyes, and skin. Inhalation may result in spasm, inflammation and edema of the larynx and bronchi, chemical pneumonitis, and pulmonary edema. Symptoms of exposure may include burning sensation, coughing, wheezing, laryngitis, shortness of breath, headache, nausea, and vomiting. Ingestion or inhalation of concentrated acetic acid causes damage to tissues of the respiratory and digestive tracts. Symptoms include: hematemesis, bloody diarrhea, edema and/or perforation of the esophagus and pylorus, hematuria, anuria, uremia, albuminuria, hemolysis, convulsions, bronchitis, pulmonary edema, pneumonia, cardiovascular collapse, shock, and death. Direct contact or exposure to high concentrations of vapor with skin or eyes can cause: erythema, blisters, tissue destruction with slow healing, skin blackening, hyperkeratosis, fissures, corneal erosion, opacification, iritis, conjunctivitis, and possible blindness. To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

FIGURE 1.1 Partial MSDS for glacial acetic acid. MSDS information is subject to change. For the most current version, contact Sigma-Aldrich. *Courtesy of Sigma-Aldrich Corp., St. Louis, MO;* www.sigma-aldrich.com.

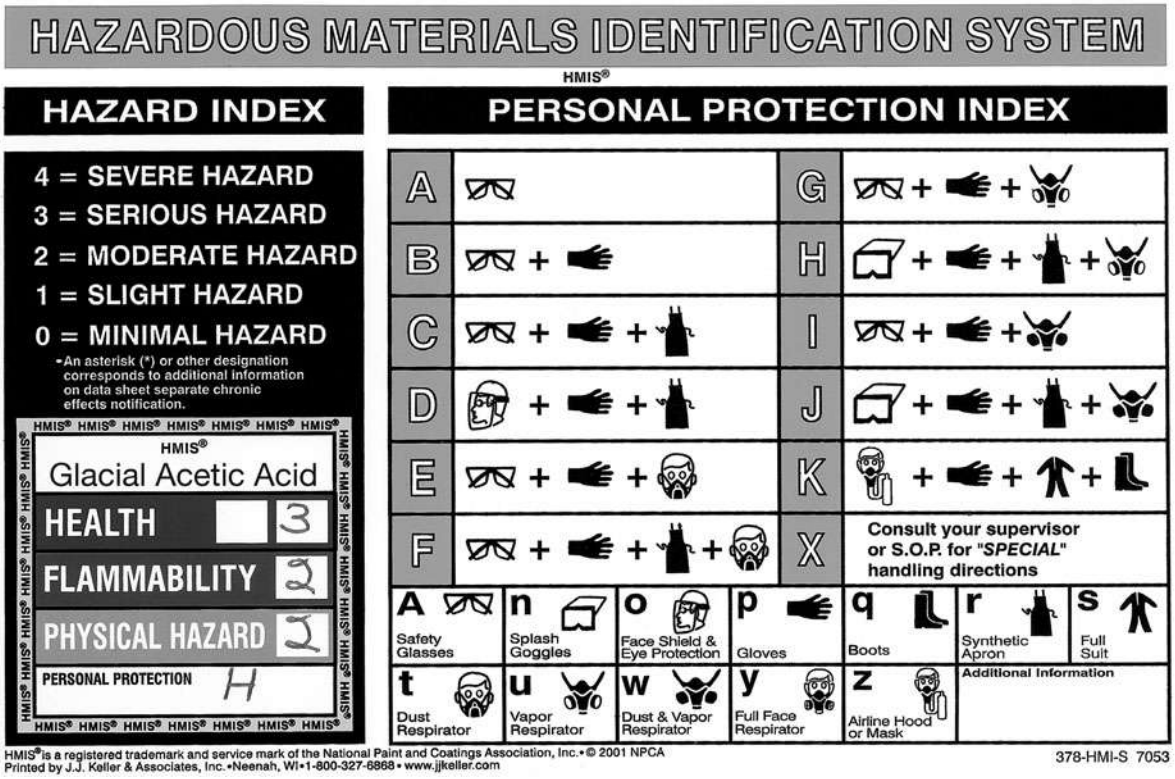

FIGURE 1.2 HMIS® III Wall Chart containing an HMIS® III label (lower left-hand corner) for glacial acetic acid displaying the hazard indices for the chemical. HMIS® III is a registered trademark of the National Paint & Coatings Association, Inc. (NPCA). *It is used with permission and may not be further reproduced. NPCA has granted an exclusive license to produce and distribute HMIS® III materials to J. J. Keller & Associates, Inc. Those wishing to utilize the HMIS® III system should contact J. J. Keller at 1-800-327-6868 or* www.jjkeller.com.

disposal will require the collection of waste materials from each laboratory worker, and the institution will be responsible for removal. For each procedure described in this book, appropriate handling of all reagents, materials, and equipment will be recommended.

It is essential that all students be aware of the potential hazards of working in a biochemistry laboratory. A set of rules is an appropriate way to communicate the importance of practicing safe science. The general rules outlined in Figure 1.3 serve as guidelines. Your institution and instructor may have their own list of rules or may want to add guidelines for specific activities. Rules of laboratory safety and chemical handling are not designed to impede productivity, nor should they instill a fear of chemicals or of laboratory procedures. Rather, their purpose is to create a healthy awareness of potential laboratory hazards, to improve the efficiency of each student worker, and to protect the general public and the environment from waste contamination. The list of references at the end of this chapter includes books, journal articles, manuals, and Web sites describing proper and detailed safety procedures.

1. Some form of eye protection is required at all times. Safety glasses with wide side shields or goggles are recommended, but normal eyeglasses with safety lenses may be permitted under some circumstances. Your instructor will inform you of the type of eye protection required. A statement regarding the wearing of contact lenses in the laboratory has been made by the American Chemical Society.[1] In general, contact lenses may be acceptable for wear in the laboratory, but the student must, of course, also wear safety glasses with side shields or goggles like all other students. Students who wear contacts must report to their lab instructor to determine the local rules for the lab.
2. Wear appropriate clothes — comfortable, well-fitting, older clothes that cover most of your skin. Sandals or bare feet are never allowed.
3. Never work alone in the laboratory.
4. Be familiar with the properties of all chemicals used in the laboratory. This includes their flammability, reactivity, toxicity, and proper disposal. This information may be obtained from your instructor, from the HMIS® III label, and from the MSDS. Always wear disposable gloves when using potentially dangerous chemicals or infectious agents.
5. Be familiar with your local rules for the safe handling and disposal of all non-chemical hazards. These include broken glass, "sharps" (needles, syringes, etc.), and biohazards (blood, bacteria, etc.).
6. Be especially careful with electrical equipment like stirrers, hot plates, and power supplies (electrophoresis, etc.). Always unplug before handling and avoid contact with water.
7. If open flames like those of Bunsen burners are necessary, make sure there are no flammable solvents in the area.
8. Eating, drinking, and smoking in the laboratory are strictly prohibited at all times.
9. Unauthorized experiments are not allowed.
10. Mouth suction should never be used to fill pipets or to start siphons.
11. Become familiar with the location and use of standard safety features in your laboratory. All laboratories should be equipped with fire extinguishers, eyewashes, safety showers, fume hoods, chemical-spill kits, fire blankets, first-aid supplies, and containers for chemical disposal. Receptacles should also be available for disposal of dangerous materials like glass, biohazards, and sharps. Any questions regarding the use of these features should be addressed to your instructor, teaching assistant, or lab director.
12. Report all chemical spills, presence of biohazards, accidents, and injuries (even minor) to your instructor.

[1]American Chemical Society, Washington, DC; Committee on Chemical Safety, 1998.

FIGURE 1.3 Guidelines for safety in the biochemistry laboratory.

B. KEEPING RECORDS AND COMMUNICATING EXPERIMENTAL RESULTS

The Laboratory Notebook

The biochemistry laboratory experience is not finished when you complete the experimental procedure and leave the laboratory. All scientists, including students, have the obligation to prepare and present written and oral reports on the results of their experimental work. Because these reports may be read and heard by many other professional scientists, they must be completed in a clear, concise, orderly, and accurate manner. Reports are most easily prepared outside of the lab using notes taken in a laboratory notebook ***while*** the experiment is in progress. These notes usually include procedural details, preparation of all reagents and solutions, setup of equipment, collection of data, and your thought processes and observations during the experiment. Experiments are often complex and move rather quickly, and it would be impossible to write down your data and

observations after you have completed the experiments and left the lab. It is also not a good practice to record results on scraps of paper or on paper towels that may easily become lost or destroyed. The lab notebook will also come in handy if you need to troubleshoot or repeat an experiment because of inconsistent results.

Your instructor may have his or her own rules for preparation of the lab notebook, but here are some useful guidelines:

- The notebook should be hardbound with quadrille-ruled (gridded) pages; writing should be done with pen. This provides a permanent, durable record and the potential for construction of tables, graphs, charts, etc. Number each page of the book.
- Save the first few pages of the book for construction of a table of contents. Keep this up-to-date by entering the name of each experiment and page number.
- Use the right-hand pages only for writing your experimental notes. The left-hand pages may be used as scratch paper for your own personal notes, reminders, or calculations not appropriate for the main entry.
- Each entry for an experiment or project must begin with a title and date. The general outline required by many instructors for the written material is shown in Figure 1.4 and described below. Note that Parts I–IIc are labeled Prelab and should be completed before you begin the actual procedures in the lab.

Details of the Experimental Write-Up (see Figure 1.4)

Below is an outline that may be used as a guideline to write a complete report on an experiment.

Prelab
- I. Introduction
  - (a) Objective or purpose
  - (b) Theory
- II. Experimental
  - (a) Table of materials and reagents
  - (b) List of equipment
  - (c) Flowchart
  - (d) Record of procedure
- III. Data and Calculations
  - (a) Record of all raw data including printouts
  - (b) Method of calculation with statistical analysis
  - (c) Present final data in tables, graphs, or figures when appropriate.
- IV. Results and Discussion
  - (a) Conclusions
  - (b) Compare results with known values
  - (c) Discuss the significance of the data
  - (d) Was the original objective achieved?
  - (e) Literature references

FIGURE 1.4 General outline for experimental write-up in your notebook.

Introduction

This section begins with a three- or four-sentence statement of the objective or purpose of the experiment. When preparing this statement, ask yourself, "What are the goals of this experiment?" This statement is followed by a brief discussion of the theory behind the experiment. If a new technique or instrumental method is introduced, give a brief description of the method. Include chemical and biochemical reactions and structures of reagents when appropriate.

Experimental

Begin this section with a list of all reagents and materials used in the experiment. The sources of all chemicals and the concentrations of solutions should be listed. Instrumentation is listed with reference to company name and model number. A flowchart to describe the stepwise procedure for the experiment should be included after the list of equipment.

The write-up to this point is to be completed as a Prelab assignment. The experimental procedure followed is then recorded in your notebook as you proceed through the activities. The details should be sufficient so that a fellow student could use your notebook to repeat the experiment. You should include observations, such as color change or gas evolution, made during the experiment. If you obtain a computer printout of numbers, a spectrum from a spectrophotometer, or a photograph, these records must be saved with the notebook.

Data and Calculations

All raw data from the experiment are to be recorded directly in your notebook, not on separate sheets of paper that can easily become lost. Calculations involving the data must be included for at least one series of measurements. All data numbers should be analyzed by appropriate statistical methods using computer programs as described in Chapter 1, Section E, p. 23.

For many experiments, the clearest presentation of data is in tabular or graphical form. A graph may be prepared directly on the gridded pages of your notebook, or by computer software.

Results and Discussion

This important section of your write-up answers the questions "Did you achieve your proposed goals and objectives?" and "What is the significance of the data?" Any conclusion that you make must be supported by experimental results. It is often possible to compare your data with known values and results from the literature. If problems were encountered in the experiments, these should be outlined with possible remedies for future experiments.

All library references (books, journal articles, and Web sites) that were used to complete the experiment should be listed at the end of the write-up. It is especially important to report references used for laboratory procedures. The standard format to follow for a reference listing is shown at the end of this chapter in the Further Reading section.

Everyone has his or her own writing style. Because there is always room for improvement, it is imperative that you continually try to enhance your writing

skills. When your instructor reviews your notebook, he or she should include helpful writing tips. References at the end of this chapter provide further instructions in scientific writing. Your instructor may accept, as a final report, the experimental write-up as described above and in Figure 1.4. However, he or she may request that you present your experimental results in one of the more formal written or oral modes described next.

Several electronic lab notebook (ELN) software packages are available commercially. For example, CERF by Resentris is an ELN designed for biology. The use of ELN's is still somewhat controversial, so you should ask your instructor if they are allowed in your lab. The primary purpose for maintaining a lab notebook, especially in academic and industrial/pharmaceutical labs, is to have a permanent and complete record for scientific and legal reasons. Lab notebooks are legal documents that are essential in patent lawsuits in order to prove authenticity and ownership of a discovery. Thus, it must be proven that the ELN is accurate, confidential, and maintained by authorized scientists, something that may be difficult with some current computer systems.

Communicating Results from Biochemistry Research

A scientific project is not complete until its discoveries have been communicated to colleagues around the world. The three most important methods or tools for communication are: the **scientific paper,** the **oral presentation,** and the **poster.** Although there are many differences in how to prepare for these three common methods of introducing new biochemical information, they all have one thing in common—the sharing of experimental results and conclusions. The distinct rules and traditions of each of the methods will be described and compared here.

The Scientific Paper

A paper published in a biochemical journal is a formal way to report research results to colleagues in the international biochemical community. Before writing such a document, one must first determine the journal to which the article will be submitted. There are hundreds of journals that accept manuscripts in the field of biochemistry (see Figure 1.5). Some have very high rank, prestige, and status based on the significance of research results published, reputation of authors, numbers of citations, whether or not manuscripts are peer-reviewed, and numbers of readers. Most journals are peer-reviewed, which indicate that before a manuscript is published, it is studied by members of the journal's editorial board to assure that the manuscript is scientifically significant, that it appears to be accurate, and that it is useful and of value to readers of the journal. Some journals accept manuscripts in all areas of biochemistry, but the manuscripts undergo rigorous peer-review by scientists with a certain specialty in the field. Other reputable journals are more specialized and accept peer-reviewed articles only in certain areas of biochemistry. Perhaps the best advice is to submit the manuscript to the most prestigious journal that has a large audience interested in his or her specialized topic. Publishing a paper in a reputable, peer-reviewed journal offers historic permanence for one's work, status, and exposure as a scientist; however, because the lag time between acceptance and publication of

Accounts of Chemical Research
Analytical Biochemistry
Annual Review of Biochemistry
Archives of Biochemistry and Biophysics
Biochemical and Biophysical Research Communications
Biochemical and Molecular Medicine
Biochemical Journal
Biochemistry
Biochemistry and Molecular Biology Education
Biochimica et Biophysica Acta: General Subjects; Molecular and Cell Biology; Protein Structure and Molecular Enzymology
BioEssays
Bioorganic Chemistry
Biophysical Journal
Canadian Journal of Biochemistry
Cell
ChemBioChem
Chemistry and Biology
Current Opinion in Structural Biology
DNA Research Online
Electrophoresis
European Journal of Biochemistry
FASEB Journal
Glycobiology
Glycoconjugate Journal
Journal of Biochemistry
Journal of Biological Chemistry
Journal of Cell Biology
Journal of Cell Biology Education
Journal of Chemical Education
Journal of Lipid Research
Journal of Molecular Biology
Journal of Neurochemistry
Journal of Plant Physiology
Macromolecules
Methods: A Companion to Methods in Enzymology
Molecular and Cellular Biochemistry
Molecular and Cellular Proteomics
Nature
Nature Reviews Molecular Cell Biology
Nature Structural Biology
Nucleic Acid Research
Phytochemistry
Proceedings of the National Academy of Sciences USA
Prostaglandins, Leukotrienes and Essential Fatty Acids
Protein Science
Proteomics
RNA
Science
Scientific American
Trends in Biochemical Sciences

FIGURE 1.5
Some journals that publish research articles in biochemistry. Web sites for the journals may be found using a search engine.

a manuscript can sometimes stretch up to one year, the data reported can become outdated or insignificant.

Most research journals are now available in electronic form and accessible through college/university or corporate libraries. The subscription costs are usually borne by the academic institutions or corporations and available to students, faculty, and research staff.

Your instructor may require that you write up the results from an experiment in the form of a journal article, so it is important to understand the conventions used in preparing a manuscript for publication. Most biochemical journal articles have the same basic organization: Title, Abstract, Introduction, Experimental Methods, Results, Discussion, and References. The specific requirements for each of these sections vary among the many journals, so it is important to review several articles in different journals to get a flavor of what is expected. All scientific journals publish "Instructions to Authors," which are available on their Web site. Although your instructor will most likely expect you to follow the requirements of a specific journal, it is instructive to study articles in the following high-ranking journals that publish biochemistry topics: *The Journal of Biological Chemistry* (published by the American Society for Biochemistry and Molecular Biology), *Biochemistry* (published by the American Chemical Society), *Science*, and *Nature*. Use a search engine such as Google, Yahoo, etc. to find Web sites for other journals.

The Oral Presentation

The purpose and mechanics of an oral presentation are quite different from preparing and publishing a paper. You may write a paper over a period of days, weeks, and even months, and the published work is available as a permanent record for readers to study and reference anytime in the future. In an oral presentation, you have a fleeting moment to present data and attempt to convince your audience of the importance of your work. One advantage of the oral presentation, however, is that it provides an opportunity for more direct contact with your audience than does a paper; thus the opportunity exists for immediate questions and feedback.

Presentations usually range from 15 to 60 minutes. Shorter presentations cover a much smaller unit of a research project, whereas 60-minute talks (often called seminars) can give a broader exposure to the research area.

Scientific presentations involve mixed media—oral and visual. The important verbal points are reinforced with the use of a visual aid such as a figure, graph, or other element. Scientific presenters today most often use PowerPoint, computer software that projects electronic slides onto a screen, although overhead transparencies are also acceptable and efficient. Whatever the type of visual aid, the slides must be carefully constructed with special concern for the total number of slides and the amount of information on each. Some presenters use the approximate ratio of one-to-two slides per minute of presentation.

The organization of a talk is similar to that of a paper—Introduction, Experimental Methods, Results, Discussion, Conclusions, Questions/Comments. If your instructor expects you to present a talk, he or she will provide specific information regarding length of time, range of topic, type of visual aids, multimedia, etc.

The Scientific Poster

The scientific poster is a communication method that may be considered a hybrid, as it combines elements of the oral presentation (verbal expression and visual aids) with elements of a paper (printed text and figures). The poster has become the primary medium by which new scientific information is exchanged at all professional conferences, including local, regional, national, and international meetings. At meetings, posters that consist of text and figures arranged in panels on a thin piece of cardboard (average 3′ × 5′) are set up in designated areas during specified times (usually for a day or two), and there is often an official time when the presenter is to be in attendance. The poster, however, may be available to readers for long periods of time in the absence of the presenter. Some of the specific characteristics that describe a poster include (Figure 1.6):

FIGURE 1.6 Template for a poster in biochemistry. *Courtesy of Professor Colin Purrington, Department of Biology, Swarthmore College,* www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm.

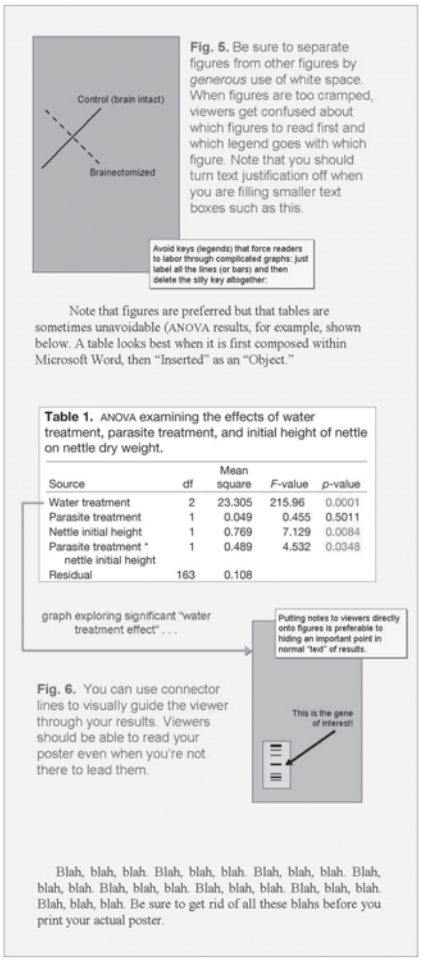

Conclusions
You can, of course, start your conclusions in column three if your results section is "data light."
Conclusions should not be mere rephrasing of your results. What would one conclude from the results? What is the broader significance? Why should anyone care? This section should refer back to the "burning issue" mentioned in the introduction.
Blah, blah, blah. Blah, blah, blah. Blah, blah, blah. Blah, blah, blah. Blah, blah, blah. Blah, blah, blah.

- poster sessions at scientific meetings are very democratic and inclusive, as the presenters and audience may consist of all levels of scientists—tenured research professors including Nobel Prize winners, as well as undergraduate research students.

Your instructor may request that you prepare a poster for local display at your institution or for presentation at a regional or national meeting. Specific details will not be given here, as all organizations sponsoring poster sessions at meetings publish their own rules and regulations (regarding poster size, font sizes, etc.) for preparing posters. Many colleges and universities now schedule local meetings where students may obtain experience preparing and presenting posters about their research results. Attend one of these local meetings or walk around the halls of your chemistry and biology departments looking for posters made by research students at your institution. These may serve as very good models for your own creation. You may also find useful information about the specific details of poster construction by searching the Internet. Some helpful Web sites with poster templates are listed in the Further Reading section at the end of this chapter.

C. USING BIOCHEMICAL REAGENTS AND SOLUTIONS

Water Purity

Water is the most common and widely-used substance in the biochemistry laboratory. Applications of water usage include: (1) solvent for preparing most buffer and reagent solutions; (2) column chromatography; (3) high-performance liquid chromatography; (4) tissue culture; and (5) washing glassware. Both the quality and quantity of water required must be considered for each lab application. Ordinary tap water is relatively abundant, but its quality is very low. It contains a variety of impurities including particulate matter (sand, silt, etc.); dissolved organics, inorganics, and gases; and microorganisms (bacteria, viruses, protozoa, and algae). In addition, the natural degradation of microorganisms leads to the presence of byproducts called pyrogens. Tap water should never be used for the preparation of reagent solutions or for any sensitive procedures. For most laboratory procedures, it is recommended that some form of purified water be used. The purity of water is usually measured in terms of **resistivity** (the ability of a liquid to restrict the flow of an electric current). Units for resistivity are Megohms $\times$ cm (MΩ.cm) with a relative scale of 1.0 MΩ.cm to 18.2 MΩ.cm (the highest theoretical purity).

There are five basic water purification technologies—distillation, ion-exchange, activated carbon adsorption, reverse osmosis, and membrane filtration. Most academic and industrial research laboratories are equipped with "in-house" purified water, which typically is produced by a combination of the above purifying processes and piped throughout all the labs in a building. The water quality necessary will depend on the solutions to be prepared and on the biochemical procedures to be investigated. For most procedures carried out in the biochemistry lab, water purified by ion-exchange, reverse osmosis, or distillation is usually acceptable. Of these three processes, distillation is the slowest, least energy-efficient, least pure (best is 1.0 MΩ.cm), and most high-maintenance—especially in areas with hard water (needs regular de-scaling). Distilled water must also be stored to prevent contamination by microbes. For special procedures such as

buffer standardization, liquid chromatography, and tissue culture, ultra-pure water, which is usually bottled and available commercially, should be used. Water that is purified only by ion-exchange will be low in metal-ion concentration, but may contain certain organics that are washed from the ion-exchange resin. These contaminants will increase the UV-absorbance properties of water. If sensitive UV-spectroscopic measurements are to be made, distilled water (especially glass-distilled) is better than de-ionized. If large volumes of high-purity water are required (18.2 MΩ.cm), reverse osmosis should be the choice.

Cleaning Laboratory Glassware

The results of your experimental work will depend, to a great extent, on the cleanliness of your equipment, especially glassware used for preparing and transferring solutions. There are at least two important reasons for this: (1) many of the chemicals and biochemicals will be used in milligram, microgram, or even nanogram amounts. Any contamination, whether on the inner walls of a beaker, in a pipet, or in a glass cuvette, could be a significant percentage of the total experimental sample; (2) many biochemicals and biochemical processes are sensitive to one or more of the following common contaminants: metal ions, detergents, and organic residues. In fact, the objective of many experiments is to investigate the effect of a metal ion, organic molecule, or other chemical agent on a biochemical process. Contaminated glassware will virtually ensure failure in these activities.

The preferred method for cleaning glassware is to begin with hot tap water. Rinse the glassware at least 10 times with this; then rinse 4–6 times with distilled or de-ionized water. Occasionally it is necessary to use a detergent for cleaning. Use a dilute detergent solution (0.5% in water) followed by 5–10 water rinses with distilled or de-ionized water.

Dry equipment is required for most processes carried out in the biochemistry laboratory. When you needed dry glassware in the organic laboratory, you probably rinsed the glassware with acetone, which rapidly evaporated, leaving a dry surface. Unfortunately, this technique coats the surface with an organic residue consisting of nonvolatile contaminants found in the acetone. Because this residue could interfere with your experiments, it is best to refrain from acetone washing. Glassware and plasticware should be rinsed well with purified water and dried in an oven designated for glassware, not one used for drying chemicals.

Never clean cuvettes or any optically polished glassware with ethanolic KOH or other strong base, as this will cause etching. All glass cuvettes should be cleaned carefully with hot tap water or 0.5% detergent solution, in a sonicator bath or in a cuvette washer, followed by thorough rinsing with purified water.

Solutions: Concentrations and Calculations

The concentrations for solutions used in the biochemistry laboratory may be expressed in several different units. The most common units are:

- ***Molarity (M):*** concentration based on the number of moles of solute per liter of solution. A 1 *M* solution of the amino acid alanine (MW = 89.1) contains 1 mole, or 89.1 g, of alanine in a solution volume of 1 liter. In biochemistry, it is more common to use concentration ranges that are

millimolar (mM, 1×10^{-3} M), micromolar (μM, 1×10^{-6} M), or nanomolar (nM, 1×10^{-9} M). A 1 mM solution of alanine contains 0.089 g, or 89 mg (89.1×0.001), of alanine in a solution volume of 1 liter. How many grams of alanine are present in 100 mL of the 1 mM alanine solution? (Ans: 0.0089 g). How many milligrams of alanine are present in 100 mL? (Ans: 8.9 mg).

- ***Percent by weight (% wt/wt):*** concentration based on the number of grams of solute per 100 g of solution. A 5% wt/wt solution of alanine contains 5 g of alanine in 100 g of solution. How many grams of alanine are present in 10 g of this solution? (Ans: 0.5 g).

STUDY EXERCISE 1.1 Preparation of Molar Solutions

a. Many solutions you use will be based on molarity. For practice, assume you require 1 liter of solution that is 0.1 M (100 mM) glucose:

$$\begin{aligned} \text{MW of glucose} &= 180.2 \\ 1 \text{ mole of glucose} &= 180.2 \text{ g} \\ 0.1 \text{ mole of glucose} &= 18.02 \text{ g} \end{aligned}$$

To prepare a 0.1 M glucose solution, weigh 18.02 g of glucose and transfer to a 1-liter volumetric flask. Add about 700–800 mL of purified water and swirl to dissolve. Then add water so that the bottom of the meniscus is at the etched line on the flask. Stopper and mix well. The flask must be labeled with solution contents (0.1 M glucose), date prepared, and name of preparer.

b. Assume that you need only 250 mL of 0.10 M glucose. Explain how you would prepare the solution. Emphasize any changes from Part (a).

STUDY EXERCISE 1.2 Concentration Unit Conversions

It is often necessary in your biochemistry lab work to convert one concentration unit to another. For example, you may need to know the concentration of the 0.1 M glucose solution (Study Exercise 1.1) in concentration terms of mg/mL. Here are some basic calculations for practice.

a. Convert the concentration units of 0.1 M glucose to the units of mg of glucose in 1 mL (mg/mL).
According to the procedure described in Study Exercise 1.1(a), the 1000-mL solution of glucose contains 18.02 g of glucose, or is 18.02 g/1000 mL. This is equivalent to 1.80 g/100 mL or 0.018 g/mL. Therefore, the 0.1 M glucose solution concentration is equivalent to about 18 mg/mL.

b. Convert the concentration units of 1 M alanine to the units of g/100 mL.

c. Convert the concentration units of 1 M alanine to the units of % wt/vol.

d. Calculate the concentration of a 0.1 M glucose solution to the units of % wt/vol.

e. Calculate the molar concentration of an ethanol solution that was prepared by adding 10 mL of 100% ethanol to a 100-mL volumetric flask followed by adding water to the line. The density of ethanol is 0.789.

- ***Percent by volume (% wt/vol):*** concentration based on the number of grams of solute per 100 mL of solution. A 10% wt/vol solution of alanine contains 10 g of alanine in 100 mL of solution. How many grams of alanine are present in 50 mL of this solution? (Ans: 5 g).
- ***Weight per volume (wt/vol):*** concentration based on the number of grams, milligrams, or micrograms of solute per unit volume; for example, mg/mL, g/L, mg/100 mL, etc. A solution of alanine, concentration wt/vol = 5 g/L, contains 5 g of alanine in a liter of solution. How many grams of alanine would be present in 2 liters of this solution? In 10 mL? (Ans: 10 g; 0.005 g).

Preparing and Storing Solutions

In general, solid solutes should be weighed on weighing paper or plastic weighing boats, with the use of an electronic analytical or top-loading balance. Liquids are more conveniently dispensed by volumetric techniques; however, this assumes that the density is known. If a small amount of a liquid is to be weighed, it should be added to a tared flask by means of a disposable Pasteur pipet with a latex bulb. The hazardous properties of all materials should be known before use (read MSDS) and the proper safety precautions obeyed.

The storage conditions of reagents and solutions in the biochemistry lab are especially critical. Although some will remain stable indefinitely at room temperature, it is good practice to store all solutions in a closed container. Often it is necessary to store some solutions in a refrigerator at 4°C. This inhibits bacterial growth and slows decomposition of the reagents. Some solutions may require storage below 0°C. If these are aqueous solutions or others that will freeze, be sure there is room for expansion inside the container. Stored solutions must always have a label containing the name and concentration of the solution, the date prepared, and the name of the preparer.

All stored containers, whether at room temperature, 4°C, or below freezing, must be properly sealed. This reduces contamination by bacteria and vapors in the laboratory air (carbon dioxide, ammonia, HCl, etc.). Volumetric flasks, of course, have glass stoppers, but test tubes, Erlenmeyer flasks, bottles, and other containers should be sealed with screw caps, corks, or hydrocarbon foil (Parafilm). Remember that hydrocarbon foil, a wax, is dissolved by solutions containing nonpolar organic solvents like chloroform, diethyl ether, and acetone.

Bottles of pure chemicals and reagents should also be properly stored. Many manufacturers now include the best storage conditions for a reagent on the label. The common conditions are: store at room temperature; store at 0–4°C; store below 0°C; or store in a desiccator at room temperature, 0–4°C, or below 0°C. Many biochemical reagents form hydrates by taking up moisture from the air. If the water content of a reagent increases, the molecular weight and purity of the reagent change. For example, when the coenzyme nicotinamide adenine dinucleotide (NAD^+) is purchased, the label usually reads "Anhydrous molecular weight = 663.5; when assayed, contained 3 H_2O per mole." The actual molecular weight that should be used for solution preparation is 663.5 + (18)(3) = 717.5. However, if this reagent is stored in a moist refrigerator or freezer outside a desiccator, the moisture content may increase to an unknown value.

D. QUANTITATIVE TRANSFER OF LIQUIDS

Practical biochemistry is highly reliant on analytical methods. Many analytical techniques must be mastered, but few are as important as the quantitative transfer of solutions. Some type of pipet will almost always be used in liquid transfer. Because students may not be familiar with the many types of pipets and the proper techniques in pipetting, this instruction is included here.

Pipets and Pipetting

Pipet Fillers

Figure 1.7 illustrates the various types of pipets and fillers. The use of any pipet requires some means of drawing reagent into the pipet. ***Liquids should never be drawn into a pipet by mouth suction on the end of the pipet!*** Small latex bulbs are available for use with disposable pipets (see Figure 1.7A). For volumetric and graduated pipets, two types of bulbs are available. One type (see Figure 1.7B) features a special conical fitting that accommodates common sizes of pipets. To use these, first place the pipet tip below the surface of the liquid. Squeeze the bulb with the left hand (if you are a right-handed pipettor) and then hold it tightly to the end of the pipet. Slowly release the pressure on the bulb to allow liquid to rise to 2 or 3 cm above the top graduated mark. Then, remove the bulb and

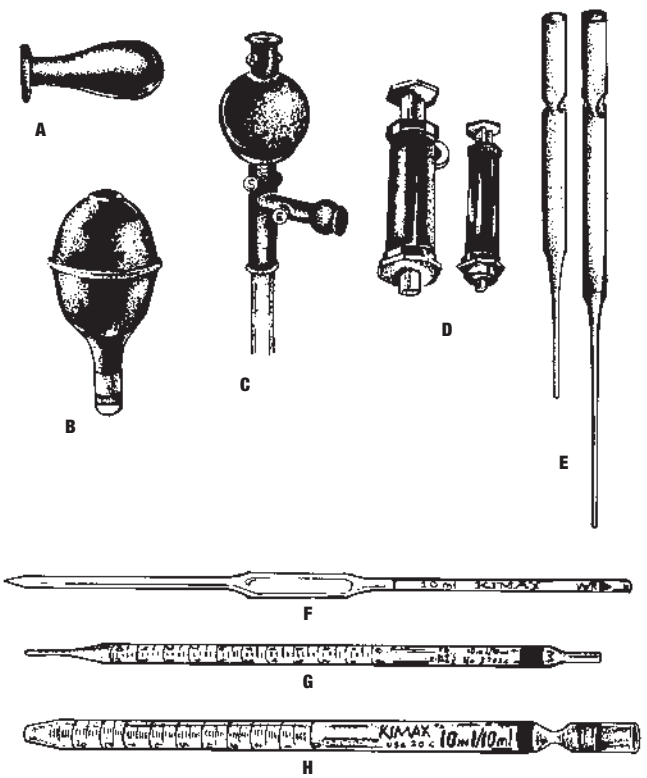

FIGURE 1.7
Examples of pipets and pipet fillers. *Courtesy of Sargent-Welch, VWR International;* www.vwr.com
A *Latex bulb,*
B *Pipet filler,*
C *Mechanical pipet filler,*
D *Pipettor pump,*
E *Pasteur pipet,*
F *Volumetric pipet,*
G *Mohr pipet,*
H *Serological pipet.*

quickly grasp the pipet with your index finger over the top end of the pipet. The level of solution in the pipet will fall slightly, but should not fall below the top graduated mark. If it does fall too low, use the bulb to refill.

Safety Pipet Fillers

Mechanical pipet fillers (made of silicone and sometimes called safety pipet fillers, propipets, or pi-fillers) are more convenient than latex bulbs. As shown in Figure 1.7C,D, these fillers are equipped with a system of hand-operated valves and can be used for the complete transfer of a liquid. The use of a safety pipet filler is outlined in Figure 1.8. ***Never allow any solvent or solution to enter the pipet bulb!*** To avoid this, two things must be kept in mind:

1. Always maintain careful control while using valve S to fill the pipet.
2. Never use valve S unless the pipet tip is below the surface of the liquid. If the tip moves above the surface of the liquid, air will be sucked into the pipet and solution will be flushed into the bulb.

Disposable Pasteur Pipets

Often it is necessary to perform a semi-quantitative transfer of a small volume (1–10 mL) of liquid from one vessel to another. Because pouring is not efficient, a **Pasteur pipet** with a small latex bulb may be used (see Figure 1.7A, E). Pasteur pipets are available in two lengths (15 and 23 cm) and hold about 2 mL of solution. These are especially convenient for the transfer of nongraduated amounts to and from test tubes. Typical recovery while using a Pasteur pipet is 90 to 95%. If dilution is not a problem, rinsing the original vessel with a solvent will increase the transfer yield. Used disposable pipets should be discarded in special containers for broken glass.

Calibrated Pipets

Although most quantitative transfers are now done with automatic pipetting devices, which are described later in the chapter, instructions will be given for the use of all types of pipets. If a quantitative transfer of a specific and accurate volume of liquid is required, some form of calibrated pipet must be used.

- ***Volumetric pipets*** (see Figure 1.7F) are used for the delivery of liquids required in whole-milliliter amounts (1, 2, 5, 10, 15, 20, 25, 50, and 100 mL). To use these pipets, draw liquid with a latex bulb or mechanical pipet filler to a level 2–3 cm above the fill line. Release liquid from the pipet until the bottom of the meniscus is directly on the fill line. Touch the tip of the pipet to the inside of the glass wall of the container from which it was filled. Transfer the pipet to the inside of the second container and release the liquid. Hold the pipet vertically, allow the solution to drain until the flow stops, and then wait an additional 5–10 seconds. Touch the tip of the pipet to the inside of the container to release the last drop from the outside of the tip. Remove the pipet from the container. Some liquid may still remain in the tip. Most volumetric pipets are calibrated as "TD" (to deliver), which

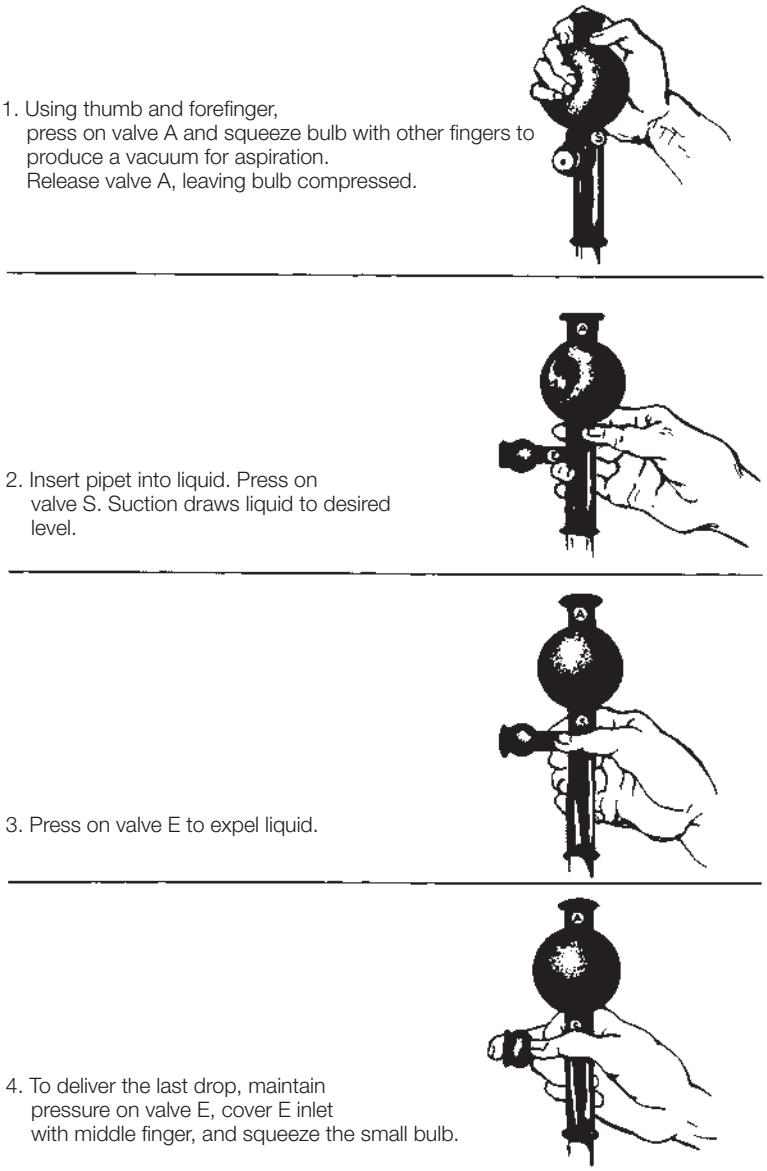

FIGURE 1.8
How to use a safety pipet filler. *Courtesy of Sargent-Welch, VWR International.*

means the intended volume is transferred *without final blow-out*; that is, the pipet delivers the correct volume.

Fractional volumes of liquid are transferred with **graduated pipets,** which are available in two types:

- ***Mohr pipets*** (see Figure 1.7G) are available in long- or short-tip styles. Long-tip pipets are especially attractive for transfer to and from vessels

with small openings. Virtually all Mohr pipets are TD, and they are available in many sizes (0.1 to 10 mL). The marked subdivisions are usually 0.01 or 0.1 mL, and the markings end a few centimeters from the tip. Selection of the proper size is especially important. For instance, do not try to transfer 0.2 mL with a 5- or 10-mL pipet. Use the smallest pipet that is practical. The use of a Mohr pipet is similar to that of a volumetric pipet. Draw the liquid into the pipet with a pipet filler to a level about 2 cm above the 0 mark. Lower the liquid level to the 0 mark. Remove the last drop from the tip by touching it to the inside of the glass container. Transfer the pipet to the receiving container and release the desired amount of solution. The solution should not be allowed to move below the last graduated mark on the pipet. Touch off the last drop.

- ***Serological pipets*** (see Figure 1.7H) are similar to Mohr pipets, except that they are graduated downward to the very tip and are designed for blow-out. Their use is identical to that of a Mohr pipet except that the last bit of solution remaining in the tip must be forced out into the receiving container with a rubber bulb. This final blow-out should be done after 15–20 seconds of draining.

Cleaning and Drying Pipets

Special procedures are required for cleaning glass pipets. Immediately after use, every pipet should be placed, tip up, in a vertical cylinder containing warm tap water or a dilute detergent solution (less than 0.5%). The pipet must be completely covered with solution. This ensures that any reagent remaining in the pipet is forced out through the tip. If reagent solutions are allowed to dry inside a pipet, the tips can easily become clogged and are very difficult to open. After several pipets have accumulated in the water or detergent solution, the pipets should be transferred to a pipet rinser. Pipet rinsers continually cycle fresh water through the pipets. Immediately after detergent wash, tap water may be used to rinse the pipets, but distilled water should be used for the final rinse. Pipets may then be dried in an oven.

Automatic Pipetting Devices

For most quantitative transfers, including many repeated small-volume transfers, a mechanical microliter pipettor (i.e., Eppendorf type, Pipetman) is ideal. This allows accurate, precise, and rapid dispensing of fixed volumes from 1 to 10,000 μL (0.001 to 10 mL). The pipet's push-button system can be operated with one hand, and it is fitted with detachable polypropylene tips (see Figure 1.9). The advantage of polypropylene tips is that the amount of reagent film remaining in the pipet after delivery is much less than for glass tips. Mechanical pipettors are available in many different sizes. Newer models offer continuous volume adjustment, so a single model can be used for delivery of specific volumes within a certain range. Multichannel pipettors are available, which fill several containers or wells at once (see Figure 1.10).

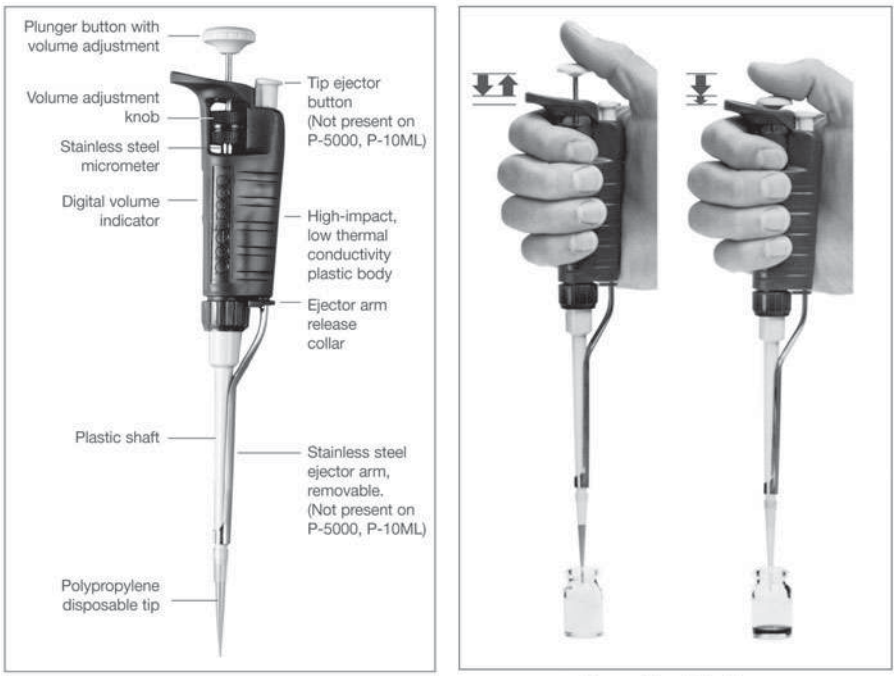

FIGURE 1.9 How to use an adjustable pipetting device. Set the desired volume with the digital micrometer or plunger button. Attach a new disposable tip to the shaft of the pipet. Press tip on firmly with a slight twisting motion. Depress the plunger to the first positive stop, immerse the disposable tip into the sample liquid to a depth of 2–4 mm, and allow the pushbutton to return slowly to the up position and wait 1–2 seconds. To dispense sample, place the tip end against the side wall of the receiving vessel and depress the plunger slowly to the first stop. Wait 2–3 seconds, and then depress the plunger to the second stop to achieve final blow-out. Withdraw the device from the vessel carefully with the tip sliding along the inside wall of the vessel. Allow the plunger to return to the up position. Discard the tip by depressing the tip ejector button. *Photos courtesy of Rainin Instrument Company, Inc., Woburn, MA. Pipetman is a registered trademark of Gilson Medical Electronics. Exclusive license to Rainin Instrument Company, Inc.,* www.rainin.com.

To use the pipettor, choose the proper size and place a polypropylene pipet tip firmly onto the cone, as shown in Figure 1.9. Tips for pipets are available in several sizes, for 1–20, 20–250, 200–1000, 1000–5000, and 10,000-μL capacities. Details of the operation of an adjustable pipet are shown in Figure 1.9.

For rapid and accurate transfer of volumes greater than 5 mL, automatic repetitive dispensers are commercially available. These are particularly useful for the transfer of corrosive materials. The dispensers, which are available in several sizes, are simple to use. The volume of liquid to be dispensed is mechanically set; the syringe plunger is lifted for filling and pressed downward for dispensing. Hold the receiving container under the spout while depressing the plunger. Touch off the last drop on the inside wall of the receiving container.

FIGURE 1.10 A multichannel pipettor. *Photo courtesy of Rainin Instrument, LLC., Oakland, CA. Pipet-Lite is a registered trademark of Rainin Instrument Company.* www.rainin.com.

E. STATISTICAL ANALYSIS OF EXPERIMENTAL DATA

The purpose of most biochemistry laboratory exercises is to observe and measure characteristics of a biomolecule or a biological process. The characteristic is often quantitative—a single number or a group of numbers. These measured quantities may be the molecular weight of a protein, the pH of a buffer solution, the absorbance of a colored solution, the rate of an enzyme-catalyzed reaction, the concentration of a protein in solution, or the radioactivity associated with a molecule. If you measure a quantitative characteristic many times under identical conditions, a slightly different result will most likely be obtained each time.

For example, if a radioactive sample is counted twice under identical experimental and instrumental conditions, the second measurement immediately following the first, the probability is very low that the numbers of counts will be identical. If the absorbance of a solution is determined several times at a specific wavelength, the value of each measurement will surely vary from the others. If an assay for cholesterol is performed several times on a blood serum sample from the same individual, the values will probably be close, but not all will be the same (see Study Problem 1.13). Which measurements, if any, are correct? Before this question can be answered, you must understand the source and treatment of numerical variations in experimental measurements.

Defining Statistical Analysis

An **error** in an experimental measurement is defined as a deviation of an observed value from the true value. There are two types of errors, **determinate** and **indeterminate.** Determinate errors are those that can be controlled by the

experimenter and are associated with malfunctioning equipment, improperly designed experiments, and variations in experimental conditions. These are sometimes called human errors because they can be corrected or at least partially alleviated by careful design and performance of the experiment. Indeterminate errors are those that are random and cannot be controlled by the experimenter. Specific examples of indeterminate errors are variations in radioactive counting and small differences in the successive measurements of glucose in a serum sample.

Two statistical terms involving error analysis that are often used and misused are **accuracy** and **precision.** Precision refers to the extent of agreement among repeated measurements of an experimental value. Accuracy is defined as the difference between the experimental value and the true value for the quantity. Because the true value is seldom known, accuracy is better defined as the difference between the experimental value and the accepted true value. Several experimental measurements may be precise (that is, in close agreement with each other) without being accurate.

If an infinite number of identical, quantitative measurements could be made on a biosystem, this series of numerical values would constitute a **statistical population.** The average of all of these numbers would be the **true value** of the measurement. It is obviously not possible to achieve this in practice. The alternative is to obtain a relatively small **sample of data,** which is a subset of the infinite population data. The significance and precision of these data are then determined by statistical analysis.

Most quantitative biological measurements can be made in duplicate, triplicate, or even quadruplicate, but it would be impractical and probably a waste of time and materials to make numerous determinations of the same measurement. Rather, when you perform an experimental measurement in the laboratory, you will collect a small sample of data from the population of infinite values for that measurement. To illustrate, imagine that an infinite number of experimental measurements of the pH of a buffer solution are made, and the results are written on slips of paper and placed in a container. It is not feasible to calculate an average value of the pH from all of these numbers, but it is possible to draw five slips of paper, record these numbers, and calculate an average pH. By doing this, you have collected a sample of data. By proper statistical manipulation of this small sample, it is possible to determine whether it is representative of the total population and the amount of confidence you should have in these numbers.

The Mean, Sample Deviation, and Standard Deviation

Radioactive decay with emission of particles is a random process. It is impossible to predict with certainty when a radioactive event will occur. Therefore, a series of measurements made on a radioactive sample will result in a series of different count rates, but they will be centered around an **average** or **mean** value of counts per minute. Table 1.1 contains such a series of count rates obtained with a scintillation counter on a single radioactive sample. A similar table could be prepared for other biochemical measurements, including the rate of an

TABLE 1.1 The Observed Counts and Sample Deviation from a Typical Radioactive Sample

Counts per Minute	Sample Deviation $x_i - \bar{x}$
1243	+21
1250	+28
1201	−21
1226	+4
1220	−2
1195	−27
1206	−16
1239	+17
1220	−2
1219	−3
Mean = 1222	

enzyme-catalyzed reaction or the protein concentration of a solution as determined by the Bradford method. The arithmetic average, or mean, of the numbers is calculated by totaling all the experimental values observed for a sample (the counting rates, the velocity of the reaction, or protein concentration) and dividing the total by the number of times the measurement was made. The mean is defined by Equation 1.1.

>>
$$\bar{x} = \frac{\sum^{n} x_i}{n} \qquad \textbf{(Eq. 1.1)}$$

where

$\bar{x}$ = arithmetic average or mean
x_i = the value for an individual measurement
n = the total number of experimental determinations
$\sum$ = sum of all the values

The mean counting rate for the data in Table 1.1 is 1222. If the same radioactive sample were again counted for a series of ten observations, that series of counts would most likely be different from those listed in the table, and a different mean would be obtained. If we were able to make an infinite number of counts on the radioactive sample, then a **true mean** could be calculated. The true mean would be the actual amount of radioactivity in the sample. Although it would be desirable, it is not possible experimentally to measure the true mean. Therefore, it is necessary to use the average of the counts as an approximation of the true mean

and to use statistical analysis to evaluate the precision of the measurements (that is, to assess the agreement among the repeated measurements).

Because it is not usually practical to observe and record a measurement many times as in Table 1.1, what is needed is a way to determine the reliability of an observed measurement. This may be stated in the form of a question. How close is the result to the true value? One approach to this analysis is to calculate the **sample deviation,** which is defined as the difference between the value for an observation and the mean value, $\bar{x}$ (Equation 1.2). The sample deviations are also listed for each count in Table 1.1.

>> $$\text{Sample deviation} = x_i - \bar{x} \qquad \textbf{(Eq. 1.2)}$$

A more useful statistical term for error analysis is **standard deviation,** a measure of the spread of the observed values. Standard deviation, s, for a sample of data consisting of n observations may be estimated by Equation 1.3.

>> $$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}} \qquad \textbf{(Eq. 1.3)}$$

It is a useful indicator of the probable error of a measurement. Standard deviation is often transformed to **standard deviation of the mean** or **standard error.** This is defined by Equation 1.4, where n is the number of measurements.

>> $$s_m = \frac{s}{\sqrt{n}} \qquad \textbf{(Eq. 1.4)}$$

It should be clear from this equation that as the number of experimental observations becomes larger, s_m becomes smaller, or the precision of a measurement is improved.

Standard deviation may also be illustrated in graphical form (see Figure 1.11). The shape of the curve in Figure 1.11 is closely approximated by the **Gaussian distribution** or **normal distribution curve.** This mathematical

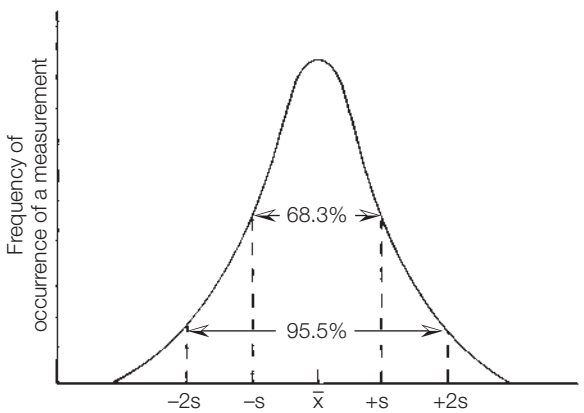

FIGURE 1.11 The normal distribution curve.

treatment is based on the fact that a plot of relative frequency of a given event yields a dispersion of values centered about the mean, $\bar{x}$. The value of $\bar{x}$ is measured at the maximum height of the curve. The normal distribution curve shown in Figure 1.11 defines the spread or dispersion of the data. The probability that an observation will fall under the curve is unity, or 100%. By using an equation derived by Gauss, it can be calculated that for a single set of sample data, 68.3% of the observed values will occur within the interval $\bar{x} \pm s$, 95.5% of the observed values within $\bar{x} \pm 2s$, and 99.7% of the observed values within $\bar{x} \pm 3s$. Stated in other terms, there is a 68.3% chance that a single observation will be in the interval $\bar{x} \pm s$.

For many experiments, a single measurement is made, so a mean value, $\bar{x}$, is not known. In these cases, error is expressed in terms of s, but is defined as the **percentage proportional error,** $\%E_x$, in Equation 1.5.

>> $$\%E_x = \frac{100k}{\sqrt{n}} \qquad \textbf{(Eq. 1.5)}$$

The parameter k is a proportional constant between E_x and the standard deviation. The percent proportional error may be defined within several probability ranges. **Standard error** refers to a confidence level of 68.3%; that is, there is a 68.3% chance that a single measurement will not exceed the $\%E_x$. For standard error, $k = 0.6745$. **Ninety-five hundredths error** means there is a 95% chance that a single measurement will not exceed the $\%E_x$. The constant k then becomes 1.45.

The previous discussion of standard deviation and related statistical analysis placed emphasis on estimating the reliability or precision of experimentally observed values. However, standard deviation does not give specific information about how close an experimental mean is to the true mean. Statistical analysis may be used to estimate, within a given probability, a range within which the true value might fall. The range or confidence interval is defined by the experimental mean and the standard deviation. This simple statistical operation provides the means to determine quantitatively how close the experimentally determined mean is to the true mean. **Confidence limits** (L_1 and L_2) are created for the sample mean as shown in Equations 1.6 and 1.7.

>> $$L_1 = \bar{x} + (t)(s_m) \qquad \textbf{(Eq. 1.6)}$$

>> $$L_2 = \bar{x} - (t)(s_m) \qquad \textbf{(Eq. 1.7)}$$

where

t = a statistical parameter that defines a distribution between a sample mean and a true mean

The parameter t is calculated by integrating the distribution between percent confidence limits. Values of t are tabulated for various confidence limits (Table 1.2). Each column in the table refers to a desired confidence level (0.05 for 95%, 0.02 for 98%, and 0.01 for 99% confidence). The table also includes the term **degrees of freedom,** which is represented by $n - 1$, the number of experimental

observations minus 1. The values of $\bar{x}$ and s_m are calculated as previously described in Equations 1.1 and 1.4.

TABLE 1.2 Values of *t* for Analysis of Statistical Confidence Limits

	Probability of Larger Value of t, Sign Ignored						
d.f.	**0.05**	**0.02**	**0.01**	**d.f.**	**0.05**	**0.02**	**0.01**
1	12.706	31.821	63.657	14	2.145	2.624	2.977
2	4.303	6.096	9.925	15	2.131	2.602	2.947
3	3.182	4.541	5.841	16	2.120	2.583	2.921
4	2.776	3.747	4.604	17	2.110	2.567	2.898
5	2.571	3.365	4.032	18	2.101	2.552	2.878
6	2.447	3.143	3.707	19	2.093	2.539	2.861
7	2.365	2.998	3.499	20	2.086	2.528	2.845
8	2.306	2.896	3.355	21	2.080	2.518	2.831
9	2.262	2.821	3.250	22	2.074	2.508	2.819
10	2.228	2.764	3.169	23	2.069	2.500	2.807
11	2.201	2.718	3.106	24	2.064	2.492	2.797
12	2.179	2.681	3.055	25	2.060	2.485	2.787
13	2.160	2.650	3.012				

Spreadsheet Statistics

It is common practice today to use computer spreadsheet programs for statistical analysis of biochemical data. A spreadsheet provides a means to collect and enter data in the form of numbers and text. Perhaps the most versatile and easy-to-use spreadsheet software is Microsoft Excel, although more specialized statistical software programs including SPSS and SyStat are also very useful (see Chapter 2 and Appendix I). Using Excel to estimate statistical terms for experimental data is relatively straightforward. Launching the Microsoft Excel program on your computer brings up the Excel spreadsheet, which consists of rows (number headings) and columns (letter headings). More detailed instructions for the statistical applications of Excel are found at www.microsoft.com.

Statistical Analysis in Practice

The equations for statistical analysis that have been introduced in this section are of little value if you have no understanding of their practical use, meaning, and limitations. A set of experimental data will first be presented, and then several statistical parameters will be calculated using the equations. This example will serve as a summary of the statistical formulas and will also illustrate their application.

STUDY EXERCISE 1.3 Statistical Analysis of Data

Ten identical protein samples were analyzed by the Bradford method for protein analysis. The following values for protein concentration were obtained.

Observation Number	Protein Concentration (mg/mL), *x*
1	1.02
2	0.98
3	0.99
4	1.01
5	1.03
6	0.97
7	1.00
8	0.98
9	1.03
10	1.01

Sample mean

$$\bar{x} = \frac{\sum x}{n} = \frac{10.02}{10} = 1.00\,\text{mg/mL}$$

Sample deviation

$$\text{Sample deviation} = x_i - \bar{x}$$

Observation	$x_i - \bar{x}$
1	+0.02
2	−0.02
3	−0.01
4	+0.01
5	+0.03
6	−0.03
7	0.00
8	−0.02
9	+0.03
10	+0.01

Calculation of the sample deviation for each measurement gives an indication of the precision of the determinations.

(*Continued*)

Standard deviation

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

$$s = 0.02$$

The mean can now be expressed as $\bar{x} \pm s$ (for this specific example, 1.00 ± 0.02 mg/mL). The probability of a single measurement falling within these limits is 68.3%. For 95.5% confidence ($2s$), the limits would be 1.00 ± 0.04 mg/mL.

Standard error of the mean

$$s_m = \frac{s}{\sqrt{n}}$$

$$s_m = \frac{0.02}{\sqrt{10}}$$

$$s_m = 0.006$$

This statistical parameter can be used to gauge the precision of the experimental data.

Confidence limits

The desired confidence limits will be set at the 95% confidence level. Therefore, we will choose a value for t from Table 1.2 in the column labeled $t_{0.05}$ and $n - 1 = 9$.

$$L_1 = \bar{x} + (t_{0.05})(s_m)$$
$$L_2 = \bar{x} - (t_{0.05})(s_m)$$
$$s_m = 0.006$$
$$t_{0.05} = 2.262$$
$$\bar{x} = 1.00$$
$$L_1 = 1.00 + (2.262)(0.006)$$
$$L_1 = 1.01$$
$$L_2 = 0.99$$

We can be 95% confident that the true mean falls between 0.99 and 1.01 mg/mL.

Study Problems

1. What personal protection items must be worn when handling glacial acetic acid?
2. Define each of the following terms.
   (a) OSHA
   (b) MSDS
   (c) Flowchart
   (d) Pasteur pipet
   (e) Purified water
   (f) Error
   (g) Standard deviation
   (h) Molarity
3. Draw a schematic picture of your biochemistry lab and mark locations of the following safety features: eyewashes, first-aid kit, shower, fire extinguisher, chemical-spill kits, and direction to nearest exit.

4. Describe how you would prepare a 1-liter aqueous solution of each of the following reagents:
   (a) 1 *M* glycine
   (b) 0.5 *M* glucose
   (c) 10 m*M* ethanol
   (d) 100 n*M* hemoglobin
5. Why is de-ionized (ion-exchange) water not suitable as a solvent for use in UV absorbance measurements?
6. Describe how you would prepare just 10 mL of each of the solutions in Problem 4.
7. If you mix 1 mL of the 1 *M* glycine solution in Problem 4a with 9 mL of water, what is the final concentration of this diluted solution in m*M*?
8. Convert each of the concentrations below to m*M* and μM
   (a) 10 mg of glucose per 100 mL
   (b) 100 mL of a solution 2% in alanine
9. You have just prepared a solution by weighing 20 g of sucrose, transferring it to a 1-liter volumetric flask, and adding water to the line. Calculate the concentration of the sucrose solution in terms of m*M*, mg/mL, and % (wt/vol).
10. The concentrations of cholesterol, glucose, and urea in blood from a fasting individual are listed below in units of mg/100 mL (sometimes called mg%). These are standard concentration units used in the clinical chemistry lab. Convert the concentrations to m*M*.
    (a) cholesterol—200 mg%
    (b) glucose—75 mg%
    (c) urea—20 mg%
11. The following optical rotation readings were taken by a polarimeter on a solution of an unknown carbohydrate. Use Excel or other statistical software to estimate statistical terms.
    (a) Calculate the sample mean.
    (b) Calculate the standard deviation.

α_{obs} (degrees)			
+3.24	+3.20	+3.17	+3.25
+3.15	+3.21	+3.23	
+3.30	+3.19	+3.20	

    (c) Calculate the 95% confidence levels for the measurement.
12. Describe how you would prepare 100 mL of a single solution containing all of the following reagents at the designated concentrations.
    (a) 0.1 *M* NaCl
    (b) 0.05 *M* glucose
    (c) 5% wt/vol alanine
    (d) 1 mg/mL urea
13. How would you prepare 1 liter of a 1 *M* ethanol solution in water? You do not have an analytical balance available, only a 1-liter volumetric flask and a 100-mL graduated cylinder. The density of ethanol is 0.789 g/mL.
14. A technician at a clinical laboratory received a blood serum sample for cholesterol analysis. In order to check the reliability of the procedure, the technician repeated the assay five times and obtained the results below. Use a spreadsheet statistical analysis to estimate the mean, standard deviation, variance, and standard error of the mean for the data. Total cholesterol in blood serum sample in mg/100 mL (mg%): 157, 154, 155, 152, 155.

Further Reading

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http://www.statistics.com
Click on free Web-based software for data analysis.

www.sciencesoftware.com/product.php?productid=131
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http://www.lib.iastate.edu/collections/eresourc/biochem.html
List of electronic journals of interest to biochemists and molecular biologists.

http://helios.hampshire.edu/~apmNS/design/RESOURCES/HOW_READ.html
How to read a scientific paper.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER 2

USING THE COMPUTER AND INTERNET FOR RESEARCH IN BIOCHEMISTRY

A. What Is Research and How Is It Done in Biochemistry? 35
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A. WHAT IS RESEARCH AND HOW IS IT DONE IN BIOCHEMISTRY?

What Is Research?

Virtually all scientists are engaged in investigative activities that are broadly called **research.** We begin this discussion on research by defining the term and continuing with details of the steps that are usually followed in the process.

According to the Merriam-Webster Collegiate Dictionary, research is:

1. to search or investigate exhaustively
2. the collecting of information about a particular subject
3. studious inquiry or examination

A more realistic and functional definition comes from librarians:

> "Research is a process of investigation. An examination of a subject from different points of view. It's not just a trip to the library to pick up a stack of materials, or

> picking the first five hits from a computer search. Research is a hunt for the truth. It is getting to know a subject by reading up on it, reflecting, playing with the ideas, choosing the areas that interest you and following up on them. Research is the way you educate yourself."[1]

The ultimate goal of all research is to seek the truth; however, the approach that is used can vary from discipline to discipline. For biochemists and other molecular life scientists, research is usually focused on elucidating the laws of nature or, in other words, addressing questions about natural phenomena. The approach taken in biochemistry research is application of the historic **"scientific method"** of discovery.

The Scientific Method

The stepwise process for a scientific research project follows the general scheme shown in Figure 2.1. One of the early originators of this organized body of techniques is thought to be Ibn al-Haythan (965–1039 A.D.; Latinized name, Alhazen), a physicist studying optics and living in Basra, Iraq. Many modifications of the process have been made over the centuries, but the key scientific premise has remained—**data must be collected by experiment and observation.**

Each of the steps in Figure 2.1 actually consists of several activities:

1. ***Select the topic.*** The topic for study is often one of strong interest to the scientist and one with which he or she may already have some familiarity. It is sometimes helpful to phrase the problem to solve as a question to which we do not yet know the answer. Some examples of research topics in biochemistry might be: (a) what is the detailed molecular mechanism for a particular enzyme?, (b) what is the base sequence of a particular gene?, (c) what is the function of a protein that has just been isolated?, (d) how can a new method for analysis of fatty acids in blood serum be designed?, and (e) how does a particular drug act?
2. ***Collect current information and resources about the topic.*** This step always begins by reading the **primary literature** in the field of study. (Primary literature refers to articles in research journals in which scientists describe their experiments, report data, and discuss important results.) When you do extensive background research, you start to become an expert in the field. The computer is often heavily used in this step. Refer to Part C (p. 40) in this chapter to learn how to use the Internet in your study of the biochemical literature. Background reading of the literature may also be done by consulting research journals in a library; however, journals are very expensive, so libraries may not have all journals available.
3. ***Propose hypotheses that may answer questions about your topic.*** The dictionary defines hypothesis as "a tentative assumption made in order to draw out and test its logical or empirical consequences." A hypothesis is an important and useful tool in research that helps lead you to answers to your questions. Proposing a hypothesis is guessing, but it is an "educated guess,"

[1] http://www.usg.edu/galileo/skills/unit01/infoage01_03.phtml

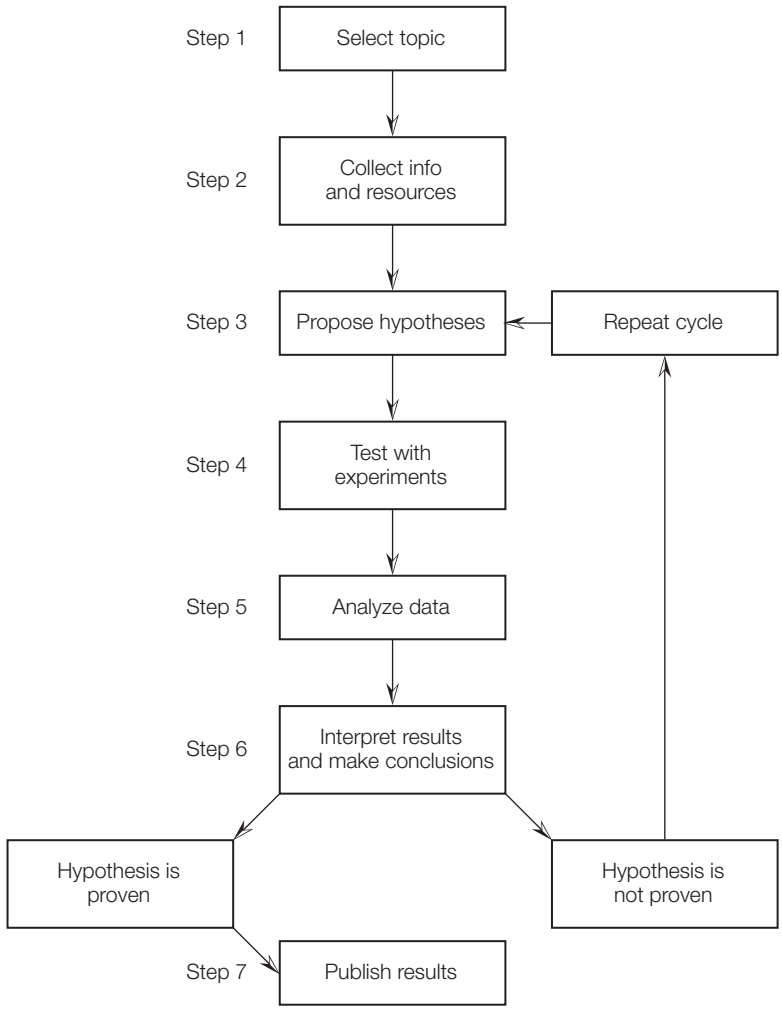

FIGURE 2.1 The steps followed in a scientific research project. The pathway is based on the premises of the historic scientific method.

as your reading of the literature will have enhanced your knowledge. Perhaps the most important reason for having hypotheses is that they tell you what experimental directions to take next on your project. (A hypothesis cannot be proven by experimental data, only supported. This will be discussed in more detail later.)

4. ***Design and perform experiments; collect data.*** For hypotheses to be tested properly, it is essential that you design experiments that provide results that are informative. Experimental results must be observable, empirical, and measurable. The best experiments result from knowing your subject well and from asking good questions about what you need to find out about your research problem. It should be obvious that experiments must be completed with accuracy and care and that safe lab techniques are used. Experiments should be repeated several times, with the same results obtained each time before they can be accepted as valid.

5. ***Analyze data.*** Data from experiments may be quantitative or qualitative. Both types can be analyzed by using a computer to prepare figures, tables, and graphs. If your results are primarily numerical, then it will be necessary to carry out calculations followed by proper statistical analysis using Excel and other software (see Chapter 1, Section E, p. 23).
6. ***Interpret results and draw conclusions.*** Are your experimental results and interpretations consistent with at least one of your hypotheses? If so, then that hypothesis can be supported by the results. It could be a likely answer to your initial question. A hypothesis cannot be proven, only supported. **Any hypothesis that is not consistent with experimental results must be rejected.** If all hypotheses are inconsistent with results, then new hypotheses must be proposed and tested. This is shown in Figure 2.1 as a branch from Step 6 to Step 3. This is called an **iteration,** or repeating process. Research is a constantly ongoing, evolving process. It is always in a state of flux, but scientists hope that each step they take moves them closer to an answer to their original question.
7. ***Publish results in a scientific journal.*** This step makes your work available so it may be studied by scientists around the world. Scientists then have the opportunity to repeat your experiments, to check their validity, and to design new experiments to test the hypothesis. Making sure that your experiments are reproducible, especially by scientists in other labs, is an important element of the scientific method.

One problem that can sometimes occur with the scientific method is a lack of objectivity. Scientists can become biased, adopt a favorite hypothesis, and design only experiments supporting that hypothesis. A balanced and objective approach is a necessity in scientific research. In addition to objectivity, another criterion that scientists must adhere to is ethical behavior. Unethical practices, such as have been observed in the form of scientific misconduct (plagiarism, falsifying data, etc.), are a danger to scientific progress. (See the Wikipedia Web site for examples of ethics in research and scientific misconduct.) The currently controversial so-called "climategate" issue is one that some scientists say lacks objectivity and is marred by unnecessary secrecy and a failure to fully share data. The last Web site at the end of this chapter contains an article criticizing the scientific process used in studying changes in the world's climate.

B. USING COMPUTERS IN BIOCHEMISTRY

The modern computer has revolutionized the way we live. Not surprisingly, the computer has also changed the way we do scientific research. The computer has become an essential tool for the investigation of all aspects of biomolecules—their structure, function, reactions, and information. The need for computers in biochemistry and the related molecular life sciences is growing because of two factors: (1) the fields are becoming increasingly quantitative, so there is a requirement for complex and accurate calculations—the computer with its access to **Internet** software and application programs is ideal for this work; and (2) because of the ease of determining protein and nucleic acid sequences and structures, there has been a proliferation of biological information that needs to

be organized, stored, and made readily available to researchers. Initially, computers in biochemistry were used in the routine tasks of word processing, graphing, and statistical analysis of research data. But when connected to the Internet, the computer's use is greatly expanded to include some of the following functions: (1) searching the biochemical literature for pertinent books and journal articles, (2) using software for analyzing experimental data, (3) accessing biological **databases** that provide nucleic acid and protein sequences and structures, (4) seeking research methodology, procedures, and protocols for lab work, and many more uses.

This application of computer technology to the analysis, management, and manipulation of biochemical data is sometimes considered a part of the broad field of **computational biochemistry.** An important subfield of computational biochemistry that we will use extensively in this text is **bioinformatics,** defined as the application of computer technology to the storage and use of biological data, especially protein and nucleic acid sequence and structure.

Your first encounter with a computer in the laboratory was probably while you were using an instrument that had a computer to control its operation, to collect data, and to analyze data. All major pieces of scientific equipment, including UV-VIS spectrophotometers, high-performance liquid chromatographs, gas chromatographs, nuclear magnetic resonance spectrometers, mass spectrometers, and DNA sequencers, are now computer controlled. But your use of the computer will not end when you leave the lab, as you will use it to prepare laboratory reports including graphical and statistical analysis of your experimental data.

The primary purpose of this chapter is to learn how to solve problems in biochemistry using computer and software technology. Here we will outline general Internet resources that may be used in later chapters. Each chapter of this text will also describe more specific Internet resources that can be applied to the topics in that chapter. It is important for your education and career that you become knowledgeable and skilled in the use of the computer and Internet. Many specialized and some new terms are introduced in this chapter. Most of the words in bold in Sections B and C on computers are defined in a glossary at the end of the chapter.

Accessing the Internet

It is probably a correct assumption that those reading this book either have their own computer system or have access to computers where they study or work. Therefore, details for setting up and using a computer will not be provided here. Questions regarding computer use may be addressed to your instructor, supervisor, or local computer services office. If you are a student at an academic institution or a worker in a biotech-related lab, you will most likely be provided access to the Internet either through **Ethernet** or by a wireless system. Ethernet is a widely-used, wired networking system appropriate for local area networks (LAN). (Low-cost adaptors, called wireless bridges, are available to make any wired Ethernet-equipped device a part of a wireless network.) Some recommendations for specific hardware and software will be given in this book, but one must be aware that new products and important upgrades are continually being developed. Many of the software programs described here are **freeware,** software available without charge.

For word processing (writing lab reports, etc.), the most popular program is Microsoft Word. Software specialized for scientific and technical writing is available, but probably not necessary at this level. Current software programs for statistical analysis, graphing, and spreadsheets with graphing capability include Excel, Sigmaplot, SPSS, and SyStat (see Chapter 1, Section E, p. 23).

In order to access the Internet, you will need a **Web browser,** which is an interface program that reads **hypertext** and displays **Web pages** on your computer. A survey of computer users in 2010 found the most popular Web browsers to be **Firefox** (Mozilla), **Chrome** (Google), **Internet Explorer** (Microsoft), and **Safari** (Apple).

The World Wide Web

A heavily used and rapidly growing component of the Internet is the **World Wide Web** (WWW, also called "the Web"). This facility, which was launched in 1992, permits the transfer of data as pages in **multimedia form** consisting of text, graphs, figures, audio, and video. Each **Web site,** which has its own address (called a **Uniform Resource Locator, URL),** is composed of **Web pages.** The pages are linked together by **hypertext** pointers so that data stored on computers (**servers**) in different locations may be retrieved via the network by your computer. Web documents are written in a special coded language called **Hypertext Markup Language (HTML).** Typing the URL into the browser dialogue box will bring you to the **home page** or starting point for the Web site. One important feature you may note is that some text on the page is emphasized with underlining, in a different color, or perhaps highlighted in some other way. If you click the mouse on this text (called **hyperlinks**), your computer will connect to another related Web page that provides information on the hyperlink. This feature greatly enhances the use of the Web because related Web sites are connected or linked together and may be quickly accessed by a click of the mouse rather than by typing in a different URL.

C. WEB SITES USEFUL IN BIOCHEMISTRY

Directories, Library Resources, Databases, and Tools

Because of the complexity and the enormous number of Web sites available, one can easily become overwhelmed. Therefore, three tables, Tables 2.1–2.3, are presented that list Web sites selected for study because they are thought to be especially instructive for beginning students in biochemistry and other molecular life sciences. Each site in the tables has a short descriptive note that defines its contents. Table 2.1 consists of Web addresses that contain directories, catalogs, and library resources. Another way to describe Table 2.1 is to say "these addresses are Web sites that help you find other Web sites." This is a good place to start if you want to become familiar with the many resources available. Table 2.2 lists Web sites that have databases and tools that are more specialized in their function. Table 2.3 lists databases that allow searches using the name of a biochemical or class of biochemicals. These Web sites are especially valuable when seeking information and properties of biomolecules, including nomenclature, physical properties, structural data, reaction characteristics, spectroscopic information, and even chromatographic data.

TABLE 2.1 Web Directories and Library Resources

Name	Description	URL
Scirus	For scientific information	http://www.scirus.com/srsapp
Intute	Finding the best Web sites for biochemistry	http://www.intute.ac.uk/biologicalsciences
BioChemWeb	The virtual library of biochemistry, molecular biology, and cell biology	http://www.biochemweb.org
Protocol-Online	Your lab's reference book	http://www.protocol-online.org
University of New Mexico Center for Advanced Research Computing	Best biotech sites in the world	http://www.hpc.unm.edu/~aroberts/main/top5%25.htm
University of Sussex	Chemistry and Biochemistry Library Guide	http://guides.lib.sussex.ac.uk/chemistry
Iowa State University	Biochemistry Library Guide	http://www.lib.iastate.edu/collections/eresourc/biochem.html
Penn. State University	Biochemistry Library Guide	http://www.libraries.psu.edu/psul/researchguides/agbiohealth/bmb.html
Alverno College	Library Resources	http://depts.alverno.edu/library/science.html

TABLE 2.2 Biochemical Databases and Tools

Name	Description	URL
Protein Data Bank (PDB)	Protein structures determined by X-ray and NMR	http://www.rcsb.org/pdb
European Bioinformatics Institute (EBI)	DNA sequences	http://www.ebi.ac.uk
National Center for Biotechnology Information (NCBI)	Variety of databases and resources	http://www.nlm.nih.gov
Swiss-Protein	Protein sequences and analysis	http://www.expasy.ch/tools
The Institute for Genomic Research	Collection of genomic databases	http://www.ebi.ac.uk/genomes/index.html
REBASE—The Restriction Enzyme Database	Restriction enzyme directory and action	http://rebase.neb.com
NCBI Molecules to Go	Structures of biomolecules	http://molbio.info.nih.gov/cgi-bin/pdb
PyMol Molecular Viewer	Structures of biomolecules	http://pymol.org
Entrez browser of NCBI	Database searching including PubMed literature	http://www.ncbi.nlm.nih.gov/Entrez
Protein Information Resource (PIR)	Database searching for proteins	http://pir.georgetown.edu
Munich Information Center for Protein Sequences (MIPS)	Protein sequences	http://www.helmholtz-muenchen.de/en/mips

(continues)

TABLE 2.2 Continued

Name	Description	URL
Journal of Chemical Education Resource Shelf	List of all current biochemistry texts	http://www.jce.divched.org/JCEWWW/Features/CERS
Chimera Molecular Modeling System (UCSF)	Advanced molecular modeling	http://www.cgl.ucsf.edu/chimera
BiomoleculesAlive (ASBMB)	Instructional material	http://www.biomoleculesalive.org
ChemDraw	Chemical structure drawing program	http://www.cambridgesoft.com
MEDLINE (PubMed)	U.S. National Library of Medicine	http://www.nlm.nih.gov

TABLE 2.3 Databases of Biochemical Compounds

Name	Description	URL
International Union of Biochemistry and Molecular Biology (IUBMB)	Nomenclature	http://www.chem.qmul.ac.uk/iubmb
IUBMB Enzyme List	Catalog of enzymes	http://www.chem.qmul.ac.uk/iubmb/enzyme
ChemBioFinder	Structures and properties	http://www.chembiofinder.com
Worthington Enzyme Manual	Properties of enzymes	http://www.worthington-biochem.com/index/manual.html
Enzyme Database of ExPASy	Enzyme names and numbers	http://www.expasy.ch/enzyme
BRENDA	A comprehensive enzyme information system	http://www.brenda-enzymes.info

An annoying aspect of using Web sites is that they can disappear from the Internet. In fact, this may happen to some of the sites in this book. This process, sometimes called "Web rot," can happen when a link becomes broken or irrelevant over time. If the reason for a Web site disappearance is due to a new address, you will usually be directed to the new site.

Many of the current Web sites you will need for your work and study are listed in the tables here; however, what about new Web sites that have been established since publication of this book? Millions of new sites are created every year. To access these new sites, you need the help of a **search engine,** a searchable directory that organizes Web pages by subject classification. The most widely used search engines are **Google** (http://www.google.com) and **Yahoo** (http://www.yahoo.com). Use of a search engine requires the input of a keyword or terms for searching. As you surf the Web, you may find sites you wish to save and review at a later date. Different Web browsers use different terms to define this saving process. Some use **favorites** and some use **bookmarks.**

STUDY EXERCISE 2.1 Using Directory Web Sites

List five of the "Best Biotech Web Sites in the World" found on the Web site from The University of New Mexico Center for Advanced Research Computing.

Solution:

4Biotech, Access Excellence, AgBiotechNet, biochemist.com, BiochemNet

STUDY EXERCISE 2.2 Using Protocol-Online

Study the home page for Protocol-Online. What are the subtopics available under the main heading of "Biochemistry"?

Solution:

On the home page, click on "Biochemistry." Here you will find hyperlinks to three subtopics: amino acids and proteins, enzyme analysis, and lipids.

STUDY EXERCISE 2.3 IUBMB Enzyme Web Site

Use the IUBMB enzyme site to find the E.C. (Enzyme Commission) number for the enzyme cellulase.

Solution:

Cellulase catalyzes the hydrolysis of the glycosidic bonds between glucose in the substrate cellulose. The E.C. number is 3.2.1.4.

Viewing Structures of Biomolecules

Determining the structure of biomolecules has now become a relatively routine activity in research labs. Thousands of structures experimentally determined by X-ray crystallography, NMR, and electron microscopy are now available on selected Web sites. The structures include those of proteins, nucleic acids, and nucleic acid/protein complexes. Some of the most accessible and useful sites for viewing structures include:

- Protein Data Bank (http://www.rcsb.org)
- Molecules to Go (http://molbio.info.nih.gov/cgi-bin/pdb)
- PyMol Molecular Viewer (http://pymol.org)

The Protein Data Bank and Molecules to Go sites are freeware, but PyMol is a user-sponsored system and requires a subscription. Academic institutions may purchase a site license for an individual, lab and classroom, or complete department.

To obtain a structure, access the Web site home page and type the name of the biomolecule desired into the dialogue box. Instructions for further analysis of the structure are given on all sites.

STUDY EXERCISE 2.4 Protein Data Bank

Use the Protein Data Bank Web site to find a structure for the enzyme cellulase. What kinds of secondary structures do you see in the cellulase molecule? What organism was the source of the cellulase you looked at?

Solution:

As of July 20, 2010, there were structures of 177 different cellulases on the PDB site. On the same date, there was a total of 66,633 structures of biomolecules on the PDB site. Each cellulase at the site will have different percentages of α-helices and β sheets. Describe the structure you looked at.

Searching the Biochemical Literature

An introduction to scientific journals and publishing a research article in a journal was given in Chapter 1 (see Section B, p. 6). Figure 1.5 provides an extensive list of journals that publish research articles in biochemistry. Generating research ideas and maintaining a research lab require an extensive knowledge of the biochemical literature (see Step 2, Figure 2.1). Much of this literature is now accessible on the Internet, but occasionally it may be necessary to use reference books in the library. The biochemical literature is massive and expanding rapidly. It is almost a full-time job just to maintain a current awareness of a specialized research area. There are few disciplinary boundaries in the study of biochemistry. The biochemical literature overlaps into the biological sciences, the physical sciences, the basic medical sciences, and information technology. The intent of the following discussion is to bring order to the many sources of information including textbooks, reference books, research journals, and Internet Web sites that are available.

Textbooks

The student's first exposure to biochemistry is usually a formal class accompanied by the reading of a general textbook of biochemistry. By providing an in-depth survey of biochemistry, textbooks allow students to build a strong foundation of important principles and concepts. By the time most books are in print, the information is one to two years old, but textbooks should still be considered the starting point for mastery of the fundamentals of biochemistry. Many textbooks are now available on-line and thus can be occasionally updated by their authors, or a Web site may be established for addition of new material.

Reference Books

For more specialized and detailed biochemical information that is not offered by textbooks, reference books must be used. Reference works range from general

surveys to specialized series. The best works are multivolume sets that continue publication of volumes on a periodic basis. Each volume usually covers a specialized area with articles written by recognized authorities in the field. It should be noted that reference articles of interest to biochemists are often found in publications that are not strictly biochemical. The best known and most widely used review publication is *Annual Review of Biochemistry*. Each volume in this series, which was introduced in 1932, contains several detailed and extensive articles written by experts in the field. For shorter reviews emphasizing current topics, *Trends in the Biochemical Sciences* (TIBS) is widely read. The active researcher has a continuing need for new methods and techniques. Several publications specialize in providing details of research methods, and many research methods are now available on the Web.

Research Journals

The core of the biochemical literature consists of peer-reviewed research journals (primary literature). It is essential for a practicing biochemist to maintain a knowledge of biochemical advances in his or her field of research and related areas. Scores of research journals are published with the intent of keeping scientists up to date. Some research journals have achieved an especially excellent reputation, and articles therein are considered to be of the highest quality. A recent ranking of the biochemical journals, based on the number of citations received, produced the following order for the top six: *Journal of Biological Chemistry, Biochimica et Biophysica Acta, Biochemistry, Proceedings of the National Academy of Sciences of the United States of America, Biochemical Journal,* and *Biochemical and Biophysical Research Communications.* The core journals used by an individual depend on the area of specialty and are best determined from experience (see Figure 1.5, p. 10).

With the expansion of scientific information has come the need for efficient storage and use of research journals. Most publishers now provide journals on-line, and libraries pay the subscription cost for the journals they want. Students, faculty, and researchers can then obtain articles free of charge. If your institution does not subscribe to a journal you need, it is possible to read article titles and abstracts on journal Web sites at no cost. If the complete text for an article is needed, usually there is a charge. The URLs for journals may be obtained by using a search engine.

Literature Searches on the Web

As you study and work in biochemistry, you will often need to complete a thorough literature search on some specialized area or topic. It is not practical to survey the hundreds of books, journals, and reports that may contain information related to the topic. Two publications that provide brief summaries of published articles, reviews, and patents are *Chemical Abstracts* and *Biological Abstracts.* If you are not familiar with the use of these abstracts, ask your instructor or reference librarian for assistance. Both of these abstracts are available on-line.

Research articles of interest to biochemists may appear in many types of research journals. Research libraries do not have the funds necessary to subscribe

to every journal, nor do scientists have the time to survey every current journal copy for articles of interest. The computer revolution has reached into the chemical and biochemical literature, and most college and university libraries now subscribe to computer bibliographic search services. One such service is STN International, the scientific and technical information network. This on-line system allows direct access to some of the world's largest scientific databases. The STN databases of most value to life scientists include BIOSIS Previews/RN (produced by Bio Sciences Information Service; covers original research reports, reviews, and U.S. patents in biology and biomedicine) and CA (produced by Chemical Abstracts service, covers research reports in all areas of chemistry including biochemistry). These networks provide on-line service, and their databases can be accessed from personal computers in the office, laboratory, or library. Subscription costs are usually paid by the library.

Excellent Web sites for searching the biochemical literature using your personal computer are available as freeware. The most widely used site is:

- **PubMed** from the National Center for Biotechnology Information (http://www.pubmed.gov)

PubMed is a service of the NIH National Library of Medicine. In addition to the direct URL listed above, it may be accessed through the NCBI site (http://www.ncbi.nlm.nih.gov), National Library of Medicine site (http://www.nlm.nih.gov) or many other database Web sites. To begin a search, enter search terms in the dialogue box at the top of the home page. Search terms may be topics, author name, or journal name. Results are reported in a table, beginning with the most recent articles, with article titles, author(s), and journal reference.

STUDY EXERCISE 2.5 Searching the Biochemical Literature on PubMed

To illustrate the use of this search service, point your Web browser to the appropriate URL above for the PubMed home page. Many features on display are available, but the most basic is the search capability. For bibliographic searching, you may enter in the dialogue box a search term, author name, or journal name. For example, type in "human alpha-lactalbumin," a calcium-binding protein found in milk. Clicking on "Search" will then provide more than 1100 citations (or articles). The lists are composed of article title, author(s), and reference in reverse chronological order. By clicking on the highlighted title (in hypertext), you can retrieve the abstract of the article. Another useful and time-saving feature is the hypertext (see "Related Articles"). Clicking on this will provide a list of papers related to the specific citation. The 1100 papers or so that you obtained in your original search are too many to screen; you may change the search parameters to reduce the number. For example, in the citation listing you see some interesting articles describing that complexes formed between human α-lactalbumin and oleic acid have been reported to display apoptotic activity against tumor cells. You can narrow down the citation list by searching the topic "complexes between human alpha-lactalbumin and oleic acid." This yields about 12 results, a reasonable number of abstracts to read. Practice using PubMed with some terms you find interesting.

Sequence Homology in Proteins

Another activity that is valuable in biochemical research is to seek proteins that have different functions, but similar sequences (sequence homology). These investigations can be done at a couple of Web sites:

- Protein Data Bank (http://www.rcsb.org)
- National Center for Biotechnology Information (http://www.ncbi.nlm.nih.gov)

Both Web sites compare biomolecules to seek to find regions of sequence similarity.

STUDY EXERCISE 2.6 Using Databases

The application of the primary databases and structural analytical tools will be introduced using a protein, α-lactalbumin from human milk. We will search databases to find and view its primary and secondary structure and also determine if there are other proteins with a similar amino acid sequence and structure. After completion of these exercises, you will be able to apply these computer tools to proteins of your own choice. Point your Web browser to the Protein Data Bank (PDB) and the Research Collaboratory for Structural Bioinformatics (http://www.rcsb.org). Become acquainted with the PDB by viewing the home page and perhaps clicking on some hyperlinks. Type "human alpha-lactalbumin" in the dialogue box at the top of the page and click on "Search." Your query will find at least 14 structure hits. An appropriate structure to work with is number 1B90: human α-lactalbumin, low temperature form. Click on the highlighted title for a structure and more information about the protein. On the top tool bar, click on "Sequence." The protein has one polypeptide chain and 123 amino acid residues. The sequence is given using one-letter abbreviations for amino acids. The sequence also shows locations of α-helices (41%) and beta sheets (9%). For a comparison of this protein with others in the database, click on "Sequence Similarity." The resulting table provides the number of proteins with % sequence similarity ranging from 100% down to 30%. For example, there are three proteins that have 90% sequence homology and 577 proteins that have 40% sequence homology. Click on the 40% column to see a list of the proteins, most of which are lysozymes. It is interesting to note that the proteins α-lactalbumin and lysozyme have similar primary, secondary, and tertiary structures, but quite different biochemical activities. The two proteins may have been derived from a common ancestral gene. You could also have used the BLAST tool at the NCBI site for the same analysis of sequence.

Virtual Biochemistry Laboratories

For some colleges and universities around the world, offering a "real" biochemistry laboratory course for students is not a possibility. Some of the reasons for this include a lack of expensive scientific instruments, equipment, and reagents; a scarcity of appropriate lab space; a lack of staff expertise; and an inability to fit scheduled lab time into a tight curriculum. Alternative activities for students are now available in the form of "virtual biochemistry labs" on the Web (Table 2.4). Although simulated labs should never be considered as a replacement or substitute

TABLE 2.4 Virtual Biochemistry Labs

Name	Description	URL
St. Olaf College	Virtual Lab Manual	http://www.stolaf.edu/people/muth/Labmanual.html
Carnegie Mellon University	Biology labs	http://telstar.ote.cmu.edu/biology/lab/index.html
Lund University	Labs in bioanalytical chemistry	http://www.drylabs.com
Changbioscience	Virtual labs for biologists	http://www.changbioscience.com/virtualab.html
HHMI Interactive	Virtual labs in biology	http://www.hhmi.org/biointeractive

for the real thing, especially for student majors in biochemistry, molecular biology, other biological sciences, and chemistry, they may be suitable for some students who will never work in a lab or manipulate lab data. In addition, viewing experiments and procedures in virtual labs may actually offer benefits to students who will perform similar experiments in the lab. The virtual lab may be considered a "prelab," where students will become acquainted with equipment, techniques, and procedures and can more efficiently conduct real experiments in the lab. This experience is especially important when students are dealing with expensive equipment and reagents. The virtual labs may also be considered a safety feature—students can receive training regarding the use of dangerous reagents and procedures.

Study Problems

1. Use PubMed or an enzyme Web site to answer the following questions about the enzyme tyrosinase.
   (a) What are sources of the enzyme besides mushroom?
   (b) What metal ion is present in the native enzyme?
   (c) Find two references for the study of the inhibition of tyrosinase. What inhibitor molecules have been investigated?
   (d) Find another substrate for the enzyme besides L-DOPA.
   (e) Search for the three-dimensional structure of the enzyme.
2. Use PubMed bibliographic searches to find two recent research articles authored by Thomas R. Cech, who won the Nobel Prize in Chemistry for the discovery of catalytic RNA (ribozymes). Write brief summaries of the articles.
3. The technique of immobilized metal-ion affinity chromatography (IMAC) is widely used to purify proteins. Find two proteins that have recently been purified by this procedure.
4. The Western blot procedure is now used to test human serum for the presence of antibodies to the AIDS virus. Find two publications that describe procedures for this assay.
5. Use the REBASE site to determine the specificity of the restriction enzyme *Hind*III.
6. Use the techniques in Study Exercise 2.6 to find the amino acid sequence of the protein recombinant goat α-lactalbumin. What is the percent of α-helices and β-sheet secondary structure?
7. What is the biological function of α-lactalbumin?

8. Study the nucleotide sequence for the human α-lactalbumin gene. Hint: Begin at the NCBI home page and enter Entrez. Click on "Nucleotides" and do a search for the protein. Review the GenBank report for a position of introns and exons. Obtain a FASTA report, download the files, and complete a BLAST search for related sequences.
9. The December 2009 issue of *The Scientist* magazine listed the ten most exciting biotech tools to be introduced in 2009. One of the top ten is "protein expression using synthesized genes." Write a paragraph of about 100 words that describes the new laboratory technique. Use computer bibliographic searches to learn about this new technology.
10. Use the BLAST tool to compare the amino acid sequences for human α-lactalbumin and lysozyme. Repeat the process with the use of BLAST to compare the nucleotide sequences for the genes coding for α-lactalbumin and lysozyme.

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The Journal of Chemical Education, Chemical Education Resource Shelf. For a complete list of current general biochemistry texts and lab manuals, scroll down to "Biochemistry."

http://www.biointeractive.org
Virtual biology labs sponsored by Howard Hughes Medical Institute.

http://www.vts.intute.ac.uk/
Helping you find the best Web sites for study and research.

http://www.usg.edu/galileo/skills/unit01/infoage01_03.phtml
What is research? The Online Library Learning Center of the University System of Georgia.

http://ugresearch.adm.ohio-state.edu/research.html
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http://en.wikipedia.org/wiki/Research
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http://en.wikipedia.org/wiki/Scientific_misconduct
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http://www.changbioscience.com/virtualab.html
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http://www.ft.com/cms/s0/8aefbf52-d9e1-11de-b2d5-00144feabdc0.html
Comment on the "Climategate" issue.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

Computer Glossary

bioinformatics the use of computer technology to solve biological problems.
biological databases computer sites that organize, store, and disseminate files that contain information consisting of literature references, nucleic acid sequences, protein sequences, and protein structures.
bookmark a function to save a Web site address for later use (Netscape Navigator).
computational biochemistry the application of computer technology to the analysis, management, and manipulation of biochemical data.
Ethernet a family of frame-based computer networking technologies for local area networks.
favorites the Internet Explorer form of a bookmark.
freeware software that is provided free of charge by its developer.

home page the beginning page for access to a Web site.
HTML HyperText Markup Language; a special, coded language that is used to write Web pages.
hyperlink link or connection between related Web pages.
hypertext a language that connects similar documents on the Web.
Internet the worldwide matrix that allows all computers and networks to communicate with each other.
multimedia several forms of media including text, graphics, video, and audio.
search engine a searchable directory that organizes Web pages by subject classification.
server a computer that acts as the storage site for retrievable data.
URL uniform resource locator; a standard address form that identifies the location of a document on the Internet.
Web site a collection of documents (Web pages) on a server.
WWW World Wide Web ("the Web"); a component of the Internet that uses a hypertext-based language to provide resources.

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CHAPTER

3 GENERAL LABORATORY PROCEDURES

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All biochemistry experimental activities, whether in the teaching or research laboratory or in an industrial biotech lab, are replete with techniques that must be carried out on an almost daily basis. This chapter outlines the theoretical and practical aspects of some of these general and routine procedures, including preparation of buffers, use of buffers, pH measurements, dialysis, membrane filtration, lyophilization, quantitative methods for protein and nucleic acid measurement, centrifugal vacuum concentration, and measurement of radioactive samples.

A. pH, BUFFERS, ELECTRODES, AND BIOSENSORS

Most biological processes in the cell take place in a water-based environment. Water is an **amphoteric** substance; that is, it may serve as a proton donor (acid) or a proton acceptor (base). Equation 3.1 shows the ionic equilibrium of water.

>> $$H_2O \rightleftharpoons H^+ + OH^-$$ **(Eq. 3.1)**

In pure water, $[H^+] = [OH^-] = 10^{-7}M$; in other words, the pH or $-\log [H^+]$ is 7. [The pH scale runs from 0 (very acidic) to 14 (very basic)]. Acidic and basic molecules, when dissolved in water in a biological cell or test tube, react with either hydrogen ions or hydroxide ions to shift the equilibrium of Equation 3.1 and result in a pH change of the solution.

Biochemical processes occurring in cells and tissues depend on strict regulation of the hydrogen ion concentration. Natural acids and bases are often generated in cells by normal biological processes and they must be neutralized by buffers. Biological pH is maintained at a constant value by naturally-occurring buffer systems such as phosphate. When biological processes are studied *in vitro,* artificial media must be prepared that mimic the cell's natural environment. Because of the dependence of biochemical reactions on pH, the accurate determination of hydrogen ion concentration has always been of major interest. Today, we consider the measurement and control of pH to be a simple and rather mundane activity. However, an inaccurate pH measurement or a poor choice of buffer can lead to failure in the biochemistry laboratory. You should become familiar with several aspects of pH measurement, electrodes, and buffers. A table of commonly used acids and bases is shown in Appendix II.

Measurement of pH

A pH measurement is usually taken by immersing a glass or plastic combination electrode into a solution and reading the pH directly from a meter. At one time, pH measurements required two electrodes, a pH-dependent glass electrode sensitive to H^+ ions and a pH-independent calomel reference electrode. The potential difference that develops between the two electrodes is measured as a voltage, as defined by Equation 3.2.

>>
$$V = E_{\text{constant}} + \frac{2.303RT}{F}\,\text{pH} \qquad \textbf{(Eq. 3.2)}$$

where

V = voltage of the completed circuit
E_{constant} = potential of reference electrode
R = the gas constant
T = the absolute temperature
F = the Faraday constant

A pH meter is standardized with buffer solutions of known pH before a measurement of an unknown solution is taken. It should be noted from Equation 3.2 that the voltage depends on temperature. Hence, pH meters must have some means for temperature correction. Older instruments usually have a knob labeled "temperature control," which is adjusted by the user to the temperature of the measured solution. Newer pH meters automatically display a temperature-corrected pH value.

Using the pH Electrode

Most pH measurements today are obtained using a single **combination electrode** (Figure 3.1). Both the reference and the pH-dependent electrode are contained in

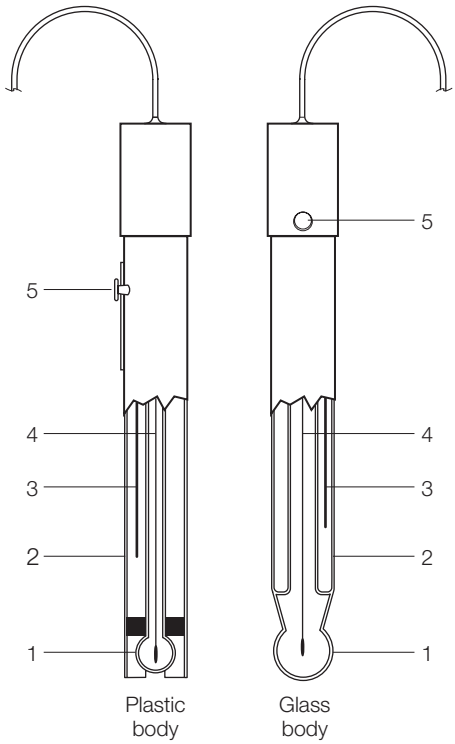

Electrodes are housed in either plastic or an all-glass body configuration. They can be either single cells or, as shown in the diagram, combined into one body for ease of use. Regardless of the configuration, there are several features common to all electrodes.

1. Sensing membrane glass: Performs actual measurement.
2. Reference junction: Acts as a liquid-path electrical conductor.
3. Internal reference: Supplies a constant equilibrium voltage.
4. pH internal element: Supplies a voltage based on the pH value of the sample.
5. Reference fill hole: Used to replace the reference electrolyte solution.

FIGURE 3.1 The combination pH electrode. *Courtesy of Hanna Instruments;* www.hannainst.com.

a single glass or plastic tube. Although these are more expensive than dual electrodes, they are much more convenient to use, especially for smaller volumes of solution. Using a pH meter with a combination electrode is relatively easy, but certain guidelines must be followed. A pH meter not in use is left in a "standby" position. Before use, check the level of saturated KCl in the electrode. If it is low, check with your instructor for the filling procedure. Turn the temperature control, if available, to the temperature of the standard calibration buffers and the test solutions. Be sure the function dial is set to pH. Lift the electrode out of the storage solution, rinse it with distilled water from a wash bottle, and *gently* clean and dry the electrode with a tissue. Immerse the electrode in a standard buffer. Common standard buffers are pH 4, 7, and 10 with an accuracy of ± 0.02 pH unit. The standard buffer should have a pH within two pH units of the expected pH of the test solution. The bulb of the electrode must be completely covered with solution. Turn the pH meter to "on" or "read" and adjust the meter with the "calibration dial" (sometimes called "intercept") until the proper pH of the standard buffer is indicated on the dial. Turn the pH meter to the standby position. Remove the electrode and again rinse with distilled water and carefully blot dry with tissue. Immerse the electrode in a standard buffer of different pH and turn the pH meter to "read." The dial should read within ± 0.05 pH unit of the known value. If it does not, adjust to the proper pH and again check the first standard pH buffer. Clean the electrode and immerse it in the test solution. Record the pH of the test solution.

As with all delicate equipment, the pH meter and electrode must receive proper care and maintenance. All electrodes should be kept clean and stored in solutions suggested by manufacturers. Glass electrodes are fragile and expensive, so

they must be handled with care. If pH measurements of protein solutions are often taken, a protein film may develop on the electrode; it can be removed by soaking in 5% pepsin in 0.1 *M* HCl for 2 hours and rinsing well with water. The pH instrument should always be set on "standby" when the electrode is not in a solution.

Measurements of pH are always susceptible to experimental errors. Some common problems are:

1. ***The Sodium Error*** Many glass combination electrodes are sensitive to Na^+ as well as H^+. The sodium error can become quite significant at high pH values, where 0.1 *M* Na^+ may decrease the measured pH by 0.4 to 0.5 unit. Several things may be done to reduce the sodium error. Some commercial suppliers of electrodes provide a standard curve for sodium error correction. Newer electrodes that are virtually Na^+ impermeable are now commercially available. If neither a standard curve nor a sodium-insensitive electrode is available, potassium salts may be substituted for sodium salts.
2. ***Concentration Effects*** The pH of a solution varies with the concentration of buffer ions or other salts in the solution. This is because the pH of a solution depends on the *activity* of an ionic species, not on the concentration. **Activity,** you may recall, is a thermodynamic term used to define species in a nonideal solution. At infinite dilution, the activity of a species is equivalent to its concentration. At finite dilutions, however, the activity of a solute and its concentration are not equal.

   It is common practice in biochemical laboratories to prepare concentrated "stock" solutions and buffers. These are then diluted to the proper concentration when needed. Because of the concentration effects described above, it is important to adjust the pH of these solutions *after* dilution.
3. ***Temperature Effects*** The pH of a buffer solution is influenced by temperature. This effect is due to a temperature-dependent change of the dissociation constant (pK_a) of ions in solution. The pH of the commonly used buffer Tris is greatly affected by temperature changes, with a $\Delta pK_a/C°$ of -0.031. This means that a pH 7.0 Tris buffer made up at 4°C would have a pH of 5.95 at 37°C. The best way to avoid this problem is to prepare the buffer solution at the temperature at which it will be used and to standardize the electrode with buffers at the same temperature as the solution you wish to measure.

Biochemical Buffers

Buffer ions are used to maintain solutions at constant pH values. The selection of a buffer for use in the investigation of a biochemical process is of critical importance. Before the characteristics of a buffer system are discussed, we will review some concepts in acid-base chemistry.

Weak acids and bases do not completely dissociate in solution, but exist as equilibrium mixtures (Equation 3.3).

>> $$HA \underset{k_2}{\overset{k_1}{\rightleftharpoons}} H^+ + A^- \qquad \textbf{(Eq. 3.3)}$$

HA represents a weak acid and A^- represents its conjugate base; k_1 represents the rate constant for dissociation of the acid and k_2 the rate constant for

association of the conjugate base and hydrogen ion. The **equilibrium constant,** K_a, for the weak acid HA is defined by Equation 3.4.

>> $$K_a = \frac{k_1}{k_2} = \frac{[H^+][A^-]}{[HA]}$$ **(Eq. 3.4)**

which can be rearranged to define $[H^+]$ (Equation 3.5).

>> $$[H^+] = \frac{K_a[HA]}{[A^-]}$$ **(Eq. 3.5)**

The $[H^+]$ is often reported as pH, which is $-\log [H^+]$. In a similar fashion, $-\log K_a$ is represented by pK_a. Equation 3.5 can be converted to the $-\log$ form by substituting pH and pK_a:

>> $$pH = pK_a + \log \frac{[A^-]}{[HA]}$$ **(Eq. 3.6)**

Equation 3.6 is the familiar **Henderson-Hasselbalch equation,** which defines the relationship between pH and the ratio of acid and conjugate base concentrations. The salt of the acid (A^-) is also referred to as the **proton acceptor (A)** and the acid (HA) as the **proton donor (D).** The Henderson-Hasselbalch equation is of great value in buffer chemistry because it can be used to calculate the pH of a solution if the molar ratio of buffer ions ($[A^-]/[HA]$) and the pK_a of HA are known. Also, the molar ratio of HA to A^- that is necessary to prepare a buffer solution at a specific pH can be calculated if the pK_a is known.

A solution containing both HA and A^- has the capacity to resist changes in pH; i.e., it acts as a **buffer.** If acid (H^+) were added to the buffer solution, it would be neutralized by A^- in solution:

>> $$H^+ + A^- \longrightarrow HA$$ **(Eq. 3.7)**

Base (OH^-) added to the buffer solution would be neutralized by reaction with HA:

>> $$OH^- + HA \longrightarrow A^- + H_2O$$ **(Eq. 3.8)**

The most effective buffering system contains equal concentrations of the acid, HA, and its conjugate base, A^-. According to the Henderson-Hasselbalch equation (3.6), when $[A^-]$ is equal to [HA], pH equals pK_a. Therefore, the pK_a of a weak acid-base system represents the center of the buffering region. The effective range of a buffer system is generally two pH units, centered at the pK_a value (Equation 3.9).

>> $$\text{Effective pH range for a buffer} = pK_a \pm 1$$ **(Eq. 3.9)**

Selection of a Biochemical Buffer

Virtually all biochemical investigations must be carried out in buffered aqueous solutions. The natural environment of biomolecules and cellular organelles is under strict pH control. When these components are extracted from cells, they are most stable if maintained in their normal pH range, usually 6 to 8. An artificial buffer system is found to be the best substitute for the natural cell milieu. It should also be recognized that many biochemical processes (especially some enzyme processes) produce or consume hydrogen ions. The buffer system neutralizes these solutions and maintains a constant chemical environment.

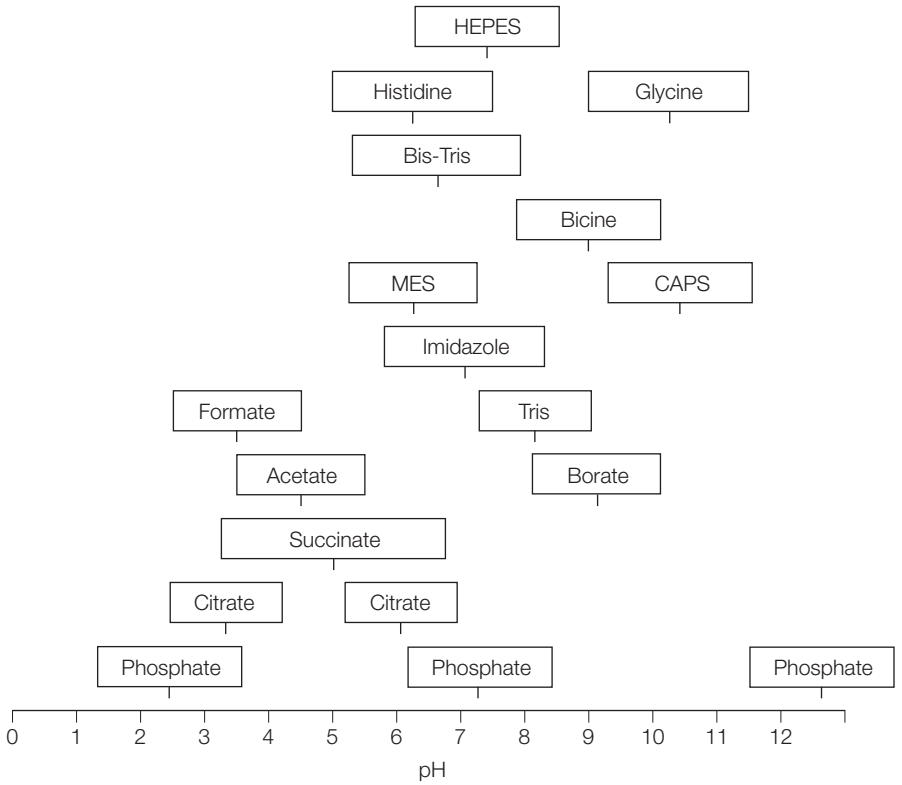

FIGURE 3.2
Effective buffering ranges of several common buffers. See Table 3.1 for abbreviations.

Although most biochemical solutions require buffer systems effective in the pH range 6 to 8, there is occasionally a need for buffering over the pH range 2 to 12. Obviously, no single acid–conjugate base pair will be effective over this entire range, but several buffer systems are available that may be used in discrete pH ranges. Figure 3.2 compares the effective buffering ranges of common biological buffers. It should be noted that some buffers (phosphate, succinate, and citrate) have more than one pK_a value, so they may be used in different pH regions. Many buffer systems are effective in the usual biological pH range (6 to 8); however, there may be major problems in their use. Several characteristics of a buffer must be considered before a final selection is made. The molecular weights and pK values of several common buffer compounds are listed in Appendix III. Following is a discussion of the advantages and disadvantages of the commonly used buffers.

Phosphate Buffers

The phosphates are among the widely used buffers. These solutions have a high buffering capacity and are very useful in the pH range 6.5 to 7.5. Because phosphate is a natural constituent of cells and biological fluids, its presence affords a more "natural" environment than many buffers. Sodium or potassium phosphate solutions of all concentrations are commonly prepared with the use of the Henderson-Hasselbalch equation. The major disadvantages of phosphate solutions are: (1) precipitation or binding of common biological cations (Ca^{2+} and Mg^{2+}), (2) inhibition of some biological processes, including some enzymes, and (3) limited useful pH range.

STUDY EXERCISE 3.1 Henderson-Hasselbalch Equation

Here we will describe the calculation method for preparation of a sodium phosphate buffer of 0.05 *M* total phosphate concentration, pH of 7.0, and a total, final volume of 1 liter. The Henderson-Hasselbalch equation (Equation 3.6) will be used to calculate the conjugate acid and conjugate base concentrations. At pH 7.0, the two forms of phosphate present are:

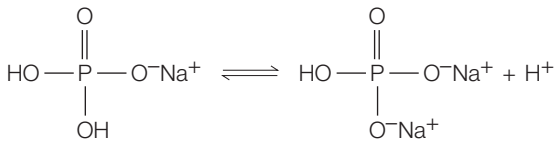

Proton donor (D) Proton acceptor (A)

We now use the Henderson-Hasselbalch equation with pH = 7.0 and pK = 7.21 (from Appendix III) to calculate the molar ratio:

$$[A]/[D] = 0.62$$

This gives only one equation, but two unknowns, the concentrations of A and D; therefore, we need another quantitative relationship between [A] and [D]. We know that the total phosphate concentration ($[A] + [D]$) is 0.05 *M*, so:

$$[A] + [D] = 0.05$$

Using these two equations for A and D, we determine that we need 0.031 mole of D and 0.019 mole of A. The appropriate phosphate reagent forms available commercially are:

D = donor: monobasic sodium phosphate monohydrate, $NaH_2PO_4 \cdot H_2O$ (MW = 138); 0.031 mole.

A = acceptor: dibasic sodium phosphate heptahydrate, $Na_2HPO_4 \cdot 7H_2O$ (MW = 268); 0.019 mole.

Converting the number of moles of each reagent to grams:

grams of D = 0.031 × 138 = 4.28 g

grams of A = 0.019 × 268 = 5.09 g

To prepare the solution, dissolve the appropriate amount of each reagent in about 975 mL of purified water in a 1-liter beaker. Check the pH of the solution and adjust to 7.0 by careful, dropwise addition (with stirring) of dilute NaOH or dilute phosphoric acid. Transfer the solution to a 1-liter volumetric flask, add water to the mark, mix well, and do a final check of the pH.

Zwitterionic Buffers (Good's Buffers)

In the mid-1960s, N. E. Good and his colleagues recognized the need for a set of buffers specifically designed for biochemical studies (Good and Izawa, 1972). He and others noted major disadvantages of the established

buffer systems. Good outlined several characteristics essential in a biological buffer system:

1. pK_a between 6 and 8.
2. Highly soluble in aqueous systems.
3. Exclusion or minimal transport by biological membranes.
4. Minimal salt effects.
5. Minimal effects on dissociation due to ionic composition, concentration, and temperature.
6. Buffer–metal ion complexes nonexistent or soluble and well defined.
7. Chemically stable.
8. Insignificant light absorption in the ultraviolet and visible regions.
9. Readily available in purified form.

Good investigated a large number of synthetic zwitterionic buffers and found many of them to meet these criteria. Table 3.1 lists several of these buffers and their properties. Good's buffers are widely used, but their main disadvantage is high cost. Some zwitterionic buffers, such as Tris, HEPES, and PIPES, have been shown to produce radicals under a variety of experimental conditions, so they should be avoided if biological redox processes or radical-based reactions are being studied. Radicals are not produced from MES or MOPS buffers.

The use of the synthetic zwitterionic buffer Tris [Tris(hydroxymethyl)-aminomethane] is now probably greater than that of phosphate. It is useful in the pH range 7.5 to 8.5. Tris is available in a basic form as highly purified crystals, which makes buffer preparation especially convenient. Although Tris is a primary amine, it causes minimal interference with biochemical processes and does not precipitate calcium ions. However, Tris has several disadvantages, including: (1) pH dependence on concentration, since the pH decreases 0.1 pH unit for each 10-fold dilution; (2) interference with some pH electrodes; and (3) a large $\Delta pK_a/C°$ compared to most other buffers. Most of these drawbacks can be minimized by: (1) adjusting the pH *after* dilution to the appropriate concentration, (2) purchasing electrodes that are compatible with Tris, and (3) preparing the buffer at the temperature at which it will be used.

STUDY EXERCISE 3.2 Buffer Made by Titration

We will illustrate the preparation of a Tris buffer using the titration method. (In Study Exercise 3.1, we used the calculation method to prepare the phosphate buffer.) Because Tris is commercially available in highly purified crystals, Tris Base (MW = 121.1), the appropriate amount may be weighed, dissolved in water, and titrated to the desired pH with an acid, usually HCl. For 1 liter of 0.1 *M* Tris-HCl buffer, pH 7.0, dissolve 12.11 g (0.1 mole) of Tris Base in about 975 mL of purified water in a 1-liter beaker. Adjust the pH (originally about 10) to 7.0 by careful, dropwise addition of concentrated hydrochloric acid. This should be done in a 1-liter beaker with gentle stirring. Transfer the solution to a 1-liter volumetric flask, add water to the mark, mix well, and make a final check of the pH.

As you can see by comparing the two procedures, the titration method for buffer preparation is faster and much more convenient than the calculation method. Is it possible to prepare the phosphate buffer in Study Exercise 3.1 by using the titration method? If so, describe the reagent(s) needed and the procedure you would use.

Carboxylic Acid Buffers

The most widely used buffers in this category are acetate, formate, citrate, and succinate. This group is useful in the pH range 3 to 6, a region that offers few other buffer choices. All of these acids are natural metabolites, so they may interfere with the biological processes under investigation. Also, citrate and succinate may interfere by binding metal ions (Fe^{3+}, Ca^{2+}, Zn^{2+}, Mg^{2+}, etc.). Formate buffers are especially useful because they are volatile and can be removed by evaporation under reduced pressure.

Borate Buffers

Buffers of boric acid are useful in the pH range 8.5 to 10. Borate has the major disadvantage of complex formation with many metabolites, especially carbohydrates.

Amino Acid Buffers

The most commonly used amino acid buffers are glycine (pH 2 to 3 and 9.5 to 10.5), histidine (pH 5.5 to 6.5), glycine amide (pH 7.8 to 8.8), and glycylglycine (pH 8 to 9). These provide a more "natural" environment similar to cellular components and extracts; however, they may interfere with some biological processes, as do the carboxylic acid and phosphate buffers.

Buffer Dilutions

In biochemistry lab activities, buffers of many different concentrations and volumes are required. It is usually not practical, economical, or convenient to prepare all needed buffers from scratch. However, it is possible to have available a few concentrated stock buffer solutions that may be diluted to produce a new buffer solution of desired concentration and amount.

Dilutions are usually defined in the following way: A dilution of 1 mL to 10 mL (also 1:10; or 1 to 10) means that you take 1 mL of stock solution and add water to a final total volume of 10 mL. It is important to note that the ***amount*** of the buffer components taken from the stock solution is equal to the ***amount*** of buffer components in the diluted solution. However, the ***concentration*** of the buffer components has been changed. If the stock solution above had a buffer concentration of 0.5 *M*, then the 1:10 diluted solution has a buffer concentration of 0.05 *M*.

Two kinds of dilutions, linear and serial, are used most often in biochemistry.

- ***Linear dilutions*** Table 3.2 shows the results of a linear dilution process in which a stock solution of 1 *M* is used to produce samples of different concentrations. Note that there is a linear (progressive) decrease in the concentration of the diluted samples, but the final volumes remain the same (10 mL). The volume of stock solution to use in each case is calculated from the following relationship:

$$\text{volume (stock)} = \frac{\text{volume (diluted)} \times \text{concentration (diluted)}}{\text{concentration (stock)}}$$

TABLE 3.2 Example of a Linear Dilution Process

Stock (*M*)	Final dilution (*M*)	Stock (mL)	Water (mL)*	Final volume (mL)
1.0	0.80	8.0	2.0	10
1.0	0.60	6.0	4.0	10
1.0	0.40	4.0	6.0	10
1.0	0.20	2.0	8.0	10
1.0	0.00	0.0	10.0	10

*Because all solutions are not additive, this number is the approximate amount of water needed to bring the final volume to 10 mL. It may be necessary to add a few drops of water to bring the final volume to 10 mL.

Sample calculation for the first diluted solution in Table 3.2:

$$\text{volume (stock)} = \frac{10\,\text{mL} \times 0.80\,M}{1.0\,M} = 8.0\,\text{mL}$$

- ***Serial dilutions*** Here dilution starts with a stock buffer solution and then each diluted solution produced is used to prepare the next, etc. For example:

  2.0 mL of Solution I is diluted to a final volume of 100 mL (Solution II)
  2.0 mL of Solution II is diluted to a final volume of 100 mL (Solution III)
  2.0 mL of Solution III is diluted to a final volume of 100 mL (Solution IV)

  If Solution I has a buffer concentration of 10 *M* and water is used for dilution in each case, what is the buffer concentration of Solution II?

  The equation above for linear dilution may also be used here:

$$\text{For Solution II: concentration (diluted)} = \frac{2.0\,\text{mL} \times 10\,M}{100\,\text{mL}} = 0.2\,M$$

STUDY EXERCISE 3.3 Serial Dilutions

What are the concentrations of Solutions III and IV made from the above serial dilution?

The Oxygen Electrode

Second in popularity only to the pH electrode is the oxygen electrode. This device is a polarographic electrode system that can be used to measure oxygen concentration in a liquid sample or to monitor oxygen uptake or evolution by a chemical or biological system.

The basic electrode was developed by L. C. Clark, Jr. in 1953. The popular Clark-type oxygen electrode with biological oxygen monitor is shown in Figure 3.3. The electrode system, which consists of a platinum cathode and silver anodes, is molded into an epoxy block and surrounded by a Lucite holder. A thin Teflon membrane is stretched over the electrode end of the probe and held in place with an O-ring. The membrane separates the electrode elements, which are bathed in an

FIGURE 3.3
Biological oxygen monitor, YSI Model 5300A. *Courtesy of YSI Life Sciences; www.ysi.com.*

electrolyte solution (saturated KCl), from the test solution in the sample chamber. The membrane is permeable to oxygen and other gases, which then come into contact with the surface of the platinum cathode. If a suitable polarizing voltage (about 0.8 volt) is applied across the cell, oxygen is reduced at the cathode.

$$O_2 + 2e^- + 2H_2O \longrightarrow [H_2O_2] + 2OH^-$$
$$[H_2O_2] + 2e^- \longrightarrow 2OH^-$$
$$\text{Total} \quad O_2 + 4e^- + 2H_2O \longrightarrow 4OH^-$$

The reaction occurring at the anode is

$$4Ag^\circ + 4Cl^- \longrightarrow 4AgCl + 4e^-$$

The overall electrochemical process is

$$4Ag^\circ + O_2 + 4Cl^- + 2H_2O \longrightarrow 4AgCl + 4OH^-$$

The current flowing through the electrode system is, therefore, directly proportional to the amount of oxygen passing through the membrane. According to the laws of diffusion, the rate of oxygen flowing through the membrane depends on the concentration of dissolved oxygen in the sample. Therefore, the magnitude of the current flow in the electrode is directly related to the concentration of dissolved oxygen. The function of the electrode can also be explained in terms of oxygen pressure. The oxygen concentration at the cathode (inside the membrane) is virtually zero because oxygen is rapidly reduced. Oxygen pressure in the sample chamber (outside the membrane) will force oxygen to diffuse through the membrane at a rate that is directly proportional to the pressure (or concentration) of oxygen in the test solution. The current generated by the electrode system is electronically amplified and transmitted to a meter, which usually reads in units of % oxygen saturation.

Many biochemical processes consume or evolve oxygen. The oxygen electrode is especially useful for monitoring such changes in the concentration of dissolved oxygen. If oxygen is consumed, for example, by a suspension of

mitochondria or by an oxygenase enzyme system, the rate of oxygen diffusion through the probe membrane will decrease, leading to less current flow. A linear relationship exists between the electrode current and the amount of oxygen consumed by the biological system.

The use of an oxygen electrode is not free of experimental and procedural problems. Probably the most significant source of trouble is the Teflon membrane. A torn, damaged, or dirty membrane is easily recognized by recorder noise or electronic "spiking." Temperature control of the sample chamber and electrode is essential because the rate of oxygen diffusion through the membrane is temperature dependent. The sample chamber is equipped with a bath assembly for temperature regulation and magnetic stirrer in order to maintain a constant oxygen concentration throughout the solution. Air bubbles in the sample chamber lead to considerable error in measurements and must be removed.

Biosensors

Electrodes or electrode-like devices are currently being developed for the specific measurement of physiologically important molecules such as urea, carbohydrates, enzymes, antibodies, and metabolic products. This type of device, now referred to as a **biosensor,** is an analytical tool or system consisting of an immobilized biological material (such as an enzyme, antibody, whole cell, organelle, or combinations thereof) in intimate contact with a suitable transducer device that will convert the biochemical signal into a quantifiable electric signal. The important components of a biosensor as shown in Figure 3.4 are: (1) a reaction center consisting of a membrane or gel containing the biochemical system to be studied, (2) a transducer, (3) an amplifier, and (4) a computer system for data acquisition and processing. When biomolecules in the reaction center interact, a physicochemical change occurs. This change in the molecular system, which may be a modification of concentration, absorbance, mass, conductance, or redox state, is converted into an electrical signal by the transducer. The signal is then amplified and displayed on a computer screen. Each biosensor is specifically designed for a particular type of molecule or biological

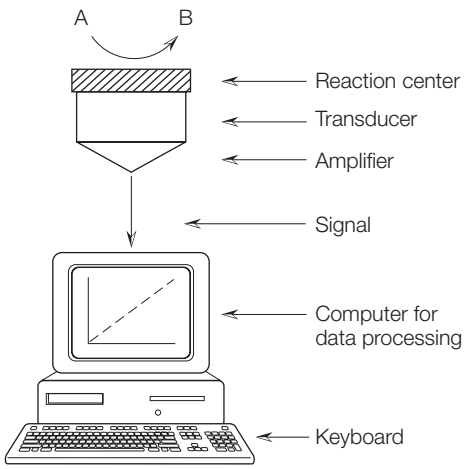

FIGURE 3.4
Components of a biosensor system for determining the identity and concentration of biomolecule A. A is stoichiometrically converted to B by a specific enzyme in the reaction center. The concentration of B is measured by the sensor.

interaction; therefore, details of construction and function vary. Some specific examples of biosensors include:

1. Electrodes based on enzyme activity. These are selective and sensitive devices that may be used to measure substrate concentrations. A biosensor based on glucose oxidase is used to measure the concentration of glucose by detecting the production of H_2O_2.

$$\text{Glucose} + O_2 \rightleftharpoons \text{gluconic acid} + H_2O_2$$

2. Optical biosensors that respond to the absorption of light from a laser. The optical response is transmitted to a computer by a fiber-optic system.

B. MEASUREMENT OF PROTEIN SOLUTIONS

Biochemical research often requires the quantitative measurement of protein concentrations in solutions. Several techniques for such measurement have been developed; however, most have limitations because either they are not sensitive enough or they are based on reactions with specific amino acids in the protein. Since the amino acid content varies from protein to protein, no single assay will be suitable for all proteins. In this section, we discuss five assays: three older, classical methods that are occasionally used today and two other methods that are widely used. In four of the methods, chemical reagents are added to protein solutions to develop a color whose intensity is measured in a spectrophotometer. A "standard protein" of known concentration is also treated with the same reagents and a calibration curve is constructed. The other assay relies on a direct spectrophotometric measurement. None of the methods is perfect because each is dependent on the amino acid content of the protein. However, each will provide a satisfactory result if the proper experimental conditions are used and/or a suitable standard protein is chosen. Other important factors in method selection include the sensitivity and accuracy desired, the presence of interfering substances, and the time available for the assay. The various methods are compared in Table 3.3.

The Biuret and Lowry Assays

When substances containing two or more peptide bonds react with the biuret reagent, alkaline copper sulfate, a purple complex is formed. The colored product is the result of coordination of peptide nitrogen atoms with Cu^{2+}. The amount of product formed depends on the concentration of protein.

In practice, a calibration curve must be prepared by using a standard protein solution. The very best protein to use as a standard is a purified preparation of the protein to be assayed. Since this is rarely available, the experimenter must choose another protein as a relative standard. A relative standard must be selected that provides a similar color yield. An aqueous solution of bovine serum albumin (BSA) is a commonly used standard. Various known amounts of this solution are treated with the biuret reagent, and the color is allowed to develop. Measurements of absorbance at 540 nm (A_{540}) are made against a blank containing biuret reagent and buffer or water. The A_{540} data

TABLE 3.3 Methods for Protein Measurement

Method	Sensitivity	Time	Principle	Interferences	Comments
Biuret	Low 1–20 mg	Moderate 20–30 min	Peptide bonds + alkaline $Cu^{2+} \rightarrow$ purple complex	Zwitterionic buffers, some amino acids	Similar color with all proteins. Destructive to protein samples.
Lowry	High ~5 μg	Slow 40–60 min	(1) Biuret reaction (2) Reduction of phosphomolybdate-phosphotungstate by Tyr and Trp	Ammonium sulfate, glycine, zwitterionic buffers, mercaptans	Time-consuming. Intensity of color varies with proteins. Critical timing of procedure. Destructive to protein samples.
Bradford	High ~1 μg	Rapid 15 min	λ_{max} of Coomassie dye shifts from 465 nm to 595 nm when protein-bound	Strongly basic buffers; detergents Triton X-100, SDS	Stable color that varies with proteins. Reagents commercially available. Destructive to protein samples. Discoloration of glassware.
BCA	High 1 μg	Slow 60 min	(1) Biuret reaction (2) Copper complex with BCA; $\lambda_{max} = 562$ nm	EDTA, DTT, ammonium sulfate	Compatible with detergents. Reagents commercially available. Destructive to protein samples.
Spectro-photometric (A_{280})	Moderate 50 − 1000 μg	Rapid 5–10 min	Absorption of 280-nm light by aromatic residues	Purines, pyrimidines, nucleic acids	Useful for monitoring column eluents. Nucleic acid absorption can be corrected. Nondestructive to protein samples. Varies with proteins.

are plotted versus protein concentration (mg/mL) or amount of protein (mg). Unknown protein samples are treated with biuret reagent and the A_{540} is measured after color development. The protein concentration is determined from the standard curve. The biuret assay has several advantages, including speed, similar color development with different proteins, and few interfering substances. Its primary disadvantage is its lack of sensitivity.

The **Lowry protein assay** is one of the more sensitive assays and has been widely used. The Lowry procedure can detect protein levels as low as 5 μg. The principle behind color development is identical to that of the biuret assay except that a second reagent (Folin-Ciocalteu) is added to increase the amount of color development. Two reactions account for the intense blue color that develops: (1) the coordination of peptide bonds with alkaline copper (biuret reaction), and (2) the reduction of the Folin-Ciocalteu reagent (phosphomolybdate-phosphotungstate)

by tyrosine and tryptophan residues in the protein. The procedure is similar to that of the biuret assay. A standard curve is prepared with bovine serum albumin or other pure protein, and the concentration of unknown protein solutions is determined from the graph.

The obvious advantage of the Lowry assay is its sensitivity, which is up to 100 times greater than that of the biuret assay; however, more time is required for the Lowry assay. Since proteins have varying contents of tyrosine and tryptophan, the amount of color development changes with different proteins, including the bovine serum albumin standard. Because of this, the Lowry protein assay should be used only for measuring changes in protein concentration, not absolute values of protein concentration.

The Bradford Assay

The many limitations of the biuret and Lowry assays have encouraged researchers to seek better methods for quantitation of protein solutions. The **Bradford assay,** based on protein binding of a dye, provides numerous advantages over other methods. The binding of Coomassie Brilliant Blue dye (Figure 3.5) to protein in acidic solution causes a shift in wavelengh of maximum absorption (λ_{max}) of the dye from 465 nm to 595 nm. The absorption at 595 nm is directly related to the concentration of protein. The dye reagent interacts primarily with positively-charged (basic) amino acid residues (arginyl, lysyl, and histidyl) in proteins. In addition, there are probably weaker interactions between the dye molecules and hydrophobic, aromatic amino acid residues (tyrosinyl, phenylalanyl, and tryptophanyl). Proteins that have more than an average number of these interacting residues show higher sensitivity and thus higher absorbance values at 595 nm.

In practice, a calibration curve is prepared by plotting μg of standard protein versus absorbance at 595 nm, which is then used to estimate the amount of protein in unknown samples (Figure 3.6). Recommended standard proteins include bovine gamma globulin (IgG), lysozyme, and ovalbumin because they have closer to the average or typical number of amino acid residues that bind the dye (see above). Although BSA is often recommended in the literature, it is not a good choice for a standard for the Bradford assay, as it has a high content of reacting amino acid residues. The 595 nm absorbance of BSA is about 2.1 times that of IgG (Figure 3.6).

The assay requires only a single reagent, an acidic solution of Coomassie Brilliant Blue G-250. After addition of dye solution to a protein sample, color

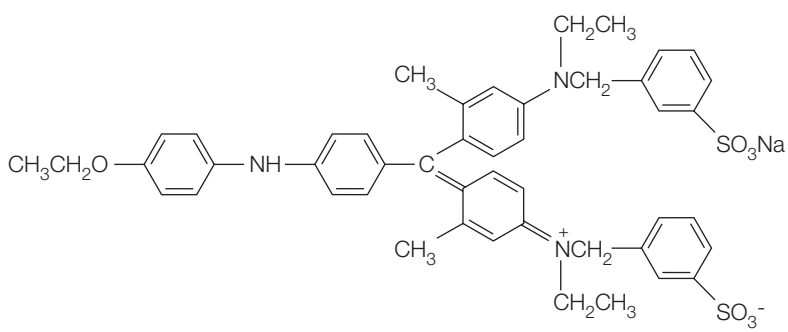

FIGURE 3.5
Coomassie Brilliant Blue G-250 dye is used to measure protein concentration in the Bradford assay.

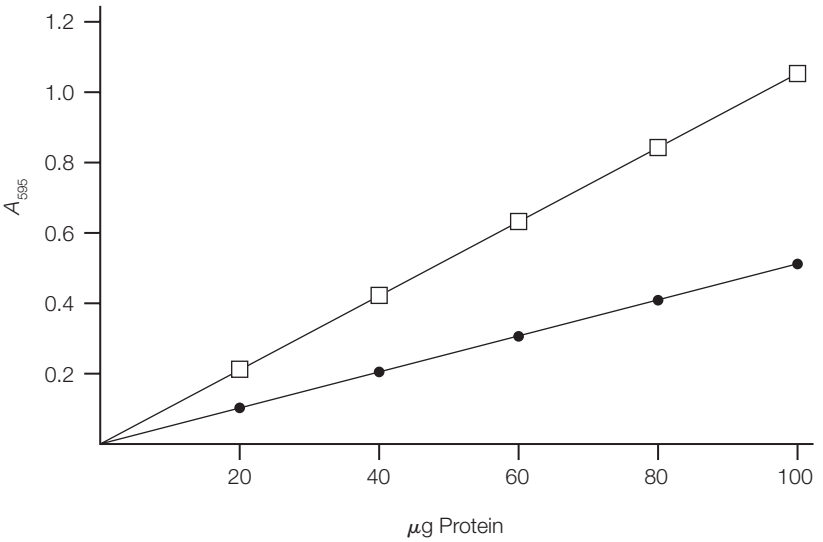

FIGURE 3.6
Student-generated, standard calibration curves for the Bradford protein assay using bovine gamma globulin (IgG, •) and bovine serum albumin (BSA, □) as the protein standards.

development is complete in 2 minutes and the color remains stable for up to 1 hour. The sensitivity of the Bradford assay rivals and may surpass that of the Lowry assay. With a microassay procedure, the Bradford assay can be used to determine proteins in the range of 1 to 20 μg. The Bradford assay shows significant variation with different proteins, but this also occurs with the Lowry assay and can be avoided by use of the proper protein standard. The Bradford method not only is rapid, but also has very few interferences by nonprotein components. The only known interfering substances are the detergents Triton X-100 and sodium dodecyl sulfate. The many advantages of the Bradford assay have led to its wide adoption in biochemical research laboratories.

The BCA Assay

The **BCA protein assay** is based on chemical principles similar to those of the biuret and Lowry assays. The protein to be analyzed is reacted with Cu^{2+} (which produces Cu^{+}) and bicinchoninic acid (BCA). The Cu^{+} is chelated by BCA, which converts the apple-green color of the free BCA to the purple color of the copper-BCA complex. Samples of unknown protein and relative standard are treated with the reagent, the absorbance is read in a spectrophotometer at 562 nm, and concentrations are determined from a standard calibration curve. This assay has the same sensitivity level as the Lowry and Bradford assays. Its main advantages are its simplicity and its usefulness in the presence of 1% detergents such as Triton or sodium dodecyl sulfate (SDS).

The Spectrophotometric Assay

Most proteins have relatively intense ultraviolet light absorption centered at 280 nm. This is due to the presence of aromatic tyrosine and tryptophan residues in the protein. However, the amount of these amino acid residues varies in different proteins, as was pointed out earlier. If certain precautions

are taken, the A_{280} value of a protein solution is proportional to the protein concentration. In practice, the procedure is simple and rapid. A protein solution is transferred to a quartz cuvette and the A_{280} is read against a reference cuvette containing the protein solvent only (buffer, water, etc.). For the average protein, a concentration of 1 mg/mL will yield an absorbance at 280 nm of about 1. If the extinction coefficient is known for the protein, its exact concentration may be calculated from the absorbance at 280 nm.

Cellular extracts contain many other compounds that absorb in the vicinity of 280 nm. Nucleic acids, which can be common contaminants in a protein extract, absorb strongly at 280 nm ($\lambda_{max} = 260$). Early researchers developed a method to correct for this interference by nucleic acids. Mixtures of pure protein and pure nucleic acid were prepared, and the ratio A_{280}/A_{260} was experimentally determined. The following empirical equation may be used for protein solutions containing up to 20% nucleic acids.

$$\text{Protein concentration (mg/mL)} = 1.55A_{280} - 0.76A_{260}$$

Although the spectrophotometric assay of proteins is fast, relatively sensitive, and requires only a small sample size, it is still only an estimate of protein concentration unless its extinction coefficient is known. It has certain advantages over the colorimetric assays in that most buffers and ammonium sulfate do not interfere and the procedure is nondestructive to protein samples. The spectrophotometric assay is particularly suited to the rapid and continuous measurement of protein elution from a chromatography column, where only protein concentration *changes* are required.

C. MEASUREMENT OF NUCLEIC ACID SOLUTIONS

The Spectrophotometric Assay

Solutions of nucleic acids strongly absorb ultraviolet light with a λ_{max} of 260 nm. The intense absorption is due primarily to the presence of aromatic rings in the purine and pyrimidine bases. The concentration of nucleic acid in a solution can be calculated if one knows the value of A_{260} of the solution. ***A solution of double-stranded DNA at a concentration of* 50 $\mu g/mL$ *in a 1-cm quartz cuvette will give an* A_{260} *reading of about 1.0. A solution of single-stranded DNA or RNA that has an* A_{260} *of 1.0 in a cuvette with a 1-cm path length has a concentration of about* 40 $\mu g/mL$.**

The spectrophotometric assay for nucleic acids is simple, rapid, nondestructive, and very sensitive; however, it should be noted that it measures both DNA and RNA. The minimum concentration of nucleic acid that can be accurately determined is 2.5–5.0 μg/mL.

Measuring the ultraviolet absorption of DNA and RNA solutions can also provide a useful structural probe and an indication of purity. DNA structural changes such as helix unwinding may be detected by measuring absorbance changes of DNA solutions at 260 nm. The ratio of A_{260}/A_{280} is often used as a relative measure of the purity of nucleic acid solutions. Pure DNA with little or no protein present has an absorbance ratio of about 1.8. Pure RNA has a ratio of

about 2. Absorbance ratios less then these numbers indicate contamination of the solution by protein material.

STUDY EXERCISE 3.4 Nucleic Acid Concentrations

Two solutions, one of double-stranded DNA and one of single-stranded RNA, were transferred to 1-cm quartz cuvettes and the absorbance (A) at 260 nm of each of the solutions was found to be 0.15. What are the concentrations of the DNA and RNA solutions? Hint: Recall that a standard solution of double-stranded DNA at a concentration of 50 μg /mL in a 1-cm quartz cuvette will yield an A_{260} reading of about 1.0. A solution of single-stranded DNA or RNA that has an A_{260} of 1.0 in a cuvette with a 1-cm path length has a concentration of about 40 μg /mL.

Other Assays for Nucleic Acids

The spectrophotometric assay for nucleic acids, DNA and RNA, is simple and rapid, but it does not have a sufficient level of sensitivity for many applications. Other assays for DNA and RNA depend on the enhanced fluorescence of dyes when bound to nucleic acids. Features of fluorescence assays are compared to the spectrophotometric assay in Table 3.4.

The fluorescence dye bisbenzimidazole, when bound to DNA, emits light at 458 nm that is about five times greater in intensity than the emission by free, unbound dye. The increase in fluorescence is linear with increasing amounts of DNA in the concentration range of 0.01 μg/mL to 5 μg/mL. One special advantage of this assay is that it can be used to quantify DNA in cell suspensions and crude homogenates. It does not respond to RNA or other biomolecules in the extracts. The assay is fast and requires only a fluorimeter, an instrument found in most laboratories.

TABLE 3.4 Measurement of Nucleic Acid Solutions

Method	Sensitivity	Time	Principle	Interferences	Comments
Spectrophotometric (A_{260})	High 2.5 μg	Rapid 5–10 min	Absorption of 260 nm light by aromatic bases	Proteins	Protein absorption may be corrected. A_{280}/A_{260} indicates purity. Nondestructive. Measures both DNA and RNA.
Bisbenzimidazole	Very high 10 ng	Rapid 5–10 min	Enhancement of fluorescence of dye when bound to DNA	None known	Not reliable with plasmids or small DNA. Does not measure RNA. May be used with crude extracts. Nondestructive.
EtBr-Agarose	Very high 1–10 ng	Moderate 30–45 min	Fluorescence of bound EtBr	None known	Measures DNA and RNA.

Another simple and relatively inexpensive fluorescence method uses ethidium bromide–agarose plates. The fluorescence emission of ethidium bromide (EtBr) at 590 nm is enhanced about 25-fold when the dye interacts with DNA. DNA samples for measurement are spotted onto 1% agarose containing (EtBr) in a Petri dish or spot plates. The samples are exposed to UV light and photographed, and the light intensity is compared to standard samples of DNA. This method is sensitive (in the 1–10 ng range), but it detects both DNA and RNA.

D. TECHNIQUES FOR SAMPLE PREPARATION

Dialysis

One of the oldest procedures applied to the purification and characterization of biomolecules is **dialysis,** an operation used to separate dissolved molecules on the basis of their molecular size. The technique involves sealing an aqueous solution containing both macromolecules and small molecules in a porous membrane. The sealed membrane is placed in a large container of low-ionic-strength buffer. The membrane pores are too small to allow diffusion of macromolecules of molecular weight greater than about 10,000. Smaller molecules diffuse freely through the openings (Figure 3.7). The passage of smaller molecules continues until their concentrations inside the dialysis tubing and outside in the large volume of buffer are equal. Thus, the concentration of small molecules inside the membrane is reduced. Equilibrium is volume dependent and is reached after 4 to 6 hours. Of course, if the outside solution (dialysate) is replaced with fresh buffer after equilibrium is reached, the concentration of small molecules inside the membrane will be further reduced by continued dialysis.

Dialysis membranes are available in a variety of materials and sizes. The most common materials are collodion, cellophane, and cellulose. Recent

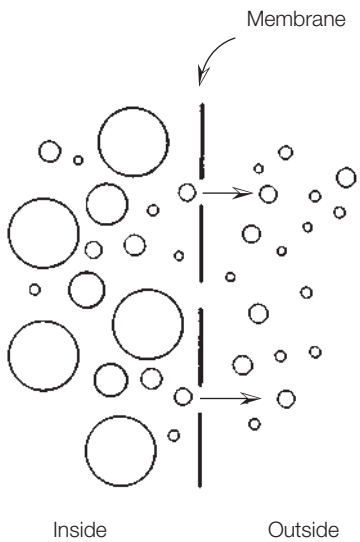

FIGURE 3.7
Diffusion of smaller molecules through dialysis membrane pores.

modifications in membrane construction make a range of pore sizes available. Spectrum Laboratories offers Spectra/Por membrane tubing with complete molecular weight cutoffs ranging from 100 to 300,000.

Dialysis is most commonly used to remove salts and other small molecules from solutions of macromolecules. During the separation and purification of biomolecules, small molecules are added to selectively precipitate or dissolve the desired molecule. For example, proteins are often precipitated by addition of organic solvents or salts such as ammonium or sodium sulfate. Since the presence of organics or salts usually interferes with further purification and characterization of the molecule, they must be removed. Dialysis is a simple, inexpensive, and effective method for removing all small molecules, ionic or nonionic.

Dialysis is also useful for removing small ions and molecules that are weakly bound to biomolecules. Protein cofactors such as NAD, FAD, and metal ions can often be dissociated by dialysis. The removal of metal ions is facilitated by the addition of a chelating agent (EDTA) to the dialysate.

Dialysis of small-volume samples (less than 3 mL) is often tedious, inconvenient, and inefficient. Commercial vials for dialysis are now available for sample sizes from 0.05 to 3.0 mL, with molecular weight cutoffs ranging from 3500 to 14,000 daltons. For example, GeBAflex tubes, offered by Gene Bio-Applications, may be used for dialysis (the removal of small molecules like urea, detergents, and ethidium bromide), buffer exchange, sample concentration, and electroelution of protein and nucleic acid samples (see Chapter 6).

Ultrafiltration

Although dialysis is still used occasionally as a purification tool, it has been largely replaced by ultrafiltration and gel filtration (see Chapter 5, Section E, p. 132). The major disadvantage of dialysis that is overcome by the newer methods is that it may take several days of dialysis to attain a suitable separation. The other methods require 1 to 2 hours or less.

Ultrafiltration involves the separation of molecular species on the basis of size, shape, and/or charge. The solution to be separated is forced through a membrane by an external force. Membranes may be chosen for optimum flow rate, molecular specificity, and molecular weight cutoff. Two applications of membrane filtration are obvious: (1) desalting buffers or other solutions, and (2) clarification of turbid solutions by removal of micron- or submicron-sized particles. Other applications are discussed below.

Ultrafiltration membranes have molecular weight cutoffs in the range of 100 to 1,000,000. They are usually composed of two layers: (1) a thin (0.1–0.5 μm), surface, semipermeable membrane made from a variety of materials including cellulose acetate, nylon, and polyvinylidene, and (2) a thicker, inert, support base (Figure 3.8). These filters function by retaining particles on the surfaces, not within the base matrix.

Membrane filters of these materials can be manufactured with a predetermined and accurately controlled pore size. Filters are available with a mean pore size ranging from 0.025 to 15 μm. These filters require suction, pressure, or centrifugal force for liquid flow. A typical flow rate for the commonly used 0.45–μm membrane is 57 mL min^{-1} cm^{-2} at 10 psi.

FIGURE 3.8 Electron micrograph of an ultrafiltration membrane showing the two layers. Particles greater than 0.1 μm in diameter are retained on the surface or within pores. *Courtesy of the Millipore Corporation;* www.millipore.com.

Ultrafiltration devices are available for macroseparations (up to 50 L) or for microseparations (milli- to microliters). For solutions larger than a few milliliters, gas-pressurized cells or suction-filter devices are used. For concentration and purification of samples in the milli- to microliter range, disposable filters are available. These devices, often called microconcentrators, offer the user simplicity, time saving, and high recovery. The sample is placed in a reservoir above the membrane and centrifuged. The time and centrifugal force required depend on the membrane, with spin times varying from 30 minutes to 2 hours and forces from 1000 $\times$ *g* to 7500 $\times$ *g*. Figure 3.9 outlines the use of a centrifuge microfilter.

The principles behind ultrafiltration are sometimes misunderstood. The nomenclature implies that separations are the result of physical trapping of the particles and molecules by the filter. With polycarbonate and fiberglass filters, separations are made primarily on the basis of physical size. Other filters (cellulose nitrate, polyvinylidene fluoride, and to a lesser extent cellulose acetate) trap particles that cannot pass through the pores, but also retain macromolecules by adsorption. In particular, these materials have protein- and nucleic acid-binding properties. Each type of membrane displays a different affinity for various molecules. For protein, the relative binding affinity is polyvinylidene fluoride > cellulose nitrate > cellulose acetate. We can expect to see many applications of the "affinity membranes" in the future as the various membrane surface chemistries are altered and made more specific. Some applications are described in the following pages.

Clarification of Solutions

Because of low solubility and denaturation, solutions of biomolecules or cellular extracts are often turbid. This is a particular disadvantage if spectrophotometric analysis is desired. The transmittance of turbid solutions can be greatly increased by passage through a membrane filter system.

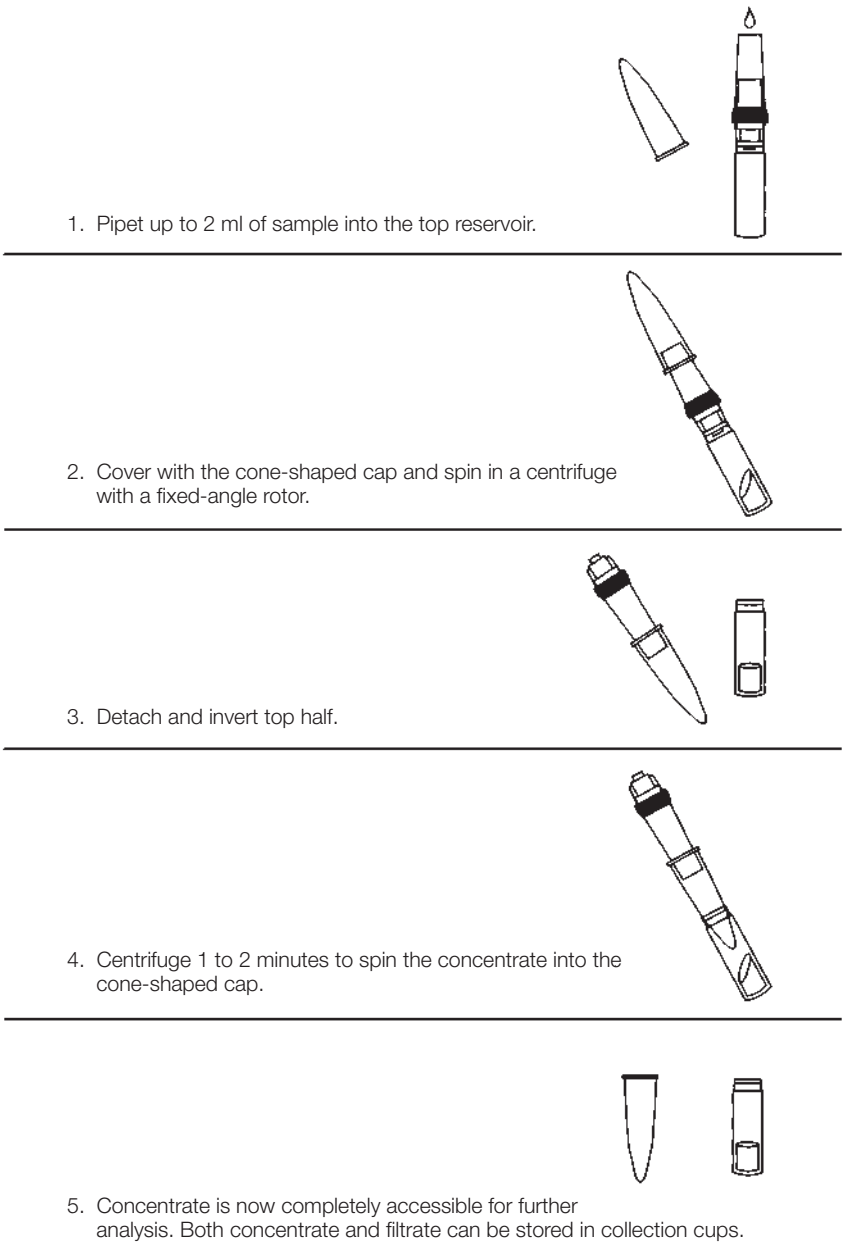

FIGURE 3.9 Use of a centrifuge microfilter. *Courtesy of the Millipore Corporation;* www.millipore.com.

This simple technique may also be applied to the sterilization of nonautoclavable materials such as protein and nucleic acid solutions or heat-labile reagents. Bacterial contamination can be removed from these solutions by passing them through filter systems that have been sterilized by autoclaving.

Collection of Precipitates for Analysis

The collection of small amounts of very fine precipitates is the basis for many chemical and biochemical analytical procedures. Membrane filtration is an ideal method for sample collection. This is of great advantage in the collection of radioactive precipitates. Cellulose nitrate and fiberglass filters are often used to collect radioactive samples because they can be analyzed by direct suspension in an appropriate scintillation cocktail.

Harvesting of Bacterial Cells from Fermentation Broths

The collection of bacterial cells from nutrient broths is typically done by batch centrifugation. This time-consuming operation can be replaced by membrane filtration. Filtration is faster than centrifugation, and it allows extensive cell washing.

Concentration of Biomolecule Solutions

Protein or nucleic acid solutions obtained from extraction or various purification steps are often too dilute for further investigation. Since they cannot be concentrated by high-temperature evaporation of solvent, gentler methods have been developed. One of the most effective is the use of ultrafiltration pressure cells, as shown in Figure 3.10. A membrane filter is placed in the bottom and the solution is poured into the cell. High pressure, exerted by compressed nitrogen (air could cause oxidation and denaturation of biomolecules), forces the flow of small molecules, including solvent, through the filter. Membranes are available in a number of sizes, allowing a large variety of molecular weight cutoffs. Larger molecules that cannot pass through the pores are concentrated in the sample chamber. This method of concentration is rapid and gentle and can be performed at cold temperatures to ensure minimal inactivation of the molecules. One major disadvantage is clogging of the pores, which reduces the flow rate through the filter; this is lessened by constant but gentle stirring of the solution.

Lyophilization and Centrifugal Vacuum Concentration

Although ultrafiltration is being used more and more for the concentration of biological solutions, the older technique of **lyophilization** (freeze-drying) is still used. There are some situations (storing or transporting biological materials) in which lyophilization is preferred. Lyophilization is a drying technique that uses the process of sublimation to change a solvent (water) in the frozen state directly to the vapor state under vacuum. The product after lyophilization is a fluffy matrix that may be reconstituted by the addition of liquid. This is one of the most effective methods for drying or concentrating heat-sensitive materials. In practice, a biological solution to be concentrated is "shell-frozen" on the walls of a round-bottom or freeze-drying flask. Freezing of the solution is accomplished by placing the flask (half full with sample) in a dry ice–acetone bath and slowly rotating it as it is held at a 45° angle. The aqueous solution freezes in layers on the wall of the flask. This provides a large surface area for evaporation of water. The flask is then connected to the lyophilizer, which consists of a refrigeration unit and a vacuum pump (see Figure 3.11). The combined unit maintains the sample

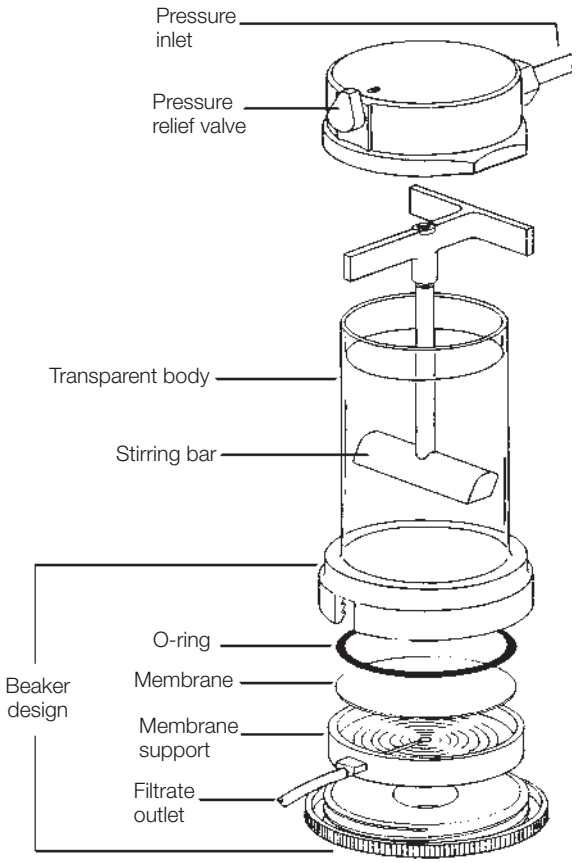

FIGURE 3.10
Schematic of an ultrafiltration cell. *Courtesy of Millipore/Amicon Corporation;* www.millipore.com.

at −40°C for stability of the biological materials and applies a vacuum of approximately 5 to 25 mm Hg on the sample. Ice formed from the aqueous solution sublimes and is pumped from the sample vial. In fact, all materials that are volatile under these conditions (−40°C, 5 to 25 mm Hg) will be removed, and nonvolatile materials (proteins, buffer salts, nucleic acids, etc.) will be concentrated into a light, sometimes fluffy precipitate. Most freeze-dried biological materials are stable for long periods of time and some remain viable for many years.

As with any laboratory method, there are precautions for and limitations of lyophilization that must be understood. Only aqueous solutions should be lyophilized. Organic solvents lower the melting point of aqueous solutions and increase the chances that the sample will melt and become denatured during freeze-drying. There is also the possibility that organic vapors will pass through the cold trap into the vacuum pump, where they may cause damage.

A new and increasingly popular technique for sample concentration and drying is **centrifugal vacuum concentration.** The method may be used to dry a wide variety of biological samples. The process starts with a sample dissolved in a solvent (water or organic). The solvent is evaporated under vacuum in a centrifuge, thus producing a pellet in the bottom of the container. The most widely used

FIGURE 3.11 A lab technician prepares a sample for lyophilization (freeze-drying) with the Labconco FreeZone benchtop freeze dryer, Model # 7740020. © *Labconco Corporation. Photo used with permission from Labconco Corporation.* www.labconco.com.

instrument is the SpeedVac, available through Savant (Figure 3.12). This method is better than freeze-drying because it is faster, it does not require a prefreezing step, it provides 100% sample recovery, and it may be used with solvents other than water. The SpeedVac is usually used for relatively small volumes—1–2-mL samples.

FIGURE 3.12 The SpeedVac centrifugal vacuum concentrator. *Image provided by Thermo Fisher Scientific Inc., all rights reserved.* www.thermofisher.com.

E. RADIOISOTOPES IN BIOCHEMISTRY

The use of radioactive isotopes in experimental biochemistry has provided us with a wealth of information about biological processes. In the earlier days of biochemistry, radioisotopes were primarily used to elucidate metabolic pathways. In modern biochemistry, few experimental techniques offer such a diverse range of applications as that provided by radioactive isotopes. The measurement of radioactivity is a tool that has the potential for use in all areas of experimental biochemistry, including enzyme assays, biochemical pathways of synthesis and degradation, analysis of biomolecules, measurement of antibodies, binding and transport studies, clinical biochemistry, and many others. Radioisotope applications have two major advantages over other analytical methods: (1) sensitive instrumentation allows the detection of minute quantities of radioactive material (some radioactive substances can be measured in the picomole, 10^{-12}, range), and (2) radioisotope techniques offer the ability to differentiate physically between substances that are chemically indistinguishable. The major disadvantages of radioisotope use are, of course, the safety and environmental concerns that must be considered when working with radioactive materials. These concerns have greatly slowed the development of new procedures using radioisotopes, as some countries and U.S. states require that all who work with radioactive materials, including students, must have completed an intensive training course. Because of the potential hazards and problems associated with using and disposing of radioactive waste materials, radioisotopes are generally not used in undergraduate biochemistry teaching labs. They are used in research, in industrial biotechnology applications, and in medicine only when there are no other techniques that can be applied to the problem. They are then handled only by experienced personnel.

The difficult problems and safety issues that arise with radioisotope use have encouraged scientists to search for alternate techniques. The last two Web site references in the Radioisotopes section at the end of the chapter describe the search for "green biochemistry" techniques that avoid the use of radioisotopes. One reference describes the design of protein kinase assays that avoid the use of phosphorus-32. Another describes the synthesis of probes for radioisotope-free photoaffinity labels for proteins.

Origin and Properties of Radioactivity

Introduction

Radioactivity results from the spontaneous nuclear disintegration of unstable isotopes. The hydrogen nucleus, consisting of a proton, is represented as ${}^{1}_{1}\mathrm{H}$. Two additional forms of the hydrogen nucleus contain one and two neutrons; they are represented as ${}^{2}_{1}\mathrm{H}$ and ${}^{3}_{1}\mathrm{H}$. These **isotopes** of hydrogen are commonly called deuterium and tritium, respectively. All isotopes of hydrogen have an identical number of protons (constant charge, +1), but they differ in the number of neutrons. Only tritium is radioactive.

The stability of a nucleus depends on the ratio of neutrons to protons. Some nuclei are unstable and undergo spontaneous nuclear disintegration

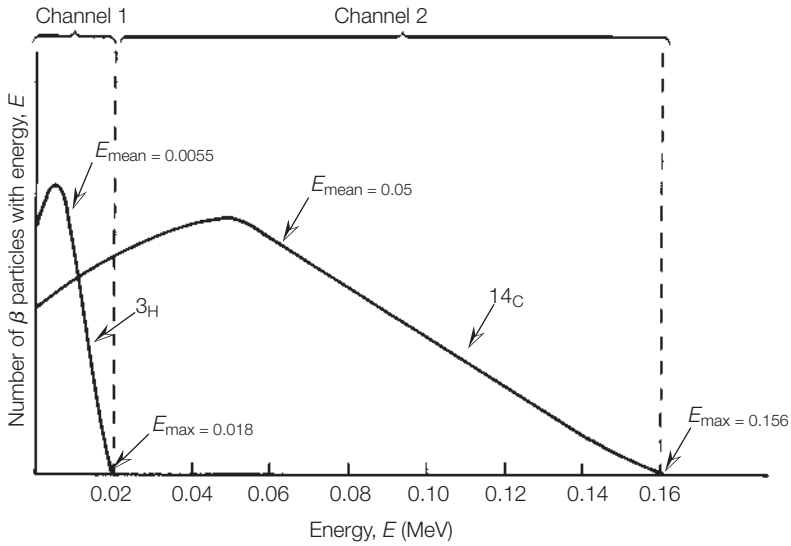

FIGURE 3.13
Energy spectra for the β emitters ^{3}H and ^{14}C. The dashed lines indicate the upper and lower limits for discrimination counting.

accompanied by emission of particles. Unstable isotopes of this type are called **radioisotopes.** Three main types of radiation are emitted during nuclear decay: α particles, β particles, and γ rays. The α particle, a helium nucleus, is emitted only by elements with a mass number greater than 140. These elements are seldom used in biochemical research.

Most of the commonly used radioisotopes in biochemistry are β emitters. The β particles exist in two forms (β^+, positrons, and β^-, electrons) and are emitted from a given radioisotope with a continuous range of energies. However, an average energy (called the *mean* energy) of β particles from an element can be determined. The mean energy is a characteristic of that isotope and can be used to identify one β emitter in the presence of a second (see Figure 3.13). Equations 3.10 and 3.11 illustrate the disintegration of two β emitters. Here $\overline{v}_e$ represents the antineutrino and v_e the neutrino.

>> $$^{32}_{15}\mathrm{P} \longrightarrow {}^{32}_{16}\mathrm{S} + \beta^- + \overline{v}_e$$ **(Eq. 3.10)**

>> $$^{65}_{30}\mathrm{Zn} \longrightarrow {}^{65}_{29}\mathrm{Cu} + \beta^+ + v_e$$ **(Eq. 3.11)**

A few radioisotopes of biochemical significance are γ emitters. Emission of a γ ray (a photon of electromagnetic radiation) is often a secondary process occurring after the initial decay by β emission. The disintegration of the isotope ^{131}I is an example of this multistep process.

>> $$^{131}_{53}\mathrm{I} \longrightarrow \beta^- + {}^{131}_{54}\mathrm{Xe} \longrightarrow {}^{131}_{54}\mathrm{Xe} + \gamma$$ **(Eq. 3.12)**

Each radioisotope emits γ rays of a distinct energy, which can be measured for identification of the isotope.

The spontaneous disintegration of a nucleus is a first-order kinetic process. That is, the rate of radioactive decay of N atoms ($-dN/dt$, the change of N with time, t) is proportional to the number of radioactive atoms present (Equation 3.13).

>> $$-\frac{dN}{dt} = \lambda N \qquad \textbf{(Eq. 3.13)}$$

The proportionality constant, λ, is called the **disintegration** or **decay constant.** Equation 3.13 can be transformed to a more useful equation by integration within the limits of $t = 0$ and t. The result is shown in Equation 3.14.

>> $$N = N_0 e^{-\lambda t} \qquad \textbf{(Eq. 3.14)}$$

where

$N_0 =$ the number of radioactive atoms present at $t = 0$

$N =$ the number of radioactive atoms present at time $= t$

Equation 3.14 can be expressed in the natural logarithmic form as in Equation 3.15.

>> $$\ln \frac{N}{N_0} = -\lambda t \qquad \textbf{(Eq. 3.15)}$$

Combining Equations 3.14 and 3.15 leads to a relationship that defines the **half-life.** Half-life, $t_{1/2}$, is a term used to describe the time necessary for one-half of the radioactive atoms initially present in a sample to decay. At the end of the first half-life, N in Equation 3.15 becomes $\frac{1}{2}N_0$, and the result is shown in Equations 3.16 and 3.17.

>> $$\ln \frac{\frac{1}{2}N_0}{N_0} = -\lambda t_{1/2}$$

$$\ln \tfrac{1}{2} = -\lambda t_{1/2} \qquad \textbf{(Eq. 3.16)}$$

>> $$t_{1/2} = \frac{0.693}{\lambda} \qquad \textbf{(Eq. 3.17)}$$

Equations 3.15 and 3.17 allow calculation of the ratio N/N_0 at any time during an experiment. This calculation is especially critical when radioisotopes with short half-lives are used.

Isotopes in Biochemistry

The properties of several radioisotopes that are important in biochemical research are listed in Table 3.5. Note that many of the isotopes are β emitters; however, a few are γ emitters.

The half-life, defined in the previous section and listed for each isotope in Table 3.5, is an important property to consider when one is designing experiments using radioisotopes. Using an isotope with a short half-life (for example, ^{24}Na with $t_{1/2} = 15$ hrs) is difficult because the radioactivity lost during the course of the experiment is significant. Quantitative measurements made before and after the experiment must be corrected for this loss of activity. Radioactive phosphorus,

TABLE 3.5 Properties of Biochemically Important Radioisotopes

Isotope	Particle Emitted	Energy of Particle (MeV)	Half-Life, $t_{1/2}$
^{3}H	β^-	0.018	12.3 yrs
^{14}C	β^-	0.155	5570 yrs
^{22}Na	β^+	0.55	2.6 yrs
	γ	1.28	
^{24}Na	β^-	1.39	15 hrs
	γ	1.7, 2.75	
^{32}P	β^-	1.71	14.2 days
^{35}S	β^-	0.167	87.1 days
^{36}Cl	β^-	0.714	3×10^5 days
^{40}K	β^-	1.33	1.3×10^9 yrs
^{45}Ca	β^-	0.25	165 days
^{59}Fe	β^-	0.46	45 days
	γ	1.1	
^{60}Co	β^-	0.318	5.3 yrs
	γ	1.3	
^{65}Zn	β^+	0.33	245 days
	γ	1.14	
^{90}Sr	β^-	0.54	29 yrs
^{125}I	γ	0.035	60 days
	γ	0.027	
^{131}I	β^-	0.61, 0.33	8.1 days
	γ	0.64, 0.36, 0.28	
^{137}Cs	β^-	0.51	30 yrs
	γ	0.66	
^{226}Ra	α	4.78	1600 yrs
	γ	0.19	

^{32}P, an isotope of significant value in biochemical research, has a relatively short half-life (14 days), so if quantitative measurements are made they must be corrected as described in Equations 3.16 and 3.17.

Mention should also be made of short-lived isotopes that are important in biotechnology and medical biochemistry. The isotopes ^{11}C, ^{13}N, ^{15}O, and ^{18}F, which are positron emitters, are crucial for use in positron emission tomography (PET).

TABLE 3.6 Units of Radioactivity

Unit's Name	Multiplication Factor (relative to curie)	Activity (dps)
Curie (Ci)	1.0	3.70×10^{10}
Millicurie (mCi)	10^{-3}	3.70×10^{7}
Microcurie (μCi)	10^{-6}	3.70×10^{4}
Nanocurie (nCi)	10^{-9}	3.70×10
Becquerel (Bq)	2.7×10^{-11}	1.0
Mega becquerel (MBq)	2.7×10^{-5}	1.0×10^{6}

Units of Radioactivity

The basic unit of radioactivity is the **curie,** Ci, named in honor of Marie and Pierre Curie. One curie is the amount of radioactive material that emits particles at a rate of 3.7×10^{10} disintegrations per second (dps), or $2.2 \times 10^{12}\,\text{min}^{-1}$ (dpm). Amounts that large are seldom used in experimentation, so subdivisions are convenient. The **millicurie** (mCi, $2.2 \times 10^{9}\,\text{min}^{-1}$) and **microcurie** ($\mu$Ci, $2.2 \times 10^{6}\,\text{min}^{-1}$) are standard units for radioactive measurements (see Table 3.6). The radioactivity unit of the meter-kilogram-seconds (MKS) system is the **becquerel** (Bq). A becquerel, named in honor of Antoine Becquerel, who studied uranium radiation, represents one disintegration per second. The two systems of measurement are related by the equation 1 curie $= 3.70 \times 10^{10}$ becquerels. Since the becquerel is such a small unit, radioactive units are sometimes reported in MBq (mega, 10^{6}) or TBq (tera, 10^{12}). Both unit systems are in common use today, and radioisotopes received through commercial sources are labeled in curies and becquerels.

The number of disintegrations emitted by a radioactive sample depends on the purity of the sample (number of radioactive atoms present) and the decay constant, λ. Therefore, radioactive decay is also expressed in terms of **specific activity,** the disintegration rate per unit mass of radioactive atoms. Typical units for specific activity are mCi/mmole and μCi/μmole.

Although radioactivity is defined in terms of nuclear disintegrations per unit of time, rarely does one measure this absolute number in the laboratory. Instruments that detect and count emitted particles respond to only a small fraction of the particles. Data from a radiation counter are in counts per minute (cpm), which can be converted to actual disintegrations per minute if the counting efficiency of the instrument is known. The percent efficiency of an instrument is determined by counting a standard compound of known radioactivity and using the ratio of detected activity (observed cpm) to actual activity (disintegrations per minute). Equation 3.18 illustrates the calculation using a standard of 1 μCi.

>>
$$\%\ \text{efficiency} = \frac{\text{observed cpm of standard}}{\text{dpm of } 1\mu\text{Ci of standard}} \times 100$$
$$= \frac{\text{observed cpm}}{2.2 \times 10^{6}\,\text{dpm}} \times 100 \qquad \textbf{(Eq. 3.18)}$$

Detection and Measurement of Radioactivity

Since most of the radioisotopes used in biochemical research are β emitters, only methods that detect and measure β particles will be emphasized.

Liquid Scintillation Counting

Samples for liquid scintillation counting consist of three components: (1) the radioactive material; (2) a solvent, usually aromatic, in which the radioactive substance is dissolved or suspended; and (3) one or more organic fluorescent substances. Components 2 and 3 make up the liquid scintillation system or cocktail. β particles emitted from the radioactive sample interact with the scintillation system, producing small flashes of light, or scintillations. The light flashes are detected by a photomultiplier tube (PMT). Electronic pulses from the PMT are amplified and registered by a counting device called a scaler. A schematic diagram of a typical scintillation counter is shown in Figure 3.14.

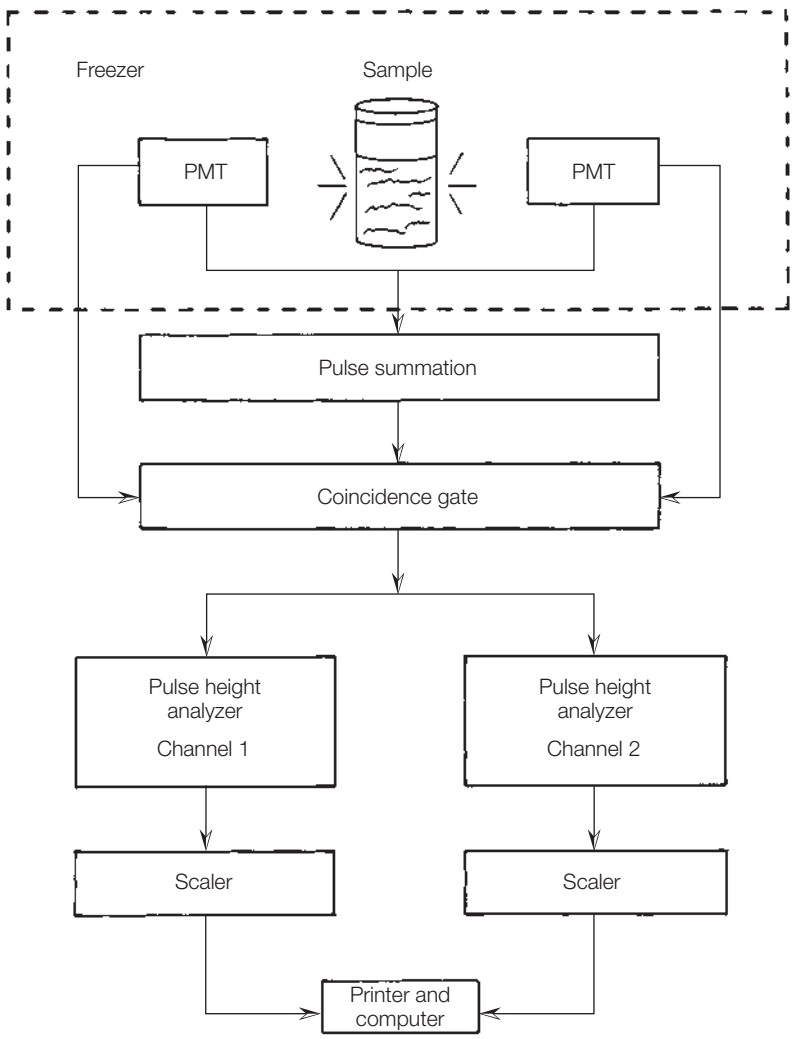

FIGURE 3.14 Diagram of a typical scintillation counter, showing coincidence circuitry.

The scintillation process, in detail, begins with the collision of emitted β particles with solvent molecules, S (Equation 3.19).

>> $$\beta + S \rightarrow S^* + \beta \text{ (less energetic)}$$ **(Eq. 3.19)**

Contact between the energetic β particles and S in the ground state results in transfer of energy and conversion of an S molecule into an excited state, S*. Aromatic solvents are most often used because their electrons are easily promoted to an excited state orbital (see discussion of fluorescence, Chapter 7, p. 220). The β particle after one collision still has sufficient energy to excite several more solvent molecules. The excited solvent molecules normally return to the ground state by emission of a photon, $S^* \longrightarrow S + h\nu$. Photons from the typical aromatic solvent are of short wavelength and are not efficiently detected by photocells. A convenient way to resolve this technical problem is to add one or more fluorescent substances (fluors) to the scintillation mixture. Excited solvent molecules interact with a **primary fluor,** F_1, as shown in Equation 3.20.

>> $$S^* + F_1 \longrightarrow S + F_1^*$$ **(Eq. 3.20)**

Energy is transferred from S* to F_1, resulting in ground state S molecules and excited F_1 molecules, $F_1^* \cdot F_1^*$ molecules are fluorescent and emit light of a longer wavelength than S* (Equation 3.21).

>> $$F_1^* \longrightarrow F_1 + h\nu_1$$ **(Eq. 3.21)**

If the light emitted during the decay of F_1^* is still of a wavelength too short for efficient measurement by a PMT, a **secondary fluor,** F_2, that accepts energy from F^*_1 may be added to the scintillation system. Equations 3.22 and 3.23 outline the continued energy transfer process and fluorescence of F_2^*.

>> $$F_1^* + F_2 \longrightarrow F_1 + F_2^*$$ **(Eq. 3.22)**

>> $$F_2^* \longrightarrow F_2 + h\nu_2$$ **(Eq. 3.23)**

The light, $h\nu_2$, from F_2^* is of longer wavelength than $h\nu_1$ from F_1^* and is more efficiently detected by a PMT. Two widely used primary and secondary fluors are 2,5-diphenyloxazole (PPO) with an emission maximum of 380 nm and 1,4-bis-2-(5-phenyloxazolyl)benzene (POPOP) with an emission maximum of 420 nm. A more efficient but more expensive fluor is 2-(4′-*t*-butylphenyl)-5-(4″-biphenyl)-1,3,4-oxadiazole (Butyl-PBD).

The most basic elements in a liquid scintillation counter are the PMT, a pulse amplifier, and a counter, called a **scaler.** This simple assembly may be used for counting; however, there are many problems and disadvantages with this setup. Many of the difficulties can be alleviated by more sophisticated instrumental features. Some of the problems and practical solutions are outlined below.

Thermal Noise in Photomultiplier Tubes

The energies of the β particles from most β emitters are very low. This, of course, leads to low-energy photons emitted from the fluors and relatively low-energy electrical pulses in the PMT. In addition, photomultiplier tubes produce thermal background noise with 25 to 30% of the energy associated

with the fluorescence-emitted photons. This difficulty cannot be completely eliminated, but its effects can be lessened by placing the samples and the PMT in a freezer at −5 to −8°C in order to decrease thermal noise.

A second way to help resolve the thermal noise problem is to use two photomultiplier tubes for detection of scintillations. Each flash of light that is detected by the photomultiplier tubes is fed into a **coincidence circuit.** A coincidence circuit counts only the flashes that arrive simultaneously at the two photodetectors. Electrical pulses that are the result of simultaneous random emission (thermal noise) in the individual tubes are very unlikely. A schematic diagram of a typical scintillation counter with coincidence circuitry is shown in Figure 3.14.

Counting More Than One Isotope in a Sample

The basic liquid scintillation counter with coincidence circuitry can be used only to count samples containing one type of isotope. Many experiments in biochemistry require the counting of just one isotope; however, more valuable experiments can be performed if two radioisotopes can be simultaneously counted in a single sample (double-labeling experiments). The basic scintillation counter just described has no means of discriminating between electrical pulses of different energies.

The size of the current generated in a photocell is nearly proportional to the energy of the β particle initiating the pulse. Recall that β particles from different isotopes have characteristic energy spectra with an average energy (see Figure 3.13). Modern scintillation counters are equipped with **pulse height analyzers** that measure the size of the electrical pulse and count only the pulses within preselected energy limits set by **discriminators.** The circuitry required for pulse height analysis and energy discrimination of β particles is shown in Figure 3.14. Discriminators are electronic "windows" that can be adjusted to count β particles within certain energy or voltage ranges called **channels.** The channels are set to a **lower limit** and an **upper limit,** and all voltages within those limits are counted. Figure 3.13 illustrates the function of discriminators for the counting of ^{3}H and ^{14}C in a single sample. Discriminator channel 1 is adjusted to accept typical β particles emitted from ^{3}H and channel 2 is adjusted to receive β particles of the energy characteristic of ^{14}C.

Quenching

Any chemical agent or experimental condition that reduces the efficiency of the scintillation and detection process leads to a reduced level of counting, or **quenching.** Quenching may be caused by a decrease in the amount of fluorescence from the primary and secondary scintillators (fluors) or a decrease in light activating the PMT. There are four common origins of quenching.

Color quenching is a problem if chemical substances that absorb photons from the secondary fluors are present in the scintillation mixture. Since the secondary fluors emit light in the visible region between 410 and 420 nm, colored substances may absorb the emitted light before it is detected by the photocells. Radioactive samples may be treated to remove colored impurities before mixing with the scintillation solvent.

Chemical quenching occurs when chemical substances in the scintillation solution interact with excited solvent and fluor molecules and decrease the efficiency

of the scintillation process. To avoid this type of quenching, the sample can be purified or the fluors can be increased in concentration. Modern scintillation counters have computer programs to correct for color and chemical quenching.

Point quenching occurs if the radioactive sample is not completely dissolved in the solvent. The emitted β particles may be absorbed before they have a chance to interact with solvent molecules. The addition of solubilizing agents such as Cab-O-Sil or Thixin decreases point quenching by converting the liquid scintillator to a gel.

Dilution quenching results when a large volume of liquid radioactive sample is added to the scintillation solution. In most cases, this type of quenching cannot be eliminated, but it can be corrected by one of the techniques discussed below.

Since quenching can occur during all experimental counting of radioisotopes, it is important to be able to determine the extent of the reduced counting efficiency. Two methods for quench correction are in common use.

In the **internal standard ratio** method, the sample, X, under study is first counted; then a known amount of a standard radioactive solution is added to the sample, and it is counted again. The absolute activity of the original sample, A_X, is represented by Equation 3.24.

>> $$A_X = A_s \frac{C_X}{C_s} \qquad \textbf{(Eq. 3.24)}$$

where

A_X = activity of the sample, X
C_X = radioactive counts from sample
A_s = activity of the standard
C_s = radioactive counts from standard

The absolute value of C_s is determined from Equation 3.25.

>> $$C_T = C_X + C_s \qquad \textbf{(Eq. 3.25)}$$

where

C_T = total radioactive counts from sample and standard

Equation 3.24 can then be modified to Equation 3.26.

>> $$A_X = \frac{A_s C_X}{C_T - C_X} \qquad \textbf{(Eq. 3.26)}$$

The internal standard ratio method for quench correction is tedious, time-consuming, and destroys the sample, so it is not an ideal method. Scintillation counters are equipped with a standard radiation source inside the instrument, but outside the scintillation solution. The radiation source, usually a gamma emitter, is mechanically moved into a position next to the vial containing the sample, and the combined system of standard and sample is counted. Gamma rays from the standard excite solvent molecules in the sample, and the scintillation process occurs as previously described. However, the instrument is adjusted to register only scintillations due to γ particle collisions with solvent

molecules. This method for quench correction, called the **external standard method,** is fast and precise.

Scintillation Cocktails and Sample Preparation

Many of the quenching problems discussed earlier can be lessened if an experiment is carefully planned. Many sample preparation methods and scintillation liquids are available for use. Only a few of the more common techniques will be mentioned here. Most liquid or solid radioactive samples can be counted by mixing them with a **scintillation cocktail,** a mixture of solvent and fluor(s). The radioactive sample and scintillation solution are placed in a glass, polyethylene, polypropylene, polyester, or polycarbonate vial for counting. Traditional counting vials include a 20-mL-standard vial, a 6-mL miniature vial, a 1-mL Eppendorf tube, or a 200-μL microfuge tube. If glass is used, the solution must contain a low potassium content because naturally occurring ^{40}K is a β emitter. Two major types of solvent systems are available: (1) those that are immiscible with water, in which only organic samples may be used, and (2) those that dissolve aqueous samples. During the early years of liquid scintillation counting, the most common solvents used were toluene and xylene for organic samples and dioxane for aqueous samples. These solvents provided high counting efficiency. However, on the downside, they were flammable (flash points between 4 and 25°C), highly toxic, and presented major disposal costs and problems. In addition, they penetrated plastic counting vials, releasing vapors and liquids into the laboratory. A new environmental awareness has prompted the development of biosafe liquid scintillation cocktails. The use of highly alkylated aromatic solvents has produced cocktails that are fully biodegradable (converted to CO_2 and H_2O), have higher flash points (above 120°C), and offer high counting efficiency. The newer solvents may be disposed of after use by incineration, which greatly reduces costs compared to road transport to a disposal site. Occupational risks are also lessened because the solutions are defined by the Environmental Protection Agency as nontoxic.

Solid radioactive samples or those that are insoluble in either type of solvent may be quantified by collection onto small pieces of a solid support (filter paper or cellulose membrane) and added directly to the cocktail for counting. The efficiency of counting these samples depends on the support, but is usually less than that of counting a homogeneous sample.

Applications of Radioisotopes

The applications of radioisotopes in biochemical measurements are too numerous to outline here. Excellent reference books and Web sites, some of which are listed at the end of this chapter, provide experimental procedures for radioisotope utilization. The technique of **autoradiography,** however, should be mentioned here. This procedure allows the detection and localization of a radioactive substance (molecule or atom) in a tissue, cell, or cell organelle. Briefly, the technique involves placing a radioactive material directly onto or close to a photographic emulsion. Radioisotopes in the material emit radiation that impinges on the photographic plate, activating silver halide crystals in the emulsion. Upon development of the plate, a pattern or image is displayed that yields information about the location and amount of radioactive material in the

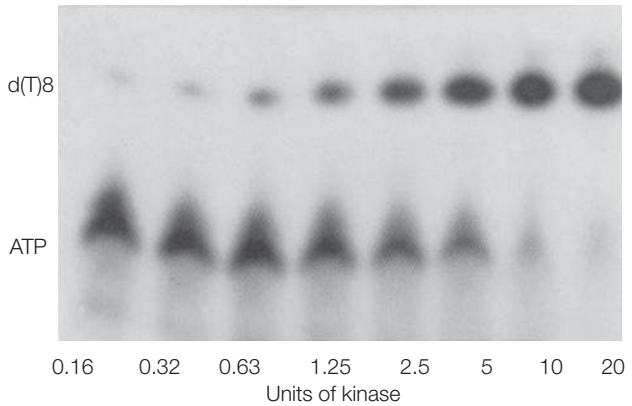

FIGURE 3.15 Autoradiograph showing the transfer of ^{32}P from γ-^{32}P-labeled ATP to the 5′ end of a polynucleotide, $(dT)_8$, catalyzed by polynucleotide kinase. Reagents were incubated for 30 min and electrophoresed on a 20% polyacrylamide, 7 *M* urea gel and autoradiographed. Note that as more units of kinase are added, more ^{32}P-labeled polynucleotide is made. The dark regions indicate the presence of ^{32}P. *Source: Copyright © New England Biolabs. Reprinted with permission.*

sample. A densitometer may be used to scan the autoradiograph and quantify the amount of radioactivity in each region. One of the most common uses of autoradiography in biochemistry and molecular biology is in the detection and quantification of ^{32}P-labeled nucleic acids on polyacrylamide or agarose gels after electrophoresis (Figure 3.15). Autoradiography has also been useful in concentration and localization studies of biomolecules in cells and cell organelles.

Statistical Analysis of Radioactivity Measurements

Radioactive decay is a random process. It is impossible to predict when a radioactive event will occur. Therefore, counting measurements provide only average rates of decay. However, counting measurements may be treated by Gaussian distribution analysis to determine an average counting rate, standard deviation, percent confidence level, and other statistical parameters. An introduction to statistical analysis of radioactivity counting data and other experimental measurements is given in Chapter 1, Section E, p. 23.

Radioisotopes and Safety

Safety should be of major concern in performing any chemistry experiment, but when radioisotopes are involved, special precautions must be taken. Many chemistry and biochemistry departments have specially equipped laboratories for radioisotope work. Alternatively, your instructor should set aside a specific area of your laboratory for using radioactive materials. In either situation, specific guidelines should be mandated and enforced by all institutions.

Study Problems

1. You need to prepare a buffer for biochemistry lab. The required solution is 0.5 *M* sodium phosphate, pH 7.0. Use the Henderson-Hasselbalch equation to calculate the number of moles and grams of monobasic sodium phosphate (NaH_2PO_4) and dibasic sodium phosphate (Na_2HPO_4) necessary to make 1 liter of the solution.
2. Design a "shortcut" method for preparing the phosphate buffer in Study Problem 1. Hint: You need only NaH_2PO_4, a solution of NaOH, and a pH meter.
3. Describe how you would prepare a 0.1 *M* glycine buffer of pH 10.0. You have available isoelectric glycine and sodium glycinate.
4. Describe how you would prepare a 0.20 *M* Tris-HCl buffer of pH 8.0. The only Tris reagent you have available is Tris base. What other reagent do you need, and how would you use it to prepare the solution?
5. Below is a table prepared by a biochemistry student to construct a standard curve for protein analysis. The Bradford assay was used with IgG (0.1 mg/mL) as standard protein. Complete the table by filling in the weight of IgG in each tube and the approximate A_{595} that will be obtained for each tube. Assume the procedure was conducted correctly.

Tube No.						
Reagents	**1**	**2**	**3**	**4**	**5**	**6**
H_2O (mL)	1.0	0.9	0.8	0.6	0.2	—
IgG volume (mL)	—	0.1	0.2	0.4	0.8	1.0
IgG weight (μg)	0					
Bradford reagent (mL)	5.0	→				
A_{595}	0.00	0.05				

6. Assume that you use the standard curve produced in Study Problem 5 to measure the concentration of an unknown protein. The A_{595} for 1.0 mL of the unknown was 0.52. Prepare a standard curve from the data in Problem 5 and estimate the concentration of unknown protein in the sample in μg/mL.
7. A solution of purified DNA gave in the spectrophotometric assay an A_{260} of 0.35 when measured in a 1-cm quartz cuvette. What is the concentration of the DNA in μg/mL?
8. An RNA sample that you isolated has an absorbance reading at 260 nm of 0.25. What is the concentration of RNA in the sample? Assume the measurement was taken in a 1-cm quartz cuvette.
9. You have just completed an experiment to isolate DNA from *E. coli*. Absorbance measurements on the DNA sample were taken at 260 nm and 280 nm. The 260/280 ratio was 1.6. Is the DNA sample pure? If not, what could be the impurity?
10. Compare the techniques of lyophilization and centrifugal vacuum concentration. Give advantages and disadvantages of each.
11. What amino acid residues are detected when the spectrophotometric assay is used to quantify proteins? Are those amino acids present in the same quantity in all proteins? Explain how this may affect measurement of proteins by this method.
12. What biomolecules would interfere with the measurement of nucleic acids using the spectrophotometric (A_{260}) assay?
13. The concentration of a purified DNA solution is 35 μg/mL. Predict the value of absorbance of the solution at 260 and 280 nm.
14. In Section B of this chapter, you read that the Bradford assay has a higher sensitivity to some proteins than other proteins and hence gives higher absorbance readings at

595 nm. For example, the absorbance readings for bovine serum albumin are more than twice those for bovine gamma globulin (Figure 3.6). Explain why higher absorbance readings are obtained for some proteins. HINT: Use the bioinformatics Web sites given in Chapter 2.

15. In the Bradford assay of a protein, what is the most ideal protein to use as a standard?

16. Prepare a linear dilution table similar to Table 3.2. Assume that the stock solution is 2.0 *M* and you require 20-mL diluted samples of final concentrations: 1.66 *M*, 1.33 *M*, 1.0 *M*, 0.66 *M*, 0.33 *M*, and 0.00 *M*.

17. Select a buffer system that can be used at each of the following pH values.
(a) pH 3.5
(b) pH 6.0
(c) pH 9.5

18. Describe how you would prepare 1 liter of the following buffer: 0.025 *M* Tris-chloride, pH 8.0, containing 0.05 *M* glucose and 0.01 *M* EDTA (MW EDTA disodium salt, dihydrate = 372.2).

19. Calculate λ, the decay constant for ^{32}P.

20. Calculate the half-life of an isotope from the following experimental measurements. At time = 0, the activity is 300 disintegrations per minute. After 1 hour, the activity is 200 disintegrations per minute.

21. The following serial dilution is carried out in the lab:
1.0 mL of Solution A is diluted to a final volume of 10 mL (Solution B).
1.0 mL of Solution B is diluted to a final volume of 10 mL (Solution C).
1.0 mL of Solution C is diluted to a final volume of 10 mL (Solution D).
Assume that Solution A has a concentration of 2.0 *M*. Calculate the concentrations of Solutions B, C, and D.

22. You need to prepare a buffer solution at each of the following concentrations:

1 *M*, 0.1 *M*, 0.01 *M*, and 0.001 *M*

Describe how you would use a single stock solution of the buffer (5.0 *M*) to prepare 10 mL of each diluted buffer solution.

23. How long will it take a sample of ^{32}P that contains 65,000 disintegrations per minute to decay to 1500 disintegrations per minute?

24. List five radioisotopes that may be measured using a liquid scintillation counter.

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http://www.hannainst.com
Complete information on the selection, use, and care of pH meters and electrodes.

http://www.ysi.com
Information on the biological oxygen monitor (oxygen electrode).

http://www.ornl.gov/sci/biosensors
Virtual poster session on biosensors in biomedicine, sponsored by the Oak Ridge National Lab.

http://en.wikipedia.org/wiki/Biosensor
Introduction to biosensors.

http://en.wikipedia.org/wiki/Buffer_solution
Buffers.

http://www.ysilifesciences.com/index.php?page=ysi-5300a-biological-oxygen-monitor
Figure 3.3 Model 5300A oxygen monitor.

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K. Leiser, ***Nuclear and Radiochemistry: Fundamentals and Applications,*** 2nd ed. (2002), John Wiley & Sons (New York).

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K. Wilson and J. Walker, Editors, ***Principles and Techniques of Practical Biochemistry,*** 5th ed. (2000), Cambridge University Press (Cambridge, U.K.), pp. 687–728.

http://beckman.com
Click on LS 6500 liquid scintillation counters.

http://en.wikipedia.org/wiki/Scintillation_counter
Scintillation counters.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2721227
Protein kinase assays avoiding radioisotope use.

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TF9-4FDMYBX-7&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=de3dc23002975c4d48063d0dfdcd6d30
Design of radioactive-free photoaffinity labels for proteins.

TECHNIQUES FOR SAMPLE PREPARATION

http://www.millipore.com/lab_filtration/clf/capability
Membranes and ultrafiltration.

http://www.thermo.com/com/cda/product/detail/0,1055,23574,00.html
or
http://www.thermo.com/eThermo/CMA/PDFs/Various/File_10350.pdf
Savant SpeedVac concentrators.

http://www.labconco.com
Freeze dryers.

http://www.labconco.com/_Scripts/editc25.asp?catid=345
Freeze dryers.

http://www.spectrapor.com
Dialysis membranes.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER

4 CENTRIFUGATION TECHNIQUES IN BIOCHEMISTRY

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A centrifuge of some kind is found in every biochemistry laboratory. Centrifuges have many applications, but they are used primarily for the preparation of biological samples and for the analysis of the physical properties of biomolecules, organelles, and cells. Centrifugation is carried out by spinning a biological sample at a high rate of speed, thus subjecting it to an intense force (artificial gravitational field). Most centrifuge techniques fit into one of two categories—**preparative centrifugation** or **analytical centrifugation.** A preparative procedure is one that can be applied to the separation or purification of biological samples (cells, organelles, macromolecules, etc.) by sedimentation. Analytical procedures are used to measure physical characteristics of biological samples. For example, the purity, size, shape, and density of macromolecules may be defined by centrifugation.

In this chapter, we will first explore the principles and theory underlying centrifugation techniques in order to provide a fundamental background. We will then turn to a discussion of the application of these techniques to the isolation and characterization of biological molecules and cellular components.

A. BASIC PRINCIPLES OF CENTRIFUGATION

A particle—whether it is a floating solid, a precipitate, a macromolecule, or a cell organelle—is subjected to a centrifugal force when it is rotated at a high rate of speed. The **centrifugal force,** F, is defined by Equation 4.1.

>> $$F = m\omega^2 r \qquad \textbf{(Eq. 4.1)}$$

where

F = intensity of the centrifugal force
m = effective mass of the sedimenting particle
ω = angular velocity of rotation in rad/sec
r = distance of the migrating particles from the central axis of rotation

The force on a sedimenting particle increases with the velocity of the rotation and the distance of the particle from the axis of rotation. A more common measurement of F, in terms of the earth's gravitational force, g, is **relative centrifugal force,** RCF, defined by Equation 4.2.

>> $$\text{RCF} = (1.119 \times 10^{-5})(\text{rpm})^2(r) \qquad \textbf{(Eq. 4.2)}$$

This equation relates RCF to revolutions per minute of the sample. Equation 4.2 dictates that the RCF on a sample will vary with r, the distance of the sedimenting particles from the axis of rotation (see Figure 4.1). It is convenient to determine RCF by use of the nomogram in Figure 4.2. It should be clear from Figures 4.1 and 4.2 that, since RCF varies with r, it is important to define r for an experimental run. Often an average RCF is determined using a value for r midway between the top and bottom of the sample container. The RCF value is reported as "a number times gravity, g."

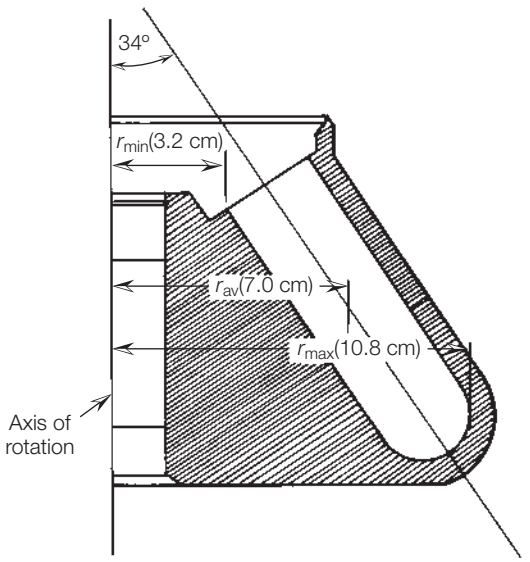

FIGURE 4.1 A diagram illustrating the variation of RCF with r, the distance of the sedimenting particles from the axis of rotation. *Courtesy of Beckman Coulter;* www.beckman.com.

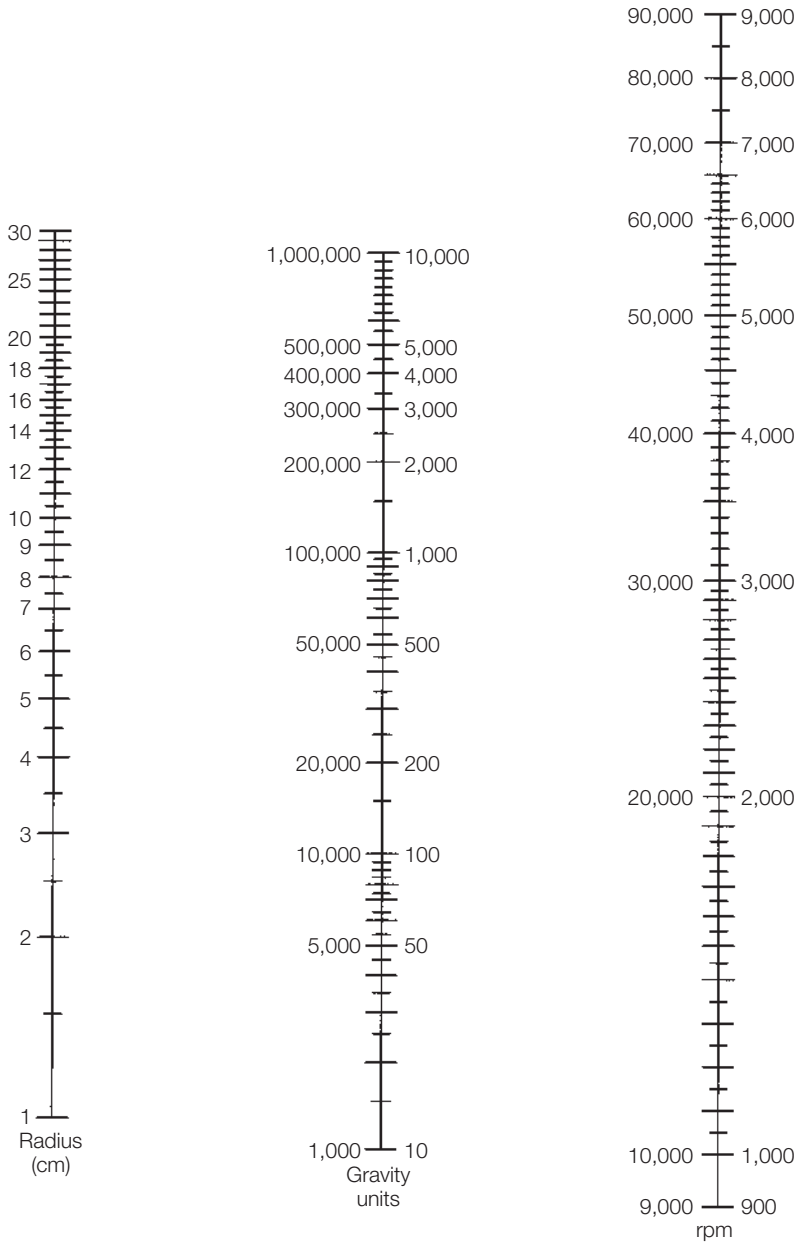

FIGURE 4.2 A nomogram for estimating RCF. To use, place a straight edge connecting the instrumental revolutions (right column) with the distance from the center of rotation (left column). The RCF is read where the straight edge crosses the middle column. *Courtesy of Beckman Coulter;* www.beckman.com.

STUDY EXERCISE 4.1 Relative Centrifugal Force

To illustrate the use of the nomogram in Figure 4.2, consider a centrifuge tube with an average r of 7 cm (see Figure 4.1) being rotated at 20,000 rpm. Use the nomogram to determine the relative centrifugal force (RCF) in gravity (g) units.

Solution: Follow the instructions in the caption for Figure 4.2 to estimate the RCF to be about 32,000 $\times$ g.

Although this introduction outlines the basic principles of centrifugation, it does not take into account other factors that influence the rate of particle sedimentation. Centrifuged particles migrate at a rate that depends on their mass, shape, and density, as well as the density of the medium. The centrifugal force felt by a particle is defined by Equation 4.1. The term m is the **effective mass** of the particle, that is, the actual mass, m_0, minus a correction factor for the weight of water displaced (buoyancy factor) (Equation 4.3).

>> $$m = m_0 - m_0 \bar{v}\rho$$ **(Eq. 4.3)**

where

m = effective mass of the sedimenting particle
m_0 = actual mass of the particle
$\bar{v}$ = partial specific volume, the volume change occurring when a particle is placed in a large excess of solvent
ρ = density of the solvent or medium

Equations 4.1 and 4.3 may be combined to describe the centrifugal force on a particle (Equation 4.4).

>> $$F = m_0(1 - \bar{v}\rho)\omega^2 r$$ **(Eq. 4.4)**

As particles sediment under the influence of the centrifugal field, their movement is countered by a resistance force, the **frictional force.** The frictional force is defined by Equation 4.5.

>> $$\text{Frictional force} = fv$$ **(Eq. 4.5)**

where

f = frictional coefficient
v = velocity of the sedimenting particle (sedimentation velocity)

The **frictional coefficient,** f, depends on the size and shape of the particle, as well as the viscosity of the solvent. The frictional force increases with the velocity of the particle until a constant velocity is reached. At this point, the two forces are balanced (Equation 4.6).

>> $$m_0(1 - \bar{v}\rho)\omega^2 r = fv = f\left(\frac{dr}{dt}\right)$$ **(Eq. 4.6)**

The rate of sedimentation, sometimes called **sedimentation velocity,** v, is defined by Equation 4.7.

>> $$v = \frac{dr}{dt} = \frac{m_0(1 - \bar{v}\rho)\omega^2 r}{f} \quad \textbf{(Eq. 4.7)}$$

It is cumbersome and sometimes impractical to express sedimentation velocity in terms of ρ, $\bar{v}$, and f, since these factors are difficult to measure. A new term, **sedimentation coefficient,** s (the ratio of sedimentation velocity to centrifugal force) is introduced by rearranging Equation 4.7 to Equation 4.8.

>> $$s = \frac{v}{\omega^2 r} = \frac{m_0(1 - \bar{v}\rho)}{f} \quad \textbf{(Eq. 4.8)}$$

The term s is most often defined under standard conditions, 20°C and water as the medium, and denoted by $s_{20,w}$. The s value is a physical characteristic used to classify biological macromolecules and cell organelles. Sedimentation coefficients are in the range of 1×10^{-13} to $10{,}000 \times 10^{-13}$ second. For numerical convenience, sedimentation coefficients are expressed in Svedberg units, S, where $1\,S = 1 \times 10^{-13}$ second. Human hemoglobin has an s value of 4.5×10^{-13} second or 4.5 S. The value of S for several biomolecules, bacterial cells, and cell organelles is shown in Figure 4.3. Note in the figure that there appears to be a direct relationship between the S value and the molecular weight or particle size. This, however, is not always true, as in the case of nonspherical molecules.

STUDY EXERCISE 4.2 Sedimentation Coefficient

The goal of many centrifugation experiments is the measurement of s. This value is important because it can be used to calculate the size (molecular weight, kilobase pairs, etc.) of a molecule or cell organelle. The units of s are not obvious from Equation 4.8. Dimensional analysis shows the following: v in cm/sec, ω in radians/sec, r in cm, m_0 in grams, $\bar{v}$ in cm^3/g, ρ in g/cm^3, and f in g/sec. Determine the units for s. (Ans. = second)

B. INSTRUMENTATION FOR CENTRIFUGATION

The basic centrifuge consists of two components, an electric motor with drive shaft to spin the sample and a **rotor** to hold tubes or other containers of the sample. A wide variety of centrifuges is available, ranging from a low-speed centrifuge used for routine pelleting of relatively heavy particles to sophisticated instruments that include accessories for making analytical measurements during centrifugation. Here we will describe three types, the low-speed or clinical centrifuge; the high-speed centrifuge, including the "microfuge"; and the ultracentrifuge. Major characteristics and applications of each type are compared in Table 4.1.

Low-Speed Centrifuges

Most laboratories have a standard low-speed centrifuge used for routine sedimentation of relatively heavy particles. The common centrifuge has a maximum speed in the range of 4000 to 5000 rpm, with RCF averaging $3000 \times g$.

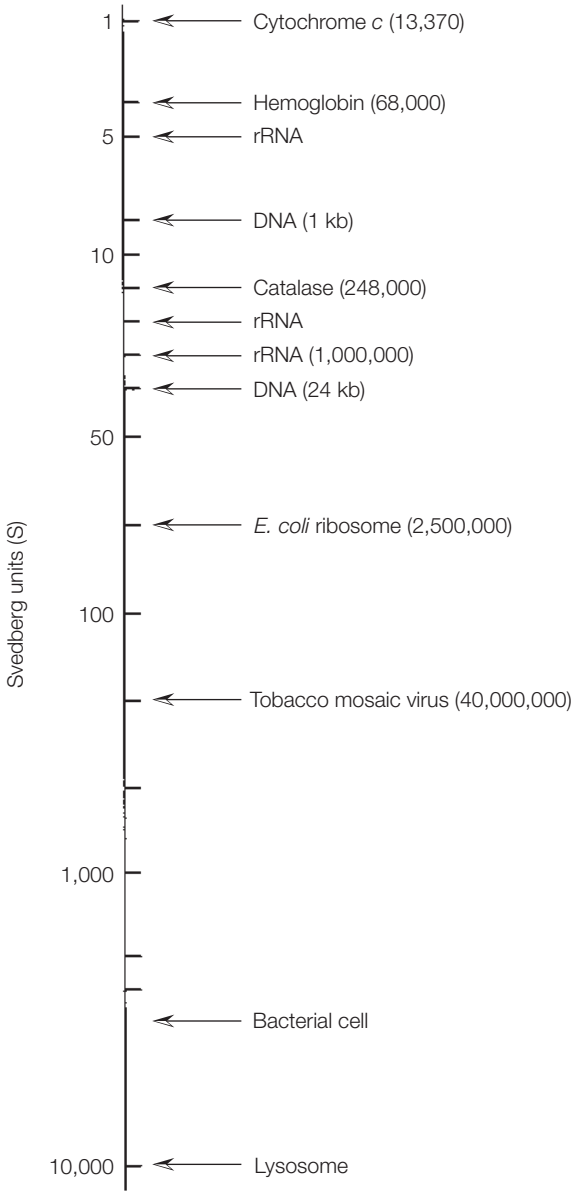

FIGURE 4.3 Range of S values for biomolecules, cell organelles, and cells. kb = kilobase pairs. Molecular weight, or kb, is shown in parentheses.

These instruments usually operate at room temperature with no means of temperature control of the samples. Two types of rotors, **fixed angle** and **swinging bucket,** may be used in the instrument. Centrifuge tubes or bottles that contain 12 or 50 mL of sample are commonly used. Low-speed centrifuges are especially useful for the rapid sedimentation of coarse precipitates or red blood cells. The sample is centrifuged until the particles are tightly packed into a **pellet** at the bottom of the tube. (This technique is sometimes

TABLE 4.1 Types of Centrifuges and Applications

Characteristic	Type of Centrifuge			
	Low Speed	Microfuge (Medium Speed)	High Speed	Ultracentrifuge
Range of speed (rpm)	1–6000	1000–15,000	1000–25,000	20–150,000
Maximum RCF (*g*)	6000	12,000	50,000	1,500,000
Refrigeration	Some	Some	Yes	Yes
Applications				
Pelleting of cells	Yes	Yes	Yes	Yes
Pelleting of nuclei	Yes	Yes	Yes	Yes
Pelleting of organelles	No	No	Yes	Yes
Pelleting of ribosomes	No	No	No	Yes
Pelleting of macromolecules	No	No	No	Yes
Analytical techniques	No	No	No	Yes

called **pelleting.**) The upper liquid portion, the **supernatant,** is then separated by decantation.

High-Speed Centrifuges

For more sophisticated biochemical applications, higher speeds and temperature control of the rotor chamber are essential. A typical high-speed centrifuge is shown in Figure 4.4. The operator of this instrument can carefully control speed and temperature, which is especially important for carrying out reproducible

FIGURE 4.4 A lab technician loads samples into a Sorvall RC-6 Plus Superspeed centrifuge, a typical high-speed centrifuge. *Image provided by Thermo Fisher Scientific Inc., all rights reserved.* www.thermofisher.com.

FIGURE 4.5
Rotors for a high-speed centrifuge. **A** Fixed-angle; **B** Swinging-bucket; **C** Vertical. *Courtesy of Beckman Coulter.*

centrifugations of temperature-sensitive biological samples. Rotor chambers in most instruments are maintained at or near 4°C.

Three types of rotors are available for high-speed centrifugation: the fixed-angle, the swinging-bucket, and the vertical rotor (Figure 4.5A–C). Fixed-angle rotors are especially useful for differential pelleting of particles (Figure 4.6A). In swinging-bucket rotors (Figure 4.5B), the sample tubes move to a position perpendicular to the axis of rotation during centrifugation, as shown in Figure 4.7. These are used most often for density gradient centrifugation (see below). In the vertical rotor (Figure 4.5C), the sample tubes remain in an upright position (Figure 4.8). These rotors are used often for gradient centrifugation. Prior to the

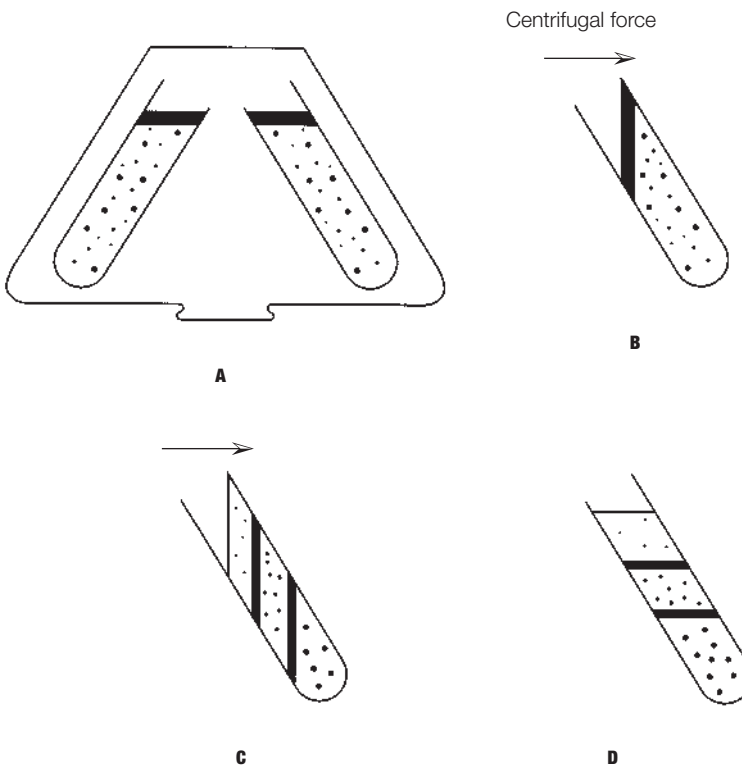

FIGURE 4.6
Operation of a fixed-angle rotor. **A** Loading of sample. **B** Sample at start of centrifugation. **C** Bands form as molecules sediment. **D** Rotor at rest showing separation of two components.

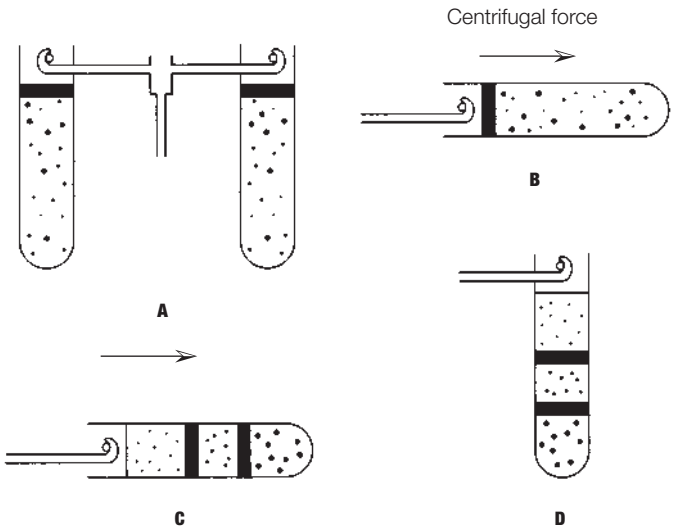

FIGURE 4.7
Operation of a swinging-bucket rotor. **A** Loading of sample. **B** Sample at start of centrifugation. **C** Sample during centrifugation separates into two components. **D** Rotor at rest.

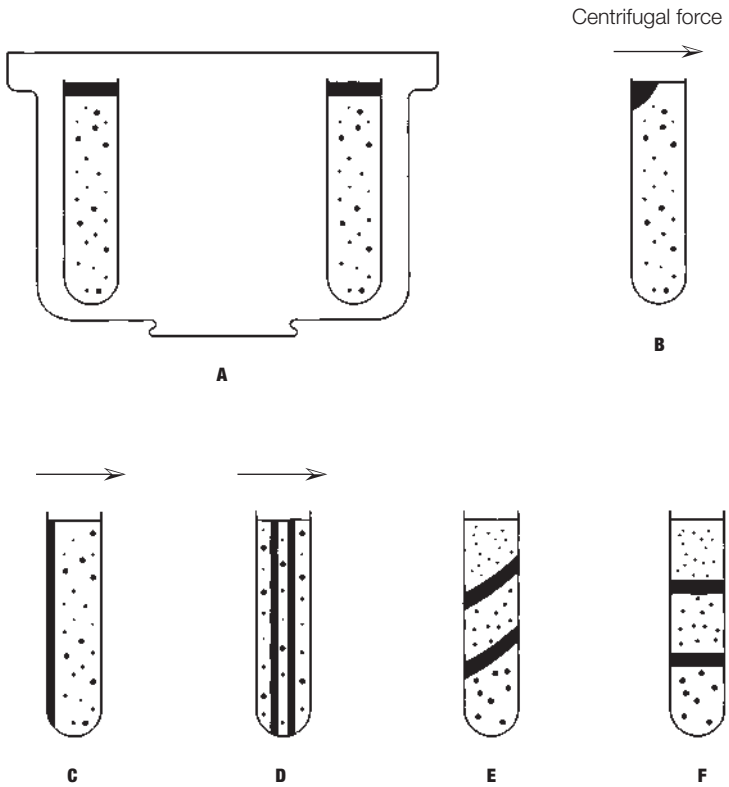

FIGURE 4.8
Operation of a vertical rotor. **A** Loading of sample. **B** Beginning of centrifugation. **C, D** During centrifugation. **E** Deceleration of sample. **F** Rotor at rest.

early 1990s, rotors were constructed from metals such as aluminum and titanium. Although metal rotors have great strength, they do have several disadvantages: they are very heavy to handle, they are not corrosion-resistant, and they become fatigued with use. Rotors are now available that are fabricated from carbon-fiber composite materials. They have several advantages over heavy metal rotors. These new rotors are 60% lighter than comparable aluminum and titanium rotors. Because of the lighter weight, acceleration and deceleration times are reduced; thus, centrifuge run times are shorter. This also results in lower service and maintenance costs. Instruments are equipped with a brake to slow the rotor rapidly after centrifugation.

Widely used in the category of medium-speed centrifuges is the **microfuge** (Table 4.1 and Figure 4.9). These instruments, which are designed for the bench-top, are used for rapid pelleting of small samples. Fixed-angle rotors are able to hold up to eighteen 1.5- or 0.5-mL tubes. The maximum speed of most commercial microfuges is between 12,000 and 15,000 rpm, which delivers a force of 11,000−12,000 $\times$ g. Some instruments can accelerate to full speed in 6 seconds and decelerate within 18 seconds. Most instruments have a variable speed control and a momentary pulse button for minispins.

The preparation of biological samples almost always requires the use of a high-speed centrifuge. Specific examples will be described later, but high-speed centrifuges may be used to sediment: (1) cell debris after cell homogenization, (2) ammonium sulfate precipitates of proteins, (3) microorganisms, and (4) cellular organelles such as chloroplasts, mitochondria, and nuclei.

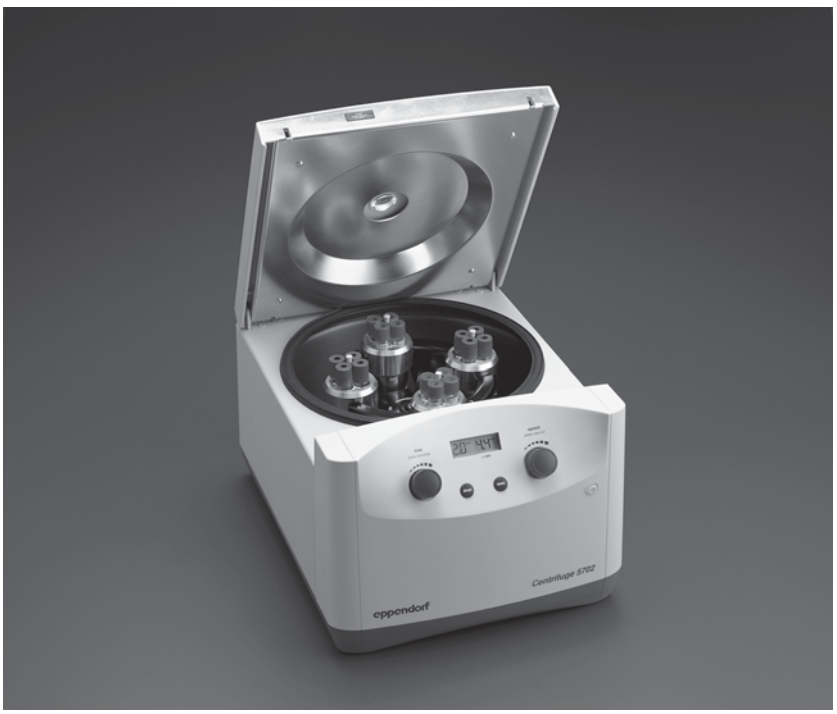

FIGURE 4.9 A variable-speed, general-purpose microcentrifuge—Eppendorf® Centrifuge Model 5702. *Courtesy of Metrohm, Inc.* http://www.metrohmusa.com/home.

Ultracentrifuges

The most sophisticated of the centrifuges are the **ultracentrifuges.** Because of the high speeds attainable (see Table 4.1), intense heat is generated in the rotor. The spin chamber must thus be refrigerated and placed under a high vacuum to reduce friction. The sample in a cell or tube is placed in a rotor, which is then driven by an electric motor. Although it is rare, metal rotors sometimes break into fragments when placed under high stress. The rotor chamber on all ultracentrifuges is covered with a protective steel armor plate. The drive shaft of the ultracentrifuge is constructed of a flexible material to accommodate any "wobble" of the rotor due to imbalance of the samples. It is still important to counterbalance samples as carefully as possible before inserting them in the rotor.

The previously discussed centrifuges—the low, medium, and high speed—are of value only for preparative work, that is, for the isolation and separation of precipitates and biological samples. Ultracentrifuges can be used both for preparative work and for analytical measurements. Thus, two types of ultracentrifuges are available: **preparative models,** primarily used for separation and purification of samples for further analysis, and **analytical models,** which are designed for performing physical measurements on the sample during sedimentation. Two of the most versatile models are Beckman Optima MAX and TLX microprocessor-controlled tabletop ultracentrifuges (Figure 4.10). With a typical fixed-angle rotor, which holds six 0.2- to 2.2-mL samples, the instruments can generate 150,000 rpm and an RCF of up to 1,500,000 $\times$ g.

Analytical ultracentrifuges have the same basic design as preparative models, except that they are equipped with optical systems to monitor directly the sedimentation of the sample during centrifugation. The first commercial instrument of this type was the Beckman Model E, introduced in 1947.

A

FIGURE 4.10
A Outside and **B** inside of the Beckman Optima TLX ultracentrifuge. *Courtesy of Beckman Coulter. Beckman Coulter and the stylized logo are registered trademarks of Beckman Coulter, Inc. Optima is a trademark of Beckman Coulter, Inc.*

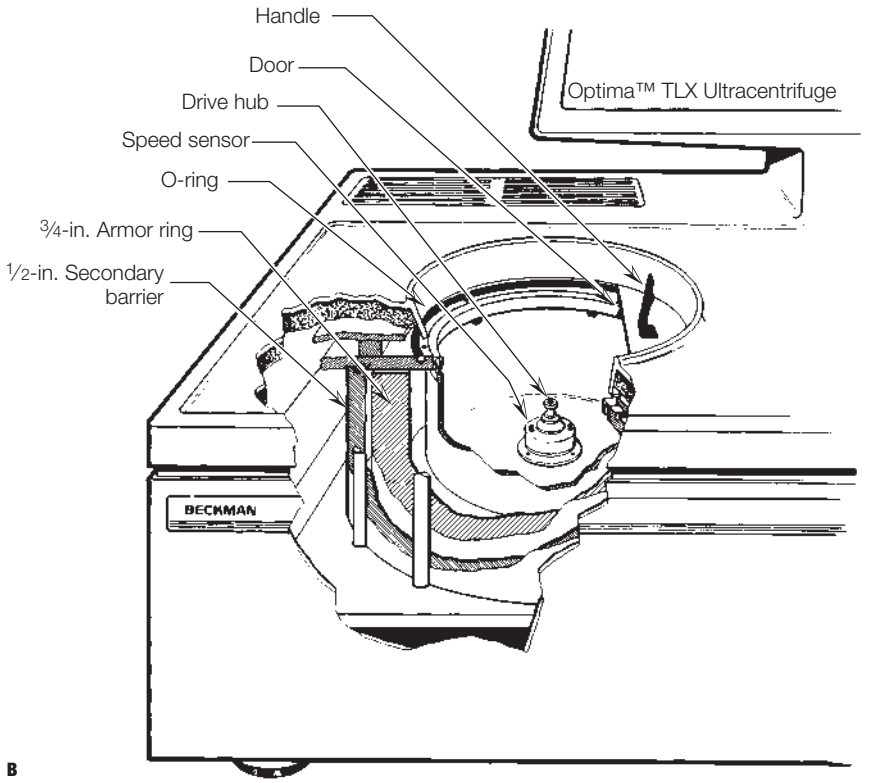

FIGURE 4.10
Continued **B**

For analysis, a sample of nucleic acid or protein (0.1 to 1.0 mL) is sealed in a special analytical cell and rotated. Light is directed through the sample parallel to the axis of rotation, and measurements of absorbance by sample molecules are made. (The Beckman instrument can scan the sample over the wavelength range 190 to 800 nm.) If sample molecules have no significant absorption bands in the wavelength range, then optical systems that measure changes in the refractive index may be used. Optical systems aided by computers are capable of relating absorbance changes or index of refraction changes to the rate of movement of particles in the sample. The optical system actually detects and measures the front edge or moving boundary of the sedimenting molecules. These measurements can lead to an analysis of concentration distributions within the centrifuge cell. Applications of these measurements will be discussed in the next section.

C. APPLICATIONS OF CENTRIFUGATION

Preparative Techniques

Centrifuges in undergraduate biochemistry laboratories are used most often for preparative-scale separation procedures. This technique is quite straightforward, consisting of placing the sample in a tube or similar container, inserting

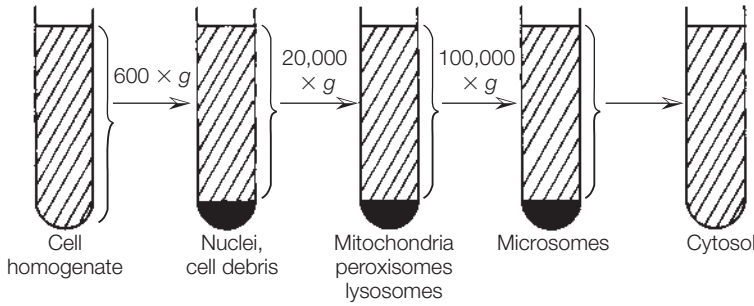

FIGURE 4.11 Fractional centrifugation of a cell homogenate. See text for details.

the tube in the rotor, and spinning the sample for a fixed period. **(Filled centrifuge tubes or bottles must be weighed and balanced before centrifugation. Tubes across from each other in the rotor should have approximately the same weight.)** The sample is removed and the two phases, pellet and supernatant (which should be readily apparent in the tube), may be separated by careful decantation. Further characterization or analysis is usually carried out on the individual phases. This technique, called **velocity sedimentation centrifugation,** separates particles ranging in size from coarse precipitates to cellular organelles. Relatively heavy precipitates are sedimented in low-speed centrifuges, whereas lighter organelles such as ribosomes require the high centrifugal forces of an ultracentrifuge.

Much of our current understanding of cell structure and function depends on separation of subcellular components by centrifugation. The specific method of separation, called **fractional centrifugation,** consists of successive centrifugations at increasing rotor speeds. Figure 4.11 illustrates the fractional centrifugation of a cell homogenate, leading to the separation and isolation of the common cell organelles. For most biochemical applications, the rotor chamber must be kept at low temperatures to maintain the native structure and function of each cellular organelle and its component biomolecules. A high-speed centrifuge equipped with a fixed-angle rotor is most appropriate for the first two centrifugations at 600 × g and 20,000 × g. After each centrifuge run, the supernatant is poured into another centrifuge tube, which is then rotated at the next higher speed. The final centrifugation at 100,000 × g to sediment microsomes and ribosomes must be done in an ultracentrifuge. The 100,000 × g supernatant, the **cytosol,** is the soluble portion of the cell and consists of soluble proteins and smaller molecules.

STUDY EXERCISE 4.3 Fractional Centrifugation

The enzymes required for the metabolic process of glycolysis are located in the cytoplasm of the cell. Describe how you could use centrifugation to prepare a cell extract containing these enzymes separated from cell organelles.

Analytical Measurements

A variety of analytical measurements can be made on biological samples during and after a centrifuge run. Most often, the measurements are taken to determine molecular weight, density, and purity of biological samples. All analytical techniques require the use of an ultracentrifuge and can be classified as **differential** or **density gradient.**

Differential Centrifugation

Differential methods involve sedimentation of particles in a medium of homogeneous density. Although the technique is similar to preparative differential centrifugation as previously discussed, the goal is to measure the sedimentation coefficient of a particle. The underlying principles of this technique are illustrated in Figure 4.12A. During centrifugation, a moving boundary is generated between pure solvent and sedimenting particles. An analytical ultracentrifuge is capable of detecting and measuring the rate of movement of the boundary. Hence, the sedimentation velocity, v, can be experimentally determined. By using Equation 4.8, the sedimentation coefficient, s, can be calculated. The value of s for a sedimenting particle is related to the molecular weight of that particle by the Svedberg equation. The Svedberg equation is derived from Equation 4.8 by recognizing that the frictional force, f, may be defined by Equation 4.9.

>>
$$f = \frac{RT}{ND} \qquad \textbf{(Eq. 4.9)}$$

where

R = the gas constant, $8.3 \times 10^7\, g\ \text{cm}^2/\text{sec/deg/mole}$

T = the absolute temperature

D = the diffusion coefficient of the solute in units of cm^2/sec

N = Avogadro's number

Thus, Equation 4.8 may be transformed into Equation 4.10.

>>
$$\text{s} = \frac{m_0(1 - \bar{v}\rho)}{RT/ND} \qquad \textbf{(Eq. 4.10)}$$

$$RTs = m_0 ND\,(1 - \bar{v}\rho)$$

Since molecular weight, MW, is equal to m_0N, Equation 4.10 is converted to Equation 4.11, the Svedberg equation. In this book, two terms are used to define the molecular masses of biomolecules:

Molecular weight (MW): defined as the ratio of the particle mass to 1/12th the mass of a C-12 atom. MW has no units because it is a ratio.

Molecular mass: defined as the mass of one molecule, or the molar mass divided by Avogadro's number. Molecular masses are expressed in the units of daltons (D, 1/12th the mass of a C-12 atom) or kilodaltons (kD).

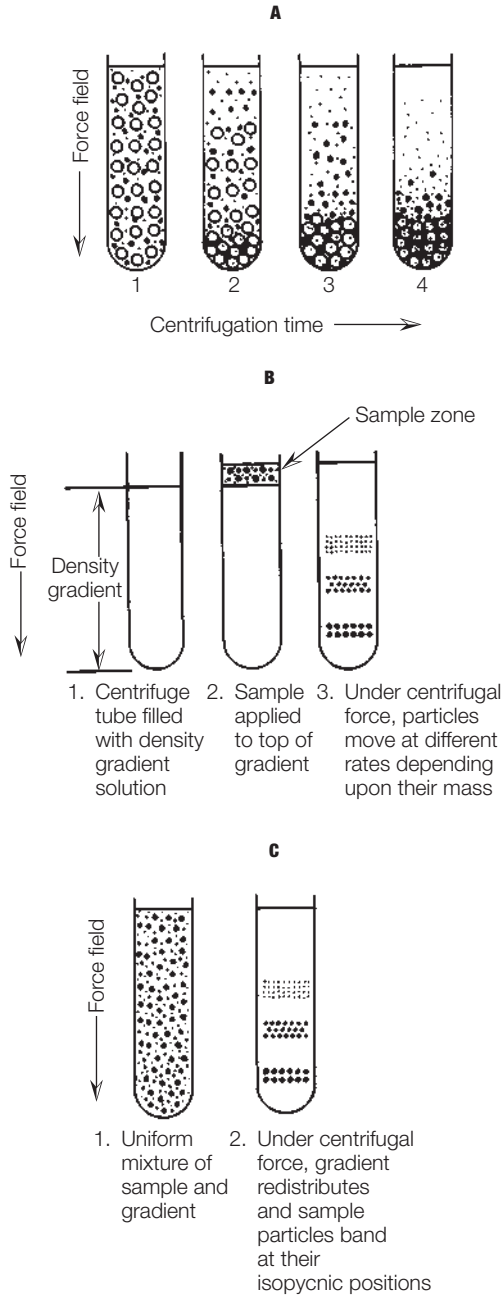

FIGURE 4.12 A comparison of differential and density gradient measurements. **A** Differential centrifugation in a medium of unchanging density. **B** Zonal centrifugation in a prepared density gradient. **C** Isopycnic centrifugation; the density gradient forms during centrifugation.

>>

$$MW = \frac{RTs}{D(1 - \bar{v}\rho)} \qquad \textbf{(Eq. 4.11)}$$

This equation provides an accurate calculation of molecular weight and is applicable to macromolecules such as proteins and nucleic acids. However, its usefulness

is limited because diffusion coefficients are difficult to measure and are not readily available in the literature.

An alternative method sometimes used to determine molecular weights of macromolecules is **sedimentation equilibrium.** In the previous example, using the Svedberg equation, the sample is rotated at a rate sufficient to sediment the particles. Here, the sample is rotated at a lower rate, and the particles sediment until they reach an equilibrium position at the point where the centrifugal force is equal to the frictional component opposing their movement (see Equation 4.6). The molecular weight is then calculated using Equation 4.12.

>>
$$\text{MW} = \frac{RT}{(1 - \overline{v}\rho)\omega^2}\left(\frac{1}{rc}\right)\left(\frac{dc}{dr}\right) \qquad \textbf{(Eq. 4.12)}$$

where

$\frac{dc}{dr}$ = change in particle concentration as a function of distance from the rotation center, as measured in the ultracentrifuge

and MW, R, T, $\overline{v}$, ρ, ω, and r have the definitions previously given. This technique is time consuming, as the system may require 1 to 2 days to reach equilibrium. Also, the use of Equation 4.12 is complicated by the difficulty of making concentration measurements in the ultracentrifuge.

Differential ultracentrifugation methods may also be used in analysis of the purity of macromolecular samples. If a single sharp moving boundary is observed in a rotating centrifuge cell, it indicates that the sample has one component and therefore is pure. In an impure sample, each component would be expected to form a separate moving boundary upon sedimentation.

Density-Gradient Centrifugation

In differential procedures, the sample is uniformly distributed in a cell before centrifugation, and the initial concentration of the sample is the same throughout the length of the centrifuge cell. Although useful analytical measurements can be made with this technique, it has disadvantages when applied to impure samples or samples with more than one component. Large particles that sediment faster pass through a medium consisting of solvent and particles of smaller size. Therefore, clear-cut separations of macromolecules are seldom obtained. This can be avoided if the sample is centrifuged in a fluid medium that gradually increases in density from top to bottom. This technique, called **density gradient centrifugation,** permits the separation of multi-component mixtures of macromolecules and the measurement of sedimentation coefficients. Two methods are used, **zonal centrifugation,** in which the sample is centrifuged in a preformed gradient, and **isopycnic centrifugation,** in which a self-generating gradient forms during centrifugation.

Zonal Centrifugation

Figure 4.12B outlines the procedure for zonal centrifugation of a mixture of macromolecules. A density gradient is prepared in a tube prior to centrifugation. This is accomplished with the use of an automatic gradient mixer. Solutions of

low-molecular-weight solutes such as sucrose or glycerol are allowed to flow into the centrifuge cell. The sample under study is layered on top of the gradient and placed in a swinging-bucket rotor. Sedimentation in an ultracentrifuge results in movement of the sample particles at a rate dependent on their individual *s* values. As shown in Figure 4.12B, the various types of particles sediment as *zones* and remain separated from the other components. The centrifuge run is terminated before any particles reach the bottom of the gradient. The various zones in the centrifuge tubes are then isolated by collecting fractions from the bottom of the tube and analyzing them for the presence of macromolecules. The zones of separated macromolecules are relatively stable in the gradient because it slows diffusion and convection. The gradient conditions can be varied by using different ranges of sucrose concentration. Sucrose concentrations up to 60% can be used, with a density limit of $1.28\ g/cm^3$. The zonal method can be applied to the separation and isolation of macromolecules (preparative ultracentrifuge) and to the determination of *s* (analytical ultracentrifuge).

Isopycnic Centrifugation

In the isopycnic technique, the density gradient is formed during the centrifugation. Figure 4.12C outlines the mechanism of isopycnic centrifugation. The sample under study is dissolved in a solution of a dense salt such as cesium chloride or cesium sulfate. The cesium salts may be used to establish gradients to an upper density limit of $1.8\ g/cm^3$. The solution of biological sample and cesium salt is uniformly distributed in a centrifuge tube and rotated in an ultracentrifuge. Under the influence of the centrifugal force, the cesium salt redistributes to form a continuously increasing density gradient from the top to the bottom. The macromolecules of the biological sample seek an area in the tube where the density is equal to their respective densities. That is, the macromolecules move to a region where the sum of the forces (centrifugal and frictional) is zero (Equation 4.6). The macromolecules either sediment or float to this region of equal density. Stable zones or bands of the individual components are formed in the gradient (see Figure 4.12C). These bands can be isolated as previously described. Cesium salt gradients are especially valuable for separation of nucleic acids.

Density gradients are widely used in separating and purifying biological samples. In addition to this preparative application, measurements of *s* can be made. Gradient techniques used to isolate and purify subcellular components such as microsomes, ribosomes, lysosomes, mitochondria, peroxisomes, chloroplasts, and others. After isolation, they may be biochemically characterized as to their protein, lipid, nucleic acid, and enzyme contents.

Nucleic acids, in particular, have been extensively studied by density gradient techniques. Both RNA and DNA are routinely classified according to their *s* values. The different structural forms of DNA discussed in Chapter 9 can be determined by density gradient centrifugation.

A summary of centrifugation techniques and applications described in this chapter is provided in Table 4.2. Space does not allow for an exhaustive review of centrifuge applications. Interested students should consult the references at the end of the chapter for recent developments.

TABLE 4.2 A Summary of Centrifuge Techniques and Applications

Centrifuge Techniques	Applications
Preparative	
Velocity sedimentation centrifugation (pelleting)	Separation and isolation of particles in a solution. May be applied to precipitates, cell organelles, cells, or biomolecules.
Fractional centrifugation	Isolation of particles, based on size, by successive centrifugation at increasing rotor speeds. May be used to separate cell organelles (Figure 4.11).
Analytical	
Differential centrifugation	Sedimentation of particles in a medium of homogeneous density. Used to measure the sedimentation coefficient, *s*, and MW of a particle (Figure 4.12A).
Sedimentation equilibrium centrifugation	Used to determine MW of a macromolecule or other particle.
Density gradient centrifugation	
Zonal	Gradient is present in the tube before centrifugation and sample is layered on top. Used to isolate purified molecules and determine *s*.
Isopycnic	Gradient is formed during centrifugation. Used to isolate purified molecules and determine *s*.

Care of Centrifuges and Rotors

Centrifuge equipment represents a sizable investment for a laboratory, so proper maintenance is essential. In addition, poorly maintained equipment is especially dangerous. Since many kinds of instruments are now available, specific instructions will not be given here, but general guidelines are outlined below.

1. Carefully read the operating manual or receive proper instructions before you use any centrifuge.
2. Check the rotor chamber for cleanliness and for damage. Clean with soap and warm water, rinse with distilled water, and dry.
3. Select the proper operating conditions on the instrument. If refrigeration is necessary, set the temperature to the appropriate level and allow 1 to 2 hours for temperature equilibration.
4. Select the proper rotor. Many sizes and types are available. Follow guidelines already stated in this chapter or consult your instructor.
5. Be sure the rotor is clean and undamaged. Observe any nicks, scratches, or other damage that may cause imbalance. If dirty, the rotor should be cleaned with warm water and a mild, nonbasic detergent. A soft brush can be used inside the cavities. Rinse well with distilled water and dry. Scratches should not be made on the surface coating, as corrosion may result.
6. Filled centrifuge tubes or bottles should be weighed carefully and balanced before centrifugation.
7. Rotor manufacturers provide a maximum allowable speed limit for each rotor. Do not exceed that limit.

8. Keep an accurate record of centrifuge and rotor use. Just as your automobile needs service after a certain number of miles, the centrifuge should be serviced after certain intervals of use. Centrifuge maintenance is usually determined by hours of use and total revolutions of the rotor. It is also essential to maintain a record of the use for each rotor. Metal rotors weaken with use, and the maximum allowable speed limit decreases. Rotor manufacturers usually provide guidelines for decreasing the allowable speed for a rotor (derating a rotor).
9. If an unusual noise or vibration develops during centrifugation, immediately turn the centrifuge off.
10. Carefully clean the rotor chamber and rotor after each centrifugation.

Study Problems

1. Which of the following factors will have an effect on the sedimentation rate of a particle during centrifugation?
   (a) Mass of the sedimenting particle
   (b) Angular velocity of rotation
   (c) Atmospheric pressure
   (d) Density of the solvent
2. You wish to centrifuge a biological sample so that it experiences an RCF of $100{,}000 \times g$. At what rpm must you set the centrifuge assuming an average r value of 4?
3. Cytochrome c has an s value of 1×10^{-13} second and hemoglobin an s value of about 4.5×10^{-13} second. Which protein has the larger molecular weight?
4. An enzyme has a sedimentation coefficient of 3.5 S. When a substrate molecule is bound into the active site of the enzyme, the sedimentation coefficient decreases to 3.0 S. Explain this change.
5. A protein with a molecular weight of 100,000 shows a single boundary when centrifuged in aqueous buffer. If the protein is centrifuged in a medium of the same buffer plus 6 M urea, two boundaries are observed, one corresponding to a molecular weight of 10,000, the other to a molecular weight of 30,000. The area of the slower peak is two-thirds that of the faster. Describe the subunit structure of the protein.
6. Describe how you would design a centrifuge experiment to isolate sediments containing cell nuclei.
7. Explain the following observation. The density of DNA in 7 M CsCl containing 0.15 M $MgCl_2$ is less than the density of the same DNA in pure 7 M CsCl.
8. Assume that you have centrifuged in a density gradient a sample of DNA that contained both closed, circular DNA and supercoiled DNA. Would you expect to see two bands in the sedimentation pattern? Explain.
9. Assume that a centrifuge is operating at 43,000 rpm. What is the relative centrifugal force at a distance from the central axis of 6 cm?
10. You are spinning a sample at 20,000 rpm in a centrifuge. Use Equation 4.2 to calculate the RCF at three locations in the tube, $r = 3.2$ cm, $r = 7.0$ cm, and $r = 10.8$ cm (see Figure 4.1). Compare and explain the differences in the RCF values at the three locations.
11. Could you use a low-speed centrifuge to sediment mitochondria? Explain.
12. The sedimentation coefficient (S, in Svedberg units) for an unknown protein you are studying is between 1 and 2. If you isolate the protein from a cell homogenate by carrying out fractional centrifugation (Figure 4.11), in what fraction do you expect to find the unknown protein?

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http://www.beckman.com
Click on "Centrifuges" and follow links to "Applications," "Literature," "Rotor Calculations," etc.

http://www.metrohmusa.com
Eppendorf centrifuges.

http://www.thermo.com/com/cda/landingpage/0,,128,00.html
Thermo Fisher Scientific Sorvall centrifuges.

http://www.piramoon.com
New carbon-fiber rotors by Fiberlite Centrifuge, Inc.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER 5

PURIFICATION AND ANALYSIS OF BIOMOLECULES BY CHROMATOGRAPHY

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The primary goal of biochemical research is to understand the molecular nature of life processes. The molecular details of a biological process cannot be fully elucidated until the interacting molecules have been isolated and characterized. Therefore, our understanding of the mechanisms of life processes has increased at about the same pace as the development of techniques for the separation and characterization of biomolecules.

Chromatography, the most important technique for isolating and purifying biomolecules, was developed by Mikhail Tswett, an Italian-born, Russian botanist. In 1902, Tswett began his studies on the isolation and characterization of the colorful pigments in plant chloroplasts. He prepared separating columns by packing fine powders like sucrose and chalk (calcium carbonate) into long glass tubes. He then poured petroleum ether-derived plant extracts through the columns. As he continued eluting the columns with solvent, he noted the formation of yellow and green zones. Tswett had invented "chromatography," which he

defined in his 1906 publication as "a method in which the components of a mixture are separated on an adsorbent in a flowing solvent." In addition to introducing a new technique, Tswett also showed by these experiments that chlorophyll exists in different forms. From such humble beginnings, chromatography has developed into the ultimate tool for not only the isolation and purification, but also for the characterization, of biomolecules. Chromatography, which has now been expanded into multiple forms, continues to be the most effective technique for separating and purifying all types of biomolecules. In addition, it is widely used as an analytical tool to measure biophysical and other quantitative properties of molecules.

A. INTRODUCTION TO CHROMATOGRAPHY

All types of chromatography are based on a very simple concept: The sample to be examined is allowed to interact with two physically distinct entities—a **mobile phase** and a **stationary phase** (see Figure 5.1). The sample most often contains a mixture of several components to be separated. The molecules targeted for analysis are called **analytes**. The mobile phase, which may be a liquid or gas, moves the sample components through a region containing the solid or liquid stationary phase, which is called the **sorbent**. Because it varies from one chromatographic method to another, the stationary phase will not be described in detail at this time. However, it may be considered as having the ability to "bind" some types of analytes. The molecular components in the sample distribute themselves between the mobile phase and sorbent and thus have the opportunity to interact intimately with the stationary phase. If some of the sample molecules (analytes) are preferentially bound by the sorbent, they spend more time in the sorbent and are retarded in their movement through the chromatographic system. Molecules that show weak affinity for the sorbent spend more time with the mobile phase and are more easily removed or **eluted** from the system. The many interactions that occur between analytes and the stationary phase sorbent bring about a separation of

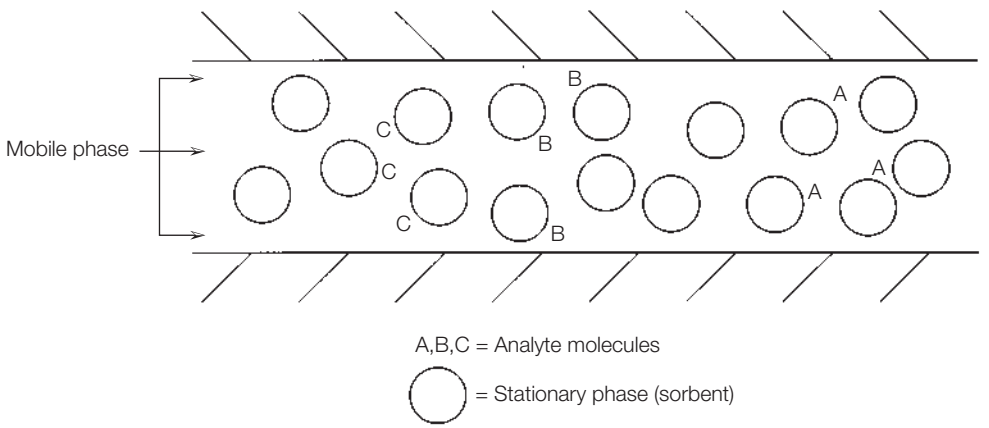

FIGURE 5.1 A representation of the principles of chromatography.

molecules because of different affinities for the stationary phase. The general process of moving a sample mixture through a chromatographic system is called **development**.

The mobile phase can be collected as a function of time at the end of the chromatographic system. The mobile phase, now called the **effluent**, contains the purified analytes. If the chromatographic process has been effective, fractions or "cuts" that are collected at different times will contain the different components of the original sample. *In summary, molecules are separated because they differ in the extent to which they are distributed between the mobile phase and the stationary phase.*

Throughout this chapter and others, biochemical techniques will be designated as **preparative** or **analytical**, or both. A preparative procedure is one that can be applied to the purification of a relatively large amount of a biological material (mg or g). The purpose of such an experiment would be to obtain purified material for further characterization and study. Analytical procedures are used most often to determine the purity of a biological sample; however, they may be used to evaluate any physical, chemical, or biological characteristic of a biomolecule or biological system.

Partition versus Adsorption Chromatography

Chromatographic methods are divided into two types according to how analytes bind to or interact with the stationary phase. **Partition** chromatography is the distribution of an analyte between two liquid phases. This may involve direct extraction using two liquids, or it may use a liquid immobilized on a solid support as in the case of paper, thin-layer, and gas–liquid chromatography. For partition chromatography, the sorbent in Figure 5.1 consists of inert solid particles coated with liquid adsorbent. The distribution of analytes between the two phases is based primarily on solubility differences. The distribution may be quantified by using the **partition coefficient**, K_D (Equation 5.1).

>> $$K_D = \frac{\text{concentration of analyte in sorbent}}{\text{concentration of analyte in mobile phase}} \qquad \textbf{(Eq. 5.1)}$$

Adsorption chromatography refers to the use of a stationary phase or support, such as an ion-exchange resin, that has a finite number of relatively specific binding sites for analytes. There is not a clear distinction between the processes of partition and adsorption. All chromatographic separations rely, to some extent, on adsorptive processes. However, in some methods (paper, thin-layer, and gas chromatography), these specific adsorptive effects are minimal and the separation is based primarily on nonspecific solubility factors. Adsorption chromatography relies on relatively specific interactions between the analytes and binding sites on the surface of the sorbent. The attractive forces between analyte and support may be ionic, hydrogen bonding, or hydrophobic interactions. Binding of analyte is, of course, reversible.

Because of the different interactions involved in partition and adsorption processes, they may be applied to different separation problems. Partition processes are the most effective for the separation of small molecules, especially

those in homologous series. Partition chromatography has been widely used for the separation and identification of amino acids, carbohydrates, and fatty acids. Adsorption techniques, represented by ion-exchange chromatography, are most effective when applied to the separation of macromolecules including proteins and nucleic acids.

In the rest of the chapter, various chromatographic methods will be discussed. You should recognize that no single chromatographic technique relies solely on adsorption or partition effects. Therefore, little emphasis will be placed on classification of the techniques; instead, theoretical and practical aspects will be discussed.

B. PLANAR CHROMATOGRAPHY (PAPER AND THIN-LAYER CHROMATOGRAPHY)

Because of the similarities in the theory and practice of these two procedures, they will be considered together. Both are examples of partition chromatography. In paper chromatography, the cellulose support is extensively hydrated, so distribution of the analyte occurs between the immobilized water (sorbent) and the mobile developing solvent. The initial stationary liquid phase in thin-layer chromatography (TLC) is the solvent used to prepare the thin layer of adsorbent. However, as developing solvent molecules move through the sorbent, polar solvent molecules may bind to the immobilized support and become the sorbent.

Preparation of the Sorbent

The support medium may be a sheet of cellulose or a glass or plastic plate covered with a thin coating of silica gel, alumina, or cellulose. Large sheets of cellulose chromatography paper are available in different porosities. These may be cut to the appropriate size and used without further treatment. The paper should never be handled with bare fingers. Although thin-layer plates can easily be prepared, it is much more convenient to purchase ready-made plates. These are available in a variety of sizes, materials, and thicknesses of stationary support. They are relatively inexpensive and have a more uniform support thickness than handmade plates.

Figure 5.2 outlines the application procedure. The sample to be analyzed is usually dissolved in a volatile solvent. A very small drop of solution is spotted onto the plate with a disposable microcapillary pipet and allowed to dry; then the spotting process is repeated by superimposing more drops on the original spot. The exact amount of sample applied is critical. There must be enough sample so the developed spots can be detected, but overloading will lead to "tailing" and lack of resolution. Finding the proper sample size is a matter of trial and error. It is usually recommended that two or three spots of different concentrations be applied for each sample tested. Spots should be applied along a very faint line drawn with a pencil and ruler. TLC plates should not be heavily scratched or marked. Identifying marks may be made on the top of the chromatogram, where solvent does not reach.

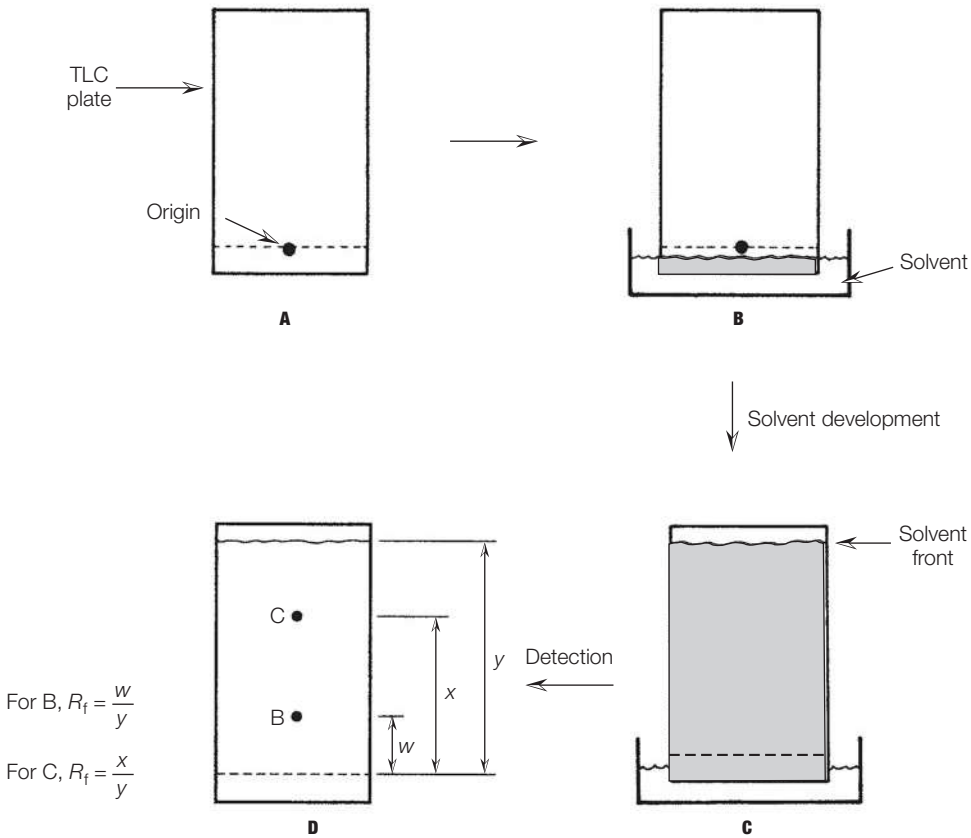

FIGURE 5.2 The procedure of paper and thin-layer chromatography. **A** Application of the sample. **B** Setting plate in solvent chamber. **C** Movement of solvent by capillary action. **D** Detection of separated components and calculation of R_f.

Solvent Development

A wide selection of solvent systems is available in the biochemical literature. If a new solvent system must be developed, a preliminary analysis must be done on the sample with a series of solvents. Solvents can be rapidly screened by developing several small chromatograms (2×6 cm) in small sealed bottles containing the solvents. For the actual analysis, the sample should be run on a larger plate with appropriate standards in a development chamber (Figure 5.3). The chamber must be airtight and saturated with solvent vapors. Filter paper on two sides of the chamber, as shown in Figure 5.3, enhances vaporization of the solvent.

Paper chromatograms may be developed in either of two types of arrangements—ascending or descending solvent flow. Descending solvent flow leads to faster development because of assistance by gravity, and it can offer better resolution for compounds with small R_f values because the solvent can be allowed to run off the paper. R_f values cannot be determined under these conditions, but it is useful for qualitative separations.

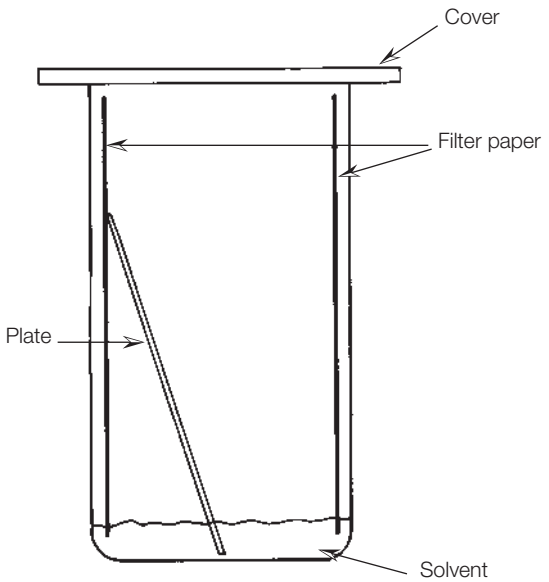

FIGURE 5.3 A typical chamber for paper and thin-layer chromatography.

Two-dimensional chromatography is used for especially difficult separations. The chromatogram is developed in one direction by a solvent system, air dried, turned 90°, and developed in a second solvent system.

Detection and Measurement of Components

Unless the components in the sample are colored, their location on a chromatogram will not be obvious after solvent development. Several methods can be used to locate the spots, including fluorescence, radioactivity, and treatment with chemicals that develop colors. Substances that are highly conjugated may be detected by fluorescence under a UV lamp. Chromatograms may be treated with different types of reagents to develop a color. **Universal reagents** produce a colored spot with any organic compound. When a solvent-developed plate is sprayed with concentrated H_2SO_4 and heated at 100°C for a few minutes, all organic substances appear as black spots. A more convenient universal reagent is I_2. The solvent-developed chromatogram is placed in an enclosed chamber containing a few crystals of I_2. The I_2 vapor reacts with most organic substances on the plate to produce brown spots. The spots are more intense with unsaturated compounds.

Specific reagents react with a particular class of compound. For example, rhodamine B is often used for visualization of lipids, ninhydrin for amino acids, and aniline phthalate for carbohydrates.

The position of each component of a mixture is quantified by calculating the distance traveled by the component relative to the distance traveled by the solvent. This is called **relative mobility** and symbolized by R_f. In Figure 5.2D, the R_f values for components B and C are calculated. The R_f for a substance is a constant for a certain set of experimental conditions. However, it varies with

solvent, type of stationary support (paper, alumina, silica gel), temperature, humidity, and other environmental factors. R_f values are always reported along with solvent and temperature.

Applications of Planar Chromatography

Thin-layer chromatography is now more widely used than paper chromatography. In addition to its greater resolving power, TLC is faster and plates are available with several sorbents (cellulose, alumina, silica gel).

Partition chromatography as described in this section may be applied to two major types of problems: (1) identification of unknown samples, and (2) isolation of the components of a mixture. The first application is, by far, the more widely used. Paper chromatography and TLC require only a minute sample size, the analysis is fast and inexpensive, and detection is straightforward. Unknown samples are applied to a plate along with appropriate standards, and the chromatogram is developed as a single experiment. In this way, any changes in experimental conditions (temperature, humidity, etc.) affect standards and unknowns to the same extent. It is then possible to compare the R_f values directly.

Purified substances can be isolated from developed chromatograms; however, only tiny amounts are present. In paper chromatography, the spot may be cut out with scissors and the piece of paper extracted with an appropriate solvent. Isolation of a substance from a TLC plate is accomplished by scraping the solid support from the region of the spot with a knife edge or razor blade and extracting the sorbent with a solvent. "Preparative" thin-layer plates with a thick coating of sorbent (up to 2 mm) are especially useful because they have higher sample capacity.

STUDY EXERCISE 5.1 Planar Chromatography

A mixture containing five amino acids (Ala, Asp, Gly, Phe, Pro) was analyzed using two methods of planar chromatography, paper and cellulose-coated thin layer. The solvent system was *n*-propanol/water (70/30 v/v). Predict the order of the mobility of the amino acids (low R_f to high R_f) on the chromatograms.

Solution: In cellulose planar chromatography, the amino acids interact with two phases, the sorbent (extensively hydrated cellulose, which is very polar) and the mobile phase (*n*-propanol/water, which is less polar than the sorbent). The more polar the amino acid, the stronger it will interact with the hydrated cellulose, thus the slower it will move with solvent during development (lower R_f). The order may be predicted by looking at the polarity of each amino acid side chain and arranging the amino acids in order of decreasing polarity. The correct order of migration (low to high R_f) is: Asp, Gly, Ala, Pro, Phe.

Advanced Planar Chromatography

The applications of planar chromatography listed above require only minimal equipment and supplies that are relatively inexpensive. It is likely that every undergraduate student majoring in biochemistry or molecular biology has

completed such an experiment in a science lab. If more complex, sophisticated chromatographic analyses are needed, such as in an academic or biotech research laboratory, then advanced equipment and specialized techniques must be used. Most new advances in planar chromatography have focused on TLC, as paper chromatography is very limited in its applications and flexibility. The major characteristics in TLC that have been improved include standardized methodology, instrumentation, and more effective stationary phases. These changes now make possible the advent of high-performance TLC (HPTLC).

One of the biggest problems with TLC analysis is that experimental conditions are difficult to duplicate. Separation of the components of a mixture is dependent on environmental conditions such as temperature, humidity, and extent of solvent saturation in the chamber. These conditions can be controlled by running the chromatography experiment in a specialized, commercially available enclosure called a **plate development chamber**. This leads to much more reproducible and standardized results.

Improvements are also being made in the development of new stationary phases. The most widely used stationary phase in TLC is silica, which separates molecules on the basis of polarity. (The more polar the component, the stronger it interacts with the very polar silica; hence, it migrates more slowly than a nonpolar component.) As silica separates primarily by polarity, this limits the types of molecules that can be separated. There is now strong interest in the development of reverse stationary phases such as C-18 functionalized silica to separate nonpolar molecules. Another limitation of silica is that it can be used only to separate biomolecules less than 2000-3000 in molecular weight. New and more porous stationary phases are being developed using photopolymerization techniques. These new stationary phases are able to separate protein mixtures containing insulin (MW = 5700), cytochrome *c* (MW = 13,000), lysozyme (MW = 14,600), and myoglobin (MW = 16,900).

C. COLUMN CHROMATOGRAPHY

Adsorption chromatography in biochemical applications usually consists of a solid stationary phase and a liquid mobile phase. The most useful technique is column chromatography, in which the stationary phase is confined to a glass or plastic tube and the mobile phase (a solvent or buffer) is allowed to flow through the solid adsorbent. A small amount of the sample to be analyzed is layered on top of the column. The sample mixture enters the column of adsorbing material and the molecules present are distributed between the mobile phase and the stationary phase. The various components in the sample have different affinities for the two phases and move through the column at different rates. Collection of the liquid phase emerging from the column yields separate fractions containing the individual components in the sample.

Specific terminology is used to describe various aspects of column chromatography. When the actual adsorbing material is made into a column, it is said to be **poured** or **packed**. Application of the sample to the top of the column is **loading** the column. Movement of solvent through the loaded column is called **developing** or **eluting** the column. The **bed volume** is the total volume of solvent

TABLE 5.1 Adsorbents Useful in Biochemical Applications

Adsorbing Materials	Uses
Alumina	Small organics, lipids
Silica gel	Amino acids, lipids, carbohydrates
Fluorisil (magnesium silicate)	Neutral lipids
Calcium phosphate (hydroxyapatite)	Proteins, polynucleotides, nucleic acids
Cellulose	Proteins

and adsorbing material taken up by the column. The volume taken up by the liquid phase in the column is the **void volume**. The **elution volume** is the amount of solvent required to remove a particular analyte from the column. This is analogous to R_f values in planar chromatography.

In adsorption chromatography, solute molecules take part in specific interactions with the stationary phase. Herein lies the great versatility of adsorption chromatography. Many varieties of adsorbing materials are available, so a specific sorbent can be chosen that will effectively separate a mixture. There is still an element of trial and error in the selection of an effective stationary phase. However, experiences of many investigators are recorded in the literature and are of great help in choosing the proper system. Table 5.1 lists the most common stationary phases employed in adsorption column chromatography.

Adsorbing materials come in various forms and sizes. The most suitable forms are dry powders or a slurry form of the material in an aqueous buffer or organic solvent. Alumina, silica gel, and fluorisil do not normally need special pretreatment. The size of particles in an adsorbing material is defined by **mesh size**. This refers to a standard sieve through which the particles can pass. A 100-mesh sieve has 100 small openings per square inch. Adsorbing material with high mesh size (400 and greater) is extremely fine and is most useful for very high resolution chromatography. Table 5.2 lists standard mesh sizes and their most appropriate applications. For most biochemical applications, 100 to 200 mesh size is suitable.

Operation of a Chromatographic Column

A typical column setup is shown in Figure 5.4. The heart of the system is, of course, the column of adsorbent. In general, the longer the column, the better the resolution of components. However, a compromise must be made because flow

TABLE 5.2 Mesh Sizes of Adsorbents and Typical Applications

Mesh Sizes	Applications
20–50	Crude preparative work, very high flow rate
50–100	Preparative applications, high flow rate
100–200	Analytical separations, medium flow rate
200–400	High-resolution analytical separations, low flow rate

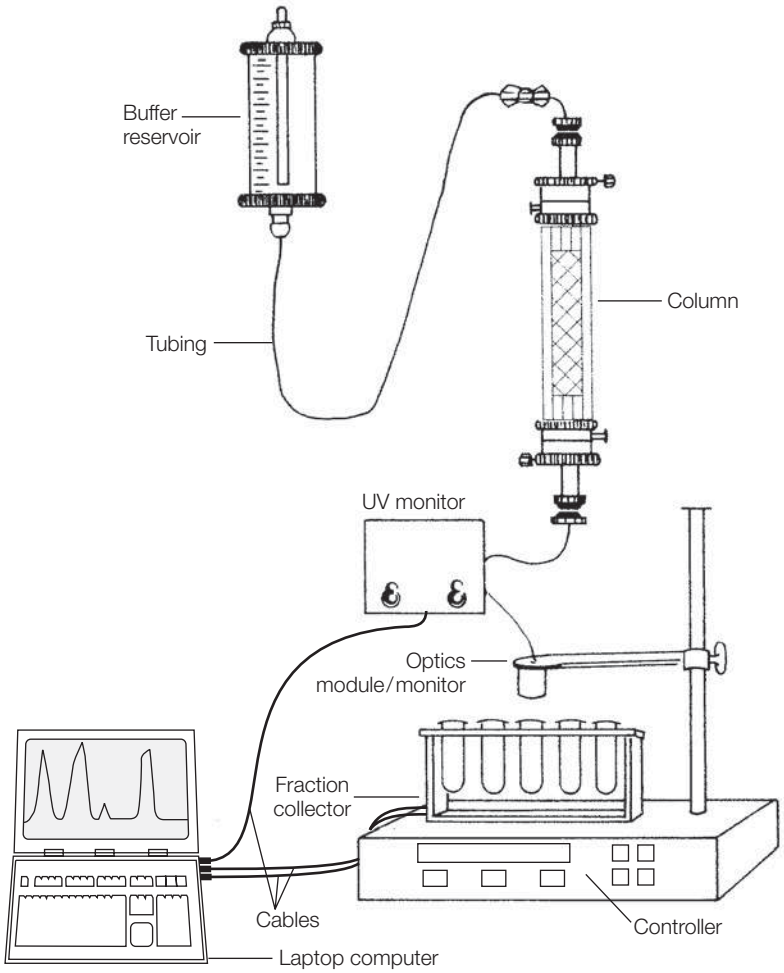

FIGURE 5.4 Setup for the operation of a chromatography column.

rate decreases with increasing column length. The actual size of a column depends on the nature of the adsorbing material and the amount of chemical sample to be separated. For preparative purposes, column heights of 20 to 50 cm are usually sufficient to achieve acceptable resolution. Column inside diameters may vary from 0.5 to 5 cm.

Packing the Column

Once the adsorbing material and column size have been selected, the column is poured. If the tube does not have a fritted disc in the bottom, a small piece of glass wool or cotton should be used to support the column. Most columns are packed by pouring a slurry of the sorbent into the tube and allowing it to settle by gravity into a tight bed. The slurry is prepared with the solvent or buffer that will be used as the initial developing solvent. Pouring of the slurry must be continuous to avoid formation of sorbent layers. Excess solvent is eluted from the

bottom of the column while the sorbent is settling. The column must never run dry. Additional slurry is added until the column bed reaches the desired height. The top of the settled adsorbent is then covered with a small circle of filter paper or glass wool to protect the surface while the column is loaded with sample or the eluting solvent is changed.

Sometimes it is necessary to pack a column under pressure (5 to 10 psi). This leads to a tightly packed bed that yields more reproducible results, especially with gradient elution (see the following subsections).

Loading the Column

The sample to be analyzed by chromatography should be applied to the top of the column in a concentrated form. If the sample is solid, it is dissolved in a minimum amount of solvent; if already in solution, it may be concentrated by ultrafiltration as described in Chapter 3, p. 74. After the sample is loaded onto the column with a graduated or disposable pipet, it is allowed to percolate into the adsorbent. A few milliliters of solvent are then carefully added to wash the sample into the column material. The column is then filled with eluting solvent.

Eluting the Column

The chromatography column is developed by continuous flow of a solvent. Maintaining the appropriate flow rate is important for effective separation. If the flow rate is set too high, there is not sufficient time for complete equilibration of the analytes with the two phases. Too low a flow rate allows diffusion of analytes, which leads to poor resolution and broad elution peaks. It is difficult to give guidelines for the proper flow rate of a column, but, in general, a column should be adjusted to a rate slightly less than "free flow." Sometimes it is necessary to find the proper flow rate by trial and error. One problem encountered during column development is a changing flow rate. As the solvent height above the column bed is reduced, there is less of a "pressure head" on the column, so the flow rate decreases. This can be avoided by storing the developing solvent in a large reservoir and allowing it to enter the column at the same rate as it is emerging from the column (see Figure 5.4).

Adsorption columns are eluted in one of three ways. All components may be eluted by a single solvent or buffer. This is referred to as **continual elution**. In contrast, **stepwise elution** refers to an incremental change of solvent to aid development. The column is first eluted with a volume of one solvent and then with a second solvent. This may continue with as many solvents or solvent mixtures as desired. In general, the first solvent should be the least polar of any used in the analysis, and each additional solvent should be of greater polarity or ionic strength. Finally, adsorption columns may be developed by **gradient elution** brought about by a gradual change in solvent composition. The composition of the eluting solvent can be changed by the continuous mixing of two different solvents to gradually change the ratio of the two solvents. Alternatively, the concentration of a component in the solvent can be gradually increased. This is most often done by addition of a salt (KCl, NaCl, etc.). Devices are commercially available to prepare predetermined, reproducible gradients.

Collecting the Eluent

The separated components emerging from the column in the eluent are usually collected as discrete fractions. This may be done manually by collecting specified volumes of eluent in Erlenmeyer flasks or test tubes. Alternatively, if many fractions are to be collected, a mechanical fraction collector is convenient and even essential. An automatic fraction collector (see Figure 5.4) directs the eluent into a single tube until a predetermined volume has been collected or until a preselected time period has elapsed; then the collector advances another tube for collection. Specified volumes are collected by a drop counter activated by a photocell, or a timer can be set to collect a fraction over a specific period.

Detection of Eluting Components

The completion of a chromatographic experiment calls for a means to detect the presence of analytes in the collected fractions. The detection method used will depend on the nature of the analytes. Smaller molecules such as lipids, amino acids, and carbohydrates can be detected by spotting fractions on a thin-layer plate or a piece of filter paper and treating them with a chemical reagent that produces a color. The same reagents that are used to visualize spots on a thin-layer or paper chromatogram are useful for this. Proteins and nucleic acids are conveniently detected by spectroscopic absorption measurements at 280 and 260 nm, respectively. Enzymes can be detected by measurements of catalytic activity associated with each fraction. Research-grade chromatographic systems are equipped with detectors that continuously monitor some physical property of the eluent and display the separation results on a computer screen (see Figure 5.4). The newest advance in detectors is the diode array (see Chapter 7, pp. 210–211). Most often the eluent is directed through a flow cell where absorbance or fluorescence characteristics can be measured. The detector is connected to a recorder or computer for a permanent record of spectroscopic changes. When the location of the various analytes is determined, adjacent fractions containing identical components are pooled and stored for later use.

D. ION-EXCHANGE CHROMATOGRAPHY

Ion-exchange chromatography is a form of adsorption chromatography in which ionic analytes display reversible electrostatic interactions with a charged stationary phase. The chromatographic setup is identical to that described in the last section and Figure 5.4. The column is packed with a stationary phase consisting of a synthetic resin that is tagged with ionic functional groups. The steps involved in ion-exchange chromatography are outlined in Figure 5.5. In stage 1, the insoluble resin material (positively charged) in the column is surrounded by buffer counterions. Loading of the column in stage 2 brings analytes of different charge into the ion-exchange medium. Solutes entering the column may be negatively charged, positively charged, or neutral under the experimental conditions. Analytes that have a charge opposite to that of the resin bind tightly but reversibly to the stationary phase (stage 3). The strength of binding depends on the size of the charge and the charge density (amount of charge per unit volume of molecule) of the analyte. The greater the charge or the charge density, the

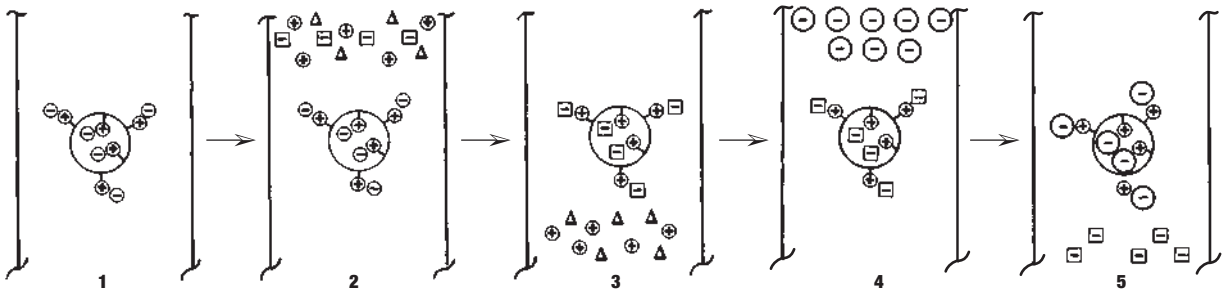

FIGURE 5.5 Illustration of the principles of ion-exchange chromatography. See text for explanation.

stronger the interaction. Neutral analytes (Δ) or those with a charge identical to that of the resin show little or no affinity for the stationary phase and move with the eluting buffer. The bound analytes can be released by eluting the column with a buffer of increased ionic strength or pH (stage 4). An increase in buffer ionic strength releases bound analytes by displacement. Increasing the buffer pH decreases the strength of the interaction by reducing the charge on the analyte or on the resin (stage 5).

The following sections will focus on the properties of ion-exchange resins, selection of experimental conditions, and applications of ion-exchange chromatography.

Ion-Exchange Resins

Ion exchangers are made up of two parts—an insoluble, three-dimensional matrix and chemically bonded charged groups within and on the surface of the matrix. The resins are prepared from a variety of materials, including polystyrene, acrylic resins, polysaccharides (dextrans), agarose, and celluloses. An ion exchanger is classified as **cationic** or **anionic** depending on whether it exchanges cations or anions. A resin that has negatively charged functional groups exchanges positive ions and is a **cation exchanger**. Each type of exchanger is also classified as **strong** or **weak** according to the ionizing strength of the functional group. An exchanger with a quaternary amino group is, therefore, a **strongly basic anion exchanger**, whereas primary or secondary aromatic or aliphatic amino groups would lead to a **weakly basic anion exchanger**. A **strongly acidic cation exchanger** contains the sulfonic acid group. Table 5.3 lists the common ion exchangers according to each of these classifications.

The ability of an ion exchanger to adsorb counterions is defined quantitatively by **capacity**. The **total capacity** of an ion exchanger is the quantity of charged and potentially charged groups per unit weight of dry exchanger. It is usually expressed as milliequivalents of ionizable groups per milligram of dry weight, and it can be experimentally determined by titration. The capacity of an ion exchanger is a function of the porosity of the resin. The resin matrix contains covalent cross-linking that creates a "molecular sieve." Ionized functional groups within the matrix are not readily accessible to large molecules that cannot fit into the pores. Only surface charges would be available to these

TABLE 5.3 Ion-Exchange Resins

Name	Functional Group	Matrix	Class
Anion Exchangers			
AG 1	Tetramethylammonium	Polystyrene	Strong
AG 3	Tertiary amine	Polystyrene	Weak
DEAE-Sephacel	Diethylaminoethyl	Sephacel	Weak
PEI-cellulose	Polyethyleneimine	Cellulose	Weak
DEAE-Sephadex	Diethylaminoethyl	Dextran	Weak
QAE-Sephadex	Diethyl-(2-hydroxyl-propyl)-aminoethyl	Dextran	Strong
DEAE-Sepharose	Diethylaminoethyl	Agarose	Weak
Cation Exchangers			
AG 50	Sulfonic acid	Polystyrene	Strong
Bio-Rex 70	Carboxylic acid	Acrylic	Weak
CM-Sephacel	Carboxymethyl	Sephacel	Weak
P-Cellulose	Phosphate	Cellulose	Intermediate
CM-Sephadex	Carboxymethyl	Dextran	Weak
SP-Sephadex	Sulfopropyl	Dextran	Strong
CM-Sepharose	Carboxymethyl	Agarose	Weak
SP-Sepharose	Sulfonic acid	Agarose	Strong

molecules for exchange. The purely synthetic resins (polystyrene and acrylic) have cross-linking ranging from 2 to 16%, with 8% being the best for general purposes.

With so many different experimental options and resin properties to consider, it is difficult to select the proper conditions for a particular separation. The next section will outline the choices and offer guidelines for proper experimental design.

Selection of the Ion Exchanger

Before a proper choice of ion exchanger can be made, the nature of the molecules to be separated must be considered. For relatively small, stable molecules (amino acids, lipids, nucleotides, carbohydrates, pigments, etc.) the synthetic resins based on polystyrene are most effective. They have relatively high capacity for small molecules because the extensive cross-linking still allows access to the interior of the resin beads. For separations of peptides, proteins, nucleic acids, polysaccharides, and other large biomolecules, one must consider the use of fibrous cellulosic ion exchangers and low-percent cross-linked dextran or acrylic exchangers. The immobilized functional groups in these resins are readily available for exchange even to larger molecules.

The choice of ion exchanger has now been narrowed considerably. The next decision is whether to use a cationic or anionic exchanger. If the analyte has only one type of charged group, the choice is simple. A molecule that has a positive

charge will bind to a cationic exchanger and vice versa. However, many biomolecules have more than one type of ionizing group and may have both negatively and positively charged groups (they are amphoteric). The net charge on such molecules depends on pH. At the isoelectric point, the substance has no net charge and would not bind to any type of ion exchanger.

In principle, amphoteric molecules should bind to both anionic and cationic exchangers. However, when one is dealing with large biomolecules, the pH **range of stability** must also be evaluated. The range of stability refers to the pH range in which the biomolecule is not denatured. Figure 5.6 shows how the net charge of a hypothetical protein changes as a function of pH. Below the isoelectric point (pH_I), the molecule has a net positive charge and would be bound to a cation exchanger. Above the isoelectric point, the net charge is negative, and the protein would bind to an anion exchanger. Superimposed on this graph is the pH range of stability for the hypothetical protein. Because it is stable in the range of pH 7.0–10.0, the ion exchanger of choice is an anionic exchanger. In most cases, the isoelectric point of the protein is not known. The type of ion exchanger must be chosen by trial and error as follows. Small samples of the protein mixture in buffer are equilibrated for 10 to 15 minutes in separate test tubes, one with each type of ion exchanger. The tubes are then centrifuged or let stand to sediment the ion exchanger. Check each supernatant for the presence of the desired analyte (A_{260} for nucleic acids, A_{280} for proteins, catalytic activity for enzymes, etc.). If a supernatant has a relatively low level of added protein, that ion exchanger would be suitable for use. This simple test can also be extended to

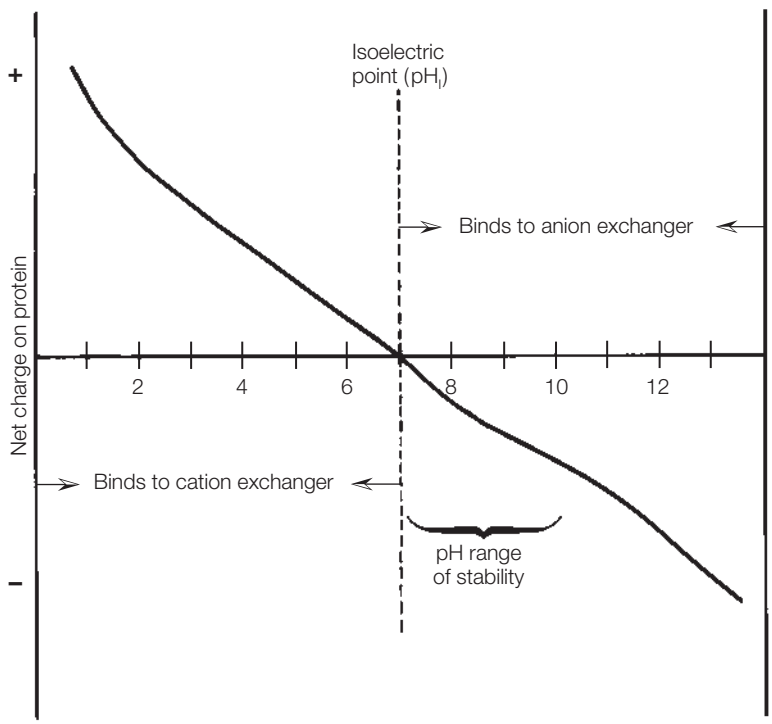

FIGURE 5.6 The effect of pH on the net charge of a protein.

find conditions for elution of the desired macromolecule from the ion exchanger. The ion exchanger charged with the macromolecule is treated with buffers of increasing ionic strength or changing pH. The supernatant after each treatment is analyzed as before for release of the macromolecule.

Choice of Buffer

This decision includes not just the buffer substance, but also the pH and the ionic strength. Buffer ions will, of course, interact with ion-exchange resins. Buffer ions with a charge opposite to that on the ion exchanger compete with analyte for binding sites and greatly reduce the capacity of the column. Cationic buffers should be used with anionic exchangers; anionic buffers should be used with cationic exchangers.

The pH chosen for the buffer depends first of all on the range of stability of the macromolecule to be separated (see Figure 5.6). Second, the buffer pH should be chosen so that the desired macromolecule will bind to the ion exchanger. In addition, the ionic strength should be relatively low to avoid "damping" of the interaction between analyte and ion exchanger. Buffer concentrations in the range 0.05 to 0.1 *M* are recommended.

Preparation of the Ion Exchanger

The commercial suppliers of ion exchangers provide detailed instructions for the preparation of the adsorbents. Failure to pretreat ion exchangers will greatly reduce the capacity and resolution of a column. Most new ion-exchange resins are commercially available in slurry form and are ready to use with a minimum number of pretreatment steps.

Sometimes pretreatment steps do not remove the small particles that are present in most ion-exchange materials. If left in suspension, these particles, called fines, result in decreased resolution and low column flow rates. The fines are removed from an exchanger by suspending the swollen adsorbent in a large volume of water in a graduated cylinder and allowing at least 90% of the exchanger to settle. The cloudy supernatant containing the fines is decanted. This process is repeated until the supernatant is completely clear. The number of washings necessary to remove most fines is variable, but for a typical ion exchanger 8 to 10 times is probably sufficient.

Using the Ion-Exchange Resin

Ion exchangers are most commonly used in a column form. The column method discussed earlier in this chapter can be directly applied to ion-exchange chromatography.

An alternative method of ion exchange is **batch separation**. This involves mixing and stirring equilibrated exchanger directly with the analyte mixture to be separated. After an equilibration time of approximately 1 hour, the slurry is filtered and washed with buffer. The ion exchanger can be chosen so that the desired analyte is adsorbed onto the exchanger or remains unbound in solution. If the latter is the case, the desired material is in the filtrate. If the desired analyte is bound to the exchanger, it can be removed by suspending the exchanger in a

buffer of greater ionic strength or different pH. Batch processes have some advantages over column methods. They are rapid, and the problems of packing, channeling, and dry columns are avoided.

Another development in ion-exchange column chromatography allows the separation of proteins according to their isoelectric points. This technique, **chromatofocusing**, involves the formation of a pH gradient on an ion-exchange column. If a buffer of a specified pH is passed through an ion-exchange column that was equilibrated at a second pH, a pH gradient is formed on the column. Proteins bound to the ion exchanger are eluted in the order of their isoelectric points. In addition, protein band concentration (focusing) takes place during elution. Chromatofocusing is similar to isoelectric focusing, introduced in Chapter 6, in which a column pH gradient is produced by an electric current.

Storage of Resins

Most ion exchangers in the dry form are stable for many years. Aqueous slurried ion exchangers are still useful after several months. One major storage problem with a wet exchanger is microbial growth. This is especially true for the cellulose and dextran exchangers. If it is necessary to store pretreated exchangers, an antimicrobial agent must be added to the slurry. Sodium azide (0.02%) is suitable for cation exchangers, and phenylmercuric salts (0.001%) are effective for anion exchangers. Since these preservative reagents are toxic, they must be used with caution.

STUDY EXERCISE 5.2 Cation-Exchange Chromatography

A mixture of amino acids (Lys, Ala, Asp) is subjected to cation exchange chromatography at pH 3.0. Predict the order of elution of the three amino acids and explain your answer. **Hint:** Draw the structures of the three amino acids as they would exist at pH 3. Study the structures and determine how each would interact with the negatively charged ion-exchange resin. Determine the relative strength of binding for each amino acid.

STUDY EXERCISE 5.3 Anion-Exchange Chromatography

A mixture of three proteins was subjected to ion-exchange chromatography using CM-cellulose as the stationary phase. Predict the order of elution of the proteins, assuming that the mixture was applied at low ionic strength and eluted with buffers of increasing ionic strength. The proteins in the mixture are listed below with isoelectric pH (pH_I).

Pepsinogen, 1.0

Cytochrome *c*, 10.6

Myoglobin, 6.8

Hint: The column separates proteins on the basis of net charge. The more negatively charged a protein, the more weakly it will bind to an anion exchange resin like CM-cellulose, and the faster it will elute. At any pH, the protein pepsinogen will have the most negative net charge of any of the three proteins.

STUDY EXERCISE 5.4 Ion-Exchange Chromatography

What kind of ion-exchange resin would be most effective for purifying RNA molecules, an anion exchanger or cation exchanger?

E. GEL-EXCLUSION CHROMATOGRAPHY

The chromatographic methods discussed up to this point allow the separation of molecules according to polarity and charge. The method of **gel-exclusion chromatography** (also called gel filtration, molecular-sieve chromatography, or gel-permeation chromatography) exploits the physical property of molecular size to achieve separation. The molecules of nature range in molecular weight from less than 100 to as large as several million. It should be obvious that a technique capable of separating molecules of molecular weight 10,000 from those of 100,000 would be very popular among research biochemists. Gel-filtration chromatography has been of major importance in the purification of thousands of proteins, nucleic acids, enzymes, polysaccharides, and other biomolecules. In addition, the technique may be applied to molecular weight determination and quantitative analysis of molecular interactions. In this section, the theory and practice of gel filtration will be introduced and applied to several biochemical problems.

Theory of Gel Filtration

The operation of a gel filtration column is illustrated in Figure 5.7. The stationary phase consists of inert particles that contain small pores of a controlled size. Microscopic examination of a particle reveals an interior resembling a sponge. A solution containing analytes of various molecular sizes is allowed to pass through the column under the influence of continuous solvent flow. Analytes larger than the pores cannot enter the interior of the gel beads, so they are limited to the space between the beads. The volume of the column accessible to very large molecules is, therefore, greatly reduced. As a result, they are not slowed in their progress through the column and elute rapidly in a single zone. Small molecules capable of diffusing in and out of the beads have a much larger volume available to them. Therefore, they are delayed in their journey through the column bed. Molecules of intermediate size migrate through the

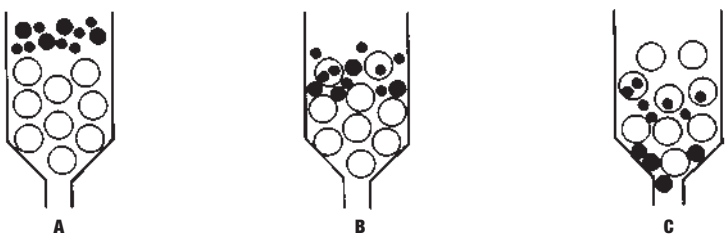

FIGURE 5.7 Separation of molecules by gel filtration. **A** Application of sample containing large and small molecules. **B** Large molecules cannot enter gel matrix, so they move rapidly through the column. **C** Elution of the large molecules first and then smaller molecules.

column at a rate somewhere between those for large and small molecules. Therefore, the order of elution of the various analytes is directly related to their molecular dimensions.

Physical Characterization of Gel Chromatography

Several physical properties must be introduced to define the performance of a gel and solute behavior. Some important properties are:

1. ***Exclusion Limit*** This is defined as the molecular mass of the smallest molecule that cannot diffuse into the inner volume of the gel matrix. All molecules above this limit elute rapidly in a single zone. The exclusion limit of a typical gel, Sephadex G-50, is 30,000 daltons. All analytes having a molecular size greater than this value would pass directly through the column bed without entering the gel pores.
2. ***Fractionation Range*** Sephadex G-50 has a fractionation range of 1500 to 30,000 daltons. Analytes within this range would be separated in a somewhat linear fashion.
3. ***Water Regain and Bed Volume*** Gel chromatography media are often supplied in dehydrated form and must be swollen in a solvent, usually water, before use. The weight of water taken up by 1 g of dry gel is known as the water regain. For G-50, this value is 5.0 ± 0.3 g. This value does not include the water surrounding the gel particles, so it cannot be used as an estimate of the final volume of a packed gel column. Most commercial suppliers of gel materials provide, in addition to water regain, a bed volume value. This is the final volume taken up by 1 g of dry gel when swollen in water. For G-50, bed volume is 9 to 11 mL/g dry gel.
4. ***Gel Particle Shape and Size*** Ideally, gel particles should be spherical to provide a uniform bed with a high density of pores. Particle size is defined either by mesh size or bead diameter (μm). Both the degree of resolution afforded by a column and the flow rate depend on particle size. Larger particle sizes (50 to 100 mesh, 100 to 300 μm) offer high flow rates but poor chromatographic separation. The opposite is true for very small particle sizes ("superfine," 400 mesh, 10 to μm). The most useful particle size, which represents a compromise between resolution and flow rate, is 100 to 200 mesh (50 to 150 μm).
5. ***Void Volume*** This is the total space surrounding the gel particles in a packed column. This value is determined by measuring the volume of solvent required to elute a solute that is completely excluded from the gel matrix. Most columns can be calibrated for void volume with a dye, blue dextran, which has an average molecular mass of 2,000,000 daltons.
6. ***Elution Volume*** This is the volume of eluting buffer necessary to remove a particular analyte from a packed column.

Chemical Properties of Gels

Four basic types of gels are available: **dextran**, **polyacrylamide**, **agarose**, and **combined polyacrylamide-dextran**. The first gels to be developed were those based on a natural polysaccharide, dextran. These are supplied by Pharmacia under the trade name Sephadex. Table 5.4 gives the physical properties of the

TABLE 5.4 Properties of Gel-Filtration Media

Name	Fractionation Range for Proteins (daltons)	Water Regain (mL/g dry gel)	Bed Volume (mL/g dry gel)
Dextran (Sephadex)[1]			
G-10	0–700	1.0 ± 0.1	2–3
G-15	0–1500	1.5 ± 0.2	2.5–3.5
G-25	1000–5000	2.5 ± 0.2	4–6
G-50	1500–30,000	5.0 ± 0.3	9–11
G-75	3000–80,000	7.5 ± 0.5	12–15
G-100	4000–150,000	10 ± 1.0	15–20
G-150	5000–300,000	15 ± 1.5	20–30
G-200	5000–600,000	20 ± 2.0	30–40
Polyacrylamide (Bio-Gels)[2]			
P-2	100–1800	1.5	3.0
P-4	800–4000	2.4	4.8
P-6	1000–6000	3.7	7.4
P-10	1500–20,000	4.5	9.0
P-30	2500–40,000	5.7	11.4
P-60	3000–60,000	7.2	14.4
P-100	5000–100,000	7.5	15.0
P-150	15,000–150,000	9.2	18.4
P-200	30,000–200,000	14.7	29.4
P-300	60,000–400,000	18.0	36.0
Dextran-polyacrylamide (Sephacryl)[1]			
S-100 HR	1000–100,000	—	—
S-200 HR	5000–250,000	—	—
S-300 HR	10,000–1,500,000	—	—
S-400 HR	20,000–8,000,000	—	—
Agarose			
Sepharose[1] 6B	10,000–4,000,000	—	—
Sepharose 4B	60,000–20,000,000	—	—
Sepharose 2B	70,000–40,000,000	—	—
Superose[1] 12 HR	1000–300,000	—	—
Superose 6 HR	5000–5,000,000	—	—
Bio-Gel[2] A-0.5	10,000–500,000	—	—
Bio-Gel A-1.5	10,000–1,500,000	—	—
Bio-Gel A-5	10,000–5,000,000	—	—
Bio-Gel A-15	40,000–15,000,000	—	—

TABLE 5.4 *Continued*

Name	Fractionation Range for Proteins (daltons)	Water Regain (mL/g dry gel)	Bed Volume (mL/g dry gel)
Bio-Gel A-50	100,000–50,000,000	—	—
Bio-Gel A-150	1,000,000–150,000,000	—	—
Vinyl (Fractogel TSK)[3]			
HW-40	100–10,000	—	—
HW-55	1000–700,000	—	—
HW-65	50,000–5,000,000	—	—
HW-75	500,000–50,000,000	—	—

[1]*Amersham – Pharmacia – LKB – Hoefer.*
[2]*Bio-Rad Laboratories.*
[3]*Pierce Biotechnology.*

various sizes of Sephadex. The number given each gel refers to the water regain multiplied by 10. Sephadex is available in various particle sizes labeled coarse, medium, fine, and superfine. Dextran-based gels cannot be manufactured with an exclusion limit greater than 600,000 daltons because the small extent of cross-linking is not sufficient to prevent collapse of the particles. If the dextran is cross-linked with *N*,*N*′-methylenebisacrylamide, gels for use in higher fractionation ranges are possible. Table 5.4 lists these gels, called Sephacryl.

Polyacrylamide gels are produced by the copolymerization of acrylamide and the cross-linking agent *N*,*N*′-methylenebisacrylamide. These are supplied by Bio-Rad Laboratories (Bio-Gel P). The Bio-Gel media are available in 10 sizes with exclusion limits ranging from 1800 to 400,000 daltons. Table 5.4 lists the acrylamide gels and their physical properties.

The agarose gels have the advantage of having very high exclusion limits. Agarose, the neutral polysaccharide component of agar, is composed of alternating galactose and anhydrogalactose units. The gel structure is stabilized by hydrogen bonds rather than by covalent cross-linking. Agarose gels, supplied by Bio-Rad Laboratories (Bio-Gel A) and by Pharmacia (Sepharose and Superose), are listed in Table 5.4.

The combined polyacrylamide-agarose gels are commercially available under the trade name Ultragel. These consist of cross-linked polyacrylamide with agarose trapped within the gel network. The polyacrylamide gel allows a high degree of separation and the agarose maintains gel rigidity, so high flow rates may be used.

Selecting a Gel

The selection of the proper gel is a critical stage in successful gel chromatography. Most gel chromatographic experiments can be classified as either **group separations** or **fractionations**. Group separations involve dividing the components of a sample into two groups, a fraction of relatively low-molecular-weight analytes and a fraction of relatively high-molecular-weight analytes. Specific examples of

this are desalting a protein solution or removing small contaminating molecules from protein or nucleic acid extracts. For group separations, a gel should be chosen that allows complete exclusion of the high-molecular-weight molecules in the void volume. Sephadex G-25, Bio-Gel P-6, and Sephacryl S-100HR are recommended for most group separations. The particle size recommended is 100 to 200 mesh or 50 to 150 μm diameter.

Gel fractionation involves separation of groups of molecules of similar molecular weights in a multicomponent mixture. In this case, the gel should be chosen so that the fractionation range includes the molecular weights of the analytes. If the mixture contains macromolecules up to 120,000 in molecular weight, then Bio-Gel P-150, Sephacryl S-200HR, or Sephadex G-150 would be most appropriate. If P-100, G-100, or Sephacryl S-100HR were used, some of the higher-molecular-weight proteins in the sample would elute in the void volume. On the other hand, if P-200, P-300, or G-200 were used, there would be a decrease in both resolution and flow rate. If the molecular weight range of the mixture is unknown, empirical selection is necessary. The recommended gel grade for most fractionations is 100–200 or 200–400 mesh (20–80 μm or 10–40 μm). The finest grade that allows a suitable flow rate should be selected. For very critical separations, superfine grades offer the best resolution, but with very low flow rates.

Gel Preparation and Storage

The dextran and acrylamide gel products are sometimes supplied in dehydrated form and must be allowed to swell in water before use. The swelling time required differs for each gel, but the extremes are 3 to 4 hours at 20°C for highly cross-linked gels and up to 72 hours at 20°C for P-300 or G-200. The swelling time can be shortened if a boiling-water bath is used. Agarose gels and combined polyacrylamide-agarose gels are supplied in a hydrated state, so there is no need for swelling.

Before a gel slurry is packed into the column, it should be defined and deaerated. Defining is necessary to remove very fine particles, which would reduce flow rates. To define, pour the gel slurry into a graduated cylinder and add water equivalent to two times the gel volume. Invert the cylinder several times and allow the gel to settle. After 90 to 95% of the gel has settled, decant the supernatant, add water, and repeat the settling process. Two or three defining operations are usually sufficient to remove most small particles.

Deaerating (removing dissolved gases) should be done on the gel slurry and all eluting buffers. Gel particles that have not been deaerated tend to float and form bubbles in the column bed. Dissolved gases are removed by placing the gel slurry in a side-arm vacuum flask and applying a vacuum from a water aspirator. The degassing process is complete when no more small air bubbles are released from the gel (usually 1 to 2 hours).

Antimicrobial agents must be added to stored, hydrated gels. One of the best agents is sodium azide (0.02%).

Operation of a Gel Column

The procedure for gel-column chromatography is very similar to the general description given earlier. The same precautions must be considered in packing, loading, and eluting the column. A brief outline of important considerations follows.

Column Size

For fractionation purposes, it is usually not necessary to use columns greater than 100 cm in length. The ratio of bed length to width should be between 25 and 100. For group separations, columns less than 50 cm long are sufficient, and appropriate ratios of bed length to width are between 5 and 10.

Eluting Buffer

There are fewer restrictions on buffer choice in gel chromatography than in ion-exchange chromatography. Dextran and polyacrylamide gels are stable in the pH range 1 to 10, whereas agarose gels are limited to pH 4 to 10. Since there is such a wide range of stability of the gels, the buffer pH should be chosen on the basis of the range of stability of the macromolecules to be separated.

Sample Volume

The sample volume is a critical factor in planning a gel chromatography experiment. If too much sample is applied to a column, resolution is decreased; if the sample size is too small, the analytes are greatly diluted. For group separations, a sample volume of 10 to 25% of the column total volume is suitable. The sample volume for fractionation procedures should be between 1 and 5% of the total volume. Column total volume is determined by measuring the volume of water in the glass column that is equivalent to the height of the packed bed.

Column Flow Rate

The flow rate of a gel column depends on many factors, including length of column and type and size of the gel. It is generally safe to elute a gel column at a rate slightly less than free flow. A high flow rate reduces sample diffusion or zone broadening, but may not allow complete equilibration of analyte molecules with the gel matrix.

A specific flow rate cannot be recommended, since each type of gel requires a different range. The average flow rate given in literature references for small-pore-size gels is 8 to 12 mL/cm^2 of cross-sectional bed area per hour (15 to 25 mL/hr). For large-pore-size gels, a value of 2 to 5 mL/cm^2 of cross-sectional bed area per hour (5 to 10 mL/hr) is average.

Eluent can be made to flow through a column by either of two methods, gravity or pump elution. Gravity elution is most often used because no special equipment is required. It is quite acceptable for developing a column used for group separations and fractionations when small-pore-sized gels are used. However, if the flow rate must be maintained at a constant value throughout an experiment or if large-pore gels are used, pump elution is recommended.

One variation of gel chromatography is ascending eluent flow. Some investigators report more reproducible results, better resolution, and a more constant flow rate if the eluting buffer is pumped backward through the gel. This type of experiment requires special equipment, including a specialized column, and a peristaltic pump.

Applications of Gel-Exclusion Chromatography

Several experimental applications of gel chromatography have already been mentioned, but more detail will be given here.

Desalting

Inorganic salts, organic solvents, and other small molecules are used extensively for the purification of macromolecules. Gel chromatography provides an inexpensive, simple, and rapid method for removal of these small molecules. One especially attractive method for desalting very small samples (0.1 mL or less) of proteins or nucleic acid solutions is to use spin columns. These are prepacked columns of polyacrylamide exclusion gels. Spin columns are used in a similar fashion to microfiltration centrifuge tubes (Chapter 3, p. 75). The sample is placed on top of the gel column and spun in a centrifuge. Large molecules are eluted from the column and collected in a reservoir. The small molecules to be removed remain in the gel.

Purification of Biomolecules

This is probably the most popular use of gel chromatography. Because of a gel's ability to fractionate molecules on the basis of size, gel filtration complements other purification techniques that separate molecules on the basis of polarity and charge.

Estimation of Molecular Weight

The elution volume for a particular analyte is proportional to its molecular size. This indicates that it is possible to estimate the molecular weight of a molecule on the basis of its elution characteristics on a gel column. An elution curve for several standard proteins separated on Sephadex G-100 is shown in Figure 5.8. This curve, a plot of protein concentration A_{280} vs. volume collected, is representative of data obtained from a gel filtration experiment. The elution volume, V_e, for each protein can be estimated as shown in the figure. A plot of log molecular

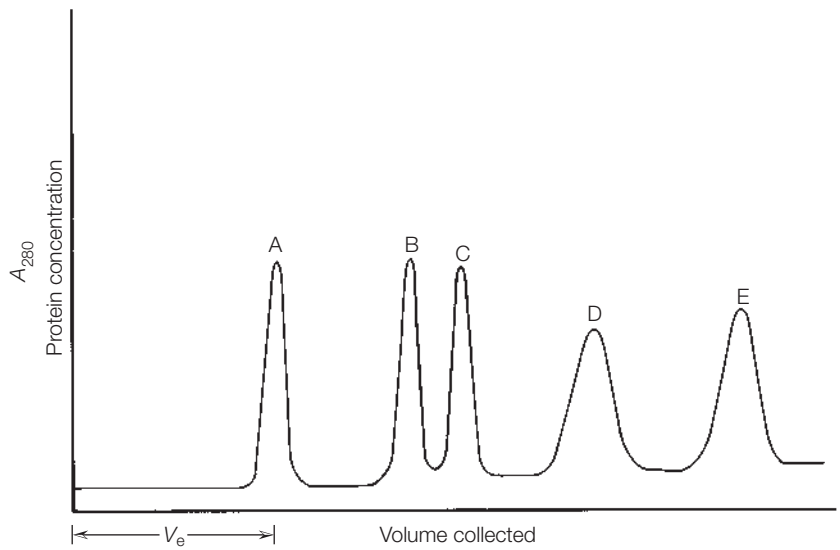

FIGURE 5.8
Elution curve for a mixture of several proteins using gel-filtration chromatography.
A = hemoglobin;
B = egg albumin;
C = chymotrypsinogen;
D = myoglobin;
E = cytochrome *c*.

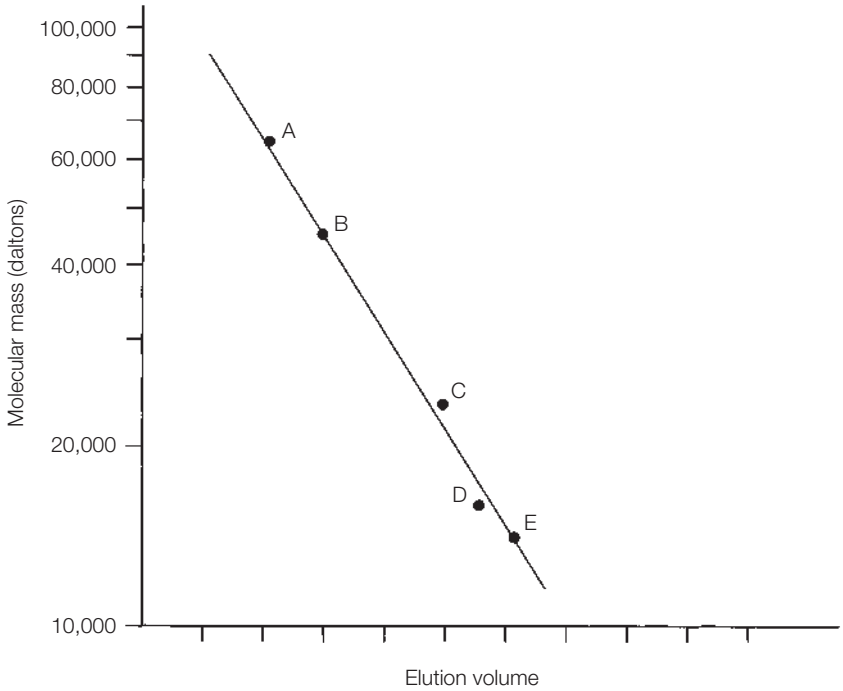

FIGURE 5.9 A plot of log molecular mass vs. elution volume for the proteins A, B, C, D, and E in Figure 5.8.

mass vs. elution volume for the proteins is shown in Figure 5.9. Note that the linear portion of the curve in Figure 5.9 covers the molecular mass range of 10,000 to 100,000 daltons. Molecules below 10,000 daltons are not eluted in an elution volume proportional to size. Since they readily diffuse into the gel particles, they are retarded. Molecules larger than 100,000 daltons are all excluded from the gel in the void volume. A solution of the unknown protein is chromatographed through the calibrated column under conditions identical to those for the standards, and the elution volume is measured. The unknown molecular size is then read directly from the graph. This method of molecular weight estimation is widely used because it is simple, inexpensive, and fast. It can be used with highly purified or impure samples. There are, of course, some limitations to consider. The gel must be chosen so that the molecular weight of the unknown is within the linear section of the curve. The method assumes that only steric and partition effects influence the elution of the standards and unknown. If a protein interacts with the gel by adsorptive or ionic processes, the estimate of molecular weight will be lower than the true value. The assumption is also made that the unknown molecules have a general spherical shape, not an elongated or rod shape. Although this is a convenient and rapid method for molecular weight determination, the final number is only an estimate.

Gel Chromatography in Organic Solvents

The gels discussed so far in this section are hydrophilic, and the inner matrix retains its integrity only in aqueous solvents. Because there is a need for gel chromatography of nonhydrophilic molecules, gels have been produced that

can be used with organic solvents. The trade names of some of these products are Sepharose CL and Sephadex LH, Bio Beads S, and Styragel. Organic solvents that are of value in gel chromatography are ethanol, acetone, dimethylsulfoxide, dimethylformamide, tetrahydrofuran, chlorinated hydrocarbons, and acetonitrile.

STUDY EXERCISE 5.5 Gel-Exclusion Chromatography

Your first experiment in biochemistry lab is to analyze a mixture with the use of gel filtration. You are instructed to run a Sephadex G-50 column on the mixture containing the components listed below. All three components are colored, so you are able to observe the separation. The components are dissolved in water, and the column is eluted with water.

Blue dextran, a blue dye (MW = about 2,000,000)

Cytochrome *c*, a red protein (MW = 12,400)

Flavin adenine dinucleotide, a yellow coenzyme (FAD, MW = 830)

Predict the results of your experiment.

Solution: According to Table 5.4, the fractionation range for G-50 is 1500–30,000. The Blue dextran is above the fractionation range, so it will elute very rapidly in the void volume. The FAD is below the fractionation range, so it will take its time and elute much later than Blue dextran and cyt *c*. The red-colored cyt *c*, within the fractionation range, will elute somewhere between the Blue dextran and FAD.

STUDY EXERCISE 5.6 Separation of Proteins

Your biochemistry lab instructor gives you a mixture of three proteins and asks you to separate the proteins on a Sephadex G-100 gel. The three proteins are serum albumin, myoglobin, and chymotrypsinogen. The column is eluted with 0.1 *M* Tris buffer, pH 7.0. Predict the order of elution of the proteins from the Sephadex column. Use Appendix V to find the molecular weights of the proteins.

F. HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)

The previous discussions on the theory and practice of the various chromatographic methods should convince you of the tremendous influence chromatography has had on our biochemical understanding. It is tempting to make comparisons about the relative importance of the methods, but doing so would be unfair because each serves a specific purpose. There will, for example, always be a need for fast, inexpensive, and qualitative analyses as afforded by planar

chromatography. Traditional column chromatography will probably always be preferred in large-scale protein purification.

However, during the past three decades, an analytical method has been developed that now surpasses the traditional liquid chromatographic techniques in importance for analytical separations. This technique, **high-performance liquid chromatography (HPLC)**, is ideally suited for the separation and identification of amino acids, carbohydrates, lipids, nucleic acids, proteins, pigments, steroids, pharmaceuticals, and many other biologically active molecules.

The future promise of HPLC is indicated by its classification as "modern liquid chromatography" when compared to other forms of column-liquid chromatography, now referred to as "classical" or "traditional." Compared to the classical forms of liquid chromatography (paper, TLC, column), HPLC has several advantages:

1. Resolution and speed of analysis far exceed the classical methods.
2. HPLC columns can be reused without repacking or regeneration.
3. Reproducibility is greatly improved because the parameters affecting the efficiency of the separation can be closely controlled.
4. Instrument operation and data analysis are easily automated.
5. HPLC is adaptable to very small sample sizes or large-scale, preparative procedures.

The advantages of HPLC are the result of two major advances: (1) the development of stationary supports with very small particle sizes and large surface areas, and (2) the improvement of elution rates by applying high pressure to the solvent flow.

The great versatility of HPLC is evidenced by the fact that all chromatographic modes, including partition, adsorption, ion exchange, chromatofocusing, and gel exclusion, are possible. In a sense, HPLC can be considered as automated liquid chromatography. The theory of each of these chromatographic modes has been discussed and needs no modification for application to HPLC. However, there are unique theoretical and practical characteristics of HPLC that should be introduced.

The **retention time** of an analyte in HPLC (t_R) is defined as the time necessary for maximum elution of the particular analyte. This is analogous to retention time measurements in GC. **Retention volume** (V_R) of an analyte is the solvent volume required to elute the analyte and is defined by Equation 5.2, where F is the flow rate of the solvent.

>> $$V_R = Ft_R$$ **(Eq. 5.2)**

In all forms of chromatography, a measure of column efficiency is **resolution**, *R*. Resolution indicates how well analytes are separated; it is defined by Equation 5.3, where t_R and t'_R are the retention times of two analytes and w and w' are the base peak widths of the same two analytes.

>> $$R = 2\frac{t_R - t'_R}{w + w'}$$ **(Eq. 5.3)**

Instrumentation

The increased resolution achieved in HPLC compared to classical column chromatography is primarily the result of adsorbents of very small particle sizes (less than 20 μm) and large surface areas. The smallest gel beads used in gel-exclusion chromatography are "superfine" grade with diameters of 20 to 50 μm. Recall that the smaller the particle size, the lower the flow rate; therefore, it is not feasible to use very small gel beads in liquid column chromatography because low flow rates lead to solute diffusion and the time necessary for completion of an analysis would be impractical. In HPLC, increased flow rates are obtained by applying a pressure differential across the column. A combination of high pressure and adsorbents of small particle size leads to the high resolving power and short analysis times characteristic of HPLC.

A schematic diagram of a typical high-pressure liquid chromatograph is shown in Figure 5.10. The basic components are a solvent reservoir, high-pressure pump, packed column, detector, and recorder. A computer is used to control the process and to collect and analyze data.

Solvent Reservoir

The solvent chamber should have a capacity of at least 500 mL for analytical applications, but larger reservoirs are required for preparative work. In order to avoid bubbles in the column and detector, the solvent must be degassed. Several

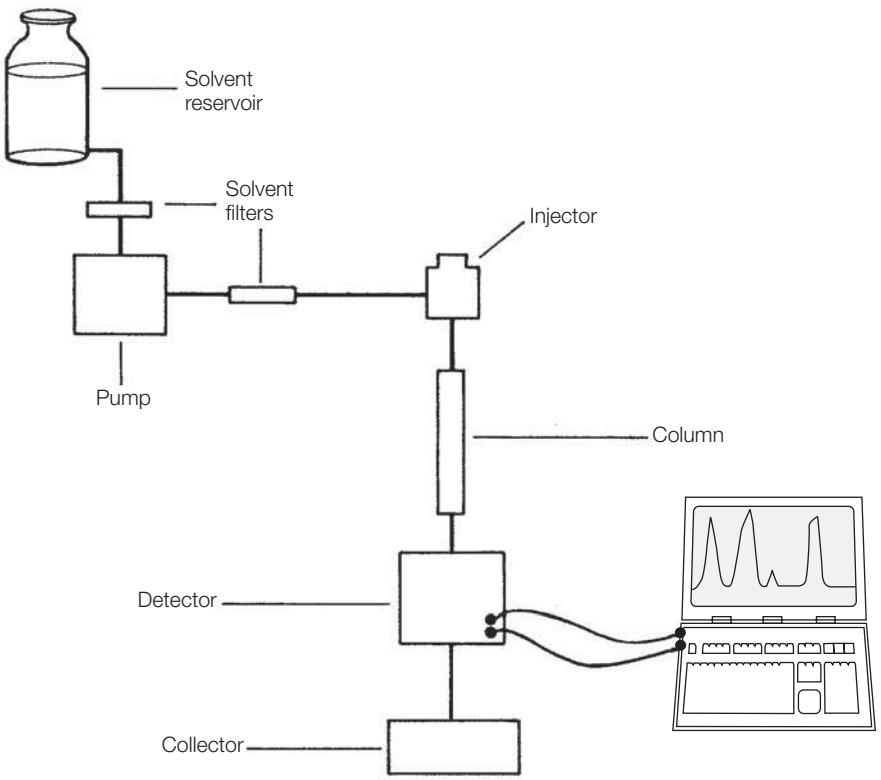

FIGURE 5.10 A schematic diagram of a high-performance liquid chromatograph.

methods may be used to remove unwanted gases, including refluxing, filtration through a vacuum filter, ultrasonic vibration, and purging with an inert gas. The solvent should also be filtered to remove particulate matter that would be drawn into the pump and column.

Pumping Systems

The purpose of the pump is to provide a constant, reproducible flow of solvent through the column. Two types of pumps are available—constant pressure and constant volume. Typical requirements for a pump are:

1. It must be capable of pressure outputs of at least 500 psi and preferably up to 5000 psi.
2. It should have a controlled, reproducible flow delivery of about 1 mL/min for analytical applications and up to 100 mL/min for preparative applications.
3. It should yield pulse-free solvent flow.
4. It should have a small holdup volume.

Although neither type of pump meets all these criteria, constant-volume pumps maintain a more accurate flow rate and allow for a more precise analysis.

Injection Port

A sample must be introduced onto the column in an efficient and reproducible manner. One of the most popular injectors is the syringe injector. The sample, in a microliter syringe, is injected through a neoprene/Teflon septum. This type of injection can be used at pressures up to 3000 psi.

Columns

HPLC columns are prepared from stainless steel or glass-Teflon tubing. Typical column inside diameters are 2.1, 3.2, or 4.5 mm for analytical separations and up to 30 mm for preparative applications. The length of the column can range from 5 to 100 cm, but 10- to 20-cm columns are common.

Detector

Liquid chromatographs are equipped with a means to continuously monitor the column effluent and recognize the presence of analyte. Only small sample sizes are used with most HPLC columns, so a detector must have high sensitivity. The type of detector that has the most universal application is the **differential refractometer**. This device continuously monitors the refractive index difference between the mobile phase (pure solvent) and the mobile phase containing sample (column effluent). The sensitivity of this detector is on the order of 0.1 μg, which, compared to other detectors, is only moderately sensitive. The major advantage of the refractometer detector is its versatility; its main limitation is that there must be at least 10^{-7} refractive index units between the mobile phase and sample.

The most widely used HPLC detectors are the **photometric detectors**. These detectors measure the extent of absorption of ultraviolet or visible radiation by a sample. Since few compounds are colored, visible detectors are of limited value. Ultraviolet detectors are the most widely used in HPLC. The

typical UV detector functions by focusing radiation from a low-pressure mercury lamp on a flow cell that contains column effluent. The mercury lamp provides a primary radiation at 254 nm. The use of filters or other lamps provides radiation at 220, 280, 313, 334, and 365 nm. Many compounds absorb strongly in this wavelength range, and sensitivities on the order of 1 ng are possible. Most biochemicals are detected, including proteins, nucleic acids, pigments, vitamins, some steroids, and aromatic amino acids. Aliphatic amino acids, carbohydrates, lipids, and other biochemicals that do not absorb UV can be detected by chemical derivatization with UV-absorbing functional groups. UV detectors have many positive characteristics, including high sensitivity, small sample volumes, linearity over wide concentration ranges, nondestructiveness to sample, and suitability for gradient elution.

A third type of detector that has only limited use is the **fluorescence detector**. This type of detector is extremely sensitive: its use is limited to samples containing trace quantities of biological materials. Its response is not linear over a wide range of concentrations, but it may be up to 100 times more sensitive than the UV detector.

Collection of Eluent

All of the detectors described here are nondestructive to the samples, so column effluent can be collected for further chemical and physical analysis.

Analysis of HPLC Data

Most HPLC instruments are on-line, with an integrator and a computer for data handling. For quantitative analysis of HPLC data, operating parameters such as rate of solvent flow must be controlled. In modern instruments, the whole system (including the pump, injector, detector, and data system) is under the control of a computer.

Figure 5.11 illustrates the separation by HPLC of several phenylhydantoin derivatives of amino acids.

Stationary Phases in HPLC

The adsorbents in HPLC are typically small-diameter, porous materials. Two types of stationary phases are available. **Porous layer beads** (Figure 5.12A) have an inert solid core with a thin porous outer shell of silica, alumina, or ion-exchange resin. The average diameter of the beads ranges from 20 to 45 μm. They are especially useful for analytical applications, but, because of their short pores, their capacities are too low for preparative applications.

Microporous particles are available in two sizes: 20 to 40 μm diameter with longer pores and 5 to 10 μm with short pores (see Figure 5.12B). These are now more widely used than the porous layer beads because they offer greater resolution and faster separations with lower pressures. The microporous beads are prepared from alumina, silica, ion-exchanger resins, and chemically bonded phases (see next section).

The HPLC can function in several chromatographic modes. Each type of chromatography will be discussed in the following subsections, with information about stationary phases.

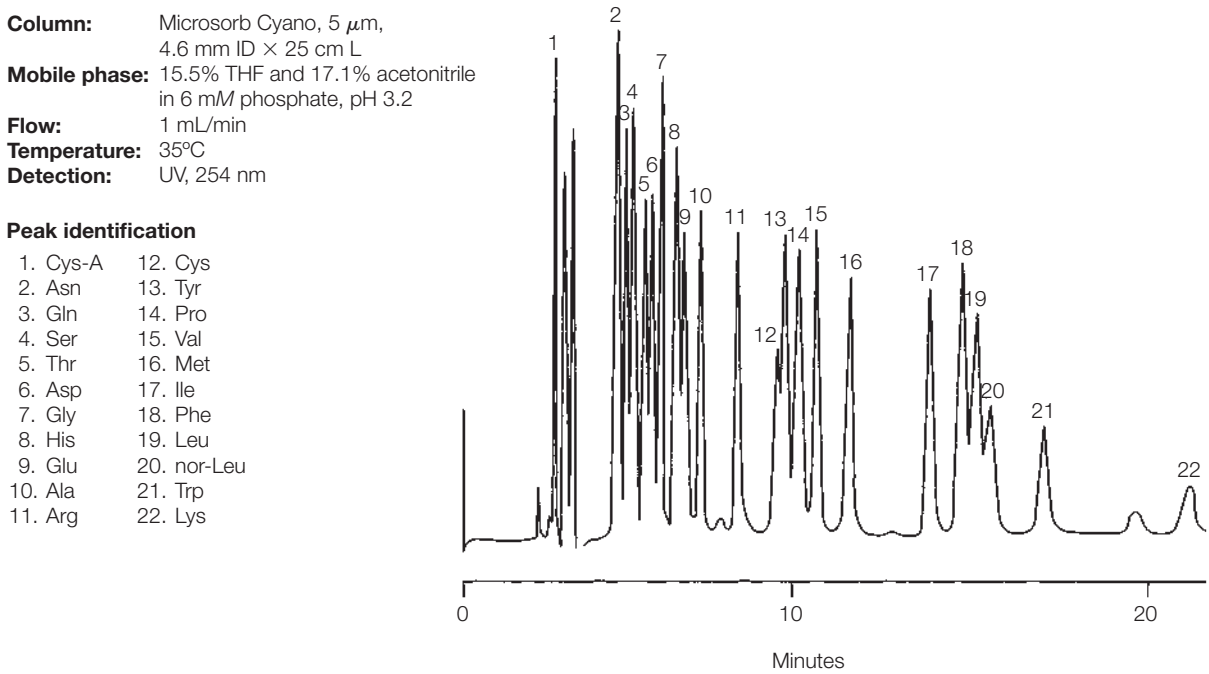

FIGURE 5.11 The separation of several amino acid phenylhydantoins by HPLC. *Courtesy of Rainin Instrument Co., Woburn, MA;* www.rainin.com.

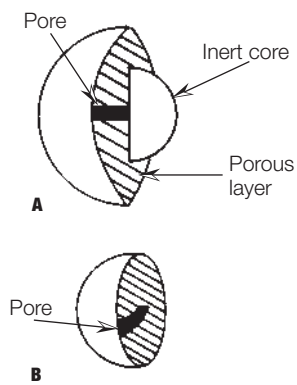

FIGURE 5.12 Adsorbents used in HPLC. **A** Porous layer with short pores. **B** Microporous particles with longer pores.

Liquid-Solid (Adsorption) Chromatography

HPLC in the adsorption mode can be carried out with silica or alumina porous-layer-bead columns. Small glass beads are often used for the inert core. Some of the more widely used packings are μ Porasil (Waters Associates), BioSilA (Bio-Rad Laboratories), LiChrosorb Si-100 Partisil, Vydac, ALOX 60D (several suppliers), and Supelcosil (Supelco).

In high-pressure adsorption chromatography, analytes adsorb with different affinities to binding sites in the solid stationary phase. Separation of analytes in a sample mixture occurs because polar molecules adsorb more strongly than nonpolar molecules. Therefore, the various components in a sample are eluted with different retention times from the column. This form of HPLC is usually called **normal phase** (a polar stationary phase and a nonpolar mobile phase).

Liquid-Liquid (Partition) Chromatography

In the early days of HPLC (1970–78), solid supports were coated with a liquid stationary phase. Columns with these packings had short lifetimes and a gradual decrease in resolution because there was continuous loss of the liquid stationary phase with use of the column.

This problem was remedied by the discovery of methods for chemically bonding the active stationary phase to the inert support. Most chemically bonded stationary phases are produced by covalent modification of the surface silica. Three modification processes are shown in Equations 5.4–5.6.

Silicate esters

$$\gg \quad \text{—Si—OH} + \text{ROH} \longrightarrow \text{—Si—O—R} \qquad \textbf{(Eq. 5.4)}$$

Silica − carbon

$$\gg \quad \text{—Si—Cl} + \begin{matrix}\text{RMgBr}\\ \text{or}\\ \text{RLi}\end{matrix} \longrightarrow \text{—Si—R} \qquad \textbf{(Eq. 5.5)}$$

Siloxanes

$$\gg \quad \text{—Si—OH} + \begin{matrix}\text{ClSiR}_3\\ \text{or}\\ \text{ROSiR}_3\end{matrix} \longrightarrow \text{—Si—O—SiR}_3 \qquad \textbf{(Eq. 5.6)}$$

The major advantage of a bonded stationary phase is stability. Since it is chemically bonded, there is very little loss of stationary phase with column use. The siloxanes are the most widely used silica supports. Functional groups that can be attached as siloxanes are alkylnitriles (—Si—CH_2CH_2—CN), phenyl (—Si—C_6H_5), alkylamines (—Si$(CH_2)_n NH_2$)—, and alkyl side chains (—Si—C_8H_{17}; —Si—$C_{18}H_{37}$).

The use of nonpolar chemically bonded stationary phases with a polar mobile phase is referred to as **reverse-phase HPLC**. This technique separates sample components according to hydrophobicity. It is widely used for the separation of all types of biomolecules, including peptides, nucleotides, carbohydrates, and derivatives of amino acids. Typical solvent systems are water-methanol, water-acetonitrile, and water-tetrahydrofuran mixtures. Figure 5.13 shows the results of protein separation on a silica-based reverse-phase column.

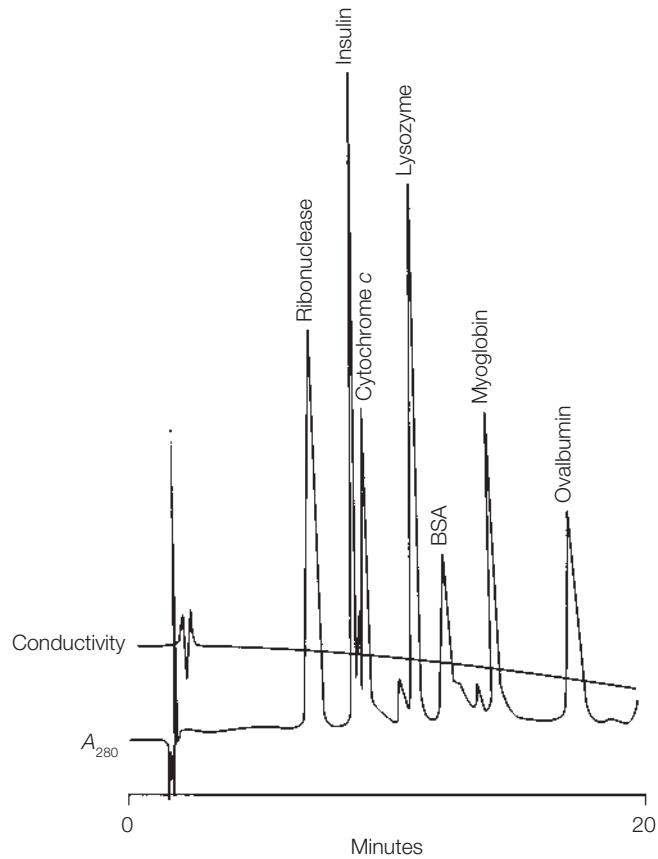

Conditions

column:	Hi-Pore RP-304 column, 250 × 4.6 mm
Sample:	Protein standard
Buffers:	A. H_2O, 0.1% B B. 95% Acetonitrile, 5% H_2O, 0.1% TFA
Gradient:	25%–100% B in 30 minutes
Flow rate:	1.5 mL/min
Temperature:	Ambient
Detection:	UV @ 280 nm; conductivity

FIGURE 5.13 Reverse-phase chromatography of a mixture of standard proteins. *Separation courtesy of Bio-Rad Laboratories, Hercules, CA;* www.bio-rad.com.

Ion-Exchange Chromatography

Ion-exchange HPLC uses column packings with charged functional groups. Structures of typical ion exchangers are shown in Figure 5.14. They are prepared by chemically bonding the ionic groups to the support via silicon atoms or by using polystyrene-divinylbenzene resins. These stationary phases may be used for the separation of proteins, peptides, and other charged biomolecules.

Gel-Exclusion Chromatography

The combination of HPLC and gel-exclusion chromatography is used extensively for the separation of large biomolecules, especially proteins and nucleic acids.

The exclusion gels discussed in Section E are not appropriate for HPLC use because they are soft and, except for small-pore beads (G-25 and less), collapse under high-pressure conditions. Semirigid gels based on cross-linked styrene-divinylbenzene, polyacrylamide, and vinyl-acetate copolymer are available with various fractionation ranges useful for the separation of molecules up to 10,000,000 daltons.

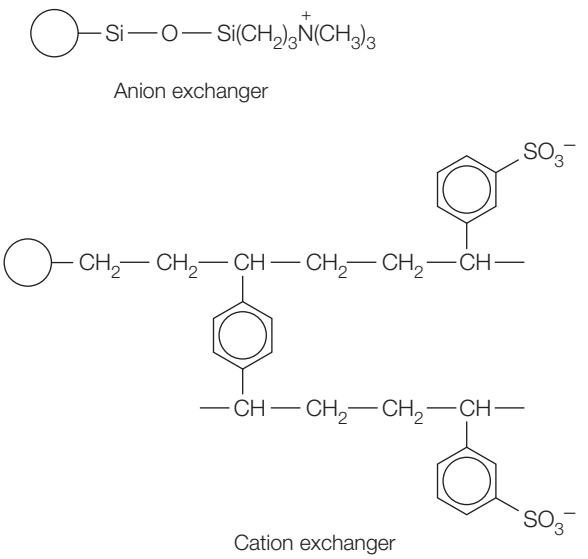

FIGURE 5.14 Ion exchangers used in HPLC.

Rigid packings for HPLC gel exclusion are prepared from porous glass or silica. They have multiple advantages over the semirigid gels, including several fractionation ranges, ease of packing, and compatibility with water and organic solvents.

Chiral Chromatography

HPLC has been extremely effective in separating and analyzing a broad range of biological molecules, including amino acids, proteins, lipids, nucleic acids, and carbohydrates, as described in the previous subsections. One class of biologically important compounds that has shown resistance to separation are the enantiomeric forms of biomolecules that exist because of the presence of a chiral center or stereocenter. For most molecules, a chiral center is a carbon atom that is surrounded by four different groups. Compounds that have a stereocenter exist in two molecular forms **(enantiomers)** that have the same physical and chemical properties. They differ only in the way they interact with plane-polarized light—one enantiomer rotates the light to the left (L), and one enantiomer rotates light to the right (D). We now know that enantiomers also differ in their biological actions or physiological effects. This has become increasingly important in medical treatment because many drugs are chiral and the enantiomers differ in how they interact with receptors. One enantiomeric form of a drug may interact to cause the desired effect, and one may lead to no effect or even to toxicity. For example, the drug thalidomide was widely used in Europe during the late 1950s and early 1960s as a sedative/tranquilizer, especially for pregnant women. The original drug form was the racemic mixture containing two thalidomide enantiomers. Thousands of women taking the drug later delivered malformed babies. We now know that only one enantiomer (D, *R*) causes the desired sedative effect. The other enantiomer (L, *S*) is teratogenic.

It has become essential to develop techniques for the separation and analysis of enantiomers by chromatography. Some current drugs whose active ingredient is a single enantiomer include Lipitor (Atorvastatin), Zocor (Simvastatin), Nexium (Esomeprazole), Plavix (Clopidogrel), Advair (Fluticasone), and Zoloft (Sertraline).

A logical approach to the separation of enantiomers is to use a chiral stationary phase, because it is known that chiral compounds are able to interact selectively, favoring one enantiomer over the other. Because of the different spatial arrangements around the stereocenters of the enantiomers, they interact differently with a chiral surface. The most effective chiral stationary phases contain proteins that are, of course, composed of amino acids, each of which has a stereocenter (except gly). Many protein sorbents have been tested, and the most successful results have come from alpha1-acid glycoproteins (AGP), human serum albumin (HSA), and cellobiohydrolase (CBH). For example, the proteins AGP and HSA on HPLC columns have been used to separate the enantiomers of the anti-inflammatory drug ibuprofen (see Figure 5.15).

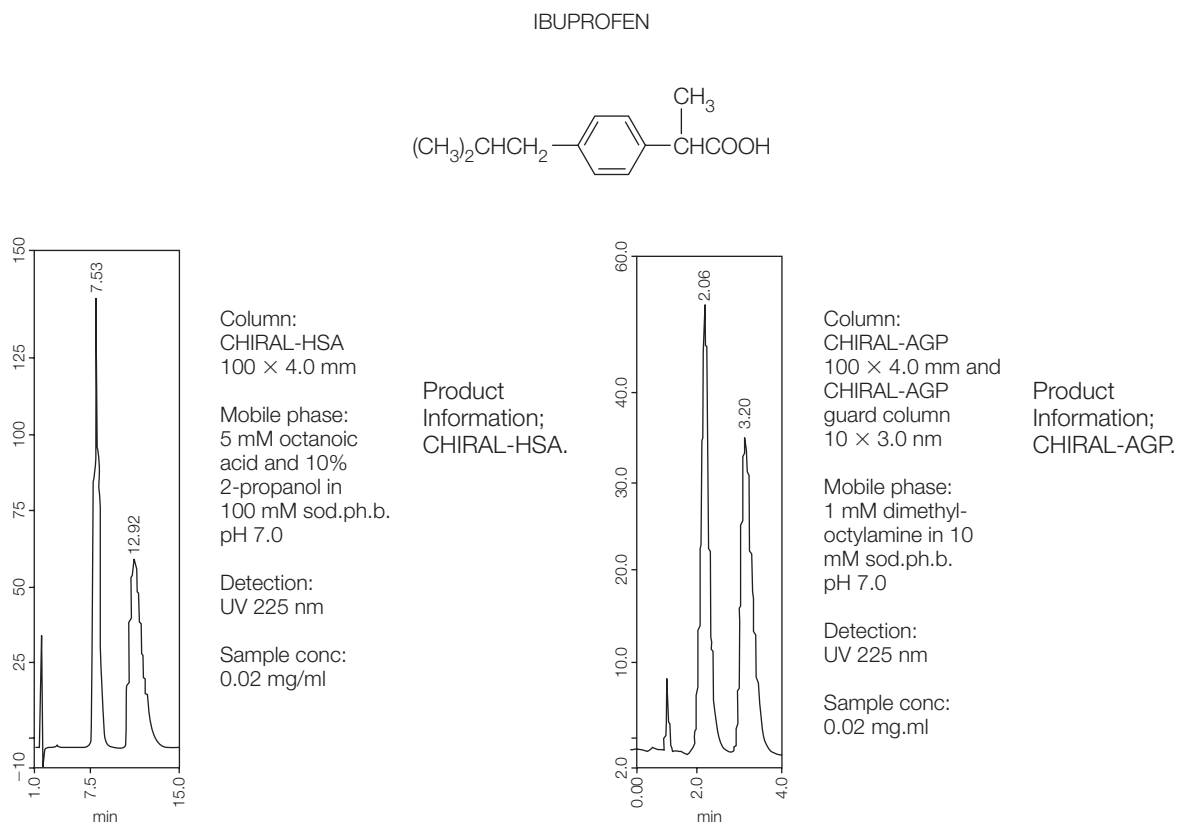

FIGURE 5.15 Separation of the enantiomers of the painkiller ibuprofen on two different chiral supports. sod.ph.b = sodium phosphate buffer. *Courtesy of Chiral Technologies, Inc.* www.chiraltech.com.

The Mobile Phase

Selection of a column packing that is appropriate for a given analysis does not ensure a successful HPLC separation. A suitable solvent system must also be chosen. Several critical solvent properties will be considered here.

Purity Very-high-purity solvents with no particulate matter are required. Many laboratory workers do not purchase expensive prepurified solvents, but, rather, purify lesser grade solvents by microfiltration through a Millipore system or distillation in glass.

Reactivity The mobile phase must not react with the analytical sample or column packing. This does not present a major limitation since many relatively unreactive hydrocarbons, alkyl halides, and alcohols are suitable.

Detector Compatibility A solvent must be carefully chosen to avoid interference with the detector. Most UV detectors monitor the column effluent at 254 nm. Any UV-absorbing solvent, such as benzene or olefins, would be unacceptable because of high background. Since refractometer detectors monitor the difference in refractive index between solvent and column effluent, a greater difference leads to greater ability to detect the solute.

Sample Preparation and Selection of HPLC Operating Conditions

During the initial stages of biochemical sample preparation, the sample is often quite crude; it may contain hundreds of components in addition to the desired biomolecules. Most samples must be pretreated before optimum HPLC results can be expected. The following procedures may be needed in order to convert a crude sample into a clean one: desalting, removal of anions and cations, removal of metal ions, concentration of the desired macromolecules, removal of detergent, and particulate removal. Sample preparation techniques used to achieve these results are gel-exclusion chromatography, ion-exchange chromatography, microfiltration, and metal-affinity chromatography. These procedures may be completed by commercially available prefilters or precolumns.

Each type of HPLC instrument has its own characteristics and operating directions. It is not feasible to describe those here. However, it is appropriate to outline the general approach taken when an HPLC analysis is desired. The following items must be considered:

1. Chemical nature and proper preparation of the sample.
2. Selection of type of chromatography (partition, adsorption, ion-exchange, gel-exclusion).
3. Choice of solvent system and mode of elution.
4. Selection of column packing.
5. Choice of equipment (type of detector).

FPLC—A Modification of HPLC

In 1982, Pharmacia introduced an innovative chromatographic method that provides a link between classical column chromatography and HPLC. This technique, called **fast protein liquid chromatography (FPLC)**, uses

experimental conditions intermediate between those of column chromatography and HPLC. The typical FPLC system requires a pump that will deliver solvent to the column in the flow rate range 1–499 mL/hr with operating pressures of 0–40 bar. (HPLC pumps deliver solvent in a flow rate range of 0.010–10 mL/min with operating pressures of 1–400 bar. Classical chromatography columns are operated at atmospheric pressure.) Also required for FPLC are a controller, detector, and fraction collector. Since lower pressures are used in FPLC than in HPLC, a wider range of column supports is possible. Chromatographic techniques incorporated in an FPLC system are gel filtration, ion exchange, affinity (see Section G, p. 152), hydrophobic interaction, reversed phase, and chromatofocusing.

Perfusion Chromatography

A separation method that improves resolution and decreases the time required for analysis of biomolecules has recently been introduced. This method, called **perfusion chromatography**, relies on a type of particle support called POROS, which may be used in low-pressure and high-pressure liquid chromatography applications. In conventional chromatographic separations, some biomolecules in the sample move rapidly around and past the media particles while other molecules diffuse slowly through the particles (Figure 5.16A). The result is loss of resolution because some biomolecules exit the column before others. To improve resolution, the researcher with conventional media found it necessary to reduce the flow rate to allow for diffusion processes, increasing the time required for analysis. In other words, before the development of perfusion chromatography, the researcher had to choose between high speed–low resolution and low speed–high resolution. POROS particles have two types of pores—**through pores** (6000–8000 Å in diameter), which provide channels through the particles, and connected **diffusion pores** (800–1500 Å in diameter), which line the through pores and have very short diffusion path lengths (Figure 5.16B). This combination

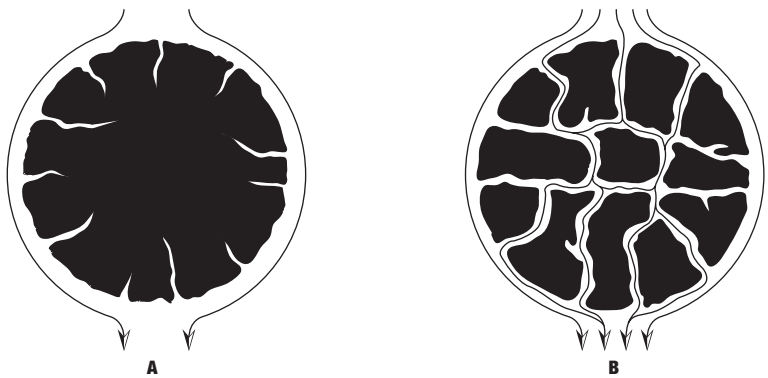

FIGURE 5.16 Transport of biomolecules through chromatographic media. **A** Conventional support particles. **B** POROS particles for perfusion chromatography.

pore system increases the porosity and the effective surface area of the particles and results in improved resolution and shorter analysis times (30 seconds to 3 minutes for POROS versus 30 minutes to several hours for conventional media).

POROS media, made by copolymerization of styrene and divinylbenzene, have high mechanical strength and are resistant to many solvents and chemicals. The functional surface chemistry of the particles can be modified to provide supports for many types of chromatography, including ion exchange, hydrophobic interaction, immobilized metal affinity, reversed phase, group-selective affinity, and conventional bioaffinity. Perfusion chromatography has been applied with success to the separation of peptides, proteins, and polynucleotides on both preparative and analytical scales.

In addition to high resolution and short analysis times, perfusion chromatography has the advantage of improved recovery of biological activity because active biomolecules spend less time on the column, where denaturing conditions may exist.

G. AFFINITY CHROMATOGRAPHY AND IMMUNOADSORPTION

The more conventional chromatographic procedures that we have studied up to this point rely on rather nonspecific physicochemical interactions between a sorbent and an analyte. The molecular characteristics of net charge, size, and polarity do not provide a basis for high selectivity in the separation and isolation of biomolecules. The desire for more specificity in chromatographic separations has led to the development of **affinity chromatography**. This technique offers the ultimate in specificity—separation on the basis of biological interactions. The biological function displayed by most macromolecules (antibodies, transport proteins, enzymes, nucleic acids, polysaccharides, receptor proteins, etc.) is a result of recognition of and interaction with specific molecules called **ligands**. This is illustrated by Equation 5.7, where M represents a macromolecule and L a smaller molecule or ligand. The two molecules interact in a specific manner to form a complex, L : M

$$L + M \rightleftharpoons L : M \longrightarrow \text{biological response} \qquad \textbf{(Eq. 5.7)}$$

In a biological system, the formation of the complex often triggers some response such as immunological action, control of a metabolic process, hormone action, catalytic breakdown of a substrate, or membrane transport. The biological response depends on proper molecular recognition and binding as shown in the reaction. The most common example of Equation 5.7 is the interaction that occurs between an enzyme molecule, E, and a substrate, S, with reversible formation of an ES complex. The biological event resulting from this interaction is the transformation of S to a metabolic product, P. Only the first step in Equation 5.7, formation of the complex, is of concern in affinity chromatography (see Chapter 8, Section B, p. 250).

In practice, affinity chromatography requires the preparation of an insoluble sorbent, to which appropriate ligand molecules (L) are covalently affixed. Thus, ligand molecules are immobilized on the stationary support. The affinity support is packed into a column through which a mixture containing

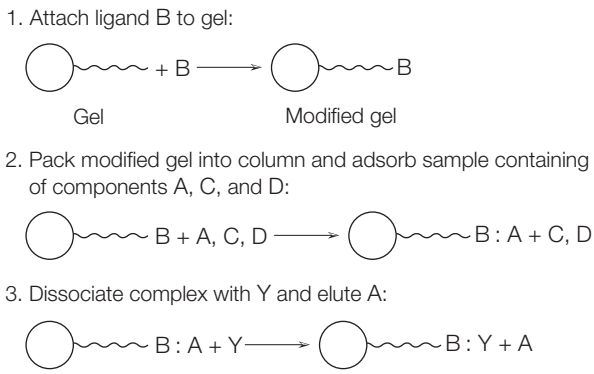

FIGURE 5.17 Purification of a macromolecule, **A,** by affinity chromatography. Ligand **B,** which has a specific affinity for **A,** is immobilized on the gel. **Y** represents an eluting agent that causes dissociation of **A**.

the desired macromolecule, M, is allowed to percolate. There are many types of molecules in the mixture, especially if it is a crude cell extract, but only macromolecules that recognize and bind to immobilized L are retarded in their movement through the column. After the nonbinding molecules have washed through the column, the desired macromolecules are eluted by gentle disruption of the L:M complex. Study Figure 5.17 for an illustration of affinity chromatography.

Affinity chromatography can be applied to the isolation and purification of virtually all biological macromolecules. It has been used to purify nucleic acids, enzymes, transport proteins, antibodies, hormone-receptor proteins, drug-binding proteins, neurotransmitter proteins, and many others.

Successful application of affinity chromatography requires careful design of experimental conditions. The essential components, which are outlined in the following subsections, are: (1) creation and preparation of a stationary matrix with immobilized ligand, and (2) design of column development and eluting conditions.

Chromatographic Media

Selection of the matrix used to immobilize a ligand requires consideration of several properties. The stationary supports used in gel-exclusion chromatography are found to be quite suitable for affinity chromatography because: (1) they are physically and chemically stable under most experimental conditions, (2) they are relatively free of nonspecific adsorption effects, (3) they have satisfactory flow characteristics, (4) they are available with very large pore sizes, and (5) they have reactive functional groups to which an appropriate ligand may be attached.

Four types of media possess most of these desirable characteristics: agarose, polyvinyl, polyacrylamide, and controlled-porosity glass (CPG) beads. Highly porous agarose beads such as Sepharose 4B (Amersham-Pharmacia-LKB-Hoefer) and Bio-Gel A-150 (Bio-Rad Laboratories) have virtually all of these characteristics and are the most widely used matrices. Polyacrylamide gels such as Bio-Gel P-300 (Bio-Rad) display many of the recommended features; however, their porosity is not especially high.

The Immobilized Ligand

The ligand, B, in Figure 5.17 can be selected only after the nature of the macromolecule to be isolated is known. When a hormone-receptor protein is to be purified by affinity chromatography, the hormone itself is an ideal candidate for the ligand. For antibody isolation, an antigen or hapten may be used as the ligand. If an enzyme is to be purified, a substrate analog, inhibitor, cofactor, or effector may be used as the immobilized ligand. The actual substrate molecule may be used as a ligand, but only if column conditions can be modified to avoid catalytic transformation of the bound substrate.

In addition to the foregoing requirements, the ligand must display a strong, specific, but reversible interaction with the desired macromolecule and it must have a reactive functional group for attachment to the matrix. It should be recognized that several types of ligand may be used for affinity purification of a particular macromolecule. Of course, some ligands will work better than others, and empirical binding studies can be performed to select an effective ligand.

Attachment of Ligand to Matrix

Several procedures have been developed for the covalent attachment of the ligand to the matrix. All procedures for gel modification proceed in two separate chemical steps: (1) activation of the functional groups on the matrix, and (2) joining of the ligand to the functional group on the matrix. The attachment method must leave the ligand in a form and position capable of binding to the desired macromolecule.

A wide variety of activated gels is now commercially available. The most widely used are described as follows.

Cyanogen Bromide-Activated Agarose

This gel is especially versatile because all ligands containing primary amino groups are easily attached to the agarose. It is available under the trade name CNBr-activated Sepahrose 4B. Since the gel is extremely reactive, very gentle conditions may be used to couple the ligand. One disadvantage of CNBr activation is that small ligands are coupled very closely to the matrix surface; macromolecules, because of steric repulsion, may not be able to interact fully with the ligand. The procedure for CNBr activation and ligand coupling is outlined in Figure 5.18A.

6-Aminohexanoic Acid (CH)-Agarose and 1,6-Diaminehexane (AH)-Agarose

These activated gels overcome the steric interference problems stated above by positioning a six-carbon spacer arm between the ligand and the matrix. Ligands with free primary amino groups can be covalently attached to CH-agarose, whereas ligands with free carboxyl groups can be coupled to AH-agarose. The attachment of ligands to AH and CH gels is outlined in Figure 5.18B,C.

Carbonyldiimidazole (CDI)-Activated Supports

Reaction with CDI produces gels that contain uncharged N-alkylcarbamate groups (see Figure 5.18D). CDI-activated agarose, dextran, and polyvinyl acetate are sold by Pierce Biotechnology Co. under the trade name Reacti-Gel.

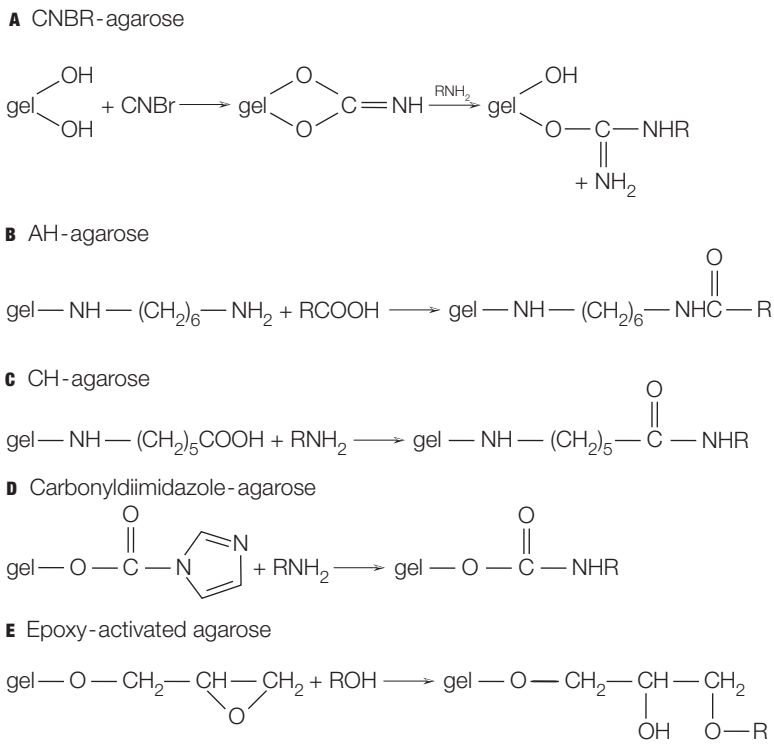

FIGURE 5.18 Attachment of specific ligands to activated gels. R = ligands.

Epoxy-Activated Agarose

The structure of this gel is shown in Figure 5.18E. It provides for the attachment of ligands containing hydroxyl, thiol, or amino groups. The hydroxyl groups of mono-, oligo-, and polysaccharides can readily be attached to the gel.

Group-Specific Adsorbents

The affinity materials described up to this point are modified with a ligand having specificity for a particular macromolecule. Therefore, each time a biomolecule is to be isolated by affinity chromatography, a new adsorbent must be designed and prepared. Ligands of this type are called substance specific. In contrast, **group-specific adsorbents** contain ligands that have affinity for a class of biochemically related substances. Table 5.5 shows several commercially available group-specific adsorbents and their specificities. The principles behind binding of nucleic acids and proteins to group-specific adsorbents depend on the actual affinity adsorbent. In most cases, the immobilized ligand and macromolecule (protein or nucleic acid) interact through one or more of the following forces: hydrogen bonding, hydrophobic interactions, and/or covalent interactions. Some group-specific adsorbents deserve special attention. Phenyl- and octyl-Sepharose are gels used for **hydrophobic interaction chromatography**. These adsorbent materials separate proteins on the basis of their hydrophobic character. Because most proteins contain hydrophobic amino acid side chains, this method is widely used. Octyl-Sepharose is strongly hydrophobic; hence, it binds strongly to nonpolar

TABLE 5.5 Group-Specific Adsorbents Useful in Biochemical Applications

Group-Specific Adsorbent	Group Specificity
5′-AMP-agarose	Enzymes that have NAD^+ cofactor, ATP-dependent kinases
Benzamidine–Sepharose	Serine proteases
Boronic acid–agarose	Compounds with cis-diol groups, sugars: catecholamines, ribonucleotides, glycoproteins
Cibracron blue–agarose	Enzymes with nucleotide cofactors (dehydrogenases, kinases, DNA polymerases); serum albumin
Concanavalin A–agarose	Glycoproteins and glycolipids
Heparin–Sepharose	Nucleic acid–binding proteins, restriction endonucleases, lipoproteins
Iminodiacetate–agarose	Proteins with affinity for metal ions, serum proteins, interferons
Lentil lectin–Sepharose	Detergent-soluble membrane proteins
Lysine–Sepharose	Nucleic acids
Octyl-Sepharose	Weakly hydrophobic proteins, membrane proteins
Phenyl-Sepharose	Strongly hydrophobic proteins
Poly(A)-agarose	Nucleic acids containing poly(U) sequences, mRNA-binding proteins
Poly(U)-agarose	Nucleic acids containing poly(A) sequences, poly(U)-binding proteins
Protein A–agarose	IgG-type antibodies
Thiopropyl-Sepharose	—SH containing proteins

proteins. Phenyl-Sepharose is more weakly hydrophobic; therefore, it is more likely to reversibly bind strongly hydrophobic proteins.

The use of thiopropyl-Sepharose and boronic acid–agarose is an example of **covalent chromatography**, since relatively strong but reversible covalent bonds are formed between the affinity gel and specific macromolecules.

Metal affinity chromatography is a relatively new method that separates proteins on the basis of metal binding.

The availability of a great variety of group-specific adsorbents in prepacked columns makes possible the combination of FPLC and affinity chromatography for the separation and purification of proteins.

Immunoadsorption

One of the most effective modifications of affinity chromatography is **immunoaffinity,** also called **immunoadsorption**. The unique high specificity of antibodies for their antigens is exploited for the purification of antigens. The interaction between antigen and antibody is very selective and very strong, perhaps the most specific in affinity chromatography. In practice, the antibody is immobilized on a column support. The antibody may be obtained by immunizing a rabbit, but you must have relatively large amounts of the purified protein antigen. The better choice is to make monoclonal antibodies against the antigen. When a mixture containing several other proteins along with the protein antigen

is passed through the column, only antigen binds; the other proteins wash off the column. Because antigen:antibody pairs form very strong complexes, it is not especially difficult to get the protein antigen to bind to the column. There is often difficulty, though, in eluting the bound protein without denaturing it. Effective eluting agents for disrupting the complexes and eluting the antigen are discussed in the next section.

Protein A-agarose in Table 5.5 is an example of immunoaffinity; however, this adsorbent does not recognize specific antibodies but, rather, the general family of immunoglobulin G antibodies.

Experimental Procedure for Affinity Chromatography

Although the procedure is different for each type of substance isolated, a general experimental plan is outlined here. Figure 5.19 provides a step-by-step plan in flowchart form. Many types of matrix-ligand systems are commercially available and the costs are reasonable, so it is not always necessary to spend valuable laboratory time for affinity gel preparation. Even if a specific gel is not available, time can be saved by purchasing preactivated gels for direct attachment of the desired ligand. Once the gel is prepared, the procedure is similar to that described earlier. The major difference is the use of shorter columns. Most affinity gels have high capacities and column beds less than 10 cm in length may be used. A second difference is the mode of elution. Ligand-macromolecule complexes immobilized on the column are held together by hydrogen bonding, ionic interactions, and hydrophobic effects. Any agent that diminishes these forces causes the release and elution of the macromolecule from the column. The elution step in affinity chromatography is represented in Figure 5.17, Step 3, where a general eluting agent, Y, dissociates the desired macromolecule, A. The common methods of elution are change of buffer pH, increase of buffer ionic strength, affinity elution, and chaotropic agents. The choice of elution method depends on many factors, including the types of forces responsible for complex formation and the stability of the ligand matrix and isolated macromolecule.

Buffer pH or Ionic Strength

If ionic interactions are important for complex formation, a change in pH or ionic strength weakens the interaction by altering the extent of ionization of ligand and macromolecule. In practice, either a decrease in pH or a gradual increase in ionic strength (continual or stepwise gradient) is used.

Affinity Elution

In this method of elution, a selective substance added to the eluting buffer competes for binding to the ligand or for binding to the adsorbed macromolecule.

Chaotropic Agents

If gentle and selective elution methods do not release the bound macromolecule, as may be the case in immunoadsorption, then mild denaturing agents can be added to the buffer. These substances deform protein and nucleic acid structure and decrease the stability of the complex formed on the affinity gel. The most useful agents are urea, guanidine · HCl, CNS^-, ClO_4^-, and CCl_3COO^-. These

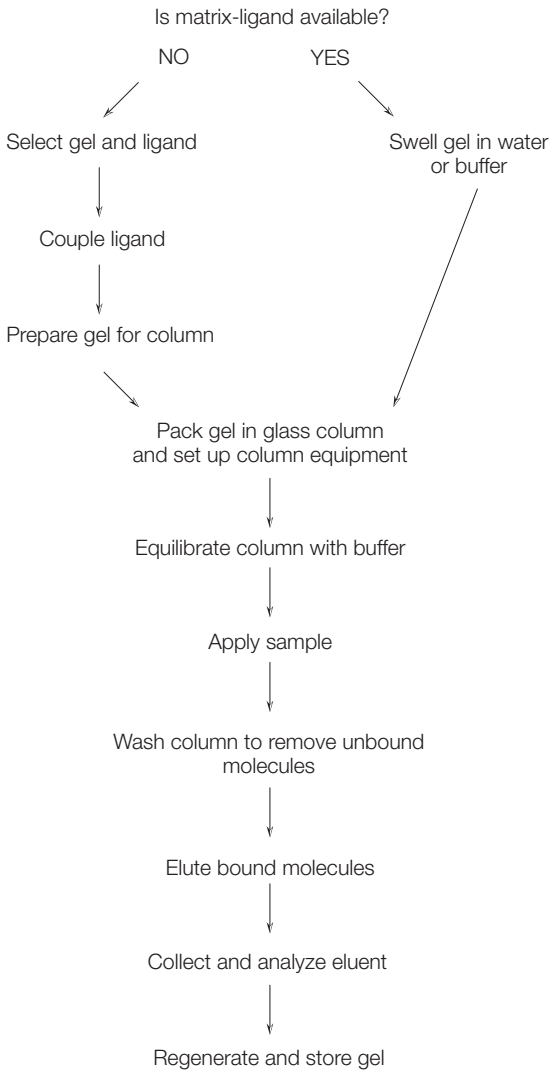

FIGURE 5.19 Experimental procedure for affinity chromatography.

substances should be used with care, as they may cause irreversible structural changes in the isolated macromolecule.

The application of affinity chromatography is limited only by the imagination of the investigator. Every year, literally hundreds of research papers appear with new and creative applications of affinity chromatography. Figure 5.20 illustrates the purification of α-chymotrypsin by affinity chromatography on immobilized D-tryptophan methyl ester. α-chymotrypsin can recognize and bind, but not chemically transform, D-tryptophan methyl ester. The enzyme catalyzes the hydrolysis of L-tryptophan methyl ester. The impure α-chymotrypsin mixture was applied to the gel, D-tryptophan methyl ester coupled to CH-Sepharose 4B, and the column washed with Tris buffer. At the point shown by the arrow, the eluent was changed to 0.1 *M* acetic acid. The decrease in pH caused release of α-chymotrypsin from the column.

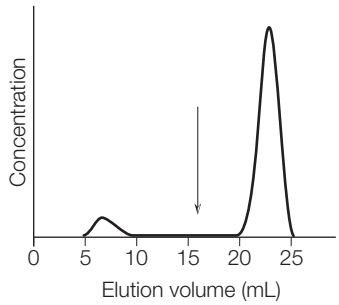

FIGURE 5.20 Purification of α-chymotrypsin by affinity chromatography on immobilized D-tryptophan methyl ester. From ***Affinity Chromatography: Principles and Methods***. Pharmacia (Uppsala, Sweden).

STUDY EXERCISE 5.7 Affinity Chromatography

You have discovered that leaves from the quaking aspen tree contain an enzyme that catalyzes the transfer of a phosphoryl group from ATP to various carbohydrates. You wish to purify the enzyme, a kinase, by affinity chromatography. Select two stationary phases from Table 5.5 that might be effective in this separation.

H. MEMBRANE-BASED CHROMATOGRAPHY

Most of the column chromatographic stationary supports discussed up to this point were based on particles, usually in the form of synthetic resin beads. Biotech labs and pharmaceutical companies involved in the manufacture of protein- and nucleic acid-based drugs require effective purification methods that offer large capacity and speed and are usually dependent on chromatography. There are several limitations to the use of bead-based stationary supports, and it is challenging to improve separating ability and speed especially in purifying large biomolecules ($>$ 200,000 daltons). Separation of biomolecules depends on their binding to functional groups (ion exchange, affinity, etc.) that are often present inside the beads and thus not readily available for binding of larger molecules. Increasing the number of functional groups by increasing the height of a column is not an option, as the resin beads are compressible and thus cause a reduction in the flow rate.

Many of the limitations of conventional bead columns may be overcome by the use of synthetic, microporous membranes as stationary supports. These membranes offer a three-dimensional structure with open pores, which are readily available to larger biomolecules (Figure 5.21). Research on chromatography membranes shows that movement of molecules takes place by convection rather than diffusion, which enhances the distribution of molecules throughout the support. Other advantages of membrane-based chromatography compared to conventional bead columns include higher flow rates (up to 100 times faster), higher capacity (10 times greater), and the fact that the membranes can be packed into layers, which greatly improves the effectiveness of biomolecule separation.

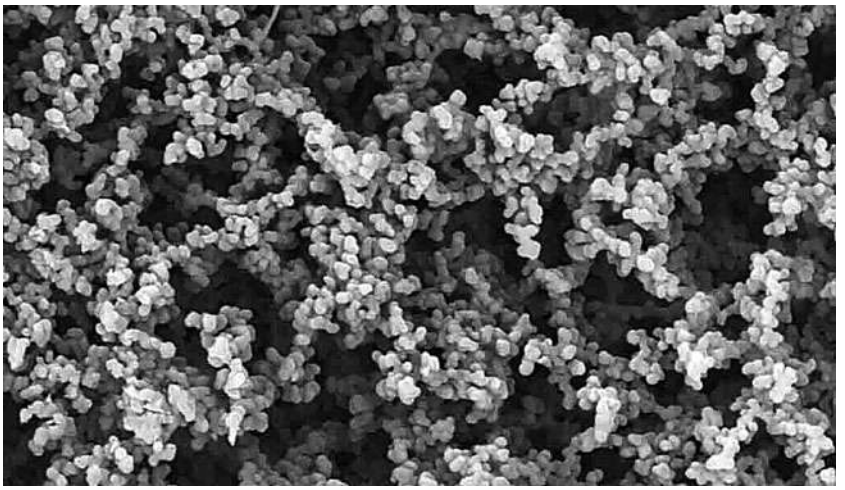

FIGURE 5.21 The inside of an ion-exchange chromatography membrane showing the readily accessible pores. *Photo courtesy of Pall Corporation,* www.pall.com.

Membranes are available for several chromatographic modes including ion exchange, affinity, hydrophobic interaction, and reverse phase. The ion-exchange membranes have a polyethersulfone base modified with sulfonic acid groups (cation exchanger) or quaternary amines (anion exchanger). The membranes have been found to be effective in separating and purifying proteins, plasmid DNA, and other biomolecules. Membranes are available in disposable plastic cartridges (5 mL, 140 mL, or 5000 mL volumes), which can be linked to HPLC or FPLC systems or used alone with a peristaltic pump or syringe (Figure 5.22). Membrane cartridges are designed so they can be set up in flow systems, which allows for purification of large sample sizes as used in industry (Figure 5.23).

FIGURE 5.22 Disposable membrane cartridges. *Photo courtesy of Pall Corporation,* www.pall.com.

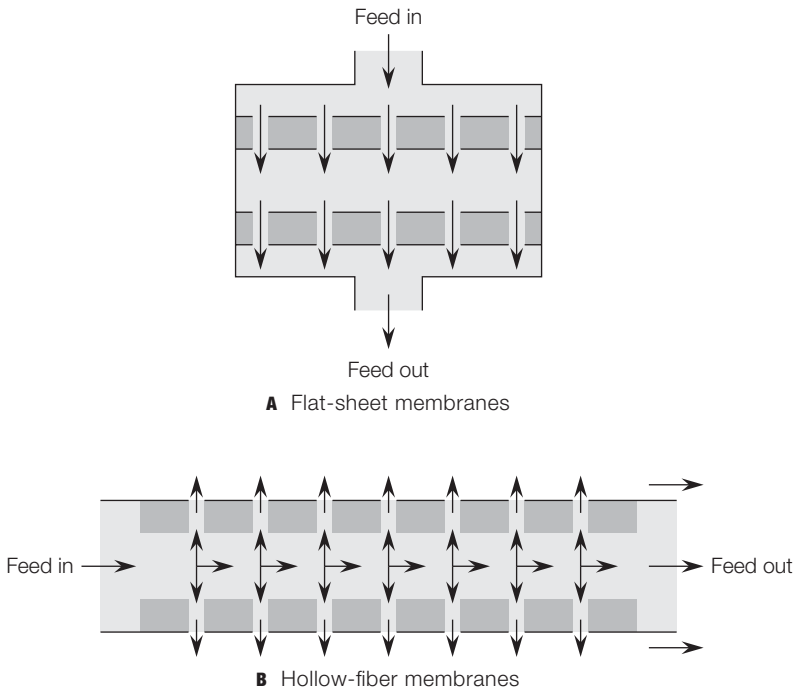

FIGURE 5.23 Flow options in membrane-based chromatography. **A** Flat-sheet and **B** Hollow-fiber membranes.

Study Problems

1. Amino acid analyzers are instruments that automatically separate amino acids by cation-exchange chromatography. Predict the order of elution (first to last) for each of the following sets of amino acids at pH = 4.
   (a) Gly, Asp, His
   (b) Arg, Glu, Ala
   (c) Phe, His, Glu
2. Predict the relative order of paper chromatography R_f values for the amino acids in the following mixture: Ser, Lys, Leu, Val, and Ala. Assume that the developing solvent is *n*-butanol, water, and acetic acid.
3. In what order would the following proteins be eluted from a DEAE-cellulose ion exchanger by an increasing salt gradient. The pH_I is listed for each protein.

Egg albumin, 4.6	Cytochrome *c*, 10.6
Pepsinogen, 1.0	Myoglobin, 6.8
Serum albumin, 4.9	Hemoglobin, 6.8

4. Describe the various detection methods that can be used in HPLC. What types of biomolecules are detected by each method?
5. Draw the elution curve (A_{280} vs. fraction number) obtained by passing a mixture of the following proteins through a column of Sephadex G-100. The molecular mass is given for each protein.

Myoglobin, 16,900	Myosin, 524,000
Catalase, 222,000	Serum albumin, 68,500
Cytochrome *c*, 13,370	Chymotrypsinogen, 23,240

6. Briefly describe how you would experimentally measure the exclusion limit for a Sephadex gel whose bottle has lost its label.
7. Name three enzymes that you predict will bind to the affinity support, 5′-AMP-agarose.
8. Explain the elution order of amino acids in Figure 5.11.
9. Describe how you would use affinity elution to remove the enzyme alcohol dehydrogenase bound to a Cibracron blue–agarose column.
10. You have read in your botany textbook that bean leaves contain an enzyme that catalyzes the hydrolysis of the methyl esters of aromatic amino acids (for example, the methyl ester of phenylalanine). You wish to design a plan for isolating and purifying the enzyme. Assume that your last step of purification is to be affinity chromatography. Describe an affinity sorbent that might be effective in purifying the protein.
11. In affinity chromatography and immunoadsorption, analytes are usually tightly bound to the sorbent. Which of the following types of bonding are important in forming these complexes?
    Hydrogen bonding
    Covalent bonds between carbon atoms
    Ionic bonds
    Hydrophobic interactions
    Van der Waals forces
12. You have isolated an unknown protein and wish to estimate its molecular weight using column gel filtration with several standard proteins. The gel material is Sephacryl S-100. The following elution volumes were measured.

Protein	MW	Elution volume (mL)
Hemoglobin	64,500	10.1
Egg albumin	45,000	14.5
Chymotrypsinogen	23,200	25.0
Myoglobin	16,900	28.2
Cytochrome *c*	13,000	31.0
Unknown	?	7.5

    What is the approximate molecular weight of the unknown protein?
    Hint: Prepare a graph like in Figure 5.9.
13. Which gel filtration medium would be more effective in separating the six proteins in Study Problem 12, Sephadex G-50 or G-100? Why?
14. Which column chromatographic method is better to separate the proteins below, ion exchange or gel filtration?

Hemoglobin	MW = 64,500;	isoelectric pH = 6.8
Myoglobin	MW = 17,000;	isoelectric pH = 7.0

15. Use information from Chapter 2 to help you find the following:
    (a) a recent research article on the purification of egg white lysozyme by membrane-based chromatography
    (b) the availability of spin columns for membrane-based chromatography
    (c) chiral chromatography using membranes

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Perfusion chromatography.

http://www.separationsnow.com/coi/cda/home.cda?chId=0
Resources for chromatography.

http://www.chiraltech.com
Supplier of chiral columns and chromatography materials.

http://www1.gelifesciences.com/aptrix/upp01077.nsf/content/na_homepage
On Home Page, select "Protein purification."

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Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER 6

CHARACTERIZATION OF PROTEINS AND NUCLEIC ACIDS BY ELECTROPHORESIS

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Electrophoresis is an analytical tool that allows biochemists to examine the differential movement of charged molecules in an electric field. A. Tiselius, a Swede who invented the technique in the 1930s, performed experiments in free solution that were severely limited by the effects of diffusion and convection currents. Modern electrophoretic techniques use a polymerized gel-like matrix, which is more stable as a support medium. The sample to be analyzed is applied to the medium as a spot or thin band; hence, the term **zonal** electrophoresis is often used. The migration of molecules is influenced by: (1) the size, shape, charge, and chemical composition of the molecules to be separated; (2) the rigid, mazelike matrix of the gel support; and (3) the applied electric field. Electrophoresis, which is a relatively rapid, inexpensive, and convenient technique, is capable of analyzing and purifying many different types of biomolecules, but is especially effective with proteins and nucleic acids. The newest version of the analytical technique, **capillary electrophoresis (CE),** provides extremely high resolution and is useful for analysis of both large and small molecules. CE has been found to be especially useful in the analysis of pharmaceuticals.

Proteomics, the discipline that attempts systematic, large-scale studies on the structure and function of gene products in an organism or cell, is expanding rapidly because of the availability of electrophoresis (especially two-dimensional techniques) to analyze proteins and peptides.

Even though electrophoresis has been studied for more than 80 years, it has been a challenge to provide an accurate, theoretical description of the electrophoretic movement of molecules in a gel support. However, the lack of theoretical understanding has not hampered growth in the use of the technique in separating and characterizing a wide variety of biomolecules.

A. THEORY OF ELECTROPHORESIS

Introduction

The movement of a charged molecule in a medium subjected to an electric field is represented by Equation 6.1.

>> $$v = \frac{Eq}{f}$$ **(Eq. 6.1)**

where

E = the electric field in volts/cm

q = the net charge on the molecule

f = frictional coefficient, which depends on the mass and shape of the molecule

ν = the velocity of the molecule

The charged particle moves at a velocity that depends directly on the electric field (E) and charge (q), but inversely on a counteracting force generated by the viscous drag (f). The applied voltage represented by E in Equation 6.1 is usually held constant during electrophoresis, although some experiments are run under conditions of constant current (where the voltage changes with resistance) or constant power (the product of voltage and current). Under constant-voltage conditions, Equation 6.1 shows that the movement of a charged molecule depends only on the ratio q/f. For molecules of similar conformation (for example, a collection of linear DNA fragments or spherical proteins), f varies with size but not shape; therefore, the only remaining variables in Equation 6.1 are the charge (q) and mass dependence of f, meaning that under such conditions molecules migrate in an electric field at a rate proportional to their charge-to-mass ratio.

Theory and Practice

The movement of a charged particle in an electric field is often defined in terms of **mobility,** μ, the velocity per unit of electric field (Equation 6.2).

>> $$\mu = \frac{v}{E}$$ **(Eq. 6.2)**

This equation can be modified using Equation 6.1.

>> $$\mu = \frac{Eq}{Ef} = \frac{q}{f}$$ **(Eq. 6.3)**

In theory, if the net charge, q, on a molecule is known, it should be possible to measure f and obtain information about the hydrodynamic size and shape of that molecule by investigating its mobility in an electric field. Attempts to define f by electrophoresis have not been successful, primarily because Equation 6.3 does not adequately describe the electrophoretic process. Important factors that are not accounted for in the equation are interaction of migrating molecules with the support medium and shielding of the molecules by buffer ions. This means that electrophoresis is not useful for describing specific details about the shape of a molecule. Instead, it has been applied to the analysis of purity and size of macromolecules. Each molecule in a mixture is expected to have a unique charge and size, and its mobility in an electric field will therefore be unique. This expectation forms the basis for analysis and separation by all electrophoretic methods. The technique is especially useful for the analysis of amino acids, peptides, proteins, nucleotides, nucleic acids, and other charged molecules, including pharmaceuticals.

B. METHODS OF ELECTROPHORESIS

All modes of electrophoresis are based on the principles just outlined. The major difference among the various methods is the type of support medium. Cellulose and cellulose acetate are used as a support medium for low-molecular-weight biochemicals like amino acids and carbohydrates. Polyacrylamide and agarose gels are widely used as support media for larger molecules. In capillary electrophoresis, several different types of support media, including the natural, untreated surfaces inside a silica narrow bore capillary tube, are used. Geometries (vertical and horizontal), buffers, and electrophoretic conditions provide many different experimental arrangements for the variety of methods described here.

Polyacrylamide Gel Electrophoresis (PAGE)

Gels formed by polymerization of acrylamide have several positive features in electrophoresis: (1) high resolving power for small and moderately sized proteins and nucleic acids (up to approximately 1×10^6 daltons), (2) acceptance of relatively large sample sizes, (3) minimal interactions of the migrating molecules with the matrix, and (4) physical stability of the matrix. Recall from the earlier discussion of gel filtration (Chapter 5, p. 132) that gels can be prepared with different pore sizes by changing the concentration of cross-linking agents. Electrophoresis through polyacrylamide gels leads to enhanced resolution of sample components because the separation is based on both molecular sieving and electrophoretic mobility. The order of molecular movement in gel filtration and PAGE is very different, however. In gel filtration, large molecules migrate through the matrix faster than small molecules. The opposite is the case for gel electrophoresis, where there is no void volume in the matrix, but only a continuous network of pores throughout the gel. The electrophoresis gel is comparable to a single bead in gel filtration. Therefore, large molecules do not move easily through the medium, and the order of movement is small molecules followed by large molecules.

Preparation of Gels

Polyacrylamide gels are prepared by the free radical polymerization of acrylamide and the cross-linking agent *N*,*N*′-methylene-bis-acrylamide (Figure 6.1). Chemical polymerization is controlled by an initiator-catalyst system, ammonium persulfate–*N*,*N*,*N*′,*N*′-tetramethylethylenediamine (TEMED). Photochemical polymerization may be initiated by riboflavin in the presence of ultraviolet (UV) radiation. A standard gel for protein separation is 7.5% polyacrylamide. It can be used over the molecular size range of 10,000 to 1,000,000 daltons; however, the best resolution is obtained in the range of 30,000 to 300,000 daltons. The resolving power and molecular size range of a gel depend on the concentrations of acrylamide and bis-acrylamide (see Table 6.1 for effective ranges of protein separation). Lower concentrations give gels with larger pores, allowing analysis of higher-molecular-weight biomolecules. In contrast, higher concentrations of acrylamide give gels with smaller pores, allowing analysis of lower-molecular-weight biomolecules (see Table 6.2 for effective ranges of DNA separation).

Polyacrylamide gel electrophoresis has been done using either of two instrumental arrangements, column or slab. Column gels are rarely used today, but they do have historical significance as they are important forerunners of

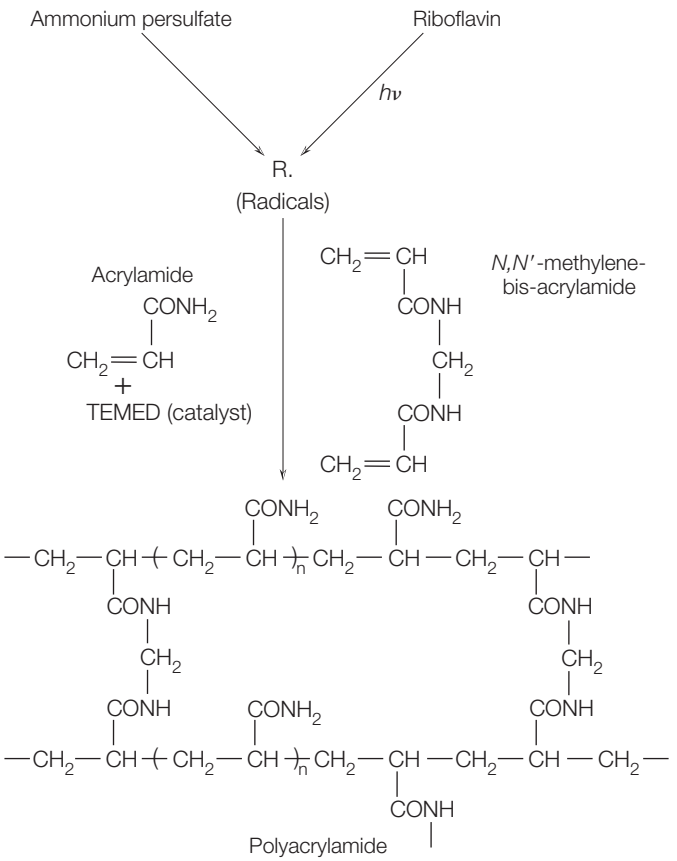

FIGURE 6.1
Chemical reactions illustrating the copolymerization of acrylamide and N,N′-methylene-bis-acrylamide. See text for details.

TABLE 6.1 Separation of Proteins by PAGE. The recommended concentrations of acrylamide (% w/v) are given that will best separate proteins of different molecular weight ranges

Protein Molecular Weight Range	Recommended % Acrylamide (w/v)[1]
<10,000	>15%
10,000–80,000	10–15%
20,000–150,000	5–10%
>100,000	3–5%

[1]Ratio of acrylamide to bis-acrylamide, 37.5:1 (g:g).

TABLE 6.2 Effective Range of Separation of DNA by PAGE

Acrylamide[1] (% w/v)	Range of Separation (bp)	Bromophenol Blue[2]	Xylene Cyanol[2]
3.5	1000–2000	100	450
5.0	80–500	65	250
8.0	60–400	50	150
12.0	40–200	20	75
20.0	5–100	10	50

[1] Ratio of acrylamide to bis-acrylamide, 20:1.
[2] The numbers (in bp) represent the size of DNA fragment with the same mobility as the dye.

more modern slab gels. Figure 6.2 shows the typical arrangement for a column gel. Glass tubes (10 cm × 6 mm i.d.) are filled with a mixture of acrylamide, *N*,*N*′-methylene-bis-acrylamide, buffer, and free radical initiator-catalyst. Polymerization occurs in 30 to 40 minutes. The gel column is inserted between two separate buffer reservoirs. The upper reservoir usually contains the cathode (−) and the lower the anode (+). Gel electrophoresis is usually carried out at basic pH, where most biological polymers are anionic; hence, they move down toward the anode. The sample to be analyzed is layered on top of the gel, and voltage is applied to the system. DNA and many proteins are colorless, so a reagent dye must be added to monitor the rate of electrophoresis. A "tracking dye" is applied, which moves more rapidly through the gel than the sample components. When the dye band has moved to the opposite end of the column, the voltage is turned off and the gel is removed from the column and stained with a dye. Chambers for column gel electrophoresis, instruments that hold several glass tubes, are commercially available or can be constructed from inexpensive materials.

Slab Gel Electrophoresis

Slab gels are now much more widely used than column gels. A slab gel on which several samples may be analyzed is more convenient to make and use than several individual column gels. Slab gels also offer the advantage that all samples are

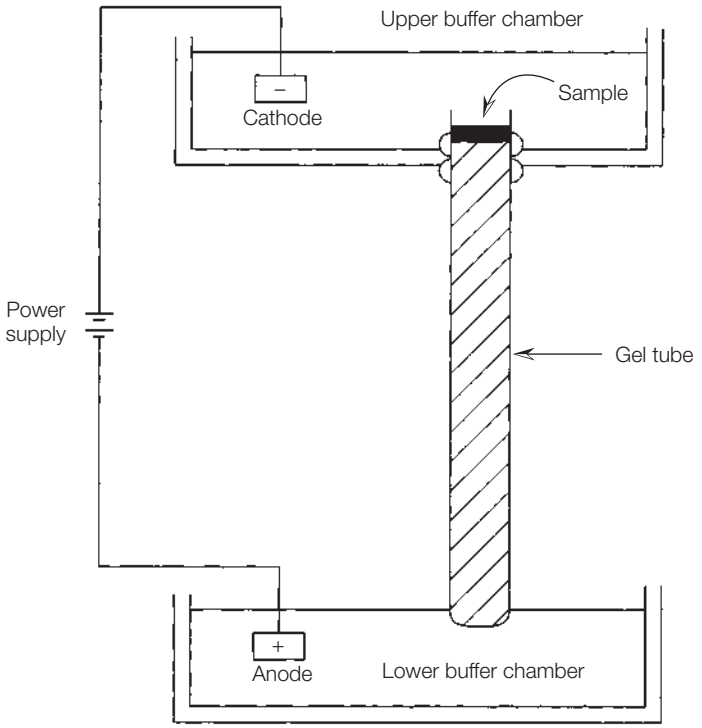

FIGURE 6.2 A column gel for polyacrylamide gel electrophoresis.

analyzed in a matrix environment that is identical in composition compared to glass tubes, which may have slightly different compositions. A typical vertical slab gel apparatus is shown in Figure 6.3. The polyacrylamide slab is prepared between two glass plates that are separated by spacers (Figure 6.4). The spacers allow a uniform slab thickness of 0.5 to 2.0 mm, which is appropriate for analytical and some preparative procedures. Slab gels are usually 8 × 10 cm or 10 × 10 cm, but for nucleotide sequencing, slab gels as large as 20 × 40 cm are often required.

A plastic "comb" inserted into the top of the slab gel during polymerization forms indentations in the gel that serve as sample wells. Up to 20 sample wells may be formed. After polymerization, the comb is carefully removed and the wells are rinsed thoroughly with buffer to remove salts and any unpolymerized acrylamide. The gel plate is clamped into place between two buffer reservoirs, a sample is loaded into each well, and voltage is applied. For visualization, the slab is removed and stained with an appropriate dye, or in some cases, the gel may be prestained with the dye before electrophoresis.

Perhaps the most difficult and inconvenient aspect of polyacrylamide gel electrophoresis is the preparation of gels. The monomer, acrylamide, is a neurotoxin and a carcinogenic agent; hence, special handling is required. Other necessary reagents including catalysts and initiators also require special handling and are unstable. In addition, it is difficult to make gels that have reproducible thicknesses and compositions. Many researchers are now turning to the use of precast polyacrylamide gels. Several manufacturers now offer gels precast in glass or plastic cassettes. Gels for all experimental operations are available, including

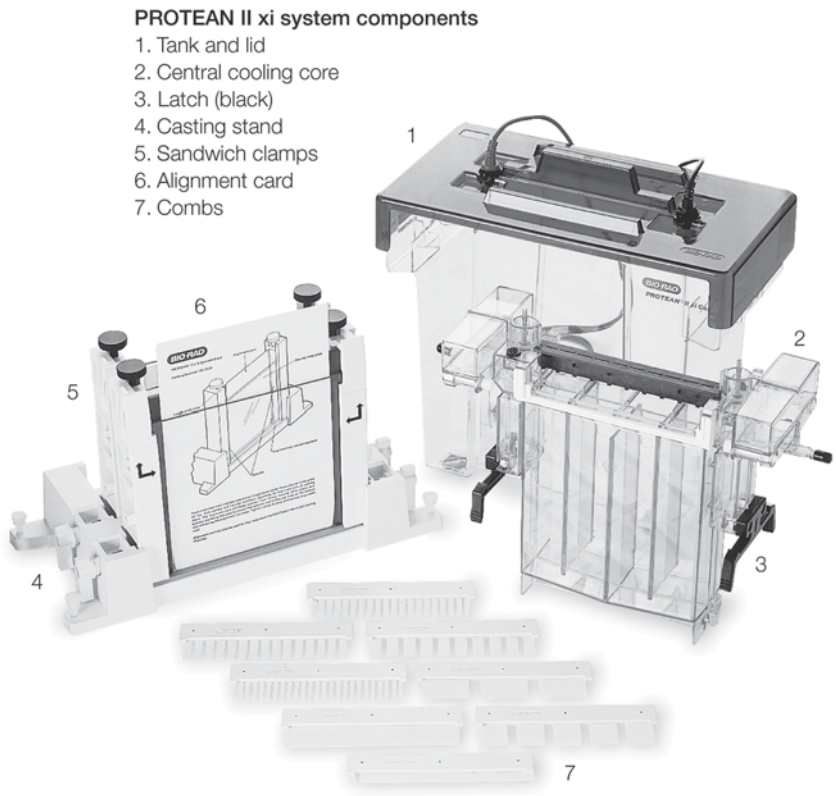

FIGURE 6.3 A vertical electrophoresis apparatus for slab gel analysis of proteins. *Permission to use the materials has been granted by Bio-Rad Laboratories, Inc.,* www.bio-rad.com.

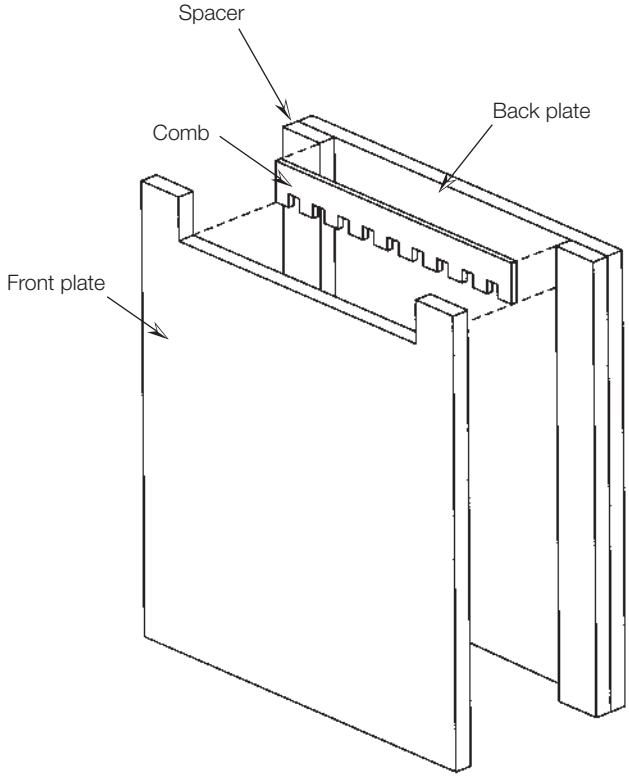

FIGURE 6.4 Arrangement of two glass plates with spacers to form a slab gel. The comb is used to prepare wells for placement of samples.

single percentage (between 3% and 27%) or gradient gel concentrations and a variety of sample well configurations and buffer chemistries. More details on precast gels will be given in Section C, Practical Aspects of Electrophoresis.

Several modifications of PAGE have greatly increased its versatility and usefulness as an analytical tool.

Discontinuous Gel Electrophoresis

The experimental arrangement for "disc" gel electrophoresis is shown in Figure 6.5. Three significant characteristics of this method are that: (1) there are two gel layers, a lower or **resolving gel** and an upper or **stacking gel;** (2) the

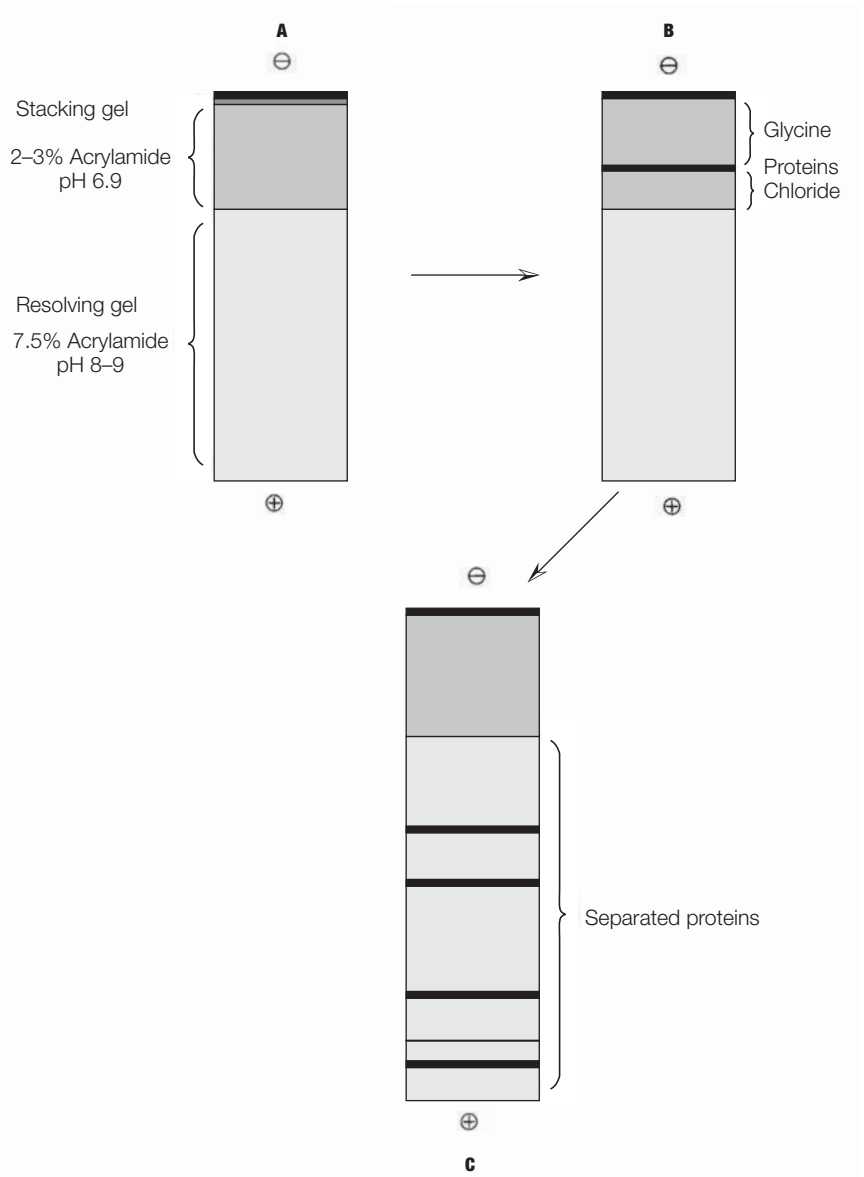

FIGURE 6.5 The process of disc gel electrophoresis. **A** Before electrophoresis. **B** Movement of chloride, glycinate, and protein through the stacking gel. **C** Separation of protein samples by the resolving gel.

buffers used to prepare the two gel layers are of different ionic strengths and pH; and (3) the stacking gel has a lower acrylamide concentration, so its pore sizes are larger. These three changes in the experimental conditions cause the formation of highly concentrated bands of sample in the stacking gel and greater resolution of the sample components in the lower gel. Sample concentration in the upper gel occurs in the following manner. The sample is usually dissolved in glycine-chloride buffer, pH 8 to 9, before loading on the gel. Glycine exists primarily in two forms at this pH, a zwitterion and an anion (Equation 6.4).

>> $$H_3\overset{+}{N}CH_2COO^- \rightleftharpoons H_2NCH_2COO^- + H^+$$ **(Eq. 6.4)**

The average charge on glycine anions at pH 8.5 is about −0.2. When the voltage is turned on, buffer ions (glycinate and chloride) and protein or nucleic acid sample move into the stacking gel, which has a pH of 6.9. Upon entry into the upper gel, the equilibrium of Equation 6.4 shifts toward the left, increasing the concentration of glycine zwitterion, which has no net charge and hence no electrophoretic mobility. In order to maintain a constant current in the electrophoresis system, a flow of anions must be maintained. Since most proteins and nucleic acid samples are still anionic at pH 6.9, they replace glycinate as mobile ions. Therefore, the relative ion mobilities in the stacking gel are chloride > protein or nucleic acid sample > glycinate. The sample will tend to accumulate and form a thin, concentrated band sandwiched between the chloride and glycinate as they move through the upper gel. Since the acrylamide concentration in the stacking gel is low (2% to 3%), there is little impediment to the mobility of the large sample molecules.

Now, when the ionic front reaches the lower gel with pH 8 to 9 buffer, the glycinate concentration increases and anionic glycine and chloride carry most of the current. The protein or nucleic acid sample molecules, now in a narrow band, encounter both an increase in pH and a decrease in pore size. The increase in pH would, of course, tend to increase electrophoretic mobility, but the smaller pores decrease mobility. The relative rate of movement of anions in the lower gel is chloride > glycinate > protein or nucleic acid sample. The separation of sample components in the resolving gel occurs as described in an earlier section on gel electrophoresis. Each component has a unique charge/mass ratio and a discrete size and shape, which directly influence its mobility. Disc gel electrophoresis yields excellent resolution and is the method of choice for analysis of proteins and nucleic acid fragments. Protein or nucleic acid bands containing as little as 1 or 2 μg can be detected by staining the gels after electrophoresis.

STUDY EXERCISE 6.1 PAGE

You are using the technique of nondenaturing PAGE to separate a mixture of two proteins, bovine serum albumin and bovine hemoglobin. Assume that you are using a buffer of pH 8.0 and a gel of 7.5% acrylamide, and that silver staining was used for detection. Show the results of your experiment by drawing a gel with dark bands for each protein.

Protein	pH_I	MW
Bovine serum albumin	4.9	65,000
Bovine hemoglobin	6.8	65,000

Sodium Dodecyl Sulfate–Polyacrylamide Gel Electrophoresis (SDS-PAGE)

If protein samples are treated so that they have a uniform charge, electrophoretic mobility then depends primarily on size (see Equation 6.3). The molecular weights of proteins may be estimated if they are subjected to electrophoresis in the presence of a detergent, sodium dodecyl sulfate (SDS), and a disulfide bond reducing agent, mercaptoethanol. This method is often called **denaturing electrophoresis**.

The electrophoretic techniques previously discussed are called **nondenaturing** or **"native" PAGE** and are used when an investigator requires that the protein analyzed still retains its biological activity. This would be the case when the protein is an enzyme or antibody, or contains a receptor binding site. The separation of proteins under these conditions in which they maintain their native conformation is influenced by both charge and size.

When protein molecules are treated with SDS, the detergent disrupts the secondary, tertiary, and quaternary structure to produce linear polypeptide chains coated with negatively charged SDS molecules. The presence of mercaptoethanol assists in protein denaturation by reducing all disulfide bonds. The detergent binds to hydrophobic regions of the denatured protein chain in a constant ratio of about 1.4 g of SDS per gram of protein. The bound detergent molecules carrying negative charges mask the native charge of the protein. In essence, polypeptide chains of a constant charge/mass ratio and uniform shape are produced. The electrophoretic mobility of the SDS-protein complexes is influenced primarily by molecular size: the larger molecules are retarded by the molecular sieving effect of the gel, and the smaller molecules have greater mobility. Empirical measurements have shown a linear relationship between the log molecular weight and the electrophoretic mobility (Figure 6.6).

In practice, a protein of unknown molecular weight and subunit structure is treated with 1% SDS and 0.1 *M* mercaptoethanol in electrophoresis buffer. A standard mixture of proteins with known molecular weights must also be subjected to electrophoresis under the same conditions. Two broad sets of standards are commercially available, one for low-molecular-weight proteins (molecular weight range 14,000 to 100,000) and one for high-molecular-weight proteins (45,000 to 200,000). Figure 6.7 shows a stained gel after electrophoresis of a standard protein mixture. (For details on stains and staining, see Section C.) After electrophoresis and dye staining, mobilities are measured and molecular weights determined graphically.

SDS-PAGE is valuable for estimating the molecular weight of protein subunits. This modification of gel electrophoresis finds its greatest use in characterizing the sizes and different types of subunits in oligomeric proteins. SDS-PAGE

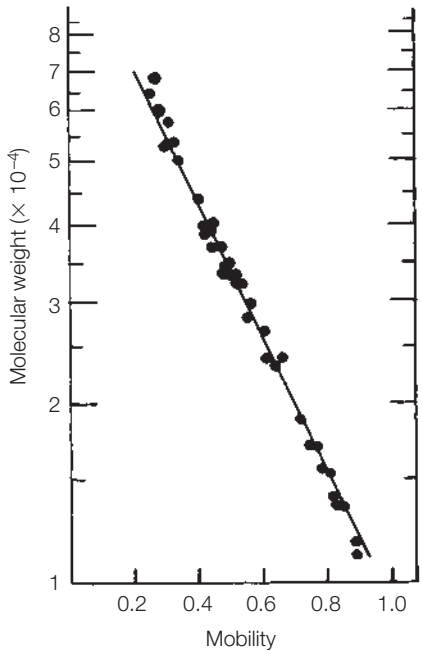

FIGURE 6.6 Graph illustrating the linear relationship between electrophoretic mobility of a protein and the log of its molecular weight. Thirty-seven different polypeptide chains with a molecular weight of 11,000 to 70,000 are shown. Gels were run in the presence of SDS. *From K. Weber and M. Osborn, J. Biol. Chem.* ***244,*** *4406 (1969). By permission of the copyright owner, the American Society for Biochemistry and Molecular Biology, Inc.*

is limited to a molecular weight range of 10,000 to 200,000. Gels of less than 2.5% acrylamide must be used for determining molecular weights above 200,000, but these gels do not set well and are very fragile because of minimal cross-linking. A modification using gels of agarose-acrylamide mixtures allows the measurement of molecular weights above 200,000.

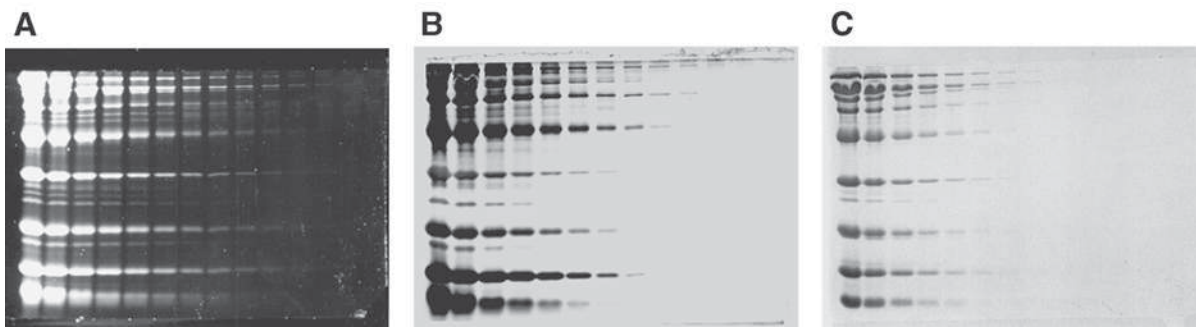

FIGURE 6.7 A comparison of the sensitivities achieved with three different protein stains. Identical SDS-polyacrylamide gels were stained with **A** SYPRO Red protein gel stain; **B** Silver stain; **C** Coomassie brilliant blue dye. *Courtesy of Molecular Probes; www.probes.com, a part of Invitrogen Corporation;* www.invitrogen.com.

STUDY EXERCISE 6.2 SDS-PAGE

You have just completed an experiment using SDS-PAGE to study the subunit structure of ferritin (iron storage protein). Ferritin is composed of two types of subunits, H and L, in about equal quantities. You have included in your electrophoresis several standard proteins of known molecular weight. Draw the final stained gel in the form of Figure 6.7.

Protein	MW
Ferritin	500,000
Subunit H	22,000
Subunit L	19,000
α-lactalbumin	14,200
Trypsinogen	24,000
Egg albumin	45,000
Bovine serum albumin	65,000

Nucleic Acid Sequencing Gels

Sequence analysis of nucleic acids is based on the generation of sets of DNA or RNA fragments with common ends and the separation of these oligonucleotide fragments by polyacrylamide electrophoresis. Two methods have been developed for sequencing nucleic acids: (1) the **partial chemical degradation method** of Maxam and Gilbert, which uses four specific chemical reactions to modify bases and cleave phosphodiester bonds, and (2) the **chain termination method** developed by Sanger, which requires a single-stranded DNA template and chain extension processes, followed by chain termination caused by the presence of dideoxynucleoside triphosphates. Both sequencing methods result in nested sets of DNA or RNA fragments that have one common end and chains varying in length. The smallest possible size difference of nucleic acid fragments is one nucleotide. Separation of the nucleic acid fragments by polyacrylamide electrophoresis allows one to "read" the sequence of nucleotides from the gel (see Chapter 9, p. 282).

Using Sequencing Gels

The experimental arrangement is the same as that previously described for PAGE; however, the gel is prepared with many sample wells to accommodate a large number of samples. Sequence gels of 6, 8, 12, and 20% polyacrylamide are routinely used. Gels of 20% may be used to sequence the first 50 to 100 nucleotides of a nucleic acid, and lower percentage gels allow sequencing out to 250 nucleotides. Sequencing gels are large (up to 40 cm), and power supplies must provide more power than for conventional methods. Precast sequencing gels are now commercially available from Stratagene and other suppliers. They have a gel concentration of 5.5%, have 32 sample wells, and will sequence up to 500 nucleotides. Denaturants such as urea and formamide are required to

prevent renaturing of the nucleic acid fragments during electrophoresis. For detection, nucleic acid chains for sequencing must be end-labeled with ^{32}P, ^{35}S, or a fluorescent tag. ^{32}P- and ^{35}S-labeled nucleic acids on gels are detected by autoradiography (see later). Nucleic acids end-labeled with fluorescent molecules are detected by fluorimeter scanning of the gels. Many researchers working on the large and expensive Human Genome Project[1] have generated huge amounts of DNA sequence data. Much of this information is stored in computer data banks for use by researchers around the world.

Agarose Gel Electrophoresis

The electrophoretic techniques discussed up to this point are useful for analyzing proteins and small fragments of nucleic acids up to 350,000 daltons (500 bp) in molecular size; however, the small pore sizes in the gel are not appropriate for analysis of large nucleic acid fragments or intact DNA molecules. The standard method used to characterize RNA and DNA in the range 200 to 50,000 base pairs (50 kilobases) is electrophoresis with agarose as the support medium.

Agarose, a product extracted from seaweed, is a linear polymer of galactopyranose derivatives. Gels are prepared by dissolving agarose in warm electrophoresis buffer. After cooling the gel mixture to 50°C, the agarose solution is poured between glass plates as described for polyacrylamide. Gels with less than 0.5% agarose are rather fragile and must be used in a horizontal arrangement (Figure 6.8). The sample to be separated is placed in a sample well made with a comb, and voltage is applied until separation is complete. Precast agarose gels of all shapes, sizes, and percent composition are commercially available.

Nucleic acids can be visualized on the slab gel after separation by soaking in a solution of ethidium bromide, a dye that displays enhanced fluorescence when intercalated between stacked nucleic acid bases. Ethidium bromide may be added directly to the agarose solution before gel formation. This method allows monitoring of nucleic acids during electrophoresis. Irradiation of ethidium bromide–treated gels by UV light results in orange-red bands where nucleic acids are present. Nucleic acids may also be stained with the new, fluorescent SYBR dyes, which are less toxic

FIGURE 6.8 An apparatus for horizontal slab gel electrophoresis of nucleic acids. *Courtesy of Hoefer, Inc.* www.hoeferinc.com.

[1] The Human Genome Project was a federal, government-sponsored program to sequence all DNA in human chromosomes. The project was completed in 2001.

TABLE 6.3 Effective Range of Separation of DNA by Agarose

Agarose (% w/v)	Effective Range (kb)
0.3	5–50
0.5	2–25
0.7	0.8–10
1.2	0.4–5
1.5	0.2–3
2.0	0.1–2

than the mutagenic ethidium bromide. The newest, least toxic, and most sensitive stains for nucleic acids are GelRed and GelGreen from Biotium, Inc. (See Section C.)

The mobility of nucleic acids in agarose gels is influenced by the agarose concentration and the molecular size and molecular conformation of the nucleic acid. Agarose concentrations of 0.3 to 2.0% are most effective for nucleic acid separation (Table 6.3). Adding ethidium bromide to the gel can retard DNA mobility. Like proteins, nucleic acids migrate at a rate that is inversely proportional to the logarithm of their molecular weights; hence, molecular weights can be estimated from electrophoresis results using standard nucleic acids or DNA fragments of known molecular weight. The DNA conformations most frequently encountered are superhelical circular (form I), nicked circular (form II), and linear (form III). The small, compact, supercoiled form I molecules usually have the greatest mobility, followed by the rodlike, linear form III molecules. The extended, circular form II molecules migrate more slowly. The relative electrophoretic mobility of the three forms of DNA, however, depends on experimental conditions such as agarose concentration and ionic strength.

The versatility of agarose gels is obvious when one reviews their many applications in nucleic acid analysis. The rapid advances in our understanding of nucleic acid structure and function in recent years are due primarily to the development of agarose gel electrophoresis as an analytical tool. Two of the many applications of agarose gel electrophoresis will be described here.

Analysis of DNA Fragments after Digestion by Restriction Endonucleases

Restriction endonucleases are enzymes that recognize a specific base sequence in double-stranded DNA and catalyze cleavage (hydrolysis of phosphodiester bonds) in or near that specific region (see Chapter 10, Section B, p. 297). Many viral, bacterial, or animal DNA molecules are substrates for the enzymes. When each type of DNA is treated with a restriction endonuclease, a specific number of DNA fragments is produced. The base sequence recognized by the enzyme occurs only a few times in any particular DNA molecule; therefore, the smaller the DNA molecule, the fewer specific cleavage sites there are. Viral or phage DNA, for example, is cleaved into about 50 fragments depending on the enzyme used, whereas larger bacterial or animal DNA may be cleaved into hundreds or thousands of fragments. Smaller DNA molecules, upon cleavage with a particular enzyme, will produce a limited set of fragments. It is unlikely that this set of fragments will be the same for any two

different DNA molecules, so the fragmentation pattern can be considered a "fingerprint" of the DNA substrate. The **restriction pattern** is produced by electrophoresis of the cleavage reaction mixture through agarose gels, followed by staining with ethidium bromide or SYBR dyes (Figure 6.9). The separation of the fragments is based on molecular size, with large fragments remaining near the origin and smaller fragments migrating farther down the gel. In addition to characterization of DNA

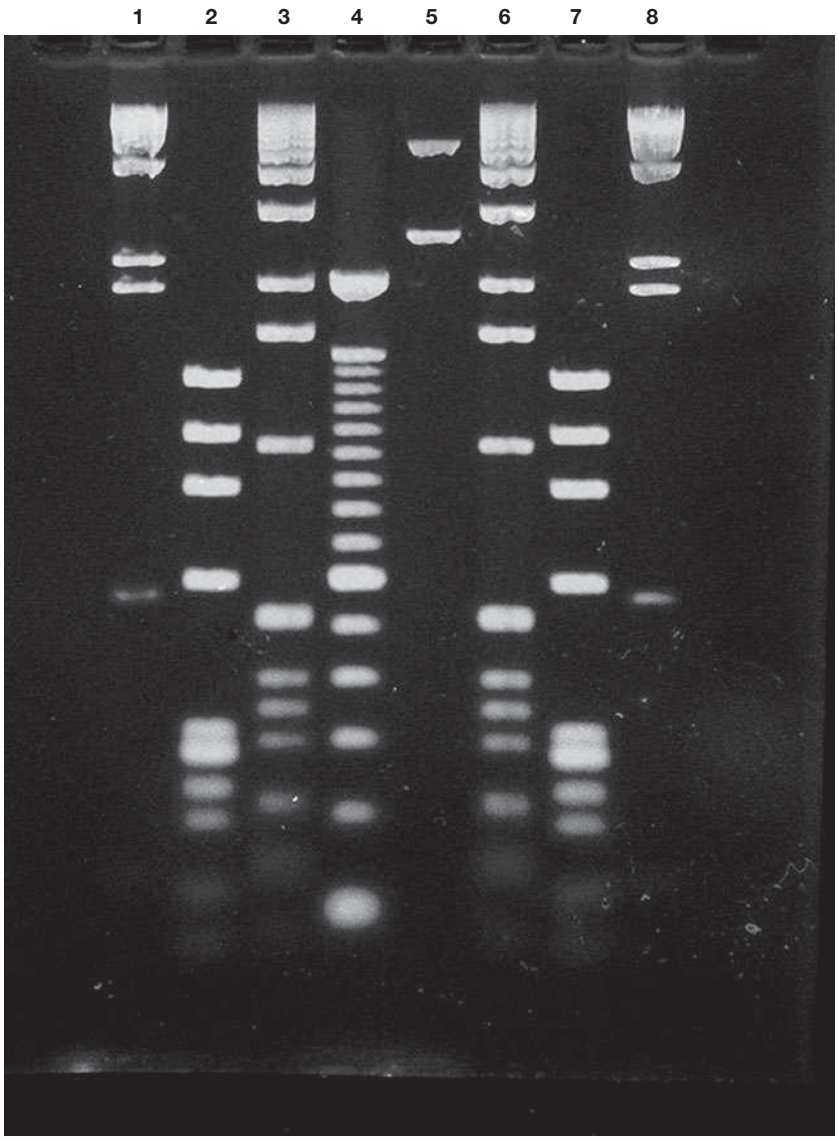

FIGURE 6.9 Restriction patterns produced by agarose electrophoresis of DNA fragments after endonuclease action. DNA molecular weight ladders have been electrophoresed on a 1% agarose gel and then stained with SYBR Green I nucleic acid gel stain. Lanes **1** and **8** contain *Hin*dIII-cut λ DNA; lanes **2** and **7,** *Hae*III-cut Φ X174 RF DNA; lanes **3** and **6,** 1 kilobase pair DNA ladder; lane **4,** 100 base pair DNA ladder; lane **5,** *Eco*R-I-cut pUC19 DNA mixed with *Pst*I-cut Φ X174 RF DNA.

structure, endonuclease digestion coupled with agarose gel electrophoresis is a valuable tool for plasmid mapping and DNA recombination experiments.

Characterization of Superhelical Structure of DNA

The structure of plasmid, viral, and bacterial DNA is often closed circular with negative superhelical turns. It is possible under various experimental conditions to induce reversible changes in the conformation of DNA. The intercalating dye ethidium bromide causes an unwinding of supercoiled DNA that affects its electrophoretic mobility. Electrophoresis of DNA on agarose in the presence of increasing concentrations of ethidium bromide provides an unambiguous method for distinguishing between closed circular and other DNA conformations.

Closed circular, negatively supercoiled DNA (form I) usually has the greatest electrophoretic mobility of all DNA forms because supercoiled DNA molecules tend to be compact. If ethidium bromide is added to form I DNA, the dye intercalates between the stacked DNA bases, causing unwinding of some of the negative supercoils. As the concentration of ethidium bromide is increased, more and more of the negative supercoils are removed until no more are present in the DNA. The conformational change of the DNA supercoil can be monitored by electrophoresis because the mobility decreases with each unwinding step. With increasing concentration of ethidium bromide, the negative supercoils are progressively unwound and the electrophoretic mobility decreases to a minimum. This minimum represents the free dye concentration necessary to remove all negative supercoils. (The free dye concentration at this minimum has been shown to be related to the superhelix density, which is a measure of the extent of supercoiling in a DNA molecule.) The circular DNA at this point is equivalent to the "relaxed" form. If more ethidium bromide is added to the relaxed DNA, positive superhelical turns are induced in the structure and the electrophoretic mobility increases. Forms II and III DNA, under the same conditions of increasing ethidium bromide concentration, show a gradual decrease in electrophoretic mobility throughout the entire concentration range.

Agarose gel electrophoresis is able to resolve topoisomers of native, covalently closed, circular DNA that differ only in their degree of supercoiling. This technique has proved useful in the analysis and characterization of enzymes that catalyze changes in the conformation or topology of native DNA. These enzymes, called **topoisomerases,** have been isolated from bacterial and mammalian cells. They change DNA conformations by catalyzing nicking and closing of phosphodiester bonds in circular duplex DNA. Agarose gel electrophoresis is an ideal method for identifying and assaying topoisomerases because the intermediate DNA molecules can be resolved on the basis of the extent of supercoiling. Topoisomerases may be assayed by incubating native DNA with an enzyme preparation, removing aliquots after various periods of time, and subjecting them to electrophoresis on an agarose gel with standard supercoiled and relaxed DNA.

Pulsed Field Gel Electrophoresis (PFGE)

Conventional agarose gel electrophoresis is limited in use for the separation of nucleic acid fragments smaller than 50,000 bp (50 kb). In practice, that limit is closer to 20,000 to 30,000 bp if high resolution is desired. Since chromosomal

DNA from most organisms contains thousands and even millions of base pairs, the DNA must be cleaved by restriction enzymes before analysis by standard electrophoresis. In the early 1980s, Schwartz and Cantor at Columbia University discovered that large molecules of DNA (yeast chromosomes, 200–3000 kb) could be separated by **pulsed field gel electrophoresis (PFGE).** There is one major distinction between standard gel electrophoresis and PFGE. In PFGE, the electric field is not constant as in the standard method, but is changed repeatedly (pulsed) in direction and strength during the separation (Figure 6.10). The physical mechanism for separation of the large DNA molecules as they move through the gel under these conditions is not yet well understood. An early explanation was that the electrical pulses abruptly perturbed the conformation of the DNA molecules. They would be oriented by the influence of the electric field coming from one direction and then reoriented as a new electric field at a different angle to the first was turned on. According to this explanation, it takes longer for larger molecules to reorient, so smaller fragments respond faster to the new pulse and move faster. More recent experiments on dyed DNA moving in gels have shown that conformational changes of the DNA are not abrupt, but more gradual, in response to the electrical pulse, and DNA molecules tend to "slither" through the gel matrix. In addition, it has been discovered that the gel becomes more fluid during electrical pulsing.

Applications of PFGE

Even though our theoretical understanding of PFGE is lacking, practical applications and experimental advances are expanding rapidly. The availability of PFGE has sparked changes in DNA research. New methods for isolating intact DNA molecules have been developed. Because of mechanical breakage, the average size of DNA isolated from cells in the presence of lysozyme, detergent, and EDTA is about 400–500 kb (see Chapter 9, Section B, p. 275). Intact chromosomal DNA can be isolated by embedding cells in an agarose matrix and disrupting the cells with detergents and enzymes. Slices or "plugs" of the agarose with intact

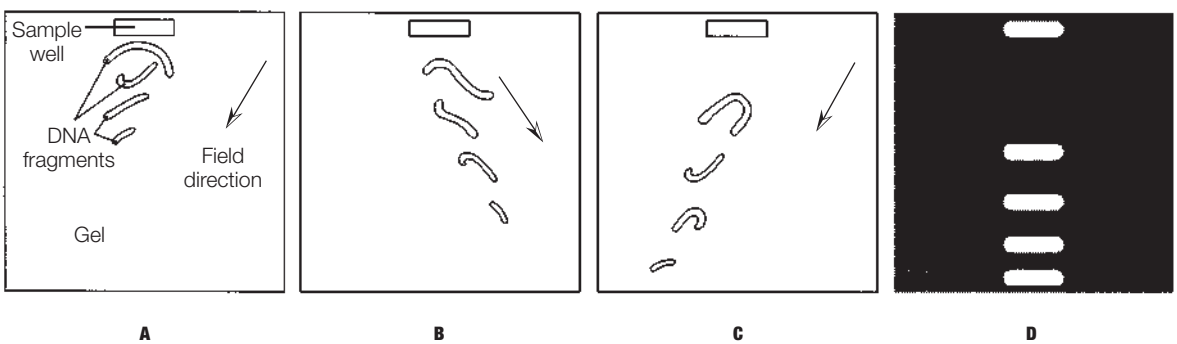

FIGURE 6.10 Pulsed field gel electrophoresis. Generalized PFGE separation of four DNA fragments of different sizes in one lane. **A** DNA molecules of various shapes and configurations move toward the positive field. **B** The new field orientation pulls the DNA in a different direction, realigning the molecules. **C** The field returns to the original configuration. **D** The bands show the final position of a large collection of the molecules. *Reprinted with permission from the Journal of NIH Research* ***1,*** *115 (1999). Illustration by Terese Winslow.*

DNA are then placed on the gel for PFGE analysis. Newly discovered restriction endonucleases that cut DNA only rarely can now be used to subdivide chromosome-sized DNA. Two important endonucleases with eight-base recognition sites are *Not* I and *Sfi* I.

There are also many instrumental advances that allow changes in the experimental design of PFGE. Some of the variables that can be changed for each experiment are voltage, pulse length, number of electrodes, relative angle of electrodes, gel box design, temperature, agarose concentration, buffer pH, and time of electrophoresis.

Like all laboratory techniques, PFGE has its disadvantages and problems. Long periods of electrophoresis are often required for good resolution, and migration of fragments is extremely dependent on experimental conditions. Therefore, it is difficult to compare gels even when they are run under similar conditions. In spite of these shortcomings, PFGE will continue to advance as a significant tool for the characterization of very large molecules. The technique, which was widely used in the Human Genome Project, will greatly increase our understanding of chromosome structure and function.

Isoelectric Focusing of Proteins

Another important and effective use of electrophoresis for the analysis of proteins is **isoelectric focusing (IEF),** which examines electrophoretic mobility as a function of pH. The net charge on a protein is pH dependent. Proteins below their **isoelectric pH** (pH_I, or sometimes P_I; the pH at which they have zero net charge) are positively charged and migrate in a medium of fixed pH toward the negatively charged cathode. At a pH above its isoelectric point, a protein is deprotonated and negatively charged and migrates toward the anode. If the pH of the electrophoretic medium is identical to the pH_I of a protein, the protein has a net charge of zero and does not migrate toward either electrode. Theoretically, it should be possible to separate protein molecules and to estimate the pH_I of a protein by investigating the electrophoretic mobility in a series of separate experiments in which the pH of the medium is changed. The pH at which there is no protein migration should coincide with the pH_I of the protein. Because such a repetitive series of electrophoresis runs is a rather tedious and time-consuming way to determine the pH_I, IEF has evolved as an alternative method for performing a single electrophoresis run in a medium of gradually changing pH (i.e., a pH gradient).

Separating Proteins by IEF

Figure 6.11 illustrates the construction and operation of an IEF pH gradient. An acid, usually phosphoric, is placed at the cathode; a base, such as triethanolamine, is placed at the anode. Between the electrodes is a medium in which the pH gradually increases from 2 to 10. The pH gradient can be formed before electrophoresis is conducted or formed during the course of electrophoresis. The pH gradient can be either broad (pH 2–10) for separating several proteins of widely ranging pH_I values, or narrow (pH 7–8) for precise determination of the pH_I of a single protein. P in Figure 6.11 represents different molecules of

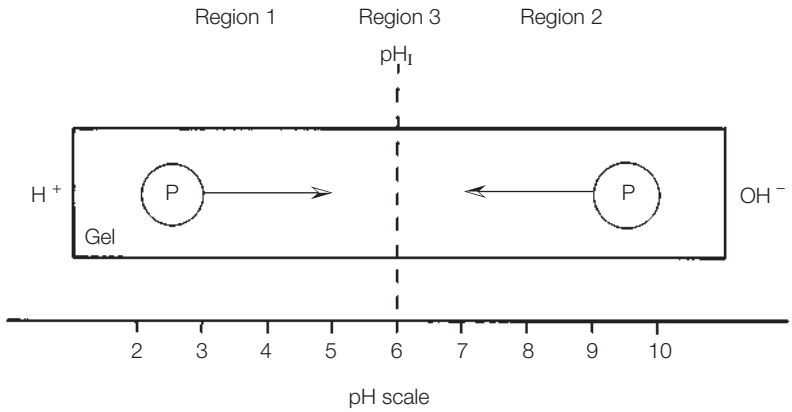

FIGURE 6.11
Illustration of isoelectric focusing. See text for details.

the same protein in two different regions of the pH gradient. Assuming that the pH in region 1 is less than the pH_I of the protein and the pH in region 2 is greater than the pH_I of the protein, molecules of P in region 1 will be positively charged and will migrate in an applied electric field toward the cathode. As P migrates, it will encounter an increasing pH, which will influence its net charge. As it migrates *up* the pH gradient, P will become increasingly deprotonated and its net charge will decrease toward zero. When P reaches a region where its net charge is zero (region 3), it will stop migrating. The pH in this region of the electrophoretic medium will coincide with the pH_I of the protein and can be measured with a surface microelectrode, or the position of the protein can be compared to that of a calibration set of proteins of known pH_I values. P molecules in region 2 will be negatively charged and will migrate toward the anode. In this case, the net charge on P molecules will gradually decrease to zero as P moves *down* the pH gradient, and P molecules originally in region 2 will approach region 3 and come to rest. The P molecules move in opposite directions, but the final outcome of IEF is that P molecules located anywhere in the gradient will migrate toward the region corresponding to their isoelectric point and will eventually come to rest in a sharp band; that is, they will "focus" at a point corresponding to their pH_I.

Since different protein molecules in mixtures have different pH_I values, it is possible to use IEF to separate proteins. In addition, the pH_I of each protein in the mixture can be determined by measuring the pH of the region where the protein is focused.

Practical Aspects of IEF

The pH gradient is prepared in a horizontal glass tube or slab. Special precautions must be taken so that the pH gradient remains stable and is not disrupted by diffusion or convective mixing during the electrophoresis experiment. The most common stabilizing technique is to form the gradient in a polyacrylamide, agarose, or dextran gel. The pH gradient is formed in the gel by electrophoresis of synthetic polyelectrolytes, called **ampholytes,** which migrate to the region of

their pH_I values just as proteins do and establish a pH gradient that is stable for the duration of the IEF run. Ampholytes are low-molecular-weight polymers that have a wide range of isoelectric points because of their numerous amino and carboxyl or sulfonic acid groups. The polymer mixtures are available in specific pH ranges (pH 5–7, 6–8, 3.5–10, etc.). It is critical to select the appropriate pH range for the ampholyte so that the proteins to be studied have pH_I values in that range. The best resolution is, of course, achieved with an ampholyte mixture over a small pH range (about two units) encompassing the pH_I of the sample proteins. If the pH_I values for the proteins under study are unknown, an ampholyte of wide pH range (pH 3–10) should be used first and then a narrower pH range selected for use.

The gel medium is prepared as previously described except that the appropriate ampholyte is mixed prior to polymerization. The gel mixture is poured into the desired form (column tubes, horizontal slabs, etc.) and allowed to set. Immediately after casting of the gel, the pH is constant throughout the medium, but application of voltage will induce migration of ampholyte molecules to form the pH gradient. The standard gel for proteins with molecular sizes up to 100,000 daltons is 7.5% polyacrylamide; however, if larger proteins are of interest, gels with larger pore sizes must be prepared. Such gels can be prepared with a lower concentration of acrylamide (about 2%) and 0.5 to 1% agarose to add strength. Precast gels for isoelectric focusing are also commercially available.

The protein sample can be loaded on the gel in either of two ways. A concentrated, salt-free sample can be layered on top of the gel as previously described for ordinary gel electrophoresis. Alternatively, the protein can be added directly to the gel preparation, resulting in an even distribution of protein throughout the medium. The protein molecules move more slowly than the low-molecular-weight ampholyte molecules, so the pH gradient is established before significant migration of the proteins occurs. Very small protein samples can be separated by IEF. For analytical purposes, 10 to 50 μg is a typical sample size. Larger sample sizes (up to 20 mg) can be used for preparative purposes.

Two-Dimensional Electrophoresis (2-DE) of Proteins

The separation of proteins by IEF is based on charge, whereas SDS-PAGE separates molecules based on molecular size. A combination of the two methods leads to enhanced resolution of complex protein mixtures. Such an experiment was first reported by O'Farrell and the combined method has since become a routine and powerful separatory technique. Figure 6.12 shows the results of O'Farrell's analysis of total *Escherichia coli* protein. The sample was first separated in one dimension by IEF. The sample gel was then transferred to an SDS-PAGE slab and electrophoresis was continued in the second dimension. At least 1000 discrete protein spots are visible.

The technique of 2-DE is a powerful tool for researchers in the new field of **proteomics,** whose goal is the systematic study of the structure, interactions, and biological function of the proteins expressed by the genome (proteome) of an organism. We see that the 1000 or so proteins in the *E. coli* cell are well resolved by 2-DE (Figure 6.12), but what about the numerous proteins expressed in higher organisms like humans? It is currently estimated from data generated by the

FIGURE 6.12
Two-dimensional electrophoresis of total *E. coli* proteins. *Photo courtesy of Dr. P. O'Farrell.*

Human Genome Project that humans have about 20,000–25,000 genes. This number does not relate directly to the number of proteins because many of the genes are alternately spliced and because of numerous post-translational modification processes. It is now estimated that there may be as many as one million different protein products in the human. This is a daunting number even for the high resolution displayed in 2-DE. It is not realistic to imagine that 2-DE techniques will ever be able to analyze this many proteins, not only because of the complexity, but also because the technique is tedious and time-consuming, and the gels are difficult to analyze. However, when 2-DE data are combined and analyzed by modern computer software, valuable on-line databases on protein expression may be constructed. In addition, when proteins separated by 2-DE are further analyzed by mass spectrometry (see Chapter 7, Section D, p. 230), partial protein sequence data can be obtained.

The 2-DE technique is also of value in developmental biochemistry, where the increase or decrease in intensity of a spot representing a specific protein may be monitored as a function of cell growth.

Capillary Electrophoresis (CE)

Capillary electrophoresis is a new technique that combines the high resolving power of electrophoresis with the speed, versatility, and automation of high-performance liquid chromatography (HPLC). It offers the ability to analyze very small samples (5–10 nL) utilizing up to 1 million theoretical plates to achieve high resolution and sensitivity to the attomole level (10^{-18} mole). It will become a widely used technique in the analysis of amino acids, peptides, proteins, nucleic acids, and pharmaceuticals.

CE in Practice

A general experimental design is diagrammed in Figure 6.13. The equipment consists of a power supply, two buffer reservoirs, a buffer-filled capillary tube, and an on-line detector. Platinum electrodes connected to the power supply are

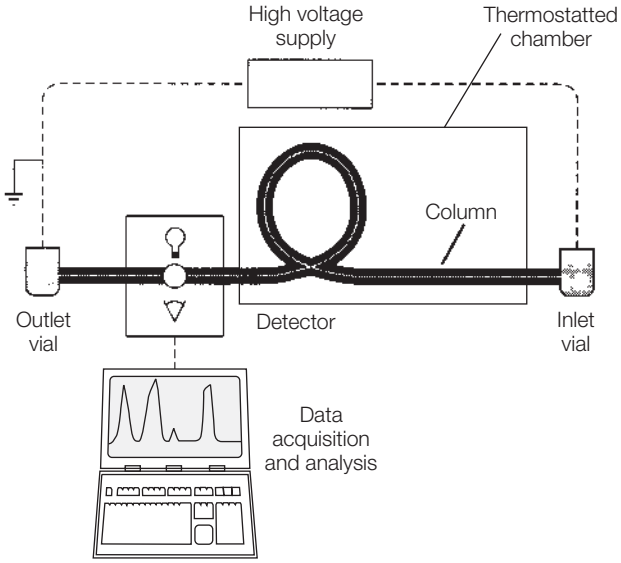

FIGURE 6.13
Experimental setup for capillary electrophoresis. *Courtesy of Bio-Rad Laboratories, Life Science Research Group, Hercules, CA.*

immersed in each buffer reservoir. A high voltage is applied along the capillary, and a small plug of sample solution is injected into one end of the capillary. Components in the solution migrate along the length of the capillary under the influence of the electric field. Molecules are detected as they exit from the opposite end of the capillary. The detection method used depends on the type of molecules separated, but the most common are UV-VIS fixed-wavelength detectors and diode-array detectors (see Chapter 7, pp. 210–211). The capillaries used are flexible, fused, silica tubes of 5−100 μm i.d. and 25–100 cm length that may or may not be filled with chromatographic matrix.

A major advantage of capillary electrophoresis is that many analytical experimental designs are possible, just as in the case of HPLC. In HPLC, a wide range of molecules can be separated by changing the column support (see Chapter 5, Section F, p. 140). In CE, the capillary tube may be coated or filled with a variety of materials. For separation of small, charged molecules, bare silica or polyimide-coated capillaries are often used. If separation by molecular sieving is desired, the tube is filled with polyacrylamide or SDS-polyacrylamide. If the capillary is filled with electrolyte and an ampholyte pH gradient, isoelectric focusing experiments on proteins may be done. We can expect to see numerous applications of CE in all aspects of biochemistry and molecular biology. New applications will include DNA sequencing, analysis of single cells, and separations of neutral molecules. (For example, see nucleotide separation in Figure 6.14.)

Immunoelectrophoresis (IE)

In immunoelectrophoresis, two sequential procedures are applied to the analysis of complex protein mixtures: (1) separation of the protein mixture by agarose gel electrophoresis, followed by (2) interaction with specific antibodies to examine the antigenic properties of the separated proteins.

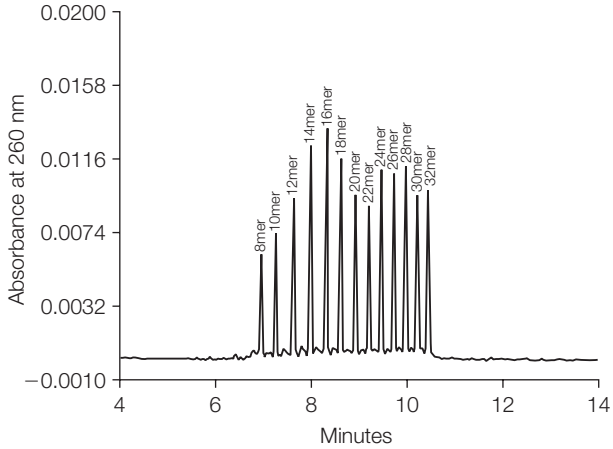

8 mer	**GACTGACT**
10 mer	**GACTGACTGT**
12 mer	**GACTGACTGACT**
14 mer	**GACTGACTGACTGT**
16 mer	**GACTGACTGACTGACT**
18 mer	**GACTGACTGACTGACTGT**
20 mer	**GACTGACTGACTGACTGACT**
22 mer	**GACTGACTGACTGACTGACTGT**
24 mer	**GACTGACTGACTGACTGACTGACT**
26 mer	**GACTGACTGACTGACTGACTGACTGT**
28 mer	**GACTGACTGACTGACTGACTGACTGACT**
30 mer	**GACTGACTGACTGACTGACTGACTGACTGT**
32 mer	**GACTGACTGACTGACTGACTGACTGACTGACT**

FIGURE 6.14 Separation of a series of oligonucleotides using capillary electrophoresis. The compounds are separated on a capillary coated on the inside with polyacryloylamino-ethoxyethanol. The structures of the standard oligonucleotides are shown in the lower diagram. Adapted from Bio-Rad Laboratories, Inc., www.bio-rad.com.

The technique of IE was first reported by Grabar and Williams in 1953 for the separation and immunoanalysis of serum proteins, but it can be applied to the analysis of any purified protein or complex mixture of proteins. In practice (Figure 6.15), a protein mixture is separated by standard electrophoresis in an agarose gel prepared on a small glass plate. This is followed by exposing the separated proteins to a specific antibody preparation. The antibody is added to a trough cut into the gel, as shown in Figure 6.15, and is allowed to diffuse through the gel toward the separated proteins. If the antibody has a specific affinity for one of the proteins, a visible precipitin arc forms. This is an insoluble complex formed at the boundary of antibody and antigen protein. The technique is most useful for the analysis of protein purity, composition, and antigenic properties. The basic IE technique described here allows only qualitative examination of antigenic proteins. If quantitative results in the form of protein antigen concentration are required, the advanced modifications rocket immunoelectrophoresis and two-dimensional (crossed) immunoelectrophoresis may be used.

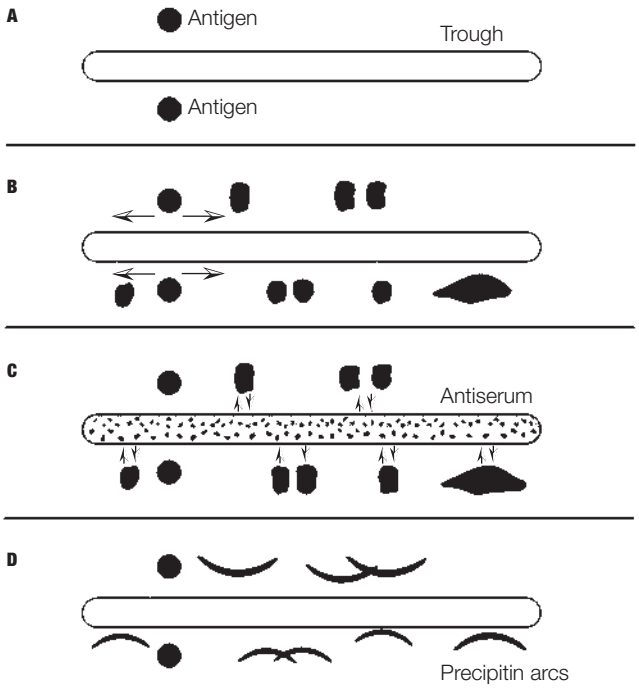

FIGURE 6.15 Immunoelectrophoresis. **A** Antigen is placed in sample wells. **B** Electrophoresis. **C** Antiserum containing antibody is placed in trough. **D** Insoluble antigen–antibody complexes form precipitin arcs.

C. PRACTICAL ASPECTS OF ELECTROPHORESIS

Instrumentation

The basic components required for electrophoresis are a power supply and an electrophoresis chamber (gel box). A power supply that provides a constant current is suitable for most conventional electrophoresis experiments. Power supplies that generate both constant voltage (up to 4 kV) and constant current (up to 200 mA) are commercially available. In order to implement the many modifications of electrophoresis, such versatile power supplies are essential in a research laboratory. If isoelectric focusing experiments are planned, a power supply that furnishes a constant voltage is necessary. DNA sequencing experiments require power supplies capable of generating 2–4 kV. Because of the high power requirements of these experiments, the glass plates sandwiching the gel must be covered with conductive aluminum plates to dissipate heat and prevent gel melting and glass plate breakage. CE also requires the use of high voltage, which generates heat as well. However, the heat is quickly dissipated through the thin walls of the capillary tubing. Pulsed field electrophoresis experiments have special requirements, including a high-voltage power supply, electrical switching devices for control of the field, equipment for temperature control, and a specially designed gel box with an array of electrodes. All types of electrophoresis chambers for both horizontal and vertical placements of gels are available from commercial suppliers.

Reagents

High-quality, electrophoresis grade chemicals must be used, since impurities may influence both the gel polymerization process and electrophoretic mobility. The reagents used for gel formation should be stored in a refrigerator.

Caution

Acrylamide, *N,N,N′N′*-tetramethylethylenediamine, *N,N′*-methylene-bis-acrylamide, and ammonium persulfate are toxic and must be used with care. Acrylamide is a neurotoxin, a carcinogenic agent, and a potent skin irritant, so gloves and a mask must be worn while handling it in the unpolymerized form.

Buffers appropriate for electrophoresis gels include Tris-glycine, Tris-acetate, Tris-phosphate, and Tris-borate at concentrations of about 0.05 *M* (Chapter 3, Section A, p. 61).

Several advances in gel electrophoresis have recently been made that have streamlined and improved many of the established techniques. Some of those improvements will be outlined here.

1. ***Precast Gels*** As previously mentioned, precast gels of polyacrylamide and agarose are now commercially available. A wide variety of gel sizes, types, configurations, and compositions may be purchased. Costs are reasonable, beginning at about $15 for an 8×10 cm single percentage polyacrylamide gel. Precast gels not only offer convenience, but also increase safety, save time, and provide more reproducible electrophoretic runs. Precast gels with dye/stain already applied are also available (prestaining).
2. ***Bufferless Precast Gels*** One of the major inconveniences of running gels is the necessity of having liquid buffer reservoirs to saturate gels during electrophoresis. There is always the chance that reservoirs will leak or that solutions perhaps containing acrylamide or ethidium bromide will be spilled. Precast gels (agarose and acrylamide) are now available in dry, plastic cassettes. They do not require liquid buffers because the gels contain ion-exchange matrices, which sustain the electric field.
3. ***Reusable Precast Gels*** Precast agarose gels are now available that may be recycled. After a run, the DNA samples on the gel are removed by reversing the direction of the electric field. The gels are then reloaded with new samples and reused.

Staining and Detecting Electrophoresis Bands

Tracking Dyes

During the electrophoretic process, it is important to know when to stop applying the voltage or current. If the process is run for too long, the desired components may pass entirely through the medium and into the buffer; if too short a period is used, the components may not be completely resolved. It is common practice to add a "tracking dye," usually bromphenol blue and/or xylene cyanol,

to the sample mixture. These dyes, which are small and anionic, move rapidly through the gel ahead of most proteins or nucleic acids. After electrophoresis, bands have a tendency to widen by diffusion. Because this broadening may decrease resolution, gels should be analyzed as soon as possible after the power supply has been turned off. In the case of proteins, gels can be treated with an agent that "fixes" the proteins in their final positions, a process that is often combined with staining.

Staining Proteins with Coomassie Blue

Reagent dyes that are suitable for visualization of biomolecules after electrophoresis were mentioned earlier. The most commonly used general stain for proteins is **Coomassie Brilliant Blue.** This dye can be used as a 0.25% aqueous solution. It is followed by destaining (removing excess background dye) by repeated washing of the gel with 7% acetic acid. Alternatively, gels may be stained by soaking in 0.25% dye in H_2O, methanol, and acetic acid (5:5:1), followed by repeated washings with the same solvent. The most time-consuming procedure in the Coomassie Blue visualization process is destaining, which often requires days of washing. Rapid destaining of gels may be brought about electrophoretically. The gel, after soaking in the stain, is subjected to electrophoresis again, using a buffer of higher concentration to remove excess stain.

The search for more rapid and sensitive methods of protein detection after electrophoresis has led to the development of fluorescent staining techniques. Two commonly used fluorescent reagents are fluorescamine and anilinonaphthalene sulfonate. New dyes based on silver salts (silver diamine or silver–tungstosilicic acid complex) have been developed for protein staining. They are 10 to 100 times more sensitive than Coomassie Blue (Figure 6.7).

A visualization procedure that is specific for a certain biomolecule, such as an enzyme, is often needed. If the enzyme remains in an active form while in the gel, any substrate that produces a colored product could be used to locate the enzyme on the gel. Although it is less desirable for detection, the electrophoresis support medium may be cut into small segments and each part extracted with buffer and analyzed for the presence of the desired component.

Fluorescent SYPRO and CF Dyes

The new fluorescent SYPRO dyes, produced by Molecular Probes, Inc. (www.probes.com), promise to challenge the use of silver staining for protein gel staining. SYPRO Orange stain, SYPRO Ruby stain, and SYPRO Red stain may be used for 1-D and 2-D gels, and their sensitivities are equal to silver staining. However, the SYPRO dyes are much easier and faster to use (they require no fixing or destaining) than both Coomassie Blue or silver. Gels treated with the SYPRO dyes may be viewed using a standard UV light or with a laser scanner.

The new CF dyes produced by Biotium, Inc., have the advantage of excellent brightness, sensitivity, and photostability compared to the SYPRO dyes. They are designed primarily for labeling antibodies (see www.biotium.com).

Viewing Nucleic Acids on Gels

Nucleic acids may be visualized in agarose and polyacrylamide gels using the fluorescent dye ethidium bromide. The gel is soaked in a solution of the dye and washed to remove excess dye. Illumination of the rinsed slab with UV light reveals red-orange stains where nucleic acids are located.

Although ethidium bromide stains both single- and double-stranded nucleic acids, the fluorescence is much greater for double-stranded molecules. The electrophoresis may be performed with the dye incorporated in the gel and buffer, although this does influence mobility. This has the advantage that the gel can be illuminated with UV light during electrophoresis to view the extent of separation. Precast gels are made in plastic cassettes that are UV transparent. The mobility of double-stranded DNA may be reduced 10 to 15% in the presence of ethidium bromide. Destaining of the gel is not necessary because ethidium bromide–DNA complexes have a much greater fluorescent yield than free ethidium bromide, so relatively small amounts of DNA can be detected in the presence of free ethidium bromide. The detection limit for DNA is 10 ng.

Caution

Ethidium bromide must be used with great care, as it is a potent mutagen. Gloves should be worn at all times while using dye solutions or handling gels; however, even this does not ensure complete safety, as ethidium bromide has been shown to leak through some plastic gloves.

The new, fluorescent SYBR dyes, produced by Molecular Probes, Inc., offer several advantages over ethidium bromide. They are far less toxic than the mutagenic ethidium bromide, and some are as much as five times more sensitive. The most widely used SYBR dye for staining DNA gels is SYBR Green I, which is a cyanine dye and has a sensitivity similar to EtBr. The detailed mechanism for SYBR dye binding to DNA is unknown, but it is most likely not base intercalation as is the case for ethidium bromide. Other new dyes now being tested include Blueview, Carolina Blu, and 4′ 6-diamidino-2-phenylindole dihydrochloride hydrate (DAPI). Currently, the safest and most sensitive dyes now available for nucleic acids are the fluorescent GelRed and GelGreen, produced by Biotium. These dyes may be used for either prestaining or poststaining.

Because single-stranded nucleic acids do not stain deeply with ethidium bromide and some fluorescent dyes, alternate techniques must be used for detection, especially when only small amounts of biological material are available for analysis. One of the most sensitive techniques is to use radio-labeled molecules. For nucleic acids, this usually means labeling the 5′ or 3′ end with ^{32}P, a strong β emitter. Bands of labeled nucleic acids on an electrophoresis gel can easily be located by **autoradiography.** For this technique, the electrophoresed slab gel is transferred to heavy chromatography paper. After covering the gel and paper with plastic wrap, they are placed on X-ray film and wrapped in a cassette to avoid external light exposure. This procedure must be done in a darkroom. The gel-film combination is stored at −70°C for exposure. The low temperature maintains the gel in a rigid form and prevents diffusion of gel bands.

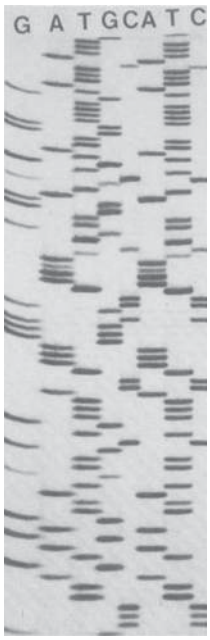

FIGURE 6.16
Autoradiogram of a DNA sequencing gel. *From Zyskind and Bernstein, DNA Laboratory Manual (1999), Academic Press (San Diego, CA).*

The exposure time depends on the amount of radioactivity, but can range from a few minutes to several days. Figure 6.16 shows the autoradiogram of a typical DNA sequencing gel. The autoradiogram also provides a permanent record of the gel for storage and future analysis. The actual gel is very fragile and difficult to store. Also, because of the short half-life of ^{32}P (14 days), an autoradiogram of the gel cannot be obtained in the distant future. Proteins labeled with ^{32}P or ^{125}I can be dealt with in a manner similar to nucleic acids. If an autoradiogram of a gel can be prepared, a permanent record of the experimental data is available.

Because of concerns about the safety of radioisotope use, researchers are developing fluorescent and chemiluminescent methods for detection of small amounts of biomolecules on gels. One attractive approach is to label biomolecules before analysis with the coenzyme biotin. Biotin forms a strong complex with enzyme-linked streptavidin. Some dynamic property of the enzyme is then measured to locate the biotin-labeled biomolecule on the gel. These new methods approach the sensitivity of methods involving radio-labeled molecules, and rapid advances are being made.

Protein and Nucleic Acid Blotting

Only a minute amount of protein or nucleic acid is present in bands on electropherograms. In spite of this, there is often a need to extract the desired biomolecule from the gel for further investigation. This sometimes involves the tedious and cumbersome process of crushing slices of the gel in a buffer to release the trapped proteins or nucleic acids. Techniques are now available for removing nucleic acids and proteins from gels and characterizing them using probes to detect certain structural features or functions. After electrophoresis, the desired biomolecules are transferred or "blotted" out of the gel onto a nitrocellulose filter or nylon membrane. The desired biomolecule is now accessible on the filter for

further analysis. The first blotting technique was reported by E. Southern in 1975. Using labeled complementary DNA probes, he searched for certain nucleotide sequences among DNA molecules blotted from the gel. This technique of detecting DNA-DNA hybridization is called **Southern blotting.** The general blotting technique has now been extended to the transfer and detection of specific RNA with labeled complementary DNA probes **(Northern blotting)** and the transfer and detection of proteins that react with specific antibodies **(Western blotting).** In practice, the electropherogram is alkali treated, neutralized, and placed in contact with the filter or nylon membrane. A buffer is used to facilitate the transfer. Figure 6.17 shows the setup for a blotting experiment. The location

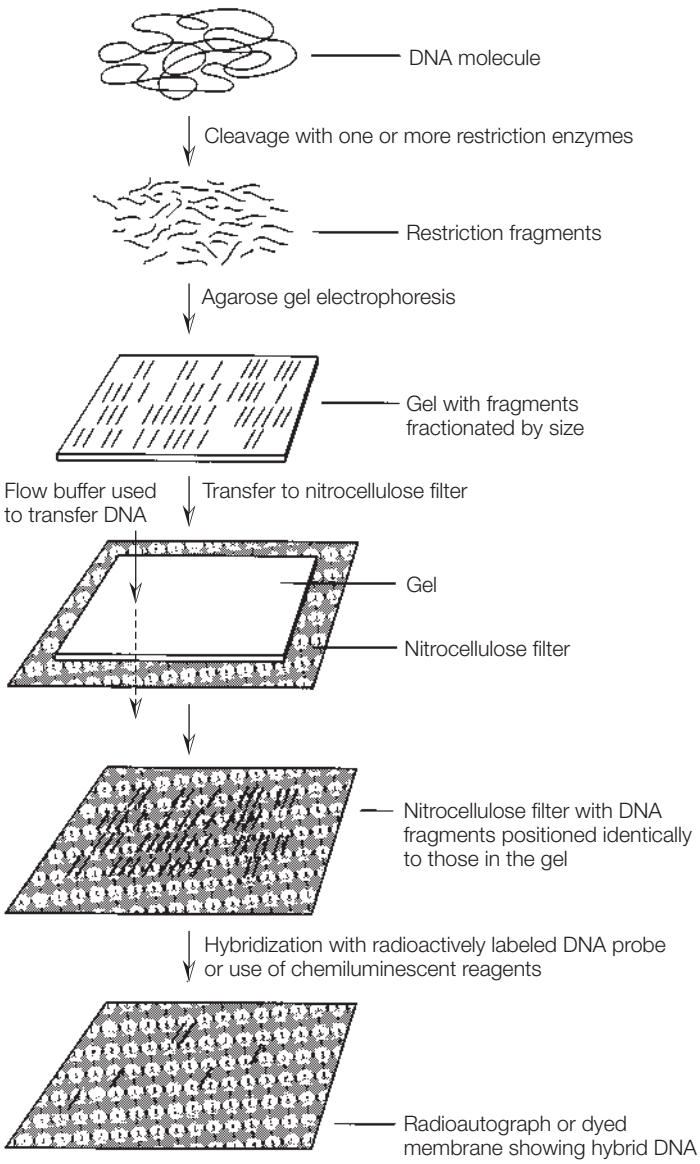

FIGURE 6.17
Diagram of a Southern blotting experiment.

of the desired nucleic acid or protein is then detected by incubation of the membrane with a radio-labeled probe and autoradiography, by use of a biotinylated probe, or by linkage to an enzyme-catalyzed reaction that generates a color.

Blotting techniques have many applications, including mapping the genes responsible for inherited diseases by using restriction fragment length polymorphisms (RFLPs), screening collections of cloned DNA fragments (DNA libraries), "DNA fingerprinting" for analysis of biological material remaining at the scene of a crime, and identification of specific proteins. More details on blotting are found in Chapter 10, Section C, p. 304.

The Western Blot

Western blotting has become an important, modern technique for analysis and characterization of proteins. The procedure consists of the electrophoretic transfer (blotting) of proteins from a polyacrylamide gel to a synthetic membrane. The transferred blots are then probed using various methods involving antibodies that bind to specific proteins.

PAGE is indeed a very effective analytical tool to achieve fractionation of protein mixtures, to analyze purity, and to estimate molecular weight, but it provides no experimental data to prove the identity of any of the protein bands. Stained spots simply indicate the presence and location of each and every protein on the gel. It is often possible to identify proteins by treating gel bands directly with chemical reagents that react with a specific protein; for example, enzymes on the gel could be treated with substrates that form a colored product. However, proteins are deeply embedded in the polyacrylamide gel matrix and are not readily accessible to most analytical reagents. This hinders specific analysis of the protein bands in order to identify individual proteins. Proteins separated by PAGE may be transferred (or blotted) from the gel to a thin support matrix, usually a nitrocellulose membrane, which strongly binds and immobilizes proteins. The protein blots on the membrane surface are more accessible to chemical or biochemical reagents for further analysis. When the transfer process is coupled with protein identification using highly specific and sensitive immunological detection techniques, the procedure is called **Western blotting.** Western blotting or immunoblotting assays of proteins have many advantages, including the need for only small reagent volumes, short processing times, relatively inexpensive equipment, and ease of performance (see immunoadsorption, Chapter 5, Section G, p. 152).

The Western Blotting Procedure

To begin the Western blot, a protein mixture for analysis and further characterization is fractionated by PAGE. Since denaturing SDS-PAGE results in better resolution than native PAGE, the SDS version is usually preferred; however, the detection method used at the conclusion of the blotting experiment must be able to recognize denatured protein subunits. The next step involves selection of the membrane matrix for transfer. Three types of support matrices are available for use: nitrocellulose, nylon, and polyvinyldifluoride (PVDF). Nitrocellulose membranes, currently the most widely used supports, have a satisfactory general

protein-binding capacity (100 $\mu g/cm^2$), but they display weak binding of proteins of molecular weights smaller than 14,000 and they are subject to tearing. Binding of proteins to nitrocellulose membranes is noncovalent, most likely involving hydrophobic interactions. Nylon membranes are stronger than nitrocellulose, and some have a binding capacity up to 450 $\mu g/cm^2$. However, since they are cationic, they only weakly bind basic proteins. During detection procedures, nylon membranes often display high background colors, so it is difficult to visualize proteins of interest. PVDF membranes bind proteins strongly (125 $\mu g/cm^2$) and, because of their hydrophobic nature, give a light background color after analysis. For overall general use in protein transfer and immunoblotting, nitrocellulose membranes are the most common choice.

The actual blotting process may be accomplished by one of two methods: **passive (or capillary) transfer** and **electroblotting.** In passive transfer, the membrane is placed in direct contact with the polyacrylamide gel and organized in a sandwich-like arrangement consisting of (from bottom to top) filter paper soaked with transfer buffer, gel, membrane, and more filter paper (see Figure 6.17). The sandwich is compressed by a heavy weight. Buffer passes by capillary action from the bottom filter paper through the gel, transferring the protein molecules to the membrane, where the macromolecules are immobilized. Passive transfer is very time-consuming, sometimes requiring 1–2 days for complete protein transfer. Faster and more efficient transfer is afforded by the use of an electroblotter. Here a sandwich of filter paper, gel, membrane, and more filter paper is prepared in a cassette, which is placed between platinum electrodes. An electric current is passed through the gel, causing the proteins to electrophorese out of the gel and onto the membrane. The electroblotting process usually is complete in 1–4 hours.

Detection of Blotted Proteins

The Western blot procedure is concluded by probing the blotted protein bands and detecting a specific protein or group of proteins among the blots. In other words, visualization of specific protein blots is now possible. The most specific identification techniques are based on immunology (antigen–antibody interactions; see Chapter 5, Section G, p. 152). A general procedure for immunoblotting is outlined in Figure 6.18. Before the protein detection process can begin, it is necessary to block protein-binding sites on the membrane that are not occupied by blotted proteins. This is essential because antibodies used to detect blotted proteins are also proteins and will bind to the membrane and interfere with detection procedures. Protein-binding sites still remaining on blotted membranes may be blocked by treatment with solutions of casein (major protein in milk), gelatin, or bovine serum albumin.

The blotted membrane, with all protein-binding sites occupied, can now be treated with analytical reagents for detection of specific proteins. Typically, the blotted membrane is incubated with an antibody specific for the protein of interest. This is called the **primary antibody,** which is a protein of the immunoglobulin G (IgG) class (see Figure 6.18). The primary antibody binds to the desired protein, forming an antigen–antibody complex. The interaction between the protein and its antibody does not usually result in a visible signal. The blot is then incubated with a **secondary antibody,** which is directed against the general class

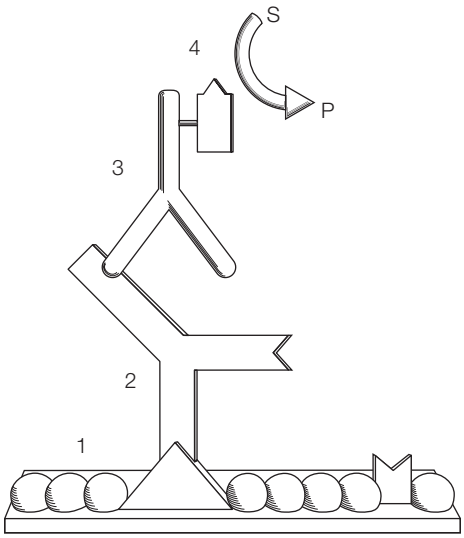

FIGURE 6.18 Specific detection of nitrocellulose membrane-bound proteins using a conjugated enzyme. **1** Proteins are transferred from electrophoresis gel to nitrocellulose membrane. Blocker proteins bind to unoccupied sites on the membrane. **2** The membrane is incubated with a primary antibody directed against the protein of interest. **3** A secondary antibody is directed against the primary antibody. **4** The secondary antibody is conjugated with an enzyme to provide a detection mechanism. Substrate solution is added to the blot. The conjugated enzyme (HRP or AP) catalyzes the conversion of substrate (S) to product (P) to form a colored precipitate at the site of the protein–antibody complex.

of primary antibody. For example, if the primary antibody was produced in rabbit serum, then the second antibody would be anti-rabbit IgG, usually from a goat or horse. The second antibody is labeled (conjugated) so that the interaction of the second antibody with the primary antibody produces some visual signal. For most detection procedures, the secondary antibody may be tagged with an enzyme, usually horseradish peroxidase (HRP) or alkaline phosphatase (AP). When the treated blot is incubated in a substrate solution, the conjugated enzyme catalyzes the conversion of the substrate into a visible product that precipitates at the blot site. The presence of a colored band indicates the position of the protein of interest (see Figure 6.19). This general procedure is also the basis for the widely used enzyme-linked immunosorptive assay (ELISA). The reactions catalyzed by conjugated enzymes are shown below:

$$>> \text{4-chloro-1-naphthol}_{\text{reduced}} + H_2O_2 \overset{\text{HRP}}{\rightleftharpoons} \text{4-chloro-1-naphthol}_{\text{oxidized}} + H_2O + \tfrac{1}{2}O_2 \quad \textbf{(Eq. 6.5)}$$

$$\text{5-bromo-4-chloro-3-indolylphosphate} + \text{nitroblue tetrazolium}_{\text{oxidized}} \overset{\text{AP}}{\rightleftharpoons}$$

$$>> \quad \text{5-bromo-4-chloro-3-indole} + P_i + \text{nitroblue tetrazolium}_{\text{reduced}} \quad \textbf{(Eq. 6.6)}$$

A modification of these coloring systems has recently been developed that leads to more sensitive detection. Chemiluminescent substrates have been

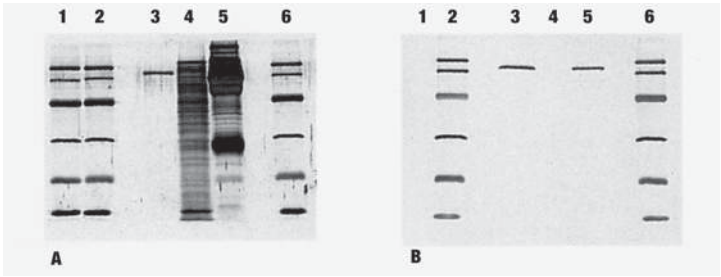

FIGURE 6.19 Results from a Western blot. **A** SDS-PAGE gels, 12%, were run and transferred to nitrocellulose. Lane **1,** MW standards; lane **2,** biotinylated standards; lane **3,** human transferrin; lane **4,** *E. coli* lysate; lane **5**, total human serum; lane **6**, biotinylated standards. Gel A was stained with a protein dye. Blot **B** was assayed using rabbit anti-human transferrin as the first antibody. The second antibody solution contained anti-rabbit HRP conjugates. Only the transferrin bands and the prestained biotinylated standards were detected by the antibodies and the avidin-HRP treatment.

designed that are converted by the enzymes to products that generate a light signal that can be captured on photographic film. This increases the level of sensitivity about 1000-fold over standard color detection methods.

Even though primary and secondary antibodies are widely used in Western blotting detection systems, they do have some disadvantages. For proteins to be detected, specific antibodies must be available. It is often very time-consuming and expensive for a research laboratory to generate the proper antibodies if they are not available commercially. Even if antibodies are commercially available, they are very expensive.

The Western blot has gained widespread use in biochemical and clinical investigations. It is one of the best methods for identifying the presence of specific proteins in complex biological mixtures. The Western blot procedure has been modified to develop a diagnostic assay that detects the presence in serum of antibodies to the AIDS virus. The presence of AIDS antibodies in a patient is an indication of viral infection.

Analysis of Electrophoresis Results

By separating biochemicals on the basis of charge, size, and conformation, electrophoresis can provide valuable information, such as purity, identity, and molecular weight. Purity is indicated by the number of stained bands in the electropherogram. One band usually means that only one detectable component is present; that is, the sample is homogeneous or "electrophoretically pure." Two or more bands usually indicate that the sample contains two or more components, contaminants, or impurities and is therefore heterogeneous or impure. There are, of course, exceptions. Other proteins or nucleic acids may be present in what appears to be a homogeneous sample, but they may be below the limit of detection of the staining method. Occasionally, a homogeneous sample may result in two or more bands because of degradation during the electrophoresis process. Information on purity may be obtained by all of the electrophoresis methods discussed.

The identity of unknown biomolecules can be confirmed by electrophoresis of the unknown along with possible known standards on the same gel. This is similar to the identification of unknowns by HPLC as discussed in Chapter 5, Section F, p. 140.

As previously discussed in this chapter, the molecular size of protein or nucleic acid samples may be determined by electrophoresis. This requires the preparation of standard curves of log molecular weight versus μ (mobility) using standard proteins or nucleic acids.

Study Problems

1. What physical characteristics of a biomolecule influence its rate of movement in an electrophoresis matrix?
2. Each of the proteins listed below is treated with sodium dodecyl sulfate and separated by electrophoresis on a polyacrylamide slab gel. Draw pictures of the final results.
   (a) Myoglobin
   (b) Hemoglobin (two α subunits, molecular weight = 15,500; two β subunits, molecular weight = 16,000)
3. Draw a slab gel to show the results of nondenaturing electrophoresis of the following mixture of proteins. The molecular weight is given for each.
   Lysozyme (13,930) Egg white albumin (45,000)
   Chymotrypsin (21,600) Serum albumin (65,400)
4. Explain the purpose of each of the chemical reagents that are used for PAGE.
   (a) acrylamide
   (b) *N*, *N*′-methylene-bis-acrylamide
   (c) TEMED
   (d) sodium dodecyl sulfate
   (e) Coomassie Blue dye
   (f) bromophenol blue
5. What is the main advantage of slab gels over column gels for PAGE?
6. Explain the purposes of protein and nucleic acid "blotting."
7. Is it possible to use polyacrylamide as a matrix for electrophoresis of nucleic acids? What are the limitations, if any?
8. Can polyacrylamide gels be used for the analysis of plasmid DNA with greater than 3000 base pairs? Why or why not?
9. Describe the toxic characteristics of acrylamide, and outline precautions necessary for its use.
10. The dye ethidium bromide is often used to detect the presence of nucleic acids on electrophoresis supports. Explain how it functions as an indicator.
11. The name "Western blot" is derived from other blotting procedures called the Southern blot (developed by Earl Southern) and the Northern blot. What are the differences among these three types of blotting techniques and what is the purpose of each?
12. An economical way to "block" a Western blot membrane is to incubate it in a 10% solution of nonfat milk powder. How does this solution function as a blocking reagent?
13. If a protein you wish to analyze by Western blotting is acidic (anionic under blotting conditions), what type of membrane would be best to ensure the tightest binding?
14. Design a diagnostic test based on the Western blot that would give an indication of infection by the AIDS virus. Assume that a blood serum sample is available from the patient.
15. A protein mixture can be fractionated either by native PAGE or by denaturing SDS-PAGE, before Western blotting. What factors would determine your choice of electrophoresis method?

16. Bromophenol blue dye is often used as a marker to tell you when to stop the electrophoresis process. What assumptions must you make about the relative movement of the dye versus sample proteins during electrophoresis?

17. In your biochemistry research project, you have isolated a new protein from spinach leaves. You wish to do a Western blot experiment with the protein to help determine its chemical structure and/or biological function. An amino acid analysis of the protein showed a great abundance of Phe, Leu, and Val. What would be your choice of membrane for the blotting experiment?

18. Define each of the following items in terms of their use in Western blotting.

(a) SDS-PAGE
(b) Nylon membrane
(c) Electroblotting
(d) Primary antibody
(e) Secondary antibody
(f) Protein molecular weight standard mixture
(g) Conjugated enzyme

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http://www.biotium.com/
View slide presentation on GelRed and GelGreen dye use and safety info.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER

7 SPECTROSCOPIC ANALYSIS OF BIOMOLECULES

A. Ultraviolet-Visible Absorption Spectrometry 202
B. Fluorescence Spectrometry 220
C. Nuclear Magnetic Resonance Spectroscopy 225
D. Mass Spectrometry 230
E. X-Ray Crystallography 233

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Some of the earliest experimental measurements on biomolecules involved studies of their interactions with electromagnetic radiation of all wavelengths, including X-ray, ultraviolet–visible, and infrared. It was experimentally observed that when light impinges on solutions or crystals of molecules, at least two distinct processes occur: **light scattering** and **light absorption.** Both processes have led to the development of fundamental techniques for characterizing and analyzing biomolecules. We now use the term **spectroscopy** to label the discipline that studies the interaction of electromagnetic radiation with matter.

Absorption of ultraviolet–visible light by molecules is an especially valuable process for measuring concentration and for molecular structure elucidation. The absorption process is dependent upon two factors: (1) the properties of the radiation (wavelength, energy, etc.), and (2) the structural characteristics of the absorbing molecules (atoms, functional groups, etc.). The interaction of electromagnetic radiation with molecules is a quantum process and described mathematically by quantum mechanics; that is, the radiation is subdivided into

discrete energy packets called **photons.** In addition, molecules have quantized excitation levels and can accept packets of only certain quantities of energy, thus allowing only certain electronic transitions.

With some molecules, the process of absorption is followed by emission of light of a longer wavelength. This process, called **fluorescence,** depends on molecular structure and environmental factors and assists in the characterization and analysis of biologically significant molecules and dynamic processes occurring between molecules.

Nuclear magnetic resonance spectroscopy and **mass spectrometry** techniques are also now being applied to the study of biological macromolecules and processes. NMR is especially versatile because, in addition to proton spectra, monitoring the presence of ^{13}C, ^{19}F, ^{15}N, and ^{31}P nuclei in biomolecules is possible. Multidimensional NMR is being applied to the study of protein secondary and tertiary structure. Accurate measurements of protein molecular weight and sequence analysis may now be carried out by mass spectrometry.

A. ULTRAVIOLET–VISIBLE ABSORPTION SPECTROMETRY

Wavelength and Energy

The electromagnetic spectrum, as shown in Figure 7.1, is composed of a continuum of waves with different properties defined by wavelength and energy. Several regions of the electromagnetic spectrum are of importance in biochemical studies, including X-ray (X-ray crystallography, up to 7 nm), the ultraviolet (UV, 180–340 nm), the visible (VIS, 340–800 nm), the infrared (IR, 1000–100,000 nm), and radio waves (NMR, 10^6-10^{10} nm). In this section, we will concentrate on the UV and VIS regions. Light in these regions has energy sufficient to excite the valence electrons of molecules and thus move the electrons from one energy level (or state) to a higher energy level (excited state).

Figure 7.2 shows that the propagation of light is due to an electrical field component E and a magnetic field component H that are perpendicular to each other. The **wavelength** of light, defined by Equation 7.1, is the distance between adjacent wave peaks, as shown in Figure 7.2.

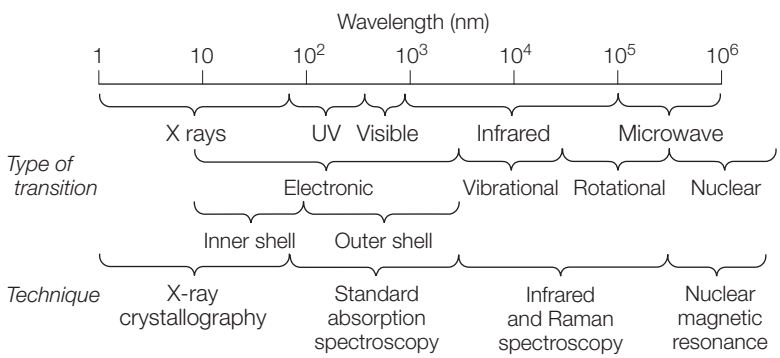

FIGURE 7.1 The electromagnetic spectrum. The wavelengths of light associated with important spectroscopy techniques are shown in the figure.

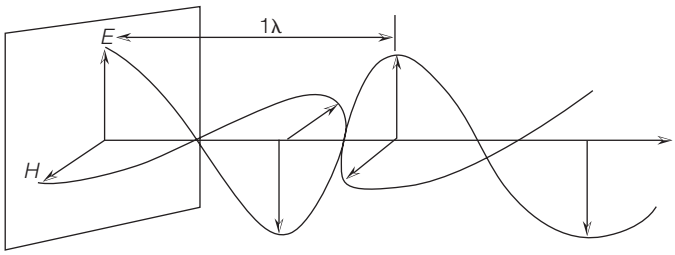

FIGURE 7.2 An electromagnetic wave, showing the *E* and *H* components.

>> $$\lambda = c/\nu$$ **(Eq. 7.1)**

where

λ = wavelength

c = speed of light, 3×10^8 m/s

ν = frequency, the number of waves passing a certain point per unit time

Light also behaves as though it were composed of energetic particles. The amount of energy E associated with these particles (or **photons**) is given by Equation 7.2:

>> $$E = h\nu$$ **(Eq. 7.2)**

where

h = Planck's constant, 6.63×10^{-34} Joules · s

Equations 7.1 and 7.2 may be combined to yield Equation 7.3:

>> $$E = hc/\lambda$$ **(Eq. 7.3)**

Note the inverse relationship between wavelength and energy. In Figure 7.1, X-rays have the shortest wavelength, but the most energy, and microwaves have long wavelengths, but the least energy.

STUDY EXERCISE 7.1 UV-VIS Spectroscopy

What is the amount of energy (E) associated with light of wavelength 300 nm in the ultraviolet range?

Solution: Using Equation 7.3:

$$E = hc/\lambda$$

$$E = \frac{(6.63 \times 10^{-34}\ \text{J} \cdot \text{s})(3 \times 10^8\ \text{m/s})}{300 \times 10^{-9}\ \text{m}}$$

$$= 6.63 \times 10^{-19}\ \text{J/photon} = 398\ \text{kJ/mole}$$

This is the approximate amount of energy associated with carbon-based covalent bonds.

Light Absorption

When a photon of specified energy interacts with a molecule, one of two processes may occur. The photon may be **scattered,** or it may transfer its energy to the molecule, producing an **excited state** of the molecule. The former process, called **Rayleigh scattering,** occurs when a photon collides with a molecule and is diffracted or scattered with unchanged frequency. Light scattering is the physical basis of several experimental methods used to characterize macromolecules. Before the development of electrophoresis, light scattering techniques were used to measure the molecular weights of macromolecules. The widely used techniques of X-ray diffraction (crystal and solution), electron microscopy, laser light scattering, and neutron scattering all rely in some way on the light scattering process.

The other process mentioned above, the transfer of energy from a photon to a molecule, is **absorption.** For a photon to be absorbed, its energy must match the energy difference between two energy levels of the molecule. Molecules possess a set of quantized energy levels, as shown in Figure 7.3. Although several states are possible, only two electronic states are shown, a **ground state,** G, and the **first excited state,** S_1. These two states differ in the distribution of valence electrons. When electrons are promoted from a ground state orbital in G to an orbital of higher energy in S_1, an **electronic transition** is said to occur. The energy associated with ultraviolet and visible light is sufficient to promote molecules from one electronic state to another, that is, to move electrons from one quantized level to another.

Within each electronic energy level is a set of **vibrational levels.** These represent changes in the stretching and bending of covalent bonds. The importance of these energy levels will not be discussed here, but transitions between the vibrational levels are the basis of infrared spectroscopy.

The electronic transition for a molecule from G to S_1, represented by the vertical arrow in Figure 7.3, has a high probability of occurring if the energy of the photon corresponds to the energy necessary to promote an electron from energy level E_1 to energy level E_2:

>> $$E_2 - E_1 = \Delta E = \frac{hc}{\lambda} \qquad \textbf{(Eq. 7.4)}$$

A transition may occur from any vibrational level in G to some other vibrational level in S_1, for example, $\nu = 3$; however, not all transitions have equal probability.

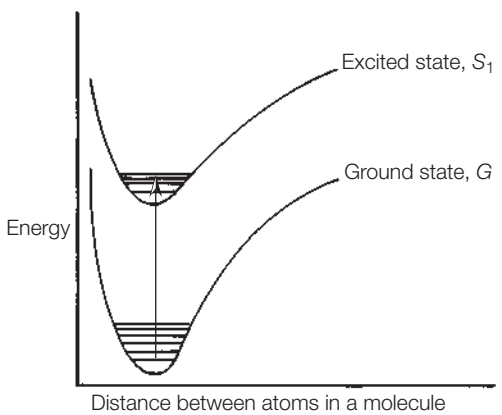

FIGURE 7.3
Energy-level diagram showing the ground state G and the first excited state S_1.

The probability of absorption is described by quantum mechanics and will not be discussed here.

Electronic Transitions in Biomolecules

Absorption of UV and VIS light occurs when the energy associated with the electromagnetic radiation matches the energy difference between molecular states in a molecule. But what are the actual electronic transitions that occur in a molecule? If this question can be answered, then it should be possible to predict which molecules will or will not absorb UV-VIS light. The reverse is also true—by observing the wavelengths of light absorbed by a molecule, it should be possible to speculate on molecular structure (what atoms and functional groups are present). Consider the electronic properties of a carbonyl group, a functional group present in many types of biomolecules including amino acids, fatty acids, carbohydrates (open chain), nucleotides, proteins, and nucleic acids. A molecular orbital diagram showing the valence electrons in the higher-energy orbitals of the carbonyl group is displayed in Figure 7.4. There are three types of orbitals shown:

- n = nonbonding orbitals with lone pairs of electrons in atoms like O, N, and S
- π = bonding orbitals formed by overlap of p atomic orbitals
- π^* = antibonding orbitals

Two kinds of electronic transitions are possible:

- $\pi \rightarrow \pi^*$, which are "allowed" by quantum mechanics and have a high probability of occurring, and
- $n \rightarrow \pi^*$, which are "forbidden" and have a low probability of occurring.

These two types of electronic transitions are shown in Figure 7.4.

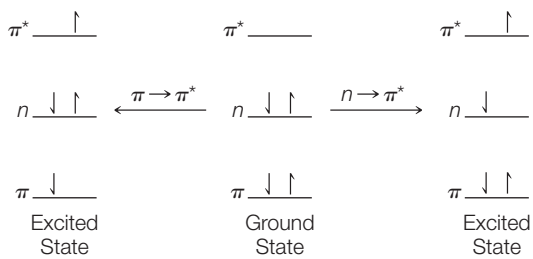

FIGURE 7.4 Molecular orbital diagram for the carbonyl group. Only valence electrons in higher-energy orbitals are shown. Two types of electronic transitions are illustrated: $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$.

Proteins

The following functional groups in proteins are responsible for absorption of UV-VIS light:

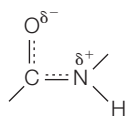

1. Peptide bonds:
   - $\pi \rightarrow \pi^*$, intense absorption at 190 nm
   - $n \rightarrow \pi^*$, very weak absorption at 210–220 nm
2. Amino acid residues containing aromatic phenyl groups: Phe, Tyr, Trp

   - $\pi \rightarrow \pi^*$
     Phe: weak absorption at 250 nm
     Tyr: weak absorption at 274 nm
     Trp: strong absorption at 280 nm
     The absorbance at 280 nm is often used to measure protein concentration (See Chapter 3, Section B, p. 70, The Spectrophotometric Assay).
3. Prosthetic groups:
   Nucleotide cofactors: NAD^+, FAD, FMN, etc.
   Heme
   Chlorophyll
   Metal ions: Cu(II), Fe(II), Fe(III), Ni(II), etc.
   Highly conjugated compounds: retinal, etc.

Many of the cofactors and prosthetic groups above absorb in both the UV and VIS regions. Absorption in the VIS region causes many of the biomolecules in Group 3 to be colored.

Nucleic Acids

Absorption is due to the presence of pyrimidine and purine bases, which have several different types of electronic transitions (see structures, Chapter 9, p. 268):

1. Extensive aromatic character, ($\pi \rightarrow \pi^*$)
2. Carbonyl groups in bases, ($\pi \rightarrow \pi^*$; $n \rightarrow \pi^*$)
3. Several nitrogen and oxygen atoms, ($n \rightarrow \pi^*$).

Nucleic acids display intense absorption in the 200–300-nm range with a maximum at 260 nm. This is the basis for the spectrophotometric assay of DNA and RNA solutions (Chapter 3, Section C, p. 71).

STUDY EXERCISE 7.2 UV-VIS Spectroscopy

Predict the types of electronic transitions in each of the following biomolecules and suggest whether UV-VIS spectroscopy might be useful in their analysis and characterization. You may need to review their structures in your biochemistry textbook.

(a) Alanine
(b) Lysine
(c) Cysteine
(d) Glucose
(e) Lauric acid
(f) Adenine
(g) β-carotene
(h) Chlorophyll
(i) Bilirubin
(j) Ferritin, a protein containing Fe(III)

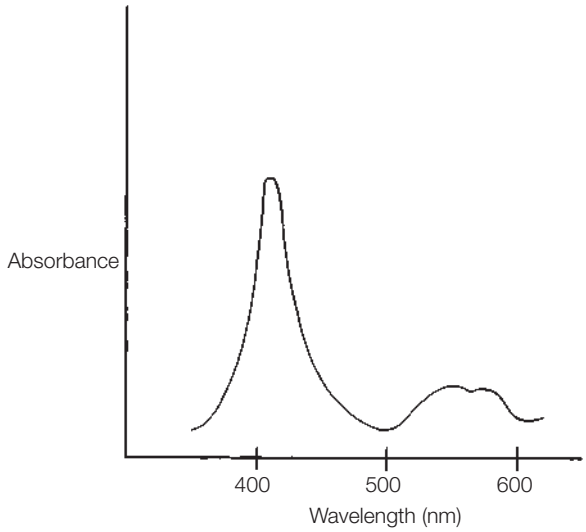

FIGURE 7.5 The visible absorbance spectrum of hemoglobin.

The Absorption Spectrum

A UV-VIS spectrum is obtained by measuring the light absorbed by a sample as a function of wavelength. Since only discrete packets of energy (specific wavelengths) are absorbed by molecules in the sample, the spectrum theoretically should consist of sharp discrete lines. However, the many vibrational levels of each electronic energy level increase the number of possible transitions. This results in several spectral lines, which together make up the familiar spectrum of broad peaks as shown in Figure 7.5.

An absorption spectrum can aid in the identification of a molecule because the wavelength of absorption depends on the functional groups or arrangement of atoms in the sample. The spectrum of oxyhemoglobin in Figure 7.5 is due to the presence of the iron porphyrin moiety and is useful for the characterization of heme derivatives or hemoproteins. Note that the spectrum consists of several peaks at wavelengths where absorption reaches a maximum (415, 542, and 577 nm). These points, called λ_{max}, are of great significance in the identification of unknown molecules and will be discussed later in the chapter.

The Beer-Lambert Law

Quantitative measurements in spectrophotometry are evaluated using the Beer-Lambert law:

>> $$A = Elc$$ **(Eq. 7.5)**

where

A = absorbance or $-\log(I/I_0)$
I_0 = intensity of light irradiating the sample
I = intensity of light transmitted through the sample
E = absorption coefficient or absorptivity

l = path length of light through the sample, or thickness of the cell

c = concentration of absorbing material in the sample

Since the absorbance, A, is derived from a ratio $(-\log I/I_0)$, it is unitless. The term E, which is a proportionality constant, defines the efficiency or extent of absorption. If this is defined for a particular chromophore at a specific wavelength, the term **absorption coefficient** or **absorptivity** is used. However, students should be aware that in the older biochemical literature, the term extinction coefficient is often used. The units of E depend on the units of l (usually cm) and c (usually molar) in Equation 7.5. For biomolecules, E is often used in the form **molar absorption coefficient,** ε, which is defined as the absorbance of a 1 M solution of pure absorbing material in a 1-cm cell under specified conditions of wavelength and solvent. The units of ε are $M^{-1}\,\text{cm}^{-1}$. To illustrate the use of Equation 7.5, consider the following calculation:

STUDY EXERCISE 7.3 Beer-Lambert Law

The absorbance, A, of a 5×10^{-4} M solution of the amino acid tyrosine, at a wavelength of 280 nm, is 0.75. The path length of the cuvette is 1 cm. What is the molar absorption coefficient, ε?

Solution:

$$A = \varepsilon lc = 0.75$$

$$l = 1\,\text{cm}$$

$$c = 5 \times 10^{-4}\,M$$

$$\varepsilon = \frac{0.75}{(1\,\text{cm})(5 \times 10^{-4}\,\text{mole/liter})}$$

$$= 1500\,\frac{\text{liter}}{\text{mole} \times \text{cm}} = 1500\,M^{-1}\,\text{cm}^{-1}$$

Notice that the units of ε are defined by the concentration units of the tyrosine solution (M) and the dimension units of the cuvette (cm). Although E is most often expressed as a molar absorption coefficient, you may encounter other units such as $E_{\lambda,}^{1\%}$ which is the absorbance of a 1% (w/v) solution of pure absorbing material in a 1-cm cuvette at a specified wavelength, λ.

STUDY EXERCISE 7.4 Absorption Coefficients

In the older biochemical literature, absorption coefficients are often reported as **extinction coefficients ($E_{\lambda}^{1\%}$)**. The extinction coefficient of the enzyme yeast alcohol dehydrogenase is:

$$E_{\lambda}^{1\%} = 12.6$$

Calculate the molar absorption coefficient for yeast alcohol dehydrogenase. The molecular weight for the enzyme is 141,000.

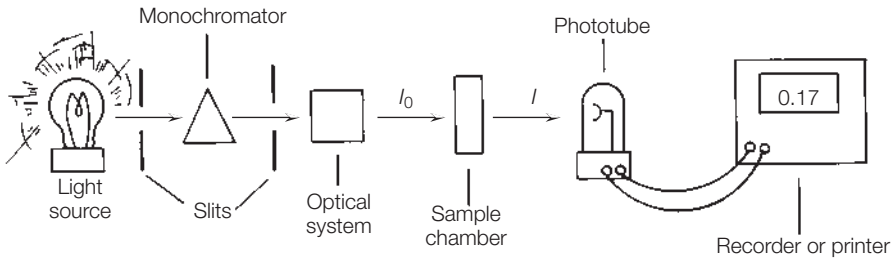

FIGURE 7.6 A diagram of a conventional, single-beam spectrophotometer.

Instrumentation

The **spectrophotometer** is used to measure absorbance experimentally. This instrument produces light of a preselected wavelength, directs it through the sample (usually dissolved in a solvent and placed in a cuvette), and measures the intensity of light transmitted by the sample. The major components are shown in Figure 7.6. These consist of a light source, a monochromator (including various filters, slits, and mirrors), a sample chamber, a detector, and a meter or recorder. All of these components are usually under the control of a computer.

Light Source

For absorption measurements in the ultraviolet region, a high-pressure hydrogen or deuterium lamp is used. These lamps produce radiation in the 200 to 340 nm range. The light source for the visible region is the tungsten-halogen lamp, with a wavelength range of 340 to 800 nm. Instruments with both lamps have greater flexibility and can be used for the study of most biologically significant molecules.

Monochromator

Both lamps discussed above produce continuous emissions of all wavelengths within their range. Therefore, a spectrophotometer must have an optical system to select monochromatic light (light of a specific wavelength). Modern instruments use a prism or, more often, a diffraction grating to produce the desired wavelengths. It should be noted that light emitted from the monochromator is not entirely of a single wavelength, but is enhanced in that wavelength. That is, most of the light is of a single wavelength, but shorter and longer wavelengths are present.

Before the monochromatic light impinges on the sample, it passes through a series of slits, lenses, filters, and mirrors. This optical system concentrates the light, increases the spectral purity, and focuses it toward the sample. The operator of a spectrophotometer has little control over the optical manipulation of the light beam, except for adjustment of slit width. Light passing from the monochromator to the sample encounters a "gate" or slit. The slit width, which is controlled by a computer, determines both the intensity of light impinging on the sample and the spectral purity of that light. Decreasing the slit width increases the spectral purity of the light, but the amount of light directed toward the sample decreases. The efficiency or sensitivity of the detector then becomes a limiting factor.

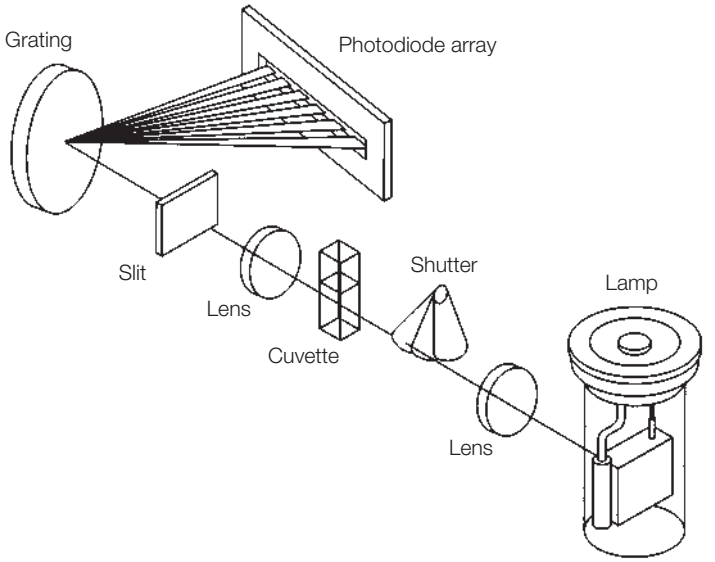

FIGURE 7.7
Optical diagram for a diode-array spectrophotometer.

In instruments equipped with photodiode array detectors (see Figure 7.7 and the following section on detectors), polychromatic light from a source passes through the sample and is focused on the entrance slit of a polychromator (a holographic grating that disperses the light into its wavelengths). The wavelength-resolved light beam is then focused onto the photodiode array detector. The relative positions of the sample and grating are reversed compared to conventional spectrometry; hence, the new configuration is often called reversed optics. (Compare Figures 7.6 and 7.7.)

Sample Chamber

The processed monochromatic light is then directed into a sample chamber, which can accommodate a wide variety of sample holders. Most UV-VIS measurements on biomolecules are taken on solutions of the molecules. The sample is placed in a tube or cuvette made of glass, quartz, or other transparent material. Figure 7.8 shows the transmission properties of several transparent materials used in cuvette construction.

Glass cuvettes are inexpensive, but, because they absorb UV light, they can be used only above 340 nm. Quartz or fused silica cuvettes may be used throughout the UV and visible regions ($\sim$200$-$800 nm). Disposable plastic cuvettes are now commercially available in polymethacrylate (280–800 nm) and polystyrene (350–800 nm). The care and use of cuvettes were discussed in Chapter 1, p. 15.

Sample chambers for spectrometers come in two varieties—those holding only one cuvette at a time (single-beam) and those holding two cuvettes, one for a reference, usually solvent, and one for a sample (double-beam). In the past, single-beam instruments were usually less expensive but more cumbersome to use because reference and sample cuvettes required constant exchange. However, modern single-beam instruments with computer control and analysis

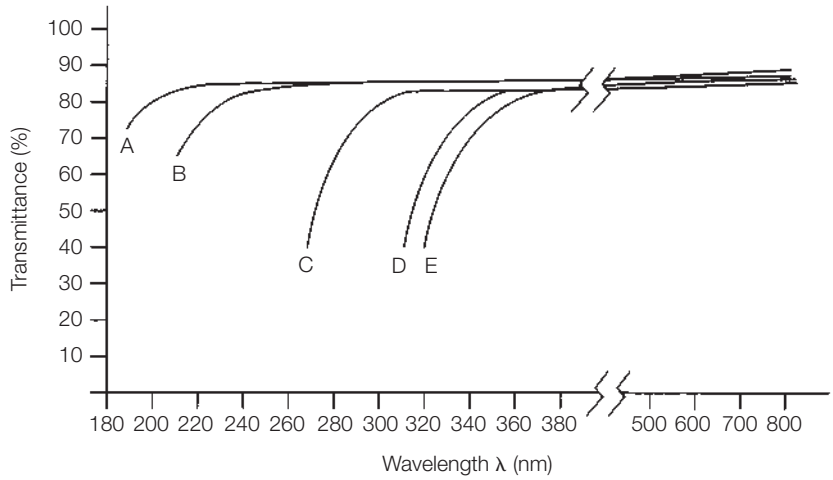

FIGURE 7.8 The transmission properties of several materials used in cuvettes.
A = silica (quartz)
B = NIR silica
C = polymethacrylate
D = polystyrene
E = glass

can be programmed to correct automatically for the reference spectrum, which may be stored in a memory file. In double-beam optics, the light beam is split into two paths by directing it through a monochromator. The two beams, which are of identical wavelength and intensity, pass through the sample cell (analyte plus solvent) and reference chamber (solvent only). This allows for the correction of sample absorbance by continuously subtracting the reference spectrum.

Detector

The intensity of the light that passes through the sample under study depends on the amount of light absorbed by the sample. Intensity is measured by a light-sensitive detector, usually a photomultiplier tube (PMT). The PMT detects a small amount of light energy, amplifies this by a cascade of electrons accelerated by dynodes, and converts it into an electrical signal that can be fed into a meter or recorder.

A new technology has been introduced during the past few years that greatly increases the speed of spectrophotometric measurements. New detectors called **photodiode arrays** are being used in modern spectrometers. Photodiodes are composed of silicon crystals that are sensitive to light in the wavelength range 170–1100 nm. Upon photon absorption by the diode, a current is generated in the photodiode that is proportional to the number of photons. Linear arrays of photodiodes are self-scanning and have response times on the order of 100 milliseconds; hence, an entire UV-VIS spectrum can be obtained with an extremely brief exposure of the sample to polychromatic light. New spectrometers designed by Hewlett-Packard, Perkin-Elmer, and others use this technology and can produce a full spectrum from 190 to 820 nm in one-tenth of a second or less.

Printers and Recorders

Less expensive instruments give a direct readout of absorbance and/or transmittance in analog or digital form. These instruments are suitable for single-wavelength measurements; however, if a scan of absorbance vs. wavelength (Figure 7.5) is desired, some type of device to display the spectrum must be available.

Modern, research-grade spectrometers are available that offer the latest in technology. All of the components discussed above are integrated into a single package and are completely under the control of a computer. By simply pushing a button, one can obtain the UV-VIS spectrum of a sample displayed on a computer screen in less than 1 second. In addition, these modern instruments with computers can be programmed to carry out several functions, such as subtraction of solvent spectrum, spectral overlay, storage, difference spectra, derivative spectra, and calculation of concentrations and rate constants.

Applications of UV–VIS Spectroscopy

Now that you are familiar with the theory and instrumentation of absorption spectrophotometry, you will more easily understand the actual operation and typical applications of a spectrophotometer. Since virtually all UV-VIS measurements are made on samples dissolved in solvents, only those applications will be described here. Although many different types of operations can be carried out on a spectrophotometer, all applications fall in one of two categories:

1. measurement of absorbance at a fixed wavelength;
2. measurement of absorbance as a function of wavelength.

Measurements at a fixed wavelength are most often used to obtain quantitative information, such as the concentration of a solute in solution or the absorption coefficient of a chromophore. Absorbance measurements as a function of wavelength provide qualitative information that assists in solving the identity and structure of a pure substance by detecting characteristic groupings of atoms in a molecule.

For fixed-wavelength measurements with a single-beam instrument, a cuvette containing solvent only is placed in the sample beam and the instrument is adjusted to read "zero" absorbance. A matched cuvette containing sample plus solvent is then placed in the sample chamber and the absorbance is read directly from the display. The adjustment to zero absorbance with only solvent in the sample chamber allows the operator to obtain a direct reading of absorbance for the sample.

Fixed-wavelength measurements using a double-beam spectrophotometer are made by first zeroing the instrument with no cuvette in either the sample or reference holder. Alternatively, the spectrophotometer can be balanced by placing matched cuvettes containing water or solvent in both sample chambers. Then, a cuvette containing pure solvent is placed in the reference position and a matched cuvette containing solvent plus sample is set in the sample position. The absorbance reading given by the instrument is that of the sample; that is, the absorbance due to solvent is subtracted by the instrument.

An **absorbance spectrum** of a compound is obtained by scanning a range of wavelengths and plotting the absorbance at each wavelength. Most double-beam spectrophotometers automatically scan the desired wavelength range and record the absorbance as a function of wavelength. If solvent is placed in the reference chamber and solvent plus sample in the sample position, the instrument will continuously and automatically subtract the solvent absorbance from the

total absorbance (solvent plus sample) at each wavelength; hence, the recorder output is really a difference spectrum (absorbance of sample plus solvent, minus absorbance of solvent).

Both types of measurements (fixed wavelength and absorbance spectrum) are common in biochemistry, and you should be able to interpret results from each. The following four examples are typical of the kinds of problems readily solved by spectrophotometry.

Measurement of the Concentration of an Analyte in Solution

According to the Beer-Lambert law, the absorbance of a material in solution is directly dependent on the concentration of that material. Two methods are commonly used to measure concentration. If the absorption coefficient is known for the absorbing species, the concentration can be calculated after experimental measurement of the absorbance of the solution.

STUDY EXERCISE 7.5 Absorbance and Concentration

A solution of the nucleotide base uracil, in a 1-cm cuvette, has an absorbance at λ_{max}(260 nm) of 0.65. Pure solvent in a matched quartz cuvette has an absorbance of 0.07. What is the molar concentration of the uracil solution? Assume the molar absorption coefficient, ε, is $8.2 \times 10^3 M^{-1}\,cm^{-1}$.

Solution:

$$A = \varepsilon l c$$

$$A = (\text{absorbance of solvent + sample}) - (\text{absorbance of solvent})$$

$$A = 0.65 - 0.07 = 0.58$$

$$\varepsilon = 8.2 \times 10^3 M^{-1}\,cm^{-1}$$

$$l = 1\,cm$$

$$c = \frac{A}{\varepsilon l} = \frac{0.58}{(8.2 \times 10^3 M^{-1}\,cm^{-1})(1\,cm)}$$

$$c = 7.1 \times 10^{-5} M$$

If the absorption coefficient for an absorbing species is known, the concentration of that species in solution can be calculated as outlined. However, there are limitations to this application. Most spectrophotometers are useful for measuring absorbances up to 1, although more sophisticated instruments can measure absorbances as high as 2. (If the absorbance is above 1, dilute sample with the same solvent.) Most absorbance readings below 0.1 are not accurate. Also, some substances do not obey the Beer-Lambert law; that is, absorbance may not increase in a linear fashion with concentration. Reasons for deviation from the Beer-Lambert law are many; however, the majority are instrumental, chemical, or physical. Spectrophotometers often display a

nonlinear response at high absorption levels because of stray light. Physical reasons for nonlinearity include hydrogen bonding of the absorbing species with the solvent and intermolecular interactions at high concentrations. Chemical reasons may include reaction of the solvent with the absorbing species and the presence of impurities. Linearity is readily tested by preparing a series of concentrations of the absorbing species and measuring the absorbance of each. A plot of A vs. concentration should be linear if the Beer-Lambert law is valid. If the absorption coefficient for a species is unknown, its concentration in solution can be measured if the absorbance of a standard solution of the compound is known.

STUDY EXERCISE 7.6 Absorbance and Concentration

The absorbance of a 1% (w/v) solution of the enzyme tyrosinase, in a 1-cm cell at 280 nm, is 24.9. What is the concentration of a tyrosinase solution that has an A_{280} of 0.25?

Since the absorption coefficient, $E\%$, is the same for both solutions, the concentration can be calculated by a direct ratio:

Solution:

$$\frac{A_{\text{std}}}{C_{\text{std}}} = \frac{A_x}{C_x}$$

A_{std} = absorbance of the 1% standard solution = 24.9

C_{std} = concentration of the standard solution = 1% (1 g/dL)

A_x = absorbance of the unknown solution = 0.25

C_x = concentration of the unknown solution in, %

$$\frac{24.9}{1\%} = \frac{0.25}{C_x}$$

$$C_x = 0.01\% = 0.01 \text{ g/dL} = 0.1 \text{ mg/mL}$$

Alternatively, the concentration of a species in solution can be determined by preparing a standard curve of absorbance vs. concentration.

STUDY EXERCISE 7.7 Bradford Protein Assay

The Bradford protein assay is one of the most used spectrophotometric assays in biochemistry. (For a discussion of the Bradford assay, see Chapter 3, Section B, p. 69.) Solutions of varying amounts of a standard protein are mixed with reagents that cause the development of a color. The amount of color produced depends on the amount of protein present. The absorbance at 595 nm of each reaction mixture is plotted against the known protein concentration. A protein sample of unknown concentration is treated with the Bradford reagents, and the color is allowed to develop.

The following absorbance measurements are typical for the standard curve of a protein:

Protein (μg per assay)	A_{595}
15	0.07
25	0.15
50	0.28
100	0.55
150	0.90
0.1 mL unknown protein solution	0.10
0.2 mL unknown protein solution	0.22

A standard curve for the data is plotted in Figure 3.6 on page 70. What standard protein was used in this case? Note the linearity, indicating that the Beer-Lambert law is obeyed over this concentration range of standard protein. Two different volumes of unknown protein were tested. This was to ensure that one volume would be in the concentration range of the standard curve. Since the accuracy of the assay is dependent on identical times for color development, the unknowns must be assayed at the same time as the standards. From graphical analysis, an A_{595} of 0.22 corresponds to 40 μg of protein per 0.20 mL. This indicates that the original protein solution concentration was approximately 200 μg/mL or 0.20 mg/mL. Using computer graphics, students can now quickly visualize experimental data and determine the need for further analysis. Most modern computer programs use the method of least squares to calculate automatically the slope, intercepts, and correlation coefficients.

Absorbance Measurements on Very Small Sample Volumes

The absorbance experiments described to this point have been applied to sample sizes of 1 and 3 mL measured in glass or quartz cuvettes. Biomolecules are often expensive, difficult to isolate, and not always available in these large sample sizes. Recent advances in the development of spectrophotometers now make available instruments for rapidly quantifying and analyzing micro-volume samples. For example, NanoDrop UV-VIS spectrophotometers from Thermo Scientific (www.thermo.com/nanodrop) can measure samples as small as 0.5µl in about 5 seconds. The wavelength range of the spectrometers is 220–750 nm, and they can make both individual absorbance measurements and absorption spectra (scans). Cuvettes and capillaries are not necessary, as the sample droplet is applied directly onto an optical pedestal for measurement. Measurements can be made on any biomolecules that absorb in the wavelength range. This includes proteins, DNA, RNA, nucleotides, cofactors, fluorescent substances, and many others.

Identification of Unknown Biomolecules by Spectrophotometry

The UV-VIS spectrum of a biomolecule reveals much about its molecular structure. Therefore, a spectral analysis is one of the first experimental measurements made on an unknown biomolecule. Natural molecules often contain

chromophoric (color-producing) functional groups that have characteristic spectra. Figure 7.9 displays spectra of the well-characterized biomolecules DNA, FMN, $FMNH_2$, NAD^+, NADH, a nucleotide, and a pyrimidine base.

The procedure for obtaining a UV-VIS spectrum begins with the preparation of a solution of the species under study. A standard solution should be prepared in an appropriate solvent. An aliquot of the solution is transferred to a

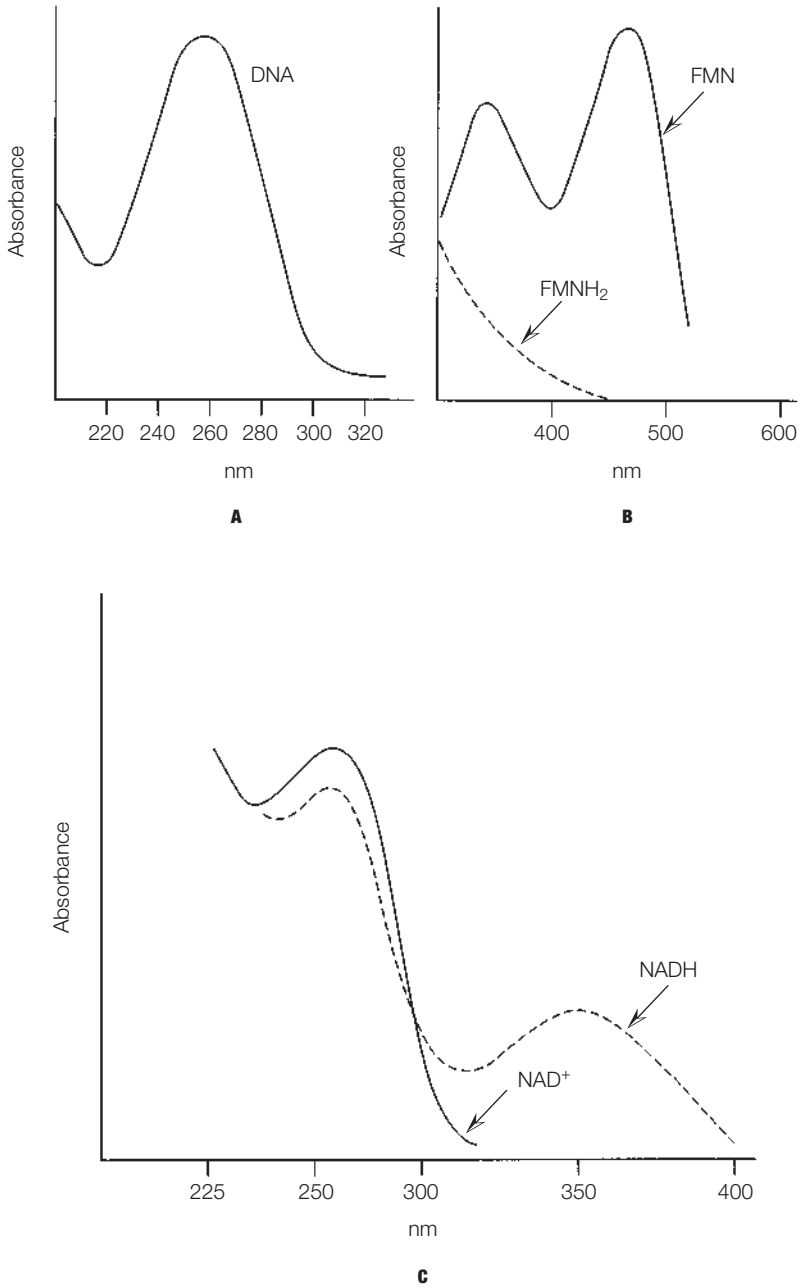

FIGURE 7.9
UV-VIS absorbance spectra of significant biomolecules. **A** DNA, **B** FMN and $FMNH_2$, **C** NAD^+ and NADH, **D** d-GMP, **E** thymine.

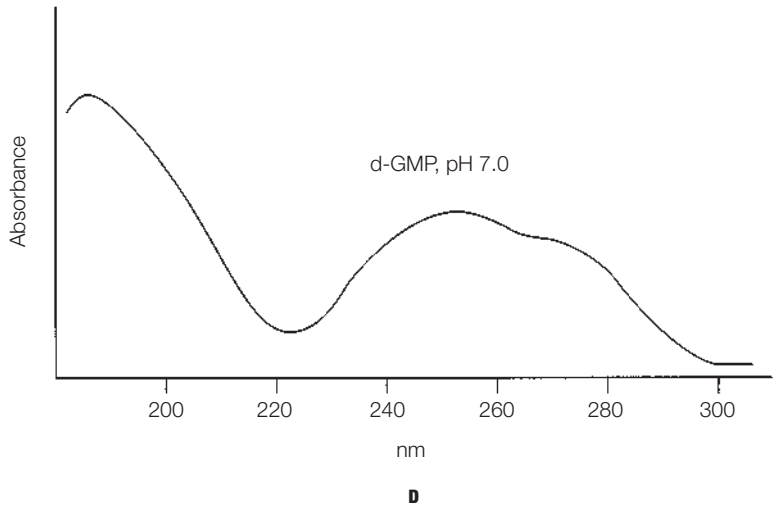

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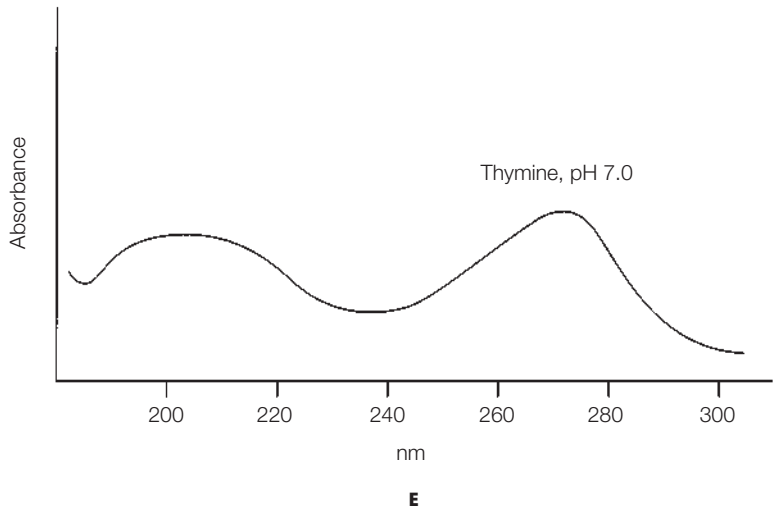

E

FIGURE 7.9
(*Continued*)

cuvette and placed in the sample chamber of a spectrophotometer. A cuvette containing solvent is placed in the reference holder. The spectrum is scanned over the desired wavelength range and an absorption coefficient is calculated for each major λ_{max}.

Kinetics of Biochemical Reactions

Spectrophotometry is one of the best methods available for measuring the rates of biochemical reactions. Consider a general reaction as shown in Equation 7.6.

>> $$A + B \rightleftharpoons C + D$$ **(Eq. 7.6)**

If reactants A or B absorb in the UV-VIS region of the spectrum at some wavelength λ_1, the rate of the reaction can be measured by monitoring the

decrease of absorbance at λ_1 due to loss of A or B. Alternatively, if products C or D absorb at a specific wavelength λ_2, the kinetics of the reaction can be evaluated by monitoring the absorbance increase at λ_2. According to the Beer-Lambert law, the absorbance change of a reactant or product is proportional to the concentration change of that species occurring during the reaction. This method is widely used to assay enzyme-catalyzed processes. Since the rates of chemical reactions vary with temperature, the sample cuvette containing the reaction mixture must be held in a thermostated chamber.

Characterization of Macromolecule-Ligand Interactions by Difference Spectroscopy

Many biological processes depend on a specific interaction between molecules. The interaction often involves a macromolecule (protein or nucleic acid) and a smaller molecule, a **ligand.** Specific examples include enzyme-substrate interactions and receptor protein–hormone interactions (see Chapter 8). One of the most effective and convenient methods for detecting and characterizing such interactions is **difference spectroscopy.** The interaction of small molecules with the transport protein hemoglobin is a classic example of the utility of difference spectroscopy. If a small molecule or ligand, such as inositol hexaphosphate, binds to hemoglobin, there is a change in the heme spectral properties. The spectral change is small and would be difficult to detect if the experimenter recorded the spectrum in the usual fashion. Normally, one would obtain a spectrum of a heme protein by placing a solution of the protein in a cuvette in the sample compartment of a spectrophotometer and the neat solvent in the reference compartment. Any absorption due to solvent is subtracted because the solvent is present in both light beams, so the spectrum is that due to the heme protein. Then the ligand to be tested would be added to the heme protein, and the spectrum would be obtained for this mixture vs. solvent. If the free or bound ligand molecule did not absorb light in the wavelength range studied, there would be no need to have ligand in the reference cell. The two spectra (heme protein in solvent vs. solvent and heme protein and ligand in solvent vs. solvent) can then be compared and differences noted.

A difference spectrum is faster than the preceding method because only one spectral recording is necessary. Two cuvettes are prepared in the following manner. The reference cuvette contains heme protein and solvent, whereas the sample cuvette contains heme protein, solvent, and ligand. There must be equal concentrations of the heme protein in the two cuvettes. (Why?) The two cuvettes are placed in a double-beam spectrophotometer and the spectrum is recorded. If the spectrum of the heme protein is not influenced by the ligand, the result would be a zero difference spectrum, that is, a straight line (Figure 7.10A). Both samples have identical spectral properties, indicating that there is probably little or no interaction between heme protein and ligand. However, such data should be treated with caution because it is possible that the heme group is not affected by ligand binding. A nonzero difference spectrum indicates that the ligand interacts with the heme protein and induces a change in the environment of the heme group (Figure 7.10B).

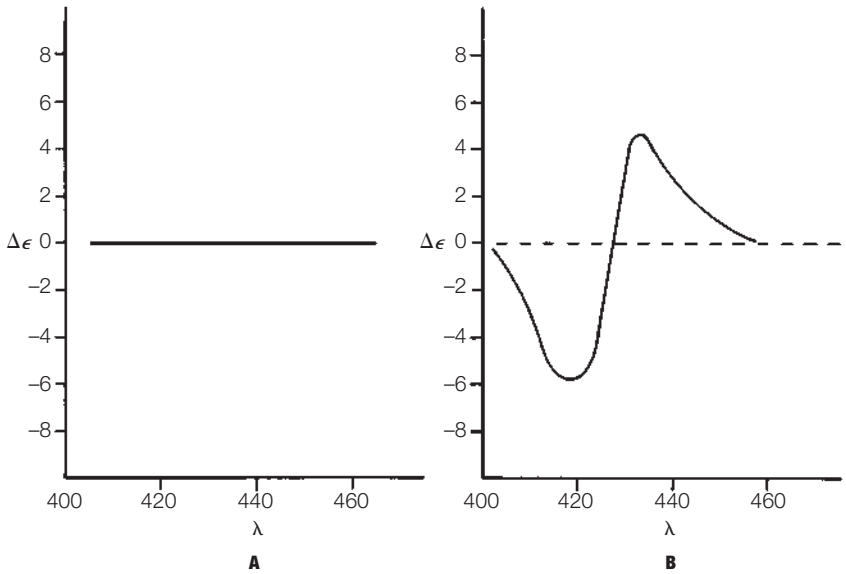

FIGURE 7.10 Difference spectroscopy. **A** Hemoglobin vs. hemoglobin. **B** Hemoglobin vs. hemoglobin + inositol hexaphosphate.

A difference spectrum can be analyzed and used in several ways. This is a useful technique for demonstrating qualitatively whether an interaction occurs between a macromolecule and a ligand. Quantitative analysis of difference spectra requires measurement of λ_{max} and ΔA at λ_{max}. This method can be used to quantify the strength of ligand-protein interaction. Note that every time you record a spectrum in a double-beam spectrometer, you are obtaining a difference spectrum between sample and reference. Although a heme protein was used in this example, this does not imply that only heme interactions can be characterized by difference spectroscopy. Any protein that contains a chromophoric group, whether it be an aromatic amino acid, cofactor, prosthetic group, or metal ion, can be studied by difference spectroscopy.

Limitations and Precautions in Spectrophotometry

The use of a spectrophotometer is relatively straightforward and can be mastered in a short period of time. There are, however, difficulties that must be considered. A common problem encountered with biochemical measurements is turbidity, or cloudiness, of biological samples. This can lead to great error in absorbance measurements because much of the light entering the cuvette is not absorbed but is scattered. This causes artificially high absorbance readings. Occasionally, absorbance readings on turbid solutions are desirable (as in measuring the rate of bacterial growth in a culture), but in most cases turbid solutions must be avoided or clarified by filtration or centrifugation.

A difficulty encountered in measuring the concentration of an unknown absorbing species in solution is deviation from the Beer-Lambert law. For reasons stated earlier in this chapter, some absorbing species do not demonstrate an increase in absorbance that is proportional to an increase in concentration. (In reality, most compounds follow the Beer-Lambert relationship over a

relatively small concentration range.) When measuring solution concentration, adherence to the Beer-Lambert law must always be tested in the concentration range under study.

B. FLUORESCENCE SPECTROMETRY

Principles

In our discussion of absorption spectroscopy, we noted that the interaction of photons with molecules resulted in the promotion of valence electrons from ground state orbitals to higher energy level orbitals. The molecules were said to be in an excited state.

Molecules in the excited state do not remain there long, but spontaneously relax to the more stable ground state. With most molecules, the relaxation process is brought about by collisional energy transfer to solvent or other molecules in the solution. Some excited molecules, however, return to the ground state by emitting the excess energy as light. This process, called **fluorescence,** is illustrated in Figure 7.11. The solid vertical arrow in the figure indicates the photon absorption process in which the molecule is excited from *G* to some vibrational level in *S*. The excited molecule loses vibrational energy by collision with solvent and ground state molecules. This relaxation process, which is very rapid, leaves the molecule in the lowest vibrational level of *S*, as indicated by the wavy arrow. The molecule may release its energy in the form of light (fluorescence, dashed arrow) to return to some vibrational level of *G*.

Two important characteristics of the emitted light should be noted: (1) The emitted light is of longer wavelength (lower energy) than the excitation light. This is because part of the energy initially associated with the *S* state is lost as heat energy, and the energy lost by emission may be sufficient only to return the excited molecule to a higher vibrational level in *G*. (2) The emitted light is composed of many wavelengths, which results in a fluorescence spectrum as shown in Figure 7.12. This is due to the fact that fluorescence from any particular excited molecule may return the molecule to one of many vibrational levels in the ground state. Just as in the case of an absorption spectrum, a wavelength of

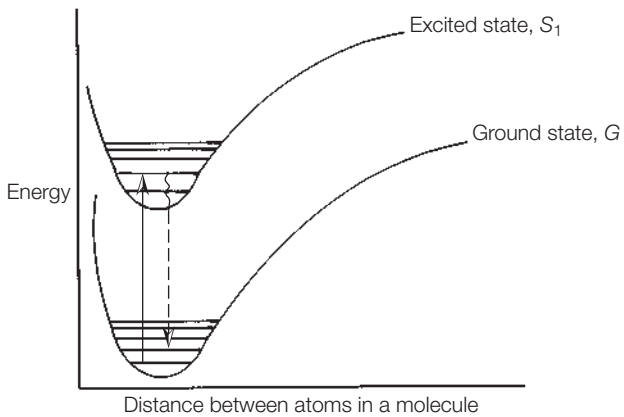

FIGURE 7.11
Energy-level diagram outlining the fluorescence process. See text for details.

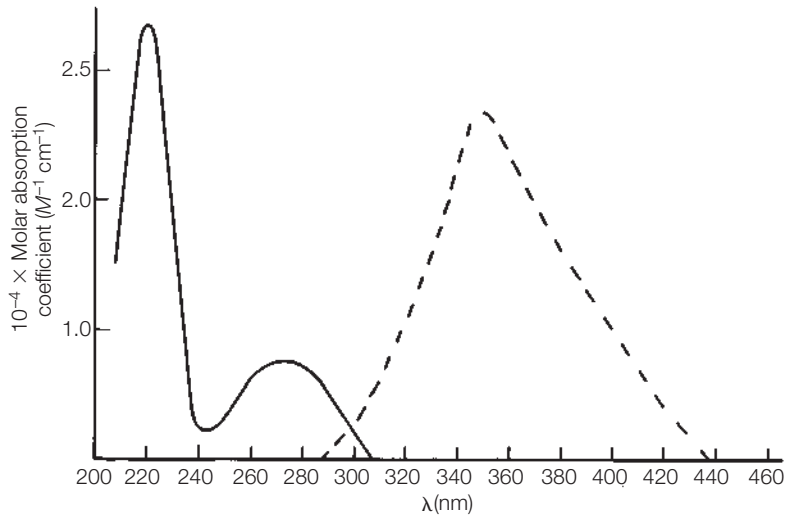

FIGURE 7.12
Absorption (—) and fluorescence (– – –) spectra of the amino acid tryptophan.

maximum fluorescence is observed, and the spectrum is composed of a wavelength distribution centered at this emission maximum.

Quantum Yield

In the foregoing discussion, it was pointed out that a molecule in the excited state can return to lower energy levels by collisional transfer or by light emission. Since these two processes are competitive, the **fluorescence intensity** of a fluorescing system depends on the relative importance of each process. The fluorescence intensity is often defined in terms of **quantum yield,** represented by Q. This describes the efficiency or probability of the fluorescence process. By definition, Q is the ratio of the number of photons emitted to the number of photons absorbed (Equation 7.7).

>>
$$Q = \frac{\text{number of photons emitted}}{\text{number of photons absorbed}} \qquad \textbf{(Eq. 7.7)}$$

Measurement of quantum yield is often the goal in fluorescence spectroscopy experiments. Q is of interest because it may reveal important characteristics of the fluorescing system. Two types of factors affect the intensity of fluorescence, internal and external (environmental) influences. Internal factors, such as the number of vibrational levels available for transition and the rigidity of the molecules, are associated with properties of the fluorescent molecules themselves. Internal factors will not be discussed in detail here because they are of more interest in theoretical studies. The external factors that affect Q are of great interest to biochemists because information can be obtained about macromolecule conformation and molecular interactions between small molecules (ligands) and larger biomolecules (proteins, nucleic acids). Of special value is the study of experimental conditions that result in **quenching** or **enhancement** of the quantum yield. Quenching in biochemical systems can be caused by chemical reactions of the

fluorescent species with added molecules, transfer of energy to other molecules by collision (actual contact between molecules), and transfer of energy over a distance (no contact, resonance energy transfer). The reverse of quenching, enhancement of fluorescent intensity, is also observed in some situations. Several fluorescent dye molecules are quenched in aqueous solution, but their fluorescence is greatly enhanced in a nonpolar or rigidly bound environment (the interior of a protein, for example). This is a convenient method for characterizing ligand binding. Both fluorescence quenching and fluorescence enhancement studies can yield important information about biomolecular structure and function.

Instrumentation

The basic instrument for measuring fluorescence is the **spectrofluorometer.** It contains a light source, two monochromators, a sample holder, and a detector. A typical experimental arrangement for fluorescence measurement is shown in Figure 7.13. The setup is similar to that for absorption measurements, with two significant exceptions. First, there are two monochromators, one for selection of the excitation wavelength and another for wavelength analysis of the emitted light. Second, the detector is at an angle (usually 90°) to the excitation beam. This is to eliminate interference by the light that is transmitted through the sample. Upon excitation of the sample molecules, the fluorescence is emitted in all directions and is detected by a photocell at right angles to the excitation light beam.

The lamp source used in most instruments is a xenon arc lamp that emits radiation in the ultraviolet, visible, and near-infrared regions (200 to 1400 nm). The light is directed by an optical system to the excitation monochromator, which allows either preselection of a wavelength or scanning of a certain wavelength range. The exciting light then passes into the sample chamber, which contains a fluorescence cuvette with dissolved sample. Because of the geometry of the optical system, a typical fused absorption cuvette with two opaque sides cannot be used; instead, special fluorescence cuvettes with four translucent

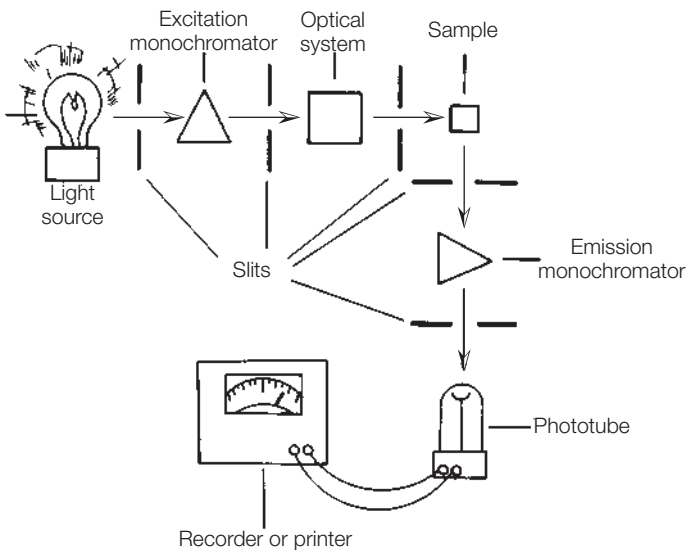

FIGURE 7.13 A diagram of a typical spectrofluorometer.

quartz or glass sides must be used. When the excitation light beam impinges on the sample cell, molecules in the solution are excited and some will emit light.

Light emitted at right angles to the incoming beam is analyzed by the emission monochromator. In most cases, the wavelength analysis of emitted light is carried out by measuring the intensity of fluorescence at a preselected wavelength (usually the wavelength of emission maximum). The analyzer monochromator directs emitted light of only the preselected wavelength toward the detector. A photomultiplier tube serves as a detector to measure the intensity of the light. The output current from the photomultiplier is fed to some measuring device that indicates the extent of fluorescence. The final readout is not in terms of Q, but in units of the photomultiplier tube current (microamperes) or in relative units of percent of full scale. Therefore, the scale must be standardized with a known. Some newer instruments provide, as output, the ratio of emitted light to incident light intensity.

Applications of Fluorescence Spectroscopy

Two types of measurements are most common in fluorescence experiments, measurements of **relative fluorescence intensities** and measurements of the **quantum yield.** Most experiments require only relative fluorescence intensity measurements, and they proceed as follows. The fluorometer is set to "zero" or "full scale" fluorescence intensity (microamps or %) with the desired biochemical system under standard conditions. Some perturbation is then made in the system (pH change, addition of a chemical agent in varying concentrations, change of ionic strength, etc.), and the fluorescence intensity is determined relative to the standard conditions. This is a straightforward type of experiment because it consists of replacing one solution with another in the fluorometer and reading the detector output for each. For these experiments, the excitation wavelength and the emission wavelength are preselected and set for each monochromator.

The measurement of quantum yield is a more complicated process. Before these measurements can be made, the instrument must be calibrated. A thermopile or chemical actinometer may be used to measure the absolute intensity of incident light on the sample. Alternatively, quantum yields may be measured relative to some accepted standard. Two commonly used fluorescence standards are quinine sulfate in 0.5 M H_2SO_4 ($Q = 0.70$) and fluorescein in 0.1 M NaOH ($Q = 0.93$). The quantum yield of the unknown, Q_x, is then calculated by Equation 7.8.

>>
$$\frac{Q_x}{Q_{std}} = \frac{F_x}{F_{std}} \qquad \textbf{(Eq. 7.8)}$$

where

Q_x = quantum yield of unknown
Q_{std} = quantum yield of standard
F_x = experimental fluorescence intensity of unknown
F_{std} = experimental fluorescence intensity of standard

Some biomolecules are **intrinsic fluors;** that is, they are fluorescent themselves. The amino acids with aromatic groups (phenylalanine, tyrosine, and

tryptophan) are fluorescent; hence, proteins containing these amino acids have intrinsic fluorescence. The purine and pyrimidine bases in nucleic acids (adenine, guanine, cytosine, uracil, thymine) and some coenzymes (NAD^+, FAD) are also intrinsic fluors. Intrinsic fluorescence is most often used to study protein conformational changes (protein folding) and to probe the location of active sites and coenzymes in enzymes.

Valuable information can also be obtained by the use of **extrinsic fluors.** These are fluorescent molecules that are added to the biochemical system under study. Many fluorescent dyes have enhanced fluorescence when they are in a nonpolar solution or bound in a rigid hydrophobic environment. Some of these dyes bind to specific sites on proteins or nucleic acid molecules, and the resulting fluorescence intensity depends on the environmental conditions at the binding site. Extrinsic fluorescence is of value in characterizing the binding of natural ligands to biochemically significant macromolecules. This is because many of the extrinsic fluors bind in the same sites as natural ligands. Extrinsic fluorescence has been used to study the binding of fatty acids to serum albumin, to characterize the binding sites for cofactors and substrates in enzyme molecules, to characterize the heme binding site in various hemoproteins, and to study the intercalation of small molecules into the DNA double helix.

Figure 7.14 shows the structures of extrinsic fluors that have been of value in studying biochemical systems. ANS, dansyl chloride, and fluorescein are used for protein studies, whereas ethidium, proflavine, and various acridines are useful for nucleic acid characterization. Ethidium bromide has the unique characteristic of enhanced fluorescence when bound to double-stranded DNA but not to single-stranded DNA. Aminomethyl coumarin (AMC) is of value as a fluorogenic leaving group in measuring peptidase activity.

Difficulties in Fluorescence Measurements

Fluorescence measurements have much greater sensitivity than absorption measurements. Therefore, the experimenter must take special precautions in making fluorescence measurements because any contaminant or impurity in the system can lead to inaccurate results. The following factors must be considered when preparing for a fluorescence experiment.

Preparation of Reagents and Solutions

Since fluorescence measurements are very sensitive, dilute solutions of biomolecules and other reagents are appropriate. Special precautions must be taken to maintain the integrity of these solutions. All solvents and reagents must be checked for the presence of fluorescent impurities, which can lead to large errors in measurement. "Blank" readings should be taken on all solvents and solutions, and any background fluorescence must be subtracted from the fluorescence of the complete system under study. Solutions should be stored in the dark, in clean glass-stoppered containers, in order to avoid photochemical breakdown of the reagents and contamination by corks and rubber stoppers. Some biomolecules, especially proteins, tend to adsorb to glass surfaces, which can lead to loss of

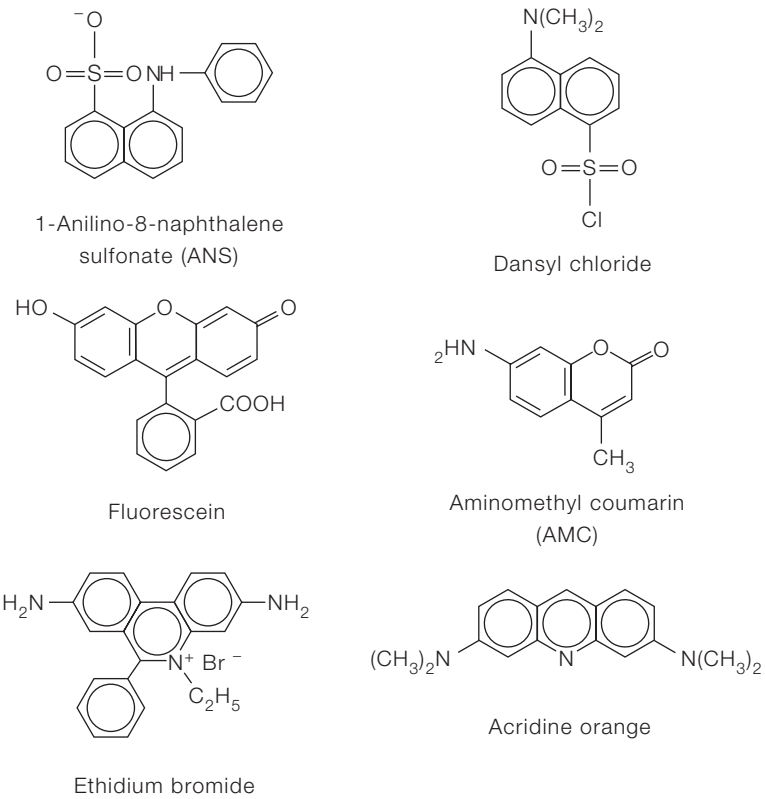

FIGURE 7.14
Molecules useful as extrinsic fluors in biochemical studies.

fluorescent material or to contamination of fluorescence cuvettes. All glassware must be scrupulously cleaned. Turbid solutions must be clarified by centrifugation or filtration.

Control of Temperature

Fluorescence measurements, unlike absorption, are temperature dependent. All solutions, especially if relative fluorescent measurements are taken, must be thermostated at the same temperature.

C. NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

Nuclear magnetic resonance (NMR) spectroscopy is a method of absorption spectroscopy that has some characteristics similar to ultraviolet and visible spectroscopy, but also some that are unique. In NMR, a molecular sample, usually dissolved in a liquid solvent, is placed in a magnetic field and the absorption of radio-frequency waves by certain nuclei (protons and others) is measured. NMR

spectroscopy was originally developed as an analytical tool to determine molecular structure by monitoring the environment of individual protons. The relative positions and intensity of absorption signals provide detailed information from which chemical structures may be elucidated. Early proton NMR studies focused primarily on small organic molecules, some of which had biological origin and significance. Since most biomolecules have a very large number of protons, the observed spectra are extremely complex and difficult to interpret. With the advent of modern techniques—superconducting magnets, Fourier transform analysis, multidimensional spectra, and powerful computer control—NMR has become an important method for the study of biological macromolecules. The fundamental principles, instrumentation, and biochemical applications for NMR will be outlined here.

NMR Theory

All nuclei possess a positive charge. For some nuclei, this charge confers the property of spin, which causes the nuclei to act like tiny magnets. The angular momentum of the spin is described by the quantum spin number I. If I is an integral number ($I = 0, 1, 2$, etc.), then there is no net spin and no NMR signal for that nucleus. However, if I is half-integral ($I = {}^1/_2, {}^3/_2, {}^5/_2$, etc.), the nuclei have spins, and when placed in a magnetic field, the spins orient themselves with (parallel) or opposed (antiparallel) to the external magnetic field. The nuclei aligned with the magnetic field have lower energy (are more stable) than those opposed. Energy in the radio-frequency range is sufficient to flip the nuclei from the parallel to the antiparallel alignment. The NMR instrument is designed to measure the energy difference between the nuclear spin states. Absorption of energy may be detected by scanning the radio-frequency range and measuring the absorption that causes spin state transition (resonance). Modern NMR instruments instead maintain a constant radio-frequency and electrically induce small changes in the strength of the magnetic field until resonance is attained. The point of resonance for a nucleus is dependent upon the electronic environment of that nucleus, so an NMR spectrum provides information that helps elucidate biochemical structures.

NMR in Biochemistry

NMR has found a wide variety of applications in biochemistry. Proton NMR has a long and rich history in organic chemistry and biochemistry. The structures of many small but significant biomolecules were elucidated by proton NMR. Protons on different atoms and in different molecular environments absorb energy of different levels (measured by radio-frequency units or magnetic field units). Two experimentally measured characteristics, **chemical shifts** and **spin-spin coupling,** provide important structural information. The chemical shift (δ) of an absorbing nucleus, measured in parts per million (ppm), is the spectral position of resonance relative to a standard signal, usually tetramethylsilane. The NMR signal for a proton is "split" by interactions with neighboring protons. This characteristic, called spin-spin coupling, helps to determine positions and numbers of equivalent and nonequivalent protons.

TABLE 7.1 Nuclei Important in Biochemical NMR

Isotope[1]	Natural Abundance (%)[2]	Relevant Biomolecules
^{1}H	100	Most biomolecules
^{13}C	1	Most biomolecules
^{15}N	0.4	Amino acids, proteins, nucleotides
^{19}F	100	Substitute for H
^{31}P	100	Nucleotides, nucleic acids, and other phosphorylated compounds

[1]All have a spin of ½.

[2]The percentage of this isotope in naturally occurring molecules containing this element.

NMR experiments are not limited to the study of protons. Resonance signals from other atomic nuclei including ^{13}C, ^{15}N, ^{19}F, and ^{31}P can be detected and measured (see Table 7.1). ^{13}C NMR techniques have been especially valuable for the study of carbohydrate, amino acid, and fatty acid structures. Just as with protons, each distinct carbon atom in a molecule yields a signal that is split by neighboring interacting nuclei (see Figure 7.15). Because of the low natural abundance of the ^{13}C isotope, it is necessary either to enrich the ^{13}C content by chemical synthesis or to use powerful computers and magnets (500–600 MHz). The ^{31}P spectra of phosphorylated biomolecules display a peak for each type of phosphorus (Figure 7.16). NMR instruments now have the sensitivity necessary to measure the *in vivo* concentrations and reactions of biomolecules in cells. For example, the catabolism of glucose by glycolysis in erythrocytes has been monitored by ^{13}C NMR, and the involvement of ATP in phosphoryl-group transfer processes has been studied by ^{31}P NMR (see Figure 7.16).

NMR and Protein Structures

New computer techniques in data analysis and improvements in instrumentation have now made it possible to carry out detailed structural and conformational studies of all biopolymers, but especially proteins. NMR, which may be done on noncrystalline materials in solution, provides a technique complementary to X-ray diffraction, which requires crystals for analysis. An advantage of NMR is that proteins can be studied in solution in an environment that mimics that in the living cell. One-dimensional NMR, as described to this point, can be applied to structural analysis of smaller molecules. But proteins and other complex biopolymers with large numbers of protons will yield very crowded spectra with many overlapping lines. In multidimensional NMR (2-D, 3-D, 4-D), peaks are spread out through two or more axes to improve resolution. Protein structure determination depends on several homonuclear 2-D ^{1}H NMR experiments: **correlation spectroscopy (COSY), nuclear Overhauser effect spectroscopy (NOESY), 2-D total correlation spectroscopy (TOCSY), foldover-corrected spectroscopy (FOCSY), spin-echo correlation spectroscopy (SECSY),** and others. These computational techniques are based on

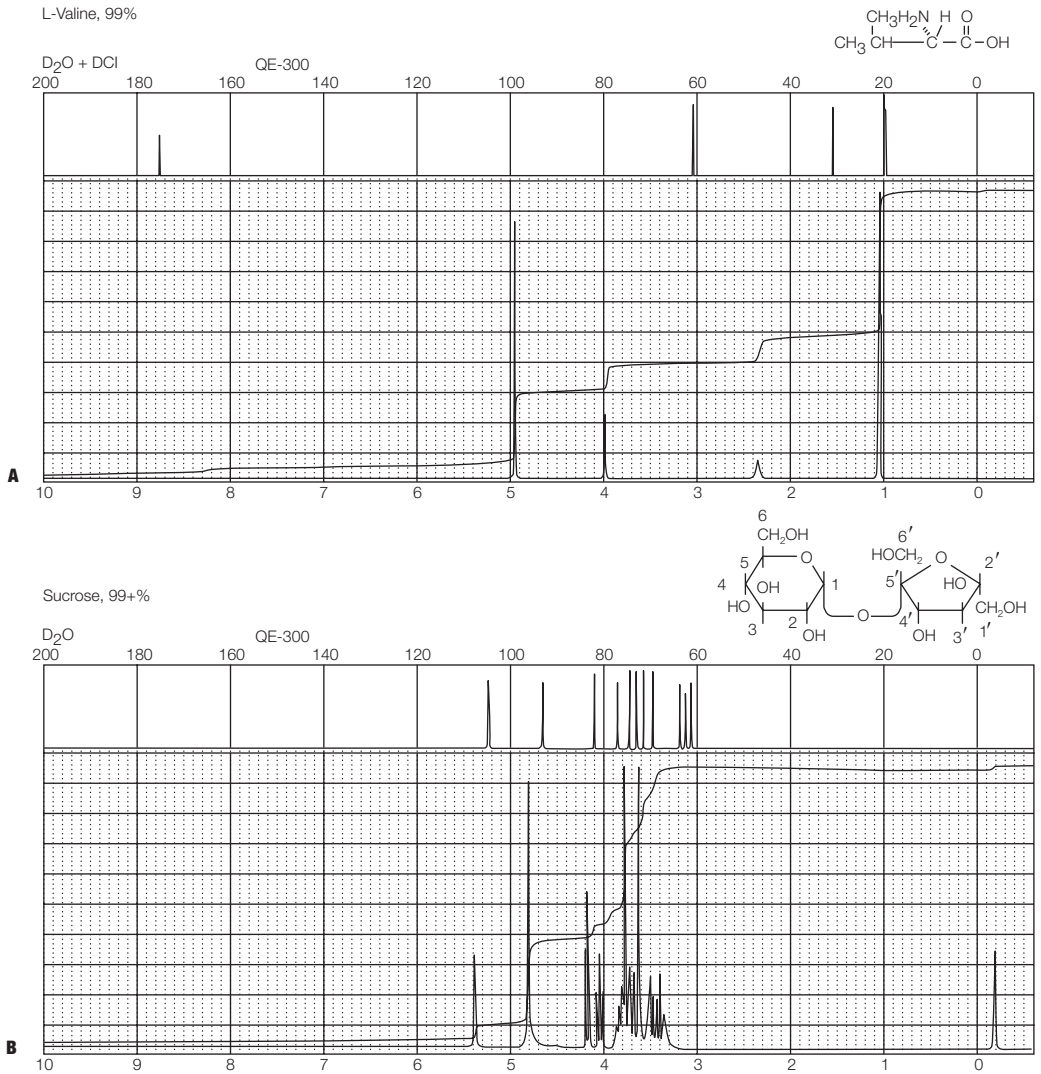

FIGURE 7.15 ^{1}H and ^{13}C FT-NMR spectra of biomolecules. The lower spectra are for ^{1}H showing a ppm scale of 0–10. TMS standard is at 0 ppm. The upper spectra are for ^{13}C showing a ppm scale of 0–200. **A.** L-valine in D_2O + DCl. Can you assign each peak to the correct protons and carbon atoms in the valine structure? Hint: The carboxyl carbon of valine has a peak at about 175 ppm. **B.** Sucrose in D_2O. Carbon numbers in the chemical structure correspond to the following peaks in order from 0 to 120 ppm: C-6; C-1'; C-6 '; C-4; C-2; C-5; C-3; C-4 '; C-3 '; C-5 '; C-1; C-2 '. *Reprinted with permission of Aldrich Chemical Co., Inc.*

the observation that nonequivalent protons interact with each other. By using multiple-pulse techniques, it is possible to perturb one nucleus and observe the effects on the spin states of other nuclei. The availability of powerful computers, strong magnets, and Fourier transform (FT) calculations makes it possible to elucidate structures of proteins up to one million daltons, and there is future promise for studies on larger proteins. In addition to structural studies, NMR

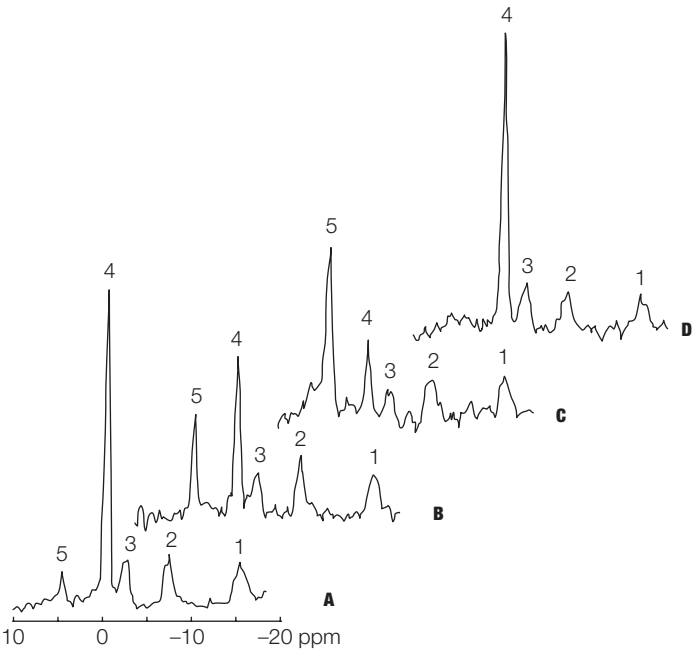

FIGURE 7.16 ^{31}P NMR spectra of human forearm muscle showing the effect of exercise. **A** Before exercise; **B** and **C** during 19 minutes of exercise; **D** 5–6 minutes after **C**. Peak assignments: 1, β-phosphorus of ATP; 2, α-phosphorus of ATP; 3, γ-phosphorus of ATP; 4, phosphocreatine; 5, Pi. Phosphocreatine is used as a major source of energy during exercise. It is hydrolyzed to creatine and Pi. Note that the level of ATP remains relatively constant during exercise because it is produced and used at about the same rate. *After G. Radda, Science* **233,** *641 (1986). Reprinted with permission from the American Association for the Advancement of Science.*

will also be applied to studies of conformational changes and interactions between ligands and biopolymers.

Many of the instrumental techniques and computational methods for NMR protein structure determination have been developed by Kurt Wüthrich of the Swiss Federal Institute of Technology (ETH) in Zurich. Beginning in the early 1980s, Wüthrich and his colleagues used NMR to determine the structure of several smaller proteins (below 10,000 daltons). By 1990, NMR structure determination could be applied to proteins of molecular masses up to about 20,000 daltons. One of the largest proteins studied so far by NMR is the GroEL-GroES complex, which is about 900,000 daltons. Some of the interesting proteins studied by Wüthrich include tendamistat (an α-amylase inhibitor), rabbit metallothionein, human cyclophilin A-cyclosporin A complex, and the murine prion protein, which may be involved in diseases related to bovine spongiform encephalopathy (BSE). Wüthrich was awarded the Nobel Prize in Chemistry in 2002 for this work, which occurred over a period of about 25 years. It is interesting to note that independent studies comparing protein three-dimensional structures derived from X-ray diffraction (on crystals) and NMR (in solution) have yielded identical results. The NMR methods have even

been used to correct structural mistakes made in the X-ray diffraction method. Protein NMR is now a very active research area and more than 7000 NMR-derived protein structures had been submitted to the Protein Data Bank (PDB) (www.rcsb.org/pdb) by the year 2010. The current total of protein structures submitted to the PDB is over 66,000.

The complex principles and techniques behind Wüthrich's studies are best described in his own words (Wüthrich, 2001):

> *"Four principal elements are combined in the NMR method for protein structure determination: (i) the nuclear Overhauser effect (NOE) as an experimentally accessible NMR parameter in proteins that can yield the information needed for de novo global fold determination of a polymer chain; (ii) sequence-specific assignment of the many hundred to several thousand NMR peaks from a protein; (iii) computational tools for the structural interpretation of the NMR data and the evaluation of the resulting molecular structures; and, (iv) multidimensional NMR techniques for efficient data collection."*

The preparation of a protein sample for NMR studies is relatively straightforward; however, a rather large amount of protein is required compared to mass spectrometry and X-ray crystallography. For NMR analysis, the protein is usually dissolved in water at concentrations of 3–6 m*M*. The protein solution may be adjusted to the ionic strength, pH, and temperature found under physiological conditions. Samples as small as 0.5 mL are sufficient for analysis.

D. MASS SPECTROMETRY

Mass spectrometry (MS) is similar to NMR in that it has historically been of great value in the structure elucidation of relatively small (MW limit around 1000) organic and biomolecules. Only in the last 15 years has the tool of MS been applied to the analysis of biological macromolecules. The MS analysis of proteins and other biopolymers was initially hindered because analytes are usually measured in the gas phase and it was very difficult to vaporize these large molecules. The development of new methods for sample preparation (ionization), multiquadrupole analysis, tandem MS instruments, and powerful computers now makes it possible to study large molecules, especially proteins.

Ionization and Analysis of Proteins

The mass spectrometer generally consists of three components that are linked together: an **ionization device,** a **mass analyzer,** and an **ion detector** (Figure 7.17). Neutral molecules are ionized, and their positively charged ion products are directed through an electric and/or magnetic field, where they are separated (analyzed) on the basis of their mass-to-charge ratio (m/z). A detector then records the ions after separation. The "spectrum" generated by MS displays ion intensity as a function of m/z.

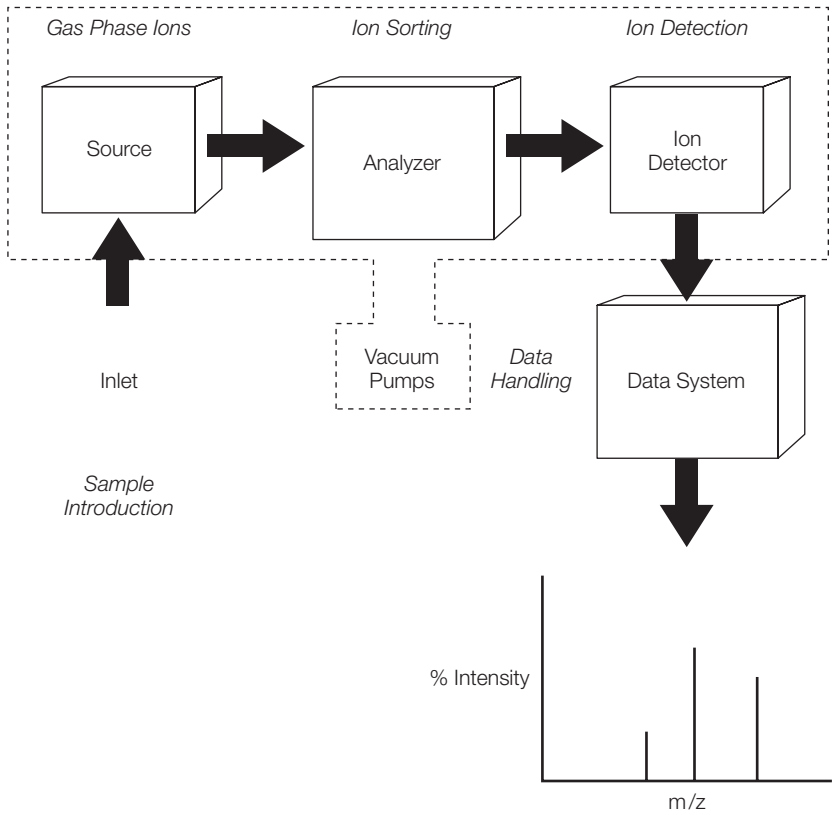

FIGURE 7.17 The components of a mass spectrometer. The final data output consists of a graph of ion intensity versus m/z. Mass spectrometry, unlike the other techniques described in this chapter, does not involve interaction of molecules with electromagnetic radiation; however, it has traditionally been combined with the spectrophotometric techniques.

Ionization of small organic and biological molecules prior to MS analysis is done by electron impact; however, ionization of nonvolatile, biological macromolecules like peptides, proteins, and nucleic acids requires special treatment. In the late 1980s, John Fenn, now at Virginia Commonwealth University, and Koichi Tanaka of the Shimadzu instrument company in Kyoto, Japan, introduced methods for the "soft ionization" of macromolecules. These methods are labeled "soft," as they cause minimal degradation to the sample during ionization. Fenn introduced the **electrospray ionization (ESI)** method, in which a solution of the sample is sprayed from a metal needle or capillary tip held at a potential of about +5000 volts. This results in a spray of tiny droplets containing positively charged ions. The solvent evaporates, and the ions are directed into the analyzer for separation. Tanaka demonstrated that pulses from a nitrogen laser could be used to ionize proteins from a surface **(soft laser desorption, SLD).** Because ESI and SLD are liquid-phase processes, the samples may be those purified by HPLC or CE. Fenn and Tanaka were awarded the Chemistry Nobel Prize (shared with K. Wüthrich) for this work in 2002.

Laser desorption has now been modified by Franz Hillenkamp of the University of Münster, Germany, to a solid phase method, **matrix-assisted laser desorption ionization (MALDI),** which is the most widely used technique for protein analysis. In MALDI, the sample is placed in a matrix of small organic molecules and irradiated by a laser pulse. The matrices absorb the laser energy,

causing ionization of the macromolecular sample. A common practice is the use of protein samples obtained from 1-D and 2-D PAGE gels.

Several types of mass analyzers are used for ion separation, including time-of-flight (TOF), quadrupoles, and ion traps. In TOF-MS, the most widely used technique, each ion produced has the same initial kinetic energy, but the speed varies with mass. Mass is determined by measurement of an ion's time-of-flight to the detector.

MS Applications in Biochemistry

MS is becoming a standard tool in the analysis of biological molecules and biological processes. Many of the applications of MS described below involve combining the technique with sample preparation and purification by HPLC, CE, and PAGE (especially 2-DE). (See section on proteomics, Chapter 6, Section B, p. 184.)

1. ***Identification of Peptides and Proteins*** Protein identification is perhaps the most widely used MS application at the present time. The most important ions resulting from the removal of an electron by ionization procedures are the positively charged **molecular ions** $(\mathbf{M}^{+})$ or **protonated molecular ions** $(\mathbf{M} + nH)^{\mathbf{n}-}$. Measurement of the molecular mass of these species provides the molecular weight of the original molecule. The accuracy of this method for molecular weight determination is about 0.01%. (Molecular mass measurements using gel filtration typically have accuracies no greater than 5–10%.) Some molecular ions are unstable and disintegrate to produce fragment ions. These fragmentation processes are useful in structural elucidation of smaller molecules. It should be expected that proteomic studies will be enhanced by coupling SDS-PAGE and 2-DE (for separation and purification) with further size analysis of the proteins by MALDI-TOF.

   One MS method for peptide identification is called **peptide mass fingerprinting.** The unknown sample is digested with the proteolytic enzyme trypsin to produce fragments that are analyzed by MALDI-MS. The resulting spectrum displays the masses of the peptide fragments. This may be used as a "fingerprint" of the sample and compared with known fragmented patterns in a sequence database.
2. ***Characterization of Post-Translational Modification Processes*** After translation, proteins in the cell are often modified by covalent attachment of specific functional groups. Such processes might include:

   (a) **phosphorylation** of hydroxyl groups in serine and tyrosine residues, or
   (b) addition of carbohydrate residues **(glycosylation)** to the hydroxyl groups of serine or threonine or to the amide nitrogen of asparagine residues.

   These chemical modifications can easily be detected by MS, as the addition of a phosphoryl group $(-PO_3^{2-})$ adds about 80 daltons to the molecular mass of a protein, whereas addition of a glucose residue adds about 180 daltons.

3. ***Peptide Sequencing*** Small peptides and proteins may be sequenced by MS procedures. The peptide sample is ionized and fragmented at the peptide bonds by collision-induced dissociation. Size analysis of the series of fragments produced leads to the sequence of amino acids.
4. ***Protein-protein Interactions*** One of the most important goals of proteomics is to study how proteins interact with each other in order to initiate biological processes. ESI-MS and MALDI-TOF are currently being used to investigate how proteins associate to form biologically active multisubunit complexes.

E. X-RAY CRYSTALLOGRAPHY

Historically, **X-ray crystallography** has been the most important tool for studying the three-dimensional structures of biomolecules. In fact, this technique was the only method available for determining macromolecular structures until the application of NMR in the 1980s. Protein crystals were first studied by X-ray crystallography in 1934 by J. D. Bernal and Dorothy Crowfoot Hodgkin. However, the diffraction patterns were extremely complex, and computers were not available for complete analysis of the proteins. John Kendrew, a biochemist working at Cambridge University, announced the first three-dimensional structure of a protein, sperm whale myoglobin, in 1958. Kendrew had determined the complex structure of the protein (153 amino acid residues) after several years of analysis by X-ray crystallography. Other important biomolecules that were studied by X-ray crystallography include DNA (Rosalind Franklin and Maurice Wilkins) and vitamin B_{12} (Dorothy Crowfoot Hodgkin). Analysis of protein structures is now routine. As of July 2010, the Protein Data Bank (www.rcsb.org/pdb) had registered approximately 66,000 proteins—about 56,000 were obtained by X-ray crystallography and about 10,000 by NMR. Although the number of structures derived by NMR is growing faster than the number derived by X-ray crystallography, crystallography is still an important source of structural data.

Methodology of X-ray Crystallography

An X-ray crystallography analysis requires three components (see Figure 7.18): (1) a protein crystal, (2) an X-ray source, and (3) a detector (i.e., radiation detector or photographic film).

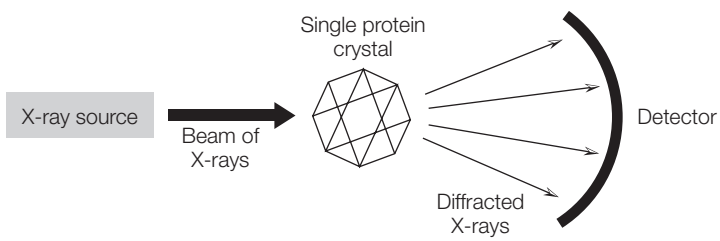

FIGURE 7.18 The components required for analysis of protein structure by X-ray crystallography.

Protein Crystals

For many proteins, this can be the most difficult step in three-dimensional analysis. The factors important in protein crystallization are not yet fully understood, so the methodology for growing crystals is still an art and involves much trial and error. Crystallization usually occurs best in a saturated or supersaturated solution of the protein. A common method often used involves changing solution conditions by adding a precipitant (like ammonium sulfate), changing the pH, or changing the ionic strength. The crystallization process may be hastened by dialysis of the protein against a solution containing the precipitating factor.

Data Collection and Analysis

The theory supporting X-ray crystallography is quite complex and beyond the scope of this text; however, some practical aspects can be described. The crystal is mounted in the diffractometer and bombarded by a collimated beam of X-rays. The crystal is rotated so that it is struck from many different directions. Many of the X-rays passing into the sample are diffracted (scattered) when they encounter electrons associated with atoms. The diffracted beams impinge upon the detector and are recorded. The data at this point are in the form of a regular array of spots called reflections. (Kendrew's pattern of myoglobin had nearly 25,000 reflections, which were analyzed by computer in order to construct the 3-D image of the protein.) The extent of scatter of the reflections depends on the size and position of each atom in the crystal. By extensive computer and mathematical analysis (by Fourier transform) of the angle of scatter and of the pattern collected by the detector, it is possible to construct an **electron density map** of the protein molecule showing the arrangement of the atoms. Using modern equipment and computer software, an analyst can collect data and determine a structure in a day or two.

Although X-ray analysis of proteins is slowly being replaced by NMR, there will continue to be interest in and a need for X-ray analysis of very large and unsymmetrical proteins and other biomolecules. NMR does have some advantages in structure determination—sample preparation is rapid and straightforward, and the sample may be studied under physiological-like conditions. Numerous comparative studies have confirmed that the analysis of an identical protein by X-ray and NMR leads to the same three-dimensional result, even though one is done in the solid state and one in the liquid state.

Study Problems

1. For each pair of wavelengths listed below, specify which one is higher in energy.
(a) 1 nm (X-ray) or 10,000 nm (IR)
(b) 280 nm (UV) or 360 nm (VIS)
(c) 200,000 nm (microwave) or 800 nm (VIS)

2. In a laboratory experiment, you are asked to determine the molar concentration of a solution of an unknown compound, X. The solution diluted in half by water (1 mL of X and 1 mL of H_2O) has an absorbance at 425 nm of 0.8 and a molar extinction coefficient of $1.5 \times 10^3 M^{-1}\,cm^{-1}$. What is the molar concentration of the original solution of X?

3. Match the spectral region listed below with the appropriate molecular transition that occurs. The first problem is worked as an example.

Spectral region	Transition
a 1. X-rays	a. inner-shell electrons
__2. UV	b. molecular rotations
__3. VIS	c. valence electrons
__4. IR	d. molecular vibrations
__5. microwave	

4. Explain the differences between a spectrophotometer that uses a phototube for a detector and one that uses a photodiode array detector.

5. Several spectroscopic techniques were studied in this chapter. Which experimental techniques involve an actual measurement of radiation absorbed?
(a) UV-VIS spectroscopy
(b) NMR spectroscopy
(c) MS
(d) Fluorescence spectroscopy

6. Why can you not use a glass cuvette for absorbance measurements in the UV spectral range?

7. What single structural characteristic do all of the fluorescent molecules in Figure 7.14 possess?

8. Study the ^{1}H spectrum of valine in Figure 7.15 and match each peak to the corresponding proton in the chemical structure. Explain any spin-spin coupling.

9. Why must a cuvette with four translucent sides be used for fluorescence measurements?

10. Study the ^{13}C spectrum of valine in Figure 7.15. Identify the carbon atom that produces each peak in the spectrum.

Further Reading

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The basics of NMR.

http://www.asms.org
Web site for the American Society of Mass Spectrometry.

http://www.rcsb.org/pdb
This Web site, the Protein Data Bank, is the single repository for the three-dimensional structures of proteins and nucleic acids.

http://www.spectroscopynow.com/coi/cda/home.cda?chId=0
Resource for spectroscopy.

http://biop.ox.ac.uk/www/mol_of_life/index.html
The Molecules of Life.

http://www.ebi.ac.uk/thornton-srv/software/PROCHECK
NMR for protein structures.

www.thermo.com/nanodrop
Information on nanodrop spectrometers.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

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CHAPTER 8

BIOMOLECULAR INTERACTIONS: LIGAND BINDING AND ENZYME REACTIONS

A. Ligand-Macromolecule Interactions (Molecular Recognition) 239
B. Biological Catalysis (Enzymes) 250

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Many of the dynamic processes occurring in biological cells and organisms are the result of interactions between molecules. Most often, these interactions involve the binding of a molecule or ion to a specific site (or sites) on a macromolecule, usually a protein or nucleic acid. The binding forces that hold the molecules together are noncovalent and they include hydrogen bonding, van der Waals forces, electrostatic bonds, and hydrophobic interactions. Usually the combination of the two molecules (formation of a complex) will lead to a specific biological action or response. For example, a hormonal response is the result of the hormone molecule interacting with its receptor protein; a chemical transformation in metabolism is the consequence of the initial binding of a substrate to an enzyme, forming an ES complex.

A. LIGAND-MACROMOLECULE INTERACTIONS (MOLECULAR RECOGNITION)

Throughout our study of biochemistry we will encounter many examples where noncovalent interactions bring together, in specific ways, two different molecules that form a complex. Such molecules display a phenomenon called **molecular recognition.** The importance of these interactions in biology is that the combination of two molecules will lead to some biological action. The action of hormones provides an excellent example. A hormonal response is the

consequence of a weak, but specific, interaction between the molecule and a receptor protein in the membrane of the target cell. The biochemical response may often be an enhancement in production of an enzyme needed for metabolism **(signal transduction)**. Another example of molecular recognition is the interaction that brings together a substrate molecule with an enzyme. Before a metabolic reaction can occur, a substrate molecule must physically interact in a certain well-defined manner with the macromolecular catalyst, an enzyme. The biochemical action of drugs also depends on molecular recognition. A drug is first distributed throughout the body via the bloodstream. Drug molecules in the bloodstream are often bound to plasma proteins (e.g., serum albumin), which act as carriers. When the drug molecules are transported to their site of action, a second molecular interaction is likely to occur. Many drugs elicit their effects by interfering with biochemical processes. This may take the form of enzyme inhibition, where the drug molecule binds to a specific enzyme and prohibits catalytic action. Table 8.1 lists several other molecular recognition events that lead to some dynamic biochemical action. Details of these processes may be found in your biochemistry textbook.

Properties of Noncovalent Binding Interactions

The process of molecular recognition may be defined by a simple, reversible reaction that brings together a **ligand (L)** and a **macromolecule (M)** (R, for receptor, in some textbooks):

>> $$L + M \rightleftharpoons LM \longrightarrow \text{Biological response}$$ **(Eq. 8.1)**

LM represents a complex, held together by noncovalent interactions, that has a specialized biological function. The ligand is usually a relatively small molecule (hormone, substrate, inhibitor, drug, coenzyme, metal ion, etc.), but not always. Examples of large ligands include protein substrates that are cleaved by a protease, a protein molecule that binds to DNA as a transcription regulator, or large antigens that interact with antibodies.

TABLE 8.1 Examples of LM Interactions and Their Biological Responses

Type of Interaction (Ligand:Macromolecule)	Biological Significance or Response
Substrate:enzyme	Metabolic reactions
Inhibitor:enzyme	Metabolic regulation
Allosteric effector:enzyme	Metabolic regulation
Coenzyme:enzyme	Metabolic reactions
Hormone:receptor protein	Metabolic regulation; signal transduction
Antigen:antibody	Immune response
Ligand:carrier or transport protein	Storage or transport
Drug:protein or nucleic acid	Disease treatment
Regulatory protein:DNA	Transcription regulation

All molecular interactions that are the basis of molecular recognition have at least three common characteristics:

1. ***The binding forces that hold the complex together are noncovalent and relatively weak.*** Four types of noncovalent bonds are important:

   (a) **hydrogen bonds**
   (b) **van der Waals forces**
   (c) **hydrophobic interactions**
   (d) **ionic or electrostatic bonds**

   Properties and examples of these interactions are reviewed in Table 8.2. The strengths of noncovalent binding forces are in the range of 1–30 kJ/mol, compared to about 350 kJ/mol for a carbon–carbon single bond, a typical covalent bond. A single, noncovalent bond is usually insufficient to hold two molecules together. Typical biopolymers that may serve as macromolecules—DNA,

TABLE 8.2 Properties and Examples of Noncovalent Binding Forces

Type	Brief Description and Example	Stabilization Energy (kJ/mol)	Length (nm)
(i) *Hydrogen bonds*	Between a hydrogen atom bonded to an electronegative atom and a second electronegative atom Between neutral groups 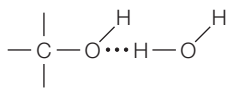 Between peptide bonds 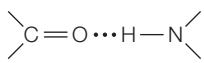	10–30	0.2–0.3
(ii) *van der Waals interactions*	Between molecules with temporary dipoles induced by fluctuating electrons. This may occur between any two atoms in close proximity.	1–5	0.1–0.2
(iii) *Hydrophobic interactions*	The presence of water forces nonpolar groups into ordered arrangements to avoid the water. 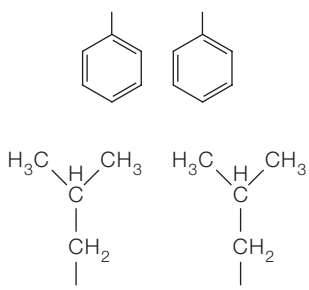	5–30	—
(iv) *Ionic bonds*	Interactions that occur between fully charged atoms or groups Na^+Cl^- 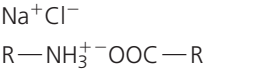	20	0.25

RNA, polysaccharides, and proteins—have numerous functional groups that participate in noncovalent interactions. A collection of many of these interactions will lead to highly stabilized complexes.

2. ***Reactions that form noncovalent complexes are reversible.*** Noncovalent interactions are initiated when diffusing (wandering or moving) molecules come into close contact. Diffusion is brought about by thermal motions. An initial close encounter may not always result in the successful formation of a complex. A few weak bonds may form, but be disrupted by thermal motions, causing the molecules to dissociate. Therefore, bonds may constantly form and break until enough bonds have accumulated to result in an intermediate with transient, but significant, existence. The complex can then initiate a specific biological process. An intermediate rarely lasts longer than a few seconds. Eventually, thermal motions cause the complex to dissociate to the individual molecules. Reversibility is an important characteristic of these interactions so that a static, gridlock situation does not occur. The biological process initiated by the complex LM must have a finite lifetime—a starting and an ending time.
3. ***The binding between molecules is specific.*** Imagine that the interactions to form LM bring together two molecular surfaces. The two surfaces will be held together if noncovalent interactions are established. If on one surface there is a nonpolar molecular group (phenyl ring, hydrophobic alkyl chain), the adjacent region on the other surface must also be hydrophobic and nonpolar. If a positive charge exists on one surface, there may be a neutralizing negative charge on the other surface. A hydrogen-bond donor on one surface can interact favorably with a hydrogen-bond acceptor on the other surface. Simply stated, the two molecules must be compatible or complementary in a chemical sense so the development of stabilizing forces can hold molecules together. In molecular terms, the binding site (or sites) on M displays high specificity; therefore, only certain ligands can bind. L molecules, for a particular M, will be limited to a single, specific molecule or perhaps a group of structurally related molecules.

Quantitative Characterization of Ligand Binding

A thorough understanding of the biochemical significance of ligand binding to macromolecules comes only from a quantitative analysis of the strength of binding (affinity) between L and M. Binding affinity between two molecules is often expressed as an equilibrium constant, the **formation constant,** K_f, which is derived from the law of mass action. Consider the specific interaction between a

STUDY EXERCISE 8.1 Examples of Noncovalent Interactions

a. Show how the carboxylate group on the side chain of the amino acid aspartate can interact with a lysyl residue in a protein. Draw structures and define the possible types of noncovalent binding forces.

b. Show how a peptide carbonyl group can form a hydrogen bond with the free amino acid serine.

small molecule, L (for ligand), and a macromolecule, M (Equation 8.1). These two species combine to form a complex, LM.

K_f, the formation constant for the complex, is defined by Equation 8.2.

>> $$K_f = \frac{[LM]}{[L][M]} \quad \textbf{(Eq. 8.2)}$$

Do not confuse K_f with K_d, the dissociation constant. The relationship between K_f and K_d is defined in Equation 8.3.

>> $$K_d = \frac{[L][M]}{[LM]} = \frac{1}{K_f} \quad \textbf{(Eq. 8.3)}$$

The larger the value of K_f, the greater the strength of binding between L and M. (Large K_f implies a high concentration of LM relative to L and M.) Return to Equation 8.2 and note that in order to determine K_f, a method must be developed to measure equilibrium concentrations of L, M, and the complex LM. In a later section, we will describe experimental techniques that are applied to these measurements of binding constants, but first we must reorganize Equation 8.2 into a form that contains more readily measurable terms. We will begin with the assumption that the macromolecule, M, has several binding sites for L and that these sites do not interact with each other. That is, K_f is identical for all binding sites. The following definitions are necessary for the reorganization of Equation 8.2:

$[L]$ = equilibrium concentration of free or unbound ligand

$[M]$ = equilibrium concentration of macromolecule with no bound L, or the concentration of unoccupied binding sites

$[LM]$ = equilibrium concentration of ligand–macromolecule complex, or the concentration of occupied sites

$[M]_0$ = total or initial concentration of macromolecule, or total concentration of available binding sites

$[L]_0$ = total concentration of bound and unbound ligand, or initial concentration of ligand

ν = fraction of available sites on M that are occupied, or the fraction of M that has L in binding site:

>> $$\nu = \frac{[LM]}{[M]_0} \quad \textbf{(Eq. 8.4)}$$

The term ν is particularly significant because it can be considered a ratio of the number of occupied sites to the total number of potential binding sites on M. It can be measured experimentally, but first it must be redefined in the following manner: Since $[M]_0 = [LM] + [M]$, then

$$\nu = \frac{[LM]}{[LM] + [M]}$$

From Equation 8.2, $[LM] = K_f[L][M]$. Therefore,

$$\nu = \frac{K_f[L][M]}{K_f[L][M] + [M]}$$

Simplifying,

$$\nu = \frac{K_f[L]}{K_f[L] + 1} \quad \textbf{(Eq. 8.5)}$$

You should recognize the similarity of Equation 8.5 to the Michaelis-Menten equation for enzyme catalysis. A graph of ν vs. [L] yields a hyperbolic curve (see Figure 8.1) that approaches a limiting value or saturation level. At this point, all binding sites on M are occupied. Because of the difficulty of measuring the exact point of saturation, this nonlinear curve is seldom used to determine K_f. Linear plots are more desirable, so Equation 8.5 is converted to an equation for a straight line. The equation will first be put into a more general form to account for any number of potential binding sites on M. The symbol $\bar{\nu}$ will be used to represent the average number of occupied sites per M, and n will represent the number of potential binding sites per M molecule. Assuming that all the binding sites on M are equivalent, Equation 8.5 becomes

$$\bar{\nu} = \frac{nK_f[L]}{K_f[L] + 1} \quad \textbf{(Eq. 8.6)}$$

Scatchard's Equation

Equation 8.6 contains terms such as [L] that are difficult to determine, so it must be converted to a form amenable to experimental measurements.

If $\bar{\nu}$ is the average number of occupied sites per M molecule, then $n - \bar{\nu}$ is the average number of unoccupied sites per M molecule.

$$n - \bar{\nu} = n - \frac{nK_f[L]}{K_f[L] + 1}$$

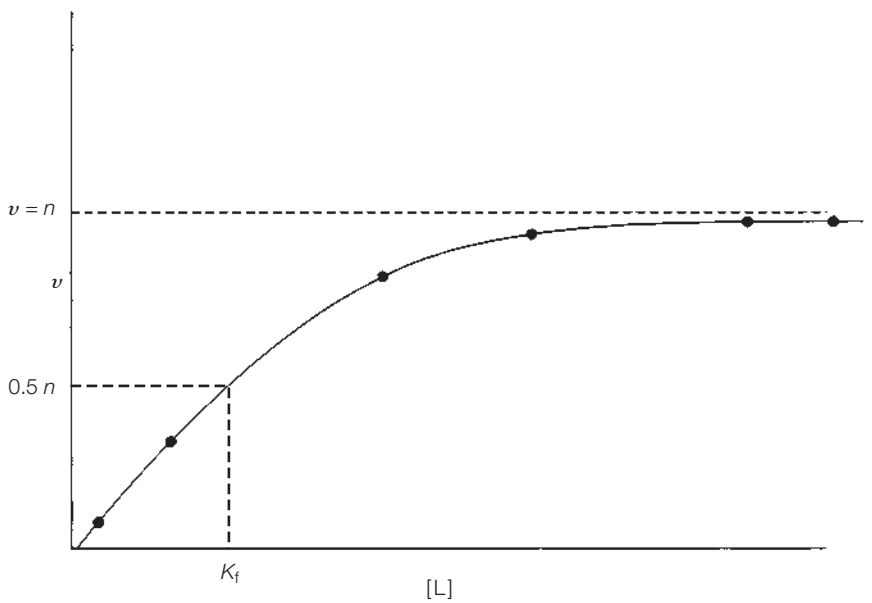

FIGURE 8.1 A plot illustrating saturation of binding sites with ligand. The n is estimated at the point when all binding sites are occupied by ligand. K_f is represented by the [L] when one-half of the sites are occupied by ligand.

Simplifying,

$$(n - \bar{\nu})(K_f[L] + 1) = n(K_f[L] + 1) - n(K_f[L])$$

>>
$$(n - \bar{\nu}) = \frac{n}{K_f[L] + 1} \quad \textbf{(Eq. 8.7)}$$

To further simplify Equation 8.7, let the term $\bar{\nu}/n - \bar{\nu}$ represent the ratio of occupied sites to nonoccupied sites on M; it can be mathematically represented as

$$\frac{\bar{\nu}}{n - \bar{\nu}} = \left(\frac{nK_f[L]}{K_f[L] + 1}\right)\left(\frac{K_f[L] + 1}{n}\right)$$

or

>>
$$\frac{\bar{\nu}}{n - \bar{\nu}} = K_f[L] \quad \textbf{(Eq. 8.8)}$$

A more desirable form for graphical use is known as **Scatchard's equation:**

>>
$$\frac{\bar{\nu}}{[L]} = K_f(n - \bar{\nu}) \quad \textbf{(Eq. 8.9)}$$

If a plot of $\bar{\nu}/[L]$ versus $\bar{\nu}$ yields a straight line, shown by the solid line in Figure 8.2, then all the binding sites on M are identical and independent, and K_f and n are estimated as shown in the figure.

Cooperative Binding of Ligands

The derivation of Equation 8.9 assumes that K_f is identical for all binding sites; that is, the binding of one molecule of L does not influence the binding of other L molecules to binding sites on M. However, it is common for ligand-macromolecule interactions to display such influences. The binding of one L molecule to M may encourage or inhibit the binding of a second L molecule to M. For example, the binding of oxygen to one of the four subunits of hemoglobin increases the affinity of the other subunits for oxygen. There is said to be **cooperativity** of sequential binding. If the sites do show cooperative binding, the plot is nonlinear, as shown by the dashed line in Figure 8.2. The shape of the nonlinear curve may be used to determine the number of types of binding sites. The dashed line in Figure 8.2 can be resolved into two lines, indicating that two types of binding sites are present on M. The n and K_f for each type of binding site may be estimated by resolving the smooth curve into straight lines as shown in Figure 8.2. K_f and n can be estimated by extrapolating the two straight lines to the axes.

Experimental Measurement of Ligand-Binding Interactions

To analyze ligand-macromolecule interactions quantitatively (to use Equation 8.9), one must be able to distinguish experimentally between bound ligand (LM) and free ligand (L). Many techniques have been developed for measuring the dynamics of LM interactions. Widely used techniques include equilibrium dialysis (Chapter 3, p. 73), ultrafiltration (Chapter 3, p. 74), and spectroscopic (especially

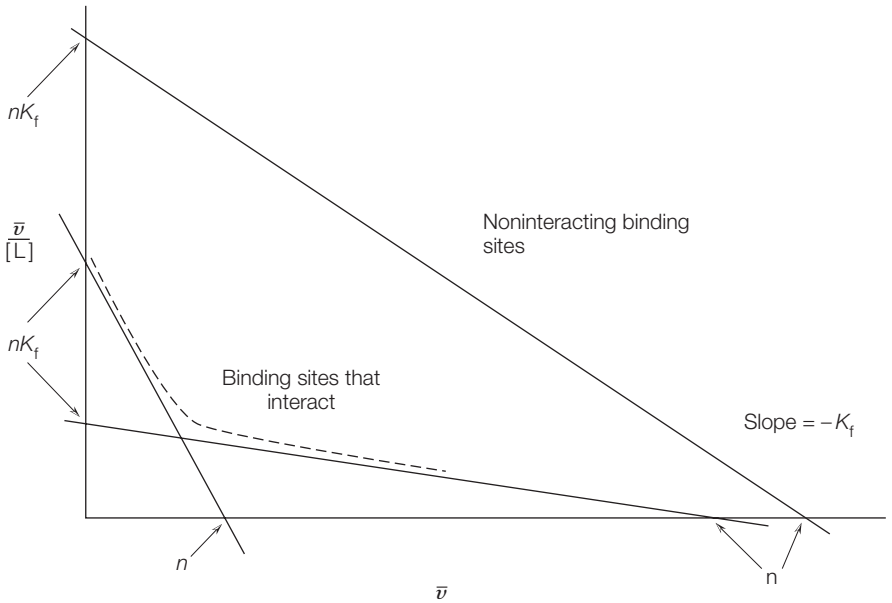

FIGURE 8.2 Scatchard plot. Two types of Scatchard curves are illustrated. The upper plot (solid line) represents binding to a macromolecule with noninteracting sites. The binding of a ligand molecule at one site is independent of the binding of a second ligand molecule at another site. The plot can be extrapolated to each axis and the n and K_f calculated. The lower, dashed line represents binding of ligand molecules to binding sites that interact. One ligand molecule bound to the macromolecule influences the rate of binding of other ligand molecules. The dashed line is evaluated as shown in the figure. The curved line has two distinct slopes. It can be resolved into two straight lines, each of which may be evaluated for n and K_f. This would indicate that there are two types of binding sites, each with a unique n and K_f.

fluorescence) measurements (Chapter 7, p. 220). Many of these methods require specialized and expensive equipment, sometimes cumbersome procedures, and the use of radio-labeled ligands.

STUDY EXERCISE 8.2 Using Equilibrium Dialysis

Ligand binding to a protein can be measured by the procedure of equilibrium dialysis (see Chapter 3, Section D, p. 73). A solution of the protein (M) is sealed in a dialysis bag, which is then placed in a large volume of solution containing the ligand (L). The pore size of the dialysis bag allows the passage of ligand molecules, but not protein molecules. After equilibrium is reached several hours later, the bag is opened and the concentrations of free ligand inside and outside are measured. The difference between these two values is the amount of ligand bound to the protein. The following experimental data are collected:

$$\text{Concentration of free ligand, [L]} = 1 \times 10^{-5}\ \text{mole/liter}$$
$$\text{Concentration of bound ligand, [LM]} = 5 \times 10^{-6}\ \text{mole/liter}$$
$$K_f \text{ for the reaction L + M} \rightleftharpoons \text{LM} = 1 \times 10^{5}\ \text{moles/liter}$$

Calculate the concentration of the protein, M, in moles per liter. Assume that M has only one binding site for the ligand.

Solution:

Use Equation 8.2 to calculate [M]. The concentration of M $= 5 \times 10^{-6}$ moles/liter.

One of the simplest and most convenient methods for monitoring ligand binding is the differential method, which detects and quantifies some measurable change in spectral absorption or fluorescence, in the UV-VIS regions, that accompanies ligand binding (see next section). A ligand may show enhanced fluorescence when bound to a macromolecule, or amino acid residues (i.e., Trp) in a protein may show enhanced fluorescence when a ligand molecule is bound.

The Bradford Protein Assay as an Example of Ligand Binding

When Coomassie Blue dye binds to proteins, the dye undergoes a significant spectral change in the visible region (Figure 8.3). The spectrum of free dye displays a minimum in the range 575–625 nm. When dye and a protein (ovalbumin) are mixed, a new absorption band appears in the region of 595 nm. The increase in absorption at 595 nm is directly related to the concentration of protein, which is the basis of the Bradford protein assay (Chapter 3, Section B, p. 69). The new absorption band is due to the presence of dye-ovalbumin complex. Note that the new band is rather broad and that a range of wavelengths may actually be used, but 595 nm is usually chosen. In this section, we will use the Bradford assay to illustrate an alternate method for using Scatchard's equation.

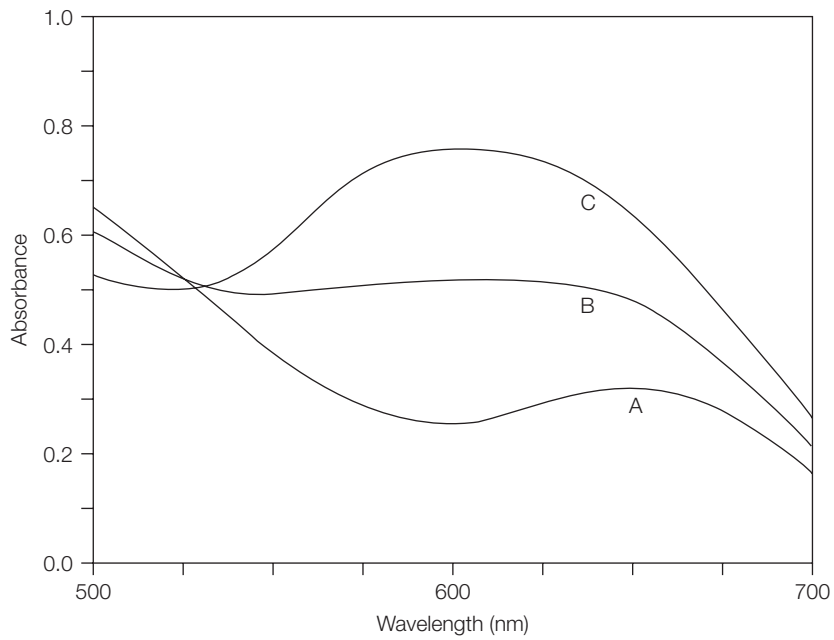

FIGURE 8.3 The spectral changes occurring during the binding of Coomassie Blue dye to ovalbumin. **A** free dye in solution, **B** dye plus 0.5 mg of ovalbumin, **C** dye plus 1.0 mg of ovalbumin. The dye concentration is identical in all three curves.

Equation 8.6 for evaluating protein-ligand interactions is easily adaptable to the spectroscopic differential method, but it must be converted into a linear form. Absorption data can be expressed in terms of [bound]/[free] ligands or [occupied]/[unoccupied] sites on the macromolecule. The data analysis described here assumes that L and LM, but not M, contribute to the measured absorbance. The measured absorbance change is proportional to the ratio of bound L to unbound L.

The absorbance observed from a mixture of L and M, A_{obs}, is

$$A_{obs} = A_L + A_{LM}$$

where

A_L = absorbance of free L

A_{LM} = absorbance of bound L

Absorbance data may be used directly to calculate the fraction of ligand bound:

>> $$\text{Fraction of ligand bound} = f = \frac{A_{obs} - A_L}{A_{max} - A_L} \qquad \textbf{(Eq. 8.10)}$$

where

A_{max} = total absorbance of LM when all the L molecules in solution are bound to M. This number is experimentally determined in this chapter, Section B.

The term $A_{max} - A_L$ is proportional to the total number of binding sites, and $A_{obs} - A_L$ represents the average number of occupied sites on M caused by a certain concentration of L.

For graphical analysis of the experimental data, $\bar{\nu}$ for Equation 8.6 can be defined in terms that can be measured experimentally:

>> $$\bar{\nu} = f\frac{[L]_0}{[M]_0} \qquad \textbf{(Eq. 8.11)}$$

If Equation 8.11 is combined with Equation 8.6, an equation for a straight line can be derived in terms that are readily measured.

$$f\frac{[L]_0}{[M]_0} = \frac{nK_f[L]}{K_f[L] + 1}$$

Take the reciprocal of each side and solve for $[M]_0/f$:

$$\frac{[M]_0}{f[L]_0} = \frac{K_f[L] + 1}{nK_f[L]}$$

$$\frac{[M]_0}{f} = \frac{[L]_0}{n} + \frac{[L]_0}{nK_f[L]}$$

The term $[L]/[L]_0 = 1 - f$; therefore:

$$\frac{[M]_0}{f} = \frac{[L]_0}{n} + \frac{1}{nK_f(1 - f)}$$

Rearrange to the form for a straight line, $y = mx + b$:

>>
$$\frac{[M]_0}{f} = \frac{1}{nK_f(1 - f)} + \frac{[L]_0}{n} \qquad \textbf{(Eq. 8.12)}$$

This is an alternate form of the Scatchard equation. The values n and K_f can be calculated from a plot of $1/(1 - f)$ vs. $[M]_0/f$. The slope of the line is represented by $1/nK_f$, whereas the y intercept is $[L]_0/n$. If the data points fall on a straight line as in Figure 8.4, then all the dye binding sites on the protein M are identical and independent.

The derivation of Equation 8.12 assumes that K_f is identical for all binding sites; that is, the binding of one molecule of L does not influence the binding of other L molecules to binding sites on M. However, it is common for ligand-macromolecule interactions to display such influences. The binding of one L molecule to M may encourage or inhibit the binding of a second L molecule to M. For example, the binding of oxygen to one of the four subunits of hemoglobin increases the affinity of the other subunits for oxygen. There is said to be cooperativity of sequential binding. If the sites do show cooperative binding, the plot becomes nonlinear, as shown by the curved line in Figure 8.4. This line is resolved into two lines, indicating that two types of binding sites are present on M. The n and K_f for each type of binding may be estimated by resolving the smooth curve into two straight lines. K_f and n may be calculated from the intercepts and slopes.

Computer Software for Analysis of LM Binding

Numerous computer programs exist that may be used for graphical analysis of ligand binding data. Most programs perform a linear or nonlinear least-squares regression analysis of experimental data. Many are available as freeware on the

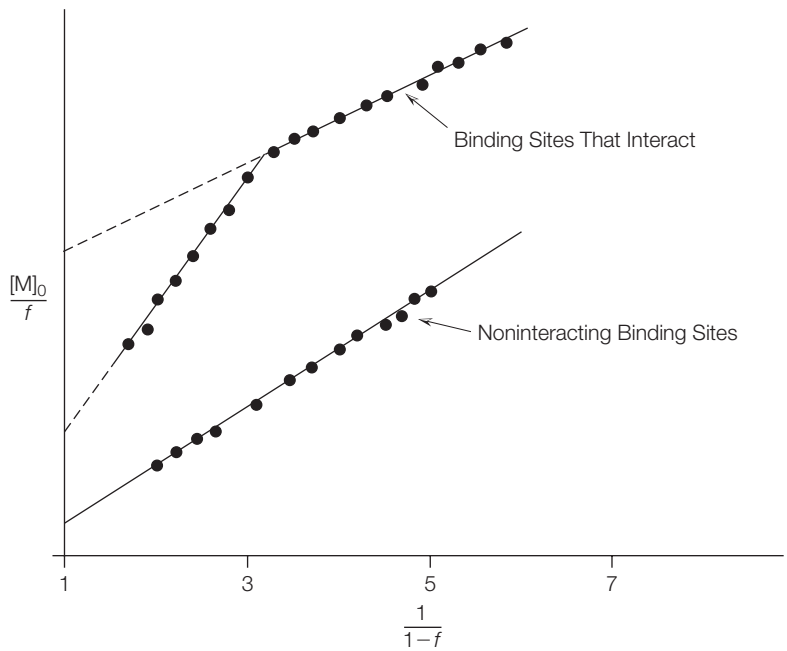

FIGURE 8.4
Scatchard plot for typical binding data. See text for details.

Internet. Some popular and effective software programs are listed and described in Table 8.6. Additional Web sites and references are available at the end of this chapter and in Appendix I. One very useful program is DynaFit (www.biokin.com), which may be applied to the analysis of ligand binding data or enzyme kinetic data. The program has been designed by Dr. Petr Kuzmic, President and CEO of Biokin Ltd. DynaFit is available free for academic users (students, professors, university researchers), but one must register for an academic license at the Web site.

B. BIOLOGICAL CATALYSIS (ENZYMES)

Enzyme-catalyzed reactions may also be described in terms of ligand-macromolecule interactions. Enzyme reactions are initiated by the interaction of a substrate molecule with an enzyme molecule:

>> $$E + S \rightleftharpoons ES$$ **(Eq. 8.13)**

Enzymes are biological catalysts. Without their presence in a cell, most biochemical reactions would not proceed at the required rate. The chemical and biological properties of enzymes have been investigated since the early 1800s. The unrelenting interest in enzymes is due to several factors—their dynamic and essential roles in the cell, their extraordinary catalytic power, and their selectivity.

Enzyme-catalyzed reactions proceed through an ES complex, as shown in Equation 8.14. Individual rate constants k are assigned to each reaction step.

>> $$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \underset{k_4}{\overset{k_3}{\rightleftharpoons}} E + P$$ **(Eq. 8.14)**

E represents the enzyme, S the substrate or reactant, and P the product. For a specific enzyme, only one or a few different substrate molecules can bind in the proper manner and produce a functional ES complex. The substrate must have a size, shape, and polarity compatible with the active site of the enzyme. Some enzymes catalyze the transformation of many different molecules as long as there is a common type of chemical linkage in the substrate. Others have absolute specificity and can form reactive ES complexes with only one molecular structure. In fact, some enzymes are able to differentiate between D and L isomers of substrates.

Classes of Enzymes

Thousands of enzymes have now been isolated and studied; confusion would reign without some system for nomenclature and classification. Common names for enzymes are usually formed by adding the suffix **–ase** to the name of the substrate. The enzyme tyrosinase catalyzes the oxidation of tyrosine; cellulase catalyzes the hydrolysis of cellulose to produce glucose. Common names of this type define the substrate, but do not describe the chemistry of the reaction. Some very early names, such as catalase, trypsin, and pepsin, are

even less descriptive and give no clue to their function or substrates. To avoid such confusion, enzymes now have official names that reflect the reactions they catalyze. All known enzymes can be classified into one of six categories (Table 8.3). Each enzyme has an official international name ending in *–ase* and a classification number, called the Enzyme Commision (E.C.) number. The number consists of four digits, each referring to a class and subclass of reaction. Table 8.3 shows an example from each class of enzyme.

TABLE 8.3 An Example of Each Class of Enzyme

1. Oxidoreductase

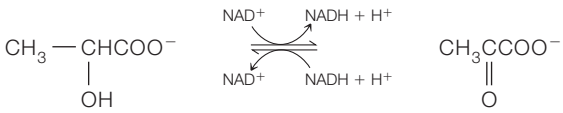

Lactate Pyruvate

Common name: Lactate dehydrogenase

Official name: L-Lactate: NAD^+ oxidoreductase

Official E.C. number: 1.1.2.3

2. Transferase

$(d - NMP)_n + d - NTP \rightleftharpoons (d - NMP)_{n+1} + PP_i$

$(d - NMP)_n$ = DNA with n nucleotides

$(d - NMP)_{n+1}$ = DNA with $n + 1$ nucleotides

PP_i = Pyrophosphate

Common name: DNA polymerase

Official name: Deoxynucleoside triphosphate: DNA deoxynucleotidyltransferase (DNA-directed)

Official E.C. Number: 2.7.7.7

3. Hydrolase

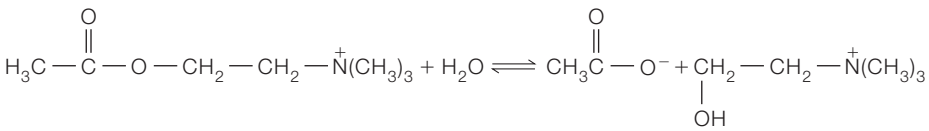

Acetylcholine Acetate Choline

Common name: Acetylcholinesterase

Official name: Acetylcholine acetylhydrolase

Official E.C. number: 3.1.1.7

4. Lyase

$CO_2 + H_2O \rightleftharpoons H_2CO_3$

Carbonic acid

Common name: Carbonic anhydrase

Official name: Carbonate hydrolyase

Official E.C. number: 4.2.1.1

(*Continued*)

TABLE 8.3 (*Continued*)

5. Isomerase

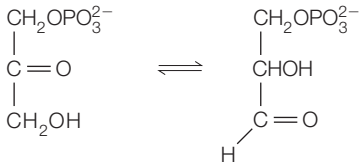

Dihydroxyacetone phosphate — Glyceraldehyde 3-phosphate

Common name: Triose phosphate isomerase

Official name: D-Glyceraldehyde-3-phosphate ketoisomerase

Official E.C. number: 5.3.1.1

6. Ligase

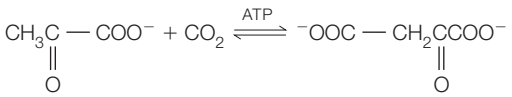

Pyruvate — Oxaloacetate

Common name: Pyruvate carboxylase

Official name: Pyruvate: CO_2 ligase (ADP-forming)

Official E.C. number: 6.4.1.1

Kinetic Properties of Enzymes

The **initial reaction velocity,** ν_0, of an enzyme-catalyzed reaction varies with the substrate concentration, [*S*], as shown in Figure 8.5. The Michaelis-Menten equation has been derived to account for the kinetic properties of enzymes. (Consult a biochemistry textbook for a derivation of this equation and for a discussion of the conditions under which the equation is valid.) The common form of the equation is

>>
$$\nu_0 = \frac{V_{\max}[\mathrm{S}]}{K_\mathrm{M} + [\mathrm{S}]} \qquad \textbf{(Eq. 8.15)}$$

where

ν_0 = initial reaction velocity

$V_{\max}$ = maximal reaction velocity; attained when all enzyme active sites are filled with substrate molecules

[S] = substrate concentration

K_M = Michaelis constant $= \dfrac{k_2 + k_3}{k_1}$

The important kinetic constants $V_{\max}$ and K_M can be graphically determined as shown in Figure 8.5. Equation 8.15 and Figure 8.5 have all of the disadvantages of nonlinear kinetic analysis. $V_{\max}$ can only be estimated because of the asymptotic nature of the line. The value of K_M, the substrate concentration

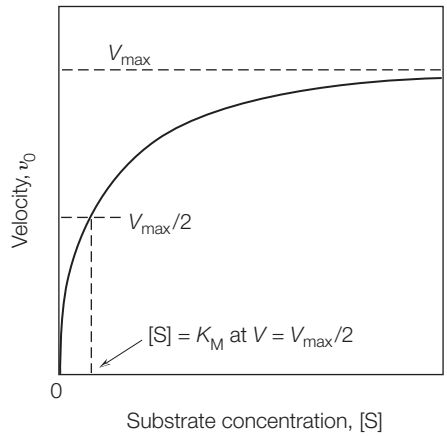

FIGURE 8.5
Michaelis-Menten plot for an enzyme-catalyzed reaction.

that results in a reaction velocity of $V_{max}/2$, depends on V_{max}, so both are just an estimate. By taking the reciprocal of both sides of the Michaelis-Menten equation, however, it is converted into the Lineweaver-Burk relationship (Equation 8.16).

>>
$$\frac{1}{v_0} = \frac{K_M}{V_{max}} \cdot \frac{1}{[S]} + \frac{1}{V_{max}} \qquad \textbf{(Eq. 8.16)}$$

This equation, which is in the form $y = mx + b$, gives a straight line when $1/\nu_0$ is plotted against 1/[S] (Figure 8.6). The intercept on the $1/\nu_0$ axis is $1/V_{max}$, and the intercept on the 1/[S] axis is $-1/K_M$. A disadvantage of the Lineweaver-Burk plot is that the data points are compressed in the high substrate concentration region.

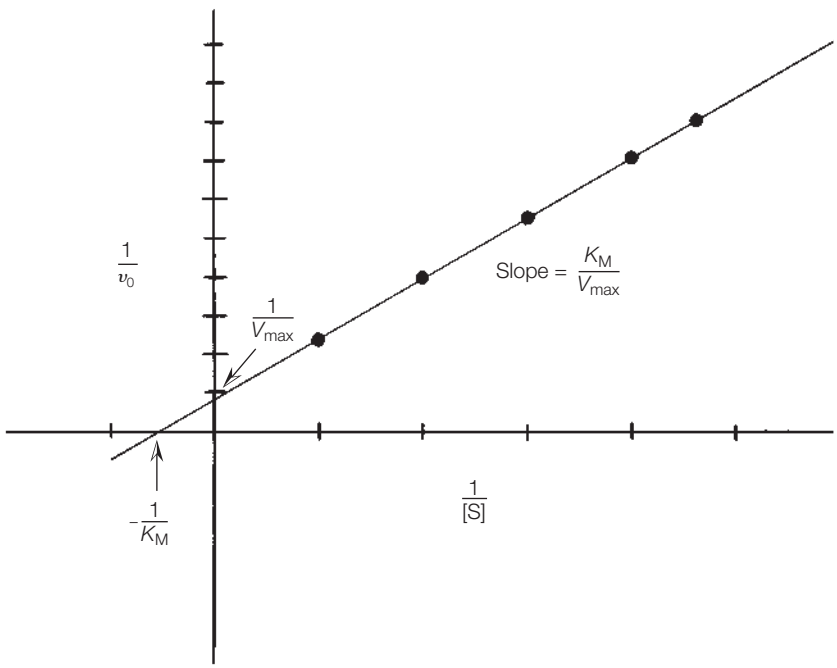

FIGURE 8.6
Lineweaver-Burk plot for an enzyme-catalyzed reaction.

Significance of Kinetic Constants

The **Michaelis constant,** K_M, for an enzyme-substrate interaction has two meanings: (1) K_M is the substrate concentration that leads to an initial reaction velocity of $V_{max}/2$ or, in other words, the substrate concentration that results in the filling of one-half of the enzyme active sites, and (2) $K_M = (k_2 + k_3)/k_1$. The second definition of K_M has special significance in certain cases. When $k_2 \gg k_3$, then $K_M = k_2/k_1$ so K_M is equivalent to the dissociation constant of the ES complex. When $k_2 \gg k_3$, a large K_M implies weak interaction between E and S, whereas a small K_M indicates strong binding between E and S.

V_{max} is important because it leads to the analysis of another kinetic constant, k_3, **turnover number.** The analysis of k_3 begins with the basic rate law for an enzyme-catalyzed process (Equation 8.17), which is derived from Equation 8.14.

>> $$\nu_0 = k_3[ES] \qquad \textbf{(Eq. 8.17)}$$

If all of the enzyme active sites are saturated with substrate, then [ES] in Equation 8.17 is equivalent to $[E_T]$, the total concentration of enzyme, and ν_0 becomes V_{max}; hence

>> $$V_{max} = k_3[E_T] \qquad \textbf{(Eq. 8.18)}$$

or

$$k_3 = \frac{V_{max}}{[E_T]}$$

For an enzyme with one active site per molecule, the turnover number, k_3, is the number of substrate molecules transformed to product by one enzyme molecule per unit time, usually in minutes or seconds. The turnover number is a measure of the efficiency of an enzyme. K_M and k_3 values for some enzymes are listed in Table 8.4.

TABLE 8.4 K_M and k_3 Values for Some Enzyme: Substrate Systems

Enzyme	Substrate	K_M (mM)	$k_3(sec^{-1})$
Catalase	H_2O_2	0.001	40,000,000
Carbonic anhydrase	HCO_3^-	9	400,000
Acetylcholinesterase	Acetylcholine	0.09	25,000
Penicillinase	Benzylpenicillin	0.050	2,000
Chymotrypsin	Glycyltyrosinylglycine	108	100
DNA polymerase	DNA	–	15
Ribulose-1,5-bis-phosphate carboxylase	Ribulose-1,5-bisphosphate	0.028	3.3
	CO_2	0.009	–

STUDY EXERCISE 8.3 Enzyme Kinetics

An enzyme displays the following reaction kinetics:

$$V_{max} = 200\ \mu\text{mol/min}$$
$$\text{Initial rate } (\nu_0) = 75\ \mu\text{mol/min}$$
$$[S] = 10\ \mu\text{M}$$

Calculate K_M.

Inhibition of Enzyme Activity

Nonsubstrate molecules may interact with enzymes, leading to a decrease in enzymatic activity. Enzyme inhibition, the phenomenon in which molecules interfere with enzymes, is of interest because it often provides clues about the mechanism of enzyme action and also reveals information about metabolic control and regulation. In addition, many toxic substances, including drugs, express their action by enzyme inhibition. Inhibition of enzymes by reversible pathways will be reviewed here. For more details on enzyme inhibition, including irreversible processes, see your biochemistry course textbook.

The process of reversible inhibition is described by an equilibrium interaction between enzyme (E) and inhibitor molecule (I):

>> $$E + I \rightleftharpoons EI$$ **(Eq. 8.19)**

Most inhibition processes can be classified as **competitive, mixed,** or **uncompetitive,** depending on how the inhibitor interferes with enzyme action.

1. ***Competitive inhibition.*** A competitive inhibitor is usually similar in structure to the substrate and is capable of reversible binding to the enzyme active site. In contrast to the substrate molecule, the inhibitor molecule cannot undergo chemical transformation to a product; however, it does interfere with substrate binding. The binding of substrate and competitive inhibitor is a mutually exclusive process: When inhibitor is bound to enzyme, substrate is unable to bind and vice versa. The kinetic scheme for competitive inhibition is as follows:

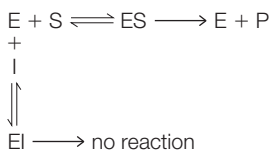

2. ***Mixed inhibition.*** A mixed inhibitor does not bind in the active site of the enzyme, but binds to some other region of the enzyme molecule. The presence of inhibitor may or may not affect substrate binding, but it does interfere with the catalytic functioning of the enzyme. [A noncompetitive inhibitor, a special type of mixed inhibitor, does not affect substrate binding

(no change in K_M), but does affect the catalytic efficiency of the enzyme (lowers V_{max}).] The enzyme with mixed inhibitor bound may be converted to a nonfunctional conformational state. The kinetic scheme for noncompetitive inhibition is as follows (note that the inhibitor may bind to the free enzyme, E, to EI, or to ES):

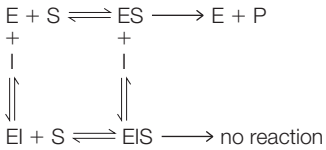

3. ***Uncompetitive inhibition.*** An uncompetitive inhibitor is similar to a noncompetitive inhibitor—it allows substrate to bind to the active site. It differs, however, because an uncompetitive inhibitor binds only to the ES complex:

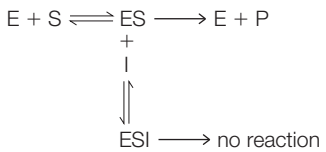

Because the inhibitor combines only with ES and not free enzyme, it will influence the activity of the enzyme only when substrate concentrations and, in turn, ES concentrations are high.

Any complete inhibition study requires the experimental differentiation among the three types of inhibition. The three inhibitory processes are kinetically distinguishable by application of the Lineweaver-Burk equation. For each inhibitor studied, at least two sets of rate experiments are completed. In all sets, the enzyme concentration is identical. In set 1, the substrate concentration is varied and no inhibitor is added. In set 2, the same variable substrate concentrations from set 1 are used, and a constant amount of inhibitor is added to each assay. If additional data are desired, more sets are prepared with variable substrate concentrations as in set 2; however, a constant, and different, concentration of inhibitor is present. These data, when plotted on a Lineweaver-Burk graph, lead to three lines as shown in Figure 8.7. In competitive inhibition, all three lines intersect at the same point on the $1/\nu_0$ axis; hence, V_{max} is not altered by the presence of the competitive inhibitor. If enough substrate is added, the competitive inhibition may be overcome. The apparent K_M value (measured on the $1/[S]$ axis) changes with each increase in inhibitor concentration. In mixed (noncompetitive) inhibition, the family of lines has a common intercept on the $1/[S]$ axis (unchanged K_M for the lines). For uncompetitive inhibition, parallel lines are obtained indicating that both V_{max} and K_M are changed. The kinetic characteristics of reversible inhibition are compared in Table 8.5.

Units of Enzyme Activity

The actual molar concentration of an enzyme in a cell-free extract or purified preparation is seldom known. Only if the enzyme is available in a pure crystalline form, carefully weighed, and dissolved in a solvent can the actual molar

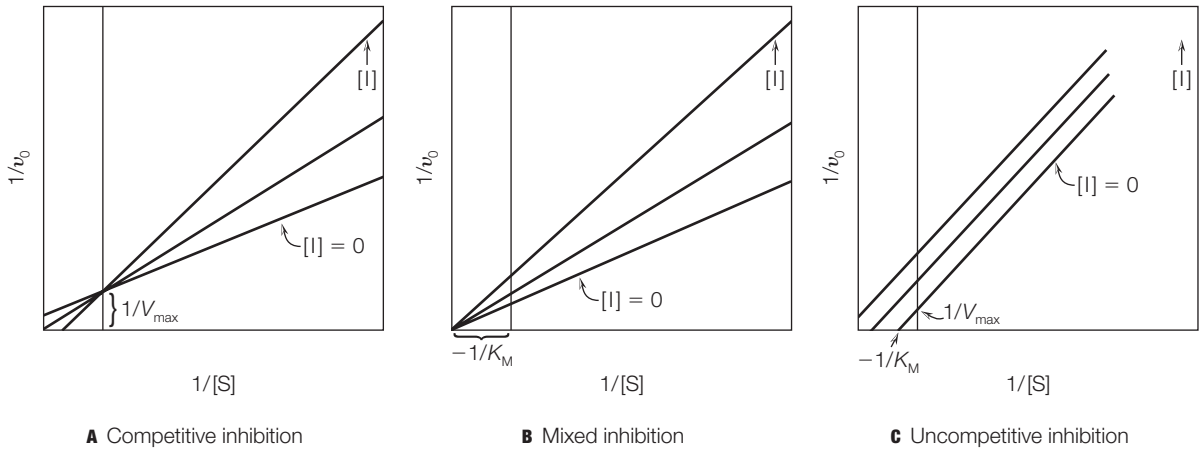

A Competitive inhibition **B** Mixed inhibition **C** Uncompetitive inhibition

FIGURE 8.7 Lineweaver-Burk plots to determine type of inhibition. Each set of three lines includes a line representing no inhibitor present, and two lines showing two different concentrations of inhibitor. **A** competitive inhibition: The lines intersect on the $1/v_0$ axis, where V_{max} can be calculated. **B** Mixed (noncompetitive) inhibition: The lines intersect on the $1/[S]$ axis, where K_M can be calculated. **C** Uncompetitive inhibition: The lines are parallel. The V_{max} and K_M can be calculated for each line as shown.

TABLE 8.5 Kinetic Characteristics of Reversible Inhibition

	Effect on Inhibited Reaction[1]		
Type of inhibition	K_m	V_{max}	K_m/V_{max} **(Slope)**
Competitive	Higher	Same	Increase
Mixed	Higher	Lower	Increase
Noncompetitive	Same	Lower	Increase
Uncompetitive	Lower	Lower	Same

[1]*Relative to uninhibited reaction.*

concentration be accurately determined. It is, however, possible to develop a precise and accurate assay for enzyme activity. Consequently, the amount of a specific enzyme present in solution is most often expressed in units of activity. Three units are in common use, the *international unit* (IU), the *katal*, and *specific activity*. The International Union of Biochemistry Commission on Enzymes has recommended the use of a standard unit, the **international unit** or simply **unit,** of enzyme activity. One IU of enzyme corresponds to the amount that catalyzes the transformation of 1 μmole of substrate to product per minute under specified conditions of pH, temperature, ionic strength, and substrate concentration. If a solution containing enzyme converts 10 μmoles of substrate to product in 5 minutes, the solution contains 2 enzyme units. A new unit of activity, the katal, has been recommended. One **katal** of enzyme activity represents the conversion of 1 mole of substrate to product in 1 second. One international unit is equivalent to 1/60 μkatal or 0.0167 μkatal. One katal, therefore,

is equivalent to 6×10^7 international units. It is convenient to represent small amounts of enzyme in millikatals (mkatals), microkatals (μkatals), or nanokatals (nkatals). The enzyme activity in the above example was 2 units, which can be converted to katals as follows: Since one katal is 6×10^7 units, 2 units are equivalent to $2/6 \times 10^7$ or 33 nkatals (0.033 μkatals). If the enzyme is an impure preparation in solution, the activity is most often expressed as units/mL or katals/mL.

Specific Activity

Another useful quantitative definition of enzyme efficiency is **specific activity**. The specific activity of an enzyme is the number of enzyme units or katals per milligram of protein. This is a measure of the purity of an enzyme. If a solution contains 20 mg of protein that express 2 units of activity (33 nkatals), the specific activity of the enzyme is $2\,\text{units}/20\,\text{mg} = 0.1\,\text{units/mg}$, or $33\,\text{nkatals}/20\,\text{mg} = 1.65\,\text{nkatals}/20\,\text{mg}$. As an enzyme is purified, its specific activity increases. That is, during purification, the enzyme concentration increases relative to the total protein concentration until a limit is reached. The maximum specific activity is attained when the enzyme is homogeneous, or in a pure form.

The activity of an enzyme depends on several factors, including substrate concentration, cofactor concentration, pH, temperature, and ionic strength. The conditions under which enzyme activity is measured are critical and must be specified when activities are reported.

Design of an Enzyme Assay

Whether an enzyme is obtained commercially or prepared (purified) in a multistep procedure, an experimental method must be developed to detect and quantify the specific enzyme activity. During isolation and purification of an enzyme, the assay is necessary to determine the amount and purity of the enzyme and to evaluate its kinetic properties. An assay is also essential for a further study of the mechanism of the catalyzed reaction.

The design of an assay requires certain knowledge of the reaction:

1. The complete stoichiometry.
2. What substances are required (substrate, metal ions, cofactors, etc.) and their kinetic dependence.
3. Effect of pH, temperature, and ionic strength.

The most straightforward approach to the design of an enzyme assay is to measure the change in substrate or product concentration during the reaction.

If an enzyme assay involves continuous monitoring of substrate or product concentration, the assay is said to be **kinetic.** If a single measurement of substrate or product concentration is made after a specified reaction time, a **fixed-time assay** results. The kinetic assay is more desirable because the time course of the reaction is directly observed and any discrepancy from linearity can be immediately detected.

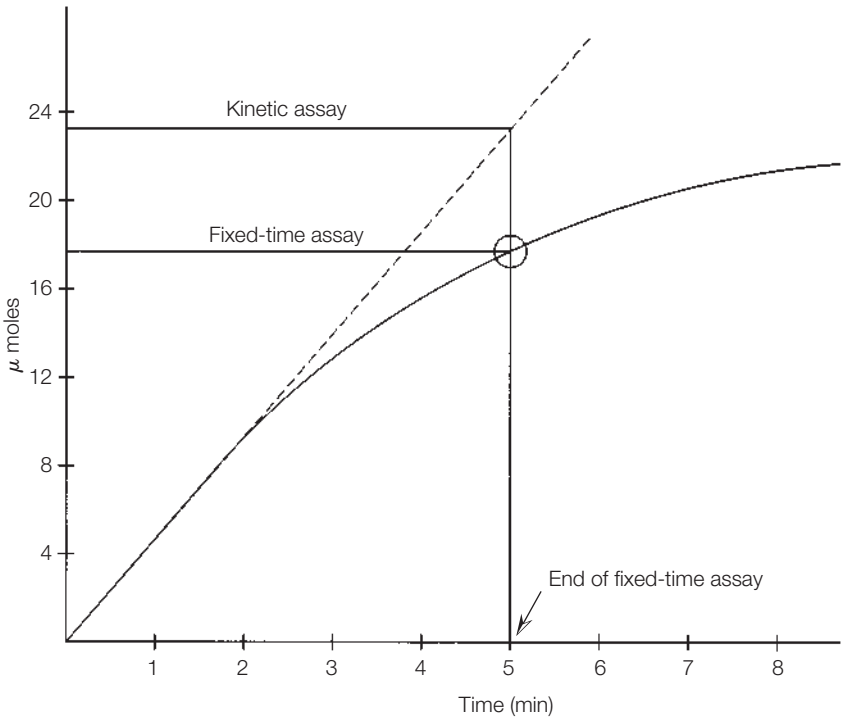

FIGURE 8.8
Kinetic progress of an enzyme-catalyzed reaction. See text for details.

Kinetic versus Fixed-time Assay

Figure 8.8 displays the kinetic progress curve of a typical enzyme-catalyzed reaction and illustrates the advantage of a kinetic assay. The rate of product formation decreases with time. This may be due to any combination of factors such as decrease in substrate concentration, denaturation of the enzyme, and product inhibition of the reaction. The solid line in Figure 8.8 represents the continuously measured time course of a reaction (kinetic assay). The true rate of the reaction is determined from the slope of the dashed line drawn tangent to the experimental result. From the data given, the rate is 5 μmoles of product formed per minute. Data from a fixed-time assay are also shown on Figure 8.8. If it is assumed that no product is present at the start of the reaction, then only a single measurement after a fixed period is necessary. This is shown by a circle on the experimental rate curve. The measured rate is now 16 μmoles of product formed every 5 minutes, or about 3 μmoles/minute, which is considerably lower than the rate derived from the continuous, kinetic assay. Which rate measurement is correct? Obviously, the kinetic assay gives the true rate because it corrects for the decline in rate with time. The fixed-time assay can be improved by changing the time of the measurement, in this example, to 2 minutes of reaction time, when the experimental rate is still linear. It is possible to obtain true rates with the fixed-time assay, but one must choose the time period very carefully. In the laboratory, this is done by removing aliquots of a reaction mixture at various times and measuring the concentration of

product formed in each aliquot. Figure 8.8 reinforces an assumption used in the derivation of the Michaelis-Menten equation. Only measurements of initial velocities lead to true reaction rates. This avoids the complications of enzyme denaturation, decrease of [S], product inhibition, and reversion of the product to substrate.

Several factors must be considered when the experimental assay conditions are developed. The reaction rate depends on the concentrations of substrate, enzyme, and necessary cofactors. In addition, the reaction rate is under the influence of environmental factors such as pH, temperature, and ionic strength. Enzyme activity increases with increasing temperature until the enzyme becomes denatured. The enzyme activity then decreases until all enzyme molecules are inactivated by denaturation. During kinetic measurement, it is essential that the temperature of all reaction mixtures be maintained as constant.

Ionic strength and pH should also be monitored carefully. Although some enzymes show little or no change in activity over a broad pH range, most enzymes display maximum activity in a narrow pH range. Any assay developed to evaluate the kinetic characteristics of an enzyme must be performed in a buffered solution, preferably at the optimal pH.

Applications of an Enzyme Assay

The conditions used in an enzyme assay depend on what is to be accomplished by the assay. There are two primary applications of an enzyme assay procedure. First, it may be used to measure the concentration of active enzyme in a preparation. In this circumstance, the measured rate of the enzyme-catalyzed reaction must be proportional to the concentration of enzyme; stated in more kinetic terms, there must be a linear relationship between initial rate and enzyme concentration (the reaction is first-order in enzyme concentration). To achieve this, certain conditions must be met: (1) the concentrations of substrate(s), cofactors, and other required substances must be in excess; (2) the reaction mixture must not contain inhibitors of the enzyme; and (3) all environmental factors such as pH, temperature, and ionic strength should be controlled. Under these conditions, a plot of enzyme activity (μmole product formed/minute) vs. enzyme concentration is a straight line and can be used to estimate the concentration of active enzyme in solution.

Second, an enzyme assay may be used to measure the kinetic properties of an enzyme, such as K_M, V_{max}, and inhibition characteristics. In this situation, different experimental conditions must be used. If K_M for a substrate is desired, the assay conditions must be such that the measured initial rate is first-order in substrate. To determine K_M of a substrate, constant amounts of enzyme are incubated with varying amounts of substrate. A Lineweaver-Burk plot ($1/v_0$ vs. 1/[S]) may be used to determine K_M and V_{max}. If a reaction involves two or more substrates, each must be evaluated separately. The concentration of only one substrate is varied, while the other is held constant at a saturating level. The same procedure holds for determining the kinetic dependence on cofactors. Substrate(s) and enzyme are held constant, and the concentration of the cofactor is varied.

Inhibition kinetics are included in the second category of assay applications. An earlier discussion outlined the kinetic differentiation among competitive, uncompetitive, and mixed inhibition. In summary, a study of enzyme kinetics is approached by measuring initial reaction velocities under conditions in which only one factor (substrate, enzyme, cofactor) is varied and all others are held constant.

STUDY EXERCISE 8.4 Converting Rate Data from ΔA/min Units to Concentration Units

Because most enzyme assays are completed with the use of spectroscopic methods, initial rate data are in the form of ΔA/min. The change of color intensity per time interval is not a useful unit for kinetics. A more valuable and widely used unit that actually defines the amount of product formed per time interval is mmol/min or μmol/min. The conversion of ΔA units to concentration units may be done using Beer's Law:

$$c = A/El$$

where

A = the absorbance
E = the molar absorption coefficient of the substrate or product
l = path length of the cuvette, usually 1 cm
c = concentration of substrate or product

For our example, let us assume that we are measuring the appearance of product that has an E value of 3600 $M^{-1}\text{cm}^{-1}$. According to Beer's Law, the absorbance change in a 3 mL cuvette during 1 minute for production of 1 molar product is 3600:

$$1\,\text{molar} = \frac{A}{3600\,M^{-1}\text{cm}^{-1} \times 1\,\text{cm}}$$

$$A = 3600$$

To convert the raw data to moles of product formed per minute per liter, each ΔA/min is divided by 3600. For example, a ΔA/min of 0.1 is converted to μmoles of product formed (Δc) in the following way:

$$\Delta c = \frac{\Delta A/\text{min}}{El} = \frac{0.1/\text{min}}{3600\,M^{-1}\text{cm}^{-1}\text{cm}} = 2.78 \times 10^{-5}\frac{M}{\text{min}}$$

Now convert to moles/min:

$$2.78 \times 10^{-5}\frac{\text{moles}}{\text{liter} \times \text{min}} \times 0.003\,\text{liters} = 8.33 \times 10^{-8}\frac{\text{moles}}{\text{min}}$$

Now convert to μmoles/min:

$$\Delta c = 8.33 \times 10^{-2}\frac{\mu\text{moles}}{\text{min}}$$

TABLE 8.6 Computer software and databases for this chapter. Web addresses are at the end of this chapter and in Appendix I.

Name	Description
DynaFit	Graphical analysis of ligand-binding data and enzyme kinetic data
CurveFit	Analysis of ligand binding and enzyme kinetics from GraphPad
SigmaPlot	Enzyme kinetics module from Systat
Systat	Statistical and graphical software
ENZYME	General enzyme information from ExPASy
BRENDA	The comprehensive enzyme information system
PDB	Contains the known enzyme structures in Protein Data Bank
Enzyme Kinetics!Pro	Statistical evaluation of enzyme kinetic data
IUBMB	EC nomenclature for enzymes from the International Union of Biochemistry and Molecular Biology

Computer Software for Analysis of Enzyme Kinetic Data

Many of the computer programs listed for use in ligand binding analysis (this chapter, Section A and Table 8.6) may also be used to analyze enzyme kinetic data. A widely used program is DynaFit (www.biokin.com), which is available free to academic users. One purpose of DynaFit is to aid the graphical analysis of enzyme kinetic data. The experimental data may be in the form of initial reaction rates with dependence on the concentration of substrate or inhibitor. Reaction progress curves (time vs. absorbance) may also be analyzed.

In addition to kinetic analysis programs, many Internet databases also contain general information on enzyme names, EC numbers, catalytic mechanisms, cofactors, structures, reactions, kinetics, associated diseases, and other facts. The most popular, current ones are the ENZYME databases, which are part of the Expert Protein Analysis System (ExPASy), BRENDA, and the Enzyme Structure Database (Table 8.6 and Appendix I).

Performing enzyme kinetic/inhibition experiments in the laboratory and analyzing data may be too complex and not appropriate for some levels of students. In addition, equipment and reagents can be quite expensive and difficult to set up. Computer simulation of enzyme kinetic experiments may be an appropriate alternative (Gonzalez-Cruz et al., 2003).

Study Problems

1. A drug, X, was studied for its affinity to serum albumin. When X was bound to albumin, an increase in absorbance was noted. The $\bar{\nu}$ values were determined from these absorbance measurements. Use the data below to determine K_f and n for the interaction between X and albumin. Prepare two types of graphs and compare the results. In one graph plot $\bar{\nu}$ vs. [X], and in the second plot $\bar{\nu}/[X]$ vs. $\bar{\nu}$. Which is the better method? Why? You may also want to try Dynafit for analysis.

[X]	$\bar{v}$
0.36	0.43
0.60	0.68
1.2	1.08
2.4	1.63
3.6	1.83
4.8	1.95
6.0	1.98

2. One of the many straight-line modifications of the Michaelis-Menten equation is the Eadie-Hofstee equation:

$$.\nu_o = -K_M\frac{\nu_0}{[S]} + V_{max}$$

Beginning with the Lineweaver-Burk equation, derive the Eadie-Hofstee equation. Explain how it may be used to plot a straight line from experimental rate data. How are V_{max} and K_M calculated?

3. A research project you are working on involves the study of sugar binding to human albumin. The sugars to be tested are not fluorescent, and you do not wish to use a secondary probe such as a dye. Human albumin has only one tryptophan residue, and you know that this amino acid is fluorescent. You find that the tryptophan fluorescence spectrum of human albumin undergoes changes when various sugars are added. Can you explain the results of this experiment and discuss the significance of the finding?

4. Equation 8.6 in this chapter can be used to determine K_f values, but hyperbolic plots are obtained. Convert Equation 8.6 into an equation that will yield a linear plot without going through all the changes necessary for the Scatchard equation. Hint: See the Michaelis-Menten equation and the Lineweaver-Burk equation.

5. You are attempting to develop a colorimetric probe for use in binding studies. List several requirements that the probe must meet in order to be effective. For example, it must bind at specific locations of the macromolecule. Can you think of other requirements?

6. Using the data in Problems 7 and 8, calculate the specific activity of the enzyme in units/mg and katal/mg. Assume the enzyme has a molecular weight of 55,000 and the reaction mixture for each assay is contained in a total volume of 1.00 mL.

7. The table below gives initial rates of an enzyme-catalyzed reaction, along with the corresponding substrate concentration. Use any graphical method or computer program to determine k_M and V_{max}.

ν_0 (μM/min)	[S] (mole/liter)
130	65×10^{-5}
116	23×10^{-5}
87	7.9×10^{-5}
63	3.9×10^{-5}
30	1.3×10^{-5}
10	0.37×10^{-5}

8. The enzyme concentration used in each assay in Problem 7 is 5×10^{-7} mole/liter. Calculate k_3, the turnover number, in units of sec^{-1}.
9. Compound X was tested as an inhibitor of the enzyme in Problem 6. Use the rate data in Problem 6 and the following inhibition data to evaluate compound X. Is it a competitive or noncompetitive inhibitor?

[X] = 3.7×10^{-4} *M* ν_0 (μM/min)	[S] (mole/liter)	[X] = 1.58×10^{-3} *M* ν_0 (μM/min)
125	6.5×10^{-4}	110
102	2.3×10^{-4}	80
70	7.9×10^{-5}	40
45	3.9×10^{-5}	20
20	1.3×10^{-5}	—
5	0.37×10^{-5}	—

10. Show the mathematical steps required to derive the Lineweaver-Burk equation beginning with the Michaelis-Menten equation.
11. Figure 8.8 displays the kinetic progress of an enzyme-catalyzed reaction. What time limit must be imposed on rate measurements taken with the use of the fixed-time assay? Why?
12. The following data were collected in a ligand binding experiment. The protein concentration was 7.5×10^{-6} mole/liter. Use a graphical analysis program to determine n and K_f.

Reaction No.	L added (μM)	L bound (μM)
1	20	11
2	50	26
3	100	44
4	150	55
5	200	60
6	400	70

13. In your biochemistry research project, you find that the binding of a ligand to a protein decreases if the ionic strength of the buffer solvent is increased. What type of noncovalent bonding might be involved in the ligand-protein complex?

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GraphPad Software for analyzing binding data. Provides an introduction to analysis of ligand-protein interactions.

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http://www.biokin.com
Contains the computer program DynaFit, which may be used for the graphical analysis of ligand-receptor binding and enzyme kinetic data.

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http://www.biochemweb.org/enzymes.shtml
The Virtual Library of Biochemistry, Molecular Biology and Cell Biology.

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Enzymes, Kinetics and Diagnostics.

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Sigmaplot by Systat Software, Inc.

www.expasy.ch/enzyme
General enzyme information.

www.biochem.ucl.ac.uk/bsm/enzymes/index.html
or
http://www.ebi.ac.uk/thornton-srv/databases/enzymes
Enzymes in PDB.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

CHAPTER 9

MOLECULAR BIOLOGY I: STRUCTURES AND ANALYSIS OF NUCLEIC ACIDS

A. Introduction to the Nucleic Acids 268
B. Laboratory Methods for Investigation of DNA and RNA 275

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In this chapter, we shall focus on the **nucleic acids,** biomolecules important for their cellular roles in the storage, transfer, and expression of genetic information. Two fundamental types of nucleic acids participate as genetic molecules: (1) **deoxyribonucleic acid (DNA)** and (2) **ribonucleic acid (RNA).** We begin this chapter with a review of the chemical and biological properties of the nucleic acids and then turn to a discussion of laboratory methods for their isolation and characterization. Several procedures are described here that provide information about the structure and function of DNA and RNA. These include the isolation of chromosomal and plasmid DNA, isolation of RNA, ultraviolet absorption of the nucleic acids, construction of thermal denaturation curves, ethidium bromide binding and fluorescence, agarose gel electrophoresis, and sequencing DNA molecules. Early studies on DNA and RNA delved into understanding the molecular details of DNA replication, RNA transcription, and translation to produce proteins. More recently, research on the nucleic acids has concentrated on the biotechnological development of **recombinant DNA** for molecular cloning procedures, which will be discussed in Chapter 10.

A. INTRODUCTION TO THE NUCLEIC ACIDS

Chemical Components of DNA and RNA

In chemical terms, the nucleic acids are linear polymers made up of monomeric units called **nucleotides.** A nucleotide is comprised of three chemical entities (see Figure 9.1):

1. A purine or pyrimidine nitrogen-containing, heterocyclic base (Figure 9.2).
2. A five-carbon carbohydrate (aldopentose), ***β*-D-ribose** or ***β* -D-2-deoxyribose** (Figure 9.3).
3. One, two, or three phosphate groups.

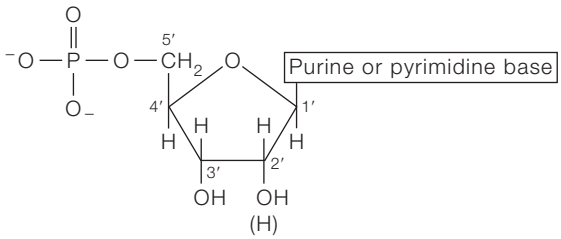

FIGURE 9.1 General structure of a nucleotide showing the three fundamental components: a purine or pyrimidine base, a ribose (or deoxyribose), and phosphate.

Major Bases **Minor Bases**

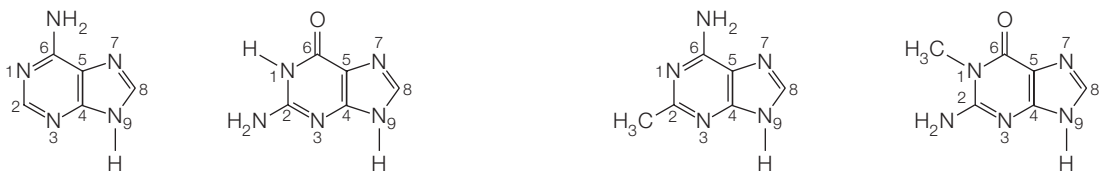

Adenine Guanine 2-Methyladenine 1-Methylguanine

Purines

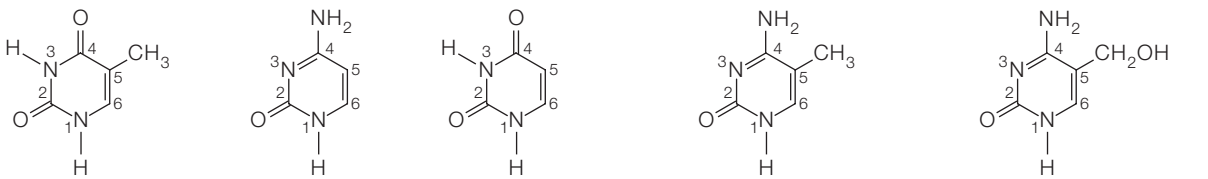

Thymine (DNA) Cytosine Uracil (RNA) 5-Methylcytosine 5-Hydroxymethylcytosine

Pyrimidines

FIGURE 9.2 The major and some minor heterocyclic bases in DNA and RNA. All are derived from purine or pyrimidine.

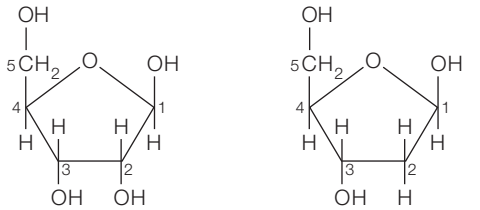

A β-D-Ribose **B** β-D-2-Deoxyribose

FIGURE 9.3 The aldopentoses in RNA and DNA: **A** β-D-ribose, **B** β-D-2-deoxyribose.

The predominant nitrogen bases in DNA include the purines, **adenine (A)** and **guanine (G),** and the pyrimidines, **thymine (T)** and **cytosine (C).** In RNA, the purines include **A** and **G** and the pyrimidines, **C** and **uracil (U).** The nucleic acids, especially RNA, contain small quantities of methylated nitrogen bases (Figure 9.2).

When a nitrogen base and aldopentose are combined via an *N*-glycosidic bond, the product is a **nucleoside** (Figure 9.4). Addition of a phosphoryl group ($-PO_3^{2-}$) to a hydroxyl group on the carbohydrate leads to a **nucleotide.** The most common site for phosphorylation is the 5′-hydroxyl group. The names of 5′ nucleotides derived from the common nitrogen bases are listed in Table 9.1.

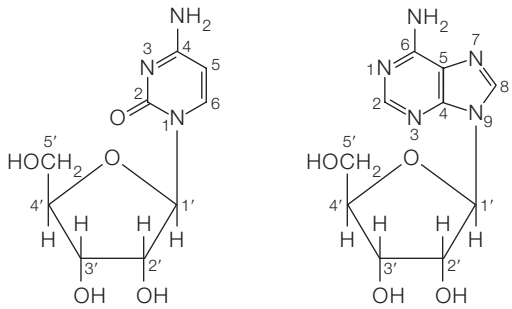

Pyrimidine nucleoside Purine nucleoside

FIGURE 9.4 A nucleoside consists of a purine or pyrimidine base linked to a ribose or deoxyribose by an *N*-glycosidic bond. Two numbering systems (primed and unprimed) are necessary to distinguish the two rings.

TABLE 9.1 Nomenclature for Nucleosides and Nucleotides in DNA and RNA

Base	Nucleoside	Nucleotide (Abbreviation)	Nucleic Acid
Purine			
Adenine	Adenosine, deoxyadenosine	Adenosine 5′-monophosphate (5′-AMP)	RNA
		Deoxyadenosine 5′-monophosphate (5′-dAMP)	DNA
Guanine	Guanosine, deoxyguanosine	Guanosine 5′-monophosphate (5′-GMP)	RNA
		Deoxyguanosine 5′-monophosphate (5′-dGMP)	DNA
Pyrimidine			
Cytosine	Cytidine, deoxycytidine	Cytidine 5′-monophosphate (5′-CMP)	RNA
		Deoxycytidine 5′-monophosphate (5′-dCMP)	DNA
Thymine	Deoxythymidine	Deoxythymidine 5′-monophosphate (5′-dTMP)	DNA
Uracil	Uridine	Uridine 5′-monophosphate (5′-UMP)	RNA

DNA Structure and Function

DNA in all forms of life is a polymer made up of nucleotides containing four major types of heterocyclic nitrogen bases. The nucleotides are held together by **3′,5′-phosphodiester bonds** (Figure 9.5). The quantitative ratio and sequence of bases vary with the source of the DNA. The covalent backbone of DNA (and RNA) consists of alternating deoxyriboses (or riboses) and phosphate groups. This feature, which is defined as a **common, invariant region,** is found in all

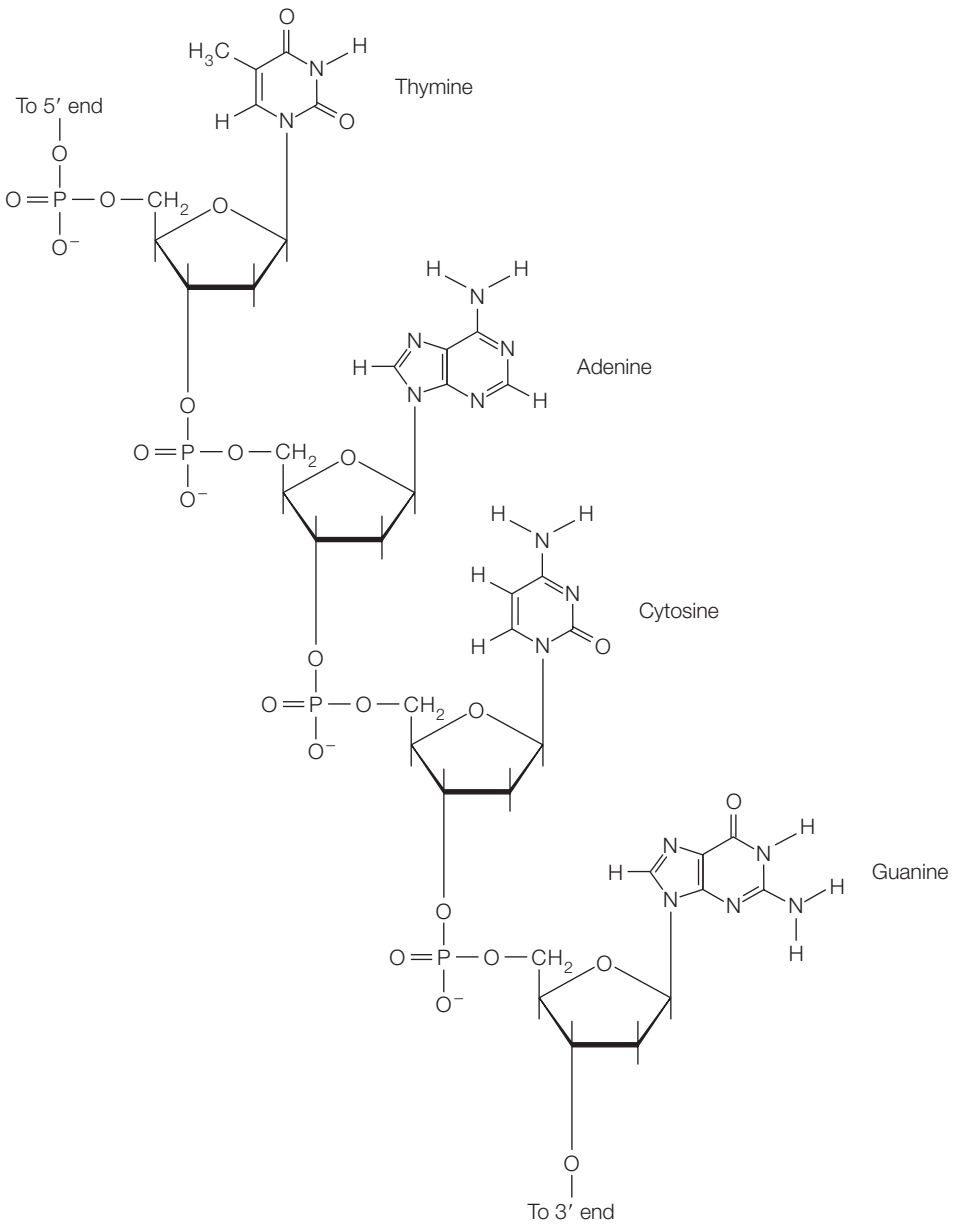

FIGURE 9.5 The covalent structure of DNA showing the phosphodiester backbone linking deoxyribose through the 3′ and 5′ hydroxyl groups.

TABLE 9.2 Comparison of DNA from Different Species

Organism	Number of Base Pairs	Length (μm)	Conformation
Viruses			
SV40	5100	1.7	Circular
Adenovirus	36,000	12	Linear
λ phage	48,600	17	Circular
Bacteria			
E. coli	4,700,000	1400	Circular
Eukaryotes			
Yeast	13,500,000	4600	Linear
Fruit fly	165,000,000	56,000	Linear
Human	3,200,000,000	$1-2 \times 10^6$	Linear

nucleic acids. The **variable region** of DNA and RNA displays the sequence of the four kinds of bases in the nucleic acid. The purine/pyrimidine nitrogen bases protrude from the backbone-like side chains. The sequence of bases carries the specific genetic message. The DNA or RNA chain also displays **directionality**—one end of the chain has a 3′-hydroxyl (or phosphate) group and the other end has a 5′-hydroxyl (or phosphate) group.

Native DNA exists as two complementary, antiparallel strands arranged in a **double helix** held together by noncovalent bonding. DNA in most prokaryotic cells (simple cells with no major organelles and a single chromosome) exists as a single molecule in a circular, double-stranded form with a molecular weight of at least 2×10^9 amu. Eukaryotic cells (cells with major organelles) contain several chromosomes and, thus, several very large DNA molecules (Table 9.2).

DNA was first isolated from biological material in 1869, but its participation in the transfer of genetic information was not recognized until the mid-1940s. Since that time, DNA has been the subject of thousands of physical, chemical, and biological investigations. A landmark discovery was Watson and Crick's elucidation of the three-dimensional structure of DNA by X-ray diffraction analysis in 1953. The double helix as envisioned by Watson and Crick is now recognized as a significant form of native DNA (Figure 9.6). The most important structural and functional feature of the double helix is its **complementary base pairing.** This not only holds the two strands of the double helix together, but also allows the DNA to function in the storage and transfer of genetic information.

The double helix is stabilized by two types of noncovalent forces (review Table 8.2):

1. ***Hydrogen bonding between pairs of complementary bases: A:T and G:C.*** This combination leads to the maximum number of hydrogen bonds for stability. Each base pair consists of a pyrimidine and a purine base. The

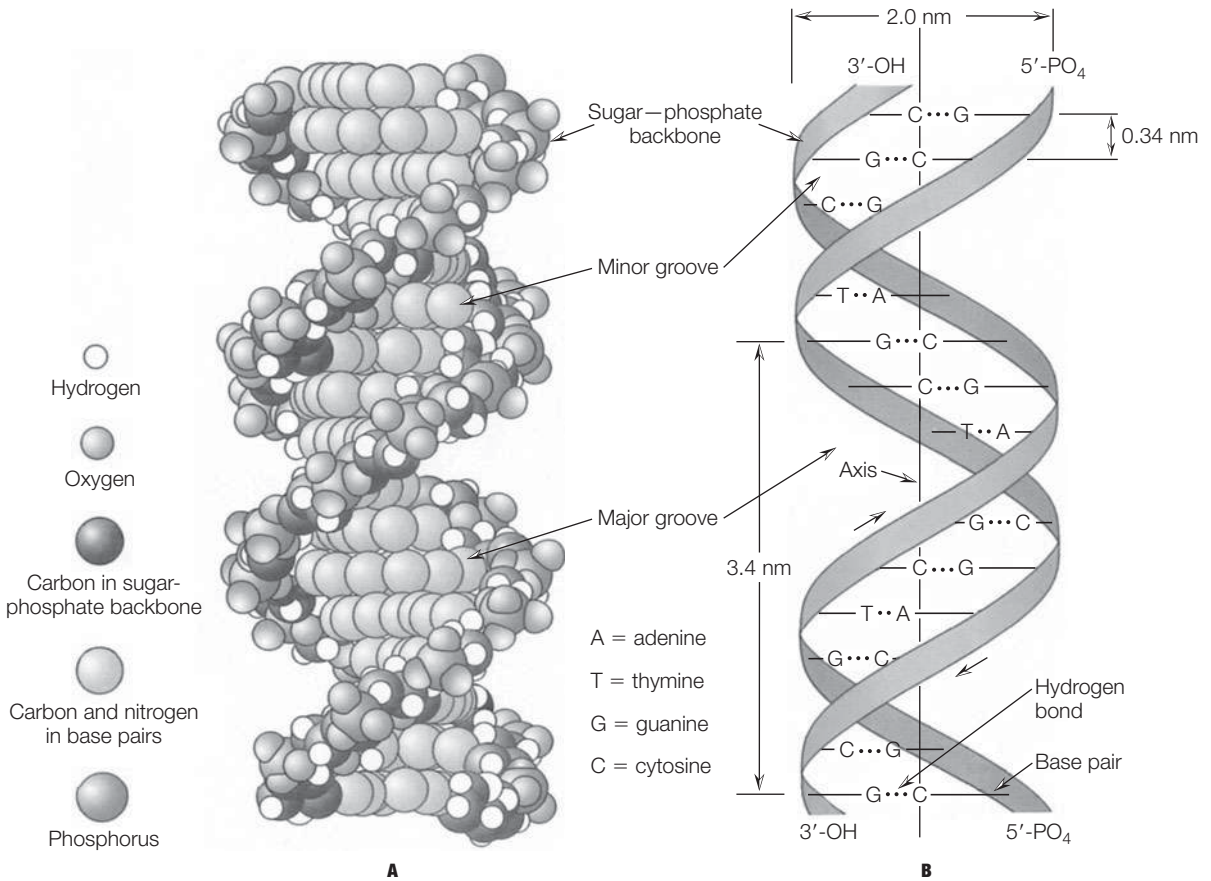

FIGURE 9.6 **A** The Watson-Crick double helix. **B** Pairing of A-T and G-C bases in the DNA double helix. Note that the two strands are antiparallel; their 3′ and 5′ phosphodiester bonds run in opposite directions.

distance spanned across the double helix is just right for a purine:pyrimidine pair. Two pyrimidines are too small to form strong hydrogen bonds, and two purines are too sterically crowded.

2. ***Hydrophobic interactions and van der Waals forces between "stacked bases" (see Chapter 8, Section A, p.241).*** The planes of the nitrogen bases are nearly perpendicular to the common axis of the helix and take on a stacking arrangement, bringing the purine and pyrimidine rings close together. This allows for favorable hydrophobic interactions between nonpolar regions of the bases and interactions between π electrons in the sp^2 hybrid orbitals of the aromatic rings.

RNA Structure and Function

Unlike DNA, which is primarily a homogeneous molecule in the cell, RNA exists in three major forms (Table 9.3). **Ribosomal RNA (rRNA),** the most abundant form, is found associated with the ribosomes, the protein-synthesizing

TABLE 9.3 RNA Molecules in *E. coli*

Type	Relative Amount (%)	*S*[a] Value	MW	Average Number of Nucleotides
Ribosomal RNA (rRNA)	80	23S 16S 5S	1.2×10^6 0.55×10^6 36,000	3700 1700 120
Transfer RNA (tRNA)	15	4S	25,000	74–93
Messenger RNA (mRNA)	5	4S	Heterogeneous mixture	

[a]The *S* value refers to the sedimentation coefficient (in Svedberg units) and is related to the size of the molecule.

organelles. The three sizes of prokaryotic rRNA, 5S, 16S, and 23S, can be separated by centrifugation (Chapter 4). **Messenger RNA (mRNA)** carries the transient message for protein synthesis from nuclear DNA to the ribosomes. The smallest RNA molecules, **transfer RNA (tRNA)**, select, bind, and activate amino acids for use in protein synthesis. Because RNA molecules are heterogeneous and short-lived in the cell, it has been a challenge to isolate them in an intact form in order to study their structures and properties. RNA is usually single-stranded, but it does have important structural features. tRNA molecules have been purified and crystallized for X-ray crystallography. The basic two-dimensional structure of all tRNAs is often shown in a cloverleaf pattern in order to display its single-stranded and double-stranded regions. mRNA and rRNA molecules recently isolated and crystallized display the structural elements of hairpin turns, right-handed double helixes, and internal loops. Complementary bases in RNA are A:U and G:C.

Now that some of the major players in the flow of biological information have been identified, it is possible to provide a schematic outline for the process of protein synthesis (see Figure 9.7). The general direction of information flow is:

$$DNA \longrightarrow RNA \longrightarrow Proteins \longrightarrow Cell\ Structure/Function$$

Note that DNA is the original source of genetic information. DNA is faithfully copied by the process of **replication.** In **transcription,** a smaller region of the DNA (gene) is converted into the language of mRNA. In **translation,** proteins are synthesized from amino acids. After synthesis, many proteins are not yet biologically active and must go through **posttranslational processing** before they are functional. Changes that are made in this process include protein folding into the native conformation (assisted by chaperones), protein shortening by proteases, amino acid residue modification (i.e., phosphorylation of seryl hydroxyl groups), attachment of carbohydrate residues, and addition of prosthetic groups. Finished and biologically active proteins play essential roles in the general maintenance, functioning, and structure of the cell.

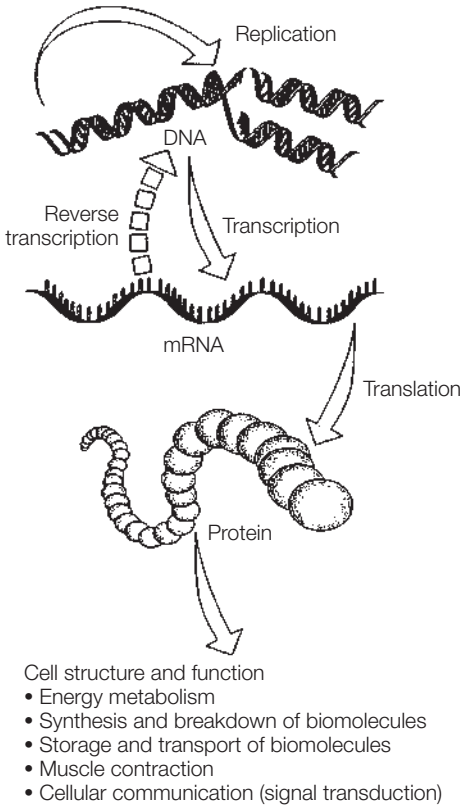

FIGURE 9.7 The storage and replication of biological information in DNA and its transfer via RNA to synthesize proteins that direct and maintain cellular structure and function.

The nucleic acids are among the most complex molecules that you will encounter in your biochemical studies. When the dynamic roles that are played by DNA and RNA in the life of the cell are realized, the complexity is understandable. The discovery of the structures and functions of the nucleic acids will always be considered as some of the most significant breakthroughs in our understanding of the chemistry of life.

This section has provided a brief review of many important concepts in molecular biology. For more details, refer to one of the standard biochemistry textbooks and Web sites listed in the Further Reading section at the end of the chapter.

STUDY EXERCISE 9.1 Complementary Bases in DNA

A short polynucleotide strand of DNA has the following sequence of bases. Write the sequence of the complementary strand.

5′AGCTTACGTCC 3′

STUDY EXERCISE 9.2 Complementary Bases in RNA

A short polynucleotide strand of double-stranded RNA has the following sequence of bases. Write the sequence of the complementary strand of RNA.

5′UAGGUACUUCG 3′

B. LABORATORY METHODS FOR INVESTIGATION OF DNA AND RNA

Isolation of Chromosomal DNA

Because of the large size and the fragile nature of chromosomal DNA, it is difficult to isolate in a completely intact, undamaged form. Several isolation procedures have been developed that provide DNA in a biologically active form, but this does not mean it is completely undamaged. These preparations yield DNA that is stable, of high molecular weight, and relatively free of RNA and proteins. Here a general method will be described for the isolation of chromosomal DNA, in a relatively pure form, from microorganisms.

Designing an isolation procedure for DNA requires extensive knowledge of the chemical stability of DNA, as well as of its condition in the cellular environment. Figures 9.5 and 9.6 illustrate several chemical bonds in DNA that may be susceptible to cleavage during the extraction process. The experimental factors that must be considered and their effects on various structural aspects of intact DNA are outlined below.

1. **pH**
   (a) Hydrogen bonding between the complementary strands is stable between pH 4 and 10.
   (b) The phosphodiester linkages in the DNA backbone are stable between pH 3 and 12.
   (c) *N*-glycosidic bonds to purine bases (adenine and guanine) are hydrolyzed at pH values of 3 and less.
2. **Temperature**
   (a) There is considerable variation in the temperature stability of the hydrogen bonds in the double helix, but most DNA begins to unwind in the range of 80−90°*C*.
   (b) Phosphodiester linkages and *N*-glycosidic bonds are stable up to 100°*C*.
3. **Ionic strength**
   (a) DNA is most stable and soluble in salt solutions. Salt concentrations of less than 0.05 *M* weaken the hydrogen bonding between complementary strands.
4. **Cellular conditions**
   (a) Before the DNA can be released, the cell wall of the organism must be lysed. The ease with which the cell wall is disrupted varies from

organism to organism. In some cases (e.g., yeast), extensive grinding or sonic treatment is required, whereas in others (e.g., *Bacillus subtilis*), enzymatic hydrolysis of the cell wall is possible.

(b) Several enzymes are present in the cell that may act to degrade DNA, but the most serious damage is caused by the deoxyribonucleases. These enzymes catalyze the hydrolysis of phosphodiester linkages.

(c) Native DNA is present in the cell as DNA-protein complexes. Basic proteins called **histones** must be dissociated from the DNA during the extraction process.

5. Mechanical stress on the DNA

(a) Gentle manipulations may not always be possible during the isolation process. Grinding, shaking, stirring, and other disruptive procedures may cause cleavage (shearing or scission) of the DNA chains. This usually does not cause damage to the secondary structure of the DNA, but it does reduce the length of the molecules.

Now that these factors are understood, a general procedure of DNA extraction from bacteria will be outlined.

Step 1. Disruption of the cell wall and release of the DNA into a medium in which it is soluble and protected from degradation The isolation procedure described here calls for the use of an enzyme, lysozyme, to disrupt the cell wall. Lysozyme catalyzes the hydrolysis of glycosidic bonds in cell wall peptidoglycans, thus causing destruction of the cell wall and allowing the release of DNA and other cellular components. The medium for solution of DNA is a buffered saline solution containing EDTA. DNA, which is ionic, is more soluble and stable in salt solution than in distilled water. The EDTA serves at least two purposes. First, it binds divalent metal ions (Ca^{2+}, Mg^{2+}, Mn^{2+}) that could form salts with the anionic phosphate groups of the DNA. Second, it inhibits deoxyribonucleases that have a requirement for Mg^{2+} or Mn^{2+}. The mildly alkaline medium (pH 8) acts to reduce electrostatic interaction between DNA and the basic histones and the polycationic amines, spermine and spermidine. The relatively high pH also tends to diminish nuclease activity and denature other proteins.

Step 2. Dissociation of the protein-DNA complexes Detergents are used at this stage to solubilize the inner membrane and disrupt the ionic interactions between positively charged histones and the negatively charged backbone of DNA. Sodium dodecyl sulfate (SDS), an anionic detergent, binds to proteins and gives them extensive anionic character. A secondary action of SDS is to denature deoxyribonucleases and other proteins. Also favoring dissociation of protein-DNA complexes is the alkaline pH, which reduces the positive character of the histones. To ensure complete dissociation of the DNA-protein complex and to remove bound cationic amines, a high concentration of a salt (NaCl or sodium perchlorate) is added. The salt acts by diminishing the ionic interactions between DNA and cations.

Step 3. Separation of the DNA from other soluble cellular components Before DNA is precipitated, the solution must be deproteinized. This is brought

about by treatment with chloroform–isoamyl alcohol followed by centrifugation. Upon centrifugation, three layers are produced: an upper aqueous phase, a lower organic layer, and a compact band of denatured protein at the interface between the aqueous and organic phases. Chloroform causes surface denaturation of proteins. Isoamyl alcohol reduces foaming and stabilizes the interface between the aqueous phase and the organic phases where the protein collects.

The upper aqueous phase containing nucleic acids is then separated and the DNA precipitated by addition of ethanol. Because of the ionic nature of DNA, it becomes insoluble if the aqueous medium is made less polar by addition of an organic solvent. The DNA forms a threadlike precipitate that can be collected by "spooling" onto a glass rod. The isolated DNA may still be contaminated with protein and RNA. Protein can be removed by dissolving the spooled DNA in saline medium and repeating the chloroform–isoamyl alcohol treatment until no more denatured protein collects at the interface.

RNA does not normally precipitate like DNA, but it could still be a minor contaminant. RNA may be degraded during the procedure by treatment with ribonuclease after the first or second deproteinization step. Removal of RNA sometimes makes it possible to denature more protein using chloroform–isoamyl alcohol. If DNA in a highly purified state is required, several deproteinization and alcohol precipitation steps may be carried out. It is estimated that up to 50% of the cellular DNA is isolated by this procedure. The average yield is 1 to 2 mg per gram of wet packed bacterial cells.

Isolation of Plasmid DNA

Many bacterial cells contain self-replicating, extrachromosomal DNA molecules called **plasmids.** This form of DNA is closed, circular, double-stranded, and much smaller than chromosomal DNA; its molecular weight ranges from 2×10^6 to 20×10^6, which corresponds to between 3000 and 30,000 base pairs. Plasmids are widely used as cloning vehicles in the preparation of recombinant DNA (see Chapter 10, p. 294). Bacterial plasmids normally contain genetic information for the translation of proteins that confer a specialized and sometimes protective characteristic (phenotype) on the organism. Examples of these characteristics include enzyme systems that degrade antibiotics, and enzymes necessary for the production of antibodies and toxins. Plasmids are replicated in the cell by one of two possible modes. **Stringent replicated plasmids** are present in only a few copies and **relaxed replicated plasmids** are present in many copies, sometimes up to 200. Some relaxed plasmids continue to be produced even after the antibiotic chloramphenicol is used to inhibit chromosomal DNA synthesis in the host cell. Under those conditions, many copies of the plasmid DNA may be produced (up to 2000 or 3000), and may compose up to 30 to 40% of the total cellular DNA.

The extensive use of plasmid DNA as a cloning vehicle often requires the isolation and characterization of plasmids. Characterization of plasmids might be necessary for any of the following reasons (see Chapter 10):

1. Construction of new recombinant DNA.
2. Analysis of molecular size by agarose gel electrophoresis.

3. Electrophoretic analysis of restriction enzyme digests and construction of a restriction enzyme map.
4. Sequence analysis of nucleotides by the Sanger or Maxam-Gilbert method.

Several methods for isolating plasmid DNA have been developed; some lead to a more highly purified product than others. All isolation methods have the same objective—separation of plasmid DNA from chromosomal DNA. Plasmid DNA has two major structural differences from chromosomal DNA.

1. Plasmid DNA is almost always extracted in a covalently closed circular form, whereas isolated chromosomal DNA usually consists of sheared linear fragments, and,
2. Plasmid DNA is much smaller than chromosomal DNA.

The structural differences cause physicochemical differences that can be exploited to separate the two types of DNA molecules. Methods for isolating plasmid DNA fall into three major categories:

1. Methods that rely on specific interaction between plasmid DNA and a solid support. Examples are adsorption to nitrocellulose microfilters and hydroxyapatite columns.
2. Methods that cause selective precipitation of chromosomal DNA by various agents. These methods exploit the relative resistance of covalently closed circular DNA to extremes of pH, temperature, or other denaturing agents.
3. Methods based on differences in sedimentation behavior between the two types of DNA. This is the approach of choice if highly purified plasmid DNA is required.

Two widely used isolation procedures based on Method 2 are described here. Both procedures yield plasmid DNA that is sufficiently pure for size analysis by agarose gel electrophoresis and for digestion by restriction enzymes.

Method A: Separation of Plasmid DNA by Boiling (Holmes and Quigley)

The total cellular DNA must first be released by lysis of the bacterial cells. This is brought about by incubation with the enzyme lysozyme in the presence of reagents that inhibit nucleases. Chromosomal DNA is then separated from the plasmid DNA by boiling the lysis mixture for a brief period, followed by centrifugation. In contrast to closed circular plasmid DNA, linear chromosomal DNA becomes irreversibly denatured by heating and forms an insoluble gel, which sediments during centrifugation. Even though plasmid DNA may become partially denatured during boiling, the closed circular helix reforms upon cooling. The boiling serves a second purpose, that of denaturing deoxyribonucleases and other proteins.

Method B: Microscale Isolation of Plasmids by Alkaline Lysis

Often it is necessary to detect and analyze plasmid DNA in a large number of small bacterial samples. One widely used microscale method is the alkaline lysis procedure. For this procedure, host bacterial cells harboring the plasmids are grown in small culture volumes (1–5 mL) or in single colonies on agar plates. The cells are lysed and their contents denatured by alkaline sodium dodecyl sulfate (SDS). Proteins and high-molecular-weight chromosomal DNA denatured under these conditions precipitate as a gel that can be centrifuged from the supernatant, which contains plasmid DNA and bacterial RNA.

Characterization of DNA

Ultraviolet Absorption

A complete understanding of the biochemical functions of DNA requires a clear picture of its structural and physical characteristics. DNA has significant absorption in the UV range because of the presence of the aromatic bases adenine, guanine, cytosine, and thymine. This provides a useful probe into DNA structure because structural changes such as helix unwinding affect the extent of absorption. In addition, absorption measurements are used as an indication of DNA purity. The major absorption band for purified DNA peaks at about 260 nm. Protein material, the primary contaminant in DNA, has a peak absorption at 280 nm. The ratio A_{260}/A_{280} is often used as a relative measure of the nucleic acid/protein content of a DNA sample. The typical A_{260}/A_{280} for isolated DNA is about 1.8. A smaller ratio indicates increased contamination by protein.

Thermal Denaturation

If DNA solutions are treated with denaturing agents (heat, alkali, organic solvents), their ultraviolet-absorbing properties are strikingly increased. Figure 9.8 shows the effect of temperature on the UV absorption of DNA. The curve is obtained by plotting $A_{260(T)}/A_{280(25°)}$ vs. temperature (T). Heating through the

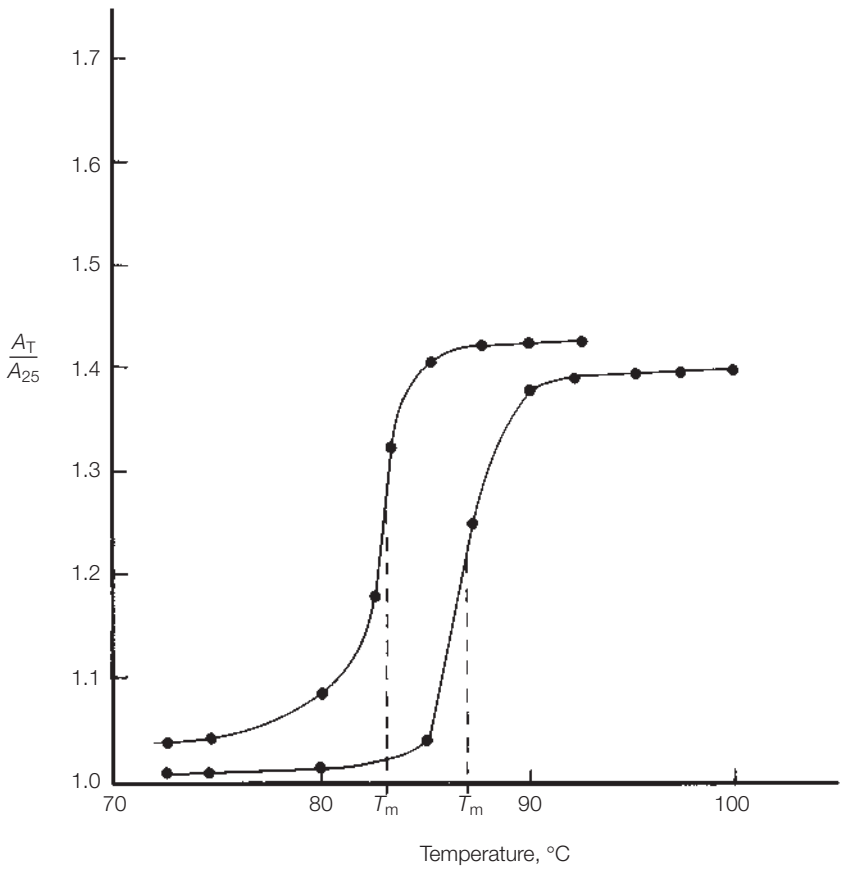

FIGURE 9.8 A typical thermal denaturation curve for DNA. T_m is measured as the midpoint of the absorbance increase.

temperature range of 25°C to about 80°C results in only minor increases in absorption. However, as the temperature is further increased, there is a sudden increase in UV absorption followed by a constant A_{260}. The total increase in absorption is usually on the order of 40% and occurs over a small temperature range. Figure 9.8 is called a **thermal denaturation curve,** a **temperature profile,** or a **melting curve.** The temperature corresponding to the midpoint of each absorption increase is defined as T_m, the **transition temperature** or **melting temperature.** (This should not be confused with melting point, the transformation of a substance from solid to liquid, as was routinely studied in the organic laboratory.) Each species of DNA has a characteristic T_m value that can be used for identification and characterization purposes.

The origin of the absorption increase, called a **hyperchromic effect,** is well understood. The absorption changes are those that result from the transition of an ordered double-helix DNA structure to a denatured state or random, unpaired DNA strands. Native DNA in solution exists in the double helix held together primarily by hydrogen bonding between complementary base pairs on each strand (see Figure 9.6). Hydrophobic and π-π interactions between stacked base pairs also strengthen the double helix. Agents that disrupt these forces (hydrogen bonding, hydrophobic and π-π interactions) cause dissociation or unwinding of the double helix. In a random coil arrangement, base-base interactions are at a minimum; this alters the resonance behavior of the aromatic rings, causing an increase in absorption. The process of DNA dissociation can, therefore, be characterized by monitoring the UV-absorbing properties of DNA under various conditions.

Ethidium Bromide Binding and Fluorescence

Fluorescence assays are considered to be among the most convenient, sensitive, and versatile of all laboratory techniques (Chapter 7, p. 220). However, the purine and pyrimidines of the nucleic acids yield only weak fluorescence spectra. The fluorescence of the dye, ethidium bromide, is enhanced about 25-fold when it interacts with DNA. Ethidium bromide, which is a relatively small planar molecule (Figure 9.9), binds to DNA by insertion between stacked base pairs (intercalation). The process of intercalation is especially significant for aromatic dyes, antibiotics, and other drugs. Some dyes, when intercalated into DNA, show enhanced fluorescence that can be used to detect DNA molecules after gel electrophoresis measurements (Chapter 6, Section C, p. 191).

The concentration of RNA and DNA solutions may be determined using ethidium bromide binding. The spectrophotometric assay for DNA/RNA (Chapter 3, p. 71) measures both double-stranded and single-stranded DNA because it measures the UV absorption by purine and pyrimidine bases. Ethidium

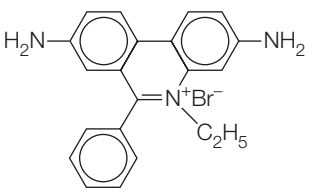

FIGURE 9.9
Structure of the fluorescent intercalation dye ethidium bromide.

bromide interaction with single-stranded DNA does not lead to increased fluorescence, so duplex DNA can be quantified in the presence of dissociated DNA. Solutions of purified DNA are commonly contaminated with RNA. Because single-stranded RNA can form hairpin loops with base pairing and duplex formation (as in tRNA), ethidium bromide also binds with enhanced fluorescence to these duplex regions of RNA. Addition of ribonuclease A results in digestion of RNA and loss of fluorescence due to ethidium binding of RNA. The amount of fluorescence lost is proportional to the concentration of RNA. The ethidium fluorescence remaining after ribonuclease treatment is directly proportional to the concentration of duplex DNA.

$$F(\text{total}) = F(\text{DNA}) + F(\text{RNA})$$

where

F = fluorescence yield due to each type of nucleic acid

When the F (RNA) term is reduced to zero, the total fluorescence is a direct measurement of concentration of double-stranded DNA. The actual concentration of DNA in solution can be calculated by using a standard solution of DNA or from a standard curve.

STUDY EXERCISE 9.3 Ethidium Bromide-Fluorescence Assay for DNA

Solution A of DNA (unknown concentration) is known to contain double-stranded DNA, damaged single-stranded DNA, and RNA. The ethidium bromide fluorescence assay was done on the solution, and the following data were collected. The fluorescence intensity values (F) were obtained on an instrument with a standardized scale of 0–100.

F of solution A = 87

F after treatment of A with ribonuclease = 80

F of a standard solution of double-stranded DNA (10 μg/mL) = 100

What is the concentration of double-stranded DNA in solution A in μg/mL?

Solution:

We begin by making several assumptions. The total fluorescence of solution A is due to double-stranded DNA and some contaminating RNA. Single-stranded DNA and RNA do not bind ethidium bromide. The concentration of double-stranded DNA is directly proportional to the fluorescence reading. The fluorescence intensity due to double-stranded DNA is 80. To calculate the concentration of double-stranded DNA in solution A, compare the fluorescence intensity (80) with that obtained for the standard DNA solution:

$$[\text{DNA-A}]/80 = [10\ \mu\text{g/mL}]/100$$

$$[\text{DNA-A}] = 8\ \mu\text{g/mL}$$

Caution

Ethidium bromide must be used with great care, as it is a potent mutagen. Gloves should be worn at all times while handling solutions of the dye. When finished with experiments, used and excess solutions of the dye must be disposed of as directed by your instructor or laboratory director.

Agarose Gel Electrophoresis

Several techniques for the characterization of nucleic acids have been introduced in this chapter, but the standard method for separation and analysis of plasmids and other smaller DNA molecules is agarose gel electrophoresis (Chapter 6, Section B, p.177). This method has several advantages, including ease of operation, sensitive staining procedures, high resolution, and the ability to analyze a wide range of molecular weights ($0.6 - 100 \times 10^6$). As discussed in Chapter 6, the mobility of nucleic acids in agarose gels is influenced by the agarose concentrations, the molecular size of the DNA, and the molecular shape of the DNA. In general, the lower the agarose concentration in the gels, the larger the DNA that can be analyzed. A practical lower limit of agarose concentration is reached at 0.3% agarose, below which gels become too fragile for ordinary use. This lower limit of agarose in the gels allows for analysis of linear double-stranded DNA within the range of 5 and 60 kilobase pairs (up to 150×10^6 in molecular weight). Gels with an agarose concentration of 0.8% can separate DNA in the range of 0.5–10 kilobase pairs, and 2% agarose gels are used to separate smaller DNA fragments (0.1–3 kilobase pairs).

Nucleic acids migrate in an agarose medium at a rate that is inversely proportional to their size (kilobase pairs or molecular weight). In fact, a near-linear relationship exists between mobility and the logarithm of kilobase pairs (or molecular weight) of a DNA fragment. A standard curve may be prepared by including on the gel a sample containing DNA fragments of known molecular weights (see Figure 9.10). Several types of molecular-weight ladders are commercially available to mark and help estimate the sizes and concentrations of unknown nucleic acids.

Agarose gel electrophoresis is an ideal technique for analysis of DNA fragments. In addition to the positive characteristics discussed previously, the technique is simple, rapid, and relatively inexpensive. Fragments that differ in molecular weight by as little as 1% can be resolved on agarose gels, and as little as 1 ng of DNA can be detected on a gel. Nucleic acids are visualized after electrophoresis by treatment with ethidium bromide or one of the less toxic SYBR and GelRed dyes mentioned in Chapter 6, p. 190.

Sequencing DNA Molecules

When it was determined that genetic information in DNA is coded in the form of nucleotide base sequence, the direction of research turned to the design of experimental procedures for determining the base order. Early sequence studies used the inefficient, insensitive, and labor-intensive methods of acid-, base-, and nuclease-catalyzed hydrolysis of DNA and analysis of fragments by electrophoresis.

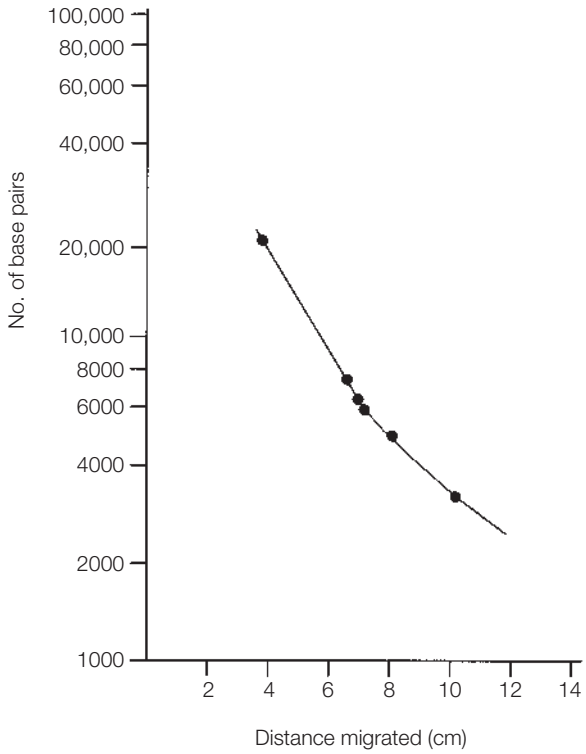

FIGURE 9.10 Standard curve obtained by electrophoresis of λ phage DNA fragments from EcoR1 cleavage.

Two sequencing methods that are both simple and inexpensive are now widely used:

1. The **Maxam-Gilbert chemical cleavage method** (also called the chemical degradation method) uses chemical modification of bases, which promotes cleavage at selected phosphodiester linkages. Cleavage products, which have one common end and vary in length, are analyzed by PAGE.
2. The **Sanger chain-terminating method** (also called the dideoxy method) uses the enzyme DNA polymerase, coupled with the presence of all four nucleoside triphosphates and one of the 2′, 3′-dideoxynucleoside triphosphates, to synthesize a DNA chain complementary to an added template. Replication stops when a dideoxynucleotide is in place on the new chain. Fragments of different lengths are produced and analyzed by PAGE.

In both sequencing methods, electrophoretic procedures are capable of separating nucleic acid fragments that differ in size by only one nucleotide. Detection of the fragments is done with chemiluminescent-labeling or ^{32}P-labeling of deoxynucleoside triphosphates (see Figure 6.16, p. 192).

Sequencing procedures that are automated and computer-controlled have now made possible the sequencing of entire genomes (Table 9.4). The first

TABLE 9.4 Sequenced Genomes

Organism	Genome Size (Kilobase Pairs)	Number of Chromosomes
Borrelia burgdorferi (carrier of Lyme disease)	1444	1
Haemophilus influenzae (human pathogenic bacterium)	1830	1
Mycobacterium tuberculosis (cause of tuberculosis)	4412	1
Escherichia coli (bacterium)	4639	1
Saccharomyces cerevisiae (yeast)	11,700	17*
Drosophila melanogaster (fruit fly)	137,000	4*
Oryza sativa (rice)	430,000	12
Homo sapiens (human)	3,200,000	23*

*in haploid chromosomes

complete genome of a free-living organism, the prokaryote *Haemophilus influenzae*, was published in 1995. This genome contains 1,830,137 bases and 1740 genes. Complete sequencing of the human genome was announced in 2001. The human genome contains over 3.2 billion base pairs and about 20,000–25,000 genes.

Genomic sequences are now made available in repositories on the Internet. Three primary resources, combined in the International Nucleotide Sequence Database Collaboration, are listed in Table 9.5. Database resources for genome projects are also listed in Table 9.5 and in Appendix I. Readers may practice using the databases by working Study Problem 12.

Isolation and Characterization of RNA

The methods used for the isolation of RNA are similar to those described for DNA at the beginning of this chapter, Section B. However, some procedural changes must be made in the purification of RNA because of the presence of

TABLE 9.5

Organization	Web site
The International Nucleotide Sequence Database Collaboration	
1. Genbank of the National Center for Biotechnology Information	http://www.ncbi.nlm.nih.gov/Genbank
2. EMBL (European Molecular Biology Laboratory)	http://www.ebi.ac.uk
3. DDBJ (DNA Data Bank of Japan)	http://www.ddbj.nig.ac.jp
Genome Project Databases	
1. dbEST (cDNA and partial sequences)	http://www.ncbi.nih.gov
2. Genethon (genetic maps based on repeat markers)	http://www.genethon.fr
3.The Broad Institute of MIT and Harvard University (Genomics)	http://www.broadinstitute.org

heterogeneous populations of molecules and the extra susceptibility to cleavage of the phosphodiester bonds in RNA. Here are some general comments on laboratory methods for the isolation and characterization of RNA:

- RNA molecules are naturally shorter than DNA. This makes RNA less susceptible to physical shearing, so more vigorous conditions may be used for cell lysis.
- The phosphodiester bonds in DNA are stable in the pH range of 3–12; however, the presence of the 2′-OH groups in RNA makes it especially susceptible to base- and enzyme-catalyzed (RNase) cleavage. Special precautions must be taken to avoid chemical agents that degrade RNA, and chemicals must be added to isolation buffers that destroy endogenous proteins that act as nucleases. The addition of chelating agents like EDTA and citrate ties up metal ions that are essential for RNase activity. Strong detergents may be added to denature proteins, especially nucleases. The chemical reagent guanidinium thiocyanate is a useful addition, as it acts as an RNase inhibitor and protein denaturant.
- It is essential for lab workers to wear plastic gloves to avoid transfer of nucleases from bare skin.
- Gradient centrifugation procedures as described in Chapter 4 may be used to isolate, purify, and characterize all types of RNA.
- Isolated RNA samples may be analyzed for purity by agarose gel electrophoresis procedures similar to those for DNA.
- Specific types of RNA may be isolated and purified using affinity chromatography. For example, eukaryotic mRNAs, which make up only about 2–5% of cellular RNA, have a poly (A) segment at their 3′ ends. This RNA may be purified using an affinity matrix consisting of poly (T) or poly (U) on agarose or cellulose gels (see Chapter 5, Section G, p. 152).

STUDY EXERCISE 9.4

Use PubMed or another computer search method to find new methods for isolation of RNA.

Study Problems

1. During the isolation of DNA, the solution becomes more viscous after treatment with lysozyme and SDS. Explain why.
2. How can RNA be removed from a DNA preparation?
3. Explain the action of SDS in disrupting the cell membrane in the extraction procedure of DNA.
4. A solution of purified DNA gave an absorbance of 0.55 at a wavelength of 260 nm. The absorbance was measured in a quartz cuvette with a path length of 1 cm. What is the concentration of DNA? (See Chapter 3, Section C, p. 71).
5. The concentration of a purified DNA solution is 35 μg/mL. Predict the absorbance of the solution at 260 nm.
6. Why is bromophenol blue dye added to a gel-loading buffer before electrophoresis?

7. What assumptions must be made about the relative mobility of bromophenol blue dye and DNA fragments during electrophoresis?
8. What is the purpose of the ethanol precipitation step in the preparation of plasmids?
9. Predict and explain the effect of each of the following conditions on the T_m of native DNA. Will the T_m be raised or lowered relative to the DNA in Tris-HCl buffer, pH 7.5?
   (a) Measure T_m in pH 12 buffer.
   (b) Measure T_m in distilled water.
   (c) Measure T_m in 50% methanol water.
   (d) Measure T_m in standard Tris-HCl, pH 7.5 buffer solution containing SDS.
10. The polyamines 1,4-diaminobutane, 1,5-diaminopentane, spermine, and spermidine are metabolic products found in many cells. Although the specific function of these compounds has not been determined, they are known to bind to the nucleic acids. Describe how you would combine the ethidium bromide fluorescence assay described in this chapter with ligand binding plots defined in Chapter 8, Section A, to characterize the binding of the polyamines to DNA or RNA. Hint: The polyamines are found to bind to some of the same sites on the nucleic acids as does ethidium bromide.
11. A solution of purified RNA gave an absorbance of 0.75 at 260 nm. The absorbance was measured in a quartz cuvette with path length of 1 cm. What is the concentration of RNA in the solution?
12. Use one of the DNA sequence databases in Table 9.5 to obtain the DNA sequence of:
   (a) Cytosolic *t*RNA-phenylalanine from yeast (Saccharomyces cerevisiae)
   (b) human insulin

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Restriction map of pBR322 in circular and linear format. Designed by CGC Scientific, a provider of software tools for biologists.

http://www.fermentas.com
Click on "conventional restriction endonucleases" for a listing of enzymes.
Click on individual enzymes for specific data including cleavage site and reaction conditions.

http://biowww.net
Molecular Cell Biology Protocol Troubleshooting.

http://learn.genetics.utah.edu/content/labs/extraction
DNA Extraction Virtual Lab, "How to Extract DNA from Anything Living."

http://www.intute.ac.uk/biologicalsciences
Helping you find the best Web sites for study and research.

http://www.genome.ou.edu/protocol_book/protocol_index.html
Protocols for recombinant DNA isolation, cloning and sequencing.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

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CHAPTER 10

MOLECULAR BIOLOGY II: RECOMBINANT DNA, MOLECULAR CLONING, AND ENZYMOLOGY

A. Recombinant DNA Biotechnology 290
B. Important Enzymes in Molecular Biology and Biotechnology 297
C. Nucleic Acid Blotting 304

Study Problems 304
Further Reading 305

Investigation of the nucleic acids during the first three quarters of the 20th century led to the significant discovery that all of the cell's attributes and activities have their origin in DNA. For example, we now believe that the information needed to make all the proteins in a cell and organism resides in DNA. This discovery prompted biochemists and molecular biologists to develop laboratory procedures for the manipulation of DNA, because it was suspected that changes to DNA could lead to molecular and genetic changes in cells and organisms. A culmination of this research activity was the recent announcement of the sequence of the human genome (Human Genome Project, 2001). Medical scientists are now applying the newly developed lab and clinical procedures to the area of gene therapy, where, dysfunctional genes that lead to disease are replaced with functional genes that produce viable proteins.

In this chapter, we will discuss some experimental procedures that have moved us to the point where the nucleic acids, especially DNA, are now among the easiest biomolecules to work with. Some of the concepts we will encounter include **molecular cloning, recombinant DNA, restriction enzymes, nucleic acid blotting,** and the **polymerase chain reaction.**

A. RECOMBINANT DNA BIOTECHNOLOGY

Students often perceive biochemistry as a very research-oriented discipline. It is easy to see how this idea can develop, because every day students listen to their instructors talk about research activities, attend research seminars, and watch their professors at work on basic research in the laboratory. Students may even participate in their own research projects. Biochemistry is very dependent on research activities that are basic and theoretical, but biochemistry has always had a very "practical" or "applied" side. Many of the early biochemical activities were encouraged and funded by companies involved in fermentation of beer and wine, baking, nutrition, and pharmaceuticals. We often refer to this practical side of biochemistry as **biotechnology,** which is defined as "the practical use of biological cells, biomolecules, and biological processes." We see many examples of the daily use of applied biochemistry:

1. Using enzymes to catalyze reactions in the industrial production of specialty chemicals.
2. The use of gene-replacement therapy to treat individuals with diseases caused by dysfunctional genes.
3. Identification of biological specimens at crime scenes.
4. Using bacterial cells to produce large quantities of proteins for medical or industrial use.
5. Using bacteria to clean up chemical waste sites.

Today, one of the most active areas of biotechnology, and also the most controversial, is the preparation of **recombinant DNA** for use in molecular cloning. This activity has bioethical considerations because it has the power to change the genetic characteristics of fundamental life forms, including humans.

Molecular Cloning

Our knowledge of DNA structure and function has increased at a gradual pace over the past 50 years, but some discoveries have had a special impact on the progress and direction of DNA research. Although DNA was first discovered in cell nuclei in 1869, it was not confirmed as the carrier of genetic information until 1944. This major discovery was closely followed by the announcement of the double-helix structure of DNA in 1953. The more recent development of technology that allows for genetic manipulation by inserting "foreign" DNA fragments into an organism's natural, replicating DNA may well have a greater impact on the direction of DNA research than the earlier discoveries. In the short time since the first construction and replication of plasmid recombinant DNA, several scientific and medical applications of the new technology have been announced. This new era of genetic engineering has captivated the general public and scientists alike. Some of the predicted achievements in recombinant DNA research have been slow in coming; however, future workers in biochemistry and related fields will continue to see advances in the use of recombinant DNA and molecular cloning (genetic engineering).

Recombinant DNA or **molecular cloning** consists of the covalent insertion of DNA fragments from one type of cell or organism into the replicating DNA of

another type of cell. Many copies of the hybrid DNA may be produced by the progeny of the recipient cells; hence, the DNA molecule is **cloned.** If the inserted fragment contains a functional gene carrying the code for a specific protein, many copies of that gene and translated protein may be produced in the host cell. This process has become important for the large-scale production of proteins (insulin, somatostatin, bovine growth hormone, and other molecules) that are of value in medicine and basic science, but are difficult and expensive to obtain by other methods (see Chapter 11, Section B and Table 11.3, p. 317).

Our current knowledge of recombinant DNA is the result of several recent biotechnological advances. The first major breakthrough was the isolation of mutant strains of *E. coli* that are not able to degrade or restrict foreign DNA. These strains are now used as host organisms for the replication of recombinant DNA. The second advance was the development of bacterial extrachromosomal DNA **(plasmids)** and bacteriophage DNA as cloning vehicles to carry the DNA to be cloned into host cells. The final, necessary advance was the development of methods for inserting the foreign DNA into the natural vehicle. Manipulation of DNA was greatly aided by the discovery of **restriction endonucleases,** enzymes that catalyze the hydrolysis of phosphodiester bonds at selected sites in DNA (for details, see this chapter, Section B). The enzymes recognize specific base sequences (usually 4–8 bases) and catalyze hydrolytic cleavage of both DNA strands in or near the base sequence region (Reaction 10.1):

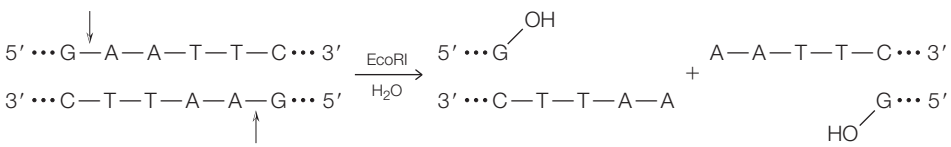

(Reaction 10.1)

The cleavage leads to one of two types of ends in the DNA (Figure 10.1):

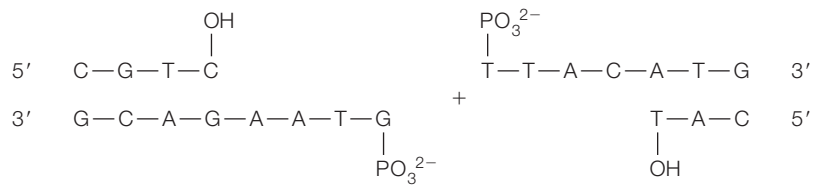

A Cohesive ends

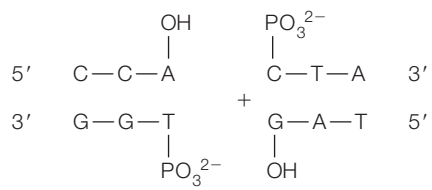

B Blunt ends

FIGURE 10.1 Results of the cleavage of DNA by a restriction endonuclease. Two types of ends after DNA cleavage: **A** Cohesive ends may remain weakly associated by hydrogen bonds between complementary bases. **B** Blunt ends do not overlap.

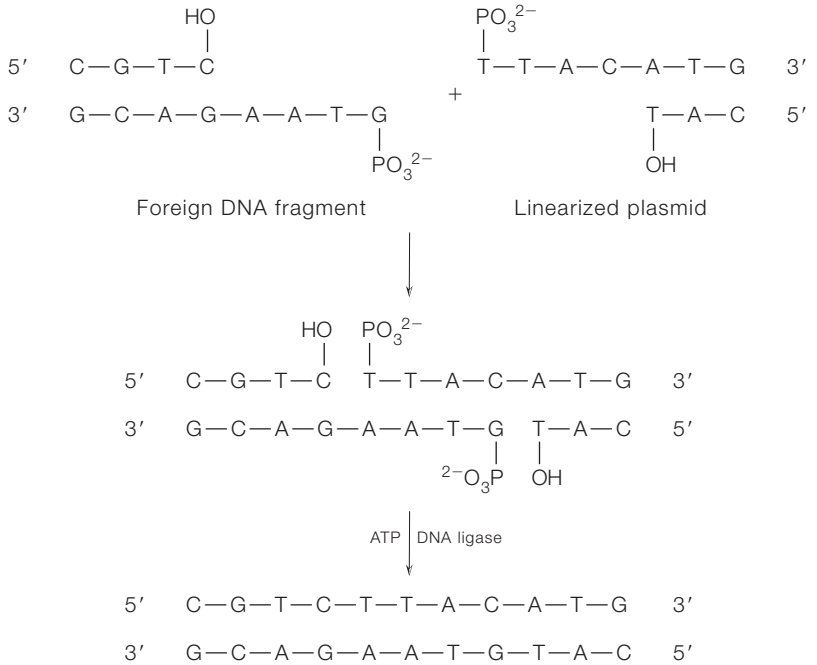

FIGURE 10.2
Insertion of a DNA fragment into a linearized plasmid using DNA ligase. DNA ligase catalyzes the formation of phosphodiester bonds.

1. ***Cohesive (or sticky) ends,*** where a few bases can remain weakly associated by hydrogen bonding, or
2. ***Blunt ends*** that do not overlap.

Restriction enzymes provide a gentle and specific method for opening (linearizing) circular vectors at predetermined sites, and for preparing fragments of DNA to be cloned.

Methods for covalent joining of the foreign DNA fragment to the vector ends and closure of the circular hybrid plasmid were then developed. The enzyme, DNA ligase, which can catalyze the ATP-dependent formation of phosphodiester linkages at the insertion sites, is used for final closure (Figure 10.2).

Steps for Preparing Recombinant DNA

The basic steps involved in performing a recombinant DNA experiment are listed below and are outlined in Figure 10.3:

1. ***Select and prepare a DNA fragment (X) that is to be incorporated into a host cell, where it will be replicated and translated into a protein product.*** Often the DNA fragment is a specific gene that carries the information for synthesis of a particular protein or proteins. As shown in Figure 10.3, the foreign DNA to be cloned may be prepared by chemical synthesis (usually by the polymerase chain reaction and sequence-specific primers; see Section B of this chapter), action of restriction endonucleases, or transcription of mRNA catalyzed by reverse transcriptase.
2. ***Choose a vector or vehicle to carry X, the DNA fragment, into the host cell.*** The vector may be plasmid DNA, DNA from a phage, or yeast artificial

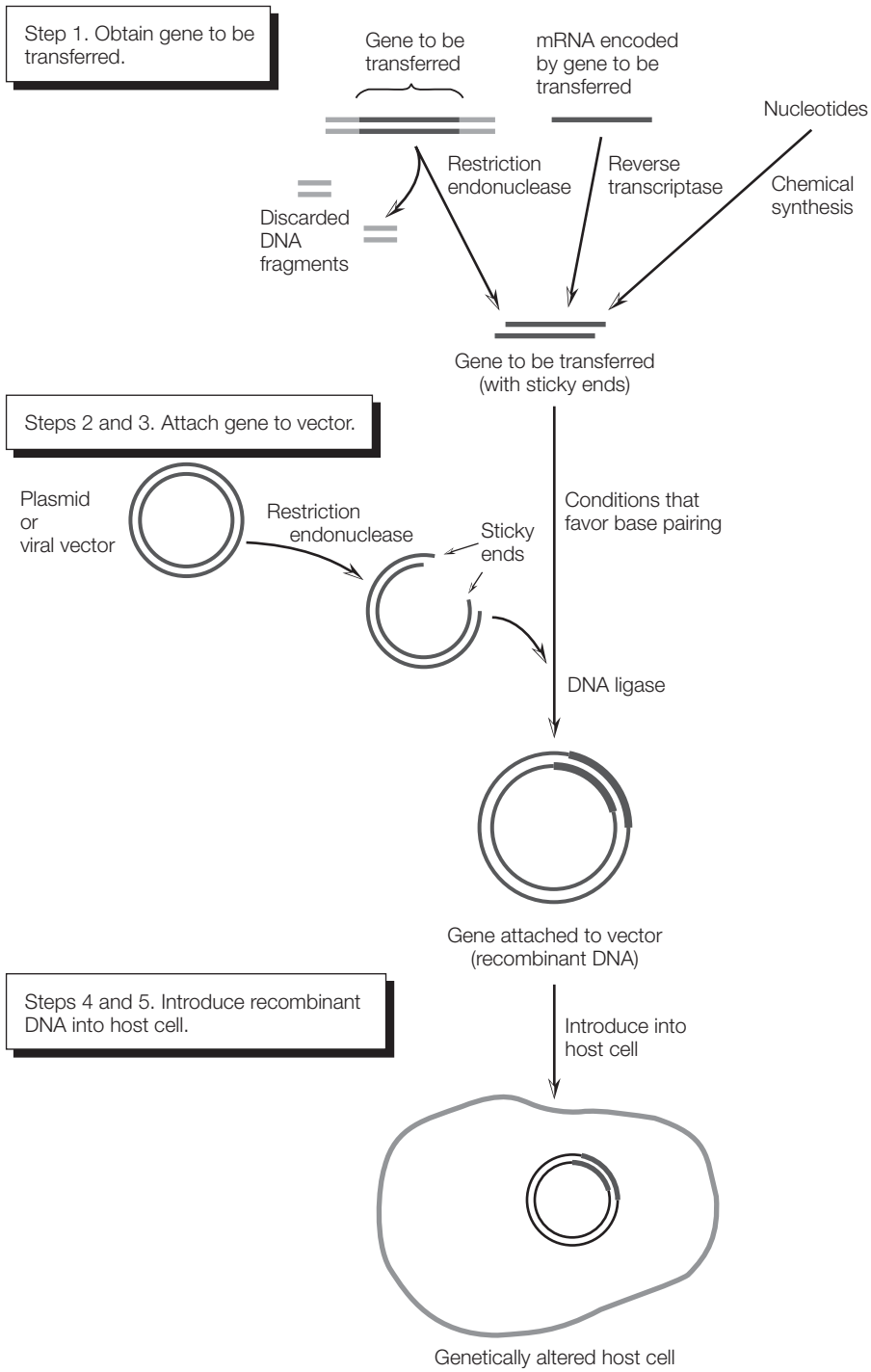

FIGURE 10.3
Outline of a typical experimental procedure for constructing recombinant DNA.

chromosomes. If a circular vector is used (i.e., a plasmid), it must be linearized (broken open) in order to accept X. Ideally, the same restriction enzyme should be used to prepare X and the vehicle so that there is the possibility of overlapping cohesive ends.

3. ***Insert the DNA fragment, X, into the vector by overlapping cohesive ends or by modifying blunt ends using homopolymer tails.*** The final covalent bonds to hold X into the vector are formed by the action of **DNA ligase.** This enzyme catalyzes the ATP-dependent formation of phosphodiester bonds (Figure 10.2). The final product represents a recombinant or hybrid DNA.
4. ***Introduce the hybrid DNA into a host organism (usually a bacterial cell), where it can be replicated.*** This process is called **transformation.** It has been demonstrated that incorporation of a hybrid plasmid or phage DNA into host *E. coli* cells is enhanced by the addition of calcium ions (Ca^{2+}).
5. ***Develop a method for identifying and screening for host cells that have accepted and are replicating the hybrid DNA.*** This is usually accomplished by screening for antibiotic resistance (Figure 10.4).

Cloning Vectors

Several types of cloning vectors are commonly used today. Some of the most effective ones include plasmids and bacteriophage DNA for prokaryotic cells, and yeast artificial chromosomes and baculovirus for eukaryotic cells.

Plasmids

Many bacterial cells contain self-replicating, extrachromosomal DNA molecules called **plasmids.** This form of DNA is closed circular, double-stranded, and much smaller than chromosomal DNA; their molecular weights range from 2×10^6 to 20×10^6, which corresponds to between 3000 and 30,000 base pairs. Bacterial plasmids normally contain genetic information for the translation of proteins that confer a specialized and sometimes protective characteristic (phenotype) on the organism. Examples of these characteristics are enzyme systems necessary for the production of antibiotics, enzymes that degrade antibiotics, and enzymes for production of toxins. Plasmids are replicated in the cell by one of two possible modes. **Stringent replicated** plasmids are present in only a few copies, and **relaxed replicated** plasmids are present in many copies, sometimes up to 200. In addition, some relaxed plasmids continue to be produced even after the antibiotic chloramphenicol is used to inhibit chromosomal DNA synthesis in the host cell. Under these conditions, many copies of the plasmid DNA may be produced (up to 2000 or 3000) and may accumulate to 30% to 40% of the total cellular DNA.

The ideal plasmid cloning vector has the following properties:

1. The plasmid should replicate in a relaxed fashion so that many copies are produced.
2. The plasmid should be small; then it is easier to separate from the larger chromosomal DNA, easier to handle without physical damage, and probably contains very few sites for attack by restriction endonucleases.
3. The plasmid should contain identifiable markers so that it is possible to screen progeny for the presence of the plasmid. At least two selective markers are

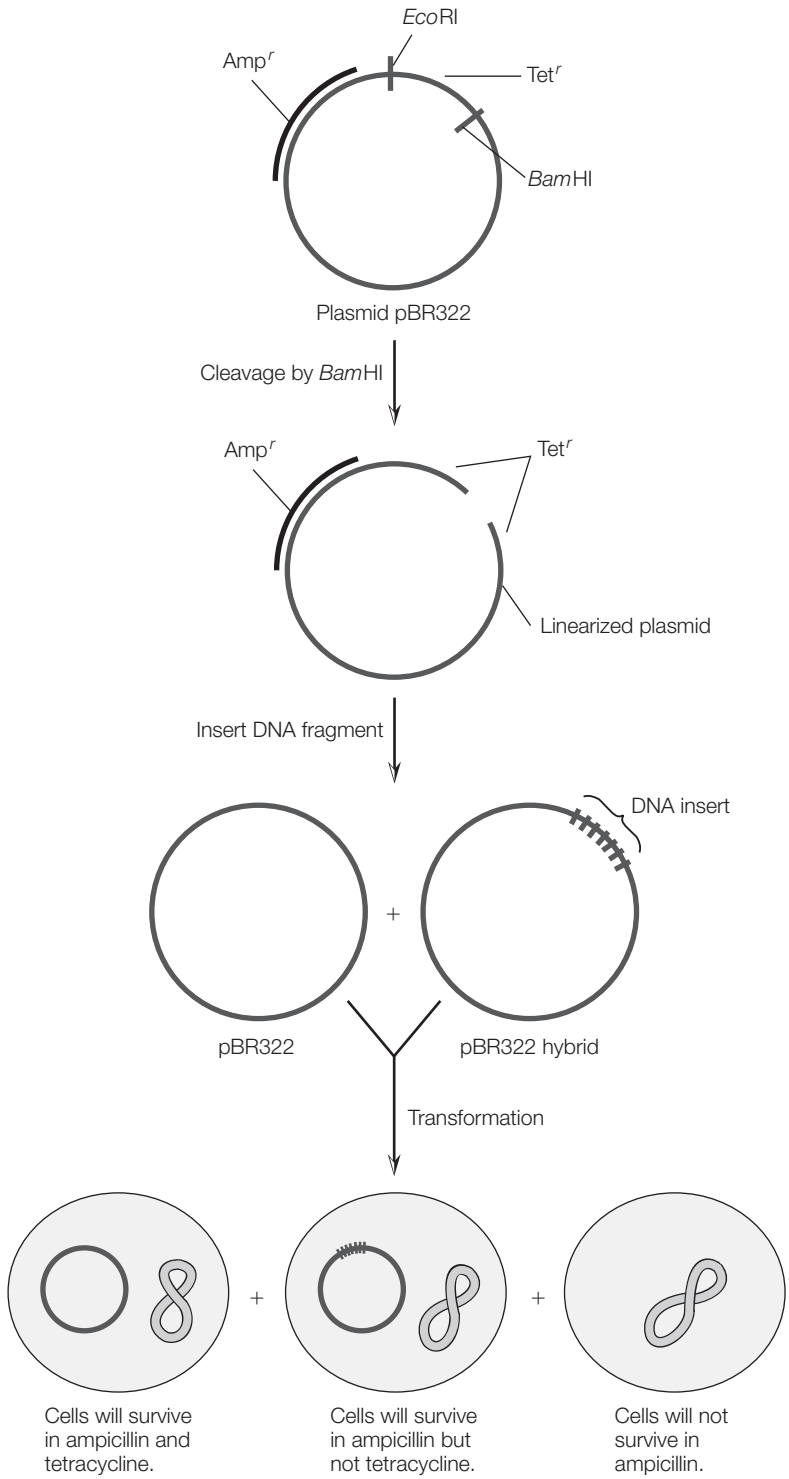

FIGURE 10.4
Procedure for selecting bacterial cells that contain hybrid DNA.

desirable, a primary one to confirm the presence of the plasmid, and a secondary one to confirm the insertion of foreign DNA. Resistance to antibiotics is a convenient type of marker.

4. The plasmid should have only one cleavage site for a specific restriction endonuclease. This provides only two "ends" to which the foreign DNA can be attached. Ideally, the single restriction site should be within a gene, so that insertion of the foreign DNA will inactivate the gene (called insertional marker inactivation).

E. coli Plasmids

Among the most widely used *E. coli* plasmids are derivatives of the replicon **plasmid ColE1.** This plasmid carries a resistance gene against the antibiotic colicin E. The plasmid is under relaxed control, and up to 3000 copies may be produced when the proper *E. coli* strain is grown in the presence of chloramphenicol. One especially useful derivative plasmid of ColE1 is pBR322. It has all the properties previously outlined; in addition, its nucleotide sequence of 4363 base pairs is known, and it contains several different restriction endonuclease cleavage sites where foreign DNA can be inserted. For example, pBR322 has a single restriction site for the restriction enzyme *Eco*RI. *In vitro* insertion of a foreign DNA fragment into the *Eco*RI cleavage site and incorporation into a host cell (transformation) lead to immunity of the host cell to colicin E1, but the cell is unable to produce colicin.

Useful modifications of the pBR322 plasmid are the **pUC plasmids** (developed at The University of California). The pUC plasmids have a resistance gene for tetracycline, and sites for restriction endonuclease cleavage are concentrated in a region called the **multiple cloning site.**

Strains of *E. coli* are most often used as host cells because they are easy to grow and maintain. The rate of growth is exponential and can be monitored by measuring the absorbance of a culture sample at 600 nm. One absorbance unit corresponds to a cell density of approximately 8×10^8 cells/mL. Some *E. coli* strains that harbor the ColE1 plasmids are RR1, HB101, GM48, 294, SK1592, JC411Thy/ColE1, and CR34/ColE1. The typical procedure for growth and amplification of plasmids is, first, to establish the cells in normal medium for several hours. An aliquot of this culture is then used to inoculate medium containing the appropriate antibiotic. After overnight growth, a new portion of medium containing the antibiotic is inoculated with an aliquot of overnight culture. After the culture has been firmly established, a solution of chloramphenicol is added to inhibit chromosomal DNA synthesis. The ColE1 plasmids continue to replicate. The culture is then incubated for 12 to 18 hours and harvested by centrifugation.

Other Cloning Vectors

Another useful and widely used cloning vector is the DNA from **bacteriophage λ.** The DNA from λ phage is a double-stranded molecule with about 50,000 base pairs. It has many advantages as a cloning vector for prokaryotic proteins:

1. Many copies of recombinant phage DNA may be replicated in a host cell.
2. The recombinant phage DNA may be packaged as a viral particle for infecting the host bacteria.

3. Because λ phage DNA is larger than plasmid DNA, it is possible to insert larger fragments of DNA that include smaller fragments of eukaryotic DNA. The inserted DNA may be as large as 25,000 base pairs.

The insertion of larger DNA, including eukaryotic DNA that may contain over a million base pairs, is more efficiently done with **yeast artificial chromosomes (YACs)** or the **baculovirus expression vector system (BEVS).** YACs containing DNA inserts of 100,000 to 1,000,000 base pairs may be prepared for cloning. The baculoviruses are double-stranded DNA viruses that have as their natural hosts different insect species. They are not known to infect vertebrate hosts. The BEVS may be used to express complex proteins that require special processes like proteolytic cleavage, intron splicing, chemical modifications (phosphorylation or glycosylation of hydroxyl group), formation of disulfide bonds, and proper protein folding.

STUDY EXERCISE 10.1 Cloning Vectors

Use PubMed or a similar computer search to look for new cloning vectors that have been developed since publication of this book.

B. IMPORTANT ENZYMES IN MOLECULAR BIOLOGY AND BIOTECHNOLOGY

The Restriction Endonucleases

Bacterial cells produce many enzymes that act to degrade various forms of DNA. Of special interest are the **restriction endonucleases,** or restriction enzymes, that recognize specific base sequences in double-stranded DNA and catalyze hydrolytic cleavage of the two strands in or near that specific region. The biological function of these enzymes is to degrade or restrict foreign DNA molecules. Host DNA is protected from hydrolysis because some bases near the cleavage sites are methylated. The action of the restriction enzyme *Eco*RI is shown in Reaction 10.1.

The site of action of *Eco*RI is a specific hexanucleotide sequence. Two phosphodiester bonds are hydrolyzed (see arrows), resulting in fragmentation of both strands. Note the twofold rotational symmetry feature at the recognition site and the formation of cohesive ends. The weak base pairing between the cohesive ends is not sufficient to hold the two fragments together.

At the present time, more than 3500 restriction enzymes have been isolated and characterized. Nomenclature for the enzymes consists of a three-letter italicized abbreviation representing the source (*Eco* = *E. coli*), a letter representing the strain (R), and a Roman numeral designating the order of discovery. *Eco*RI is the first to be isolated from *E. coli* (strain R) and characterized. Table 10.1 lists several other restriction enzymes, their recognition sequence for cleavage, and optimum reaction conditions. A useful Web site for the restriction enzymes is REBASE: http://rebase.neb.com.

TABLE 10.1 Specificity and Optimal Conditions for Several Restriction Endonucleases

Name	Recognition Sequence 5′ … … … 3′	*T* (°C)	pH	Tris (m*M*)	NaCl (m*M*)	$MgCl_2$ (m*M*)	DTT[2] (m*M*)
*Aat*II	G — A — C — G — T ↓ — C	37	7.9	20	50	10	10
*Alu*I	A — G ↓ — C — T	37	7.5	10	50	10	10
*Bal*I	T — G — G ↓ — C — C — A	37	7.9	6	–	6	6
*Bam*HI	G ↓ — G — A — T — C — C	37	8.0	20	100	0.7	1
*Bcl*I	T ↓ — G — A — T — C — A	60	7.5	10	50	10	1
*Eco*RI	G ↓ — A — A — T — T — C	37	7.5	10	100	10	1
*Hae*II	Pu[1] — G — C — G — C ↓ — Py[1]	37	7.5	10	50	10	10
*Hind*III	A ↓ — A — G — C — T — T	37–55	7.5	10	60	10	1
*Hpa*I	G — T — T ↓ — A — A — C	37	7.5	10	50	10	1
*Mse*I	T ↓ — T — A — A	37	7.9	10	50	10	1
*Not*I	G — C ↓ — G — G — C — C — G — C	37	7.9	10	150	10	–
*Sal*I	G ↓ — T — C — G — A — C	37	8.0	10	150	10	1
*Sca*I	A — G — T ↓ — A — C — T	37	7.4	10	100	10	1
*Taq*I	T ↓ — C — G — A	65	8.4	10	100	10	10

[1]Pu = *a purine base;* Py = *a pyrimidine base.*
[2]DTT = *dithiothreitol.*

Applications of Restriction Enzymes

Restriction enzymes are used extensively in nucleic acid chemistry. They may be used to cleave large DNA molecules into smaller fragments that are more amenable to analysis. For example, λ phage DNA, a linear, double-stranded molecule of 48,502 base pairs (molecular weight 31×10^6), is cleaved into six fragments by *Eco*RI or into more than 50 fragments by *Hinf* I (*Haemophilus influenzae*, serotype f). The base sequence recognized by a restriction enzyme is likely to occur only a very few times in any particular DNA molecule; therefore, the smaller the DNA molecule, the fewer the number of specific sites. The λ phage DNA is cleaved into 0 to 50 or more fragments, depending on the restriction enzyme used, whereas larger bacterial or animal DNA will most likely have many recognition sites and be cleaved into hundreds of fragments. Smaller DNA molecules, therefore, have a much greater chance of producing a unique set of fragments with a particular restriction enzyme. It is unlikely that this set of fragments will be the same for any two different DNA molecules, so the fragmentation pattern is unique and can be considered a "fingerprint" of the DNA substrate. The fragments are readily separated and sized by agarose gel electrophoresis.

Restriction endonucleases are also valuable tools in the construction of hybrid DNA molecules. Several restriction enzymes act on bacterial plasmid vehicles that have only a single site of cleavage. This linearizes the circular plasmid and allows for the insertion of a foreign DNA fragment. For example, the

popular plasmid vehicle pBR322 has a single restriction site for *Bam*HI (*Bacillus amyloliquefaciens*, H) that is within the tetracycline resistance gene. The enzyme not only opens the plasmid for insertion of a DNA fragment, but also destroys a phenotype; this fact aids in the selection of transformed bacteria.

Restriction enzymes can be used to produce physical maps of DNA molecules. Important information can be obtained from maps of DNA, whether the molecules are small and contain only a few genes, such as viral or plasmid DNA, or large and complex, such as bacterial or eukaryotic chromosomal DNA. An understanding of the genetics, metabolism, and regulation of an organism requires knowledge of the precise arrangement of its genetic material. The construction of a **restriction enzyme map** for a DNA molecule provides some of this information. Such a map displays the sites of cleavage by restriction endonucleases and the number of fragments obtained after digestion with each enzyme.

A restriction enzyme map is constructed by first digesting plasmid DNA with restriction endonucleases that yield only a few fragments. Each digest of DNA obtained with a single nuclease is analyzed by agarose gel electrophoresis, using standards for molecular weight determination. These are referred to as the primary digests. Second, each of the primary digests is treated with a series of additional restriction enzymes, and the digests are analyzed by agarose gel electrophoresis. The restriction map is then constructed by combining the various fragments by trial and error and logic, much as in sequencing a protein by proteolytic digestion by several enzymes and searching for overlap regions in the fragments. In the case of the restriction endonuclease digests, two characteristics of the DNA fragments are known: the approximate molecular weights (from electrophoresis) and the nature of the fragment ends (from the known selectivity of the individual restriction enzymes). The fragments may also be sequenced by the Sanger or Maxam-Gilbert method. A restriction enzyme map for the plasmid pBR322 is shown in Figure 10.5.

Practical Aspects of Restriction Enzyme Use

Restriction enzymes are heat-labile and expensive biochemical reagents. Their use requires considerable planning and care. Each restriction nuclease has been examined for optimal reaction conditions in regard to specific pH range, buffer composition, and incubation temperature. This information for each enzyme is readily available from the commercial supplier of the enzyme or from the literature. Table 10.1 gives important reaction information for several enzymes. The temperature range and pH optima for most restriction nucleases are similar (37°C, 7.5–8.0); however, optimal buffer composition is variable. Typical buffer components are Tris, NaCl, $MgCl_2$, and a sulfhydryl reagent (β-mercaptoethanol or dithiothreitol). Proper reaction conditions are crucial for optimal reaction rate, but, more importantly, changing reaction conditions have been shown to alter the specificity of some restriction enzymes.

Although restriction enzymes are very unstable reagents, they can be stored at −20°C in a buffer containing 50% glycerol. They are usually prepared in an appropriate buffer and shipped in packages containing dry ice.

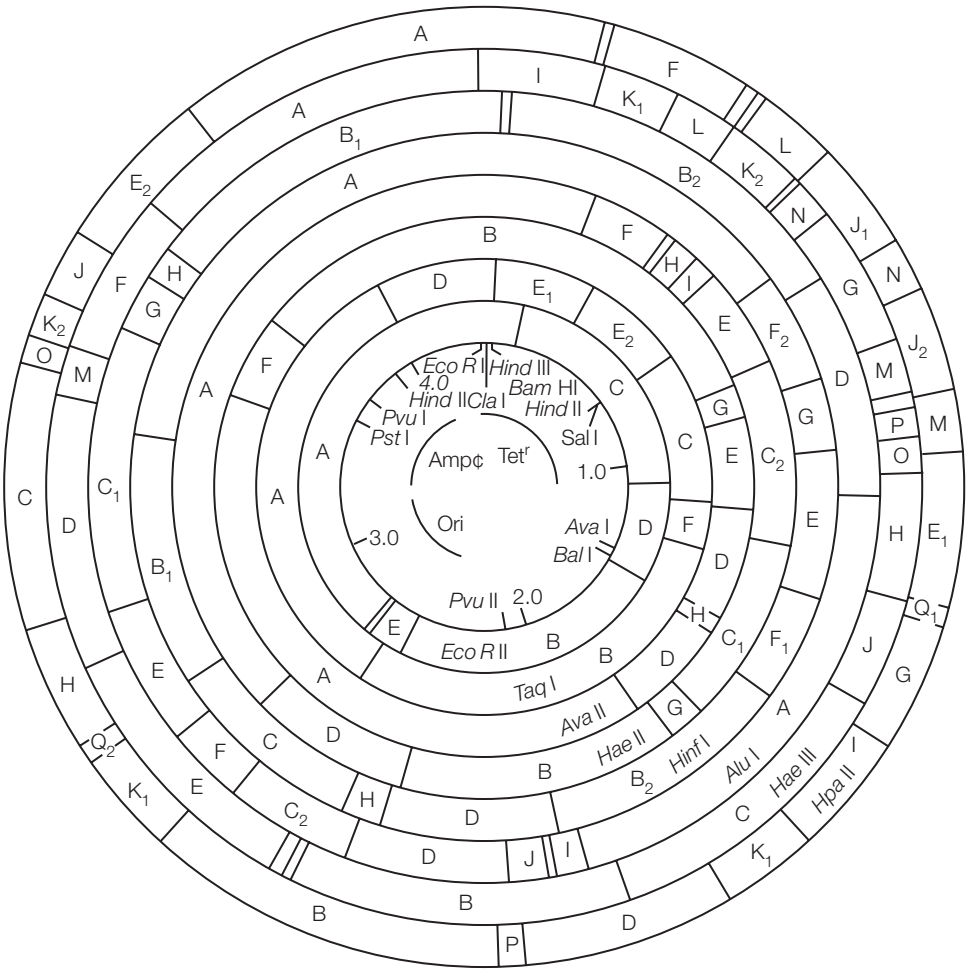

FIGURE 10.5
A restriction enzyme map for the plasmid pBR322. *From* Molecular Cloning: A Laboratory Manual, *by T. Maniatis, E. Fritsch, and J. Sambrook, Cold Spring Harbor Laboratory (Cold Spring Harbor, NY), 1982.*

Disposable gloves should be worn when you are handling the enzyme container. Remove the enzyme from the freezer just before you need it. Store the enzyme in an ice bucket at all times when it is outside the freezer. The enzyme should never be stored at room temperature. Because of high cost, digestion by restriction enzymes is carried out on a microscale level. A typical reaction mixture will contain about 1 μg or less of DNA and 1 unit of enzyme in the appropriate incubation buffer. One unit is the amount of enzyme that will degrade 1 μg of λ phage DNA in 1 hour at the optimal temperature and pH. The total reaction volume is usually between 20 and 50 μL. Incubation is most often carried out at the recommended temperature for about 1 hour. The reaction is stopped by adding EDTA solution, which complexes divalent metal ions essential for nuclease activity.

Reaction mixtures from restriction enzyme digestion may be analyzed directly by agarose gel electrophoresis. This technique combines high resolving power and sensitive detection to allow the analysis of minute amounts of DNA fragments.

STUDY EXERCISE 10.2 Restriction Enzymes

What is the class of the restriction enzyme, *Eco*RI? See Table 8.3 for classes, p. 251.

The Polymerase Chain Reaction

Producing multiple copies of a particular DNA fragment need not always require the tedious and time-consuming procedures of molecular cloning as described in Section A of this chapter. If at least part of the sequence of a DNA fragment is known, it is possible to make many copies using the **polymerase chain reaction (PCR).** The PCR method was conceived by Kary Mullis (1993 recipient of the Nobel Prize in chemistry) during a moonlit drive through the mountains of northern California.

Fundamentals of the PCR

The fundamentals of this relatively simple process are outlined here using a fragment of double-stranded DNA. The DNA template is divided into five regions, designated I to V in Figure 10.6. The complementary regions are I′ to V′. The region targeted for amplification is III (and III′), which can be reproduced by PCR if the nucleotide sequences of the flanking regions, II′ and IV′, are known. Experimental requirements for the PCR include:

1. Two synthetic oligonucleotide primers of about 20 base pairs each, which are complementary to the flanking sequences II and IV and also have similar binding ability.
2. A heat-stable DNA polymerase.
3. The four deoxyribonucleoside triphosphates, dATP, dGTP, dCTP, and dTTP.

The PCR is performed in cycles of three steps. Each cycle consists of:

1. Denaturation to achieve template DNA strand separation is done by heating a mixture of all components at 95°C for about 15 s.
2. Abrupt cooling of the mixture to the range of 37–55°C allows the primers to hybridize with the appropriate flanking regions. The primers are oriented on the template so their 3′ ends are directed toward each other. Synthesis of DNA extends across regions III and III′. Note the dual roles played by the complementary oligonucleotides: they locate the starting points for duplication of the desired DNA segment, and they serve as 3′-hydroxy primers to initiate DNA synthesis. A large excess of primers to DNA is added to the reaction mixture to favor hybridization and prevent reannealing of the DNA template strands.
3. Synthesis of the targeted DNA is catalyzed by *Taq* DNA polymerase. The temperature is raised to 72°C to enhance the rate of the polymerization reaction. The enzyme extends both primers, producing two new strands of DNA, II-III-IV-V and I′-II′-III′-IV′. The chosen polymerase is from a thermophilic bacterium, *Thermus aquaticus*, an organism originally discovered in a Yellowstone National Park hot spring. Other useful polymerases have

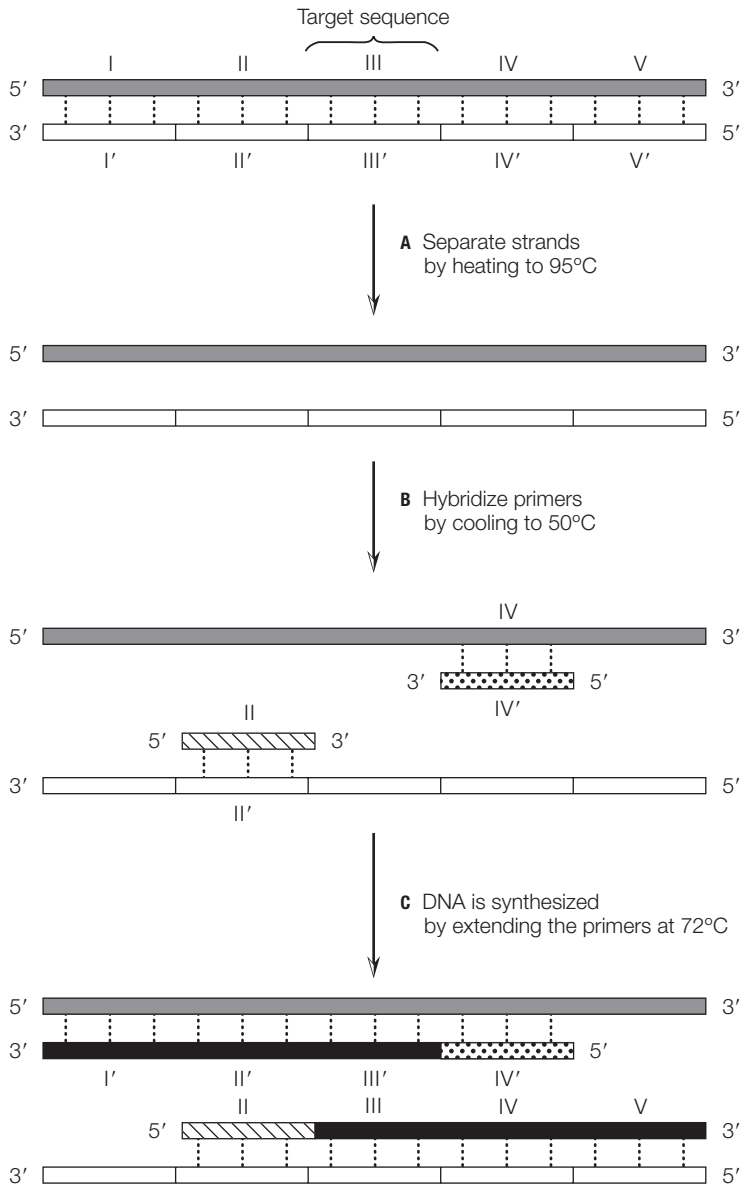

FIGURE 10.6 The polymerase chain reaction has three steps: **A** Strand separation by heating at 95°C. **B** Hybridization of the primers. **C** Extension of the primers by DNA synthesis. Segments are labeled I, II, III, IV, and V on the original DNA strand and I′, II′, III′, IV′, and V′ on the complementary strand. Primer II has diagonal lines and primer IV′ has dots. Newly synthesized DNA is shown in black.

been isolated from bacteria found in geothermal vents on the ocean floor. These enzymes are heat stable, so the reaction can be carried out at a high temperature, leading to a high rate of DNA synthesis. The DNA synthesis reaction is usually complete in about 30 s.

The usefulness of the PCR lies in its three steps—denaturation, hybridization, and DNA synthesis—that can be repeated many times simply by changing the temperature of the reaction mixture. Each newly synthesized strand of DNA can serve as a template, so the target DNA concentration increases at an exponential rate. In a process consisting of 20 cycles, the amplification for the DNA fragment is about

a millionfold. Thirty cycles, which can be completed in 1–3 hours, provide a billionfold amplification. Theoretically, one could begin with a single molecule of target DNA and produce in 1 hour enough DNA for the Sanger dideoxy chain-terminating sequence procedure. Another benefit of the PCR is its simplicity. Commercially available instruments called **thermocyclers** allow the laboratory technician to mix the reagents and insert the reaction mixture in the cycler, which then automatically repeats the reaction steps by changing temperatures.

The PCR has become a routine tool in basic research carried out in universities, hospitals, and pharmaceutical companies. It is especially useful for amplifying small amounts of DNA for sequencing. It was used widely in the Human Genome Project, which in 2001 announced the sequence of the 3 billion base pairs in the human genome.

Applications of the PCR

Diagnostic Medicine

PCR may be used to detect the presence of infectious bacteria and viruses in an individual even before symptoms begin to appear. HIV infection is usually confirmed using tests that detect serum antibody proteins made against the viral proteins. However, there may be a period of at least six months between infection and when the anti-HIV antibodies reach a detectable concentration. PCR can be used to detect proviral DNA. An especially important application is the identification of HIV-infected infants. The antibody-based test cannot be done on infants because they have maternal antibodies for up to 15 months after birth. Other medical applications of PCR include early detection of tuberculosis and cancers, especially leukemias, and analysis of small samples of amniotic fluid to detect genetic abnormalities in fetuses.

Forensics

Recovery of fingerprints from a crime scene has been a long-standing and well-accepted method in forensics. A new procedure, **DNA fingerprinting,** is being developed and achieving widespread use. DNA fingerprinting is the biochemical analysis of DNA in biological samples (semen, blood, saliva) remaining at a crime scene. Since every individual possesses a unique hereditary composition, each individual has a characteristic phenotype that is reflected in his or her DNA sequence. DNA fingerprinting attempts to show the genetic variations that are found from person to person. These differences can be detected by analysis of an individual's DNA. Two experimental methods are currently used in DNA fingerprinting:

1. ***Restriction Fragment Length Polymorphisms (RFLPs)*** In this method, DNA samples are digested with restriction enzymes. The resulting fragments are separated by gel electrophoresis, blotted onto a membrane, hybridized to a DNA probe, and analyzed by autoradiography (see Section C on blotting in this chapter). Results vary from individual to individual (except in the case of identical twins, who have identical DNA) because of their differences in DNA sequence. Since each person's DNA has a unique sequence pattern, the restriction enzymes cut differently and lead to different-sized fragments.
2. ***PCR-Based Analysis*** The second method of DNA fingerprinting involves the use of PCR-amplified DNA. Allele-specific oligonucleotide (ASO)

primers are used for amplification of specific sequences. PCR-based DNA fingerprinting has many advantages over RFLP methods, including speed, simplicity, no requirements for radioactive probes, and greater sensitivity. DNA from a single hair or minute samples of blood, saliva, and semen can be analyzed.

C. NUCLEIC ACID BLOTTING

Many of the procedures for isolating and characterizing DNA and RNA molecules discussed in Chapters 9 and 10 depend on the separation of nucleic acids by an electrophoresis step, followed by some kind of analysis of the gel bands. Although electrophoresis provides excellent separation of molecules, the method gives no indication as to the identity of the molecules at each band. As described in Chapter 6, Section C, p. 192, **membrane blotting techniques** are now available for functional analysis of the molecules at each electrophoresis band.

The first blotting technique was reported by E. Southern in 1975. Using labeled complementary DNA probes, he searched for certain nucleotide sequences among DNA molecules blotted from the gel. This technique of detecting DNA-DNA hybridization is called **Southern blotting.** The general blotting technique has now been extended to the transfer and detection of specific RNA (for example, mRNA) using labeled complementary DNA probes **(Northern blotting)** and the transfer and detection of proteins that react with specific antibodies (**Western blotting**).

Blotting techniques have many applications, including mapping the genes responsible for inherited diseases by using restriction fragment length polymorphisms (RFLPs), screening collections of cloned DNA fragments (DNA libraries), and DNA fingerprinting for analysis of biological material remaining at the scene of a crime.

Study Problems

1. Explain the action of ampicillin as an inducer of plasmid replication.
2. How does chloramphenicol inhibit protein synthesis?
3. Why is polyacrylamide gel electrophoresis not suitable for analysis of most plasmid DNA?
4. Why is a wavelength of 600 nm used to measure growth of bacteria? Could other wavelengths be used?
5. How does the addition of an EDTA solution stop a restriction enzyme reaction?
6. What kind of chemical bonding holds cohesive ends together after action of a restriction enzyme?
7. Which of the following base sequences are probably not recognition sites for cleavage by restriction endonucleases? Why not?
   (a) 5′ GAATTC 3′
   (b) 5′ CATTAG 3′
   (c) 5′ CATATG 3′
   (d) 5′ CAATTG 3′

8. Use the REBASE Web site (http://rebase.neb.com) to search for information about the restriction enzymes listed below. For each enzyme, find the recognition sequence and the cleavage site, and determine if the DNA cut ends are blunt or cohesive.
   (a) *Apa*I
   (b) *Spm*I
   (c) *Alu*I
9. How many DNA fragments result from the action of restriction enzyme *Hae*II on the plasmid pBR322?
10. Assume the reaction digest from Problem 8 is analyzed by agarose gel electrophoresis. Draw an electrophoresis gel and show the approximate locations of each fragment.

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http://rebase.neb.com
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http://www.tutorvista.com/content/biology/biology-iii/biotechnology/biotechnology-tools.php
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http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Projects00/rdna/rdna.html
Recombinant DNA.

http://biog-101-104.bio.cornell.edu/BIOG101_104/tutorials/recomb_DNA.html
Recombinant DNA.

http://www.biochem.arizona.edu/classes/bioc471/pages/materials.html
An excellent resource on recombinant DNA.

http://en.wikipedia.org/wiki/Restriction_enzyme
Restriction enzymes.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.)

CHAPTER 11

PROTEIN PRODUCTION, PURIFICATION, AND CHARACTERIZATION

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Proteins are often considered the workhorses among biomolecules, as they are responsible for the general maintenance and daily functioning of cells and organisms. The proteins are extremely versatile functional molecules, as they serve roles in biological catalysis (enzymes), immune response (antibodies), structural integrity, muscle contraction, cell regulation, and storage/transport processes. Because of their roles as essential biomolecules, there has always been intense interest in the extraction of proteins from their natural sources and in their characterization in terms of structure and biological function. In this chapter, we will focus on the purification procedures that are used to obtain native protein molecules that may be further characterized. The new discipline of **proteomics**, the study of the thousands of proteins expressed in cells and organisms and how the proteins interact with each other, has renewed interest in the development of methods for their isolation and characterization. Because the normal concentration of proteins in cells is quite low, there is a strong interest in designing methods to enhance their production. Recombinant DNA procedures now play a major role in the production of relatively large quantities of scarce proteins for basic scientific study and for medical and industrial applications. In the medical technique of **gene therapy**, a hybrid DNA containing the genes for the desired protein is transferred into a host cell, which acts as a factory to produce the desired protein.

A. PROCEDURES FOR THE PURIFICATION OF PROTEINS

Protein purification is an activity that has occupied the time of biochemists and molecular life scientists throughout the last two centuries. In fact, a large percentage of the biochemical literature is a description of how specific proteins have been separated from thousands of other proteins and other biomolecules in tissues, cells, and biological fluids. Biochemical investigations of all biological processes require, at some time, the isolation, purification, and characterization of a protein. In contrast to the repetitive procedures for isolation of DNA and RNA (see Chapter 9, Section B, p. 275), there is no single technique or sequence of techniques that can be followed to isolate and purify all proteins. It is sometimes still necessary to proceed by trial and error. Fortunately, the experiences and discoveries of thousands of scientists have been combined so that, today, a general, systematic approach is available for protein isolation and purification.

Composition of Proteins

All proteins found in nature are constructed by amide linkages between α-amino acids. The amino acids are selected from a group of 20 molecules that have common structural characteristics. They each have at least one carboxyl group and at least one amino group (Figure 11.1). The distinctive physical, chemical, and biological properties associated with an amino acid are the result of the R group, a side chain that is unique for each amino acid. A list of the 20 common amino acids and their one-letter and three-letter abbreviations are given in Table 11.1. If you are not yet familiar with the general structures and properties of amino acids and proteins, refer to your general biochemistry text.

STUDY EXERCISE 11.1 Peptide Structure

Draw the structure of this peptide: Asp-Phe-Ala-Lys-Trp.

Amount of Protein Versus Purity of Protein Versus Expense

The procedure selected for protein purification is dependent primarily on how much of the protein is needed and how pure the protein must be; in other words, what is the purpose for isolating the protein? In terms of amount, one usually thinks on two scales: **preparative,** isolation of larger quantities (several milligrams or grams) to use for further characterization or structure and function studies; or **analytical,** isolation of microgram or milligram quantities in order to make a few precise measurements such as molecular weight, sequencing, or structure determination by NMR or X-ray diffraction.

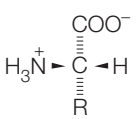

FIGURE 11.1 The general structure of the zwitterionic form of an L-amino acid. R represents the side chain.

TABLE 11.1 Abbreviations of the 20 Common Amino Acids Found in Proteins

	Abbreviation	
Name	**One-letter**	**Three-letter**
Glycine	G	Gly
Alanine	A	Ala
Valine	V	Val
Leucine	L	Leu
Isoleucine	I	Ile
Methionine	M	Met
Phenylalanine	F	Phe
Proline	P	Pro
Serine	S	Ser
Threonine	T	Thr
Cysteine	C	Cys
Asparagine	N	Asn
Glutamine	Q	Gln
Tyrosine	Y	Tyr
Tryptophan	W	Trp
Aspartate	D	Asp
Glutamate	E	Glu
Histidine	H	His
Lysine	K	Lys
Arginine	R	Arg

In terms of purity, a protein sample is considered pure when it contains a single type of protein. It is not practically possible to obtain a protein in 100% purity, but most studies can be done on samples that are 90–95% pure. It often is not worth the extra time and reagent expense to purify a protein greater than 90% unless absolutely necessary. In general, the best purification scheme is one that yields the maximum (or appropriate) amount of the protein, of desired purity, with a minimum amount of time and expense. The following discussion outlines the basic steps available to develop a protein purification scheme (Table 11.2).

Basic Steps in Protein Purification

Development of Protein Assay

First and foremost in any protein purification scheme is the development of an assay for the protein. This procedure, which may have a physical, chemical, or biological basis, is necessary in order to determine quantitatively and/or

TABLE 11.2 Typical Sequence for the Purification of a Protein

1. Develop an assay for the desired protein.
2. Select the biological source of the protein, including use of recombinant DNA techniques.
3. Release the protein from the source and solubilize it in an aqueous buffer system.
4. Fractionate the cell components by physical methods (centrifugation).
5. Separate the biomolecules present by differential solubility.
6. Apply chromatographic procedures.
   (a) Gel-filtration chromatography
   (b) Ion-exchange chromatography
   (c) Affinity chromatography
7. Isoelectric focusing, if desired.
8. Determine purity by electrophoresis or HPLC.

qualitatively the presence of the specific protein. During the early stages of the purification, the particular protein desired must be distinguished from thousands of other proteins present in the crude cell homogenate. The desired protein may be less than 0.1% of the total protein. It should be obvious that the general protein assays (spectrophotometric, Bradford, Lowry, etc.; see Chapter 3, Section B, p. 67) are not useful as assays for a specific protein, because they simply indicate the total protein present. If the desired protein is an enzyme, the obvious assay should be based on biological function, that is, a measurement of the enzymatic activity after each isolation–purification step. If the protein to be isolated is not an enzyme or if the biological activity is unknown, physical or chemical methods must be used. One of the most useful analytical methods is electrophoresis. If an antibody has been prepared against the desired protein, it may be analyzed by electrophoresis and monitored during purification using Western blotting (see Chapter 6, Section C, p. 192).

Source of the Protein

We next consider the selection of the source from which the protein will be isolated. If the objective is simply to obtain a large quantity of a protein for further study, you would choose a source that contains large amounts of the protein. A possible choice is an organ from a large animal that can be obtained from a local slaughterhouse. Microorganisms are also good sources because they can be harvested in large quantities. If, however, you desire a specific protein from a specific type of organism, tissue, cell, cell organelle, or biological fluid, the source is limited. For example, if one desires to study the enzymes involved in glycolysis in the alfalfa plant, one would begin with leaves of the plant.

If the desired protein is known to be located in an organelle or subcompartment of the cell, partial purification of the protein is achieved by isolating the organelle by fractional centrifugation (Chapter 4, Section C, Figure 4.11, p. 107). If the protein is, instead, in the soluble cytoplasm of the cell, it will remain dissolved in the final supernatant obtained after centrifugation at 100,000 $\times$ g.

With the introduction of techniques in recombinant DNA research, it is now possible to synthesize relatively large quantities of specific proteins in selected host cells. One begins by preparing the recombinant DNA, which consists of inserting the specific gene that contains the code for the desired protein, along with appropriate promoters and markers, into a plasmid or other vector. The recombinant DNA may then be transferred to a host cell (*E. coli,* or other bacteria, or yeast), and the host cell is then allowed to grow and synthesize the desired protein (molecular cloning, Chapter 10, Section A, p. 290). This procedure has several advantages over the traditional method of isolating and purifying proteins as described in the previous paragraphs and in Table 11.2. Some of the benefits of using recombinant DNA include:

- Overexpression of the protein is possible, which produces relatively large amounts; this is especially helpful when dealing with scarce proteins, or with proteins for commercial or medical applications.
- Conditions can be controlled so there is less degradation of the desired protein by proteases and less contamination by other biomolecules. This makes it easier to isolate and purify the protein from the host cell. Some steps in Table 11.2 may be eliminated.
- With the use of genetic engineering techniques, including mutation, it is possible to produce modified proteins, i.e., proteins with one or more amino acid changes.

Because the techniques for purifying a protein using recombinant DNA procedures are somewhat different than those of traditional isolation and purification, a special section will be devoted to protein production by cloning (Section B of this chapter, p. 317).

Preparation of the Crude Extract

Once the protein source has been selected, the next step is to release the desired protein from its natural cellular environment and solubilize it in aqueous solution. This calls for disruption of the cell membrane without damage to the cell contents. Proteins are relatively fragile molecules, and only gentle procedures are allowed at this stage. The gentlest methods for cell breakage are osmotic lysis, gentle grinding in hand-operated glass homogenizers, and disruption by ultrasonic waves. These methods are useful for "soft tissue," as found in green plants and animals. When dealing with bacterial cells, in which rigid cell walls are present, the most effective methods are grinding in a mortar with an inert abrasive such as sand or alumina, or treatment with lysozyme and/or a detergent. Lysozyme is an enzyme that catalyzes the hydrolysis of polysaccharide moieties present in cell walls. When very resistant cell walls are encountered (yeast, for example), the French press must be used. Here the cells are disrupted by passage, under high pressure, through a small hole.

Osmotic lysis consists of suspending cells in a solution of relatively high ionic strength. This causes water inside the cell to diffuse out through the membrane. The cells are then isolated by centrifugation and transferred to pure water. Water rapidly diffuses into the cell, bursting the membrane.

Another alternative, gentle **grinding,** is best accomplished with a glass or Teflon homogenizer. This consists of a glass tube with a close-fitting piston. Several varieties are shown in Figure 11.2A, B. The cells are forced against the glass walls under the pressure of the piston, and the cell components are released into an aqueous solution.

Ultrasonic waves, produced by a sonicator, are transmitted into a suspension of cells by a metal probe (Figure 11.2C). The vibration set up by the ultrasonic waves disrupts the cell membrane, releasing the cell components into the surrounding aqueous solution.

A less gentle, but widely used, solubilization device is the common electric blender. This method may be used for plant or animal tissue, but it is not effective for disruption of bacterial cell walls. A tool that is more scientifically designed is the **rotor stator homogenizer** (Figure 11.2D). The stator is a hollow tube and the rotor, attached to the stator, is a rapidly turning knife blade. Cells are torn apart by the turbulence and shear generated by the rotor.

The most recently developed homogenizer is the so-called **cell bomb,** which makes use of high pressure and decompression to disrupt cells. In this technique, a gas, usually nitrogen, helium, or air, is forced into cells under high pressure. When the pressure is released, expanding bubbles of the gas (nebulization) rupture the cell membrane. Cell bombs are available with pressure ranges of 250 to 25,000 psi. Cell bombs have an advantage over sonicators in that they cause no temperature increase that can denature proteins. A disadvantage of cell bombs is the potential for explosions because of the high-pressure conditions.

Since so many cell disruption methods are available, the experimenter must, by trial and error, find a convenient method that yields the maximum quantity of the protein with minimal damage to the molecules.

Stabilization of Proteins in a Crude Extract

Continued stabilization of the protein must always be considered in protein purification processes. While the protein is inside the cell, it is in a highly regulated environment. Cell components in these surroundings are protected against sudden changes in pH, temperature, or ionic strength and against oxidation and enzymatic degradation. Once the cell wall/membrane barrier is destroyed, the protective processes are no longer functional and degradation of the desired protein is likely to begin. An artificial environment that mimics the natural one must be maintained so that the protein retains its chemical integrity and biological function throughout the purification procedure. What factors are important in maintaining an environment in which proteins are stable? Although numerous factors must be considered, the following are the most critical:

1. ***Ionic strength and polarity*** The standard cellular environment is, of course, aqueous; because of the presence of inorganic salts, though, its ionic strength is relatively high. Addition of KCl, NaCl, or $MgCl_2$ to the cell extract may be necessary to maintain this condition. Proteins that are normally found in the hydrophobic regions of cells (i.e., membranes) are generally more stable in aqueous environments in which the polarity has been reduced by the addition of 1 to 10% glycerol or sucrose.

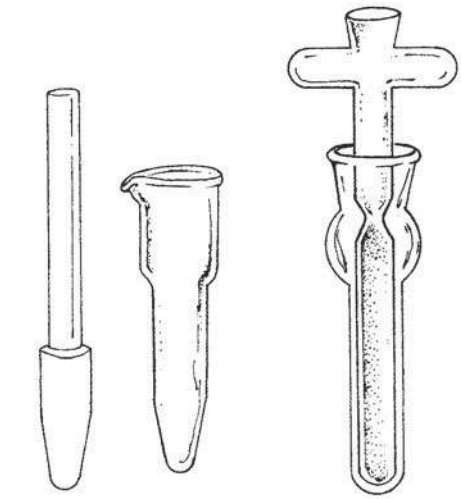

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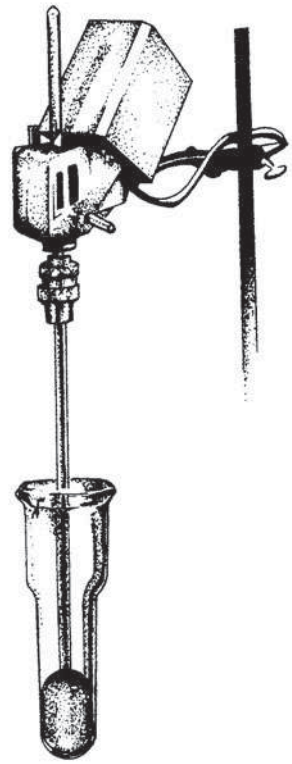

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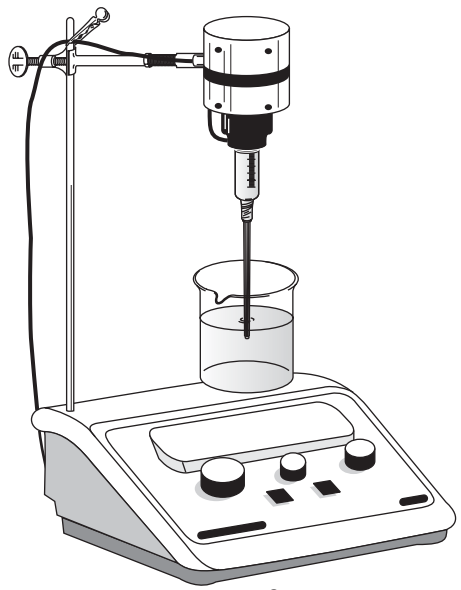

C

D

FIGURE 11.2 Tools for the preparation of a crude cell extract. **A** Hand-operated homogenizers, *courtesy of Ace Glass, Inc. Vineland, NJ.* **B** Homogenizer with electric motor, *courtesy of Sargent-Welch/VWR; www.sargentwelch.com.* **C** Ultrasonic homogenizer, *courtesy of BioLogics, Inc., www.biologics-inc.com.* **D** Rotor-stator, *courtesy of Omni International, Inc. www.omni-inc.com.*

2. ***pH*** The pH of a biological cell is controlled by the presence of natural buffers. Since protein structure is often irreversibly altered by extremes in pH, a buffer system must be maintained for protein stabilization. The importance of proper selection of a buffer system cannot be overemphasized. The criteria that must be considered in selecting a buffer are discussed in Chapter 3, Section A, p. 57. For most cell homogenates at physiological pH values, Tris and phosphate buffers are widely used.
3. ***Metal ions*** The presence of metal ions in mixtures of biomolecules can be both beneficial and harmful. Metal ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, and Fe^{3+} may actually increase the stability of dissolved proteins. Many enzymes require specific metal ions for activity. In contrast, heavy metal ions such as Ag^{1+}, Cu^{2+}, Pb^{2+}, and Hg^{2+} are deleterious, particularly to proteins that depend on sulfhydryl groups for structural and functional integrity. The main sources of contaminating metals are buffer salts, water used to make buffer solutions, and metal containers and equipment. To avoid heavy-metal contamination, you should use high-purity buffers, glass-distilled water, and glassware specifically cleaned to remove extraneous metal ions (see Chapter 1, Section C, p. 15). If metal contamination still persists, a chelating agent such as ethylenediaminetetraacetic acid (EDTA, $1 \times 10^{-4}\,M$) may be added to the buffer.
4. ***Oxidation*** Many proteins are susceptible to oxidation. This is especially a problem with proteins having free sulfhydryl groups, which are easily oxidized and converted to disulfide bonds. A reducing environment can be maintained by adding mercaptoethanol, cysteine, or dithiothreitol ($1 \times 10^{-3}\,M$) to the buffer system.
5. ***Proteases*** Many biological cells contain degradative enzymes (proteases) that catalyze the hydrolysis of peptide linkages. In the intact cell, functional proteins are protected from these destructive enzymes because the enzymes are stored in cell organelles (lysosomes, etc.) and released only when needed. The proteases are freed upon cell disruption and immediately begin to catalyze the degradation of protein material. This detrimental action can be slowed by the addition of specific protease inhibitors such as phenylmethylsulfonyl fluoride or certain bioactive peptides. These inhibitors are to be used with extreme caution because they are potentially toxic.
6. ***Temperature*** Many of the above conditions that affect the stability of proteins in solution are dependent on chemical reactions. In particular, metal ions, oxidative processes, and proteases bring about chemical changes in proteins. It is a well-accepted tenet in chemistry that lower temperatures slow down chemical processes. We generally assume that proteins are more stable at low temperatures. Although there are a few exceptions to this, it is fairly common practice to carry out all procedures of protein isolation under reduced-temperature conditions (usually in ice bath, 0–4°C).

After cell disruption, gross fractionation of the properly stabilized, crude cell homogenate may be achieved by physical methods, specifically centrifugation. Figure 4.11 outlines the stepwise procedure commonly used to separate subcellular organelles such as nuclei, mitochondria, lysosomes, and microsomes.

Separation of Proteins Based on Solubility Differences

Proteins are soluble in aqueous solutions primarily because their charged and polar amino acid residues are solvated by water. Any agent that disrupts these protein-water interactions decreases protein solubility because the protein-protein interactions become more important. Protein-protein aggregates are no longer sufficiently solvated, and they precipitate from solution. Because each specific type of protein has a unique amino acid composition and sequence, the degree and importance of water solvation vary from protein to protein. Therefore, different proteins precipitate at different concentrations of precipitating agent. The agents and factors most often used for protein precipitation are (1) inorganic salts, (2) organic solvents, (3) polyethylene glycol (PEG), (4) pH, and (5) temperature.

The most commonly used inorganic salt, ammonium sulfate, is highly solvated in water and actually reduces the water available for interaction with protein. As ammonium sulfate is added to a protein solution, a concentration of salt is reached at which there is no longer sufficient water present to maintain a particular type of protein in solution. The protein precipitates or is "salted out" of solution. The concentration of ammonium sulfate at which the desired protein precipitates from solution cannot be calculated, but must be established by trial and error. In practice, ammonium sulfate precipitation is carried out in stepwise intervals. For example, a crude cell extract is treated by slow addition of dry, solid, high-purity ammonium sulfate in order to achieve a change in salt concentration from 0 to 25%, is gently stirred for up to 60 minutes, and is subjected to centrifugation at 20,000 $\times$ g. The precipitate that separates upon centrifugation and the supernatant are analyzed for the desired protein. If the protein is still predominantly present in the supernatant, the salt concentration is increased from 25 to 35%. This process of ammonium sulfate addition and centrifugation is continued until the desired protein is salted out.

Organic solvents also decrease protein solubility, but they are not as widely used as ammonium sulfate because they sometimes denature proteins. They are thought to function as precipitating agents in two ways: (1) by dehydrating proteins, much as ammonium sulfate does, and (2) by decreasing the dielectric constant of the solution. The organic solvents used (which, of course, must be miscible with water) include methanol, ethanol, and acetone.

A relatively new method of selective protein precipitation involves the use of nonionic polymers. The most widely used agent in this category is polyethylene glycol. This polymer is available in a variety of molecular weights ranging from 400 to 7500. The biochemical literature reports successful use of different weights, but lower-molecular-weight polymer has been shown to be the most specific. The principles behind the action of PEG as a protein precipitating agent are not completely understood. Possible modes of action include (1) complex formation between protein and polymer, and (2) exclusion of the protein from part of the solvent (dehydration), followed by protein aggregation and precipitation. The most attractive advantage of PEG is its ability to fractionate proteins on the basis of size and shape, as in gel filtration.

Finally, changes in pH and temperature have been used effectively to promote selective protein precipitation. A change in the pH of the solution alters the ionic state of a protein and may even bring some proteins to a state of charge neutrality.

Charged protein molecules tend to repel each other and remain in solution; however, neutral protein molecules do not repel each other, so they tend to aggregate and precipitate from solution. A protein is least soluble in aqueous solution when it has no net charge, that is, when it is isoelectric. This characteristic can be used in protein purification, since different proteins usually have different isoelectric pH values (see Chapter 6, Section B, p. 182). An increase in temperature generally causes an increase in the solubility of solutes. This general rule is followed by most proteins up to about 40°C. Above this temperature, however, many proteins aggregate and precipitate from solution. If the protein of interest is heat stable and still water soluble above 40°C, a major step in protein purification can be achieved because most other proteins precipitate at these temperatures and can be removed by centrifugation.

Selective Techniques in Protein Purification

After gross fractionation of proteins, as discussed above and listed in Table 11.2 Step 5, more refined methods with greater resolution can be attempted. These methods, in order of increasing resolution, are gel-filtration chromatography, ion-exchange chromatography, affinity chromatography, and isoelectric focusing. Since the basis of protein separation is different for each of these techniques, it is often most effective and appropriate to use all of the techniques in the order given.

Chromatographic methods for protein purification are discussed in Chapter 5. However, we must consider another important topic, preparation of protein solutions for chromatography. Fractionation of heterogeneous protein mixtures by inorganic salts, organic solvents, or PEG usually precedes column chromatography. The presence of the precipitating agents will interfere with the later chromatographic steps. In particular, the presence of ammonium sulfate increases the ionic strength of the protein solution and damps the ionic protein–ion-exchange resin interactions. Procedures that are in current use to remove undesirable small molecules from protein solutions include ultrafiltration (see Chapter 3, Section D, p. 74), dialysis (see Chapter 3, Section D, p. 73), and gel filtration (see Chapter 5, Section E, p. 132).

Chromatography is now, and will continue to be for many years, the most effective method for selective protein purification. The more conventional methods (ion exchange and gel filtration) rely on rather nonspecific physicochemical interactions between a stationary support and protein molecule. These techniques, which separate proteins on the basis of net charge, size, and polarity, do not have a high degree of specificity. The highest level of selectivity in protein purification is offered by affinity chromatography—the separation of proteins on the basis of specific biological interactions (see Chapter 5, Section G. p. 152).

To some individuals, especially those who recall their experiences in the organic chemistry laboratory, the ultimate step in purification of a molecule is crystallization. The desire to obtain crystalline protein has long been strong, and many proteins have been crystallized. However, there is a common misconception that the ability to form crystals of a protein ensures that the protein is homogeneous. For many reasons (entrapment of contaminants within crystals, aggregation of protein molecules, etc.), the ability to crystallize a protein should not be used as a criterion of purity. The interest in protein crystals today has its origin in the demand for X-ray crystallographic analysis of protein structure (see Chapter 7, p. 233).

STUDY EXERCISE 11.2 Protein Purification

List at least three types of chromatography useful for protein purification, and identify the basis of separation for each type.

B. PRODUCTION OF PROTEINS BY EXPRESSION OF FOREIGN GENES

It is now possible to produce large quantities of selected proteins by using recombinant DNA technology. In general, a hybrid DNA is prepared by inserting the gene to be expressed (the gene carries the code for the desired protein) into a vector (plasmid, etc.; see Chapter 10, Section A, p. 294) and transferring it into a host cell where the desired protein is synthesized. These procedures have been used in the production of hundreds of proteins for scientific, medical, agricultural, and industrial purposes. Table 11.3 lists some of the important protein products now made by recombinant DNA methods.

Gene Expression in Prokaryotic Organisms

Bacterial cells, especially *E. coli*, have been widely used as host cells for the large-scale production of proteins. Special requirements must be considered while preparing the recombinant DNA containing the "foreign" gene. The cloned structural gene that contains the message for the desired protein is incorporated into an expression vector that has all the necessary transcriptional and translational

TABLE 11.3 Recombinant Proteins and Their Use

Protein	Use
Human insulin	Treatment of diabetes
Human somatotropin (growth hormone)	Treatment of dwarfism
Bovine somatotropin (BST)	Enhances milk production in dairy cattle
Porcine somatotropin (PST)	Enhances growth in pigs
Pulmozyme (DNase)	Treatment of cystic fibrosis
Tissue plasminogen activator (TPA)	Treatment of heart attack, stroke; dissolves blood clots
Erythropoietin	Treatment of anemia by stimulating erythrocyte production
Interferons	Treatment of cancers; antiviral agent
Atrial natriuretic factor	Reduces high blood pressure
Leptin	Treatment of obesity
Hepatitis B vaccine	Treatment of hepatitis
Herceptin	Treatment of metastatic breast cancer; monoclonal antibody
Amylase and cellulase	Removes carbohydrate precipitates from fruit juice

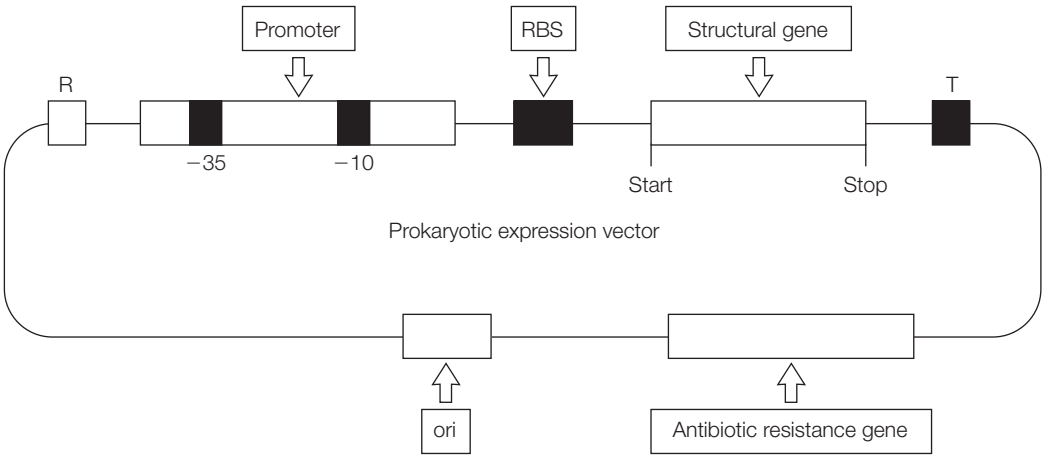

FIGURE 11.3 Components of a typical recombinant DNA prokaryotic expression vector. The structural gene contains the coding sequence for the protein. Essential components include the promoter (P), ribosome binding site (RBS), regulatory gene (R), and transcription terminator (T). "ori" refers to the origin of replication.

control sequences (Figure 11.3). If a relaxed plasmid is used as the vector (see Chapter 10, Section A, p. 294) and the proper signals for gene expression are present, it is possible to overexpress the desired protein so that its concentration may reach up to 40% of the host bacteria's total cellular protein. Although this provides a high yield of the expressed protein, the bacterial cells often concentrate the foreign protein into insoluble **inclusion bodies** in which the protein is present in a denatured, aggregated form. The protein may be renatured by isolating the inclusion bodies by centrifugation and incubating them with a denaturing agent (6 *M* guanidinium ion or urea) and then slowly removing the denaturing agent by ultrafiltration or dialysis (see Chapter 3, Section D, p. 73). Initially, the presence of the desired protein in the inclusion bodies seems to be a disadvantage in the production of the protein, but it turns out sometimes to be a benefit, as it may actually save time in further purification steps. Because the inclusion bodies contain the desired protein in the absence of most other cellular proteins, this serves as a major purification step. The renatured protein often is ready for further purification using the final steps of chromatography in Table 11.2. However, the renaturing process is very slow, and percent recovery of the protein may be as low as 50%.

Host-Cell Secretion of Protein

The formation of inclusion bodies and other technical problems of gene expression can be avoided if the coding gene is genetically engineered to induce the host cell to secrete the protein into the periplasmic space (the area between the cell wall and the plasma membrane). The protein can be released from this space using the procedure of osmotic lysis (see this chapter, p. 311). These procedures greatly facilitate purification of the protein, as they avoid the preparation of a crude cell homogenate in which the protein is in a mixture of all other cellular molecules. The host bacterial cell can be coaxed into secreting the desired protein

by incorporating a signal sequence for protein targeting into the expression vector.

The yield of biologically active protein can also be increased by reducing its intracellular degradation. Because the host bacterial cell recognizes the cloned protein as "foreign" (and, indeed, some proteins are toxic to the bacterium), it attempts to remove the protein by protease-catalyzed hydrolysis. Degradation by protease action is lessened if the protein is secreted. Protein degradation can also be reduced if the expression vector is modified to add or label the desired protein with a protease-resistant sequence of amino acids.

Many of the above problems, including inclusion body formation, can also be minimized or even eliminated by tagging the desired protein with a protein of bacterial origin. This is accomplished by inserting into the vector a DNA fragment carrying the code for a bacterial protein. The bacteria can be tricked into recognizing the conjugated protein (bacterial protein covalently linked to the desired protein) as "native." The "label" is often added to the N-terminus of the cloned protein. Such modified proteins are called **hybrid** or **fusion proteins.** The label may be removed from the desired protein, after extraction, by using a proteolytic enzyme.

Histidine-Tagged Proteins

A unique approach to eliminating some of the problems outlined above and also facilitating protein purification is to program the expression vector to add a string of six or more histidine residues to the N-terminus of the desired protein. The histidine residues (along with the protein) will bind to an affinity chromatography column containing nickel ions immobilized to a nitrilotriacetic acid solid support. Protein purification is achieved by passing the cell lysate (prepared by treatment of the host cells with lysozyme and/or a detergent) directly through the affinity column (Figure 11.4; see immobilized metal-ion affinity chromatography, Chapter 5, Section G, p. 152). Equipment and reagents for these procedures are available in kit form from QIAGEN Inc. and Clontech Laboratories Inc. A modified version of this procedure, the MagneHis Protein Purification System, is available from Promega. The MagneHis system involves the use of paramagnetic precharged nickel particles to isolate His-tagged protein directly from a crude cell lysate. In all procedures described above, the His-tagged protein is recovered from the solid support by eluting with imidazole, which binds to the nickel ions and displaces the protein.

Other peptide fusion labels that facilitate protein purification include:

- ***Polyarginine***—A series of arginine residues is added to the C-terminus of the protein. This makes the protein highly basic and thus able to be purified using a cation-exchange resin.
- ***Flag***—A short amino acid sequence (Asp-Tyr-Lys-Asp-Asp-Asp-Asp-Lys–) is attached to the N-terminus of the protein. The protein may then be purified by immunoaffinity chromatography with the use of a commercially available monoclonal antibody that recognizes the hydrophilic peptide sequence.

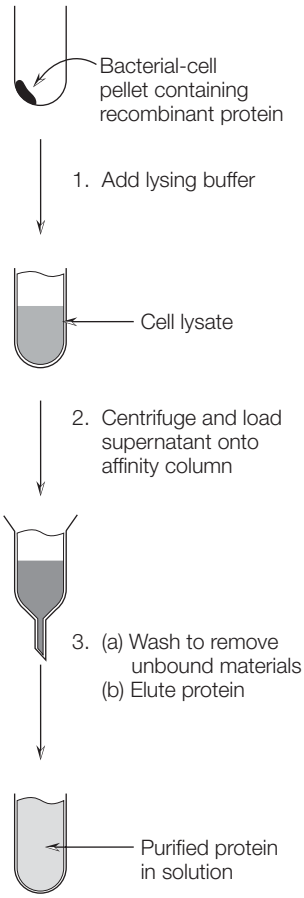

FIGURE 11.4
Purification of a His-tagged protein using immobilized metal-affinity chromatography. See text for details. www.clontech.com.

An extremely useful application of recombinant DNA technology is the ability to modify protein structures by changing the identity of amino acid residues. This provides a powerful tool for monitoring which amino acid residues are important in a protein's biological function. Amino acid changes may be made by a technique called **site-directed mutagenesis,** where an altered gene carrying the message for different amino acids is inserted into a recombinant DNA.

STUDY EXERCISE 11.3 Genetic Engineering and Chromatography

What kind of chromatography is used to separate His-tagged proteins?

Gene Expression in Eukaryotic Cells

Expression of a eukaryotic gene in a bacterial host cell often leads to many technical problems. Among these problems are:

1. Bacterial cells are unable to carry out gene splicing processes that remove introns from the eukaryotic mRNA.
2. Bacterial cells do not recognize and respond to eukaryotic transcriptional and translational regulatory elements.
3. Bacterial cells do not have the enzyme systems to direct post translational modifications of proteins, as eukaryotic cells are capable of doing. These protein modifications include chemical changes such as addition of carbohydrates (glycosylation), formation of correct disulfide bonds, proteolytic cleavage of inactive precursors, phosphorylation of amino acid hydroxyl groups (tyrosine, serine, etc.), and other changes that assist the protein to fold into its native conformation and become biologically active.

The challenges of incorporating all of these messages into an expression vector for bacterial cells are great, if not insurmountable. The best approach is to use eukaryotic cells such as yeast as hosts.

The many challenges presented above, such as preparing complex recombinant DNA with all the proper signals and messages, and maintaining and using bacterial and eukaryotic host-cell cultures, have encouraged scientists to search for more efficient systems for producing proteins.

cDNA

One procedure for making recombinant proteins that is growing in popularity is the use of **complementary DNA (cDNA).** All of the proteins in a cell are made from their specific mRNAs by translation, so it would seem logical to isolate the mRNA associated with a specific protein and then use it to make that protein. However, mRNA is too difficult to purify and too unstable to use directly for protein synthesis. Instead, the mRNA is converted into a DNA form using the RNA-viral enzyme system **reverse transcriptase (RT)**. RT is able to read an RNA template and catalyze the synthesis of a complementary strand of DNA (cDNA). (RT is the enzyme that retroviruses use to copy their genes, originally in the form of RNA, into DNA, in order to "take over" a cell or organism.) Researchers now can isolate and purify the mRNA associated with the desired protein, transform it into cDNA with RT, and insert the cDNA into a suitable vector for cloning.

Cell-Free Systems

Another promising alternative for protein production is to use cell-free transcription and translation systems for expression of the recombinant DNA. Two *in vitro* systems currently being used are wheat-germ extracts and rabbit reticulocyte lysates. The *in vitro* systems require the addition of the isolated mRNA fragment that contains the coded message for the protein, as well as amino acids, tRNAs, and ribosomes.

Protein Expression Using Synthesized Genes

Producing large quantities of a protein from naturally-occurring gene sequences as described above is not always efficient. It can be a challenging, time consuming, and costly process. Some of the most valuable and desired proteins needed by biochemists are often expressed in wild-type cells, but in very low amounts. Biochemists have begun to experiment with synthesized genes in which the three

nucleotides in the codons are revised or rewritten with the hope of optimizing protein expression. How is this possible? Recall that the genetic code is degenerate. Almost all of the 20 amino acids have at least two codons (Leu has six); thus, different codons can specify the same amino acid. For example, a codon for Phe, U-U-U, could be changed to U-C-U, which would also specify Phe. Three of the codons signal termination, which leaves 61 of the 64 total codons to specify amino acids. Thus, it is possible to change about a third (20/61) of the nucleotides and still produce the same protein. The number of alternate gene sequences that will produce the same protein is enormous. According to Wikipedia, there are 10^{150} codon combinations for an average-sized protein of 300 amino acids. It has been shown experimentally that some combinations lead to better protein yields than others. Thus, modifying a synthetic gene can potentially enhance protein expression. Synthetic biology companies including DNA2.0, PolyQuant (Entelechon), GENEWIZ, GENEART, GenScript, Epoch Bioloabs, and others are developing computer software based on new design algorithms to predict the set of codons most effective for protein expression. Gene optimization can offer protein yields up to at least 10 times higher than the more conventional procedures. Finding just the right gene, however, requires extensive computer analysis. A major goal of these investigations is to determine the gene sequence characteristics that have a significant influence on protein expression.

C. PROTEIN CHARACTERIZATION

Now that the sought-after protein has been obtained in a highly purified state, it is usually suitable for further characterization and study. The characterization techniques applied to the protein depend on what is already known about the molecule and what kind of protein it is. One is, of course, interested in knowing the biological role the protein plays in the organism; however, such a determination must wait until more is known about its physical and chemical properties. Here is an outline of procedures one should apply to the protein for general characterization and for specific analysis. References are made to coverage of the characterization procedures in this book (see Appendix I for a table of useful Web sites, p. 331).

- Concentration of protein solutions—general assays like the Bradford, Lowry, spectrophotometric, etc. (see Chapter 3, Section B, p. 67).
- Purity of protein—PAGE and SDS-PAGE (see Chapter 6, Section B, p. 167), HPLC (see Chapter 5, Section F, p. 140), capillary electrophoresis (see Chapter 6, Section B, p. 185), isoelectric focusing (see Chapter 6, Section B, p. 182), and 2D electrophoresis (see Chapter 6, Section B, p. 184).
- Molecular weight, subunit structure—gel-filtration chromatography (see Chapter 5, Section E, p. 132), SDS-PAGE (see Chapter 6, p. 174), and MS (see Chapter 7, Section D, p. 230).
- Identity and structure determination (including cofactors, coenzymes, metal ions, carbohydrates, etc.)—UV/VIS spectroscopy (see Chapter 7, Section A, p. 202), NMR spectroscopy (see Chapter 7, Section C, p. 225), MS (see Chapter 7, Section D, p. 230), X-ray diffraction (see Chapter 7, Section E, p. 233), and protein databases (Table 11.4).
- Sequence of amino acids in the protein and of nucleotides in the coding gene—Web sites, databases (see Table 11.4 and Chapters 2, 9, and 10). For

TABLE 11.4 Protein Database Resources

Name	URL
ExPASy—UniProt Knowledgebase: Swiss-Prot and TrEMBL	http://ca.expasy.org/sprot
PIR—Protein Information Resource	http://pir.georgetown.edu
RCSB Protein Data Bank (PDB)	http://www.rcsb.org
The National Center for Biotechnology	http://www.ncbi.nlm.nih.gov
The European Bioinformatics Institute	http://www.ebi.ac.uk

analysis of the amino acid sequence (primary structure), see this chapter, Section D.

- Biological function:

  Enzyme–substrate specificity, kinetics, inhibition, regulation (see Chapter 8, Section B, p. 250).

  Transport protein–ligand binding (fluorescence spectroscopy, see Chapter 7, Section B, p. 220, and Chapter 8, Section A, p. 239).

  Other type of protein–procedures depend on function.

- Proteomics: identity of unknown proteins by amino acid composition and prediction of structure (see Web sites and databases in Table 11.4 and Chapter 2), analysis by 2D electrophoresis (see Chapter 6, Section B, p. 184), interactions with other proteins—MALDI-MS (see Chapter 7, Section D, p. 230).

D. DETERMINATION OF PRIMARY STRUCTURE

Structural elucidation of natural macromolecules is an important step in understanding the relationships between the chemical properties of a biomolecule and its biological function. The techniques used in organic structure determination (NMR, IR, UV, and MS; Chapter 7) are quite useful when applied to biomolecules, but the unique nature of natural molecules also requires the application of specialized chemical procedures. Proteins, polysaccharides, and nucleic acids are polymeric materials, each composed of hundreds or sometimes thousands of monomeric units (amino acids, monosaccharides, and nucleotides, respectively). But there is only a limited number of these types of units from which the biomolecules are synthesized. For example, only 20 different amino acids are found in proteins, but these different amino acids may appear several times in the same protein molecule. Therefore, the structure of a peptide or protein can be recognized only after the amino acid composition ***and*** sequence have been determined.

Amino Acid Composition

The amide bonds in peptides and proteins can be hydrolyzed in a strong acid or base. Treatment of a peptide or protein under either of these conditions yields a mixture of the constituent amino acids. Neither acid- nor base-catalyzed hydrolysis of a protein leads to ideal results because both tend to destroy some constituent amino acids. Acid-catalyzed hydrolysis destroys tryptophan and cysteine, causes some loss of serine and threonine, and converts asparagine and

glutamine to aspartic acid and glutamic acid, respectively. Base-catalyzed hydrolysis leads to destruction of serine, threonine, cysteine, and cystine, and also results in racemization of the free amino acids. Because acid-catalyzed hydrolysis is less destructive, it is often the method of choice. The hydrolysis procedure consists of dissolving the protein sample in aqueous acid, usually 6 *M* HCl, and heating the solution in a sealed, evacuated vial at 100°C for 12 to 24 hours.

Now that the free amino acids present in a peptide or protein have been released by hydrolysis, they must be separated and identified. The most versatile, economical, and convenient techniques for separation are based on chromatographic methods (see Chapter 5 for a review, p. 118). Earlier workers relied on paper chromatography (PC) and thin-layer chromatography (TLC); however, more sensitive techniques are now available. Automated ion-exchange chromatography (amino acid analyzers), capillary electrophoresis (CE), and high-performance liquid chromatography (HPLC) are now powerful tools for the qualitative and quantitative analysis of amino acids and their derivatives. Because there is still some demand for rapid, qualitative, routine analysis of amino acids, thin-layer and paper chromatographic methods are still being developed and improved. Amino acids and their derivatives may be analyzed directly by PC and TLC without further derivatization. Several support materials are available, but most analyses are carried out on silica gel or cellulose. The free amino acids can be detected on the developed chromatographic plates by reaction with ninhydrin. A pink-purple color is obtained for all amino acids except proline. A yellow color develops with proline.

High-performance liquid chromatographic techniques have been successfully applied to the analysis of phenylthiohydantoin, 2,4-dinitrophenyl, and dansyl amino acid derivatives.

If only very small samples of amino acids are available for analysis, fluorescence is used for detection. One of the most sensitive methods of microanalysis is based on the reaction of amino acids with *o*-phthalaldehyde and β-mercaptoethanol (Equation 11.1). The isoindole derivative is fluorescent, and amounts as small as 10^{-12} mole may be measured.

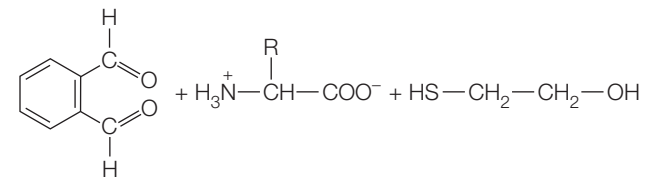

o-Phthalaldehyde Amino acid β-Mercaptoethanol **(Eq. 11.1)**

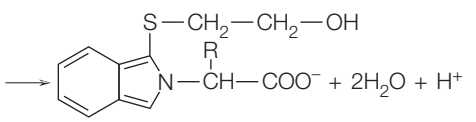

Isoindole derivative of amino acid

Another important derivatizing reagent for amino acids is 9-fluorenylmethyl chloroformate (FMOC) (Equation 11.2). This reagent has the advantages that: (1) the reaction with amino acids is very fast, occurring in less than 1 min; (2) the

products are stable for long periods of time; (3) the derivatives can be separated by reversed-phase column chromatography and capillary electrophoresis procedures; and (4) the products are fluorescent, allowing for easy detection.

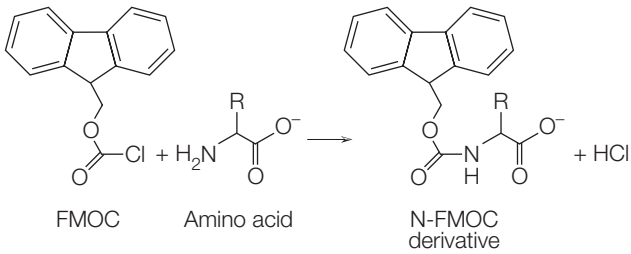

(Eq. 11.2)

Sequential Analysis

Sequential analysis of amino acids in purified peptides and proteins is best initiated by analysis of the terminal amino acids. A peptide has one amino acid with a free α amino group (NH_2-terminus) and one amino acid with a free α carboxyl group (COOH-terminus). Many chemical methods have been developed to selectively tag and identify these terminal amino acids.

N-Terminal Analysis

NH_2-terminal amino acid analysis is achieved by the use of: (1) 2,4-dinitrofluorobenzene (Sanger reagent), (2) 1-dimethylaminonaphthalene-5-sulfonyl chloride (dansyl chloride), or (3) phenylisothiocyanate (Edman reagent). Figure 11.5 shows the structures of these reagents. Although the chemistry is different for

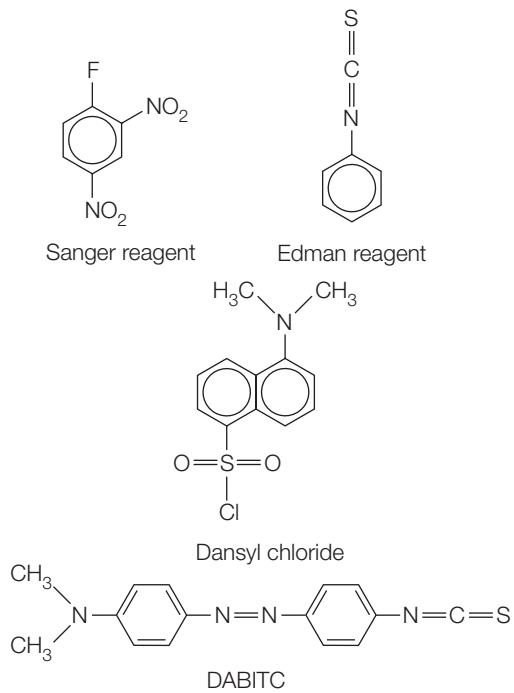

FIGURE 11.5
Reagents useful in amino-terminal analysis of proteins.

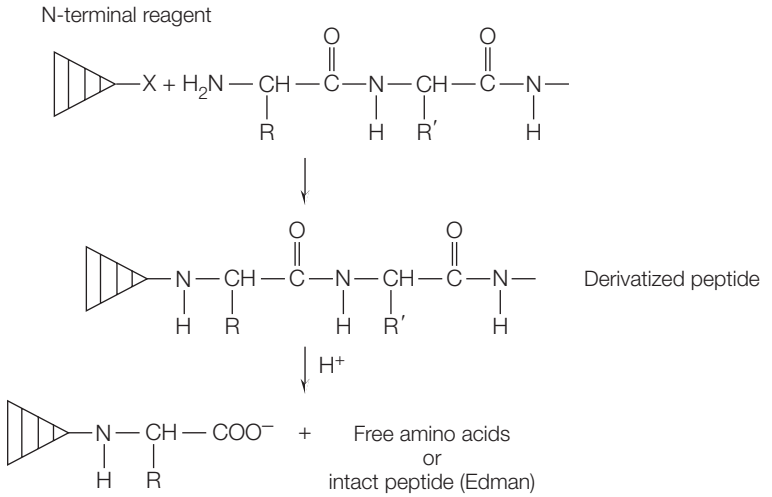

FIGURE 11.6
Scheme to show analysis of amino-terminal residue of protein.

each of these reagents, the same general concept applies. These compounds react with the NH_2-terminal amino acid of a peptide or protein to produce covalent derivatives that are stable to acid-catalyzed hydrolysis. The process is illustrated in Figure 11.6. The mixture of modified amino acid and free amino acids is separated, and the NH_2-terminal amino acid is identified by thin-layer, paper, or high-performance liquid chromatography; or capillary electrophoresis. The first NH_2-terminal method to be widely used was based on the Sanger reagent, which produces yellow-colored 2,4-dinitrophenyl (DNP) derivatives of NH_2-terminal amino acids. The Sanger method has several disadvantages, including poor yield of the DNP-peptide derivative, low sensitivity of analysis, and instability of some DNP-amino acids during acid hydrolysis. The dansyl chloride method has largely replaced the Sanger method because very sensitive fluorescence techniques may be used for detection and analysis of the dansyl amino acid derivatives, and the derivatives are more stable during acid hydrolysis.

Edman Sequence Method

Even more versatile than the dansyl method is the Edman method (Figure 11.7). The NH_2-terminal amino acid is removed as its phenylthiohydantoin (PTH) derivative under anhydrous acid conditions, while all other amide bonds in the peptide remain intact. The derivatized amino acid is then extracted from the reaction mixture and identified by paper, thin-layer, or high-performance liquid chromatography. The intact peptide (minus the original NH_2-terminal amino acid) may be isolated and recycled by reaction with phenylisothiocyanate. Since this method is nondestructive to the remaining peptide (aqueous acid hydrolysis is not required) and results in good yield, it can be used for stepwise sequential analysis of peptides.

Microsequencing

The development of new chemical reagents and instrumentation has now made it possible to achieve end-group analysis and sequencing on extremely small samples of protein (microsequencing). By using a chromophoric derivative of

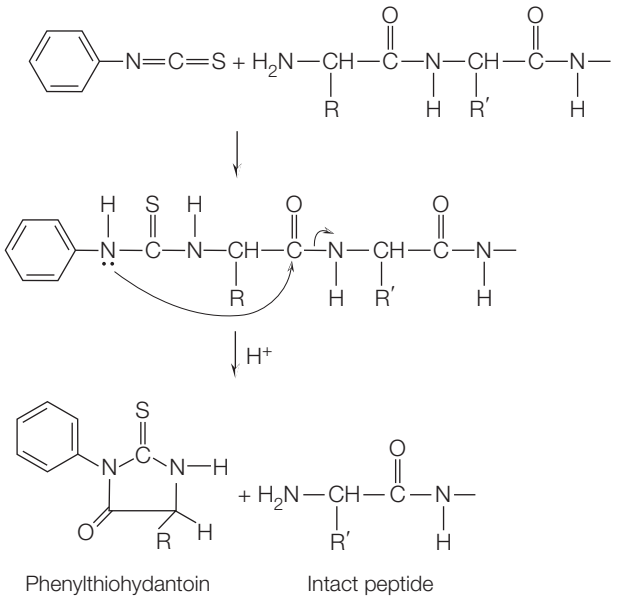

FIGURE 11.7 The Edman method for analysis of proteins.

phenylisothiocyanate, 4-*N*,*N*-dimethylaminoazobenzene-4′-isothiocyanate (DABITC; see Figure 11.5), and analyzing the derivatives by HPLC, it is possible to sequence peptides and proteins at the nanomolar level.

C-Terminal Analysis

The COOH-terminal amino acid of a peptide or protein may be analyzed by enzymatic methods. The method of choice is peptide hydrolysis catalyzed by carboxypeptidases A and B. These two enzymes catalyze the hydrolysis of amide bonds at the COOH-terminal end of a peptide (Equation 11.3), since carboxypeptidase action requires the presence of a free α carboxyl group in the substrate.

Carboxypeptidase A catalyzes the hydrolysis of carboxyl-terminal acidic or neutral amino acids; however, the rate of hydrolysis depends on the structure of the side chain R′. Amino acids with nonpolar aryl or alkyl side chains are cleaved more rapidly. Carboxypeptidase B is specific for the hydrolysis of basic COOH-terminal amino acids (lysine and arginine). Neither peptidase functions if proline occupies the COOH-terminal position or is the next to last amino acid.

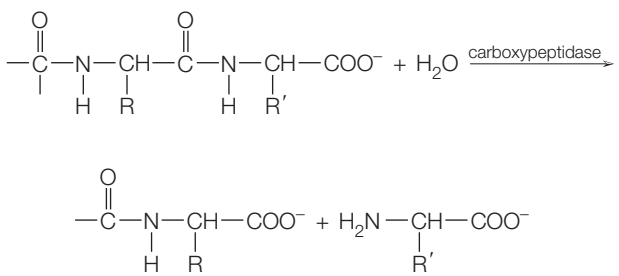

(Eq. 11.3)

Sequencing DNA Instead of the Protein

New techniques for protein sequence analysis have emerged from recombinant DNA research. It is now possible to clone long stretches of DNA. Genes carrying the message for selected proteins can be isolated in quantities sufficient for nucleotide sequencing. By using the genetic code, the structure of the protein product from a specific gene can be deduced from the sequence of nucleotides in the DNA. Techniques for DNA sequencing are faster and more reliable than for protein sequencing; however, determining protein sequences indirectly from DNA sequences will never completely replace direct analysis of the protein product. An amino acid sequence determined from DNA will be that of the initial protein product synthesized. That initial form (which is often not biologically active) is changed by post translational modification processes. These changes may include removal of short stretches of amino acid residues, formation of disulfide bonds, and chemical changes on some amino acid residues.

Study Problems

1. A solution of a purified protein yielded an A_{280}/A_{260} of 1.3. Estimate the protein concentration of the solution.
2. Describe the action of the enzyme lysozyme in breaking bacterial cells for protein isolation and purification.
3. What amino acid residues in a protein absorb light of 280 nm?
4. Use a flowchart format to show how you would isolate a protein from an inclusion body.
5. A protein you wish to study is present in the mitochondria of the cell. Show how you would use fractional centrifugation to isolate mitochondria to begin purification of the protein.
6. When would you use the technique of isoelectric focusing in the isolation and characterization of a protein?
7. What type of electrophoresis would be better to study the subunit structure of a protein, PAGE or SDS-PAGE? Explain.
8. During the expression of a protein in a bacterial host cell, what are some of the advantages of fusing a natural, bacterial protein to the "foreign" protein?
9. When the histidine-tagged protein procedure is used for purification, the expressed protein is recovered from an affinity column by eluting with a solution of imidazole. What atoms of imidazole displace the protein by binding to nickel?
10. Use a protein database to find the primary structure of the active form of human insulin (51 amino acids).

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http://www.piercenet.com
A discussion on protein purification.

http://www.promega.com
A discussion of the MagneHis Protein Purification System.

Additional Web sites for this chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

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APPENDIX I

List of Software Programs and Web Sites Useful for Each Chapter

This table lists Web sites that are particularly relevant to specific chapters. The list is not all-inclusive, but it does include popular and especially helpful URLs. Individual chapters also contain detailed lists of associated Web sites. Additional Web sites for each chapter are available on the book's Companion Website, which can be found at http://www.chemplace.com.

Chapter No.	Name	Description	URL
1	Sigma-Aldrich	MSDS	www.sigma-aldrich.com
1	Swarthmore College	Scientific posters	http://www.swarthmore.edu/NatSci/courrin1/posteradvice.htm
1-3	Rainin	Pipetting	http://www.rainin.com
1-3	Graphpad	Statistics	http://www.graphpad.com/prism/Prism.htm
1-3	Journal of Chemical Education Resource Shelf	List of all current biochemistry textbooks	http://www.umsl.edu/divisions/artscience/chemistry/books/welcome.html
1-3	ChemDraw	Chemical structure drawing program	http://www.cambridgesoft.com
1-11	Intute	Best Web sites	http://www.intute.ac.uk/biologicalsciences
1-11	BioChemWeb	Biochemistry library	http://www.biochemweb.org
2-11	Protocol-Online	Your lab's reference book	http://www.protocol-online.org
2-11	Protein Data Bank (PDB)	Protein structures determined by X-ray and NMR	http://www.rcsb.org/pdb
2-11	ChemBioFinder	Life science solutions	http://www.chembiofinder.com
2-11	NCBI Molecules to Go	Structures of biomolecules	http://molbio.info.nih.gov.cgi-bin/pdb
2-11	PyMol Molecular Viewer	Structures of biomolecules	http://pymol.org
2-11	Chimera Molecular Modeling System (UCSF)	Advanced molecular modeling	http://www.cgl.ucsf.edu/chimera
2-11	Biomolecules Alive	Instructional material	http://www.biomoleculesalive.org
2-11	Entrez Browser of NCBI	Database searching including PubMed literature	http://www.ncbi.nlm.nih.gov/Entrez

(continued)

Chapter No.	Name	Description	URL
2-11	MEDLINE (PubMed)	U.S. National Library of Medicine	http://www.nlm.nih.gov
2-11	International Union of Biochemistry and Molecular Biology (IUBMB)	Nomenclature	http://www.chem.qmul.ac.uk/iubmb
7	Biological Magnetic Resonance Data Bank	NMR data of biomolecules	http://bmrb.wisc.edu
7	Science of Spectroscopy	Spectroscopy applications and techniques	http://www.scienceofspectroscopy.info/index.htm
8	DynaFit	Ligand binding	http://www.biokin.com
8	SigmaPlot	Enzyme kinetics module	http://www.sigmaplot.com/products/sigmaplot/enzyme-mod.php
8	Enzyme Structures Database	Enzyme structures in Protein Data Bank	http://www.biochem.ucl.ac.uk/bsm/enzymes/index.html
8-11	IUBMB Enzyme List	Catalog of enzymes	http://www.chem.qmul.ac.uk/iubmb/enzyme
8-11	Worthington Enzyme Manual	Properties of enzymes	http://www.worthington-biochem.com/index/manual/html
8-11	BRENDA	A comprehensive enzyme information system	http://www.brenda-enzymes.info
9-10	European Bioinformatics Institute (EBI)	DNA sequences	http://www.ebi.ac.uk
9-10	GenBank of the NCBI	Nucleotide sequence database	http://www.ncbi.nlm.nih.gov/Genbank
9-10	EMBL	Nucleotide sequence database	http://www.ebi.ac.uk
9-10	The Institute for Genomic Research	Collection of genomic databases	http://www.ebi.ac.uk/genomes/index.html
9-11	Enzyme Database of ExPASy	Enzyme names and numbers	http://www.expasy.ch/enzyme
9-11	The Broad Institute of MIT and Harvard	Genomics	http://www.broadinstitutes.org
10	REBASE-The Restriction Enzyme Database	Restriction enzyme directory and action	http://rebase.neb.com
10	Fermentas	Restriction enzymes	http://www.fermentas.com

(continued)

Chapter No.	Name	Description	URL
11	Munich Information Center for Protein Sequences (MIPS)	Protein sequences	http://www.helmholtz-muenchen.de/en/mips
11	Protein Information Resource (PIR)	Database searching for proteins	http://pir.georgetown.edu
11	Swiss-Protein	Protein sequences	http://ca.expasy.org/sprot

APPENDIX II

Properties of Common Acids and Bases

Compound	Formula	Molecular Weight	Specific Gravity	% by Weight	Molarity (*M*)
Acetic acid, glacial	CH_3COOH	60.1	1.05	99.5	17.4
Ammonium hydroxide	NH_4OH	35.0	0.89	28	14.8
Formic acid	HCOOH	46.0	1.20	90	23.4
Hydrochloric acid	HCl	36.5	1.18	36	11.6
Nitric acid	HNO_3	63.0	1.42	71	16.0
Perchloric acid	$HClO_4$	100.5	1.67	70	11.6
Phosphoric acid	H_3PO_4	98.0	1.70	85	18.1
Sulfuric acid	H_2SO_4	98.1	1.84	96	18.0

APPENDIX III

Properties of Common Buffer Compounds

Compound	Abbreviation	Molecular Weight	(20°C) pK_1	pK_2	pK_3	pK_4
N-(2-Acetamido)-2-aminoethanesulfonic acid	ACES	182.2	6.9	–	–	–
N-(2-Acetamido)-2-iminodiacetic acid	ADA	212.2	6.60	–	–	–
Acetic acid	–	60.1	4.76	–	–	–
Arginine	Arg	174.2	2.17	9.04	12.48	–
Barbituric acid	–	128.1	3.79	–	–	–
N,N-bis (2-Hydroxyethyl)-2-aminoethane-sulfonic acid	BES	213.1	7.15	–	–	–
N,N-bis (2-Hydroxyethyl)glycine	Bicine	163.2	8.35	–	–	–
Boric acid	–	61.8	9.23	12.74	13.80	–
Citric acid	–	210.1	3.10	4.75	6.40	–
Ethylenediaminetetraacetic acid	EDTA	292.3	2.00	2.67	6.24	10.88
Formic acid	–	46.03	3.75	–	–	–
Fumaric acid	–	116.1	3.02	4.39	–	–
Glycine	Gly	75.1	2.45	9.60	–	–
Glycylglycine	–	132.1	3.15	8.13	–	–
N-2-Hydroxyethylpiperazine-*N*′-2-ethanesulfonic acid	HEPES	238.3	7.55	–	–	–
N-2-Hydroxyethylpiperazine-*N*′-3-propanesulfonic acid	HEPPS	252.3	8.0	–	–	–
Histidine	His	209.7	1.82	6.00	9.17	–
Imidazole	–	68.1	6.95	–	–	–
2-(*N*-Morpholino) ethanesulfonic acid	MES	195	6.15	–	–	–
3-(*N*-Morpholino) propanesulfonic acid	MOPS	209.3	7.20	–	–	–
Phosphoric acid	–	98.0	2.12	7.21	12.32	–
Succinic acid	–	118.1	4.18	5.60	–	–
3-Tris (hydroxymethyl) aminopropanesulfonic acid	TAPS	243.2	8.40	–	–	–

(continued)

Compound	Abbreviation	Molecular Weight	(20°C) pK_1	pK_2	pK_3	pK_4
N-Tris (hydroxymethyl)methyl-2-aminoethanesulfonic acid	TES	229.2	7.50	–	–	–
N-Tris (hydroxymethyl)methylglycine	Tricine	179	8.15	–	–	–
Tris (hydroxymethyl)aminomethane	Tris	121.1	8.30	–	–	–

APPENDIX IV

pK_a Values and pH_I Values of Amino Acids

Name	Abbreviations		pK_1 (α-carboxyl)	pK_2 (α-amino)	pK_R (side chain)	pH_I
Alanine	Ala	A	2.3	9.7	–	6.0
Arginine	Arg	R	2.2	9.0	12.5	10.8
Asparagine	Asn	N	2.0	8.8	–	5.4
Aspartate	Asp	D	2.1	9.8	3.9	3.0
Cysteine	Cys	C	1.7	10.8	8.3	5.0
Glutamate	Glu	E	2.2	9.7	4.3	3.2
Glutamine	Gln	Q	2.2	9.1	–	5.7
Glycine	Gly	G	2.3	9.6	–	6.0
Histidine	His	H	1.8	9.2	6.0	7.6
Isoleucine	Ile	I	2.4	9.7	–	6.1
Leucine	Leu	L	2.4	9.6	–	6.0
Lysine	Lys	K	2.2	9.0	10.5	9.8
Methionine	Met	M	2.3	9.2	–	5.8
Phenylalanine	Phe	F	1.8	9.1	–	5.5
Proline	Pro	P	2.0	10.6	–	6.3
Serine	Ser	S	2.2	9.2	–	5.7
Threonine	Thr	T	2.6	10.4	–	6.5
Tryptophan	Trp	W	2.4	9.4	–	5.9
Tyrosine	Tyr	Y	2.2	9.1	10.1	5.7
Valine	Val	V	2.3	9.6	–	6.0

APPENDIX V

Molecular Weight of Some Common Proteins

Name (Source)	Molecular Weight
Albumin (bovine serum)	65,400
Albumin (egg white)	45,000
Carboxypeptidase A (bovine pancreas)	35,268
Carboxypeptidase B (porcine)	34,300
Catalase (bovine liver)	250,000
Chymotrypsinogen (bovine pancreas)	23,200
Cytochrome *c*	13,000
Hemoglobin (bovine)	64,500
Insulin (bovine)	5,700
α-Lactalbumin (bovine milk)	14,200
Lysozyme (egg white)	14,600
Myoglobin (horse heart)	16,900
Pepsin (porcine)	35,000
Peroxidase (horseradish)	40,000
Ribonuclease I (bovine pancreas)	12,600
Trypsinogen (bovine pancreas)	24,000
Trypsin (bovine pancreas)	23,800
Tyrosinase (mushroom)	128,000
Uricase (pig liver)	125,000

APPENDIX VI

Common Abbreviations Used in This Text

A	adenine or absorbance
A	absorbance
AMP, ADP, ATP	adenosine mono-, di-, or triphosphate
AP	alkaline phosphatase
BCA	bicinchoninic acid
bp	base pairs
Bq	Becquerel
BSA	bovine serum albumin
C	cytosine
cDNA	complementary DNA
CE	capillary electrophoresis
Ci	Curie
CM cellulose	carboxymethyl cellulose
COSY	correlation spectroscopy
CPM	counts per minute
D	dalton
DANSYL	1,1-dimethylaminonaphthalene-5-sulfonyl chloride
2-DE	two-dimensional electrophoresis
DEAE cellulose	diethylaminoethyl cellulose
DNA	deoxyribonucleic acid
DNase	deoxyribonuclease
DNP	dinitrophenyl
DOPA	dihydroxyphenylalanine
E	absorption coefficient
EDTA	ethylenediaminetetraacetic acid
ELISA	enzyme-linked immunosorbent assay
ELN	electronic lab rolebook
ESI	electrospray ionization
EtBr	ethidium bromide
FAB	fast-atom bombardment
FAD (H_2)	flavin adenine dinucleotide (reduced form)

(continued)

FAME	fatty-acid methyl ester
FMN (H_2)	flavin mononucleotide (reduced form)
FOCSY	foldover-corrected spectroscopy
FPLC	fast-protein liquid chromatography
FT	Fourier transform
g	gravitational force
G	guanine
GC	gas chromatography
GMP, GDP, GTP	guanosine mono-, di-, or triphosphate
Hb	hemoglobin
HMIS	Hazardous Materials Identification System
HPLC	high-performance liquid chromatography
HRP	horseradish peroxidase
HTML	hypertext markup language
IE	immunoelectrophoresis
IEF	isoelectric focusing
IHP	inositol hexaphosphate
IgG	immunoglobulin gamma
IMAC	immobilized metal-ion affinity chromatography
IR	infrared
ISP	Internet service provider
IVS	intervening sequence
kb	kilobase pairs
L	ligand
M	macromolecule
M	molarity
MALDI	matrix-assisted laser desorption ionization
MS	mass spectrometry
MSDS	material safety data sheet
NAD(H)	nicotinamide adenine dinucleotide (reduced form)
NADP(H)	nicotinamide adenine dinucleotide phosphate (reduced form)
NMR	nuclear magnetic resonance
NOESY	nuclear Overhauser effect spectroscopy
OSHA	Occupational Safety and Health Administration
PAGE	polyacrylamide gel electrophoresis
PC	paper chromatography

PCR	polymerase chain reaction
PEG	polyethylene glycol
PFGE	pulsed-field gel electrophoresis
PMT	photomultiplier tube
POPOP	1,4-bis[5-phenyl-2-oxazolyl]benzene
PPO	2,5-diphenyloxazole
PVDF	polyvinyldifluoride
RCF	relative centrifugal force
R_f	relative mobility in chromatography
RFLP	restriction fragment length polymorphism
RIA	radioimmunoassay
RNA	ribonucleic acid
RNase	ribonuclease
RT	reverse transcriptase
s	sedimentation coefficient
S	Svedberg unit (10^{-13} *s*)
SDS	sodium dodecyl sulfate
SECSY	spin-echo correlation spectroscopy
SMP	submitochondrial particles
T	thymine
TAG	triacylglycerol
TEMED	*N, N*, *N*′, *N*′-tetramethylethylenediamine
TLC	thin-layer chromatography
TOCSY	2-D total correlation spectroscopy
TOF	time of flight
Tris	tris(hydroxymethyl)aminomethane
TROSY	transverse relaxation-optimized spectroscopy
U	uracil
URL	uniform resource locator
UV	ultraviolet
VIS	visible
WWW	World Wide Web

APPENDIX VII

Units of Measurement

The International System of Units (SI)		
Quantity	**Unit**	**Abbreviation**
length	meter	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electric current	ampere	A
amount of substance	mole	mol
radioactivity	becquerel	Bq
volume	liter	L

Metric Prefixes		
Name	**Abbreviation**	**Multiplication Factor (relative to "1")**
atto	a	10^{-18}
femto	f	10^{-15}
pico	p ($\mu\mu$)	10^{-12}
nano	n (mμ)	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deca	da	10
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}

Units of Length		
Name	**Abbreviation**	**Multiplication Factor (relative to meter)**
Kilometer	km	10^3
meter	m	1
centimeter	cm	10^{-2}
millimeter	mm	10^{-3}
micrometer	μm	10^{-6}
nanometer	nm	10^{-9}
Angstrom	Å	10^{-10}

Units of Mass		
Name	**Abbreviation**	**Multiplication Factor (relative to gram)**
kilogram	kg	10^3
gram	g	1
milligram	mg	10^{-3}
microgram	μg	10^{-6}
nanogram	ng	10^{-9}

Units of Volume		
Name	**Abbreviation**	**Multiplication Factor (relative to liter)**
liter	L	1
deciliter	dL	10^{-1}
milliliter	mL	10^{-3}
microliter	μL	10^{-6}

APPENDIX VIII

Table of the Elements*

	Symbol	Atomic No.	Atomic Mass
Actinium	Ac	89	227.0278
Aluminum	Al	13	26.98154
Americium	Am	95	[243]†
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.9216
Astatine	At	85	[210]
Barium	Ba	56	137.33
Berkelium	Bk	97	[247]
Beryllium	Be	4	9.01218
Bismuth	Bi	83	208.9804
Bohrium	Bh	107	[264]
Boron	B	5	10.81
Bromine	Br	35	79.904
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Californium	Cf	98	[251]
Carbon	C	6	12.011
Cerium	Ce	58	140.12
Cesium	Cs	55	132.9054
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copernicium	Cn	112	[285]
Copper	Cu	29	63.546
Curium	Cm	96	[247]
Darmstadtium	Ds	110	[281]
Dubnium	Db	105	[262]
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	[252]

	Symbol	Atomic No.	Atomic Mass
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	[257]
Fluorine	F	9	18.998403
Francium	Fr	87	[223]
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.9665
Hafnium	Hf	72	178.49
Hassium	Hs	108	[270]
Helium	He	2	4.00260
Holmium	Ho	67	164.9304
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.9045
Iridium	Ir	77	192.22
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.9055
Lawrencium	Lr	103	[262]
Lead	Pb	82	207.2
Lithium	Li	3	6.941
Lutetium	Lu	71	174.967
Magnesium	Mg	12	24.305
Manganese	Mn	25	54.9380
Meitnerium	Mt	109	[268]
Mendelevium	Md	101	[258]
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.179
Neptunium	Np	93	237.0482
Nickel	Ni	28	58.70
Niobium	Nb	41	92.9064

(continued)

	Symbol	Atomic No.	Atomic Mass
Nitrogen	N	7	14.0067
Nobelium	No	102	[259]
Osmium	Os	76	190.2
Oxygen	O	8	15.9994
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97376
Platinum	Pt	78	195.09
Plutonium	Pu	94	[244]
Polonium	Po	84	[209]
Potassium	K	19	39.0983
Praseodymium	Pr	59	140.9077
Promethium	Pm	61	[145]
Protactinium	Pa	91	231.0359
Radium	Ra	88	226.0254
Radon	Rn	86	[222]
Rhenium	Re	75	186.207
Rhodium	Rh	45	102.9055
Rubidium	Rb	37	85.4678
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	[261]
Samarium	Sm	62	150.4
Scandium	Sc	21	44.9559
Seaborgium	Sg	106	[266]
Selenium	Se	34	78.96
Silicon	Si	14	28.0855
Silver	Ag	47	107.868
Sodium	Na	11	22.98977
Strontium	Sr	38	87.62
Sulfur	S	16	32.06
Tantalum	Ta	73	180.9479
Technetium	Tc	43	[98]
Tellurium	Te	52	127.60
Terbium	Tb	65	158.9254
Thallium	Tl	81	204.37
Thorium	Th	90	232.0381

	Symbol	Atomic No.	Atomic Mass
Thulium	Tm	69	168.9342
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.029
Vanadium	V	23	50.9415
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.9059
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22

*Atomic masses are based on carbon-12.

†*A value given in brackets denotes the mass number of the longest-lived or best-known isotope.*

APPENDIX IX

Answers to Odd-Numbered Study Problems

Chapter 1

1. Personal Protection Index for glacial acetic acid: splash goggles, gloves, synthetic apron, and vapor respirator.
3. Every biochemistry lab is different, so a general picture is not possible. You should know where safety features are present in your lab.
5. Water purified by ion exchange will contain organic molecules that are washed from the ion-exchange resin. These contaminants will increase the UV-absorbance properties of the water.
7. 100 m*M*.
9. 58.5 m*M*; 20 mg/mL; 2%.
11. **a.** Sample mean = +3.21°.
    b. Standard deviation = ±0.043°.
    c. 95% confidence limits = +3.21° ± 0.03° at a probability of 0.05.
13. Use the graduated cylinder to measure and pour 46.1 mL (1 mole) of 100% ethanol into the volumetric flask. Add water to the etched mark and mix well.

Chapter 2

1. **a.** The enzyme tyrosinase is found in a wide variety of plants, animals, and fungal species.
   b. Copper.
   c. Inhibitors: benzoic acid, cyanide, and other compounds that complex with copper. Search for references in PubMed.
   d. Another substrate: catechol.
   e. Use PDB or other site to search for a structure.
3. Proteins purified by IMAC: histidine-tagged proteins used in recombinant protein expression (see Chapter 11, Section B, p. 319); human and bovine α-lactalbumin.
5. -A-A-G-C-T-T-; between A and A.
7. α-lactalbumin is a regulatory protein in milk that when complexed with the enzyme galactosyl transferase stimulates the synthesis of milk sugar, lactose.
9. For a start, see Chapter 11, Section B, p. 321.

Chapter 3

1. NaH_2PO_4: 0.31 mole; 37.2 g.
   Na_2HPO_4: 0.19 mole; 26.9 g.
3. Use 0.03 mole of isoelectric glycine and 0.07 mole of sodium glycinate for 1 liter of solution.
5.

Tube No.	1	2	3	4	5	6
μg IgG	0	10	20	40	80	100
A_{595}	0.0	0.05	0.10	0.20	0.40	0.50

7. 17.5 μg/mL.
9. Pure DNA has a 260/280 ratio of about 1.8. The sample is probably contaminated with protein.
11. Primarily Tyr and Trp; no.
13. A at 260 nm = 0.7; A at 280 nm = 0.39.
15. The very best protein to use as a standard is a purified preparation of the protein being assayed; however, it is often not available.
17. **a.** Citrate.
b. Imidazole.
c. Glycine.
19. 0.49/day
21. Solution B: 0.2 *M*.
Solution C: 0.02 *M*.
Solution D: 0.002 *M*.
23. 77 days.

Chapter 4

1. (a), (b), (d).
3. Hemoglobin.
5. There are four subunits each with molecular weight 10,000 and two subunits each with molecular weight 30,000.
7. Magnesium ions bind to DNA in place of smaller protons, causing the DNA to spread out and thus become less dense.
9. 125,000 $\times$ g.
11. Most mitochondria sediment at 20,000 $\times$ g.

Chapter 5

1. **a.** Asp, Gly, His.
b. Glu, Ala, Arg.
c. Glu, Phe, His.
3. Cyt *c*, myoglobin = hemoglobin, serum albumin, egg albumin, pepsinogen.
5. Myosin, catalase, serum albumin, chymotrypsinogen, myoglobin, cyt *c*.
7. Malate dehydrogenase, alcohol dehydrogenase, glucokinase.
9. A dilute solution of NAD^+ should elute the enzyme from the affinity gel.
11. Hydrogen bonding, ionic bonds, hydrophobic interactions, van der Waals forces.
13. Sephadex G-100.
15. Use PubMed or other computer bibliographic searches.

Chapter 6

1. Charge, size.
3. From top to bottom: serum albumin, egg white albumin, chymotrypsin, lysozyme.
5. The gel matrix in slab gels is more uniform than the gel in column gels, which are made individually.
7. Polyacrylamide gels may be used for nucleic acids up to 2000 base pairs.
9. Acrylamide is a potent neurotoxin, suspected carcinogen, and skin irritant. Gloves and a mask must be worn while handling it in the unpolymerized form.

Weighing and making solutions of acrylamide should be carried out in a well-ventilated hood.

11. Western blotting: used to identify a specific protein or group of proteins by immunoblotting (detection by antibodies). Southern blotting: used to identify a specific base sequence in DNA. Northern blotting: used to identify a specific base sequence in RNA.

13. Nylon membranes, because they are cationic and strongly bind acidic proteins.

15. If SDS-PAGE is used for separation, the proteins to be blotted are denatured. The antibodies used for the detection process must be able to recognize and bind to denatured proteins.

17. The protein has an abundance of nonpolar amino acid residues; thus, it will bind best to polyvinyldifluoride (PVDF) membranes, which are hydrophobic.

Chapter 7

1. **a.** X-ray.
b. Ultraviolet.
c. Visible.

3. **(1)** a.
(2) a.
(3) c.
(4) d.
(5) b.

5. (a), (b), and (d).

7. All the molecules contain alternating double bonds (are highly conjugated).

9. Fluorescing light is measured at right angles to the light irradiating the sample.

Chapter 8

1. First plot: $n = 2$; $K_f = 1.1$ mM. Second plot: $n = 2.5$; $K_f = 0.6$ mM.

3. The tryptophan residue must be close to a site on the human albumin where sugars bind. Bound sugars interact with the tryptophan.

5. The binding of the molecular probe must be reversible; the bound probe must have a different absorbance spectrum from the unbound probe.

7. From Michaelis-Menten plot: $V_{max} = 140\ \mu M$/min; $K_M = 40–45\ \mu M$.

9. Type of inhibition: competitive.

11. The rate is linear for only about 2 minutes.

13. Ionic bonding.

Chapter 9

1. DNA, which forms viscous solutions, is released from the cells into the medium.

3. SDS is a detergent that dissociates protein-lipid complexes in cell membranes.

5. The absorbance at 260 nm = 0.70.

7. It must be assumed that the blue dye marker moves faster in electrophoresis than any of the proteins or nucleic acids analyzed in the gel.

9. **a.** Lowered.
b. Lowered.
c. Lowered.
d. Probably little or no effect.

11. 30 μg/mL.

Chapter 10

1. Many plasmids contain genes that carry messages for the synthesis of proteins that protect microorganisms against antibiotics. The presence of certain antibiotics is a signal to a microorganism that more of these proteins are necessary. The microorganism responds by increasing the rate of production of plasmids.
3. Natural DNA molecules and restriction fragments are too large to penetrate polyacrylamide gels. Even gels with low percentage cross linking are not useful.
5. Restriction endonucleases require the presence of magnesium ions for activity. The quench buffer contains EDTA which complexes transition metal ions in the solution. The metal ions are no longer available for binding by the nuclease molecules and enzyme activity is inhibited.
7. (b).
9. Ten fragments.

Chapter 11

1. The protein concentration is about 1.2 mg/mL.
3. Tyrosine and tryptophan.
5. See Figure 4.11.
7. SDS-PAGE.
9. Nitrogen atoms in imidazole.

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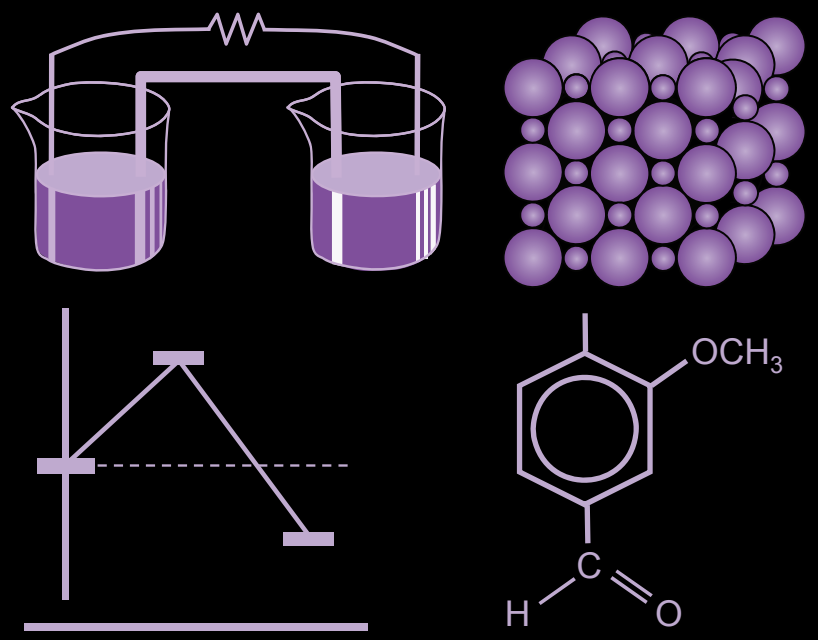

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1. Structure of Matter

Summary

Energy levels Bohr H-like atom:

$$E_n = -\frac{m_e Z^2 {q_e}^4}{8{\varepsilon_o}^2 h^2 n^2}$$

Energy levels Schrödinger equation,
Coulomb potential:

$$E_n = -\frac{Z^2 {q_e}^4 m}{(4\pi\varepsilon_o)^2 2\hbar^2 n^2}$$

Covalent bond: the co-sharing of valence electrons.

Ionic bond: the electrostatic attraction between ions formed after electrons are transferred from one atom to another.

Metallic bond: free electrons in the valence band reduce the energy of the system and so act to hold atoms together.

The electronegativity describes the relative ability of an atom, when it combines with another atom, to become “more negative” by more strongly capturing a shared electron or electron pair.

1.1 Atoms

Sixth century BC Thales of Miletos proposes that the basic element from which all things are made is water. 450 BC Empedocles teaches that all matter is composed of earth, air, water and fire. Around 400 BC, Greek philosophers (Leucippus, **Democritus**, Epicurus) proposed that if one could divide a piece of matter again and again, eventually a limit would be reached where no further subdivision could take place, this limiting amount of matter was called the **atom**. About 300 BC, **Aristotle** rejects the atomistic view and argues that matter is based upon the four basic elements of Empedocles but adds the qualities of coldness, hotness, dryness and moistness. Aristotle's considerable reputation ensured that his ideas became embodied in religious teaching for many hundreds of years.

In the fifteenth century, new advances in physics suggested that matter was made from particles, in agreement with the ancient Greek atomists. Robert **Boyle** taught that matter consists of different types of **elements** that were composed of atoms of the same type. Different elements could join together in fixed proportions to form **compounds**. Later, in 1803, John **Dalton** proposed the **atomic theory of matter** that was based on quantitative experimental evidence from the weighing of different elements in combination. He created a scale atomic mass for the different elements that were then known. Dalton's reference atom was the lightest element known, hydrogen, which was assigned an atomic mass of one. Other elements were given atomic masses according to how heavy they were compared to a hydrogen atom.

In 1807, Humphry Davy decomposed potash into sodium and potassium metals using electrolysis. In 1832, Michael **Faraday** discovered a quantitative connection between electricity and the separation of compounds into elements in electrolysis. These observations suggested that atoms themselves contain electric charge. Experiments by William Crookes demonstrated visible "cathode rays" that emanated from a negatively charged electrode (cathode) and travelled towards the positive electrode (anode) in an evacuated tube.

In 1872, **Mendeleev** arranged elements in increasing order of atomic mass and discovered that the properties of certain elements were repeated at regular intervals. When elements were ordered in columns with the atomic mass going across from left to right, and similar chemical properties going down, a **periodic table** was formed whereby, using the known elements at the time, Mendeleev was able to predict the properties of some as-yet undiscovered elements from gaps in the table.

1.2 Bohr Atom

In 1897, **Thomson** demonstrated that the rays observed to be emitted from the cathodes of vacuum tubes were in fact charged particles which he called **electrons**. Thomson proposed that atoms consisted of a positively charged sphere within which were embedded negatively charged electrons.

Rutherford found in 1911 that the electrons were actually located at some distance from a central positively charged **nucleus**. He proposed that electrons orbited the nucleus and the electrostatic attraction between the nucleus and the electron was balanced by the centrifugal force arising from the orbital motion. However, a major problem with this was that if this were the case, then the electrons would continuously radiate all their energy as **electromagnetic waves** and very quickly fall into the nucleus.

In 1913, **Bohr** postulated two important additions to Rutherford's theory of atomic structure:

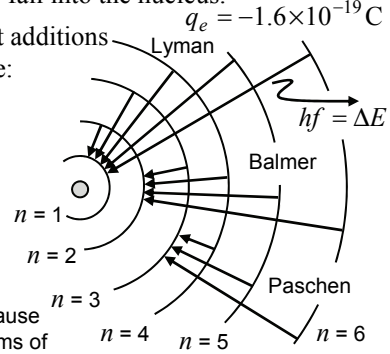

1. Electrons of mass m_e can orbit the nucleus at radius r with velocity v in what are called **stationary states** in which no emission of radiation occurs and in which the **angular momentum** L is constrained to have values:

$$L = m_e v r = \frac{nh}{2\pi}$$

The 2π appears because L is expressed in terms of ω rather than f.

2. Electrons can make transitions from one state to another accompanied by the emission or absorption of a single **photon** of energy $E = hf$, this being the absorption and emission spectra observed experimentally.

As in the Rutherford atom, the centrifugal force is balanced by Coulomb attraction:

$$\frac{1}{4\pi\varepsilon_o}\frac{{q_e}^2}{r^2} = \frac{m_e v^2}{r}$$

with the addition that: $m_e v r = \frac{nh}{2\pi}$

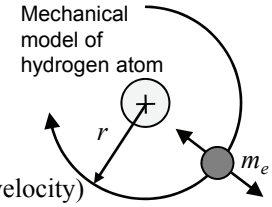

By summing the **kinetic energy** (from the orbital velocity) and the **potential energy** from the electrostatic force, the **total energy** of an electron at a given energy level n is given by:

$$E_n = -\frac{m_e Z^2 {q_e}^4}{8{\varepsilon_o}^2 h^2 n^2}$$

Note: **atomic number** Z = 1 for the hydrogen atom where the energy of the ground state is −13.6 eV. The energy levels for each state n rise as Z^2. Thus, according to the Bohr model, the energy level of the innermost shell for multi-electron atoms can in principle be several thousand eV.

1.3 Energy Levels

The stationary states or energy levels allowed by the Bohr model are called **electron shells** or orbitals, and are labelled K, L, M, N, etc. with K corresponding to n = 1. The number n is called the **principal quantum number**. According to the Bohr model, the electron energy only depends on n, but experiments show that in multi-electron atoms, electron shells consist of sub-levels (evidenced by fine splitting of spectral lines). For example, the L shell n =2 has two **sub-shells**, 2s and 2p.

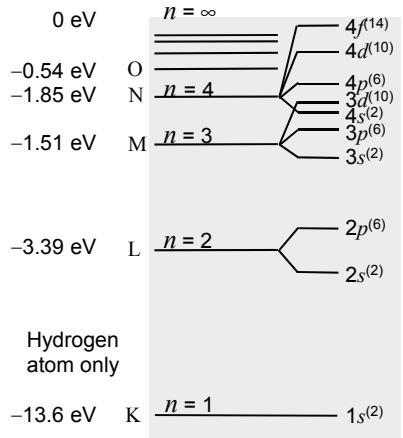

It is convenient to assign the energy at infinity as being 0 since as an electron moves closer to the nucleus, which is positively charged, its potential to do work is less and thus the energy levels for each shell shown are negative. In hydrogen, a single-electron atom, the energies for each shell are given by:

$$E = -\frac{13.6}{n^2}$$ for hydrogen

The electron-volt is a unit of energy. 1 eV = 1.602×10^{-19} J.

Sometimes the splitting of principal shells into sub-shells results in some overlap (e.g. 4s is lower in energy than 3d).

At each value of n the **angular momentum** can take on several distinct values. The number of values is described by the second quantum number l. The allowed values of l are 0, 1, … (n−1). Each value of l is indicated by a letter that indicates the sub-shell:

l = 0	s
l = 1	p
l = 2	d
l = 3	f
l = 4	g
l = 5	h

A third quantum number m describes the allowable changes in angle of the **angular momentum** vector in the presence of an electric field. It takes the values $-l$ to 0 to $+l$.

A fourth quantum number describes the **spin** of an electron where the spin can be either −1/2 or +1/2.

According to the **Pauli exclusion principle**, no electron in any one atom can have the same combination of quantum numbers. When all the electrons in an atom are in the lowest possible energy levels, the atom is said to be in its **ground state**. The outermost electrons in an atom are called the **valence electrons**.

For example, the 3d sub-shell can hold up to 10 electrons:

n = 3

thus: l = 0, 1, 2 (s, p, d)

and: m = -2, -1, 0, 1, 2

5 values of m times 2 for spin, thus 10 possible electrons

1.4 Schrödinger Equation

The total energy E of an electron in an atom is the sum of the potential and kinetic energies. Expressed in terms of **momentum**, p, and mass of electron m, this is stated:

$$E = \frac{p^2}{2m} + V$$

The value of the potential function may depend on both position and time. The form of $V(x,t)$ is different for different arrangements of atoms (e.g. a single isolated atom, an atom in a regular array of a crystal).

Thus: $$hf = \frac{p^2}{2m} + V(x,t)$$ since $E = hf$

Let $$p = -i\hbar\frac{\delta\Psi}{\delta x}$$ $$E = i\hbar\frac{\delta\Psi}{\delta t}$$

Ψ is a variable, the form and value of which provide information about the motion of a wave/particle.

Thus: $$\boxed{-\frac{\hbar^2}{2m}\frac{\delta^2\Psi}{\delta x^2} + V(x,t)\Psi = i\hbar\frac{\delta\Psi}{\delta t}}$$ **Schrödinger equation**

The solution to the Schrödinger wave equation is the **wave function** Ψ. If V is a function of x only, then the wave equation can be separated into time-independent and time-dependent equations that can be readily solved.

$$-\frac{\hbar^2}{2m}\frac{\delta^2\psi}{\delta x^2} + V(\psi) = E\psi \qquad \phi(t) = e^{i\frac{E}{\hbar}t}$$

The resulting solutions of these equations, when multiplied together, give the **wave function**: $$\Psi(x,t) = \psi(x)\phi(t)$$

The wave function gives all the information about the motion of an electron in an atom. Ψ is a complex quantity, the magnitude of which $|\Psi|$ is interpreted as a **probability density function** which in turn can be used to determine the probability of an electron being at some position between x and Δx.

Quantum mechanics is concerned with determining the wave function (i.e. solving the Schrödinger equation) for particular potential energy functions such as those inside atoms. It is found that valid solutions to the time-independent wave equation occur only when the total energy is quantised. The solutions correspond to **stationary states**.

Solutions to the Schrödinger equation can be found for potential functions which are a function of both x and t. This enables time-dependent phenomena (e.g. the probability of transitions of electrons between energy levels in an atom) to be calculated and hence the intensity of spectral lines.

1.5 The Infinite Square Well

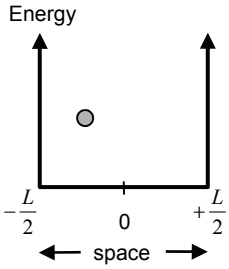

Consider an electron that is confined to be located in one-dimensional space $-L/2$ and $+L/2$ and where the **potential energy** of the electron is a constant (which can be conveniently set to zero). This is an example of an **infinite square well potential**. This potential is not usually found around electrons in an isolated atom, but does often represent that experienced by electrons in a solid and also in a chemical bond.

In the infinite square well potential, the electron cannot move more than a distance $x = \pm L/2$ from the centre position because it is constrained or bound by the infinite potential at the walls. In classical physics, the electron can have any value of total energy as it moves within this space.

In quantum physics, the allowed **stationary states** indicate the possible total energy of the electron. That is, the electron is moving as a particle whose probability of being in a particular position x is described by the standing wave patterns from the solutions to the **Schrödinger equation**. For the simple case of ***zero*** **potential energy** within the well, the energy levels are given by:

$$E = \frac{n^2\pi^2\hbar^2}{2L^2m} \qquad n = 1,2,3,4\ldots,\ V(x) = 0$$

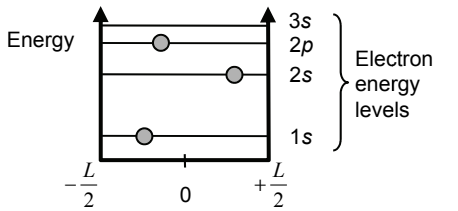

The electron can move anywhere within the confines $\pm L$, but can only have kinetic energies allowable by the stationary states.

It can be seen that the energy increases as n increases. That is, the electron has a greater **kinetic energy** if it exists in a **stationary state** with a larger n. The minimum allowable energy is greater than the minimum potential energy (in this case, 0). This is the **zero point energy**.

Note also that the kinetic energy of the electron, for a given value of n, decreases as the length of the well L increases. That is, if the electron is given more room to move, then its total energy is lowered (in this case, the total energy is kinetic, since the potential energy was set to be 0). "Available space" is effectively a mechanism for providing a reduction in total energy of the system. This is important when the **valence electrons** of different atoms come near each other during the formation of **chemical bonds**.

1.6 The Coulomb Potential

In the **infinite square well potential**, the potential energy of the electron inside the well was constant, and independent of position. In an isolated **single-electron atom**, a more realistic scenario is the case where electrons are bound by the **Coulomb potential**.

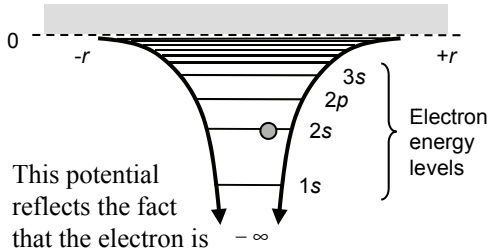

This potential reflects the fact that the electron is attracted more strongly by the nucleus at shorter distances r and so the potential energy is no longer constant – i.e. the potential varies with distance from the nucleus. Mathematically, the Coulomb potential is:

$$V(r) = -\frac{Zq_e^{\,2}}{4\pi\varepsilon_o r}$$

where Z is the **atomic number**, the number of protons in the nucleus.

By convention, an electron is assigned a zero total energy when it is at rest, at an infinite distance from the nucleus. As the negatively charged electron moves towards the positively charged nucleus (opposite to the direction of the electric field), it can acquire kinetic energy and/or do work and so its electrical potential is reduced. That is, the potential energy becomes negative. This is the same convention in electric field theory, where it is usual to consider a *positive* test charge moving in the *same* direction of the electric field – whereupon potential energy is reduced.

Note that in this potential, the energy (the potential energy) becomes more negative as r decreases. That is, electrons further away from the nucleus have a higher potential energy.

The total energy levels for an electron for this potential are given by the solution to the **Schrödinger equation** with $V(r)$ as above and are expressed:

$$E_n = -\frac{Z^2 q_e^{\,4} m}{(4\pi\varepsilon_o)^2 2\hbar^2 n^2} \qquad n = 1,2,3,4\ldots$$

This applies to an isolated **single electron atom** (e.g. hydrogen). Compare with Bohr model 1.2.

Here, the energy E becomes more negative as n decreases, and for a single electron ($Z = 1$) , and at $n = 1$, we obtain the total energy $E = -13.6$ eV. The Coulomb potential, as drawn above, also reflects the greater range of movement available to the electron as r increases.

When an electron is bound by a potential, it is forced into having discrete allowable energies. That is, the allowable states $E < 0$ are **bound states**. Above this level, the electron is free and can have any energy. This is indicated by the grey band in the figure above. Note that in this potential, the energy depends on the principle quantum number n. As n increases, the energy becomes less negative and is therefore at a higher potential.

1.7 Covalent Bond

Consider a **hydrogen atom**. Here we have one electron orbiting the nucleus. In the ground state, the electron is in one of the available 1*s* energy states.

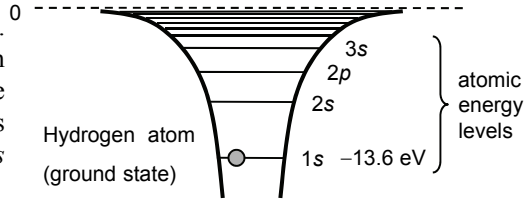

When a hydrogen atom comes into proximity with another hydrogen atom, we might be tempted to draw the energy levels like this:

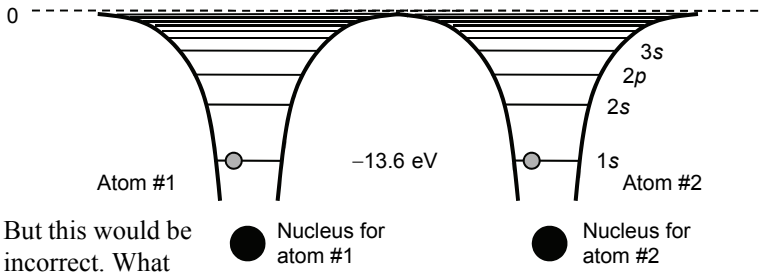

But this would be incorrect. What happens is that the electron in atom #2 is attracted by the positively charged nucleus of atom #1 and vice versa. Overall, the nucleus from atom #1 is attracted to both electrons. The nucleus from atom #2 is attracted to the same two electrons. Therefore, the two nuclei behave as if they were bonded together. The ***co***-sharing of these ***valence*** electrons and the resulting attraction of the two atoms is called a ***covalent*** **bond**.

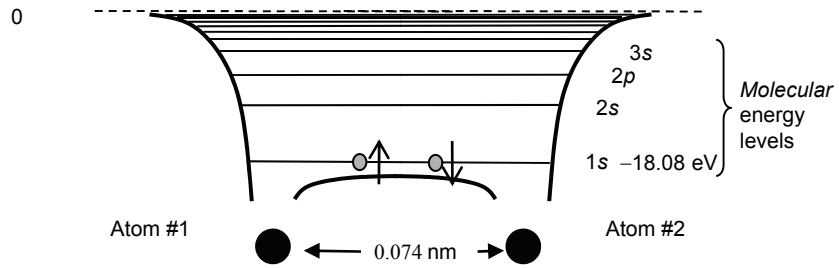

When this attraction occurs, the sides of the "well" are reduced so the extent that the electrons are completely shared between the two atoms. The electrons (by the **Pauli exclusion principle**) have to have different spins ↑↓. Since this is energetically favourable (electrons have more space to move), then hydrogen naturally forms the **molecule** H_2. When a covalent bond is formed, energy is released (heat). To break the bond and separate the atoms, energy –(18.08–13.6) = –4.48 eV has to be supplied.

1.8 Ionisation Energy

In order for an electron to make a transition from a lower state to a higher state in an atom, it must absorb energy (via collision with a photon of sufficient energy, by heat, etc). The energy required to move the outermost (highest potential energy) electron in an isolated atom from its ground state to infinity is called the **first ionisation energy** and is usually expressed in units of eV. The resulting positively charged atom is called an **ion**.

The energy required to move the next outermost bound electron from its **ground state** to infinity is called the second ionisation energy, and so on.

Sometimes ionisation energies are expressed as kJ per mole. Since 1 eV is 1.602×10^{-19}J, then 1 eV per atom is 96.49 kJ per mole.

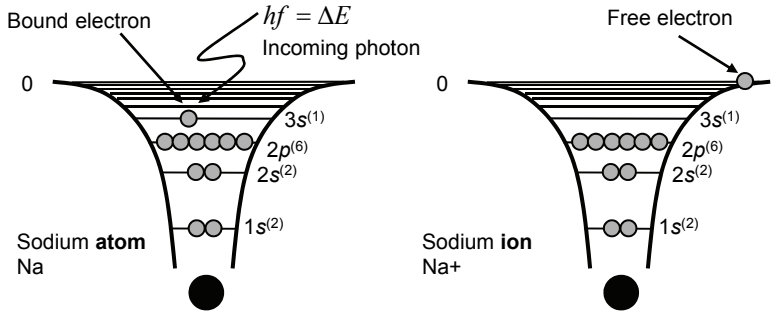

The incoming photon must have sufficient energy (in this example, > +5.1 eV for Na) to lift the electron to infinity distance from the nucleus for the atom to be ionised. If it does not, and if the incoming photon has sufficient energy to lift the electron to a higher energy level, then the atom may become "**excited**" rather than "**ionised**". If the incoming photon has insufficient energy to excite or ionise an atom, then it will just pass through or be scattered by the atom.

Important: We cannot just assign energies to these levels by calculation like we did with the hydrogen atom. The energies associated with each level in a multi-electron atom depend on the size of the atom, the atomic number, the degree of screening of outer electrons by the inner electrons, whether or not the atom is bonded with another, or exists in the gaseous phase, and most importantly, whether the level is filled or not. The ionisation energies are usually measured experimentally. The formula worked OK for hydrogen because we were dealing with just a single electron.

1.9 Electron Affinity

Consider a neutral chlorine atom. The first ionisation energy for Cl is 13 eV.

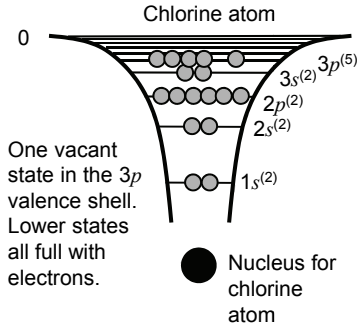

What happens when a free electron comes into contact with the neutral atom? The electron may occupy a vacancy in the 3p level, thus endowing the atom with a full outer energy shell. This condition is energetically desirable and is called a **noble gas configuration**. When the electron is bought from infinity into the 3p shell, its potential energy is lowered and experiments show that −3.7 eV is released (perhaps as heat). This energy that is released is called the **electron affinity** of the atom.

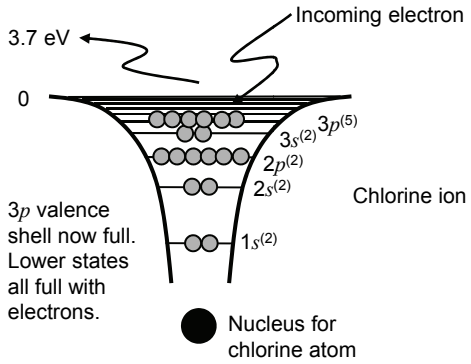

The **electron affinity** is the energy released when an electron is bought from infinity into a neutral atom. Like **ionisation energy**, it is measured experimentally (although usually indirectly). The incoming electron has to overcome the repulsion of the electrons already there, but, in the case of elements like Cl, the attainment of a **noble gas configuration** is a sufficient payoff.

1.10 Ionic Bond

Ionic bonds usually form between elements that have unpaired valence electrons. Consider the reaction between sodium and chlorine.

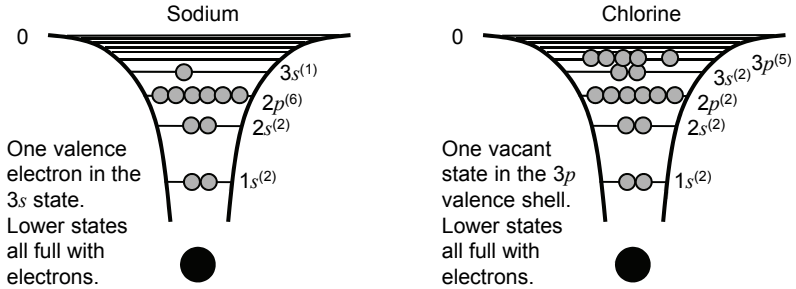

The ionisation energy for Na is +5.1 eV. The electron affinity for Cl is –3.7 eV. Thus, if the lone electron in the 3*s* band in Na can climb over the energy barrier (–5.1 – –3.7 = –1.4 eV), then this will create an Na^+ sodium **ion** and a Cl^- chlorine ion, leaving each with a net charge q_e. The resulting electrostatic (Coulomb) attraction is called an **ionic bond**.

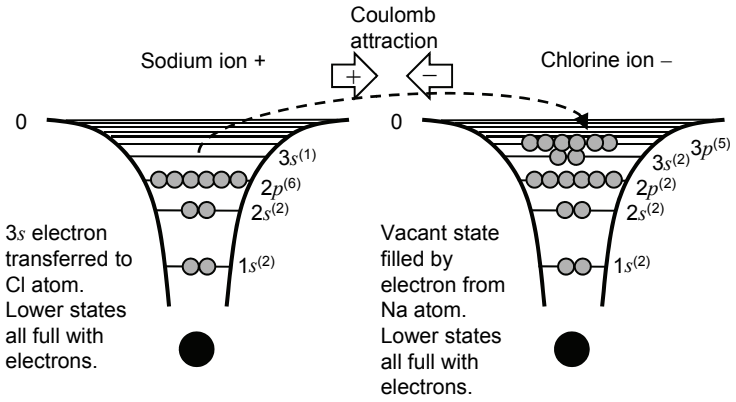

When the ions are formed, the attraction between them causes them to move towards each other and the electrical potential between them drops. The ions reach an **equilibrium distance** determined by the electrostatic attraction of their overall charge and the repulsion offered by their positively charged nuclei. Experiments show that the **bond energy** is –5.5 eV. This energy is lower than the –1.4 eV barrier and so an ionic bond between these two atoms is energetically favourable (since atomic systems tend settle to a state of minimum energy).

1.11 Electronegativity

It is energetically favourable for an atom to have completely filled outer energy shells (**noble gas configuration**). Metals tend to lose electrons to achieve this configuration because their few loosely bound outer shell valence electrons are easily removed (low **ionisation energy**). Non-metals, on the other hand, may have only a few vacancies in their outer shells and so prefer to gain electrons to attain a noble gas configuration.

When two atoms come together to form a **chemical bond**, the ability for one atom to gain, or pull, an electron from the other atom depends on both the ionisation energies and the electron affinities of the two atoms. A combined property that includes these two characteristics is called the **electronegativity** of the element.

Here's how it works in simplified terms. Hydrogen and chlorine can combine to form HCl by the formation of a covalent bond. An electron pair is shared between the H atom and the Cl atom. But is this sharing equal? The ionisation energy for H is +13.6 eV, and for Cl is +13 eV. The electron affinity of H is −0.75 eV and for Cl is −3.7 eV. Thus, for an electron to be transferred from Cl to H, a net energy of 13 − 0.75 = +12.25 eV is required. For an electron to be transferred from H to Cl, a net energy of 13.6 − 3.7 = +9.9 eV is required. Thus, in this covalent bond, the shared electron is biased towards being over near the Cl atom because less energy is required to transfer the electron from H to Cl compared to Cl to H. This unequal sharing makes the bond **polar** (since one end, the Cl end, has a net negative charge). Although we call the bond "covalent" it does have an ionic character as well. In general, there is a gradation of bond types from ionic to covalent depending on the nature of the atoms.

The **electronegativity** describes the relative ability for an atom, when it combines with another atom, to become "more negative" by more strongly capturing a shared electron or electron pair. It is measured by a variety of means, but at its simplest, depends on both the ionisation energy and the electron affinity of the atom. Electronegativities (no units) range from 4 (for Fl on the right-hand side of the periodic table) down to <1 (for elements on the left-hand side of the periodic table).

Two atoms with very different electronegativities are expected to form **ionic bonds**. Atoms with much the same electronegativities are expected to form **covalent bonds**.

An example is when an Na atom (with electronegativity 0.9) meets a Cl atom (electronegativity 3.0). The bond between them is expected to be predominantly ionic, with the chlorine atom becoming more negative. When H (with electronegativity 2.1) meets a Cl, the bond is expected to be predominantly covalent.

1.12 Metallic Bond

Consider what happens when we have two Li atoms close together. We might be first tempted to draw the potentials as:

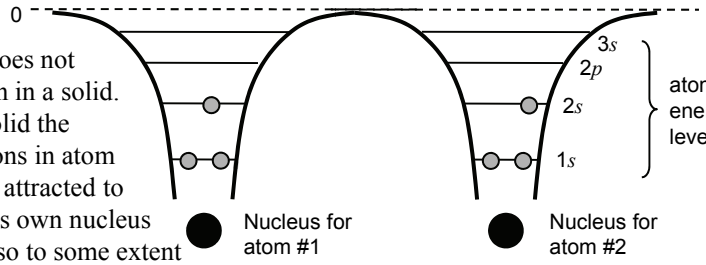

This does not happen in a solid. In a solid the electrons in atom #1 are attracted to both its own nucleus and also to some extent by the nucleus of atom #2. For example, the 1*s* electron orbiting the nucleus of atom #1 is also captured to some extent by the nucleus of atom #2. But, due to the **Pauli exclusion principle**, for each atom, we cannot have more than two electrons in the same energy level (i.e. the two 1*s* electrons for atom #1 as seen by atom #2 are no longer permitted to have energies at the 1*s* level because there are already two electrons from its own atom at that level).

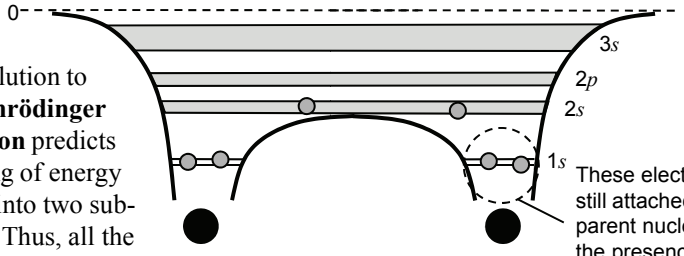

The solution to the **Schrödinger equation** predicts splitting of energy levels into two sub-levels. Thus, all the electrons (say at the 1*s* level) for the pair of atoms can coexist by shifting their energies a little up and down so that their wave functions do not coincide and so the exclusion principle is satisfied. When there are many atoms present, the splitting of many levels into fine gradations creates a **band** of energies and if the energy barrier between the atoms is low enough for the upper bands to carry across to meet those of neighbouring atoms, the electrons in these bands become free to migrate from atom to atom. The electrons behave as if they were in a **potential well**. Because of the large range of movement of these electrons (compared to if they were still attached to their parent nuclei), their kinetic energy is lower (see Section 1.5) and a lowering of energy equates to stability – that is, the free electrons in the valence band reduce the energy of the system and so act to hold the two atoms together. This is called a **metallic bond.**

1.13 Electronic Structure of Solids

In a solid, the interacting potentials of many millions of relatively closely spaced atoms causes atomic energy levels to split into a very large number of sub-levels. The energy difference between each sub-level is so fine that each molecular level is considered to be virtually a continuous **band** of energies.

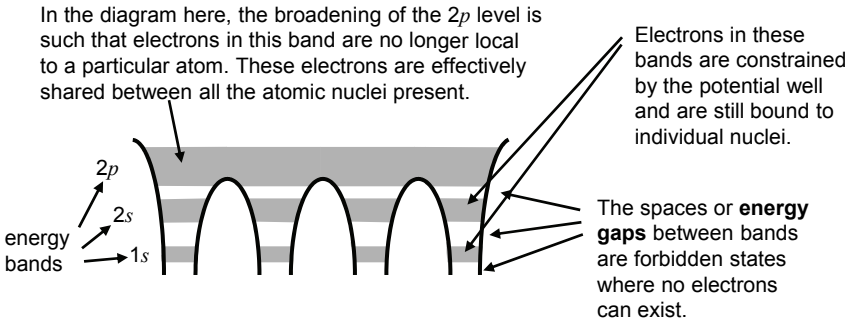

If the highest energy band that contains electrons in the ground state (the **valence band**) in a solid is not completely full, then electrons within that band can easily move around from state to state *within the band*. Such movement can be readily obtained by applying an electric field to the solid. Such solids are thermal and electrical **conductors**.

If the valence band in a solid is full, and the next highest available band is positioned some distance away in terms of its energy levels, then the electrons within the topmost band cannot easily move from place to place or to the next highest band. Such materials are thermal and electrical **insulators**.

If the next highest available band is positioned fairly closely to the valence band, then even at room temperature, there may be sufficient thermal energy given to some electrons to be promoted to this higher level. The material becomes conducting and is a **semiconductor**. The band containing the conducting electrons is called the **conduction band**. In a conductor, the valence band is the conduction band. In a semiconductor, the conduction band (at 0K) is separated from the valence band (defined at 0K) by an **energy gap**.

Atoms in a solid generally form molecules which either arrange themselves in a regular pattern (**crystalline solids**) or the molecules do not repeat themselves in an orderly way (**amorphous solids**). When a solid forms, atoms are pushed and pulled around and settle into place when the interaction electron potentials reach a minimum level.

2. Chemical Components

Summary

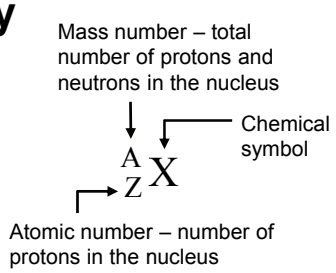

One atomic mass unit (amu) is 1/12th the mass of a carbon 12 atom. 1 amu = 1.6602×10^{-27} kg.

Avogadro's number: $6.022 \times 10^{23} = 1$ mole.

Atoms that lose or gain electrons are called ions:

- Cations (+) (electrons lost)
- Anions (–) (electrons gained)

A molecule is the smallest collection of atoms that is electrically neutral and can exist as a separate identifiable unit.

The molecular weight of a substance is the sum of the atomic weights of its constituents.

Stoichiometry is the process of accounting for the masses of atoms, molecules and compounds in chemical reactions.

2.1 Matter

Elements: cannot be reduced to simpler units by physical processes or chemical reactions. (Examples are oxygen, iron, carbon.) Generally, elements are substances which have only one kind of atom (as having a certain number of protons on the nucleus). There are just over 100 elements known, with about 95% of these occurring naturally, the remainder being created synthetically by nuclear processes.

Elements can be broadly divided into non-metals, semi-metals and metals.

Mixtures: can be separated into constituent parts by physical means. Mixtures are a product of mechanical or physical processes, such as metal alloys, suspensions, dispersions and colloids. **Homogenous** mixtures have uniform composition and appearance (examples are air, salty water) over a molecular length scale while **heterogeneous** mixtures have physically distinct regions. (Examples are fruit cake, concrete, fruit juice with pulp.)

Compounds: combinations of two or more elements in definite proportions where the composition of the compound is uniform throughout. Compounds have a chemical structure, the atoms being held in place by chemical bonds. Compounds keep their chemical identity when altered physically, and can only be reduced to their constitutive elements by chemical reactions. (Examples are water, salt, sulphuric acid.)

2.2 Atomic Weight

Except in the case of nuclear transformations, we can usually treat atoms as being much like the Bohr atom. Atoms are characterised by an **atomic number**, a **chemical symbol**, and the **mass number**.

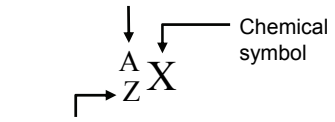

$m_e = 9.1096 \times 10^{-31}$ kg

$m_p = 1.6726 \times 10^{-27}$ kg

$m_N = 1.6749 \times 10^{-27}$ kg

The mass number is approximately equal to the atomic weight of the element. The **atomic weight** of an element is the mass (in relative terms) of an "average" atom of an element. The more precise term **atomic mass** is used to denote the absolute mass of a particular atom (in kg).

Since the **mass of an electron** m_e is very small nearly all of the mass of an atom is contributed by the **protons** and **neutrons** in the nucleus. Protons and neutrons have very nearly the same mass, so the number of neutrons in an atom is given by Z – A. However, it is found in nature that many atoms of the same element with atomic number Z have different mass numbers A because of having a different number of neutrons in the nucleus. Each type of atom A of an element is called a **nuclide**, or **isotope**.

By international agreement, one **atomic mass unit** (**amu**) is 1/12th the mass of a single carbon 12 atom. The atomic weight (or **relative atomic mass**) of an element is the ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C.

Note: The atomic weight of an element is not found from adding the masses of protons, neutrons and electrons. When an atom is formed, some of the mass is used as nuclear binding energy via the **Einstein** relationship $E = mc^2$.

The **carbon 12** isotope has 6 protons and 6 neutrons in the nucleus. The **carbon 13** atom has 6 protons and 7 neutrons in the nucleus. Both isotopes have 6 electrons. Experiments show that carbon in nature consists of 1.11% ^{13}C and 98.89% ^{12}C. The atomic weight of carbon is determined to be 12.011.

In chemistry, much of the arithmetic of chemical reactions involves the atomic weights for the atoms that take part. However, the actual nature of the chemical reactions is due to the number and arrangement of the outer-shell **valence electrons** in the atoms rather than the heavy nuclei. "Valence" is a word that means "power" and in some sense, it is the number and arrangement of valence electrons that give an atom "combining power" to form **chemical bonds** with other atoms.

2.3 Ions

Atoms that lose or gain electrons are called **ions**. When an atom loses one or more electrons, it is called a **cation**. When an atom gains one or more electrons, it is called an **anion**.

Examples of ions:

Atom	Z (atomic number)	No. electrons gained or lost	No. electrons remaining	Formula of ion
H	1	-1	0	H^+
Na	11	-1	10	Na^+
Ca	20	-2	18	Ca^{2+}
F	9	+1	10	F^-
S	16	+2	18	S^{2-}

When an ion is formed, the atom is no longer electrically neutral. The formula of the ion signifies the net electronic charge. Atoms may lose electrons, especially unpaired outer shell or valence electrons, by physical removal, absorption of **ionising radiation**, the electron being taken by another type of atom which has a stronger attraction for it, and so on.

Metallic elements tend to lose one or more electrons when they combine with other elements and so form cations. Non-metallic elements tend to gain electrons to form anions. When naming compounds, it is usual to list the more metallic element first. In **binary ionic compounds**, we list the metal cation first followed by the non-metal anion with an "ide" suffix. For covalent compounds, the more metallic element is listed first.

Sodium chloride
Carbon monoxide
Carbon dioxide
Nitrogen oxide
} Where there is more than one possible compound, prefixes are used to distinguish them.

2.4 Molecules

Most elements bond with others to form **molecules**. A molecule is the smallest collection of atoms, that is electrically neutral, and can exist as a separate identifiable unit. The concept was first proposed by **Avogadro** in 1811, who, on the basis of observations made by Dalton and Gay-Lussac proposed that atoms combine to form molecules, *and* at the same temperature and pressure, equal volumes of *all* gases contain the same number of molecules. **Avogadro's law** provides the justification for a method of determining relative molecular weights

→ because there was now a way to obtain equal numbers of different molecules by using different gases all at the same temperature, pressure and volume.

A molecule is most conveniently described in terms of a **molecular formula**.

H_2O

A water molecule consists of two H atoms and one O atom.

In some cases, such as in a crystalline solid, the concept of a molecule is not appropriate because the atoms which make up the substance are arranged in a regular repeating pattern. In this case, we speak of the **empirical formula**.

NaCl

A sodium chloride crystal consists of equal numbers of sodium and chlorine atoms arranged in a regular array or crystal lattice.

The **molecular weight** (or **relative molar mass**, or **relative molecular mass**) M_r of a substance is the sum of the atomic weights of its constituents.

If we had a certain mass of an element (or a molecule), say 12 grams of ^{12}C, how many atoms would this be? This number is called **Avogadro's number** N_A and has the value 6.0220943×10^{23}. N_A is found by experimental methods.

By international agreement, one **atomic mass unit** (**amu**) is 1/12th the mass of a carbon 12 atom.

"But!", you might say, "How can you have 6.022... atoms if atoms are indivisible? Shouldn't this be a whole number?" Look at the 10^{23}. If you write Avogadro's number out in full, it *is* a whole number.

12 g of $^{12}C = 6.0220943 \times 10^{23}$ atoms; therefore the mass of one ^{12}C atom is:

$$\text{mass} = \frac{0.012}{6.02 \times 10^{23}} \text{kg}$$

$$= 1.99 \times 10^{-23} \text{kg}$$

It is convenient when working with quantities usually involved in chemical reactions to round down Avogadro's number to 6.02×10^{23}.

2.5 Mole

Chemical reactions usually involve large numbers of atoms and molecules. It is convenient to have a unit of measure that relates weight (i.e. mass in grams or kilograms, etc) of bulk chemicals with atomic or molecular weight. By definition, this unit of measure is called a **mole**, and it is the Avogadro number of atoms or molecules.

12 grams of ^{12}C contains 6.02×10^{23} atoms and is called 1 mole of ^{12}C

18 grams of H_2O also contains 6.02×10^{23} molecules and is called 1 mole of H_2O

The word "mole" is a shorthand way of saying "**Avogadro's number**". That is, it is easier to say "Consider one mole of sodium atoms" rather than "Consider one Avogadro's number of sodium atoms" or "Consider 6.02×10^{23} of sodium atoms". To find out the mass in grams of a mole of some atoms, we simply look up the **atomic weight**. → because the atomic weight (in amu) is expressed relative to the ^{12}C atom, and thanks to Avogadro, we know that 12 g of ^{12}C has N_A atoms.

To find out the mass in grams of a mole of some molecules, we simply use the molecular weight.

Moles, why bother? It's convenient. One mole of *anything* is 6.02×10^{23} of the "anythings". When we are talking about atoms or molecules, we know that one mole has a mass equal to the atomic weight of the element, or the molecule because that's the way Avogadro's number was determined. It's the link between the *relative* atomic mass and the *actual* mass in grams.

Units of chemical accounting:

- One **atomic mass unit** (amu) is 1/12th the mass of a carbon 12 atom by international agreement. 1 amu is $1.66020943 \times 10^{-27}$ kg.
- The **atomic weight** (or **relative atomic mass**) of an element is the ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C.
- The total sum of the atomic weights for a molecule of substance is called the **molecular weight** or **relative molar mass** M_r.
- The molecular/atomic weight expressed in grams contains one mole of molecules/atoms. This is Avogadro's number 6.0220943×10^{23}.
- The **molar mass** M of an element is the atomic weight of the element expressed in g/mol. The molar mass of a compound is the sum of the atomic weights of the constituent elements expressed in g/mol.

2.6 Compounds

Compounds consist of two or more different elements which are chemically combined in a definite fixed ratio (as distinct from mixtures, which can have any proportions of ingredients). There are generally two types of compounds:

Molecular compounds are composed of atoms held together by chemical bonds in fixed proportion and are electrically neutral overall. For example, the water molecule H_2O is a molecular compound and the **molecular formula** shows the proportions of the atomic species within it.

Name	Molecular formula
Methane	CH_4
Carbon dioxide	CO_2
Ammonia	NH_3
Acetylene	C_2H_2
Ethylene	C_2H_4
Ethane	C_2H_6
Water	H_2O
Benzene	C_6H_6
Ethanol	C_2H_5OH
Naphthalene	$C_{10}H_8$
Aspirin	$C_9H_8O_4$

There is a distinction to be made between the **molecular formula** and the **empirical formula** of a compound. The empirical formula gives the ratio of component atoms in the lowest possible numerical terms. The empirical formula shows the ratio of component atoms as found to exist in practice. In many cases, the formulae are the same, but this cannot be always assumed. For example, the empirical formula for benzene is CH but the molecular formula is C_6H_6.

Ionic compounds are composed of charged atoms, or a charged group of atoms, of opposite sign that are held together by **ionic bonds**. When an ionic compound is formed from the joining of a charged group of atoms, it is said to be a **complex ion** (or a polyatomic ion, or a molecular ion). The ion with the positive charge in the compound is the **cation**. The ion with the negative charge is the **anion**. The ionic formula gives the ratio of anions and cations. The ionic formula is electrically neutral overall.

Name	Ions formed	Formula
Magnesium chloride	Mg^{2+} Cl^-	$MgCl_2$
Silver sulphate	Ag^+ SO_4^{2-}	Ag_2SO_4
Ammonium sulphate	NH_4^+ SO_4^{2-}	$(NH_4)_2SO_4$
Chromium (III) hydroxide	Cr^{3+} OH^-	$Cr(OH)_3$
Sodium chloride	Na^+ Cl^-	NaCl

2.7 Cations

+1

Name	Formula
Hydrogen	H^+
Lithium	Li^+
Sodium	Na^+
Potassium	K^+
Rubidium	Rb^+
Caesium	Cs^+
Silver	Ag^+
Copper	Cu^+
Mercury (I)	Hg_2^{2+}
Ammonium	NH_4^+

+2

Name	Formula
Beryllium	Be^{2+}
Magnesium	Mg^{2+}
Calcium	Ca^{2+}
Strontium	Sr^{2+}
Barium	Ba^{2+}
Lead	Pb^{2+}
Zinc	Zn^{2+}
Cadmium	Cd^{2+}
Nickel	Ni^{2+}
Manganese	Mn^{2+}
Tin (II)	Sn^{2+}
Iron (II)	Fe^{2+}
Mercury (II)	Hg^{2+}
Cobalt (II)	Co^{2+}
Chromium (II)	Cr^{2+}
Copper (II)	Cu^{2+}

+3 , +4

Name	Formula
Aluminium	Al^{3+}
Bismuth	Bi^{3+}
Iron (III)	Fe^{3+}
Cobalt (III)	Co^{3+}
Chromium (III)	Cr^{3+}
Tin (IV)	Sn^{4+}

In the naming of chemical compounds, it is customary to write the name of the most metallic element first, followed by the more non-metallic one. The second element or ion is given the *ide* suffix (e.g. sodium chloride).

Prefixes
1 – mono
2 – di
3 – tri
4 – tetra
5 – penta
6 – hexa

2.8 Anions

−1

Name	Formula
Fluoride	F^-
Chloride	Cl^-
Bromide	Br^-
Iodide	I^-
Hydroxide	OH^-
Nitrite	NO_2^-
Nitrate	NO_3^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Cyanide	CN^-
Permanganate	MnO_4^-
Thiocyanate	NCS^-
Bicarbonate	HCO_3^-
Bisulphate	HSO_4^-
Dihydrogen phosphate	$H_2PO_4^-$
Acetate	$CH_3CO_2^-$

−2

Name	Formula
Oxide	O^{2-}
Peroxide	O_2^{2-}
Sulphide	S^{2-}
Sulphate	SO_4^{2-}
Sulphite	SO_3^{2-}
Thiosulphate	$S_2O_3^{2-}$
Carbonate	CO_3^{2-}
Oxalate	$C_2O_4^{2-}$
Chromate	CrO_4^{2-}
Dichromate	$Cr_2O_7^{2-}$
Monohydrogen phosphate	HPO_4^{2-}

−3 , −4

Name	Formula
Nitride	N^{3-}
Phosphate	PO_4^{3-}
Hexacyanoferrate (III)	$Fe(CN)_6^{3-}$
Hexacyanoferrate (II)	$Fe(CN)_6^{4-}$

For polyatomic anions, the assignment of a suffix depends on the **oxidation number** (see Section 4.8) of the central non-metal atom.

Suffixes	
ide	
ite	ous
ate	ic

In some cases, the oxidation number of the metal is stated in roman numerals to distinguish compounds which would otherwise have the same name (e.g. iron (II) chloride and iron (III) chloride).

2.9 Chemical Equation

When atoms or molecules (the **reactants**) combine with other atoms or molecules to form compounds (the **products**), a **chemical reaction** is said to take place. Chemical reactions involve the breaking and formation of **chemical bonds**.

$$\text{Reactants} \rightarrow \text{Products}$$ This is the forward reaction

$$\text{Products} \rightarrow \text{Reactants}$$ This is the reverse reaction

Often one can tell if a chemical reaction has occurred by observation of products that are considerably different in appearance than the reactants. Examples are the formation of a **precipitate**, evolution of gas, change of colour, production of heat and so on. Often, chemical reactions proceed spontaneously, other times they have to be forced to proceed by the input of energy or the lowering of energy barriers.

Chemical equations are written using chemical formulae where the number of atoms or molecules is written before the formula:

$$2CO + O_2 \rightarrow 2CO_2$$

This equation says that two molecules of carbon monoxide react with one molecule of oxygen to product two molecules of carbon dioxide. This is a **balanced equation**, because the number of atoms in each reactant equals the number of atoms in each product. That is, we have two carbon atoms on the left-hand side and two carbon atoms on the right-hand side, and two oxygen atoms on the left side and two on the right side. We can also say that two **moles** of carbon monoxide combine with one mole of oxygen to form two moles of carbon dioxide. Since the mass of a mole of an atom or a molecule is the atomic or molecular weight expressed in grams, a balanced equation is balanced in terms of both number of atoms and mass on both sides of the equation. The net electric charge must also be the same on both sides of the equation.

Usually, reactions proceed until there is **chemical equilibrium**. Dynamic chemical equilibrium occurs when the rate of the forward reaction becomes equal to the rate of the reverse reaction:

$$\text{Reactants} \leftrightarrow \text{Products}$$ Dynamic equilibrium

By rate, we mean the rate of formation of products in units of mol/s.

2.10 Stoichiometry

Stoichiometry is the process of accounting for the masses of atoms, molecules and compounds in chemical reactions. The basic component of such accounting is the arrangement of chemical formulae in chemical equations. Stoichiometric calculations are performed in a logical sequence:

1. Write a balanced equation for the reaction.
2. Convert known masses of reactants and/or products into moles.
3. Calculate the number of moles of the reactants and/or products whose masses are unknown.
4. Calculate the masses of the unknown reactants and/or products.

Balancing an equation involves both a balance of atoms and also electric charge. This is particularly important in the case of ionic equations where spectator ions may be present and do not take part in the reaction. Some examples of unbalanced equations (with spectator ions) and the corresponding **net ionic equations** are:

$$\mathrm{Pb(NO_3)_2(aq) + KCl(aq) \rightarrow PbCl_2(s) + K^+ + NO^{3-}}$$
$$\mathrm{Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)}$$

$$\mathrm{Ni(OH)_2(s) + HNO_3(aq) \rightarrow NiNO_3(aq) + H_2O}$$
$$\mathrm{Ni(OH)_2(s) + 2H^+ \rightarrow Ni^{2+} + 2H_2O}$$

$$\mathrm{NaCO_3(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O + CO_2}$$
$$\mathrm{CO_3^{2-} + 2H^+ \rightarrow 2H_2O + CO_2}$$

Practical difficulties can arise when attempting to determine masses of reactants and products. For example, some reactants may be present in excess (more present than combine with one or other reactants). More than one reaction may take place at the same time, or a reaction may proceed in a series of intermediate steps. Products (such as gases) may escape and alter the equilibrium state of the reaction. The nature of the reactants may prevent mixing of the reactants and so there is incomplete yield of product.

2.11 Example

Acetylene gas is used together with oxygen in an "oxy" welding set. It is prepared from a reaction of calcium carbide and water:

$$CaC_2 + H_2O \rightarrow Ca(OH)_2 + C_2H_2 \quad \text{Unbalanced eqn.}$$

Balance this equation and determine the mass of acetylene that is produced from the reaction of 130 g CaC_2 and 100 g water.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2 \quad \text{Balanced eqn.}$$

$$\begin{aligned} CaC_2 &= 130\,\text{g} \\ &= \frac{130}{40.1 + 2(12)} \\ &= 2.03\,\text{moles} \\ H_2O &= 100\,\text{g} \\ &= \frac{100}{2 + 16} \\ &= 5.56\,\text{moles} \end{aligned}$$

But according to the balanced equation, for each mole of CaC_2, two moles of H_2O are required. Therefore, 2(2.03) = 4.06 moles of H_2O required, and so the mass of C_2H_2 formed would be:

$$\begin{aligned} C_2H_2 &= 2.03\,\text{moles} \\ 2.03 &= \frac{m}{2(12) + 2(1)} \\ &= 52.8\,\text{g} \end{aligned}$$

3. The Periodic Table

Summary

Atomic radius decreases

Atomic radius increases

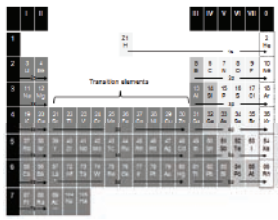

Bohr radius

$$r = n^2\left(\frac{\varepsilon_o h^2}{\pi m_e Z q_e^2}\right)$$

Ionisation energy increases

Ionisation energy decreases

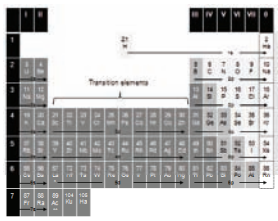

Noble gases

He	$1s^2$
Ne	$He2s^22p^6$
Ar	$Ne3s^23p^6$
Kr	$Ar3d^{10}4s^24p^6$
Xe	$Kr4d^{10}5s^25p^6$
Rn	$Xe5d^{10}6s^26p^6$

Electronegativity increases

Electronegativity decreases

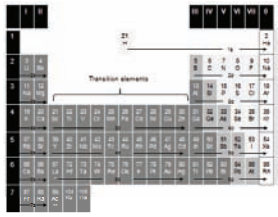

3.1 Electron Configuration

In a **multi-electron atom**, the electrons do not find themselves in a **Coulomb potential** of the form $1/r$ as in the **hydrogen atom** due to the **screening effect** of inner-shell electrons on the outer-shell electrons. In a multi-electron atom, the potential in which an electron finds itself (and hence its energy) depends on not only n (as in the single-electron atom), but also the second quantum number l. The arrangement of electrons in atoms in the **ground state** can be complicated, but follows certain rules:

1. Electrons occupy the lower energy levels first, before occupying higher levels.
2. Electrons at a particular energy level have opposite spin (**Pauli exclusion principle**).
3. Electrons tend to occupy an energy level as single electrons before pairing up (**Hund's rule**).

Examples of the ground-state electron configuration of the first few elements arranged in order of increasing **atomic number** Z

Hydrogen	$1s^1$
Helium	$1s^2$
Lithium	$1s^2 2s^1$
Beryllium	$1s^2 2s^2$
Boron	$1s^2 2s^2 2p^1$
Carbon	$1s^2 2s^2 2p^2$
Nitrogen	$1s^2 2s^2 2p^3$
Oxygen	$1s^2 2s^2 2p^4$
Fluorine	$1s^2 2s^2 2p^5$
Neon	$1s^2 2s^2 2p^6$
Sodium	$1s^2 2s^2 2p^6 3s^1$
Magnesium	$1s^2 2s^2 2p^6 3s^2$
Aluminium	$1s^2 2s^2 2p^6 3s^2 3p^1$
Silicon	$1s^2 2s^2 2p^6 3s^2 3p^2$
Phosphorus	$1s^2 2s^2 2p^6 3s^2 3p^3$
Sulphur	$1s^2 2s^2 2p^6 3s^2 3p^4$
Chlorine	$1s^2 2s^2 2p^6 3s^2 3p^5$
Argon	$1s^2 2s^2 2p^6 3s^2 3p^6$
Potassium	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Calcium	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
Scandium	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$

Electrons spread out to occupy unfilled sub-shells before pairing up. For example, in oxygen, the arrangement of electrons is:

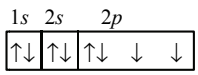

When we write the electron configuration of elements, we keep the principal quantum numbers together even if they are not arranged in energy order. For example, in potassium, the 4*s* sub-shell actually has a lower energy than the 3*d* sub-shell, but we usually write the 3*d* along with the 3*s* and 3*p* sub-shells.

Note 4*s* has lower energy than 3*d* in K.

Note 4*s* has lower energy than 3*d* in Ca.

Keep sub-shells together even if no longer in increasing energy order.

3.2 Periodic Law

In the nineteenth century, it was noticed that if elements were arranged in order of increasing **atomic weight**, certain properties of the elements tended to occur at periodic intervals. This is a striking observation. It is now known that **periodicity** occurs when the elements are arranged in increasing **atomic number** Z. Consider the first few elements and the property of reactivity:

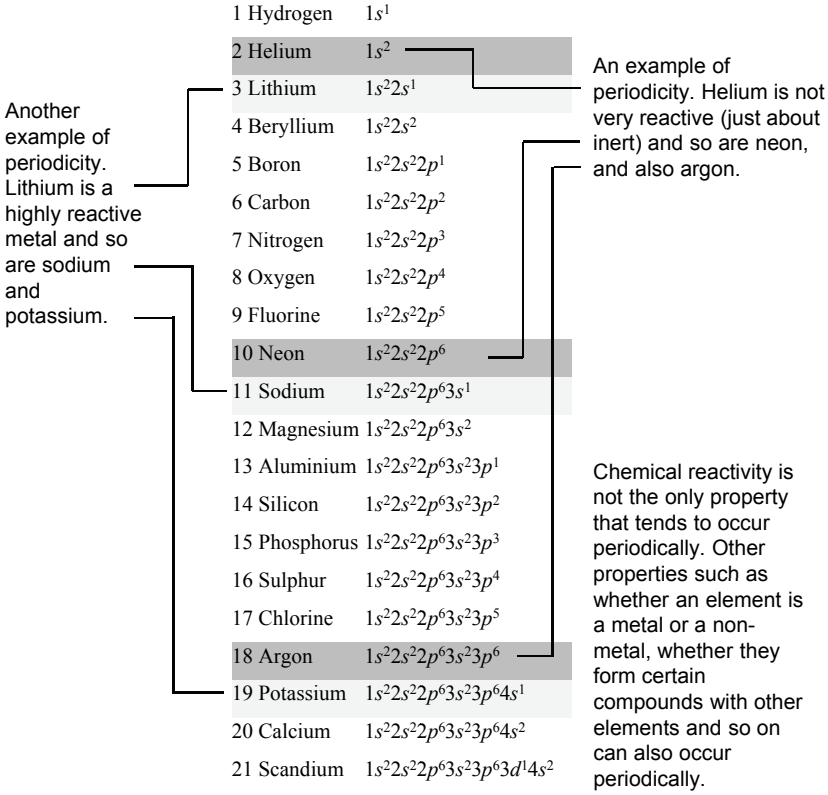

Initially it seems that the chemical reactivity of elements repeats in intervals of eight in atomic number Z. However, when the elements are arranged more completely we see that the periodicity actually depends upon the arrangement of outer-shell **valence electrons** – a not surprising observation in hindsight because it is the valence electrons that are involved in the formation of **chemical bonds**. For example, neon (10), argon (18), krypton (36), xenon (54) and radon (86) all have eight electrons in the outer shell and are inert. Na and K have one valence electron and easily form positive ions.

3.3 Periodic Table

Periodicity in chemical (and sometimes physical) properties can more readily be appreciated when elements are arranged in a table. Vertical columns in the table (**groups**) show elements with similar properties. Each horizontal row is called a **period**. The table also indicates (approximately) the way in which electron shells are occupied.

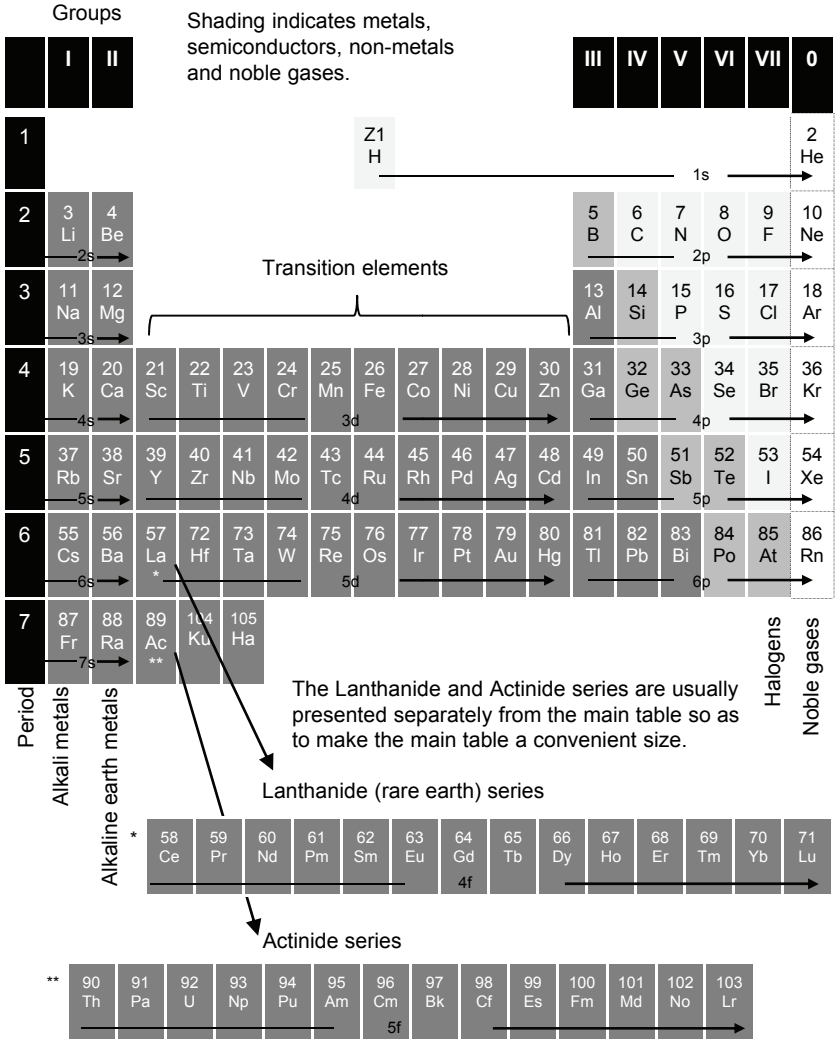

3.4 Groups

Hydrogen is placed in a separate position in the periodic table.

Hydrogen has one electron, which in the ground state is in the 1*s* orbital. This unpaired electron makes hydrogen a reactive element that is able to form compounds with many other elements, including itself, to form a gas H_2.

$^{1}_{1}H$ Protium 99.9% abundance

$^{2}_{1}H$ Deuterium (heavy hydrogen)

$^{3}_{1}H$ Tritium (radioactive)

Group I elements are the **alkali metals**. Having one weakly bound outer valence electron, they are highly reactive, and metallic in character. Elements in this group usually form M^+ ions which are water soluble.

Group II elements are the **alkaline earth metals**. Elements in this group usually form M^{2+} ions and are generally insoluble, occurring naturally as silicates, carbonates, sulphates and phosphates.

The **transition elements** generally occupy the positions between Groups II and III. All these elements are metals since their outermost shells contain only a few electrons. However, unlike alkali metals, transition metals are hard, brittle and have a high melting point (with the exception of mercury).

Group III elements are also considered metals (although boron has only semi-metallic properties). With the exception of boron, they form M^{3+} ions and are relatively soft.

Group IV elements range from non-metal, semi-metals (or semiconductors) to metals down the group with increasing size of atom (and hence screening effect of electrons). All have four electrons in their outer shell. **Carbon** is responsible for the formation of hydrocarbons and derivatives, the basis of life on Earth. **Silicon**, unlike carbon, tends to form bonds with oxygen and is the basis for most of the minerals of the Earth.

Group V elements range from non-metallic to metallic down the group with increasing atomic size and five valence electrons.

Group VI elements show little metallic character due to the increasing ionisation potentials as we go across the periodic table. Increasing atomic size going down the group confers some metallic properties to Se, Te and Po.

Group VII elements are referred to as the halogens. They all have a high tendency to complete their electron shells by forming salts. These elements are largely non-metallic, and mostly reactive.

Group 0 elements are the **noble gases**, so called because of their inertness, although they are able to form compounds with oxygen and fluorine under certain conditions. Argon was discovered in 1894.

3.5 Energy Levels

The ordering of the outer electron shells in terms of energy is the basis for interpretation of the **periodic table**. Calculations show that the ordering of the energy shells proceeds in the following sequence from lowest (more negative) to highest (less negative potential):

1*s*, 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, 6*s*, 4*f*, 5*d*, 6*p*, 7*s*, 5*f*, 6*d*

From 1*s* to 3*p*, it is easy to understand because the electron shells are at an increasing radial distance from the nucleus (*n* quantum number dominates the energy distribution just as in the one-electron atom). The *n* quantum number determines the distance the electrons are from the nucleus. The *l* quantum number determines the shape of the electron shell. When $l = 0$, we have an *s* sub-shell which is spherical. When $l = 1$, we have a p sub-shell which is lobed. $l = 2$ gives *d* sub-shells which are four-lobed geometries. The significance of this is that in the fourth period, in K and Ca, the 4*s* sub-shell has a lower energy than the 3*d* sub shell. In these elements, electrons prefer to be in 4*s* rather than 3*d* in the ground state even though the radius of the 4*s* shell is larger than the 3*d* shell.

$l = 0$	*s*
$l = 1$	*p*
$l = 2$	*d*
$l = 3$	*f*
$l = 4$	*g*
$l = 5$	*h*

For the first row of the **transition elements**, the 3*d* levels become occupied only after the 4*s* levels are filled (except for Cr). In these elements, the electrons in the 4*s* shell, being further from the nucleus (but having lower energy than the 3*d* electrons) shield those in the inner 3*d* shell and so the chemical properties for these elements are all very similar since in each case, the valence electrons are the 4*s* *outer* electrons while it is the number of inner 3*d* electrons that is changing. It is the outer **valence electrons** (with the highest principal quantum number) that interact with other atoms to form chemical bonds.

The ordering of shells given above is not the ordering of *all* the energy levels *within* an atom, only the *energy* ordering of the *outer* shells. For example, in K, the 4*s* shell is at a lower energy than the 3*d* shell ($3s^2 3p^6 4s^1$). By the time we get to Zn, the 3*d* shell is at a lower energy than the 4*s* shell ($3d^{10} 4s^2$). There is no one sequence of energy shells that applies to all elements.

This is a consequence of the increasing dominance of the *l* quantum number in the *d* sub-shell in determining the energy for a sub-shell. The *l* quantum number is connected with the angular momentum of the electrons and so, much like the case where the angular momentum for a rotating wheel is greater if the mass is concentrated at the outer edge compared to the case when the mass is evenly distributed, the concentration of mass of electrons in *d*-shaped shells results in a greater kinetic energy component to the total energy compared to spherical *s* shells.

3.6 Noble Gases

The **noble gas** elements are extremely stable and generally do not form compounds with any other elements. The notable feature of noble gas elements is the interesting property of having full outer electron energy shells. Consider the second period elements. As we go from left to right, the number of electrons in the energy level with principal quantum number $n = 2$ is increasing. At neon, we have eight valance electrons: $2s^2\ 2p^6$. A group of eight (**octet**) valence electrons that completely fills an energy shell is very energetically stable and is called the **noble gas configuration**.

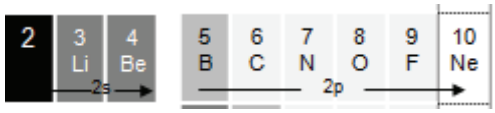

An atom with one more valence electron makes the element sodium, a highly reactive metal. Sodium is highly reactive because its single $3s^1$ valence electron is easily removed so that the sodium **cation** has a noble gas configuration in its outer shell. An atom with one electron less than sodium is the highly reactive gas fluorine. Fluorine readily attracts an electron from another atom to form an **anion** to achieve a **noble gas configuration**.

He	$\mathbf{1s^2}$
Ne	$1s^2\mathbf{2s^2 2p^6}$
Ar	$1s^2 2s^2 2p^6\mathbf{3s^2 3p^6}$
Kr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}\mathbf{4s^2 4p^6}$
Xe	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10}\mathbf{5s^2 5p^6}$
Rn	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10}\mathbf{6s^2 6p^6}$

The noble gas configuration is where there is a completely filled energy shell and the next available higher energy level is an *s* shell. This is true for He where the 1*s* shell is filled and the next energy level is the 2*s* shell. For the other noble gases, we have completely filled *p* shells and the next highest energy level is the *s* sub-shell for the next quantum number *n*. There is a large energy gap between a *p* sub-shell and the next highest *s* shell and this gives the noble gas elements a high **ionisation energy**. Because all the occupied energy shells are filled, the electric charge distribution within noble gas elements is symmetric, resulting in no external electric field. The total angular momenta within these atoms adds up to zero, resulting in no external magnetic fields. These elements find it very difficult to form bonds with other atoms because they have little opportunity to interact electrostatically magnetically, or energetically.

3.7 Atomic Size

The size of an atom cannot be precisely stated since the location of the electrons can only be described statistically. **Atomic size**, for practical purposes, can be defined as the most probable distance from the nucleus to the most outer-shell electron but depends on whether the atom is free or combined with another.

Electrons are attracted to the nucleus by **electrostatic forces**, but are constrained to occupy defined orbits, or energy shells, by the principles of **quantum mechanics**. The electrostatic attraction between the nucleus and a near-shell electron is much larger than between the nucleus and an outer-shell electron, not only because of the increased distance, but also because of the **screening effect** that the inner electrons have on the outer electrons.

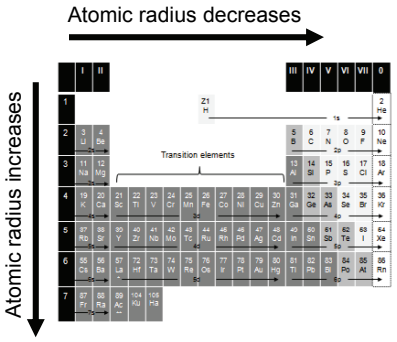

As we go across a **period** in the periodic table, the atomic number increases and so the magnitude of the positive nuclear charge also increases, and therefore so does the magnitude of the **electric field** within which the electrons find themselves. However, across any one period, the outer electrons exist in energy levels for one particular quantum number n. For example, in the 3rd period, the 3s and 3p levels are occupied. Because the electric field is also increasing as we go from left to right, so the electrons are acted upon by a larger Coulomb force and the **atomic radius** decreases across a period. However, because of the **screening effect** offered by the inner-shell electrons, the decrease in size is not as large as expected on the basis of the nuclear charge alone.

For a given vertical **group** of elements in the periodic table, the size of atoms increases as the atomic number Z increases (as we go down the column). We may therefore expect that the atomic radii would decrease but as we go down a group, electrons are filling states with a higher quantum number n and this more than offsets the effect of increasing Z.

Therefore **atomic radius** increases as we go down a group in the periodic table.

$$r = n^2\left(\frac{\varepsilon_o h^2}{\pi m_e Z q_e^2}\right)$$

The Bohr model of the atom shows how the atomic radius increases in proportion to n^2 and decreases (inversely) with Z.

3.8 Covalent Radii

When atoms form a **covalent bond**, the nuclei of the two atoms move close together (see Section 1.7) compared to two isolated atoms adjacent to each other.

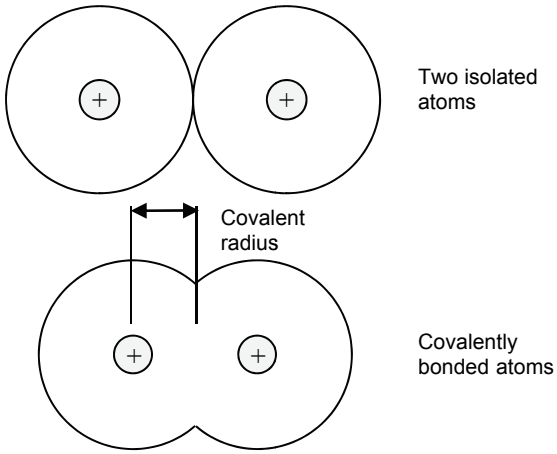

The **covalent radius** of an atom is defined as one half the distance between the nuclei of two identical *covalently bonded* atoms. The actual covalent radius of an atom in a molecule where the atoms are not identical depends on the atoms involved. The general term "**atomic radius**" usually means the covalent radius (where the two atoms are identical) and this serves as a useful benchmark for comparison with other atomic sizes.

For metallic atoms, the atomic or **metallic radius** is usually defined as half the distance between two nuclei of the atoms in the solid metallic state.

The shapes of the orbitals in which the valence electrons participate in bonding is important. The *s* orbital has a somewhat spherical shape centred on the nucleus, while the *p* orbitals have a dumbbell shape along the three coordinate axes. The shapes of the atomic orbitals involved in the formation of a particular bond determine the shape of the molecule.

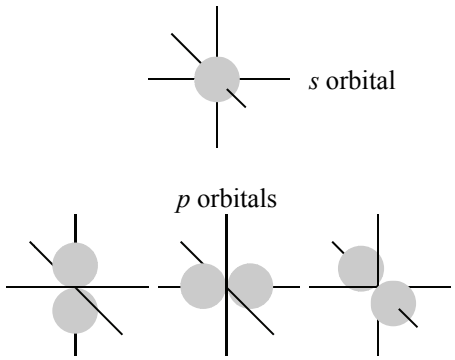

3.9 Ionic Radii

When a metal atom loses an electron to become a positively charged **ion**, a reduction in **atomic size** occurs. The electron that is lost is usually an outer-shell electron and so this electron shell becomes vacant and so the outermost electron shell is the next one closer in towards the nucleus. However, the reduction in size is not just due to an outer electron shell becoming vacant. When a positive ion is formed, the remaining electrons can bunch together a little more closely because of the reduced degree of mutual repulsion (since there are now fewer electrons surrounding the nucleus).

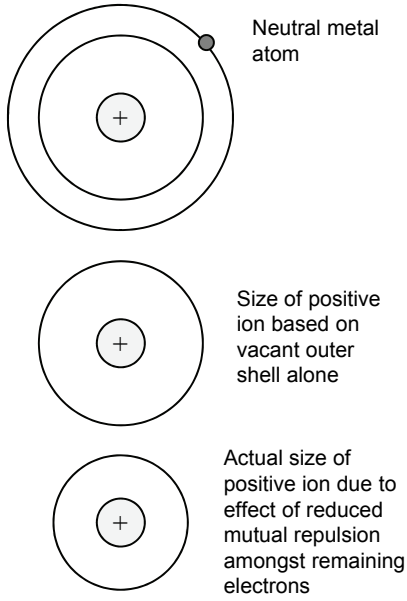

When a non-metal atom gains an electron to become a negative ion, this usually results in an outer-level electron shell accepting an additional electron – which would not ordinarily cause an appreciable increase in size, but the addition of this electron means that there is now an excess of negative charge in the outer shell and mutual repulsion causes these electrons to move apart and the atom "expands".

In a sodium chloride ionic crystal, therefore, the positive sodium ions shrink and the negative chlorine ions expand such that the sodium ions are almost packed in between the spaces of the chlorine ions.

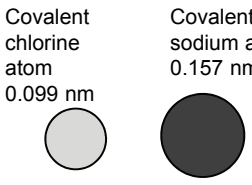

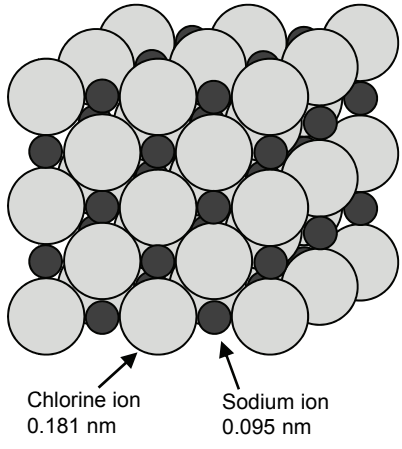

3.10 Ionisation Energy

The **ionisation energy**, or **ionisation potential**, is the amount of energy needed to remove an electron from an isolated atom. The first ionisation energy is that needed to remove one outermost electron from an atom. Successive ionisation energies are those needed to remove further electrons from the atom.

Successive ionisation energies always increase at each electron removal. As each electron is removed, the size of the atom decreases markedly and so the remaining electrons are closer to the positively charged nucleus, and so more energy is needed to remove them. Further, a particularly large increase in energy is needed to remove an electron from a filled energy level because a noble gas configuration of electrons is extremely stable.

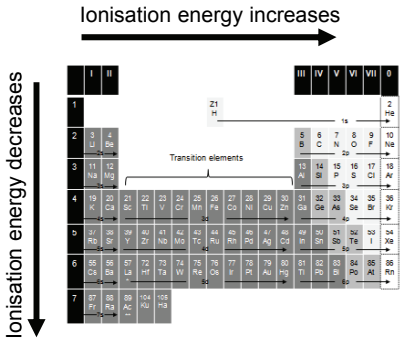

Within a horizontal **period**, there is an increase in nuclear charge. As the **nuclear charge** increases (number of protons on the nucleus), the magnitude of the electric field within which the electrons find themselves also increases, and so generally speaking, the ionisation energy increases within a period. Also, the **atomic size** decreases from left to right and so the electrons for atoms towards the right are closer to the nucleus compared to those on the left, and so this also results in a general increase of **ionisation energy** from left to right.

Within a vertical **group**, there is generally a decrease of ionisation energy from top to bottom which is predicted on the basis of size of the atom alone. Any potential increase in ionisation energy on the basis of increased nuclear charge, going from top to bottom, is essentially cancelled out by the increased **screening effect** of the inner electrons on the outer electrons.

Generally speaking, elements with a low ionisation energy are on the left-hand side of the periodic table and those with a high ionisation energy are on the right. Noble gas configurations (eight valence electrons) can cause exceptions to these general rules.

3.11 Electronegativity

The **electronegativity** describes the relative ability for an atom, when it combines with another atom, to become "more negative" by more strongly capturing a shared electron or electron pair.

It is found that the more difficult it becomes for an atom to lose an electron, the easier it is for the atom to add an extra electron. That is, a higher **ionisation energy** also means a higher electronegativity.

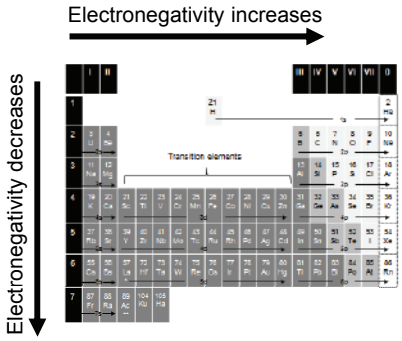

Some electronegativities within a **group** are:

Be	1.5
Mg	1.3
Ca	1.0
Sr	0.95
Ba	0.9
Ra	0.9

Some electronegativities within a **period** are:

Li	Be	B	C	N	O	F	Ne
1.0	1.5	2.0	2.5	3.0	3.5	4.0	-

The electronegativity of fluorine is so strong that in some circumstances, it is able to attract an electron from helium and so produce a compound that involves a noble gas.

The electronegativity of an atom influences the nature of the bonding between different types of atoms. Even when a bond is covalent, the shared electron spends more time nearer to the atom which has a higher electronegativity. The resulting molecule becomes polar.

4. Chemical Bonds

Summary

Lewis electron dot structures

Van der Waals

Hydrogen bond

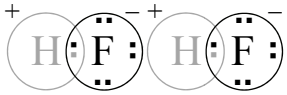

Oxidation numbers:

a) In free, uncombined, elements, the oxidation number of each atom is set to 0.

b) In compounds involving hydrogen, the oxidation number of hydrogen is 1+ .

c) In compounds involving oxygen, the oxidation number of O is usually 2−.

d) The sum of all the oxidation numbers of all atoms in an ion is equal (in both magnitude and sign) to the charge on the ion.

e) The sum of all the oxidation numbers of all atoms in a neutral molecule is 0.

Oxidation $\rightarrow$ Increase in Oxidation No. $\rightarrow$ Loss of Electrons

Reduction $\rightarrow$ Decrease in Oxidation No. $\rightarrow$ Gain of Electrons

4.1 Chemical Bond

Consider two hydrogen atoms that are initially a long way apart from each other. The two atoms are both electrically neutral, and have no ionic character. Why should they then be attracted to each other and form a stable H_2 molecule? Atoms tend to arrange themselves in the lowest possible energy state. In a **covalent bond** (like in H_2), the sharing of electrons provides the necessary reduction in total energy since the shared electrons, now having more space to move (over two atoms instead of one) have a lower **energy** than a single electron orbiting a single nucleus (see Section 1.5). This reduction in energy appears to us like a force of attraction acting between the atoms.

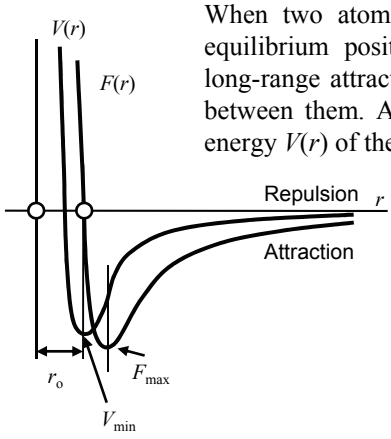

When two atoms form a **chemical bond**, they take up equilibrium positions according to the balance between long-range attractive and short-range repulsive forces $F(r)$ between them. At the **equilibrium position**, the potential energy $V(r)$ of the bond is a minimum.

The potential energy function (V(r)) acting between two atoms can be very complex. Simple models are usually used, a very popular one being the **Lennard-Jones potential**:

$$V(r) = -\frac{A}{r^6} + \frac{B}{r^{12}}$$

In this potential, the negative term is the energy associated with the attractive forces and the positive term is the energy associated with the repulsive forces.

It is convenient to assign a potential energy of zero to widely spaced molecules or atoms so that when they approach, the potential energy becomes more negative. Since we generally assign a positive number to **work** done on a system (energy entering a system) and a negative number to work done by a system (energy leaving a system), work has to be done on the molecules or atoms to separate them. Thus, when the atoms are at the equilibrium position, energy is required to be done on the system to move one atom from the equilibrium distance to infinity against the force of attraction. This energy is called the **bond energy** (usually in kJ/mol).

To be consistent with the assignment of energy, we must therefore treat **attractive forces** as negative and repulsive forces as positive. The force F, with this sign convention, when multiplied by the distance of movement r, then results in an energy of the correct sign.

4.2 Lewis (Electron Dot) Formulae

Molecules and compounds form when bonds exist between atoms involving the transfer or sharing of valence electrons. The **Lewis symbol** for an atom is the element symbol surrounded by dots that represent the possible **valence electrons** for the atom.

Lewis recognised that bonding or sharing of electrons occurred so that an element tended to acquire eight valence electrons (noble gas configuration): the **octet rule**. To represent a bond between two atoms, a **Lewis structure** is written so as to indicate the position of the valence electrons:

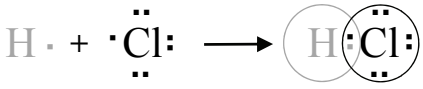

This **Lewis structure** shows how each element acquires a noble gas configuration when a chemical (in this case, ionic) bond is formed.

Group	Lewis formula
I	
II	
III	
IV	
V	
VI	
VII	

"E" denotes an element.

When determining a Lewis structure, the total number of dots that appear (the total number of **valence electrons**) is the sum of the number of valence electrons for each participating atom.

In some cases, it is not easily determined what the Lewis or **electron dot** formula for an atom should be. For example, in carbon, the electronic configuration is: $1s^2\ 2s^2\ 2p^2$ and we might be tempted to write the **electron dot** formula as:

Although this arrangement can occur, when carbon usually combines with other atoms, the 2*s* orbitals combine with the 2*p* orbitals and the electrons are spread out over the resulting combined "*sp*" energy level giving four valence electrons. Carbon is **tetravalent**.

4.3 Multiple Bonds

Covalent bonds between atoms often involve sharing of more than one electron at a time. For example, carbon has a bonding capacity, or valence, of four, and so the carbon compound **ethane** is a stable molecule and is fairly unreactive.

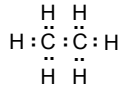

Ethylene, with molecular formula C_2H_4 should therefore leave two lone valence electrons:

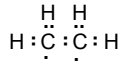

We would therefore expect ethylene to be a very reactive compound, in much the same way as Group I elements. However, this is not the case. Instead, the two carbon atoms arrange for the orbits of the two lone electrons to overlap and be shared. That is, two pairs of electrons are shared between the carbon atoms to form a **double bond**.

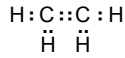

Triple bonds are also possible whereby three pairs of electrons are shared. The double and triple bonds offer even a greater range of movement of valence electrons (since more electrons are shared and so more electrons have more overall room to move) compared to a single bond. The strength of the bond is higher, and the C nuclei are closer together (shorter bond length).

Although the bond energy associated with a double bond is higher, the double bond results in a more reactive compound than a comparable single-bonded structure. This is because the double bond offers more opportunities for other more reactive elements than carbon to attach to these valence electrons – as if other elements can open up the bond and find two potential bonding sites rather than one. It is energetically more favourable to have two single bonds than one double bond.

Molecule	Structural formula	C – C length (Å)	C – C energy (kJ/mol)
C_2H_6 Ethane	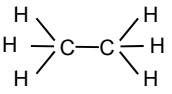	1.54	334
C_2H_4 Ethylene	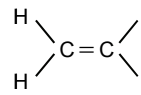	1.33	606
C_2H_2 Acetylene	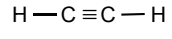	1.20	828

4.4 Lewis Single-Bonded Structures

Some examples of single-bonded structures are:

Molecular formula	Total No. valence electrons	Lewis formula	N	Shape	Note
F_2 Fluorine gas	14		-		Linear
CH_4 Methane	8		4	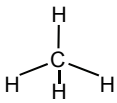	Tetrahedral
$SiCl_4$	32	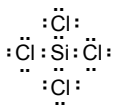	4	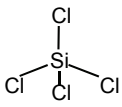	Tetrahedral
NH_3 Ammonia	8		4	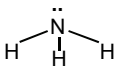	Pyramidal
H_2O Water	8		4	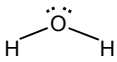	Bent
NH_4^+	8		4	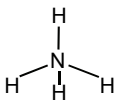	Tetrahedral
C_2H_6 Ethane	14	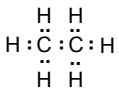	4,4	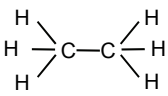	2 tetrahedral
H_2O_2	14	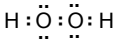	4,4	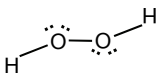	

Note that **lone pairs**, being closer to the central atom, have a greater repulsive effect than bonded pairs and so influence the shape of the molecule. Note that each atom is surrounded by eight electrons (except for H which requires two electrons for noble gas configuration).

4.5 Lewis Multiple-Bonded Structures

Examples of multiple-bonded structures:

Molecular formula	No. valence electrons	Lewis formula	N	Shape	Note
N_2 Nitrogen gas	10		-	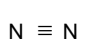	Linear
C_2H_4 Ethylene	12	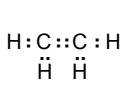	3,3	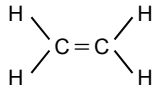	2 Tetrahedral
C_2H_2 Acetylene	10	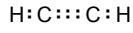	2,2	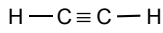	Linear
CO_2 Carbon dioxide	16	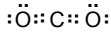	2	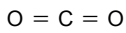	Linear
HCN Hydrogen cyanide	10	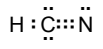	2	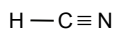	Linear
$COCl_2$ Phosgene	24		3	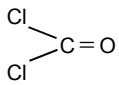	Planar
H_2CO Formaldehyde	12		3	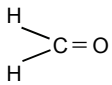	Planar

Note that each atom is surrounded by eight electrons (except for H which requires two electrons for noble gas configuration).

4.6 Lewis Exceptions to the Octet Rule

Examples of structures that do not obey the **octet rule** include:

(1) Atoms having more than eight electrons involved in bonding:

Molecular formula	No. valence electrons	Lewis formula	N	Shape	Note
PCl_5	40	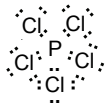	5	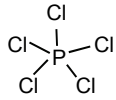	More than an octet
SF_4	43	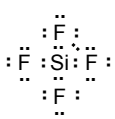	5		More than an octet with lone pair

When there are more than eight electrons involved, such as in PCl_5, the bonding usually involves electrons from the *d* sub-shell.

(2) Atoms having less than eight electrons involved in bonding:

BeH_2	4	H:Be:H		H — Be — H	Less than an octet
NO	11		2	N = O	Less than an octet

When more than one valid structure can be written and the true structure cannot be written, the actual or true structure is called a **resonance hybrid** of the different structures. An example is NO. The unpaired electron (as shown above) can be written as attached to either the N or the O atom.

Example of **resonance structure**: CO_3^{2-}

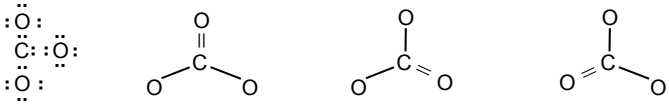

4.7 Oxidation Number

The **oxidation number**, or **oxidation state**, is a quantity that describes the number of electrons that appear to be gained or lost by an atom when a chemical bond is formed. That is, it is essentially the number of electrons that participate in the formation of the chemical bond. If we imagine all bonds to involve a transfer of electrons (even if in reality the bond may be covalent), the oxidation number is essentially the electronic charge that an atom appears to have after the bond has formed. The oxidation number is determined by a set of agreed rules. It is not strictly a physical quantity.

In a molecule or a compound, electrons that are shared between atoms are counted as belonging to the more **electronegative** atom. Electrons that are shared between two identical atoms are equally divided between the two atoms.

(a) In free, uncombined elements the oxidation number of each atom is set to zero. For example, the oxidation number of H in H_2 is zero.

(b) In compounds involving hydrogen, the oxidation number of hydrogen is 1+ except in the case of metal hydrides (where the hydrogen is bonded to an atom which is less electronegative) where it is 1–.

(c) In compounds involving oxygen, the oxidation number of O is usually 2–. The exceptions are the oxygen atom in peroxides and when oxygen is bonded with fluorine.

(d) The sum of all the oxidation numbers of all atoms in an ion is equal (in both magnitude and sign) to the charge on the ion.

(e) The sum of all the oxidation numbers of all atoms in a neutral molecule is 0.

Consider the compound H_2O. The oxygen atom, being more **electronegative** than the hydrogen, is seen to gain two electrons and so is given an oxidation number of 2– (since it seems to have acquired a net "negative" charge). Each hydrogen atom is seen to lose an electron and so the oxidation number of hydrogen in this compound is assigned as 1+.

When the oxidation number of an atom has increased, the atom is said to have been **oxidised** (as in the hydrogen above). This usually involves the loss of electrons. When the oxidation number of an atom has decreased, the atom is said to have been **reduced**, that is, its oxidation number has decreased. This usually involves a gain of electrons (as in the oxygen above).

The oxidation number is useful when naming some compounds. Prefixes like *hypo* and *per*, and suffixes like *ous*, *ic*, *ite*, are assigned according to the oxidation number of the central metal or non-metal atom in a compound.

4.8 Oxidation Number Examples

Example	Element	Oxidation state	Rule
S	S	0	a
H_2S	S	-2	b, e
Fe^{2+}	Fe	+2	d
Fe^{3+}	Fe	+3	d
MnO_4^-	Mn	+7	c, e
Mn^{2+}	Mn	+2	d
$Cr_2O_7^{2-}$	Cr	+6	c, e
Cr^{3+}	Cr	+3	d
NO_3^-	N	+5	c, e
NO	N	+2	c, e
NO_2	N	+4	c, e
SO_4^{2-}	S	+6	c, e
CO_2	C	+4	c, e
H_2O_2	O	-1	special case

When a substance is **oxidised**, it can be done so by either adding oxygen or removing hydrogen. Similarly, when a substance is **reduced**, it can be done so by either removing oxygen or adding hydrogen. For example, consider the production of methane CH_4 from carbon and hydrogen:

$$C + 2H_2 \rightarrow CH_4 \qquad \text{Oxidation No.}$$
$$2H_2 \rightarrow 4H^+ + 4e^- \qquad 0 \text{ to } 4+$$
$$C + 4e^- \rightarrow C^{4-} \qquad 0 \text{ to } 4-$$

From the point of view of the hydrogen, it has lost electrons and so is oxidised. From the point of view of the carbon, it has gained electrons and so is reduced. Of course in this compound, CH_4, the electrons are shared between the C and H atoms as covalent bonds, but from the perspective of oxidation numbers, the electrons are effectively transferred from H to C.

In some biochemical reactions, electrons (in the company of protons H^+) are transferred during oxidation and reduction reactions as a means of passing energy from one molecule to another. The addition of an electron via the addition of hydrogen stores energy in the compound being reduced. The energy is released when the compound is oxidised.

When CH_4 is combined with oxygen (e.g. when it is burnt), the C is oxidised to CO_2 and water:

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

4.9 Polar Bonds

Although bonds between atoms may be classified as being **covalent** or **ionic**, in many different substances, there is a gradation from one type to the other. Unequal sharing of electrons in a covalent bond gives the bond an ionic character. Further, such a covalent molecule may acquire regions of net positive and negative charge and become **polarised**.

Separation of charges within a covalent molecule usually results in electrons spending more time on the atom which has the greatest **electronegativity**.

:C :::O:

In CO, the shared electrons spend more time near O than C and so the centre of positive charge is offset from the centre of negative charge.

For example, in the molecule carbon monoxide, there is a difference in electronegativity between carbon (2.5) and oxygen (3.5) and so the shared electrons spend more time near the oxygen atom than the carbon atom. This results in a net separation of centres of **electric charge** within the molecule. The molecule is thus polarised and is a **dipole**. The molecule as a whole remains electrically neutral, but the distribution of charge within the molecule shifts so that the geometrical centre of positive charge is different than the centre of negative charge.

Although it is straightforward to determine if a diatomic molecule is polar or non-polar, by a consideration of the electronegativities of their atoms, the situation is more complicated for molecules with more than two atoms. For example, in CO_2, the individual bonds between the carbon and the oxygen molecules may be polar, but the molecule as a whole is non-polar because of the symmetry of the shape of the molecule.

:Ö::C::Ö: O = C = O μ = 0 debye

When CO_2 is placed in an electric field there is no net **dipole moment**.

Experiments show that **water** has a permanent dipole moment due to the presence of the electron pairs on the oxygen.

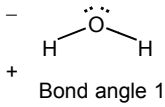

μ = 1.84 debye

Bond angle 104.5°

Polarization is responsible for **physical bonds** forming between molecules which in turn result in molecules forming liquids and solids.

4.10 Hybrid Orbitals

In a covalent bond, when valence electrons are shared between atoms, they do so by overlapping orbitals. Consider an oxygen atom: $1s^2$, $2s^2$, $2p^4$

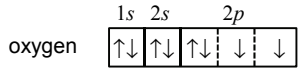

The shapes of molecules are difficult to predict on the basis of the orbitals of isolated atoms because the nature of these orbitals change when there are more than one electron in an atom and when atoms come together to form molecules.

When a molecule of water forms, the 2*s* and the three 2*p* orbitals in the oxygen combine to form a new molecular orbital called the sp^3 **hybrid**. The superscript 3 indicates that three of the original *p* orbitals are involved in the hybrid orbital $2sp^3$ that combines with the *s* orbitals of the H atoms.

Hybrid	Shape
sp	linear
sp^2	plane triangular
sp^3	tetrahedral

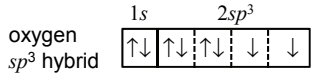

Each of the $2sp^3$ hybrid orbitals is at the same energy level.

When hybridization occurs, the rearrangement of electrons often results in there being more unpaired valence electrons than there were originally. For example, in carbon compounds, we have:

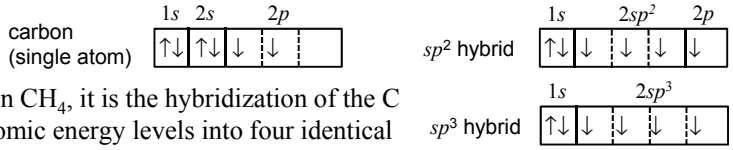

In CH_4, it is the hybridization of the C atomic energy levels into four identical $2sp^3$ orbitals that results in a regular tetrahedral geometry with bond angle 109.5°. In PCl_5 (more than eight electrons bonded), the hybrid orbitals are sp^3d.

In the double C=C bond of C_2H_4 one of the bonds is the end-to-end overlap of one of the sp^2 hybrid orbitals (this is called the σ **sigma bond**) along the line of the two C atoms (the other two sp^2 orbitals overlap with the *s* orbitals of the H atoms), while the other C bond is formed by the side-by-side overlap of the unhybridised (dumbbell shaped) 2*p* orbitals parallel to the plane of the C and H atoms (this is called the π **pi bond**).

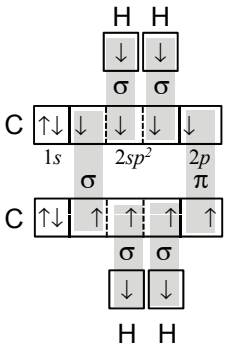

4.11 Polarisation

When an electric field E is applied to a molecule in a non-polar insulating material, the centre of charge of electrons moves left, the centre of charge of protons move right and the two centres of charge are then separated by distance d. The atom or molecule becomes **polarised** in the presence of E.

Polarisation in a material may occur due to several mechanisms, all of which may occur to some extent depending on the atom. Most often, polarisation occurs when an external electric field E is applied.

1. **Electronic polarisation**

   Small induced dipole moment arising from difference in the net centres of nucleus and electrons in an atom.

   $\varepsilon_r \approx 2-4$

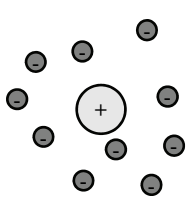

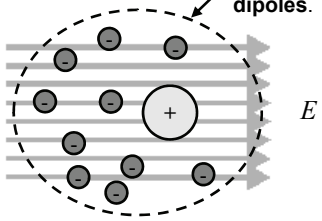

2. **Ionic polarisation**

   Dipole moment created by shift of positive ions with respect to negative ions in unit cell.

   $\varepsilon_r \approx 6-10$

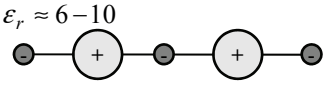

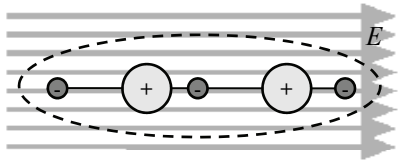

When field is applied, movement of ions produces a net dipole moment in a unit cell and hence a net polarisation.

3. **Dipolar polarisation**

   Net dipole moment created by alignment of molecule with external field due to presence of internal permanent dipoles from geometrical structure of molecule.

   $\varepsilon_r \approx 20-100$

Water molecule has a permanent dipole moment.

CO_2 molecule has no permanent dipole moment. No dipolar polarisation can occur.

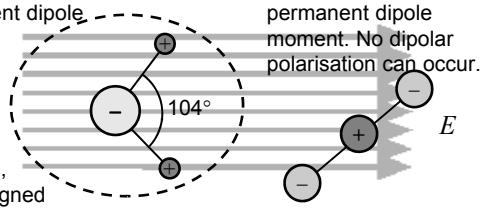

Note: Even though there is a permanent dipole moment, in the absence of an electric field, these dipole moments are not aligned (due to thermal agitation) and so the net polarisation over all molecules in the material is zero. When a field E is applied, molecular dipoles tend to align themselves with the field and there exists a net polarisation.

4.12 van der Waals Forces

The arrangement of electrons around atoms is not constant in time. Electrons move within their energy shells or levels with kinetic energy. An instantaneous movement of an electron within an atom may result in the atom becoming **polarised** for a short period of time. During this time, the polarisation in one atom may induce polarisation in a neighbour atom, resulting in a very brief electrostatic attraction between them. These instantaneous forces of attraction and repulsion are termed **London forces** after the scientist who proposed the explanation for them and are found in all covalent materials.

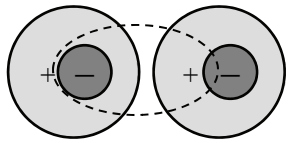

Instantaneous polarisation of one molecule results in induced dipole in neighbour molecule and a net instantaneous attraction between the two molecules.

In materials containing molecules that have permanent dipole moments, the molecules tend to align themselves (against the tendency of thermal agitation to keep them in random orientation). The electrostatic attraction between the polarised ends of the molecules draws them together. **Dipole-dipole interaction** may persist over many molecules and appears to us like a force holding the molecules together.

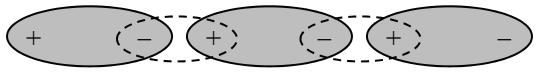

When considered over millions of atoms, the London and permanent dipole forces can be substantial and are called physical, as distinct from chemical, bonds between molecules. The intermolecular forces of this type are called **van der Waals forces**. In most cases, it is the van der Waals forces that bind atoms and molecules into liquids.

Intermolecular forces on this scale are responsible for deviations from ideal behaviour in liquids and gases. Van der Waals forces operate over a small scale in comparison to distances between molecules in a gas. It is only when gas molecules become closer together (such as under increased pressure) that these forces become strong enough to cause the molecules to then clump together and **condense** into a **liquid**. The forces become less effective when the temperature increases due to the tendency for an increase in random order associated with thermal agitation of molecules.

4.13 Hydrogen Bond

Hydrogen has one valence electron and so can readily form a single covalent bond. However, there are some compounds involving hydrogen in which the hydrogen atom can be said to be bonded to two atoms at the same time. Such compounds involve hydrogen bonding with small electronegative atoms.

Consider the **hydrogen fluoride** molecule:

Because fluorine has a large **electronegativity**, the shared electron spends much of its time near the fluorine atom. The molecule, as shown above, is **polar**. Now, if there are other HF molecules nearby, then the positively charged H side of the molecule will be drawn into contact with the negatively charged F end of the other molecule. Two molecules thus join up so:

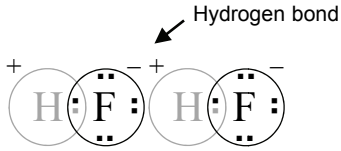

It looks to us like the H atom in the middle is holding the two outer F atoms in place like a tie bar. This electrostatic attraction is called a **hydrogen bond**. The hydrogen bond can only form between hydrogen and small electronegative atoms because the H "ion" is very small and only has space for one other atom to be located near enough to its polar end to form an **electrostatic** bond.

Hydrogen bonds also form between **water molecules**. Hydrogen bonding between water molecules gives rise to a characteristic crystal structure in **ice**, which in turn is reflected in the shape of **snowflakes**.

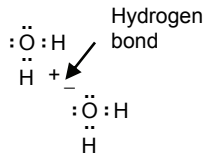

Hydrogen bonding is very important in biological processes. The bonds, having an energy of about 20 kJ, are stronger than those due to van der Waals forces (about 0.2 kJ) but are significantly weaker than those in chemical bonds (about 200 kJ). Certain biological processes rely on these bonds being of just the right strength for events to occur with ease (such as in the forming and breaking of the two halves of the molecular spiral in **DNA** – these hydrogen bonds involve H, O and N atoms).

5. States of Matter

Summary

Gases: $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ Combined gas law

$p_1V_1 = p_2V_2$ Boyle's law

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ Charles' law

$pV = nRT$

Volume

Absolute temperature

Absolute pressure

no. moles

Universal gas constant 8.3145 J/mol/K

Liquids: $\text{Molarity} = \frac{\text{No. moles of solute}}{\text{Volume of solution in litres}}$

Solids:

- Molecular solids - in which the binding forces between discrete atoms or molecules are due to van der Waals interactions between instantaneous electric dipoles.
- Ionic solids - in which the binding energy is due to Coulomb electrostatic forces between positively and negatively charged ions in the crystal.
- Covalent solids - in which the binding energy is due to shared valence electrons between atoms in the solid.
- Metallic solids - in which valence electrons are effectively shared amongst all the atoms in the solid.
- Amorphous solids – no long-range structure.

5.1 Changes of State

When a solid is heated, atoms/molecules within the solid absorb heat energy and this is stored as **internal energy** of vibration. As the temperature increases, the magnitude or amplitude of the vibration increases until the bonds holding the molecules together become temporarily ruptured and molecules flow over one another. This is called **melting**.

At the **melting point**, further heating results in no increase in temperature. The energy input in this case goes to breakage of bonds between the molecules and the material changes phase from solid to liquid.

Upon further heating, molecules of liquid increase their translational energy until they acquire sufficient kinetic energy to escape the liquid into the gaseous phase.

The presence of impurities lowers the melting point. A measurement of the melting point can be used as an index of the purity of a particular substance.

When a liquid cools, molecules begin to lose their internal energy of motion until eventually, intermolecular forces are able to hold them in place as a solid. The temperature at which this occurs is called the **freezing point** – which is usually equal to the melting point.

If the molecules in the cooling solid do not immediately lock into the pattern of the solid, then the temperature may fall below the official freezing point and the material remains in the liquid phase. This is called **supercooling**. Introduction of a seed crystal may cause the liquid to avoid the supercooling condition.

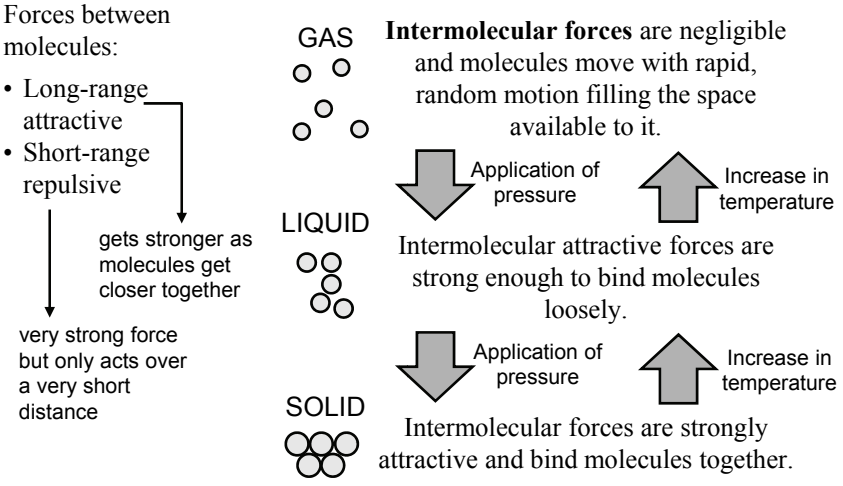

5.2 Changes of State of Liquids/Gases

Closed system

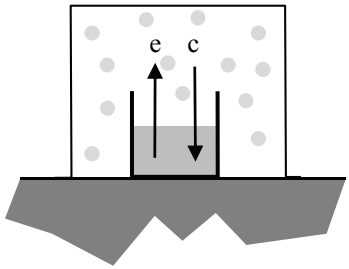

A dynamic equilibrium is set up where the rate of evaporation = the rate of condensation.

The **equilibrium vapour pressure** (**EVP**) or **saturated vapour pressure** is the pressure exerted by the vapour when in equilibrium with its liquid. The magnitude of the EVP depends on the nature of the liquid and the temperature.

- Nature of liquid. The stronger the **van der Waals forces** between molecules, the lower is their ability to escape the liquid and the lower the EVP.
- Temperature. Increase in temperature increases kinetic energy of molecules in the liquid and hence their ability to escape from the surface and hence the higher the EVP.

Open system

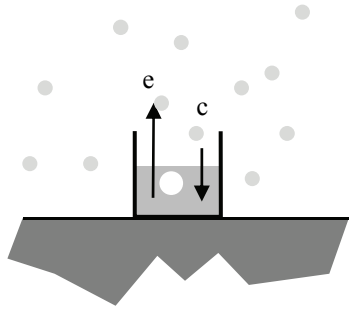

A liquid is said to boil at a temperature called the **boiling point**, at which the EVP of the liquid becomes equal to the prevailing atmospheric pressure. Vapour bubbles form in the liquid and rise to the surface.

The **normal boiling point** is the boiling point at 1 atm of pressure (101.3 kPa).

Increasing the prevailing atmospheric pressure increases the boiling point.

5.3 Phases of Matter

In a ***p*–*V* diagram**, the temperature is kept constant, volume decreased and pressure recorded.

Critical Temperature T_c
There is, for each gas, a temperature above which the attractive forces between molecules are not strong enough to produce liquefaction no matter how high a pressure is applied.

T_c H_2O = 647K at 218 atm
T_c He = 5.2K at 2.3 atm

Vapour pressure
The partial pressure exerted by the vapour when it is in equilibrium with its liquid. It depends on the temperature and nature of the substance. The temperature at which the vapour pressure equals the prevailing atmospheric pressure is called the **boiling point**.

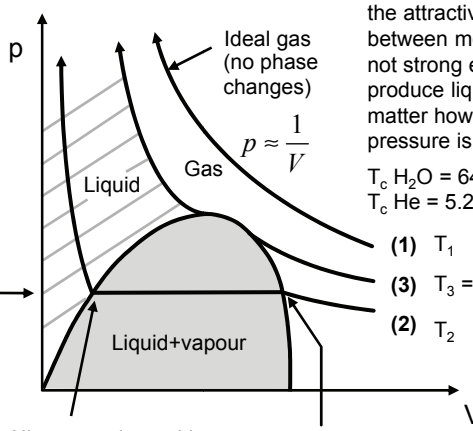

All gas condensed into liquid, attempts to further reduce volume produce large increase in pressure as liquid is compressed.

Gas starts condensing into liquid, no change in pressure as volume decreases.

In a **phase diagram**, we keep the volume *V* constant and plot pressure versus temperature.

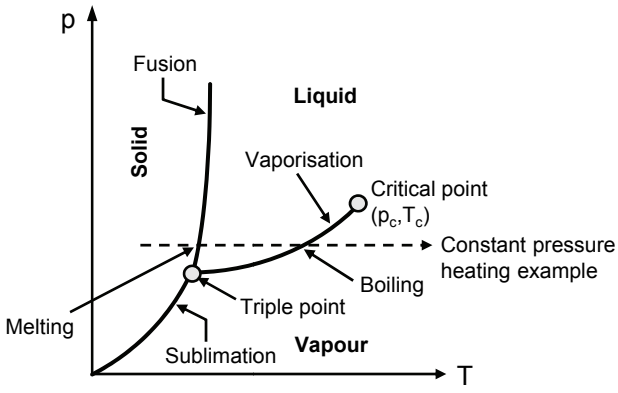

At each point (*p*,*T*) only a single phase can exist except on the lines where there is phase equilibrium. At the **triple point**, solid, liquid and vapour exist together in **equilibrium**.

5.4 Gases

The properties of a perfect or ideal gas are the most convenient to study. The properties of an ideal gas are:

- The molecules of the gas occupy a very small volume compared to the volume of the container.
- The molecules are very distant from one another and only interact elastically during collisions.

Real gases often behave like ideal gases at conditions in which no phase changes occur.

Macroscopic properties of a gas:

- Pressure
- Temperature
- Volume
- Mass

} These quantities specify the **state** of a gas

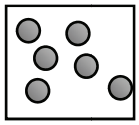

Consider a mass (m) of gas:

If p, V and T all vary, then:

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$ **Combined gas law**

If temperature T is a constant:

$$p_1V_1 = p_2V_2$$ **Boyle's law**

If pressure p is a constant:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ **Charles' law**

Note: These laws cannot be applied when the mass of gas changes during the process. Pressures and temperatures are absolute.

Let us express the mass of a gas indirectly by specifying the number of moles. Experiment shows that Boyle's law and Charles' law lead to:

Volume → $pV = nRT$ ← Absolute temperature

Absolute pressure → p

n ← No. moles

R ← Universal gas constant 8.3145 J/mol/K

This equation links all the macroscopic quantities needed to describe the (steady) state of an *ideal* gas and is thus called an **equation of state**.

Mass in kg → m

No. moles → $n = \frac{m}{M_m}$ ← Molar mass

By using moles, we get the ideal gas equation with the universal gas constant R (units J/mol/K). Otherwise, value of R depends on the nature of the gas (i.e. no longer universal) and has units J/kg/K.

Example: Calculate the volume occupied by one mole of an ideal gas at 273 K at atmospheric pressure.

$$pV = nRT$$
$$101.3(V) = 1(8.314)(273)$$
$$V = 22.406\ \text{L}$$

5.5 Solutions

Homogenous mixtures of two or more gases, liquids, or solids are called **solutions**.

- Gases usually mix in any proportion. Air is a solution of predominantly nitrogen, oxygen and carbon dioxide.
- Liquid solutions can be made by dissolving a solid, liquid or gas (the **solute**) in a liquid (the **solvent**). When the solvent is water, the solution is called an **aqueous solution**.
- Solid solutions occur where atoms of one solid are randomly dispersed throughout the other solid. **Alloys** are common examples of solid solutions although some alloys are **compounds** (combine in definite proportions). Some alloys are also heterogeneous **mixtures**.

Intermediate between heterogeneous mixtures and homogenous solutions is the case where the dispersed solid particles are not broken up into molecular units and yet are not in collections large enough to be called a separate phase. In this case, the dispersion is called a **colloid**.

The strength, or **concentration**, of a solution can be described as:

- The ratio of the number of moles of one of the components (the solute or the solvent) relative to the total number of moles present is called the **mole fraction** of the component.
- The number of moles of solute per litre of final *solution* is called the **molarity** and given the symbol M (this is the most common method but depends on volume, which in turn is temperature dependent).
- The number of moles per kilogram of *solvent* is called the **molality** and is given the symbol m (has the advantage of not being dependent on temperature).
- The percent solute by mass or volume of the final solution.
- % by weight (**w/w**) is the number of grams of solute per 100 g of solution.
- % by volume (**w/v**) is the number of grams of solute per 100 mL of solution.

The limiting concentration of the solution to which a solute can be dissolved in a solvent is called the **solubility**. At this concentration, the solution is said to be **saturated**. Addition of excess solute results in no increase in concentration and a portion of the solute remains undissolved.

5.6 Aqueous Solutions

Many chemical reactions involve chemicals that exist as water, or **aqueous solutions**.

$$\text{Molarity} = \frac{\text{No. moles of solute}}{\text{Volume of solution in litres}}$$

Examples:

(1) Calculate the mass of solute needed to make up 1 litre solution of 0.5M sodium hydroxide:

$$\begin{aligned} 1\,\text{mole NaOH} &= 23+16+1 \\ &= 40\,\text{g} \\ \text{mass required for 1 L solution at 0.5M} &= 40(0.5) \\ &= 20\,\text{g} \end{aligned}$$

(2) Calculate the volume of 10M acid required to make up 250 mL of 0.4M solution of HCl:

$$\begin{aligned} 1\,\text{L} &= 0.4\text{M} \qquad\qquad \text{Cl} = 35.5 \\ &= (0.4)(36.5)\,\text{g} \qquad\quad \text{H} = 1 \\ &= 14.6\,\text{g} \\ 0.25\,\text{L} &= 3.65\,\text{g HCl required} \\ 10\text{M} &= 365\,\text{g/L HCl} \\ 3.65\,\text{g HCl} &= 10\,\text{mL} \end{aligned}$$

It is often observed that for dilute aqueous solutions, the addition of the solute lowers the **freezing point** and raises the **boiling point** (reduction in vapour pressure) compared to pure water.

When an aqueous solution evaporates, a **hydrated ionic compound** may be formed. The hydrated compound contains water of crystallization:

$$\text{Co}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq}) \xrightarrow{\text{evap}} \text{CoCl}_2 + 2\text{H}_2\text{O(s)}$$

5.7 Solubility of Solids

When a solute dissolves in a solvent, three distinct processes can be identified:

- Solute-solute interactions – whereby the solute atoms or molecules are separated from each other (such as the dissociation of Na^+ and Cl^- into ions). This is an **endothermic** process (heat is required to break the ionic bonds).
- Solvent-solvent interactions – whereby the solvent atoms or molecules may be separated from each other (such as when H_2O molecules are separated from one another to accommodate the incoming solute molecules). This is an **endothermic** process.
- Solute-solvent interactions – whereby processes occur between the solute and the solvent. These are usually **exothermic** (reduction in total energy).

Some ionic compounds are soluble in water, but insoluble in non-polar solvents (like benzene and carbon tetrachloride). When water is the solvent, a **hydration** process can occur which serves to insulate the positive and negative ions from each other and prevent them reforming into a solid. This is a solute-solvent interaction.

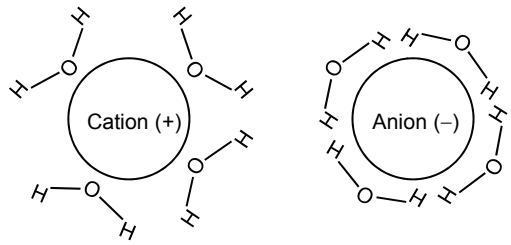

Hydration involves the formation of bonds and so is exothermic (heat is released as the total energy is lowered) and so the solute-solvent interactions dominate the solute-solute interactions. Non-polar solvents cannot hydrate the ions.

Some non-polar molecular solids are soluble in non-polar solvents but are insoluble in water (a polar solvent). Non-polar solute molecules are not hydrated by water, and so solute-solvent interactions are not significant here. If more energy is required to break the hydrogen bonds linking water molecules together than that required to break the bonds holding the components of the solute together, then the solute components remain insoluble. When placed in a non-polar solvent, solvent-solvent interactions may occur and the solvent molecules separate easily to accommodate solute molecules and the solute dissolves.

5.8 Solubility Equilibrium

If a solute is added to the solvent in increasing quantity, a point is reached where the atomic or molecular species being dissolved can no longer be accommodated in the solute. As more solute is added, the reverse process begins to occur so that some of the previously dissolved solute returns to the solute phase. This is called **precipitation**. This is most vividly illustrated when a solid solute is added to a liquid solvent. When the rate of precipitation becomes equal to the rate of **dissolution**, dynamic equilibrium is achieved and the solution is said to be **saturated**.

The **concentration** of a solute in a given solvent at **saturation** is called the **solubility** of the solute in the solvent.

Solubility depends on **temperature**. When a solute is dissolved in a solvent and heat is generated, the solubility generally decreases with increasing temperature. If heat is absorbed, the solubility generally increases with increasing temperature. Often, whether or not heat is absorbed or generated depends on the physical processes involved in any chemical reactions that may occur in the solution.

Solubility depends on **pressure**. For a non-reactive gas being dissolved in a liquid, the solubility C increases as the pressure P increases according to **Henry's law**: $C \propto P$

For example, dissolved CO_2 in a soft drink readily precipitates (observed as bubbles) when the pressure above the liquid is released (such as when the bottle is opened). An easy way to remember Henry's law is to think of it as the soft drink law.

For example, air dissolves in water to some extent and when it does so, heat is produced (since the gas "condenses" into a liquid form). The solubility of air in water thus decreases as the temperature increases. When water is heated, the dissolved air can be seen to "precipitate" as bubbles before the boiling point of water is reached.

One of the most common solvents is water, but not all compounds are soluble in water.

Compound	General rule	Exceptions
Nitrates	Soluble	
Chlorides	Soluble	AgCl, $PbCl_2$, Hg_2Cl_2
Sulphates	Soluble	$PbSO_4$, $BaSO_4$
Carbonates	Insoluble	Na_2CO_3, K_2CO_3, $(NH_4)2CO_3$
Hydroxides	Insoluble	NaOH, KOH, $Ba(OH)_2$, (NH_4OH)
Oxides	Insoluble	Na_2O, K_2O, BaO

5.9 Electrolytes

Some molecular and ionic compounds dissolve in water to give a solution that is able to conduct electric current. The compounds, when dissolved in water, dissociate into **ions**. The ions, being electrically charged, are thus able to move under the influence of an electric field and the movement of these ions is therefore an electric current.

- **Strong electrolytes** dissociate completely into ions. Many ionic compounds are strong electrolytes. Molecular compounds that are strong electrolytes are usually acids.
- **Weak electrolytes** only partially dissociate into ions. Usually, molecular compounds that are weak electrolytes are either an acid or a base.
- **Non-electrolytes** do not dissociate into ions when placed in solution. Molecular compounds that are neither acids or bases are usually non-electrolytes.

Molecular compounds that are **strong electrolytes**:

	Molecular formula	Ions formed in solution	
Hydrochloric acid	HCl	H^+, Cl^-	Strong acid
Nitric acid	HNO_3	H^+, NO_3^-	Strong acid
Sulphuric acid	H_2SO_4	H^+, SO_4^{2-}	Strong acid
Perchloric acid	$HClO_4$	H^+, ClO_4^-	Strong acid

Molecular compounds that are **weak electrolytes**:

	Molecular formula	Ions formed in solution	
Acetic acid	CH_3COOH	H^+, $CH_3CO_2^-$	Weak acid
Benzoic acid	C_6H_5COOH	H^+, $C_6H_5CO_2^-$	Weak acid
Ammonia	NH_3	NH_4^+, OH^-	Weak base

Molecular compounds that are **non-electrolytes**:

	Molecular formula	Ions formed in solution
Ethyl alcohol	C_2H_5OH	
Sucrose	$C_{12}H_{22}O_{11}$	

5.10 Osmosis

Osmosis is a movement of molecules through a **semi-permeable membrane**. A **semi-permeable membrane** is a sheet of substance that can allow some molecules through it but not others. Semi-permeable membranes can be things like **cell walls** in living tissue that contain openings that allow small molecules to pass through but not large molecules.

The concept of **osmosis** depends on the phenomenon of **diffusion**. Diffusion occurs when there is a **concentration gradient**. The concentration gradient drives the diffusion process. It is a fundamental consequence of the **second law of thermodynamics**. Diffusion happens in a wide variety of physical processes (e.g. the formation of the barrier potential at the p-n junction of a **semiconductor**).

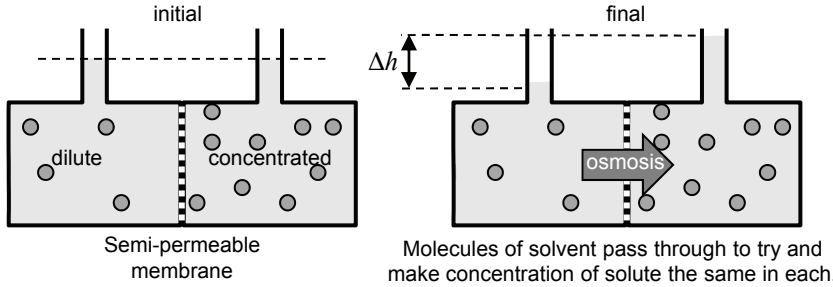

Consider a **dilute solution** on one side of a semi-permeable membrane and a **concentrated solution** on the other side. In this example, the semi-permeable membrane allows molecules of **solvent** to pass through it, but not the **solute**. Be careful. In this case, the **concentration gradient** has to be looked at from the point of view of the solvent. In this case, molecules of solvent tend to pass from the dilute solution into the concentrated solution so as to attempt to achieve uniformity of concentration throughout. Molecules of solute from the concentrated solution would very much like to pass into the dilute side to achieve the same aim, but cannot pass through the membrane. The movement of solvent from one side to the other results in an increase in pressure on the concentrated side. The increase in pressure tends to inhibit the further flow of solvent and an equilibrium condition is reached where no more net movement occurs across the membrane. This pressure increase is called **osmotic pressure**.

For dilute solutions, the osmotic pressure π in atm (atmospheres) of non-electrolytes is given by $\pi = MRT$ where M is the molar concentration of the non-electrolyte, T is in K, and $R = 0.0821$ L atm/mol/K.

5.11 Solids

Generally speaking, there are two kinds of solids. **Crystalline solids** possess a repeating order of atoms, ions, complex ions, or molecules. The repeating pattern is called the **crystal lattice**. The repeating unit in the crystal lattice is called a **unit cell**. **Amorphous solids** have no repeating structure of atoms, ions or molecules.

Crystalline solids can be broadly classified as follows:

Molecular solids are those in which the binding forces between discrete molecules are due to instantaneous van der Waals interactions in addition to dipole-dipole attractions in polar molecules. Covalent bonds exist within the molecules between the atoms.

- Generally soft
- Gas, liquid or solid at room temperature
- Low melting point (about 20 ± 200°C)
- Not usually soluble in water
- Poor conductors of electricity
- Heat insulator

Examples: molecular crystals of noble gases, halogens. Compounds such as CO_2, CH_4, H_2O, C_6H_6, $C_{12}H_{22}O_{11}$ (sucrose) and most organic compounds.

Ionic solids are those in which the binding energy is due to Coulomb electrostatic forces between positively and negatively charged ions in the crystal. That is, ionic solids are composed of **cations** and **anions**.

- Generally hard
- Solid at room temperature
- High melting point (about 800°C)
- Usually soluble in water
- Poor conductors of electricity in solid form
- Heat insulator

Examples: cations from Group I (e.g. Na^+) or Group II (e.g. Mg^{2+}) with anions O^{2-}, S^{2-}, NO_3^-, CO_3^{2-}, ClO_4^-, SO_4^{2-}, CrO_4^{2-}, PO_4^{3-}, H^+, OH^-, MnO_4^-, CN^-.

Covalent solids are those in which the binding energy is due to shared valence electrons (**covalent bonds**) between atoms in the solid.

- Generally hard
- Solid at room temperature
- Very high melting point (about 1200°C)
- Insoluble in water
- Poor conductors of electricity
- Heat insulator

Examples : Si, C (**diamond**), Ge, SiO_2 (**quartz**), BN, SiC.

Metallic solids in which valence electrons are effectively shared amongst all the atoms in the solid.

Amorphous solids have no long-range regular repeating pattern of atoms or molecules. Examples are glass and most plastics. In these materials, there is an orderly structure in the neighbourhood of any one atom, but this is not regularly repeated throughout the material.

5.12 Crystalline Lattice Structures

For geometrical reasons, there are only fourteen types of lattices that satisfy symmetry operations such as translation, rotation, reflection and inversion. Each of these fourteen lattices is called a **Bravais lattice**. There are seven convenient **crystal systems** in the set of Bravais lattices: cubic, tetragonal, orthorhombic, trigonal, monoclinic, hexagonal and triclinic.

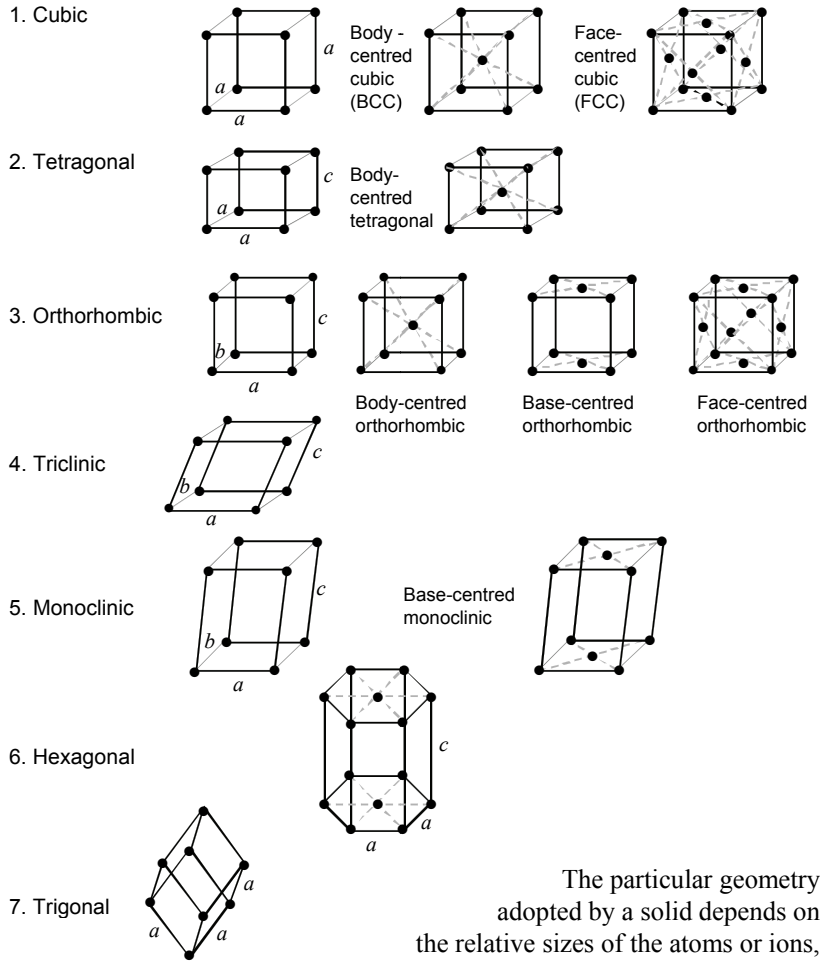

The particular geometry adopted by a solid depends on the relative sizes of the atoms or ions, their charge (for ions). Note: The lines shown in these images do not actually exist in a real material, but just serve to illustrate the overall shape of the lattice.

5.13 Metallic Solids

Metallic solids are those in which valence electrons are effectively shared amongst all the atoms in the solid. Atoms are held in place by the **metallic bond**.

- Can be either hard or soft
- Solid at room temperature (except Hg)
- Low to high melting point (room temperature and above)
- Insoluble in water
- Good conductors of electricity
- Heat conductor

Most metals crystallise into either body-centred cubic (BCC), hexagonal close-packed, and face-centred cubic (FCC). Common metals with **BCC** structure are Fe (**iron**), Cr (**chromium**), Mo (**molybdenum**), W (**tungsten**), V (**vanadium**). Common metals with **FCC** structure are Al (**aluminium**), Cu (**copper**), Au (**gold**), Pb (**lead**), Ni (**nickel**), Pt (**platinum**), Ag (**silver**). Common metals with close-packed hexagonal form are Cd (**cadmium**), Co (**cobalt**), Mg (**magnesium**), Ti (**titanium**), Zn (**zinc**). Metals with BCC structure have a higher yield strength than those with FCC structure.

At room temperature, iron has a BCC structure, but above 910°C, iron rearranges into an FCC structure (at which time it becomes non-magnetic). This change in structure takes place in the solid state and is called an **allotropic change**.

Solid solutions are very important in **metallurgy**, where they are called **alloys**. In a true solid solution, one component is randomly dispersed throughout the other component. Other types of alloys are molecular compounds (in fixed proportions) and heterogeneous mixtures. A particularly important alloy is that of iron and carbon, which makes **steel**.

Carbon Content:

0.05–0.3%	Low-carbon steel	Mild steel, tough, ductile, easily forged and welded.
0.3–0.45%	Medium-carbon steel	Strong, hard, not so easily forged or welded.
0.45–0.75%	High-carbon steel	Very strong (high-strength steel) and hard. May be annealed for machining or heat treated for different degrees of hardness.
0.75–1.5%	Very high-carbon steel	

6. Chemical Thermodynamics

Summary

Internal energy: $\Delta U = nC_p(\Delta T)$

Work: $W = p\Delta V$

First Law: $Q_p = \Delta U + p\Delta V$

Enthalpy: $\Delta H = \Delta U + p\Delta V$
$= Q_p$

Entropy: $\Delta S = \frac{Q}{T}$

$\Delta S_{\text{total}} > 0$ irreversible process
$\Delta S_{\text{total}} = 0$ reversible process
$\Delta S_{\text{total}} < 0$ impossible process

Gibbs energy: $\Delta G = \Delta H - T\Delta S$

Spontaneous reactions:

$$\Delta G_{\text{reaction}} = \Delta_f G^0{}_{\text{products}} - \Delta_f G^0{}_{\text{reactants}}$$

6.1 Molecular Energy

Molecules in a gas are capable of **independent motion**. Consider a diatomic gas molecule:

(a) the molecule itself can travel as a whole from one place to another

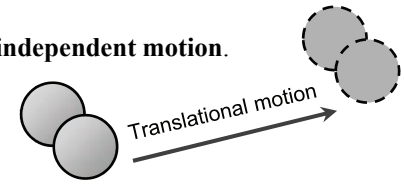

(b) the molecule can spin around on its axis

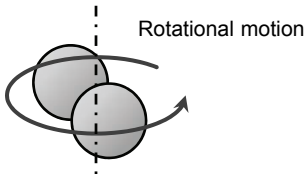

(c) the atoms within the molecule can vibrate backwards and forwards

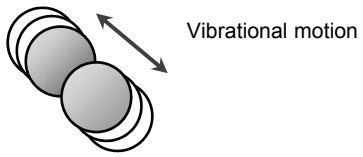

These **kinetic energy** terms represent the **internal energy** and have significance for the interpretation of the **specific heat** capacity of a substance. Changes in internal energy of a molecule manifest themselves physically as changes in **temperature** of the molecule.

The total energy of the molecule also contains some **potential energy** components. Firstly, there are **intermolecular forces** (such as **van der Waals forces**) that lead to the formation of liquids, and hydrogen bonds.

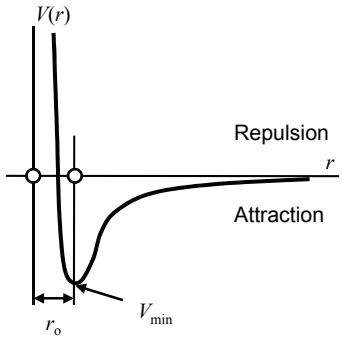

Secondly, there is the potential energy associated with the **chemical bond** between the atoms of the molecule, the **bond energy**.

These potential energy terms are associated with the *position* of the atoms within a molecule, and the position of molecules in relation to other molecules, as distinct from the *motion* of the atoms or molecules.

6.2 Specific Heat Capacity

The amount of energy (ΔQ) required to change the temperature of a mass of material is found to be dependent on the:

- Mass of the body (m) kg
- Temperature increase (ΔT) ^{o}C, K
- Nature of the material (c) J/kg$^{/}$/K

$$\Delta Q = mc(\Delta T)$$

Specific heat or **heat capacity**

Material	**c (kJ/kg/K)**
water	4.186
steel	0.45
cast iron	0.54
aluminium	0.92

The **specific heat** is the amount of heat required to change the temperature of 1 kg of material by 1^{o}C

Molar specific heat, or **molar heat capacity** (C), is the amount of heat required to raise the temperature of 1 mole of the substance by 1^{o}C.

$$\Delta Q = nC(\Delta T)$$

Experiments show that when a gas is heated at constant volume, the **molar heat capacity** C_v is always less than that if the gas is heated at constant pressure C_p. This is because for a constant volume process, there is no opportunity for there to be mechanical work done on or by the system.

For a constant pressure process, for a given temperature rise ΔT, there will always be a volume change ΔV . Therefore the energy into the system has to both raise the temperature *and* do work, thus C_p is always greater than C_v.

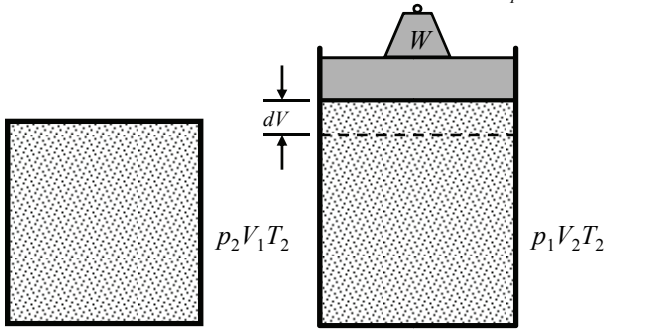

For a constant pressure process, a volume change involves a force acting through a distance and hence work is done on or by the system. Volume change in solids and liquids very small, and hence distinction between C_p and C_v not usually made.

Q_p is a very important quantity in industrial processes and is given the name **enthalpy**.

6.3 Enthalpy

Consider a beaker of solution which is heated from an external source. That is, heat energy is transferred into the system across the boundary.

The temperature of the solution increases by an amount dependent on the **molar heat capacity** C_V of the solution. The change in **internal energy** of the system will be:

$$\Delta U = nC_v(\Delta T)$$

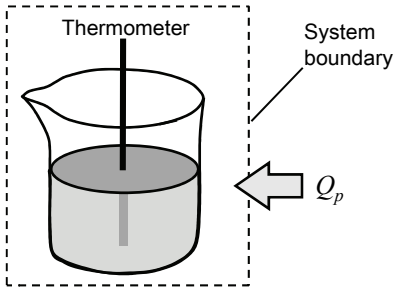

The solution may also expand by an amount ΔV and perform mechanical **work** (e.g. by a piston that fits into the top of the beaker and floats on the surface of the solution):

$$W = p\Delta V$$

The relationship between the heat entering the system, the work done by the system and the rise in internal energy is expressed by the **first law of thermodynamics**:

$$Q_p = \Delta U + p\Delta V$$

Q_p is positive when heat enters the system.
W is positive when work is done by the system on the surroundings. ΔU is positive when ΔT is positive.

If heat energy Q_p is added to the system, then some of this heat goes into mechanical work and some into internal energy. The sum of the change in internal energy and the work done on or by the system is called the change in **enthalpy** ΔH of the system:

$$\Delta H = \Delta U + p\Delta V$$
$$= Q_p$$

Note: $p\Delta V$ is usually small in comparison to ΔU in experiments in the laboratory whereupon ΔH is approximately equal to ΔU.

That is, the change in enthalpy of the system is the same as the amount of heat energy that has been put into it.

If the heating of the solution involves a **phase change**, then some of the heat energy input would be consumed by latent heat which would have to be accounted for.

If the heating of the solution initiates a **chemical reaction**, then heat energy may be released (e.g. as happens during combustion) or absorbed by the solution as the potential energy of the **chemical bonds** (chemical energy) changes. This is called the **heat of reaction**. The heat of reaction is a release, or absorption of potential energy of the chemical bonds.

6.4 Heat of Reaction

Consider the reaction between two chemical species in an aqueous solution in a beaker which is placed in a temperature controlled water bath so that the beaker is maintained at a constant temperature. That is, heat flow can occur across the system boundary but the solution is held **isothermal**.

If, as a result of the reaction, heat energy is released, then this heat must pass out through the system boundary. The surrounding water bath ensures that the heat energy is taken away fast enough to prevent any temperature rise of the solution.

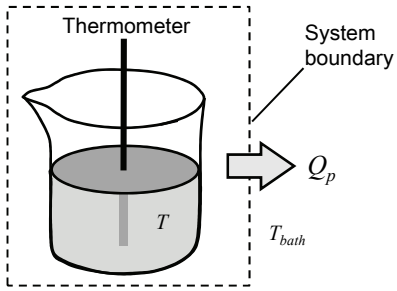

- The **internal energy** of the system remains the same after the reaction as indicated by no rise in temperature.
- **Energy** has come from the **heat of reaction** and been transferred into the water bath.
- If there has been a volume change, then mechanical **work** also would have been performed on (+ve) or by (-ve) the system.

In this example, there must have been a net release of bond energy as a result of the chemical reaction. Some of this energy has been carried away across the boundary by the water bath, and some (a small amount in this case) has gone into mechanical work against the pressure of the atmosphere. The change in **enthalpy** of the system is:

$$\Delta H = \Delta U + p\Delta V$$

We can assume that the mechanical work involved in this example is small compared to the heat lost by the system to the surroundings. Thus, $\Delta H = Q_p$. In this example, heat Q_p has passed out of the system and so the change in enthalpy is a decrease. When heat is passed out to the surroundings, the reaction is said to be **exothermic**. If the reaction involved an absorption of heat from the surroundings, then the change in enthalpy would be positive, and the reaction is called **endothermic**.

The heat of reaction represents the change in enthalpy in this isothermal system. The question now is, if there is a chemical reaction, *and* the temperature changes, how is the change in enthalpy calculated?

6.5 Heat of Reaction

Consider the reaction between two chemical species in an aqueous solution in an insulated beaker. A **thermometer** measures the temperature change during the reaction.

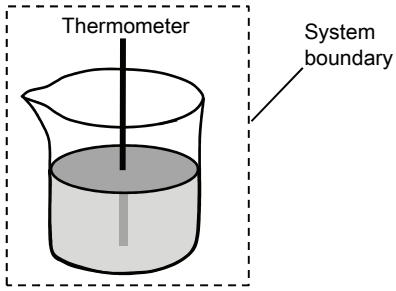

The reaction takes place inside the boundary of a system. For the present example, we will assume that the system boundary is **adiabatic**. That is, no heat flow will occur across the boundary, as if the beaker were fully insulated.

If, as a result of the reaction, the temperature of the solution rises, then:

- The **internal energy** of the system is higher after the reaction, as indicated by a rise in temperature.
- **Energy** has come from the **heat of reaction** and been transferred into internal energy of motion of the molecules in the solution.
- If there has been a volume change, then mechanical **work** also would have been performed on (+ve) or by (-ve) the system.

Since no external heat energy was involved (no heat flow across the system boundary), the heat energy needed to raise the temperature of the solution must have come from the net sum of energies from the breakage and formation of the **chemical bonds** involved in the reaction. In this example, there must have been a net release of bond energy as a result of the reaction. Some of this energy has gone into internal energy of motion of the molecules, while some (a small amount in this case) has gone into mechanical work against the pressure of the atmosphere. In this case, $\Delta H = \Delta U + p\Delta V$. If the work done is negligible, then $\Delta H \approx \Delta U$. In this case, the change in enthalpy is equal to the **heat of reaction**. Although no heat has crossed the system boundary, heat has appeared as a result of the chemical reaction – just as if it had come from outside the system. That is, in this *adiabatic* example, heat Q_p has entered the system from the chemical reaction and $\Delta H \approx \Delta U$.

6.6 Enthalpy of Formation

A chemical reaction is the process of breakage and formation of chemical bonds. Energy is absorbed when a bond is broken, and energy is released when a bond is formed. When a chemical reaction occurs, heat may be either given off, or absorbed to or from the surroundings. That is, the change in enthalpy may be either positive (**endothermic**) or negative (**exothermic**).

Liquid water molecules are made by the reaction between H_2 and O_2 gas molecules:

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(aq)$$

The equation is written in terms of the formation of 1 mole of product. Under standard conditions (1 atm pressure and 25ºC) it is found that 286 kJ of heat energy is produced. That is, the change in enthalpy of the system is $\Delta H = -286$ kJ. This is the **heat of reaction**.

When the reactants are at standard conditions, and the products are also kept at standard conditions (e.g. by use of a water bath to maintain temperature), the heat of reaction is referred to as the **heat of formation**, or **enthalpy of formation**. Standard heats of formation are determined by experiment.

Name	Molecular Formula	Heat of Formation ΔH, kJ/mol
Methane	CH_4	-75
Carbon dioxide	CO_2	-394
Ammonia	NH_3	-46
Acetylene	C_2H_2	+227
Ethylene	C_2H_4	+227
Ethane	C_2H_6	-85
Water	H_2O	-286
Hydrochloric acid	HCl	-92
Sodium hydroxide	NaOH	-427
Aluminium oxide	Al_2O_3	-1670
Carbon monoxide	CO	-110

When the reaction proceeds in reverse, the sign of the heat of formation is reversed.

The reference point for heats of formation are elements at standard conditions. For example the heat of formation of $O_{2(g)}$ is set to zero.

Heats of any reaction can be obtained by addition of heats of formations of known compounds, or **Hess' law**. The change in enthalpy for the combustion of ethane is:

$$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$$

$$\left(C_2H_6(g) \rightarrow 2C(s) + 3H_2(g)\right) \quad \Delta H = +85$$

$$2\left(C + O_2 \rightarrow CO_2\right) \quad \Delta H = 2(-394)$$

$$3\left(H_2 + \frac{1}{2}O_2 \rightarrow H_2O\right) \quad \Delta H = 3(-286)$$

$$\Delta H = 85 - 2(394) - 3(286) = -1561 \text{ kJ/mol}$$

Note that the sign of ΔH for C_2H_6 has been reversed in this calculation since the reaction splits this compound rather than forms it. ΔH for the combustion of ethane is called the **calorific value**.

6.7 Entropy

Consider a beaker of ice which is heated from an external source. The ice remains at 0°C (273K) and melts. The amount of energy Q_p needed is determined by the **latent heat of fusion** of ice.

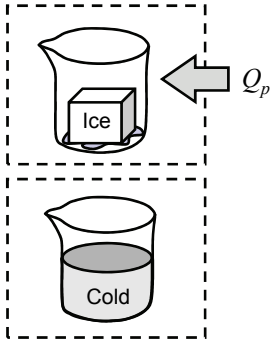

The water molecules have a greater amount of disorder after melting compared to that before heating due to their increased velocity. A quantitative measure of disorder is **entropy**.

Absolute values of entropy S can be calculated from thermodynamic theory or measured in the laboratory. Of more interest to us in chemistry are changes in entropy as a result of physical changes of state, and chemical reactions. When a system undergoes a process at temperature T involving heat flow, the *change* in entropy of the **system** is:

$$\Delta S = \frac{Q}{T}$$

When a system absorbs heat, Q is positive and so the entropy increases, $\Delta S>0$. When a system rejects heat, Q is negative and the entropy decreases, $\Delta S<0$.

If the process occurs at a low temperature, then the change in entropy is greater than if the same process occurs at a higher temperature. At high temperatures, the entropy is already high and so the proportional change in entropy for a given heat flow Q is less compared to that which would occur at low temperatures.

For 1 mole ice:

$$\Delta S = \frac{mL}{T}$$
$$= \frac{0.018(335000)}{273}$$
$$= 22.1 \text{ J/K}$$

When a system undergoes a process and interacts with its surroundings (i.e. a non-isolated system), the total **entropy change** (of the universe) is:

$$\Delta S_{total} = \Delta S + \Delta S_{\text{surroundings}}.$$

The sign of ΔS_{total} signifies the presence of the following types of processes:

$\Delta S_{\text{total}} > 0$ irreversible process
$\Delta S_{\text{total}} = 0$ reversible process
$\Delta S_{\text{total}} < 0$ impossible process

Entropy is not energy. There is no "law of conservation of entropy". Irreversible processes *create* entropy.

When a phase change or a chemical reaction involves heat flow to or from the surroundings, entropy must be considered. The **total entropy** of the system and the surroundings cannot decrease. If the total entropy change is zero, then the process is reversible and so cannot be **spontaneous** in any one direction. For a reaction to proceed spontaneously from reactants to products, the total entropy ΔS_{total} must increase.

6.8 Entropy Calculations

Changes in entropy of a system at constant temperature are expressed as:

$$\Delta S = \frac{Q}{T}$$

When the temperature is not constant, we add up incremental changes in entropy for incremental transfers of heat:

$$dQ = mcdT$$

$$\Delta S = \int_{Q_1}^{Q_2} \frac{1}{T} dQ$$

$$= \int_{T_1}^{T_2} \frac{1}{T} mc\, dT$$

$$= mc \ln \frac{T_2}{T_1}$$

The **standard molar entropy** S^o is the entropy content of one mole of substance under standard conditions of 1 atm pressure and 25ºC. Standard entropies are absolute values and represent the change in entropy to bring the substance from 0K to 273K in its standard state. Standard entropies are always positive. The zero point for entropy is 0K. This statement of zero point for entropy is called the **third law of thermodynamics**.

For a chemical reaction or a physical process, the change in entropy can be calculated from:

$$\Delta S_{\text{reaction}} = S^{\text{o}}{}_{\text{products}} - S^{\text{o}}{}_{\text{reactants}}$$

For example:

$$\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g})$$

$$\Delta S^{\text{o}} = 188 - (131 + 0.5 \times 205)$$

$$= -45.5 \text{ J/K/mol}$$

Element	S^o. (J/K/mol)
H_2(g)	131
O_2(g)	205
N_2(g)	192
Si(s)	19
C(s)	6
Fe(s)	27

Compound	S^o (J/K/mol)
NH_3(g)	192.8
H_2O(l)	70.0
H_2O(g)	188.8
CO_2(g)	213.8
CO(g)	197.7
CH_4(g)	186.2

Note that in this example, the change in entropy for this system is < 0 at the expense of an increase in entropy elsewhere in the universe. Hydrogen and oxygen will, under certain conditions, form water since it is energetically favourable to do so.

6.9 Gibbs Energy

It is a natural tendency of systems to attain the lowest possible potential energy, such as a ball rolling down a hill, electrons moving in an electric field, and so on. In an **exothermic** process, heat leaves a system ($\Delta H < 0$) and we might expect that such processes are always spontaneous and that **endothermic** processes are not. However, this is not observed. For example, when water evaporates spontaneously at room temperature, $\Delta H > 0$ and the water vapour has a higher energy than the liquid.

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(aq) \quad \Delta H = -286\ \text{kJ/mol}$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g) \quad \Delta H = -242\ \text{kJ/mol}$$

$+\Delta H$ signifies energy of products is greater than reactants (endothermic)

$$H_2O(aq) \rightarrow H_2O(g) \quad \Delta H = 286 + -242 = +44\ \text{kJ/mol}$$

Whether or not a phase change or a chemical reaction proceeds spontaneously cannot be judged on the basis of energy alone. The change in entropy ΔS_{total} of both the system (the reaction) and the surroundings must also be considered. Whether or not the change in entropy or enthalpy is the more important factor in any particular process depends on the absolute temperature T.

Now, the total energy of a system is given by the **enthalpy** and this consists of the internal energy and the external work. Changes in total energy are expressed as: $\Delta H = \Delta U + p\Delta V$.

Part of the total energy H is unavailable for conversion into work. This part is connected with changes in **entropy**. Since the units of entropy are J/K, and the determining factor that quantifies the contribution of entropy in a particular process is T, then the unavailable energy can be calculated from the product TS. Thus, the total energy of a *system* can be written as:

$$H = G + TS$$

where G represents that part of the total energy that is freely available for conversion into work. This freely available energy is called the **Gibbs energy**. As the temperature increases, the amount of Gibbs energy decreases and the unavailable term TS increases. Changes in the amount of Gibbs energy in a constant temperature process are thus: $\Delta G = \Delta H - T\Delta S$.

The concept of Gibbs energy allows us to predict the direction of spontaneous chemical reactions by considering both energy and entropy. A spontaneous chemical reaction will proceed only when there is a decrease in available Gibbs energy: $\Delta G < 0$.

6.10 Spontaneous Processes

The concept of Gibbs free energy embodies both energy and entropy considerations in determining in which direction a chemical reaction proceeds. A decrease in Gibbs energy can arise due to a decrease in **enthalpy** or an increase in the product *TS*. In a particular chemical reaction, ΔH and ΔTS may have the same or opposite signs. For a constant pressure process, at constant temperature:

$$\Delta G = \Delta H - T\Delta S.$$

- If a reaction is exothermic $\Delta H < 0$ and the entropy change $\Delta S > 0$, then the free energy change $\Delta G < 0$ and the process is **spontaneous**.
- If a reaction is endothermic $\Delta H > 0$ and the entropy change $\Delta S < 0$, then the free energy change $\Delta G > 0$ and the process is not spontaneous.
- If the enthalpy change $\Delta H > 0$ and the entropy change $\Delta S > 0$, then the process is spontaneous at high temperature. When $\Delta H < 0$ and $\Delta S < 0$, the process is spontaneous at low temperature.

It is important to know that ΔS in the above equation is the entropy change of the *system*, not the total entropy change (of the universe). This enables us to conveniently predict and quantify the direction of a process based upon attributes of the system only.

In chemical reactions, the change in Gibbs energy depends on the physical states of the reactants and products, the temperature and pressure, and the concentration of the reactants and products. When reactants and products are at standard conditions (1 atm and 25°C), the free energy change is referred to as the **standard Gibbs energy change** ΔG^{o}.

The standard Gibbs energy change of the formation of a compound from its elements is called the **standard Gibbs energy of formation** $\Delta_f G^{o}$. Elements at their standard states have zero standard Gibbs energy of formation.

For a process or a chemical reaction, the change in Gibbs energy can be calculated from:

$$\Delta G_{\text{reaction}} = \Delta_f G^{o}{}_{\text{products}} - \Delta_f G^{o}{}_{\text{reactants}}$$

Compound	$\Delta_f G^{o}$. (kJ/mol)
$NH_3(g)$	−16.6
$H_2O(l)$	−237.2
$H_2O(g)$	−228.6
$CO_2(g)$	−394.3
$CO(g)$	−137.3
$CH_4(g)$	−50.8

6.11 Melting of Ice

Consider a mole of ice initially at 0°C. Now, let the temperature of the surroundings be 283K (+10°C).

For the system: $\Delta H = mL + mc\Delta T$

$= 0.018(335000) + 0.018(4186)(10)$

For the surroundings: $= 6780$ J (endothermic)

$$\Delta S_{\text{surroundings}} = \frac{-6780}{283} = -23.9 \text{ J/K}$$

For the system: $dQ = mL + mcdT$

$$\Delta S = \frac{mL}{T_1} + \int_{Q_1}^{Q_2} \frac{1}{T} dQ$$

$$= \frac{mL}{T_1} + \int_{T_1}^{T_2} \frac{1}{T} mc\, dT$$

$$= \frac{0.018(335000)}{273} + 0.018(4186)\ln\frac{283}{273} = 24.8 \text{ J/K}$$

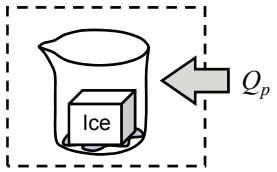

Total change in entropy:

$$\Delta S_{\text{total}} = \Delta S + \Delta S_{\text{surroundings}}$$

$$= 24.8 - 23.9$$

$$= +0.9 \text{ J/K}$$

This is an **irreversible process**. Even though the change in entropy is < 0 for the *surroundings*, the change in entropy of the system is greater, and so the change in **total entropy** is > 0.

$$\Delta G = \Delta H - T\Delta S$$

$$= 6780 - 283(24.8)$$

$$= 6780 - 7018$$

$$= -238 \text{ J}$$

The **Gibbs free energy** change is < 0 so this process is spontaneous.

Data:
c_{water} = 4186 J/kg/K
c_{Al} = 920 J/kg/K
$L_v = 22.57 \times 10^5$ J/kg
$L_f = 3.35 \times 10^5$ J/kg
ρ_{water} = 1000 kg/m^3
c_{ice} = 2110 J/kg/K

6.12 Freezing of Water

Consider a mole of water, initially at 0°C. Now, let the temperature of the surroundings be 263K (−10°C).

For the system: $\Delta H = -mL + -mc\Delta T$

$= -0.018(335000) + -0.018(2110)(10)$

$= -6.03 - 0.38$

For the surroundings: $= -6410$ J (exothermic)

$$\Delta S_{\text{surroundings}} = \frac{6410}{263} = 24.4 \text{ J/K}$$

For the system: $dQ = -mL + mcdT$

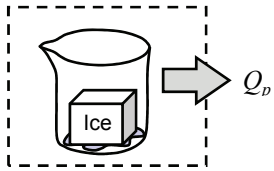

$$\Delta S = \frac{-mL}{T_1} + \int_{Q_1}^{Q_2} \frac{1}{T} dQ$$

$$= \frac{-mL}{T_1} + \int_{T_1}^{T_2} \frac{1}{T} mc\, dT$$

$$= \frac{-0.018(335000)}{273} + 0.018(2110)\ln\frac{263}{273} = -23.52 \text{ J/K}$$

Total change in entropy:

$$\Delta S_{\text{total}} = \Delta S + \Delta S_{\text{surroundings}}$$

$$= -23.52 + 24.4$$

$$= +0.88 \text{ J/K}$$

$$> 0$$

This is an **irreversible process**. Even though the change in entropy is < 0 for the *system*, the change in entropy of the surroundings is greater, and so the change in **total entropy** is > 0.

$$\Delta G = \Delta H - T\Delta S$$

$$= -6410 - 263(-23.5)$$

$$= -6410 + 6180$$

$$= -229 \text{ J}$$

This is a spontaneous process since the freezing of ice results in a decrease in **Gibbs free energy**.

Data:
c_{water} = 4186 J/kg/K
c_{Al} = 920 J/kg/K
$L_v = 22.57 \times 10^5$ J/kg
$L_f = 3.35 \times 10^5$ J/kg
ρ_{water} = 1000 kg/m^3
c_{ice} = 2110 J/kg/K

6.13 Ice/Water Equilibrium

Consider the conversion of one mole of water to ice at 273K:

For the system: $\Delta H = -mL$

$= -0.018(335000)$

$= -6030\text{ J}$ (endothermic)

For the surroundings:

$$\Delta S_{\text{surroundings}} = \frac{6030}{273} = 22.08\text{ J/K}$$

For the system: $dQ = -mL$

$$\Delta S = -\frac{mL}{T}$$

$$= \frac{-0.018(335000)}{273}$$

$$= -22.08\text{ J/K}$$

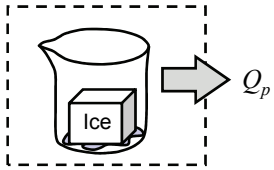

Total change in entropy:

$$\Delta S_{\text{total}} = \Delta S + \Delta S_{\text{surroundings}}$$

$$= -22.08 + 22.08$$

$$= 0\text{ J/K}$$

The total change of entropy is zero. This is a **reversible process**. Extraction of Q_p from the melted ice would cause it to re-freeze.

$$\Delta G = \Delta H - T\Delta S$$

$$= -6030 - 273(-22.08)$$

$$= 0\text{ J}$$

This process is at **phase equilibrium**.

Data:
c_{water} = 4186 J/kg/K
c_{Al} = 920 J/kg/K
$L_v = 22.57 \times 10^5$ J/kg
$L_f = 3.34 \times 10^5$ J/kg
ρ_{water} = 1000 kg/m^3
c_{ice} = 2110 J/kg/K

6.14 Chemical Equilibrium

A chemical reaction involves reactants and products. Whether or not a chemical reaction proceeds spontaneously depends on the sign of the change in free energy.

$$\Delta G_{\text{reaction}} = \Delta_f G^0{}_{\text{products}} - \Delta_f G^0{}_{\text{reactants}}$$

$$\text{Reactants} \rightarrow \text{Products}$$

If a chemical reaction proceeds from reactants to products spontaneously, we may at first expect the process to continue until the reactants are all converted to product. This is not observed. Usually, reactions proceed until there is **chemical equilibrium**:

$$\text{Reactants} \leftrightarrow \text{Products}$$

At equilibrium, the rate of forward reaction = rate of reverse reaction.

In chemical reactions, the **free energy** change depends on the temperature, physical state, pressure, and concentrations of the reactants and the products. That is, as the reaction proceeds, the reactants are consumed and the products are created – and the free energy change changes as the reaction proceeds in time. When the free energy change becomes equal to zero, the rate of forward reaction has become equal to the rate of the reverse reaction. This usually happens (for spontaneous reactions) when the concentration of the products is somewhat greater than those of the reactants – but it is important to note that this does not necessarily mean that all the products are used up. At **chemical equilibrium**, the forward and reverse reactions are both happening at the same rate.

Precisely what is meant by **rate of reaction** depends upon the context. Rates of reaction may be expressed as the change in concentration of one of the reactants per unit time where concentration is expressed in terms of moles per unit volume.

State	Concentration units
Gases	Partial pressure units
Liquids	Molarity (moles per litre)
Solids	Moles or mass units

The appropriate time period may be expressed in milliseconds, seconds, days or years depending on the reaction.

6.15 Statistical entropy

The change in entropy of a system can be calculated from macroscopic quantities, Q and T. Molecules of gas in a volume V at temperature T have a distribution of velocities, and hence, kinetic energies. The distribution of velocities over the total number of molecules was determined by Boltzmann:

The number of molecules N with an energy E was computed by Boltzmann using the **Maxwell velocity distribution** function:

$$N = Ce^{\frac{-E}{kT}}$$

Maxwell-Boltzmann *energy* distribution

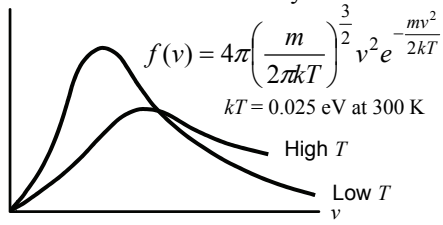

Consider a partitioned volume V containing N molecules. There is a discrete number of energies possible, and there is a finite number of ways that the molecules present can have a distribution of energies that matches the macroscopic properties of P, T and V. Each of these possibilities is called a **microstate**.

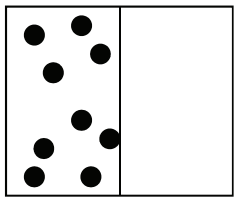

Now, one such possible state is if all the energy of the system were concentrated in one molecule and the others had zero energy. We know that this is very unlikely to ever happen, just as we know that the likelihood of throwing zero heads and 100 tails in 100 tosses of a coin is unlikely. The most likely scenario for our N molecules is that the energies will follow the Maxwell-Boltzmann distribution.

In mathematical symbols, the **statistical weight function** of the system $\Omega(E,V,N)$ is the number of possible microstates that are consistent with the observed **macrostate**. The lower the number of possible microstates, the more accurately we know information about the molecules. The entropy of the system is:

$$S = k \ln \Omega.$$

If there were only one possible microstate, then S would be zero. As the number of possible microstates increases, the entropy becomes larger. When the partition is removed, the molecules rush to fill the entire volume. It is exceedingly unlikely that at any one instant, all the molecules will be located over on one half of the now larger volume. The number of possible microstates has increased. However, one might ask what if the container had only two molecules in it? In this case, it is likely that at any one time, the two molecules *will* find themselves over to one side of the container. The number of possible microstates, for the two-molecule scenario, is very small, and so is the entropy.

7. Rates of Reaction

Summary

Rates of reactions:

- The nature of the reactants
- The concentration of the reactants
- The temperature
- The presence of a catalyst

Rate law (concentrations):

$$a\mathrm{A} + b\mathrm{B} \rightarrow \mathrm{P}$$

$$\frac{d[\mathrm{P}]}{dt} = k[\mathrm{A}]^n[\mathrm{B}]^m$$

Rate law (temperature):

$$k = Ae^{\frac{-E}{RT}}$$ Arrhenius equation

Catalyst:

- Has no effect on the stoichiometry of the overall reaction.
- Does not affect the equilibrium position of the reaction.
- Affects the reaction mechanism so as to lower the activation energy, thus increasing the number of molecules that can make a productive collision.

7.1 Rates of Reaction

Consider the reaction between hydrogen gas and oxygen gas to produce liquid water:

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(aq) \quad \Delta H = -286\ \text{kJ/mol}$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(aq)$$

$$\begin{aligned}\Delta S^{o} &= 70 - (131 + 0.5 * 205) \\ &= -163.3\ \text{J/K/mol}\end{aligned}$$

$$\begin{aligned}\Delta G &= \Delta H - T\Delta S \\ &= -286000 - 273(-163.3) \\ &= -286000 + 44580.9 \\ &\approx -240\ \text{kJ/mol}\end{aligned}$$

The indications are that this reaction should proceed spontaneously when these two gases are mixed. While this might be so, experience indicates that this reaction does not proceed at all unless there is a spark or source of ignition present – in which case the reaction proceeds with explosive violence.

Clearly then, the **rates of reaction** are an important part of chemical reactions. While thermodynamics might provide information about the direction in which a reaction might proceed on its way to chemical equilibrium, more information is needed to determine at what rate the products are produced.

Associated with the rate of reaction is the **reaction mechanism**. The production of products and the consumption of reactants, while observable, only represents the net reaction in general. Chemical reactions may proceed in several steps. Intermediate species may form and be consumed, and these intermediate steps often influence the overall rate of the reaction as a whole.

The most important factors that govern the rate of a reaction are

- The nature of the reactants
- The concentration of the reactants
- The temperature
- The presence of a catalyst

The rate of reaction is the rate of change of **concentration** of either the reactants or the products.

7.2 Collision Theory

Chemical reactions involve the breaking and formation of bonds between atoms, ions or molecules. Elements or compounds that comprise the reactants form new compounds as products. The relationship between energy and entropy – the **Gibbs free energy** – determines which direction a chemical reaction will proceed. The question now is to ask just how a chemical reaction takes place.

Central to the answer of this question is the fact that atoms, ions and molecules are in constant motion – especially when they are in liquid and gaseous form. Because they are in motion, they undergo collisions with other atoms and molecules.

The notion of chemical reactions only taking place between atoms or molecules when they contact each other in a certain way is not so obvious as it might seem and was only proposed in the early 1900s.

No reaction

Reaction

When atoms, ions or molecules collide, a chemical reaction may occur. That is, chemical reactions occur as a result of collisions between molecules. This is known as **collision theory**.

During the collision, bonds are broken and formed as atoms and electrons are rearranged into new compounds. Several variables serve to determine how fast reactants are converted into products:

- Particles (either atoms, ions or molecules) have to collide in a particular way. That is, the orientation of the colliding particles has to be a certain way in order that the collision be effective at breaking bonds and forming new ones.
- The particles have to possess enough kinetic energy to allow them to interact to the extent that bonds may be broken and allow new ones to be formed.
- The number of collisions per unit time determines how fast the reaction proceeds and this is related to the concentration of the reactants.

The nature of the reactants, the temperature, and concentration and action of **catalysts** can be all explained by collision theory. Not all collisions result in a reaction. Only a small proportion are **productive collisions**.

7.3 Reaction Mechanism

We have agreed that for a chemical reaction to proceed, atoms, ions, or molecules must collide. Further, they must not just touch or brush past one another. They must collide with a certain amount of kinetic energy, and be in the right orientation with respect to one another in order for bonds to be broken and allow new ones to form. That is, there has to be a **productive collision**.

Consider the rusting of iron. Simply put, the reaction is:

$$4\mathrm{Fe(s)} + 3\mathrm{O_2(g)} \rightarrow 2\mathrm{Fe_2O_3(s)}.$$

This is a reasonably slow reaction. However, if one were to just take collision theory at face value, it would be luck indeed if four atoms of iron were to collide with three molecules of oxygen at the same time to form two molecules of iron oxide. In reality, reactions usually proceed as a series of smaller steps. The series of smaller steps is called the **reaction mechanism**.

$$\mathrm{Fe^{2+}} + 2\mathrm{OH^-} \rightarrow \mathrm{Fe(OH)_2}$$

$$4\mathrm{Fe(OH)_2} + \mathrm{O_2} + 2\mathrm{H_2O} \rightarrow \mathrm{Fe(OH)_3(s)}$$

$$\mathrm{Fe(OH)_3(s)} \rightarrow \mathrm{Fe_2O_3, H_2O} + 2\mathrm{H_2O}$$

The chances of a collision occurring between two atoms, ions or molecules is significantly greater than the chances of a collision between three or four of the required chemical species at the same time. Most reaction steps in chemical reactions involve two atoms or molecules. The slowest step in the reaction mechanism is the **rate-determining step**. The nature of the reaction steps cannot be deduced from the net reaction. The reaction steps can only be found by experiment.

Identification of the rate-determining step is important for establishing a quantitative rate law for the reaction as a whole. Often, the rates of reaction depend on the concentration of the reactants, but it is the concentration of the reactants within the rate-determining step that is they key issue. During the **elementary reactions**, or the **reaction steps**, intermediate chemical species may be formed which are used up in a later step and do not appear in the net equation.

Some reaction mechanisms are noted for their explosive properties. In these cases, the steps become a self-sustaining **chain reaction** (such as in **combustion**).

7.4 Activation Energy

A reaction step usually involves a two-particle collision (either atoms, ions or molecules). As two molecules approach each other, the outer electrons of one molecule will begin to feel the electrostatic repulsion of the other molecule. The kinetic energy of motion will be converted into electrical potential energy. The potential energy rises as the molecules come closer and closer together.

When all the kinetic energy has been expended, the molecules are in very close proximity and are in a somewhat unstable state. The molecules at this point form what is called an **activated complex**. The activated complex is a conglomeration of the participating atoms. At this point, the activated complex may split into the product molecules (the forward reaction) or bounce backwards and reform the original molecules (the reverse reaction).

The colliding molecules require sufficient **kinetic energy** to overcome mutual repulsion and allow the collision and formation of the activated complex. This is called the **activation energy** E_{act}. The activation energy depends on the nature of the reactants.

When a spark is introduced into a mixture of H_2 and O_2, the energy of the spark overcomes the activation energy and allows the reaction to proceed. The heat of the reaction furnishes the required activation energy for further reactions. That is, the H_2 gas undergoes **ignition**.

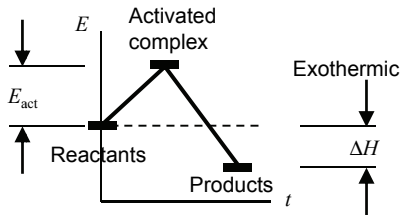

The activation energy is the difference in energy between the activated complex and the average energy of the reactants.

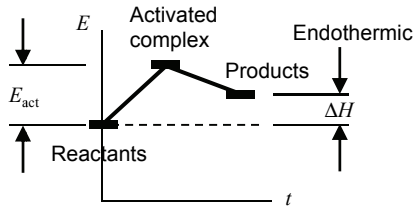

If a particular reaction has a large activation energy, then only a small proportion of collisions may result in enough kinetic energy to overcome it, and the reaction will be slow. If a particular reaction has a lower activation energy, then a greater proportion of collisions will have enough kinetic energy to overcome it and the reaction proceeds at a faster rate.

7.5 Nature of Reactants

The rate of a chemical reaction, that is, the rate of change of concentration of either the reactants or the products, depends on the nature of the reactants. When the permanganate ion is reduced by an Fe^{2+} ion in an acidic solution, the reaction is very fast and is limited by the time it takes to mix the solutions:

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O \quad \text{fast}$$

But when the permanganate ion is reduced by oxalic acidic $H_2C_2O_4$, the reaction is fairly slow, taking several minutes.

$$5C_2O_4^{2-}(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O \quad \text{slow}$$

The main difference between the two reactions is the reducing agent. It could be argued that in the case of $H_2C_2O_4$, many more bonds must be broken compared to the case of the Fe^{2+} solution and this might influence the rate of the reaction. That is, the reaction mechanism for the second reaction may be quite different in character than that of the first reaction.

Experiments indicate that:

- Reactions that involve the breaking and formation of **covalent bonds** are usually slow at room temperature.
- Reactions that involve electron transfer, such as **ionic reactions** in aqueous solutions, are generally fast. Examples are precipitation reactions, **acid** on **base** reactions, most oxidation/reduction reactions.

Since the **activation energy** depends on the chemical species involved, then so does the rate of reaction. There is more chance of a successful or productive collision in the case of a low activation energy because a greater number of particles will have sufficient kinetic energy to overcome it.

It is not only the chemical nature of the reactants, but the physical nature as well. Since collision theory requires atoms or molecules to make contact to form the activated complex, any mechanism that affects the degree of contact between atoms or molecules will affect the rate of reaction. In homogenous systems, such as aqueous solutions, there is intimate contact, whereas in inhomogeneous systems, such as solid/liquids, or solid/gas, reactions only take place at the surface of contact of the atoms or molecules. Increasing the surface area by mixing or grinding increases the rate of reaction. A common example is that sawdust is almost explosive in air, while a block of wood burns relatively slowly in comparison.

7.6 Concentration

One of the most important effects on the rate of reaction is the **concentration** of one or more of the reactants. Generally speaking, increasing the concentration of a reactant increases the rate of the reaction (but not always). It is easy to accept that the chances of a successful, or productive, collision between two reacting particles is increased if there are more of them, per unit volume, involved in the process. Consider a reaction:

$$A + B \rightarrow AB.$$

If we only had one molecule of A and one of B, then we may have to wait some time before they encounter each other and collide in a way so as to produce the reaction. The collision rate, and hence the reaction rate, would be low.

If we now increase the concentration of A, but putting more molecules of A in the reaction chamber, then there would be an increase in the chances of a successful collision – the reaction rate would increase. It is possible that doubling the concentration of one or other of the reactants would double the reaction rate.

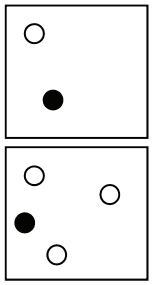

The concentration of a species in moles per litre can be conveniently written using [ ] notation. Thus, the reaction rate is indicated by the rate of change of appearance of the product, or the rate of change of concentration of AB.

Reaction rate is expressed as moles/litre/second

$$\frac{d[AB]}{dt} = k[A][B]$$

This equation is called a **rate law**. k is the constant of proportionality, or the **rate constant**. It should be noted that the rate law actually observed for a reaction cannot be necessarily deduced from the balanced net equation. This is because one of the intermediate reaction steps may be the rate-determining reaction, in which case the rate law for that step would be required. Unless more of the reactants are continually added, the rate of reaction will generally decrease with time as the reactants are consumed (and their concentrations decrease).

7.7 Rate Law

Consider the reaction: $A + A \rightarrow A_2$

$2A \rightarrow A_2$ Balanced equation

The **rate law** would be written:

$$\frac{d[A_2]}{dt} = k[A][A]$$

$$= k[A]^2 \quad \text{Rate law}$$

Note that the exponent of [A] in the rate law is the same as the coefficient of A in the reactants in the balanced equation. This is a second-order reaction.

In general, for an equation of the form: $aA + bB \rightarrow P$ the rate law is written as:

$$\frac{d[P]}{dt} = k[A]^n[B]^m.$$

For a single-step reaction, the exponents *n* and *m* are equivalent to *a* and *b*. However, a chemical reaction nearly always proceeds via a **reaction mechanism**, that is, a series of reaction steps. Thus, in most cases, there is no connection between the exponents *n*, *m* and the coefficients *a*, *b* for the net reaction. In general, the rate law for the net reaction has to be determined by experiment.

The exponents *n* and *m* indicate the **order of the reaction** with respect to that reactant. For example, when $n = 2$ and $m = 1$, we say that the reaction is second order with respect to A and first order with respect to B. The overall order of the reaction is the sum $m+n$. When *n* or *m* equals zero, then the rate of reaction is independent of the concentration of the reactant and is a **zero-order reaction** with respect to that reactant.

The **rate constant**, *k*, is specific to the particular reaction and depends on the experimental conditions. The units of *k* depend on the order of the reaction. A high value of *k* indicates fast reaction. For first-order reactions, if $k > 10$ sec^{-1}, then the reaction is considered instantaneous.

The **rate law** shows how the instantaneous rate of a reaction changes with the concentration of the reactants, as long as other factors such as temperature, the nature of the reactants and the presence of catalysts remain constant.

The rate of a reaction with respect to either reactants or products is expressed in terms of the **rate constant** *k* and the **order** of the reaction.

7.8 Rates of Reactions

There are several methods of expressing the rates of a reaction:

Average rate of disappearance of a reactant R:	$-\frac{[\mathrm{R}]_2 - [R]_1}{t_2 - t_1}$
Average rate of appearance of a product P:	$\frac{[\mathrm{P}]_2 - [P]_1}{t_2 - t_1}$
Instantaneous rate of disappearance of a reactant:	$-\frac{d[\mathrm{R}]}{dt}$
Instantaneous rate of appearance of a product:	$\frac{d[\mathrm{P}]}{dt}$
Half-life (the time taken for half of a reactant to be consumed or product to be formed):	$t_{1/2}$

The rate of formation of products P as a whole is equal to the negative of the rate of disappearance of the reactants R:

$$\frac{d[\mathrm{P}]}{dt} = -\frac{d[\mathrm{R}]}{dt}$$

But we must be careful in expressing the rate in terms of a single product or reactant. For example, consider the following reaction:

$$\mathrm{H_2(g) + I_2(g) \rightarrow 2HI(s).}$$

Two moles of HI are produced at the rate of disappearance of 1 mole of H_2 per second. Thus, the rate of change of concentration, from **stoichiometry**, is

$$\frac{d[\mathrm{HI}]}{dt} = -2\frac{d[\mathrm{H_2}]}{dt}.$$

The rate at which H_2 disappears is the same as the rate at which I_2 disappears, and is half the rate at which HI appears. We cannot determine the order of the reaction from this net equation; we can only determine the relative magnitudes of the rates of products and reactants, no matter what the order for each participant might be.

7.9 Determination of Order

One of the most common ways of determining the rate law for a reaction is to measure the **initial rate of reaction** (e.g. formation of products) while varying the concentration of one of the reactants and holding the concentration of the other reactants constant.

$$\frac{d[\mathrm{P}]}{dt} = k[\mathrm{A}]^n[\mathrm{B}]^m$$

Let us hold the concentration of B constant and express the rate as the rate of change of concentration of A:

$$-\frac{d[\mathrm{A}]}{dt} = k'[\mathrm{A}]^n$$

$$\log\frac{d[\mathrm{A}]}{dt} = -n\log[A] - \log k'$$

By plotting the log of the initial reaction rate (d[A]/dt) versus log of the initial concentration [A], then the slope of the resulting straight line will be the order n.

Similarly, we may hold the concentration of A constant and vary the concentration of B to obtain a value for m.

$$-\frac{d[\mathrm{B}]}{dt} = k''[\mathrm{B}]^m$$

$$\log\frac{d[\mathrm{B}]}{dt} = -m\log[B] - \log k''$$

It is important to know that the concentrations, and the rates, are determined at the initial conditions, that is, the rate of the reaction is measured as the slope of the tangent of the rate curve at $t = 0$.

The procedure can also be performed numerically, where we substitute values of reaction rate and concentration into the general rate law and solve simultaneous equations for the two unknowns n and m.

This method (either graphical or arithmetic) is called the **initial rate method**.

7.10 Determination of 1st Order Rate Law

An example for a simple **first-order reaction** is the decomposition of hydrogen peroxide to water and oxygen:

$$2H_2O_2 \rightarrow 2H_2O + O_2(g)$$

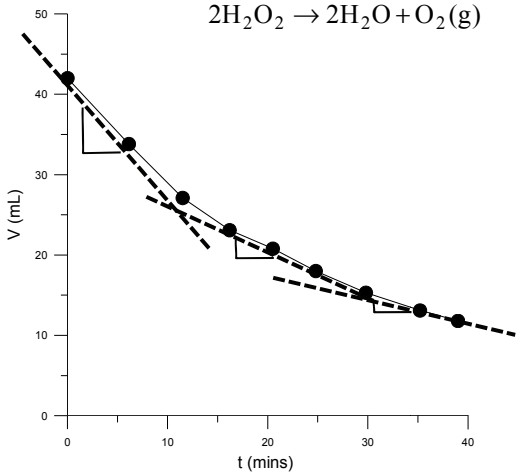

This is ordinarily a very slow reaction, but may be sped up by the addition of a catalyst. The concentration of H_2O_2 at any point is found by inhibiting the reaction by addition of dilute sulphuric acid, and the titration with $KMnO_4$. The volume of $KMnO_4$ used in the titration is an indication of the concentration of H_2O_2 left in the solution.

The slope of the tangent to the curve decreases as t increases, thus indicating that the rate of the reaction decreases with time. Since there is only one reactant, the decrease in reaction rate is therefore due to the decrease in concentration of H_2O_2. In general, the rate law would be written:

$$\frac{d[H_2O_2]}{dt} = k[H_2O_2]^n$$

For a first-order reaction, $n = 1$ and thus:

$$-\frac{d[H_2O_2]}{dt} = k[H_2O_2]$$

$$\frac{1}{[H_2O_2]}d[H_2O_2] = -k\,dt$$

$$\int_{[H_2O_2]_o}^{[H_2O_2]} \frac{1}{[H_2O_2]}d[H_2O_2] = -\int_0^t k\,dt$$

$$\ln[H_2O_2] - \ln[H_2O_2]_o = -kt$$

$$\ln[H_2O_2] = -kt + \ln[H_2O_2]_o$$

$$\log[H_2O_2] = -\frac{k}{2.303}t + \log[H_2O_2]_o \quad \text{(change of base to 10)}$$

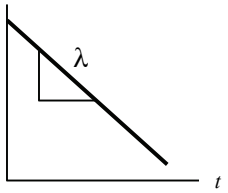

$[H_2O_2]$ is proportional to the titration volume in this experiment, and so a plot of log V versus t is a straight line if the reaction is first order, and the value of k can be found from the slope of a plot of log V versus t.

7.11 Half-Life Method

The **half-life** $t_{1/2}$ of a reaction is the time for half of a reactant to be consumed, or half of a product to be formed. Consider previous case of a first-order reaction with one reactant:

$$2H_2O_2 \rightarrow 2H_2O + O_2(g)$$

Proceeding as before, we obtain

$$-\frac{d[H_2O_2]}{dt} = k[H_2O_2]$$

$$\ln[H_2O_2] = -kt + \ln[H_2O_2]_o$$

$$[H_2O_2]_t = [H_2O_2]_o e^{-kt}$$

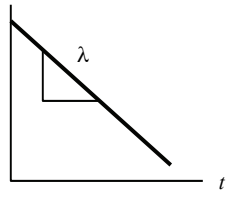

The half-life $t_{1/2}$ is the time for one half of the reactant to be consumed:

$$\frac{[H_2O_2]_t}{[H_2O_2]_o} = e^{-kt_{1/2}} = \frac{1}{2}$$

$$\ln\frac{1}{2} = -kt_{1/2}$$

$$t_{1/2} = \frac{0.69}{k}$$

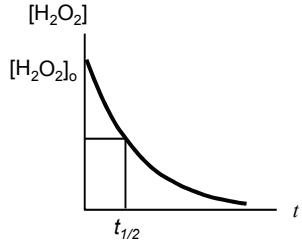

Either the rate constant *k* or the half-life (time measured for half the reactant to be consumed) can be determined from experimental data to give the other quantity. In a first-order reaction, the half-life is a constant and depends only on *k*.

7.12 Temperature

The rate of a chemical reaction depends on the frequency of collisions between atoms, ions or molecules, and also the fraction of which these particles have an energy greater than the activation energy. Increasing the concentration of reactants generally increases the frequency of collisions. Increasing the temperature also increases the collision frequency because the particles are moving faster and make more collisions per unit time. However, the most profound effect of an increase in temperature is to increase the fraction of particles with an energy above the activation energy.

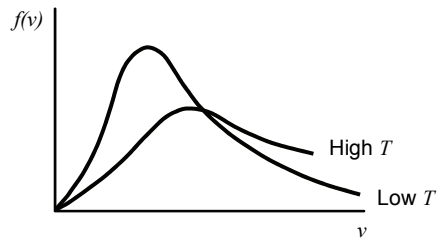

In gases, the distribution of velocities of molecules can be given by the Maxwell velocity distribution:

$$f(v) = 4\pi\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}}.$$

At low temperature, a greater proportion of the molecules have a more narrow range of relatively low velocities compared to high temperature, where the range of velocities is more spread out, but shifted to higher values. Increasing the temperature therefore

- Shifts the molecular distribution of energies to a higher value
- Increases the proportion of molecules having higher energies

thus increasing the frequency and number of productive collisions per unit time and hence increasing the reaction rate.

The number of particles N with a total energy E was computed by Boltzmann using the **Maxwell velocity distribution** function:

$$N = Ce^{\frac{-E}{kT}}.$$

The rate constant for a specific reaction increases as the temperature increases, roughly in accordance with the **Arrhenius equation**:

$$k = Ae^{\frac{-E}{RT}},$$

where it can be seen that k is an exponential function of $1/T$. At room temperature, an increase of about 10°C results in an increase in reaction rate in the order of 2 to 3.

If E represents the activation energy, then this may be determined by experiment by plotting the logarithm of k versus $1/T$ over a range of temperatures.

7.13 Catalysts

The decomposition of hydrogen peroxide is a spontaneous, but slow reaction:

$$2H_2O_2 \rightarrow 2H_2O + O_2(g)$$

If powdered MnO_2 is added, the reaction proceeds much faster. Further, the MnO_2 molecules do not get used up during the reaction nor do they appear in the net equation. Substances which increase the rate of a reaction without appearing in the net reaction are called **catalysts** and the reaction is said to be **catalysed**.

The role of a catalyst is to alter the reaction mechanism by insertion of additional steps so that the activation energy is reduced, allowing the reaction rate to increase.

While the catalyst may be consumed in one reaction step, and regenerated in another, it does not appear in the net reaction.

Catalysts may be solids, liquids or gases. When the reaction being catalysed is all of the same phase (e.g. all liquid), it is called **homogenous catalysis**. When the reaction occurs at the surface of a catalyst, such as over the platinum bed of a **catalytic converter** in an automobile exhaust system, it is called **heterogeneous catalysis**.

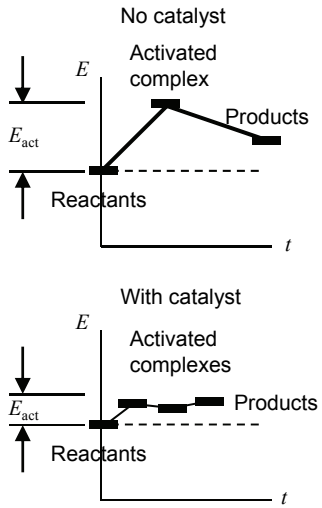

- A catalyst has no effect on the stoichiometry of the overall reaction.
- A catalyst does not affect the equilibrium position of the reaction. That is, the reaction proceeds to the same point of chemical equilibrium as it would without the catalyst. It just gets to equilibrium faster.
- A catalyst affects the reaction mechanism so as to lower the activation energy, thus increasing the number of molecules that can make a productive collision.

A negative catalyst decreases the rate of reaction and is called an **inhibitor**. The means by which this does so may not necessarily be to increase the activation energy, but is sometimes due to the inhibitor preventing another chemical present from acting as a catalyst. Auto catalysis, or **self-catalysis**, occurs when one of the products of a reaction acts as a catalyst for the reaction.

Enzymes act as catalysts in biological processes. Indeed, nearly all biological chemical reactions occur due to the action of catalysts.

8. Chemical Equilibrium

Summary

Law of chemical equilibrium:

$$K_c = \frac{[\mathrm{C}]^c [\mathrm{D}]^d}{[\mathrm{A}]^a [\mathrm{B}]^b}$$

Le Chatelier's principle:

> When a chemical system is at equilibrium, and that equilibrium is disturbed in some way, then the system will change in a way so as to counteract the disturbance until equilibrium is re-established.

Gaseous equilibrium:

$$K_p = \frac{K_c}{RT} = \frac{P_c}{P_a P_b}$$

Solid/solubility equilibrium:

$$K_{sp} = \left[\mathrm{A}^+(\mathrm{aq})\right]\left[\mathrm{B}^-(\mathrm{aq})\right]$$

Common ion effect:

> The presence of a common ion has reduced the solubility of a compound by several orders of magnitude.

8.1 Chemical Equilibrium

If a chemical reaction proceeds from reactants to products spontaneously, we may at first expect the process to continue until the reactants are all converted to product. This is not observed. Usually, reactions proceed until there is **chemical equilibrium**.

$$\text{Reactants} \leftrightarrow \text{Products}$$

At equilibrium, the rate of forward reaction = rate of reverse reaction.

As the reaction proceeds, the reactants are consumed and the products are created. The concentration of the reactants decreases (unless they are continuously replenished) and the concentration of the products increases. The rate of a chemical reaction depends on the concentration of the reactants. Therefore if the concentration of reactants is steadily decreasing, then the rate of conversion of reactants to products (in moles/litre/second) is also decreasing. At the same time, the rate of the conversion of products back to reactants is increasing because the concentration of the products is increasing. At chemical equilibrium, the rates of both forward and reverse reactions are equal.

$$A + B \leftrightarrow C + D$$

At equilibrium, we cannot tell from this equation how many moles of A and B exist, and how many moles of the product C or D exist.

The concentrations of A and B start off at some particular values, then decrease and level off with time. The concentrations of C and D start from zero and increase and level off with time. At equilibrium, the concentrations of A, B, C and D are all constant.

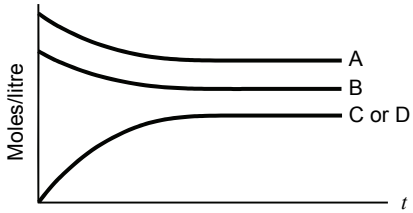

Although the balanced equation does not indicate the concentrations of reactants or products at any one time, they may be measured experimentally.

At equilibrium:

- The rate of formation of product C or D in moles per litre per second is equal to the rate of conversion of C and D back to molecules A and B.
- The concentrations of A, B and C, D are constant.

Chemical equilibrium is a **dynamic equilibrium**. Chemical activity still occurs at the equilibrium condition, but externally, we see no change in concentration of reactants or products.

It is important to know that **catalysts** do not alter the equilibrium state; they only serve to increase the rate of both forward and reverse reactions.

8.2 Law of Chemical Equilibrium

Consider the following single-step forward reaction:

$$\mathrm{A} + \mathrm{B} \rightarrow \mathrm{C} + \mathrm{D}$$

The rate law for this reaction is written:

$$\frac{d[\mathrm{C}+\mathrm{D}]}{dt} = k[\mathrm{A}][\mathrm{B}]$$

Now, consider the reverse reaction and its **rate law**:

$$\mathrm{C} + \mathrm{D} \rightarrow \mathrm{A} + \mathrm{B}$$

$$\frac{d[\mathrm{A}+\mathrm{B}]}{dt} = k'[\mathrm{C}][\mathrm{D}]$$

At equilibrium, the rate of forward reaction must equal the rate of the reverse reaction, and so:

$$k[\mathrm{A}][\mathrm{B}] = k'[\mathrm{C}][\mathrm{D}]$$

$$\frac{[\mathrm{C}][\mathrm{D}]}{[\mathrm{A}][\mathrm{B}]} = \frac{k}{k'} = K_c$$

That is, the ratio of the concentrations of the products over the reactants is a constant *at equilibrium*. A similar treatment can be written for more complex reaction steps.

More generally, it is found from experiment that for the general chemical equation $a\mathrm{A} + b\mathrm{B} \rightarrow c\mathrm{C} + d\mathrm{D}$ the **equilibrium constant** K_c is given by

$$K_c = \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b}$$

law of chemical equilibrium

The magnitude of K_c indicates the extent of the reaction.

$K_c \leq 10^{-5}$	Forward reaction is negligible
$10^{-5} \leq K_c \leq 10^{5}$	Appreciable concentration of products and reactants
$K_c \geq 10^{5}$	Reverse reaction is negligible and almost complete conversion of reactants to products

The value of the equilibrium constant depends on the temperature and the chemical species involved. However, it does not depend on the starting concentrations of either reactants or products. Whatever concentrations of A, B, C and D there are, when equilibrium is reached, the ratio of the concentrations expressed in this way will have the same value at that temperature. The value of *K* also depends on how the balanced equation is written (i.e. the choice of coefficients). The equilibrium constant must be associated with a particular balanced equation.

Note that the equilibrium constant does not provide any information on how long it takes for equilibrium to be established. It only provides information on the extent to which equilibrium favours the products over the reactants.

8.3 Equilibrium Constant

For any chemical reaction, the ratio of concentrations raised to the power of the coefficients can be written as:

$$\frac{[C]^c[D]^d}{[A]^a[B]^b}$$

This is more formally called the **mass-action expression**. It is only at chemical equilibrium that this expression becomes equal to a constant value K_c (the subscript c indicates concentrations in moles/litre).

K_c depends on the temperature. The units of K_c depend on the powers to which the concentrations are raised.

$$N_2O_4 \rightarrow 2NO_2(g)$$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]} = \text{mol/L}$$

$$2CO_{(g)} + O_2 \rightarrow 2CO_2$$

$$K_c = \frac{[CO_2]^2}{[CO]^2[O_2]} = \text{L/mol}$$

A particular value of K_c depends on the form of the balanced equation.

$$\frac{1}{2}N_2O_4 \rightarrow NO_2(g)$$

$$K_c' = \frac{[NO_2]}{[N_2O_4]^{1/2}} = \text{mol}^{1/2}\ \text{L}^{1/2}$$

$$= (K_c)^{1/2}$$

compare

Homogenous equilibrium occurs when all reactants and products are in the same physical state. **Heterogeneous equilibrium** occurs when reactants and products are in different physical states.

The concentrations of pure **solids** and **liquids** are constant. This is because if more *pure* solid or liquid is added, then the volume of that solid or liquid is also increased in the same proportion and so the number of moles per litre remains the same as before. The concentrations of these substances are removed from the equilibrium expression and are effectively incorporated into the value of K_c.

Gases cannot be removed from the equilibrium expression because their concentration changes during the reaction.

Writing a chemical equation in reverse inverts the value of K_c.

8.4 Le Chatelier's Principle

When a chemical system is at equilibrium, and that equilibrium is disturbed in some way, then the system will change in a way so as to counteract the disturbance until equilibrium is re-established. This is known as **Le Chatelier's principle**.

One way of disturbing the equilibrium condition is to add more of a reactant or a product. When more of a reactant is added, the forward reaction increases in rate (since reaction rate depends on the concentration) and more product is formed until the equilibrium condition, and the value of K_c, is restored. When more of product is added, then the concentration of the products increases, thus increasing the rate of the reverse reaction until the equilibrium condition is re-established. Similarly, if either a reactant or product is removed, then the forward or reverse reaction proceeds at a faster rate so as to restore the concentration of the removed species until the equilibrium condition is re-established.

Consider the effect of an increase in concentration of one reactant in the equilibrium expression:

$$N_2O_4 \rightarrow 2NO_2(g)$$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]} = 0.87 \text{ at } 55^\circ C$$

Increasing the amount of N_2O_4 makes the denominator of the expression larger, and makes the computed value of K_c smaller. The concentration of NO_2 must increase until the original value of K_c is re-established. Note that at the new equilibrium, the concentrations of both products and reactants will have increased but their ratio, as expressed by the equilibrium expression, remains the same. Looked at another way, introducing more reactant tends to increase the rate of the forward reaction until the equilibrium constant is re-established back to its former level.

Another way of disturbing the equilibrium condition is to alter the temperature. The value of K_c at equilibrium depends very much on the temperature. In an exothermic reaction, increasing the temperature tends to favour the reverse reaction. A new equilibrium is reached with a new value of K_c.

8.5 Summary of Le Chatelier's Principle

Summary of Le Chatelier's Principle:

Change	**Effect on K_c**	**Shift in reaction**
Increase in concentration of one reactant	Constant	Forward reaction
Decrease in concentration of one reactant	Constant	Reverse reaction
Increase in concentration of one of the products	Constant	Reverse reaction
Decrease in concentration of one of the products	Constant	Forward reaction
Pressure increase with volume decrease	Constant	Decrease in number of gaseous molecules
Pressure decrease with volume increase	Constant	Increase in number of gaseous molecules
Temperature increase (exothermic reaction)	Decrease	Reverse reaction
Temperature increase (endothermic reaction)	Increase	Forward reaction
Temperature decrease (exothermic)	Increase	Forward reaction
Temperature decrease (endothermic)	Decrease	Reverse reaction
Catalyst added	Constant	No shift, but rate of both forward and reverse reactions increased

8.6 Equilibrium in Gaseous Systems

For reactions involving gases, the law of chemical equilibrium can be written in terms of **partial pressures**. The amount of gas in a mixture can be measured in terms of its partial pressure. The total of all the partial pressures is the total pressure in the system. Consider the reaction

$$\mathrm{A(g)} + \mathrm{B(g)} \rightarrow \mathrm{C(g)}$$

General gas equation: $PV = nRT$

Therefore, for A(g) $P_a V = nRT$ where P_a is the partial pressure of gas A in volume V

$$P_a = \frac{n}{V} RT$$

$$= [\mathrm{A}]RT$$ and similarly for B(g) and C(g).

Therefore,

$$K_c = \frac{[\mathrm{C}]}{[\mathrm{A}][\mathrm{B}]}$$

$$= RT \frac{P_c}{P_a P_b}$$

$$\frac{K_c}{RT} = \frac{P_c}{P_a P_b}$$ a constant.

$$= K_p$$

That is, a **gaseous equilibrium constant** K_p is the ratio of the partial pressures of the products over the partial pressures of the reactants.

Example: $\mathrm{N_2(g)} + 3\mathrm{H_2(g)} \rightarrow 2\mathrm{NH_3(g)}$

$$K_p = \frac{P_{NH_3}^2}{(P_{N_2})(P_{H_2})^3}$$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$= \frac{(P_{NH_3}/RT)^2}{(P_{N_2}/RT)(H_2/RT)^3}$$

$$= \frac{P_{NH_3}^2}{(P_{N_2})(P_{H_2})^3}(RT)^2$$

$$= K_p (RT)^2$$

8.7 Solubility of Solids

Many chemical species dissolve in water. They can do so by a simple dissolution where the molecules just become separated from each other and are surrounded by water molecules, by dissociation into ions, and by chemical reaction with the water molecules.

Silver chloride, AgCl, has a low solubility in water. Those molecules that do dissolve, do so by forming ions. The **equilibrium constant** is therefore written as:

$$\mathrm{AgCl(s)} \leftrightarrow \mathrm{Ag^+(aq) + Cl^-(aq)}$$

$$K_c = \frac{\left[\mathrm{Ag^+(aq)}\right]\left[\mathrm{Cl^-(aq)}\right]}{\left[\mathrm{AgCl(s)}\right]}$$

Note that the chemical equation is written with the ions on the product side.

The concentration of a solid is a constant, and so is incorporated into the equilibrium constant to form a new constant, the **solubility product constant**, K_{sp}:

$$K_{sp} = \left[\mathrm{Ag^+(aq)}\right]\left[\mathrm{Cl^-(aq)}\right] = 1.7\times10^{-10} \text{ at } 25^\circ\mathrm{C}$$

The **solubility product constant**, K_{sp}, applies to saturated aqueous solutions. The product of the ion concentrations is called the ion product. At equilibrium, the ion product equals K_{sp}. A low value of K_{sp} indicates that the concentration of ions in solution is low at equilibrium – in other words, the solubility of the compound is low.

The **solubility** of a compound in water is the number of moles of that compound that can be dissolved in 1 litre of water (at a specific temperature). The solubility of a compound can be obtained from the solubility product constant.

$$\begin{aligned} K_{sp} &= \left[\mathrm{Ag^+(aq)}\right]\left[\mathrm{Cl^-(aq)}\right] \\ &= 1.7\times10^{-10} \text{ at } 25^\circ\mathrm{C} \\ s &= \left[\mathrm{Ag^+(aq)}\right] = \left[\mathrm{Cl^-(aq)}\right] \\ 1.7\times10^{-10} &= s^2 \\ s &= 1.3\times10^{-5}\,\mathrm{mol/L} \end{aligned}$$

From the balanced equation, 1 mole of AgCl will produce one mole of Ag^+ and 1 mole of Cl^- ions. Therefore in a 1 litre solution, there will be *s* moles of Ag^+ and *s* moles of Cl^- ions.

At equilibrium, the rate of **dissolution** is equal to the rate of **precipitation**.

In general, the solubility product constant is

$$\mathrm{M}_n\mathrm{X}_m \leftrightarrow n\mathrm{M}^{n+}(\mathrm{aq}) + m\mathrm{X}^{n-}(\mathrm{aq})$$

$$K_{sp} = \left[\mathrm{M}^{n+}(\mathrm{aq})\right]^n\left[\mathrm{X}^{n-}(\mathrm{aq})\right]^m \quad \text{at solubility equilibrium}$$

Ionic solids (salts) and some molecular solids may dissociate into ions in aqueous solution.

8.8 Factors Affecting Equilibrium

A system tends towards a state of minimum **energy** and maximum **entropy**. The two tendencies can oppose or reinforce one another.

- If the forward reaction is exothermic $\Delta H < 0$ and the entropy change $\Delta S > 0$, then the forward reaction is favoured.
- If the forward reaction is endothermic $\Delta H > 0$ and the entropy change $\Delta S < 0$, then the reverse reaction is favoured.
- If the enthalpy change $\Delta H > 0$ and the entropy change $\Delta S > 0$, then the forward reaction is favoured at high temperature. When $\Delta H < 0$ and $\Delta S < 0$, the forward reaction is favoured at low temperature.

For a **solid** dissolving in a **liquid**, in saturated solution, the position of minimum energy can be on either side of the equation. The position of maximum entropy is on the dissolved side:

$$\text{Solid} \leftrightarrow \text{Saturated solution}$$
$$\text{entropy gain} \rightarrow$$
$$\leftarrow \text{energy minimum} \rightarrow$$

For the dissolving of a **gas** in a **liquid**, entropy decreases as the gas dissolves and so the tendency is to oppose the dissolving process, however, when a gas dissolves, the gas molecules, being attracted to the liquid molecules, enter a state of lower potential energy and so this favours the dissolving process.

$$\text{Gas} \leftrightarrow \text{Saturated solution}$$
$$\leftarrow \text{entropy gain}$$
$$\text{energy minimum} \rightarrow$$

It is important to realise that the **equilibrium constant** is not the same thing as the **solubility product constant**. The solubility product constant is an experimentally derived value that applies to the solubility of a compound in **aqueous solution**. The equilibrium constant applies to any chemical reaction, not just those in aqueous (water) solution.

Many chemical reactions occur in dilute aqueous solutions. In these cases, for reactions that consume, or produce, water molecules, the concentration of the water is considered constant and is incorporated into the equilibrium constant. This is because the amount of water consumed or produced is usually a small fraction of the overall total amount of water present.

8.9 Common Ion Effect

The solubility of an ionic solid in a solution containing a common ion is greatly reduced. This is because the concentration of the common ion appears in the expression for the solubility product constant.

K_{sp} = 1.5×10^{-9} for $BaSO_4$ in water . The solubility of this salt in water can be calculated and compared with the solubility in 0.1M Na_2SO_4.

Solubility in water:

$$\begin{aligned} K_{sp} &= \left[Ba^{2+}(aq)\right]\left[SO_4^{2-}(aq)\right] \\ &= (s)(s) \\ s^2 &= 1.5\times10^{-9} \\ s &= 3.9\times10^{-5}\ \text{mol/L} \end{aligned}$$

Solubility in 0.1M Na_2SO_4:

$$\begin{aligned} K_{sp} &= \left[Ba^{2+}(aq)\right]\left[SO_4^{2-}(aq)\right] \\ &= (s)(s+0.1) \\ &= 1.5\times10^{-9} \\ (s+0.1) &\approx 0.1 \quad \text{since } s \text{ will be} << 0.1 \\ 1.5\times10^{-9} &= s(0.1) \\ s &= 1.5\times10^{-8}\ \text{mol/L} \end{aligned}$$

The presence of the **common ion** has reduced the solubility of this compound by several orders of magnitude.

8.10 Precipitation

The **solubility product constant** K_{sp} can be used to predict whether or not a solid precipitate will form as a result of a chemical reaction between solutions.

The product of the concentrations of the ions in a solution is called the **ion product**. When the ion product is greater than the solubility product constant, **precipitation** will occur until the concentration of the ion reduces to the extent that the ion product becomes equal to K_{sp}.

Consider the mixing of 1 litre of 0.5M $Ca(NO_3)_2$ and 1 litre of 0.2M Na_2SO_4. We begin by writing the ionic equation of interest:

$$CaSO_4 \leftrightarrow Ca^{2+} + SO_4^{2-}$$

Note that the equation has been written with the ions on the product side of the equation so that the ion product can be related to K_{sp} directly, and not the inverse.

The final volume of the mixed solution is 2 litres, and therefore the concentrations of the original solutions are:

$$\left[Ca^{2+}\right] = 0.25$$
$$\left[SO_4^{2-}\right] = 0.1$$
$$IP = \left[Ca^{2+}(aq)\right]\left[SO_4^{2-}(aq)\right] \quad \text{ion product}$$
$$= (0.25)(0.1)$$
$$= 0.025$$

K_{sp} for $CaSO_4$ = 2.6×10^{-4}. Since the ion product is greater than K_{sp}, then $CaSO_4$ will form as a precipitate until the concentration of the Ca^{2+} and SO_4^{2-} ions fall until the ion product becomes equal to K_{sp}. That is, precipitation is a method of forcing out ions from the solution until the ion product becomes equal to K_{sp}, at which time the solid and the solution are in equilibrium. Precipitation has important economic consequences whereby the extraction of the desired product must be achieved as economically as possible. Precipitates are sometimes washed with a solution containing a **common ion** to further reduce their solubility.

8.11 Complex Ions

Some molecules or anions have a lone pair of electrons. This enables them to combine, or coordinate, with some transition metal ions to form a **complex ion**. For example, the molecule ammonia, NH_3, has a lone pair of electrons:

NH_3 can coordinate to Ag^+, Co^{3+}, Zn^{2+}, Ni^{2+} to form complex ions:

$$Ag(NH_3)_2^+, Co(NH_3)_4^{2+}, Zn(NH_3)_4^{2+}, Ni(NH_3)_6^{2+}$$

The OH- ion also has a lone pair of electrons and can coordinate with Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} :

$$Pb(OH)_4^{2-}, Zn(OH)_4^{2-}, Sn(OH)_4^{2-}, Al(OH)_4^-$$

The **ligand** (the species with the lone pair) arranges itself around the metal ion and the electron pairs fill up vacant energy levels to create a noble gas configuration for the metal ion. The electron orbitals that are associated with isolated atoms are rearranged to give **hybrid orbitals** to accommodate the electron pairs. The overall charge on the complex ion remains unchanged.

The equilibrium condition between the reactants and products for complex ion formation is called the **stability constant** K_{stab}.

$$Ni^{2+} + 4CN^- \rightarrow Ni(CN)_4^{2-}$$ Tetracyanonickelate

$$K_{stab} = \frac{\left[Ni(CN)_4^{2-}\right]}{\left[Ni^{2+}\right]\left[CN^-\right]^4}$$

$$Pt^{2+} + 6NH_3 \rightarrow Pt(NH_3)_6^{2+}$$ Hexaamineplatinum (II)

$$K_{stab} = \frac{\left[Pt(NH_3)_6^{2+}\right]}{\left[Pt^{2+}\right]\ \left[NH_3\right]^6}$$

$$Zn^{2+} + 4OH^- \rightarrow Zn(OH)_4^{2-}$$ Tetrahydroxozincate

$$K_{stab} = \frac{\left[Zn(OH)_4^{2-}\right]}{\left[Zn^{2+}\right]\left[OH^-\right]^4}$$

9. Ionic Equilibrium

Summary

- Strong electrolytes dissociate completely into ions.
- Weak electrolytes only partially dissociate into ions.
- Non-electrolytes do not dissociate into ions when placed in solution.

Ion product of water:

$$K = \frac{[H^+][OH^-]}{[H_2O]}$$

$$K_w = [H^+][OH^-]$$

[H+] mol/L	pH	pOH
1	0	14
1×10^{-7}	7	7
1×10^{-14}	14	0

$$pH = -\log_{10}[H^+] \qquad pOH = -\log_{10}[OH^-]$$

Acids – proton (H^+) donors

Bases – proton (H^+) acceptors

Acid equilibrium constant:

$$K_A = \frac{[H_3O^+][A^-]}{[HA]}$$

Base equilibrium constant:

$$K_B = \frac{[BH^+][OH^-]}{[B]}$$

Neutralisation: An acid on a base gives salt and water

Titration: The progressive addition of an acid to a base, or a base to an acid.

Hydrolysis: The chemical reaction of ions with water.

9.1 Electrolytes

When a substance dissolves, it may do so by simply separating from its neighbour molecules and become surrounded by water molecules, or the constituent molecules may break apart, or dissociate, and form negatively charged **anions** and positively charged **cations**. Such solutions conduct electricity by virtue of the movement of the ions under the influence of an applied electric field. Substances which dissolve to produce conducting solutions are called **electrolytes**. Substances which do not are called **non-electrolytes**.

- **Strong electrolytes** dissociate completely into ions.
- **Weak electrolytes** only partially dissociate into ions.
- **Non-electrolytes** do not dissociate into ions when placed in solution.

When an ionic substance dissociates into ions in an aqueous solution, the ions themselves are attracted to the polar water molecules and become **hydrated**. That is, a negative anion is surrounded by the positive (or H) end of water molecules and this hydrated ion can move around in solution under the influence of an electric field because as a whole, it is still negatively charged. Similarly, a positive cation is surrounded by the oxygen end of nearby water molecules and becomes hydrated, but the hydrated ion remains positively charged.

Both ionic and molecular compounds may be strong electrolytes. In the case of HCl, a molecular compound, we have

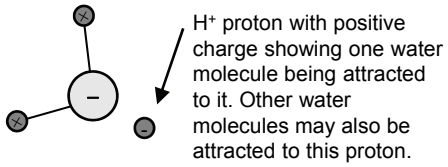

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

The **hydronium ion**, H_3O^+, is a hydrated H^+ ion. For convenience, we omit the water of hydration and just write

$$HCl \rightarrow H^+ + Cl^-$$

Examples of ionic compounds which are strong electrolytes are NaCl, $MgCl_2$, KBr, $CuSO_4$, $LiNO_3$. Examples of molecular covalent compounds which are strong electrolytes are HCl, HBr, HNO_3. Examples of weak electrolytes are $HC_2H_3O_2$, HNO_2, NH_3, HCN.

The degree to which dissociation occurs depends on energy changes (in particular, the energy of hydration) and entropy considerations as well as the nature of the solvent, the concentration of the solute, and the temperature. The dissociation of HCl is an example of **ionic equilibrium**.

9.2 Ionisation of Water

Experiments indicate that pure **water** is a very poor conductor of electricity, but it does conduct, indicating the presence of ions. Water is a weak **electrolyte**. Water dissociates into ions according to

$$H_2O \leftrightarrow H^+ + OH^-$$

The H^+ ions attach themselves to other water molecules to form the **hydronium** ion H_3O^+, but here we will simply write the H^+ ions as if they exist on their own.

The degree of dissociation is very small, and so the concentration of the H^+ and OH^- ions is also very small.

The concentration of water, expressed as moles/litre, can be readily established from its molecular weight and its density:

$$\begin{aligned} \text{m.w.}_{\cdot H_2O} &= 16 + 2 \\ &= 18 \end{aligned}$$

One litre of water has a mass of 1000 g, therefore the number of moles n in a litre of water is:

$$\begin{aligned} n &= \frac{1000}{18} \\ &= 55.6 \text{ moles} \end{aligned}$$

That is, water has a concentration of 55.6M.

Since the concentration of the H^+ and OH^- ions in a litre of water is exceedingly small, the concentration of H_2O is virtually a constant, and so the **ion product** K_w is formed:

$$K = \frac{[H^+][OH^-]}{[H_2O]}$$

$$K_w = [H^+][OH^-]$$

The concentration of H_2O (55.6M) is taken to be a constant and incorporated into K_w.

Experiments show that the **ion product of pure water** at 25°C is 1.0×10^{-14} mole^2/litre^2. The concentrations of H^+ and OH^- ions are 1.0×10^{-7} moles/litre respectively.

A solution containing equal concentrations of H^+ and OH^- ions at these concentrations are said to be **neutral**.

$$[H^+] = 1 \times 10^{-7} \text{ mol/litre}$$

$$[OH^-] = 1 \times 10^{-7} \text{ mol/litre}$$

9.3 H^+ and OH^- Concentrations

Consider a 0.1M solution of HCl:

$$HCl \rightarrow H^+ + Cl^-$$

because HCl dissociates completely to H^+ and Cl^- ions.

The concentration of H^+ ions will be 0.1M and Cl^- ions 0.1M. We can ignore the small amount of H^+ ions from the dissociation of the water solvent. But, the equilibrium between the H^+ and the OH^- ions in the solution must still be established such that

$$\begin{aligned} 1\times10^{-14} &= [H^+][OH^-] \\ &= 0.1[OH^-] \\ [OH^-] &= 1\times10^{-13}\ \text{mol/litre} \end{aligned}$$

That is, compared to neutral water, the concentration of the OH^- has been reduced from 1×10^{-7} to 1×10^{-13} due to a **common ion effect**.

Consider now an aqueous solution of 0.1M NaOH. Using the same calculation as above, we find that

$$NaOH \rightarrow Na^+ + OH^-$$

$$[H^+] = 1\times10^{-13}\ \text{mol/litre}$$

The added H^+ or OH^- ions suppress or inhibit the dissociation of the water molecules (in accordance with Le Chatelier).

Because the changes in concentration of these ions can cover such a large range of magnitudes, it is convenient to express them on a logarithmic scale – the "p" scale. The **pH** is the concentration of H^+ ions found from:

$$pH = -\log_{10}[H^+]$$

The pH is a measure of the potential to combine with H^+ ions. A high pH means a high potential for H^+ combination.

The **pOH** is the concentration of OH^- ions found from

$$pOH = -\log_{10}[OH^-]$$

Since the logarithm is the index to which the base must be raised to equal the number, the pH is the index of the H^+ concentration. For example, for a neutral solution,

$$\begin{aligned} pH &= -\log^{10}[H^+] = -\log_{10}\left(10^{-7}\right) \\ &= 7 \end{aligned}$$

It is easy to show that for a solution at equilibrium,

$$pH + pOH = 14$$

[H+] (mol/L)	pH	pOH
1	0	14
1×10^{-7}	7	7
1×10^{-14}	14	0

Say we have a 5M solution of HCl. What is the pH? $pH = -\log_{10} 5 = -0.7$

A negative pH is possible, but at high concentrations, the assumptions we make about the derivation of these equilibrium formulae breaks down.

9.4 Acids and Bases

A wide variety of substances can be generally classified into being either **acids**, **bases** or **salts**. Each of these has several distinctive characteristics when dissolved in water.

Acids	Bases
Electrical conductor	Electrical conductor
Sharp sensation on skin	Slippery feel
Sour taste	Bitter taste
Change the colour of litmus from blue to red	Change colour of litmus from red to blue.
React with some metals to form H_2 gas	
Dissolve carbonates to form CO_2 gas	

It was noticed that substances such as HCl, HNO_3, $HC_2H_3O_2$, H_2SO_4 and so on had the characteristics of acids. Substances such as NaOH, KOH, $Ca(OH)_2$, $Mg(OH)_2$ had the characteristics of bases. It was therefore postulated by **Arrhenius** (1859-1927) that acids are substances which dissolve in water to form H^+ ions, and bases are substances that dissolve in water to form OH^- ions:

Acid	Base
$HA \rightarrow H^+ + A^-$	$BOH \rightarrow B^+ + OH^-$

According to Arrhenius, all acids have the general formula HA and all bases have the general formula BOH.

A slightly more general definition of Arrhenius' scheme is that acids dissociate so as to increase the H^+ ions in water while bases dissociate and result in an increase in OH^- ions.

It was also known that when an acid was mixed with a base, the resulting solution lost its properties of either (except for being an electrical **conductor**) and formed a **salt** with the general form BA.

The degree of dissociation in water indicates the strength of the acid or the base:

$HCl \rightarrow H^+ + Cl^-$	Strong acid (equilibrium favours products)
$HC_2H_3O_2 \rightarrow H^+ + C_2H_3O_2^-$	Weak acid (equilibrium favours reactants)
$NaOH \rightarrow Na^+ + OH^-$	Strong base (equilibrium favours products)
$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$	Weak base (equilibrium favours reactants)
$HCl + NaOH \rightarrow NaCl + H_2O$	acid + base = salt + water

The Arrhenius definition of acids and bases remains the simplest and most popular despite it having some limitations in only dealing with H^+ and OH^- ions as the cause of acidic or basic properties of substances.

9.5 Bronsted–Lowry

Reactions can take place in other solvents besides water. H^+ and OH^- ions may not be involved at all, yet the reactions still have the characteristics of acids and bases. The **Bronsted–Lowry** definitions of acids and bases are

Acids – proton (H^+) donors
Bases – proton (H^+) acceptors

The Bronsted–Lowry classification is consistent with the Arrhenius definition of acids and bases but includes certain substances that act as bases which are not covered by the Arrhenius definition.

Consider the dissociation of HCl in water, and this time, we write the equation in full with the **hydronium ion**:

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

Now, let's focus our attention on the water molecule. The water molecule accepts a H^+ ion, a proton, to become a hydronium ion. That is, the water molecule, according to Bronsted and Lowry, acts as a base. At equilibrium, the reverse reaction also occurs:

$$HCl + H_2O \leftarrow H_3O^+ + Cl^-$$

Here, the hydronium ion donates a proton to the proceedings and the result is a water molecule. For all intents and purposes, the hydronium ion acts as an acid. In the Bronsted–Lowry scheme, the water molecule is the **conjugate base** of the hydronium ion. Or, the hydronium ion is the **conjugate acid** of the water molecule.

In the forward reaction, HCl donates a proton and becomes a Cl^- ion. HCl acts as an acid. In the reverse reaction, the Cl^- ion becomes HCl. That is, the Cl^- ion acts like a base, accepting a proton and becoming HCl. HCl is the **conjugate acid** of Cl^- and Cl^- is the **conjugate base** of HCl.

Every Bronsted–Lowry acid is accompanied by a Bronsted–Lowry base. The Bronsted–Lowry scheme has this extra dimension of creation of a **conjugate pair** compared to the Arrhenius theory:

$$\underset{\text{acid}}{HA} + \underset{\text{base}}{H_2O} \rightarrow \underset{\text{acid}}{H_3O^+} + \underset{\text{base}}{A^-}$$

In the forward reaction, HA is the acid and H_2O is the base. For the reverse reaction, H_3O^+ is the acid and A^- is the base.

The degree of dissociation indicates the strength of the acid or the base. A strong Bronsted–Lowry acid implies a weak conjugate base. One of the greatest strengths of this system is that acid-base reactions that do not involve the OH^- ion can be accommodated.

9.6 Strength of Acids

The strength of an acid is described by its tendency to dissociate into ions and produce H^+. The **pH** scale does not necessarily indicate whether a solution contains a strong acid (or base); it only indicates the concentration of H^+ (and OH^-) ions which depends on both the intrinsic strength of the acid and the molar concentration used to make the solution.

HCl is considered an intrinsically strong acid because it almost completely dissociates into H^+ and Cl^- ions:

$$HCl \rightarrow H^+ + Cl^-$$

The **equilibrium constant** K_{HCl} for this reaction is very large ($\approx 10^7$), favouring he products. Acetic acid is a weak acid:

$$HC_2H_3O_2 \leftrightarrow H^+ + C_2H_3O_2^-$$

where we always know that H^+ is actually hydrated

The equilibrium constant for this reaction is very small (about 1.8×10^{-5}), favouring the reactants.

The general expression for the **acid equilibrium constant** is given as

$$HA + H_2O \leftrightarrow H_3O^+ + A^-$$

$$K = \frac{[H_3O^+][A^-]}{[HA][H_2O]}$$

$$K_A = \frac{[H_3O^+][A^-]}{[HA]}$$

since the concentration of H_2O is considered constant.

K_A provides a quantitative measure of the strength of an acid. That is, its tendency for dissociation to provide H^+ ions. pH is an indication of the concentration of H^+ ions in a particular solution. A highly concentrated solution of a weak acid may have a similar pH to a dilute solution of a strong acid.

Acid	K_A	Conjugate base
$HClO_4$	$\approx 10^{10}$	ClO_4^-
H_2SO_4	$\approx 10^9$	HSO_4^-
HCl	$\approx 10^7$	Cl^-
HSO_4	1.3×10^{-2}	SO_4^-
H_3PO_4	8×10^{-3}	$H_2PO_4^-$
$HC_2H_3O_2$	1.74×10^{-5}	$CH_3CO_2^-$
NH_4^+	6.3×10^{-10}	NH_3
NH_3	$\approx 10^{-30}$	NH_2^-

The strength of a base can be expressed in a similar manner by the **base equilibrium constant** K_B.

$$B + H_2O \leftrightarrow BH^+ + OH^-$$

$$K_B = \frac{[BH^+][OH^-]}{[B]}$$

These equilibrium constants can be expressed on a logarithmic scale:

$$pK_A = -\log_{10}[K_A]$$

$$pK_B = -\log_{10}[K_B]$$

For an acid and its conjugate base,

$$pK_A + pK_B = 14$$

9.7 Acid–Base Reactions

A few acids and bases are strong, but most are weak. Consider the dissociation of acetic acid $HC_2H_3O_2$, a weak acid with $K_A = 1.74 \times 10^{-5}$.

$$HC_2H_3O_2 + H_2O \leftrightarrow H_3O^+ + C_2H_3O_2^-$$

The concentration of H_3O^+ is found from:

$$K = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2][H_2O]}$$

$$[H_3O^+] = 1.74\times10^{-5}\,\frac{[HC_2H_3O_2]}{[C_2H_3O_2^-]}$$

Strong acids: HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$

If a solution is made with 0.1 moles of $HC_2H_3O_2$, then the concentration $[HC_2H_3O_2]$ is 0.1M. What then is the concentration of $[C_2H_3O_2^-]$? It must be small since the value of K_A implies a low incidence of dissociation. Now, let us add 0.1 moles of solid $NaC_2H_3O_2$. Since the salt, $NaC_2H_3O_2$ dissociates almost completely, the concentration of the acetate ion is now approximately 0.1M. Thus

$$[H_3O^+] = 1.74\times10^{-5}\,\frac{0.1}{0.1}$$

$$pH = 4.75$$

If to this solution we now add a small amount of a strong base, say 0.001 moles (a drop) of 2M NaOH, then the NaOH reacts with the acetic acid molecules: $HC_2H_3O_2 + NaOH \leftrightarrow H_2O + NaC_2H_3O_2$

The quantity $[HC_2H_3O_2]$ is reduced from 0.1M to 0.099M. The quantity $[C_2H_3O_2^-]$ increases to 0.11M (since the $NaC_2H_3O_2$ dissociates). The pH of this new solution is

$$pH = \log\left(1.74\times10^{-5}\,\frac{0.099}{0.11}\right) = 4.8$$

The $HC_2H_3O_2$ / $C_2H_3O_2^-$ solution is called a **buffer solution**, because of its ability to resist changes in pH. If a small amount of acid is added to the solution, this reacts with the acetate ion and the concentrations shift slightly the other way, and the pH remains almost unchanged.

If the concentration of the introduced acid or base becomes too large, then the **buffering capacity** of the solution is exhausted and the pH changes appreciably.

Note, without the common ion, addition of small amounts of acid or base can significantly alter the pH by several units.

9.8 Buffer Solutions

Buffer solutions have the important property of being able to maintain pH when disturbed by the addition of other acids or bases. Buffer solutions can be made in two ways:

1. Weak acid/salt of conjugate base (e.g. acetic acid and sodium acetate)

$$NaA_{(s)} \rightarrow Na^+ + A^-$$

$$HA + H_2O \leftrightarrow H_3O^+ + A^-$$

$$\left[H_3O^+\right] = K_A \frac{[HA]}{\left[A^-\right]}$$

$$pH = -\log\left(K_A \frac{[HA]}{\left[A^-\right]} \right)$$

There are two equilibrium reactions going on here. One is the almost complete dissociation of the salt into its ions, and the other is the partial dissociation of the acid. The $[A^-]$ is dominated by the molarity of the salt solution. The other reaction is the acid equilibrium. Because of the presence of the common ion A^-, the equilibrium for this reaction lies on the reactants side of the equation and [HA] is therefore practically equal to the molarity of the acid.

Since [HA] is high (equilibrium to the left), any added OH^- from an introduced chemical will react with these ions:

$$\underset{\text{added}}{OH^-} + \underset{\text{in buffer}}{HA} \rightarrow A^- + H_2O$$

$$\underset{\text{added}}{H_3O^+} + \underset{\text{in buffer}}{A^-} \rightarrow HA + H_2O$$

The added H_3O^+ or OH^- ions will be prevented from affecting the pH by combing with either the HA or A^- ions already in the solution.

2. Weak base/salt of conjugate acid (e.g. ammonia/ammonium chloride)

$$BH^+X^- \rightarrow BH^+ + X^-$$

$$B + H_2O \leftrightarrow BH + OH^-$$

$$\left[OH^-\right] = K_B \frac{[B]}{\left[BH^+\right]}$$

$$pOH = -\log\left(K_B \frac{[B]}{\left[BH^+\right]} \right)$$

$$pH = 14 - pOH$$

Complete dissociation of the salt into its ions results in the $[BH^+]$ being dominated by the molarity of the salt solution. Because of the presence of the common ion BH^+, the equilibrium for the base reaction lies on the reactants side of the equation and [B] is therefore practically equal to the molarity of the base.

Any added H_3O^+ or OH^- ions will be prevented from affecting the pH by combing with either the B or BH^+ ions already in the solution.

9.9 Indicators

Indicators are either a weak acid or a weak base with the property of exhibiting a change in colour depending on the pH of the solution. The molecular form of the acid HA has one colour, and the ionic form, A^-, another colour.

$$\underset{\text{Colour 1}}{HA} + H_2O \leftrightarrow H_3O^+ + \underset{\text{Colour 2}}{A^-}$$

If a small amount of indicator is added to a solution containing a large concentration of H_3O^+, then the equilibrium for the indicator solution shifts towards the reactants and Colour 1 dominates. If the indicator is added to a solution of large concentration of OH^-, then the equilibrium shifts towards the products and Colour 2 dominates.

Typically, a few drops of indicator are added to a solution whose pH is to be determined, and the resulting colour of the solution indicates the pH when read off against a colour chart.

For the indicator:

$$HA + H_2O \leftrightarrow H_3O^+ + A^-$$

$$K_A = \frac{[H_3O^+][A^-]}{[HA]}$$

$$[H_3O^+] = K_A \frac{[HA]}{[A^-]}$$

Indicator	K_A	pH of colour change
Methyl orange	2×10^{-4}	3.7
Litmus	1×10^{-7}	7
Phenolphthalein	7×10^{-10}	9.1

An indicator changes colour when $[HA] = [A^-]$,

$$\therefore [H_3O^+] = K_A$$

Indicators are useful when they exist in a solution whose pH is slowly changing. If the pH, or the $[H_3O^+]$ of a solution changes so that [HA] becomes equal to $[A^-]$, and the $[H_3O^+]$ of the solution becomes equal to the K_A of the indicator and the colour changes.

It is important to know that an indicator does not necessarily change colour when $[H_3O^+] = [OH^-]$. Some indicators change colour on the basic side, while others change on the acidic side, and some at the neutral position, or **equivalence point**.

The **end point** occurs when the indicator changes colour. The reason why this is called the end point becomes clear when indicators are used in the process of **titration**.

9.10 Neutralisation

When an acid reacts with a base, the H^+ ions combine with the OH^- ions to form water, and the acidic and basic properties of the solution disappear along with the disappearing ions. This is **neutralisation**. That is, an acid on a base gives salt and water.

Consider 0.1M HCl added to 0.1M NaOH:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

More specifically, in 0.1M solutions, we do not have HCl molecules and NaOH molecules. They are already dissociated into their constituent ions. The reaction is therefore actually

$$H_3O^+ + Cl^- + Na^+ + OH^- \rightarrow Na^+ + Cl^- + 2H_2O$$

The net reaction is therefore

$$H_3O^+ + OH^- \rightarrow 2H_2O$$

We know from experience that the products of this reaction are salt and water, or more specifically, Na^+ ions and Cl^- ions and water. That is, salty water, and not a mixture of acidic and basic solutions. But, how do we know this? Because in any aqueous solution at equilibrium, $K_w = 1 \times 10^{-14}$.

Equilibrium favours the products because the reverse reaction, the dissociation of water, has such a low **equilibrium constant** (or **ion product** in this case). The H_3O^+ ions combine with the OH^- ions to form water until such time as the product of the concentrations of H_3O^+ and OH^- ions fall to 1×10^{-14} moles/litre.

For strict neutralisation of a solution to occur, the initial concentrations of the H_3O^+ and OH^- ions must be similar – that is, the acid and the base must be of about the same strength. That is, if equal moles of acid and base are added, the final solution $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$.

In a solution of acetic acid, very little dissociation occurs and so the reaction with a strong base in aqueous solution is:

$$HC_2H_3O_2 + Na^+ + OH^- \rightarrow H_2O + Na + C_2H_3O_2^-$$

$$HC_2H_3O_2 + OH^- \rightarrow H_2O + C_2H_3O_2^-$$

The resulting solution is not neutral, but slightly basic in the sense that one of the products, $C_2H_3O_2^-$, is a Bronsted–Lowry base. In general,

$$HA + OH^- \rightarrow H_2O + A^-$$

An interesting application of neutralisation is the use of antacids for relief of heartburn. In order to raise the pH in the stomach, sodium bicarbonate can be used to react with HCl in the gastric juices to give H_2O and CO_2(g).

9.11 Titration

The progressive addition of an acid to a base, or a base to an acid, is called **titration**. Typically, when a base of known concentration is added to an acid of unknown pH, we say that the acid is titrated with the base. A known number of moles of base is added to the acid, either in solid form, or more commonly, as a solution via a burette.

As the base is added, the concentration of $[H_3O^+]$ changes due to neutralisation. If the pH is monitored during the process, a titration curve can be plotted showing pH against moles of added base.

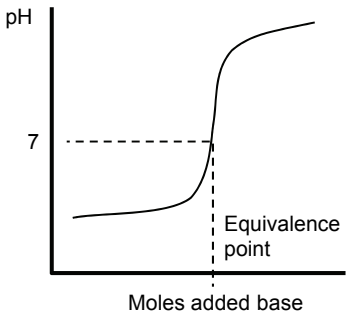

The moles of added base are measured usually by use of a burette. For the case of a strong acid and a strong base, there is a sharp change in pH at the equivalence point, where $[H_3O^+] = [OH^-]$. At or near this point, a very small addition of base results in a large increase in pH.

At the start of the titration, $[H_3O^+]$ is the molarity of the acid (for a strong acid). Before the equivalence point is reached, $[H_3O^+]$ is found from the initial moles of $[H_3O^+]$ less the moles of added OH^- (from the burette). At the equivalence point, $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$. After the equivalence point, there is an excess of OH^-. Since we know how much OH^- is used to neutralise the acid, we know how much excess $[OH^-]$ exists after the equivalence point (from the burette reading) and the pH can be calculated from 14 – pOH.

The change in pH of the solution as the base is added can be measured using a pH meter, or more conventionally, using an **indicator**. When the indicator changes colour, the **end point**, the titration is finished.

9.12 Choice of Indicator

During a titration, the indicator to be used should have an **end point** which corresponds to the **equivalence point**. At first sight, this might sound like that the only useful indicator would be one that has an end point at pH = 7. However, the choice of indicator depends on the nature of the reactants.

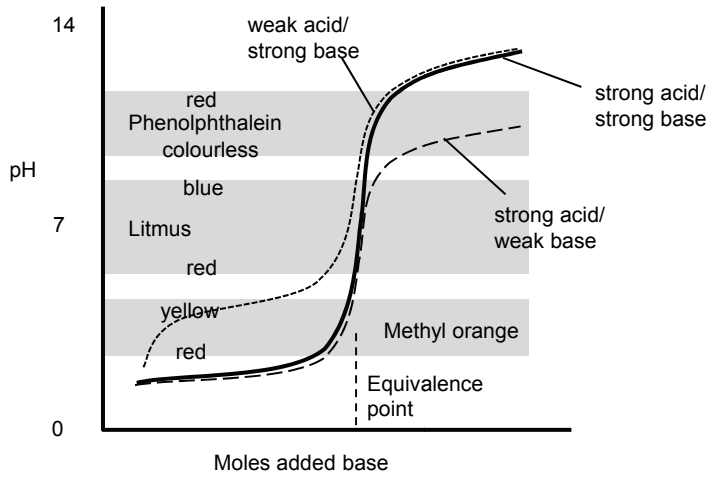

In the case of a strong acid being titrated with a strong acid, any of the three indicators above are suitable. However, for the case of a weak acid and a strong base, **Methyl orange** would not be suitable because it would change colour too early. **Phenolphthalein** would be a better choice because its end point (pH at which colour changes) more closely coincides with the equivalence point. For the case of a strong acid and a weak base, Methyl orange would be suitable, but not Phenolphthalein. **Litmus** is usually considered a poor choice because it changes colour over too wide a range of pH compared to other indicators. Weak acids are not usually used with weak bases in titration experiments.

A **universal indicator** is a mixture of other indicators designed so that different colours indicate different pH values.

In swimming pool maintenance, a few drops of phenol red (colour change from yellow to red over a pH range of 6.8 to 8.4) are used to measure pH. When the water is basic, the acid demand test involves putting a few drops of acid into the test mixture to determine how much acid is required to bring the solution back to the desired range of pH (usually 7.2 to 7.6).

9.13 Hydrolysis

Hydrolysis is the chemical reaction of ions with water. **Anions** may function as Bronsted-Lowry bases and receive a proton from the water molecule:

$$B^{n-} + H_2O \leftrightarrow OH^- + BH^{n-1}$$

Halide ions do not **hydrolyse** to any appreciable extent:

$$Cl^- + H_2O \leftarrow HCl + OH^- \qquad pH \approx 7$$

Oxide and sulphide ions hydrolyse:

$$O_2^{2-} + H_2O \rightarrow 2OH^- \qquad pH < 7$$

$$S^{2-} + H_2O \rightarrow HS^- + 2OH^-$$

Weak conjugate bases of strong acids do not hydrolyse:

$$ClO_4^- + H_2O \leftarrow HClO_4 + OH^- \qquad pH \approx 7$$

Strong conjugate bases of weak acids do hydrolyse:

$$C_2H_3O_2^- + H_2O \leftrightarrow HC_2H_3O_2 + OH^- \qquad pH < 7$$

Cations may function as Bronsted-Lowry acids and donate proton to the water molecule:

$$A^{n+} + H_2O \leftrightarrow H_3O^+ + A^{n-1}$$

Hydrated cations of groups I and II do not hydrolyse. Hydrated transition metal ions (Al_3^+, NH_4^+) hydrolyse to give acid solutions.

$$\left[Fe(H_2O)_6\right]^{3+} + H_2O \rightarrow H_3O^+ + \left[Fe(H_2O)_5OH\right]^{2+}$$

The **salts** of strong acids to not hydrolyse. For example, NaCl dissolved in water produces

$$NaCl \rightarrow Na^+ + Cl^-$$

$$Na^+ + H_2O \rightarrow \text{no reaction} \qquad pH = 7$$

$$Cl^- + H_2O \rightarrow \text{no reaction}$$

The salts of weak acids and strong bases do hydrolyse. For example, $NaC_2H_3O_2$ (sodium acetate) when dissolved in water produces

$$NaC_2H_3O_2 \rightarrow Na^+ + C_2H_3O_2^-$$

$$Na^+ + H_2O \rightarrow \text{no reaction}$$

$$C_2H_3O_2^- + H_2O \leftrightarrow HC_2H_3O_2 + OH^- \qquad pH > 7$$

The salts of strong acids and weak bases do hydrolyse:

$$NH_4Cl \rightarrow NH^{4+} + Cl^-$$

$$Cl^- + H_2O \rightarrow \text{no reaction}$$

$$NH^{4+} + H_2O \rightarrow NH_3 + H_3O^+ \qquad pH < 7$$

The salts of weak acids and weak bases do hydrolyse but the resulting pH depends on the solubility constants K_A and K_B.

Many elements occur in compounds as oxides and hydroxides. When hydrolysed, water molecules attach themselves to anions or cations formed by their dissociation in solution and these hydrolysed ions may act as acids or bases. The extent to which this occurs depends on the size of the atom and the charge.

9.14 Simultaneous Equilibria

In the ideal case, only one equilibrium constant need be satisfied in a chemical reaction, but in practice, several equilibria are operating at the same time. For example, consider the hydrolysis reaction involving the dissociation of $(NH_4)_2S$ in solution:

$$NH_4^+ + H_2O \leftrightarrow NH_3 + H_3O^+$$
$$S^{2-} + H_2O \leftrightarrow HS^- + OH^-$$

There are two equilibria to be satisfied:

$$pK_{A(NH_4^+)} = 9.2$$
$$pK_{B(S^{2-})} = 0.2$$
$$pK_{B(S^{2-})} > pK_{B(NH_4^+)}$$
$$\therefore pH > 7$$

The quantitative analysis of hydrolysis involves the simultaneous equilibria of two reactions. For example consider the hydrolysis of the acetate ion:

$$C_2H_3O_2^- + H_2O \leftrightarrow HC_2H_3O_2 + OH^-$$

$$K_w = [H_3O^+][OH^-]$$
$$= 1\times10^{-14}$$
$$K_h = \frac{[OH^-][HC_2H_3O_2]}{[C_2H_3O_2^-]}$$

the **hydrolysis equilibrium constant**

$$[OH^-] = \frac{K_w}{[H_3O^+]}$$
$$K_h = \frac{K_w[HC_2H_3O_2]}{[C_2H_3O_2^-]}$$
$$= \frac{K_w}{K_A}$$

The hydrolysis equilibrium constant is expressed in terms of the associated acid (or base) equilibrium constant.

9.15 Complex Ions

Ligands are molecules or anions that have a lone pair of electrons. NH_3, H_2O and CN^- are examples. Some ligands combine with transition elemental metal ions – they become coordinated with the ion to form a **complex ion**.

$[Cu(NH_3)_4]^{2+}$

$[Al(H_2O)_6]^{3+}$

$[Ag(CN)_2]^-$

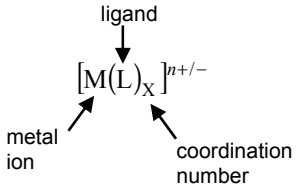

The **coordination number** usually equals twice the charge on the metal ion. The overall complex ion charge equals the sum of the cation and ligand charges. Complex ions may be anionic, cationic or neutral.

The properties of complex ions depend very much on the geometrical arrangement of molecules around the central atom. In general terms, the ligand provides electron pairs which find a place to attach themselves at available electron *d* orbitals around the central metal ion. However, this can happen in several ways. For example, consider the complex ion formed by Co and the ligands Cl^- and H_2O:

$[Co(Cl)_4]^{2-}$ coordination number 4

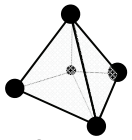

$[Co(H_2O)_6]^{2+}$ coordination number 6

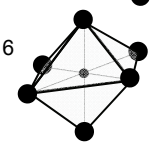

The lone pairs on the ligands face inwards towards and occupy *d* orbitals on the central metal ion. The reaction in water is

$$\underset{\text{blue}}{[Co(Cl)_4]^{2-}} + 6H_2O \leftrightarrow \underset{\text{pink}}{[Co(H_2O)_6]^{2+}} + 4Cl^-$$

Colours are often prominent in these compounds because the energy levels associated within the *d* orbitals are in the **visible light** range. Certain wavelength components of white light passing through solutions containing these ions are absorbed and the transmitted light that we see appears coloured.

10. Electronic Equilibrium

Summary

- **Oxidation** occurs at the **anode**. Neutral atoms being oxidised **lose** their electrons and become positively charged **cations** which tend to move towards the **cathode**.

$$4Fe(s) \rightarrow 2Fe_2^{2+}(aq) + 4e^-$$
$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$
$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$
$$H_2^{2+}(g) \rightarrow 2H^+ + 2e^-$$

Oxidation occurs when the oxidation number of an atom is increased (loss of electrons).

- **Reduction** occurs at the **cathode**. Positively charged ions in solution take up the electrons coming from the oxidation reaction and become neutral atoms. The remaining negatively charged **anions** tend to move towards the **anode**.

$$3O_2 + 4e^- \rightarrow 2O_3^{2-}$$
$$2Ag^{2+} + 2e^- \rightarrow 2Ag(s)$$
$$2H^+ + 2e^- \rightarrow 2H_2(g)$$
$$Cu^{2+} + 2e^- \rightarrow Cu(s)$$

Reduction occurs when the oxidation number of an atom is decreased (gain of electrons).

10.1 Oxidation and Reduction

Oxidation and reduction reactions involve the **equilibrium** of a competition for electrons between atoms and ions. It is **electronic equilibrium**. To see how this comes about, we need to look at some numbers that quantify what drives this type of reaction.

The **oxidation number**, or **oxidation state**, is a quantity that describes the number of electrons that seem to be gained or lost by an atom when a chemical bond is formed. During a chemical reaction, **oxidation** occurs when the oxidation number of an atom is increased (loss of electrons). **Reduction** occurs when the oxidation number of an atom is decreased (gain of electrons). That is, the term reduction indicates a reduction in oxidation number.

Consider a simplified version of the oxidation of iron:

$$4\mathrm{Fe(s)} + 3\mathrm{O_2(g)} \rightarrow 2\mathrm{Fe_2O_3(s)}$$

The **oxidation half-reaction** is

$$4\mathrm{Fe(s)} \rightarrow 2\mathrm{Fe_2^{2+}} + 4\mathrm{e^-}$$

In this half-reaction, the oxidation number of the Fe atoms increases from 0 to 2+ (loses electrons)

The **reduction half-reaction** is

$$3\mathrm{O_2} + 4\mathrm{e^-} \rightarrow 2\mathrm{O_3^{2-}}$$

In this half-reaction, the oxidation number of the O atoms decreases from 0 to 2− (gains electrons).

The terms oxidation and reduction are historical in origin. They arose from the common observation that some reactants combine with oxygen (and so are said to be **oxidised**) while others lose oxygen atoms (and so are said to be **reduced**). Now it is recognised that it is the loss and gain of electrons that is the important feature of such reactions.

The **oxidising agent**, or **oxidant**, is the substance that is reduced. In the example above, oxygen is the oxidising agent since oxygen oxidises the iron. The **reducing agent**, or the **reductant**, is the substance that is oxidised. A **redox couple** is an oxidant and its complementary reductant. In the above example, the redox couples are written

$$\mathrm{Fe}/\mathrm{Fe_2^{2+}} \quad \text{and} \quad \mathrm{O_2}/\mathrm{O_3^{2-}} \qquad \begin{matrix}\text{Oxidant/Reductant} \\ \text{(or Reduction/Oxidation)}\end{matrix}$$

The processes of oxidation and reduction do not occur in all chemical reactions. In many reactions, the oxidation numbers of the participating atoms do not change. Examples of **non-redox reactions** are some precipitation reactions, acids reacting with bases, acids and oxides, hydroxides, sulphides and carbonates. In **acid-base reactions**, it is more an exchange of protons that is important, not electrons.

10.2 Redox Reaction

Consider the redox reaction: $Cu(s) + 2Ag^{2+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

We can separate out the oxidation and reduction processes physically using separate beakers of solution, a wire for electrons to flow along, and a salt bridge for ions to move across and electrodes where reactions take place.

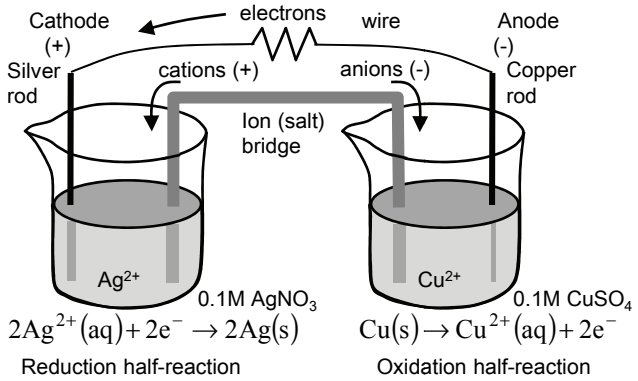

The salt bridge is a tube containing a salt solution (e.g. $NaNO_3$) and allows negatively charged anions to move into the anode solution and positively charged cations to move into the cathode solution while at the same time preventing bulk mixing of the solutions.

The electrode where reduction occurs is called the **cathode**. Silver has a greater affinity for **electrons** than copper. So, the Ag^{2+} ions in the solution combine with the free electrons in the cathode to form solid silver. This loss of free electrons at the cathode represents a net positive charge. The Ag^{2+} ions are pulling the electrons off the silver rod and forming solid silver at the cathode. But the consumption of Ag^{2+} ions in the solution results in a build-up of negative charge (the NO_3^- ions), and if this is not balanced in some way, the reaction will come to a stop as the ions in the solution repel any more electrons arriving at the cathode wanting to take part in the reaction.

The electrode where oxidation occurs is called the **anode.** The copper rod at the anode dissolves away to form Cu^{2+} ions and free **electrons**. These free electrons travel along the wire and are consumed at the cathode. The build-up of positively charge Cu^{2+} ions would eventually overcome the affinity for electrons by the silver and the reaction would come to a stop.

If the NO_3^- **anions** are allowed to flow from the cathode solution to the anode solution, and the Cu^{2+} **cations** flow from the anode solution to the cathode solution, then build-up of excess charge would be prevented and the reactions at each electrode would proceed spontaneously.

The redox reactions, arranged in this way, constitute an **electrochemical cell** (or **galvanic cell**) since a **voltage** is produced between the cathode and the anode. The sign of the anode and cathode is determined by the flow of electrons in the external wire, not the ion flow in the solutions.

10.3 Single-Cell Redox Reaction

Consider the redox reaction

$$Cu(s) + 2Ag^{2+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

We have seen that this is an oxidation-reduction reaction whereby each half-reaction can be arranged to occur in separate solutions. This reaction can also occur in a single solution.

$2Ag^{2+}(aq) + 2e^- \rightarrow 2Ag(s)$
Reduction half-reaction

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
Oxidation half-reaction

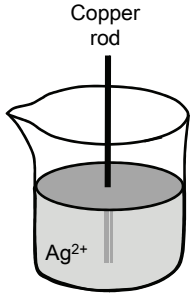

1M $AgNO_3$

Redox reactions of this kind find application in the silvering of copper conductors in electrical switch gear whereby the oxidation (dulling) of copper due to atmospheric contaminants is to be avoided.

When a copper rod is dipped into a silver nitrate solution, silver metal is spontaneously deposited on the rod. The solution turns blue. Electron transfer occurs from the copper to the silver ions in the vicinity of the rod.

Another good example of a single-cell reaction is when a zinc rod is dipped into hydrochloric acid.

$2H^+ + 2e^- \rightarrow 2H_2(g)$
Reduction half-reaction

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
Oxidation half-reaction

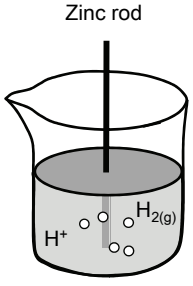

1M HCl

The metal dissolves in the acid, producing H_2 gas. The same thing happens with Mg, Al, Fe and Ni, but not with Cu, Ag and Au. The reason for some metals being able to be dissolved in HCl and others not can be found by a consideration of **standard electrode potentials**.

10.4 Standard Hydrogen Electrode

Consider the redox reaction

$$Cu^{2+}(aq) + H_2(g) \rightarrow Cu(s) + 2H^+(aq)$$

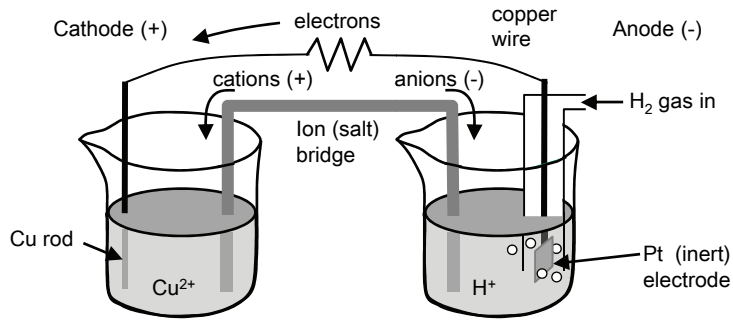

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \qquad H_2^{2+}(g) \rightarrow 2H^+ + 2e^-$$

Reduction half-reaction — Oxidation half-reaction

$$Cu^{2+}/Cu \text{ Redox couple} \qquad H^+/H_2(g) \text{ Redox couple}$$

When the H_2 gas is at 1 atm and the H^+ solution is 1 M, the H^+/H_2 redox couple is referred to as a **standard hydrogen electrode** and is assigned a 0V potential. The potential difference between the hydrogen standard cell and the other electrode is called the **standard electrode potential** E^o for the half-reaction occurring at that other electrode.

Standard electrode potentials are provided from the point of view of **oxidation** at the hydrogen standard electrode. That is, positive values of standard electrode potentials for a redox reaction indicate that the reaction will be one of **reduction** when the other half-cell is the standard cell. When the standard electrode potential for a redox reaction is listed as negative, it indicates that this reaction will be an **oxidation** reaction if the other electrode is the standard hydrogen electrode.

The standard electrode potential E^o for the Cu^{2+}/Cu half-reaction above is +0.34V and so the copper is reduced and the hydrogen is oxidised. The value of E^o for Zn is –0.76V and so if a zinc electrode and solution were used in place of the copper, the zinc would be oxidised and the hydrogen would be reduced.

10.5 Standard Electrode Potentials

Standard electrode potentials E^{o} for some **reduction half-reactions** where gases are at 1 atm and solutions are 1M:

$F_2(g) + 2e^- \rightarrow 2F^-$	+2.87
$O_3(g) + 2H^+(aq) + 2e^- \rightarrow 2H_2O$	+2.07
$MnO_4^{2+}(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2-}(aq) + 4H_2O$	+1.51
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.229
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.799
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.771
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.52
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.337
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$S(aq) + 2H^+ + 2e^- \rightarrow H_2S(g)$	+0.141
$2H^+(aq) + 2e^- \rightarrow H_2^{2+}(g)$	0
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	-0.126
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	-0.136
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.440
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	-0.763
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.66
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	-2.37
$Na^+(aq) + e^- \rightarrow Na(s)$	-2.714
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	-2.89
$K^+(aq) + e^- \rightarrow K(s)$	-2.925
$Li^+(aq) + e^- \rightarrow Li(s)$	-3.045

10.6 Spontaneous Redox Reactions

A very useful application of standard electrode potentials is the determination of whether a redox reaction will proceed spontaneously or not. Consider the copper and zinc redox couples:

$$Cu^{2+}/Cu \qquad Zn^{2+}/Zn$$

$$E^{o} = +0.34\,V \qquad E^{o} = -0.76\,V$$

There are four possible reactants and two possible reactions:

1 $Cu^{2+}_{(ox)} + Zn^{2+}_{(ox)}$ No reaction (simultaneous oxidation)

2 $Cu^{2+}_{(ox)} + Zn_{(red)}$ $Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$

3 $Cu_{(red)} + Zn^{2+}_{(ox)}$ $Cu_{(red)} + Zn^{2+}_{(ox)} \rightarrow Cu^{2+}(aq) + Zn(s)$

4 $Cu_{(red)} + Zn_{(red)}$ No reaction (simultaneous reduction)

The first and fourth possibilities cannot happen since we must have complementary oxidation and reduction processes happening. To determine which of the second and third possibilities will happen spontaneously when these chemicals are in an **electrochemical cell**, we add the **standard electrode potentials**. However, the standard electrode potentials are expressed in terms of reduction reactions, and so we must reverse the sign for a corresponding oxidation reaction.

For the second possibility, the electrode potential for the oxidation of copper in solution would be –0.34V. This is added to –0.76 for the reduction of zinc to obtain –1.1V. Since this total is a negative voltage for the cell as a whole, we say that this reaction will not proceed of its own accord.

For the third possibility, the electrode potential for the reduction of copper in solution is +0.34V. This is added to +0.76 for the oxidation of zinc to obtain +1.1V. Since this total is a positive value, we say that this reaction will proceed of its own accord and what's more, we would measure a **potential difference** of +1.1V across the terminals of the cell.

Standard electrode potentials for a redox reaction indicate the **reduction** potential of the half-reaction. Generally speaking, a redox reaction will proceed spontaneously if the **oxidant** (the one that is reduced) from the redox couple with the higher value of E^{o} reacts with the **reductant** of the other.

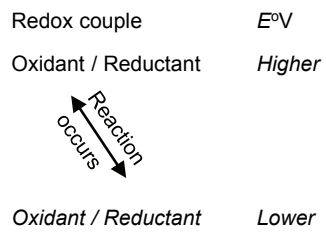

10.7 Oxidation Numbers

Although we can predict which redox reactions will occur spontaneously from a consideration of **standard electrode potentials**, we have yet to consider why the standard potentials are what they are. Consider the redox reaction

$$Cu(s) + 2Ag^{2+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s) \quad \text{Redox reaction}$$

$$2Ag^{2+}(aq) + 2e^{-} \rightarrow 2Ag(s) \quad \text{Reduction half-reaction}$$

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^{-} \quad \text{Oxidation half-reaction}$$

From the above, we can conclude that silver ions have a stronger affinity for attracting **electrons** than do copper ions, and so the silver ions are reduced to a solid by taking up electrons and the solid copper is oxidised by releasing electrons, rather than the reverse. It is the relative affinity of ions to attract electrons that places a particular element in the list of standard potentials – which as will be remembered is presented from the point of view of reduction half-reactions.

This affinity for electrons by atoms is something we have met before: **electronegativity**. It was found that a practical measure of electronegativity is the method of electron counting by **oxidation numbers**. In a chemical reaction, when the oxidation number of an atom (i.e. its apparent charge) has increased, the atom is said to have been **oxidised**. When the oxidation number of an atom has decreased, the atom is said to have been **reduced**.

In the above reactions, the oxidation number of copper is initially 0. After reaction, the copper atoms have apparently lost two electrons and so its oxidation number is now 2+ (its apparent charge), and is thus an increase. The oxidation number of silver in the Ag^{2+} ions is initially 2+, and after reaction is 0. The oxidation number has decreased and the silver is therefore reduced. All this comes down to a competition for the attraction of electrons.

- **Oxidation** represents a loss of electrons or increase in oxidation number.
- **Reduction** represents a gain of electrons or decrease in oxidation number.

Oxidation numbers allow us to recognise oxidation-reduction reactions and are also useful for balancing the equations for these reactions. Changes in oxidation number do not necessarily indicate that an atom has gained or lost an electron, or has gained or lost net electric charge, even though we use them in this way for the purpose of establishing the numbers. Rather, they indicate how many electrons are involved for the atom in a chemical reaction.

10.8 Balancing Redox Half-Reactions

In redox reactions, both atoms and charges must be conserved. A convenient method of balancing redox equations is to use the equations for the half-reactions.

Consider the reaction between copper and nitric acid, HNO_3. The redox couples involved are

$Cu^{2+}/Cu(s)$	$H^+, NO_3^-/NO(g)$
$E^o = +0.34V$	$E^o = +0.96V$
Since E^o for the nitric acid is more positive, then the copper must undergo oxidation:	and the NO_3 must undergo reduction:
$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	$4H^+ + NO_3^- + 3e^- \rightarrow NO(g) + H_2O$

Both these half-reactions are balanced, but they now need to be combined to form the net reaction, which is required also to be balanced. The procedure is to balance the charge. The lowest common factor in this example is 6, and so

$$3Cu(s) \rightarrow 3Cu^{2+}(aq) + 6e^- \qquad 8H^+ + 2NO_3^- + 6e^- \rightarrow 2NO(g) + 4H_2O$$

These half-reactions can now be combined:

$$3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO(g) + 4H_2O$$

Not all reactions can be balanced so easily. A general method is to

1. Balance for atoms other than O and H
2. Balance for O by adding water
3. Balance for H by adding H^+
4. Add OH^- ions to both sides for basic solution to form water with the H^+ added from (3)
5. Balance for charge by adding electrons

It should be noted that balancing a half-reaction by adjusting coefficients does not alter the electrode potential for that half-reaction.

10.9 Balancing Redox Reactions with Oxidation Numbers

Another method of balancing redox reactions is by the use of oxidation numbers. Consider the reaction between copper and nitric acid HNO_3. The redox couples involved are:

$$Cu^{2+}/Cu(s) \qquad NO_3^-/NO(g)$$
$$E^o = +0.34\ V \qquad E^o = +0.96\ V$$

Since E^o for the nitric acid is more positive, then the copper must undergo oxidation. The unbalanced equation is:

$$Cu + NO_3^- \rightarrow Cu^{2+} + NO(g)$$

Next, we write the oxidation numbers to each element in the reaction:

$$\begin{array}{ccccc} Cu & + & NO_3^- & \rightarrow & Cu^{2+} + NO(g) \\ 0 & & 5+,2- & & 2+ \qquad 2+,2- \end{array}$$

Cu has undergone a change in oxidation number from 0 to 2+. An increase in oxidation number indicates oxidation. The change in oxidation number in this element is +2.

Rules for oxidation numbers

a) In free, uncombined, elements, the oxidation number of each atom is set to be 0.
b) In compounds involving hydrogen, the oxidation number of hydrogen is usually 1+.
c) In compounds involving oxygen, the oxidation number of O is usually 2–.
d) The sum of all the oxidation numbers of all atoms in an ion is equal (in both magnitude and sign) to the charge on the ion.
e) The sum of all the oxidation numbers of all atoms in a neutral molecule is 0.

N has undergone a change in oxidation number of 5+ to 2+. The change in oxidation number is –3. A decrease in oxidation number indicates reduction. There is no net change in oxidation number for the oxygen atoms.

We now introduce a further rule for oxidation numbers, and that is, the net *change* in oxidation number for the overall reaction is to be zero. That is, the overall *change* in oxidation number for the left side of the reaction has to be equal to the negative of the overall *change* oxidation number for the right side. The only way to do this here is to multiply the Cu atoms by 3 and the NO_3^- ions by 2. That is, operating on the changes in oxidation numbers, we have: $3(+2)+2(-3)=0$ Thus,

$$3Cu + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO(g).$$

We need to add H_2O to get a balance for oxygen atoms:

$$3Cu + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO(g) + 4H_2O$$

And finally, add H^+ ions to balance for H atoms:

$$3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO(g) + 4H_2O$$

10.10 Electrochemical Cell

An **electrochemical cell**, **or galvanic cell**, is a redox reaction that proceeds spontaneously and has an **electrical potential difference** at its electrodes. This potential difference, when measured at a negligible current draw, is called the **emf** of the cell E_{cell}.

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$$

reduction oxidation

When the half-cells are standard electrodes, the standard emf of the cell is given by

$$E^{\text{o}}_{\text{cell}} = E^{\text{o}}_{\text{cathode}} - E^{\text{o}}_{\text{anode}}$$

Example of electrochemical cell:

$$\text{Cu}^{2+}/\text{Cu} \qquad \text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq}),\text{Pt}$$

$$E^{\text{o}} = +0.34\text{V} \qquad E^{\text{o}} = +0.77\text{V}$$

All at 1M concentrations

Since E^{o} for the iron reaction is higher than that for copper, then the Fe^{3+} is undergoing reduction (it is the oxidant) and so is the **cathode** for the cell. Copper is being oxidised and so is the **anode**.

$$\begin{aligned} E^{\text{o}}_{\text{cell}} &= E^{\text{o}}_{\text{cathode}} - E^{\text{o}}_{\text{anode}} \\ &= 0.77 - 0.34 \\ &= +0.43\text{V} \end{aligned}$$

Note: we do not have to "balance" the half-equations to determine the overall cell potential. For example, the **standard electrode potential** of the copper half cell is still +0.34 if we write

$$2\text{Cu}^{2+} + 4\text{e}^{-} \rightarrow 2\text{Cu}(\text{s})$$

The potentials do depend on the concentration of the species, but not the number of atoms that participate in the overall reaction.

In an electrochemical cell that does not have a connection between the anode and cathode, the redox reaction proceeds until the build-up of positive charge on the cathode prevents any more cations from moving from the anode and vice versa and the reaction stops. The system has acquired **electrical potential energy** as a result of the reaction proceeds. The reduction of energy of the system as a whole (i.e. the chemical reaction tending to send the system towards a lower energy state) appears as mechanical work or heat by virtue of the current flow.

10.11 EMF vs. Concentration

The potential of an electrochemical cell depends upon the concentration of the reactants. Standard potentials are given for 1M solutions. As the cell operates, the concentrations of the reactants change. The dependence of the cell potential on concentration is given by the **Nernst equation**.

$$p\mathrm{Ox} + ne^- \rightarrow q\mathrm{Red}$$

$$E = E^{\circ} + \frac{RT}{nF}\ln\frac{[\mathrm{Ox}]^p}{[\mathrm{Red}]^q}$$

$$= E^{\circ} + \frac{0.059}{n}\log_{10}\frac{[\mathrm{Ox}]^p}{[\mathrm{Red}]^q} \quad \text{at } 25^{\circ}\mathrm{C}$$

R - universal gas constant
T - temperature (K)
F - Faraday's constant 96487 C/mol

Consider the electrochemical cell at 25°C:

$$\mathrm{Pt}\,|\,\mathrm{Sn}^{4+}(0.5M), \mathrm{Sn}^{2+}(1.5M)\,||\,\mathrm{Fe}^{3+}(1.0M), \mathrm{Fe}^{2+}(0.5M)\,|\,\mathrm{Pt}$$

Anode

$$\mathrm{Sn}^{4+} + 2\mathrm{e}^- \leftrightarrow \mathrm{Sn}^{2+}$$

$$E_{\mathrm{Sn}} = E^{\circ}_{\mathrm{Sn}} + \frac{0.059}{2}\log_{10}\frac{[\mathrm{Sn}^{4+}]}{[\mathrm{Sn}^{2+}]}$$

$$= 0.15 + \frac{0.059}{2}\log_{10}\frac{[0.5]}{[1.5]}$$

$$= 9.14\mathrm{V}$$

Cathode

$$\mathrm{Fe}^{3+} + \mathrm{e}^- \leftrightarrow \mathrm{Fe}^{2+}$$

$$E_{\mathrm{Fe}} = E^{\circ}_{\mathrm{Fe}} + \frac{0.059}{1}\log_{10}\frac{[\mathrm{Fe}^{4+}]}{[\mathrm{Fe}^{2+}]}$$

$$= 0.77 + \frac{0.059}{1}\log_{10}\frac{[1.0]}{[0.5]}$$

$$= 0.79\,\mathrm{V}$$

Since $E_{\mathrm{Fe}} > E_{\mathrm{Sn}}$, $\mathrm{Fe}^{3+}|\mathrm{Fe}^{2+}$ is the cathode and the cell reaction is

$$2\mathrm{Fe}^{3+} + \mathrm{Sn}^{2+} \rightarrow 2\mathrm{Fe}^{2+} + \mathrm{Sn}^{4+}$$

$$E_{\mathrm{cell}} = 0.79 + -0.14$$

$$= 0.65\mathrm{V}$$

When the electrode is a metal in contact with its cation (e.g. $\mathrm{Cu}^{2+}|\mathrm{Cu}$), then

$$\mathrm{Cu}^{2+} + 2\mathrm{e}^- \leftrightarrow \mathrm{Cu}_{(\mathrm{s})}$$

$$E = E^{\circ} + \frac{0.059}{2}\log_{10}[\mathrm{Cu}^{2+}]$$

When the electrode is a gas in contact with its ion (e.g. $\mathrm{H}^+|\mathrm{H}_2(\mathrm{g})$), then

$$2\mathrm{H}^+ + 2\mathrm{e}^- \leftrightarrow \mathrm{H}_2(\mathrm{g})$$

$$E = E^{\circ} + \frac{0.059}{2}\log_{10}\frac{[\mathrm{H}^+]^2}{(P_{H2})}$$

→ Pressure in atm

10.12 Electronic Equilibrium

Thus far we have considered the conditions under which an oxidation-reduction reaction will proceed. Consider an electrochemical cell:

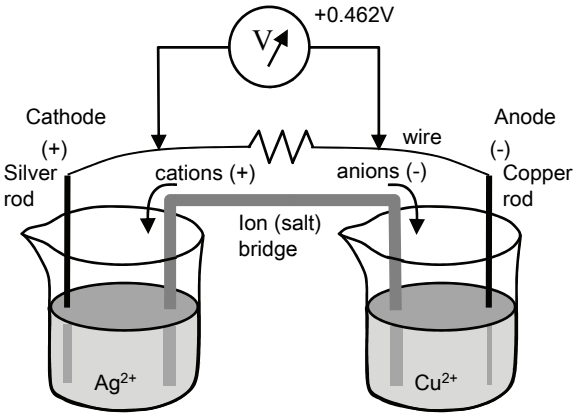

$2Ag^{2+} + 2e^- \rightarrow 2Ag(s)$ $\qquad$ $Cu(s) \rightarrow Cu^{2+} + 2e^-$

Reduction half-reaction $\qquad$ Oxidation half-reaction

How long does the spontaneous reaction proceed for? Does this cell "run down"? Does the voltmeter reading start to drop and then go to zero?

Initially, we know from our standard electrode potentials that the attainment of equilibrium, the objective of all chemical reactions, favours the forward reaction as written:

$$Cu(s) + 2Ag^{2+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

As the reaction proceeds, the Ag^{2+} ions are being used up in the cathode solution, and there is a build-up of Cu^{2+} ions in the anode solution. Electrons lose potential energy as they pass through the wire and this energy is converted to heat in the resistor. When the electrons combine with the silver ions at the cathode, they are in a lower energy state compared to when they were bound to the copper. Attainment of a lower energy state is the driving force behind most spontaneous chemical reactions.

When the silver ions are in short supply, then not all the electrons coming from the wire will find a home to go to and there will be a slight increase in negative charge at the cathode. When there are no more silver ions to accept these electrons, the build-up of negative electric charge will be great enough to prevent any more from arriving. At this point, the electrical potential difference between the anode and cathode will be zero and the cell will be exhausted.

10.13 Equilibrium Constant

The potential of an electrochemical cell depends upon the concentration of the reactants. When the cell is exhausted, we reach a state of equilibrium and the **equilibrium constant** for the reaction is satisfied. Consider the redox reaction:

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

$$K_c = \frac{\left[Fe^{3+}\right]^5\left[Mn^{2+}\right]}{\left[Fe^{2+}\right]^5\left[MnO_4^-\right]\left[H^+\right]^8}$$

At equilibrium, $E = 0$, and so

$$E^o_{Fe} + 0.059\log_{10}\frac{\left[Fe^{3+}\right]}{\left[Fe^{2+}\right]} = E^o_{MnO_4^-} + \frac{0.059}{5}\log_{10}\frac{\left[MnO_4^-\right]\left[H^+\right]^8}{\left[Mn^{2+}\right]}$$

$$E^o_{MnO_4^-} - E^o_{Fe} = 0.059\log_{10}\frac{\left[Fe^{3+}\right]}{\left[Fe^{2+}\right]} - \frac{0.059}{5}\log_{10}\frac{\left[MnO_4^-\right]\left[H^+\right]^8}{\left[Mn^{2+}\right]}$$

$$\Delta E^o = \frac{0.059}{5}\left(\log_{10}\frac{\left[Fe^{3+}\right]^5}{\left[Fe^{2+}\right]^5} - og_{10}\frac{\left[MnO_4^-\right]\left[H^+\right]^8}{\left[Mn^{2+}\right]}\right)$$

$$= \frac{0.059}{5}\log 10\frac{\left[Fe^{3+}\right]^5\left[Mn^{2+}\right]}{\left[Fe^{2+}\right]^5\left[MnO_4^-\right]\left[H^+\right]^8}$$

$$= \frac{0.059}{5}\log_{10} K_c$$

$$K_c = \log 10\frac{5\Delta E^o}{0.059}$$

$$= 5.1\times10^{62}$$

$$E^o{}_{MnO_4^-} = +1.51\text{V}$$

$$E^o{}_{Fe} = +0.77\text{V}$$

10.14 Lead/Acid Battery

A **battery** is a collection of cells arranged in series. In a motor vehicle **lead acid battery**, there are six cells, each producing about 2V, arranged in series to provide 12V for the vehicle. The redox couples involved are:

$$\mathrm{PbSO_4(s)/Pb(s),SO_4^{2-}} \qquad \mathrm{PbO_2(s),H^+,SO_4^{2-}/PbSO_4(s)}$$
$$E^{\circ} = -0.36\mathrm{V} \qquad E^{\circ} = +1.69\mathrm{V}$$

Since the standard potential for the PbO_2 reaction is higher, then this species undergoes reduction and is the cathode.

Reduction (cathode) $\mathrm{PbO_2(s) + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4(s) + 2H_2O}$

Oxidation (anode) $\mathrm{Pb(s) + SO_4^{2-} \rightarrow PbSO_4(s) + 2e^-}$

$\mathrm{PbO_2(s) + 4H^+ + 2SO_4^{2-} \rightarrow 2PbSO_4(s) + 2H_2O}$ **Discharge** reaction

$$E^{\circ}_{\mathrm{cell}} = E^{\circ}_{\mathrm{cathode}} - E^{\circ}_{\mathrm{anode}}$$
$$= 1.69 - -0.36$$
$$= 2.05\mathrm{V}$$

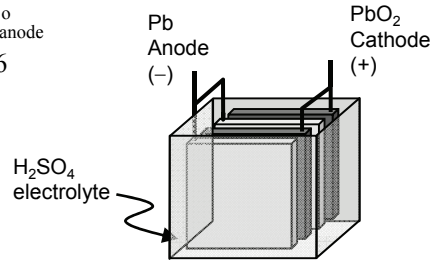

The concentration of H_2SO_4 in a motor vehicle battery is usually about 5M and so the actual cell potential is about 2.15V.

The **anode** (the negative plates) is solid lead, Pb, while the **cathode** (the positive plates) is **lead peroxide**, PbO_2, in a solution of **sulphuric acid**. The reaction product, **lead sulphate** $PbSO_4$, sometimes appears as a white precipitate on the battery terminals.

As the cell discharges, the concentration of H_2SO_4 decreases and the density of the solution also decreases. The density of the solution is thus a measure of the state of **charge** of the battery and is measured with a **hydrometer**.

When the battery is charged, the above reaction proceeds in reverse. Overcharging results in the evolution of gaseous H_2 at the anode and O_2 at the cathode, and the water in the electrolyte has to be replenished.

10.15 Dry Cell

In a conventional **dry cell**, or **Leclanché cell**, oxidation occurs at a zinc anode and reduction occurs at an inert carbon cathode. The electrolyte is not a liquid, but a paste of magnesium dioxide MnO_2, zinc chloride $ZnCl_2$, ammonium chloride NH_4Cl, and carbon black particles.

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$ Oxidation (anode –)

$$2MnO_2(s) + H_2O + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-$$ Reduction (cathode +)

$$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O$$

$$Zn^{2+}(aq) + 4NH_3(aq) \rightarrow [Zn(NH_3)_4]^{2+}(aq)$$

Acid/base absorbs the OH^- ions
Complex ion formation absorbs NH_3 gas

$$Zn(s) + 2MnO_2(s) \rightarrow ZnMn_2O_4(s)$$ Overall cell reaction

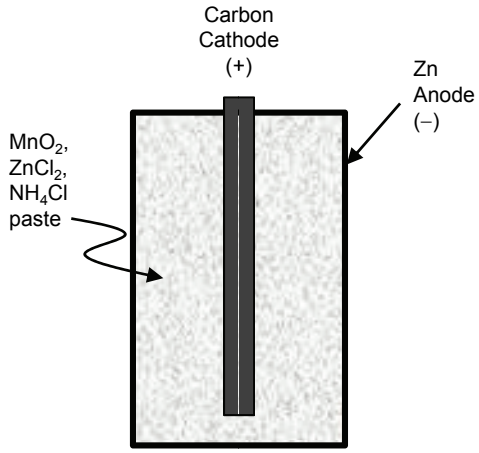

Modern **alkaline cells** use an alkaline electrolyte of KOH instead of the MnO_2, $ZnCl_2$, NH_4Cl paste of the zinc-carbon type of dry cell. In an alkaline cell, the half-reactions are

$$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$$

$$2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$$

10.16 Corrosion

Corrosion is the undesirable oxidation of a metal. The most well-known example is the **rusting of iron**. In simple terms, the complex redox reaction for the rusting of iron is written as

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

In practice, the rusting of iron requires both air (O_2) and water, and the reaction proceeds as a series of steps.

$Fe(s) \rightarrow Fe_2^{2+} + 2e^-$ Oxidation half-reaction

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ Reduction half-reaction

The OH^- ions react with the Fe^{2+} ions:

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$$

then $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow Fe(OH)_3(s)$

and finally $Fe(OH)_3(s) \rightarrow Fe_2O_3, H_2O + 2H_2O$

The brown coloured metal we usually associate with rust is the compound Fe_2O_3, H_2O, an Fe(III) hydrated oxide

Iron and steel often rust badly because the rust has a lower density than the parent metal and tends to flake off, thus exposing more of the material to water and oxygen and promoting further rusting.

Water and oxygen are typically excluded by painting the iron article. However, a very effective way to reduce rusting of iron is to attach a more reactive metal (i.e. one with a lower E^o so that the iron undergoes reduction and the **sacrificial anode** (usually zinc) undergoes oxidation. This process is often called **cathodic protection**.

Fe/Fe_2^{2+}	Zn^{2+}/Zn	Iron or steel coated with zinc is said to be **galvanised** (since it acts like a galvanic cell).
$E^o = -0.44V$	$E^o = -0.76V$	

Water and oxygen are typically excluded by painting the iron article. However, a very effective way to reduce rusting of iron is to attach a more reactive metal (i.e. one with a lower E^o so that the iron undergoes reduction and the sacrificial metal (usually zinc) undergoes oxidation.

Aluminium undergoes corrosion in the presence of atmospheric oxygen. A very thin (nm) tough layer of Al_2O_3 (**alumina**) appears within nanoseconds on the metallic surface which shields the parent metal from further corrosion. Alumina is a very hard ceramic material and is a non-conductor of electricity.

10.17 Electrolysis

An **electrolytic cell** is not a spontaneous redox reaction, and requires an electrical energy input to proceed.

Consider the redox reaction:

$$Cu^{2+}(aq) + 2Ag(s) \rightarrow Cu(s) + 2Ag^{2+}(aq)$$

Arranged in this way, the half-reactions are:

$2Ag(s) \rightarrow 2Ag^{2+}(aq) + 2e^-$ $\quad$ $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Oxidation half-reaction	Reduction half-reaction
-0.799V	+0.337V

The total potential is −0.462V and so this is not a spontaneous reaction. If a cell were constructed and connected with a wire between the two electrodes, the reaction would proceed in the reverse to that as shown above. However, if we apply an external **potential difference** to the electrodes, say a 1V potential, then

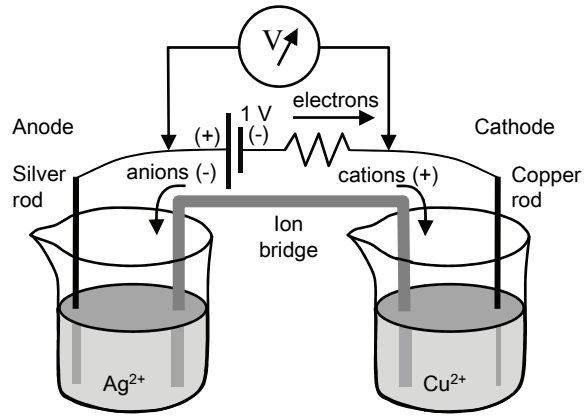

$2Ag(s) \rightarrow 2Ag^{2+}(aq) + 2e^-$ $\quad$ $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Oxidation half-reaction $\quad$ Reduction half-reaction

Note: **oxidation** occurs at the **anode** which in this case is the silver. **Reduction** occurs at the **cathode**, in this case the copper. The silver rod dissolves away and copper particles coat the copper rod.

The applied external potential has to overcome +0.462V in order for the reaction to proceed, and so the potential difference across the electrodes would be 1 – 0.462 = 0.538V.

Arranged in this way, we have an **electrolytic cell** in which the copper rod is the cathode (+) and the silver rod is the anode (-). The reaction proceeds as written.

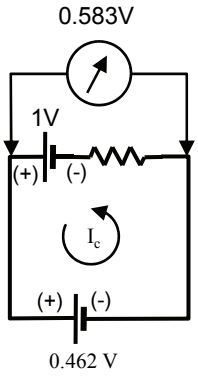

I_c indicates conventional current flow

11. Carbon Chemistry

Summary

Functional groups

H	Alkanes	Single C bond
C=C	Alkenes	Double C bond
C≡C	Alkynes	Triple C bond
OH	Alcohols	ROH
O	Ethers	ROR'
CHO	Aldehydes	RCHO
CO	Ketones	R(C=)OR
COOH	Acids	RCOOH
COO	Esters	RCOOR'
NH_2	Amines	RNH_2 R_2NH, R_3N

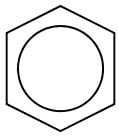

Benzene ring

Alkyl groups

Methyl
Ethyl
Propyl
Butyl
Pentyl
Hexyl
Heptyl
Octyl
Nonyl
Decyl

11.1 Carbon

The element **carbon** has four outer valence electrons and is the first element of Group IV in the periodic table. The other elements in this group become more metallic in nature with increasing atomic number. At room temperature, carbon is relatively inert. At high temperatures, it can form covalent bonds with itself and many other elements. Carbon compounds are the basis for all life on Earth. It is interesting to note that **silicon**, the next element down in the group and also with four valence electrons, is the basis of the composition for nearly all of the Earth's minerals.

With four valence electrons, carbon has the choice of either losing or gaining four electrons to achieve a noble gas configuration but in practice, it tends to share its four electrons via covalent bonds. On the other hand, tin and lead, the heaviest elements in Group IV, with more loosely bound valence electrons, find it energetically favourable to share these electrons in the form of **metallic bonds**.

Carbon reacts with metals to form carbides: e.g. silicon carbide SiC; with non-metals to form molecular compounds: e.g. methane CH_4; with oxygen to form carbon monoxide CO and carbon dioxide CO_2; and with nitrogen to form cyanides (e.g. HCN).

Pure carbon forms three crystalline structures found naturally: **diamond**, **graphite,** and the **fullerenes**. These are **allotropes**. These have significantly different mechanical, thermal and electrical properties and differ only in the geometrical arrangement of their atoms in the crystal structures.

Diamond has a three-dimensional tetrahedral structure. Each carbon atom has four neighbours, and all the valence electrons are equally shared with no vacancies or lone electrons. Thus, diamond is a poor electrical conductor, has a high **hardness** and **elastic modulus**. Diamond is a good heat conductor due to the free passage of **phonons**.

Graphite has a two-dimensional hexagonal sheet structure with the sheets bonded together as layers by **van der Waals forces**. Each carbon atom has three neighbours. Thus, three valence electrons are involved in covalent bonding while the fourth is left in a relatively free state and is responsible for graphite being an electrical conductor.

The **fullerene** form of carbon consists of a three-dimensional arrangement of C atoms in a pentagon which together form a sphere or tube. The most famous is the C_{60} molecule, often referred to as a **buckyball**.

11.2 Carbon Compounds

Carbon forms a great number of compounds with hydrogen. These are called **hydrocarbons**. In addition, **hydrocarbon derivatives** are formed when other atoms in addition to hydrogen become involved in the bonding.

Central to this remarkable ability to form such a wide variety of compounds is the formation of chains of atoms. For example, consider the simple hydrocarbon **methane** CH_4:

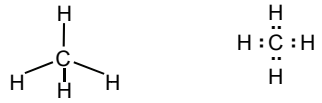

This molecule can be easily expanded to form **ethane** C_2H_6:

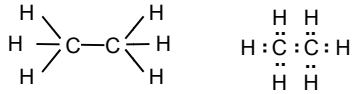

And so on for **propane**, C_3H_8, and **butane**, C_4H_{10}.

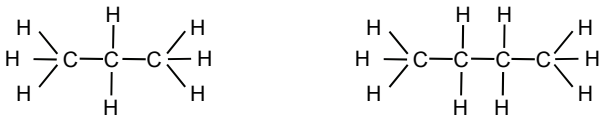

Other possibilities abound, including compounds involving a double carbon bond such as in **ethylene** and the triple bond in **acetylene**:

Compounds with single bonds between carbon atoms are **saturated hydrocarbons**. Compounds with double or triple bonds are called **unsaturated hydrocarbons**.

Hydrocarbons with the same chemical formula but with different structures are possible. For example, **butene** C_4H_8, can exist in four different structural arrangements, each of which is called an **isomer**.

The reason for this is that saturated compounds are saturated with H atoms. When there is a double bond, the maximum possible number of H atoms that can attached to a C atom is decreased and so the C atoms is unsaturated.

The substitution of other elements in place of one or more hydrogen atoms in carbon compounds is responsible for the existence of a large number of hydrocarbon derivatives. Alcohols are hydrocarbons with an attached OH **functional group**.

The ability of carbon to form chains, double bonds, isomers and contain functional groups is responsible for the great variety of carbon compounds which form the chemistry of life on Earth – or **organic chemistry**.

11.3 Functional Groups

Hydrocarbon derivatives are formed when other atoms in addition to hydrogen become involved in the bonding. In these cases, the core hydrocarbon is written with an attached **functional group**. The core or hydrocarbon compound (also called the **remainder** or **residue)** is written with the symbol R. A common functional group is the alcohol, or OH group.

methanol CH_3OH:

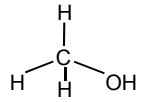

Alcohols can be written as ROH where R is the hydrocarbon residue, or the core hydrocarbon component, and OH is the alcohol functional group.

ethanol C_2H_5OH:

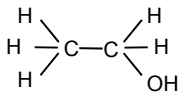

Functional groups

H	Alkanes
C=C	Alkenes
C≡C	Alkynes
OH	Alcohols
O	Ethers
CHO	Aldehydes
CO	Ketones
COOH	Acids
COO	Esters
NH_2	Amines

Functional groups determine the nature of the reactivity of the hydrocarbon involved. The chemistry of the compound is usually determined by the character of the functional group while the hydrocarbon residue is relatively inert.

Consider some compounds based upon the CH_3CH_2- residue:

Ethane: $CH_3CH_2 - H$

Ethanol: $CH_3CH_2 - OH$

Ethyl bromide: $CH_3CH_2 - Br$

The CH_3CH_2- residue is called the **ethyl group**. Similarly, the CH_3- is the **methyl group** and the $CH_3CH_2CH_2-$ is the **propyl group**.

These named **alkyl groups** form bonds with various different functional groups and the resulting compounds R–X are thus **derivatives** of the parent hydrocarbon (e.g. methane, ethane, etc).

11.4 Alkanes

Alkanes are **saturated hydrocarbons** since the bonds with the carbon atoms are single bonds and they contain only carbon and hydrogen. The names of the compounds are derived from the number of carbon atoms.

The first 10 alkanes

Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Pentane	C_5H_{12}
Hexane	C_6H_{14}
Heptane	C_7H_{16}
Octane	C_8H_{18}
Nonane	C_9H_{20}
Decane	$C_{10}H_{22}$

Alkanes can have chain or branched chain (**aliphatic**), or cyclic (**alicyclic**) structures. As the complexity of the molecules increases, there are increased ways in which molecules can form structures with the same molecular formula.

Compounds having the same molecular formula but different structure are called **isomers**.

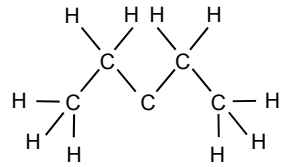

n-pentane (or normal pentane):

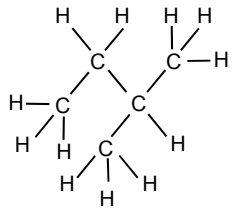

iso-pentane (single branch at the end)

Alkanes with a chain structure have the molecular formula C_nH_{2n+2}.

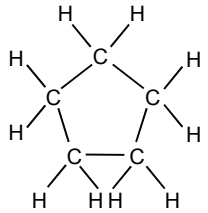

cyclo-pentane (ring structure)

Alkanes having a cyclic or a ring structure have the formula C_nH_{2n}.

Alkanes are the principal components of **petroleum**. Low molecular weight compounds are generally gases at room temperature and pressure. Gasoline (petrol) and turpentine typically contain light fractions (C_7H_{16} to $C_{10}H_{22}$). Kerosene, diesel oil, lubricating oils, pitch, and so on consist of heavier compounds. Alkanes are relatively inert, but can undergo exothermic oxidation (**combustion**) which make them useful sources of energy.

Fuel	**Calorific value** (MJ/kg)
Petrol	45
Diesel	44.4
Ethanol	27.2

Alkanes are sometimes called **paraffins** because they have little (parum) affinity for forming bonds with other atoms or molecules. When they do participate in reactions, this usually involves the **substitution** of a hydrogen atom with another atomic species.

11.5 Alkenes

Alkenes (also known as **olefins**) are unsaturated hydrocarbons because they contain a double bond between two of the available carbon atoms instead of single bonds. As a consequence, there are fewer than four atoms attached to each of the carbon atoms.

Alkenes in a chain configuration have the general formula C_nH_{2n}. Ethene or **ethylene** (C_2H_4) is the simplest alkene.

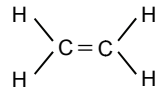

Bond length: 1.33 Å
Energy: 606 kJ/mol
ΔH = +52.5 kJ/mol

Note that the carbon double bond can occur in different places in the structure, leading to formation of isomers. In **propylene** (C_3H_6):

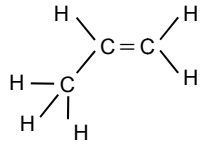

Ethene, propene, and butene are gases. Higher alkenes are generally liquids and those with greater than sixteen carbon atoms are generally waxy solids.

While alkenes are relatively inert, they are more reactive than alkanes because of the double bond. The carbon double bond has a higher bond strength compared to the single bond, but the double bond allows a greater potential for attachment for other atoms and this leads to greater reactivity compared to single-bonded structures. Chemical reactions involving alkenes are usually associated with the breaking of the double bond and the **addition** of other atoms.

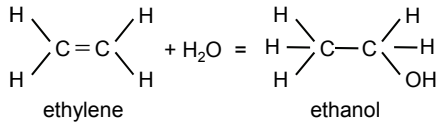

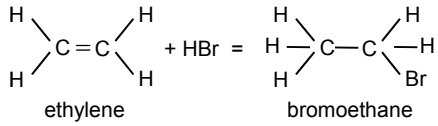

An important reaction involving alkenes is that of **polymerisation**, where a chain reaction occurs in which the C=C double bonds are successively broken and employed to form larger and larger single-bonded structures.

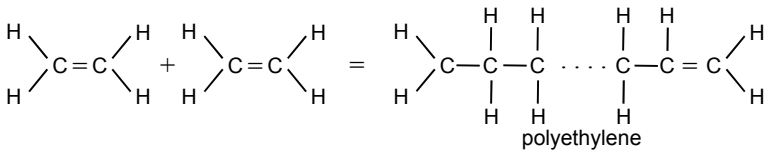

11.6 Alkynes

Alkynes are similar to alkenes except that they feature a carbon-carbon triple bond. Alkynes are unsaturated hydrocarbons and have the general formula C_nH_{2n-2}. Alkynes are also known as **acetylenes**, but the common use of this term refers to **ethyne**: C_2H_2.

C_2H_2
acetylene

H — C ≡ C — H

Bond length: 1.2 Å
Bond energy: 828 kJ/mol
ΔH = +226.9 kJ/mol

The triple bond can occur anywhere in the chain in higher alhynes. Consider the compound 1-butyne. The 1- indicates that the triple bond is at the end of the chain:

$CH_3CH_2C{\equiv}CH$

The CH_3CH_2 is the ethyl group, and so this compound can also be named **ethylacetylene**.

Ethyne	$HC{\equiv}CH$
Propyne	$CH_3C{\equiv}CH$
1-Butyne	$CH_3CH_2C{\equiv}CH$
1-Pentyne	$CH_3(CH_2)_2C{\equiv}CH$
1-Hexyne	$CH_3(CH_2)_3C{\equiv}CH$
1-Heptyne	$CH_3(CH_2)_4C{\equiv}CH$
1-Octyne	$CH_3(CH_2)_5C{\equiv}CH$
1-Nonyne	$CH_3(CH_2)_6C{\equiv}CH$
1-Decyne	$CH_3(CH_2)_7C{\equiv}CH$

Alkynes have a similar chemistry to alkenes. The C≡CH unit is a linear structure and in acetylene, the molecules are therefore rod-like in shape.

The triple bond is capable of opening up and accommodating additional atoms during reactions. Additions may occur with halides, halogens, water, and ammonia.

The C≡CH unit, located at the end of the structure, imparts an acidic nature to alkynes and so acid-base reactions are also possible. Alkynes can also undergo **polymerisation** to give **polyacetylenes**.

One of the most common uses of acetylene is in gas welding. The combustion of acetylene in oxygen provides a flame temperature of about 3300°C making it one of the hottest flames available in industry.

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$

Acetylene is a gas, but an unstable one, especially at moderate to high pressures. In welding gas bottle sets, acetylene is usually dissolved in liquid **acetone** or dimethylformamide and stored under pressure in a cylinder containing a porous medium, **agamassam**.

11.7 Benzene

An important class of carbon compounds arises when carbon atoms are arranged in a special ring formation.

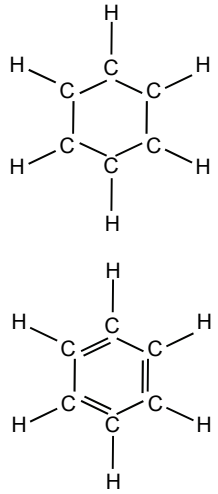

The **benzene ring** C_6H_6 has all the atoms in a plane, with a 120° angle between the carbon atoms. The initial difficulty with this structure is that each carbon atoms has three neighbours sharing one electron, but there are four valence electrons in carbon. Evidently, there either has to be three double bonds present or some way of accommodating the fourth valence electron. If each second carbon atom had a double bond, then all available valence electrons would be shared, but experimental evidence indicates that the bond strength for the C-C bonds are equal around the ring, and that it is stronger than a single bond, but not as strong as a double bond.

The bonding in a benzene ring is explained by the allowable movement of the **valence electrons** in the ring structure. Rather than forming single or double bonds, electrons in the ring form a resonance hybrid, or a superposition of single and double bonds, whereby they may have movement throughout the ring, much like valence electrons in a metal have movement throughout the **conduction band**.

To signify this, the benzene ring is often written in shorthand form using one of the following diagrams:

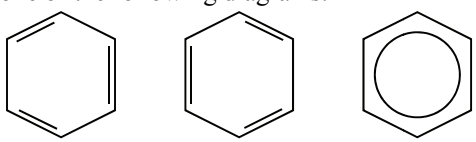

It should be always remembered that there are not single or double bonds, but a special bond somewhere between the two based upon electron movement around the ring.

Ring compounds of this type are called **aromatic compounds**. When they consist of C and H only, they are called **aromatic hydrocarbons**. Note: **aliphatic** compounds in a ring structure are not aromatic; they are simple ring structures (**alicyclic**). Aromatic compounds have mobile electrons within the ring and it is these that determine the chemistry of these compounds. In contrast to the addition reactions for alkenes with a chain structure, benzene undergoes substitution reactions in which H atoms are replaced by other atoms.

11.8 Alcohols

Hydrocarbon derivatives arise when functional groups combine with a residual hydrocarbon core. **Alcohols** are those compounds which have one or more OH (**hydroxyl**) groups attached, ROH.

Three types of alcohol are to be found depending on the number of C atoms attached to the C atom with the OH group. Primary (n) alcohols are written RCH_2OH.

$CH_3CH_2CH_2 — OH$ 1-propyl alcohol / n-propanol

Secondary (s) alcohols are written RR'CHOH:

$CH_3CH(OH)CH_3$ isopropyl alcohol / 2-propanol / s-propanol

Tertiary (t) alcohols are RR'R"COH.

$(CH_3)_3C-OH$ t-butyl alcohol

Lower alcohols are soluble in water due to the presence of the polar OH group. In higher alcohols, the longer the carbon chain, the less water-like the compound is and behaves more like a hydrocarbon – volatile and relatively inert. **Pentanol** and higher compounds are insoluble in water.

Alcohols can react with other atoms and can act as weak **bases** (due to the unshared electron pairs on the O atom) or weak **acids** – where the H atom on the OH group can act as a proton donor.

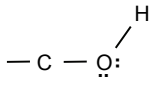

Phenol (hydroxybenzene) has the OH group attached to a benzene ring and forms the basis of synthesis for many other compounds.

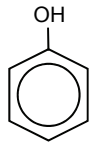

Ethanol (C_2H_5OH) is "alcohol" to the common person (e.g. in alcoholic drinks). **Denatured ethanol** is the usual form used for cleaning and other uses. Additives render it unpalatable and, in some cases poisonous (such as when methanol is added to the ethanol to give **methylated spirits**).

Methanol (CH_3OH) is highly toxic and may cause blindness or death when only a few millilitres are ingested.

A common cleaning alcohol is **isopropyl alcohol**, or 2-propanol $(CH_3)_2CHOH$.

Ethylene glycol $C_2H_4(OH)_2$ is commonly used as an anti-freeze/ anti-boil additive in motor vehicle cooling systems. In its pure form it has a boiling point of 197.3 °C but has a lower heat capacity than water and so is used diluted. It does this by depressing the hydrogen bonding between water molecules so that, upon freezing, the temperature must be significantly lowered before ice crystals can form.

An interesting compound prepared from phenol, sodium hydroxide, and carbon dioxide is **aspirin**.

11.9 Ethers

Ethers have the general formula ROR' where R is an alkyl group. They can occur as aliphatic (chained), alicyclic, or aromatic (**benzene ring**) formations, or a combination. They are relatively unreactive hydrocarbon derivatives.

The lone pairs of electrons on the O atom allow ethers to form **hydrogen bonds** with water molecules and so they are generally partially soluble in water.

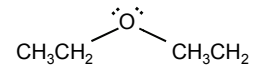

diethyl ether

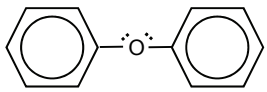

diphenyl ether

However, they cannot form hydrogen bonds between themselves and so generally have a lower boiling point than comparable alcohols.

In some respects, ethers are similar to alcohols in that they can be considered derivatives of water. In an alcohol, the R takes the place of one of the H atoms in the water molecule. In an ether, both of the H atoms are replaced by alkyl groups R and R'. Ethers are generally isomers of the corresponding alcohols. For example, ethanol, C_2H_5OH, has the same formula as dimethylether, but of course has quite different chemical and physical properties.

Perhaps one of the most well known ethers is **diethyl ether**, $CH_3CH_2OCH_2CH_3$, a low boiling point colourless liquid used as an anaesthetic. Diethyl ether can be formed from the removal of water from ethanol.

Dimethyl ether, CH_3OCH_3, (or **DME**) is a gas at room temperature is often used as an aerosol propellant since it can be stored as a liquid under pressure in equilibrium with the gas phase, evaporates readily and leaves the desired product as an aerosol mist for the application.

Methyl phenyl ether $CH_3OC_6H_5$ is found in aniseed oil.

Ethers are generally unreactive substances and can withstand attack from either acids or bases, but are more reactive than comparable alkanes.

Simple ethers have the alkyl groups on each end of the oxygen atom and if the groups are the same, are thus named dialkyl ether (such as in dimethyl-ether). If one of the groups is a more complex group, then the structure of the name is alk-oxy-alkane. For example, $CH_3CH_2CH_2OCH_3$ is **methoxypropane**.

11.10 Aldehydes

Alcohols can be thought of as a step towards complete oxidation of the corresponding alkane. Primary alcohols can also undergo oxidation to form **aldehydes** and **carboxylic acids**, and secondary alcohols can oxidise to form **ketones**.

Aldehydes have a carbon-to-oxygen double bond (which itself is called the **carbonyl group**) with the general formula RCHO. They are usually prepared by **oxidation** of the corresponding alcohol.

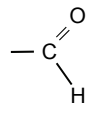

aldehyde group

Perhaps one of the most well known aldehyde is that made from **formaldehyde** dissolved in water to give **formalin**, a preservative fluid used for embalming biological tissues.

Consider the reaction between **methanol** and potassium dichromate:

$$3CH_3OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_2O + 2Cr^{3+} + 7H_2O$$

In this equation, the Cr_2 ion has been reduced to the Cr^{3+} ion, and the methanol has lost two electrons (and two protons H^+) and hence has been oxidised to give CH_2O, formaldehyde.

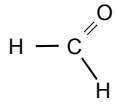

methanal (formaldehyde)

Methanal	HCHO	Formaldehyde
Ethanal	CH_3CHO	Acetaldehyde
Propanal	CH_3CH_2CHO	Propionaldehyde
Butanal	$CH_3CH_2CH_2CHO$	Butyraldehyde

Aldehydes often have a pleasant odour or flavour, such as in the benzene derivative vanillin:

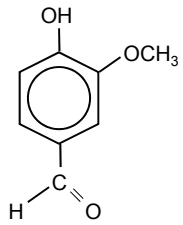

and cinnamaldehyde, the active ingredient in cinnamon.

To avoid confusion with alcohols (OH), the carbonyl group with an attached H is written CHO and not COH.

Cyclic forms also exist, such as **benzaldehyde**, an aromatic aldehyde:

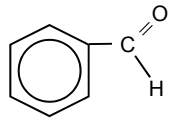

Aldehydes are closely related to **ketones**, but have the **carbonyl group** C=O at the end of a carbon chain rather than in between two C atoms. Lower aldehydes are soluble in water. Aldehydes can be further oxidised to form **carboxylic acids**.

11.11 Ketones

Ketones have a **carbonyl group** C=O attached to two other C atoms that form part of the same or different **alkyl groups**. (In an aldehyde, one of the other atoms is an H atom.) The general formula is RC(=O)R'.

The oxygen atom is more **electronegative** than attached carbon (i.e. the electron pairs that constitute the double bond are closer to the oxygen atom than the carbon atom), making this group polar. Unlike aldehydes, ketones do not have an H atom attached to the carbonyl group.

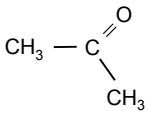

2-propanone
(acetone)

Acetone CH_3COCH_3 is widely used as a relatively non-toxic solvent for various carbon compounds (e.g. paint, plastics, nail varnish, superglue, etc). It also has the useful property of being soluble in water and is commonly used as a drying agent for glassware in chemistry laboratories. It is very volatile and dries without leaving a residue.

Acetone can be formed by the oxidation of 2-propanol according to

$$3CH_3CHOHCH_3 + Cr_2O_7^{2-} + 8H^+ \rightarrow$$
$$3CH_3COCH_3 + 2Cr^{3+} + 7H_2O$$

Aldehydes and **ketones** have many similarities and both are formed from the oxidation of an alcohol.

Ketones cannot be further oxidised to an acid since there is no H atom available on the functional group (as in the case of **aldehydes**). The absence of an H atom bonded to an oxygen atom means that both aldehydes and ketones do not form **hydrogen bonds** with each other and so generally have a lower boiling point than comparable alcohols. However, the lone pairs of electrons on the oxygen atom can form a hydrogen bond with an H atom in a water molecule and so lower ketones (and also aldehydes) are generally soluble in water.

The names of ketones (and aldehydes) are formed by the number of C atoms in the longest chain, and include the C atom in the carbonyl group.

Another common ketone used as a solvent for paints, varnish and gums is 2-butanone, or **methyl ethyl ketone** (**MEK**), or methyl acetone, $CH_3COCH_2CH_3$, a flammable clear liquid that is soluble in water. It has a characteristic sweet odour. As well as industrial uses as a solvent, it is also used as a polystyrene cement in plastic model kits.

Another significant ketone, with a cyclic (but not aromatic) structure, is **cyclohexanone** $(CH_2)_5CO$ which is used in the manufacture of **nylon**.

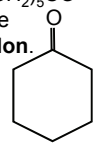

cyclohexanone

Ketones have significant biochemical functions and are produced when body fat is used as a source of energy when there is a shortage of **glucose** (such as during fasting).

11.12 Carboxylic Acids

Hydrocarbon derivatives that contain both the carbonyl (C=O) and hydroxyl (OH) functional groups are called **carboxylic acids** with the general formula RCOOH. When R is an aliphatic residue, the compound is called a **fatty acid**. When R is an aromatic ring, the acid is a **benzene ring derivative**.

The COOH group is called the **carboxyl group**. Carboxylic acids can be prepared from the oxidation of the corresponding alcohol.

$$5CH_3OH + 4MnO_4^- + 12H^+ \rightarrow 5HCOOH + 4Mn^{2+} + 11H_2O$$

In this reaction CH_3OH and H_2O produces HCOOH and four protons and four electrons. Since there is a loss of four electrons (compared to two for the oxidation of methanol to methanal, or formaldehyde) , formic acid is a more highly oxidised compound than **formaldehyde**.

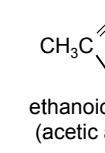

ethanoic acid
(acetic acid)

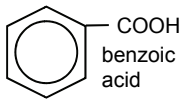

benzoic acid

A very common aliphatic acid is **acetic acid**, written CH_3COOH and is found in vinegar. Formic acid (from the latin formica for ant) in the found in venom of ants. Stearic acid is found in soaps, waxes and plant oils. Other carboxylic acids can be found in coconuts, chocolate,

Some carboxylic acids:

Formic	Methanoic	HCOOH
Acetic	Ethanoic	CH_3COOH
Propionic	Propionic	CH_3CH_2COOH
Butyric	Butanoic	CH_32CH_2COOH
Stearic	Octa decanoic	CH_316CH_2COOH

Similarly, ethanol can be oxidised to form **acetic acid**. Acetic acid can also be formed from the oxidation of acetaldehyde. Further oxidation of these compounds can be obtained via the rather energetic process of **combustion**, in which case the product is CO_2 and water.

Carboxylic acids are weak acids and dissociate only slightly, giving H^+ ions in water, and act as proton donors in reactions. The H^+ ions come from the COOH functional group. Lower carboxylic acids are soluble in water.

A common chemical demonstration reaction involves that between vinegar and **baking soda** to give sodium ethanoate, carbon dioxide and water:

$$CH_3COOH + NaHCO_3 \rightarrow 3CH_3COONa + CO_2 + 7H_2O$$

There is an ionic bond between the CH_3COO^- and Na^+ ions. By convention, the ionic compound is written with the metal ion last.

Carboxylic acids react with alcohols to form fats and oils (esters). **Fatty acids** are those needed by the body and are obtained from digestion of animal and vegetable oils and fats.

11.13 Esters

Carboxylic acids contain the functional group COOH. The H atom can be easily given up (proton donor): hence the acid classification.

Derivatives of carboxylic acids are formed when the OH group is replaced by something else. When the OH group is replaced by OR, then an **ester** is formed. Esters are generally colourless liquids insoluble in water and have the general formula RCOOR'. For example, a reaction between methanol and acetic acid forms the ester **methyl acetate**:

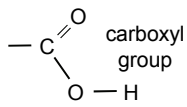

$$CH_3OH + CH_3COOH \rightarrow CH_3COOCH_3 + H_2O$$

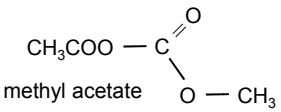

Note that the methyl group is the CH_3 at the end of the molecule. The "acetate" is from the carboxylic acid. Esters are written with the functional group first.

In this reaction, water is formed from the H atom in the incoming alcohol, and the OH group from the carboxylic acid, leaving behind an ester.

Esters are commonly used in food flavourings and perfumes due to their pleasant odour.

Methyl butyrate	Apple	$CH_3CH_2CH_2COOCH_3$
Ethyl butyrate	Strawberry	$CH_3CH_2CH_2COOCH_2CH_3$
Pentyl butyrate	Apricot	$CH_3CH_2CH_2COO(CH_2)_4CH_3$
Pentyl acetate	Banana	$CH_3COO(CH_2)_4CH_3$
Isoamyl acetate	Pear	$CH_3COOCH_2CH_2\ CH(CH_3)_2$
Octyl acetate	Orange	$CH_3COO(CH_2)_7CH_3$

Most naturally occurring fats and oils are very large esters made from organic acids and alcohols (usually **glycerol**). When there are no C=C bonds, the acid is said to be **saturated**. When the acid contains C=C bonds, it is **unsaturated**. When an acid has one C=C bond it is **monounsaturated**, and when there is more than one C=C bond, it is referred to as being **polyunsaturated**. These **fatty acids** form saturated, unsaturated and polyunsaturated fats and oils (oils are esters that are liquid at room temperature whereas waxes are solid).

Esters also undergo polymerisation to form common products such as **polyesters** used for clothing and recyclable polyethylene terephthalate (**PET**) drink bottles. An interesting example of an ester is nitroglycerine (which is somewhat incorrectly named).

11.14 Amides

Amides are derivatives of carboxylic acids in a similar manner to esters. When the OH group is replaced by NH_2, then an **amide** is formed. A special class of amides occurs when the OH group is replaced by NHR. Amides can be produced by the reaction between ammonia and an ester.

The reaction between methyl acetate and ammonia produces **ethanamide** (acetamide) and methanol:

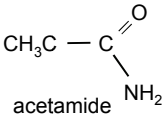

acetamide

$$CH_3COOCH_3 + NH_3 \rightarrow CH_3CONH_2 + CH_3OH$$

In the NH_2 group, the electrons are more strongly drawn towards the more electronegative N atoms, leaving the H end with a positive charge and so amides are able to form **hydrogen bonds** with each other as they are attracted to the negatively charged lone pairs on neighbouring O atoms. This confers a relatively high melting point for these compounds. Amides have much the same solubility as comparable esters, with lower amides being soluble in water.

The most notable characteristic of amides are their mechanical strength and are often used, both in nature and industrially, as structural items.

In nature, amides for the basis of links between amino acids in **proteins**.

In industrial use, amides are joined together in long chains to produce polyamides, the most well known of which are **nylon** and **kevlar**.

Lysergic acid diethylamide (**LSD**) is also an amide.

Methanamide	$HCONH_2$
Ethanamide	CH_3CONH_2
Propanamide	$CH_3CH_2CONH_2$

The **amide link** joins amino acids together in biological processes to form **proteins**. **Amino acids** are carboxylic acids with an amine group of the form $H_2NCHRCOOH$. During polymerisation, water is eliminated between two acid groups to be joined together.

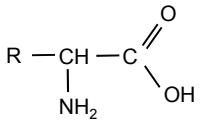

amino acid

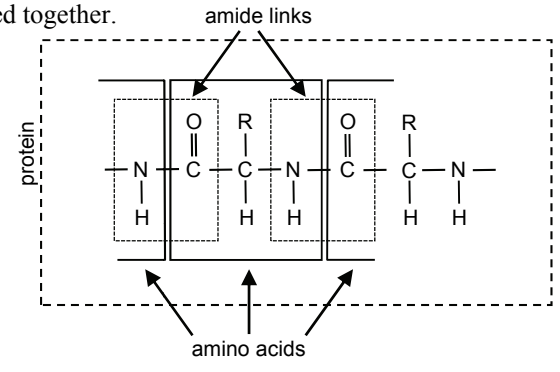

11.15 Amines

In an alcohol, the R takes the place of one of the H atoms in the water molecule to give the general formula ROH. Now consider the molecule **ammonia** NH_3.

If one or more H atoms are replaced by an alkyl group, then the resulting compound is called an **amine**. Primary amines RNH_2 have one R substitution, secondary amines R_2NH have two, and tertiary amines R_3N have all three H atoms replaced with alkyl groups. Aliphatic and aromatic structures are found.

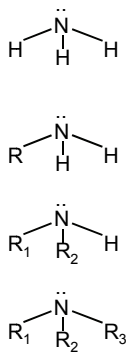

Ammonia	NH_3
Methylamine	CH_3NH_2
Ethylamine	$CH_3CH_2NH_2$
Propylamine	$CH_3CH_2CH_2NH_2$
Butylamine	$CH_3CH_2CH_2CH_2NH_2$
Aniline	$C_6H_5NH_2$

Just as in the case of ammonia, amines are bases due to the lone electron pair on the N atom. Primary and secondary amines can form hydrogen bonds with each other and all can form **hydrogen bonds** with water, thus making them soluble, the lower gaseous amines being very soluble.

Phenylamine, or **aniline**, is a primary amine where an H atom on the ammonia is replaced with a benzene ring. This has the interesting consequence of the lone pair of electrons on the N atom interacting with, and to some extent being absorbed into the ring, which in turn decreases its solubility and raises its boiling point compared to comparable aromatic compounds.

Ammonia is a colourless gas with a very sharp odour. Ammonium hydroxide in household cleaning products is a solution of ammonia gas in water where it slightly dissociates into the ammonium NH^{4+} and hydroxide OH^- ions.

Many primary aromatic amines are used as dyes.

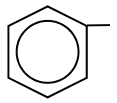

Aniline

Amines are important in biological functions and are produced from the breakdown of amino acids in the body. **Amino acids** are carboxylic acids with an amine group of the form $H_2NCHRCOOH$. Amines serve as neurotranmitters. A common natural amine is **histamine** which triggers an immune response. Anti-histamines suppress this activity in severe allergic reactions.

Methylphenethylamine (or **amphetamine**) is a powerful drug that modifies the action of natural neurotransmitters in the brain.

11.16 Polymers

The chemical and physical properties of hydrocarbon compounds and derivatives depend very much on the size of the molecule. Smaller groups such as methyl and ethyl compounds generally have a high solubility, a low boiling point. When these small molecular units, collectively called **monomers**, and joined together into long chains, the molecular size can increase greatly with the production of a variety of useful substances which are called **polymers**, or **plastics**.

For example, in ethylene, the C=C bonds may be successively broken and joined to form larger and larger molecules of polyethylene. This process is usually performed with the help of a catalyst. The resulting compounds are called **addition polymers**. When other atoms or functional groups are involved, polymers of a great variety of properties are possible.

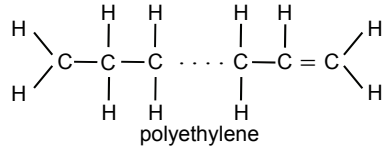

Another class of polymers are **condensation polymers**. In these, chains are formed by the expulsion of a water molecule from between the monomers to be joined. In **Nylon**, amide links are used to join monomers into large chain molecules.

One of the monomers used to make **Nylon** 6,6 is adipic (hexanedioic) acid:

$$HOOC—CH_2—CH_2—CH_2—CH_2—COOH$$

This is used with another monomer, 1,6 diaminehexane:

$$H_2N—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—NH_2$$

When these two monomers are chained together, water drops out as shown:

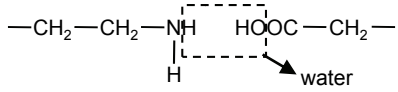

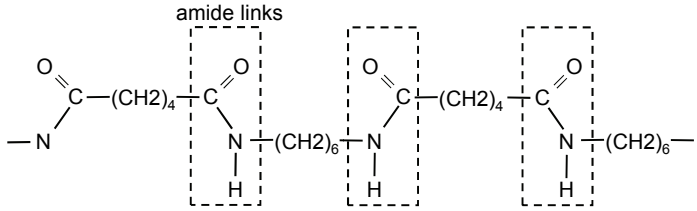

During polymerisation, these molecules continue to chain together, expelling a water molecule each time and forming amide linkages. **Kevlar** is a similar polymer but the amide links join benzene rings together.

11.17 Physical and Chemical Properties

Group	Boiling point	Solubility	Notes
Alkanes	Lower compounds are gases at room temp. Boiling point increases as size of molecule increases.	Do not form H bonds, insoluble in water.	Mainly unreactive with other compounds.
Alkenes	Similar to alkenes.	Similar to alkenes.	Slightly more reactive due to presence of C=C.
Alkynes			More reactive than alkenes due to C≡C.
Alcohols	H bonding causes boiling point to be higher than comparable alkanes.	Lower alcohols are soluble in water. Compounds become less water-like with increasing size.	OH group makes the molecules polar, and able to form H bonds.
Ethers	Cannot form H bonds between themselves so lower boiling point than comparable alcohol.	Can form H bonds with water molecules. Lower ethers soluble in water.	More reactive than comparable alkanes.
Aldehydes	Cannot form H bonds with each other and so generally have a lower boiling point than comparable alcohols.	Lower aldehydes soluble in water due to presence of lone pair electrons on O atom.	
Ketones	Similar to aldehydes.	Similar to aldehydes.	
Carboxylic acids	High boiling point due to H bonding.	Lower acids soluble.	Typically weak acids.
Esters	Lower boiling point due to lack of self-H bonds.	H bond with water confer solubility on lower esters.	
Amines	Reasonably high boiling point but lower than alcohols.	Lower amines soluble.	

12. Biochemistry

Summary

Glucose
$C_6H_{12}O_6$

Glycerol

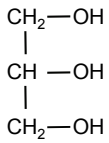

Amino acid

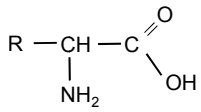

Base-pairing rules
A-T
G-C

Nucleotide

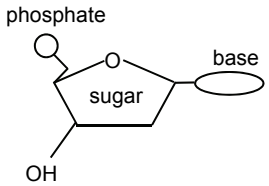

Anaerobic metabolism $C_6H_{12}O_6 + 2NAD^+ + 4ADP \rightarrow 2C_3H_4O_3 + 2NADH + 2H^+ + 4ATP$

Aerobic metabolism $C_6H_{12}O_6 + 6O_2 + 36ADP + 36P \rightarrow 6CO_2 + 6H_2O + 36ATP$

Photosynthesis $6CO_2 + 12H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

$NAD^+ + 2H^+ + 2e^- \rightarrow NADH + H^+$ reduction

$NADH + H^+ \rightarrow NAD^+ + 2H^+ + 2e^-$ oxidation

12.1 Sugars

Sugars are part of a larger group of compounds called **carbohydrates**. Carbohydrates have the general formula $C_m(H_2O)_n$ and can be thought of as hydrated carbon compounds.

Glucose, $C_6H_{12}O_6$, an important sugar in biochemistry is an aldehyde .

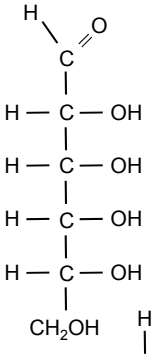

Fructose, an isomer of glucose, $C_6H_{12}O_6$, and is a ketone.

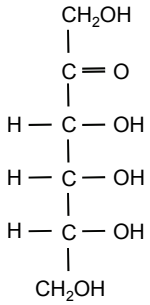

These compounds can readily form cyclic structures, which are often more common than the chain structures.

Glucose and fructose are examples of **monosaccharides**. **Sucrose**, or table sugar, is a **disaccharide** and is formed by the condensation (with the elimination of one water molecule) of one molecule of fructose and one of glucose. The reverse reaction, hydrolysis of sucrose, splits sucrose into glucose and fructose.

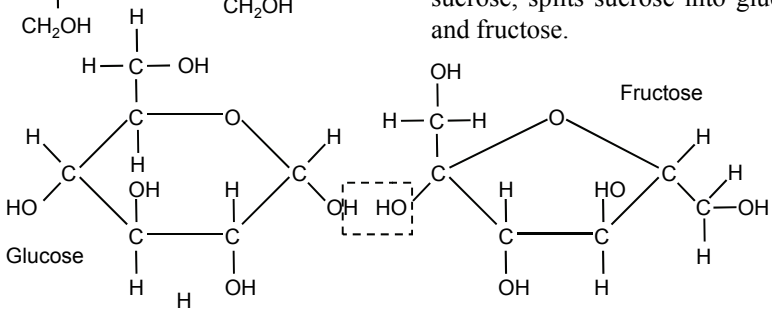

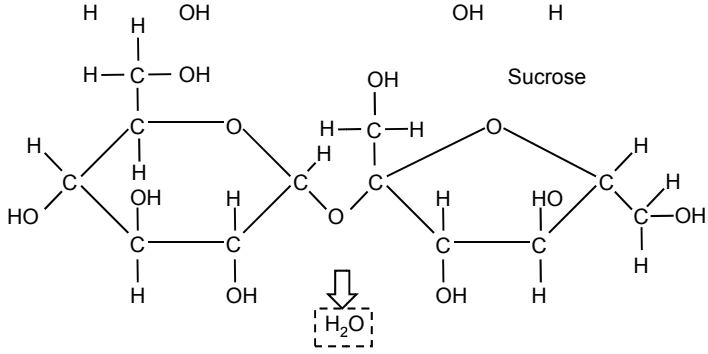

Glucose is the basic fuel for the process of **metabolism**. Glucose is recovered from fats and sugars in the diet and stored as **glycogen** in the body until converted back to glucose for use directly by cells.

12.2 Polysaccharides

Cellulose is a straight-chain polysaccharide $(C_6H_{10}O_5)_n$ consisting of thousands of glucose units. It is insoluble in water. The nature of particular forms of cellulose in organisms depends mainly upon the chain length of the molecule.

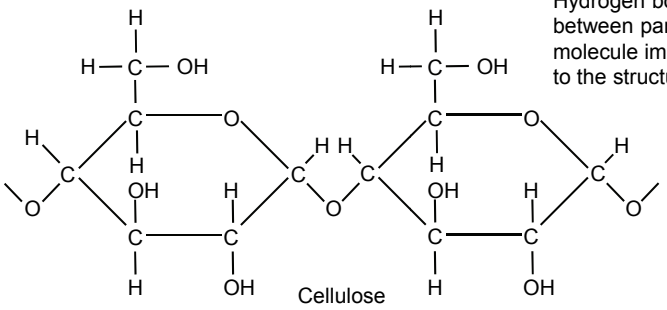

Cellulose

Hydrogen bonding between parts of the molecule impart strength to the structure.

Starch is similar to cellulose in that it is constructed from glucose monosaccharide units, but has a different orientation of linkage between the glucose elements, with more branching than cellulose. It is generally a mixture of glucose polymers of varying lengths, the shorter constituents (of molecular weight ≈4000) being water soluble.

Starch typically contains a mixture of linear (soluble) amylose and branched (relatively insoluble) amylopectin molecules. Complete hydrolysis gives glucose. Partial hydrolysis results in various starch sugars called dextrins.

Starch is broken down into glucose in the body by enzymes, (chiefly amylase, which is a constituent of saliva and pancreatic juice).

Glycogen is similar to the amylopectin form of starch in structure and is found in the liver and muscles of animals as an energy store. It is synthesised from glucose from digestion by enzymes in the liver where it is stored until released as **glucose** into the bloodstream as needed.

Cellulose acts as the main structural element of plants and forms the cell wall that gives plants their rigidity. Wood is about 50% cellulose. Mammals generally are incapable of breaking down cellulose to glucose although cows and sheep, and other ruminants, have the necessary bacteria in their digestive system that perform this function. Insects (e.g. termites) can also digest cellulose.

Starch is used as an energy store in plants. The glucose produced by photosynthesis is stored in plant tissue as starch until it is needed by the plant. Starch in plants, when eaten as food, is an important source of glucose for animals.

12.3 Lipids

Fats and oils are **esters**. Esters are derivatives of **carboxylic acids** where the H on the OH group is replaced by R so that the general formula is RCOOR'. Esters are usually derived from the reaction between acids and alcohols with the elimination of a water molecule.

Animal and plant fats are triple esters, or **triglycerides**, of **glycerol** (**glycerin**) $C_3H_8O_3$. Each of the three available OH groups in glycerol is available for combination with three molecules of **fatty acid**. Fatty acids typically have from 12 to 20 carbon atoms.

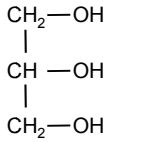

Glycerol
(propane 1,2,3 triol)

Fats, which are solid at room temperature, are made from **saturated fatty acids**, while **oils**, which are liquid at room temperature, are formed mainly from **unsaturated fatty acids**. Fats and oils from plants and animals typically contain a mixture of different types of esters, two or three fatty acids attached to a glycerol molecule.

Linolenic acid has the general formula

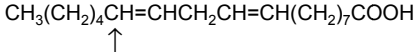

and is called an omega-6 fatty acid because the first C=C double bond is on the sixth carbon atom from the (left-hand) end. **Linoleic acid** is am omega-3 acid. (Note: normally numbering of atom positions is from the right.)

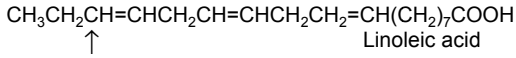

Linoleic acid

Fats, along with oils and waxes, are one example of a broader group of **lipids**. Compared to carbohydrates, lipids generally contain a smaller proportion of O atoms. Lipids are relatively insoluble in water.

Fat in the body acts as a storage place for glucose. When fat reserves are called upon, the fats are converted back into glycerol and **fatty acids**. The glycerol in turn is converted into glucose by the liver.

Fats in the diet are also a source of **linolenic** $C_{17}H_{29}CO_2H$ and **linoleic** $C_{17}H_{31}CO_2H$ unsaturated fatty acids which are essential in animal dietary intake because they are unable to be synthesised by the body directly and are required for metabolism into a variety of other acids required by various bodily functions.

Fats also serve a structural role in the body by providing heat insulation and a barrier against mechanical shock for organs.

When fats hydrolyse, or react with water, in an alkaline solution, glycerol is formed along with the metal salt of the carboxylic acid. Such a reaction is called **saponification**, from which soaps (e.g. sodium stearate) is formed.

12.4 Proteins

Proteins are amino acids joined together by **amide** (or **peptide**) links and are classified as **polyamides**. The arrangement, or sequence, of amino acids within the protein structure determines the function of the protein. A typical protein may contain 100 or more amino acids.

Amino acids with the amine group attached to the same C atom as the COOH group are called **alpha-amino acids** and are the most important in biochemistry.

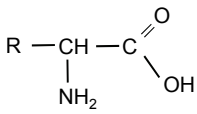

amino acid

The twenty or so amino acids found in proteins differ in the makeup of the R residual. In **glycine**, R is just an H atom, while in phenylaniline, R is a ring structure.

On one end of the chain, there is a free NH_2 group; this is the N terminal. At the other end of the chain, there is a COOH group, the C terminal. In between, water molecules have been eliminated to leave amino acid units, or residues.

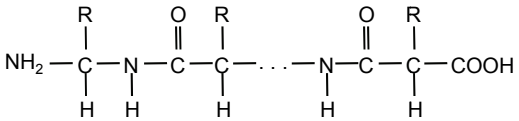

A typical **polypeptide** protein consists of between 100 and 500 or more amino acid residues. The sequence of amino acids is the **primary structure** of the molecule. The long chains of proteins themselves have a **secondary structure**, usually in the form of a helix or spiral. **Hydrogen bonds** between different amino acid groups are responsible for this structure. Often, there is more than one polypeptide chain present and they exist as intertwined helixes held together by hydrogen or ionic bonds leading to a **tertiary structure**.

When a protein undergoes complete hydrolysis, the amino acids are recovered.

The mechanical structure of proteins (i.e. the sequence of amino acids and hydrogen bonds) has great significance for living organisms. Proteins form the basis of skin, hair, muscle, tendons, and other tissues in the body.

Some proteins are enzymes and act as catalysts for chemical reactions which would otherwise proceed too slowly for use in organisms.

The secondary structure of proteins is stable within narrow temperature and pH ranges. When the secondary structure of a protein is disrupted, either by heat (such as by cooking), or immersion in acids or alkalis, the protein is said to be denatured and the physical properties change markedly.

12.5 Nucleic Acids

Carbohydrates, lipids and proteins make up the bulk of living organisms. A fourth major class of compounds comprise the nucleic acids **DNA** and **RNA**. Nucleic acids are long-chain polymers that consist of smaller units, **nucleotides**, joined together.

In DNA, there are four types of nucleotide. Each nucleotide consists of a 5-carbon sugar (**deoxyribose**), with an attached phosphate, and a nitrogen base. Each type is distinguished by the identity of the nitrogenous bases.

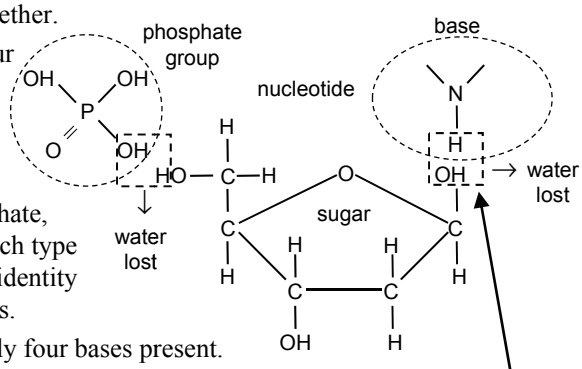

In DNA, there are only four bases present.

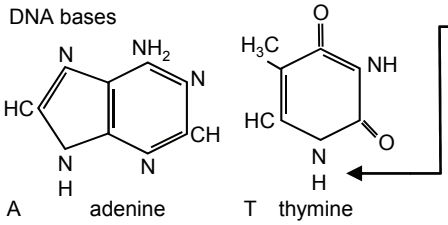

The NH group on the base combines with the OH group on the sugar and a H_2O is lost.

The primary structure of DNA is a sequence of nucleotides bonded together as long chains. The phosphate group of one nucleotide bonds with the sugar of another (losing a molecule of water in the process).

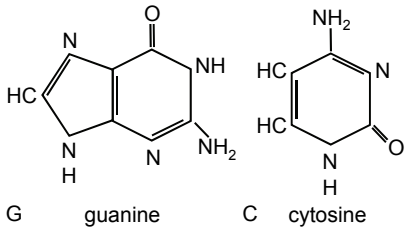

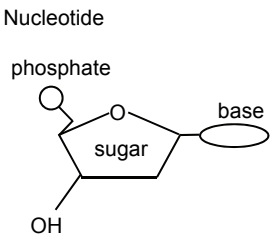

A shorthand way of writing these groups is to just show the covalent bonds between the groups, and leave out the C and H atoms.

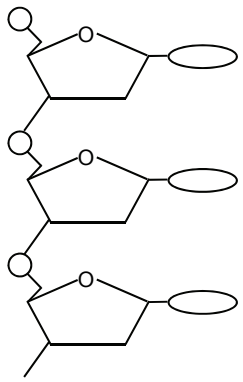

12.6 DNA

The primary structure of DNA is essentially the sequence of bases in the nucleotides in the chain. However, DNA does not ordinarily exist as a single chain, but is paired with an opposite chain so that the bases are paired and held together by **hydrogen bonds**.

The bases can only pair according to certain rules: A is always paired with T by a double hydrogen bond. G is always paired with C by a triple hydrogen bond.

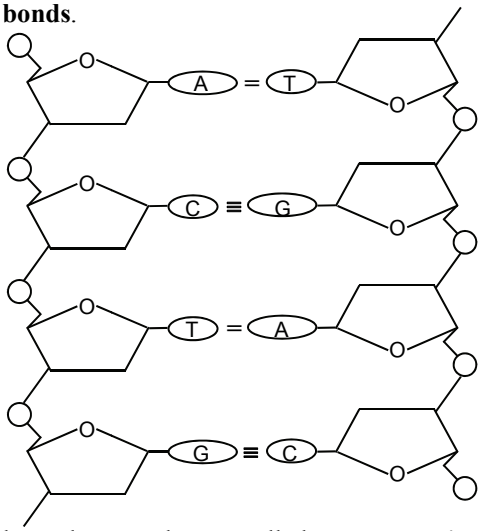

The ladder-like structure is further characterised by being coiled up in a spiral, each chain with bases pointing inwards and bonding with the corresponding base on the other – the so-called **double-helix**. The nucleotides, identified by their bases, can appear in any particular order, but the sequence on one chain has to be reflected in the other by virtue of the **base-pairing rules** A-T and G-C.

Sequences of nucleotides fall into functional groups called **genes**, which in turn lie along a single large DNA molecule called a **chromosome**. In most cells, chromosomes occur in duplicated pairs. When cell division by **mitosis** occurs, the DNA molecules are replicated by rupturing the hydrogen bonds between the two chains and then each chain forming bonds with new nucleotides according to base-pairing rules. When cell division is complete, the two new cells each contain paired chromosomes of the same genetic sequence as the parent cell.

Although there are only four bases in human DNA, the molecule typically consists of about 1500 nucleotides in the chain, allowing billions of combinations of base sequences possible in a single molecule.

RNA is similar to DNA but consists of ribose as the sugar and a single chain structure with the base **uracil** rather than thymine. There are different types of RNA; some act as messengers, carrying the DNA template to the site of protein synthesis (**ribosomes**) in the cell, while others transport amino acids to the ribosomes.

12.7 Enzymes

The many chemical reactions which take place in an organism to sustain life are collectively called **metabolism**. Typical reactions are **condensation** and **hydrolysis** reactions:

sugars	Condensation →	polysaccharides (cellulose, starch)
fatty acids + glycerol		fats
amino acids	Hydrolysis ←	proteins

These reactions occur at temperatures of about 37°C under atmospheric pressure. The reaction rates would be too slow unless reaction pathways were altered by use of **catalysts**. Nearly every biological chemical reaction involves the use of a specific biological catalyst called an **enzyme**.

Enzymes are very large protein molecules of a specific shape. The enzyme molecule is typically much larger than the molecules actually involved in the chemical reaction. The reaction molecule (or molecules in the case of a condensation reaction), called the substrate, attaches itself to an **active site** on the enzyme molecule.

An **activated complex** is formed, and the reaction proceeds along a different pathway than would normally occur in the laboratory.

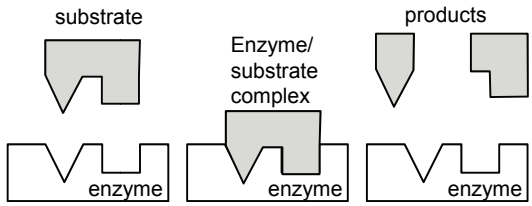

When the reaction is complete, the products detach from the enzyme and the enzyme is available to catalyse another reaction.

Enzymes lower the **activation energy** by increasing the collision frequency of molecules by virtue of bringing the molecules together spatially in an optimum manner, or altering the bond energies involved in the reaction by forming temporary bonds on the reacting molecules, and in some cases, applying mechanical stress to the reacting molecules to facilitate contact.

Enzyme inhibitors are used within the organism to control the activity of enzymes by masking or blocking the active sites on the enzyme to regulate reaction rates as a whole.

The importance of enzymes cannot be over-stated. In a living cell, the reagents of all the chemical reactions are not stored in isolated bottles and mixed when needed as in a laboratory, but exist all together in solution. The process of chemical reactions between these mixed reagents is orchestrated by the action of enzymes.

12.8 ATP

Organisms need nutrients to stay alive. Nutrients comprise carbohydrates, proteins and fats and, in animals, are usually ingested as food. Nutrients provide a source of energy, essential amino acids and essential fatty acids. Vitamins and other trace elements are also required for the proper functioning of enzymes.

Metabolism is the oxidation of glucose to carbon dioxide, water and energy:

$$C_6H_{12}O_6 + 6O_2 + 36ADP + 36P \rightarrow 6CO_2 + 6H_2O + 36ATP$$

Energy stored as phosphate bonds via the conversion of ADP (adenosinediphosphate) to ATP (adenosinetriphosphate)

The energy released by the oxidation process is stored as chemical potential energy in the formation of **ATP** molecules from **ADP** molecules. **Adenosinediphosphate** consists of a molecule of adenine, ribose, and two phosphate groups:

$$ADP + P + \text{energy} \leftrightarrow ATP + H_2O$$

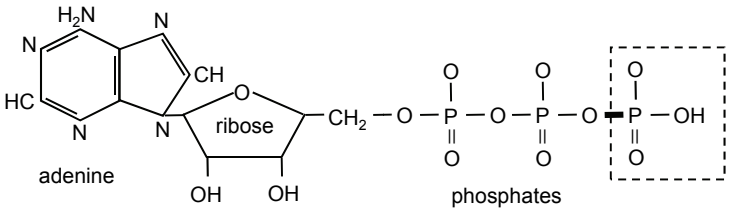

When energy is used to bind a third phosphate group to the end of the molecule, **adenosinetriphosphate** is formed. This is an endothermic process and is called **phosphorylation**. The energy used to create ATP is stored in the phosphate bond. Energy-rich ATP molecules are then hydrolysed to release their energy when used directly in other biological processes such as muscle action, protein synthesis and nerve impulse transmission.

Another important molecule involved in metabolism is the co-enzyme NAD (**nicotinamide adenine dinucleotide phosphate**). NAD takes part in oxidation-reduction reactions in metabolism by losing and accepting electrons ultimately necessary for conversion of ADP to ATP. The redox reactions are

$$NAD^+ + 2H^+ + 2e^- \rightarrow NADH + H^+ \quad \text{reduction}$$

$$NADH + H^+ \rightarrow NAD^+ + 2H^+ + 2e^- \quad \text{oxidation}$$

Reduction can occur by adding hydrogen.
Oxidation can occur by removing hydrogen.

When NAD^+ is reduced, it stores energy by storing an excited electron in the form of NADH and a H^+ ion. When $NADH+H^+$ is oxidised, it releases energy, usually to form ATP from ADP.

12.9 Anaerobic Metabolism

Anabolic processes build up low-energy reactants into high-energy products. Photosynthesis in plants is an anabolic process. **Catabolic** processes break down high-energy reactants to low-energy products, releasing energy in doing so. This energy is transferred to **ATP**.

Anaerobic metabolism involves two steps: (i) the breakdown of glucose from a **carbohydrate** into **pyruvic acid**:

$$C_6H_{12}O_6 + 2NAD^+ + 4ADP \rightarrow 2C_3H_4O_3 + 2NADH + 2H^+ + 4ATP$$

and (ii) the fermentation of pyruvic acid into either CO_2 and ethanol, or lactic acid. The ultimate aim is to produce ATP from ADP.

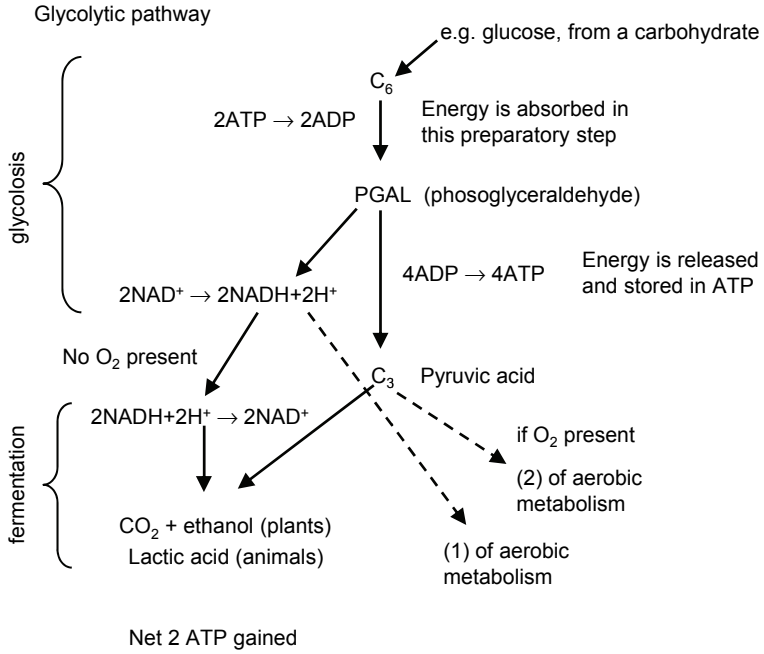

Anaerobic metabolism occurs in all cells. It does result in a particularly high yield of ATP since the products, ethanol, lactic acid and pyruvic acid, still contain a substantial portion of the original energy from the glucose. While anaerobic metabolism can provide ATP for energy use (in muscles) when O_2 is in short supply, or none at all, it also provides a source of **pyruvic acid** for use in **aerobic respiration**.

12.10 Aerobic Metabolism

Aerobic metabolism, or **respiration**, is the process by which glycerol is oxidised with the production of ATP molecules from ADP molecules in the presence of molecular oxygen:

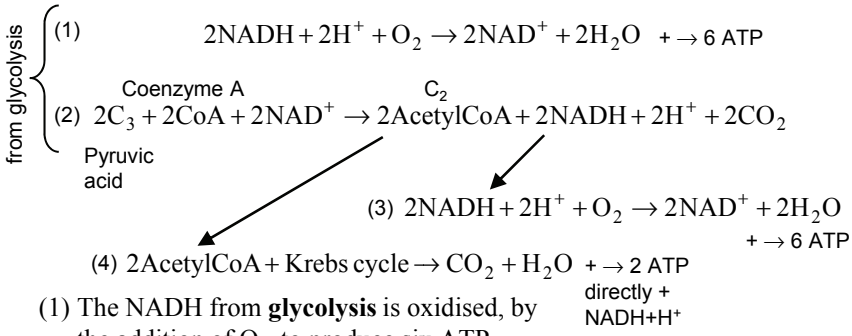

(1) The NADH from **glycolysis** is oxidised, by the addition of O_2, to produce six ATP.

(2) **Pyruvic acid** C_3 is oxidised to an activated form of acetic acid C_2. NAD^+ is reduced to $NADH+H^+$.

(3) $NADH+H^+$ from (2) is oxidised by O_2, to form six ATP.

(4) **AcetylCoA** enters the **Krebs cycle** (or **citric acid cycle**). This consists of multiple reactions, the net effect of which is to form two molecules of ATP plus energy-rich NADH.

During the Krebs cycle, six molecules of $NADH+H^+$ and two molecules of a related compound, FADH, are formed. These electron-carrier molecules are energy-rich and can be further oxidised as in (1) and (3) which require O_2. The net result of (4) is the production of twenty two ATP molecules. **Anaerobic metabolism** produces two molecules of ATP, which added to the thirty four ATP molecules from aerobic metabolism makes thirty six molecules of ATP from the complete oxidation of one molecule of **glucose**.

Fats and **proteins** are also sources of ATP, by virtue of their breakdown into components which can be inserted into glycolytic and aerobic pathways.

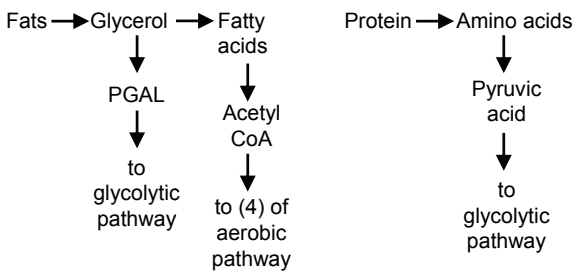

12.11 Cyclic Photophosphorylation

Ultimately, the energy contained within glucose used in animal metabolism comes from **photosynthesis** in plants. The overall reaction in plants, for the production of glucose, is

$$6CO_2 + 12H_2O + \text{Energy} \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Note that O_2 is a product of this reaction.

Chlorophyll is the unique ingredient of plants that captures photons to promote an electron of low energy into an excited state. The excited electron is passed from one transfer molecule to another, losing energy at each step, until it returns to a chlorophyll molecule in an unexcited state. At each step, the energy lost is used to convert ADP to ATP:

$$ADP + P + \text{Energy} \leftrightarrow ATP + H_2O$$

As the excited electron is passed from molecule to molecule, *some* of the energy is used to create ATP. The process is not 100% efficient.

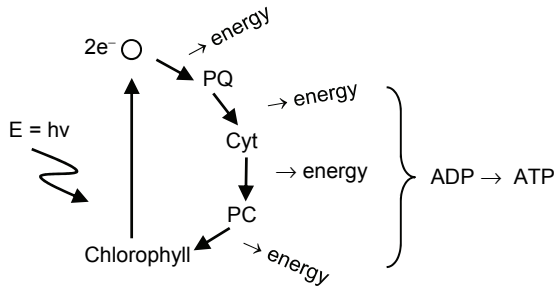

PQ, Cyt and PC are electron carrier molecules that undergo reduction (when they accept the electron) and oxidation (when they donate the electron).

Because electrons are donated by chlorophyll from the high-energy state and then to acceptance in a low-energy state, this synthesis of ATP is called **cyclic photophosphorylation**. The ATP, essentially created from ADP by the energy of sunlight, is ultimately used to create high-energy glucose (which is stored in the plant as starch) from low-energy CO_2. Animals eat the plants and convert starch into glucose, which is then used to create ATP for their own metabolic processes.

In this mode of photophosphorylation, electrons are transported around in a cycle; no oxygen or $NADH+H^+$ is produced.

12.12 Non-Cyclic Photophosphorylation

Another way of producing ATP used by plants has a beginning similar to cyclic photophosphorylation, but employs a more complicated path for extraction of energy from excited electrons. This non-cyclic photophosphorylation is used by modern green plants :

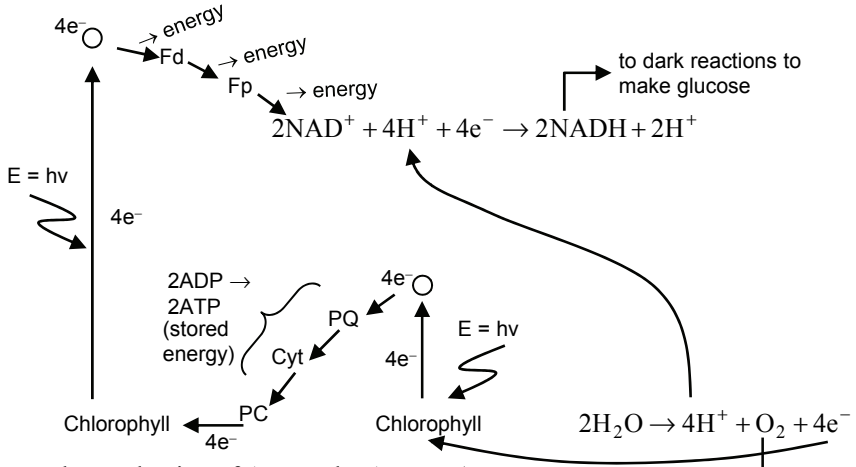

The production of ATP and NADH+H$^+$ involves two **light reactions**. Electron deficiency in one chlorophyll is balanced by different electrons from those from the water dissociation.

Additional reactions take place in which the energy obtained from the light reactions is converted into carbohydrates for storage. That is, CO_2 is reduced, and (if the energy is coming from NADH+H$^+$) the NDAH+H$^+$ is oxidised with the net result being glucose. These are known as **dark reactions** since no light is required.

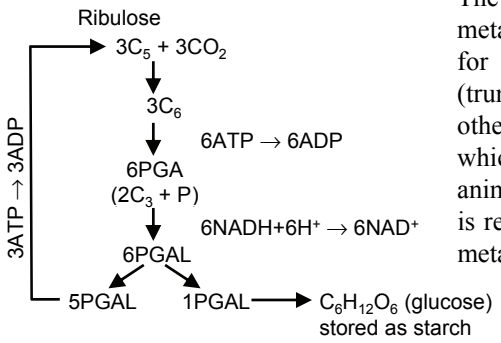

The resulting glucose is used in metabolism by the plant cells for making cellulose/starch (trunks and branches, etc) and other sugars (such as in fruit), which may in turn be eaten by animals from which the glucose is recovered and used in animal metabolism.

12.13 Metabolism

Summary:

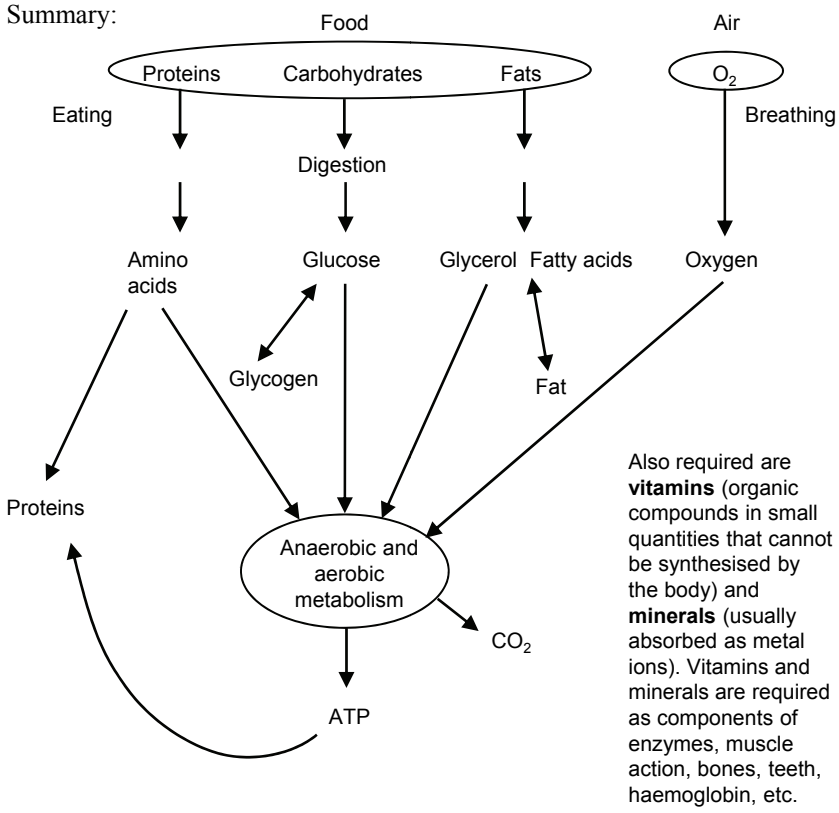

ATP is used to provide the energy source for conversion of amino acids into proteins required by the body for the production of skin, hair, cells, enzymes, muscles, nerves, signalling, anaerobic respiration, as well as for energising DNA replication. It also provides energy for muscle action, vision, brain activity, and nearly all biological energy transformations. Glycogen and fats can be stored in the body and sent back into the metabolism pathway as glucose and glycerol for oxidation into CO_2 and energy when there is no food being digested.

Chemistry

Like the author's other companion books, **The Chemistry Companion** provides high quality information in unique one-page-per-topic presentations that do not overburden and distract readers with excessive details. The book offers concise summaries of general chemistry concepts, easily accessible in a convenient, reader-friendly format.

Suitable as an introduction or study guide, this companion presents the minimum of what readers need to know to understand the subject. It emphasizes the physics underlying chemistry. By looking at chemistry processes from a physics point of view, readers better appreciate what is happening from the chemical perspective that is usually found in traditional chemistry books.

The author focuses on the structure of matter, chemical components and bonds, the periodic table, states of matter, thermodynamics, reaction rates, carbon chemistry, biochemistry, and chemical, ionic, and electronic equilibria. Each topic is covered in a single-page outline format with just enough detail to enable a good understanding of the subject.

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- Presents clear explanations of difficult material, working through any inconsistencies in understanding
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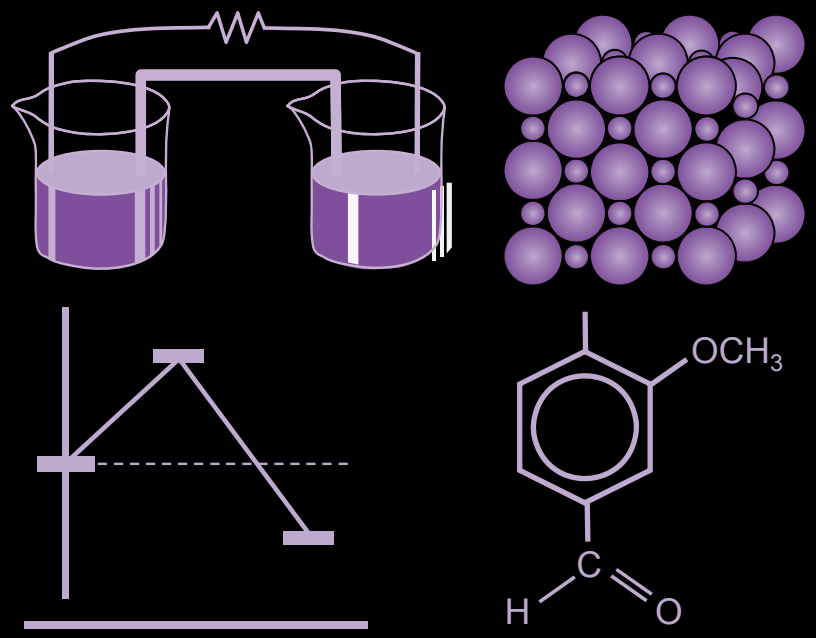

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Author: Derek McMonagle BSc PhD CSci CChem FRSC

Editors: Eleanora von Dehsen, Jamie Stokes, Judith Bazler

Design: Anthony Atherton, Richard Hummerstone, Lee Lawrence, Phil Richardson

Illustration: Peter Wilkinson

Picture research: Neil McKenna

Indexer: Martin Hargreaves

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Introduction

Chemistry is one of eight volumes of the **Science Visual Resources** set. It contains eight sections, a comprehensive glossary, a Web site guide, and an index.

Chemistry is a learning tool for students and teachers. Full-color diagrams, graphs, charts, and maps on every page illustrate the essential elements of the subject, while parallel text provides key definitions and step-by-step explanations.

Atomic Structure provides an overview of the very basic structure of physical matter. It looks at the origins of the elements and explains the nature of atoms and molecules.

Elements and Compounds examines the characteristics of the elements and their compounds in detail. Tables give the boiling points, ionization energies, melting points, atomic volumes, atomic numbers, and atomic masses key elements. Plates also describe crystal structures and covalent bonding.

Changes in Matter is an overview of basic chemical processes and methods. It looks at mixtures and solutions, solubility, chromatography, and the pH scale.

Patterns—Non-Metals and **Patterns—Metals** focus on the properties of these two distinct groups of elements. These sections also include descriptions of the industrial processes used when isolating important elements of both types.

Chemical Reactions looks at the essential factors that influence reactions. It includes information on proton transfer, electrolysis, redox reactions, catalysts, and the effects of concentration and temperature.

Chemistry of Carbon details the chemical reactions involving carbon that are vital to modern industry—from the distillation of crude oil to the synthesis of polymers and the manufacture of soaps and detergents. This section also includes an overview of the chemistry of life.

Radioactivity is concerned with ionizing radiation, nuclear fusion, nuclear fission, and radioactive decay, as well as the properties of radiation. Tables describe all known isotopes, both radioactive and non-radioactive.

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Key words

Big Bang
black hole
brown dwarf
neutron star
protostar
supernova
white dwarf

Beginnings

- According to the *Big Bang* theory, the universe resulted from a massive explosion that created matter, space, and time.
- During the first thee minutes following the Big Bang, hydrogen and helium were formed as the universe began to cool.

Initial formation

- Stars were formed when gravity caused clouds of interstellar gas and dust to contract. These clouds became denser and hotter, with their centers boiling at about a million kelvins.
- These heaps became round, glowing blobs called *protostars*.
- Under the pressure of gravity, contraction continued, and a protostar gradually became a genuine star.
- A star exists when all solid particles have evaporated and when light atoms such as hydrogen have begun building heavier atoms through nuclear reactions.
- Some cloud fragments do not have the mass to ignite nuclear reactions. These become *brown dwarfs*.
- The further evolution of stars depends on their size (See page 9).
- Stars the size of our Sun will eventually shed large amounts of matter and contract into a very dense remnant—a *white dwarf*, composed of carbon and oxygen atoms.
- More massive stars collapse quickly shedding much of their mass in dramatic explosions called *supernovae*. After the explosion, the remaining material contracts into an extremely dense *neutron star*.
- The most massive stars eventually collapse from their own gravity to *black holes*, whose density is infinite.

Formation of stars

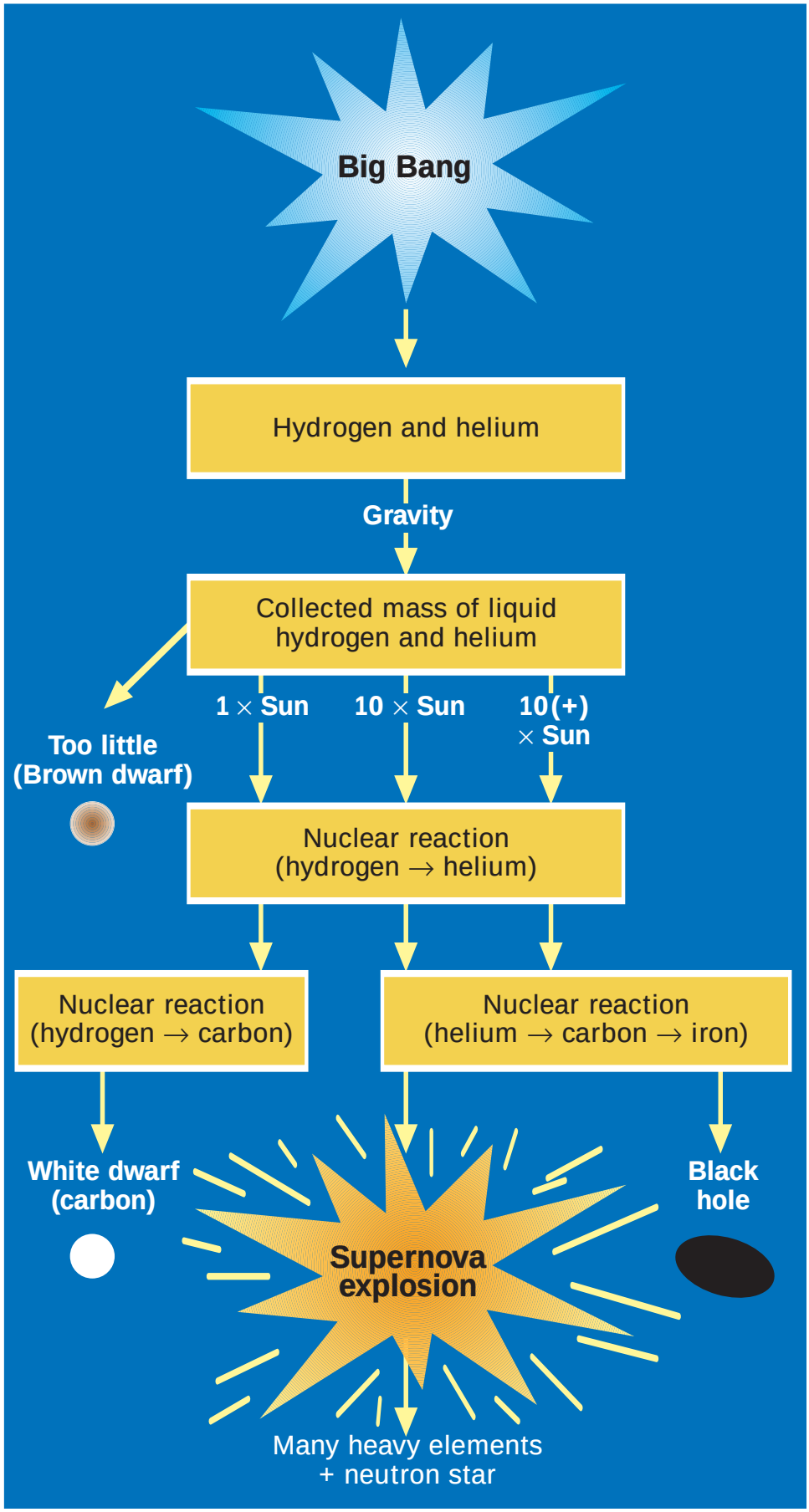

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Fate of stars

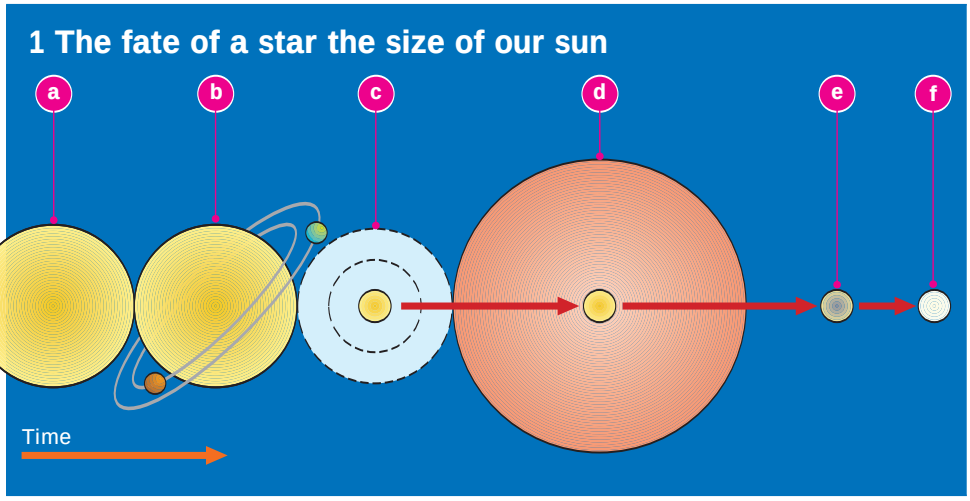

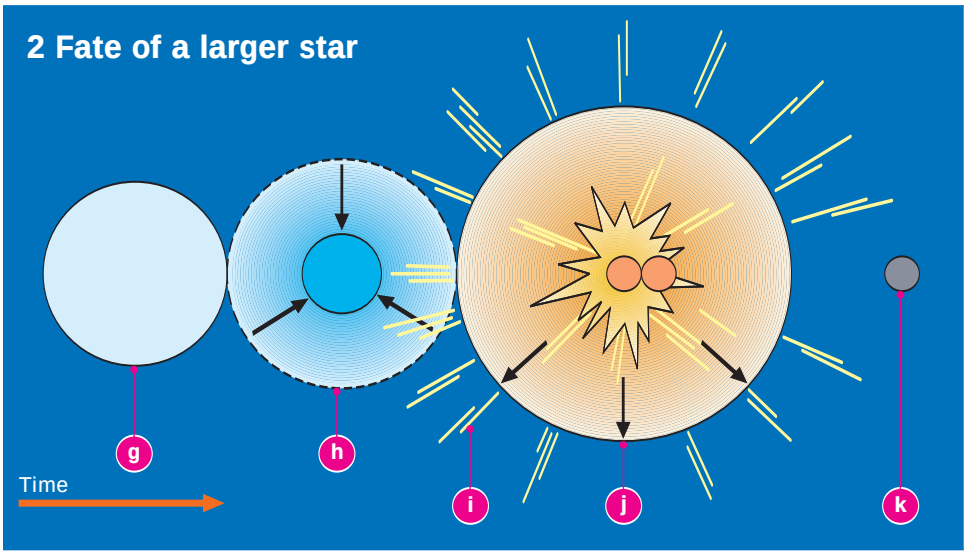

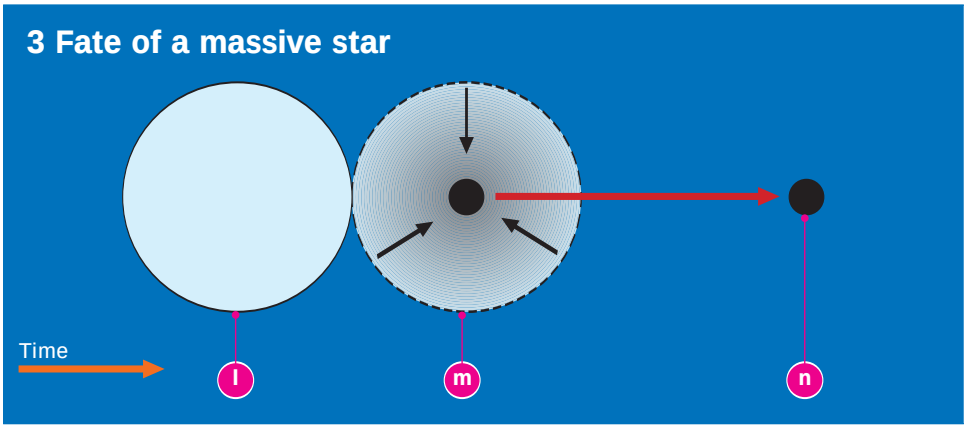

a hydrogen is converted to helium
b planetary system evolves
c hydrogen runs out and helium is converted to carbon
d star cools to form a red giant
e carbon
f star evolves to form a white dwarf
g hydrogen is converted to helium and carbon, and eventually iron
h hydrogen runs out, and star undergoes gravitational collapse
i The collapsed star suddenly expands rapidly, creating a supernova explosion
j creates many different elements
k the core of the dead star becomes a neutron star
l hydrogen converted to many different elements
m hydrogen runs out, and the star collapses to form a black hole
n black hole

Key words

black hole
fusion
neutron star
red giant
supernova
white dwarf

Fate of stars

- During most of a star's life, the outward pressure from nuclear fusion balances the pull of gravity, but as nuclear fuel is exhausted, gravity compresses the star inward and the core collapses. How and how far it collapses depends on the size of the star.

1 The fate of a star the size of our sun

- A star the size of our Sun burns hydrogen into helium until the hydrogen is exhausted and the core begins to collapse. This results in nuclear *fusion* reactions in a shell around the core. The outer shell heats up and expands to produce a *red giant*.
- Ultimately, as its nuclear reactions subside, a red giant cools and contracts. Its core becomes a very small, dense hot remnant, a *white dwarf*.

2 Fate of a larger star

- Stars with an initial mass 10 times that of our Sun go further in the nuclear fusion process until the core is mostly carbon. The fusion of carbon into larger nuclei releases a massive amount of energy. The result is a huge explosion in which the outer layers of the star are blasted out into space. This is called a *supernova*.
- After the explosion, the remaining material contracts, and the core collapses into an extraordinary dense object composed only of neutrons—a neutron star.

3 Fate of a massive star

- Stars with an initial mass of 30 times our Sun undergo a different fate altogether. The gravitational field of such stars is so powerful that material cannot escape from them. As nuclear reactions subside, all matter is pulled into the core, forming a *black hole*.

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Key words

ammonia
fission
helium
hydrogen
methane

1 Birth of the solar system

- The solar system is thought to have formed about 4.6 billion years ago as a result of nuclear *fission* in the Sun.
- A nebula (cloud) of gases and dust that resulted from the explosion. flattened into a disk with a high concentration of matter at the center.

2 Formation of the inner and outer planets

- Near the Sun, where the temperature was high, volatile substances could not condense, so the inner planets (Mercury, Venus, Earth, and Mars) are dominated by rock and metal. They are smaller and more dense than those farther from the Sun.
- In the colder, outer areas of the disk, substances like *ammonia* and *methane* condensed, while *hydrogen* and *helium* remained gaseous. In this region, the planets formed (Jupiter, Saturn, Uranus, and Neptune) were gas giants.

3 Inner planets

- Inner planets consist of a light shell surrounding a dense core of metallic elements.
- Mercury, the planet closest to the Sun, has a proportionately larger core than Mars, the inner planet farthest from the Sun.

4 Outer planets

- The outer planets have low densities and are composed primarily of hydrogen and helium.
- The outer planets are huge in comparison to the inner planets.
- Jupiter and Saturn, the largest of the gas giants, contain the greatest percentages of hydrogen and helium; the smaller Uranus and Neptune contain larger fractions of water, ammonia, and methane.

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The solar system

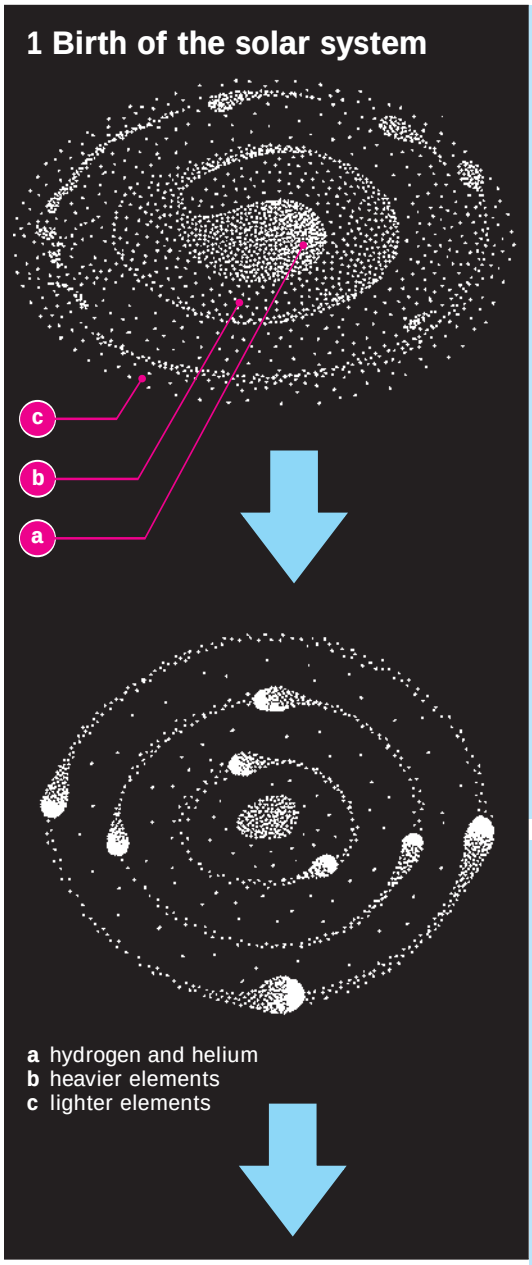

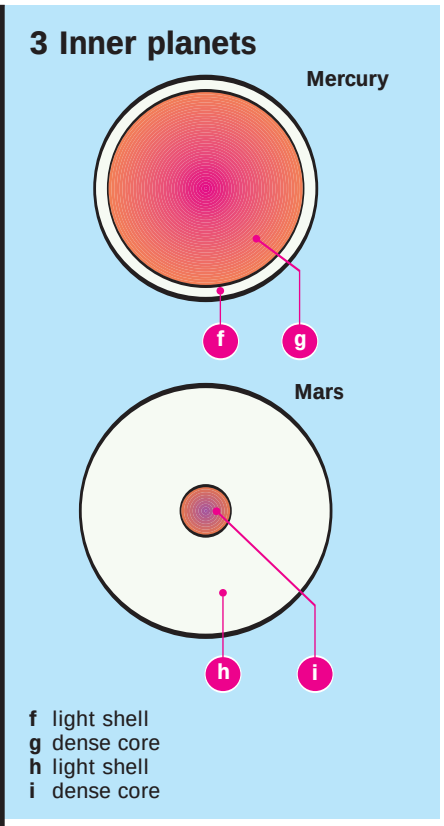

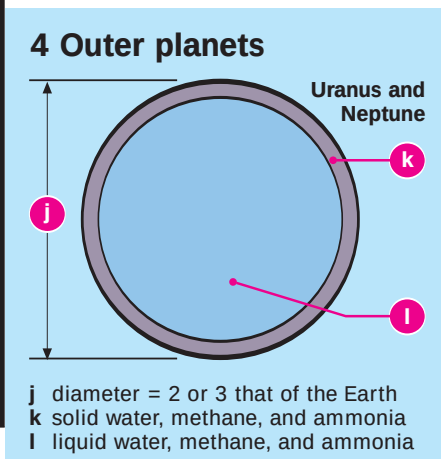

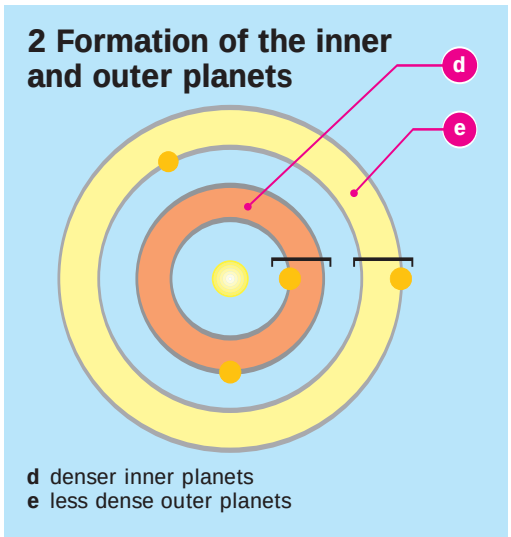

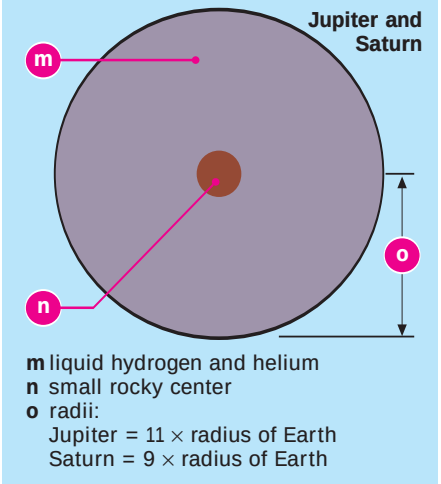

Planet composition

1 Basic composition of the planets

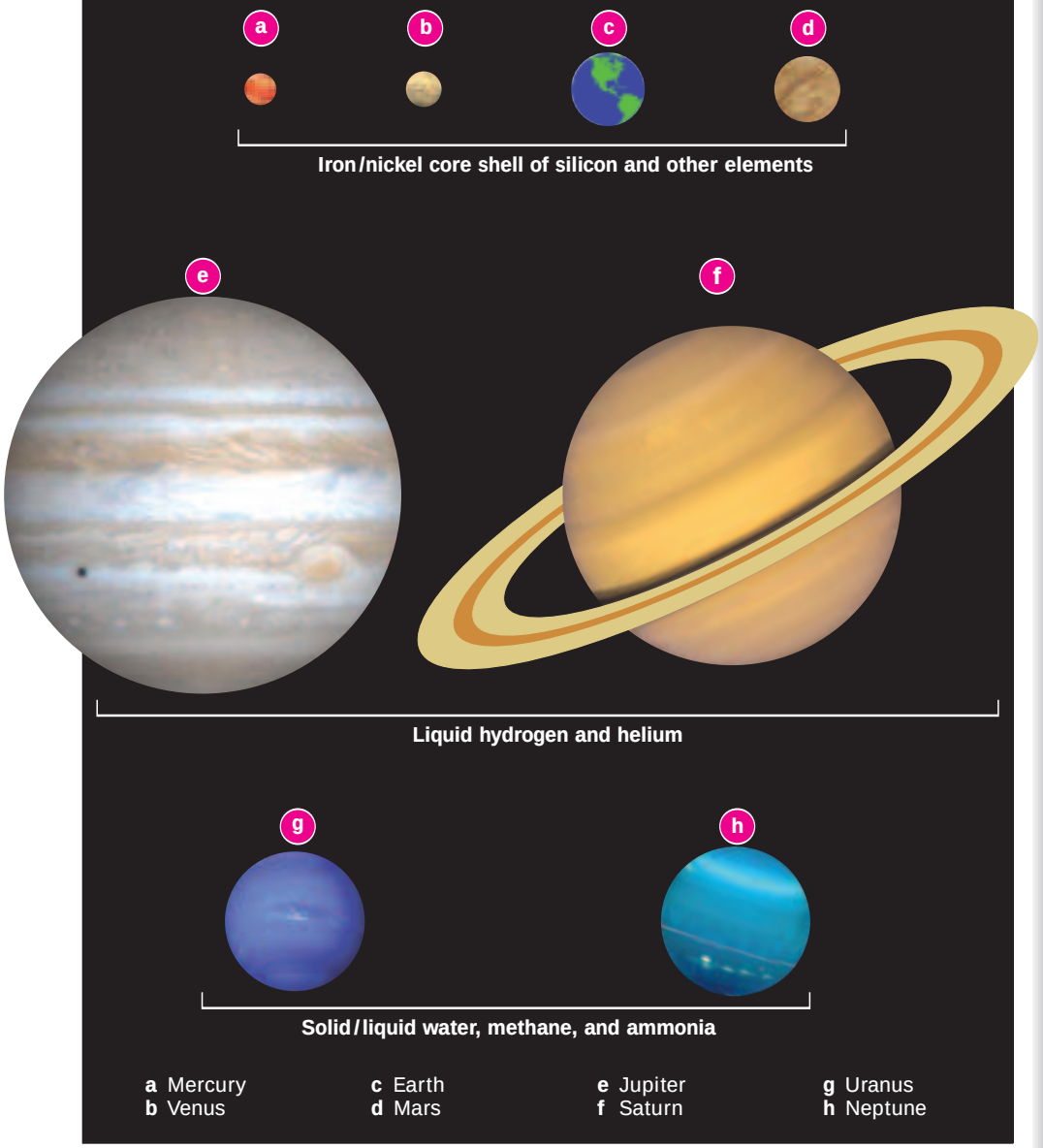

2 Composition of Earth

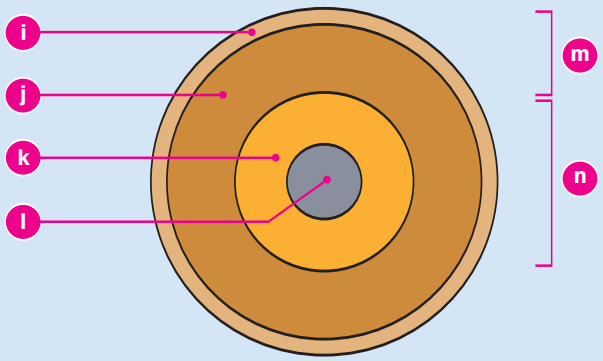

Composition of Earth	%
oxygen	46
silicon	28
aluminum	8
iron	5
calcium	4
sodium	3
potassium	3
magnesium	2

i crust
j mantle (oxygen, silicon, aluminum, iron)
k outer core (liquid – nickel and iron)
l inner core (solid – nickel and iron)
m crust, mantle, and oceans = $^{2}/_{3}$ of mass)
n core = $^{1}/_{3}$ of mass

Key words

atmosphere
carbonate
crust
mantle
nitrate
oxide
sulfate

1 Basic composition of the planets

- The inner planets—Mercury, Venus, Earth, and Mars—consist of an iron–nickel core surrounded by a shell of silicon and other elements.
- The outer planets—Jupiter, Saturn, Uranus, and Neptune—consist largely of solid or liquid methane, ammonia, liquid hydrogen, and helium.
- Pluto is not included in this comparison because it is atypical of the other outer planets, and its origins are uncertain.

2 Composition of Earth

- Earth consists of a dense, solid inner core and a liquid outer core of nickel and iron. The core is surrounded by the *mantle* (a zone of dense, hot rock), and finally by the *crust*, which is the surface of Earth.
- Since most of the materials of Earth are inaccessible (the deepest drilled holes only penetrate a small distance into the crust), we can only estimate the composition of Earth by looking at the composition of the materials from which Earth formed. Meteorites provide this information.
- Oxygen is the most common element on Earth, and about one fifth of Earth's *atmosphere* is gaseous oxygen.
- Oxygen is also present in many compounds, including water (H_2O), carbon dioxide (CO_2), and silica (SiO_2), and metal salts such as *oxides*, *carbonates*, *nitrates*, and *sulfates*.

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Key words

atmosphere
carbon dioxide
chlorophyll
photosynthesis

1 Densities and radii of the planets

- The inner planets—Mercury, Venus, Earth, and Mars—are relatively small but have a higher density than the outer planets.
- The outer planets—Jupiter, Saturn, Uranus, and Neptune—are relatively large but have a lower density than the inner planets.

2 Atmospheric composition of the inner planets

- Earth's *atmosphere* was probably similar to that of Venus and Mars when the planets formed. However, the particular conditions on Earth allowed life to start and flourish. With this came drastic changes to the composition of the atmosphere. Of particular importance is the evolution of green plants.
- Green plants contain a pigment called *chlorophyll*. Plants use this pigment to trap energy from sunlight and make carbohydrates. The process is called *photosynthesis*.
- As Earth became greener, the proportion of *carbon dioxide* in the atmosphere fell until it reached the present level of about 0.04 percent.
- The green plants provided a means of turning the Sun's energy into food, which in turn, provided animals with the energy they needed to survive. Thus, animals could evolve alongside plants.
- Conditions on the two planets adjacent to Earth—Venus and Mars—were not suitable for life as we know it, and the atmospheres on these planets have remained unchanged.

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Planetary density, size, and atmosphere

1 Densities and radii of the planets

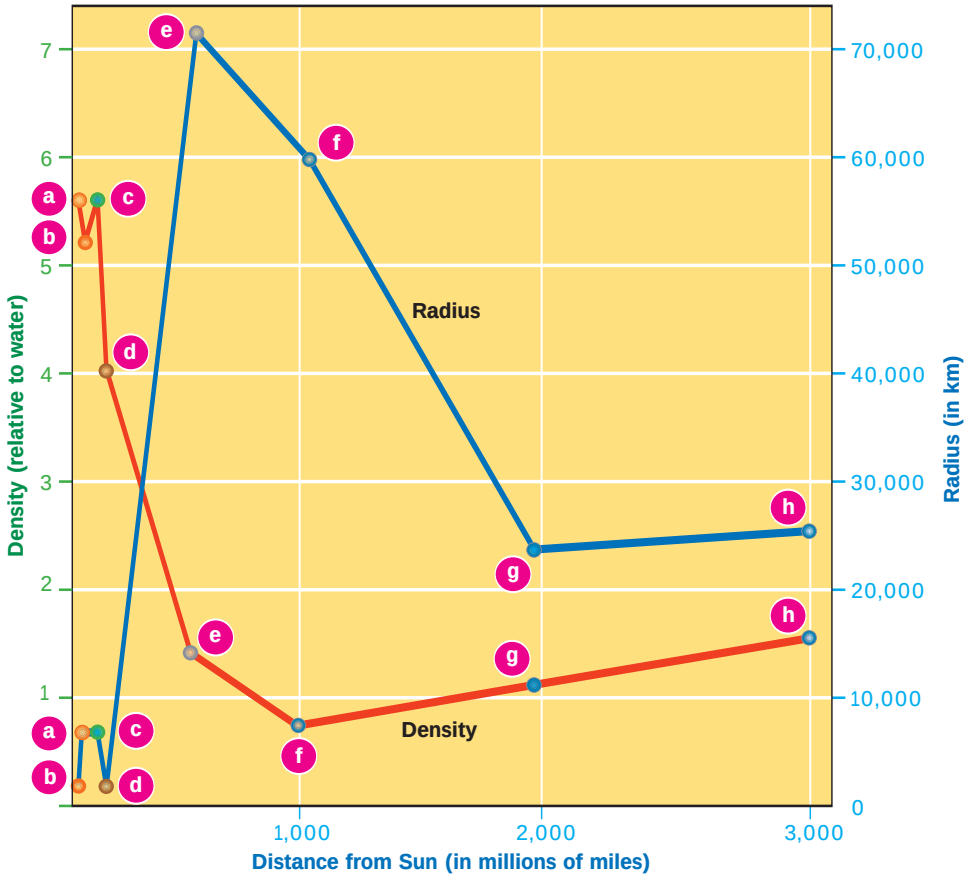

a Mercury
b Venus
c Earth
d Mars
e Jupiter
f Saturn
g Uranus
h Neptune

2 Atmospheric composition of the inner planets

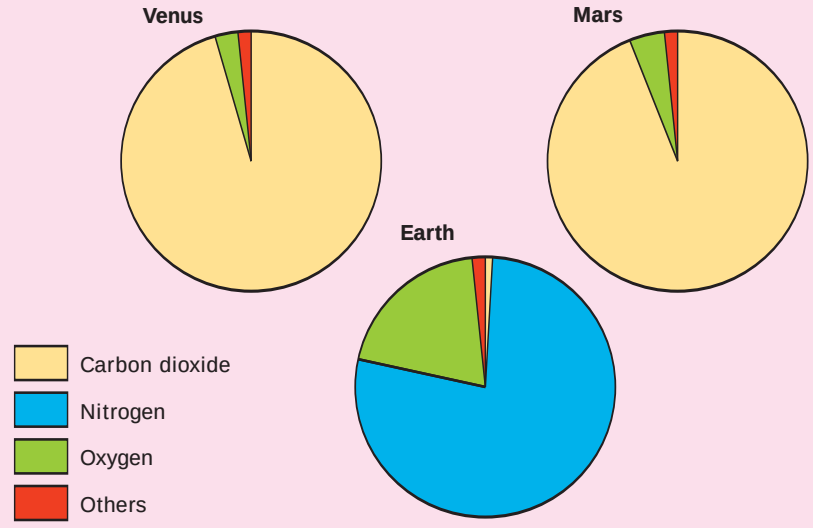

Atomic structure

1 Principle subatomic particles

Particle	Relative atomic mass	Relative charge
Electron	$\frac{1}{1836}$	–1
Neutron	1	0
Proton	1	1

2 The atom

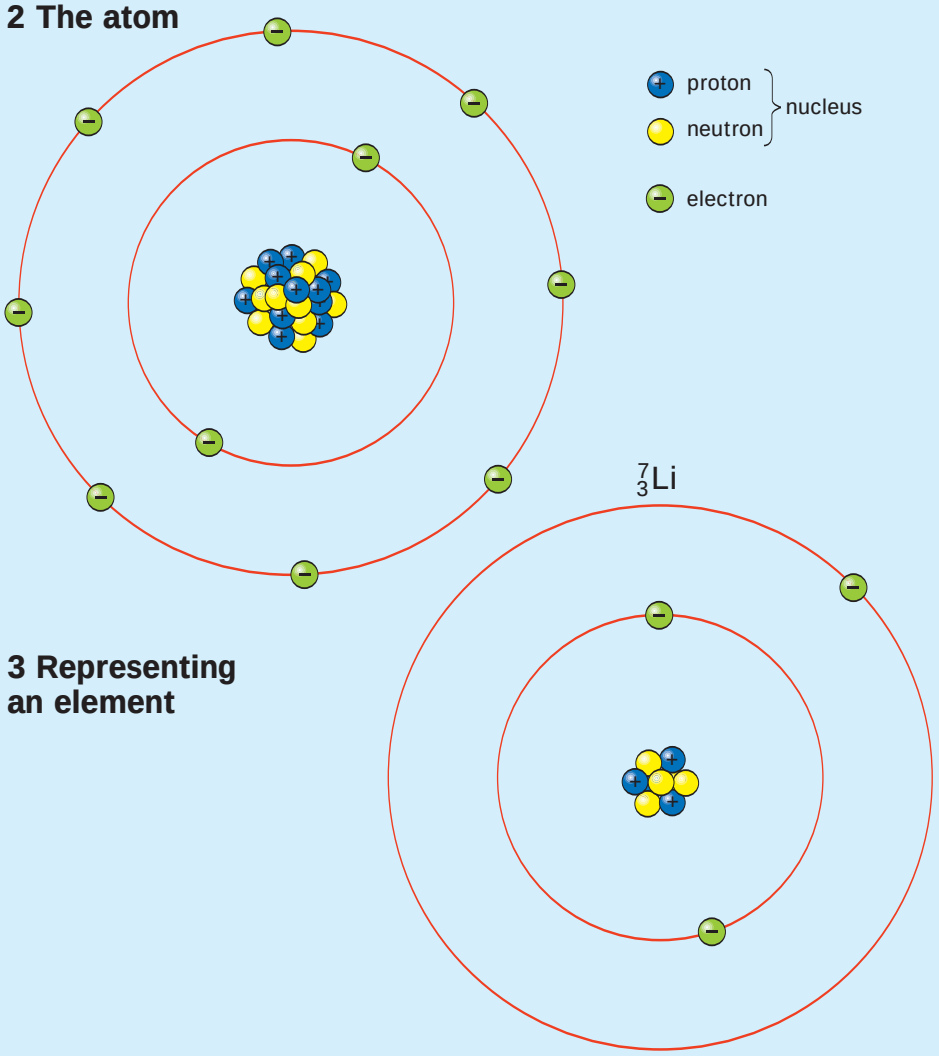

3 Representing an element

4 Isotopes

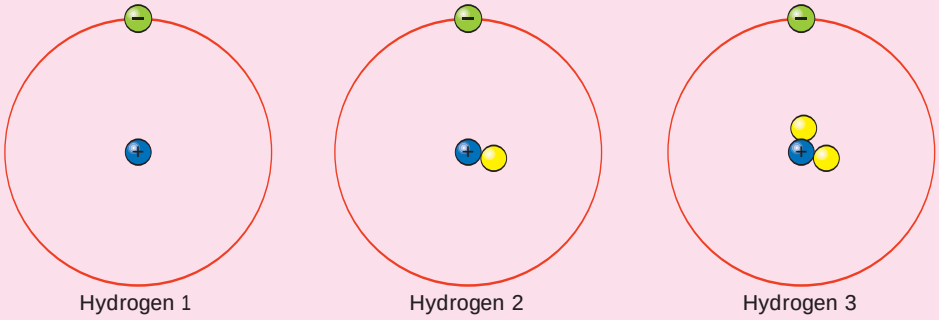

Key words

atom
atomic number
electron
isotope
mass number
neutron
nucleus
proton
subatomic particle

1 Principle subatomic particles

- An *atom* is the smallest particle of an element. It is made up of even smaller *subatomic particles*: negatively charged *electrons*, positively charged *protons*, and *neutrons*, which have no charge.

2 The atom

- An atom consists of a *nucleus* of protons and neutrons surrounded by a number of electrons.
- Most of the mass of an atom is contained in its nucleus.
- The number of protons in the nucleus is always equal to the number of electrons around the nucleus. Atoms have no overall charge.

3 Representing an element

- Elements can be represented using their *mass number*, *atomic number*, and atomic symbol:

  $^{\text{mass number}}_{\text{atomic number}}$Symbol
- The atomic number of an atom is the number of protons in its nucleus.
- The mass number is the total number of protons and neutrons in its nucleus. Thus, an atom of one form of lithium (Li), which contains three protons and four neutrons, can be represented as: $^{7}_{3}$Li

4 Isotopes

- All atoms of the same element have the same atomic number; however, they may not have the same mass number because the number of neutrons may not always be the same. Atoms of an element that have different mass numbers are called isotopes. The diagram at left illustrates isotopes of hydrogen.

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Key words

alpha particle
atom
atomic mass

Developing the atomic model

- At end of the 19th century, scientists thought that the *atom* was a positively charged blob with negatively charged electrons scattered throughout it. At the suggestion of British physicist Ernest Rutherford, Johannes Geiger and Earnest Marsden conducted an experiment that changed this view of the atomic model.
- Scientists had recently discovered that some elements were radioactive—they emitted particles from their nuclei as a result of nuclear instability. One type of particle, alpha radiation, is positively charged. Geiger and Marsden investigated how *alpha particles* scattered by bombarding them against thin sheets of gold, a metal with a high *atomic mass*.
- They used a tube of radon, a radioactive element, in a metal block (a) as the source of a narrow beam of alpha particles and placed a sheet of gold foil in the center of their apparatus (b). After they bombarded the sheet, they detected the pattern of alpha particle scattering by using a fluorescent screen (c) placed at the focal length of a microscope (d).
- If the existing model had been correct, all of the particles would have been found within a fraction of a degree of the beam. But Geiger and Marsden found that alpha particles were scattered at angles as large as 140°.
- From this experiment, Rutherford deduced that the positively charged alpha particles had come into the repulsive field of a highly concentrated positive charge at the center of the atom. He, therefore, concluded that an atom has a small dense nucleus in which all of the positive charge and most of the mass is concentrated. Negatively charged electrons surround the nucleus—similar to the way the planets orbit the Sun.

Geiger and Marsden's apparatus

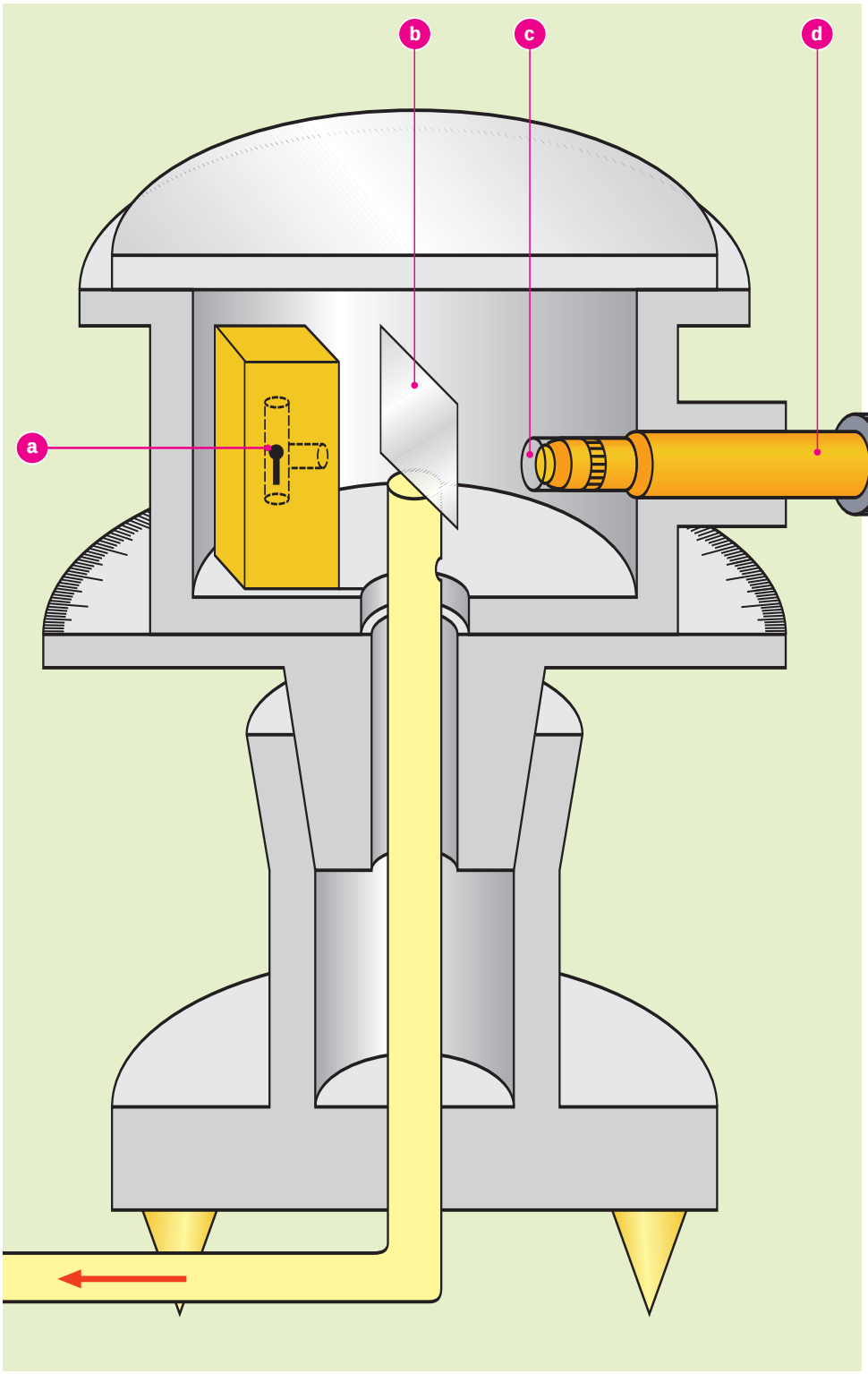

a source of alpha particles (radon tube)
b gold foil
c screen
d microscope

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Investigating the electron 1

1 Maltese-Cross tube

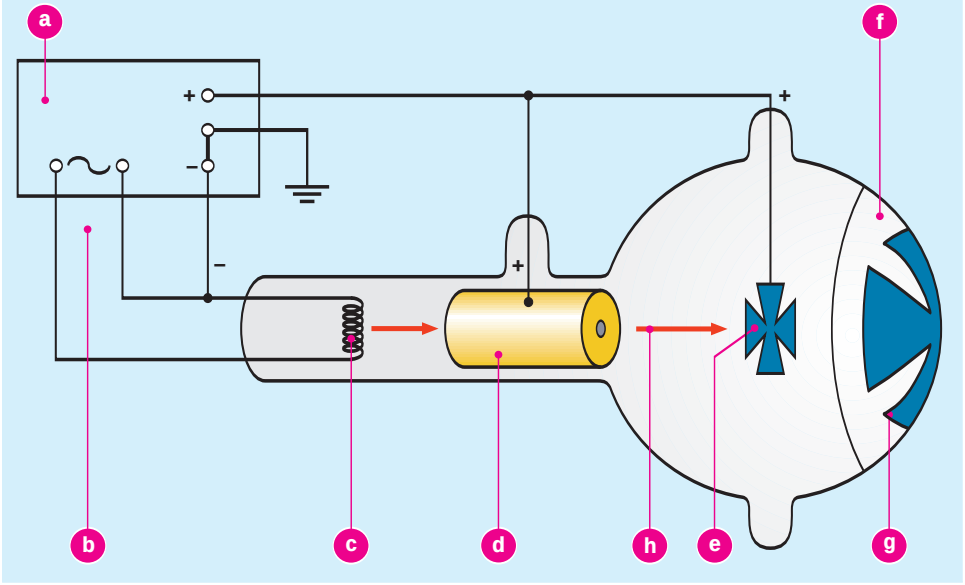

a E.h.t. supply
b low voltage
c heated filament and cathode
d anode
e Maltese-Cross (connected to anode)
g shadow
h invisible cathode rays
f fluorescent screen

2 The Perrin tube

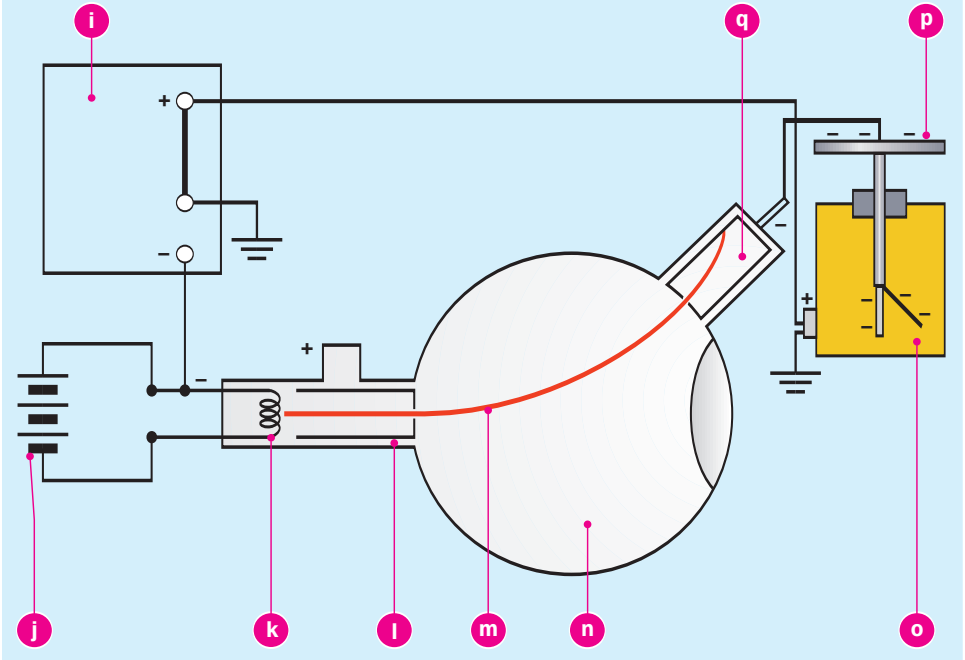

i E.h.t. supply
j 6 V supply
k cathode
l anode
m track of electron beam in magnetic field
n vacuum
o gold-leaf electroscope
p electrons are collected
q insulated metal cylinder

Key words

anode
cathode
cathode rays
electron
fluorescence

Investigating the electron

- During the last half of the nineteenth century, scientists observed that when an electric current passes through a glass tube containing a small amount of air, the air glowed. As air was removed, a patch of *fluorescence* appeared on the tube, which they called *cathode rays*. Scientists then began investigated these streams of *electrons* traveling at high speed.

1 Maltese cross tube

- In the 1880s, William Crookes experimented on cathode rays using a Maltese cross tube.
- The stream of electrons emitted by the hot *cathode* is accelerated toward the *anode*. Some are absorbed, but the majority passes through and travels along the tube. Those electrons that hit the Maltese cross are absorbed. Those electrons that miss the cross strike the screen, causing it to fluoresce with a green light.
- The result of this experiment is that a shadow of the cross is cast on the screen. This provides evidence that cathode rays travel in straight lines.

2 The Perrin tube

- In 1895 Jean Perrin devised an experiment to demonstrate that cathode rays convey negative charge.
- He constructed a cathode ray tube in which the cathode rays were accelerated through the anode, in the form of a cylinder open at both ends, into an insulated metal cylinder called a Faraday cylinder.
- This cylinder has a small opening at one end. Cathode rays enter the cylinder and build up charge, which is indicated by the electroscope. Perrin found that the electroscope had become negatively charged.
- Perrin's experiments helped to prepare the way for English physicist J. J. Thompson's work on electrons a few years later.

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Key words

anode
cathode
cathode rays
electron
photoelectric effect
radiation

1 J.J. Thomson's cathode ray tube

- In 1897 J.J. Thomson devised an experiment with *cathode rays* that resulted in the discovery of the *electron*.
- Up to this time, it was thought that the hydrogen atom was the smallest particle in existence. Thomson demonstrated that electrons (which he called corpuscles) comprising cathode rays were nearly 2,000 times smaller in mass than the then lightest-known particle, the hydrogen ion.
- When a high voltage is placed across a pair of plates, they become charged relative to each other. The positively charged plate is the *anode*, and the negatively charged plate the *cathode*.
- Electrons pass from the surface of the cathode and accelerate toward the oppositely charged anode. The anode absorbs many electrons, but if the anode has slits, some electrons will pass through.
- The electrons travel into an evacuated tube, where they move in a straight line until striking a fluorescent screen. This screen is coated with a chemical that glows when electrons strike it.

2 Evidence of the photoelectric effect

- The *photoelectric effect* is the emission of electrons from metals upon the absorption of electromagnetic *radiation*.
- Scientists observed the effect in the nineteenth century, but they could not explain it until the development of quantum physics.
- To observe the effect, a clean zinc plate is placed in a negatively charged electroscope. The gold leaf and brass plate carry the same negative charge and repel each other.
- When ultraviolet radiation strikes the zinc plate, electrons are emitted. The negative charge on the electroscope is reduced, and the gold leaf falls.

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Investigating the electron 2

1 J.J. Thomson's cathode ray tube

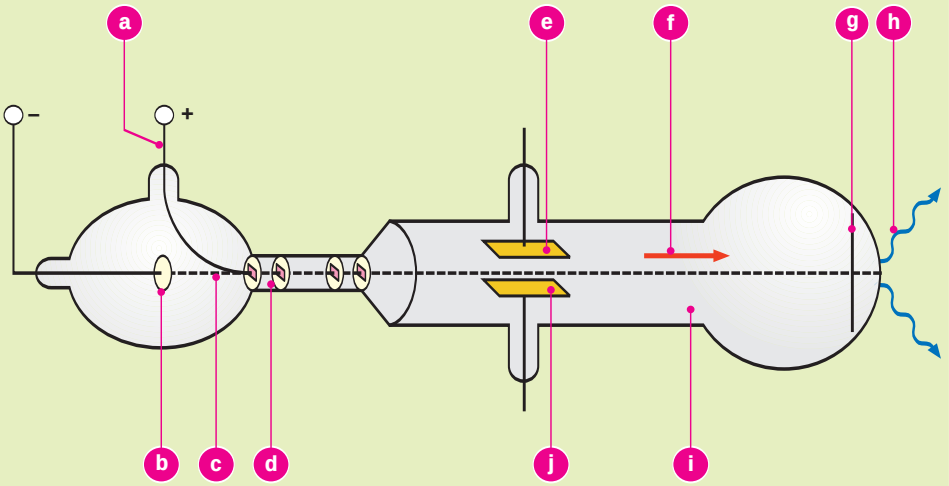

a high voltage
b cathode
c gas discharge provides free electrons
d anode with slit
e y-deflecting plate
f direction of travel of the cathode rays
g flourescent screen
h light
i evacuated tube
j x-deflecting plate

2 Evidence of the photoelectric effect

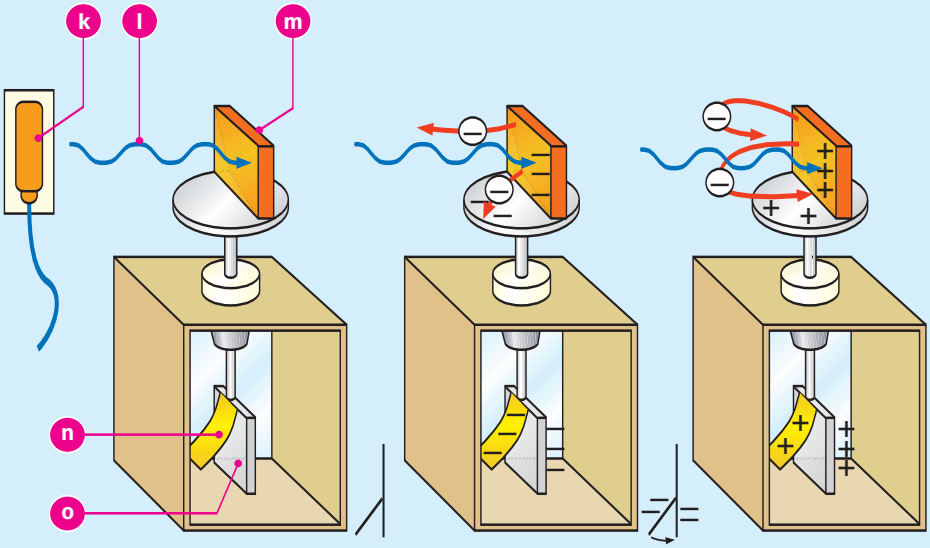

k mercury vapor lamp
l ultraviolet light
m brass plate
n gold leaf
o zinc plate

Cathode ray oscilloscope

1 The cathode ray oscilloscope

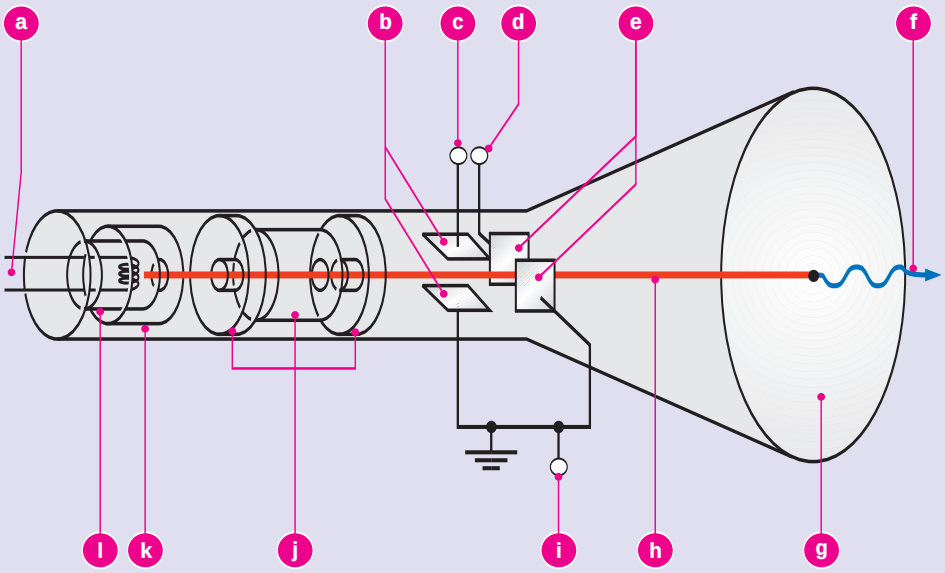

a heater
b y-deflection plates
c y-input terminal
d x-input terminal
e x-deflection plates
f light
g phosphor coating
h electron beam
i common-input terminal
j accelerating and focusing anodes
k grid
l cathode

2 Electron gun

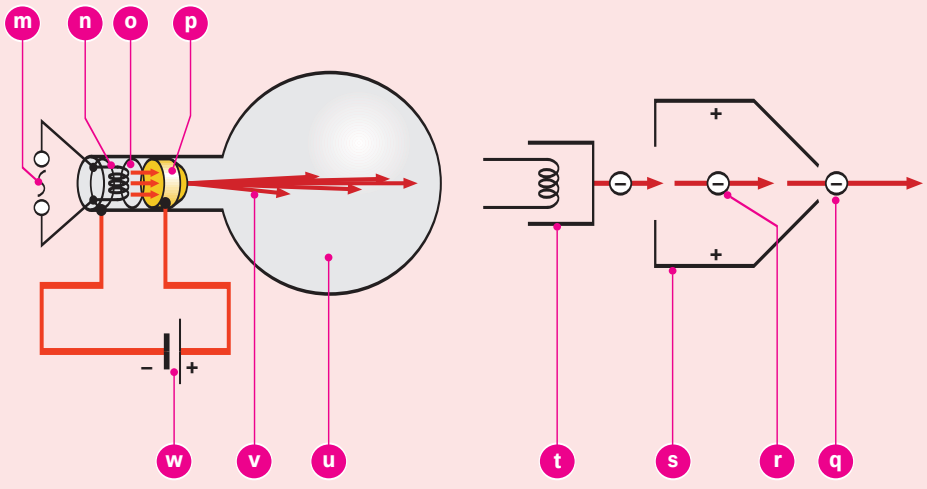

m low voltage
n heater
o cathode
p cyclindrical anode
q high speed electrons
r accelerated electrons
s anode
t cathode
u evacuated tube
v electron beam
w high voltage

Key words

anode
cathode
cathode rays

1 Cathode ray oscilloscope

- The *cathode ray* oscilloscope (CRO) is one of the most important scientific instruments ever to be developed. It is often used as a graph plotter to display a waveform showing how potential difference changes with time. The CRO has three essential parts: the electron gun, the deflecting system, and the fluorescent gun.
- The electron gun consists of a heater and *cathode*, a grid, and several *anodes*. Together these provide a stream of cathode rays. The grid is at negative potential with respect to the cathode and controls the number of electrons passing through its central hole. It is the brightness control.
- The deflecting system consists of a pair of deflecting plates across which potential differences can be applied. The Y-plates are horizontal but deflect the beam vertically. The X-plates are vertical and deflect the bean horizontally.
- A bright spot appears on the fluorescent screen where the beam hits it.

2 Electron gun

- When a current passes through the heater, electrons are emitted from the surface of the cathode and attracted towards an oppositely charged anode. Some will be absorbed by the anode, while others pass through and are accelerated, forming a stream of high-speed electrons.

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Key words

electron
radiation

Measuring the charge on the electron

- In the early part of the 20th century, American physicist Robert Millikan constructed an experiment to accurately determine the electric charge carried by a single *electron*.
- Millikan's apparatus consisted of two horizontal plates about 20 cm in diameter and 1.5 cm apart, with a small hole in the center of the upper plate.
- At the beginning of the experiment, an atomizer sprayed a fine mist of oil on to the upper plate.
- As a result of gravity, a droplet would pass through the hole in the plate into a chamber that was ionized by *radiation*. Electrons from the air attached themselves to the droplet, causing it to acquire a negative charge. A light source illuminated the droplet, making it appear as a pinpoint of light. Millikan then measured its downward velocity by timing its fall through a known distance.
- Millikan measured hundreds of droplets and found that the charge on them was always a simple multiple of a basic unit, 1.6 x 10^{-19} coulomb. From this he concluded that the charge on an electron was numerically 1.6 x 10^{-19} coulomb.

Measuring the charge on the electron

Millikan's apparatus

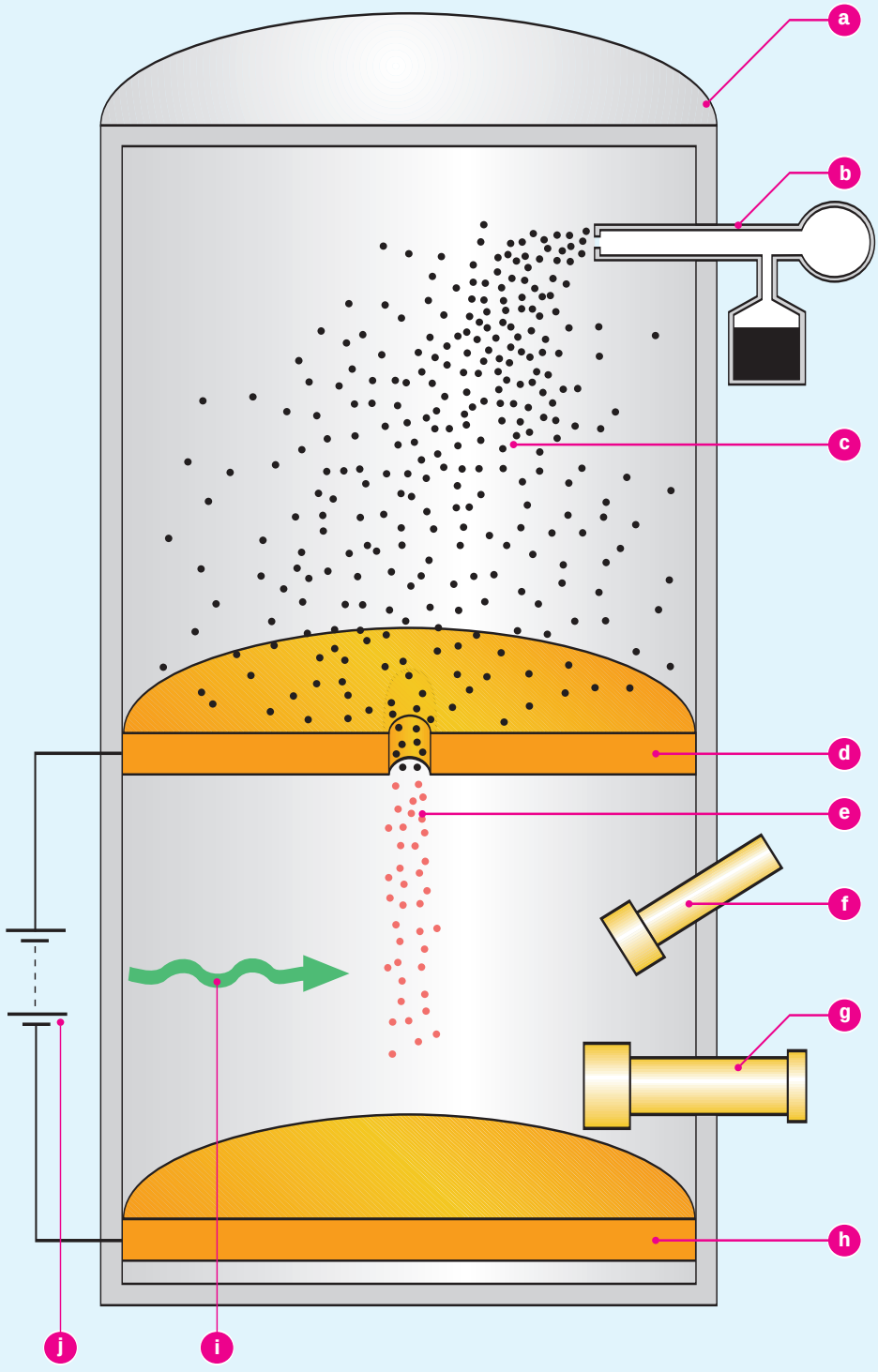

a sealed container
b atomizer
c oil droplets
d charged metal plate (+)
e charged oil droplets
f light source
g viewing microscope
h charged metal plate (–)
i ionizing radiation
j power source

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Size and motion of molecules

1 Estimating the size of a molecule

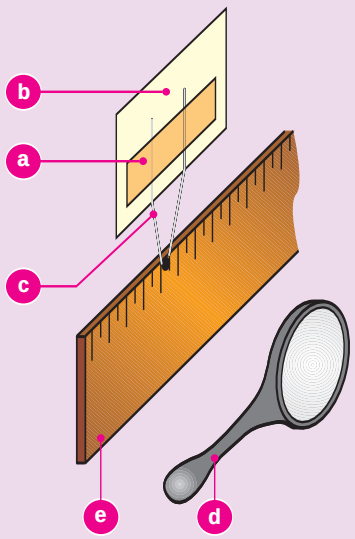

Determining the radius of an oil drop

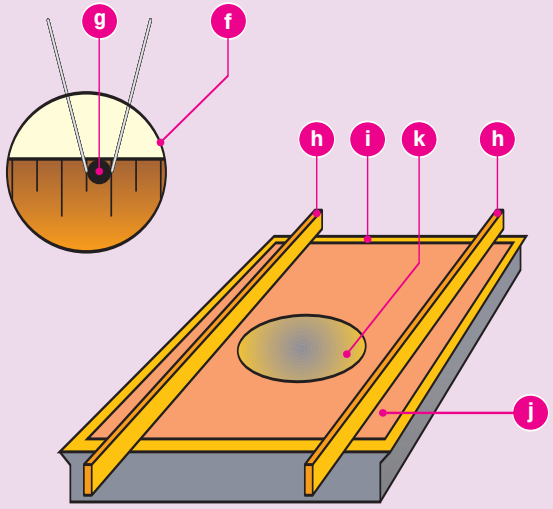

Determining the radius of an oil drop spread

2 Brownian motion in air

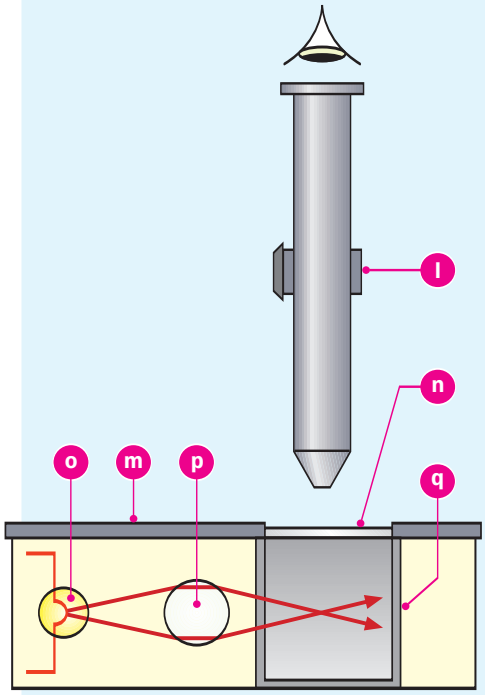

3 Diffusion

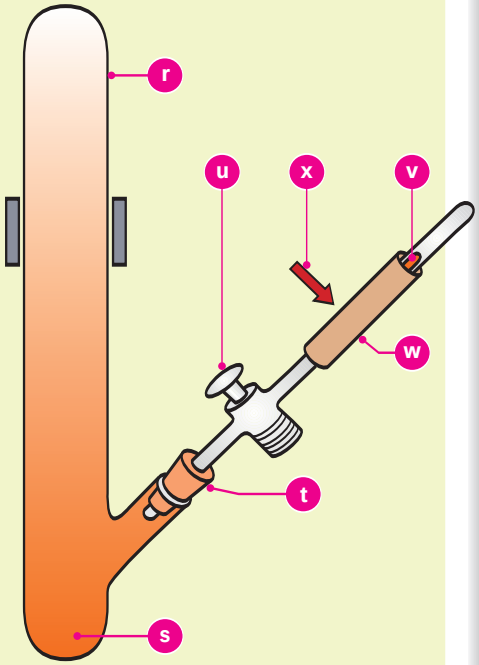

a tape
b cardboard
c fine stainless steel wire
d magnifying glass
e 1/2 mm scale
f view through magnifying glass
g oil drop
h waxed sticks
i wax-coated tray
j lycopodium powder
k oil patch
l microscope
m removable lid
n window
o lamp
p glass rod for converging light
q glass smoke chamber
r glass diffusion tube
s liquid bromine capsule
t rubber stopper
u tap
v bromine capsule
w rubber tube
x point at which pressure is applied to break capsule

Key words

Brownian motion
diffusion
molecule

1 Estimating the size of a molecule

- Scientists can estimate the size of a *molecule* by dividing the volume of a sphere by the volume of a cylinder.
- In the example in the diagram, the volume of a spherical oil drop of radius, r_s, is given by:
  $\frac{4 \times \pi \times r_s^3}{3}$
- When the oil drop spreads across the surface of water, it takes the shape of a cylinder of radius, r_c, and thickness, h. The volume of such a cylinder is:
  $\pi \times r_c^2 \times h$
- If we assume that the layer of oil is one molecule thick, then h gives the size of an oil molecule.
- When spread on water the drop of oil will have the same volume therefore:
  $h = \frac{4 \times \pi \times r_s^3}{3} \times \frac{1}{\pi \times r_c^2}$
  $h = \frac{4\ r_s^3}{3\ r_c^2}$

2 Brownian motion in air

- *Brownian motion* is the random motion of particles through a liquid or gas. Scientists can observe this by using a glass smoke chamber.
- Smoke consists of large particles that can be seen using a microscope.
- In the smoke chamber, the smoke particles move around randomly due to collisions with air particles.

3 Diffusion

- *Diffusion* is the spreading out of one substance through another due to the random motion of particles.
- The diagram illustrates how scientists use a diffusion tube to observe this. Initially the color of the substance is strongest at the bottom of the tube.
- After a period of time, as a result of diffusion, the particles of the substance mix with air particles, and the color becomes uniform down the length of the tube.

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Key words

anode
Avogadro's constant
electrolysis
Faraday constant
mole

Defining Avogadro's constant

- *Avogadro's constant* is the number of particles in a *mole* of a substance. It equals 6.023×10^{23} mol^{-1}.
- It is F, the *Faraday constant*—96,500 coulombs per mole, the amount of electric charge of one mole of electrons—divided by 1.60×10^{-19} coulomb—the charge on one electron (expressed as e).
- Thus, the Avogadro constant, N, is given by: $N = \frac{F}{e}$

or:

$$\frac{96{,}500}{1.60 \times 10^{-19}} = 6.023 \times 10^{23}\ mol^{-1}$$

Determining the Constant

- The number of molecules in one mole of substance can be determined by using electrochemistry.
- During *electrolysis*, current (electron flow) over time is measured in an electrolytic cell (see diagram). The number of atoms in a weighed sample is then related to the current to calculate Avogadro's constant.

Illustrating the Procedure

- The diagram illustrates the electrolysis of copper sulfate. To calculate Avogadro's constant, the researcher weighs the rod to be used as the *anode* before submerging the two copper rods in copper sulfate. She then connects the rods to a power supply and an ammeter (an instrument used to measure electric current). She measures and records the current at regular intervals and calculates the average amperage (the unit of electric current). Once she turns off the current, she weighs the anode to see how much mass was lost. Using the figures for anode mass lost, average current, and duration of the electrolysis, she calculates Avogadro's constant.

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Determination of Avogadro's constant

Determination of Avogadro's constant

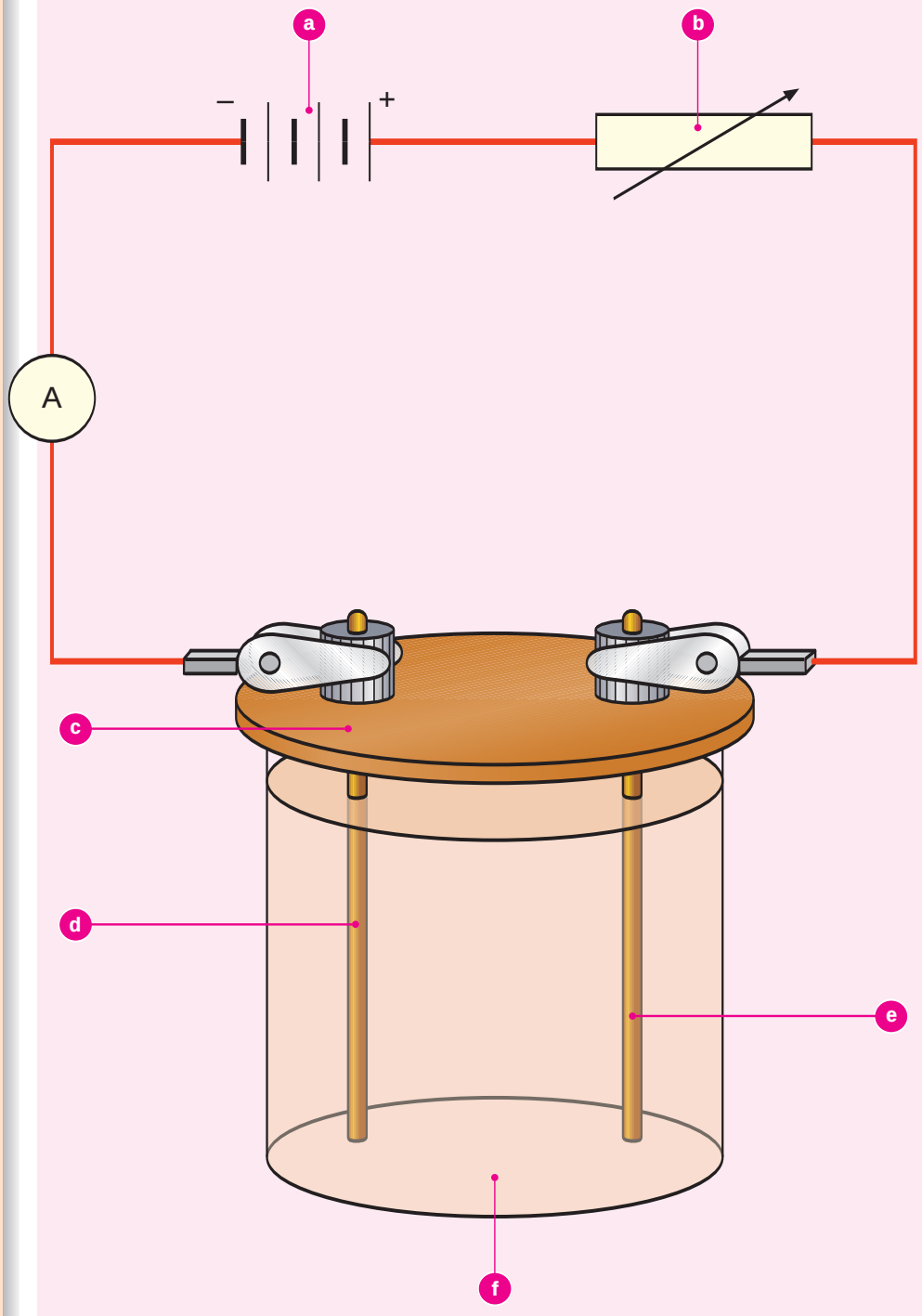

a power supply with ammeter
b rheostat
c hardboard or wooden electrode holder
d copper rod cathode
e copper rod anode
f copper sulfate solution

The mole

1 Defining a mole

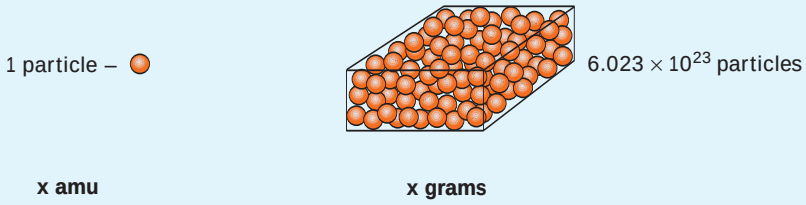

2 Moles of gas

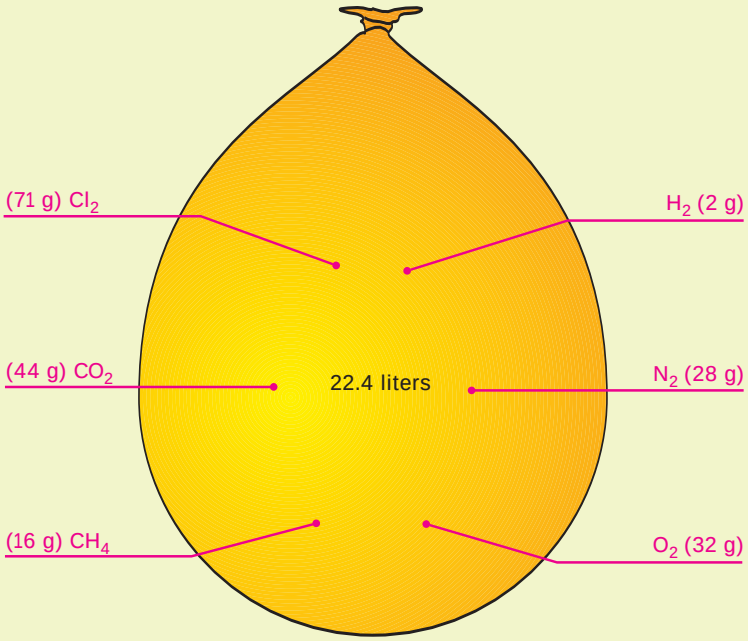

3 Molarity

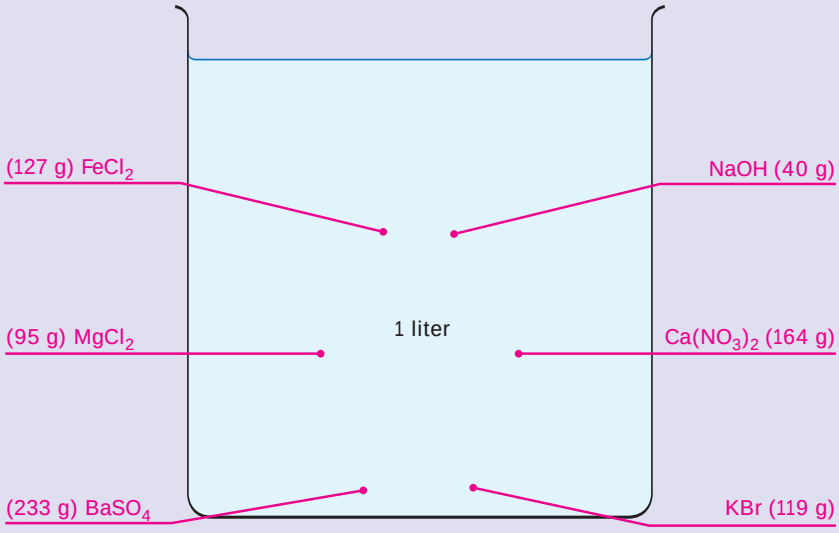

21

ATOMIC STRUCTURE

Key words

atom
ion
molarity
mole
molecule

1 Defining a mole

- Because *atoms*, *ions*, and *molecules* have very small masses, it is impossible to count or weigh them individually. As a result, scientists use *moles* in a chemical reaction.
- A mole is the amount of substance that contains as many elementary entities (atoms, molecules, ions, any group of particles) as there are atoms in exactly 0.012 kilogram of carbon-12. This quantity is Avogadro's constant (6.023×10^{23} mol^{-1}).
- The significance of this number is that it scales the mass of a particle in atomic mass units (amu) exactly into grams (g).
- Chemical equations usually imply that the quantities are in moles.

2 Moles of gas

- One mole of any gas occupies 22.4 liters at standard temperature and pressure, (which is 0 °C and atmospheric pressure).
- The diagram shows the mass in grams of one mole of the following gases: chlorine (Cl_2), carbon dioxide (CO_2), methane (CH_4), hydrogen (H_2), nitrogen (N_2), and oxygen (O_2).

3 Molarity

- *Molarity* is concerned with the concentration of a solution. It indicates the number of particles in 1 liter of solution.
- A 1 molar solution contains 1 mole of a substance dissolved in water or some other solvent to make 1 liter of solution.
- The diagram shows the mass in grams of one mole of the following substances: iron(II) chloride ($FeCl_2$), magnesium chloride ($MgCl_2$), barium sulfate ($BaSO_4$), sodium hydroxide ($NaOH$), calcium nitrate ($Ca(NO_3)_2$), and potassium bromide (KBr).

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Key words

atomic emission spectrum
infrared
spectrum
ultraviolet
wavelength

Atomic spectrum

- The *atomic emission spectrum* of an element is the amount of electromagnetic radiation it emits when excited. This pattern of wavelengths is a discrete line *spectrum*, not a continuous spectrum. It is unique to each element.

Investigating hydrogen

- Toward the end of the nineteenth century, scientists discovered that when excited in its gaseous state, an element produces a unique spectral pattern of brightly colored lines. Hydrogen is the simplest element and, therefore, was the most studied. Hydrogen has three distinctively observable lines in the visible spectrum—red, blue/cyan, and violet.

Series

- In 1885 Swiss mathematician and physicist Johannes Jakob Balmer proposed a mathematical relationship for lines in the visible part of the hydrogen emission spectrum that is now known as the Balmer series.
- The series in the *ultraviolet* region at a shorter *wavelength* than the Balmer series is known as the Lyman series.
- The series in the *infrared* region at the longer wavelength than the Balmer series is known as the Paschen series.
- The Brackett series and the Pfund series are at the far infrared end of the hydrogen emission series.

Atomic emission spectrum: hydrogen

Emission spectrum in the near ultra-violet and visible Balmer series

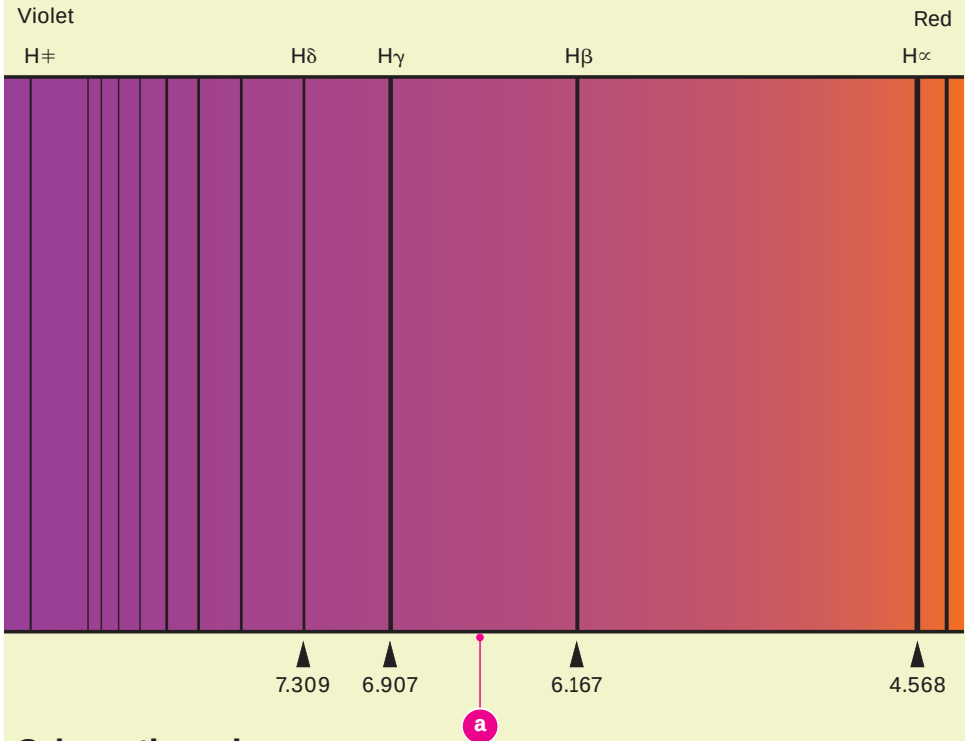

Schematic series

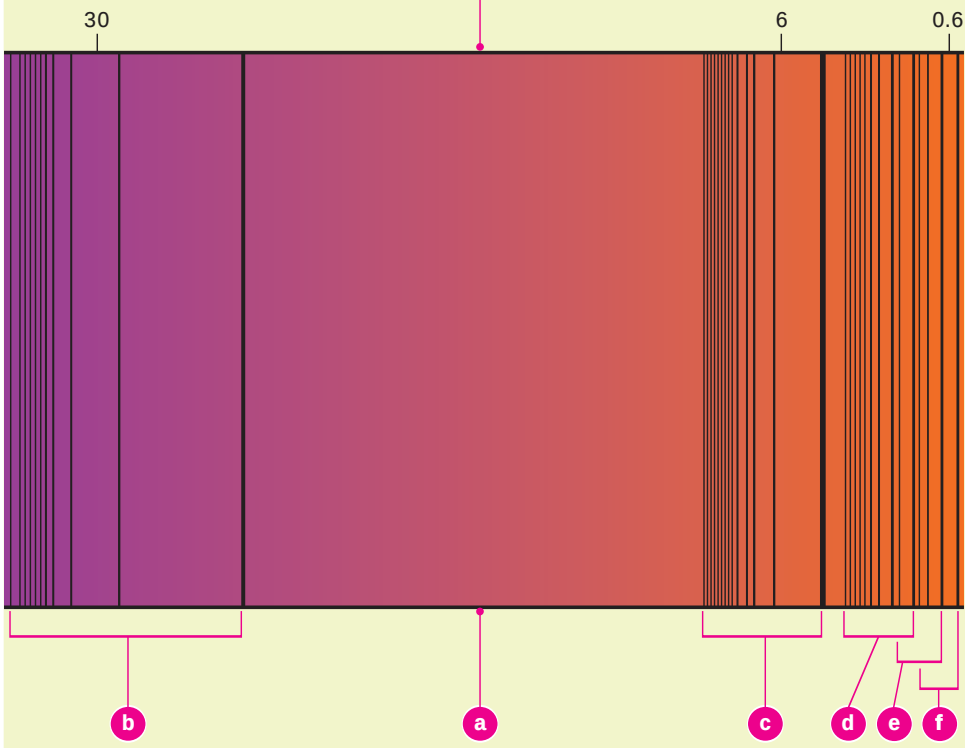

a frequency ($\times 10^{14}$Hz)
b Lyman series
c Balmer series
d Paschen series
e Bracket series
f Pfund series

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Energy levels: hydrogen atom

Energy-level schematic

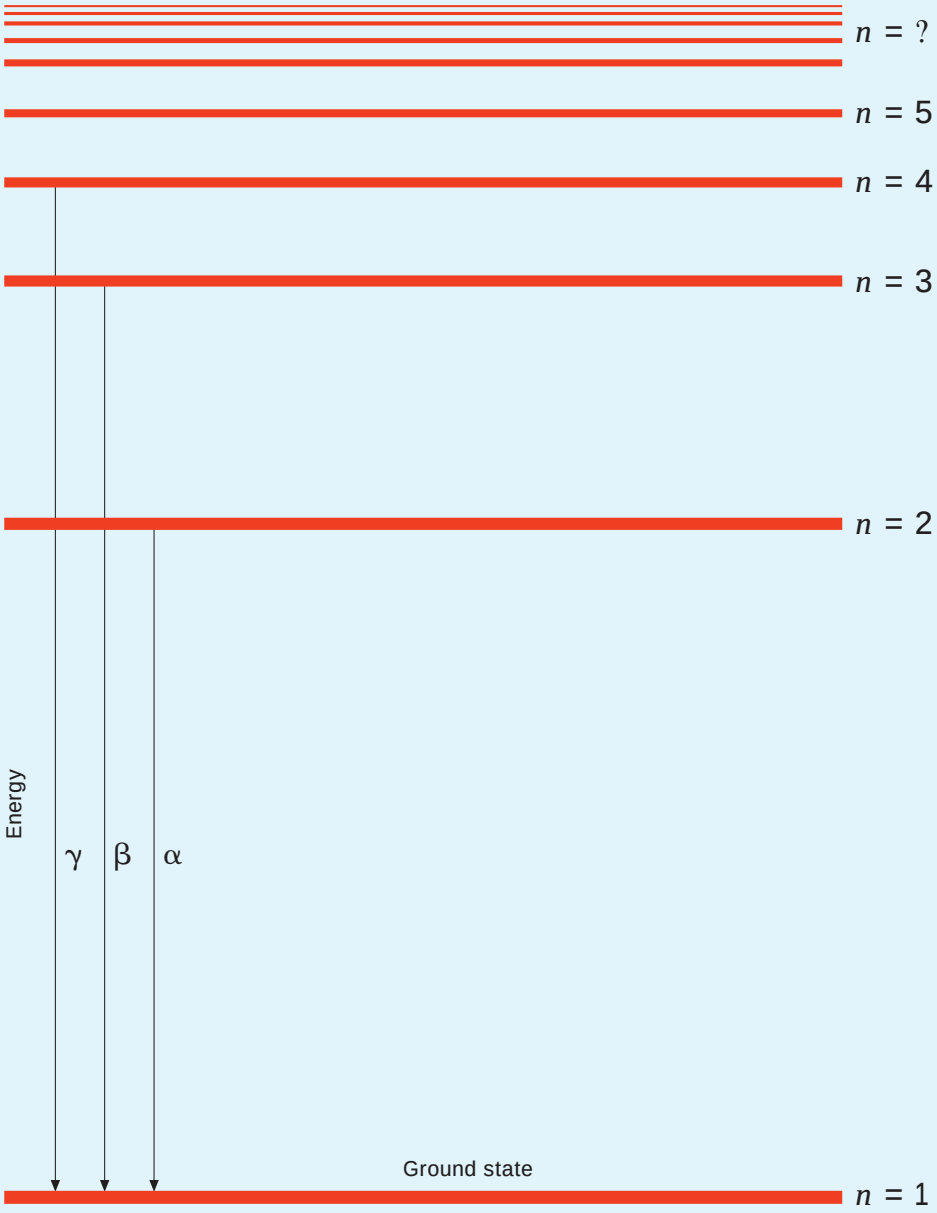

Line spectrum

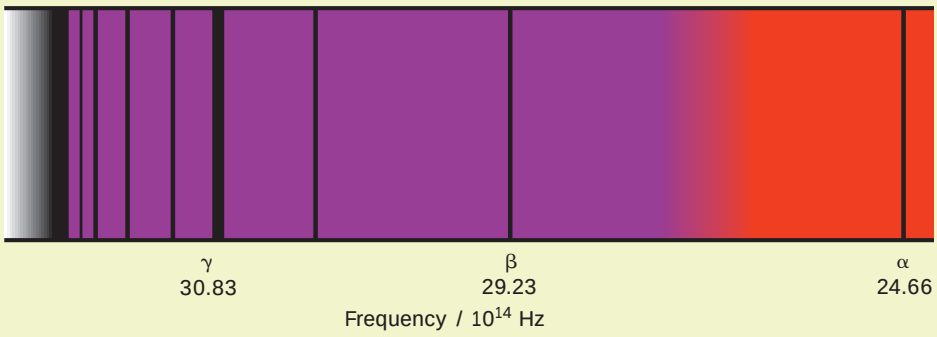

Key words

ground state
orbital
quantum number
shell
ultraviolet

Energy levels

- Electrons are arranged in definite energy levels (also called *shells* or *orbitals*), at a considerable distance from the nucleus.
- Electrons jump between the orbits by emitting or absorbing energy.
- The energy emitted or absorbed is equal to the difference in energy between the orbits.

Energy levels of hydrogen

- The graph shows the energy levels for the hydrogen atom. Each level is described by a *quantum number* (labeled by the integer n).
- The shell closest to the nucleus has the lowest energy level. It is generally termed the *ground state*. The states farther from the nucleus have successively more energy.

Transition from n level to ground state

- Transition from n=2 to the ground state, n=1:
  Frequency =24.66 x 10^{14} Hz
- Transition from n=3 to the ground state, n=1:
  Frequency =29.23 x 10^{14} Hz
- Transition from n=4 to the ground state, n=1:
  Frequency =30.83 x 10^{14} Hz

Line spectrum

- This radiation is in the *ultraviolet* region of the electromagnetic spectrum and cannot be seen by the human eye.

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Key words

fluorescence
luminescence
phosphorescence

1 Luminescence

- *Luminescence* is the emission of light caused by an effect other than heat.
- Luminescence occurs when a substance is stimulated by radiation and subsequently emits visible light.
- The incident radiation excites electrons, and as the electrons return to their ground state, they emit visible light.
- If the electrons remain in their excited state and emit light over a period of time, the phenomenon is called *phosphorescence*.
- If the electrons in a substance return to the ground state immediately after excitation, the phenomenon is called *fluorescence*.

2 Fluorescence

- In this diagram, a fluorescent light tube contains mercury vapor at low pressure. Electrons are released from hot filaments at each end of the tube and collide with the mercury atoms, exciting the electrons in the mercury atoms to higher energy levels. As the electrons fall back to lower energy states, photons of ultraviolet light are emitted.
- The ultraviolet photons collide with atoms of a fluorescent coating on the inside of the tube. The electrons in these atoms are excited and then return to lower energy levels, emitting visible light.

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Luminescence

1 Luminescence

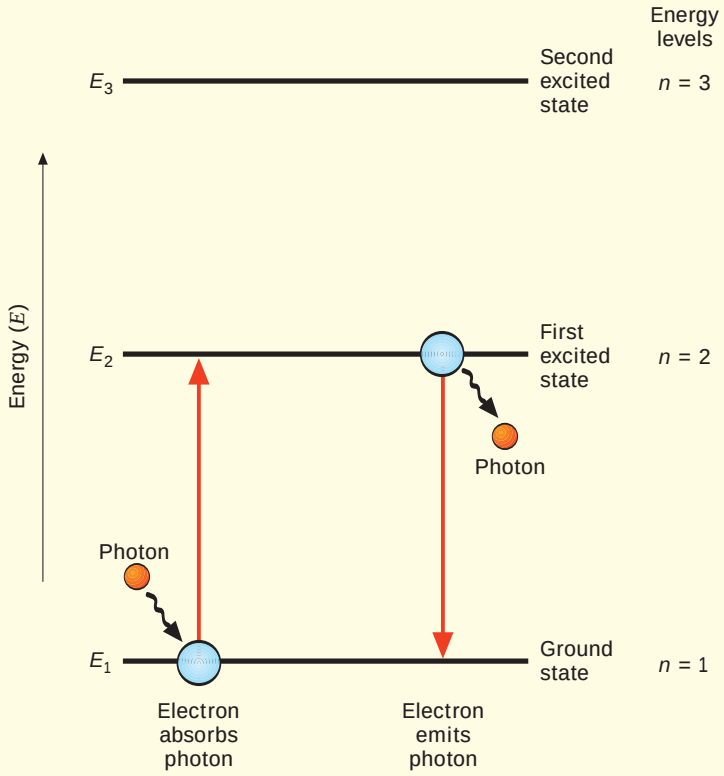

2 Fluorescence

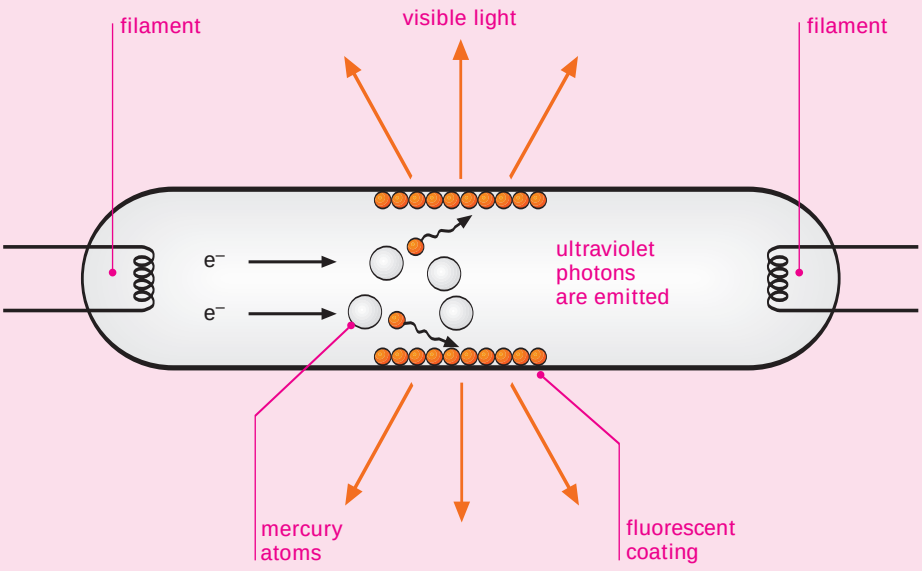

Organizing the elements

1 Antoine Lavoisier

Group 1	Group 2	Group 3	Group 4
heat	sulfur	copper	lime
light	phosphorus	tin	baryta
oxygen		lead	magnesia
nitrogen		zinc	alumina
			silica

2 Johann Dobereiner

Triad			Relative atomic mass		
Li	Na	K	7	23	39
S	Se	Te	32	79	128
Cl	Br	I	35.5	80	127
Ca	Sr	Ba	40	88	137

3 John Newlands

H	Li	Be	B	C	N	O
1	2	3	4	5	6	7
F	Na	Mg	Al	Si	P	S
8	9	10	11	12	13	14
Cl	K	Ca	Cr	Ti	Mn	Fe
15	16	17	18	19	20	21

4 Lothar Meyer

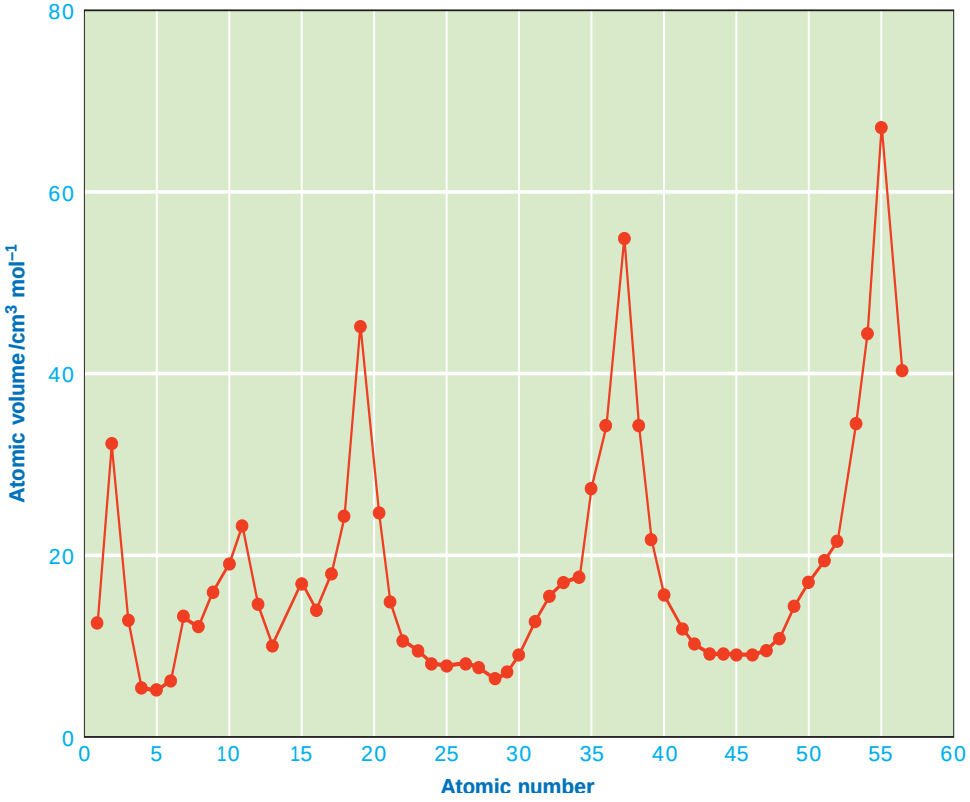

Key words

atomic mass
atomic volume
element

1 Antoine Lavoisier

- In 1789, French chemist Antoine Lavoisier organized what he believed were the *elements* into four groups: Group 1 gases, Group 2 non-metals, Group 3 metals, and Group 4 earths.

2 Johann Dobereiner

- In 1817, German chemist Johann Dobereiner noticed that the *atomic mass* of strontium was about half way between that of calcium and barium. After further study, he found that he could organize other elements into similar groups based on the same relationship to each other. He called these groups triads. Subsequently, scientists attempted to arrange all of the known elements into triads.

3 John Newlands

- In 1864, English chemist John Newlands noticed that if the elements were arranged in increasing order of atomic mass, the eighth element after any given one had similar properties. He likened this to an octave of music and called the regularity the "law of octaves."
- Newlands's arrangement worked well for the first 17 elements but broke down thereafter. Consequently, it was not well received by other scientists.

4 Lothar Meyer

- In 1870, German chemist Lothar Meyer plotted a graph of *atomic volume* against atomic mass.
- He found a pattern in which elements of similar properties appeared in similar positions on the graph.

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Key words

atomic mass
atomic number
element
group
group 1
noble gases
period
periodic table

1 Mendeleyev's periodic table

- The modern *periodic table* is based on that developed by Russian chemist Dmitry Mendeleyev in the 1860s.
- He arranged the *elements* in order of increasing *atomic mass*. He called the horizontal rows *periods* and the vertical columns *groups*. He grouped the elements on the basis of their properties.
- Mendeleyev made a separate group for those elements that did not appear to fit the pattern. He also left spaces where there was no known element that fit the pattern and made predictions about the missing elements.
- There were some problems with Mendeleyev's table. For example, iodine was placed after tellurium on the basis of its chemistry, even though its atomic mass was lower than tellurium. Also, there was no obvious place for the *noble gases*. These problems were subsequently resolved when, in 1914, English physicist Henry Moseley showed that the elements could be arranged in a pattern on the basis of their *atomic number*.

2 The modern periodic table

- Metals occupy positions to the left and center, while non-metals are found to the right. Hydrogen is the exception to this pattern. The atomic structure of hydrogen would indicate that it belongs at the top left of the table; however, it is a non-metal and has very different properties from the *group 1* elements.

The periodic table

1 Part of Mendeleyev's periodic table

	Group							
Period	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
1	H							
2	Li	Be	B	C	N	O	F	
3	Na	Mg	Al	Si	P	S	Cl	
	K	Ca	*	Ti	V	Cr	Mn	Fe Co Ni
4	Cu	Zn	*	*	As	Se	Br	
	Rb	Sr	Y	Zr	Nb	Mo	*	Ru Rh Pd
5	Ag	Cd	In	Sn	Sb	Te	I	

Spaces were left for elements that had not been discovered. They were candium, gallium, germanium, and technetium.

2 Modern Periodic Table

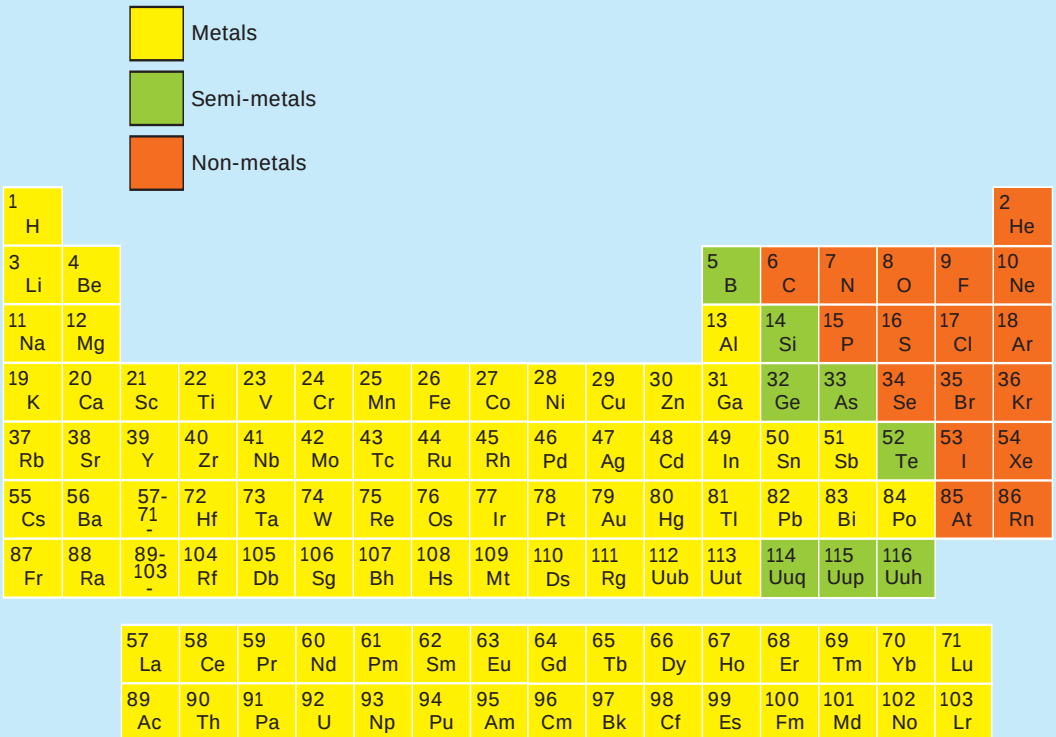

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First ionization energies of the elements

1	H 1310																He 2370
2	Li 520	Be 900											B 800	C 1090	N 1400	O 1310	F 1680	Ne 2080
3	Na 500	Mg 740											Al 580	Si 790	P 1010	S 1000	Cl 1250	Ar 1520
4	K 420	Ca 590	Sc 630	Ti 660	V 650	Cr 650	Mn 720	Fe 760	Co 760	Ni 740	Cu 750	Zn 910	Ga 580	Ge 760	As 950	Se 940	Br 1140	Kr 1350
5	Rb 400	Sr 550	Y 620	Zr 660	Nb 660	Mo 680	Tc 700	Ru 710	Rh 720	Pd 800	Ag 730	Cd 870	In 560	Sn 710	Sb 830	Te 870	I 1010	Xe 1170
6	Cs 380	Ba 500	La 540	Hf 680	Ta 760	W 770	Re 760	Os 840	Ir 880	Pt 870	Au 890	Hg 1010	Tl 590	Pb 720	Bi 700	Po 810	At	Rn

Key words

electron	*lanthanide series*
element	*mole*
group 1	*nucleus*
ion	*period*
ionization energy	*shell*

First ionization energy

- The first *ionization energy* of an element is the energy needed to remove a single *electron* from 1 *mole* of atoms of the *element* in the gaseous state, in order to form 1 mole of positively charged *ions*.
- Reading down *group 1*, there is a decrease in the first ionization energies. This can be explained by considering the electronic configuration of the elements in the group. Reading down, the outer electron is further from the positively charged *nucleus*, and there is an increasing number of complete *shells* of inner electrons, which to some extent, shield the outer electron from the nucleus. The result is that less energy is needed to remove the outer electron. A similar situation exists in other groups.

Increase in ionization energy

- There is a general increase in the first ionization energies across a *period*. This increase is due to electrons at the same main energy level being attracted by an increasing nuclear charge. This charge is caused by the increasing number of protons in the nucleus. The increase makes it progressively more difficult to remove an electron; thus more energy is needed.
- The diagram illustrates this principle using the first six periods minus the *lanthanide series*.

Elements whose ionization energies are the greatest in their period

He	Helium
Ne	Neon
Ar	Argon
Kr	Krypton
Xe	Xenon
Rn	Radon

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Key words

ionization energy
noble gases
period
periodicity
shell

First ionization energies

- The graph shows a repeating pattern, or *periodicity*, corresponding to reading down the *periods* of the periodic table.
- Within a period, it becomes increasingly more difficult to remove an electron due to the increasing nuclear charge. The graph peaks at the last element in each period, which is a *noble gas* (labeled on the graph).
- The noble gases have complete outer *shells* of electrons. This electron configuration provides great stability, and consequently, the noble gases are very unreactive. Some are totally unreactive. The first *ionization energies* of the noble gases are very high.

Variation of first ionization energy

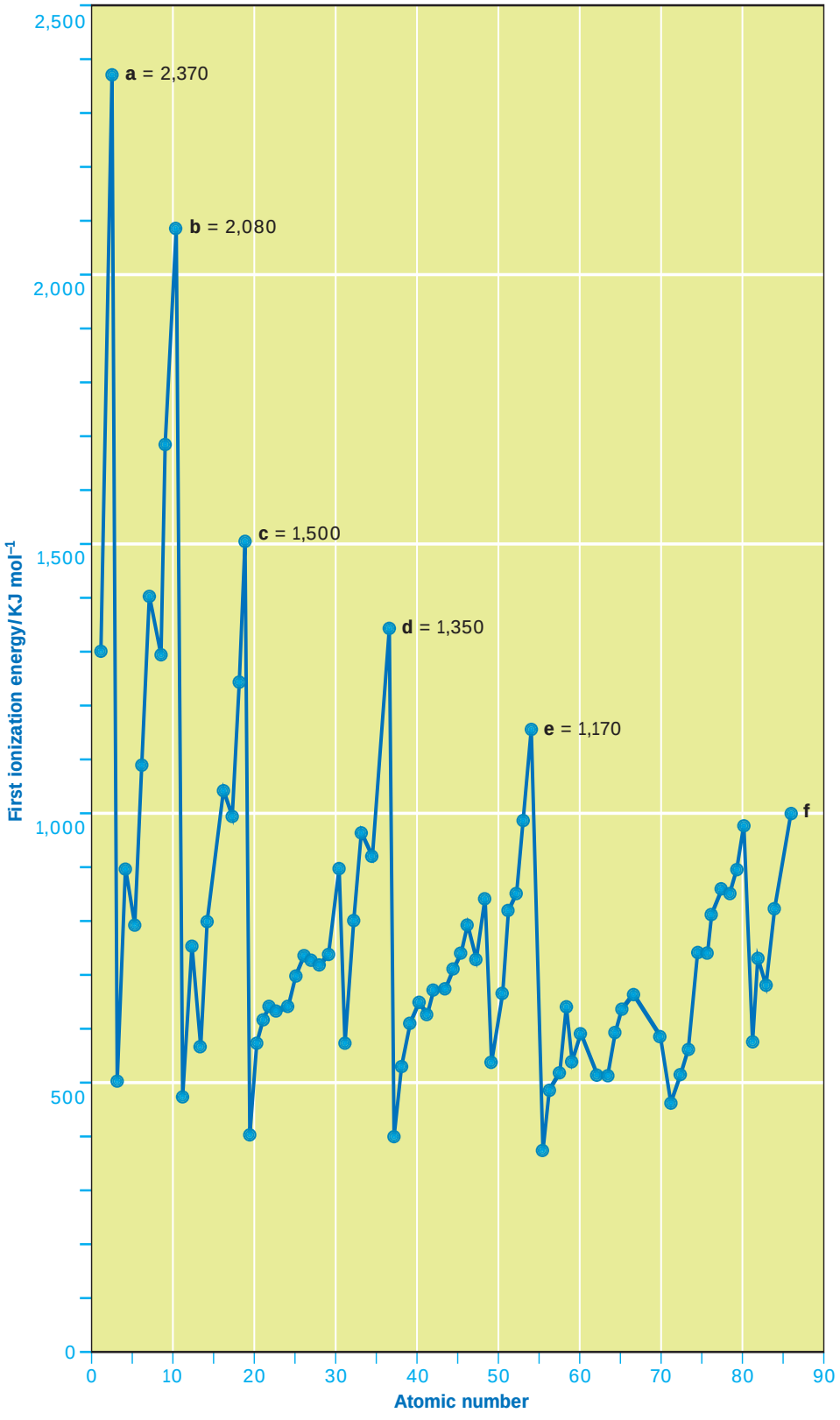

a Helium
b Neon
c Argon
d Krypton
e Xenon
f Radon

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Melting points of the elements °C

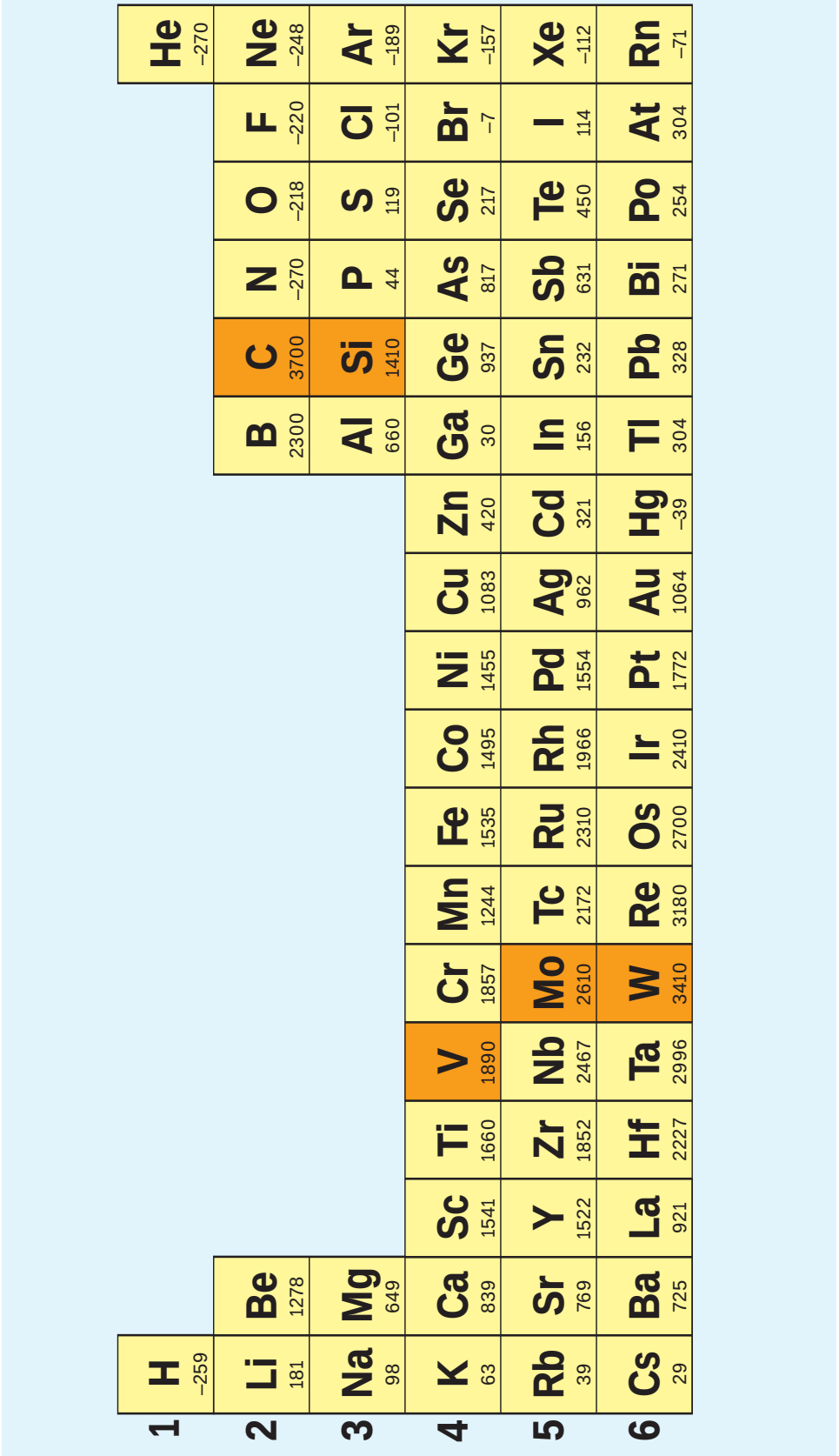

Key words

group
group 1
lanthanide series
liquid
melting point
noble gases
period
solid
transition metals

Melting points

- The *melting point* is the point at which the solid and *liquid* phase of a substance is in equilibrium at a given pressure.
- In a *solid*, the particles are held in a rigid structure by the strong forces of attraction that exist between them. They vibrate but cannot move position. When a solid is heated to its melting point, the particles gain sufficient energy to overcome these forces of attraction, and the particles are able to move position.
- Within *groups* of metallic elements, the melting point decreases down the group. The converse is true for non-metals, where the melting point increases down the group.
- Reading across *periods* 2 and 3, the elements follow a pattern of metallic structure, giant covalent structure, and simple covalent structure. The melting point increases until a maximum is reached with the element that exists as a giant covalent structure.
- The more reactive metals in *group 1* are soft and have low melting points. *Transition metals* (elements that have an incomplete inner electron structure) are generally harder and have higher melting points.
- The *noble gases* exist as single atoms with only weak forces of attraction between them. Consequently, their melting points are very low.
- Using the first six periods minus the *lanthanide series*, the diagram highlights the element with the highest melting point in a period.

Elements whose melting points are the greatest in their period

C	Carbon
Si	Silicon
V	Vanadium
Mo	Molybdenum
W	Tungsten

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Key words

element
melting point
period
periodicity
periodic table

Melting points

- The graph shows a repeating pattern, or *periodicity*, corresponding to reading down the *periods* of the *periodic table*.
- The structure of periods 2 and 3 with regard to the nature of the *elements*, is:
  Elements having a metallic structure: *melting point* increasing
  Elements having a giant covalent structure: melting point maximum
  Elements having a simple covalent structure: melting point decreasing
- In general, the melting point increases at the start of these periods, corresponding to elements that have metallic structure. The melting point is at maximum for elements that have a giant covalent structure (labeled on the graph). After this, the melting point rapidly falls to low values, corresponding to those elements that have a simple covalent structure.

Variation of melting points

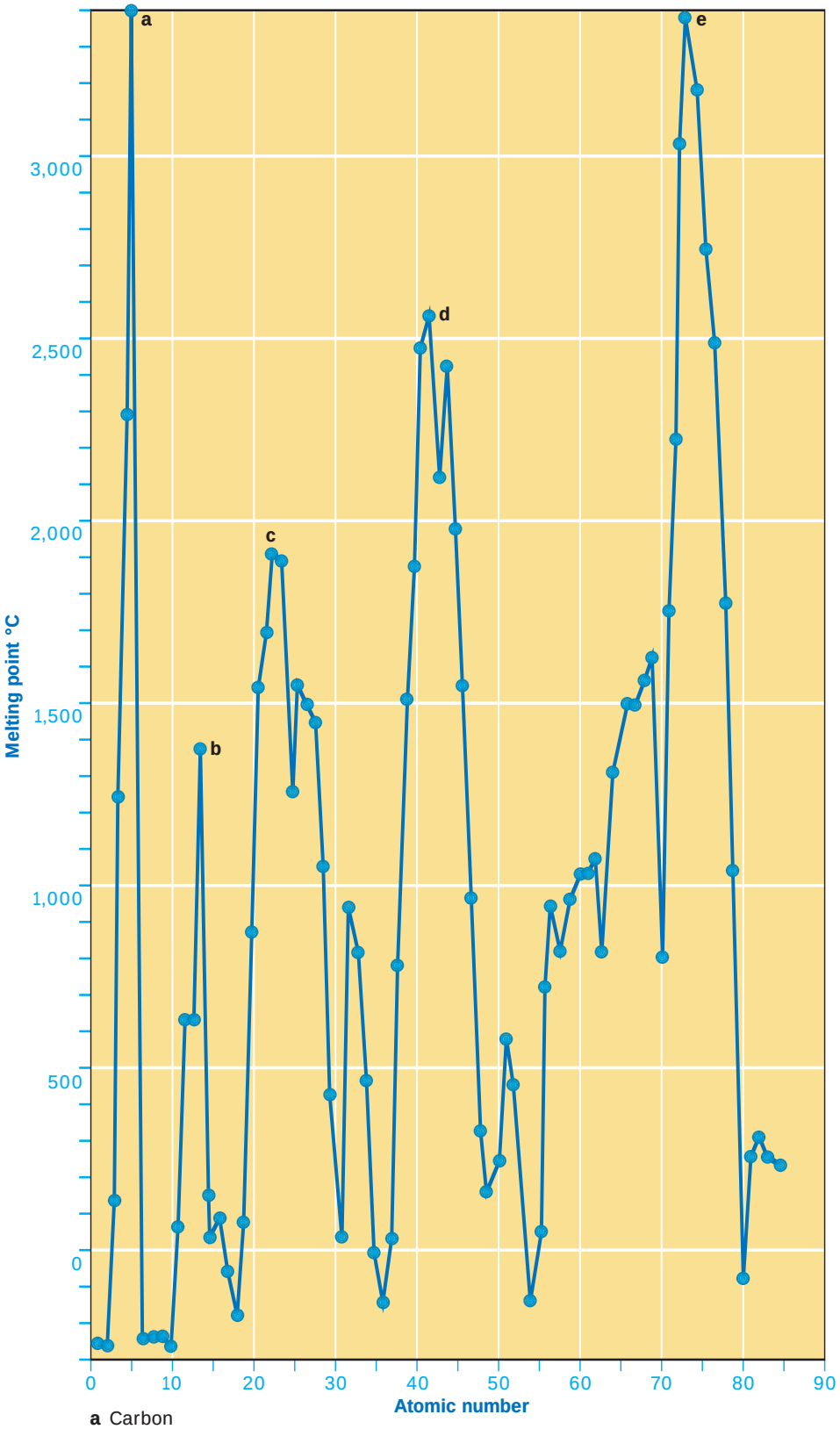

a Carbon
b Silicon
c Vanadium
d Molybdenum
e Tungsten

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Boiling points of the elements °C

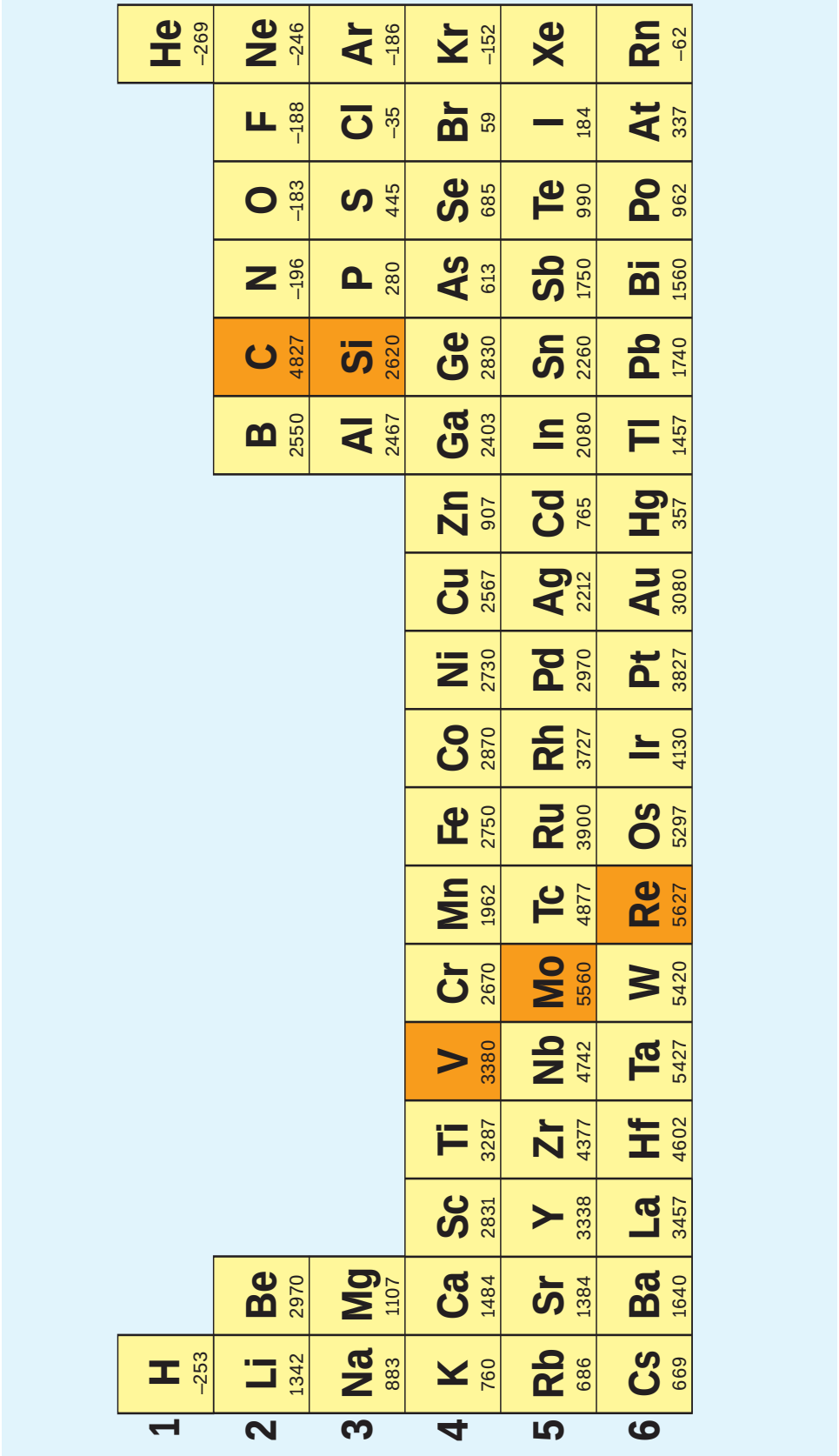

Key words

boiling point
gas
group
group 1
kinetic energy
lanthanide series
liquid
noble gases
transition metals

Boiling points

- The *boiling point* is the temperature at which a *liquid* becomes a *gas*.
- The particles in a liquid are held together by the strong forces of attraction that exist between them. The particles vibrate and are able to move around, but they are held closely together. When a liquid is heated to its boiling point, the particles gain *kinetic energy*, moving faster and faster. Eventually, they gain sufficient energy to break away from each other and exist separately. There is a large increase in the volume of any substance going from a liquid to a gas.
- Within *groups* of metallic elements, the boiling point decreases down the group. The converse is true for non-metals: the melting point increases down the group.
- The more reactive metals in *group 1* have relatively low boiling points. *Transition metals* generally have very high boiling points.
- The *noble gases* exist as single atoms with only weak forces of attraction between them. Consequently, their boiling points are very low because it takes relatively little energy to overcome these forces.
- Using the first six periods minus the *lanthanide series*, the diagram highlights the element with the highest boiling point in a period.

Elements whose boiling points are the greatest in their period

C	Carbon
Si	Silicon
V	Vanadium
Mo	Molybdenum
Re	Rhenium

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Key words

boiling point
gas
group 1
group 2
transition metals

Variation of boiling point

- The majority of non-metallic elements are *gases* at room temperature and atmospheric pressure. Most non-metallic elements have simple covalent structures and have very low *boiling points*.
- Elements with metallic and giant covalent structures have very high boiling points (see diagram). The boiling points of *transition metals* are generally much higher than those of the *group 1* and *group 2* metals.

Variation of boiling points

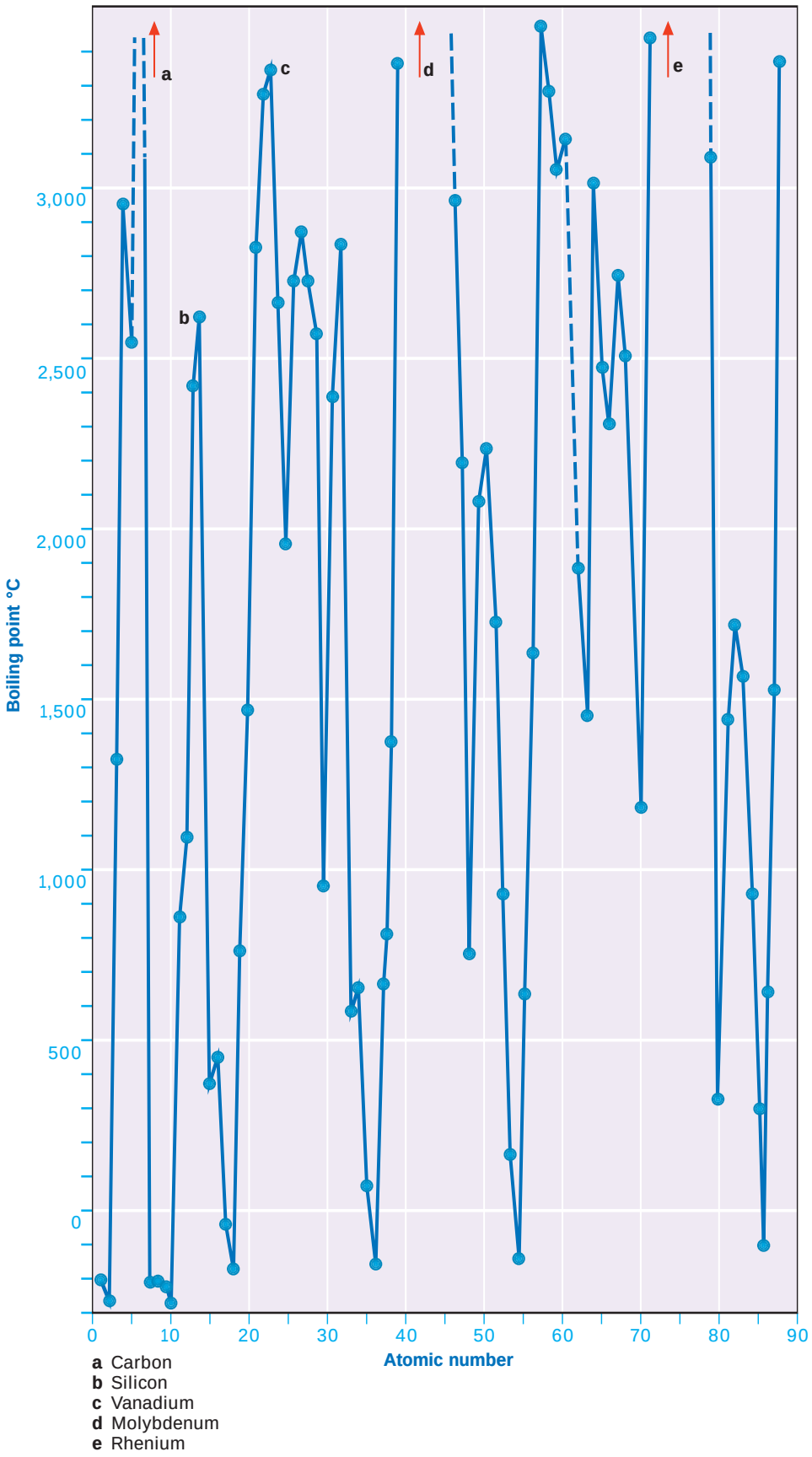

a Carbon
b Silicon
c Vanadium
d Molybdenum
e Rhenium

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Atomic volumes of the elements

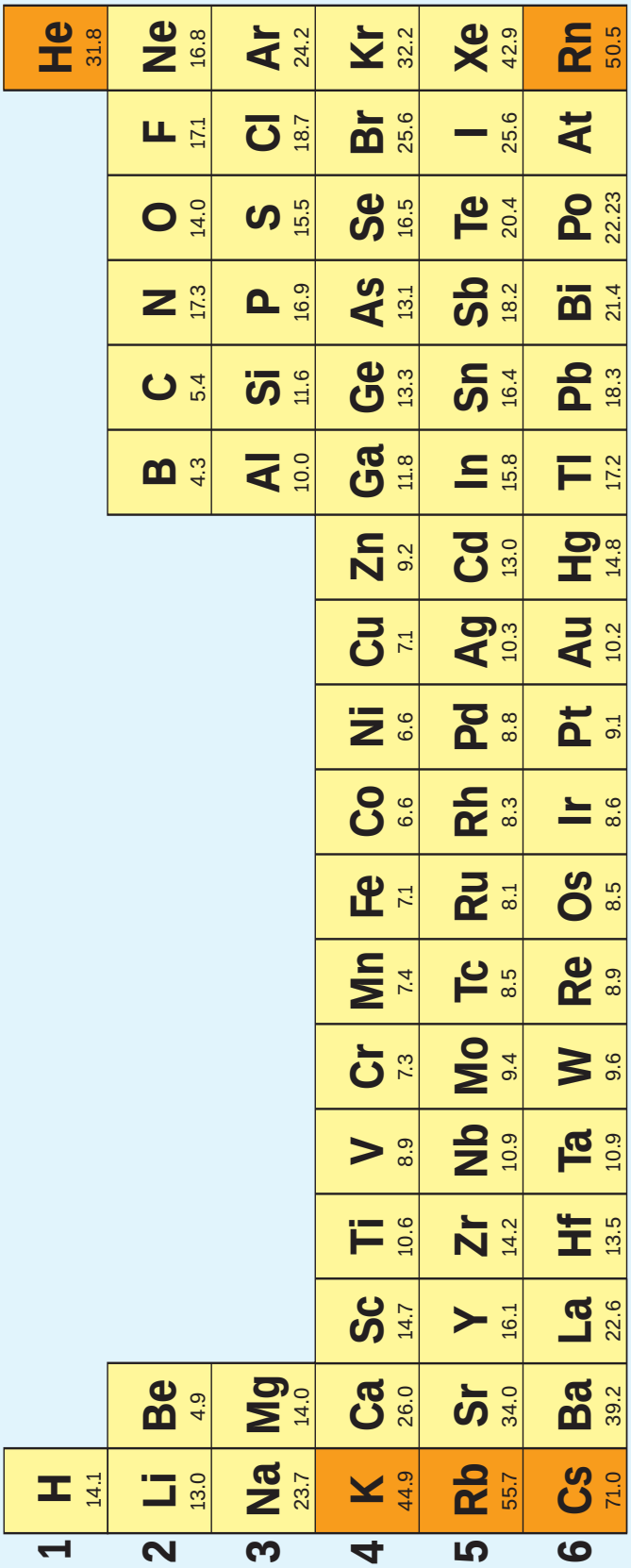

Key words

atomic mass	*group 8*
atomic volume	*lanthanide series*
density	*mole*
element	*noble gases*
group	*period*

Atomic volume

- The *atomic volume* is the volume of one *mole* of the atoms of an *element*. It can be found by dividing the *atomic mass* of one mole of atoms by the density of the element:

  $$\text{Atomic volume} = \frac{\text{Atomic mass}}{\text{Density}}$$

- Since there are 6.023×10^{23} atoms per mole of atoms, it would seem possible to use the atomic volume to calculate the volume of a single atom, and thus its radius. However there are two problems with doing this. First, the state of an element, and therefore its density, changes with temperature and pressure. Second, using the atomic volume to calculate the volume of a single atom assumes that an element consists of atoms that are not bonded to each other. This is true only of the *group 8* elements (*noble gases*). For these reasons, it is not possible to consider the volume of an atom in isolation, but only as part of the structure of an element.
- In general, atomic volume increases down a *group*. Across a *period*, it decreases and then increases.
- The diagram highlights the element with the highest atomic volume in the first six periods (minus the *lanthanide series*).

Elements with peak atomic volumes

He	Helium
K	Potassium
Rb	Rubidium
Cs	Cesium
Rn	Radon

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Key words

atomic mass
atomic number
atomic volume
periodicity

Periodicity

- As early as the Middle Ages, scientists recognized that elements could be differentiated by their properties and that these physical and chemical properties were periodic.
- The German chemist Lothar Meyer demonstrated *periodicity* by plotting *atomic volumes* against atomic weights (the term *atomic mass* is now used).
- This periodicity is better shown by plotting atomic volumes against *atomic number*.
- You can see periodicity most clearly by the pattern between potassium (b) and rubidium (c), and between rubidium (c) and cesium (d) in the diagram. These correspond to the changing values across period 4 and period 5, respectively.

Variation of atomic volumes

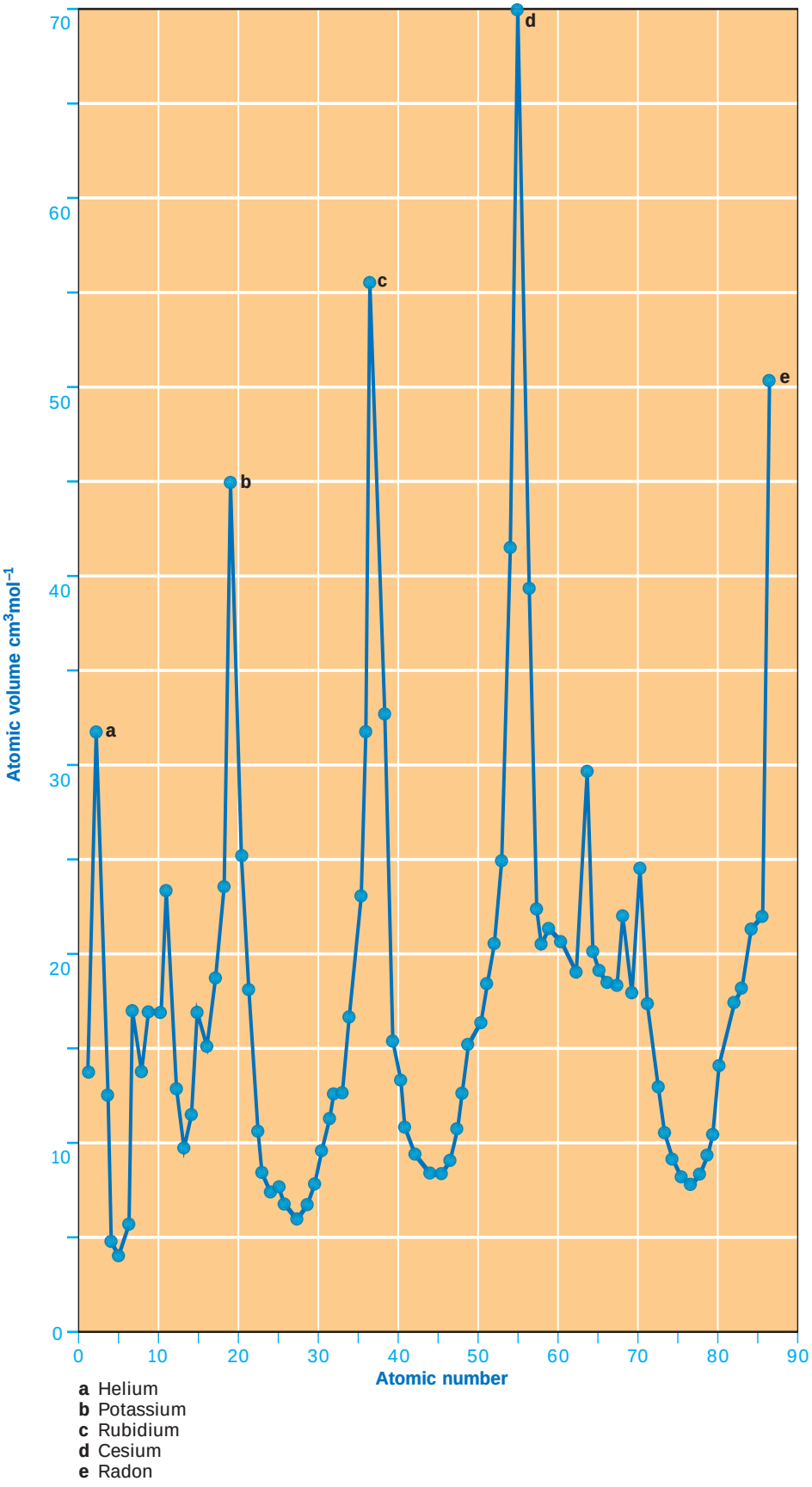

a Helium
b Potassium
c Rubidium
d Cesium
e Radon

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Atomic mass

Key words

atomic mass
isotope

1 Carbon-12

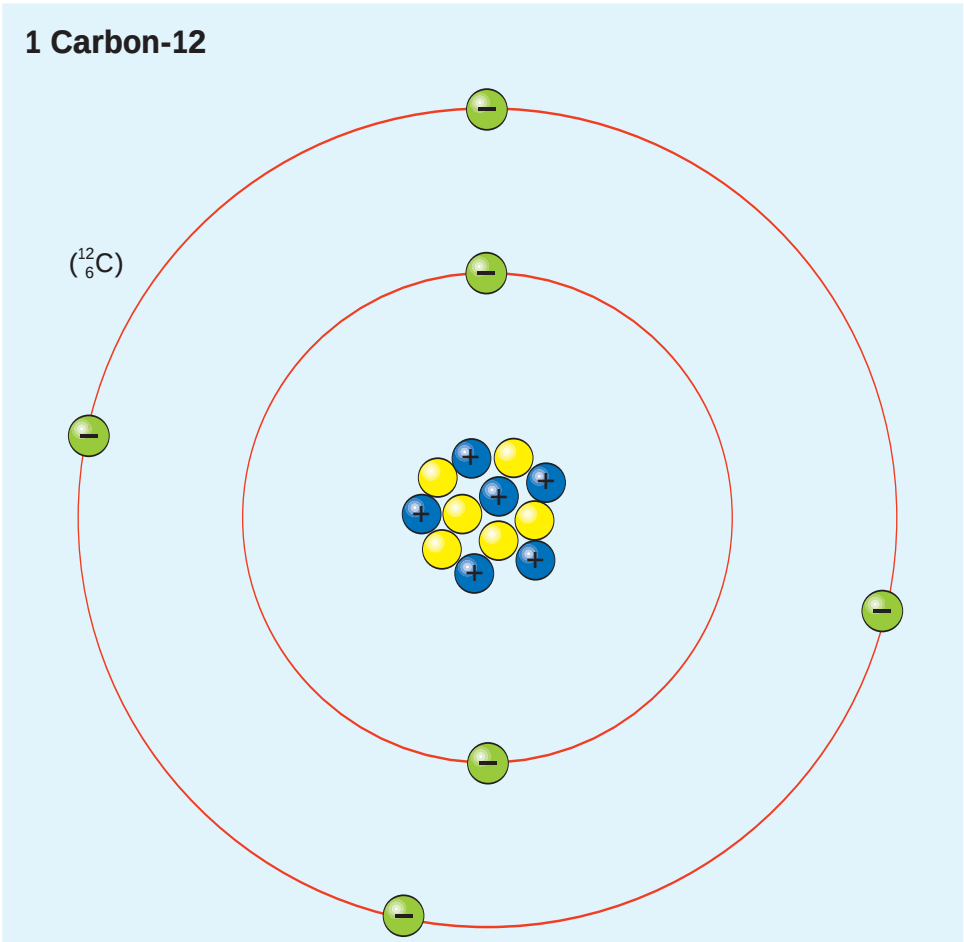

- To compare the masses of different atoms accurately, scientists need a standard mass against which all other masses can be calculated. Masses are given relative to this standard.
- The *isotope* carbon-12 is used as the standard. On this scale, atoms of carbon-12 are given a mass of exactly 12. The *atomic masses* of all other atoms are given relative to this standard.
- If an element contained only one isotope, its atomic mass would be the relative mass of that isotope. However, most elements contain a mixture of several isotopes in varying proportions.
- Natural abundance gives the proportion of each isotope in a sample of the element.
- If more than one isotope of an element is present, the atomic mass is calculated by taking an average that takes into account the relative proportion of each isotope. Diagrams 2 and 3 illustrate how the atomic mass of common isotopes of lithium and chlorine would be calculated.

2 Lithium

Isotope		Natural abundance
Lithium-6	($^{6}_{3}$Li)	7.5%
Lithium-7	($^{7}_{3}$Li)	92.5%

The relative atomic mass of lithium is given by:

$$\frac{(6 \times 7.5) + (7 \times 92.5)}{100} = 6.925$$

- There are two common isotopes of lithium: lithium-6 and lithium-7.
- The atomic mass of lithium is 6.925, but for most calculates a value of 7 is sufficiently accurate.

3 Chlorine

Isotope		Natural abundance
Chlorine-35	($^{35}_{17}$Cl)	75.77%
Chlorine-37	($^{37}_{17}$Cl)	24.23%

The relative atomic mass of lithiumis given by:

$$\frac{(35 \times 75.77) + (37 \times 24.23)}{100} = 35.4846$$

- There are also two common isotopes of chlorine: chlorine-35 and chlorine-37.
- The atomic mass of chlorine is 35.4846, but for most calculations a value of 35.5 is sufficiently accurate.
- Rounding the atomic mass of chlorine to the nearest whole number would lead to significant errors in calculations.

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Key words

atomic mass
atomic number
element
isotope

Atomic mass

- The *atomic mass* of an *element* is the average of the relative masses of its *isotopes*. It provides the relative mass of an "average" atom of the element, which is useful for calculations.
- The atomic mass is represented by the symbol A(r)
- The atomic mass of an isotope is its mass relative to the isotope carbon-12.
- The atomic mass of an isotope is the sum of the protons and neutrons in its nucleus.
- The atomic masses of the elements are presented below the element on the periodic table at right.

Atomic number

- The *atomic number* of an element is the number of protons in its nucleus.
- The atomic number is usually represented by Z.
- The number of neutrons in the nucleus of an isotope is:
  A(r) – Z
- The atomic numbers of the elements are presented above the element in the periodic table at right.

Periodic table with masses and numbers

																	2 **He** 4.00
											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
1 **H** 1.008											13 **Al** 27.00	14 **Si** 28.08	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
3 **Li** 6.94	4 **Be** 9.01										31 **Ga** 69.72	32 **Ge** 72.64	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
11 **Na** 23.00	12 **Mg** 24.31										49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.84	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.41					
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.90	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.00	44 **Ru** 101.07	45 **Rh** 102.90	46 **Pd** 106.42	47 **Ag** 106.90	48 **Cd** 112.41	81 **Tl** 204.38	82 **Pb** 207.20	83 **Bi** 208.98	84 **Po** 210	85 **At** 210	86 **Rn** 220
55 **Cs** 132.90	56 **Ba** 137.33	57–71	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	113 **Uut** 284	114 **Uuq** 289	115 **Uup** 288	116 **Uuh** 292		
87 **Fr** 223	88 **Ra** 226	89–103	104 **Rf** 261	105 **Db** 262	106 **Sg** 266	107 **Bh** 264	108 **Hs** 277	109 **Mt** 268	110 **Ds** 271	111 **Rg** 272	112 **Uub** 285						

57 **La** 138.90	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 145.00	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
89 **Ac** 227	90 **Th** 232.04	91 **Pa** 231.03	92 **U** 238.03	93 **Np** 237	94 **Pu** 244	95 **Am** 243	96 **Cm** 247	97 **Bk** 247	98 **Cf** 251	99 **Es** 252	100 **Fm** 257	101 **Md** 258	102 **No** 259	103 **Lr** 262

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Calculating the molecular mass of compounds

1 Diatomic molecule (chlorine)

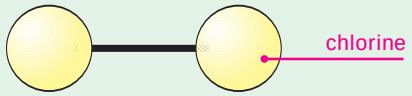

Cl = 35.45

2 Covalent compound (ethanol)

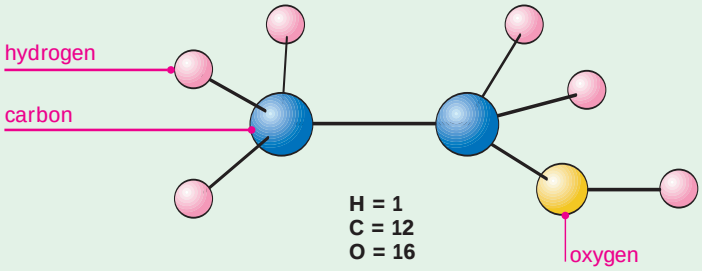

H = 1
C = 12
O = 16

3 Ionic compound (sodium chloride)

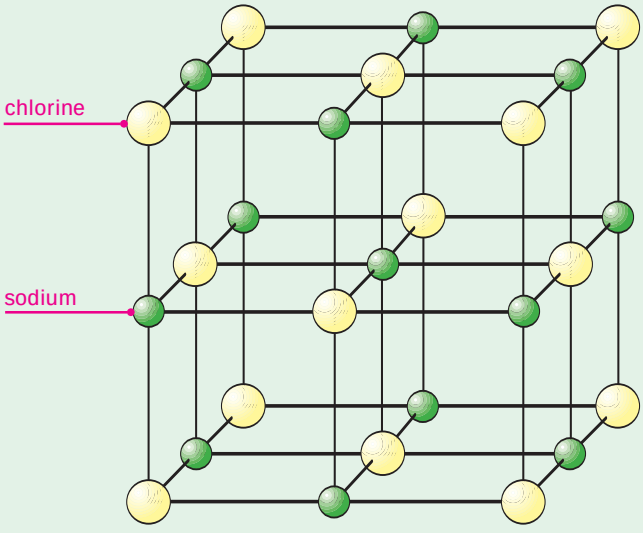

Na = 23.00
Cl = 35.45

Key words

atomic mass
covalent compound
diatomic molecule
ionic compound
lattice
molecular mass

Calculating molecular mass

You calculate the *molecular mass* of a compound the same way regardless of structure:

1. Multiply the number of atoms in an element by its *atomic mass.*
2. Repeat this process for each element in the compound, then
3. Add the numbers.

1 Diatonic molecule (chlorine)

- The element chlorine exists as a *diatomic molecule* Cl_2.
  Atomic mass of chlorine = 35.5
  Molecular mass of chlorine
  = 2 x 35.5 = 71

2 Covalent compound (ethanol)

- Ethanol is a simple *covalent compound* that has the formula C_2H_5OH.
  Atomic mass of carbon = 12;
  hydrogen = 1; oxygen = 16.
  Molecular mass of ethanol
  = (2 x 12) + (6 x 1) + (1 x 16) = 46

3 Ionic compound (sodium chloride)

- *Ionic compounds* do not exist as molecules but as a giant *lattice* composed of ions in a fixed ratio. The formula mass of an ionic compound is the sum of the atomic masses of the ions in their simplest ratio.
- Sodium chloride consists of an ionic lattice in which the ions are present in the ratio 1:1. Therefore, the formula of sodium chloride is taken to be NaCl.
  Atomic mass of sodium = 23;
  chlorine = 35.5.
  Formula mass of sodium chloride
  = 23 + 35.5 = 58.5

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Key words

anion
bond
cation
coordination number
ionic crystal
ion
lattice

Ionic crystals

- In an *ionic crystal*, each *ion* is surrounded by a number of oppositely charged ions in a *lattice* structure.
- There are several types of ionic structures.
  Simple: The atoms form grids.
  Body centered: One atom sits in the center of each cube.
  Face centered: One atom sits in each "face" of the cube.
- The lattice structure is determined by two factors:
  1. the ratio of the number of *cations* (positively charged ions) to *anions* (negatively charged ions)
  2. the ratio of the radii of the ions.
- In general, the higher the value of the radius ratio the higher the *coordination number* of the lattice. The coordination number is the number of atoms, ions, or molecules to which *bonds* can be formed.

1 Simple cubic structure (CsCl)

- In cesium chloride, the radius ratio is 0.94 (due to the large cesium ion). The coordination is 8:8. Each ion is surrounded by 8 oppositely charged ions.

2 Face-centered cubic structure (NaCl)

- The radius ratio in the sodium chloride lattice is 0.57. The coordination is 6:6. Each ion is surrounded by 6 oppositely charged ions.

3 Body-centered cubic structure (CaF_2)

- In calcium fluoride the radius ratio is 0.75. The coordination is 8:4. Each calcium ion is surrounded by 8 fluoride ions, while each fluoride ion is surrounded by 4 calcium ions.

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Structure of some ionic crystals

1 Simple cubic structure (CsCl)

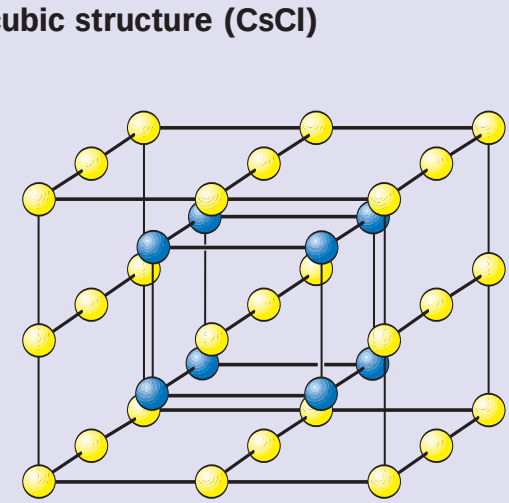

2 Face-centered cubic structure (NaCl)

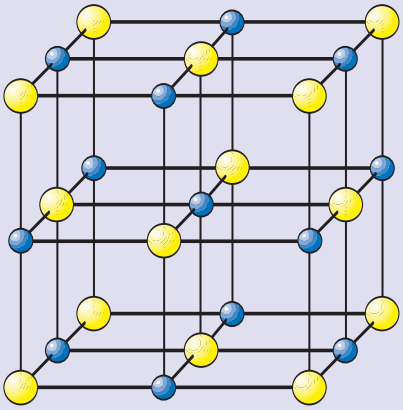

3 Body-centered cubic structure (CaF_2)

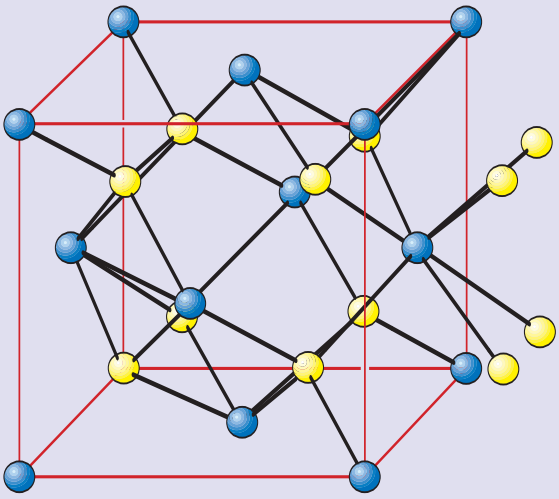

Crystal structure of metals: lattice structure

Key words

body centered cubic packing
crystal
face-centered cubic close packing
hexagonal close packing
lattice
unit cell

1 Hexagonal close packing

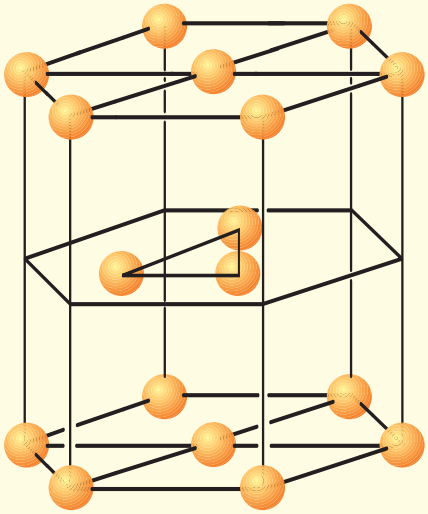

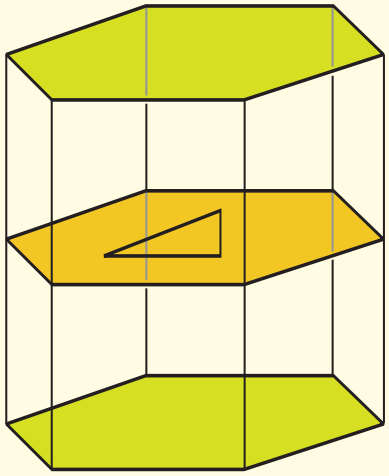

2 Face-centered cubic close packing

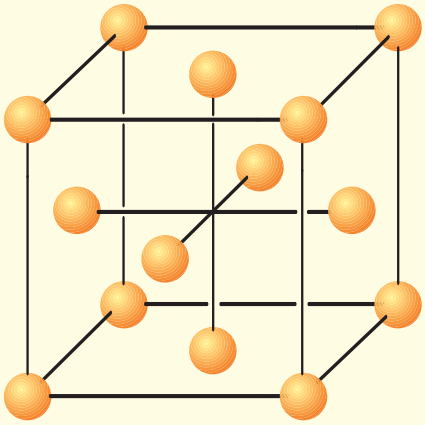

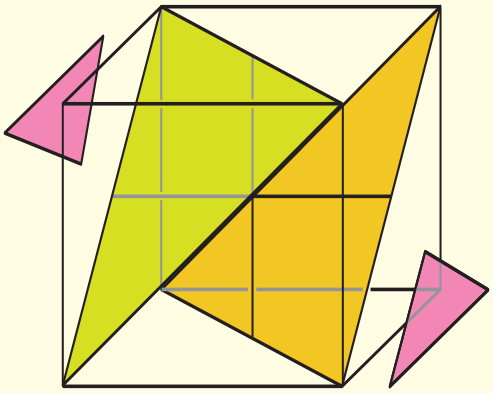

3 Body-centered cubic packing

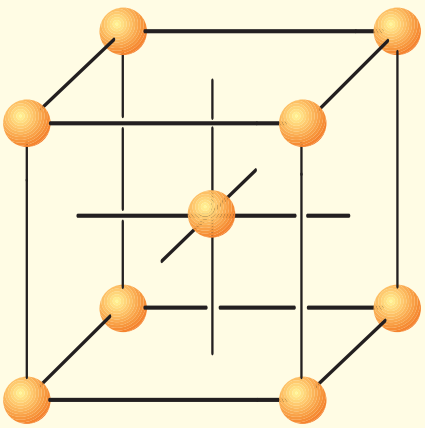

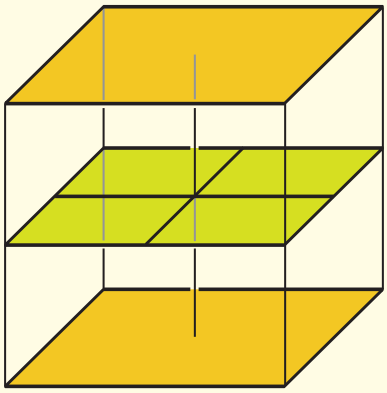

Metallic crystals

- Like all other *crystals*, metallic crystals are composed of *unit cells*, sets of atoms, ions, or molecules in orderly three dimensional arrangements called *lattices*.

1 Hexagonal close packing

- When arranged in a single layer, the most efficient method of packing the ions is in the form of a hexagon in which each ion is surrounded by six other ions.
- In *hexagonal close packing*, a second layer is positioned so that each ion in the second layer is in contact with three ions in the first layer. The third layer is placed directly above the first, and the fourth layer directly above the second, etc. This arrangement is sometimes represented as ABABAB.

2 Face-centered cubic close packing

- Here the third layer does not sit directly above either the first or second layers. The pattern is repeated after three layers, giving rise to an ABCABCABC arrangement.

3 Body-centered cubic packing

- Here the layers are formed from ions arranged in squares. The second layer is positioned so that each sphere in the second layer is in contact with four spheres in the first layer. The third layer sits directly above the first layer, giving rise to an ABABAB arrangement.

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Key words

body-centered cubic packing
coordination number
face-centered cubic close packing
hexagonal close packing

1 Efficient packing

- Both *hexagonal close packing* and *face-centered cubic close packing* may be considered as efficient packing since the spheres occupy 74 percent of the available space. In both arrangements, each sphere is in contact with 12 others, and is said to have a *coordination number* of 12.

2 Less efficient packing

- *Body-centered cubic packing* is less efficient than hexagonal and face-centered cubic close packing. Spheres occupy only 68 percent of the available space. Each sphere is in contact with eight others (four in the layer above and four in the layer below) and, therefore, has a coordination number of eight.

Metals showing hexagonal close packing

- Cobalt
- Magnesium
- Titanium
- Zinc

Metals showing face-centered cubic close packing

- Aluminum
- Calcium
- Copper
- Lead
- Nickel

Metals showing body-centered cubic packing

- Group 1 metals
- Barium
- Chromium
- Iron
- Vanadium

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Crystal structure of metals: efficient packing

1 Efficient packing

Hexagonal close packing

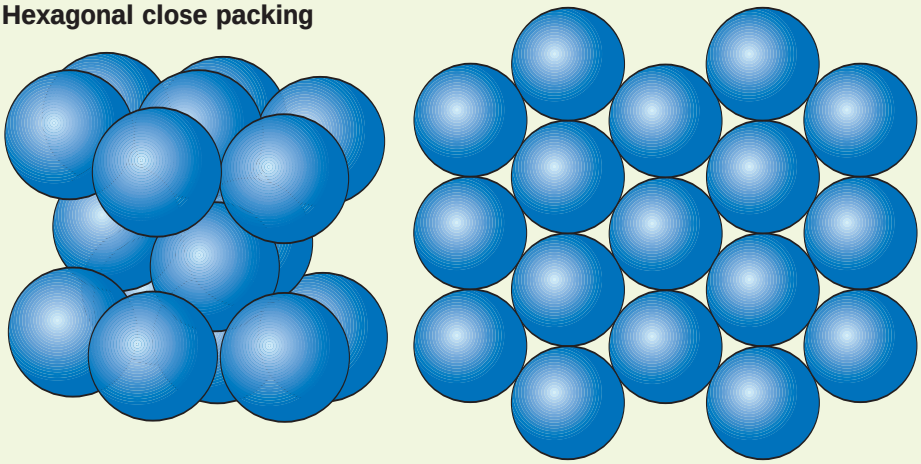

Face-centered cubic close packing

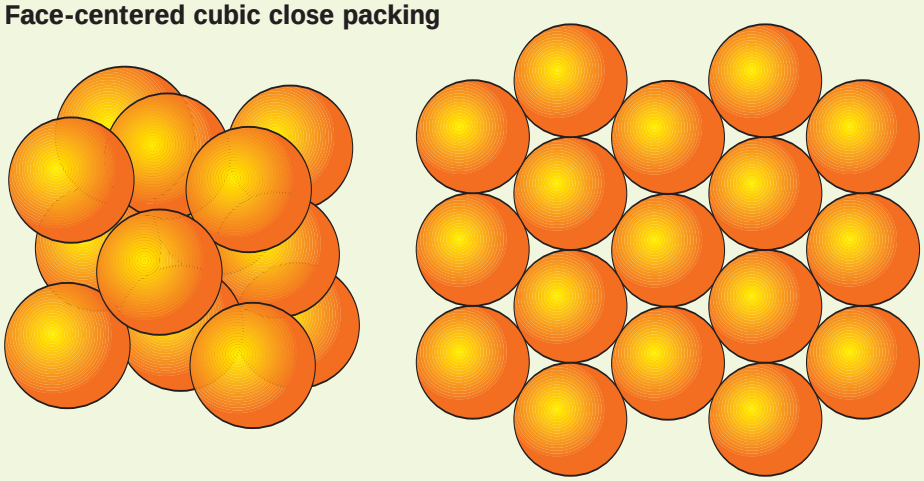

2 Less efficient packing

Body-centered cubic packing

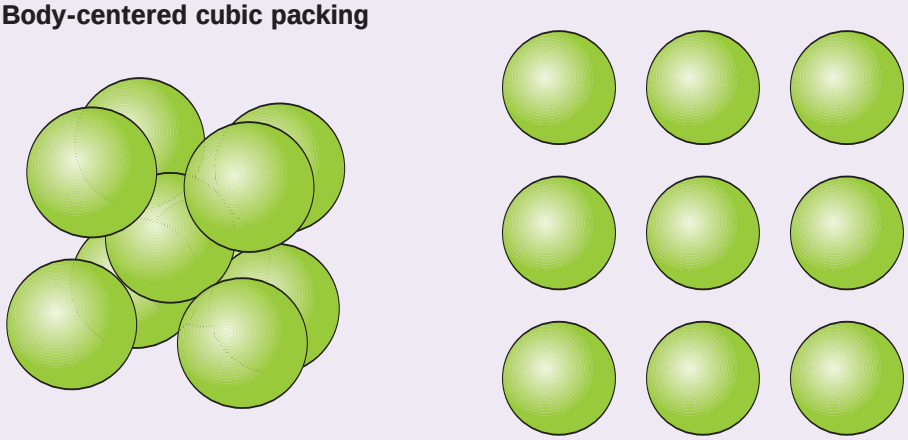

Chemical combination: ionic bonding

1 Formation of sodium chloride (NaCl)

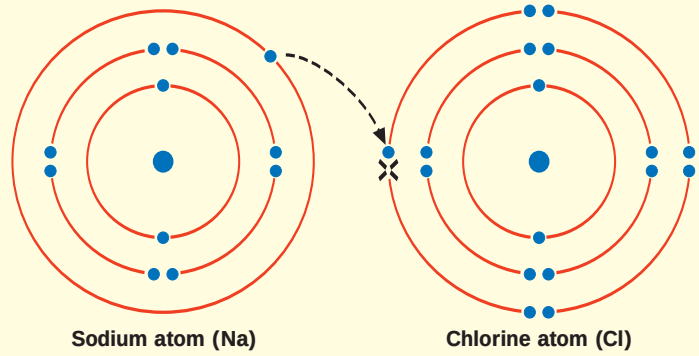

Sodium atom (Na) Chlorine atom (Cl)

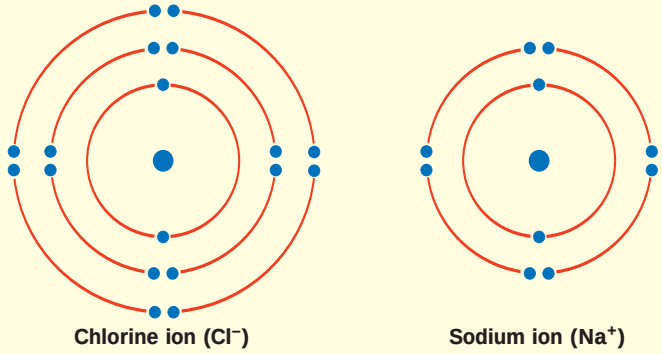

Chlorine ion (Cl^-) Sodium ion (Na^+)

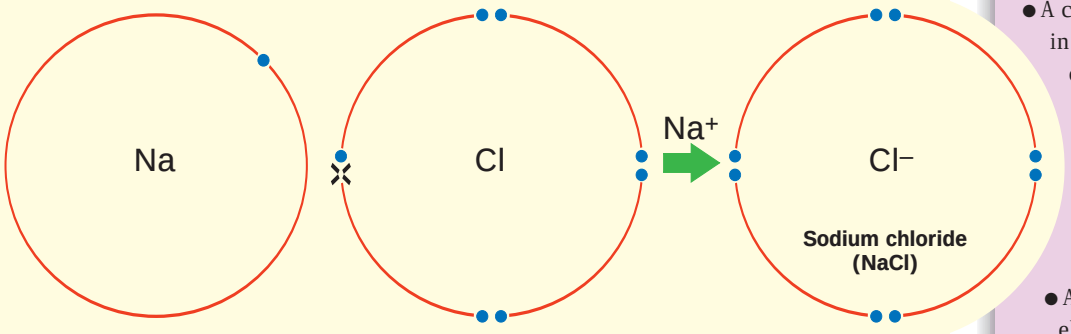

2 Formation of magnesium oxide (MgO)

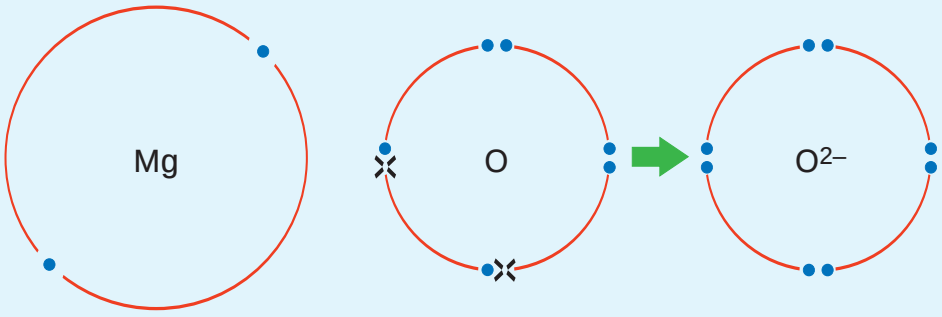

Magnesium ion (Mg^{2+}) Oxygen ion (O^{2-}) Magnesium oxide

Key words

anion
bond
cation
chloride
ionic bonding
noble gases
oxide
shell

Ionic bonding

- Ionic *bonds* are formed by the attraction of opposite charges.
- In *ionic bonding*, the atoms in a compound gain, lose, or share electrons so the number of electrons in their outer *shell* is the same as the nearest *noble gas* on the periodic table.
- Non-metals gain electrons to give negatively charged ions (*anions*).
- Metal atoms loose electrons to give positively charged ions (*cations*).

1 Formation of sodium chloride (NaCl)

- A sodium atom has one electron in its outer shell. The easiest way it can attain a complete outer shell is by losing this electron to form a sodium ion, Na^+.
- A chlorine atom has seven electrons in its outer shell. The easiest way it can attain a complete outer shell is by gaining one more electron to form a *chloride* ion, Cl^-.

2 Formation of magnesium oxide (MgO)

- A magnesium atom has two electrons in its outer shell. It loses these electrons to form a magnesium ion, Mg^{2+}.
- An oxygen atom has six electrons in its outer shell. It gains two electrons to form an *oxide* ion, O^{2-}.

Electronic configuration

Na (sodium atom)	2.8.1
Na^+ (sodium ion)	2.8
Cl (chlorine atom)	2.8.7
Cl^- (chloride ion)	2.8.8
Mg (magnesium atom)	2.8.2
Mg^{2+} (magnesium ion)	2.8
O (oxygen atom)	2.6
O^{2-} (oxide ion)	2.8

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Key words

carbonate
ion
limiting form
nitrate
radical
resonance structure
sulfate

Radicals

- A *radical* is a group of atoms that cannot be represented by one structural formula. It can pass unchanged through a series of chemical reactions. Radicals include the *carbonate* ion, CO_3^{2-}, the *nitrate* ion, NO_3^-, and the *sulfate* ion, SO_4^{2-}.

1 Carbonate ion

- The carbon atom is bonded to three oxygen atoms. By transferring electrons, it is possible to write three *limiting forms* for this *ion*. (Limiting forms are the possibilities for the distribution of electrons in a molecule or ion.)
- Electrons are continually being transferred in the ion. Thus its exact form is constantly changing. The ion is best represented as a *resonance structure* (the average of the limiting forms) in which dotted lines indicate that the charge on the ion, 2-, is spread over all three of the carbon–oxygen bonds.

2 Nitrate ion

- The nitrogen atom is bonded to three oxygen atoms. This ion has three limiting forms.
- It is best represented as a resonance structure in which dotted lines indicate that the charge on the ion, 1-, is spread over all three of the nitrogen–oxygen bonds.

3 Sulfate ion

- The sulfur atom is bonded to four oxygen atoms. This ion has three limiting forms.
- The ion's exact form is constantly changing. It is best represented as a resonance structure in which dotted lines indicate that the charge on the ion, 2-, is spread over all four of the sulfur–oxygen bonds.

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Chemical combination: ionic radicals

1 Carbonate ion

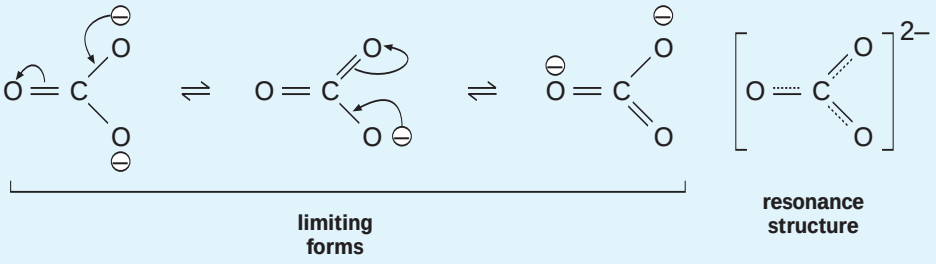

2 Nitrate ion

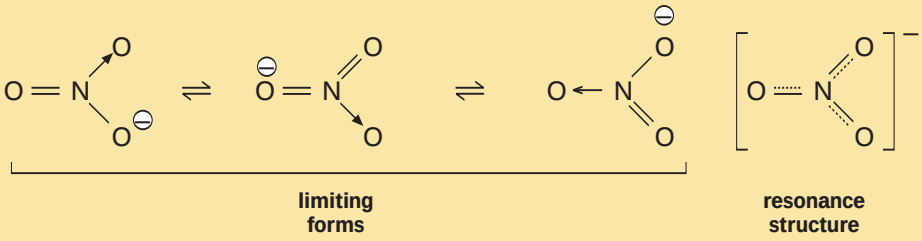

3 Sulfate ion

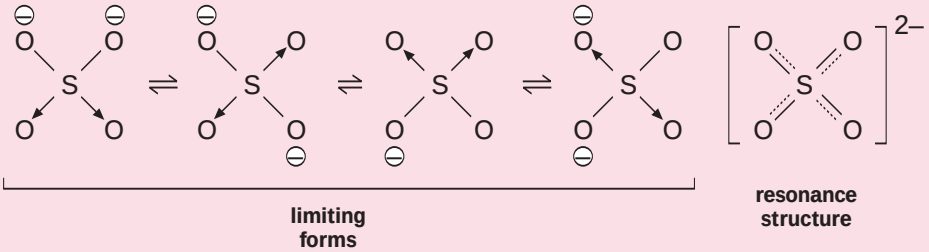

Chemical combination: covalent bonding

1 The hydrogen molecule

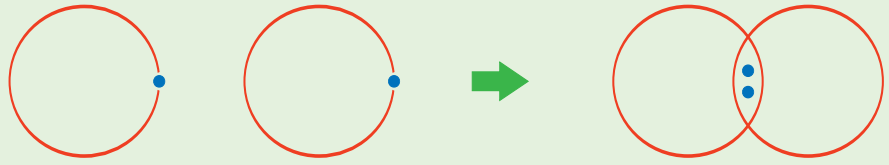

2 hydrogen atoms

hydrogen molecule (H_2)

3 The ammonia molecule

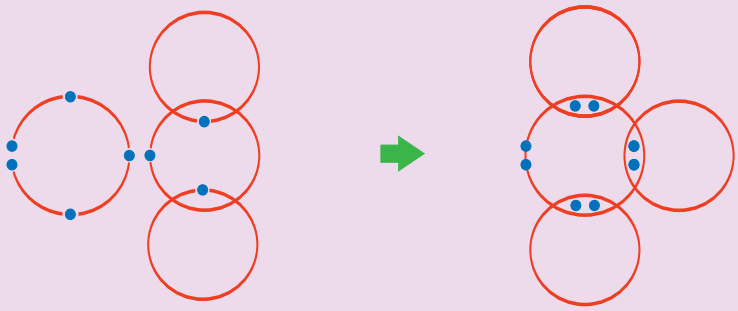

nitrogen atom

3 hydrogen atoms

ammonia molecule (NH_3)

4 The methane molecule

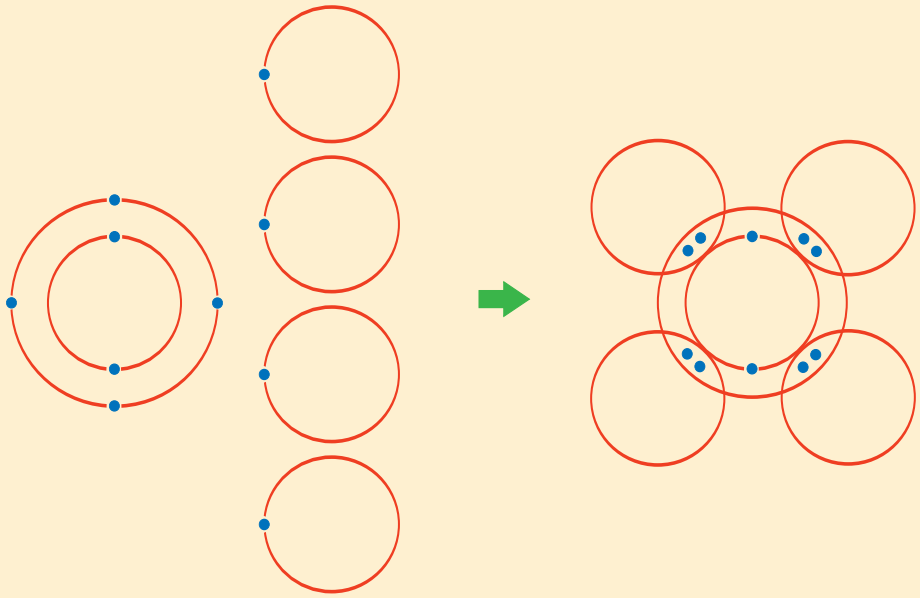

carbon atom

4 hydrogen atoms

amolecule (CH_4)

Key words

ammonia
bond
carbon
hydrogen
ionic compound
methane
nitrogen
shell

Covalent bonding

- Atoms gain stability by having a complete outer *shell* of electrons. In *ionic compounds*, this is achieved by the transfer of electrons. In covalent bonding, atoms share electrons.

1 The hydrogen molecule

- A *hydrogen* atom has one electron in its outer shell. In a hydrogen molecule, two hydrogen atoms each donate this electron to form a *bond*. Each hydrogen atom can be thought of as having control of the pair of electrons in the bond. Thus, each can be thought of as having a full outer shell of electrons. The single bond is shown as H-H.

2 The ammonia molecule

- A *nitrogen* atom has five electrons in its outer shell and needs another three electrons to complete the shell. In *ammonia*, three hydrogen atoms each donate one electron to form three N-H bonds. The nitrogen atom now has control of eight electrons and has a complete outer shell, while each hydrogen atom has control of two electrons and also has a complete outer shell.

3 The methane molecule

- A *carbon* atom has four electrons in its outer shell and needs another four electrons to complete the shell. In *methane*, four hydrogen atoms each donate one electron to form four C-H bonds. The carbon atom now has control of eight electrons and has a complete outer shell, while each hydrogen atom has control of two electrons and also has a complete outer shell.

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Key words

ammonium ion
coordinate bonding
covalent bond
covalent compound
hydronium ion
lone pair

Coordinate bonding

- *Coordinate bonding* is a particular form of covalent bonding in which one atom provides both electrons that the two atoms share.

1 Ammonium ion

- There is a non-bonding or *lone pair* of electrons on the nitrogen atom of an ammonia molecule. Nitrogen uses this lone pair to form a coordinate bond with a hydrogen ion, forming the *ammonium ion*, NH_4^+.

2 Hydronium ion

- The *hydronium ion*, H_3O^+, forms in a similar way.

3 Aluminum chloride

- The Al^{3+} ion is very small and carries a high charge. It attracts electrons so strongly that aluminum chloride is a *covalent compound*. It exists as Al_2Cl_6 molecules in which two $AlCl_3$ molecules are linked by coordinate bonds formed by the donation of lone pairs of electrons from two chlorine atoms.

4 Ionic compounds with covalent character

- The ions in a sodium chloride lattice are perfectly spherical. Thus the bonds in this compound are said to be perfectly ionic.
- But in an ionic compound consisting of a small, highly charged positive ion and a large negative ion such as lithium iodide, the positive ion attracts electron charge away from the negative ion. The result is that the negative ion becomes distorted, and electron density becomes concentrated between the ions, creating a bond similar to a *covalent bond*. Compounds like lithium iodide are said to be ionic with covalent character.

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Chemical combination: coordinate bonding

1 Ammonium ion

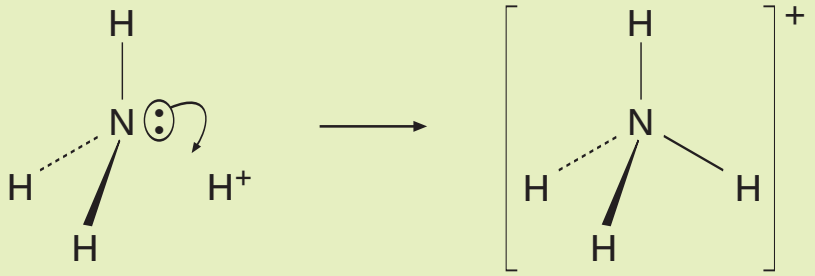

2 Hydronium ion

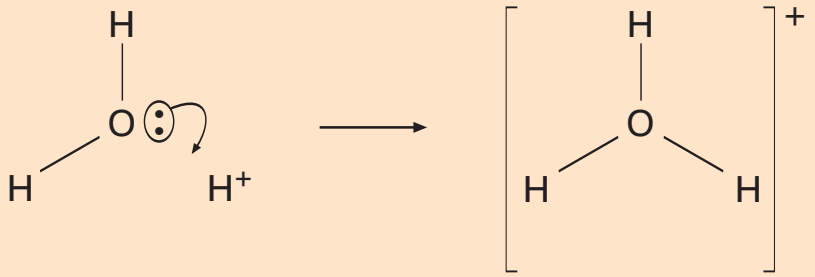

3 Aluminum chloride

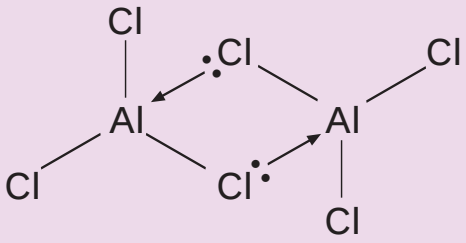

4 Ionic compounds with covalent character

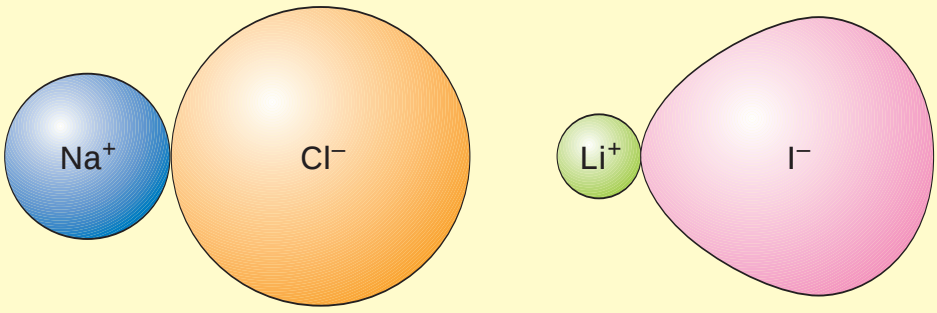

Mixtures and solutions

Producing a solution

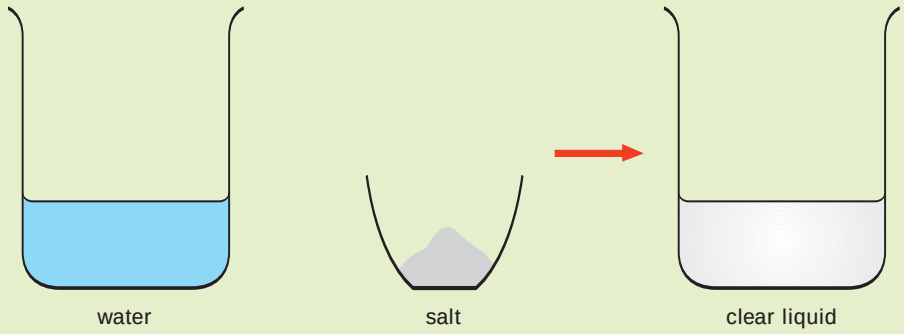

Producing a suspension

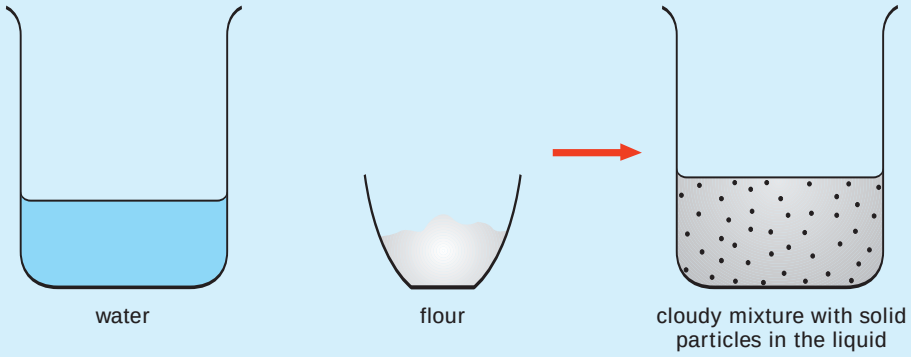

Producing an emulsion

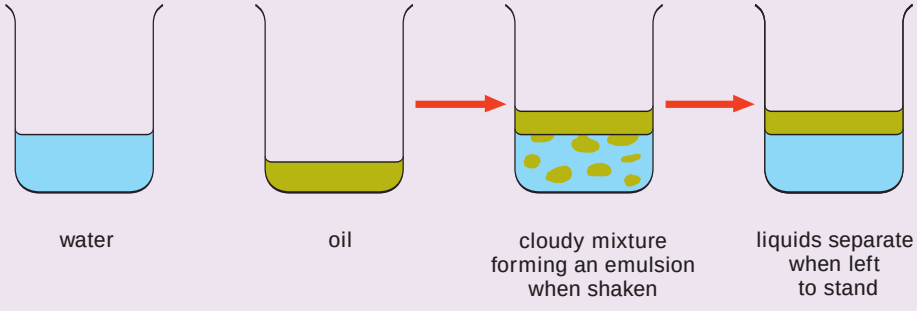

Key words

emulsion
ionic compound
mixture
soluble
solution
suspension

1 Solutions

- A *solution* is a homogeneous *mixture* of substances. Particles in solutions are very small and cannot be seen. The particles may be atoms, ions, or molecules, and their diameters are typically less than 5 nm. Salt dissolves in water to form a clear colorless solution.
- Many, but not, all *ionic compounds* are *soluble* in water.
- A small proportion of organic compounds are soluble in water. However, organic compounds are generally more soluble in organic solvents such as hexane and ethanol.

2 Suspensions

- A *suspension* is a heterogeneous mixture of two components. The particles will settle out over a period of time. Suspended particles have diameters that are typically 1,000 nm or more.
- When flour is mixed with water, it forms a white suspension. Tiny particles of flour are suspended in the water. The flour particles can be filtered off from the suspension.

3 Emulsions

- An *emulsion* is a colloidal dispersion of small droplets of one liquid in another (See page 46).
- When oil and water are mixed, they form an emulsion. Oil is less dense than water and forms the upper layer.
- Tiny oil droplets are suspended in the water. After a while, the oil droplets join together, and two layers are formed.
- The mixture of oil and water can be separated using a separating funnel.

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Key words

aerosol
colloid
emulsion
filtration
foam
gel
sol
solution
suspension

Colloids

- A *colloid* is a substance made of particles whose size is intermediate between those in *solutions* and *suspensions*.
- The particles in a suspension have a diameter of typically 1,000 nm or more. The particles in a suspension will settle over a period of time.
- The particles in a colloid are approximately 500 nm or less in diameter and do not settle on standing.
- The particles in a colloid cannot be separated from the dispersion medium by ordinary techniques like *filtration* and centrifugation.
- A colloid consists of a dispersing medium and dispersed substance. These terms are analogous to the terms solute and solvent.
- Colloids are classified according to the original phases of their constituents. The main types are: *aerosols*, *foams*, *emulsions*, *sols*, and *gels*.
- Aerosols are extremely small solid or liquid particles suspended in air or another gas.
- Foams form when a gas is suspended in a liquid or a solid.
- Emulsions form when small particles of a liquid are suspended in another liquid.
- Sols form when solid particles are suspended in a liquid.
- Gels are solid particles arranged as a fine network in a liquid to form a jelly.

Colloids

1 In Air

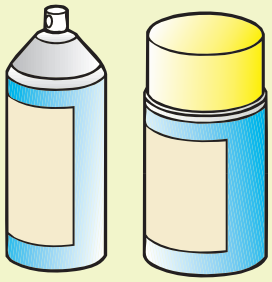

aerosol

1 Colloid type	2 Phase of dispersing medium	3 Phase of dispersed substance	Examples
aerosol	gas	liquid	clouds, fog, insecticide spray
aerosol	gas	solid	dust, smoke

2 In liquids

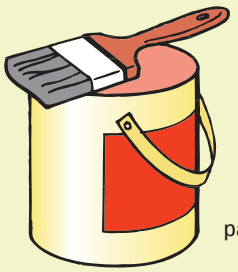

paint

1 Colloid type	2 Phase of dispersing medium	3 Phase of dispersed substance	Examples
foam	liquid	gas	froth, whipped cream
emulsion	liquid	liquid	milk, salad dressing
sol	liquid	solid	milk of magnesia, paint

3 In solids

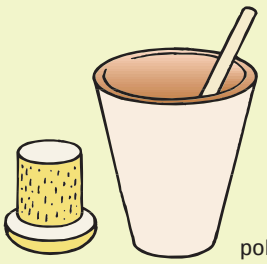

cork polystyrene

1 Colloid type	2 Phase of dispersing medium	3 Phase of dispersed substance	Examples
solid foam	solid	gas	cork, polyurethane
gel	solid	liquid	agar, geletine, jelly
solid sol	solid	solid	alloys

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Simple and fractional distillation

Simple distillation of sea water

	boiling point (°C)
water	100
salt	1,420

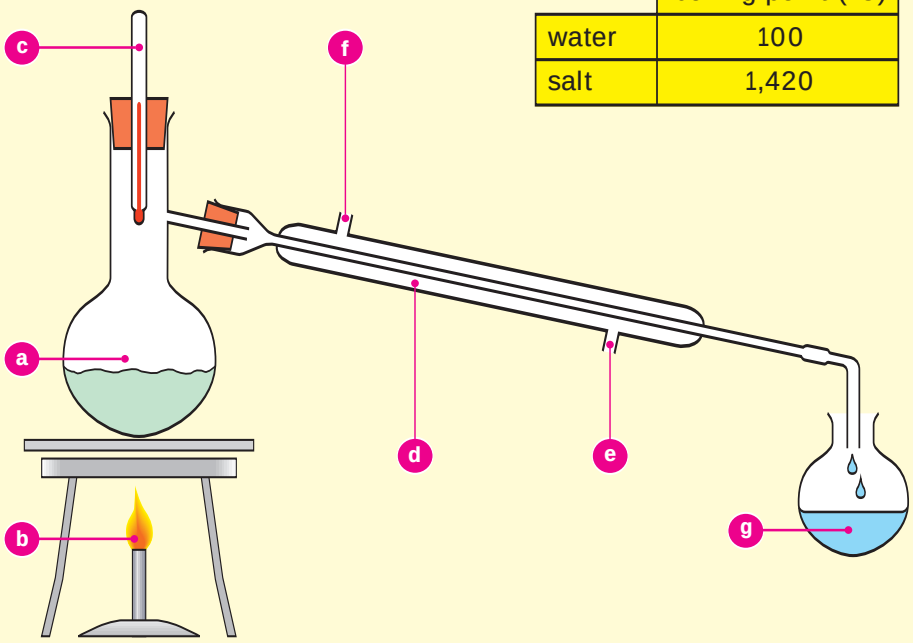

Fractional distillation of ethanol

	boiling point (°C)
water	100
ethanol	78

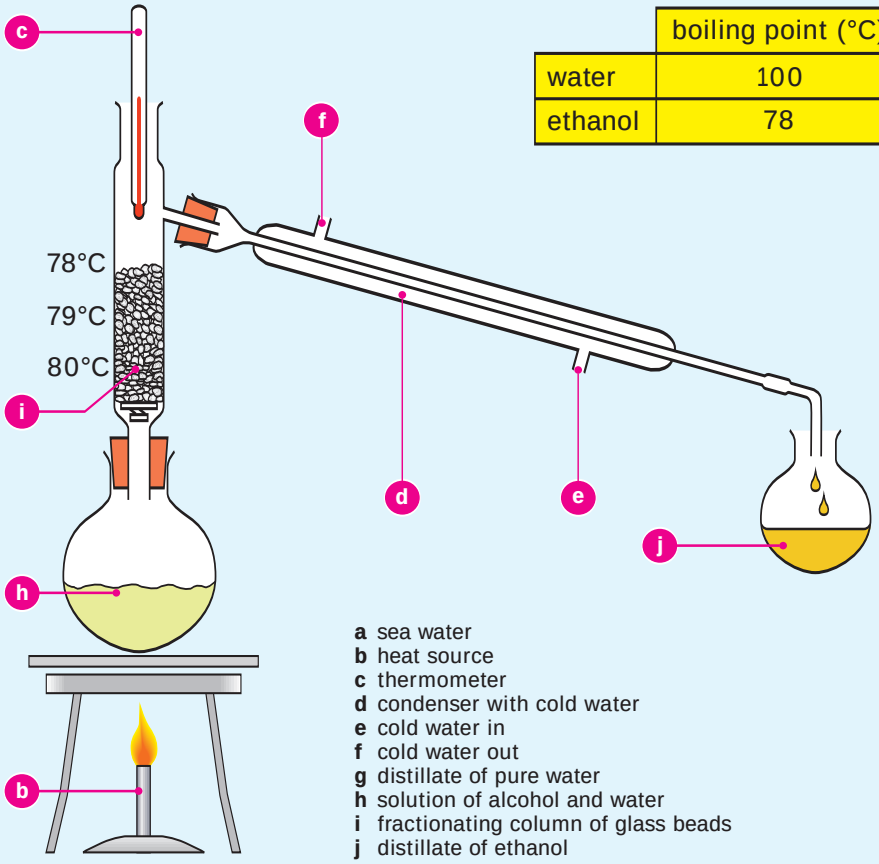

a sea water
b heat source
c thermometer
d condenser with cold water
e cold water in
f cold water out
g distillate of pure water
h solution of alcohol and water
i fractionating column of glass beads
j distillate of ethanol

Key words

boiling point
distillation
fractional distillation
mixture

1 Simple distillation

- *Distillation* is a process in which a *mixture* of materials is heated to separate the components.
- Simple distillation is used when the *boiling points* of the components are widely separated.
- In the diagram, salt water is placed in a round-bottom flask. Water boils at 100°C and becomes water vapor.
- A condenser consists of an inner tube surrounded by a jacket of cold water. This jacket ensures that the inner tube remains cool.
- The vapor passes into the condenser, where it is cooled and changes back into liquid.
- The water runs out of the condenser and is collected in a second flask.
- The salt remains in the round-bottomed flask.

2 Fractional distillation

- *Fractional distillation* is used to separate components whose boiling points are similar.
- Ethanol boils at 78°C and turns to vapor. Because the boiling point of water is only 100°C, a significant amount of water also becomes vapor as a result of evaporation.
- The fractionating column contains glass beads, which provide a large surface area for vapor to condense and the resulting liquid to subsequently boil.
- As the vapor mixture moves up the fractionating column, it condenses and then boils again to become vapor. Each time, the proportion of ethanol in the mixture increases.

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Key words

filtrate
immiscible
insoluble
mixture
residue
soluble
solvent

1 Separating a mixture of two solids

- Sugar is *soluble* in ethanol, while salt is *insoluble*. When a *mixture* of sugar and salt is mixed with ethanol, the sugar dissolves while the salt does not.
- When the mixture is filtered, the undissolved salt remains as the *residue* in the filter. The *filtrate*, sugar solution, passes through the filter.
- If the filtrate is left open to the air, the ethanol evaporates, and solid sugar remains.

2 Separating two solutes in solution

- Salt dissolves in water but not in carbon tetrachloride.
- Iodine is slightly soluble in water but is far more soluble in carbon tetrachloride.
- When a mixture of salt and iodine is shaken in a mixture of water and carbon tetrachloride, the salt dissolves in the water and the iodine in carbon tetrachloride.
- Water and carbon tetrachloride are *immiscible*, they do not mix, and form two layers in a separating funnel. Carbon tetrachloride is more dense than water and forms the lower layer.
- When the layers are run into separate evaporating basins and left, the *solvents*—carbon tetrachloride and water—evaporate, leaving salt and iodine respectively.

Separating solutions

1 Separating a mixture of two solids

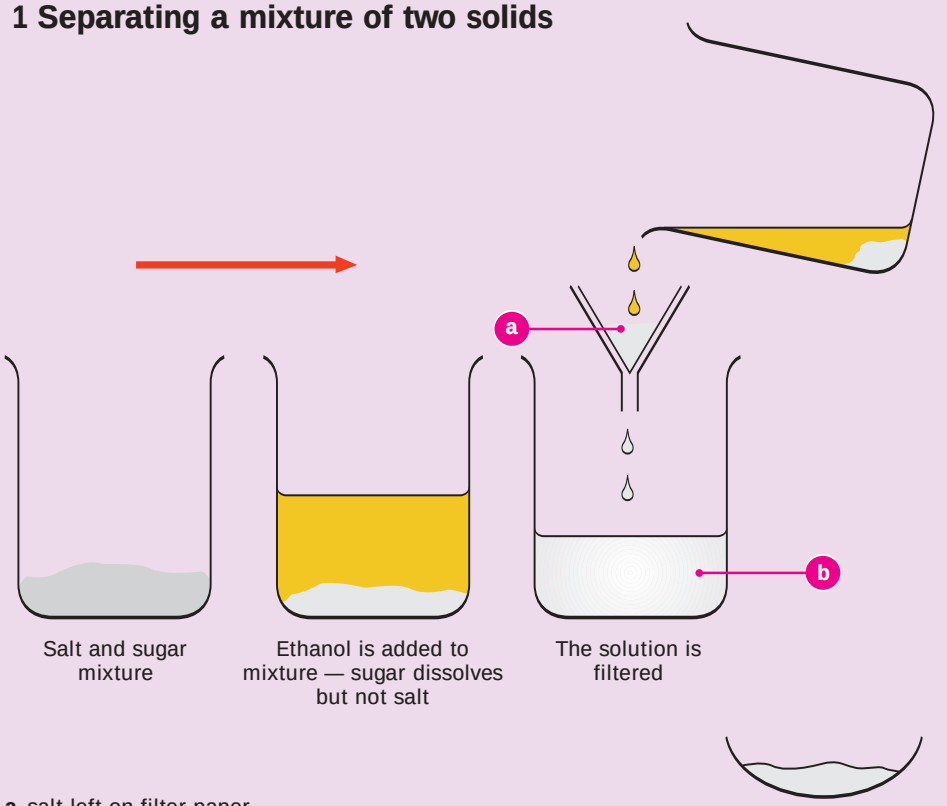

a salt left on filter paper
b sugar solution

2 Separating two solutes in solution

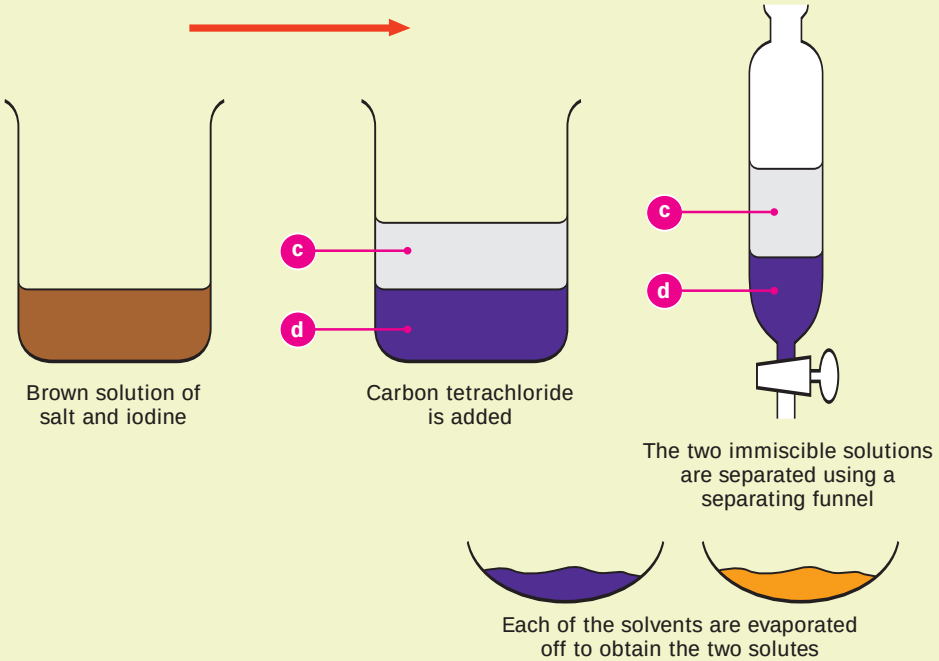

c salt solution in water
d purple solution of iodine in carbon tetrachloride

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Paper chromatography

1 Paper chromatography

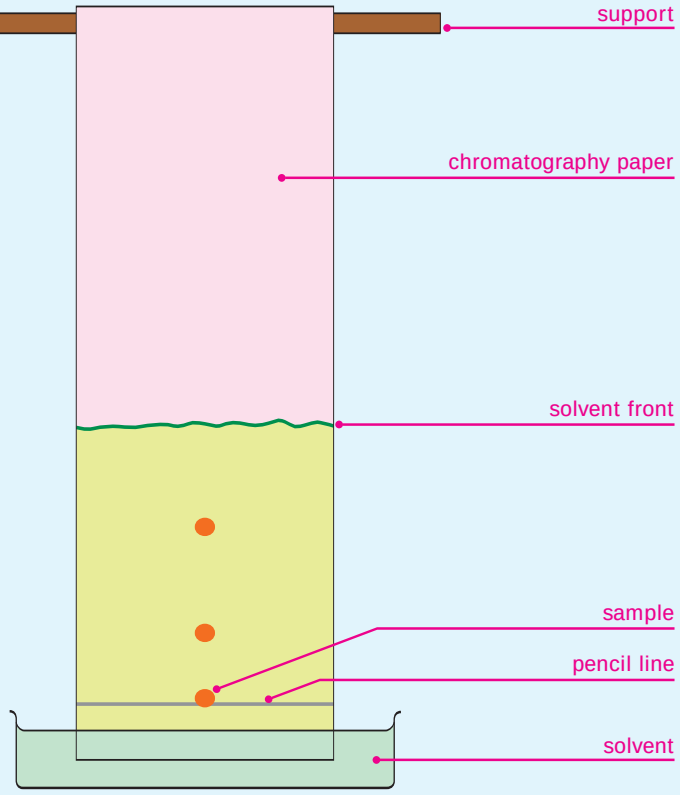

2 R_f value

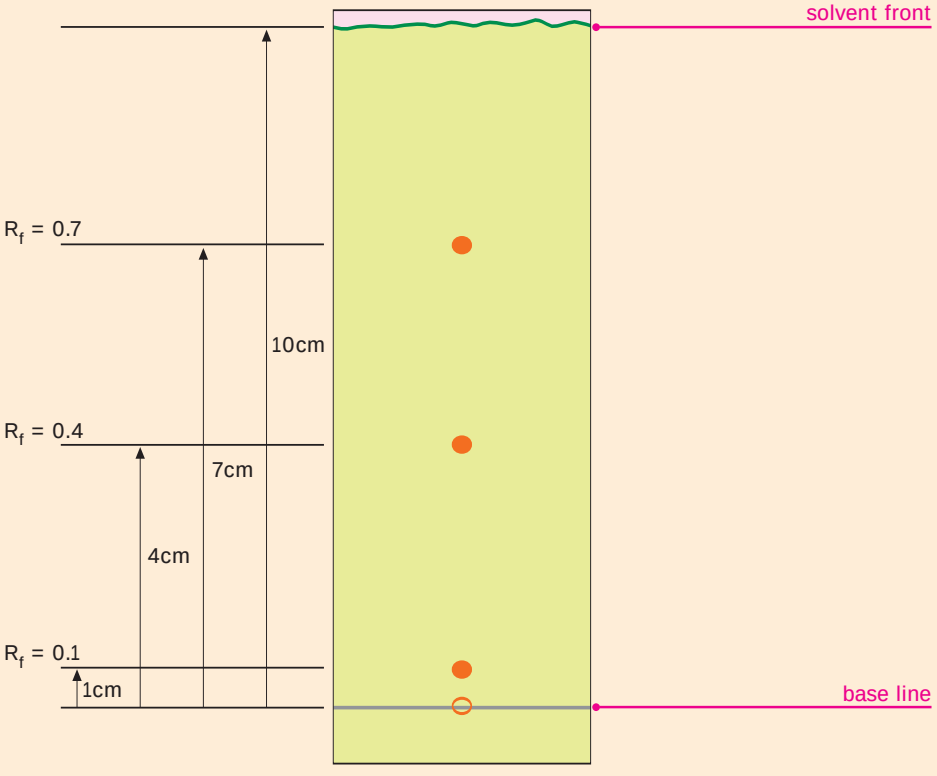

Key words

chromatography
R_f value
mixture
solute
solution
solvent

1 Paper chromatography

- *Chromatography* is a technique for separating and identifying *mixtures* of *solutes* in *solutions*.
- In paper chromatography, absorbent paper is suspended on a support so that only the bottom rests in the *solvent*.
- A base line is drawn in pencil above the level of the solvent. (If ink were used, the dyes in the ink would separate during the process and mix with the sample.)
- A concentrated solution of the sample mixture is made by dissolving as much as possible in a very small volume of solvent.
- A small amount of the concentrated solution is spotted onto the base line. The chromatography paper is suspended over the solvent.
- The solvent rises up the chromatography paper.

2 R_f value

- The *R_f value* is the ratio of the distance moved by a substance in a chromatographic separation to the distance moved by the solvent. The greater the attraction between a substance and the solvent molecules, the greater the R_f value.
- The molecules of each substance in a mixture are attracted both to the chromatography paper and to the solvent molecules.
- The greater the attraction between a substance and the solvent molecules, the quicker it will be carried up the chromatography paper. Dyes that are very soluble in the solvent are carried up to the top of the paper, while those that are less soluble remain lower down.
- The R_f value is independent of the height of the solvent front but is dependent on the solvent used.

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Key words

alkane
chromatography
gas-liquid chromatography
mass spectrometry
mobile phase
stationary phase

Gas-liquid chromatography and mass spectrometry

1 Gas-liquid chromatography

- In chromatography, substances are partitioned between a *stationary phase* and a *mobile phase*. The stationary phase is the substance that retards the components of the sample. The mobile phase is the components of the sample.
- In *gas-liquid chromatography*, the stationary phase, packed into the column, consists of a high-boiling point liquid, such as a long-chain *alkane*, supported by a porous inert solid, such as charcoal or silica.
- The mobile phase consists of a carrier gas—usually nitrogen, hydrogen, helium, or argon.
- A sample mixture is injected into the chamber where it vaporizes and is carried through the column by the carrier gas. Various compounds in the sample pass through the column at different rates due to their attraction to the stationary phase.
- The separated compounds pass to a detector or directly into a mass spectrometer.

2 Mass spectrometry

- *Mass spectrometry* is a technique used to identify the chemical constitution of a substance by means of analyzing its ions.
- The sample passes into the ionization chamber, where it is bombarded by electrons and forms a series of positive ions.
- The ions are accelerated by an electric field and deflected along a circular path by a magnetic field. The lighter the ions, the greater the deflection.
- The intensity of the ion beam is detected electrically, amplified, and finally recorded.
- Each compound gives a characteristic spectrum from which it can be identified.

1 Gas-liquid chromatography

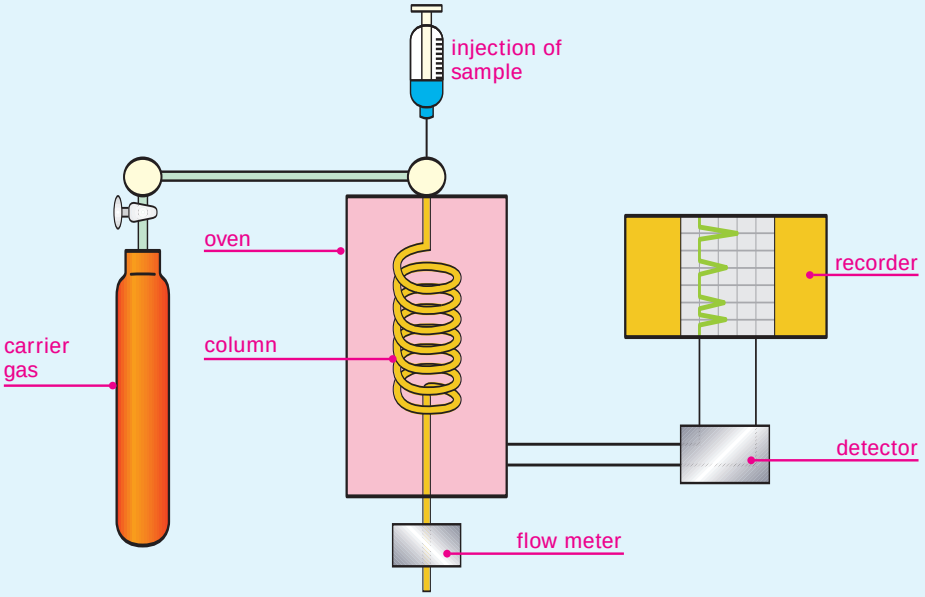

2 Mass spectrometry

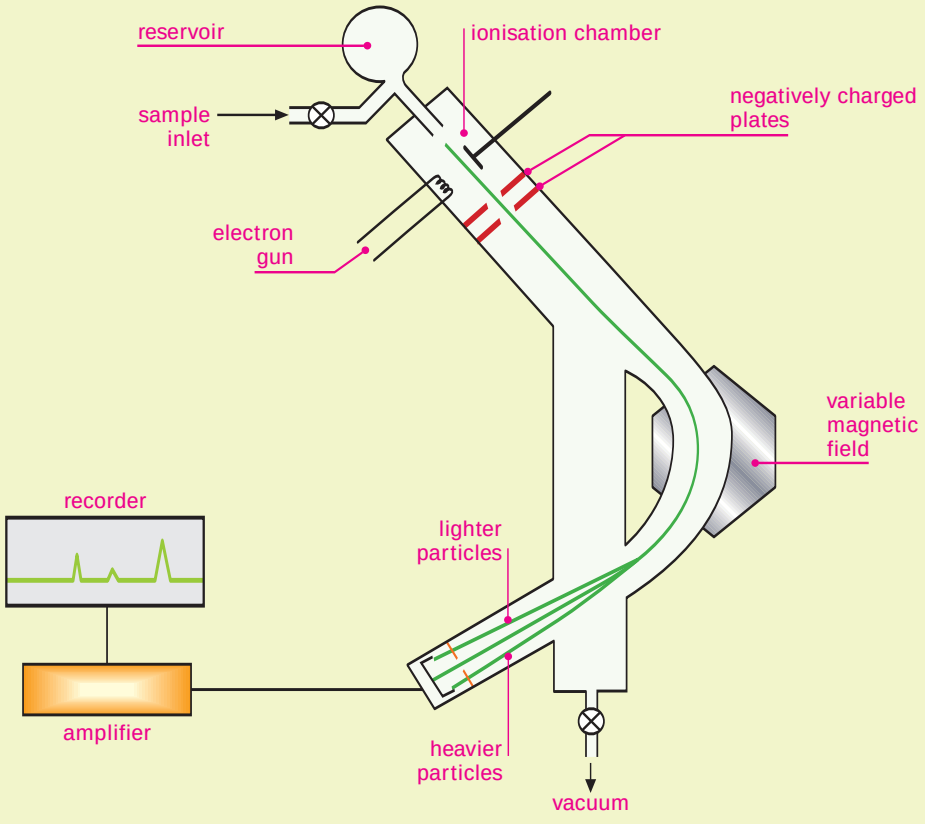

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The pH scale

1 pH scale

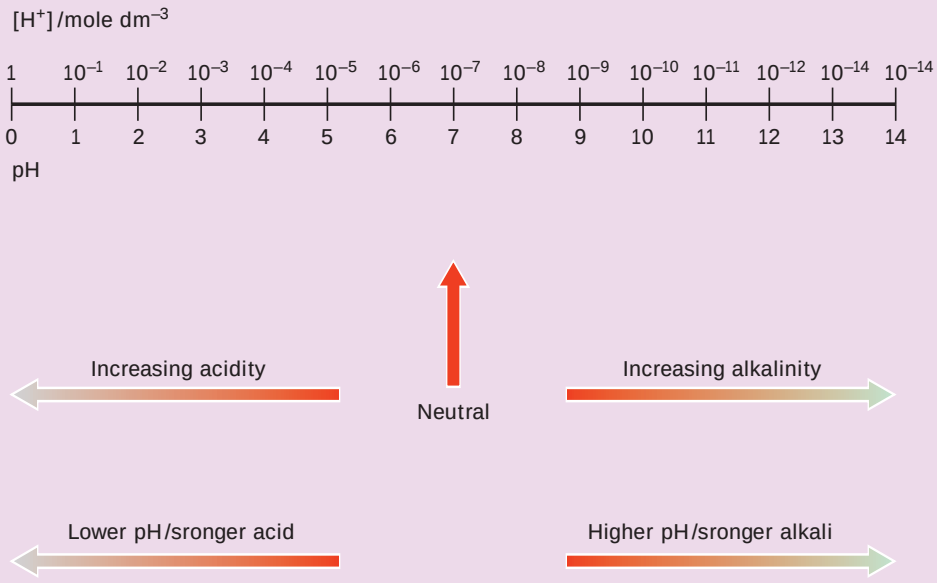

2 Schematic of a pH meter

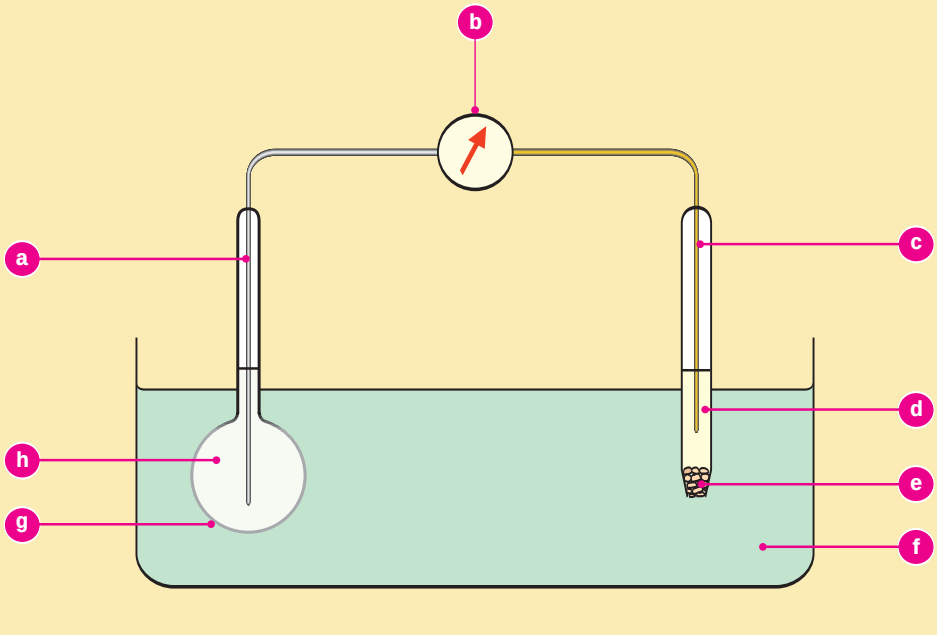

a platinum wire
b sensitive voltmeter
c silver wire coated with silver chloride (AgCl)
d saturated potassium chloride (KCl)
e capillary opening with porous plug
f solution of unknown pH
g Thin glass membrane through which H^+ ions can pass
h solution of fixed acid pH

Key words

acidity
alkalinity
pH
pH meter

1 pH scale

- *pH* is a measure of the *acidity* or *alkalinity* of a solution. The term pH was originally introduced by the Danish biochemist Søren Sørensen in 1909 while working on methods of improving the quality control of beer. The letters pH stand for "potential of hydrogen."
- Acidic solutions always have a pH of less than 7, and alkaline solutions always have a pH of more than 7. The lower the pH value, the more acidic the solution; conversely, the higher the pH value, the more alkaline the solution.
- The pH of a solution is the logarithm to base 10 of the reciprocal of the numerical value of the hydrogen ion concentration:
  $pH = lg(1/[H^+]0 = -lg\ [H^+]$
- The pH of a neutral solution can be calculated directly from the ionic product (K_w) of water:
  $K_w = [H^+][OH^-] = 10^{-14}\ mol^2\ dm^{-6}$
  For a neutral solution:
  $[H^+] = [OH^-] = 10^{-7}\ mol\ dm^{-3}$
  therefore the pH of a neutral solution = 7.
- The pH scale is logarithmic, so hydrogen ion concentration increases or decreases by a power of 10 for each step down or up the scale.

2 pH meter

- A *pH meter* is an electrochemical cell consisting of an electrode, such as a glass electrode, which is sensitive to hydrogen ion concentration, and a reference electrode.
- The emf (electromotive force) of the cell can be measured using a high-resistance voltmeter. A pH meter is a high-resistance voltmeter calibrated with the pH scale.

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Key words

acid
acid-base indicator
alkali
end point
equilibrium
titration
universal indicator

1 Common indicators

- *Acid-base indicators* are substances that are different colors in *acids* and *alkalis* so they "indicate" whether a solution is an acid or alkali.

2 Changing equilibrium

- Acid-base indicators are usually weak acids that disassociate to give an ion that is a different color than the acid. A change in pH causes a change in the position of the equilibrium of the reaction and, therefore, the color of the solution.
- Phenolphthalein is such an indicator. It is a colorless, weak acid that dissociates in water, forming pink anions. Under acidic conditions, the *equilibrium* of the reaction is to the left, and the concentration of the anions is too low for the color to be visible. Under alkaline conditions, the equilibrium is to the right, and the concentration of anions is high enough for the pink to be seen.

3 Universal indicator

- In contrast to an indicator such as phenolphthalein, which is able to show whether a substance is an acid or base only in the broadest terms, a *universal indicator* has a range of colors that indicate how acidic or how alkaline a solution is.

4 pH range of indicators

- Most indicators do not change color when the pH of a solution is exactly 7. This means that the *end point* of the *titration*, the point at which the indicator undergoes the maximum color change, occurs at a different time to the equivalence point of the titration, the point at which there are equivalent amounts of acid and alkali.
- The suitability of an indicator for use in a titration depends on what combination of strong and weak acid and alkali is to be used.

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Indicators

1 Table of common indicators

Indicator	Color in acid	Color in alkali
litmus	red	blue
methyl orange	red	yellow
phenolphthalein	colorless	pink

2 Changing equilibrium (phenol phthalein)

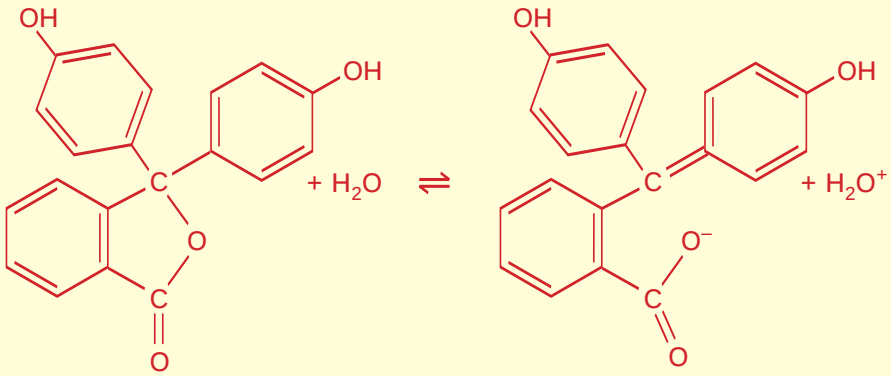

colorless (acid) ⇌ pink (base)

3 Universal indicator

pH														
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
red					orange	yellow	green	blue			purple			
Color														

4 Table of pH range over which acid–base indicators change color

Indicator	Color		pH range over which color change occurs
	Acid	Alkali	
bromocresol green	yellow	blue	3.8–5.4
bromothymol blue	yellow	blue	6.0–7.6
methyl orange	red	yellow	3.2–4.4
methyl red	yellow	red	4.8–6.0
phenolphthalein	colorless	pink	8.2–10.0
phenol red	yellow	red	6.8–8.4

Titration of strong acids

1 Titration of strong acid against strong alkali

(pH changes during the titration of 50 cm^3 of 0.1M HCl with 0.1M NaOH)

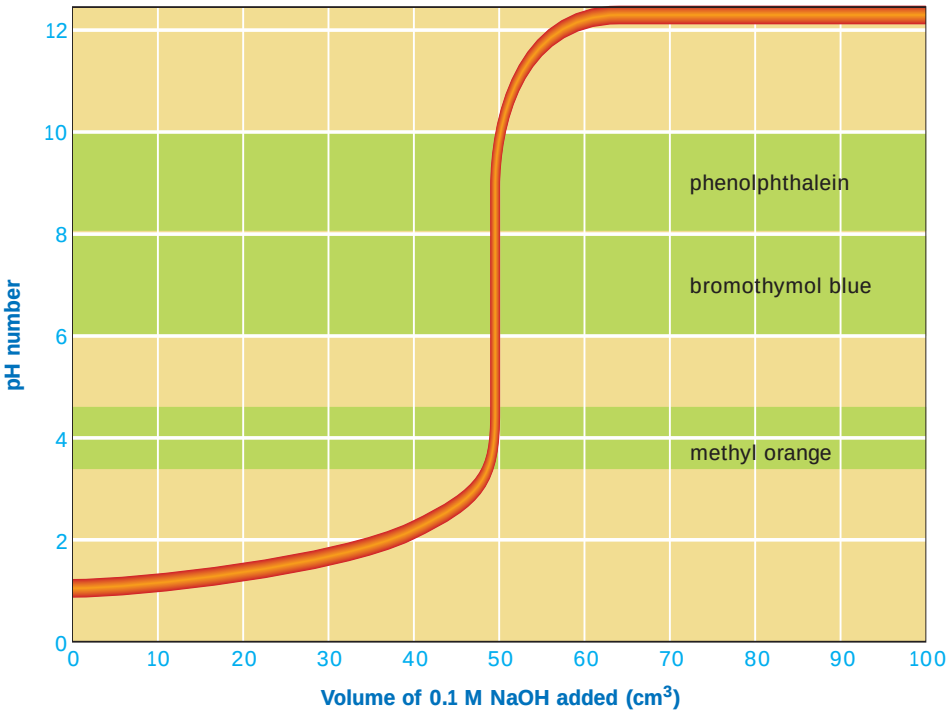

2 Titration of strong acid against weak alkali

(pH changes during the titration of 50 cm^3 of 0.1 M HCl with 0.1 M NH_3)

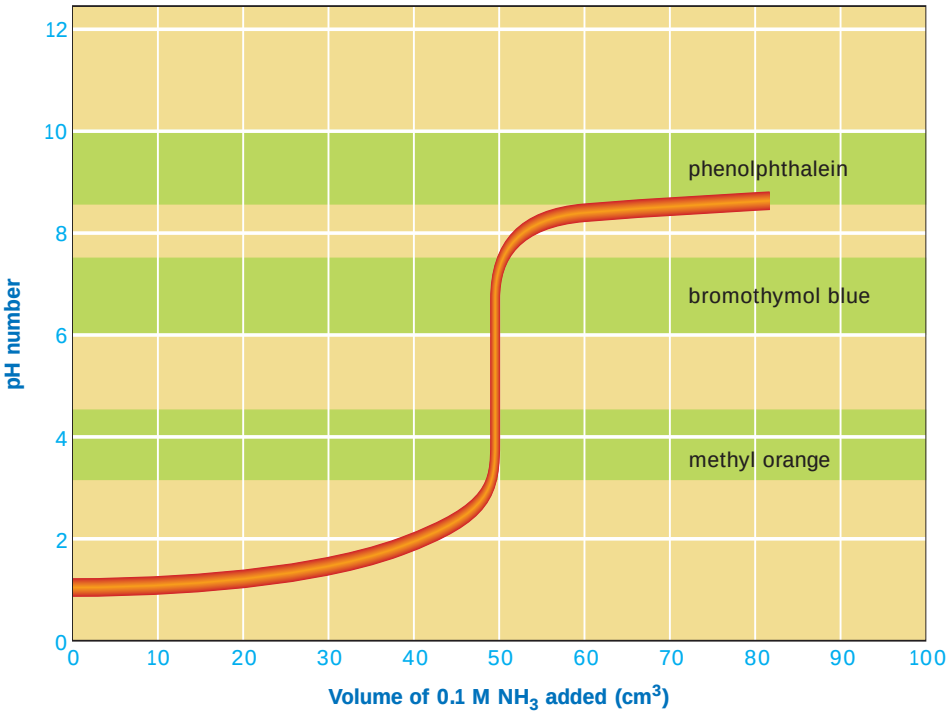

Key words

acid
alkali
base
end point
pH
titration

1 Titration of strong acid against strong alkali

- At the *end point* of strong *acid*–strong *base alkali titration*, the *pH* changes by 5 or 6 pH units when only 1 drop of acid or alkali is added.
- Methyl orange, bromothymol blue, and phenolphthalein are all suitable indicators for this titration because they all change color within a very small change in volume of sodium hydroxide solution.

2 Titration of strong acid against weak alkali

- At the end point of a strong acid–weak alkali titration, the pH change for the addition of one drop of acid or alkali is significant. However, the pH at equivalence (when there are equivalent amounts of acid and alkali) is less than 7. A suitable indicator should change color below or around pH 7. Thus both methyl orange and bromothymol blue would be suitable indicators because they change color between pH 3.2 and 7.6. Within this range, the pH of the titration mixture changes significantly for a very small change in volume of sodium hydroxide solution.
- Phenolphthalein would not be a good choice of indicator because it changes color between pH 8.2 and 10.0. In order to change the pH of the titration mixture over this pH range, a significant volume of sodium hydroxide solution must be added. The result would be an overestimate of the volume of sodium hydroxide solution needed to neutralize the acid.

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Key words

acid
alkali
end point
equivalence point
pH
titration

1 Titration of weak acid against strong alkali

- At the *end point* of a weak *acid*–strong *alkali titration*, the *pH* change for the addition of one drop of acid or alkali is significant. However, the pH at equivalence (when there are equivalent amounts of acid and alkali) is greater than 7. A suitable indicator should change color above pH 7. Thus phenolphthalein would be a good choice because it changes color between pH 8.2 and 10.0. Within this range, the pH of the titration mixture changes significantly for a very small change in volume of sodium hydroxide solution.
- Conversely, bromothymol blue and methyl orange would not be good choices because they change color between pH 3.2 and 7.6, which is before the *equivalence point* of the titration is reached. The result would be an underestimate of the volume of sodium hydroxide solution needed to neutralize the acid.

2 Titration of weak acid against weak alkali

- The pH changes too slowly around the equivalence point to give a color change with the addition of one drop of acid or alkali. The use of methyl orange, bromothymol blue, or phenolphthalein would not give accurate results.
- It is not usual to titrate weak acids with weak alkali, but if it must be done, a pH meter is necessary to find the equivalence point accurately. There is no suitable indicator for this type of titration.

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Titration of weak acids

1 Titration of weak acid against strong alkali

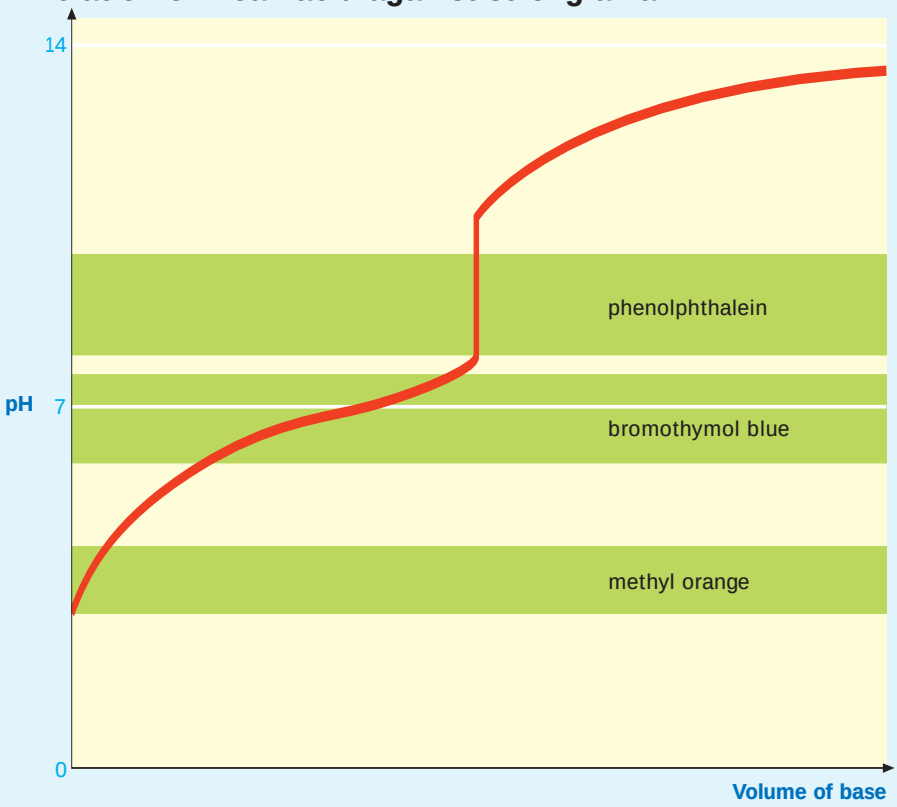

2 Titration of weak acid against weak alkali

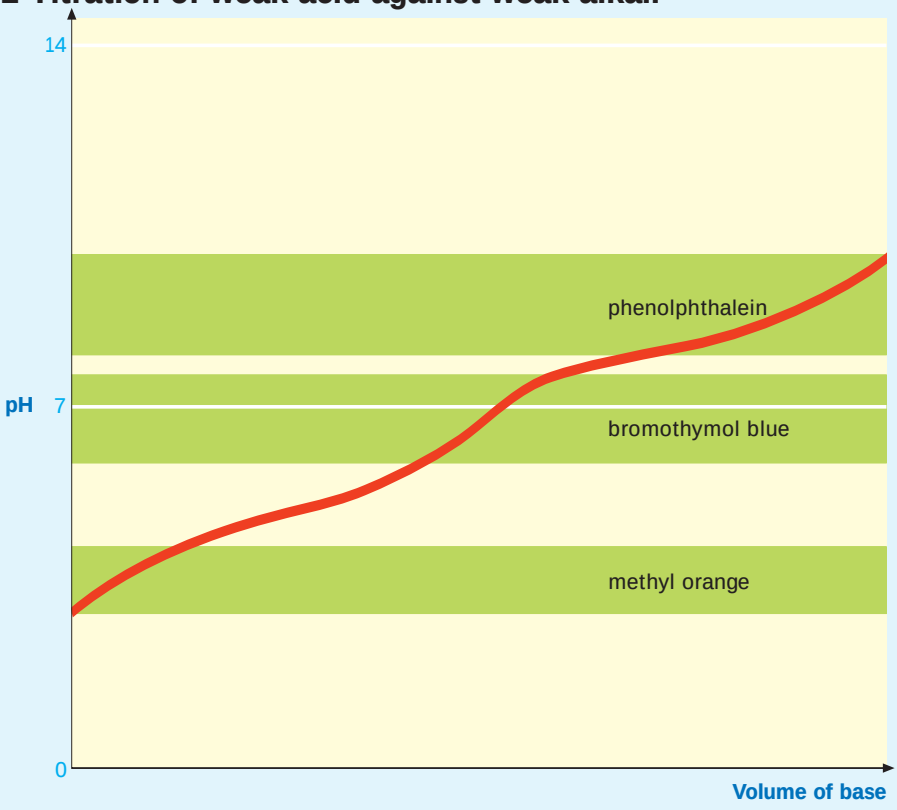

pH and soil

1 Soil classification

pH	Description
< 5.5	strongly acid
5.5 – 5.9	medium acid
6.0 – 6.4	slightly acid
6.4 – 6.9	very slightly acid
7.0	neutral
7.1 – 7.5	very slightly alkaline
7.6 – 8.0	slightly alkaline
8.1 – 8.5	medium alkaline
> 8.5	strongly alkaline

2 pH range of common fruit and vegetables

Fruit or vegetable	Soil pH range
cabbage	6.0 – 7.5
cauliflower	6.5 – 7.5
celery	6.5 – 7.5
cucumber	5.5 – 7.0
potato	5.0 – 6.0
peas	6.0 – 7.5
strawberry	5.0 – 6.0
tomato	5.5 – 7.0

3 Elements needed by plants

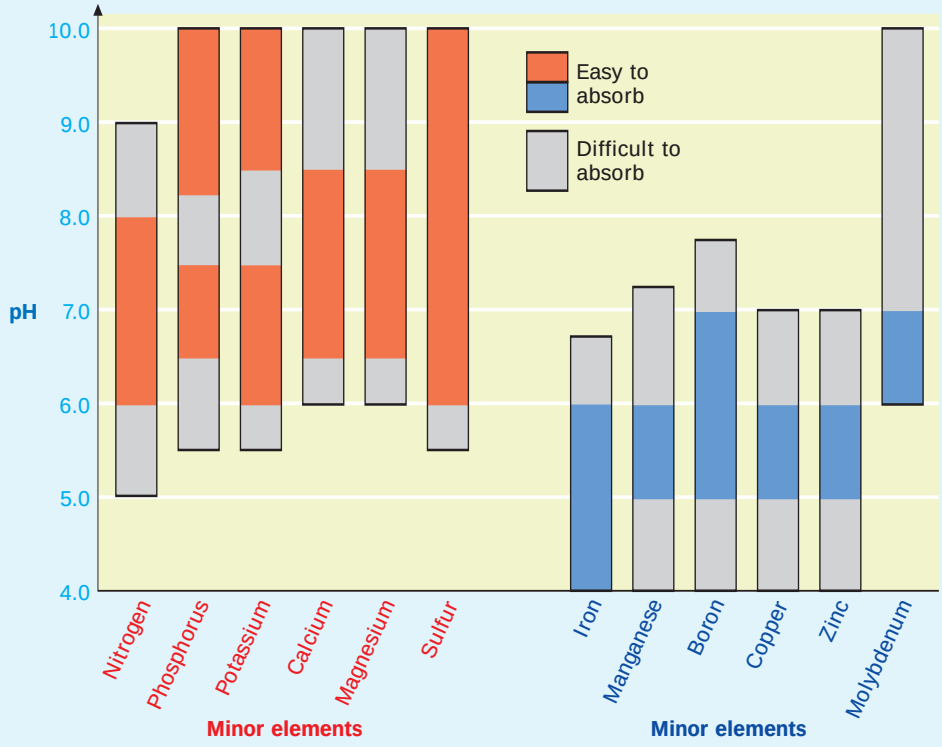

Key words

pH

1 Soil classification

- Soil can be classified according to its *pH*.
- Soils naturally tend to become more acidic due to organic acids being released into the soil as a result of the decay of organic material.
- The acidity of soil can be reduced by spreading slaked lime (calcium hydroxide) or lime (calcium carbonate).

2 pH range of common fruits and vegetables

- Most plants grow best in soil that is slightly acidic, with a pH value between 6.3 and 7.2. Plants will grow outside this range but not as well. This has serious implications for food crops.
- The soil pH is an important consideration in preparing soil to grow crops.

3 Elements needed by plants

- Plants need a number of major and minor elements in order to grow well, and they obtain these from the soil. The minerals dissolve in soil water and are absorbed into the plant through the roots.
- The pH of the soil determines how easily minerals containing these elements can be absorbed. At soil pH values between 6.0 and 7.0, all major elements and minor elements can be absorbed, although some are absorbed more easily than others. In very acidic or very alkaline soils, relatively few plants prosper because they cannot absorb all of the minerals needed for healthy growth.

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Key words

atmosphere
convection current

The water cycle

- Earth's water is always moving in a cycle called the hydrologic or water cycle.
- The Sun provides the energy driving the cycle.

1 Evaporation

- Heat energy causes water to evaporate from the surface of the oceans, leaving all dissolved substances behind. The rate of evaporation is greater in areas of Earth where the seas are warmer.
- Water vapor rises into the *atmosphere*, where it eventually condenses to form clouds. These are dispersed by winds, which carry them to the colder regions of Earth.

2 Transportation

- When clouds reach landmasses, they are carried up on *convection currents*. As they rise, the temperature decreases, and eventually the water vapor condenses, forming precipitation, which falls to Earth.
- Rainwater contains dissolved gases, which makes it slightly acidic.

3 Deposition

- The fresh water flows over rocks and through soils before gathering in streams and rivers. As the water flows through the ground, solids dissolve in it.
- Water is removed from rivers for both industrial and domestic use. Much of this water is ultimately returned to the rivers. Finally, the water flows out to sea, thus completing the cycle. Any dissolved solids are carried in it and eventually deposited in the oceans.

The water cycle

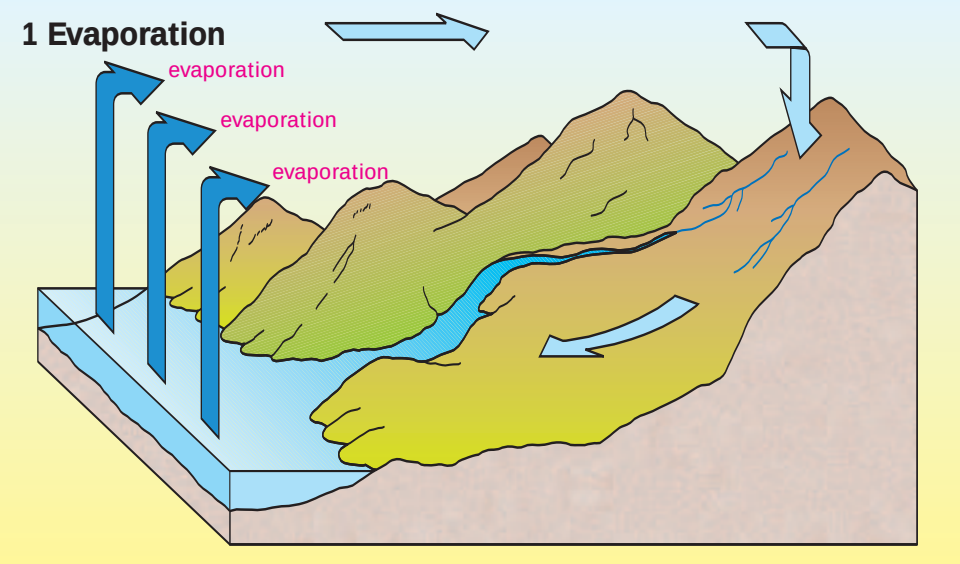

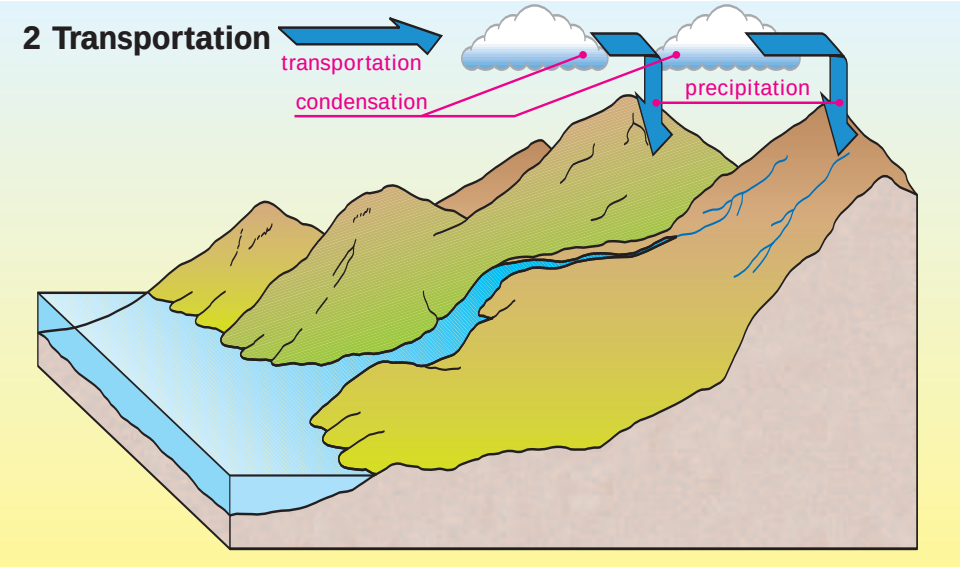

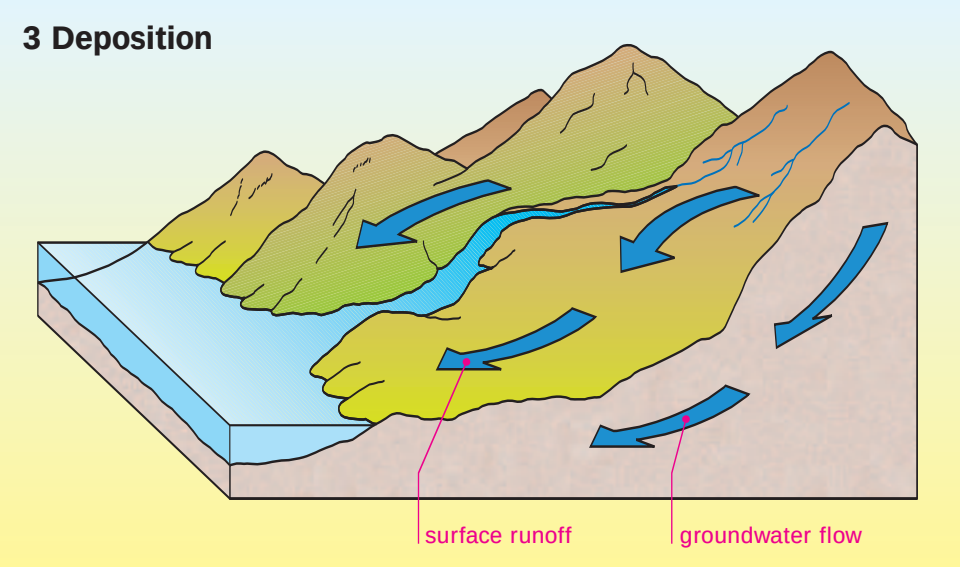

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Treatment of water and sewage

1 water treatment

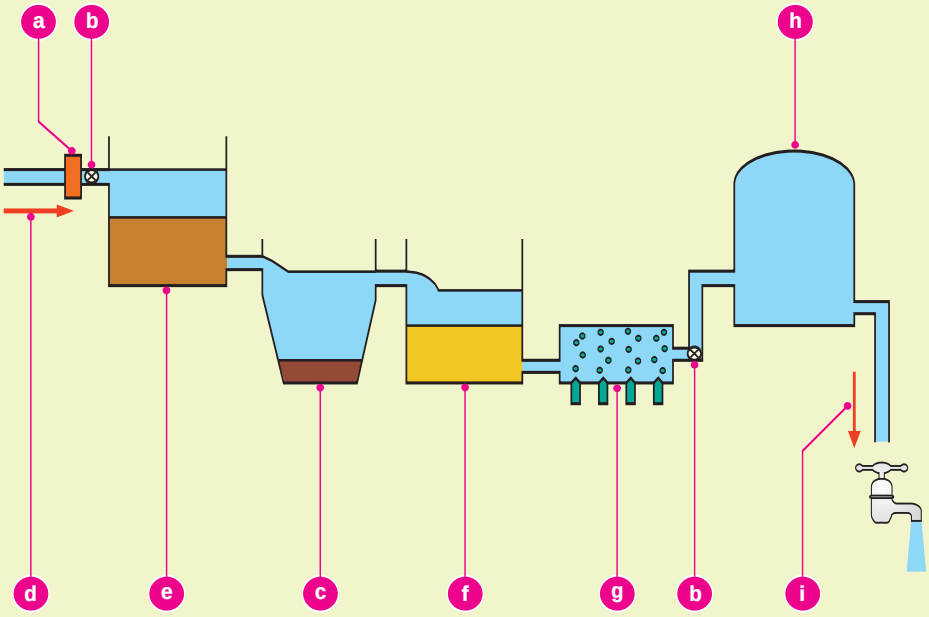

2 Sewage treatment

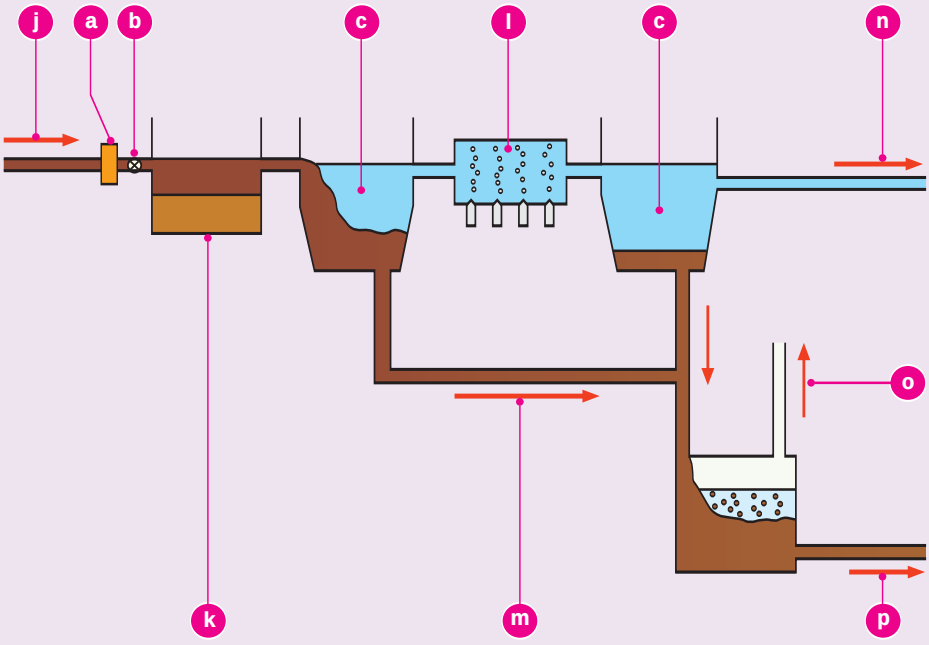

a screen
b pump
c sedimentation tank
d water in
e coarse sand filter
f fine sand filter
g chlorine added
h covered storage tank
i to homes and factories
j sewage in
k settling tank
l digester aeration tank
m sludge collected
n clean water to river
o methane out
p digested sludge out

Key words

methane
oxidizing agent
sewage

1 Water treatment

- Particles are removed from water by passing it through a series of sand filter beds and sedimentation tanks. The filter beds also contain bacteria, which break down and destroy micro-organisms in the water.
- Chlorine is a powerful *oxidizing agent* that is used to kill any remaining microorganisms in the water before is stored ready for distribution. Storage tanks are covered to prevent the entry of foreign bodies.

2 Sewage treatment

- Raw *sewage* cannot be released into rivers because of the threat to health and the effects on the environment. The waste materials it contains must first be broken down by the action of decomposing bacteria.
- Solids are removed from the sewage by a series of screens and settling tanks. The remaining liquid passes into a digester, where bacteria break down the waste products. Streams of air are blown into the tank in order to provide the bacteria with the oxygen needed to survive and to keep the mixture circulating.
- After settling, the clean water is allowed to pass into the river, while the sludge undergoes further digestion during which *methane* is released. The digested sludge contains nitrogenous compounds and is often used as a fertilizer.

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Key words

bond
covalent compound
hydrogen
lone pair
oxygen

1 A covalent compound

- Water is essentially a *covalent compound* formed by two atoms of *hydrogen* and one atom of *oxygen*.

2 The water molecule

- The oxygen atom in a water molecule has two pairs of bonding electrons (sometimes called shared pairs) and two pairs of non-bonding electrons (sometimes called *lone pairs*).
- These four pairs of electrons are directed toward the corners of a tetrahedron. However, the tetrahedral shape is distorted. The non-bonding pairs of electrons repel each other more strongly than the bonding pairs of electrons. Repulsion between these and the bonding pairs of electrons reduces the angle between the oxygen–hydrogen bonds to 104.5 °.

3 The polar nature of the molecule

- Oxygen is more electronegative than hydrogen and, therefore, has a stronger attraction for the electrons in the oxygen–hydrogen *bond*. The result is that the electrons in the bond reside closer to the oxygen atom. Since electrons are negatively charged, this leaves the oxygen atom slightly negative and the hydrogen atom slightly positive. This is shown using δ notation; oxygen is δ- and hydrogen is δ+.

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The water molecule

1 A covalent compound

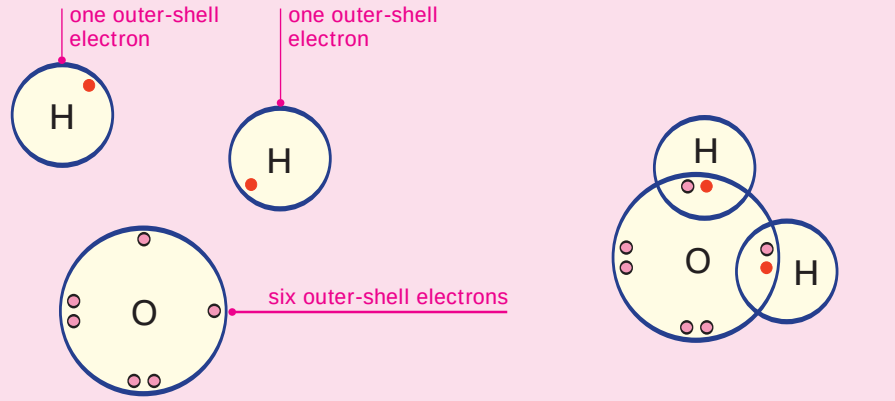

Atoms present

Full shells of a water molecule

2 The water molecule

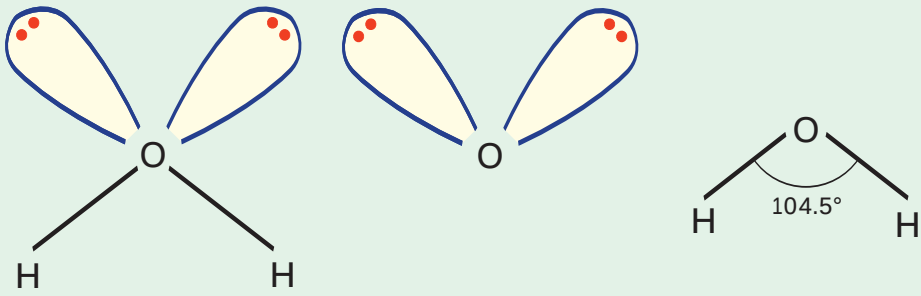

Water molecule

Non-bonding pairs (lone pairs)

Bonding pairs

3 The polar nature of the molecule

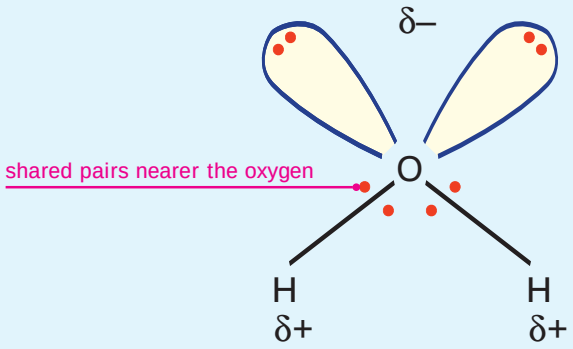

Water as a solvent of ionic salts

1 Ionic lattices

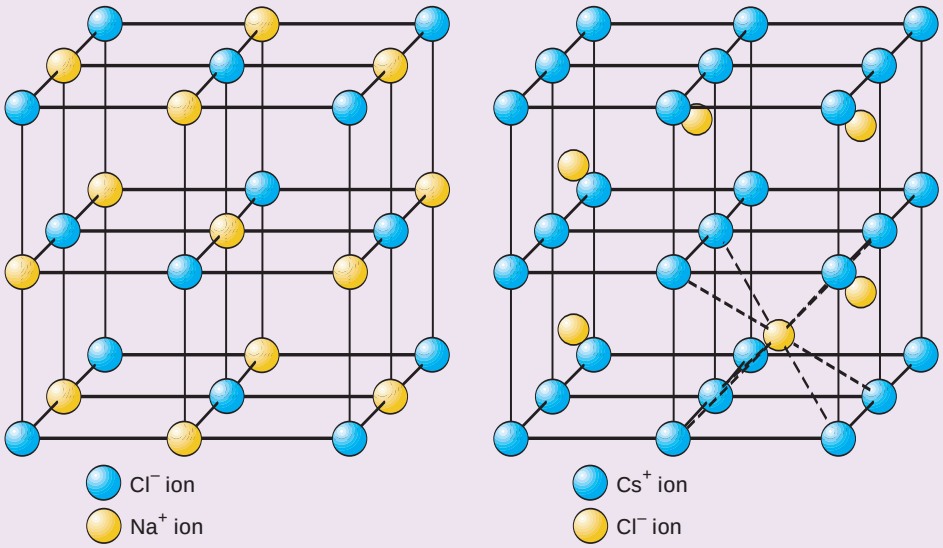

2 The effect of water on an ionic lattice

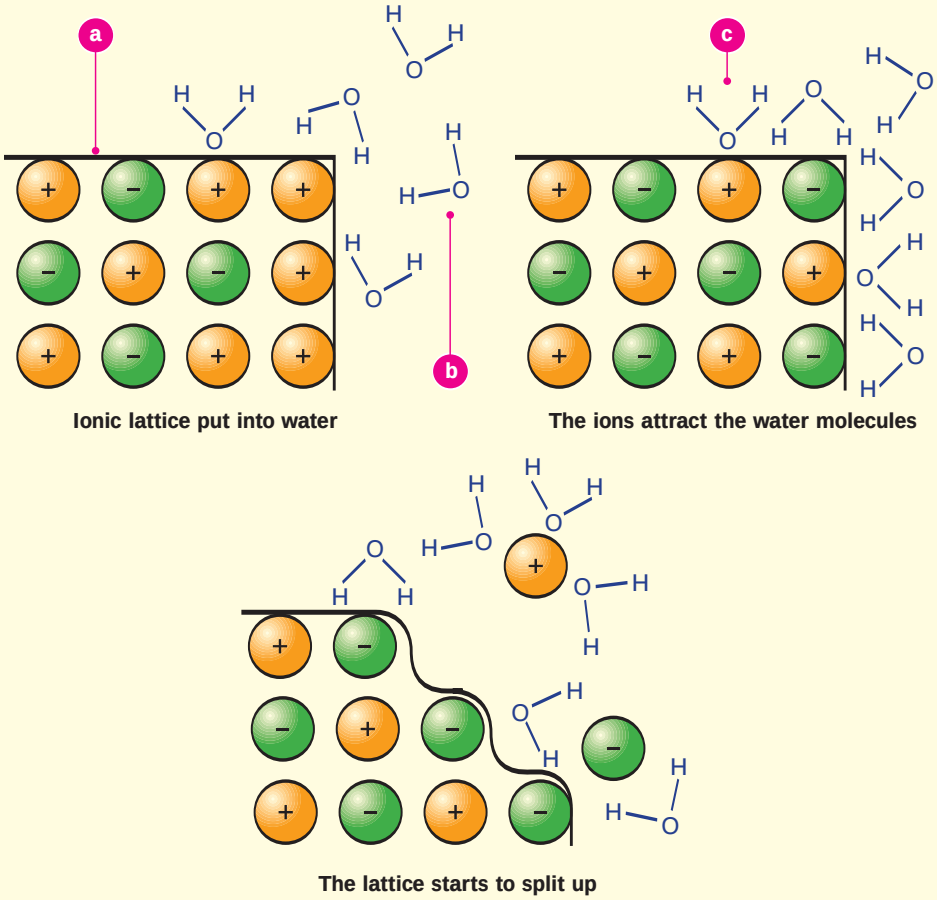

a lattice
b water molecules
c charged ends of molecules attracted to ions of opposite charge

Key words

anion
body-centered cubic
cation
face-centered cubic
hydration
ionic crystal lattice

1 Ionic lattices

- The ions in an *ionic crystal* are arranged in a *lattice*. Each ion is surrounded by a number of oppositely charged ions. The lattice structure is determined by:
  - the ratio of the number of positively charged ions (*cations*) to negatively charged ions (*anions*)
  - the ratio of the radii of the ions (r_{cation} / r_{anion})
- The radius ratio in sodium chloride is 0.57. The ions are arranged in a *face-centered cubic* structure in which each sodium ion is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions.
- The radius ratio of cesium chloride is 0.94 (due to the larger cesium ion). The ions are arranged in a *body-centered cubic* structure in which each cesium ion is surrounded by eight chloride ions, and each chloride ion is surrounded by eight cesium ions.

2 The effect of water on an ionic lattice

- When an ionic compound is placed in water, the water molecules collide with the lattice. If the water molecules collide with sufficient energy to overcome the forces of attraction between the oppositely charged ions, *hydration* occurs, and the compound will dissolve, forming a solution.

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Key words

anion
bond
cation
ion
ionic compound
lattice
transition metals

Ionic solutions

- Ionic solutions are *ionic compounds* dissolved in water.

1 Stabilizing free ions

- Due to the uneven sharing of electrons in the oxygen–hydrogen *bonds* of a water molecule, the oxygen atom is slightly negatively charged and the hydrogen atoms are slightly positively charged.
- Water molecules surround and stabilize the *ions* in the compound: positively charged *cations* are stabilized by the negative oxygen atoms, and negatively charged *anions* are stabilized by the positive hydrogen atoms.

2 Transition metals in solution

- *Transition metal* ions form complexes with water.
- Transition metals have an incomplete outer shell and can fill this with the electric charge on the water molecule. Non-bonding pairs of electrons from the water molecules are donated to form coordinate bonds.
- The bonds between the metal ions and water are so strong that they remain when solids are obtained from their solutions.

3 Production of silver chloride

- When silver nitrate solution and sodium chloride solution are mixed, insoluble silver chloride forms a white precipitate.

  $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
- The silver ions and chloride ions are more stable when bonded together in an ionic *lattice* than existing apart surrounded by water molecules.

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Ionic solutions

1 Stabilizing free ions

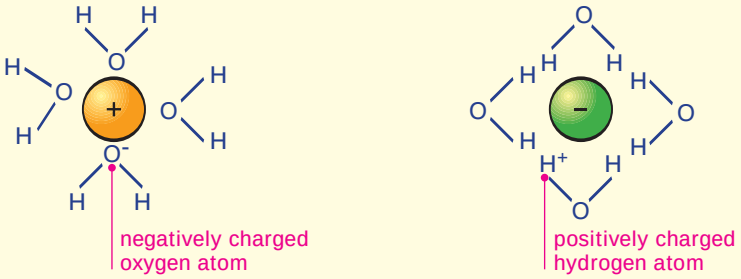

2 Transition metals in solution

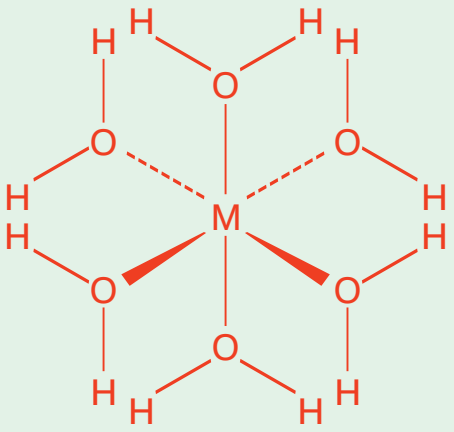

3 Production of silver chloride when a metal chloride is added to silver nitrate solution

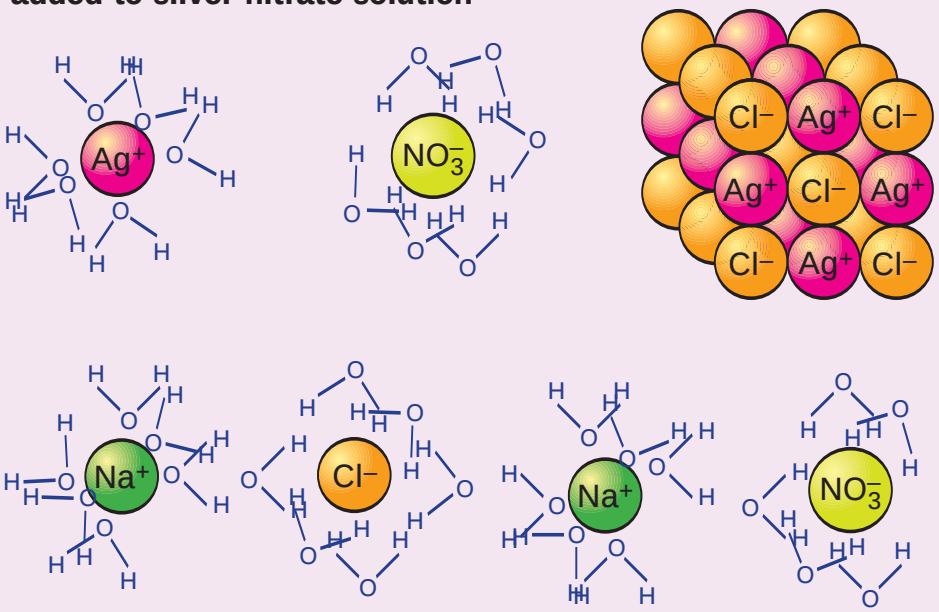

Silver nitrate solution and sodium chloride solution

After reaction, clusters of water molecules have been forced away from aqueous silver and chloride ions to leave solid silver chloride

Solubility

1 Table of solubility of ionic compounds

Soluble	Insoluble
all salts of ammonium, potassium, and sodium	
all nitrates	
most bromides, chlorides, and iodides	lead and silver bromides, chlorides, and iodides
most sulphates (calcium sulfate is slightly soluble)	barium and lead sulfate
ammonium, potassium, and sodium carbonate	most other carbonates
ammonium, potassium, and sodium hydroxides (calcium hydroxide is slightly soluble)	most other hydroxides

2 Table of the most abundant compounds in seawater

Name of compound	Formula of compound	Percentage of solids in seawater
sodium chloride	NaCl	78
magnesium chloride	$MgCl_2$	9
magnesium sulphate	$MgSO_4$	7
calcium sulphate	$CaSO_4$	4
potassium chloride	KCl	2
calcium carbonate	$CaCO_3$	less than 1
magnesium bromide	$MgBr_2$	less than 1

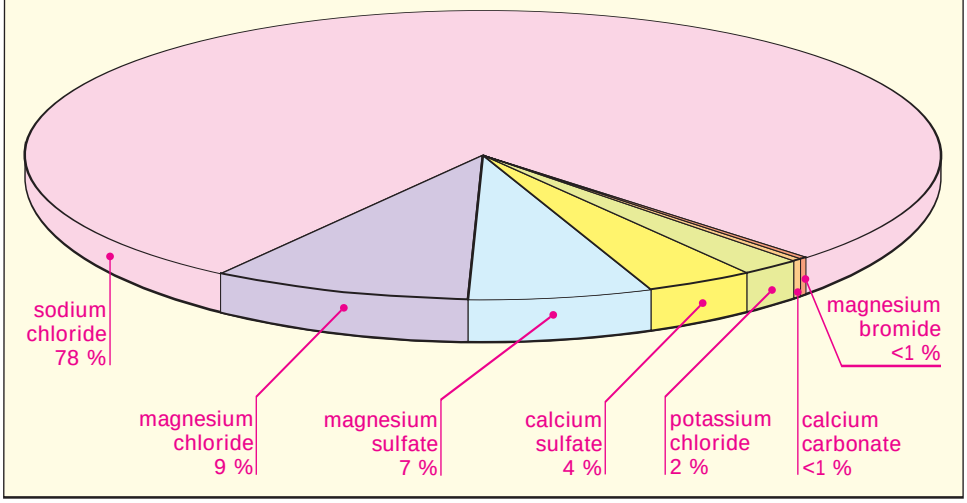

Key words

ionic compound
insoluble
soluble

1 Solubility of ionic compounds

- All *ionic compounds* are *soluble* in water to some extent. However the solubility of some is so low that they are best regarded as *insoluble*. Solubility generally follows the following rules.
- All ammonium, potassium, and sodium salts are soluble.
- All nitrates are soluble.
- With the exception of lead and sliver bromides, chlorides, and iodides, bromides, chlorides, and iodides are soluble.
- Most sulfates are soluble, with the exception of barium and lead sulfate.
- Most carbonates are insoluble, with the exception of ammonium, potassium, and sodium carbonate.
- Most hydroxides are insoluble, with the exception of ammonium, potassium, and sodium hydroxides.
- Calcium hydroxide is only slightly soluble.

2 Most abundant compounds in seawater

- Seawater is a solution of many different salts. The main salt present in seawater is sodium chloride.
- The concentration of solids in seawater depends on the location. The saltiest water occurs in the Red Sea, where there is 40 g of dissolved solids per 1,000 g of water. The North Atlantic is the saltiest of the major oceans, with an average of 37.9 g of dissolved solids per 1,000 g of water. The least salty waters are found in polar seas and the Baltic Sea, which contains only 5–15 g of dissolved solids per 1,000g of water.

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Key words

solubility curve

Expressing solubility

- Solubility is normally expressed in g / 100 g of water. The solubility of a compound varies (normally increases) with temperature, so when quoting solubility, it is necessary to state the temperature for which it is given.
- A *solubility curve* is a graph that shows how the solubility of a salt varies between 0°C (the freezing point of water) and 100°C (the boiling point of water).
- The solubility curve of a compound is plotted using data about the solubility of the compound over the whole temperature range. Solubility curves are generally not straight lines.
- Over the temperature range 0–100°C, the solubility of some salts remains nearly constant (sodium chloride), while the solubility of others either increases gradually (potassium sulfate) or increases very rapidly (potassium nitrate).

Solubility curves

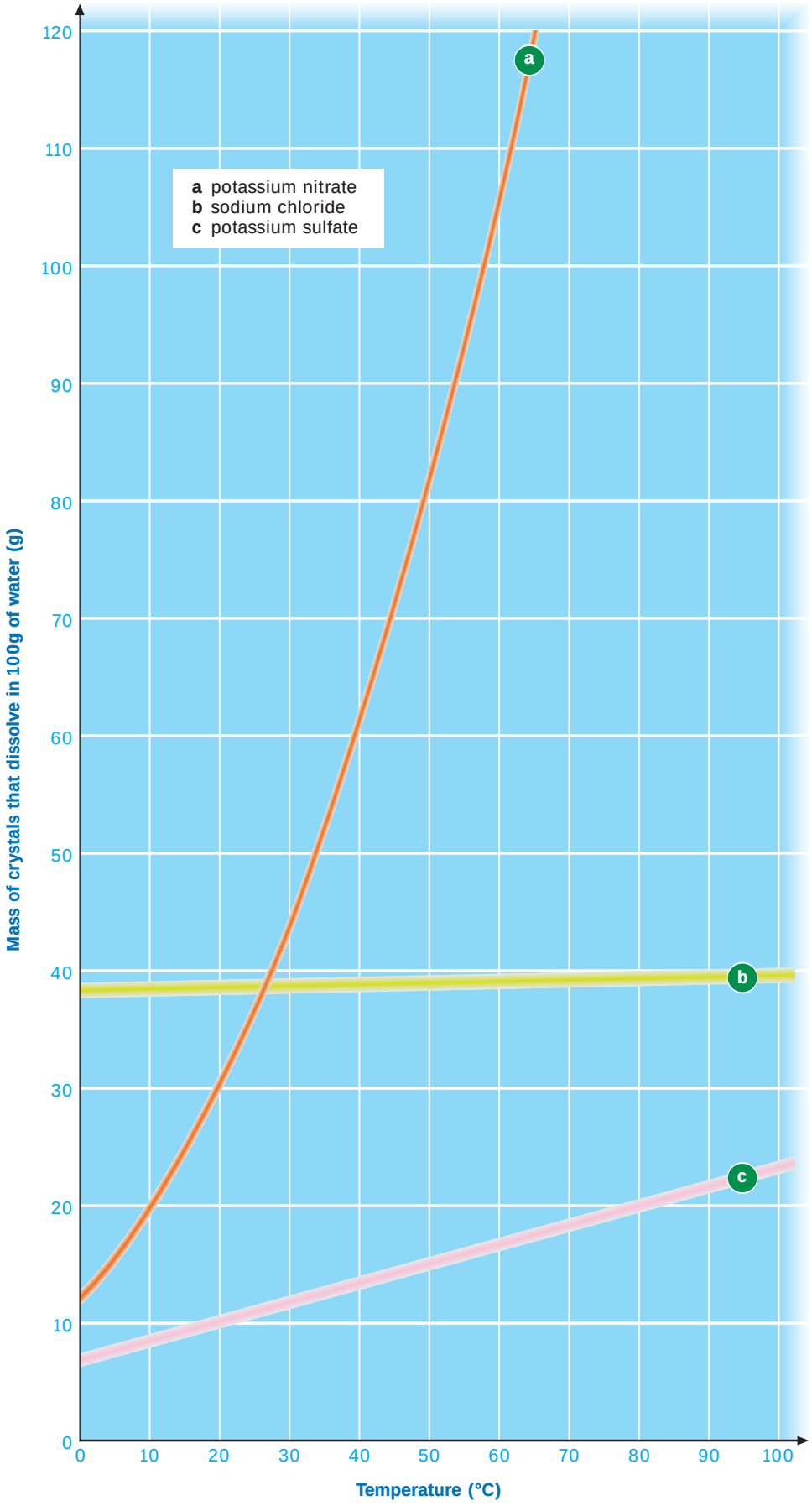

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Solubility of copper(II) sulfate

1 Table of solubility of copper(II) sulfate at different temperatures

Temperature °C	Solubility g/100g water	Temperature °C	Solubility g/100g water
0	14.3	60	40.0
10	17.4	70	47.1
20	20.7	80	55.0
30	24.3	90	64.8
40	28.5	100	75.4
50	34.0		

2 Solubility curve for copper(II) sulfate

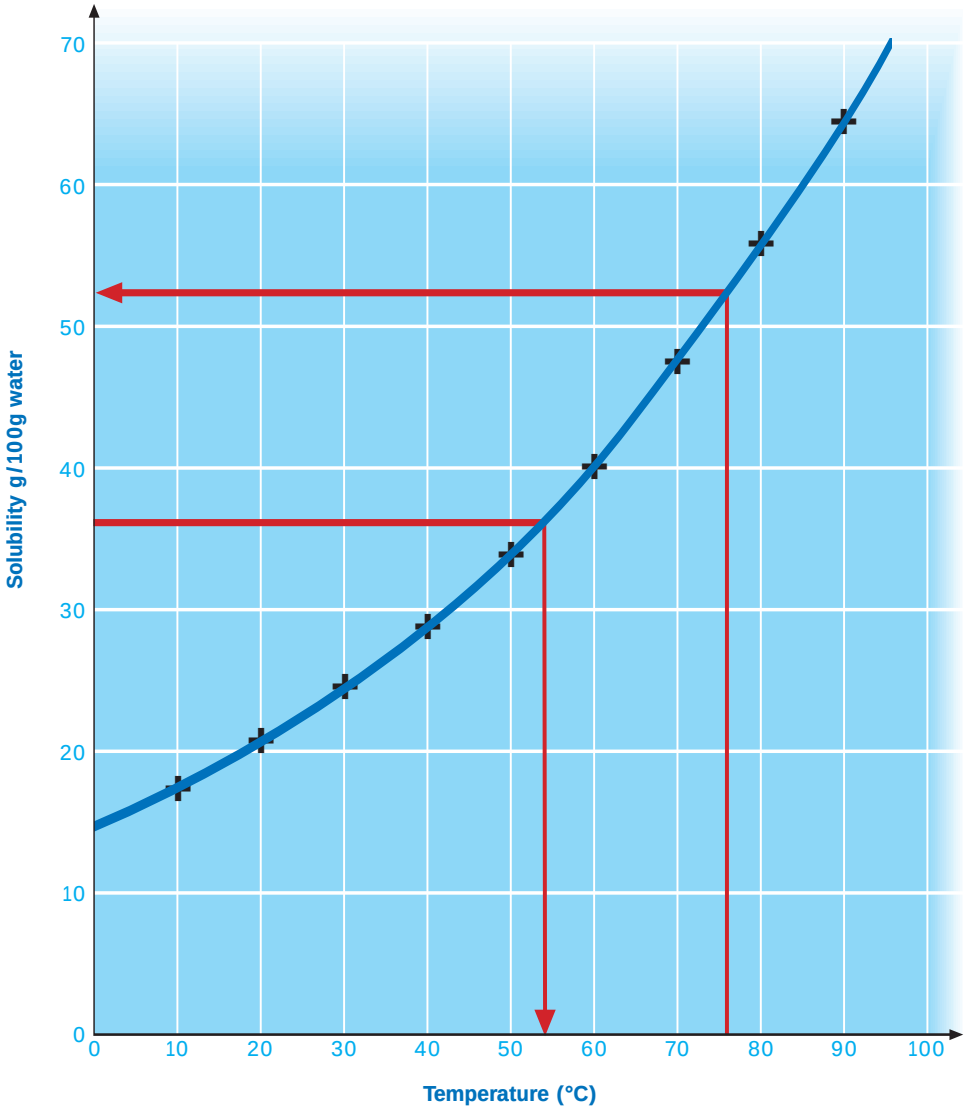

Key words

saturated
solute
solution
solubility curve

1 Solubility of copper(II) sulfate at different temperatures

- When no more solid will dissolve in a *solution* at a given temperature, the solution is said to be *saturated*.
- Normally when a solution is cooled below the saturation temperature for the quantity of *solute* present, some solute crystallizes out. Under certain conditions a solution may be cooled below this temperature without crystallization occurring. Such a solution is said to be supersaturated.
- A *solubility curve* is plotted by finding the amount of solid needed to make a saturated solution at a number of different temperatures over the range 0–100°C.

2 Solubility curve for copper(II) sulfate

- The solubility of copper(II) sulfate at 76°C is found by drawing a vertical line from 76°C to the solubility curve and then a horizontal line to the solubility axis. The value is 52 g of copper(II) sulfate per 100 g of water.
- The temperature at which the solubility of copper(II) sulfate is exactly 36 g per 100 g of water is found by drawing a horizontal line from 36 g / 100 g water to the solubility curve and then a vertical line to the temperature axis. The temperature is 54°C.
- The solubility of copper(II) sulfate at 90°C is 64.8 g / 100 g water and at 20°C is 20.7 g / 100 g water. If 100 g of saturated copper(II) sulfate solution was allowed to cool from 90°C to 20°C the mass of copper(II) sulfate crystals formed would be 64.8 – 20.7 = 44.1 g.
- The size of crystals formed is related to how quickly the solution is cooled. If cooling is rapid many small crystals are formed but if cooling is slow a smaller number of large crystals are formed.

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Key words

anhydrous
dry gas
hydrochloric acid
hydrogen

1 Obtaining hydrogen using Kipps apparatus

- Traditionally, *hydrogen* is generated using a Kipps apparatus. When the tap is opened, dilute *hydrochloric acid* floods the bottom compartment and the level rises until it reacts with granulated zinc in the middle compartment. Zinc reacts with dilute hydrochloric acid to produce hydrogen:
  $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
- If the tap is closed, hydrogen continues to be produced for a short time, and the pressure of the gas in the middle compartment gradually increases. Eventually the pressure is sufficient to force the dilute hydrochloric acid back down and out of the middle compartment, and the reaction stops.
- In a modern laboratory, hydrogen is often obtained directly from a cylinder of the gas.

2 Collecting dry hydrogen

- A *dry gas* is a natural gas from which all water vapor has been reduced.
- Hydrogen is dried by passing through *anhydrous* calcium chloride. The gas is collected by upward delivery (downward displacement of air) because it is less dense than air.

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Hydrogen: preparation

1 Obtaining hydrogen using Kipps apparatus

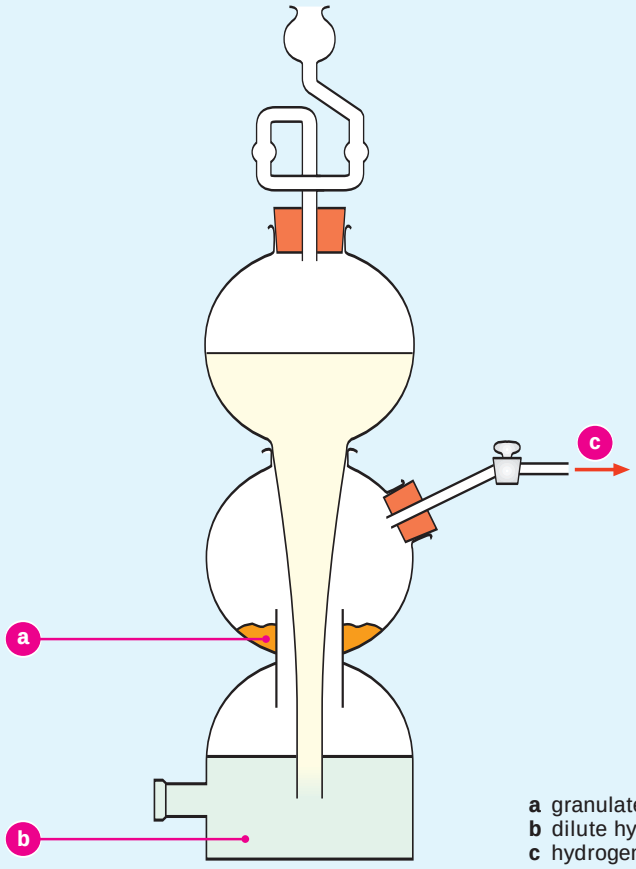

a granulated zinc
b dilute hydrochloric acid
c hydrogen gas

2 Collecting dry hydrogen

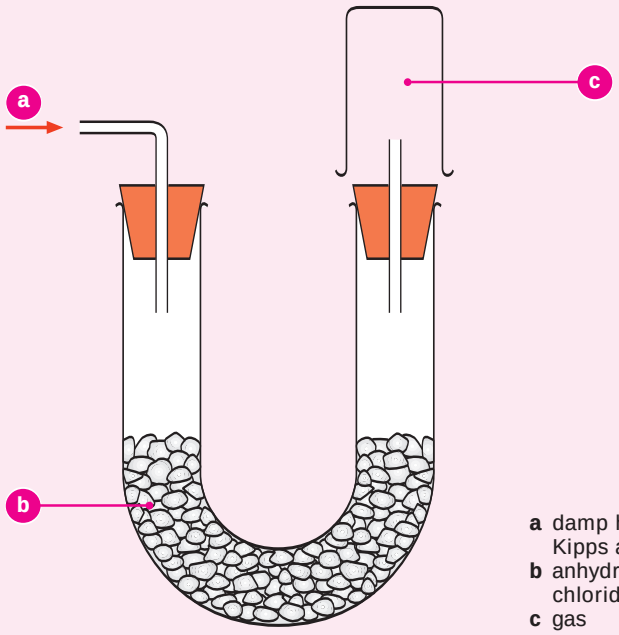

a damp hydrogen from Kipps apparatus
b anhydrous calcium chloride
c gas

Hydrogen: comparative density

1 Gaseous diffusion of hydrogen in air

1A 1B

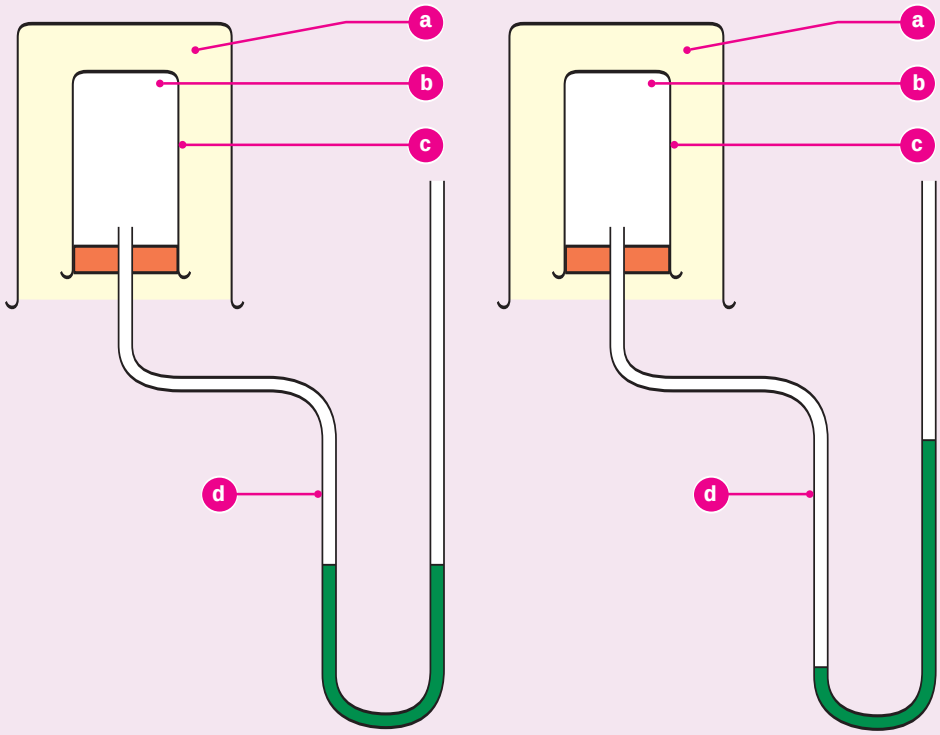

2 Gaseous diffusion of carbon dioxide in air

2A 2B

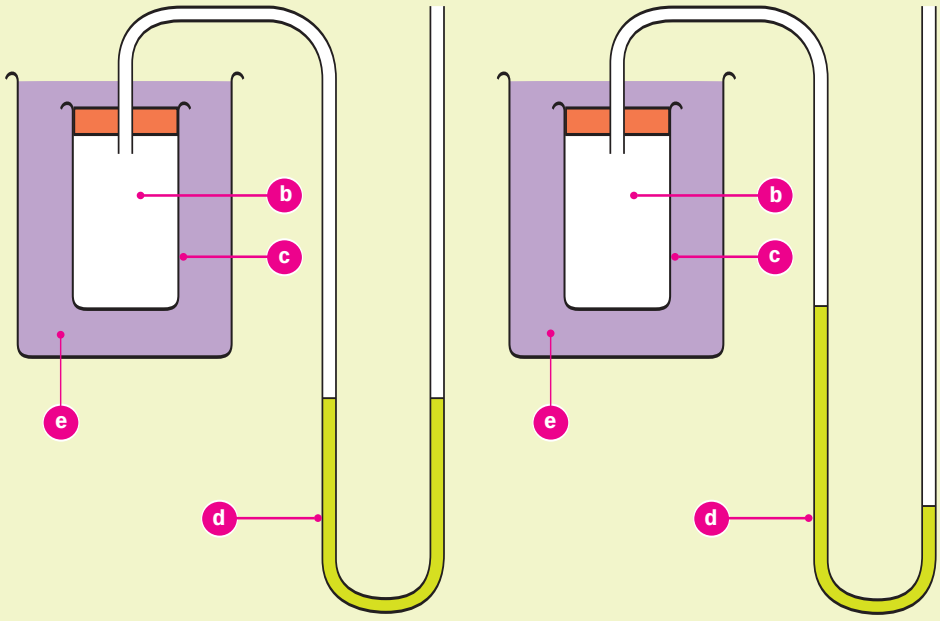

a hydrogen
b air
c porous vessel
d manometer
e carbon dioxide

Key words

carbon dioxide
diffusion
Graham's law
hydrogen

1 Gaseous diffusion of hydrogen

- Gases are able to pass into and out of a porous vessel.
- *Hydrogen* is less dense than air, so it is contained in an inverted beaker (1A).
- Hydrogen diffuses into the porous vessel more quickly than air diffuses out of it.
- The gas pressure inside the porous vessel increases and becomes greater than atmospheric pressure (1B). Liquid is forced up the right side of the manometer (an instrument used to measure the pressure of a fluid).

2 Gaseous diffusion of carbon dioxide

- *Carbon dioxide* is more dense than air, so it is contained in an upright beaker (2A).
- Carbon dioxide diffuses into the porous vessel more slowly than air diffuses out of it.
- The gas pressure inside the porous vessel decreases and becomes less than atmospheric pressure. Liquid is forced up the left side of the manometer (2B).

Comparative density

- *Graham's law* of *diffusion* states that the rate at which a gas diffuses (r) is proportional to the square root of 1 over its density (d):
  $r \propto \sqrt{1/d}$
- The density of hydrogen is lower that air. Therefore, it diffuses more quickly.
- The density of carbon dioxide is higher that air. Therefore it diffuses more slowly.

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Hydrogen: reaction with other gases

Key words

anhydrous
anode
calcium carbonate
cathode
electrolysis
hydrogen sulfide
lead sulfide
photochemical reaction
sulfuric acid

1 Hydrogen and oxygen

- *Electrolysis* of dilute *sulfuric acid* produces oxygen at the *anode* (positive electrode) and hydrogen at the *cathode* (negative electrode).
- At the anode:
  $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$
- At the cathode:
  $4H^+(aq) + 4e^- \rightarrow 2H_2(g)$
- A mixture of hydrogen and oxygen explodes when ignited:
  $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

2 Hydrogen and air

- Hydrogen burns in air to produce water.
- The hydrogen gas is dried by passing it through *anhydrous calcium carbonate* so any water produced must be the result of combustion.
- Water vapor condenses on the outer surface of the beaker of cold water and collects in the water glass.
- The liquid turns anhydrous blue cobalt chloride paper pink, showing it is water.

3 Hydrogen and sulfur

- Hydrogen reacts with sulfur to produce *hydrogen sulfide*:
  $H_2(g) + S(l) \rightarrow H_2S$
- Hydrogen sulfide turns damp lead acetate paper black due to the formation of *lead sulfide*:
  $Pb^{2+}(aq) + H_2S(g) \rightarrow PbS(s) + 2H^+(aq)$

4 hydrogen and chlorine

- A mixture of hydrogen and chlorine react in bright light.
- This is an example of a *photochemical reaction*. Light provides the energy needed for the reaction to start:
  $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

1 Explosion of hydrogen/oxygen mixture

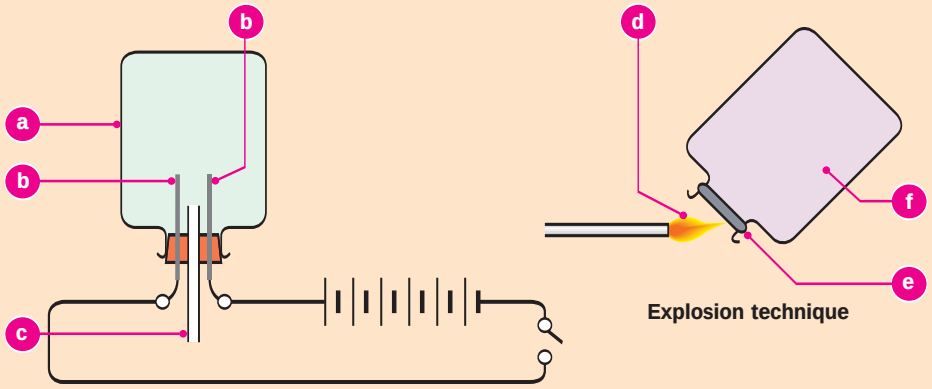

Explosion technique

Preparation of hydrogen and oxygen from electrolysis of sulfuric acid

2 Hydrogen and air

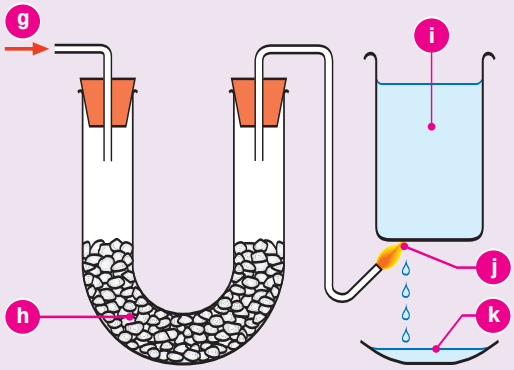

3 Reaction of hydrogen with sulfur

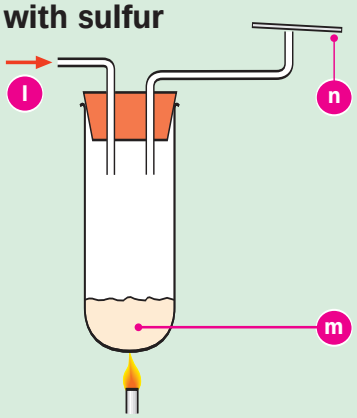

4 Photocatalytic explosion of hydrogen with chlorine

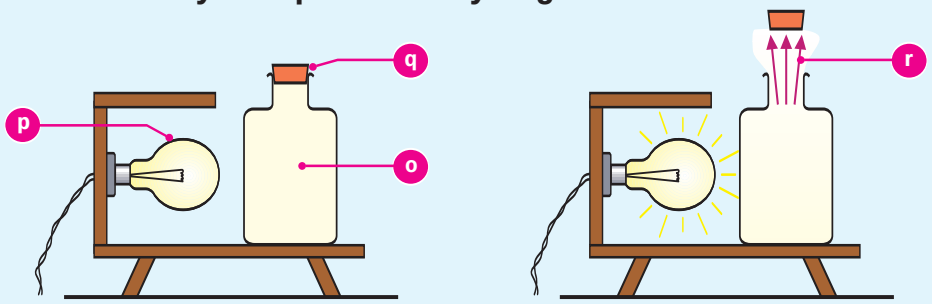

Before light is switched on

Light is switched on

a polyethylene bottle containing dilute H_2SO_4
b platinum electrodes
c polyethelene tubing
d bunsen flame
e loose support
f hydrogen/oxygen mixture
g hydrogen from Kipps apparatus
h anhydrous calcium chloride
i beaker containg cold water
j hydrogen burning
k water collected
l dry hydrogen
m boiling sulfur
n filter paper soaked in lead acetate
o polyethylene bottle containing mixture of chlorine and hydrogen
p powerful light source
q rubber bung
r white fumes of hydrogen chloride

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Hydrogen: anomalies in ammonia and water

1 Anomalous boiling points of ammonia and water

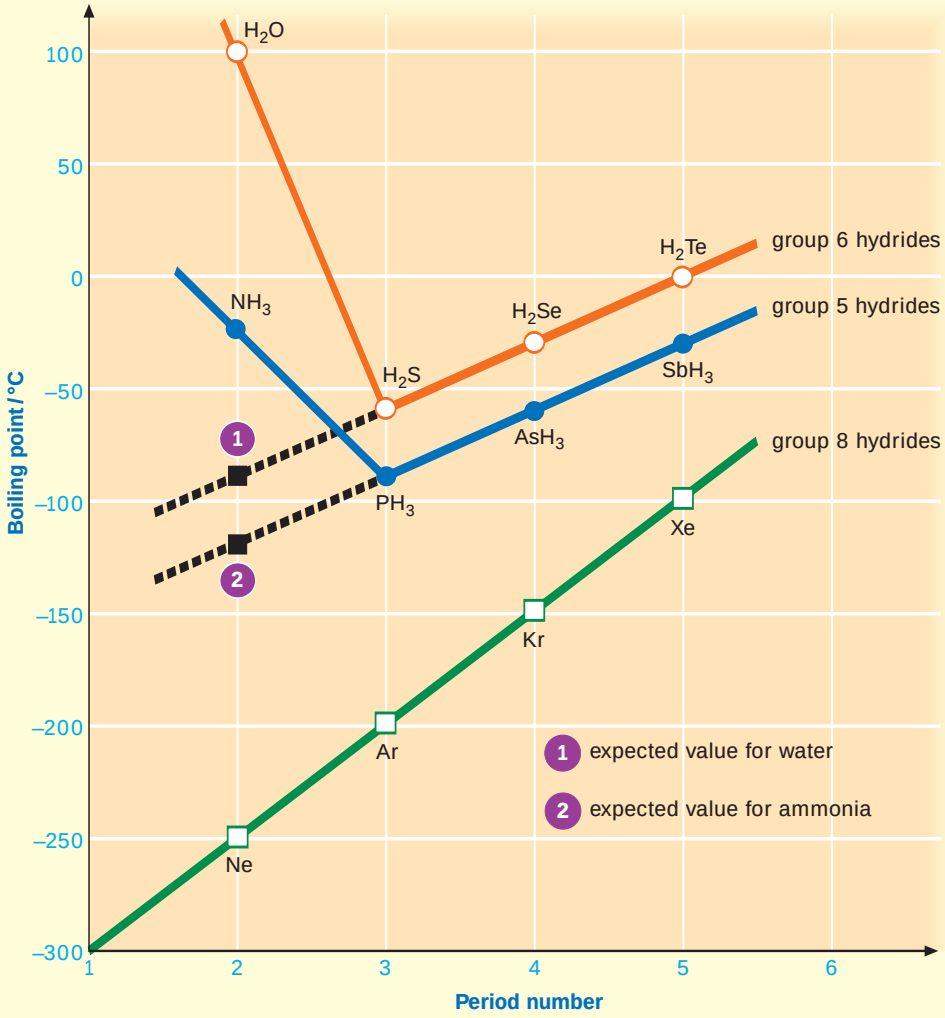

2 Strong bonding between water molecules

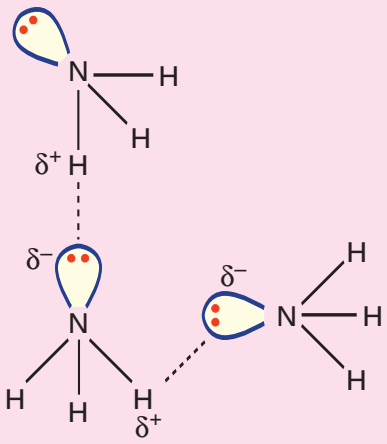

Key words

ammonia
boiling point
dipole
group 5
group 6
group 8
hydride
lone pair
orbital

1 Anomalous boiling points of ammonia and water

- Atoms of the *group 8* elements have a full outer *orbital* of electrons. They exist as single atoms, and there are very weak forces of attraction between them. The *boiling point* of these elements increases in proportion to the size of the atom.
- The boiling points of the *group 5* and *group 6 hydrides* also increases with molecular size. However, the boiling point of water and *ammonia* are significantly higher than might be expected when compared to the other hydrides in their groups. This is the result of strong forces of attraction, called hydrogen bonding, between water molecules and between ammonia molecules.

2 Strong bonding between water molecules

- There are five electrons in the outer orbital of a nitrogen atom. In ammonia, three of the electrons are used in nitrogen–hydrogen bonds, while the remaining two form a non-bonding or *lone pair*.
- The nitrogen atom in ammonia is more electronegative than the hydrogen atoms. The result is that a pair of bonding electrons lies nearer to the nitrogen atom than the hydrogen atom in each nitrogen–hydrogen bond.
- This forms a *dipole*, a chemical compound with an unequally distributed electric charge. The nitrogen–hydrogen bond is polarized, leaving the nitrogen slightly negative (sometimes shown as δ-) and the hydrogen slightly positive (sometimes shown as δ+).
- The slightly positive hydrogen atom is attracted to the slightly negative nitrogen atom and the non-bonding pair of electrons on neighboring ammonia molecules.

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Basic reactions of hydrogen

Key words

alkali
base
catalyst
hydride
hydrogen
hydrocarbon
hydroxide
oxide
peroxide

1 Preparation

- Water, in the form of steam, can be reduced by either carbon or *hydrocarbons* to give *hydrogen*.
- This reaction is used to provide hydrogen for the Haber process in the industrial manufacture of ammonia (See page 74):
  $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

2 Reactions of hydrogen

- Hydrogen forms hydrides with both metals and non-metals.
- Hydrogen can be used to reduce the *oxides* of metals that are low in the reactivity series, such as copper(II) oxide.

3 The oxides

- Hydrogen reacts with oxygen to form both an oxide (water) and a *peroxide* (hydrogen peroxide).
- Hydrogen peroxide contains an unstable peroxide –O-O- bond.
- A variety of substances, including manganese(IV) oxide, act as *catalysts* to break this bond, forming water and oxygen.

4 The hydroxy compounds

- All metal *hydroxides* are *bases*.
- Metal hydroxides that dissolve in water are *alkalis*.
- Sodium hydroxide solution can be used to form precipitates of insoluble metal hydroxides like copper(II) hydroxide.

5 Acids

- All acids produce solutions containing hydrogen ions, H^+.

1 Preparation

A $C + H_2O \longrightarrow CO + H_2$

B $C_7H_{16} + 7H_2O \longrightarrow 7CO + 15H_2$

C $2H_2O + 2e^- \longrightarrow 2OH^- + H_2$

D $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

2 Reactions of hydrogen

A $2Na + H_2 \longrightarrow 2NaH$

$N_2 + 3H_2 \longrightarrow 2NH_3$

$O_2 + 2H_2 \longrightarrow 2H_2O$

$Cl_2 + H_2 \longrightarrow 2HCl$

B $CuO + H_2 \longrightarrow Cu + H_2O$

3 The oxides

A $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

B $2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2$

4 The hydroxy compounds

$NaOH + HCl \longrightarrow NaCl + H_2O$

$2NaOH + CuCl_2 \longrightarrow Cu(OH)_2\downarrow + 2NaCl$

5 Acids

$HCl \longrightarrow H^+ + Cl^-$

$HNO_3 \longrightarrow H^+ + NO_3^-$

$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$

1A from coal
1B from oil
1C electrolysis of brine
1D laboratory preparation
2A it reduces other elements
2B it reduces compound

3A water
3B hydrogen peroxide
4 metallic hydroxides are bases

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The gases in air

1 Composition of air

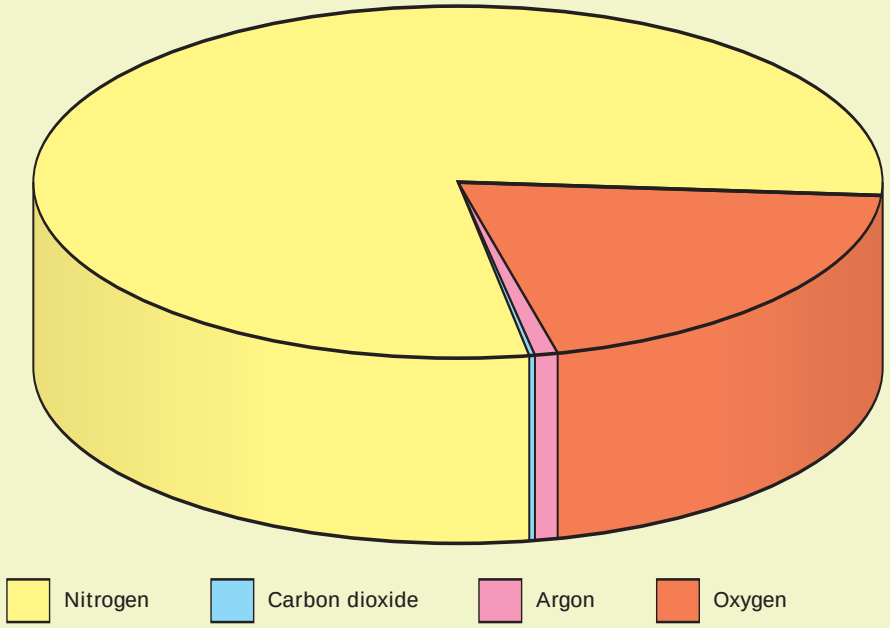

2 Gases present in clean dry air

Gases	Symbol or formula	Percentage of volume
Nitrogen	N	78.08
Oxygen	O	20.95
Argon	Ar	0.93
Carbon dioxide	CO_2	0.04
Neon	Ne	traces
Helium	He	
Krpton	Kr	
Xenon	Xe	

3 Gases that may be found in polluted air

Gases	Symbol or formula	Example of source
Ammonia	NH_3	Industrial processes
Carbon monoxide	CO	Motor vehicle exhaust
Methane	CH_4	Decay of organic material, passed in wind by herbivorous animals
Nitrogen oxides	NO_x	Motor vehicle and furnace exhaust
Ozone	O_3	Motor vehicle exhaust
Sulphur dioxide	SO_2	Coal-fired power stations

Key words

argon
carbon dioxide
carbon monoxide
compound
element
methane
ozone
pollutant
sulfur dioxide

1 Composition of air

- Air is not a chemical *compound* but a mixture of *elements* and compounds. The exact composition of air varies slightly from place to place depending on conditions. For example, the proportion of *carbon dioxide* in the air above a forest will be less than in the air above a city. Trees remove carbon dioxide for photosynthesis, while burning fossil fuels releases carbon dioxide.

2 Gases present in clean dry air

- Clean dry air is approximately 80 percent nitrogen and 20 percent oxygen.
- *Argon* makes up the largest portion of the remaining 10 percent.
- Air usually contains water vapor, with the amount depending on local conditions.

3 Gases in polluted air

- Air may contain *pollutants* released from a variety of sources.
- *Sulfur dioxide* and nitrogen oxides dissolve in water in the atmosphere and increase the acidity of rainwater.
- *Carbon monoxide* is a poisonous gas. If it is inhaled, it bonds onto the hemoglobin in red blood cells and prevents them from transporting oxygen.
- *Ozone* is essential in the upper atmosphere (ozone layer), where it prevents harmful ultraviolet radiation from reaching Earth. At ground level, however, it is responsible for the formation of smog.
- *Methane* and carbon dioxide are greenhouse gases. In the upper atmosphere, they prevent heat radiation from passing out into space, thus causing the global temperature to rise.

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Key words

group 5
nitrogen
solubility
triple bond

1 Nitrogen atom and molecule

- *Nitrogen* is in *group 5* of the periodic table. Nitrogen atoms have five electrons in the outer orbital and require an additional three electrons in order to fill the shell.
- Nitrogen exists as nitrogen molecules, N_2, in which each nitrogen atom provides three electrons. The nitrogen atoms are held together by a *triple bond*. A large amount of energy is needed to break the N≡N triple bond (945.4 kJ mol^{-1}), which accounts for the unreactive nature of nitrogen.

2 Physical properties of nitrogen

- The melting point and boiling point of nitrogen are both very low, and nitrogen is only a liquid over a small range of temperature. This indicates that the intermolecular forces in nitrogen are weak.
- The *solubility* of gases decreases with increasing temperature. The solubility of nitrogen falls from 2.3 cm^3 per 100 g water at 0°C to 1.0 cm^3 per 100 g water at 100°C.

3 Laboratory preparation of nitrogen

- Nitrogen is formed by the thermal decomposition of ammonium nitrite:
  $NH_4NO_2(s) \rightarrow 2H_2O(g) + N_2(g)$
- Ammonium nitrite is difficult to store because it decomposes over time. It is best made when it is needed by mixing ammonium chloride and sodium nitrite:
  $NH_4Cl(s) + NaNO_2(s) \rightarrow NH_4NO_2(s) + NaCl(s)$

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Nitrogen

1 Nitrogen atom and molecule

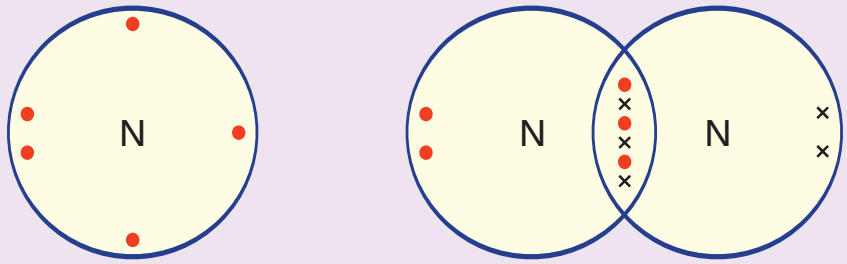

Nitrogen atom, $^{14}_{7}N$ — Nitrogen molecule, N_2

2 Physical properties of nitrogen

Physical properties	m.p./°C	b.p./°C	density (relative to air)	color	smell	solubility at STP
Nitrogen	–120	–196	0.97	none	none	1.52 cm^3 in 100g of water

3 Laboratory preparation of nitrogen from ammonium chloride and sodium nitrate

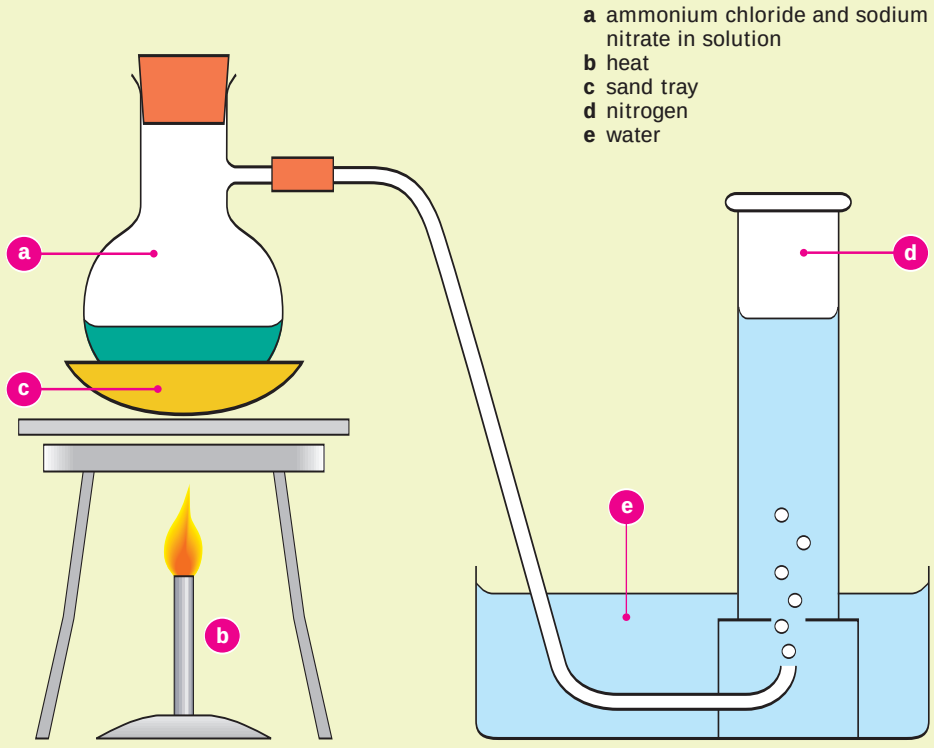

Other methods of preparing nitrogen

1 Extraction of nitrogen from the atmosphere

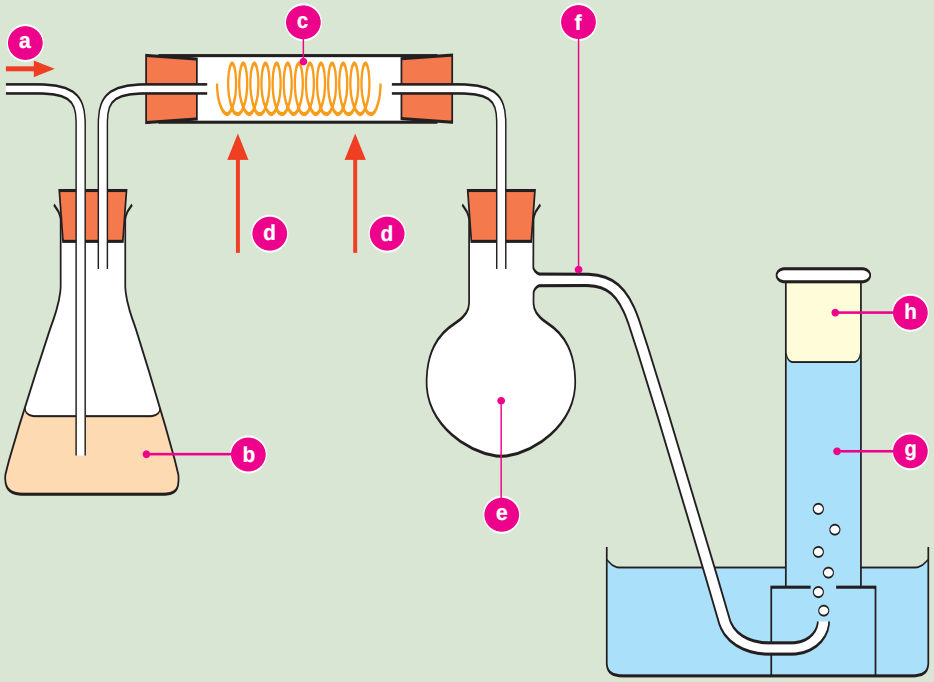

2 Preparation of nitrogen from ammonia

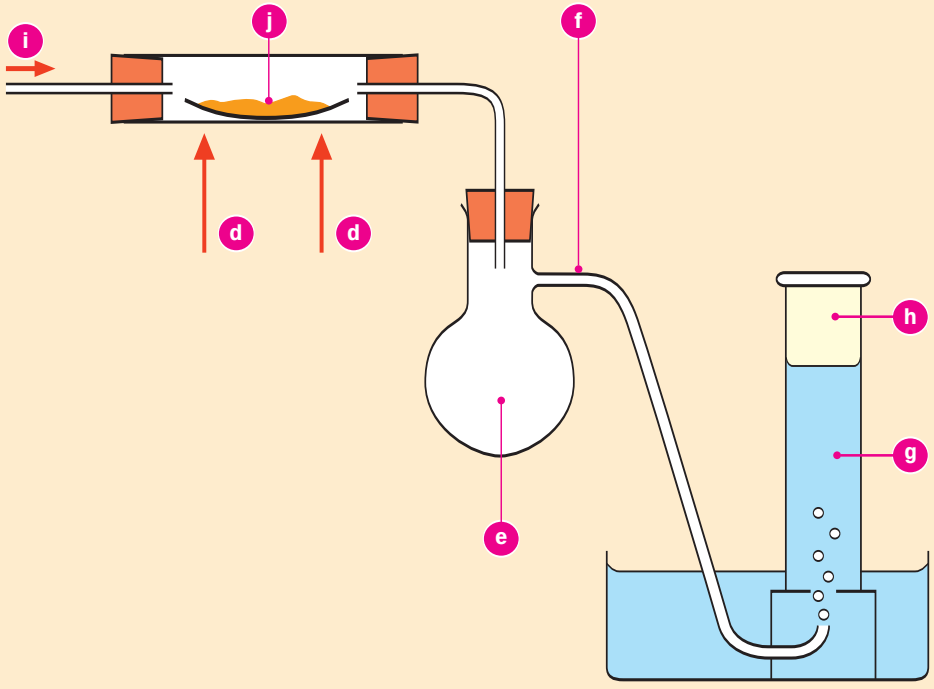

a air intake
b potassium hydroxide solution to absorb carbon
c hot copper coil to remove oxygen
d heat
e safety trap
f delivery tube
g water
h nitrogen collected over water
i dry ammonia gas
j dry copper(II) oxide

Key words

ammonia
group 8
inert
nitrogen
soluble

Other methods

- In addition to preparing *nitrogen* from ammonium chloride and sodium nitrate, it can be extracted from the air or from the reduction of copper(II) oxide by *ammonia*.

1 Extraction of nitrogen from the atmosphere

- Air is approximately 80 percent nitrogen and 20 percent oxygen. Impure nitrogen can be obtained by removing carbon dioxide and oxygen from air.
- Potassium hydroxide solution reacts with carbon dioxide:
  $KOH(aq) + CO_2(g) \rightarrow KHCO_3(aq)$
- A hot copper pile reacts with oxygen:
  $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$
- Nitrogen prepared in this way contains argon and other *group 8* gases. However, because these are chemically *inert*, they would not interfere with any subsequent reactions.

2 Preparation of nitrogen from ammonia

- Ammonia can be used to reduce copper(II) oxide to copper. Nitrogen is one of the other products of this reaction:
  $3CuO(s) + 2NH_3(g) \rightarrow$
  $3Cu(s) + 3H_2O(g) + N_2(g)$
- Nitrogen is not very *soluble* and is readily collected over water.
- Water vapor condenses in the water trough. Ammonia is very soluble, and unreacted ammonia dissolves in the water.

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The nitrogen cycle

Key words

ammonia
nitrate
nitrite
nitrogen
nitrogen cycle

Nitrogen cycle

- *Nitrogen* is continually being recycled between the soil and the air by natural processes.
- Lightning provides the energy for atmospheric nitrogen and oxygen to react, forming nitrogen oxides. For example:
  $N_2(g) + O_2(g) \rightarrow 2NO(g)$
  $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
- These oxides dissolve in water vapor in the atmosphere and eventually fall to the ground as rain.
- Atmospheric nitrogen is also converted into nitrogen compounds by nitrogen-fixing bacteria found in the root nodules of some plants.
- Nitrogen compounds are released into the soil as a result of the decay of animal waste products and by the decay of dead plants and animals. In the soil, the *ammonia* formed during decay processes is converted into *nitrates* by the action of nitrifying bacteria:
  Ammonia → Ammonium compounds → *Nitrites* → Nitrates
- Nitrogen compounds may also be added to soil as artificial fertilizers. Ammonium nitrate is widely used by farmers and gardeners to provide growing plants with essential nitrogen.
- Nitrogen compounds are taken out of the soil by plants, which use them to make proteins and other essential chemicals. Animals subsequently eat the plants.
- Nitrogen compounds in the soil are converted to nitrogen gas by denitrifying bacteria.

Nitrogen cycle schematic

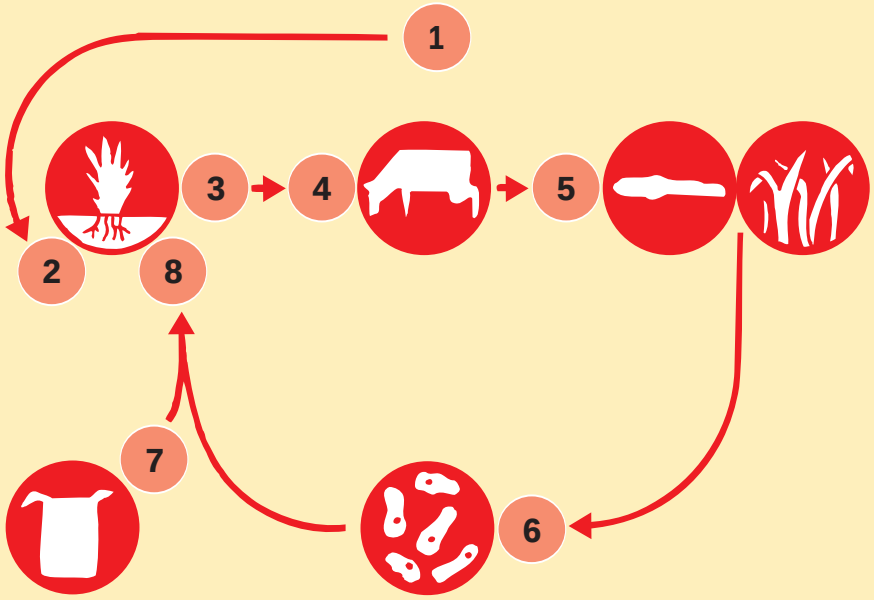

All plants and animals need nitrogen, present in proteins and nucleic acids. Most living things, however, cannot use nitrogen directly from the atmosphere.

1 Nitrogen in the air.
2 Nitrogen in the atmosphere is trapped by some plant roots.
3 Plants use nitrogen for making proteins.
4 Animals eat plant proteins.
5 The proteins in dead organisms and in body wastes are converted to ammonia by bacteria and fungi.
6 Other bacteria convert the ammonia to nitrates.
7 Artificial nitrates are added to the soil as fertilizer.
8 Plants absorb the nitrates.

Nitrogen cycle

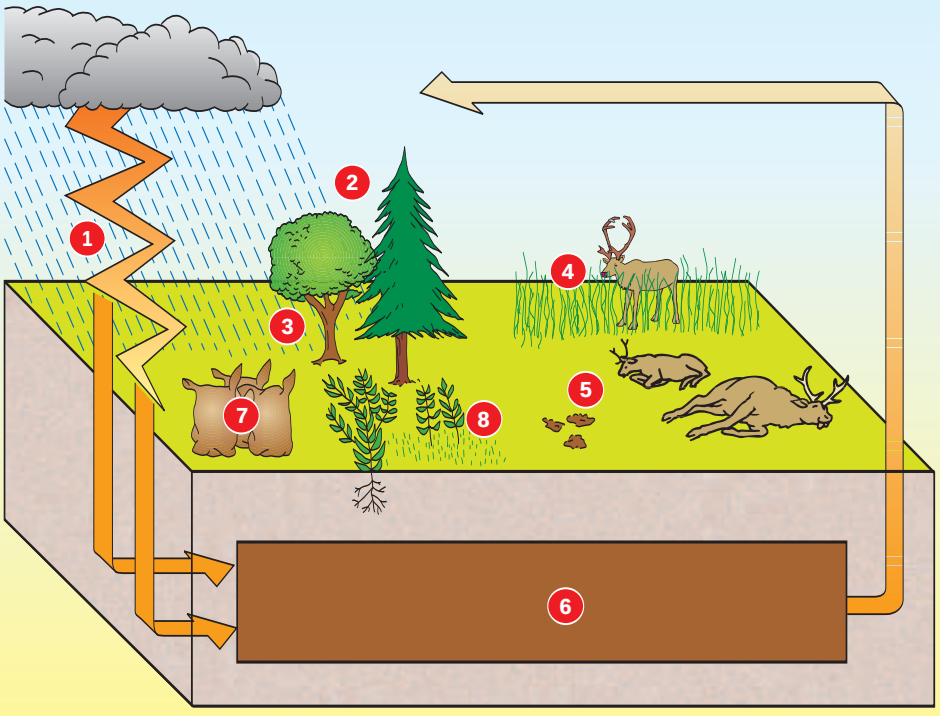

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Preparation and properties of ammonia

1 Laboratory preparation of ammonia

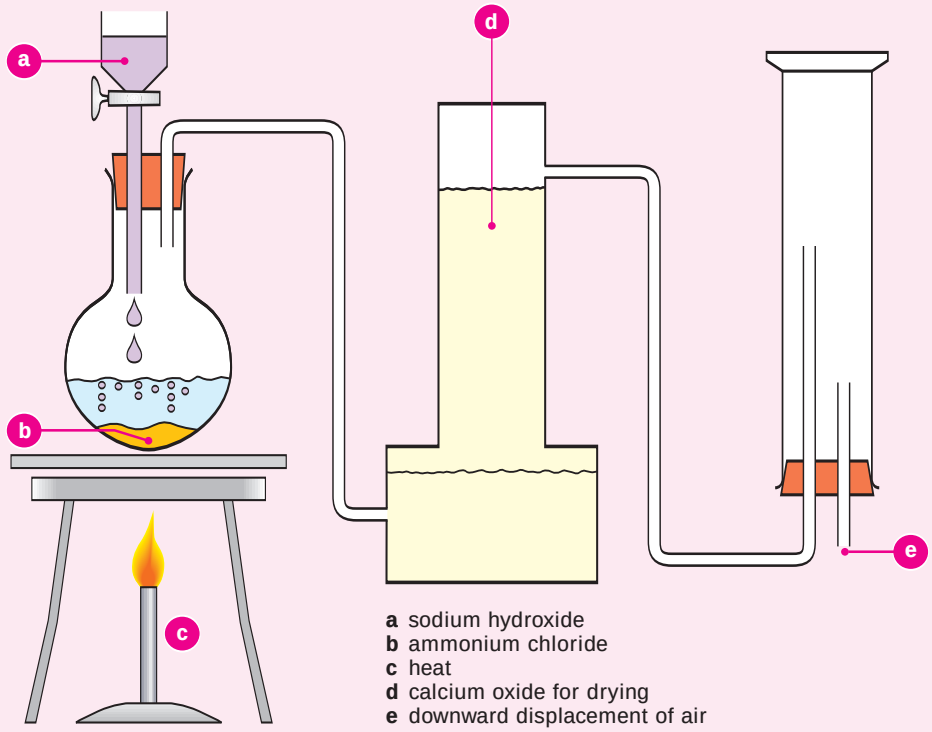

a sodium hydroxide
b ammonium chloride
c heat
d calcium oxide for drying
e downward displacement of air

2 Bonding angle

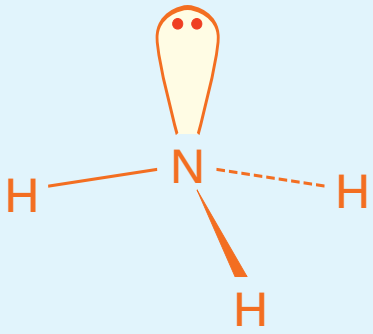

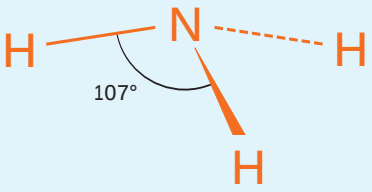

3 Physical properties of ammonia

Physical property	Ammonia
Ammonia	–77.7
Carbon monoxide	–33.5
Methane	0.59
Nitrogen oxides	colorless
Ozone	characteristic unpleasant odour
Sulphur dioxide	68 000 cm^3 in 100 g of water

Key words

alkali
ammonia
ammonium hydroxide
bond angle
lone pair
shell

1 Laboratory preparation of ammonia

- *Ammonia* is formed by the reaction of an ammonium compound, such as ammonium chloride, with an *alkali*, such as sodium hydroxide:
  $NH_4Cl(s) + NaOH(aq) \rightarrow NH_3(g) + NaCl(aq) + H_2O(l)$
- Ammonia gas is dried by passing it through a column of calcium oxide.

2 Bonding angle

- The five electrons in the outer electron *shell* of nitrogen plus three shared electrons from the hydrogen atoms form three pairs of bonding electrons and one pair of non-bonding electrons (*lone pair*).
- The four pairs of electrons are directed toward the corners of a tetrahedron. However, repulsion between the non-bonding pair of electrons and the bonding pairs of electrons forces the nitrogen–hydrogen bonds slightly closer to each other, resulting in a *bond angle* of 107°. By comparison, the bond angle in methane is 109.5°.

3 Physical properties of ammonia

- Ammonia is less dense than air and is collected by upward delivery (downward displacement of air).
- Ammonia is exceptionally soluble and cannot be collected over water. 680 cm^3 of ammonia will dissolve in 1 g of water at 20°C.
- Ammonia dissolves in water to form a solution that is a weak alkali:
  $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
- Ammonia solution is sometimes referred to as *ammonium hydroxide*.

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Key words

ammonia
equilibrium
Le Chatelier's principle
product
reactant

1 Reversible reaction

- *Ammonia* is made industrially by the reaction of nitrogen and hydrogen.
- The reaction is reversible.
  Forward reaction:
  $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
  Backward reaction:
  $N_2(g) + 3H_2(g) \leftarrow 2NH_3(g)$
- The concentration of ammonia in the equilibrium mixture depends on the pressure and temperature at which the reaction is carried out.
- According to *Le Chatelier's principle*, if any change is made to the external conditions (such as temperature, concentration and pressure) of a system at *equilibrium*, the equilibrium position will alter so as to oppose the change.

2 Variation of percent ammonia with pressure

- In the forward reaction, four moles of *reactants* are converted into two moles of *product* so there is a drop in pressure.
- According to Le Chatelier's principle, an increase in pressure will favor the forward reaction. The equilibrium position will move to the right in order to oppose the increase in pressure, so the equilibrium mixture will contain more ammonia.

3 Variation of percent ammonia with temperature

- The reaction is exothermic; heat is given out.
- According to Le Chatelier's principle, a decrease in temperature will favor the forward reaction. The equilibrium position will move to the right in order to oppose the decrease in temperature, so the equilibrium mixture will contain more ammonia.

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Industrial preparation of ammonia (the Haber process): theory

1 Reversible reaction

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

4 moles → 2 moles

2 Variation of percent ammonia with pressure

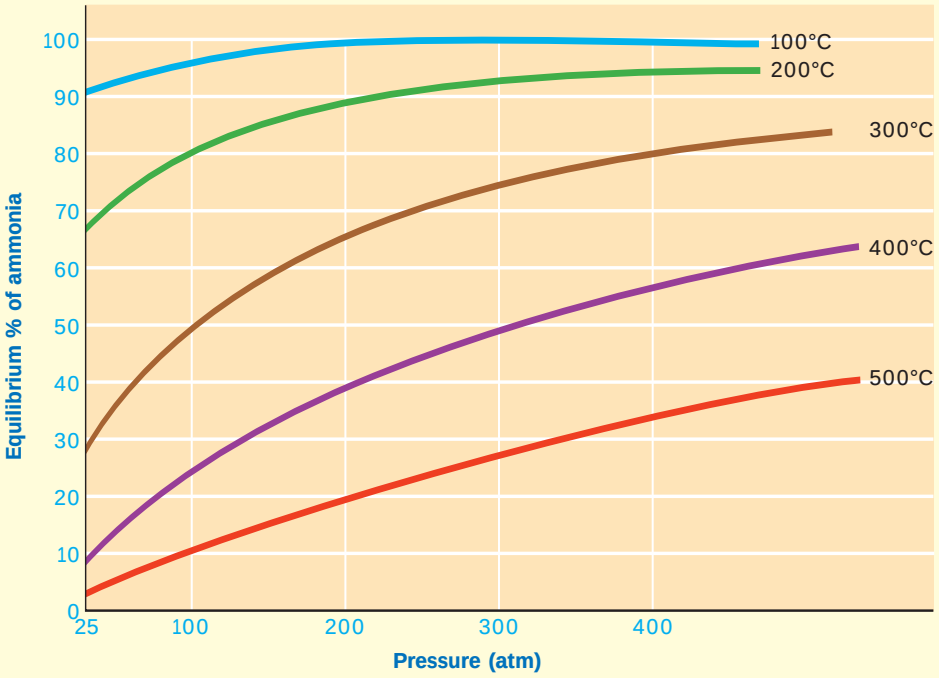

3 Variation of percent ammonia with temperature

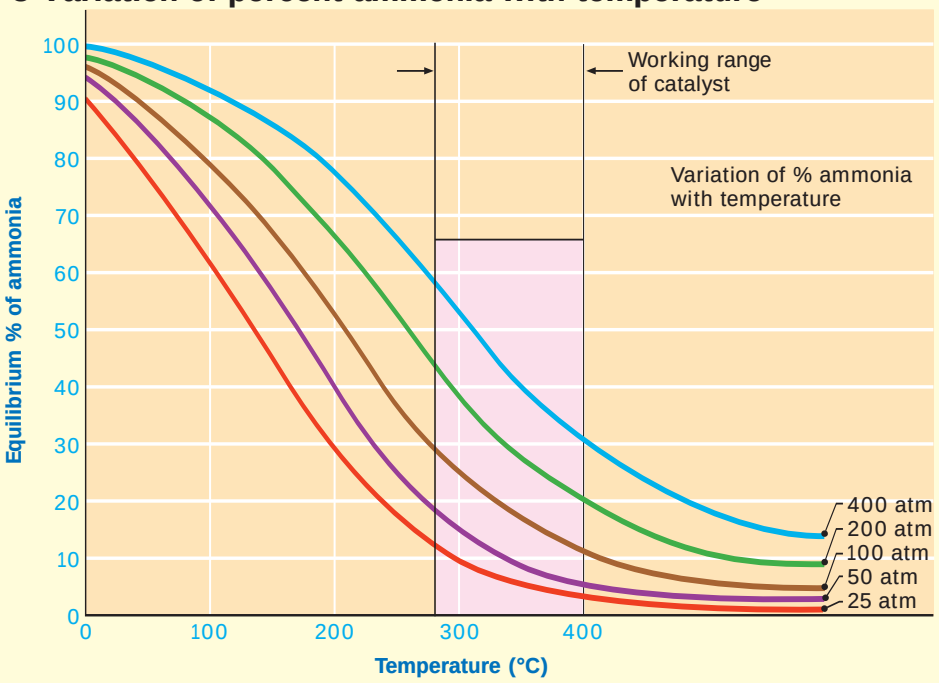

Industrial preparation of ammonia (the Haber process): schematic

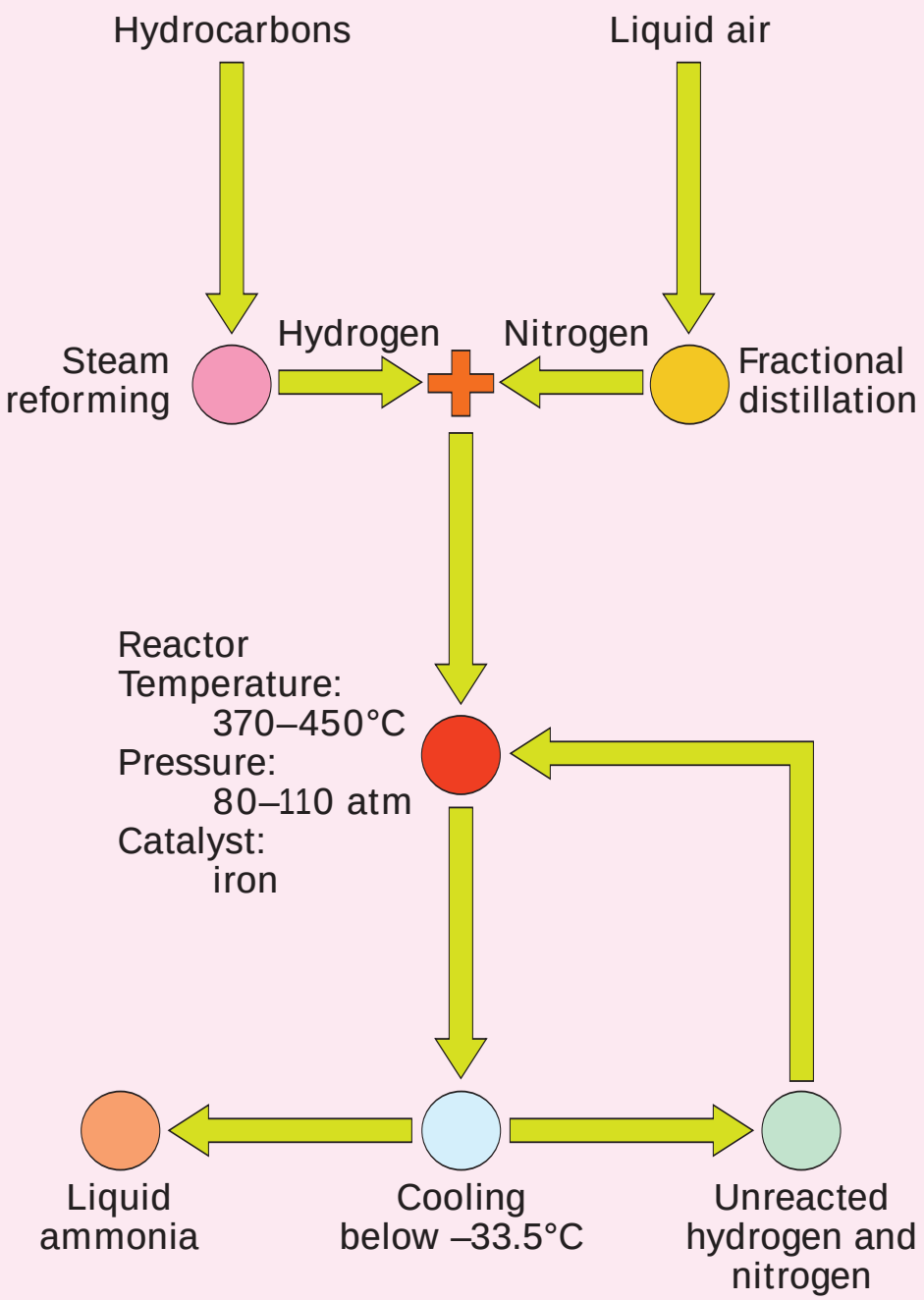

Key words

ammonia
catalyst
equilibrium
fractional distillation
hydrocarbon
hydrogen
nitrogen

The process

- The raw materials for the Haber process are *hydrogen* and *nitrogen*.
- Hydrogen is obtained by the steam reforming of *hydrocarbons*, such as methane, or the reaction of steam with coke.
  $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$
  $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$
- Nitrogen is obtained from the *fractional distillation* of liquid air.
- The formation of *ammonia* is favored by high pressure, and the reaction is normally carried out at 80–110 atm. It is also favored by low temperature, but this also lowers the rate of reaction, so a *catalyst* is used. The reaction is normally carried out at 370–450°C in the presence of a finely divided iron catalyst.
- In reality, the reaction is not allowed to reach *equilibrium*. A single pass through the reactor results in about 15 percent conversion to ammonia.
- The reaction mixture is cooled to below the boiling point of ammonia, at which point liquid ammonia condenses out and is removed. The mixture of unreacted hydrogen and nitrogen is recycled back into the reactor.
- Around 80 percent of the ammonia produced each year is used to make fertilizers, including ammonia solution, ammonium nitrate, ammonium sulfate, and urea.

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Key words

ammonia
azeotropic mixture
exothermic
nitric acid
oxidation

1 Preparation

- The industrial production of *nitric acid* involves two stages: the *oxidation* of *ammonia* and the absorption of the resulting nitrogen oxides.
- In the converter, a mixture of ammonia and air is passed through a platinum–rhodium gauze and the ammonia is oxidized:
  $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$
  $\Delta H = -909\ kj\ mol^{-1}$
- The reaction is *exothermic*, and a large quantity of heat is produced.
- Conditions are carefully controlled to minimize a competing reaction in which ammonia is oxidized to nitrogen:
  $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$
- Air is added to the nitrogen oxides in order to make nitrogen dioxide and, subsequently, dinitrogen tetroxide.
  $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$
  $2NO_2(g) \rightleftharpoons N_2O_4(g)$
- Dinitrogen tetroxide reacts with water to produce nitric acid.
  $3N_2O_4(g) + 2H_2O(l) \rightleftharpoons 4HNO_3(aq) + 2NO(g)$
- The acid from the absorption towers typically contains 55–60 percent nitric acid by mass. Most of the modern demand is for acid of this concentration.
- Nitric acid and water form an *azeotropic mixture* (a mixture that boils without a change in composition) containing 68.5 percent nitric acid by mass. Thus, concentrated nitric cannot be obtained by distillation. Concentrated sulfuric acid is used to reduce the water content and give concentrated nitric acid.

2 Uses of nitric acid

- Over two thirds of nitric acid production is directed to making ammonium nitrate, which is used as a fertilizer and in explosives.

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Industrial preparation of nitric acid

1 Industrial manufacture of nitric acid

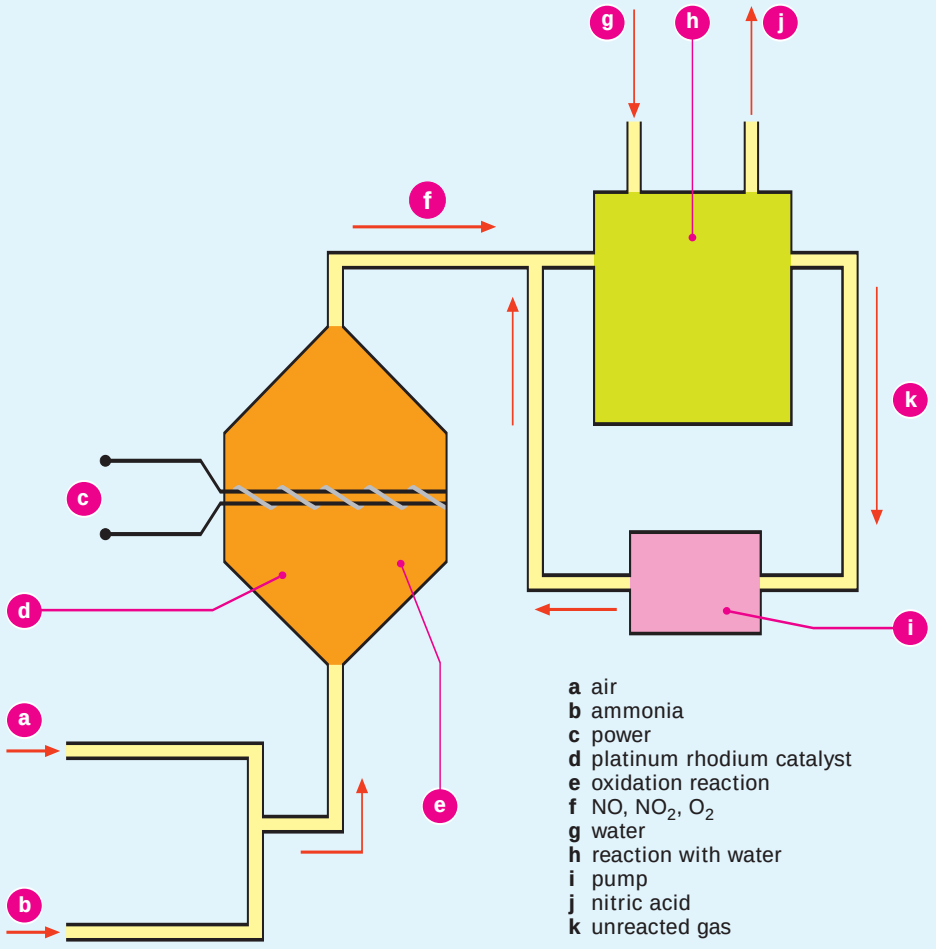

2 Summary of uses

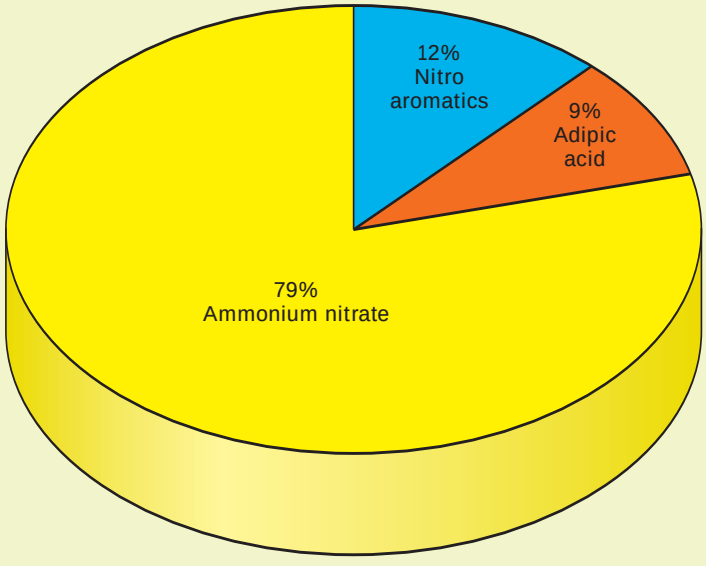

Nitrogen: reactions in ammonia and nitric acid

1 Redox chemistry (ammonia)

$$2NH_3 + 3Cl_2 \longrightarrow N_2 + 6HCl$$

Ammonia reduces chlorine to hydrogen chloride and nitrogen

$$2NH_3 + 3CuO \longrightarrow 3Cu + 3H_2O + N_2$$

Ammonia reduces copper oxide to copper, water, and nitrogen

2 Redox chemistry (nitric acid)

$$C + 4HNO_3 \longrightarrow CO_2 + 4NO_2 + 2H_2O$$

Concentrated nitric acid oxidizes carbon to carbon dioxide

$$3Cu + 8HNO_3(dilute) \longrightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO\uparrow$$

Dilute nitric acid oxidizes copper to produce copper nitrate, water, and nitrogen oxide

$$Cu + 4HNO_3(conc) \longrightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2\uparrow$$

Concentrayed nitric acid oxidizes copper to produce copper nitrate, water, and nitrogen dioxide

3 Complex ammonia salts

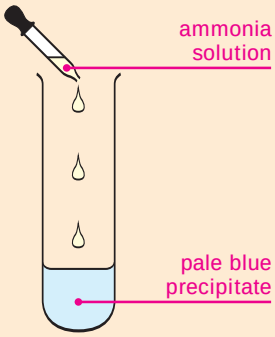

Ammonia solutionis added to $CuSo_4$ solution

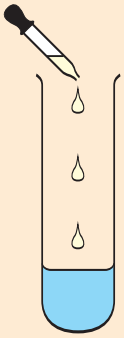

More ammonia solution is added

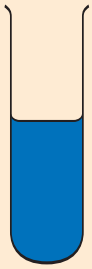

The precipitate diasppears, leaving a deep royal blue solution (a complex salt)

4 Tetraamminecopper(II) ion

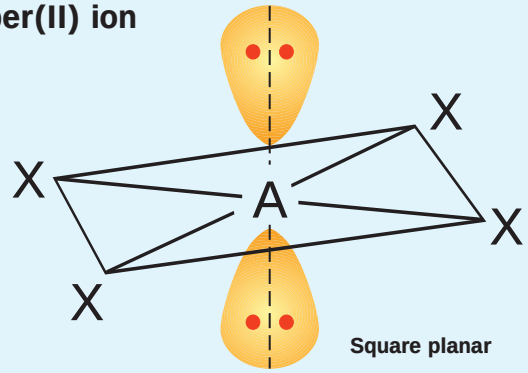

Square planar

Key words

ammonia
nitric acid
oxide
oxidizing agent
reducing agent

1 Redox chemistry (ammonia)

- *Ammonia* is a *reducing agent* and will reduce chlorine and heated metal *oxides* such as copper oxide. During the reactions, the ammonia is oxidized to nitrogen.

2 Redox chemistry (nitric acid)

- In addition to its properties as an acid, *nitric acid* is also a powerful *oxidizing agent*. It is able to oxidize both non-metals and metals.

3 Complex ammonia salts

- When ammonia solution is added drop by drop to copper(II) sulfate solution, a pale blue precipitate of copper(II) hydroxide is formed:
  $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$
- When an excess of ammonia solution is added, the pale blue precipitate redissolves, forming a deep blue solution:
  $Cu(OH)_2(s) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}$
- The deep blue solution contains the complex ion tetraamminecopper(II), $[Cu(NH_3)_4]^{2+}$.
- Ammonia also forms complex ions with other metals, such as diamminesilver(I), $[Ag(NH_3)_2]^+$ and hexaamminenickel(II), $[Ni(NH_3)_6]^{2+}$.

4 Tetraamminecopper(II)

- In the tetraamminecopper(II) ion, a copper ion is surrounded by four ammonia molecules in a square planar arrangement. The non-bonding pair of electrons on each nitrogen atom is attracted to the central positively charged copper ion.

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Basic reactions of nitrogen

Key words

acid
ammonia
nitrate
nitric acid
nitrite
nitrogen
oxide
oxidizing agent
salt

1 With metals and non-metals

- *Nitrogen* combines directly with both metals, such as magnesium, and non-metals, such as sodium and hydrogen.

2 Basic reactions of ammonia

- *Ammonia* reacts with water to produce a soluble alkaline gas (2A).
- Ammonia reacts with an *acid* to produce a *salt* (2B).
- Ammonia reacts with an *oxide* to produce a metal and nitrogen (2C).
- Ammonia reacts with oxygen to produce *nitric acid* (2D).

3 Nitric acid

- Nitric acid is both a strong acid (3A) and a powerful *oxidizing agent* (3B).
- Cold, dilute nitric acid produces nitrogen oxide when reacting with a metal (3C).
- Hot, concentrated nitric acid produces nitrogen dioxide when reacting with a metal (3D).

4 Nitrates

- All *nitrates* are very soluble in water.
- Group 1 metal nitrates (apart form lithium nitrate) decompose on heating to form metal *nitrites* and oxygen.
- Other metal nitrates decompose on heating to form metal oxides, nitrogen dioxide, and oxygen.
- Ammonium nitrate decomposes on heating, forming water and dinitrogen oxide.

1 With metals and non-metals

$3Mg + N_2 \longrightarrow Mg_3N_2$

$6Na + N_2 \longrightarrow 2Na_3N$

$N_2 + 3H_2 \overset{\text{Fe catalyst}}{\rightleftharpoons} 2NH_3$

2 Basic reactions of ammonia

A $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH_2^-$

$NH_3 + HCl \rightleftharpoons NH_4Cl$

B $2NH_3 + 3CuO \longrightarrow 3Cu + 3H_2O + N_2$

C $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

then $2NO + O_2 \longrightarrow 2NO_2$

and $4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3$

D $Cu(OH)_2 + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+} + 2OH^-$

3 Nitric acid

A $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$

B $C + 2HNO_3 \longrightarrow CO_2 + 2NO_2 + H_2O$

$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2$

4 Nitrates

A $2NaNO_3 \longrightarrow 2NaNO_2 + O_2$

B $2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2$

C $NH_4NO_3 \longrightarrow 2H_2O + N_2O$

2A soluble alkaline gas
2B reducing agent
2C ammonia with oxygen to make nitric acid
2D complexing agent
3A strong acid
3B oxidizing agent
4A group 1 (excluding $LiNO_3$)
4B others
4C ammonium nitrate

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Nitrate fertilizers

1 Atmospheric nitrogen

Nitrogen → Ammonia → Nitric acid

Ammonia → Ammonium nitrate

$$NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$$

2 Ammonia nitrate

Formula mass of ammonium nitrate = 14 + 4 + 14 + 3 × 16 = 80

Percentage of nitrogen in ammonium nitrate = $\frac{2 \times 14 \times 100}{80}$ = 35%

3 Nitrogen in plants

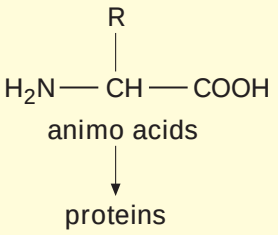

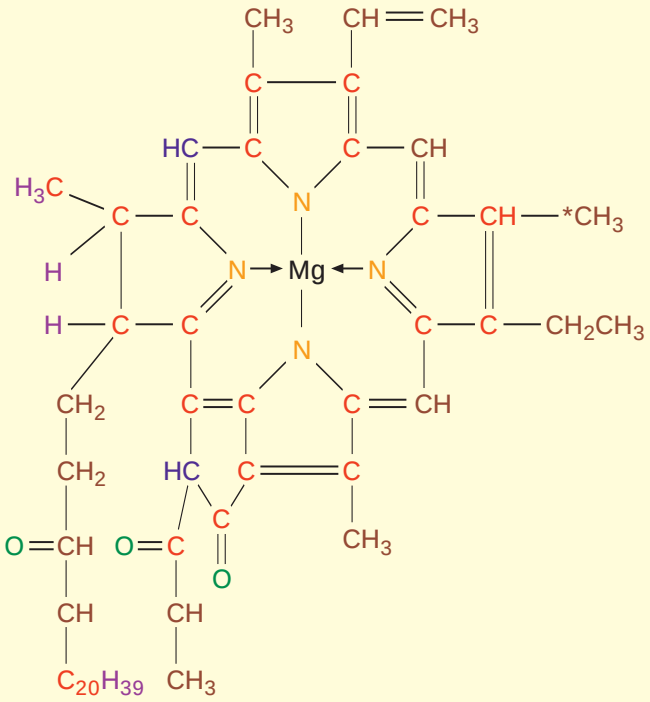

Chlorophyll a
(In chlorophyll b, the methyl group marked by an asterisk is replaced by a —CHO group)

4 Table of nitrogen fertilizers

Compound	Formula	Percentage of nitrogen
Ammonium nitrate	NH_4NO_3	35.00
Ammonium sulphate	$(NH_4)_2SO_4$	21.21
Urea	H_2NCONH_2	46.67

Key words

alkali
amino acid
ammonia
chlorophyll
neutralization
nitric acid
protein

1 Atmospheric nitrogen

- Atmospheric nitrogen is an important raw material in the manufacture of *ammonia* and *nitric acid*.
- Ammonia solution is *alkali*, while nitric acid is acidic.
- The two solutions undergo a *neutralization* reaction to form the salt ammonium nitrate.

2 Ammonia nitrate

- The percentage of nitrogen in a nitrogenous fertilizer is an important factor in determining how much fertilizer should be used on an area of crops.
- Ammonium nitrate is very soluble in water. Any excess that is applied to soil is readily washed out into streams and rivers, where it causes environmental problems.

3 Nitrogen in plants

- Plants use nitrogen to make *amino acids* and, from these, to make *proteins*.
- Plants also use nitrogen to make other important chemicals, such as *chlorophyll*.

4 Nitrogen fertilizers

- Ammonium sulfate is formed by the neutralization reaction between ammonia solution and sulfuric acid:
  $2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$
- Urea is a waste product of animal metabolism and is excreted from the body in sweat and urine. It is made industrially by the reaction of ammonia with carbon dioxide. This reaction is carried out at 200 °C and 200 atmospheres:
  $CO_2(g) + 2NH_3(g) \rightarrow H_2NCONH_2(l) + H_2O(g)$

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Key words

catalyst
double bond
enzyme
group 6
oxygen
sulfur

1 Atoms and molecules

- *Oxygen* and *sulfur* are both in *group 6* of the periodic table. Atoms of each element have six electrons in the outer electron shell and require two electrons to fill the shell.
- Oxygen exists as oxygen molecules, O_2, in which each oxygen atom provides two electrons. The oxygen atoms are held together by a *double bond*, O=O.
- At room temperature, sulfur exists as a molecule composed of eight sulfur atoms, S_8, arranged in the shape of a crown.

2 Laboratory preparation of oxygen

- Oxygen is prepared in the laboratory by the decomposition of hydrogen peroxide using a suitable *catalyst*, such as manganese dioxide:
  $2H_2O_2(l) \rightarrow O_2(g) + 2H_2O(l)$
- Hydrogen peroxide is rapidly decomposed by a variety of catalysts, including the *enzyme* catalase. In one second, one molecule of catalase can decompose up to 50,000 molecules of hydrogen peroxide.
- Oxygen is only slightly soluble and can be collected over water.
- Hydrogen peroxide is usually supplied in solutions designated by volume strength. For example, 20-volume hydrogen peroxide yields 20 volumes of oxygen gas per volume of solution.

3 Physical properties of oxygen and sulfur

- At room temperature, oxygen is a colorless, odorless gas, while sulfur is a yellow solid.

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Oxygen and sulfur

1 Atoms and molecules

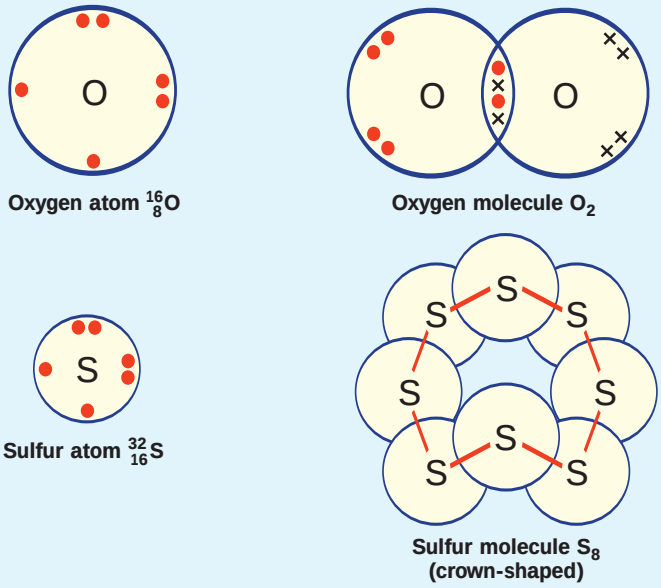

2 Laboratory preparation of oxygen

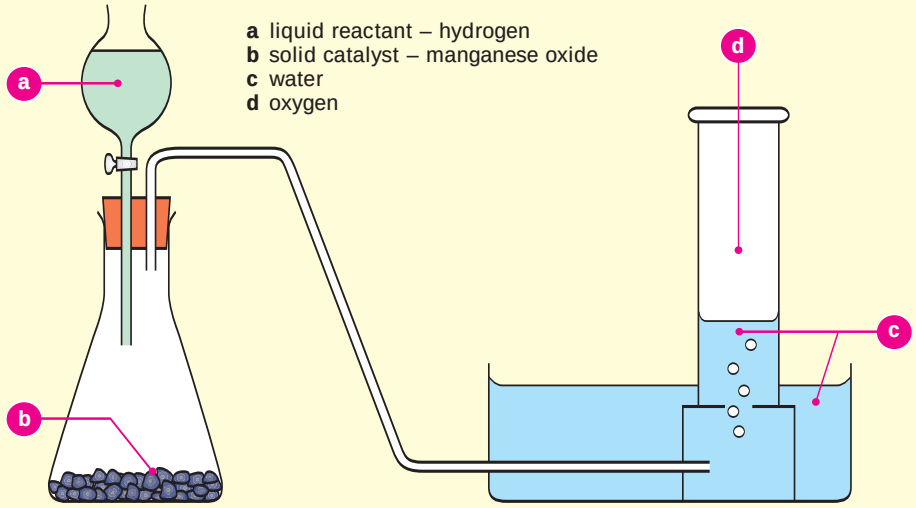

3 Physical properties of oxygen and sulfur

Physical properties	Oxygen	Sulfur
m.p./°C	–218	119
b.p./°C	–183	444
Density g/dm^3	1.31	2070
Color	none	yellow
Smell	none	slight
Solubility	0.007g per 100g/H_2O	almost insoluble

Extraction of sulfur—the Frasch process

The Frasch process

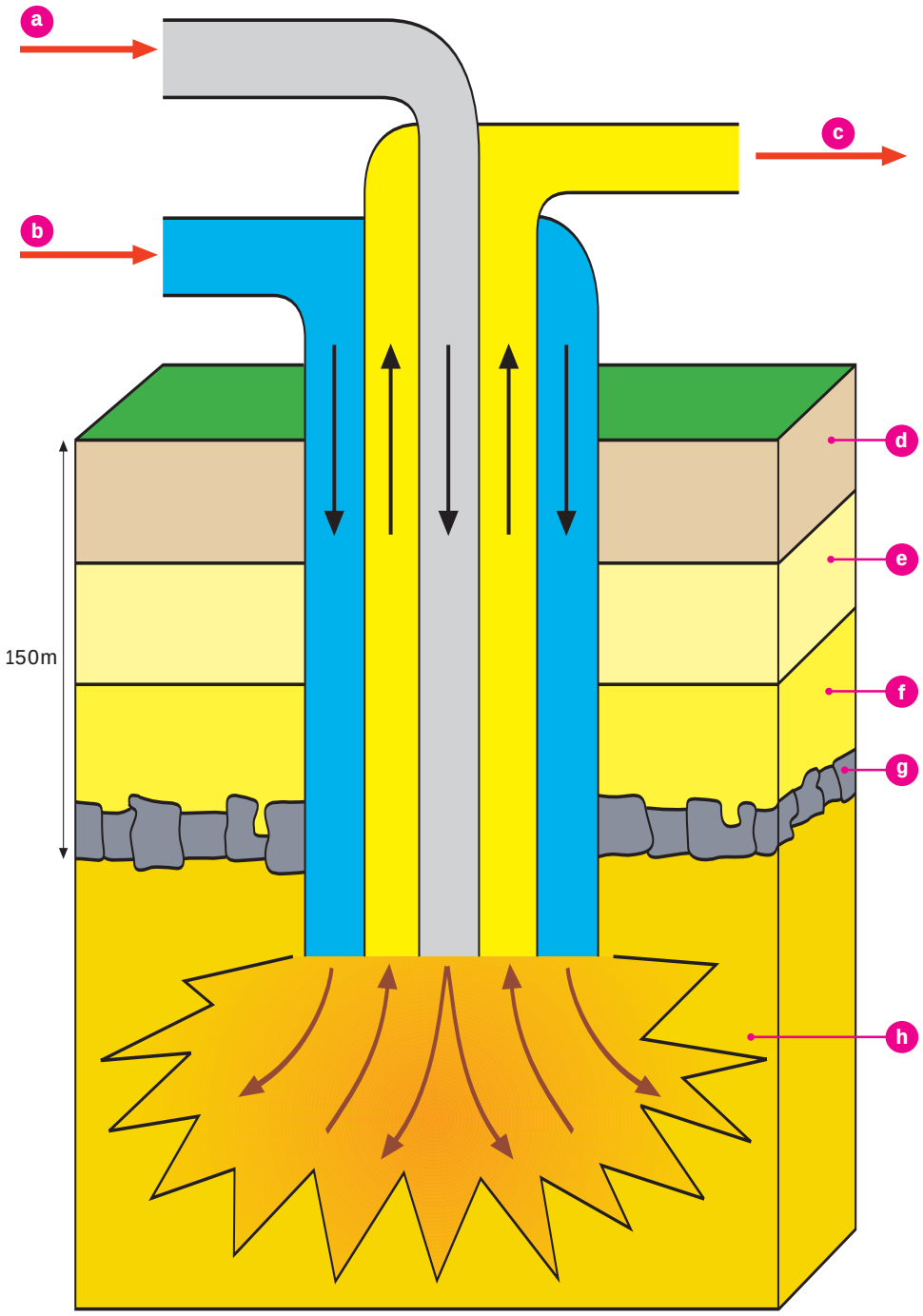

a hot compressed air
b superheated water (at 170°C)
c molten sulfur and water
d clay
e quicksand
f sand
g limestone
h sulfur

Key words

ore
sulfide
sulfur
sulfur dioxide

Processing and uses

- Hot compressed air and superheated steam are piped underground. This forces water and molten *sulfur* to the surface.
- The sulfur obtained is about 99.5 percent pure, and may be stored and transported molten or allowed to cool and solidify.
- A significant proportion of the elemental sulfur used in industry is obtained as a by-product of other industrial processes such as the refining of metal *sulfide ores* and petroleum refining.
- In petroleum refining, sulfur compounds like thiols (R-SH) and disulphides (R-S-S-R) are removed from some of the petroleum fractions because they would damage the catalysts used in refining processes and also because of their potential to cause environmental problems. For example, if they were not removed from fuels like gasoline, they would burn to form *sulfur dioxide*. This gas dissolves in water in the atmosphere, forming an acid, and would significantly increase the acidity of rain water.
- Sulfur compounds are converted to hydrogen sulfide by catalytic hydrogenation:

  $R\text{-}SH(g) + H_2(g) \rightarrow R\text{-}H(g) + H_2S(g)$

  $R\text{-}S\text{-}S\text{-}R(g) + 3H_2(g) \rightarrow 2R\text{-}H(g) + 2H_2S(g)$
- Hydrogen sulfide can be converted to sulfur using the Claus process:

  $6H_2S(g) + 5O_2(g) \rightarrow 2SO_2(g) + 2S_2(g) + 6H_2O(g)$

  $4H_2S(g) + 2SO_2(g) \rightarrow 3S_2(g) + 4H_2O(g)$

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Key words

allotrope
bond
diatomic molecule
oxygen
ozone
sulfur
viscosity

Oxygen and sulfur: allotropes

Allotropes

- *Allotropes* are different forms of the same element in the same physical state. Many elements, including *oxygen* and *sulfur*, exist as more than one allotrope.

1 Oxygen

- The most common form of oxygen is a *diatomic molecule*, O_2. The gas also exists as a triatomic molecule, O_3, which is called *ozone*.
- Oxygen has two *bonds* between the atoms. Each atom donates one electron to each bond.
- In ozone, the central oxygen atom donates a pair of electrons to form a bond with the other two atoms. One of the other atoms also donates a pair of electrons, while the other does not.

2 Sulfur

- Sulfur has several allotropes in the solid form, including rhombic sulfur and monocline sulfur.
- Rhombic sulfur crystals have a lemon-yellow appearance.
- Monocline sulfur crystals are needle-like and have a deeper yellow color.
- Each allotrope is composed of S8 puckered molecular rings, but arranged in different ways.

3 Heating sulfur

- Sulfur melts when gently heated, and the sulfur molecules are able to move around, forming a low-*viscosity* liquid.
- On stronger heating, the sulfur rings break open, yielding sulfur molecules. These molecules join by cross-linking, causing a sharp increase in viscosity.
- On even stronger heating, the cross-linked structure breaks, yielding small sulfur molecules, which are free-moving, and the viscosity falls.

1 Allotrope of oxygen

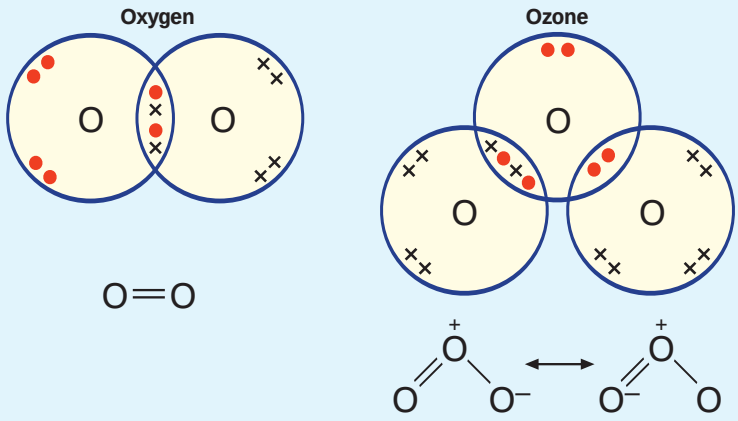

2 Allotropes of sulfur

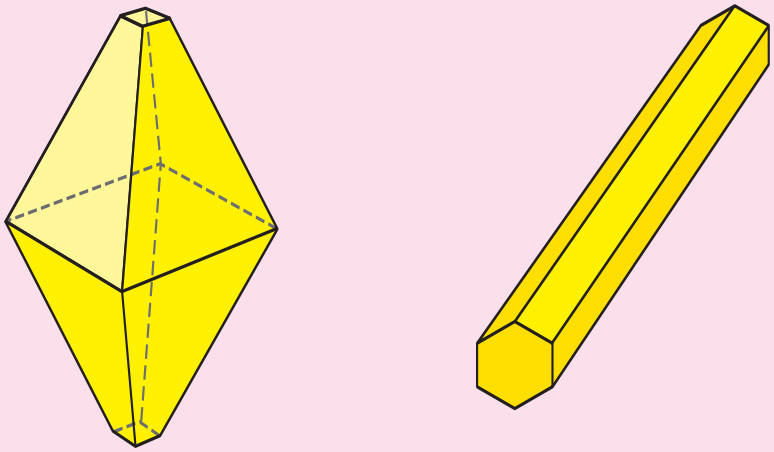

Rhombic sulfur

Monoclinic sulfur

3

Structure	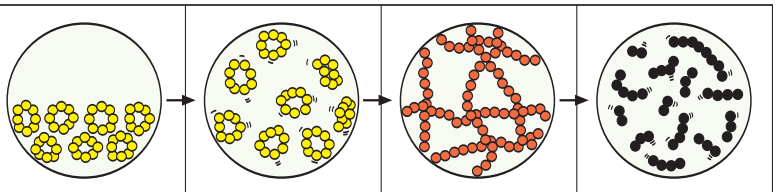			
Color	yellow	yellow	red	black
State of matter	solid	liquid	liquid	liquid
Viscosity	–	low	high	low

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Oxygen and sulfur: compound formation

1 Oxygen and magnesium

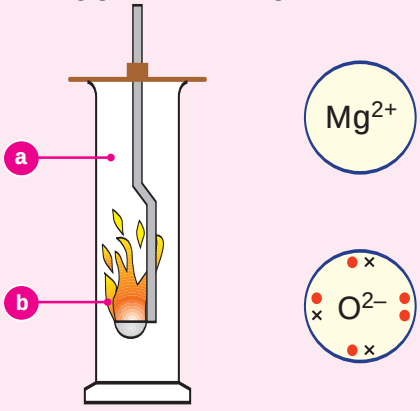

Oxygen reacts with magnesiun

Magnesium oxide is ionic

2 Reaction of sulfur and iron

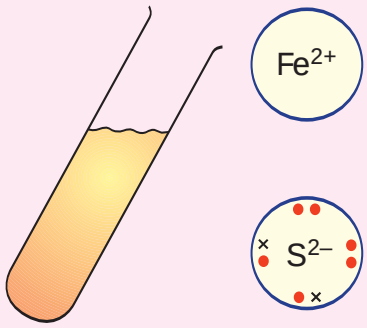

Sulfur and iron glow

Iron sulfide is also ionic

3 Phosphorous reacts with atmospheric oxygen

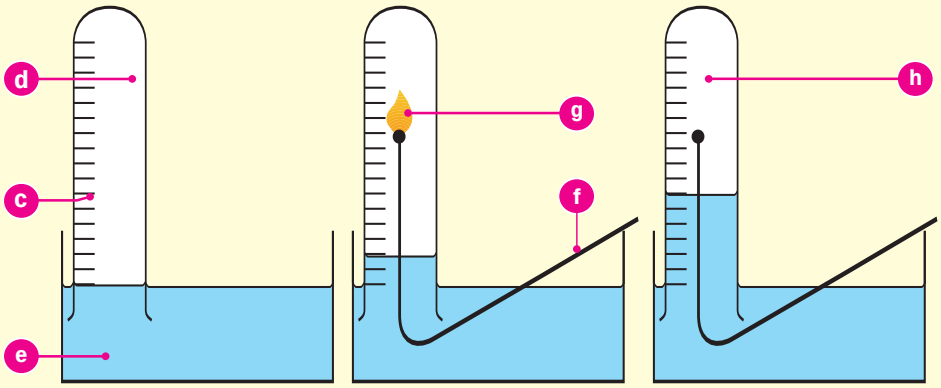

A tube full of air

Phosphorus is added

Unreacted phosphorus is left behind

a oxgen
b magnesium burning
c volume scale
d 100 cm^3 of air
e water
f stiff wire
g phosphorus reacting
h 79 cm^3 of air is left behind

4 Water, hydrogen peroxide, and hydrogen sulfide

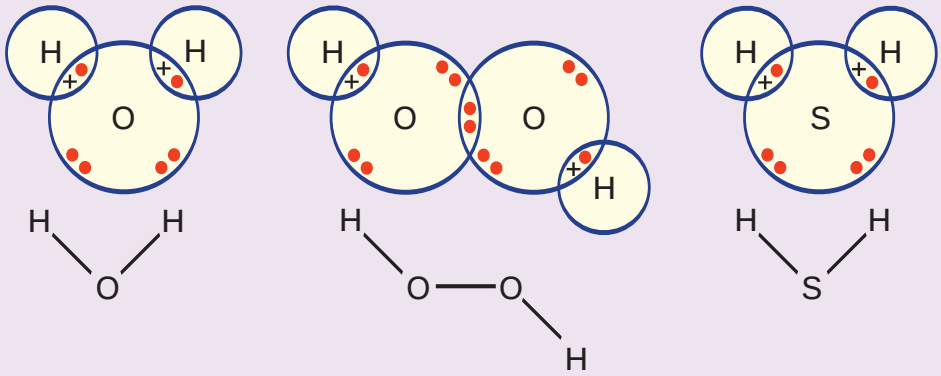

Water is formed when oxygen and hydrogen are exploded together

Hydrogen peroxide is made by reacting a metal peroxide with acid

Hydrogen sulfide is made by the reaction of a metal sulfide with dilute acid

Key words

hydrogen	*oxide*
hydrogen peroxide	*oxygen*
hydrogen sulfide	*peroxide*
magnesium	*sulfide*
	sulfur

1 Oxygen and magnesium

- *Oxygen* reacts with most metals to form metal *oxides*. Magnesium burns in air with a bright flame, producing a white smoke of magnesium oxide. The reaction is even more vigorous in pure oxygen:
  $2Mg(s) + O_2(g) \rightarrow 2MgO$
- Soluble metal oxides dissolve in water to form alkaline solutions:
  $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$

2 Sulfur and iron

- *Sulfur* forms *sulfides* with many metals. When iron and sulfur are heated together, iron sulfide is formed:
  $8Fe + S_8 = 8FeS$

3 Oxygen and phosphorous

- Oxygen also reacts with non-metals to form oxides. Phosphorus burns in air to form phosphorus(V) oxide. Approximately 20 percent of the air is used:
  $P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$
- Non-metal oxides dissolve in water to form acids:
  $P_4O_{10}(s) + H_2O(l) \rightarrow 4H_3PO_4(aq)$

4 Other common reactions

- *Hydrogen* burns in oxygen to form water:
  $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
- *Hydrogen peroxide* is formed by the reaction of metal *peroxides*, such as barium peroxide, with dilute acids:
  $BaO_2(s) + H_2SO_4(aq) \rightarrow H_2O_2(aq) + BaSO_4(s)$
- *Hydrogen sulfide* is formed by the reaction of a metal sulfide with a dilute acid:
  $FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$

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The oxides of sulfur

Key words

catalyst
lone pair
oxide
sulfite
sulfur
sulfur dioxide
sulfurous acid
sulfur trioxide

Sulfur oxides

- *Sulfur* combines with oxygen to form two *oxides*: *sulfur dioxide* (sulfur(IV) oxide) and *sulfur trioxide* (sulfur(VI) oxide.

1 Laboratory preparation of sulfur dioxide

- Metal *sulfites*, such as sodium sulfite, react with dilute acids to from sulfur dioxide:
  $Na_2SO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g)$
- Sulfur dioxide is dried by passing it through anhydrous calcium chloride and collected by downward delivery.
- Sulfur dioxide dissolves in water to form *sulfurous acid*:
  $H_2O(l) + SO_2(g) \rightarrow H_2SO_3(aq)$

2 Laboratory preparation of sulfur trioxide

- Sulfur trioxide is formed when dry sulfur dioxide and oxygen are heated in the presence of a platinized asbestos *catalyst*:
  $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
- Sulfur trioxide forms needle-like crystals when cooled.
- Sulfur trioxide dissolves in water to form sulfuric acid:
  $H_2O(l) + SO_3(g) \rightarrow H_2SO_4(aq)$

3 SO_2 and SO_3 molecules

- In sulfur dioxide, there are four pairs of bonding electrons and a non-bonding or *lone pair* of electrons around the sulfur atom. The pairs of electrons are kept as far from each other as possible by adopting a bent shape in which the double bonds between the sulfur and oxygen atoms are at an angle of 120°.
- In sulfur trioxide, the three double bonds form a trigonal planar structure around the sulfur atom in which the bond angle is also 120°.

1 Laboratory preparation of sulfur dioxide

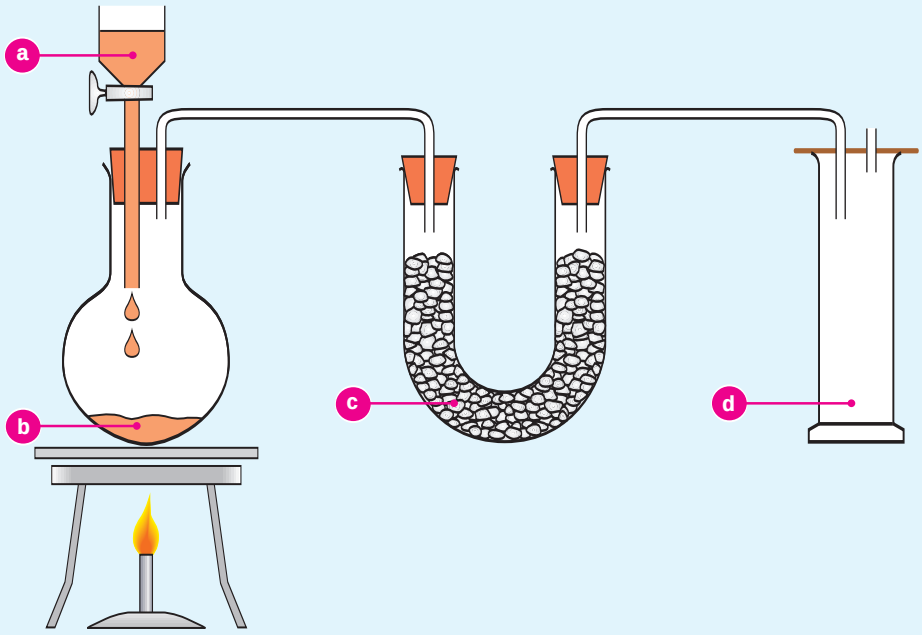

2 Laboratory preparation of sulfur trioxide

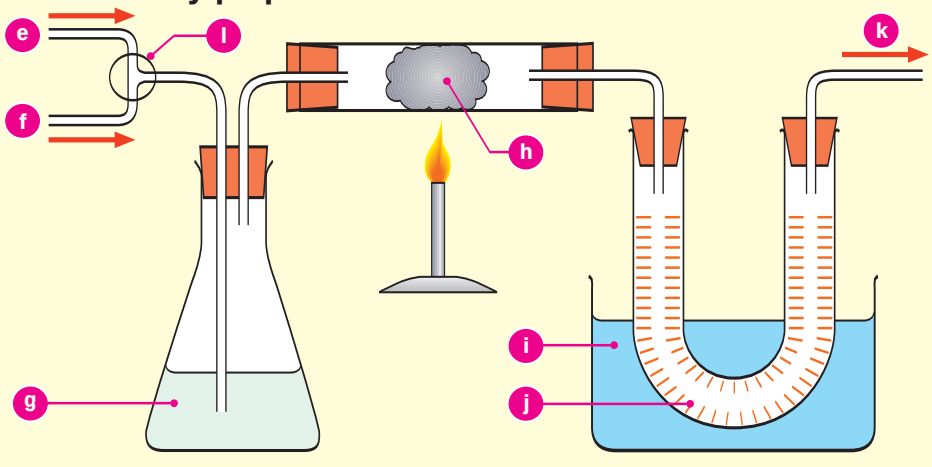

a dilute
b sodium sulfite
c anhydrous $CaCl_2$
d upward displacement
e oxygen
f sulfur dioxide
g concentrated sulfuric acid for drying
h plantinized asbestos
i freezing mixture of ice and salt
j needles of sulfur oxide
k to the fume cupboard
l 3-way tap

3 SO_2 and SO_3 molecules

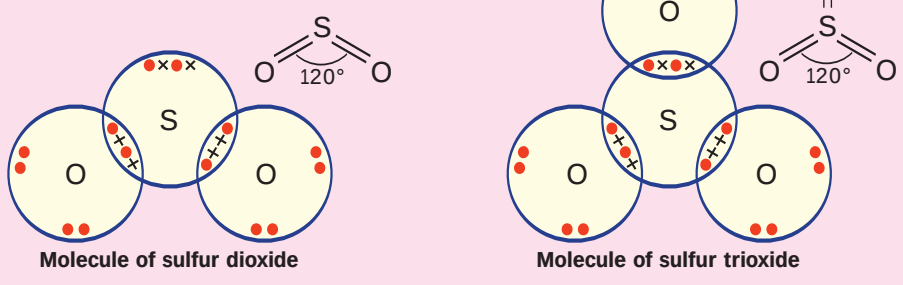

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Industrial preparation of sulfuric acid (the contact process): theory

1 Sulfur burning

$$S(1) + O_2(g) \rightarrow SO_2(g) \qquad \Delta H = -297 \text{ kJ mol}^{-1}$$

2 Conversion

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -192 \text{ kJ mol}^{-1}$$

4 moles 2 moles

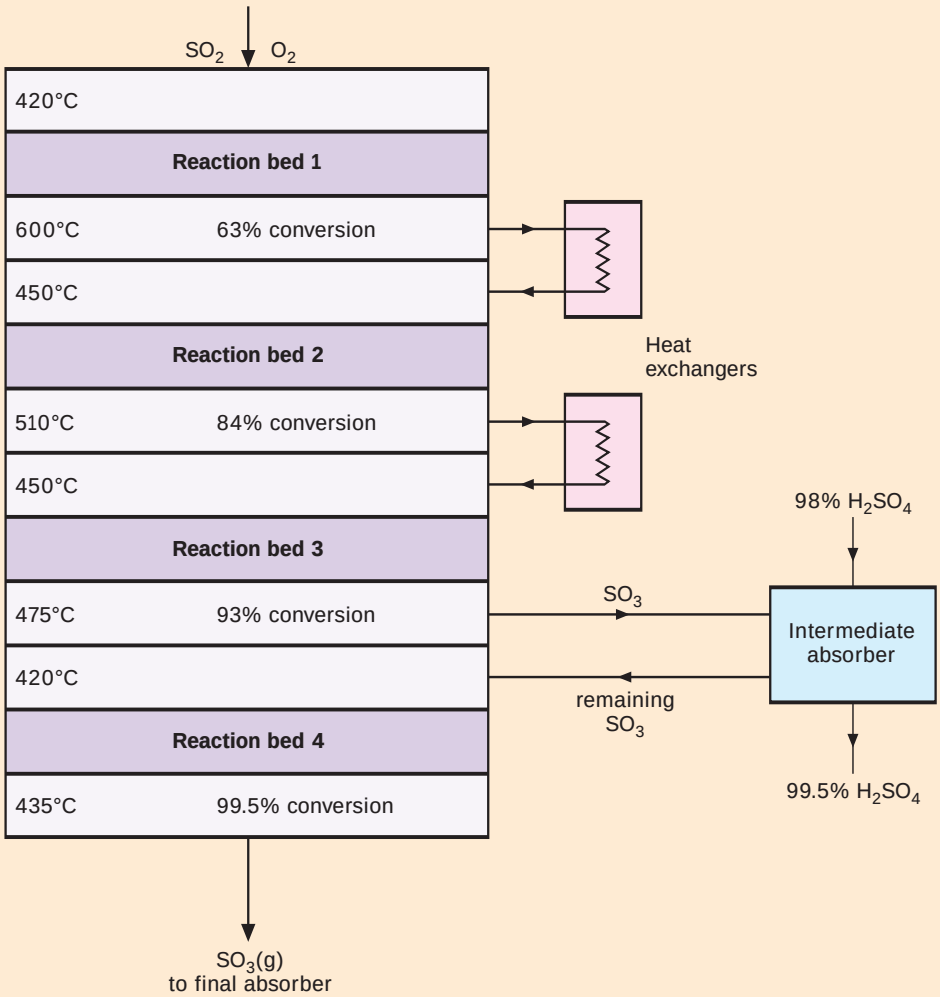

3 Absorption

$$H_2SO_4(1) + SO_3(g) \rightleftharpoons H_2S_2O_7(1)$$

$$H_2S_2O_7(1) + H_2O(1) \rightarrow 2H_2SO_4(1)$$

Key words

catalyst
exothermic
equilibrium
sulfur
sulfur dioxide
sulfuric acid
sulfur trioxide

Preparation of sulfuric acid

- The industrial preparation of *sulfuric acid* is a three stage process:
  1. *Sulfur* burning
  2. Conversion of *sulfur dioxide* to *sulfur trioxide*
  3. Absorption of sulfur trioxide to form sulfuric acid.

1 Sulfur burning

- Molten sulfur is sprayed into a furnace and burned in a blast of dry air. The reaction is very *exothermic*, and the reaction temperature rises to over 1,000°C. The mixture of gases, containing sulfur dioxide and oxygen, is cooled before conversion.

2 Conversion

- The conversion of sulfur dioxide into sulfur trioxide is an exothermic reaction. The forward reaction is favored by a low temperature. However, this would also reduce the rate of reaction, so it would take longer for the reaction mixture to reach *equilibrium*.
- The reaction is carried out at temperatures between 420–620°C in the presence of a vanadium(V) oxide *catalyst*.
- Modern converters consist of four reaction beds. The reaction mixture is cooled after passing through each of the first two beds in order to maximize conversion in subsequent beds.

3 Absorption

- Sulfur trioxide is removed and absorbed after the reaction mixture has passed through both the third and fourth beds.
- Sulfur trioxide is absorbed into 98 percent sulfuric acid to form 99.5 percent sulfuric acid, which is sometimes referred to as oleum and given the chemical formula $H_2S_2O_7$.
- Oleum is then diluted to give 98 percent sulfuric acid.

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Key words

catalyst
ore
sulfide
sulfur
sulfur dioxide
sulfuric acid
sulfur trioxide

Preparing sulfuric acid

- The *sulfur* needed for the manufacture of *sulfuric acid* is obtained either directly from the ground or as a by-product of other industrial processes, such as the refining of metal *sulfide ores* and the refining of crude oil.
- An excess of dry air is used to ensure there is sufficient oxygen remaining in the reaction mixture for the conversion of *sulfur dioxide* to *sulfur trioxide*.
- The vanadium(V) oxide (vanadium pentoxide) *catalyst* is activated by potassium sulfate on a silica support. It is generally in the form of small cylindrical pellets that ensure a large surface area for reaction. The catalyst is inactive below about 380°C and has an optimum working temperature between 420–620°C.
- The catalyst pellets are packed onto perforated plate supports to form reaction beds. In a modern converter, there four reaction beds, each consisting of a layer of catalyst pellets about 0.6 m deep.
- A conversion of 99.5 percent of sulfur dioxide to sulfur trioxide is essential for both economic and environmental reasons. This can only be attained by removing heat between reaction beds and by removing the sulfur trioxide produced between the third and fourth beds.
- The mixture of gases that remain after absorption consists mostly of nitrogen, together with a small proportion of oxygen and traces of sulfur dioxide. The gases are filtered to remove any sulfuric acid before being released into the atmosphere at high level via a stack.
- Sulfuric acid is used in a wide variety of industries. Important uses include the manufacture of general chemicals, paints and pigments, detergents and soaps, and phosphatic fertilizers.

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Industrial preparation of sulfuric acid (the contact process): schematic

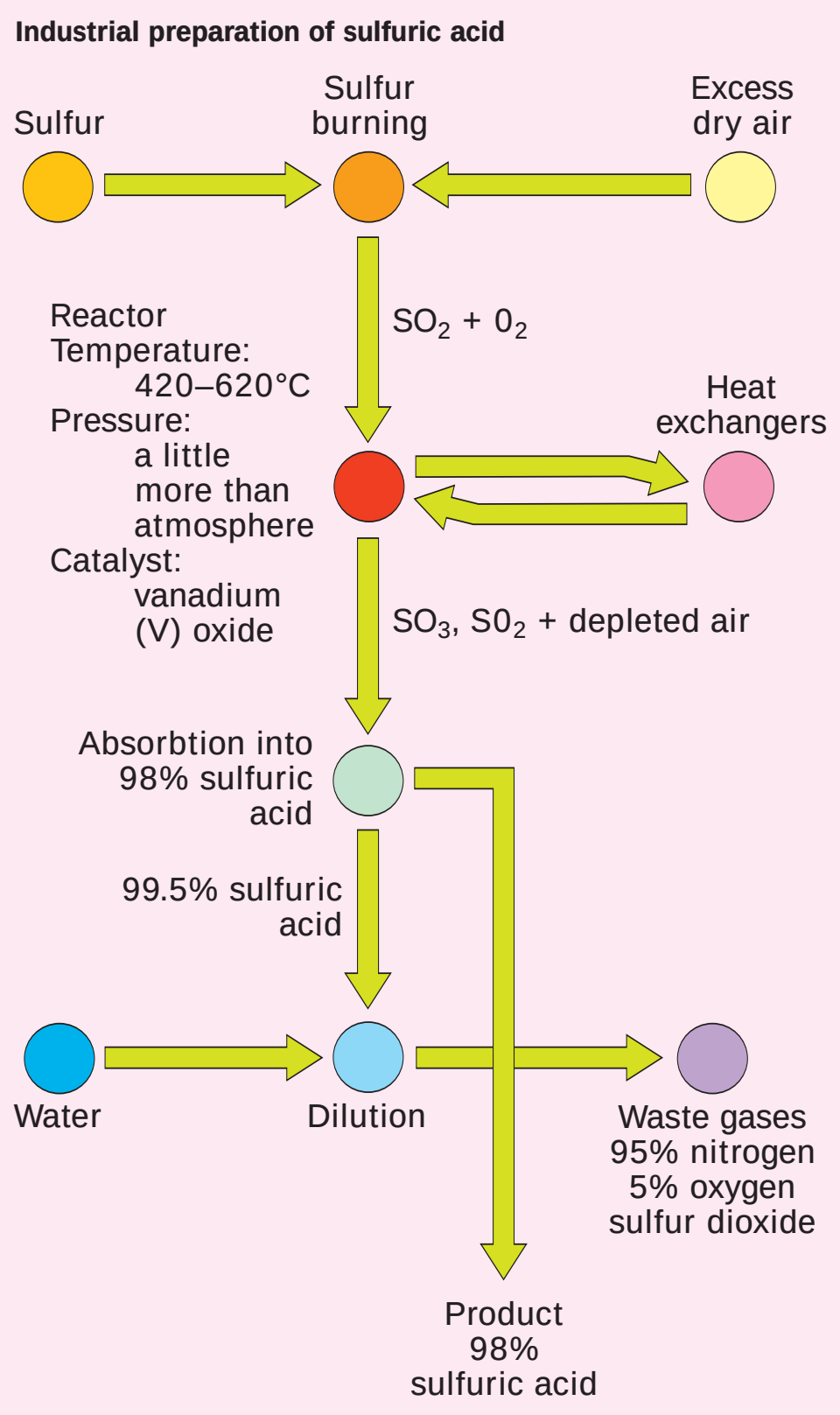

Affinity of concentrated sulfuric acid for water

1 Sulfuric acid and atmospheric water

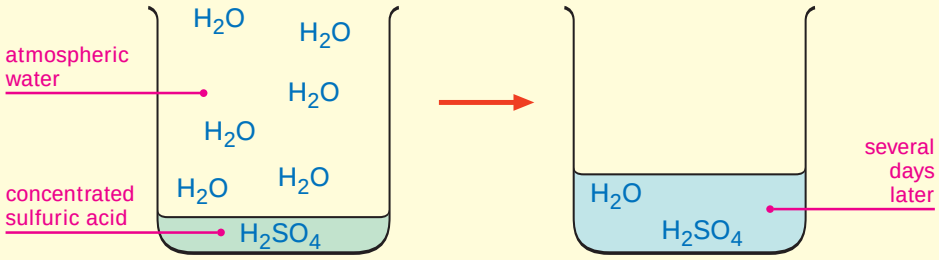

2 Illustrating sulfuric acid's affinity for water

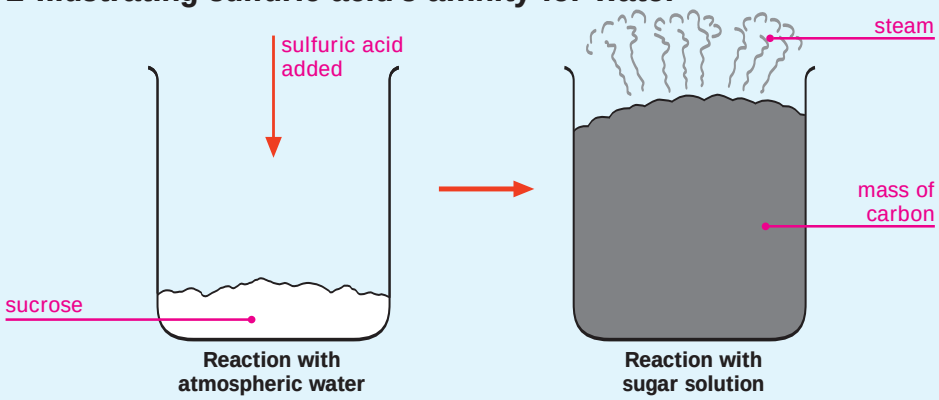

3 Drying gases

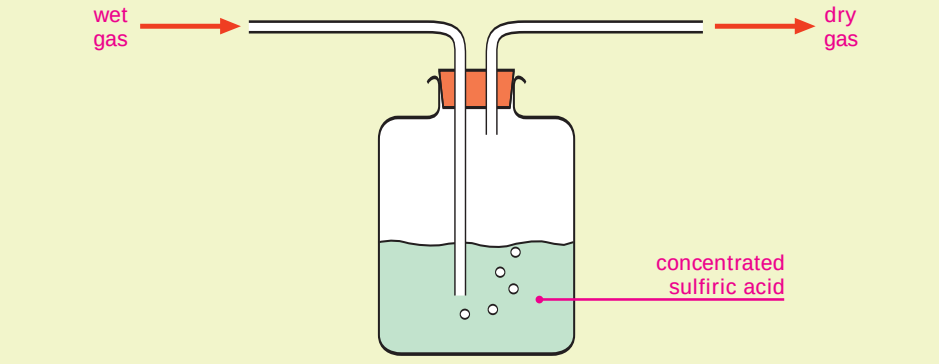

4 Forming esters and alkenes

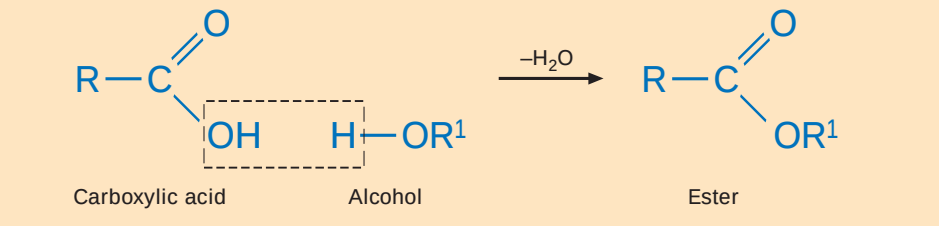

Key words

alcohol
alkene
carboxylic acid
catalyst
ester
sulfuric acid

1 Sulfuric acid and atmospheric water

- Concentrated *sulfuric acid* will absorb water from the air.
- The level of liquid in a beaker containing concentrated sulfuric acid rises as water is absorbed and the acid becomes more dilute.

2 Sulfuric acid's affinity for water

- Concentrated sulfuric acid will remove the elements of water from organic chemicals such as sucrose ($C_{12}H_{22}O_{11}$).
- When concentrated sulfuric acid is poured onto sucrose, the crystalline white sucrose turns into a black amorphous mass of carbon.

3 Drying gases

- Concentrated sulfuric acid can be used to dry gases, such as hydrogen. The gas is bubbled through the acid in a suitable container.
- Some gases, such as ammonia, react with concentrated sulfuric acid and cannot be dried in this way.

4 Forming esters and alkenes

- Concentrated sulfuric acid is used as a *catalyst* in the formation of *esters* from *carboxylic acids* and *alcohols*. Concentrated sulfuric acid removes the elements of water from alcohols to form *alkenes*:

$$R\text{-}CH_2\text{-}CH_2OH \xrightarrow{-H_2O} R\text{-}CH{=}CH_2$$

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Key words

hydrogen peroxide
hydrogen sulfide
oxidizing agent
oxygen
redox reaction
reduction
sulfur
sulfur dioxide

1 Common redox reactions

- *Oxidation* reactions and *reduction* reactions are more accurately described as *redox reactions* because they cannot occur in isolation. One substance is reduced and another is oxidized at the same time.
- *Hydrogen sulfide* reduces chlorine gas to chloride ions. The sulfide is oxidized to elemental *sulfur*:
  $Cl_2 + 2e^- \rightarrow 2Cl^-$ reduction
  $S^{2-} \rightarrow S + 2e^-$ oxidation
- *Hydrogen peroxide* is an oxidizing agent but is itself oxidized by a more powerful oxidizing agent such as potassium manganate(VII).
- *Sulfur dioxide* is a reducing agent both in the gaseous form and in aqueous solution. It reduces iron(III) to iron(II) while being itself oxidized to a sulfate:
  $Fe^{3+} + e^- \rightarrow Fe^{2+}$ reduction
- Sulfur dioxide can be oxidized to sulfur trioxide by reaction with *oxygen*.
- Copper reacts with concentrated sulfuric acid. In this reaction, the concentrated sulfuric acid acts as an oxidizing agent, oxidizing copper metal to copper(II). The sulfuric acid is itself reduced to sulfur dioxide:
  $Cu \rightarrow Cu^{2+} + 2e^-$ oxidation

2 Sulfuric acid and sulfate reactions

- Sulfuric acid reacts with metal oxides to form sulfates and water.
- Sulfuric acid reacts with metal hydroxides to form sulfates and water
- Sulfuric acid reacts with metal carbonates to form salts, carbon dioxide, and water
- In all of these reactions, no oxidation or reduction takes place. The charge on the metal ion in the oxide, hydroxide, and carbonate is the same as it is in the sulfate.

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Oxygen and sulfur: oxidation and reduction

1 Common redox reactions

$8H_2S + 8Cl_2 \longrightarrow S_8 + 16HCl$

Hydrogen sulfide reduces chlorine gas

$H_2O_2 + 3KMnO_4 \longrightarrow 2KOH + 2MnO_2 + 2O_2$

Hydrogen peroxide reduces potassium manganate(VII) solution

$SO_2 + 2FeCl_3 + 2H_2O \longrightarrow 2FeCl_2 + 2HCl + H_2SO_4$

Sulfur oxide reduces iron chloride solution

$O_2 + 2SO_2 \longrightarrow 2SO_3$

Oxygen oxidizes sulfur dioxide

$Cu + 2H_2SO_4 \longrightarrow CUSO_4 + H_2O + SO_2\uparrow$

Concentrated sulfuric acid oxidizes copper

2 Sulfuric acid and sulfate reactions

Acid + metal oxide = Salt + water

$H_2SO_4 + MgO \longrightarrow MgSO_4 + H_2O$

Acid + metal hydroxide = Salt + water

$H_2SO_4 + Cu(OH)_2 \longrightarrow CuSO_4 + 2H_2O$

Acid + metal carbonate = Salt + carbon dioxide + water

$H_2SO_4 + ZnCO_3 \longrightarrow ZnSO_4 + CO_2 + H_2O$

Basic reactions of oxygen

1 Reactions

Oxidizes other elements

$2H_2 + O_2 \longrightarrow 2H_2O$

$4Na + O_2 \longrightarrow 2Na_2O$

$2Na + O_2 \longrightarrow Na_2O_2$

$S_8 + 8O_2 \longrightarrow 8SO_2$

$P_4 + 5O_2 \longrightarrow P_4O_{10}$

$2Cu + O_2 \longrightarrow 2CuO$

Oxidizes other elements

$2CO + O_2 \longrightarrow 2CO_2$

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

2 The hydrides

Water

a $2Na + 2H_2O \longrightarrow 2NaOH + H_2\uparrow$

b $H_2O + HCl \longrightarrow H_3O^+ + Cl^-$

c $H_2O + NH_3 \rightleftharpoons NH_4^+ + OH^-$

d $H_2O + CO_2 \rightleftharpoons H_2CO_3$

$H_2O + SO_2 \rightleftharpoons H_2SO_3$

Oxidizes other elements

e $BaO_2 + H_2SO_4 \longrightarrow H_2O_2 + BaO_4\downarrow$

f $H_2O_4 + 2FeCl_2 + 2HCl \longrightarrow 2FeCl_3 + 2H_2O$

g $H_2O_2 + 2KMnO_4 \longrightarrow 2KOH + 2MnO_2 + 2O_2$

3 The oxides

Oxidizes other elements

h $CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$

i $ZnO + H_2SO_4 \longrightarrow ZnSO_4 + H_2O$

$ZnO + 2NaOH \longrightarrow Na_2Zn(CH)_4 + H_2O$

Oxidizes other elements

j SO_2, CO_2

k H_2O, CO

a oxidizes reactive metals
b accepts protons from acids
c gives protons to bases
d reacts with non-metal oxides
e preparation
f an oxiding agent
g a reducing agent
h basic
i amphoteric
j acidic
k neutral

Key words

alkali
amphoteric
cation
hydroxide
oxide
oxygen
transition metals
valency

1 Reactions

- *Oxygen* reacts with both metals and non-metals to form *oxides*.
- Group 1 and group 2 metals often form more than one oxide:
  Na_2O sodium monoxide
  Na_2O_2 sodium peroxide
  NaO_2 sodium dioxide
- *Transition metals* form oxides in which the metal exhibits different *valency* states:
  Cu_2O copper(I) oxide
  CuO copper(II) oxide
- Non-metallic elements also form more than one oxide:
  P_4O_6 phosphorus(III) oxide
  P_4O_{10} phosphorus(V) oxide

2 The hydrides

- Water reacts with group 1 and group 2 metals to give the metal *hydroxide* and hydrogen. In these reactions, the metal is oxidized to a metal *cation* and the water is reduced:
  $M \rightarrow M^+$ and $M \rightarrow M^{2+}$
- In the Brønsted-Lowry theory of acids and bases, an acid is defined as a substance that donates protons and a base as a substance that accepts protons. Water acts as both an acid and a base.
- Non-metallic oxides dissolve in water to form acids:
  $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ carbonic acid
  $H_2SO_3 \rightleftharpoons H^+ + HSO_3$ sulfurous acid

3 The oxides

- Metal oxides are basic and react with acids to form salts and water.
- Non-metallic oxides are acidic or neutral.
- Some metal oxides are *amphoteric*: they react with both acids and *alkalis*.

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Key words

dehydrating agent
hydrogen sulfide
oxidizing agent
redox reaction
sulfide
sulfur
sulfur dioxide
sulfuric acid

1 Reactions of sulfur

- *Sulfur* reacts with most metals and hydrogen to form *sulfides*. Metal sulfides react with acids to give *hydrogen sulfide*:
  $FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$
- Sulfur combines with non-metals such as oxygen and chlorine.
- *Sulfur dioxide* is formed by the reaction between concentrated *sulfuric acid* and sulfur.

2 The hydrides

- Hydrogen sulfide dissolves in water to form a weak acid.
- Group 1 metal sulfides are soluble in water, however, other metal sulfides are only sparingly soluble and form characteristically colored precipitates. Moist lead(II) ethanoate paper turns black in the presence of hydrogen sulfide due to the formation of lead sulfide:
  $Pb^{2+} + S^{2-} \rightarrow PbS$
- Hydrogen sulfide and sulfur dioxide undergo a *redox reaction* to form elemental sulfur.

3 The oxides SO_2 and SO_3

- Sulfur dioxide dissolves in water to form sulfurous acid, a weak acid.
- Sulfur dioxide is oxidized to sulfur trioxide.
- Sulfur trioxide dissolves in water to form sulfuric acid, a strong acid.

4 The hydroxy compound

- Concentrated sulfuric acid is a strong *oxidizing agent* and will oxidize both metals and non-metals.
- Concentrated sulfuric acid is a strong *dehyrating agent* and will remove water or the elements of water.

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Basic reactions of sulfur

1 Reactions of sulfur

Oxidizes some elements

$$Fe + S \longrightarrow FeS$$
$$2Cu + S \longrightarrow Cu_2S$$
$$H_2 + S \longrightarrow H_2S$$

Reduces other elements elements

$$S + O_2 \longrightarrow SO_2$$
$$2S + Cl_2 \longrightarrow S_2Cl_2$$

Reduces some compounds

$$3S + 2H_2SO_4 \longrightarrow 3SO_2\uparrow + 2H_2O$$

2 The hydrides

Is a sparingly soluble acidic gas

$$H_2S + H_2O \rightleftharpoons H_3O^+ + HS^-$$

Is a reducing agent

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3S\downarrow$$

Causes precipitation of insoluble metel sulfides

$$CuSO_4 + H_2S \longrightarrow CuS\downarrow + H_2SO_4$$

3 The oxides SO_2 and SO_3

Is a sparingly soluble acidic gas

$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

Is reducing agent

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$
$$SO_2 + 2H_2S \longrightarrow 3S\downarrow + 2H_2O$$

SO_3 is very acidic

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

4 The hydroxy compound

As a strong acid

$$H_2SO_4 + H_2O \longrightarrow H_3O^+ + HSO_4^-$$

As an oxidizing agent

$$2H_2SO_4 + C \longrightarrow CO_2 + 2SO_2\uparrow + 2H_2O$$
$$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2\uparrow + 2H_2O$$

As a dehydrating agent

$$CH_3CH_2OH \xrightarrow[170°C]{H_2SO_4} CH_2 = CH_2$$
$$C_{12}H_{22}O_{11} \xrightarrow[-11H_2O]{H_2SO_4} 12C$$
$$CuSO_4.5H_2O \xrightarrow[-5H_2O]{H_2SO_4} CuSO_4$$

The halogens: group 7

1 Electron structure

F			2	7
Cl			8	7
Br		2	18	7
I	2	8	18	7

inner electrons | outer shell

2 Halogen atom and molecule

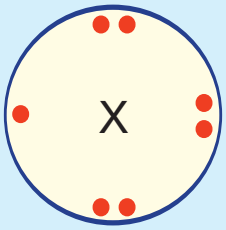

Halogen atom

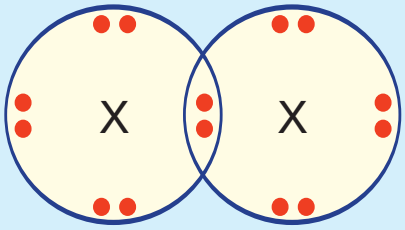

Halogen molecule

3 Physical properties

Element	Fluorine	Chlorine	Bromine	Iodine
Atomic number	9	17	35	53
Relative atomic mass	19.0	35.5	79.9	126.9
State at 20°C	gas	gas	liquid	solid
Color	pale yellow	pale green	red-brown	black
m.p./°C	–220	–101	–7	113
b.p./°C	–188	–35	59	183
Solubility/g per 100g of water at 20°C	reacts readily with water	0.59 (reacts slightly	3.6	0.018

Key words

astatine
bromine
chlorine
covalent bond
covalent compound
fluorine
halogens
iodine
ionic compound

Halogens

- The elements of group 7 are sometimes referred to as the *halogens*. They are *flourine*, *chlorine*, *bromine*, *iodine*, and *astatine*. The symbol 'X' is often used to denote a halogen atom and 'X^-' a halogen ion.

1 Electron structure

- All halogen atoms have seven electrons in their outer shell. A halogen atom needs one more electron to fill the outer shell, and it can obtain this either by forming a single *covalent bond* or by forming an ion, X^-. Halogens form both *covalent compounds* and *ionic compounds*.

2 Halogen atom and molecule

- Halogens exist as diatomic molecules. Each atom in the molecule provides a single electron to form a covalent bond. The result is that each atom has control over eight electrons.

3 Physical properties

- There is a gradation of physical properties going down group 7.
  1. State changes from solid to liquid to gas. Bromine is one of only two elements that exist as liquids at room temperature.
  2. The color darkens from pale yellow to black.
  3. Melting point and boiling point increase.
- There is a gradual decrease in chemical reactivity going down group 7.
- Fluorine oxidizes water to give oxygen: $2F_2 + 2H_2O \rightarrow 4HF + O_2$
- Chlorine reacts less vigorously with water, forming an acidic solution: $C_2 + H_2O \rightleftharpoons HCl + HOCl$
- Bromine and iodine form solutions in water, although the latter is not very soluble.

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Key words

bromine
chlorine
distillation
iodine
oxidation
oxidizing agent

1 Laboratory preparation of chlorine

- *Chlorine* is made in the laboratory by the *oxidation* of concentrated hydrochloric acid using a suitable *oxidizing agent* such as manganese dioxide (manganese(IV) oxide):
  $MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$
- The gas is first passed through water to remove any hydrogen chloride gas, and then through concentrated sulfuric acid to dry the gas. Chlorine is more dense than air and is collected by downward delivery.
- Chlorine can also be conveniently made in the laboratory from bleaching powder, using dilute hydrochloric acid:
  $Ca(OCl)_2(s) + 4HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l) + 2Cl_2(g)$

2 Laboratory preparation of bromine

- *Bromine* is made in a similar way to chlorine:
  $MnO_2(s) + 2NaBr(aq) + 2H_2SO_4(aq) \rightarrow MnSO_4(aq) + Na_2SO_4(aq) + 2H_2O(l) + Br_2(g)$
- Because it boils at 59°C, bromine is removed from the reaction mixture by *distillation*.

3 Laboratory preparation of iodine

- *Iodine* is made in a similar way to bromine. Hydrogen iodide is made *in situ* by reacting sodium iodide with concentrated sulfuric acid:
  $MnO_2(s) + 2KI(aq) + 2H_2SO_4(aq) \rightarrow MnSO_4(aq) + K_2SO_4(aq) + 2H_2O(l) + I_2(g)$
- Iodine is removed from the reaction mixture by sublimation. On heating, it changes directly from solid to vapor and then back to solid on cooling.

Laboratory preparation of the halogens

1 Laboratory preparation of chlorine

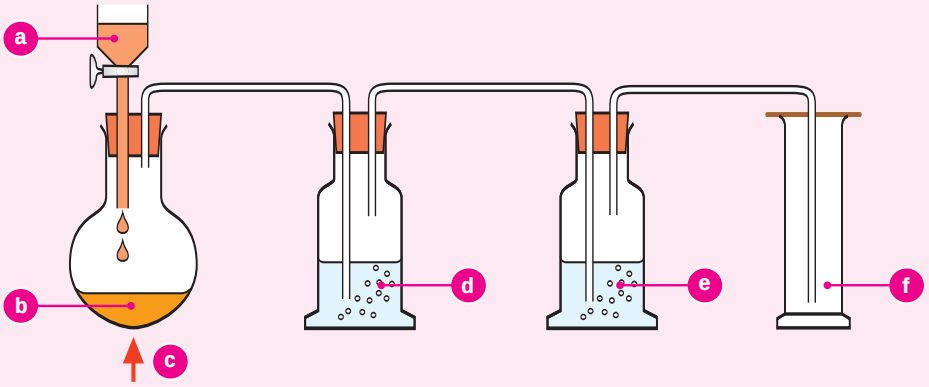

2 Laboratory preparation of bromine

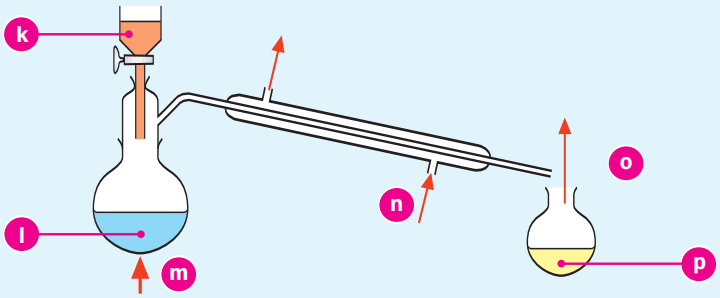

3 Laboratory preparation of iodine

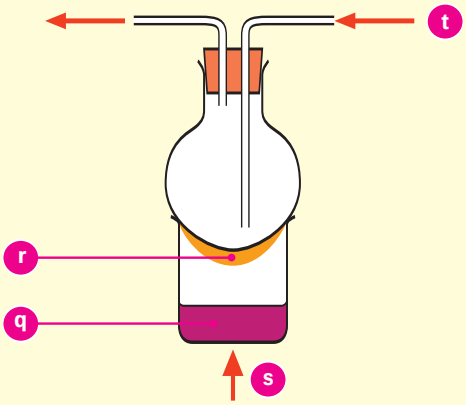

a concentrated hydrochloric acid
b manganese dioxide
c warm gently
d water to remove HCl fumes
e concentrated H_2SO_4 to dry Cl_2
f chlorine gas
g concentrated brine
h chlorine gas
i hydrogen gas
j water
k concentrated sulfuric acid
l manganese oxide + sodium bromide
m warm gently
p cold water
o fumes of HBr
p bromine
q manganese oxide + potassium iodine + concentrated H_2SO_4
s warm gently
t cold water

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Compounds of chlorine

1 Chlorine and metals

Calcium burns in chlorine

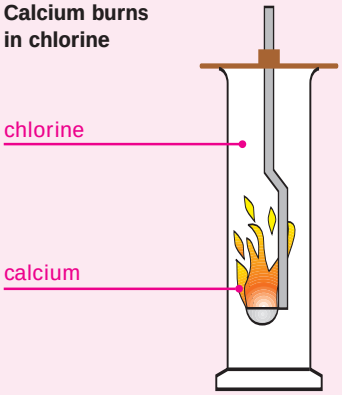

Aluminum reacts when warmed in a stream of chloride

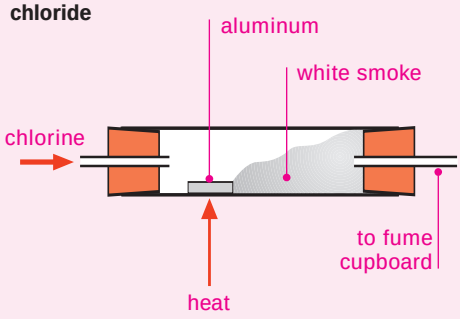

2 Laboratory preparation of hydrogen chloride

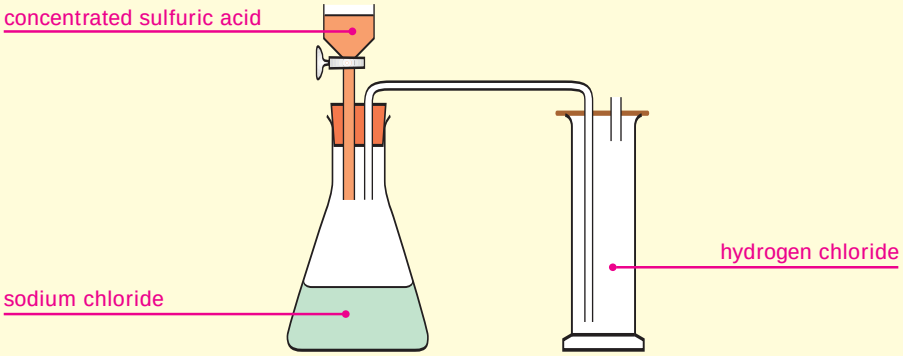

3 Compounds with non-metals

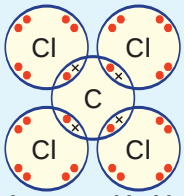

Carbon tetrachloride (CCl_4)

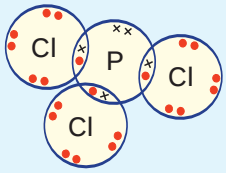

Phosphorus trichloride (PCl_3)

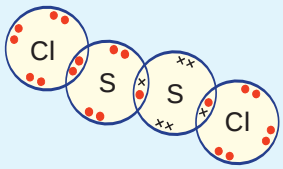

Sulfur monochloride (S_2Cl_2)

4 The structure of some chlorinated pesticides

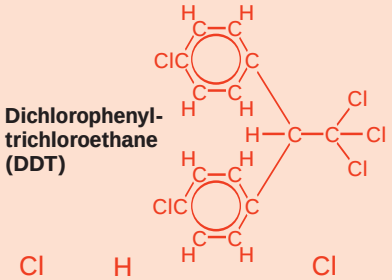

Dichlorophenyl-trichloroethane (DDT)

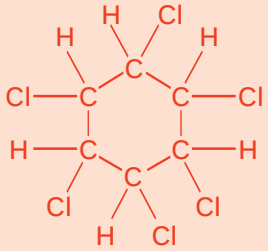

Benzene hexachloride (BHC)

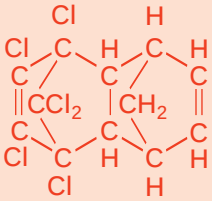

Aldrin

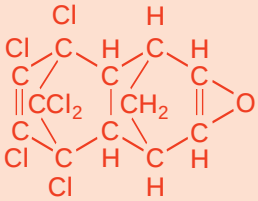

Dieldrin

Key words

chloride
chlorine
covalent compound
halide
hydrogen chloride
sodium chloride
sulfuric acid

1 Chlorine and metals

- Metals, such as calcium, burn in *chlorine* to produce the corresponding metal *chloride*:
  $Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$
- Aluminum reacts with chlorine to form aluminum chloride:
  $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$
- Unlike many metal chlorides, aluminum chloride is hydrolyzed by water, giving off *hydrogen chloride* gas:
  $AlCl_3(s) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3HCl(g)$
  It is for this reason that aluminum halides fume when they come into contact with moist air.

2 Laboratory preparation of hydrogen chloride

- Hydrogen chloride is made by the reaction of *sodium chloride* with concentrated *sulfuric acid*:
  $NaCl(s) + H_2SO_4(aq) \rightarrow NaHSO_4(s) + HCl(g)$

3 Compounds with non-metals

- Chlorine forms *covalent compounds* with non-metals such as carbon, phosphorus, and sulfur.

4 Pesticides

- Chlorinated compounds provide a range of pesticides.
- DDT, BHC, Aldrin, and Dieldrin have been the source of environmental concern, and their use is now prohibited or severely restricted.

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Key words

carbonate
covalent bond
covalent compound
hydrogen chloride
ion
ionic compound

Hydrogen chloride

- *Hydrogen chloride* gas is a *covalent compound*. In solutions in organic solvents, it remains a covalent compound. It becomes an *ionic compound* in aqueous solutions.

1 In organic solvents

- In solution in organic solvents such as methylbenzene, hydrogen chloride remains a covalent compound. The hydrogen atom and the chlorine atom each donate one electron to form the *covalent bond*.
- The solution contains no ions and does not conduct electricity.
- The solution has no effect on blue litmus paper or on *carbonates*, thus showing that it is not an acid.

2 In aqueous solution

- In aqueous solution, hydrogen chloride becomes an ionic compound. The hydrogen atom loses an electron to become a hydrogen *ion*, H^+, and the chlorine atom gains an electron to become a chloride ion, Cl^-.
- The solution contains ions and conducts electricity. The ions are able to carry a charge through the solution.
- The solution turns blue litmus paper red and reacts with carbonates, showing that it is an acid:

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$

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Hydrogen chloride in solution

1 In organic solvents

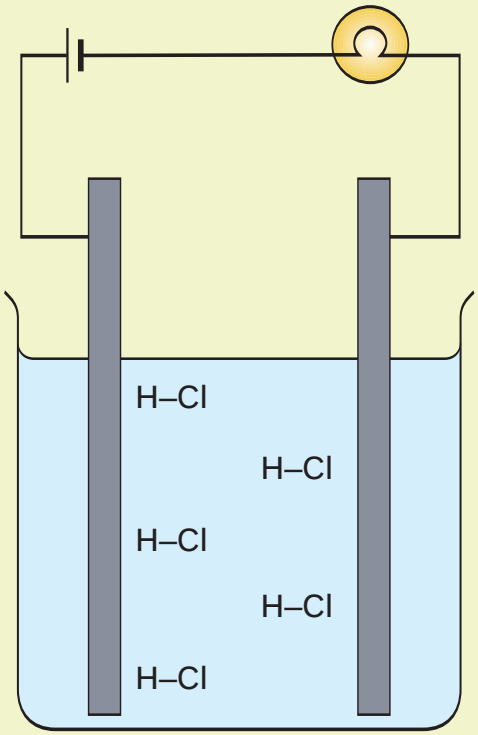

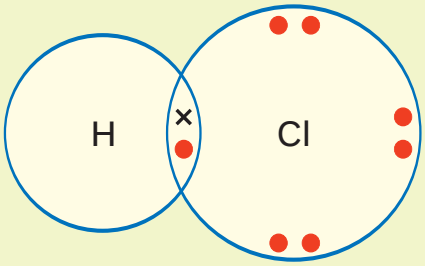

2 In aqueous solution

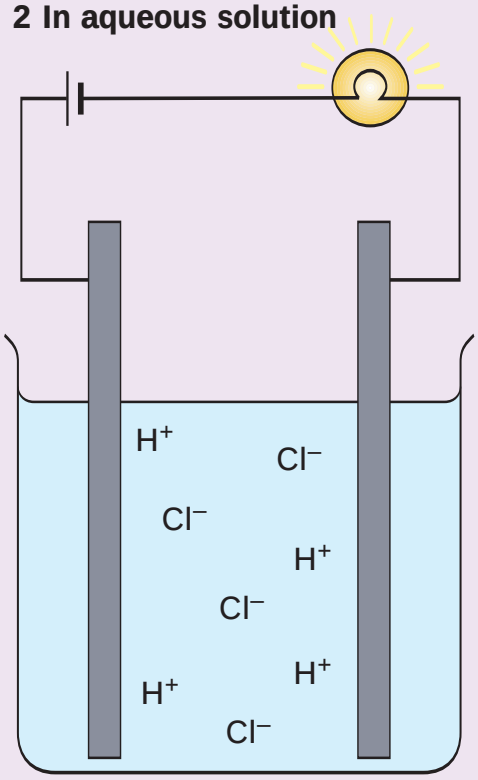

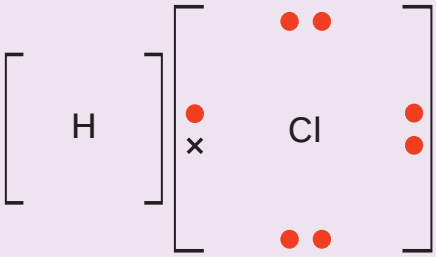

Acid/base chemistry of the halogens

1 Laboratory preparation of hydrochloric acid

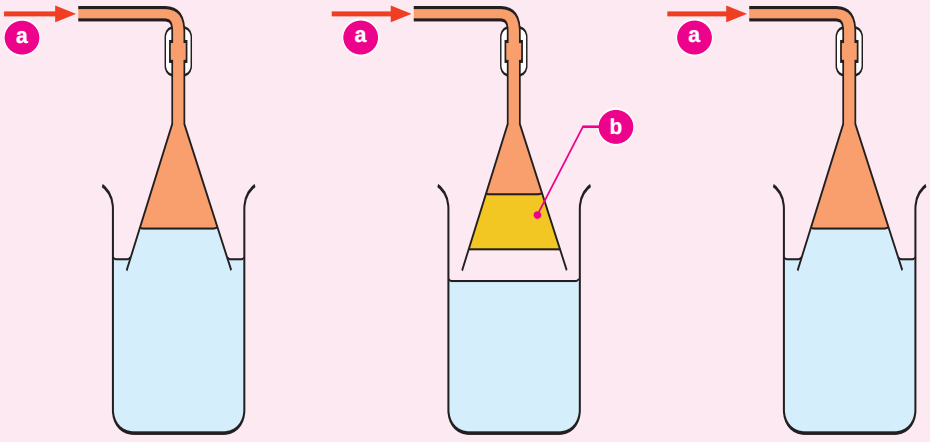

Hydrogen chloride enters water via a filter funnel

The level in the beaker drops

The cycle starts again

a hydrochloric acid (HCl)
b plug of liquid in funnel

2 Solubility of the halogens

$$2F_2 + 2H_2O \longrightarrow 4HF + O_2$$

Flouorine is so reactive it decomposes water producing hydrofluoric acid and oxygen

$$Cl_2 + H_2O \rightleftharpoons HCl + HOCl$$

Chlorine is the next most reactive halogen after fluorine

3 Chloride test

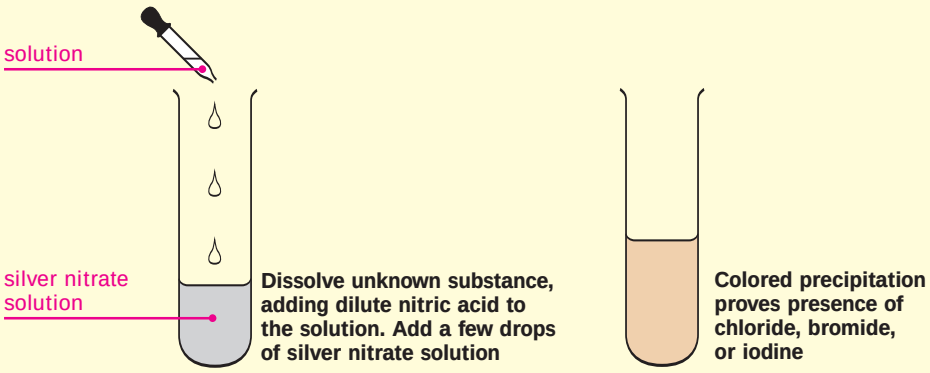

Dissolve unknown substance, adding dilute nitric acid to the solution. Add a few drops of silver nitrate solution

Colored precipitation proves presence of chloride, bromide, or iodine

Key words

halide
hydrochloric acid
hydrogen chloride
nitric acid
oxidizing agent
reducing agent
silver nitrate

1 Laboratory preparation of hydrochloric acid

- *Hydrochloric acid* is made in the laboratory by dissolving *hydrogen chloride* gas in water.
- Hydrogen chloride is very soluble in water. It is dissolved by passing through an inverted filter funnel, the rim of which sits just below the water level. When water is sucked into the funnel, the water level drops, and the funnel rim is no longer submerged. This prevents water being sucked back into the apparatus.

2 Solubility of the halogens

- All halogens are *oxidizing agents*. However, oxidizing power decreases down the group:
  fluorine > chlorine > bromine > iodine
- *Halide* ions are *reducing agents*. The reducing power increases down the group:
  fluorine < chlorine < bromine < iodine

3 Chloride test

- The presence of halide ions in solution can be detected by adding a few drops of dilute *nitric acid* followed by several drops of *silver nitrate* solution.
  1. Chloride ions form a white precipitate of insoluble silver chloride:
  $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
  2. Bromide ions form a cream precipitate of insoluble silver bromide:
  $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$
  3. Iodide ions form a yellow precipitate of insoluble silver iodide:
  $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$

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Key words

chloride
chlorine
noble gases
oxidizing agent
reactivity series
redox reaction
sulfur

Redox reactions of the halogens

1 Calcium and chlorine

- When hydrogen sulfide and chlorine are mixed, elemental *sulfur* is formed. *Chlorine* acts as an *oxidizing agent* and oxidizes the hydrogen sulfide by removing hydrogen. In turn, the chlorine gains hydrogen and is reduced to hydrogen chloride:
  $8H_2S(g) + 8Cl_2(g) \rightarrow S_8(s) + 16HCl(g)$

2 Chlorine and ferrous chloride

- Chlorine can also be used to oxidize iron(II) to iron(III). When chlorine is bubbled into iron(II) chloride solution, the color changes from green to yellow-brown, showing the formation of iron(III). The chlorine atoms are reduced to *chloride* ions:
  $2FeCl_2(aq) + Cl_2(g) \rightarrow 2FeCl_3(aq)$

3 Halogens and metals

- Halogens readily oxidize metals. Fluorine oxidizes all metals, including gold and silver, easily.
- Chlorine oxidizes all but the least reactive metals. When iron is heated in a stream of dry chlorine, iron(III) chloride is produced:
  $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$
- The ease with which halogens oxidize metals decreases down the group, but even iodine will slowly oxidize metals low in the *reactivity series*.

4 Halogens and non-metals

- Fluorine oxidizes most non-metals except nitrogen and most of the *noble gases*.
- Chlorine reacts directly with phosphorus and sulfur, but carbon, nitrogen, and oxygen do not react directly with chlorine, bromine, or iodine.
- The relative reactivities of the halogens in *redox reactions* with non-metals is illustrated at right by their reaction with hydrogen.

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1 Calcium burns in chlorine

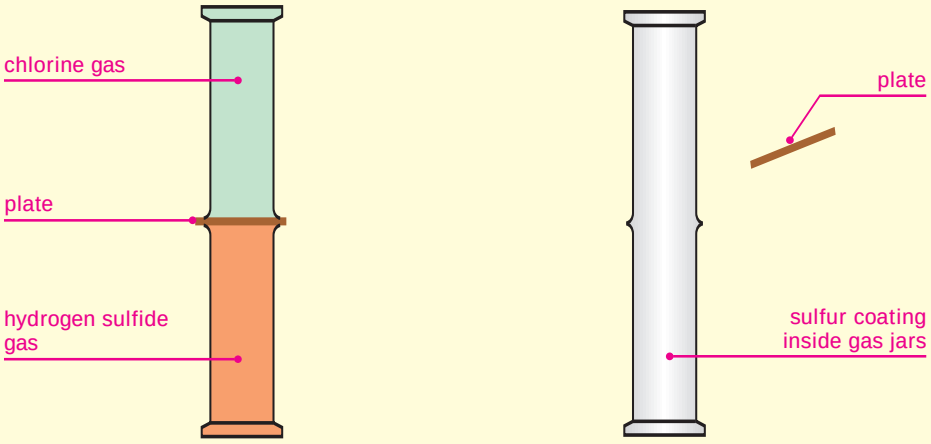

Chlorine gas and hydrogen sulfide gas are separated by plate

Plate is removed

2 Reaction of chlorine with ferrous chloride

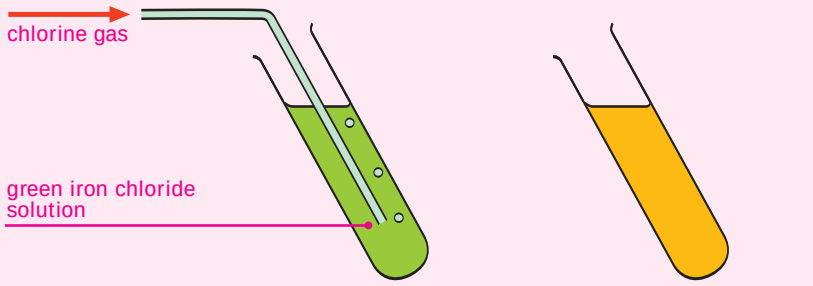

Chlorine gas is passed into ferrous chloride solution

Yellow-brown iron chloride solution

3 Halogens and metals

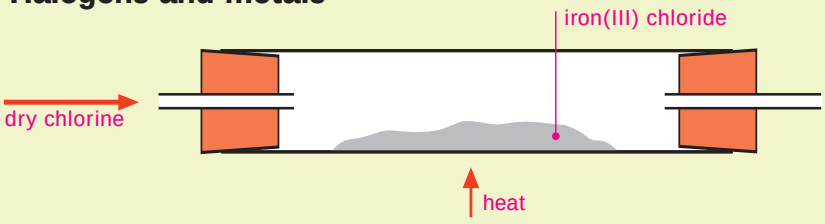

4 Halogens and non-metals

Reaction	Observations
$H_2(g) + F_2(g) \rightarrow 2HF(g)$	explosive
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$	explosive in sunlight but slow in the dark
$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$	needs heat and a catalyst
$H_2(g) + I_2(g) \rightarrow 2HI(g)$	slow even when heated

Reactivity of the halogens

1 Chemical reactivity of halogens with each other

	Chlorine	Bromine	Iodine
Chloride		✗	✗
Bromide	✓		✗
Iodide	✓	✓	

2 Reaction of chlorine and bromine

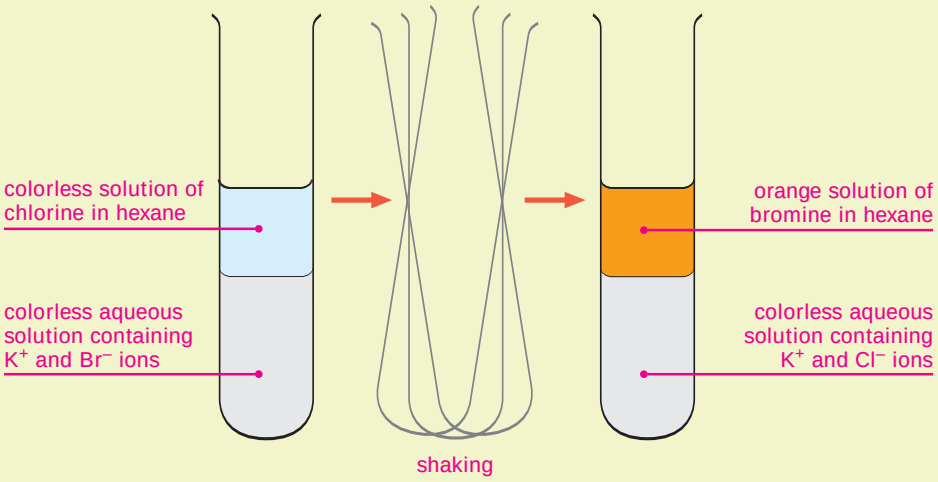

3 Reaction of chlorine and iodine

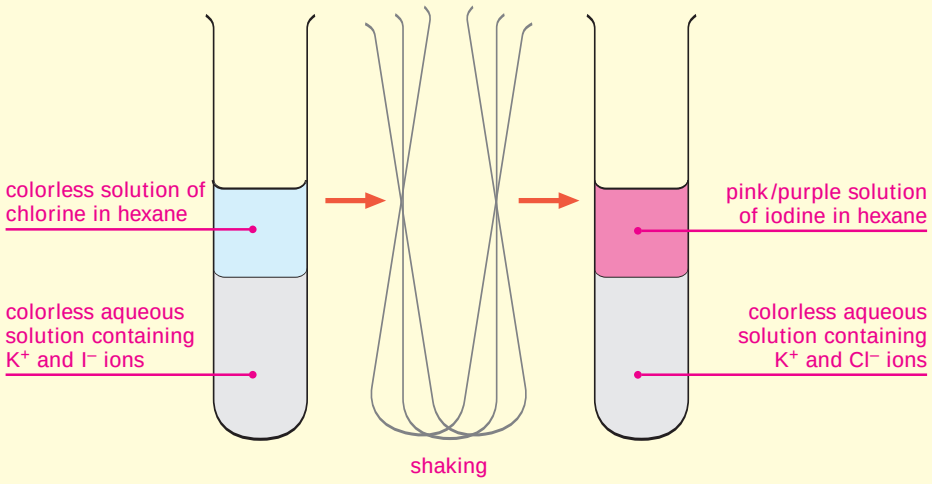

Key words

displacement reaction
halide
halogens
immiscible

1 Reactivity of halogens

- The chemical reactivity of the *halogens* decreases down group 7: fluorine > chlorine > bromine > iodine
- A more reactive halogen will displace the ions of a less reactive halogen from a metal *halide* solution. This is called a *displacement reaction*.
- Chlorine will displace bromide ions and iodide ions from solution.
- Bromine will displace iodide ions from solution.
- In a displacement reaction, the halogen acts as an oxidizing agent and is reduced while the halide ion is oxidized.

2 Chlorine and bromine

- Chlorine dissolves in the organic solvent hexane to give a colorless or slightly green solution, depending on concentration.
- Hexane is *immiscible* with water. When the two liquids are mixed, hexane forms a layer above water.
- When solutions of chlorine in hexane and potassium bromide in water are shaken together, chlorine displaces bromide ions from the aqueous solution. Bromine is more soluble in hexane than in water, and an orange layer of bromine in hexane forms:

$2KBr + Cl_2 \rightarrow 2KCl + Br_2$

$2Br^- + Cl_2 \rightarrow 2Cl^- + Br_2$

3 Chlorine and iodine

- When solutions of chlorine in hexane and potassium iodide in water are shaken together, chlorine displaces iodide ions from the aqueous solution. Iodine is more soluble in hexane than in water, and a pink-purple layer of iodine in hexane forms:

$2KI + Cl_2 \rightarrow 2KCl + I_2$

$2I^- + Cl_2 \rightarrow 2Cl^- + I_2$

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Key words

aluminum
copper
gold
iron
lead
platinum
silver
uranium
zinc

1 Gold, sliver, platinum, and uranium

- *Gold*: South Africa, USA, Canada, Russia
- *Silver*: USA, South America
- *Platinum*: South Africa, USA, South America
- *Uranium*: North America, Europe, Central and South Africa, Australia

2 Aluminum and copper

- *Aluminum*: South America, Jamaica, West Africa, Russia, India, Australia
- *Copper*: North America, Central and South Africa, Europe, Russia

3 Iron, zinc, and lead

- *Iron*: North and South America, Russia, Europe, Angola, Australia
- *Zinc* and *lead*: USA, Europe, Australia, Russia

World distribution of metals

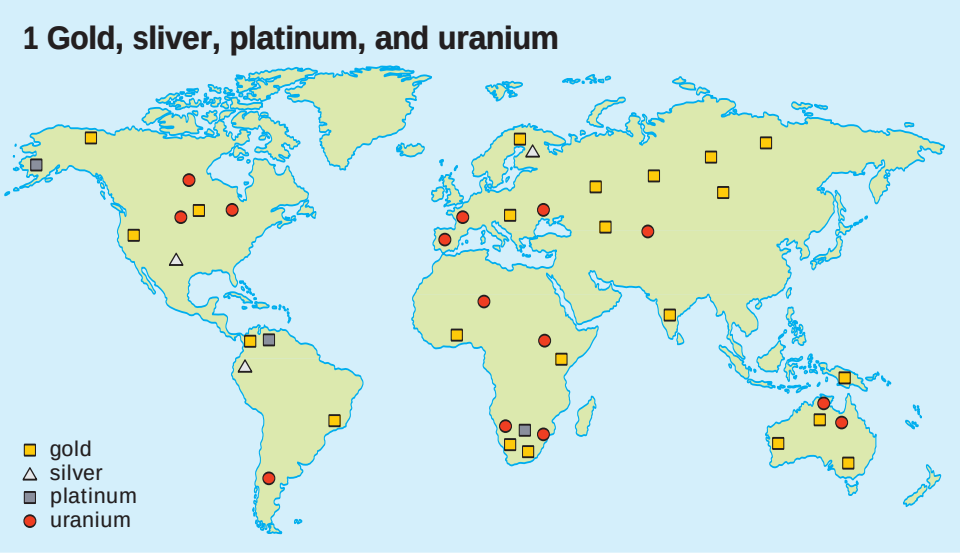

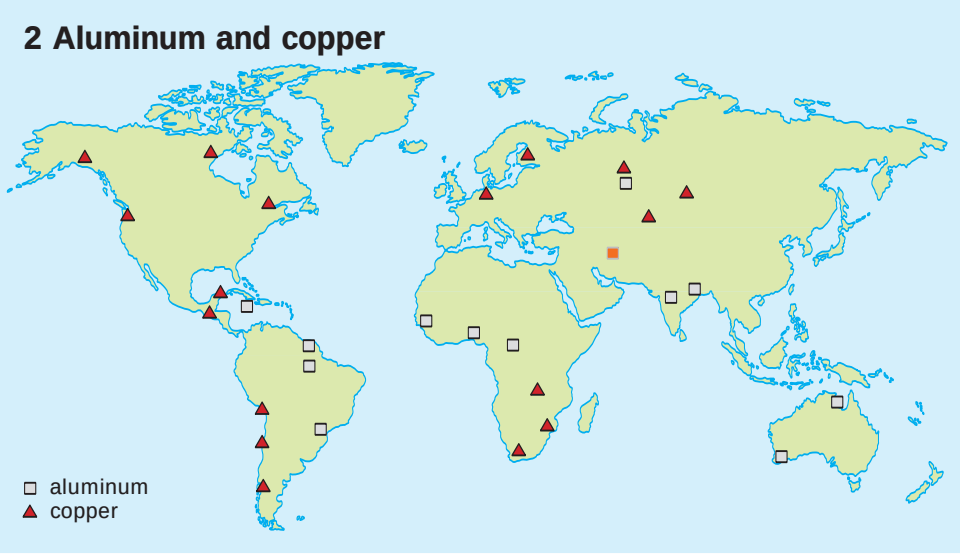

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Main ores of metals

Metal Common name for ore(s)	Chemical name for ore(s)	Formula of ore(s)
aluminum bauxite	aluminum oxide	$Al_2O_3.2H_2O$
chromium chromite	iron chromium oxide	$FeCr_2O_4$
copper chalcopyrite bornite chalcocite	copper iron sulfide copper iron sulfide copper(I) sulfide	$CuFeS_2$ Cu_5FeS_4 Cu_2S
iron haematite magnetite	iron(III) oxide iron(II)iron(III) oxide	Fe_2O_3 Fe_3O_4
lead galena cerussite anglesite	lead(II) sulfide lead(II) carbonate lead(II) sulfate	PbS $PbCO_3$ $PbSO_4$
magnesium magnesite	magnesium carbonate	$MgCO_3$
mercury cinnabar	mercury sulfide	HgS
silver argentite	silver sulfide	Ag_2S
sodium salt	sodium chloride	$NaCl$
tin cassiterite	tin oxide	SnO_2
titanium rutile ilmenite	titanium oxide iron titanium oxide	TiO_2 $FeTiO_3$
uranium uraninite	uranium oxide	UO_2
zinc zinc blende calamine	zinc sulfide zinc carbonate	ZnS $ZnCO_3$

Key words

grade
mineral
ore
oxide
sulfide

Ores

- An *ore* is a *mineral* from which a metal (or non-metal) can be extracted.
- Metal ores are often metal *oxides* or metal *sulfides*.
- A metal may be present in a range of different minerals, but not all minerals will be suitable sources of that metal.

Recovering ores

- To be appropriate for mining, an ore must contain minerals that are valuable and that are concentrated enough to be mined profitably. It must also be economically viable to extract the ore from waste rock.
- Mineral deposits that are economically recoverable are called ore deposits. Not all mineral deposits are suitable for recovery. Some may be too low in *grade* (the concentration of the ore in the rock) or technically impossible to extract.

Formation

- The process of ore formation is called ore genesis.
- Ore genesis involves a variety of geological, internal, hydrothermal, metamorphic, and surficial processes.

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Key words

alkali metals
boiling point
group 1
melting point
orbital
radioactive
shell

1 Position in periodic table

- The *group 1* metals occupy the first column of the periodic table. Historically, they were known as the *alkali metals* because they all react with water to give alkaline solutions.
- The elements include lithium, sodium, potassium, rubidium, and cesium. Francium lies below cesium in the periodic table. However, it is not considered when discussing the group because it is *radioactive*, and little is known of its chemistry.

2 Electron-shell structure

- The electrons surrounding the nucleus of an atom are arranged in a series of *orbitals*, areas around the atom where there is a high probability of finding an electron. Orbitals are grouped in a series of *shells* (energy levels) at a gradually increasing distance from the nucleus. Different orbitals have different shapes: s orbitals are spherically symmetric; p orbitals point in a particular direction; and d orbitals have complicated shapes. Scientists describe an atom by describing the orbital structure. Thus, as the table indicates, sodium has 2s orbitals in the first shell, 2s and 6p orbitals in the second shell, and 1s orbital in the third shell.

3 Physical properties

- Reading down the group, the *melting point* decreases, the *boiling point* increases, the density increases, and the hardness decreases.

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The group 1 metals

1 Position in the periodic table

2 Electron-shell structure

Li	$1s^2 2s^1$
Na	$1s^2\ 2s^2\ 2p^6\ 3s^1$
K	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
Rb	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1$
Cs	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^1$

3 Physical properties of group I elements compared with a typical metal

Group 1 element		m.p. / °C	b.p. / °C	Density / g cm^{-3}	Hardness / Moh	Conductivity Ω^{-1}cm^{-1}
Lithium	Li	180	1336	0.53	0.6	11700
Sodium	Na	98	883	0.97	0.4	23800
Potassium	K	64	759	0.86	0.5	16400
Rubidium	Rb	39	700	1.53	0.3	9100
Cesium	Cs	29	669	1.88	0.2	2000
Typical metal						
Iron	Fe	1530	3000	7860	4–5	11300

The group 1 metals: sodium

1 Reaction of sodium hydroxide (NaOH) with hydrochloric acid (HCl)

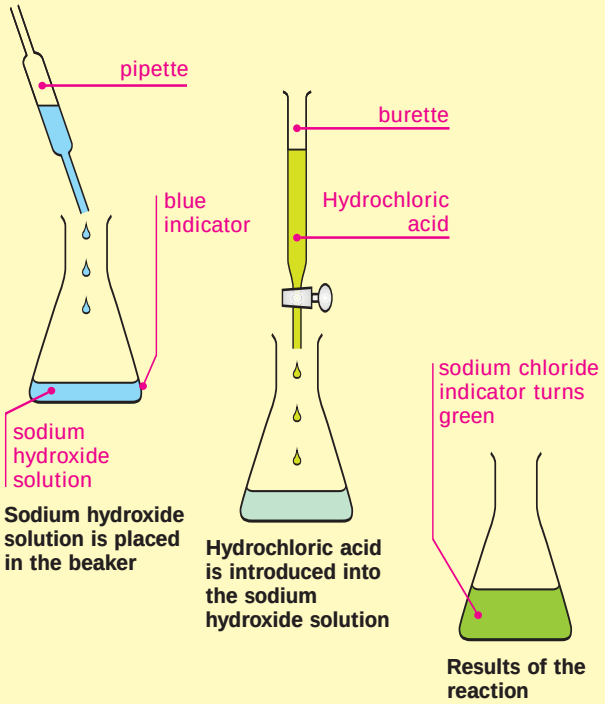

2 Sodium burns readily in chlorine or oxygen

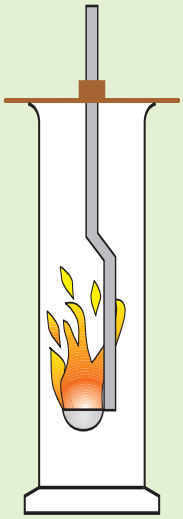

3 Sodium reacts with nitrogen gas

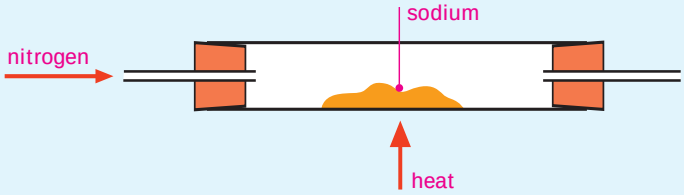

4 Commercial preparation of sodium

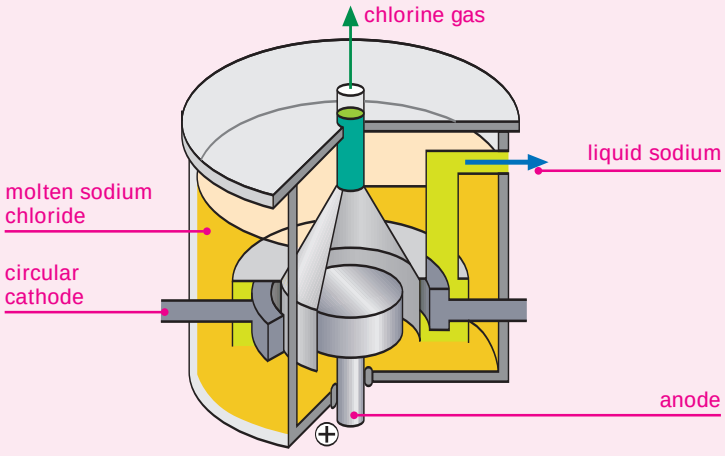

Key words

acid
acid-base indicator
alkali
anode
cathode
electrolysis
salt
titration

1 Reaction of NaOH with HCl

- Group 1 hydroxides are *alkalis*. They can be used to form *salts* by neutralizing them with *acids* in a process call *titration*. Sodium chloride is made by neutralizing sodium hydroxide with hydrochloric acid.
  $NaOH + HCl \rightarrow NaCl + H_2O$
- A given volume of sodium hydroxide solution is put into a conical flask.
- A few drops of an *acid–base indicator* are added to the sodium hydroxide solution. The indicator is a different color in acids and alkalis.
- Hydrochloric acid is run into the sodium hydroxide solution burette until the indicator just changes color.

2 Burning sodium

- Sodium burns vigorously in chlorine to form sodium chloride:
  $2Na + Cl_2 \rightarrow 2NaCl$
- Sodium also burns vigorously in oxygen to form sodium oxide:
  $4Na + O_2 \rightarrow 2Na_2O$

3 Sodium and nitrogen

- When heated in a stream of nitrogen, sodium reacts to form sodium nitride:
  $6Na + N_2 \rightarrow 2Na_3N$

4 Preparation of sodium

- Sodium is obtained by the *electrolysis* of molten sodium chloride in a Downs cell. Sodium is discharged at the negative electrode (*cathode*):
  $Na^+ + e^- \rightarrow Na$
  The product at the positive electrode (*anode*) is chlorine gas:
  $2Cl^- \rightarrow Cl_2 + 2e^-$

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Key words

alkaline earth metals
group 2
ion
ionization energy
orbital
radioactive
reactivity

1 Position in periodic table

- The *group 2* metals occupy the second column of the periodic table. They include beryllium, magnesium, calcium, strontium, and barium. Radium, which lies below barium, is not usually considered when discussing the group because it is *radioactive*. Historically, group 2 metals were known as the *alkaline earth metals* because all but beryllium react with water to give alkaline solutions.
- The atomic radius and, therefore, the size of the atoms increases going down the group.

2 Electron-shell structure

- Scientists can describe an atom by describing its electron-shell structure (see page 150).
- All group 2 elements form *ions* by losing two outer electrons. The energy needed to do this is the sum of the first and second *ionization energies*, i.e., the energy needed to remove the first electron and the second electron.
- Going down the group, there is an increase in the number of *orbitals* of electrons. This affects the value of the ionization energy in two ways: 1) the two outer electrons are further from the positively charged nucleus, and 2) there are more layers of electrons between the nucleus and the outer electrons, which partially shields the outer electrons from the nucleus. Consequently, going down the group, less energy is needed to remove the outer two electrons, and the metals become progressively more reactive.

3 Reactivity

- As with the group 1 metals, the *reactivity* of the group 2 metals increases going down the group.
- The group 2 metals have similar chemical properties as group 1 metals; however, the reactivity of group 2 metals in the same period is less.

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The group 2 metals

1 Position in the periodic table

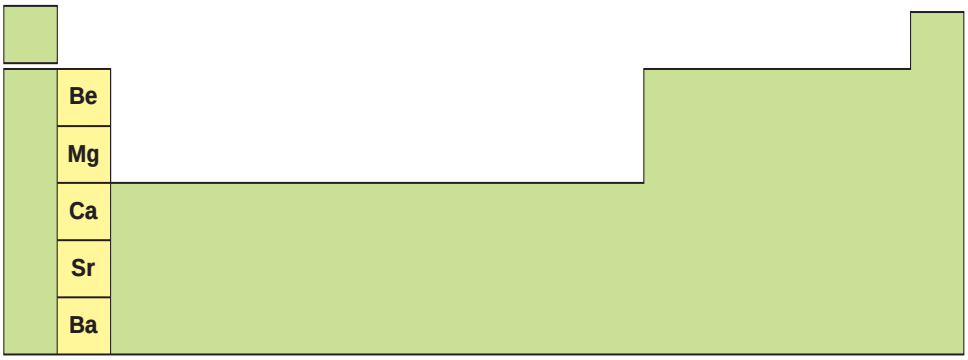

2 Electron-shell structure

Be	$1s^2 2s^2$
Mg	$1s^2\ 2s^2\ 2p^6\ 3s^2$
Ca	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
Sr	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2$
Ba	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2$

3 Reactivity comparison with group I

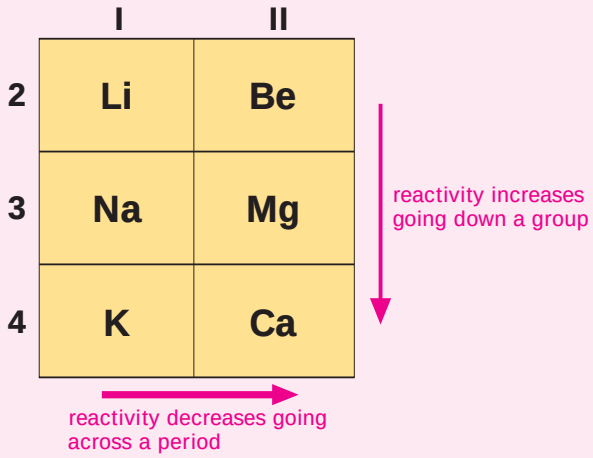

The group 2 metals: general reactions

1 Sodium and water

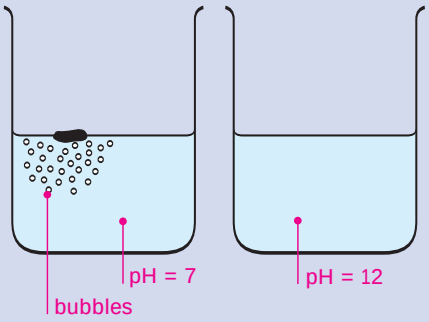

$2Na + 2H_2O = 2Na(OH) + H_2\uparrow$

Solution

2 Calcium and water

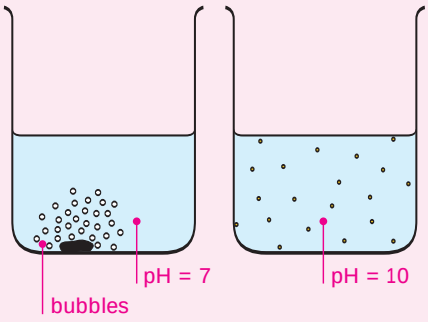

$Ca + 2H_2O = Ca(OH)_2 + H_2\uparrow$

Suspension

3 Production of "rainwater"

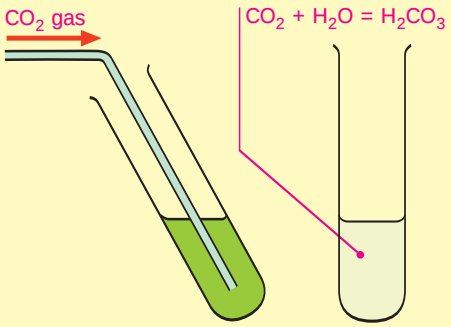

Bubble unknown gas into limewater $Ca(OH_2)$

Result if the gas is CO_2

4 Effect of rainfall on fresh water

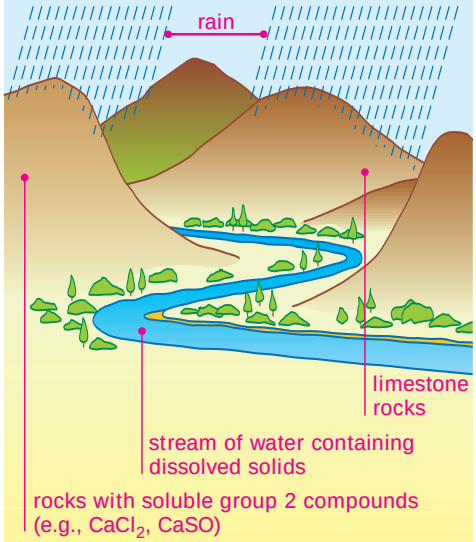

5 Calcium hydroxide [$Ca(OH)_2$] test for carbon dioxide gas

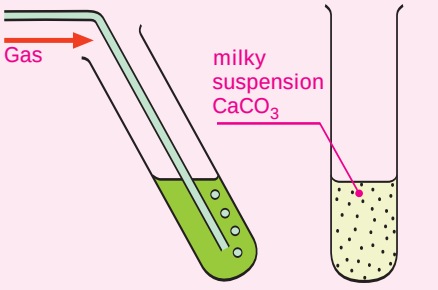

Bubble unknown gas into limewater $Ca(OH_2)$

Result if the gas is CO_2

6 Barium chloride ($BaCl_2$) test for metal sulfates

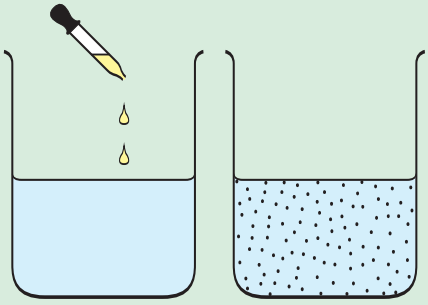

Add barium chloride dissolved in hydrochloric acid to the known solution

A white suspension is produced if the solution contains a sulfate

Key words

alkali
carbonic acid
group 2
hydrochloric acid
insoluble
limewater
soluble

1 Sodium and water

- Sodium reacts vigorously with water to form sodium hydroxide solution (a strong alkali) and hydrogen gas.

2 Calcium and water

- Calcium reacts less vigorously with water than sodium to form calcium hydroxide solution and hydrogen gas.
- Calcium hydroxide is less *soluble* than sodium hydroxide and forms a weak *alkali* solution containing suspended particles of undissolved solid.

3 Rainwater

- Naturally occurring rainwater is always weakly acidic because carbon dioxide from the air dissolves in it, forming weak *carbonic acid*, H_2CO_3.

4 Effect of rainfall

- What rain flows over rocks, *group 2* metal compounds dissolve in it, resulting in water that contains dissolved solids.
- Magnesium and calcium carbonates are effectively *insoluble* in water, but they react with rainwater, because it is acidic, to form soluble hydrogencarbonates.

5 $Ca(OH)_2$ test

- *Limewater*, an aqueous solution of calcium hydroxide, is used to test for carbon dioxide.
- When carbon dioxide is bubbled into limewater, it turns milky due to the formation of insoluble calcium carbonate, $CaCo_3$.

6 $BaCl_2$ test

- The test solution is first acidified with dilute *hydrochloric acid*, and a few drops of barium chloride solution are then added. If the solution contains sulfate ions, a white precipitate of barium sulfate is formed.

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Key words

actinides
catalyst
orbital
oxidation state
shell
tensile strength
transition metals

Characteristics of transition metals

- The *transition metals* are any of the metallic elements with an incomplete inner electronic structure. While the outermost *shell* contains at most two electrons, their next-to-outermost shells have incompletely filled *orbitals*, which fill up going across a period. The filling is not always regular.
- The 40 transitional metals are organized into four series: The first series, shown in the table, runs from element 21 (scandium) to element 30 (zinc) and is in period 4. The second series, elements 39 (yttrium) to 48 (cadmium), is in period 5. The third, elements 71 (lanthanum) to 80 (mercury), is in period 6. The fourth series, from 103 (lawrencium) to 112 (ununbium), is the *actinides* and transactinides.
- Moving away from the nucleus, successive electron shells become progressively closer in energy. The energy levels of the third and fourth orbitals are close in the first series of transition metals.
- The electronic structure of all of the elements in period 4 can be written as that of the element argon together with additional electrons filling the 3d and 4s orbitals (see table).
- Transition metals often have colored compounds because their ions contain electrons in the 3d orbitals that can move between energy levels, giving out light.
- Transition metals tend to have high *tensile strength* (the maximum stress a material can withstand without breaking), density, and melting and boiling points. They have a variety of different *oxidation states* and are often good *catalysts*.

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The transition metals: electron structure

Table to show the electron structures of atoms and ions of elements from scandium to zinc

Element	Symbol	Electronic structure of atom	Common ion	Electronic structure of ion
Scandium	Sc	(Ar)$3d^1 4s^2$	Sc^{3+}	(Ar)
Titanium	Ti	(Ar)$3d^2 4s^2$	Ti^{4+}	(Ar)
Vanadium	V	(Ar)$3d^3 4s^2$	V^{3+}	(Ar)$3d^2$
Chromium	Cr	(Ar)$3d^5 4s^1$	Cr^{3+}	(Ar)$3d^3$
Manganese	Mn	(Ar)$3d^5 4s^2$	Mn^{2+}	(Ar)$3d^5$
Iron	Fe	(Ar)$3d^6 4s^2$	Fe^{2+}	(Ar)$3d^6$
			Fe^{3+}	(Ar)$3d^5$
Cobalt	Co	(Ar)$3d^7 4s^2$	Co^{2+}	(Ar)$3d^7$
Nickel	Ni	(Ar)$3d^8 4s^2$	Ni^{2+}	(Ar)$3d^8$
Copper	Cu	(Ar)$3d^{10} 4s^1$	Cu^{+}	(Ar)$3d^{10}$
			Cu^{2+}	(Ar)$3d^9$
Zinc	Zn	(Ar)$3d^{10} 4s^2$	Zn^{2+}	(Ar)$3d^{10}$

(Ar) = electron structure of argon

Note: As the shells of electrons get further and further from the nucleus successive shells become closer in energy

The transition metals: ionization energies and physical properties

Key words

boiling point
conductor
ionization energy
melting point
transition metals

1 Graphs showing the second and third ionization energies of the elements from scandium to zinc

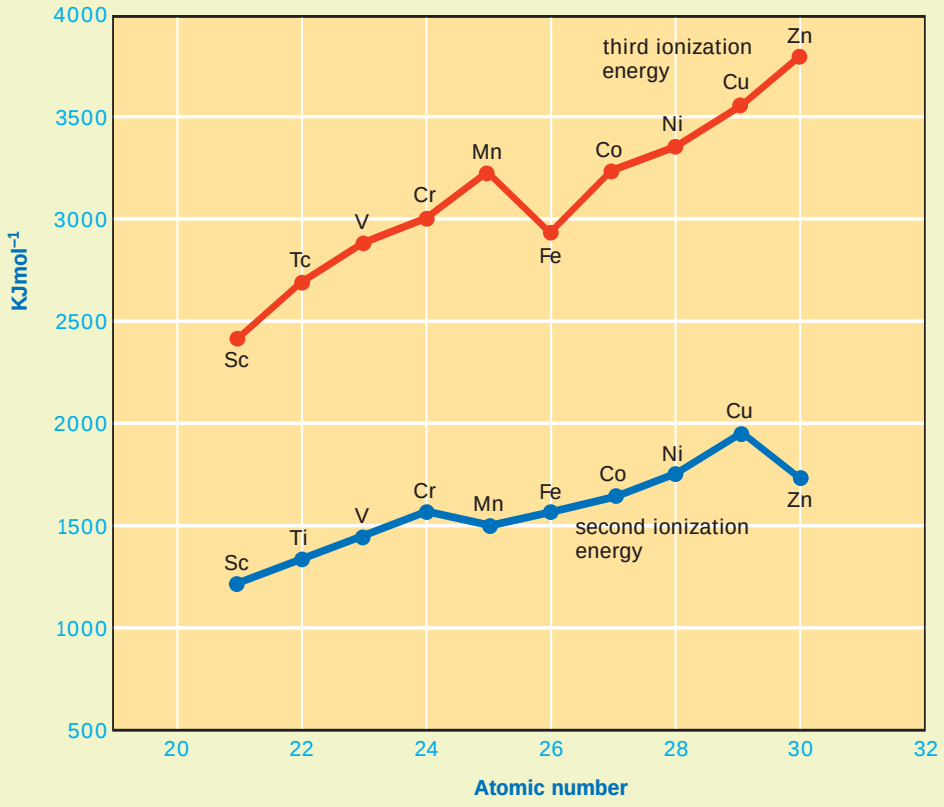

2 Physical properties of the elements from scandium to zinc

Element		Atomic radius/nm	m.p./°C	b.p./°C	Density/ gcm–3	Ionic radius/nm M^{2+}	Ionic radius/nm M^{3+}
Scandium	Sc	0.16	1540	2730	3.0		0.081
Titanium	Ti	0.15	1680	3260	4.5	0.090	0.076
Vanadium	V	0.14	1900	3400	6.1	0.088	0.074
Chromium	Cr	0.13	1890	2480	7.2	0.084	0.069
Manganese	Mn	0.14	1240	2100	7.4	0.080	0.066
Iron	Fe	0.13	1540	3000	7.9	0.076	0.064
Cobalt	Co	0.13	1500	2900	8.9	0.074	0.063
Nickel	Ni	0.13	1450	2730	8.9	0.072	0.062
Copper	Cu	0.13	1080	2600	8.9	0.070	
Zinc	Zn	0.13	420	910	7.1	0.074	

1 Ionization energies

- *Ionization energy* is the energy needed to remove an electron from a neutral gaseous atom or ion against the attraction of the nucleus.
- The second ionization energy is the energy needed to go from M^+ to M^{2+}, (where M = metal), and the third ionization energy is the energy needed to go from M^{2+} to M^{3+}.
- The second ionization energy increases across period 4 because there is an increasing positive charge on the nucleus of the ion, making it increasingly more difficult to remove the second electron.
- The third ionization energy for all elements is significantly higher than the second. Removal of the second electron results in a greater net difference between the positive charge on the nucleus of the ion and the negative charge surrounding it, so it requires more energy to remove a third electron.

2 Physical properties

- Like other metals, *transition metals* are good *conductors* of both heat and electricity.
- The transition metals in general have higher *melting points* and *boiling points* than groups 1 and 2 metals.
- The atomic radii and ionic radii for the M^{2+} ion decrease across period 4 because the increasing positive charge on the nucleus of the atom and of the ion provides a greater attraction for the surrounding electrons.

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Aluminum

Key words

acid	*electrolysis*
alkali	*electrolyte*
aluminum	*filtrate*
amphoteric	*ore*
cryolite	*precipitate*

1 Extraction

- Bauxite, the *ore* from which *aluminum* is obtained, contains impurities, principally iron(III) oxide (Fe_2O_3), that must be removed before the ore can be processed to obtain aluminum.
- Aluminum oxide is an *amphoteric* oxide (it reacts with both *acids* and *alkalis*). After grinding, the ore is mixed with an excess of sodium hydroxide solution, forming sodium tetrahydroxoaluminate(III) solution.
- Iron(III) oxide and the other impurities remain undissolved in the sodium hydroxide solution and are filtered off.
- The *filtrate*, containing sodium tetrahydroxoaluminate(III), is transferred into a precipitation tank, where the solution decomposes, giving a *precipitate* of pure solid aluminum oxide.

2 Manufacture

- Aluminum oxide is reduced by *electrolysis* in a Hall-Hérault cell.
- For electrolysis to occur, the *electrolyte* must be molten so that the ions are mobile and able carry electric charge. The electrolyte consists of a solution of aluminum oxide and molten *cryolite* (a compound of aluminum fluoride and sodium fluoride).
- Aluminum oxide dissociates in the cryolite solution, giving aluminum ions, Al^{3+}, and oxide ions, O^{2-}.
- Aluminum ions are reduced to aluminum metal, which is tapped off molten from the bottom of the cell. Oxide ions are oxidized to oxygen.
- The graphite anode readily reacts with the oxygen produced to give carbon dioxide. The graphite anode is gradually eaten away and must be replaced at regular intervals.

1 Extraction of pure aluminum oxide (Al_2O_3)

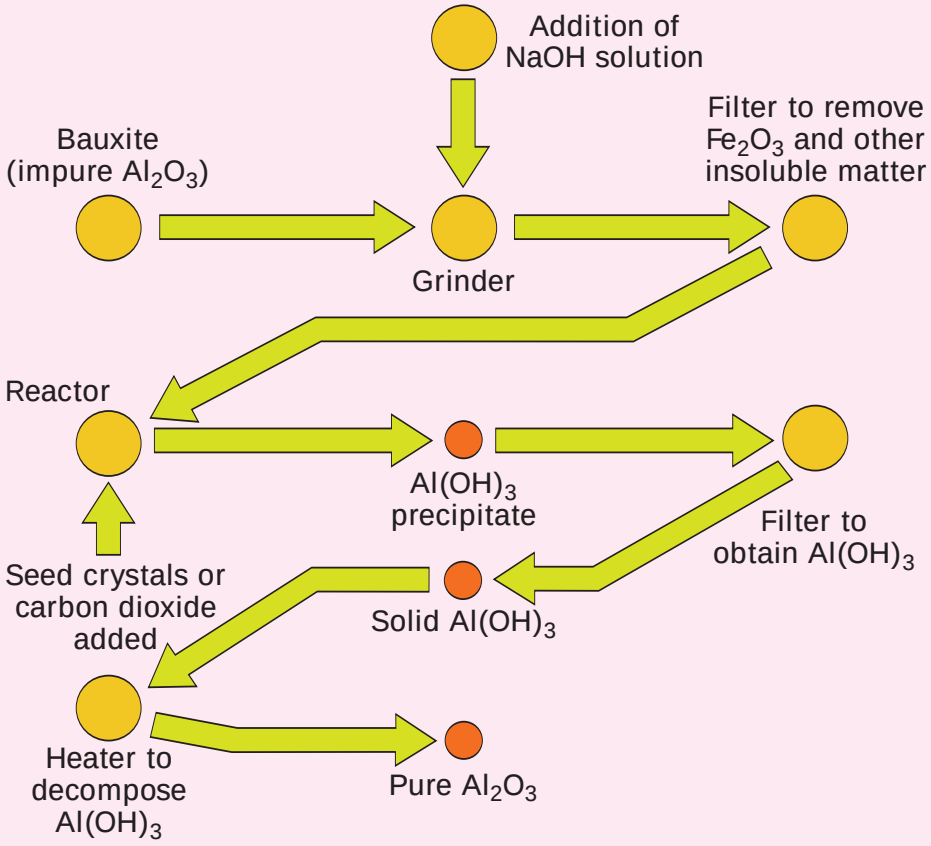

2 The electrolytic manufacture of aluminum

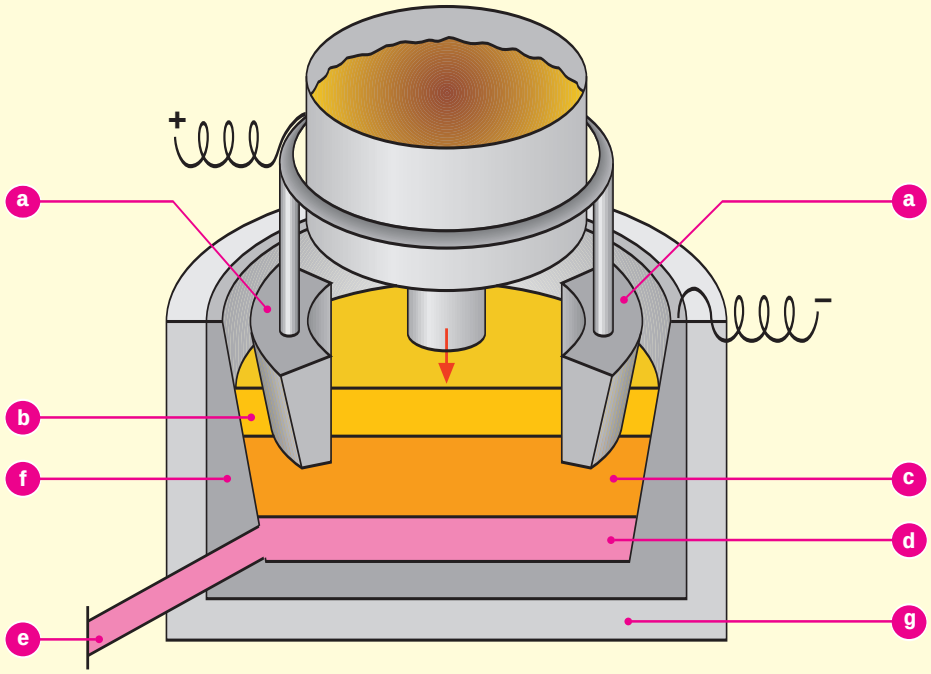

a graphite anodes
b solid crust of electrolyte
c molten electrolyte (aluminum oxide dissolved in cryolite)
d molten aluminum oxide
e tapping hole
f graphite lining to cell (cathode)
g insulation

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Iron: smelting

1 The blast furnace

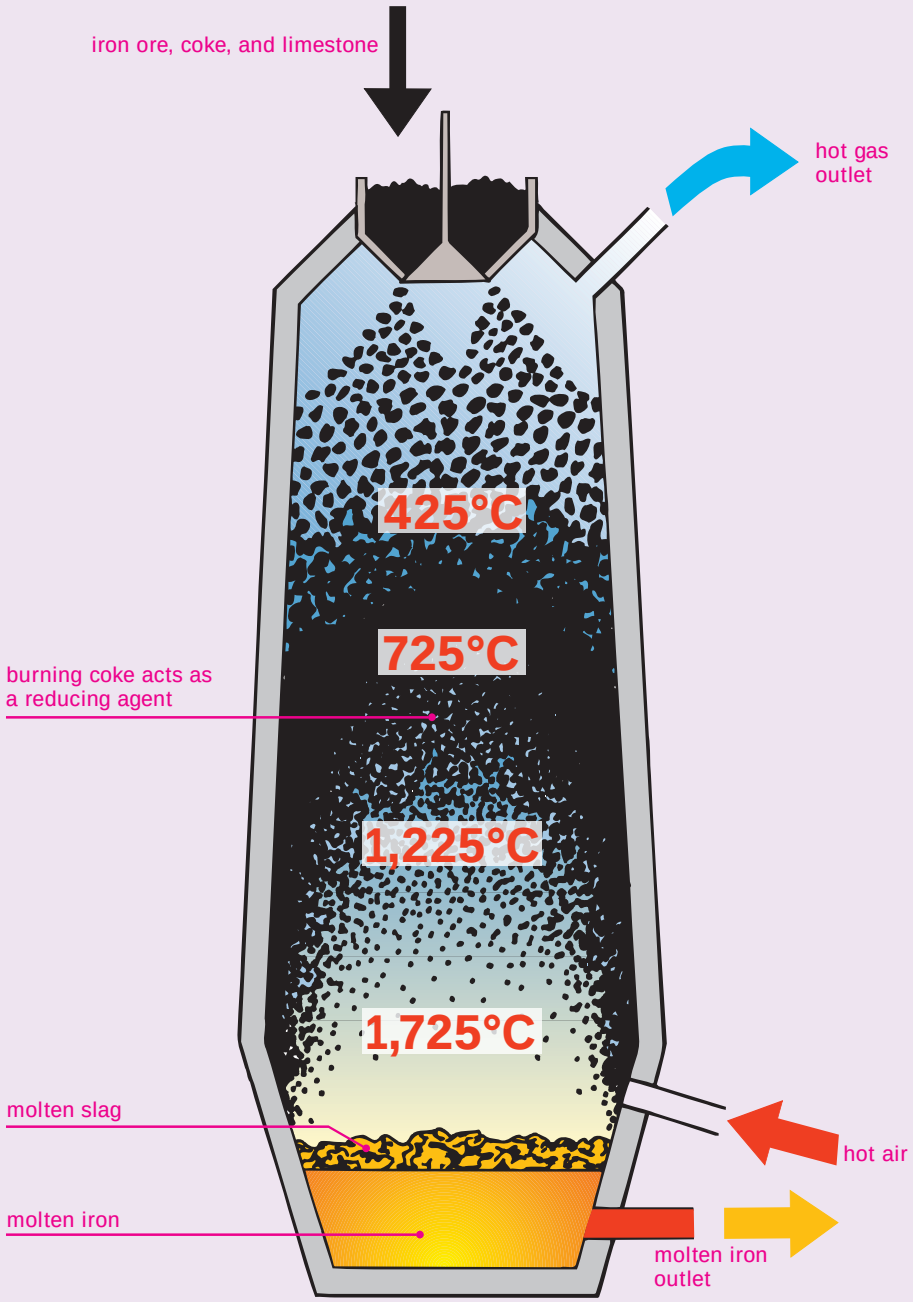

2 Table of impurities of pig iron

Impurity	% impurity in pig iron
Carbon	3 to 5
Silicon	1 to 2
Sulfur	0.05 to 0.10
Phosphorus	0.05 to 1.5
Manganese	0.5 to 1.0

Key words

flux
ore
reducing agent
reduction
slag
smelting

1 The blast furnace

- Iron *ores* such as hematite and magnetite contain oxygen. To create pure iron, the ores are smelted in a blast furnace to remove the oxygen.
- A charge of iron ore, limestone, and coke is fed into the top of the furnace, and hot air is blown in toward the bottom through pipes called tuyeres.
- The coke is used as a fuel, as a *reducing agent*, and also to supply carbon, which dissolves in the molten iron formed.
- The limestone acts as a *flux* (cleaning agent), combining with acidic impurities in the iron ore to form a liquid *slag* (the waste produce of *smelting*).
- Molten iron falls to the bottom of the furnace, where it is tapped.
- Molten slag floats on the molten iron and is drawn off.
- Hot gases (carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen, and unreacted oxygen) are removed at the top of the furnace.
- The conversion of iron oxide to iron is a *reduction*. The main reducing agent is carbon monoxide.
- Iron oxide is reduced to iron by carbon monoxide, which itself is oxidized to carbon dioxide.
- The temperature inside the blast furnace is sufficient to decompose limestone into calcium oxide and carbon dioxide. Calcium oxide then combines with impurities such as silicon dioxide to form slag.

2 Impurities

- The iron that leaves the blast furnace (called pig iron) contains a variable amount of impurities, including carbon, silicon, sulfur, phosphorus, and manganese.

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The manufacture of steel

Key words

alloy
slag

1 Basic oxygen process

- Steel is an *alloy* of iron, carbon, and other metals and non-metals.
- In the basic oxygen process, the furnace is charged with controlled amounts of steel scrap and molten iron from a blast furnace. An oxygen lance, cooled by circulating water, is lowered into the furnace, and high purity oxygen is injected into the vessel at twice the speed of sound. Impurities are readily oxidized. Molten iron is also oxidized.
- With the exception of carbon monoxide, the remaining oxides all react with calcium oxide, which is added during the oxygen blow, to form a *slag*.
- The resulting steel is highly oxidized and not suitable for casting. It is deoxidized by adding controlled amounts of aluminum and silicon in a separate reaction vessel. Additional metals and non-metals are added at this point to make different types of steel.

2 Electric arc furnace

- The electric arc furnace process uses only cold scrap metal. The furnace is a circular bath with a moveable roof through which carbon electrodes can be raised or lowered as required.
- Scrap steel is placed in the furnace, the roof closed, and the electrodes lowered into position. When a current is passed, an arc forms between the scrap steel and the electrodes, and the heat generated melts the scrap steel.
- Lime, fluorspar, and iron ore are added, and these combine with impurities forming a slag. When the steel has reached the correct composition, the slag is poured off, and the steel is tapped from the furnace.

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1 Basic oxygen process

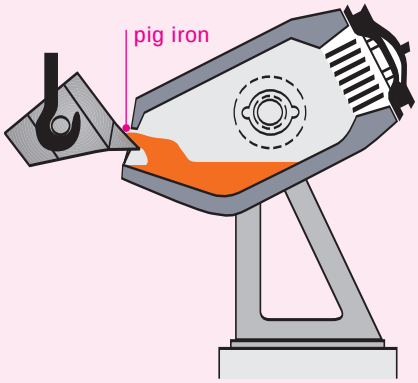

Charging the converter

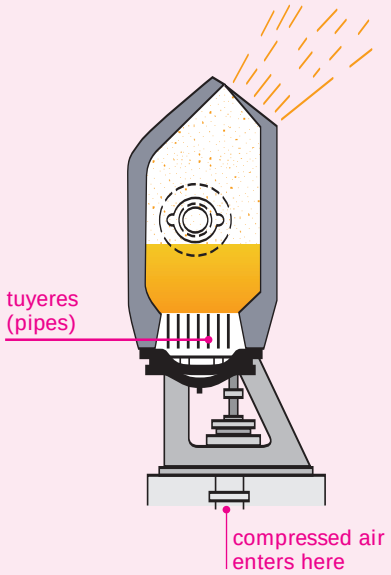

Position during blowing

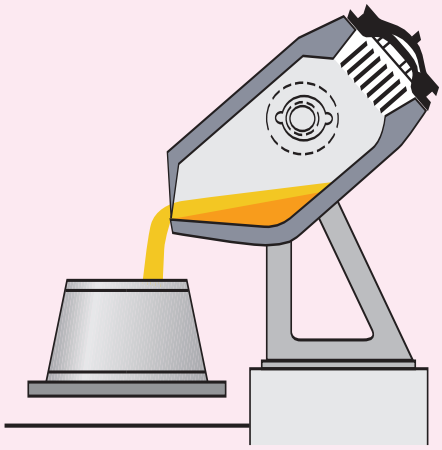

Discharging the slag

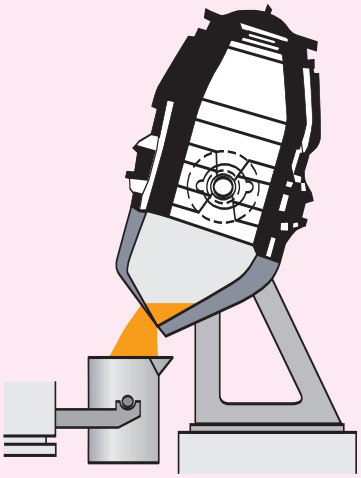

Discharging the steel

2 Electric arc furnace

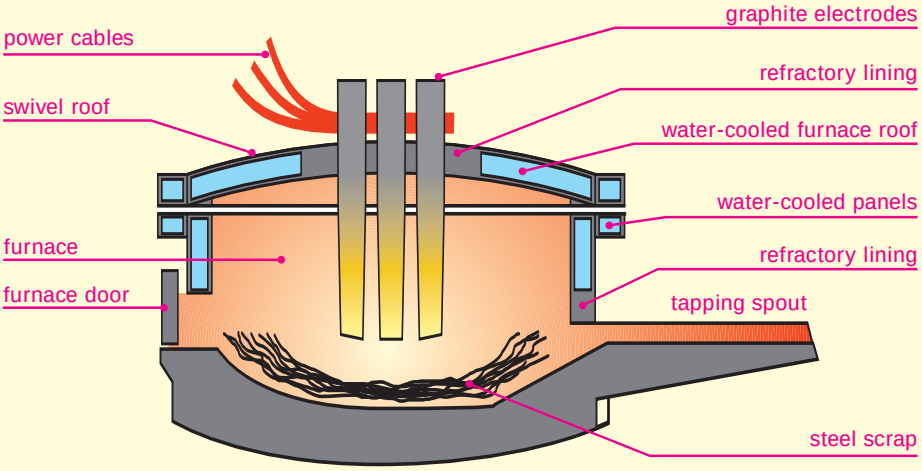

Rusting

1 Rust experiment

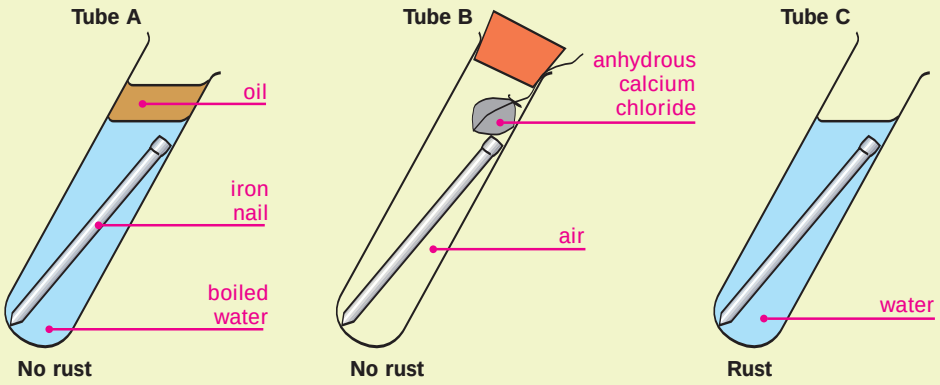

2 Chemical process

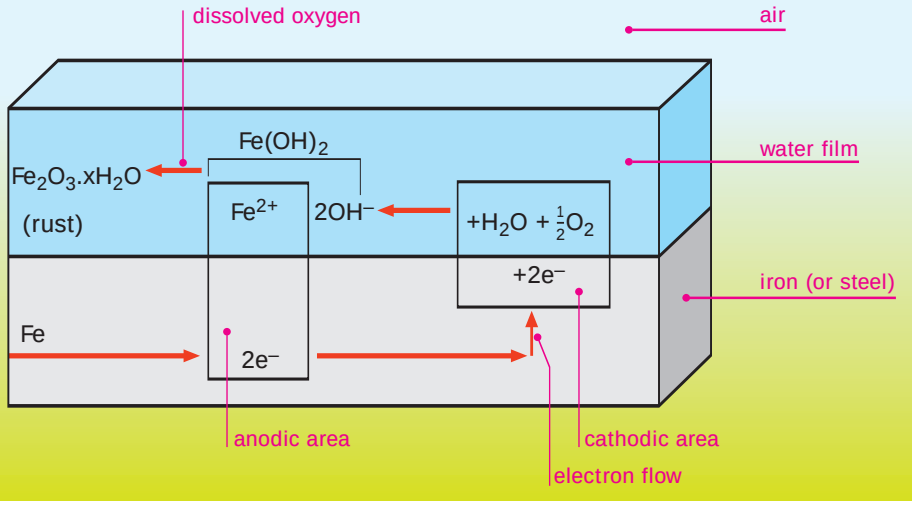

3 Rust prevention

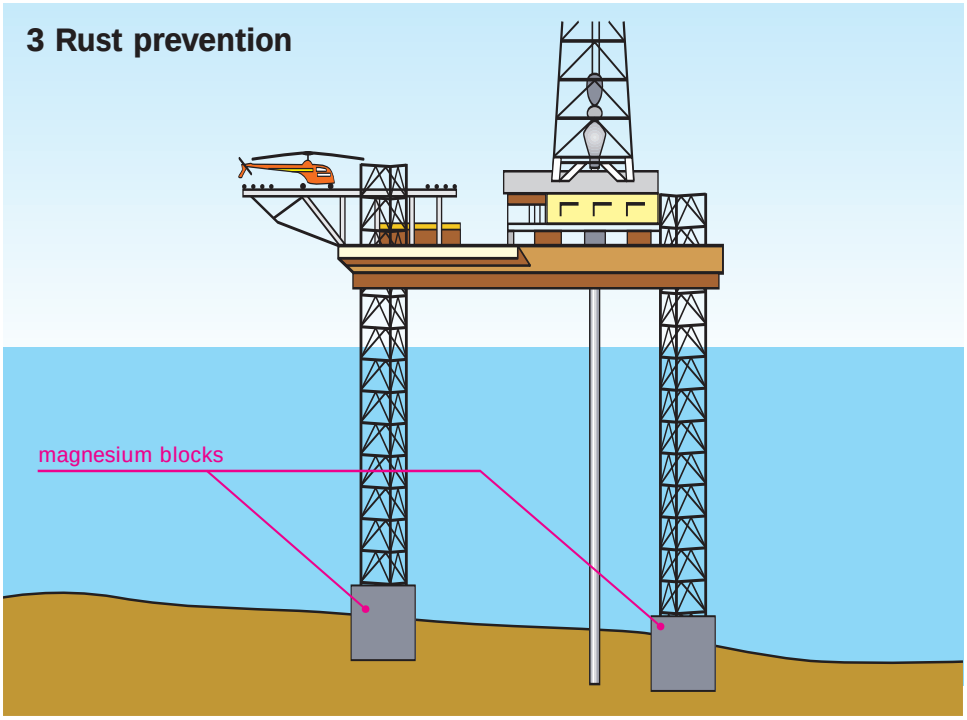

Key words

galvanizing
hydroxide ion
iron
magnesium
rust

Rusting

- Rusting is the result of a chemical cell being formed on the surface of *iron* when it is in contact with water and oxygen from the air.

1 Rust experiment

- The experiment at left proves that both water and oxygen are needed for rusting.
- Tube A: When water is boiled, the air it contains is expelled, and oil prevents any air redissolving in the water. The nail is exposed to water but not oxygen and does not *rust*.
- Tube B: Anhydrous calcium chloride removes moisture from the air. The nail is exposed to oxygen but not water and does not rust.
- Tube C: The nail is exposed to both water and oxygen, and rust forms on it.

2 Chemical process

- Iron atoms are oxidized to form first iron(II) ions, Fe^{2+}, and then iron(III) ions, Fe^{3+}, present in rust, $Fe_2O_3.xH_2O$.
- Oxygen is reduced and combined with water to form *hydroxide ions*, OH^-.

3 Rust prevention

- Most methods of rust prevention involve stopping iron or, more commonly, steel from coming into contact with water and/or oxygen in air. These methods include painting, greasing, coating in plastic, coating in zinc (*galvanizing*), and coating in tin.
- Sacrificial protection involves bolting blocks of a more reactive metal, such as *magnesium*, to a steel structure. The magnesium will oxidize more readily than the iron and will thus "sacrifice itself" in order to prevent iron from rusting.

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Key words

anode
cathode
electrolyte
slag

1 Matte smelting

- Matte smelting is used to produce a liquid sulfide phase (matte) containing as much copper as possible, and an immiscible liquid *slag*, which contains virtually no copper.
- Copper sulfide ores, such as chalcopyrite ($CuFeS_2$) are mixed with sand and blown into the flash furnace:
  $4CuFeS_2(s) + 5O_2(g) + 2SiO_2(s) \rightarrow \underbrace{2Cu_2S.FeS(l)}_{\text{matte}} + \underbrace{2FeSiO_3(l)}_{\text{slag}} + 4SO_2(g)$
- As the iron content of the matte falls to about 1 percent, copper starts to form. This product is called “blister copper” and is 98–99.5 percent pure. It is porous and brittle and requires further refining to be commercially useful.
- Blister copper is melted to drive off sulfur dioxide, and air is blown through it to remove any sulfur. The impure copper is cast into *anodes* for electro-refining.

2 Electro-refining

- In electro-refining, a large impure copper anode and a small pure copper *cathode* are suspended in an *electrolyte* consisting of copper(II) sulfate solution and sulfuric acid.
- At the anode, copper atoms are oxidized to copper ions and pass into solution. The anode gradually becomes smaller:
  $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
- At the cathode, copper ions are removed from solution as they are reduced to copper atoms. The cathode gradually becomes larger:
  $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
- Impurities that are insoluble in the electrolyte fall to the bottom of the cell. These may include gold, silver, platinum, and tin, and in some circumstances may be more valuable than the copper produced.

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Copper smelting and converting

1 Matte smelting

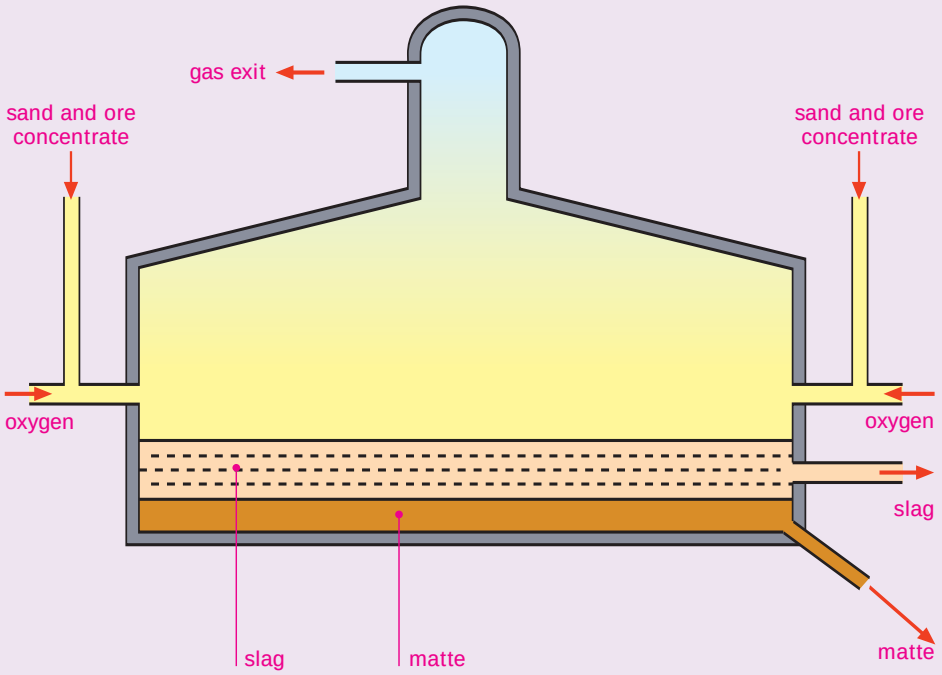

2 Electro-refining

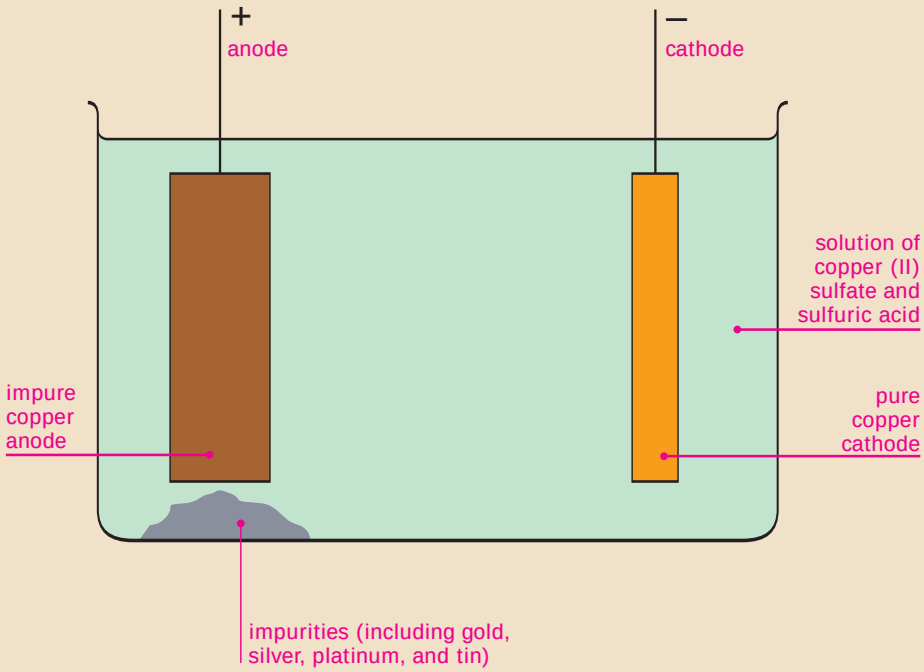

Reactions of copper

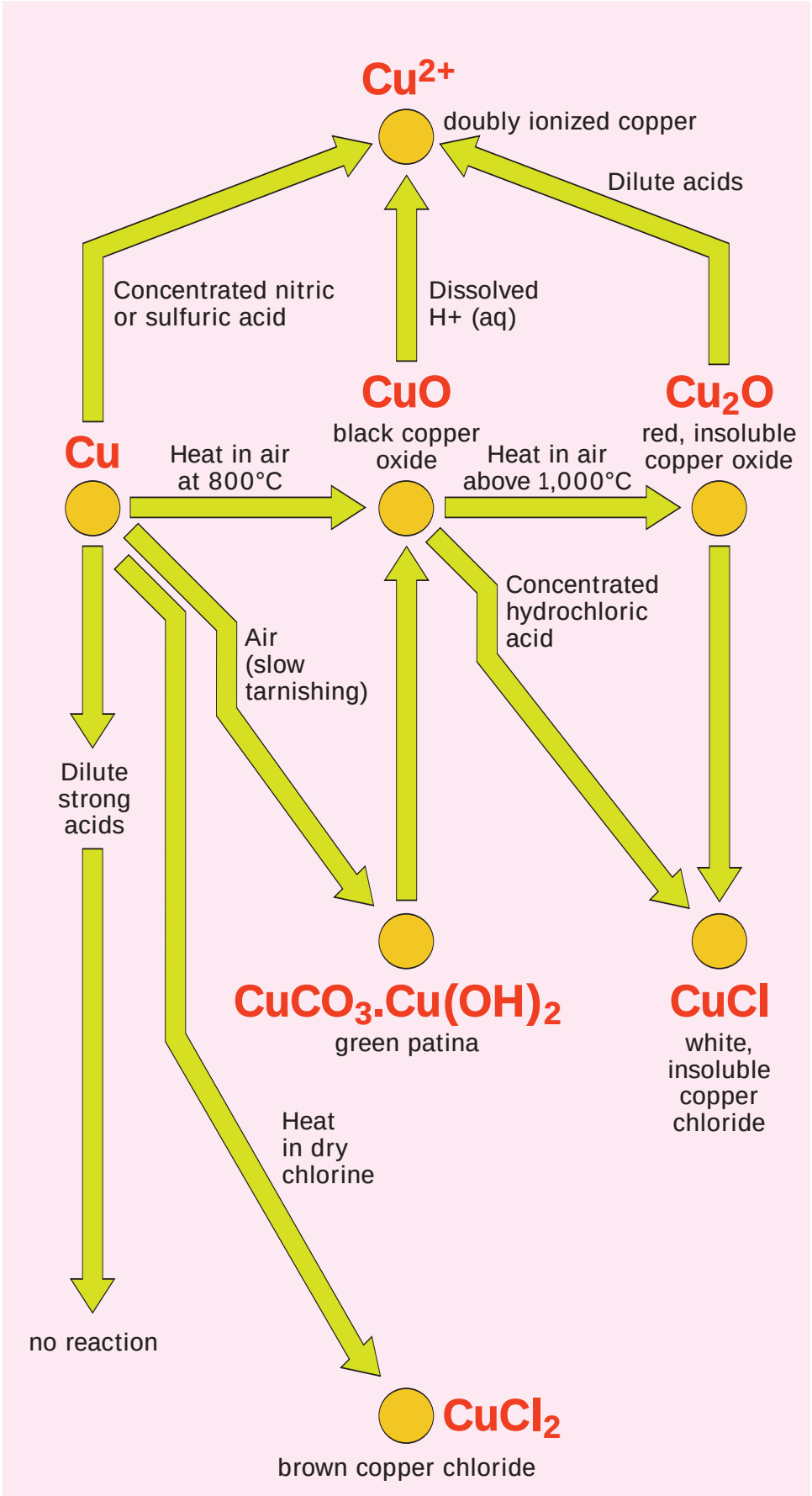

Key words

hydrochloric acid
nitric acid
oxidation state
oxidizing agent
sulfuric acid
transition metals

Reactions of copper

- Copper is a *transition metal*. Its normal *oxidation state* is copper(II), Cu^{2+}, but it also forms some copper(I), Cu^{+}, compounds. Copper is a relatively unreactive metal. It does not react with dilute strong acids, water, or steam.
- When heated in air at 800°C, copper is oxidized to black copper(II) oxide:
  $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$
  At temperatures over 1,000°C, red copper(I) oxide is formed:
  $4Cu(s) + O_2(g) \rightarrow 2Cu_2O(s)$
  Both oxides react with dilute acids to form copper(II) salts.
- When heated in chlorine, copper forms brown copper(II) chloride.
  $Cu(s) + Cl_2(g) \rightarrow CuCl_2(s)$
- White copper(I) chloride also exists and can be made by strongly heating copper(II) chloride:
  $2CuCl_2(s) \rightarrow 2CuCl(s) + Cl_2(g)$
  It is also formed by the reaction of copper(II) oxide with concentrated *hydrochloric acid* via an complex ion, $[CuCl_2]^-$. When a solution containing this ion is poured into water, copper(I) chloride is precipitated.
- Copper tarnishes slowly in air, forming basic copper(II) carbonate, a compound of copper(II) carbonate, and copper(II) hydroxide, $CuCO_3.Cu(OH)_2$. It is this compound that produces the green coloration, referred to as patina, on weathered copper.
- Copper reacts with both concentrated nitric and concentrated *sulfuric acid*. Both of these concentrated acids are powerful *oxidizing agents* and react with copper in a different way than a dilute acid reacts with a metal. Copper does not react with dilute acids.
  With concentrated sulfuric acid:
  $Cu(s) + 2H_2SO_4(l) \rightarrow$
  $CuSO_4(aq) + 2H_2O(l) + SO_2(g)$
  With concentrated *nitric acid*:
  $Cu(s) + 4HNO_3 \rightarrow$
  $Cu(NO_3)_2(aq) + 2H_2O(l) + 2NO_2(g)$

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Key words

aluminum
amphoteric
carbonate
copper
hydroxide
iron
oxidation state
oxide
transition metals
valency

Reactivity

- *Aluminum* is the most reactive and *copper* is least reactive of the three metals.
- All three metals react directly with non-metals.

Oxides

- Aluminum has one *oxide*, Al_2O_3, which is *amphoteric* and thus reacts with both acids and alkalis. *Iron* has three oxides: FeO, Fe_2O_3, and Fe_3O_4. Copper has two: Cu_2O and CuO. All metal oxides react with dilute acids to form salts and water.

Hydroxides

- Aluminum *hydroxide*, like aluminum oxide, is amphoteric. Iron forms two hydroxides by the addition of sodium hydroxide solution to solutions of its salts. Iron(II) salts produce a dirty green precipitate of iron(II) hydroxide, while iron(III) salts produce a red-brown precipitate of iron(III) hydroxide. Copper(II) hydroxide forms as a blue precipitate when sodium hydroxide is added to a solution of a copper salt.
- All metal hydroxides react with alkalis to give metal salts and water.

Carbonates

- Aluminum and iron(III) do not form *carbonates*. Iron(II) carbonate and copper(II) carbonate decompose on heating to the corresponding metal oxide with the loss of carbon dioxide gas. The carbonates also react with dilute acids to forms metal salts, carbon dioxide, and water.

Valency

- Aluminum is in group 3 of the periodic table and exhibits only one *oxidation state*, +3, in its compounds. Iron and copper are both *transition metals* and exhibit two oxidation states in their compounds.

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Reaction summary: aluminum, iron, and copper

Aluminum	
Preparation	Electrolysis of aluminum oxide $Al^{3+} + 3e^- \rightarrow Al$ at cathode
Reaction of elements	$4Al + 3O_2 \rightarrow 2Al_2O_3$ oxide layer formed $2Al + 3Cl_2 \rightarrow Al_2Cl_6$ $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$
Oxide	$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$ $Al_2O_3(s) + 2NaOH(aq) \rightarrow Na[Al(OH)_4](aq)$
Hydroxide	$AlCl_3 + 3NaOH \rightarrow Al(OH)_3 + 3NaCl$ $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$ $Al(OH)_3(s) + NaOH(aq) \rightarrow 2Na[Al(OH)_4](aq)$ (amphoteric)
Carbonate	Not formed
Change of valency	Only on oxidation

Iron	
Preparation	Chemical reduction in blast furnace $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
Reaction of elements	$2Fe + 2H_2O + O_2 \rightarrow 2Fe(OH)_2$ rust $Fe + 2HCl \rightarrow FeCl_2 + H_2$ $2Fe + 3Cl_2 \rightarrow 2FeCl_3$ $Fe + S \rightarrow FeS$ $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$
Oxide	$FeO + H_2SO_4 \rightarrow FeSO_4 + H_2O$ $Fe_2O_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2O$
Hydroxide	$FeCl_2 + 2NaOH \rightarrow Fe(OH)_2 + 2NaCl$ $FeCl_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaCl$ $Fe(OH)_2 + 2HCl \rightarrow FeCl_2 + 2H_2O$ $Fe(OH)_3 + 3HCl \rightarrow FeCl_3 + 3H_2O$
Carbonate	Unstable to heat. $FeCO_3 \rightarrow FeO + CO_2$ $FeCO_3 + H_2SO_4 \rightarrow FeSO_4 + CO_2 + H_2O$
Change of valency	$2Fe^{2+}_{(aq)} + Cl_{2(g)} \rightarrow 2Fe^{3+}_{(aq)} + 2Cl^-_{(aq)}$

Copper	
Preparation	Thermal decomposition in furnace $Cu_2S \xrightarrow{air} 2Cu + SO_2$
Reaction of elements	$2Cu + O_2 \rightarrow 2CuO$ $Cu + Cl_2 \rightarrow CuCl_2$ $2Cu + S \rightarrow Cu_2S$ $CuCl_2 + H_2SO_4 \rightarrow$ no reaction with dilute acid $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$ with conc. acid
Oxide	$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$
Hydroxide	$CuCl_2 + 2NaOH \rightarrow Cu(OH)_2 + 2NaCl$ $Cu(OH)_2 + 2HCl \rightarrow CuCl_2 + 2H_2O$
Carbonate	Unstable to heat. $CuCO_3 \rightarrow CuO + CO_2$ $CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + CO_2 + H_2O$
Change of valency	$2Cu^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow 2Cu^+_{(aq)} + I_{2(s)}$ then $Cu^+_{(aq)} + I^-_{(aq)} \rightarrow CuI_{(s)}$

The extraction of metals from their ores

Metal (Date of discovery) Ranked from highest to lowest in reactivity series	Main ore from which it is obtained	Main method of extraction
Sodium (1807) Group 1	Rock salt NaCl	Electrolysis of molten NaCl
Magnesium (1808) Group 2	Magnesite $MgCO_3$ and Mg^{2+} ions in seawater	Electrolysis of molten $MgCl_2$
Aluminum (1827) Group 3	Bauxite $Al_2O_3.2H_2O$	Electrolysis of Al_2O_3 in molten cryolite (Na_3AlF_6)
Zinc (1746) Transition metal	Zinc blende ZnS	Heat sulfide in air → oxide. Dissolve oxide in H_2SO_4, electrolyze
Iron (ancient) Transition metal	Hematite Fe_2O_3	Reduce Fe_2O_3 with carbon monoxide
Tin (ancient) Group 4	Tinstone SnO_2	Reduce SnO_2 with carbon
Lead (ancient) Group 4	Galena PbS	Heat sulfide in air → oxide. Reduce oxide with carbon
Copper (ancient) Transition metal	Copper pyrites $CuFeS_2$ (CuS + FeS)	Controlled heating with correct amount of air → Cu + SO_2
Mercury (ancient) Transition metal	Cinnabar HgS	Heat in air → Hg + SO_2

Key words

electrolysis
ore
reactivity series
reduction

Extraction of metals

- The ease with which a metal is obtained from its *ore* is directly related to its position in the *reactivity series* of metals.

Electrolytic reduction

- All of the group 1 and group 2 metals and aluminum from group 3 are reactive metals and in the upper half of the reactivity series. They cannot be obtained from their ores by chemical *reduction*, i.e., by heating the ore with a reducing agent such as carbon monoxide or carbon. These metals can only be obtained by electrolytic reduction or *electrolysis*.
- Consequently, it was impossible to obtain these metals before the discovery and development of electricity at the end of the eighteenth century. All of these metals were first made in the early years of the nineteenth century, several by English chemist Sir Humphrey Davy.

Heating

- Zinc oxide and iron oxide are reduced by heating with carbon monoxide. Although zinc can be obtained by chemical reduction, approximately 80 percent of the world's annual production is, in fact, obtained by electrolysis.
- All of the metals from iron and below in the reactivity series are relatively easy to obtain from their ores by heating.
- Iron is obtained by reduction with carbon monoxide
- Tin is obtained by reduction with carbon
- Lead is obtained by heating lead sulfide in air to produce an oxide, which is then reduced with carbon.
- Copper is obtained by controlled heating with the correct amount of air
- Mercury is obtained by heating in air.

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Reactivity summary: metals

Key words

oxide
reactivity
reactivity series

Reactivity summary

- Metals can be arranged in order of their *reactivity*, starting with the most reactive. This is called the *reactivity series*. The relative reactivity of metals is reflected through all of their chemistry.

Reaction with oxygen

- Metals at the top of the reactivity series readily burn in oxygen. Less reactive metals do not burn but form a surface layer of *oxide*. Metals at the bottom of the reactivity series are not oxidized by atmospheric oxygen.

Reaction with cold water

- Metals at the top of the reactivity series react readily with cold water but with decreasing vigor down to magnesium. The metals below magnesium do not react with cold water.

Reaction with steam

- Metals react more vigorously with steam than with cold water. All of the metals down to iron react with steam with decreasing vigor. The metals below iron do not react with steam.

Reaction with dilute acid

- All of the metals down to lead react with dilute acids, with decreasing vigor. The metals below lead do not react with dilute acids.

	K Na	Ca Mg Al Zn Fe	Pb Cu Hg	Ag Pt Au
Reaction with $O_{2(g)}$ on heating	form oxides (e.g.,Na_2O) in limited supplies of O_2, but peroxides (e.g., Na_2O_2) with excess O_2	burn with decreasing vigor to form oxides	do *not* burn, but only form a surface layer of oxide	do *not* burn or oxidize on surface
Heat evolved when metal reacts with 1 mole of O_2 to form oxide shown / kJ	**K** K_2O 723 **Na** Na_2O 832	**Ca** CaO 1272 **Mg** MgO 1204 **Al** Al_2O_3 1114 **Zn** ZnO 697 **Fe** Fe_2O_3 548	**Pb** PbO 436 **Cu** CuO 311 **Hg** HgO 182	**Ag** Ag_2O 61 **Pt** — — Au Au_2O_3 54
Reaction with cold water	displace $H_{2(g)}$ from cold water with decreasing reactivity **K**, violently	displace $H_{2(g)}$ from cold water with decreasing reactivity **Mg**, very slowly	do *not* displace $H_{2(g)}$ from cold water	do *not* displace $H_{2(g)}$ from cold water
Reaction with steam	displace $H_{2(g)}$ from steam with decreasing vigor **K**, very violently	displace $H_{2(g)}$ from steam with decreasing vigor **Fe**, very slowly)	do *not* displace $H_{2(g)}$ from steam	do *not* displace $H_{2(g)}$ from steam
Reaction with dilute acid	displace $H_{2(g)}$ from dilute acid with decreasing vigor **K**, explosively	**Mg,**very vigorous **Fe**,steadily	do *not* displace $H_{2(g)}$ from dilute acid **Pb**, very slowly	do *not* displace $H_{2(g)}$ from dilute acid

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Tests on metals: flame test

1 Flame test

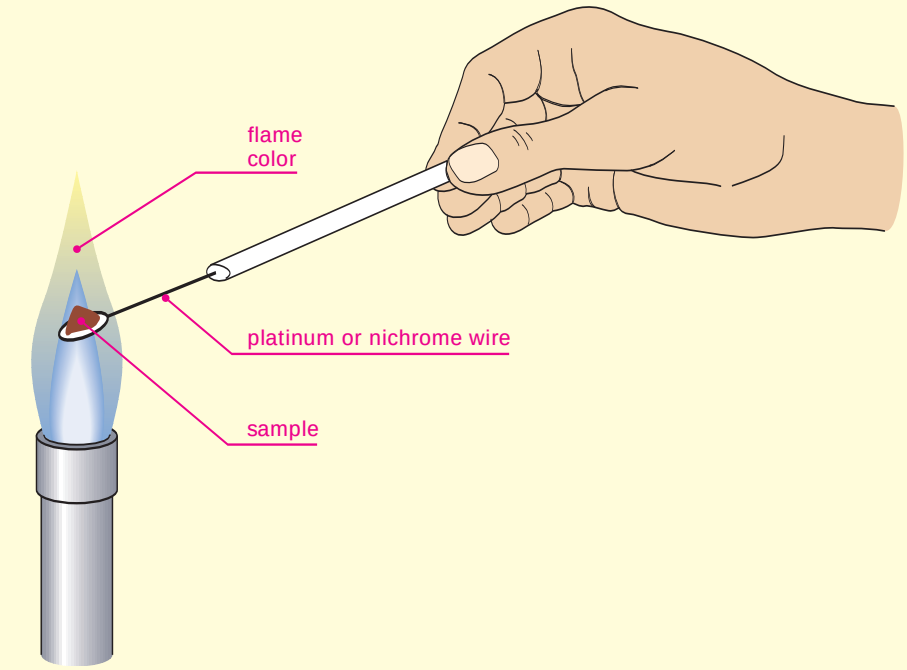

2 Table of flame coloration

Color of flame	Likely ion present	Metal
Apple green	Ba^{2+}	barium
Blue-green	Cu^{2+}	copper
Brick red	Ca^{2+}	calcium
Crimson	Sr^{2+}	strontium
Lilac	K^{+}	potassium
Orange-yellow	Na^{+}	sodium
Red	Li^{+}	lithium

Key words

ion
salt
solution

1 Flame test

- Several metal *ions* produce characteristic colors when introduced to a bunsen flame either as a solid or as a *solution* of a *salt*.
- A clean platinum or nichrome wire is dipped in concentrated hydrochloric acid and then into the solid or solution.
- The sample is introduced to the middle of a non-luminous bunsen flame.

2 Flame coloration

- The following metals produce the following colors in the flame test:
  barium: apple green
  calcium: brick red
  copper: blue-green
  lithium: red
  potassium: lilac
  sodium: orange-yellow
  strontium: crimson
- The lilac color of potassium is sometimes difficult to see and is better observed through blue glass that makes the flame appear purple.
- The orange-yellow color of sodium is very intense and may mask the color of other metal ions present.

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Key words

amphoteric
hydroxide
precipitate
salt
sodium hydroxide
transition metals

1 Producing the hydroxide

- Group 1 metal *hydroxides* are very soluble and form strong alkaline solutions. Group 2 metal hydroxides are less soluble but still dissolve sufficiently to form weak alkaline solutions. All other metals form insoluble hydroxides. If several drops of sodium hydroxide (NaOH) solution are added to a solution of a metal *salt*, a *precipitate*, often gelatinous, is formed. Care must be taken when carrying out this reaction because some metals form precipitates that redissolve in excess *sodium hydroxide* solution. If sodium hydroxide solution is added too quickly, the initial precipitate may not be seen.

2 The reactions

- The reactions of metal salt solutions with sodium hydroxide solution can be used to identify the metal.
- Aluminum, zinc, and lead hydroxides are all *amphoteric*. When sodium hydroxide solution is added to solutions of salts of these metals, an initial white precipitate is formed. However, if excess sodium hydroxide solution is added, the precipitate dissolves, forming a solution of a soluble complex compound.

$Al(OH)_3(s) + NaOH(aq) \rightarrow Na[Al(OH)_4](aq)$
sodium tetrahydroxoaluminate(III)

$Zn(OH)_2(s) + 2NaOH(aq) \rightarrow Na_2[Zn(OH)_4](aq)$
sodium tetrahydroxozincate(II)

$Pb(OH)_2(s) + 2NaOH(aq) \rightarrow Na_2[Pb(OH)_4](aq)$
sodium tetrahydroxoplumbate(II).

- Iron and copper are *transition metals* and form characteristic colored precipitates with sodium hydroxide solution.

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Tests on metals: metal hydroxides

1 Producing the hydroxide from the metallic salt

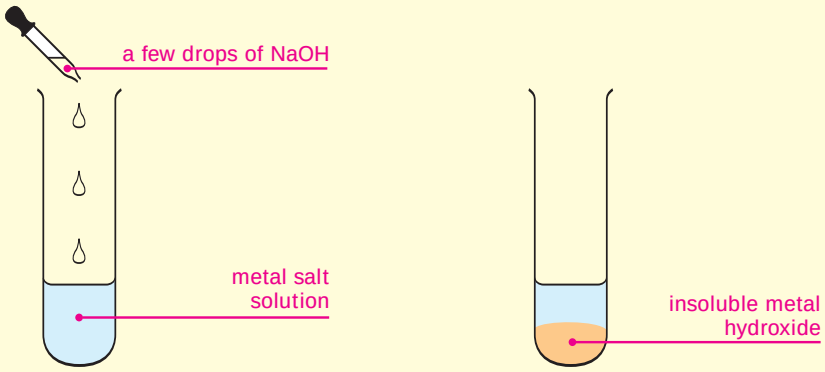

Add a small amount of NaOH to metal salt solution

A jelly-like solid forms

2 The reactions

Aluminum nitrate → white precipitate of aluminum hydroxide
$Al(NO_3)_3 + 3NaOH \rightarrow 3NaNO_3 + Al(OH)_3 \downarrow$

Zinc nitrate → white precipitate of zinc hydroxide
$Zn(NO_3)_2 + 2NaOH \rightarrow 2NaNO_3 + Zn(OH)_2 \downarrow$

Lead nitrate → white precipitate of lead hydroxide
$Pb(NO_3)_2 + 2NaOH \rightarrow 2NaNO_3 + Pb(OH)_2 \downarrow$

Iron(II) nitrate → green precipitate of iron(II) hydroxide
$Fe(NO_3)_2 + 2NaOH \rightarrow 2NaNO_3 + Fe(OH)_2 \downarrow$

Iron(III) nitrate → rust-brown precipitate of iron(III) hydroxide
$Fe(NO_3)_3 + 3NaOH \rightarrow 3NaNO_3 + Fe(OH)_3 \downarrow$

Copper nitrate → royal blue precipitate of copper hydroxide
$Cu(NO_3)_2 + 2NaOH \rightarrow 2NaNO_3 + Cu(OH)_2 \downarrow$

Tests on metals: metal ions

Key words

hydroxide
reagent

Reacations with reagents

- In addition to flame tests and the properties of their hydroxides, the presence of some metal ions in solution can be demonstrated by their reactions with particular reagents.

Metal ion in solution	To the test solution	Positive result
Alumnum Al^{3+}	Add 1 or 2 drops of litmus solution followed by dilute hydrochloric acid until the mixture is just acidic. Then add ammonia solution until just alkaline.	Blue lake – a gelatinous precipitate of aluminum hydroxide – is formed, and this absorbs the litmus, leaving the solution almost colorless.
Barium Ba^{2+}	Add several drops of potassium chromate solution.	A yellow precipitate of barium chromate. Lead ions also give a yellow precipitate, but lead chromate is deeper yellow and turns orange on heating.
Copper Cu^{2+}	Add ammonia solution drop by drop until it is in excess.	An initial blue precipitate of copper(II) hydroxide that dissolves in excess ammonia solution to give a deep blue solution containing the complex ion $[Cu(NH_3)_4]^{2+}$.
Iron(II) Fe^{2+}	Add several drops of potassium hexacyanoferrate(III) solution.	A deep blue solution is formed.
Iron(III) Fe^{3+}	Add several drops of ammonium thiocyanate solution.	Deep blood-red coloration.
Lead Pb^{2+}	Add several drops of potassium iodide solution.	A yellow precipitate of lead(II) iodide.
Silver Ag^{+}	Add several drops of potassium chromate solution.	A brick-red precipitate of silver chromate.
Zinc Zn^{2+}	Add ammonium chloride and ammonia solution, then pass hydrogen sulfide through the mixture.	A white, or more often dirty white, precipitate of zinc sulfide.

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Key words

alloy
aluminum
copper
ductile
galvanizing
iron
lead
reactivity series
zinc

Uses of metals

- The uses of metals are related to both their physical and chemical properties. The physical properties of a metal are sometimes altered by mixing it with other metals or non-metals to form *alloys*.

Aluminum

- *Aluminum* has a low density but is too soft for many applications. It is frequently used as duralumin (an alloy of aluminum and *copper*) as a structural material in the manufacture of airplanes.

Zinc

- *Zinc* is above *iron* in the *reactivity series*. During *galvanizing*, iron is dipped in molten zinc, and the layer of zinc formed on the iron protects it from rusting. If the galvanized iron is scratched, exposing the iron, an electrolytic cell forms between the iron and zinc, and the zinc corrodes in preference to the iron.

Iron

- Iron is used for all sorts of structures, most often as steel (an alloy of iron and carbon). The one serious problem with iron and steel is that they rust on exposure to water and oxygen in the air.

Lead

- *Lead* has a high density and is impervious to water, so it used as flashing on roofs. It is also used as in the manufacture of car batteries. In the past, before its toxic nature was understood, lead was also used for water pipes and in paints. Solder (an alloy of lead and tin) is widely used to join copper wires and copper pipes.

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Uses of metals

Metal	Use	Reason
Aluminum 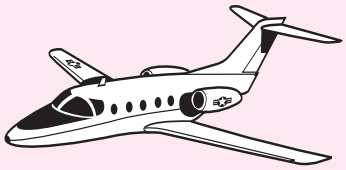	Structural material for ships, planes, cars, cookware Electric cables	Strong but light; oxide layer prevents corrosion. Light, but good conductor.
Zinc 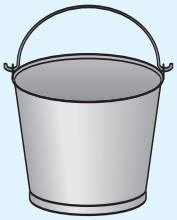	Coating (galvanizing) steel Alloys: brass (Zn/Cu) bronze (Zn/Sn/Cu)	Reactive — gives sacrificial protection to iron; does not corrode easily. Modifies the properties of the other elements.
Iron 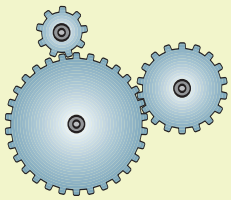	Structural material for all industries (in the form of steel)	Strong and cheap; properties can be made suitable by alloying.
Lead 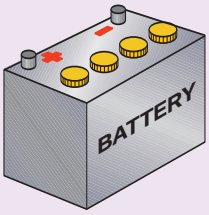	Roofing Car batteries Solder (Pb/Sn alloy)	Very malleable and does not corrode. Design of battery makes recharging possible. Low melting point.
Copper	Electric cables Pipes Alloys (see above) Coins (alloyed with nickel)	Very good conductor. Very ductile, does not corrode easily.

Copper

- Copper is very *ductile* and can be easily drawn into wires. It is a good conductor of electricity and is used for the conducting parts of electric cables. Copper does not react with water and is a good conductor of heat. It is used for water pipes and radiators.

Reactivity of metals 1

1 Forming oxides and chlorides

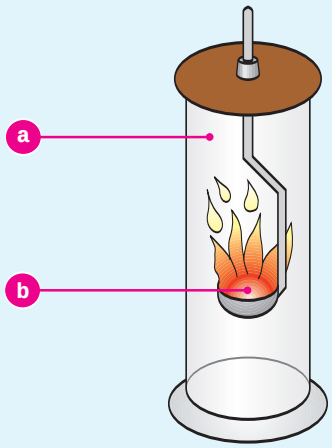

a oxygen or chlorine
b burning piece of reactive metal

2 Forming hydroxides

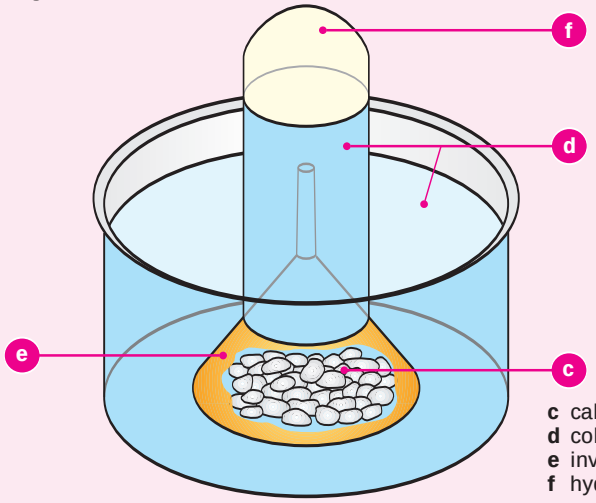

c calcium
d cold water
e inverted filter funnel
f hydrogen

3 Less reactive metals

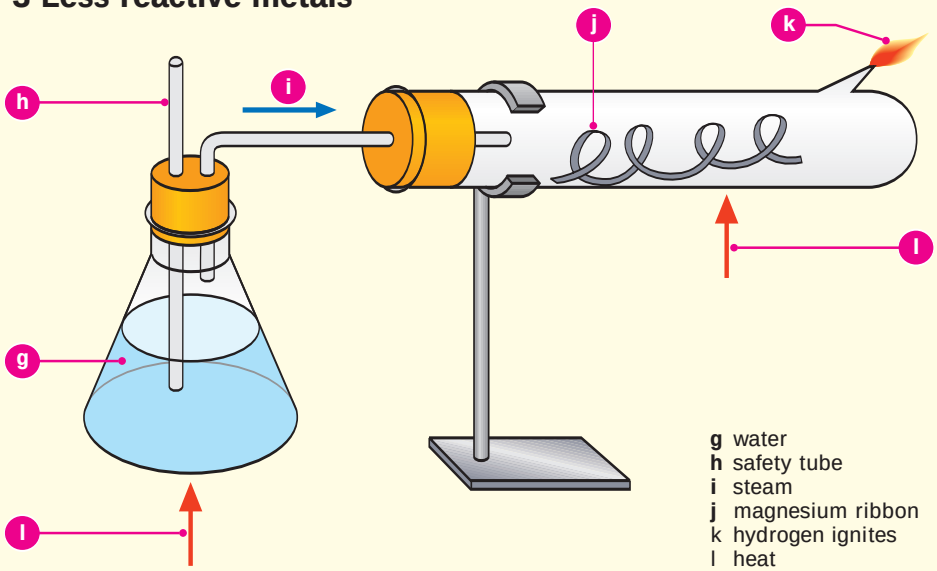

g water
h safety tube
i steam
j magnesium ribbon
k hydrogen ignites
l heat

Key words

alkali	*hydroxide*
calcium	*magnesium*
chloride	*oxide*
copper	*sodium*
iron	

1 Forming oxides and chlorides

- Most metals react with air to form metal *oxides*. Reactive metals like *magnesium* burn, producing light and heat. Less reactive metals like *copper* simply change color on heating:
  $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
  $2Cu(s) + O_2 \rightarrow 2CuO(s)$
- Metals will also form *chlorides* when heated in chlorine:
  $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
  $Cu(s) + Cl_2 \rightarrow CuCl_2(s)$

2 Forming hydroxides

- Very reactive metals like *calcium* and *sodium* react with water to form solutions of metal *hydroxides* and hydrogen gas:
  $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$
  $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
- Calcium hydroxide is less soluble in water and forms a weak *alkali*.
- Sodium hydroxide is very soluble in water and forms a strong alkali.

3 Less reactive metals

- Less reactive metals, which react with water very slowly or not at all, react with steam to form metal oxides and hydrogen gas.
- Magnesium reacts very slowly with water but readily with steam:
  $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$
- Iron does not react with water but reacts with steam to form iron(II) diiron(III) oxide:
  $3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$
- The least reactive metals, such as copper, do not react with water or steam.

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Reactivity of metals 2

Key words

anode
carbonate
cathode
limewater
oxide
reactivity series
sulfuric acid

1 Metal compounds

- The *oxides* of metals that are low in the *reactivity series*, like copper, can be reduced by heating them in a stream of hydrogen gas.
- All group 1 metal *carbonates*, with the exception of lithium carbonate, are not decomposed on heating. All other metal carbonates decompose on heating, forming the metal oxide and carbon dioxide gas:
  $Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$
  $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$
  $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$
- Carbon dioxide gas is more dense than air and can be poured from one test tube into another. Carbon dioxide turns *limewater* milky.

2 Generating electric current

- When rods of zinc and copper are placed in dilute *sulfuric acid*, a simple electrical cell is formed, and there is a potential voltage difference between the two metals. If the two metals are connected externally, electric current flows.
- The zinc rod becomes the positive electrode (*anode*) of the cell. Zinc atoms are oxidized to form zinc ions:
  $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
- The copper rod becomes the negative electrode (*cathode*) of the cell. Hydrogen ions are reduced to hydrogen gas:
  $2H^+(aq) + 2e^- \rightarrow H_2(g)$
- If the copper rod is surrounded by a porous vessel containing copper(II) sulfate solution, a different reaction occurs at the cathode:
  $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
- Zinc atoms are oxidized to zinc ions, while copper ions are reduced to copper atoms.

1 Reactions of metal compounds

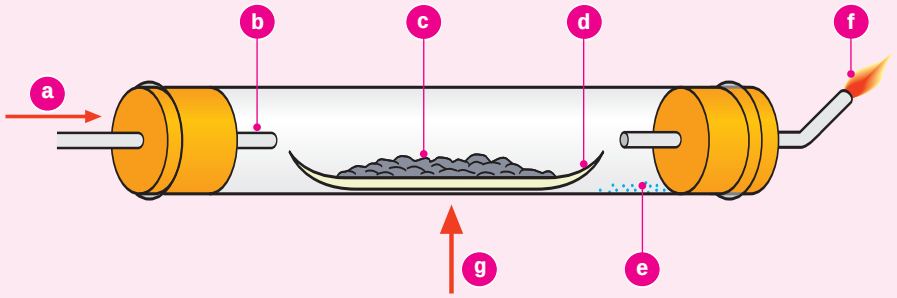

Reduction of oxides
a hydrogen
b combustion tube clamped to slope downward
c metallic oxide
d porcelain vessel
e moisture collects here
f hydrogen ignited
g heat

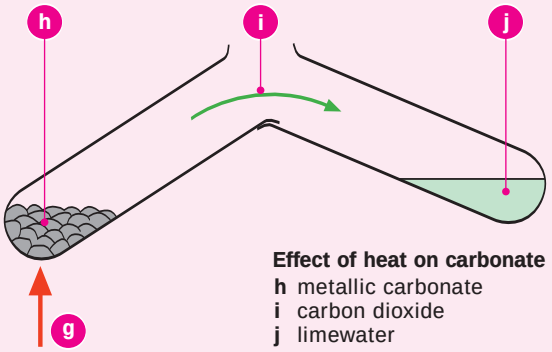

Effect of heat on carbonate
h metallic carbonate
i carbon dioxide
j limewater

2 Generation of electric current by mechanical reaction

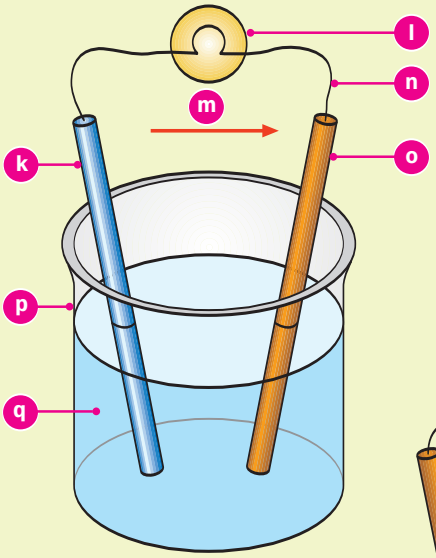

Method 1: simple cell
k zinc rod
l electric bulb
m electron transfer
n connecting wire
o copper rod
p beaker
q dilute sulfuric acid

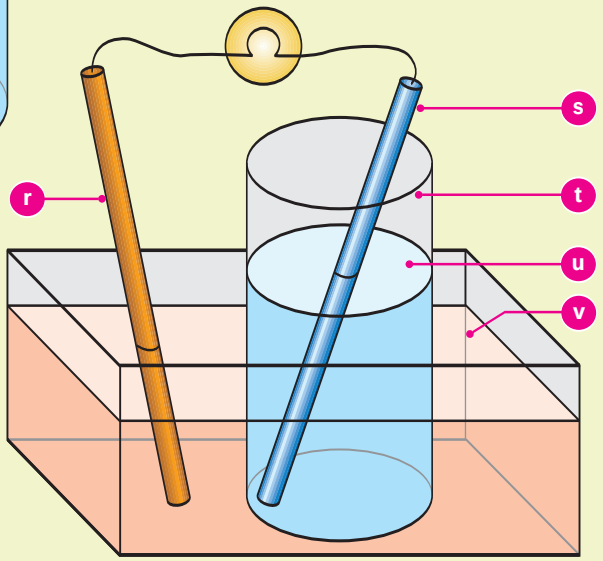

Method 2
r copper rod
s zinc rod
t porous vessel
u dilute sulfuric acid
v copper sulfate solution

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Electrolysis

1 Electrolysis: schematic

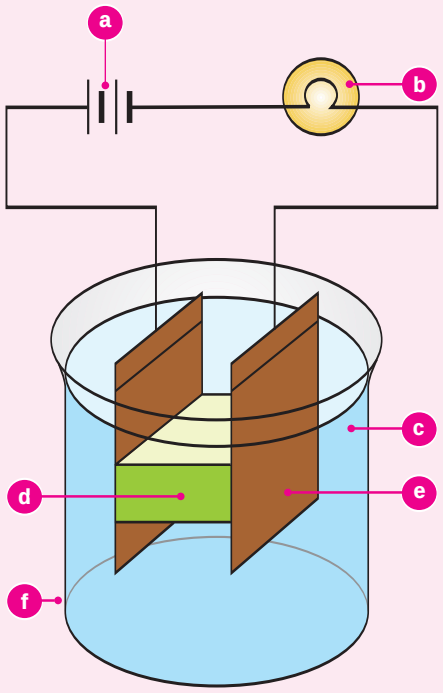

2 Electrolysis of salt solutions

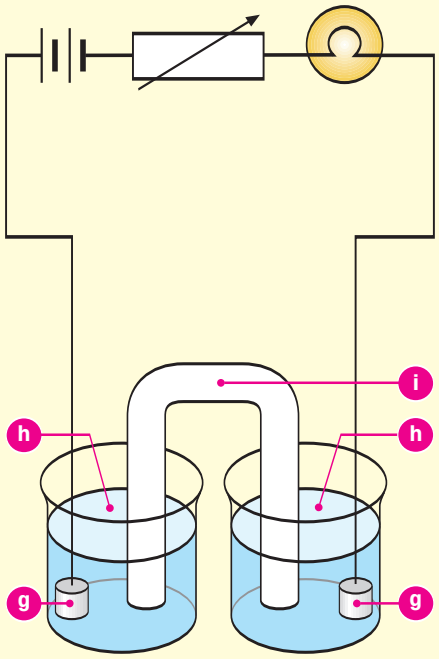

3 Electrolysis of water

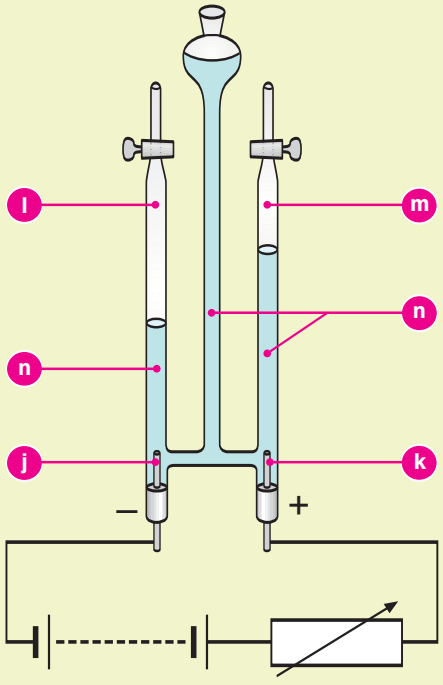

4 U tube

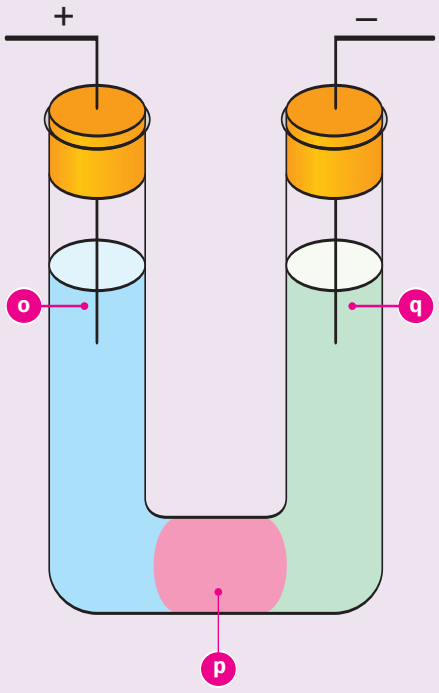

a battery
b electric bulb
c liquid under test
d poly(ethene) support
e copper plates
f glass vessel
g platinum electrodes
h electrolyte solution in beakers
i salt bridge
j platinum cathode
k platinum anode
l hydrogen
m oxygen
n water acidified with dilute sulfuric acid
o dilute sulfuric acid
p agar jelly colored pink by phenolphthalein and alkali
q sodium sulfate solution

Key words

anion
anode
cathode
cation
electrode
electrolysis
electrolyte

1 Electrolysis

- *Electrolysis* is the process by which an *electrolyte* (a substance that conducts electricity) is decomposed when a direct current is passed through it between *electrodes*. Positive *cations* move to the *cathode* to gain electrons; negative *anions* move to the *anode* to lose electrons.
- Substances are either deposited or liberated at the electrodes depending on the nature of the electrodes and electrolyte.

2 Salt solutions

- Two electrolytes undergo electrolysis at the same time when they are connected in a circuit by a salt bridge.
- The platinum electrode in the left-hand beaker is the anode and attracts negative ions, which are oxidized.
- The platinum electrode in the right-hand beaker is the cathode and attracts positive ions, which are reduced.

3 Water

- The electrolysis of water yields hydrogen at the cathode and oxygen at the anode. Hydrogen and oxygen are formed in the ratio of 2:1.

4 U tube

- The ions present in dilute sulfuric acid are H^+, OH^-, and SO_4^{2-}. Hydroxide ions are discharged at the anode, leaving a surplus of hydrogen ions, so the electrolyte in the left side of the U tube becomes increasingly acidic.
- The ions present in sodium sulfate solution are H^+, Na^+, OH^-, and SO_4^{2-}. Hydrogen ions are discharged at the cathode, leaving a surplus of hydroxide ions, so the electrolyte in the right side of the U tube becomes increasingly alkaline.

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Key words

anode
cathode
electrode
electrolysis
inert

Electrode activity and concentration

- The results of *electrolysis* differ depending on the concentration of the solution and type of *electrodes* used.
- *Inert* electrodes take no part in the reaction; active electrodes take part in the reaction.

1 Dilute solution

- Reaction at the *anode*: oxygen produced
- Reaction at the *cathode*: hydrogen produced

2 Concentrated solution

- Reaction at the anode: chlorine produced
- Reaction at the cathode: hydrogen produced

3 Inert electrodes

- The following reactions occur at the electrodes when copper(II) sulfate undergoes electrolysis using carbon (inert) electrodes.
- Reaction at the anode: oxygen is produced
- Reaction at the cathode: copper metal is deposited on the cathode.

4 Active electrodes

- The following reactions occur at the electrodes when copper(II) sulfate undergoes electrolysis using copper (active) electrodes.
- Reaction at the anode: copper goes into solution as copper ions, and the anode grows smaller.
- Reaction at the cathode: copper metal is deposited, and the cathode grows bigger.

Electrolysis: electrode activity and concentration

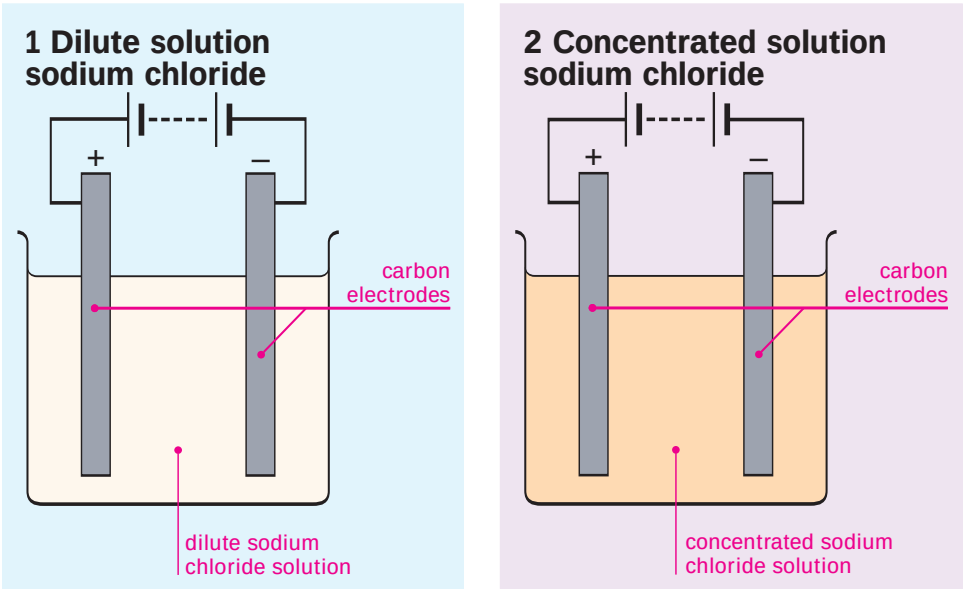

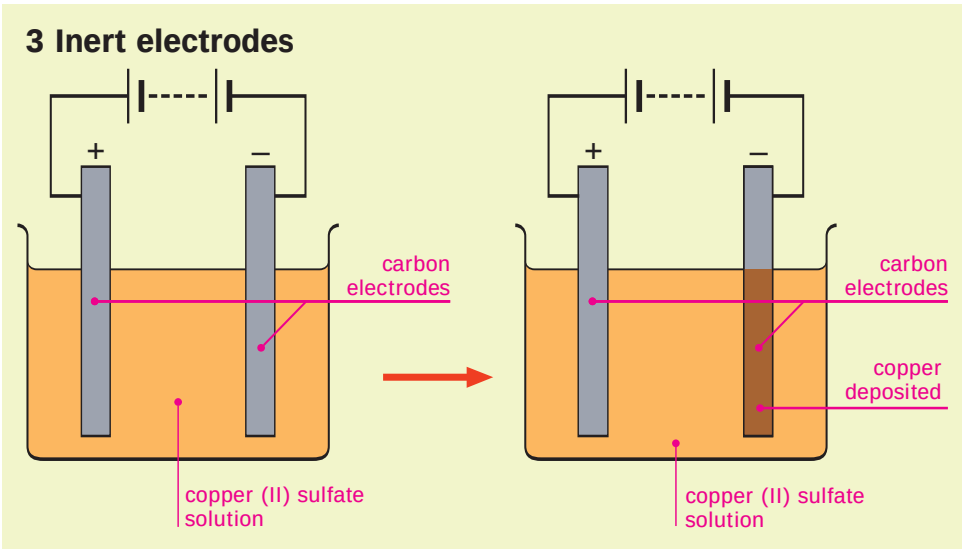

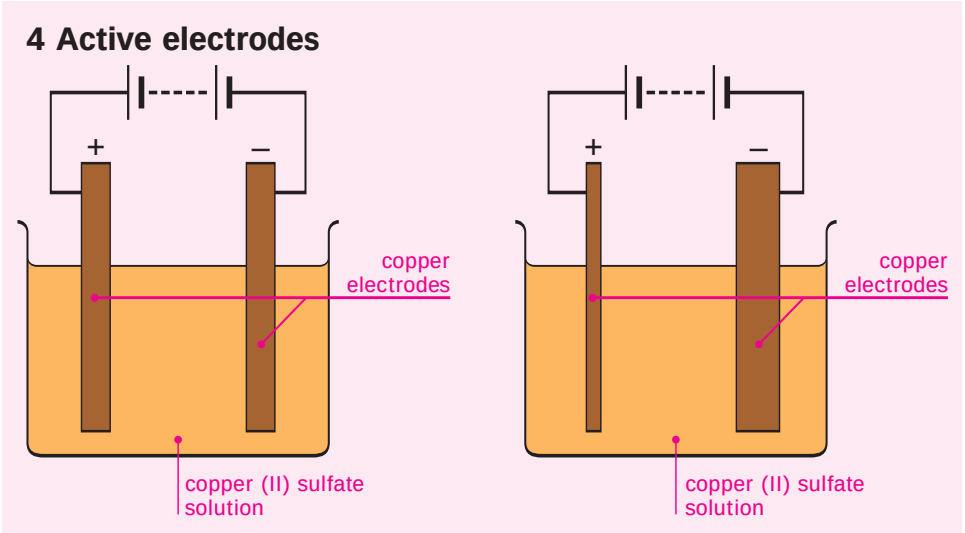

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Acids: reactions

1 Main reactions of an acid

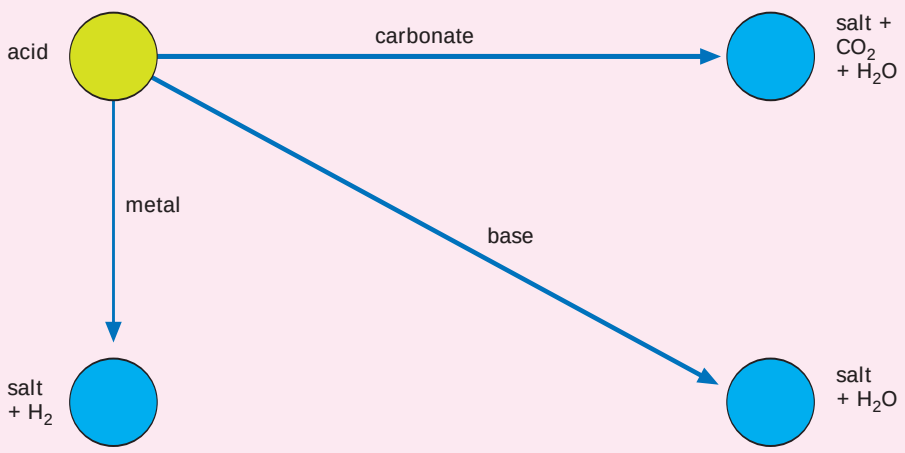

2 Examples of reaction type

Acid with carbonate	$Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$
Acid with base	$HCl(aq) + NaOH(s) \rightarrow NaCl(s) + H_2O(l)$
Acid with metal	$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
Acid neutralized by oxide	$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

3 Laboratory preparation of sulfur trioxide

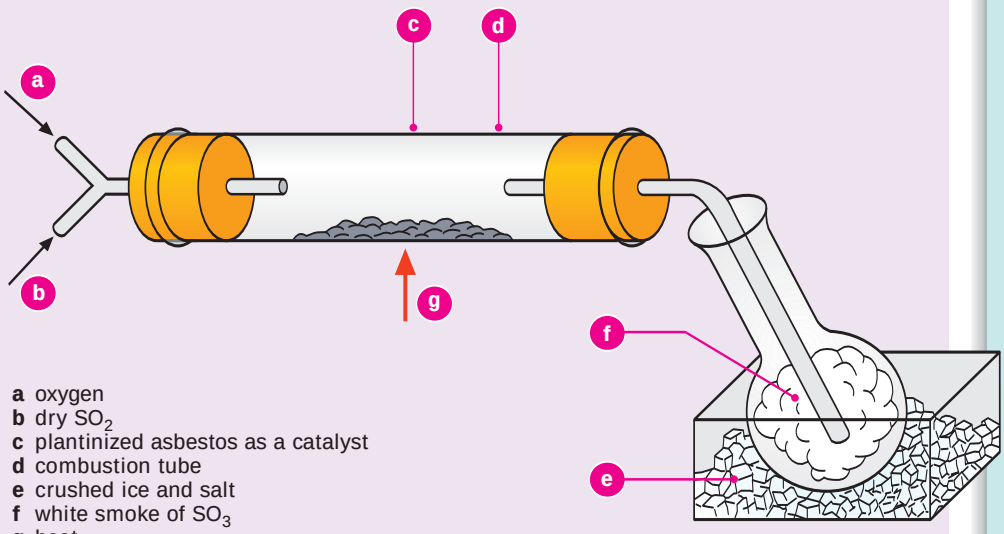

a oxygen
b dry SO_2
c plantinized asbestos as a catalyst
d combustion tube
e crushed ice and salt
f white smoke of SO_3
g heat

Key words

acid
base
carbonate
catalyst
hydroxide
oxidation
oxide
salt

1 Main reactions of an acid

- Dilute *acids* react with all metal *carbonates* to give a metal *salt*, carbon dioxide, and water.
- Dilute acids react with *bases* to give salts plus water.
- Dilute acids react with most metals to give a metal salt and hydrogen.
- Dilute acids are neutralized by metal *oxides* and metal *hydroxides* to form a metal salt and water.

2 Example of reaction type

- Sodium carbonate reacts with dilute nitric acid to give sodium nitrate, carbon dioxide, and water.
- Hydrochloric acid reacts with sodium hydroxide to form a salt and water.
- Zinc reacts with dilute hydrochloric acid to give zinc chloride and hydrogen.
- Copper(II) oxide reacts with dilute sulfuric acid to give copper(II) sulfate and water.

3 Sulfur trioxide

- Sulfur trioxide is a white crystalline solid obtained by *oxidation* of sulfur dioxide. It dissolves in water with a hissing noise and the production of heat, forming sulfuric acid. Sulfur trioxide is employed as a dehydrating agent.
- Sulfur trioxide is made in the laboratory by passing a mixture of dry sulfur dioxide and dry oxygen over a heated platinum *catalyst*. Sulfur trioxide melts at 17°C and condenses as a solid in a suitably cooled beaker.
- Industrially it is made using the contact process (see pages 75 & 76).

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Key words

hydrochloric acid *sulfuric acid*
hydrogen chloride
nitric acid
soluble

1 Preparing HCl gas

- *Hydrogen chloride* gas is made by the reaction of sodium chloride and concentrated sulfuric acid:
  $2NaCl(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HCl(g)$

The gas is more dense than air and is collected by downward delivery.

2 Preparing HCl acid

- Hydrogen chloride is extremely *soluble* in water, forming *hydrochloric acid*. It cannot be dissolved simply by placing a delivery tube carrying the gas directly into water because the water would be sucked back into the reaction vessel.
- The gas is dissolved in water by passing it into an inverted funnel positioned so the lip is just under the surface of the water. The funnel prevents suck back.

3 Preparing nitric acid

- *Nitric acid* can be made by the reaction of solid sodium or potassium nitrate with concentrated *sulfuric acid*:
  $KNO_3(s) + H_2SO_4(aq) \rightarrow KHSO_4(aq) + HNO_3$
- The product of this reaction is normally yellow due to the presence of nitrogen dioxide, formed by the thermal decomposition of the acid:
  $4HNO_3(l) \rightarrow 4NO_2(g) + 2H_2O(g) + O_2(g)$

4 Industrial preparation of HNO_3

- Nitric acid is made industrially by the oxidation of ammonia in a process involving three stages (see page 76): production of nitrogen oxide gas, oxidation of nitrogen oxide to nitrogen dioxide gas, reaction of nitrogen dioxide and water.
- This process can be modeled in the laboratory by passing ammonia vapor over a heated platinum catalyst.

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Preparation of acids

1 Preparation of hydrogen chloride (gas)

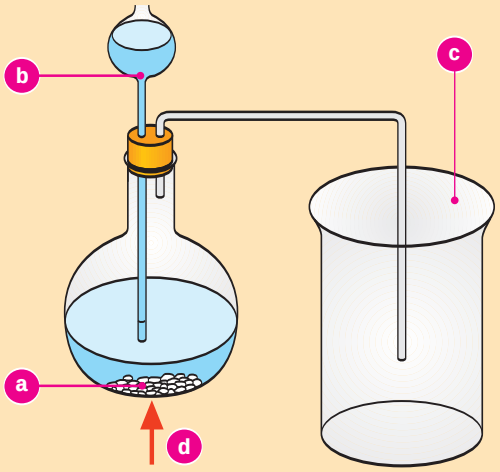

a rock salt
b concentrated sulfuric acid
c HCl gas collected
d heat

2 Preparation of hydrochloric acid

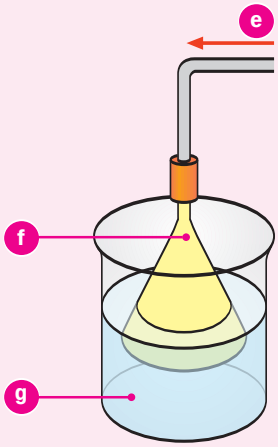

e HCl filter
f filter funnel
g water (to become dilute HCl acid)

3 Laboratory preparation of nitric acid

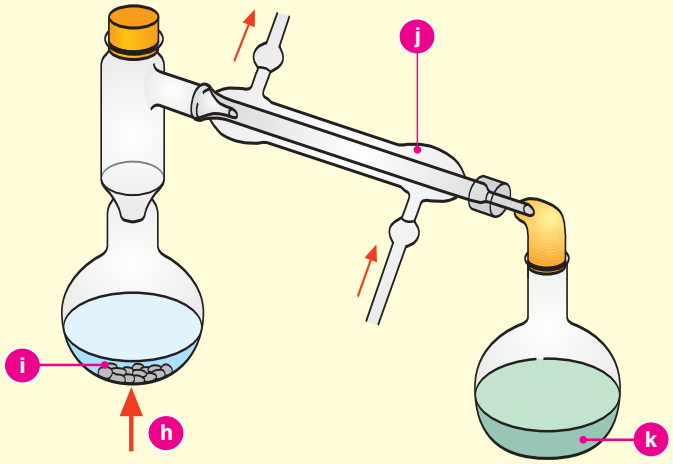

h heat
i solid sodium nitrate plus concentrated sulfuric acid
j water jacket
k pure nitric acid

4 Industrial preparation of nitric acid

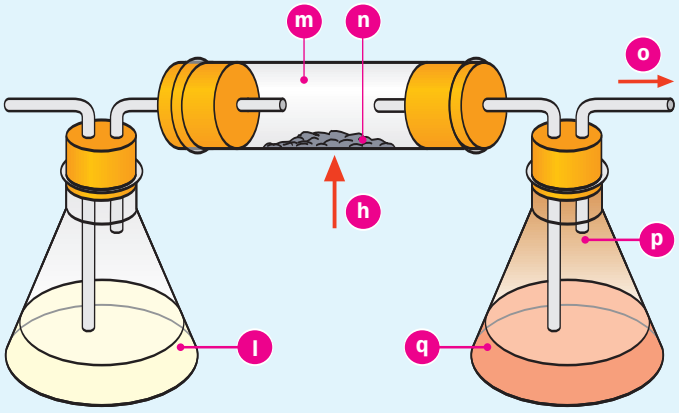

l concentrated ammonia diluted with water (50%)
m combustion tube
n platinized asbestos
o pump sucks gases through apparatus
p brown gas
q litmus goes red

Bases: reactions

1 General reactions of a base with an acid

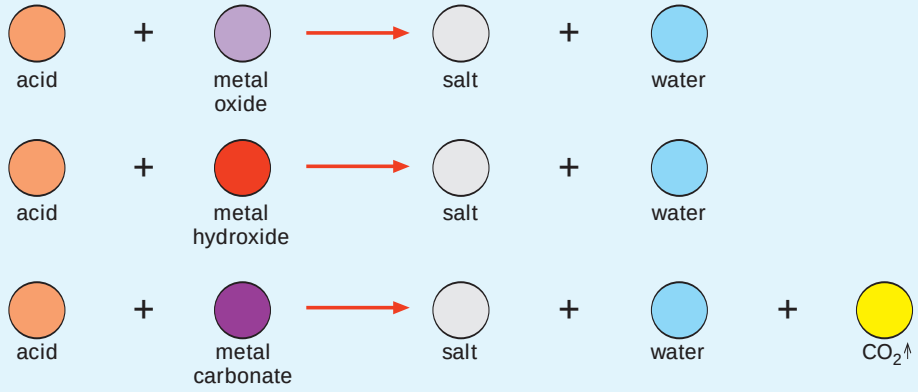

2 Metal oxide and acid

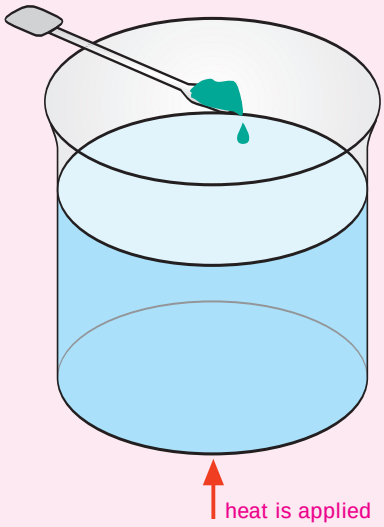

Magnesium oxide is added to hydrochloric acid and indicator

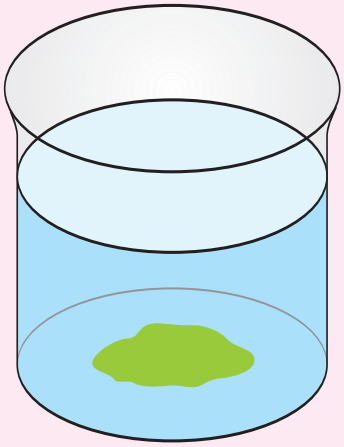

Neutral solution, indicator is green

3 Carbonate and acid

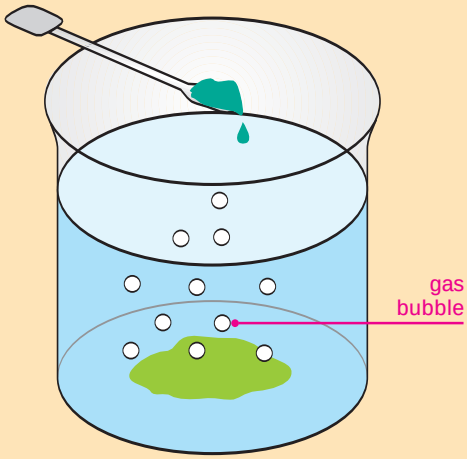

Cabonate is added to hydrochloric acid and indicator

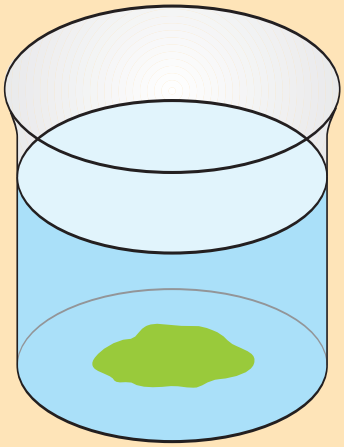

Neutral solution, indicator is green

Key words

acid
base
carbonate
hydroxide
oxide
salt
universal indicator

Bases

- A *base* is a compound that reacts with an *acid* to form a *salt*. Common bases are metal *oxides*, metal *hydroxides*, and metal *carbonates*.

1 General reactions with acids

- Metal oxides react with acids to form salts and water.
- Metal hydroxides also react with acids to form salts and water.
- Metal carbonates react with acids to form salts, water, and carbon dioxide.

2 Metal oxide and acid

- The reaction of magnesium oxide (MgO) with hydrochloric acid (HCl) can be followed by adding a few drops of *universal indicator* to the acid.
- Initially the indicator is red. When magnesium oxide is added to the reaction, the following reaction occurs:
  $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$
- When there are equivalent amounts of magnesium oxide and hydrochloric acid, the indicator turns green, signifying all of the acid has reacted and the mixture is neutral.

3 Carbonate and acid

- The reaction of magnesium carbonate ($MgCO_3$) with hydrochloric acid (HCl) can be followed by observing the carbon dioxide gas evolved.
- Initially bubbles of gas are evolved as the following reaction occurs:
  $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$
- When all of the hydrochloric acid has reacted, no gas is produced, and excess insoluble magnesium carbonate remains in the beaker.

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Bases: forming pure salts

Key words

acid
base
indicator
insoluble
neutral
salt
soluble
titration

1 From a soluble base

- *Titration* is used to make *salts* from *acids* and *soluble bases*, e.g., sodium chloride from hydrochloric acid and sodium hydroxide.
- The burette is filled with hydrochloric acid, and a known volume of sodium hydroxide solution is placed in a conical flask. A few drops of a suitable *indicator* are added to the sodium hydroxide solution. Hydrochloric acid is run into the flask until the color of the indicator changes, showing that the reaction mixture is *neutral*. The volume of hydrochloric acid in the burette is noted before and after addition so the volume of acid needed can be calculated.
- The flask contains a solution of sodium chloride, which is impure due to the presence of the indicator. The procedure must be repeated using exactly the same volumes of hydrochloric acid and sodium hydroxide solution but no indicator.
- Sodium chloride crystals are obtained by boiling off some of the water from the sodium chloride solution and allowing the remaining solution to cool.

2 From an insoluble base

- Salts are made from *insoluble* bases by adding an excess of the base to an acid. For example, copper(II) sulfate is formed by the reaction of copper(II) oxide and sulfuric acid.
- An excess of copper(II) oxide is used to ensure that all of the sulfuric acid has reacted and no acid residue remains. The excess is filtered off, leaving a blue solution of copper(II) sulfate.
- Copper(II) sulfate crystals are obtained by boiling off some of the water from the copper(II) sulfate solution and allowing the remaining solution to cool.

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1 From a soluble base (alkali)

Example: sodium chloride from sodium hydroxide and hydrochloric acid

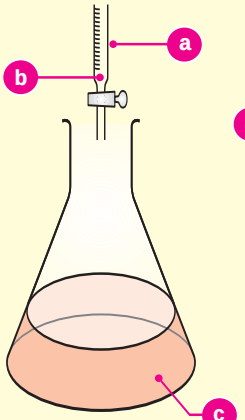

Set up the apparatus as shown

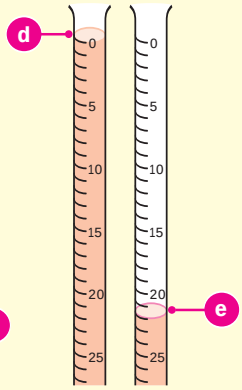

Measure the volume of acid needed for neutralization (e–d)

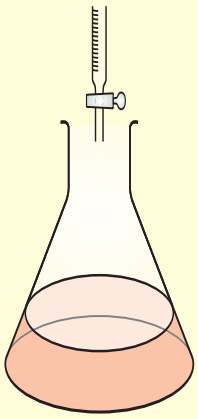

Repeat the procedure, but without using the indicator, adding the amount of acid measured above (i.e., e–d)

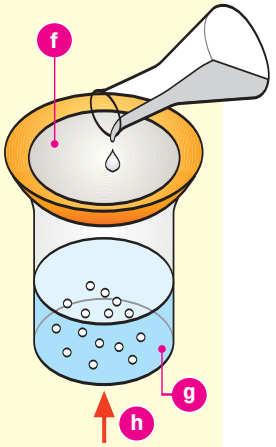

Evaporate off excess water

2 From an insoluble base

Example: copper oxide and sulfuric acid

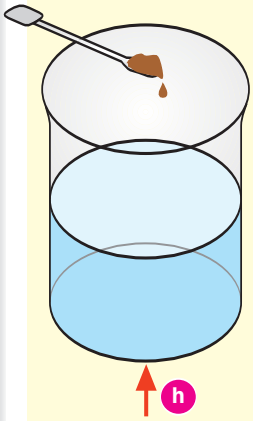

Add the base to dilute acid

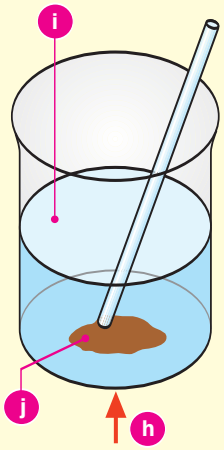

Warm gently, adding the base until no more will dissolve

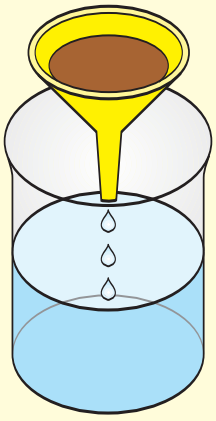

Filter off excess solid and collect the filtrate

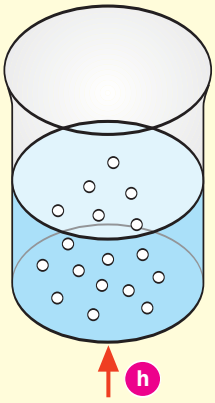

Evaporate off filtrate

a burette
b acid
c alkali and phenolphthalein indicator
Add the acid until the solution just turns colorless.
d volume of acid in the burette before carrying out the procedure
e volume of acid remaining when the indicator has turned colorless
f salt solution
g boiling water
h heat
i neutralized acid
j excess solid

Proton transfer: neutralization of alkalis

1 Water particles

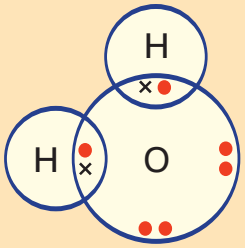

Neutral water molecule

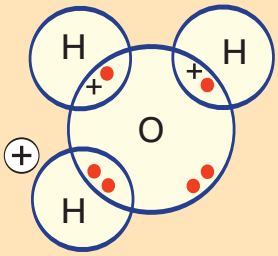

Hydronium ion: protonated water molecule

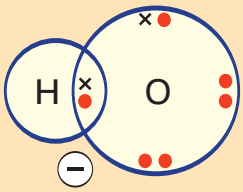

Hydroxide ion: deprotonated water molecule

2 Ammonia solution turns universal indicator blue

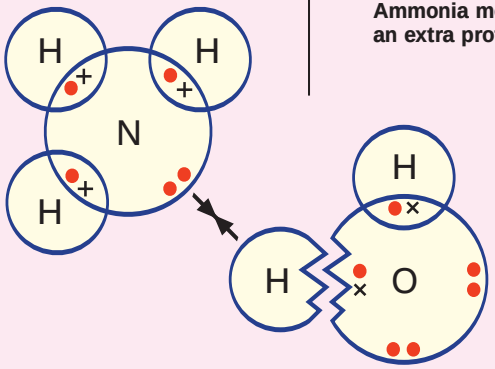

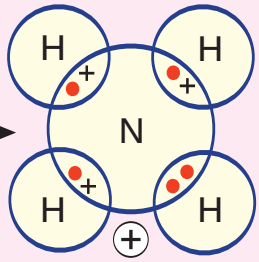

Ammonia molecule has an extra proton

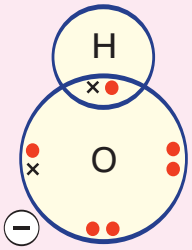

To show the extra-electron in the hydroxide ion

To show the attraction between the molecules and the breaking of the bond in the molecule

3 Schematic of proton transfer in diagram 2

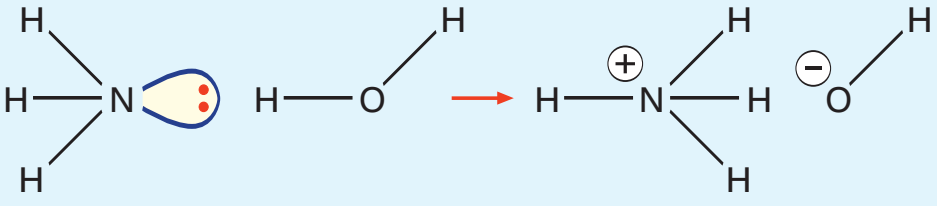

molecules ions

Key words

ammonium hydroxide
ammonium ion
hydronium ion
hydroxide ion
proton
species

1 Water particles

- In a water molecule, the oxygen atom forms bonds with two hydrogen atoms. The oxygen atom and the hydrogen atom each donate one electron to the bond. The oxygen atom also has two pairs of non-bonding electrons, which can be donated to form bonds with other *species*.
- In acidic solutions, each proton reacts with a water molecule to form a *hydronium ion*. A pair of non-bonding electrons forms the new H-O bond: $H^+ + H_2O \rightarrow H_3O^+$
- An *hydroxide ion* is formed by the loss of a *proton* from a water molecule: $H_2O \rightleftharpoons H^+ + OH^-$

2 Ammonium ions

- The ammonia molecule, NH_3, has a similar structure to the water molecule, H_2O, in the sense that the nitrogen atom has a pair of non-bonding electrons that it can donate to form a bond with another species.
- Ammonia reacts with the protons in an acid to form the *ammonium ions*: $NH_3 + H^+ \rightarrow NH_4^+$
- The four N-H bonds in the ammonium ion are directed toward the corners of a tetrahedron, giving a similar structure to methane. This keeps the bonding pairs of electrons as far away from each other as possible.

3 Schematic of proton transfer

- Ammonia is very soluble in water and dissolves to form a weak alkaline solution that is sometimes referred to as *ammonium hydroxide*: $NH_3 + H_2O \rightleftharpoons NH_4OH \rightleftharpoons NH_4^+ + OH^-$
- Ammonia solution contains ammonium ions, NH_4^+, and hydroxide ions, OH^-, and has similar reactions to solutions of soluble metal hydroxides, such as sodium hydroxide.

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Key words

acid	*magnesium oxide*
base	*oxide*
hydronium ion	*proton*
lattice	*salt*

Neutralizing bases

- Metallic *bases* neutralize *acids* to form a *salt* plus water.

1 MgO in acid

- *Magnesium oxide* consists of a regular *lattice* of magnesium ions, Mg^{2+}, and *oxide* ions, O^{2-}.
- An acid contains *hydronium ions*, H_3O^+.

2 Attractions

- Hydronium ions carry a positive charge, while oxide ions carry a negative charge. When solid magnesium oxide is added to an acid, these oppositely charged ions are attracted to each other.

3 Transfer

- In an oxide ion, there are eight electrons in the outer orbital of the oxygen atom. Two pairs of electrons are donated to form bonds with oppositely charged hydronium ions:

$2H_3O^+ + O^{2-} \rightarrow 3H_2O$

4 Neutral solution

- Each hydronium ion transfers a *proton* to the oxide ion, forming a molecule of water.
- The magnesium oxide lattice breaks down, releasing magnesium ions into solution.
- The acid is neutralized, and a solution of a magnesium salt is formed. The nature of the salt depends on the acid used.

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$

Hydrochloric acid → magnesium chloride

$MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$

Nitric acid → magnesium nitrate

$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$

Sulfuric acid → magnesium sulfate

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Proton transfer: neutralization of bases

1 Magnesium oxide (MgO) solid and dilute acid

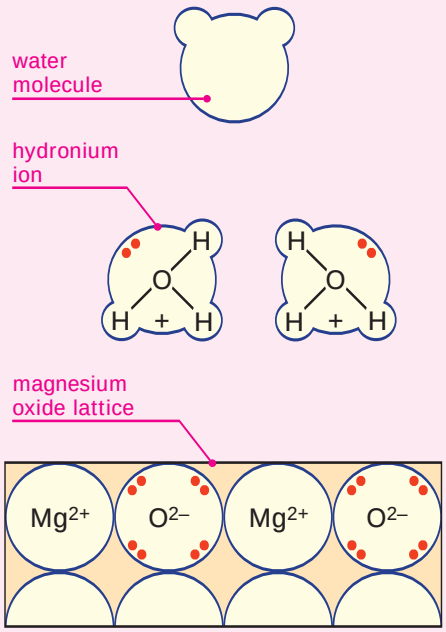

2 The oxide ions attract the hydronium ions

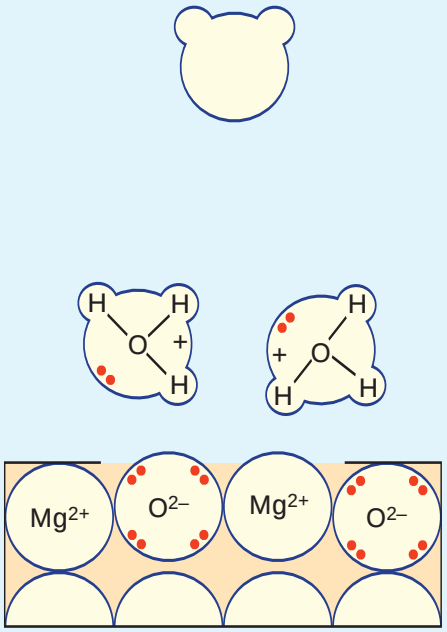

3 Proton transfer takes place

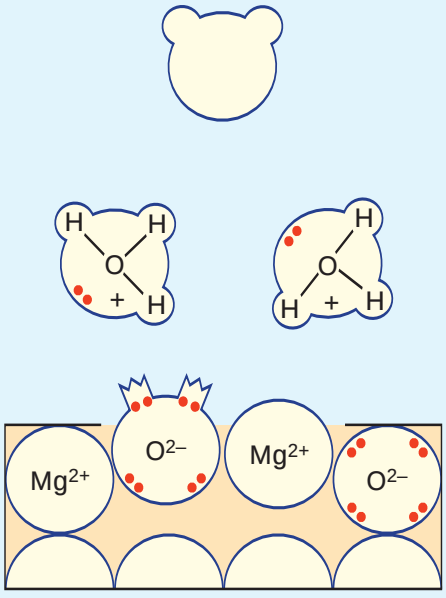

4 A neutral solution is produced and part of the oxide lattice has dissolved

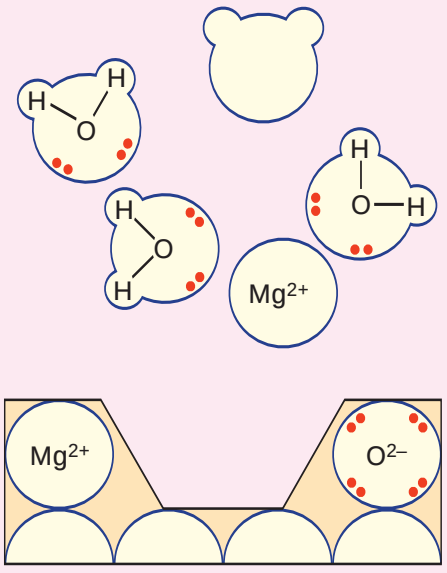

Proton transfer: metallic carbonates

1 Carbonate ions attract hydronium ions

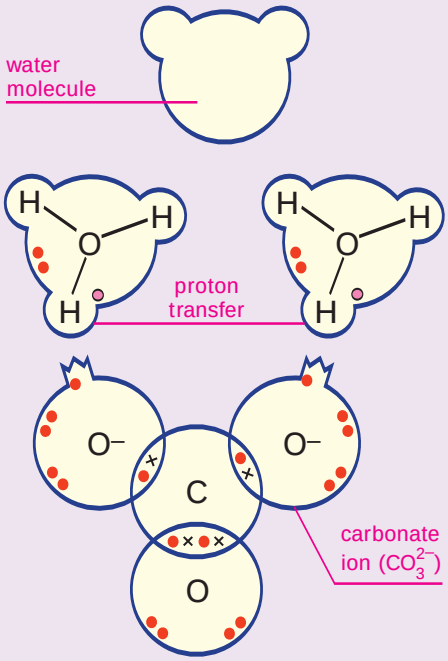

2 Hydrogen carbonate molecules and water molecules are produced

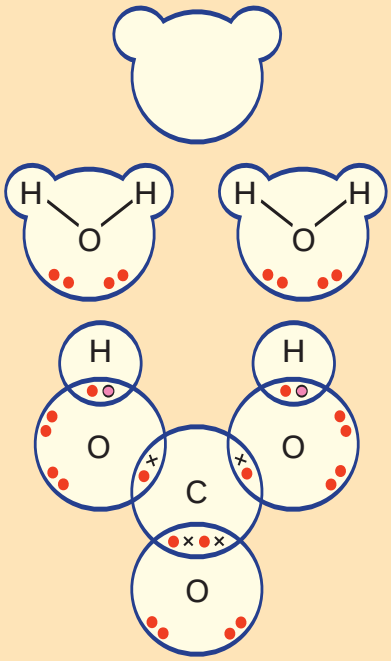

3 A hydrogen carbonate molecule splits

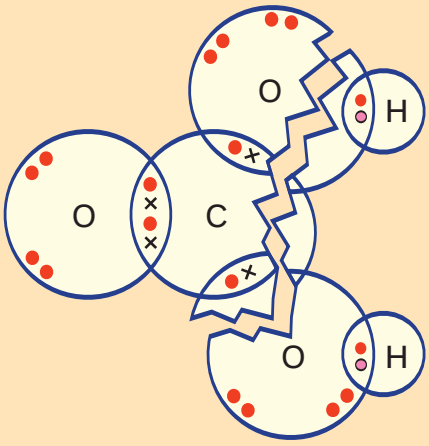

4 A carbon dioxide molecule and water molecule are produced

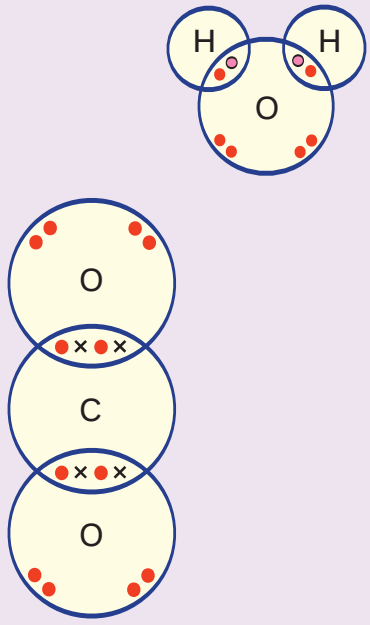

Key words

carbonate
carbonic acid
hydronium ion
orbital
salt

Metallic carbonates

- Metallic *carbonates* neutralize acids to form a metal *salt*, carbon dioxide, and water.

1 Attraction

- Group 1 metal carbonates are soluble in water and can be used as solids or in solution. Other metal carbonates are insoluble in water and are used as solids.
- All metal carbonates contain the carbonate ion, CO_3^{2-}. All acids contain the *hydronium ion*, H_3O^+.
- Hydronium ions carry a positive charge, while carbonate ions carry a negative charge. When a carbonate is added to an acid, these oppositely charged ions are attracted to each other.
- In a carbonate ion, each of the three oxygen atoms has eight electrons in its outer *orbital*. A pair of electrons is donated from two of the oxygen atoms to form bonds with oppositely charged hydronium ions.

2 H_2CO_3 and water

- The result is the formation of *carbonic acid*, H_2CO_3, and water:
  $2H_3O^+ + CO_3^{2-} \rightarrow H_2CO_3 + 2H_2O$

3 H_2CO_3 splits

- Carbonic acid is a weak acid that only exists in solution. It readily breaks down to carbon dioxide and water:
  $H_2CO_3 \rightleftharpoons H_2O + CO_2$

4 CO_2 and water

- In an acid–carbonate reaction, some of the carbon dioxide will remain in solution, but most will be given off as bubbles of gas.
- The gas can be identified by bubbling it into limewater. Carbon dioxide turns limewater milky due to the formation of insoluble calcium carbonate.
- The acid is neutralized by the carbonate, and a salt is formed. The nature of the salt depends on the metal carbonate and the acid used.

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Key words

ammonia *hydrogen*
covalent bond *chloride*

Neutralizing acids

- Bases react with acids to produce a salt and water.

1 Molecules

- A chlorine atom has seven electrons in its outer orbit. In *hydrogen chloride*, the chlorine atom forms a *covalent bond* with one hydrogen atom, forming the molecule HCl.
- An oxygen atom has six electrons in its outer orbit. In hydrogen oxide (water), the oxygen atom forms covalent bonds with two hydrogen atoms, forming the molecule H_2O.
- A nitrogen atom has five electrons in its outer orbit. In *ammonia*, the nitrogen atom forms covalent bonds with three hydrogen atoms, forming the molecule NH_3.

2 Schematic

- In a hydrogen chloride molecule, each chlorine atom is surrounded by eight electrons: one pair of bonding electrons and three pairs of non-bonding electrons (lone pairs).
- In a water molecule, each oxygen atom is surrounded by eight electrons: two pairs of bonding electrons and two lone pairs of electrons.
- In an ammonia molecule, each nitrogen atom is surrounded by eight electrons: three pairs of bonding electrons and one pair lone pair of electrons.

3 & 4 Proton transfer and schematic

- Hydrogen chloride gas is a covalent compound and exists as diatomic molecules.
- When hydrogen chloride dissolves in water, an acidic solution is formed: $H_2O + HCl \rightarrow H_3O^+ + Cl^-$
- A lone pair of electrons from an oxygen atom is donated to create a covalent bond between the oxygen atom and a hydrogen atom, forming a hydronium ion and a chloride ion.
- When hydrogen chloride is dissolved in water, it forms an ionic compound.

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Proton transfer: neutralization of acids

1 Examples of molecules

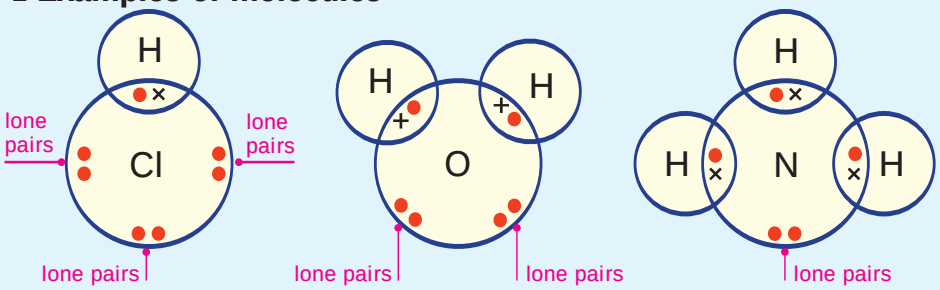

Hydrogen chloride molecule | Water molecule | Ammonia molecule

2 Schematic of the molecules shown in diagram 1

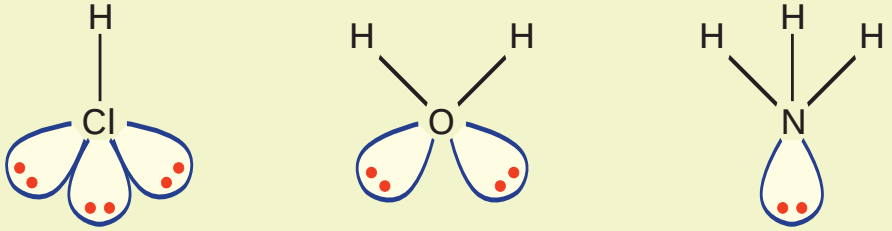

Hydrogen chloride molecule | Water molecule | Ammonia molecule

3 Proton transfer

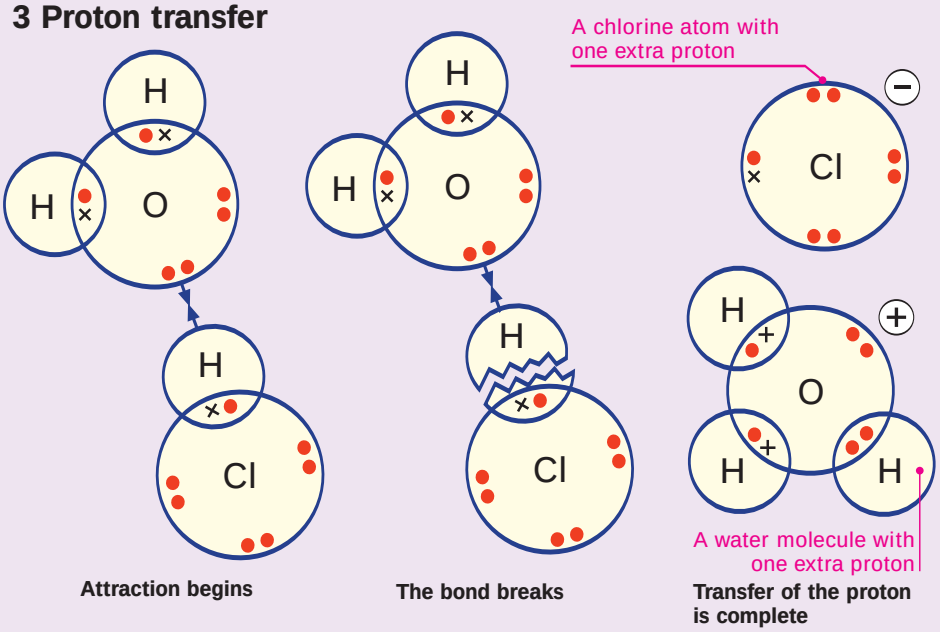

Attraction begins | The bond breaks | Transfer of the proton is complete

4 Schematic of proton transfer

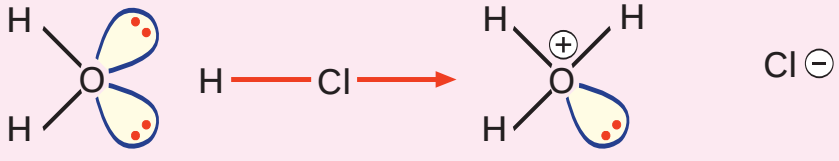

Collision theory

1 Collision theory

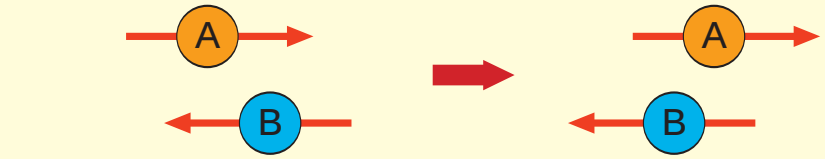

No collision between the particles of the reactants: no reaction

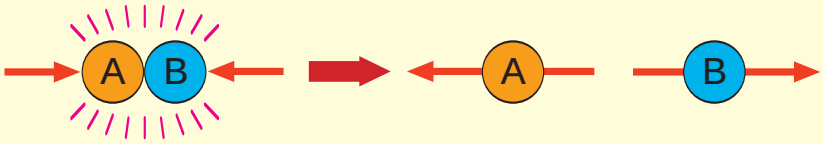

Weak collision: no reaction

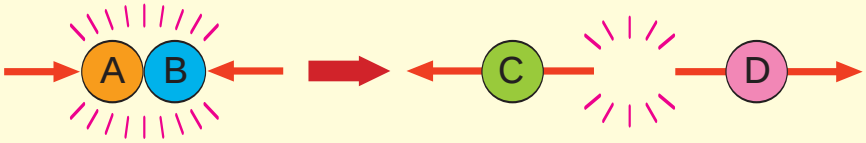

Effective collision: reaction

2 Maxwell-Boltzman distribution

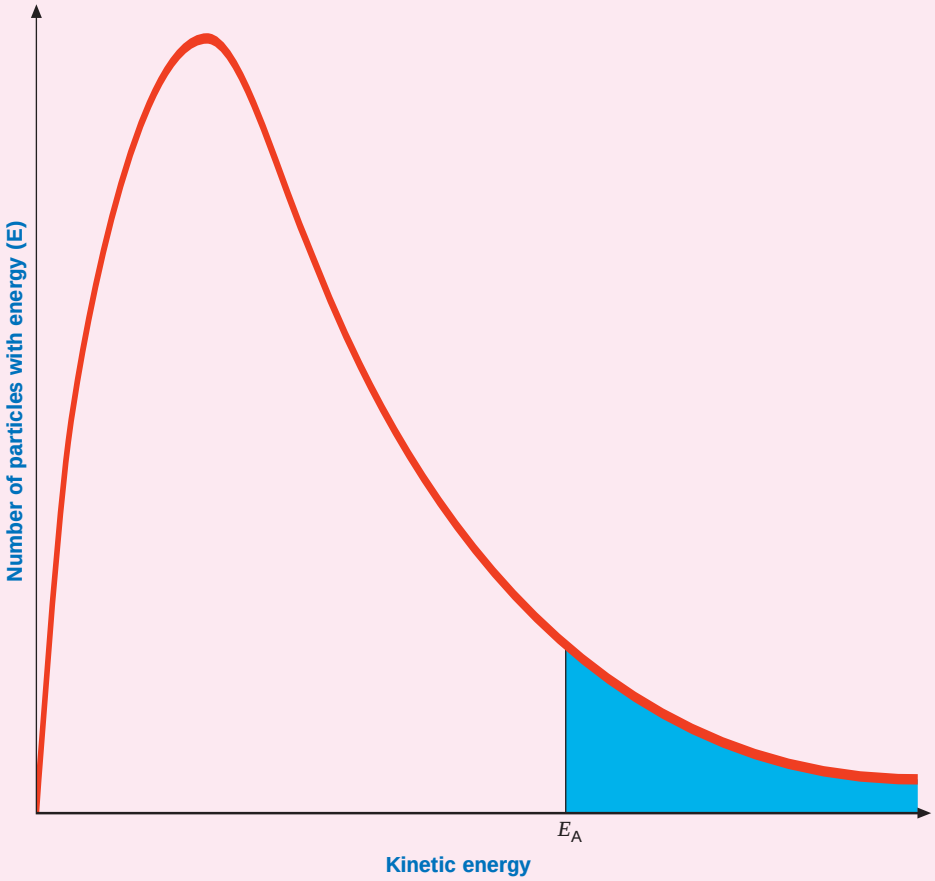

Key words

activation energy
effective collision
product
reactant

1 Collision theory

- Reactions occur when particles collide with sufficient force to provide the energy needed to start a reaction.
- If particles collide with insufficient force to start a reaction, they simply bounce off each other.
- A collision that brings about a reaction is called an *effective collision*. Particles of *reactant* collide, and particles of *product* are formed:

$$\underbrace{A + B}_{\text{reactants}} \rightarrow \underbrace{C + D}_{\text{products}}$$

- Not every collision between particles gives rise to a reaction, but every set of particles that do react have to collide.

2 Maxwell-Boltzman distribution

- Because all the particles of a particular chemical, element, or compound have the same mass, the energy of the particles is directly related to their speed.
- In any mixture of moving particles, the energy at which an individual particle is moving will vary.
- The Maxwell-Boltzman distribution shows how the number of particles in a sample is distributed at different energies at a particular temperature.
- There are no particles at zero energy. There are relatively few particles at very high energy, but there is no maximum energy value.
- In order to react, particles need to have a minimum amount of energy, called *activation energy*. The activation energy is marked on the graph by a line, parallel to the Y axis, at a point on the X axis that symbolizes the activation energy (E_A).

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Key words

diffusion
immiscible
reactant
surface area

Surface area

- In order for a reaction to take place, the *reactants* must come into contact with each other. Thus, for a given mass of reactant, the smaller the objects, the greater the *surface area* on which the chemical reaction can occur. If all of the reactants are gases or liquids, it is easy for them to mix, giving the maximum opportunity for the particles to collide.

1 Total surface area

- The reaction can only take place on the surface of the solid.
- A cube with sides 2 cm has a total surface area of 2 x 2 x 6 = 24 cm^2. If the same cube is divided into 8 cubes with sides 1 cm, the total surface area now becomes 1 x 1 x 6 x 8 = 48 cm^2.

2 Reduced surface area

- Zinc reacts with dilute hydrochloric acid to form zinc chloride and hydrogen gas:
  $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
- This reaction proceeds much more quickly if zinc dust (fine powder) is used rather than granulated zinc (large lumps).

3 Mixing

- When reactant particles are added together, they will eventually mix by *diffusion*, and a reaction will take place.
- Stirring reactants speeds the process of mixing so the reaction takes place more quickly.

4 Interface surface area

- If one of the reactants is a liquid and one a gas, or if the two reactants are *immiscible* liquids, then the reaction can only take place at the interface. The larger the surface area of the interface, the faster the reaction will take place.

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Rates of reaction: surface area and mixing

1 Total suface area

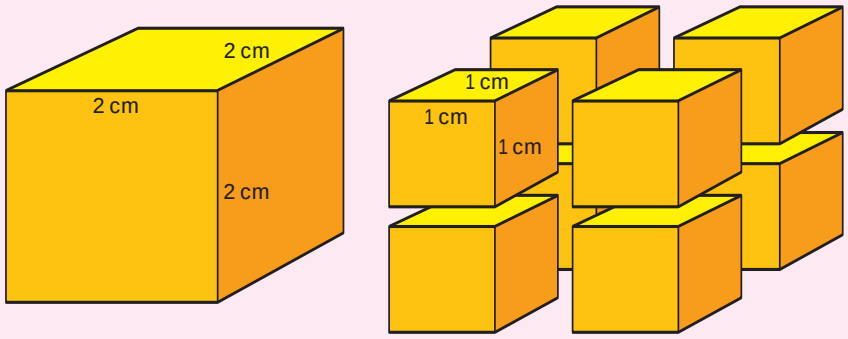

2 Reduced surface area reaction

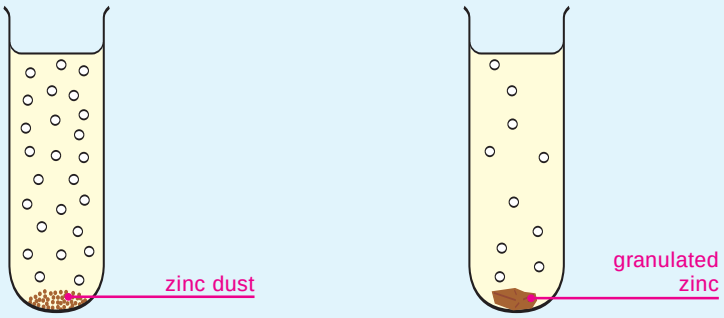

3 Mixing

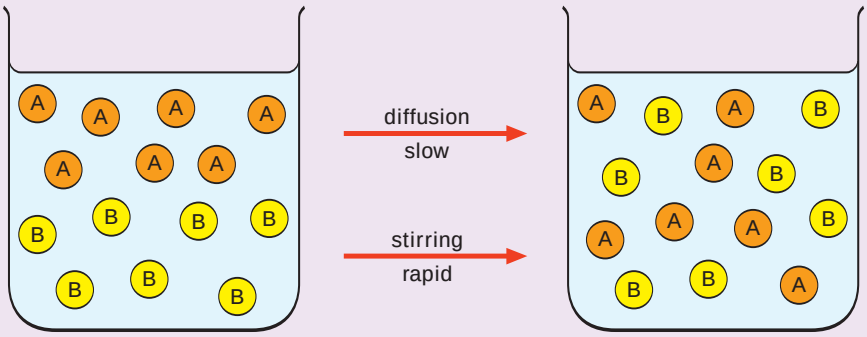

4 Interface surface area

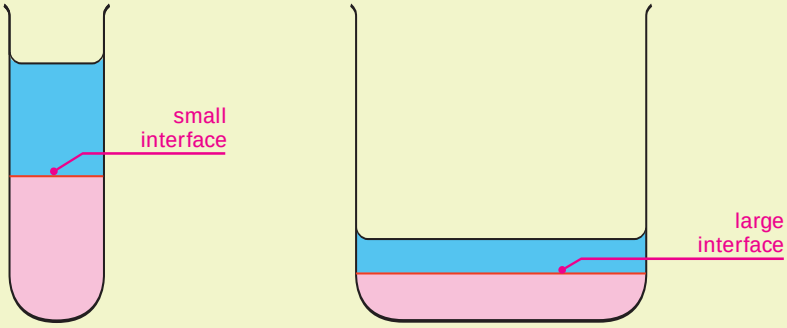

Rates of reaction: temperature and concentration

Key words

activation energy
product
reactant

1 Temperature

- Temperature is an important factor in determining rate of reaction.
- When temperature increases, the average speed of the particles in a substance increases. The graph shows the Maxwell-Boltzman distribution at two temperatures, T_2 is greater than T_1.
- The number of particles is constant, so the area under the two curves is the same. However, the average energy of the particles at T_2 is greater. The area of the curve to the right of the *activation energy* line (E_A) is greater for T_2. Therefore, at this temperature a higher proportion of particles have sufficient energy to react.

2 Concentration

- An increase in the concentration of a chemical, or the pressure of a gas, means that there will be more particles within a given space, so particles will collide more often.

3 Rate of reaction

- The rate of any reaction is the speed at which the *reactants* are converted to *products*. This can be qualified as the change of concentration of reactants or products.
- Changes in concentration can be measured by:
  1. appearance or disappearance of color in reactants or products
  2. volume of gas evolved
  3. changes in pH
  4. heat produced
  5. changes in pressure.

1 Temperature (distribution of molecular energies at T_1 and T_2)

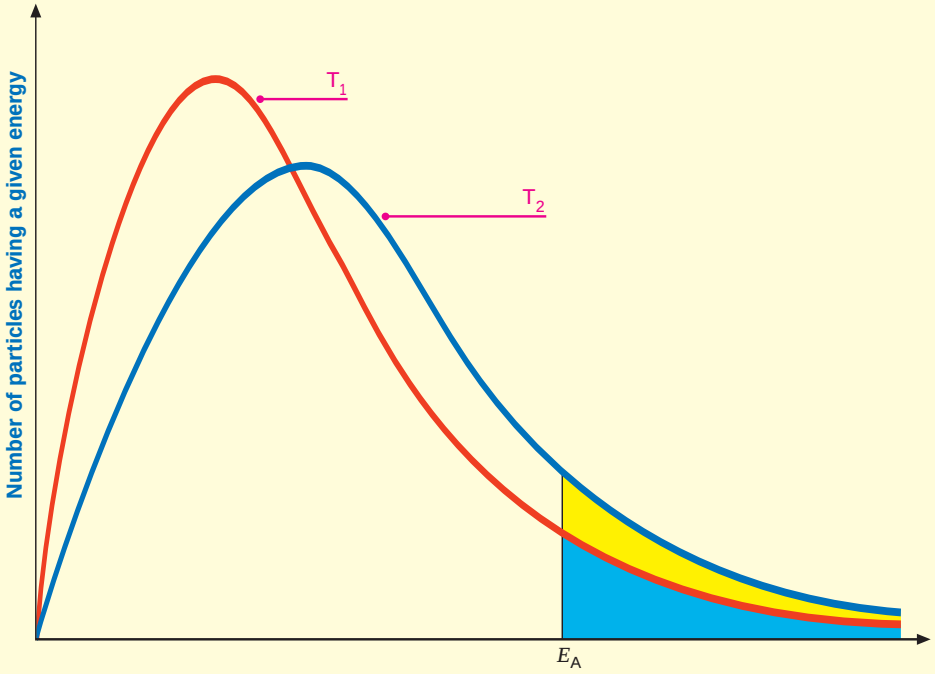

2 Concentration

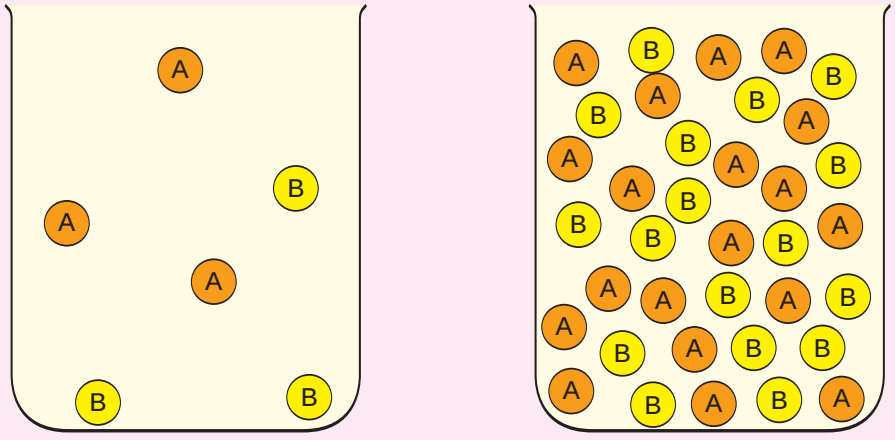

3 Rate of reaction

$$\text{Rate of reaction} = \frac{\text{Change in concentration}}{\text{Time}}$$

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Key words

concentration
rate of reaction

Rates of reaction: concentration over time

Concentration over time

- Bromine reacts with an excess of methanoic acid in aqueous solution according to the following equation. The reaction is catalyzed by acid:

$$Br_2(aq) + HCOOH(aq) \xrightarrow{H^+} 2Br^-(aq) + 2H^+(aq) + CO_2(g)$$

- The reaction can be followed by measuring the intensity of the red-brown at different time intervals and relating this to the *concentration* of bromine.
- The concentration of bromine, $[Br_2]$, falls during the reaction, so the rate of the reaction can be expressed in terms of the rate at which the bromine concentration changes.
- The *rate of reaction* = - rate of change of bromine concentration = $-\frac{d[Br_2]}{dt}$
- The rate of change of bromine concentration is negative because the bromine is being used up. The negative sign in the expression is necessary to give the rate of reaction a positive value.
- In order to obtain the rate of reaction at any given time, a tangent to the curve must be drawn at that particular time and the gradient measured. The concentration of bromine after 300 seconds (s) is 0.0035 mol dm^{-3}. The rate of reaction at this time is 1.2×10^{-5} mol dm^{-3} s^{-1}.

Graph to show the variation of bromine concentration with time in the reaction between methanoic acid and bromine

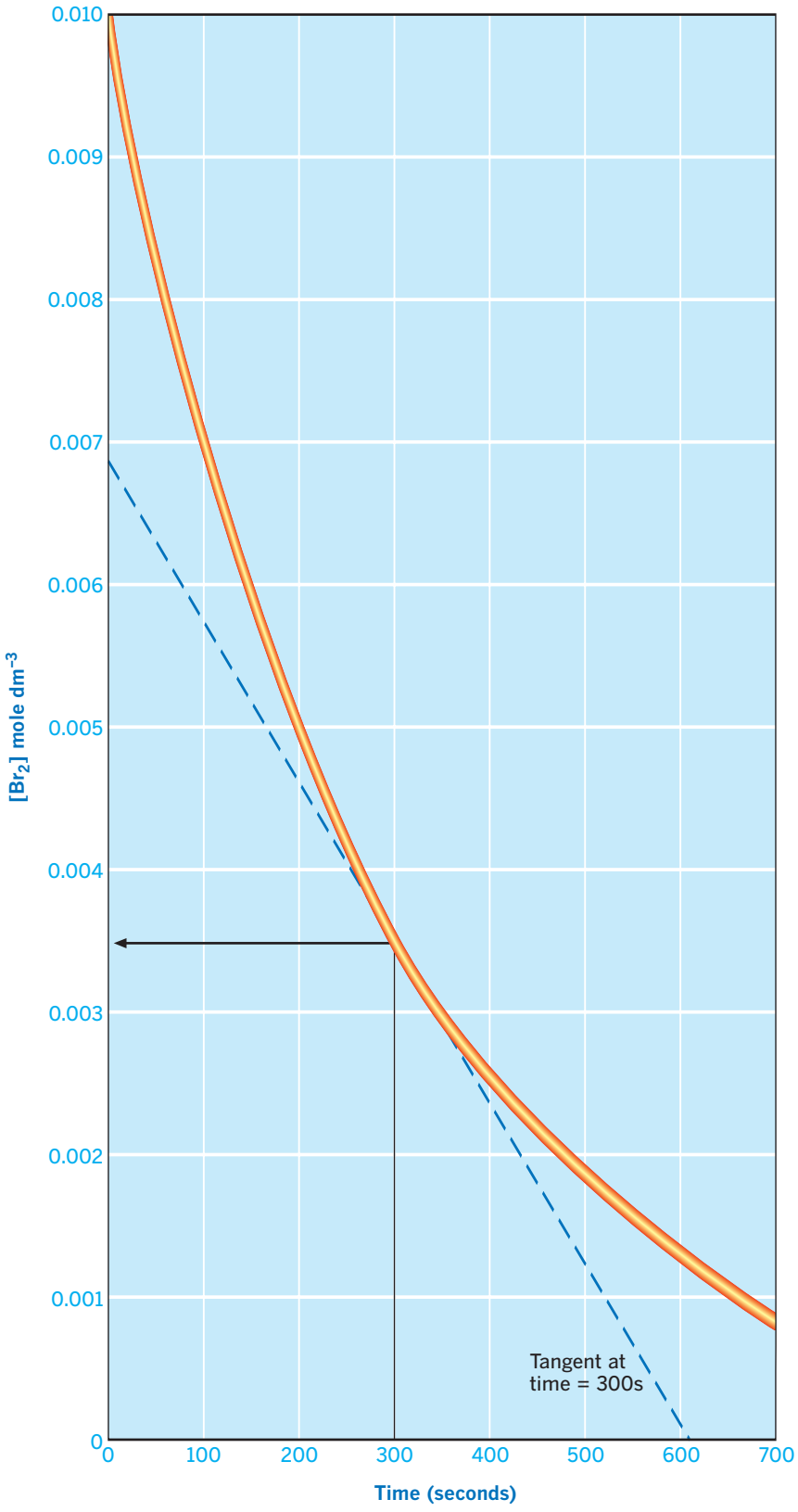

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Rate of reaction vs. concentration

Graph to show the variation of reaction rate with bromine concentration

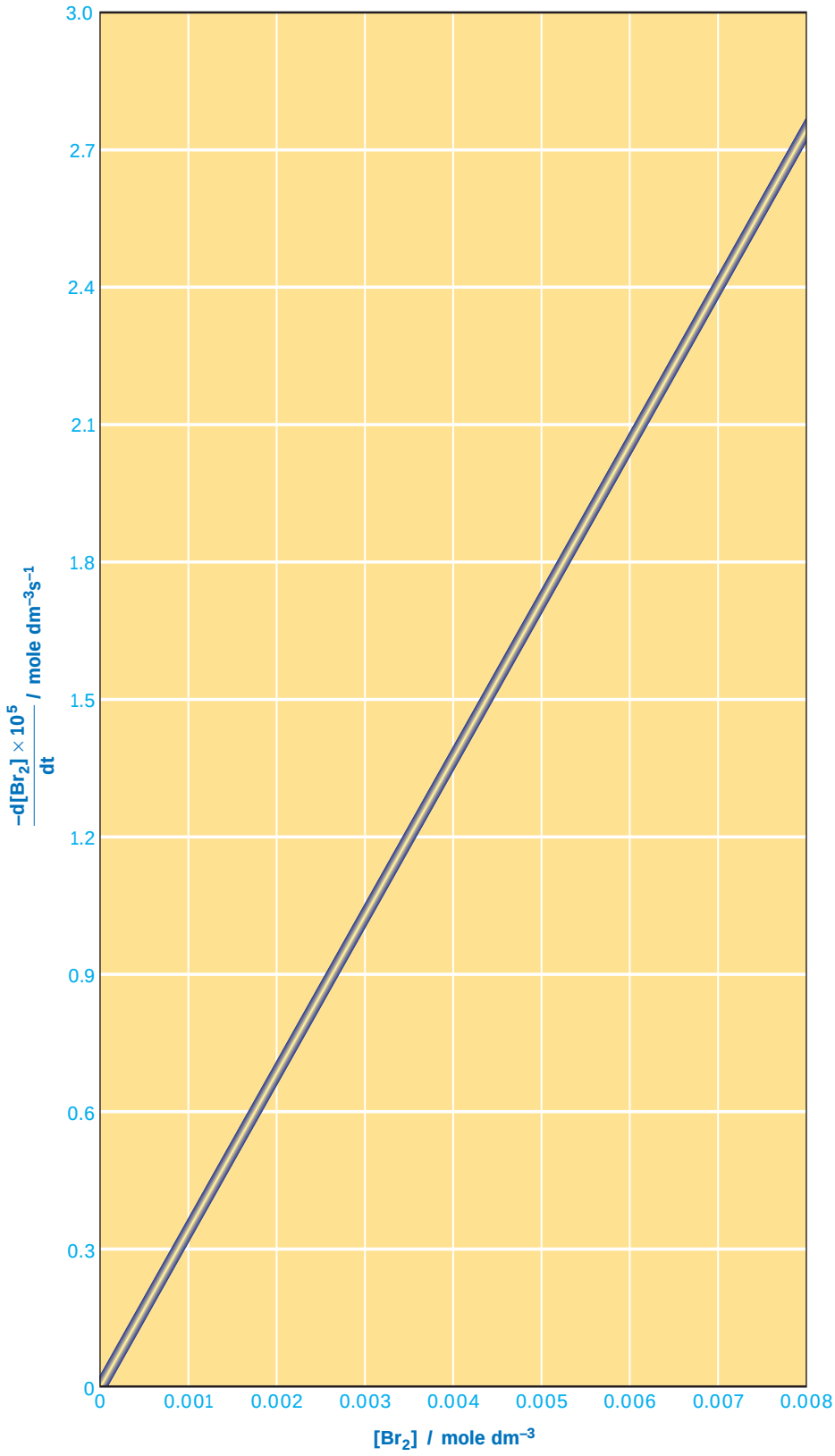

Key words

concentration
rate of reaction

Rate vs. concentration

- In order to draw a graph showing how the *rate of reaction* varies with bromine *concentration*, it is necessary to find the rate of reaction at different times and, therefore, different bromine concentrations.
- The graph shows that the rate of reaction is directly proportional to the bromine concentration.
  Reaction rate $\propto [Br_2]$, therefore,
  Rate of reaction = $k[Br_2]$ where k is a constant, known as the rate constant or the velocity constant for the reaction.
- This reaction is said to be first rate with respect to bromine since doubling the concentration of bromine doubles the rate of the reaction.
- Since rate of reaction = $k[Br_2]$, then to find the units of k:

  $$k = \frac{\text{rate of reaction}}{[Br_2]} = \frac{\text{mol dm}^{-3}\ \text{s}^{-1}}{\text{mol dm}^{-3}} = \text{s}^{-1}$$

  The unit of the rate constant, k, for first order reactions is s^{-1}.

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Key words

concentration
product
rate of reaction
reactant

1 Clock technique

- *Rate of reaction* = $\frac{\text{change in concentration of a substance}}{\text{time}}$
- In order to monitor the progress of a reaction, we could measure the *concentration* of a *reactant* or a *product* at regular time intervals, say every 10 seconds.
- Strictly speaking, this would give us the average reaction rate during the 10 second period. By measuring the change in concentration over shorter and shorter time periods, we would obtain an increasingly more accurate estimate of the rate of reaction at any particular moment.
- Using a clock technique, the rate is obtained as the inverse of the time for a certain proportion of the reaction to occur. Provided the reaction has only gone a small way toward completion, the error is very small, but the error increases as the reaction moves further to completion.

2 Increasing concentration

- If doubling the concentration of a reactant has no effect on the rate of a reaction, then the reaction is said to be zero order with respect to the reactant. The rate equation is:
  rate = k[reactant]^0 = k
- If doubling the concentration of a reactant doubles the rate of a reaction, then the reaction is said to be first order with respect to the reactant. The rate equation is:
  rate = k[reactant]
- If doubling the concentration of a reactant quadruples the rate of a reaction, then the reaction is said to be second order with respect to the reactant. The rate equation is:
  rate = k[reactant]^2

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Variation of reaction rate

1 Clock technique for measuring reaction rates

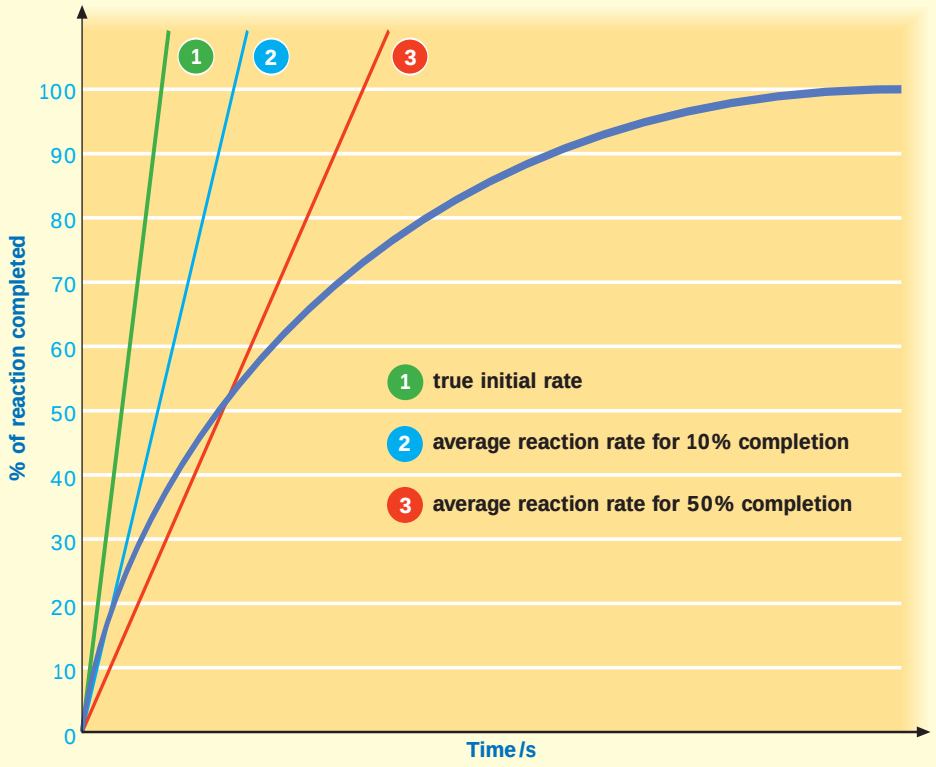

2 Increasing concentration

The variation of reaction rate with concentration for reactions which are zero, first, and second order

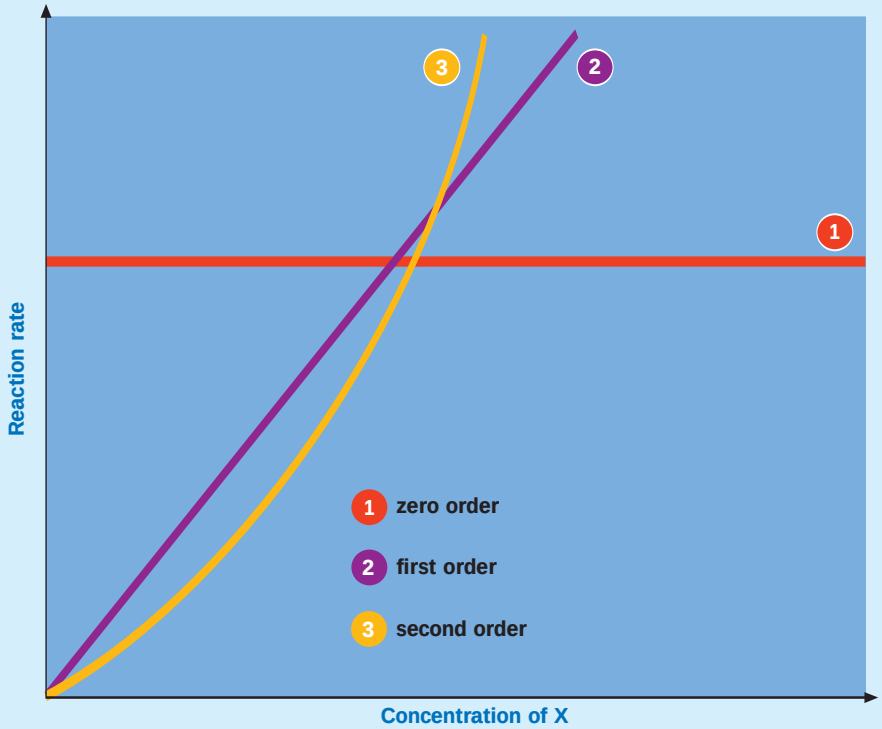

Rates of reaction: effect of temperature 1

The effect of temperature on different reactions

1 Most reactions

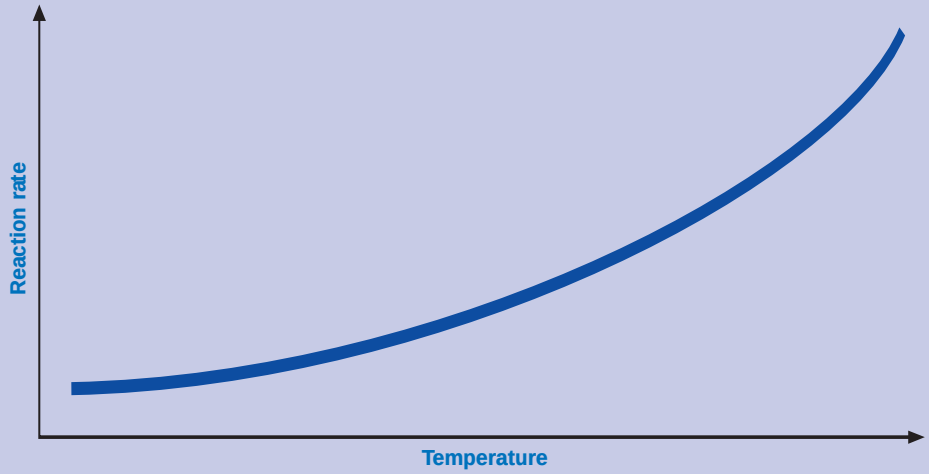

2 Enzyme-catalyzed reactions

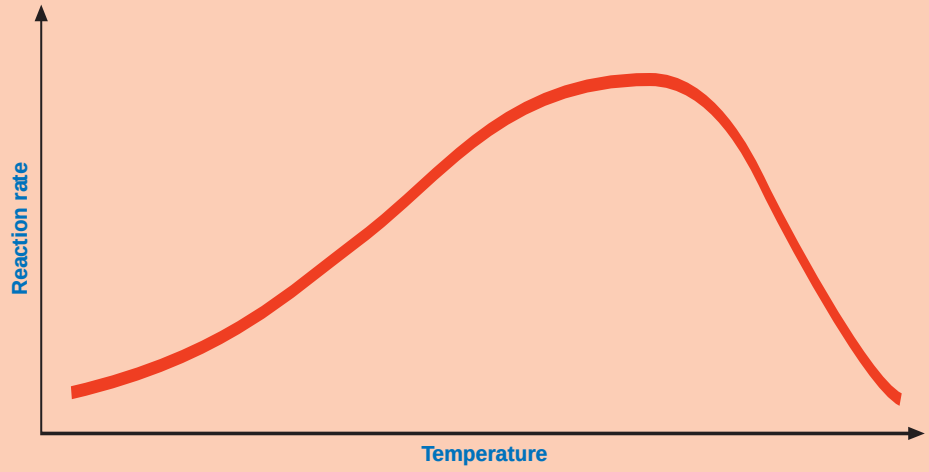

3 Explosive reactions

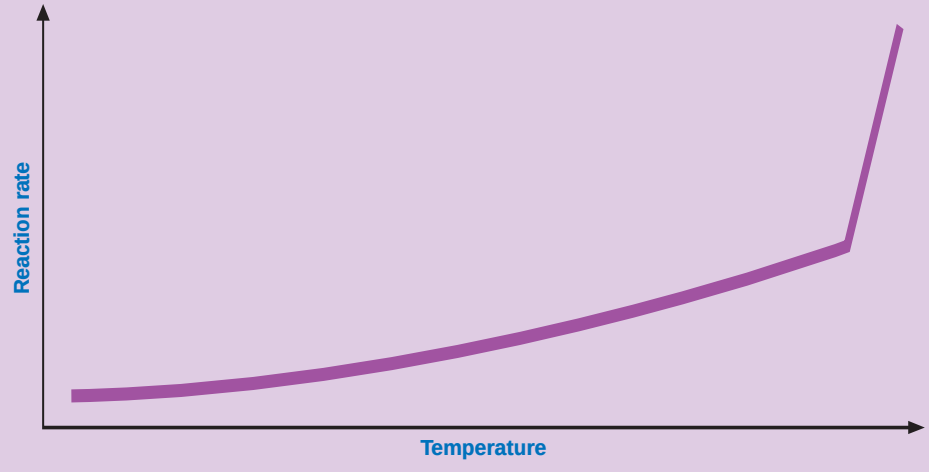

Key words

effective collision
enzyme
kinetic energy
polymer
rate of reaction

Effect of temperature

- When a substance is heated, its particles gain *kinetic energy* and move around more quickly. The frequency of collisions increases, and because the particles have a greater momentum, the frequency of *effective collisions* also increases. The result is an increase in the *rate of reaction*.

1 Most reactions

- In most chemical reactions, the rate of reaction increases steadily with rising temperature. It is for this reason that chemical reactions are often heated.

2 Enzyme-catalyzed reactions

- *Enzymes* catalyze chemical reactions with a high degree of specificity and efficiency. An enzyme molecule is a *polymer* composed of a long chain of amino acids that folds over on itself, giving it a particular shape. Reacting molecules, called the substrate, fit into this shape rather like a key in a lock.
- Up to a point, the rate of an enzyme-catalyzed reaction increases with rising temperature in the same way as most other reactions. However, after reaching an optimum temperature at which the activity of the enzyme is greatest, the reaction rate rapidly falls.
- Heating an enzyme causes its shape to change, and thus the enzyme ceases to be able to catalyze the reaction. It is said to be denatured.

3 Explosive reactions

- In an explosive reaction, the reaction rate increases with rising temperature up to some point where the reaction rate suddenly rises sharply.

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Key words

activation energy

1 Rate constant for reaction

- As a general rule of thumb, the rate of a reaction doubles for every 10 K rise in temperature. This would seem to suggest that there is an exponential relationship between rate and temperature.
- The exact relationship was proposed by the Swedish chemist Svante Arrhenius in 1889. The Arrhenius equation relates the rate constant (not the rate of reaction) to temperature.
- The equation can be expressed in a logarithmic form and in terms of log to the base 10. The latter form of the equation is the most useful for calculation purposes.

2 Plotting the Arrhenius constant

- The constants A and E_a for a given reaction can be obtained by plotting log k against 1/T: the temperature, T, must be expressed in kelvin.
  The slope of the graph is equal to E_a / 2.303R.
- The Arrhenius constant, A, can be obtained by substituting values for the slope (E_a / 2.303R), log k and T in the Arrhenius equation.
- The *activation energy*, E_a, can also be found from the slope of the graph.
  Slope = - E_a / 2.303 R
  The slope of the graph is negative, and its unit is K therefore
  E_a = 2.303 x R x slope
  The gas constant, R, = 0.008314 kJ K^{-1} mol^{-1} therefore
  E_a = 2.303 x 0.008314 x slope kJ mol^{-1}

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Rates of reaction: effect of temperature 2

1 Rate constant for reaction

$$k = Ae^{-Ea/RT}$$

$$\ln k = \ln A - E_a/RT$$

$$\log k = \log A - E_a/2.303RT$$

k = rate constant for the reaction

A = constant for the reaction (Arrhenius constant)

E_a = activation energy

R = gas constant

T = absolute temperature

2 Plotting the Arrhenius constant

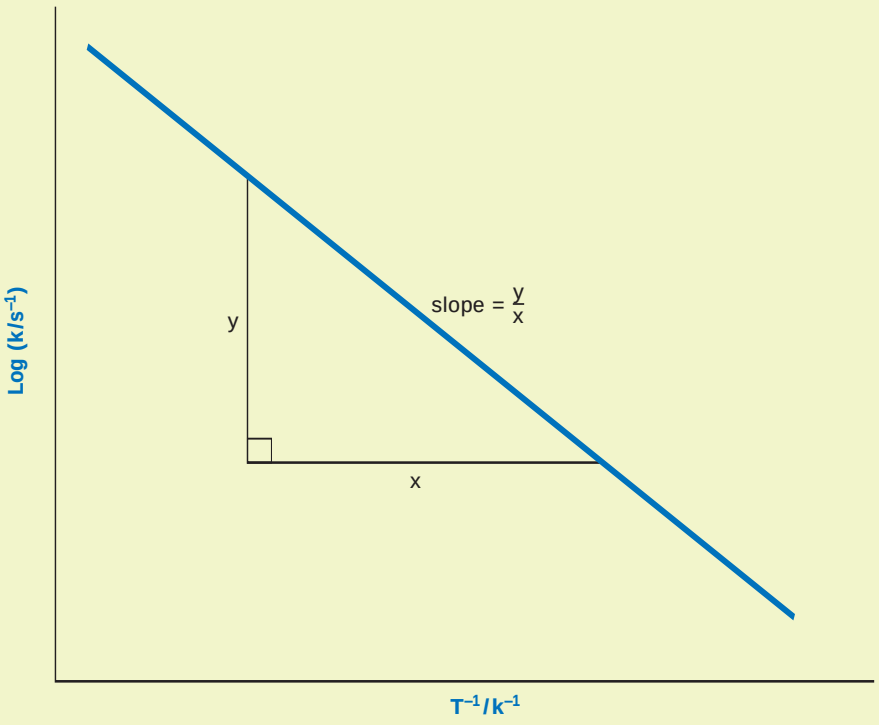

Exothermic and endothermic reactions

1 Exothermic

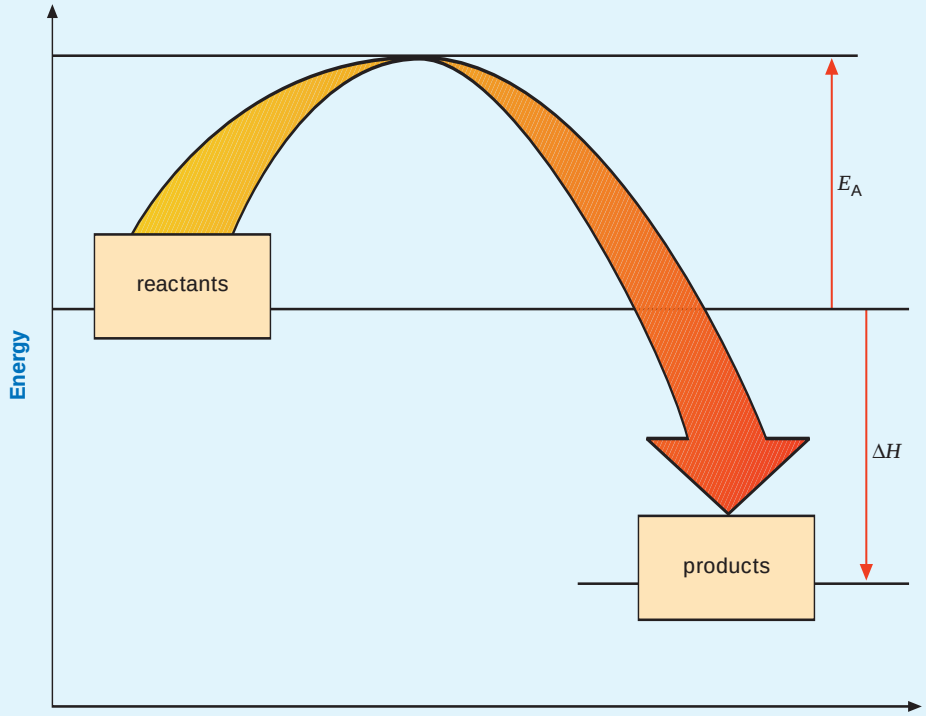

E_A = activation energy ΔH = heat of reaction

2 Endothermic

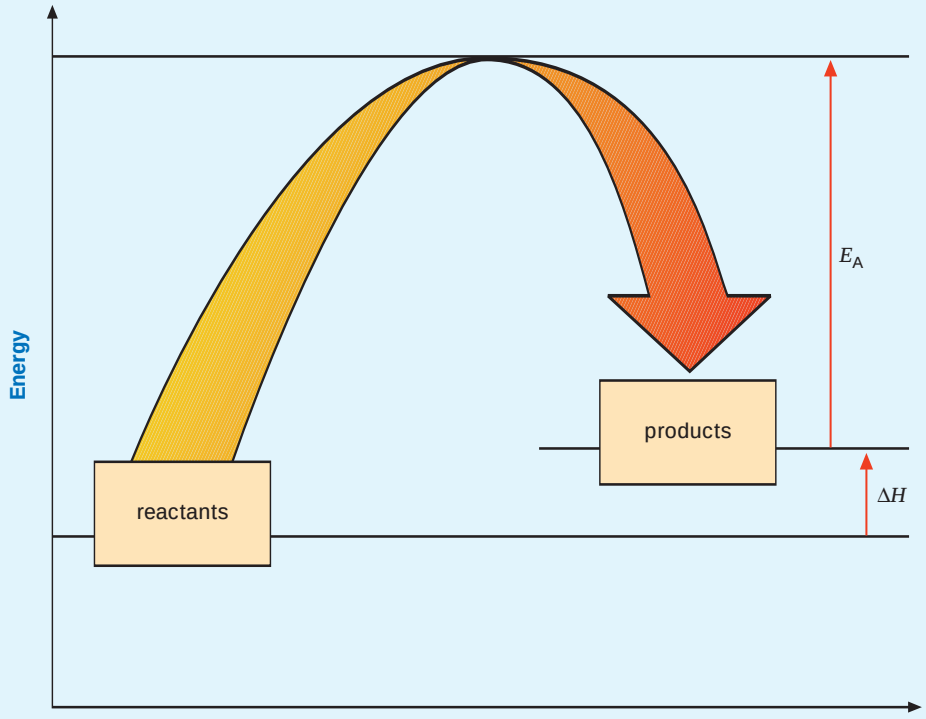

Key words

endothermic
enthalpy
exothermic
product
reactant

1 Exothermic

- In an *exothermic* reaction, energy is given out, and the temperature of the reaction mixture increases as the reaction proceeds. The *products* are at a lower energy than the *reactants*.
- The energy released is due to a decrease in the *enthalpy*, ΔH, of the system. Enthalpy is a measure of the stored heat energy of a substance. Therefore, ΔH is negative for an exothermic reaction.
- The following equation represents the combustion of methane in a good supply of air:

  $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

  $\Delta H = -890\ kJ\ mol^{-1}$

  This is an exothermic reaction. 890 kJ of energy are released per mole of methane combusted.

2 Endothermic

- In an *endothermic* reaction, energy is taken in, and the temperature of the reaction mixture decreases as the reaction proceeds. The products are at a higher energy than the reactants.
- The energy taken in is due to an increase in the enthalpy, ΔH, of the system. Therefore, ΔH is positive for an endothermic reaction.
- The following equation represents the steam reforming of methane:

  $CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$

  $\Delta H = +206\ kJ\ mol^{-1}$

  This reaction is an endothermic reaction. 206 kJ of energy are taken in per mole of methane reformed.

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Key words

dissociation
enthalpy

1 Average bond enthalpy

- Bond *dissociation* energy is the energy change when one mole of bonds is broken. It refers to a specific bond in a molecule. However, the exact value depends on the local environment of the bond. For example, if the C-H bonds in methane are broken one after another, each will have a different bond dissociation *enthalpy*:

$CH_4(g) \rightarrow CH_3(g) + H(g)$
$\Delta H = +425$ kJ mol^{-1}
$CH_3(g) \rightarrow CH_2(g) + H(g)$
$\Delta H = +470$ kJ mol^{-1}
$CH_2(g) \rightarrow CH(g) + H(g)$
$\Delta H = +416$ kJ mol^{-1}
$CH(g) \rightarrow C(g) + H(g)$
$\Delta H = +335$ kJ mol^{-1}

- For this reason, in a molecule composed of more than one atom, it is more useful to know the average amount of energy needed to break a particular bond.

2 Estimating enthalpy change

- The table at right utilizes the complete combustion of propane to illustrate how bond enthalpies can be used to estimate the enthalpy change in a reaction.
- 6,488 kJ mol^{-1} of total energy is taken in to break the bonds.
- 8,542 kJ mol^{-1} of total energy is given out when the bonds are formed.
- The enthalpy change when 1 mole of propane is completely combusted is 6,488 – 8,542 = 2,054 kJ mol^{-1}.

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Average bond dissociation energies

1 Average bond enthalpy

Bond	Average bond enthalpy / kJ mol^{-1}	Bond	Average bond enthalpy / kJ mol^{-1}
C–C	347	C=O	805
C=C	612	H–Cl	432
C–Cl	346	H–H	436
C–H	413	N–H	391
C–N	286	O–H	464
C–O	336	O=O	498

2 Estimating the enthalpy change in a reaction.

Complete combustion of propane.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Energy is taken in to break bonds:

Bond	Average bond dissociation energy / kJ mol^{-1}	Number of bonds	Energy taken in / kJ mol^{-1}
C–H	413	8	3,304
C–C	347	2	694
O=O	498	5	2,490
Total energy taken in			6,488

Energy is given out when bonds are formed:

Bond	Average bond dissociation energy / kJ mol^{-1}	Number of bonds	Energy taken in / kJ mol^{-1}
C=O	805	6	4,830
O–H	464	8	3,712
Total energy taken in			8,542

The enthalpy change when 1 mole of propane is completely combusted is 6,488 – 8,542 = 2,054 kJ mol^{-1}.

Catalysts: characteristics

1 Characteristics of catalysts

Stoichiometry	The overall stoichiometry of a reaction is unaltered.
Specificity	Catalysts may alter the rate of one reaction but have no effect on others.
Reaction mechanism	A catalyst provides an alternative reaction pathway for a reaction to take place.
Chemical involvement	A catalyst is chemically involved in a reaction. It is consumed during one step and regenerated in another. A catalyst does not undergo a net chemical change, but it may change its physical form.
Equilibrium	A catalyst speeds up the rates of both forward and backward reactions, and this speeds up the rate at which equilibrium is attained.
Yield	A catalyst does not alter the yield of a reaction.

2 Increasing reaction rate

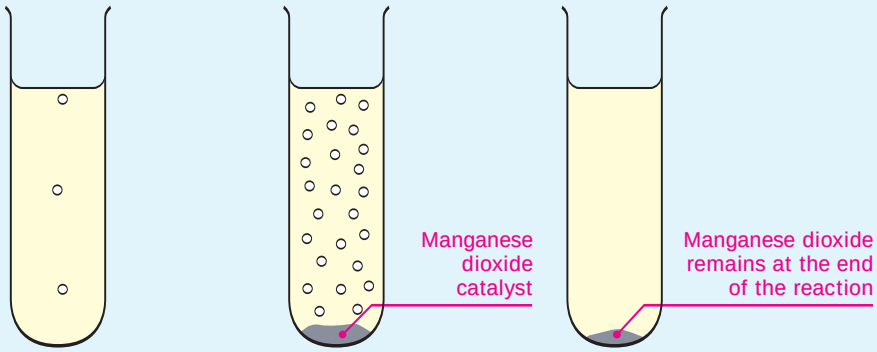

3 Distribution of the kinectic energies of reacting particles and the activation energies for catalyzed and uncatalyzed reactions

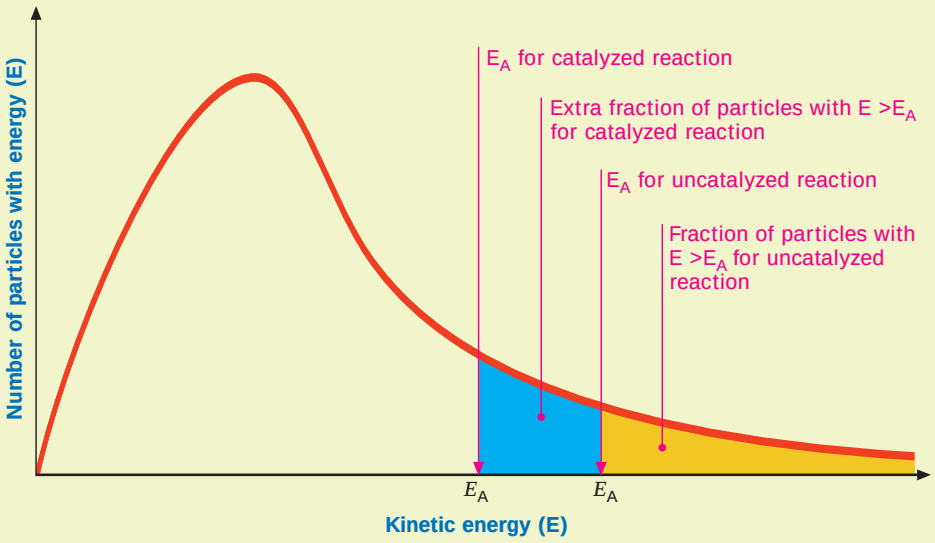

Key words

activation energy
active site
catalyst
effective collision

Catalysts

- A *catalyst* is a substance that alters the rate of a chemical reaction but remains chemically unchanged by it.

1 Characteristics of catalysts

- Catalysts may be classified as homogenous or heterogeneous. Homogenous catalysts are in the same phase (solid, liquid, or gas) as the reactants; heterogeneous catalysts are in a different phase.
- A large number of reactions are catalyzed on the surface of solid catalysts. The surface provides *active sites* where reactions can occur. Thus, an increase in the surface area will increase the effect of the catalyst.

2 Increasing reaction rate

- Hydrogen peroxide decomposes very slowly on its own to form water and oxygen gas:
  $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$
  The rate of this reaction is greatly increased by adding manganese dioxide, MnO_2.
- Manganese dioxide acts as a catalyst and remains unchanged after all of the hydrogen peroxide has decomposed.

3 Activation energies

- A catalyst lowers the minimum energy, or *activation energy* (E_A), required for a reaction to occur. The frequency of *effective collisions* is, therefore, increased, resulting in an increase in the rate of a reaction.

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Key words

catalyst
equilibrium
exothermic
Le Chatelier's principle
oxidation
oxidation state
reduction
transition metals
vanadium

1 Reaction catalyzed

- *Catalysts* are often *transition metals* or transition metal compounds. Transitional metals are useful as catalysts because or their ability to exist in different *oxidation states.*

2 V_2O_5 as catalyst

- The contact process is an important step in the manufacture of sulfuric acid (see pages 85 and 86). Sulfur dioxide is oxidized to sulfur trioxide in the presence of a *vanadium* pentoxide, V_2O_5, catalyst.
- This reaction involves the *reduction* and subsequent *oxidation* of the catalyst. In the reduction reaction, the oxidation state of vanadium changes from +5 to +4. In the oxidation reaction, it changes back from +4 to +5.

3 Iron as catalyst

- The Haber process for the manufacture of ammonia uses finely divided iron as the catalyst (see pages 74 and 75):

$$N_2 + 3H_2 \overset{Fe(s)}{\rightleftharpoons} 2NH_3$$

$\Delta H = -92$ kJ mol^{-1}

- This reaction is *exothermic*. According to *Le Chatelier's principle*, a low temperature would produce more ammonia in the *equilibrium* mixture, but it would take longer to reach equilibrium.
- The catalyst does not alter the yield of ammonia in the equilibrium mixture, but it does increase the speed with which equilibrium is attained. Using a catalyst, a reasonable rate of reaction is achieved at a lower temperature than would otherwise be the case.

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Catalysts: transition metals

1 Transition metals and reaction catalyzed

Transition metal /compound	Reaction catalyzed
$TiCl_3$	polymerization of ethene to poly(ethene)
V_2O_5	contact process in production of sulfuric acid
Fe	Haber process on production of ammonia
Ni	hydrogenation of alkenes in hardening of vegetable oils
Cu	oxidation of ethanol to ethanal
Pt	oxidation of ammonia in manufacture of nitric acid

2 Vanadium oxide as catalyst in contact process

$$2SO_2(g) + O_2(g) \overset{V_2O_5(s)}{\rightleftharpoons} 2SO_3(g)$$

$$SO_2 + V_2O_5 \longrightarrow SO_3 + V_2O_4$$

$$2V_2O_4 + O_2 \longrightarrow 2V_2O_5$$

3 Iron as catalyst in Haber process

(Energy profiles for the reaction $N_2 + 3H_2 \overset{Fe(s)}{\rightleftharpoons} 2NH_3$)

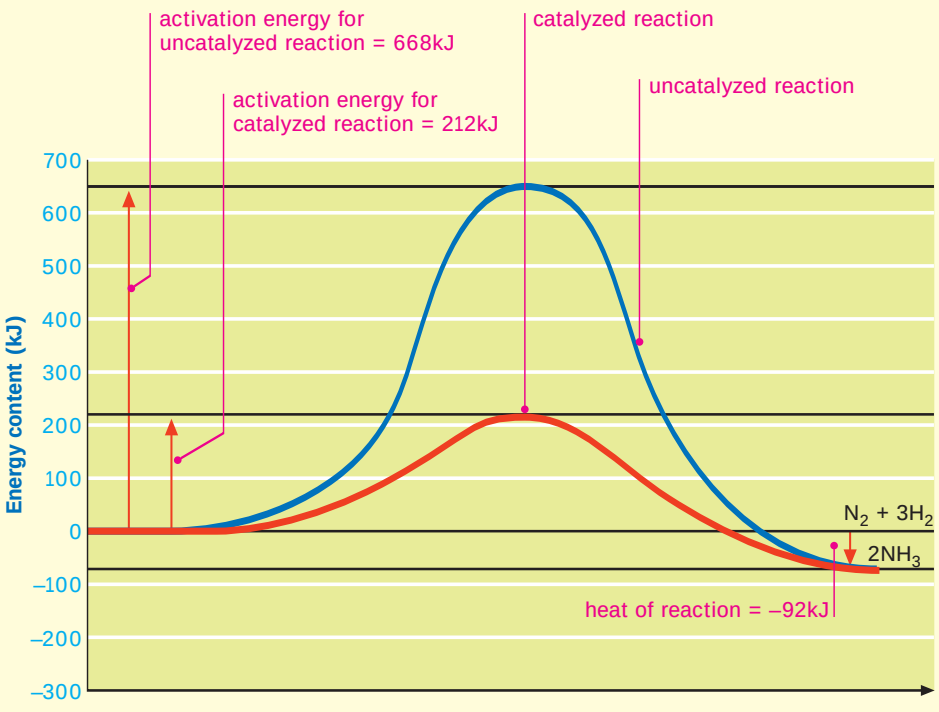

Oxidation and reduction

1 Oxygen

Oxidation is the addition of oxygen to a substance

Reduction is the removal of oxygen from a substance

2 Hydrogen

Oxidation is the removal of hydrogen from a substance

Reduction is the addition of hydrogen to a substance

3 Modern definition

Oxidation is the loss of electrons from a substance

Reduction is the gain of electrons by a substance

4 Redox reaction

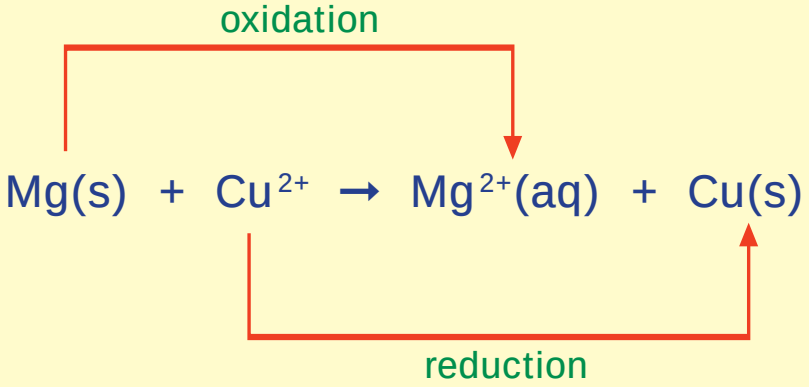

Key words

oxidation
oxidation state
redox reaction
reduction

Evolving definition

- Over time, scientists have extended the definitions of *oxidation* and *reduction*.

1 Oxygen

- Historically the terms oxidation and reduction were applied to reactions involving either the addition or the removal of oxygen. For example:
  $2Cu(s) + O_2 \rightarrow 2CuO(s)$
  copper is oxidized
  $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
  iron is reduced

2 Hydrogen

- The terms were extended to include the removal or addition of hydrogen:
  $CH_3\text{-}CH_3(g) \rightarrow CH_2{=}CH_2(g) + H_2(g)$
  ethane is oxidized
  $CH_3COH(l) + H_2(g) \rightarrow CH_3CH_2OH(l)$
  ethanal is reduced

3 Modern definition

- The terms oxidation and reduction are now used more widely to describe changes in *oxidation state*:
  $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
  copper is oxidized to copper(II)
  $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$
  iron(III) is reduced to iron(II)
- This definition covers all of those reactions involving the gain or loss of oxygen and other reactions that do not involve oxygen.

4 Redox reaction

- Reactions that involve a reduction must also involve an oxidation. If one reactant is reduced, then another must be oxidized. Such reactions are described as *redox reactions*.

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Key words

displacement reaction
oxidation
redox reaction
reduction

Redox reactions

- *Reduction* and *oxidation* reactions always occur together and are collectively referred to as *redox reactions*.

1 Oxidation and reduction

- When magnesium is heated in air, it forms magnesium oxide:
  $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
- Magnesium atoms are oxidized to magnesium ions by losing two electrons.
- Oxygen atoms are reduced to oxide ions by gaining two electrons.
- This is true of all metals when they are converted to metal oxides.

2 Electron transfer

- A more reactive metal displaces the ions of a less reactive metal from a solution of its salts. This type of reaction is called a *displacement reaction*:
  $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$
  Zinc atoms are oxidized to zinc ions by losing two electrons.
- Copper ions are reduced to copper atoms by gaining two electrons.

3 Balancing redox reactions

- In balancing redox reactions, the electrons lost must equal the electrons gained.
- In the example at right, bromine (a) is gaining two electrons and iron (b) is losing 1 electron.
- In order to balance the equation, the entire reaction has to be multiplied by 2 (c).
- The result is a balanced equation (d).

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Redox reactions 1

1 Redox reactions: oxidation and reduction

$$2Mg + O_2 \rightarrow 2Mg^{2+} + 2O^{2-}$$

$$4Na + O_2 \rightarrow 2(Na^2)_2O^{2-}$$

When metals react with oxygen they form oxides

$$2Mg \rightarrow 2Mg^{2+} + 4e^-$$

$$O_2 + 4e^- \rightarrow 2O^{2-}$$

The metal is oxidized and the metal is reduced. The oxygen takes the electrons given up by the metal

2 Electron transfer in redox reactions

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

When powered zinc is added to copper sulfate (II) solution, an exothermic reaction occurs

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

Redox equations for the reaction

3 Balancing redox reactions

$$Br_2 + 2e^- \rightarrow 2Br^-$$

(a) The oxidizing agent is Br^2

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

(b) The reducing agent is Fe^{2+}

$$2Fe^{2+} \rightarrow 2Fe^{3+} + 2e^-$$

$$Br_2 + 2e^- \rightarrow 2Br^-$$

(c) Redox reaction

$$2Fe^{2+} + Br_2 \rightarrow 2Fe^{3+} + 2Br^-$$

(d) Balance equation

Redox reactions 2

1 The reaction of metals with non-metals

$Fe + S \rightarrow Fe^{2+}S^{2-}$

Iron and sulfur

$Fe \rightarrow Fe^{2+} + 2e^-$

$S + 2e^- \rightarrow S^{2-}$

Redox equation

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

Iron and chlorine

$2Fe \rightarrow 2Fe^{3+} + 6e^-$

$3Cl_2 + 6e^- \rightarrow 6Cl^-$

Redox equation

2 The reaction of metals with water

$Ca + 2H_2O \rightarrow Ca^{2+}(OH^-)_2 + H_2$

Calcium and water

$Ca \rightarrow Ca^{2+} + 2e^-$

$2H_2O + 2e^- \rightarrow 2OH^- + H_2$

Redox equation

3 The reaction of metals with acids

$Zn(s) + 2H^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_2\uparrow$

The reaction of zinc

$Zn \rightarrow Zn^{2+} + 2e^-$

$2H^+ + 2e^- \rightarrow H^2$

Redox equation

Key words

redox reaction

1 Metals with non-metals

- Iron undergoes *redox reactions* with non-metals.

Iron and sulfur:

$Fe(s) + S(s) \rightarrow Fe^{2+}S^{2-}(s)$

Iron atoms are oxidized to iron(II) ions by losing two electrons.

Sulfur is reduced to sulfide ions by gaining two electrons.

Iron and chlorine:

$2Fe(s) + 3Cl_2(s) \rightarrow 2Fe^{3+}Cl^-_3(s)$

Iron atoms are oxidized to iron(III) ions by losing three electrons.

Chlorine is reduced to chloride ions by gaining one electron.

2 Metals with water

- Metals are oxidized when they react with water.

Metal + water → metal hydroxide + hydrogen

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

$Ca(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$

In the example at left, calcium atoms are oxidized to calcium ions by the loss of two electrons. Hydrogen ions are reduced to hydrogen atoms by gaining one electron.

3 Metals with acids

- Metals are oxidized when they react with acids.

Metal + acid → metal salt + hydrogen

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

In the example at left, zinc atoms are oxidized to zinc ions by the loss of two electrons. Hydrogen ions are reduced to hydrogen atoms by gaining one electron.

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Key words

reactivity series
redox reaction

1 Electron transfer in redox reactions

- The movement of electrons during *redox reactions* can be demonstrated using a simple cell consisting of two metals rods, suspended in solutions of their salts, connected by a wire and a salt bridge.
- At the zinc rod, zinc atoms lose two electrons to become zinc ions. The electrons pass along the wire and through the bulb to the copper rod. The zinc ions pass into solution.
- At the copper rod, copper ions gain two electrons to become copper atoms. The copper ions come out of solution and are deposited as copper metal on the copper rod.
- Electric current passes through the wire in the external circuit as a flow of negatively charged electrons.
- Ions flow through the salt bridge: positive ions from the zinc sulfate solution to the copper sulfate, and negative ions in the opposite direction from the copper sulfate solution to the zinc sulfate solution.
- Electric current passes through ionic solutions as a flow of positively charged and negatively charged ions.

2 Reaction equations

- Zinc is higher than copper in the *reactivity series*. Zinc atoms are oxidized to zinc ions, while copper ions are reduced to copper atoms.
- When any two metals are placed in a cell, the direction of electrons in the external circuit depends on their reactivities. The metal that is higher in the reactivity series will be oxidized, while the ions of the metal that is lower in the reactivity series will be reduced.

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Demonstrating redox reactions

1 Electron transfer in redox reactions

Experimental set-up

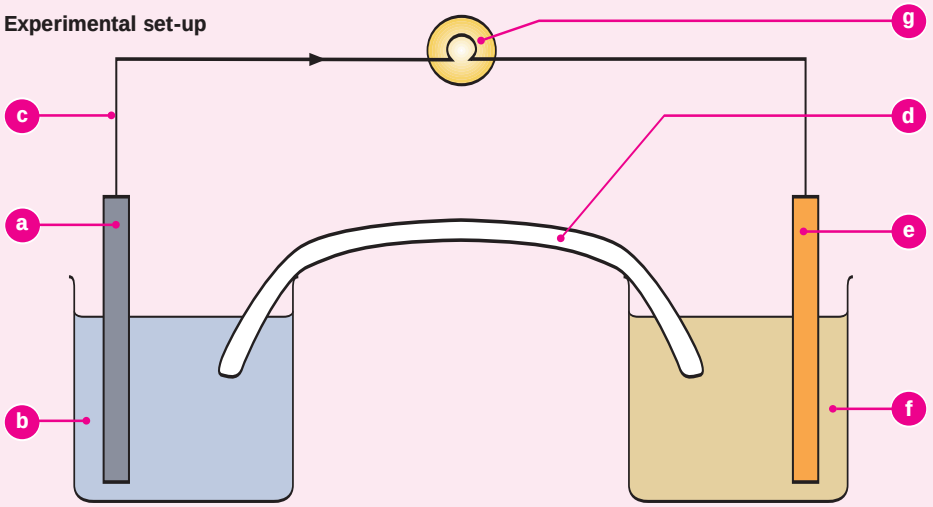

Movement of charge around the circuit

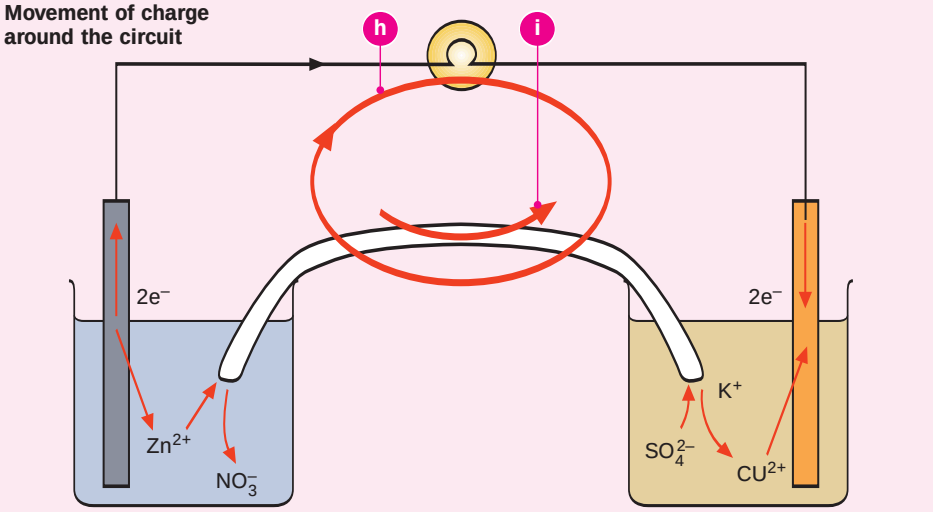

a zinc rod
b zinc sulfate solution
c electron flow
d filter paper soaked in potassium nitrate as a salt bridge
e copper rod
f copper sulfate solution
g small light bulb
h movement of negative charge (electrons and anions)
i movement of positive charge (cations)

2 Reaction equations

$$Zn(s) + Cu^{2+} \rightarrow Zn^{2+}_{(aq)} + Cu(s)$$

$$Zn(s) \rightarrow Zn^{2+}_{(aq)} + 2e^-$$

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu(s)$$

Copper ions are reduced to a deposit of red-brown

Assigning oxidation state

1 Oxidation state

Component	Oxidation state
uncombined elements	0
Group 2 metals in compounds	+2
Group 1 metals in compounds	+1
combined hydrogen except in metal hydrides	+1
combined hydrogen in metal hydrides	–1
combined halogens	–1
combined oxygen	–2

2 Tetrachlorocuprate ion

$$CuCl_4^{2-}$$

the tetrachlorocuprate ion contains the transition metal copper

3 Manganate ion

$$MnO_4^-$$

the manganate ion contains the transition metal manganese

4 Dichromate ion

$$Cr_2O_7^{2-}$$

the dichromate ion contains the transition metal chromium

Key words

oxidation state
transition metals

1 Oxidation state

- The ability of *transition metals* to exhibit different *oxidation states* in different compounds is central to the behavior of these elements.
- The oxidation state of simple ions is given by the charge they carry, e.g.:
  Na^+ has an oxidation state of +1
  O^{2-} has an oxidation state of -2
- The situation is more complicated in a complex ion. The oxidation state of the central atom in a complex ion is the charge that the ion would have if it were a simple ion. This is found by adding the oxidation states of the various components in the complex ion.

2 Tetrachlorocuprate ion

- Total oxidation number due to chlorine = 4 x -1 = -4.
- Overall charge on the ion = -2.
- Oxidation state of the central copper atom = -2 – (-4) = +2.
- This complex ion is more correctly called the tetrachlorocuprate(II) ion.

3 Manganate ion

- Total oxidation number due to oxygen = 4 x -2 = -8.
- Overall charge on the ion = -1.
- Oxidation state of the central manganese atom = -1 – (-8) = +7.
- This complex ion is more correctly called the manganate(VII) ion.

4 Dichromate ion

- Total oxidation number due to oxygen = 7 x -2 = -14.
- Overall charge on the ion = -2.
- Total oxidation state of the two central chromium atoms = -2 – (-14) = +12.
- Oxidation state of each chromium atom = +12 / 2 = +6.
- This complex ion is more correctly called the dichromate(VI) ion.

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Key words

allotrope
carbon
diamond
fullerenes
graphite

Carbon allotropes

- *Carbon* exists in three *allotropes: diamond*, *graphite*, and *fullerenes*.

1 Diamond

- In diamond, each carbon atom is covalently bonded to four other carbon atoms.
- The four bonds are directed toward the corners of a pyramid or tetrahedron, and all bonds are the same length, 0.154 nm. The angle between any two bonds is 109.5°.
- All four of the outer electrons on the carbon atom form bonds with other carbon atoms so there are no mobile electrons. Diamond does not, therefore, conduct electricity.
- Diamond has a rigid structure and is very hard.

2 Graphite

- The carbon atoms in graphite are arranged in layers consisting of interlocking hexagons in which each carbon atom is covalently bonded to three other carbon atoms. The length of the bond is 0.141 nm, and the angle between bonds is 120°.
- The fourth outer electron on each carbon atom forms bonds with adjacent layers. The bond length is much greater than between carbon atoms within a layer.
- The electrons between the layers are mobile; therefore, graphite conducts electricity. Also, the layers are able to slide over each other relatively easily.
- Graphite is soft.

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The allotropes of carbon: diamond and graphite

Diamond

Bond angle 109.5°
Bond length 0.154 nm

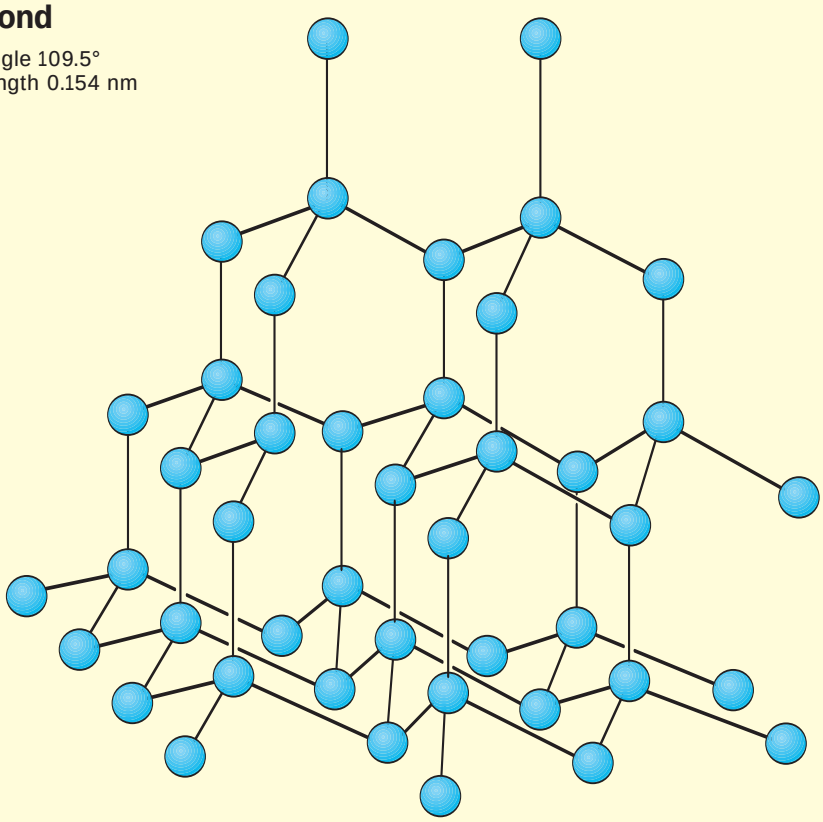

Graphite

Bond angle 120°
Bond lengths
– in layers 0.141 nm
– between layers 0.335 nm

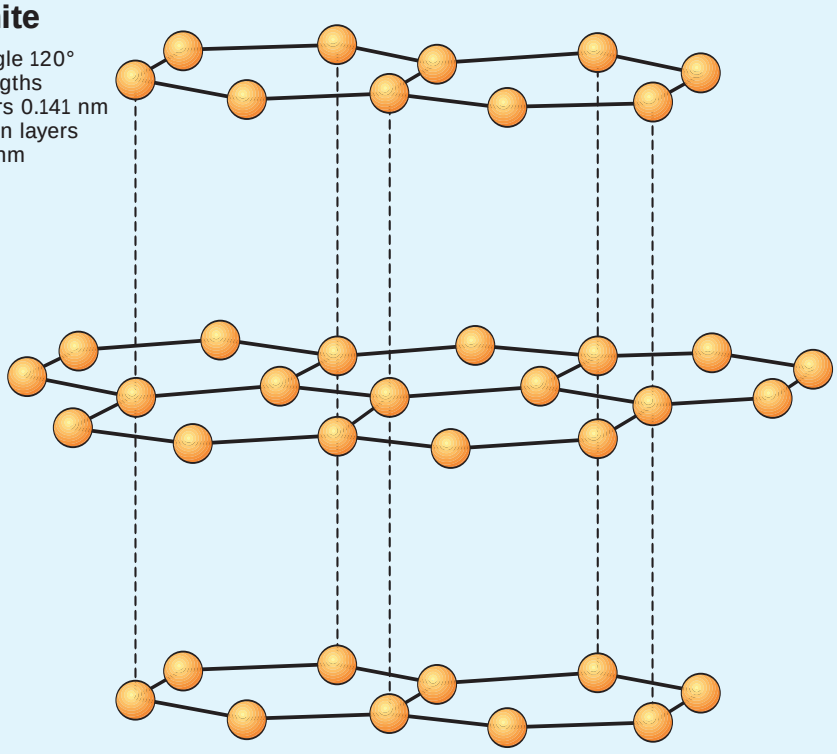

The allotropes of carbon: fullerenes

Key words

allotrope	*fullerenes*
buckyball	*graphite*
carbon	*nanotube*

Buckyball

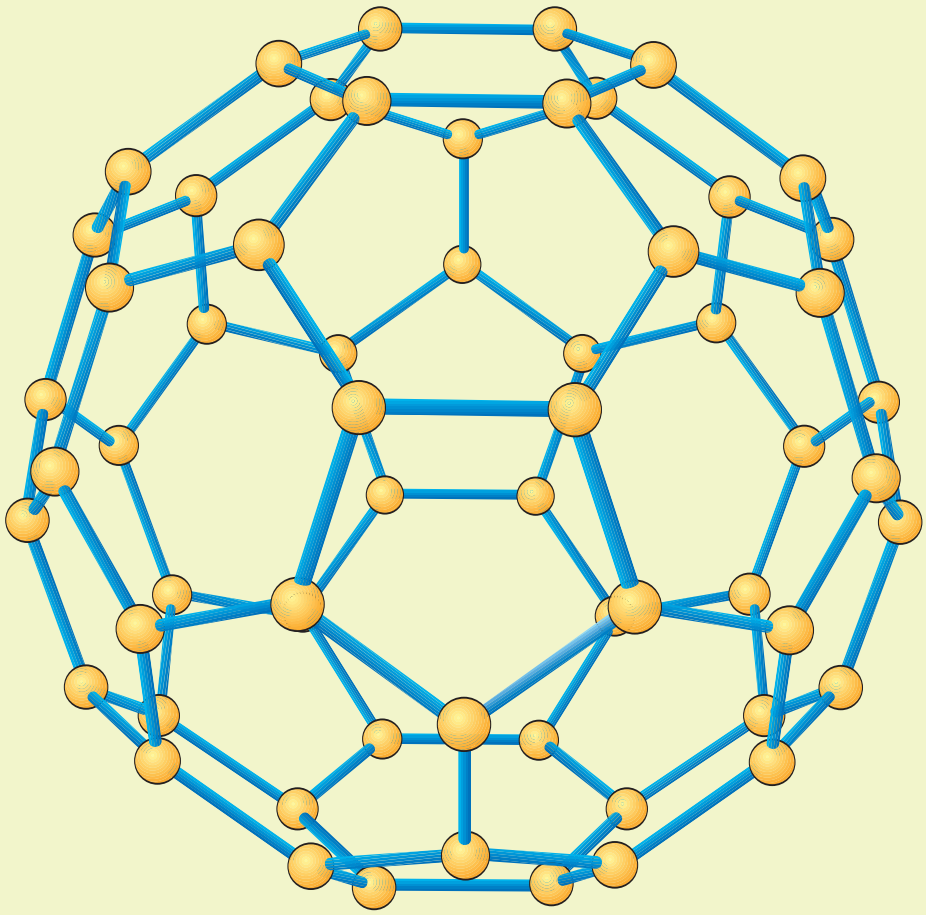

Nanotube

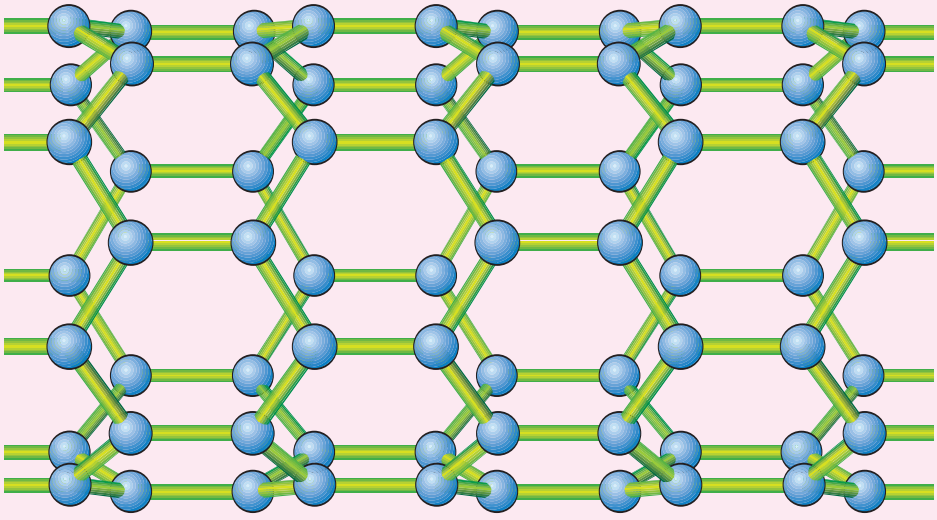

Fullerenes

- *Fullerenes* are *allotropes* of *carbon* in the form of a hollow sphere or tube. Spherical fullerenes are sometimes called *buckyballs*, and cylindrical fullerenes are called *nanotubes*.
- Because the allotrope was only discovered in the late twentieth century, its physical and chemical properties are still being studied.
- Fullerenes are not very reactive and are only slightly soluble in many solvents. They are the only known allotrope of carbon that can be dissolved.

Buckminsterfullerene

- This form of carbon is composed of 60 carbon atoms bonded together in a polyhedral structure composed of pentagons and hexagons. The molecules are made when an electric arc is struck between *graphite* electrodes in an inert atmosphere. This method also produces small amounts of other fullerenes that have less symmetrical molecular structures, such as C_{70}.
- Buckminsterfullerene was first identified in 1985 and named after the architect Richard Buckminster Fuller because of the resemblance of its structure to the geodesic dome.
- The substance is a yellow crystalline solid that is soluble in benzene, an organic solvent.
- It is possible to trap metal ions within the C_{60} sphere. Some of these structures are semiconductors.

Nanotubes

- Nanotubes, first identified in 1991, are long thin cylinders of carbon closed at either end with caps containing pentagonal rings.
- Nanotubes have a very broad range of electronic, thermal, and structural properties that change depending on the kind of nanotube (defined by its diameter, length, and twist).

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Key words

atmosphere
carbon
carbon cycle
chlorophyll
glucose
photosynthesis
respiration

The carbon cycle

- *Carbon* is the fourth most abundant element in the Universe.
- The total amount of carbon on planet Earth is fixed. The same carbon atoms have been used in countless other molecules since Earth began. The *carbon cycle* is the complex set of processes through which all carbon atoms rotate.
- Carbon exists in Earth's *atmosphere* primarily as carbon dioxide.
- All green plants contain *chlorophyll*, a pigment that gives them their characteristic color. During *photosynthesis*, chlorophyll traps energy from sunlight and uses it to convert carbon dioxide and water into *glucose* and oxygen.
- Carbon is transferred from green plants to animals when animals eat plants or other animals.
- All animals and plants need energy to drive their various metabolic processes. This energy is provided by *respiration*. During this process, glucose reacts with oxygen to form carbon dioxide and water. These waste products are subsequently released into the atmosphere. In essence, respiration is the opposite process to photosynthesis.
- When plants and animals die, their bodies decompose. In the presence of air, the carbon they contain becomes carbon dioxide, which is released into the atmosphere.
- When plants and animals decay in the absence of air, carbon cannot be converted into carbon dioxide. Instead, it remains and forms fossil fuels such as coal, crude oil, and natural gas.
- When fossil fuels are burned, the carbon they contain becomes carbon dioxide and is released into the atmosphere.

The carbon cycle

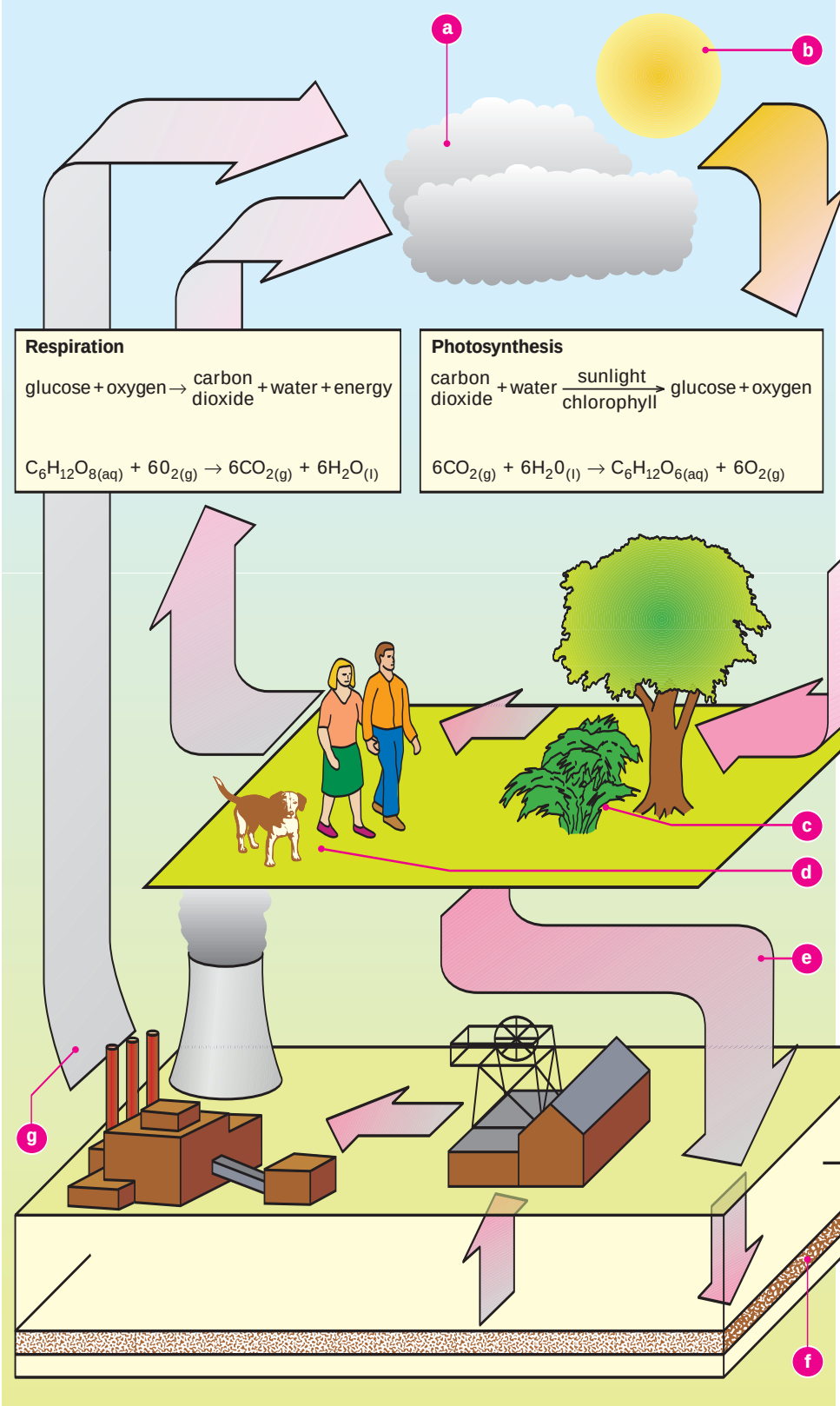

a carbon dioxide in the air
b sunlight
c plants take in carbon dioxide and give out oxygen
d animals take in oxygen, eat plants and vegetables, and breath out CO_2
e death and decay
f carbon compounds (e.g., in oil and coal)
g burning fuel produces CO_2

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Laboratory preparation of carbon oxides

1 Preparation of carbon dioxide

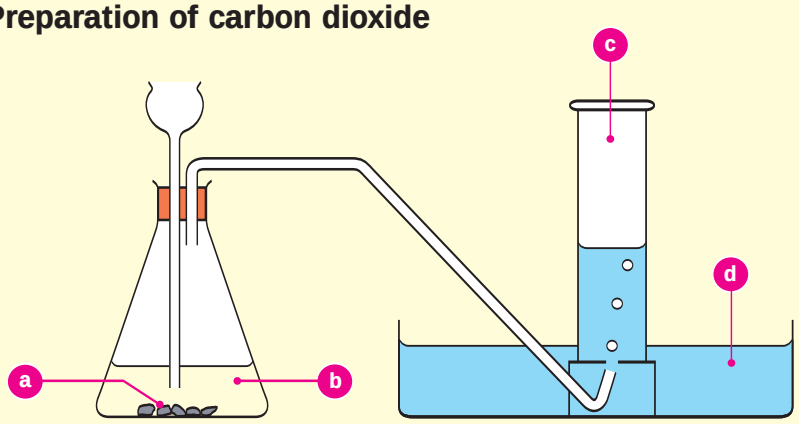

2 Preparation of dry carbon dioxide

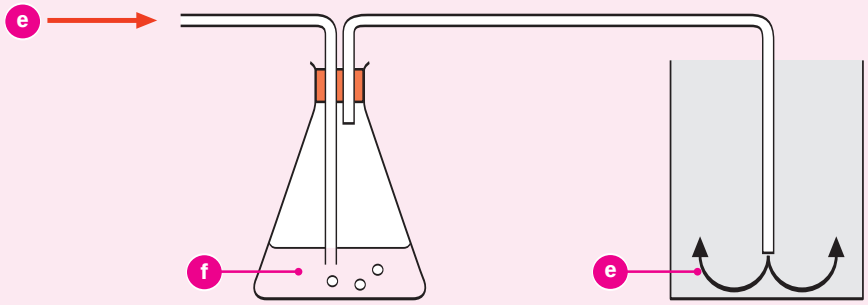

3 Preparation of carbon monoxide

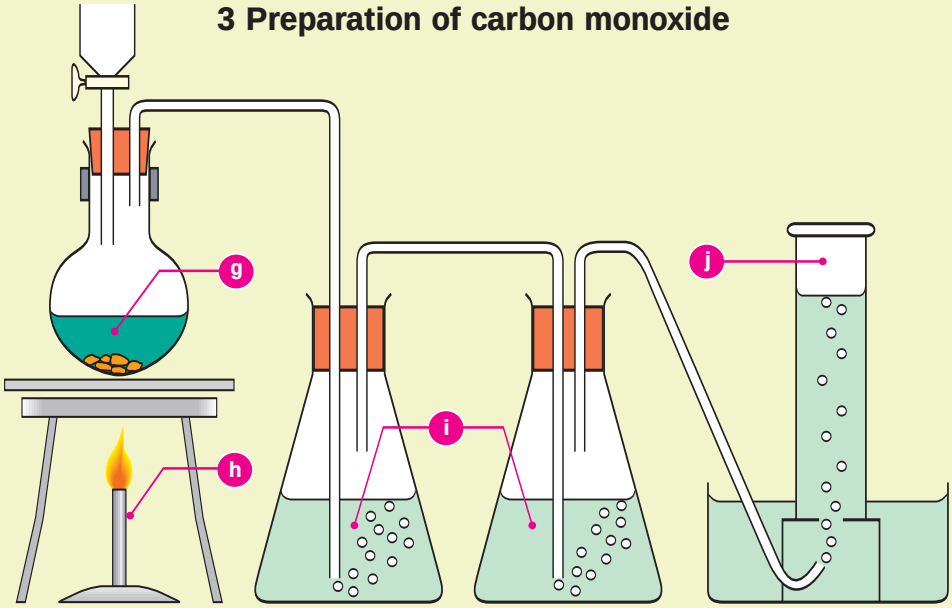

a marble chips
b dilute hydrochloric acid
c carbon dioxide
d water
e carbon dioxide
f concentrated sulfuric acid
g ethanedioic (oxalic) acid crystals and concentrated sulfuric acid
h heat
i concentrated potassium hydroxide solution
j carbon monoxide

Key words

carbonate
carbon dioxide
carbon monoxide

Carbon oxides

- The most common forms of carbon oxides are *carbon dioxide*, which is instrumental in the carbon cycle, and *carbon monoxide*, a colorless, odorless gas that is the result of the incomplete combustion of fuels. They can be prepared in the laboratory using the following techniques.

1 Carbon dioxide

- Carbon dioxide is formed when a metal *carbonate* reacts with a dilute acid:

  metal carbonate + dilute acid → metal salt + carbon dioxide + water

- When calcium carbonate (marble chips) reacts with dilute hydrochloric acid:

  $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

- Carbon dioxide is not very soluble in water, so it can be conveniently collected over water.

2 Dry carbon dioxide

- Carbon dioxide can be dried by passing it through concentrated sulfuric acid and collected by downward delivery (upward displacement) because it is denser than air.

3 Carbon monoxide

- Carbon monoxide is formed by the dehydration of ethanedioic (oxalic) acid using concentrated sulfuric acid:

  $HOOC\text{-}COOH(l) \xrightarrow{\text{conc. sulfuric acid}} CO_2(g) + CO(g) + H_2O(l)$

- Acid residues and carbon dioxide are removed by passing the gas through a potassium hydroxide solution. Carbon monoxide can be collected over water because it is only slightly soluble.

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Key words

fractional distillation
hydrocarbon

Fractional distillation

- *Fractional distillation* is one of several processes used to refine crude oil. Refining converts crude oil into a range of useful products.
- Crude oil is a complex mixture of *hydrocarbons*. During fractional distillation, this mixture is separated into a series of fractions (components) on the basis of boiling point.
- The crude oil is passed through a furnace, where it is heated to 400°C and turns mostly into vapor. The gases pass into a distillation column within which there is a gradation of temperature. The column is hottest at the bottom and coolest at the top.
- Hydrocarbons with the highest boiling points are the first to condense at the bottom of the column, along with any remaining liquid residue from the crude oil. This fraction provides bitumen for use in road building.
- Rising up the column, other fractions condense out: first diesel oil, then kerosene, and finally gasoline. All of these fractions are used as fuels.
- The hydrocarbons with the lowest boiling points remain as gases and rise to the top of the column. This fraction is used as a fuel in the refinery.
- The hydrocarbon vapor moves up the column through a series of bubble caps. At each level, the hydrocarbon vapor passes through condensed hydrocarbon liquid. This helps to ensure a good separation into the various fractions.

Crude oil composition

- Crude oil varies in composition, depending on where it was obtained. Fractional distillation of different crude oils provides different proportions of the various fractions.

The fractional distillation of crude oil

1 Fractional distillation of crude oil

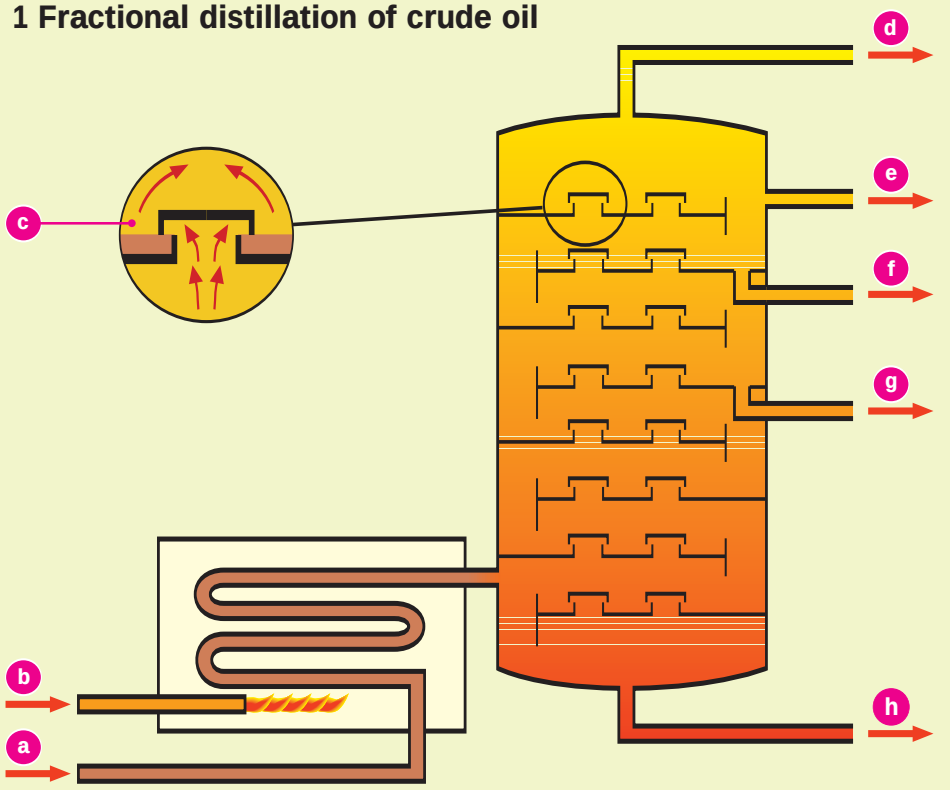

2 Crude oil composition (percent yields and uses of oil)

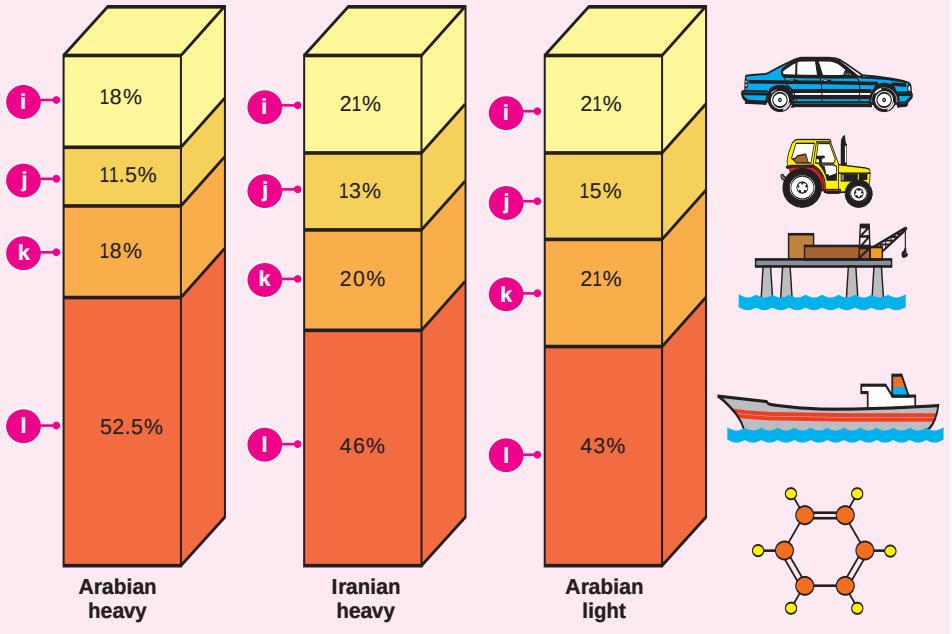

a crude oil
b heater
c bubble cap
d refinery gas
e gasoline (110°C)
f kerosine (180°C)
g diesel oil (260°C)
h residue — bitumen tar (400°C)
i gasoline and chemical feedstock
j kerosine
k gas oil
l fuel oil

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Other refining processes

1 Other refining processes

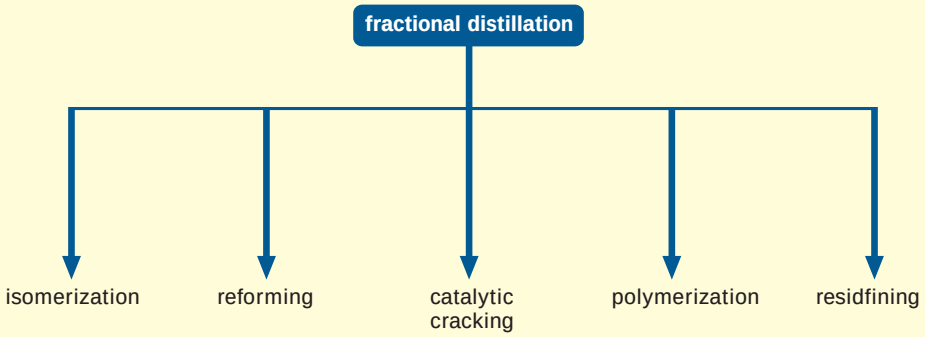

2 Isomerization

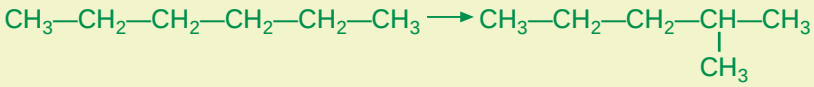

3 Reforming

Dehydration

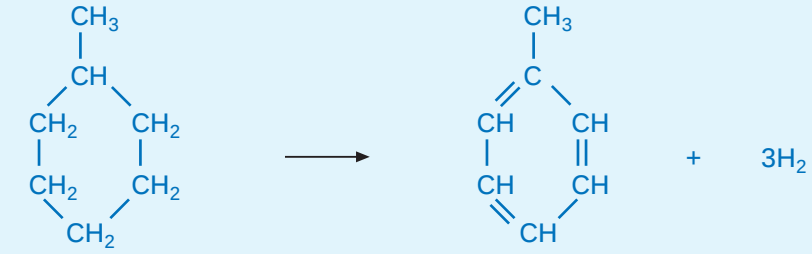

Cyclization

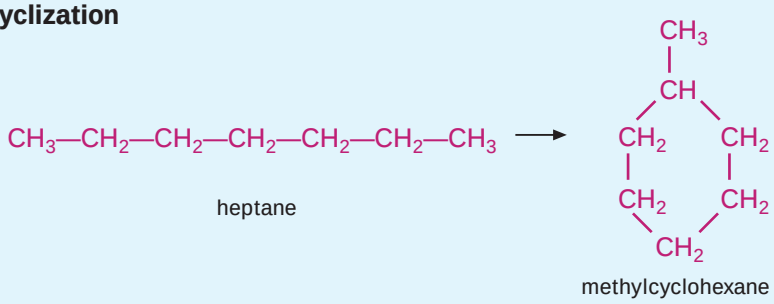

4 Catalytic cracking

Octane → propane and pent-1-ene

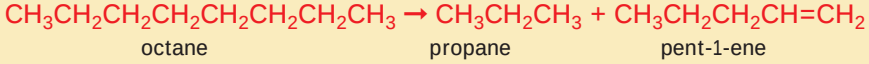

5 Polymerization

Two propene molecules combine to form hexene

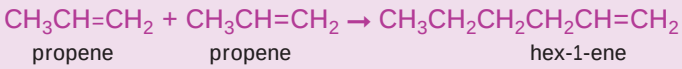

Key words

alkane
alkene
catalytic cracking
fractional distillation
isomerization
polymerization
reforming
residfining

1 Other processes

- Other refining processes are used to modify the products of *fractional distillation*. These include *isomerization*, *reforming*, *catalytic cracking*, *polymerization*, and *residfining*.

2 Isomerization

- Isomerization changes the shape of hydrocarbon molecules. For example, pentane is converted into 2-methlybutane.

3 Reforming

- Reforming converts straight chain molecules into branched molecules in order to improve the efficiency of gasoline. One type of reaction involves the dehydration of saturated compounds to unsaturated compounds. Another involves the cyclization of hydrocarbons.

4 Catalytic cracking

- In general, smaller hydrocarbon molecules, such as those in gasoline, are in greater demand than larger ones. Catalytic cracking redresses this balance by breaking (cracking) large alkane molecules into smaller *alkane* and *alkene* molecules.

5 Polymerization

- Polymerization combines small molecules to form larger molecules that can be used to make various products.

Residfining

- Resifining is the process used on the residue fraction to convert it into usable products. It also removes impurities that would damage the catalyst used in catalytic cracking.

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Key words

alkane
alkene
alkyne
bond
carbon
catenation
van der Waals forces

1 Catenation

- *Carbon* has the ability to form long chains of carbon atoms in its compounds. This is called *catenation*.

2 Melting and boiling points

- Forces of attraction, called *van der Waals forces*, exist between molecules. As molecular size increases, there is more overlap between the molecules, and the intermolecular forces of attraction increase.
- In order to melt and to boil, the forces of attraction between molecules must be overcome. The greater these forces, the more energy is needed. This is reflected in a steady increase in melting point and boiling point as molecules increase in size.

3 Types of bonds

- A carbon atom may form one, two, or three *bonds* with another carbon atom in its compounds. These bonds are described as single bonds (C–C), double bonds (C=C), and triple bonds (C≡C).
- *Alkanes* contain only carbon–carbon single bonds.
- *Alkenes* contain a carbon–carbon double bond.
- *Alkynes* contain a carbon–carbon triple bond.
- Alkanes, alkenes, and alkynes are all hydrocarbons since they consist only of hydrogen and carbon atoms.

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Carbon chains

1 Catenation

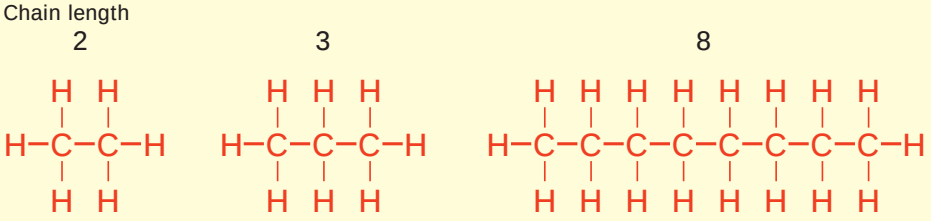

2 Melting and boiling points of some chains

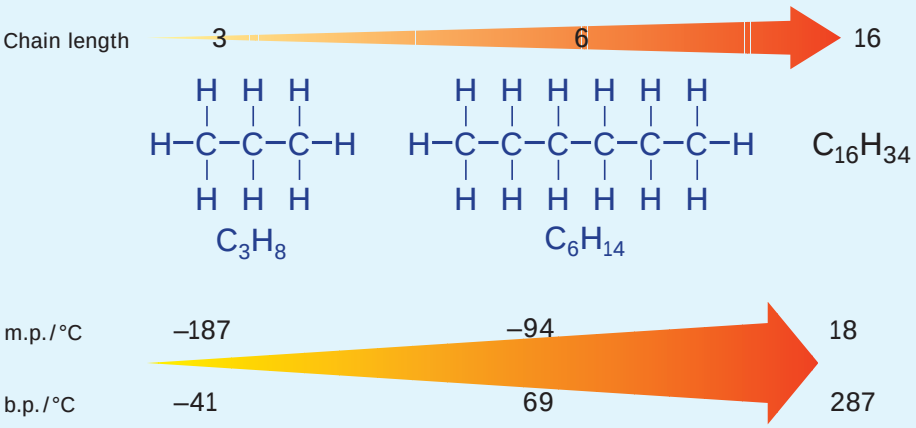

3 Types of bonds

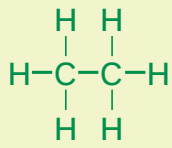

Alkanes

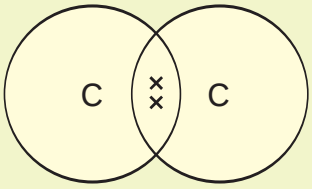

Single bond

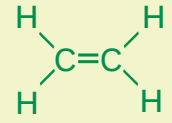

Alkenes

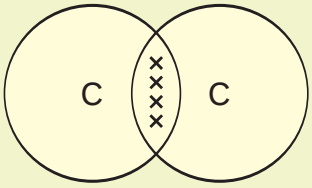

Double bond

Alkynes

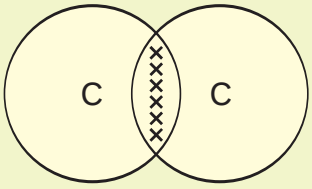

Triple bond

Naming hydrocarbons

1 Chain length gives first part of name

Chain length	C_1	C_2	C_3	C_4	C_5	C_6
First part of name	meth-	eth-	prop-	but-	pent-	hex-

2 Functional group gives second part of name

Functional group	Alkane	Alkene	Alkyne
	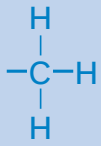	C=C	C≡C
Second part of name	-ane	-ene	-yne

3 Examples of organic compound names

Molecule	Chain length	Functional group	Name
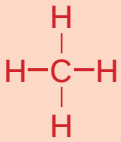	1 → meth-	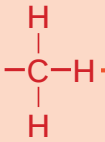 → -ane	methane
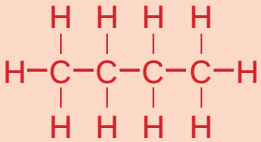	4 → but-	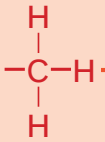 → -ane	butane
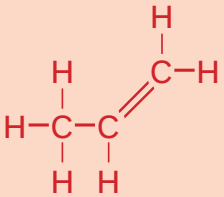	3 → prop-	C=C → -ene	propene
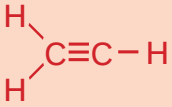	2 → eth-	C≡C → -yne	ethyne

Key words

alkane
alkene
alkyne
functional group
hydrocarbon

Naming hydrocarbons

- The name of a *hydrocarbon* indicates the number of carbon atoms in the molecule and what sort of carbon–carbon bonds is present.

1 Chain length

- The first part of name is determined by the number of carbon atoms in the molecule. The same prefixes are used for all groups of organic compounds.

2 Functional group

- The second part of the name is determined by the type of carbon–carbon bonds present. Each *functional group* has a unique suffix.
- The position of the functional group in a carbon chain is identified by numbering the carbon atoms in the carbon chain.

3 Examples of compound names

- The first two examples in the diagram are *alkanes*. If there is one carbon atom in the molecule it is:
  "meth" (1 carbon atom in the chain) + "ane" (for alkane): methane.
  If there are four carbon atoms in the molecule it is:
  "but" (4 carbon atoms in the chain) + "ane" (for alkane): butane.
- The third example is propane, an *alkene* with three carbon atoms:
  "pro" (3 carbon atoms in the chain) + "ene" (for alkene).
- The fourth example is ethyne, an *alkyne* with a two carbon chain:
  "eth" (2 carbon atoms in the chain) + "yne" (for alkyne).

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Key words

alkane
homologous series
hydrocarbon
van der Waals forces

The first six alkanes

- The *alkanes* form an *homologous series* of compounds that have the general formula C_nH_{2n+2}, where n is a positive integer. Each alkane molecule differs from the previous one in the series by $-CH_2-$.
- They have similar chemical properties and show a gradation of physical properties, such as melting point and boiling point, as the molecular size increases.
- Alkane molecules are attracted to each other by *van der Waals forces*. As molecular size increases, there is more overlap between the molecules, and the intermolecular forces of attraction increase.
- Alkane molecules are frequently shown as having a flat two-dimensional structure because this is easy to draw, but in reality, the four bonds around each carbon atom are directed toward the corners of a tetrahedron. The angle between any two bonds is 109.5°.
- Alkanes are relatively unreactive substances when compared with other groups of *hydrocarbons*. Their most important reaction is combustion, and they are the main constituent of a range of fuels. Natural gas is largely composed of methane:
  $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- In a good supply of air, hydrocarbons burn to give carbon dioxide and water. In a restricted supply of air, carbon monoxide and/or carbon may be formed:
  $C_2H_6 + 2O_2 \rightarrow CO + C + 3H_2O$

Table of the first six alkanes

Alkane	Methane	Ethane	Propane
Formula	CH_4	C_2H_6	C_3H_8
Structural formula	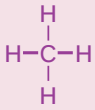	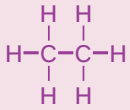	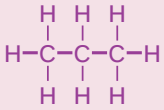
Boiling point (°C)	–164	–87	–42
Physical state at room temperature	Gas	Gas	Gas
Molecular model	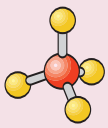	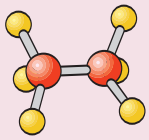	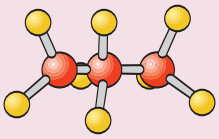

Alkane	Butane	Pentane	Hexane
Formula	C_4H_{10}	C_5H_{12}	C_6H_{14}
Structural formula	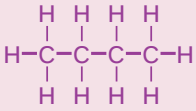	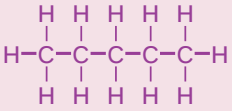	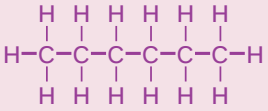
Boiling point (°C)	0	36	69
Physical state at room temperature	Gas	Liquid	Liquid
Molecular model	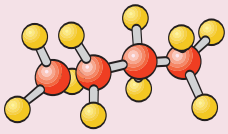	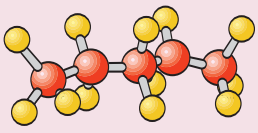	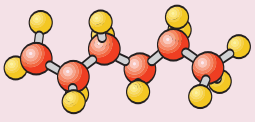

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Table of the first five alkenes

Alkene	Formula	Number of carbon atoms per molecule	Structural formula	Boiling point (°C)	Physical state at room temperature	Molecular model
Ethene	C_2H_4	2	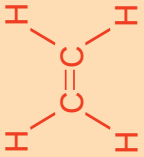	–104	Gas	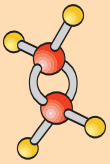
Propene	C_3H_6	3	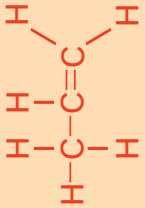	–47	Gas	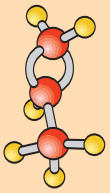
Butene	C_4H_8	4	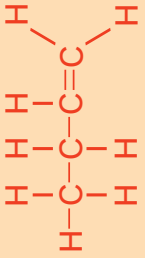	–6	Gas	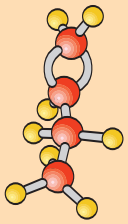
Pentene	C_5H_{10}	5	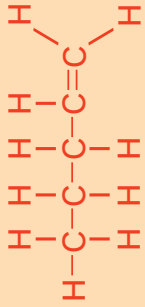	30	Liquid	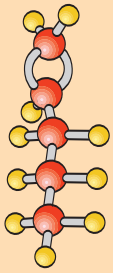
Hexene	C_6H_{12}	6	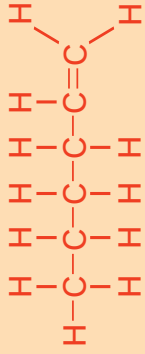	64	Liquid	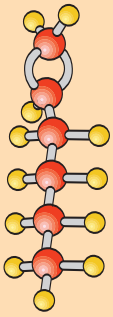

Key words

addition reaction
alkene
functional group
homologous series
van der Waals forces

The first five alkenes

- The *alkenes* form an *homologous series* of compounds with the general formula C_nH_{2n}, where n is a positive integer. Each alkene molecule differs from the previous one in the series by $-CH_2-$.
- Alkene molecules are attracted to each other by *van der Waals forces*. As molecular size increases, there is more overlap between the molecules, and the intermolecular forces of attraction increase. The series thus shows a gradation of physical properties, such as melting point and boiling point.
- Alkenes all contain the same *functional group*, a carbon–carbon double bond, represented by C=C.
- The bonds around each of the carbon atoms in a carbon–carbon double bond are in the same plane and directed toward the corners of an equilateral triangle. The angle between any two bonds is 120°.
- Alkenes undergo combustion in the same way as alkanes. However, they have other chemistry resulting from the reactive carbon–carbon double bond.
- Alkenes undergo addition reactions in which a molecule is added across the carbon–carbon double bond. For example, ethene undergoes the following *addition reactions*:

$CH_2=CH_2 + H\text{-}H \rightarrow CH_3\text{-}CH_3$
ethene + hydrogen → ethane

$CH_2=CH_2 + H\text{-}OH \rightarrow CH_3\text{-}CH_2\text{-}OH$
ethene + steam → ethanol

$CH_2=CH_2 + H\text{-}Br \rightarrow CH_3\text{-}CH_2Br$
ethene + hydrogen bromide → bromoethane

$CH_2=CH_2 + Br\text{-}Br \rightarrow CH_2Br\text{-}CH_2Br$
ethene + bromine → 1,2-dibromoethane

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Key words

alkene
ethane
ethene
ethanol
geometric isomerism
halogens
isomer

Ethene

- *Ethene* is the first member of the *alkene* series. It is a colorless, flammable gas.

1 Preparation

- In the laboratory, ethene can be made by the dehydration of *ethanol* using concentrated sulfuric acid.

2 Structure

- Ethene, like all alkenes, contains a carbon–carbon double bond about which rotation is impossible.

3 Isomerism

- *Isomers* are compounds having the same molecular formula and relative molecular mass but different three-dimensional structures.
- The existence of two compounds with the same molecular formula but where groups are distributed differently around a carbon–carbon double bond is described as *geometric isomerism* or cis / trans isomerism.
- The prefix “cis” is used when the substituent groups (an atom or group of atoms substituted in place of a hydrogen atom or chain) of a hydrocarbon are or the same side of a plane through the carbon–carbon double bond. The prefix “trans” is used when the substituent groups are on the opposite side.
- In trans-1,2-dibromoethene the bromine atoms are on opposite sides of a plane through the carbon–carbon double bond.
- In cis-1,2-dibromoethene the bromine atoms are on the same side.

4 Reactivity

- The carbon–carbon double bond in ethene is very reactive and will undergo various addition reactions. Ethene reacts with: *halogens* (such as chlorine) to form 1,2-dihaloethane, hydrogen to form *ethane*, and hydrogen halides to form haloethane.

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Ethene

1 Dehydration of ethanol to produce ethene

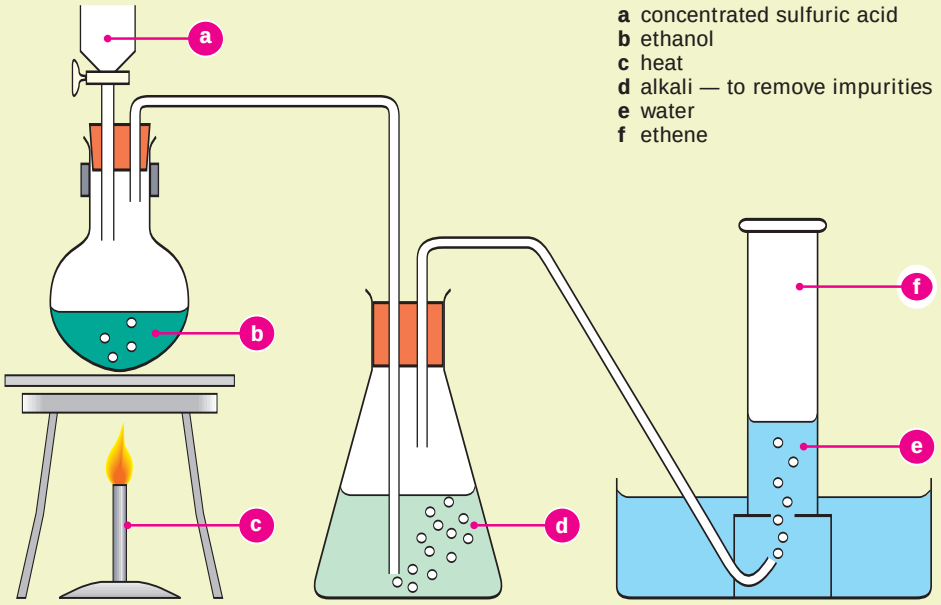

$$CH_3CH_2OH \xrightarrow{-H_2O} CH_2{=}CH_2$$

ethanol — ethene

2 Structure

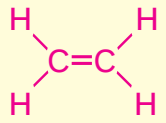

Ethene

3 Isomerism

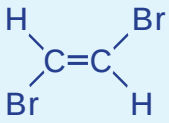

Trans-1, 2-dibromoethene

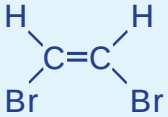

Cis-1, 2-dibromoethene

4 Reactivity

$$CH_2{=}CH_2 + Cl_2 \longrightarrow CH_2Cl{-}CH_2Cl$$

Reaction with chlorine to form 1, 2-dichloroethane

$$CH_2{=}CH_2 + H_2 \xrightarrow{Ni} CH_3CH_3$$

Reaction with hydrogen to form ethane

$$CH_2{=}CH_2 + HX \longrightarrow CH_3CH_2X$$

Reaction with hydrogen halides to form haloethane

Polymers

1 Types of branching

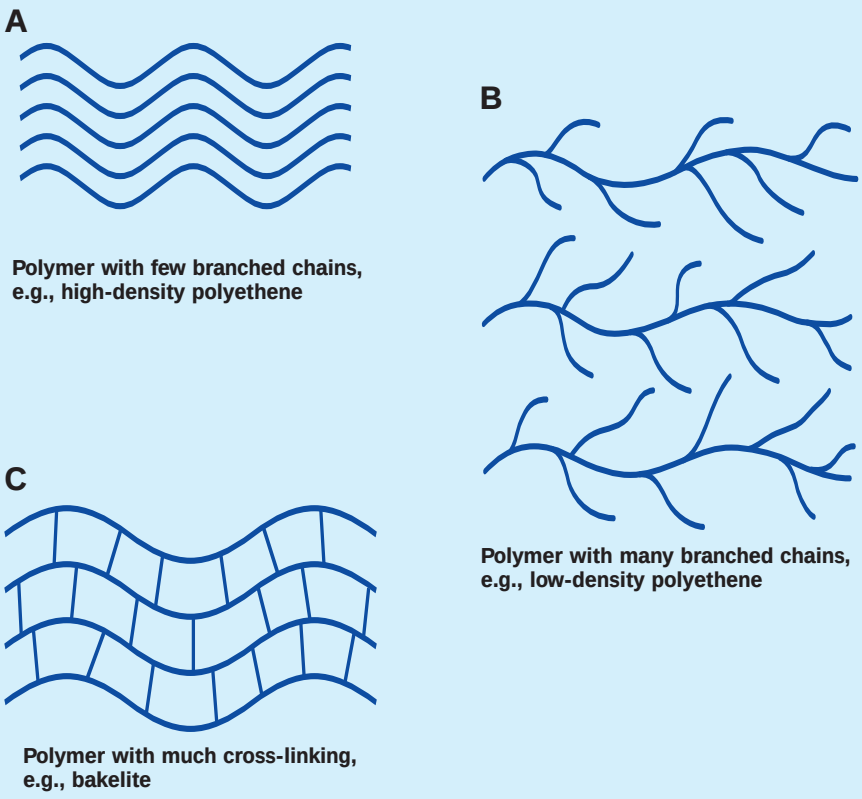

2 Additional polymerization (illustrating how ethene can be restructured to form poly(ethylene) i.e., polyethene)

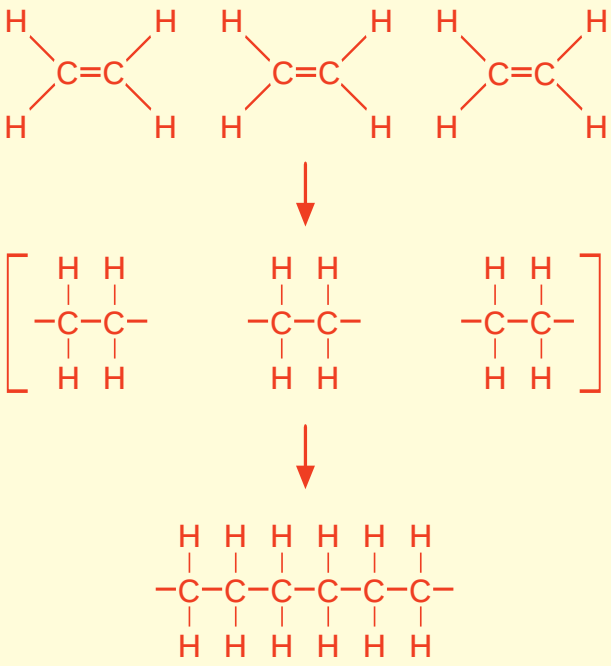

Key words

addition polymerization
bakelite
ethene
polyethene
polymer
polymerization

Polymers

- A *polymer* is a large organic molecule composed of repeating carbon chains. The physical properties of a polymer depend on the nature of these carbon chains and how they are arranged.

1 Types of branching

- A certain amount of side branching occurs during *polymerization*, depending on the reaction conditions.
- Low pressure and low temperature results in a high-density polymer.
- Very high pressure and moderate temperatures produce a low-density polymer.
- In high-density polymers, the carbon chains are unbranched, and they can be packed closely together forming a dense substance, e.g., high-density *polyethene* (1A).
- In low-density polymers, the carbon chains are branched, and it is not possible to pack them as closely together, e.g., low-density polyethene (1B).
- In polymers like *bakelite*, there are cross links between the carbon chains, producing a hard, rigid structure (1C).

2 Addition polymerization

- *Ethene* forms a polymer by a process called *addition polymerization*.
- In this process, one of the bonds from the carbon–carbon double bond is used to form a bond with an adjacent molecule. This process is repeated many times, resulting in long chains containing thousands of carbon atoms.

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Key words

alkene *polymer*
monomer

Monomers

- *Monomers* are the basic units from which a polymer is made.
- The systematic name for a *polymer* is derived from the name of the monomer. For example, polypropene is "poly" (for polymer) + the *alkene* propene.
- The diagrams at right illustrate the formation of some alkene polymers.

1 Forming polypropene

- Propene molecules combine to form polypropene.
- Most polypropene is produced as a monopolymer (a polymer formed from propene only).

2 Forming polychloroethene

- Chloroethene molecules combine to form polychloroethene.
- 1,2-dichloroethane is made by chlorinating ethene. This product is then cracked to form chloroethene.

3 Forming polyphenylethene

- Phenylethene molecules combine to form polyphenylethene.
- Phenylethane is made from ethene and benzene by a Friedel-Crafts reaction using aluminum(III) chloride/hydrochloric acid catalyst. This is dehydrogenated to give the phenylethene monomer.

4 Forming polytetrafluoroethene

- Tetrafluoroethene molecules combine to form polytetrafluoroethene.
- Trichloromethane is produced by the reaction of methane with controlled amounts of chlorine/hydrochloric acid. This is reacted with anhydrous hydrogen fluoride in the presence of antimony(III) chloride to give chlorodifluoromethane, which is subsequently cracked to produce tetrafluoroethene.

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Polymers: formation

1 Restructuring of propene to make poly(propene)

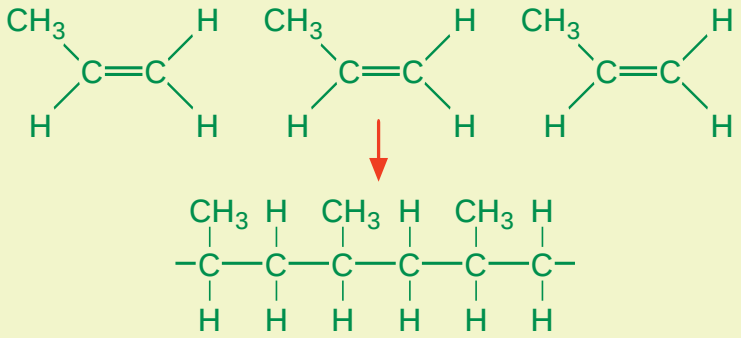

2 Restructuring of chloroethene to make poly(chloroethene) i.e., polyvinylchloride

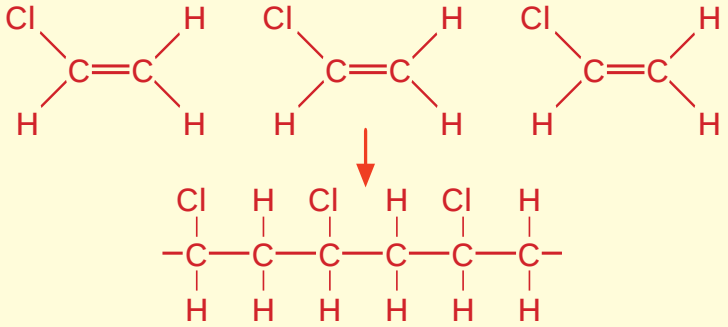

3 Poly(phenylethene)

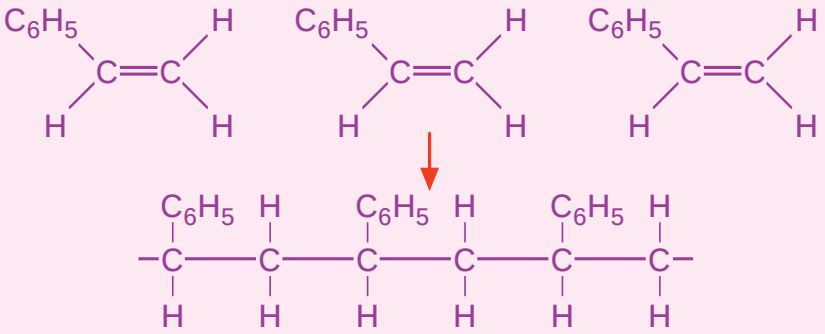

4 Poly(tetrafluoroethene)

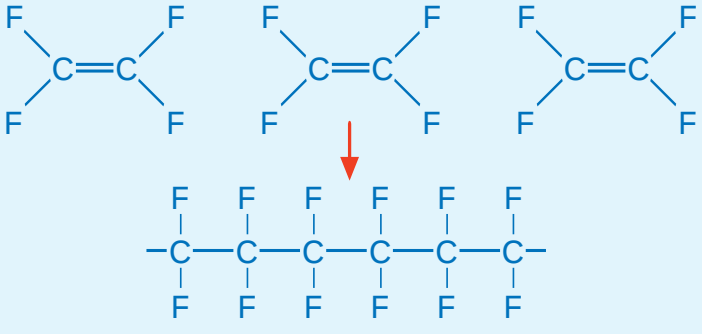

Polymers: table of properties and structure

Polymer systematic name	Polymer common name	Properties	Uses	Structure of monomer
Poly(ethene)	Polyethene	low density; high density	film and bags; molding rigid articles	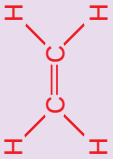
Poly(propane)	Polypropylene	high density	molding rigid articles, film and fibers	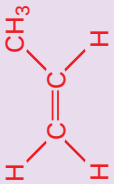
Poly(chloroethene)	PVC (polyvinylchloride)	flexible	coating fabrics and insulation on wires and cables	
Poly(phenylethene)	Polystyrene	brittle but cheap	plastic toys, expanded with air and used for insulation	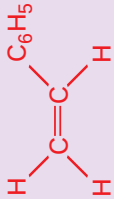
Poly(ethene)	PTFE (polytetrafluoroethene)	low friction and stable to heat	non-stick coating on pans	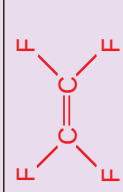
Poly(methyl-2-methyl-propenoate)	Perspex	transparent	substitute for glass	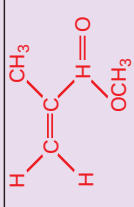
Poly(propenenitrile)	Acrilan	strong fibers	wool substitute in textiles	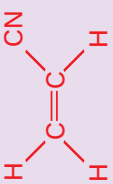

Key words

monomer
polymer
polymerization

Polymers

- Most *polymers* have common names that are used in everyday language.
- The uses of polymers depend on their properties.

Classification

- There are several ways in which polymers can be classified.
- Heat. Thermoplastics soften when heated and harden on cooling, so they can be reshaped many times without changing their chemical structure. Thermosets are chemically altered on heating and produce a permanently hard material that cannot be softened by heating.
- Method of polymerization. Addition polymers are usually formed from *monomers* containing a –CH=CH- unit to which different atoms or groups are attached. On *polymerization*, one of the carbon–carbon bonds becomes a bond to another unit. Condensation polymers are formed from condensation reactions in which a small molecule, sometimes but not always water, is lost.
- Formula. Homopolymers are formed from one monomer unit. Co-polymers are formed from two or more monomers.
- Chemical structure. Linear chains may have straight, zigzag, coiled, or random spatial arrangements. Branched chains have side branch chains attached to the main chains. Cross-linked chains have two or three dimensional cross-linkage between chains.
- Steric structure. Isotactic: in which all side groups are on the same side of the main chain. Syndiotactic: in which each alternative side group has the same orientation. Atactic: in which there is no specific pattern to the distribution of side groups.

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Key words

alcohol
alkene
carboxylic acid
ester
functional group
homologous series
oxidation

Functional groups

- A *functional group* is the atom or group of atoms present in a molecule that determines the characteristic properties of the molecule.
- A *homologous series* is a group of compounds that contain the same functional group. The physical properties of a homologous series show a gradation as molecular size increases. The chemical properties of a homologous series are similar because they are determined by the functional group.

1 Alkenes

- *Alkenes* contain the functional group C=C.
- Their general formula is C_nH_{2n}.
- Alkenes are reactive and undergo additional reactions.

2 Alcohols

- *Alcohols* contain the functional group C-OH.
- Their general formula is $C_nH_{2n+1}OH$.
- Alcohols can also undergo *oxidation* to give carboxylic acids, or they can be dehydrated to alkenes. They can also react to form ester compounds

3 Carboxylic acids

- *Carboxylic acids* contain the functional group -COOH.
- Carboxylic acids are typically weak acids that partially dissociate into H^+ cations and $RCOO^-$ anions in aqueous solution.
- Carboxylic acids are widespread in nature.

4 Esters

- *Esters* contain the functional group $-COOC^-$.
- Esters are formed by a reaction between a carboxylic acid and an alcohol.
- Esters are used in flavorings and perfumes.

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Functional groups and homologous series

Functional group	Example
1 Alkenes	**Propene**
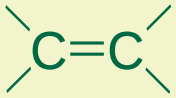	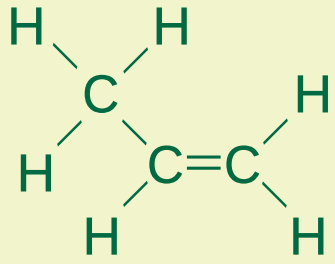
2 Alcohols	**Ethanol**
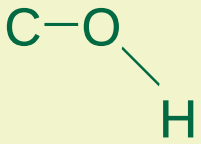	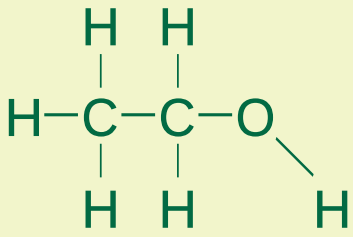
3 Carboxylic acids	**Ethanoic acid**
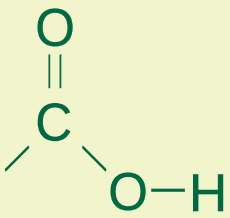	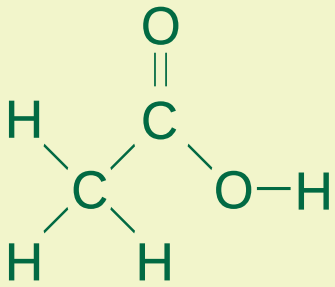
4 Esters	**Methylethanoate**
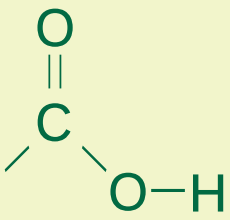	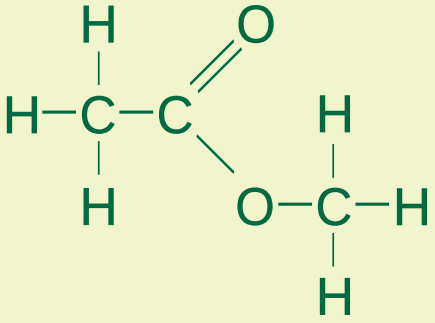

Alcohols

1 The first six alcohols

Structure	Name
CH_3-OH	methanol
CH_3CH_2-OH	ethanol
$CH_3CH_2CH_2$-OH	propan-1-ol
$CH_3CH_2CH_2CH_2$-OH	butan-1-ol
$CH_3CH_2CH_2CH_2CH_2$-OH	pentan-1-ol
$CH_3CH_2CH_2CH_2CH_2CH_2$-OH	hexan-1-ol

2 Classification

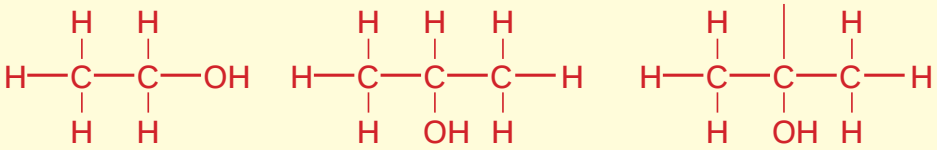

Primary alcohol | Secondary alcohol | Tertiary alcohol

3 Sharing of electrons

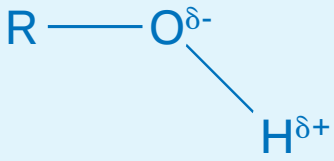

4 Hydrogen bonding

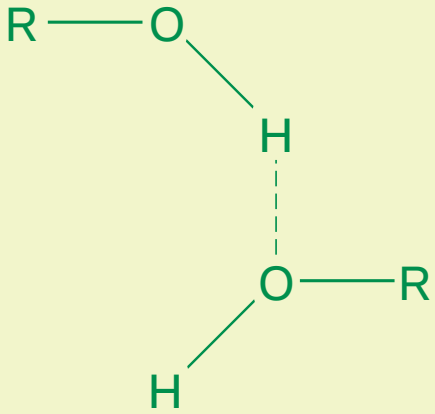

Key words

alcohol
alkane
functional group
hydrogen bond

1 Naming

- *Alcohols* are named by dropping the terminal "e" from the *alkane* chain and adding "ol." For example, methane is the alkane; methanol is the alkanol, or alcohol. When necessary, the position of the hydroxyl (-OH) group is indicated by a number between the alkane name and the "ol," e.g., propan-1-ol, or in front of the name, e.g., 2-propanol.

2 Classification

- Alcohols may be classified as primary, secondary, or tertiary on the basis of the number of carbon atoms bonded to the carbon carrying the *functional group* (-OH).

3 Sharing of electrons

- An oxygen atom is more electronegative than a hydrogen atom, and this leads to an unequal sharing of the electrons in the O-H bond. The bonding electrons are drawn more toward the oxygen atom and, because the electrons carry a negative charge, the oxygen atom becomes slightly negative. This is described as delta minus and is denoted by δ-. Conversely, the hydrogen atom becomes slightly positive—delta plus, denoted by δ+. (R represents the carbon group attached to the oxygen.)

4 Hydrogen bonding

- The -OH functional group generally makes the alcohol molecule polar. It has a positive charge at one end and a negative at the other. Molecules can form *hydrogen bonds* with one another and other compounds when the oppositely charged parts are attracted to each other, forming hydrogen bonds.

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Key words

alkali
carbonate
carboxylic acid
dissociation
homologous series
pH
salt

1 Naming

- *Carboxylic acids* are named by adding the suffix "anoic acid" to the prefixes used for all *homologous series* of organic compounds. For example, the carboxylic acid containing three carbon atoms is "prop" + "anoic acid" = "propanoic acid."

2 Hydrogen bonding

- Hydrogen bonding is present between carboxylic acid molecules, resulting in higher boiling points than might otherwise be expected and miscibility with water.

3 Ionization

- Carboxylic acids ionize to give hydrogen ions, H^+; however, they are weak acids because they are only partially ionized.
- The *dissociation* constant for ethanoic acid, for example, is 1.75×10^{-5} mol^3dm^{-6}. This means that only about 4 molecules in every 1,000 are ionized at any one time.

Characteristics

- Carboxylic acids have a *pH* value of approximately 3–5.
- Carboxylic acids react with *carbonates* and hydrogencarbonates to produce carbon dioxide:

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

$H^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_2(g)$

- Carboxylic acids form *salts* with *alkalis*:

$CH_3COOH(aq) + NaOH(aq) \rightarrow$

ethanoic acid sodium hydroxide

$CH_3COO^-Na^+(aq) + H_2O(l)$

sodium ethanoate water

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Carboxylic acids

1 The first six carboxylic acids

Structure	Name
$CHOOH$	methanoic acid
CH_3COOH	ethanoic acid
CH_3CH_2COOH	propanoic acid
$CH_3CH_2CH_2COOH$	butanoic acid
$CH_3CH_2CH_2CH_2COOH$	pentanoic acid
$CH_3CH_2CH_2CH_2CH_2COOH$	hexanoic acid

2 Hydrogen bonding

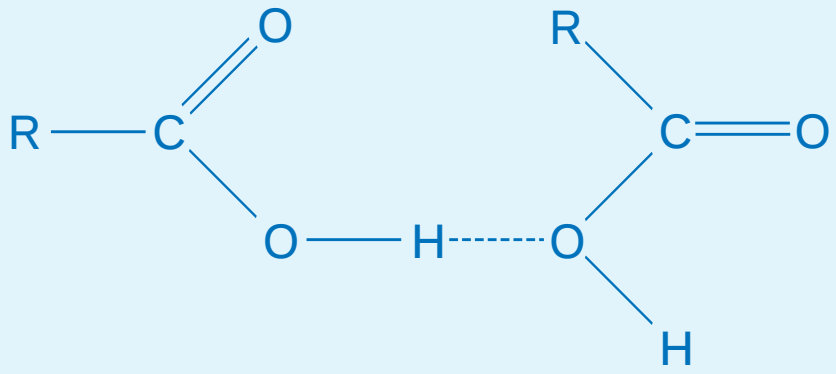

3 Ionization

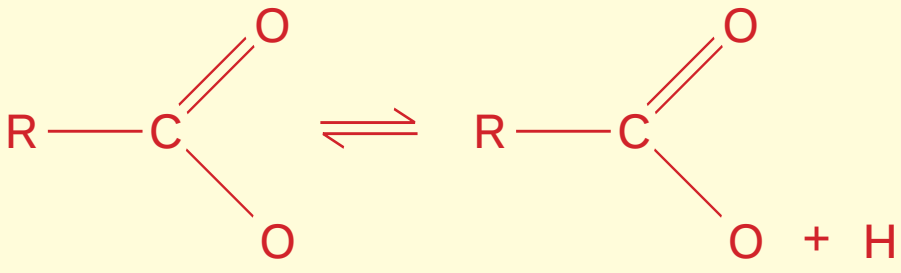

Esters

1 Forming esters

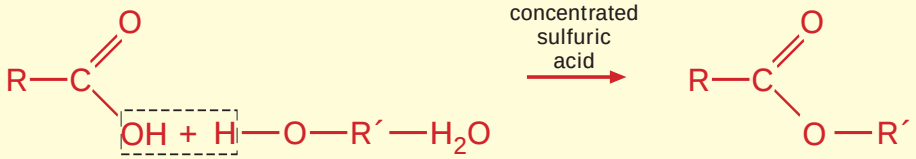

2 Naming

Structure of ester	Name of ester
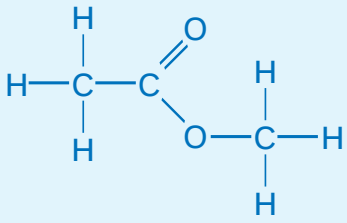	methyl ethanoate
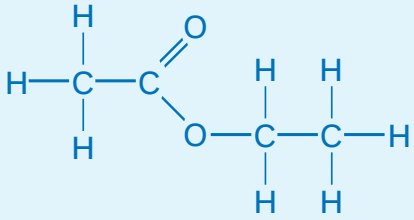	ethyl ethanoate
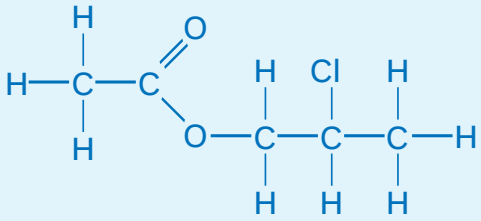	propyl ethanoate
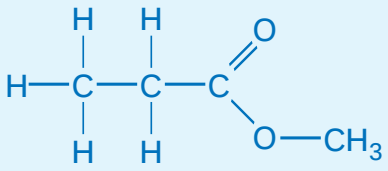	methyl propanoate

3 Saponification

Key words

alcohol
alkyl
aryl
carbon
carboxylic acid
ester
functional group
saponification

Esters

- *Esters* contain the *functional group* –COOR, where R is an *alkyl* or an *aryl* group.

1 Forming esters

- Esters are formed by the reaction of *carboxylic acids* with *alcohols* in the presence of a strong acid catalyst, such as concentrated sulfuric acid. The reaction involves the loss of water.
- Esters generally have a fruity smell that can be used to identify their presence. They are used for food flavorings and in cosmetics.
- Esters have no –OH group, so they cannot form hydrogen bond like carboxylic acids and alcohols. Consequently, they are more volatile and are insoluble in water.

2 Naming

- The name of an ester is derived from the carboxylic acid and the alcohol from which it is formed.
- The alcohol part of an ester is written at the beginning of the ester name; from methanol we get methyl, from ethanol we get ethyl, etc.
- The acid part of an ester is written at the end of the ester name. It is written as if it was an ionic carboxylate group in a salt; from ethanoic acid we get ethanoate, from propanoic acid we get propanoate, etc.

3 Saponification

- When esters are heated with an alkali, such as sodium hydroxide, they are readily hydrolyzed to form an alcohol and a carboxylic acid salt.
- This may be described as a *saponification* reaction. It is important in the production of soaps from fats and oils.

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Key words

carboxylic acid
detergent
ester
fatty acid
hydrophilic
hydrophobic
soap

Soaps and Detergents

- *Soaps* are cleansing agents made from *fatty acids* derived from natural oils and fats. *Detergents* are made from synthetic chemical compounds.

1 Fatty acids

- *Carboxylic acids* occur in animal and plant fats and oils. They may contain from 7 to 21 carbon atoms and are often referred to as fatty acids.

2 Making soap

- Most naturally occurring fats and oils are *esters* of propane-1,2,3-triol (glycerine). When the fats are boiled with sodium hydroxide, propane1,2,3,-triol and a mixture of sodium salts of the three carboxylic acids are formed. These salts are what we call soaps.

3 Soap molecule

- One end of a soap molecule is ionic, while the other end is covalent. The ionic end is described as *hydrophilic* because it dissolves in water. Conversely, the covalent end is described as *hydrophobic* because it does not dissolve in water, but it will dissolve in organic substances like oils.

4 Cleaning action

- The cleaning action of soap is the result of the different affinities of the two ends of the soap molecule.
- The hydrophobic end of the molecule dissolves in oils and fats on the fabric, while the hydrophilic end of the molecule remains in the water.
- The oil and fat particles are lifted off the fabric and held in the water by soap molecules.

5 Detergent molecule

- Alkylbenzene sulfonates are common examples of detergents.

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Soaps and detergents

1 Common fatty acids

Name	Formula	Found in
palmitic acid	$CH_3(CH_2)_{14}COOH$	animal and vegetable fats
stearic acid	$CH_3(CH_2)_{16}COOH$	animal and vegetable fats
oleic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	most fats and oils
linoleic acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	soya-bean oil and nut oil

2 Making soap

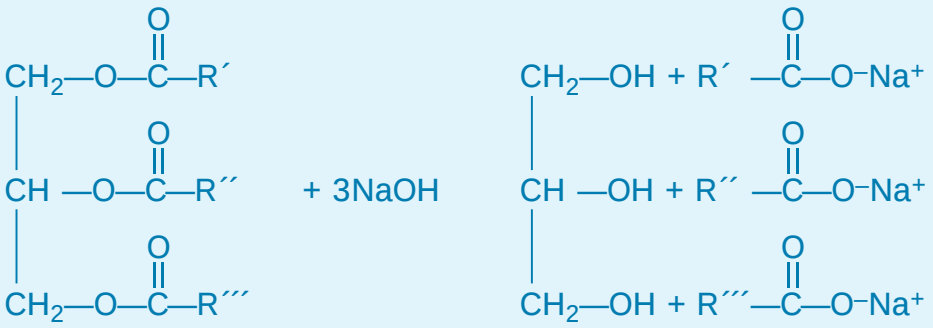

3 Soap molecule

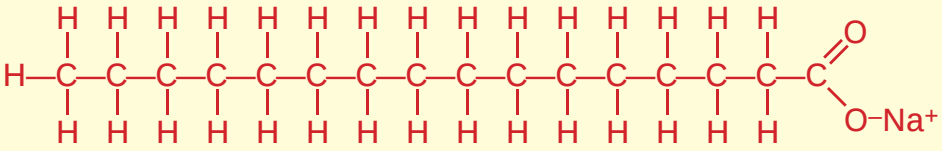

4 Cleaning action

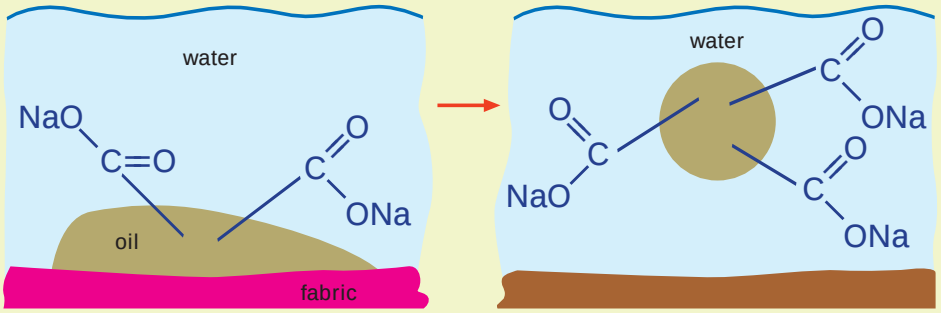

5 Detergent molecule

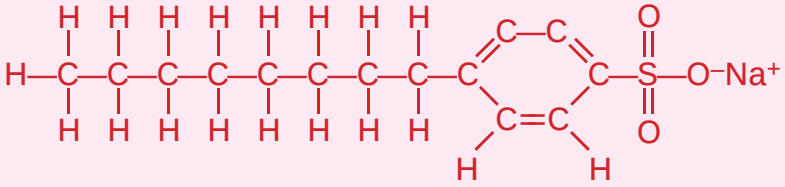

Organic compounds: states

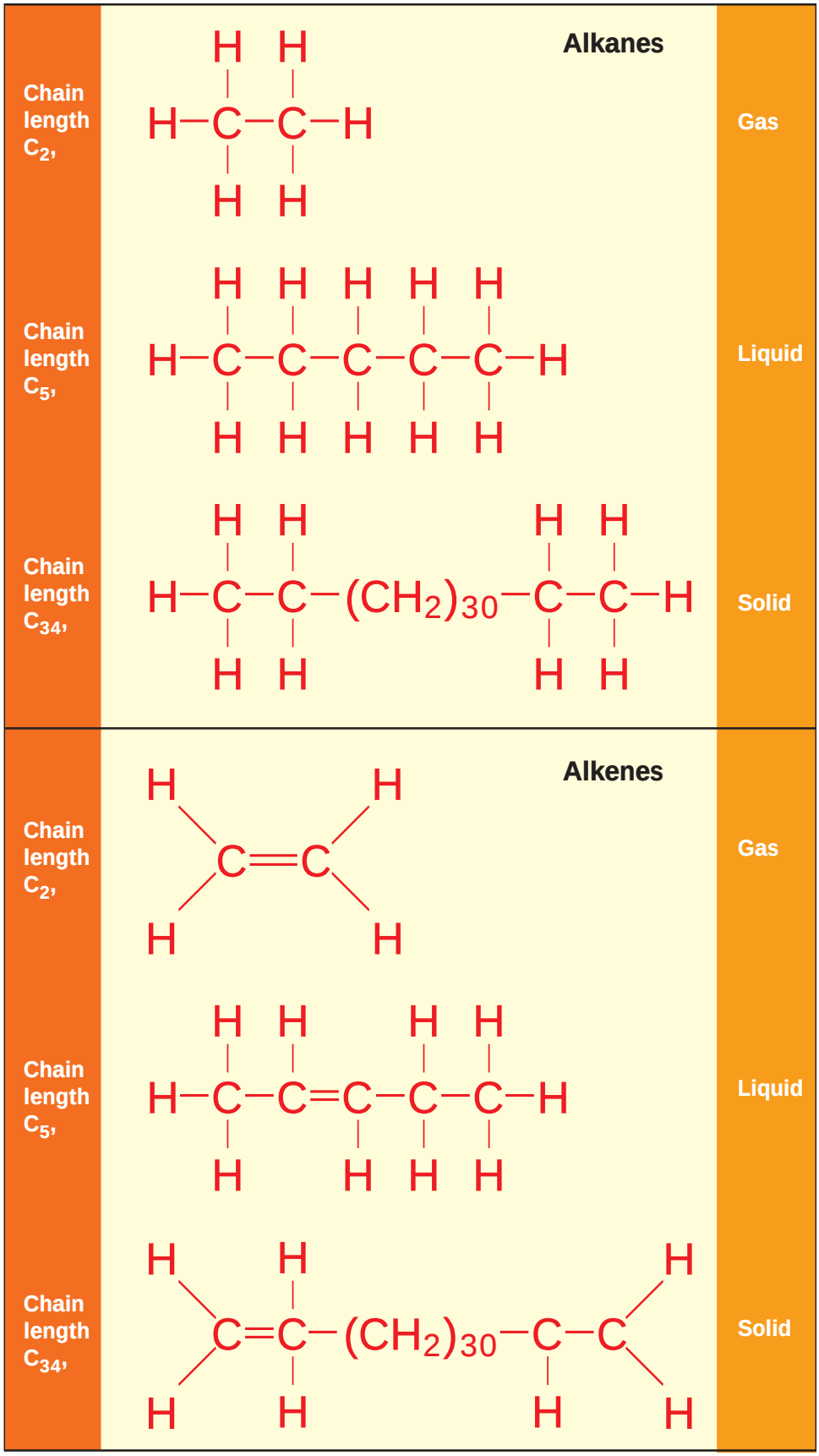

Key words

alkane
alkene
homologous series

Physical properties

- All *homologous series* of compounds show a gradation of physical properties as the carbon chain length increases.

Alkanes

- The simplest *alkane* is CH_4, methane. The next simplest alkane is the two carbon alkane, ethane (C_2H_6). Both of these are gases.
- The five carbon alkane, pentane (C_5H_{12}), is a liquid.
- The 34 carbon compound, butadecane is a solid.

Alkenes

- The simplest *alkene* is the two carbon alkene, ethene (C_2H_4), which is a gas.
- 2-pentene (C_5H_{10}), which is a five carbon alkene, is a liquid.
- 2-butedecane, which is a 34 carbon alkene, is a solid.

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Key words

alcohol
aldehyde
alkene
carboxylic acid
ester
functional group
homologous series
ketone
polymer

Functional groups and properties

- All members of an *homologous series* of compounds has the same *functional group*. Because the functional group determines most of the chemistry of a compound, members of a particular homologous series will have similar chemical reactions.
- *Alkenes* are unsaturated compounds because they all contain a carbon–carbon double bond that makes them very reactive. Typically, they will undergo addition reactions with hydrogen, halogens, and water. They also form a variety of *polymers*.
- *Alcohols* with a small relative molecular mass are flammable liquids and readily dissolve in water. Primary alcohols are readily oxidized: first to *aldehydes* and then to *carboxylic acids*. Secondary alcohols are oxidized to *ketones*:

$$R\text{-}CH_2\text{-}OH \xrightarrow{[O]} R\text{-}CHO \xrightarrow{[O]} R\text{-}COOH$$

primary alcohol → aldehyde → carboxylic acid

$$R\text{-}CHOH\text{-}R \xrightarrow{[O]} R\text{-}CO\text{-}R$$

secondary alcohol → ketone

- Carboxylic acids are weak acids since they only partially ionize. They have similar reactions to fully ionized mineral acids but they react with less vigor. Sodium salts of carboxylic acids are ionic compounds. Those with short carbon chains are readily soluble in water.
- *Esters* are volatile liquids or low-melting solids. They are usually insoluble in water but soluble in ethanol and diethyl ether. Esters have sweet fruity smells and are used in perfumes, flavorings, and essences.

Functional groups and properties

Class of compound	Example	Functional group
Alkene	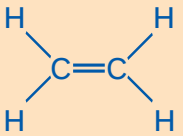 Ethene	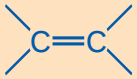
Alcohol	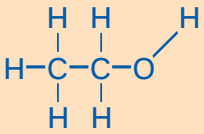 Ethanole	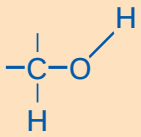
Carboxylic acid	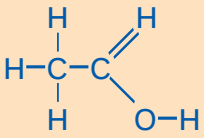 Ethanoic acid	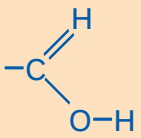
Ester	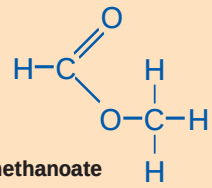 Methyl methanoate	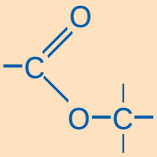

Class of compound	Typical chemical property
Alkene	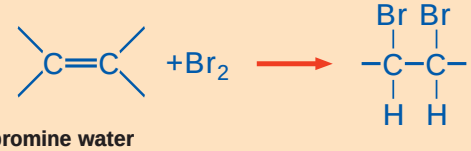 Decolorizes bromine water
Alcohol	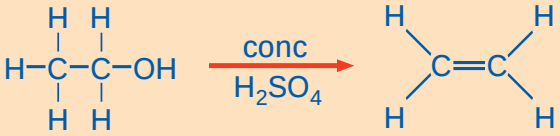 Decolorizes bromine water
Carboxylic acid	$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COO^-Na^+ + CO_2\uparrow + H_2O$ Reacts with sodium carbonate solution
Ester	$HCOOH_3 + NaOH \rightarrow HCOO^-Na^+ + CO_3OH$ Can be hydrolized by alkali

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Reaction summary: alkanes and alkenes

Alkanes

Combustion

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

Substitution

$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$

Cracking

$C_8H_{18} \longrightarrow H_2C = CH_2 + C_6H_{14}$

Alkenes

Hydrogenation

$H_2C = CH_2 + H_2 \longrightarrow H_3C - CH_3$

Substitution

$H_2C = CH_2 + Br_2 \longrightarrow$

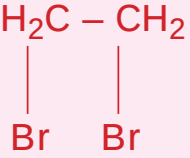

General reaction alkene to alkane

$nCH_2 = CH_2 \longrightarrow (CH_2 - CH_2)_n-$

Key words

addition polymerization
alkane
alkene
solvent

Reaction of alkanes and alkenes

- Both *alkanes* and *alkenes* burn readily in a good supply of air to produce carbon dioxide and water.
- Crude oil is a complex mixture of alkanes, which are separated into fractions (components) on the basis of boiling point during the refining process. Some of these fractions provide gasoline, diesel, aviation fuel, and fuel oil.
- The quality of gasoline (how smoothly it burns) in indicated by its octane number, which ranges from 0–100: the higher the octane number the smoother burning the gasoline. The octane number is the percentage by volume of 2,2,4-trimethylpentane (also known as iso-octane) in a mixture of 2,2,4-trimethylpentane and heptane, which has the same knocking characteristics as the gasoline being tested.
- Historically, tetraethyllead(IV) $Pb(C_2H_5)_4$ was added to gasoline as an anti-knock additive to make it burn more smoothly. A growing knowledge of the poisonous nature of lead has resulted in the development of lead-free fuels in which other anti-knock additives, such as MTBE (methyltert-butyl ether), are used.
- Crude oil contains no alkenes, but they are produced in cracking and other refining processes. Alkenes are important feedstock for *addition polymerization* but are also used in gasoline blending, making plasticizers, and as *solvents*.
- Much of the chemistry of the alkenes is the result of the reactive nature of the carbon–carbon double bond. Alkenes undergo addition reactions with a variety of substances.

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Key words

alcohol
aldehyde
carboxylic acid
ester
ethanol
ethene
oxidizing agent

1 Alcohols

- The majority of the world's annual production of *ethanol* is made by the catalytic hydration of *ethene*. A mixture of ethene and steam at 300°C and 70 atmospheres is passed over a phosphoric acid catalyst.
- Ethanol is also made industrially by the fermentation of carbohydrates.
- It can also be prepared in the laboratory using concentrated sulfuric acid and heat.
- Ethanol burns readily in air. In some countries it is used as a blending agent in motor fuels.
- *Alcohols* can be oxidized to *carboxylic acids* by heating with a suitable *oxidizing agent* such as acidified potassium dichromate. The oxidation involves two stages and goes via a group of compounds called *aldehydes*. Under suitable conditions, the ethanal can be removed from the reaction mixture before it is further oxidized to ethanoic acid.

2 Acids

- Salts of short-chain carboxylic acids, like sodium ethanoate, are ionic compounds and are soluble in water.
- Ethanoic acid and ethanol react in the presence of a concentrated sulfuric acid catalyst to form the *ester* ethyl ethanoate. This reaction is reversed by heating ethyl ethanoate with an alkali such as sodium hydroxide solution. The sodium salt formed, sodium ethanoate, can be neutralized by dilute mineral acid to regenerate ethanoic acid.

ethanoic acid + ethanol $\xrightarrow{\text{esterification}}$ ethyl ethanoate

ethyl ethanoate $\xrightarrow{\text{hydrolysis}}$ ethanoic acid + ethanol

Reaction summary: alcohols and acids

Alcohols

Preparation in industry

$$CH_2 = CH_2 + H_2O \xrightarrow[+70\ \text{Atmospheres}]{H_3PO_4\ \text{at}\ 300°C} CH_3CH_2OH$$

Fermentation

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{catalyst}]{\text{enzyme}} 2C_6H_{12}O_6 \xrightarrow[\text{catalyst}]{\text{enzyme}} 4CH_3CH_2OH + 4CO_2$$

Preparation in the laboratory

$$CH_2 = CH_2 + H_2O \xrightarrow[+\ \text{heat}]{\text{conc}\ H_2SO_4} CH_3CH_2OH$$

Oxidation by burning

$$CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

Oxidation by oxidizing agent

$$CH_3CH_2OH \xrightarrow{K_2CR_2O_7 + \text{dil}\ H_2SO_4} CH_3 + COOH$$

Reaction to produce an ester

$$CH_3CH_2OH + CH_3CO_2H \xrightarrow[H_2SO_4]{\text{conc}} H_2O + CH_3CO_2CH_2CH_3$$

Organic acids

Reaction giving ionic salt

$$CH_3CO_2 + NaOH \longrightarrow CH_3COO^-Na^+ + H_2O$$

Reaction giving covalent ester

$$CH_3CO_2 + CH_3CH_2OH \longrightarrow CH_3COOCH_2CH_3 + H_2O$$

Reaction giving hydrolysis of an ester

$$CH_3COOCH_2CH_3 + NaOH \longrightarrow CH_3COO^-Na^+ + CH_3CH_2OH$$

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Optical isomerism

1 Chiral molecule

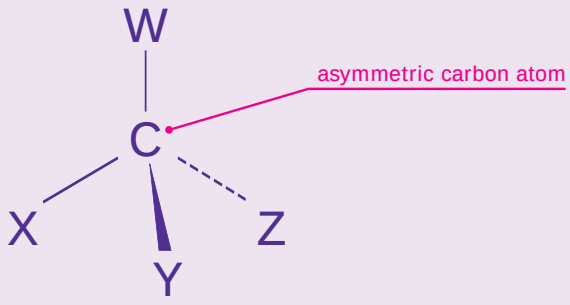

2 Enantioners

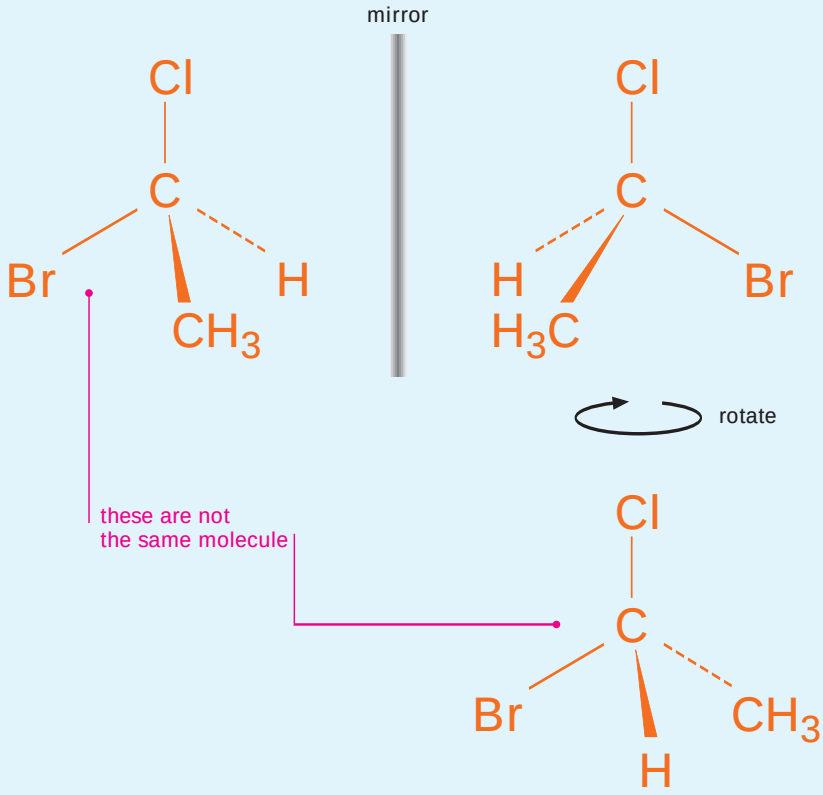

3 Optical activity

Polarized light	→	dextro-rotatory or (+) rotatory
	←	laevo-rotatory or (–) rotatory

Key words

chiral
enantiomer
optical isomerism
racemate

Optical isomerism

- *Optical isomerism* is a form of isomerism in which two isomers are the same in every way except that they are mirror images that cannot be superimposed on each other.

1 Chiral molecule

- When four different groups are attached to a carbon atom, the resulting molecule has no symmetry. The molecule is said to be *chiral*, and the carbon atom at the center is described as asymmetric.

2 Enantiomers

- 1-bromo-1-chloroethane is a chiral molecule. It exists in two forms, called *enantiomers*, that differ only in the way that the bonds are arranged in space.
- The enatiomers of a chiral molecule are mirror images of each other and cannot be superimposed on each other.

3 Optical activity

- Chiral molecules are said to be optically active since they rotate the plane of polarized light. If polarized light is passed through a solution containing only one of the enantiomers, the plane of the light will be rotated either to the right (dextro-rotatory) or to the left (laevo-rotatory). A similar solution containing only the other enantiomer will rotate the plane of the light by the same amount in the opposite direction.
- A solution containing equal amounts of the enantiomers is called a racemic mixture or *racemate*. It is optically inactive since the two effects cancel each other out.

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Key words

amine
amino acid
carboxylic acid
functional group
optical isomerism
protein
zwitterion

1 Amino acids

- *Amino acids* are compounds that contain both *amine* (-NH_2) and a *carboxylic acid* (-COOH) *functional groups.*
- Amino acids are generally crystalline solids that decompose on melting. They are soluble in water and insoluble in organic solvents such as ethanol.

2 Alanine

- Like most α-amino acids, alanine contains an asymmetric carbon atom and exhibits *optical isomerism*. There are two forms of alanine; L-alanine and D-alanine (L = laevo-[left] rotatory; D = dextro-[right] rotatory.)

3 Zwitterions

- In aqueous solution, amino acids are able to form ions that carry both positive and negative charge. Such ions are called *zwitterions.* They form by the loss of a proton from the carboxylic acid group and the gain of a proton on the amine group.

4 Proteins

- *Proteins* are polymers consisting of long chains of amino acids. The amino acids join together forming peptide bonds by the loss of water:

$$H_2N\text{-}CHR\text{-}COOH + H_2N\text{-}CHR\text{-}COOH \xrightarrow{-H_2O} H_2N\text{-}CHR\text{-}CONH\text{-}CHR\text{-}COOH$$

- All of the amino acids in proteins are the L-isomers.

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Amino acids and proteins

1 Amino acids

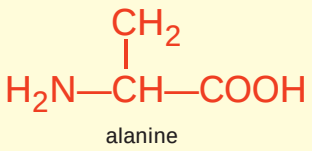

alanine

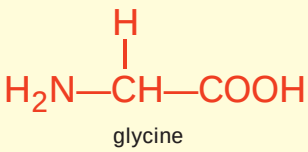

glycine

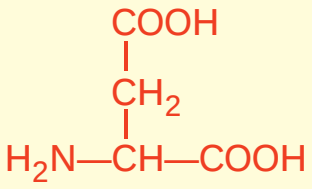

aspartic acid

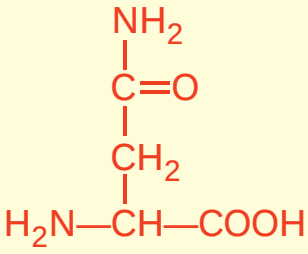

asparagine

2 Alanine

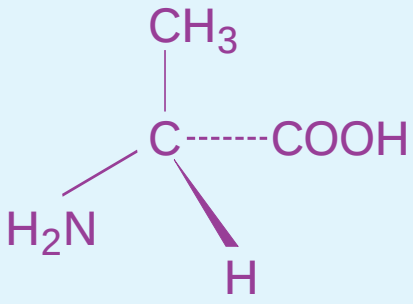

L-alanine

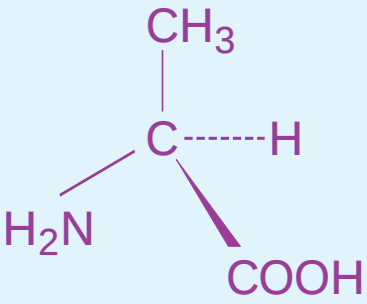

D-alanine

3 Zwitterions

4 Proteins

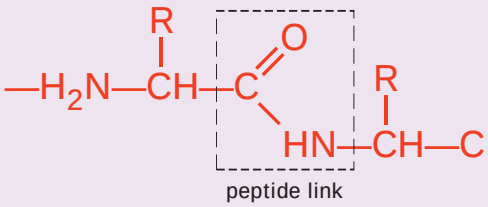

peptide link

Monosaccharides

1 Chain structure

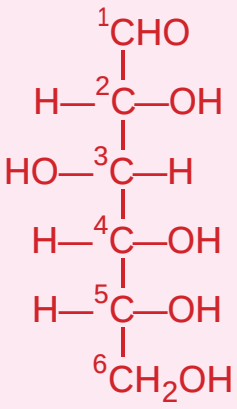

D-glucose

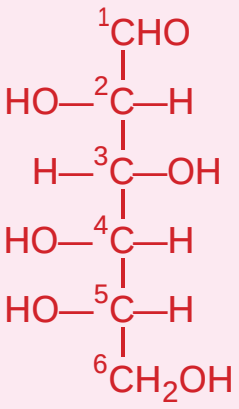

L-glucose

2 Ring structure

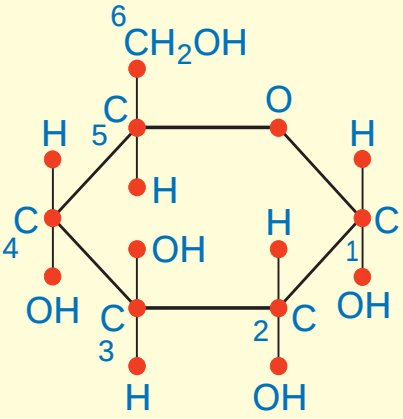

α-D-glucose

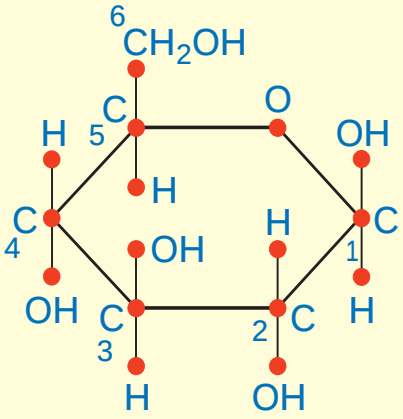

β-D-glucose

3 Hexagonal ring

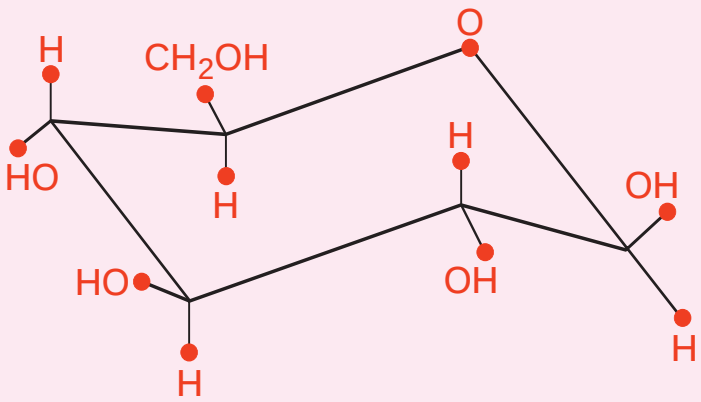

Key words

aldehyde
aldohexose
aldose
anomer
glucose
hexose
monosaccharide

Monosaccharides

- *Monosaccharides* are simple sugars that have between three and six carbon atoms. Those with six carbon atoms are known as the *hexoses* and have the general formula $C_6H_{12}O_6$.
- Monosaccharides with an *aldehyde* group (-CHO) are called *aldoses*.
- *Glucose* has both an aldehyde group and six carbon atoms and is therefore an *aldohexose*.

1 Chain structure

- For simplicity, monosaccharides are sometimes displayed as vertical open chain structures to which the -H and –OH groups are attached.
- Aldohexoses contain four asymmetrical carbon atoms: C-2, C-3, C-4, and C-5. There are 8 different possible ways of arranging the –H and –OH groups on these carbon atoms, and each of these has two optical isomers, making a total of 16.
- The most important of these are the two optical isomers of glucose.
- For glucose the D- and L- indicate the configuration of the –H and –OH groups on C-5.

2 Ring structure

- In reality, solid monsaccharides do not exist as open chain structures but as ring structures.
- In Howarth projections of monosaccharides, groups are shown on vertical bonds above and below a flat hexagonal ring.
- D-glucose can exist in two separate crystalline forms known and α-D-glucose and β-D-glucose. These forms are known as *anomers*.

3 Hexagonal ring

- The hexagonal ring in a monosaccharide is not flat but in the form of a chair.

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Key words

cellulose
disaccharide
glycogen
monosaccharide
polysaccharide
starch
sucrose

Di-and polysaccharides

- A *disaccharide* is formed when two *monosaccharides* join together. A molecule of water is lost and a glycosidic link is formed.
- A *polysaccharide* is a polymer formed by the joining of many monosaccharide units.

1 Sucrose

- *Sucrose*, the sugar widely used on foods, is a disaccharide.

2 Cellulose

- *Cellulose*, a polysaccharide, provides plant cells with a rigid structure.

3 Starch

- *Glycogen* is the storage polysaccharide of animals.
- *Starch* is the storage polysaccharide of plants.

Disaccharides and polysaccharides

1 Sucrose

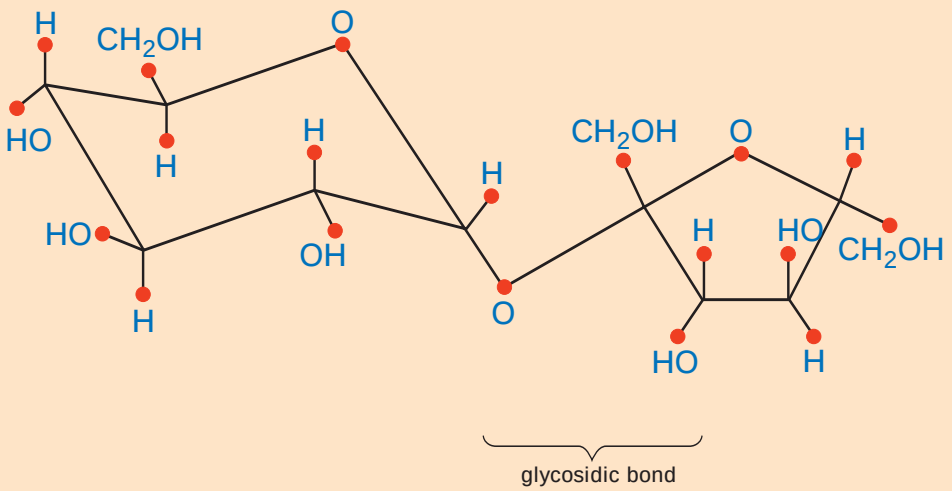

2 Cellulose

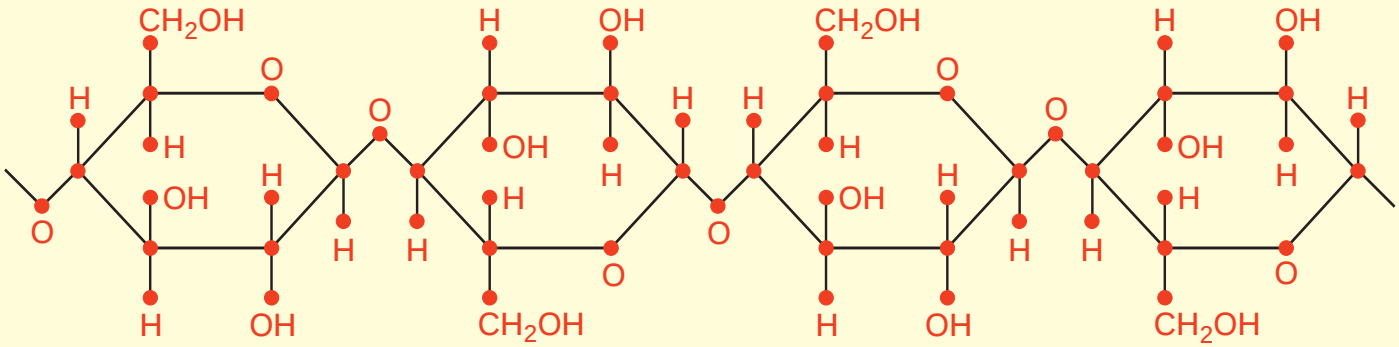

3 Starch

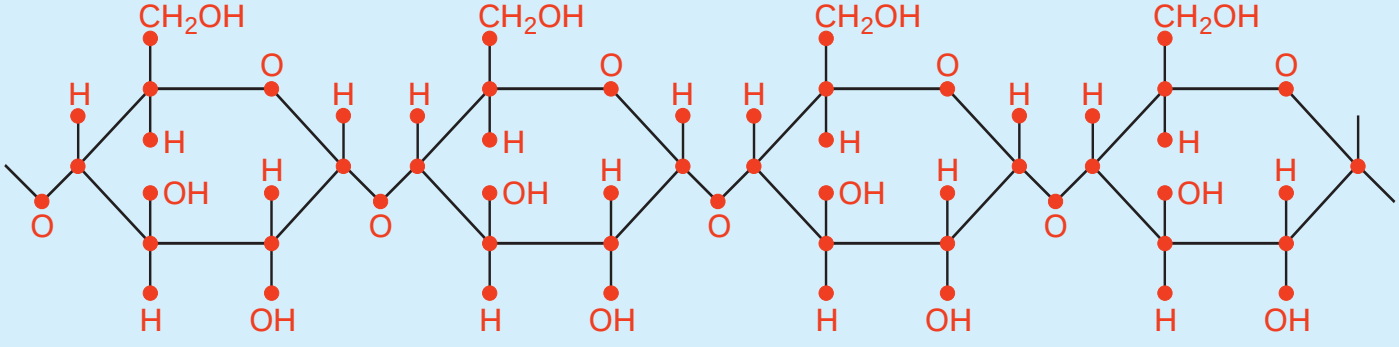

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Ionizing radiation

1 Alpha particles

α-radiation consists of a stream of α particles

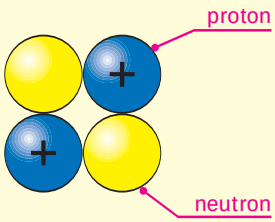

Produces intense ionization in a gas

2 Beta particles

β-radiation consists of a stream of β particles

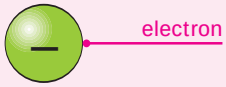

Produces less intense ionization in a gas than a particles

3 Gamma radiation

γ-radiation is a form of electromagnetic radiation

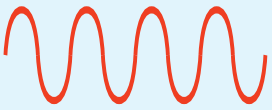

Wavelength $<10^{-12}$ m
Frequency $>10^{21}$ Hz

Only weakly ionizes a gas

4 Radiation in laboratories

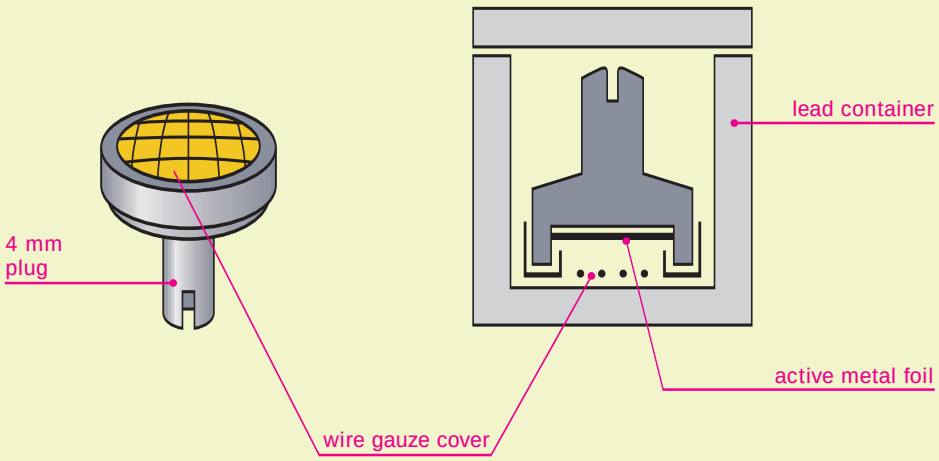

Key words

alpha particle
beta particle
gamma radiation
ionizing radiation

Ionizing radiation

- *Ionizing radiation* is any radiation capable of displacing electrons from atoms or molecules and so producing ions. Examples include *alpha particles*, *beta particles*, and *gamma radiation*.

1 Alpha particles

- An alpha (α) particle has the same structure as a helium nucleus (two protons and two neutrons).
- Alpha particles are relatively heavy, high-energy particles with a positive charge.
- Alpha particles produce intense ionization in a gas.
- Emission speeds are typically of the order of 5–7 percent of the speed of light.

2 Beta particles

- A beta (β) particle is a fast-moving electron with a negative charge.
- Beta particles produce less ionization in a gas than alpha particles and on average produce only 1/1000th as many ions per unit length.
- Emission speeds can be as high as 99 percent of the speed of light.

3 Gamma radiation

- Gamma (γ) rays ionize gas only weakly and on average produce only 1/1000th as many ions per unit length as beta particles.

4 Radiation in laboratories

- Sources of radiation used for laboratory experiments are usually supplied mounted in a holder. The active material is sealed in metal foil, which is protected by a wire gauze cover. When not in use, the material is stored in a small lead container.

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Radiation detectors

Key words

ionizing radiation
radiation
radioactivity

Detectors

- *Radioactivity* is invisible, but because it affects the atoms that it passes, scientists can easily detect it using a variety of methods.

1 Spark counter

- High voltage is applied between the stiff wire (anode) and the gauze (cathode) and reduced until it just stops sparking.
- When a radium source is brought near the gauze, the air between the wire and the gauze is ionized, and sparks are seen and heard at irregular intervals.

2 Cloud chamber

- When air containing ethanol vapor is cooled, it becomes saturated. If *ionizing radiation* passes through this air, further cooling causes the vapor to condense on the ions created in the air. The result is a white line of tiny liquid droplets that shows up as a track when illuminated.

3 GM tube

- When *radiation* enters the metal tube, either through the mica window or through the tube wall, it creates argon ions and electrons. These are accelerated toward the electrodes and collide with other argon atoms. On reaching the electrodes, the ions produce a current pulse, which is amplified before being fed to a pulse counter.

4 Testing absorption

- The ability of materials to absorb alpha, beta, and gamma radiation can be tested by placing the material between a radioactive source and a GM tube and comparing the count per minute with the count over the same period when the material is removed.

1 Spark counter

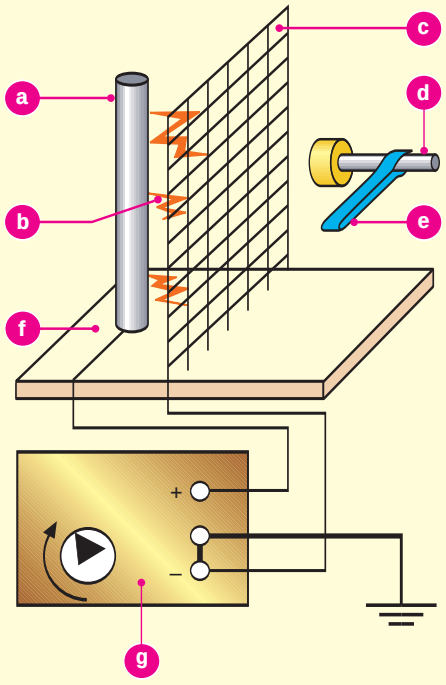

2 Cloud chamber

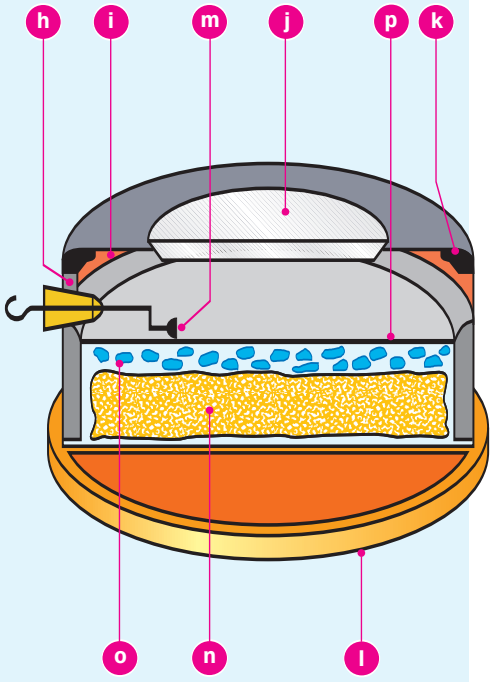

3 Geiger-Muller tube (GM tube)

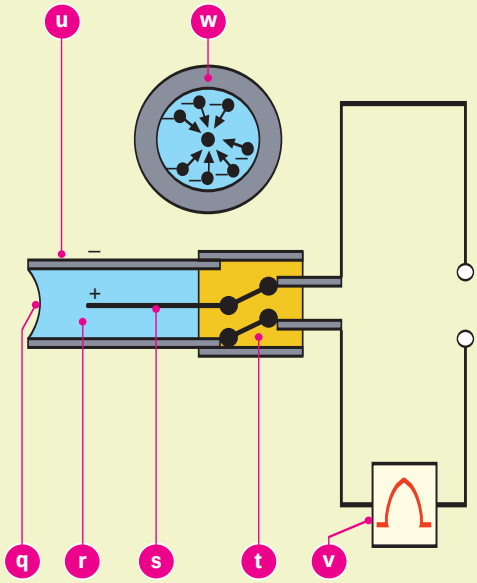

4 Testing absorbtion of alpha, beta, and gamma radiation

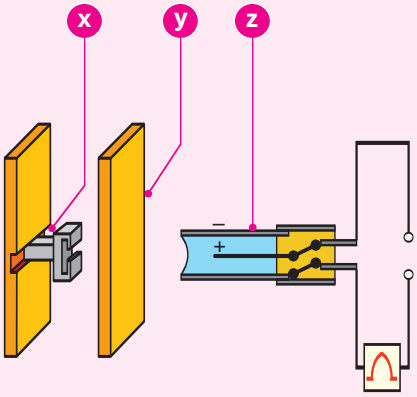

a stiff wire (anode)
b sparks
c wire gauze (cathode)
d radium source
e forceps
f insulating base
g E.h.t. supply
h circular transparent plastic chamber
i super-cooled vapor
j transparent lid
k felt strip soaked with alcohol and water
l base
m radioactive source
n foam sponge
o crushed dry ice
p black metal base plate
q mica window
r argon gas at low pressure
s anode wire
t insulator
u cathode metal tube
v pulse counter
w electrons are pulled toward the anode wire in an avalanche
x source
y absorbing material
z GM tube

Properties of radiations: penetration and range

1 Penetration of radiation

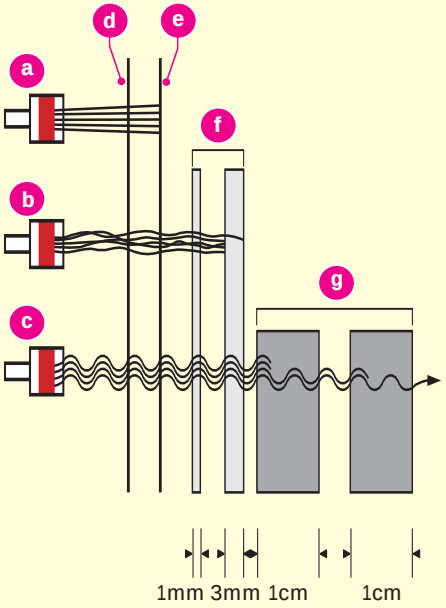

a α – source
b β – source
c γ – source
d metal foil
e paper
f aluminum
g lead

2 Range of radiation in air

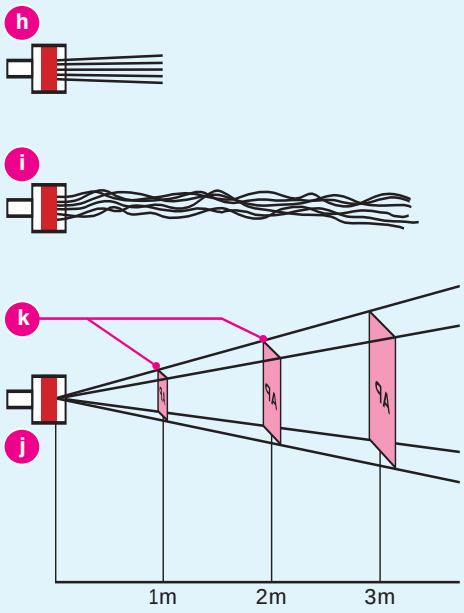

h α – a few centimeters
i β – a few meters
j γ – many meters
k area covered by γ radiation at 1m distances

3 The inverse square law for gamma radiation penetration

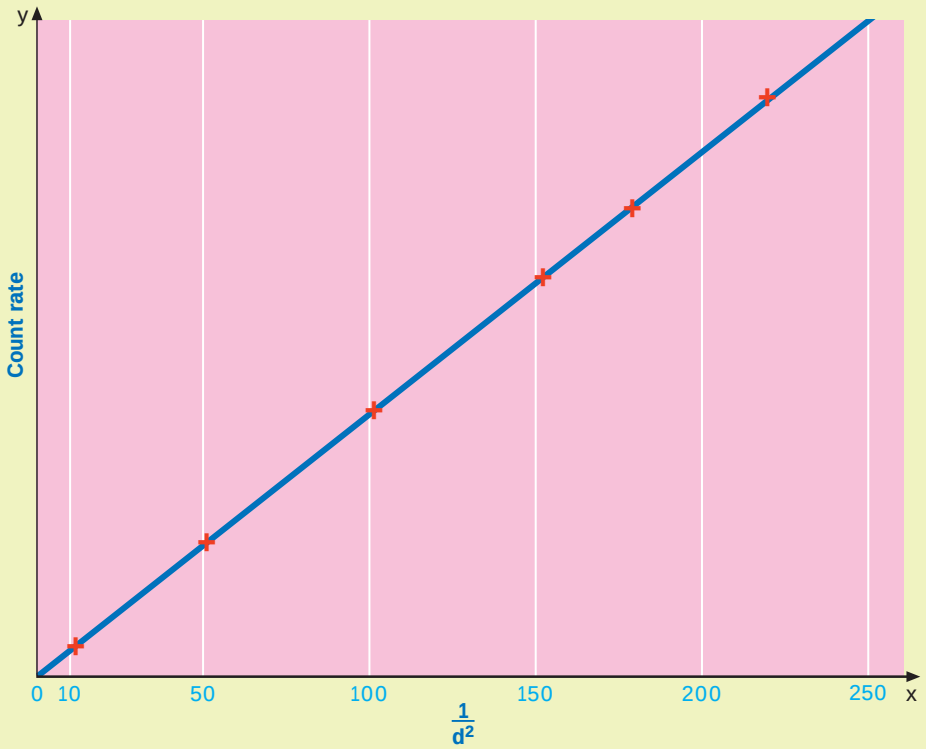

Key words

alpha particle
beta particle
gamma radiation
radiation

1 Penetration

- Alpha, beta, and *gamma radiation* penetrate by different amounts.
- Alpha radiation is the least penetrating and is stopped by a sheet of paper or very thin metal foil.
- Beta radiation is stopped by aluminum a few millimeters thick.
- Gamma radiation is most penetrating, and is only stopped by a thick block of lead.

2 Range

- The penetrating power of alpha, beta, and gamma radiation is reflected in the distance that they can travel through air. *Alpha particles* can only travel a few centimeters before colliding with air particles. *Beta particles* travels a few meters, while gamma radiation can travel many meters.

3 Gamma penetration

- Gamma rays are highly penetrating because they have relatively little interaction with matter. There is very little absorption or scattering as they pass through air.
- The intensity falls off with distance according to the inverse square law:

$$I = \frac{k}{d^2}$$

where I is intensity, d is the distance from the source, and k is a constant. At a distance x, the intensity of the gamma radiation:

$$I_x = \frac{k}{x^2}$$

At a distance 2x, the intensity of the gamma radiation:

$$I_{2x} = \frac{k}{(2x)^2} = \frac{k}{4x^2}$$

As the distance increases by a factor of 2, the intensity of the gamma radiation decreases by a factor of 4.

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Key words

alpha particle
beta particle
electric field
gamma radiation

Electric and magnetic fields

- An *electric field* is a field extending outward in all directions from a charged particle.
- A magnetic field is an area of force that exists around a magnetic body or a current-carrying conductor. Alpha, beta, and gamma radiation behave differently in both.

1 Electric field

- Alpha radiation is composed of positively charged particles. A stream of *alpha particles* is deflected when passing through the electric field between two oppositely charged plates. The particles are repelled from the positively charged plate and attracted toward the negatively charged plate.
- Beta radiation is composed of negatively charged particles. A stream of *beta particles* is deflected by an electric field in the opposite direction to alpha particles. The deflection is greater because the beta particles have a much smaller mass.
- *Gamma radiation* is not deflected by an electric field. This is evidence that gamma radiation carries no charge.

2 Magnetic field

- Alpha radiation is deflected by a strong magnetic field. Weak magnetic fields have no noticeable effect due to the greater mass of alpha particles compared to beta particles.
- Beta radiation is deflected by a relatively weak magnetic field. Beta radiation is deflected in the opposite direction to alpha radiation, indicating its particles carry an opposite charge.
- Gamma radiation is not deflected by a magnetic field, indicating that gamma radiation carries no charge.

Properties of radiations: in fields

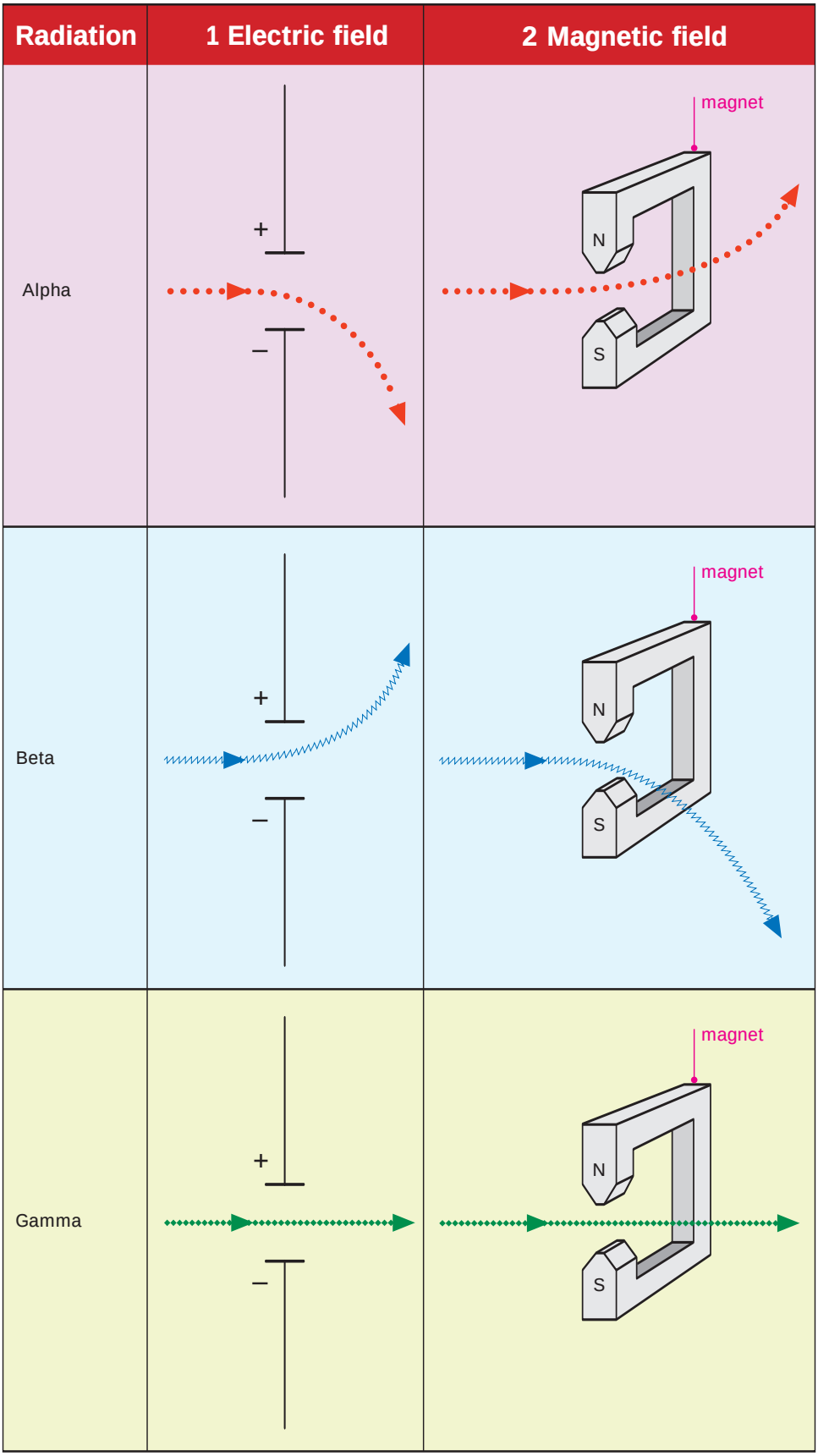

Stable and unstable isotopes

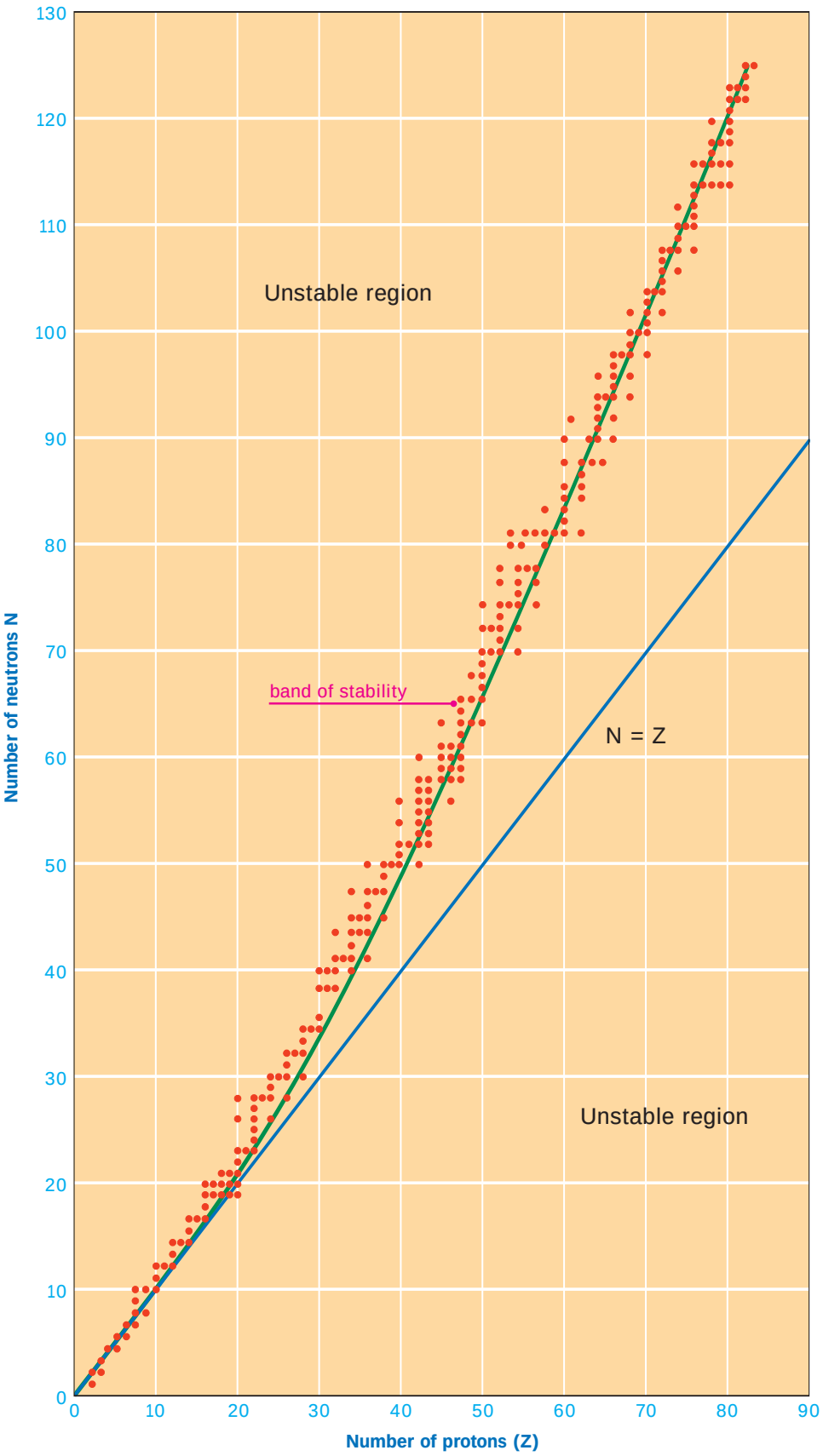

Key words

isotope
nucleon
nuclide

Stability

- The stability of *isotopes* is based on the ratio of neutrons and protons in their nucleus. Although most nuclei are stable, some are not and spontaneously decay, emitting radiation.
- The lightest stable *nuclides* (particular isotopes of an element) have almost equal numbers of protons and neutrons. The heavier stable nuclides require more neutrons than protons. The heaviest stable nuclides have approximately 50 percent more neutrons than protons.

Odd-even rule

- Isotopes tend to be more stable when they have even numbers of protons and neutrons than when they have odd. This is the result of the spins of the *nucleons* (the constituents of the atomic nucleus). When two protons or neutrons have paired spins (spins in opposite directions), their combined energy is less than when they are unpaired.

Decay

- When unstable nuclides disintegrate, they tend to produce new nuclides that are nearer to the stability line. This will continue until a stable nuclide is formed.
- An unstable nuclide above the band of stability decays by beta emission. This increases the proton number and decreases the neutron number. Thus, the neutron to proton ratio is decreased.
- An unstable nuclide below the band of stability disintegrates so as to decrease the proton number and increase the neutron to proton ratio. In heavy nuclides this can occur by alpha emission.

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Half-life

Key words

alpha particle
half-life
isotope
nuclide

1 Half-life

- *Half-life* is the time required for half the nuclei in a sample of an *isotope* to undergo *radioactive decay*.
- Radioactive decay is a completely random process in which nuclei disintegrate independently of each other or external factors such as temperature and pressure.

2 Rate of decay

- There are always very large numbers of active *nuclides* even in small amounts of radioactive material, so statistical methods can be employed to predict the fraction that will have decayed, on average, over a given period of time.
- The rate of decay of a nuclide at any time is directly proportional to the number of nuclei, N, of the nuclide:

$$-\frac{dN}{dt} \propto N \text{ or } \frac{dN}{dt} = -\lambda N$$

where N is the number of undecayed nuclei and λ is the decay constant. The minus sign indicates that the number of undecayed nuclei falls with time. Integrating this gives the exponential law equation:

$$N_t = N_0 e^{-\lambda t}$$

where N_0 is the number of undecayed atoms at time t = 0 and N_t the number of undecayed atoms after time t.

- After one half life ($t_{1/2}$) has passed, the number of undecayed atoms remaining in the sample will be $N_0/2$. Substituting this into the exponential law equation for N_t and taking natural logs of both sides provides a mathematical relationship between the decay constant and the half life of a radioactive atom:

$$t_{(1/2)} = \frac{0.693}{\lambda}$$

1 Half-life

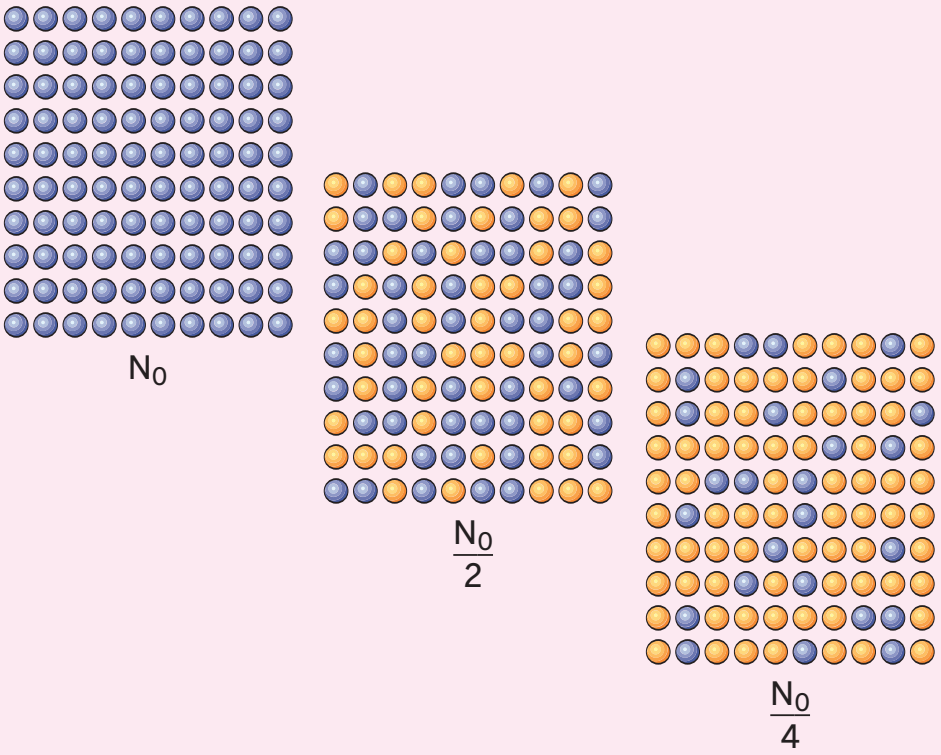

2 Rate of decay

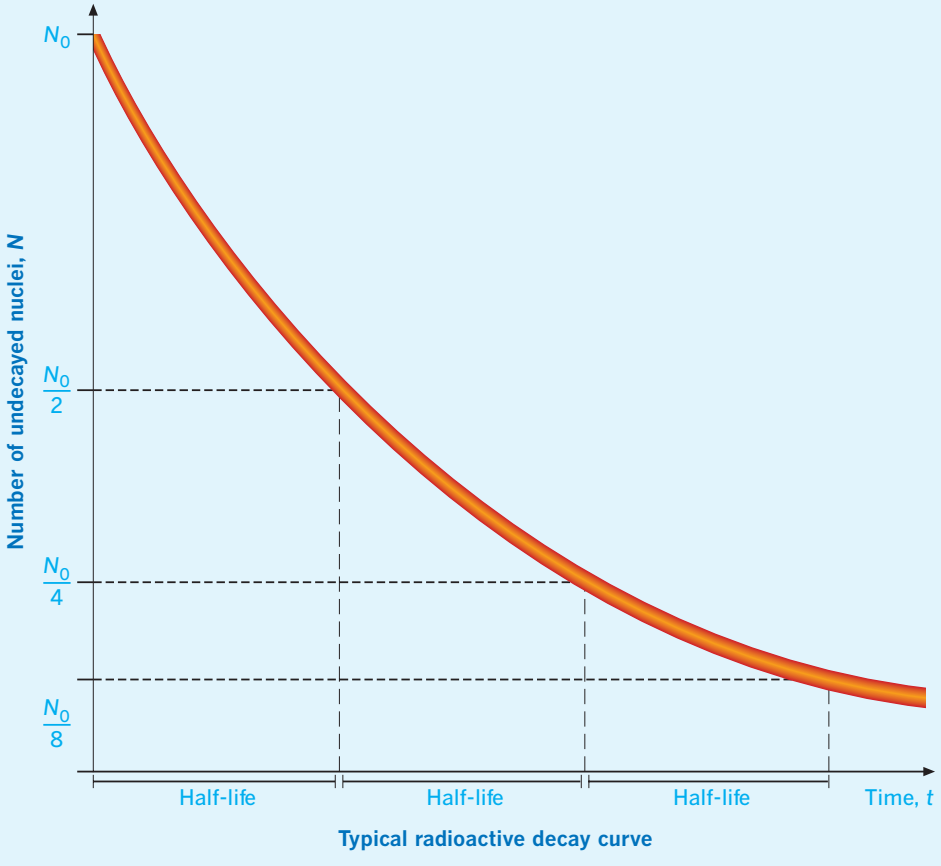

Typical radioactive decay curve

Measuring half-life

1 Half-life of radon

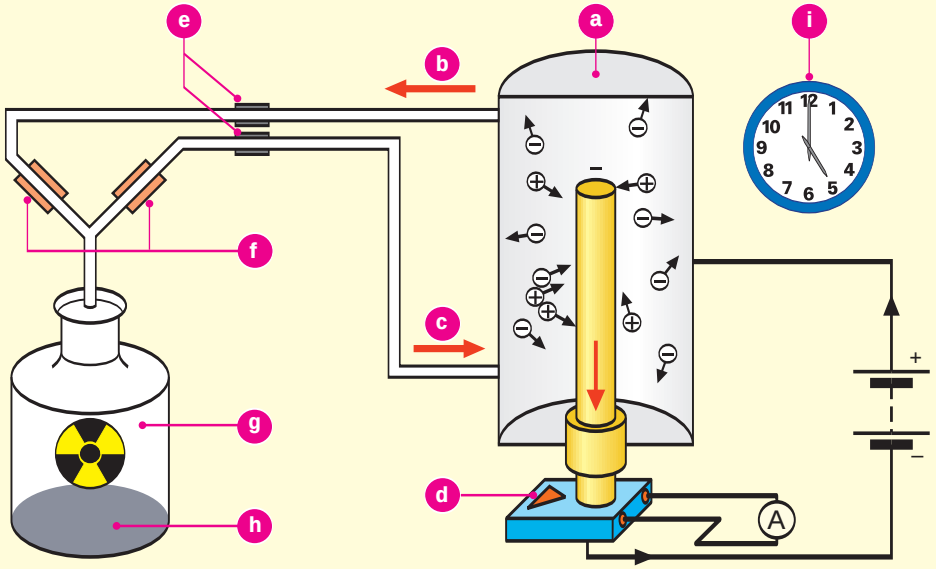

a ionization chamber
b air
c radon
d d.c. amplifier
e clips
f valves
g squeezable polyethylene bottle
h thorium hydroxide powder
i clock

2 Exponential decay: decay curve for radon gas

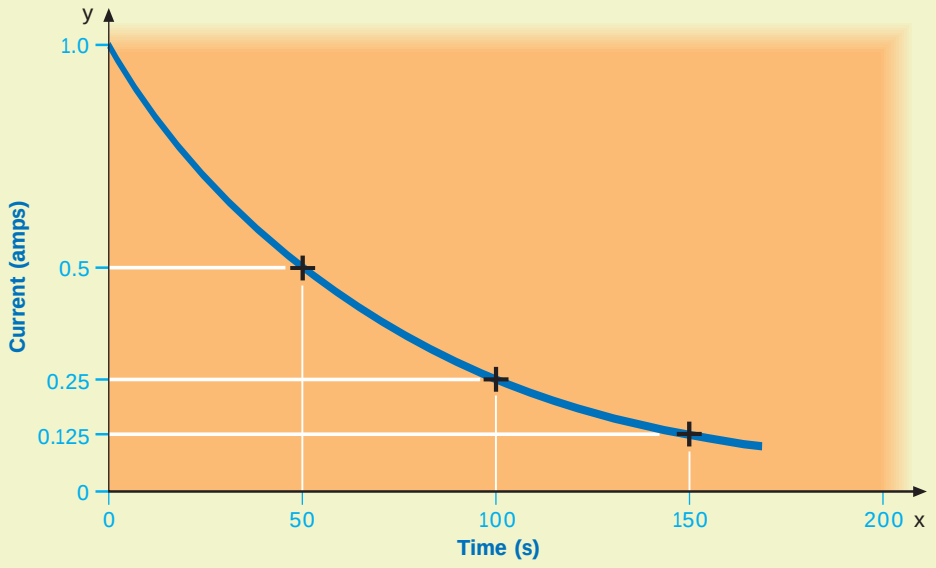

3 Radon decay

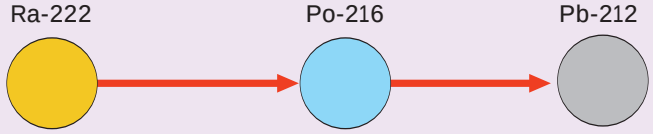

Key words

alpha particle
half-life
isotope

1 Half-life of radon

- Thorium decays to produce the radioactive *isotope* radon-220. This isotope is sometimes referred to as thoron.
- The bottle containing thorium hydroxide powder is squeezed a few times to transfer some radon-220 to the flask. The clips are then closed.
- As the radon decays, the ionization current decreases. It is always a measure of the number of *alpha particles* present and, therefore, the proportion of radon-220 remaining.
- The current is noted every 15 seconds for 2 minutes and then every 60 seconds for several minutes.

2 Exponential decay

- A graph of current against time is plotted.
- In this experiment, the *half-life* is indicated by the amount of time taken for the current to fall to half of its original value.
- The half-life of radon-220 is approximately 55 seconds.

3 Radon decay

- Radon-220 decays with the loss of an alpha particle to form polonium-216, which decays to form lead-212. The half life of polonium-216 is 0.145 seconds, and the half life of lead-212 is 10.64 hours.

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Radioactive isotopes

Key words

alpha particle
gamma radiation
irradiation
isotope

1 Tracers

- Radioactive *isotopes* are used as tracers to monitor the movement of substances in plants and animals. A solution containing radioactive phosphorus-32 is introduced into the stem of a plant. A Geiger counter is used to detect the movement of the isotope through the plant.

2 Thyroid monitor

- A solution containing iodine-131 is introduced to the bloodstream of a patient with a defective thyroid. A Geiger counter is used to detect the isotope and monitor thyroid activity.

3 Food preservation

- Food is irradiated by exposing it to *gamma radiation*. *Irradiation* destroys disease-causing bacteria as well as those that spoil food, so the shelf life of food is extended.

4 Sterilization

- Gamma radiation is used to sterilize medical equipment.

5 Smoke detectors

- Americium-241, a source of alpha radiation, is widely used in smoke detectors. The *alpha particles* ionize the air in the sensing circuit. Any smoke particles interfere with this and cause a change in the current, which triggers an alarm.

6 Duration of death

- All organisms contain a specific ratio of radioactive carbon-14 to carbon-12. When an organism dies, no carbon-14 is added. After death, carbon-14 decays at a predictable rate: the half-life is 5,700 years. By comparing the ratio of carbon-14 to carbon-12, it is possible to say when an organism died.

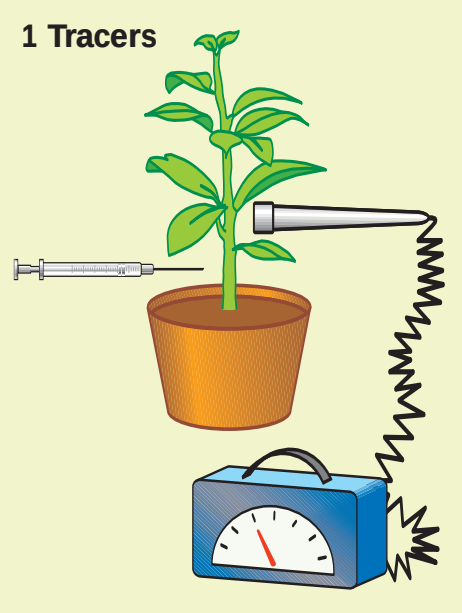

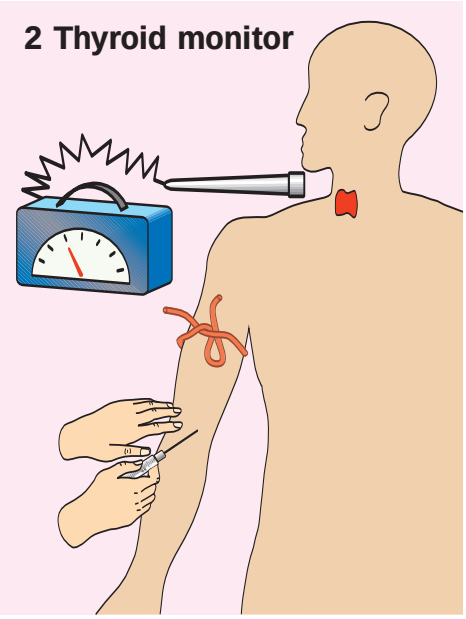

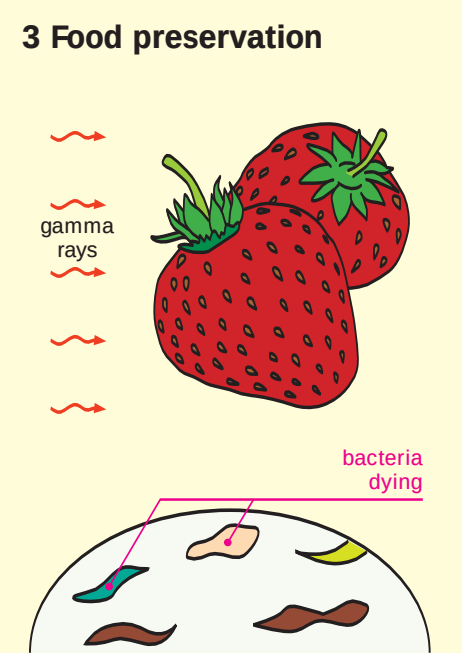

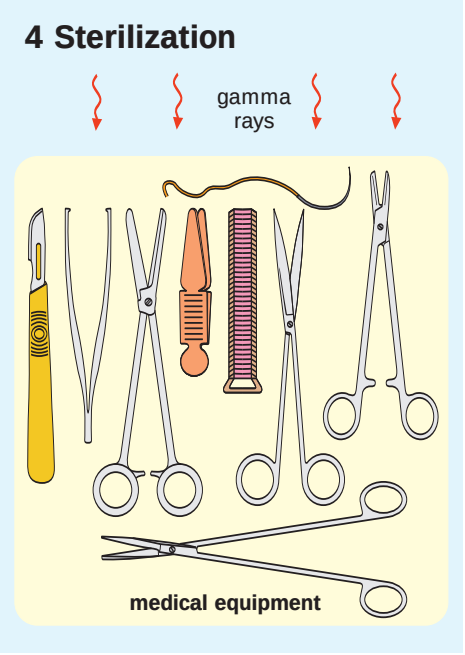

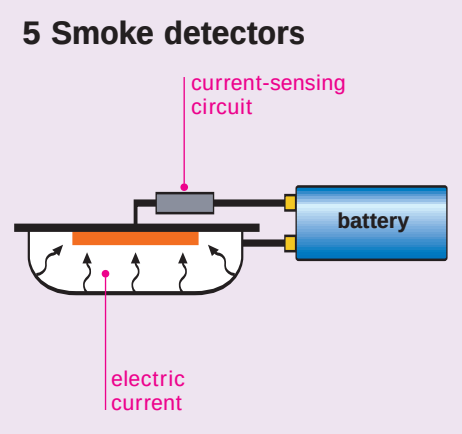

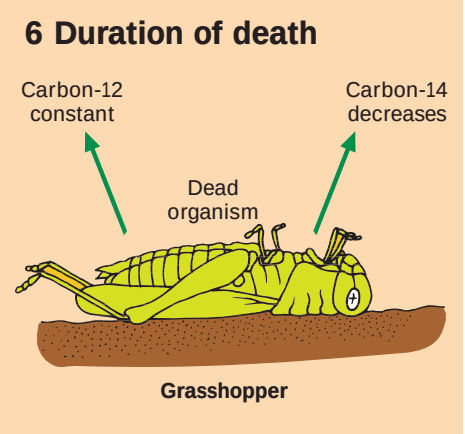

Nuclear fusion

1 Nuclear fusion

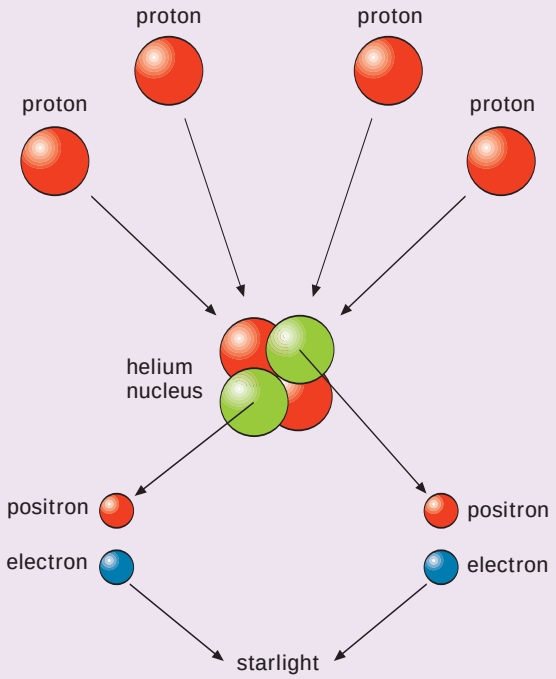

2 Fusion of deuterium

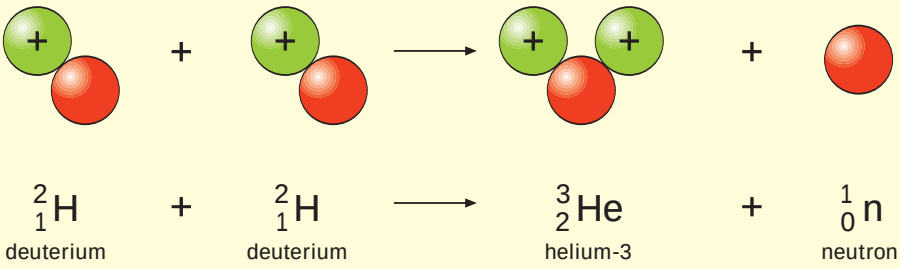

3 Fusion of deuterium and tritium

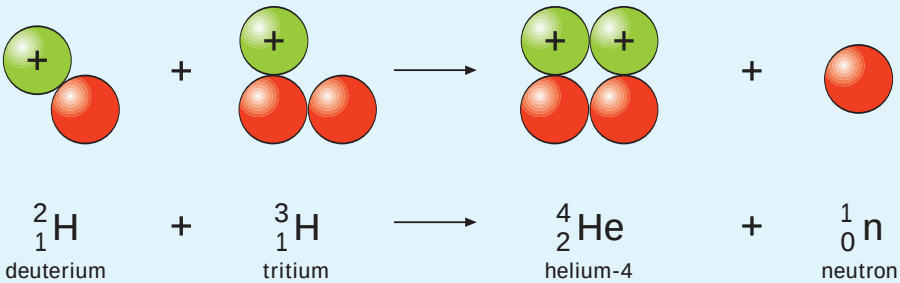

Key words

fusion
isotope

1 Nuclear fusion

- In nuclear *fusion*, two or more light atomic nuclei join to make a more massive one. During the process, some of the mass of the nuclei is converted into energy. Nuclear fusion, which first occurred during the Big Bang, powers stars. It also occurs in hydrogen bombs. Currently scientists are working to control fusion so it can be used in nuclear reactors.

2 Deuterium

- Deuterium is an *isotope* of hydrogen known as heavy hydrogen. The nucleus of a deuterium atom consists of one neutron and one proton.
- The fusion of two deuterium nuclei results in the formation of a helium-3 nucleus. A small amount of mass is converted into energy:
  Mass of two deuterium nuclei = 2 x 2.014 = 4.028 u
  Mass of helium-3 nucleus plus a neutron = 3.016 + 1.009 = 4.025 u
  Mass converted to energy by fusion = 4.028 – 4.025 = 0.003 u
  Energy released by the fusion reaction = 4.5×10^{-13} J
  Energy released per kilogram of deuterium is approximately 9×10^{13} J.

3 Tritium

- Tritium is another isotope of hydrogen. The nucleus of a tritium atom consists of two neutrons and one proton.
- The fusion of a deuterium nucleus and a tritium nucleus results in the formation of a helium-4 nucleus and the release of energy. The energy released per kilogram of deuterium and tritium is approximately 30×10^{13} J.
- This reaction produces more energy, and the fusion takes place at a lower temperature.

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Key words

chain reaction
fission

Nuclear fission

- In nuclear *fission*, a heavy atomic nucleus divides to make two smaller ones. Some of the mass of the nuclei is converted into energy during the process.

1 Reaction with uranium

- In a nuclear reaction with uranium and slow-moving neutrons, the nucleus of the uranium-235 atom undergoes fission and forms two smaller nuclei (lanthanum-148 and bromine-85) plus three neutrons. A small amount of mass is converted to energy.

2 Chain reaction

- A nuclear *chain reaction* is a series of self-sustaining reactions in which the particles released by one nucleus trigger the fission of at least as many other nuclei.
- Under normal circumstances, only a very small proportion of fission neutrons act in this way. However, if there is a sufficient amount of a radioactive isotope, a chain reaction can start.
- In an atomic bomb, an increasing uncontrolled chain reaction occurs in a very short time when two pieces of uranium-235 (or plutonium-239) are rapidly brought together.
- In a nuclear power station, the chain reaction is steady and controlled, so only a limited number of fission neutrons bring about further fission reactions.

Nuclear fission

1 Reaction with uranium

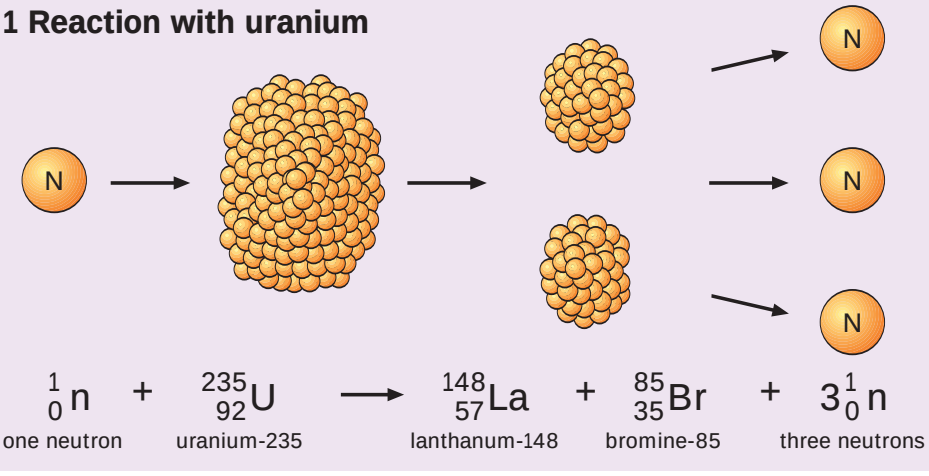

2 Chain reaction

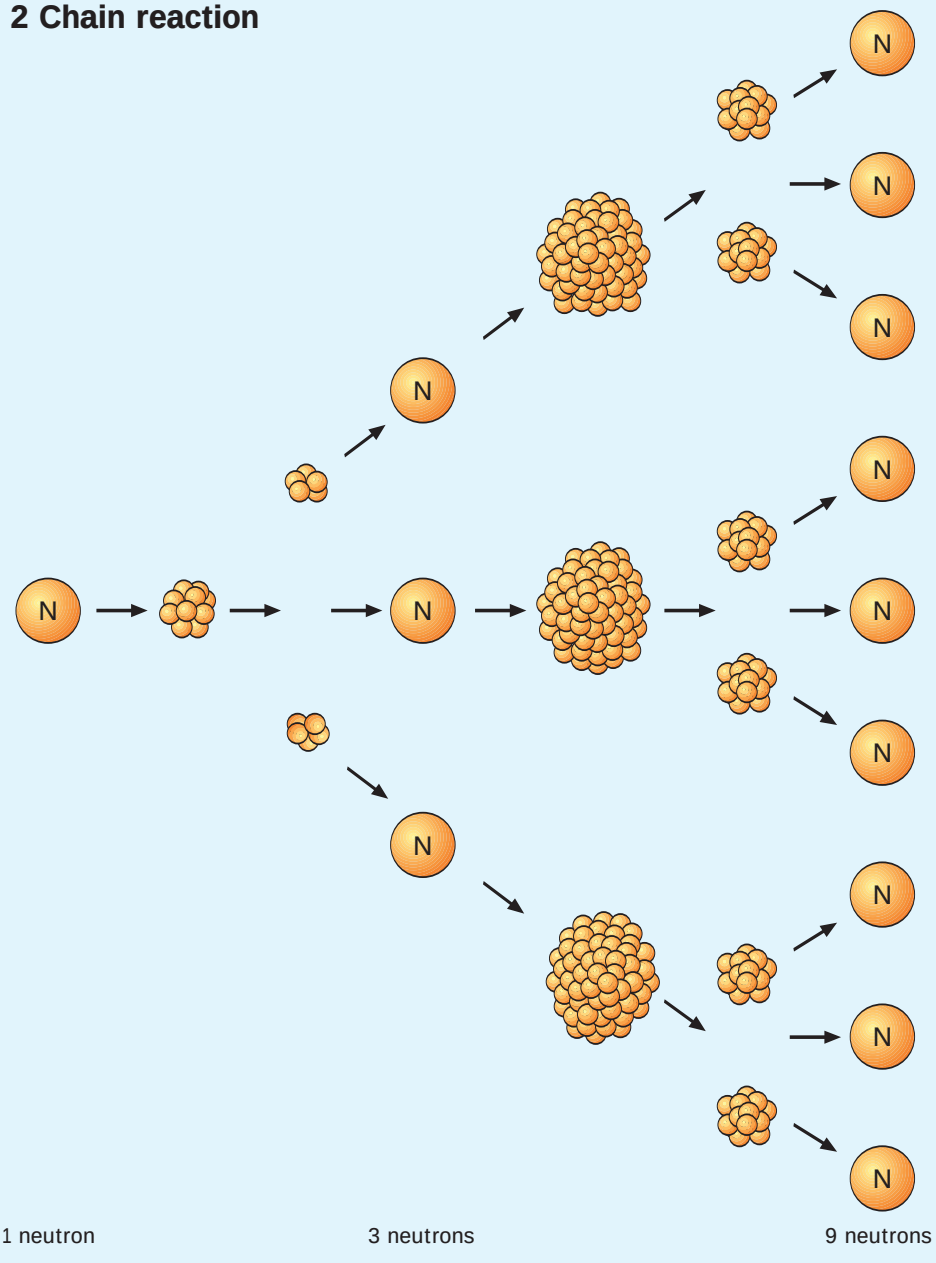

Nuclear reactor

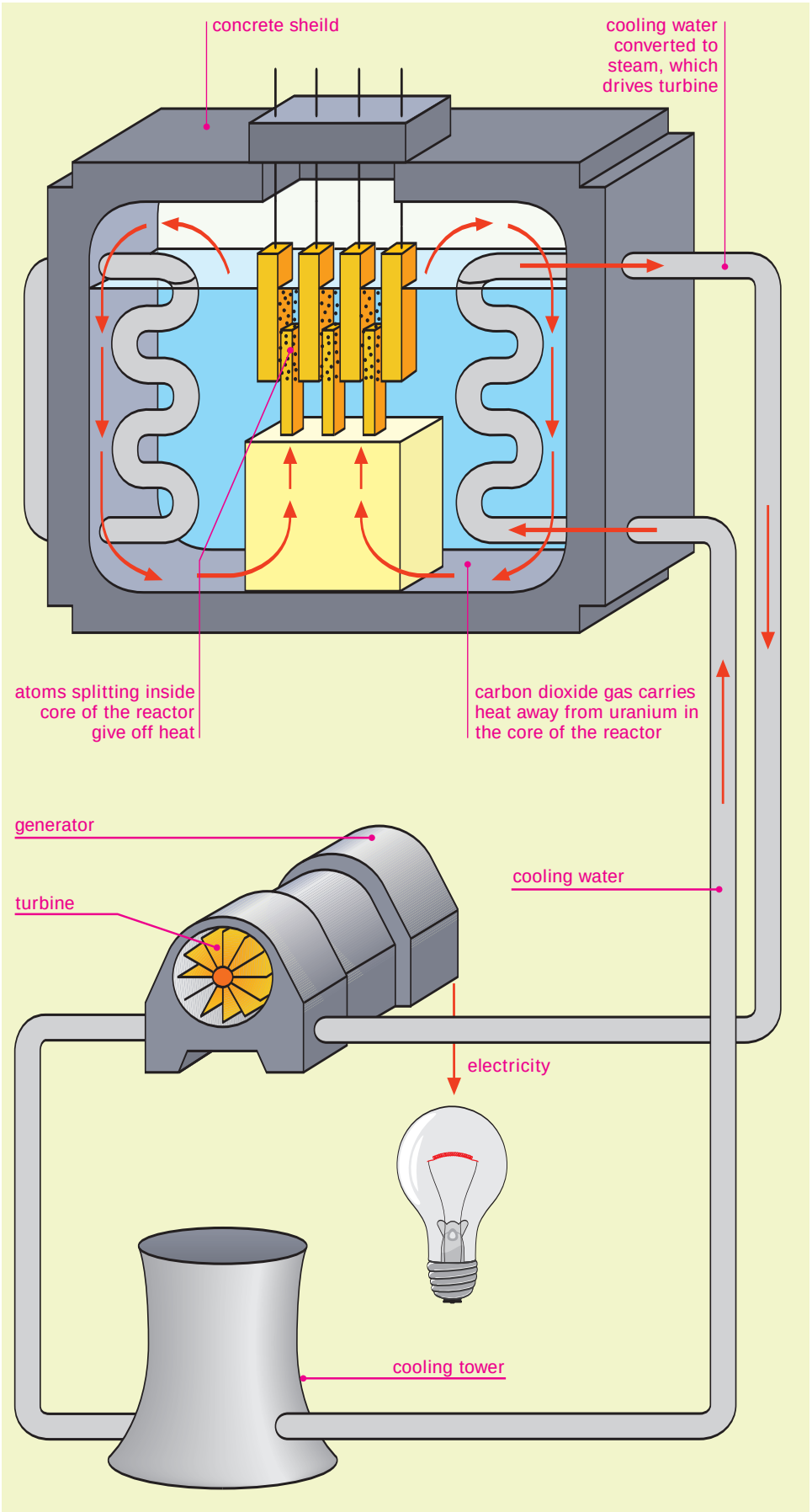

Key words

fission
isotope
uranium

Nuclear reactor

- *Uranium*, either the metal or the metal oxide, is used as fuel in nuclear reactors. The fuel is in the form of fuel rods, which are suspended in the reactor.
- Naturally occurring uranium contains 99.3 percent uranium-238 and only 0.7 percent of the radioactive *isotope* uranium-235. The uranium-235 content must be increased to approximately 3 percent before the uranium can be use as a fuel.
- Uranium-235 undergoes spontaneous *fission*. However, in a nuclear power station, the fission is brought about by bombarding the uranium nuclei with neutrons.
- The fission of one atom of uranium-235 absorbs one neutron and releases three others. In order to increase the chances that these neutrons will strike other uranium-235 atoms, they are slowed down by a moderator.
- Control rods are suspended between the fuel rods. These can be raised or lowered as needed to control the nuclear reaction. The control rods are made of alloys that absorb neutrons. When they are lowered, more neutrons are absorbed.
- The heat produced by the fission reaction is removed through a heat exchanger. The loop between the nuclear reactor and the heat exchanger is sealed so there is no danger of radioactive material escaping into the environment.
- The heat is used to convert water into pressurized steam. The high pressure steam drives a turbine connected to a generator, which produces electricity.

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Key words

alpha particle	*mass number*
atomic number	*nuclide*
beta particle	*radioactive decay*
daughter nucleus	*uranium*
half-life	*uranium series*

Radioactive decay

- Radioactive nuclei break down by a process known as *radioactive decay* in order to become more stable. In a radioactive decay series, each member of the series is formed by the decay of the *nuclide* before it until a stable nuclide is produced. As the nuclei disintegrate, they emit *alpha* (α) or *beta* (β) *particles*.
- There are three naturally occurring radioactive decay series: the *uranium series*, the actinium series, and the thorium series. Each ends with a stable isotope of lead.

The uranium series

- The uranium series involves the radioactive decay of U-238 to stable Pb-206. It is also known as the 4n+2 series (where n is an integer), because each member of the series has a mass equivalent to 4n+2.
- The graph indicates how the decay occurs. *Atomic numbers* are plotted on the x-axis. The *mass numbers* are on the y-axis. The symbol for the element is at the top of the graph. Each diagonal line represents an alpha (α) decay; each horizontal line a beta (β) decay. A circle indicates the *daughter nucleus* (the nucleus produced by the decay of the previous nucleus). *Half-life* is indicated in years (a), days (d), hours (h), minutes (m), and seconds (s).

Decay chain

U-238 → Th-234 → Pa-234 → U-234 → Th-230 → Ra-226 → Rn-222 → Po-218 → At-218 → Pb-214 → Bi-214 → Po-214 → Ti-210 → Pb-210 → Bi-210 → Po-210 → Pb-206 (stable)

The uranium series

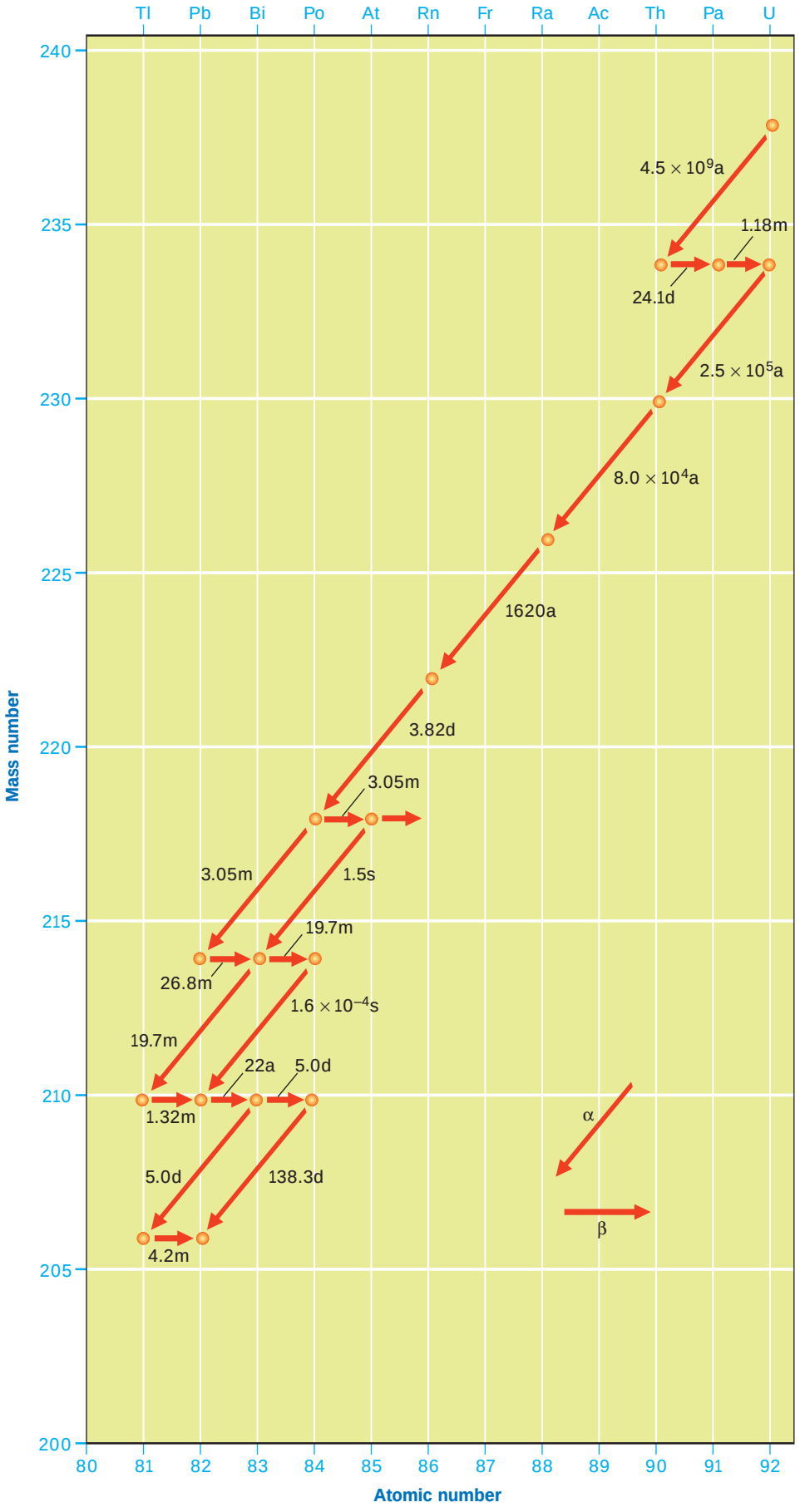

The actinium series

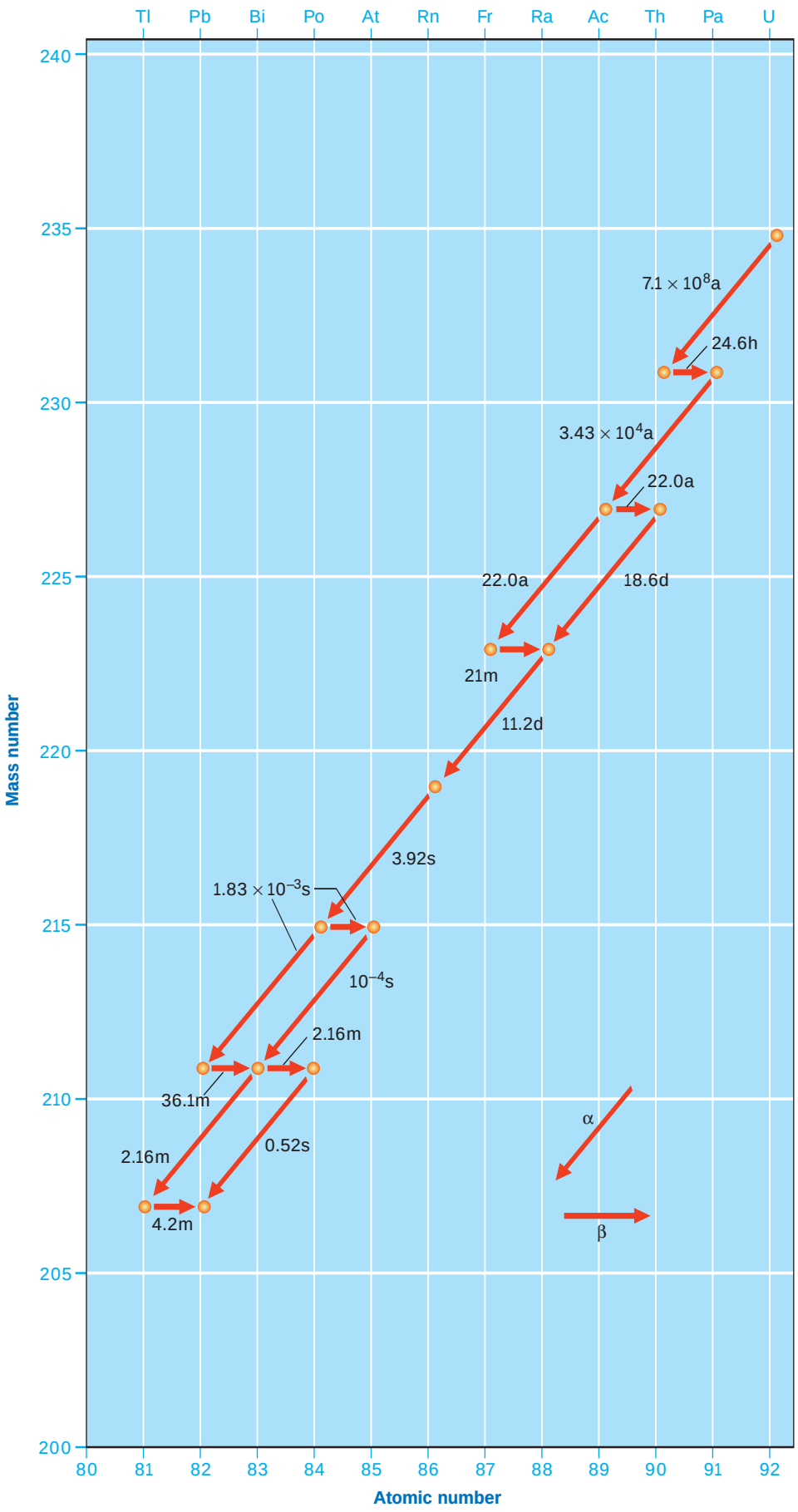

Key words

actinium	*daughter nucleus*
actinium series	*half-life*
alpha particle	*mass number*
atomic number	*nuclide*
beta particle	*radioactive decay*

Radioactive decay

- Radioactive nuclei break down by a process known as *radioactive decay* in order to become more stable. In a radioactive decay series, each member of the series is formed by the decay of the *nuclide* before it until a stable nuclide is produced. As the nuclei disintegrate, they emit *alpha* (α) or *beta* (β) *particles.*
- There are three naturally occurring radioactive decay series: the uranium series, the *actinium series*, and the thorium series. Each ends with a stable isotope of lead.

The actinium series

- The actinium series involves the radioactive decay of U-235 to stable Pb-207. It is also known as the 4n+3 series (where n is an integer), because each member of the series has a mass equivalent to 4n+3.
- The graph indicates how the decay occurs. *Atomic numbers* are plotted on the x-axis. The *mass numbers* are on the y-axis. The symbol for the element is at the top of the graph. Each diagonal line represents an alpha (α) decay; each horizontal line a beta (β) decay. A circle indicates the *daughter nucleus* (the nucleus produced by the decay of the previous nucleus). *Half-life* is indicated in years (a), days (d), hours (h), minutes (m), and seconds (s).

Decay chain

U-235 → Th-231 → Pa-231 → Ac-227 → Th-227 → Fr-223 → Ra-223 → Rn-219 → Po-215 → At-215 → Pb-211 → Bi-211 → Po-211 → Tl-207 → Pb-207 (stable)

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Key words

alpha particle	*mass number*
atomic number	*nuclide*
beta particle	*radioactive decay*
daughter nucleus	*thorium*
half-life	*thorium series*

Radioactive decay

- Radioactive nuclei break down by a process known as *radioactive decay* in order to become more stable. In a radioactive decay series, each member of the series is formed by the decay of the *nuclide* before it until a stable nuclide is produced. As the nuclei disintegrate, they emit *alpha* (α) or *beta* (β) *particles*.
- There are three naturally occurring radioactive decay series: the uranium series, the actinium series, and the *thorium series*. Each ends with a stable isotope of lead.

The thorium series

- The thorium series involves the radioactive decay of Th-232 to stable Pb-208. It is also known as the (4n) series (where n is an integer) because each member of the series has a mass equivalent to 4n.
- The graph indicates how the decay occurs. *Atomic numbers* are plotted on the x-axis. The *mass numbers* are on the y-axis. The symbol for the element is at the top of the graph. Each diagonal line represents an alpha (α) decay; each horizontal line a beta (β) decay. A circle indicates the *daughter nucleus* (the nucleus produced by the decay of the previous nucleus). *Half-life* is indicated in years (a), days (d), hours (h), minutes (m), and seconds (s).

Decay chain

Th-232 → Ra-228 → Ac-228 → Th-228 → Ra-224 → Rn-220 → Po-216 → Pb-212 → Bi-212 → Po-212 → Tl-208 → Pb-208 (stable)

The thorium series

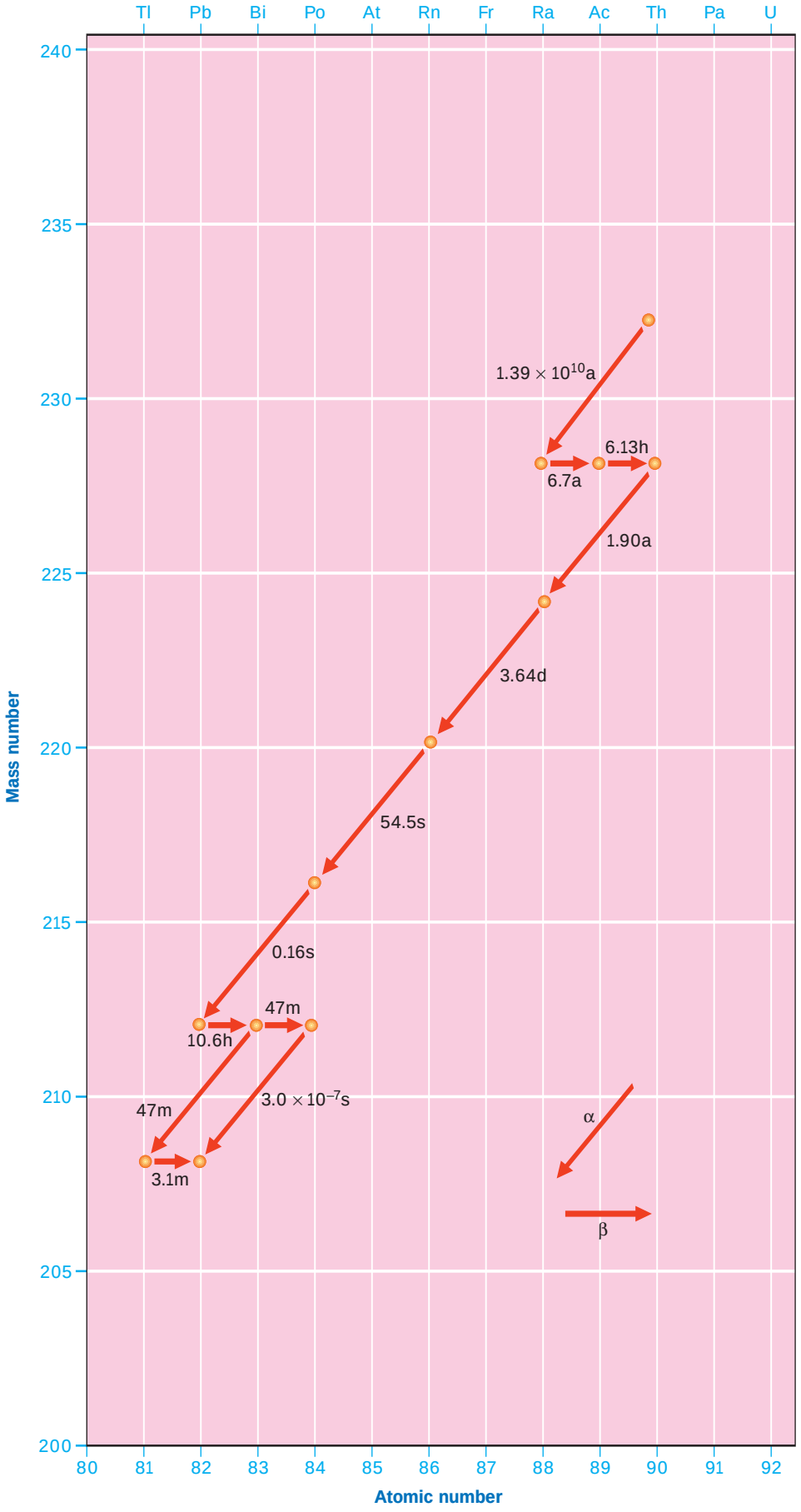

The neptunium series

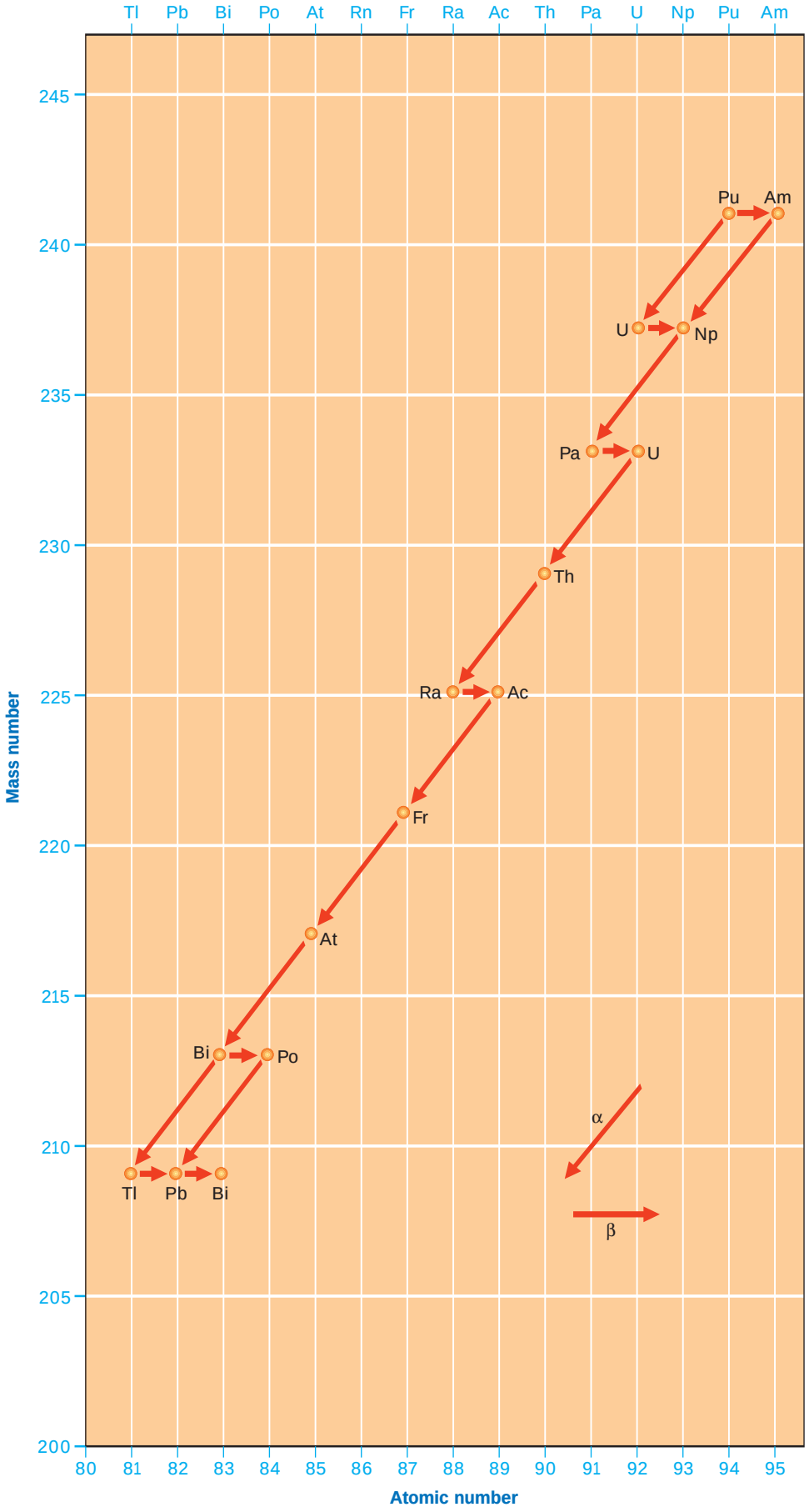

Key words

alpha particle
atomic number
beta particle
daughter nucleus
half-life
mass number
neptunium
neptunium series
nuclide
radioactive decay

Radioactive decay

- Radioactive nuclei break down by a process known as *radioactive decay* in order to become more stable. In a radioactive decay series, each member of the series is formed by the decay of the *nuclide* before it until a stable nuclide is produced. As the nuclei disintegrate, they emit *alpha* (α) or *beta* (β) *particles.*
- The *neptunium* series is composed of isotopes that do not occur in nature.

The neptunium series

- The neptunium series starts with the artificial isotope plutonium-241 and ends with bismuth-209. Each member of the series has a mass equivalent to 4n+1 (where n is an integer).
- The graph indicates how the decay occurs. *Atomic numbers* are plotted on the x-axis. The *mass numbers* are on the y-axis. The symbol of the element is at the top of the graph. Each diagonal line represents an alpha (α) decay; each horizontal line a beta (β) decay. A circle indicates the *daughter nucleus* (the nucleus produced by the decay of the previous nucleus).

Decay chain

Pu-241 → Am-241 → Np-237 → Pa-233 → U-233 → Th-229 → Ra-225 → Ac-225 → Fr-221 → At-217 → Bi-213 → Po-213 → Pb-209 → Bi-209 (stable)

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Key words

alpha decay
alpha particle
atomic number
beta decay
beta particle
gamma radiation
ground state
kinetic energy
mass number
nuclide

1 Alpha decay

- *Alpha decay* is the process in which the nucleus of an atom emits an *alpha particle* (which has the same structure as the helium-4 nucleus: $^{4}_{2}He$).
- The new atom's atomic *mass number* (A) is reduced by 4 and its *atomic number* (Z) is decreased by 2.
- Uranium-238 decays to thorium-234 by the loss of an alpha particle.
- Energy is also released as *gamma* (γ) *radiation*.

2 Alpha particle spectrum

- The *ground state* of the uranium nucleus (the natural state of the lowest energy of the nucleus) is at a higher energy than the ground state of the thorium nucleus.
- Some energy is released in the form of *kinetic energy*, which is carried by the alpha particle.
- The remaining energy is released as gamma radiation.

3 Beta decay

- *Beta decay* is the process in which the nucleus of an atom emits a *beta particle* (an electron).
- The new atom's atomic number (Z) is increased by 1, while the atomic mass number (A) remains unchanged.
- Thorium-234 decays to protactinium-234 by the loss of a beta particle. The half-life for this decay is 6.75 hours.

4 Beta particle spectrum

- The ground state of the thorium *nuclide* is at a higher energy than the ground state of the protractinium nucleus.
- Some energy is released in the form of kinetic energy, which is carried by the beta particle.
- The remaining energy is released as gamma radiation.

Radioactivity of decay sequences

1 Alpha decay

$$^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \gamma$$

General sequence of alpha decay

$$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}Th + {}^{4}_{2}He + \gamma$$

Example of alpha decay: uranium decay to thorium

2 Alpha particle spectrum

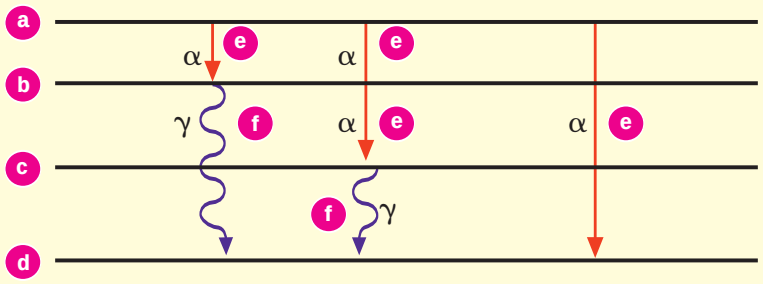

3 Beta decay

$$^{A}_{Z}X \xrightarrow{\beta} {}^{A}_{Z+1}Y + e^{-} + \bar{\nu}$$

General sequence of beta decay

$$^{234}_{90}Th \xrightarrow{\beta} {}^{A}_{91}Pa + e^{-} + \bar{\nu}$$

Example of beta decay: thorium decay to protactinium

4 Beta particle spectrum

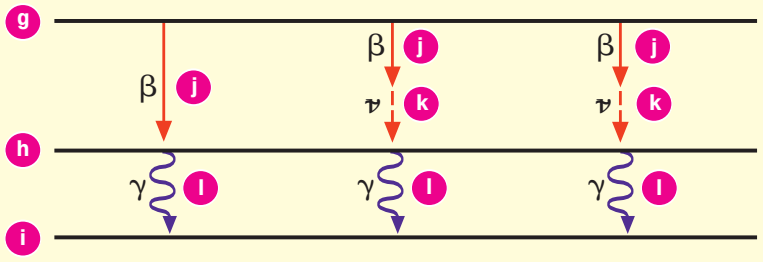

a nuclide *z*
b excited states of *Z* – 2
c excited states of *Z* – 2
d ground state of *Z* – 2
e alpha particle energy
f gamma radiation
g nuclide *Z*
h excited state of *Z* + 1
i ground state of *Z* + 1
j beta particle energy
k neutrino energy
l gamma radiation

Table of naturally occurring isotopes 1

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
0	Neutron	n	1	—	1.008665
1	Hydrogen	H	1	99.99	1.007825
			2	0.01	2.014102
2	Helium	He	3	1.3×10^{-1}	3.016030
			4	100	4.002604
3	Lithium	Li	6	7.4	6.015126
			7	92.6	7.016005
4	Beryllium	Be	9	100	9.012186
5	Boron	B	10	19.6	10.012939
			11	80.4	11.009305
6	Carbon	C	12	98.9	12.000000
			13	1.1	13.003354
7	Nitrogen	N	14	99.6	14.003074
			15	0.4	15.000108
8	Oxygen	O	16	99.76	15.994915
			17	0.04	16.999133
			18	0.20	17.999160
9	Fluorine	F	19	100	18.998405
10	Neon	Ne	20	90.9	19.992440
			21	0.3	20.993849
			22	8.8	21.991384
11	Sodium	Na	23	100	22.989773
12	Magnesium	Mg	24	78.8	23.985045
			25	10.2	24.985840
			26	11.1	25.982591
13	Aluminum	Al	27	199	26.981535
14	Silicon	Si	28	92.2	27.976927
			29	4.7	28.976491
			30	3.1	29.973761
15	Phosphorus	P	31	100	30.973763
16	Sulfur	S	32	95.0	31.972074
			33	0.8	32.971460
			34	4.2	33.967864
			36	0.01	35.967091
17	Chlorine	Cl	35	75.5	34.968854
			37	24.5	36.965895
18	Argon	Ar	36	0.34	35.967548
			38	0.06	37.962724
			40*	99.6	30.962384
19	Potassium	K	39	93.1	38.963714
			40	0.012	39.964008
			41	6.9	49.961835
20	Calcium	Ca	40	97.0	39.962589
			42	0.6	41.958628
			43	0.1	42.958780
			44	2.1	43.955490
			46	0.003	45.953689
			48	0.2	47.952519
21	Scandium	Sc	45	100	44.955919

*denotes radioactive isotope

Key words

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atomic number
isotope
mass number

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Table of naturally occurring isotopes 2

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
22	Titanium	Ti	46	8.0	45.952633
			47	7.3	46.95176
			48	74.0	47.947948
			49	5.5	48.947867
			50*	5.2	49.944789
23	Vanadium	V	50	0.25	49.947165
			51	99.75	50.943978
24	Chromium	Cr	50	4.3	49.946051
			52	83.8	51.940514
			53	9.5	52.940651
			54	2.4	53.938879
25	Manganese	M	55	100	54.938054
26	Iron	Fe	54	5.8	53.93962
			56	91.7	55.93493
			57	2.2	56.93539
			58	0.3	57.93327
27	Cobalt	Co	59	100	58.933189
28	Nickel	Ni	58	67.8	57.93534
			60	26.2	59.93078
			61	1.2	60.93105
			62	3.7	61.92834
			64	1.1	63.92796
29	Copper	Cu	63	69.1	62.92959
			65	30.9	64.92779
30	Zinc	Zn	64	48.9	63.929145
			66	27.8	65.92605
			67	4.1	66.92715
			68	18.6	67.92486
			70	0.6	69.92535
31	Gallium	Ga	69	60.5	68.92568
			71	39.5	70.92484
32	Germanium	Ge	70	20.5	69.92428
			72	27.4	71.92174
			73	7.7	72.9234
			74	36.7	73.9211
			76	7.7	75.9214
33	Arsenic	As	75	100	74.92158
34	Selenium	Se	74	0.9	73.9224
			76	9.0	75.91923
			77	7.6	76.91993
			78	23.5	77.91735
			80	49.8	79.91651
			82	9.2	81.9167
35	Bromine	Br	79	50.6	78.91835
			81	49.4	80.91634
36	Krypton	Kr	78	0.3	77.920368
			80	2.3	79.91639
			82	11.6	81.91348
			83	11.5	82.91413
			84	56.9	83.911504
			86	17.4	85.91062

*denotes radioactive isotope

Table of naturally occurring isotopes 3

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
37	Rubidium	Rb	85	72.1	84.9117
			87*	27.9	86.9092
38	Strontium	Sr	84	0.6	83.91338
			86	9.9	85.9093
			87	7.0	86.9089
			88	82.5	87.9056
39	Yttrium	Y	89*	100	88.9054
40	Zirconium	Zr	90	51.5	89.9043
			91	11.2	90.9052
			92	17.1	91.9046
			94	17.4	93.9061
			96	2.8	95.9082
41	Niobium	Nb	93	100	92.9060
42	Molybdenum	Mo	92	15.9	91.9063
			94	9.1	93.9047
			95	15.7	94.9057
			96	16.5	95.9045
			97	9.4	96.9057
			98	23.8	97.9055
			100	9.6	99.9076
43	Technetium	Tc	has no stable or naturally-occuring isotopes		
44	Ruthenium	Ru	96	5.6	95.9076
			98	1.9	97.905
			99	12.7	98.9061
			100	12.6	
			101	17.1	
			102	31.6	101.9037
			104	18.5	103.9055
45	Rhodium	Rh	103	100	102.9048
46	Palladium	Pd	102	1.0	101.9049
			104	11.0	103.9036
			105	22.2	104.9046
			106	27.3	105.9032
			108	26.7	107.9039
			110	11.8	109.9045
47	Silver	Ag	107	51.4	106.9050
			109	48.6	108.9047
48	Cadmium	Cd	106	1.2	105.9059
			108	0.9	107.9040
			110	12.4	109.9030
			111	12.7	110.9041
			112	24.1	111.9028
			113	12.3	112.9046
			114	28.8	113.9036
			116	7.6	115.9050
49	Indium	In	113	4.3	112.9043
			115*	95.7	114.9041

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Key words

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mass number

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Table of naturally occurring isotopes 4

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
50	Tin	Sn	112	1.0	111.9049
			114	0.6	113.9030
			115	0.3	114.9035
			116	14.2	115.9021
			117	7.6	116.9031
			118	24.0	117.9018
			119	8.8	118.9034
			120	33.0	119.9021
			122	4.7	121.9034
			124	6.0	123.9052
51	Antimony	Sb	121	57.3	120.9037
			123	42.7	122.9041
52	Tellurium	Te	120	0.1	119.9045
			122	2.4	121.9030
			123	0.9	122.9042
			124	4.6	123.9028
			125	7.0	124.9044
			126	18.7	125.90324
			128	31.8	127.9047
			130	34.5	129.9067
53	Iodine	I	127	100	126.90435
54	Xenon	Xe	124	0.1	123.9061
			126	0.1	125.90417
			128	1.9	127.90354
			129	26.4	128.90478
			130	4.1	129.90351
			131	21.2	130.90509
			132	26.9	131.90416
			134	10.4	133.90540
			136	8.9	135.90722
55	Cesium	Ca	133	100	132.9051
56	Barium	Ba	130	0.1	129.90625
			132	0.2	131.9051
			134	2.6	133.9043
			135	6.7	134.9056
			136	8.1	135.9044
			137	11.9	136.9056
			138	70.4	137.9050
57	Lanthanum	La	138*	0.1	137.9068
			139	99.9	138.9061
58	Cerium	Ce	136	0.2	135.9071
			138	0.2	137.9057
			140	88.5	139.90528
			142*	11.1	141.9090
59	Praseodymium	Pr	141	100	140.90739

*denotes radioactive isotope

Table of naturally occurring isotopes 5

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
60	Neodymium	Nd	142	27.3	141.90748
			143	12.3	142.90962
			144*	23.8	143.90990
			145	8.3	144.9122
			146	17.1	145.9127
			148	5.7	147.9165
			150	5.5	149.9207
61	Promethium	Pm	has no naturally occuring isotope		
62	Samarium	Sm	144	3.1	143.9116
			147*	15.1	146.91462
			148	11.3	146.9146
			149	14.0	148.9169
			150	7.5	149.9170
			152	26.6	151.9193
			154	22.4	153.9217
63	Europium	Eu	151	47.8	150.9196
			153	52.2	152.9207
64	Gadolinium	Gd	152	0.2	151.9194
			154	2.2	153.9202
			155	15.1	154.9220
			156	20.6	155.9222
			157	15.7	156.9240
			158	24.5	157.9242
			160	21.7	159.9273
65	Terbium	Tb	159	100	158.924
66	Dysprosium	Dy	156	0.1	
			158	0.1	
			160	2.3	159.924
			161	19.0	160.926
			162	25.5	161.926
			163	24.9	162.928
			164	28.1	163.928
67	Holmium	Ho	165	100	164.930
68	Erbium	Er	162	0.1	
			164	1.6	163.929
			166	33.4	165.929
			167	22.9	166.931
			168	27.1	167.931
			170	14.9	169.935
69	Thulium	Tm	169	100	
70	Ytterbium	Yb	168	0.1	
			170	3.1	
			171	14.4	
			172	21.9	171.929
			173	16.2	
			174	31.7	173.926
			176	12.6	
71	Lutetium	Lu	175	97.4	
			176*	2.6	175.9414

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Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
72	Hafnium	Hf	174	0.2	
			176	5.2	175.9403
			177	18.6	176.9419
			178	27.1	177.9425
			179	13.7	178.9444
			180	35.2	179.9451
73	Tantalum	Ta	180	0.01	179.9457
			181	99.99	180.9462
74	Tungsten	W	180	0.2	179.9450
			182	26.4	181.9465
			183	14.4	182.9485
			184	30.6	183.9491
			186	28.4	185.951
75	Rhenium	Re	185	37.1	184.950
			187*	62.9	186.9550
76	Osmium	Os	184	0.02	
			186	1.6	185.9529
			187	1.6	186.9550
			188	13.3	187.9550
			189	16.1	188.9572
			190*		189.9574
			192*		191.9605
77	Iridium	Ir	191	38.5	190.9599
			193	61.5	192.9623
78	Platinum	Pt	190		189.9592
			192	0.8	191.9605
			194	32.9	193.9624
			195		194.9645
			196		195.9646
			198	7.2	197.9675
79	Gold	Au	197	100	196.96655
80	Mercury	Hg	196	0.1	195.96582
			198	10.0	197.96677
			199	16.9	198.96826
			200	23.1	199.96834
			201	13.2	200.97031
			202	29.8	201.97063
			204	6.9	203.97348
81	Thallium	Tl	203	29.5	202.97233
			205	70.5	204.97446
			206*	—	205.97608
			207*	—	206.97745
			208*	—	207.98201
			210*	—	209.99000

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Table of naturally occurring isotopes 7

Table of masses and abundance of naturally occurring isotopes

Atomic number (Z)	Element	Symbol	Mass number (A)	Percentage	Atomic mass
82	Lead	Pb	204	1.4	203.97307
			206	25.2	205.97446
			207	21.7	206.97590
			208	51.7	207.97664
			210*	—	209.98418
			211*	—	210.98880
			212*	—	211.99190
			214*	—	213.99976
83	Bismuth	Bi	209	100	208.98042
			210*	—	209.98411
			211*	—	210.98729
			212*	—	211.99127
			214*	—	213.99863
84	Polonium	Po	210*	—	209.98287
			211*	—	210.98665
			212*	—	211.98886
			214*	—	213.99519
			215*	—	214.99947
			216*	—	216.00192
			218*	—	218.0089
85	Astatine	At	215*	—	214.99866
			218*	—	218.00855
86	Emanation	Em	219*	—	219.00952
			220*	—	220.01140
			222*	—	222.0175
87	Francium	Fr	223*	—	223.01980
88	Radium	Ra	223*	—	223.01857
			224*	—	224.02022
			226*	—	226.0254
			228*	—	228.03123
89	Actinium	Ac	227*	—	227.02781
			228*	—	228.03117
			230*	—	230.0331
			231*	—	231.03635
			232*	100	232.03821
			234*	—	234.0436
91	Protactinium	Pa	231*	—	231.03594
			234*	—	234.0434
92	Uranium	U	234*	0.006	234.04090
			235*	0.718	235.04393
			238*	99.276	238.0508

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Key words

accelerator A chemical that increases the rate of a chemical reaction.
acid Any substance that releases hydrogen ions when added to water. It has a pH of less than 7.
acid-base indicator A chemical compound that changes color when going from acidic to basic solutions. An example is Methyl orange.
acidity The level of hydrogen ion concentration in a solution.
actinides The name of the radioactive group of elements with atomic numbers from 89 (actinium) to 103 (lawrencium).
actinium (Ac) A silvery radioactive metallic element that occurs naturally in pitchblende and can be synthesized by bombarding radium with neutrons.
actinium series One of the naturally occurring radioactive series.
activation energy The energy barrier to be overcome in order for a reaction to occur.
active site The part of an enzyme where the chemical reaction occurs.
addition polymerization A chemical reaction in which simple molecules are added to each other to form long-chain molecules without by-products.
addition reaction A reaction in which a molecule of a substance reacts with another molecule to form a single compound.
adsorption The process by which molecules of gases or liquids become attached to the surface of another substance.
aerosol Extremely small liquid or solid particles suspended in air or another gas.
alcohol A member of a family of organic compounds whose structure contains the –OH functional group.
aldehyde One of a group of organic compounds containing the aldehyde group (–CHO). Names have the suffix -al.
aldohexose A monosaccharide having six carbon atoms and an aldehyde group.
aldose A sugar containing one aldehyde group per molecule
alkali A solution of a substance in water that has a pH of more than 7 and has an excess of hydroxide ions in the solution.
alkali metals Metallic elements found in group 1 of the periodic table. They are very reactive, electropositive, and react with water to form alkaline solutions.
alkaline earth metals Metallic elements found in group 2 of the periodic table.
alkalinity Having a pH greater than 7.
alkane A member of the hydrocarbon group whose general formula is C_nH_{2n+2}. They have single bonds between the carbon atoms and are not very reactive.
alkanol See alcohol
alkene A member of the hydrocarbon group whose general formula is C_nH_{2n}. They have a double bond between a pair of carbon atoms and are thus reactive.
alkyl A member of the hydrocarbon group whose general formula is CnH_{2n+1}.
alkyne A member of the hydrocarbon group with the general formula CnH_{2n-1}. They have a triple bond between a pair of carbon atoms in each molecule and are thus reactive.
allotrope An element that can exist in more than one physical form while in the same state.
alloy A metallic material made of two or more metals or of a metal and non-metal.
alpha decay The process of radioactive decay in which the nucleus of an atom emits an alpha particle.
alpha particle A particle released during radioactive decay that consists of two neutrons and two protons.
aluminum (Al) A silvery-white. metallic element that is non-magnetic and oxidizes easily.
amine A member of a group of organic compounds containing the amino functional group $–NH_2$.
amino acid An organic compound containing both the carboxyl group (–COOH) and the amino group ($–NH_2$).
ammonia (NH_3) A colorless, strong-smelling poisonous gas that is very soluble in water.
ammonium hydroxide (NH_4OH) An aqueous solution of ammonia. It is a corrosive chemical with a strong odor.
ammonium ion (NH_4^+) An ion found in ammonia solution and in ammonium compounds.
amphoteric Exhibiting properties of both an acid and a base.
anhydride The substance remaining when one or more molecules of water have been removed from an acid or a base.
anhydrous Containing no water. Term applied to salts without water of crystallization.
anion An ion having a negative charge.
anode The electrode carrying the positive charge in a solution undergoing electrolysis.
anomer A stereoisomeric form of a sugar, involving different arrangements of atoms or molecules around a central atom,
aqueous solution A solution in which water is the solvent.
argon Ar. A colorless, odorless. gaseous element. One of the noble gases.
aryl A member of an aromatic hydrocarbon group formed by the removal of a hydrogen atom from an aromatic hydrocarbon.
association The process by which molecules of a substance combine to form a larger structure.
astatine At. A non-metallic radioactive element that is highly unstable and rare in nature.
atmosphere The layer of gases surrounding Earth.
atom The smallest particle of an element that can exhibit that element's properties.
atomic emission spectrum The amount of electromagnetic radiation an element emits when excited.
atomic mass The ratio of the mass of an average atom of an element to 1/12th of the mass of an atom of the carbon-12 isotope.
atomic number The number of protons in the nucleus of an atom.
atomic volume The volume of one mole of the atoms of an element.
Avogadro's constant The number of particles present in a mole of substance.

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azeotropic mixture A mixture of liquids that boils without a change in composition.
bakelite A phenol/methanal resin that has good electrical and heat insulation properties.
base A substance existing as molecules or ions that can take up hydrogen ions.
beta decay The process of radioactive decay in which the nucleus of an atom emits a beta particle.
beta particle A high-speed electron emitted by the nucleus of certain radioactive elements during beta decay.
Big Bang The primeval explosion that most astronomers think gave rise to the Universe.
black hole An object with infinite density.
body-centered cubic packing A crystalline structure in which one atom sits in the center of each cube.
boiling point The point at which a substance changes from the liquid state to the gas state.
bond The chemical connection between atoms within a molecule. Bonds are forces and are caused by electrons.
bond angle In a molecule, the angle between the two straight lines joining the centers of the atoms concerned.
bromine (Br) A non-metallic element that is isolated as a dark red liquid. It is a very reactive oxidizing agent.
brown dwarf A ball of gas like a star but whose mass is too small to have nuclear fusion occur at its core.
Brownian motion The random movement of particles through a liquid or gas.
buckminsterfullerene See buckyball.
buckyball The nickname for buckminsterfullerene. An allotropic form of carbon. It has a cage-like structure and has the formula C_{50}, C_{60}, or C_{70}.
burette A long, graduated glass tube with a tap at the lower end. It is used to measure a volume of liquid accurately.
calcium (Ca) A soft, slivery-white metal.
calcium carbonate A white solid, occurring naturally in marble and limestone, that dissolves in dilute acids.
carbide A compound that contains carbon and an element with lower electronegativity.
carbon (C) A non-metallic element whose compounds occur widely in nature.
carbonate A salt of carbonic acid (containing the ion CO_3^{2-}).
carbon cycle The circulation of carbon through the biosphere.
carbon dioxide (CO_2) A dense, colorless, odorless gas that does not support combustion. It exists in the atmosphere and is instrumental in the carbon cycle.
carbonic acid (H_2CO_3) A very weak acid formed by dissolving carbon dioxide in water.
carbon monoxide(CO) A colorless, odorless, very poisonous gas. It is sparingly soluble in water.
carboxyl group The organic radical –CO.OH.
carboxylic acid An organic acid that contains one or more carboxyl groups.
catalyst A substance that alters the rate of a chemical reaction but remains chemically unchanged by it.
catalytic cracking The process used in the petroleum industry to convert large-chain hydrocarbon molecules to smaller ones.
catenation The formation of chains of bonded atoms.
cathode The electrode carrying the negative charge in a solution undergoing electrolysis.
cathode rays A stream of electrons emitted from the cathode in a vacuum tube.
cation An ion having a positive charge.
cellulose A complex carbohydrate that is the main component of the cell walls of plants.
centrifuge A machine that rotates an object at high speed.
chain reaction A self-sustaining nuclear reaction yielding energy and electrons emitted by the fission of an atomic nucleus, which proceeds to cause further fissions.
chemical compound A substance composed of two or more elements linked by chemical bonds that may be ionic or covalent.
chemical energy The energy stored in the bonds between atoms and molecules that is released during a chemical reaction.
chemical reaction The process in which one or more substances reacts to form new substances.
chiral An object or a system that differs from its mirror image.
chloride A compound containing chlorine and another element.
chlorine (Cl) A poisonous, greenish, gaseous element that is a powerful oxidizing agent.
chlorophyll A green pigment found in most plants. It absorbs light energy during photosynthesis.
chromatography A technique for separating and identifying mixtures of solutes in a solution.
chromium (Cr) A hard, brittle, gray-white metallic element that is very resistant to corrosion and takes a high polish.
cobalt (Co) A hard, lustrous, silvery-white metallic element found in ores,
colloid A substance made of very small particles whose size (1–100 nm) is between those of a suspension and those in solution.
compound See chemical compound
concentration A measure of the quantity of solute dissolved in a solution at a given temperature.
conductor A material that is able to conduct heat and electricity.
convection current A circular current in a fluid such as air.
coordinate bonding A type of covalent bond in which one of the atoms supplies both electrons.
coordination number The number of atoms, ions, or molecules to which bonds can be formed.
copper (Cu) A pinkish metallic element used widely in alloys and electrical wires.
covalent bond A bond formed when two electrons are shared between two atoms (usually between two non-metallic atoms), one contributed by each atom.
covalent compound A compound in which the atoms in the molecules are held together by covalent bonds.
crust The outer layer of Earth.
cryolite A compound of aluminum fluoride and sodium fluoride.
crystal A substance with an orderly arrangement of atoms, ions, or molecules in a regular geometrical shape.
daughter nucleus In radio active decay, the nucleus produced by the decay of the previous nucleus.

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KEY WORDS

dehydrating agent A substance that has an attraction for water and is therefore used as a drying agent.
dehydrogenation The chemical process of removal of hydrogen atoms from a molecule (a form of oxidation), increasing its degree of unsaturation.
density The mass per unit volume of a given substance.
detergent The term for a synthetic soap substitute.
diamond A transparent crystalline allotrope of carbon. It is the hardest naturally occurring substance.
diatomic molecule A molecule that consists of two atoms.
diffusion The process of rapid random movement of the particles of a liquid or gas that eventually form a uniform mixture.
dipole A chemical compound with an unequally distributed electric charge.
disaccharide A sugar molecule formed by a condensation reaction between two monosaccharide molecules.
displacement reaction A reaction in which a more reactive substance displaces the ions of a less reactive substance.
dissociation The breaking down of a molecule into smaller molecules, atoms, or ions.
dissolve To add a solute to a solvent to form a uniform solution.
distillation A process in which a solution is boiled and its vapor then condensed.
double bond A covalent bond formed between two atoms in which two pairs of electrons contribute to the bond..
dry gas A gas from which all water has been removed
ductile Capable of being drawn out, shaped, or bent.
effective collision A collision that brings about a reaction.
electric field A field of force around a charged particle.
electrode A conductor that allows current to flow through an electrolyte, gas, vacuum, or semiconductor.
electrolysis The process by which an electrolyte is decomposed when a direct current is passed through it between electrodes.
electrolyte A substance that forms ions when molten or dissolved in a solvent and that carries an electric current during electrolysis.
electron One of the three basic subatomic particles. Very light and carrying a negative charge, it orbits around the nucleus of an atom.
element A substance that cannot be split into simpler substances using chemical methods.
emulsion A colloidal dispersion of small droplets of one liquid dispersed within another, such as oil in water or water in oil.
enantiomer One of two "mirror images" of a chiral molecule.
end point The point at which a reaction is complete.
endothermic a chemical change during which heat is absorbed.
enthalpy A measure of the stored heat energy of a substance.
enzyme An organic catalyst, made of proteins, that increases the rate of a specific biochemical reaction.
equilibrium The state of a reversible chemical reaction where the forward and backward reactions take place at the same rate.
equivalence point The point at which there are equivalent amounts of acid and alkali.
ester A member of a hydrocarbon group that is formed by a reaction between a carboxylic acid and an alcohol.
ethane (C_2H_6) A colorless, flammable alkane that occurs in natural gas.
ethanol (C_2H_5OH) A volatile, colorless liquid alcohol used in beverages and as a gasoline octane enhancer.
ethene (C_2H_4) A colorless, flammable unsaturated gas, manufactured by cracking petroleum gas, used in ethanol and polyethene production.
evaporation The change in state from liquid to vapor.
exothermic A chemical change resulting in the liberation of heat.
face-centered cubic close packing A crystal structure in which one atom sits in each "face" of the cube.
Faraday constant The amount of electricity needed to liberate one mole of a monovalent ion during electrolysis ($9.648\ 670 \times 10^{-4}$ C mol^{-1}).
fatty acid A hydrocarbon chain with a carboxyl group at one end.
filtrate A clear liquid that has passed through a filter.
filtration The process of removing particulate matter from a liquid by passing the liquid through a porous substance.
fission A process during which a heavy atomic nucleus disintegrates into two lighter atoms and the lost mass is converted to energy.
fluorescence The emission of light from an object that has been irradiated by light or other radiations.
fluorine (F) A gaseous non-metallic element that is poisonous and very reactive gas.
flux A substance that combines with another substance (usually an oxide), forming a compound with a lower melting point than the oxide.
foam A dispersion of gas in a liquid or solid. Small bubbles of gas are separated by thin films of the liquid or solid.
formula mass The relative molecular mass of a compound calculated using its molecular formula. The mass of a mole of the substance.
forward reaction A reaction in which reactants are converted to products.
fractional distillation The separation of a mixture or liquids that have differing but similar boiling points.
fullerenes Allotropes of carbon in the form of a hollow sphere (buckyball) or tube (nanotube).
functional group The atom (or group of atoms) present in a molecule that determines the characteristic properties of that molecule.
fusion The process by which two or more light atomic nuclei join, forming a single heavier nucleus. The products of fusion are lighter than the components. The mass lost is liberated as energy.
galvanizing The coating of iron or steel plates with a layer of zinc to protect against rusting.
gamma radiation Very short-wave electromagnetic radiation emitted as a result of radioactive decay.
gas One of the states of matter. In a gas, the particles can move freely throughout the space in which it is contained. Gas is the least dense of the states of matter.

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gas-liquid chromatography A type of chromatography in which the mobile phase is a carrier gas and the stationary phase is a microscopic layer of liquid on an inert solid support.
gel A colloidal solution that has formed a jelly. The solid particles are arranged as a fine network in the liquid phase.
geometric isomerism A form of isomerism that describes the orientation of functional groups at the ends of a bond where no rotation is possible.
glucose In animals and plants, the most widely distributed hexose sugar and the most common energy source in respiration.
glycogen A polysaccharide composed of branched chains of glucose, used to store energy in animals and some fungi..
gold (Au) A shiny, yellow metallic element used in coins, jewelry, and electrical contacts.
grade The concentration of ore in rock.
Graham's law The velocity with which a gas will diffuse is inversely proportional to the square root of its density.
graphite A soft, grayish-black, solid allotrope of carbon.
ground state The lowest allowed energy state of an atom, molecule, or ion.
group The vertical columns of elements in the periodic table. Elements in a group react in a similar way and have similar physical properties.
group 1 elements The alkali metals. The elements lithium, sodium, potassium, rubidium, cesium, and francium. These elements have one electron in their outer shell.
group 2 elements The alkaline earth metals. The elements beryllium, magnesium, calcium, strontium, barium, and radium. These elements have two electrons in their outer shell.
group 3 elements The elements boron, aluminum, gallium, indium, and thallium. These elements have a full s orbital and one electron in a p orbital in their outer shell.
group 4 elements The elements carbon, silicon, germanium, tin, and lead. These elements have a full s orbital and two electrons in two p orbitals in their outer shell.
group 5 elements The elements nitrogen, phosphorus, arsenic, antimony, and bismuth. These elements have a full s orbital and three electrons in three p orbitals in their outer shell.
group 6 elements The chalcogens. The elements oxygen, sulfur, selenium, tellurium, and polonium. These elements have a full s orbital, one full p orbital, and two half-full p orbitals in their outer shell.
group 7 elements The halogens. The elements fluorine, chlorine, bromine, iodine, and astatine. These elements have a full s orbital, two full p orbitals, and one half-full p orbital in their outer shell.
group 8 elements. The noble or inert gases. The elements helium, neon, argon, krypton, xenon, and radon. The outer shell of the atoms in these elements is complete, rendering these elements unreactive.
half-life The time required for half the atoms of a radioactive substance to disintegrate.
halide A compound that a halogen makes with another element. Metal halides are ionic; non-metal halides are formed by covalent bonding.
halogens See Group 7 elements.
helium (He) A colorless, odorless gaseous element that is the second most abundant element on Earth.
hexagonal close packing In crystalline structures, a way of packing atoms so that alternating layers overlie one another in an ABABAB pattern.
hexose A monosaccharide with six carbon atoms.
homologous series A series of related organic compounds. The formula of each member differs from the preceding member by the addition of a $–CH_2–$ group.
hydration The combination of water and another substance to produce a single product.
hydride A compound formed between hydrogen and another element.
hydrocarbon An organic molecule consisting only of carbon and hydrogen.
hydrochloric acid (HCl) A colorless fuming solution of hydrogen chloride.
hydrogen (H) An odorless, easily flammable gaseous element that is the most abundant on Earth.
hydrogen bond A weak bond between hydrogen and another element with partial but opposite electrical charges.
hydrogen chloride (HCl) A colorless gas with a pungent smell that fumes in moist air. It is very soluble in water.
hydrogen peroxide (H_2O_2) A colorless or pale blue viscous liquid. It is a strong oxidizing agent, but it can also act as a reducing agent.
hydrogen sulfide (H_2S) A colorless, poisonous gas smelling of bad eggs that is moderately soluble in water. It is a reducing agent.
hydronium ion The positive ion $(H_3O)^+$. It is the hydrated form of the hydrogen ion (H^+) or proton.
hydrophilic Water-loving. In solution, it refers to a chemical or part of a chemical that is highly attracted to water.
hydrophobic Water-hating. It refers to a chemical or part of a chemical that repels water.
hydroxide A compound containing the hydroxide ion or the hydroxyl group bonded to a metal atom.
hydroxide ion The negative ion $(OH^–)$ present in alkalis.
immiscible Incapable of mixing.
indicator A substance that indicates by a change in its color the degree of acidity or alkalinity of a solution or the presence of a given substance.
inert A substance that is either very or completely unreactive.
inert gases See noble gases.
infrared Electromagnetic radiation with a greater wavelength than the red end of the visible spectrum.
insoluble A substance that does not dissolve in a particular solvent under certain conditions of temperature and pressure.
iodine (I) A grayish-black non-metallic element that is essential in the diet and is used in disinfectants and photography.
ion An electrically charged atom or group of atoms.
ionic bonding A type of bonding that occurs when atoms form ions and electrons are transferred from one atom to another.
ionic compound Compounds consisting of ions held together by strong ionic bonds. Ionic compounds are electrolytes.

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KEY WORDS

ionic crystal A type of crystal where ions of two of more elements form a regular three-dimensional arrangement (crystal structure).
ionization energy The energy needed to remove completely an electron from a neutral gaseous atom or ion against the attraction of the nucleus.
ionizing radiation Any radiation capable of displacing electrons from atoms or molecules and so producing ions
iron (Fe) A silvery, malleable and ductile metallic element used in construction.
irradiation The use of radiation to destroy microorganisms in foods.
isomer One of two or more (usually organic) compounds having the same molecular formula and relative molecular mass but different three-dimensional structures.
isomerism The rearrangement atoms in a molecule to make it more efficient.
isomerization The transformation of a molecule into a different isomer.
isotope Atoms of the same element (all chemically identical) having the same atomic number but containing different numbers of neutrons, giving a different mass number.
ketone An organic compound that contain two organic radicals connected to a carbonyl group.
kinetic energy The energy a body has by virtue of its motion.
lanthanide series A series of metallic elements with the atomic numbers 57 to 71. The metals are shiny and are attacked by water and acids.
lattice The orderly three-dimensional arrangements of atoms, molecules, or ions seen in crystals.
lead (Pb) A silvery-white metallic element used in batteries and in water, noise, and radiation shielding.
lead sulfide (PbS) A brownish-black insoluble crystal. It occurs naturally as the mineral galena.
Le Chatelier's principle If a chemical reaction is at equilibrium and a change is made to any of the conditions, further reaction will take place to counteract the changes in order to re-establish equilibrium.
limewater A solution of calcium hydroxide that is used to test for the presence of carbon dioxide.
limiting form The possibilities for the distribution of electrons in a molecule or ion.
liquid A state of matter between solid and gas. Particles are loosely bonded, so can move relatively freely.
lone pair A pair of electrons in the outermost shell of an atom that are not involved in the formation of covalent bonds.
luminescence Light emission from a substance caused by an effect other than heat.
magnesium (Mg) A silvery-white metallic element used in alloys and castings.
magnesium oxide (MgO) A white solid used for reflective coatings and as a component of semiconductors.
manganese (Mn) A soft, gray metallic element used in making steel alloys.
mantle The layer of Earth between the crust and the core.
mass The measure of a body's resistance to acceleration.
mass number The total number of protons and neutrons in the nucleus of an atom.
mass spectrometry A technique for determining the composition of molecules by using the mass of their basic constituents
melting point The point at which a substance changes state from solid to liquid.
methane (CH_4) The simplest alkane. A colorless, tasteless, odorless flammable gas used as a fuel.
mineral A natural inorganic substance with distinct chemical composition and internal structure.
mixture A system consisting of two or more substances that are not chemically combined.
mobile phase The phase that moves along the stationary phase. It is the solvent in paper chromatography.
molarity The concentration of solution giving the number of moles of solute dissolved in 1 kg of solvent.
mole The amount of a substance that contains the same number of entities (atoms, molecules, ions, etc.) as there are atoms in 12 g of the carbon-12 isotope.
molecular mass The sum of the atomic masses of all atoms in a molecule. The mass of a mole of the substance.
molecule The smallest part of an element or chemical compound that can exist independently with all the properties of the element or compound.
monomer A basic unit from which a polymer is made.
monosaccharide A simple sugar such as glucose.
nanotube An isotope of carbon consisting of long thin cylinders closed at either end with caps containing pentagonal rings.
neptunium (Np) A radioactive metallic element that can be synthesized by bombarding U-238 with neutrons.
neptunium series A radioactive series composed of artificial isotopes.
neutral A solution whose pH is 7.
neutralization The reaction of an acid and a base forming a salt and water..
neutron One of the two major components of the atomic nucleus. It has no electric charge.
neutron star The smallest but densest kind of star, apparently resulting from a supernova explosion.
nickel (Ni) A hard, malleable and ductile, silvery-white metallic element that is a component of Earth's core.
nitrate A salt of nitric acid.
nitric acid (HNO_3) A colorless, corrosive, poisonous, fuming liquid that is a strong oxidizing agent.
nitrite A salt of nitrous acid.
nitrogen (N) A colorless gaseous element essential for the growth of plants and animals.
nitrogen cycle The process by which nitrogen is recycled in the ecosystem.
noble gases Group 8 elements: helium, neon, argon, krypton, xenon, and radon. These gases do not combine chemically with other materials.
nucleon A proton or neutron.
nucleus The positively charged core of an atom that contains almost all its mass.
nuclide A particular isotope of an element, identified by the number of protons and neutrons in the nucleus.
optical isomerism A form of isomerism in which two isomers are the same in every way except that they are mirror images that cannot be superimposed on each other.

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orbital An area around an atom or molecule where there is a high probability of finding an electron.
ore A mineral from which a metal or non-metal may be profitably extracted.
oxidation The process by which a substance gains oxygen, loses hydrogen, or loses electrons.
oxidation state The sum of negative and positive charges in an atom.
oxide A compound consisting only of oxygen and another element. Oxides can be either ionic or covalent.
oxidizing agent A substance that can cause the oxidation of another substance by being reduced itself.
oxygen (O) A colorless, odorless gaseous element. It the most common element in Earth's crust and is the basis for respiration in plants and animals..
ozone (O_3) One of the two allotropes of oxygen. A bluish gas with a penetrating smell, it is a strong oxidizing agent.
period The horizontal rows of elements in the periodic table.
periodic table A table of elements, arranged in ascending order of atomic number, that summarizes the major properties of the elements.
periodicity Recurring at regular intervals.
peroxide A compound that contains the peroxide ion O_2^{2-}. Peroxides are strong oxidizing agents.
pH A scale from 0 to 14 that measures the acidity or alkalinity of a solution. A neutral solution has a pH of 7, while an acidic solution has a lower value and an alkaline solution a higher value.
pH meter A device that uses an electrochemical cell to measure pH.
phosphorescence The emission of light by an object, and the persistence of this emission over long periods, following irradiation by light or other forms of radiation.
photochemical reaction A chemical reaction that is initiated by a particular wavelength of light.
photoelectric effect The emission of electrons from metals upon the absorption of electromagnetic radiation.
photosynthesis The photochemical reaction by which green plants make carbohydrates using carbon dioxide and water.
platinum (Pt) A soft, shiny, silver metallic transition element that is malleable and ductile.
pollutant A substance that harms the environment when it mixes with air, soil, or water.
polyethene A thermoplastic polymer made by addition polymerization of ethene.
polymer A material containing very large molecules built up from a series of repeated small basic units (monomers).
polymerization The building up of long chain hydrocarbons from smaller ones.
polysaccharide A organic polymer composed of many simple sugars (monosaccharides).
precipitate An insoluble substance formed by a chemical reaction.
product A substance produced during a chemical reaction.
protein A large, complex molecule composed of a long chain of amino acids.
proton The positively charged particle found in the nucleus of the atom.
protostar The early stage in a star's formation before the onset of nuclear burning.
quantum number The number used when describing the energy levels available to atoms and molecules.
racemate A mixture of equal amounts of left- and right-handed stereoisomers of a chiral molecule.
radiation Energy that is transmitted in the form of particles, rays, or waves.
radical A group of atoms forming part of many molecules.
radioactive decay The process by which unstable radioactive atoms are transformed into stable, non-radioactive atoms.
radioactivity The spontaneous disintegration of certain isotopes accompanied by the emission of radiation.
rate of reaction The speed at which a chemical reaction proceeds.
reactant A substance present at the start of a chemical reaction that takes part in the reaction.
reaction A process in which substances react to form new substances.
reactivity The ability of substances to react to form new substances.
reactivity series of metals Metallic elements arranged in order of their decreasing chemical reactivity.
reagent A substance that takes part in a chemical reaction, one that is usually used to bring about a chemical change.
red giant A very large, cool star in the final stages of its life.
redox reaction A process in which one substance is reduced and another is oxidized at the same time.
reducing agent A chemical that can reduce another while being oxidized itself.
reduction A chemical reaction in which a substance gains electrons, looses oxygen, or gains hydrogen. It is the reverse of oxidation.
reforming The conversion of straight chain molecules into those that are branched in order to improve their efficiencies.
residfining The process used on the residue fraction of crude oil to convert it into a usable product.
residue The solid remaining after the completion of a chemical process.
resonance structure In organic chemistry, a diagrammatic tool to symbolize bonds between atoms in molecules.
respiration The chemical reaction by which an organism derives energy from food.
reverse reaction A reaction in which the products are converted into reactants.
reversible reaction A chemical reaction that can proceed in either direction. It does not reach completion but achieves dynamic equilibrium.
R_f value The ratio of the distance moved by a substance in a chromatographic separation to the distance moved by the solvent.
rust A reddish-brown oxide coating on iron or steel caused by the action of oxygen and water.
salt A compound formed from an acid in which all or part of the hydrogen atoms are replaced by a metal or metal-like group. Salts are generally crystalline.
saponification The treatment of an ester (hydrolysis) with a strong alkaline solution to form a salt of a carboxylic acid and an alcohol.

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KEY WORDS

saturated A solution where there is an equilibrium between the solution and its solute.
scandium (Sc) Silvery-white metallic element in the lanthanide series found in nature only in minute quantities.
sewage Wastewater from domestic and industrial sources.
shell A group of orbitals at a similar distance from an atomic nucleus.
silver (Ag) A white, shiny, ductile metallic element.
silver nitrate ($AgNO_3$) A very soluble white salt that decomposes to form silver, oxygen, and nitrogen dioxide on heating.
slag Waste material that collects on the surface of a molten metal during the process of either extraction or refining.
smelting The process of extracting a metal from its ores.
soap A cleansing agent made from fatty acids derived from natural oils and fats.
sodium (Na) A soft, silver-white metallic element.
sodium chloride (NaCl) A nonvolatile ionic compound that is soluble in water.
sodium hydroxide (NaOH) A white, translucent, crystalline solid that forms a strongly alkaline solution in water.
sol A liquid solution or suspension of a colloid.
solid A state of matter in which the particles are not free to move but in which they can vibrate about fixed positions.
solubility A measure of the quantity of a solute that will dissolve in a certain amount of solvent to form a saturated solution under certain conditions of temperature and pressure.
solubility curve A graphic representation of the changing solubility of a solute in a solvent at different temperatures.
soluble A relative term that describes a substance that can dissolve in a particular solvent.
solute A substance that dissolves in a solvent and thus forms a solution.
solution A uniform mixture of one or more solutes in a solvent.
solvent A substance, usually a liquid, in which a solute dissolves to form a solution.
species The common name for entities (atoms, molecules, molecular fragments, and ions) being subjected to investigation.
spectrum The arrangement of electromagnetic radiation into its constituent wavelengths.
starch A polysaccharide with the formula ($C_6H_{10}O_5$). It is composed of many molecules of glucose.
stationary phase That which the mobile phase moves on. In paper chromatography it is the paper.
stoichiometry The calculation of the quantities of reactants and products involved in a chemical reaction.
subatomic particles The particles from which atoms are made. Neutrons and protons are found in the nucleus of the atom. Electrons form a cloud around the nucleus.
sucrose A disaccharide sugar that occurs naturally in most plants.
sulfate A salt or ester of sulfuric acid.
sulfide A compound of sulfur and a more electropositive element.
sulfur (S) A yellow, non-metallic element that is found abundantly in nature.
sulfuric acid (H_2SO_4) An oily, colorless, odorless liquid that is extremely corrosive.
sulfur dioxide (SO_2) A colorless gas with a pungent odor of burning sulfur. It is very soluble in water.
sulfur trioxide (SO_3) A white, soluble solid that fumes in moist air. It reacts violently with water to form sulfuric acid.
supernova The explosion caused when a massive star dies and collapses.
surface area The sum of the area of the faces of a solid.
suspension A type of dispersion. Small solid particles are dispersed in a liquid or gas.
tensile strength The amount of stress a material can stand without breaking.
thorium Th. A gray, radioactive metallic element used as fuel in nuclear reactors.
thorium series One of the naturally occurring radioactive series.
titanium (Ti) A lightweight, gray metallic element that is very strong and resistant to corrosion.
titration In analytical chemistry, A technique used to determine the concentration of a solute in a solution.
transition metals Metallic elements that have an incomplete inner electron structure and exhibit variable valencies.
triple bond A covalent bond formed between two atoms in which three pairs of electrons contribute to the bond.
ultraviolet Electromagnetic radiation of shorter wavelengths than visible light, but of longer wavelength than X rays.
unit cell The smallest repeating array of atoms, ions, or molecules in a crystal.
universal indicator A mixture of substances that shows a gradual color change over a wide range of pH values.
uranium (U) A hard, white, radioactive metallic element used in nuclear reactors and nuclear weapons.
uranium series One of the naturally occurring radioactive series.
valency The measure of an element's ability to combine with other elements.
vanadium (V) A silvery-white or gray metallic element used as a steel additive and in catalysts.
van der Waals forces Weak intermolecular or interatomic forces between neutral molecules or atoms. They are much weaker than chemical bonds.
viscosity A measure of the resistance of a fluid to flow.
wavelength The distance between two corresponding points on a wave.
white dwarf The small, dense remnant of a star near the end of its period of nuclear fusion.
zinc (Zn) A hard, brittle, bluish-white metallic element used in alloys and in galvanizing.
zwitterion An ion that carries both a positive and negative charge.

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Internet resources

There is a lot of useful information on the internet. Information on a particular topic may be available through a search engine such as Google (**http://www.google.com**). Some of the Web sites that are found in this way may be very useful, others not. Below is a selection of Web sites related to the material covered by this book.

The publisher takes no responsibility for the information contained within these Web sites. All the sites were accessible on March 1, 2006.

About Chemistry
Includes links to a glossary, encyclopedia, experiments, periodic table, chemical structure archive, chemistry problems, and articles.
http://chemistry.about.com

Allchemicals.info
Hundreds of definitions and descriptions from absolute zero to zinc.
http://www.allchemicals.info

Chem4Kids
Accessible information on matter, atoms, elements, reactions, biochemistry, and much more, for grades 5–9.
http://www.chem4kids.com

Chemistry Carousel: A Trip Around the Carbon Cycle
Site explaining the carbon cycle.
http://library.thinkquest.org/11226

Chemistry Central
Offers basic atomic information, information on the periodic table, chemical bonding, and organic chemistry as well as extensive links to a wide variety of other resources.
http://users.senet.com.au/~rowanb/chem

Chemistry.org
Offers publications, career advice, information, and curriculum materials for K–12.
http://www.acs.org/

The Chemistry Research Center
Offers high school students links to useful sites for help with homework.
http://library.thinkquest.org/21192

Chemistry Tutor
Help for high school students with chemistry homework. Includes an introduction to chemistry, equations, calculations, types of reactions, information on lab safety, and links to other sources.
http://library.thinkquest.org/2923

ChemSpy.com
Links to chemistry and chemical engineering terms, definitions, synonyms, acronyms, and abbreviations.
http://www.chemspy.com

Chemtutor
A guide to the basics of chemistry for high school and college students.
http://www.chemtutor.com

CHEMystery
A virtual chemistry textbook, providing an interactive guide for high school chemistry students and links to other resources.
http://library.thinkquest.org/3659

Common Molecules
Information and 3-D presentation on molecules studied in chemistry classes or of interest for their structural properties.
http://www.reciprocalnet.org/edumodules/commonmolecules

Delights of Chemistry
Presents more than 40 chemistry demonstrations and 500 photographs/animations of experiments and chemical reactions.
http://www.chem.leeds.ac.uk/delights

EnvironmentalChemistry.com
Includes a chemical and environmental dictionary; a detailed periodic table of elements; articles on environmental and hazardous materials issues; a geologic timeline.
http://environmentalchemistry.com

Eric Weisstein's World of CHEMISTRY
Online encyclopedia, still under construction, with excellent graphics; good source for chemical reactions.
http://scienceworld.wolfram.com/chemistry

General Chemistry Online
Contains searchable glossary, frequently asked questions, database of compounds, tutorials, simulations, and toolbox of periodic table and calculators.
http://antoine.frostburg.edu/chem/senese/101

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INTERNET RESOURCES

IUPAC Nomenclature Home Page
Definitions of terms used in chemistry provided by the International Union of Pure and Applied Chemistry. The "Gold book" is particularly good for basic terms.
http://www.chem.qmul.ac.uk/iupac

The Learning Matters of Chemistry
Offers visualizations of molecules and atomic orbits, interactive chemistry exercises, and links to other resources.
http://www.knowledgebydesign.com/tlmc

The Macrogalleria: A Cyberwonderland of Polymer Fun
An Internet "mall" for learning about polymers and polymer science.
http://www.pslc.ws/macrog

Nuclear Chemistry and the Community
Introduction to nuclear chemistry and its impact on society.
http://www.chemcases.com/nuclear

Open Directory Project: Biochemistry and Molecular Biology
A comprehensive listing of internet resources in the field of biochemistry.
http://dmoz.org/Science/Biology/Biochemistry_and_Molecular_Biology

Open Directory Project: Chemistry
A comprehensive listing of internet resources in the field of chemistry.
http://dmoz.org/science/chemistry

The pH Factor
Introduction to acids and bases for middle school students.
http://www.miamisci.org/ph

PSIgate: Chemistry
Offers interactive tutorials, timeline, and links, in many areas.
http://www.psigate.ac.uk/newsite/chemistry-gateway

Reactive Reports
Web chemistry magazine offering news stories and links to sites.
http://www.reactivereports.com

ScienceMaster
News, information, links, columns, and homework help in all major areas of science.
http://www.sciencemaster.com

Science News for Kids
Science Service Suggestions for hands-on activities, books, articles, Web resources, and other useful materials for students ages 9–13.
http://www.sciencenewsforkids.org

The Science of Spectroscopy
Introduction to spectroscopy with descriptions of common spectroscopic analysis techniques, as well as applications of spectroscopy in consumer products, medicine, and space science.
http://www.scienceofspectroscopy.info

Virtual Chemistry
3-D simulated laboratory for teaching chemistry, with links to an online encyclopedia, tutorials, and close-ups of molecules.
http://neon.chem.ox.ac.uk/vrchemistry

A Visual Interpretation of the Table of Elements
Striking visual representations of 110 elements. Site includes detailed information on the elements and on the history of the periodic table.
http://www.chemsoc.org/viselements

Web Elements™ Periodic Table Scholar Edition
High quality source of information about the periodic table for students. There is also a professional edition.
http://www.webelements.com/webelements/scholar

What's that Stuff?
Explores the chemistry of everyday objects.
http://pubs.acs.org/cen/whatstuff/stuff.html

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Flexibook

Color Atlas of Biochemistry

J. Koolman
K. H. Roehm

Second edition, revised and enlarged

basic sciences

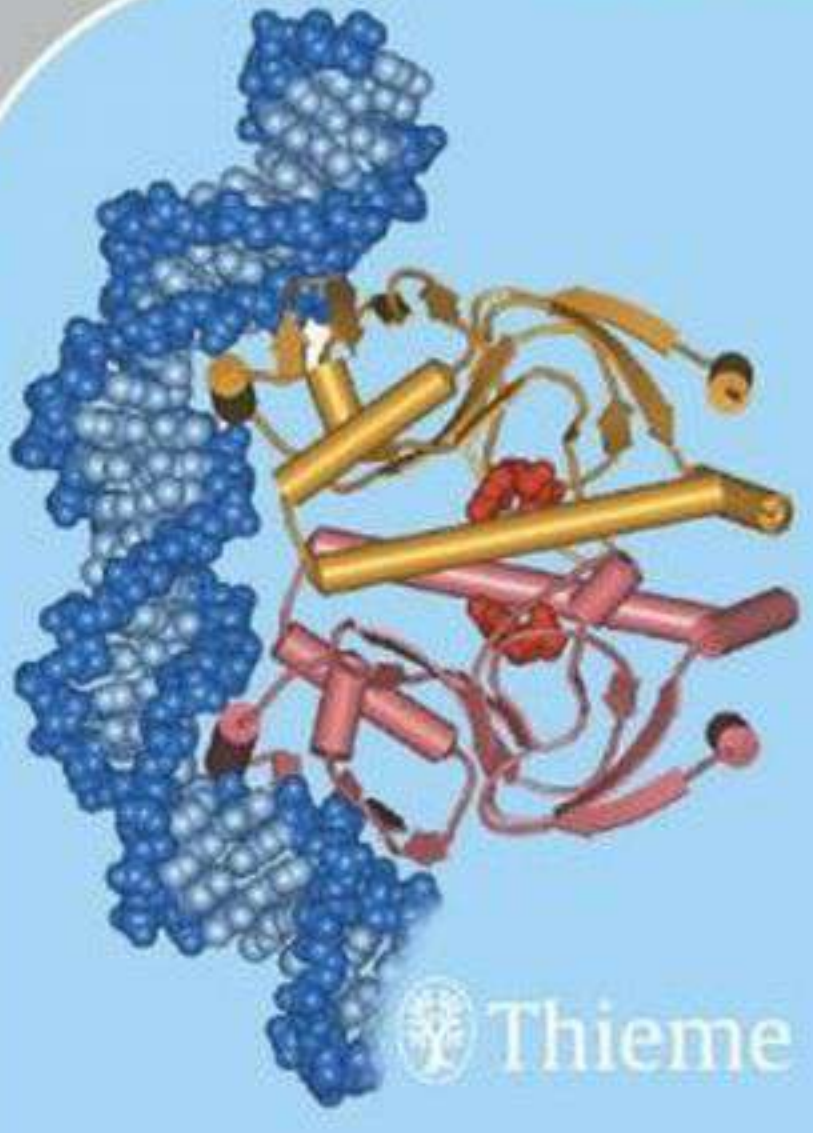

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Key to color-coding:
see front and rear inside covers

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Introduction

This paperback atlas is intended for students of medicine and the biological sciences. It provides an introduction to biochemistry, but with its modular structure it can also be used as a reference book for more detailed information. The 216 color plates provide knowledge in the field of biochemistry, accompanied by detailed information in the text on the facing page. The degree of dif - culty of the subject-matter is indicated by symbols in the text:

- ● stands for "basic biochemical knowledge"
- ◑ indicates "standard biochemical knowledge"
- ○ means "specialist biochemical knowledge."

Some general rules used in the structure of the illustrations are summed up in two *explanatory plates* inside the front and back covers. Keywords, definitions, explanations of unfamiliar concepts and chemical formulas can be found using the *index*. The book starts with a few **basics** in biochemistry (pp. 2–33). There is a brief explanation of the concepts and principles of chemistry (pp. 2–15). These include the periodic table of the elements, chemical bonds, the general rules governing molecular structure, and the structures of important classes of compounds. Several basic concepts of *physical chemistry* are also essential for an understanding of biochemical processes. Pages 16–33 therefore discuss the various forms of energy and their interconversion, reaction kinetics and catalysis, the properties of water, acids and bases, and redox processes.

These basic concepts are followed by a section on the structure of the important biomolecules (pp. 34–87). This part of the book is arranged according to the different classes of metabolites. It discusses carbohydrates, lipids, amino acids, peptides and proteins, nucleotides, and nucleic acids.

The next part presents the reactions involved in the interconversion of these compounds—the part of biochemistry that is commonly referred to as **metabolism** (pp. 88–195). The section starts with a discussion of the enzymes and coenzymes, and discusses the mechanisms of metabolic regulation and the so-called *energy metabolism*. After this, the central metabolic pathways are presented, once again arranged according to the class of metabolite (pp. 150–195).

The second half of the book begins with a discussion of the functional compartments within the cell, the **cellular organelles** (pp. 196–235). This is followed on pp. 236–265 by the current field of **molecular genetics** (*molecular biology*). A further extensive section is devoted to the biochemistry of individual **tissues and organs** (pp. 266–359). Here, it has only been possible to focus on the most important organs and organ systems—the digestive system, blood, liver, kidneys, muscles, connective and supportive tissues, and the brain.

Other topics include the biochemistry of **nutrition** (pp. 360–369), the structure and function of important **hormones** (pp. 370–393), and **growth and development** (pp. 394–405).

The paperback atlas concludes with a series of schematic **metabolic "charts"** (pp. 407–419). These plates, which are not accompanied by explanatory text apart from a brief introduction on p. 406, show simplified versions of the most important synthetic and degradative pathways. The charts are mainly intended for reference, but they can also be used to review previously learned material. The enzymes catalyzing the various reactions are only indicated by their EC numbers. Their names can be found in the systematically arranged and annotated enzyme list (pp. 420–430).

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Periodic table

A. Biologically important elements ◑

There are 81 stable elements in nature. Fifteen of these are present in all living things, and a further 8–10 are only found in particular organisms. The illustration shows the first half of the **periodic table**, containing all of the biologically important elements. In addition to physical and chemical data, it also provides information about the distribution of the elements in the living world and their abundance in the human body. The laws of atomic structure underlying the periodic table are discussed in chemistry textbooks.

More than 99% of the atoms in animals' bodies are accounted for by just four elements—hydrogen (H), oxygen (O), carbon (C) and nitrogen (N). Hydrogen and oxygen are the constituents of water, which alone makes up 60–70% of cell mass (see p. 196). Together with carbon and nitrogen, hydrogen and oxygen are also the major constituents of the **organic compounds** on which most living processes depend. Many biomolecules also contain sulfur (S) or phosphorus (P). The above **macroelements** are essential for all organisms.

A second biologically important group of elements, which together represent only about 0.5% of the body mass, are present almost exclusively in the form of **inorganic ions**. This group includes the *alkali metals* sodium (Na) and potassium (K), and the *alkaline earth metals* magnesium (Mg) and calcium (Ca). The halogen *chlorine* (Cl) is also always ionized in the cell. All other elements important for life are present in such small quantities that they are referred to as **trace elements**. These include transition metals such as iron (Fe), zinc (Zn), copper (Cu), cobalt (Co) and manganese (Mn). A few *nonmetals,* such as iodine (I) and selenium (Se), can also be classed as essential trace elements.

B. Electron configurations: examples ○

The chemical properties of atoms and the types of bond they form with each other are determined by their electron shells. The **electron configurations** of the elements are therefore also shown in Fig. **A**. Fig. **B** explains the symbols and abbreviations used. More detailed discussions of the subject are available in chemistry textbooks.

The possible states of electrons are called **orbitals**. These are indicated by what is known as the principal quantum number and by a letter—s, p, or d. The orbitals are filled one by one as the number of electrons increases. Each orbital can hold a maximum of two electrons, which must have oppositely directed "spins." Fig. **A** shows the distribution of the electrons among the orbitals for each of the elements. For example, the six electrons of carbon (**B1**) occupy the 1s orbital, the 2s orbital, and two 2p orbitals. A filled 1s orbital has the same electron configuration as the noble gas helium (He). This region of the electron shell of carbon is therefore abbreviated as "He" in Fig. **A**. Below this, the numbers of electrons in each of the other filled orbitals (2s and 2p in the case of carbon) are shown on the right margin. For example, the electron shell of chlorine (**B2**) consists of that of neon (Ne) and seven additional electrons in 3s and 3p orbitals. In iron (**B3**), a transition metal of the first series, electrons occupy the 4s orbital even though the 3d orbitals are still partly empty. Many reactions of the transition metals involve empty d orbitals—e. g., redox reactions or the formation of complexes with bases.

Particularly stable electron arrangements arise when the outermost shell is fully occupied with eight electrons (the "**octet rule**"). This applies, for example, to the noble gases, as well as to ions such as Cl^- ($3s^2 3p^6$) and Na^+ ($2s^2 2p^6$). It is only in the cases of hydrogen and helium that two electrons are already suf cient to fill the outermost 1s orbital.

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A. Biologically important elements

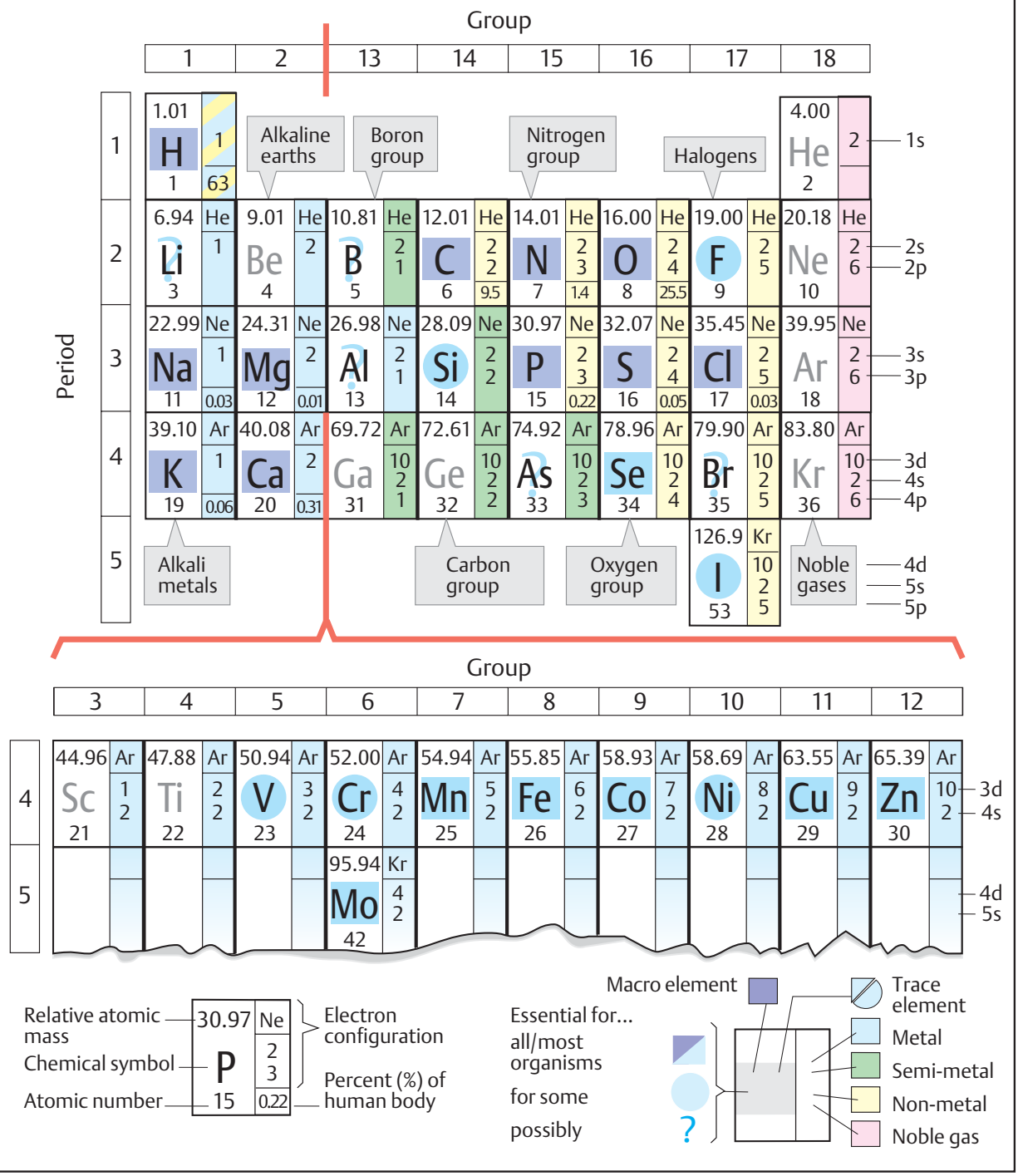

B. Electron configurations: examples

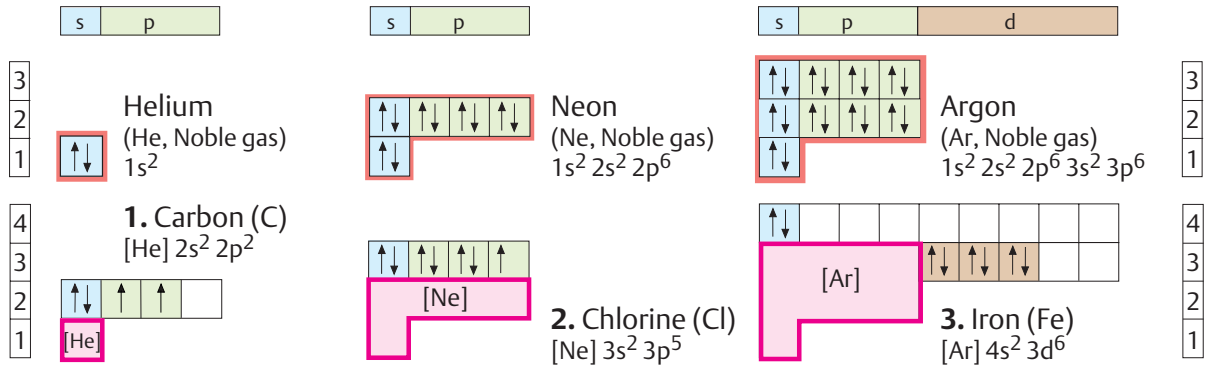

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Bonds

A. Orbital hybridization and chemical bonding ○

Stable, covalent bonds between nonmetal atoms are produced when orbitals (see p. 2) of the two atoms form **molecular orbitals** that are occupied by one electron from each of the atoms. Thus, the four bonding electrons of the carbon atom occupy 2s and 2p atomic orbitals (**1a**). The 2s orbital is spherical in shape, while the three 2p orbitals are shaped like dumbbells arranged along the x, y, and z axes. It might therefore be assumed that carbon atoms should form at least *two different* types of molecular orbital. However, this is not normally the case. The reason is an effect known as **orbital hybridization**. Combination of the s orbital and the three p orbitals of carbon gives rise to four equivalent, tetrahedrally arranged sp^3 atomic orbitals (**sp^3 hybridization**). When these overlap with the 1s orbitals of H atoms, four equivalent σ-molecular orbitals (**1b**) are formed. For this reason, carbon is capable of forming four bonds—i. e., it has a valency of four. Single bonds between nonmetal atoms arise in the same way as the four σ or **single bonds** in methane (CH_4). For example, the hydrogen phosphate ion (HPO_4^{2-}) and the ammonium ion (NH_4^+) are also tetrahedral in structure (**1c**).

A second common type of orbital hybridization involves the 2s orbital and only *two* of the three 2p orbitals (2a). This process is therefore referred to as **sp^2 hybridization**. The result is three equivalent sp^2 hybrid orbitals lying in one plane at an angle of 120° to one another. The remaining $2p_x$ orbital is oriented perpendicular to this plane. In contrast to their sp^3 counterparts, sp^2-hybridized atoms form two *different* types of bond when they combine into molecular orbitals (**2b**). The three sp^2 orbitals enter into σ bonds, as described above. In addition, the electrons in the two $2p_x$ orbitals, known as **π electrons**, combine to give an additional, elongated π molecular orbital, which is located above and below the plane of the σ bonds. Bonds of this type are called **double bonds**. They consist of a σ bond and a π bond, and arise only when both of the atoms involved are capable of sp^2 hybridization. In contrast to single bonds, double bonds are not freely rotatable, since rotation would distort the π-molecular orbital. This is why all of the atoms lie in one plane (**2c**); in addition, *cis–trans* isomerism arises in such cases (see p. 8). Double bonds that are common in biomolecules are C=C and C=O. C=N double bonds are found in aldimines (Schiff bases, see p. 178).

B. Resonance ◑

Many molecules that have several double bonds are much less reactive than might be expected. The reason for this is that the double bonds in these structures cannot be localized unequivocally. Their π orbitals are not confined to the space between the double-bonded atoms, but form a shared, extended **π-molecular orbital**. Structures with this property are referred to as **resonance hybrids**, because it is impossible to describe their actual bonding structure using standard formulas. One can either use what are known as **resonance structures**—i. e., idealized configurations in which π electrons are assigned to specific atoms (cf. pp. 32 and 66, for example)—or one can use dashed lines as in Fig. **B** to suggest the extent of the delocalized orbitals. (Details are discussed in chemistry textbooks.)

Resonance-stabilized systems include carboxylate groups, as in *formate*; aliphatic hydrocarbons with conjugated double bonds, such as *1,3-butadiene*; and the systems known as **aromatic ring systems**. The best-known aromatic compound is *benzene,* which has six delocalized π electrons in its ring. Extended resonance systems with 10 or more π electrons absorb light within the visible spectrum and are therefore *colored.* This group includes the aliphatic carotenoids (see p. 132), for example, as well as the heme group, in which 18 π electrons occupy an extended molecular orbital (see p. 106).

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A. Orbital hybridization and chemical bonding

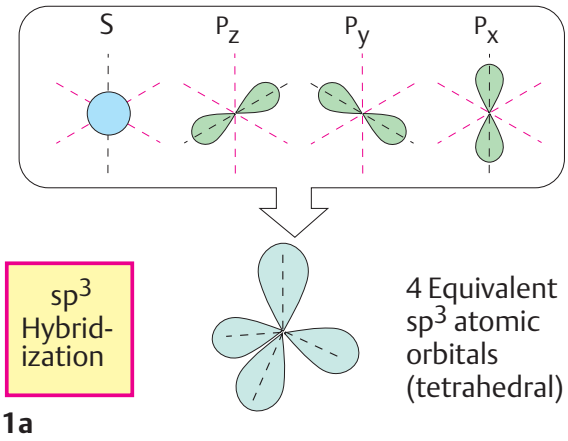

1a

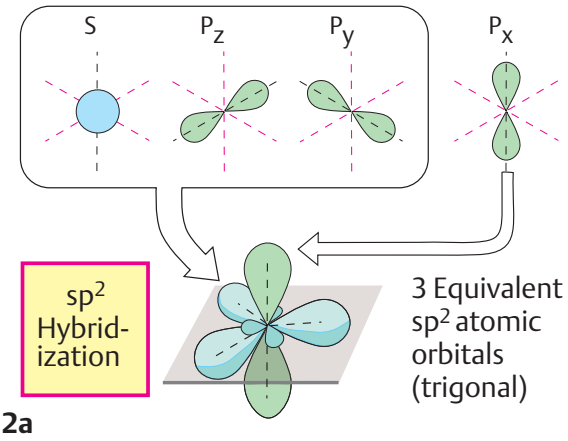

2a

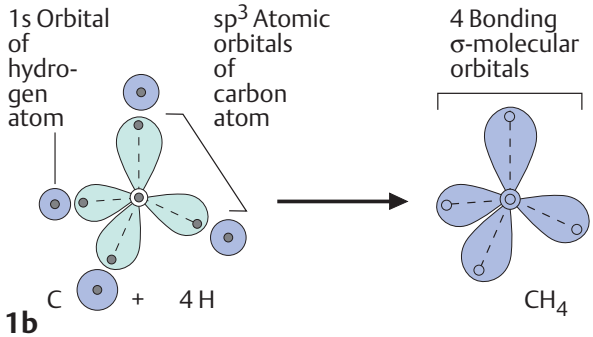

1b

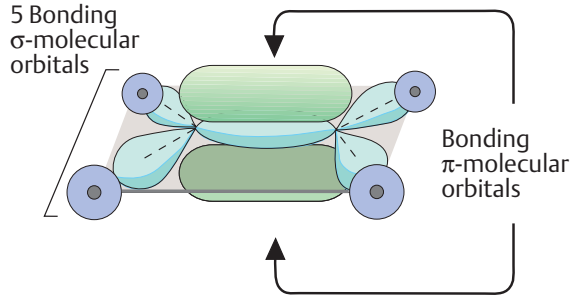

2b

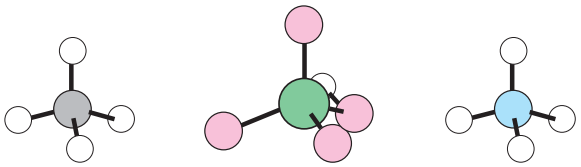

1c

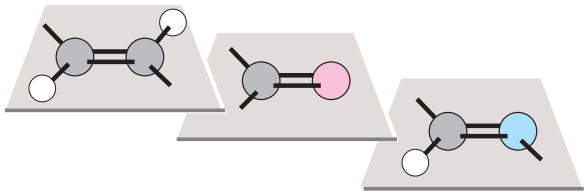

2c

B. Resonance

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π-Molecular orbitals	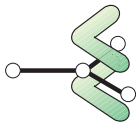	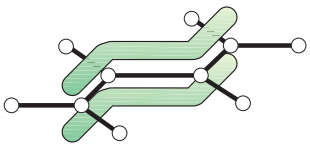	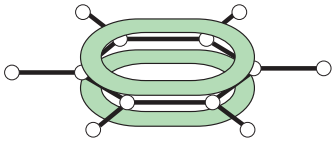
Formula	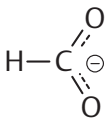	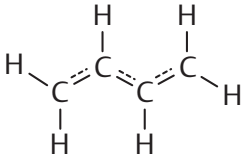	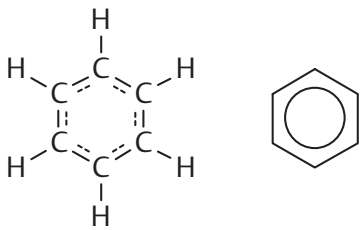

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Molecular structure

The physical and chemical behavior of molecules is largely determined by their **constitution** (the type and number of the atoms they contain and their bonding). Structural formulas can therefore be used to predict not only the chemical reactivity of a molecule, but also its size and shape, and to some extent its conformation (the spatial arrangement of the atoms). Some data providing the basis for such predictions are summarized here and on the facing page. In addition, L-dihydroxyphenylalanine (L-dopa; see p. 352), is used as an example to show the way in which molecules are illustrated in this book.

A. Molecule illustrations ◑

In traditional two-dimensional **structural formulas** (**A1**), atoms are represented as letter symbols and electron *pairs* are shown as lines. Lines between two atomic symbols symbolize two **bonding electrons** (see p. 4), and all of the other lines represent **free electron pairs**, such as those that occur in O and N atoms. Free electrons are usually not represented explicitly (and this is the convention used in this book as well). Dashed or continuous circles or arcs are used to emphasize delocalized electrons.

Ball-and-stick models (**A2**) are used to illustrate the spatial structure of molecules. Atoms are represented as colored balls (for the color coding, see the inside front cover) and bonds (including multiple bonds) as gray cylinders. Although the relative bond lengths and angles correspond to actual conditions, the size at which the atoms are represented is too small to make the model more comprehensible.

Space-filling **van der Waals models** (**A3**) are useful for illustrating the actual shape and size of molecules. These models represent atoms as truncated balls. Their effective extent is determined by what is known as the van der Waals radius. This is calculated from the energetically most favorable distance between atoms that are not chemically bonded to one another.

B. Bond lengths and angles ○

Atomic radii and distances are now usually expressed in picometers (pm; 1 pm = 10^{-12} m). The old angstrom unit (Å, Å = 100 pm) is now obsolete. The length of single bonds approximately corresponds to the sum of what are known as the **covalent radii** of the atoms involved (see inside front cover). Double bonds are around 10–20% shorter than single bonds. In sp^3-hybridized atoms, the angle between the individual bonds is approx. 110°; in sp^2-hybridized atoms it is approx. 120°.

C. Bond polarity ○

Depending on the position of the element in the periodic table (see p. 2), atoms have different **electronegativity**—i. e., a different tendency to take up extra electrons. The values given in **C2** are on a scale between 2 and 4. The higher the value, the more electronegative the atom. When two atoms with very different electronegativities are bound to one another, the bonding electrons are drawn toward the more electronegative atom, and the **bond** is **polarized**. The atoms involved then carry positive or negative partial charges. In **C1**, the van der Waals surface is colored according to the different charge conditions (red = negative, blue = positive). Oxygen is the most strongly electronegative of the biochemically important elements, with C=O double bonds being especially highly polar.

D. Hydrogen bonds ◑

The **hydrogen bond**, a special type of noncovalent bond, is extremely important in biochemistry. In this type of bond, hydrogen atoms of OH, NH, or SH groups (known as hydrogen bond **donors**) interact with free electrons of **acceptor** atoms (for example, O, N, or S). The bonding energies of hydrogen bonds (10–40 kJ mol^{-1}) are much lower than those of covalent bonds (approx. 400 kJ mol^{-1}). However, as hydrogen bonds can be very numerous in proteins and DNA, they play a key role in the stabilization of these molecules (see pp. 68, 84). The importance of hydrogen bonds for the properties of water is discussed on p. 26.

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A. Molecule illustrations

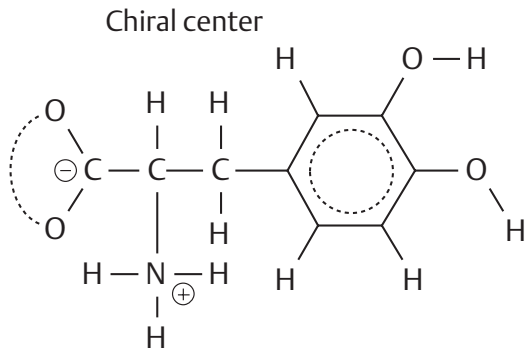

1. Formula illustration

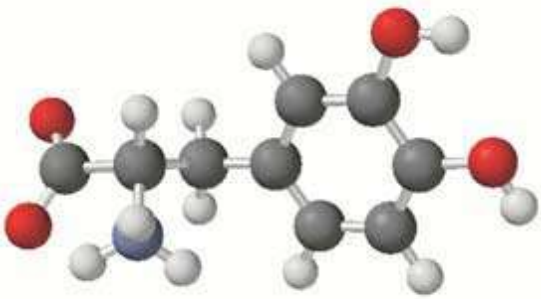

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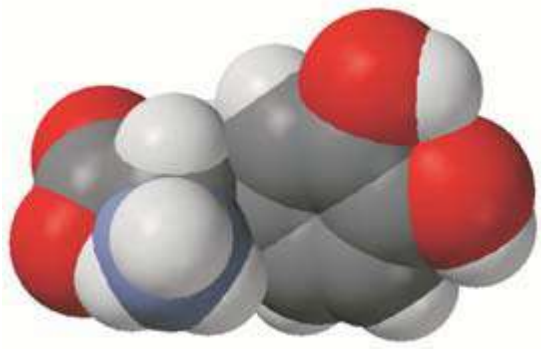

3. Van der Waals model

B. Bond lengths and angles

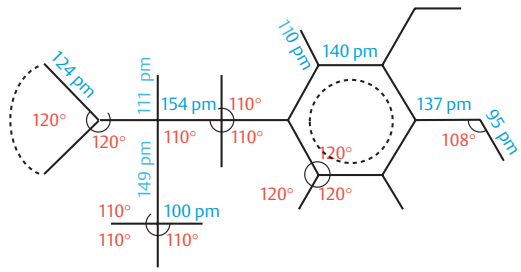

C. Bond polarity

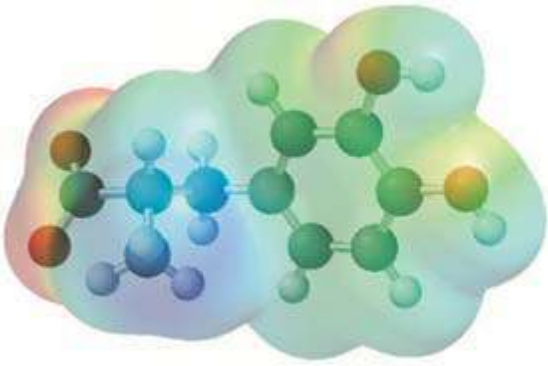

Positive Neutral Negative

1. Partial charges in L-dopa

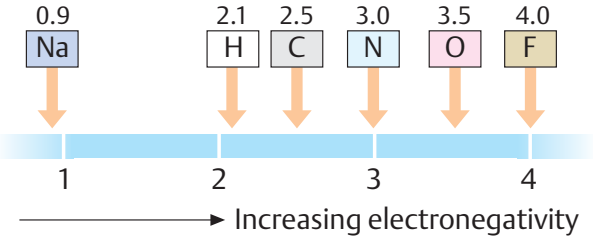

2. Electronegativities

D. Hydrogen bonds

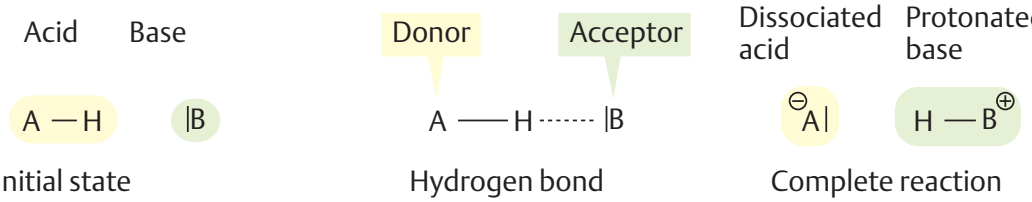

1. Principle

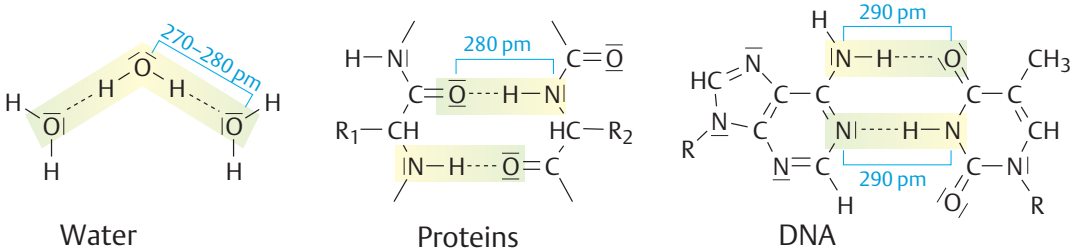

2. Examples

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Isomerism

Isomers are molecules with the same composition (i.e. the same molecular formula), but with different chemical and physical properties. If isomers differ in the way in which their atoms are bonded in the molecule, they are described as **structural isomers** (cf. citric acid and isocitric acid, **D**). Other forms of isomerism are based on different arrangements of the substituents of bonds (**A**, **B**) or on the presence of chiral centers in the molecule (**C**).

A. cis–trans isomers ◑

Double bonds *are not freely rotatable* (see p. 4). If double-bonded atoms have different substituents, there are two possible orientations for these groups. In **fumaric acid**, an intermediate of the tricarboxylic acid cycle (see p. 136), the carboxy groups lie on *different* sides of the double bond (*trans* or *E* position). In its isomer **maleic acid**, which is not produced in metabolic processes, the carboxy groups lie on the *same* side of the bond (*cis* or *Z* position). *Cis–trans* isomers (**geometric isomers**) have different chemical and physical properties—e.g., their melting points (Fp.) and pK_a values. They can only be interconverted by chemical reactions.

In lipid metabolism, *cis–trans* isomerism is particularly important. For example, double bonds in natural fatty acids (see p. 48) usually have a *cis* configuration. By contrast, unsaturated intermediates of β oxidation have a *trans* configuration. This makes the breakdown of unsaturated fatty acids more complicated (see p. 166). Light-induced *cis–trans* isomerization of retinal is of central importance in the visual cycle (see p. 358).

B. Conformation ◑

Molecular forms that arise as a result of rotation around freely rotatable bonds are known as **conformers**. Even small molecules can have different conformations in solution. In the two conformations of **succinic acid** illustrated opposite, the atoms are arranged in a similar way to fumaric acid and maleic acid. Both forms are possible, although conformation 1 is more favorable due to the greater distance between the COOH groups and therefore occurs more frequently. Biologically active macromolecules such as proteins or nucleic acids usually have well-defined ("native") conformations, which are stabilized by interactions in the molecule (see p. 74).

C. Optical isomers ◑

Another type of isomerism arises when a molecule contains a **chiral center** or is chiral as a whole. Chirality (from the Greek *cheir,* hand) leads to the appearance of structures that behave like image and mirror-image and that cannot be superimposed ("mirror" isomers). The most frequent cause of chiral behavior is the presence of an asymmetric C atom—i.e., an atom with four *different* substituents. Then there are two forms **(enantiomers)** with different **configurations.** Usually, the two enantiomers of a molecule are designated as L and D forms. Clear classification of the configuration is made possible by the *R/S system* (see chemistry textbooks).

Enantiomers have very similar chemical properties, but they rotate polarized light in opposite directions (**optical activity**, see pp. 36, 58). The same applies to the enantiomers of **lactic acid**. The dextrorotatory L-lactic acid occurs in animal muscle and blood, while the D form produced by microorganisms is found in milk products, for example (see p. 148). The Fischer projection is often used to represent the formulas for chiral centers (cf. p. 58).

D. The aconitase reaction ○

Enzymes usually function *stereospecifically.* In chiral substrates, they only accept one of the enantiomers, and the reaction products are usually also sterically uniform. *Aconitate hydratase* (aconitase) catalyzes the conversion of citric acid into the constitution isomer isocitric acid (see p. 136). Although citric acid is not chiral, aconitase only forms one of the four possible isomeric forms of isocitric acid (*2R,3S*-isocitric acid). The intermediate of the reaction, the unsaturated tricarboxylic acid *aconitate,* only occurs in the *cis* form in the reaction. The *trans* form of aconitate is found as a constituent of certain plants.

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A. *cis–trans* isomers

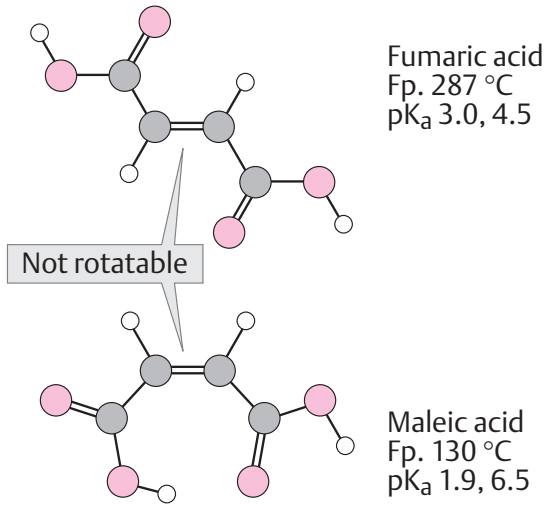

B. Conformers

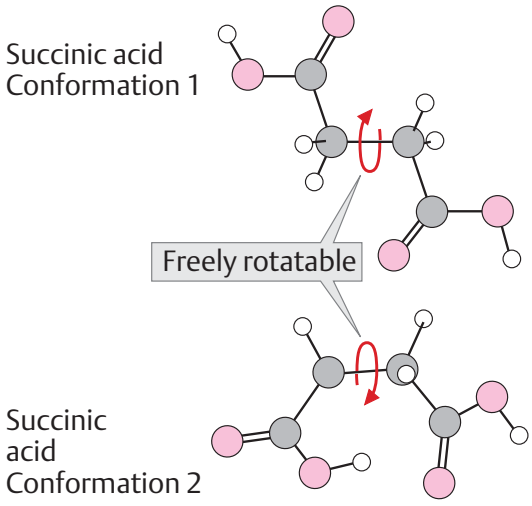

C. Optical isomers

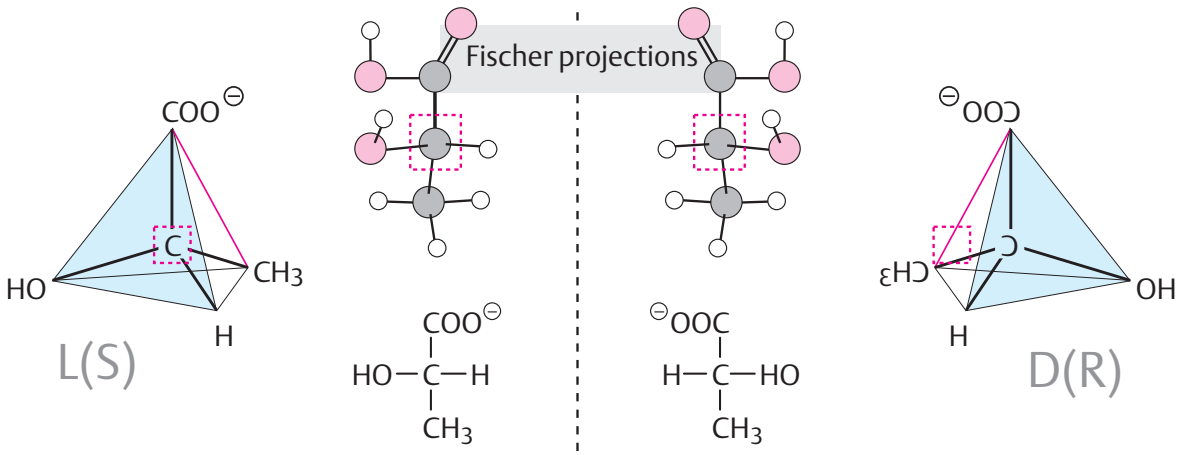

	L-lactic acid
Fp.	53 °C
pKa value	3.7
Specific rotation	+ 2.5°

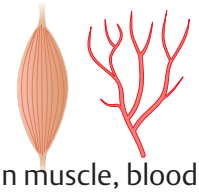

In muscle, blood

In milk products

D-lactic acid	
53 °C	Fp.
3.7	pKa value
-2.5°	Specific rotation

D. The aconitase reaction

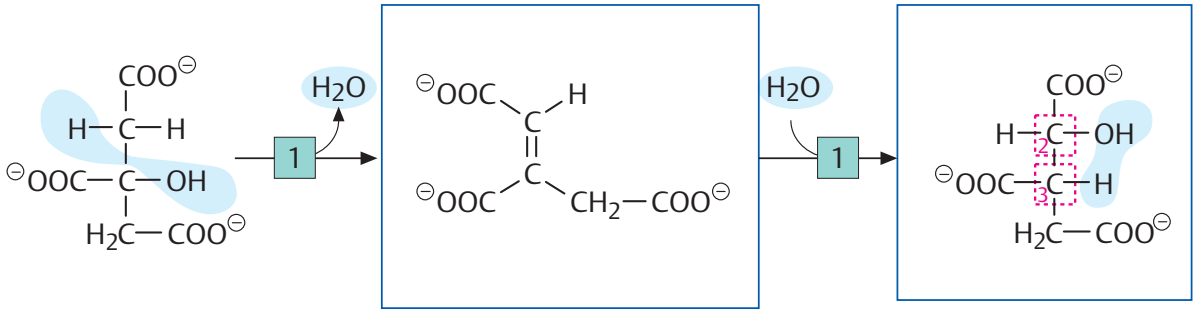

Citrate (prochiral) — *cis*-Aconitate (intermediate product) — (*2R,3S*)-Isocitrate

trans-Aconitate occurs in plants

1 Aconitase *4.2.1.3*

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Biomolecules I

A. Important classes of compounds ●

Most biomolecules are derivatives of simple compounds of the non-metals oxygen (O), hydrogen (H), nitrogen (N), sulfur (S), and phosphorus (P). The biochemically important oxygen, nitrogen, and sulfur compounds can be formally derived from their compounds with hydrogen (i.e., H_2O, NH_3, and H_2S). In biological systems, phosphorus is found almost exclusively in derivatives of phosphoric acid, H_3PO_4.

If one or more of the hydrogen atoms of a non-metal hydride are replaced formally with another group, R—e.g., alkyl residues—then derived compounds of the type R-XH_{n-1}, R-XH_{n-2}-R, etc., are obtained. In this way, **alcohols** (R-OH) and **ethers** (R-O-R) are derived from water (H_2O); primary **amines** (R-NH_2), secondary amines (R-NH-R) and tertiary amines (R-N-R′R″) amines are obtained from ammonia (NH_3); and **thiols** (R-SH) and **thioethers** (R-S-R′) arise from hydrogen sulfide (H_2S). Polar groups such as -OH and -NH_2 are found as substituents in many organic compounds. As such groups are much more reactive than the hydrocarbon structures to which they are attached, they are referred to as **functional groups**.

New functional groups can arise as a result of **oxidation** of the compounds mentioned above. For example, the oxidation of a thiol yields a **disulfide** (R-S-S-R). Double oxidation of a primary alcohol (R-CH_2-OH) gives rise initially to an **aldehyde** (R-C(O)-H), and then to a **carboxylic acid** (R-C(O)-OH). In contrast, the oxidation of a secondary alcohol yields a **ketone** (R-C(O)-R). The carbonyl group (C=O) is characteristic of aldehydes and ketones.

The addition of an amine to the carbonyl group of an aldehyde yields—after removal of water—an **aldimine** (not shown; see p. 178). Aldimines are intermediates in amino acid metabolism (see p. 178) and serve to bond aldehydes to amino groups in proteins (see p. 62, for example). The addition of an alcohol to the carbonyl group of an aldehyde yields a **hemiacetal** (R-O-C(H)OH-R). The cyclic forms of sugars are well-known examples of hemiacetals (see p. 36). The oxidation of hemiacetals produces carboxylic acid esters.

Very important compounds are the **carboxylic acids** and their derivatives, which can be formally obtained by exchanging the OH group for another group. In fact, derivatives of this type are formed by nucleophilic substitutions of activated intermediate compounds and the release of water (see p. 14). **Carboxylic acid esters** (R-O-CO-R′) arise from carboxylic acids and alcohols. This group includes the fats, for example (see p. 48). Similarly, a carboxylic acid and a thiol yield a **thioester** (R-S-CO-R′). Thioesters play an extremely important role in carboxylic acid metabolism. The best-known compound of this type is acetyl-coenzyme A (see p. 12).

Carboxylic acids and primary amines react to form **carboxylic acid amides** (R-NH-CO-R′). The amino acid constituents of peptides and proteins are linked by carboxylic acid amide bonds, which are therefore also known as peptide bonds (see p. 66).

Phosphoric acid, H_3PO_4, is a tribasic (triprotic) acid—i.e., it contains three hydroxyl groups able to donate H^+ ions. At least one of these three groups is fully dissociated under normal physiological conditions, while the other two can react with alcohols. The resulting products are phosphoric acid monoesters (R-O-P(O)O-OH) and diesters (R-O-P(O)O-O-R′). **Phosphoric acid monoesters** are found in carbohydrate metabolism, for example (see p. 36), whereas **phosphoric acid diester** bonds occur in phospholipids (see p. 50) and nucleic acids (see p. 82).

Compounds of one acid with another are referred to as **acid anhydrides**. A particularly large amount of energy is required for the formation of an acid—anhydride bond. Phosphoric anhydride bonds therefore play a central role in the storage and release of chemical energy in the cell (see p. 122). Mixed anhydrides between carboxylic acids and phosphoric acid are also very important "energy-rich metabolites" in cellular metabolism.

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A. Important classes of compounds

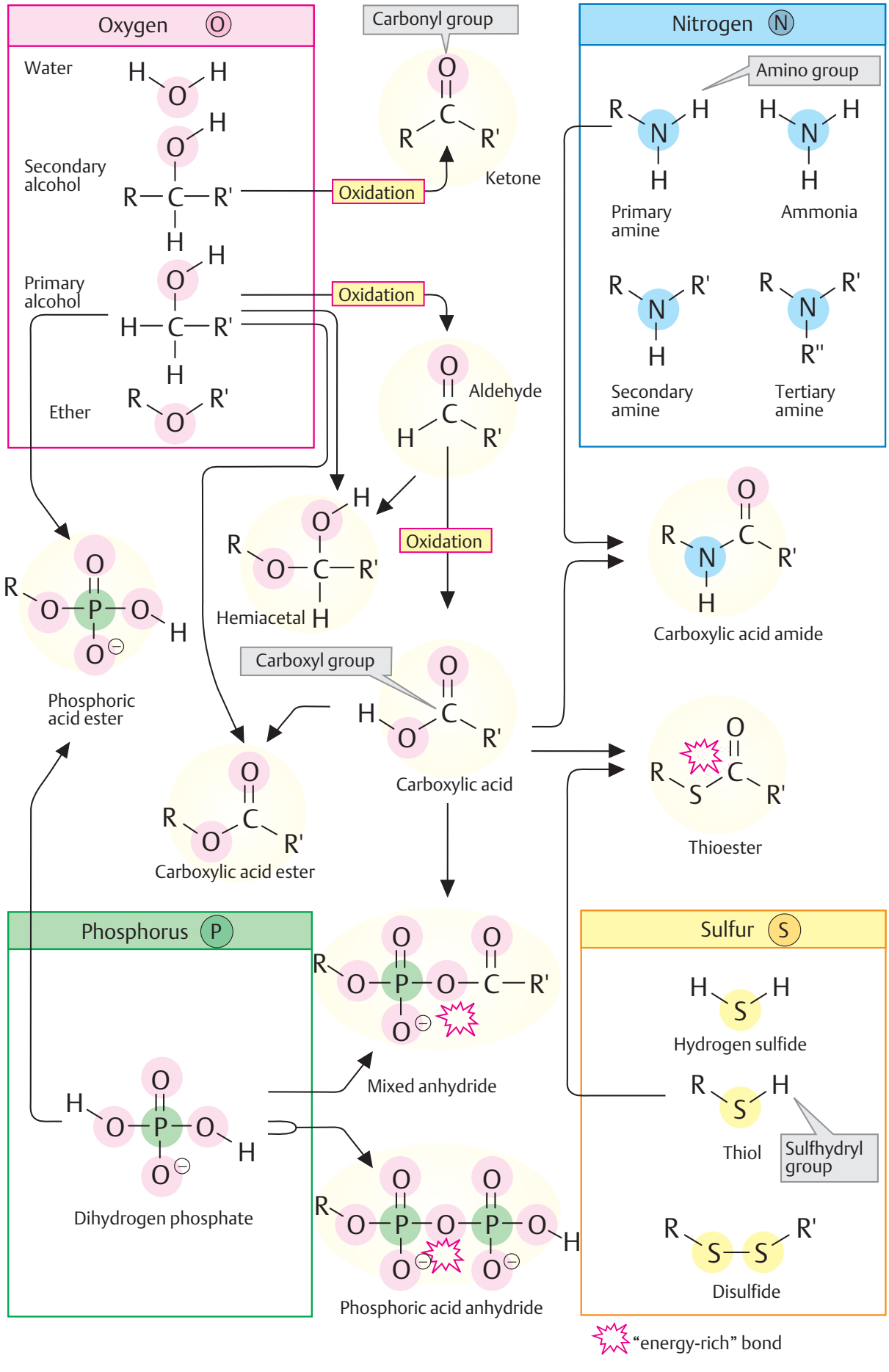

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Biomolecules II

Many biomolecules are made up of smaller units in a modular fashion, and they can be broken down into these units again. The construction of these molecules usually takes place through condensation reactions involving the removal of water. Conversely, their breakdown functions in a hydrolytic fashion—i.e., as a result of water uptake. The page opposite illustrates this modular principle using the example of an important coenzyme.

A. Acetyl CoA ◑

Coenzyme A (see also p. 106) is a nucleotide with a complex structure (see p. 80). It serves to activate residues of carboxylic acids (acyl residues). Bonding of the carboxy group of the carboxylic acid with the thiol group of the coenzyme creates a **thioester bond** (-S-CO-R; see p. 10) in which the **acyl residue** has a **high chemical potential**. It can therefore be transferred to other molecules in exergonic reactions. This fact plays an important role in lipid metabolism in particular (see pp. 162 ff.), as well as in two reactions of the tricarboxylic acid cycle (see p. 136).

As discussed on p. 16, the **group transfer potential** can be expressed quantitatively as the change in free enthalpy (ΔG) during hydrolysis of the compound concerned. This is an arbitrary determination, but it provides important indications of the chemical energy stored in such a group. In the case of acetyl-CoA, the reaction to be considered is:

$$\text{Acetyl CoA} + H_2O \rightarrow \text{acetate} + \text{CoA}$$

In standard conditions and at pH 7, the change in the chemical potential G (ΔG^0, see p. 18) in this reaction amounts to −32 kJ mol^{-1} and it is therefore as high as the ΔG^0 of ATP hydrolysis (see p. 18). In addition to the "energy-rich" **thioester bond**, acetyl-CoA also has seven other hydrolyzable bonds with different degrees of stability. These bonds, and the fragments that arise when they are hydrolyzed, will be discussed here in sequence.

(1) The reactive thiol group of coenzyme A is located in the part of the molecule that is derived from **cysteamine**. Cysteamine is a *biogenic amine* (see p. 62) formed by decarboxylation of the amino acid cysteine.

(2) The amino group of cysteamine is bound to the carboxy group of another biogenic amine via an **acid amide bond** (-CO-NH-). β-**Alanine** arises through decarboxylation of the amino acid aspartate, but it can also be formed by breakdown of pyrimidine bases (see p. 186).

(3) Another **acid amide bond** (-CO-NH-) creates the compound for the next constituent, **pantoinate**. This compound contains a *chiral center* and can therefore appear in two enantiomeric forms (see p. 8). In natural coenzyme A, only one of the two forms is found, the (*R*)-pantoinate. Human metabolism is not capable of producing pantoinate itself, and it therefore has to take up a compound of β-alanine and pantoinate—**pantothenate** ("pantothenic acid")—in the form of a vitamin in food (see p. 366).

(4) The hydroxy group at C-4 of pantoinate is bound to a **phosphate** residue by an **ester bond**.

The section of the molecule discussed so far represents a functional unit. In the cell, it is produced from pantothenate. The molecule also occurs in a protein-bound form as **4′-phosphopantetheine** in the enzyme *fatty acid synthase* (see p. 168). In coenzyme A, however, it is bound to 3′,5′-adenosine diphosphate.

(5) When two phosphate residues bond, they do not form an ester, but an "energy-rich" **phosphoric acid anhydride bond**, as also occurs in other nucleoside phosphates. By contrast, (6) and (7) are ester bonds again.

(8) The base **adenine** is bound to C-1 of **ribose** by an **N-glycosidic** bond (see p. 36). In addition to C-2 to C-4, C-1 of ribose also represents a *chiral* center. The *β-configuration* is usually found in nucleotides.

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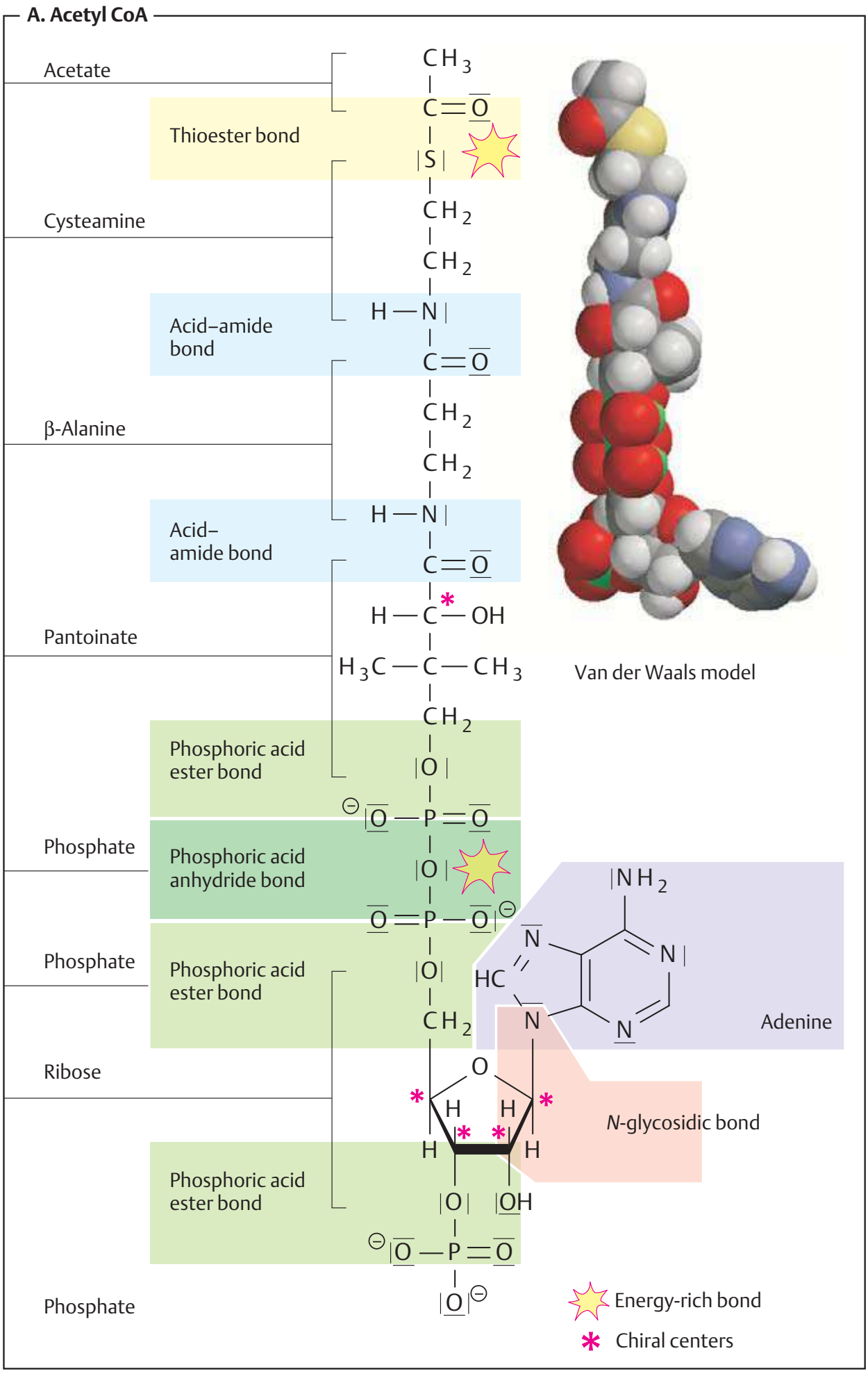

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Chemical reactions

Chemical reactions are processes in which electrons or groups of atoms are taken up into molecules, exchanged between molecules, or shifted within molecules. Illustrated here are the most important types of reaction in organic chemistry, using simple examples. Electron shifts are indicated by red arrows.

A. Redox reactions ◑

In redox reactions (see also p. 32), **electrons** are **transferred** from one molecule (the reducing agent) to another (the oxidizing agent). One or two protons are often also transferred in the process, but the decisive criterion for the presence of a redox reaction is the electron transfer. The reducing agent is oxidized during the reaction, and the oxidizing agent is reduced.

Fig. **A** shows the oxidation of an alcohol into an aldehyde (**1**) and the reduction of the aldehyde to alcohol (**2**). In the process, one *hydride ion* is transferred (two electrons and one proton; see p. 32), which moves to the oxidizing agent A in reaction **1**. The superfluous proton is bound by the catalytic effect of a base B. In the reduction of the aldehyde (**2**), A-H serves as the reducing agent and the acid H-B is involved as the catalyst.

B. Acid–base reactions ◑

In contrast to redox reactions, only **proton transfer** takes place in acid–base reactions (see also p. 30). When an acid dissociates (**1**), water serves as a proton acceptor (i. e., as a base). Conversely, water has the function of an acid in the protonation of a carboxylate anion (**2**).

C. Additions/eliminations ◑

A reaction in which atoms or molecules are taken up by a multiple bond is described as **addition**. The converse of addition—i. e., the removal of groups with the formation of a double bond, is termed **elimination**. When water is added to an alkene (**1a**), a proton is first transferred to the alkene. The unstable carbenium cation that occurs as an intermediate initially takes up water (not shown), before the separation of a proton produces alcohol (**1b**). The elimination of water from the alcohol (**2**, dehydration) is also catalyzed by an acid and passes via the same intermediate as the addition reaction.

D. Nucleophilic substitutions ◑

A reaction in which one functional group (see p. 10) is replaced by another is termed **substitution**. Depending on the process involved, a distinction is made between nucleophilic and electrophilic substitution reactions (see chemistry textbooks). Nucleophilic substitutions start with the addition of one molecule to another, followed by elimination of the so-called *leaving group*.

The hydrolysis of an ester to alcohol and acid (**1**) and the esterification of a carboxylic acid with an alcohol (**2**) are shown here as an example of the S_N2 mechanism. Both reactions are made easier by the marked polarity of the C=O double bond. In the form of ester hydrolysis shown here, a proton is removed from a water molecule by the catalytic effect of the base B. The resulting strongly nucleophilic OH^- ion attacks the positively charged carbonyl C of the ester (**1a**), and an unstable sp^3-hybridized transition state is produced. From this, either water is eliminated (**2b**) and the ester re-forms, or the alcohol ROH is eliminated (**1b**) and the free acid results. In esterification (**2**), the same steps take place in reverse.

Further information

In **rearrangements** (isomerizations, not shown), groups are shifted within one and the same molecule. Examples of this in biochemistry include the isomerization of sugar phosphates (see p. 36) and of methylmalonyl-CoA to succinyl CoA (see p. 166).

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A. Redox reactions

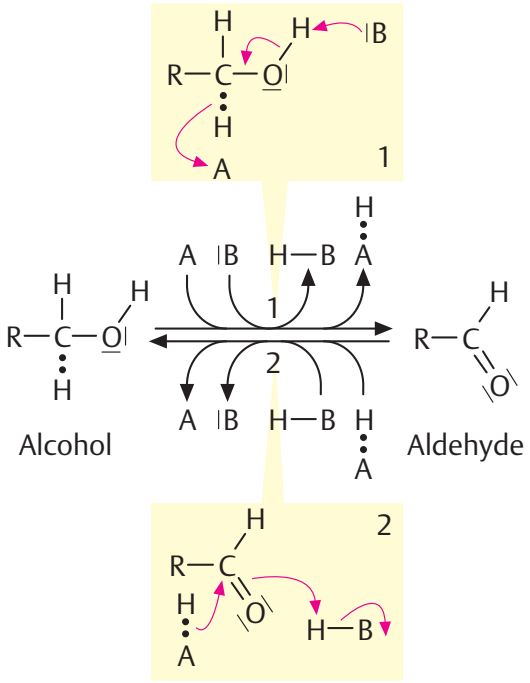

B. Acid–base reactions

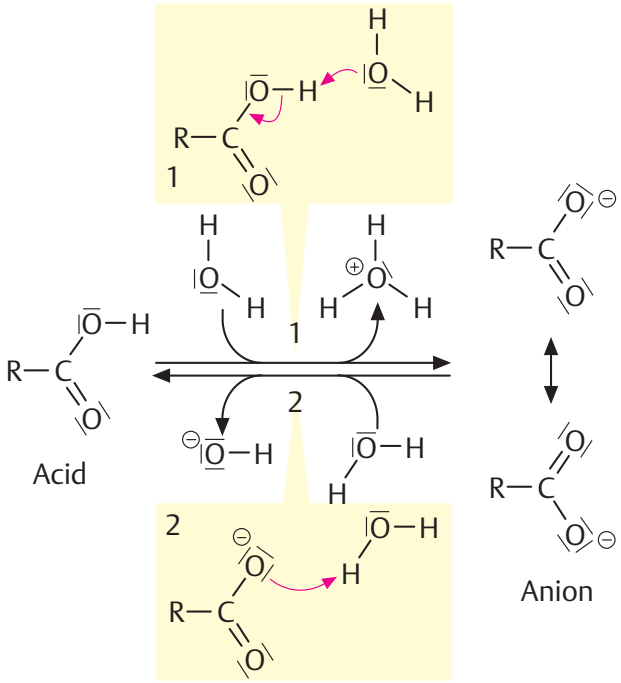

C. Additions/eliminations

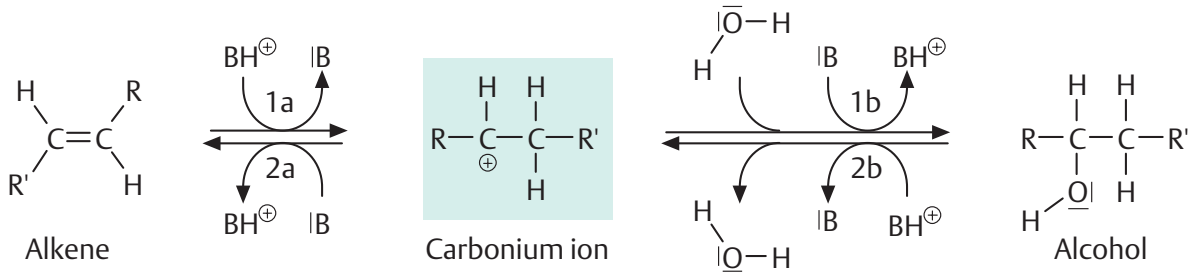

D. Nucleophilic substitutions

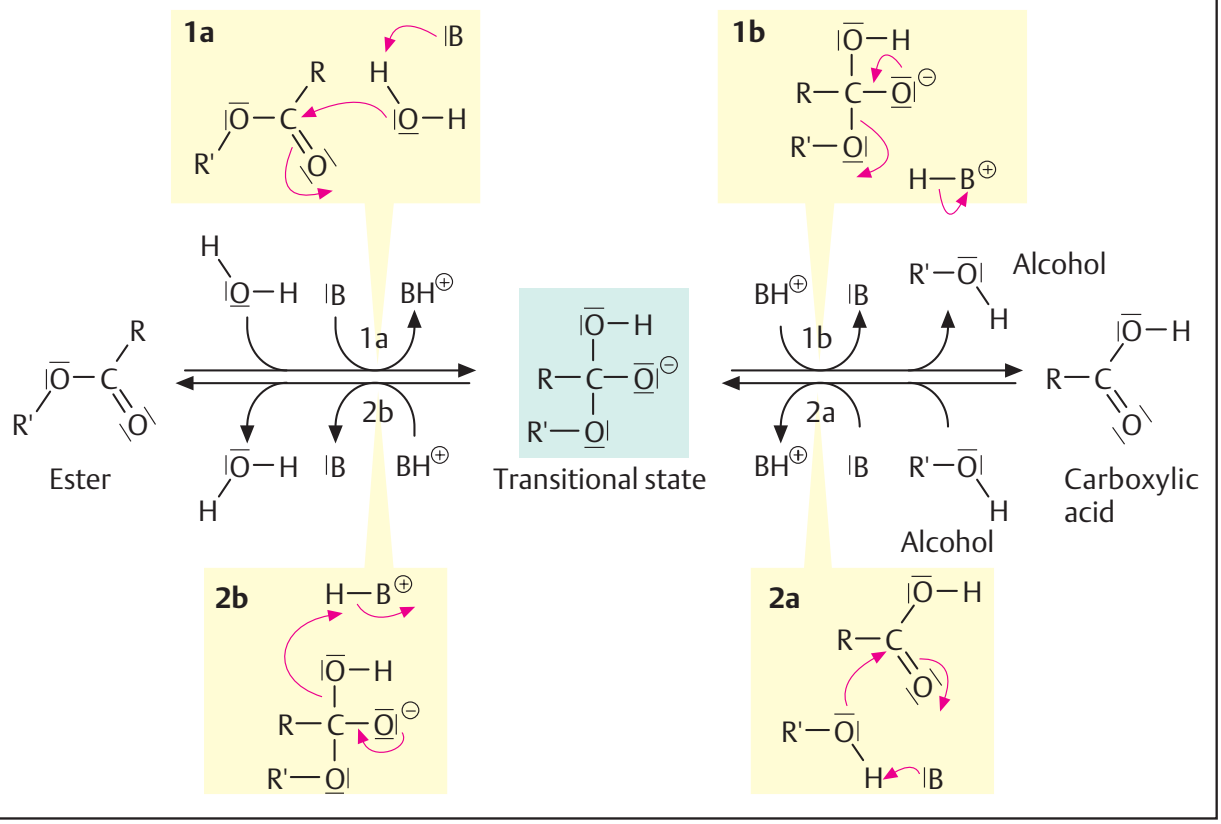

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Energetics

To obtain a better understanding of the processes involved in energy storage and conversion in living cells, it may be useful first to recall the physical basis for these processes.

A. Forms of work ●

There is essentially no difference between work and energy. Both are measured in **joule** (J = 1 N m). An outdated unit is the **calorie** (1 cal = 4.187 J). **Energy is defined as the ability of a system to perform work.** There are many different forms of energy—e.g., mechanical, chemical, and radiation energy.

A system is capable of performing work when matter is moving along a potential gradient. This abstract definition is best understood by an example involving mechanical work (**A1**). Due to the earth's gravitational pull, the mechanical potential energy of an object is the greater the further the object is away from the center of the earth. A **potential difference** (ΔP) therefore exists between a higher location and a lower one. In a waterfall, the water spontaneously follows this potential gradient and, in doing so, is able to perform work—e.g., turning a mill.

Work and energy consist of two quantities: an **intensity** factor, which is a measure of the potential difference—i.e., the "driving force" of the process—(here it is the height difference) and a **capacity factor**, which is a measure of the quantity of the substance being transported (here it is the weight of the water). In the case of electrical work (**A2**), the intensity factor is the voltage—i.e., the electrical potential difference between the source of the electrical current and the "ground," while the capacity factor is the amount of charge that is flowing.

Chemical work and chemical energy are defined in an analogous way. The intensity factor here is the **chemical potential** of a molecule or combination of molecules. This is stated as **free enthalpy** *G* (also known as "Gibbs free energy"). When molecules spontaneously react with one another, the result is products at lower potential. The difference in the chemical potentials of the educts and products (the **change in free enthalpy**, ΔG) is a measure of the "driving force" of the reaction. The capacity factor in chemical work is the amount of matter reacting (in mol). Although absolute values for free enthalpy G cannot be determined, ΔG can be calculated from the equilibrium constant of the reaction (see p. 18).

B. Energetics and the course of processes ●

Everyday experience shows that water never flows uphill *spontaneously*. Whether a particular process can occur spontaneously or not depends on whether the potential difference between the final and the initial state, $\Delta P = P_2 - P_1$, is positive or negative. If P_2 is smaller than P_1, then ΔP will be negative, and the process will take place and perform work. Processes of this type are called **exergonic** (**B1**). If there is no potential difference, then the system is in **equilibrium** (**B2**). In the case of **endergonic** processes, ΔP is positive (**B3**). Processes of this type do *not* proceed spontaneously.

Forcing endergonic processes to take place requires the use of the principle of **energetic coupling**. This effect can be illustrated by a mechanical analogy (**B4**). When two masses M_1 and M_2 are connected by a rope, M_1 will move upward even though this part of the process is endergonic. The *sum* of the two potential differences ($\Delta P_{eff} = \Delta P_1 + \Delta P_2$) is the determining factor in coupled processes. When ΔP_{eff} is negative, the entire process can proceed.

Energetic coupling makes it possible to convert different forms of work and energy into one another. For example, in a flashlight, an exergonic chemical reaction provides an electrical voltage that can then be used for the endergonic generation of light energy. In the luminescent organs of various animals, it is a chemical reaction that produces the light. In the musculature (see p. 336), chemical energy is converted into mechanical work and heat energy. A form of storage for chemical energy that is used in all forms of life is **adenosine triphosphate** (ATP; see p. 122). Endergonic processes are usually driven by coupling to the strongly exergonic breakdown of ATP (see p. 122).

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A. Forms of work

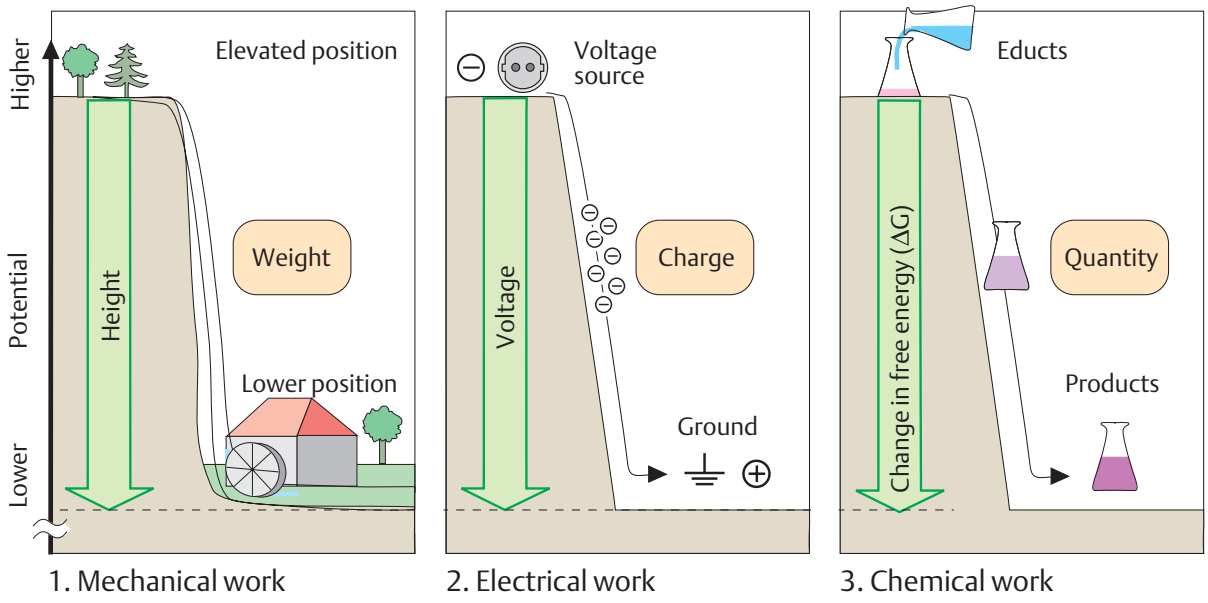

J = Joule = N · m = 1 kg · m^2 · s^{-2}, 1 cal = 4.187 J

Form of work	Intensity factor	Unit	Capacity factor	Unit	Work = ⇨ · ▭	Unit
Mechanical	Height	m	Weight	$J \cdot m^{-1}$	Height · Weight	J
Electrical	Voltage	$V = J \cdot C^{-1}$	Charge	C	Voltage · Charge	J
Chemical	Free-enthalpy change ΔG	$J \cdot mol^{-1}$	Quantity	mol	ΔG · Quantity	J

B. Energetics and the course of processes

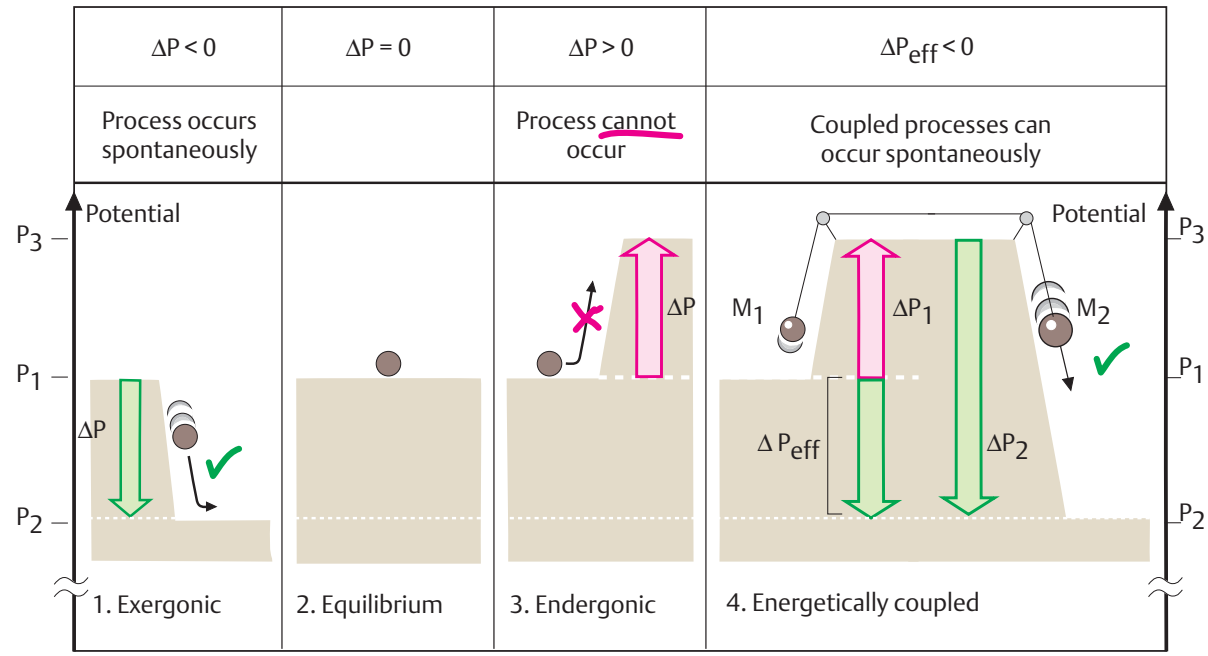

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Equilibriums

A. Group transfer reactions ◑

Every chemical reaction reaches after a time a **state of equilibrium** in which the forward and back reactions proceed at the same speed. The **law of mass action** describes the concentrations of the educts (A, B) and products (C, D) *in equilibrium.* The **equilibrium constant K** is directly related to ΔG^0, the change in free enthalpy *G* involved in the reaction (see p. 16) under standard conditions ($\Delta G^0 = -$ R T ln K). For any given concentrations, the lower equation applies. At $\Delta G < 0$, the reaction proceeds spontaneously for as long as it takes for equilibrium to be reached (i. e., until $\Delta G = 0$). At $\Delta G > 0$, a *spontaneous* reaction is no longer possible (endergonic case; see p. 16). In biochemistry, ΔG is usually related to pH 7, and this is indicated by the "prime" symbol ($\Delta G^{0\prime}$ or $\Delta G'$).

As examples, we can look at two group transfer reactions (on the right). In ATP (see p. 122), the terminal phosphate residue is at a high chemical potential. Its transfer to water (reaction **a**, below) is therefore strongly **exergonic**. The equilibrium of the reaction ($\Delta G = 0$; see p. 122) is only reached when more than 99.9% of the originally available ATP has been hydrolyzed. ATP and similar compounds have a high **group transfer potential** for phosphate residues. Quantitatively, this is expressed as the **ΔG of hydrolysis** ($\Delta G^{0\prime} = -32$ kJ mol^{-1}; see p. 122).

In contrast, the **endergonic** transfer of ammonia (NH_3) to glutamate (Glu, reaction **b**, $\Delta G^{0\prime} = +14$ kJ mol^{-1}) reaches equilibrium so quickly that only minimal amounts of the product glutamine (Gln) can be formed in this way. The synthesis of glutamine from these preliminary stages is only possible through **energetic coupling** (see pp. 16, 124).

B. Redox reactions ◑

The course of electron transfer reactions (redox reactions, see p. 14) also follows the law of mass action. For a single redox system (see p. 32), the Nernst equation applies (top). The **electron transfer potential** of a redox system (i. e., its tendency to give off or take up electrons) is given by its **redox potential E** (in standard conditions, E^0 or $E^{0\prime}$). The *lower* the redox potential of a system is, the *higher* the chemical potential of the transferred electrons. To describe reactions between two redox systems, ΔE—the difference between the two systems' redox potentials—is usually used instead of ΔG. ΔG and ΔE have a simple relationship, but opposite signs (below). A redox reaction proceeds spontaneously when $\Delta E > 0$, i. e. $\Delta G < 0$.

The right side of the illustration shows the way in which the redox potential E is dependent on the composition (the proportion of the reduced form as a %) in two biochemically important redox systems (pyruvate/lactate and NAD^+/NADH+H^+; see pp. 98, 104). In the standard state (both systems reduced to 50%), electron transfer from lactate to NAD^+ is *not* possible, because ΔE is negative ($\Delta E = -0.13$ V, red arrow). By contrast, transfer can proceed successfully if the pyruvate/lactate system is reduced to 98% and NAD^+/NADH is 98% oxidized (green arrow, $\Delta E = +0.08$ V).

C. Acid–base reactions ◑

Pairs of *conjugated* acids and bases are always involved in proton exchange reactions (see p. 30). The dissociation state of an acid–base pair depends on the H^+ concentration. Usually, it is not this concentration itself that is expressed, but its negative decadic logarithm, the **pH value**. The connection between the pH value and the dissociation state is described by the *Henderson–Hasselbalch equation* (below). As a measure of the **proton transfer potential** of an acid–base pair, its **pK_a value** is used—the negative logarithm of the acid constant K_a (where "a" stands for acid).

The *stronger* an acid is, the *lower* its pK_a value. The acid of the pair with the lower pK_a value (the stronger acid—in this case acetic acid, CH_3COOH) can protonate (green arrow) the base of the pair with the higher pK_a (in this case NH_3), while ammonium acetate (NH_4^+ and CH_3COO^-) only forms very little CH_3COOH and NH_3.

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A. Group transfer reactions

Reaction: $A + B \rightleftharpoons C + D$

Law of mass action: $K = \frac{[C] \cdot [D]}{[A] \cdot [B]}$ (Only applies in chemical equilibrium; Equilibrium constant)

Relationship between ΔG^0 and K: $\Delta G^\circ = -R \cdot T \cdot \ln K$, $R = 8.314\ J \cdot mol^{-1} \cdot K^{-1}$

In any conditions: $\Delta G = \Delta G^\circ + R \cdot T \cdot \ln \frac{[C] \cdot [D]}{[A] \cdot [B]}$ (Measure of group transfer potential)

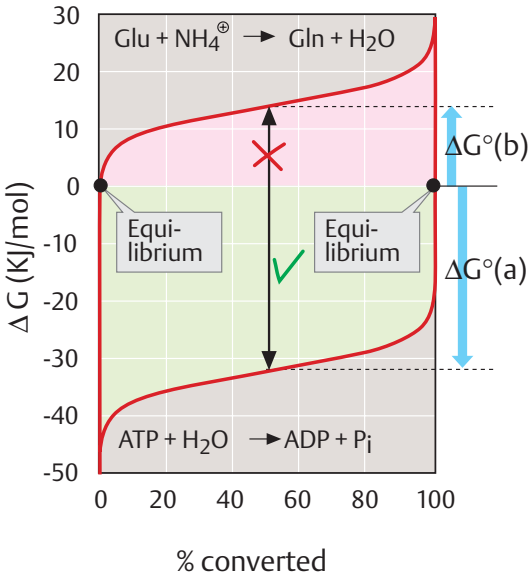

B. Redox reactions

$A_{red} \rightleftharpoons A_{ox}$

For a redox system: $E = E^\circ + \frac{R \cdot T}{n \cdot F} \cdot \ln \frac{[A_{ox}]}{[A_{red}]}$ (Measure of electron transfer potential)

For any redox reaction: $\Delta E = \Delta E^\circ + \frac{R \cdot T}{n \cdot F} \cdot \ln \frac{[B_{ox}] \cdot [A_{red}]}{[B_{red}] \cdot [A_{ox}]}$

Definition and sizes: $\Delta E = E_{Acceptor} - E_{Donor}$, $\Delta G = -n \cdot F \cdot \Delta E$

n = No. of electrons transferred
F = Faraday constant

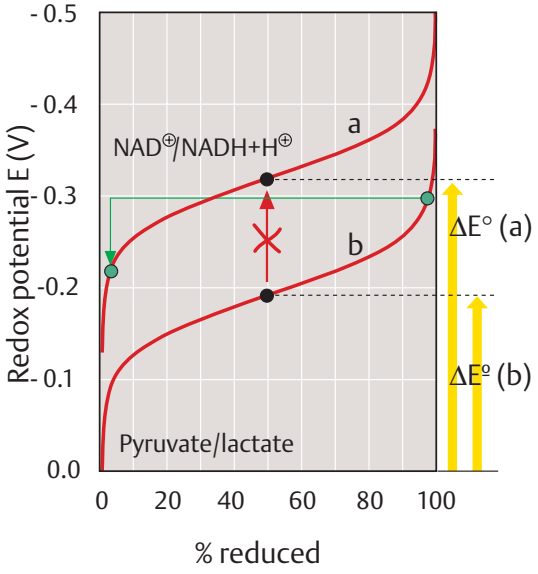

C. Acid–base reactions

Standard reaction: $HA + H_2O \rightleftharpoons A^\ominus + H_3O^\oplus$

Law of mass action: $K = \frac{[A^\ominus] \cdot [H_3O^\oplus]}{[HA] \cdot [H_2O]}$

Simplified: $K_a = \frac{[A^\ominus] \cdot [H^\oplus]}{[HA]}$

Henderson–Hasselbalch equation: $pH = pK_a + \log \frac{[A^\ominus]}{[HA]}$ (Measure of proton transfer potential)

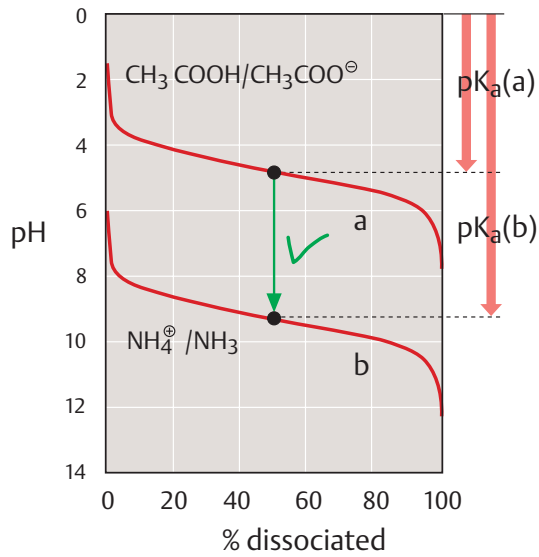

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Enthalpy and entropy

The change in the free enthalpy of a chemical reaction (i.e., its ΔG) depends on a number of factors—e.g., the concentrations of the reactants and the temperature (see p. 18). Two further factors associated with molecular changes occurring during the reaction are discussed here.

A. Heat of reaction and calorimetry ◑

All chemical reactions involve heat exchange. Reactions that release heat are called **exothermic**, and those that consume heat are called **endothermic**. Heat exchange is measured as the enthalpy change ΔH (the heat of reaction). This corresponds to the heat exchange at constant pressure. In exothermic reactions, the system *loses* heat, and ΔH is negative. When the reaction is endothermic, the system gains heat, and ΔH becomes positive.

In many reactions, ΔH and ΔG are similar in magnitude (see **B1**, for example). This fact is used to estimate the caloric content of foods. In living organisms, nutrients are usually oxidized by oxygen to CO_2 and H_2O (see p. 112). The maximum amount of chemical work supplied by a particular foodstuff (i.e., the ΔG for the oxidation of the utilizable constituents) can be estimated by burning a weighed amount in a **calorimeter** in an oxygen atmosphere. The heat of the reaction increases the water temperature in the calorimeter. The reaction heat can then be calculated from the temperature difference ΔT.

B. Enthalpy and entropy ◑

The reaction enthalpy ΔH and the change in free enthalpy ΔG are not always of the same magnitude. There are even reactions that occur spontaneously ($\Delta G < 0$) even though they are endothermic ($\Delta H > 0$). The reason for this is that changes in the degree of order of the system also strongly affect the progress of a reaction. This change is measured as the **entropy change (ΔS)**.

Entropy is a physical value that describes the **degree of order of a system**. The *lower* the degree of order, the larger the entropy. Thus, when a process leads to increase in disorder—and everyday experience shows that this is the normal state of affairs—ΔS is positive for this process. An increase in the order in a system ($\Delta S < 0$) always requires an input of energy. Both of these statements are consequences of an important natural law, the Second Law of Thermodynamics. The connection between changes in enthalpy and entropy is described quantitatively by the **Gibbs–Helmholtz equation** ($\Delta G = \Delta H - T\ \Delta S$). The following examples will help explain these relationships.

In the *knall-gas* **(oxyhydrogen) reaction** (**1**), gaseous oxygen and gaseous hydrogen react to form liquid water. Like many redox reactions, this reaction is strongly exothermic (i.e., $\Delta H < 0$). However, during the reaction, the degree of order increases. The total number of molecules is reduced by one-third, and a more highly ordered liquid is formed from freely moving gas molecules. As a result of the increase in the degree of order ($\Delta S < 0$), the term $-T\ \Delta S$ becomes positive. However, this is more than compensated for by the decrease in enthalpy, and the reaction is still strongly exergonic ($\Delta G < 0$).

The **dissolution of salt in water** (**2**) is endothermic ($\Delta H > 0$)—i.e., the liquid cools. Nevertheless, the process still occurs spontaneously, since the degree of order in the system *decreases*. The Na^+ and Cl^- ions are initially rigidly fixed in a crystal lattice. In solution, they move about independently and in random directions through the fluid. The decrease in order ($\Delta S > 0$) leads to a negative $-T\ \Delta S$ term, which compensates for the positive ΔH term and results in a negative ΔG term overall. Processes of this type are described as being **entropy-driven**. The folding of proteins (see p. 74) and the formation of ordered lipid structures in water (see p. 28) are also mainly entropy-driven.

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A. Heat of reaction and calorimetry

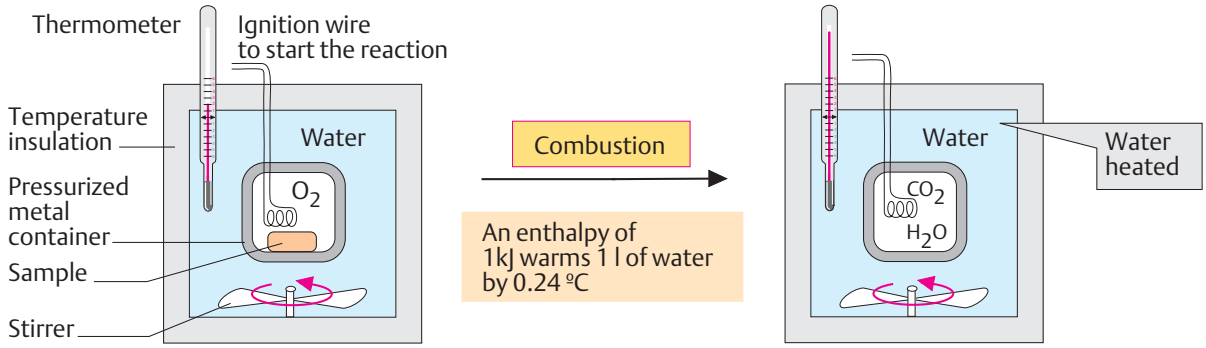

B. Enthalpy and entropy

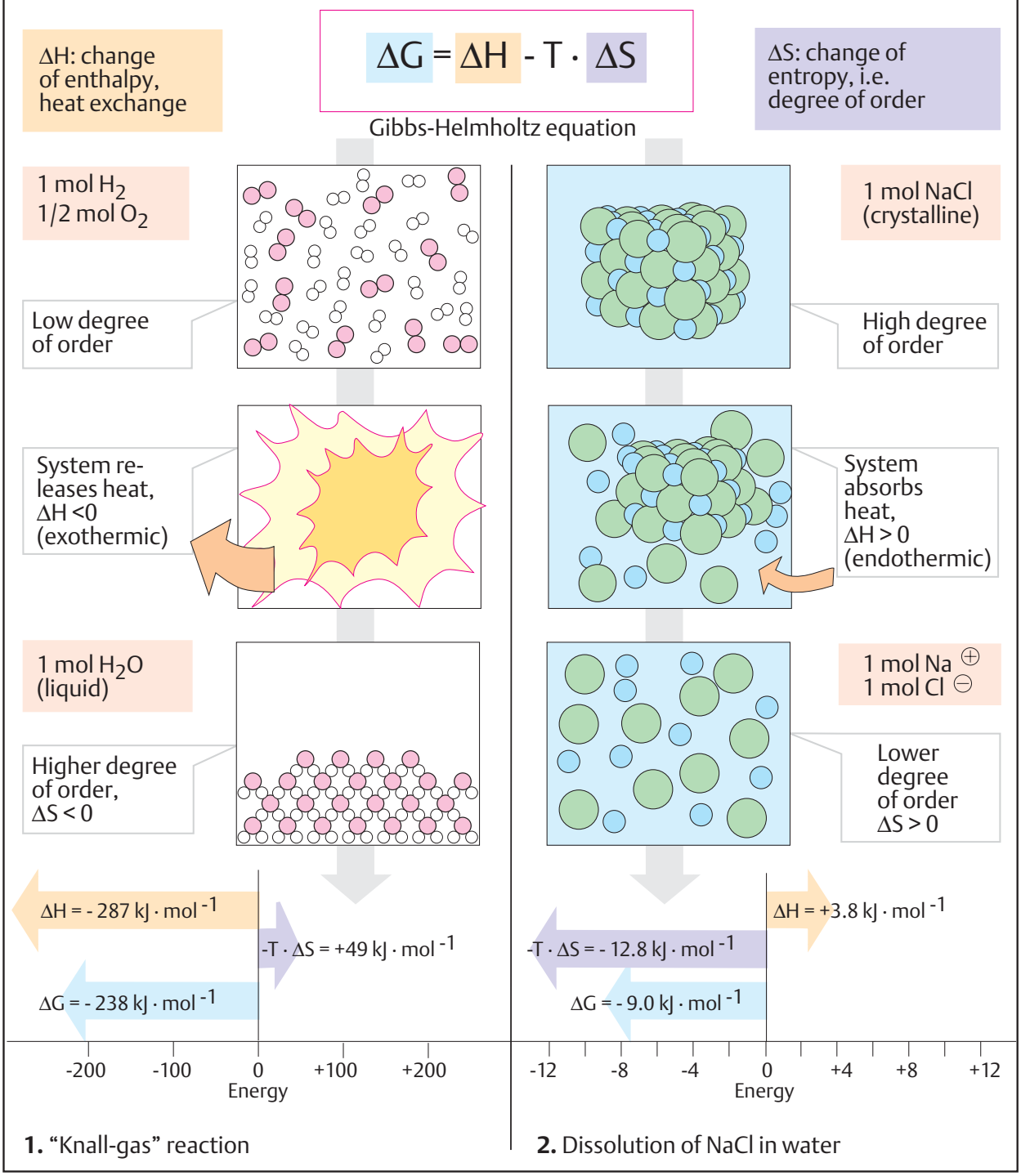

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Reaction kinetics

The change in free enthalpy ΔG in a reaction indicates whether or not the reaction can take place spontaneously in given conditions and how much work it can perform (see p. 18). However, it does not tell us anything about the *rate* of the reaction—i. e., its **kinetics**.

A. Activation energy ◑

Most organic chemical reactions (with the exception of acid–base reactions) proceed only very slowly, regardless of the value of ΔG. The reason for the slow reaction rate is that the molecules that react—the educts—have to have a certain minimum energy before they can enter the reaction. This is best understood with the help of an energy diagram (**1**) of the simplest possible reaction $A \rightarrow B$. The educt A and the product B are each at a specific **chemical potential** (G_e and G_p, respectively). The change in the free enthalpy of the reaction, ΔG, corresponds to the difference between these two potentials. To be converted into B, A first has to overcome a potential energy barrier, the peak of which, G_a, lies well above G_e. The potential difference $G_a - G_e$ is the **activation energy E_a** of the reaction (in kJ mol^{-1}).

The fact that A can be converted into B at all is because the potential G_e only represents the average potential of all the molecules. Individual molecules may occasionally reach much higher potentials—e. g., due to collisions with other molecules. When the increase in energy thus gained is greater than E_a, these molecules can overcome the barrier and be converted into B. The energy distribution for a group of molecules of this type, as calculated from a simple model, is shown in (**2**) and (**3**). $\Delta n/n$ is the fraction of molecules that have reached or exceeded energy E (in kJ per mol). At 27 °C, for example, approximately 10% of the molecules have energies > 6 kJ mol^{-1}. The typical activation energies of chemical reactions are much higher. The course of the energy function at energies of around 50 kJ mol^{-1} is shown in (**3**). Statistically, at 27 °C only two out of 10^9 molecules reach this energy. At 37 °C, the figure is already four. This is the basis for the long-familiar "Q_{10} law"—a rule of thumb that states that the speed of biological processes approximately doubles with an increase in temperature of 10 °C.

B. Reaction rate ◑

The velocity *v* of a chemical reaction is determined experimentally by observing the change in the concentration of an educt or product over time. In the example shown (again a reaction of the $A \rightarrow B$ type), 3 mmol of the educt A is converted per second and 3 mmol of the product B is formed per second in one liter of the solution. This corresponds to a rate of

$$v = 3 \text{ mM } s^{-1} = 3 \text{ } 10^{-3} \text{ mol } L^{-1} \text{ } s^{-1}$$

C. Reaction order ◑

Reaction rates are influenced not only by the activation energy and the temperature, but also by the concentrations of the reactants. When there is only one educt, A (**1**), *v* is proportional to the concentration [A] of this substance, and a **first-order reaction** is involved. When *two* educts, A and B, react with one another (**2**), it is a **second order reaction** (shown on the right). In this case, the rate *v* is proportional to the *product* of the educt concentrations (12 mM^2 at the top, 24 mM^2 in the middle, and 36 mM^2 at the bottom). The proportionality factors k and k′ are the **rate constants** of the reaction. They are *not* dependent on the reaction concentrations, but depend on the external conditions for the reaction, such as temperature.

In **B**, only the kinetics of simple irreversible reactions is shown. More complicated cases, such as reaction with three or more reversible steps, can usually be broken down into first-order or second-order partial reactions and described using the corresponding equations (for an example, see the Michaelis–Menten reaction, p. 92).

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A. Activation energy

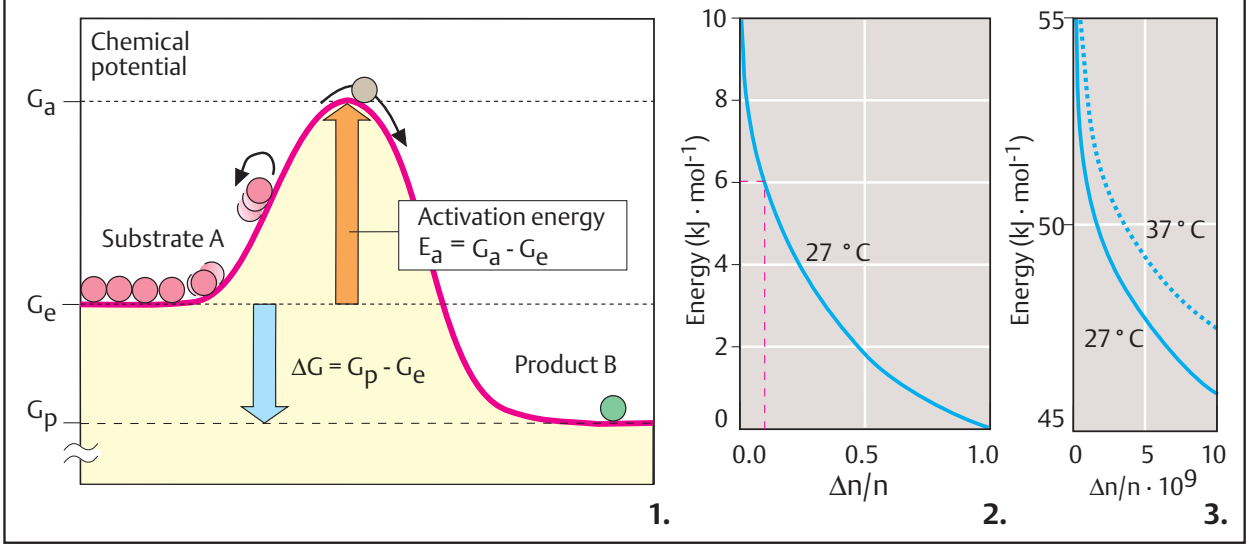

B. Reaction rate

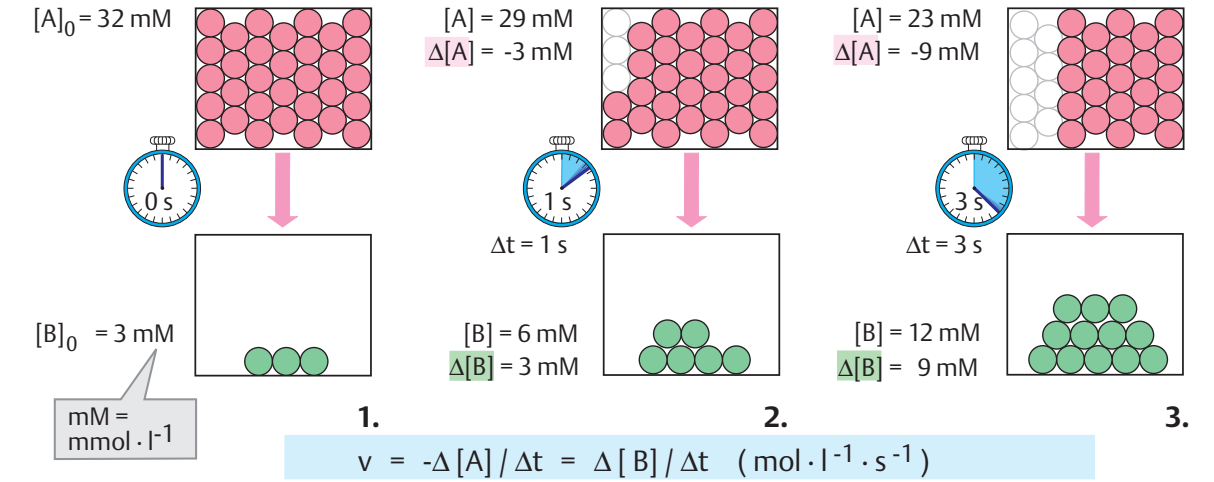

$$v = -\Delta[A]/\Delta t = \Delta[B]/\Delta t \quad (\text{mol} \cdot \text{l}^{-1} \cdot \text{s}^{-1})$$

C. Reaction order

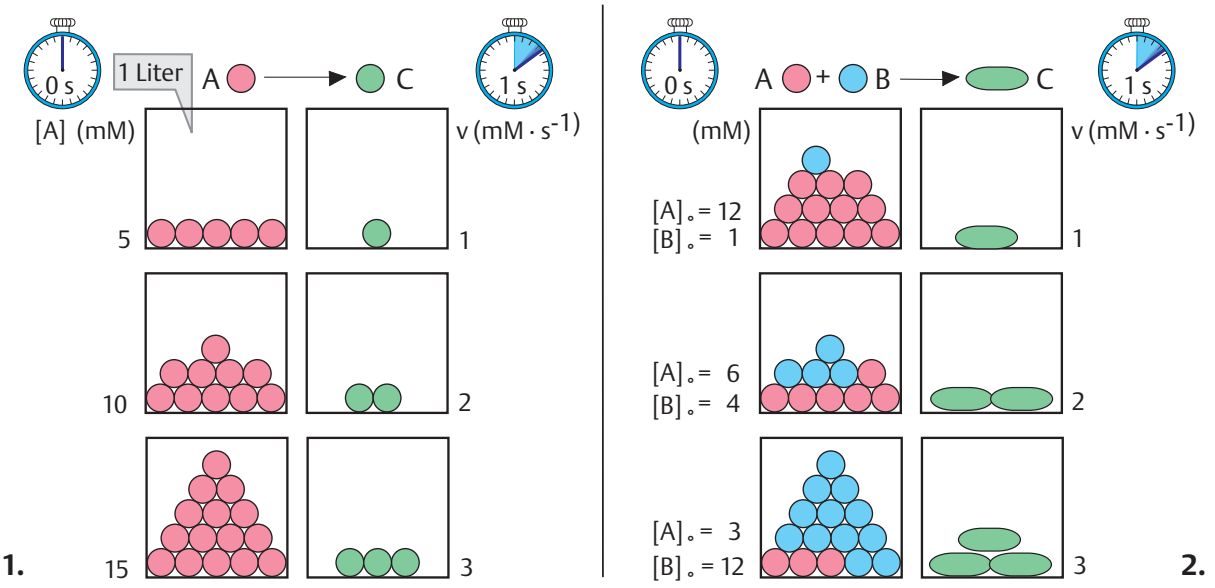

$v = k \cdot [A]$ | k, k' : Rate constants | $v = k' \cdot [A] \cdot [B]$

First-order reaction: $k = 1/5\ s^{-1}$

Second-order reaction: $k' = 1/12\ l \cdot mmol^{-1} \cdot s^{-1}$

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Catalysis

Catalysts are substances that accelerate chemical reactions without themselves being consumed in the process. Since catalysts emerge from the catalyzed reaction without being changed, even small amounts are usually suf cient to cause a powerful acceleration of the reaction. In the cell, **enzymes** (see p. 88) generally serve as catalysts. A few chemical changes are catalyzed by special RNA molecules, known as *ribozymes* (see p. 246).

A. Catalysis: principle ●

The reason for the slow rates of most reactions involving organic substances is the high **activation energy** (see p. 22) that the reacting molecules have to reach before they can react. In aqueous solution, a large proportion of the activation energy is required to remove the hydration shells surrounding the educts. During the course of a reaction, resonance-stabilized structures (see p. 4) are often temporarily suspended; this also requires energy. The highest point on the reaction coordinates corresponds to an energetically unfavorable **transition state** of this type (**1**).

A catalyst creates a new pathway for the reaction (**2**). When all of the transition states arising have a lower activation energy than that of the uncatalyzed reaction, the reaction will proceed more rapidly along the alternative pathway, even when the number of intermediates is greater. Since the starting points and end points are the same in both routes, the change in the enthalpy ΔG of the reaction is not influenced by the catalyst. Catalysts—including enzymes—are in principle *not* capable of altering the equilibrium state of the catalyzed reaction.

The often-heard statement that "a catalyst reduces the activation energy of a reaction" is not strictly correct, since a *completely different* reaction takes place in the presence of a catalyst than in uncatalyzed conditions. However, its activation energy is lower than in the uncatalyzed reaction.

B. Catalysis of H_2O_2 – breakdown by iodide ○

As a simple example of a catalyzed reaction, we can look at the disproportionation of hydrogen peroxide (H_2O_2) into oxygen and water. In the uncatalyzed reaction (at the top), an H_2O_2 molecule initially decays into H_2O and atomic oxygen (O), which then reacts with a second H_2O_2 molecule to form water and molecular oxygen (O_2). The activation energy E_a required for this reaction is relatively high, at 75 kJ mol^{-1}. In the presence of **iodide** (I^-) as a catalyst, the reaction takes a different course (bottom). The intermediate arising in this case is hypoiodide (OI^-), which also forms H_2O and O_2 with another H_2O_2 molecule. In this step, the I^- ion is released and can once again take part in the reaction. The lower activation energy of the reaction catalyzed by iodide (E_a = 56 kJ mol^{-1}) causes acceleration of the reaction by a factor of 2000, as the reaction rate depends exponentially on E_a ($v \sim e^{-Ea/R\,T}$).

Free metal ions such as iron (Fe) and platinum (Pt) are also effective catalysts for the breakdown of H_2O_2. **Catalase** (see p. 284), an enzyme that protects cells against the toxic effects of hydrogen peroxide (see p. 284), is much more catalytically effective still. In the enzyme-catalyzed disproportionation, H_2O_2 is bound to the enzyme's heme group, where it is quickly converted to atomic oxygen and water, supported by amino acid residues of the enzyme protein. The oxygen atom is temporarily bound to the central iron atom of the heme group, and then transferred from there to the second H_2O_2 molecule. The activation energy of the enzyme-catalyzed reaction is only 23 kJ mol^{-1}, which in comparison with the uncatalyzed reaction leads to acceleration by a factor of 1.3 10^9.

Catalase is one of the most ef cient enzymes there are. A single molecule can convert up to 10^8 (a hundred million) H_2O_2 molecules per second.

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A. Catalysis: principle

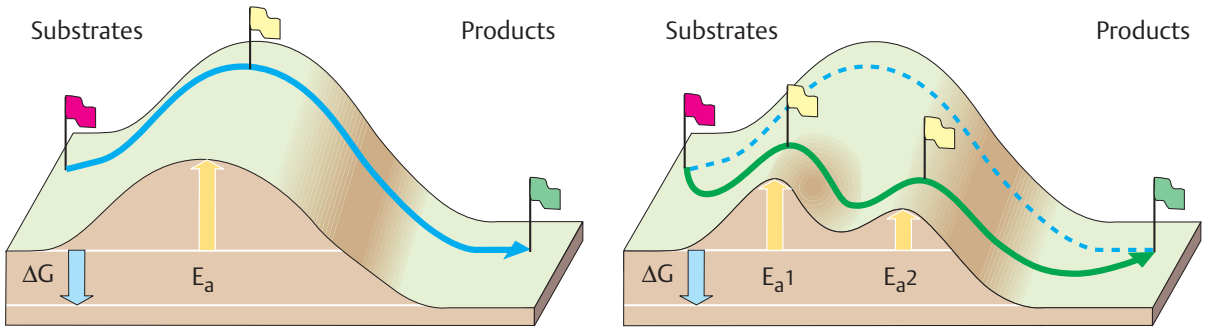

1. Energy profile without catalyst

2. Energy profile with catalyst

B. Catalysis of H_2O_2 – breakdown by iodide

1. Breakdown of hydrogen peroxide

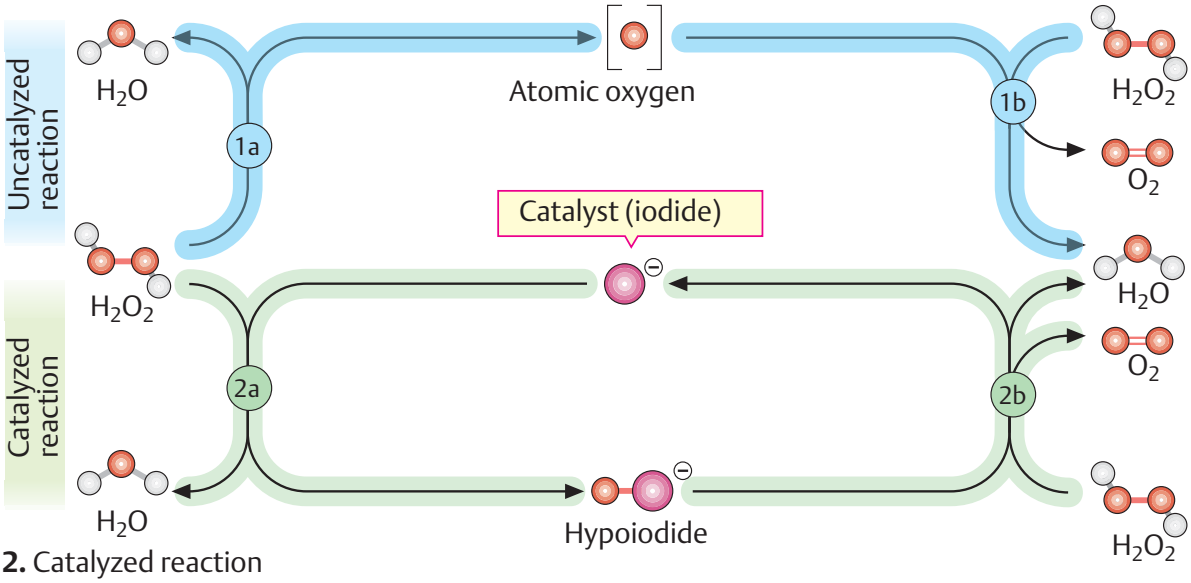

2. Catalyzed reaction

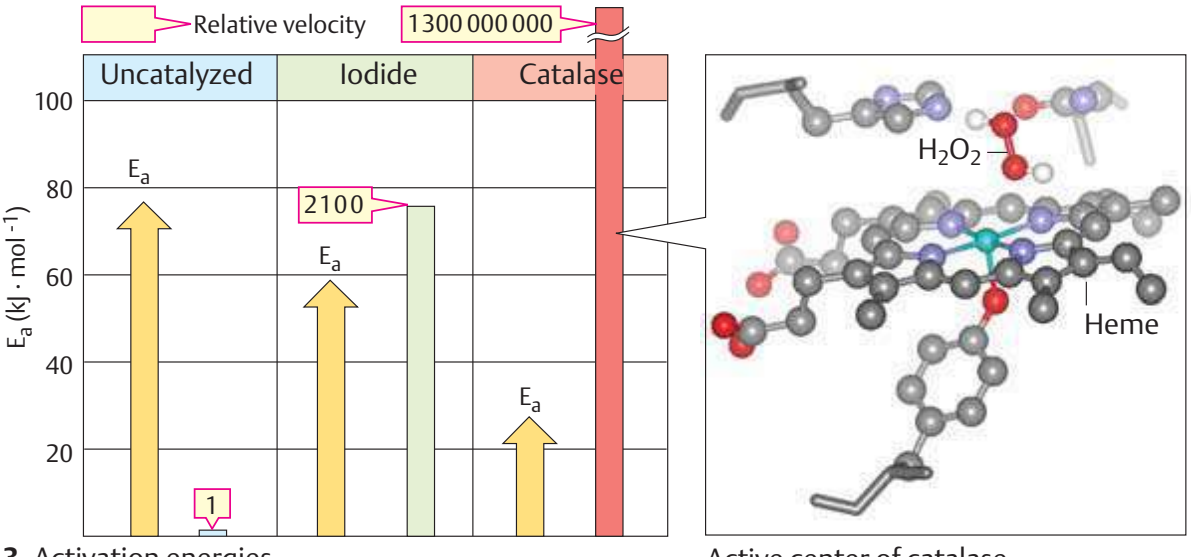

3. Activation energies

Active center of catalase

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Water as a solvent

Life as we know it evolved in water and is still absolutely dependent on it. The properties of water are therefore of fundamental importance to all living things.

A. Water and methane ◑

The special properties of **water (H_2O)** become apparent when it is compared with **methane (CH_4)**. The two molecules have a similar mass and size. Nevertheless, the boiling point of water is more than 250 °C above that of methane. At temperatures on the earth's surface, water is liquid, whereas methane is gaseous. The high boiling point of water results from its high vaporization enthalpy, which in turn is due to the fact that the density of the electrons within the molecule is unevenly distributed. Two corners of the tetrahedrally-shaped water molecule are occupied by unshared electrons (green), and the other two by hydrogen atoms. As a result, the H–O–H bond has an angled shape. In addition, the O–H bonds are polarized due to the high electronegativity of oxygen (see p. 6). One side of the molecule carries a partial charge (δ) of about –0.6 units, whereas the other is correspondingly positively charged. The spatial separation of the positive and negative charges gives the molecule the properties of an **electrical dipole**. Water molecules are therefore attracted to one another like tiny magnets, and are also connected by hydrogen bonds (**B**) (see p. 6). When liquid water vaporizes, a large amount of energy has to be expended to disrupt these interactions. By contrast, methane molecules are not dipolar, and therefore interact with one another only weakly. This is why liquid methane vaporizes at very low temperatures.

B. Structure of water and ice ◑

The dipolar nature of water molecules favors the formation of **hydrogen bonds** (see p. 6). Each molecule can act either as a donor or an acceptor of H bonds, and many molecules in liquid water are therefore connected by H bonds (**1**). The bonds are in a state of constant fluctuation. Tetrahedral networks of molecules, known as water "clusters," often arise. As the temperature decreases, the proportion of water clusters increases until the water begins to crystallize. Under normal atmospheric pressure, this occurs at 0 °C. In **ice**, most of the water molecules are fixed in a **hexagonal lattice** (**3**). Since the distance between the individual molecules in the frozen state is on average greater than in the liquid state, the density of ice is lower than that of liquid water. This fact is of immense biological importance—it means, for example, that in winter, ice forms on the surface of open stretches of water first, and the water rarely freezes to the bottom.

C. Hydration ◑

In contrast to most other liquids, water is an excellent **solvent for ions**. In the electrical field of cations and anions, the dipolar water molecules arrange themselves in a regular fashion corresponding to the charge of the ion. They form **hydration shells** and shield the central ion from oppositely charged ions. Metal ions are therefore often present as hexahydrates ($[Me(H_2O)_6^{2+}]$, on the right). In the inner hydration sphere of this type of ion, the water molecules are practically immobilized and follow the central ion. Water has a high dielectric constant of 78—i. e., the electrostatic attraction force between ions is reduced to 1/78 by the solvent. Electrically charged groups in organic molecules (e. g., carboxylate, phosphate, and ammonium groups) are also well hydrated and contribute to water solubility. Neutral molecules with several hydroxy groups, such as glycerol (on the left) or sugars, are also easily soluble, because they can form H bonds with water molecules. The higher the proportion of polar functional groups there is in a molecule, the more water-soluble (**hydrophilic**) it is. By contrast, molecules that consist exclusively or mainly of hydrocarbons are poorly soluble or insoluble in water. These compounds are called **hydrophobic** (see p. 28).

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A. Water and methane

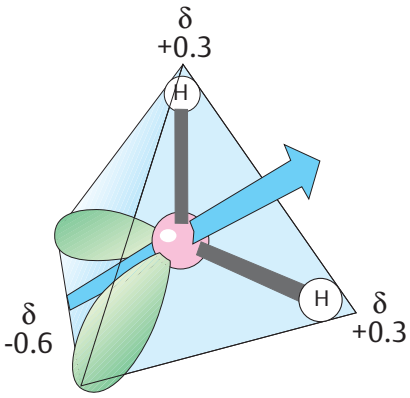

Water (H_2O)

H_2O		CH_4
18 Da	Molecular mass	16 Da
+100 °C	Boiling point	-162 °C
41	Heat of vaporization ($kJ \cdot mol^{-1}$)	8
6.2	Dipole moment (10^{-30} C · m)	0

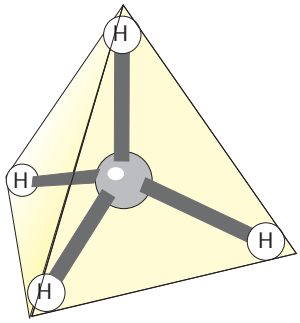

Methane (CH_4)

B. Structure of water and ice

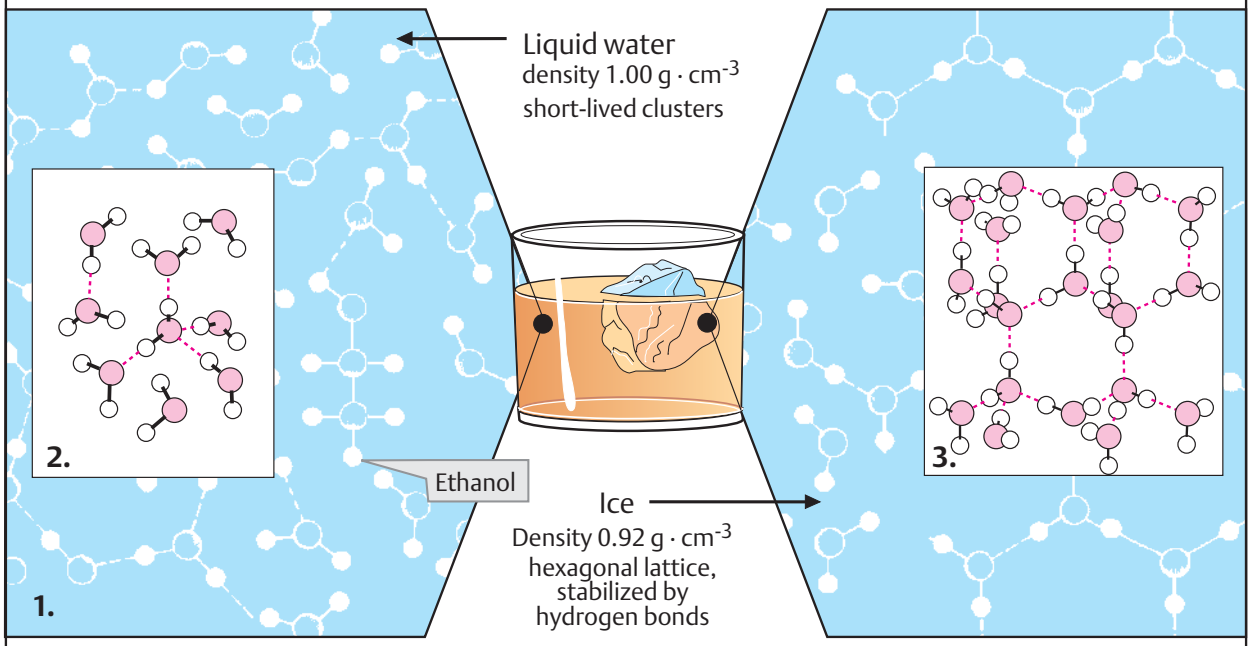

C. Hydration

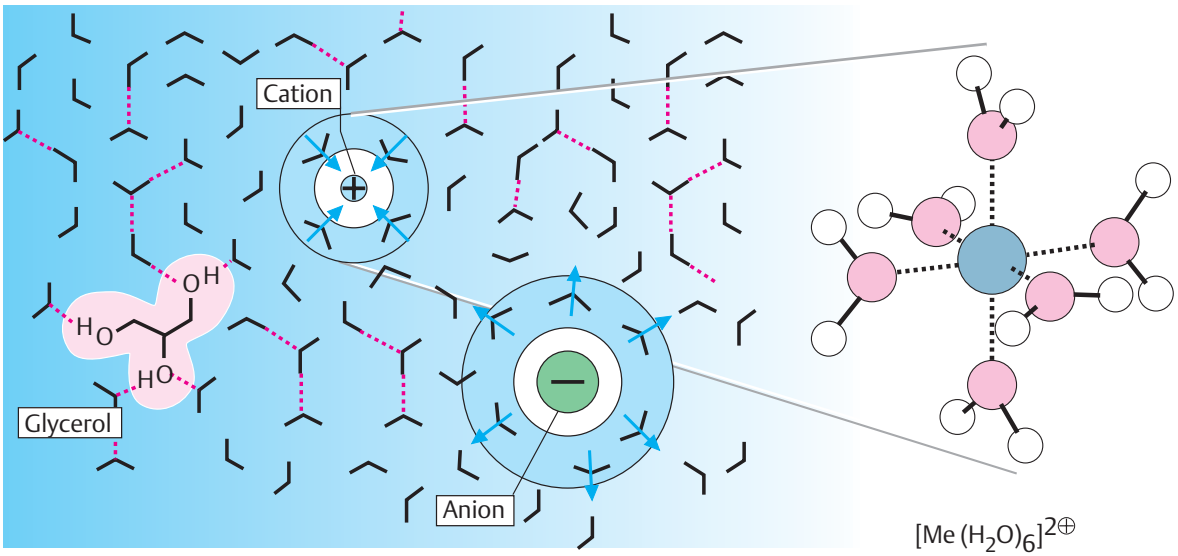

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Hydrophobic interactions

Water is an excellent solvent for ions and for substances that contain polarized bonds (see p. 20). Substances of this type are referred to as **polar** or **hydrophilic** ("water-loving"). In contrast, substances that consist mainly of hydrocarbon structures dissolve only poorly in water. Such substances are said to be **apolar** or **hydrophobic**.

A. Solubility of methane ○

To understand the reasons for the poor water solubility of hydrocarbons, it is useful first to examine the energetics (see p. 16) of the processes involved. In (**1**), the individual terms of the Gibbs–Helmholtz equation (see p. 20) for the simplest compound of this type, **methane**, are shown (see p. 4). As can be seen, the transition from gaseous methane to water is actually exothermic ($\Delta H^0 < 0$). Nevertheless, the change in the free enthalpy ΔG^0 is positive (the process is endergonic), because the entropy term $T\ \Delta S^0$ has a strongly positive value. The entropy change in the process (ΔS^0) is evidently negative—i. e., a solution of methane in water has a *higher* degree of order than either water or gaseous methane. One reason for this is that the methane molecules are less mobile when surrounded by water. More importantly, however, the water around the apolar molecules forms cage-like **"clathrate" structures**, which—as in ice—are stabilized by H bonds. This strongly increases the degree of order in the water—and the more so the larger the area of surface contact between the water and the apolar phase.

B. The "oil drop effect" ◑

The spontaneous separation of oil and water, a familiar observation in everyday life, is due to the energetically unfavorable formation of clathrate structures. When a mixture of water and oil is firmly shaken, lots of tiny oil drops form to begin with, but these quickly coalesce spontaneously to form larger drops—the two phases separate. A larger drop has a smaller surface area than several small drops with the same volume. Separation therefore reduces the area of surface contact between the water and the oil, and consequently also the extent of clathrate formation. The ΔS for this process is therefore positive (the *dis*order in the water increases), and the negative term $-T\ \Delta S$ makes the separation process exergonic ($\Delta G < 0$), so that it proceeds spontaneously.

C. Arrangements of amphipathic substances in water ◑

Molecules that contain both polar *and* apolar groups are called **amphipathic** or amphiphilic. This group includes soaps (see p. 48), phospholipids (see p. 50), and bile acids (see p. 56).

As a result of the "oil drop effect" amphipathic substances in water tend to arrange themselves in such a way as to minimize the area of surface contact between the apolar regions of the molecule and water. On water surfaces, they usually form single-layer **films** (top) in which the polar "head groups" face toward the water. **Soap bubbles** (right) consist of double films, with a thin layer of water enclosed between them. In water, depending on their concentration, amphipathic compounds form **micelles**—i. e., spherical aggregates with their head groups facing toward the outside, or extended bilayered **double membranes**. Most biological membranes are assembled according to this principle (see p. 214). Closed hollow membrane sacs are known as **vesicles**. This type of structure serves to transport substances within cells and in the blood (see p. 278).

The separation of oil and water (**B**) can be prevented by adding a strongly amphipathic substance. During shaking, a more or less stable **emulsion** then forms, in which the surface of the oil drops is occupied by amphipathic molecules that provide it with polar properties externally. The emulsification of fats in food by bile acids and phospholipids is a vital precondition for the digestion of fats (see p. 314).

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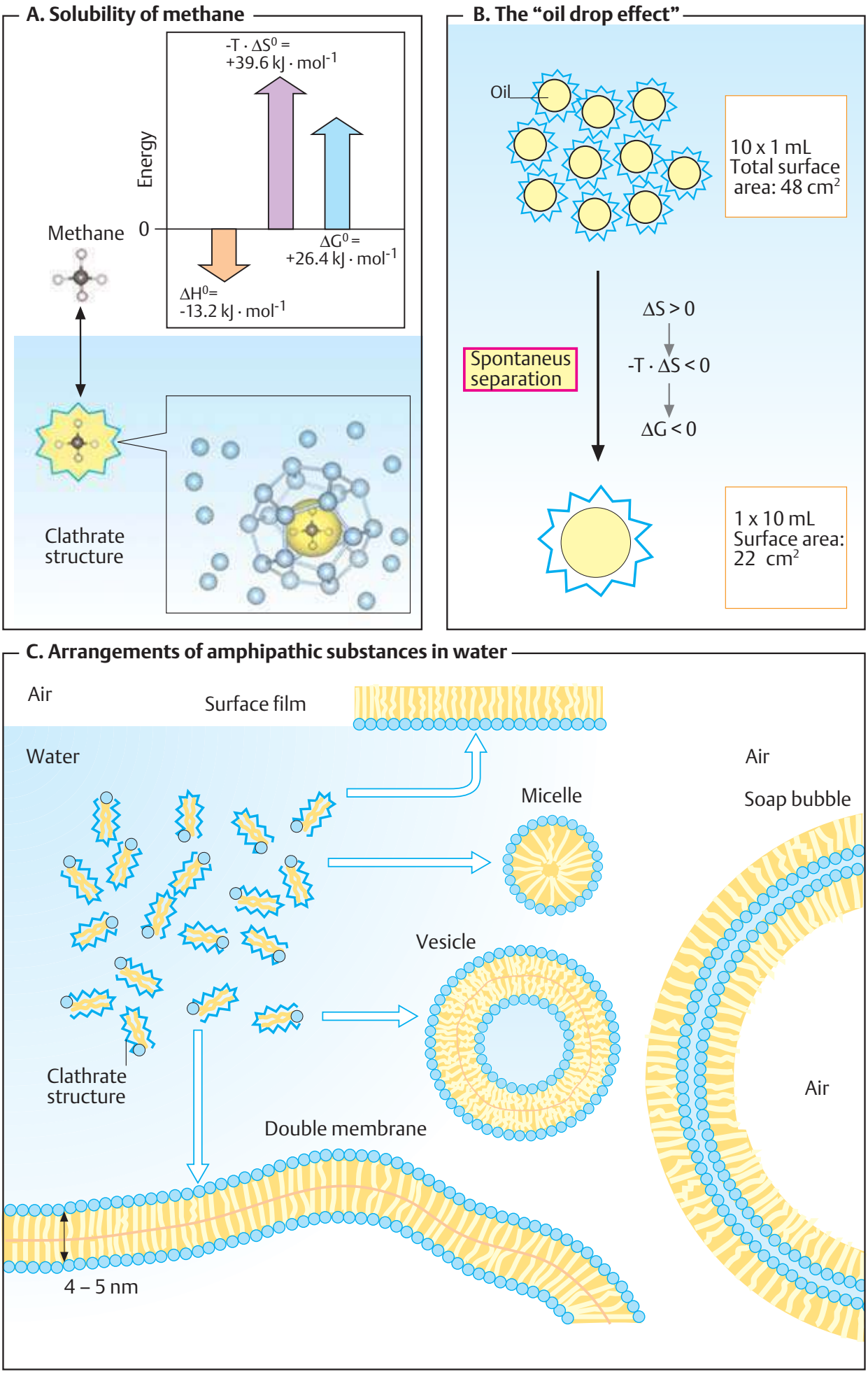

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Acids and bases

A. Acids and bases ●

In general, **acids** are defined as substances that can donate hydrogen ions (protons), while **bases** are compounds that accept protons.

Water enhances the acidic or basic properties of dissolved substances, as water itself can act as either an acid or a base. For example, when **hydrogen chloride** (HCl) is in aqueous solution, it donates protons to the solvent (**1**). This results in the formation of chloride ions (Cl^-) and protonated water molecules (**hydronium ions, H_3O^+**, usually simply referred to as H^+). The proton exchange between HCl and water is virtually quantitative: in water, HCl behaves as a *very strong acid* with a negative pK_a value (see p. 18).

Bases such as **ammonia** (NH_3) take over protons from water molecules. As a result of this, **hydroxyl ions** (OH^-) and positively charged ammonium ions (NH_4^+, **3**) form. Hydronium and hydroxyl ions, like other ions, exist in water in hydrated rather than free form (see p. 26).

Acid–base reactions always involve *pairs* of **acids** and the associated **conjugated bases** (see p. 18). The stronger the acid or base, the *weaker* the conjugate base or acid, respectively. For example, the very strongly acidic hydrogen chloride belongs to the very weakly basic chloride ion (**1**). The weakly acidic ammonium ion is conjugated with the moderately strong base ammonia (**3**).

The equilibrium constant K for the acid—base reaction between H_2O molecules (**2**) is very small. At 25 °C,

$$K = [H^+]\ [OH^-] / [H_2O] = 2\ \ 10^{-16}\ \text{mol}\ \ L^{-1}$$

In pure water, the concentration $[H_2O]$ is practically constant at 55 mol L^{-1}. Substituting this value into the equation, it gives:

$$K_w = [H^+]\ [OH^-] = 1\ \ 10^{-14}\ \text{mol}\ \ L^{-1}$$

The product $[H^+]\ [OH^-]$—the **ion product** of water—is constant even when additional acid–base pairs are dissolved in the water. At 25 °C, pure water contains H^+ and OH^- at concentrations of $1\ \ 10^{-7}$ mol L^{-1} each; it is **neutral** and has a pH value of exactly 7.

B. pH values in the organism ◑

pH values in the cell and in the extracellular fluid are kept constant within narrow limits. In the blood, the pH value normally ranges only between 7.35 and 7.45 (see p. 288). This corresponds to a maximum change in the H^+ concentration of ca. 30%. The pH value of cytoplasm is slightly lower than that of blood, at 7.0–7.3. In lysosomes (see p. 234; pH 4.5–5.5), the H^+ concentration is several hundred times higher than in the cytoplasm. In the lumen of the gastrointestinal tract, which forms part of the outside world relative to the organism, and in the body's excretion products, the pH values are more variable. Extreme values are found in the stomach (ca. 2) and in the small bowel (> 8). Since the kidney can excrete either acids or bases, depending on the state of the metabolism, the pH of urine has a particularly wide range of variation (4.8–7.5).

C. Buffers ●

Short–term pH changes in the organism are cushioned by **buffer systems**. These are mixtures of a weak acid, HB, with its conjugate base, B^-, or of a weak base with its conjugate acid. This type of system can neutralize both hydronium ions and hydroxyl ions.

In the first case (left), the base (B^-) binds a large proportion of the added protons (H^+) and HB and water are formed. If hydroxyl ions (OH^-) are added, they react with HB to give B^- and water (right). In both cases, it is primarily the $[HB]/[B^-]$ ratio that shifts, while the pH value only changes slightly. The **titration curve** (top) shows that buffer systems are most effective at the pH values that correspond to the pK_a value of the acid. This is where the curve is at its steepest, so that the pH change, ΔpH, is at its smallest with a given increase Δc in $[H^+]$ or $[OH^-]$. In other words, the **buffer capacity** $\Delta c / \Delta$pH is highest at the pK_a value.

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A. Acids and bases

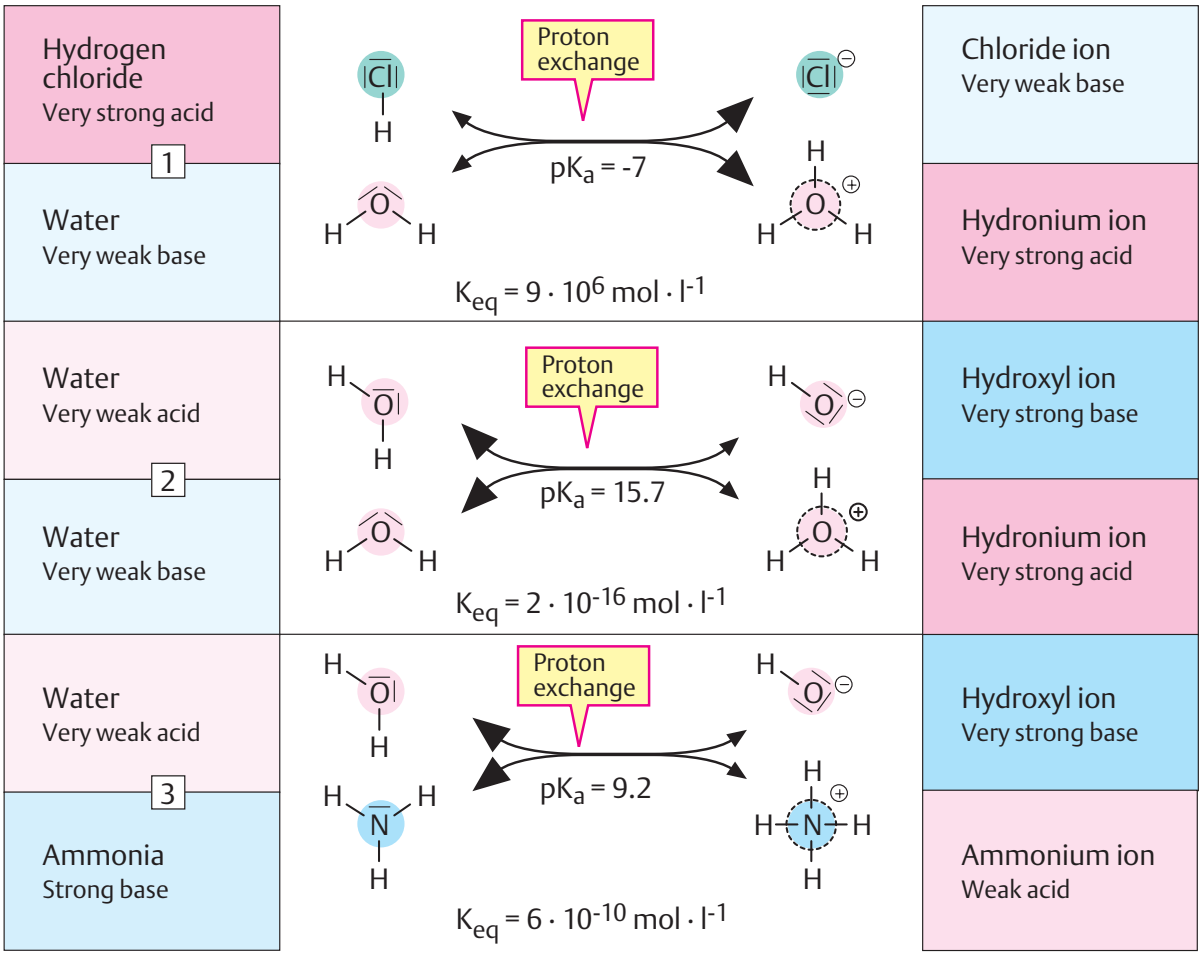

B. pH values in the body

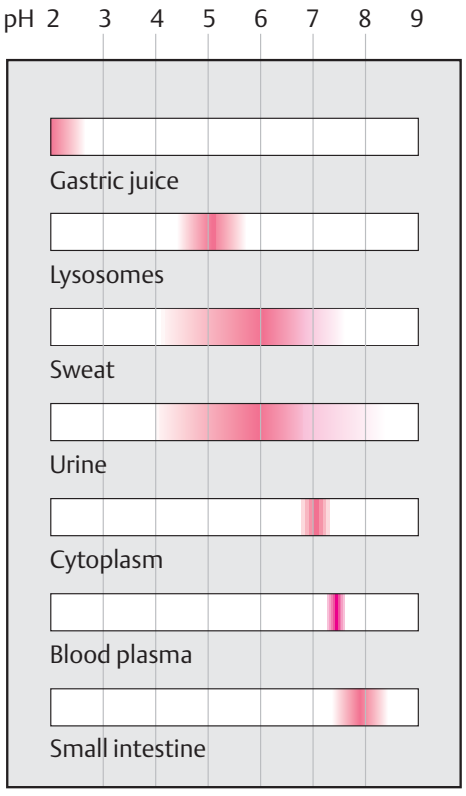

C. Buffers

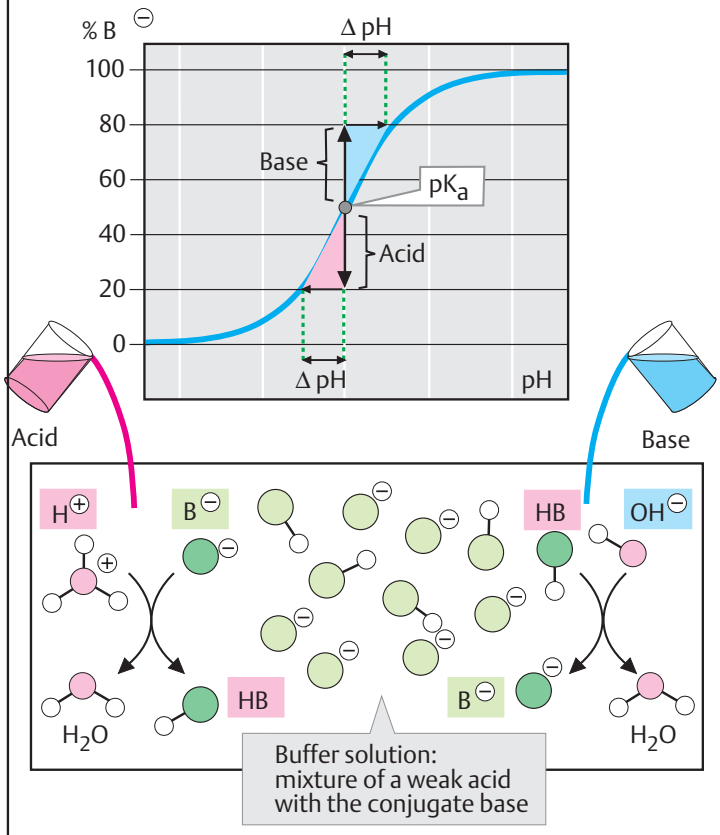

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Redox processes

A. Redox reactions ●

Redox reactions are chemical changes in which electrons are transferred from one reaction partner to another (**1**; see also p. 18). Like acid–base reactions (see p. 30), redox reactions always involve *pairs* of compounds. A pair of this type is referred to as a **redox system** (**2**). The essential difference between the two components of a redox system is the number of electrons they contain. The more electronrich component is called the **reduced form** of the compound concerned, while the other one is referred to as the **oxidized form**. The reduced form of one system (the **reducing agent**) donates electrons to the oxidized form of another one (the **oxidizing agent**). In the process, the reducing agent becomes oxidized and the oxidizing agent is reduced (**3**). Any given reducing agent can reduce only certain other redox systems. On the basis of this type of observation, redox systems can be arranged to form what are known as **redox series** (**4**).

The position of a system within one of these series is established by its **redox potential E** (see p. 18). The redox potential has a sign; it can be more negative or more positive than a reference potential arbitrarily set at zero (the normal potential of the system [2 H^+/H_2]). In addition, E depends on the concentrations of the reactants and on the reaction conditions (see p. 18). In redox series (**4**), the systems are arranged according to their increasing redox potentials. Spontaneous electron transfers are only possible if the redox potential of the donor is *more negative* than that of the acceptor (see p. 18).

B. Reduction equivalents ◑

In redox reactions, protons (H^+) are often transferred along with electrons (e^-), or protons may be released. The combinations of electrons and protons that occur in redox processes are summed up in the term **reduction equivalents**. For example, the combination 1 e^-/1 H^+ corresponds to a hydrogen *atom,* while 2 e^- and 2 H^+ together produce a hydrogen *molecule.* However, this does not mean that atomic or molecular hydrogen is actually transferred from one molecule to the other (see below). Only the combination 2 e^-/ 1 H^+, the **hydride ion**, is transferred as a unit.

C. Biological redox systems ◑

In the cell, redox reactions are catalyzed by enzymes, which work together with soluble or bound redox cofactors.

Some of these factors contain **metal ions** as redox-active components. In these cases, it is usually single electrons that are transferred, with the metal ion changing its valency. Unpaired electrons often occur in this process, but these are located in d orbitals (see p. 2) and are therefore less dangerous than single electrons in non-metal atoms ("free radicals"; see below).

We can only show here a few examples from the many organic redox systems that are found. In the complete reduction of the **flavin coenzymes** FMN and FAD (see p. 104), 2 e^- and 2 H^+ are transferred. This occurs in two separate steps, with a *semiquinone radical* appearing as an intermediate. Since organic radicals of this type can cause damage to biomolecules, flavin coenzymes never occur freely in solution, but remain firmly bound in the interior of proteins.

In the reduction or oxidation of **quinone/ quinol systems**, free radicals also appear as intermediate steps, but these are less reactive than flavin radicals. Vitamin E, another quinone-type redox system (see p. 104), even functions as a radical scavenger, by delocalizing unpaired electrons so effectively that they can no longer react with other molecules.

The **pyridine nucleotides** NAD^+ and $NADP^+$ always function in unbound form. The oxidized forms contain an aromatic nicotinamide ring in which the positive charge is delocalized. The right-hand example of the two *resonance structures* shown contains an electron-poor, positively charged C atom at the *para* position to nitrogen. If a **hydride ion** is added at this point (see above), the reduced forms NADH or NADPH arise. No radical intermediate steps occur. Because a proton is released at the same time, the reduced pyridine nucleotide coenzymes are correctly expressed as NAD(P)H+H^+.

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A. Redox reactions

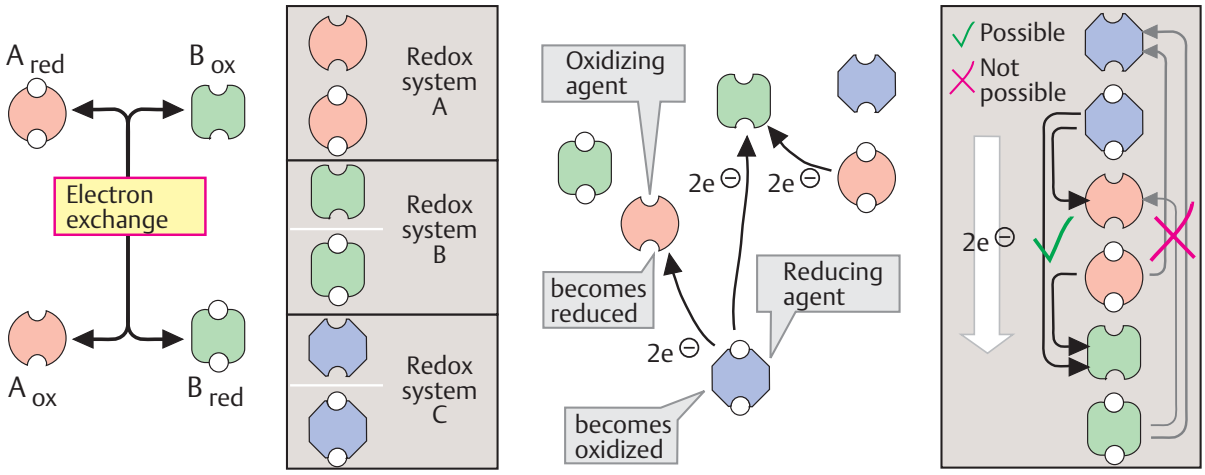

1. Principle **2.** Redox systems **3.** Possible electron transfers **4.** Redox series

B. Reducing equivalents

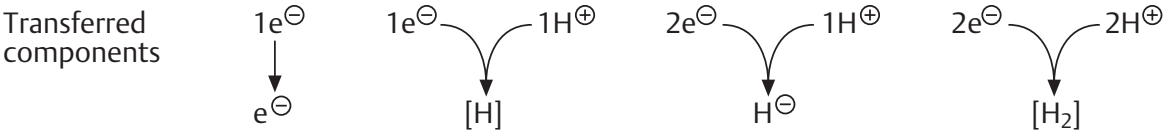

C. Biological redox systems

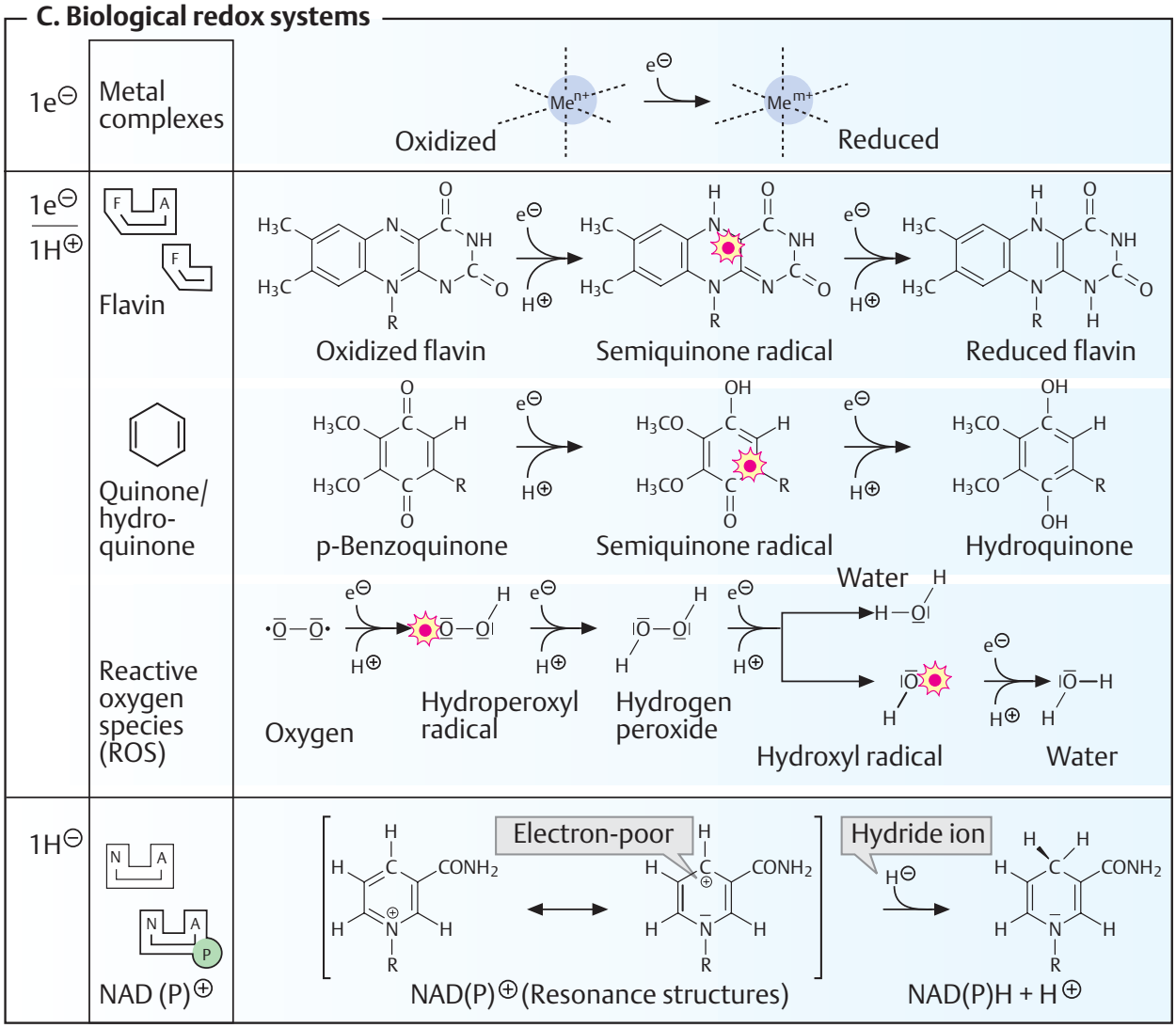

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Overview

The **carbohydrates** are a group of naturally occurring carbonyl compounds (aldehydes or ketones) that also contain several hydroxyl groups. The carbohydrates include **single sugars (monosaccharides)** and their polymers, the **oligosaccharides** and **polysaccharides**.

A. Carbohydrates: overview ●

Polymeric carbohydrates–above all starch, as well as some disaccharides–are important (but not essential) **components of food** (see p. 360). In the gut, they are broken down into monosaccharides and resorbed in this form (see p. 272). The form in which carbohydrates are distributed by the blood of vertebrates is *glucose* ("blood sugar"). This is taken up by the cells and either broken down to obtain energy (glycolysis) or converted into other metabolites (see pp. 150–159). Several organs (particularly the liver and muscles) store *glycogen* as a polymeric **reserve carbohydrate** (right; see p. 156). The glycogen molecules are covalently bound to a protein, *glycogenin*. Polysaccharides are used by many organisms as **building materials**. For example, the cell walls of bacteria contain *murein* as a stabilizing component (see p. 40), while in plants *cellulose* and other polysaccharides fulfill this role (see p. 42). Oligomeric or polymeric carbohydrates are often covalently bound to lipids or proteins. The **glycolipids** and **glycoproteins** formed in this way are found, for example, in cell membranes (center). Glycoproteins also occur in the blood in solute form (plasma proteins; see p. 276) and, as components of *proteoglycans,* form important constituents of the intercellular substance (see p. 346).

B. Monosaccharides: structure ◑

The most important natural monosaccharide, **D-glucose**, is an aliphatic aldehyde with six C atoms, five of which carry a hydroxyl group (**1**). Since C atoms 2 to 5 represent chiral centers (see p. 8), there are 15 further isomeric *aldohexoses* in addition to D-glucose, although only a few of these are important in nature (see p. 38). Most natural monosaccharides have the same configuration at C-5 as D-glyceraldehyde–they belong to the D **series**.

The open-chained form of glucose shown in (**1**) is found in neutral solution in less than 0.1% of the molecules. The reason for this is an intramolecular reaction in which one of the OH groups of the sugar is added to the aldehyde group of the *same* molecule (**2**). This gives rise to a cyclic **hemiacetal** (see p. 10). In aldohexoses, the hydroxy group at C-5 reacts preferentially, and a six-membered pyran ring is formed. Sugars that contain this ring are called **pyranoses**. By contrast, if the OH group at C-4 reacts, a five-part furan ring is formed. In solution, *pyranose* forms and *furanose* forms are present in equilibrium with each other and with the open-chained form, while in glucose polymers only the pyranose form occurs.

The **Haworth projection** (**2**) is usually used to depict sugars in the cyclic form, with the ring being shown in perspective as viewed from above. Depending on the configuration, the substituents of the chiral C atoms are then found above or below the ring. OH groups that lie on the *right* in the Fischer projection (**1**) appear *under* the ring level in the Haworth projection, while those on the *left* appear *above* it.

As a result of hemiacetal formation, an additional chiral center arises at C-1, which can be present in both possible configurations (anomers) (see p. 8). To emphasize this, the corresponding bonds are shown here using wavy lines.

The Haworth formula does not take account of the fact that the pyran ring is not plain, but usually has a *chair conformation*. In **B3**, two frequent conformations of D-glucopyranose are shown as ball-and-stick models. In the $^1C_4$ conformation (bottom), most of the OH groups appear vertical to the ring level, as in the Haworth projection (**axial** or **a** position). In the slightly more stable $^4C_1$ conformation (top), the OH groups take the **equatorial** or **e** position. At room temperature, each form can change into the other, as well as into other conformations.

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A. Carbohydrates: overview

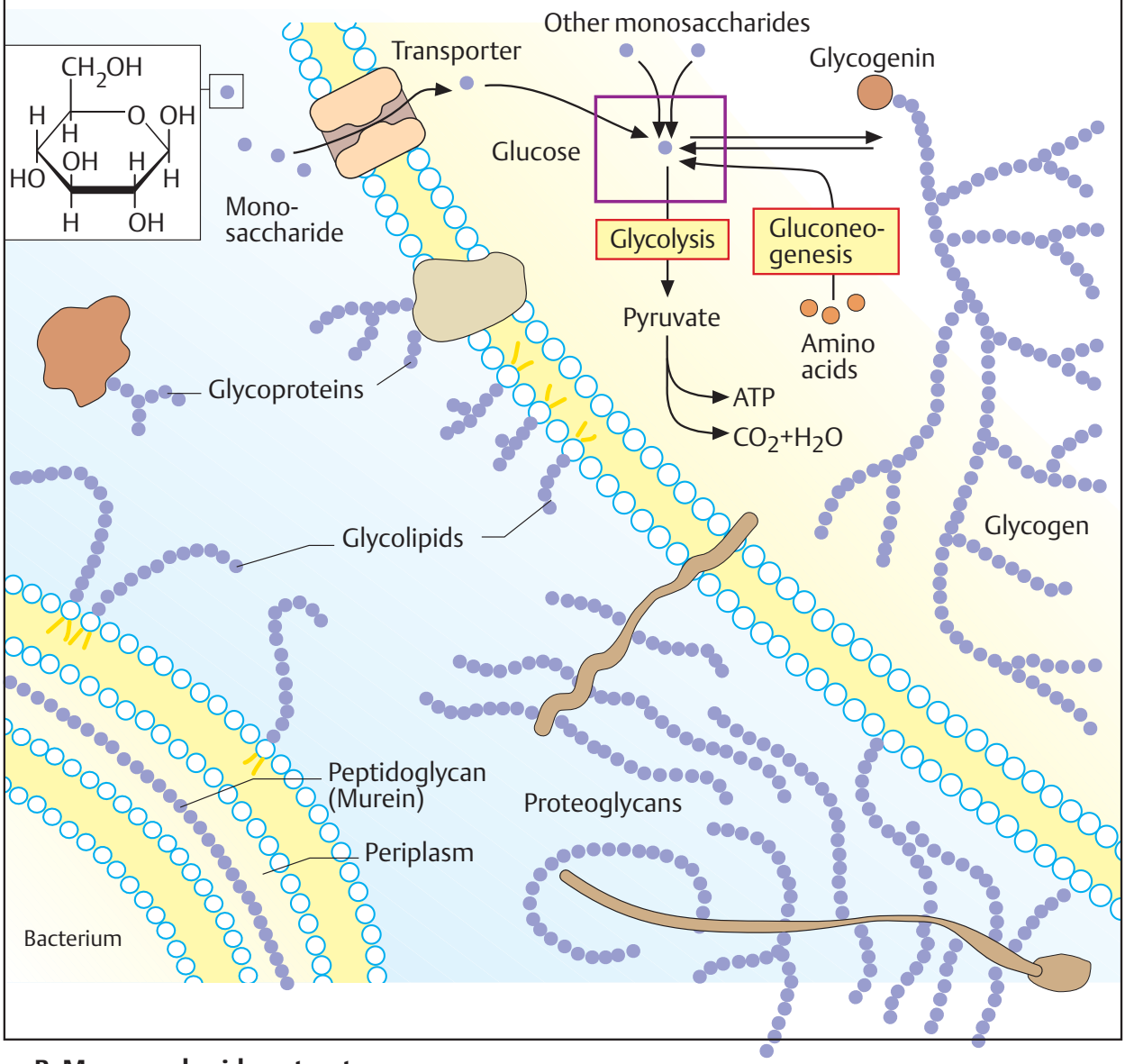

B. Monosaccharides: structure

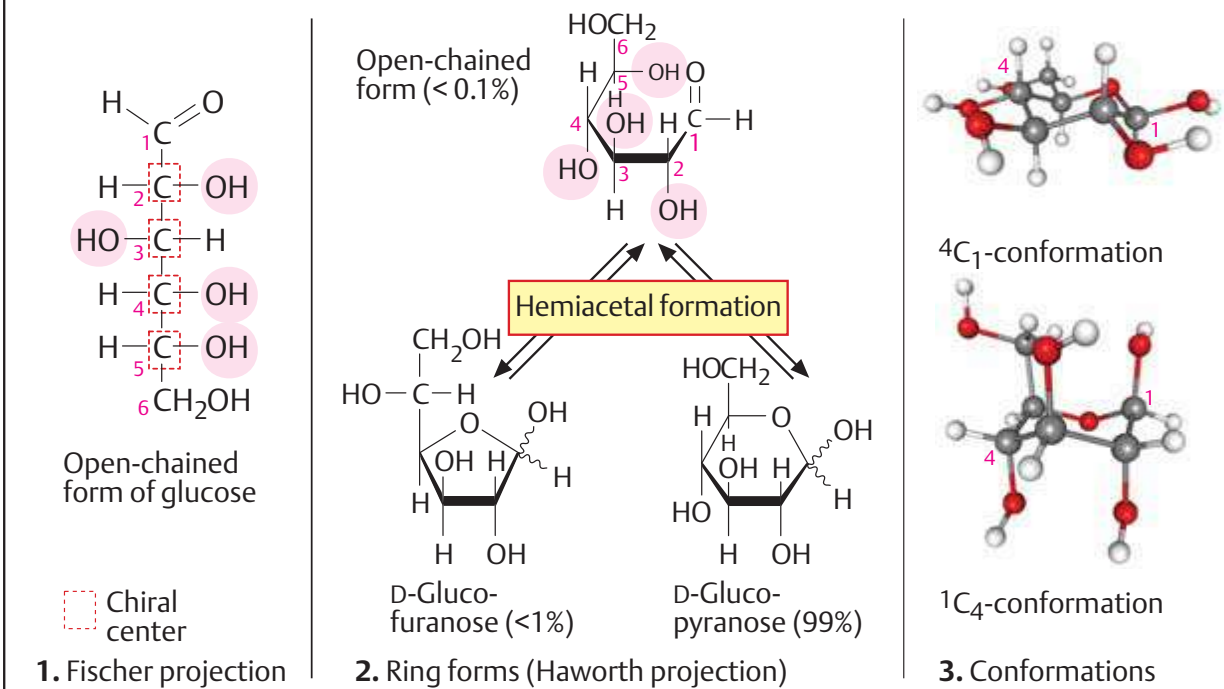

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Chemistry of sugars

A. Reactions of the monosaccharides ◑

The sugars (monosaccharides) occur in the metabolism in many forms (derivatives). Only a few important conversion reactions are discussed here, using **D**-glucose as an example.

1. Mutarotation. In the cyclic form, as opposed to the open-chain form, aldoses have a chiral center at C-1 (see p. 34). The corresponding isomeric forms are called **anomers**. In the β-anomer (center left), the OH group at C-1 (the anomeric OH group) and the CH_2OH group lie on the *same* side of the ring. In the α-anomer (right), they are on different sides. The reaction that interconverts anomers into each other is known as *mutarotation* (**B**).

2. Glycoside formation. When the anomeric OH group of a sugar reacts with an alcohol, with elimination of water, it yields an *O–glycoside* (in the case shown, α–methylglucoside). The glycosidic bond is not a normal ether bond, because the OH group at C-1 has a hemiacetal quality. Oligosaccharides and polysaccharides also contain *O*-glycosidic bonds. Reaction of the anomeric OH group with an NH_2 or NH group yields an *N-glycoside* (not shown). *N*-glycosidic bonds occur in nucleotides (see p. 80) and in glycoproteins (see p. 44), for example.

3. Reduction and oxidation. Reduction of the anomeric center at C-1 of glucose (2) produces the sugar alcohol *sorbitol*. Oxidation of the aldehyde group at C-1 gives the intramolecular ester (lactone) of *gluconic acid* (a glyconic acid). Phosphorylated gluconolactone is an intermediate of the pentose phosphate pathway (see p. 152). When glucose is oxidized at C-6, *glucuronic acid* (a glycuronic acid) is formed. The strongly polar glucuronic acid plays an important role in biotransformations in the liver (see pp. 194, 316).

4. Epimerization. In weakly alkaline solutions, glucose is in equilibrium with the ketohexose D-*fructose* and the aldohexose D-*mannose,* via an enediol intermediate (not shown). The only difference between glucose and mannose is the configuration at C-2. Pairs of sugars of this type are referred to as *epimers*, and their interconversion is called *epimerization*.

5. Esterification. The hydroxyl groups of monosaccharides can form *esters* with acids. In metabolism, phosphoric acid esters such as *glucose 6-phosphate* and *glucose 1-phosphate* (6) are particularly important.

B. Polarimetry, mutarotation ○

Sugar solutions can be analyzed by **polarimetry**, a method based on the interaction between chiral centers and linearly polarized light—i.e., light that oscillates in only *one* plane. It can be produced by passing normal light through a special filter (a **polarizer**). A second polarizing filter of the same type (the **analyzer**), placed behind the first, only lets the polarized light pass through when the polarizer and the analyzer are in alignment. In this case, the field of view appears bright when one looks through the analyzer (**1**). Solutions of chiral substances rotate the plane of polarized light by an angle α either to the left or to the right. When a solution of this type is placed between the polarizer and the analyzer, the field of view appears darker (**2**). The angle of rotation, α, is determined by turning the analyzer until the field of view becomes bright again (**3**). A solution's **optical rotation** depends on the type of chiral compound, its concentration, and the thickness of the layer of the solution. This method makes it possible to determine the sugar content of wines, for example.

Certain procedures make it possible to obtain the α and β anomers of glucose in pure form. A 1-molar solution of α-D-glucose has a rotation value $[\alpha]_D$ of +112°, while a corresponding solution of β-D-glucose has a value of +19°. These values change spontaneously, however, and after a certain time reach the same end point of +52°. The reason for this is that, in solution, **mutarotation** leads to an equilibrium between the α and β forms in which, independently of the starting conditions, 62% of the molecules are present in the β form and 38% in the α form.

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A. Reactions of the monosaccharides

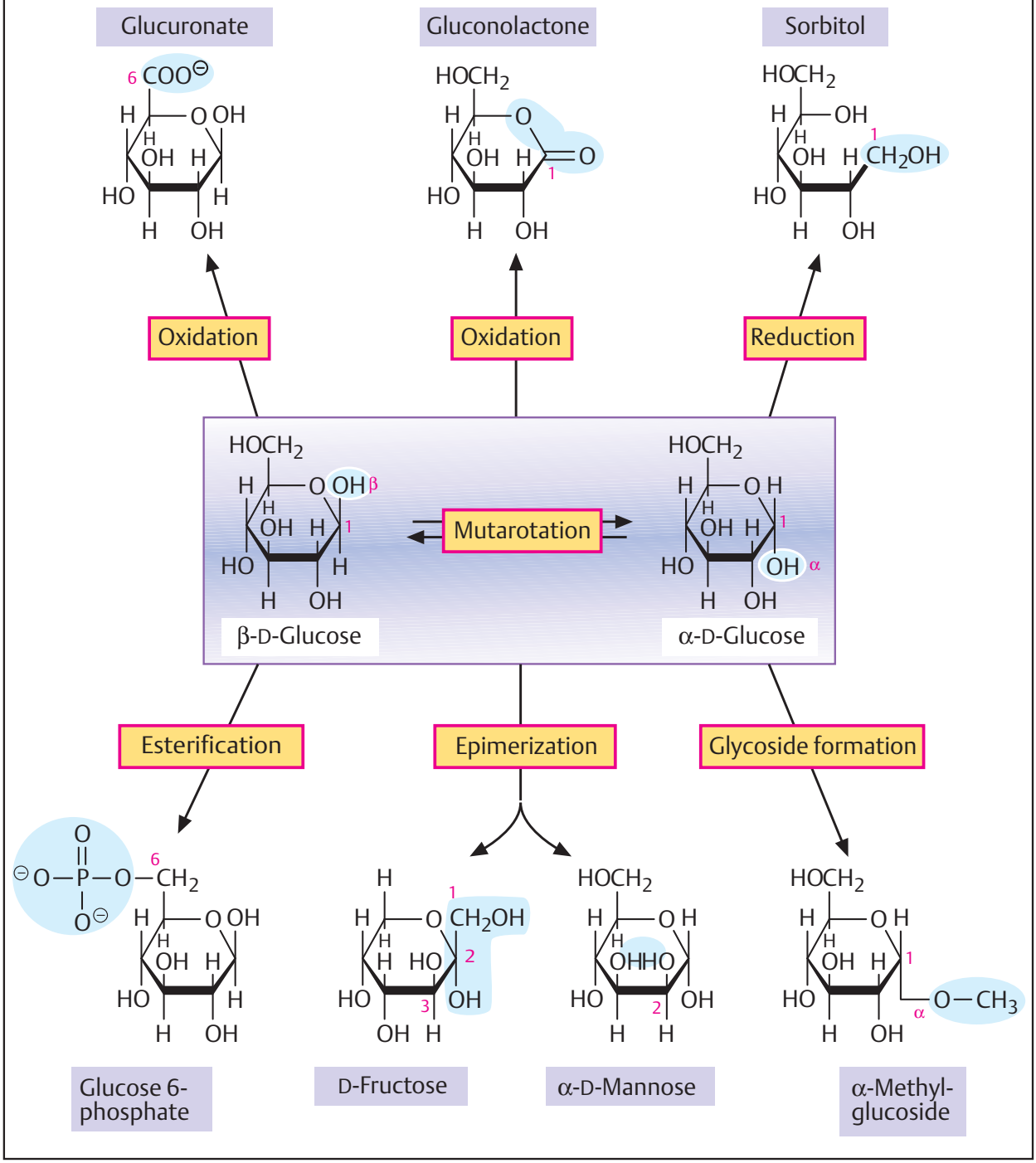

B. Polarimetry, mutarotation

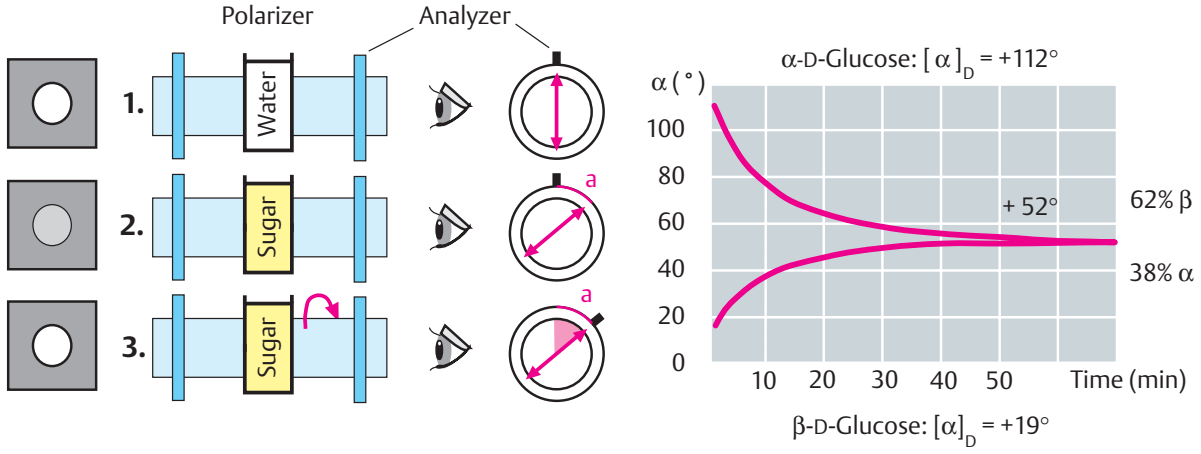

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Monosaccharides and disaccharides

A. Important monosaccharides ◑

Only the most important of the large number of naturally occurring **monosaccharides** are mentioned here. They are classified according to the number of C atoms (into pentoses, hexoses, etc.) and according to the chemical nature of the carbonyl function into aldoses and ketoses.

The best-known **aldopentose** (**1**), D-*ribose*, is a component of RNA and of nucleotide coenzymes and is widely distributed. In these compounds, ribose always exists in the furanose form (see p. 34). Like ribose, D-*xylose* and L-*arabinose* are rarely found in free form. However, large amounts of both sugars are found as constituents of polysaccharides in the walls of plant cells (see p. 42).

The most important of the **aldohexoses** (**1**) is D-glucose. A substantial proportion of the biomass is accounted for by glucose polymers, above all cellulose and starch. Free D-glucose is found in plant juices ("grape sugar") and as "blood sugar" in the blood of higher animals. As a constituent of lactose (milk sugar), D-galactose is part of the human diet. Together with D-mannose, galactose is also found in glycolipids and glycoproteins (see p. 44).

Phosphoric acid esters of the **ketopentose** D-*ribulose* (**2**) are intermediates in the pentose phosphate pathway (see p. 152) and in photosynthesis (see p. 128). The most widely distributed of the **ketohexoses** is D-*fructose*. In free form, it is present in fruit juices and in honey. Bound fructose is found in sucrose (**B**) and plant polysaccharides (e. g., inulin).

In the **deoxyaldoses** (**3**), an OH group is replaced by a hydrogen atom. In addition to 2-*deoxy-D-ribose*, a component of DNA (see p. 84) that is reduced at C-2, L-fucose is shown as another example of these. Fucose, a sugar in the λ series (see p. 34) is reduced at C-6.

The **acetylated amino sugars** *N-acetyl-D-glucosamine* and *N-acetyl-D-Galactosamine* (**4**) are often encountered as components of glycoproteins.

N-acetylneuraminic acid (sialic acid, **5**), is a characteristic component of glycoproteins. Other **acidic monosaccharides** such as D-*glucuronic acid*, D-*galacturonic acid*, and *liduronic acid*, are typical constituents of the glycosaminoglycans found in connective tissue.

Sugar alcohols (**6**) such as *sorbitol* and *mannitol* do not play an important role in animal metabolism.

B. Disaccharides ◑

When the anomeric hydroxyl group of one monosaccharide is bound glycosidically with one of the OH groups of another, a **disaccharide** is formed. As in all glycosides, the glycosidic bond does *not* allow mutarotation. Since this type of bond is formed stereospecifically by enzymes in natural disaccharides, they are only found in *one* of the possible configurations (α or β).

Maltose (**1**) occurs as a breakdown product of the starches contained in malt ("malt sugar"; see p. 148) and as an intermediate in intestinal digestion. In maltose, the anomeric OH group of one glucose molecule has an α-glycosidic bond with C-4 in a second glucose residue.

Lactose ("milk sugar," **2**) is the most important carbohydrate in the milk of mammals. Cow's milk contains 4.5% lactose, while human milk contains up to 7.5%. In lactose, the anomeric OH group of galactose forms a β-glycosidic bond with C-4 of a glucose. The lactose molecule is consequently elongated, and both of its pyran rings lie in the same plane.

Sucrose (**3**) serves in plants as the form in which carbohydrates are transported, and as a soluble carbohydrate reserve. Humans value it because of its intensely sweet taste. Sources used for sucrose are plants that contain particularly high amounts of it, such as sugar cane and sugar beet (*cane sugar, beet sugar*). Enzymatic hydrolysis of sucrose-containing flower nectar in the digestive tract of bees—catalyzed by the enzyme *invertase*—produces **honey**, a mixture of glucose and fructose. In sucrose, the two anomeric OH groups of glucose and fructose have a glycosidic bond; sucrose is therefore one of the non-reducing sugars.

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A. Important monosaccharides

① Aldoses

D-Ribose (Rib) | D-Xylose (Xyl) | L-Arabinose (Ara)

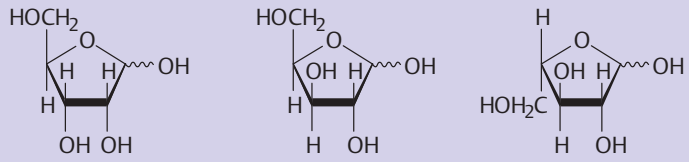

Pentoses

D-Glucose (Glc) | D-Mannose (Man) | D-Galactose (Gal)

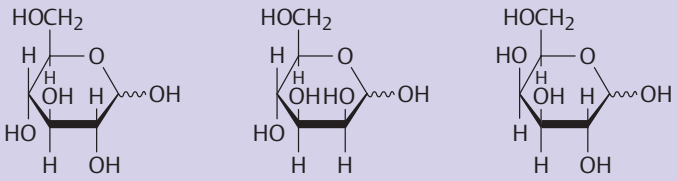

Hexoses

② Ketoses

D-Ribulose (Rub)

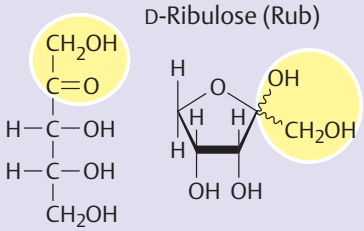

D-Fructose (Fru)

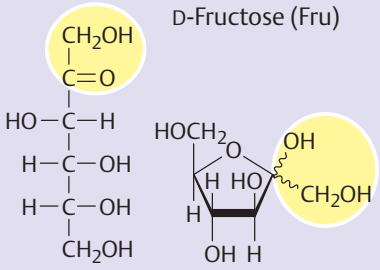

③ Deoxyaldoses

2-Deoxy-D-ribose (dRib) | L-Fucose (Fuc)

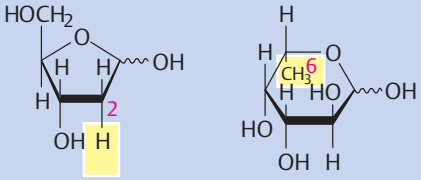

④ Acetylated amino sugars

N-Acetyl-D-glucosamine (GlcNAc) | *N*-Acetyl-D-galactosamine (GalNAc)

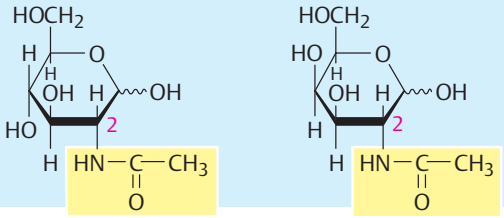

⑤ Acidic monosaccharides

D-Glucuronic acid (GlcUA) | L-Iduronic acid (IduUA) | *N*-Acetylneuraminic acid (NeuAc)

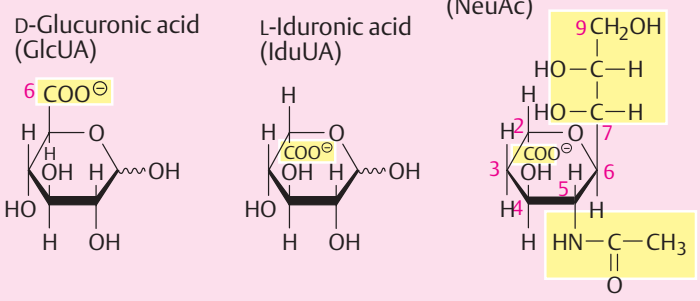

⑥ Sugar alcohols (alditoles)

D-Sorbitol | D-Mannitol

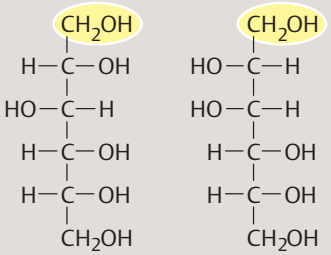

B. Disaccharides

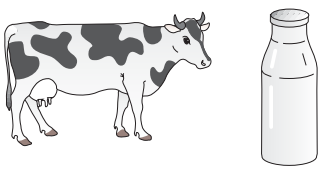

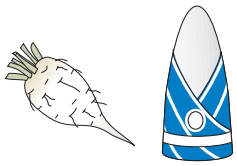

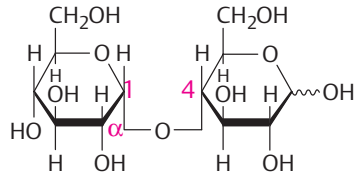

1. Maltose
α-D-Glucopyranosyl-(1→4)-D-glucopyranose

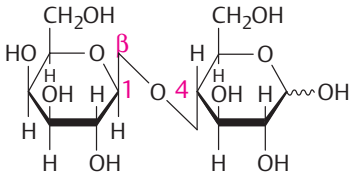

2. Lactose
β-D-Galactopyranosyl-(1→4)-D-glucopyranose

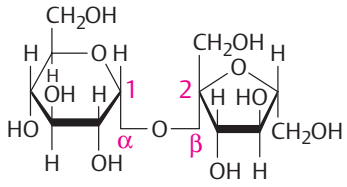

3. Sucrose
α-D-Glucopyranosyl-(1↔2)-β-D-fructofuranoside

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Polysaccharides: overview

Polysaccharides are ubiquitous in nature. They can be classified into three separate groups, based on their different *functions*. **Structural polysaccharides** provide mechanical stability to cells, organs, and organisms. **Waterbinding polysaccharides** are strongly hydrated and prevent cells and tissues from drying out. Finally, **reserve polysaccharides** serve as carbohydrate stores that release monosaccharides as required. Due to their polymeric nature, reserve carbohydrates are osmotically less active, and they can therefore be stored in large quantities within the cell.

A. Polysaccharides: structure ◑

Polysaccharides that are formed from only *one* type of monosaccharide are called **homoglycans**, while those formed from different sugar constituents are called **heteroglycans**. Both forms can exist as either linear or branched chains.

A section of a **glycogen** molecule is shown here as an example of a branched homoglycan. Amylopectin, the branched component of vegetable starch (see p. 42), has a very similar structure. Both molecules mainly consist of α1→4-linked glucose residues. In glycogen, on average every 8th to 10th residue carries —via an α1→6 bond—another 1,4-linked chain of glucose residues. This gives rise to branched, tree-like structures, which in animal glycogen are covalently bound to a protein, *glycogenin* (see p. 156).

The linear heteroglycan **murein**, a structural polysaccharide that stabilizes the cell walls of bacteria, has a more complex structure. Only a short segment of this thread-like molecule is shown here. In murein, two different components, both β1→4-linked, alternate: *N-acetylglucosamine* (GlcNAc) and *N-acetylmuraminic acid* (MurNAc), a lactic acid ether of *N*-acetylglucosamine. *Peptides* are bound to the carboxyl group of the lactyl groups, and attach the individual strands of murein to each other to form a three-dimensional network (not shown). Synthesis of the network-forming peptides in murein is inhibited by *penicillin* (see p. 254).

B. Important polysaccharides ◑

The table gives an overview of the composition and make-up both of the glycans mentioned above and of several more.

In addition to murein, bacterial polysaccharides include **dextrans**—glucose polymers that are mostly α1→6-linked and α1→3-branched. In water, dextrans form viscous slimes or gels that are used for chromatographic separation of macromolecules after chemical treatment (see p. 78). Dextrans are also used as components of blood plasma substitutes (plasma expanders) and foodstuffs.

Carbohydrates from algae (e.g., **agarose** and **carrageenan**) can also be used to produce gels. Agarose has been used in microbiology for more than 100 years to reinforce culture media ("agar-agar"). Algal polysaccharides are also added to cosmetics and ready-made foods to modify the consistency of these products.

The **starches**, the most important vegetable reserve carbohydrate and polysaccharides from plant cell walls, are discussed in greater detail on the following page. **Inulin**, a fructose polymer, is used as a starch substitute in diabetics' dietary products (see p. 160). In addition, it serves as a test substance for measuring renal clearance (see p. 322).

Chitin, a homopolymer from β1→4-linked *N*-acetylglucosamine, is the most important structural substance in insect and crustacean shells, and is thus the most common animal polysaccharide. It also occurs in the cell wall of fungi.

Glycogen, the reserve carbohydrate of higher animals, is stored in the liver and musculature in particular (**A**, see pp. 156, 336). The formation and breakdown of glycogen are subject to complex regulation by hormones and other factors (see p. 120).

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A. Polysaccharides: structure

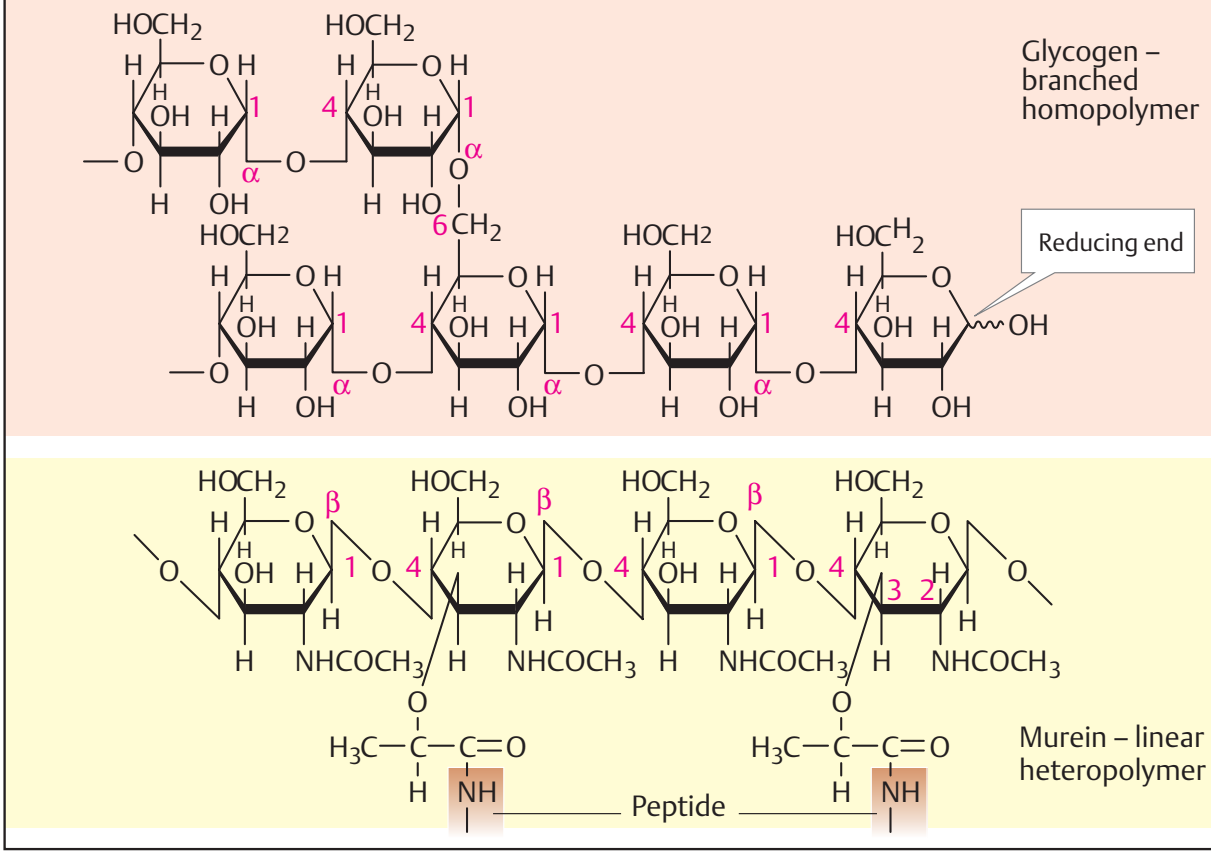

B. Important polysaccharides

Poly-saccharide	Mono-saccharide 1	Mono-saccharide 2	Linkage	Branch-ing	Occurrence	Function
Bacteria						
Murein	D-GlcNAc	D-MurNAc[1)]	β 1 →4	—	Cell wall	SC
Dextran	D-Glc	—	α 1 →6	α 1→3	Slime	WB
Plants						
Agarose	D-Gal	L-aGal[2)]	β 1 →4	β 1→3	Red algae (agar)	WB
Carrageenan	D-Gal	—	β 1 →3	α 1→4	Red algae	WB
Cellulose	D-Glc	—	β 1 →4	—	Cell wall	SC
Xyloglucan	D-Glc	D-Xyl (D-Gal, L-Fuc)	β 1 →4	β 1→6 (β 1→2)	Cell wall (Hemicellulose)	SC
Arabinan	L-Ara	—	α 1 →5	α 1→3	Cell wall (pectin)	SC
Amylose	D-Glc	—	α 1 →4	—	Amyloplasts	RC
Amylopectin	D-Glc	—	α 1 →4	α 1→6	Amyloplasts	RC
Inulin	D-Fru		β 2 →1	—	Storage cells	RC
Animals						
Chitin	D-GlcNAc	—	β 1 →4	—	Insects, crabs	SK
Glycogen	D-Glc	—	α 1 →4	α 1 →6	Liver, muscle	RK
Hyaluronic acid	D-GlcUA	D-GlcNAc	β 1 →4 β 1 →3	—	Connective tissue	SK,WB

SC= structural carbohydrate, RC= reserve carbohydrate,
WB = water-binding carbohydrate; [1)] *N*-acetylmuramic acid, [2)] 3,6-anhydrogalactose

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Plant polysaccharides

Two glucose polymers of plant origin are of special importance among the polysaccharides: β1→4-linked polymer **cellulose** and **starch**, which is mostly α1→4-linked.

A. Cellulose ◑

Cellulose, a linear homoglycan of β1→4-linked glucose residues, is the *most abundant organic substance* in nature. Almost half of the total biomass consists of cellulose. Some 40–50% of plant *cell walls* are formed by cellulose. The proportion of cellulose in *cotton fibers,* an important raw material, is 98%. Cellulose molecules can contain more than 10^4 glucose residues (mass 1–2 10^6 Da) and can reach lengths of 6–8 μm.

Naturally occurring cellulose is *extremely mechanically stable* and is highly *resistant* to chemical and enzymatic hydrolysis. These properties are due to the conformation of the molecules and their supramolecular organization. The unbranched β1→4 linkage results in linear chains that are stabilized by hydrogen bonds within the chain and between neighboring chains (**1**). Already during biosynthesis, 50–100 cellulose molecules associate to form an **elementary fibril** with a diameter of 4 nm. About 20 such elementary fibrils then form a **microfibril** (**2**), which is readily visible with the electron microscope.

Cellulose microfibrils make up the basic framework of the **primary wall** of young plant cells (**3**), where they form a complex network with other polysaccharides. The linking polysaccharides include **hemicellulose**, which is a mixture of predominantly neutral heteroglycans (xylans, xyloglucans, arabinogalactans, etc.). Hemicellulose associates with the cellulose fibrils via noncovalent interactions. These complexes are connected by neutral and acidic **pectins**, which typically contain galacturonic acid. Finally, a collagen-related protein, **extensin**, is also involved in the formation of primary walls.

In the higher animals, including humans, cellulose is **indigestible**, but important as **roughage** (see p. 273). Many herbivores (e. g., the ruminants) have symbiotic unicellular organisms in their digestive tracts that break down cellulose and make it digestible by the host.

B. Starch ◑

Starch, a **reserve polysaccharide** widely distributed in plants, is the *most important carbohydrate in the human diet.* In plants, starch is present in the chloroplasts in leaves, as well as in fruits, seeds, and tubers. The starch content is especially high in cereal grains (up to 75% of the dry weight), potato tubers (approximately 65%), and in other plant storage organs.

In these plant organs, starch is present in the form of microscopically small granules in special organelles known as **amyloplasts**. *Starch granules* are virtually insoluble in cold water, but swell dramatically when the water is heated. Some 15–25% of the starch goes into solution in colloidal form when the mixture is subjected to prolonged boiling. This proportion is called amylose ("soluble starch").

Amylose consists of *unbranched* α1→4-linked chains of 200–300 glucose residues. Due the α configuration at C-1, these chains form a *helix* with 6–8 residues per turn (**1**). The blue coloring that soluble starch takes on when iodine is added (the "iodine–starch reaction") is caused by the presence of these helices—the iodine atoms form chains inside the amylose helix, and in this largely nonaqueous environment take on a deep blue color. Highly branched polysaccharides turn brown or reddishbrown in the presence of iodine.

Unlike amylose, **amylopectin**, which is practically insoluble, is *branched*. On average, one in 20–25 glucose residues is linked to another chain via an α1→6 bond. This leads to an extended tree-like structure, which—like amylose—contains only *one* anomeric OH group (a "reducing end"). Amylopectin molecules can contain hundreds of thousands of glucose residues; their mass can be more than 10^8 Da.

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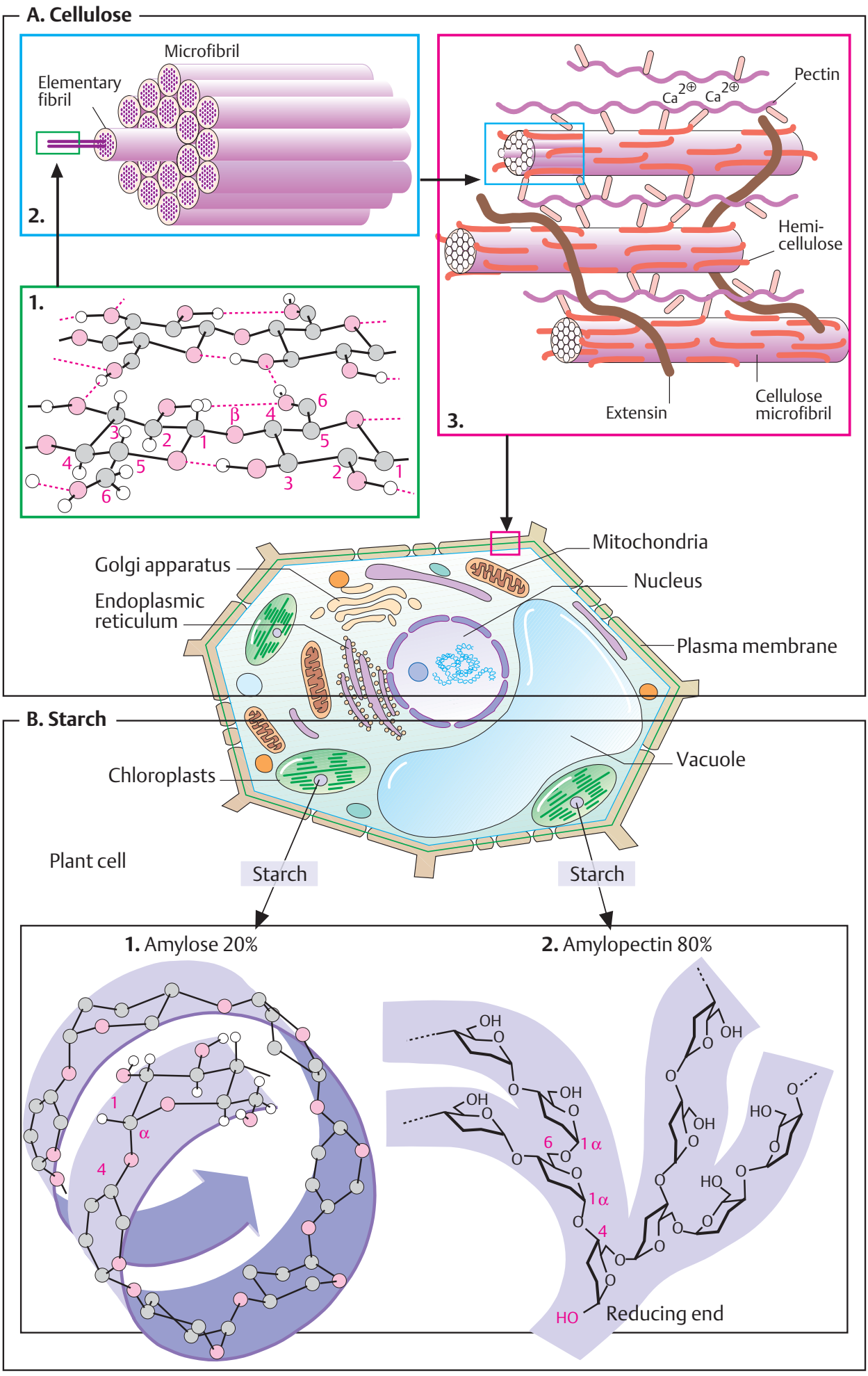

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Glycosaminoglycans and glycoproteins

A. Hyaluronic acid ○

As constituents of proteoglycans (see p. 346), the glycosaminoglycans—a group of acidic heteropolysaccharides—are important structural elements of the extracellular matrix.

Glycosaminoglycans contain *amino sugars* as well as *glucuronic acid* and *iduronic acid* as characteristic components (see p. 38). In addition, most polysaccharides in this group are esterified to varying extents by sulfuric acid, increasing their acidic quality. Glycosaminoglycans can be found in free form, or as components of proteoglycans throughout the organism.

Hyaluronic acid, an unesterified glycosaminoglycan with a relatively simple structure, consists of disaccharide units in which *N-acetylglucosamine* and *glucuronic acid* are alternately β1→4-linked and β1→3-linked. Due to the unusual β1→3 linkage, hyaluronic acid molecules–which may contain several thousand monosaccharide residues—are coiled like a helix. Three disaccharide units form each turn of the helix. The outwardfacing hydrophilic carboxylate groups of the glucuronic acid residues are able to bind Ca^{2+} ions. The **strong hydration** of these groups enables hyaluronic acid and other glycosaminoglycans to bind water up to 10 000 times their own volume in gel form. This is the function which hyaluronic acid has in the *vitreous body* of the eye, which contains approximately 1% hyaluronic acid and 98% water.

B. Oligosaccharide in immunoglobulin G (IgG) ○

Many proteins on the surface of the plasma membrane, and the majority of secreted proteins, contain oligosaccharide residues that are post-translationally added to the endoplasmic reticulum and in the Golgi apparatus (see p. 230). By contrast, cytoplasmic proteins are rarely glycosylated. **Glycoproteins** can contain more than 50% carbohydrate; however, the proportion of protein is generally much greater.

As an example of the carbohydrate component of a glycoprotein, the structure of one of the oligosaccharide chains of immunoglobulin G (IgG; see p. 300) is shown here. The oligosaccharide has an *N-glycosidic* link to the amide group of an asparagine residue in the F_c part of the protein. Its function is not known.

Like all *N*-linked carbohydrates, the oligosaccharide in IgG contains a T-shaped **core structure** consisting of two *N-acetylglucosamines* and three *mannose* residues (shown in violet). In addition, in this case the structure contains two further *N-acetylglucosamine* residues, as well as a *fucose* residue and a *galactose* residue. Glycoproteins show many different types of branching. In this case, we not only have β1→4 linkage, but also β1→2, α1→3, and α1→6 bonds.

C. Glycoproteins: forms ◑

On the cell surface of certain glycoproteins, **O-glycosidic** links are found between the carbohydrate part and a serine or threonine residue, instead of *N*-glycosidic links to asparagine residues. This type of link is less common than the ***N*-glycosidic** one.

There are two types of oligosaccharide structure with *N*-glycosidic links, which arise through two different biosynthetic pathways. During glycosylation in the ER, the protein is initially linked to an oligosaccharide, which in addition to the core structure contains six further mannose residues and three terminal glucose residues (see p. 230). The simpler from of oligosaccharide (the **mannose-rich** type) is produced when only the glucose residues are cleaved from the primary product, and no additional residues are added. In other cases, the mannose residues that are located outside the core structure are also removed and replaced by other sugars. This produces oligosaccharides such as those shown on the right (the **complex type**). At the external end of the structure, glycoproteins of the complex type often contain *N*-acetylneuraminic acid residues, which give the oligosaccharide components negative charges.

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A. Hyaluronic acid

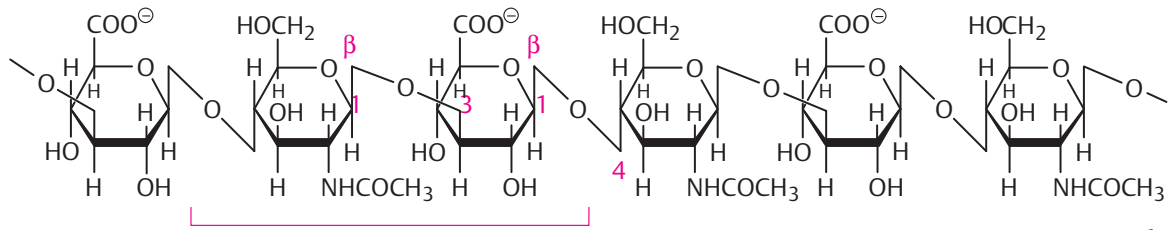

[→3)-β-D-GlcNAc-(1 →4)-β-D-GlcUA-(1 →4]$_n$

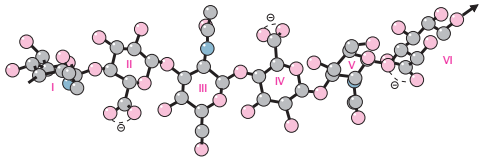

B. Oligosaccharide in immunoglobulin G (IgG)

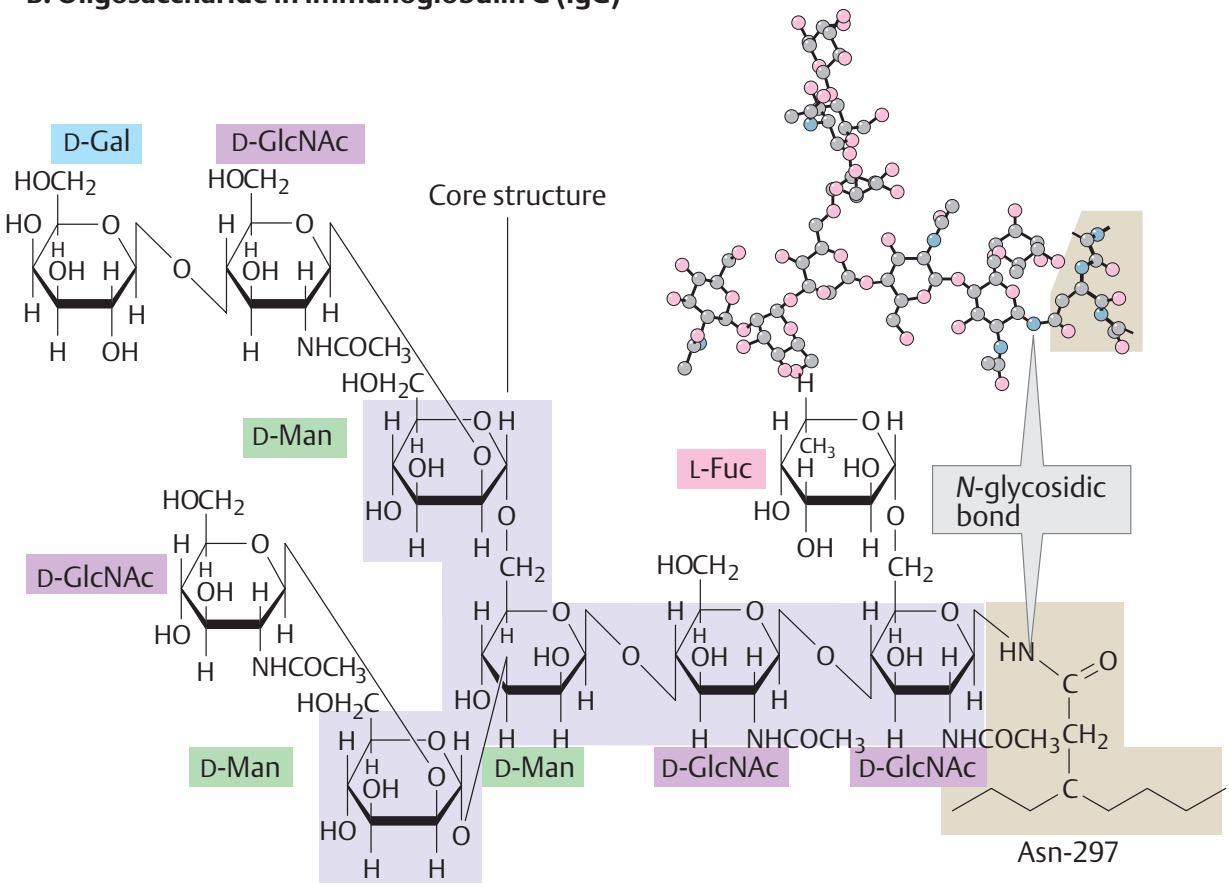

C. Glycoproteins: forms

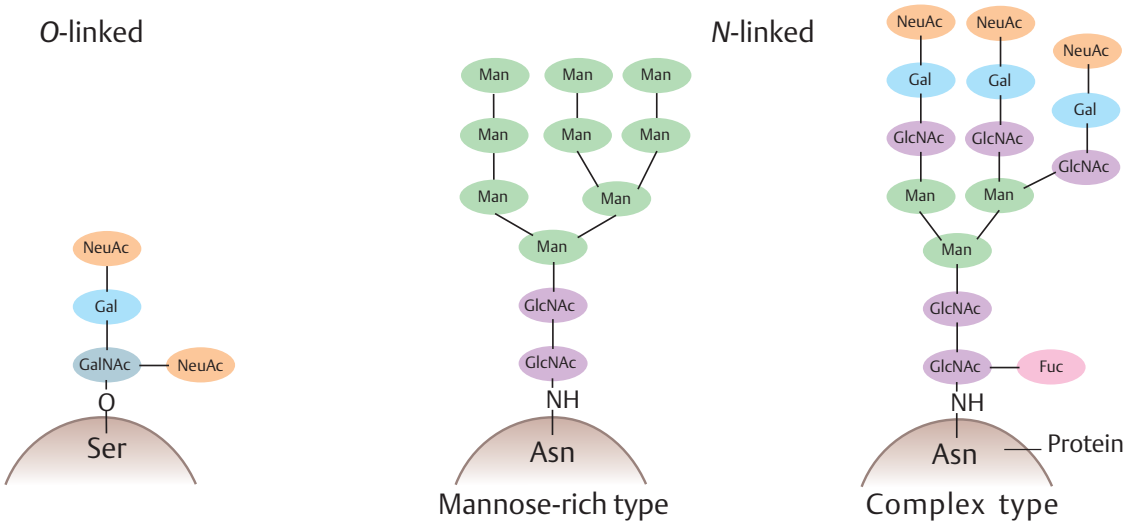

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Overview

A. Classification ●

The **lipids** are a large and heterogeneous group of substances of biological origin that are easily dissolved in organic solvents such as methanol, acetone, chloroform, and benzene. By contrast, they are either insoluble or only poorly soluble in water. Their low water solubility is due to a lack of polarizing atoms such as O, N, S, and P (see p. 6).

Lipids can be classified into substances that are either *hydrolyzable*— i. e., able to undergo hydrolytic cleavage—or *nonhydrolyzable*. Only a few examples of the many lipids known can be mentioned here. The individual classes of lipids are discussed in more detail in the following pages.

Hydrolyzable lipids (components shown in brackets). The simple **esters** include the *fats* (triacylglycerol; one glycerol + three acyl residues); the *waxes* (one fatty alcohol + one acyl residue); and the *sterol esters* (one sterol + one acyl residue). The **phospholipids** are esters with more complex structures. Their characteristic component is a phosphate residue. The phospholipids include the *phosphatidic acids* (one glycerol + two acyl residues + one phosphate) and the *phosphatides* (one glycerol + two acyl residues + one phosphate + one amino alcohol). In the **sphingolipids**, glycerol and one acyl residue are replaced by sphingosine. Particularly important in this group are the sugar-containing **glycolipids** (one sphingosine + one fatty acid + sugar). The *cerebrosides* (one sphingosine + one fatty acid + one sugar) and *gangliosides* (one sphingosine + one fatty acid + several different sugars, including neuraminic acid) are representatives of this group.

The components of the hydrolyzable lipids are linked to one another by **ester bonds**. They are easily broken down either enzymatically or chemically.

Non-hydrolyzable lipids. The **hydrocarbons** include the *alkanes* and *carotenoids*. The **lipid alcohols** are also not hydrolyzable. They include long-chained *alkanols* and cyclic *sterols* such as cholesterol, and *steroids* such as estradiol and testosterone. The most important **acids** among the lipids are *fatty acids*. The *eicosanoids* also belong to this group; these are derivatives of the polyunsaturated fatty acid arachidonic acid (see p. 390).

B. Biological roles ●

1. Fuel. Lipids are an important source of energy in the diet. In quantitative terms, they represent the principal energy reserve in animals. Neutral fats in particular are stored in specialized cells, known as *adipocytes*. Fatty acids are released from these again as needed, and these are then oxidized in the mitochondria to form water and carbon dioxide, with oxygen being consumed. This process also gives rise to reduced coenzymes, which are used for ATP production in the respiratory chain (see p. 140).

2. Nutrients. Amphipathic lipids are used by cells to build membranes (see p. 214). Typical membrane lipids include phospholipids, glycolipids, and cholesterol. Fats are only weakly amphiphilic and are therefore not suitable as membrane components.

3. Insulation. Lipids are excellent insulators. In the higher animals, neutral fats are found in the subcutaneous tissue and around various organs, where they serve as mechanical and thermal insulators. As the principal constituent of cell membranes, lipids also insulate cells from their environment mechanically and electrically. The impermeability of lipid membranes to ions allows the formation of the membrane potential (see p. 126).

4. Special tasks. Some lipids have adopted special roles in the body. Steroids, eicosanoids, and some metabolites of phospholipids have *signaling functions*. They serve as hormones, mediators, and second messengers (see p. 370). Other lipids form *anchors* to attach proteins to membranes (see p. 214). The lipids also produce *cofactors for enzymatic reactions*—e. g., vitamin K (see p. 52) and ubiquinone (see p. 104). The carotenoid retinal, a light-sensitive lipid, is of central importance in the *process of vision* (see p. 358).

Several lipids are not formed independently in the human body. These substances, as **essential fatty acids** and **fat-soluble vitamins**, are indispensable components of nutrition (see pp. 364 ff.)

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A. Classification

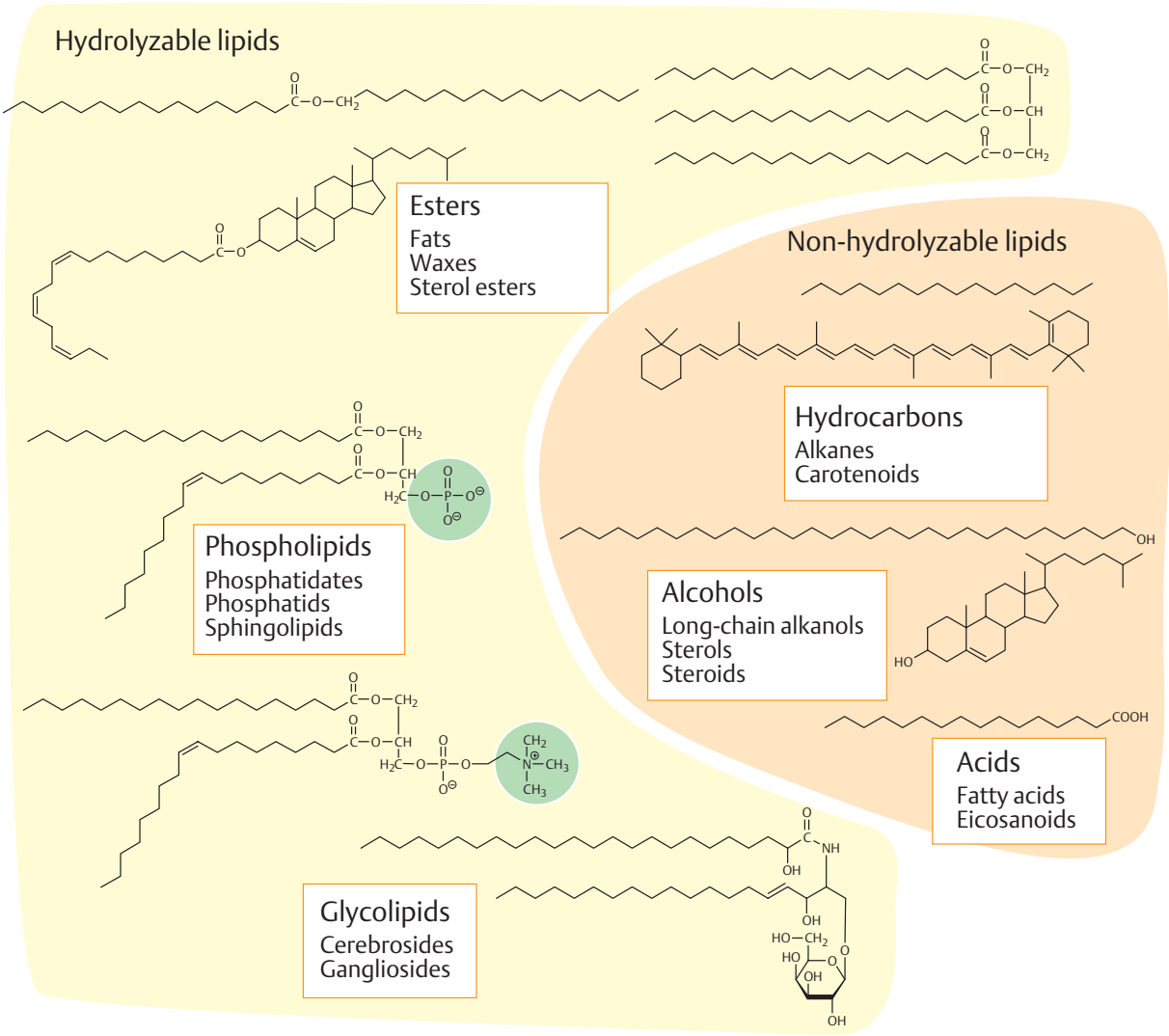

B. Biological roles

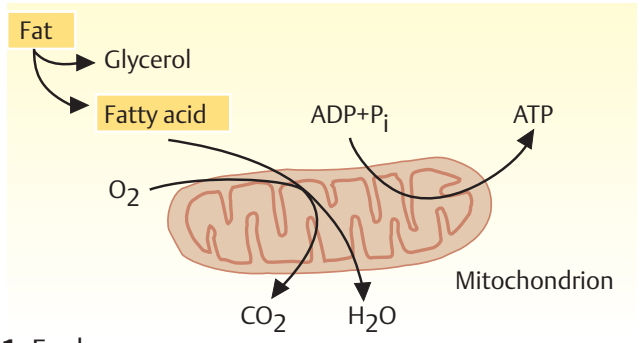

1. Fuel

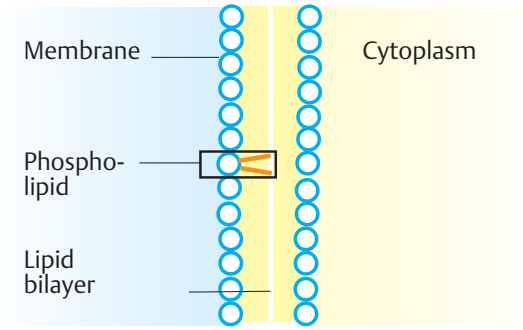

2. Building block

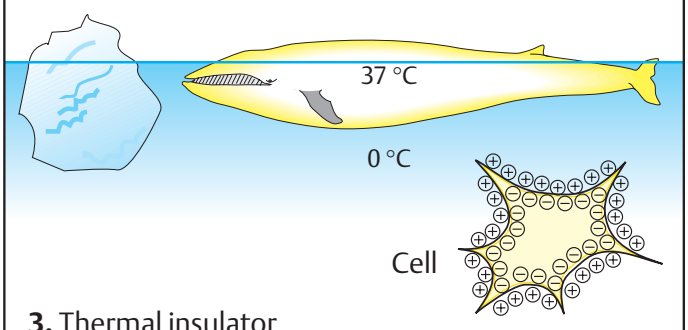

3. Thermal insulator

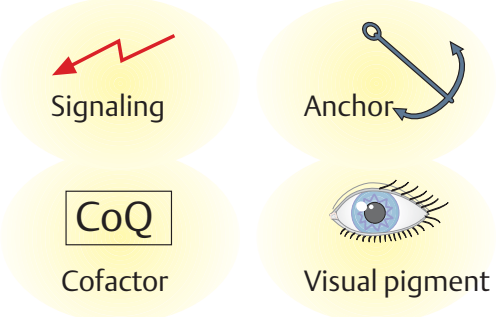

4. Special tasks

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Fatty acids and fats

A. Carboxylic acids ◑

The naturally occurring **fatty acids** are carboxylic acids with unbranched hydrocarbon chains of 4–24 carbon atoms. They are present in all organisms as components of fats and membrane lipids. In these compounds, they are esterified with alcohols (glycerol, sphingosine, or cholesterol). However, fatty acids are also found in small amounts in unesterified form. In this case, they are known as *free fatty acids* (FFAs). As free fatty acids have strongly amphipathic properties (see p. 28), they are usually present in protein-bound forms.

The table lists the full series of aliphatic carboxylic acids that are found in plants and animals. In higher plants and animals, unbranched, longchain fatty acids with either 16 or 18 carbon atoms are the most common—e. g., palmitic and stearic acid. The number of carbon atoms in the longer, natural fatty acids is always even. This is because they are biosynthesized from C_2 building blocks (see p. 168).

Some fatty acids contain one or more isolated *double bonds*, and are therefore *"unsaturated."* Common **unsaturated fatty acids** include oleic acid and linoleic acid. Of the two possible *cis–trans* isomers (see p. 8), usually only the *cis* forms are found in natural lipids. Branched fatty acids only occur in bacteria. A shorthand notation with several numbers is used for precise characterization of the structure of fatty acids—e g., 18:2;9,12 for linoleic acid. The first figure stands for the number of C atoms, while the second gives the number of double bonds. The positions of the double bonds follow after the semicolon. As usual, numbering starts at the carbon with the highest oxidation state (i. e., the carboxyl group corresponds to C-1). Greek letters are also commonly used (α = C-2; β = C-3; ω = the last carbon, ω-3 = the third last carbon).

Essential fatty acids are fatty acids that have to be supplied in the diet. Without exception, these are all polyunsaturated fatty acids: the C_{20} fatty acid *arachidonic acid* (20:4;5,8,11,14) and the two C_{18} acids *linoleic acid* (18:2;9,12) and *linolenic acid* (18:3;9,12,15). The animal organism requires arachidonic acid to synthesize eicosanoids (see p. 390). As the organism is capable of elongating fatty acids by adding C_2 units, but is not able to introduce double bonds into the end sections of fatty acids (after C-9), arachidonic acid has to be supplied with the diet. Linoleic and linolenic acid can be converted into arachidonic acid by elongation, and they can therefore replace arachidonic acid in the diet.

B. Structure of fats ◑

Fats are esters of the trivalent alcohol *glycerol* with three fatty acids. When a single fatty acid is esterified with glycerol, the product is referred to as a *monoacylglycerol* (fatty acid residue = acyl residue).

Formally, esterification with additional fatty acids leads to *diacylglycerol* and ultimately to *triacylglycerol,* the actual fat (formerly termed "triglyceride"). As triacylglycerols are uncharged, they are also referred to as *neutral fats*. The carbon atoms of glycerol are not usually equivalent in fats. They are distinguished by their *"sn"* number, where sn stands for "stereospecific numbering."

The three acyl residues of a fat molecule may differ in terms of their chain length and the number of double bonds they contain. This results in a large number of possible combinations of individual fat molecules. When extracted from biological materials, fats always represent mixtures of very similar compounds, which differ in their fatty acid residues. A chiral center can arise at the middle C atom (*sn* -C-2) of a triacylglycerol if the two external fatty acids are different. The monoacylglycerols and diacylglycerols shown here are also chiral compounds. Nutritional fats contain palmitic, stearic, oleic acid, and linoleic acid particularly often. Unsaturated fatty acids are usually found at the central C atom of glycerol.

The length of the fatty acid residues and the number of their double bonds affect the melting point of the fats. The shorter the fatty acid residues and the more double bonds they contain, the lower their melting points.

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A. Carboxylic acids

Name	Number of carbons : Number of double bonds; Position of double bonds
Formic acid	1 : 0
Acetic acid	2 : 0
Propionic acid	3 : 0
Butyric acid	4 : 0
Valerianic acid	5 : 0
Caproic acid	6 : 0
Caprylic acid	8 : 0
Capric acid	10 : 0
Lauric acid	12 : 0
Myristic acid	14 : 0
Palmitic acid	16 : 0
Stearic acid	18 : 0
Oleic acid	18 : 1; 9
Linoleic acid	18 : 2; 9,12
Linolenic acid	18 : 3; 9,12,15
Arachidic acid	20 : 0
Arachidonic acid	20 : 4; 5,8,11,14
Behenic acid	22 : 0
Erucic acid	22 : 1; 13
Lignoceric acid	24 : 0
Nervonic acid	24 : 1; 15

Not contained in lipids

$HOOC-CH_2-CH_2-CH_2-CH_2-CH_3$

Caproic acid

Essential in human nutrition

B. Structure of fats

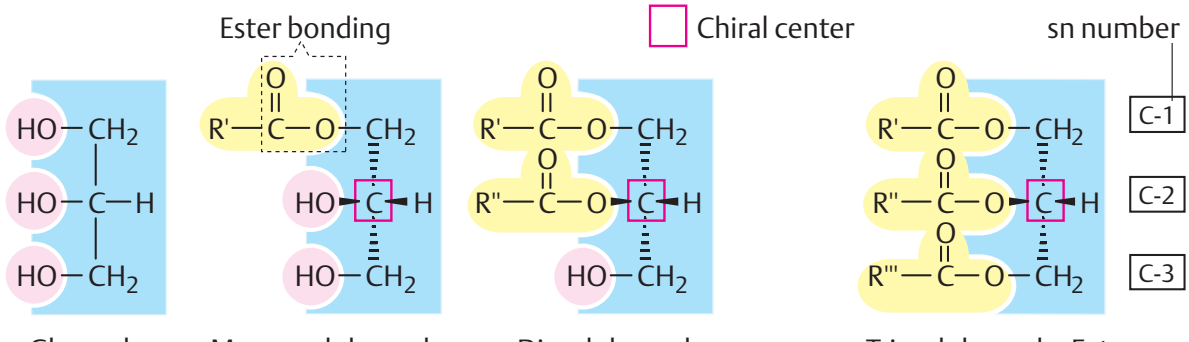

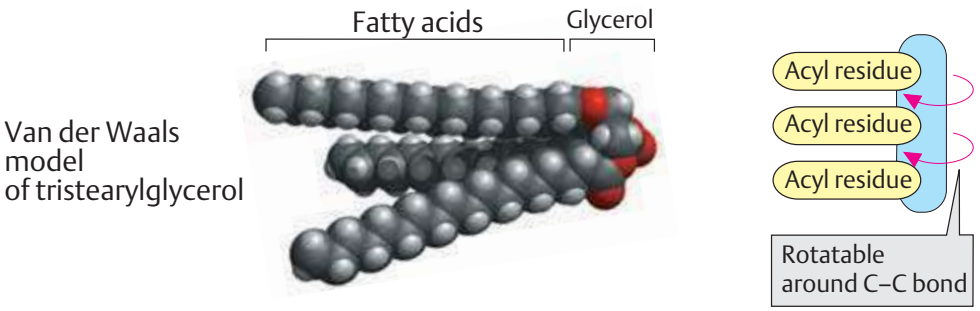

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Phospholipids and glycolipids

A. Structure of phospholipids and glycolipids ◑

Fats (triacylglycerol, **1**) are esters of glycerol with three fatty acids (see p. 48). Within the cell, they mainly occur as fat droplets. In the blood, they are transported in the hydrophobic interior of lipoproteins (see p. 278).

Phospholipids (**2**) are the main constituents of biological membranes (see pp. 214–217). Their common feature is a phosphate residue that is esterified with the hydroxyl group at C-3 of glycerol. Due to this residue, phospholipids have at least one negative charge at a neutral pH.

Phosphatidates (anions of the phosphatidic acids), the simplest phospholipids, are phosphate esters of diacylglycerol. They are important intermediates in the biosynthesis of fats and phospholipids (see p. 170). Phosphatidates can also be released from phospholipids by phospholipases.

The other phospholipids can be derived from phosphatidates (residue = phosphatidyl). Their phosphate residues are esterified with the hydroxyl group of an amino alcohol (*choline*, *ethanolamine*, or *serine*) or with the cyclohexane derivative *myo-inositol*. *Phosphatidylcholine* is shown here as an example of this type of compound. When two phosphatidyl residues are linked with one glycerol, the result is *cardiolipin* (not shown), a phospholipid that is characteristic of the inner mitochondrial membrane. *Lysophospholipids* arise from phospholipids by enzymatic cleavage of an acyl residue. The hemolytic effect of bee and snake venoms is due in part to this reaction.

Phosphatidylcholine (lecithin) is the most abundant phospholipid in membranes. *Phosphatidylethanolamine* (cephalin) has an ethanolamine residue instead of choline, and *phosphatidylserine* has a serine residue. In *phosphatidylinositol,* phosphatidate is esterified with the sugarlike cyclic polyalcohol *myo*-inositol. A doubly phosphorylated derivative of this phospholipid, phosphatidylinositol 4,5-bisphosphate, is a special component of membranes, which, by enzymatic cleavage, can give rise to two *second messengers*, diacylglycerol (DAG) and inositol 1,4,5trisphosphate ($InsP_3$; see p. 386).

Some phospholipids carry additional charges, in addition to the negative charge at the phosphate residue. In phosphatidylcholine and phosphatidylethanolamine, the *N*-atom of the amino alcohol is positively charged. As a whole, these two phosphatides therefore appear to be neutral. In contrast, phosphatidylserine—with one additional positive charge and one additional negative charge in the serine residue—and phosphatidylinositol (with no additional charge) have a negative net charge, due to the phosphate residue.

Sphingolipids (**3**), which are found in large quantities in the membranes of nerve cells in the brain and in neural tissues, have a slightly different structure from the other membrane lipids discussed so far. In sphingolipids, *sphingosine*, an amino alcohol with an unsaturated alkyl side chain, replaces glycerol and one of the acyl residues. When sphingosine forms an amide bond to a fatty acid, the compound is called *ceramide* (**3**). This is the precursor of the sphingolipids. *Sphingomyelin* (2)—the most important sphingolipid—has an additional phosphate residue with a choline group attached to it on the sphingosine, in addition to the fatty acid.

Glycolipids (**3**) are present in all tissues on the outer surface of the plasma membrane. They consist of sphingosine, a fatty acid, and an oligosaccharide residue, which can sometimes be quite large. The phosphate residue typical of phospholipids is absent. *Galactosylceramide* and *glucosylceramide* (known as cerebroside) are simple representatives of this group. Cerebrosides in which the sugar is esterified with sulfuric acid are known as *sulfatides*. *Gangliosides* are the most complex glycolipids. They constitute a large family of membrane lipids with receptor functions that are as yet largely unknown. A characteristic component of many gangliosides is *N*-acetylneuraminic acid (sialic acid; see p. 38).

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A. Structure of fats, phospholipids, and glycolipids

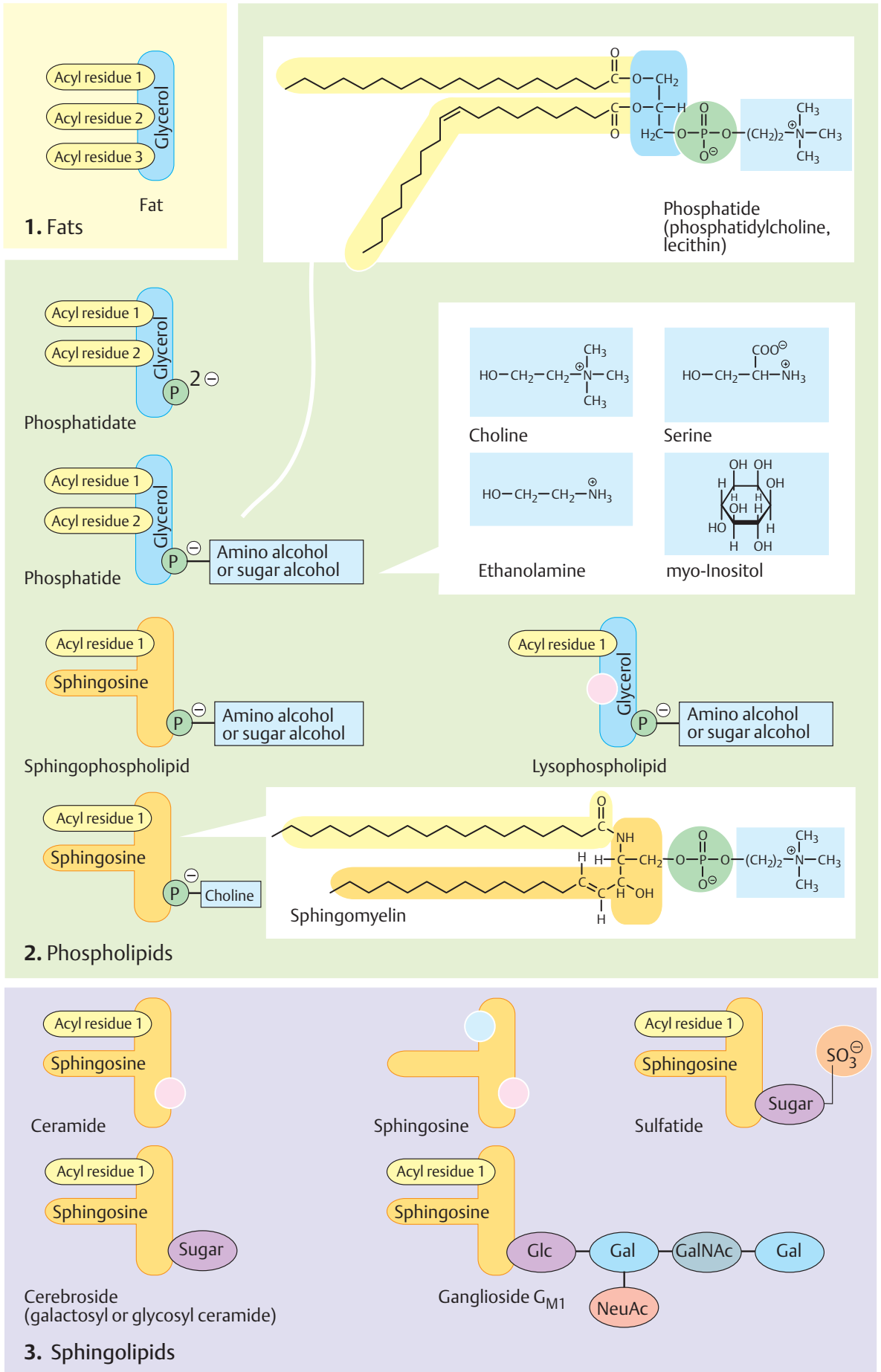

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Isoprenoids

A. Activated acetic acid as a component of lipids ◑

Although the lipids found in plant and animal organisms occur in many different forms, they are all closely related biogenetically; they are all derived from **acetyl-CoA**, the "activated acetic acid" (see pp. 12, 110).

1. One major pathway leads from acetyl-CoA to the activated fatty acids (**acyl-CoA**; for details, see p. 168). *Fats, phospholipids,* and *glycolipids* are synthesized from these, and fatty acid derivatives in particular are formed. Quantitatively, this is the most important pathway in animals and most plants.

2. The second pathway leads from acetyl-CoA to isopentenyl diphosphate (*"active isoprene"*), the basic component for the **isoprenoids**. Its biosynthesis is discussed in connection with biosynthesis of the isoprenoid, cholesterol (see p. 172).

B. Isoprenoids ◑

Formally, isoprenoids are derived from a single common building block, isoprene (2-methyl-1,3-butadiene), a methyl-branched compound with five C atoms. Activated isoprene, *isopentenyl diphosphate,* is used by plants and animals to biosynthesize linear and cyclic oligomers and polymers. For the isoprenoids listed here—which only represent a small selection—the number of isoprene units (I) is shown.

From activated isoprene, the metabolic pathway leads via dimerization to activated *geraniol* (I = 2) and then to activated *farnesol* (I = 3). At this point, the pathway divides into two. Further extension of farnesol leads to chains with increasing numbers of isoprene units—e. g., *phytol* (I = 4), *dolichol* (I = 14–24), and *rubber* (I = 700–5000). The other pathway involves a "head-to-head" linkage between two farnesol residues, giving rise to *squalene* (I = 6), which, in turn, is converted to *cholesterol* (I = 6) and the other *steroids*.

The ability to synthesize particular isoprenoids is limited to a few species of plants and animals. For example, rubber is only formed by a few plant species, including the rubber tree (*Hevea brasiliensis*). Several isoprenoids that are required by animals for metabolism, but cannot be produced by them independently, are vitamins; this group includes *vitamins A, D, E,* and *K*. Due to its structure and function, vitamin D is now usually classified as a steroid hormone (see pp. 56, 330).

Isoprene metabolism in plants is very complex. Plants can synthesize many types of aromatic substances and volatile oils from isoprenoids. Examples include *menthol* (I= 2), *camphor* (I = 2), and *citronellal* (I = 2). These C_{10} compounds are also called *monoterpenes*. Similarly, compounds consisting of three isoprene units (I = 3) are termed *sesquiterpenes*, and the steroids (I = 6) are called *triterpenes*.

Isoprenoids that have hormonal and signaling functions form an important group. These include *steroid hormones* (I = 6) and *retinoate* (the anion of retinoic acid; I = 3) in vertebrates, and *juvenile hormone* (I = 3) in arthropods. Some plant hormones also belong to the isoprenoids—e. g., the cytokinins, abscisic acid, and brassinosteroids.

Isoprene chains are sometimes used as lipid anchors to fix molecules to membranes (see p. 214). Chlorophyll has a *phytyl* residue (I = 4) as a lipid anchor. Coenzymes with isoprenoid anchors of various lengths include *ubiquinone* (coenzyme Q; I = 6–10), *plastoquinone* (I = 9), and *menaquinone* (vitamin K; I = 4–6). Proteins can also be anchored to membranes by *isoprenylation*.

In some cases, an isoprene residue is used as an element to modify molecules chemically. One example of this is *N'*-isopentenyl-AMP, which occurs as a modified component in tRNA.

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A. Activated acetic acid as a component of lipids

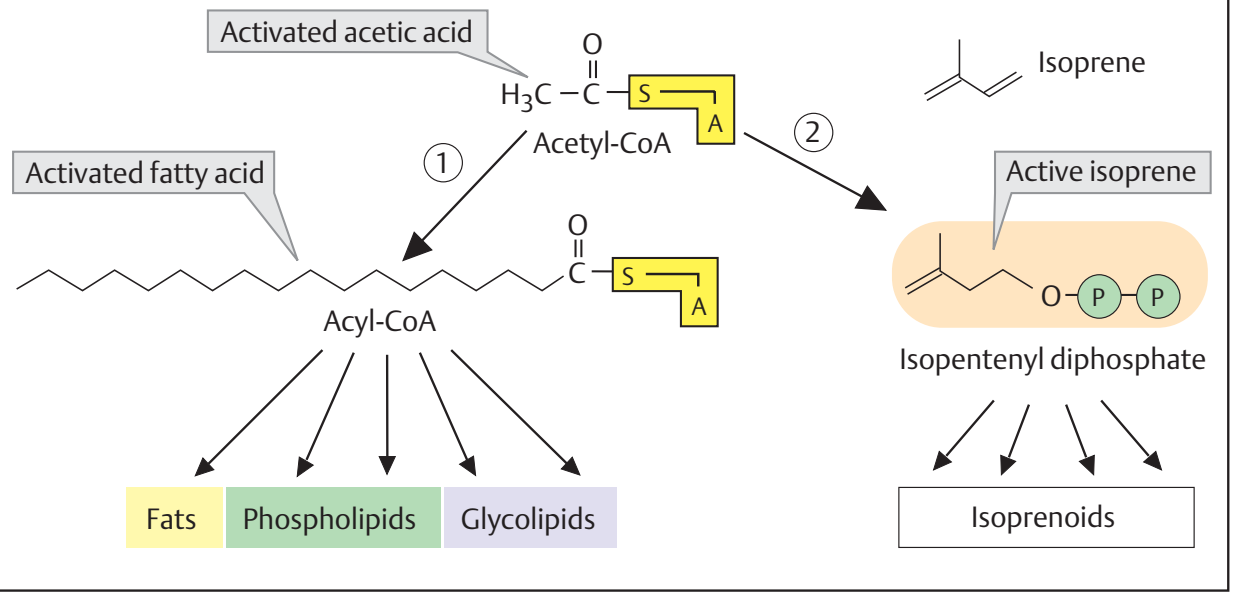

B. Isoprenoids

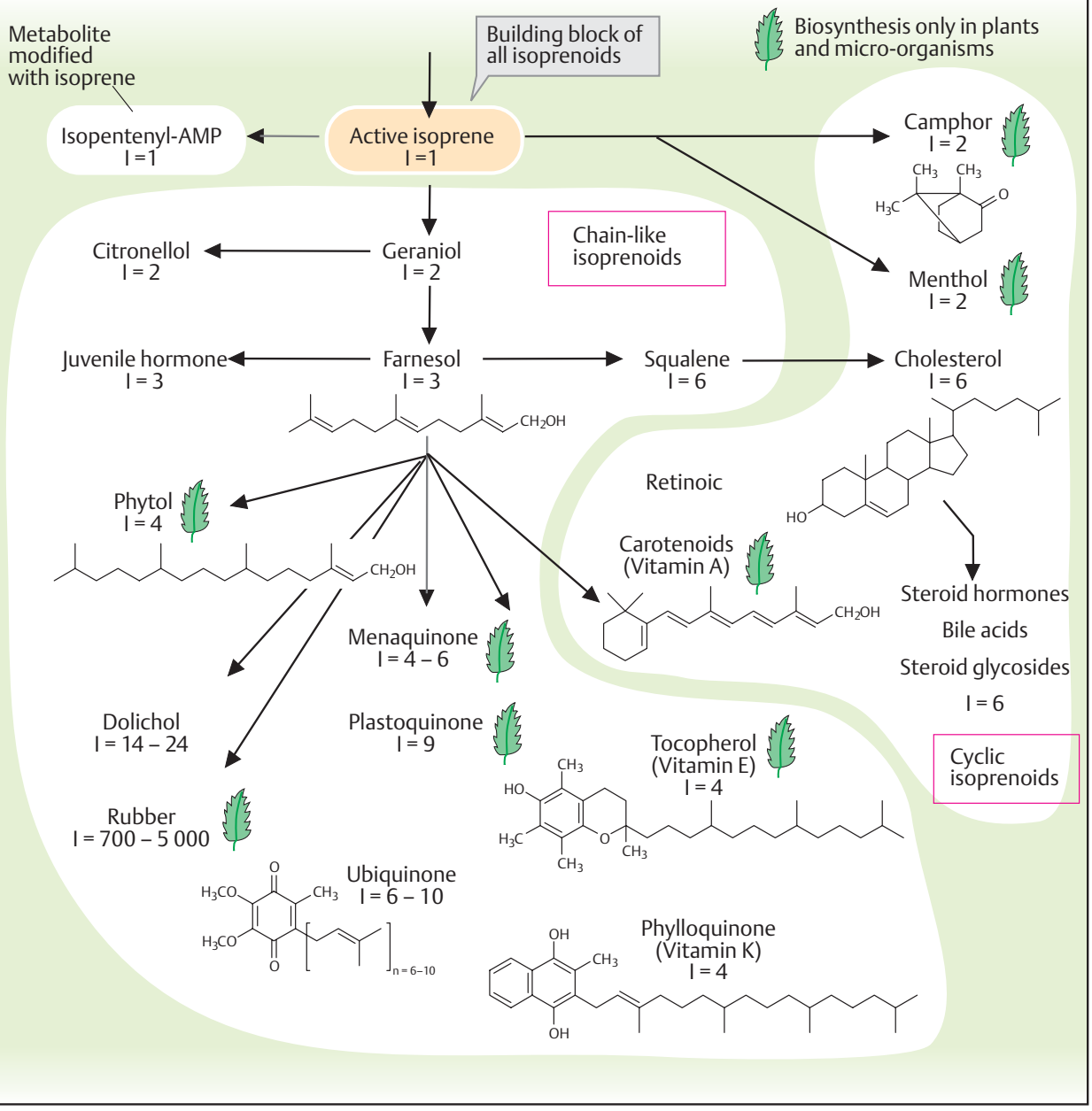

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Steroid structure

A. Steroid building blocks ◑

Common to all of the steroids is a molecular core structure consisting of four saturated rings, known as *gonane*. At the end of the steroid core, many steroids also carry a side chain, as seen in *cholestane*, the basic component of the *sterols* (steroid alcohols).

B. Spatial structure ○

The four rings of the steroids are distinguished using the letters A, B, C, and D. Due to the tetrahedral arrangement of the single carbon bonds, the rings are not flat, but puckered. Various *ring conformations* are known by the terms "chair," "boat," and "twisted" (not shown). The *chair* and *boat* conformations are common. Fivemembered rings frequently adopt a conformation referred to as an "envelope". Some rings can be converted from one conformation to another at room temperature, but with steroids this is dif cult.

Substituents of the steroid core lie either approximately in the same plane as the ring (e = *equatorial*) or nearly perpendicular to it (a = *axial*). In threedimensional representations, substituents pointing toward the observer are indicated by an unbroken line (β position), while bonds pointing into the plane of the page are indicated by a dashed line (α position). The so-called *angular* methyl groups at C-10 and C-13 of the steroids always adopt the β position.

Neighboring rings can lie in the same plane (*trans*; **2**) or at an angle to one another (*cis*; **1**). This depends on the positions of the substituents of the shared ring carbons, which can be arranged either *cis* or *trans* to the angular methyl group at C-10. The substituents of steroid that lie at the points of intersection of the individual rings are usually in *trans* position. As a whole, the core of most steroids is more or less planar, and looks like a flat disk. The only exceptions to this are the ecdysteroids, bile acids (in which A:B is *cis*), cardiac glycosides, and toad toxins.

A more realistic impression of the threedimensional structure of steroids is provided by the space-filling model of *cholesterol* (**3**). The four rings form a fairly rigid scaffolding, onto which the much more mobile side chain is attached.

Steroids are relatively apolar (hydrophobic). Some polar groups—e. g., hydroxyl and oxo groups—give them amphipathic properties. This characteristic is especially pronounced with the bile acids (see p. 314).

C. Thin-layer chromatography ○

Thin-layer chromatography (TLC) is a powerful, mainly analytic, technique for rapidly separating lipids and other small molecules such as amino acids, nucleotides, vitamins, and drugs. The *sample* being analyzed is applied to a *plate* made of glass, aluminum, or plastic, which is covered with a thin layer of silica gel or other material (**1**). The plate is then placed in a chromatography chamber that contains some *solvent*. Drawn by capillary forces, the solvent moves up the plate (**2**). The substances in the sample move with the solvent. The speed at which they move is determined by their distribution between the *stationary phase* (the hydrophilic silica), and the *mobile phase* (the hydrophobic solvent). When the solvent reaches the top edge of the plate, the chromatography is stopped. After evaporation of the solvent, the separated substances can be made visible using appropriate staining methods or with physical processes (e. g., ultraviolet light) (**3**). The movement of a substance in a given TLC system is expressed as its R_f value. In this way, compounds that are not known can be identified by comparison with reference substances.

A process in which the polarity of the stationary and mobile phases is reversed—i. e., the stationary phase is apolar and the solvent is polar—is known as "reversed-phase thin-layer chromatography" (RP-TLC).

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A. Steroid building blocks

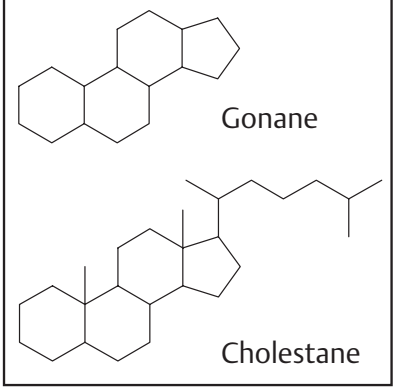

B. 3D structure

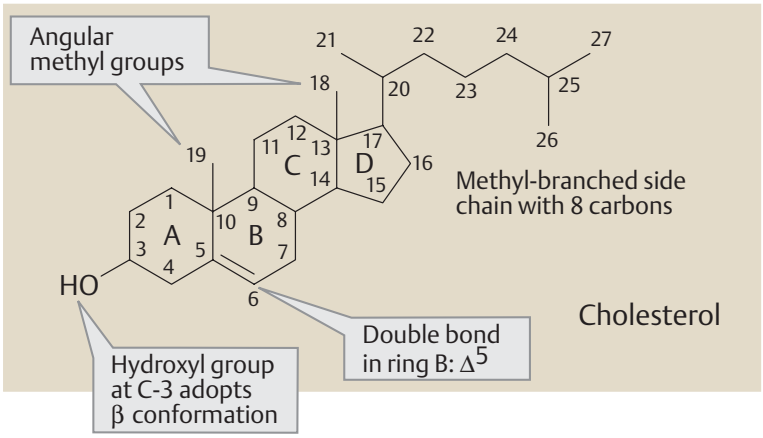

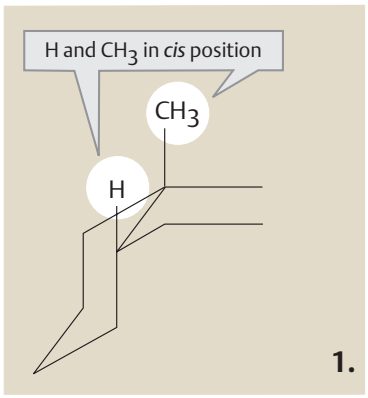

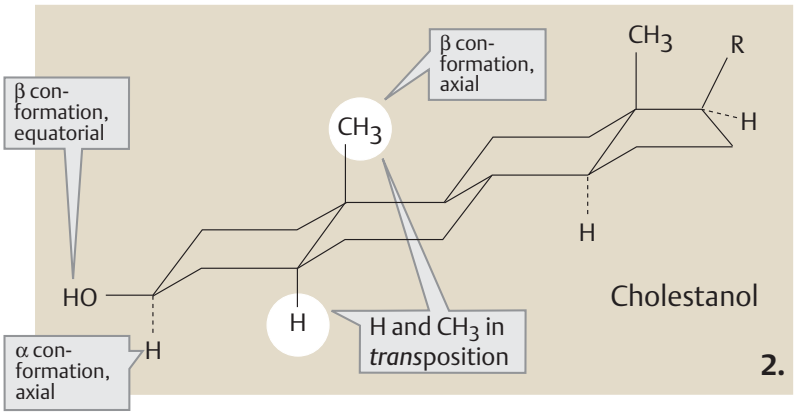

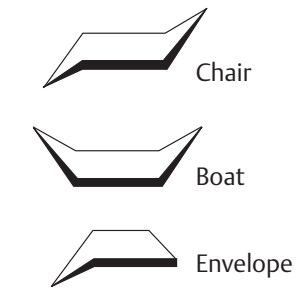

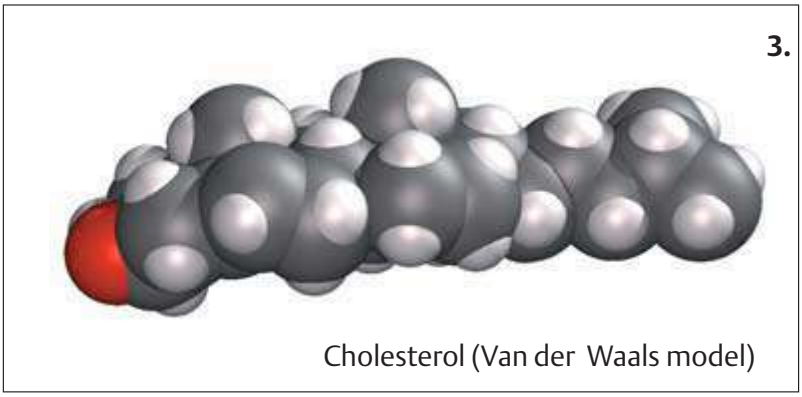

C. Thin-layer chromatography

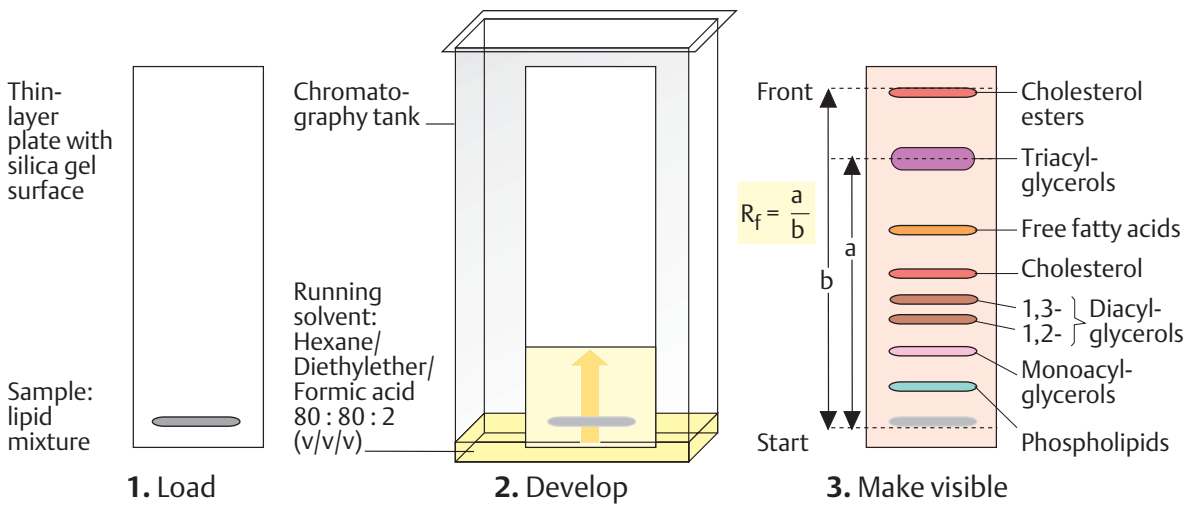

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Steroids: overview

The three most important groups of steroids are the *sterols*, *bile acids*, and *steroid hormones*. Particularly in plants, compounds with steroid structures are also found that are notable for their pharmacological effects—steroid alkaloids, digitalis glycosides, and saponins.

A. Sterols ◑

Sterols are *steroid alcohols*. They have a β-positioned hydroxyl group at C-3 and one or more double bonds in ring B and in the side chain. There are no further oxygen functions, as in the carbonyl and carboxyl groups.

The most important sterol in animals is **cholesterol**. Plants and microorganisms have a wide variety of closely related sterols instead of cholesterol—e.g., **ergosterol**, β-**sitosterol**, and **stigmasterol**.

Cholesterol is present in all animal tissues, and particularly in neural tissue. It is a major constituent of cellular membranes, in which it regulates fluidity (see p. 216). The storage and transport forms of cholesterol are its esters with fatty acids. In lipoproteins, cholesterol and its fatty acid esters are associated with other lipids (see p. 278). Cholesterol is a constituent of the bile and is therefore found in many gallstones. Its biosynthesis, metabolism, and transport are discussed elsewhere (see pp. 172, 312).

Cholesterol-rich lipoproteins of the LDL type are particularly important in the development of arteriosclerosis, in which the arterial walls are altered in connection with an excess plasma cholesterol level. In terms of dietary physiology, it is important that plant foodstuffs are low in cholesterol. By contrast, animal foods can contain large amounts of cholesterol—particularly butter, egg yolk, meat, liver, and brain.

B. Bile acids ◑

Bile acids are synthesized from cholesterol in the liver (see p. 314). Their structures can therefore be derived from that of cholesterol. Characteristic for the bile acids is a side chain shortened by three C atoms in which the last carbon atom is oxidized to a carboxyl group. The double bond in ring B is reduced and rings A and B are in *cis* position relative to each other (see p. 54). One to three hydroxyl groups (in α position) are found in the steroid core at positions 3, 7, and 12. Bile acids keep bile cholesterol in a soluble state as micelles and promote the digestion of lipids in the intestine (see p. 270). **Cholic acid** and **chenodeoxycholic acid** are *primary bile acids* that are formed by the liver. Their dehydroxylation at C-7 by microorganisms from the intestinal flora gives rise to the *secondary bile acids* **lithocholic acid** and **deoxycholic acid**.

C. Steroid hormones ◑

The conversion of cholesterol to *steroid hormones* (see p. 376) is of minor importance quantitatively, but of major importance in terms of physiology. The steroid hormones are a group of lipophilic signal substances that regulate metabolism, growth, and reproduction (see p. 374).

Humans have six steroid hormones: **progesterone**, **cortisol**, **aldosterone**, **testosterone**, **estradiol**, and **calcitriol**. With the exception of calcitriol, these steroids have either no side chain or only a short side one consisting of two carbons. Characteristic for most of them is an oxo group at C-3, conjugated with a double bond between C-4 and C-5 of ring A. Differences occur in rings C and D. Estradiol is aromatic in ring A, and its hydroxyl group at C-3 is therefore phenolic. Calcitriol differs from other vertebrate steroid hormones; it still contains the complete carbon framework of cholesterol, but lightdependent opening of ring B turns it into what is termed a "secosteroid" (a steroid with an open ring).

Ecdysone is the steroid hormone of the arthropods. It can be regarded as an early form of the steroid hormones. Steroid hormones with signaling functions also occur in plants.

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A. Sterols

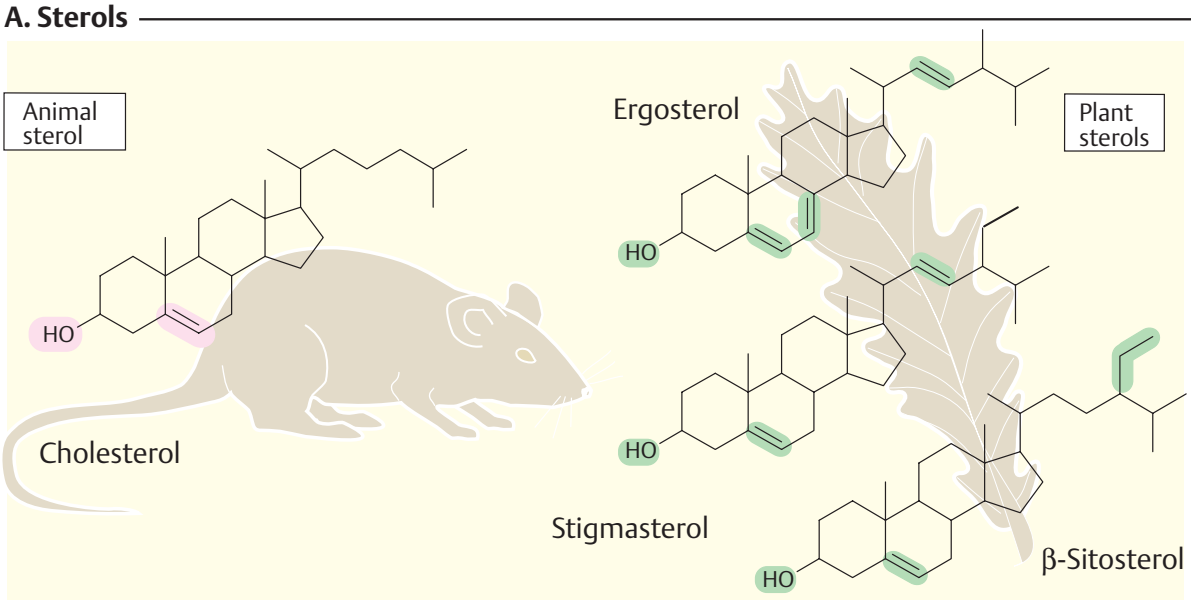

B. Bile acids

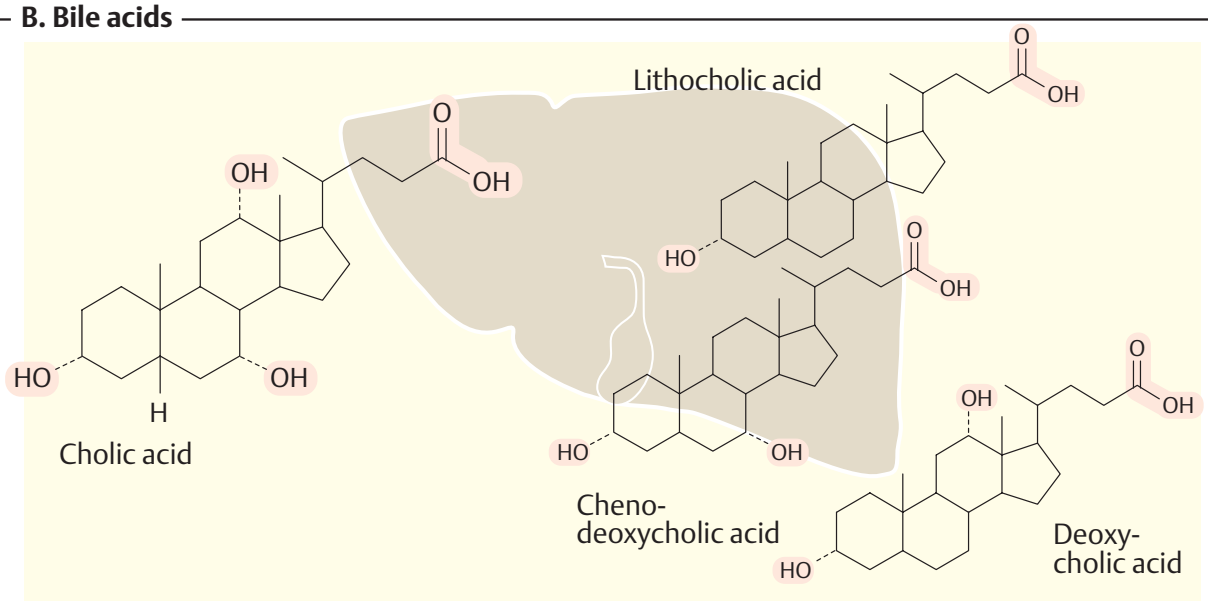

C. Steroid hormones

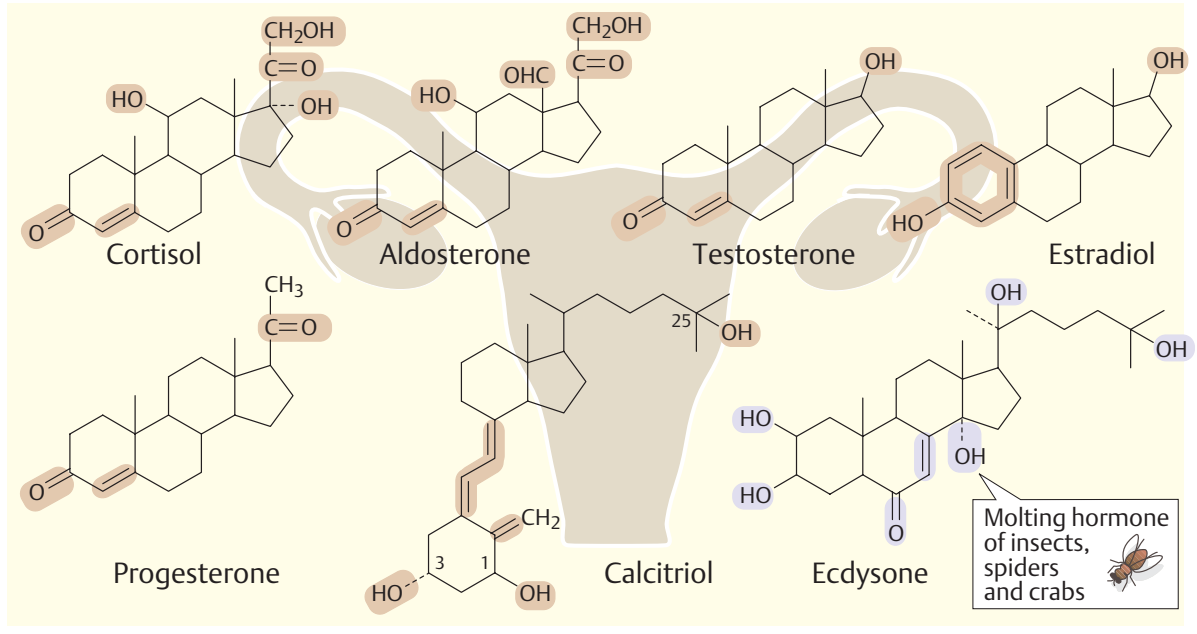

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Amino acids: chemistry and properties

A. Amino acids: functions ●

The amino acids (2-aminocarboxylic acids) fulfill various functions in the organism. Above all, they serve as the **components of peptides and proteins**. Only the 20 *proteinogenic amino acids* (see p. 60) are included in the genetic code and therefore regularly found in proteins. Some of these amino acids undergo further (post-translational) change following their incorporation into proteins (see p. 62). Amino acids or their derivatives are also form components of **lipids**—e. g., serine in phospholipids and glycine in bile salts. Several amino acids function as **neurotransmitters** themselves (see p. 352), while others are precursors of neurotransmitters, mediators, or hormones (see p. 380). Amino acids are important (and sometimes essential) components of food (see p. 360). Specific amino acids form **precursors** for other metabolites—e. g., for glucose in gluconeogenesis, for purine and pyrimidine bases, for heme, and for other molecules. Several nonproteinogenic amino acids function as intermediates in the synthesis and breakdown of proteinogenic amino acids (see p. 412) and in the urea cycle (see p. 182).

B. Optical activity ◑

The natural amino acids are mainly α-amino acids, in contrast to β-amino acids such as β-alanine and taurine. Most α-amino acids have four different substituents at C-2 (Cα). The α atom therefore represents a *chiral center*—i. e., there are two different **enantiomers** (L- and D-amino acids; see p. 8). Among the proteinogenic amino acids, only glycine is *not* chiral (R = H). In nature, it is almost exclusively **L-amino acids** that are found. **D**-Amino acids occur in bacteria—e. g., in murein (see p. 40)—and in peptide antibiotics. In animal metabolism, D-Amino acids would disturb the enzymatic reactions of L-amino acids and they are therefore broken down in the liver by the enzyme *D-amino acid oxidase*.

The **Fischer projection** (center) is used to present the formulas for chiral centers in biomolecules. It is derived from their three-dimensional structure as follows: firstly, the tetrahedron is rotated in such a way that the most oxidized group (the carboxylate group) is at the top. Rotation is then continued until the line connecting line COO^- and R (red) is level with the page. In L-amino acids, the NH_3^+ group is then on the left, while in **D**-amino acids it is on the right.

C. Dissociation curve of histidine ◑

All amino acids have at least two ionizable groups, and their net charge therefore depends on the pH value. The COOH groups at the α-C atom have pK_a values of between 1.8 and 2.8 and are therefore more acidic than simple monocarboxylic acids. The basicity of the α-amino function also varies, with pK_a values of between 8.8 and 10.6, depending on the amino acid. Acidic and basic amino acids have additional ionizable groups in their side chain. The pK_a values of these side chains are listed on p. 60. The electrical charges of peptides and proteins are mainly determined by groups in the side chains, as most α-carboxyl and α-amino functions are linked to peptide bonds (see p. 66).

Histidine can be used here as an example of the pH-dependence of the net charge of an amino acid. In addition to the carboxyl group and the amino group at the α-C atom with pK_a values of 1.8 and 9.2, respectively, histidine also has an imidazole residue in its side chain with a pK_a value of 6.0. As the pH increases, the net charge (the sum of the positive and negative charges) therefore changes from +2 to –1. At pH 7.6, the net charge is zero, even though the molecule contains two almost completely ionized groups in these conditions. This pH value is called the **isoelectric point**.

At its isoelectric point, histidine is said to be **zwitterionic**, as it has both anionic *and* cationic properties. Most other amino acids are also zwitterionic at neutral pH. Peptides and proteins also have isoelectric points, which can vary widely depending on the composition of the amino acids.

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A. Amino acids: functions

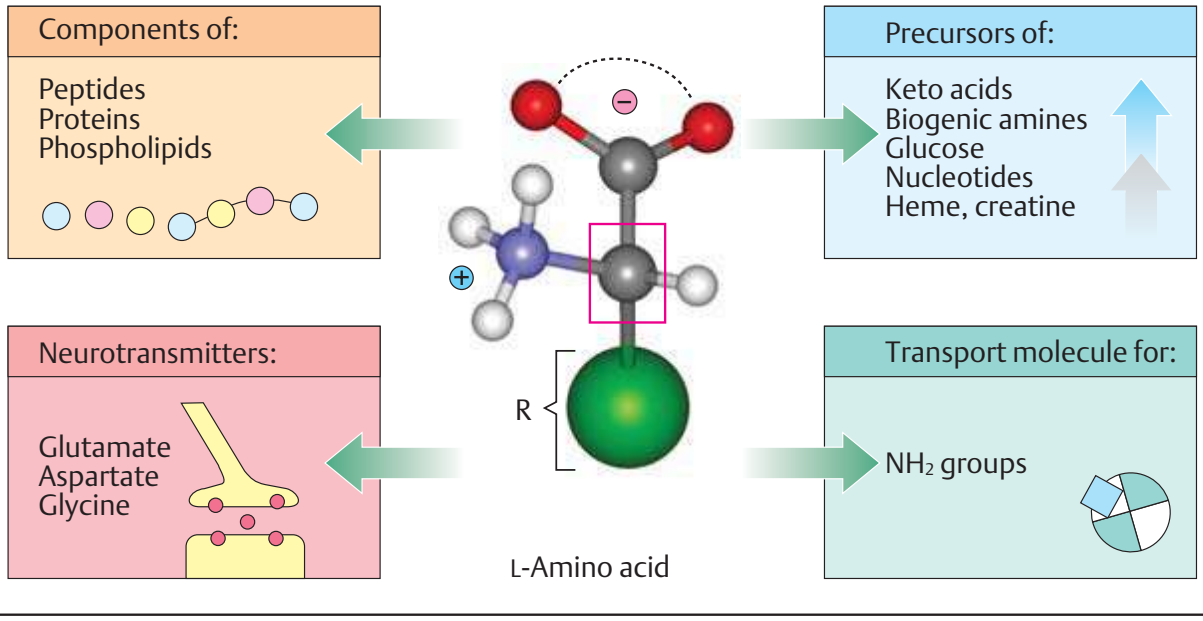

B. Optical activity

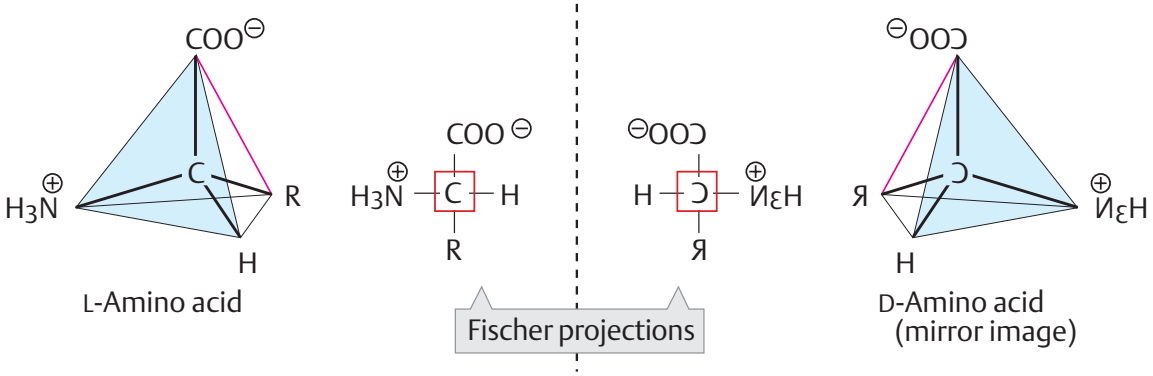

C. Dissociation curve of histidine

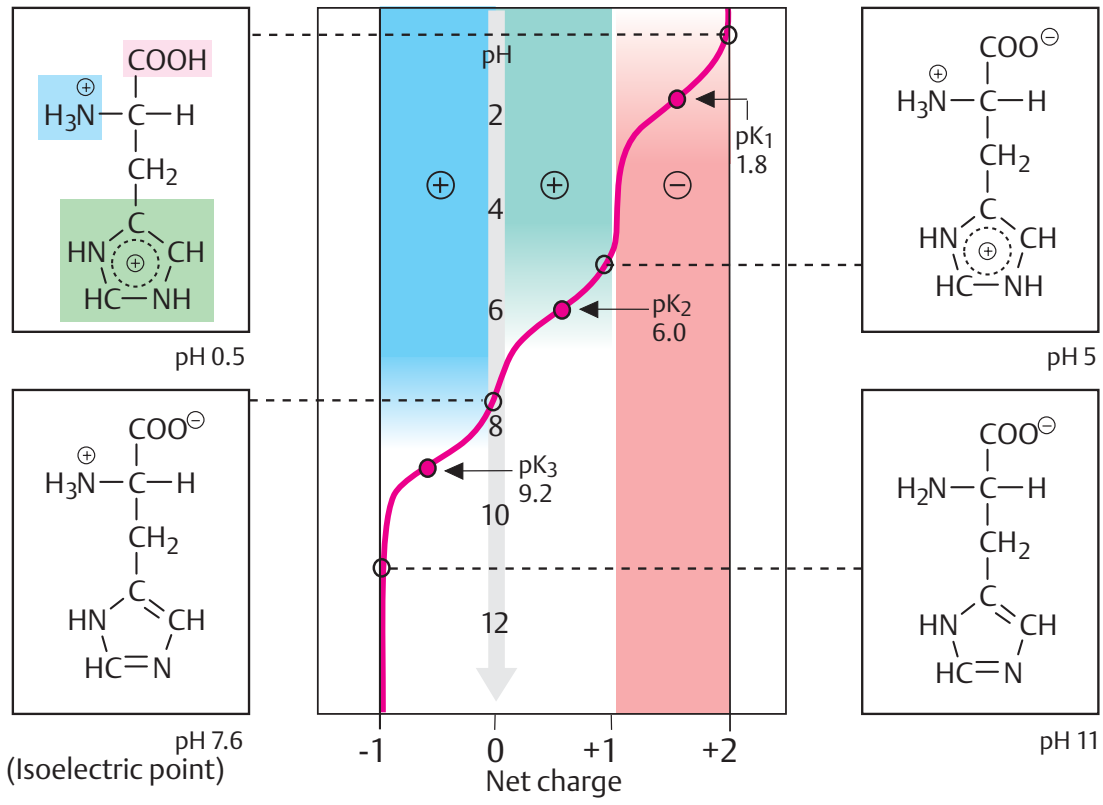

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Proteinogenic amino acids

A. The proteinogenic amino acids ◑

The amino acids that are included in the genetic code (see p. 248) are described as "proteinogenic." With a few exceptions (see p. 58), only these amino acids can be incorporated into proteins through *translation*. Only the side chains of the 20 proteinogenic amino acids are shown here. Their classification is based on the chemical structure of the side chains, on the one hand, and on their polarity on the other (see p. 6). The literature includes several slightly different systems for classifying amino acids, and details may differ from those in the system used here.

For each amino acid, the illustration names:
- *Membership of structural classes* I–VII (see below; e. g., III and VI for histidine)
- Name and abbreviation, formed from the first three letters of the name (e. g., histidine, His)
- The *one-letter symbol* introduced to save space in the electronic processing of sequence data (H for histidine)
- A quantitative *value for the polarity* of the side chain (bottom left; 10.3 for histidine). The more positive this value is, the *more polar* the amino acid is.

In addition, the polarity of the side chains is indicated by color. It increases from yellow, through light and dark green, to bluish green. For ionizing side chains, the corresponding pK_a values are also given (red numbers).

The **aliphatic** amino acids (class I) include *glycine, alanine, valine, leucine,* and *isoleucine*. These amino acids do not contain heteroatoms (N, O, or S) in their side chains and do not contain a ring system. Their side chains are markedly apolar. Together with threonine (see below), valine, leucine, and isoleucine form the group of *branched-chain amino acids*. The **sulfurcontaining amino acids** *cysteine* and *methionine* (class II), are also apolar. However, in the case of cysteine, this only applies to the undissociated state. Due to its ability to form disulfide bonds, cysteine plays an important role in the stabilization of proteins (see p. 72). Two cysteine residues linked by a disulfide bridge are referred to as *cystine* (not shown).

The **aromatic amino acids** (class III) contain resonancestabilized rings. In this group, only *phenylalanine* has strongly apolar properties. *Tyrosine* and *tryptophan* are moderately polar, and *histidine* is even strongly polar. The imidazole ring of histidine is already protonated at weakly acidic pH values. Histidine, which is only aromatic in protonated form (see p. 58), can therefore also be classified as a basic amino acid. Tyrosine and tryptophan show strong light absorption at wavelengths of 250–300 nm.

The **neutral** amino acids (class IV) have hydroxyl groups (*serine, threonine*) or amide groups (*asparagine, glutamine*). Despite their nonionic nature, the amide groups of asparagine and glutamine are markedly polar.

The carboxyl groups in the side chains of the **acidic** amino acids *aspartic acid* and *glutamic acid* (class V) are almost completely ionized at physiological pH values. The side chains of the **basic** amino acids *lysine* and *arginine* are also fully ionized—i. e., positively charged—at neutral pH. Arginine, with its positively charge guanidinium group, is particularly strongly basic, and therefore extremely polar.

Proline (VII) is a special case. Together with the α-C atom and the α-NH_2 group, its side chain forms a fivemembered ring. Its nitrogen atom is only weakly basic and is not protonated at physiological pH. Due to its ring structure, proline causes *bending of the peptide chain* in proteins (this is important in collagen, for example; see p. 70).

Several proteinogenic amino acids cannot be synthesized by the human organism, and therefore have to be supplied from the diet. These **essential amino acids** (see p. 360) are marked with a star in the illustration. Histidine and possibly also arginine are essential for infants and small children.

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A. The proteinogenic amino acids

Aliphatic

Glycine (Gly, G)	Alanine (Ala, A)	Valine (Val, V) ☆	Leucine (Leu, L) ☆	Isoleucine (Ile, I) ☆
H	CH_3	$H_3C-CH(CH_3)$	$CH_2(CH(CH_3)CH_3)$	$H_3C-C(H)(CH_2CH_3)$
Polarity				
−2.4	−1.9	−2.0	−2.3	−2.2

Sulfur-containing

Cysteine (Cys, C)	Methionine (Met, M) ☆
CH_2SH (8.3)	$CH_2CH_2SCH_3$
pK_a value	
−1.2	−1.5

Aromatic

Phenylalanine (Phe, F) ☆	Tyrosine (Tyr, Y)	Tryptophan (Trp, W) ☆
CH_2-phenyl	CH_2-phenyl-OH (10.1)	CH_2-indole
		Indole ring
+0.8	+6.1	+5.9

Cyclic

Proline (Pro, P)
Pyrrolidine ring
+6.0

Neutral

Serine (Ser, S)	Threonine (Thr, T) ☆
CH_2OH	$H_3C-C(H)(OH)$
+5.1	+4.9

☆ Essential amino acids

□ Chiral center

Neutral

Asparagine (Asn,N)	Glutamine (Gln, Q)
CH_2CONH_2	$CH_2CH_2CONH_2$
+9.7	+9.4

Acidic

Aspartic acid (Asp, D)	Glutamic acid (Glu, E)
CH_2COO^- (4.0)	$CH_2CH_2COO^-$ (4.3)
+11.0	+10.2

Basic

Histidine (His, H)	Lysine (Lys,K) ☆	Arginine (Arg, R)
Imidazole ring (6.0)	$CH_2CH_2CH_2CH_2NH_3^+$ (10.8)	$CH_2CH_2CH_2NH$-C(=NH_2^+)-NH_2 (12.5)
+10.3	+15.0	+20.0

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Non-proteinogenic amino acids

In addition to the 20 proteinogenic amino acids (see p. 60), there are also many more compounds of the same type in nature. These arise during metabolic reactions (**A**) or as a result of enzymatic modifications of amino acid residues in peptides or proteins (**B**). The "biogenic amines" (**C**) are synthesized from α-amino acids by decarboxylation.

A. Rare amino acids ○

Only a few important representatives of the non-proteinogenic amino acids are mentioned here. The basic amino acid **ornithine** is an analogue of lysine with a shortened side chain. Transfer of a carbamoyl residue to ornithine yields **citrulline**. Both of these amino acids are intermediates in the urea cycle (see p. 182). **Dopa** (an acronym of 3,4-**d**ihydr**o**xy-**p**henyl**a**lanine) is synthesized by hydroxylation of tyrosine. It is an intermediate in the biosynthesis of catecholamines (see p. 352) and of melanin. It is in clinical use in the treatment of *Parkinson's disease*. **Selenocysteine**, a cysteine analogue, occurs as a component of a few proteins—e. g., in the enzyme glutathione peroxidase (see p. 284).

B. Post-translational protein modification ◑

Subsequent alteration of amino acid residues in finished peptides and proteins is referred to as *post-translational modification.* These reactions usually only involve polar amino acid residues, and they serve various purposes.

The free α-amino group at the *N*-terminus is blocked in many proteins by an acetyl residue or a longer acyl residue (**acylation**). *N*-terminal glutamate can cyclize into a pyroglutamate residue, while the *C*-terminal carboxylate group can be present in an amidated form (see TSH, p. 380). The side chains of serine and asparagine residues are often linked to oligosaccharides (**glycosylation**, see p. 230). **Phosphorylation** of proteins mainly affects serine and tyrosine residues. These reactions have mainly regulatory functions (see p. 114). Aspartate and histidine residues of enzymes are sometimes phosphorylated, too. A special modification of glutamate residues, **γ-carboxylation**, is found in coagulation factors. It is essential for blood coagulation (see p. 290). The ε-amino group of lysine residues is subject to a particularly large number of modifications. Its **acetylation** (or deacetylation) is an important mechanism for controlling genetic activity (see p. 244). Many coenzymes and cofactors are covalently linked to lysine residues. These include biotin (see p. 108), lipoic acid (see p. 106), and pyridoxal phosphate (see p. 108), as well as retinal (see p. 358). Covalent modification with **ubiquitin** marks proteins for breakdown (see p. 176). In collagen, lysine and proline residues are modified by **hydroxylation** to prepare for the formation of stable fibrils (see p. 70). Cysteine residues form **disulfide bonds** with one another (see p. 72). Cysteine **prenylation** serves to anchor proteins in membranes (see p. 214). Covalent bonding of a cysteine residue with heme occurs in cytochrome *c*. Flavins are sometimes covalently bound to cysteine or histidine residues of enzymes. Among the modifications of tyrosine residues, conversion into iodinated **thyroxine** (see p. 374) is particularly interesting.

C. Biogenic amines ◑

Several amino acids are broken down by *decarboxylation.* This reaction gives rise to what are known as biogenic amines, which have various functions. Some of them are **components of biomolecules**, such as *ethanolamine* in phospholipids (see p. 50). *Cysteamine* and *γ-alanine* are components of coenzyme A (see p. 12) and of pantetheine (see pp. 108, 168). Other amines function as signaling substances. An important **neurotransmitter** derived from glutamate is γ-aminobutyrate (GABA, see p. 356). The transmitter *dopamine* is also a precursor for the catecholamines epinephrine and norepinephrine (see p. 352). The biogenic amine *serotonin*, a substance that has many effects, is synthesized from tryptophan via the intermediate 5-hydroxytryptophan.

Monamines are inactivated into aldehydes by *amine oxidase* (monoamine oxidase, "MAO") with deamination and simultaneous oxidation. MAO inhibitors therefore play an important role in pharmacological interventions in neurotransmitter metabolism.

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A. Rare amino acids

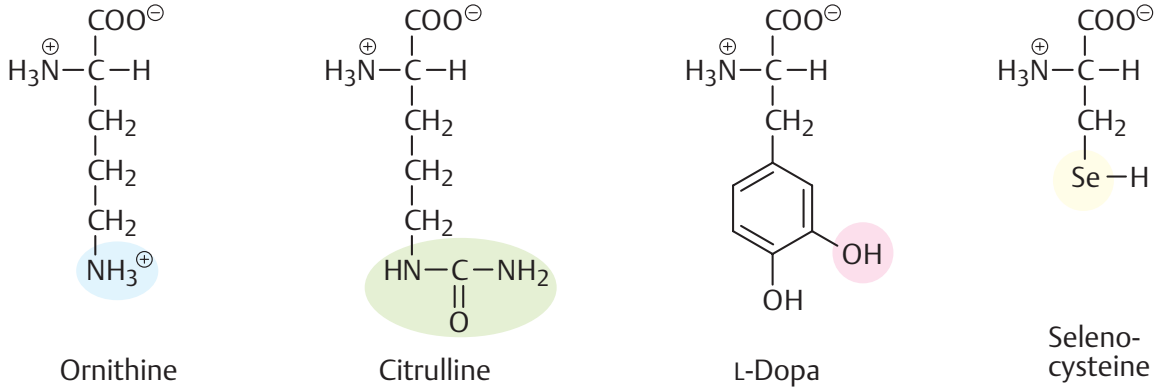

B. Post-translational protein modification

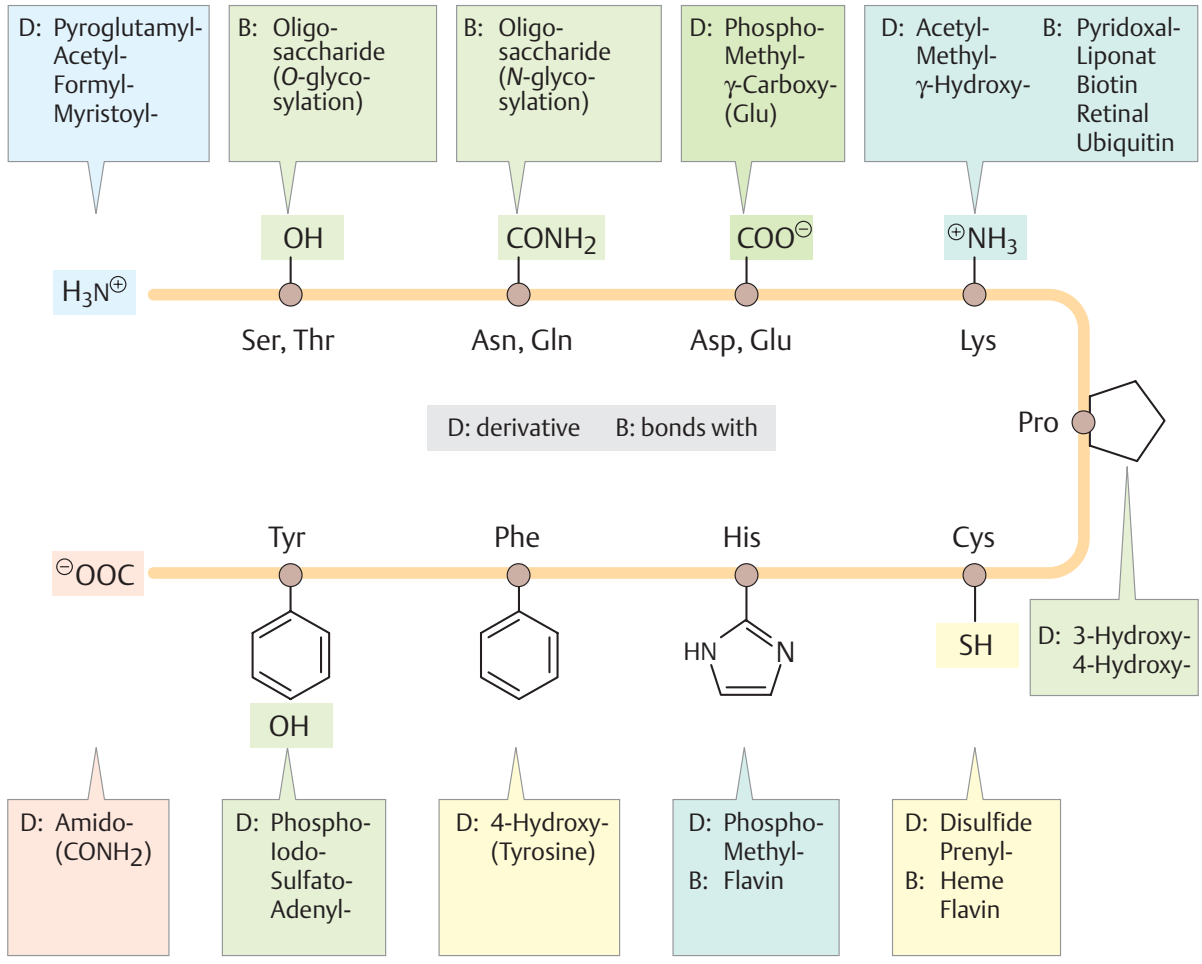

C. Biogenic amines

Amino acid	Amine	Function
Serine	Ethanol-amine	Glutamate
Cysteine	Cysteamine	Component of coenzyme A
Threonine	Amino-propanol	Component of vitamin B_{12}
Aspartate	β-Alanine	Component of coenzyme A

Amino acid	Amine	Function
Glutamate	γ-Amino-butyrate	Neurotrans-mitter (GABA)
Histidine	Histamine	Mediator, neuro-transmitter
Dopa	Dopamine	Neurotransmitter
5-Hydroxy-tryptophan	Serotonin	Mediator, neuro-transmitter

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Peptides and proteins: overview

A. Proteins ◑

When amino acids are linked together by acid–amide bonds, linear macromolecules (peptides) are produced. Those containing more than ca. 100 amino acid residues are described as **proteins** (polypeptides). Every organism contains thousands of different proteins, which have a variety of functions. At a magnification of ca. 1.5 million, the semischematic illustration shows the structures of a few intra and extracellular proteins, giving an impression of their variety. The functions of proteins can be classified as follows.

Establishment and maintenance of structure. Structural proteins are responsible for the *shape and stability* of cells and tissues. A small part of a **collagen** molecule is shown as an example (right; see p. 70). The complete molecule is 1.5 300 nm in size, and at the magnification used here it would be as long as three pages of the book. **Histones** are also structural proteins. They organize the arrangement of DNA in chromatin. The basic components of chromatin, the *nucleosomes* (top right; see p. 218) consist of an octameric complex of histones, around which the DNA is coiled.

Transport. A wellknown transport protein is **hemoglobin** in the erythrocytes (bottom left). It is responsible for the transport of oxygen and carbon dioxide between the lungs and tissues (see p. 282). The blood plasma also contains many other proteins with transport functions. **Prealbumin** (transthyretin; middle), for example, transports the thyroid hormones thyroxin and triiodothyronine. **Ion channels** and other integral membrane proteins (see p. 220) facilitate the transport of ions and metabolites across biological membranes.

Protection and defense. The immune system protects the body from pathogens and foreign substances. An important component of this system is **immunoglobulin G** (bottom left; see p. 300). The molecule shown here is bound to an erythrocyte by complex formation with surface glycolipids (see p. 292).

Control and regulation. In biochemical signal chains, proteins function as signaling substances (hormones) and as hormone receptors. The complex between the growth hormone **somatotropin** and its **receptor** is shown here as an example (middle). Here, the extracellular domains of two receptor molecules here bind one molecule of the hormone. This binding activates the cytoplasmic domains of the complex, leading to further conduction of the signal to the interior of the cell (see p. 384). The small peptide hormone **insulin** is discussed in detail elsewhere (see pp. 76, 160). DNA-binding proteins (*transcription factors;* see p. 118) are decisively involved in regulating the metabolism and in differentiation processes. The structure and function of the **catabolite activator protein** (top left) and similar bacterial transcription factors have been particularly well investigated.

Catalysis. *Enzymes,* with more than 2000 known representatives, are the largest group of proteins in terms of numbers (see p. 88). The smallest enzymes have molecular masses of 10–15 kDa. Intermediatesized enzymes, such as **alcohol dehydrogenase** (top left) are around 100–200 kDa, and the largest—including **glutamine synthetase** with its 12 monomers (top right)—can reach more than 500 kDa.

Movement. The interaction between actin and myosin is responsible for muscle contraction and cell movement (see p. 332). **Myosin** (right), with a length of over 150 nm, is among the largest proteins there are. Actin filaments (**F-actin**) arise due to the polymerization of relatively small protein subunits (G-actin). Along with other proteins, **tropomyosin,** which is associated with F-actin, controls contraction.

Storage. Plants contain special **storage proteins**, which are also important for human nutrition (not shown). In animals, *muscle proteins* constitute a nutrient reserve that can be mobilized in emergencies.

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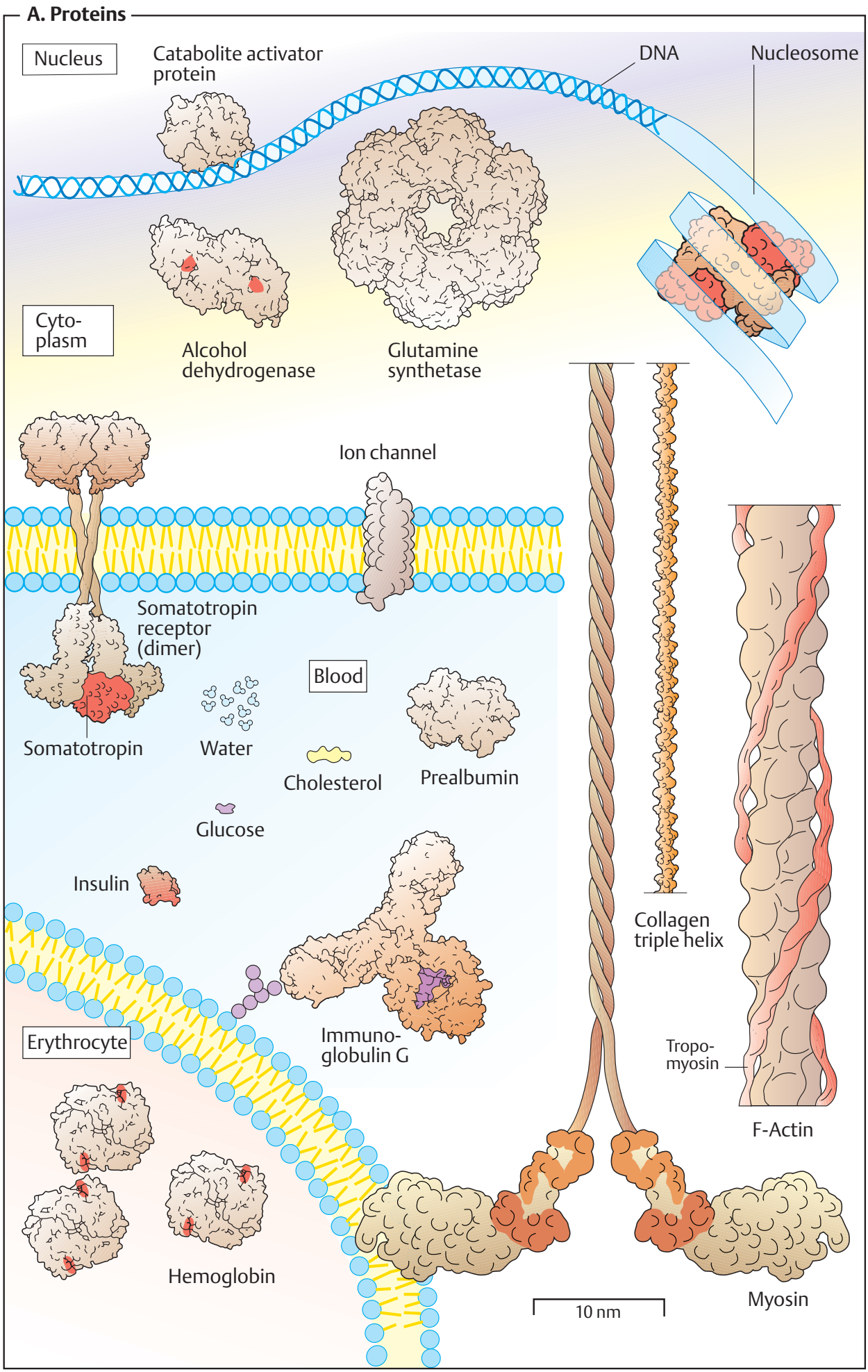

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Peptide bonds

A. Peptide bond ◑

The amino acid components of peptides and proteins are linked together by *amide* bonds (see p. 60) between α-carboxyl and α-amino groups. This type of bonding is therefore also known as **peptide bonding**. In the **dipeptide** shown here, the serine residue has a free ammonium group, while the carboxylate group in alanine is free. Since the amino acid with the free NH_3^+ group is named first, the peptide is known as **seryl alanine**, or in abbreviated form Ser-Ala or SA.

B. Resonance ◑

Like all acid–amide bonds, the peptide bond is **stabilized by resonance** (see p. 4). In the conventional notation (top right) it is represented as a combination of a C=O double bond with a C–N single bond. However, a C=N double bond with charges at O and N could also be written (middle). Both of these are only extreme cases of electron distribution, known as *resonance structures*. In reality, the π electrons are *delocalized* throughout all the atoms (bottom). As a mesomeric system, the peptide bond is *planar*. Rotation around the C–N bond would only be possible at the expense of large amounts of energy, and the bond is therefore *not freely rotatable*. Rotations are only possible around the single bonds marked with arrows. The state of these is expressed using the angles ϕ and ψ (see **D**). The plane in which the atoms of the peptide bond lie is highlighted in light blue here and on the following pages.

C. Peptide nomenclature ◑

Peptide chains have a *direction* and therefore two different ends. The amino terminus (**N terminus**) of a peptide has a free ammonium group, while the carboxy terminus (**C terminus**) is formed by the carboxylate group of the last amino acid. In peptides and proteins, the amino acid components are usually linked in linear fashion. To express the **sequence** of a peptide, it is therefore suf cient to combine the three-letter or single-letter abbreviations for the amino acid residues (see p. 60). This sequence always starts at the N terminus. For example, the peptide hormone *angiotensin II* (see p. 330) has the sequence Asp-Arg-Val-Tyr-Ile-His-Pro-Phe, or DRVYIHPF.

D. Conformational space of the peptide chain ○

With the exception of the terminal residues, every amino acid in a peptide is involved in *two* peptide bonds (one with the preceding residue and one with the following one). Due to the restricted rotation around the C–N bond, rotations are only possible around the N–C_α and C_α–C bonds (**2**). As mentioned above, these rotations are described by the dihedral angles ϕ (phi) and ψ (psi). The angle describes rotation around the N–C_α bond; ψ describes rotation around C_α–C—i. e., the position of the subsequent bond.

For steric reasons, only specific combinations of the dihedral angles are possible. These relationships can be illustrated clearly by a so-called ϕ/ψ *diagram* (**1**). Most combinations of ϕ and ψ are sterically "forbidden" (red areas). For example, the combination ϕ = 0° and ψ = 180° (**4**) would place the two carbonyl oxygen atoms less than 115 pm apart—i. e., at a distance much smaller than the sum of their van der Waals radii (see p. 6). Similarly, in the case of ϕ = 180° and ψ = 0° (**5**), the two NH hydrogen atoms would collide. The combinations located within the green areas are the only ones that are sterically feasible (e. g., **2** and **3**). The important secondary structures that are discussed in the following pages are also located in these areas. The conformations located in the yellow areas are energetically less favorable, but still possible.

The ϕ/ψ diagram (also known as a **Ramachandran plot**) was developed from modeling studies of small peptides. However, the conformations of most of the amino acids in proteins are also located in the permitted areas. The corresponding data for the small protein, insulin (see p. 76), are represented by black dots in **1**.

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A. Peptide bonds

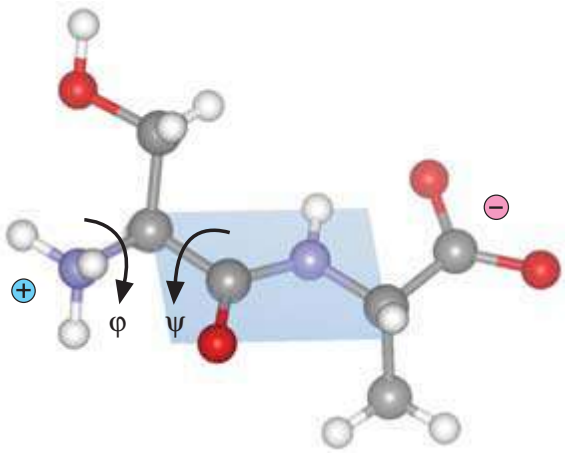

Seryl alanine
(Ser-Ala, $^{\oplus}H_3N$-Ser-Ala-$COO^{\ominus}$, SA)

B. Resonance

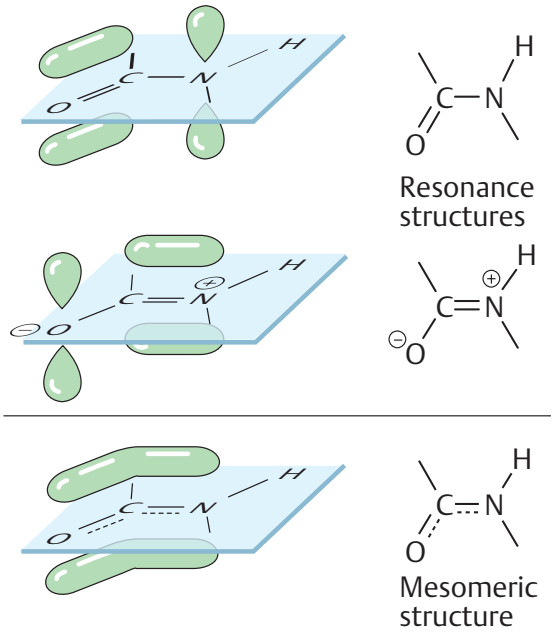

C. Peptide nomenclature

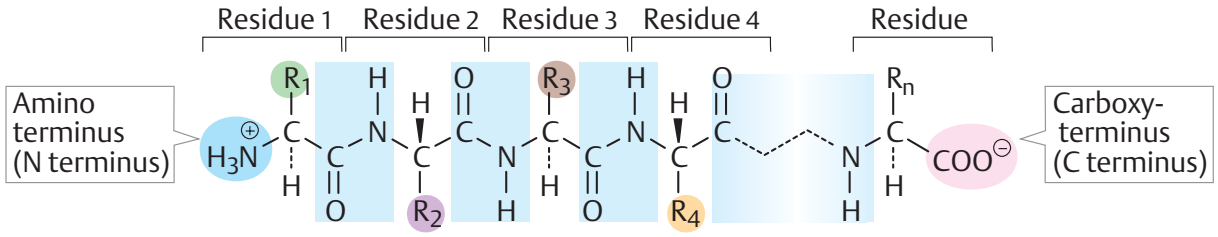

D. Conformation space of the peptide chain

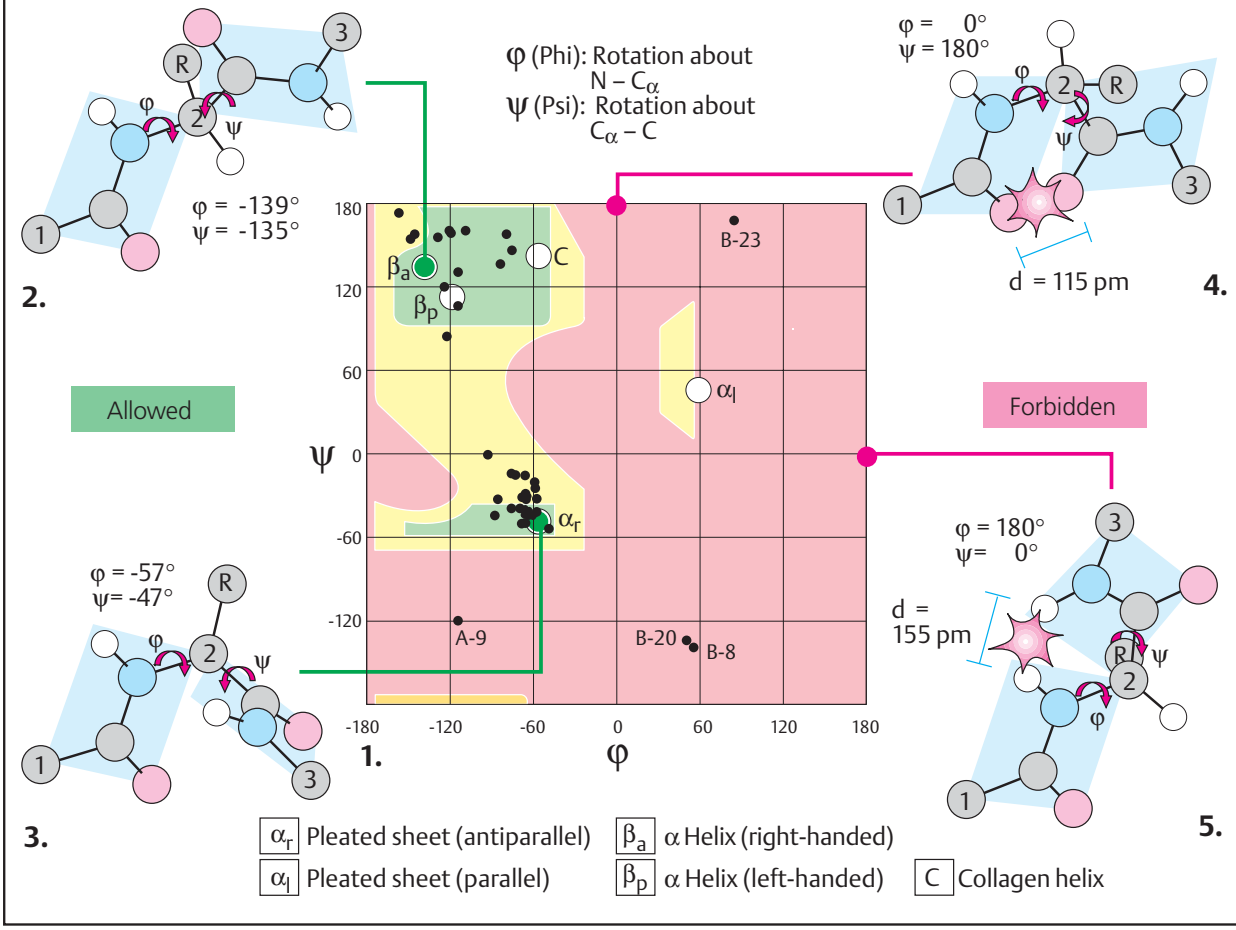

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Secondary structures

In proteins, specific combinations of the dihedral angles ϕ and ψ (see p. 66) are much more common than others. When several successive residues adopt one of these conformations, defined **secondary structures** arise, which are stabilized by hydrogen bonds either within the peptide chain or between neighboring chains. When a large part of a protein takes on a defined secondary structure, the protein often forms mechanically stable filaments or fibers. **Structural proteins** of this type (see p. 70) usually have characteristic amino acid compositions.

The most important secondary structural elements of proteins are discussed here first. The illustrations only show the course of the peptide chain; the side chains are omitted. To make the course of the chains clearer, the levels of the peptide bonds are shown as blue planes. The dihedral angles of the structures shown here are also marked in diagram D1 on p. 67.

A. α-Helix ◑

The **right-handed** α-helix (α_R) is one of the most common secondary structures. In this conformation, the peptide chain is wound like a screw. Each turn of the screw (the screw axis in shown in orange) covers approximately 3.6 amino acid residues. The *pitch* of the screw (i. e., the smallest distance between two equivalent points) is 0.54 nm. α-Helices are stabilized by almost linear *hydrogen bonds* between the NH and CO groups of residues, which are four positions apart from each another in the sequence (indicated by red dots; see p. 6). In longer helices, most amino acid residues thus enter into *two* H bonds. Apolar or amphipathic α-helices with five to seven turns often serve to anchor proteins in biological membranes (*transmembrane helices;* see p. 214).

The mirror image of the α_R helix, the **left-handed α-helix** (α_L), is rarely found in nature, although it would be energetically "permissible."

B. Collagen helix ◑

Another type of helix occurs in the collagens, which are important constituents of the connectivetissue matrix (see pp. 70, 344). The **collagen helix** is **left-handed**, and with a pitch of 0.96 nm and 3.3 residues per turn, it is steeper than the α-helix. In contrast to the α-helix, H bonds are not possible *within* the collagen helix. However, the conformation is stabilized by the association of three helices to form a righthanded **collagen triple helix** (see p. 70).

C. Pleated-sheet structures ◑

Two additional, almost stretched, conformations of the peptide chain are known as **β pleated sheets**, as the peptide planes are arranged like a regularly folded sheet of paper. Again, H bonds can only form between *neighboring chains* ("strands") in pleated sheets. When the two strands run in opposite directions (**1**), the structure is referred to as an **antiparallel pleated sheet** (β_a). When they run in the same direction (**2**), it is a **parallel pleated sheet** (β_p). In both cases, the α-C atoms occupy the highest and lowest points in the structure, and the side chains point alternately straight up or straight down (see p. 71 C). The β_a structure, with its almost linear H bonds, is energetically more favorable. In extended pleated sheets, the individual strands of the sheet are usually not parallel, but twisted relative to one another (see p. 74).

D. β Turns ◑

β Turns are often found at sites where the peptide chain changes direction. These are sections in which four amino acid residues are arranged in such a way that the course of the chain reverses by about 180° into the opposite direction. The two turns shown (types I and II) are particularly frequent. Both are stabilized by hydrogen bonds between residues 1 and 4. β Turns are often located between the individual strands of antiparallel pleated sheets, or between strands of pleated sheets and α helices.

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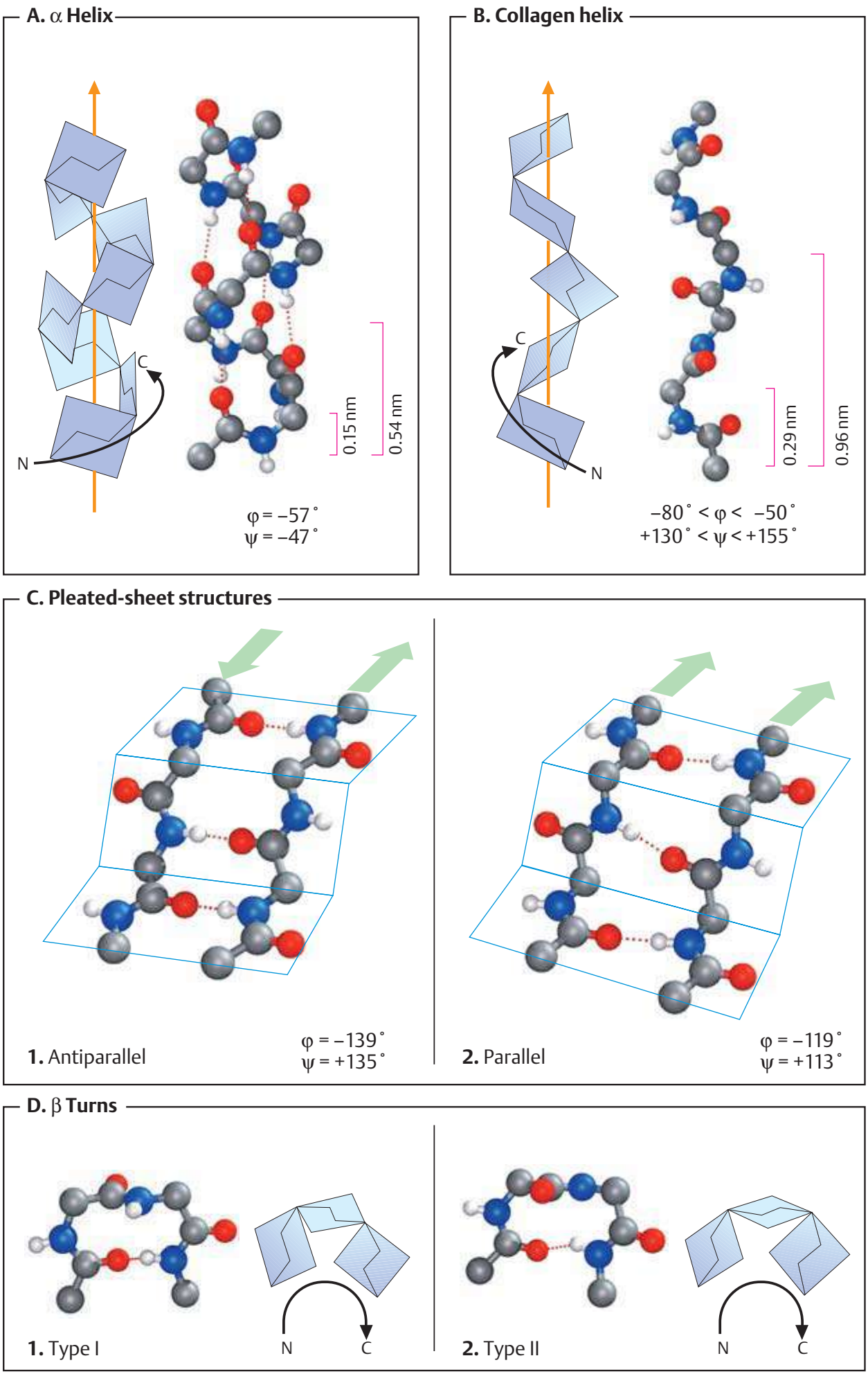

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Structural proteins

The **structural proteins** give extracellular structures mechanical stability, and are involved in the structure of the cytoskeleton (see p. 204). Most of these proteins contain a high percentage of specific secondary structures (see p. 68). For this reason, the amino acid composition of many structural proteins is also characteristic (see below).

A. α Keratin ○

α-Keratin is a structural protein that predominantly consists of α helices. Hair (wool), feathers, nails, claws and the hooves of animals consist largely of keratin. It is also an important component of the cytoskeleton (cytokeratin), where it appears in intermediate filaments (see p. 204).

In the keratins, large parts of the peptide chain show right-handed α-helical coiling. Two chains each form a left-handed **superhelix**, as is also seen in myosin (see p. 65). The superhelical keratin dimers join to form tetramers, and these aggregate further to form **protofilaments**, with a diameter of 3 nm. Finally, eight protofilaments then form an **intermediate filament**, with a diameter of 10 nm (see p. 204).

Similar keratin filaments are found in **hair**. In a single wool fiber with a diameter of about 20 μm, millions of filaments are bundled together within dead cells. The individual keratin helices are cross-linked and stabilized by numerous disulfide bonds (see p. 72). This fact is exploited in the *perming* of hair. Initially, the disulfide bonds of hair keratin are disrupted by reduction with thiol compounds (see p. 8). The hair is then styled in the desired shape and heat-dried. In the process, new disulfide bonds are formed by oxidation, which maintain the hairstyle for some time.

B. Collagen ◑

Collagen is the quantitatively most important protein in mammals, making up about 25% of the total protein. There are many different types of collagen, particularly in connective tissue. Collagen has an unusual amino acid composition. Approximately one-third of the amino acids are *glycine* (Gly), about 10% *proline* (Pro), and 10% *hydroxyproline* (Hyp). The two latter amino acids are only formed during collagen biosynthesis as a result of *posttranslational modification* (see p. 344).

The triplet Gly-X-Y (**2**) is constantly repeated in the sequence of collagen, with the X position often being occupied by Pro and the Y position by Hyp. The reason for this is that collagen is largely present as a **triple helix** made up of three individual collagen helices (**1**). In triple helices, every third residue lies on the inside of the molecule, where for steric reasons there is only room for glycine residues (**3**; the glycine residues are shown in yellow). Only a small section of a triple helix is illustrated here. The complete collagen molecule is approximately 300 nm long.

C. Silk fibroin ○

Silk is produced from the spun threads from silkworms (the larvae of the moth *Bombyx mori* and related species). The main protein in silk, **fibroin**, consists of antiparallel *pleated sheet structures* arranged one on top of the other in numerous layers (**1**). Since the amino acid side chains in pleated sheets point either straight up or straight down (see p. 68), only compact side chains fit between the layers. In fact, more than 80% of fibroin consists of glycine, alanine, and serine, the three amino acids with the shortest side chains. A typical repetitive amino acid sequence is *(Gly-Ala-Gly-Ala-Gly-Ser).* The individual pleated sheet layers in fibroin are found to lie alternately 0.35 nm and 0.57 nm apart. In the first case, only glycine residues (R = H) are opposed to one another. The slightly greater distance of 0.57 nm results from repulsion forces between the side chains of alanine and serine residues (**2**).

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A. α-Keratin

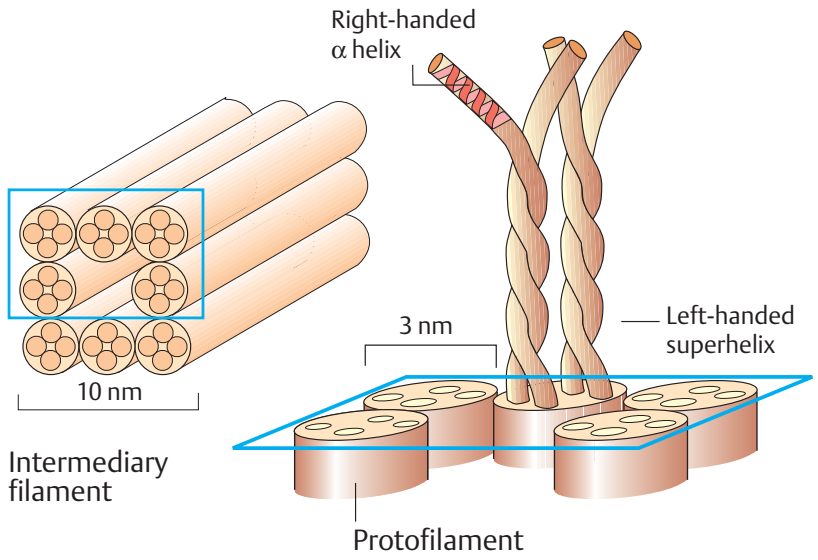

B. Collagen

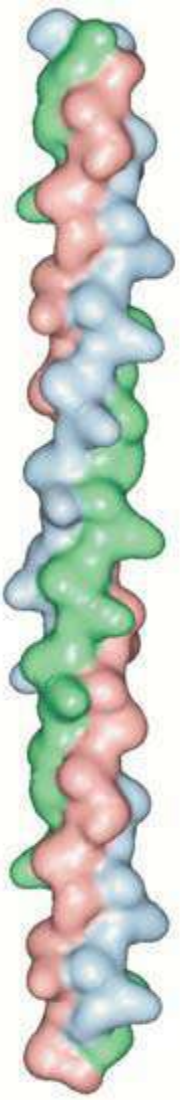

1. Triple helix (section)

Gly	Arg	Hyp
Gly	Gln	Arg
Gly	Pro	Hyp
Gly	Pro	Gln
Gly	Ala	Arg
Gly	X	Y

2. Typical sequence

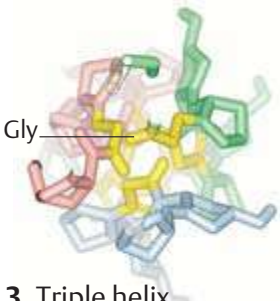

3. Triple helix
(view from above)

C. Silk fibroin

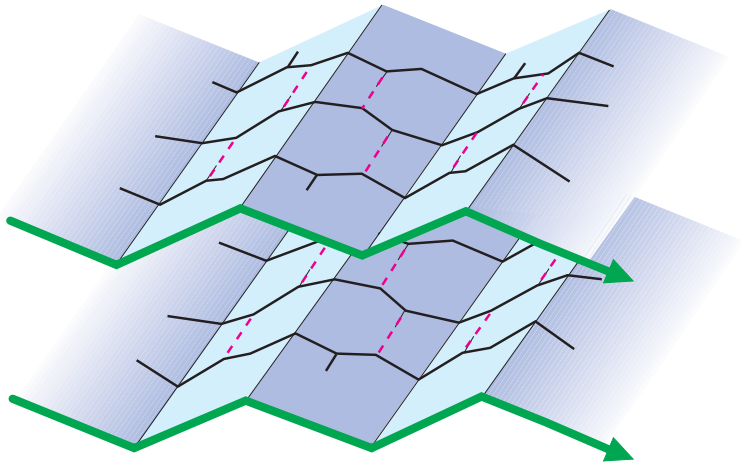

1. Spatial illustration

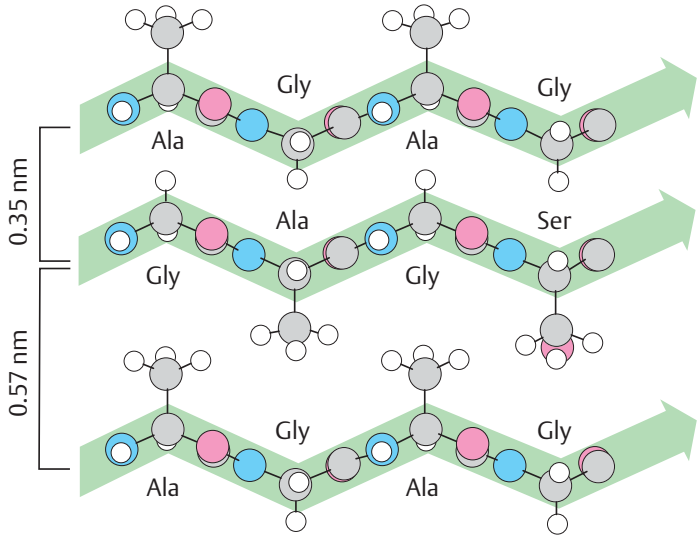

2. Front view

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Globular proteins

Soluble proteins have a more complex structure than the fibrous, completely insoluble structural proteins. The shape of soluble proteins is more or less spherical (globular). In their biologically active form, **globular proteins** have a defined spatial structure (the **native conformation**). If this structure is destroyed (**denaturation**; see p. 74), not only does the biological effect disappear, but the protein also usually precipitates in insoluble form. This happens, for example, when eggs are boiled; the proteins dissolved in the egg white are denatured by the heat and produce the solid egg white.

To illustrate protein conformations in a clear (but extremely simplified) way, *Richardson diagrams* are often used. In these diagrams, α-helices are symbolized by red cylinders or spirals and strands of pleated sheets by green arrows. Less structured areas of the chain, including the β-turns, are shown as sections of gray tubing.

A. Conformation-stabilizing interactions ◑

The native conformation of proteins is stabilized by a number of different interactions. Among these, only the **disulfide bonds** (**B**) represent covalent bonds. **Hydrogen bonds**, which can form inside secondary structures, as well as between more distant residues, are involved in all proteins (see p. 6). Many proteins are also stabilized by **complex formation** with metal ions (see pp. 76, 342, and 378, for example). The **hydrophobic effect** is particularly important for protein stability. In globular proteins, most hydrophobic amino acid residues are arranged in the interior of the structure in the native conformation, while the polar amino acids are mainly found on the surface (see pp. 28, 76).

B. Disulfide bonds ◑

Disulfide bonds arise when the SH groups of two cysteine residues are covalently linked as a dithiol by oxidation. Bonds of this type are only found (with a few exceptions) in extracellular proteins, because in the interior of the cell *glutathione* (see p. 284) and other reducing compounds are present in such high concentrations that disulfides would be reductively cleaved again. The small plant protein *crambin* (46 amino acids) contains three disulfide bonds and is therefore very stable. The high degree of stability of insulin (see p. 76) has a similar reason.

C. Protein dynamics ◑

The conformations of globular proteins are not rigid, but can change dramatically on binding of ligands or in contact with other proteins. For example, the enzyme *adenylate kinase* (see p. 336) has a mobile domain (domain = independently folded partial structure), which folds shut after binding of the substrate (yellow). The larger domain (bottom) also markedly alters its conformation. There are large numbers of **allosteric proteins** of this type. This group includes, for example, *hemoglobin* (see p. 280), *calmodulin* (see p. 386), and many allosteric enzymes such as *aspartate carbamoyltransferase* (see p. 116).

D. Folding patterns ○

The globular proteins show a high degree of variability in folding of their peptide chains. Only a few examples are shown here. Purely helically folded proteins such as *myoglobin* (**1**; see p. 74, heme yellow) are rare. In general, pleated sheet and helical elements exist alongside each other. In the hormone-binding domain of the *estrogen receptor* (**2**; see p. 378), a small, two-stranded pleated sheet functions as a "cover" for the hormone binding site (estradiol yellow). In *flavodoxin,* a small flavoprotein with a redox function (**3**; FMN yellow), a fan-shaped, pleated sheet made up of five parallel strands forms the core of the molecule. The conformation of the β subunit of the G-protein *transducin* (**4**; see pp. 224, 358) is very unusual. Seven pleated sheets form a large, symmetrical "β propeller." The *N*-terminal section of the protein contains one long and one short helix.

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A. Conformation-stabilizing interactions

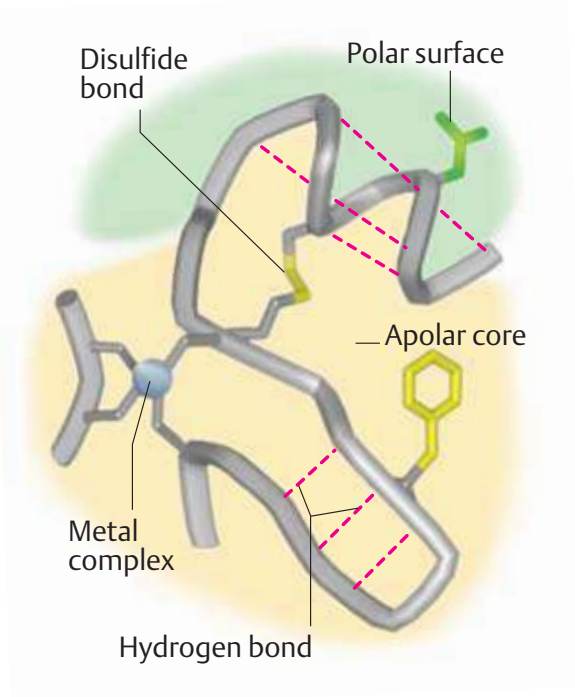

B. Disulfide bonds

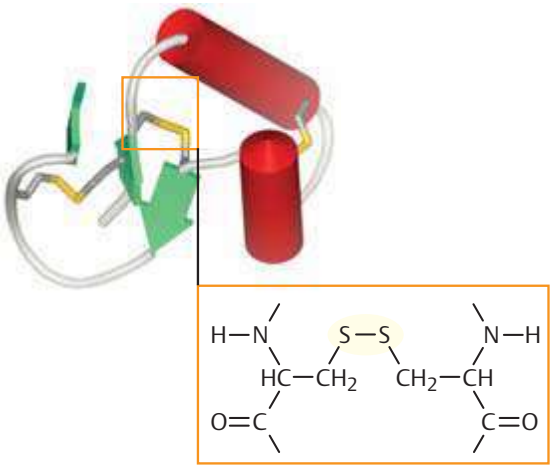

C. Protein dynamics

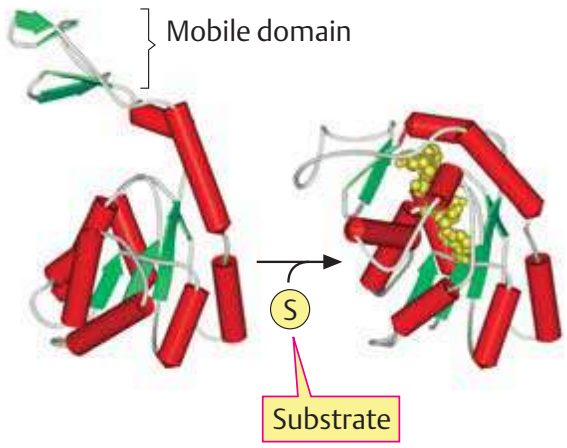

Adenylate kinase

D. Folding patterns

1. Myoglobin

2. Estrogen receptor (domain)

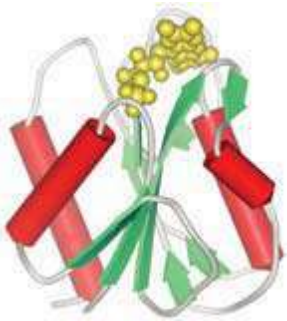

3. Flavodoxin

4. Transducin (β subunit)

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Protein folding

Information about the biologically active (*native*) conformation of proteins is already encoded in their amino acid sequences. The native forms of many proteins arise spontaneously in the test tube and within a few minutes. Nevertheless, there are special auxiliary proteins (chaperonines) that support the folding of other proteins in the conditions present within the cell (see p. 232). An important goal of biochemistry is to understand the laws governing **protein folding**. This would make it possible to predict the conformation of a protein from the easily accessible DNA sequence (see p. 260).

A. Folding and denaturation of ribonuclease A ◑

The **folding** of proteins to the native form is favored under physiological conditions. The native conformation is lost, as the result of **denaturation**, at extreme pH values, at high temperatures, and in the presence of organic solvents, detergents, and other denaturing substances, such as urea.

The fact that a denatured protein can spontaneously return to its native conformation was demonstrated for the first time with **ribonuclease**, a digestive enzyme (see p. 266) consisting of 124 amino acids. In the native form (top right), there are extensive pleated sheet structures and three α helices. The eight cysteine residues of the protein are forming four disulfide bonds. Residues His-12, Lys-41 and His-119 (pink) are particularly important for catalysis. Together with additional amino acids, they form the enzyme's *active center.*

The disulfide bonds can be reductively cleaved by *thiols* (e.g., mercaptoethanol, $HO\text{-}CH_2\text{-}CH_2\text{-}SH$). If *urea* at a high concentration is also added, the protein unfolds completely. In this form (left), it is up to 35 nm long. Polar (green) and apolar (yellow) side chains are distributed randomly. The denatured enzyme is completely inactive, because the catalytically important amino acids (pink) are too far away from each other to be able to interact with each other and with the substrate.

When the urea and thiol are removed by dialysis (see p. 78), secondary and tertiary structures develop again spontaneously. The cysteine residues thus return to a suf ciently close spatial vicinity that disulfide bonds can once again form under the oxidative effect of atmospheric oxygen. The active center also reestablishes itself. In comparison with the denatured protein, the native form is astonishingly compact, at 4.5 2.5 nm. In this state, the apolar side chains (yellow) predominate in the interior of the protein, while the polar residues are mainly found on the surface. This distribution is due to the "hydrophobic effect" (see p. 28), and it makes a vital contribution to the stability of the native conformation (**B**).

B. Energetics of protein folding ○

The **energetics** of protein folding are not at present satisfactorily understood. Only a simplified model is discussed here. The conformation of a molecule is stable in any given conditions if the change in its free enthalpy during folding (ΔG_{fold}) is negative (see p. 16). The magnitude of the folding enthalpy is affected by several factors. The main factor working *against* folding is the strong increase in the ordering of the molecule involved. As discussed on p. 20, this leads to a negative change in entropy of ΔS_{conf} and therefore to a strongly positive entropy term $-T\ \Delta S$ (violet arrow). By contrast, the covalent and noncovalent bonds in the interior of the protein have a *stabilizing* influence. For this reason, the change in folding enthalpy ΔH_{fold} is negative (red arrow). A third factor is the change in the system's entropy due to the hydrophobic effect. During folding, the degree of order in the *surrounding water* decreases—i.e., ΔS_{water} is positive and therefore $-T\ \Delta S$ is negative (blue arrow). When the sum of these effects is negative (green arrow), the protein folds spontaneously into its native conformation.

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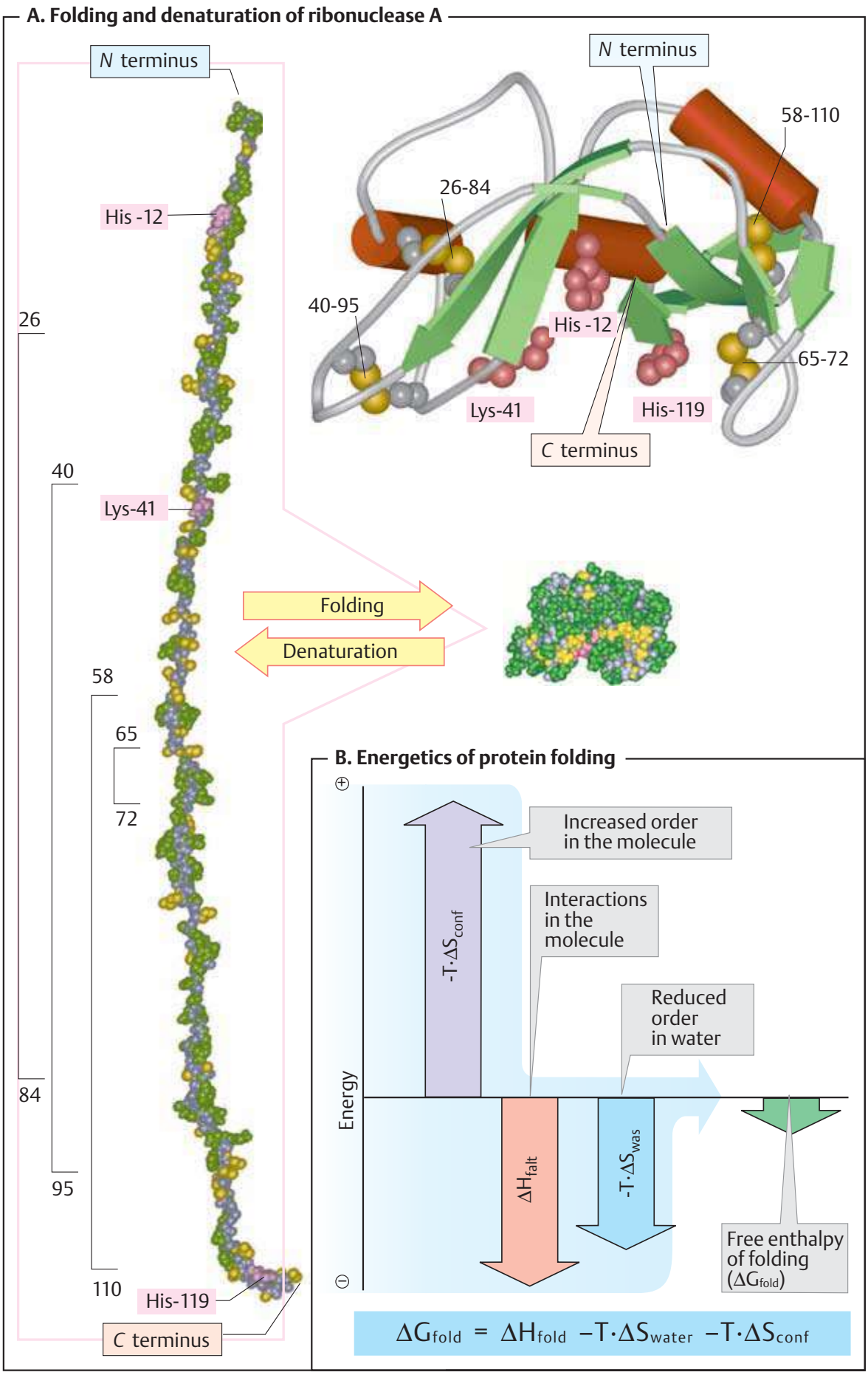

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Molecular models: insulin

The opposite page presents models of insulin, a small protein. The biosynthesis and function of this important hormone are discussed elsewhere in this book (pp. 160, 388). Monomeric insulin consists of 51 amino acids, and with a molecular mass of 5.5 kDa it is only half the size of the smallest enzymes. Nevertheless, it has the typical properties of a globular protein.

Large quantities of pure insulin are required for the treatment of *diabetes mellitus* (see p. 160). The annual requirement for insulin is over 500 kg in a country the size of Germany. Formerly, the hormone had to be obtained from the pancreas of slaughtered animals in a complicated and expensive procedure. **Human insulin**, which is produced by *overexpression* in genetically engineered bacteria, is now mainly used (see p. 262).

A. Structure of insulin ○

There are various different structural levels in proteins, and these can be briefly discussed again here using the example of insulin.

The **primary structure** of a protein is its amino acid sequence. During the biosynthesis of insulin in the pancreas, a continuous peptide chain with 84 residues is first synthesized—*proinsulin* (see p. 160). After folding of the molecule, the three disulfide bonds are first formed, and residues 31 to 63 are then proteolytically cleaved releasing the so-called *C peptide*. The molecule that is left over (**1**) now consists of two peptide chains, the *A chain* (21 residues, shown in yellow) and the *B chain* (30 residues, orange). One of the disulfide bonds is located inside the A chain, and the two others link the two chains together.

Secondary structures are regions of the peptide chain with a defined conformation (see p. 68) that are stabilized by H-bonds. In insulin (**2**), the α-helical areas are predominant, making up 57% of the molecule; 6% consists of β-pleated-sheet structures, and 10% of β-turns, while the remainder (27%) cannot be assigned to any of the secondary structures.

The three-dimensional conformation of a protein, made up of secondary structural elements and unordered sections, is referred to as the **tertiary structure**. In insulin, it is compact and wedge-shaped (**B**). The tip of the wedge is formed by the B chain, which changes its direction at this point.

Quaternary structure. Due to non-covalent interactions, many proteins assemble to form symmetrical complexes (oligomers). The individual components of oligomeric proteins (usually 2–12) are termed *subunits* or *monomers*. Insulin also forms quaternary structures. In the blood, it is partly present as a dimer. In addition, there are also hexamers stabilized by Zn^{2+} ions (light blue) (**3**), which represent the form in which insulin is stored in the pancreas (see p. 160).

B. Insulin (monomer) ○

The van der Waals model of monomeric insulin (**1**) once again shows the wedge-shaped tertiary structure formed by the two chains together. In the second model (**3**, bottom), the side chains of polar amino acids are shown in blue, while apolar residues are yellow or pink. This model emphasizes the importance of the "hydrophobic effect" for protein folding (see p. 74). In insulin as well, most hydrophobic side chains are located on the inside of the molecule, while the hydrophilic residues are located on the surface. Apparently in contradiction to this rule, several apolar side chains (pink) are found on the surface. However, all of these residues are involved in hydrophobic interactions that stabilize the dimeric and hexameric forms of insulin.

In the third model (**2**, right), the colored residues are those that are located on the surface and occur *invariably* (red) or *almost invariably* (orange) in all known insulins. It is assumed that amino acid residues that are not replaced by other residues during the course of evolution are essential for the protein's function. In the case of insulin, almost all of these residues are located on one side of the molecule. They are probably involved in the binding of the hormone to its receptor (see p. 224).

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A. Structure of insulin

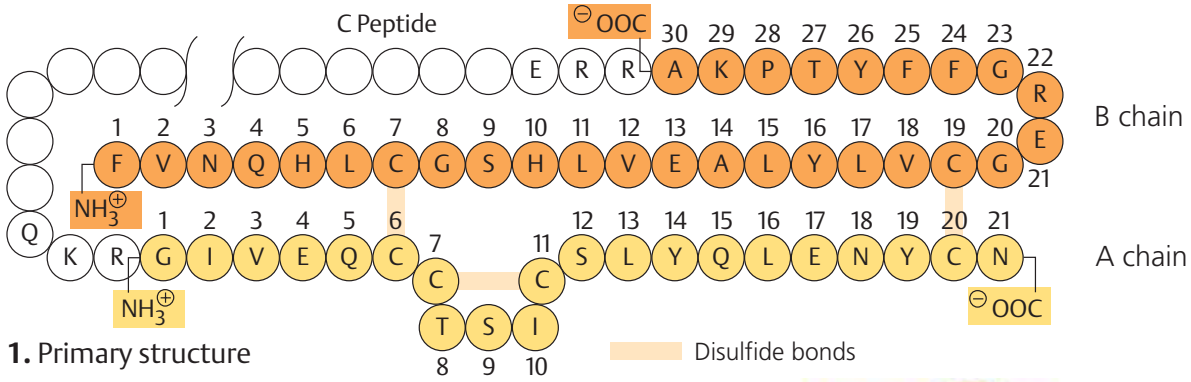

1. Primary structure

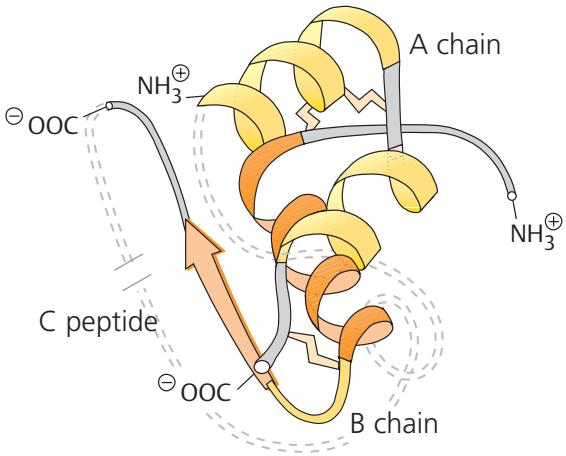

2. Secondary and tertiary structure

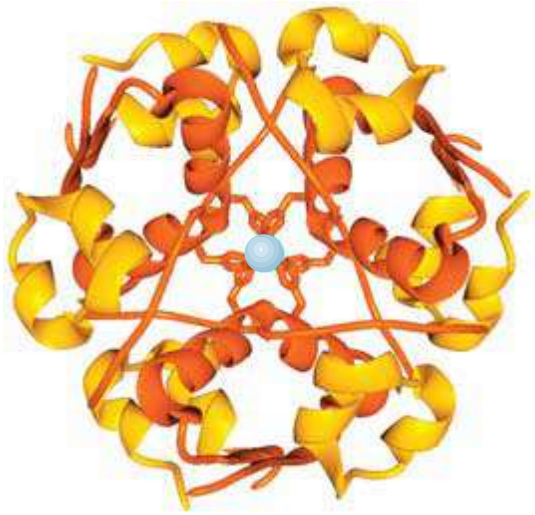

3. Quaternary structure

B. Insulin (monomer)

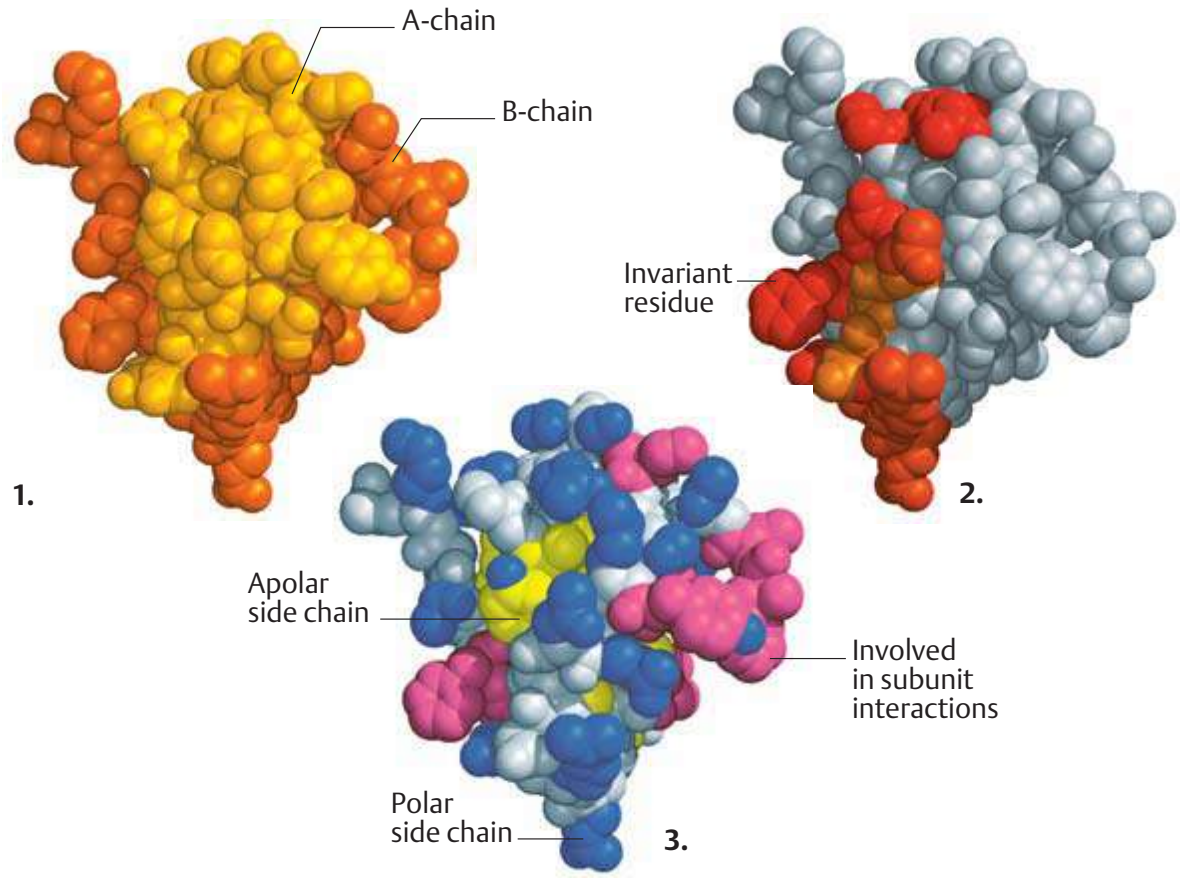

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Isolation and analysis of proteins

Purified proteins are nowadays required for a wide variety of applications in research, medicine, and biotechnology. Since the globular proteins in particular are very unstable (see p. 72), purification is carried out at low temperatures (0–5 °C) and particularly gentle separation processes are used. A few of the methods of purifying and characterizing proteins are discussed on this page.

A. Salt precipitation ○

The solubility of proteins is strongly dependent on the salt concentration (*ionic strength*) of the medium. Proteins are usually poorly soluble in pure water. Their solubility increases as the ionic strength increases, because more and more of the well-hydrated anorganic ions (blue circles) are bound to the protein's surface, preventing aggregation of the molecules (**salting in**). At very high ionic strengths, the salt withdraws the hydrate water from the proteins and thus leads to aggregation and precipitation of the molecules (**salting out**). For this reason, adding salts such as ammonium sulfate $(NH_4)_2SO_4$ makes it possible to separate proteins from a mixture according to their degree of solubility (fractionation).

B. Dialysis ○

Dialysis is used to remove lower-molecular components from protein solutions, or to exchange the medium. Dialysis is based on the fact that due to their size, protein molecules are unable to pass through the pores of a **semipermeable membrane**, while lower-molecular substances distribute themselves evenly between the inner and outer spaces over time. After repeated exchanging of the external solution, the conditions inside the *dialysis tube* (salt concentration, pH, etc.) will be the same as in the surrounding solution.

C. Gel filtration ○

Gel permeation chromatography ("gel filtration") separates proteins according to their size and shape. This is done using a *chromatography column,* which is filled with spherical *gel particles* (diameter 10–500 μm) of polymeric material (shown schematically in **1a**). The insides of the particles are traversed by channels that have defined diameters. A protein mixture is then introduced at the upper end of the column (**1b**) and *elution* is carried out by passing a buffer solution through the column. Large protein molecules (red) are unable to penetrate the particles, and therefore pass through the column quickly. Medium-sized (green) and small particles (blue) are delayed for longer or shorter periods (**1c**). The proteins can be collected separately from the ef uent (*eluate*) (**2**). Their elution volume V_e depends mainly on their molecular mass (**3**).

D. SDS gel electrophoresis ○

The most commonly used procedure for checking the purity of proteins is sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). In electrophoresis, molecules move in an electrical field (see p. 276). Normally, the speed of their movement depends on three factors—their size, their shape, and their electrical charge.

In SDS-PAGE, the protein mixture is treated in such a way that only the molecules' mass affects their movement. This is achieved by adding *sodium dodecyl sulfate* ($C_{12}H_{25}$-OSO_3Na), the sulfuric acid ester of lauryl alcohol (dodecyl alcohol). SDS is a *detergent* with strongly amphipathic properties (see p. 28). It separates oligomeric proteins into their subunits and denatures them. SDS molecules bind to the unfolded peptide chains (ca. 0.4 g SDS / g protein) and give them a strongly negative charge. To achieve complete denaturation, thiols are also added in order to cleave the disulfide bonds (**1**).

Following electrophoresis, which is carried out in a vertically arranged gel of polymeric acrylamide (**2**), the separated proteins are made visible by staining. In example (**3**), the following were separated: **a**) a cell extract with hundreds of different proteins, **b**) a protein purified from this, and **c**) a mixture of proteins with known masses.

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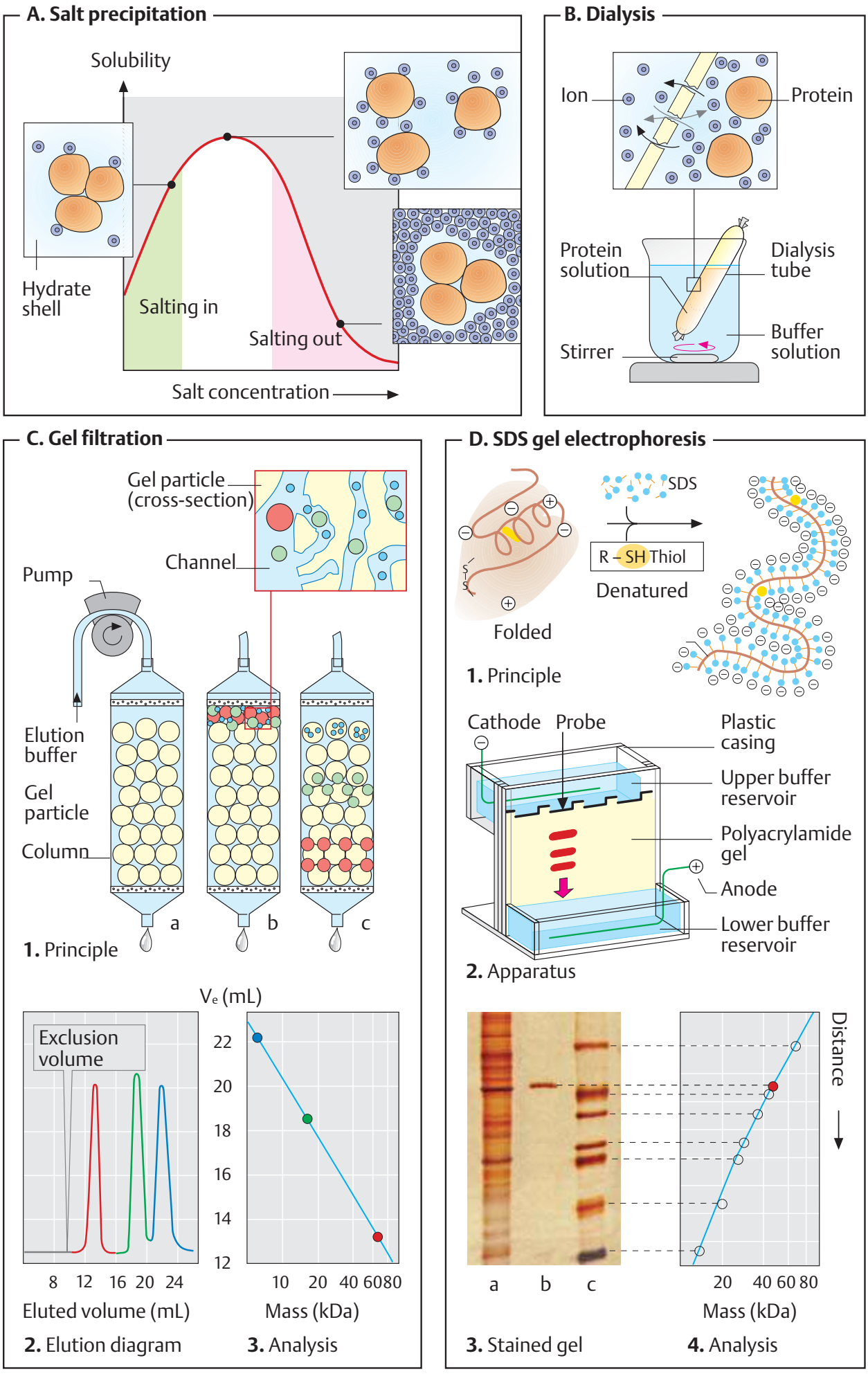

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Bases and nucleotides

The nucleic acids play a central role in the storage and expression of genetic information (see p. 236). They are divided into two major classes: **deoxyribonucleic acid (DNA)** functions solely in information storage, while **ribonucleic acids (RNAs)** are involved in most steps of gene expression and protein biosynthesis. All nucleic acids are made up from **nucleotide components**, which in turn consist of a *base*, a *sugar*, and a *phosphate residue*. DNA and RNA differ from one another in the type of the sugar and in one of the bases that they contain.

A. Nucleic acid bases ◑

The bases that occur in nucleic acids are *aromatic* heterocyclic compounds derived from either **pyrimidine** or **purine**. Five of these bases are the main components of nucleic acids in all living creatures. The purine bases **adenine** (abbreviation Ade, *not* "A"!) and **guanine** (Gua) and the pyrimidine base **cytosine** (Cyt) are present in both RNA *and* DNA. In contrast, **uracil** (Ura) is only found in RNA. In DNA, **uracil** is replaced by thymine (Thy), the 5-methyl derivative of uracil. 5-methylcytosine also occurs in small amounts in the DNA of the higher animals. A large number of other modified bases occur in tRNA (see p. 82) and in other types of RNA.

B. Nucleosides, nucleotides ◑

When a nucleic acid base is N-glycosidically linked to ribose or 2-deoxyribose (see p. 38), it yields a **nucleoside**. The nucleoside **adenosine** (abbreviation: A) is formed in this way from adenine and ribose, for example. The corresponding derivatives of the other bases are called *guanosine* (G), *uridine* (U), *thymidine* (T) and *cytidine* (C). When the sugar component is 2-deoxyribose, the product is a **deoxyribonucleoside**—e. g., 2′-deoxyadenosine (dA, not shown). In the cell, the 5′OH group of the sugar component of the nucleoside is usually esterified with phosphoric acid. 2′-Deoxythymidine (dT) therefore gives rise to **2′-deoxythymidine-5′-monophosphate (dTMP)**, one of the components of DNA (**2**). If the 5′phosphate residue is linked via an acid–anhydride bond to additional phosphate residues, it yields nucleoside diphosphates and triphosphates—e. g., ADP and ATP, which are important coenzymes in energy metabolism (see p. 106). All of these nucleoside phosphates are classified as **nucleotides**.

In nucleosides and nucleotides, the pentose residues are present in the furanose form (see p. 34). The sugars and bases are linked by an *N*-**glycosidic bond** between the C-1 of the sugar and either the N-9 of the purine ring or N-1 of the pyrimidine ring. This bond always adopts the β-configuration.

C. Oligonucleotides, polynucleotides ◑

Phosphoric acid molecules can form acid–anhydride bonds with each other. It is therefore possible for two nucleotides to be linked via the phosphate residues. This gives rise to *dinucleotides with a phosphoric acid–anhydride* structure. This group includes the coenzymes $NAD(P)^+$ and CoA, as well as the flavin derivative **FAD** (**1**; see p. 104).

If the phosphate residue of a nucleotide reacts with the 3′-OH group of a second nucleotide, the result is a *dinucleotide with a phosphoric acid diester structure*. Dinucleotides of this type have a free phosphate residue at the *5′end* and a free OH group at the *3′end*. They can therefore be extended with additional mononucleotides by adding further phosphoric acid diester bonds. This is the way in which **oligonucleotides**, and ultimately **polynucleotides**, are synthesized.

Polynucleotides consisting of ribonucleotide components are called **ribonucleic acid (RNA)**, while those consisting of deoxyribonucleotide monomers are called **deoxyribonucleic acid (DNA**; see p. 84). To describe the structure of polynucleotides, the abbreviations for the *nucleoside* components are written from left to right *in the 5′→3′* direction. The position of the phosphate residue is also sometimes indicated by a "p". In this way, the structure of the RNA segment shown Fig. **2** can be abbreviated as ..pUpG.. or simply as $..^{UG}..$.

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A. Nucleic acid bases

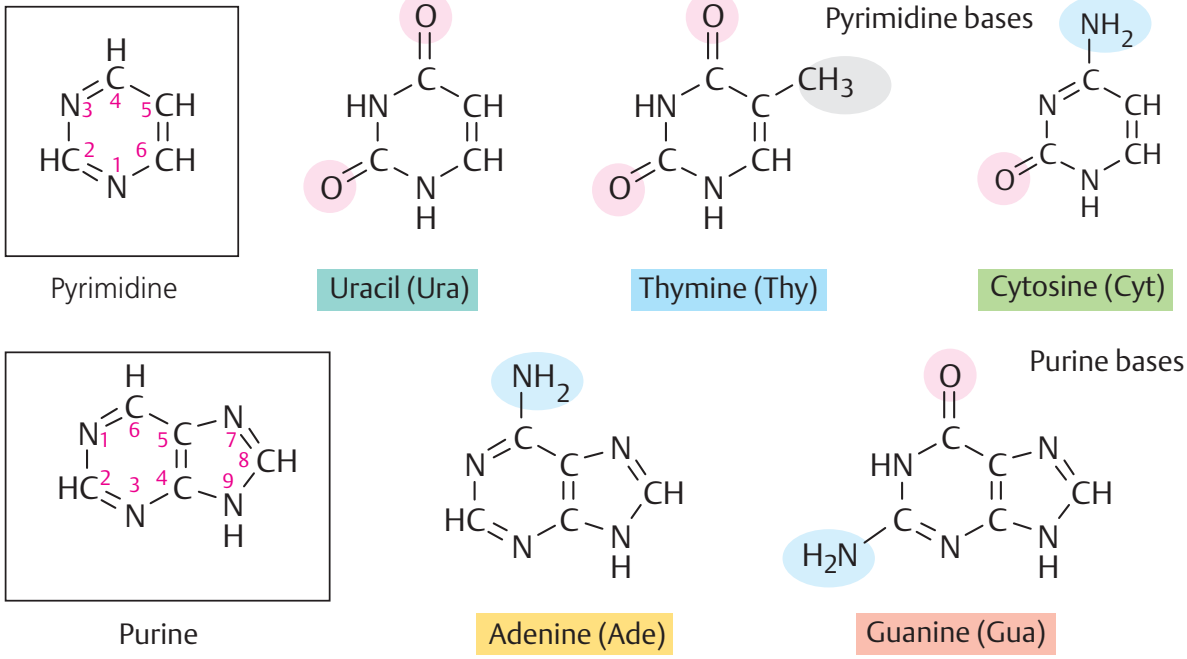

B. Nucleosides, nucleotides

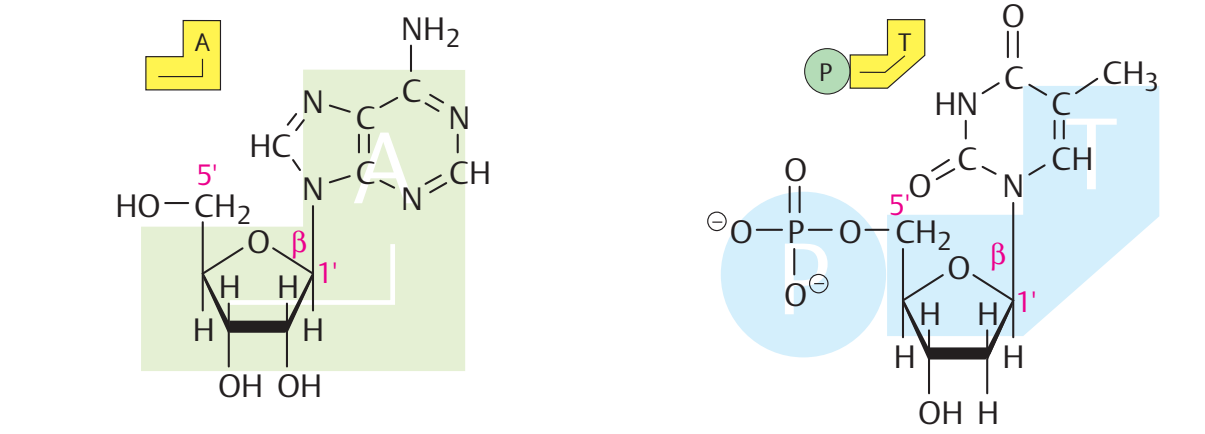

1. Adenosine (Ado)

2. 2'-Deoxythymidine 5'-monophosphate (dtMP)

C. Oligonucleotides, polynucleotides

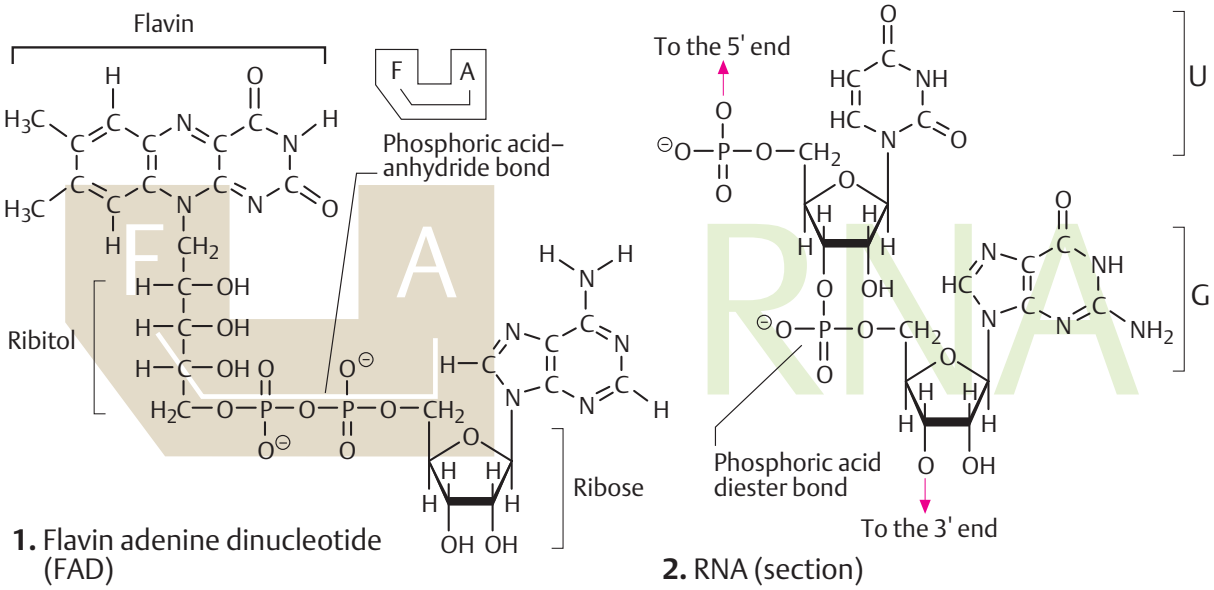

1. Flavin adenine dinucleotide (FAD)

2. RNA (section)

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RNA

Ribonucleic acids (RNAs) are polymers consisting of nucleoside phosphate components that are linked by phosphoric acid diester bonds (see p. 80). The bases the contain are mainly uracil, cytosine, adenine, and guanine, but many unusual and modified bases are also found in RNAs (**B**).

A. Ribonucleic acids (RNAs) ◑

RNAs are involved in all the individual steps of gene expression and protein biosynthesis (see pp. 242–253). The properties of the most important forms of RNA are summarized in the table. The schematic diagram also gives an idea of the secondary structure of these molecules.

In contrast to DNA, RNAs do not form extended double helices. In RNAs, the base pairs (see p. 84) usually only extend over a few residues. For this reason, substructures often arise that have a finger shape or clover-leaf shape in two-dimensional representations. In these, the paired stem regions are linked by loops. Large RNAs such as ribosomal 16S-rRNA (center) contain numerous "stem and loop" regions of this type. These sections are again folded three-dimensionally—i. e., like proteins, RNAs have a tertiary structure (see p. 86). However, tertiary structures are only known of small RNAs, mainly tRNAs. The diagrams in Fig. **B** and on p. 86 show that the "clover-leaf" structure is not recognizable in a three-dimensional representation.

Cellular RNAs vary widely in their size, structure, and lifespan. The great majority of them are ribosomal RNA **(rRNA)**, which in several forms is a structural and functional component of *ribosomes* (see p. 250). Ribosomal RNA is produced from DNA by transcription in the nucleolus, and it is processed there and assembled with proteins to form ribosome subunits (see pp. 208, 242). The bacterial 16S-rRNA shown in Fig. **A**, with 1542 nucleotides (nt), is a component of the small ribosomae subunit, while the much smaller 5S-rRNA (118 nt) is located in the large subunit.

Messenger RNAs **(mRNAs)** transfer genetic information from the cell nucleus to the cytoplasm. The primary transcripts are substantially modified while still in the nucleus (mRNA maturation; see p. 246). Since mRNAs have to be read codon by codon in the ribosome, they must not form a stable tertiary structure. This is ensured in part by the attachment of *RNA-binding proteins,* which prevent base pairing. Due to the varying amounts of information that they carry, the lengths of mRNAs also vary widely. Their lifespan is usually short, as they are quickly broken down after translation.

Small nuclear RNAs **(snRNAs)** are involved in the splicing of mRNA precursors (see p. 246). They associate with numerous proteins to form "spliceosomes."

B. Transfer RNA ($tRNA^{Phe}$) ◑

The transfer RNAs **(tRNAs)** function during translation (see p. 250) as links between the nucleic acids and proteins. They are small RNA molecules consisting of 70–90 nucleotides, which "recognize" specific mRNA codons with their *anticodons* through base pairing. At the same time, at their 3′ end (sequence .. CCA-3′) they carry the amino acid that is assigned to the relevant mRNA codon according to the genetic code (see p. 248).

The base sequence and the tertiary structure of the yeast tRNA specific for phenylalanine ($tRNA^{Phe}$) is typical of all tRNAs. The molecule (see also p. 86) contains a high proportion of unusual and modified components (shaded in dark green in Fig. **1**). These include *pseudouridine* (Ψ), *dihydrouridine* (D), *thymidine* (T), which otherwise only occurs in DNA, and many methylated nucleotides such as *7-methylguanidine* (m^7G) and—in the anticodon—*2′-O-methylguanidine* (m^2G). Numerous base pairs, sometimes deviating from the usual pattern, stabilize the molecule's conformation (**2**).

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A. Ribonucleic acids (RNAs)

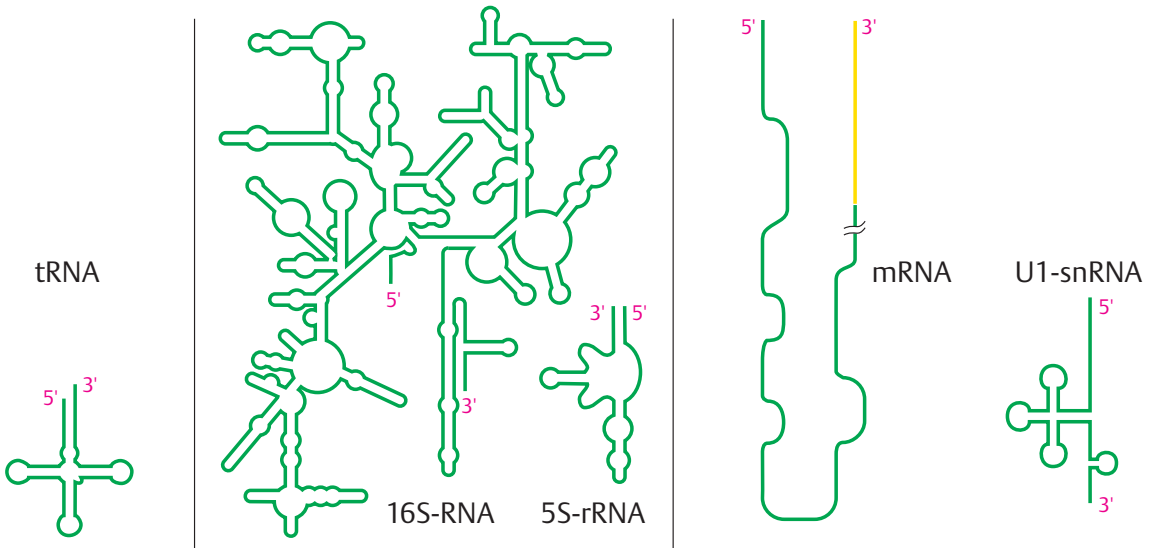

tRNA	rRNA	Type	mRNA	snRNA
>50	4	Species per cell	> 1000	~ 10
74 - 95	120 - 5000	Length (b)	400 - 6000	100 - 300
10-20%	80%	Proportion	5%	< 1%
Long	Long	Lifespan	Short	Long
Translation	Translation	Function	Translation	Splicing

B. Transfer RNA (tRNA^{Phe})

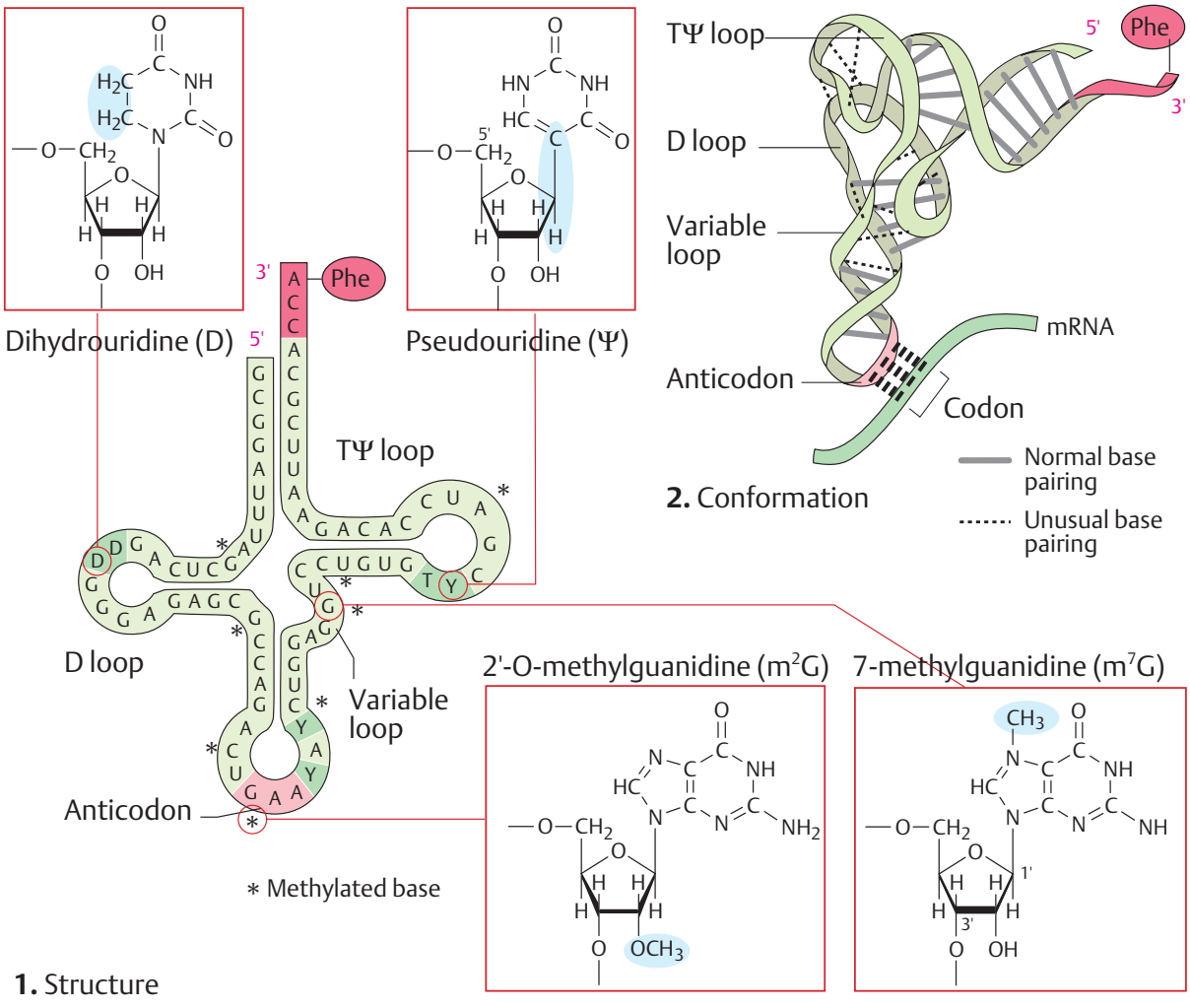

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DNA

A. DNA: structure ●

Like RNAs (see p. 82), deoxyribonucleic acids (DNAs) are polymeric molecules consisting of nucleotide building blocks. Instead of ribose, however, DNA contains 2′-deoxyribose, and the *uracil* base in RNA is replaced by *thymine*. The spatial structure of the two molecules also differs (see p. 86).

The first evidence of the special structure of DNA was the observation that the amounts of adenine and thymine are almost equal in every type of DNA. The same applies to guanine and cytosine. The model of DNA structure formulated in 1953 explains these *constant base ratios:* intact DNA consists of *two* polydeoxynucleotide molecules ("strands"). Each base in one strand is linked to a *complementary* base in the other strand by H-bonds. Adenine is complementary to thymine, and guanine is complementary to cytosine. One purine base and one pyrimidine base are thus involved in each **base pair**.

The complementarity of A with T and of G with C can be understood by considering the H bonds that are possible between the different bases. Potential donors (see p. 6) are amino groups (Ade, Cyt, Gua) and ring NH groups. Possible acceptors are carbonyl oxygen atoms (Thy, Cyt, Gua) and ring nitrogen atoms. *Two* linear and therefore highly stable bonds can thus be formed in A–T pairs, and *three* in G–C pairs.

Base pairings of this type are only possible, however, when the *polarity* of the two strands differs—i. e., when they run in opposite directions (see p. 80). In addition, the two strands have to be intertwined to form a **double helix**. Due to steric hindrance by the 2′-OH groups of the ribose residues, RNA is unable to form a double helix. The structure of RNA is therefore less regular than that of DNA (see p. 82).

The conformation of DNA that predominates within the cell (known as **B-DNA**) is shown schematically in Fig. **A2** and as a van der Waals model in Fig. **B1**. In the schematic diagram (**A2**), the deoxyribose–phosphate "backbone" is shown as a ribbon. The bases (indicated by lines) are located on the inside of the **double helix**. This area of DNA is therefore apolar. By contrast, the molecule's surface is polar and negatively charged, due to the sugar and phosphate residues in the backbone. Along the whole length of the DNA molecule, there are two depressions—referred to as the "minor groove" and the "major groove"—that lie between the strands.

B. Coding of genetic information ●

In all living cells, DNA serves to **store genetic information**. Specific segments of DNA ("genes") are transcribed as needed into RNAs, which either carry out structural or catalytic tasks themselves or provide the basis for synthesizing proteins (see p. 82). In the latter case, the DNA codes for the primary structure of proteins. The "language" used in this process has four letters (A, G, C, and T). All of the words ("codons") contain three letters ("triplets"), and each triplet stands for one of the 20 proteinogenic amino acids.

The two strands of DNA are not functionally equivalent. The **template strand** (the (–) strand or "codogenic strand," shown in light gray in Fig. **1**) is the one that is read during the synthesis of RNA (transcription; see p. 242). Its sequence is complementary to the RNA formed. The **sense strand** (the (+) strand or "coding strand," shown in color in Figs. **1** and **2**) has the *same sequence as the RNA,* except that T is exchanged for U. By convention, it is agreed that gene sequences are expressed by reading the sequence of the sense strand in the 5′→3′ direction. Using the genetic code (see p. 248), in this case the protein sequence (**3**) is obtained directly in the reading direction usual for proteins—i. e., from the *N* terminus to the *C* terminus.

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A. DNA: structure

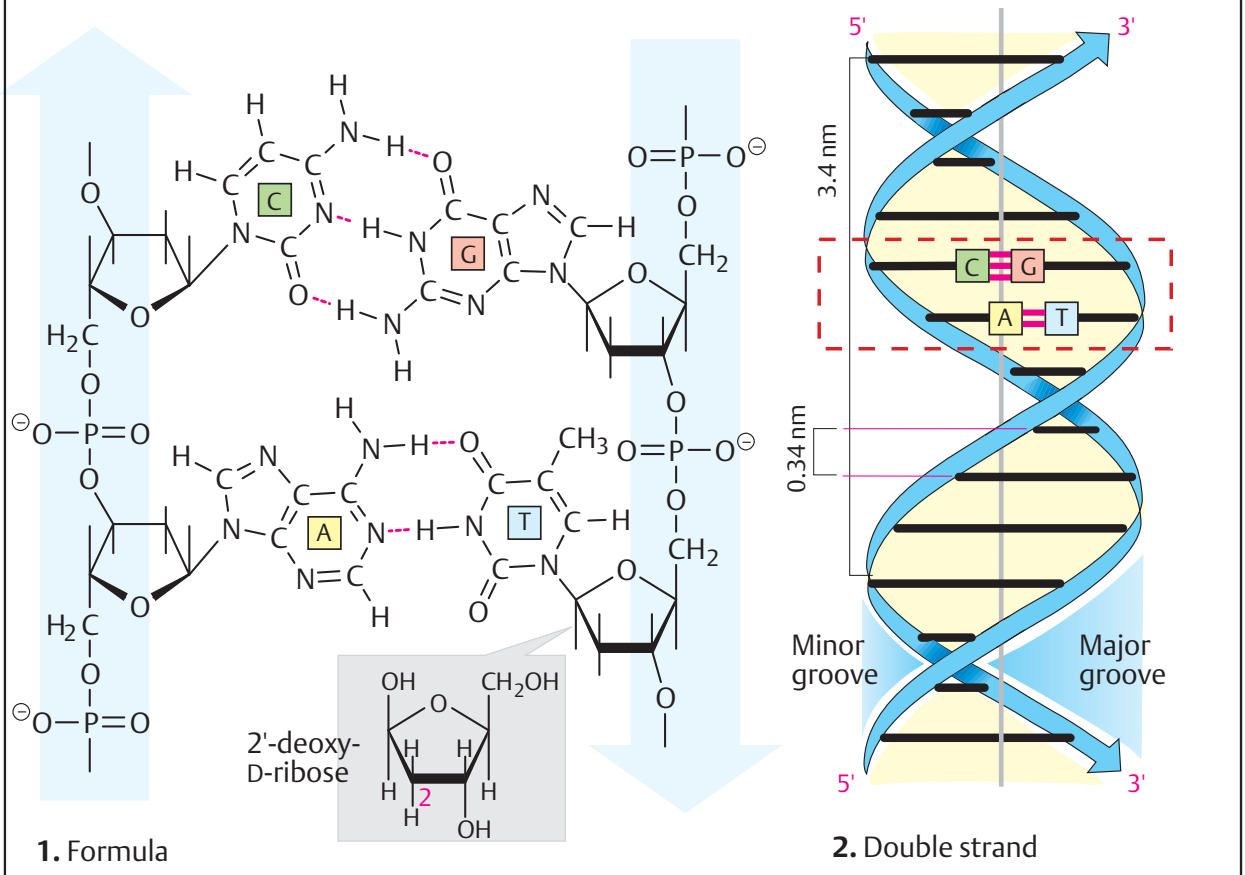

B. Coding of genetic information

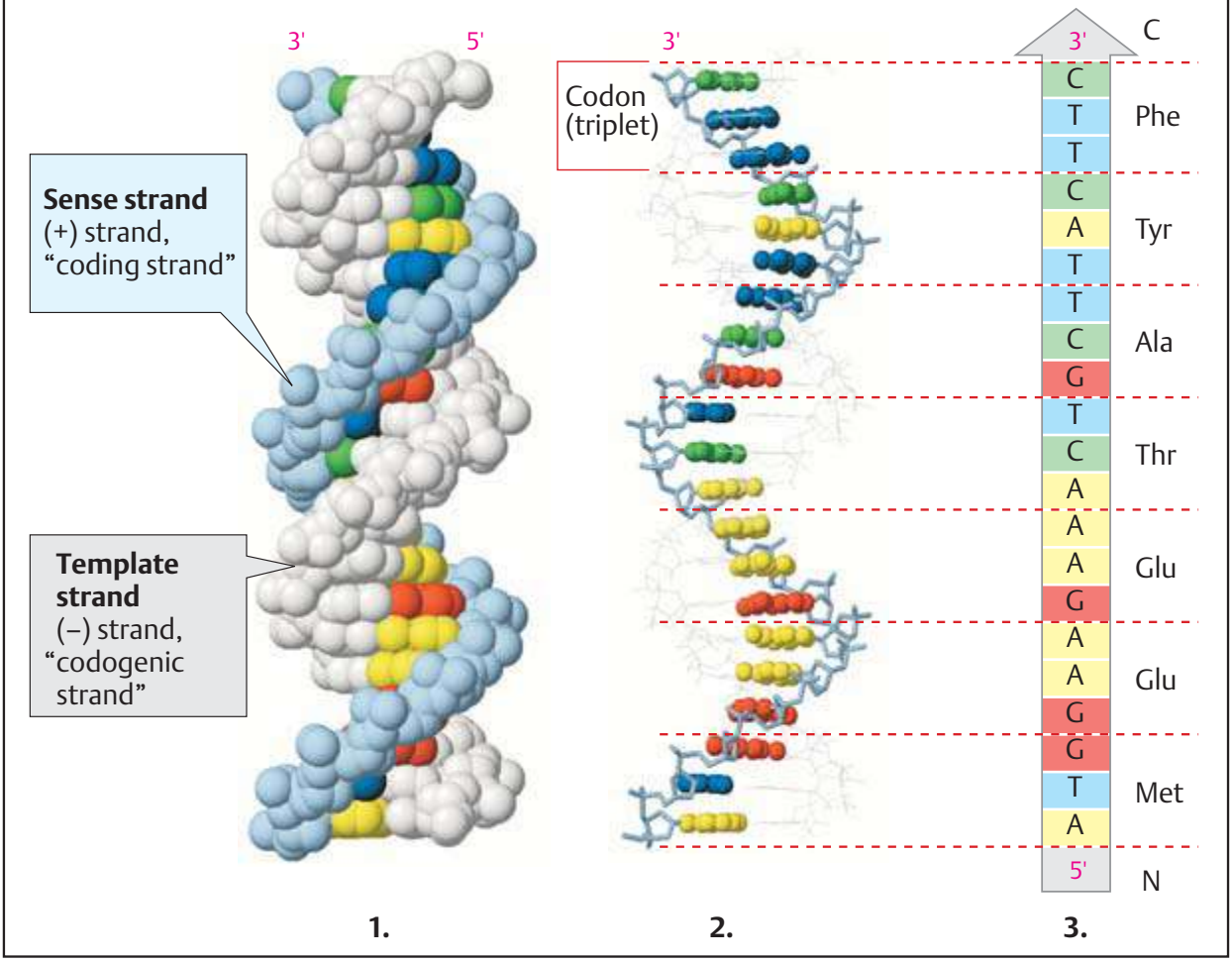

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Molecular models: DNA and RNA

The illustration opposite shows selected nucleic acid molecules. Fig. **A** shows various conformations of DNA, and Fig. **B** shows the spatial structures of two small RNA molecules. In both, the van der Waals models (see p. 6) are accompanied by ribbon diagrams that make the course of the chains clear. In all of the models, the polynucleotide "backbone" of the molecule is shown in a darker color, while the bases are lighter.

A. DNA: conformation ○

Investigations of synthetic DNA molecules have shown that DNA can adopt several different conformations. All of the DNA segments shown consist of 21 base pairs (bp) and have the same sequence.

By far the most common form is **B-DNA** (**2**). As discussed on p. 84, this consists of two antiparallel polydeoxynucleotide strands intertwined with one another to form a **right-handed double helix**. The "backbone" of these strands is formed by deoxyribose and phosphate residues linked by phosphoric acid diester bonds.

In the B conformation, the aromatic rings of the nucleobases are stacked at a distance of 0.34 nm almost at right angles to the axis of the helix. Each base is rotated relative to the preceding one by an angle of 35°. A complete turn of the double helix (360°) therefore contains around 10 base pairs (abbreviation: bp), i. e., the *pitch* of the helix is 3.4 nm. Between the backbones of the two individual strands there are two grooves with different widths. The *major groove* is visible at the top and bottom, while the narrower *minor groove* is seen in the middle. DNA-binding proteins and transcription factors (see pp. 118, 244) usually enter into interactions in the area of the major groove, with its more easily accessible bases.

In certain conditions, DNA can adopt the **A conformation** (**1**). In this arrangement, the double helix is still right-handed, but the bases are no longer arranged at right angles to the axis of the helix, as in the B form. As can be seen, the A conformation is more compact than the other two conformations. The minor groove almost completely disappears, and the major groove is narrower than in the B form. A-DNA arises when B-DNA is dehydrated. It probably does not occur in the cell.

In the **Z-conformation** (**3**), which can occur within GC-rich regions of B-DNA, the organization of the nucleotides is completely different. In this case, the helix is *left-handed,* and the backbone adopts a characteristic *zig-zag* conformation (hence "Z-DNA"). The Z double helix has a smaller pitch than B-DNA. DNA segments in the Z conformation probably have physiological significance, but details are not yet known.

B. RNA ○

RNA molecules are unable to form extended double helices, and are therefore less highly ordered than DNA molecules. Nevertheless, they have defined secondary and tertiary structures, and a large proportion of the nucleotide components enter into base pairings with other nucleotides. The examples shown here are **5S-rRNA** (see p. 242), which occurs as a structural component in ribosomes, and a **tRNA** molecule from yeast (see p. 82) that is specific for phenylalanine.

Both molecules are folded in such a way that the 3′ end and the 5′ end are close together. As in DNA, most of the bases are located in the inside of the structures, while the much more polar "backbone" is turned outwards. An exception to this is seen in the three bases of the *anticodon* of the tRNA (pink), which have to interact with mRNA and therefore lie on the surface of the molecule. The bases of the conserved CCA triplet at the 3′ end (red) also jut outward. During amino acid activation (see p. 248), they are recognized and bound by the ligases.

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A. DNA: conformation

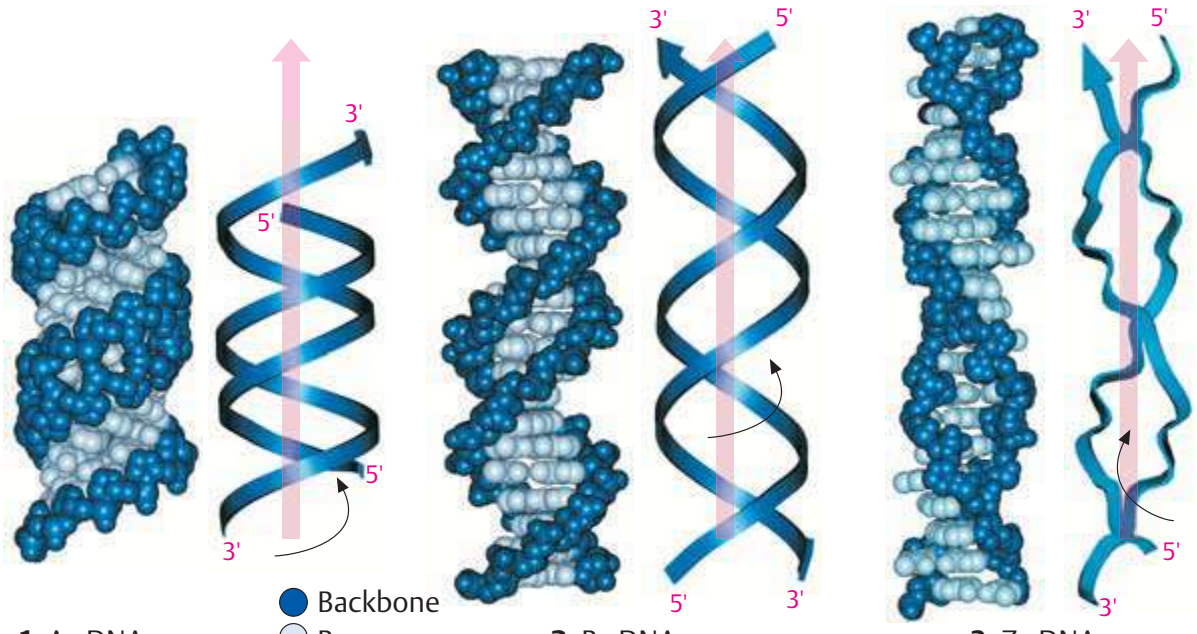

B. RNA

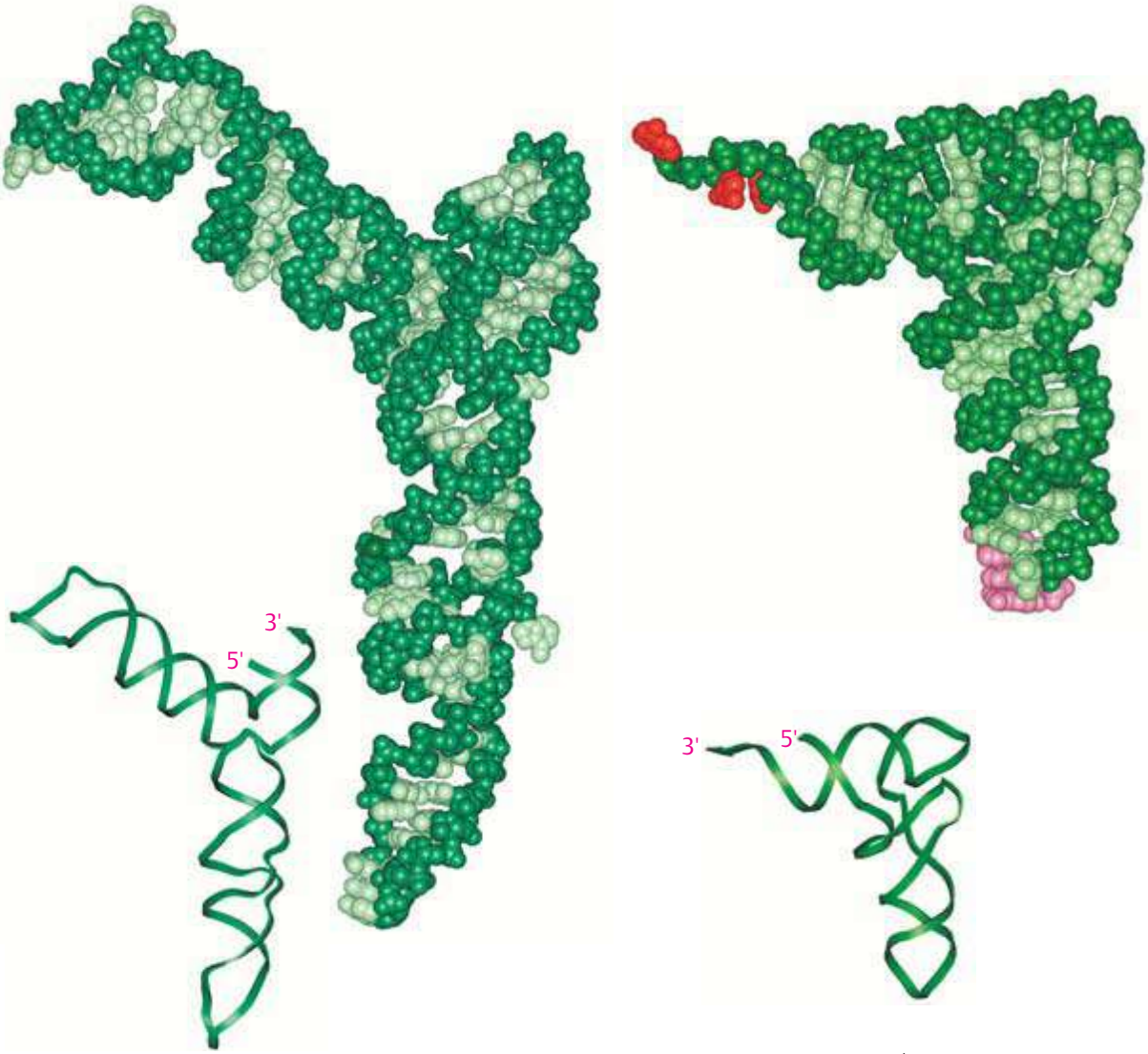

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Enzymes: basics

Enzymes are **biological catalysts**—i.e., substances of biological origin that accelerate chemical reactions (see p. 24). The orderly course of metabolic processes is only possible because each cell is equipped with its own genetically determined set of enzymes. It is only this that allows coordinated sequences of reactions (**metabolic pathways**; see p. 112). Enzymes are also involved in many regulatory mechanisms that allow the metabolism to adapt to changing conditions (see p. 114). Almost all enzymes are **proteins**. However, there are also catalytically active ribonucleic acids, the *"ribozymes"* (see pp. 246, 252).

A. Enzymatic activity ●

The catalytic action of an enzyme, its **activity**, is measured by determining the **increase in the reaction rate** under precisely defined conditions—i.e., the difference between the turnover (violet) of the catalyzed reaction (orange) and uncatalyzed reaction (yellow) in a specific time interval. Normally, reaction rates are expressed as the *change in concentration per unit of time* (mol 1^{-1} s^{-1}; see p. 22). Since the catalytic activity of an enzyme is independent of the volume, the unit used for enzymes is usually *turnover per unit time*, expressed in **katal** (kat, mol s^{-1}). However, the **international unit U** is still more commonly used (μmol turnover min^{-1}; 1 U = 16.7 nkat).

B. Reaction and substrate specificity ●

The action of enzymes is usually very *specific*. This applies not only to the type of reaction being catalyzed (**reaction specificity**), but also to the nature of the reactants ("substrates") that are involved (**substrate specificity**; see p. 94). In Fig. **B**, this is illustrated schematically using a bond-breaking enzyme as an example. Highly specific enzymes (type A, top) catalyze the cleavage of only *one* type of bond, and only when the structure of the substrate is the correct one. Other enzymes (type B, middle) have narrow reaction specificity, but broad substrate specificity. Type C enzymes (with low reaction specificity *and* low substrate specificity, bottom) are very rare.

C. Enzyme classes ◑

More than 2000 different enzymes are currently known. A system of *classification* has been developed that takes into account both their *reaction specificity* and their *substrate specificity*. Each enzyme is entered in the *Enzyme Catalogue* with a four-digit Enzyme Commission number (**EC number**). The first digit indicates membership of one of the six **major classes**. The next two indicate subclasses and subsubclasses. The last digit indicates where the enzyme belongs in the subsubclass. For example, lactate dehydrogenase (see pp. 98–101) has the EC number *1.1.1.27* (class 1, oxidoreductases; subclass 1.1, CH–OH group as electron *donor*; sub-subclass 1.1.1, $NAD(P)^+$ as electron *acceptor*).

Enzymes with similar reaction specificities are grouped into each of the six major classes:

The **oxidoreductases** (*class 1*) catalyze the transfer of reducing equivalents from one redox system to another.

The **transferases** (*class 2*) catalyze the transfer of other groups from one molecule to another. Oxidoreductases and transferases generally require coenzymes (see pp. 104 ff.).

The **hydrolases** (*class 3*) are also involved in group transfer, but the acceptor is always a *water molecule.*

Lyases (*class 4*, often also referred to as "synthases") catalyze reactions involving either the cleavage or formation of chemical bonds, with double bonds either arising or disappearing.

The **isomerases** (*class 5*) move groups within a molecule, without changing the gross composition of the substrate.

The ligation reactions catalyzed by **ligases** ("synthetases," *class 6*) are energy-dependent and are therefore always coupled to the hydrolysis of nucleoside triphosphates.

In addition to the enzyme name, we also usually give its EC number. The *annotated enzyme list* (pp. 420 ff.) includes all of the enzymes mentioned in this book, classified according to the Enzyme Catalog system.

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A. Enzymatic activity

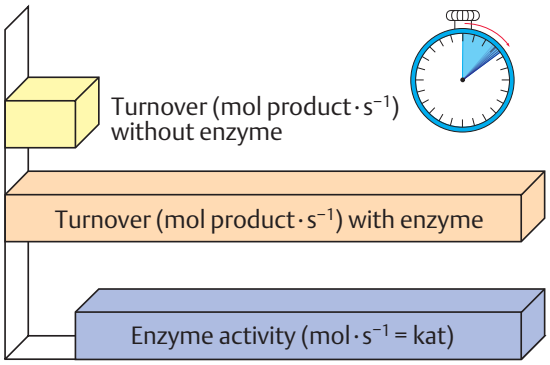

1 Katal (kat): Amount of enzyme which increases turnover by 1 mol · s^{-1}

B. Reaction and substrate specificity

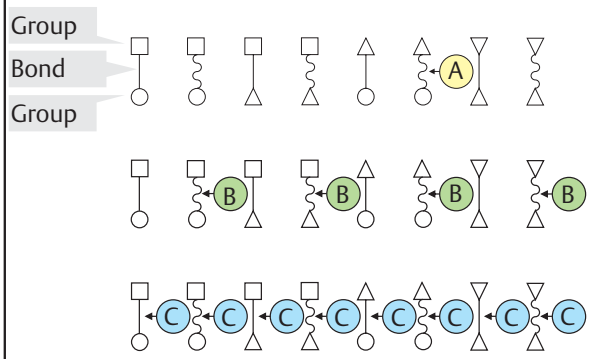

	Reaction specificity	Substrate specificity
A	High	High
B	High	Low
C	Low	Low

C. The enzyme classes

Class	Reaction type	Important subclasses
1 Oxidoreductases	○ = Reduction equivalent $A_{red} + B_{ox} \rightleftharpoons A_{ox} + B_{red}$	Dehydrogenases Oxidases, peroxidases Reductases Monooxygenases Dioxygenases
2 Transferases	A–B + C ⇌ A + B–C	C_1-Transferases Glycosyltransferases Aminotransferases Phosphotransferases
3 Hydrolases	A–B + H_2O ⇌ A–H + B–OH	Esterases Glycosidases Peptidases Amidases
4 Lyases ("synthases")	A + B ⇌ A–B	C-C-Lyases C-O-Lyases C-N-Lyases C-S-Lyases
5 Isomerases	A ⇌ Iso-A	Epimerases *cis trans* Isomerases Intramolecular transferases
6 Ligases ("synthetases")	B + A + XTP (X = A, G, U, C) ⇌ A–B + XDP + P	C-C-Ligases C-O-Ligases C-N-Ligases C-S-Ligases

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Enzyme catalysis

Enzymes are extremely effective **catalysts**. They can increase the rate of a catalyzed reaction by a factor of 10^{12} or more. To grasp the mechanisms involved in enzyme catalysis, we can start by looking at the course of an uncatalyzed reaction more closely.

A. Uncatalyzed reaction ○

The reaction A + B → C + D is used as an example. In solution, **reactants A and B** are surrounded by a shell of water molecules (the *hydration shell*), and they move in random directions due to thermal agitation. They can only react with each other if they collide in a favorable orientation. This is not very probable, and therefore only occurs rarely. Before conversion into the products C + D, the **collision complex A-B** has to pass through a **transition state**, the formation of which usually requires a large amount of **activation energy, E_a** (see p. 22). Since only a few A–B complexes can produce this amount of energy, a productive transition state arises even less often than a collision complex. In solution, a large proportion of the activation energy is required for the *removal of the hydration shells* between A and B. However, charge displacements and other *chemical processes* within the reactants also play a role. As a result of these limitations, conversion only happens occasionally in the absence of a catalyst, and the reaction rate v is low, even when the reaction is thermodynamically possible—i. e., when $\Delta G < 0$ (see p. 18).

B. Enzyme-catalyzed reaction ◑

Shown here is a *sequential mechanism* in which substrates A and B are bound and products C and D are released, in that order. Another possible reaction sequence, known as the *"ping-pong mechanism,"* is discussed on p. 94.

Enzymes are able to bind the reactants (their *substrates*) specifically at the **active center**. In the process, the substrates are oriented in relation to each other in such a way that they take on the *optimal orientation* for the formation of the transition state (**1**–**3**). The **proximity and orientation of the substrates** therefore strongly increase the likelihood that *productive* A–B complexes will arise. In addition, binding of the substrates results in removal of their hydration shells. As a result of the **exclusion of water**, very different conditions apply in the active center of the enzyme during catalysis than in solution (**3**–**5**). A third important factor is the **stabilization of the transition state** as a result of interactions between the amino acid residues of the protein and the substrate (**4**). This further reduces the activation energy needed to create the transition state. Many enzymes also take up groups from the substrates or transfer them to the substrates during catalysis.

Proton transfers are particularly common. This **acid–base catalysis** by enzymes is much more effective than the exchange of protons between acids and bases in solution. In many cases, chemical groups are temporarily bound covalently to the amino acid residues of the enzyme or to coenzymes during the catalytic cycle. This effect is referred to as **covalent catalysis** (see the transaminases, for example; p. 178). The principles of enzyme catalysis sketched out here are discussed in greater detail on p. 100 using the example of lactate dehydrogenase.

C. Principles of enzyme catalysis ◑

Although it is dif cult to provide quantitative estimates of the contributions made by individual catalytic effects, it is now thought that the enzyme's **stabilization of the transition state** is the most important factor. It is not tight binding of the *substrate* that is important, therefore—this would increase the activation energy required by the reaction, rather than reducing it—but rather the binding of the transition state. This conclusion is supported by the very high af nity of many enzymes for analogues of the transition state (see p. 96). A simple mechanical analogy may help clarify this (right). To transfer the metal balls (the reactants) from location EA (the substrate state) via the higher-energy transition state to EP (the product state), the magnet (the catalyst) has to be orientated in such a way that its attractive force acts on the transition state (bottom) rather than on EA (top).

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A. Uncatalyzed reaction

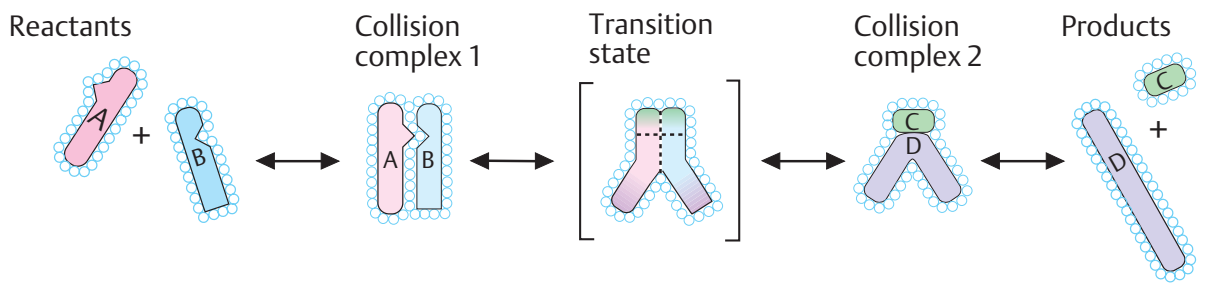

B. Enzyme-catalyzed reaction

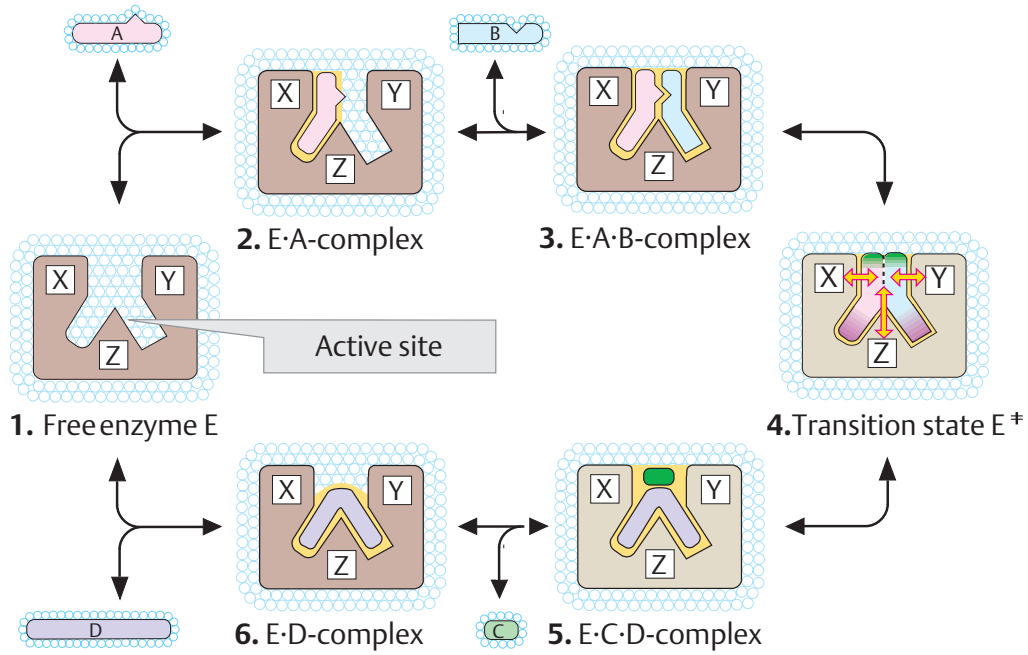

C. Principles of enzyme catalysis

a Approximation and orientation of the substrates

b Exclusion of water

c Stabilization of the transition state

d Group transfer

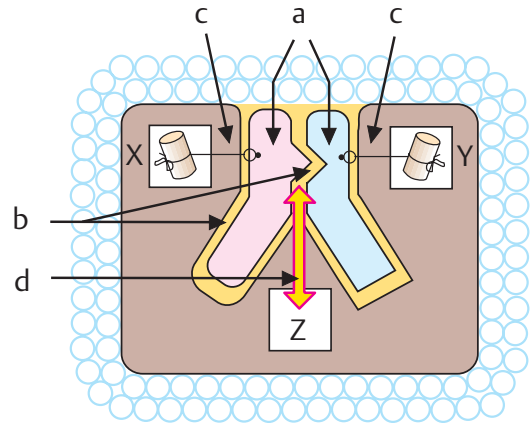

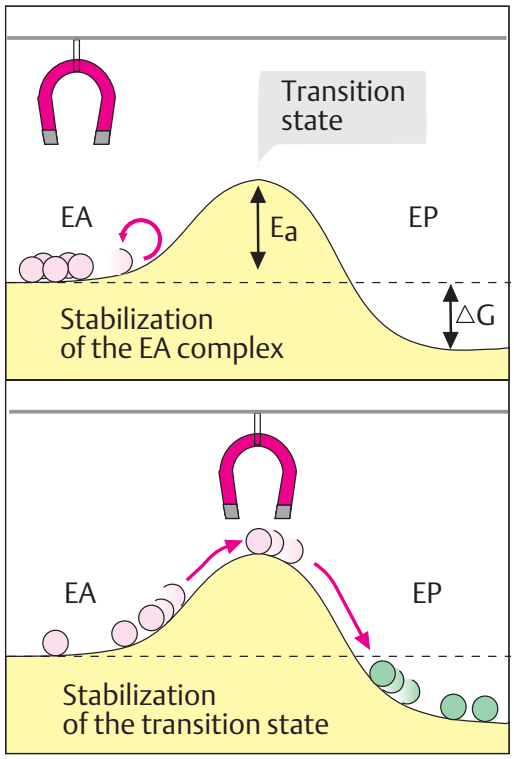

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Enzyme kinetics I

The **kinetics** of enzyme-catalyzed reactions (i. e., the dependence of the reaction rate on the reaction conditions) is mainly determined by the *properties of the catalyst.* It is therefore more complex than the kinetics of an uncatalyzed reaction (see p. 22). Here we discuss these issues using the example of a simple first-order reaction (see p. 22)

A. Michaelis–Menten kinetics ◑

In the absence of an enzyme, the reaction rate *v* is proportional to the concentration of substance A (top). The constant k is the *rate constant* of the uncatalyzed reaction. Like all catalysts, the enzyme E (total concentration $[E]_t$) creates a new reaction pathway. Initially, A is bound to E (partial reaction 1, left). If this reaction is in chemical equilibrium, then with the help of the law of mass action—and taking into account the fact that $[E]_t = [E] + [EA]$—one can express the concentration [EA] of the *enzyme–substrate* complex as a function of [A] (left). The **Michaelis constant** K_m thus describes the state of equilibrium of the reaction. In addition, we know that $k_{cat} > k$—in other words, enzyme-bound substrate reacts to B much faster than A alone (partial reaction 2, right). k_{cat}, the enzyme's **turnover number**, corresponds to the number of substrate molecules converted by one enzyme molecule per second. Like the conversion $A \rightarrow B$, the formation of B from EA is a first-order reaction—i. e., $v = k\ [EA]$ applies. When this equation is combined with the expression already derived for EA, the result is the **Michaelis–Menten equation.**

In addition to the *variables* v and [A], the equation also contains two *parameters* that do not depend on the substrate concentration [A], but describe properties of the enzyme itself: the product $k_{cat}\ [E]_g$ is the limiting value for the reaction rate at a very high [A], the **maximum velocity V_{max}** of the reaction (recommended abbreviation: V). The **Michaelis constant** K_m characterizes the *af nity* of the enzyme for a substrate. It corresponds to the substrate concentration at which *v* reaches half of V_{max} (if $v = V_{max}/2$, then $[A]/(K_m + [A]) = 1/2$, i. e. [A] is then $= K_m$). A *high* af nity of the enzyme for a substrate therefore leads to a *low* K_m value, and vice versa. Of the two enzymes whose *substrate saturation curves* are shown in diagram 1, enzyme 2 has the higher af nity for A [$K_m = 1$ mmol l^{-1}); V_{max}, by contrast, is much lower than with enzyme 1.

Since v approaches V *asymptotically* with increasing values of [A], it is dif cult to obtain reliable values for V_{max}—and thus for K_m as well—from diagrams plotting v against [A]. To get around this, the Michaelis–Menten equation can be arranged in such a way that the measured points lie on a *straight line.* In the **Lineweaver–Burk plot (2)**, 1/v is plotted against 1/[A]. The intersections of the line of best fit with the axes then produce $1/V_{max}$ and $-1/K_m$. This type of diagram is very clear, but for practical purposes it is less suitable for determining V_{max} and K_m. Calculation methods using personal computers are faster and more objective.

B. Isosteric and allosteric enzymes ◑

Many enzymes can occur in various *conformations* (see p. 72), which have different catalytic properties and whose proportion of the total number of enzyme molecules is influenced by substrates and other ligands (see pp. 116 and 280, for example). **Allosteric enzymes** of this type, which are usually present in oligomeric form, can be recognized by their S-shaped (*sigmoidal*) saturation curves, which cannot be described using the Michaelis model. In the case of isosteric enzymes (with only *one* enzyme conformation, **1**), the ef ciency of substrate binding (dashed curve) declines constantly with increasing [A], because the number of free binding sites is constantly decreasing. In most allosteric enzymes (**2**), the binding ef ciency initially rises with increasing [A], because the free enzyme is present in a low-af nity conformation (square symbols), which is gradually converted into a higher-af nity form (round symbols) as a result of binding with A. It is only at high [A] values that a lack of free binding sites becomes noticeable and the binding strength decreases again. In other words, the af nity of allosteric enzymes is not constant, but depends on the type and concentration of the ligand.

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A. Michaelis Menten kinetics

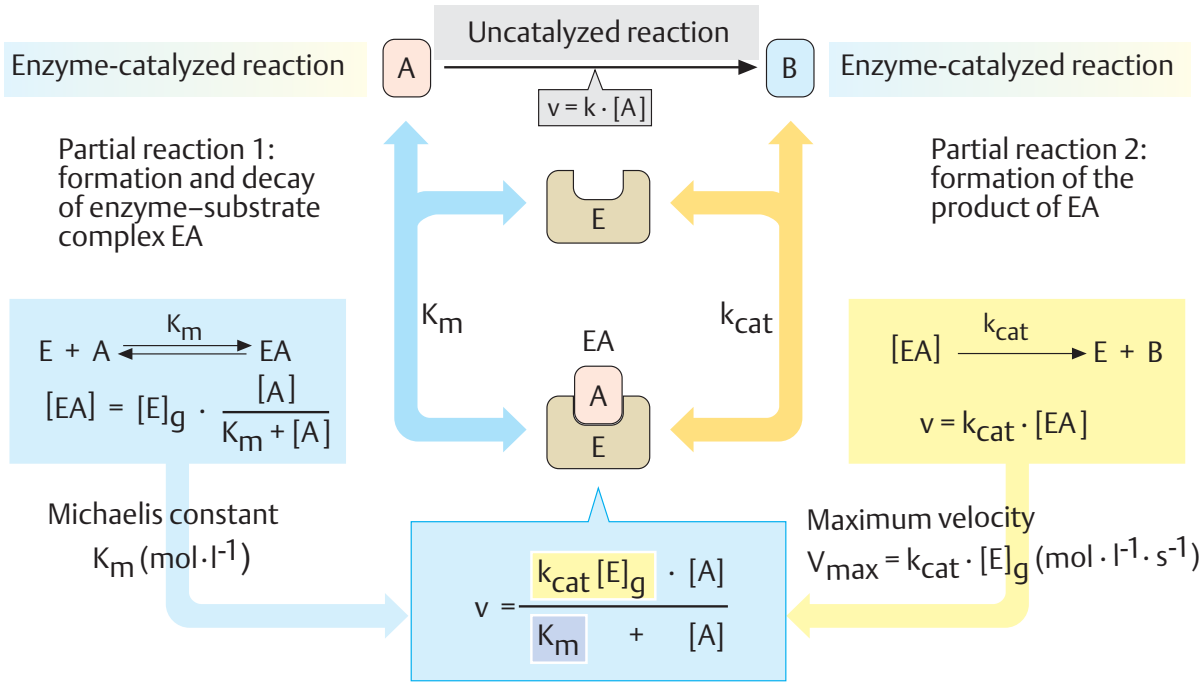

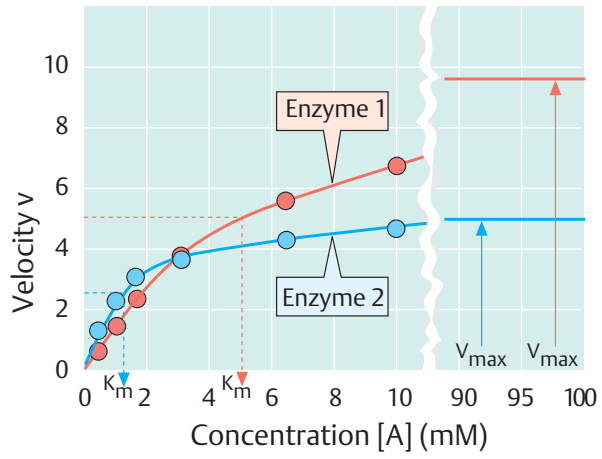

1. Hyperbolic plot

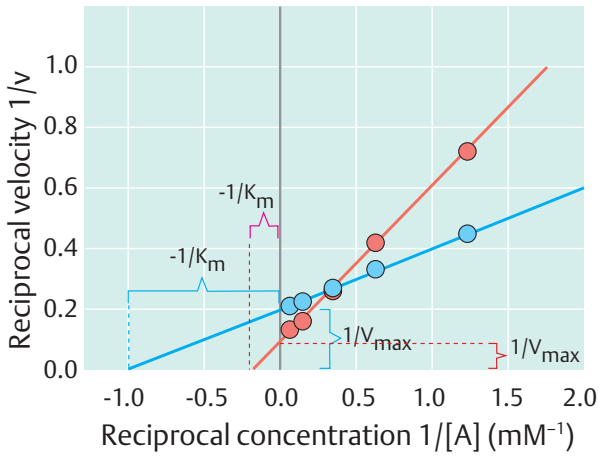

2. Lineweaver–Burk plot

B. Isosteric and allosteric enzymes

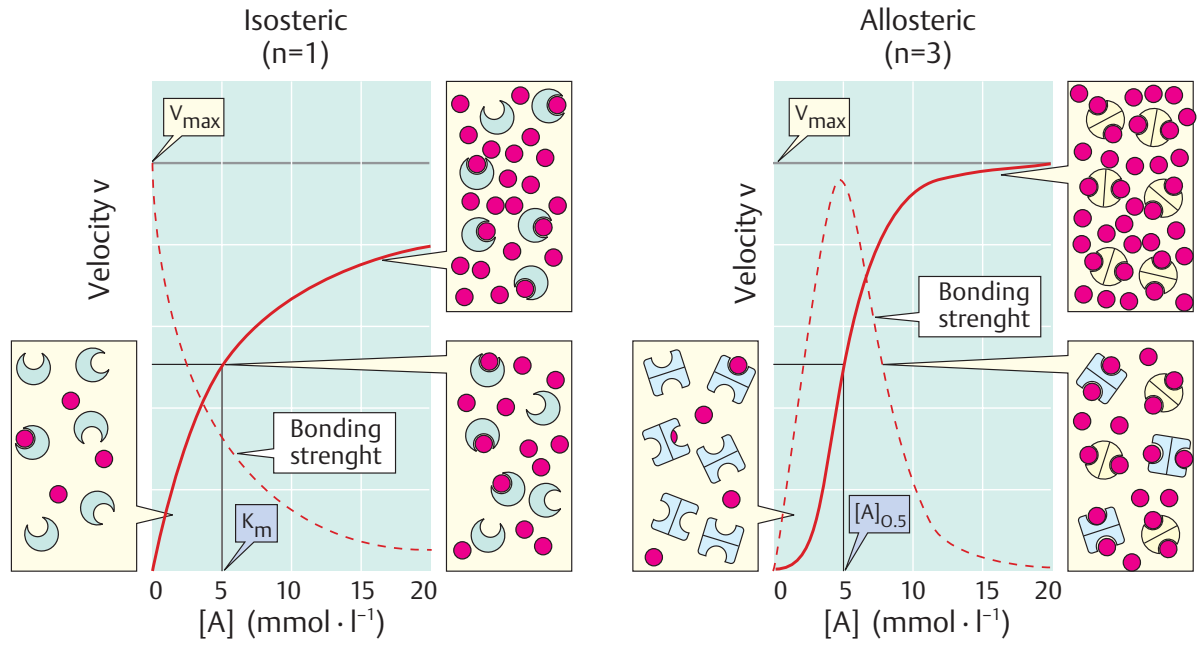

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Enzyme kinetics II

The catalytic properties of enzymes, and consequently their activity (see p. 90), are influenced by numerous factors, which all have to be optimized and controlled if activity measurements are to be carried out in a useful and reproducible fashion. These factors include physical quantities (temperature, pressure), the chemical properties of the solution (pH value, ionic strength), and the concentrations of the relevant substrates, cofactors, and inhibitors.

A. pH and temperature dependency of enzyme activity ◑

The effect of enzymes is strongly dependent on the pH value (see p. 30). When the activity is plotted against pH, a *bell-shaped curve* is usually obtained (**1**). With animal enzymes, the **pH optimum**—i. e., the pH value at which enzyme activity is at its maximum—is often close to the pH value of the cells (i. e., pH 7). However, there are also exceptions to this. For example, the proteinase *pepsin* (see p. 270), which is active in the acidic gastric lumen, has a pH optimum of 2, while other enzymes (at least in the test tube) are at their most active at pH values higher than 9. The bell shape of the activity–pH profile results from the fact that amino acid residues with ionizable groups in the side chain are essential for catalysis. In example (**1**), these are a basic group B ($pK_a = 8$), which has to be protonated in order to become active, and a second acidic amino acid AH ($pK_a = 6$), which is only active in a dissociated state. At the optimum pH of 7, around 90% of both groups are present in the active form; at higher and lower values, one or the other of the groups increasingly passes into the inactive state.

The **temperature dependency** of enzymatic activity is usually asymmetric. With increasing temperature, the increased thermal movement of the molecules initially leads to a rate acceleration (see p. 22). At a certain temperature, the enzyme then becomes unstable, and its activity is lost within a narrow temperature difference as a result of denaturation (see p. 74). The optimal temperatures of the enzymes in higher organisms rarely exceed 50 °C, while enzymes from thermophilic bacteria found in hot springs, for instance, may still be active at 100 °C.

B. Substrate specificity ◑

Enzymes "recognize" their substrates in a highly specific way (see p. 88). It is only the marked **substrate specificity** of the enzymes that makes a regulated metabolism possible. This principle can be illustrated using the example of the two closely related proteinases *trypsin* and *chymotrypsin*. Both belong to the group of serine proteinases and contain the same "triad" of catalytically active residues (Asp–His–Ser, shown here in green; see p. 176). Trypsin selectively cleaves peptide bonds on the C-terminal side of basic amino acids (lysine and arginine), while chymotrypsin is specific for hydrophobic residues. The substrate binding "pockets" of both enzymes have a similar structure, but their amino acid sequences differ slightly. In trypsin, a negatively charged aspartate residue (Asp-189, red) is arranged in such a way that it can bind and fix the basic group in the side chain of the substrate. In chymotrypsin, the "binding pocket" is slightly narrower, and it is lined with neutral and hydrophobic residues that stabilize the side chains of apolar substrate amino acids through hydrophobic interactions (see p. 28).

C. Bisubstrate kinetics ○

Almost all enzymes—in contrast to the simplified description given on p. 92—have more than one substrate or product. On the other hand, it is rare for more than two substrates to be bound *simultaneously*. In bisubstrate reactions of the type $A + B \rightarrow C + D$, a number of reaction sequences are possible. In addition to the *sequential mechanisms* (see p. 90), in which all substrates are bound in a specific sequence before the product is released, there are also mechanisms in which the first substrate A is bound and immediately cleaved. A part of this substrate remains bound to the enzyme, and is then transferred to the second substrate B after the first product C has been released. This is known as the **ping-pong mechanism**, and it is used by *transaminases*, for example (see p. 178). In the Lineweaver–Burk plot (right; see p. 92), it can be recognized in the parallel shifting of the lines when [B] is varied.

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A. pH and temperature dependency of enzyme activity

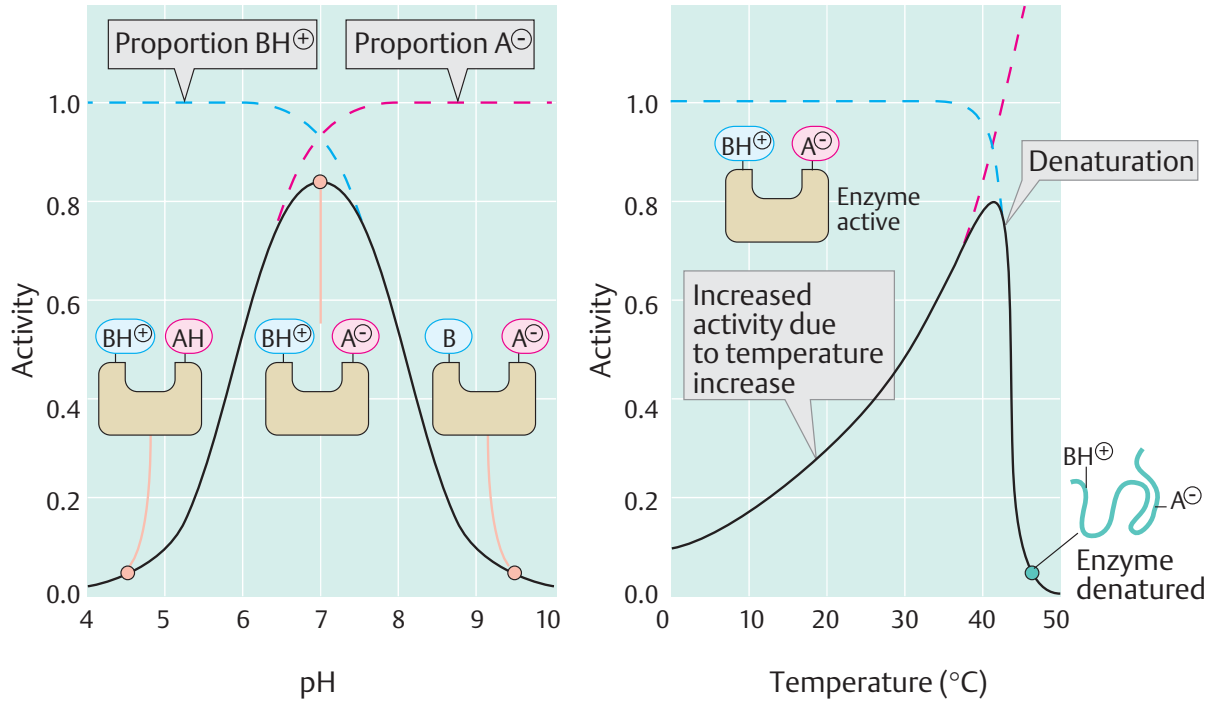

B. Substrate specificity

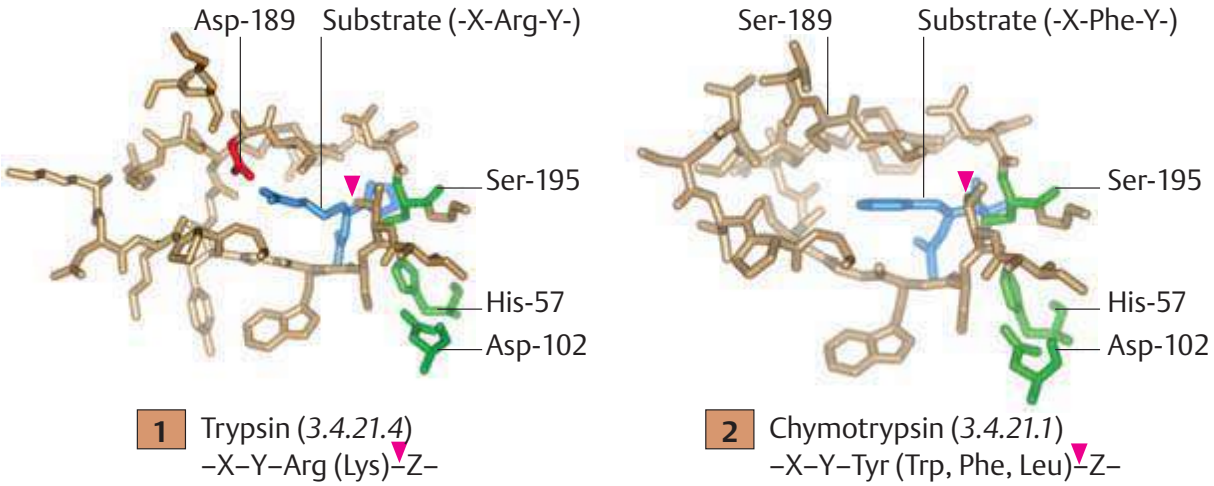

1 Trypsin (*3.4.21.4*)
–X–Y–Arg (Lys)–Z–

2 Chymotrypsin (*3.4.21.1*)
–X–Y–Tyr (Trp, Phe, Leu)–Z–

C. Bisubstrate kinetics

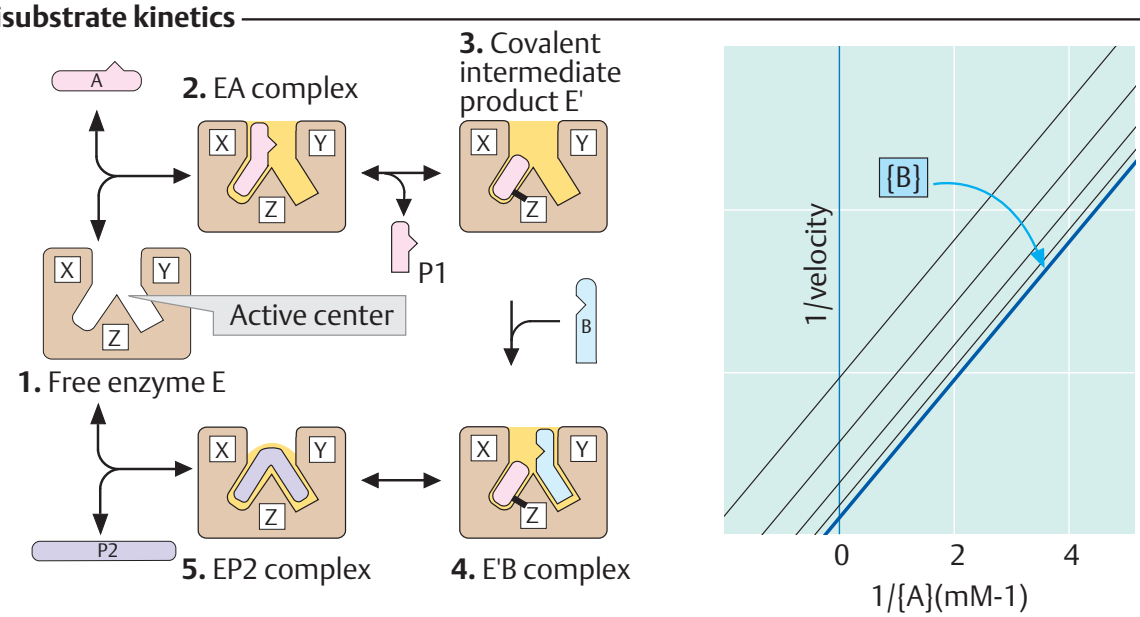

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Inhibitors

Many substances can affect metabolic processes by influencing the activity of enzymes. **Enzyme inhibitors** are particularly important here. A large proportion of **medicines** act as enzyme inhibitors. Enzyme-kinetic experiments are therefore an important aspect of drug development and testing procedures. Natural *metabolites* are also involved in regulatory processes as inhibitors (see p. 114).

A. Types of inhibitor ◑

Most enzyme inhibitors act **reversibly**—i. e., they do not cause any permanent changes in the enzyme. However, there are also **irreversible** inhibitors that permanently modify the target enzyme. The mechanism of action of an inhibitor—its **inhibition type**—can be determined by comparing the kinetics (see p. 92) of the inhibited and uninhibited reactions (**B**). This makes it possible to distinguish *competitive inhibitors* (left) from *noncompetitive inhibitors* (right), for example. *Allosteric inhibition* is particularly important for metabolic regulation (see below).

Substrate analogs (**2**) have properties similar to those of one of the substrates of the target enzyme. They are bound by the enzyme, but cannot be converted further and therefore *reversibly* block some of the enzyme molecules present. A *higher* substrate concentration is therefore needed to achieve a half-maximum rate; the Michaelis constant K_m increases (**B**). High concentrations of the substrate displace the inhibitor again. The maximum rate V_{max} is therefore not influenced by this type of inhibition. Because the substrate and the inhibitor compete with one another for the *same* binding site on the enzyme, this type of inhibition is referred to as **competitive**. **Analogs of the transition state** (**3**) usually also act competitively.

When an inhibitor interacts with a group that is important for enzyme activity, but does not affect binding of the substrate, the inhibition is **non-competitive** (right). In this case, K_m remains unchanged, but the concentration of functional enzyme $[E]_t$, and thus V_{max}, decrease. Non-competitive inhibitors generally act irreversibly, by modifying functional groups of the target enzyme (**4**).

"Suicide substrates" (**5**) are substrate analogs that also contain a reactive group. Initially, they bind reversibly, and then they form a covalent bond with the active center of the enzyme. Their effect is therefore also non-competitive. A well-known example of this is the antibiotic *penicillin* (see p. 254).

Allosteric inhibitors bind to a separate binding site outside the active center (**6**). This results in a *conformational change* in the enzyme protein that indirectly reduces its activity (see p. 116). Allosteric effects practically only occur in *oligomeric enzymes.* The kinetics of this type of system can no longer be described using the simple Michaelis–Menten model.

B. Inhibition kinetics ◑

In addition to the Lineweaver–Burk plot (see p. 92), the *Eadie–Hofstee plot* is also commonly used. In this case, the velocity v is plotted against v /[A]. In this type of plot, V_{max} corresponds to the intersection of the approximation lines with the v axis, while K_m is derived from the gradient of the lines. Competitive and non-competitive inhibitors are also easily distinguishable in the Eadie—Hofstee plot. As mentioned earlier, **competitive** inhibitors only influence K_m, and not V_{max}. The lines obtained in the absence and presence of an inhibitor therefore intersect on the ordinate. **Non-competitive inhibitors** produce lines that have the same slope (K_m unchanged) but intersect with the ordinate at a lower level. Another type of inhibitor, not shown here, in which V_{max} and K_m are reduced by the same factor, is referred to as **uncompetitive**. Inhibitors with purely uncompetitive effects are rare. A possible explanation for this type of inhibition is selective binding of the inhibitor to the EA complex.

Allosteric enzymes shift the target enzyme's saturation curve to the left (see p. 92). In Eadie–Hofstee and Lineweaver–Burk plots (see p. 92), allosteric enzymes are recognizable because they produce curved lines (not shown).

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A. Types of inhibitor

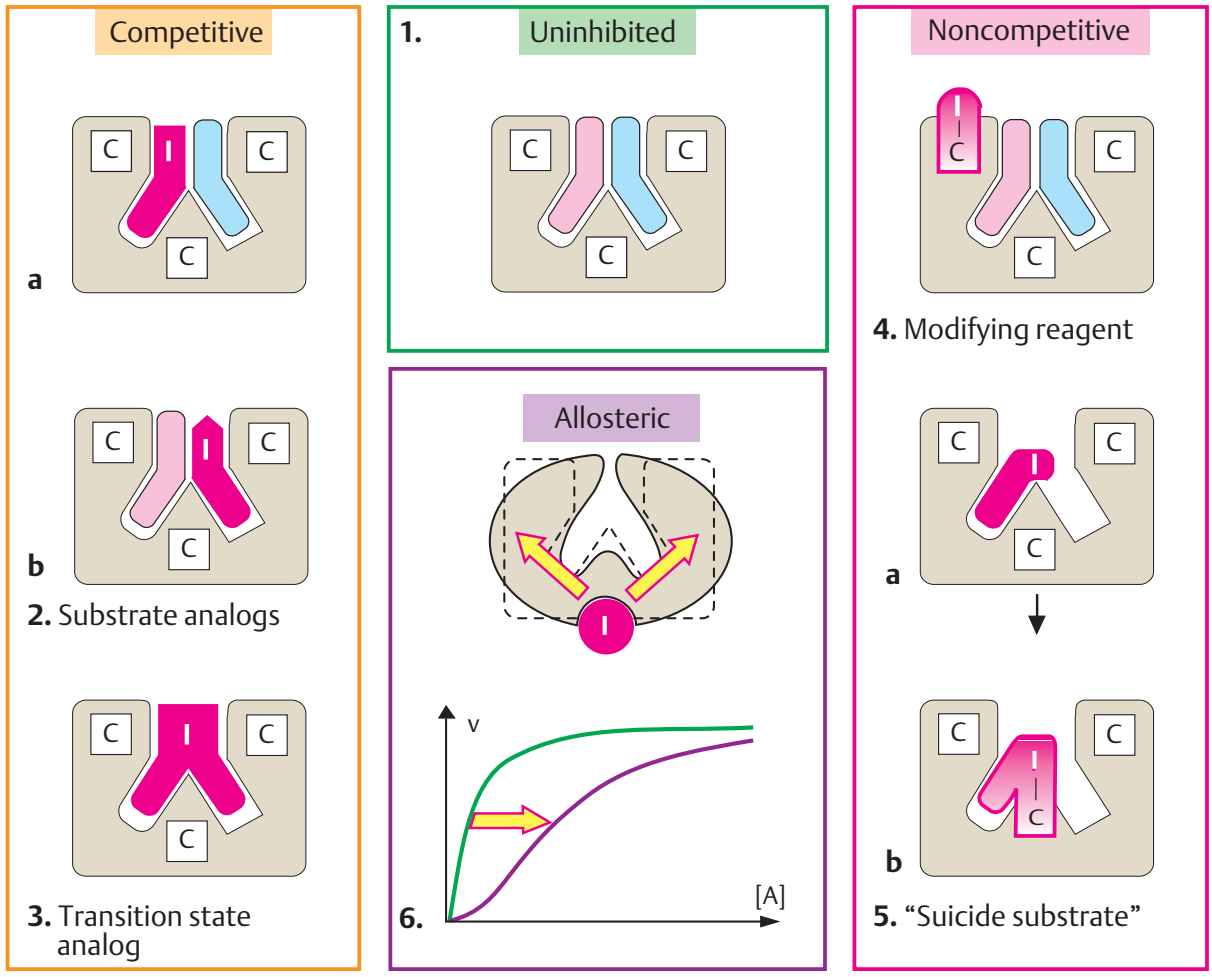

B. Kinetics of inhibition

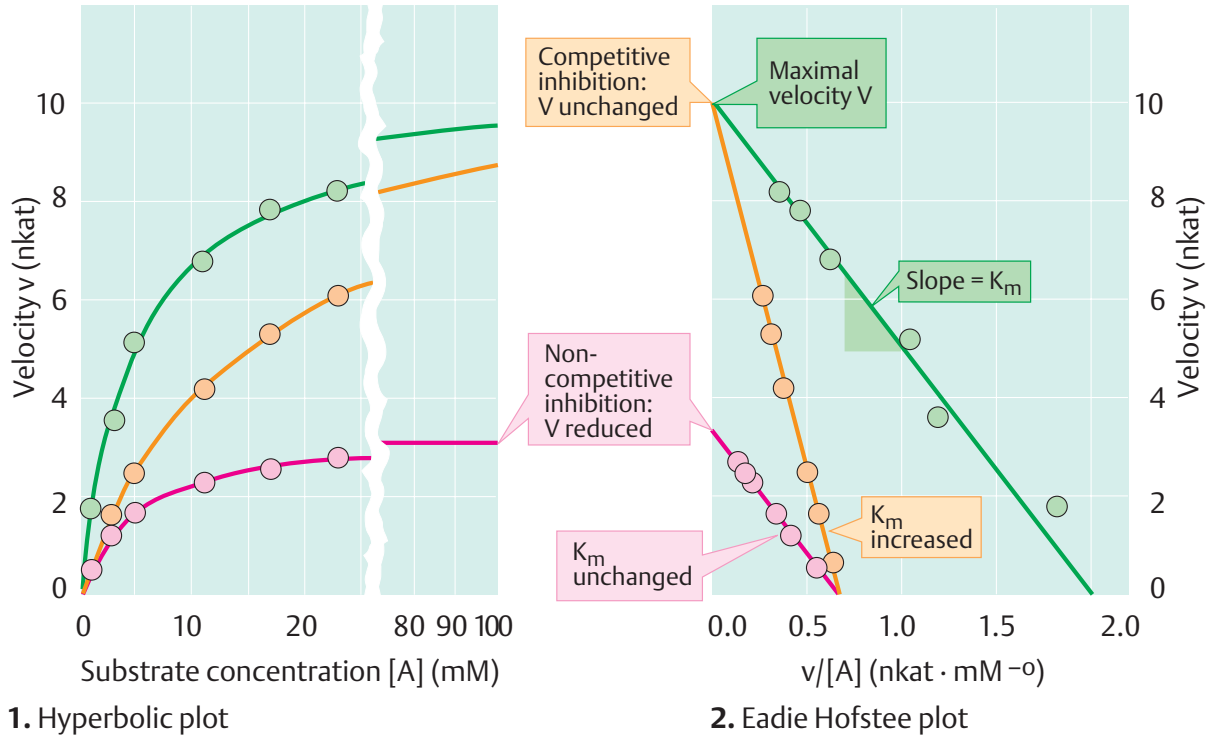

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Lactate dehydrogenase: structure

Lactate dehydrogenase (LDH, *EC 1.1.1.27*) is discussed in some detail here and on the next page as an example of the structure and function of an enzyme.

A. Lactate dehydrogenase: structure ○

The active form of lactate dehydrogenase (mass 144 kDa) is a **tetramer** consisting of four subunits (**1**). Each monomer is formed by a peptide chain of 334 amino acids (36 kDa). In the tetramer, the subunits occupy *equivalent positions* (**1**); each monomer has an active center. Depending on metabolic conditions, LDH catalyzes NADH-dependent reduction of pyruvate to lactate, or NAD^+-dependent oxidation of lactate to pyruvate (see p. 18).

The active center of an LDH subunit is shown schematically in Fig. **2**. The peptide backbone is shown as a light blue tube. Also shown are the substrate *lactate* (red), the coenzyme *NAD^+* (yellow), and three amino acid side chains (Arg-109, Arg-171, and His-195; green), which are directly involved in the catalysis. A *peptide loop* (pink) formed by amino acid residues 98–111 is also shown. In the absence of substrate and coenzyme, this partial structure is open and allows access to the substrate binding site (not shown). In the enzyme lactate NAD^+ complex shown, the peptide loop closes the active center. The catalytic cycle of lactate dehydrogenase is discussed on the next page.

B. Isoenzymes ◑

There are two *different* LDH subunits in the organism—M and H—which have a slightly different amino acid sequence and consequently different catalytic properties. As these two subunits can associate to form tetramers randomly, a total of five different **isoenzymes** of LDH are found in the body.

Fig. **1** shows sections from the amino acid sequences of the two subunits, using the single-letter notation (see p. 60). A common precursor gene was probably duplicated at some point in evolution. The two genes then continued to develop further independently of each other through mutation and selection.

The differences in sequence between the M and H subunits are mainly *conservative*—i. e., both residues are of the same type, e. g. glycine (G) and alanine (A), or arginine (R) and lysine (K). Non-conservative exchanges are less frequent—e. g., lysine (K) for glutamine (Q), or threonine (T) for glutamic acid (E). Overall, the H subunit contains more acidic and fewer basic residues than the M form, and it therefore has a more strongly negative charge. This fact is exploited to separate the isoenzymes using electrophoresis (**2**; see pp. 78, 276). The isoenzyme LDH-1, consisting of four H subunits, migrates fastest, and the M_4 isoenzyme is slowest.

The separation and analysis of isoenzymes in blood samples is important in the diagnosis of certain diseases. Normally, only small amounts of enzyme activity are found in serum. When an organ is damaged, intracellular enzymes enter the blood and can be demonstrated in it (**serum enzyme diagnosis**). The total activity of an enzyme reflects the severity of the damage, while the type of isoenzyme found in the blood provides evidence of the site of cellular injury, since each of the genes is expressed in the various organs at different levels. For example, the liver and skeletal muscles mainly produce M subunits of lactate dehydrogenase (M for muscle), while the brain and cardiac muscle mainly express H subunits (H for heart). In consequence, each organ has a characteristic *isoenzyme pattern* (**3**). Following cardiac infarction, for example, there is a strong increase in the amount of LDH-1 in the blood, while the concentration of LDH-5 hardly changes. The isoenzymes of *creatine kinase* (see p. 336) are also of diagnostic importance.

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A. Lactate dehydrogenase: structure

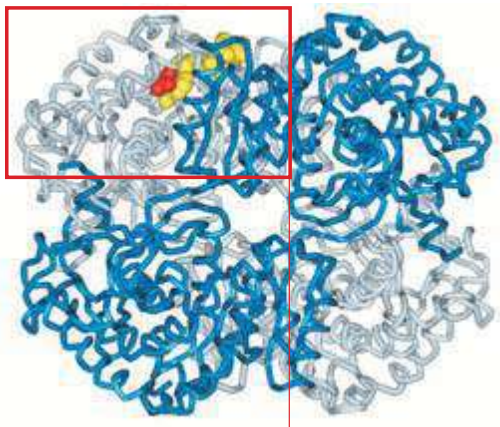

1. Tetramer 144 kDa

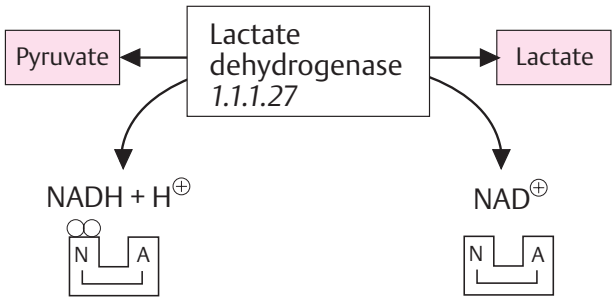

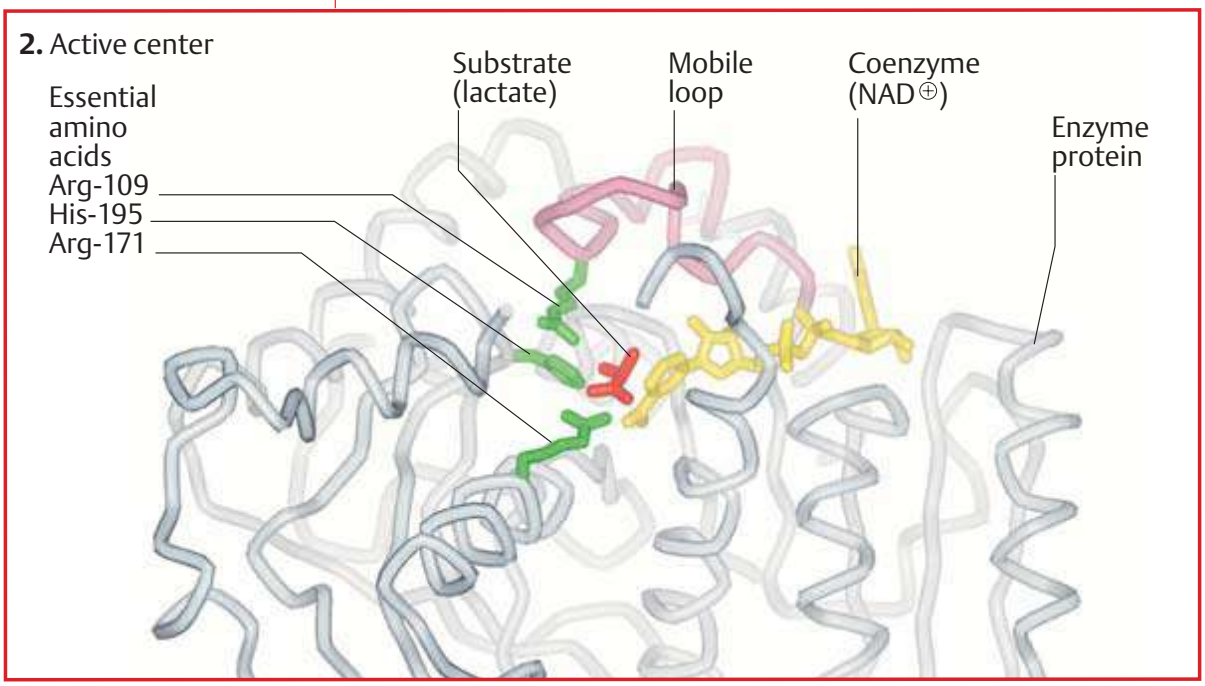

B. Isoenzymes

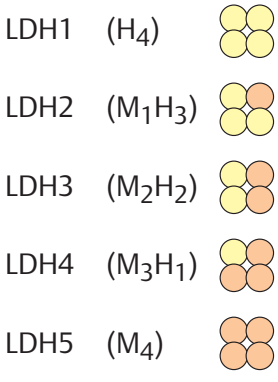

2. Forms

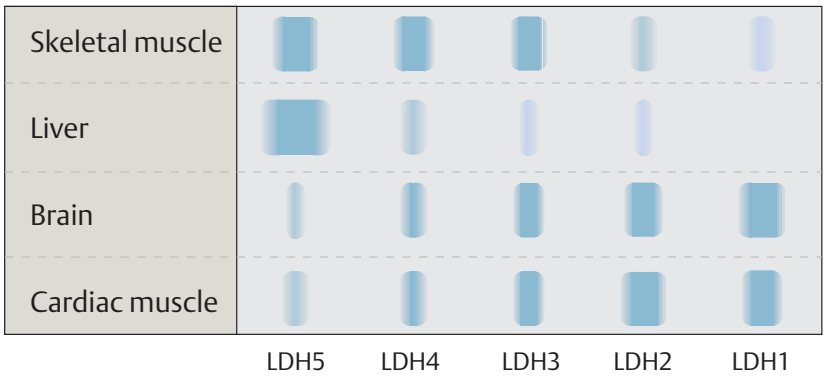

3. Separation by gel electrophoresis

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Lactate dehydrogenase: mechanism

The principles of enzyme catalysis discussed on p. 90 can be illustrated using the reaction mechanism of lactate dehydrogenase (LDH) as an example.

A. Lactate dehydrogenase: catalytic cycle ○

LDH catalyzes the transfer of hydride ions (see p. 32) from lactate to NAD^+ or from NADH to pyruvate.

$$\text{L-lactate} + NAD^+ \leftrightarrows \text{pyruvate} + NADH + H^+$$

The equilibrium of the reaction strongly favors lactate *formation*. At high concentrations of lactate and NAD^+, however, oxidation of lactate to pyruvate is also possible (see p. 18). LDH catalyzes the reaction in *both* directions, but—like all enzymes—it has *no* effect on chemical equilibrium.

As the reaction is reversible, the catalytic process can be represented as a closed loop. The **catalytic cycle** of LDH is reduced to six "snapshots" here. Intermediate steps in catalysis such as those shown here are extremely short-lived and therefore dif cult to detect. Their existence was deduced indirectly from a large number of experimental findings—e. g., kinetic and binding measurements.

Many amino acid residues play a role in the **active center** of LDH. They can mediate the binding of the substrate and coenzyme, or take part in one of the steps in the catalytic cycle directly. Only the side chains of three particularly important residues are shown here. The positively charged guanidinium group of **arginine-171** binds the carboxylate group of the substrate by electrostatic interaction. The imidazole group of **histidine-195** is involved in acid–base catalysis, and the side chain of **arginine-109** is important for the stabilization of the transition state. In contrast to His-195, which changes its charge during catalysis, the two essential arginine residues are constantly protonated. In addition to these three residues, the **peptide loop 98–111** mentioned on p. 98 is also shown here schematically (red). Its function consists of closing the active center after binding of the substrate and coenzyme, so that water molecules are largely excluded during the electron transfer.

We can now look at the **partial reactions** involved in LDH-catalyzed pyruvate reduction.

In the free enzyme, His195 is protonated (**1**). This form of the enzyme is therefore described as E H^+. The coenzyme NADH is bound first (**2**), followed by pyruvate (**3**). It is important that the carbonyl group of the pyruvate in the enzyme and the active site in the nicotinamide ring of the coenzyme should have a fairly optimal position in relation to each other, and that this orientation should become fixed (*proximity and orientation of the substrates*). The 98–111 loop now closes over the active center. This produces a marked decrease in polarity, which makes it easier to achieve the **transition state** (**4**; *water exclusion*). In the transition state, a hydride ion, H^- (see p. 32), is transferred from the coenzyme to the carbonyl carbon (*group transfer*). The transient—and energetically unfavorable—negative charge on the oxygen that occurs here is stabilized by electrostatic interaction with Arg-109 (*stabilization of the transition state*). At the same time, a proton from His-195 is transferred to this oxygen atom (*group transfer*), giving rise to the enzyme-bound products lactate and NAD^+ (**5**). After the loop opens, lactate dissociates from the enzyme, and the temporarily uncharged imidazole group in His-195 again binds a proton from the surrounding water (**6**). Finally, the oxidized coenzyme NAD^+ is released, and the initial state (**1**) is restored. As the diagram shows, the proton that appears in the reaction equation ($NADH + H^+$) is not bound together with NADH, but after release of the lactate—i. e., between steps (**5**) and (**6**) of the *previous* cycle.

Exactly the same steps occur during the oxidation of lactate to pyruvate, but in the opposite direction. As mentioned earlier, the direction which the reaction takes depends not on the enzyme, but on the equilibrium state—i. e., on the concentrations of all the reactants and the pH value (see p. 18).

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A. Lactate dehydrogenase: catalytic cycle

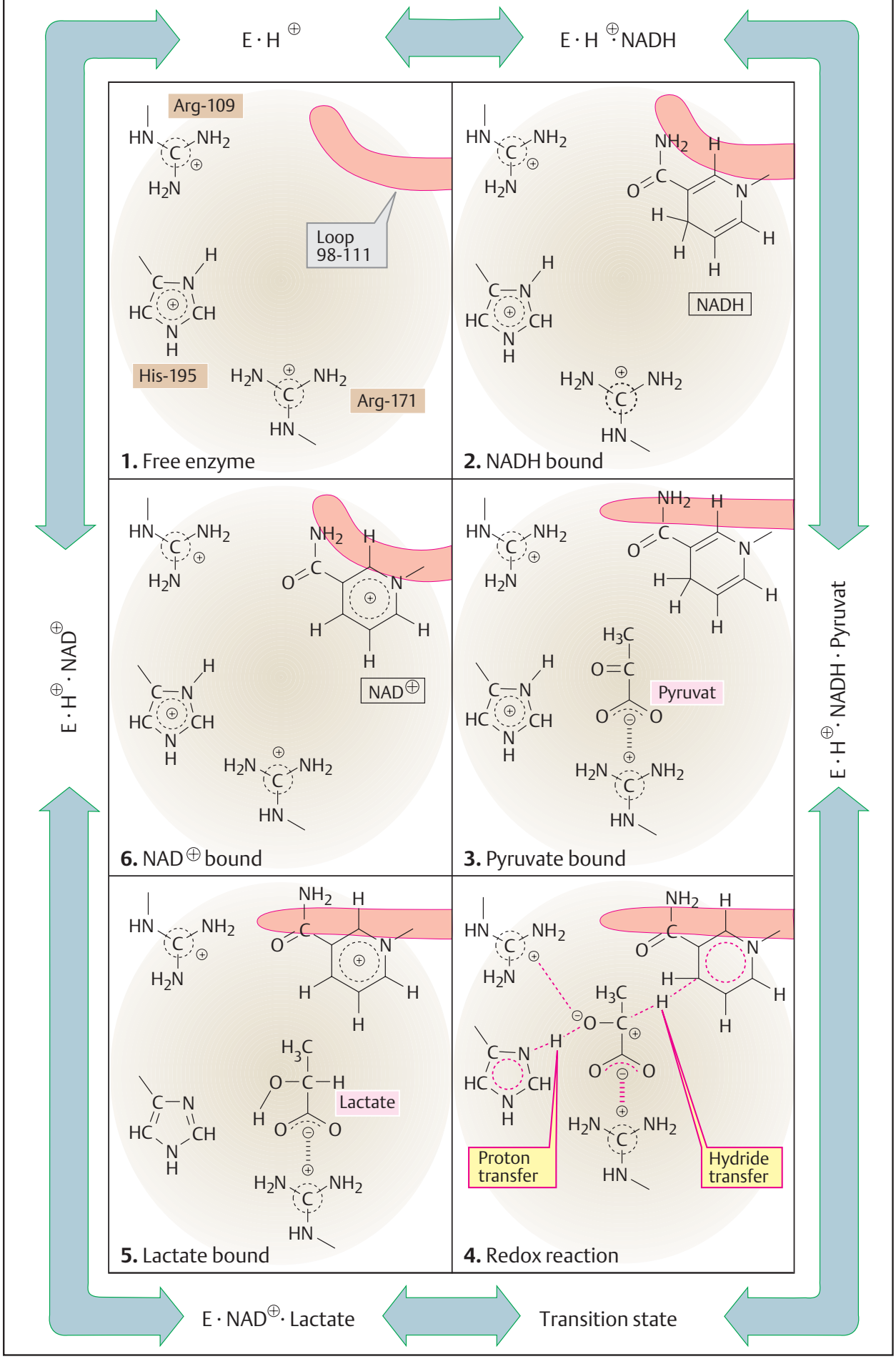

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Enzymatic analysis

Enzymes play an important role in *biochemical analysis*. In biological material—e. g., in body fluids—even tiny quantities of an enzyme can be detected by measuring its catalytic activity. However, enzymes are also used as *reagents* to determine the concentrations of metabolites—e. g., the blood glucose level (**C**). Most enzymatic analysis procedures use the method of spectrophotometry (**A**).

A. Principle of spectrophotometry ○

Many substances *absorb* light in the visible or ultraviolet region of the spectrum. This property can be used to determine the concentration of such a substance. The extent of light absorption depends on the type and concentration of the substance and on the wavelength of the light used. **Monochromatic light**—i. e., light with a defined wavelength isolated from white light using a monochromator—is therefore used. Monochromatic light with an intensity of I_0 is passed through a rectangular vessel made of glass or quartz (a *cuvet*), which contains a solution of the absorbing substance. The **absorption A** of the solution (often also referred to as its *extinction*) is defined as the *negative decadic logarithm of the quotient* I/I_0. The **Beer–Lambert law** states that A is proportional to the concentration c of the absorbing substance and the thickness d of the solution it passes through. As mentioned earlier, the **absorption coef•cient** ε depends on the type of substance and the wavelength.

B. Measurement of lactate dehydrogenase activity ○

Measurement of lactate dehydrogenase (LDH) activity takes advantage of the fact that while the reduced coenzyme NADH + H^+ absorbs light at 340 nm, oxidized NAD^+ does not. *Absorption spectra* (i. e., plots of A against the wavelength) for the substrates and the coenzymes of the LDH reaction are shown in Fig. **1**. Differences in absorption behavior between NAD^+ and NADH between 300 and 400 nm result from changes in the nicotinamide ring during oxidation or reduction (see p. 32). To measure the activity, a solution containing lactate and NAD^+ is placed in a cuvet, and absorption is recorded at a *constant wavelength* of 340 nm. The uncatalyzed LDH reaction is very slow. It is only after addition of the enzyme that measurable quantities of NADH are formed and absorption increases. Since according to the Beer–Lambert law the rate of the increase in absorption $\Delta A/\Delta t$ is proportional to the reaction rate $\Delta c/\Delta t$. The absorption coef cient ε at 340 nm or comparison with a standard solution can be used to calculate LDH activity.

C. Enzymatic determination of glucose ○

Most biomolecules do not show any absorption in the visible or ultraviolet spectrum. In addition, they are usually present in the form of mixtures with other—similar—compounds that would also react to a chemical test procedure. These two problems can be avoided by using an appropriate enzyme to produce a colored dye selectively from the metabolite that is being analyzed. The absorption of the dye can then be measured.

A procedure (**1**) that is often used to measure glucose when monitoring blood glucose levels (see p. 160) involves two successive reactions. The glucose-specific enzyme *glucose oxidase* (obtained from fungi) first produces hydrogen peroxide, H_2O_2, which in the second step—catalyzed by a *peroxidase*—oxidizes a colorless precursor into a green dye (**2**). When all of the glucose in the sample has been used up, the amount of dye formed—which can be measured on the basis of its light absorption—is equivalent to the quantity of glucose originally present.

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A. Principle of spectrophotometry

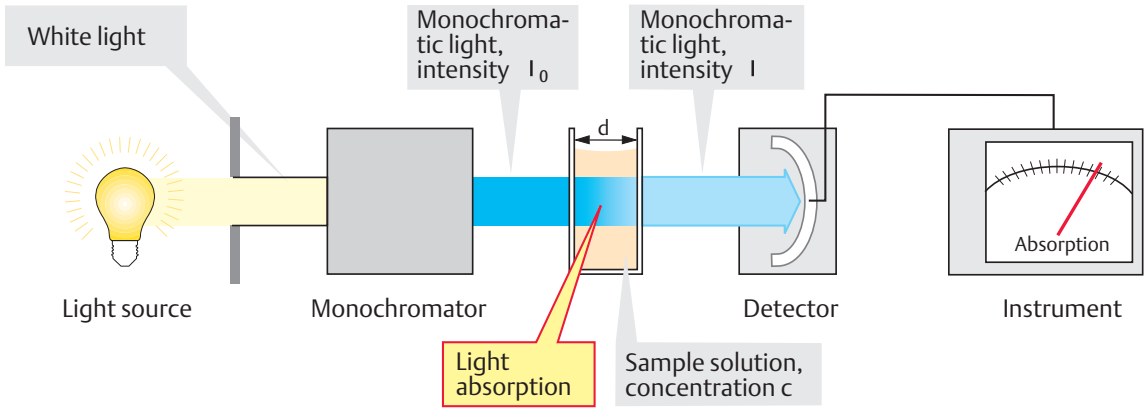

Absorption $A = -\log \frac{I}{I_0} = \varepsilon \cdot c \cdot d$ Beer Lambert law

B. Assay of lactate dehydrogenase activity

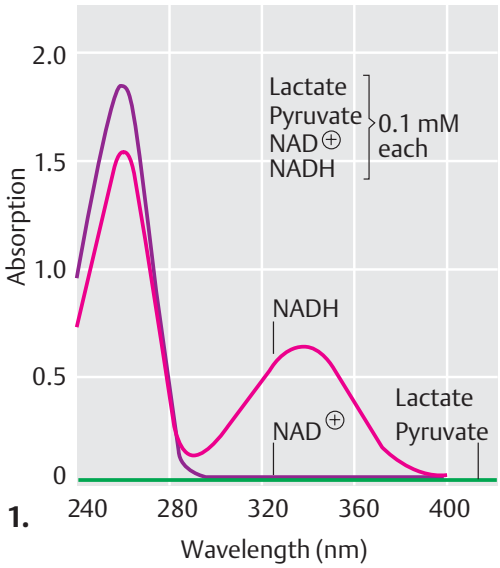

1.

$\frac{\Delta A}{\varepsilon} = \Delta c$; $\frac{\Delta A}{\Delta t \cdot \varepsilon} = \frac{\Delta c}{\Delta t} = v$; $v \approx$ Activity

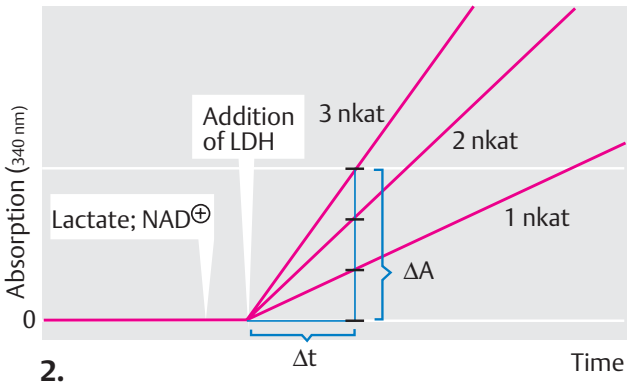

2.

C. Enzymatic determination of glucose

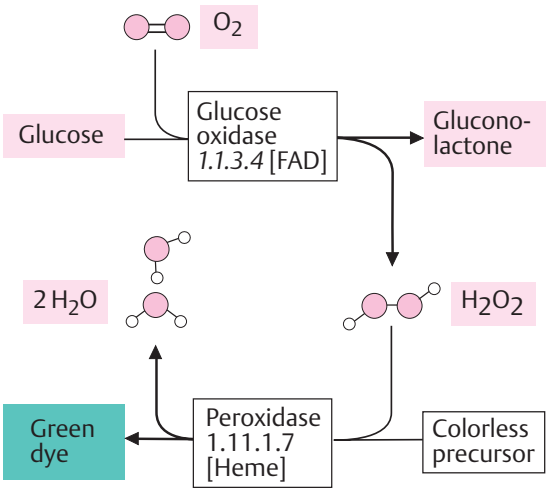

1. Reaction

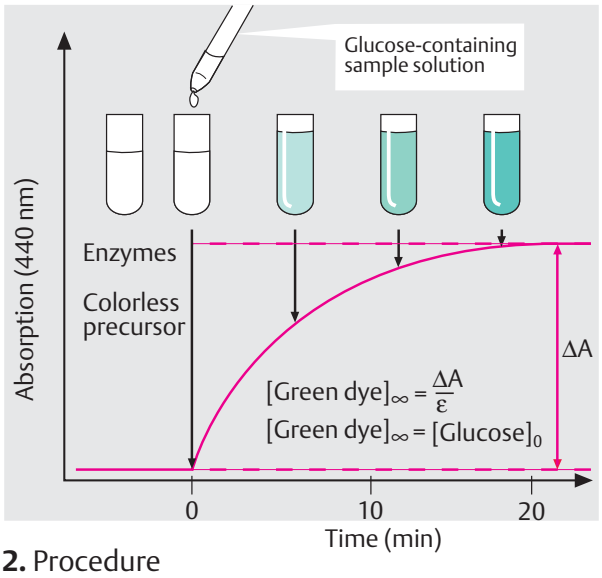

2. Procedure

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Coenzymes 1

A. Coenzymes: definitions ●

In many enzyme-catalyzed reactions, electrons or groups of atoms are transferred from one substrate to another. This type of reaction always also involves additional molecules, which temporarily accept the group being transferred. Helper molecules of this type are called **coenzymes**. As they are not catalytically active themselves, the less frequently used term *"cosubstrate"* would be more appropriate. In contrast to substrates for which a given enzyme is usually specific (see p. 88), coenzymes cooperate with many enzymes of varying substrate specificity. We have rather arbitrarily divided the coenzymes here into group-transferring and redox coenzymes. Strictly speaking, redox coenzymes also transfer groups—namely, reducing equivalents (see p. 32).

Depending on the type of interaction with the enzyme, a distinction is made between soluble coenzymes and prosthetic groups. **Soluble coenzymes** (**1**) are *bound like substrates* during a reaction, undergo a chemical change, and are then *released again*. The original form of the coenzyme is regenerated by a second, independent reaction. **Prosthetic groups** (**2**), on the other hand, are coenzymes that are *tightly bound to the enzyme* and remain associated with it during the reaction. The part of the substrate bound by the coenzyme is later transferred to another substrate or coenzyme of the *same* enzyme (not shown in Fig. **2**).

B. Redox coenzymes 1 ◑

All oxidoreductases (see p. 88) require coenzymes. The most important of these redox coenzymes are shown here. They can act in soluble form (S) or prosthetically (P). Their normal potentials $E^{0'}$ are shown in addition to the type of reducing equivalent that they transfer (see p. 18).

The pyridine nucleotides **NAD^+** and **$NADP^+$** (**1**) are widely distributed as coenzymes of dehydrogenases. They transport *hydride ions* ($2e^-$ and $1\ H^+$; see p. 32) and *always* act in soluble form. NAD^+ transfers reducing equivalents from catabolic pathways to the respiratory chain and thus contributes to energy metabolism. In contrast, reduced $NADP^+$ is the most important *reductant* involved in biosynthesis (see p. 112).

The flavin coenzymes **FMN** and **FAD** (**2**, **3**) contain *flavin* (isoalloxazine) as a redox-active group. This is a three-membered, *N*-containing ring system that can accept a maximum of two electrons and two protons during reduction. FMN carries the phosphorylated sugar alcohol *ribitol* at the flavin ring. FAD arises from FMN through bonding with AMP. The two coenzymes are functionally similar. They are found in *dehydrogenases, oxidases,* and *monooxygenases*. In contrast to the pyridine nucleotides, flavin reactions give rise to *radical intermediates* (see p. 32). To prevent damage to cell components, the flavins always remain bound as prosthetic groups in the enzyme protein.

The role of **ubiquinone** (coenzyme Q, **4**) in transferring reducing equivalents in the respiratory chain is discussed on p. 140. During reduction, the *quinone* is converted into the *hydroquinone* (ubiquinol). The isoprenoid side chain of ubiquinone can have various lengths. It holds the molecule in the membrane, where it is freely mobile. Similar coenzymes are also found in photosynthesis (plastoquinone; see p. 132). *Vitamins E and K* (see p. 52) also belong to the quinone/hydroquinone systems.

L-Ascorbic acid (vitamin C, **5**) is a powerful reducing agent. As an **antioxidant**, it provides nonspecific protection against oxidative damage (see p. 284), but it is also an essential **cofactor** for various monooxygenases and dioxygenases. Ascorbic acid is involved in the hydroxylation of proline and lysine residues during the biosynthesis of collagen (see p. 344), in the synthesis of catecholamines (see p. 352) and bile acids (see p. 314), as well as in the breakdown of tyrosine (see p. 415). The reduced form of the coenzyme is a relatively strong acid and forms salts, the **ascorbates**. The oxidized form is known as **dehydroascorbic acid**. The stimulation of the immune system caused by ascorbic acid has not yet been fully explained.

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A. Coenzymes: definitions

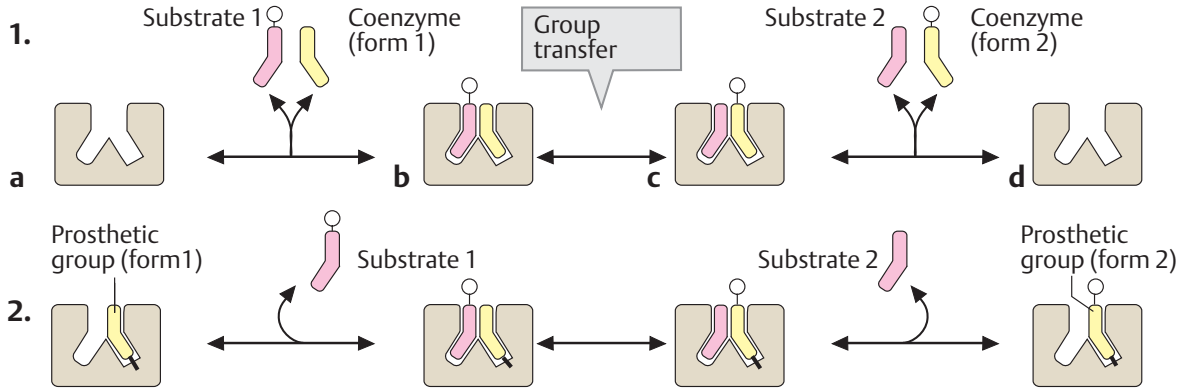

B. Redox coenzymes

Coenzyme	Oxidized form	Reduced form	Type	Trans-ferred	$E^{0\prime}$ (V)
1. NAD(P)$^{\oplus}$ 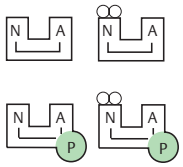	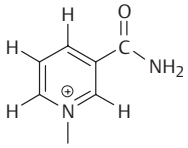	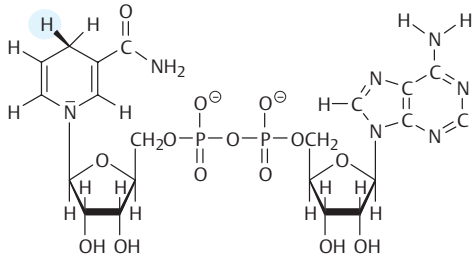	L	$H^{\ominus}$	−0.32
2. Flavin mononucleotide (FMN) 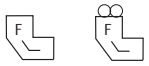	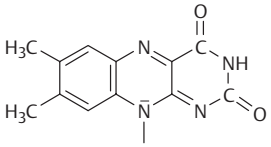	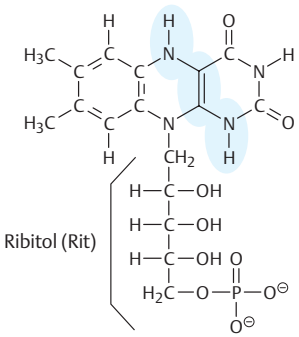	P	2[H]	−0.3 to +0.2
3. Flavin adenine dinucleotide (FAD) 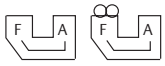	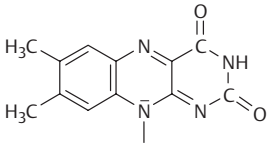	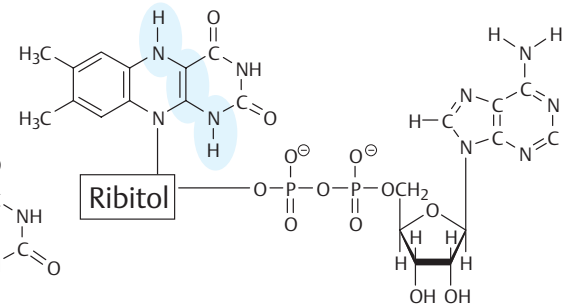	P	2[H]	−0.3 to +0.2
4. Ubiquinone (coenzym Q) 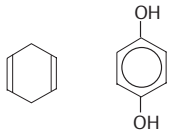	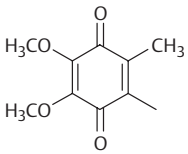	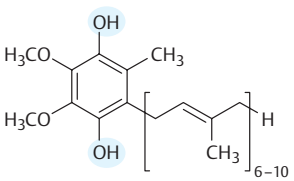	L	2[H]	−0 to +0.2
5. Ascorbic acid	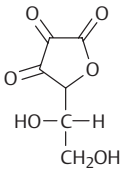	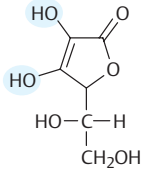	L	2[H]	+0.1

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Coenzymes 2

A. Redox coenzymes 2 ◑

In **lipoic acid** (**6**), an intramolecular *disulfide bond* functions as a redox-active structure. As a result of reduction, it is converted into the corresponding *dithiol*. As a prosthetic group, lipoic acid is usually covalently bound to a lysine residue (R) of the enzyme, and it is then referred to as **lipoamide**. Lipoamide is mainly involved in oxidative decarboxylation of 2-oxo acids (see p. 134). The peptide coenzyme **glutathione** is a similar disulfide/dithiol system (not shown; see p. 284).

Iron–sulfur clusters (**7**) occur as prosthetic groups in oxidoreductases, but they are also found in lyases—e.g., *aconitase* (see p. 136) and other enzymes. Iron–sulfur clusters consist of 2–4 iron ions that are coordinated with cysteine residues of the protein (–SR) and with anorganic sulfide ions (S). Structures of this type are only stable in the interior of proteins. Depending on the number of iron and sulfide ions, distinctions are made between $[Fe_2S_2]$, $[Fe_3S_4]$, and $[Fe_4S_4]$ clusters. These structures are particularly numerous in the respiratory chain (see p. 140), and they are found in all complexes except complex IV.

Heme coenzymes (**8**) with redox functions exist in the *respiratory chain* (see p. 140), in *photosynthesis* (see p. 128), and in *monooxygenases* and *peroxidases* (see p. 24). Heme-containing proteins with redox functions are also referred to as **cytochromes**. In cytochromes, in contrast to hemoglobin and myoglobin, the iron changes its valence (usually between +2 and +3). There are several classes of heme (a, b, and c), which have different types of substituent $-R_1$ to $-R_3$. Hemoglobin, myoglobin, and the heme enzymes contain heme b. Two types of heme a are found in cytochrome *c* oxidase (see p. 132), while heme c mainly occurs in cytochrome *c*, where it is covalently bound with cysteine residues of the protein part via thioester bonds.

B. Group-transferring coenzymes 1 ◑

The **nucleoside phosphates** (**1**) are not only *precursors* for nucleic acid biosynthesis; many of them also have coenzyme functions. They serve for *energy conservation,* and as a result of *energetic coupling* (see p. 124) also allow endergonic processes to proceed. Metabolites are often made more reactive ("activated") as a result of the transfer of phosphate residues (*phosphorylation*). Bonding with nucleoside diphosphate residues (mainly UDP and CDP) provides activated precursors for polysaccharides and lipids (see p. 110). Endergonic formation of bonds by *ligases* (enzyme class 6) also depends on nucleoside triphosphates.

Acyl residues are usually activated by transfer to **coenzyme A** (**2**). In coenzyme A (see p. 12), *pantetheine* is linked to 3′-phospho-ADP by a phosphoric acid anhydride bond. Pantetheine consists of three components connected by amide bonds—*pantoic acid*, *β-alanine*, and *cysteamine*. The latter two components are biogenic amines formed by the decarboxylation of aspartate and cysteine, respectively. The compound formed from pantoic acid and β–alanine (*pantothenic acid*) has vitamin-like characteristics for humans (see p. 368). Reactions between the thiol group of the cysteamine residue and carboxylic acids give rise to **thioesters**, such as acetyl CoA. This reaction is strongly endergonic, and it is therefore coupled to exergonic processes. Thioesters represent the *activated form of carboxylic acids,* because acyl residues of this type have a high chemical potential and are easily transferred to other molecules. This property is often exploited in metabolism.

Thiamine diphosphate (TPP, **3**), in cooperation with enzymes, is able to activate aldehydes or ketones as *hydroxyalkyl groups* and then to pass them on to other molecules. This type of transfer is important in the transketolase reaction, for example (see p. 152). Hydroxyalkyl residues also arise in the decarboxylation of oxo acids. In this case, they are released as aldehydes or transferred to lipoamide residues of 2-oxoacid dehydrogenases (see p. 134). The functional component of TPP is the sulfur- and nitrogen-containing *thiazole ring*.

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A. Redox coenzymes 2

Coenzyme	Oxidized form	Reduced form	Type	Trans-ferred	$E^{0\prime}$
6. Lipoamide	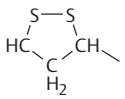	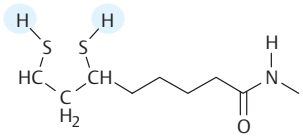	P	2[H]	−0.29
7. Iron–sulfur cluster	$[Fe_2S_2]^{n+}$ 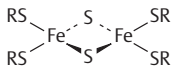	$[Fe_4S_4]^{m+}$ 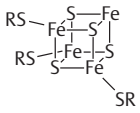	P	$1e^{\ominus}$	−0.6 to +0.5
8. Heme 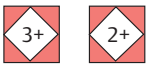	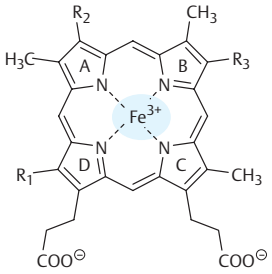	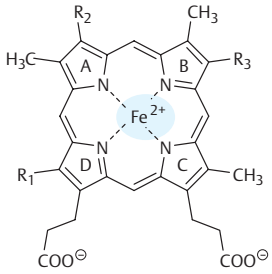	P	$1e^{\ominus}$	0 to +0.5

B. Group-transferring coenzymes 1

Coenzyme (symbol)	Free form	Charged form	Group(s) trans-ferred	Important enzymes
1. Nucleoside phosphates 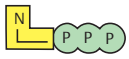	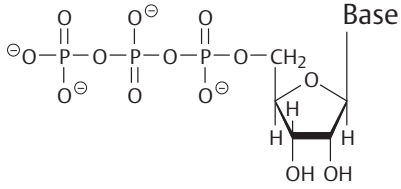		P B-Rib B-Rib-P B-Rib-PP	Phospho-transferases Nucleotidyl-transferases (2.7.n.n) Ligases (6.n.n.n)
2. Coenzyme A	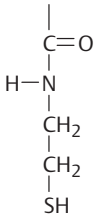	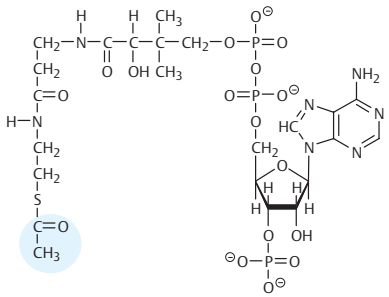	Acyl residues	Acyltrans-ferases (2.3.n.n) CoA trans-ferases (2.8.3.n)
3. Thiamine diphosphate	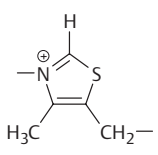	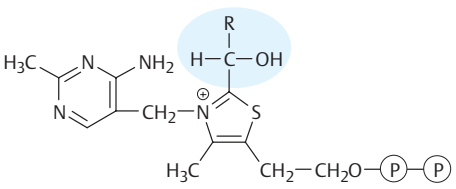	Hydroxy-alkyl residues	Decarboxy-lases (4.1.1.n) Oxoacid de-hydrogenases (1.2.4. n) Transketolase (2.2.1.1)

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Coenzymes 3

A. Group-transferring coenzymes 2 ◑

Pyridoxal phosphate (**4**) is the most important coenzyme in amino acid metabolism. Its role in *transamination* reactions is discussed in detail on p. 178. Pyridoxal phosphate is also involved in other reactions involving amino acids, such as *decarboxylations* and *dehydrations*. The aldehyde form of pyridoxal phosphate shown here (left) is not generally found in free form. In the absence of substrates, the aldehyde group is covalently bound to the ε-amino group of a lysine residue as *aldimine* ("Schiff's base"). **Pyridoxamine phosphate** (right) is an intermediate of transamination reactions. It reverts to the aldehyde form by reacting with 2-oxoacids (see p. 178).

Biotin (**5**) is the coenzyme of the *carboxylases*. Like pyridoxal phosphate, it has an amide-type bond via the carboxyl group with a lysine residue of the carboxylase. This bond is catalyzed by a specific enzyme. Using ATP, biotin reacts with hydrogen carbonate (HCO_3^-) to form ***N*-carboxybiotin** . From this activated form, *carbon dioxide* (CO_2) is then transferred to other molecules, into which a carboxyl group is introduced in this way. Examples of biotindependent reactions of this type include the formation of oxaloacetic acid from pyruvate (see p. 154) and the synthesis of malonyl-CoA from acetyl-CoA (see p. 162).

Tetrahydrofolate (THF, **6**) is a coenzyme that can transfer *C_1 residues* in different oxidation states. THF arises from the vitamin *folic acid* (see p. 366) by double hydrogenation of the heterocyclic pterin ring. The C_1 units being transferred are bound to N-5, N-10, or both nitrogen atoms. The most important derivatives are:

a) N^5**-formyl-THF** and N^{10}**-formyl-THF**, in which the formyl residue has the oxidation state of a carboxylic acid;

b) N^5**-methylene-THF**, with a C_1 residue in the oxidation state of an aldehyde; and

c) N^5**-methyl-THF**, in which the methyl group has the oxidation state of an alcohol.

C_1 units transferred by THF play a role in the synthesis of methionine (see p. 412), purine nucleotides (see p. 188), and dTMP (see p. 190), for example. Due to the central role of THF derivatives in the biosynthesis of DNA precursors, the enzymes involved in THF metabolism are primary targets for cytostatic drugs (see p. 402).

The **cobalamins** (**7**) are the chemically most complex form of coenzyme. They also represent the only natural substances that contain the transition metal *cobalt* (Co) as an essential component. Higher organisms are unable to synthesize cobalamins themselves, and are therefore dependent on a supply of **vitamin B_{12}** synthesized by bacteria (see p. 368).

The central component of the cobalamins is the **corrin** ring, a member of the tetrapyrroles, at the center of which the cobalt ion is located. The end of one of the side chains of the ring carries a nucleotide with the unusual base *dimethylbenzimidazole.* The ligands for the metal ion are the four N atoms of the pyrrole ring, a nitrogen from dimethylbenzimidazole, and a **group X**, which is organometallically bound—i. e., *mainly covalently.*

In **methylcobalamin**, X is a methyl group. This compound functions as a coenzyme for several *methyltransferases,* and among other things is involved in the synthesis of methionine from homocysteine (see p. 418). However, in human metabolism, in which methionine is an essential amino acid, this reaction does not occur.

Adenosylcobalamin (coenzyme B_{12}) carries a covalently bound adenosyl residue at the metal atom. This is a coenzyme of various *isomerases,* which catalyze rearrangements following a radical mechanism. The radical arises here through *homolytic cleavage* of the bond between the metal and the adenosyl group. The most important reaction of this type in animal metabolism is the rearrangement of methylmalonyl-CoA to form succinyl-CoA, which completes the breakdown of odd-numbered fatty acids and of the branched amino acids valine and isoleucine (see pp. 166 and 414).

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A. Group-transferring coenzymes 2

Coenzyme	Free form	Charged form	Group(s) transferred	Important enzymes
4. Pyridoxal phosphate PLP	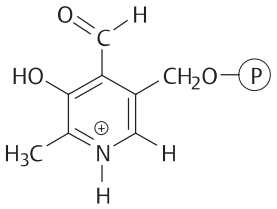	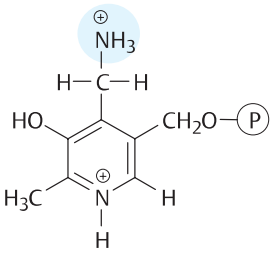	Amino group Amino acid residues	Transaminases (2.6.1.n) Many lyases (4.n.n.n)
5. Biotin B	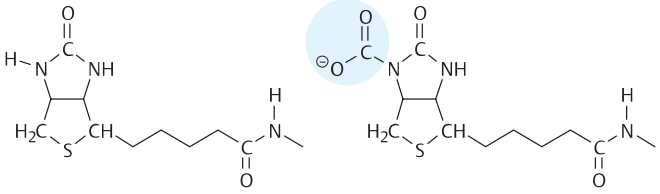		$[CO_2]$	Carboxylases (6.4.1.n)
4. Pyridoxal phosphate THF	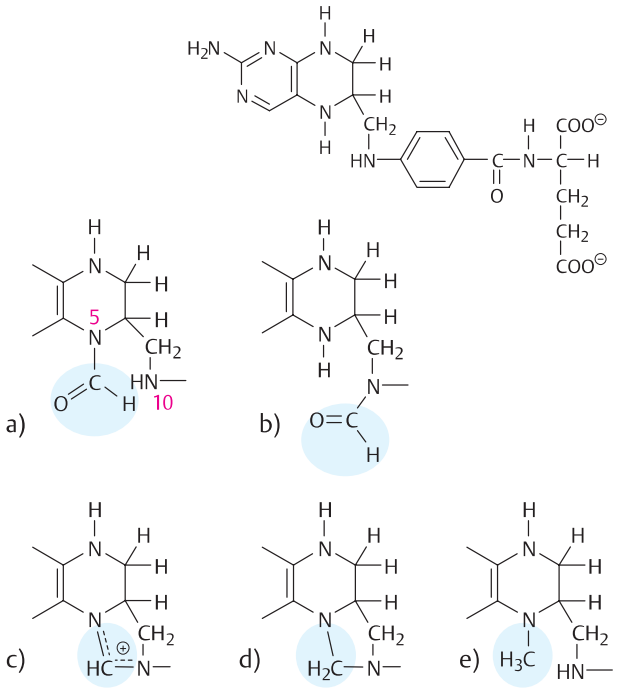		C_1 groups a) N^5-Formyl b) N^{10}-Formyl c) N^5N^{10}-Methenyl d) N^5N^{10}-Methylene e) N^5N^{10}-Methyl	C_1 transferases (2.1.n.n)
7. Cobalamin coenzymes	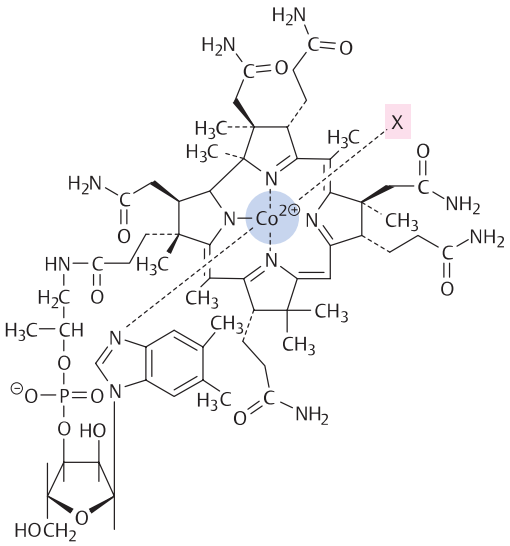		X = Adenosyl- X = Methyl-	Mutases *(5.4.n.n)* Methyltransferases *(2.1.1.n.)*

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Activated metabolites

Many coenzymes (see pp. 104ff.) serve to *activate* molecules or groups that are poorly reactive. Activation consists of the formation of reactive intermediate compounds in which the group concerned is located at a higher chemical potential and can therefore be transferred to other molecules in an exergonic reaction (see p. 124). Acetyl-CoA is an example of this type of compound (see p. 12).

ATP and the other **nucleoside triphosphate coenzymes** not only transfer phosphate residues, but also provide the nucleotide components for this type of activation reaction. On this page, we discuss metabolites or groups that are activated in the metabolism by bonding with nucleosides or nucleotides. Intermediates of this type are mainly found in the metabolism of complex carbohydrates and lipids.

A. Activated metabolites ◑

1. Uridine diphosphate glucose (UDPglucose)

The inclusion of glucose residues into polymers such as glycogen or starches is an endergonic process. The activation of the **glucose** building blocks that is required for this takes places in several steps, in which two ATPs are used per glucose. After the phosphorylation of free glucose, glucose 6-phosphate is isomerized to glucose 1-phosphate (**a**), reaction with UTP (**b**) then gives rise to UDPglucose, in which the anomeric OH group at C-1 of the sugar is bound with phosphate. This "energy-rich" compound (an acetal phosphate) allows exergonic transfer of glucose residues to glycogen (**c**; see pp. 156, 408) or other acceptors.

2. Cytidine diphosphate choline (CDPcholine)

The amino alcohol **choline** is activated for inclusion in phospholipids following a similar principle (see p. 170). Choline is first phosphorylated by ATP to form choline phosphate (**a**), which by reaction with CTP and cleavage of diphosphate, then becomes CDPcholine. In contrast to (**1**), it is not choline that is transferred from CDPcholine, but rather choline phosphate, which with diacylglycerol yields phosphatidylcholine (lecithin).

3. Phosphoadenosine phosphosulfate (PAPS)

Sulfate residues occur as strongly polar groups in various biomolecules—e. g., in *glycosaminoglycans* (see p. 346) and *conjugates* of steroid hormones and xenobiotics (see p. 316). In the synthesis of the "activated sulfate" PAPS, ATP first reacts with anorganic sulfate to form adenosine phosphosulfate (APS, **a**). This intermediate already contains the "energy-rich" mixed anhydride bond between phosphoric acid and sulfuric acid. In the second step, the 3′-OH group of APS is phosphorylated, with ATP being used again. After transfer of the sulfate residue to OH groups (**c**), adenosine-3′,5′-bisphosphate remains.

4. *S*-adenosyl methionine (SAM)

The coenzyme *tetrahydrofolate* (THF) is the main agent by which C_1 fragments are transferred in the metabolism. THF can bind this type of group in various oxidation states and pass it on (see p. 108). In addition, there is "activated methyl," in the form of *S*-adenosyl methionine (SAM). SAM is involved in many **methylation reactions**—e. g., in creatine synthesis (see p. 336), the conversion of norepinephrine into epinephrine (see p. 352), the inactivation of norepinephrine by methylation of a phenolic OH group (see p. 316), and in the formation of the active form of the cytostatic drug 6-mercaptopurine (see p. 402).

SAM is derived from degradation of the proteinogenic amino acid **methionine**, to which the adenosyl residue of an ATP molecule is transferred. After release of the activated methyl group, *S*-adenosyl homocysteine (SAH) is left over. This can be converted back into methionine in two further steps. Firstly, cleavage of the adenosine residue gives rise to the non-proteinogenic amino acid **homocysteine**, to which a methyl group is transferred once again with the help of N^5-methyl-THF (see p. 418). Alternatively, homocysteine can also be broken down into propionyl-CoA.

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A. Activated metabolites

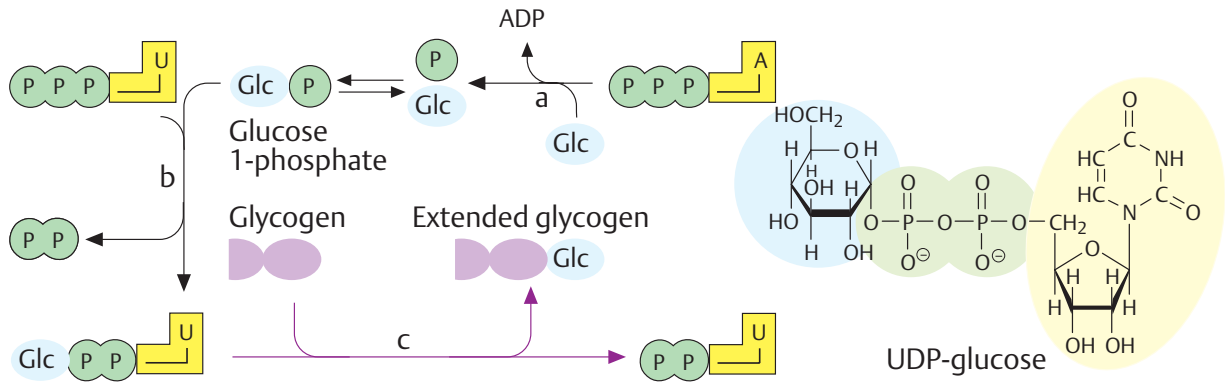

1. Uridine diphosphate glucose (UDP-glucose)

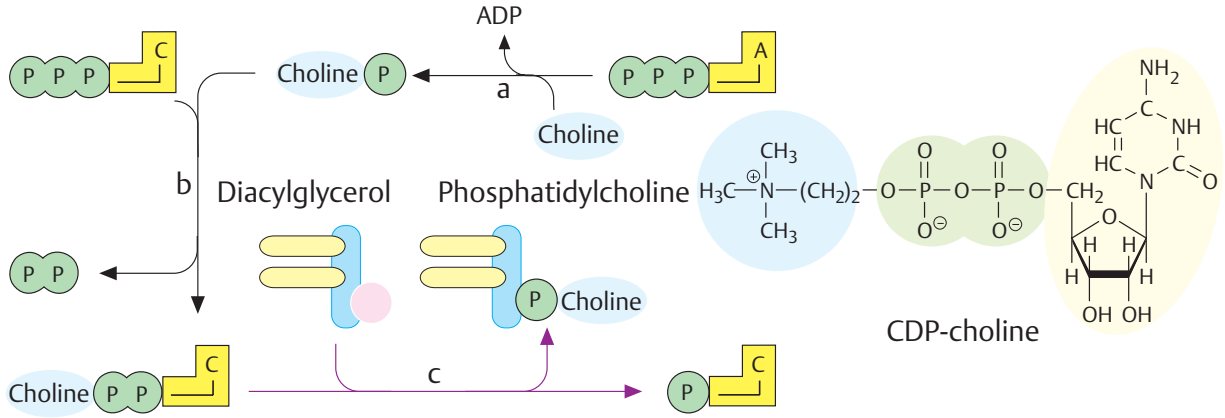

2. Cytidine diphosphate choline (CDPcholine)

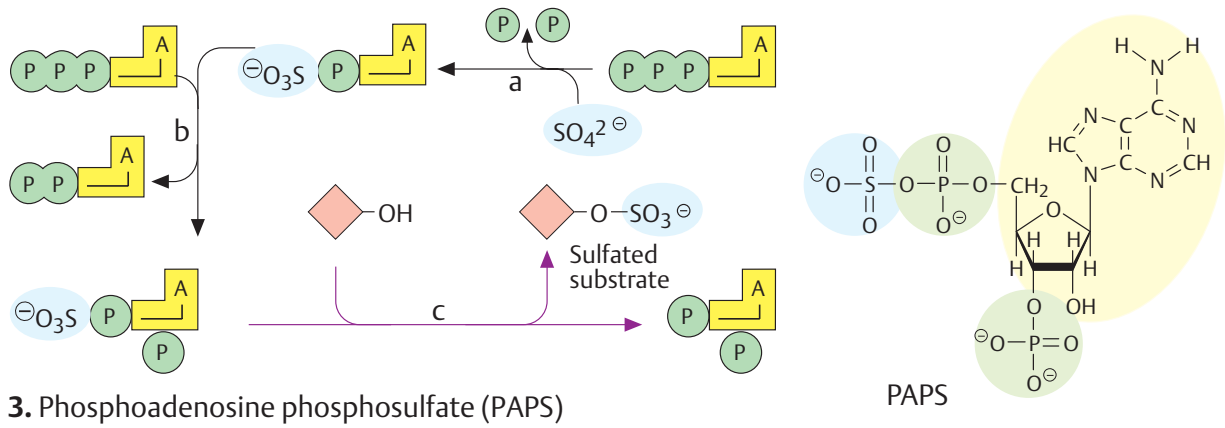

3. Phosphoadenosine phosphosulfate (PAPS)

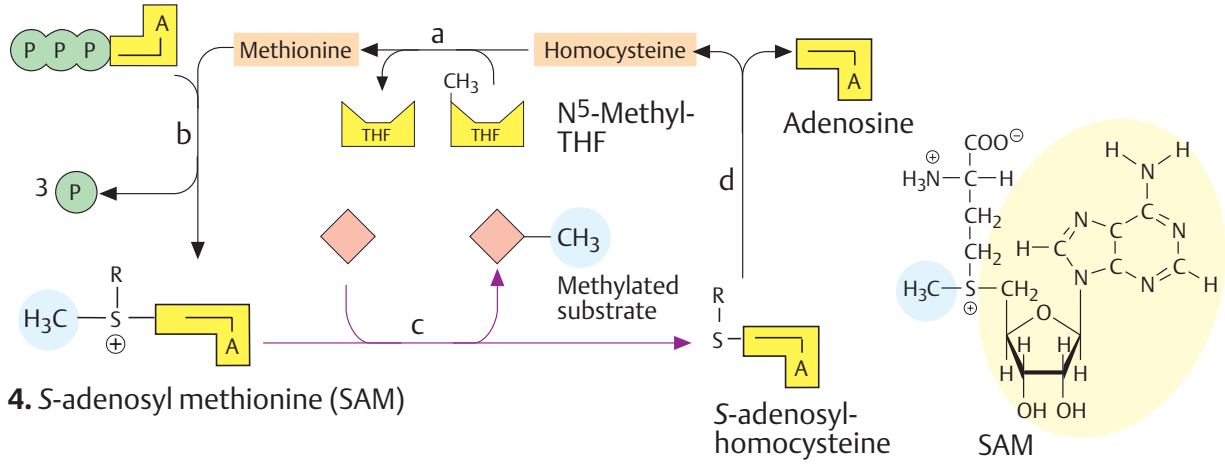

4. *S*-adenosyl methionine (SAM)

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Intermediary metabolism

Hundreds of chemical reactions are constantly taking place in every cell, and taken together these are referred to as the **metabolism**. The chemical compounds involved in this are known as **metabolites**. Outside of the cell, almost all of the chemical changes in metabolites would only take place very slowly and without any specific direction. By contrast, organized sequences of chemical reactions with a high rate of throughput, known as **metabolic pathways**, become possible through the existence of specific **enzymes** (see p. 88).

A. Intermediary metabolism: overview ●

A number of central metabolic pathways are common to most cells and organisms. These pathways, which serve for synthesis, degradation, and interconversion of important metabolites, and also for energy conservation, are referred to as the **intermediary metabolism**.

In order to survive, all cells constantly require organic and inorganic *nutrients*, as well as *chemical energy,* which is mainly derived from ATP (see below). Depending on the way in which these needs are satisfied, organisms can be classified into autotrophic and heterotrophic groups. The **autotrophs**, which include plants and many microorganisms, can synthesize organic molecules from inorganic precursors (CO_2). An autotrophic lifestyle is possible through **photosynthesis**, for example (see p. 128). The **heterotrophs**—e. g., animals and fungi—depend on organic substances supplied in their diet. The schema shown on this page provides an overview of animal metabolism.

The polymeric substances contained in the diet (proteins, carbohydrates, and nucleic acids—top) cannot be used by the organism directly. Digestive processes first have to degrade them to monomers (amino acids, sugars, nucleotides). These are then mostly broken down by **catabolic pathways** (pink arrows) into smaller fragments. The metabolites produced in this way (generally referred to as the "metabolite pool") are then either used to obtain energy through further catabolic conversion, or are built up again into more complex molecules by **anabolic pathways** (blue arrows). Of the numerous metabolites in the pool, only three particularly important representatives—pyruvate, acetyl-CoA, and glycerol—are shown here. These molecules represent connecting links between the metabolism of proteins, carbohydrates, and lipids. The metabolite pool also includes the intermediates of the tricarboxylic acid cycle (**6**). This cyclic pathway has both catabolic and anabolic functions—i. e., it is **amphibolic** (violet; see p. 138).

Waste products from the degradation of organic substances in animal metabolism include *carbon dioxide* (CO_2), *water* (H_2O), and *ammonia* (NH_3). In mammals, the toxic substance ammonia is incorporated into *urea* and excreted in this form (see p. 182).

The most important form of storage for chemical energy in all cells is **adenosine triphosphate** (ATP, see p. 122). ATP *synthesis* requires energy—i. e., the reaction is *endergonic*. Conversely, cleavage of ATP into ADP and phosphate releases energy. *Exergonic* hydrolysis of ATP, as a result of **energetic coupling** (see p. 16), makes energy-dependent (*endergonic*) processes possible. For example, most anabolic pathways, as well as movement and transport processes, are energy-dependent.

The most important pathway for the synthesis of ATP is **oxidative phosphorylation** (see p. 122). In this process, catabolic pathways first form reduced cofactors ($NADH+H^+$, QH_2, $ETFH_2$). Electrons are then transferred from these compounds to oxygen. This strongly exergonic process is catalyzed by the **respiratory chain** and used indirectly for the ATP synthesis (see p. 140). In *anaerobic conditions*—i. e., in the absence of oxygen—most organisms can fall back on ATP that arises in glycolysis (**3**). This less ef cient type of ATP synthesis is referred to as **fermentation** (see p. 146).

While NADH exclusively supplies oxidative phosphorylation, $NADPH+H^+$—a very similar coenzyme—is the reducing agent for anabolic pathways. $NADPH + H^+$ is mainly formed in the pentose phosphate pathway (PPP, **1**; see p. 152).

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A. Intermediary metabolism: overview

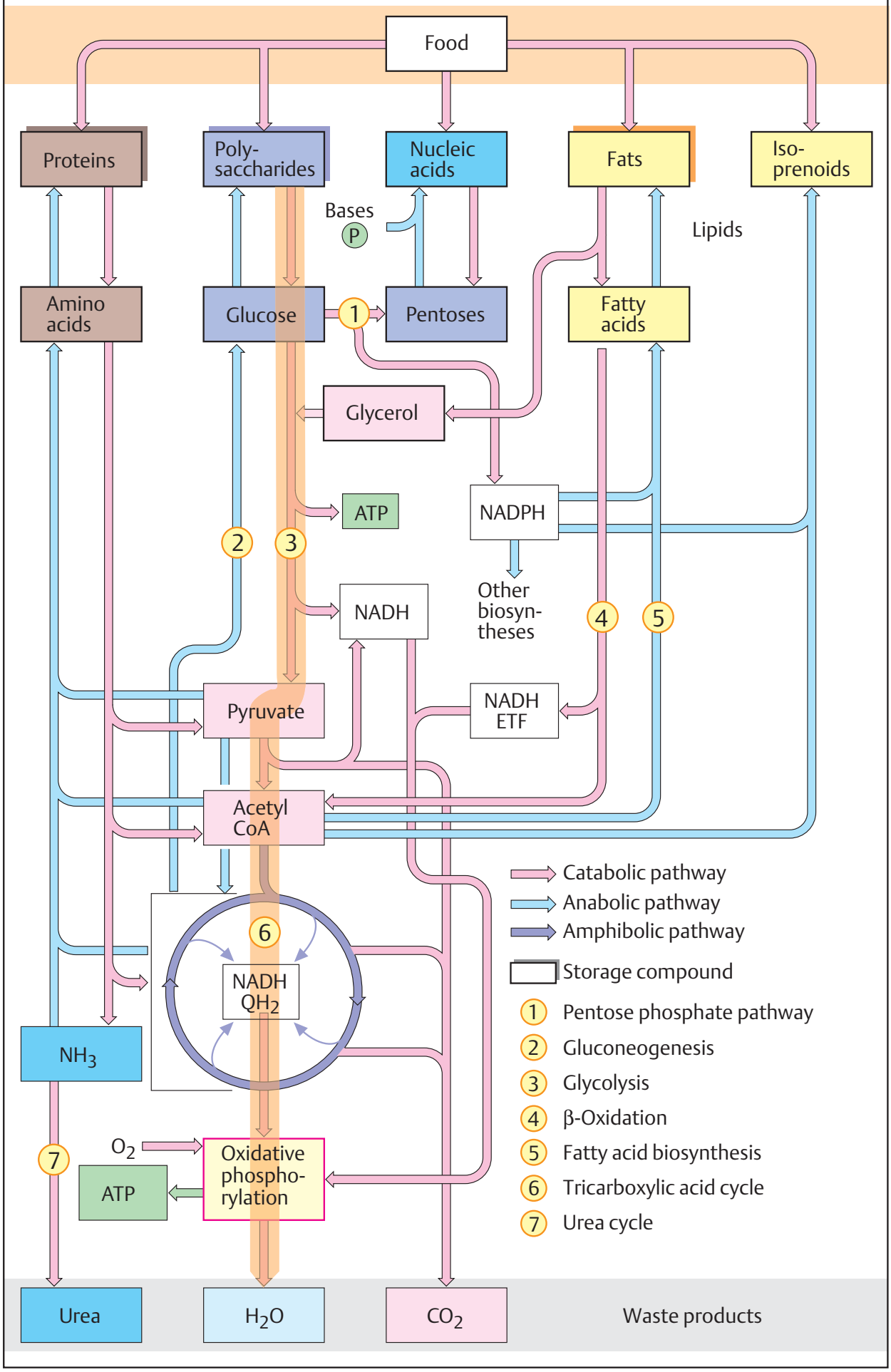

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Regulatory mechanisms

A. Fundamental mechanisms of metabolic regulation ◑

The activities of all metabolic pathways are subject to precise regulation in order to adjust the synthesis and degradation of metabolites to physiological requirements. An overview of the regulatory mechanisms is presented here. Further details are shown on pp. 116ff.

Metabolite flow along a metabolic pathway is mainly determined by the activities of the **enzymes** involved (see p. 88). To regulate the pathway, it is suf cient to change the activity of the enzyme that catalyzes the *slowest* step in the reaction chain. Most metabolic pathways have **key enzymes** of this type on which the regulatory mechanisms operate. The activity of key enzymes is regulated at three independent levels:

Transcriptional control. Here, Biosynthesis of the enzyme protein is influenced at the genetic level (**1**). Interventions in enzyme synthesis mainly affect synthesis of the corresponding mRNA—i. e., *transcription* of the gene coding for the enzyme. The term "transcriptional control" is therefore used (see pp. 118, 244). This mechanism is mediated by *regulatory proteins* (transcription factors) that act directly on DNA. The genes have a special regulatory segment for this purpose, known as the *promoter* region, which contains binding sites (control elements) for regulatory proteins. The activity of these proteins is, in turn, affected by metabolites or hormones. When synthesis of a protein is increased by transcriptional control, the process is referred to as **induction**; when it is reduced or suppressed, it is referred to as **repression**. Induction and repression processes take some time and are therefore not immediately effective.

Interconversion of key enzymes (**2**) takes effect considerably faster than transcriptional control. In this case, the enzyme is already present at its site of effect, but it is initially still inactive. It is only when needed that it is converted into the catalytically active form, after signaling and mediation from second messengers (see p. 120) through an *activating enzyme* (E_1). If the metabolic pathway is no longer required, an *inactivating enzyme* (E_2) returns the key enzyme to its inactive resting state.

Interconversion processes in most cases involve **ATP-dependent phosphorylation** of the enzyme protein by a *protein* kinase or **dephosphorylation** of it by a *protein phosphatase* (see p. 120). The phosphorylated form of the key enzyme is usually the more active one, but the reverse may also occur.

Modulation by ligands. An important variable that regulates flow through a metabolic pathway is **precursor availability** (metabolite A in the case shown here). The availability of precursor A increases along with the activity of the metabolic pathways that form A (**3**) and it decreases with increasing activity of other pathways that also consume A (**4**). Transport from one cell compartment to another can also restrict the availability of A.

Coenzyme availability can also often have a limiting effect (**5**). If the coenzyme is regenerated by a second, independent metabolic pathway, the speed of the second pathway can limit that of the first one. For example, glycolysis and the tricarboxylic acid cycle are mainly regulated by the availability of NAD^+ (see p. 146). Since NAD^+ is regenerated by the respiratory chain, the latter indirectly controls the breakdown of glucose and fatty acids (respiratory control, see p. 144).

Finally, the activity of key enzymes can be regulated by *ligands* (substrates, products, coenzymes, or other effectors), which as *allosteric effectors* do not bind at the active center itself, but at another site in the enzyme, thereby modulating enzyme activity (**6**; see p. 116). Key enzymes are often inhibited by immediate reaction products, by end products of the reaction chain concerned (*"feedback" inhibition*), or by metabolites from completely different metabolic pathways. The precursors for a reaction chain can stimulate their own utilization through enzyme activation.

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A. Fundamental mechanisms of metabolic regulation

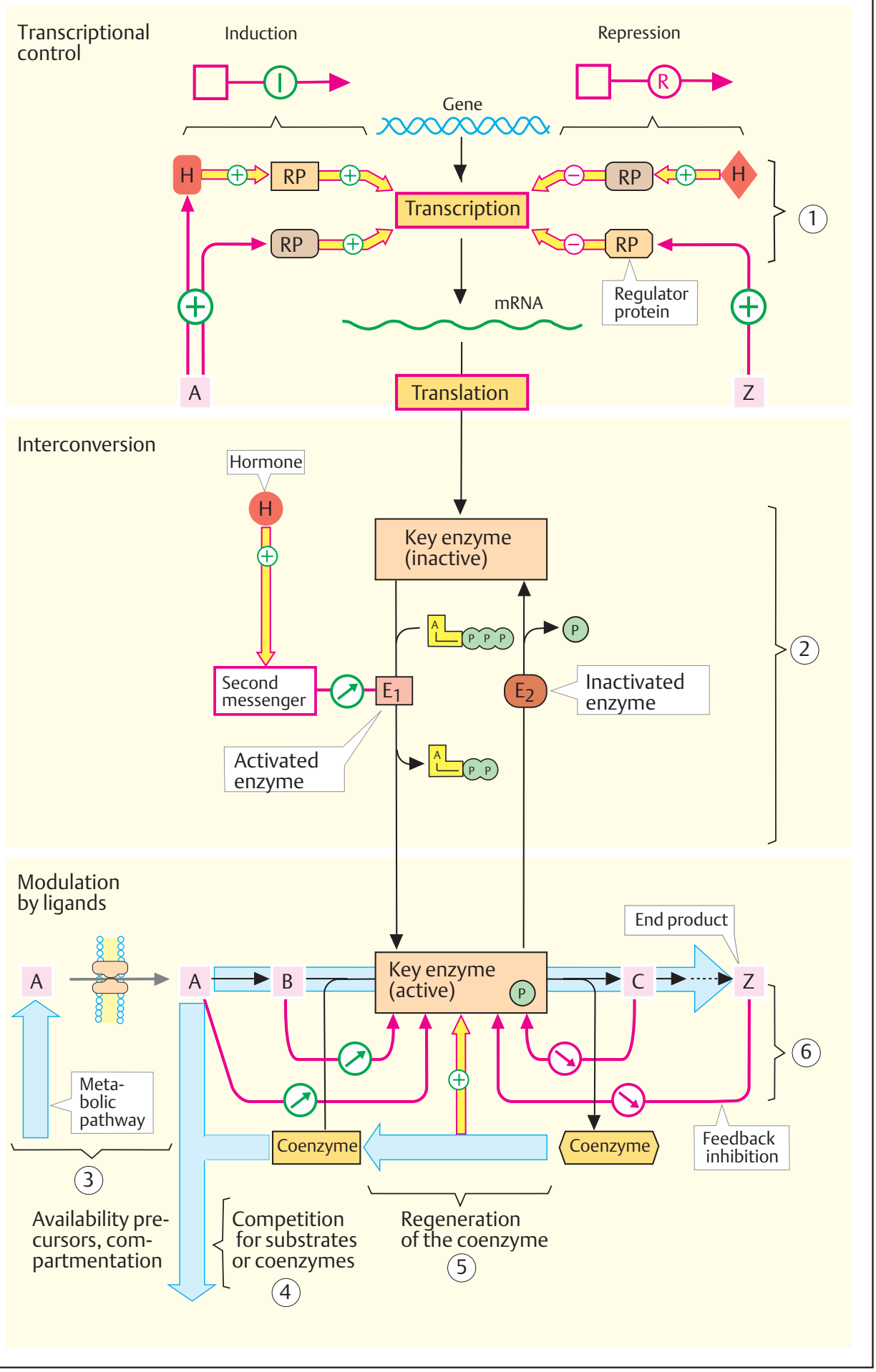

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Allosteric regulation

The regulation of **aspartate carbamoyltransferase** (ACTase), a key enzyme of pyrimidine biosynthesis (see p. 188) is discussed here as an example of allosteric regulation of enzyme activity. Allosteric effects are mediated by the substrate itself or by inhibitors and activators (*allosteric effectors,* see p. 114). The latter bind at special sites outside the active center, producing a conformational change in the enzyme protein and thus indirectly lead to an alteration in its activity.

A. Aspartate carbamoyltransferase: reaction ○

ACTase catalyzes the transfer of a carbamoyl residue from carbamoyl phosphate to the amino group of L-aspartate. The *N*-carbamoyl L-aspartate formed in this way already contains all of the atoms of the later pyrimidine ring (see p. 188). The ACTase of the bacterium *Escherichia coli* is inhibited by cytidine triphosphate (CTP), an end product of the anabolic metabolism of pyrimidines, and is activated by the precursor ATP.

B. Kinetics ◑

In contrast to the kinetics of isosteric (normal) enzymes, allosteric enzymes such as ACTase have **sigmoidal** (S-shaped) **substrate saturation curves** (see p. 92). In allosteric systems, the enzyme's af nity to the substrate is not constant, but depends on the substrate concentration [A]. Instead of the Michaelis constant K_m (see p. 92), the *substrate concentration at half-maximal rate* ($[A]_{0.5}$) is given. The sigmoidal character of the curve is described by the **Hill coef•cient h**. In isosteric systems, h = 1, and h increases with increasing sigmoidicity.

Depending on the enzyme, *allosteric effectors* can influence the maximum rate V_{max}, the semi-saturation concentration $[A]_{0.5}$, and the Hill coef cient h. If it is mainly V_{max} that is changed, the term "**V system**" is used. Much more common are "**K systems**", in which allosteric effects only influence $[A]_{0.5}$ and h.

The K type also includes ACTase. The inhibitor CTP in this case leads to *right-shifting* of the curve, with an increase in $[A]_{0.5}$ and h (curve II). By contrast, the activator ATP causes a *left shift;* it reduces both $[A]_{0.5}$ and h (curve III). This type of allosteric effect was first observed in *hemoglobin* (see p. 280), which can be regarded as an "honorary" enzyme.

C. R and T states ○

Allosteric enzymes are almost always *oligomers* with 2–12 subunits. ACTase consists of six catalytic subunits (blue) and six regulatory subunits (yellow). The latter bind the allosteric effectors CTP and ATP. Like hemoglobin, ACTase can also be present in two conformations—the less active **T state** (for "tense") and the more active **R state** (for "relaxed"). Substrates and effectors influence the equilibrium between the two states, and thereby give rise to sigmoidal saturation behavior. With increasing aspartate concentration, the equilibrium is shifted more and more toward the R form. ATP also stabilizes the R conformation by binding to the regulatory subunits. By contrast, binding of CTP to the same sites promotes a transition to the T state. In the case of ACTase, the structural differences between the R and T conformations are particularly dramatic. In T → R conversion, the catalytic subunits separate from one another by 1.2 nm, and the subunits also rotate around the axis of symmetry. The conformations of the subunits themselves change only slightly, however.

D. Structure of a dimer ○

The subunits of ACTase each consist of two *domains*—i. e., independently folded partial structures. The *N*-terminal domain of the regulatory subunit (right) mediates interaction with CTP or ATP (green). A second, Zn^{2+}-containing domain (Zn^{2+} shown in light blue) establishes contact with the neighboring catalytic subunit. Between the two domains of the catalytic subunit lies the active center, which is occupied here by two substrate analogs (red).

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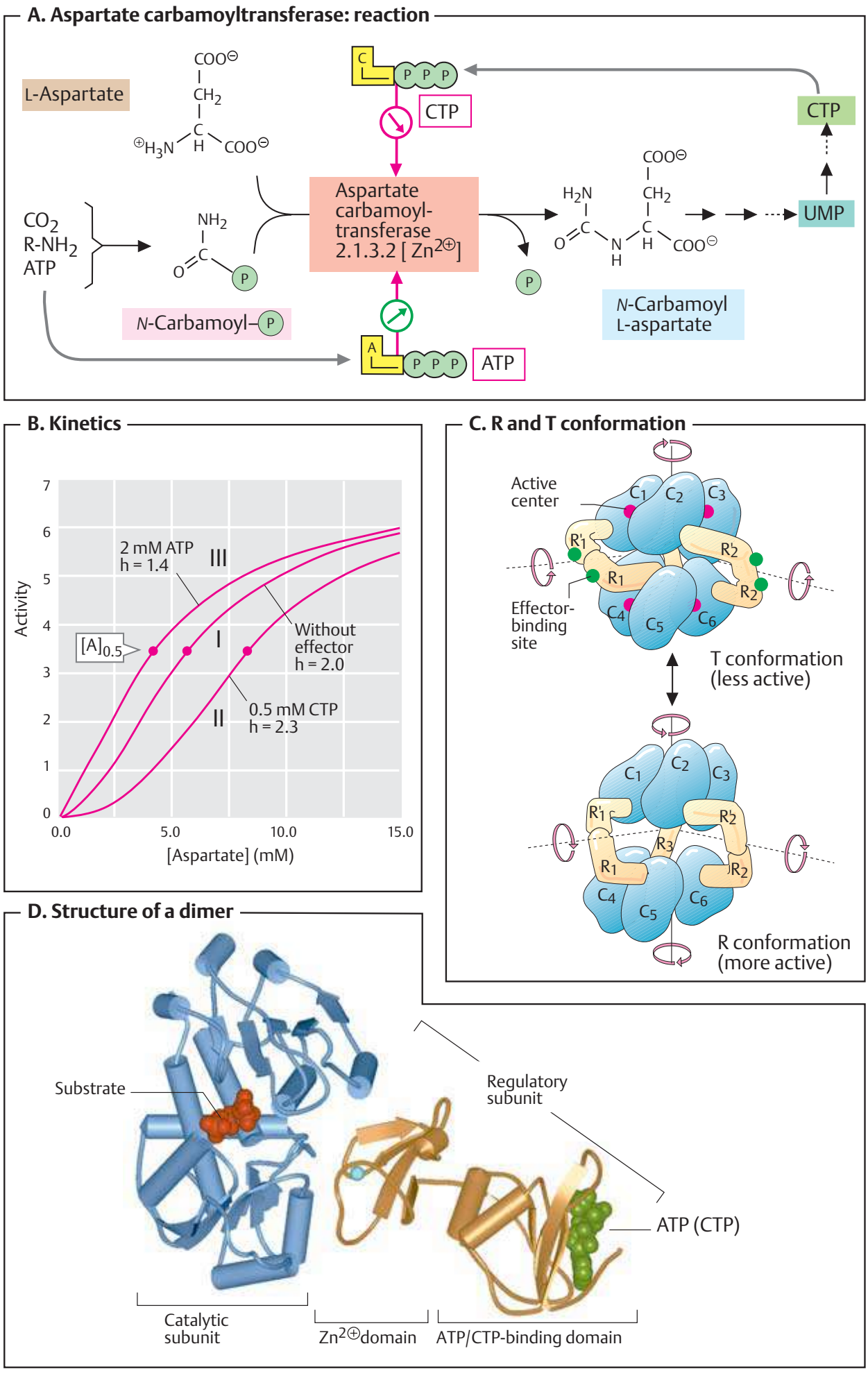

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Transcription control

A. Functioning of regulatory proteins ◑

Regulatory proteins (transcription factors) are involved in controlling gene expression in all cells. These regulatory proteins bind to specific DNA sequences and thereby activate or inhibit the transcription of genes **(Transcription control)**. The effects of transcription factors are usually reversible and are often controlled by *ligands* or by *interconversion.*

The nomenclature for transcription factors is confusing. Depending on their mode of action, various terms are in use both for the proteins themselves and for the DNA sequences to which they bind. If a factor blocks transcription, it is referred to as a **repressor**; otherwise, it is called an **inducer.** DNA sequences to which regulatory proteins bind are referred to as **control elements.** In prokaryotes, control elements that serve as binding sites for RNA polymerases are called **promoters,** whereas repressor-binding sequences are usually called **operators**. Control elements that bind activating factors are termed **enhancers**, while elements that bind inhibiting factors are known as **silencers**.

The numerous regulatory proteins that are known can be classified into four different groups (**1**–**4**), based on their mechanisms of action. **Negative gene regulation**—i. e., switching off of the gene concerned—is carried out by **repressors**. Some repressors only bind to DNA (**1a**) in the absence of specific ligands (L). In this case, the complex between the repressor and the ligand loses its ability to bind to the DNA, and the promoter region becomes accesible for binding of RNA polymerase (**1b**). It is often the free repressor that does not bind to the DNA, so that transcription is only blocked in the presence of the ligand (**2a**, **2b**). A distinction between two different types of **positive gene regulation** can be made in the same way. If it is only the free inducer that binds, then transcription is inhibited by the appropriate ligand (**3**). Conversely, many **inducers** only become active when they have bound a ligand (**4**). This group includes the receptors for steroid hormones, for example (see p. 378).

B. Lactose operon ○

The well-investigated **lactose operon** of the bacterium *Escherichial coli* can be used here as an example of transcriptional control. The *lac* operon is a DNA sequence that is simultaneously subject to negative and positive control. The operon contains the *structural genes* for three proteins that are required for the utilization of lactose (one transporter and two enzymes), as well as *control elements* that serve to regulate the operon.

Since lactose is converted to glucose in the cell, there is no point in expressing the genes if glucose is already available. And indeed, the genes are in fact only transcribed when *glucose is absent* and *lactose is present* (**3**). This is achieved by interaction between two regulatory proteins. In the absence of lactose, the ***lac repressor*** blocks the promoter region (**2**). When lactose is available, it is converted into *allolactose*, which binds to the repressor and thereby detaches it from the operator (**3**). However, this is still not suf cient for the transcription of the structural genes. For binding of the RNA polymerase to take place, an *inducer*—the **catabolite activator protein (CAP)**—is required, which only binds to the DNA when it is present as a complex with 3,5′-cyclo-AMP (cAMP; see p. 386). cAMP, a signal for nutrient deficiency, is only formed by *E. coli* in the *absence* of glucose.

The interaction between the CAP–cAMP complex and DNA is shown in Fig. **4**. Each subunit of the dimeric inducer (yellow or orange) binds one molecule of cAMP (red). Contact with the DNA (blue) is mediated by two "recognition helices" that interact with the major groove of the DNA. The bending of the DNA strand caused by CAP has functional significance.

Transcription control is much more complex in eukaryotes (see p. 244). The number of transcription factors involved is larger, and in addition the gene activity is influenced by the state of the chromatin (see p. 238).

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A. Functions of regulatory proteins

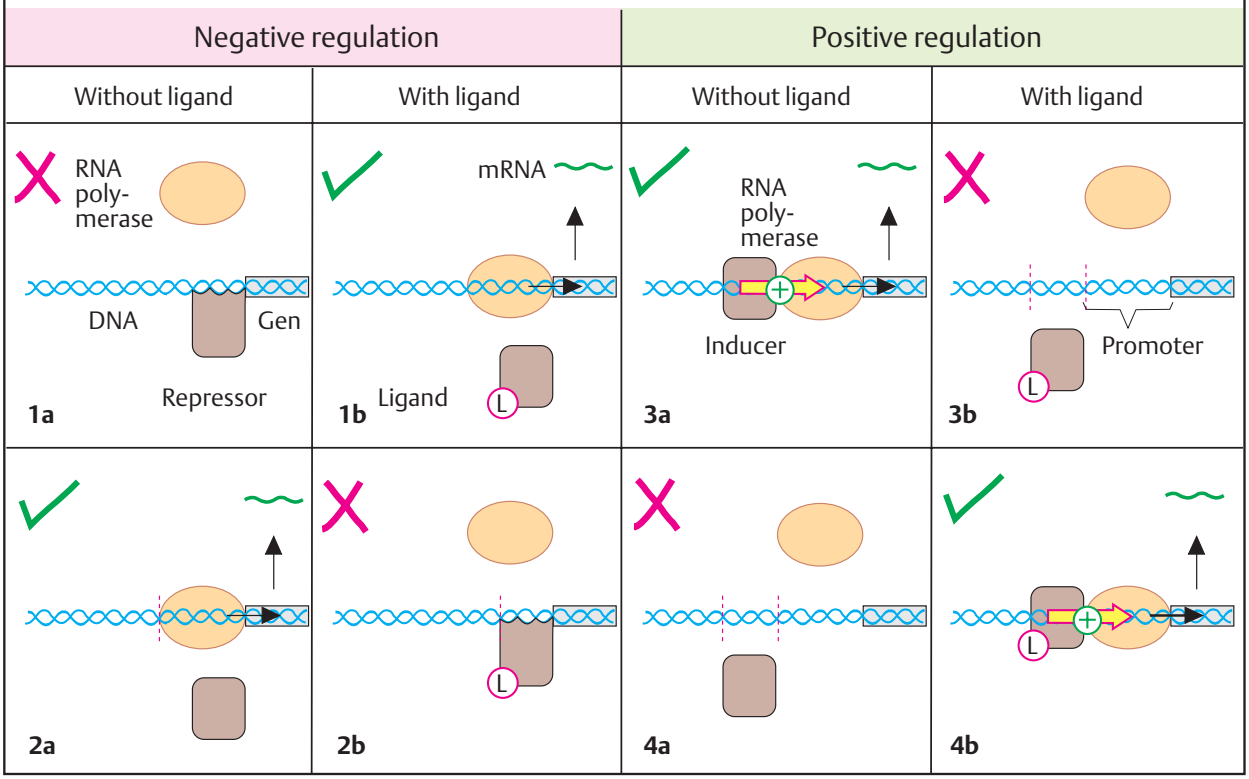

B. Lactose operon

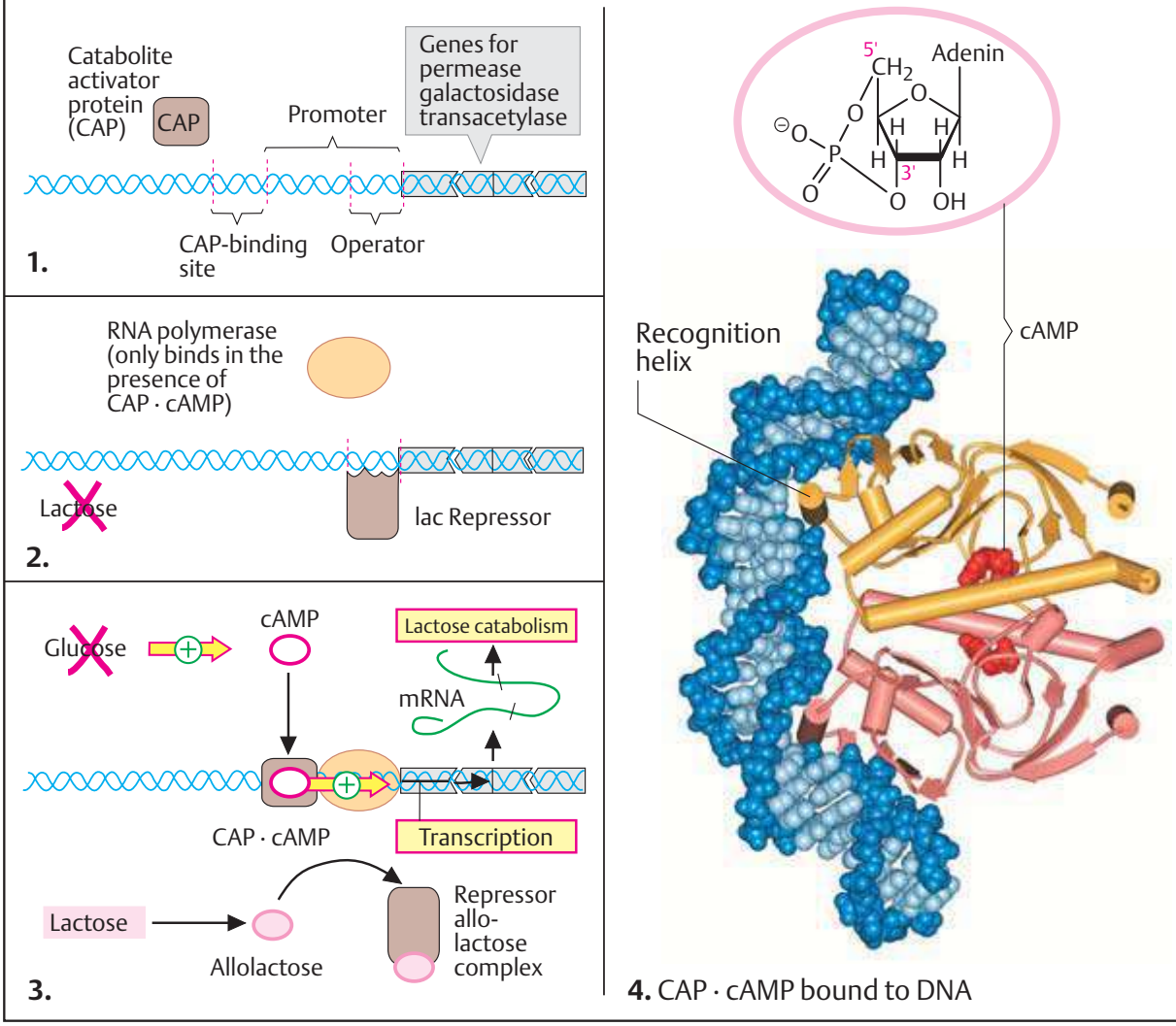

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Hormonal control

In higher organisms, metabolic and other processes (growth, differentiation, control of the internal environment) are controlled by **hormones** (see pp. 370ff.)

A. Principles of hormone action ●

Depending on the type of hormone, hormone signals are transmitted to the target cells in different ways. Apolar (lipophilic) hormones penetrate the cell and act in the cell nucleus, while polar (hydrophilic) hormones act on the external cell membrane.

Lipophilic hormones, which include the steroid hormones, thyroxine, and retinoic acid, bind to a specific *receptor protein* inside their target cells. The complex formed by the hormone and the receptor then influences *transcription* of specific genes in the cell nucleus (see pp. 118, 244). The group of **hydrophilic hormones** (see p. 380) consists of hormones derived from amino acids, as well as peptide hormones and proteohormones. Their *receptors* are located in the plasma membrane. Binding of the hormone to this type of receptor triggers a signal that is transmitted to the interior of the cell, where it controls the processes that allow the hormone signal to take effect (**signal transduction**; see pp. 384ff.)

B. Hormonal regulation of glucose metabolism in the liver ◑

The liver plays a major role in glucose homeostasis in the organism (see p. 310). If glucose deficiency arises, the liver releases glucose into the blood, and when blood sugar levels are high, it takes glucose up from the blood and converts it into different metabolites. Several hormones from both groups are involved in controlling these processes. A very simplified version of the way in which they work is presented here. **Glycogen** is the form in which glucose is stored in the liver and muscles. The rate of glycogen synthesis is determined by *glycogen synthase* (bottom right), while its breakdown is catalyzed by *glycogen phosphorylase* (bottom left).

Regulation by interconversion (bottom). If the blood glucose level falls, the peptide hormone **glucagon** is released. This activates glycogen breakdown, releasing glucose, and at the same time inhibits glycogen synthesis. Glucagon binds to receptors in the plasma membrane (bottom left) and, with mediation by a G-protein (see p. 386), activates the enzyme *adenylate cyclase*, which forms the *second messenger* 3,5′-cyclo-AMP (**cAMP**) from ATP. cAMP binds to another enzyme, *protein kinase A* (PK-A), and activates it. PK-A has several points of attack. Through *phosphorylation,* it converts the active form of *glycogen synthase* into the inactive form, thereby terminating the synthesis of glycogen. Secondly, it activates another protein kinase (not shown), which ultimately converts the inactive form of *glycogen phosphorylase* into the active form through phosphorylation. The active phosphorylase releases glucose 1-phosphate from glycogen, which after conversion into glucose 6-phosphate supplies free glucose. In addition, via an inhibitor (I) of protein phosphatase (PP), active PK-A inhibits inactivation of glycogen phosphorylase. When the cAMP level falls again, *phosphoprotein phosphatases* become active, which dephosphorylate the various phosphoproteins in the cascade described, and thereby arrest glycogen breakdown and re-start glycogen synthesis. Activation and inactivation of proteins through phosphorylation or dephosphorylation is referred to as **interconversion**.

In contrast to glucagon, the peptide hormone **insulin** (see p. 76) increases glycogen synthesis and inhibits glycogen breakdown. Via several intermediates, it inhibits protein kinase GSK-3 (bottom right; for details, see p. 388) and thereby prevents inactivation of glycogen synthase. In addition, insulin reduces the cAMP level by activating *cAMP phosphodiesterase* (PDE).

Regulation by transcriptional control (top). If the liver's glycogen reserves have been exhausted, the steroid hormone **cortisol** maintains glucose release by initiating the conversion of amino acids into glucose (*gluconeogenesis;* see p. 154). In the cell nucleus, the complex of cortisol and its receptor (see p. 378) binds to the promoter regions of various key enzymes of gluconeogenesis and leads to their transcription. The active enzymes are produced through translation of the mRNA formed. Control of the transcription of the gluconeogenesis enzyme *PEP carboxykinase* is discussed on p. 244.

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A. Principles of hormone action

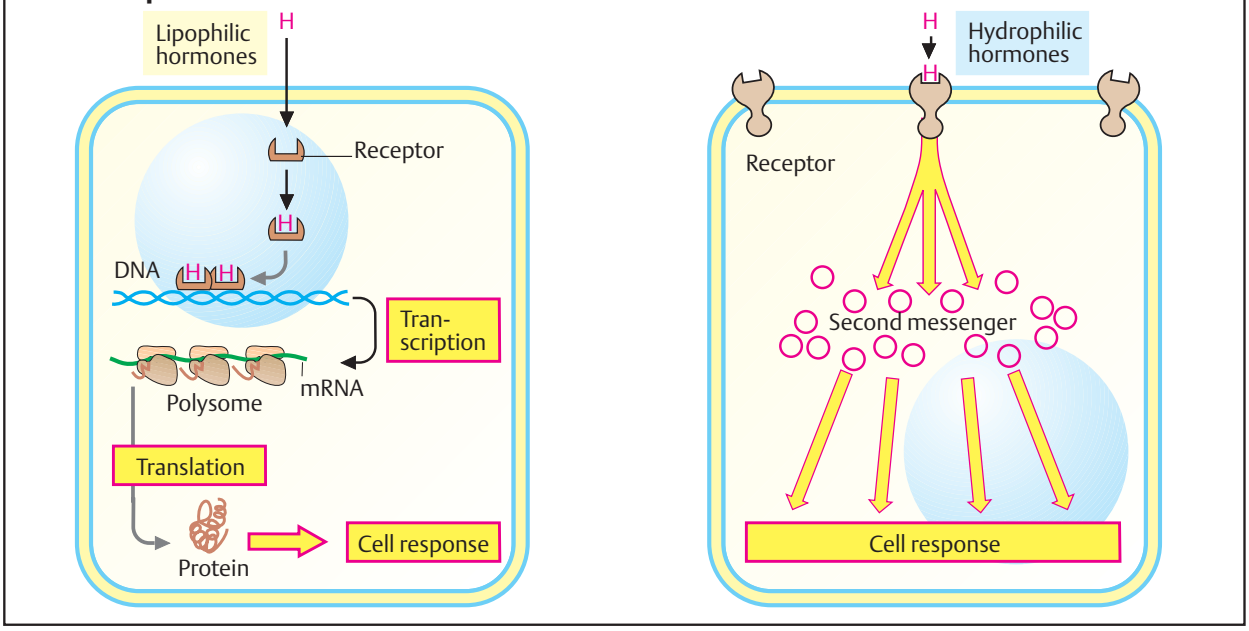

B. Hormonal regulation of glucose metabolism in the liver

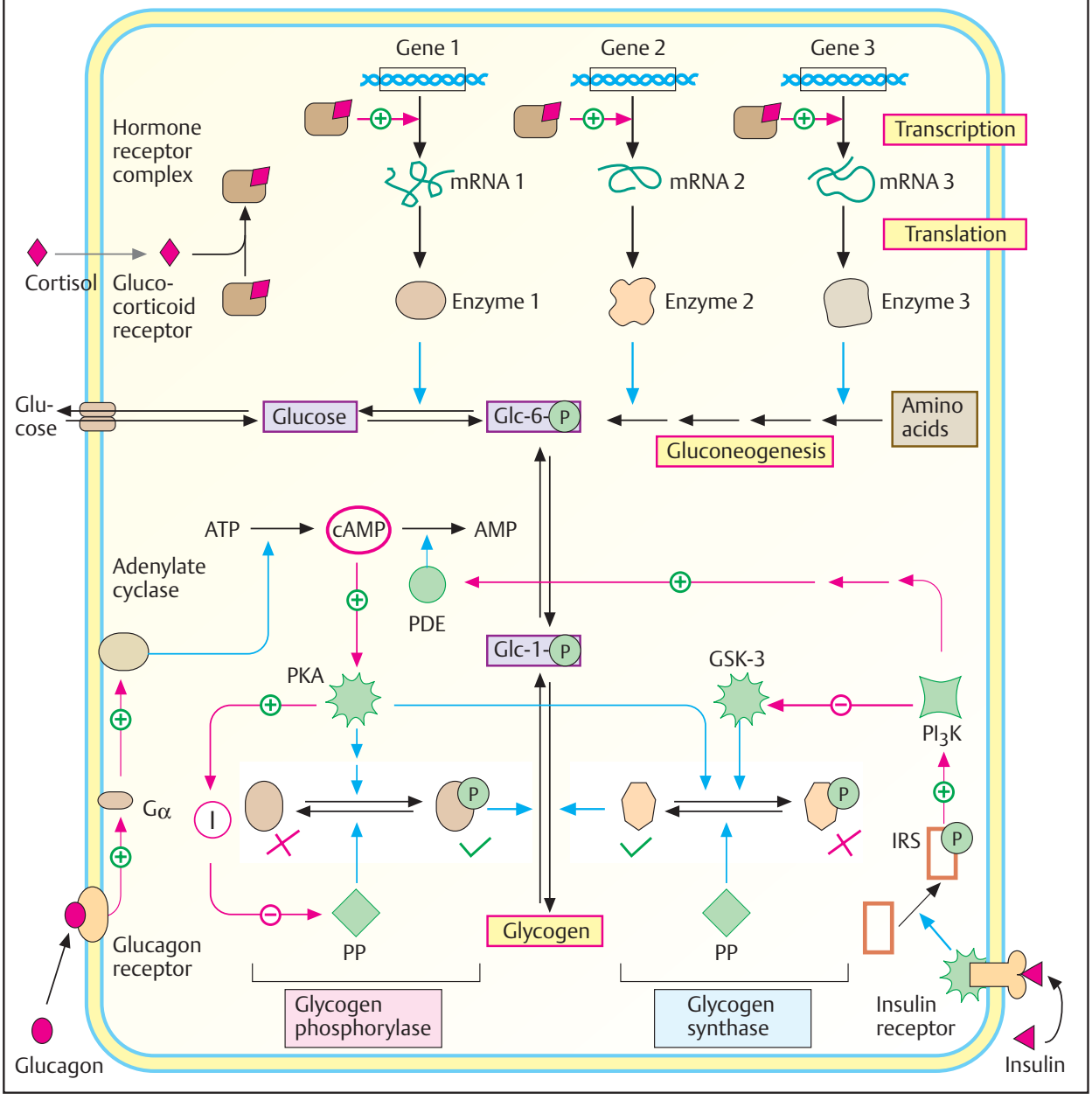

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ATP

The nucleotide coenzyme **adenosine triphosphate** (ATP) is the most important **form of chemical energy** in all cells. Cleavage of ATP is strongly exergonic. The energy this provides (ΔG; see p. 16) is used to drive endergonic processes (such as biosynthesis and movement and transport processes) through *energetic coupling* (see p. 124). The other *nucleoside triphosphate coenzymes* (GTP, CTP, and UTP) have similar chemical properties to ATP, but they are used for different tasks in metabolism (see p. 110).

A. ATP: structure ◑

In ATP, a chain of three phosphate residues is linked to the 5′-OH group of the nucleoside adenosine (see p. 80). These phosphate residues are termed α, β, and γ. The α phosphate is bound to ribose by a *phosphoric acid ester bond*. The linkages *between* the three phosphate residues, on the other hand, involve much more unstable *phosphoric acid anhydride bonds*. The active coenzyme is in fact generally a complex of ATP with an Mg^{2+} ion, which is coordinatively bound to the α and β phosphates (Mg^{2+} ATP^{4-}). However, the term "ATP" is usually used for the sake of simplicity.

B. Hydrolysis energies ◑

The formula for phosphate residues shown in Fig. **A**, with single and double bonds, is not an accurate representation of the actual charge distribution. In ATP, the oxygen atoms of all three phosphate residues have similarly strong negative charges (orange), while the phosphorus atoms represent centers of positive charge. One of the reasons for the instability of phosphoric anhydride bonds is the *repulsion between these negatively charged oxygen atoms*, which is partly relieved by cleavage of a phosphate residue. In addition, the free phosphate anion formed by hydrolysis of ATP is *better hydrated* and *more strongly resonance-stabilized* than the corresponding residue in ATP. This also contributes to the strongly exergonic character of ATP hydrolysis.

In *standard conditions*, the change in free enthalpy $\Delta G^{0'}$ (see p. 18) that occurs in the hydrolysis of phosphoric acid anhydride bonds amounts to –30 to –35 kJ mol^{-1} at pH 7. The particular anhydride bond of ATP that is cleaved only has a minor influence on $\Delta G^{0'}$ (**1**–**2**). Even the hydrolysis of diphosphate (also known as pyrophosphate; **4**) still yields more than –30 kJ mol^{-1}. By contrast, cleavage of the ester bond between ribose and phosphate only provides –9 kJ mol^{-1} (**3**).

In the cell, the ΔG of ATP hydrolysis is substantially larger, because the concentrations of ATP, ADP and P_i are much lower than in standard conditions and there is an excess of ATP over ADP (see p. 18). The pH value and Mg^{2+} concentration also affect the value of ΔG. The *physiological energy yield* of ATP hydrolysis to ADP and anorganic phosphate (P_i) is probably around –50 kJ mol^{-1}.

C. Types of ATP formation ●

Only a few compounds contain phosphate residues with a group transfer potential (see p. 18) that is high enough to transfer them to ADP and thus allow **ATP synthesis**. Processes that raise anorganic phosphate to this type of high potential are called **substrate level phosphorylations** (see p. 124). Reactions of this type take place in glycolysis (see p. 150) and in the tricarboxylic acid cycle (see p. 136). Another "energy-rich" phosphate compound is *creatine phosphate*, which is formed from ATP in muscle and can regenerate ATP as needed (see p. 336).

Most cellular ATP does not arise in the way described above (i. e., by transfer of phosphate residues from organic molecules to ADP), but rather by **oxidative phosphorylation**. This process takes place in mitochondria (or as light-driven phosphorylation in chloroplasts) and is energetically coupled to a proton gradient over a membrane. These H^+ gradients are established by electron transport chains and are used by the enzyme *ATP synthase* as a source of energy for direct linking of anorganic phosphate to ADP. In contrast to substrate level phosphorylation, oxidative phosphorylation requires the presence of oxygen (i. e., *aerobic* conditions).

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A. ATP: structure

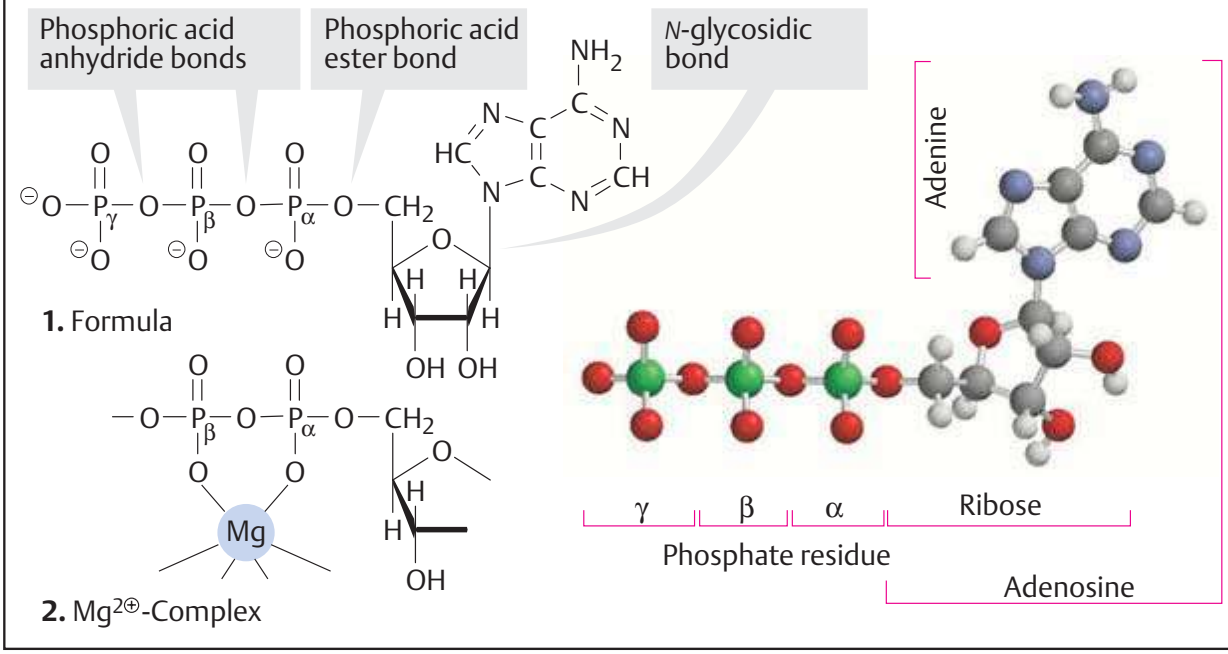

1. Formula

2. $Mg^{2\oplus}$-Complex

B. Hydrolysis energies

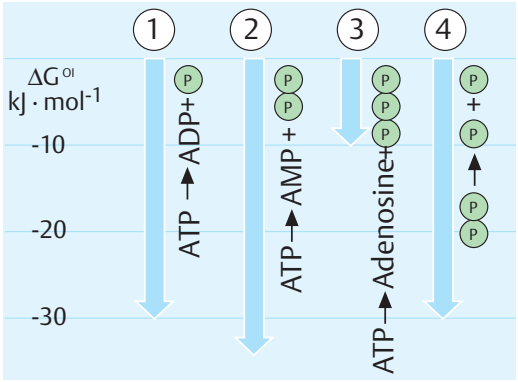

1. Hydrolysis energies

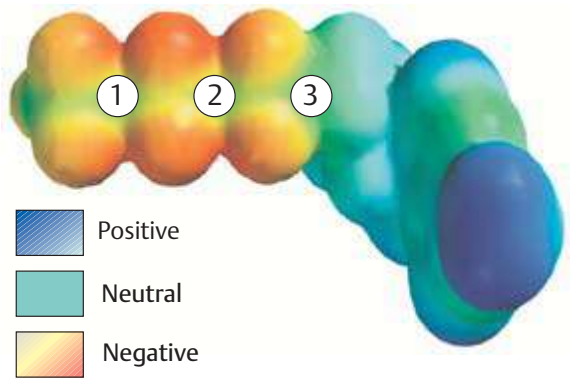

2. ATP: charge density

C. Types of ATP formation

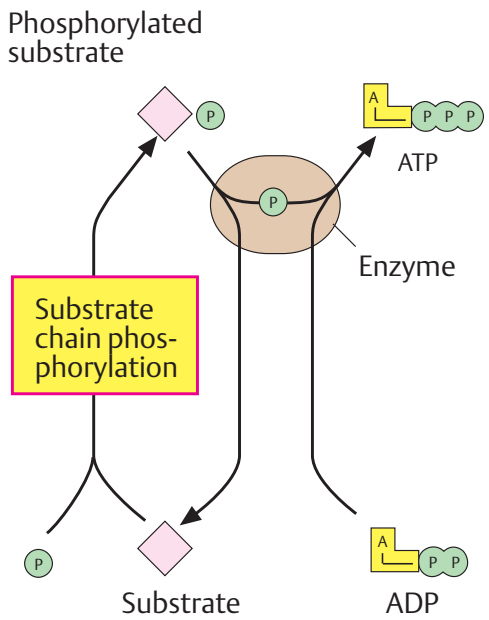

1. Phosphate transfer

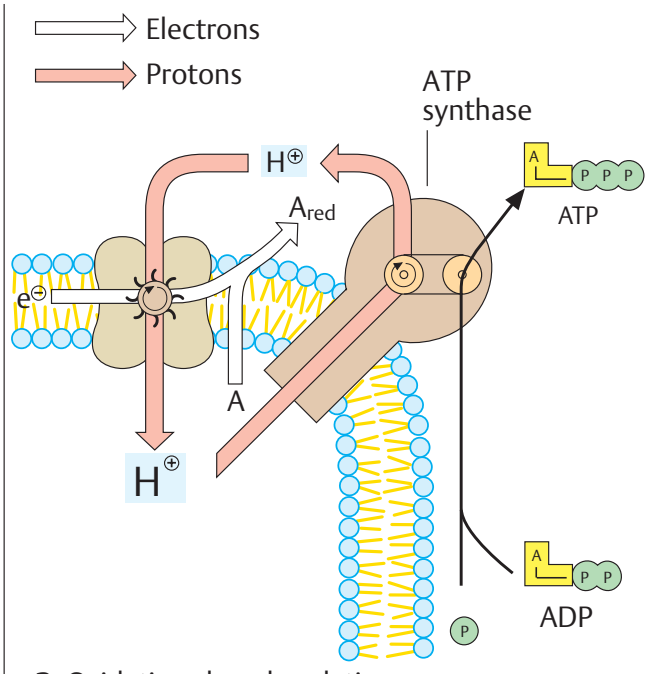

2. Oxidative phosphorylation

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Energetic coupling

The cell stores chemical energy in the form of "energy-rich" metabolites. The most important metabolite of this type is adenosine triphosphate (**ATP**), which drives a large number of energy-dependent reactions via **energetic coupling** (see p. 16).

A. Energetic coupling ◑

The change in free enthalpy ΔG^0 during hydrolysis (see p. 18) has been arbitrarily selected as a measure of the group transfer potential of "energy-rich" compounds. However, this does not mean that ATP is in fact hydrolyzed in energetically coupled reactions. If ATP hydrolysis and an endergonic process were simply allowed to run alongside each other, the hydrolysis would only produce heat, without influencing the endergonic process. For coupling, the two reactions have to be linked in such a way that a *common intermediate* arises. This connection is illustrated here using the example of the **glutamine synthetase reaction**.

Direct transfer of NH_3 to glutamate is endergonic ($\Delta G^{0'}$ = +14 kJ mol^{-1}; see p. 18), and can therefore not take place. In the cell, the reaction is divided into two exergonic steps. First, the γ-phophate residue is transferred from ATP to glutamate. This gives rise to an "energy-rich" *mixed acid anhydride*. In the second step, the phosphate residue from the intermediate is substituted by NH_3, and glutamine and free phosphate are produced. The energy balance of the reaction as a whole ($\Delta G^{0'}$ = –17 kJ mol^{-1}) is the sum of the changes in free enthalpy of direct glutamine synthesis ($\Delta G^{0'}$ = 14 kJ mol^{-1}) plus ATP hydrolysis ($\Delta G^{0'}$ = –31 kJ mol^{-1}), although ATP has not been hydrolyzed at all.

B. Substrate-level phosphorylation ◑

As mentioned earlier (see p. 122), there are a few metabolites that transfer phosphate to ADP in an exergonic reaction and can therefore form ATP. In ATP synthesis, anorganic phosphate or phosphate bound in an ester-like fashion is transferred to bonds with a high phosphate transfer potential. Reactions of this type are termed *"substrate-level phosphorylations,"* as they represent individual steps within metabolic pathways.

In the **glyceraldehyde 3-phosphate dehydrogenation** reaction, a step involved in glycolysis (**1**; see also **C**), the aldehyde group in glyceraldehyde 3-phosphate is oxidized into a carboxyl group. During the reaction, an anorganic phosphate is also introduced into the product, producing a mixed acid anhydride—1,3-bisphosphoglycerate. **Phosphopyruvate hydratase** ("enolase", **2**) catalyzes the elimination of water from 2-phosphoglycerate. In the *enol phosphate* formed (phospho*enol* pyruvate), the phosphate residue—in contrast to 2-phosphoglycerate—is at an extremely high potential ($\Delta G^{0'}$ of hydrolysis: –62 kJ mol^{-1}). A third reaction of this type is the formation of succinyl phosphate, which occurs in the tricarboxylic acid cycle as an individual step in the **succinyl CoA ligase** reaction. Here again, anorganic phosphate is introduced into a mixed acid anhydride bond to be transferred from there to GDP. Succinyl phosphate is only an intermediate here, and is not released by the enzyme.

In the literature, the term "substrate level phosphorylation" is used inconsistently. Some authors use it to refer to reactions in which *anorganic* phosphate is raised to a high potential, while others use it for the subsequent reactions, in which ATP or GTP is formed from the energy-rich intermediates.

C. Glyceraldehyde-3-phosphate dehydrogenase ○

The reaction catalyzed during glycolysis by *glyceraldehyde-3-phosphate dehydrogenase* (GADPH) is shown here in detail. Initially, the SH group of a cysteine residue of the enzyme is added to the carbonyl group of glyceraldehyde 3-phosphate (**a**). This intermediate is oxidized by NAD^+ into an "energy-rich" thioester (**b**). In the third step (**c**), anorganic phosphate displaces the thiol, and the mixed anhydride *1,3-bisphosphoglycerate* arises. In this bond, the phosphate residue is at a high enough potential for it to be transferred to ADP in the next step (not shown; see p. 150).

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A. Energetic coupling

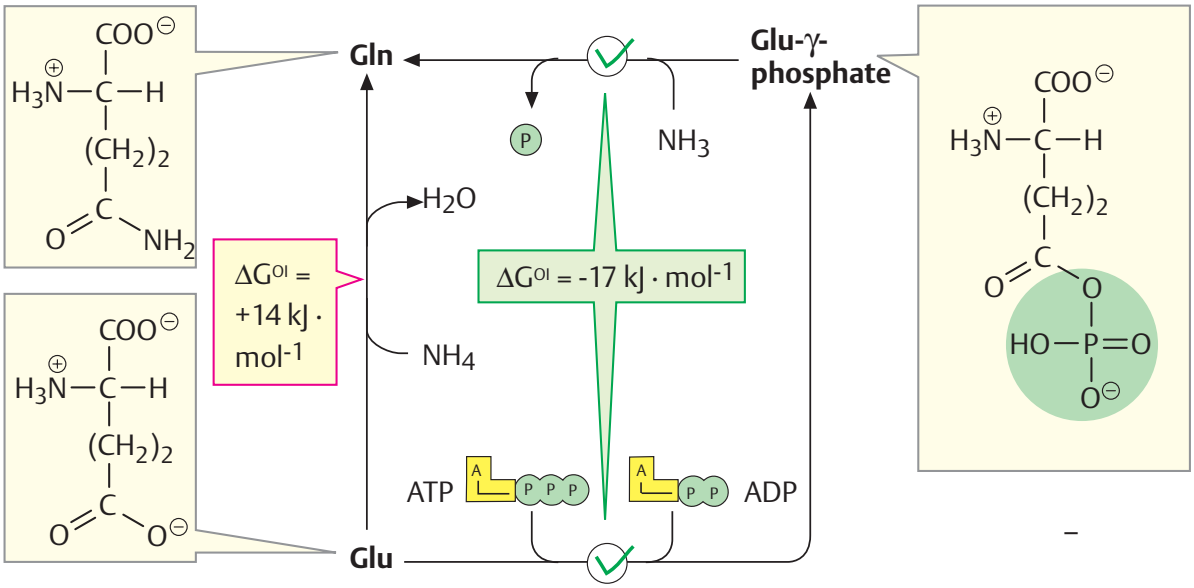

1. Glutamine synthetase reaction

Reaction 1:	Glutamate	+	NH_3	+14 kJ · mol^{-1}	Glutamine	+	H_2O	
Reaction 2:	ATP	+	H_2O	− 31 kJ · mol^{-1}	ADP	+	P	
Total:	Glutamate	+	NH_3 + ATP	− 17 kJ · mol^{-1}	Glutamine	+	ADP	+ P

2. Energy balance

B. Substrate level phosphorylation

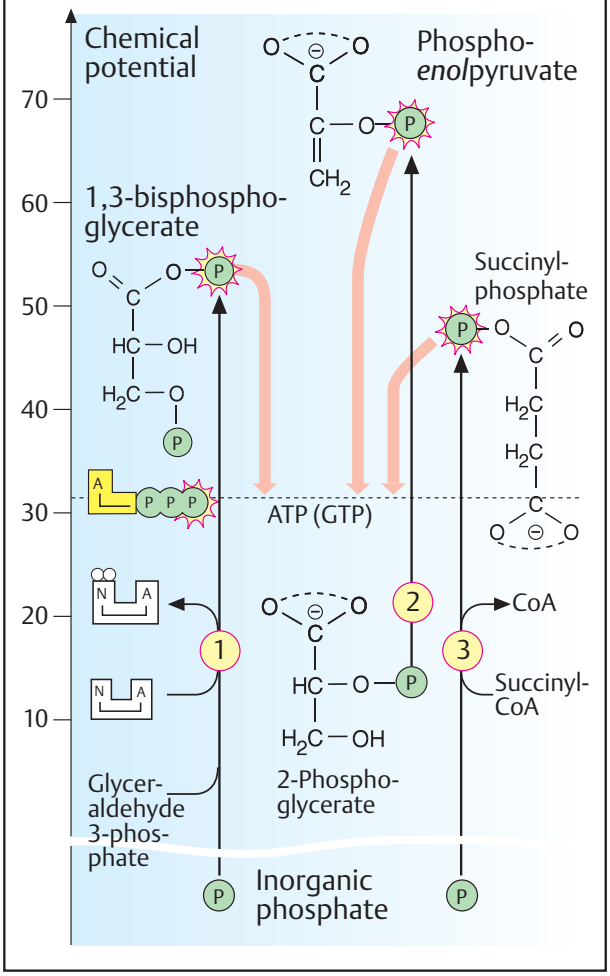

C. Glyceraldehyde 3-phosphate dehydrogenase

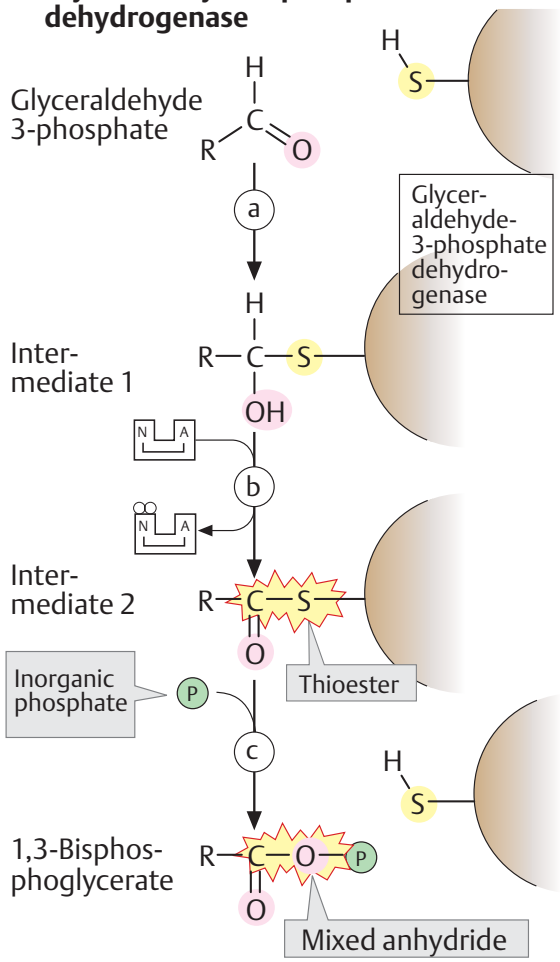

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Energy conservation at membranes

Metabolic energy can be stored not only in the form of "energy-rich" bonds (see p. 122), but also by separating electric charges from each other using an insulating layer to prevent them from redistributing. In the field of technology, this type of system would be called a *condenser*. Using the same principle, energy is also stored ("conserved") at cell membranes. The membrane functions as an insulator; electrically charged atoms and molecules (*ions*) function as charges.

A. Electrochemical gradient ◑

Although artificial lipid membranes are almost impermeable to ions, biological membranes contain **ion channels** that selectively allow individual ion types to pass through (see p. 222). Whether an ion can cross this type of membrane, and if so in which direction, depends on the **electrochemical gradient**—i. e., on the concentrations of the ion on each side of the membrane (the *concentration gradient*) and on the *difference* in the electrical potential between the interior and exterior, the **membrane potential**.

The membrane potential of resting cells (**resting potential**; see p. 350) is –0.05 to –0.09 V—i. e., there is an excess negative charge on the inner side of the plasma membrane. The main contributors to the resting potential are the two cations Na^+ and K^+, as well as Cl^- and organic anions (**1**). Data on the concentrations of these ions outside and inside animal cells, and permeability coef - cients, are shown in the table (**2**).

The behavior of an ion type is described quantitatively by the **Nernst equation** (**3**). $\Delta\psi_G$ is the membrane potential (in volts, V) at which there is *no* net transport of the ion concerned across the membrane (**equilibrium potential**). The factor R T/F n has a value of 0.026 V for monovalent ions at 25 °C. Thus, for K^+, the table (**2**) gives an equilibrium potential of ca. –0.09 V—i. e., a value more or less the same as that of the resting potential. By contrast, for Na^+ ions, $\Delta\psi_G$ is much higher than the resting potential, at +0.07 V. Na^+ ions therefore immediately flow into the cell when Na^+ channels open (see p. 350). The disequilibrium between Na^+ and K^+ ions is constantly maintained by the enzyme *Na^+/K^+-ATPase*, which consumes ATP.

B. Proton motive force ◑

Hydronium ions ("H^+ ions") can also develop electrochemical gradients. Such a **proton gradient** plays a decisive part in cellular ATP synthesis (see p. 142). As usual, the energy content of the gradient depends on the concentration gradients—i. e., on the **pH difference** эpH between the two sides of the membrane. In addition, the **membrane potential** $\Delta\psi$ also makes a contribution. Together, these two values give the **proton motive force** Δp, a measure for the work that the H^+ gradient can do. The proton gradient across the inner mitochondrial membrane thus delivers approximately 24 kJ per mol H^+.

C. Energy conservation in proton gradients ◑

Proton gradients can be built up in various ways. A very unusual type is represented by **bacteriorhodopsin** (**1**), a *light-driven proton pump* that various bacteria use to produce energy. As with rhodopsin in the eye, the light-sensitive component used here is covalently bound retinal (see p. 358). In photosynthesis (see p. 130), reduced *plastoquinone* (QH_2) transports protons, as well as electrons, through the membrane (**Q cycle**, **2**). The formation of the proton gradient by the **respiratory chain** is also coupled to redox processes (see p. 140). In complex III, a Q cycle is responsible for proton translocation (not shown). In *cytochrome c oxidase* (complex IV, **3**), H^+ transport is coupled to electron flow from cytochrome *c* to O_2.

In each of these cases, the H^+ gradient is utilized by an **ATP synthase** (**4**) to form ATP. ATP synthases consist of two components—a proton channel (F_0) and an inwardly directed protein complex (F_1), which conserves the energy of back-flowing protons through ATP synthesis (see p. 142).

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A. Electrochemical gradient

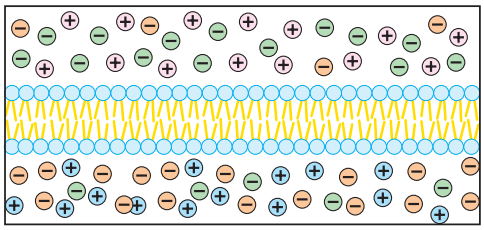

⊕ Na ⊕ K ⊖ Cl ⊖ Organic anions

1. Cause

Ion	Concentrations		Permeability coefficient
	Cyto-plasm (mM)	Extracelluar space (mM)	($cm \cdot s^{-1} \cdot 10^9$)
$K^{\oplus}$	100	5	500
$Na^{\oplus}$	15	150	5
$Ca^{2\oplus}$	0.0002	2	
$Cl^{\ominus}$	13	150	10
Organic anions	138	34	0

2. Concentrations

$$\Delta\Psi_G = \frac{R \cdot T}{F \cdot n} \cdot \ln \frac{C_{outside}}{C_{inside}}$$

R = gas constant
T = temperature (K)
n = Ion charge
F = Faraday constant

3. Nernst equation

B. Proton motive force

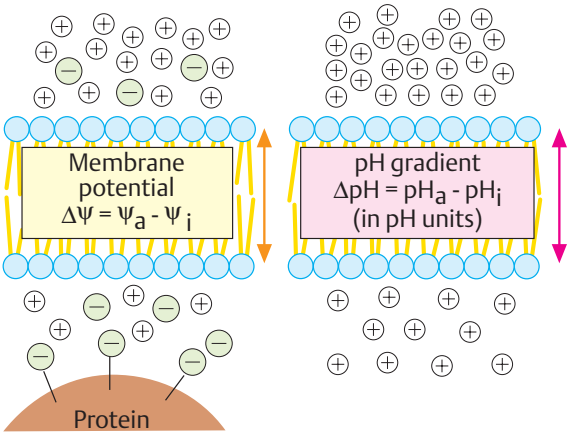

Proton motive force ≈ 0.06 V

$$\Delta p = \Delta\psi - \frac{2.3 \cdot R \cdot T}{F} \cdot \Delta pH$$

$$\Delta G_{H^{\oplus}_a \leftrightarrow H^{\oplus}_i} = -F \cdot \Delta p$$

C. Energy conservation in proton gradients

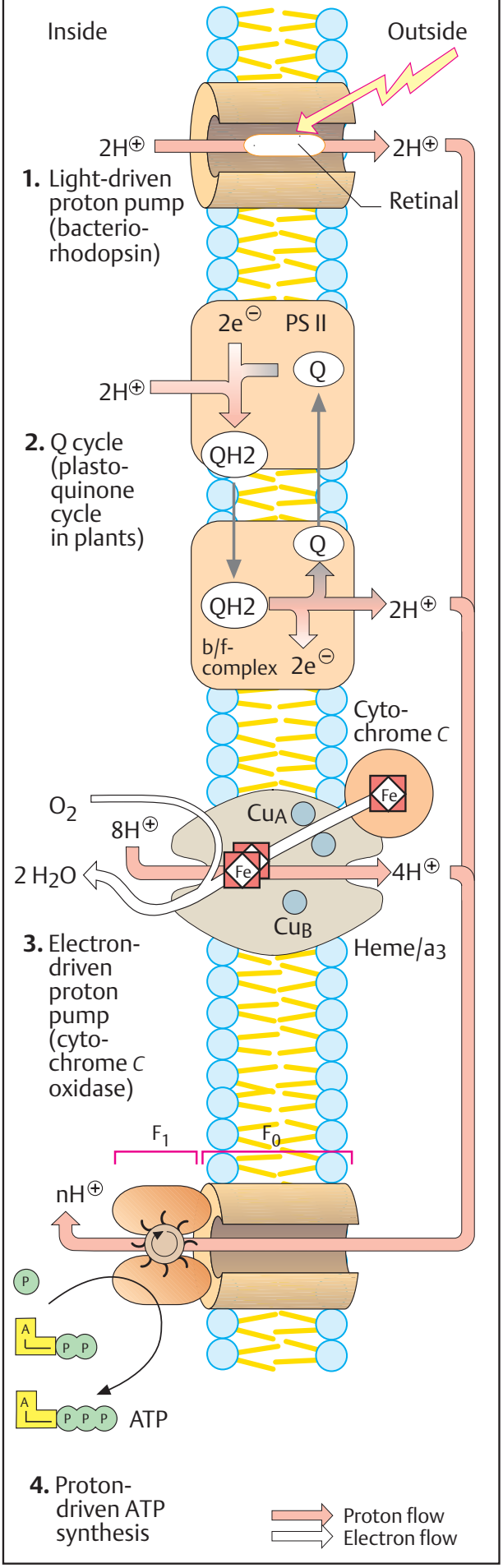

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Photosynthesis: light reactions

Sunlight is the most important source of energy for nearly all living organisms. With the help of **photosynthesis,** light energy is used to produce organic substances from CO_2 and water. This property of *phototrophic organisms* (plants, algae, and some bacteria) is exploited by *heterotrophic* organisms (e.g., animals), which are dependent on a supply of organic substances in their diet (see p. 112). The atmospheric *oxygen* that is vital to higher organisms is also derived from photosynthesis.

A. Photosynthesis: overview ◑

The chemical balance of photosynthesis is simple. Six molecules of CO_2 are used to form one hexose molecule (right). The hydrogen required for this reduction process is taken from water, and molecular oxygen is formed as a by-product (left). Light energy is required, since water is a very poor reducing agent and is therefore not capable of reducing CO_2.

In the light-dependent part of photosynthesis—the "**light reactions** "—H_2O molecules are split into protons, electrons, and oxygen atoms. The electrons undergo *excitation* by light energy and are raised to an energy level that is high enough to reduce $NADP^+$. The $NADPH+H^+$ formed in this way, in contrast to H_2O, is capable of "fixing" CO_2 reductively—i.e., of incorporating it into organic bonds. Another product of the light reactions is ATP, which is also required for CO_2 fixation. If $NADPH+H^+$, ATP, and the appropriate enzymes are available, CO_2 fixation can also take place in darkness. This process is therefore known as the "**dark reaction**."

The excitation of electrons to form NADPH is a complex photochemical process that involves **chlorophyll**, a tetrapyrrole dye containing Mg^{2+} that bears an extra phytol *residue* (see p. 132).

B. Light reactions ○

In green algae and higher plants, photosynthesis occurs in **chloroplasts.** These are organelles, which—like mitochondria—are surrounded by two membranes and contain their own DNA. In their interior, the *stroma*, *thylakoids* or flattened membrane sacs are stacked on top of each other to form *grana*. The inside of the thylakoid is referred to as the *lumen*. The light reactions are catalyzed by enzymes located in the thylakoid membrane, whereas the dark reactions take place in the stroma.

As in the respiratory chain (see p. 140), the light reactions cause electrons to pass from one redox system to the next in an **electron transport chain.** However, the *direction of transport* is opposite to that found in the respiratory chain. In the respiratory chain, electrons flow from $NADH+H^+$ to O_2, with the production of water and energy.

In photosynthesis, electrons are taken up from water and transferred to $NADP^+$, with an *expenditure of energy.* Photosynthetic electron transport is therefore energetically "uphill work." To make this possible, the transport is stimulated at two points by the *absorption of light energy.* This occurs through two **photosystems**—protein complexes that contain large numbers of chlorophyll molecules and other pigments (see p. 132). Another component of the transport chain is the **cytochrome b/f complex,** an aggregate of integral membrane proteins that includes two cytochromes (b_{563} and f). **Plastoquinone**, which is comparable to ubiquinone, and two soluble proteins, the coppercontaining **plastocyanin** and **ferredoxin**, function as mobile electron carriers. At the end of the chain, there is an enzyme that transfers the electrons to $NADP^+$.

Because photosystem II and the cytochrome b/f complex release protons from reduced plastoquinone into the lumen (via a Q cycle), photosynthetic electron transport establishes an **electrochemical gradient** across the thylakoid membrane (see p. 126), which is used for ATP synthesis by an *ATP synthase.* ATP and $NADPH+H^+$, which are both needed for the dark reactions, are formed in the stroma.

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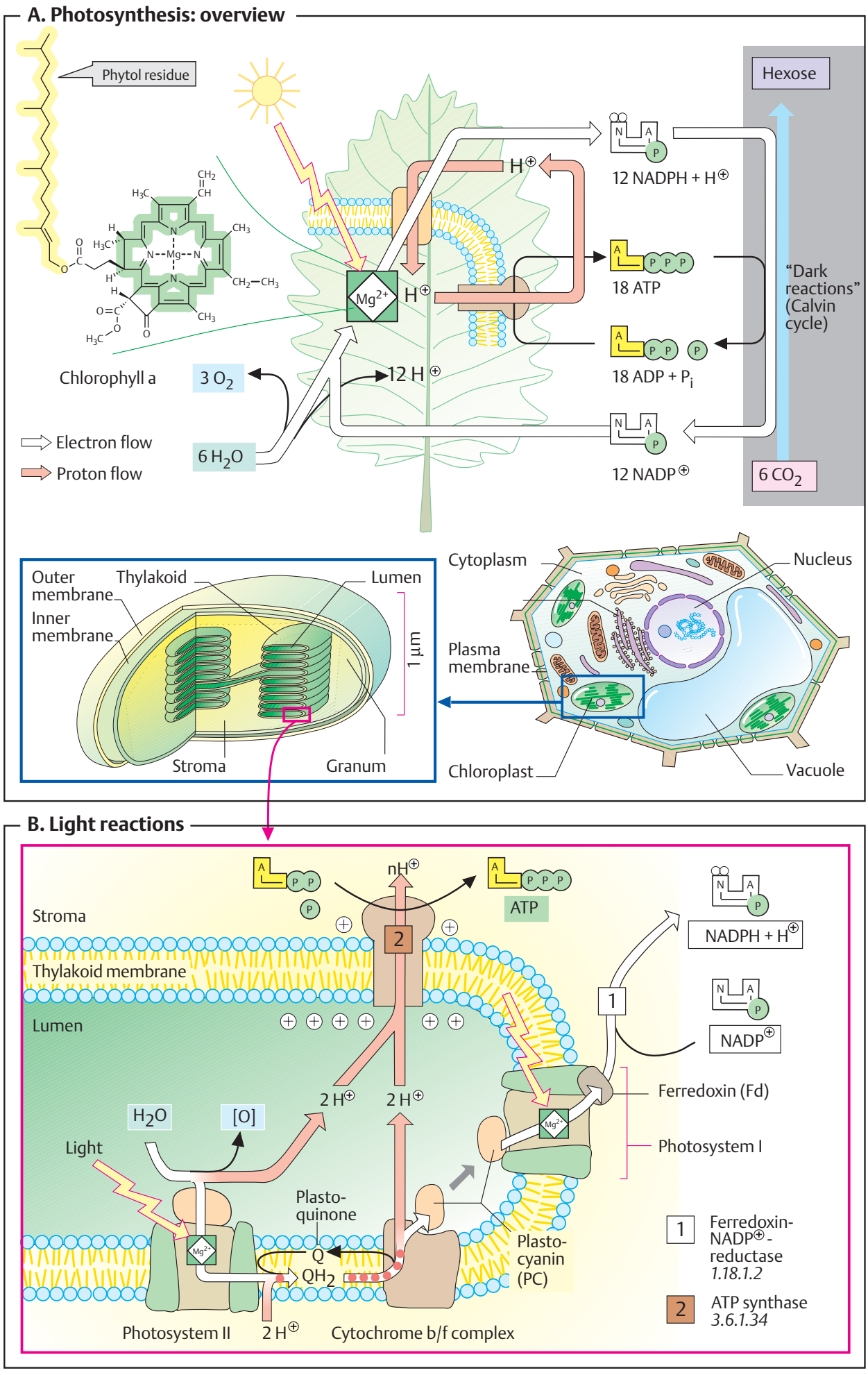

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Photosynthesis: dark reactions

The "light reactions" in photosynthesis bring about two strongly endergonic reactions—the reduction of $NADP^+$ to $NADPH+H^+$ and ATP synthesis (see p. 122). The chemical energy needed for this is produced from radiant energy by two photosystems.

A. Photosystem II ○

The photosynthetic electron transport chain in plants starts in **photosystem II** (PS II; see p. 128). PS II consists of numerous protein subunits (brown) that contain bound **pigments**—i. e., dye molecules that are involved in the absorption and transfer of light energy.

The schematic overview of PS II presented here (**1**) only shows the important pigments. These include a special chlorophyll molecule, the *reaction center* P_{680}; a neighboring Mg^{2+} free chlorophyll (*pheophytin*); and two bound *plastoquinones* (Q_A and Q_B). A third quinone (Q_P) is not linked to PS II, but belongs to the plastoquinone pool. The white arrows indicate the direction of electron flow from water to Q_P. Only about 1% of the chlorophyll molecules in PS II are *directly* involved in photochemical excitation (see p. 128). Most of them are found, along with other pigments, in what are known as light-harvesting or antenna complexes (green). The energy of light quanta striking these can be passed on to the reaction center, where it can be utilized.

In Fig. **2**, photosynthetic electron transport in PS II is separated into the individual steps involved. Light energy from the light-harvesting complexes (**a**) raises an electron of the chlorophyll in the reaction center to an excited *"singlet state."* The excited electron is immediately passed on to the neighboring pheophytin. This leaves behind an "electron gap" in the reaction center—i. e., a positively charged P_{680} radical (**b**). This gap is now filled by an electron removed from an H_2O molecule by the *water-splitting enzyme* (b). The excited electron passes on from the pheophytin via Q_A to Q_B, converting the latter into a *semiquinone radical* (**c**). Q_B is then reduced to *hydroquinone* by a second excited electron, and is then exchanged for an oxidized quinone (Q_P) from the plastoquinone pool. Further transport of electrons from the plastoquinone pool takes place as described on the preceding page and shown in **B**.

B. Redox series ○

It can be seen from the *normal potentials* E^0 (see p. 18) of the most important redox systems involved in the light reactions why two excitation processes are needed in order to transfer electrons from H_2O to $NADP^+$. After excitation in PS II, E^0 *rises* from around –1 V back to positive values in plastocyanin (PC)—i. e., the energy of the electrons has to be increased again in PS I. If there is no $NADP^+$ available, photosynthetic electron transport can still be used for ATP synthesis. During *cyclic photophosphorylation,* electrons return from ferredoxin (Fd) via the plastoquinone pool to the b/f complex. This type of electron transport does not produce any NADPH, but does lead to the formation of an H^+ gradient and thus to ATP synthesis.

C. Calvin cycle ○

The synthesis of hexoses from CO_2 is only shown in a very simplified form here; a complete reaction scheme is given on p. 407. The actual **CO_2 fixation**—i. e., the incorporation of CO_2 into an organic compound—is catalyzed by *ribulose bisphosphate carboxylase/oxygenase* ("rubisco"). Rubisco, the most abundant enzyme on Earth, converts ribulose 1,5-bisphosphate, CO_2 and water into *two molecules* of 3-phosphoglycerate. These are then converted, via 1,3-bisphosphoglycerate and 3-phosphoglycerate, into glyceraldehyde 3-phosphate (glyceral 3-phosphate). In this way, 12 glyceraldehyde 3-phosphates are synthesized from six CO_2. Two molecules of this intermediate are used by gluconeogenesis reactions to synthesize *glucose 6-phosphate* (bottom right). From the remaining 10 molecules, six molecules of *ribulose 1,5-bisphosphate* are regenerated, and the cycle then starts over again. In the Calvin cycle, ATP is required for phosphorylation of 3-phosphoglycerate and ribulose 5-phosphate. $NADPH+H^+$, the second product of the light reaction, is consumed in the reduction of 1,3-bisphosphoglycerate to glyceraldehyde 3-phosphate.

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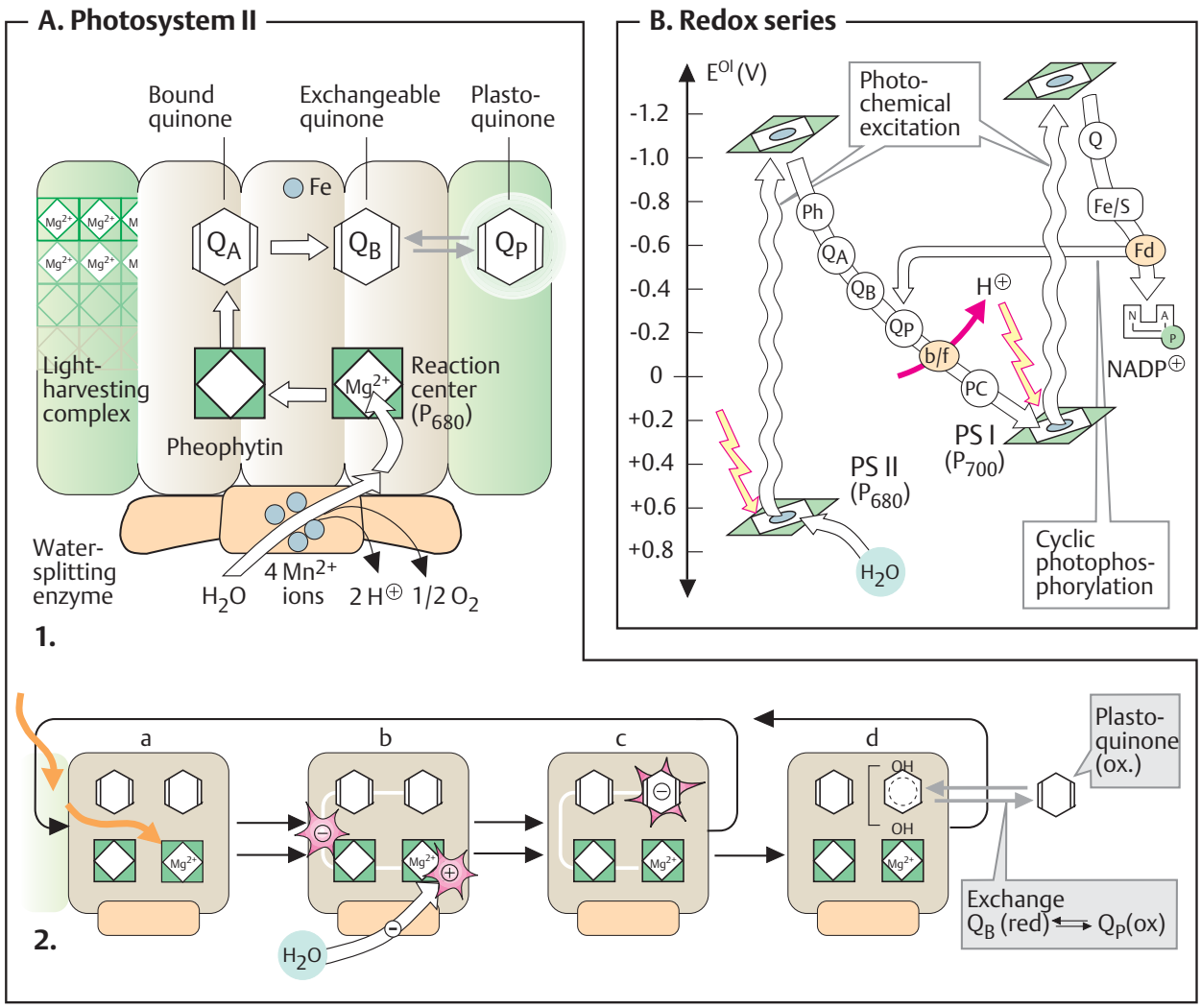

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Molecular models: membrane proteins

The plates show, in simplified form, the structures of **cytochrome *c* oxidase** (**A**; complex IV of the respiratory chain) and of **photosystem I** of a cyanobacterium (**B**). These two molecules are among the few integral membrane proteins for which the structure is known in detail. Both structures were determined by X-ray crystallography.

A. Cytochrome *c* oxidase ○

The enzyme cytochrome *c* oxidase ("COX," *EC 1.9.3.1*) catalyzes the final step of the respiratory chain. It receives electrons from the small heme protein cytochrome *c* and transfers them to molecular oxygen, which is thereby reduced to water (see p. 140). At the same time, 2–4 protons per water molecule formed are pumped from the matrix into the intermembrane space.

Mammalian COX (the illustration shows the enzyme from bovine heart) is a dimer that has two identical subunits with masses of 204 kDa each. Only one subunit is shown in detail here; the other is indicated by gray lines. Each subunit consists of 13 different polypeptides, which all span the inner mitochondrial membrane. Only polypeptides I (light blue) and II (dark blue) and the linked cofactors are involved in electron transport. The other chains, which are differently expressed in the different organs, probably have regulatory functions. The two heme groups, heme a (orange) and heme a_1 (red) are bound in polypeptide 1. The copper center Cu_A consists of two copper ions (green), which are coordinated by amino acid residues in polypeptide II. The second copper (Cu_B) is located in polypeptide I near heme a_3.

To reduce an O_2 molecule to two molecules of H_2O, a total of four electrons are needed, which are supplied by cytochrome *c* (pink, top left) and initially given off to Cu_A. From there, they are passed on via heme a and heme a_3 to the enzyme's reaction center, which is located between heme a_3 and Cu_B. The reduction of the oxygen takes place in several steps, without any intermediate being released. The four protons needed to produce water and the H^+ ions pumped into the intermembrane space are taken up by two channels (D and K, not shown). The mechanism that links proton transport to electron transfer is still being investigated.

B. Reaction center of *Synechococcus elongatus* ○

Photosystem I (PS I) in the cyanobacterium *Synechococcus elongatus* is the first system of this type for which the structure has been solved in atomic detail. Although the bacterial photosystem differs slightly from the systems in higher plants, the structure provides valuable hints about the course of the light reactions in photosynthesis (see p. 128). The functioning of the photosystem is discussed in greater detail on p. 130.

The functional form of PS I in *S. elongatus* consists of a trimer with a mass of more than 10^6 Da that is integrated into the membrane. Only one of the three subunits is shown here. This consists of 12 different polypeptides (gray-blue), 96 chlorophyll molecules (green), 22 carotenoids (orange), several phylloquinones (yellow), and other components. Most of the chlorophyll molecules are so-called **antenna pigments**. These collect light energy and conduct it to the **reaction center**, which is located in the center of the structure and therefore not visible. In the reaction center, an electron is excited and transferred via various intermediate steps to a ferredoxin molecule (see p. 128). The **chlorophylls** (see formula) are heme-like pigments with a highly modified tetrapyrrole ring, a central Mg^{2+} ion, and an apolar phytol side chain. Shown here is chlorophyll a, which is also found in the reaction center of the *S. elongatus* photosystem.

The yellow and orange-colored **carotenoids**—e. g., *β-carotene* (see formula)—are auxiliary pigments that serve to protect the chloroplasts from oxidative damage. Dangerous radicals can be produced during the light reaction—particularly *singlet oxygen*. Carotenoids prevent compounds of this type from arising, or render them inactive. Carotenoids are also responsible for the coloring of leaves seen during fall. They are left behind when plants break down chlorophyll in order to recover the nitrogen it contains.

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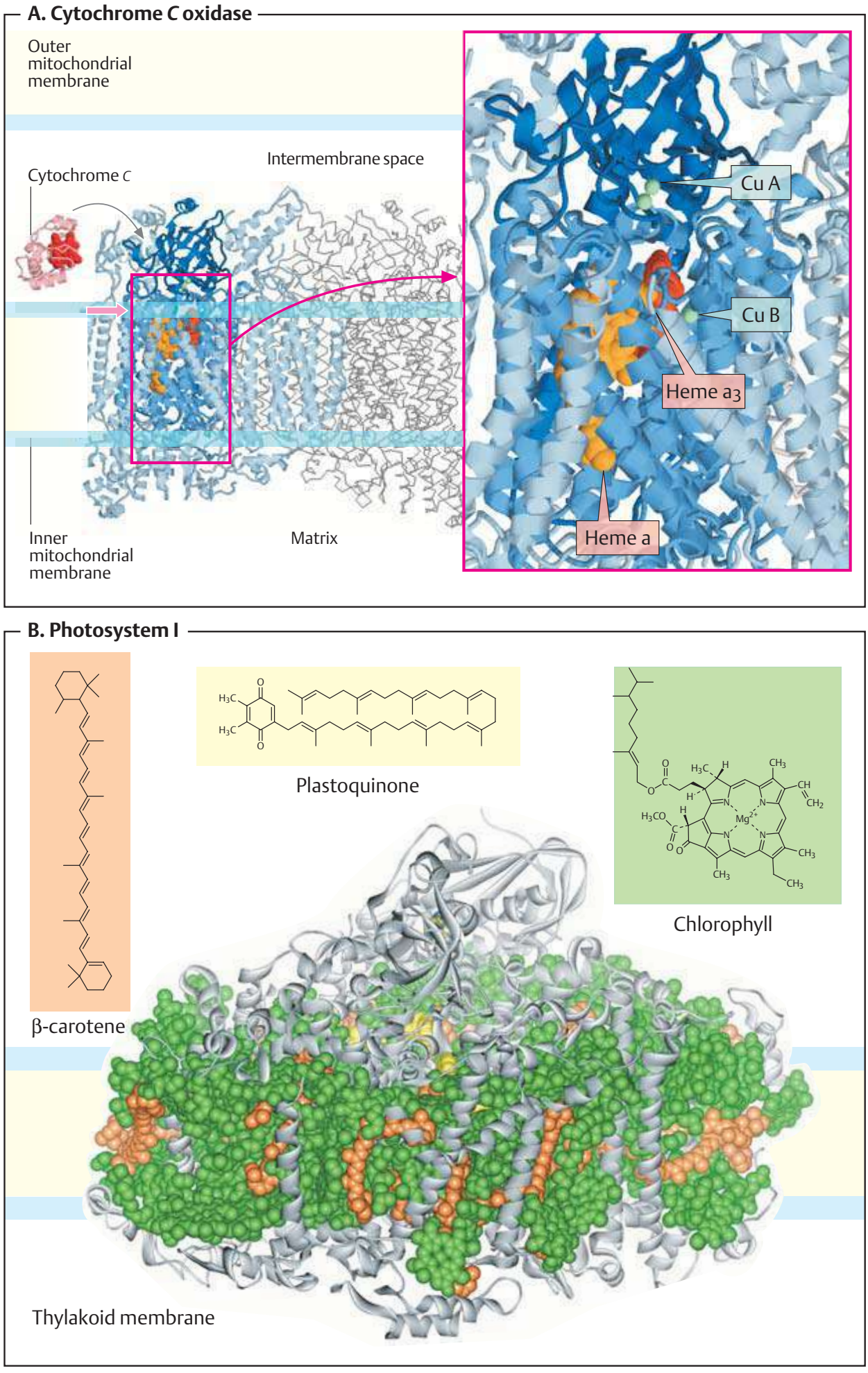

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Oxoacid dehydrogenases

The intermediary metabolism has *multienzyme complexes* which, in a complex reaction, catalyze the **oxidative decarboxylation** of 2-oxoacids and the transfer to coenzyme A of the acyl residue produced. NAD^+ acts as the electron acceptor. In addition, thiamine diphosphate, lipoamide, and FAD are also involved in the reaction. The *oxoacid dehydrogenases* include a) the *pyruvate dehydrogenase complex* (PDH, pyruvate → acetyl CoA), b) the *2-oxoglutarate dehydrogenase complex* of the tricarboxylic acid cycle (ODH, 2-oxoglutarate → succinyl CoA), and c) the *branched chain dehydrogenase complex,* which is involved in the catabolism of valine, leucine, and isoleucine (see p. 414).

A. Pyruvate dehydrogenase: reactions ◑

The pyruvate dehydrogenase reaction takes place in the mitochondrial matrix (see p. 210). Three different enzymes [E1–E3] form the PDH multienzyme complex (see **B**).

[1] Initially, *pyruvate dehydrogenase* [E1] catalyzes the decarboxylation of pyruvate and the transfer of the resulting hydroxyethyl residue to **thiamine diphosphate** (TPP, **1a**). The same enzyme then catalyzes oxidation of the TPP-bound hydroxyethyl group to yield an acetyl residue. This residue and the reducing equivalents obtained are then transferred to **lipoamide** (**1b**).

[2] The second enzyme, *dihydrolipoamide acetyltransferase* [E2], shifts the acetyl residue from lipoamide to **coenzyme A** (**2**), with dihydrolipoamide being left over.

[3] The third enzyme, *dihydrolipoamide dehydrogenase* [E3], reoxidizes dihydrolipoamide, with **$NADH+H^+$** being formed. The electrons are first taken over by enzyme-bound **FAD** (**3a**) and then transferred via a catalytically active disulfide bond in the E3 subunit (not shown) to soluble NAD^+ (**3b**).

The five different **coenzymes** involved are associated with the enzyme components in different ways. Thiamine diphosphate is non-covalently bound to E1, whereas lipoamide is covalently bound to a lysine residue of E2 and FAD is bound as a *prosthetic group* to E3. NAD^+ and coenzyme A, being soluble coenzymes, are only temporarily associated with the complex.

An important aspect of PDH catalysis is the spatial relationship between the components of the complex. The covalently bound lipoamide coenzyme is part of a mobile domain of E2, and is therefore highly mobile. This structure is known as the *lipoamide arm,* and swings back and forth between E1 and E3 during catalysis. In this way, lipoamide can interact with the TPP bound at E1, with solute coenzyme A, and also with the FAD that serves as the electron acceptor in E3.

B. PDH complex of *Escherichia coli* ○

The PDH complex of the bacterium *Escherichia coli* has been particularly well studied. It has a molecular mass of 5.3 10^6, and with a diameter of more than 30 nm it is larger than a ribosome. The complex consists of a total of 60 polypeptides (**1**, **2**): 24 molecules of E2 (eight trimers) form the almost cube-shaped core of the complex. Each of the six surfaces of the cube is occupied by a dimer of E3 components, while each of the twelve edges of the cube is occupied by dimers of E1 molecules. Animal oxoacid dehydrogenases have similar structures, but differ in the numbers of subunits and their molecular masses.

Further information

The PDH reaction, which is practically irreversible, occupies a strategic position at the interface between carbohydrate and fatty acid metabolism, and also supplies acetyl residues to the tricarboxylic acid cycle. PDH activity is therefore strictly regulated (see p. 144). **Interconversion** is particularly important in animal cells (see p. 120). Several PDH-specific *protein kinases* inactivate the E1 components through phosphorylation, while equally specific *protein phosphatases* reactivate it again. The binding of the kinases and phosphatases to the complex is in turn regulated by metabolites. For example, high concentrations of acetyl CoA promote binding of kinases and thereby inhibit the reaction, while Ca^{2+} increases the activity of the phosphatase. Insulin activates PDH via inhibition of phosphorylation.

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A. Pyruvate dehydrogenase: reactions

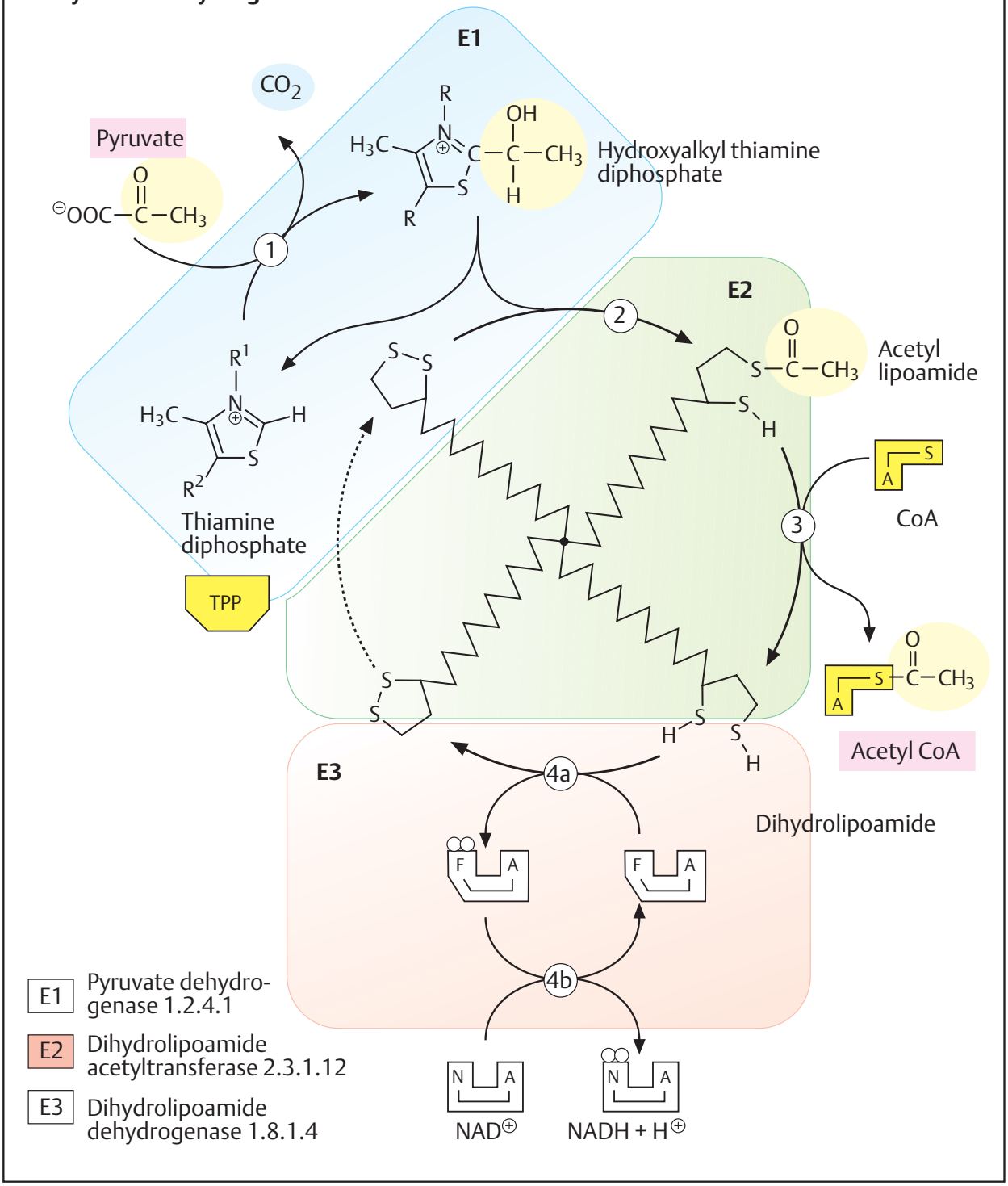

B. PDH complex of *Escherichia coli*

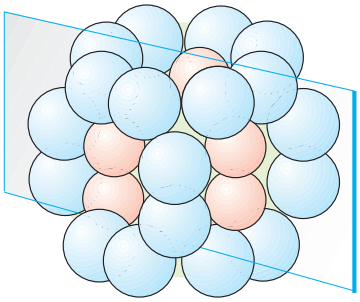

1.

E1	12 · 2 = 24
E2	8 · 3 = 24
E3	6 · 2 =12
E1+ E2 + E3 = 60	

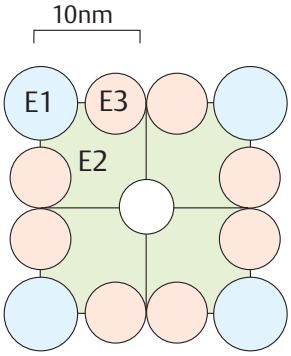

2.

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Tricarboxylic acid cycle: reactions

The **tricarboxylic acid cycle** (TCA cycle, also known as the citric acid cycle or Krebs cycle) is a cyclic metabolic pathway in the mitochondrial matrix (see p. 210). In eight steps, it oxidizes acetyl residues (CH_3-CO-) to carbon dioxide (CO_2). The reducing equivalents obtained in this process are transferred to NAD^+ or ubiquinone, and from there to the respiratory chain (see p. 140). Additional metabolic functions of the cycle are discussed on p. 138.

A. Tricarboxylic acid cycle ◑

The acetyl-CoA that supplies the cycle with acetyl residues is mainly derived from *β-oxidation* of fatty acids (see p. 164) and from the *pyruvate dehydrogenase reaction.* Both of these processes take place in the mitochondrial matrix.

[1] In the first step of the cycle, *citrate synthase* catalyzes the transfer of an acetyl residue from **acetyl CoA** to a carrier molecule, oxaloacetic acid. The product of this reaction, **tricarboxylic acid,** gives the cycle its name.

[2] In the next step, tricarboxylic acid undergoes isomerization to yield **isocitrate.** In the process, only the hydroxyl group is shifted within the molecule. The corresponding enzyme is called *aconitate hydratase* ("aconitase"), because unsaturated *aconitate* arises as an enzyme-bound intermediate during the reaction (not shown; see p. 8). Due to the properties of aconitase, the isomerization is absolutely *stereospecific*. Although citrate is not chiral, isocitrate has two chiral centers, so that it could potentially appear in *four* isomeric forms. However, in the tricarboxylic acid cycle, only one of these stereoisomers, (*2R,3S*)-isocitrate, is produced.

[3] The first oxidative step now follows. *Isocitrate dehydrogenase* oxidizes the hydroxyl group of isocitrate into an oxo group. At the same time, a carboxyl group is released as CO_2, and **2-oxoglutarate** (also known as α-ketoglutarate) and $NADH+H^+$ are formed.

[4] The next step, the formation of **succinyl CoA,** also involves one oxidation and one decarboxylation. It is catalyzed by *2-oxoglutarate dehydrogenase,* a multienzyme complex closely resembling the PDH complex (see p. 134). $NADH+H^+$ is once again formed in this reaction.

[5] The subsequent cleavage of the thioester succinylCoA into **succinate** and coenzyme A by *succinic acid-CoA ligase* (succinyl CoA synthetase, succinic thiokinase) is strongly *exergonic* and is used to synthesize a phosphoric acid anhydride bond ("*substrate level phosphorylation*", see p. 124). However, it is not ATP that is produced here as is otherwise usually the case, but instead **guanosine triphosphate (GTP)**. However, GTP can be converted into ATP by a *nucleoside diphosphate kinase* (not shown).

[6] Via the reactions described so far, the acetyl residue has been completely oxidized to CO_2. At the same time, however, the carrier molecule oxaloacetate has been reduced to succinate. Three further reactions in the cycle now regenerate oxaloacetate from succinate. Initially, *succinate dehydrogenase* oxidizes succinate to **fumarate**. In contrast to the other enzymes in the cycle, succinate dehydrogenase is an integral protein of the inner mitochondrial membrane. It is therefore also assigned to the respiratory chain as complex II. Although succinate dehydrogenase contains FAD as a prosthetic group, **ubiquinone** is the real electron acceptor of the reaction.

[7] Water is now added to the double bond of fumarate by *fumarate hydratase* (*"fumarase"*), and chiral *(2S)*-**malate** is produced.

[8] In the last step of the cycle, malate is again oxidized by *malate dehydrogenase* into **oxaloacetate**, with $NADH+H^+$ again being produced. With this reaction, the cycle is complete and can start again from the beginning. As the equilibrium of the reaction lies well on the side of malate, the formation of oxaloacetic acid by reaction [8] depends on the strongly exergonic reaction [1], which immediately removes it from the equilibrium.

The **net outcome** is that each rotation of the tricarboxylic acid cycle converts one acetyl residue and two molecules of H_2O into two molecules of CO_2. At the same time, one GTP, three $NADH+H^+$ and one reduced ubiquinone (QH_2) are produced. By oxidative phosphorylation (see p. 122), the cell obtains around nine molecules of ATP from these reduced coenzymes (see p. 146). Together with the directly formed GTP, this yields a total of 10 ATP per acetyl group.

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A. Tricarboxylic acid cycle

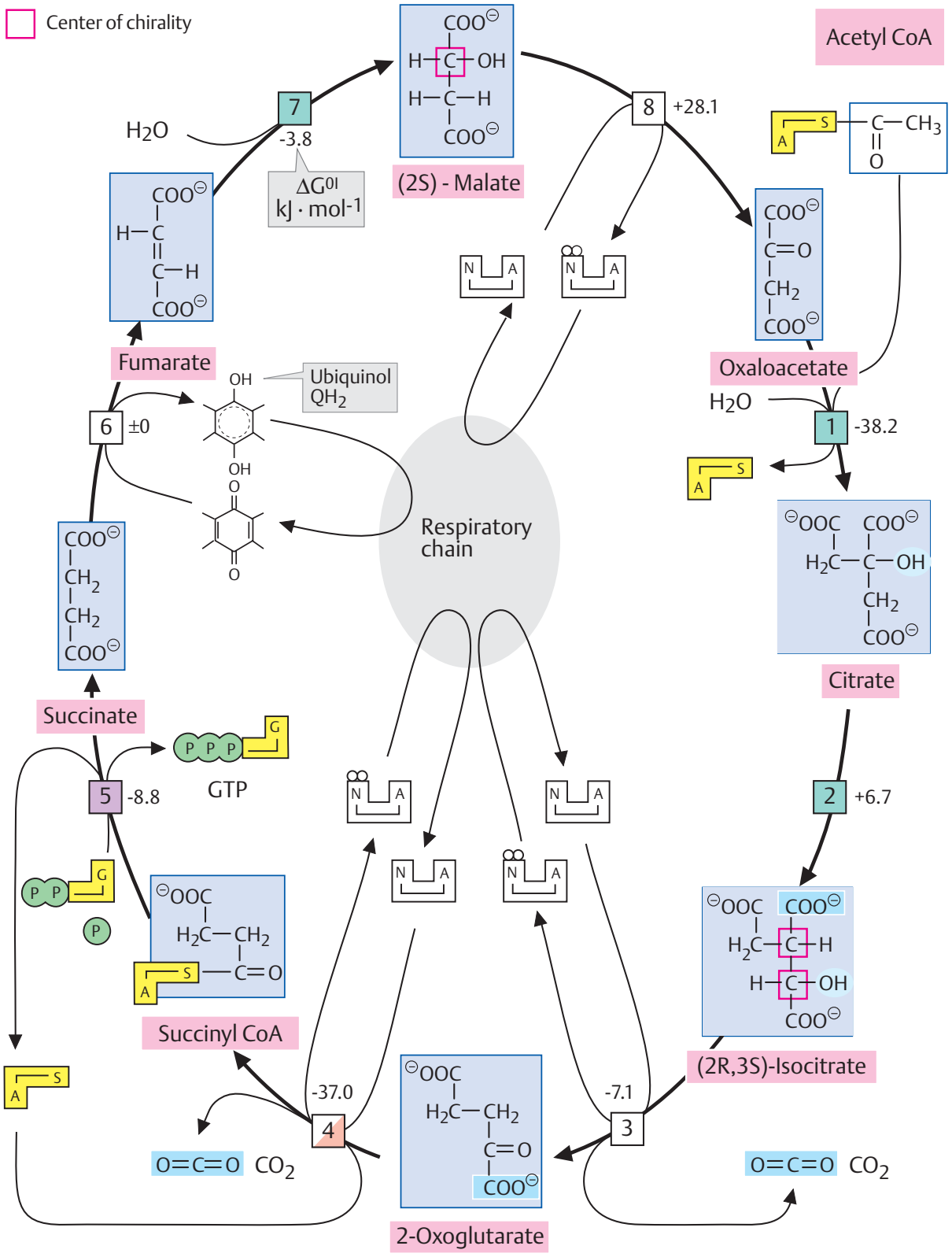

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Tricarboxylic acid cycle: functions

A. Tricarboxylic acid cycle: functions ◑

The tricarboxylic acid cycle (see p. 136) is often described as the "hub of intermediary metabolism." It has both catabolic and anabolic functions—it is **amphibolic.**

As a **catabolic pathway**, it initiates the **"terminal oxidation"** of energy substrates. Many catabolic pathways lead to intermediates of the tricarboxylic acid cycle, or supply metabolites such as pyruvate and acetyl-CoA that can enter the cycle, where their C atoms are oxidized to CO_2. The reducing equivalents (see p. 14) obtained in this way are then used for *oxidative phosphorylation*—i. e., to aerobically synthesize ATP (see p. 122).

The tricarboxylic acid cycle also supplies important **precursors for anabolic pathways.** Intermediates in the cycle are converted into:

- Glucose (gluconeogenesis; precursors: oxaloacetate and malate—see p. 154)
- Porphyrins (precursor: succinyl-CoA—see p. 192)
- Amino acids (precursors: 2-oxoglutarate, oxaloacetate—see p. 184)
- Fatty acids and isoprenoids (precursor: citrate—see below)

The intermediates of the tricarboxylic acid cycle are present in the mitochondria only in very small quantities. After the oxidation of acetyl-CoA to CO_2, they are constantly regenerated, and their concentrations therefore remain constant, averaged over time. Anabolic pathways, which remove intermediates of the cycle (e. g., gluconeogenesis) would quickly use up the small quantities present in the mitochondria if metabolites did not reenter the cycle at other sites to replace the compounds consumed. Processes that replenish the cycle in this way are called **anaplerotic reactions**.

The degradation of most amino acids is anaplerotic, because it produces either intermediates of the cycle or pyruvate (*glucogenic amino acids;* see p. 180). Gluconeogenesis is in fact largely sustained by the degradation of amino acids. A particularly important anaplerotic step in animal metabolism leads from pyruvate to oxaloacetic acid. This ATP-dependent reaction is catalyzed by *pyruvate carboxylase* [1]. It allows pyruvate yielding amino acids and lactate to be used for gluconeogenesis.

By contrast, *acetyl CoA does not have anaplerotic effects* in animal metabolism. Its carbon skeleton is completely oxidized to CO_2 and is therefore no longer available for biosynthesis. Since fatty acid degradation only supplies acetyl CoA, animals are unable to convert fatty acids into glucose. During periods of hunger, it is therefore not the fat reserves that are initially drawn on, but proteins. In contrast to fatty acids, the amino acids released are able to maintain the blood glucose level (see p. 308).

The tricarboxylic acid cycle not only takes up acetyl CoA from fatty acid degradation, but also supplies the material for the *biosynthesis of fatty acids* and isoprenoids. Acetyl CoA, which is formed in the matrix space of mitochondria by pyruvate dehydrogenase (see p. 134), is not capable of passing through the inner mitochondrial membrane. The acetyl residue is therefore condensed with oxaloacetate by mitochondrial *citrate synthase* to form citrate. This then leaves the mitochondria by antiport with malate (right; see p. 212). In the cytoplasm, it is cleaved again by ATP-dependent *citrate lyase* [4] into acetyl-CoA and oxaloacetate. The oxaloacetate formed is reduced by a cytoplasmic *malate dehydrogenase* to malate [2], which then returns to the mitochondrion via the antiport already mentioned. Alternatively, the malate can be oxidized by *"malic enzyme"* [5], with decarboxylation, to pyruvate. The $NADPH+H^+$ formed in this process is also used for fatty acid biosynthesis.

Additional information

Using the so-called **glyoxylic acid cycle**, plants and bacteria are able to convert acetyl-CoA into succinate, which then enters the tricarboxylic acid cycle. For these organisms, fat degradation therefore functions as an anaplerotic process. In plants, this pathway is located in special organelles, the *glyoxysomes.*

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A. Tricarboxylic acid cycle: functions

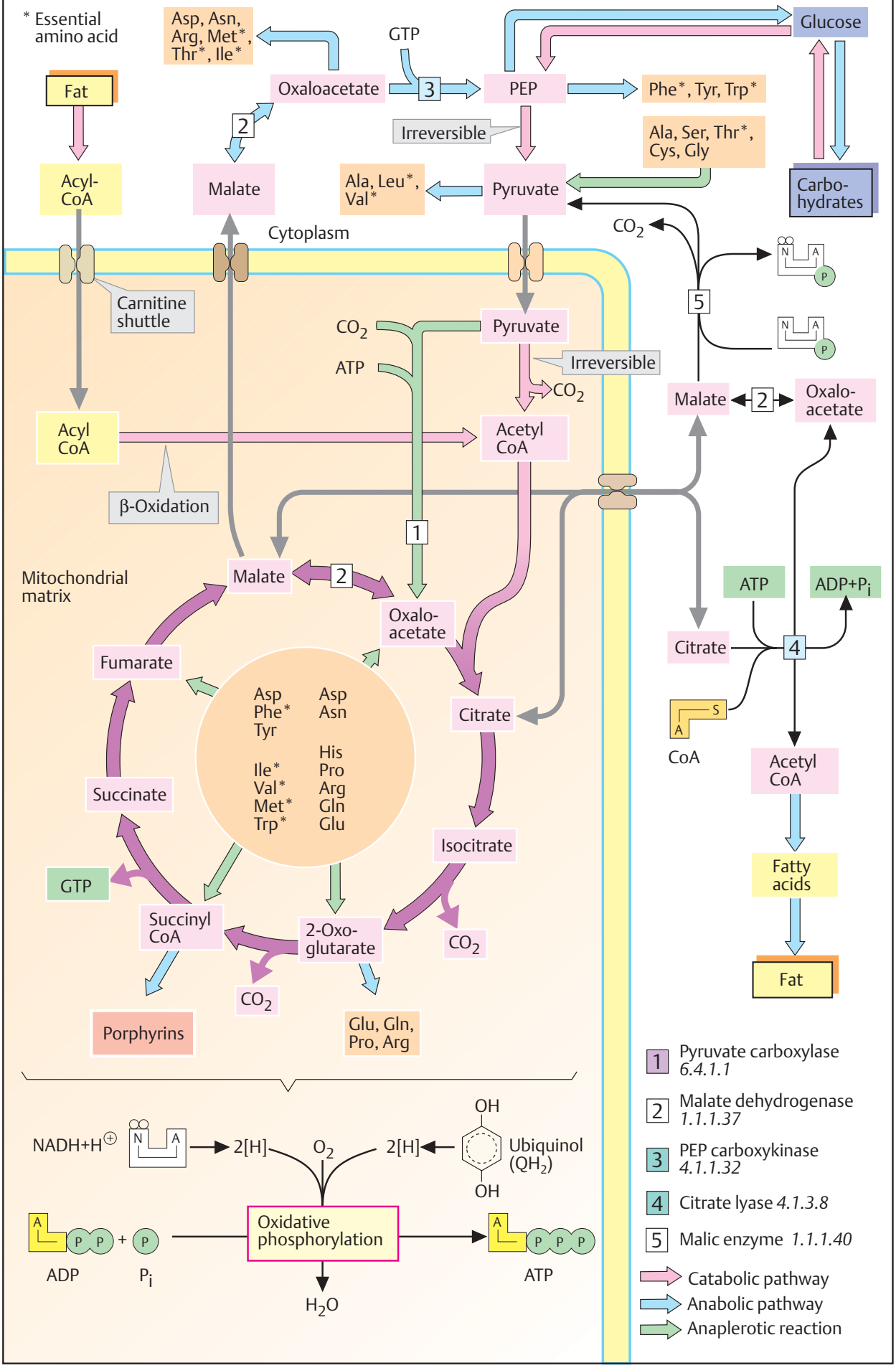

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Respiratory chain

The **respiratory chain** is one of the pathways involved in *oxidative phosphorylation* (see p. 122). It catalyzes the steps by which electrons are transported from $NADH+H^+$ or reduced ubiquinone (QH_2) to molecular oxygen. Due to the wide difference between the redox potentials of the donor ($NADH+H^+$ or QH_2) and the acceptor (O_2), this reaction is strongly exergonic (see p. 18). Most of the energy released is used to establish a proton gradient across the inner mitochondrial membrane (see p. 126), which is then ultimately used to synthesize ATP with the help of *ATP synthase.*

A. Components of the respiratory chain ◑

The **electron transport chain** consists of three protein complexes (**complexes I, III, and IV**), which are integrated into the inner mitochondrial membrane, and two mobile carrier molecules—**ubiquinone** (coenzyme Q) and **cytochrome *c***. *Succinate dehydrogenase,* which actually belongs to the tricarboxylic acid cycle, is also assigned to the respiratory chain as **complex II**. *ATP synthase* (see p. 142) is sometimes referred to as **complex V**, although it is not involved in electron transport. With the exception of complex I, detailed structural information is now available for every complex of the respiratory chain.

All of the complexes in the respiratory chain are made up of numerous polypeptides and contain a series of different protein bound **redox coenzymes** (see pp. 104, 106). These include *flavins* (FMN or FAD in complexes I and II), *iron–sulfur clusters* (in I, II, and III), and *heme groups* (in II, III, and IV). Of the more than 80 polypeptides in the respiratory chain, only 13 are coded by the mitochondrial genome (see p. 210). The remainder are encoded by nuclear genes, and have to be imported into the mitochondria after being synthesized in the cytoplasm (see p. 228).

Electrons enter the respiratory chain in various different ways. In the oxidation of $NADH+H^+$ by *complex I,* electrons pass via FMN and Fe/S clusters to ubiquinone (Q). Electrons arising during the oxidation of succinate, acyl CoA, and other substrates are passed to ubiquinone by *succinate dehydrogenase* or other *mitochondrial dehydrogenases* via enzyme-bound $FADH_2$ and the electron-transporting flavoprotein (ETF; see p. 164). Ubiquinol passes electrons on to *complex III,* which transfers them via two b-type heme groups, one Fe/S cluster, and heme c_1 to the small heme protein *cytochrome c*. Cytochrome *c* then transports the electrons to complex IV—*cytochrome c oxidase*. Cytochrome *c* oxidase contains redox-active components in the form of two copper centers (Cu_A and Cu_B) and hemes a and a_3, through which the electrons finally reach *oxygen* (see p. 132). As the result of the two-electron reduction of O_2, the strongly basic O^{2-} anion is produced (at least formally), and this is converted into water by binding of two protons. The electron transfer is coupled to the **formation of a proton gradient** by complexes I, III, and IV (see p. 126).

B. Organization ○

Proton transport via complexes I, III, and IV takes place *vectorially* from the matrix into the intermembrane space. When electrons are being transported through the respiratory chain, the H^+ concentration in this space increases—i. e., the pH value there is reduced by about one pH unit. For each H_2O molecule formed, around 10 H^+ ions are pumped into the intermembrane space. If the inner membrane is intact, then generally only *ATP synthase* (see p. 142) can allow protons to flow back into the matrix. This is the basis for the coupling of electron transport to ATP synthesis, which is important for regulation purposes (see p. 144).

As mentioned, although complexes I through V are all integrated into the inner membrane of the mitochondrion, they are not usually in contact with one another, since the electrons are transferred by ubiquinone and cytochrome *c*. With its long apolar side chain, ubiquinone is freely mobile within the membrane. Cytochrome *c* is water-soluble and is located on the *outside* of the inner membrane.

NADH oxidation via complex I takes place on the *inside* of the membrane—i. e., in the matrix space, where the tricarboxylic acid cycle and β-oxidation (the most important sources of NADH) are also located. O_2 reduction and ATP formation also take place in the matrix.

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A. Components of the respiratory chain

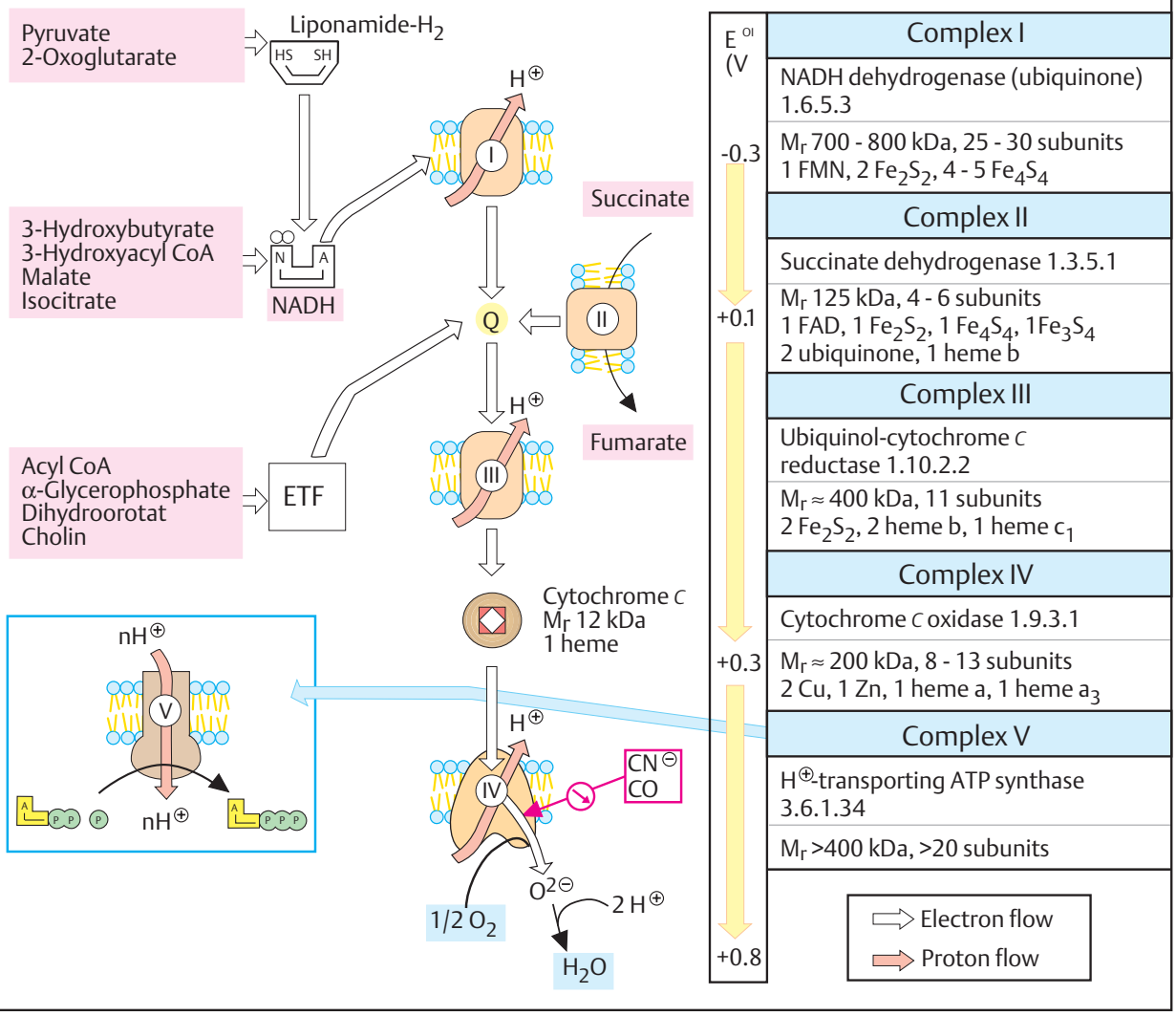

B. Organization

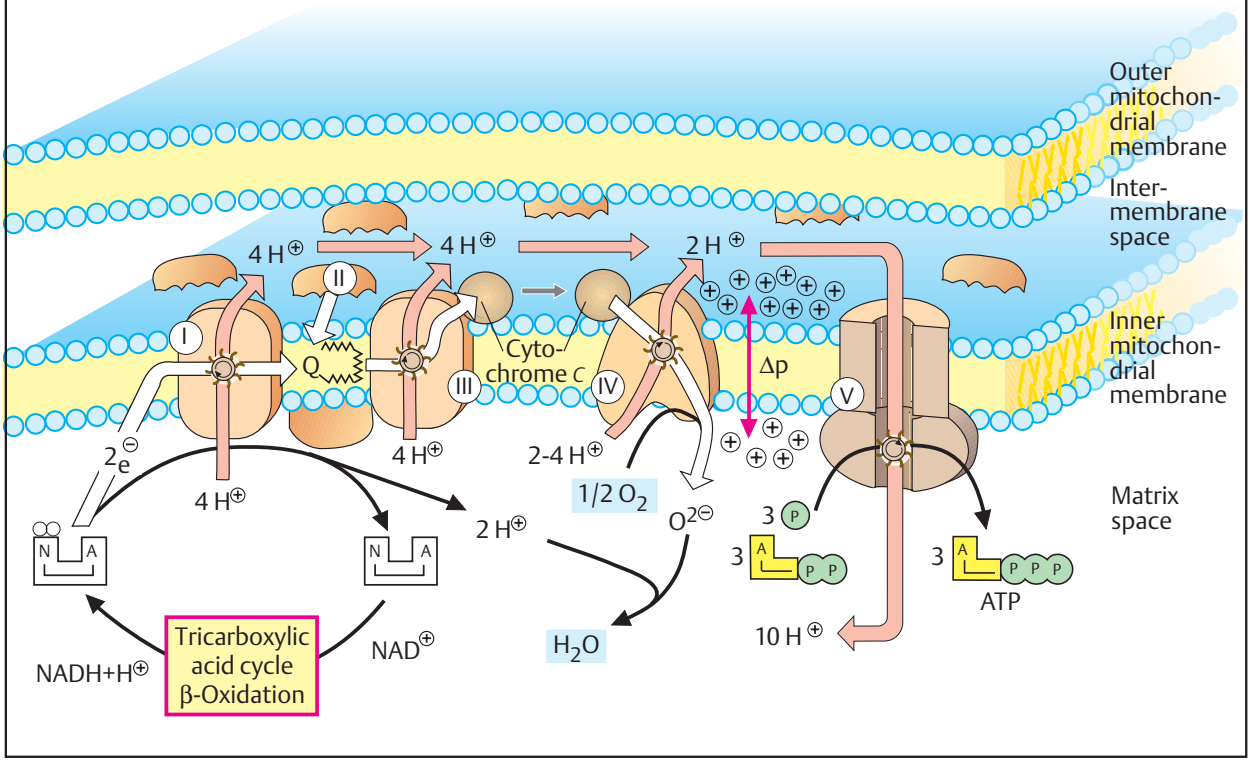

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ATP synthesis

In the **respiratory chain** (see p. 140), electrons are transferred from NADH or ubiquinol (QH_2) to O_2. The energy obtained in this process is used to establish a proton gradient across the inner mitochondrial membrane. ATP synthesis is ultimately coupled to the return of protons from the intermembrane space into the matrix.

A. Redox systems of the respiratory chain ◑

The electrons provided by NADH do not reach oxygen directly, but instead are transferred to it in various steps. They pass through at least 10 intermediate redox systems, most of which are bound as **prosthetic groups** in complexes I, III, and IV. The large number of coenzymes involved in electron transport may initially appear surprising. However, as discussed on p. 18, in redox reactions, the *change in free enthalpy* ΔG—i. e., the chemical work that is done—depends only on the difference in redox potentials ΔE between the donor and the acceptor. Introducing additional redox systems does not alter the reaction's overall energy yield. In the case of the respiratory chain, the difference between the normal potential of the donor ($NAD^+/NADH+H^+$, $E^{0'} = -0.32$ V) and that of the acceptor (O_2/H_2O, $E^{0'} = +0.82$ V) corresponds to an energy difference $\Delta G^{0'}$ of more than 200 kJ mol^{-1}. This large amount is divided into smaller, more manageable "packages," the size of which is determined by the difference in redox potentials between the respective *intermediates*. It is assumed that this division is responsible for the astonishingly high energy yield (about 60%) achieved by the respiratory chain.

The illustration shows the important redox systems involved in mitochondrial electron transport and their approximate redox potentials. These potentials determine the path followed by the electrons, as the members of a **redox series** have to be arranged in order of increasing redox potential if transport is to occur spontaneously (see p. 32).

In complex 1, the electrons are passed from *$NADH+H^+$* first to *FMN* (see p. 104) and then on to several *iron–sulfur (Fe/S) clusters*. These redox systems are only stable in the interior of proteins. Depending on the type, Fe/S clusters may contain two to six iron ions, which form complexes with inorganic sulfide and the SH groups of cysteine residues (see p. 286). *Ubiquinone* (coenzyme Q; see p. 104) is a mobile carrier that takes up electrons from complexes I and II and from reduced ETF and passes them on to complex III. *Heme groups* are also involved in electron transport in a variety of ways. Type b hemes correspond to that found in hemoglobin (see p. 280). Heme c in cytochrome *c* is covalently bound to the protein, while the tetrapyrrole ring of heme a is isoprenylated and carries a formyl group. In complex IV, a *copper ion* (Cu_B) and heme a_3 react directly with oxygen.

B. ATP synthase ◑

The ATP synthase (*EC 3.6.1.34,* complex V) that transports H^+ is a complex molecular machine. The enzyme consists of two parts—a *proton channel* (F_o, for "oligomycin-sensitive") that is integrated into the membrane; and a *catalytic unit* (F_1) that protrudes into the matrix. The F_o part consists of 12 membrane-spanning c-peptides and one a-subunit. The "head" of the F_1 part is composed of three α and three β subunits, between which there are three active centers. The "stem" between F_o and F_1 consists of one γ and one ε subunit. Two more polypeptides, b and δ, form a kind of "stator," fixing the α and β subunits relative to the F_o part.

The catalytic cycle can be divided into three phases, through each of which the three active sites pass in sequence. First, ADP and P_i are bound (**1**), then the anhydride bond forms (**2**), and finally the product is released (**3**). Each time protons pass through the F_o channel protein into the matrix, all three active sites change from their current state to the next. It has been shown that the energy for proton transport is initially converted into a rotation of the γ subunit, which in turn cyclically alters the conformation of the α and β subunits, which are stationary relative to the F_o part, and thereby drives ATP synthesis.

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A. Redox systems of the respiratory chain

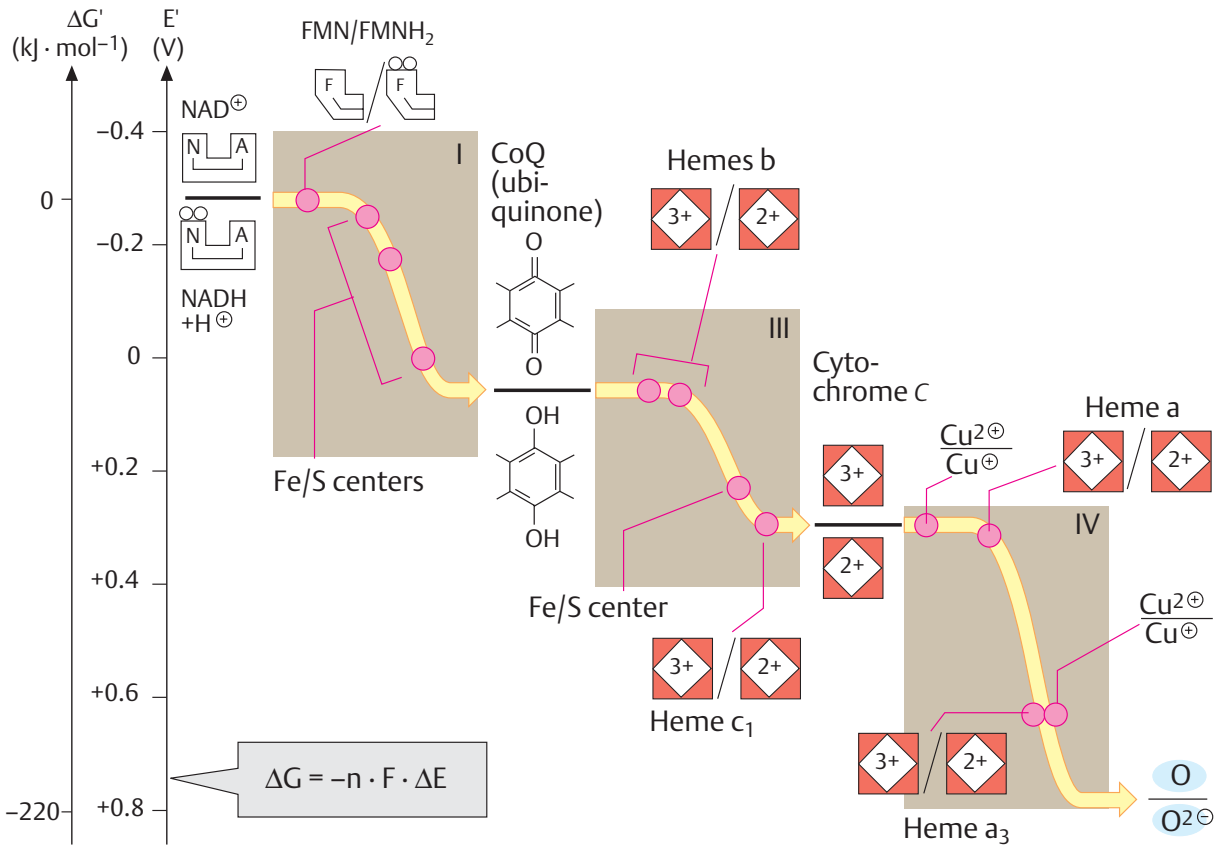

B. ATP synthase

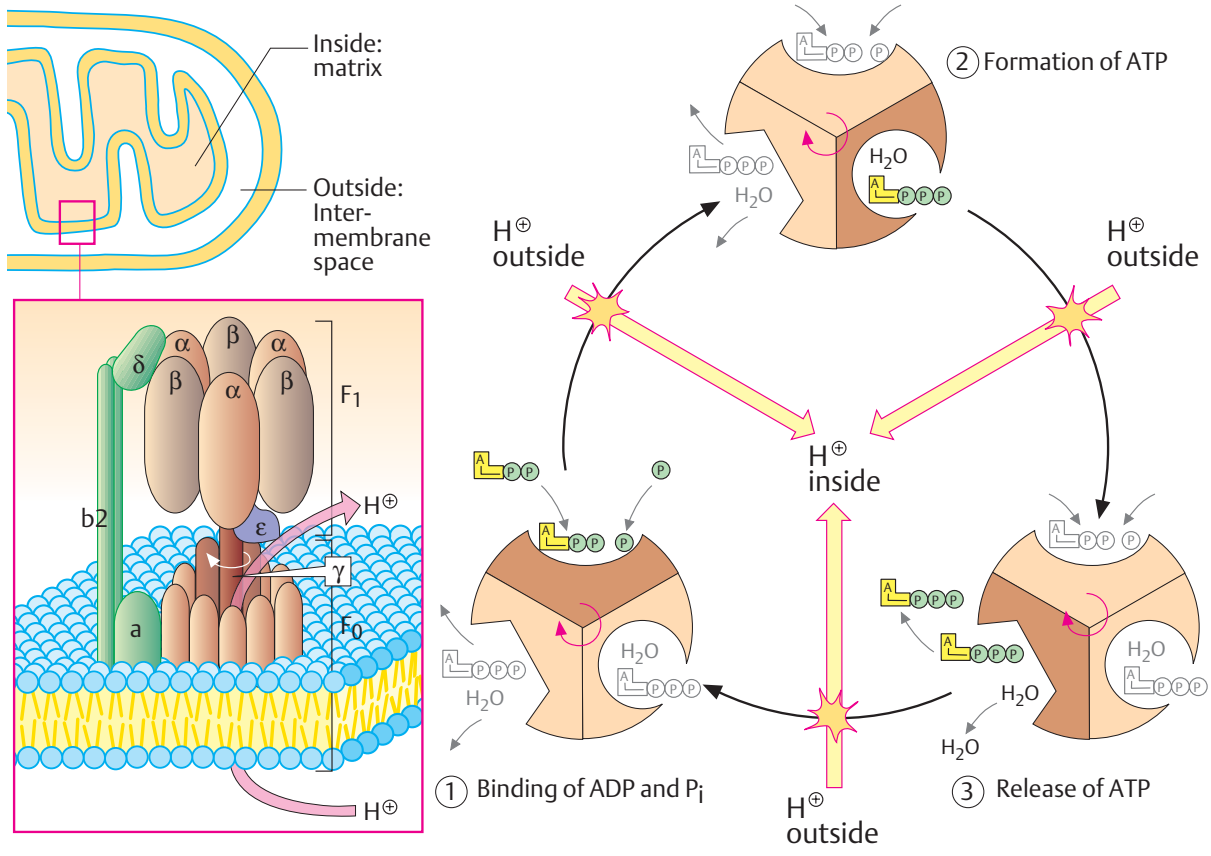

1. Structure and location **2.** Catalytic cycle

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Regulation

The amount of nutrient degradation and ATP synthesis have to be continually adjusted to the body's changing energy requirements. The need to coordinate the production and consumption of ATP is already evident from the fact that the *total amounts* of coenzymes in the organism are low. The human body forms about 65 kg ATP per day, but only contains 3–4 g of adenine nucleotides (AMP, ADP, and ATP). Each ADP molecule therefore has to be phosphorylated to ATP and dephosphorylated again many thousand times a day.

A. Respiratory control ◑

The simple regulatory mechanism which ensures that ATP synthesis is "automatically" coordinated with ATP consumption is known as **respiratory control**. It is based on the fact that the different parts of the oxidative phosphorylation process are *coupled* via shared coenzymes and other factors (left).

If a cell is not using any ATP, hardly any ADP will be available in the mitochondria. Without ADP, *ATP synthase* (**3**) is unable to break down the proton gradient across the inner mitochondrial membrane. This in turn inhibits electron transport in the respiratory chain (**2**), which means that $NADH+H^+$ can no longer be reoxidized to NAD^+. Finally, the resulting high $NADH/NAD^+$ ratio inhibits the tricarboxylic acid cycle (**C**), and thus slows down the degradation of the substrate SH_2 (**1**). Conversely, high rates of ATP utilization stimulate nutrient degradation and the respiratory chain via the same mechanism.

If the formation of a proton gradient is prevented (right), substrate oxidation (**1**) and electron transport (**2**) proceed much more rapidly. However, instead of ATP, only heat is produced.

B. Uncouplers ◑

Substances that functionally separate oxidation and phosphorylation from one another are referred to as uncouplers. They break down the proton gradient by allowing H^+ ions to pass from the intermembrane space back into the mitochondrial matrix without the involvement of ATP synthase. Uncoupling effects are produced by **mechanical damage** to the inner membrane (**1**) or by lipid-soluble substances that can transport protons through the membrane, such as **2,4-dinitrophenol** (DNP, **2**). **Thermogenin** (uncoupling protein-1, UCP-1, **3**)—an ion channel (see p. 222) in mitochondria of *brown fat* tissue—is a naturally occurring uncoupler. Brown fat is found, for example, in newborns and in hibernating animals, and serves exclusively to generate heat. In cold periods, norepinephrine activates the *hormone-sensitive lipase* (see p. 162). Increased lipolysis leads to the production of large quantities of free fatty acids. Like DNP, these bind H^+ ions in the intermembrane space, pass the UCP in this form, and then release the protons in the matrix again. This makes fatty acid degradation independent of ADP availability—i.e., it takes place at maximum velocity and only produces heat (**A**). It is becoming increasingly clear that there are also UCPs in other cells, which are controlled by hormones such as thyroxine (see p. 374). This regulates the ATP yield and what is known as the basal metabolic rate.

C. Regulation of the tricarboxylic acid cycle ◑

The most important factor in the regulation of the cycle is the **$NADH/NAD^+$ ratio**. In addition to *pyruvate dehydrogenase* (PDH) and *oxoglutarate dehydrogenase* (ODH; see p. 134), *citrate synthase* and *isocitrate dehydrogenase* are also inhibited by NAD^+ deficiency or an excess of $NADH+H^+$. With the exception of isocitrate dehydrogenase, these enzymes are also subject to **product inhibition** by acetyl-CoA, succinyl-CoA, or citrate.

Interconversion processes (see p. 120) also play an important role. They are shown here in detail using the example of the PDH complex (see p. 134). The *inactivating protein kinase* [1a] is inhibited by the substrate pyruvate and is activated by the products acetyl-CoA and $NADH+H^+$. The p*rotein phosphatase* [1b]—like *isocitrate dehydrogenase* [3] and the *ODH complex* [4]—is activated by Ca^{2+}. This is particularly important during muscle contraction, when large amounts of ATP are needed. *Insulin* also activates the PDH complex (through inhibition of phosphorylation) and thereby promotes the breakdown of glucose and its conversion into fatty acids.

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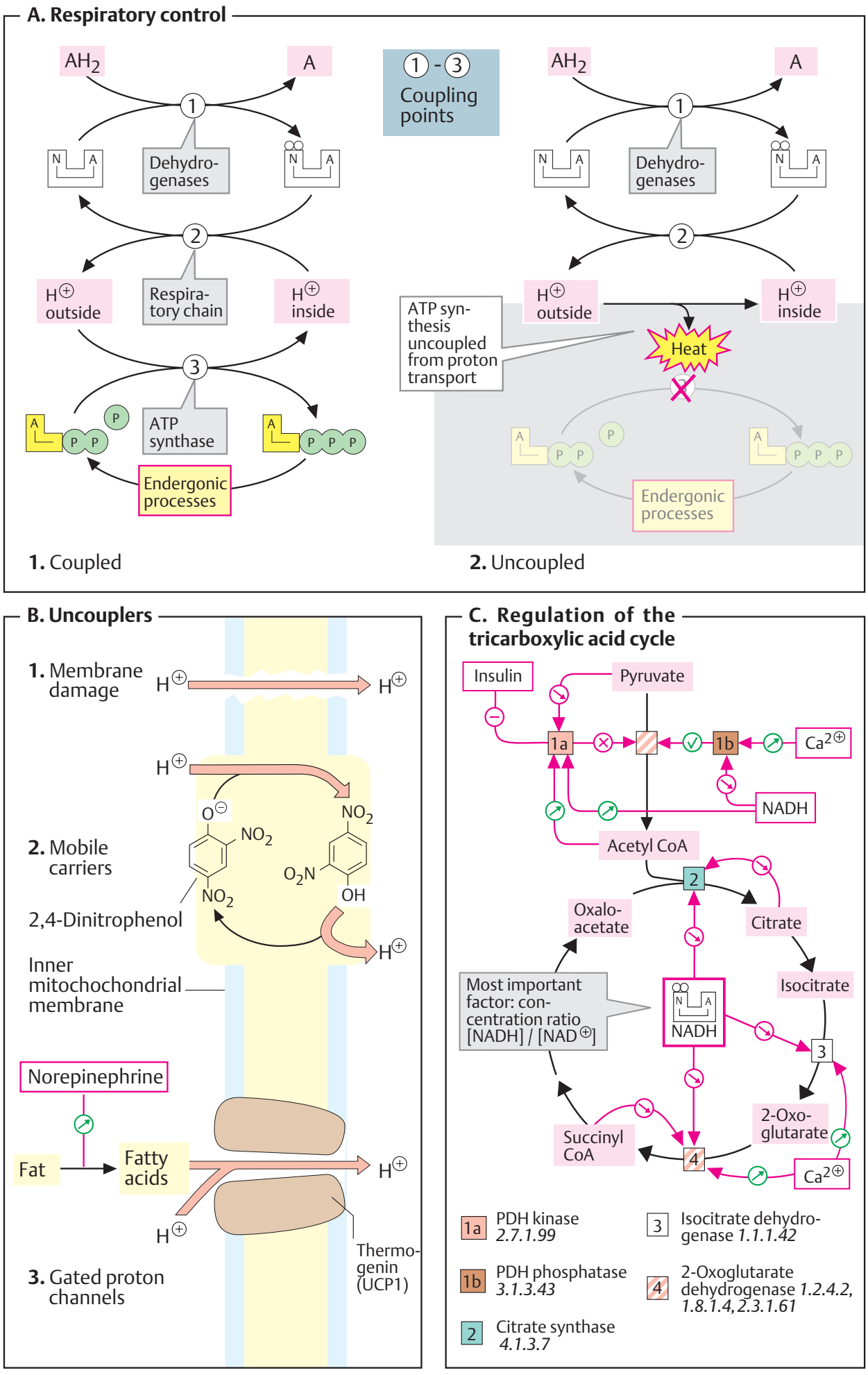

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Respiration and fermentation

A. Aerobic and anaerobic oxidation of glucose ◑

In the presence of oxygen (i.e., in *aerobic* conditions), most animal cells are capable of "respiring" various types of nutrient (lipids, amino acids, and carbohydrates)—i.e., using oxidative processes to break them down completely. If oxygen is lacking (i.e., in *anaerobic* conditions), only glucose can be used for ATP synthesis. Although in these conditions glucose breakdown in animals already ends in lactate and only produces small quantities of ATP, it is decisively important for the survival of cells at times of oxygen deficiency.

In **aerobic conditions** (left), ATP is derived almost exclusively from oxidative phosphorylation (see p. 140). **Fatty acids** enter the mitochondria with the help of carnitine (see p. 164), and are broken down there into CoA-bound acetyl residues. **Glucose** is converted into pyruvate by glycolysis (see p. 150) in the cytoplasm. Pyruvate is then also transported into the mitochondrial matrix, where it is oxidatively decarboxylated by the pyruvate dehydrogenase complex (see p. 134) to yield acetyl-CoA. The reducing equivalents (2 $NADH+H^+$ per glucose) that arise in glycolysis enter the mitochondrial matrix via the malate shuttle (see p. 212). The acetyl residues that are formed are oxidized to CO_2 in the tricarboxylic acid cycle (see p. 136). Breakdown of **amino acids** also produces acetyl residues or products that can directly enter the tricarboxylic acid cycle (see p. 180). The reducing equivalents that are obtained are transferred to oxygen via the respiratory chain as required. In the process, chemical energy is released, which is used (via a proton gradient) to synthesize ATP (see p. 140).

In the absence of oxygen—i.e., in **anaerobic conditions**—the picture changes completely. Since O_2 is missing as the electron acceptor for the respiratory chain, $NADH+H^+$ and QH_2 can no longer be reoxidized. Consequently, not only is mitochondrial ATP synthesis halted, but also almost the whole metabolism in the mitochondrial matrix. The main reason for this is the high $NADH+H^+$ concentration and lack of NAD^+, which inhibit the tricarboxylic acid cycle and the pyruvate dehydrogenase reaction (see p. 144). β-Oxidation and the malate shuttle, which are dependent on free NAD^+, also come to a standstill. Since amino acid degradation is also no longer able to contribute to energy production, the cell becomes totally dependent on ATP synthesized via the degradation of glucose by **glycolysis.** For this process to proceed continuously, the $NADH+H^+$ formed in the cytoplasm has to be constantly reoxidized. Since this can no longer occur in the mitochondria, in anaerobic conditions animal cells reduce pyruvate to lactate and pass it into the blood. This type of process is called **fermentation** (see p. 148). The ATP yield is low, with only two ATPs per glucose arising during lactate synthesis.

To estimate the number of ATP molecules formed in an aerobic state, it is necessary to know the **P/O quotient**—i.e., the molar ratio between synthesized ATP ("P") and the water formed ("O"). During transport of two electrons from $NADH+H^+$ to oxygen, about 10 protons are transported into the intermembrane space, while from ubiquinol (QH_2), the number is only six. ATP synthase (see p. 142) probably requires three H^+ to synthesize one ATP, so that maximum P/O quotients of around **3 or 2** are possible. This implies a yield of up to 38 ATP per mol of glucose. However, the actual value is much lower. It needs to be taken into account that the transport of specific metabolites into the mitochondrial matrix and the exchange of ATP^{4-} for ADP^{3-} are also driven by the proton gradient (see p. 212). The P/O quotients for the oxidation of $NADH+H^+$ and QH_2 are therefore more in the range of **2.5 and 1.5**. If the energy balance of aerobic glycolysis is calculated on this basis, the result is a yield of around **32 ATP per glucose**. However, this value is also not constant, and can be adjusted as required by the cell's own uncouplers (UCPs; see p. 144) and other mechanisms.

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A. Aerobic and anaerobic oxidation of glucose

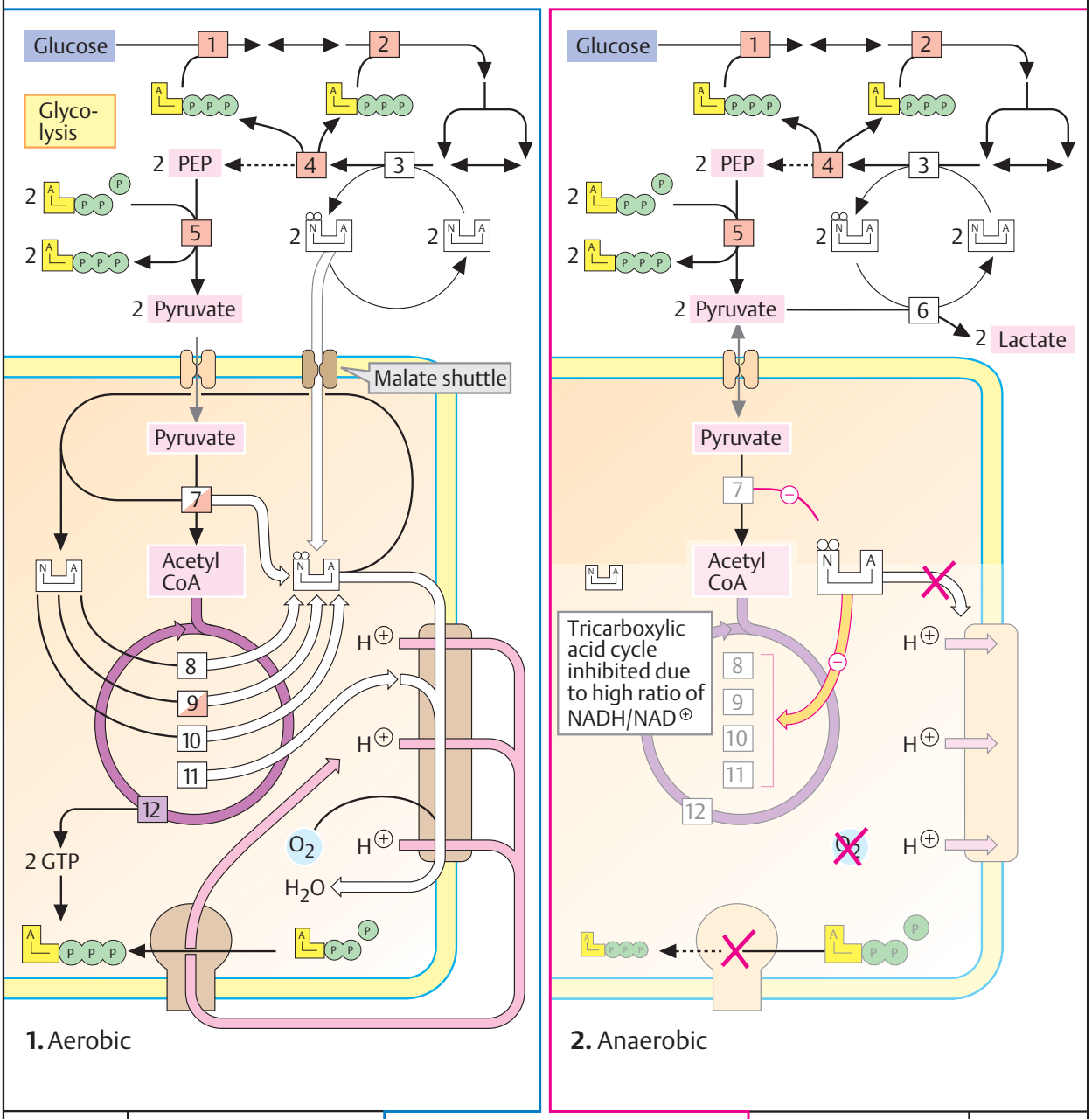

ATP	Coenzymes		Enzymes	Coenzymes	ATP
−1		−1 ATP	1 Hexokinase	−1 ATP	−1
−2		−1 ATP	2 6-Phosphofructokinase	−1 ATP	−2
+3	+5 ATP ←	+2 NADH	3 Glyceraldehyde-3(P)DH	+2 NADH ←	−2
+5		+2 ATP	4 Phosphoglycerate kinase	+2 ATP NAD⊕	0
+7		+2 ATP	5 Pyruvate kinase	+2 ATP recycled	+2
			6 Lactate dehydrogenase	−2 NADH ←	
+12	+5 ATP ←	+2 NADH	7 Pyruvate dehydrogenase		
+17	+5 ATP ←	+2 NADH	8 Isocitrate dehydrogenase		
+22	+5 ATP ←	+2 NADH	9 Oxoglutarate dehydrogenase		
+27	+5 ATP ←	+2 NADH	10 Malate dehydrogenase		
+30	+3 ATP ←	+2 QH_2	11 Succinate dehydrogenase		
+32	+2 ATP ←	+2 GTP	12 Succinate-CoA ligase		

Sum: 32 ATP/glucose

DH = dehydrogenase

Sum: 2 ATP/glucose

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Fermentations

As discussed on p. 146, degradation of glucose to pyruvate is the only way for most organisms to synthesize ATP in the *absence of oxygen*. The $NADH+H^+$ that is also formed in this process has to be constantly reoxidized to NAD^+ in order to maintain glycolysis and thus ATP synthesis. In the animal organism, this is achieved by the reduction of pyruvate to lactate. In microorganisms, there are many other forms of NAD^+ regeneration. Processes of this type are referred to as **fermentations.** Microbial fermentation processes are often used to produce foodstuffs and alcoholic beverages, or to preserve food. Features common to all fermentation processes are that they start with pyruvate and only occur under *anaerobic conditions.*

A. Lactic acid and propionic acid fermentation ○

Many milk products, such as sour milk, yogurt, and cheese are made by *bacterial lactic acid fermentation* (**1**). The reaction is the same as in animals. Pyruvate, which is mainly derived from degradation of the disaccharide *lactose* (see p. 38), is reduced to lactate by *lactate dehydrogenase* [1]. Lactic acid fermentation also plays an important role in the production of sauerkraut and silage. These products usually keep for a long time, because the *pH reduction* that occurs during fermentation inhibits the growth of putrefying bacteria.

Bacteria from the genera *Lactobacillus* and *Streptococcus* are involved in the first steps of dairy production (**3**). The raw materials produced by their effects usually only acquire their final properties after additional fermentation processes. For example, the characteristic taste of Swiss cheese develops during a subsequent propionic acid fermentation. In this process, bacteria from the genus *Propionibacterium* convert pyruvate to propionate in a complex series of reactions (**2**).

B. Alcoholic fermentation ○

Alcoholic beverages are produced by the fermentation of plant products that have a high carbohydrate content. Pyruvate, which is formed from glucose, is initially decarboxylated by *pyruvate decarboxylase* [2], which does not occur in animal metabolism, to produce acetaldehyde (ethanal). When this is reduced by alcohol dehydrogenase [3], with NADH being consumed, *ethanol* [3] is formed.

Yeasts, unicellular fungi that belong to the eukaryotes (**3**), rather than bacteria, are responsible for this type of fermentation. Yeasts are also often used in baking. They produce CO_2 and ethanol, which raise the dough. Brewers' and bakers' yeasts *(Saccharomyces cerevisiae)* are usually haploid and reproduce asexually by budding (**3**). They can live both aerobically and anaerobically. Wine is produced by other types of yeast, some of which already live on the grapes. To promote the formation of ethanol, efforts are made to generally exclude oxygen during alcoholic fermentation—for example, by covering dough with a cloth when it is rising and by fermenting liquids in barrels that exclude air.

C. Beer brewing ○

Barley is the traditional starting material for the brewing of beer. Although cereal grains contain starch, they hardly have any *free* sugars. The barley grains are therefore first allowed to germinate so that starch-cleaving *amylases* are formed. Careful warming of the sprouting grain produces **malt.** This is then ground, soaked in water, and kept warm for a certain time. In the process, a substantial proportion of the starch is broken down into the disaccharide *maltose* (see p. 38). The product (the wort) is then boiled, **yeast** and **hops** are added, and the mixture is allowed to ferment for several days. The addition of hops makes the beer less perishable and gives it its slightly bitter taste. Other substances contained in hops act as sedatives and diuretics.

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A. Lactic acid and propionic acid fermentation

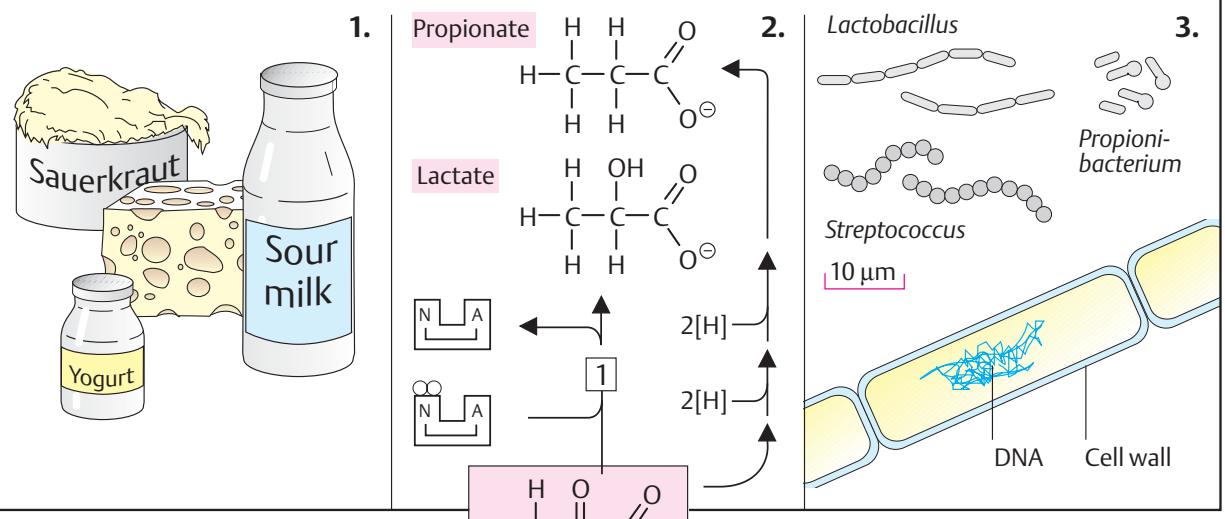

B. Alcoholic fermentation

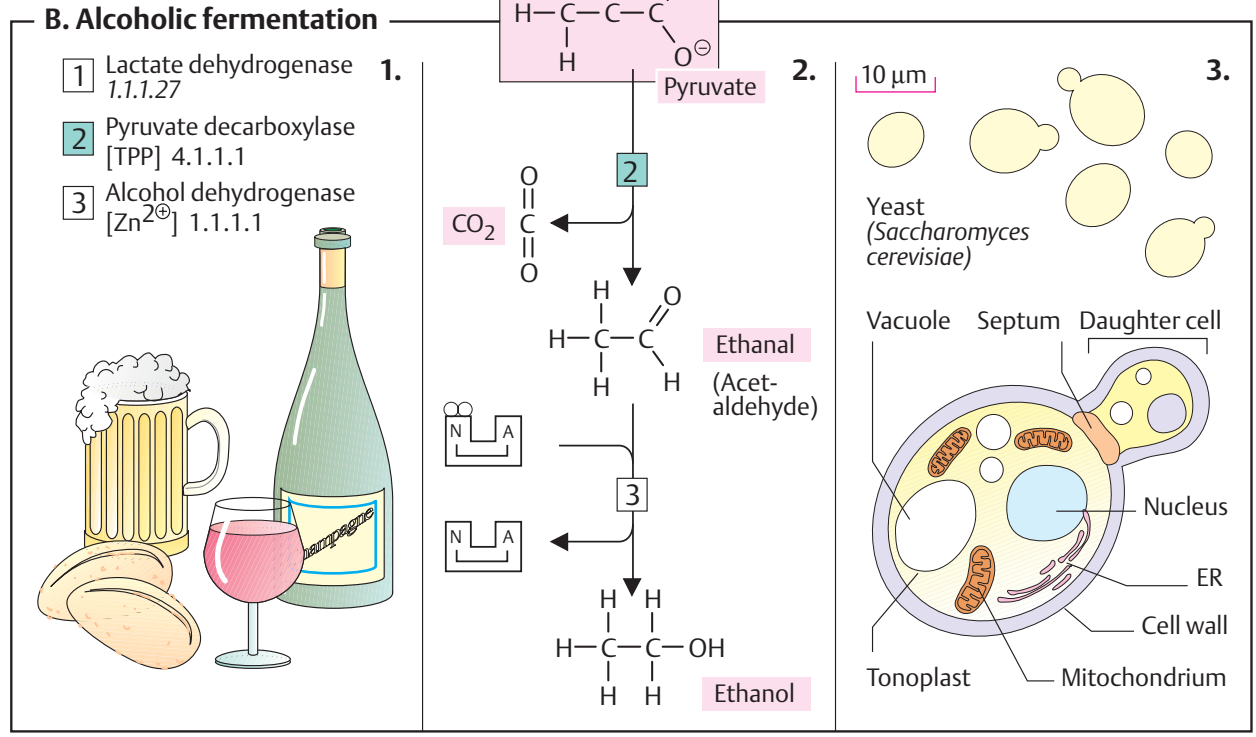

C. Beer brewing

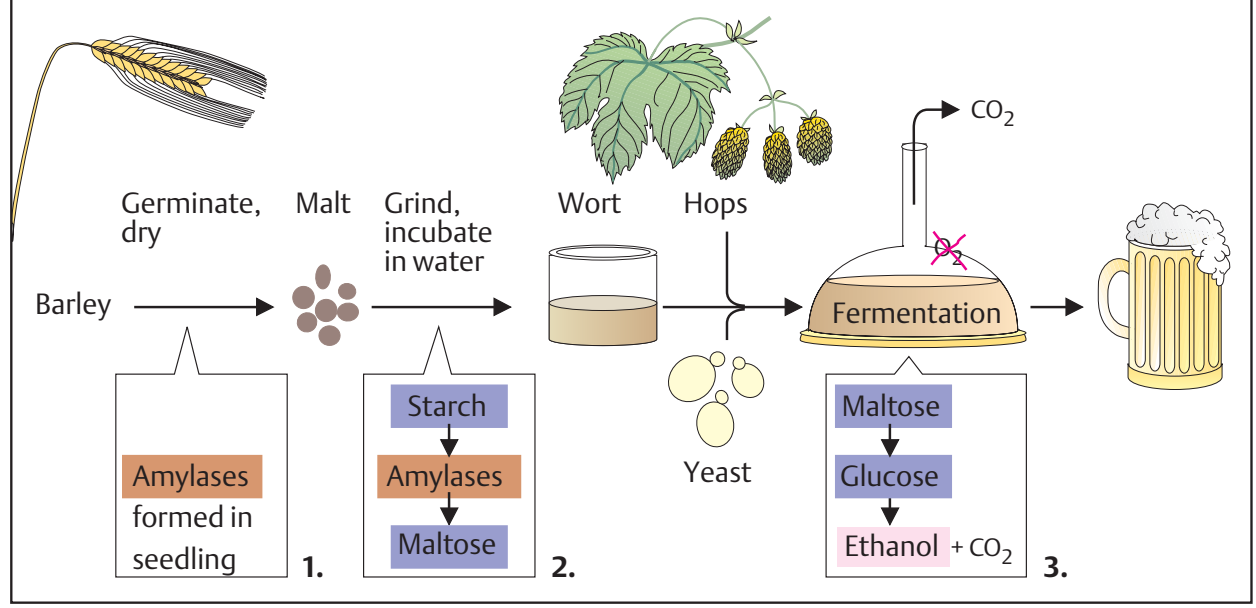

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Glycolysis

A. Balance ●

Glycolysis is a catabolic pathway in the cytoplasm that is found in almost all organisms—irrespective of whether they live aerobically or anaerobically. The balance of glycolysis is simple: glucose is broken down into two molecules of pyruvate, and in addition two molecules of ATP and two of $NADH+H^+$ are formed.

In the presence of oxygen, pyruvate and $NADH+H^+$ reach the mitochondria, where they undergo further transformation (**aerobic glycolysis**; see p. 146). In anaerobic conditions, *fermentation products* such as lactate or ethanol have to be formed in the cytoplasm from pyruvate and $NADH+H^+$, in order to regenerate NAD^+ so that glycolysis can continue (**anaerobic glycolysis**; see p. 146). In the anaerobic state, glycolysis is the only means of obtaining ATP that animal cells have.

B. Reactions ◑

Glycolysis involves ten individual steps, including three isomerizations and four phosphate transfers. The only redox reaction takes place in step [6].

[1] Glucose, which is taken up by animal cells from the blood and other sources, is first phosphorylated to **glucose 6-phosphate**, with ATP being consumed. The glucose 6-phosphate is not capable of leaving the cell.

[2] In the next step, glucose 6-phosphate is isomerized into **fructose 6-phosphate**.

[3] Using ATP again, another phosphorylation takes place, giving rise to **fructose 1,6-bisphosphate.** *Phosphofructokinase* is the most important key enzyme in glycolysis (see p. 144).

[4] Fructose 1,6-bisphosphate is broken down by *aldolase* into the C_3 compounds **glyceraldehyde 3-phosphate** (also known as glyceral 3-phosphate) and **glycerone 3-phosphate** (dihydroxyacetone 3-phosphate).

[5] The latter two products are placed in fast equilibrium by *triosephosphate isomerase.*

[6] Glyceraldehyde 3-phosphate is now oxidized by *glyceraldehyde-3-phosphate dehydrogenase,* with $NADH+H^+$ being formed. In this reaction, *inorganic phosphate* is taken up into the molecule (*substrate-level phosphorylation*; see p. 124), and **1,3-bisphosphoglycerate** is produced. This intermediate contains a *mixed acid–anhydride bond,* the phosphate part of which is at a high chemical potential.

[7] Catalyzed by *phosphoglycerate kinase,* this phosphate residue is transferred to ADP, producing **3-phosphoglycerate** and ATP. The ATP balance is thus once again in equilibrium.

[8] As a result of shifting of the remaining phosphate residue within the molecule, the isomer **2-phosphoglycerate** is formed.

[9] Elimination of water from 2-phosphoglycerate produces the phosphate ester of the *enol form* of pyruvate—**phospho*enol*pyruvate** (PEP). This reaction also raises the second phosphate residue to a high potential.

[10] In the last step, *pyruvate kinase* transfers this residue to ADP. The remaining enol pyruvate is immediately rearranged into **pyruvate**, which is much more stable. Along with step [7] and the thiokinase reaction in the tricarboxylic acid cycle (see p. 136), the pyruvate kinase reaction is one of the three reactions in animal metabolism that are able to produce ATP independently of the respiratory chain.

In glycolysis, two molecules of ATP are initially used for activation ([1], [3]). Later, two ATPs are formed *per C_3 fragment.* Overall, therefore, there is a small net gain of 2 mol ATP per mol of glucose.

C. Energy profile ○

The energy balance of metabolic pathways depends not only on the standard changes in enthalpy ΔG^0, but also on the concentrations of the metabolites (see p. 18). Fig. **C** shows the *actual* enthalpy changes ΔG for the individual steps of glycolysis in erythrocytes.

As can be seen, only three reactions ([1], [3], and [10]), are associated with large changes in free enthalpy. In these cases, the equilibrium lies well on the side of the products (see p. 18). All of the other steps are freely reversible. The same steps are also followed—in the reverse direction—in gluconeogenesis (see p. 154), with the same enzymes being activated as in glucose degradation. The non-reversible steps [1], [3], and [10] are bypassed in glucose biosynthesis (see p. 154).

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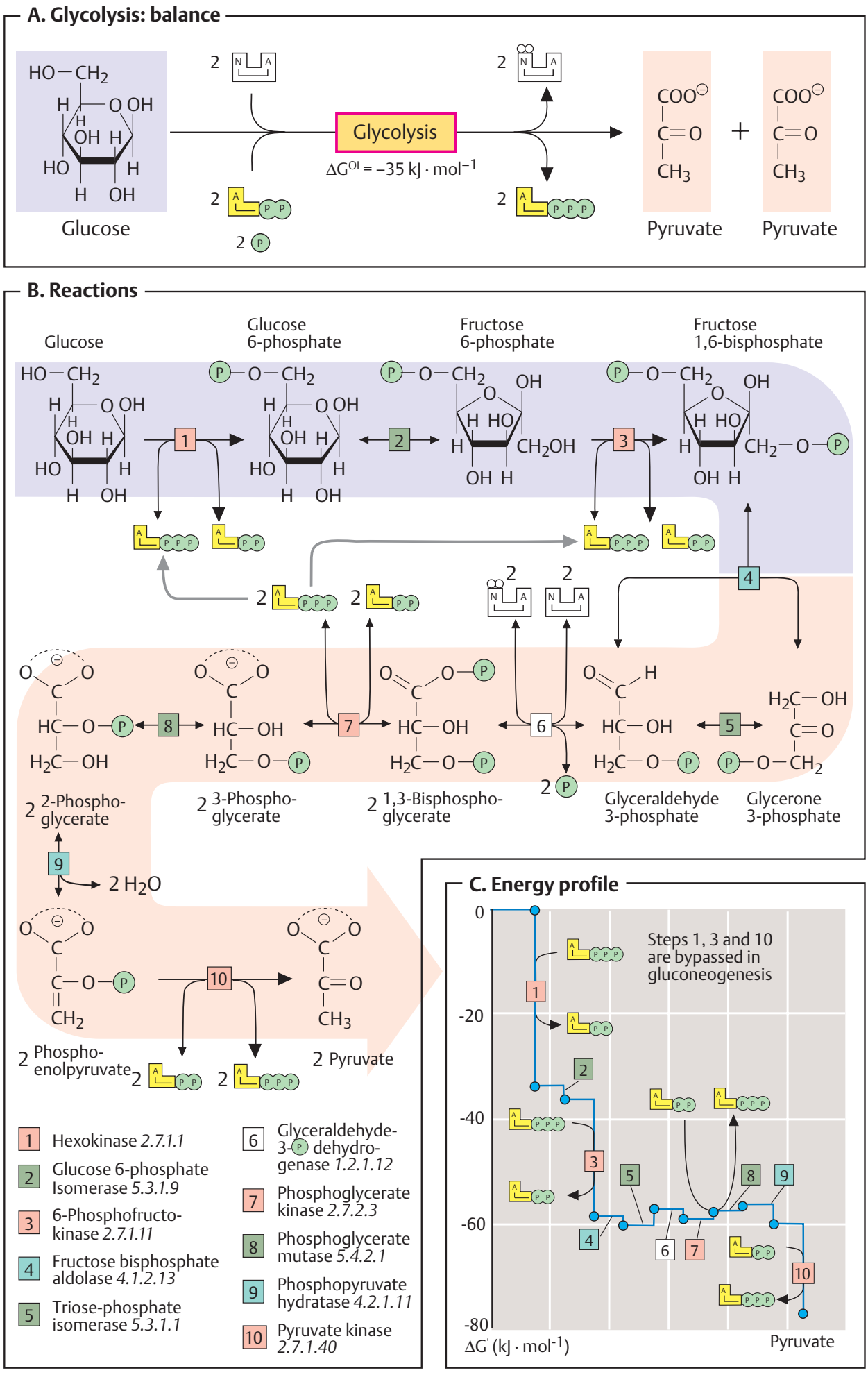

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Pentose phosphate pathway

The pentose phosphate pathway (PPP, also known as the *hexose monophosphate pathway)* is an oxidative metabolic pathway located in the cytoplasm, which, like glycolysis, starts from glucose 6-phosphate. It supplies two important precursors for anabolic pathways: **NADPH+H+,** which is required for the biosynthesis of fatty acids and isoprenoids, for example (see p. 168), and **ribose 5-phosphate,** a precursor in nucleotide biosynthesis (see p. 188).

A. Pentose phosphate pathway: oxidative part ◑

The **oxidative segment** of the PPP converts glucose 6-phosphate to ribulose 5-phosphate. One CO_2 and two NADPH+H^+ are formed in the process. Depending on the metabolic state, the much more complex **regenerative part** of the pathway (see **B**) can convert some of the pentose phosphates back to hexose phosphates, or it can pass them on to glycolysis for breakdown. In most cells, less than 10% of glucose 6-phosphate is degraded via the pentose phosphate pathway.

B. Reactions ◑

[1] The **oxidative part** starts with the oxidation of **glucose 6-phosphate** by *glucose-6-phosphate dehydrogenase*. This forms NADPH+H^+ for the first time. The second product, **6-phosphogluconolactone**, is an intramolecular ester (*lactone*) of 6-phosphogluconate.

[2] A specific hydrolase then cleaves the lactone, exposing the carboxyl group of **6-phosphogluconate**.

[3] The last enzyme in the oxidative part is *phosphogluconate dehydrogenase* [3], which releases the carboxylate group of 6-phosphogluconate as CO_2 and at the same time oxidizes the hydroxyl group at C_3 to an oxo group. In addition to a second NADPH+H^+, this also produces the ketopentose **ribulose 5-phosphate.** This is converted by an isomerase to ribose 5-phosphate, the initial compound for nucleotide synthesis (top).

The **regenerative part** of the PPP is only shown here schematically. A complete reaction scheme is given on p. 408. The function of the regenerative branch is to adjust the *net* production of NADPH+H^+ and pentose phosphates to the cell's current requirements. Normally, the demand for NADPH+H^+ is much higher than that for pentose phosphates. In these conditions, the reaction steps shown first convert six ribulose 5-phosphates to five molecules of fructose 6-phosphate and then, by isomerization, regenerate five glucose 6-phosphates. These can once again supply NADPH+H^+ to the oxidative part of the PPP. Repeating these reactions finally results in the oxidation of one glucose 6-phosphate into six CO_2. Twelve NADPH+H^+ arise in the same process. In sum, no pentose phosphates are produced via this pathway.

In the recombination of sugar phosphates in the regenerative part of the PPP, there are two enzymes that are particularly important:

[5] *Transaldolase* transfers C_3 units from sedoheptulose 7-phosphate, a ketose with seven C atoms, to the aldehyde group of glyceraldehyde 3-phosphate.

[4] *Transketolase,* which contains thiamine diphosphate, transfers C_2 fragments from one sugar phosphate to another.

The reactions in the regenerative segment of the PPP are freely reversible. It is therefore easily possible to use the regenerative part of the pathway to convert hexose phosphates into pentose phosphates. This can occur when there is a high demand for pentose phosphates—e.g., during DNA replication in the S phase of the cell cycle (see p. 394).

Additional information

When energy in the form of ATP is required in addition to NADPH+H^+, the cell is able to channel the products of the regenerative part of the PPP (fructose 6-phosphate and glyceraldehyde 3-phosphate) into glycolysis. Further degradation is carried out via the tricarboxylic acid cycle and the respiratory chain to CO_2 and water. Overall, the cell in this way obtains 12 mol NADPH+H^+ and around 150 mol ATP from 6 mol glucose 6-phosphate. PPP activity is stimulated by *insulin* (see p. 388). This not only increases the rate of glucose degradation, but also produces additional NADPH+H^+ for fatty acid synthesis (see p. 168).

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A. Pentose phosphate pathway: oxidative part

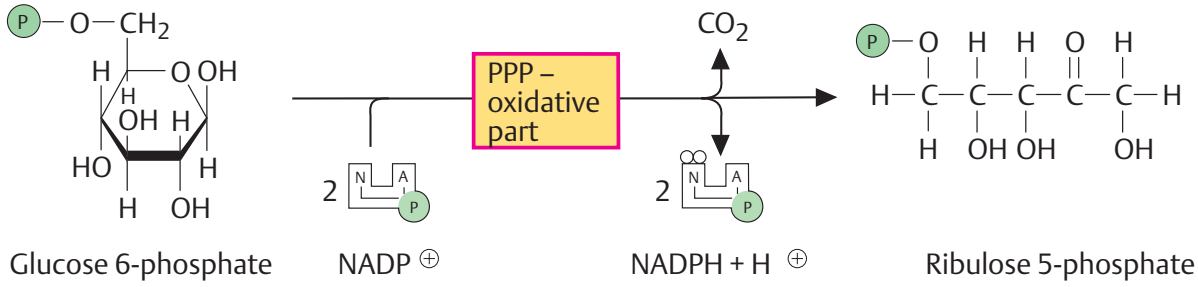

B. Reactions

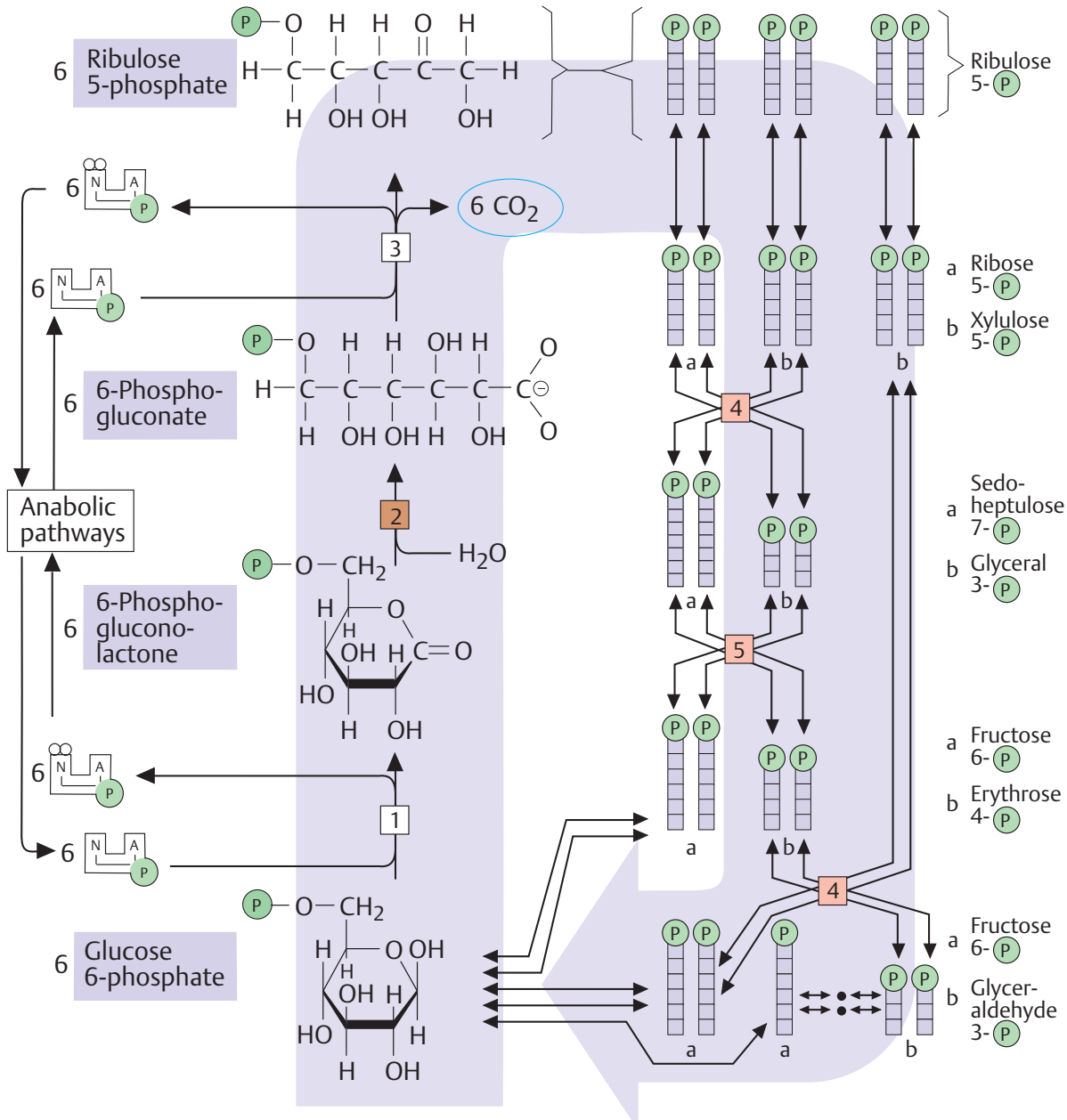

1 Glucose 6-phosphate dehydrogenase *1.1.1.49*

2 Gluconolactonase *3.1.1.17*

3 Phosphogluconate dehydrogenase (decarboxylating) *1.1.1.44*

4 Transketolase *2.2.1.1*

5 Transaldolase *2.2.1.2*

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Gluconeogenesis

Some tissues, such as *brain* and *erythrocytes*, depend on a constant supply of glucose. If the amount of carbohydrate taken up in food is not suf cient, the blood sugar level can be maintained for a limited time by *degradation of hepatic glycogen* (see p. 156). If these reserves are also exhausted, de-novo synthesis of glucose (**gluconeogenesis**) begins. The **liver** is also mainly responsible for this (see p. 310), but the tubular cells of the **kidney** also show a high level of gluconeogenetic activity (see p. 328). The main precursors for gluconeogenesis are **amino acids** derived from muscle proteins. Another important precursor is **lactate,** which is formed in erythrocytes and muscle proteins when there is oxygen deficiency. **Glycerol** produced from the degradation of fats can also be used for gluconeogenesis. However, the conversion of fatty acids into glucose is *not* possible in animal metabolism (see p. 138). The human organism can synthesize several hundred grams of glucose per day by gluconeogenesis.

A. Gluconeogenesis ◑

Many of the reaction steps involved in gluconeogenesis are catalyzed by the same enzymes that are used in glycolysis (see p. 150). Other enzymes are specific to gluconeogenesis and are only synthesized, under the influence of *cortisol* and *glucagon* when needed (see p. 158). Glycolysis takes place exclusively when needed in the cytoplasm, but gluconeogenesis also involves the *mitochondria* and the *endoplasmic reticulum* (ER). Gluconeogenesis consumes 4 ATP (3 ATP + 1 GTP) per glucose—i. e., twice as many as glycolysis produces.

[1] **Lactate** as a precursor for gluconeogenesis is mainly derived from muscle (see Cori cycle, p. 338) and erythrocytes. LDH (see p. 98) oxidizes lactate to pyruvate, with $NADH+H^+$ formation.

[2] The first steps of actual gluconeogenesis take place in the *mitochondria.* The reason for this "detour" is the equilibrium state of the pyruvate kinase reaction (see p. 150). Even coupling to ATP hydrolysis would not be sufficient to convert pyruvate *directly* into phospho*enol* pyruvate (PEP). **Pyruvate** derived from lactate or amino acids is therefore initially transported into the mitochondrial matrix, and—in a biotin-dependent reaction catalyzed by *pyruvate carboxylase*—is carboxylated there to **oxaloacetate**. Oxaloacetate is also an intermediate in the tricarboxylic acid cycle. *Amino acids* with breakdown products that enter the cycle or supply pyruvate can therefore be converted into glucose (see p. 180).

[3] The oxaloacetate formed in the mitochondrial matrix is initially reduced to **malate**, which can leave the mitochondria via inner membrane transport systems (see p. 212).

[4] In the cytoplasm, oxaloacetate is reformed and then converted into **phosphoenol pyruvate** by a GTP-dependent *PEP carboxykinase.* The subsequent steps up to fructose 1,6-bisphosphate represent the reverse of the corresponding reactions involved in glycolysis. One additional ATP per C_3 fragment is used for the synthesis of 1,3-bisphosphoglycerate.

Two gluconeogenesis-specific phosphatases then successively cleave off the phosphate residues from **fructose 1,6-bisphosphate**. In between these reactions lies the isomerization of fructose 6-phosphate to **glucose 6-phosphate**—another glycolytic reaction.

[5] The reaction catalyzed by *fructose 1,6-bisphosphatase* is an important regulation point in gluconeogenesis (see p. 158).

[6] The last enzyme in the pathway, *glucose 6-phosphatase,* occurs in the liver, but not in muscle. It is located in the interior of the smooth endoplasmic reticulum. Specific transporters allow glucose 6-phosphate to enter the ER and allow the **glucose** formed there to return to the cytoplasm. From there, it is ultimately released into the blood.

Glycerol initially undergoes phosphorylation at C-3 [7]. The **glycerol 3-phosphate** formed is then oxidized by an NAD^+-dependent dehydrogenase to form **glycerone 3-phosphate** [8] and thereby channeled into gluconeogenesis. An FAD-dependent mitochondrial enzyme is also able to catalyze this reaction (known as the "glycerophosphate shuttle"; see p. 212).

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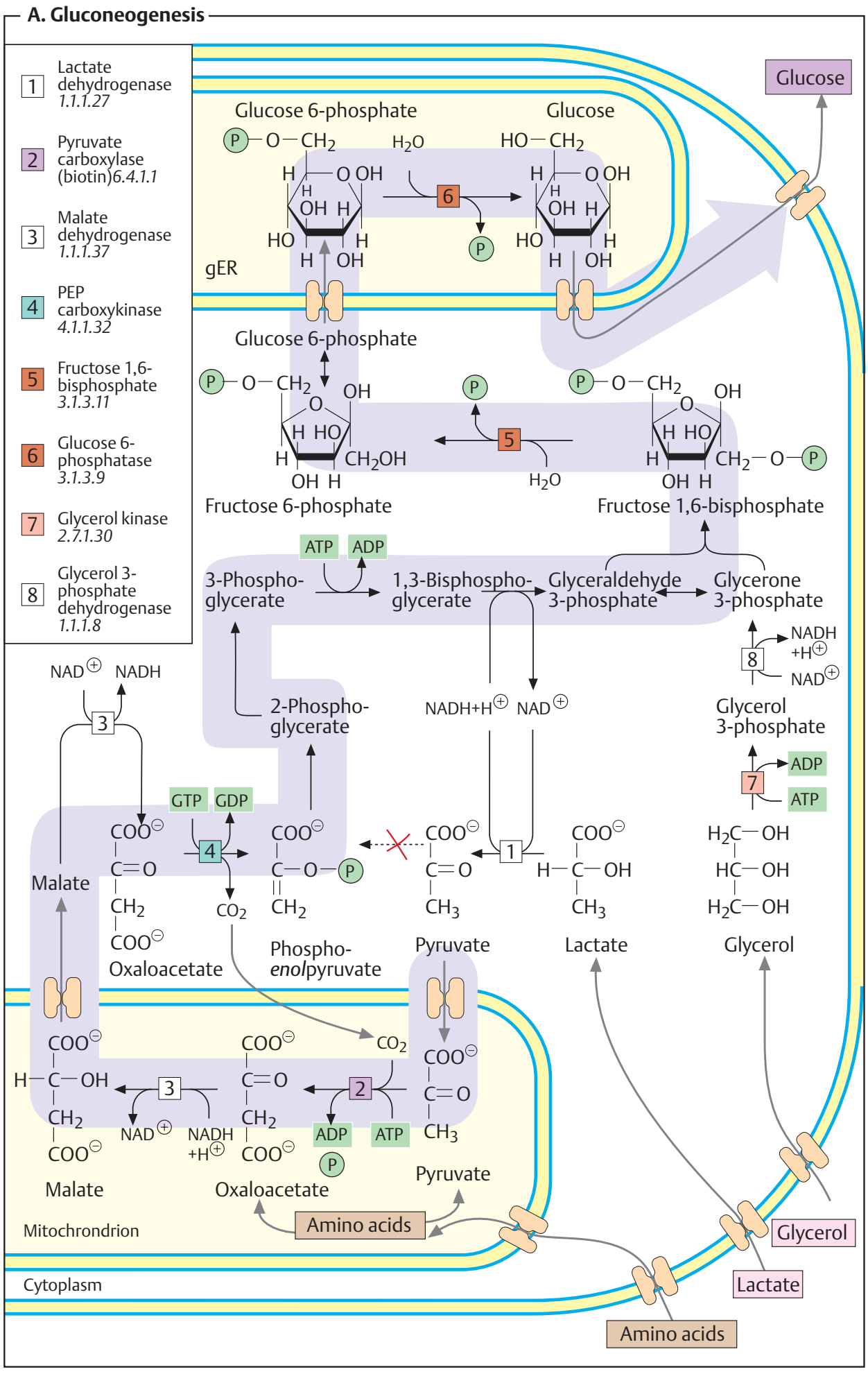

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Glycogen metabolism

Glycogen (see p. 40) is used in animals as a **carbohydrate reserve,** from which glucose phosphates and glucose can be released when needed. Glucose storage itself would not be useful, as high concentrations within cells would make them strongly hypertonic and would therefore cause an influx of water. By contrast, insoluble glycogen has only low osmotic activity.

A. Glycogen balance ◑

Animal glycogen, like amylopectin in plants, is a *branched homopolymer of glucose.* The glucose residues are linked by an α1→4-glycosidic bond. Every tenth or so glucose residue has an additional α1→6 bond to another glucose. These branches are extended by additional α1→4-linked glucose residues. This structure produces tree-shaped molecules consisting of up to 50000 residues ($M > 1 \quad 10^7$ Da).

Hepatic glycogen is never completely degraded. In general, only the nonreducing ends of the "tree" are shortened, or—when glucose is abundant—elongated. The reducing end of the tree is linked to a special protein, **glycogenin**. Glycogenin carries out autocatalytic covalent bonding of the first glucose at one of its tyrosine residues and elongation of this by up to seven additional glucose residues. It is only at this point that *glycogen synthase* becomes active to supply further elongation.

[1] The formation of glycosidic bonds between sugars is *endergonic.* Initially, therefore, the activated form—**UDP-glucose**—is synthesized by reaction of glucose 1-phosphate with UTP (see p. 110).

[2] *Glycogen synthase* now transfers glucose residues one by one from UDP-glucose to the non-reducing ends of the available "branches."

[3] Once the growing chain has reached a specific length (> 11 residues), the *branching enzyme* cleaves an oligosaccharide consisting of 6–7 residues from the end of it, and adds this into the interior of the same chain or a neighboring one with α1→6 linkage. These **branches** are then further extended by glycogen synthase.

[4] The branched structure of glycogen allows rapid release of sugar residues. The most important degradative enzyme, *glycogen phosphorylase,* cleaves residues from a nonreducing end one after another as **glucose 1-phosphate**. The larger the number of these ends, the more phosphorylase molecules can attack simultaneously. The formation of glucose 1-phosphate instead of glucose has the advantage that no ATP is needed to channel the released residues into glycolysis or the PPP.

[5] [6] Due to the structure of glycogen phosphorylase, degradation comes to a halt four residues away from each branching point. Two more enzymes overcome this blockage. First, a *glucanotransferase* moves a trisaccharide from the side chain to the end of the main chain [5]. A *1,6-glucosidase* [6] then cleaves the single remaining residue as a free glucose and leaves behind an unbranched chain that is once again accessible to phosphorylase.

The **regulation of glycogen metabolism** by interconversion, and the role of hormones in these processes, are discussed on p. 120.

B. Glycogen balance ◑

The human organism can store up to 450 g of glycogen—one-third in the **liver** and almost all of the remainder in **muscle.** The glycogen content of the other organs is low.

Hepatic glycogen is mainly used to maintain the *blood glucose level* in the postresorptive phase (see p. 308). The glycogen content of the liver therefore varies widely, and can decline to almost zero in periods of extended hunger. After this, gluconeogenesis (see p. 154) takes over the glucose supply for the organism. *Muscle glycogen* serves as an *energy reserve* and is not involved in blood glucose regulation. Muscle does not contain any glucose 6-phosphatase and is therefore unable to release glucose into the blood. The glycogen content of muscle therefore does not fluctuate as widely as that of the liver.

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A. Glycogen metabolism

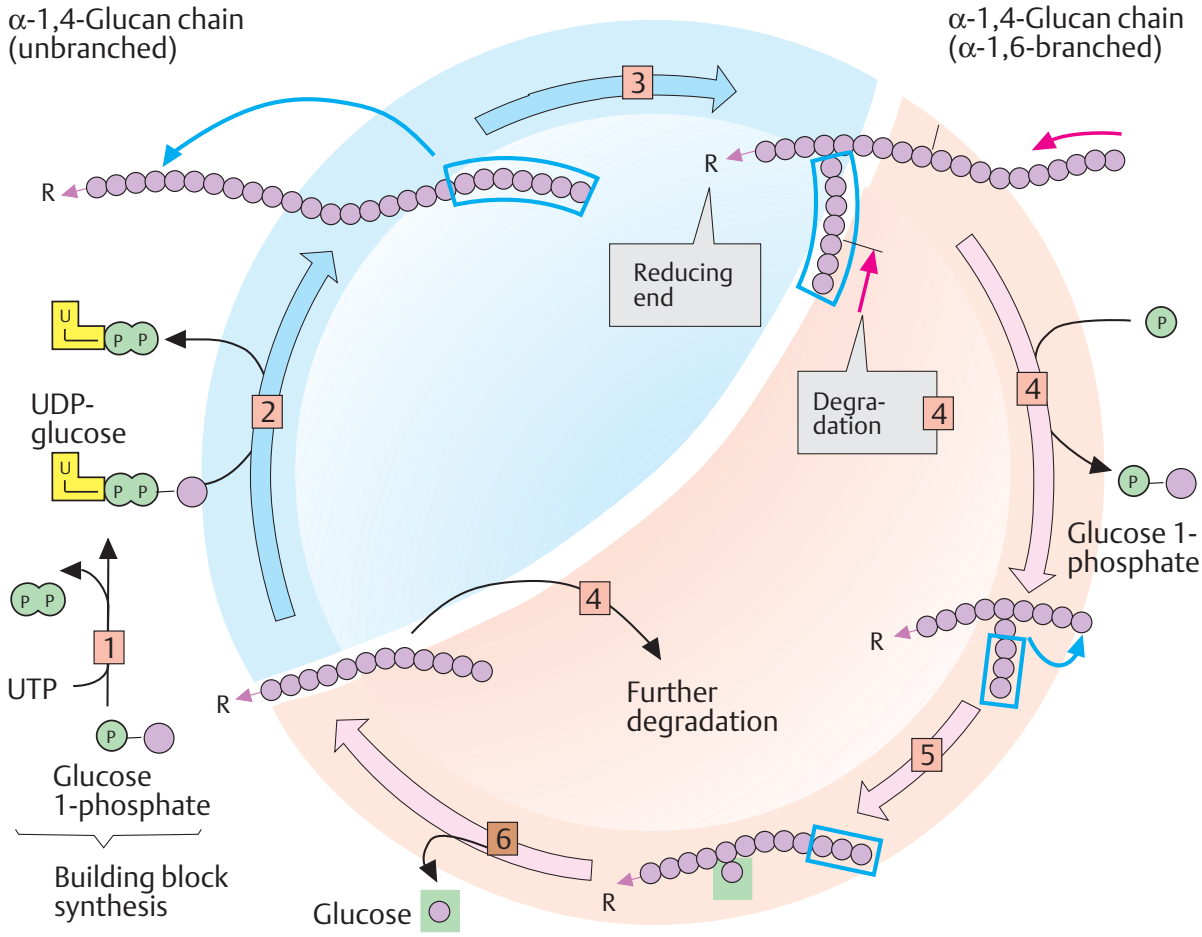

1 UTP-glucose 1-phosphate uridyltransferase *2.7.7.9*

2 Glycogen synthase *2.4.1.11*

3 Glucan branching enzyme *2.4.1.18*

4 Phosphorylase *2.4.1.1*

5 4-α-Glucanotransferase *2.4.1.25*

6 Amylo-1,6-glucosidase *3.2.1.33*

B. Glycogen balance

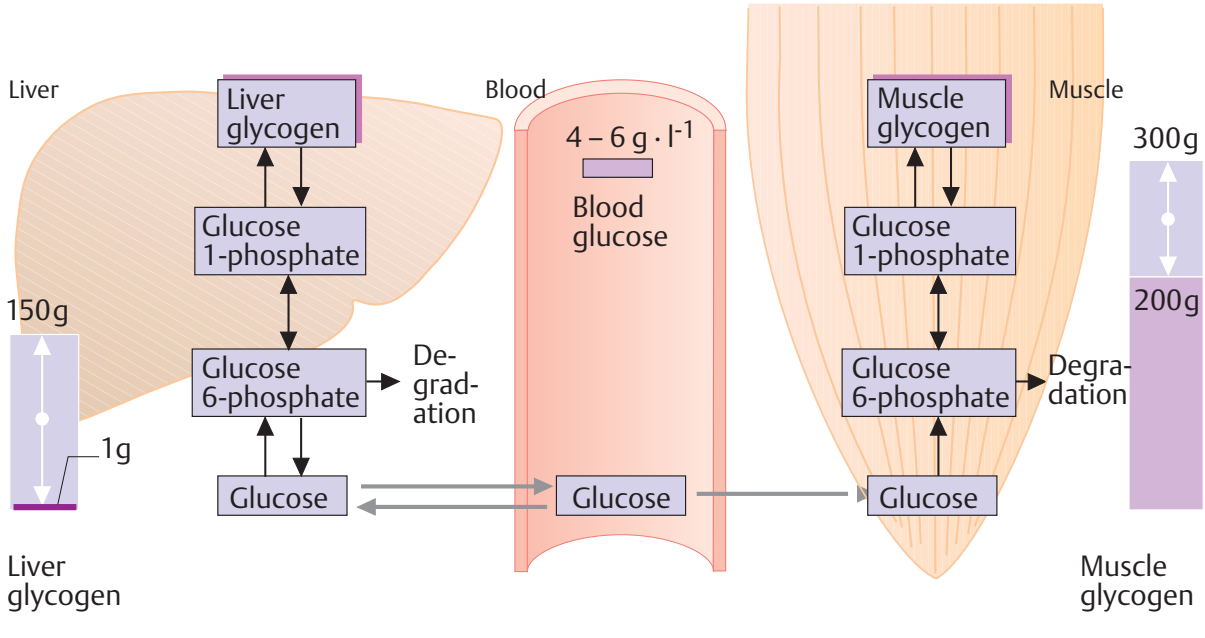

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Regulation

A. Regulation of carbohydrate metabolism ◑

In all organisms, carbohydrate metabolism is subject to complex regulatory mechanisms involving *hormones, metabolites*, and *coenzymes*. The scheme shown here (still a simplified one) applies to the liver, which has central functions in carbohydrate metabolism (see p. 306). Some of the control mechanisms shown here are not effective in other tissues.

One of the liver's most important tasks is to store excess glucose in the form of glycogen and to release glucose from glycogen when required *(buffer function)*. When the glycogen reserves are exhausted, the liver can provide glucose by de novo synthesis (*gluconeogenesis*; see p. 154). In addition, like all tissues, the liver breaks glucose down via glycolysis. These functions have to be coordinated with each other. For example, there is no point in glycolysis and gluconeogenesis taking place *simultaneously*, and glycogen synthesis and glycogen degradation should not occur simultaneously either. This is ensured by the fact that two *different* enzymes exist for important steps in both pathways, each of which catalyzes only the anabolic or the catabolic reaction. The enzymes are also regulated differently. Only these key enzymes are shown here.

Hormones. The hormones that influence carbohydrate metabolism include the peptides insulin and glucagon; a glucocorticoid, cortisol; and a catecholamine, epinephrine (see p. 380). **Insulin** activates *glycogen synthase* ([1]; see p. 388), and induces several enzymes involved in glycolysis [3, 5, 7]. At the same time, insulin inhibits the synthesis of enzymes involved in gluconeogenesis (*repression;* [4, 6, 8, 9]). **Glucagon,** the antagonist of insulin, has the opposite effect. It induces gluconeogenesis enzymes [4, 6, 8, 9] and represses *pyruvate kinase* [7], a key enzyme of glycolysis. Additional effects of glucagon are based on the *interconversion* of enzymes and are mediated by the second messenger cAMP. This inhibits glycogen synthesis [1] and activates glycogenolysis [2]. Epinephrine acts in a similar fashion. The inhibition of *pyruvate kinase* [7] by glucagon is also due to interconversion.

Glucocorticoids—mainly **cortisol** (see p. 374)—induce all of the key enzymes involved in gluconeogenesis [4, 6, 8, 9]. At the same time, they also induce enzymes involved in amino acid degradation and thereby provide precursors for gluconeogenesis. Regulation of the expression of *PEP carboxykinase,* a key enzyme in gluconeogenesis, is discussed in detail on p. 244.

Metabolites. High concentrations of **ATP** and **citrate** inhibit glycolysis by allosteric regulation of *phosphofructokinase*. ATP also inhibits *pyruvate kinase*. **Acetyl-CoA,** an inhibitor of *pyruvate kinase,* has a similar effect. All of these metabolites arise from glucose degradation *(feedback inhibition)*. **AMP** and **ADP**, signals for ATP deficiency, activate glycogen degradation and inhibit gluconeogenesis.

B. Fructose 2,6-bisphosphate ◑

Fructose 2,6-bisphosphate (Fru-2,6-bP) plays an important part in carbohydrate metabolism. This metabolite is formed in small quantities from fructose 6-phosphate and has purely *regulatory functions*. It stimulates glycolysis by allosteric activation of *phosphofructokinase* and inhibits gluconeogenesis by inhibition of *fructose 1,6-bisphosphatase*.

The synthesis and degradation of Fru-2,6-bP are catalyzed by one and the same protein [10a, 10b]. If the enzyme is present in an unphosphorylated form [10a], it acts as a kinase and leads to the formation of Fru-2,6-bP. After phosphorylation by cAMP-dependent protein kinase A (PK-A), it acts as a phosphatase [10b] and now catalyzes the degradation of Fru-2,6-bP to fructose 6-phosphate. The equilibrium between [10a] and [10b] is regulated by hormones. Epinephrine and glucagon increase the cAMP level (see p. 120). As a result of increased PK-A activity, this reduces the Fru-2,6-bP concentration and inhibits glycolysis, while at the same time activating gluconeogenesis. Conversely, via [10a], insulin activates the synthesis of Fru-2,6-bP and thus glycolysis. In addition, insulin also inhibits the action of glucagon by reducing the cAMP level (see p. 120).

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A. Regulation of carbohydrate metabolism

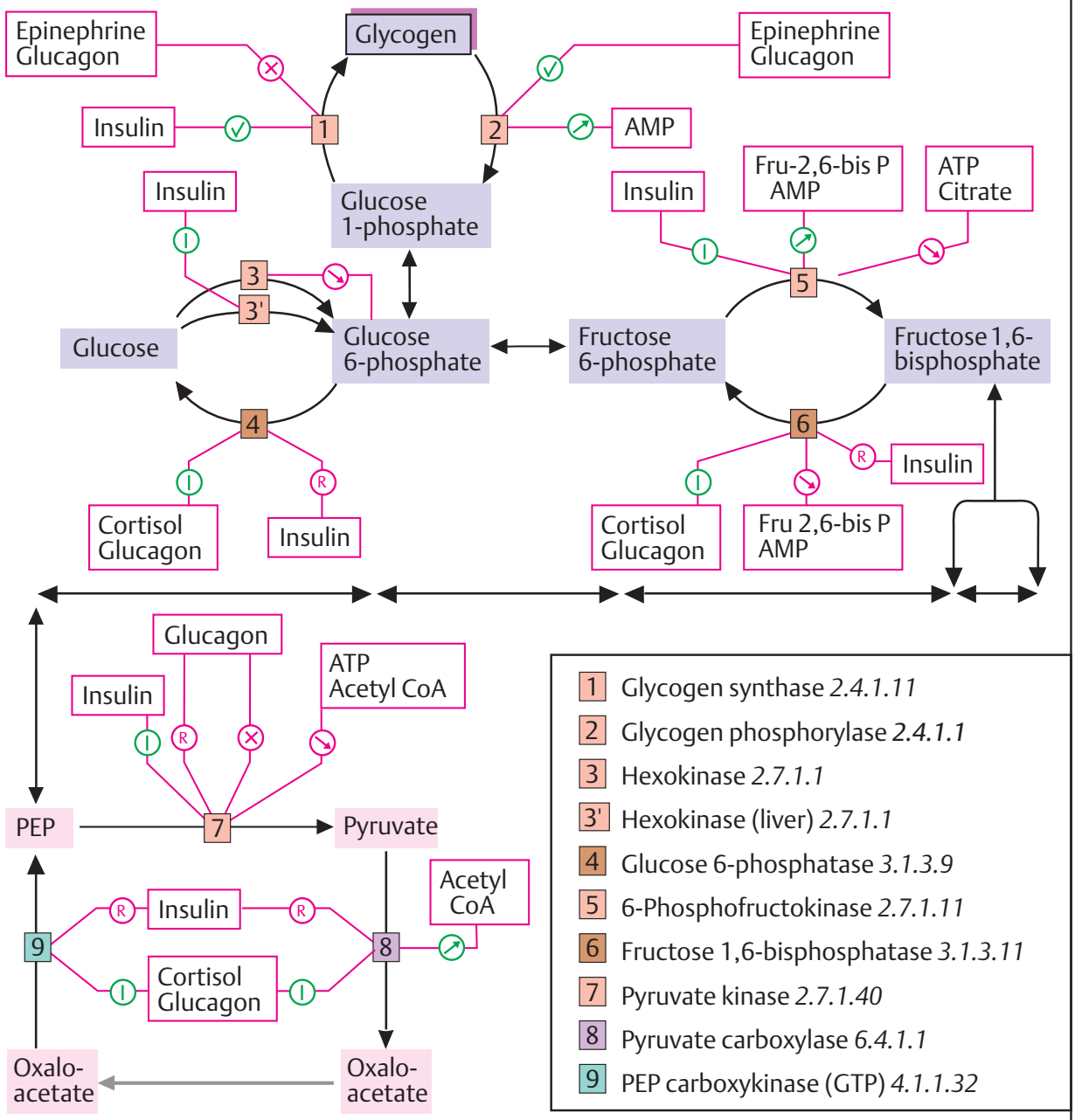

B. Fructose 2,6-bisphosphate

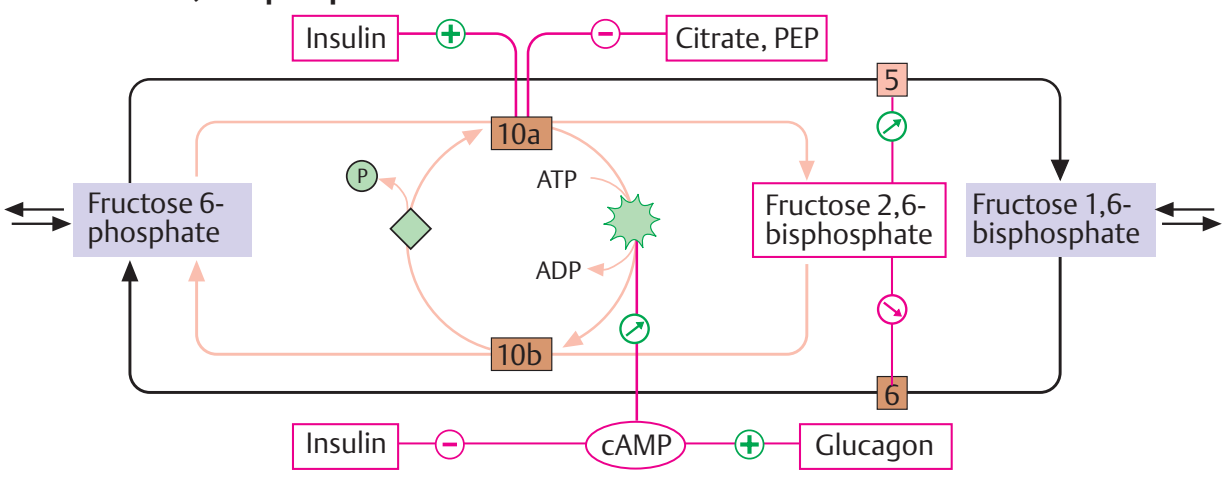

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Diabetes mellitus

Diabetes mellitus is a very common metabolic disease that is caused by absolute or relative insulin deficiency. The lack of this peptide hormone (see p. 76) mainly affects carbohydrate and lipid metabolism. Diabetes mellitus occurs in two forms. In **type 1** diabetes (insulin-dependent diabetes mellitus, IDDM), the insulin-forming cells are destroyed in young individuals by an autoimmune reaction. The less severe **type 2** diabetes (non-insulin-dependent diabetes mellitus, NIDDM) usually has its first onset in elderly individuals. The causes have not yet been explained in detail in this type.

A. Insulin biosynthesis ○

Insulin is produced by the B cells of the *islets of Langerhans* in the pancreas. As is usual with secretory proteins, the hormone's precursor (*preproinsulin*) carries a signal peptide that directs the peptide chain to the interior of the endoplasmic reticulum (see p. 210). *Proinsulin* is produced in the ER by cleavage of the signal peptide and formation of disulfide bonds. Proinsulin passes to the Golgi apparatus, where it is packed into vesicles—the β-*granules.* After cleavage of the *C peptide*, *mature insulin* is formed in the β-granules and is stored in the form of zinc-containing hexamers until secretion.

B. Effects of insulin deficiency ◑

The effects of insulin on **carbohydrate metabolism** are discussed on p. 158. In simplified terms, they can be described as *stimulation of glucose utilization* and *inhibition of gluconeogenesis*. In addition, the transport of glucose from the blood into most tissues is also insulin-dependent (exceptions to this include the liver, CNS, and erythrocytes).

The **lipid metabolism** of adipose tissue is also influenced by the hormone. In these cells, insulin stimulates the reorganization of glucose into fatty acids. This is mainly based on activation of *acetyl CoA carboxylase* (see p. 162) and increased availability of $NADPH+H^+$ due to increased PPP activity (see p. 152). On the other hand, insulin also inhibits the degradation of fat by hormone-sensitive lipases (see p. 162) and prevents the breakdown of muscle protein.

The effects of insulin *deficiency* on metabolism are shown by arrows in the illustration. Particularly noticeable is the increase in the glucose concentration in the blood, from 5 mM to 9 mM (90 mg dL^{-1}) or more (**hyperglycemia,** elevated blood glucose level). In *muscle* and *adipose tissue* – the two most important glucose consumers—glucose uptake and glucose utilization are impaired by insulin deficiency. Glucose utilization in the *liver* is also reduced. At the same time, gluconeogenesis is stimulated, partly due to increased proteolysis in the muscles. This increases the blood sugar level still further. When the capacity of the *kidneys* to resorb glucose is exceeded (at plasma concentrations of 9 mM or more), glucose is excreted in the urine (**glucosuria**).

The increased degradation of fat that occurs in insulin deficiency also has serious effects. Some of the fatty acids that accumulate in large quantities are taken up by the liver and used for lipoprotein synthesis **(hyperlipidemia)**, and the rest are broken down into acetyl CoA. As the tricarboxylic acid cycle is not capable of taking up such large quantities of acetyl CoA, the excess is used to form **ketone bodies** (*acetoacetate* and *β-hydroxybutyrate* see p. 312). As H^+ ions are released in this process, diabetics not receiving adequate treatment can suffer severe **metabolic acidosis** (diabetic coma). The *acetone* that is also formed gives these patients' breath a characteristic odor. In addition, large amounts of ketone body anions appear in the urine (**ketonuria**).

Diabetes mellitus can have serious secondary effects. A constantly raised blood sugar level can lead in the long term to changes in the blood vessels (diabetic angiopathy), kidney damage (nephropathy) and damage to the nervous system (neuropathy), as well as to cataracts in the eyes.

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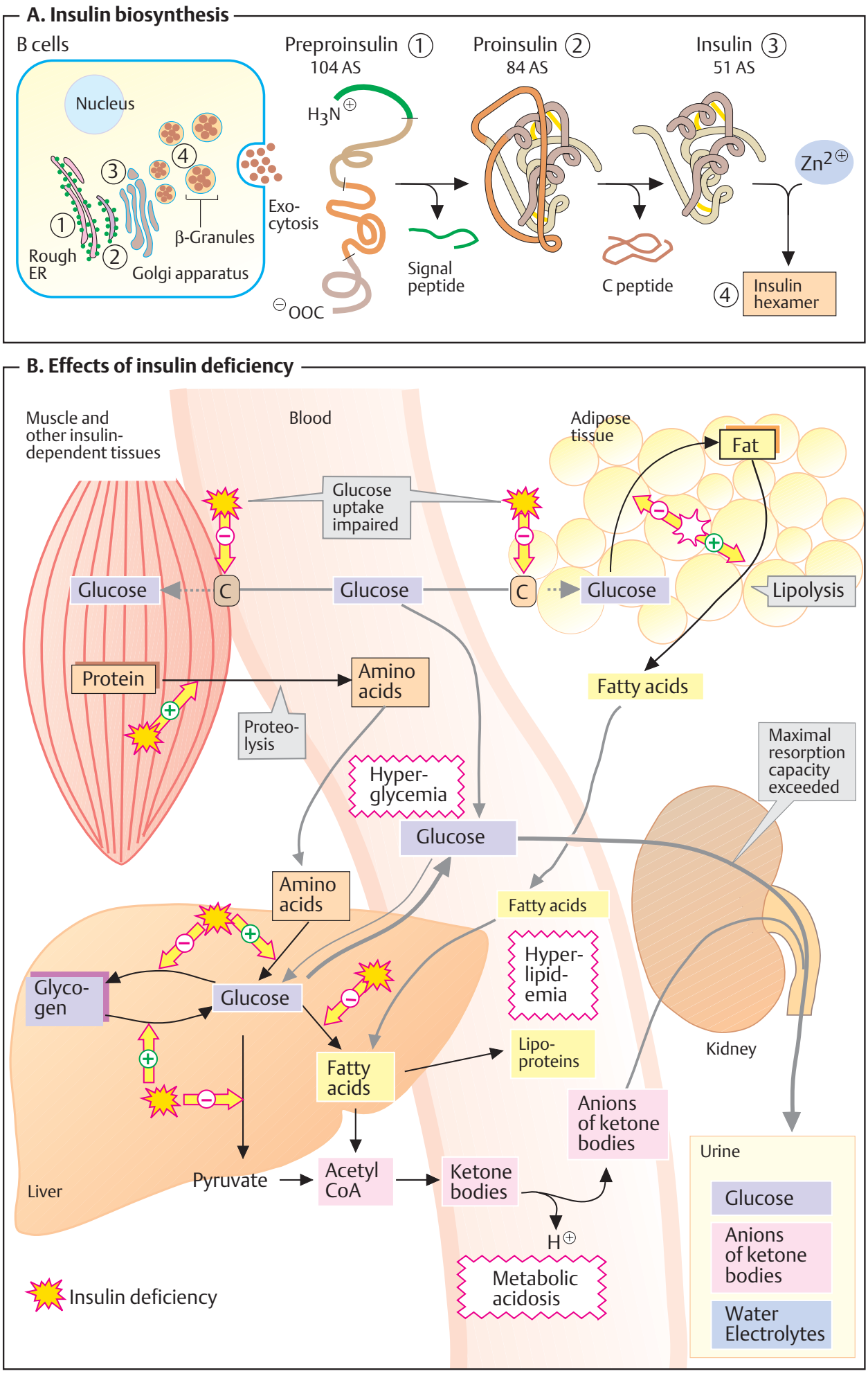

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Overview

A. Fat metabolism ◑

Fat metabolism in adipose tissue (top). Fats (triacylglycerols) are the most important energy reserve in the animal organism. They are mostly stored in insoluble form in the cells of adipose tissue—the *adipocytes*—where they are constantly being synthesized and broken down again.

As precursors for the biosynthesis of fats (**lipogenesis**), the adipocytes use triacylglycerols from lipoproteins (VLDLs and chylomicrons; see p. 278), which are formed in the liver and intestines and delivered by the blood. *Lipoprotein lipase* [1], which is located on the inner surface of the blood capillaries, cleaves these triacylglycerols into glycerol and fatty acids, which are taken up by the adipocytes and converted back into fats.

The degradation of fats (**lipolysis**) is catalyzed in adipocytes by *hormone-sensitive lipase* [2]—an enzyme that is regulated by various hormones by cAMP-dependent *interconversion* (see p. 120). The amount of fatty acids released depends on the activity of this lipase; in this way, the enzyme regulates the plasma levels of fatty acids.

In the blood plasma, fatty acids are transported in free form—i. e., non-esterified. Only short-chain fatty acids are soluble in the blood; longer, less water-soluble fatty acids are transported bound to albumin.

Degradation of fatty acids in the liver (left). Many tissues take up fatty acids from the blood plasma in order to synthesize fats or to obtain energy by oxidizing them. The metabolism of fatty acids is particularly intensive in the hepatocytes in the liver.

The most important process in the degradation of fatty acids is **β-oxidation**—a metabolic pathway in the mitochondrial matrix (see p. 164). Initially, the fatty acids in the cytoplasm are activated by binding to coenzyme A into **acyl CoA** [3]. Then, with the help of a transport system (the carnitine shuttle [4]; see p. 164), the activated fatty acids enter the mitochondrial matrix, where they are broken down into **acetyl CoA**. The resulting acetyl residues can be oxidized to CO_2 in the tricarboxylic acid cycle, producing reduced coenzyme and ATP derived from it by oxidative phosphorylation. If acetyl CoA production exceeds the energy requirements of the hepatocytes—as is the case when there is a high level of fatty acids in the blood plasma (typical in hunger and diabetes mellitus)—then the excess is converted into **ketone bodies** (see p. 312). These serve exclusively to supply other tissues with energy.

Fat synthesis in the liver (right). Fatty acids and fats are mainly synthesized in the liver and in adipose tissue, as well as in the kidneys, lungs, and mammary glands. Fatty acid biosynthesis occurs in the cytoplasm—in contrast to fatty acid degradation. The most important precursor is **glucose**, but certain amino acids can also be used.

The first step is carboxylation of **acetyl CoA** to **malonyl CoA**. This reaction is catalyzed by *acetyl-CoA carboxylase* [5], which is the *key enzyme in fatty acid biosynthesis.* Synthesis into fatty acids is carried out by *fatty acid synthase* [6]. This multifunctional enzyme (see p. 168) starts with one molecule of acetyl-CoA and elongates it by adding malonyl groups in seven reaction cycles until palmitate is reached. One CO_2 molecule is released in each reaction cycle. The fatty acid therefore grows by two carbon units each time. $NADPH+H^+$ is used as the reducing agent and is derived either from the *pentose phosphate pathway* (see p. 152) or from *isocitrate dehydrogenase* and *malic enzyme* reactions.

The elongation of the fatty acid by *fatty acid synthase* concludes at C_{16}, and the product, **palmitate** (16:0), is released. Unsaturated fatty acids and long-chain fatty acids can arise from palmitate in subsequent reactions. Fats are finally synthesized from activated fatty acids (acyl CoA) and glycerol 3-phosphate (see p. 170). To supply peripheral tissues, fats are packed by the hepatocytes into lipoprotein complexes of the VLDL type and released into the blood in this form (see p. 278).

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A. Fat metabolism

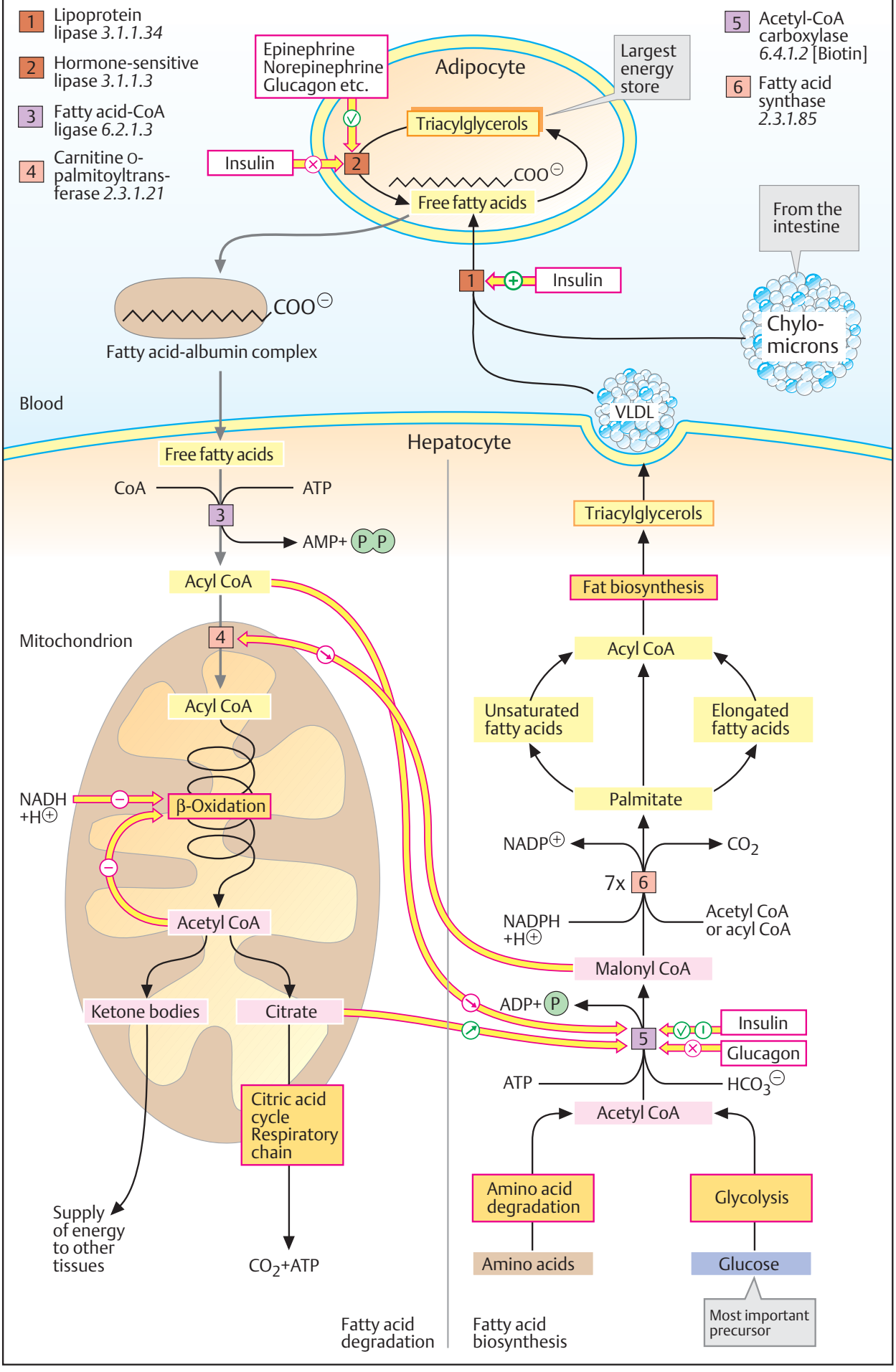

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Fatty acid degradation

A. Fatty acid degradation: β-oxidation ◑

After uptake by the cell, fatty acids are activated by conversion into their CoA derivatives—**acyl CoA** is formed. This uses up two energy-rich anhydride bonds of ATP per fatty acid (see p. 162). For channeling into the mitochondria, the acyl residues are first transferred to *carnitine* and then transported across the inner membrane as **acyl carnitine** (see **B**).

The degradation of the fatty acids occurs in the mitochondrial matrix through an oxidative cycle in which C_2 units are successively cleaved off as **acetyl CoA** (*activated acetic acid*). Before the release of the acetyl groups, each CH_2 group at C-3 of the acyl residue (the β-C atom) is oxidized to the keto group—hence the term **β-oxidation** for this metabolic pathway. Both spatially and functionally, it is closely linked to the tricarboxylic acid cycle (see p. 136) and to the respiratory chain (see p. 140).

[1] The first step is dehydrogenation of **acyl CoA** at C-2 and C-3. This yields an unsaturated Δ^2-enoyl-CoA derivative with a *trans*-configured double bond. The two hydrogen atoms are initially transferred from FAD-containing *acyl CoA dehydrogenase* to the **electron-transferring flavoprotein (ETF)**. *ETF dehydrogenase* [5] passes them on from ETF to ubiquinone (coenzyme Q), a component of the *respiratory chain* (see p. 140). Other FAD-containing mitochondrial dehydrogenases are also able to supply the respiratory chain with electrons in this fashion.

There are three *isoenzymes* (see p. 98) of *acyl CoA dehydrogenase* that are specialized for long-chain fatty acids (12–18 C atoms), medium-chain fatty acids (4–14), and short-chain fatty acids (4–8).

[2] The next step in fatty acid degradation is the addition of a water molecule to the double bond of the enoyl CoA (*hydration*), with formation of **β-hydroxyacyl CoA**.

[3] In the next reaction, the OH group at C-3 is oxidized to a carbonyl group (*dehydrogenation*). This gives rise to **β-ketoacyl CoA**, and the reduction equivalents are transferred to NAD^+, which also passes them on to the *respiratory chain.*

[4] β-Ketoacyl-CoA is now broken down by an *acyl transferase* into **acetyl CoA** and an **acyl CoA shortened by 2 C atoms** (*"thioclastic cleavage"*).

Several cycles are required for complete degradation of long-chain fatty acids—eight cycles in the case of stearyl-CoA (C18:0), for example. The acetyl CoA formed can then undergo further metabolism in the *tricarboxylic acid cycle* (see p. 136), or can be used for biosynthesis. When there is an excess of acetyl CoA, the liver can also form ketone bodies (see p. 312).

When oxidative degradation is complete, one molecule of palmitic acid supplies around 106 molecules of ATP, corresponding to an energy of 3300 kJ mol^{-1}. This high energy yield makes fats an ideal form of storage for metabolic energy. Hibernating animals such as polar bears can meet their own energy requirements for up to 6 months solely by fat degradation, while at the same time producing the vital water they need via the respiratory chain ("respiratory water").

B. Fatty acid transport ◑

The inner mitochondrial membrane has a group-specific transport system for fatty acids. In the cytoplasm, the acyl groups of activated fatty acids are transferred to **carnitine** by *carnitine acyltransferase* [1]. They are then channeled into the matrix by an acylcarnitine/carnitine antiport as **acyl carnitine**, in exchange for free carnitine. In the matrix, the mitochondrial enzyme *carnitine acyltransferase* catalyzes the return transfer of the acyl residue to CoA.

The carnitine shuttle is the rate-determining step in mitochondrial fatty acid degradation. Malonyl CoA, a precursor of fatty acid biosynthesis, inhibits *carnitine acyltransferase* (see p. 162), and therefore also inhibits uptake of fatty acids into the mitochondrial matrix.

The most important regulator of β-oxidation is the $NAD^+/NADH+H^+$ ratio. If the respiratory chain is not using any $NADH+H^+$, then not only the tricarboxylic acid cycle (see p. 136) but also β-oxidation come to a standstill due to the lack of NAD^+.

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A. Fatty acid degradation: β-oxidation

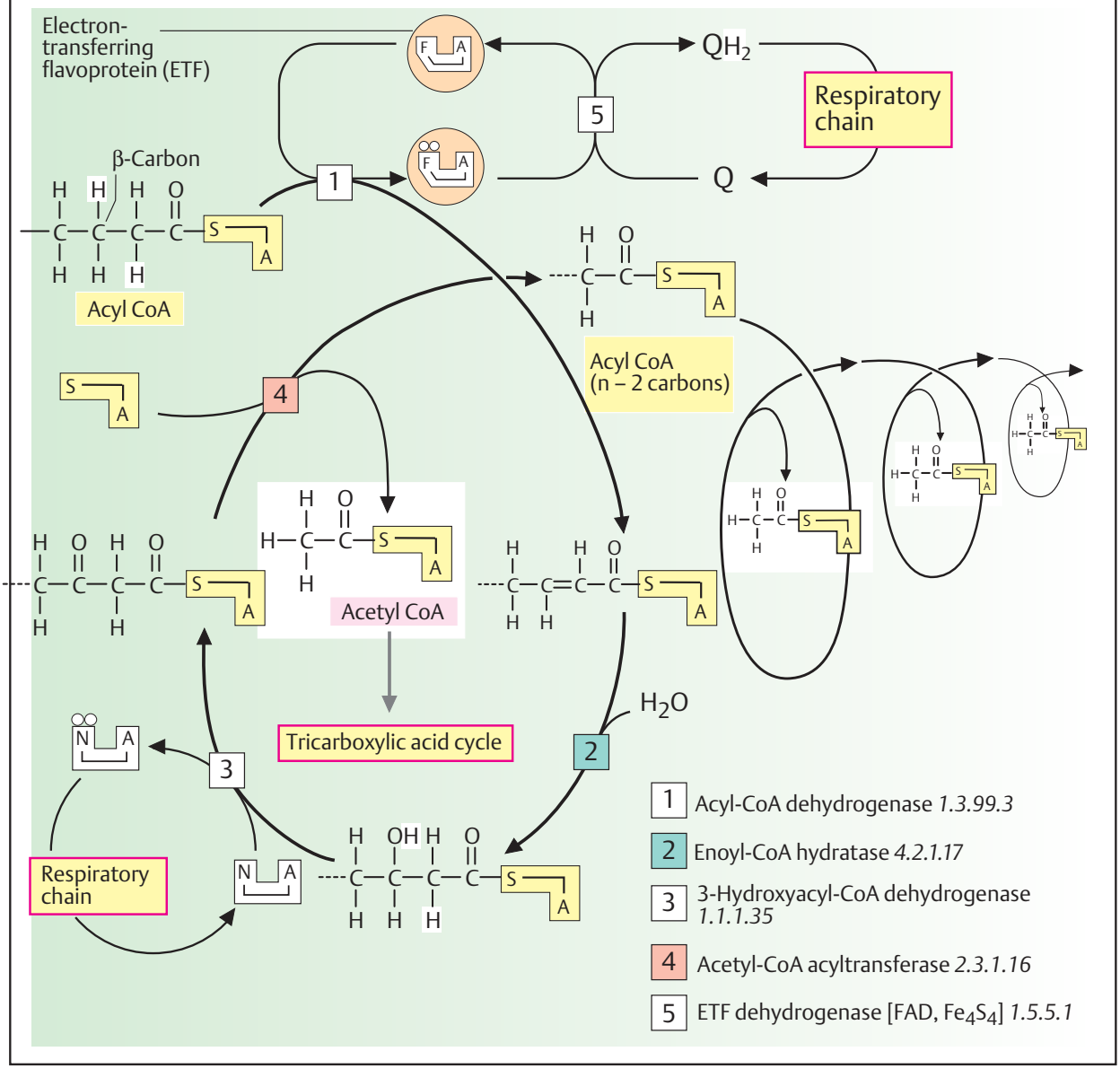

B. Fatty acid transport

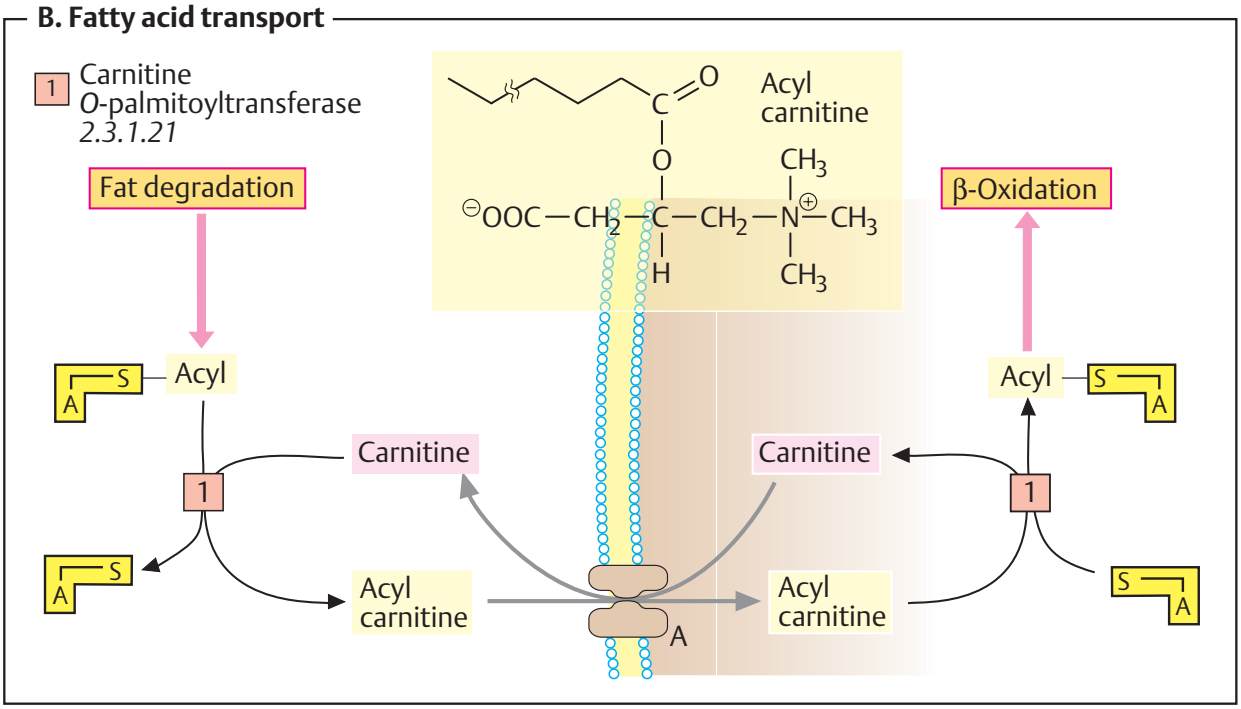

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Minor pathways of fatty acid degradation

Most fatty acids are saturated and even-numbered. They are broken down via **β-oxidation** (see p.164). In addition, there are special pathways involving degradation of unsaturated fatty acids (**A**), degradation of fatty acids with an odd number of C atoms (**B**), α and ω oxidation of fatty acids, and degradation in peroxisomes.

A. Degradation of unsaturated fatty acids ○

Unsaturated fatty acids usually contain a *cis* double bond at position 9 or 12—e. g., linoleic acid (18:2; 9,12). As with saturated fatty acids, degradation in this case occurs via β-oxidation until the C-9-*cis* double bond is reached. Since *enoyl-CoA hydratase* only accepts substrates with *trans* double bonds, the corresponding enoyl-CoA is converted by an isomerase from the *cis*-Δ^3, *cis*- Δ^6 isomer into the *trans*-Δ^3,*cis*-Δ^6 isomer [1]. Degradation by β-oxidation can now continue until a shortened *trans*-Δ^2, *cis*-Δ^4 derivative occurs in the next cycle. This cannot be isomerized in the same way as before, and instead is reduced in an NADPH-dependent way to the *trans*-Δ^3 compound [2]. After rearrangement by *enoyl-CoA isomerase* [1], degradation can finally be completed via normal β-oxidation.

B. Degradation of oddnumbered fatty acids ○

Fatty acids with an odd number of C atoms are treated in the same way as "normal" fatty acids—i. e., they are taken up by the cell with ATP-dependent activation to acyl CoA and are transported into the mitochondria with the help of the carnitine shuttle and broken down there by β–oxidation (see p. 164). In the last step, **propionyl CoA** arises instead of acetyl CoA. This is first carboxylated by *propionyl CoA carboxylase* into ***(S)*-methylmalonyl CoA** [3], which—after isomerization into the (*R*) enantiomer (not shown; see p. 411)—is isomerized into **succinyl CoA** [4].

Various coenzymes are involved in these reactions. The carboxylase [3] requires *biotin,* and the mutase [4] is dependent on *coenzyme* B_{12} (5′-deoxyadenosyl cobalamin; see p. 108). Succinyl-CoA is an intermediate in the tricarboxylic acid cycle and is available for *gluconeogenesis* through conversion into oxaloacetate. Odd-numbered fatty acids from propionyl-CoA can therefore be used to synthesize glucose.

This pathway is also important for ruminant animals, which are dependent on symbiotic microorganisms to break down their food. The microorganisms produce large amounts of propionic acid as a degradation product, which the host can channel into the metabolism in the way described.

Further information ○

In addition to the degradation pathways described above, there are also additional special pathways for particular fatty acids found in food.

~ Oxidation is used to break down methyl-branched fatty acids. It takes place through step-by-step removal of C_1 residues, begins with a hydroxylation, does not require coenzyme A, and does not produce any ATP.

∂ Oxidation—i. e., oxidation starting at the end of the fatty acid—also starts with a hydroxylation catalyzed by a *monooxygenase* (see p. 316), and leads via subsequent oxidation to fatty acids with two carboxyl groups, which can undergo β-oxidation from both ends until C_8 or C_6 dicarboxylic acids are reached, which can be excreted in the urine in this form.

Degradation of unusually long fatty acids. An alternative form of β-oxidation takes place in *hepatic peroxisomes*, which are specialized for the degradation of particularly long fatty acids (n > 20). The degradation products are acetyl-CoA and hydrogen peroxide (H_2O_2), which is detoxified by the *catalase* (see p. 32) common in peroxisomes.

Enzyme defects are also known to exist in the minor pathways of fatty acid degradation. In **Refsum disease**, the methyl-branched phytanic acid (obtained from vegetable foods) cannot be degraded by α-oxidation. In **Zellweger syndrome**, a peroxisomal defect means that long-chain fatty acids cannot be degraded.

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A. Degradation of unsaturated fatty acids

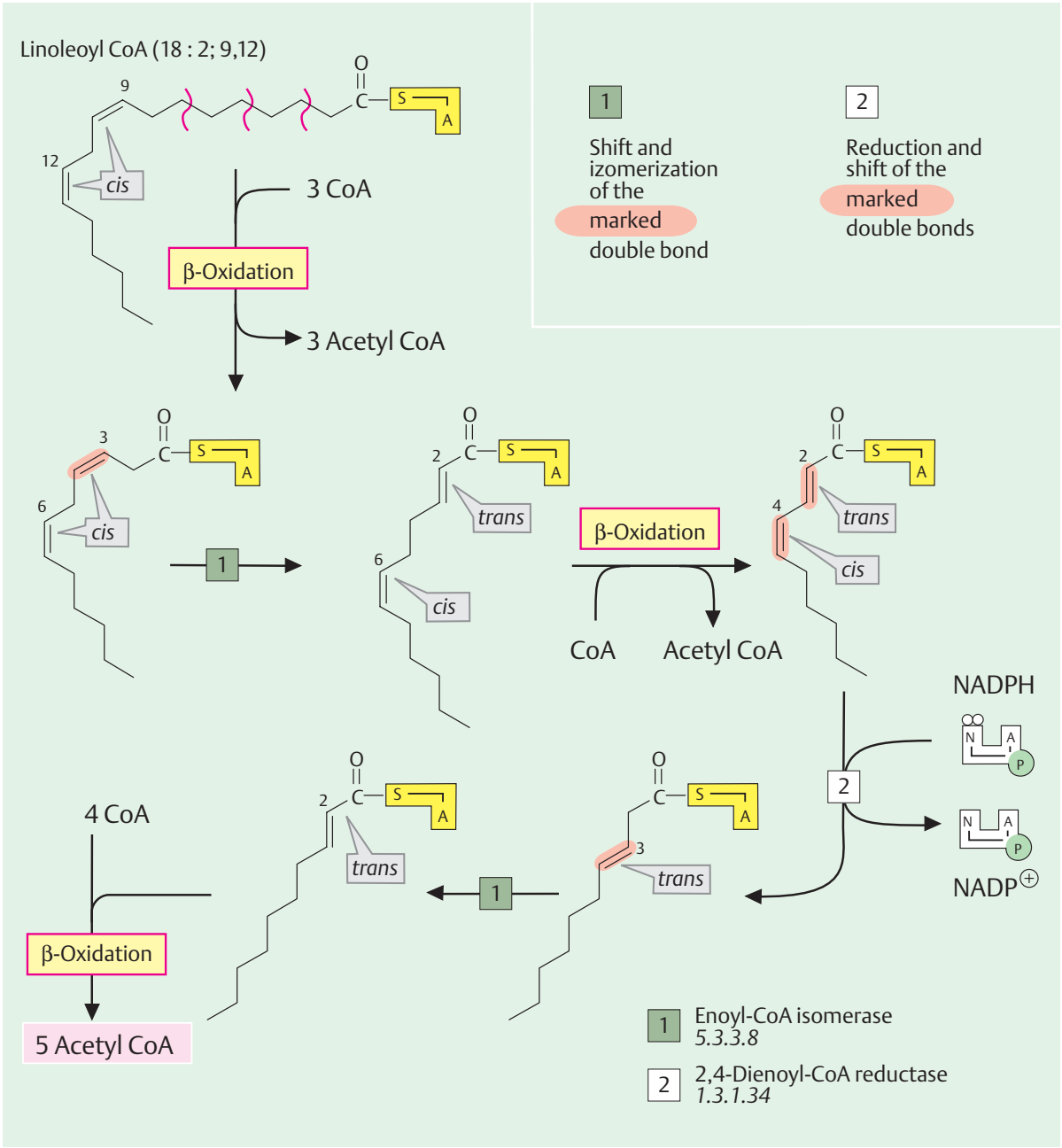

B. Degradation of odd-numbered fatty acids

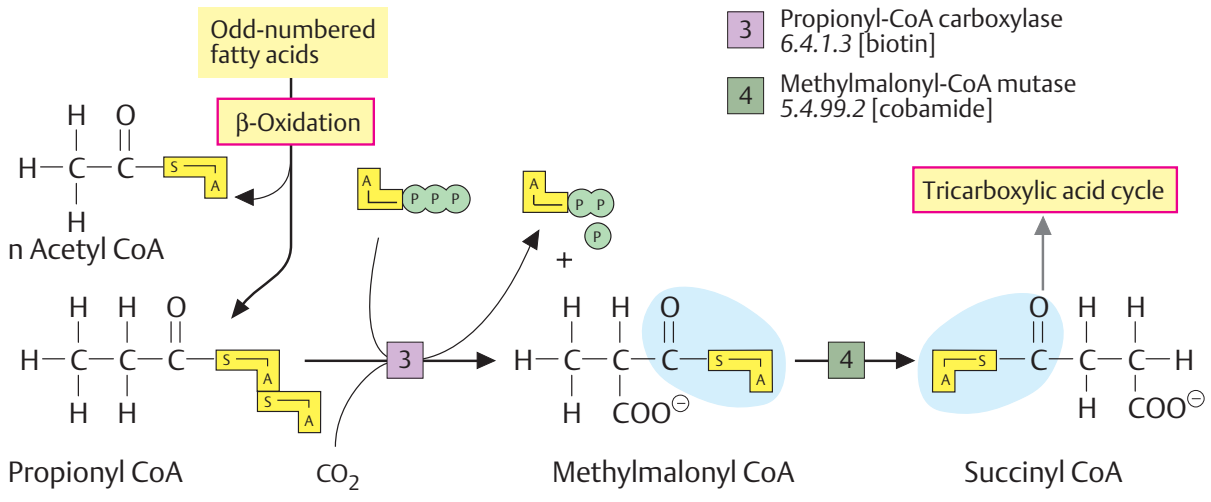

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Fatty acid synthesis

In the vertebrates, biosynthesis of fatty acids is catalyzed by *fatty acid synthase,* a multifunctional enzyme. Located in the cytoplasm, the enzyme requires acetyl CoA as a starter molecule. In a cyclic reaction, the acetyl residue is elongated by one C_2 unit at a time for seven cycles. NADPH+H^+ is used as a reducing agent in the process. The end product of the reaction is the saturated C_{16} acid, *palmitic acid.*

A. Fatty acid synthase ◑

Fatty acid synthase in vertebrates consists of two identical peptide chains—i. e., it is a homodimer. Each of the two peptide chains, which are shown here as hemispheres, catalyzes all seven of the partial reactions required to synthesize palmitate. The spatial compression of several successive reactions into a single multifunctional enzyme has advantages in comparison with separate enzymes. Competing reactions are prevented, the individual reactions proceed in a coordinated way as if on a production line, and due to low diffusion losses they are particularly ef cient.

Each subunit of the enzyme binds acetyl residues as thioesters at two different SH groups: at one peripheral *cysteine residue* (CysSH) and one central *4′-phosphopantetheine group* (Pan-SH). Pan-SH, which is very similar to coenzyme A (see p. 12), is covalently bound to a protein segment of the synthase known as the *acyl-carrier protein* (ACP). This part functions like a long arm that passes the substrate from one reaction center to the next. The two subunits of fatty acid synthase cooperate in this process; the enzyme is therefore only capable of functioning as a dimer.

Spatially, the enzyme activities are arranged into three different domains. **Domain 1** catalyzes the entry of the substrates acetyl CoA and malonyl CoA by *[ACP]-S-acetyltransferase* [1] and *[ACP]-Smalonyl transferase* [2] and subsequent condensation of the two partners by *3-oxoacyl-[ACP]-synthase* [3]. **Domain 2** catalyzes the conversion of the 3-oxo group to a CH_2 group by *3-oxoacyl-[ACP]-reductase* [4], *3-hydroxyacyl-[ACP]-dehydratase* [5], and *enoyl-[ACP]-reductase* [6]. Finally, **domain 3** serves to release the finished product by *acyl-[ACP]-hydrolase* [7] after seven steps of chain elongation.

B. Reactions of fatty acid synthase ◑

The key enzyme in fatty acid synthesis is **acetyl CoA carboxylase** (see p. 162), which precedes the synthase and supplies the malonyl-CoA required for elongation. Like all carboxylases, the enzyme contains covalently bound *biotin* as a prosthetic group and is hormone-dependently *inactivated* by phosphorylation or *activated* by dephosphorylation (see p. 120). The precursor *citrate* (see p. 138) is an allosteric activator, while *palmitoyl-CoA* inhibits the end product of the synthesis pathway.

[1] The first cycle (n = 1) starts with the transfer of an acetyl residue from acetyl CoA to the peripheral cysteine residue (Cys-SH). At the same time,

[2] a malonyl residue is transferred from malonyl CoA to 4-phosphopantetheine (Pan-SH).

[3] By condensation of the acetyl residue—or (in later cycles) the acyl residue—with the malonyl group, with simultaneous decarboxylation, the chain is elongated.

[4]–[6] The following three reactions (reduction of the 3-oxo group, dehydrogenation of the 3-hydroxyl derivative, and renewed reduction of it) correspond in principle to a reversal of β-oxidation, but they are catalyzed by other enzymes and use NADPH+H^+ instead of NADH+H^+ for reduction. They lead to an acyl residue bound at Pan-SH with 2n + 2 C atoms (n = the number of the cycle). Finally, depending on the length of the product,

[1′] The acyl residue is transferred back to the peripheral cysteine, so that the next cycle can begin again with renewed loading of the ACP with a malonyl residue, or:

[7] After seven cycles, the completed **palmitic acid** is hydrolytically released.

In all, one acetyl-CoA and seven malonyl-CoA are converted with the help of 14 NADPH+H^+ into one palmitic acid, 7 CO_2, 6 H_2O, 8 CoA and 14 $NADP^+$. Acetyl CoA carboxylase also uses up seven ATP.

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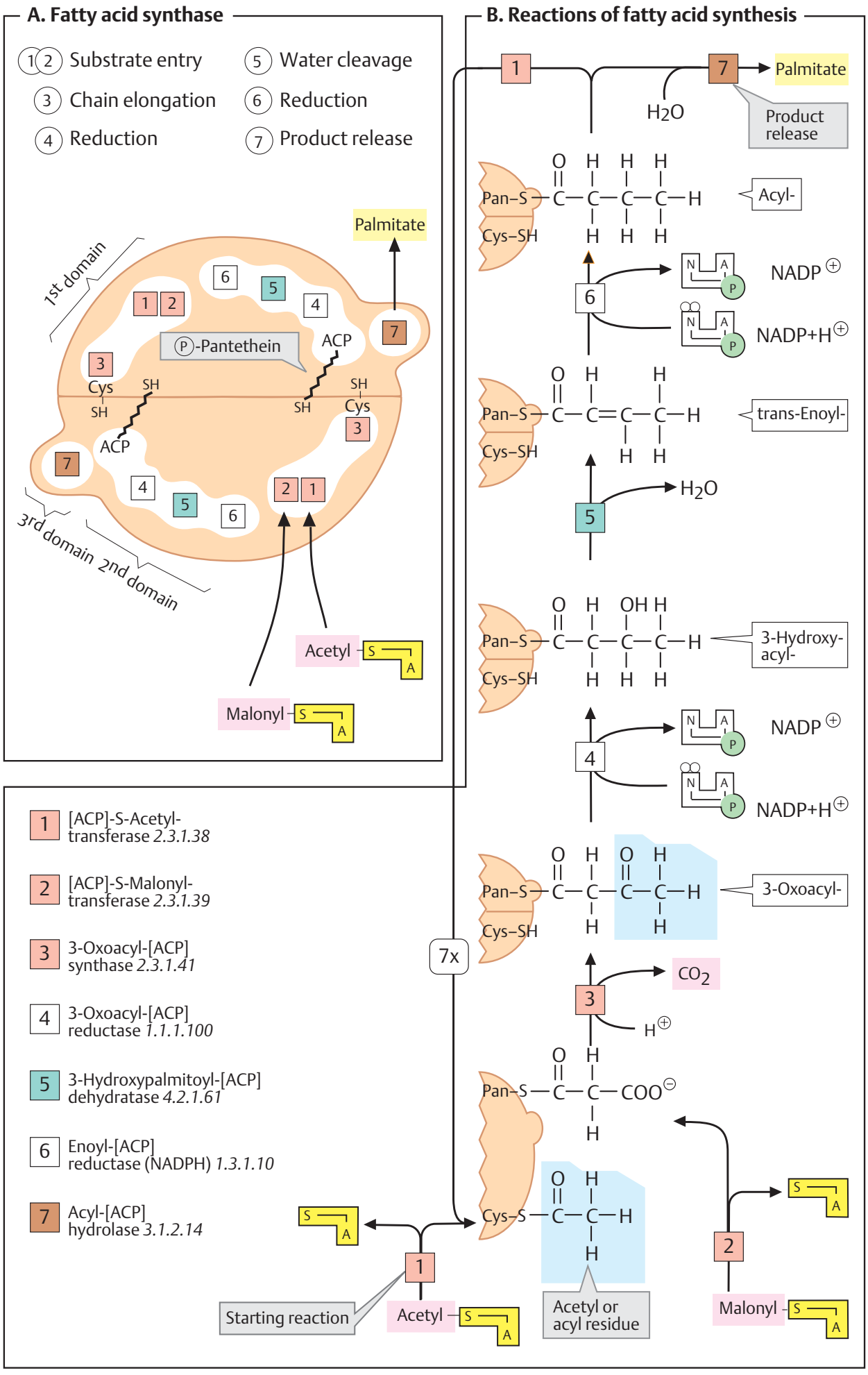

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Biosynthesis of complex lipids

A. Biosynthesis of fats and phospholipids ◑

Complex lipids, such as neutral fats (triacylglycerols), phospholipids, and glycolipids, are synthesized via common reaction pathways. Most of the enzymes involved are associated with the membranes of the smooth endoplasmic reticulum.

The synthesis of fats and phospholipids starts with **glycerol 3-phosphate**. This compound can arise via two pathways:

[1] By reduction from the glycolytic intermediate **glycerone 3-phosphate** (dihydroxyacetone 3-phosphate; enzyme: *glycerol-3-phosphate dehydrogenase (NAD+) 1.1.1.8*), or:

[2] By phosphorylation of **glycerol** deriving from fat degradation (enzyme: *glycerol kinase 2.7.1.30*).

[3] Esterification of glycerol 3-phosphate with a long-chain fatty acid produces a strongly amphipathic **lysophosphatidate** (enzyme: *glycerol-3-phosphate acyltransferase 2.3.1.15*). In this reaction, an acyl residue is transferred from the activated precursor **acyl-CoA** to the hydroxy group at C-1.

[4] A second esterification of this type leads to a **phosphatidate** (enzyme: *1-acylglycerol-3-phosphate acyltransferase 2.3.1.51*). Unsaturated acyl residues, particularly oleic acid, are usually incorporated at C-2 of the glycerol. Phosphatidates (anions of phosphatidic acids) are the key molecules in the biosynthesis of fats, phospholipids, and glycolipids.

[5] To biosynthesize fats (triacylglycerols), the phosphate residue is again removed by hydrolysis (enzyme: *phosphatidate phosphatase 3.1.3.4*). This produces **diacylglycerols (DAG)**.

[6] Transfer of an additional acyl residue to DAG forms **triacylglycerols** (enzyme: *diacylglycerol acyltransferase 2.3.1.20*). This completes the biosynthesis of neutral fats. They are packaged into VLDLs by the liver and released into the blood. Finally, they are stored by adipocytes in the form of insoluble fat droplets.

The biosynthesis of most phospholipids also starts from DAG.

[7] Transfer of a phosphocholine residue to the free OH group gives rise to **phosphatidylcholine** (lecithin; enzyme: *1-alkyl-2-acetylglycerolcholine phosphotransferase 2.7.8.16*). The phosphocholine residue is derived from the precursor CDP-choline (see p. 110). **Phosphatidylethanolamine** is similarly formed from CDP-ethanolamine and DAG. By contrast, **phosphatidylserine** is derived from phosphatidylethanolamine by an exchange of the amino alcohol. Further reactions serve to interconvert the phospholipids—e.g., phosphatidylserine can be converted into phosphatidylethanolamine by decarboxylation, and the latter can then be converted into phosphatidylcholine by methylation with S-adenosyl methionine (not shown; see also p. 409). The biosynthesis of **phosphatidylinositol** starts from phosphatidate rather than DAG.

[8] In the lumen of the intestine, fats from food are mainly broken down into **monoacylglycerols** (see p. 270). The cells of the intestinal mucosa re-synthesize these into neutral fats. This pathway also passes via **DAG** (enzyme: *acylglycerolpalmitoyl transferase 2.3.1.22*).

[9] Transfer of a CMP residue gives rise first to **CDP-diacylglycerol** (enzyme: *phosphatidatecytidyl transferase 2.3.1.22*).

[10] Substitution of the CMP residue by inositol then provides **phosphatidylinositol** (**PtdIns**; enzyme: *CDPdiacylglycerolinositol-3-phosphatidyl transferase 2.7.8.11*).

[12] An additional phosphorylation (enzyme: *phosphatidylinositol-4-phosphate kinase 2.7.1.68*) finally provides **phosphaditylinositol-4,5-bisphosphate** (PIP_2, PtdIns(4,5)P_2). PIP_2 is the precursor for the second messengers *2,3-diacylglycerol* (DAG) and *inositol-1,4,5-trisphosphate* ($InsP_3$, IP_3; see p. 367).

The biosynthesis of the **sphingolipids** is shown in schematic form on p. 409.

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A. Biosynthesis of fats and phospholipids

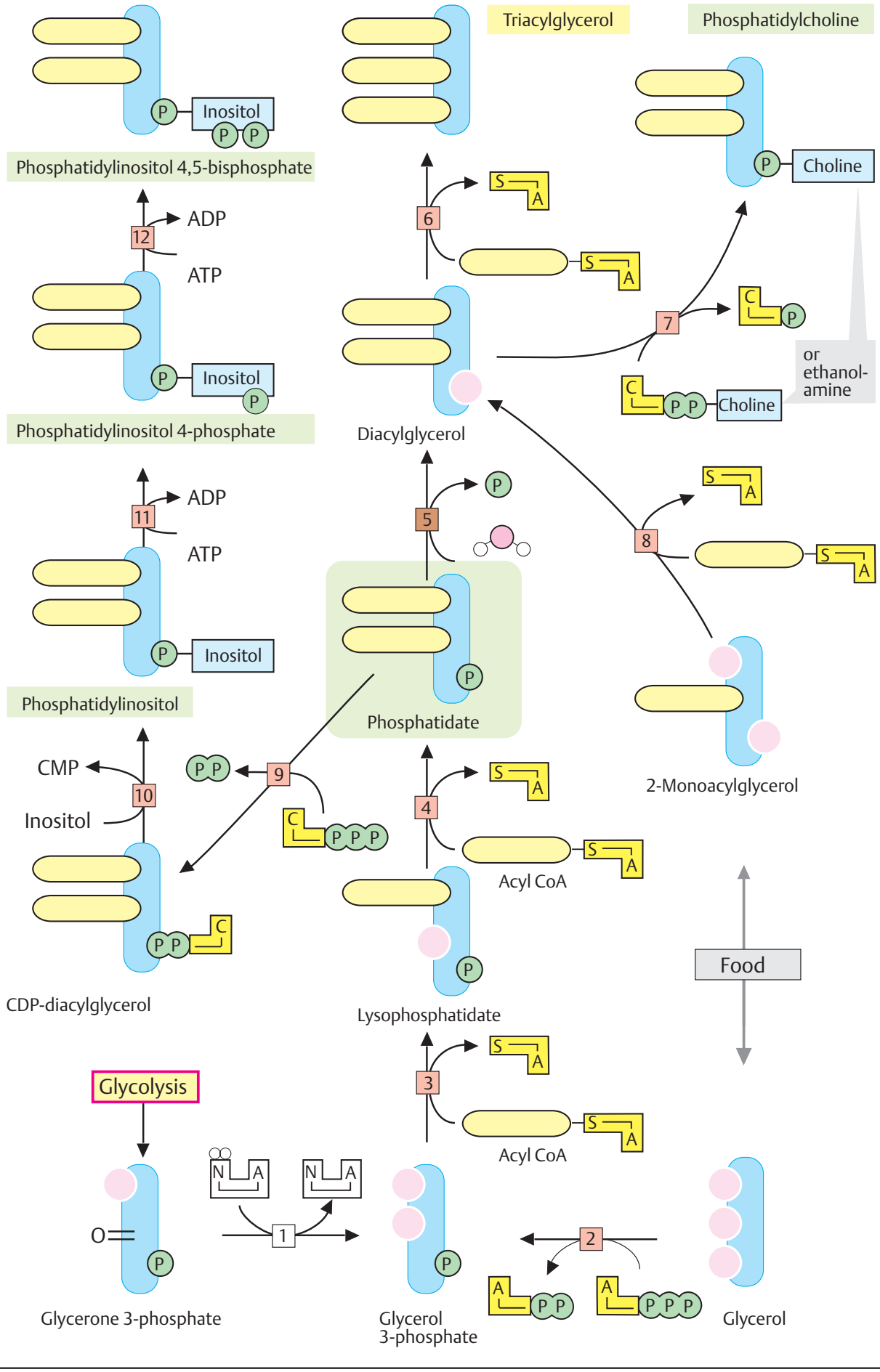

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Biosynthesis of cholesterol

Cholesterol is a major constituent of the *cell membranes* of animal cells (see p. 216). It would be possible for the body to provide its full daily cholesterol requirement (ca. 1 g) by synthesizing it itself. However, with a mixed diet, only about half of the cholesterol is derived from *endogenous biosynthesis*, which takes place in the intestine and skin, and mainly in the liver (about 50%). The rest is taken up from *food*. Most of the cholesterol is incorporated into the lipid layer of plasma membranes, or converted into **bile acids** (see p. 314). A very small amount of cholesterol is used for biosynthesis of the **steroid hormones** (see p. 376). In addition, up to 1 g cholesterol per day is released into the *bile* and thus excreted.

A. Cholesterol biosynthesis ○

Cholesterol is one of the isoprenoids, synthesis of which starts from **acetyl CoA** (see p. 52). In a long and complex reaction chain, the C_{27} sterol is built up from C_2 components. The biosynthesis of cholesterol can be divided into four sections. In the first (**1**), **mevalonate,** a C_6 compound, arises from three molecules of **acetyl CoA**. In the second part (**2**), mevalonate is converted into **isopentenyl diphosphate,** the "active isoprene." In the third part (**3**), six of these C_5 molecules are linked to produce **squalene,** a C_{30} compound. Finally, squalene undergoes cyclization, with three C atoms being removed, to yield cholesterol (**4**). The illustration only shows the most important intermediates in biosynthesis.

(1) Formation of mevalonate. The conversion of acetyl CoA to acetoacetyl CoA and then to *3-hydroxy-3-methylglutaryl CoA* (3-HMG CoA) corresponds to the biosynthetic pathway for *ketone bodies* (details on p. 312). In this case, however, the synthesis occurs not in the mitochondria as in ketone body synthesis, but in the smooth endoplasmic reticulum. In the next step, the 3-HMG group is cleaved from the CoA and at the same time reduced to mevalonate with the help of $NADPH+H^+$. *3-HMG CoA reductase* is the *key enzyme* in cholesterol biosynthesis. It is regulated by *repression* of transcription (effectors: oxysterols such as cholesterol) and by *interconversion* (effectors: hormones). Insulin and thyroxine stimulate the enzyme and glucagon inhibits it by cAMP-dependent phosphorylation. A large supply of cholesterol from food also inhibits 3-HMG-CoA reductase.

(2) Formation of isopentenyl diphosphate. After phosphorylation, mevalonate is decarboxylated to *isopentenyl diphosphate,* with consumption of ATP. This is the component from which all of the isoprenoids are built (see p. 53).

(3) Formation of squalene. Isopentenyl diphosphate undergoes isomerization to form dimethylallyl diphosphate. The two C_5 molecules condense to yield geranyl diphosphate, and the addition of another isopentenyl diphosphate produces farnesyl diphosphate. This can then undergo dimerization, in a *head-to-head reaction,* to yield squalene. Farnesyl diphosphate is also the starting-point for other polyisoprenoids, such as dolichol (see p. 230) and ubiquinone (see p. 52).

(4) Formation of cholesterol. Squalene, a linear isoprenoid, is cyclized, with O_2 being consumed, to form lanosterol, a C_{30} sterol. Three methyl groups are cleaved from this in the subsequent reaction steps, to yield the end product cholesterol. Some of these reactions are catalyzed by *cytochrome P450 systems* (see p. 318).

The endergonic biosynthetic pathway described above is located entirely in the *smooth endoplasmic reticulum.* The energy needed comes from the CoA derivatives used and from ATP. The reducing agent in the formation of mevalonate and squalene, as well as in the final steps of cholesterol biosynthesis, is $NADPH+H^+$.

The division of the intermediates of the reaction pathway into three groups is characteristic: CoA compounds, diphosphates, and highly lipophilic, poorly soluble compounds (squalene to cholesterol), which are bound to *sterol carriers* in the cell.

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A. Cholesterol biosynthesis

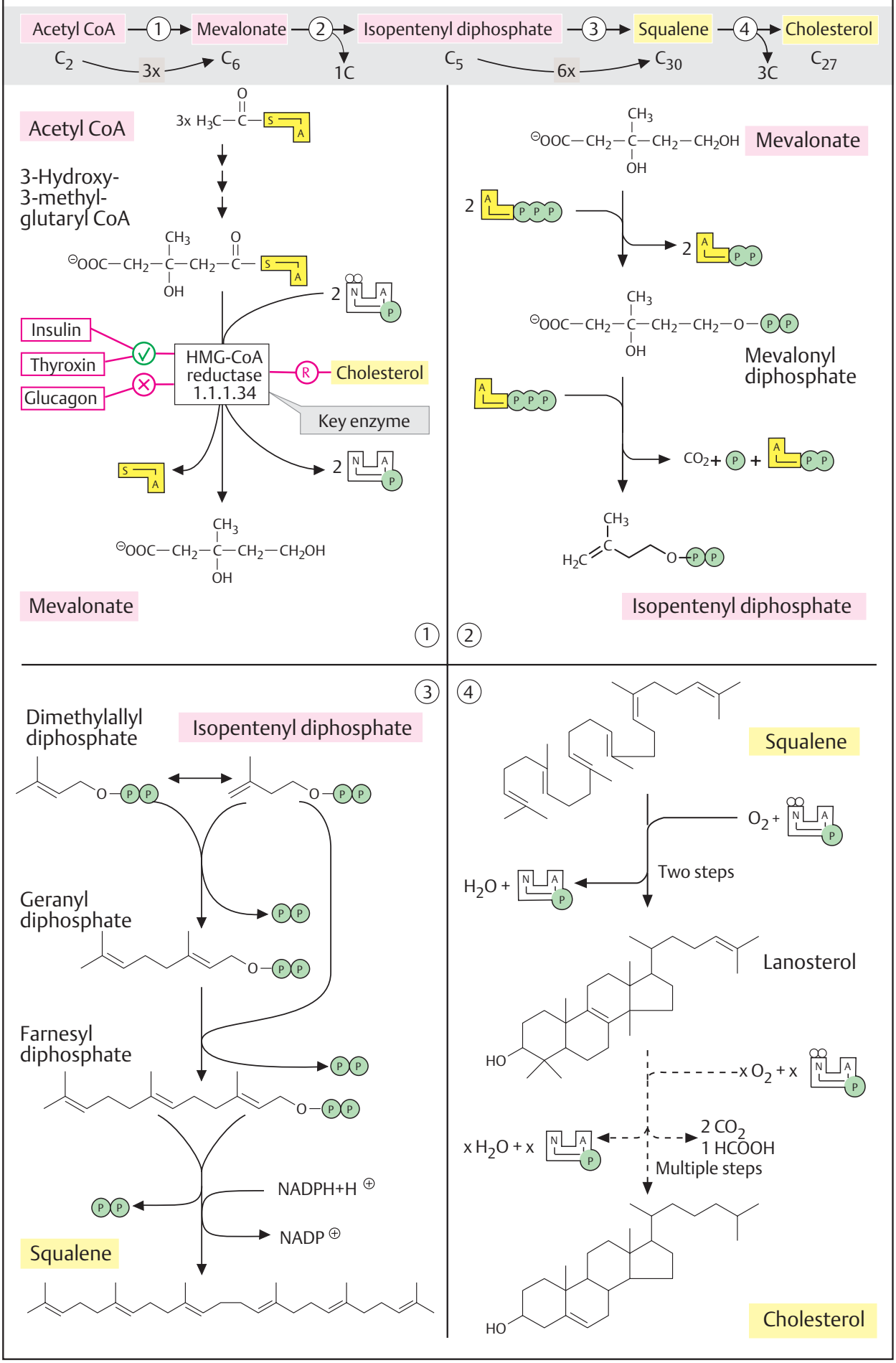

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Protein metabolism: overview

Quantitatively, proteins are the most important group of endogenous macromolecules. A person weighing 70 kg contains about 10 kg protein, with most of it located in muscle. By comparison, the proportion made up by other nitrogencontaining compounds is minor. The organism's nitrogen balance is therefore primarily determined by protein metabolism. Several hormones—mainly *testosterone* and *cortisol*—regulate the nitrogen balance (see p. 374).

A. Protein metabolism: overview ●

In adults, the **nitrogen balance** is generally in *equilibrium*—i. e., the quantities of protein nitrogen taken in and excreted per day are approximately equal. If only some of the nitrogen taken in is excreted again, then the balance is *positive*. This is the case during growth, for example. *Negative* balances are rare and usually occur due to disease.

Proteins taken up in food are initially broken down in the gastrointestinal tract into amino acids, which are resorbed and distributed in the organism via the blood (see p. 266). The human body is not capable of synthesizing 8–10 of the 20 proteinogenic amino acids it requires (see p. 60). These amino acids are **essential**, and have to be supplied from food (see p. 184).

Proteins are constantly being lost via the intestine and, to a lesser extent, via the kidneys. To balance these inevitable losses, at least 30 g of protein have to be taken up with food every day. Although this minimum value is barely reached in some countries, in the industrial nations the protein content of food is usually much higher than necessary. As it is not possible to store amino acids, up to 100 g of excess amino acids per day are used for biosynthesis or degraded in the liver in this situation. The nitrogen from this excess is converted into urea (see p. 182) and excreted in the urine in this form. The carbon skeletons are used to synthesize carbohydrates or lipids (see p. 180), or are used to form ATP.

It is thought that adults break down 300–400 g of protein per day into amino acids (**proteolysis**). On the other hand, approximately the same amount of amino acids is reincorporated into proteins (**protein biosynthesis**). The body's high level of protein turnover is due to the fact that many proteins are relatively *short-lived*. On average, their half-lives amount to 2–8 days. The *key enzymes* of the intermediary metabolism have even shorter half-lives. They are sometimes broken down only a few hours after being synthesized, and are replaced by new molecules. This constant process of synthesis and degradation makes it possible for the cells to quickly adjust the quantities, and therefore the activity, of important enzymes in order to meet current requirements. By contrast, structural proteins such as the histones, hemoglobin, and the components of the cytoskeleton are particularly long-lived.

Almost all cells are capable of carrying out **biosynthesis** of proteins (top left). The formation of peptide chains by **translation** at the ribosome is described in greater detail on pp. 250–253. However, the functional forms of most proteins arise only after a series of additional steps. To begin with, supported by auxiliary proteins, the biologically active conformation of the peptide chain has to be formed (**folding**; see pp. 74, 232). During subsequent "post-translational" **maturation**, many proteins remove part of the peptide chain again and attach additional groups—e. g., oligosaccharides or lipids. These processes take place in the endoplasmic reticulum and in the Golgi apparatus (see p. 232). Finally, the proteins have to be transported to their site of action (**sorting**; see p. 228).

Some *intracellular* protein degradation (**proteolysis**) takes place in the lysosomes (see p. 234). In addition, there are protein complexes in the cytoplasm, known as *proteasomes,* in which incorrectly folded or old proteins are degraded. These molecules are recognized by a special **marking** (see p. 176). The proteasome also plays an important part in the presentation of antigens by immune cells (see p. 296).

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A. Protein metabolism: overview

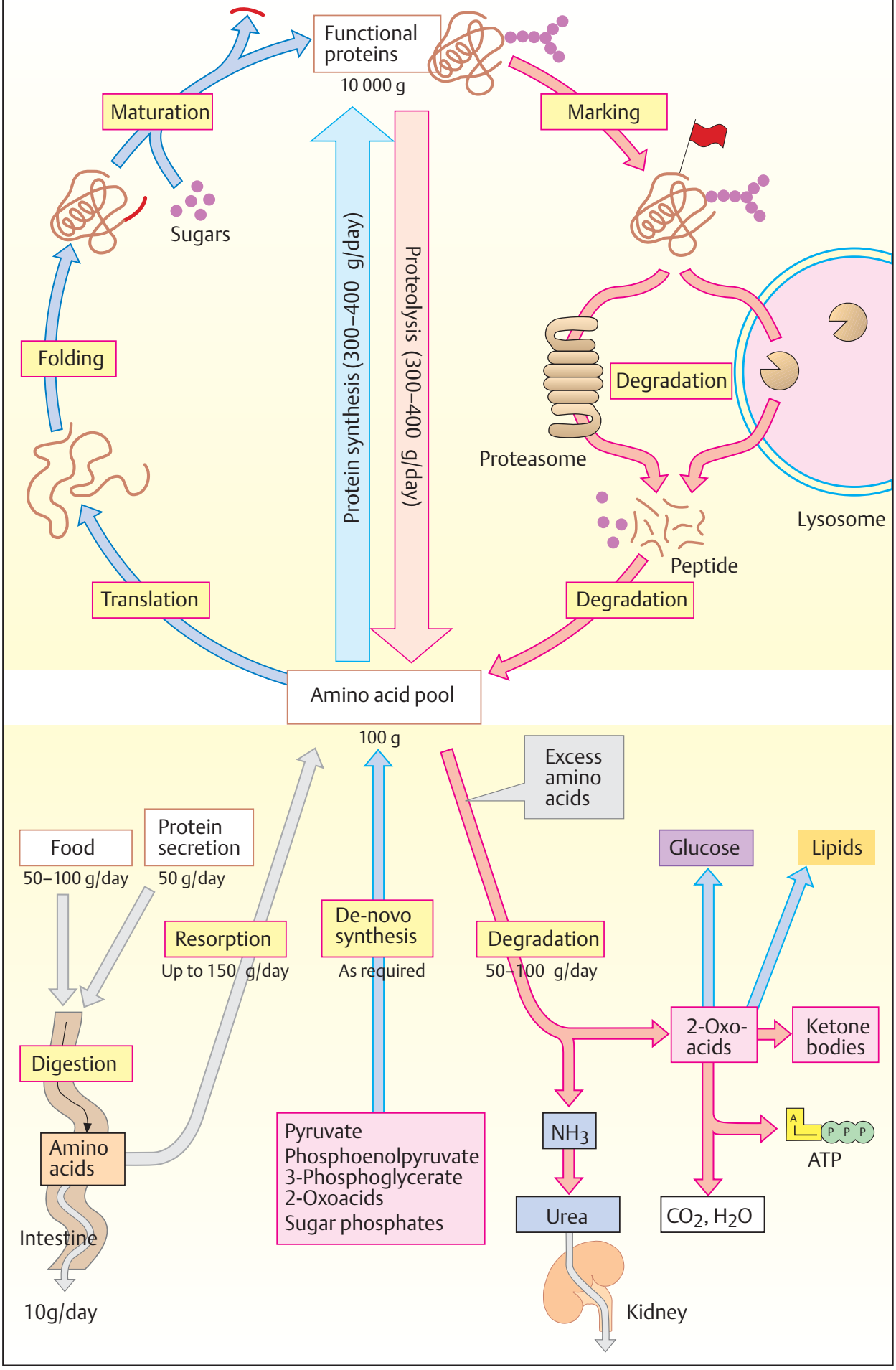

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Proteolysis

A. Proteolytic enzymes ◑

Combinations of several enzymes with different specificities are required for complete degradation of proteins into free amino acids. **Proteinases** and **peptidases** are found not only in the gastrointestinal tract (see p. 268), but also inside the cell (see below).

The proteolytic enzymes are classified into **endopeptidases** and **exopeptidases**, according to their site of attack in the substrate molecule. The *endopeptidases* or *proteinases* cleave peptide bonds *inside* peptide chains. They "recognize" and bind to short sections of the substrate's sequence, and then hydrolyze bonds between particular amino acid residues in a relatively specific way (see p. 94). The **proteinases** are classified according to their reaction mechanism. In *serine proteinases,* for example (see **C**), a serine residue in the enzyme is important for catalysis, while in *cysteine proteinases,* it is a cysteine residue, and so on.

The exopeptidases attack peptides from their termini. Peptidases that act at the N terminus are known as **aminopeptidases**, while those that recognize the C terminus are called **carboxypeptidases**. The **dipeptidases** only hydrolyze dipeptides.

B. Proteasome ○

The functional proteins in the cell have to be protected in order to prevent premature degradation. Some of the intracellularly active proteolytic enzymes are therefore enclosed in lysosomes (see p. 234). The proteinases that act there are also known as **cathepsins**. Another carefully regulated system for protein degradation is located in the cytoplasm. This consists of large protein complexes (mass 2 10^6 Da), the **proteasomes**. Proteasomes contain a barrel-shaped core consisting of 28 subunits that has a sedimentation coef cient (see p. 200) of 20 S. Proteolytic activity (shown here by the scissors) is localized in the interior of the 20-S core and is therefore protected. The openings in the barrel are sealed by 19-S particles with a complex structure that control access to the core.

Proteins destined for degradation in the proteasome (e. g., incorrectly folded or old molecules) are marked by covalent linkage with chains of the small protein **ubiquitin**. The ubiquitin is previously activated by the introduction of reactive thioester groups. Molecules marked with ubiquitin ("ubiquitinated") are recognized by the 19S particle, unfolded using ATP, and then shifted into the interior of the nucleus, where degradation takes place. Ubiquitin is not degraded, but is reused after renewed activation.

C. Serine proteases ○

A large group of proteinases contain serine in their active center. The serine proteases include, for example, the digestive enzymes *trypsin, chymotrypsin,* and *elastase* (see pp. 94 and 268), many *coagulation factors* (see p. 290), and the fibrinolytic enzyme *plasmin* and its *activators* (see p. 292).

As described on p. 270, pancreatic proteinases are secreted as **proenzymes** (zymogens). Activation of these is also based on proteolytic cleavages. This is illustrated here in detail using the example of **trypsinogen**, the precursor of trypsin (**1**). Activation of trypsinogen starts with cleavage of an N-terminal hexapeptide by *enteropeptidase* (enterokinase), a specific serine proteinase that is located in the membrane of the intestinal epithelium. The cleavage product (β-trypsin) is already catalytically active, and it cleaves additional trypsinogen molecules at the sites marked in red in the illustration (autocatalytic cleavage). The precursors of chymotrypsin, elastase, and carboxypeptidase A, among others, are also activated by trypsin.

The active center of trypsin is shown in Fig. **2**. A serine residue in the enzyme (Ser-195), supported by a histidine residue and an aspartate residue (His-57, Asp-102), nucleophilically attacks the bond that is to be cleaved (red arrow). The cleavage site in the substrate peptide is located on the C-terminal side of a lysine residue, the side chain of which is fixed in a special "binding pocket" of the enzyme (left) during catalysis (see p. 94).

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A. Proteolytic enzymes

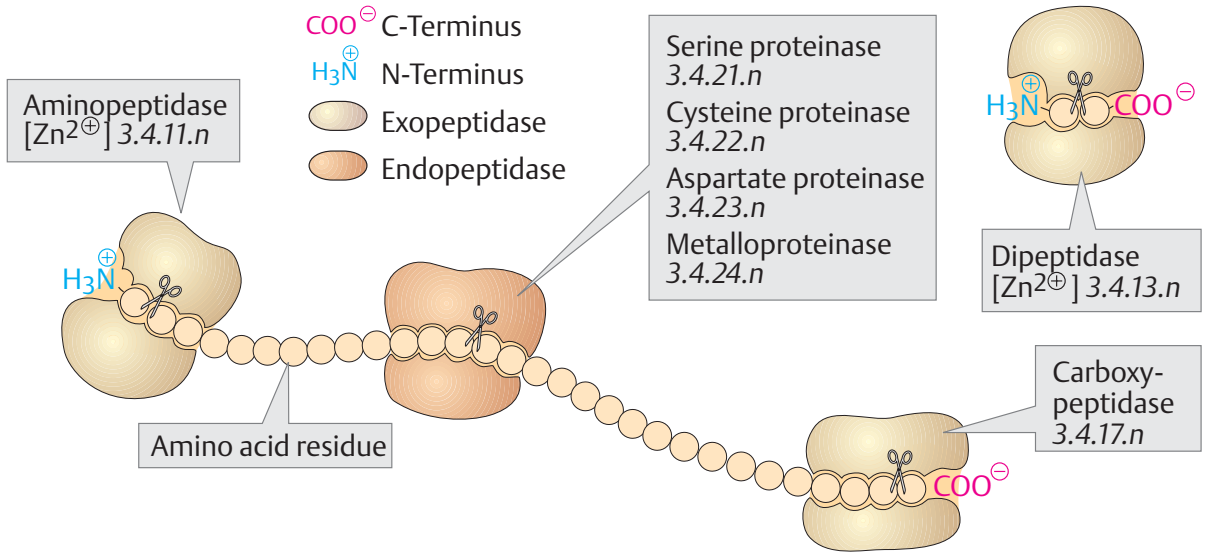

B. Proteasome

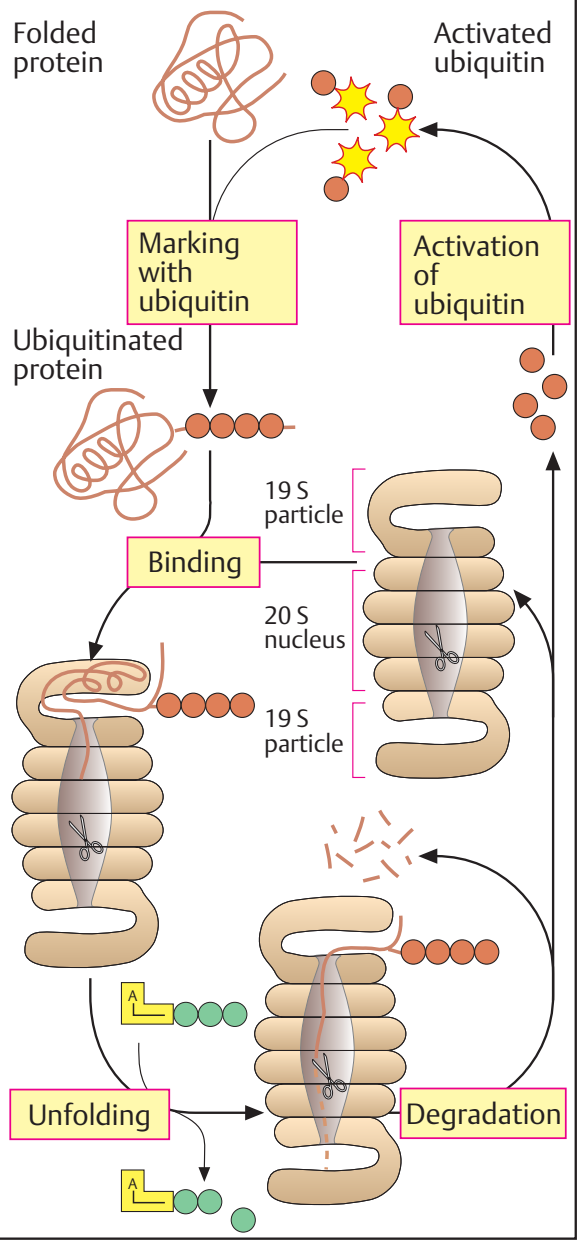

C. Serine proteases

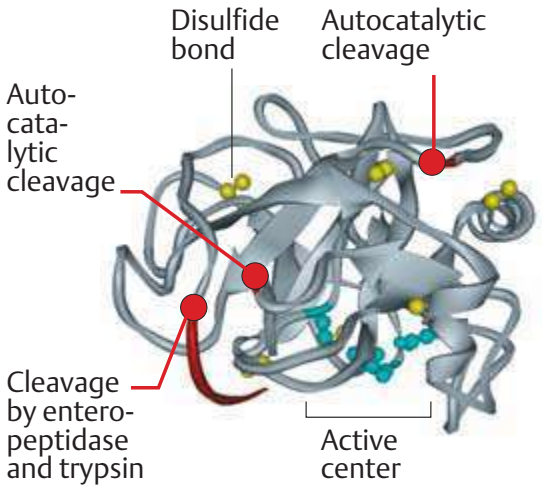

1 Enteropeptidase *3.4.21.9*

2 Trypsin *3.4.21.4*

1. Trypsinogen activation

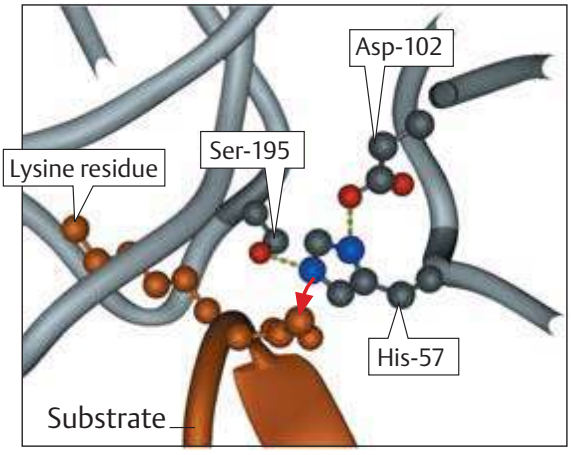

2. Trypsin: active center

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Transamination and deamination

Amino nitrogen accumulates during protein degradation. In contrast to carbon, amino nitrogen is not suitable for oxidative energy production. If they are not being reused for biosynthesis, the amino groups of amino acids are therefore incorporated into urea (see p. 182) and excreted in this form.

A. Transamination and deamination ◑

Among the NH_2 transfer reactions, **transaminations** (**1**) are particularly important. They are catalyzed by *transaminases*, and occur in both catabolic and anabolic amino acid metabolism. During transamination, the amino group of an amino acid (amino acid 1) is transferred to a 2-oxoacid (oxoacid 2). From the amino acid, this produces a 2-oxoacid (a), while from the original oxoacid, an amino acid is formed (b). The NH_2 group is temporarily taken over by enzyme-bound **pyridoxal phosphate** (PLP; see p. 106), which thus becomes pyridoxamine phosphate.

If the NH_2 is released as ammonia, the process is referred to as **deamination**. There are different mechanisms for this (see p. 180). A particularly important one is **oxidative deamination** (**2**). In this reaction, the α-amino group is initially *oxidized* into an imino group (2a), and the reducing equivalents are transferred to NAD^+ or $NADP^+$. In the second step, the imino group is then cleaved by *hydrolysis*. As in transamination, this produces a 2-oxoacid (**C**). Oxidative deamination mainly takes place in the liver, where glutamate is broken down in this way into 2-oxoglutarate and ammonia, catalyzed by *glutamate dehydrogenase.* The reverse reaction initiates biosynthesis of the amino acids in the glutamate family (see p. 184).

B. Mechanism of transamination ○

In the absence of substrates, the aldehyde group of pyridoxal phosphate is covalently bound to a lysine residue of the transaminase (**1**). This type of compound is known as an **aldimine** or "Schiff's base." During the reaction, amino acid 1 (**A**, **1a**) displaces the lysine residue, and a new aldimine is formed (**2**). The double bond is then shifted by isomerization. The ketimine (**3**) is hydrolyzed to yield the 2-oxoacid and **pyridoxamine phosphate** (**4**).

In the second part of the reaction (see **A**, 1b), these steps take place *in the opposite direction:* pyridoxamine phosphate and the second 2-oxoacid form a ketimine, which is isomerized into aldimine. Finally, the second amino acid is cleaved and the coenzyme is regenerated.

C. NH_3 metabolism in the liver ◑

In addition to urea synthesis itself (see p. 182), the precursors NH_3 and aspartate are also mainly formed in the liver. Amino nitrogen arising in tissue is transported to the liver by the blood, mainly in the form of **glutamine** (Gln) and **alanine** (Ala; see p. 338). In the liver, Gln is hydrolytically deaminated by *glutaminase* [3] into **glutamate** (Glu) and NH_3. The amino group of the alanine is transferred by *alanine transaminase* [1] to **2-oxoglutarate** (2-OG; formerly known as α-ketoglutarate). This transamination (**A**) produces another glutamate. NH_3 is finally released from glutamate by oxidative deamination (**A**). This reaction is catalyzed by *glutamate dehydrogenase* [4], a typical liver enzyme. **Aspartate** (Asp), the second amino group donor in the urea cycle, also arises from glutamate. The *aspartate transaminase* [2] responsible for this reaction is found with a high level of activity in the liver, as is *alanine transaminase* [1].

Transaminases are also found in other tissues, from which they leak from the cells into the blood when injury occurs. Measurement of serum enzyme activity (**serum enzyme diagnosis**; see also p. 98) is an important method of recognizing and monitoring the course of such injuries. Transaminase activity in the blood is for instance important for diagnosing liver disease (e.g., hepatitis) and myocardial disease (cardiac infarction).

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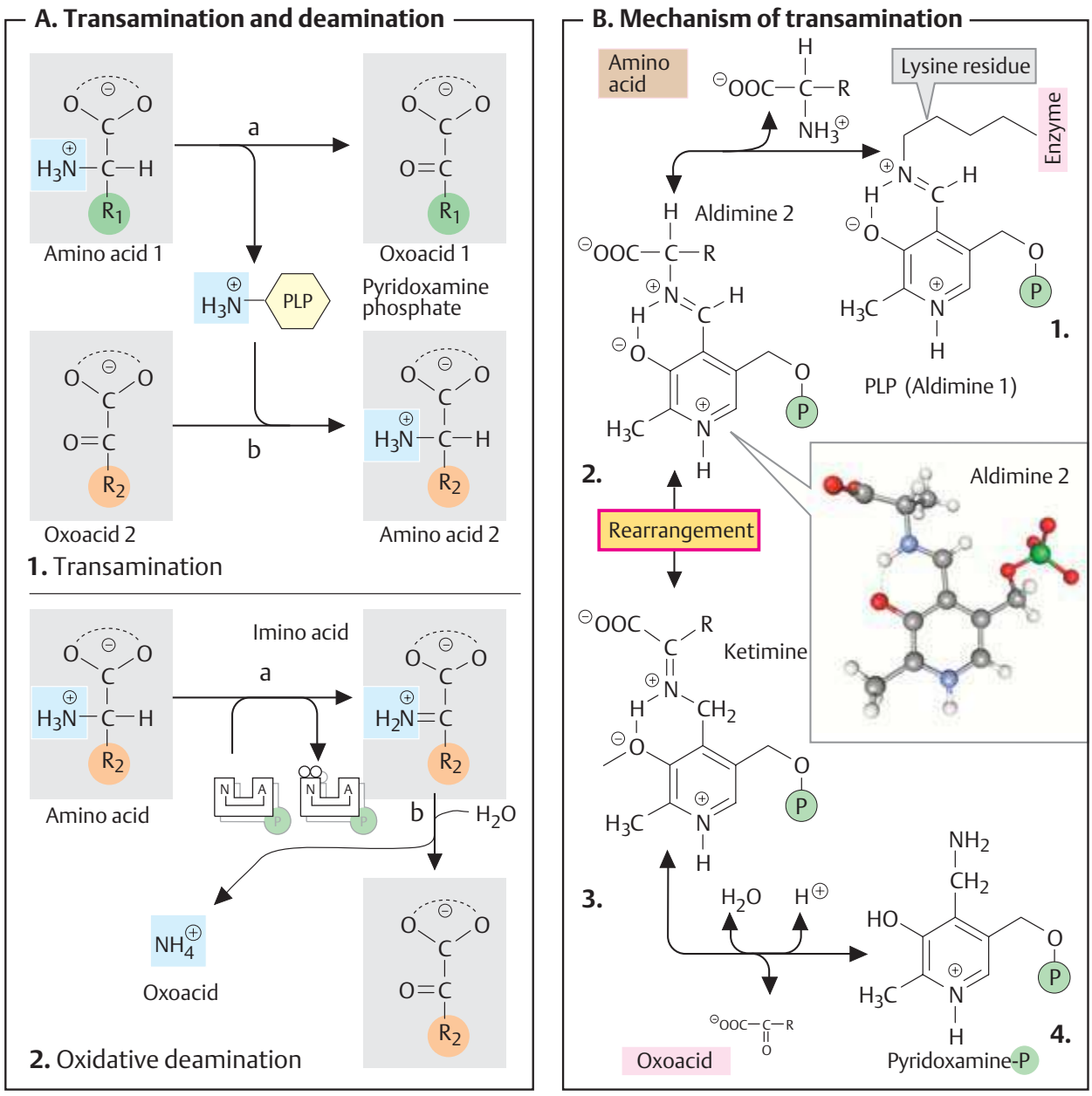

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Amino acid degradation

A large number of metabolic pathways are available for amino acid degradation, and an overview of these is presented here. Further details are given on pp. 414 and 415.

A. Amino acid degradation : overview ◑

During the degradation of most amino acids, the α-amino group is initially removed by **transamination** or **deamination**. Various mechanisms are available for this, and these are discussed in greater detail in **B**. The carbon skeletons that are left over after deamination undergo further degradation in various ways.

During degradation, the 20 proteinogenic amino acids produce only seven different **degradation products** (highlighted in pink and violet). Five of these metabolites (2-oxoglutarate, succinyl CoA, fumarate, oxaloacetate, and pyruvate) are precursors for gluconeogenesis and can therefore be converted into glucose by the liver and kidneys (see p. 154). Amino acids whose degradation supplies one of these five metabolites are therefore referred to as **glucogenic amino acids**. The first four degradation products listed are already intermediates in the tricarboxylic acid cycle, while pyruvate can be converted into oxaloacetate by *pyruvate carboxylase* and thus made available for gluconeogenesis (green arrow).

With two exceptions (lysine and leucine; see below), all of the proteinogenic amino acids are also glucogenic. Quantitatively, they represent the most important precursors for gluconeogenesis. At the same time, they also have an **anaplerotic** effect—i. e., they replenish the tricarboxylic acid cycle in order to feed the anabolic reactions that originate in it (see p. 138).

Two additional degradation products (acetoacetate and acetyl CoA) cannot be channeled into gluconeogenesis in animal metabolism, as there is no means of converting them into precursors of gluconeogenesis. However, they can be used to synthesize ketone bodies, fatty acids, and isoprenoids. Amino acids that supply acetyl CoA or acetoacetate are therefore known as **ketogenic amino acids.** Only leucine and lysine are *purely* ketogenic. Several amino acids yield degradation products that are both *glucogenic and ketogenic*. This group includes phenylalanine, tyrosine, tryptophan, and isoleucine.

Degradation of acetoacetate to acetyl CoA takes place in two steps (not shown). First, acetoacetate and succinyl CoA are converted into acetoacetyl CoA and succinate (enzyme: *3-oxoacid-CoA transferase 2.8.3.5*). Acetoacetyl CoA is then broken down by β-oxidation into two molecules of acetyl CoA (see p. 164), while succinate can be further metabolized via the tricarboxylic acid cycle.

B. Deamination ○

There are various ways of releasing ammonia (NH_3) from amino acids, and these are illustrated here using the example of the amino acids glutamine, glutamate, alanine, and serine.

[1] In the branched-chain amino acids (Val, Leu, Ile) and also tyrosine and ornithine, degradation starts with a **transamination**. For alanine and aspartate, this is actually the only degradation step. The mechanism of transamination is discussed in detail on p. 178.

[2] **Oxidative deamination**, with the formation of $NADH+H^+$, only applies to glutamate in animal metabolism. The reaction mainly takes place in the liver and releases NH_3 for urea formation (see p. 178).

[3] Two amino acids—asparagine and glutamine—contain acid–amide groups in the side chains, from which NH_3 can be released by hydrolysis (**hydrolytic deamination**). In the blood, glutamine is the most important transport molecule for amino nitrogen. Hydrolytic deamination of glutamine in the liver also supplies the urea cycle with NH_3.

[4] **Eliminating deamination** takes place in the degradation of histidine and serine. H_2O is first eliminated here, yielding an unsaturated intermediate. In the case of serine, this intermediate is first rearranged into an imine (not shown), which is hydrolyzed in the second step into NH_3 and pyruvate, with H_2O being taken up. H_2O does not therefore appear in the reaction equation.

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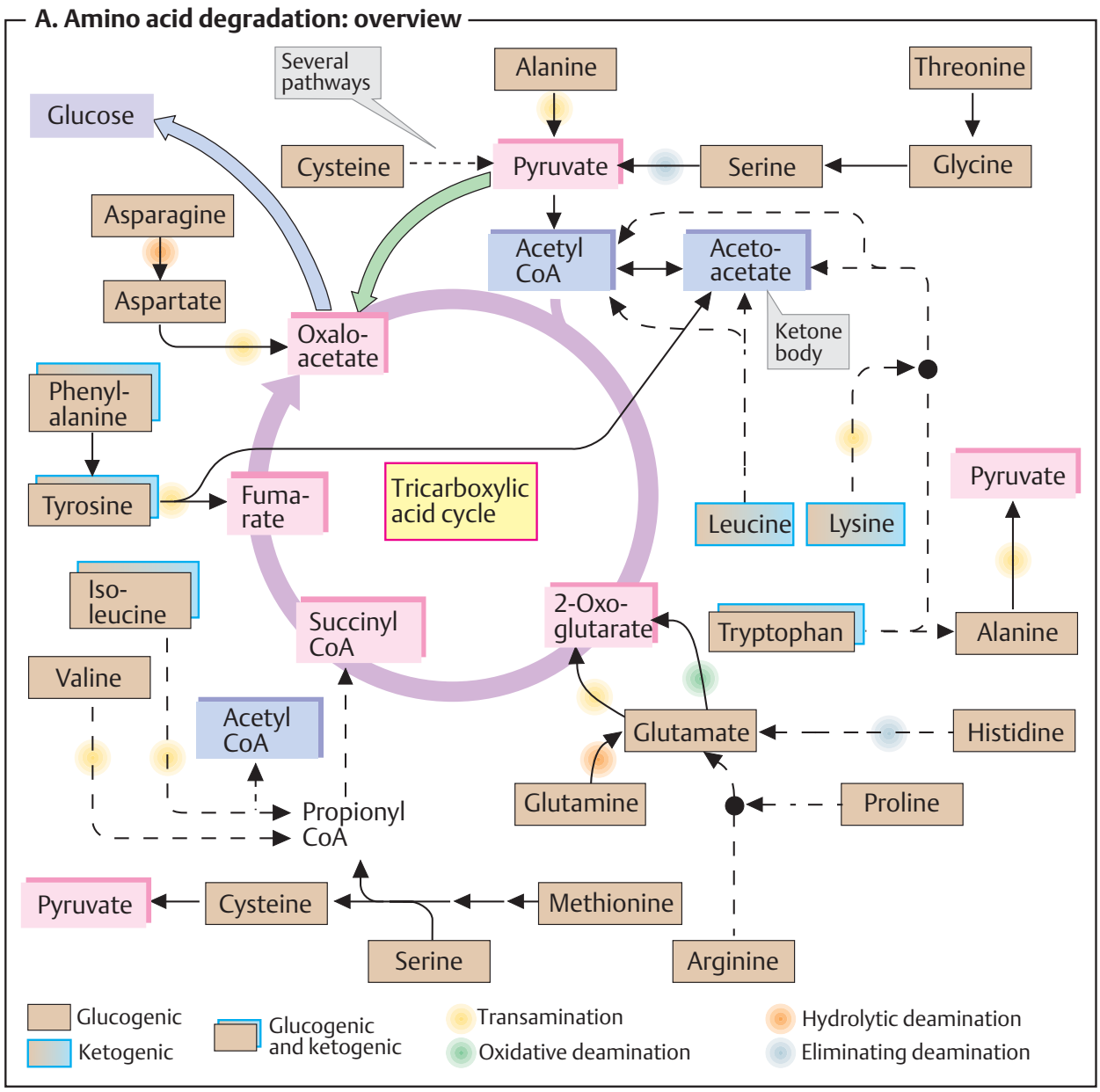

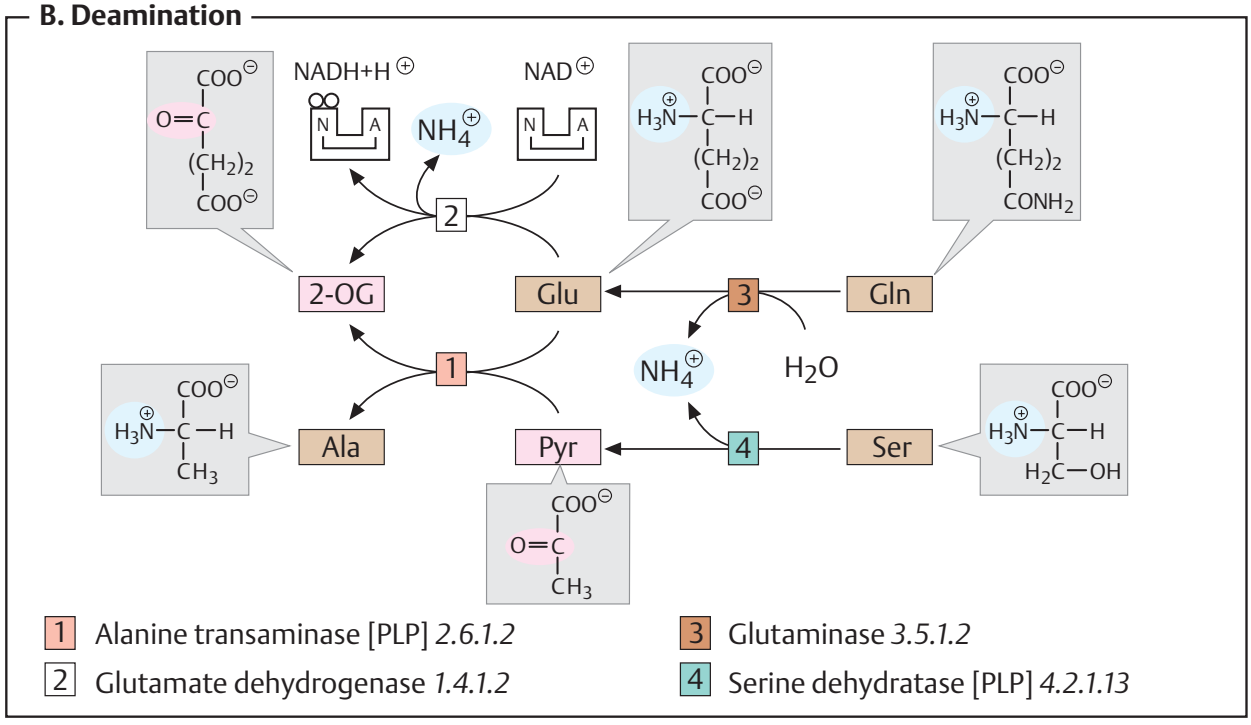

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Urea cycle

Amino acids are mainly broken down in the liver. Ammonia is released either directly or indirectly in the process (see p. 178). The degradation of nucleobases also provides significant amounts of ammonia (see p. 186).

Ammonia (NH_3) is a relatively strong **base**, and at physiological pH values it is mainly present in the form of the **ammonium ion** $\mathbf{NH_4^+}$ (see p. 30). NH_3 and NH_4^+ are toxic, and at higher concentrations cause brain damage in particular. Ammonia therefore has to be effectively inactivated and excreted. This can be carried out in various ways. Aquatic animals can excrete NH_4^+ directly. For example, fish excrete NH_4^+ via the gills (*ammonotelic animals*). Terrestrial vertebrates, including humans, hardly excrete any NH_3, and instead, most ammonia is converted into urea before excretion (*ureotelic animals*). Birds and reptiles, by contrast, form *uric acid,* which is mainly excreted as a solid in order to save water (*uricotelic animals*).

The reasons for the neurotoxic effects of ammonia have not yet been explained. It may disturb the metabolism of glutamate and its precursor glutamine in the brain (see p. 356).

A. Urea cycle ◑

Urea ($H_2N–CO–NH_2$) is the diamide of carbonic acid. In contrast to ammonia, it is **neutral** and therefore relatively **non-toxic**. The reason for the lack of basicity is the molecule's mesomeric characteristics. The free electron pairs of the two nitrogen atoms are *delocalized* over the whole structure, and are therefore no longer able to bind protons. As a small, uncharged molecule, urea is able to cross biological membranes easily. In addition, it is easily transported in the blood and excreted in the urine.

Urea is produced **only in the liver**, in a cyclic sequence of reactions (the **urea cycle**) that starts in the mitochondria and continues in the cytoplasm. The two nitrogen atoms are derived from $\mathbf{NH_4^+}$ (the second has previously been incorporated into aspartate; see below). The keto group comes from **hydrogen carbonate** (HCO_3^-), or CO_2 that is in equilibrium with HCO_3^-.

[1] In the first step, **carbamoyl phosphate** is formed in the mitochondria from hydrogen carbonate (HCO_3^-) and NH_4^+, with two ATP molecules being consumed. In this compound, the carbamoyl residue ($–O–CO–NH_2$) is at a high chemical potential. In hepatic mitochondria, enzyme [1] makes up about 20% of the matrix proteins.

[2] In the next step, the carbamoyl residue is transferred to the non-proteinogenic amino acid **ornithine**, converting it into **citrulline**, which is also non-proteinogenic. This is passed into the cytoplasm via a transporter.

[3] The second NH_2 group of the later urea molecule is provided by **aspartate**, which condenses with citrulline into **argininosuccinate**. ATP is cleaved into AMP and diphosphate (PP_i) for this endergonic reaction. To shift the equilibrium of the reaction to the side of the product, diphosphate is removed from the equilibrium by hydrolysis.

[4] Cleavage of fumarate from argininosuccinate leads to the proteinogenic amino acid **arginine**, which is synthesized in this way in animal metabolism.

[5] In the final step, isourea is released from the guanidinium group of the arginine by hydrolysis (not shown), and is immediately rearranged into **urea**. In addition, ornithine is regenerated and returns via the ornithine transporter into the mitochondria, where it becomes available for the cycle once again.

The **fumarate** produced in step [4] is converted via malate to oxaloacetate [6, 7], from which **aspartate** is formed again by transamination [9]. The glutamate required for reaction [9] is derived from the glutamate dehydrogenase reaction [8], which fixes the second NH_4^+ in an organic bond. Reactions [6] and [7] also occur in the tricarboxylic acid cycle. However, in urea formation they take place in the cytoplasm, where the appropriate isoenzymes are available.

The rate of urea formation is mainly controlled by reaction [1]. *N*-**acetyl glutamate**, as an allosteric effector, activates *carbamoylphosphate synthase.* In turn, the concentration of acetyl glutamate depends on arginine and ATP levels, as well as other factors.

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A. Urea cycle

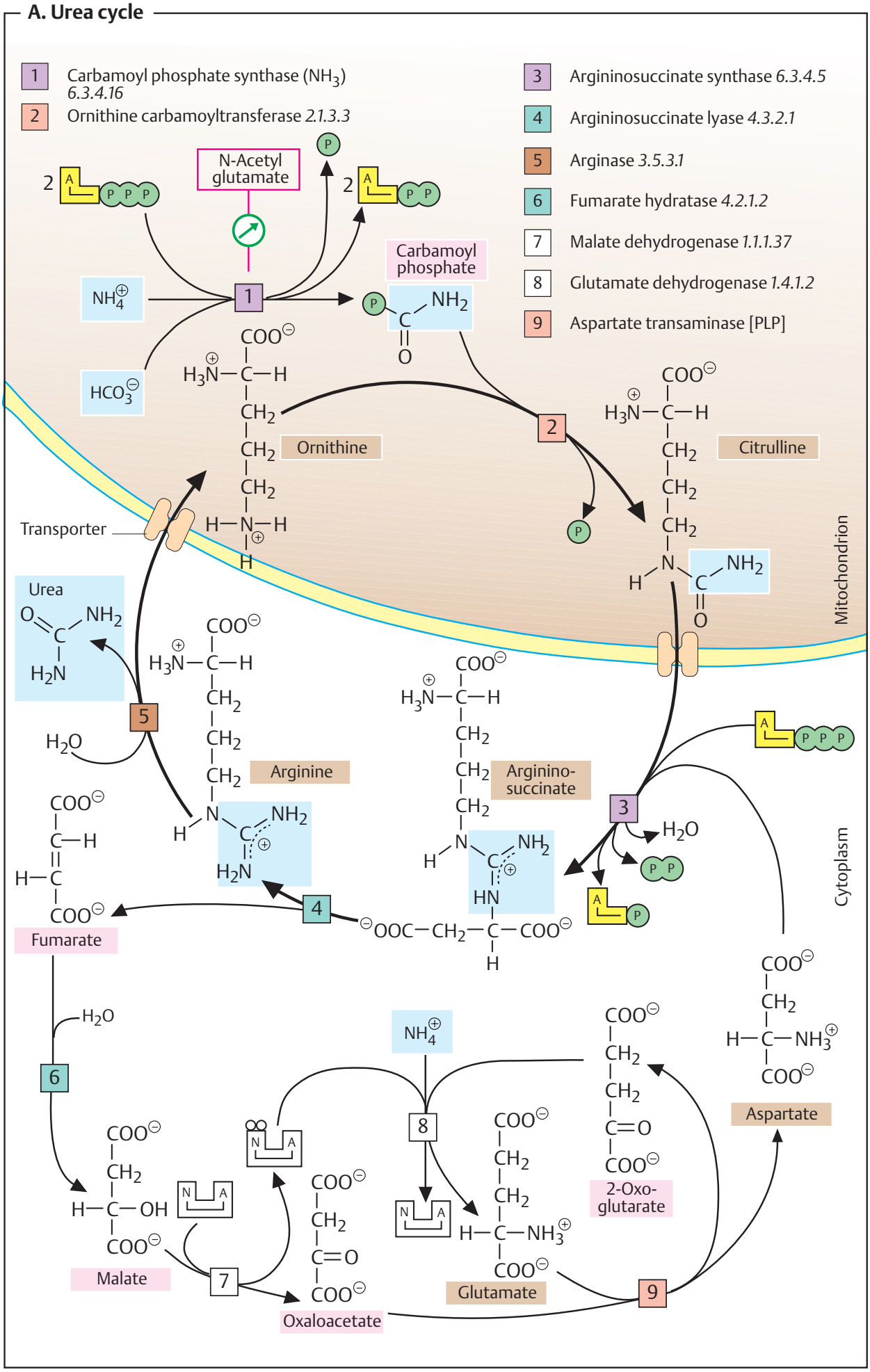

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Amino acid biosynthesis

A. Symbiotic nitrogen fixation ○

Practically unlimited quantities of elementary nitrogen (N_2) are present in the atmosphere. However, before it can enter the natural nitrogen cycle, it has to be reduced to NH_3 and incorporated into amino acids ("fixed"). Only a few species of bacteria and bluegreen algae are capable of fixing atmospheric nitrogen. These exist freely in the soil, or in **symbiosis** with plants. The symbiosis between bacteria of the genus *Rhizobium* and legumes (*Fabales*)—such as clover, beans, and peas—is of particular economic importance. These plants are high in protein and are therefore nutritionally valuable.

In symbiosis with *Fabales*, bacteria live as *bacteroids* in **root nodules** inside the plant cells. The plant supplies the bacteroids with nutrients, but it also benefits from the fixed nitrogen that the symbionts make available.

The N_2-fixing enzyme used by the bacteria is *nitrogenase*. It consists of two components: an *Fe protein* that contains an $[Fe_4S_4]$ cluster as a redox system (see p. 106), accepts electrons from *ferredoxin*, and donates them to the second component, the *Fe–Mo protein*. This molybdenum-containing protein transfers the electrons to N_2 and thus, via various intermediate steps, produces ammonia (NH_3). Some of the reducing equivalents are transferred in a side-reaction to H^+. In addition to NH_3, hydrogen is therefore always produced as well.

B. Amino acid biosynthesis: overview ◑

The proteinogenic amino acids (see p. 60) can be divided into **five families** in relation to their biosynthesis. The members of each family are derived from common precursors, which are all produced in the tricarboxylic acid cycle or in catabolic carbohydrate metabolism. An overview of the biosynthetic pathways is shown here; further details are given on pp. 412 and 413.

Plants and microorganisms are able to synthesize all of the amino acids from scratch, but during the course of evolution, mammals have lost the ability to synthesize approximately half of the 20 proteinogenic amino acids. These **essential amino acids** therefore have to be supplied in food. For example, animal metabolism is no longer capable of carrying out de-novo synthesis of the **aromatic amino acids** (tyrosine is only non-essential because it can be formed from phenylalanine when there is an adequate supply available). The **branched-chain amino acids** (valine, leucine, isoleucine, and threonine) as well as **methionine** and **lysine**, also belong to the essential amino acids. Histidine and arginine are essential in rats; whether the same applies in humans is still a matter of debate. A supply of these amino acids in food appears to be essential at least during growth.

The nutritional value of proteins (see p. 360) is decisively dependent on their essential amino acid content. Vegetable proteins—e.g., those from cereals—are low in lysine and methionine, while animal proteins contain all the amino acids in balanced proportions. As mentioned earlier, however, there are also plants that provide high-value protein. These include the soy bean, one of the plants that is supplied with NH_3 by symbiotic N_2 fixers (**A**).

Non-essential amino acids are those that arise by transamination from 2-oxoacids in the intermediary metabolism. These belong to the **glutamate family** (Glu, Gln, Pro, Arg, derived from 2-oxoglutarate), the **aspartate family** (only Asp and Asn in this group, derived from oxaloacetate), and **alanine**, which can be formed by transamination from pyruvate. The amino acids in the **serine family** (Ser, Gly, Cys) and **histidine**, which arise from intermediates of glycolysis, can also be synthesized by the human body.

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A. Symbiotic nitrogen fixation

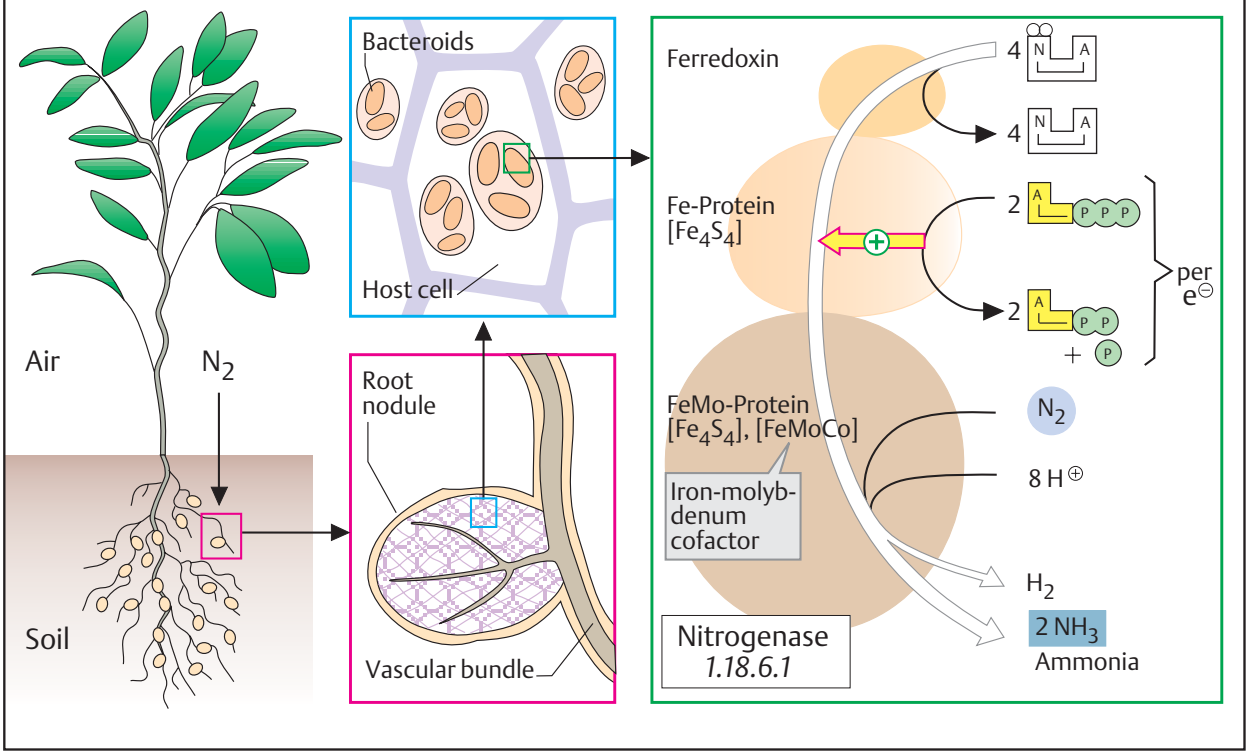

B. Amino acid biosynthesis: overview

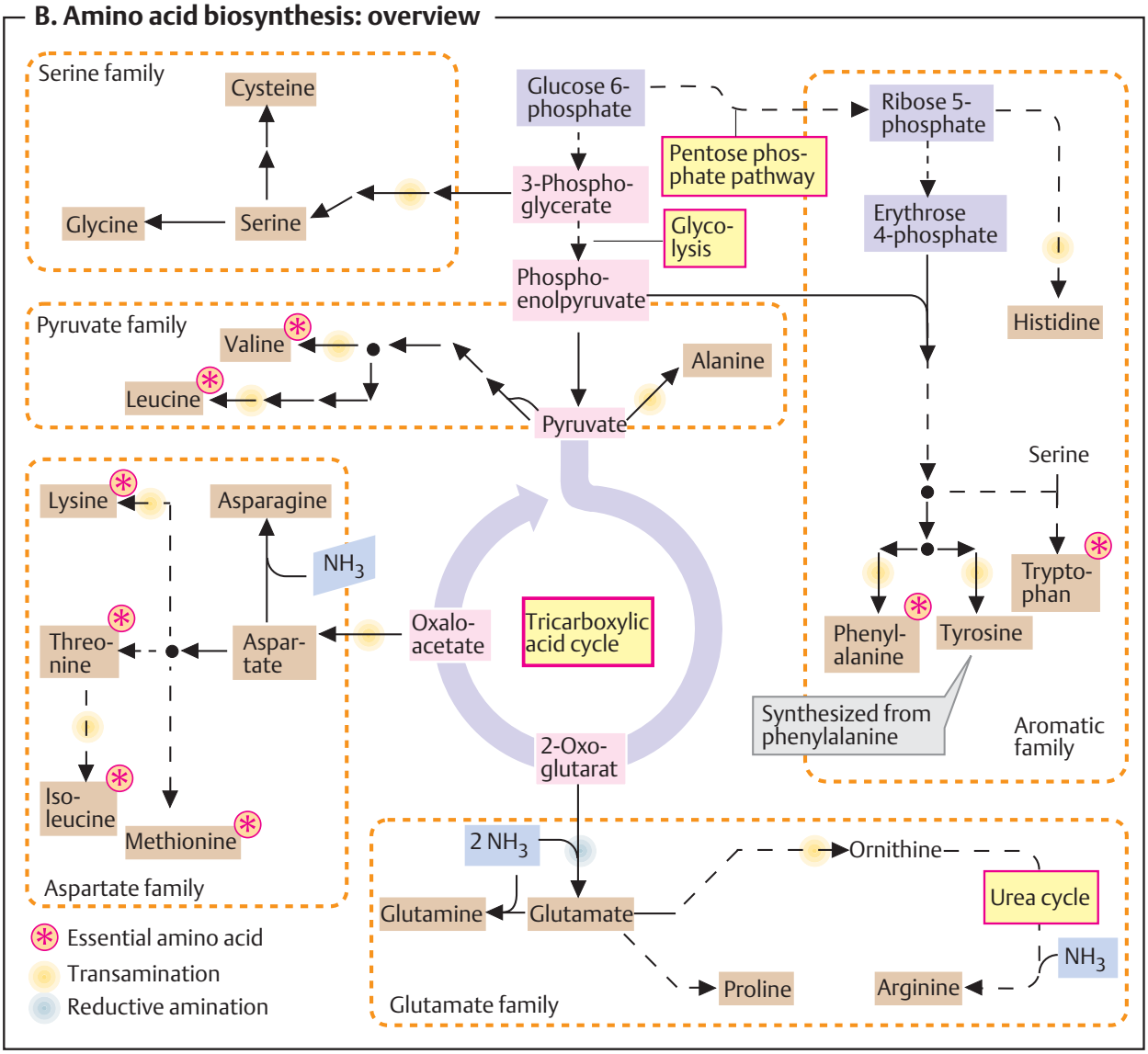

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Nucleotide degradation

The nucleotides are among the most complex metabolites. Nucleotide biosynthesis is elaborate and requires a high energy input (see p. 188). Understandably, therefore, bases and nucleotides are not completely degraded, but instead mostly recycled. This is particularly true of the purine bases adenine and guanine. In the animal organism, some 90% of these bases are converted back into nucleoside monophosphates by linkage with phosphoribosyl diphosphate (PRPP) (enzymes [1] and [2]). The proportion of pyrimidine bases that are recycled is much smaller.

A. Degradation of nucleotides ◑

The principles underlying the degradation of purines (**1**) and pyrimidines (**2**) differ. In the human organism, purines are degraded into uric acid and excreted in this form. The purine ring remains intact in this process. In contrast, the ring of the pyrimidine bases (uracil, thymine, and cytosine) is broken down into small fragments, which can be returned to the metabolism or excreted (for further details, see p. 419).

Purine (left). The purine nucleotide **guanosine monophosphate** (**GMP**, **1**) is degraded in two steps—first to the *guanosine* and then to *guanine* (Gua). Guanine is converted by deamination into another purine base, *xanthine*.

In the most important degradative pathway for **adenosine monophosphate** (**AMP**), it is the nucleotide that deaminated, and *inosine monophosphate* (IMP) arises. In the same way as in GMP, the purine base *hypoxanthine* is released from IMP. A single enzyme, *xanthine oxidase* [3], then both converts hypoxanthine into xanthine and xanthine into **uric acid**. An oxo group is introduced into the substrate in each of these reaction steps. The oxo group is derived from *molecular oxygen;* another reaction product is *hydrogen peroxide* (H_2O_2), which is toxic and has to be removed by peroxidases.

Almost all mammals carry out further degradation of uric acid with the help of *uricase*, with further opening of the ring to **allantoin**, which is then excreted. However, the primates, including humans, are not capable of synthesizing allantoin. *Uric acid* is therefore the form of the purines excreted in these species. The same applies to birds and many reptiles. Most other animals continue purine degradation to reach allantoic acid or urea and glyoxylate.

Pyrimidine (right). In the degradation of pyrimidine nucleotides (**2**), the free bases *uracil* (Ura) and *thymine* (Thy) are initially released as important intermediates. Both are further metabolized in similar ways. The pyrimidine ring is first reduced and then hydrolytically cleaved. In the next step, *β-alanine* arises by cleavage of CO_2 and NH_3 as the degradation product of uracil. When there is further degradation, *β-alanine* is broken down to yield acetate, CO_2, and NH_3. Propionate, CO_2, and NH_3 arise in a similar way from *γ-aminoisobutyrate,* the degradation product of thymine (see p. 419).

B. Hyperuricemia ○

The fact that purine degradation in humans already stops at the uric acid stage can lead to problems, since—in contrast to allantoin—uric acid is *poorly soluble in water*. When large amounts of uric acid are formed or uric acid processing is disturbed, excessive concentrations of uric acid can develop in the blood (*hyperuricemia*). This can result in the accumulation of uric acid crystals in the body. Deposition of these crystals in the joints can cause very painful attacks of **gout.**

Most cases of hyperuricemia are due to disturbed uric acid excretion via the kidneys (1). A high-purine diet (e.g., meat) may also have unfavorable effects (2). A rare hereditary disease, *Lesch–Nyhan syndrome,* results from a defect in *hypoxanthine phosphoribosyltransferase* (A, enzyme [1]). The impaired recycling of the purine bases caused by this leads to hyperuricemia and severe neurological disorders.

Hyperuricemia can be treated with *allopurinol,* a competitive inhibitor of xanthine oxidase. This substrate analogue differs from the substrate hypoxanthine only in the arrangement of the atoms in the 5-ring.

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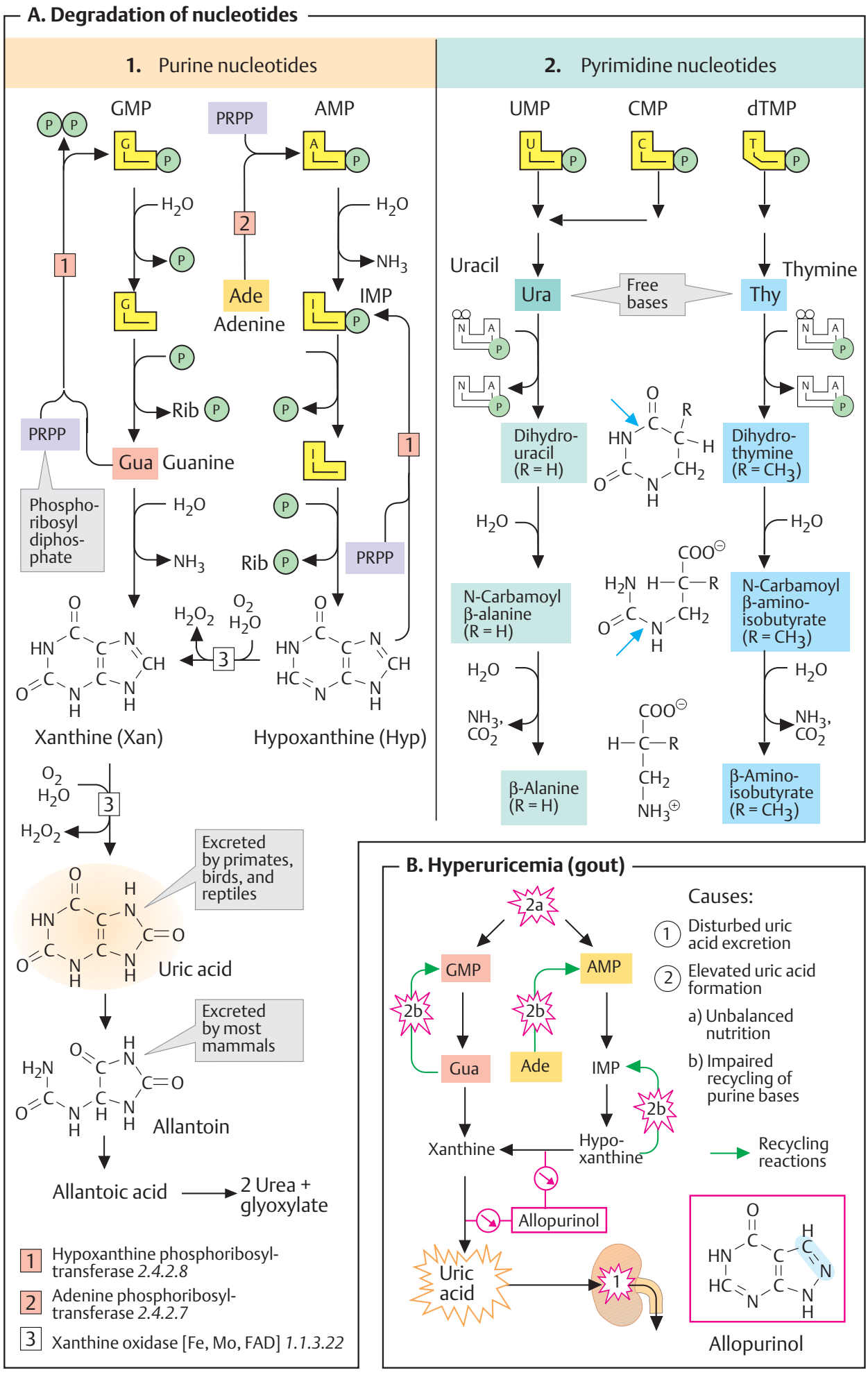

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Purine and pyrimidine biosynthesis

The bases occurring in nucleic acids are derivatives of the aromatic heterocyclic compounds *purine* and *pyrimidine* (see p. 80). The biosynthesis of these molecules is complex, but is vital for almost all cells. The synthesis of the nucleobases is illustrated here schematically. Complete reaction schemes are given on pp. 417 and 418.

A. Components of nucleobases ○

The **pyrimidine ring** is made up of three components: the nitrogen atom N-1 and carbons C-4 to C-6 are derived from *aspartate,* carbon C-2 comes from HCO_3^-, and the second nitrogen (N-3) is taken from the amide group of *glutamine*.

The synthesis of the **purine ring** is more complex. The only major component is *glycine*, which donates C-4 and C-5, as well as N-7. All of the other atoms in the ring are incorporated individually. C-6 comes from HCO_3^-. Amide groups from *glutamine* provide the atoms N-3 and N-9. The amino group donor for the inclusion of N-1 is *aspartate,* which is converted into fumarate in the process, in the same way as in the urea cycle (see p. 182). Finally, the carbon atoms C-2 and C-8 are derived from formyl groups in N^{10}-formyl-tetrahydrofolate (see p. 108).

B. Pyrimidine and purine synthesis ○

The major intermediates in the biosynthesis of nucleic acid components are the mononucleotides *uridine monophosphate* (UMP) in the pyrimidine series and *inosine monophosphate* (IMP, base: hypoxanthine) in the purines. The synthetic pathways for pyrimidines and purines are fundamentally different. For the pyrimidines, the pyrimidine ring is first constructed and then linked to ribose 5′-phosphate to form a nucleotide. By contrast, synthesis of the purines starts directly from ribose 5′-phosphate. The ring is then built up step by step on this carrier molecule.

The precursors for the synthesis of the pyrimidine ring are **carbamoyl phosphate**, which arises from glutamate and HCO_3^- (**1a**) and the amino acid **aspartate.** These two components are linked to *N*-**carbamoyl aspartate** (**1b**) and then converted into **dihydroorotate** by closure of the ring (**1c**). In mammals, steps 1a to 1c take place in the cytoplasm, and are catalyzed by a single multifunctional enzyme. In the next step (**1d**), dihydroorotate is oxidized to **orotate** by an FMN-dependent dehydrogenase. Orotate is then linked with **phosphoribosyl diphosphate** (PRPP) to form the nucleotide **orotidine 5′-monophosphate (OMP)**. Finally, decarboxylation yields **uridine 5′-monophosphate (UMP)**.

Purine biosynthesis starts with PRPP (the names of the individual intermediates are given on p. 417). Formation of the ring starts with transfer of an amino group, from which the later N-9 is derived (**2a**). Glycine and a formyl group from N^{10}-formyl-THF then supply the remaining atoms of the five-membered ring (**2b**, **2c**). Before the five-membered ring is closed (in step **2f**), atoms N-3 and C-6 of the later six-membered ring are attached (**2d**, **2e**). Synthesis of the ring then continues with N-1 and C-2 (**2g**, **2i**). In the final step (**2j**), the six-membered ring is closed, and **inosine 5′-monophosphate** arises. However, the IMP formed does not accumulate, but is rapidly converted into AMP and GMP. These reactions and the synthesis of the other nucleotides are discussed on p. 190.

Further information

The regulation of bacterial *aspartate carbamoyltransferase* by ATP and CTP has been particularly well studied, and is discussed on p. 116. In animals, in contrast to prokaryotes, it is not ACTase but *carbamoylphosphate synthase* that is the key enzyme in pyrimidine synthesis. It is activated by ATP and PRPP and inhibited by UTP.

The biosynthesis of the purines is also regulated by *feedback inhibition.* ADP and GDP inhibit the formation of PRRPP from ribose-5′-phosphate. Similarly, step **2a** is inhibited by AMP and GMP.

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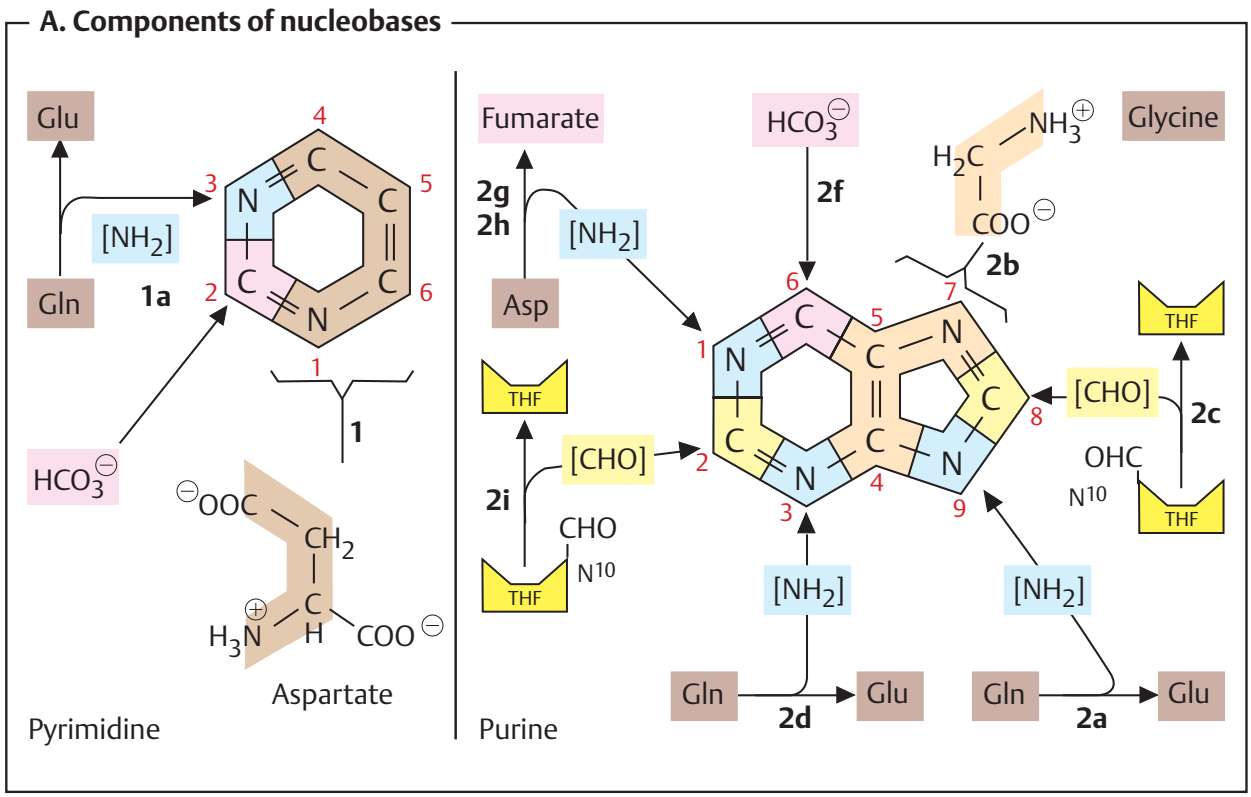

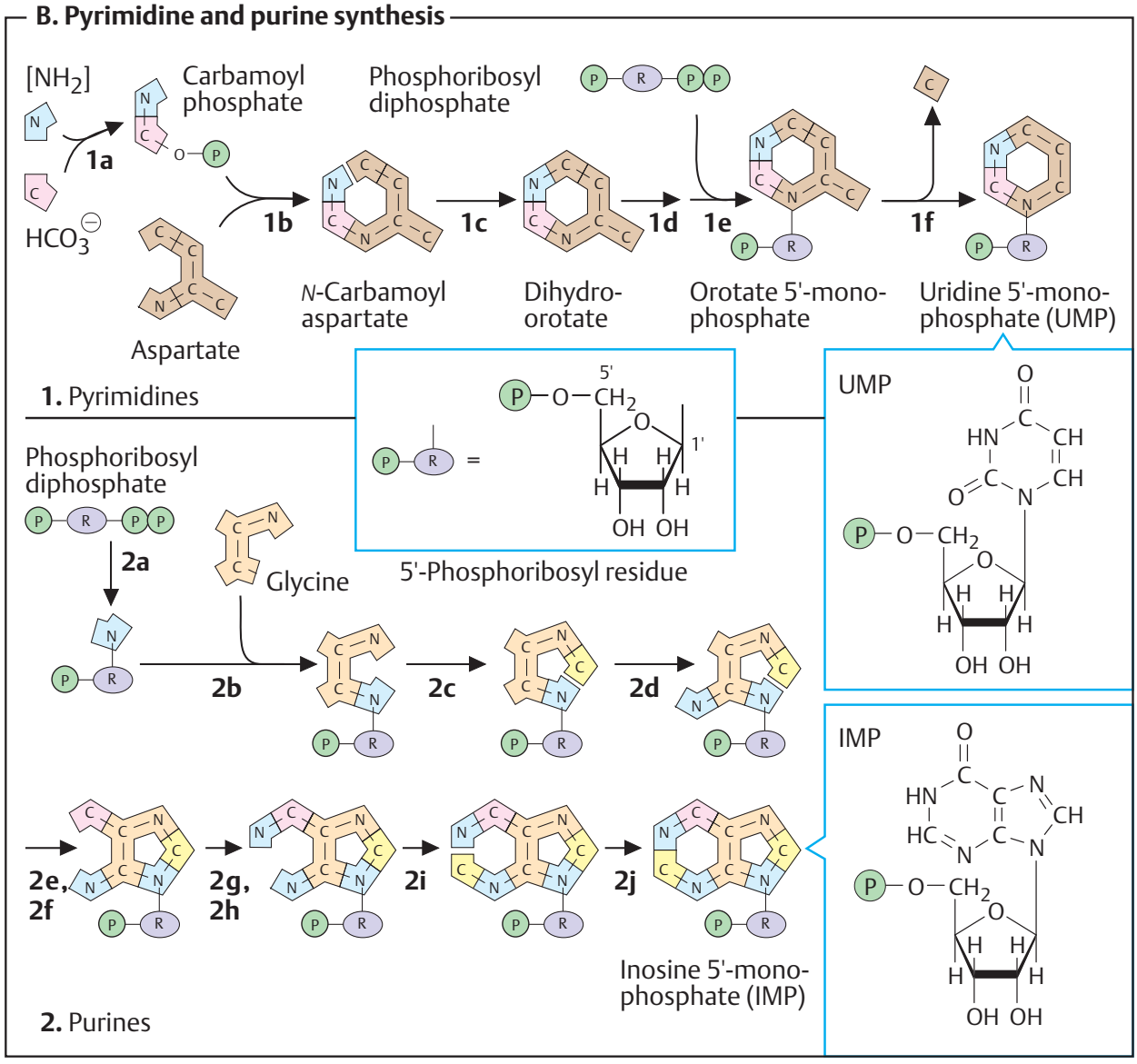

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Nucleotide biosynthesis

De novo synthesis of purines and pyrimidines yields the monophosphates IMP and UMP, respectively (see p. 188). All other nucleotides and deoxynucleotides are synthesized from these two precursors. An overview of the pathways involved is presented here; further details are given on p. 417. Nucleotide synthesis by recycling of bases (the salvage pathway) is discussed on p. 186.

A. Nucleotide synthesis: overview ◑

The synthesis of **purine nucleotides** (**1**) starts from **IMP**. The base it contains, *hypoxanthine*, is converted in two steps each into adenine or guanine. The nucleoside monophosphates **AMP** and **GMP** that are formed are then phosphorylated by *nucleoside phosphate kinases* to yield the diphosphates **ADP** and **GDP**, and these are finally phosphorylated into the triphosphates **ATP and GTP**. The nucleoside triphosphates serve as components for RNA, or function as coenzymes (see p. 106). Conversion of the ribonucleotides into deoxyribonucleotides occurs at the level of the *diphosphates* and is catalyzed by *nucleoside diphosphate reductase* (**B**).

The biosynthetic pathways for the **pyrimidine nucleotides** (**2**) are more complicated. The first product, **UMP**, is phosphorylated first to the diphosphate and then to the triphosphate, **UTP**. *CTP synthase* then converts UTP into **CTP**. Since pyrimidine nucleotides are also reduced to deoxyribonucleotides at the diphosphate level, CTP first has to be hydrolyzed by a *phosphatase* to yield **CDP** before **dCDP and dCTP** can be produced.

The DNA component deoxythymidine triphosphate (**dTTP**) is synthesized from UDP in several steps. The base thymine, which only occurs in DNA (see p. 80), is formed by methylation of **dUMP** at the nucleoside monophosphate level. *Thymidylate synthase* and its helper enzyme *dihydrofolate reductase* are important target enzymes for cytostatic drugs (see p. 402).

B. Ribonucleotide reduction ○

2′-Deoxyribose, a component of DNA, is not synthesized as a free sugar, but arises at the diphosphate level by reduction of ribonucleoside diphosphates. This reduction is a complex process in which several proteins are involved. The reducing equivalents needed come from **NADPH+H$^+$**. However, they are not transferred directly from the coenzyme to the substrate, but first pass through a *redox series* that has several steps (**1**).

In the first step, *thioredoxin reductase* reduces a small redox protein, **thioredoxin**, via enzyme-bound FAD. This involves cleavage of a disulfide bond in thioredoxin. The resulting SH groups in turn reduce a catalytically active disulfide bond in *nucleoside diphosphate reductase* ("ribonucleotide reductase"). The free SH groups formed in this way are the actual electron donors for the reduction of ribonucleotide diphosphates.

In eukaryotes, ribonucleotide reductase is a tetramer consisting of two R1 and two R2 subunits. In addition to the **disulfide bond** mentioned, a **tyrosine radical** in the enzyme also participates in the reaction (**2**). It initially produces a substrate radical (**3**). This cleaves a water molecule and thereby becomes radical cation. Finally, the deoxyribose residue is produced by reduction, and the tyrosine radical is regenerated.

The regulation of ribonucleotide reductase is complex. The substrate-specificity and activity of the enzyme are controlled by two allosteric binding sites (a and b) in the R1 subunits. ATP and dATP increase or reduce the activity of the reductase by binding at site a. Other nucleotides interact with site b, and thereby alter the enzyme's specificity.

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A. Nucleotide synthesis: overview

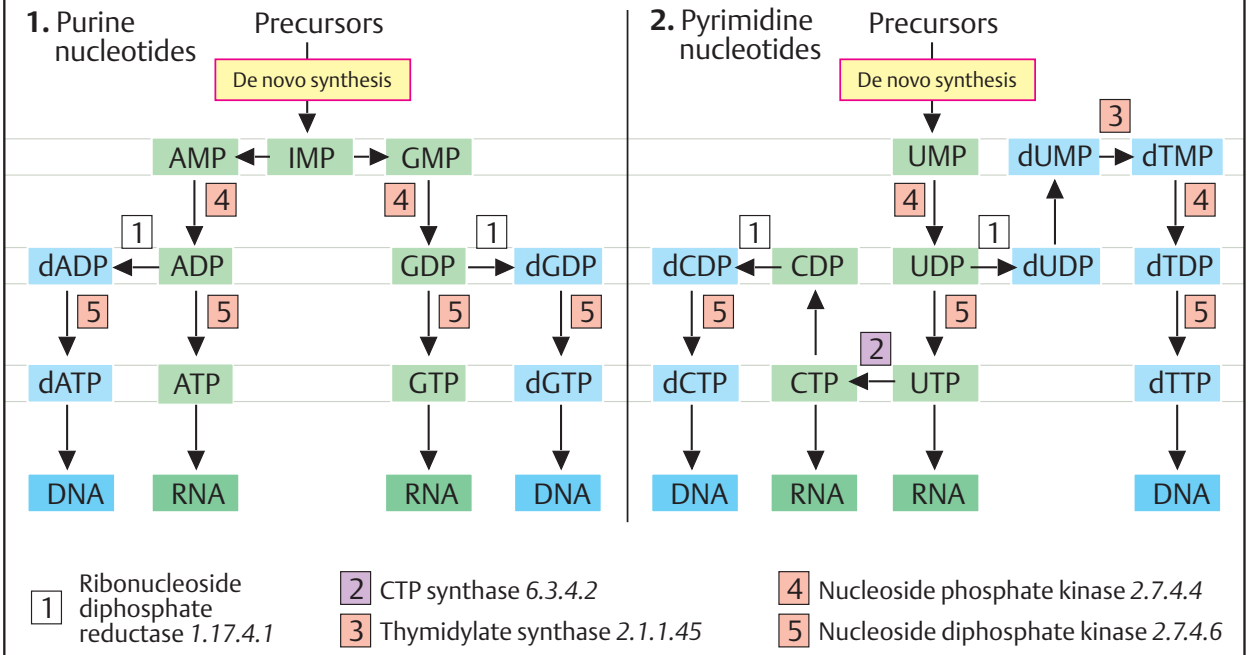

B. Ribonucleotide reduction

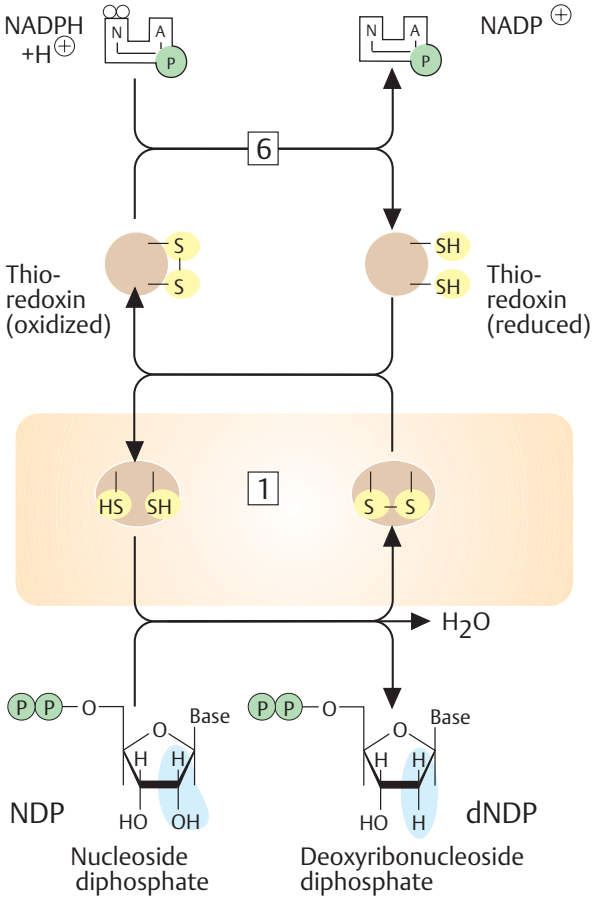

1. Overview

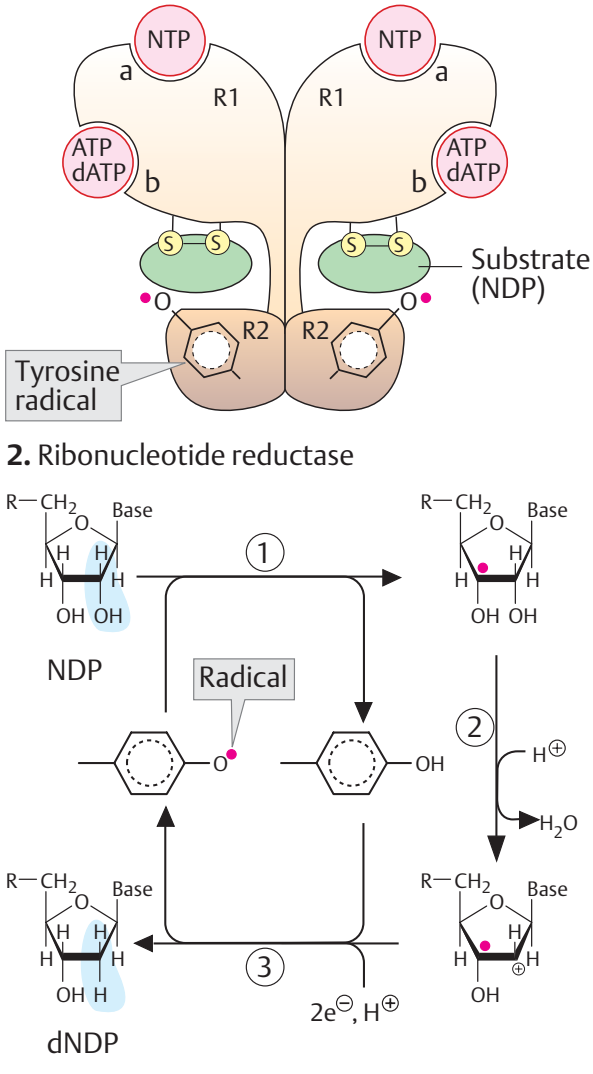

3. Reaction mechanism

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Heme biosynthesis

Heme, an iron-containing tetrapyrrole pigment, is a component of O_2-binding proteins (see p. 106) and a coenzyme of various oxidoreductases (see p. 32). Around 85% of heme biosynthesis occurs in the bone marrow, and a much smaller percentage is formed in the liver. Both mitochondria and cytoplasm are involved in heme synthesis.

A. Biosynthesis of heme ○

Synthesis of the tetrapyrrole ring starts in the mitochondria.

[1] **Succinyl CoA** (upper left), an intermediate in the tricarboxylic acid cycle, undergoes condensation with **glycine** and subsequent decarboxylation to yield **5-aminolevulinate** (ALA). The *ALA synthase* responsible for this step is the key enzyme of the whole pathway. Synthesis of ALA synthase is *repressed* and existing enzyme is inhibited by heme, the end product of the pathway. This is a typical example of end-product or *feedback inhibition.*

[2] 5-Aminolevulinate now leaves the mitochondria. In the cytoplasm, two molecules condense to form **porphobilinogen,** a compound that already contains the pyrrole ring. *Porphobilinogen synthase* is inhibited by lead ions. This is why acute lead poisoning is associated with increased concentrations of ALA in the blood and urine.

[3] The tetrapyrrole structure characteristic of the porphyrins is produced in the next steps of the synthetic pathway. *Hydroxymethylbilane synthase* catalyzes the linkage of four porphobilinogen molecules and cleavage of an NH_2 group to yield **uroporphyrinogen III**.

[4] Formation of this intermediate step requires a second enzyme, *uroporphyrinogen III synthase*. If this enzyme is lacking, the "wrong" isomer, uroporphyrinogen I, is formed.

The tetrapyrrole structure of uroporphyrinogen III is still very different from that of heme. For example, the central iron atom is missing, and the ring contains only eight of the 11 double bonds. In addition, the ring system only carries charged R side chains (four acetate and four propionate residues). As heme groups have to act in the apolar interior of proteins, most of the polar side chains have to be converted into less polar groups.

[5] Initially, the four acetate residues (R_1) are decarboxylated into methyl groups. The resulting **coproporphyrinogen III** returns to the mitochondria again. The subsequent steps are catalyzed by enzymes located either on or inside the *inner mitochondrial membrane.*

[6] An *oxidase* first converts two of the propionate groups (R_2) into vinyl residues. The formation of **protoporphyrinogen IX** completes the modification of the side chains.

[7] In the next step, another oxidation produces the conjugated π-electron system of **protoporphyrin IX**.

[8] Finally, a divalent iron is incorporated into the ring. This step also requires a specific enzyme, *ferrochelatase.* The **heme b** or **Fe-protoporphyrin IX** formed in this way is found in hemoglobin and myoglobin, for example (see p. 280), where it is noncovalently bound, and also in various oxidoreductases (see p. 106).

Further information

There are a large number of hereditary or acquired disturbances of porphyrin synthesis, known as **porphyrias**, some of which can cause severe clinical pictures. Several of these diseases lead to the excretion of heme precursors in feces or urine, giving them a dark red color. Accumulation of porphyrins in the skin can also occur, and exposure to light then causes disfiguring, poorly healing blisters. Neurological disturbances are also common in the porphyrias.

It is possible that the medieval legends about human vampires ("Dracula") originated in the behavior of porphyria sufferers (avoidance of light, behavioral disturbances, and drinking of blood in order to obtain heme—which markedly improves some forms of porphyria).

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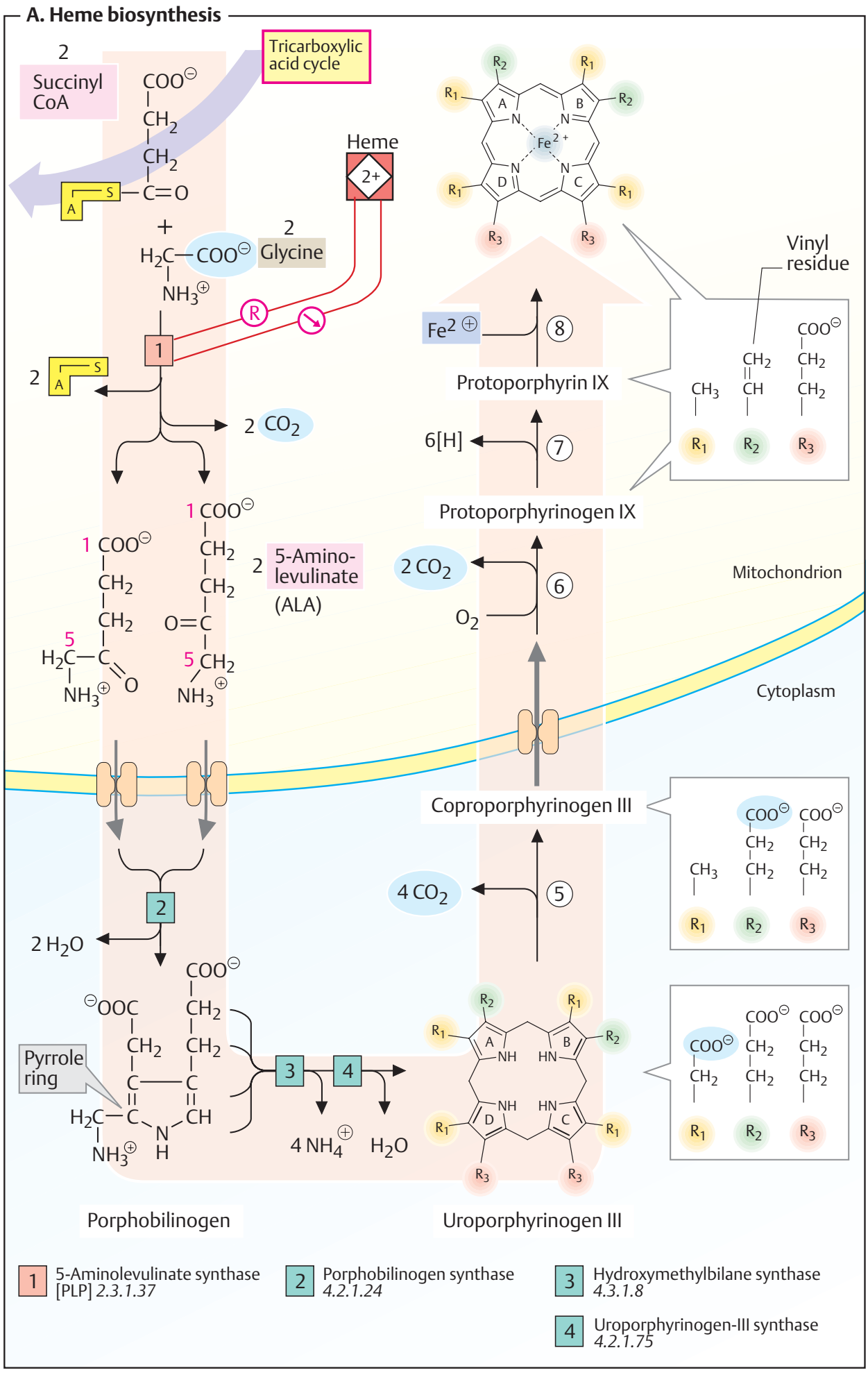

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Heme degradation

A. Degradation of heme groups ○

Heme is mainly found in the human organism as a prosthetic group in erythrocyte hemoglobin. Around 100–200 million aged erythrocytes per hour are broken down in the human organism. The degradation process starts in reticuloendothelial cells in the spleen, liver, and bone marrow.

[1] After the protein part (globin) has been removed, the tetrapyrrole ring of heme is oxidatively cleaved between rings A and B by *heme oxygenase.* This reaction requires molecular oxygen and $NADPH+H^+$, and produces green **biliverdin**, as well as CO (carbon monoxide) and Fe^{2+}, which remains available for further use (see p. 286).

[2] In another redox reaction, biliverdin is reduced by *biliverdin reductase* to the orange-colored **bilirubin.** The color change from purple to green to yellow can be easily observed in vivo in a bruise or hematoma.

The color of heme and the other *porphyrin systems* (see p. 106) results from their numerous conjugated double bonds. Heme contains a cyclic conjugation (highlighted in pink) that is removed by reaction [1]. Reaction [2] breaks the π system down into two smaller separate systems (highlighted in yellow).

For further degradation, bilirubin is transported to the liver via the blood. As bilirubin is poorly soluble, it is bound to **albumin** for transport**.** Some drugs that also bind to albumin can lead to an increase in free bilirubin.

[3] The hepatocytes take up bilirubin from the blood and conjugate it in the endoplasmic reticulum with the help of **UDP-glucuronic acid** into the more easily soluble **bilirubin monoglucuronides** and **diglucuronides**. To do this, *UDP-glucuronosyltransferase* forms ester-type bonds between the OH group at C-1 of glucuronic acid and the carboxyl groups in bilirubin (see p. 316). The glucuronides are then excreted by active transport into the **bile**, where they form what are known as the **bile pigments**.

Glucuronide synthesis is the rate-determining step in hepatic bilirubin metabolism. Drugs such as *phenobarbital,* for example, can induce both conjugate formation and the transport process.

Some of the bilirubin conjugates are broken down further in the intestine by bacterial *β-glucuronidases.* The bilirubin released is then reduced further via intermediate steps into colorless **stercobilinogen**, some of which is oxidized again into orange to yellow-colored stercobilin. The end products of bile pigment metabolism in the intestine are mostly excreted in feces, but a small proportion is resorbed *(enterohepatic circulation;* see p. 314). When high levels of heme degradation are taking place, stercobilinogen appears as **urobilinogen** in the urine, where oxidative processes darken it to form **urobilin**.

In addition to hemoglobin, other *heme proteins* (myoglobin, cytochromes, catalases, and peroxidases; see p. 32) also supply heme groups that are degraded via the same pathway. However, these contribute only about 10–15% to a total of ca. 250 mg of bile pigment formed per day.

Further information

Hyperbilirubinemias. An elevated bilirubin level (> 10 mg L^{-1}) is known as *hyperbilirubinemia.* When this is present, bilirubin diffuses from the blood into peripheral tissue and gives it a yellow color (jaundice). The easiest way of observing this is in the white conjunctiva of the eyes.

Jaundice can have various causes. If increased erythrocyte degradation (hemolysis) produces more bilirubin, it causes *hemolytic jaundice.* If bilirubin conjugation in the liver is impaired—e.g., due to hepatitis or liver cirrhosis—it leads to *hepatocellular jaundice,* which is associated with an increase in unconjugated (*"indirect"*) bilirubin in the blood. By contrast, if there is a disturbance of bile drainage (*obstructive jaundice,* due to gallstones or pancreatic tumors), then conjugated (*"direct"*) bilirubin in the blood increases. *Neonatal jaundice* (physiologic jaundice) usually resolves after a few days by itself. In severe cases, however, unconjugated bilirubin can cross the blood–brain barrier and lead to brain damage (*kernicterus*).

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A. Degradation of heme groups

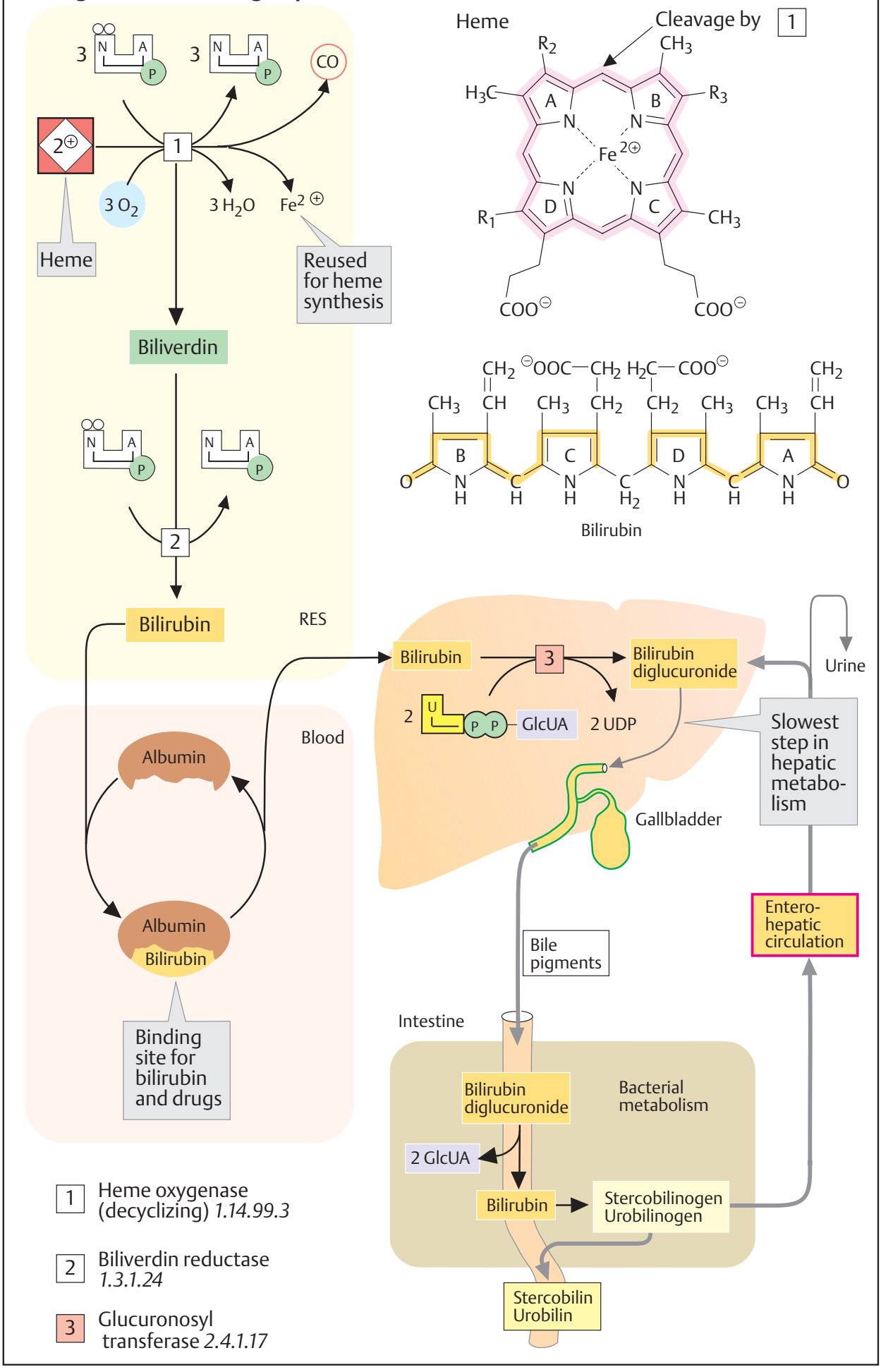

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Structure of cells

A. Comparison of prokaryotes and eukaryotes ●

Present-day living organisms can be divided into two large groups—the prokaryotes and eukaryotes. The **prokaryotes** are represented by bacteria *(eubacteria* and *archaebacteria).* These are almost all small unicellular organisms only a few microns (10^{-6} m) in size. The **eukaryotes** include *fungi*, *plants*, and *animals* and comprise both unicellular and multicellular organisms. Multicellular eukaryotes are made up of a wide variety of cell types that are specialized for different tasks. Eukaryotic cells are much larger than prokaryotic ones (volume ratio approximately 2000 : 1). The most important distinguishing feature of these cells in comparison with the prokaryotes is the fact that they have a **nucleus** (*karyon* in Greek—hence the term).

In comparison with the prokaryotes, eukaryotic cells have greater specialization and complexity in their structure and functioning. Eukaryotic cells are structured into *compartments* (see below). The metabolism and synthesis of macromolecules are distributed through these reaction spaces and are separately regulated. In prokaryotes, these functions are organized in a simpler fashion and are spatially closely related.

Although the storage and transfer of genetic information function according to the same principle in the prokaryotes and eukaryotes, there are also differences. Eukaryotic DNA consists of very long, linear molecules with a total of 10^7 to more than 10^{10} base pairs (bp), only a small fraction of which are used for genetic information. In eukaryotes, the genes (20000–50000 per genome) are usually interrupted by non-coding regions (*introns*). Eukaryotic DNA is located in the nucleus, where together with histones and other proteins it forms the chromatin (see p. 238).

In prokaryotes, by contrast, DNA is ring-shaped, much shorter (up to 5 10^6 bp), and located in the cytoplasm. Almost all of it is used for information storage, and it does not contain any introns.

B. Structure of an animal cell ●

In the human body alone, there are at least 200 different cell types. The illustration outlines the basic structures of an animal cell in an extremely simplified way. The details given regarding the proportion of the compartments relative to cell volume (highlighted in yellow) and their numbers per cell frequency (blue) refer to mammalian hepatocytes (liver cells). The figures can vary widely from cell type to cell type.

The eukaryotic cell is subdivided by membranes. On the outside, it is enclosed by a **plasma membrane.** Inside the cell, there is a large space containing numerous components in solution—the **cytoplasm**. Additional membranes divide the internal space into *compartments* (confined reaction spaces). Welldefined compartments of this type are known as **organelles**.

The largest organelle is the **nucleus** (see p. 208). It is easily recognized using the light microscope. The **endoplasmic reticulum** (ER), a closed network of shallow sacs and tubules (see pp. 226ff.), is linked with the outer membrane of the nucleus. Another membrane-bound organelle is the **Golgi apparatus** (see p. 228), which resembles a bundle of layered slices. The **endosomes** and **exosomes** are bubble-shaped compartments *(* vesicles*)* that are involved in the exchange of substances between the cell and its surroundings. Probably the most important organelles in the cell's metabolism are the **mitochondria,** which are around the same size as bacteria (see pp. 210ff.). The **lysosomes** and **peroxisomes** are small, globular organelles that carry out specific tasks. The whole cell is traversed by a framework of proteins known as the **cytoskeleton** (see pp. 204ff.).

In addition to these organelles, plant cells (see p. 43) also have plastids—eg., **chloroplasts**, in which photosynthesis takes place (see p. 128). In their interior, there is a large, fluid-filled **vacuole**. Like bacteria and fungi, plant cells have a rigid cell wall consisting of polysaccharides and proteins.

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A. Comparison of prokaryotes and eukaryotes

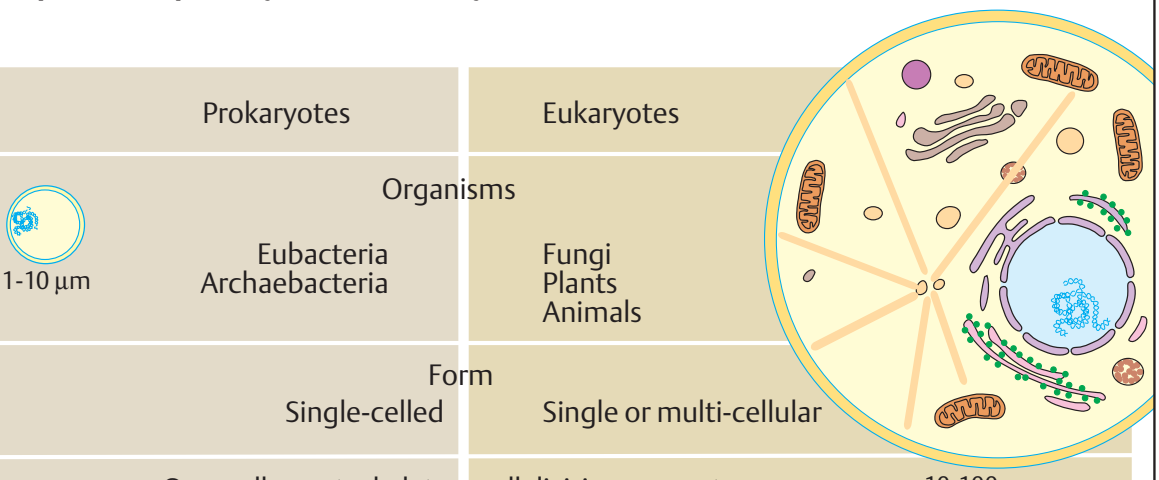

Prokaryotes	Eukaryotes
Organisms	
Eubacteria Archaebacteria	Fungi Plants Animals
Form	
Single-celled	Single or multi-cellular
Organelles, cytoskeleton, cell division apparatus	
Missing	Present, complicated, specialized
DNA	
Small, circular, no introns, plasmids	Large, in nucleus, many introns
RNA: Synthesis and maturation	
Simple, in cytoplasm	Complicated, in nucleus
Protein: Synthesis and maturation	
Simple, coupled with RNA synthesis	Complicated, in the cytoplasm and the rough endoplasmic reticulum
Metabolism	
Anaerobic or aerobic very flexible	Mostly aerobic, compartmented
Endocytosis and Exocytosis	
no	yes

B. Structure of an animal cell

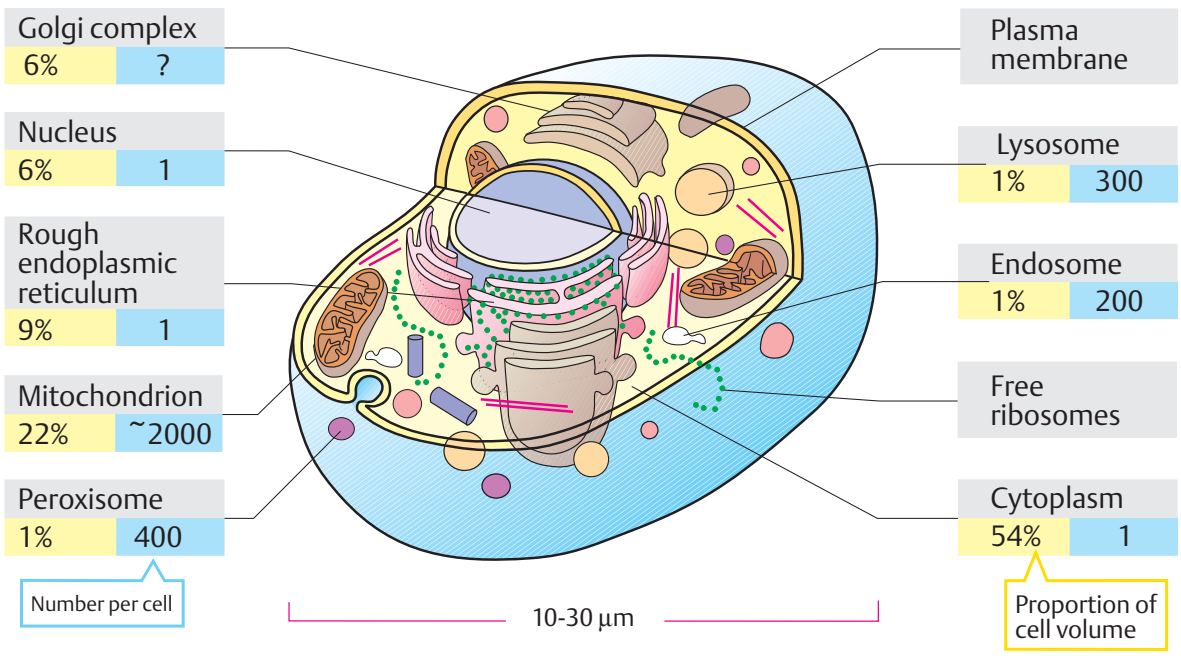

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Cell fractionation

A. Isolation of cell organelles ○

To investigate the individual compartments of the cell (see p. 196), various procedures have been developed to enrich and isolate cell organelles. These are mainly based on the size and density of the various organelles.

The isolation of cell components starts with **disruption** of the tissue being examined and subsequent **homogenization** of it (breaking down the cells) in a suitable buffer (see below). Homogenization using the "Potter" (the Potter–Elvehjem homogenizer, a rotating Teflon pestle in a glass cylinder) is particularly suitable for animal tissue. This method is very gentle and is therefore used to isolate fragile structures and molecules. Other cell disruption procedures include **enzymatic lysis** with the help of enzymes that break down the cell wall, **mechanical disruption** by grinding frozen tissue, cutting or smashing with rotating knives, large pressure changes, osmotic shock, and repeated freezing and thawing.

To isolate intact organelles, it is important for the homogenization solution to be *isotonic*—i.e., the osmotic value of the buffer has to be the same as that of the interior of the cell. If hypotonic solutions were used, the organelles would take up water and burst, while in hypertonic solutions they would shrink.

Homogenization is followed by coarse **filtration** through gauze to remove intact cells and connective-tissue fragments. The actual fractionation of cellular components is then carried out by **centrifugation steps**, in which the gravitational force (given as multiples of the earth's gravity, $g = 9.81\ m\ s^{-2}$) is gradually increased (*differential centrifugation*; see p. 200). Due to the different shapes and densities of the organelles, this leads to successive sedimentation of each type out of the suspension.

Nuclei already sediment at low accelerations that can be achieved with bench-top centrifuges. Decanting the residue (the "supernatant") and carefully suspending the sediment (or "pellet") in an isotonic medium yields a fraction that is enriched with nuclei. However, this fraction may still contain other cellular components as contaminants—e.g., fragments of the cytoskeleton.

Particles that are smaller and less dense than the nuclei can be obtained by step-by-step acceleration of the gravity on the supernatant left over from the first centrifugation. However, this requires very powerful centrifuges (high-speed centrifuges and ultracentrifuges). The sequence in which the fractions are obtained is: **mitochondria, membrane vesicles**, and **ribosomes**. Finally, the supernatant from the last centrifugation contains the **cytosol** with the cell's soluble components, in addition to the buffer.

The isolation steps are carried out at low temperatures on principle (usually 0–5 °C), to slow down degradation reactions—e.g., due to released enzymes and other influencing factors. The addition of thiols and chelating agents protects functional SH groups from oxidation. Isolated cell organelles quickly lose their biological activity despite these precautions. Nevertheless, it is possible by working carefully to isolate mitochondria that will still take up substrates for a few hours in the test tube and produce ATP via oxidative phosphorylation.

B. Marker molecules ○

During cell fractionation, it is very important to analyze the purity of the fractions obtained. Whether or not the intended organelle is present in a particular fraction, and whether or not the fraction contains other components, can be determined by analyzing characteristic **marker molecules.** These are molecules that occur exclusively or predominantly in one type of organelle. For example, the activity of organelle-specific enzymes **(marker enzymes)** is often assessed. The distribution of marker enzymes in the cell reflects the compartmentation of the processes they catalyze. These reactions are discussed in greater detail here under the specific organelles.

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A. Isolation of cell organelles

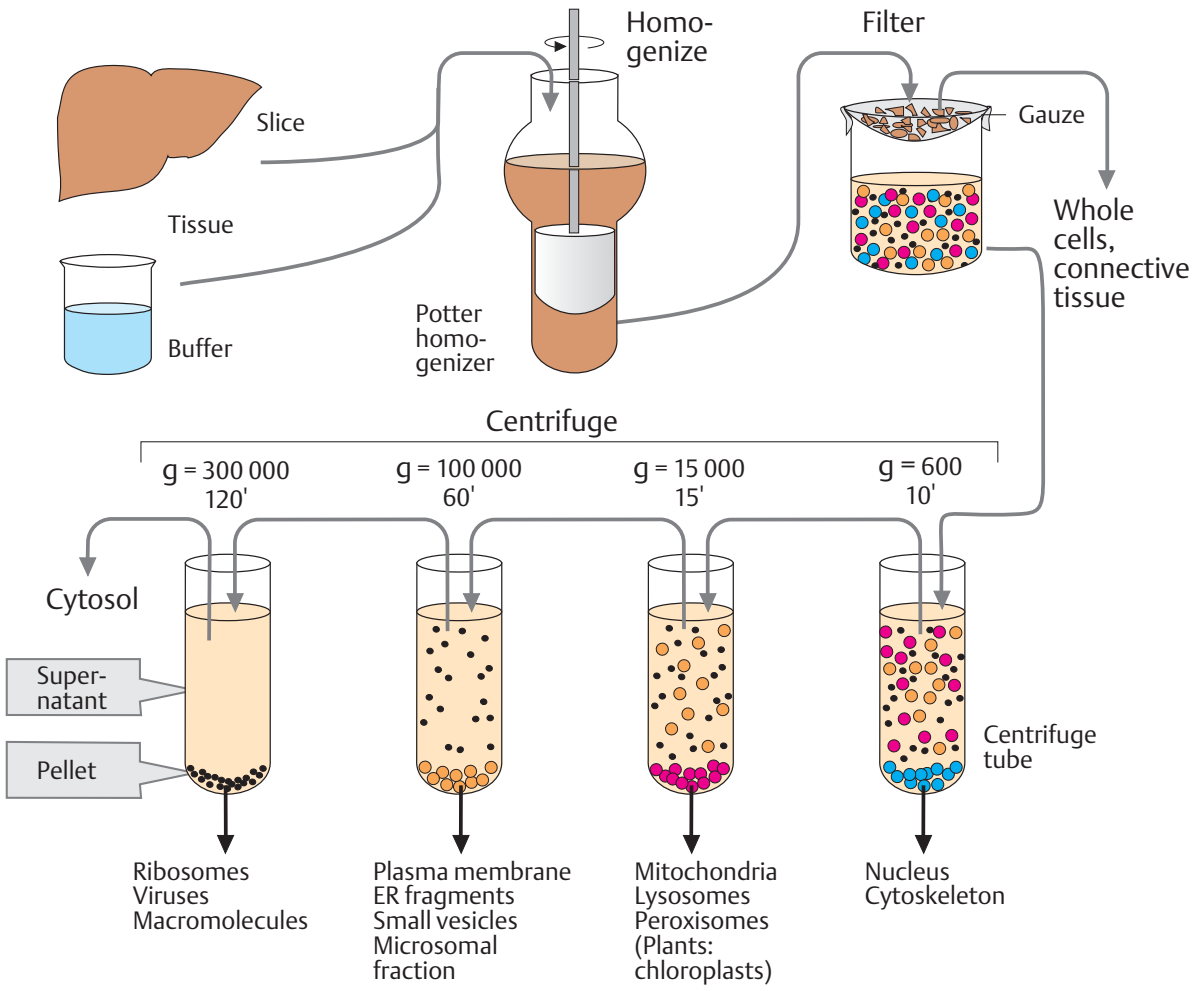

B. Marker molecules

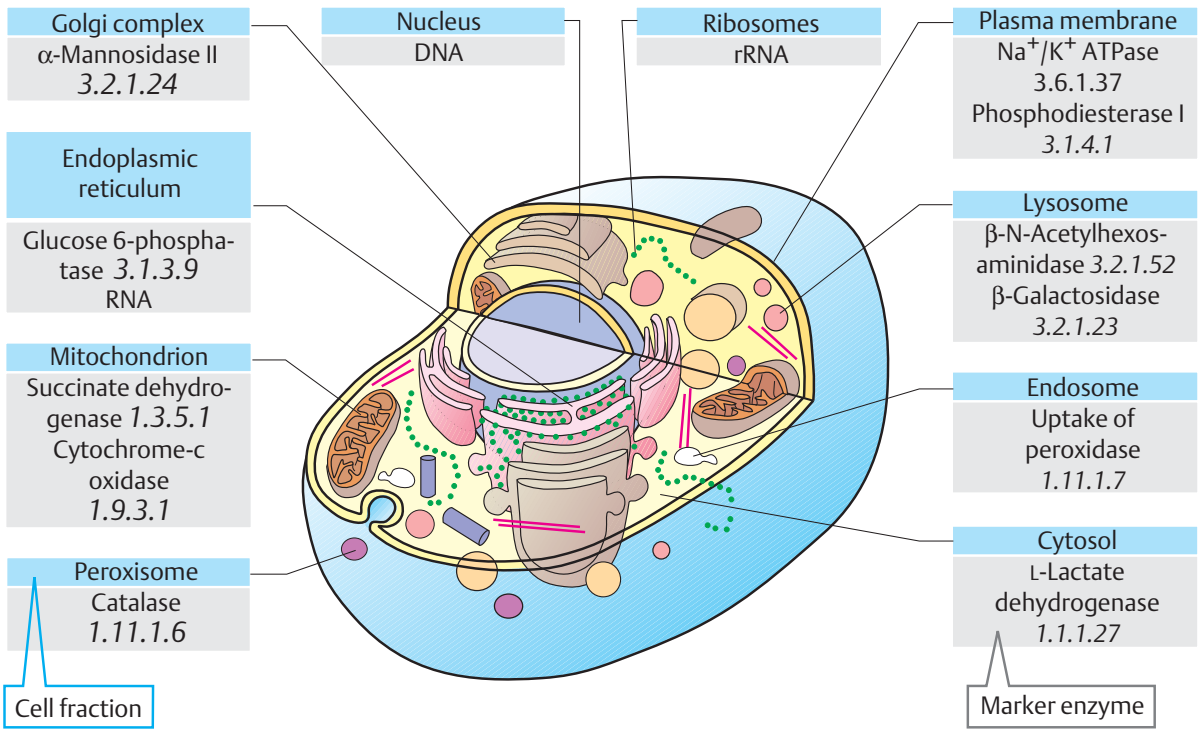

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Centrifugation

A. Principles of centrifugation ○

In a solution, particles whose density is higher than that of the solvent sink (*sediment*), and particles that are lighter than it *float* to the top. The greater the difference in density, the faster they move. If there is no difference in density (isopyknic conditions), the particles *hover*. To take advantage of even tiny differences in density to separate various particles in a solution, gravity can be replaced with the much more powerful "centrifugal force" provided by a centrifuge.

Equipment. The acceleration achieved by centrifugation is expressed as a multiple of the earth's gravitational force (g = 9.81 m s^{-2}). Bench-top centrifuges can reach acceleration values of up to 15000 g, while highspeed refrigerated centrifuges can reach 50000 g and ultracentrifuges, which operate with refrigeration and in a vacuum, can reach 500000 g. Two types of rotor are available in high-powered centrifuges: *fixed angle rotors* and *swingout rotors* that have movable bucket containers. The tubes or buckets used for centrifugation are made of plastic and have to be very precisely adjusted to avoid any imbalances that could lead to accidents.

Theory. The velocity (v) of particle sedimentation during centrifugation depends on the angular velocity ω of the rotor, its effective radius (r_{eff}, the distance from the axis of rotation), and the particle's sedimentation properties. These properties are expressed as the **sedimentation coef•cient** S (1 Svedberg, = 10^{-13} s). The sedimentation coef cient depends on the mass M of the particle, its shape (expressed as the coef cient of friction, f), and its density (expressed as the reciprocal density $\bar{v}$, "partial specific volume").

At the top right, the diagram shows the densities and sedimentation coef cients for biomolecules, cell organelles, and viruses. Proteins and protein-rich structures have densities of around 1.3 g cm^{-3}, while nucleic acids show densities of up to 2 g cm^{-3}. Equilibrium sedimentation of nucleic acids therefore requires high-density media—e.g., concentrated solutions of cesium chloride (CsCl). To allow comparison of S values measured in different media, they are usually corrected to values for water at 20 °C ("S_{20w}").

B. Density gradient centrifugation ○

Density gradient centrifugation is used to separate macromolecules that differ only slightly in size or density. Two techniques are commonly used.

In **zonal centrifugation,** the sample being separated (e.g., a cell extract or cells) is placed on top of the centrifugation solution as a thin layer. During centrifugation, the particles move through the solution due to their greater density. The rate of movement basically depends on their molecular mass (see **A**, formulae). Centrifugation stops before the particles reach the bottom of the tube. Drilling a hole into the centrifugation tube and allowing the contents to drip out makes it possible to collect the different particles in separate fractions. During centrifugation, the solution tube is stabilized in the tube by a **density gradient**. This consists of solutions of carbohydrates or colloidal silica gel, the concentration of which increases from the surface of the tube to the bottom. Density gradients prevent the formation of convection currents, which would impair the separation of the particles.

Isopyknic centrifugation, which takes much longer, starts with a CsCl solution in which the sample material (e.g., DNA, RNA, or viruses) is homogeneously distributed. A density gradient only forms *during* centrifugation, as a result of sedimentation and diffusion processes. Each particle moves to the region corresponding to its own *buoyant density*. Centrifugation stops once equilibrium has been reached. The samples are obtained by fractionation, and their concentration is measured using the appropriate methods.

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A. Principles of centrifugation

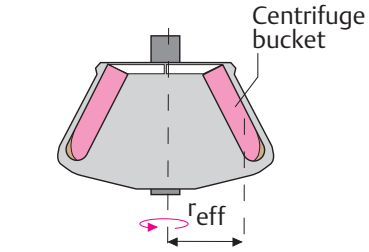

Fixed angle rotor

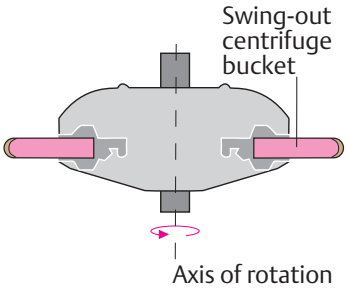

Swing-out bucket rotor

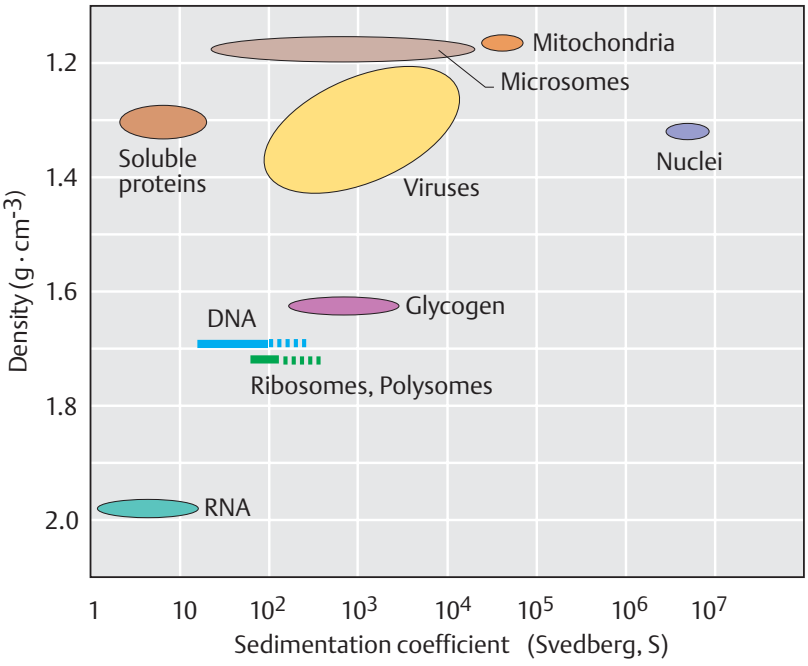

g: Gravitational acceleration

v: Sedimentation velocity (cm · s^{-1})

ω: Angular velocity (rad · s^{-1})

r_{eff}: Effective radius (cm)

$$g = \omega^2 \cdot r_{eff}$$

$$v = \omega^2 \cdot r_{eff} \cdot s$$

$$s = \frac{M \cdot (1 - \bar{v} \cdot r)}{f}$$

s: Sedimentation coefficient ($S = 10^{-13}$ s)

M: Molecular mass

$\bar{v}$: Partial specific particle volume ($cm^3 \cdot g^{-1}$)

r: Density of the solution ($g \cdot cm^3$)

f: Coefficient of friction

B. Density gradient centrifugation

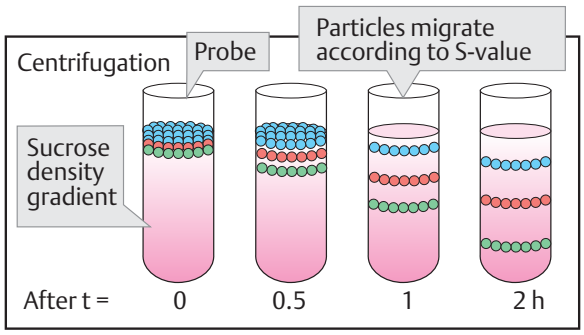

Zonal centrifugation

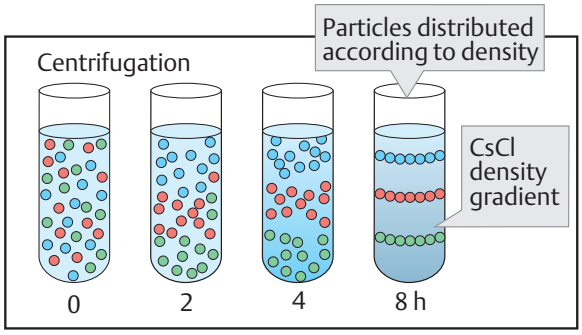

Isopyknic centrifugation

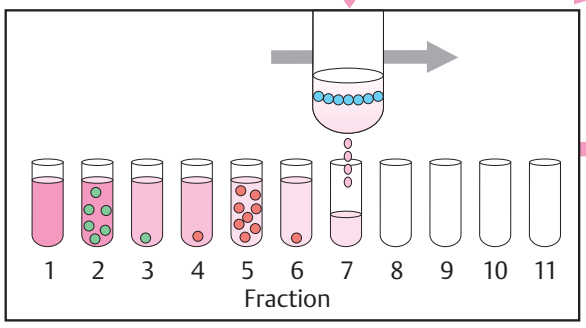

Fractionation

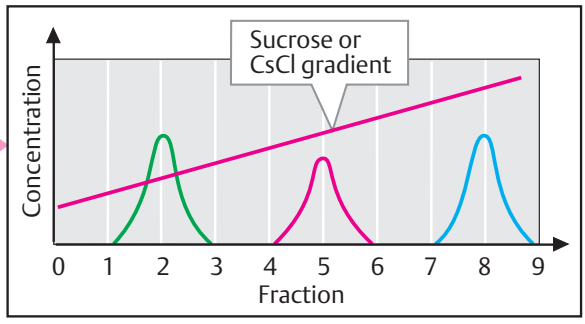

Detection

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Cell components and cytoplasm

The Gram-negative bacterium *Escherichia coli (E. coli)* is a usually harmless symbiont in the intestine of mammals. The structure and characteristics of this organism have been particularly well characterized. *E. coli* is also frequently used in genetic engineering (see p. 258).

A. Components of a bacterial cell ◑

A single *E. coli* cell has a **volume** of about 0.88 μm^3. One-sixth of this consists of membranes and one-sixth is DNA (known as the "nucleoid"). The rest of the internal space of the cell is known as **cytoplasm** (not "cytosol"; see p. 198).

The main component of *E. coli*—as in all cells—is **water** (70%). The other components are **macromolecules** (proteins, nucleic acids, polysaccharides), **small organic molecules**, and **inorganic ions**. The majority of the macromolecules are proteins, which represent ca. 55% of the dry mass of the cell. When a number of assumptions are made about the distribution and size (average mass 40 kDa) of proteins, it can be estimated that there are approximately 250000 protein molecules in the cytoplasm of an *E. coli* cell. In eukaryotic cells, which are about a thousand times larger, it is estimated that the number of protein molecules is in the order of several billion.

B. Looking inside a bacterial cell ○

The illustration shows a schematic view inside the **cytoplasm** of *E. coli*, magnified approximately one million times. At this magnification, a single carbon atom would be the size of a grain of salt, and an ATP molecule would be as large as a grain of rice. The detail shown is 100 nm long, corresponding to about 1/600th of the volume of a cell in *E. coli*. To make the macromolecules clearer, small molecules such as water, cofactors, and metabolites have all been omitted from the illustration. The section of the cytoplasm shown contains:

- Several hundred **macromolecules**, which are needed for protein biosynthesis—i. e., 30 ribosomes, more than 100 protein factors, 30 aminoacyl–tRNA synthases, 340 tRNA molecules, 2–3 mRNAs (each of which is 10 times the length of the section shown), and six molecules of RNA polymerase.
- About 330 other enzyme molecules, including 130 glycolytic enzymes and 100 enzymes from the tricarboxylic acid cycle.
- 30000 **small organic molecules** with masses of 100–1000 Da—e. g., metabolites of the intermediary metabolism and coenzymes. These are shown at a magnification 10 times higher in the bottom right corner.
- And finally, 50000 **inorganic ions.** The rest consists of water.

The illustration shows that the cytoplasm of cells is a compartment densely packed with macromolecules and smaller organic molecules. The distances between organic molecules are small. They are only separated by a few water molecules.

All of the molecules are in motion. Due to constant collisions, however, they do not advance in a straight path but move in zigzags. Due to their large mass, proteins are particularly slow. However, they do cover an average of 5 nm in 1 ms—a distance approximately equal to their own length. Statistically, a protein is capable of reaching any point in a bacterial cell in less than a second.

C. Biochemical functions of the cytoplasm ◑

In eukaryotes, the cytoplasm, representing slightly more than 50% of the cell volume, is the most important cellular compartment. It is the *central reaction space of the cell.* This is where many important pathways of the intermediary metabolism take place—e. g., glycolysis, the pentose phosphate pathway, the majority of gluconeogenesis, and fatty acid synthesis. Protein biosynthesis (translation; see p. 250) also takes place in the cytoplasm. By contrast, fatty acid degradation, the tricarboxylic acid cycle, and oxidative phosphorylation are located in the mitochondria (see p. 210).

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A. Components of a bacterial cell

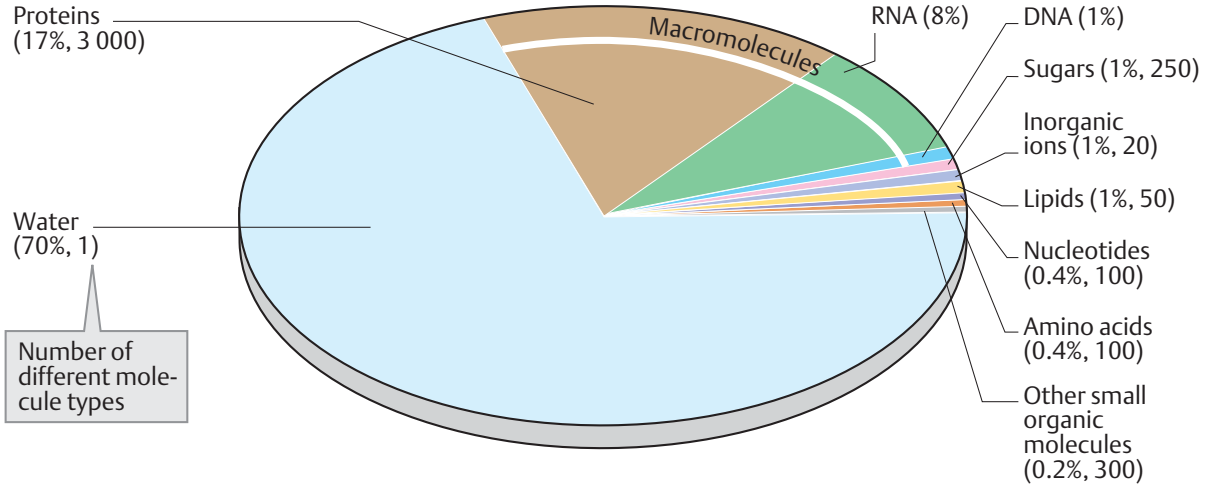

B. View into a bacterial cell

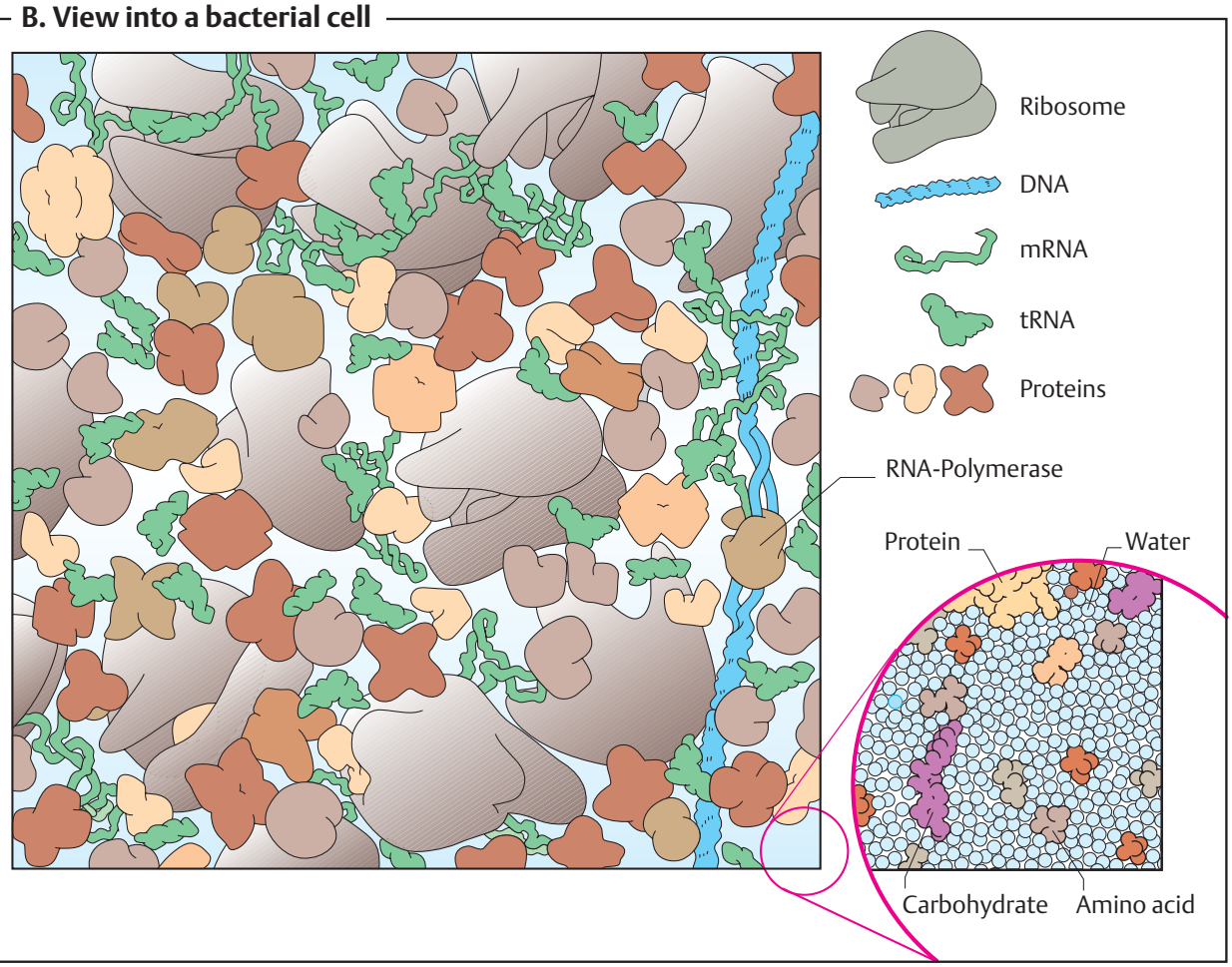

C. Biochemical functions of the cytoplasm

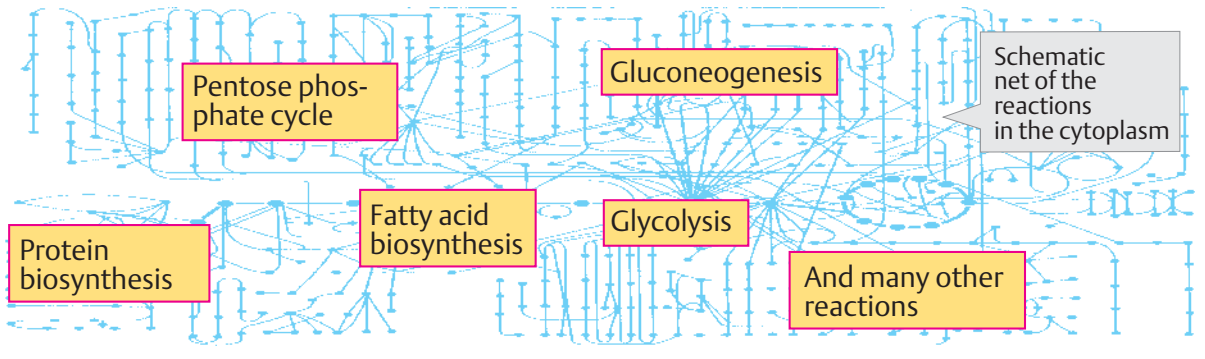

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Cytoskeleton: components

The cytoplasm of eukaryotic cells is traversed by three–dimensional scaffolding structures consisting of filaments (long protein fibers), which together form the **cytoskeleton**. These filaments are divided into three groups, based on their *diameters*: **microfilaments** (6–8 nm), **intermediate filaments** (ca. 10 nm), and **microtubules** (ca. 25 nm). All of these filaments are polymers assembled from protein components.

A. Actin ◑

Actin, the most abundant protein in eukaryotic cells, is the protein component of the **microfilaments** (actin filaments). Actin occurs in two forms—a monomolecular form (**G actin**, globular actin) and a polymer (**F actin**, filamentous actin). G actin is an asymmetrical molecule with a mass of 42 kDa, consisting of two domains. As the ionic strength increases, G actin aggregates reversibly to form F actin, a helical homopolymer. G actin carries a firmly bound ATP molecule that is slowly hydrolyzed in F actin to form ADP. Actin therefore also has enzyme properties (*ATPase* activity).

As individual G actin molecules are always oriented in the same direction relative to one another, F actin consequently has *polarity*. It has two different ends, at which polymerization takes place at different rates. If the ends are not stabilized by special proteins (as in muscle cells), then at a critical concentration of G actin the (+) end of F actin will constantly grow, while the (–) end simultaneously decays. These partial processes can be blocked by fungal toxins experimentally. **Phalloidin**, a toxin contained in the *Amanita phalloides* mushroom, inhibits decay by binding to the (–) end. By contrast, **cytochalasins**, mold toxins with cytostatic effects, block polymerization by binding to the (+) end.

Actin–associated proteins. The cytoplasm contains more than 50 different proteins that bind specifically to G actin and F actin. Their actin uptake has various different functions. This type of bonding can serve to regulate the G actin pool (example: *profilin*), influence the polymerization rate of G actin (*villin*), stabilize the chain ends of F actin (*fragin, γ–actinin*), attach filaments to one another or to other cell components (*villin, α–actinin, spectrin),* or disrupt the helical structure of F actin (*gelsolin*). The activity of these proteins is regulated by protein kinases via Ca^{2+} and other second messengers (see p. 386).

B. Intermediate filaments ◑

The components of the intermediate filaments belong to five related protein families. They are specific for particular cell types. Typical representatives include the *cytokeratins, desmin, vimentin, glial fibrillary acidic protein* (GFAP), and *neurofilament*. These proteins all have a rod–shaped basic structure in the center, which is known as a *superhelix* ("coiled coil"; see keratin, p. 70). The dimers are arranged in an antiparallel fashion to form tetramers. A staggered head-to–head arrangement produces **protofilaments**. Eight protofilaments ultimately form an intermediary filament.

Free protein monomers of intermediate filaments rarely occur in the cytoplasm, in contrast to microfilaments and microtubules. Their polymerization leads to stable polymers that have no polarity.

C. Tubulins ◑

The basic components of the tube-shaped **microtubules** are α– and β–**tubulin** (53 and 55 kDa). These form α,β-heterodimers, which in turn polymerize to form linear protofilaments. Thirteen protofilaments form a ring-shaped complex, which then grows into a long tube as a result of further polymerization.

Like microfilaments, microtubules are dynamic structures with (+) and (–) ends. The (–) end is usually stabilized by bonding to the centrosome. The (+) end shows *dynamic instability*. It can either grow slowly or shorten rapidly. GTP, which is bound by the microtubules and gradually hydrolyzed into GDP, plays a role in this. Various proteins can also be associated with microtubules.

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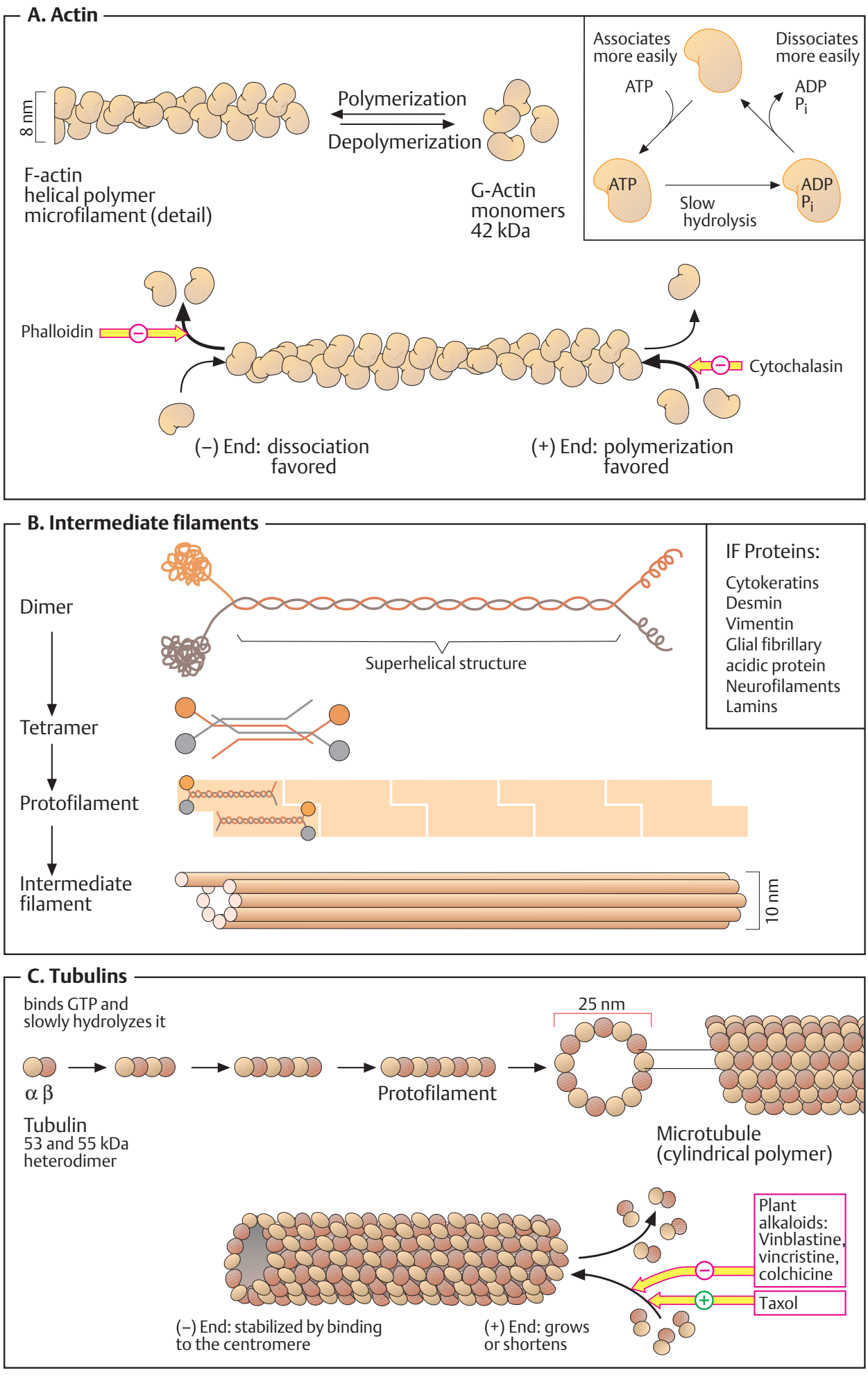

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Structure and functions

The cytoskeleton carries out three major tasks:

- It represents the cell's **mechanical scaffolding**, which gives it its typical shape and connects membranes and organelles to each other. This scaffolding has dynamic properties; it is constantly being synthesized and broken down to meet the cell's requirements and changing conditions.
- It acts as the **motor for movement** of animal cells. Not only muscle cells (see p. 332), but also cells of noncontractile tissues contain many different *motor proteins,* which they use to achieve coordinated and directed movement. Cell movement, shape changes during growth, cytoplasmic streaming, and cell division are all made possible by components of the cytoskeleton.
- It serves as a **transport track** within the cell. Organelles and other large protein complexes can move along the filaments with the help of the motor proteins.

A. Microfilaments and intermediate filaments ○

The illustration schematically shows a detail of the **microvilli** of an intestinal epithelial cell as an example of the structure and function of the components of the cytoskeleton (see also **C1**).

Microfilaments of *F actin* traverse the microvilli in ordered bundles. The microfilaments are attached to each other by actin–associated proteins, particularly *fimbrin* and *villin. Calmodulin* and a myosin–like *ATPase* connect the microfilaments laterally to the plasma membrane. *Fodrin,* another microfilament–associated protein, anchors the actin fibers to each other at the base, as well as attaching them to the cytoplasmic membrane and to a network of **intermediate filaments.** In this example, the microfilaments have a mainly static function. In other cases, actin is also involved in dynamic processes. These include muscle contraction (see p. 332), cell movement, phagocytosis by immune cells, the formation of microspikes and lamellipodia (cellular extensions), and the acrosomal process during the fusion of sperm with the egg cell.

B. Microtubules ○

Only the cell's **microtubules** are shown here. They radiate out in all directions from a center near the nucleus, the **centrosome**. The tube-shaped microtubules are constantly being synthesized and broken down at their (+) ends. In the centriole, the (–) end is blocked by associated proteins (see p. 204). The (+) end can also be stabilized by associated proteins—e.g., when the microtubules have reached the cytoplasmic membrane.

The microtubules are involved in defining the shape of the cell and also serve as guiding tracks for the transport of organelles. Together with associated proteins (*dynein, kinesin*), microtubules are able to carry out mechanical work—e.g., during the transport of mitochondria, the movement of cilia (hair-like cell protrusions in the lungs, intestinal epithelium, and oviduct) and the beating of the flagella of sperm. Microtubules also play a special role in the mitotic period of cell division (see p. 394).

C. Architecture ○

The complex structure and net-like density of the cytoskeleton is illustrated here using three examples in which the cytoskeletal components are visualized with the help of antibodies.

1. The border of an *intestinal epithelial cell* is seen here (see also **B**). There are **microfilaments** (**a**) passing from the interior of the cell out into the microvilli. The filaments are firmly held together by **spectrin** (**b**), an associated protein, and they are anchored to **intermediate filaments** (**c**).

2. Only **microtubules** are seen in this *fibroblast cell.* They originate from the microtubule organizing center (centrosome) and radiate out as far as the plasma membrane.

3. **Keratin filaments** are visible here in an *epithelial cell.* Keratin fibers belong to the group of **intermediate filaments** (see pp. 70, 204; **d** = nucleus).

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A. Microfilaments and intermediate filaments

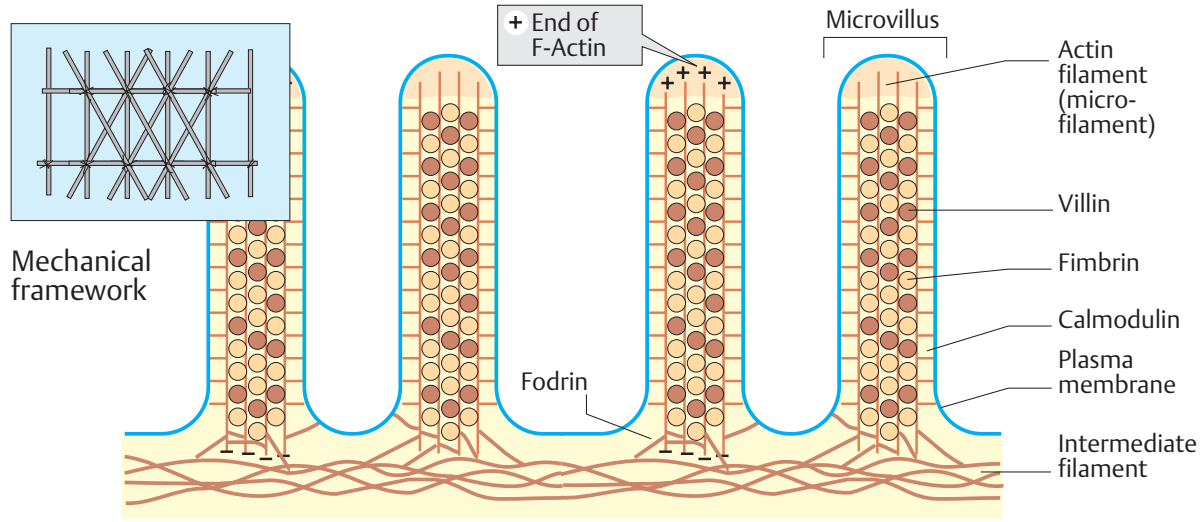

B. Microtubules

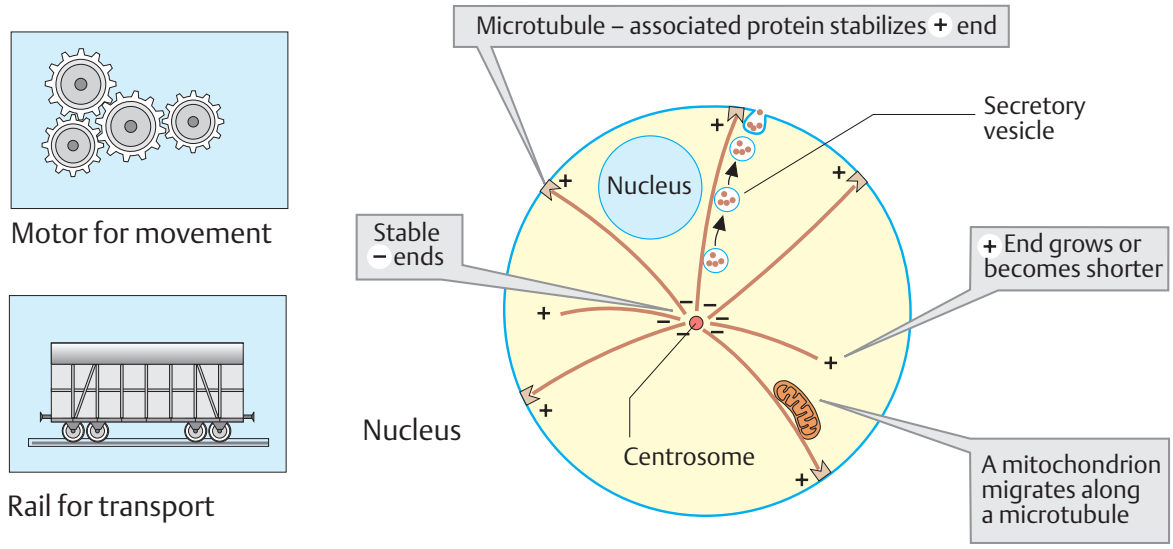

C. Architecture

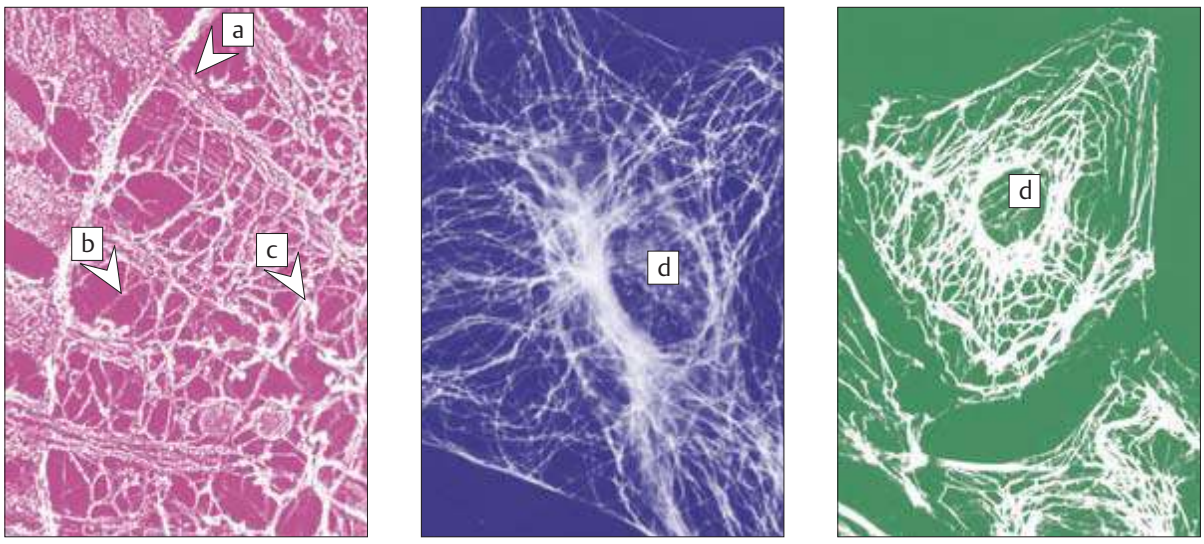

1. Microfilaments **2.** Microtubules **3.** Intermediate filaments

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Nucleus

A. Nucleus ●

The nucleus is the largest organelle in the eukaryotic cell. With a diameter of about 10 μm, it is easily recognizable with the light microscope. This is the location for *storage, replication,* and *expression* of genetic information.

The nucleus is separated from the cytoplasm by the **nuclear envelope**, which consists of the **outer** and **inner nuclear membranes**. Each of the two nuclear membranes has two layers, and the membranes are separated from each other by the **perinuclear space**. The outer nuclear membrane is continuous with the rough endoplasmic reticulum and is covered with ribosomes. The inner side of the membrane is covered with a protein layer (the nuclear lamina), in which the nuclear structures are anchored.

The nucleus contains almost all of the cell's **DNA** (around 1% of which is mitochondrial DNA). Together with histones and structural proteins, the nuclear DNA forms the **chromatin** (see p. 238). It is only during cell division that chromatin condenses into *chromosomes,* which are also visible with the light microscope. During this phase, the nuclear membrane temporarily disintegrates.

During the phase between cell divisions, the *interphase,* it is possible to distinguish between the more densely packed **heterochromatin** and loose **euchromatin** using an electron microscope. Active *transcription* of DNA into mRNA takes place in the region of the euchromatin. A particularly electron-dense region is noticeable in many nuclei—the **nucleolus** (several nucleoli are sometimes present). The DNA in the nucleolus contains numerous copies of the genes for rRNAs (see p. 242). They are constantly undergoing transcription, leading to a high local concentration of RNA.

B. Nuclear pores ◑

The exchange of substances between the nucleus and the cytoplasm is mediated by **pore complexes** with complicated structures, which traverse the nuclear membrane. The nuclear pores consist of numerous proteins that form several connected rings of varying diameter. Low-molecular structures and small proteins can enter the nucleus without difficulty. By contrast, larger proteins (over 40 kDa) can only pass through the nuclear pores if they carry a **nuclear localization sequence** consisting of four successive basic amino acids inside their peptide chains (see p. 228). mRNAs and rRNAs formed in the nucleus cross the pores into the cytoplasm as complexes with proteins (see below).

C. Relationships between the nucleus and cytoplasm ◑

Almost all of the RNA in the cell is synthesized in the nucleus. In this process, known as **transcription**, the information stored in DNA is transcribed into RNA (see p. 242). As mentioned above, *ribosomal RNA* (rRNA) is mainly produced in the nucleolus, while *messenger* and *transfer RNA* (mRNA and tRNA) are formed in the region of the euchromatin. Enzymatic duplication of DNA—**replication**—also only takes place in the nucleus (see p. 240).

The nucleotide components required for transcription and replication have to be imported into the nucleus from the cytoplasm. Incorporation of these components into RNA leads to primary products, which are then altered by cleavage, excision of introns, and the addition of extra nucleotides (**RNA maturation**; see p. 242). It is only once these process have been completed that the RNA molecules formed in the nucleus can be exported into the cytoplasm for protein synthesis (**translation**; see p. 250).

The nucleus is not capable of synthesizing proteins. All of the nuclear proteins therefore have to be imported—the *histones* with which DNA is associated in chromatin, and also the so–called *non–histone proteins* (DNA polymerases and RNA polymerases, auxiliary and structural proteins, transcription factors, and ribosomal proteins). Ribosomal RNA (rRNA) already associates with proteins in the nucleolus to form ribosome precursors.

A special metabolic task carried out by the nucleus is **biosynthesis of NAD^+**. The immediate precursor of this coenzyme, *nicotinamide mononucleotide* (NMN^+), arises in the cytoplasm and is then transported into the nucleolus, where it is enzymatically converted into the dinucleotide NAD^+. Finally, NAD^+ then returns to the cytoplasm.

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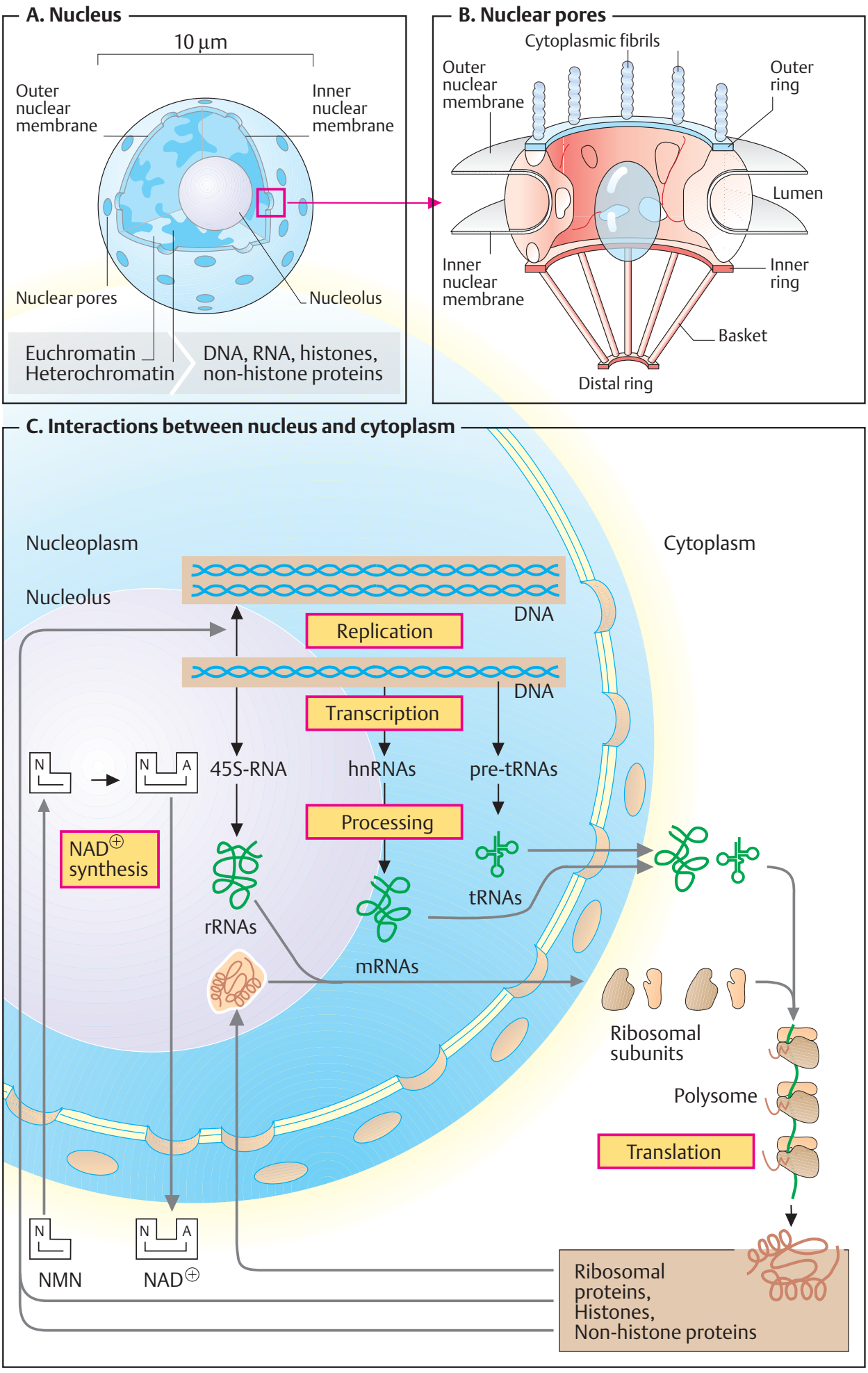

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Structure and functions

A. Mitochondrial structure ◑

Mitochondria are bacteria-sized organelles (about 1 × 2 μm in size), which are found in large numbers in almost all eukaryotic cells. Typically, there are about 2000 mitochondria per cell, representing around 25% of the cell volume. Mitochondria are enclosed by two membranes—a smooth **outer** membrane and a markedly folded or tubular **inner mitochondrial membrane**, which has a large surface and encloses the **matrix space**. The folds of the inner membrane are known as **cristae**, and tube-like protrusions are called **tubules**. The **intermembrane space** is located between the inner and the outer membranes.

The number and shape of the mitochondria, as well as the numbers of cristae they have, can differ widely from cell type to cell type. Tissues with intensive oxidative metabolism—e.g., heart muscle—have mitochondria with particularly large numbers of cristae. Even within one type of tissue, the shape of the mitochondria can vary depending on their functional status. Mitochondria are mobile, plastic organelles.

Mitochondria probably developed during an early phase of evolution from aerobic bacteria that entered into symbiosis with primeval anaerobic eukaryotes. This **endosymbiont theory** is supported by many findings. For example, mitochondria have a ring-shaped DNA (four molecules per mitochondrion) and have their own ribosomes. The mitochondrial genome became smaller and smaller during the course of evolution. In humans, it still contains 16 569 base pairs, which code for two rRNAs, 22 tRNAs, and 13 proteins. Only these 13 proteins (mostly subunits of respiratory chain complexes) are produced in the mitochondrion. All of the other mitochondrial proteins are coded by the nuclear genome and have to be imported into the mitochondria after translation in the cytoplasm (see p. 228). The mitochondrial envelope consisting of two membranes also supports the endosymbiont theory. The inner membrane, derived from the former symbiont, has a structure reminiscent of prokaryotes. It contains the unusual lipid cardiolipin (see p. 50), but hardly any cholesterol (see p. 216).

Both mitochondrial membranes are very rich in proteins. **Porins** (see p. 214) in the outer membrane allow small molecules (< 10 kDa) to be exchanged between the cytoplasm and the intermembrane space. By contrast, the inner mitochondrial membrane is completely impermeable even to small molecules (with the exception of O_2, CO_2, and H_2O). Numerous **transporters** in the inner membrane ensure the import and export of important metabolites (see p. 212). The inner membrane also transports **respiratory chain** complexes, **ATP synthase**, and other enzymes. The matrix is also rich in enzymes (see **B**).

B. Metabolic functions ◑

Mitochondria are also described as being the cell's *biochemical powerhouse,* since—through **oxidative phosphorylation** (see p. 112)—they produce the majority of cellular ATP. **Pyruvate dehydrogenase** (PDH), the **tricarboxylic acid cycle**, β-**oxidation** of fatty acids, and parts of the **urea cycle** are located in the matrix. The **respiratory chain**, **ATP synthesis**, and enzymes involved in **heme biosynthesis** (see p. 192) are associated with the inner membrane.

The inner membrane itself plays an important part in oxidative phosphorylation. As it is impermeable to protons, the respiratory chain—which pumps protons from the matrix into the intermembrane space via complexes I, III, and IV—establishes a **proton gradient** across the inner membrane, in which the chemical energy released during NADH oxidation is conserved (see p. 126). ATP synthase then uses the energy stored in the gradient to form ATP from ADP and inorganic phosphate. Several of the transport systems are also dependent on the H^+ gradient.

In addition to the endoplasmic reticulum, the mitochondria also function as an intracellular **calcium reservoir**. The mitochondria also play an important role in "programmed cell death"—**apoptosis** (see p. 396).

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A. Mitochondrial structure

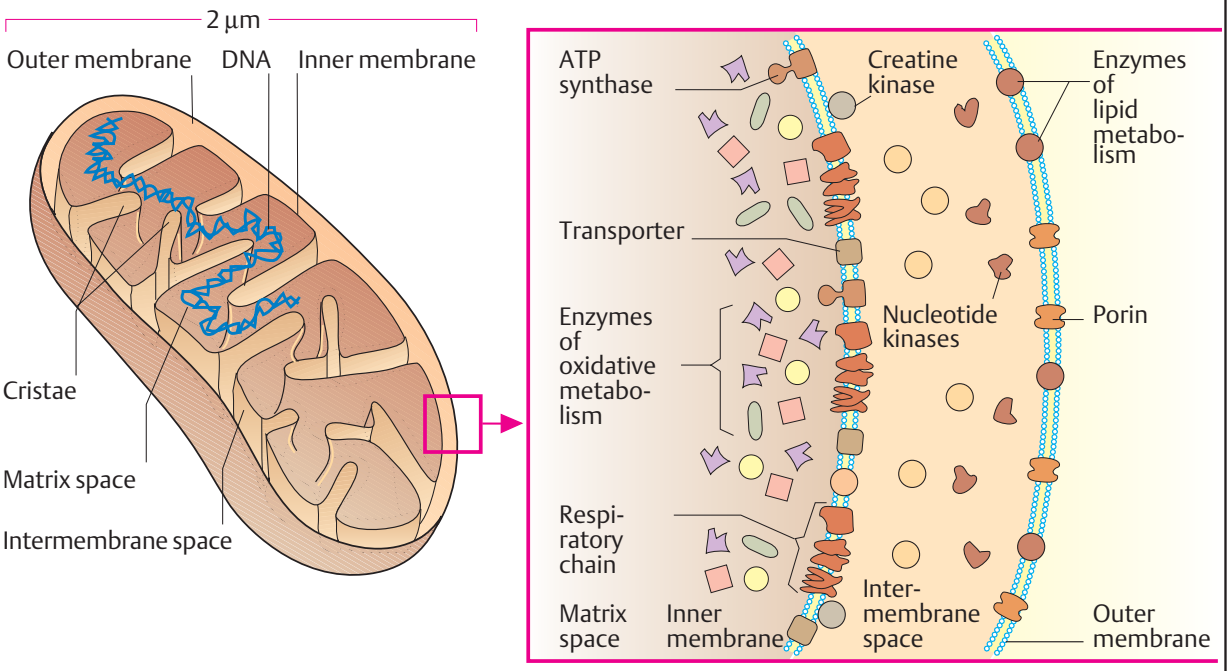

B. Metabolic functions

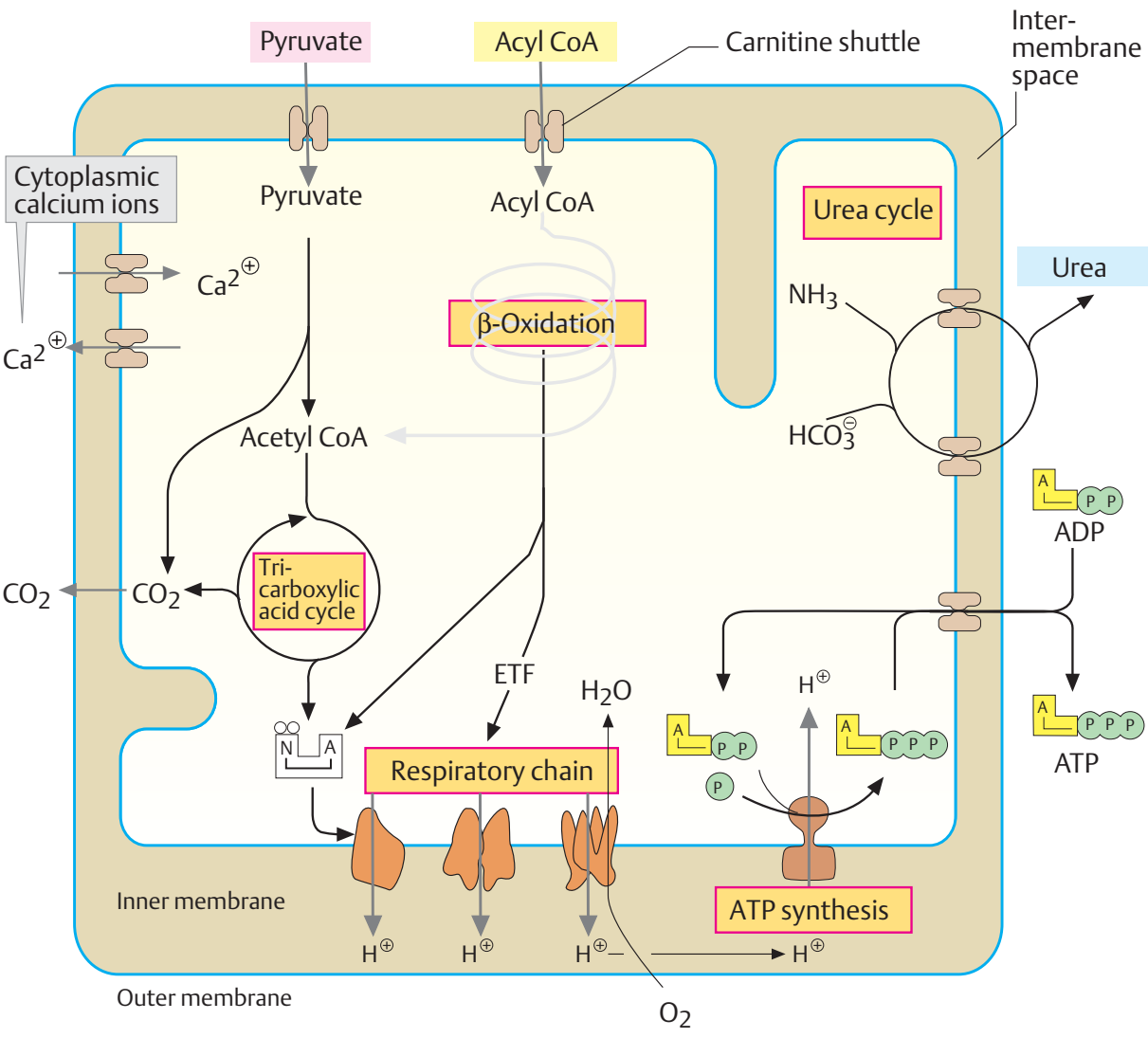

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Transport systems

Mitochondria are surrounded by an inner and an outer membrane (see p. 210). The **outer membrane** contains porins, which allow smaller molecules up to 10 kDa in size to pass. By contrast, the **inner membrane** is also impermeable to small molecules (with the exception of water and the gases O_2, CO_2, and NH_3). All of the other substrates of mitochondrial metabolism, as well as its products, therefore have to be moved through the inner membrane with the help of special **transporters**.

A. Transport systems ◑

The transport systems of the inner mitochondrial membrane use various mechanisms. Metabolites or ions can be transported alone (uniport, **U**), together with a second substance (symport, **S**), or in exchange for another molecule (antiport, **A**). Active transport—i. e., transport coupled to ATP hydrolysis—does not play an important role in mitochondria. The driving force is usually the **proton gradient** across the inner membrane (blue star) or the general membrane potential (red star; see p. 126).

The **pyruvate** (left) formed by glycolysis in the cytoplasm is imported into the matrix in antiport with OH^-. The OH^- ions react in the intermembrane space with the H^+ ions abundantly present there to form H_2O. This maintains a concentration gradient of OH^-. The import of **phosphate** ($H_2PO_4^-$) is driven in a similar way. The exchange of the **ATP** formed in the mitochondrion for **ADP** via an *adenine nucleotide translocase* (center) is also dependent on the H^+ gradient. ATP with a quadruple negative charge is exchanged for ADP with a triple negative charge, so that overall one negative charge is transported into the H^+-rich intermembrane space. The import of malate by the *tricarboxylate transporter*, which is important for the malate shuttle (see **B**) is coupled to the export of citrate, with a net export of one negative charge to the exterior again. In the opposite direction, malate can leave the matrix in antiport for phosphate. When Ca^{2+} is imported (right), the metal cation follows the membrane potential. An electroneutral antiport for two H^+ or two Na^+ serves for Ca^{2+} export.

B. Malate and glycerophosphate shuttles ◑

Two systems known as "shuttles" are available to allow the **import of reducing equivalents** that arise from glycolysis in the cytoplasm in the form of $NADH+H^+$. There is no transporter in the inner membrane for $NADH+H^+$ itself.

In the **malate shuttle** (left)—which operates in the heart, liver, and kidneys, for example—oxaloacetic acid is reduced to malate by malate dehydrogenase (MDH, [2a]) with the help of $NADH+H^+$. In antiport for 2-oxoglutarate, malate is transferred to the matrix, where the mitochondrial isoenzyme for MDH [2b] regenerates oxaloacetic acid and $NADH+H^+$. The latter is reoxidized by complex I of the respiratory chain, while oxaloacetic acid, for which a transporter is not available in the inner membrane, is first transaminated to aspartate by aspartate aminotransferase (AST, [3a]). Aspartate leaves the matrix again, and in the cytoplasm once again supplies oxaloacetate for step [2a] and glutamate for return transport into the matrix [3b]. On balance, only $NADH+H^+$ is moved from the cytoplasm into the matrix; ATP is not needed for this.

The **glycerophosphate shuttle** (right) was discovered in insect muscle, but is also active in the skeletal musculature and brain in higher animals. In this shuttle, $NADH+H^+$ formed in the cytoplasm is used to reduce glycerone 3-phosphate, an intermediate of glycolysis (see p. 150) to glycerol 3-phosphate. Via porins, this enters the intermembrane space and is oxidized again there on the exterior side of the inner membrane by the flavin enzyme *glycerol 3-phosphate dehydrogenase* back into glycerone 3-phosphate. The reducing equivalents are passed on to the respiratory chain via **ubiquinone (coenzyme Q)**.

The **carnitine shuttle** for transporting acyl residues into the mitochondrial matrix is discussed on p. 164.

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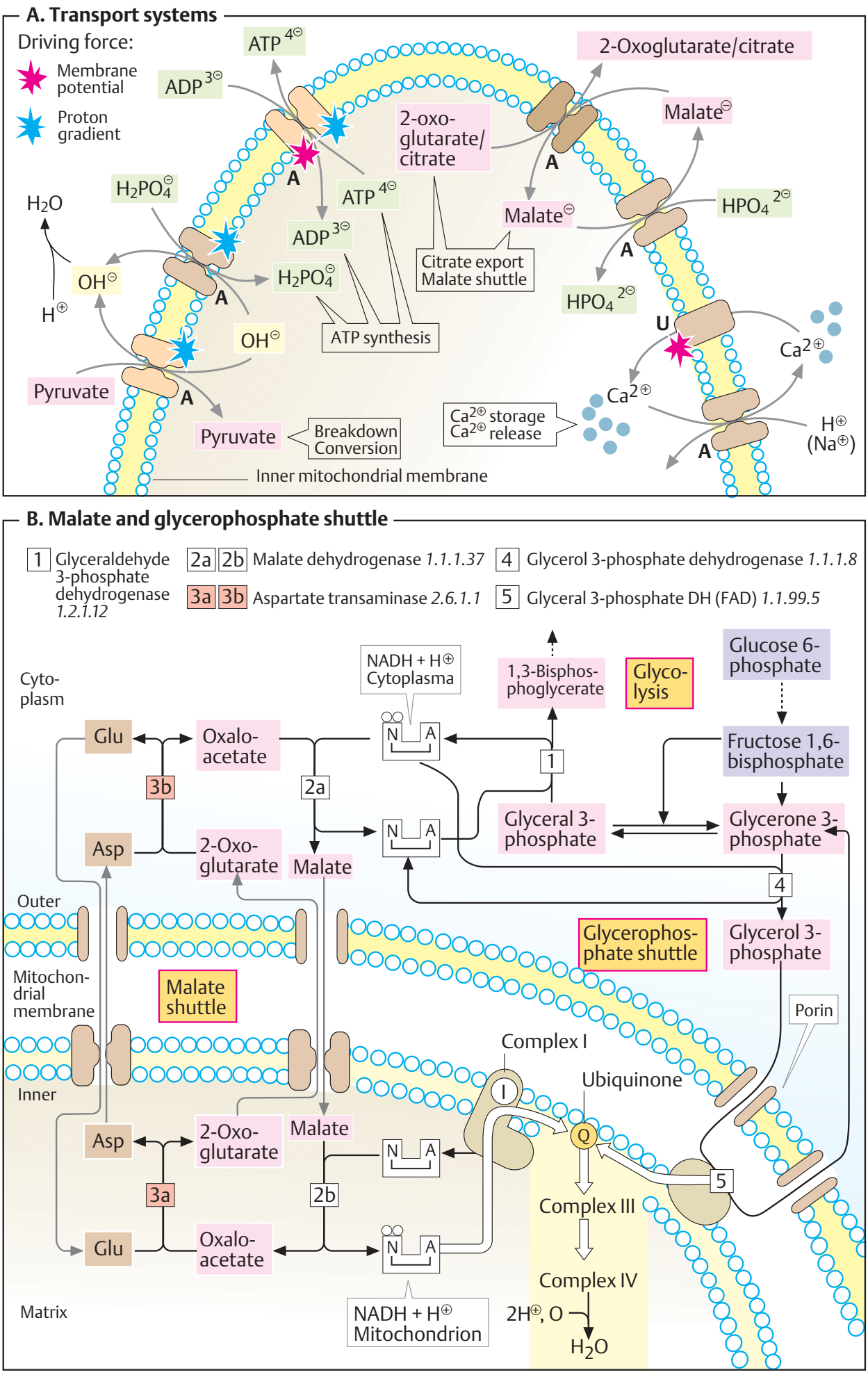

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Structure and components

A. Structure of the plasma membrane ◑

All biological membranes are constructed according to a standard pattern. They consist of a continuous **bilayer of amphipathic lipids** approximately 5 nm thick, into which **proteins** are embedded. In addition, some membranes also carry **carbohydrates** (mono- and oligosaccharides) on their exterior, which are bound to lipids and proteins. The proportions of lipids, proteins, and carbohydrates differ markedly depending on the type of cell and membrane (see p. 216).

Membrane lipids are strongly *amphipathic molecules* with a polar hydrophilic "head group" and an apolar hydrophobic "tail." In membranes, they are primarily held together by the hydrophobic effect (see p. 28) and weak Van der Waals forces, and are therefore mobile relative to each other. This gives membranes a more or less fluid quality.

The **fluidity** of membranes primarily depends on their lipid composition and on temperature. At a specific **transition temperature**, membranes pass from a semicrystalline state to a more fluid state. The double bonds in the alkyl chains of unsaturated acyl residues in the membrane lipids disturb the semicrystalline state. The *higher* the proportion of unsaturated lipids present, therefore, the *lower* the transition temperature. The cholesterol content also influences membrane fluidity. While cholesterol increases the fluidity of semicrystalline, closely-packed membranes, it *stabilizes* fluid membranes that contain a high proportion of unsaturated lipids.

Like lipids, proteins are also mobile within the membrane. If they are not fixed in place by special mechanisms, they float within the lipid layer as if in a two-dimensional liquid; biological membranes are therefore also described as being a "fluid mosaic."

Lipids and proteins can shift easily *within* one layer of a membrane, but switching between the two layers (*"flip/flop"*) is not possible for proteins and is only possible with difficulty for lipids (with the exception of cholesterol). To move to the other side, phospholipids require special auxiliary proteins (translocators, "flipases").

B. Membrane lipids ◑

The illustration shows a model of a small section of a membrane. The **phospholipids** are the most important group of membrane lipids. They include *phosphatidylcholine* (lecithin), *phosphatidylethanolamine*, *phosphatidylserine, phosphatidylinositol,* and *sphingomyelin* (for their structures, see p. 50). In addition, membranes in animal cells also contain **cholesterol** (with the exception of inner mitochondrial membranes). **Glycolipids** (a *ganglioside* is shown here) are mainly found on the outside of the plasma membrane. Together with the *glycoproteins,* they form the exterior coating of the cell (the *glycocalyx*).

C. Membrane proteins ◑

Proteins can be anchored in or on membranes in various ways. **Integral membrane proteins** cross right through the lipid bilayer. The sections of the peptide chains that lie within the bilayer usually consist of 20 to 25 mainly hydrophobic amino acid residues that form a right-handed α-helix.

Type I and II membrane proteins only contain *one* **transmembrane helix** of this type, while type III proteins contain several. Rarely, type I and II polypeptides can aggregate to form a type IV transmembrane protein. Several groups of integral membrane proteins—e.g., the porins (see p. 212)—penetrate the membrane with antiparallel β-sheet structures. Due to its shape, this tertiary structure is known as a "β-barrel."

Type V and VI proteins carry **lipid anchors.** These are fatty acids (palmitic acid, myristic acid), isoprenoids (e.g., farnesol), or glycolipids such as glycosyl phosphatidylinositol (GPI) that are covalently bound to the peptide chain.

Peripheral membrane proteins are associated with the head groups of phospholipids or with another integral membrane protein (not shown).

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A. Structure of the plasma membrane

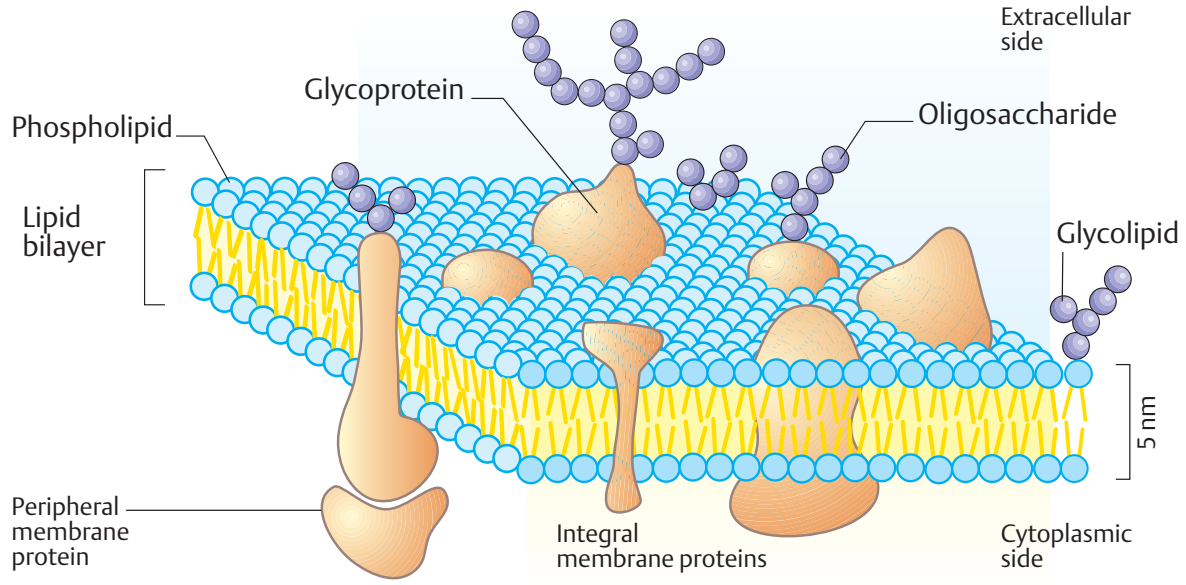

B. Membrane lipids

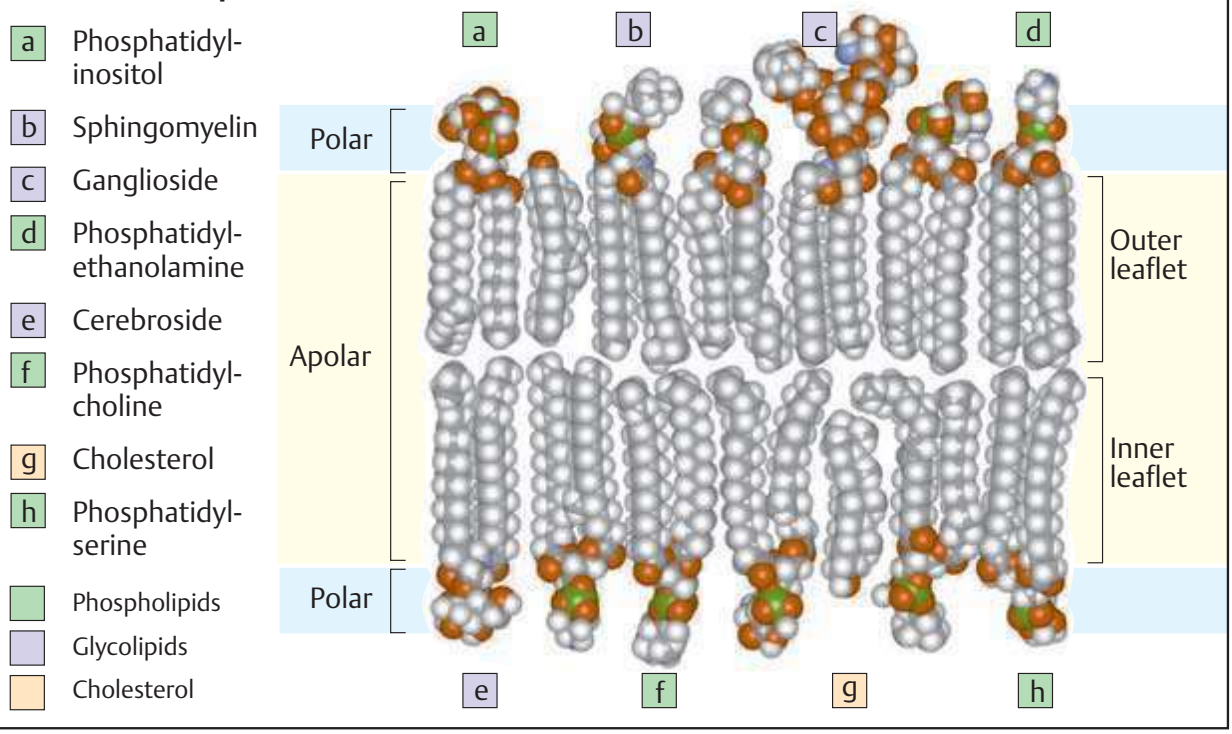

C. Membrane proteins

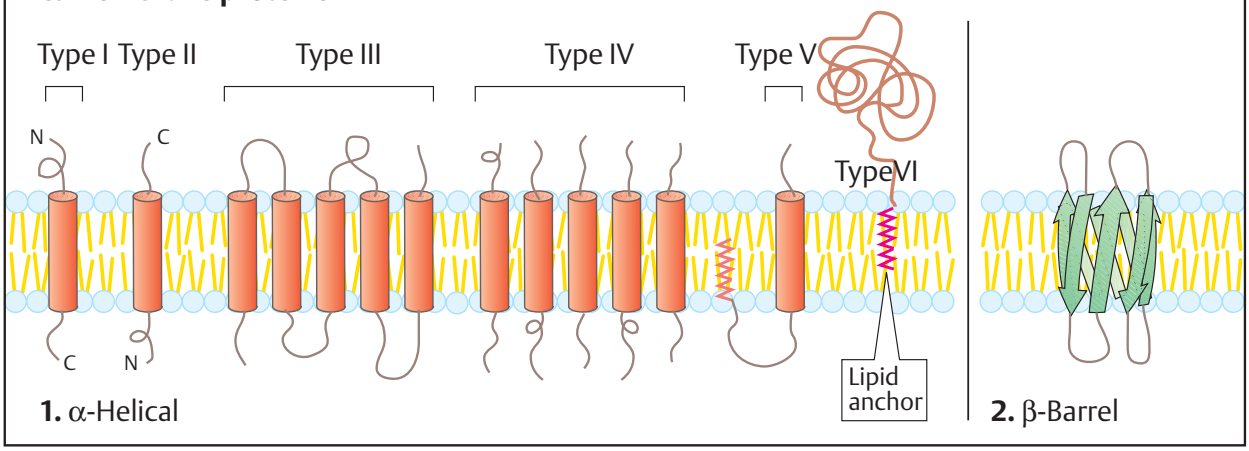

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Functions and composition

The most important membranes in animal cells are the *plasma membrane,* the inner and outer *nuclear membranes,* the membranes of the *endoplasmic reticulum* (ER) and the *Golgi apparatus,* and the inner and outer *mitochondrial membranes*. *Lysosomes, peroxisomes,* and various *vesicles* are also separated from the cytoplasm by membranes. In plants, additional membranes are seen in the plastids and vacuoles. All membranes show *polarity*—i. e., there is a difference in the composition of the inner layer (facing toward the cytoplasm) and the outer layer (facing away from it).

A. Functions of membranes ●

Membranes and their components have the following functions:

1. **Enclosure and insulation** of cells and organelles. The *enclosure* provided by the plasma membrane protects cells from their environment both mechanically and chemically. The plasma membrane is essential for maintaining differences in the concentration of many substances between the intracellular and extracellular compartments.

2. **Regulated transport of substances**, which determines the *internal milieu* and is a precondition for *homeostasis*—i. e., the maintenance of constant concentrations of substances and physiological parameters. Regulated and selective transport of substances through pores, channels, and transporters (see p. 218) is necessary because the cells and organelles are enclosed by membrane systems.

3. **Reception of extracellular signals** and transfer of these signals to the inside of the cell (see pp. 384 ff.), as well as the production of signals.

4. **Enzymatic catalysis** of reactions. Important enzymes are located in membranes at the interface between the lipid and aqueous phases. This is where reactions with apolar substrates occur. Examples include *lipid biosynthesis* (see p. 170) and the *metabolism of apolar xenobiotics* (see p. 316). The most important reactions in energy conversion—i. e., *oxidative phosphorylation* (see p. 140) and *photosynthesis* (see p. 128)—also occur in membranes.

5. **Interactions with other cells** for the purposes of cell fusion and tissue formation, as well as communication with the extracellular matrix.

6. **Anchoring of the cytoskeleton** (see p. 204) to maintain the shape of cells and organelles and to provide the basis for movement processes.

B. Composition of membranes ◑

Biological membranes consist of **lipids**, **proteins**, and **carbohydrates** (see p. 214). These components occur in varying proportions (left). Proteins usually account for the largest proportion, at around half. By contrast, carbohydrates, which are only found on the side facing away from the cytoplasm, make up only a few percent. An extreme composition is seen in *myelin,* the insulating material in nerve cells, three-quarters of which consists of lipids. By contrast, the inner *mitochondrial membrane* is characterized by a very low proportion of lipids and a particularly high proportion of proteins.

When the individual proportions of **lipids** in membranes are examined more closely (right part of the illustration), typical patterns for particular cells and tissues are also found. The illustration shows the diversity of the membrane lipids and their approximate quantitative composition. *Phospholipids* are predominant in membrane lipids in comparison with *glycolipids* and *cholesterol*. Triacylglycerols (neutral fats) are not found in membranes.

Cholesterol is found almost exclusively in eukaryotic cells. Animal membranes contain substantially more cholesterol than plant membranes, in which cholesterol is usually replaced by other sterols. There is no cholesterol at all in prokaryotes (with a few exceptions). The inner mitochondrial membrane of eukaryotes is also low in cholesterol, while it is the only membrane that contains large amounts of cardiolipin. These facts both support the endosymbiotic theory of the development of mitochondria (see p. 210).

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A. Functions of membranes

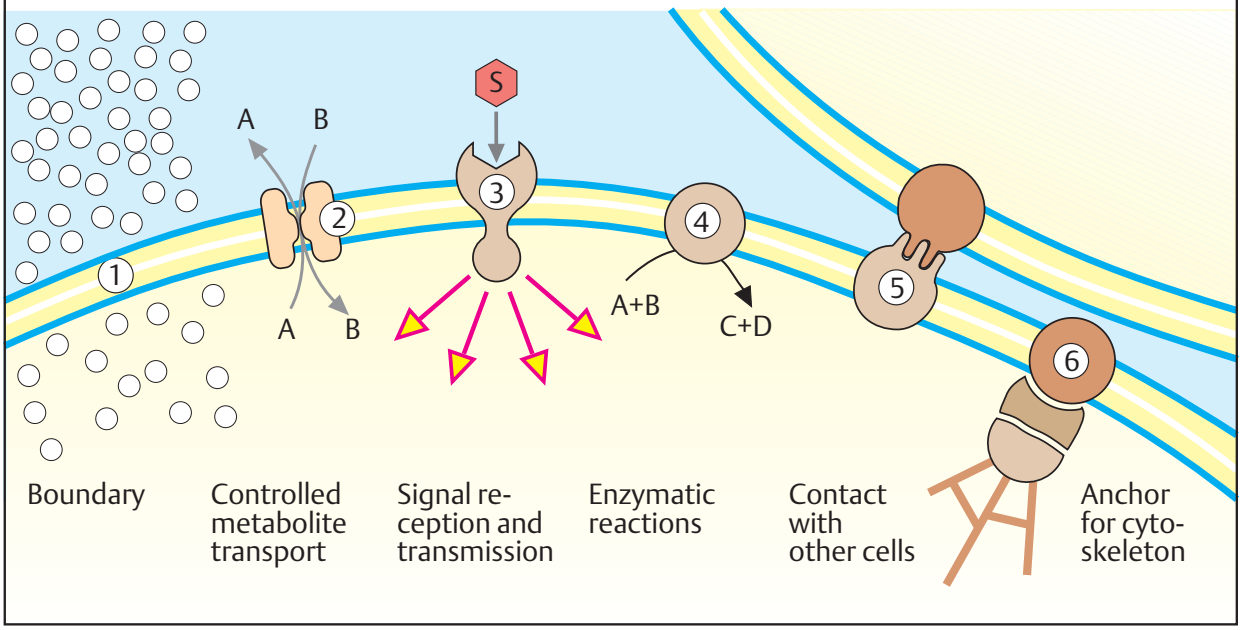

B. Composition of membranes

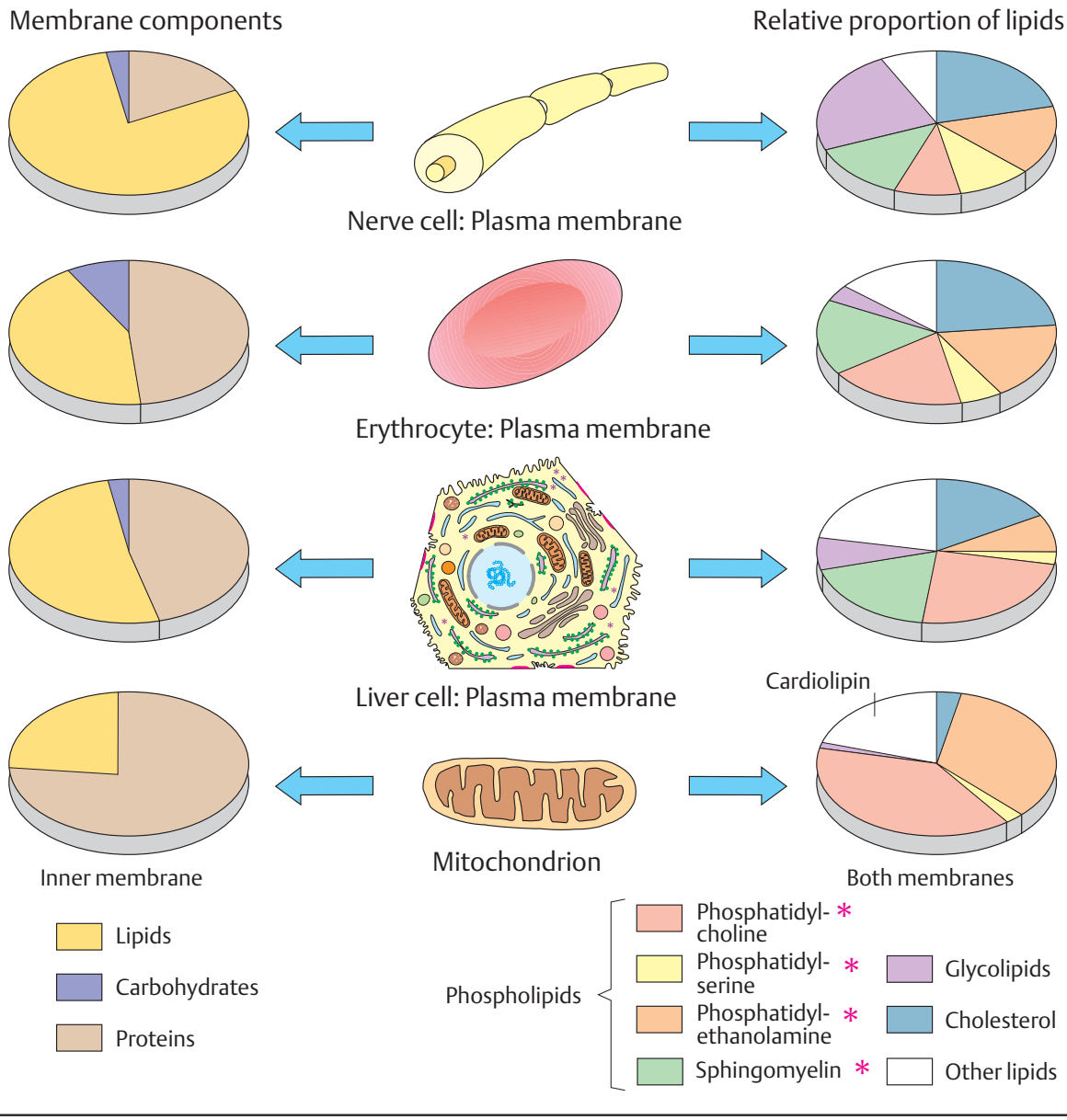

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Transport processes

A. Permeability ●

Only small, uncharged molecules such as gases, water, ammonia, glycerol, or urea are able to pass through biological membranes by *free diffusion*. With increasing **size**, even compounds of this type are no longer able to pass through. Membranes are impermeable to glucose and other sugars, for example.

The **polarity** of a molecule is also important. Apolar substances, such as benzene, ethanol, diethyl ether, and many narcotic agents are able to enter biological membranes easily. By contrast, membranes are impermeable to strongly polar compounds, particularly those that are electrically charged. To be able to take up or release molecules of this type, cells have specialized *channels* and *transporters* in their membranes (see below).

B. Passive and active transport ●

Free diffusion is the simplest form of membrane transport. When it is supported by integral membrane proteins, it is known as **facilitated diffusion** (or facilitated transport).

1. **Channel proteins** have a polar pore through which ions and other hydrophilic compounds can pass. For example, there are channels that allow selected ions to pass (**ion channels**; see p. 222) and **porins** that allow molecules below a specific size to pass in a more or less nonspecific fashion (see p. 212).
2. **Transporters** recognize and bind the molecules to be transported and help them to pass through the membrane as a result of a conformational change. These proteins (permeases) are thus comparable with enzymes—although with the difference that they "catalyze" vectorial transport rather than an enzymatic reaction. Like enzymes, they show a certain *affinity* for each molecule transported (expressed as the dissociation constant, K_d in mol L^{-1}) and a *maximum transport capacity* (V).

Free diffusion and transport processes facilitated by ion channels and transport proteins always follow a *concentration gradient*—i.e., the direction of transport is from the site of higher concentration to the site of lower concentration. In ions, the *membrane potential* also plays a role; the processes are summed up by the term *"electrochemical gradient"* (see p. 126). These processes therefore involve **passive transport**, which runs "downhill" on the slope of a gradient.

By contrast, **active transport** can also run "uphill"—i.e., against a concentration or charge gradient. It therefore requires an input of *energy,* which is usually supplied by the hydrolysis of ATP (see p. 124). The transporter first binds its "cargo" on one side of the membrane. ATP-dependent phosphorylation then causes a conformation change that releases the cargo on the other side of the membrane (see p. 220). A non-spontaneous transport process can also take place through coupling to another active transport process (known as *secondary active transport;* see p. 220).

Using the transport systems in the membranes, cells regulate their volume, internal pH value, and ionic environment. They concentrate metabolites that are important for energy metabolism and biosynthesis, and exclude toxic substances. Transport systems also serve to establish *ion gradients,* which are required for oxidative phosphorylation and stimulation of muscle and nerve cells, for example (see p. 350).

C. Transport processes ◑

Another classification of transport processes is based on the number of particles transported and the direction in which they move. When a *single* molecule or ion passes through the membrane with the help of a channel or transporter, the process is described as a **uniport** (example: the transport of glucose into liver cells). Simultaneous transport of *two different* particles can take place either as a **symport** (example: the transport of amino acids or glucose together with Na^+ ions into intestinal epithelial cells) or as an **antiport**. Ions are often transported in an antiport in exchange for another similarly charged ion. This process is **electroneutral** and therefore more energetically favorable (example: the exchange of HCO_3^- for Cl^- at the erythrocyte membrane).

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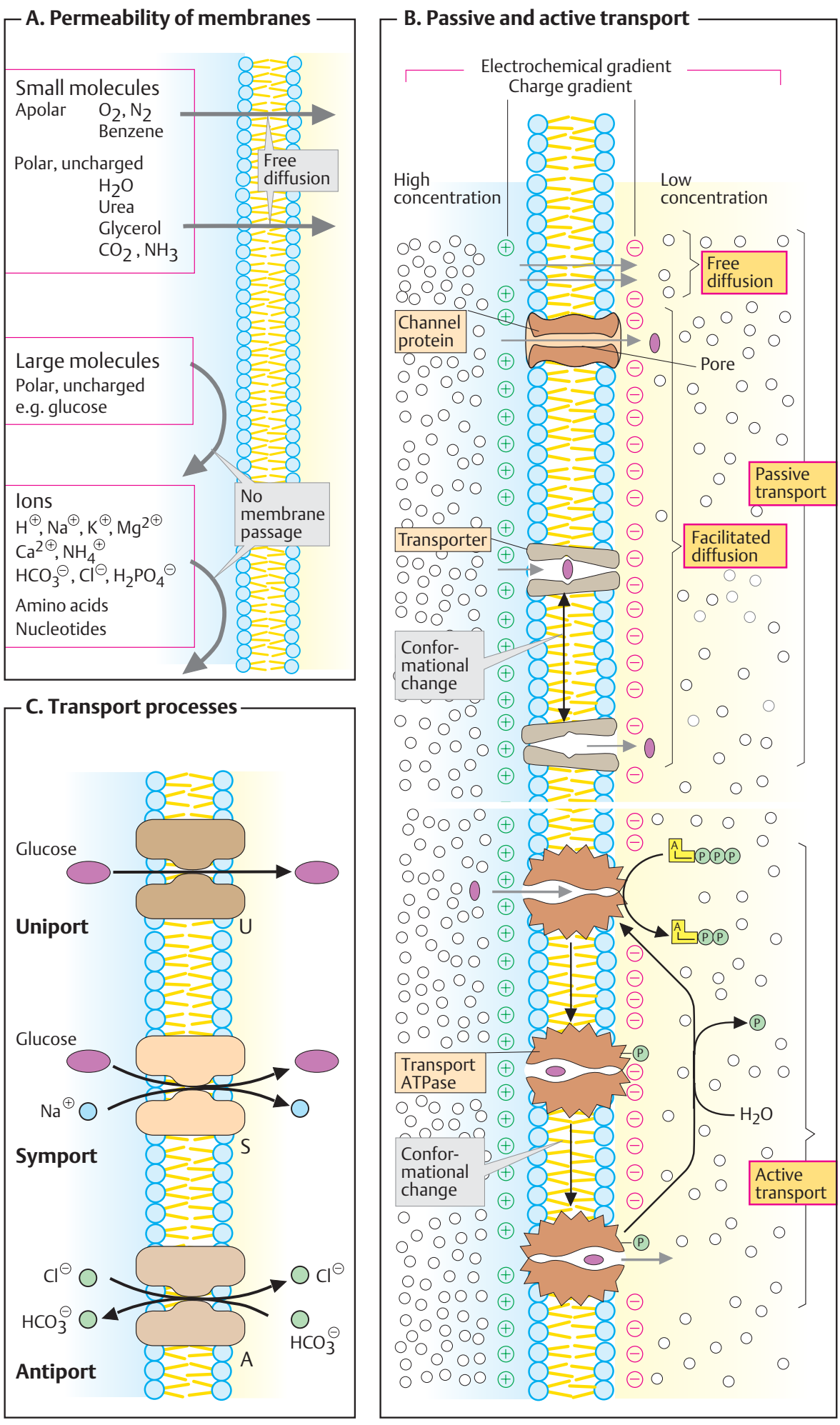

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Transport proteins

Illustrations **B–D** show transporters whose structure has been determined experimentally or established on analogy with other known structures. They all belong to group III of the α-helical transmembrane proteins (see p. 214).

A. Transport mechanisms ◑

Some cells couple the "pure" transport forms discussed on p. 218—i. e., passive transport (**1**) and active transport (**2**)—and use this mechanism to take up metabolites. In **secondary active transport** (**3**), which is used for example by epithelial cells in the small intestine and kidney to take up glucose and amino acids, there is a **symport** (S) located on the luminal side of the membrane, which takes up the metabolite M together with an Na^+ ion. An ATP-dependent Na^+ transporter (Na^+/K^+ ATPase; see p. 350) on the other side keeps the intracellular Na+ concentration low and thus indirectly drives the uptake of M. Finally, a uniport (U) releases M into the blood.

B. Glucose transporter Glut-1 ○

The glucose transporters (Glut) are a family of related membrane proteins with varying distribution in the organs. Glut-1 and Glut-3 have a relatively high af nity for glucose (K_d = 1 mM). They occur in nearly all cells, and ensure continuous glucose uptake. Glut-2 is found in the liver and pancreas. This form has a lower af nity (K_d = 15–20 mM). The rate of glucose uptake by Glut-2 is therefore strongly dependent on the blood glucose level (normally 4–8 mM). Transport by Glut-4 (K_d = 5 mM), which is mainly expressed in muscle and fat cells, is controlled by insulin, which increases the number of transporters on the cell surface (see p. 388). Glut-5 mediates secondary active resorption of glucose in the intestines and kidney (see **A**).

Glut-1 consists of a single peptide chain that spans the membrane with 12 α-helices of different lengths. The glucose is bound by the peptide loops that project on each side of the membrane.

C. Aquaporin-1 ○

Aquaporins help water to pass through biological membranes. They form hydrophilic pores that allow H_2O molecules, but not hydrated ions or larger molecules, to pass through. Aquaporins are particularly important in the kidney, where they promote the reuptake of water (see p. 328). Aquaporin-2 in the renal collecting ducts is regulated by **antidiuretic hormone** (ADH, vasopressin), which via cAMP leads to shifting of the channels from the ER into the plasma membrane.

Aquaporin-1, shown here, occurs in the proximal tubule and in Henle's loop. It contains eight transmembrane helices with different lengths and orientations. The yellow-colored residues form a narrowing that only H_2O molecules can overcome.

D. Sarcoplasmic Ca^{2+} pump ○

Transport ATPases transport cations—they are "ion pumps." ATPases of the **F type**—e. g., mitochondrial ATP synthase (see p. 142)—use H^+ transport for *ATP synthesis.* Enzymes of the **V type**, using up ATP, "pump" protons into lysosomes and other acidic cell compartments (see p. 234). **P type** transport ATPases are particularly numerous. These are ATP-driven cation transporters that undergo covalent phosphorylation during the transport cycle.

The **Ca^{2+} ATPase** shown also belongs to the P type. In muscle, its task is to pump the Ca^{2+} released into the cytoplasm to trigger muscle contraction back into the sarcoplasmic reticulum (SR; see p. 334). The molecule (**1**) consists of a single peptide chain that is folded into various domains. In the transmembrane part, which is formed by numerous α-helices, there are binding sites for two Ca^{2+} ions (blue) ATP is bound to the cytoplasmic N domain (green).

Four different stages can be distinguished in the enzyme's catalytic cycle (**2**). First, binding of ATP to the N domain leads to the uptake of two Ca^{2+} into the transmembrane part (**a**). Phosphorylation of an aspartate residue in the P domain (**b**) and dissociation of ADP then causes a conformation change that releases the Ca^{2+} ions into the SR (**c**). Finally, dephosphorylation of the aspartate residue restores the initial conditions (**d**).

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A. Transport mechanisms

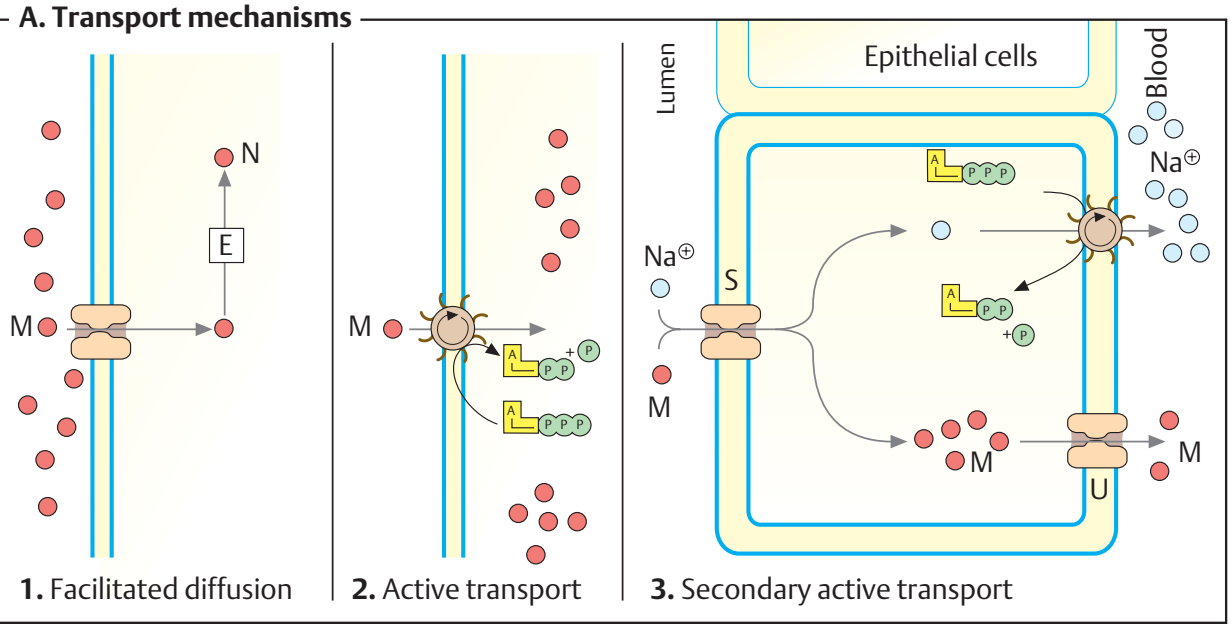

B. Glucose transporter Glut-1

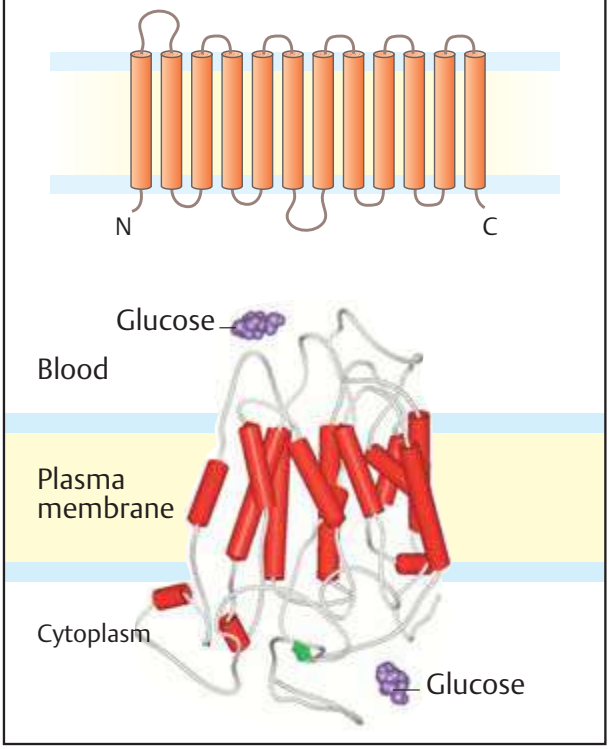

C. Aquaporin-1

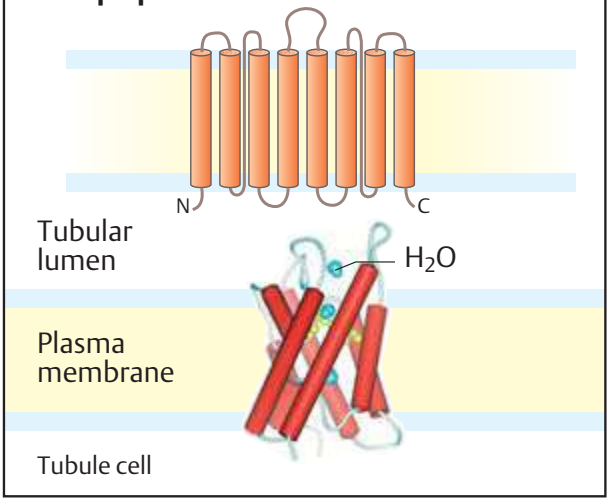

D. Sarcoplasmic $Ca^{2\oplus}$ pump

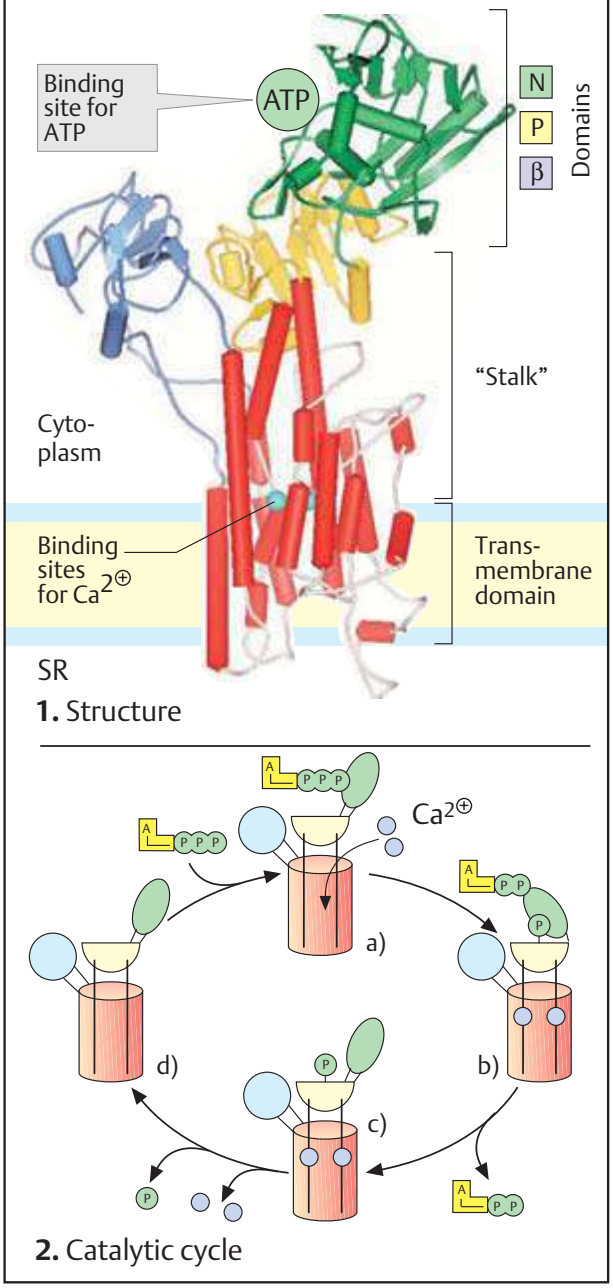

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Ion channels

Ion channels facilitate the diffusion of ions through biological membranes. Some ion channels open and close depending on the membrane potential (**voltage-gated channels, A**) or in response to specific ligands (**ligand-gated channels, B**). Other channels operate passively. In these cases, transport depends only on the concentration gradient (**C**).

A. Voltage-gated Na^+ channel ○

Voltage-gated Na^+ channels play a decisive part in the conduction of electrical impulses in the nervous system (see p. 350). These channels open when the membrane potential in their environment reverses. Due to the high equilibrium potential for Na^+ (see p. 126), an inflow of Na^+ ions takes place, resulting in local **depolarization** of the membrane, which propagates by activation of neighboring voltage-dependent Na^+ channels. A spreading depolarization wave of this type is known as an **action potential** (see p. 350). Externally directed K^+ channels are involved in the repolarization of the membrane. In their functioning, these resemble the much more simply structured K^+ channels shown in **C**. The Ca^{2+} channels that trigger exocytosis of vesicles (see p. 228) are also controlled by the action potential.

The voltage-gated Na^+ channels in higher animals are large complexes made up of several subunits. The α-subunit shown here mediates Na^+ transport. It consists of a very long peptide chain (around 2000 amino acid residues), which is folded into four domains, each with six transmembrane helices (left). The S6 helices of all the domains (blue) together form a centrally located hydrophilic pore which can be made narrow or wide depending on the channel's functional status. The six S4 helices (green) function as voltage sensors.

The current conception of the way in which the opening and closing mechanism functions is shown in a highly simplified form on the right. For the sake of clarity, only one of the four domains (domain IV) is shown. The S4 helices contain several positively charged residues. When the membrane is polarized (**a**), the surplus negative charges on the inner side keep the helix in the membrane. If this attraction is removed as a result of local depolarization, the S4 helices are thought to snap upwards like springs and thus open the central pore (**b**).

B. Nicotinic acetylcholine receptor ○

Many receptors for neurotransmitters function as ligand-gated channels for Na^+, K^+ and/or Ca^{2+} ions (see p. 354). The ones that have been studied in the greatest detail are the nicotinic receptors for **acetylcholine** (see p. 352). These consist of five separate but structurally closely related subunits. Each forms four transmembrane helices, the second of which is involved in the central pore in each case. The type of monomer and its arrangement in the complex is not identical in all receptors of this type. In the neuromuscular junction (see p. 334), the arrangement $\alpha\beta\gamma\alpha\delta$ is found (**1**).

In the interior of the structure, acetylcholine binds to the two α-subunits and thus opens the pore for a short time (1–2 ms). Negatively charged residues are arranged in three groups in a ring shape inside it. They are responsible for the receptor's ion specificity. It is thought that binding of the neurotransmitter changes the position of the subunits in such a way that the pore expands (**3**). The bound acetylcholine dissociates again and is hydrolytically inactivated (see p. 356). The receptor is thus able to function again.

C. K^+ channel in *Streptomyces lividans* ○

The only detailed structures of ion channels established so far are those of potassium channels like that of an outwardly directed K^+ channel in the bacterium *Streptomyces lividans*. It consists of four identical subunits (blue, yellow, green, and red), each of which contains two long α-helices and one shorter one. In the interior of the cell (bottom), the K^+ ions (violet) enter the structure's central channel. Before they are released to the outside, they have to pass through what is known as a "selectivity filter." In this part of the channel, several C=O groups in the peptide chain form a precisely defined opening that is only permeable to non-hydrated K^+ ions.

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A. Voltage-gated $Na^{\oplus}$ channel

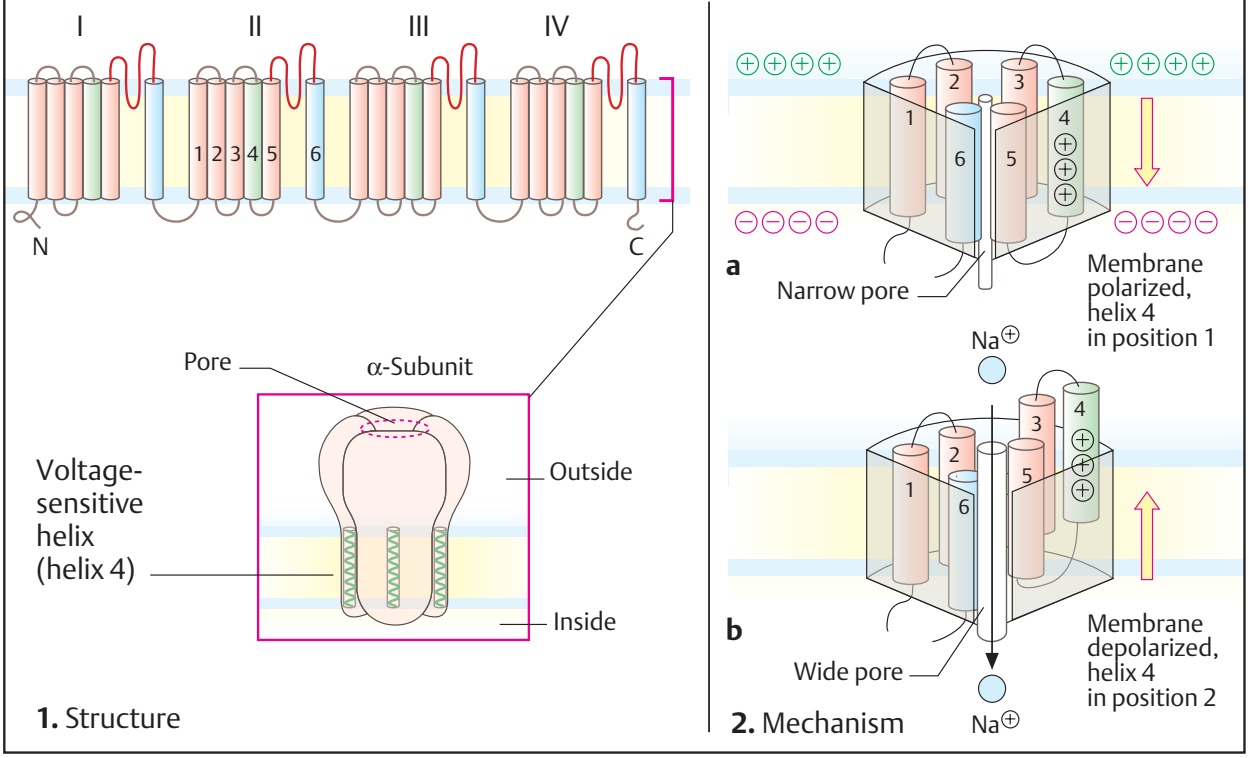

B. Nicotinic acetylcholine receptor

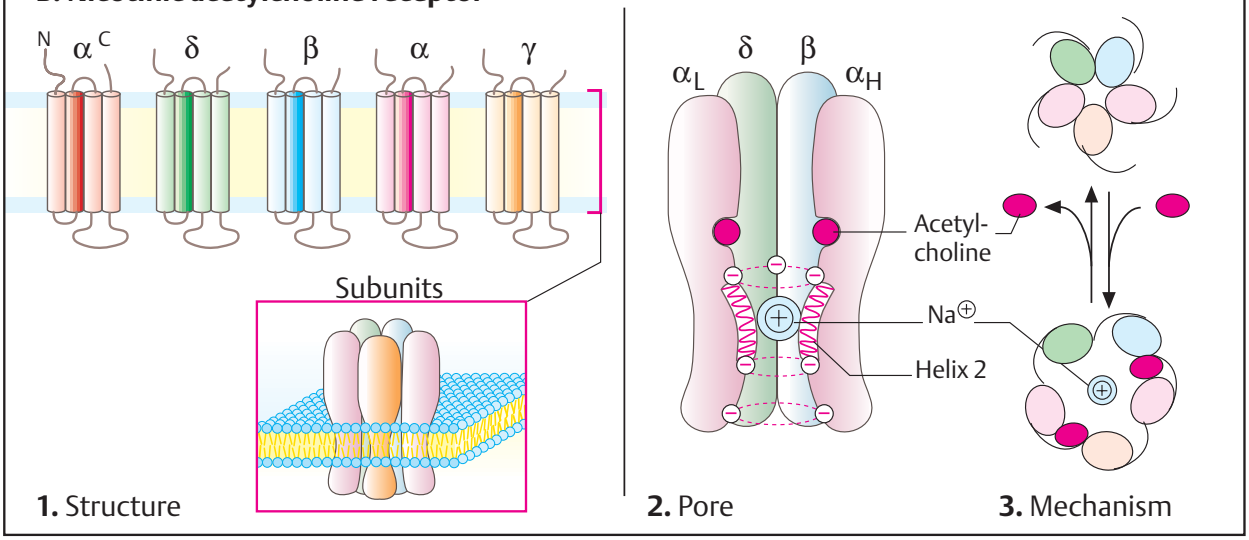

C. $K^{\oplus}$ channel in *Streptomyces lividans*

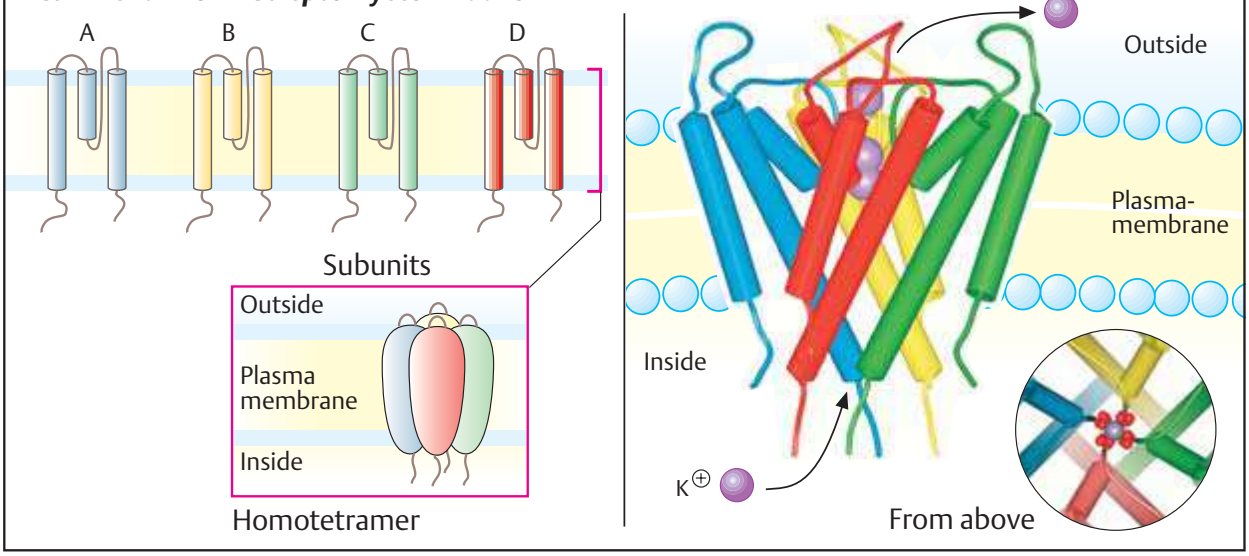

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Membrane receptors

To receive and pass on chemical or physical signals, cells are equipped with **receptor proteins**. Many of these are integral membrane proteins in the plasma membrane, where they receive signals from their surroundings. Other receptor proteins are located in intercellular membranes. The receptors for lipophilic hormones are among the few that function in a soluble form. They regulate gene transcription in the nucleus (see p. 378).

A. Principle of receptor action ●

Membrane-located receptors can be divided into three parts, which have different tasks. The **receptor domain** reacts specifically to a given signal. Signals of this type can be of a purely physical nature. For example, many organisms react to light. In this way, plants adapt growth and photosynthesis to light conditions, while animals need light receptors for visual processing (**C**; see p. 358). Mechanoreceptors are involved in hearing and in pressure regulation, among other things. Channels that react to action potentials (see p. 350) can be regarded as receptors for electrical impulses.

However, most receptors do not react to physical stimuli, but rather to signal molecules. Receptors for these chemical signals contain binding sites in the receptor domain that are complementary to each ligand. In this respect, they resemble enzymes (see p. 94). As the **effector domain** of the receptor is usually separated by a membrane, a mechanism for **signal transfer** between the domains is needed. Little is yet known regarding this. It is thought that conformation changes in the receptor protein play a decisive part. Some receptors dimerize after binding of the ligand, thereby bringing the effector domains of two molecules into contact (see p. 392).

The way in which the effector works differs from case to case. By binding or interconversion, many receptors activate special **mediator proteins**, which then trigger a signal cascade (signal transduction; see p. 384). Other receptors function as **ion channels**. This is particularly widespread in receptors for neurotransmitters (see p. 354).

B. Insulin receptor ◑

The receptor for the hormone insulin (see p. 76) belongs to the family of **1-helix receptors**.

These molecules span the membrane with only one α-helix. The subunits of the dimeric receptor (red and blue) each consist of two polypeptides (α and β) bound by disulfide bonds. The α-chains together bind the insulin, while the β-chains contain the transmembrane helix and, at the C-terminus, domains with **tyrosine kinase** activity. In the activated state, the kinase domains phosphorylate themselves and also mediator proteins (receptor substrates) that set in motion cascades of further phosphorylations (see pp. 120 and 388).

C. 7-helix receptors ◑

A large group of receptors span the membrane with α-helices seven times. These are known as **7-helix receptors**. Via their effector domains, they bind and activate trimeric proteins, which in turn bind and hydrolyze GTP and are therefore called G proteins. Most G proteins, in turn, activate or inhibit enzymes that create secondary signaling molecules (**second messengers**; see p. 386). Other G proteins regulate ion channels. The illustration shows the complex of the light receptor **rhodopsin**, with the associated G protein **transducin** (see p. 358). The GTP-binding α-subunit (green) and the γ-subunit (violet) of transducin are anchored in the membrane via lipids (see p. 214). The β-subunit is shown in detail on p. 72.

D. T-cell receptor ◑

The cells of the immune system communicate with each other particularly intensively. The **T-cell receptor** plays a central role in the activation of T lymphocytes (see p. 296). The cell at the top has been infected with a virus, and it indicates this by presenting a viral peptide (violet) with the help of a class I **MHC protein** (yellow and green). The combination of the two molecules is recognized by the dimeric T-cell receptor (blue) and converted into a signal that activates the T cell (bottom) and thereby enhances the immune response to the virus.

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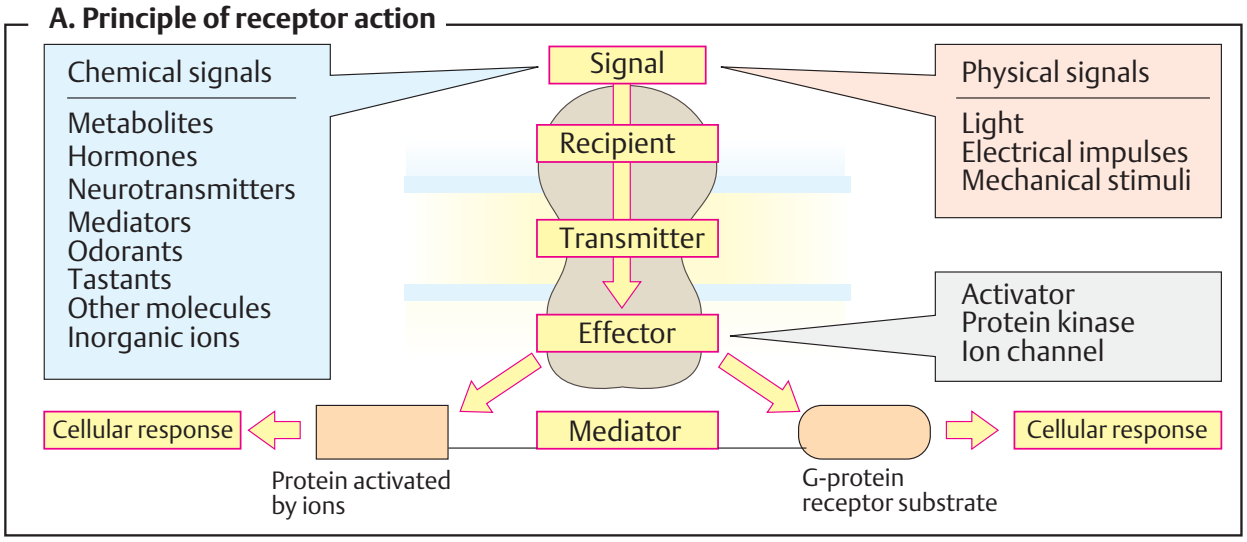

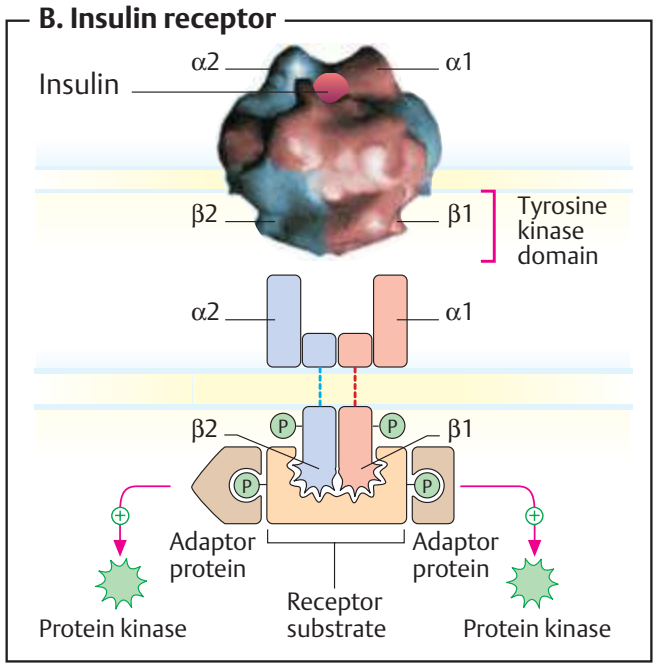

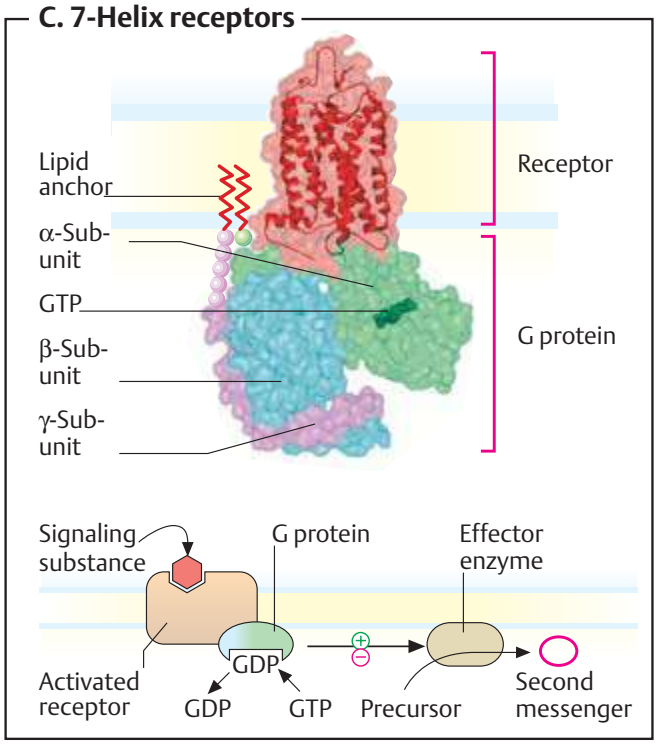

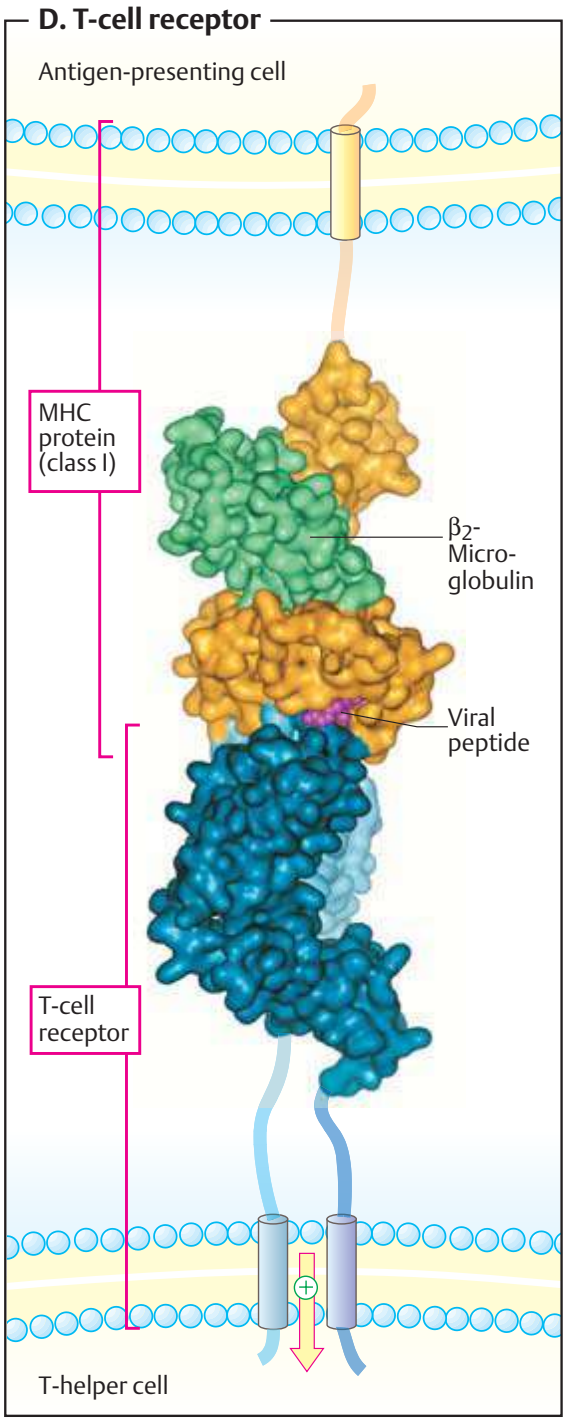

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ER: structure and function

The endoplasmic reticulum (ER) is an extensive closed membrane system consisting of tubular and saccular structures. In the area of the nucleus, the ER turns into the external nuclear membrane. Morphologically, a distinction is made between the **rough ER** (rER) and the **smooth ER** (sER). Large numbers of ribosomes are found on the membranes of the rER, which are lacking on the sER. On the other hand, the sER is rich in membrane-bound **enzymes**, which catalyze partial reactions in the lipid metabolism as well as biotransformations.

A. Rough endoplasmic reticulum and the Golgi apparatus ◑

The **rER** (**1**) is a site of active *protein biosynthesis.* This is where proteins destined for membranes, lysosomes, and export from the cell are synthesized. The remaining proteins are produced in the cytoplasm on ribosomes that are not bound to membranes.

Proteins synthesized at the rER (**1**) are folded and modified after translation (protein maturation; see p. 230). They remain either in the rER as membrane proteins, or pass with the help of transport vesicles (**2**) to the Golgi apparatus (**3**). Transport vesicles are formed by budding from existing membranes, and they disappear again by fusing with them (see p. 228).

The **Golgi apparatus** (**3**) is a complex network, also enclosed, consisting of flattened membrane saccules ("cisterns"), which are stacked on top of each other in layers. Proteins mature here and are sorted and packed. A distinction is made between the *cis, medial,* and *trans* Golgi regions, as well as a *trans* Golgi network (tGN). The *post–translational modification of proteins,* which starts in the ER, continues in these sections.

From the Golgi apparatus, the proteins are transported by vesicles to various targets in the cells—e.g., to lysosomes (**4**), the plasma membrane (**6**), and secretory vesicles (**5**) that release their contents into the extracellular space by fusion with the plasma membrane (**exocytosis**; see p. 228). Protein transport can either proceed continuously (*constitutive*), or it can be *regulated* by chemical signals. The decision regarding which pathway a protein will take and whether its transport will be constitutive or regulated depends on the signal sequences or signal structures that proteins carry with them like address labels (see p. 228). In addition to proteins, the Golgi apparatus also transports membrane lipids to their targets.

B. Smooth endoplasmic reticulum ◑

Regions of the ER that have no bound ribosomes are known as the **smooth endoplasmic reticulum** (sER). In most cells, the proportion represented by the sER is small. A marked sER is seen in cells that have an active lipid metabolism, such as hepatocytes and Leydig cells. The sER is usually made up of branching, closed tubules.

Membrane-located enzymes in the sER catalyze **lipid synthesis**. Phospholipid synthesis (see p. 170) is located in the sER, for example, and several steps in cholesterol biosynthesis (see p. 172) also take place there. In endocrine cells that form *steroid hormones,* a large proportion of the reaction steps involved also take place in the sER (see p. 376).

In the liver's hepatocytes, the proportion represented by the sER is particularly high. It contains enzymes that catalyze so-called **biotransformations**. These are reactions in which apolar foreign substances, as well as endogenous substances—e.g., steroid hormones—are chemically altered in order to inactivate them and/or prepare them for conjugation with polar substances (phase I reactions; see p. 316). Numerous *cytochrome P450 enzymes* are involved in these conversions (see p. 318) and can therefore be regarded as the major molecules of the sER.

The sER also functions as an intracellular **calcium store**, which normally keeps the Ca^{2+} level in the cytoplasm low. This function is particularly marked in the *sarcoplasmic reticulum*, a specialized form of the sER in muscle cells (see p. 334). For release and uptake of Ca^{2+}, the membranes of the sER contain signal-controlled Ca^{2+} channels and energy-dependent Ca^{2+} ATPases (see p. 220). In the lumen of the sER, the high Ca^{2+} concentration is buffered by Ca^{2+}-binding proteins.

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A. Rough endoplasmic reticulum and Golgi apparatus

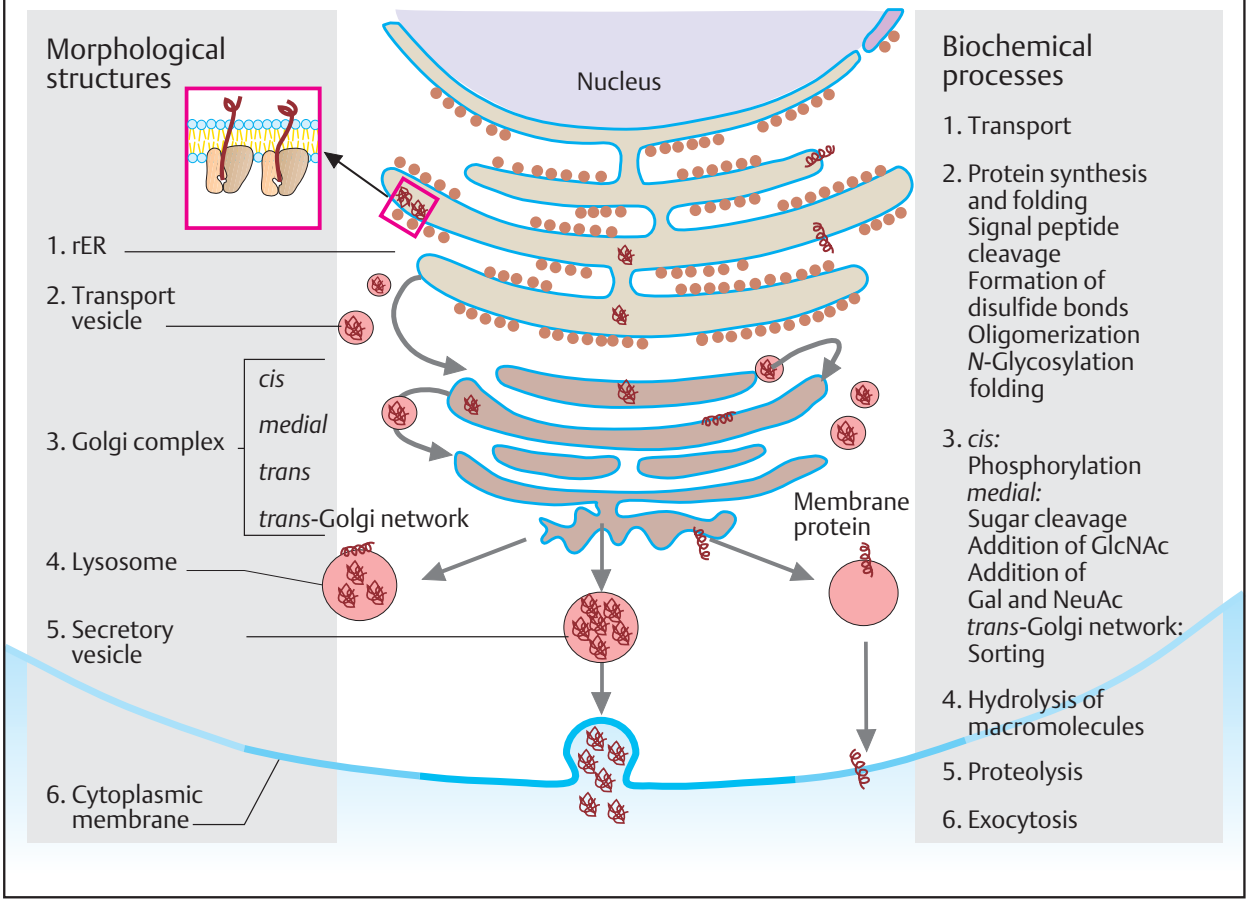

B. Smooth endoplasmic reticulum

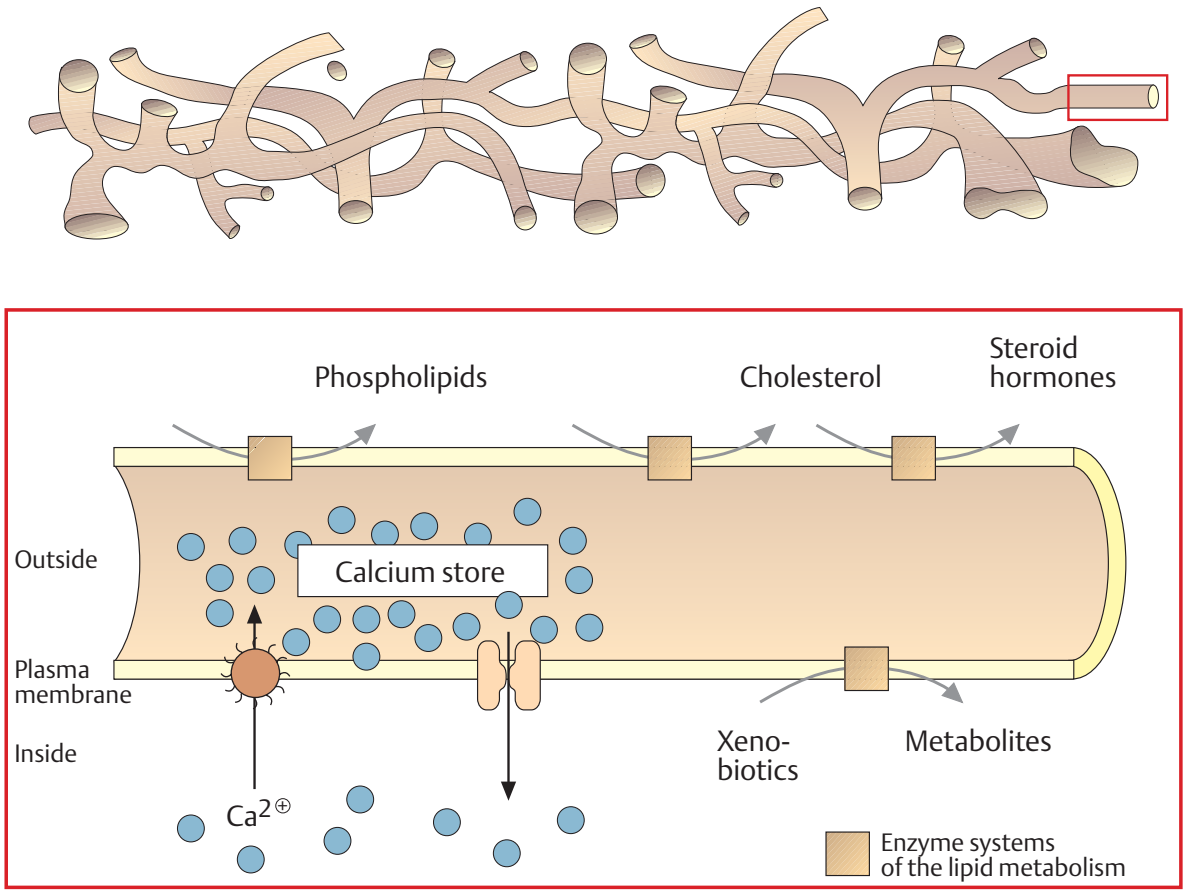

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Protein sorting

A. Protein sorting ◑

The biosynthesis of all proteins starts on free ribosomes (top). However, the paths that the proteins follow soon diverge, depending on which target they are destined for. Proteins that carry a *signal peptide for the ER* (**1**) follow the *secretory pathway* (right). Proteins that do not have this signal follow the *cytoplasmic pathway* (left).

Secretory pathway. Ribosomes that synthesize a protein with a signal peptide for the ER settle on the ER (see p. 228). The peptide chain is transferred into the lumen of the rER. The presence or absence of other signal sequences and signal regions determines the subsequent transport pathway.

Proteins that have *stop-transfer sequences* (**4**) remain as integral membrane proteins in the ER membrane. They then pass into other membranes via vesicular transport (see p. 226). From the rER, their pathway then leads to the Golgi apparatus and then on to the plasma membrane. Proteins destined to remain in the rER—e. g., enzymes—find their way back from the Golgi apparatus to the rER with the help of a *retention signal* (**2**). Other proteins move from the Golgi apparatus to the lysosomes (**3**; see p. 234), to the cell membrane (integral membrane proteins or constitutive exocytosis), or are transported out of the cell (**9;** signal-regulated exocytosis) by secretory vesicles (**8**).

Cytoplasmic pathway. Proteins that do not have a signal peptide for the ER are synthesized in the cytoplasm on free ribosomes, and remain in that compartment. Special signals mediate further transport into the mitochondria (**5**; see p. 232), the nucleus (**6**; see p. 208) or peroxisomes (**7**).

B. Translocation signals ○

Signal peptides are short sections at the N or C terminus, or within the peptide chain. Areas on the protein surface that are formed by various sections of the chain or by various chains are known as **signal regions**. Signal peptides and signal regions are *structural signals* that are usually recognized by *receptors* on organelles (see **A**). They move the proteins, with the help of additional proteins, into the organelles (*selective protein transfer*). Structural signals can also activate *enzymes* that modify the proteins and thereby determine their subsequent fate. Examples include lysosomal proteins (see p. 234) and membrane proteins with lipid anchors (see p. 214).

After they have been used, signal peptides at the N terminus are cleaved off by specific hydrolases (symbol: scissors). In proteins that contain several successive signal sequences, this process can expose the subsequent signals. By contrast, signal peptides that have to be read several times are not cleaved.

C. Exocytosis ○

Exocytosis is a term referring to processes that allow cells to expel substances (e. g., hormones or neurotransmitters) quickly and in large quantities. Using a complex protein machinery, secretory vesicles fuse completely or partially with the plasma membrane and release their contents. Exocytosis is usually *regulated* by chemical or electrical signals. As an example, the mechanism by which neurotransmitters are released from synapses (see p. 348) is shown here, although only the most important proteins are indicated.

The decisive element in exocytosis is the interaction between proteins known as SNAREs that are located on the vesicular membrane (v-SNAREs) and on the plasma membrane (t-SNAREs). In the resting state (**1**), the v-SNARE *synaptobrevin* is blocked by the vesicular protein *synaptotagmin.* When an action potential reaches the presynaptic membrane, voltage-gated Ca^{2+} channels open (see p. 348). Ca^{2+} flows in and triggers the machinery by conformational changes in proteins. Contact takes place between synaptobrevin and the t-SNARE *synaptotaxin* (**2**). Additional proteins known as SNAPs bind to the SNARE complex and allow fusion between the vesicle and the plasma membrane (**3**). The process is supported by the hydrolysis of GTP by the auxiliary protein *Rab.*

The toxin of the bacterium *Clostridium botulinum,* one of the most poisonous substances there is, destroys components of the exocytosis machinery in synapses through enzymatic hydrolysis, and in this way blocks neurotransmission.

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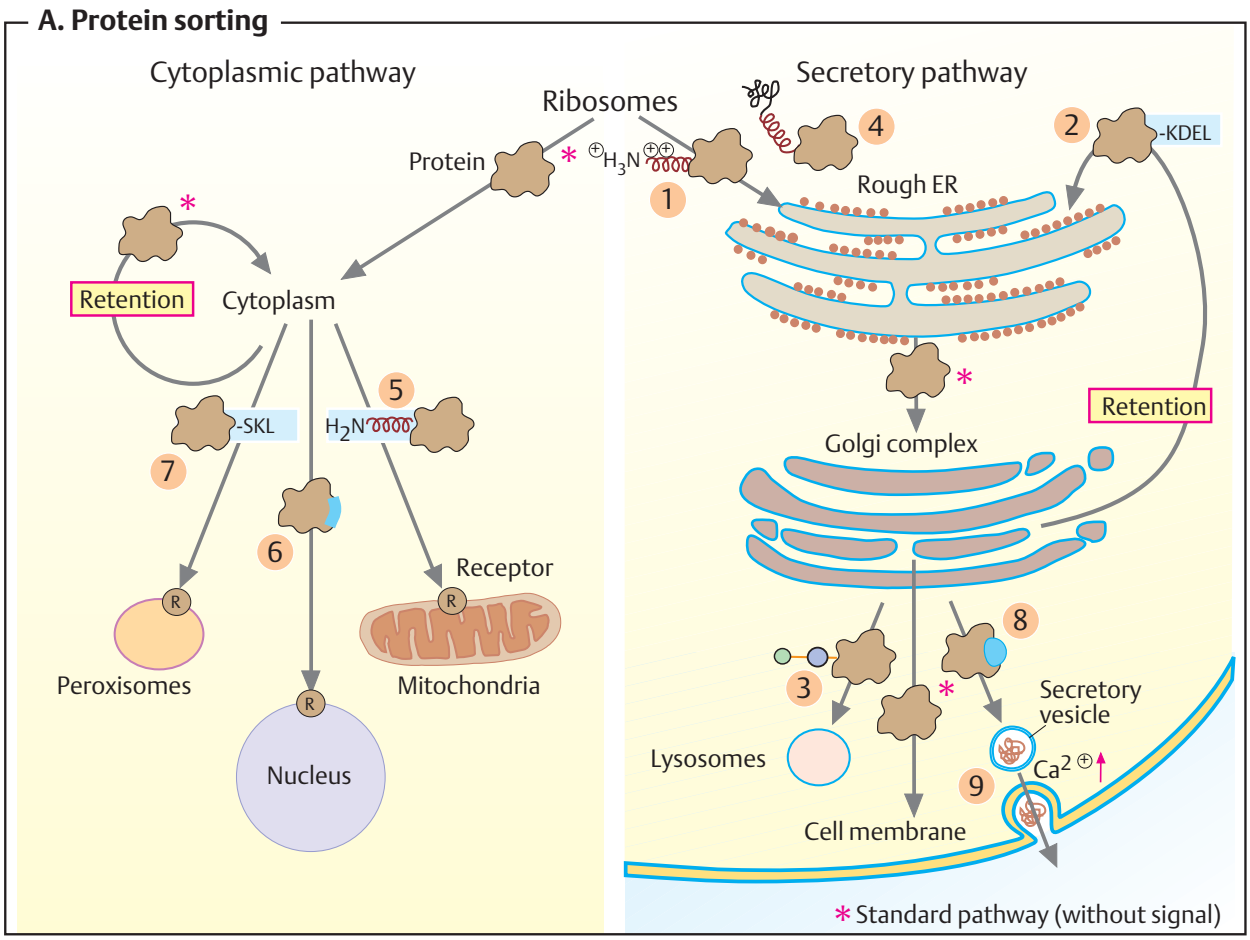

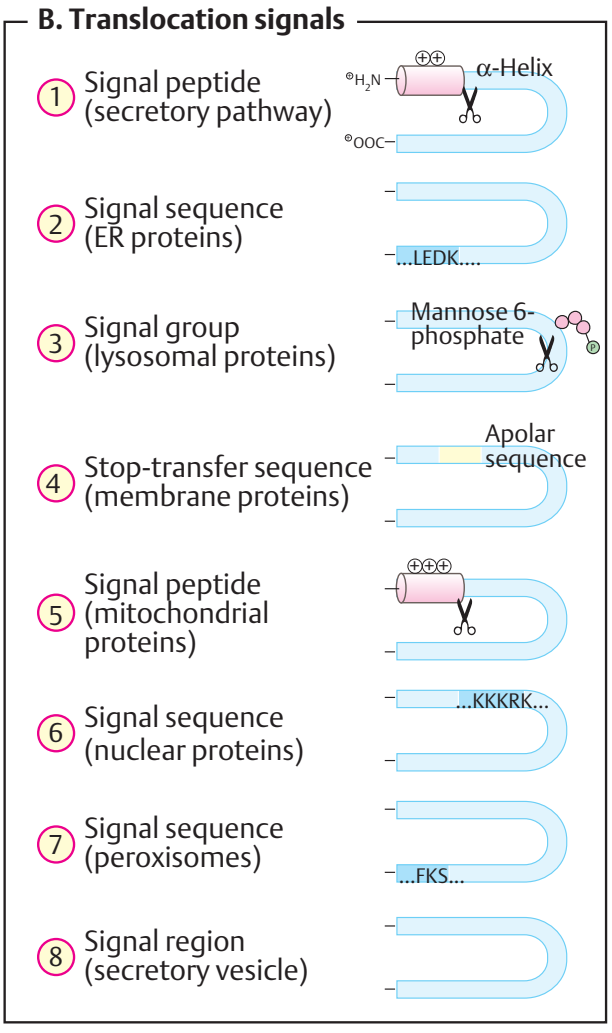

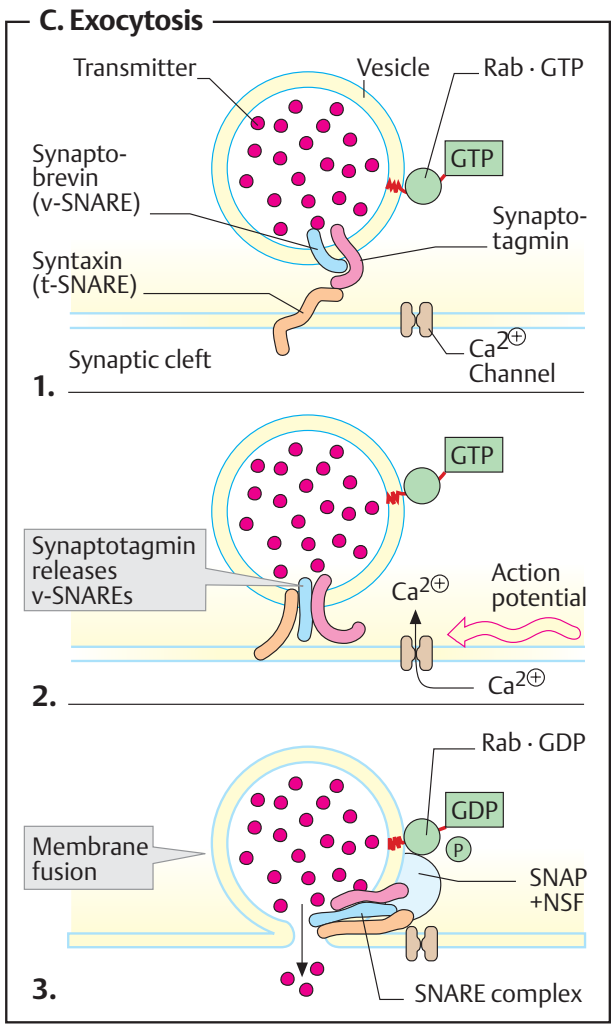

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Protein synthesis and maturation

A. Protein synthesis in the rER ◑

With all proteins, protein biosynthesis (**Translation**; for details, see p. 250) starts on free ribosomes in the cytoplasm (**1**). Proteins that are exported out of the cell or into lysosomes, and membrane proteins of the ER and the plasma membrane, carry a **signal peptide for the ER** at their N-terminus. This is a section of 15–60 amino acids in which one or two strongly basic residues (Lys, Arg) near the N-terminus are followed by a strongly hydrophobic sequence of 10–15 residues (see p. 228).

As soon as the signal peptide (red) appears on the surface of the ribosome (**2**), an RNA-containing *signal recognition particle* (**SRP**, green) binds to the sequence and initially interrupts translation (**3**). The SRP then binds to an **SRP receptor** in the rER membrane, and in this way attaches the ribosome to the ER (**4**). After this, the SRP dissociates from the signal peptide and from the SRP receptor and is available again for step 3. This endergonic process is driven by GTP hydrolysis (**5**). Translation now resumes. The remainder of the protein, still unfolded, is gradually introduced into a channel (the **translocon**) in the lumen of the rER (**6**), where a *signal peptidase* located in the inner ER membrane cleaves the signal peptide while translation is still taking place (**7**). This converts the **preprotein** into a **proprotein**, from which the mature protein finally arises after additional post-translational modifications (**8**) in the ER and in the Golgi apparatus.

If the growing polypeptide contains a **stop-transfer signal** (see p. 228), then this hydrophobic section of the chain remains stuck in the membrane outside the translocon, and an *integral membrane protein* arises. In the course of translation, an additional signal sequence can re-start the transfer of the chain through the translocon. Several repetitions of this process produce integral membrane proteins with several transmembrane helices (see p. 214).

B. Protein glycosylation ○

Most extracellular proteins contain covalently bound oligosaccharide residues. For example, all plasma proteins with the exception of albumin are glycosylated. Together with glycolipids, numerous **glycoproteins** on the cell surface form the **glycocalyx**. Inside the ER, the carbohydrate parts of the glycoproteins are cotranslationally transferred to the growing chain, and are then converted into their final form while passing through the ER and Golgi apparatus.

N-bound oligosaccharides (see p. 44) are always bound to the acid-amide group of asparagine residues. If a **glycosylation sequence** (–Asn–X–Ser(Thr)–, where X can be any amino acid) appears in the growing peptide chain, then a *transglycosylase* in the ER membrane [1] transfers a previously produced **core oligosaccharide** consisting of 14 hexose residues *en-bloc* from the carrier molecule **dolichol diphosphate** to the peptide.

Dolichol is a long-chain isoprenoid (see p. 52) consisting of 10–20 isoprene units, which is embedded in the ER membrane. A hydroxyl group at the end of the molecule is bound to diphosphate, on which the nuclear oligosaccharide is built up in an extended reaction sequence (not shown here in detail). The core structure consists of two residues of N-acetylglucosamine (GlcNAc), a branched group of nine mannose residues (Man) and three terminal glucose resides (Glc).

As the proprotein passes through the ER, *glycosidases* [2] remove the glucose residues completely and the mannoses partially ("trimming"), thereby producing the **mannose-rich type** of oligosaccharide residues. Subsequently, various *glycosyltransferases* [3] transfer additional monosaccharides (e.g., GlcNAc, galactose, fucose, and N-acetylneuraminic acid; see p. 38) to the mannose-rich intermediate and thereby produce the **complex type** of oligosaccharide. The structure of the final oligosaccharide depends on the type and activity of the glycosyltransferases present in the ER of the cell concerned, and is therefore genetically determined (although indirectly).

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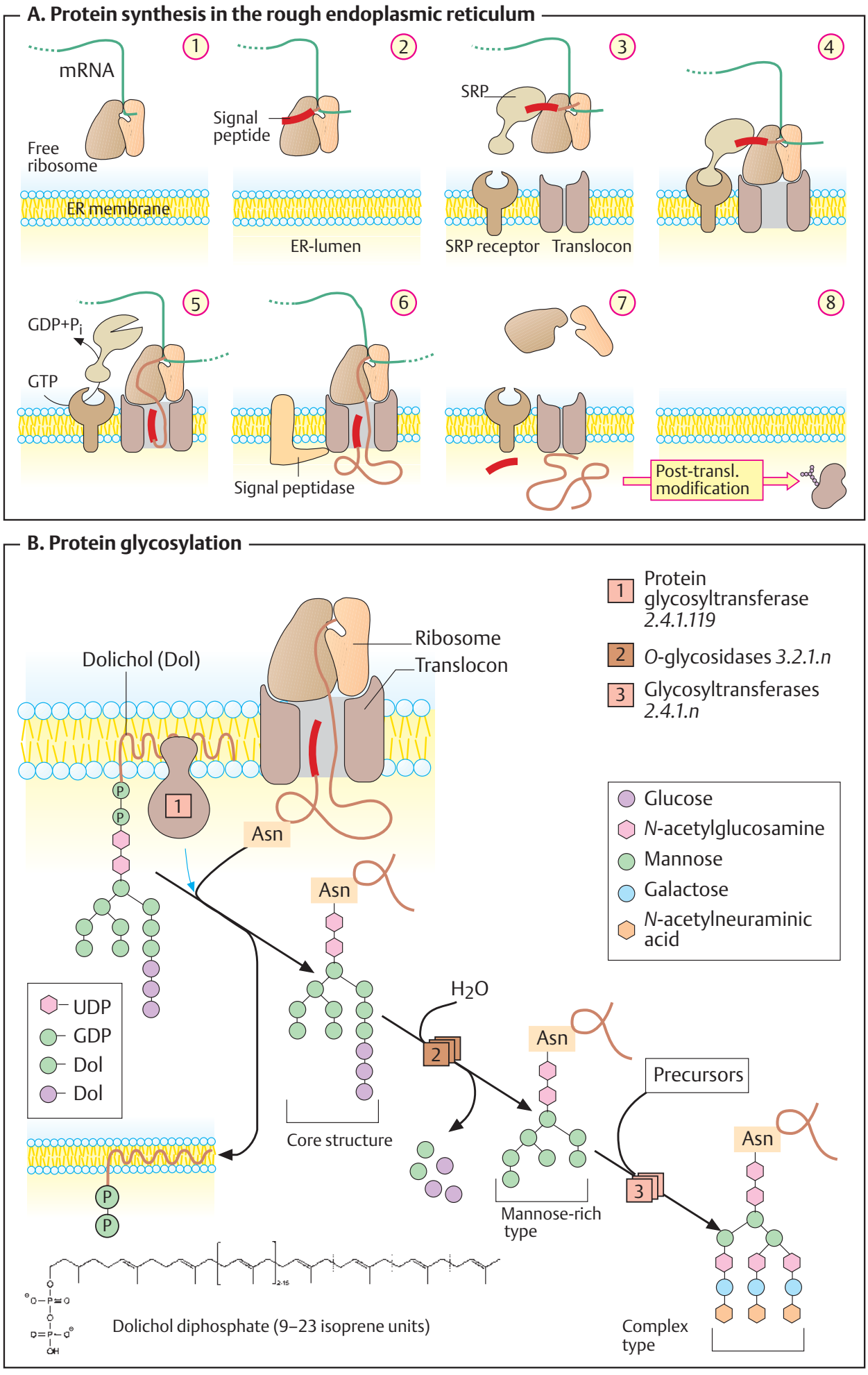

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Protein maturation

After translation, proteins destined for the secretory pathway (see p. 228) first have to fold into their native conformation within the rER (see p. 230). During this process they are supported by various *auxiliary proteins.*

A. Protein folding in the rER ●

To prevent incorrect folding of the growing protein during protein biosynthesis, **chaperones** (see **B**) in the lumen of the rER bind to the peptide chain and stabilize it until translation has been completed. Binding protein (**BiP**) is an important chaperone in the ER.

Many secretory proteins—e. g., pancreatic ribonuclease (RNAse; see p. 74)—contain several disulfide bonds that are only formed oxidatively from SH groups after translation. The eight cysteine residues of the RNAse can in principle form 105 different pairings, but only the combination of the four disulfide bonds shown on p. 75 provides active enzyme. Incorrect pairings can block further folding or lead to unstable or insoluble conformations. The enzyme *protein disulfide isomerase* [1] accelerates the equilibration between paired and unpaired cysteine residues, so that incorrect pairs can be quickly split before the protein finds its final conformation.

Most peptide bonds in proteins take on the *trans* conformation (see p. 66). Only bonds with proline residues (–X–Pro–) can be present in both *cis* and *trans* forms.

In the protein's native conformation, every X–Pro bond has to have the correct conformation (*cis* or *trans*). As the uncatalyzed transition between the two forms is very slow, there is a *proline* cis–trans *isomerase* [2] in the ER that accelerates the conversion.

B. Chaperones and chaperonins ●

Most proteins fold spontaneously into their native conformation, even in the test tube. In the cell, where there are very high concentrations of proteins (around 350 g L^{-1}), this is more dif cult. In the unfolded state, the apolar regions of the peptide chain (yellow) tend to aggregate—due to the hydrophobic effect (see p. 28)—with other proteins or with each other to form insoluble products (2). In addition, unfolded proteins are susceptible to proteinases. To protect partly folded proteins, there are auxiliary proteins called **chaperones** because they guard immature proteins against damaging contacts. Chaperones are formed increasingly during temperature stress and are therefore also known as **heat-shock proteins** (hsp). Several classes of hsp are distinguished. Chaperones of the hsp70 type (Dna K in bacteria) are common, as are type hsp60 **chaperonins** (GroEL/ES in bacteria). Class hsp90 chaperones have special tasks (see p. 378).

While small proteins can often reach their native conformation without any help (1), larger molecules require hsp70 proteins for protection against aggregation which bind as monomers and can dissociate again, dependent on ATP (3). By contrast, type hsp60 chaperonins form large, barrel-shaped complexes with 14 subunits in which proteins can fold independently while shielded from their environment (4). The function of hsp60 has been investigated in detail in the bacterial chaperonin **GroEL** (right). The barrel has two chambers, which are closed with a lid (**GroES**) during folding of the guest protein. Driven by ATP hydrolysis, the chambers open and close alternately—i. e., the release of the fully folded protein from one chamber is coupled to the uptake of an unfolded peptide in the second chamber.

C. Protein import in mitochondria ●

Class hsp70 chaperones are also needed for translocation of nuclear-coded proteins from the cytoplasm into the mitochondria (see p. 228). As two membranes have to be crossed to reach the matrix, there are two translocator complexes: **TOM (**"transport outer membrane") and **TIM** ("transport inner membrane"). For transport, proteins are unfolded in the cytoplasm and protected by hsp70. TOM recognizes the positively charged signal sequence at the protein's N terminus (see p. 228) and with the help of the membrane potential threads the chains through the central pores of the two complexes. Inside TIM, further hsp70 molecules bind and pull the chain completely into the matrix. As with import into the ER, the signal peptide is proteolytically removed by a signal peptidase during translocation.

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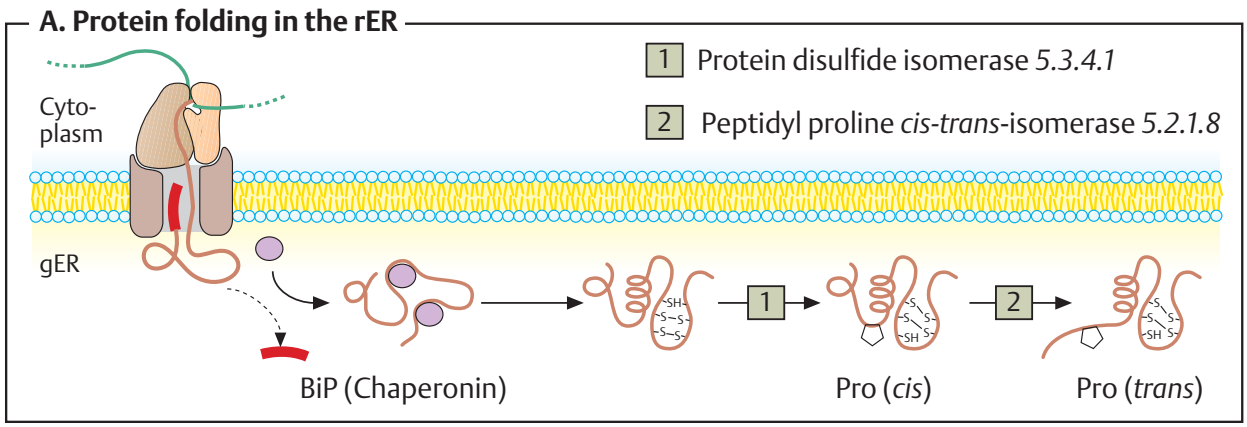

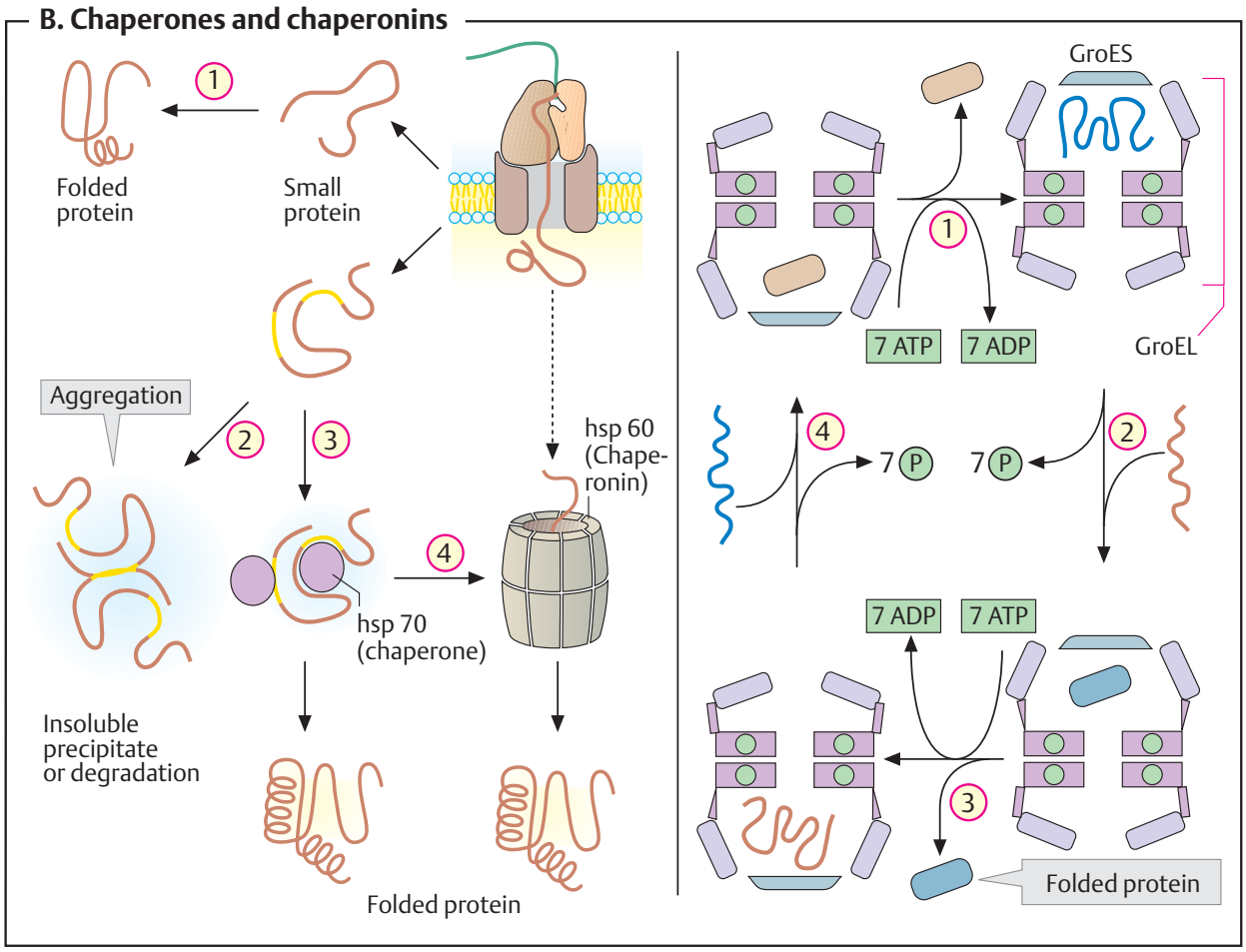

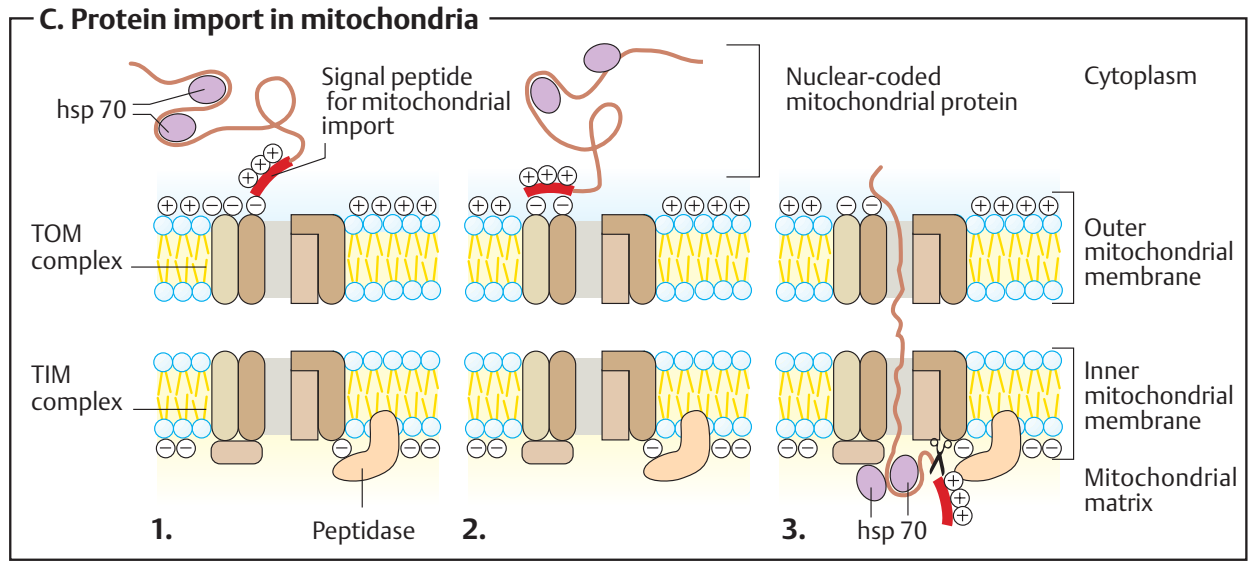

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Lysosomes

A. Structure and contents ◑

Animal lysosomes are organelles with a diameter of 0.2–2.0 μm with various shapes that are surrounded by a single membrane. There are usually several hundred lysosomes per cell. ATP-driven V-type proton pumps are active in their membranes (see p. 220). As these accumulate H^+ in the lysosomes, the content of lysosomes with pH values of 4.5–5 is much more acidic than the cytoplasm (pH 7–7.3).

The lysosomes are the cell's "stomach," serving to break down various cell components. For this purpose, they contain some 40 different types of **hydrolases**, which are capable of breaking down every type of macromolecule. The marker enzyme of lysosomes is *acid phosphatase.* The pH optimum of lysosomal enzymes is adjusted to the acid pH value and is also in the range of pH 5. At neutral pH, as in the cytoplasm, lysosomal enzymes only have low levels of activity. This appears to be a mechanism for protecting the cells from digesting themselves in case lysosomal enzymes enter the cytoplasm at any time. In plants and fungi, the **cell vacuoles** (see p. 43) have the function of lysosomes.

B. Functions ◑

Lysosomes serve for enzymatic degradation of macromolecules and cell organelles, which are supplied in various ways. The example shows the degradation of an overaged mitochondrion by *autophagy.* To accomplish this, the lysosome encloses the organelle (**1**). During this process, the **primary lysosome** converts into a **secondary lysosome**, in which the hydrolytic degradation takes place (**2**). Finally, **residual bodies** contain the indigestible residues of the lysosomal degradation process. Lysosomes are also responsible for the degradation of macromolecules and particles taken up by cells via *endocytosis* and *phagocytosis*—e. g., lipoproteins, proteohormones, and bacteria (*heterophagy*). In the process, lysosomes fuse with the **endosomes** (**3**) in which the endocytosed substances are supplied.

C. Synthesis and transport of lysosomal proteins ◑

Primary lysosomes arise in the region of the Golgi apparatus. **Lysosomal proteins** are synthesized in the rER and are glycosylated there as usual (**1**; see p. 228). The next steps are specific for lysosomal proteins (right part of the illustration). In a two-step reaction, terminal mannose residues (Man) are phosphorylated at the C–6 position of the mannose. First, *N*-acetylglucosamine 1-phosphate is transferred to the OH group at C-6 in a terminal mannose residue, and *N*-acetylglucosamine is then cleaved again. Lysosomal proteins therefore carry a terminal **mannose 6–phosphate** (Man6–P; **2**).

The membranes of the Golgi apparatus contain receptor molecules that bind Man 6–P. They recognize lysosomal proproteins by this residue and bind them (**3**). With the help of *clathrin,* the receptors are concentrated locally. This allows the appropriate membrane sections to be pinched off and transported to the endolysosomes with the help of transport vesicles (**4**), from which primary lysosomes arise through maturation (**5**). Finally, the phosphate groups are removed from Man 6–P (**6**).

The *Man 6–P receptors* are reused. The fall in the pH value in the endolysosomes releases the receptors from the bound proteins (**7**) which are then transported back to the Golgi apparatus with the help of transport vesicles.

Further information

Many hereditary diseases are due to genetic defects in lysosomal enzymes. The metabolism of glycogen (→ *glycogenoses*), lipids (→ *lipidoses*), and proteoglycans (→ *mucopolysaccharidoses*) is particularly affected. As the lysosomal enzymes are indispensable for the intracellular breakdown of macromolecules, unmetabolized macromolecules or degradation products accumulate in the lysosomes in these diseases and lead to irreversible cell damage over time. In the longer term, enlargement takes place, and in severe cases there may be failure of the organ affected—e. g., the liver.

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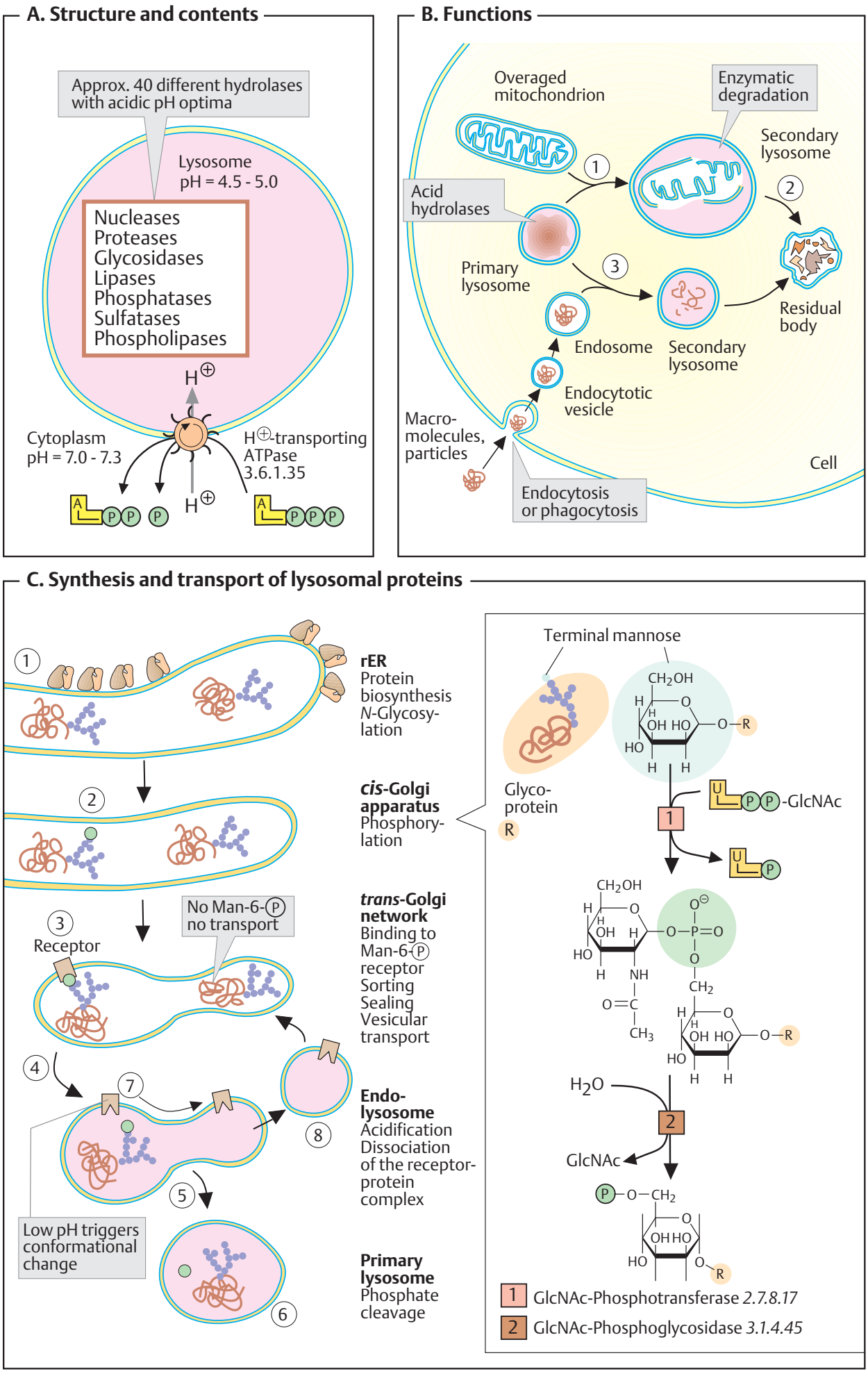

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Molecular genetics: overview

Nucleic acids (**DNA** and various **RNAs**) are of central importance in the storage, transmission, and expression of genetic information. The decisive factor involved is their ability to enter into specific base pairings with each other (see p. 84). The individual processes involved, which are summed up in an overview here, are discussed in more detail on the following pages.

A. Expression and transmission of genetic information ●

Storage. The genetic information of all cells is stored in the base sequence of their DNA (RNA only occurs as a genetic material in viruses; see p. 404). Functional sections of DNA that code for inheritable structures or functions are referred to as **genes**. The 30 000–40 000 human genes represent only a few percent of the **genome**, which consists of approximately $5 \cdot 10^9$ base pairs (bp). Most genes code for proteins—i. e., they contain the information for the sequence of amino acid residues of a protein (its sequence). Every amino acid residue is represented in DNA by a code word (a **codon**) consisting of a sequence of three base pairs (a triplet). At the level of DNA, codons are defined as sequences of the sense strand read in the 5′→3′ direction (see p. 84). A DNA codon for the amino acid phenylalanine, for example, is thus *TTC* (**2**).

Replication. During cell division, all of the genetic information has to be passed on to the daughter cells. To achieve this, the whole of the DNA is copied during the S phase of the cell cycle (see p. 394). In this process, each strand serves as a matrix for the synthesis of a complementary second strand (**1**; see p. 240).

Transcription. For *expression* of a gene—i. e., synthesis of the coded protein—the DNA sequence information has to be converted into a protein sequence. As DNA itself is not involved in protein synthesis, the information is transferred from the nucleus to the site of synthesis in the cytoplasm. To achieve this, the *template strand* in the relevant part of the gene is transcribed into an **RNA** (hnRNA). The sequence of this RNA is thus complementary to that of the *template strand* (**3**), but—with the exception of the exchange of thymine for uracil—it is identical to that of the sense strand. In this way, the DNA triplet *TTC* gives rise in hnRNA to the RNA codon *UUC*.

RNA maturation. In eukaryotes, the hnRNA initially formed is modified several times before it can leave the nucleus as **messenger RNA** (mRNA, **4**). During RNA maturation, superfluous ("intervening") sequences (introns) are removed from the molecule, and both ends of the transcript are protected by the addition of further nucleotides (see p. 246).

Translation. Mature mRNA enters the cytoplasm, where it binds to **ribosomes**, which convert the RNA information into a peptide sequence. The ribosomes (see p. 250) consist of more than 100 proteins and several RNA molecules (rRNA; see p. 82). rRNA plays a role as a ribosomal structural element and is also involved in the binding of mRNA to the ribosome and the formation of the peptide bond.

The actual information transfer is based on the interaction between the mRNA codons and another type of RNA, **transfer RNA** (tRNA; see p. 82). tRNAs, of which there are numerous types, always provide the correct amino acid to the ribosome according to the sequence information in the mRNA. tRNAs are loaded with an amino acid residue at the 3′ end. Approximately in the middle, they present the triplet that is complementary to each mRNA codon, known as the *anticodon* (*GAA* in the example shown). If the codon *UUC* appears on the mRNA, the anticodon binds a molecule of Phe-t-RNA^{Phe} to the mRNA (**5**) and thus brings the phenylalanine residue at the other end of the molecule into a position in which it can take over the growing polypeptide chain from the neighboring tRNA (**6**).

Amino acid activation. Before binding to the ribosomes, tRNAs are loaded with the correct amino acids by specific ligases (**7**; see p. 248). It is the amino acid tRNA ligases that carry out the transfer (translation) of the genetic information from the nucleic acid level to the protein level.

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A. Expression and transmission of genetic information

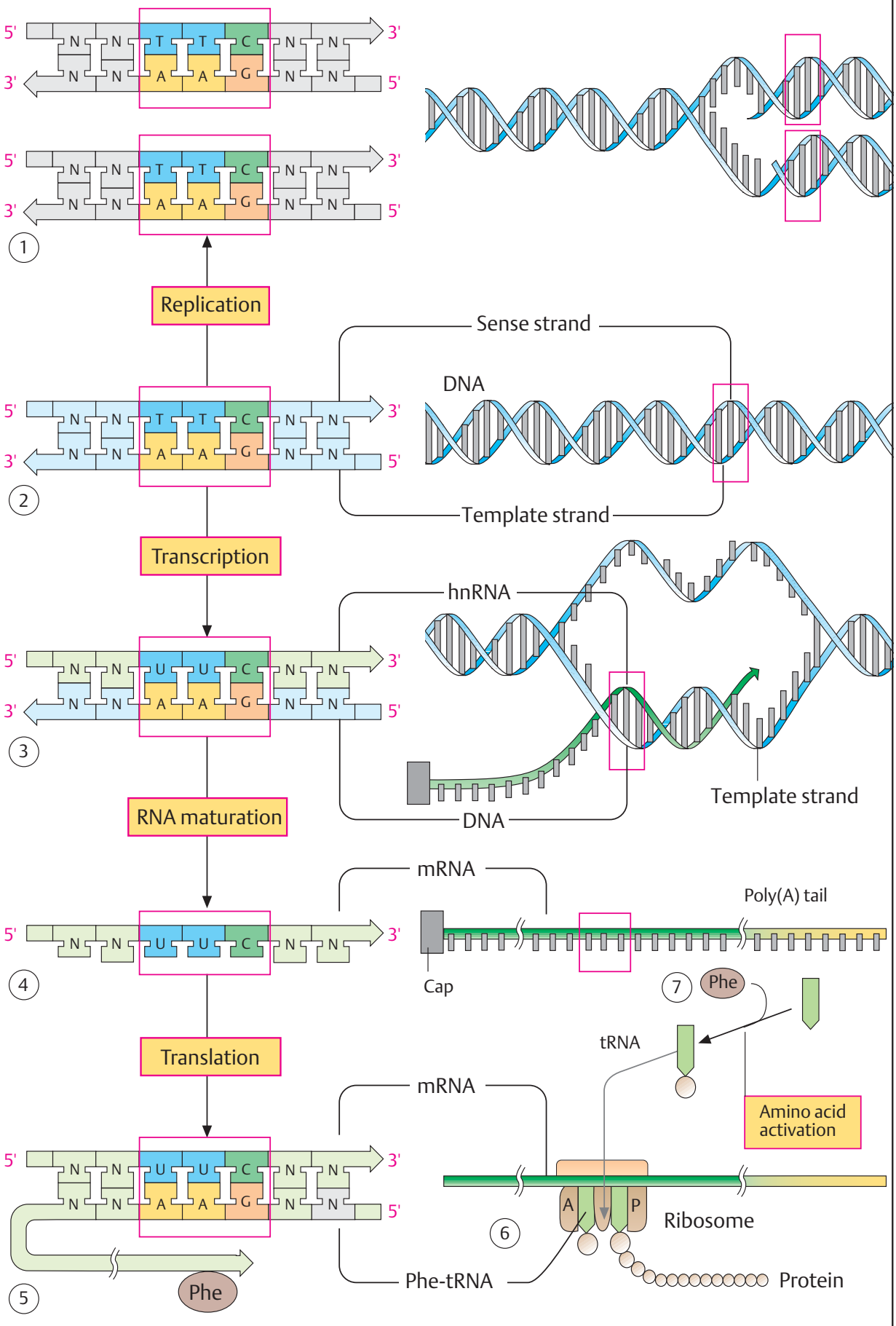

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Genome

A. Chromatin ◑

In the nuclei of eukaryotes (see p. 196), DNA is closely associated with proteins and RNA. These nucleoprotein complexes, with a DNA proportion of approximately one-third, are known as **chromatin**. It is only during cell division (see p. 394) that chromatin condenses into **chromosomes** that are visible under light microscopy. During interphase, most of the chromatin is loose, and in these conditions a morphological distinction can be made between tightly packed **heterochromatin** and the less dense **euchromatin**. Euchromatin is the site of active transcription.

The proteins contained in chromatin are classified as either histone or non-histone proteins. **Histones** (**B**) are small, strongly basic proteins that are directly associated with DNA. They contribute to the structural organization of chromatin, and their basic amino acids also neutralize the negatively charged phosphate groups, allowing the dense packing of DNA in the nucleus. This makes it possible for the 46 DNA molecules of the diploid human genome, with their 5 10^9 base pairs (bp) and a total length of about 2 m, to be accommodated in a nucleus with a diameter of only 10 μm. Histones also play a central role in regulating transcription (see p. 244).

Two histone molecules each of types **H2A** (blue), **H2B** (green), **H3** (yellow), and **H4** (red) form an octameric complex, around which 146 bp of DNA are wound in 1.8 turns. These particles, with a diameter of 7 nm, are referred to as **nucleosomes**. Another histone (**H1**) binds to DNA segments that are not directly in contact with the histone octamers ("linker" DNA). It covers about 20 bp and supports the formation of spirally wound superstructures with diameters of 30 nm, known as **solenoids**. When chromatin condenses into chromosomes, the solenoids form **loops** about 200 nm long, which already contain about 80 000 bp. The loops are bound to a protein framework (the **nuclear scaffolding**), which in turn organizes some 20 loops to form **minibands**. A large number of stacked minibands finally produces a chromosome. In the chromosome, the DNA is so densely packed that the smallest human chromosome already contains more than 50 million bp.

The **non-histone proteins** are very heterogeneous. This group includes *structural proteins* of the nucleus, as well as many *enzymes* and *transcription factors* (see p. 118), which selectively bind to specific segments of DNA and regulate gene expression and other processes.

B. Histones ○

The histones are remarkable in several ways. With their high proportions of lysine and arginine (blue shading), they are strongly basic, as mentioned above. In addition, their amino acid sequence has hardly changed at all in the course of evolution. This becomes clear when one compares the histone sequences in mammals, plants, and fungi (yeasts are single-celled fungi; see p. 148). For example, the H4 histones in humans and wheat differ only in a single amino acid residue, and there are only a few changes between humans and yeast. In addition, all of these changes are "conservative"—i. e., the size and polarity barely differ. It can be concluded from this that the histones were already "optimized" when the last common predecessor of animals, plants, and fungi was alive on Earth (more than 700 million years ago). Although countless mutations in histone genes have taken place since, almost all of these evidently led to the extinction of the organisms concerned.

The histones in the octamer carry N-terminal mobile "tails" consisting of some 20 amino acid residues that project out of the nucleosomes and are important in the regulation of chromatin structure and in controlling gene expression (see **A2**; only two of the eight tails are shown in full length). For example, the condensation of chromatin into chromosomes is associated with *phosphorylation* (P) of the histones, while the transcription of genes is initiated by *acetylation* (A) of lysine residues in the N-terminal region (see p. 244).

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A. Chromatin

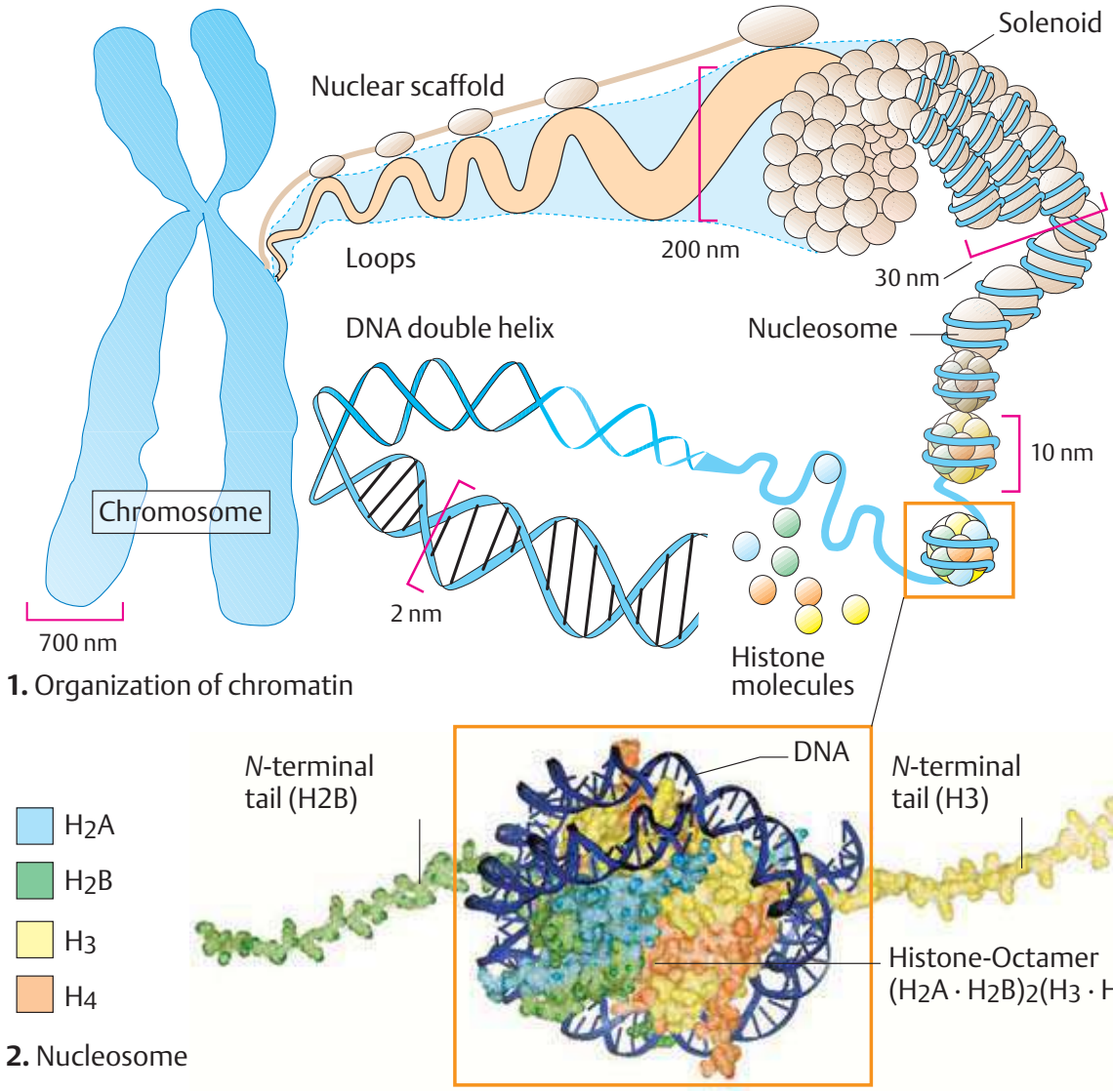

1. Organization of chromatin

2. Nucleosome

B. Histone

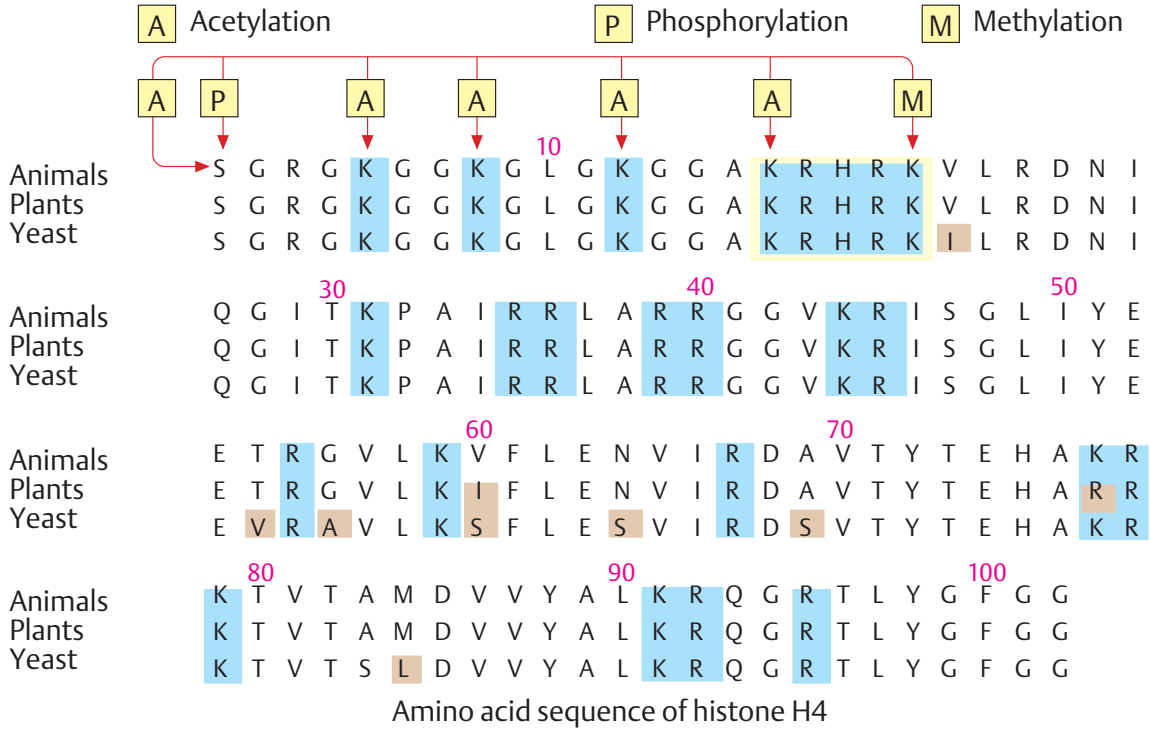

Amino acid sequence of histone H4

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Replication

For genetic information to be passed on during cell division, a complete copy of the genome has to be produced before each mitosis. This process is known as DNA **replication**.

A. Mechanism of DNA polymerases ◑

Replication is catalyzed by *DNA–dependent DNA polymerases.* These enzymes require a single strand of DNA, known as the **template**. Beginning at a short starting sequence of RNA (the **primer**), they synthesize a second complementary strand on the basis of this template, and thus create a complete DNA double helix again. The substrates of the DNA polymerases are the four deoxynucleoside triphosphates **dATP**, **dGTP**, **dCTP**, and **dTTP**. In each step, base pairing first binds the nucleotide that is complementary to the current base in the template strand. The α–phosphate residue of the newly bound nucleoside triphosphate is then subjected to nucleophilic attack by the 3′–OH group of the nucleotide incorporated immediately previously. This is followed by the elimination of diphosphate and the formation of a new phosphoric acid diester bond. These steps are repeated again for each nucleotide. The mechanism described means that the matrix can only be read in the 3′→5′ direction. In other words, the newly synthesized strand always grows in the **5′→3′ direction**. The same mechanism is also used in transcription by *DNA-dependent RNA polymerases* (see p. 242). Most DNA and RNA polymerases consist of more than 10 subunits, the role of which is still unclear to some extent.

B. Replication in *E. coli* ◑

Although replication in prokaryotes is now well understood, many details in eukaryotes are still unclear. However, it is certain that the process is in principle similar. A simplified scheme of replication in the bacterium *Escherichia coli* is shown here.

In bacteria, replication starts at a specific point in the circular DNA—the **origin of replication**—and proceeds in both directions. This results in two diverging **replication forks**, in which the two strands are replicated simultaneously. Numerous proteins are involved in the processes taking place in this type of fork, and only the most important are shown here. The two strands of the initial DNA (**1**) are shown in blue and violet, while the newly formed strands are pink and orange.

Each fork (**2**) contains two molecules of **DNA polymerase III** and a number of helper proteins. The latter include **DNA topoisomerases** and **single–strand-binding proteins**. Topoisomerases are enzymes that unwind the superhelical DNA double strand (*gyrase, topoisomerase II*) and then separate it into the two individual strands (*helicase, topoisomerase I*). Since the template strand is always read from 3′ to 5′ (see above), only one of the strands (known as the **leading** strand; violet/pink) can undergo *continuous* replication. For the **lagging strand** (light blue), the reading direction is the *opposite* of the direction of movement of the fork. In this matrix, the new strand is first synthesized in individual pieces, which are known as **Okazaki fragments** after their discoverer (green/orange).

Each fragment starts with a short RNA primer (green), which is necessary for the functioning of the DNA polymerase and is synthesized by a special *RNA polymerase* (*"primase,"* not shown). The primer is then extended by *DNA polymerase III* (orange). After 1000–2000 nucleotides have been included, synthesis of the fragment is interrupted and a new one is begun, starting with another RNA primer that has been synthesized in the interim. The individual Okazaki fragments are initially not bound to one another and still have RNA at the 5′ end (**3**). At some distance from the fork, *DNA polymerase I* therefore starts to remove the RNA primer and replace it with DNA components. Finally, the gaps still remaining are closed by a *DNA ligase.* In DNA double helices formed in this way, only *one* of the strands has been newly synthesized—i. e., replication is *semiconservative*.

In bacteria, some 1000 nucleotides are replicated per second. In eukaryotes, replication takes place more slowly (about 50 nucleotides s^{-1}) and the genome is larger. Thousands of replication forks are therefore active simultaneously in eukaryotes.

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A. Mechanism of DNA polymerases

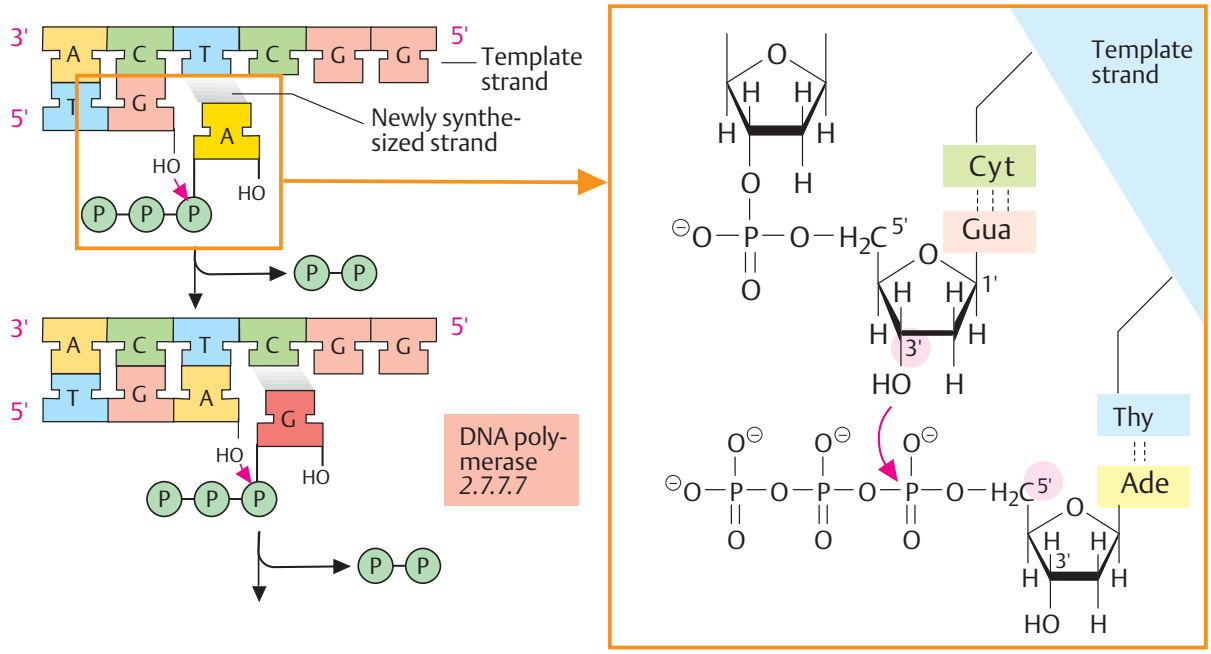

B. Replication in *E. coli*

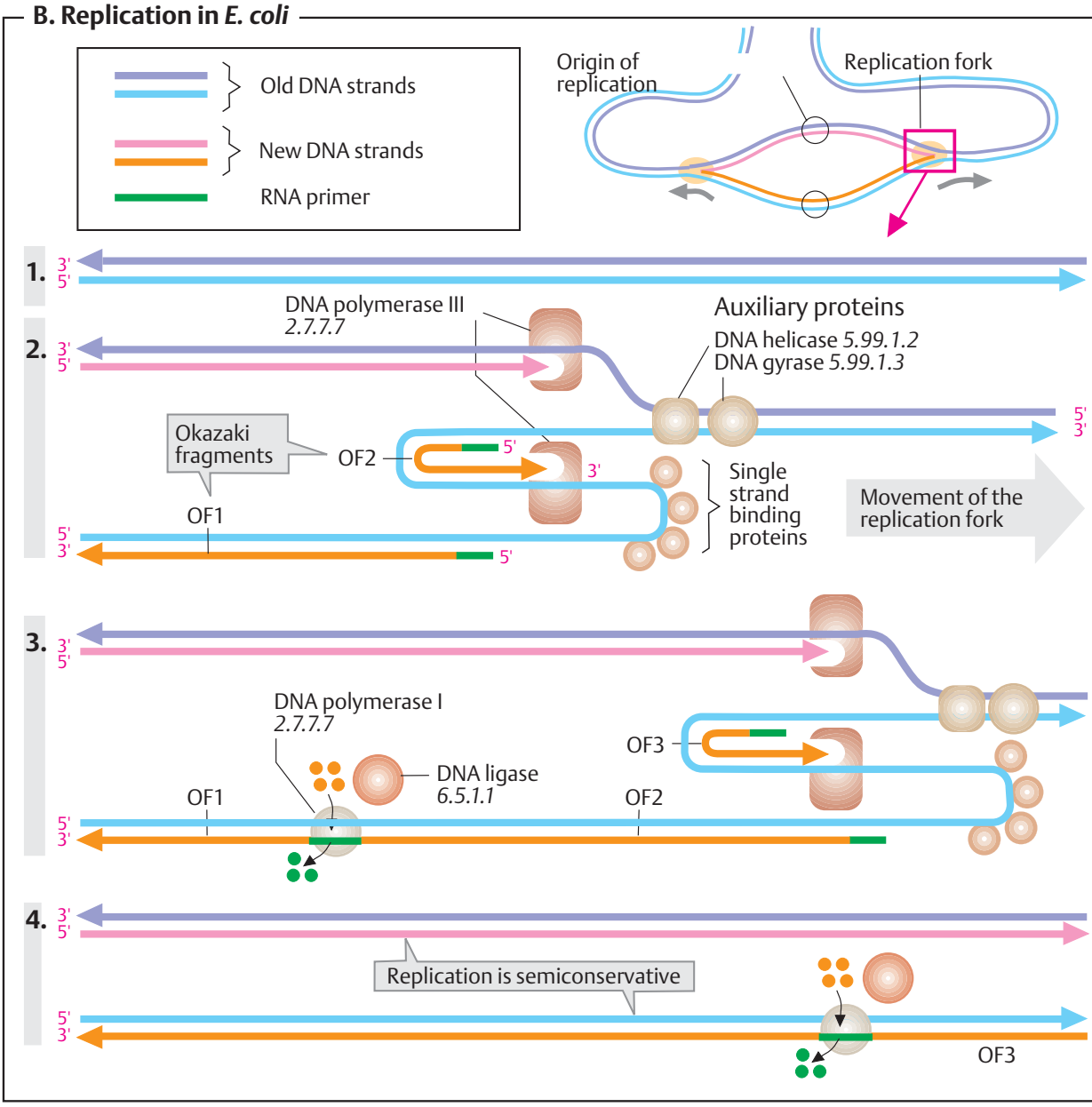

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Transcription

For the genetic information stored in DNA to become effective, it has to be rewritten (transcribed) into RNA. DNA only serves as a template and is not altered in any way by the **transcription** process. Transcribable segments of DNA that code for a defined product are called **genes**. It is estimated that the mammalian genome contains 30 000–40 000 genes, which together account for less than 5% of the DNA.

A. Transcription and maturation of RNA: overview ◑

Transcription is catalyzed by *DNA–dependent RNA polymerases.* These act in a similar way to DNA polymerases (see p. 240), except that they incorporate *ribonucleotides* instead of deoxyribonucleotides into the newly synthesized strand; also, they do not require a primer. Eukaryotic cells contain at least three different types of RNA polymerase. *RNA polymerase I* synthesizes an RNA with a sedimentation coef cient (see p. 200) of 45 S, which serves as precursor for three ribosomal RNAs. The products of *RNA polymerase II* are hnRNAs, from which mRNAs later develop, as well as precursors for snRNAs. Finally, *RNA polymerase III* transcribes genes that code for tRNAs, 5S rRNA, and certain snRNAs. These precursors give rise to functional RNA molecules by a process called **RNA maturation** (see p. 246). Polymerases II and III are inhibited by *α–amanitin,* a toxin in the *Amanita phalloides* mushroom.

B. Organization of the PEP-CK gene ○

The way in which a typical eukaryotic gene is organized is illustrated here using a gene that codes for a key enzyme in gluconeogenesis (see p. 154)—the *phosphoenolpyruvate carboxykinase* (PEP-CK).

In the rat, the PEP-CK gene is nearly 7 kbp (kilobase pairs) long. Only 1863 bp, distributed over 10 coding segments (**exons**, dark blue) carry the information for the protein's 621 amino acids. The remainder is allotted to the promoter (pink) and intervening sequences (**introns**, light blue). The gene's promoter region (approximately 1 kbp) serves for regulation (see p. 188). Transcription starts at the 3′ end of the promoter ("transcription start") and continues until the polyadenylation sequence (see below) is reached. The primary transcript (**hnRNA**) still has a length of about 6.2 kbp. During RNA maturation, the noncoding sequences corresponding to the introns are removed, and the two ends of the hnRNA are modified. The translatable mRNA still has half the length of the hnRNA and is modified at both ends (see p. 246).

In many eukaryotic genes, the proportion of introns is even higher. For example, the gene for *dihydrofolate reductase* (see p. 402) is over 30 kbp long. The information is distributed over six exons, which together have a length of only about 6 kbp.

C. Transcription process ◑

As mentioned above, *RNA polymerase II* (green) binds to the 3′ end of the promoter region. A sequence that is important for this binding is known as the **TATA box**—a short A– and T–rich sequence that varies slightly from gene to gene. A typical base sequence *("consensus sequence")* is …TATAAA… Numerous proteins known as *basal transcription factors* are necessary for the interaction of the polymerase with this region. Additional factors can promote or inhibit the process (transcriptional control; see p. 244). Together with the polymerase, they form the **basal transcription complex**.

At the end of **initiation** (**2**), the polymerase is repeatedly phosphorylated, frees itself from the basal complex, and starts moving along the DNA in the 3′ direction. The enzyme separates a short stretch of the DNA double helix into two single strands. The complementary nucleoside triphosphates are bound by base pairing in the *template strand* and are linked step by step to the hnRNA as it grows in the 5′→3′ direction (**3**). Shortly after the beginning of **elongation**, the 5′ end of the transcript is protected by a "cap" (see p. 246). Once the polyadenylation sequence has been reached (typical sequence: …AATAA…), the transcript is released (**4**). Shortly after this, the RNA polymerase stops transcribing and dissociates from the DNA.

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A. Transcription and maturation of RNA: overview

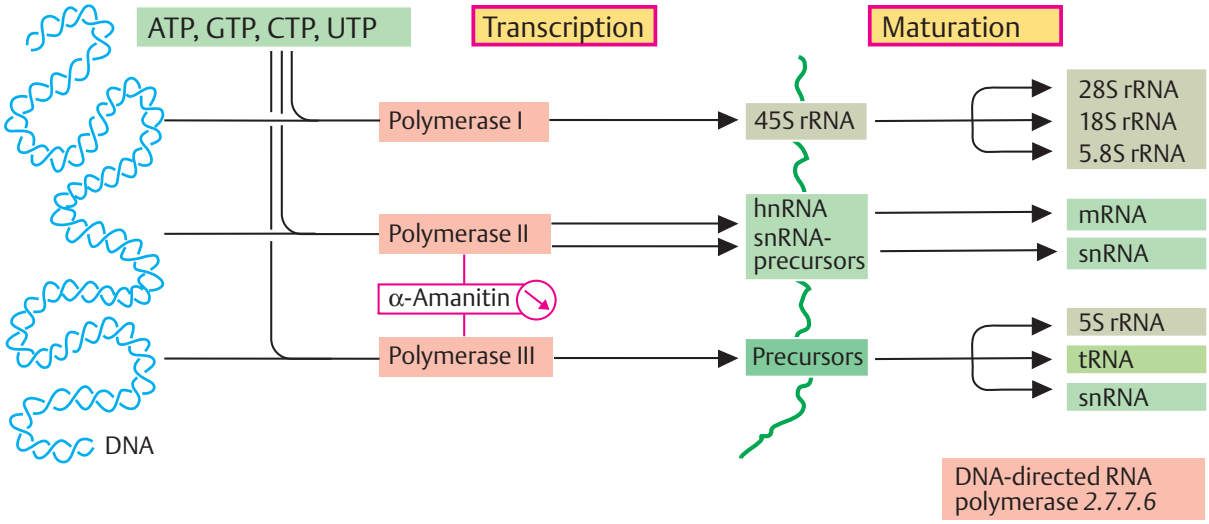

B. Organization of the PEP-CK gene

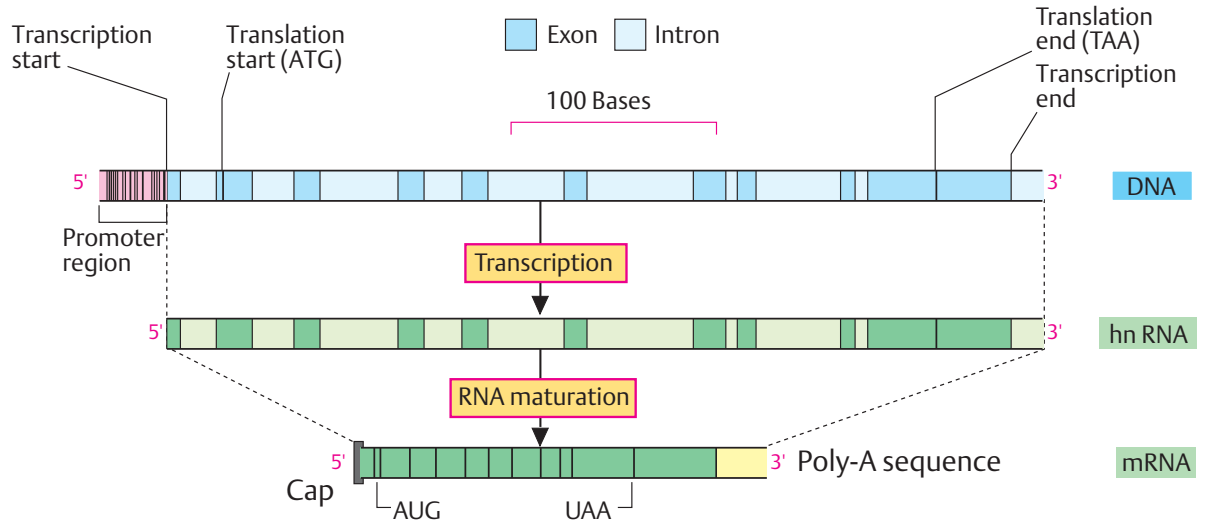

C. Process of transcription

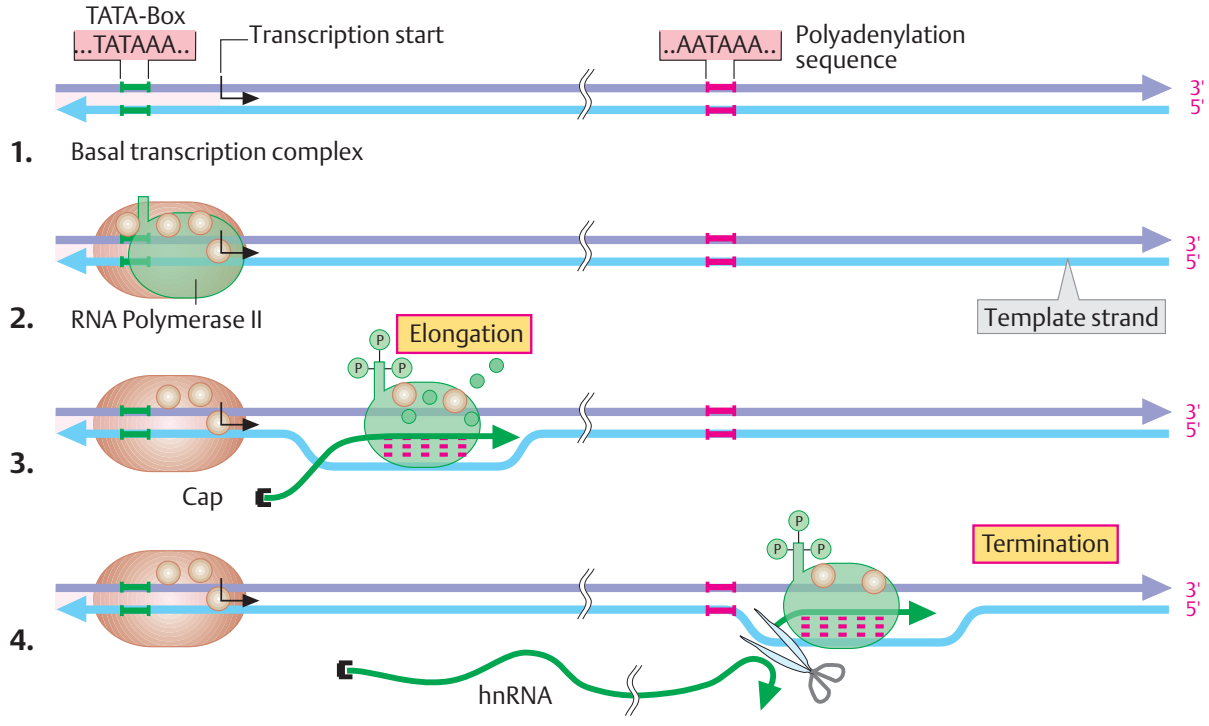

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Transcriptional control

Although all cells contain the complete genome, they only use a fraction of the information in it. The genes known as "housekeeping genes," which code for structural molecules and enzymes of intermediate metabolism, are the only ones that undergo constant transcription. The majority of genes are only active in certain cell types, in specific metabolic conditions, or during differentiation. Which genes are transcribed and which are not is regulated by **transcriptional control** (see also p. 118). This involves *control elements* (*cis*-active elements) in the gene's promoter region and gene-specific regulatory proteins (transcription factors, *trans* -active factors), which bind to the control elements and thereby activate or inhibit transcription.

A. Initiation of transcription ○

In the higher organisms, DNA is blocked by histones (see p. 238) and is therefore not capable of being transcribed without special positive regulation. In eukaryotes, it is therefore histones that play the role of *repressors* (see p. 118). For transcription to be set in motion at all, the chromatin first has to be restructured.

In the resting state, the lysine residues in the N-terminal "tail" of the histones (see p. 238) are not acetylated. In this state, which can be produced by *histone deacetylases* [1], the nucleosomes are stable. It is only the interaction of activator and regulator proteins with their control elements that allows the binding of coactivator complexes that have *histone acetylase* activity [2]. They acetylate the histone tails and thereby loosen the nucleosome structure suf ciently for the basal transcription complex to form.

This consists of *DNA-dependent RNA polymerase II* and basal transcription factors (TFIIX, X = A – H). First, the basal factor TFIID binds to the promoter. TFIID, a large complex of numerous proteins, contains *TATA box-binding protein* (TBP) and so-called TAFs (TBP-associated factors). The polymerase is attached to this core with the help of TFIIB. Before transcription starts, additional TFs have to bind, including TFIIH, which has *helicase* activity and separates the two strands of DNA during elongation. In all, some 35 different proteins are involved in the basal complex. This alone, however, is still not suf cient for transcription to start. In addition, positive signals have to be emitted by more distant *trans*-active factors, integrated by the coactivator/mediator complex, and passed on to the basal complex (see **B**).

The actual signal for starting elongation consists of the multiple phosphorylation of a domain in the C-terminal region of the polymerase. In phosphorylated form, it releases itself from the basal complex along with a few TFs and starts to synthesize hnRNA.

B. Regulation of PEP-CK transcription ○

Phosphoenolpyruvate carboxykinase (PEP-CK), a key enzyme in gluconeogenesis, is regulated by several hormones, all of which affect the transcription of the PEP-CK gene. Cortisol, glucagon, and thyroxin induce PEP-CK, while insulin inhibits its induction (see p. 158).

More than ten **control elements** (dark red), distributed over approximately 1 kbp, have so far been identified in the promoter of the PEP-CK gene (top). These include response elements for the glucocorticoid receptor (GRE; see p. 378), for the thyroxin receptor (TRE), and for the steroid-like retinoic acid (AF-1). Additional control elements (CRE, cAMP-responsive element) bind the transcription factor C/EBP, which is activated by cAMP-dependent protein kinase A through phosphorylation. This is the way in which glucagon, which raises the cAMP level (see p. 158), works. Control element P1 binds the hormone-independent factor NF-1 (nuclear factor-1). All proteins that bind to the control elements mentioned above are in contact with a **coactivator/mediator complex** (CBP/p300), which integrates their input like a computer and transmits the result in the form of stronger or weaker signals to the basal transcription complex. Inhibition of PEP-CK transcription by insulin is mediated by an insulin-responsive element (IRE) in the vicinity of the GRE. Binding of an as yet unknown factor takes place here, inhibiting the binding of the glucocorticoid receptor to the GRE.

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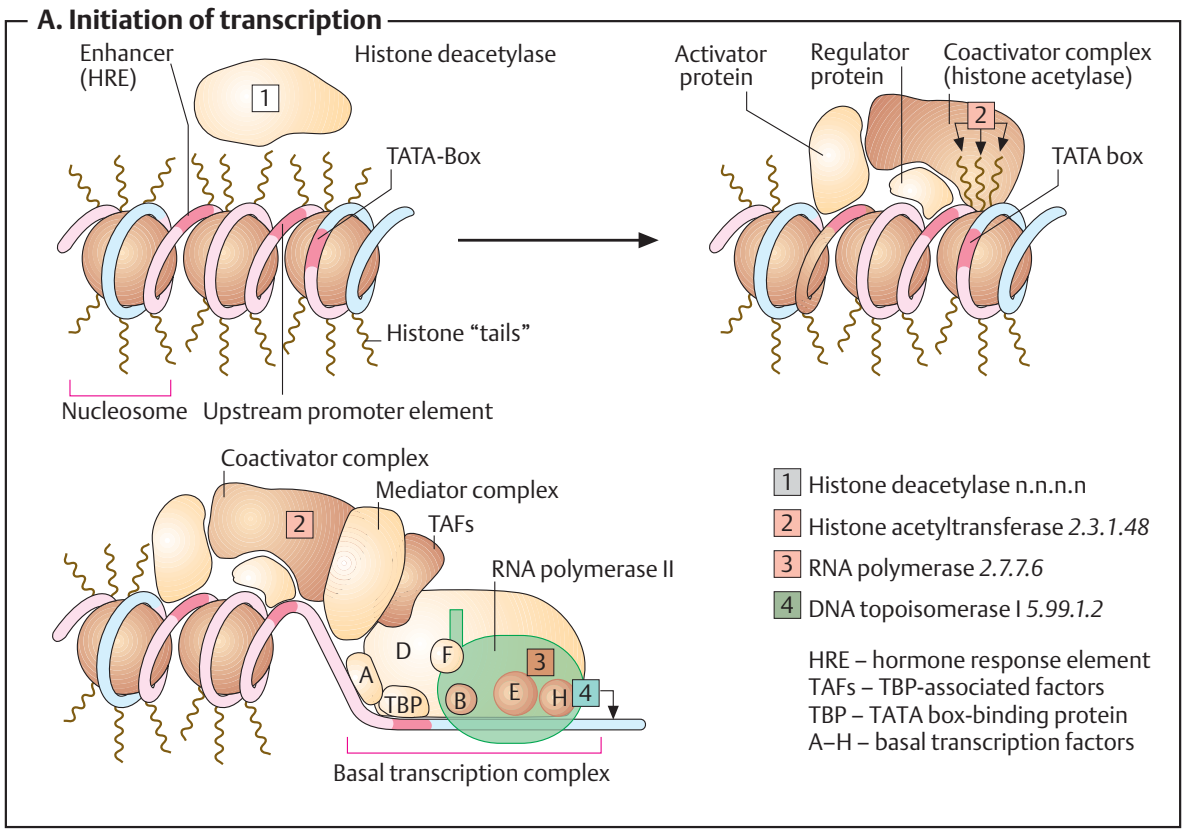

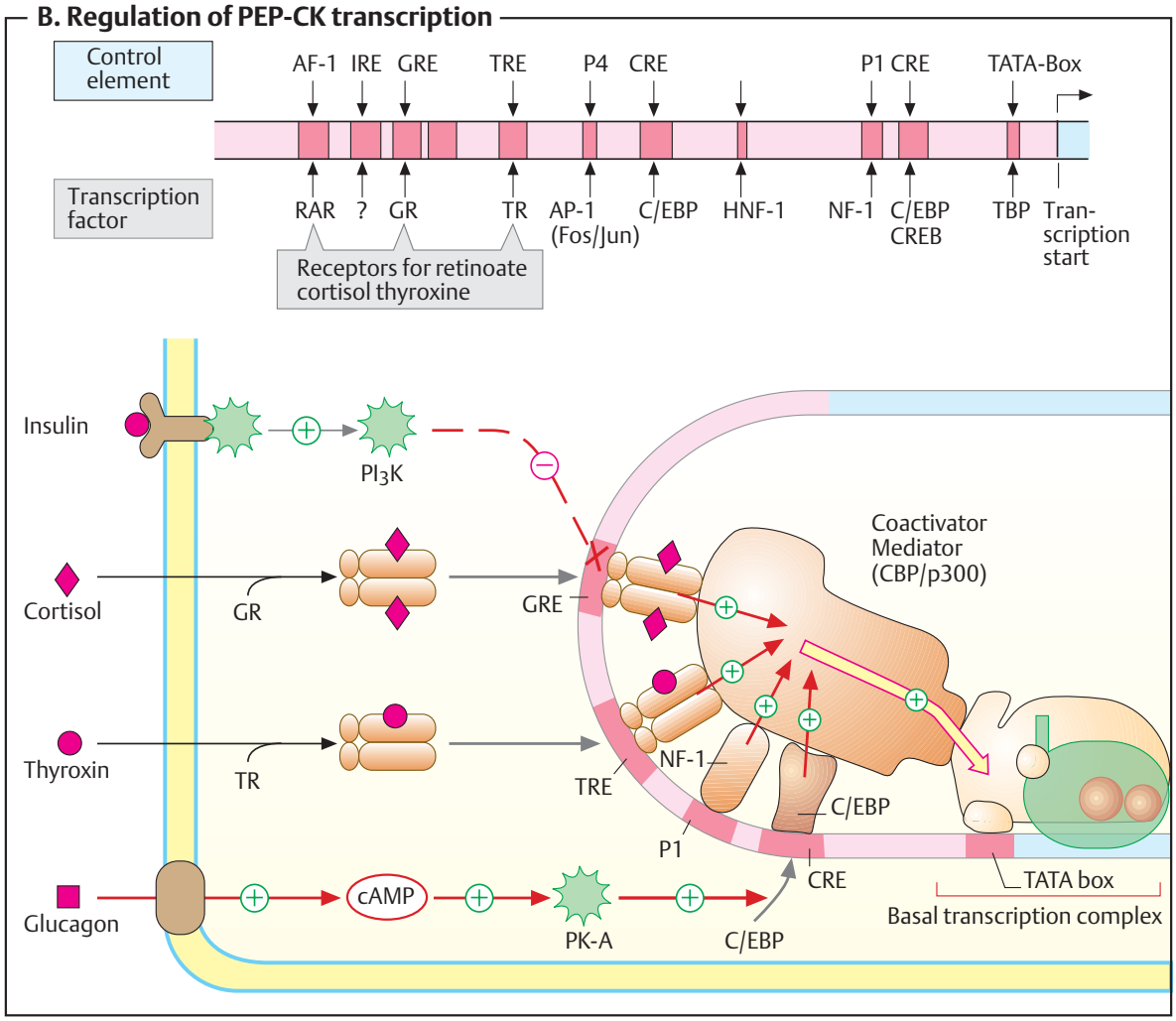

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RNA maturation

Before the hnRNA produced by RNA polymerase II (see p. 242) can leave the nucleus in order to serve as a template for protein synthesis in the cytoplasm, it has to undergo several modifications first. Even during transcription, the two ends of the transcript have additional nucleotides added (**A**). The sections that correspond to the intervening gene sequences in the DNA (introns) are then cut out (splicing; see **B**). Other transcripts—e.g., the 45 S precursor of rRNA formed by polymerase I (see p. 242)—are broken down into smaller fragments by nucleases before export into the cytoplasm.

A. 5′ and 3′ modification of mRNA ◑

Shortly after transcription begins in eukaryotes, the end of the growing RNA is blocked in several reaction steps by a structure known as a "**cap**." In hnRNAs, this consists of a GTP residue that is methylated at N-7 of the guanine ring. The β-phosphate residue of the cap is linked to the free 5′-OH group of the terminal ribose via an ester bond. After the "polyadenylation signal" has been reached (typical sequence: …AAUAAA…; see p. 242), a **polyadenylate "tail"** consisting of up to 200 AMP nucleotides is also added at the free 3′ end of the transcript. This reaction is catalyzed by a special *polyadenylate polymerase*. It is only at this point that the mRNA leaves the nucleus as a complex with RNA-binding proteins.

Both the cap and the poly-A tail play a vital part in initiating eukaryotic translation (see p. 250). They help position the ribosome correctly on the mRNA near to the starting codon. The protection which the additional nucleotides provide against premature enzymatic degradation appears to be of lesser importance.

B. Splicing of hnRNA ◑

Immediately after transcription, the hnRNA introns are removed and the exons are linked to form a continuous coding sequence. This process, known as **splicing**, is supported by complicated RNA–protein complexes in the nucleus, the so-called **spliceosomes**. The components of these macromolecular machines are called **snRNPs** (*small nuclear ribonucleoprotein particles,* pronounced "snurps"). SnRNPs occur in five different forms (U1, U2, U4, U5, and U6). They consist of numerous *proteins* and one molecule of *snRNA* each (see p. 82).

To ensure that the RNA message is not destroyed, splicing has to take place in a very precise fashion. The start and end of the hnRNA introns are recognized by a characteristic sequence (…AGGT… at the 5′ end or …[C,U]AGG… at the 3′ end). Another important structure is the so-called *branching point* inside the intron. Its sequence is less conserved than the terminal splicing sites, but it always contains one adenosine residue (A). During splicing, the 2′-OH group of this residue—supported by the spliceosome (see **C**)—attacks the phosphoric acid diester bond at the 5′ end of the intron and cleaves it (**b**). Simultaneously, an unusual 2′→5′ bond is formed inside the intron, which thereby takes on a *lasso shape* (**c**; see formula). In the second step of the splicing process, the free 3′-OH group at the end of the 5′ terminal exon attacks the A–G bond at the 3′ end of the intron. As a result, the two exons are linked and the intron is released, still in a lasso shape (d).

C. Spliceosome ○

As described above, it is residues of the hnRNA that carry out bond cleavage and bond formation during the splicing process. It is therefore not a protein enzyme that acts as a catalyst here, but rather an RNA. Catalytic RNAs of this type are called *ribozymes* (see also p. 88). The task of the spliceosomes is to fix and orientate the reacting groups by establishing base pairings between snRNAs and segments of the hnRNA. The probable situation before the adenosine attack at the branching point on the 5′ splicing site (see **B**, Fig. **b**) is shown schematically on the right side of the illustration. In this phase, the U1 snRNA fixes the 5′ splicing site, U2 fixes the branching site, and U5 fixes the ends of the two exons.

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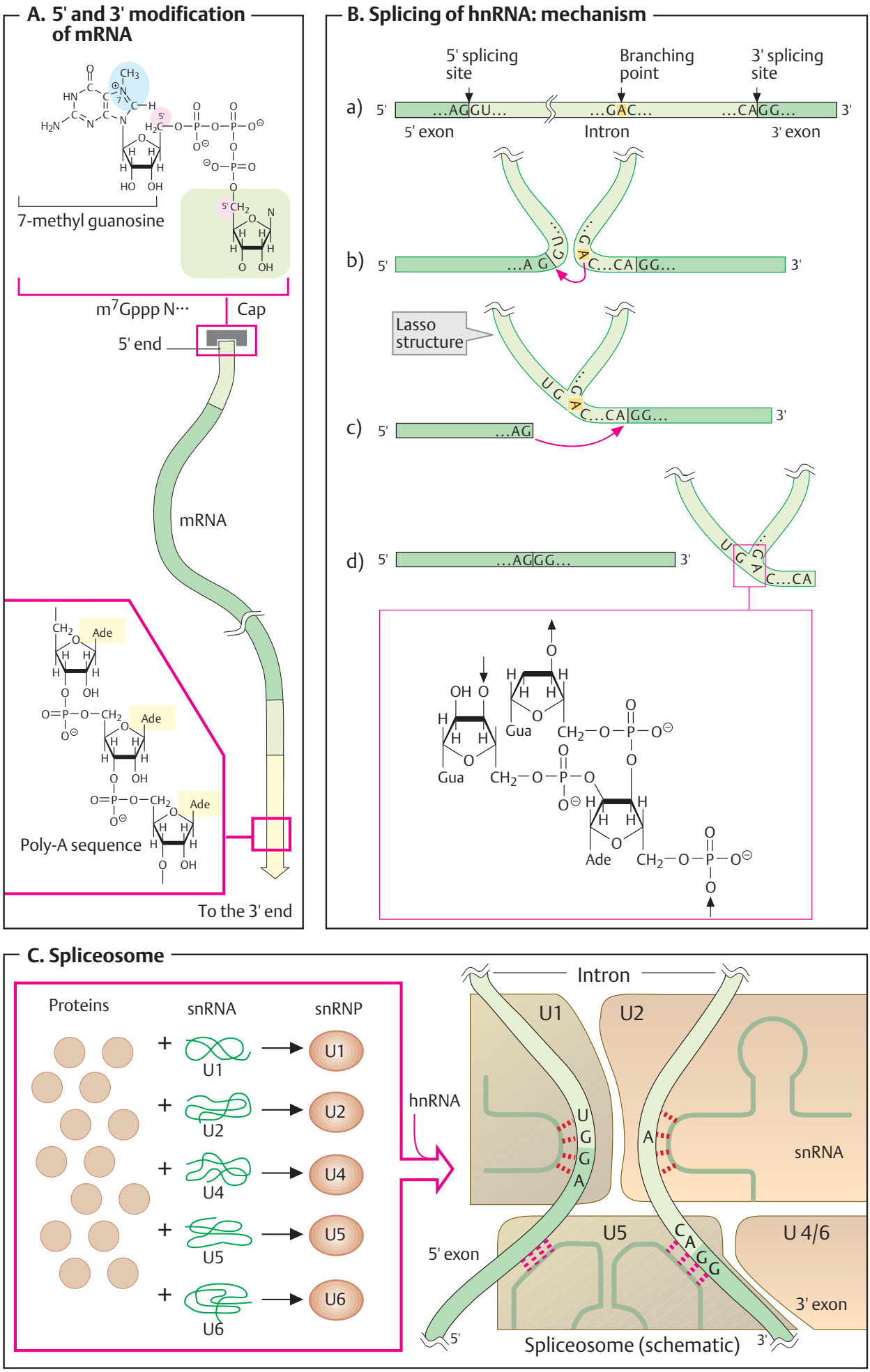

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Amino acid activation

A. The genetic code ◑

Most of the genetic information stored in the genome codes for the amino acid sequences of proteins. For these proteins to be expressed, a text in "nucleic acid language" therefore has to be translated into "protein language." This is the origin of the use of the term **translation** to describe protein biosynthesis. The dictionary used for the translation is the **genetic code.**

As there are 20 proteinogenic amino acids (see p. 60), the nucleic acid language has to contain at least as many words **(codons)**. However, there are only four letters in the nucleic acid alphabet (A, G, C, and U or T). To obtain 20 different words from these, each word has to be at least three letters long (with two letters, there would only be $4^2 = 16$ possibilities). And in fact the codons do consist of three sequential bases **(triplets)**.

Figure 1 shows the standard code in "DNA language" (i. e., as a sequence of triplets in the *sense strand* of DNA, read in the 5′→3′ direction; see p. 84), represented as a circular diagram. The scheme is read from the inside to the outside. For example, the triplet CAT codes for the amino acid histidine. With the exception of the exchange of U for T, the DNA codons are identical to those of mRNA.

As the genetic code provides $4^3 = 64$ codons for the 20 amino acids, there are several synonymous codons for most amino acids—the code is **degenerate**. Three triplets do not code for amino acids, but instead signal the end of translation **(stop codons)**. Another special codon, the **start codon**, marks the start of translation. The code shown here is almost universally applicable; only the mitochondria (see p. 210) and a few microorganisms deviate from it slightly.

As an example of the way in which the code is read, Fig. 2 shows small sections from the normal and a mutated form of the β-globin gene (see p. 280), as well as the corresponding mRNA and protein sequences. The **point mutation** shown, which is relatively frequent, leads to replacement of a glutamate residue in position 6 of the β-chain by valine (G**A**G → G**T**G). As a consequence, the mutated hemoglobin tends to aggregate in the deoxygenated form. This leads to sickle-shaped distortions of the erythrocytes and disturbances of O_2 transport (sickle-cell anemia).

B. Amino acid activation ◑

Some 20 different *amino acid tRNA ligases* in the cytoplasm each bind one type of tRNA (see p. 82) with the corresponding amino acid. This reaction, known as **amino acid activation**, is endergonic and is therefore coupled to ATP cleavage in two steps.

First, the amino acid is bound by the enzyme and reacts there with ATP to form diphosphate and an "energy–rich" mixed acid anhydride (**aminoacyl adenylate**). In the second step, the 3′-OH group (in other ligases it is the 2′-OH group) of the terminal ribose residue of the tRNA takes over the amino acid residue from the aminoacyl adenylate. In **aminoacyl tRNAs**, the carboxyl group of the amino acid is therefore esterified with the ribose residue of the terminal adenosine of the sequence …CCA-3′.

The accuracy of translation primarily depends on the specificity of the amino acid tRNA ligases, as incorrectly incorporated amino acid residues are not recognized by the ribosome later. A *"proofreading mechanism"* in the active center of the ligase therefore ensures that incorrectly incorporated amino acid residues are immediately removed again. On average, an error only occurs once every 1300 amino acid residues. This is a surprisingly low rate considering how similar some amino acids are—e. g., leucine and isoleucine.

C. Asp–tRNA ligase (dimer) ○

The illustration shows the ligase responsible for the activation of aspartate. Each subunit of the dimeric enzyme (protein parts shown in orange) binds one molecule of $tRNA^{Asp}$ (blue). The active centers can be located by the bound ATP (green). They are associated with the 3′ end of the tRNA. Another domain in the protein (upper left) is responsible for "recognition" of the tRNA anticodon.

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A. The genetic code

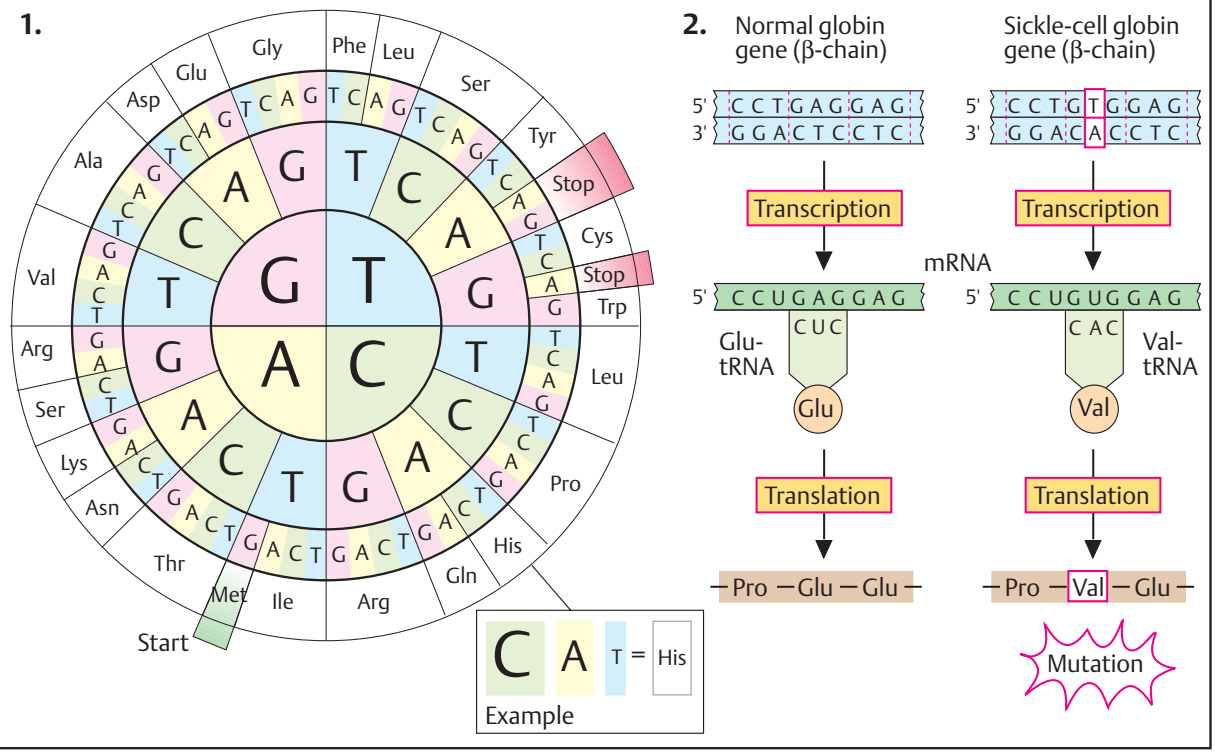

B. Amino acid activation

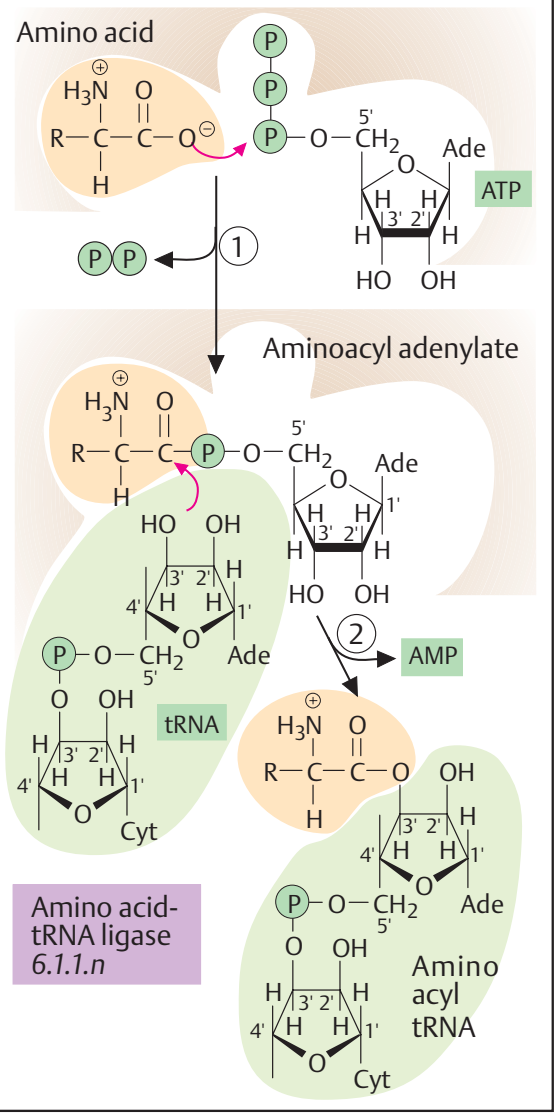

C. Asp-tRNA-Ligase (Dimer)

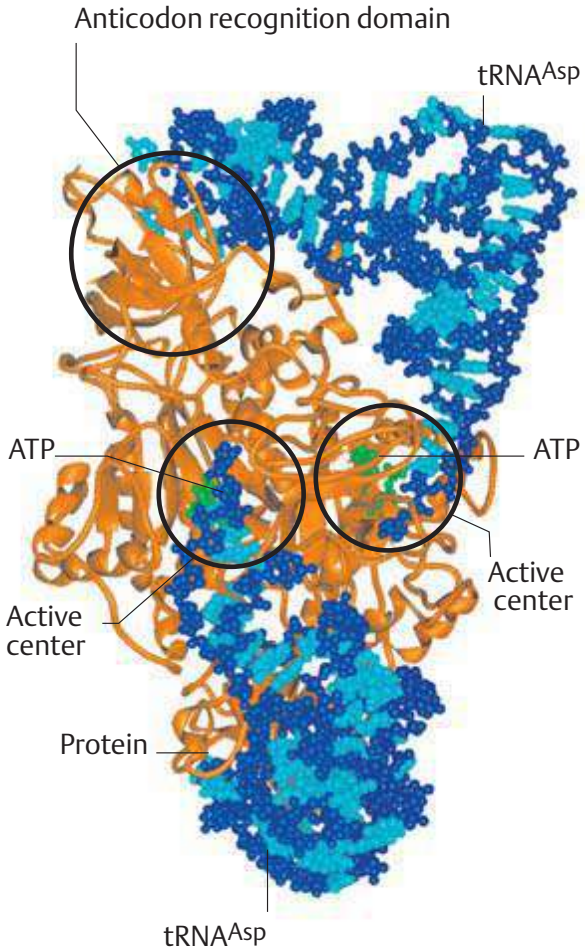

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Translation I: initiation

Like amino acid activation (see p. 248), protein biosynthesis (**translation**) takes place in the cytoplasm. It is catalyzed by complex nucleoprotein particles, the **ribosomes**, and mainly requires GTP to cover its energy requirements.

A. Structure of the eukaryotic ribosome ◑

Ribosomes consist of two subunits of different size, made up of **ribosomal RNA (rRNA)** and nearly 80 **proteins** (the number of proteins applies to rat liver ribosomes). It is customary to give the sedimentation coef cients (see p. 200) of ribosomes and their components instead of their masses. For example, the eukaryotic ribosome has a sedimentation coefficient of 80 Svedberg units (80 S), while the sedimentation coef cients of its subunits are 40 S and 60 S (S values are not additive).

The smaller 40 S subunit consists of one molecule of 18 S rRNA and 33 protein molecules. The larger 60 S subunit contains three types of rRNA with sedimentation coef cients of 5 S, 5.8 S, and 28 S and 47 proteins. In the presence of mRNA, the subunits assemble to form the complete ribosome, with a mass about 650 times larger than that of a hemoglobin molecule.

The arrangement of the individual components of a ribosome has now been determined for prokaryotic ribosomes. It is known that filamentous mRNA passes through a cleft between the two subunits near the characteristic "horn" on the small subunit. tRNAs also bind near this site. The illustration shows the size of a tRNA molecule for comparison.

Prokaryotic ribosomes have a similar structure, but are somewhat smaller than those of eukaryotes (sedimentation coef cient 70 S for the complete ribosome, 30 S and 50 S for the subunits). Mitochondrial and chloroplast ribosomes are comparable to prokaryotic ones.

B. Polysomes ◑

In cells that are carrying out intensive protein synthesis, ribosomes are often found in a linear arrangement like a string of pearls; these are known as **polysomes**. This arrangement arises because several ribosomes are translating a single mRNA molecule simultaneously. The ribosome first binds near the **start codon** (AUG; see p. 248) at the 5′ end of the mRNA (top). During translation, the ribosome moves in the direction of the 3′ end until it reaches a **stop codon** (UAA, UAG, or UGA). At this point, the newly synthesized chain is released, and the ribosome dissociates again into its two subunits.

C. Initiation of translation in E. coli ◑

Protein synthesis in prokaryotes is in principle the same as in eukaryotes. However, as the process is simpler and has been better studied in prokaryotes, the details involved in translation are discussed here and on p. 252 using the example of the bacterium *Escherichia coli.*

The first phase of translation, **initiation**, involves several steps. First, two proteins, **initiation factors** IF–1 and IF–3, bind to the 30 S subunit (**1**). Another factor, IF–2, binds as a complex with GTP (**2**). This allows the subunit to associate with the mRNA and makes it possible for a special tRNA to bind to the start codon (**3**). In prokaryotes, this starter tRNA carries the substituted amino acid *N-formylmethionine* (fMet). In eukaryotes, it carries an unsubstituted *methionine*. Finally, the 50 S subunit binds to the above complex (**4**). During steps 3 and 4, the initiation factors are released again, and the GTP bound to IF–2 is hydrolyzed to GDP and P_i.

In the **70 S initiation complex**, formylmethionine tRNA is initially located at a binding site known as the **peptidyl site (P)**. A second binding site, the **acceptor site (A)**, is not yet occupied during this phase of translation. Sometimes, a third tRNA binding site is defined as an *exit site (E),* from which uncharged tRNAs leave the ribosome again (see p. 252; not shown).

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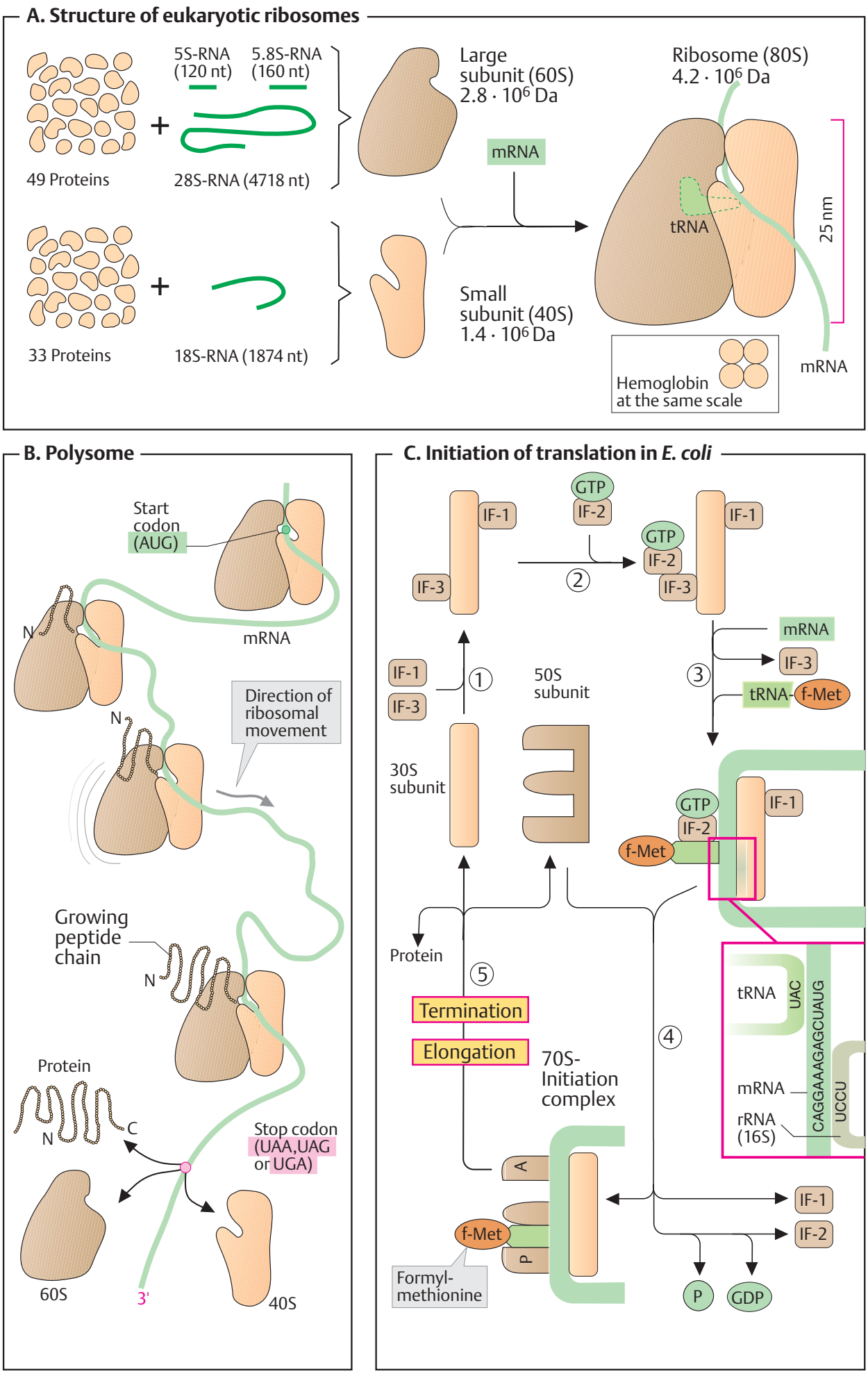

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Translation II: elongation and termination

After translation has been initiated (see p. 250), the peptide chain is extended by the addition of further amino acid residues (**elongation**) until the ribosome reaches a stop codon on the mRNA and the process is interrupted (**termination**).

A. Elongation and termination of protein biosynthesis in E. coli ◑

Elongation can be divided into four phases:

[1] **Binding of aminoacyl tRNA.** First, the peptidyl site (P) of the ribosome is occupied by a tRNA that carries at its 3′ end the complete peptide chain formed up to this point (top left). A second tRNA, loaded with the next amino acid (Val–$tRNA^{Val}$ in the example shown), then binds via its complementary anticodon (see p. 82) to the mRNA codon exposed at the acceptor site (in this case GUG). The tRNA binds as a complex with a GTP-containing protein, the *elongation factor Tu* (EF–Tu) (**1a**). It is only after the bound GTP has been hydrolyzed to GDP and phosphate that EF–Tu dissociates again (**1b**). As the binding of the tRNA to the mRNA is still loose before this, GTP hydrolysis acts as a delaying factor, making it possible to check whether the correct tRNA has been bound. A further protein, the *elongation factor Ts* (EF-Ts), later catalyzes the exchange of GDP for GTP and in this way regenerates the EF–Tu GTP complex. EF-Tu is related to the G proteins involved in signal transduction (see p. 384).

[2] **Synthesis of the peptide bond** takes place in the next step. Ribosomal *peptidyltransferase* catalyzes (without consumption of ATP or GTP) the transfer of the peptide chain from the tRNA at the P site to the NH_2 group of the amino acid residue of the tRNA at the A site. The ribosome's peptidyltransferase activity is not located in one of the ribosomal proteins, but in the 28 S rRNA. Catalytically active RNAs of this type are known as *ribozymes* (cf. p. 246). It is thought that the few surviving ribozymes are remnants of the *"RNA world"*—an early phase of evolution in which proteins were not as important as they are today.

[3] After the transfer of the growing peptide to the A site, the free tRNA at the P site dissociates and another GTP–containing elongation factor (EF-G GTP) binds to the ribosome. Hydrolysis of the GTP in this factor provides the energy for **translocation** of the ribosome. During this process, the ribosome moves three bases along the mRNA in the direction of the 3′ end. The tRNA carrying the peptide chain is stationary relative to the mRNA and reaches the ribosome's P site during translocation, while the next mRNA codon (in this case GUG) appears at the A site.

[4] The uncharged Val-tRNA then dissociates from the E site. The ribosome is now ready for the next elongation cycle.

When one of the three stop codons (UAA, UAG, or UGA) appears at the A site, **termination** starts.

[5] There are no complementary tRNAs for the stop codons. Instead, two *releasing factors* bind to the ribosome. One of these factors (RF–1) catalyzes hydrolytic cleavage of the ester bond between the tRNA and the C–terminus of the peptide chain, thereby releasing the protein.

[6] Hydrolysis of GTP by factor RF–3 supplies the energy for the dissociation of the whole complex into its component parts.

Energy requirements in protein synthesis are high. Four energy-rich phosphoric acid anhydride bonds are hydrolyzed for each amino acid residue. Amino acid activation uses up two energy-rich bonds per amino acid (ATP → AMP + PP; see p. 248), and two GTPs are consumed per elongation cycle. In addition, initiation and termination each require one GTP per chain.

Further information

In eukaryotic cells, the number of initiation factors is larger and initiation is therefore more complex than in prokaryotes. The cap at the 5′ end of mRNA and the polyA tail (see p. 246) play important parts in initiation. However, the elongation and termination processes are similar in all organisms. The individual steps of bacterial translation can be inhibited by antibiotics (see p. 254).

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A. Elongation and termination of protein biosynthesis in *E. coli*

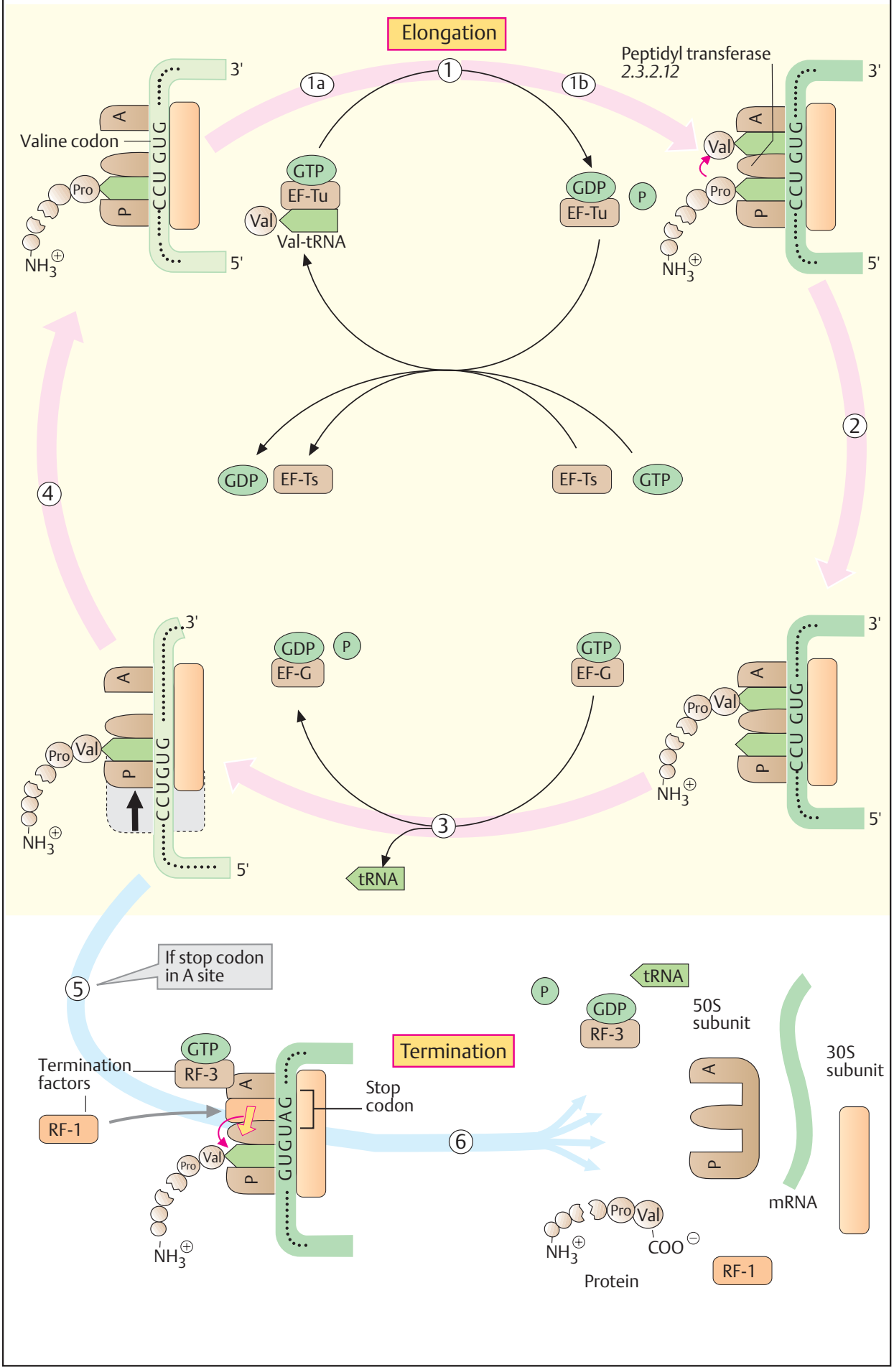

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Antibiotics

A. Antibiotics: overview ◑

Antibiotics are substances which, even at low concentrations, inhibit the growth and reproduction of bacteria and fungi. The treatment of infectious diseases would be inconceivable today without antibiotics. Substances that only restrict the reproduction of bacteria are described as having *bacteriostatic* effects (or *fungistatic* for fungi). If the target cells are killed, then the term *bactericidal* (or *fungicidal*) is used. Almost all antibiotics are produced by microorganisms—mainly bacteria of the genus *Streptomyces* and certain fungi. However, there are also synthetic antibacterial substances, such as sulfonamides and gyrase inhibitors.

A constantly increasing problem in antibiotic treatment is the development of resistant pathogens that no longer respond to the drugs available. The illustration shows a few of the therapeutically important antibiotics and their sites of action in the bacterial metabolism.

Substances known as **intercalators**, such as *rifamycin* and *actinomycin D* (bottom) are deposited in the DNA double helix and thereby interfere with replication and transcription (**B**). As DNA is the same in all cells, intercalating antibiotics are also toxic for eukaryotes, however. They are therefore only used as cytostatic agents (see p. 402). Synthetic inhibitors of DNA topoisomerase II (see p. 240), known as **gyrase inhibitors** (center), restrict replication and thus bacterial reproduction.

A large group of antibiotics attack bacterial ribosomes. These **inhibitors of translation** (left) include the *tetracyclines*—broad-spectrum antibiotics that are effective against a large number of different pathogens. The *aminoglycosides*, of which *streptomycin* is the best-known, affect all phases of translation. *Erythromycin* impairs the normal functioning of the large ribosomal subunit. *Chloramphenicol,* one of the few natural nitro compounds, inhibits ribosomal peptidyltransferase. Finally, *puromycin* mimics an aminoacyl tRNA and therefore leads to premature interruption of elongation.

The **β–lactam antibiotics** (bottom right) are also frequently used. The members of this group, the *penicillins* and *cephalosporins,* are synthesized by fungi and have a reactive β-lactam ring. They are mainly used against Gram-positive pathogens, in which they inhibit cell wall synthesis (**C**).

The first synthetic antibiotics were the **sulfonamides** (right). As analogues of p–aminobenzoic acid, these affect the synthesis of *folic acid,* an essential precursor of the coenzyme THF (see p. 108). **Transport antibiotics** (top center) have the properties of ion channels (see p. 222). When they are deposited in the plasma membrane, it leads to a loss of ions that damages the bacterial cells.

B. Intercalators ○

The effects of intercalators (see also p. 262) are illustrated here using the example of the **daunomycin–DNA complex**, in which two daunomycin molecules (red) are inserted in the double helix (blue). The antibiotic's ring system inserts itself between G/C base pairs (bottom), while the sugar moiety occupies the minor groove in the DNA (above). This leads to a localized change of the DNA conformation that prevents replication and transcription.

C. Penicillin as a "suicide substrate" ○

The site of action in the β–lactam antibiotics is *muramoylpentapeptide carboxypeptidase,* an enzyme that is essential for cross–linking of bacterial cell walls. The antibiotic resembles the substrate of this enzyme (a peptide with the C-terminal sequence D-Ala–D–Ala) and is therefore reversibly bound in the active center. This brings the β–lactam ring into proximity with an essential serine residue of the enzyme. Nucleophilic substitution then results in the formation of a stable covalent bond between the enzyme and the inhibitor, blocking the active center (see p. 96). In dividing bacteria, the loss of activity of the enzyme leads to the formation of unstable cell walls and eventually death.

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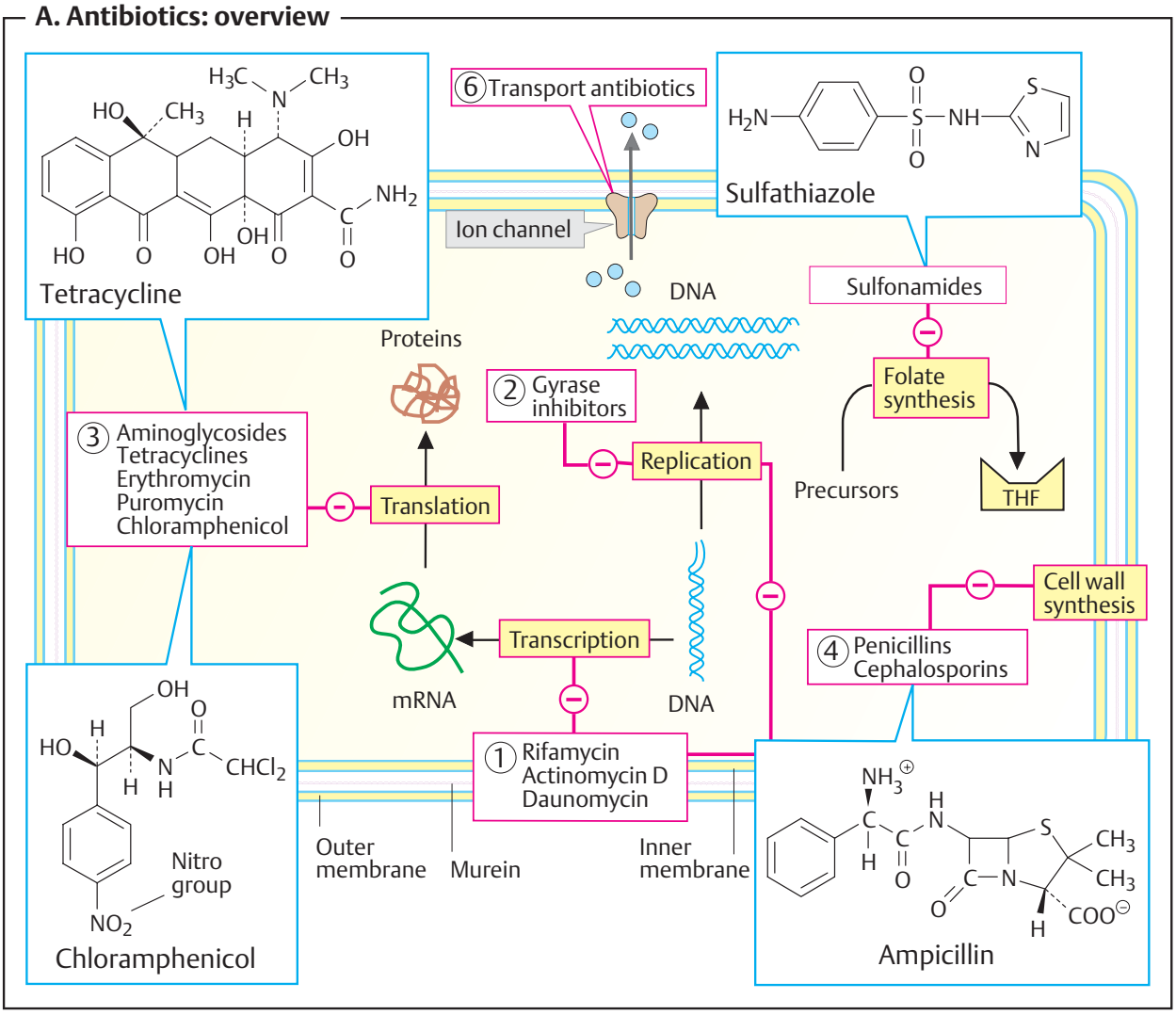

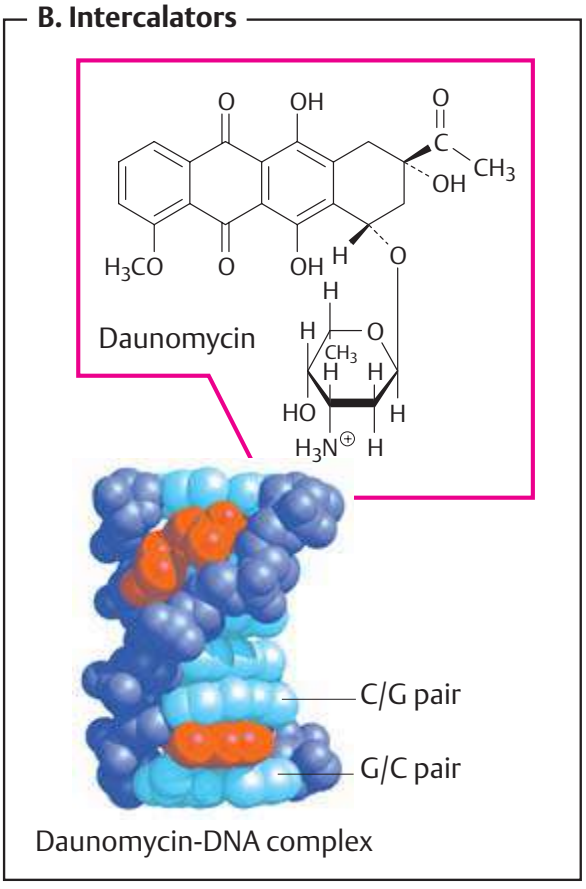

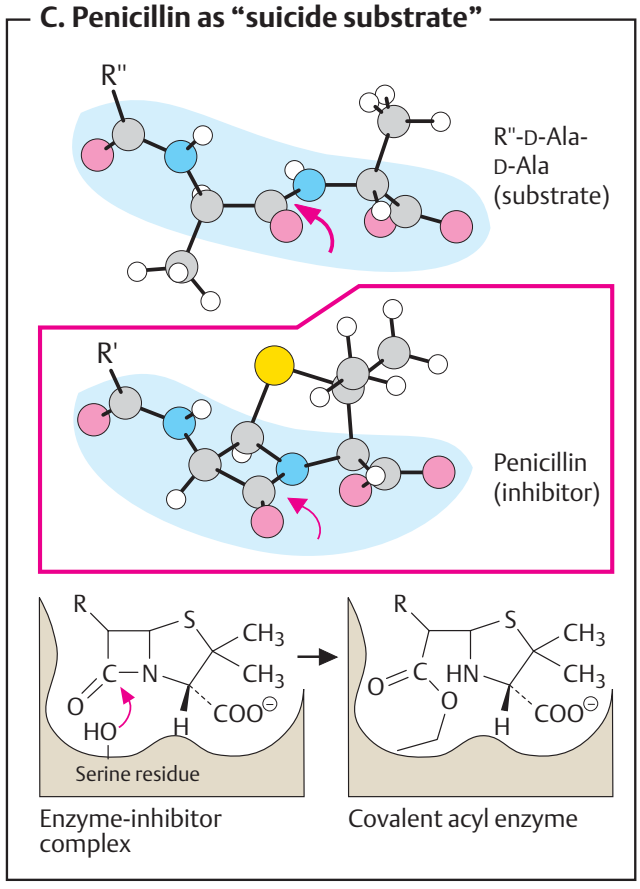

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Mutation and repair

Genetic information is set down in the base sequence of DNA. Changes in the DNA bases or their sequence therefore have *mutagenic* effects. Mutagens often also damage growth regulation in cells, and they are then also *carcinogenic* (see p. 400). Gene alterations (**mutations**) are one of the decisive positive factors in biological evolution. On the other hand, an excessive mutation frequency would threaten the survival of individual organisms or entire species. For this reason, every cell has **repair mechanisms** that eliminate most of the DNA changes arising from mutations (**C**).

A. Mutagenic agents ◑

Mutations can arise as a result of physical or chemical effects, or they can be due to accidental errors in DNA replication and recombination.

The principal physical mutagen is **ionizing radiation** (α, β, and γ radiation, X-rays). In cells, it produces **free radicals** (molecules with unpaired electrons), which are extremely reactive and can damage DNA. Short-wavelength **ultraviolet light** (UV light) also has mutagenic effects, mainly in skin cells (sunburn). The most common chemical change due to UV exposure is the formation of **thymine dimers**, in which two neighboring thymine bases become covalently linked to one another (**2**). This results in errors when the DNA is read during replication and transcription.

Only a few examples of the group of **chemical mutagens** are shown here. *Nitrous acid* (HNO_2; salt: nitrite) and *hydroxylamine* (NH_2OH) both deaminate bases; they convert cytosine to uracil and adenine to inosine.

Alkylating compounds carry reactive groups that can form covalent bonds with DNA bases (see also p. 402). *Methylnitrosamines* (**3**) release the reactive methyl cation (CH_3^+), which methylates OH and NH_2 groups in DNA. The dangerous carcinogen *benzo*[a]*pyrene* is an aromatic hydrocarbon that is only converted into the active form in the organism (**4**; see p. 316). Multiple hydroxylation of one of the rings produces a reactive epoxide that can react with NH_2 groups in guanine residues, for example. Free radicals of benzo[*a*]pyrene also contribute to its toxicity.

B. Effects ◑

Nitrous acid causes **point mutations** (**1**). For example, C is converted to U, which in the next replication pairs with A instead of G. The alteration thus becomes permanent. Mutations in which a number of nucleotides not divisible by three are inserted or removed lead to reading errors in whole segments of DNA, as they move the reading frame (**frameshift mutations**). This is shown in Fig. **2** using a simple example. From the inserted C onwards, the resulting mRNA is interpreted differently during translation, producing a completely new protein sequence.

C. Repair mechanisms ○

An important mechanism for the removal of DNA damage is **excision repair** (**1**). In this process, a specific *excision endonuclease* removes a complete segment of DNA on both sides of the error site. Using the sequence of the opposite strand, the missing segment is then replaced by a *DNA polymerase*. Finally, a *DNA ligase* closes the gaps again.

Thymine dimers can be removed by **photoreactivation** (**2**). A specific *photolyase* binds at the defect and, when illuminated, cleaves the dimer to yield two single bases again.

A third mechanism is **recombination repair** (**3**, shown in simplified form). In this process, the defect is omitted during replication. The gap is closed by shifting the corresponding sequence from the correctly replicated second strand. The new gap that results is then filled by polymerases and ligases. Finally, the original defect is corrected by excision repair as in Fig. **1** (not shown).

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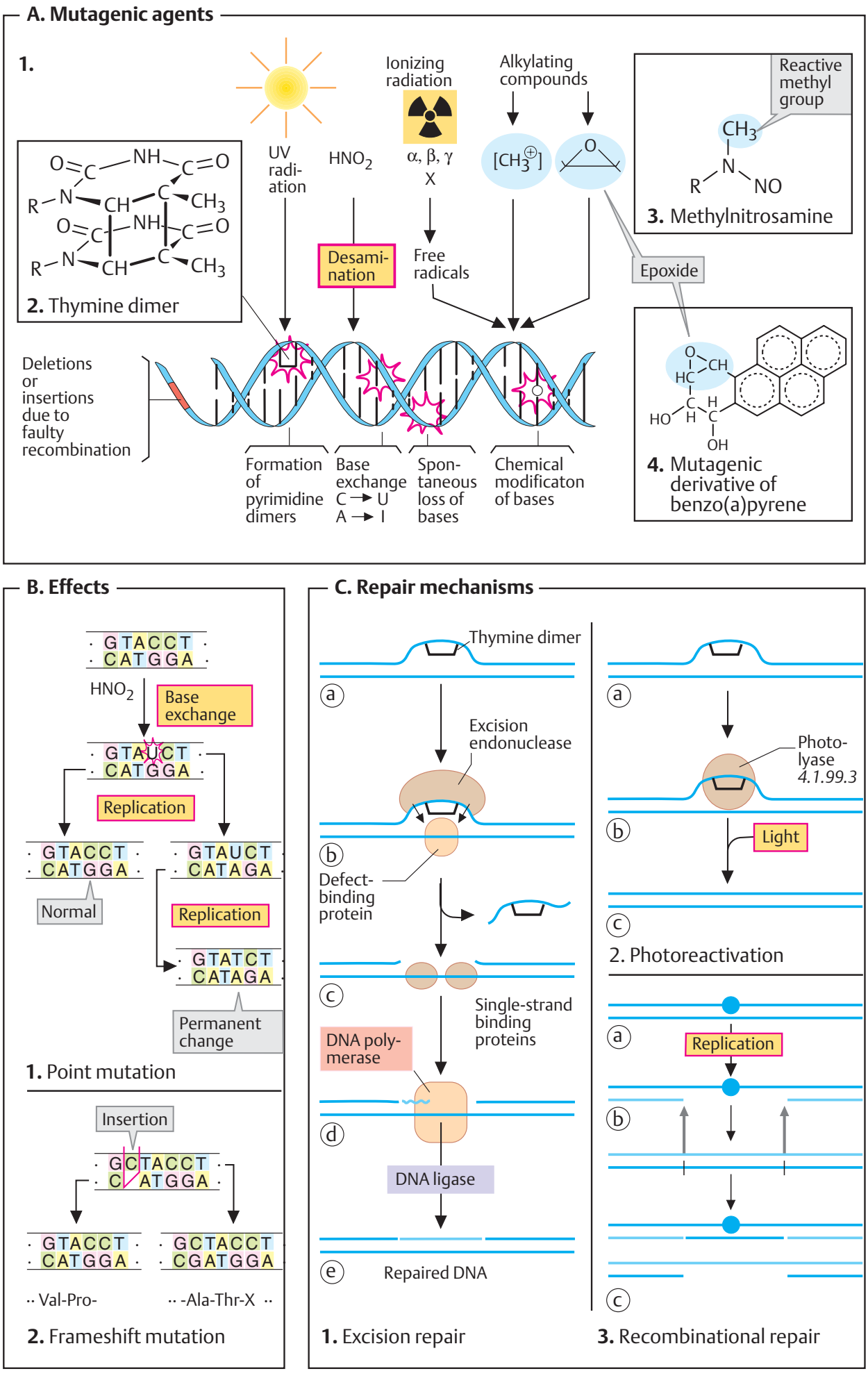

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DNA cloning

The growth of molecular genetics since 1970 has mainly been based on the development and refinement of methods of analyzing and manipulating DNA. **Genetic engineering** has practical applications in many fields. For example, it has provided new methods of diagnosing and treating diseases, and it is now also possible to create targeted changes in specific characteristics of organisms. Since biological risks cannot be completely ruled out with these procedures, it is particularly important to act responsibly when dealing with genetic engineering. A short overview of important methods involved in genetic engineering is provided here and on the following pages.

A. Restriction endonucleases ◑

In many genetic engineering procedures, defined DNA fragments have to be isolated and then newly combined with other DNA segments. For this purpose, enzymes are used that can cut DNA and join it together again inside the cell. Of particular importance are *restriction endonucleases*—a group of bacterial enzymes that cleave the DNA double strand in a sequence–specific way. The numerous restriction enzymes known are named using abbreviations based on the organism from which they originate. The example used here is *Eco*RI, a nuclease isolated from the bacterium *Escherichia coli.*

Like many other restriction endonucleases, EcoRI cleaves DNA at the site of a *palindrome*—i. e., a short segment of DNA in which both the strand and counter-strand have the same sequence (each read in the 5′→3′ direction). In this case, the sequence is 5′-GAATTC-3′. *Eco*RI, a homodimer, cleaves the phosphoric acid diester bonds in both strands between G and A. This results in the formation of complementary *overhanging* or *"sticky" ends* (AATT), which are held together by base pairing. However, they are easily separated—e. g. by heating. When the fragments are cooled, the overhanging ends hybridize again in the correct arrangement. The cleavage sites can then be sealed again by a *DNA ligase*.

B. DNA cloning ○

Most DNA segments—e. g., genes—occur in very small quantities in the cell. To be able to work with them experimentally, a large number of identical copies (**"clones"**) first have to be produced. The classic procedure for cloning DNA takes advantage of the ability of bacteria to take up and replicate short, circular DNA fragments known as **plasmids**.

The segment to be cloned is first cut out of the original DNA using restriction endonucleases (see above; for the sake of simplicity, cleavage using *Eco*RI alone is shown here, but in practice two different enzymes are usually used). As a vehicle (*"vector"*), a plasmid is needed that has only *one Eco*RI cleavage site. The plasmid rings are first opened by cleavage with *Eco*RI and then mixed with the isolated DNA fragments. Since the fragment and the vector have the same overhanging ends, some of the molecules will hybridize in such a way that the fragment is incorporated into the vector DNA. When the cleavage sites are now closed again using *DNA ligase,* a newly combined *("recombinant") plasmid* arises.

By pretreating a large number of host cells, one can cause some of them to take up the plasmid (a process known as **transformation**) and replicate it along with their own genome when reproducing. To ensure that only host bacteria that contain the plasmid replicate, plasmids are used that give the host *resistance* to a particular antibiotic. When the bacteria are incubated in the presence of this antibiotic, only the cells containing the plasmid will replicate. The plasmid is then isolated from these cells, cleaved with *Eco*RI again, and the fragments are separated using agarose gel electrophoresis (see p. 262). The desired fragment can be identified using its size and then extracted from the gel and used for further experiments.

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A. Restriction endonucleases

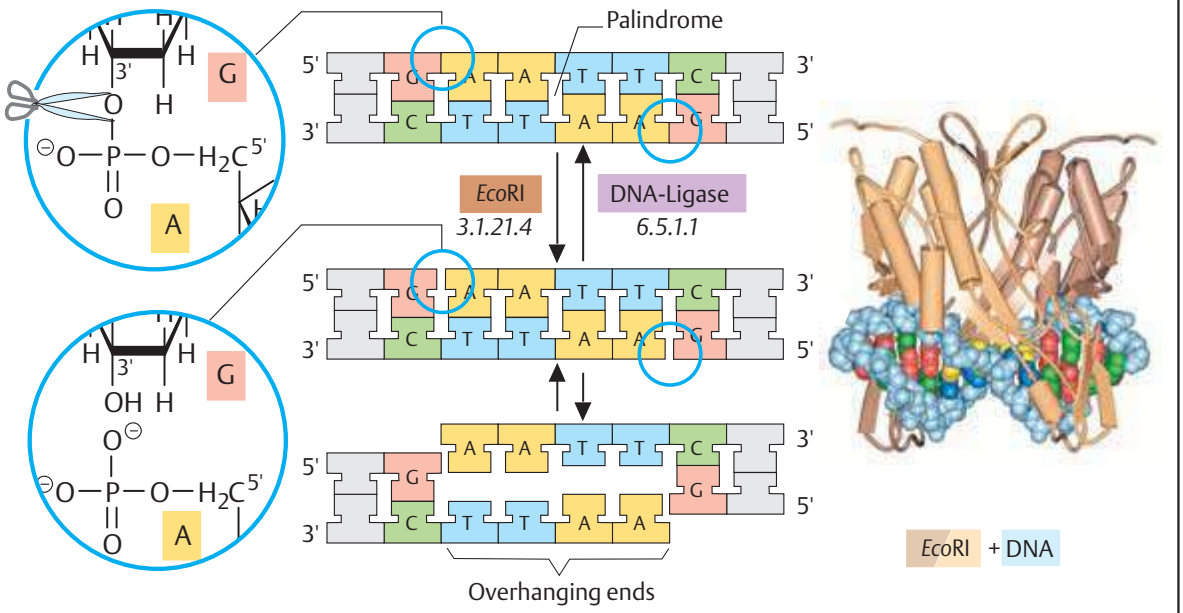

B. DNA cloning

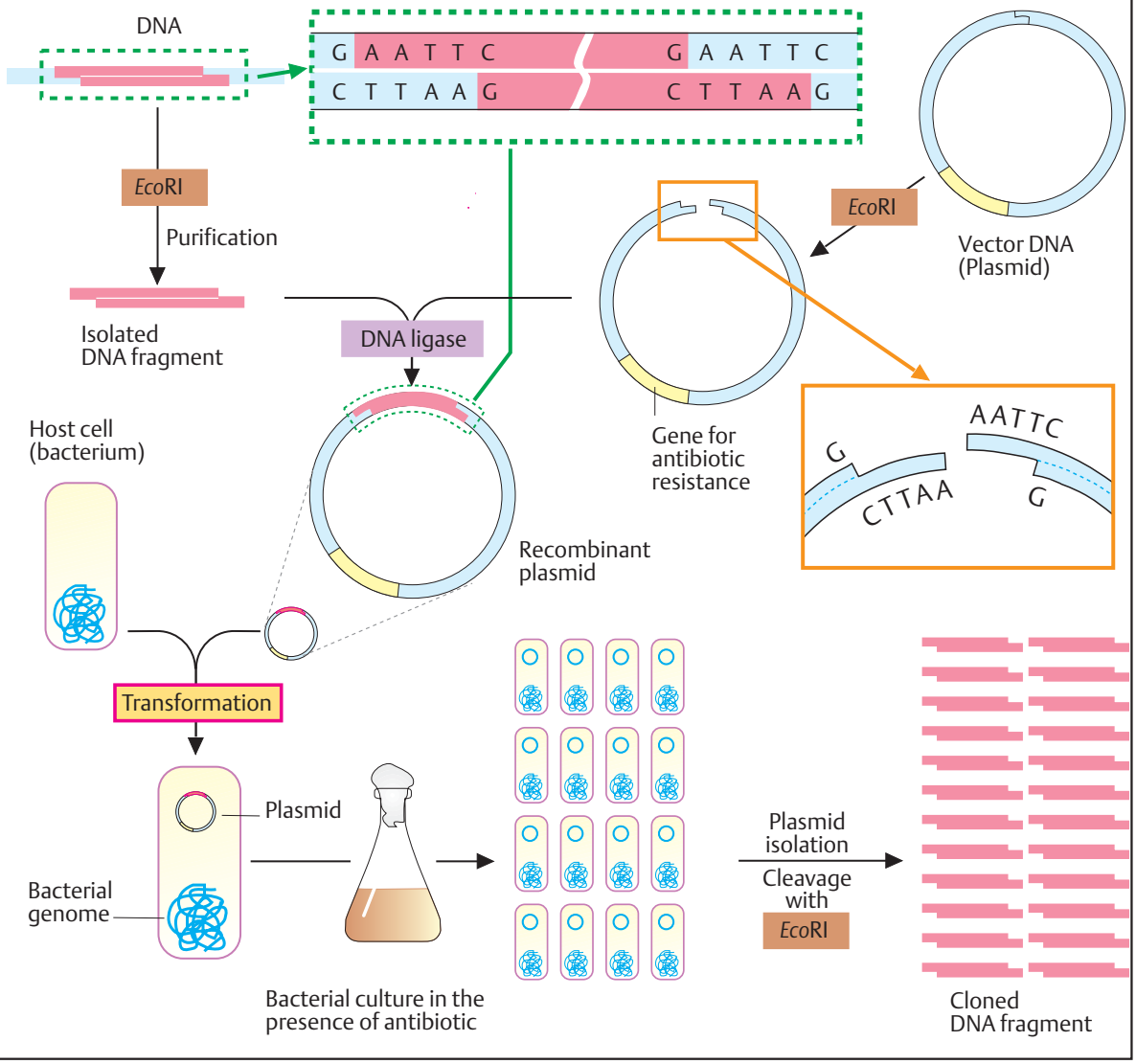

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DNA sequencing

A. Gene libraries ○

It is often necessary in genetic engineering to isolate a DNA segment when its details are not fully known—e.g., in order to determine its nucleotide sequence. In this case, one can use what are known as **DNA libraries**. A DNA library consists of a large number of *vector DNA molecules* containing different fragments of *foreign DNA.* For example, it is possible to take all of the mRNA molecules present in a cell and transcribe them into DNA. These DNA fragments (known as copy DNA or **cDNA**) are then randomly introduced into vector molecules.

A library of genomic DNA can be established by cleaving the total DNA from a cell into small fragments using restriction endonucleases (see p. 258), and then incorporating these into vector DNA. Suitable vectors for gene libraries include **bacteriophages**, for example ("phages" for short). Phages are viruses that only infect bacteria and are replicated by them (see p. 404). Gene libraries have the advantage that they can be searched for specific DNA segments, using hybridization with oligonucleotides.

The first step is to strongly dilute a small part of the library (10^5–10^6 phages in a small volume), mix it with host bacteria, and plate out the mixture onto nutrient medium. The bacteria grow and form a continuous cloudy layer of cells. Bacteria infected by phages grow more slowly. In their surroundings, the bacterial "lawn" is less dense, and a clearer circular zone known as a **plaque** forms. The bacteria in this type of plaque exclusively contain the offspring of a single phage from the library.

The next step is to make an impression of the plate on a plastic foil, which is then heated. This causes the phage DNA to adhere to the foil. When the foil is incubated with a DNA fragment that hybridizes to the DNA segment of interest (a **gene probe**), the probe binds to the sites on the imprint at which the desired DNA is attached. Binding of the gene probe can be detected by prior radioactive or other labeling of the probe. Phages from the positive plaques in the original plate are then isolated and replicated. Restriction cleavage finally provides large amounts of the desired DNA.

B. Sequencing of DNA ○

The nucleotide sequence of DNA is nowadays usually determined using the so-called **chain termination method**. In single-strand sequencing, the DNA fragment (**a**) is cloned into the DNA of **phage M13** (see p. 404), from which the coded single strand can be easily isolated. This is *hybridized* with a **primer**—a short, synthetically produced DNA fragment that binds to 3′ end of the introduced DNA segment (**b**).

Based on this hybrid, the missing second strand can now be generated in the test tube by adding the four *deoxyribonucleoside triphosphates* (*dNTP*) and a suitable *DNA polymerase* (**c**). The trick lies in also adding small amounts of *dideoxynucleoside triphosphates (ddNTP).* Incorporating a ddNTP leads to the *termination of second-strand synthesis.* This can occur whenever the corresponding dNTP ought to be incorporated. The illustration shows this in detail using the example of ddGTP. In this case, fragments are obtained that each include the primer plus three, six, eight, 13, or 14 additional nucleotides. *Four separate reactions,* each with a different ddNTP, are carried out (**c**), and the products are placed side by side on a supporting material. The fragments are then separated by *gel electrophoresis* (see p. 76), in which they move in relation to their length.

Following *visualization* (**d**), the sequence of the fragments in the individual lanes is simply read from bottom to top (**e**) to directly obtain the nucleotide sequence. A detail from such a sequencing gel and the corresponding protein sequence are shown in Fig. **2**.

In a more modern procedure, the four ddNTPs are covalently marked with fluorescent dyes, which produce a different color for each ddNTP on laser illumination. This allows the sequence in which the individual fragments appear at the lower end of the gel to be continuously recorded and directly stored in digital form.

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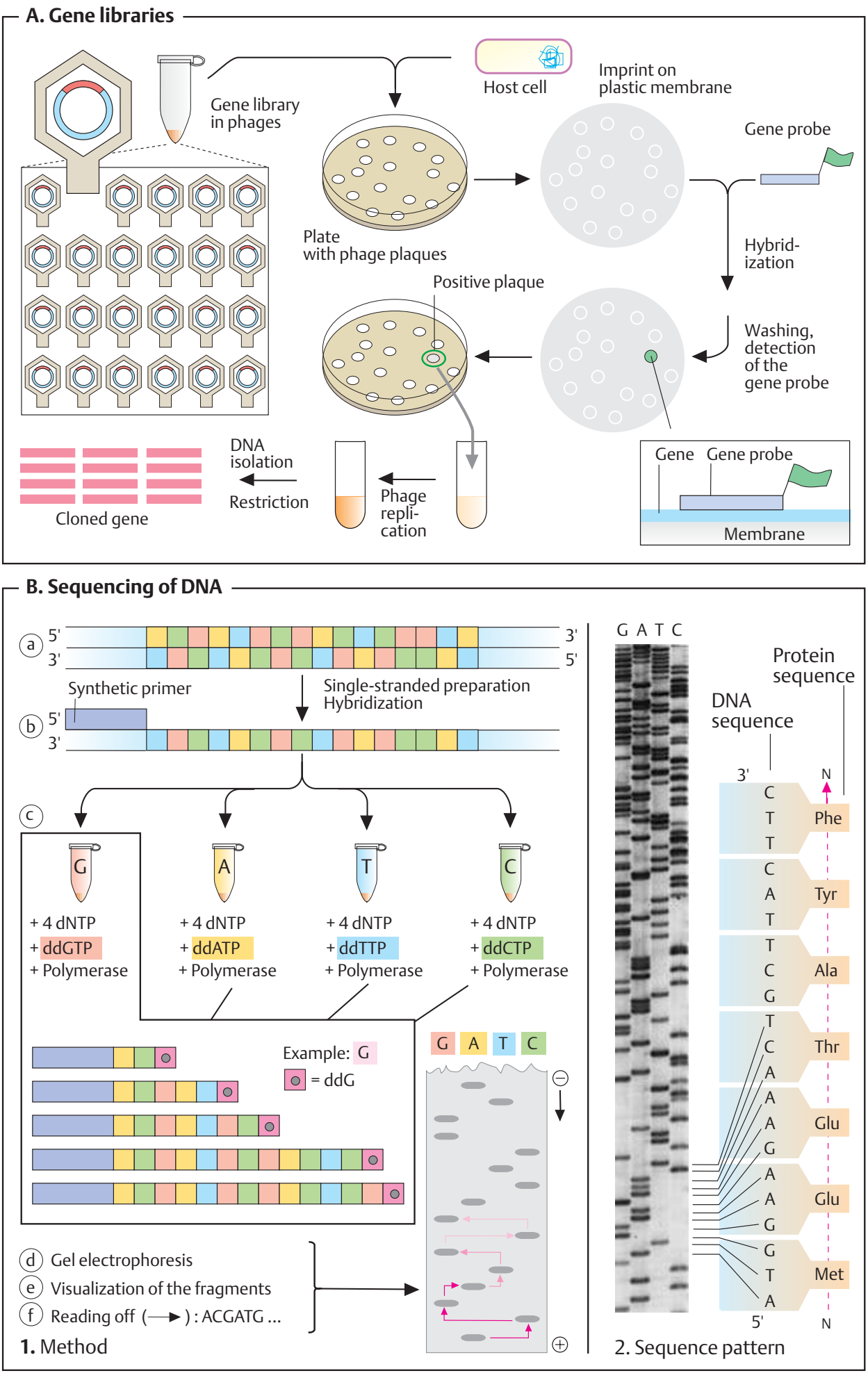

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PCR and protein expression

A. Polymerase chain reaction (PCR) ◑

The polymerase chain reaction (PCR) is an important procedure in genetic engineering that allows any DNA segment to be replicated (**amplified**) without the need for restriction enzymes, vectors, or host cells (see p. 258). However, the nucleotide sequence of the segment has to be known. Two oligonucleotides (**primers**) are needed, which each hybridize with one of the strands at each end of the DNA segment to be amplified; also needed are sufficient quantities of the four **deoxyribonucleoside triphosphates** and a special heat-tolerant DNA polymerase. The primers are produced by chemical synthesis, and the polymerase is obtained from thermostable bacteria.

First, the starter is heated to around 90 °C to separate the DNA double helix into single strands (**a**; cf. p. 84). The mixture is then cooled to allow hybridization of the primers (**b**). Starting from the primers, complementary DNA strands are now synthesized in both directions by the polymerase (**c**). This *cycle* (cycle 1) is *repeated 20–30 times* with the same reaction mixture (cycle 2 and subsequent cycles). The cyclic heating and cooling are carried out by *computer-controlled thermostats.*

After only the third cycle, double strands start to form with a length equal to the distance between the two primers. The proportion of these approximately doubles during each cycle, until almost all of the newly synthesized segments have the correct length.

B. DNA electrophoresis ○

The separation of DNA fragments by electrophoresis is technically simpler than protein electrophoresis (see p. 78). The mobility of molecules in an electrical field of a given strength depends on the size and shape of the molecules, as well as their charge. In contrast to proteins, in which all three factors vary, the ratio of mass to charge in nucleic acids is constant, as all of the nucleotide components have similar masses and carry one negative charge. When electrophoresis is carried out in a wide-meshed support material that does not separate according to size and shape, the mobility of the molecules depends on their mass alone. The supporting material generally used in genetic engineering is a gel of the polysaccharide **agarose** (see p. 40). Agarose gels are not very stable and are therefore poured horizontally into a plastic chamber in which they are used for separation (top).

To make the separated fragments visible, after running the procedure the gels are placed in solutions of **ethidium bromide**. This is an intercalator (see p. 254) that shows strong fluorescence in UV light after binding to DNA, although it barely fluoresces in an aqueous solution. The result of separating two PCR amplificates (lanes 1 and 2) is shown in the lower part of the illustration. Comparing their distances with those of polynucleotides of known lengths (lane 3; bp = base pairs) yields lengths of approximately 800 bp for fragment 1 and 1800 bp for fragment 2. After staining, the bands can be cut out of the gel and the DNA can be extracted from them and used for further experiments.

C. Overexpression of proteins ◑

To treat some diseases, proteins are needed that occur in such small quantities in the organism that isolating them on a large scale would not be economically feasible. Proteins of this type can be obtained by *overexpression* in bacteria or eukaryotic cells. To do this, the corresponding *gene* is isolated from human DNA and cloned into an **expression plasmid** as described on p. 258. In addition to the gene itself, the plasmid also has to contain DNA segments that allow replication by the host cell and transcription of the gene. After *transformation* and *replication* of suitable host cells, **induction** is used in a targeted fashion to trigger ef cient *transcription* of the gene. *Translation* of the mRNA formed in the host cell then gives rise to large amounts of the desired protein. Human insulin (see p. 76), plasminogen activators for dissolving blood clots (see p. 292), and the growth hormone somatotropin are among the proteins produced in this way.

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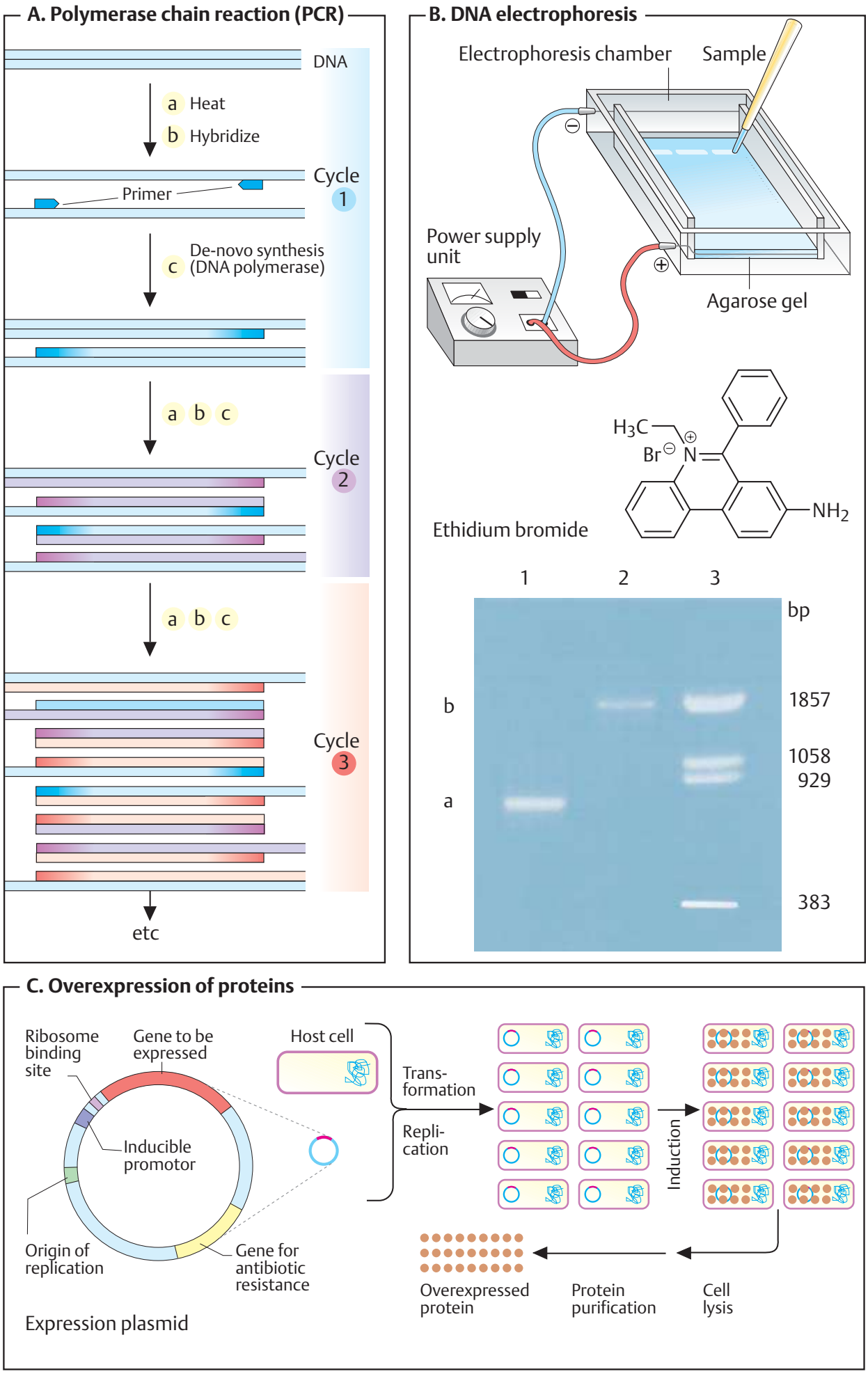

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Genetic engineering in medicine

Genetic engineering procedures are becoming more and more important in medicine for diagnostic purposes (**A**–**C**). New genetic approaches to the treatment of severe diseases are still in the developmental stage ("gene therapy," **D**).

A. DNA fingerprinting ○

DNA fingerprinting is used to link small amounts of biological material—e. g., traces from the site of a crime—to a specific person. The procedure now used is based on the fact that the human genome contains non-coding repetitive DNA sequences, the length of which varies from individual to individual. **Short tandem repeats** (**STRs**) thus exist in which dinucleotides (e. g., -T-X-) are frequently repeated. Each STR can occur in five to 15 different lengths (alleles), of which one individual possesses only one or two. When the various allele combinations for several STRs are determined after PCR amplification of the DNA being investigated, a "genetic fingerprint" of the individual from whom the DNA originates is obtained. Using comparative material—e. g., saliva samples—definite identification is then possible.

B. Diagnosis of sickle-cell anemia using RFLP ○

This example illustrates a procedure for diagnosing a point mutation in the β-globin gene that leads to sickle-cell anemia (see p. 248). The mutation in the first exon of the gene destroys a cleavage site for the restriction endonuclease *Mst*II (see p. 258). When the DNA of healthy and diseased individuals is cleaved with *Mst*II, different fragments are produced in the region of the β-globin gene, which can be separated by electrophoresis and then demonstrated using specific probes (see p. 260). In addition, heterozygotic carriers of the sickle-cell gene can be distinguished from homozygotic ones.

C. Identification of viral DNA using RT-PCR ○

In viral infections, it is often dif cult to determine the species of the pathogen precisely. **RT-PCR** can be used to identify RNA viruses. In this procedure, reverse transcriptase (see p. 404) is used to transcribe the viral RNA into dsDNA, and then PCR is employed to amplify a segment of this DNA with virus-specific primers. In this way, an amplificate with a characteristic length can be obtained for each pathogen and identified using gel electrophoresis as described above.

D. Gene therapy ◑

Many diseases, such as hereditary metabolic defects and tumors, can still not be adequately treated. About 10 years ago, projects were therefore initiated that aimed to treat diseases of this type by transferring genes into the affected cells (gene therapy). The illustration combines conceivable and already implemented approaches to gene therapy for metabolic defects (left) and tumors (right). None of these procedures has yet become established in clinical practice.

If a mutation leads to failure of an enzyme E1 (left), its substrate B will no longer be converted into C and will accumulate. This can lead to cell damage by B itself or by a toxic product formed from it. Treatment with intact E1 is not possible, as the proteins are not capable of passing through the cell membrane. By contrast, it is in principle possible to introduce **foreign genes** into the cell using viruses as vectors (adenoviruses or retroviruses are mainly used). Their gene products could replace the defective E1 or convert B into a harmless product. Another approach uses the so-called **antisense DNA** (bottom right). This consists of polynucleotides that hybridize with the mRNA for specific cellular proteins and thereby prevent their translation. In the case shown, the synthesis of E2 could be blocked, for example.

The main problem in chemotherapy for **tumors** is the lack of tumor-specificity in the highly toxic cytostatic agents used (see p. 402). Attempts are therefore being made to introduce into tumor cells genes with products that are only released from a precursor to form active cytostatics once they have reached their target (left). Other gene products are meant to force the cells into apoptosis (see p. 396) or make them more susceptible to attack by the immune system. To steer the viral vectors to the tumor (targeting), attempts are being made to express proteins on the virus surface that are bound by tumor-specific receptors. Fusion with a tumor-specific promoter could also help limit the effect of the foreign gene to the tumor cells.

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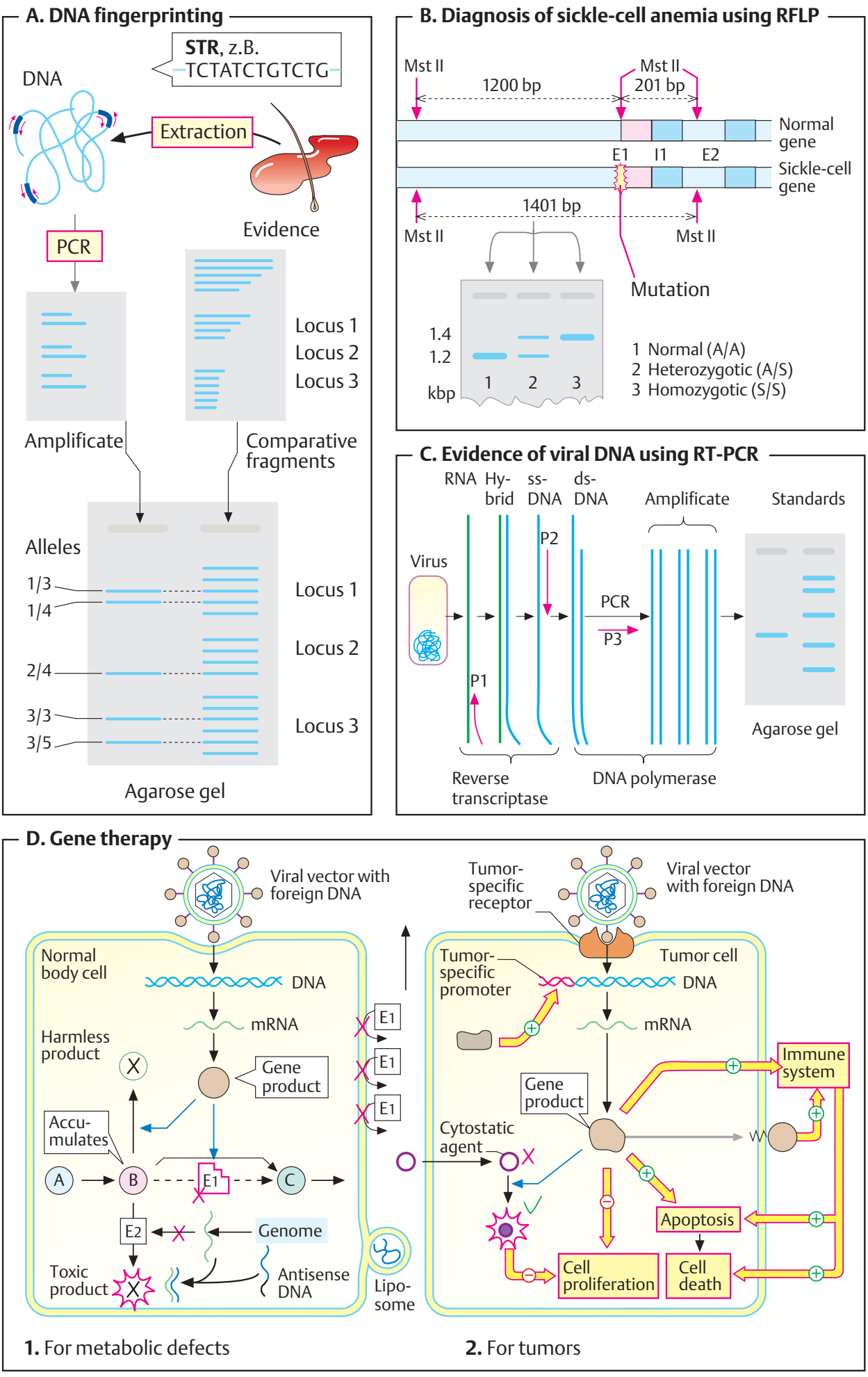

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Digestion: overview

Most components of food (see p. 360) cannot be resorbed directly by the organism. It is only after they have been broken down into smaller molecules that the organism can take up the essential nutrients. *Digestion* refers to the mechanical and enzymatic breakdown of food and the resorption of the resulting products.

A. Hydrolysis and resorption of food components ●

Following mechanical fragmentation of food during chewing in the mouth, the process of enzymatic degradation starts in the stomach. For this purpose, the chyme is mixed with *digestive enzymes* that occur in the various digestive secretions or in membrane-bound form on the surface of the intestinal epithelium (see p. 268). Almost all digestive enzymes are *hydrolases* (class 3 enzymes; see p. 88); they catalyze the cleavage of composite bonds with the uptake of water.

Proteins are first denatured by the stomach's *hydrochloric acid* (see p. 270), making them more susceptible to attack by the *endopeptidases* (proteinases) present in gastric and pancreatic juice. The peptides released by endopeptidases are further degraded into amino acids by *exopeptidases*. Finally, the amino acids are resorbed by the intestinal mucosa in cotransport with Na^+ ions (see p. 220). There are separate transport systems for each of the various groups of amino acids.

Carbohydrates mainly occur in food in the form of polymers (starches and glycogen). They are cleaved by *pancreatic amylase* into oligosaccharides and are then hydrolyzed by *glycosidases,* which are located on the surface of the intestinal epithelium, to yield monosaccharides. Glucose and galactose are taken up into the enterocytes by secondary active cotransport with Na^+ ions (see p. 220). In addition, monosaccharides also have passive transport systems in the intestine.

Nucleic acids are broken down into their components by *nucleases* from the pancreas and small intestine (ribonucleases and deoxyribonucleases). Further breakdown yields the nucleobases (purine and pyrimidine derivatives), pentoses (ribose and deoxyribose), phosphate, and nucleosides (nucleobase pentose). These cleavage products are resorbed by the intestinal wall in the region of the jejunum.

Lipids are a special problem for digestion, as they are not soluble in water. Before enzymatic breakdown, they have to be emulsified by *bile salts* and *phospholipids* in the bile (see p. 314). At the water–lipid interface, *pancreatic lipase* then attacks triacylglycerols with the help of *colipase* (see p. 270). The cleavage products include *fatty acids, 2–monoacylglycerols, glycerol,* and *phosphate* from phospholipid breakdown. After resorption into the epithelial cells, fats are resynthesized from fatty acids, glycerol and 2–monoacylglycerols and passed into the lymphatic system (see p. 272). The lipids in milk are more easily digested, as they are already present in emulsion; on cleavage, they mostly provide short-chain fatty acids.

Inorganic components such as water, electrolytes, and *vitamins* are directly absorbed by the intestine.

High-molecular-weight indigestible components, such as the fibrous components of plant cell walls, which mainly consist of cellulose and lignin, pass through the bowel unchanged and form the main component of feces, in addition to cells shed from the intestinal mucosa. Dietary fiber makes a positive contribution to digestion as a *ballast material* by binding water and promoting intestinal peristalsis.

The food components resorbed by the epithelial cells of the intestinal wall in the region of the jejunum and ileum are transported directly to the liver via the *portal vein*. Fats, cholesterol, and lipid–soluble vitamins are exceptions. These are first released by the enterocytes in the form of *chylomicrons* (see p. 278) into the *lymph system,* and only reach the blood via the thoracic duct.

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A. Hydrolysis and resorption of dietary constituents

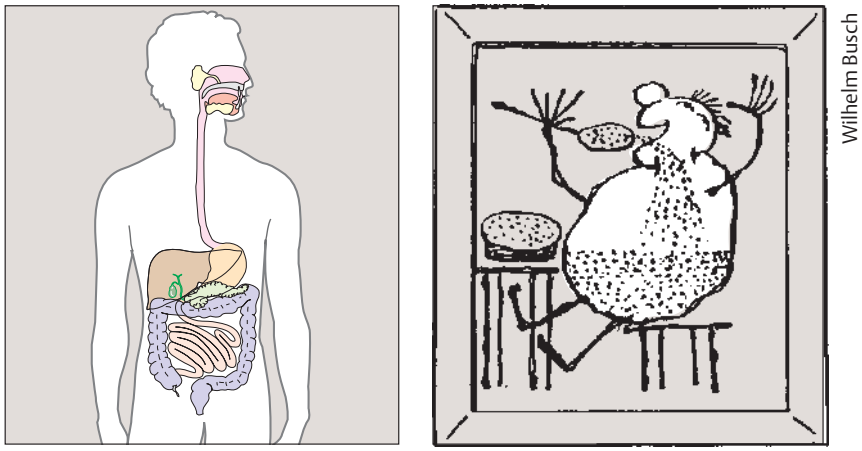

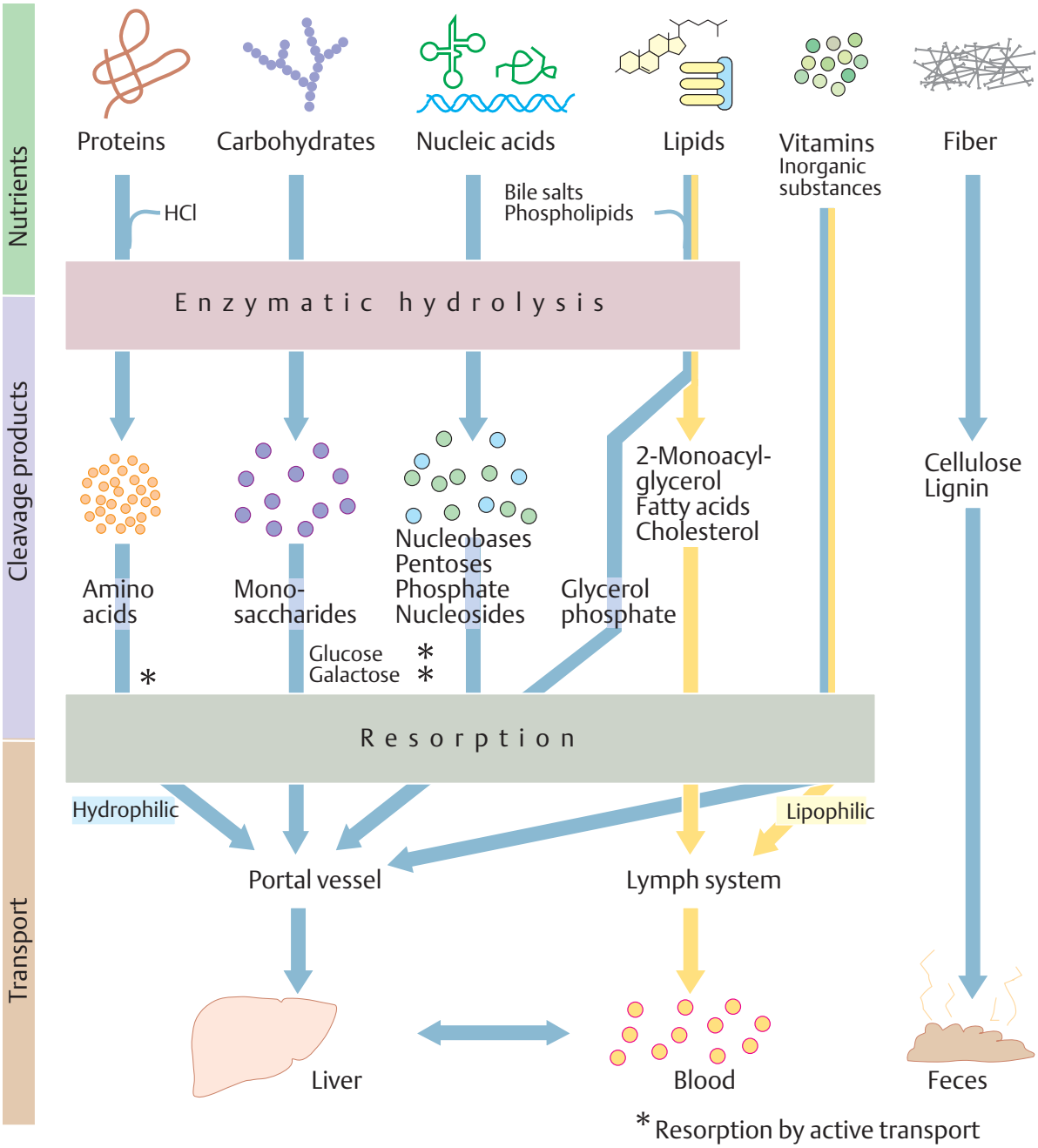

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Digestive secretions

A. Digestive juices ◑

Saliva. The salivary glands produce a slightly alkaline secretion which—in addition to water and salts—contains *glycoproteins* (mucins) as lubricants, *antibodies,* and *enzymes.* *α–Amylase* attacks polysaccharides, and a lipase hydrolyzes a small proportion of the neutral fats. α–Amylase and *lysozyme,* a murein-cleaving enzyme (see p. 40), probably serve to regulate the oral bacterial flora rather than for digestion (see p. 340).

Gastric juice. In the stomach, the chyme is mixed with gastric juice. Due to its hydrochloric acid content, this secretion of the gastric mucosa is strongly acidic (pH 1–3; see p. 270). It also contains *mucus* (mainly glycoproteins known as mucins), which protects the mucosa from the hydrochloric acid, *salts,* and *pepsinogen*—the proenzyme ("zymogen") of the aspartate proteinase *pepsin* (see pp. 176, 270). In addition, the gastric mucosa secretes what is known as *"intrinsic factor"*—a glycoprotein needed for resorption of vitamin B_{12} ("extrinsic factor") in the bowel.

In the stomach, pepsin and related enzymes initiate the enzymatic digestion of proteins, which takes 1–3 hours. The acidic gastric contents are then released into the duodenum in batches, where they are neutralized by alkaline pancreatic secretions and mixed with cystic bile.

Pancreatic secretions. In the acinar cells, the pancreas forms a secretion that is alkaline due to its HCO_3^- content, the buffer capacity of which is suf cient to neutralize the stomach's hydrochloric acid. The pancreatic secretion also contains many *enzymes* that catalyze the hydrolysis of high–molecular-weight food components. All of these enzymes are hydrolases with pH optimums in the neutral or weakly alkaline range. Many of them are formed and secreted as proenzymes and are only activated in the bowel lumen (see p. 270).

Trypsin, chymotrypsin, and *elastase* are endopeptidases that belong to the group of serine proteinases (see p. 176). Trypsin hydrolyzes specific peptide bonds on the C side of the basic amino acids Arg and Lys, while chymotrypsin prefers peptide bonds of the apolar amino acids Tyr, Trp, Phe, and Leu (see p. 94). Elastase mainly cleaves on the C side of the aliphatic amino acids Gly, Ala, Val, and Ile. Smaller peptides are attacked by *carboxypeptidases,* which as exopeptidases cleave individual amino acids from the C–terminal end of the peptides (see p. 176).

~–Amylase, the most important endoglycosidase in the pancreas, catalyzes the hydrolysis of α1→4 bonds in the polymeric carbohydrates starch and glycogen. This releases maltose, maltotriose, and a mixture of other oligosaccharides.

Various pancreatic enzymes hydrolyze lipids, including *lipase* with its auxiliary protein *colipase* (see p. 270), *phospholipase* A_2, and *sterol esterase.* Bile salts activate the lipid-cleaving enzymes through micelle formation (see below).

Several hydrolases—particularly *ribonuclease* (RNAse) and *deoxyribonuclease* (DNAse)—break down the nucleic acids contained in food.

Bile. The liver forms a thin secretion (bile) that is stored in the gallbladder after water and salts have been extracted from it. From the gallbladder, it is released into the duodenum. The most important constituents of bile are *water* and inorganic *salts, bile acids* and *bile salts* (see p. 314), *phospholipids, bile pigments,* and *cholesterol.* Bile salts, together with phospholipids, emulsify insoluble food lipids and activate the lipases. Without bile, fats would be inadequately cleaved, if at all, resulting in "fatty stool" (steatorrhea). Resorption of fat-soluble vitamins would also be affected.

Small-intestinal secretions. The glands of the small intestine (the Lieberkühn and Brunner glands) secrete additional digestive enzymes into the bowel. Together with enzymes on the microvilli of the intestinal epithelium (peptidases, glycosidases, etc.), these enzymes ensure almost complete hydrolysis of the food components previously broken down by the endoenzymes.

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A. Digestive juices

Saliva

Daily secretion 1.0–1.5 l
pH 7

Water	Moistens food
Salts	
Mucus	Lubricant
Antibodies	Bind to bacteria
α-Amylases (3.2.1.1)	Cleave starch ↓
Lysozyme (3.2.1.17)	Attacks bacterial cell walls ↓

Bile

Daily secretion 0.6 l
pH 6.9–7.7

Water	
HCO_3^-	Neutralizes gastric juice
Bile salts	Facilitate lipid digestion
Phospholipids	Facilitate lipid digestion
Bile pigments	Waste products
Cholesterol	Waste product

↓ Endoenzyme
-◂ Exoenzyme

Gastric juice

Daily secretion 2–3 l
pH 1

Components	Function or substrate
Water	
Salts	
HCl	Denatures proteins, kills bacteria
Mucus	Protects stomach lining
Pepsins (3.4.23.1-3)	Cleave proteins ↓
Chymosin (3.4.23.4)	Precipitates casein ↓
Triacylglycerol lipase (3.1.1.3)	Cleaves fats
Intrinsic factor	Protects vitamin B_{12}

Pancreatic secretions

Daily secretion 0.7–2.5 l
pH 7.7 (7.5–8.8)

Water	
HCO_3^-	Neutralizes gastric juice
Trypsin (3.4.21.4)	Proteins ↓
Chymotrypsin (3.4.21.1)	Proteins ↓
Elastase (3.4.21.36)	Proteins ↓
Carboxypeptidases (3.4.n.n)	Peptides -◂
α-Amylase (3.2.1.1)	Starch and glycogen ↓
Triacylglycerol lipase (3.1.1.3)	Fats
Co-Lipase	Cofactor for lipase
Phospholipase A_2 (3.1.1.4)	Phospholipids
Sterol esterase (3.1.1.13)	Cholesterol esters
Ribonuclease (3.1.27.5)	RNA
Deoxyribonuclease I (3.1.21.1)	DNA

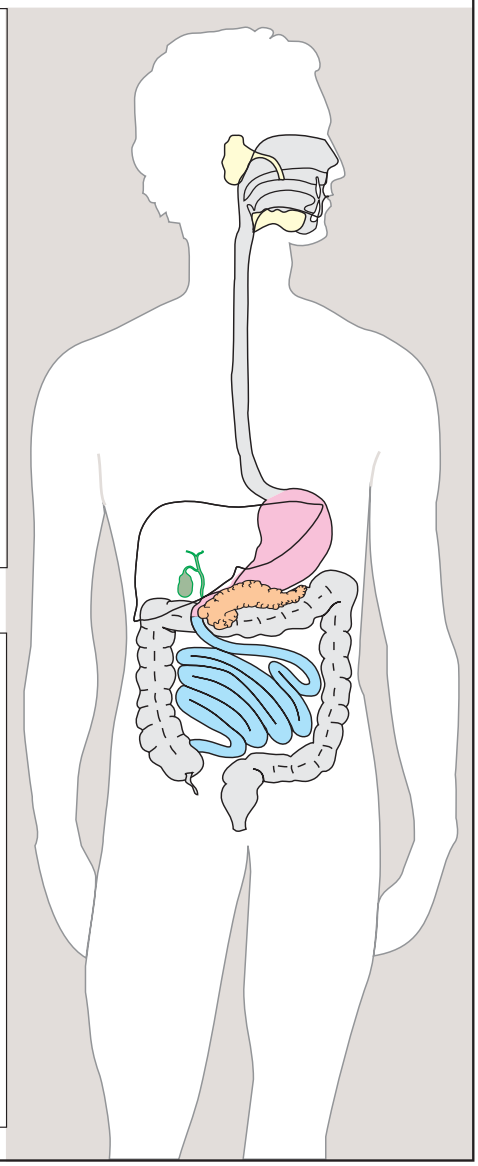

Secretions of the small intestine

Daily secretion unknown
pH 6.5–7.8

Aminopeptidases (3.4.11.n)	Peptides -◂
Dipeptidases (3.4.13.n)	Dipeptides
α-Glucosidase (3.2.1.20)	Oligosaccharides ↓
Oligo-1,6-glucosidase (3.2.1.10)	Oligosaccharides ↓
β-Galactosidase (3.2.1.23)	Lactose
Sucrose α-glucosidase (3.2.1.48)	Sucrose
α, α-Trehalase (3.2.1.28)	Trehalose
Alkaline phosphatase (3.1.3.1)	Phosphoric acid esters
Polynucleotidases (3.1.3.n)	Nucleic acids, nucleotides ↓
Nucleosidases (3.2.2.n)	Nucleosides -◂
Phospholipases (3.1.n.n)	Phospholipids

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Digestive processes

Gastric juice is the product of several cell types. The *parietal cells* produce hydrochloric acid, *chief cells* release pepsinogen, and *accessory cells* form a mucin-containing mucus.

A. Formation of hydrochloric acid ◑

The secretion of **hydrochloric acid** (H^+ and Cl^-) by the parietal cells is an active process that uses up ATP and takes place against a concentration gradient (in the gastric lumen, with a pH of 1, the H^+ concentration is some 10^6 times higher than in the parietal cells, which have a pH of 7).

The precursors of the exported H^+ ions are carbon dioxide (CO_2) and water (H_2O). CO_2 diffuses from the blood into the parietal cells, and in a reaction catalyzed by *carbonate dehydratase* (carbonic anhydrase [2]), it reacts with H_2O to form H^+ and hydrogen carbonate (HCO_3^-). The H^+ ions are transported into the gastric lumen in exchange for K^+ by a membrane-bound *H^+/K^+-exchanging ATPase* [1] (a transport ATPase of the P type; see p. 220). The remaining hydrogen carbonate is released into the interstitium in electroneutral antiport in exchange for chloride ions (Cl^-), and from there into the blood. The Cl^- ions follow the secreted protons through a channel into the gastric lumen.

The hydrochloric acid in gastric juice is important for digestion. It activates pepsinogen to form pepsin (see below) and creates an optimal pH level for it to take effect. It also denatures food proteins so that they are more easily attacked by proteinases, and it kills micro-organisms.

Regulation. HCl secretion is stimulated by the peptide hormone *gastrin,* the mediator *histamine* (see p. 380), and—via the neurotransmitter *acetylcholine*—by the autonomous nervous system. The peptide *somatostatin* and certain *prostaglandins* (see p. 390) have inhibitory effects. Together with cholecystokinin, secretin, and other peptides, gastrin belongs to the group of **gastrointestinal hormones** (see p. 370). All of these are formed in the gastrointestinal tract and mainly act in the vicinity of the site where they are formed—i. e., they are paracrine hormones (see p. 372). While gastrin primarily enhances HCl secretion, *cholecystokinin* and *secretin* mainly stimulate pancreatic secretion and bile release.

B. Zymogen activation ◑

To prevent self–digestion, the pancreas releases most proteolytic enzymes into the duodenum in an inactive form as *proenzymes* (zymogens). Additional protection from the effects of premature activation of pancreatic proteinases is provided by *proteinase inhibitors* in the pancreatic tissue, which inactivate active enzymes by complex formation (right).

Trypsinogen plays a key role among the proenzymes released by the pancreas. In the bowel, it is proteolytically converted into active trypsin (see p. 176) by **enteropeptidase**, a membrane enzyme on the surface of the enterocytes. Trypsin then autocatalytically activates additional trypsinogen molecules and the other proenzymes (left).

C. Fat digestion ◑

Due to the "hydrophobic effect" (see p. 28), water-insoluble neutral fats in the aqueous environment of the bowel lumen would aggregate into drops of fat in which most of the molecules would not be accessible to pancreatic lipase. The amphipathic substances in bile (bile acids, bile salts, phospholipids) create an **emulsion** in which they occupy the surface of the droplets and thereby prevent them from coalescing into large drops. In addition, the bile salts, together with the auxiliary protein colipase, mediate binding of *triacylglycerol lipase* [1] to the emulsified fat droplets. Activation of the lipase is triggered by a conformation change in the C-terminal domain of the enzyme, which uncovers the active center.

During passage through the intestines, the active lipase breaks down the triacylglycerols in the interior of the droplets into free fatty acids and amphipathic monoacylglycerols. Over time, smaller **micelles** develop (see p. 28), in the envelope of which monoacylglycerols are present in addition to bile salts and phospholipids. Finally, the components of the micelles are resorbed by the enterocytes in ways that have not yet been explained.

Monoacylglycerols and fatty acids are reassembled into fats again (see p. 272), while the bile acids return to the liver (enterohepatic circulation; see p. 314).

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A. Formation of hydrochloric acid

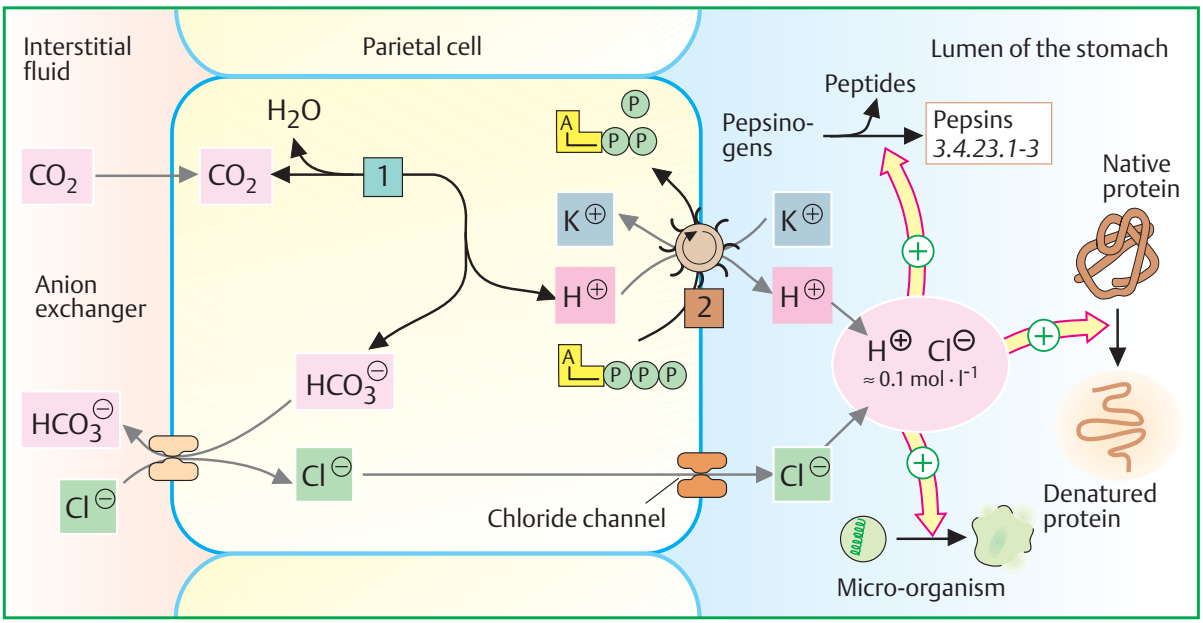

1 Carbonate dehydratase *4.2.1.1* [Zn^{2+}] 2 H^+/K^+-exchanging ATPase *3.6.1.36*

B. Zymogen activation

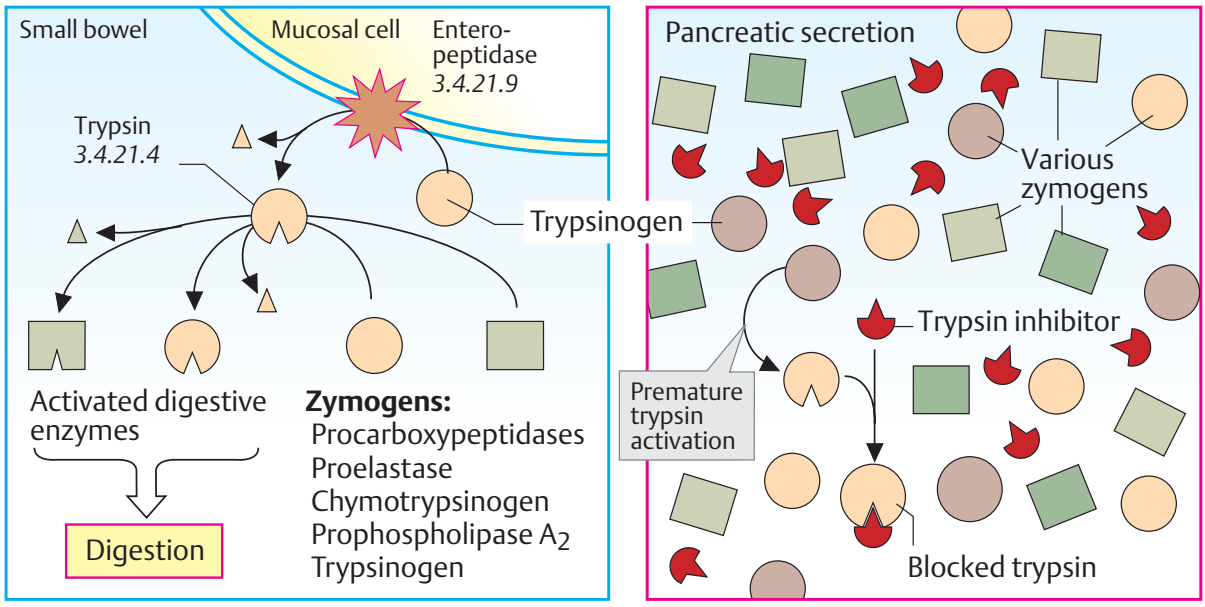

C. Fat digestion

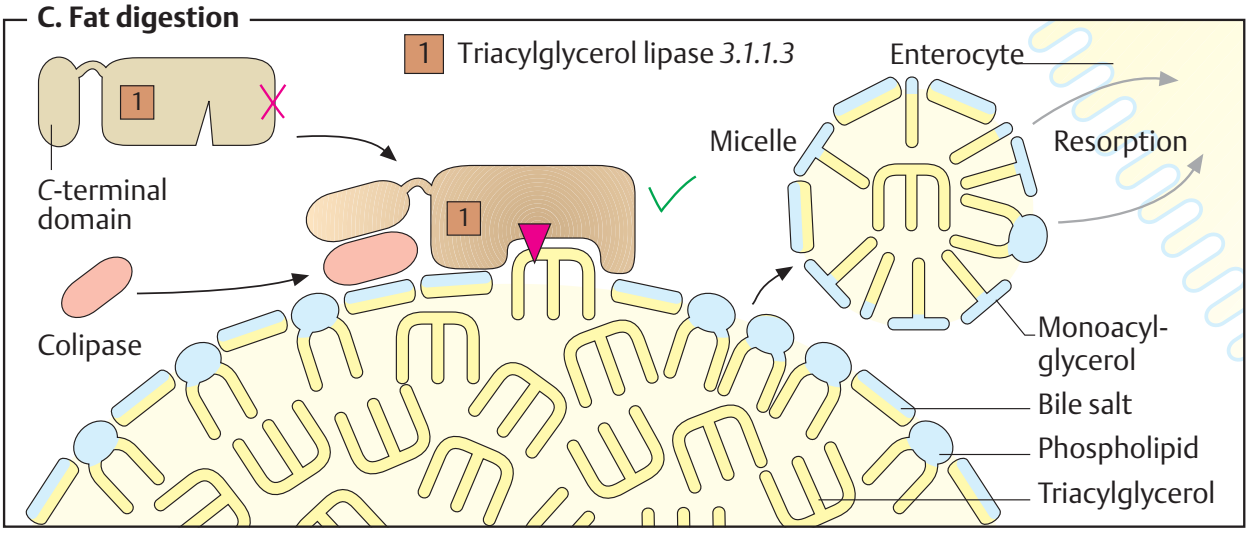

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Resorption

Enzymatic hydrolysis in the digestive tract breaks down foodstuffs into their resorbable components. *Resorption* of the cleavage products takes place primarily in the small intestine. Only ethanol and short–chain fatty acids are already resorbed to some extent in the stomach.

The resorption process is facilitated by the large inner surface of the intestine, with its brush–border cells. Lipophilic molecules penetrate the plasma membrane of the mucosal cells by simple diffusion, whereas polar molecules require *transporters* (facilitated diffusion; see p. 218). In many cases, carrier-mediated cotransport with Na^+ ions can be observed. In this case, the difference in the concentration of the sodium ions (high in the intestinal lumen and low in the mucosal cells) drives the import of nutrients against a concentration gradient (secondary active transport; see p. 220). Failure of carrier systems in the gastrointestinal tract can result in diseases.

A. Monosaccharides ◑

The cleavage of polymeric carbohydrates by *~–amylase* [1] leads to **oligosaccharides**, which are broken down further by *exoglycosidases* (oligosaccharidases and disaccharidases [2]) on the membrane surface of the brush border. The monosaccharides released in this way then pass with the help of various *sugar–specific transporters* into the cells of intestinal epithelium. *Secondary active transport* serves for the uptake of **glucose** and **galactose**, which are transported against a concentration gradient in cotransport with Na^+. The Na^+ gradient is maintained on the basal side of the cells by *Na^+/K^+-ATPase* [3]. Another passive transporter then releases glucose and galactose into the blood. **Fructose** is taken up by a special type of transporter using facilitated diffusion.

Amino acids (not illustrated)

Protein degradation is initiated by *proteinases*—by pepsins in the stomach and by trypsin, chymotrypsin, and elastase in the small intestine. The resulting peptides are then further hydrolyzed by various *peptidases* into amino acids. Individual amino acid groups have *group–specific amino acid transporters,* some of which transport the amino acids into the enterocytes in cotransport with Na^+ ions (secondary active transport), while others transport them in an Na^+–independent manner through facilitated diffusion. Small peptides can also be taken up.

B. Lipids ◑

Fats and other lipids are poorly soluble in water. The larger the accessible surface is—i. e., the better the fat is emulsified—the easier it is for enzymes to hydrolyze it (see p. 270). Due to the special properties of milk, milk fats already reach the gastrointestinal tract in emulsified form. Digestion of them therefore already starts in the oral cavity and stomach, where lipases in the saliva and gastric juice are available. Lipids that are less accessible—e. g., from roast pork—are emulsified in the small intestine by *bile salts* and *bile phospholipids.* Only then are they capable of being attacked by *pancreatic lipase* [4] (see p. 270).

Fats (triacylglycerols) are mainly attacked by pancreatic lipase at positions 1 and 3 of the glycerol moiety. Cleavage of two fatty acid residues gives rise to **fatty acids** and **2-monoacylglycerols**, which are quantitatively the most important products. However, a certain amount of **glycerol** is also formed by complete hydrolysis. These cleavage products are resorbed by a non-ATP-dependent process that has not yet been explained in detail.

In the mucosal cells, *long-chain fatty acids* are resynthesized by an ATP-dependent ligase [5] to form acyl-CoA and then triacylglycerols (fats; see p. 170). The fats are released into the lymph in the form of **chylomicrons** (see p. 278) and, bypassing the liver, are deposited in the thoracic duct—i. e., the blood system. *Cholesterol* also follows this route.

By contrast, *short-chain fatty acids* (with chain lengths of less than 12 C atoms) pass directly into the blood and reach the liver via the portal vein. Resorbed glycerol can also take this path.

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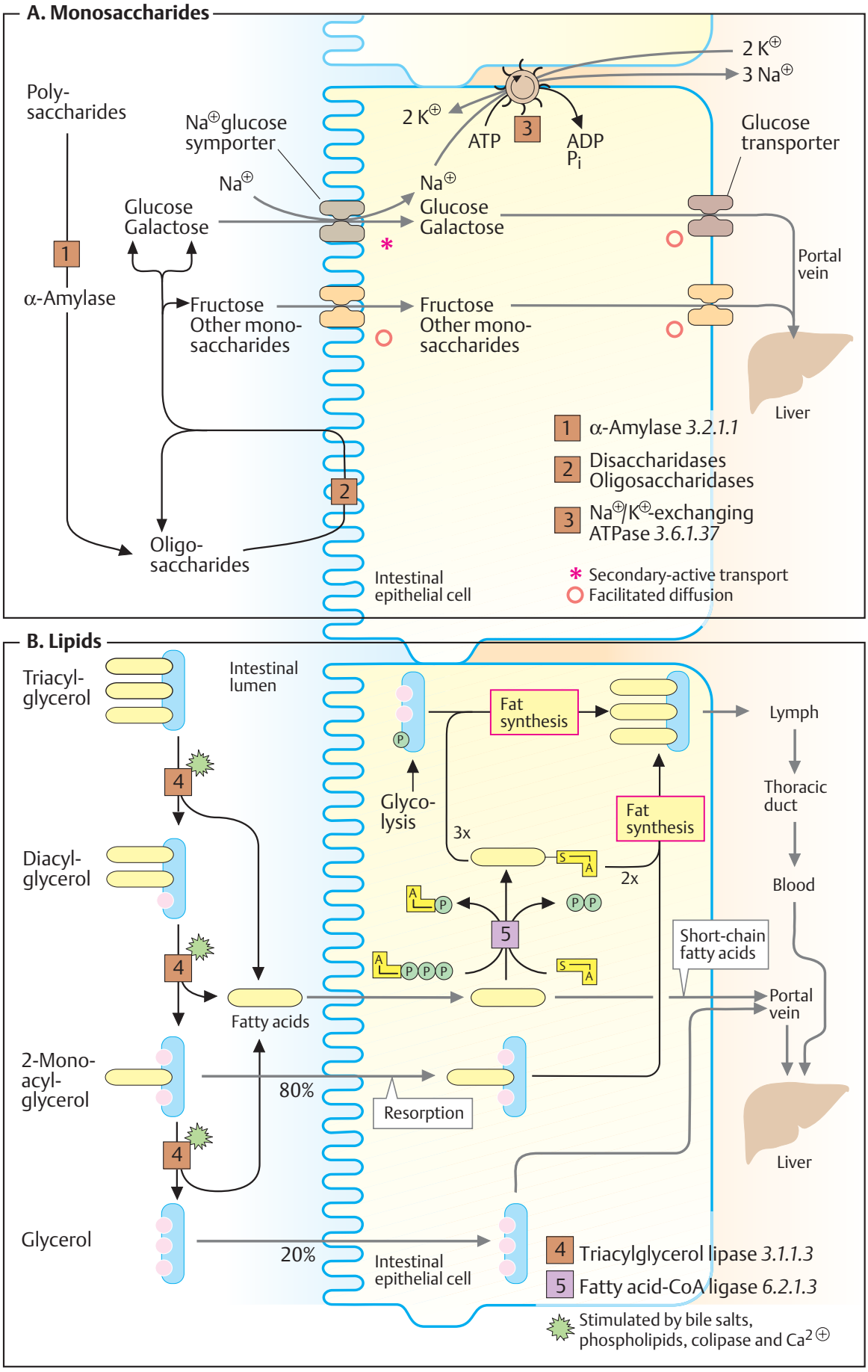

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Blood: composition and functions

Human blood constitutes about 8% of the body's weight. It consists of **cells** and cell fragments in an aqueous medium, the **blood plasma.** The proportion of cellular elements, known as *hematocrit,* in the total volume is approximately 45%.

A. Functions of the blood ●

The blood is the most important transport medium in the body. It serves to keep the "internal milieu" constant (homeostasis) and it plays a decisive role in defending the body against pathogens.

Transport. The *gases* oxygen and carbon dioxide are transported in the blood. The blood mediates *the exchange of substances between organs* and takes up *metabolic end products* from tissues in order to transport them to the lungs, liver, and kidney for excretion. The blood also distributes *hormones* throughout the organism (see p. 370).

Homeostasis. The blood ensures that a balanced distribution of water is maintained between the vascular system, the cells (intracellular space), and the extracellular space. The *acid–base balance* is regulated by the blood in combination with the lungs, liver, and kidneys (see p. 288). The regulation of *body temperature* also depends on the controlled transport of heat by the blood.

Defense. The body uses both non-specific and specific mechanisms to defend itself against pathogens. The defense system includes the *cells of the immune system* and certain *plasma proteins* (see p. 294).

Self-protection. To prevent blood loss when a vessel is injured, the blood has systems for stanching blood flow and coagulating the blood (hemostasis; see p. 290). The dissolution of blood clots (fibrinolysis) is also managed by the blood itself (see p. 292).

B. Cellular elements ◑

The solid elements in the blood are the erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (platelets).

The **erythrocytes** provide for gas transport in the blood. They are discussed in greater detail on pp. 280–285.

The **leukocytes** include various types of granulocyte, monocyte, and lymphocyte. All of these have immune defense functions (see p. 294). The *neutrophil granulocytes, monocytes,* and the *macrophages* derived from monocytes are phagocytes. They can ingest and degrade invading pathogens. The *lymphocytes* are divided into two groups, B lymphocytes and T lymphocytes. B lymphocytes produce *antibodies,* while T lymphocytes regulate the immune response and destroy virus-infected cells and tumor cells. *Eosinophilic* and *basophilic granulocytes* have special tasks for defense against animal parasites.

Thrombocytes are cell fragments that arise in the bone marrow from large precursor cells, the megakaryocytes. Their task is to promote hemostasis (see p. 290).

C. Blood plasma: composition ◑

The **blood plasma** is an aqueous solution of electrolytes, nutrients, metabolites, proteins, vitamins, trace elements, and signaling substances. The fluid phase of coagulated blood is known as **blood serum**. It differs from the plasma in that it lacks fibrin and other coagulation proteins (see p. 290).

Laboratory assessment of the composition of the blood plasma is often carried out in clinical chemistry. Among the electrolytes, there is a relatively high concentration of Na^+, Ca^{2+}, and Cl^- ions in the blood in comparison with the cytoplasm. By contrast, the concentrations of K^+, Mg^{2+}, and phosphate ions are higher in the cells. Proteins also have a higher intracellular concentration. The electrolyte composition of blood plasma is similar to that of seawater, due to the evolution of early forms of life in the sea. The solution known as *"physiological saline"* (NaCl at a concentration of 0.15 mol L^{-1}) is almost isotonic with blood plasma.

A list of particularly important **metabolites** in the blood plasma is given on the right.

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A. Functions of the blood

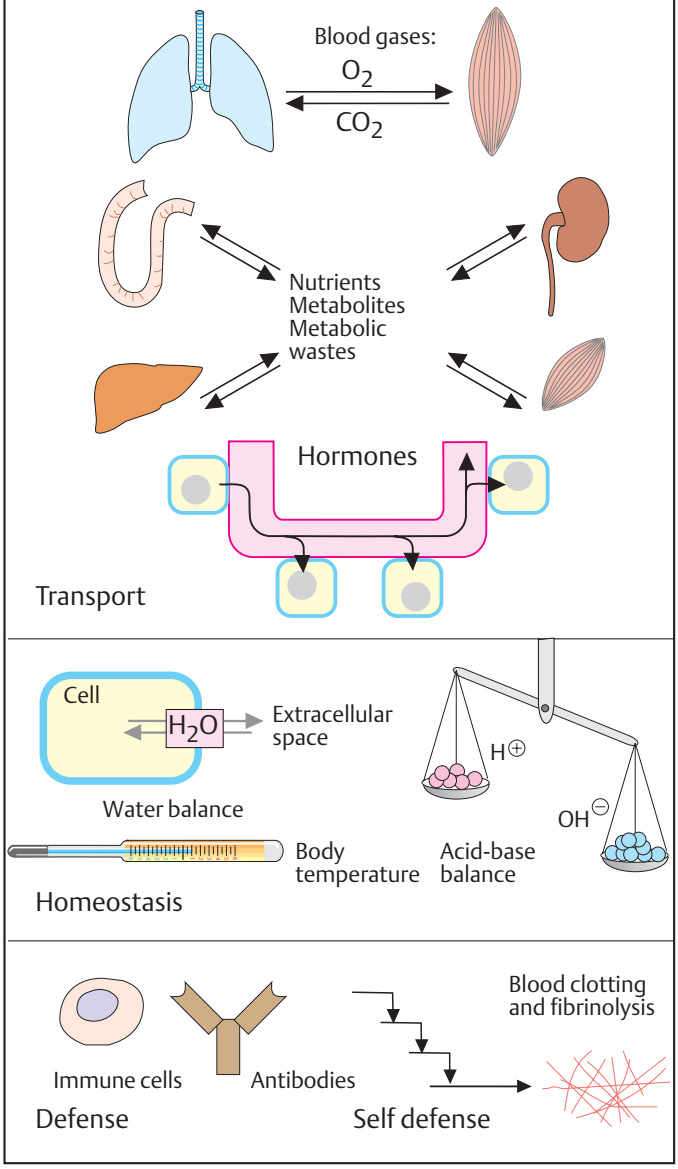

B. Cellular elements

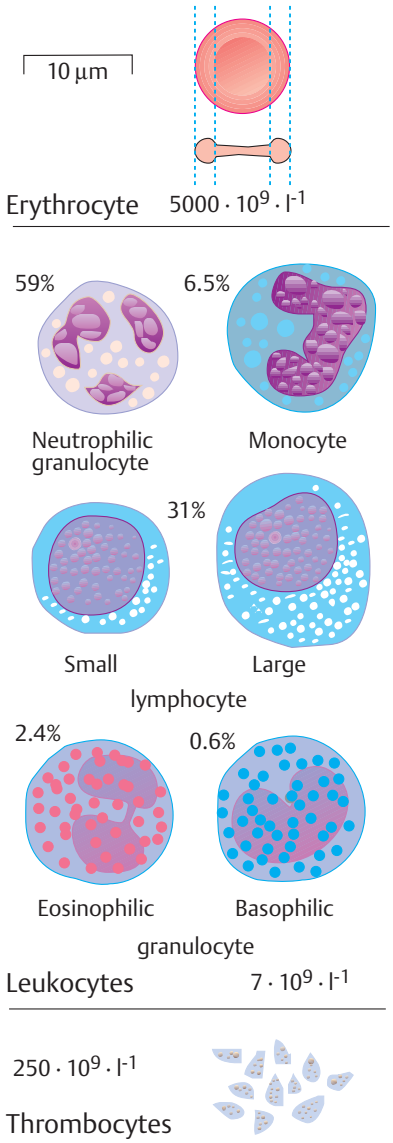

C. Blood plasma: composition

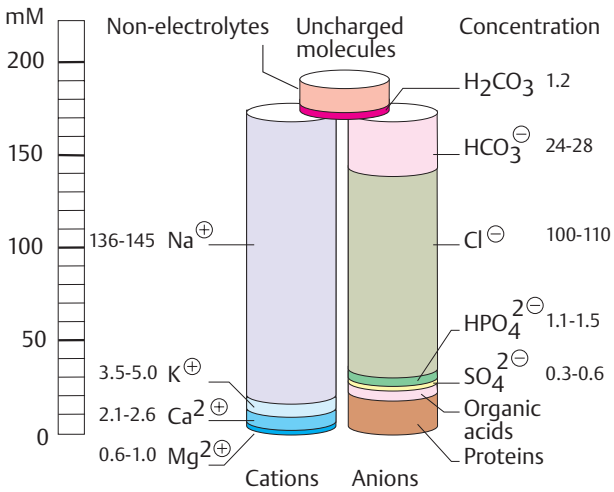

Metabolite	Concentration (mM)
Glucose	3.6 – 6.1
Lactate	0.4 – 1.8
Pyruvate	0.07 – 0.11
Urea	3.5 – 9.0
Uric acid	0.18 – 0.54
Creatinin	0.06 – 0.13
Amino acids	2.3 – 4.0
Ammonia	0.02 – 0.06
Lipids (total)	5.5 – 6.0 $g \cdot l^{-1}$
Triacylglycerols	1.0 – 1.3 $g \cdot l^{-1}$
Cholesterol	1.7 – 2.1 $g \cdot l^{-1}$

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Plasma proteins

Quantitatively, proteins are the most important part of the soluble components of the blood plasma. With concentrations of between 60 and 80 g L^{-1}, they constitute approximately 4% of the body's total protein. Their tasks include transport, regulation of the water balance, hemostasis, and defense against pathogens.

A. Plasma proteins ◑

Some 100 different proteins occur in human blood plasma. Based on their behavior during electrophoresis (see below), they are broadly divided into *five fractions:* **albumins** and α_1–, α_2–, β– and γ-**globulins**. Historically, the distinction between the albumins and globulins was based on differences in the proteins' solubility –albumins are soluble in pure water, whereas globulins only dissolve in the presence of salts.

The most frequent protein in the plasma, at around 45 g L^{-1}, is **albumin**. Due to its high concentration, it plays a crucial role in maintaining the blood's colloid osmotic pressure and represents an important amino acid reserve for the body. Albumin has binding sites for apolar substances and therefore functions as a transport protein for long-chain fatty acids, bilirubin, drugs, and some steroid hormones and vitamins. In addition, serum albumin binds Ca^{2+} and Mg^{2+} ions. It is the only important plasma protein that is not glycosylated.

The albumin fraction also includes *transthyretin* (prealbumin), which together with other proteins transports the hormone thyroxine and its metabolites.

The table also lists important **globulins** in blood plasma, with their mass and function. The α- and β-globulins are involved in the transport of lipids (lipoproteins; see p. 278), hormones, vitamins, and metal ions. In addition, they provide coagulation factors, protease inhibitors, and the proteins of the complement system (see p. 298). Soluble antibodies (immunoglobulins; see p. 300) make up the γ-globulin fraction.

Synthesis and degradation. Most plasma proteins are synthesized by the liver. Exceptions to this include the immunoglobulins, which are secreted by B lymphocytes known as plasma cells (see p. 302) and peptide hormones, which derive from endocrine gland cells.

With the exception of albumin, almost all plasma proteins are *glycoproteins.* They carry oligosaccharides in *N*-and *O*-glycosidic bonds (see p. 44). *N*-acetylneuraminic acid (sialic acid; see p. 38) often occurs as a terminal carbohydrate among sugar residues. *Neuraminidases* (sialidases) on the surface of the vascular endothelia gradually cleave the sialic acid residues and thereby release galactose units on the surfaces of the proteins. These *asialoglycoproteins* ("asialo-" = without sialic acid) are recognized and bound by galactose receptors on hepatocytes. In this way, the liver takes up aged plasma proteins by endocytosis and breaks them down. The oligosaccharides on the protein surfaces thus determine the half-life of plasma proteins, which is a period of days to weeks.

In healthy individuals, the concentration of plasma proteins is constant. Diseases in organs that are involved in protein synthesis and breakdown can shift the protein pattern. For example, via cytokines (see p. 392), severe injuries trigger increased synthesis of *acute-phase proteins,* which include C-reactive protein, haptoglobin, fibrinogen, complement factor C-3, and others. The concentrations of individual proteins are altered in some diseases (known as *dysproteinemias*).

B. Carrier electrophoresis ◑

Proteins and other electrically charged macromolecules can be separated using electrophoresis (see also pp. 78, 262). Among the various procedures used, **carrier electrophoresis** on cellulose acetate foil (CAF) is particularly simple. Using this method, serum proteins—which at slightly alkaline pH values all move towards the anode, due to their excess of negative charges—can be separated into the five fractions mentioned. After the proteins have been stained with dyes, the resulting bands can be quantitatively assessed using densitometry.

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A. Plasma proteins

Group	Protein	M_r in kDa	Function
Albumins:	Transthyretin	50-66	Transport of thyroxin and triiodothyronin
	Albumin: 45 g · l^{-1}	67	Maintenance of osmotic pressure; transport of fatty acids, bilirubin, bile acids, steroid hormones, pharmaceuticals and inorganic ions.
α_1-Globulins:	Antitrypsin	51	Inhibition of trypsin and other proteases
	Antichymotrypsin	58-68	Inhibition of chymotrypsin
	Lipoprotein (HDL)	200-400	Transport of lipids
	Prothrombin	72	Coagulation factor II, thrombin precursor (*3.4.21.5*)
	Transcortin	51	Transport of cortisol, corticosterone and progesterone
	Acid glycoprotein	44	Transport of progesterone
	Thyroxin-binding globulin	54	Transport of iodothyronins
α_2-Globulins:	Ceruloplasmin	135	Transport of copper ions
	Antithrombin III	58	Inhibition of blood clotting
	Haptoglobin	100	Binding of hemoglobin
	Cholinesterase (3.1.1.8)	ca. 350	Cleavage of choline esters
	Plasminogen	90	Precursor of plasmin (*3.4.21.7*), breakdown of blood clots
	Macroglobulin	725	Binding of proteases, transport of zinc ions
	Retinol-binding protein	21	Transport of vitamin A
	Vitamin D-binding protein	52	Transport of calciols
β-Globulins:	Lipoprotein (LDL)	2.000-4.500	Transport of lipids
	Transferrin	80	Transport of iron ions
	Fibrinogen	340	Coagulation factor I
	Sex hormone-binding globulin	65	Transport of testosterone and estradiol
	Transcobalamin	38	Transport of vitamin B_{12}
	C-reactive protein	110	Complement activation
γ-Globulins:	IgG	150	Late antibodies
	IgA	162	Mucosa-protecting antibodies
	IgM	900	Early antibodies
	IgD	172	B-lymphocyte receptors
	IgE	196	Reagins

B. Electrophoresis

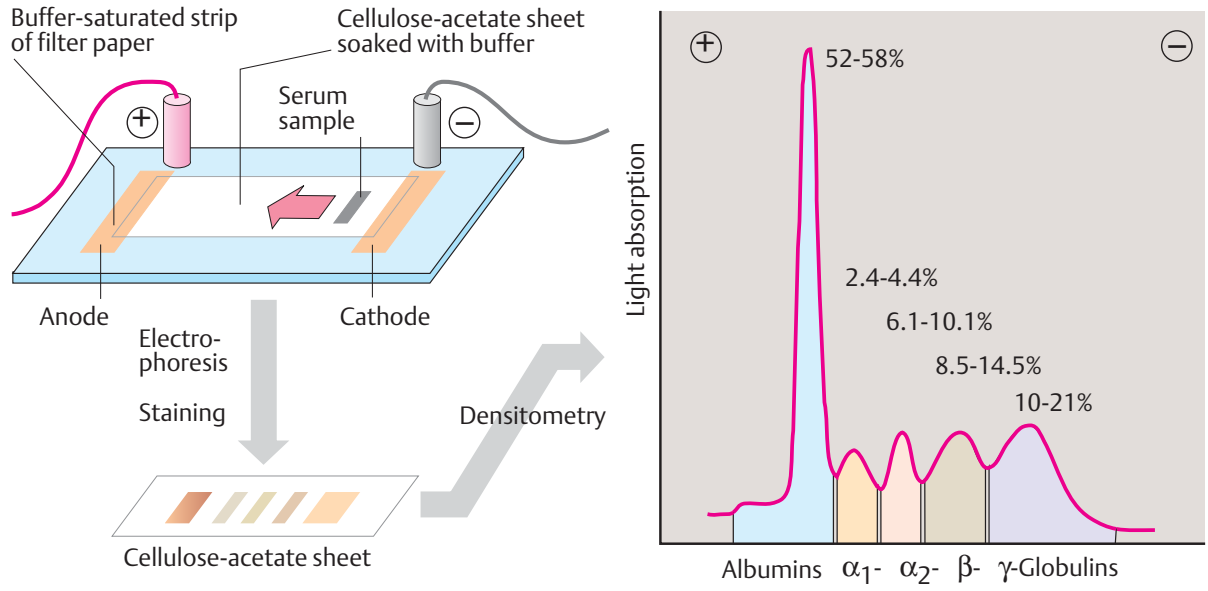

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Lipoproteins

Most lipids are barely soluble in water, and many have amphipathic properties. In the blood, free triacylglycerols would coalesce into drops that could cause fat embolisms. By contrast, amphipathic lipids would be deposited in the blood cells' membranes and would dissolve them. Special precautions are therefore needed for lipid transport in the blood. While long-chain fatty acids are bound to albumin and short-chain ones are dissolved in the plasma (see p. 276), other lipids are transported in **lipoprotein complexes**, of which there several types in the blood plasma, with different sizes and composition.

A. Composition of lipoprotein complexes ◑

Lipoproteins are spherical or discoid aggregates of **lipids** and **apoproteins**. They consist of a nucleus of apolar lipids (triacylglycerols and cholesterol esters) surrounded by a single-layered shell approximately 2 nm thick of amphipathic lipids (phospholipids and cholesterol; the example shown here is LDL). The shell, in which the apoproteins are also deposited, gives the surfaces of the particles polar properties and thereby prevents them from aggregating into large particles. The larger the lipid nucleus of a lipoprotein is—i. e., the larger the number of apolar lipids it contains—the lower its density is.

Lipoproteins are classified into five groups. In order of decreasing size and increasing density, these are: *chylomicrons, VLDLs* (very-low-density lipoproteins), *IDLs* (intermediate-density lipoproteins), *LDLs* (low-density lipoproteins), and *HDLs* (high-density lipoproteins). The proportions of apoproteins range from 1% in chylomicrons to over 50% in HDLs. These proteins serve less for solubility purposes, but rather function as recognition molecules for the membrane receptors and enzymes that are involved in lipid exchange.

B. Transport functions

The classes of lipoproteins differ not only in their composition, but also in the ways in which they originate and function.

The **chylomicrons** take care of the transport of triacylglycerols from the intestine to the tissues. They are formed in the intestinal mucosa and reach the blood via the lymphatic system (see p. 266). In the peripheral vessels—particularly in muscle and adipose tissue—*lipoprotein lipase* [1] on the surface of the vascular endothelia hydrolyzes most of the triacylglycerols. Chylomicron breakdown is activated by the transfer of apoproteins E and C from HDL. While the fatty acids released and the glycerol are taken up by the cells, the chylomicrons gradually become converted into **chylomicron remnants**, which are ultimately removed from the blood by the liver.

VLDLs, **IDLs**, and **LDLs** are closely related to one another. VLDLs formed in the liver (see p. 312) transport triacylglycerols, cholesterol, and phospholipids to other tissues. Like chylomicrons, they are gradually converted into IDL and LDL under the influence of *lipoprotein lipase* [1]. This process is also stimulated by HDL. Cells that have a demand for cholesterol bind LDL through an interaction between their **LDL receptor** and ApoB-100, and then take up the complete particle through **receptor-mediated endocytosis**. This type of transport is mediated by depressions in the membrane (*"coated pits"*), the interior of which is lined with the protein *clathrin.* After LDL binding, clathrin promotes invagination of the pits and pinching off of vesicles (*"coated vesicles"*). The clathrin then dissociates off and is reused. After fusion of the vesicle with lysosomes, the LDL particles are broken down (see p. 234), and cholesterol and other lipids are used by the cells.

The **HDLs** also originate in the liver. They return the excess cholesterol formed in the tissues to the liver. While it is being transported, cholesterol is acylated by *lecithin cholesterol acyltransferase* (LCAT). The cholesterol esters formed are no longer amphipathic and can be transported in the core of the lipoproteins. In addition, HDLs promote chylomicron and VLDL turnover by exchanging lipids and apoproteins with them (see above).

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A. Composition of lipoprotein complexes

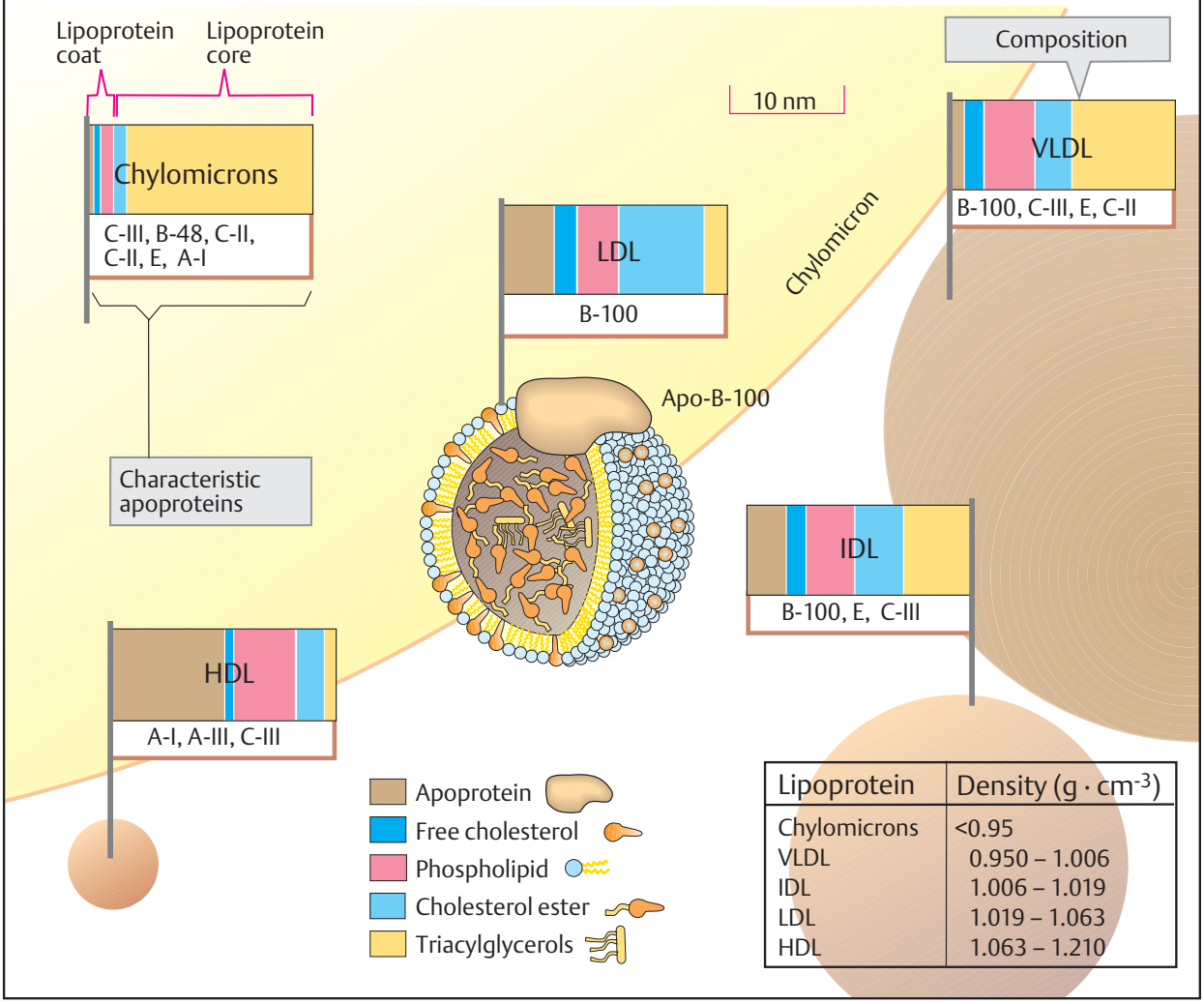

Lipoprotein	Density ($g \cdot cm^{-3}$)
Chylomicrons	<0.95
VLDL	0.950 – 1.006
IDL	1.006 – 1.019
LDL	1.019 – 1.063
HDL	1.063 – 1.210

B. Transport functions

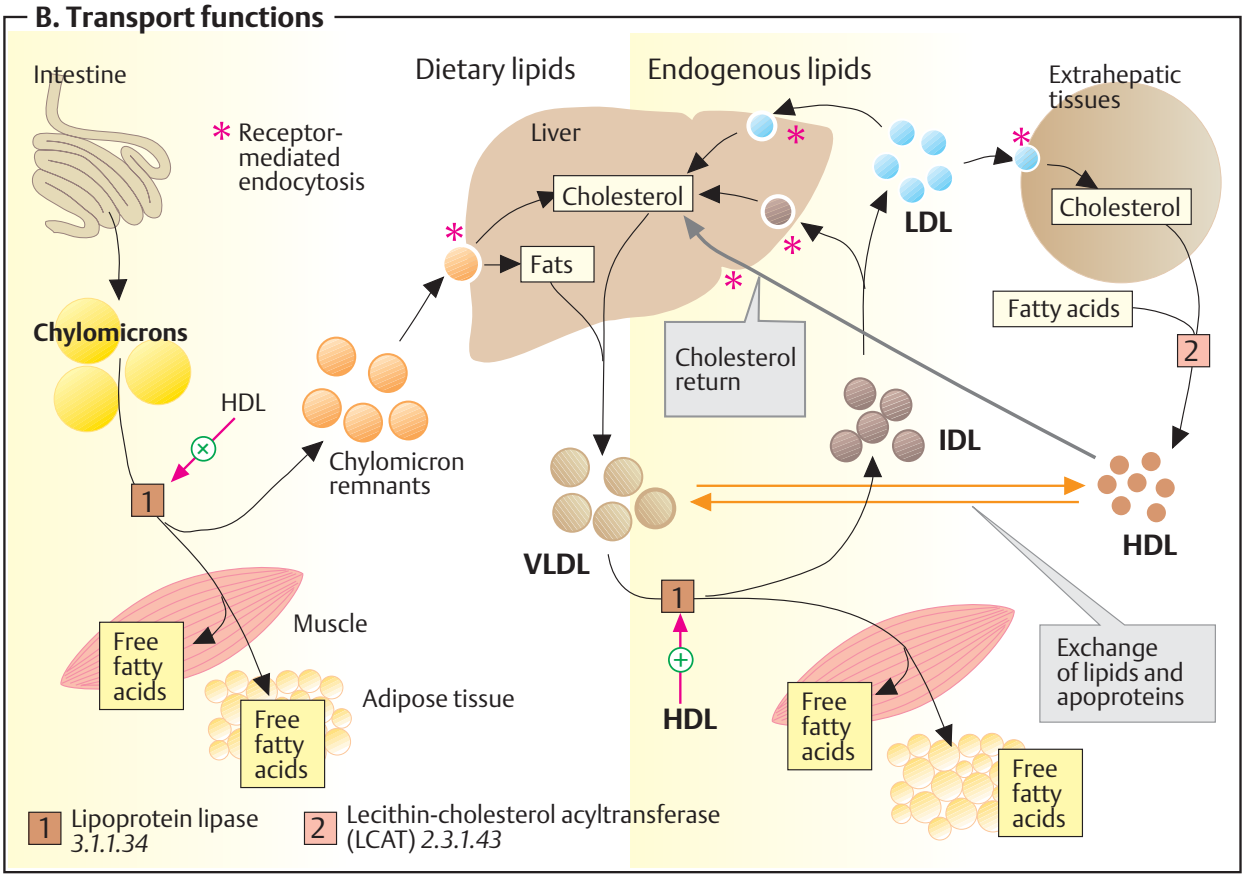

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Hemoglobin

The most important task of the red blood cells (erythrocytes) is to **transport** molecular oxygen ($\mathbf{O_2}$) from the lungs into the tissues, and carbon dioxide ($\mathbf{CO_2}$) from the tissues back into the lungs. To achieve this, the higher organisms require a special transport system, since O_2 is *poorly soluble in water.* For example, only around 3.2 mL O_2 is soluble in 1 L blood plasma. By contrast, the protein **hemoglobin** (Hb), contained in the erythrocytes, can bind a maximum of 220 mL O_2 per liter—70 times the physically soluble amount.

The Hb content of blood, at 140–180 g L^{-1} in men and 120–160 g L^{-1} in women, is twice as high as that of the plasma proteins (50–80 g L^{-1}). Hb is therefore also responsible for the majority of the blood proteins' pH buffer capacity (see p. 288).

A. Hemoglobin: structure ◑

In adults, hemoglobin (**HbA**; see below) is a *heterotetramer* consisting of two α-chains and two β-chains, each with masses of 16 kDa. The α- and β-chains have different sequences, but are similarly folded. Some 80% of the amino acid residues form *α-helices,* which are identified using the letters A–H.

Each subunit carries a **heme group** (formula on p. 106), with a central bivalent **iron ion**. When O_2 binds to the heme iron (**Oxygenation** of Hb) and when O_2 is released (**Deoxygenation**), the oxidation stage of the iron does *not* change. Oxidation of Fe^{2+} to Fe^{3+} only occurs occasionally. The oxidized form, *methemoglobin,* is then no longer able to bind O_2. The proportion of Met-Hb is kept low by reduction (see p. 284) and usually amounts to only 1–2%.

Four of the six coordination sites of the iron in hemoglobin are occupied by the nitrogen atoms of the pyrrol rings, and another is occupied by a histidine residue of the globin (the *proximal histidine*). The iron's sixth site is coordinated with oxygen in oxyhemoglobin and with H_2O in deoxyhemoglobin.

B. Hemoglobin: allosteric effects ◑

Like aspartate carbamoyltransferase (see p. 116), Hb can exist in two different states (*conformations*), known as the T form and the R form. The **T form** (for *tense;* left) and has a much *lower O_2* af nity than the R form (for *relaxed;* right).

Binding of O_2 to one of the subunits of the T form leads to a local conformational change that weakens the association between the subunits. Increasing O_2 partial pressure thus means that more and more molecules convert to the higher–af nity R form. This **cooperative interaction** between the subunits increases the O_2 af nity of Hb with increasing O_2 concentrations—i. e., the O_2 saturation curve is **sigmoidal** (see p. 282).

Various **allosteric effectors** influence the equilibrium between the T and R forms and thereby regulate the O_2 binding behavior of hemoglobin (yellow arrows). The most important effectors are *CO_2, H^+,* and *2,3-bisphosphoglycerate* (see p. 282).

Further information

As mentioned above, hemoglobin in adults consists of two α- and two β-chains. In addition to this main form (**HbA_1**, $\alpha_2\beta_2$), adult blood also contains small amounts of a second form with a higher O_2 af nity in which the β-chains are replaced by δ-chains (**HbA_2**, $\alpha_2\delta_2$). Two other forms occur during embryonic and fetal development. In the first three months, **embryonic hemoglobins** are formed, with the structure $\zeta_2\varepsilon_2$ and $\alpha_2\varepsilon_2$. Up to the time of birth, **fetal hemoglobin** then predominates (HbF, $\alpha_2\gamma_2$), and it is gradually replaced by HbA during the first few months of life. Embryonic and fetal hemoglobins have higher O_2 af nities than HbA, as they have to take up oxygen from the maternal circulation.

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A. Hemoglobin: structure

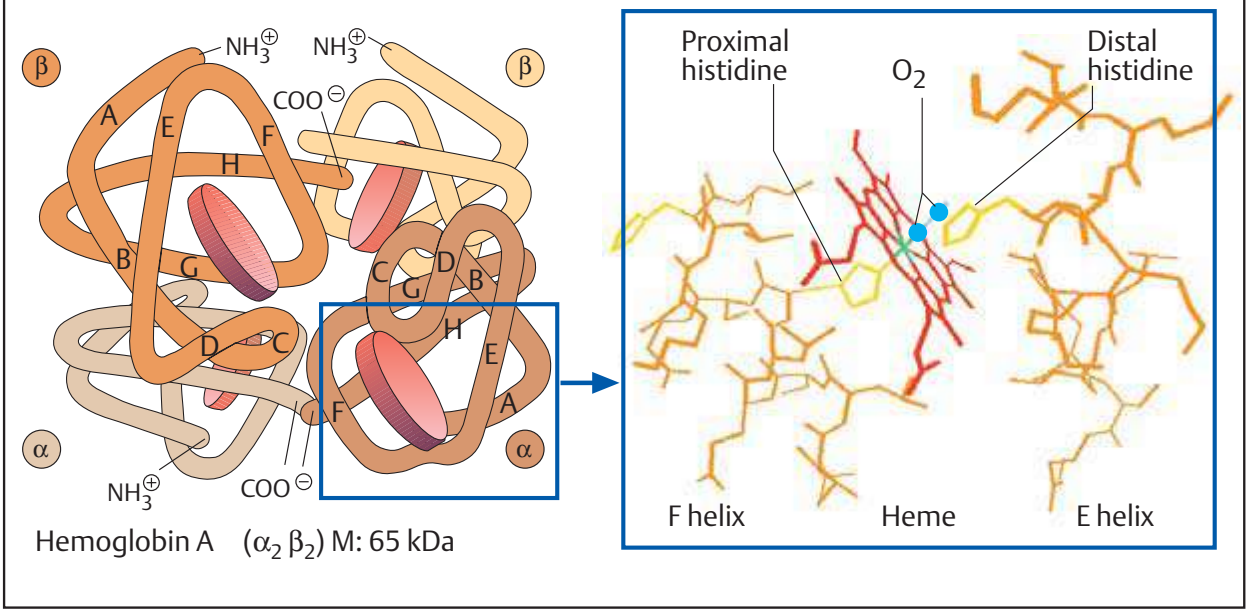

Hemoglobin A $(\alpha_2 \beta_2)$ M: 65 kDa

B. Hemoglobin: allosteric effects

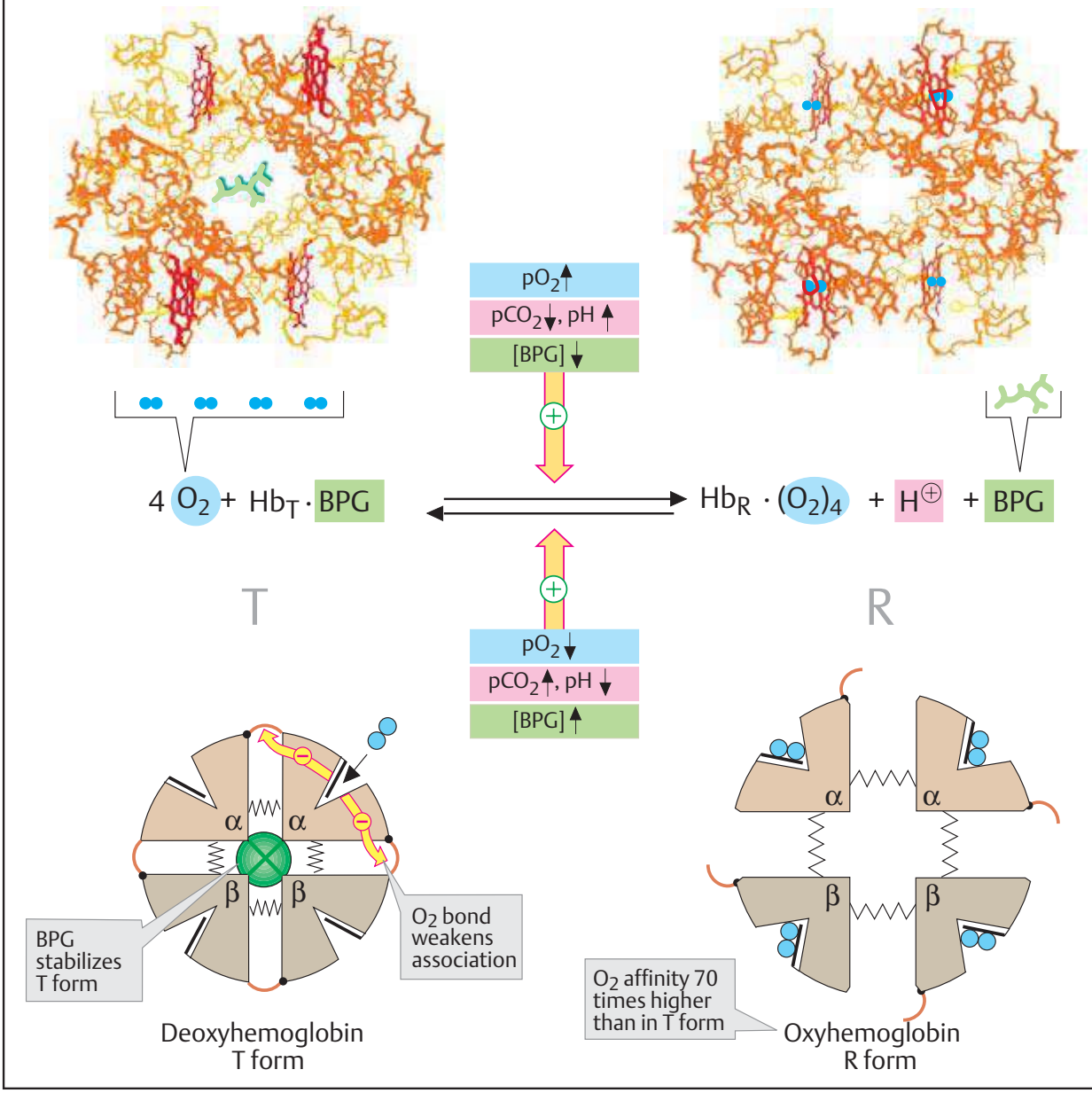

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Gas transport

Most tissues are constantly dependent on a supply of molecular oxygen (O_2) to maintain their oxidative metabolism. Due to its poor solubility, O_2 is bound to hemoglobin for transport in the blood (see p. 280). This not only increases the oxygen transport capacity, but also allows regulation of O_2 uptake in the lungs and O_2 release into tissues.

A. Regulation of O_2 transport ◑

When an enzyme reacts to effectors (substrates, activators, or inhibitors) with conformational changes that increase or reduce its activity, it is said to show *allosteric behavior* (see p. 116). Allosteric enzymes are usually oligomers with several subunits that mutually influence each other.

Although **hemoglobin** is not an enzyme (it releases the bound oxygen without changing it), it has all the characteristics of an allosteric protein. Its effectors include oxygen, which as a *positive homotropic effector* promotes its own binding. The **O_2 saturation curve** of hemoglobin is therefore markedly sigmoidal in shape (**2**, curve 2). The non-sigmoidal saturation curve of the muscular protein **myoglobin** is shown for comparison (curve 1). The structure of myoglobin (see p. 336) is similar to that of a subunit of hemoglobin, but as a monomer it does not exhibit any allosteric behavior.

CO_2, H^+, and a special metabolite of erythrocytes—**2,3-bisphosphoglycerate (BPG)**—act as *heterotropic effectors* of hemoglobin. BPG is synthesized from *1,3–bisphosphoglycerate,* an intermediate of glycolysis (see p. 150), and it can be returned to glycolysis again by breakdown into 2–phosphoglycerate (**1**), with loss of an ATP.

BPG binds selectively to *deoxy–Hb,* thereby increasing its amount of equilibrium. The result is *increased O_2 release* at constant pO_2. In the diagram, this corresponds to a **right shift** of the saturation curve (**2**, curve 3). CO_2 and H^+ act in the same direction as BPG. Their influence on the position of the curve has long been known as the **Bohr effect**.

The effects of CO_2 and BPG are *additive.* In the presence of both effectors, the saturation curve of isolated Hb is similar to that of whole blood (curve 4).

B. Hemoglobin and CO_2 transport ◑

Hemoglobin is also decisively involved in the transport of carbon dioxide (CO_2) from the tissues to the lungs.

Some 5% of the CO_2 arising in the tissues is covalently bound to the N terminus of hemoglobin and transported as *carbaminohemoglobin* (not shown). About 90% of the CO_2 is first converted in the periphery into *hydrogen carbonate* (HCO_3^-), which is more soluble (bottom). In the lungs (top), CO_2 is regenerated again from HCO_3^- and can then be exhaled.

These two processes are coupled to the oxygenation and deoxygenation of Hb. *Deoxy–Hb* is a stronger base than oxy–Hb. It therefore binds additional protons (about 0.7 H^+ per tetramer), which promotes the formation of HCO_3^- from CO_2 in the peripheral tissues. The resulting HCO_3^- is released into the plasma via an antiporter in the erythrocyte membrane in exchange for Cl^-, and passes from the plasma to the lungs. In the lungs, the reactions described above then proceed in reverse order: deoxy-Hb is oxygenated and releases protons. The protons shift the HCO_3/CO_2 equilibrium to the left and thereby promote CO_2 release.

O_2 binding to Hb is regulated by H^+ ions (i.e., by the pH value) via the same mechanism. High concentrations of CO_2 such as those in tissues with intensive metabolism locally increase the H^+ concentration and thereby reduce hemoglobin's O_2 af nity (Bohr effect; see above). This leads to increased O_2 release and thus to an improved oxygen supply.

The adjustment of the equilibrium between CO_2 and HCO_3^- is relatively slow in the uncatalyzed state. It is therefore accelerated in the erythrocytes by *carbonate dehydratase* (carbonic anhydrase) [1])—an enzyme that occurs in high concentrations in the erythrocytes.

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A. Regulation of O_2 transport

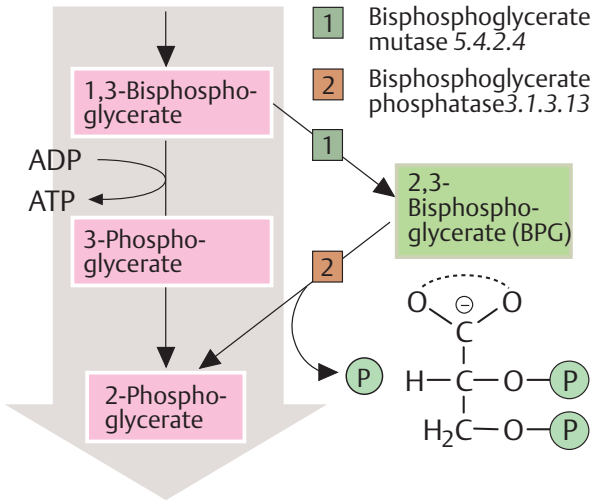

1. BPG metabolism

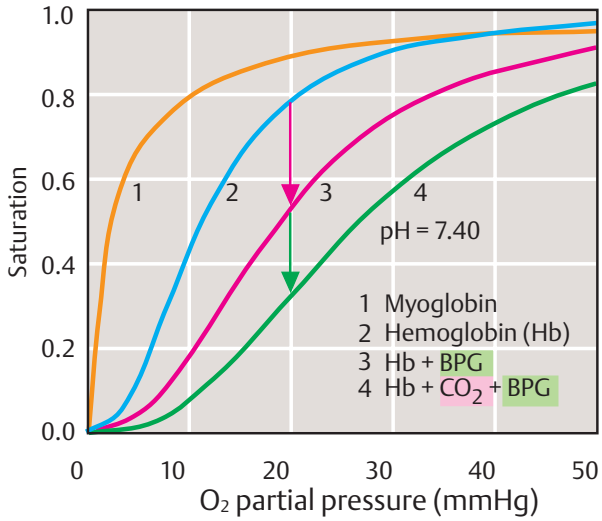

2. Saturation curves

D. Hemoglobin and CO_2 transport

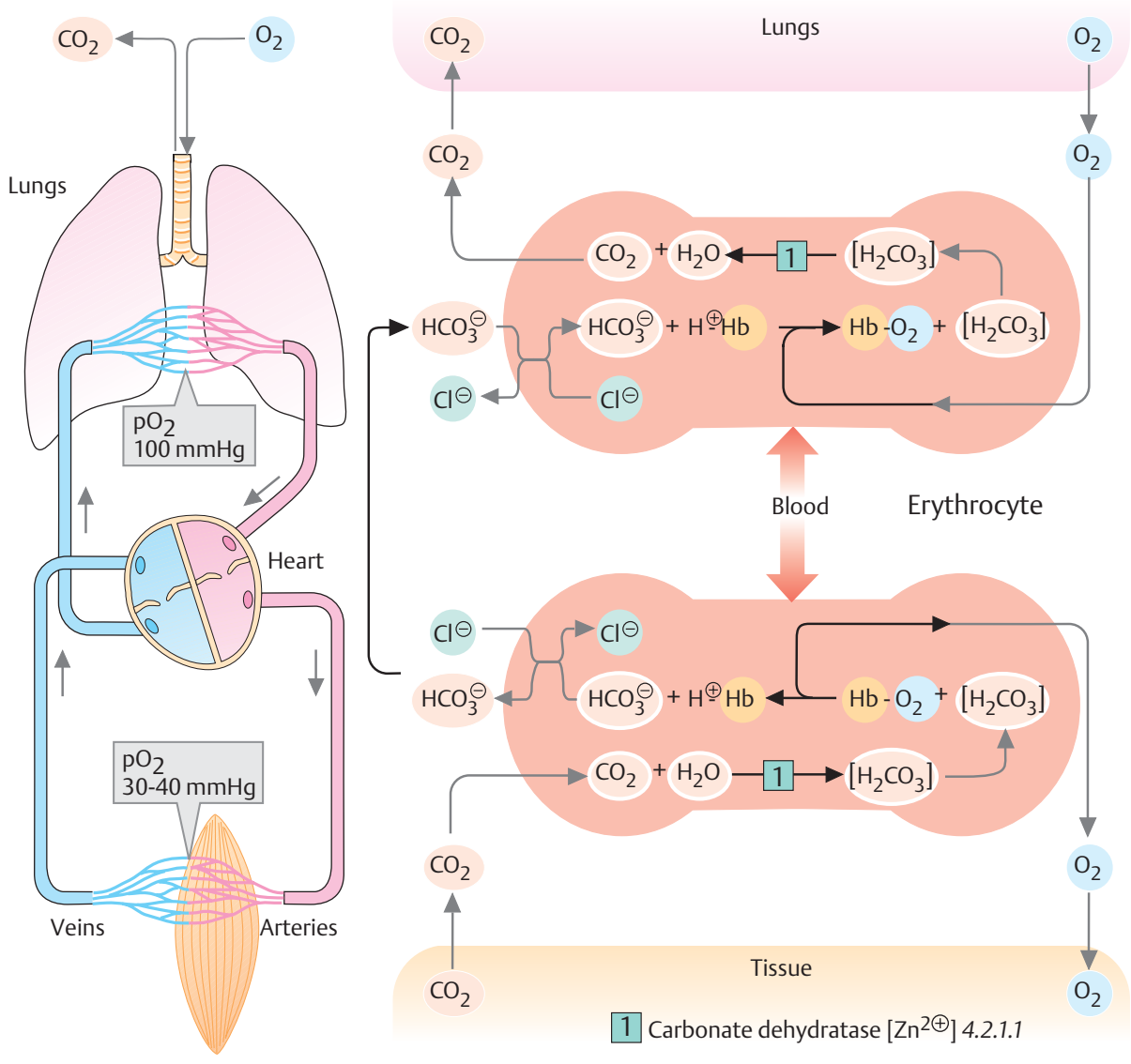

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Erythrocyte metabolism

Cells living in aerobic conditions are dependent on molecular oxygen for energy production. On the other hand, O_2 constantly gives rise to small quantities of toxic substances known as **reactive oxygen species** (ROS). These substances are powerful *oxidation agents* or extremely reactive *free radicals* (see p. 32), which damage cellular structures and functional molecules. Due to their role in O_2 transport, the erythrocytes are constantly exposed to high concentrations of O_2 and are therefore particularly at risk from ROS.

A. Reactive oxygen species ◑

The dioxygen molecule (O_2) contains two unpaired electrons—i. e., it is a *diradical.* Despite this, O_2 is relatively stable due to its special electron arrangement. However, if the molecule takes up an extra electron (**a**), the highly reactive **superoxide radical** (O_2^-) arises. Another reduction step (**b**) leads to the **peroxide anion** (O_2^{2-}), which easily binds protons and thus becomes **hydrogen peroxide** (H_2O_2). Inclusion of a third electron (**c**) leads to cleavage of the molecule into the ions O^{2-} and O^-. While O^{2-} can form **water** by taking up two protons, protonation of O^- provides the extremely dangerous **hydroxy radical** (OH). A fourth electron transfer and subsequent protonation also convert O^- into water.

The synthesis of ROS can be catalyzed by iron ions, for example. Reaction of O_2 with FMN or FAD (see p. 32) also constantly produces ROS. By contrast, reduction of O_2 by *cytochrome c-oxidase* (see p. 140) is "clean," as the enzyme does not release the intermediates. In addition to antioxidants (**B**), **enzymes** also provide protection against ROS: *superoxide dismutase* [1] breaks down ("disproportionates") two superoxide molecules into O_2 and the less damaging H_2O_2. The latter is in turn disproportionated into O_2 and H_2O by heme-containing *catalase* [2].

B. Biological antioxidants ◑

To protect them against ROS and other radicals, all cells contain **antioxidants**. These are *reducing agents* that react easily with oxidative substances and thus protect more important molecules from oxidation. Biological antioxidants include vitamins C and E (see pp. 364, 368), coenzyme Q (see p. 104), and several carotenoids (see pp. 132, 364). Bilirubin, which is formed during heme degradation (see p. 194), also serves for protection against oxidation.

Glutathione, a tripeptide that occurs in high concentrations in almost all cells, is particularly important. Glutathione (sequence: Glu–Cys–Gly) contains an atypical γ-peptide bond between Glu and Cys. The thiol group of the cysteine residue is redox-active. Two molecules of the reduced form (GSH, top) are bound to the disulfide (GSSG, bottom) during oxidation.

C. Erythrocyte metabolism ◑

Erythrocytes also have systems that can inactivate ROS (superoxide dismutase, catalase, GSH). They are also able to repair damage caused by ROS. This requires products that are supplied by the erythrocytes' **maintenance metabolism**, which basically only involves anaerobic glycolysis (see p. 150) and the pentose phosphate pathway (PPP; see p. 152).

The **ATP** formed during glycolysis serves mainly to supply *Na^+/K^+-ATPase,* which maintains the erythrocytes' membrane potential. The allosteric effector **2,3-BPG** (see p. 282) is also derived from glycolysis. The PPP supplies **NADPH+H^+**, which is needed to regenerate **glutathione** (GSH) from GSSG with the help of *glutathione reductase* [3]. GSH, the most important antioxidant in the erythrocytes, serves as a coenzyme for *glutathione peroxidase* [5]. This selenium-containing enzyme detoxifies H_2O_2 and hydroperoxides, which arise during the reaction of ROS with unsaturated fatty acids in the erythrocyte membrane. The reduction of methemoglobin (Hb Fe^{3+}) to Hb (Hb Fe^{2+}, [4]) is carried out by GSH or ascorbate by a non-enzymatic pathway; however, there are also NAD(P)H-dependent Met-Hb reductases.

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A. Reactive oxygen species

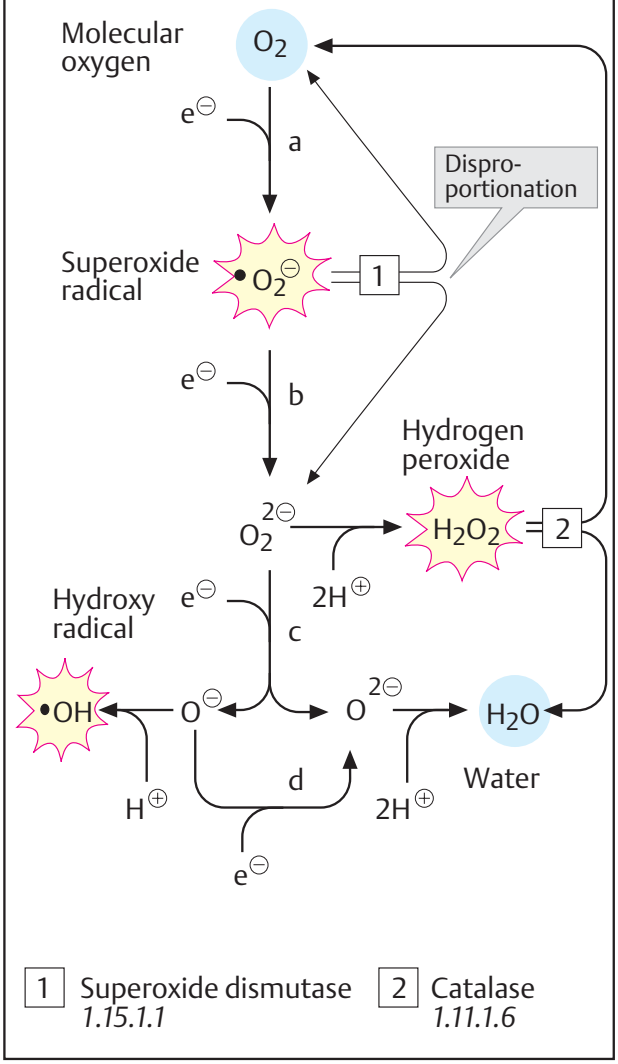

1 Superoxide dismutase *1.15.1.1*

2 Catalase *1.11.1.6*

B. Biological antioxidants

Quinols and enols	α-Tocopherol (vitamin E) Ubiquinol (coenzyme Q) Ascorbic acid (vitamin C)
Carotenoids	β-Carotin Lycopin
Others	Glutathione Bilirubin

1. Examples

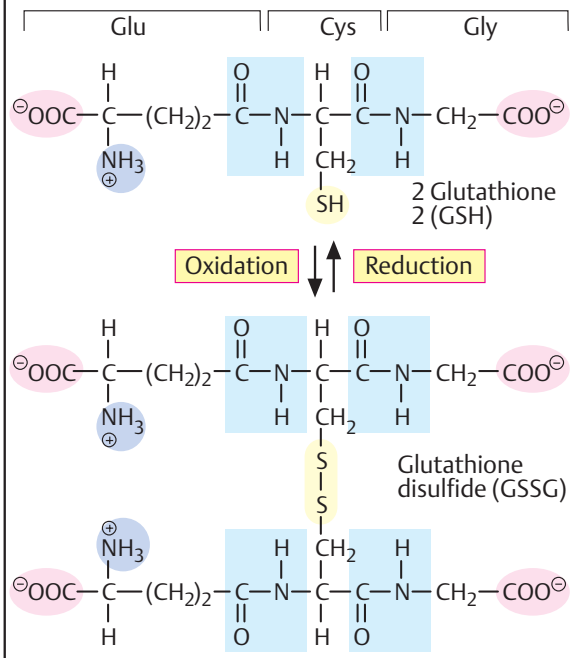

2. Glutathione

C. Erythrocyte metabolism

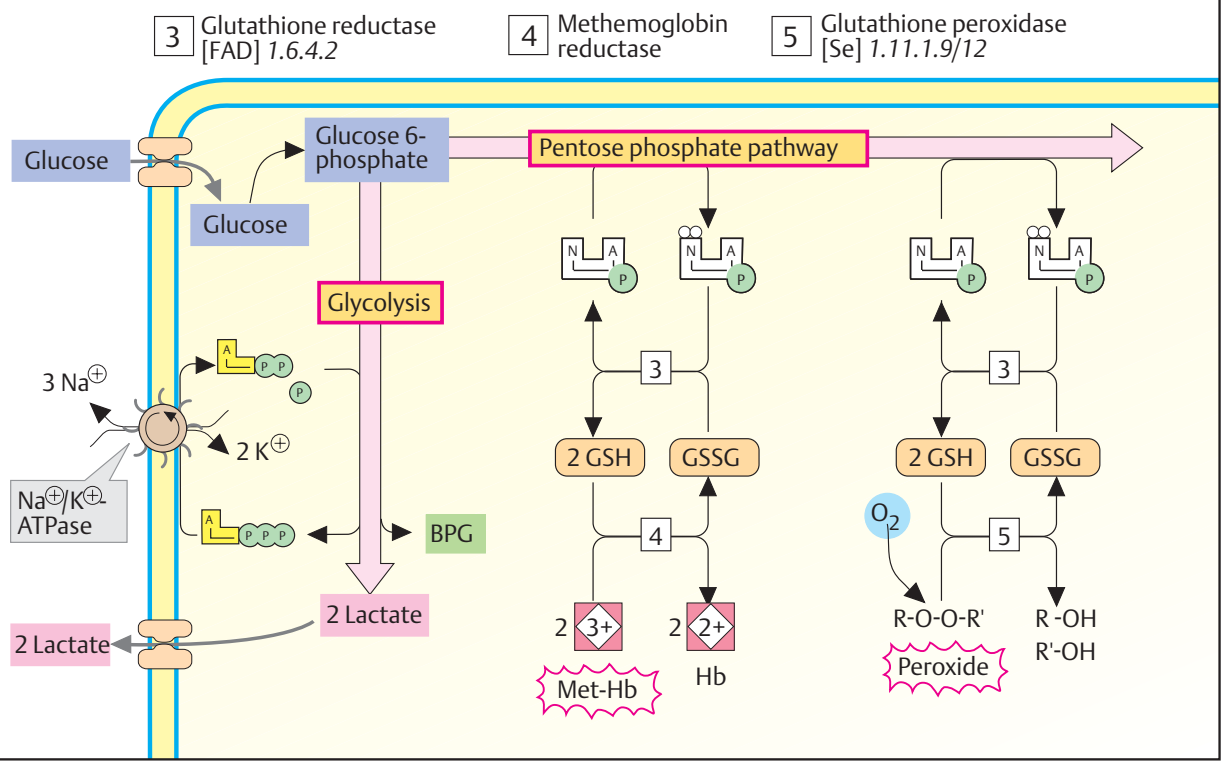

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Iron metabolism

A. Distribution of iron ◑

Iron (Fe) is quantitatively the most important trace element (see p. 362). The human body contains 4–5 g iron, which is almost exclusively present in protein-bound form. Approximately three-quarters of the total amount is found in **heme proteins** (see pp. 106, 192), mainly hemoglobin and myoglobin. About 1% of the iron is bound in **iron–sulfur clusters** (see p. 106), which function as cofactors in the respiratory chain, in photosynthesis, and in other redox chains. The remainder consists of iron in transport and storage proteins (transferrin, ferritin; see **B**).

B. Iron metabolism ◑

Iron can only be resorbed by the bowel in bivalent form (i. e., as Fe^{2+}). For this reason, reducing agents in food such as ascorbate (vitamin C; see p. 368) promote **iron uptake**. Via transporters on the luminal and basal side of the enterocytes, Fe^{2+} enters the blood, where it is bound by *transferrin*. Part of the iron that is taken up is stored in the bowel in the form of *ferritin* (see below). Heme groups can also be resorbed by the small intestine.

Most of the resorbed iron serves for the formation of red blood cells in the bone marrow (**erythropoiesis**, top). As discussed on p. 192, it is only in the final step of hem biosynthesis that Fe^{2+} is incorporated by *ferrochelatase* into the previously prepared tetrapyrrol framework.

In the blood, 2.5–3.0 g of hemoglobin iron circulates as a component of the erythrocytes (top right). Over the course of several months, the flexibility of the red blood cells constantly declines due to damage to the membrane and cytoskeleton. Old erythrocytes of this type are taken up by macrophages in the spleen and other organs and broken down. The organic part of the heme is oxidized into bilirubin (see p. 194), while the iron returns to the plasma pool. The quantity of heme iron recycled per day is much larger than the amount resorbed by the intestines.

Transferrin, a β-globulin with a mass of 80 kDa, serves to transport iron in the blood. This monomeric protein consists of two similar domains, each of which binds an Fe^{2+} ion very tightly. Similar iron transport proteins are found in secretions such as saliva, tears, and milk; these are known as lactoferrins (bottom right). Transferrin and the lactoferrins maintain the concentration of *free* iron in body fluids at values below 10^{-10} mol L^{-1}. This low level prevents bacteria that require free iron as an essential growth factor from proliferating in the body. Like LDLs (see p. 278), transferrin and the lactoferrins are taken up into cells by *receptor-mediated endocytosis*.

Excess iron is incorporated into **ferritin** and stored in this form in the liver and other organs. The ferritin molecule consists of 24 subunits and has the shape of a hollow sphere (bottom left). It takes up Fe^{2+} ions, which in the process are oxidized to Fe^{3+} and then deposited in the interior of the sphere as *ferrihydrate*. Each ferritin molecule is capable of storing several thousand iron ions in this way. In addition to ferritin, there is another storage form, **hemosiderin**, the function of which is not yet clear.

Further information

Disturbances of the iron metabolism are frequent and can lead to severe disease pictures.

Iron deficiency is usually due to blood loss, or more rarely to inadequate iron uptake. During pregnancy, increased demand can also cause iron deficiency states. In severe cases, reduced hemoglobin synthesis can lead to **anemia** ("iron-deficiency anemia"). In these patients, the erythrocytes are smaller and have less hemoglobin. As their membrane is also altered, they are prematurely eliminated in the spleen.

Disturbances resulting from raised iron concentrations are less frequent. Known as **hemochromatoses**, these conditions can have genetic causes, or may be due to repeated administration of blood transfusions. As the body has practically no means of excreting iron, more and more stored iron is deposited in the organs over time in patients with untreated hemochromatosis, ultimately leading to severe disturbances of organ function.

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A. Distribution of iron

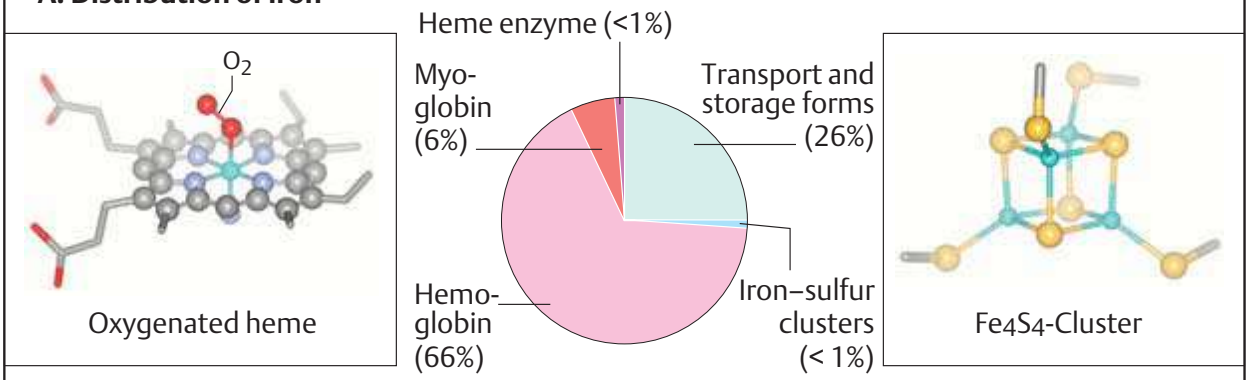

B. Iron metabolism

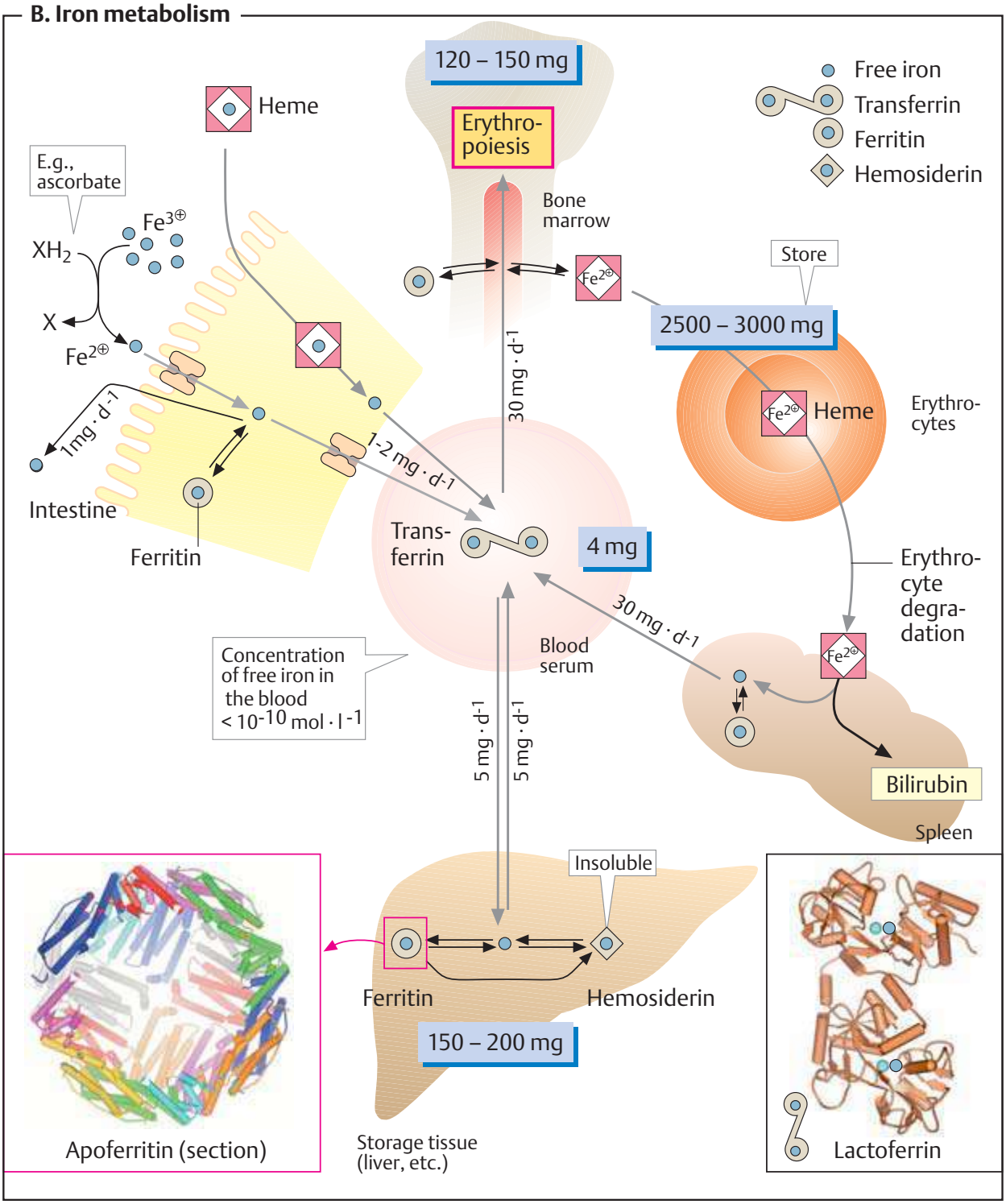

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Acid–base balance

A. Hydrogen ion concentration in the blood plasma ◑

The H^+ concentration in the blood and extracellular space is approximately 40 nM ($4 \cdot 10^{-8}$ mol L^{-1}). This corresponds to a pH of 7.40. The body tries to keep this value constant, as large shifts in pH are incompatible with life.

The pH value is kept constant by **buffer systems** that cushion minor disturbances in the *acid–base balance* (**C**). In the longer term, the decisive aspect is maintaining a balanced equilibrium between H^+ production and uptake and H^+ release. If the blood's buffering capacity is not suf cient, or if the acid–base balance is not in equilibrium—e. g., in kidney disease or during *hypoventilation* or *hyperventilation*—shifts in the plasma pH value can occur. A reduction by more than 0.03 units is known as **acidosis,** and an increase is called **alkalosis.**

B. Acid–base balance ◑

Protons are mainly derived from two sources—free acids in the diet and sulfur–containing amino acids. *Acids* taken up with food—e. g., citric acid, ascorbic acid, and phosphoric acid—already release protons in the alkaline pH of the intestinal tract. More important for proton balance, however, are the amino acids **methionine** and **cysteine**, which arise from protein degradation in the cells. Their S atoms are oxidized in the liver to form sulfuric acid, which supplies protons by dissociation into sulfate.

During anaerobic glycolysis in the muscles and erythrocytes, glucose is converted into **lactate**, releasing protons in the process (see p. 338). The synthesis of the **ketone bodies** acetoacetic acid and 3–hydroxybutyric acid in the liver (see p. 312) also releases protons. Normally, the amounts formed are small and of little influence on the proton balance. If acids are formed in large amounts, however (e. g., during *starvation* or in *diabetes mellitus;* see p. 160), they strain the buffer systems and can lead to a reduction in pH (**metabolic acidoses**; *lactacidosis* or *ketoacidosis*).

Only the **kidney** is capable of excreting protons in exchange for Na^+ ions (see p. 326). In the urine, the H^+ ions are buffered by NH_3 and phosphate.

C. Buffer systems in the plasma ◑

The **buffering capacity** of a buffer system depends on its concentration and its pK_a value. The strongest effect is achieved if the pH value corresponds to the buffer system's pK_a value (see p. 30). For this reason, weak acids with pK_a values of around 7 are best suited for buffering purposes in the blood.

The most important buffer in the blood is the **CO_2/bicarbonate buffer**. This consists of water, carbon dioxide (CO_2, the anhydride of carbonic acid H_2CO_3), and hydrogen carbonate (HCO_3^-, bicarbonate). The adjustment of the balance between CO_2 and HCO_3^- is accelerated by the zinc-containing enzyme *carbonate dehydratase* (carbonic anhydrase [1]; see also p. 282). At the pH value of the plasma, HCO_3^- and CO_2 are present in a ratio of about 20 : 1. However, the CO_2 in solution in the blood is in equilibrium with the gaseous CO_2 in the pulmonary alveoli. The CO_2/HCO_3^- system is therefore a powerful *open buffer system,* despite having a not entirely optimal pK_a value of 6.1. Faster or slower respiration increases or reduces CO_2 release in the lungs. This shifts the CO_2/HCO_3^- ratio and thus the plasma pH value (respiratory acidosis or alkalosis). In this way, respiration can compensate to a certain extent for changes in plasma pH values. However, it does *not* lead to the excretion of protons.

Due to their high concentration, **plasma proteins**—and **hemoglobin** in the erythrocytes in particular—provide about one-quarter of the blood's buffering capacity. The buffering effect of proteins involves contributions from all of the ionizable side chains. At the pH value of blood, the acidic amino acids (Asp, Glu) and histidine are particularly effective.

The second dissociation step in **phosphate** (H_2PO_4/HPO_4^{2-}) also contributes to the buffering capacity of the blood plasma. Although the pK_a value of this system is nearly optimal, its contribution remains small due to the low total concentration of phosphate in the blood (around 1 mM).

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A. Hydrogen ion concentration in the blood plasma

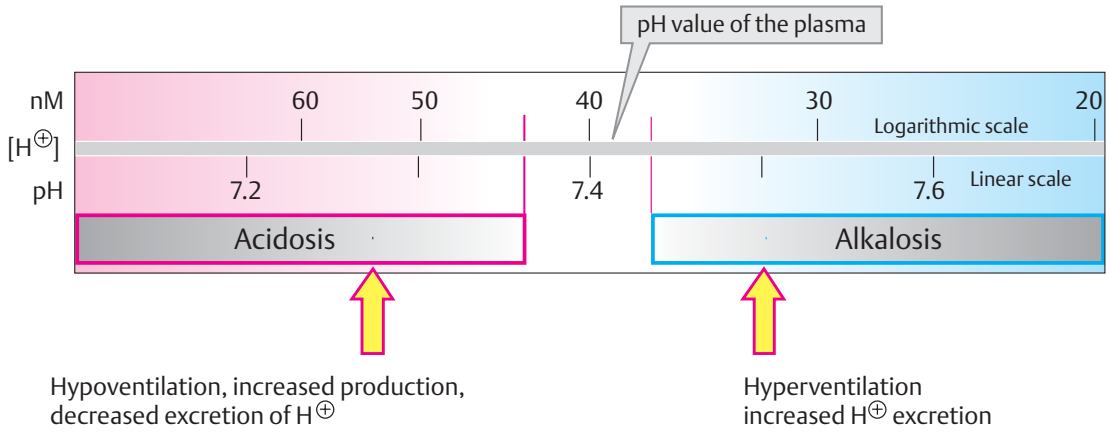

B. Acid–base balance

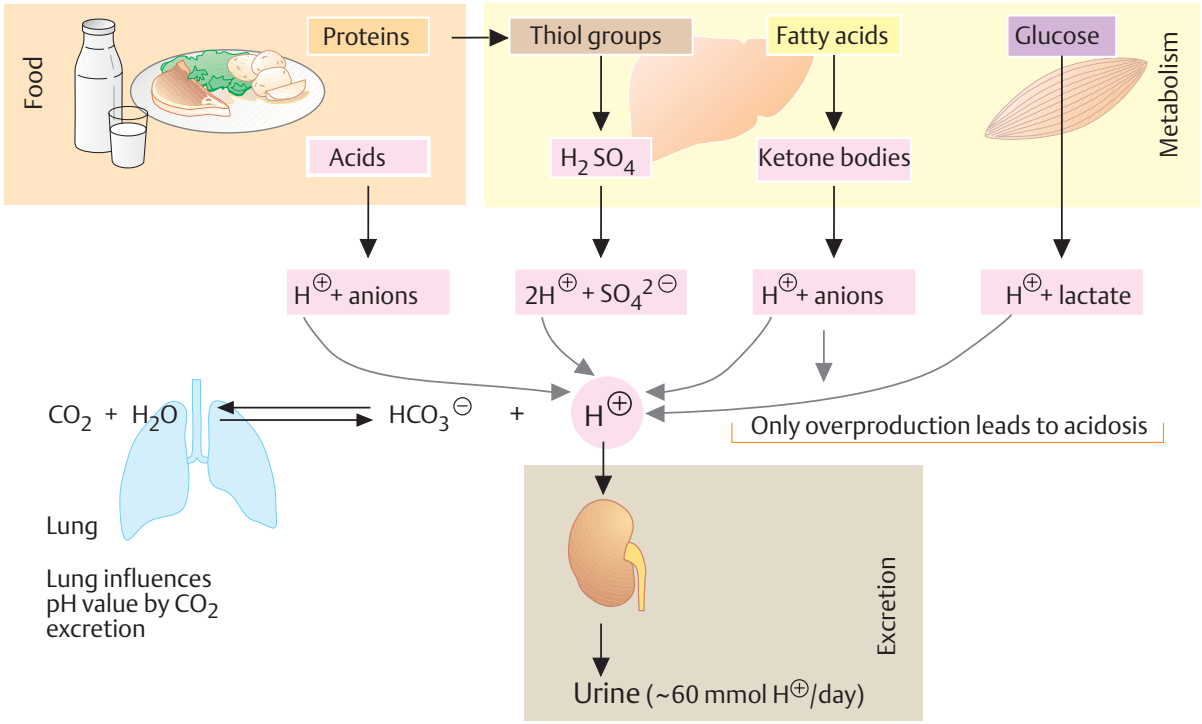

C. Buffer systems in the plasma

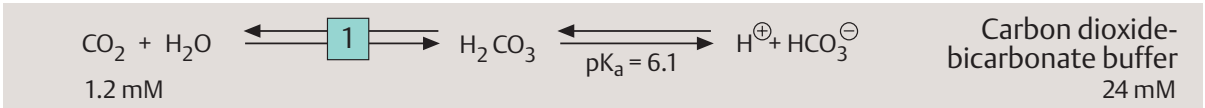

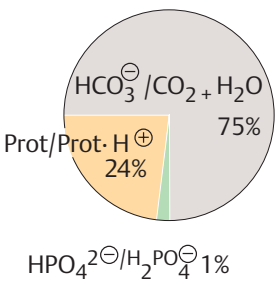

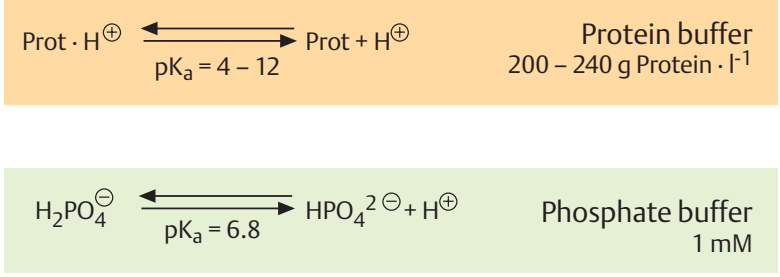

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Blood clotting

Following injury to blood vessels, **hemostasis** ensures that blood loss is minimized. Initially, thrombocyte activation leads to contraction of the injured vessel and the formation of a loose clot consisting of thrombocytes (**hemostasis**). Slightly later, the action of the enzyme *thrombin* leads to the formation and deposition in the thrombus of polymeric fibrin (**coagulation, blood clotting**). The coagulation process is discussed here in detail.

A. Blood clotting ◑

The most important reaction in blood clotting is the conversion, catalyzed by *thrombin,* of the soluble plasma protein *fibrinogen* (factor I) into polymeric *fibrin,* which is deposited as a fibrous network in the primary thrombus. Thrombin (factor IIa) is a serine proteinase (see p. 176) that cleaves small peptides from fibrinogen. This exposes binding sites that spontaneously allow the fibrin molecules to aggregate into polymers. Subsequent covalent cross-linking of fibrin by a *transglutaminase* (factor XIII) further stabilizes the thrombus.

Normally, thrombin is present in the blood as an inactive proenzyme (see p. 270). Prothrombin is activated in two different ways, both of which represent cascades of enzymatic reactions in which inactive proenzymes (zymogens, symbol: circle) are proteolytically converted into active **proteinases** (symbol: sector of a circle). The proteinases activate the next proenzyme in turn, and so on. Several steps in the cascade require additional **protein factors** (factors III, Va and VIIIa) as well as anionic **phospholipids** (PL; see below) and **Ca^{2+}** ions. Both pathways are activated by injuries to the vessel wall.

In the **extravascular pathway** (right), *tissue thromboplastin* (factor III), a membrane protein in the deeper layers of the vascular wall, activates coagulation factor VII. The activated form of this (VIIa) autocatalytically promotes its own synthesis and also generates the active factors IXa and Xa from their precursors. With the aid of factor VIIIa, PL, and Ca^{2+}, factor IXa produces additional Xa, which finally—with the support of Va, PL, and Ca^{2+}—releases active thrombin.

The **intravascular pathway** (left) is probably also triggered by vascular injuries. It leads in five steps via factors XIIa, XIa, IXa, and Xa to the activation of prothrombin. The significance of this pathway in vivo has been controversial since it was found that a genetic deficiency in factor XII does not lead to coagulation disturbances.

Both pathways depend on the presence of activated **thrombocytes**, on the surface of which several reactions take place. For example, the *prothrombinase complex* (left) forms when factors Xa and II, with the help of Va, bind via Ca^{2+} ions to anionic phospholipids in the thrombocyte membrane. For this to happen, factors II and X have to contain the nonproteinogenic amino acid **γ-carboxyglutamate** (Gla; see p. 62), which is formed in the liver by post-translational carboxylation of the factors. The Gla residues are found in groups in special domains that create contacts to the Ca^{2+} ions. Factors VII and IX are also linked to membrane phospholipids via Gla residues.

Substances that bind Ca^{2+} ions (e. g., *citrate*) prevent Gla-containing factors from attaching to the membrane and therefore inhibit coagulation. Antagonists of *vitamin K,* which is needed for synthesis of the Gla residues (see p. 364) also have anticoagulatory effects. These include dicumarol, for example.

Active **thrombin** not only converts fibrinogen into fibrin, but also indirectly promotes its own synthesis by catalyzing the activation of factors V and VIII. In addition, it catalyzes the activation of factor XIII and thereby triggers the cross-linking of the fibrin.

Regulation of blood clotting (not shown). To prevent the coagulation reaction from becoming excessive, the blood contains a number of anticoagulant substances, including highly effective proteinase inhibitors. For example, *antithrombin III* binds to various serine proteinases in the cascade and thereby inactivates them. *Heparin,* an anticoagulant glycosaminoglycan (see p. 346), potentiates the effect of antithrombin III. *Thrombomodulin,* which is located on the vascular endothelia, also inactivates thrombin. A glycoprotein known as *Protein C* ensures proteolytic degradation of factors V and VIII. As it is activated by thrombin, coagulation is shut down in this way.

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A. Blood clotting

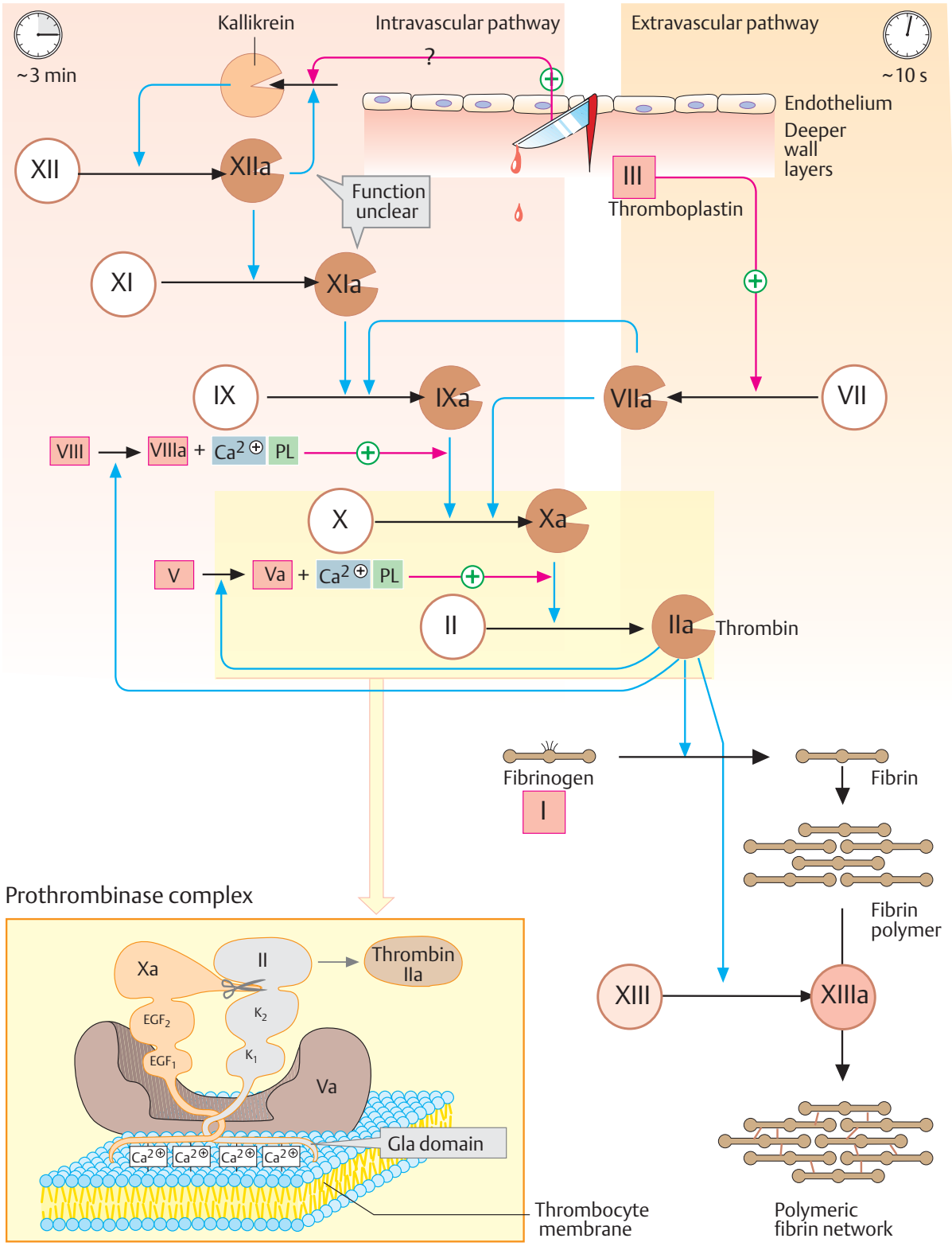

Coagulation factors

- I Fibrinogen
- ◆ II Prothrombin* *3.4.21.5*
- III Tissue factor/thromboplastin
- IV $Ca^{2\oplus}$
- V Proaccelerin
- VI Synonym for Va
- ◆ VII Proconvertin* *3.4.21.21*
- VIII Antihemophilic factor A
- ◆ IX Christmas factor* *3.4.21.22*
- ◆ X Stuart–Prower factor* *3.4.21.6*
- XI Plasma thromboplastin antecedent* (PTA) *3.4.21.27*
- XII Hageman factor* *3.4.21.38*
- XIII Fibrin-stabilizing factor* *2.3.2.13*

* Proenzyme
◆ Contains γ-carboxyglutamate

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Fibrinolysis, blood groups

A. Fibrinolysis ◑

The fibrin thrombus resulting from blood clotting (see p. 290) is dissolved again by *plasmin,* a serine proteinase found in the blood plasma. For this purpose, the precursor *plasminogen* first has to be proteolytically activated by enzymes from various tissues. This group includes the *plasminogen activator* from the kidney (*urokinase*) and *tissue plasminogen activator* (t-PA) from vascular endothelia. By contrast, the plasma protein α_2-antiplasmin, which binds to active plasmin and thereby inactivates it, inhibits fibrinolysis.

Urokinase, t-PA, and streptokinase, a bacterial proteinase with similar activity, are used clinically to dissolve thrombi following *heart attacks.* All of these proteins are expressed recombinantly in bacteria (see p. 262).

B. Blood groups: the ABO system ◑

During blood transfusions, immune reactions can occur that destroy the erythrocytes transfused from the donor. These reactions result from the formation of antibodies (see p. 300) directed to certain surface structures on the erythrocytes. Known as **blood group antigens**, these are *proteins* or *oligosaccharides* that can differ from individual to individual. More than 20 different blood group systems are now known. The ABO system and the Rh system are of particular clinical importance.

In the **ABO system**, the carbohydrate parts of glycoproteins or glycolipids act as antigens. In this relatively simple system, there are four *blood groups* (A, B, AB, and 0). In individuals with blood groups A and B, the antigens consist of tetrasaccharides that only differ in their terminal sugar (galactose or *N*-acetylgalactosamine). Carriers of the AB blood group have both antigens (A *and* B). Blood group 0 arises from an oligosaccharide (the H antigen) that lacks the terminal residue of antigens A and B. The molecular causes for the differences between blood groups are mutations in the *glycosyl transferases* that transfer the terminal sugar to the core oligosaccharide.

Antibodies are only formed against antigens that the individual concerned does *not* possess. For example, carriers of blood group A form antibodies against antigen B ("anti-B"), while carriers of group B form antibodies against antigen A ("anti-A"). Individuals with blood group 0 form both types, and those with blood group AB do not form any of these antibodies.

If blood from blood group A is transfused into the circulation of an individual with blood group B, for example, then the anti-A present there binds to the A antigens. The donor erythrocytes marked in this way are recognized and destroyed by the complement system (see p. 298). In the test tube, *agglutination* of the erythrocytes can be observed when donor and recipient blood are incompatible.

The recipient's serum should not contain any antibodies against the donor erythrocytes, and the donor serum should not contain any antibodies against the recipient's erythrocytes. Donor blood from blood group 0 is unproblematic, as its erythrocytes do not possess any antibodies and therefore do not react with anti-A or anti-B in the recipient's blood. Conversely, blood from the AB group can only be administered to recipients with the AB group, as these are the only ones without antibodies.

In the **Rh system** (not shown), proteins on the surface of the erythrocytes act as antigens. These are known as "rhesus factors," as the system was first discovered in rhesus monkeys.

The rhesus D antigen occurs in 84% of all white individuals, who are therefore *"Rh-positive."* If an Rh-positive child is born to an Rh-negative mother, fetal erythrocytes can enter the mother's circulation during birth and lead to the formation of antibodies (IgG) against the D antigen. This initially has no acute effects on the mother or child. Complications only arise when there is a second pregnancy with an Rh-positive child, as maternal anti-D antibodies cross the placenta to the fetus even before birth and can trigger destruction of the child's Rh-positive erythrocytes (*fetal erythroblastosis*).

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A. Fibrinolysis

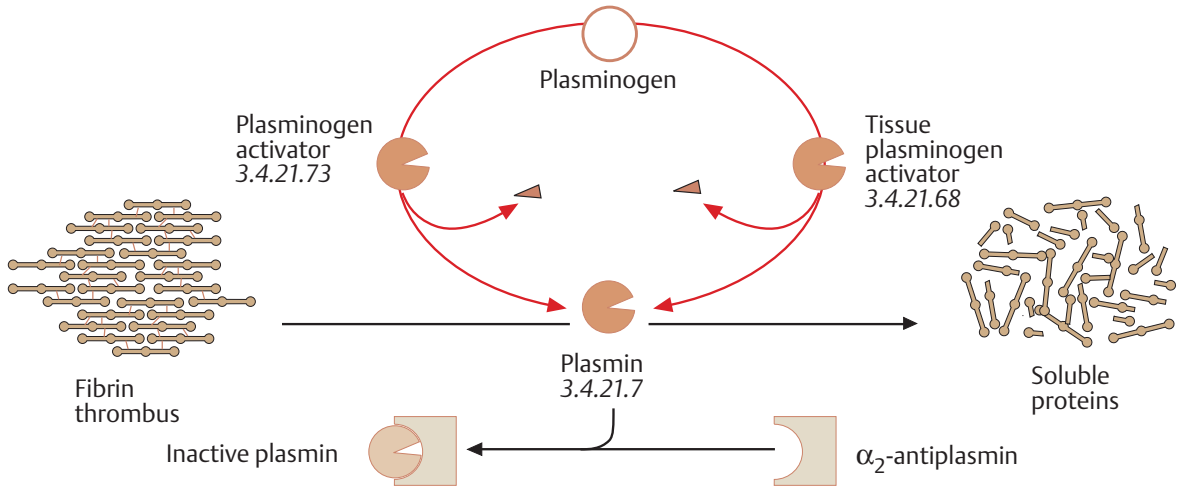

B. Blood groups: the AB0 system

Blood group	A	B	AB	0
Genotypes	AA and A0	BB and B0	AB	00
Antigens	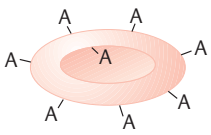	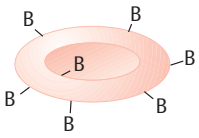	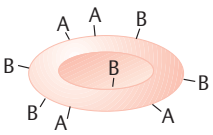	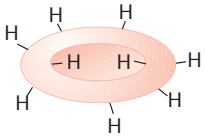
Antibodies in blood	anti-B	anti-A	—	anti-A anti-B
Frequency in central Europe	40%	16%	4%	40%

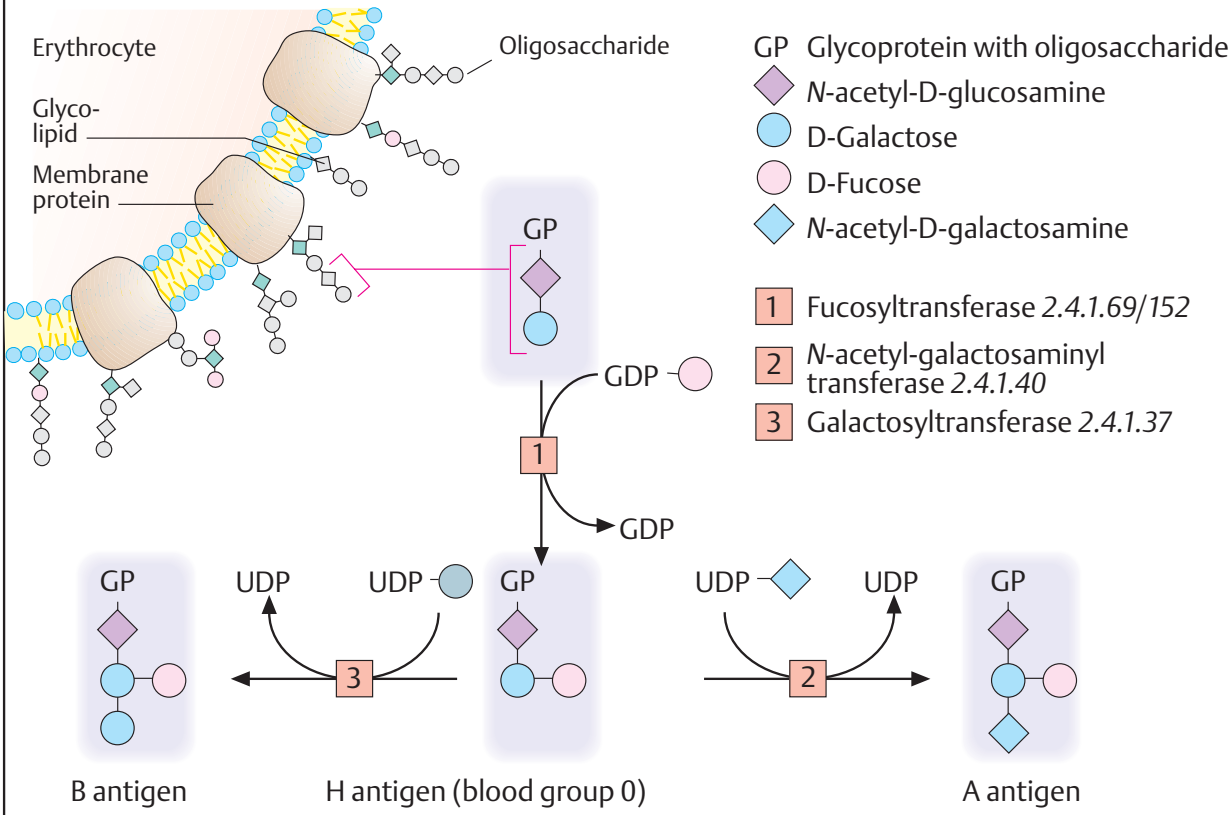

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Immune response

Viruses, bacteria, fungi, and parasites that enter the body of vertebrates of are recognized and attacked by the **immune system**. Endogenous cells that have undergone alterations—e. g., tumor cells—are also usually recognized as foreign and destroyed. The immune system is supported by physiological changes in infected tissue, known as **inflammation**. This reaction makes it easier for the immune cells to reach the site of infection.

Two different systems are involved in the immune response. The **innate immune system** is based on receptors that can distinguish between bacterial and viral surface structures or foreign proteins (known as *antigens*) and those that are endogenous. With the help of these receptors, *phagocytes* bind to the pathogens, absorb them by endocytosis, and break them down. The complement system (see p. 298) is also part of the innate system.

The **acquired** (adaptive) **immune system** is based on the ability of the *lymphocytes* to form highly specific antigen receptors "on suspicion," without ever having met the corresponding antigen. In humans, there are several billion different lymphocytes, each of which carries a different antigen receptor. If this type of receptor recognizes "its" cognate antigen, the lymphocyte carrying it is activated and then plays its special role in the immune response.

In addition, a distinction is made between cellular and humoral immune responses. The *T lymphocytes* (T cells) are responsible for **cellular immunity**. They are named after the thymus, in which the decisive steps in their differentiation take place. Depending on their function, another distinction is made between *cytotoxic T cells* (green) and *helper T cells* (blue). **Humoral immunity** is based on the activity of the *B lymphocytes* (B cells, light brown), which mature in the bone marrow. After activation by T cells, B cells are able to release soluble forms of their specific antigen receptors, known as *antibodies* (see p. 300), into the blood plasma. The immune system's "memory" is represented by memory cells. These are particularly long–lived cells that can arise from any of the lymphocyte types described.

A. Simplified diagram of the immune response ◑

Pathogens that have entered the body—e. g., viruses (top)—are taken up by **antigen-presenting cells** (APCs) and proteolytically degraded (**1**). The viral fragments produced in this way are then presented on the surfaces of these cells with the help of special membrane proteins (MHC proteins; see p. 296) (**2**). The APCs include B lymphocytes, macrophages, and dendritic cells such as the skin's Langerhans cells.

The complexes of MHC proteins and viral fragments displayed on the APCs are recognized by T cells that carry a receptor that matches the antigen ("T-cell receptors"; see p. 296) (**3**). Binding leads to activation of the T cell concerned and selective replication of it (**4**, *"clonal selection"*). The proliferation of immune cells is stimulated by *interleukins* (IL). These are a group of more than 20 signaling substances belonging to the cytokine family (see p. 392), with the help of which immune cells communicate with each other. For example, activated macrophages release IL-1 (**5**), while T cells stimulate their own replication and that of other immune cells by releasing IL-2 (**6**).

Depending on their type, activated T cells have different functions. **Cytotoxic T cells** (green) are able to recognize and bind virus-infected body cells or tumor cells (**7**). They then drive the infected cells into apoptosis (see p. 396) or kill them with *perforin*, a protein that perforates the target cell's plasma membrane (**8**).

B lymphocytes, which as APCs present viral fragments on their surfaces, are recognized by **helper T cells** (blue) or their T cell receptors (**9**). Stimulated by interleukins, selective clonal replication then takes place of B cells that carry antigen receptors matching those of the pathogen (**10**). These mature into **plasma cells** (**11**) and finally secrete large amounts of soluble **antibodies** (**12**).

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A. Simplified scheme of the immune response

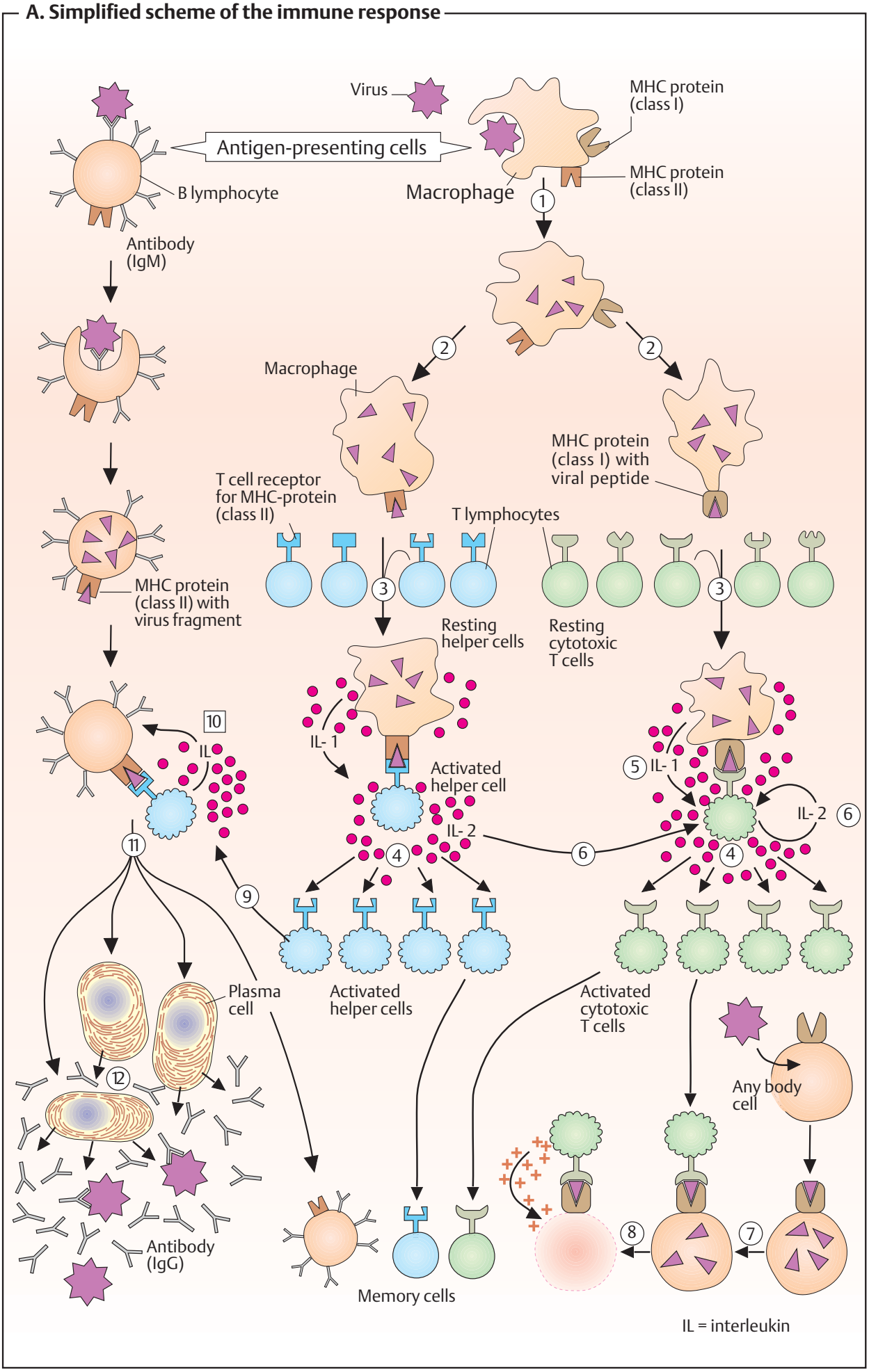

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T-cell activation

For the selectivity of the immune response (see p. 294), the cells involved must be able to recognize foreign antigens and proteins on other immune cells safely and reliably. To do this, they have antigen receptors on their cell surfaces and co-receptors that support recognition.

A. Antigen receptors ○

Many antigen receptors belong to the **immunoglobulin superfamily**. The common characteristic of these proteins is that they are made up from "immunoglobulin domains." These are characteristically folded substructures consisting of 70–110 amino acids, which are also found in soluble immunoglobulins (Ig; see p. 300). The illustration shows schematically a few of the important proteins in the Ig superfamily. They consist of constant regions (brown or green) and variable regions (orange). Homologous domains are shown in the same colors in each case. All of the receptors have transmembrane helices at the C terminus, which anchor them to the membranes. Intramolecular and intermolecular disulfide bonds are also usually found in proteins belonging to the Ig family.

Immunoglobulin M (IgM), a membrane protein on the surface of B lymphocytes, serves to bind free antigens to the B cells. By contrast, **T cell receptors** only bind antigens when they are presented by another cell as a complex with an MHC protein (see below). Interaction between MHC-bound antigens and T cell receptors is supported by **co-receptors**. This group includes **CD8**, a membrane protein that is typical in cytotoxic T cells. T helper cells use **CD4** as a co-receptor instead (not shown). The abbreviation "CD" stands for "cluster of differentiation." It is the term for a large group of proteins that are all located on the cell surface and can therefore be identified by antibodies. In addition to CD4 and CD8, there are many other co-receptors on immune cells (not shown).

The **MHC proteins** are named after the *"major histocompatibility complex"*—the DNA segment that codes for them. Human MHC proteins are also known as HLA antigens ("human leukocyte-associated" antigens). Their polymorphism is so large that it is unlikely that any two individuals carry the same set of MHC proteins—except for monozygotic twins.

Class I MHC proteins occur in almost all nucleated cells. They mainly interact with cytotoxic T cells and are the reason for the rejection of transplanted organs. Class I MHC proteins are heterodimers ($\alpha\beta$). The β subunit is also known as β_2-microglobulin.

Class II MHC proteins also consist of two peptide chains, which are related to each other. MHC II molecules are found on all antigen-presenting cells in the immune system. They serve for interaction between these cells and CD4-carrying T helper cells.

B. T-cell activation ◑

The illustration shows an interaction between a virus-infected body cell (bottom) and a CD8-carrying cytotoxic T lymphocyte (top). The infected cell breaks down viral proteins in its cytoplasm (**1**) and transports the peptide fragments into the endoplasmic reticulum with the help of a special transporter (*TAP*) (**2**). Newly synthesized class I MHC proteins on the endoplasmic reticulum are loaded with one of the peptides (**3**) and then transferred to the cell surface by vesicular transport (**4**). The viral peptides are bound on the surface of the α_2 domain of the MHC protein in a depression formed by an insertion as a "floor" and two helices as "walls" (see smaller illustration).

Supported by CD8 and other co-receptors, a T cell with a matching T cell receptor binds to the MHC peptide complex (**5**; cf. p. 224). This binding activates protein kinases in the interior of the T cell, which trigger a chain of additional reactions (*signal transduction;* see p. 388). Finally, destruction of the virus-infected cell by the cytotoxic T lymphocytes takes place.

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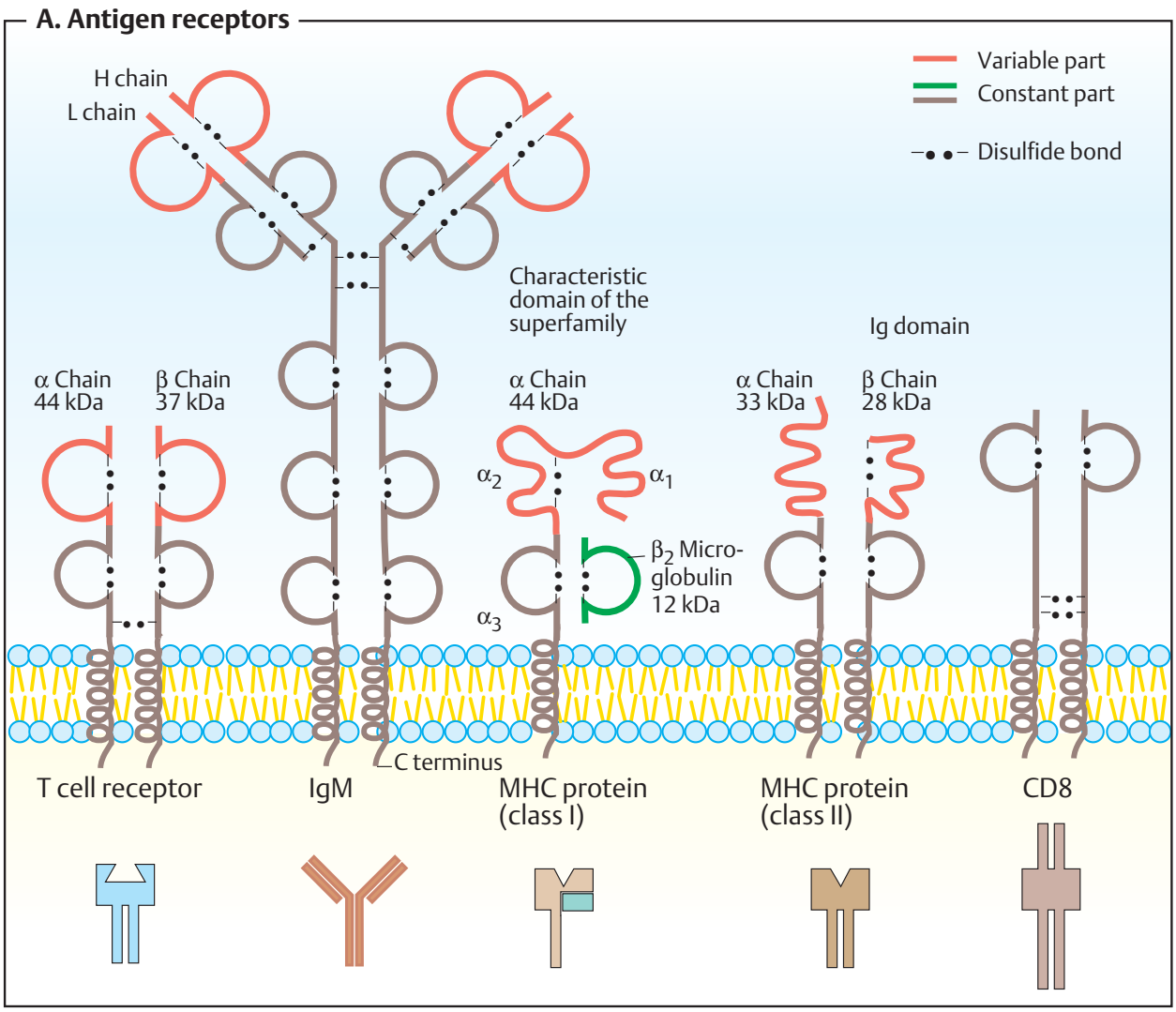

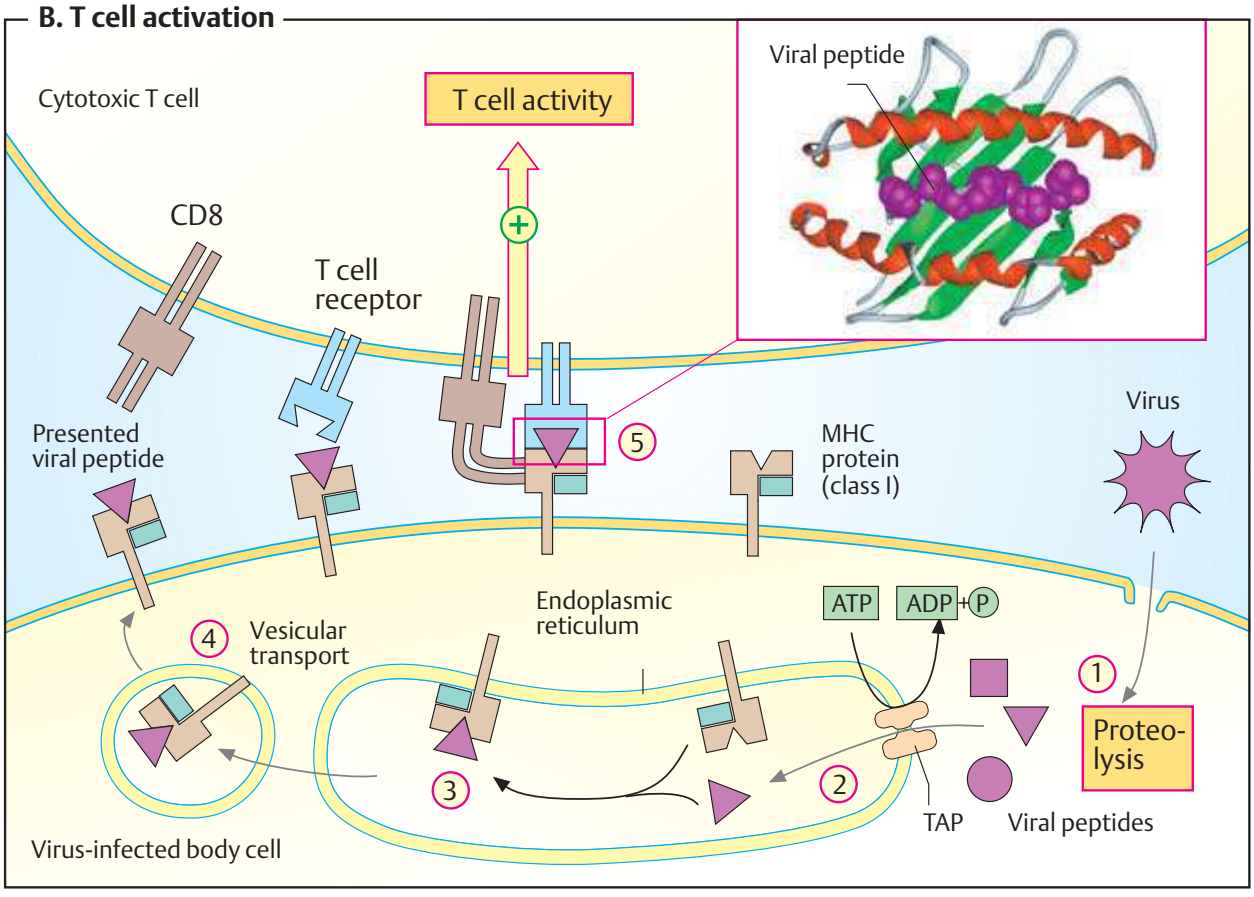

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Complement system

The complement system is part of the innate immune system (see p. 294). It supports *nonspecific defense* against microorganisms. The system consists of some 30 different proteins, the *"complement factors,"* which are found in the blood and represent about 4% of all plasma proteins there. When inflammatory reactions occur, the complement factors enter the infected tissue and take effect there.

The complement system works in three different ways:

Chemotaxis. Various complement factors attract immune cells that can attack and phagocytose pathogens.

Opsonization. Certain complement factors ("opsonins") bind to the pathogens and thereby mark them as targets for phagocytosing cells (e. g., macrophages).

Membrane attack. Other complement factors are deposited in the bacterial membrane, where they create pores that lyse the pathogen (see below).

A. Complement activation ◑

The reactions that take place in the complement system can be initiated in several ways. During the early phase of infection, lipopolysaccharides and other structures on the surface of the pathogens trigger the *alternative pathway* (right). If antibodies against the pathogens become available later, the antigen–antibody complexes formed activate the *classic pathway* (left). Acute-phase proteins (see p. 276) are also able to start the complement cascade (*lectin pathway,* not shown).

Factors C1 to **C4** (for "complement") belong to the classic pathway, while **factors B** and **D** form the reactive components of the alternative pathway. Factors **C5** to **C9** are responsible for membrane attack. Other components not shown here regulate the system.

As in blood coagulation (see p. 290), the *early components* in the complement system are *serine proteinases,* which mutually activate each other through limited proteolysis. They create a self-reinforcing **enzyme cascade**. Factor **C3**, the products of which are involved in several functions, is central to the complement system.

The **classic pathway** is triggered by the formation of factor C1 at IgG or IgM on the surface of microorganisms (left). C1 is an 18-part molecular complex with three different components (C1q, C1r, and C1s). C1q is shaped like a bunch of tulips, the "flowers" of which bind to the F_c region of antibodies (left). This activates C1r, a *serine proteinase* that initiates the cascade of the classic pathway. First, C4 is proteolytically activated into C4b, which in turn cleaves C2 into C2a and C2b. C4B and C2a together form *C3 convertase* [1], which finally catalyzes the cleavage of C3 into C3a and C3b. Small amounts of C3b also arise from non-enzymatic hydrolysis of C3.

The **alternative pathway** starts with the binding of factors C3b and B to bacterial lipopolysaccharides (endotoxins). The formation of this complex allows cleavage of B by factor D, giving rise to a second form of *C3 convertase (C3bBb).*

Proteolytic cleavage of factor **C3** provides two components with different effects. The reaction exposes a highly *reactive thioester group* in C3b, which reacts with hydroxyl or amino groups. This allows C3b to bind covalently to molecules on the bacterial surface (*opsonization,* right). In addition, C3b initiates a chain of reactions leading to the formation of the *membrane attack complex* (see below). Together with C4a and C5a (see below), the smaller product C3a promotes the inflammatory reaction and has chemotactic effects.

The "late" factors C5 to C9 are responsible for the development of the **membrane attack complex** (bottom). They create an ion-permeable pore in the bacterial membrane, which leads to lysis of the pathogen. This reaction is triggered by *C5 convertase* [2]. Depending on the type of complement activation, this enzyme has the structure *C4b2a3b* or *C3bBb3b,* and it cleaves C5 into C5a and C5b. The complex of C5b and C6 allows deposition of C7 in the bacterial membrane. C8 and numerous C9 molecules—which form the actual pore—then bind to this core.

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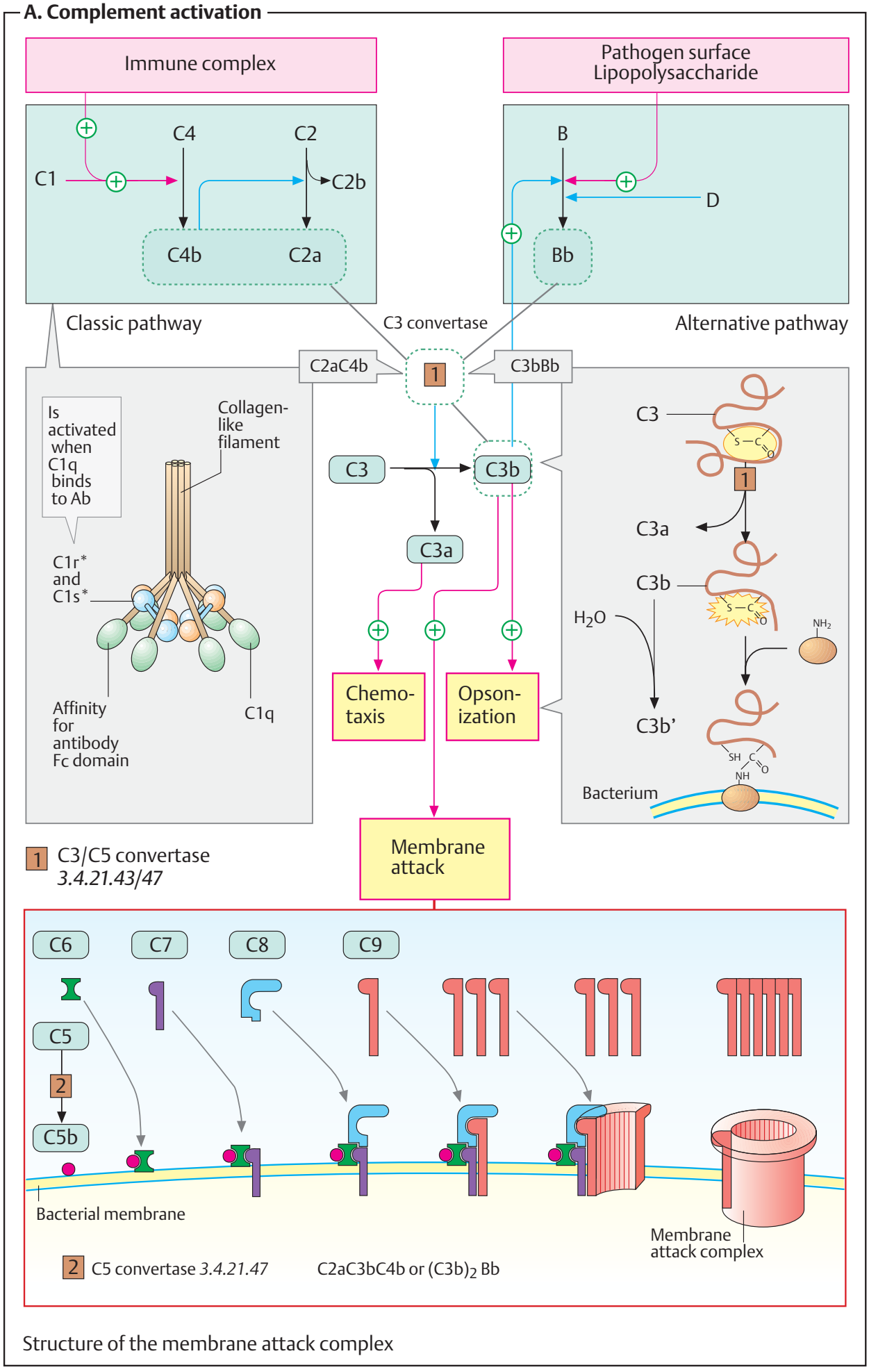

Structure of the membrane attack complex

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Antibodies

Soluble antigen receptors, which are formed by activated B cells (plasma cells; see p. 294) and released into the blood, are known as **antibodies**. They are also members of the immunoglobulin family (Ig; see p. 296). Antibodies are an important part of the humoral immune defense system. They have no antimicrobial properties themselves, but support the cellular immune system in various ways:

1. They bind to antigens on the surface of pathogens and thereby prevent them from interacting with body cells (*neutralization;* see p. 404, for example).

2. They link single-celled pathogens into aggregates (immune complexes), which are more easily taken up by phagocytes (*agglutination*).

3. They activate the complement system (see p. 298) and thereby promote the innate immune defense system (*opsonization*).

In addition, antibodies have become indispensable aids in medical and biological diagnosis (see p. 304).

A. Domain structure of immunoglobulin G ◑

Type G immunoglobulins (**IgG**) are quantitatively the most important antibodies in the blood, where they form the fraction of γ-globulins (see p. 276). IgGs (mass 150 kDa) are tetramers with two **heavy chains** (H chains; red or orange) and two **light chains** (L chains; yellow). Both H chains are glycosylated (violet; see also p. 43).

The proteinase *papain* cleaves IgG into two F_{ab} fragments and one F_c fragment. The **F_{ab}** ("antigen-binding") fragments, which each consist of one L chain and the N-terminal part of an H chain, are able to bind antigens. The **F_c** ("crystallizable") fragment is made up of the C-terminal halves of the two H chains. This segment serves to bind IgG to cell surfaces, for interaction with the complement system and antibody transport.

Immunoglobulins are constructed in a modular fashion from several **immunoglobulin domains** (shown in the diagram on the right in Ω form). The H chains of IgG contain four of these domains (**V_H**, **C_H1**, **C_H2**, and **C_H3**) and the L chains contain two (**C_L** and **V_L**). The letters C and V designate constant or variable regions.

Disulfide bonds link the two heavy chains to each other and also link the heavy chains to the light chains. Inside the domains, there are also disulfide bonds that stabilize the tertiary structure. The domains are approximately 110 amino acids (AA) long and are homologous with each other. The antibody structure evidently developed as a result of gene duplication. In its central region, known as the "hinge" region, the antibodies are highly mobile.

B. Classes of immunoglobulins ◑

Human immunoglobulins are divided into five classes. **IgA** (with two subgroups), **IgD, IgE, IgG** (with four subgroups), and **IgM** are defined by their H chains, which are designated by the Greek letters α, δ, ε, γ, and μ. By contrast, there are only two types of **L chain** (κ and λ). IgD and IgE (like IgG) are tetramers with the structure H_2L_2. By contrast, soluble IgA and IgM are multimers that are held together by disulfide bonds and additional **J peptides** (joining peptides).

The antibodies have different tasks. **IgMs** are the first immunoglobulins formed after contact with a foreign antigen. Their early forms are located on the surface of B cells (see p. 296), while the later forms are secreted from plasma cells as pentamers. Their action targets microorganisms in particular. Quantitatively, **IgGs** are the most important immunoglobulins (see the table showing serum concentrations). They occur in the blood and interstitial fluid. As they can pass the placenta with the help of receptors, they can be transferred from mother to fetus. **IgAs** mainly occur in the intestinal tract and in body secretions. **IgEs** are found in low concentrations in the blood. As they can trigger degranulation of mast cells (see p. 380), they play an important role in allergic reactions. The function of **IgDs** is still unexplained. Their plasma concentration is also very low.

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A. Domain structure of immunoglobulin G

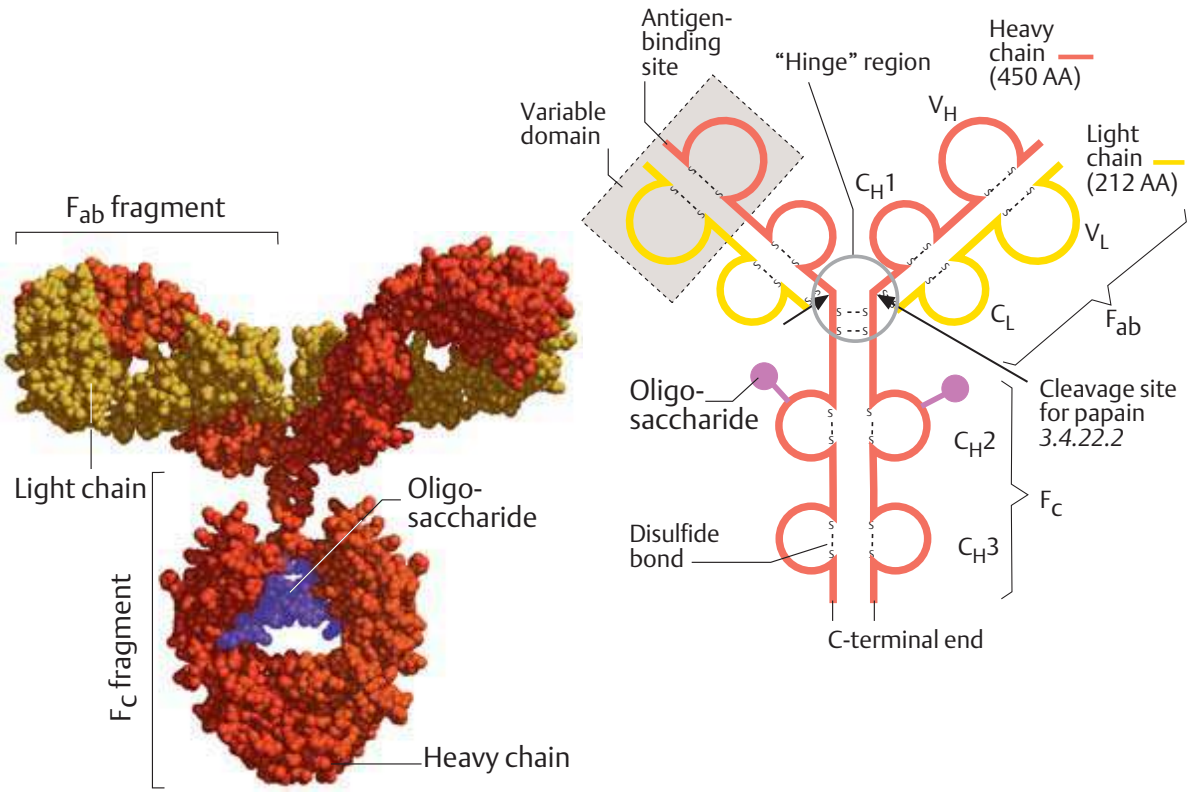

B. Classes of immunoglobulins

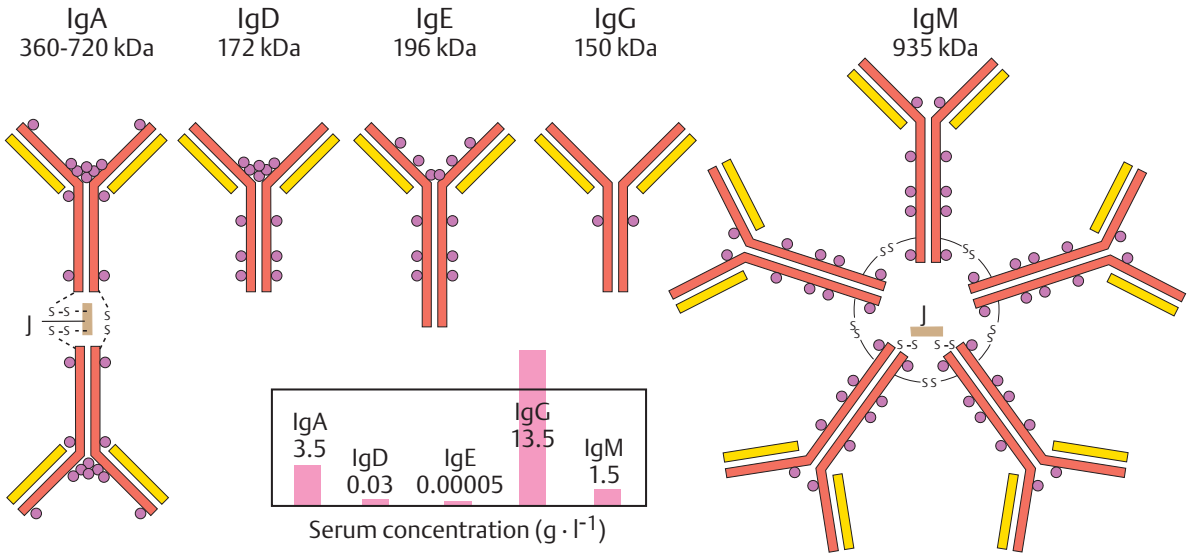

Chain:					
H	α	δ	ε	γ	μ
L	κ or λ	κ or λ	κ or λ	κ or λ	κ or λ
Structure:					
	$(\alpha_2 \kappa_2)_n J$	$\delta_2 \kappa_2$	$\varepsilon_2 \kappa_2$	$\gamma_2 \kappa_2$	$(\mu_2 \kappa_2)_5 J$
	$(\alpha_2 \lambda_2)_n J$	$\delta_2 \lambda_2$	$\varepsilon_2 \lambda_2$	$\gamma_2 \lambda_2$	$(\mu_2 \lambda_2)_5 J$
	n = 1, 2 or 3				

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Antibody biosynthesis

The acquired (adaptive) immune system (see p. 294) is based on the ability of the lymphocytes to keep an extremely large repertoire of antigen receptors and soluble antibodies ready for use, so that even infections involving new types of pathogen can be combated. The wide range of immunoglobulins (Ig) are produced by genetic recombination and additional mutations during the development and maturation of the individual lymphocytes.

A. Variability of immunoglobulins ◑

It is estimated that more than 10^8 different antibody variants occur in every human being. This **variability** affects both the heavy and the light chains of immunoglobulins.

There are five different types of heavy (H) chain, according to which the antibody classes are defined (α, δ, ε, γ, μ), and two types of light (L) chain (κ and λ; see p. 300). The various Ig types that arise from combinations of these chains are known as **isotypes**. During immunoglobulin biosynthesis, plasma cells can switch from one isotype to another ("gene switch"). **Allotypic variation** is based on the existence of various alleles of the same gene—i. e., genetic differences between individuals. The term **idiotypic variation** refers to the fact that the antigen binding sites in the F_{ab} fragments can be highly variable. Idiotypic variation affects the *variable domains* (shown here in pink) of the light and heavy chains. At certain sites—known as the *hypervariable regions* (shown here in red)—variation is particularly wide; these sequences are directly involved in the binding of the antigen.

B. Causes of antibody variety ◑

There are three reasons for the extremely wide variability of antibodies:

1. **Multiple genes.** Various genes are available to code for the variable protein domains. Only one gene from among these is selected and expressed.

2. **Somatic recombination.** The genes are divided into several segments, of which there are various versions. Various ("untidy") combinations of the segments during lymphocyte maturation give rise to randomly combined new genes ("mosaic genes").

3. **Somatic mutation.** During differentiation of B cells into plasma cells, the coding genes mutate. In this way, the "primordial" *germline genes* can become different *somatic genes* in the individual B cell clones.

C. Biosynthesis of a light chain ○

We can look at the basic features of the genetic organization and synthesis of immunoglobulins using the biosynthesis of a mouse κ chain as an example. The gene segments for this light chain are designated L, V, J, and C. They are located on chromosome 6 in the **germ-line DNA** (on chromosome 2 in humans) and are separated from one another by introns (see p. 242) of different lengths.

Some 150 identical **L segments** code for the signal peptide ("leader sequence," 17–20 amino acids) for secretion of the product (see p. 230). The **V segments**, of which there are 150 different variants, code for most of the variable domains (95 of the 108 amino acids). L and V segments always occur in pairs—in tandem, so to speak. By contrast, there are only five variants of the **J segments** (joining segments) at most. These code for a peptide with 13 amino acids that links the variable part of the κ chains to the constant part. A single **C segment** codes for the constant part of the light chain (84 amino acids).

During the differentiation of B lymphocytes, individual *V/J combinations* arise in each B cell. One of the 150 L/V tandem segments is selected and linked to one of the five J segments. This gives rise to a *somatic gene* that is much smaller than the germline gene. Transcription of this gene leads to the formation of the **hnRNA** for the κ chain, from which introns and surplus J segments are removed by splicing (see p. 246). Finally, the completed **mRNA** still contains one each of the L–V–J–C segments and after being transported into the cytoplasm is available for translation. The subsequent steps in Ig biosynthesis follow the rules for the synthesis of membrane-bound or secretory proteins (see p. 230).

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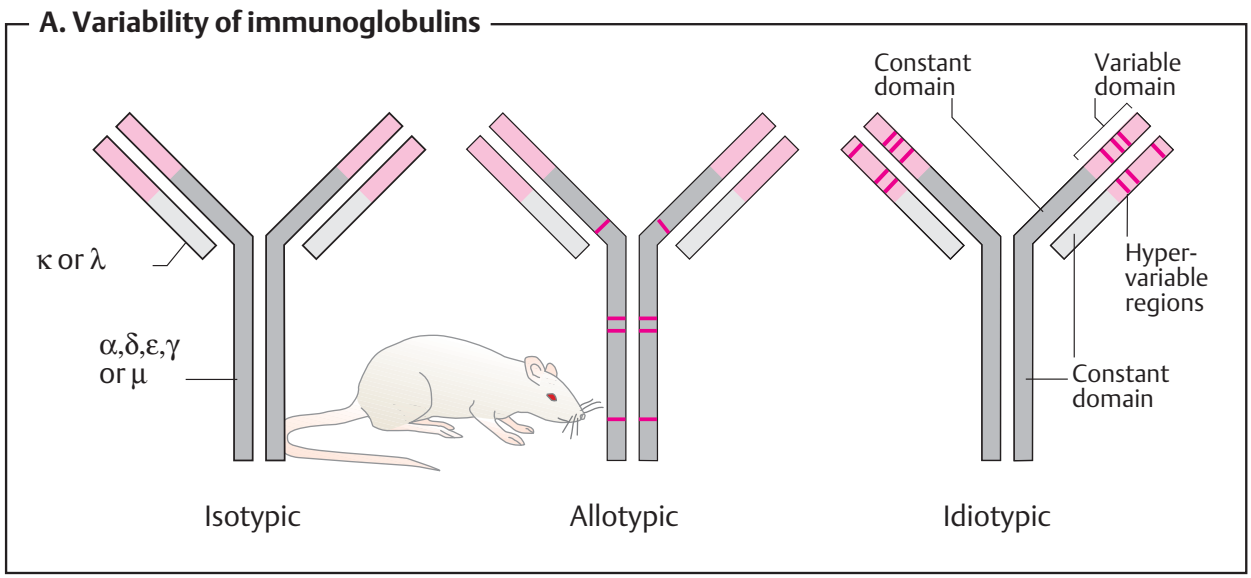

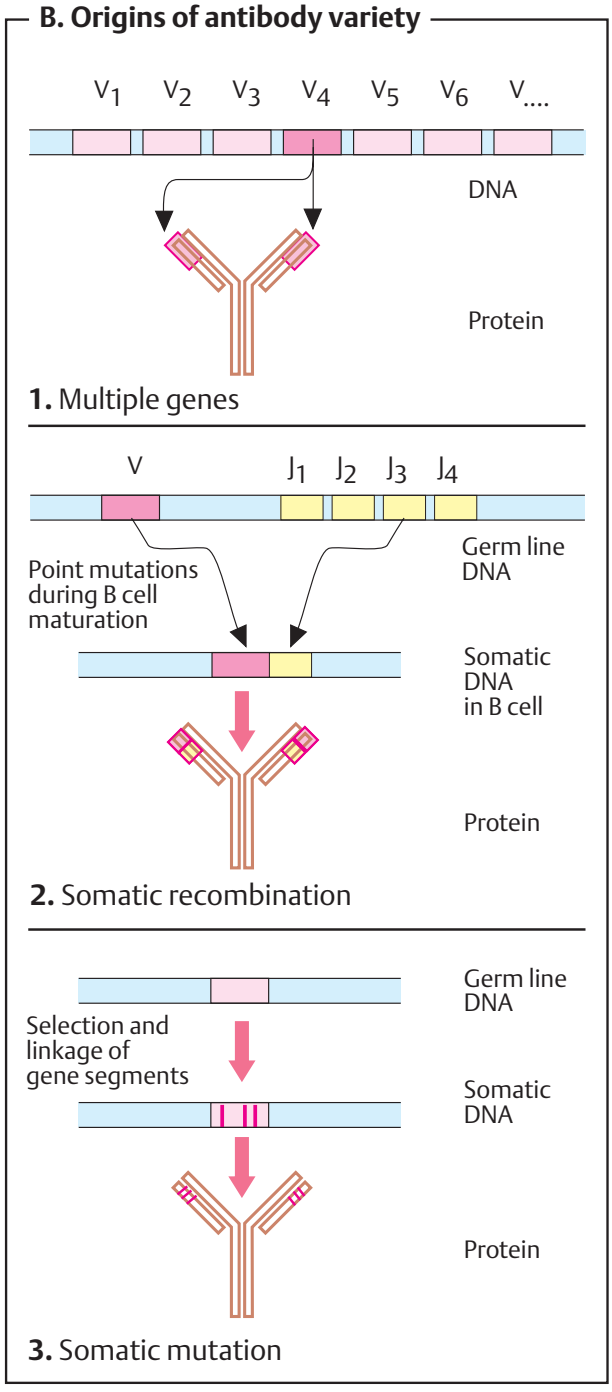

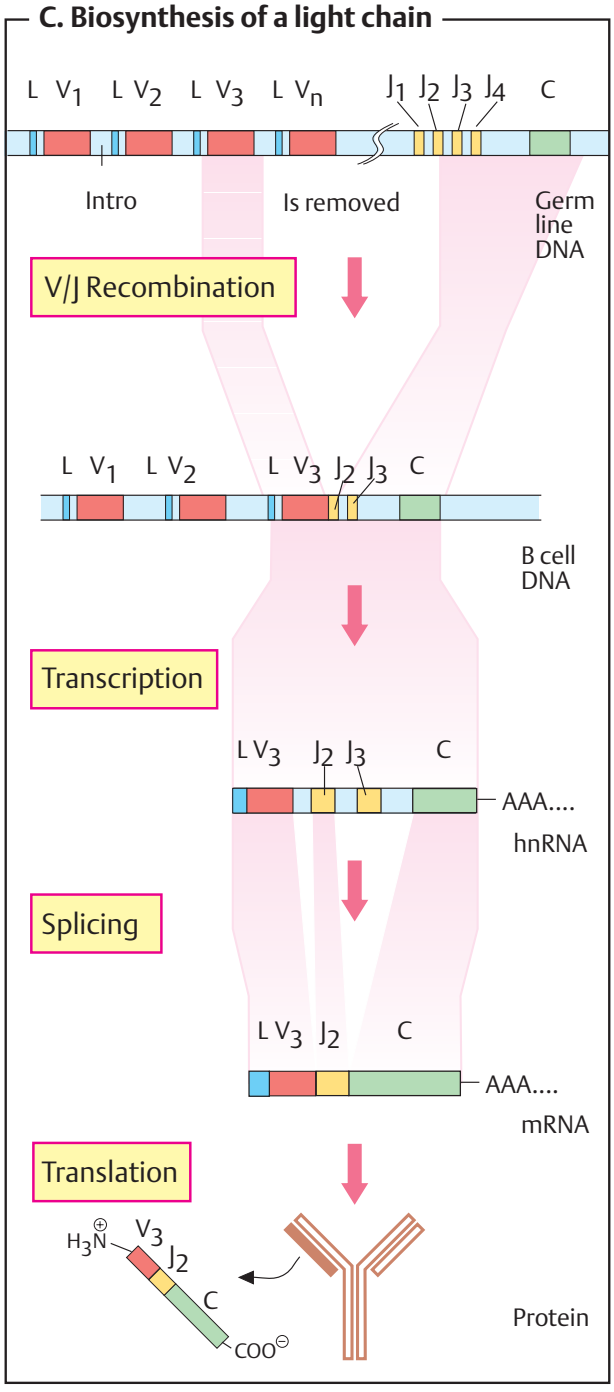

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Monoclonal antibodies, immunoassay

A. Monoclonal antibodies ○

Monoclonal antibodies (MABs) are secreted by immune cells that derive from a single antibody-forming cell (from a single cell *clone*). This is why each MAB is directed against only one specific *epitope* of an immunogenic substance, known as an *"antigenic determinant."* Large molecules contain several epitopes, against which various antibodies are formed by various B cells. An antiserum containing a mixture of all of these antibodies is described as being *polyclonal.*

To obtain MABs, **lymphocytes** isolated from the spleen of immunized mice (**1**) are fused with mouse tumor cells (**myeloma cells**, **2**). This is necessary because antibody-secreting lymphocytes in culture have a lifespan of only a few weeks. Fusion of lymphocytes with tumor cells gives rise to cell hybrids, known as **hybridomas,** which are potentially immortal.

Successful *fusion* (**2**) is a rare event, but the frequency can be improved by adding polyethylene glycol (PEG). To obtain only successfully fused cells, incubation is required for an extended period in a **primary culture** with *HAT medium* (**3**), which contains hypoxanthine, aminopterin, and thymidine. *Aminopterin*, an analogue of dihydrofolic acid, competitively inhibits *dihydrofolate reductase* and thus inhibits the synthesis of dTMP (see p. 402). As dTMP is essential for DNA synthesis, myeloma cells cannot survive in the presence of aminopterin. Although spleen cells are able to circumvent the inhibitory effect of aminopterin by using *hypoxanthine* and *thymidine,* they have a limited lifespan and die. Only hybridomas survive culture in HAT medium, because they possess both the immortality of the myeloma cells and the spleen cells' metabolic side pathway.

Only a few fused cells actually produce antibodies. To identify these cells, the hybridomas have to be isolated and replicated by **cloning** (**4**). After the clones have been tested for antibody formation, positive cultures are picked out and selected by further cloning (**5**). This results in hybridomas that synthesize *monoclonal antibodies.* Finally, MAB production is carried out in vitro using a bioreactor, or in vivo by producing ascites fluid in mice (**6**).

B. Immunoassay ○

Immunoassays are semiquantitative procedures for assessing substances with low concentrations. In principle, immunoassays can be used to assess any compound against which antibodies are formed.

The basis for this procedure is the *antigen–antibody "reaction"*—i. e., specific binding of an antibody to the molecule being assayed. Among the many different immunoassay techniques that have been developed—e. g., *radioimmunoassay* (RIA), and *chemoluminescence immunoassay* (CIA)—a version of the **enzyme-linked immunoassay** (EIA) is shown here.

The substance to be assayed—e. g., the hormone thyroxine in a serum sample—is pipetted into a microtiter plate (**1**), the walls of which are coated with *antibodies* that specifically bind the hormone. At the same time, a small amount of thyroxine is added to the incubation to which an enzyme known as the *"tracer"* (**1**) has been chemically coupled. The tracer and the hormone being assayed compete for the small number of antibody binding sites available. After binding has taken place (**2**), all of the unbound molecules are rinsed out. The addition of a substrate solution for the enzyme (a *chromogenic solution*) then triggers an indicator reaction (**3**), the products of which can be assessed using photometry (**4**).

The larger the amount of enzyme that can bind to the antibodies on the container's walls, the larger the amount of dye that is produced. Conversely, the larger the amount of the substance being assayed that is present in the sample, the *smaller* the amount of tracer that can be bound by the antibodies. Quantitative analysis can be carried out through parallel measurement using standards with a known concentration.

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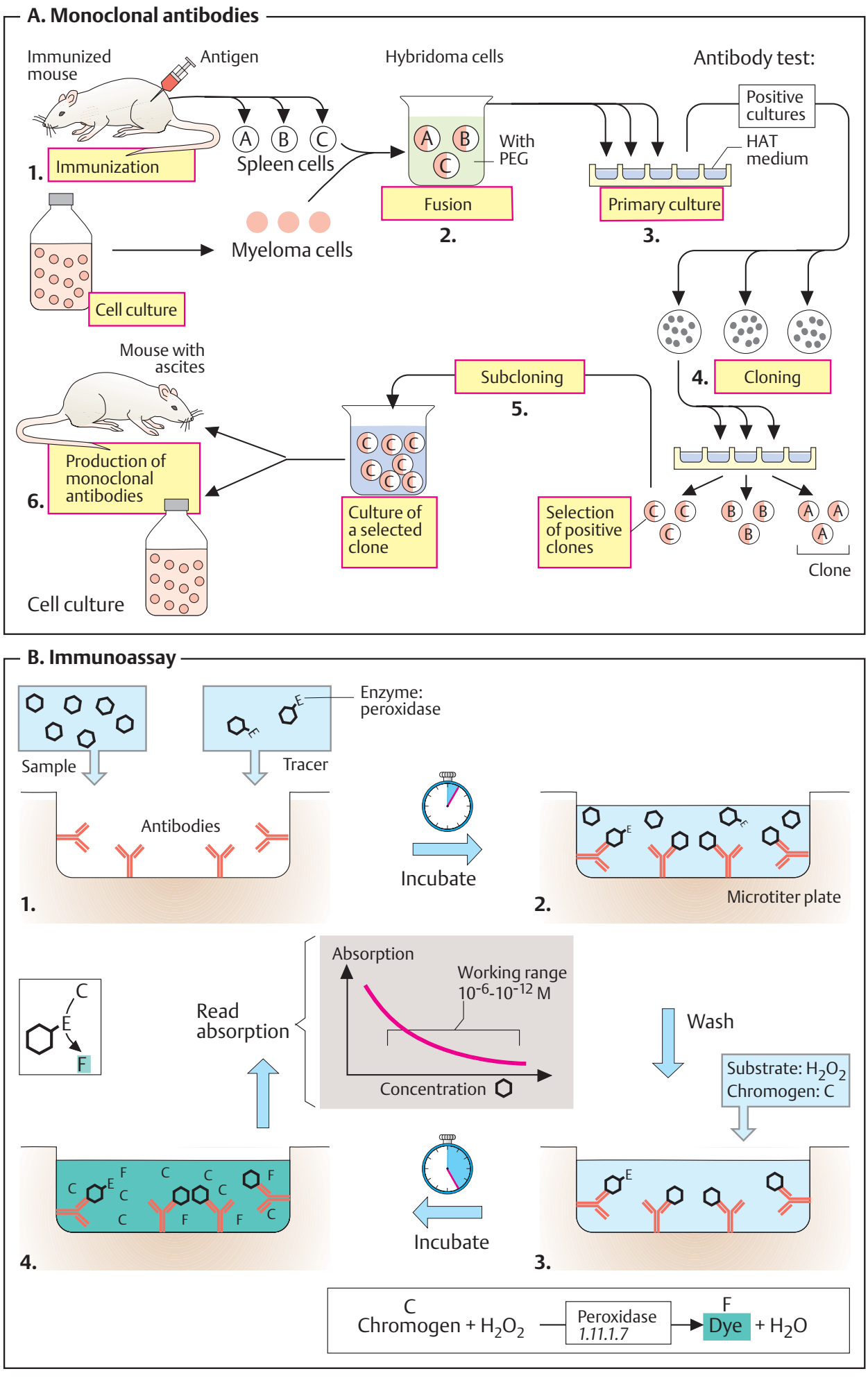

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Liver: functions

Weighing 1.5 kg, the liver is one of the largest organs in the human body. Although it only represents 2–3% of the body's mass, it accounts for 25–30% of oxygen consumption.

A. Diagram of a hepatocyte ◑

The 3 10^{11} cells in the liver—particularly the **hepatocytes**, which make up 90% of the cell mass—are the central location for the body's *intermediary metabolism.* They are in close contact with the blood, which enters the liver from the portal vein and the hepatic arteries, flows through capillary vessels known as sinusoids, and is collected again in the central veins of the hepatic lobes. Hepatocytes are particularly rich in endoplasmic reticulum, as they carry out intensive protein and lipid synthesis. The cytoplasm contains granules of insoluble glycogen. Between the hepatocytes, there are bile capillaries through which bile components are excreted.

B. Functions of the liver ●

The most important functions of the liver are:

1. **Uptake** of nutrients supplied by the intestines via the portal vein.
2. Biosynthesis of endogenous compounds and storage, conversion, and degradation of them into excretable molecules (**metabolism**). In particular, the liver is responsible for the biosynthesis and degradation of almost all plasma proteins.
3. **Supply** of the body with metabolites and nutrients.
4. **Detoxification** of toxic compounds by biotransformation.
5. **Excretion** of substances with the bile.

C. Hepatic metabolism ●

The liver is involved in the metabolism of practically all groups of metabolites. Its functions primarily serve to cushion fluctuations in the concentration of these substances in the blood, in order to ensure a constant supply to the peripheral tissues (*homeostasis*).

Carbohydrate metabolism. The liver takes up glucose and other monosaccharides from the plasma. Glucose is then either stored in the form of the polysaccharide *glycogen* or converted into fatty acids. When there is a drop in the blood glucose level, the liver releases glucose again by breaking down glycogen. If the glycogen store is exhausted, glucose can also be synthesized by *gluconeogenesis* from lactate, glycerol, or the carbon skeleton of amino acids (see p. 310).

Lipid metabolism. The liver synthesizes fatty acids from acetate units. The fatty acids formed are then used to synthesize fats and phospholipids, which are released into the blood in the form of *lipoproteins.* The liver's special ability to convert fatty acids into *ketone bodies* and to release these again is also important (see p. 312).

Like other organs, the liver also synthesizes cholesterol, which is transported to other tissues as a component of lipoproteins. Excess cholesterol is converted into bile acids in the liver or directly excreted with the bile (see p. 314).

Amino acid and protein metabolism. The liver controls the plasma levels of the amino acids. Excess amino acids are broken down. With the help of the urea cycle (see p. 182), the nitrogen from the amino acids is converted into urea and excreted via the kidneys. The carbon skeleton of the amino acids enters the intermediary metabolism and serves for glucose synthesis or energy production. In addition, most of the plasma proteins are synthesized or broken down in the liver (see p. 276).

Biotransformation. Steroid hormones and bilirubin, as well as drugs, ethanol, and other xenobiotics are taken up by the liver and inactivated and converted into highly polar metabolites by conversion reactions (see p. 316).

Storage. The liver not only stores energy reserves and nutrients for the body, but also certain mineral substances, trace elements, and vitamins, including iron, retinol, and vitamins A, D, K, folic acid, and B_{12}.

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A. Diagram of a hepatocyte

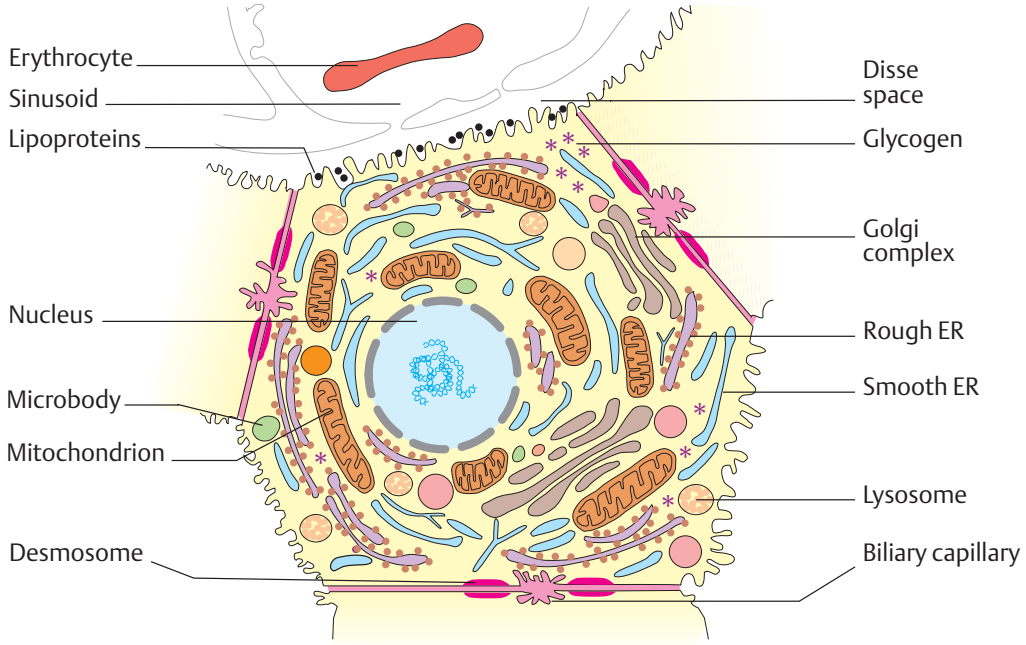

B. Functions of the liver

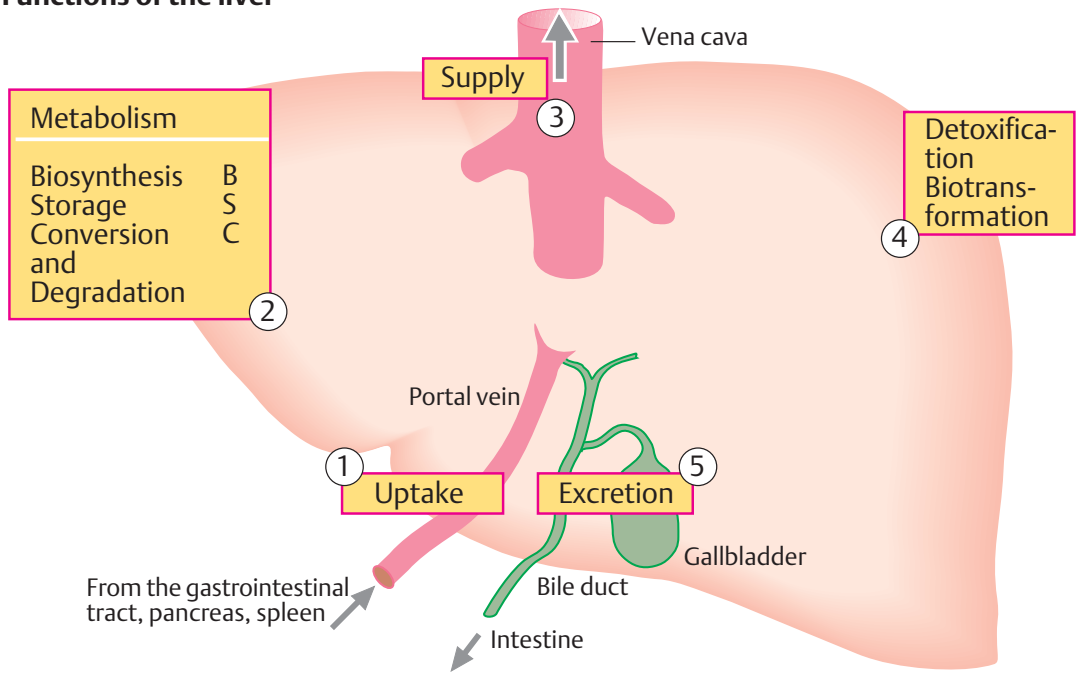

C. Liver metabolism

Carbohydrate metabolism	
Glucose	BSC
Galactose	C
Fructose	C
Mannose	C
Pentoses	BC
Lactate	C
Glycerol	BC
Glycogen	BSC

Lipid metabolism	
Fatty acids	BC
Fats	BC
Ketone bodies	B
Cholesterol	BEC
Bile acids	BE
Vitamins	SC

Amino acid metabolism	
Amino acids	C
Urea	B

Plasma proteins	
Lipoproteins	BC
Albumin	BC
Coagulation factors	BC
Hormones	C
Enzymes	BC

Biotransformation	
Steroid hormones	EC
Bile pigments	EC
Ethanol	C
Drugs	EC

B	Biosynthesis
C	Conversion and degradation
E	Excretion
S	Storage

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Buffer function in organ metabolism

All of the body's tissues have a constant requirement for energy substrates and nutrients. The body receives these metabolites with food, but the supply is irregular and in varying amounts. The liver acts here along with other organs, particularly adipose tissue, as a balancing *buffer* and *storage organ.*

In the metabolism, a distinction is made between the *absorptive state (well-fed state)* immediately after a meal and the *postabsorbtive state (state of starvation)*, which starts later and can merge into hunger. The switching of the organ metabolism between the two phases depends on the concentration of energy-bearing metabolites in the blood (plasma level). This is regulated jointly by hormones and by the autonomic nervous system.

A. Absorptive state ◑

The absorptive state continues for 2–4 hours after food intake. As a result of food digestion, the plasma levels of glucose, amino acids, and fats (triacylglycerols) temporarily increase.

The endocrine **pancreas** responds to this by altering its hormone release—there is an increase in *insulin* secretion and a reduction in *glucagon* secretion. The increase in the insulin/glucagon quotient and the availability of substrates trigger an *anabolic phase* in the tissues—particularly liver, muscle, and adipose tissues.

The **liver** forms increased amounts of glycogen and fats from the substrates supplied. Glycogen is stored, and the fat is released into the blood in very low density lipoproteins (VLDLs).

Muscle also refills its glycogen store and synthesizes proteins from the amino acids supplied.

Adipose tissue removes free fatty acids from the lipoproteins, synthesizes triacylglycerols from them again, and stores these in the form of insoluble droplets.

During the absorptive state, the **heart** and **neural tissue** mainly use glucose as an energy source, but they are unable to establish any substantial energy stores. Heart muscle cells are in a sense "omnivorous," as they can also use other substances to produce energy (fatty acids, ketone bodies). By contrast, the central nervous system (CNS) is dependent on glucose. It is only able to utilize ketone bodies after a prolonged phase of hunger (**B**).

B. Postabsorptive state ◑

When the food supply is interrupted, the postabsorbtive state quickly sets in. The pancreatic A cells now release increased amounts of *glucagon,* while the B cells reduce the amount of *insulin* they secrete. The reduced insulin/glucagon quotient leads to switching of the intermediary metabolism. The body now falls back on its energy reserves. To do this, it breaks down *storage substances* (glycogen, fats, and proteins) and shifts energy-supplying metabolites between the organs.

The **liver** first empties its glycogen store (*glycogenolysis;* see p. 156). It does not use the released glucose itself, however, but supplies the other tissues with it. In particular, the brain, adrenal gland medulla, and erythrocytes depend on a constant supply of glucose, as they have no substantial glucose reserves themselves. When the liver's glycogen reserves are exhausted after 12–24 hours, *gluconeogenesis* begins (see p. 154). The precursors for this are derived from the musculature (amino acids) and adipose tissue (glycerol from fat degradation). From the fatty acids that are released (see below), the liver starts to form ketone bodies (*ketogenesis;* see p. 312). These are released into the blood and serve as important energy suppliers during the hunger phase. After 1–2 weeks, the CNS also starts to use ketone bodies to supply part of its energy requirements, in order to save glucose.

In **muscle**, the extensive glycogen reserves are exclusively used for the muscles' own requirements (see p. 320). The slowly initiated protein breakdown in muscle supplies amino acids for gluconeogenesis in the liver.

In **adipose tissue**, glucagon triggers *lipolysis,* releasing fatty acids and glycerol. The fatty acids are used as energy suppliers by many types of tissue (with the exception of brain and erythrocytes). An important recipient of the fatty acids is the liver, which uses them for ketogenesis.

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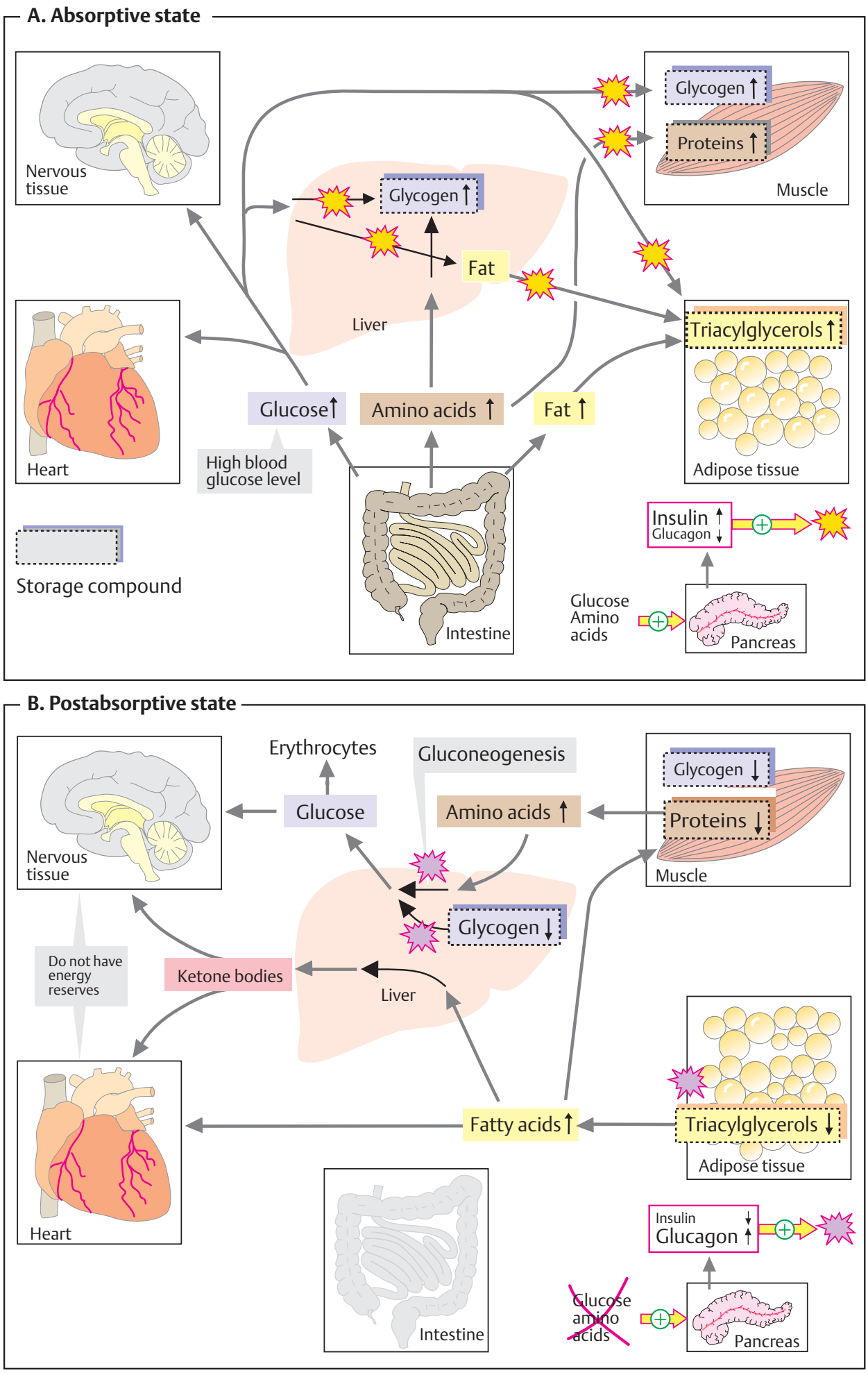

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Carbohydrate metabolism

Besides fatty acids and ketone bodies, glucose is the body's most important energy supplier. The concentration of glucose in the blood (the *"blood glucose level"*) is maintained at 4–6 mM (0.8–1.0 g L^{-1}) by precise regulation of glucosesupplying and glucose-utilizing processes. Glucose suppliers include the intestines (glucose from food), liver, and kidneys. The liver plays the role of a "glucostat" (see p. 308).

The liver is also capable of forming glucose by converting other sugars—e. g., *fructose* and *galactose*—or by synthesizing from other metabolites. The conversion of lactate to glucose in the *Cori cycle* (see p. 338) and the conversion of alanine to glucose with the help of the *alanine cycle* (see p. 338) are particularly important for the supply of erythrocytes and muscle cells.

Transporters in the plasma membrane of hepatocytes allow insulin-independent transport of glucose and other sugars in both directions. In contrast to muscle, the liver possesses the enzyme *glucose-6-phosphatase,* which can release glucose from glucose-6-phosphate.

A. Gluconeogenesis: overview ◑

Regeneration of glucose (up to 250 g per day) mainly takes place in the liver. The tubule cells of the kidney are also capable of carrying out gluconeogenesis, but due to their much smaller mass, their contribution only represents around 10% of total glucose formation. Gluconeogenesis is regulated by hormones. *Cortisol, glucagon,* and *epinephrine* promote gluconeogenesis, while *insulin* inhibits it (see pp. 158, 244).

The main precursors of gluconeogenesis in the liver are *lactate* from anaerobically working muscle cells and from erythrocytes, glucogenic *amino acids* from the digestive tract and muscles (mainly alanine), and *glycerol* from adipose tissue. The kidney mainly uses amino acids for gluconeogenesis (Glu, Gln; see p. 328).

In mammals, fatty acids and other suppliers of acetyl CoA are not capable of being used for gluconeogenesis, as the acetyl residues formed during β-oxidation in the tricarboxylic acid cycle (see p. 132) are oxidized to CO_2 and therefore cannot be converted into oxaloacetic acid, the precursor for gluconeogenesis.

B. Fructose and galactose metabolism ◑

Fructose is mainly metabolized by the liver, which channels it into glycolysis (left half of the illustration).

A special *ketohexokinase* [1] initially phosphorylates fructose into **fructose 1-phosphate**. This is then cleaved by an *aldolase* [2], which is also fructose-specific, to yield **glycerone 3-phosphate** (dihydroxyacetone phosphate) and **glyceraldehyde**. Glycerone 3-phosphate is already an intermediate of glycolysis (center), while glyceraldehyde can be phosphorylated into glyceraldehyde 3-phosphate by *triokinase* [3].

To a smaller extent, glyceraldehyde is also reduced to glycerol [4] or oxidized to glycerate, which can be channeled into glycolysis following phosphorylation (not shown). The reduction of glyceraldehyde [4] uses up NADH. As the rate of degradation of alcohol in the hepatocytes is limited by the supply of NAD^+, fructose degradation accelerates alcohol degradation (see p. 320).

Outside of the liver, fructose is channeled into the sugar metabolism by reduction at C-2 to yield sorbitol and subsequent dehydration at C-1 to yield glucose (the *polyol pathway;* not shown).

Galactose is also broken down in the liver (right side of the illustration). As is usual with sugars, the metabolism of galactose starts with a phosphorylation to yield **galactose 1-phosphate** [5]. The connection to the glucose metabolism is established by C-4 epimerization to form **glucose 1-phosphate**. However, this does not take place directly. Instead, a *transferase* [6] transfers a uridine 5′-monophosphate (UMP) residue from uridine diphosphoglucose (UDPglucose) to galactose 1-phosphate. This releases glucose 1-phosphate, while galactose 1-phosphate is converted into uridine diphosphogalactose (UDPgalactose). This then is isomerized into UDPglucose. The *biosynthesis* of galactose also follows this reaction pathway, which is freely reversible up to reaction [5]. Genetic defects of enzymes [5] or [6] can lead to the clinical picture of *galactosemia.*

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A. Gluconeogenesis: overview

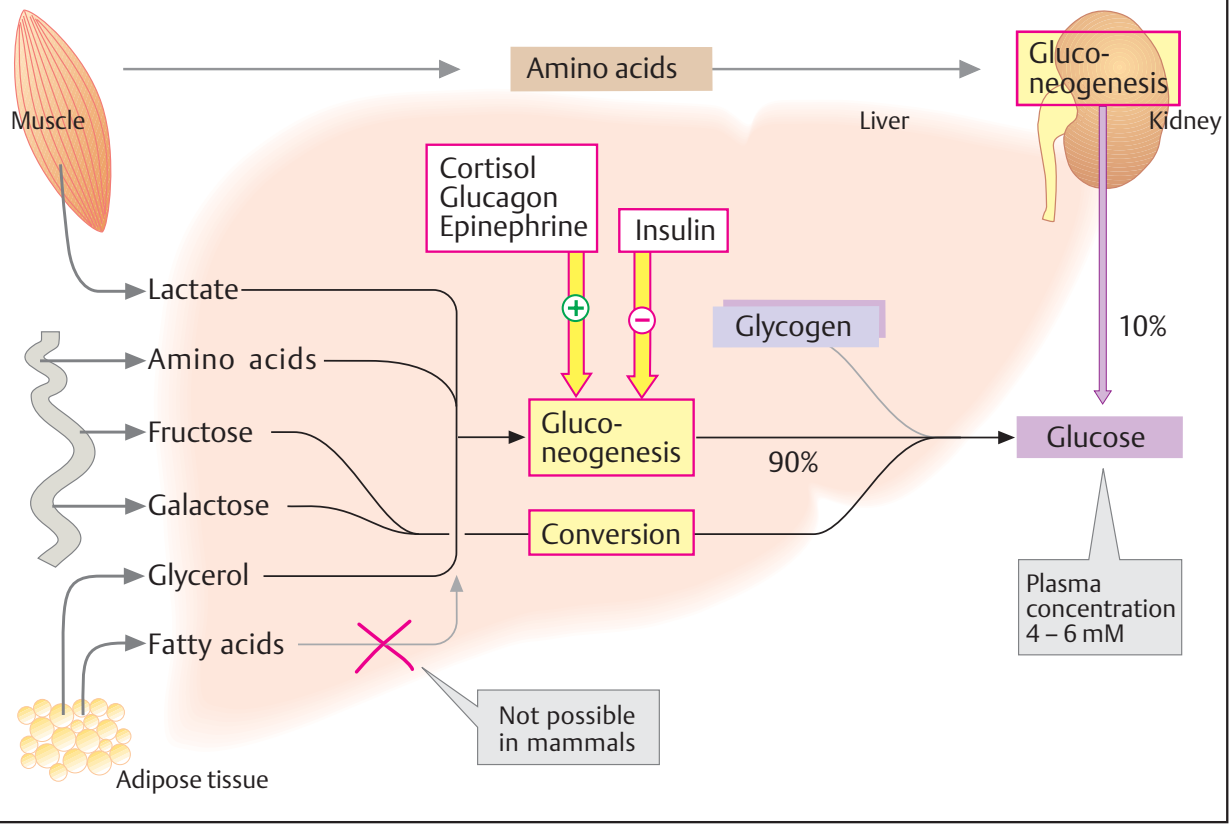

B. Fructose and galactose metabolism

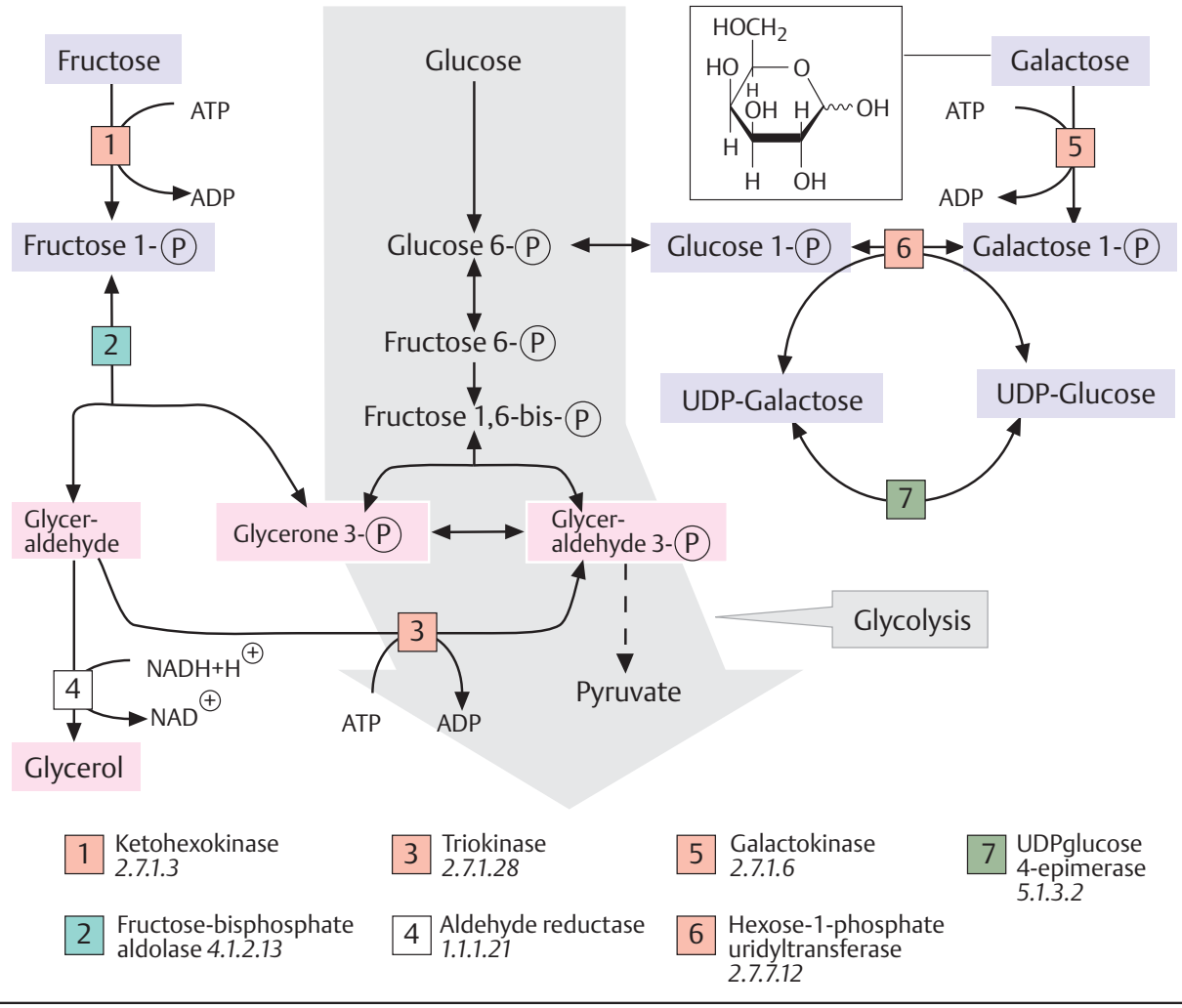

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Lipid metabolism

The liver is the most important site for the formation of *fatty acids, fats (triacylglycerols), ketone bodies,* and *cholesterol.* Most of these products are released into the blood. In contrast, the triacylglycerols synthesized in adipose tissue are also stored there.

A. Lipid metabolism ◑

Lipid metabolism in the liver is closely linked to the carbohydrate and amino acid metabolism. When there is a good supply of nutrients in the *resorptive (wellfed) state* (see p. 308), the liver converts glucose via acetyl CoA into **fatty acids**. The liver can also take up fatty acids from *chylomicrons,* which are supplied by the intestine, or from fatty acid–albumin complexes (see p. 162). Fatty acids from both sources are converted into **fats** and **phospholipids**. Together with apoproteins, they are packed into very-low-density lipoproteins (**VLDLs**; see p. 278) and then released into the blood by exocytosis. The VLDLs supply extrahepatic tissue, particularly adipose tissue and muscle.

In the *postresorptive state* (see p. 292)—particularly during fasting and starvation—the lipid metabolism is readjusted and the organism falls back on its own reserves. In these conditions, adipose tissue releases fatty acids. They are taken up by the liver and are mainly converted into **ketone bodies** (**B**).

Cholesterol can be derived from two sources—food or endogenous synthesis from acetyl-CoA. A substantial percentage of endogenous cholesterol synthesis takes place in the liver. Some cholesterol is required for the synthesis of **bile acids** (see p. 314). In addition, it serves as a building block for cell membranes (see p. 216), or can be esterified with fatty acids and stored in lipid droplets. The rest is released together into the blood in the form of lipoprotein complexes (VLDLs) and supplies other tissues. The liver also contributes to the cholesterol metabolism by taking up from the blood and breaking down lipoproteins that contain cholesterol and cholesterol esters (HDLs, IDLs, LDLs; see p. 278).

B. Biosynthesis of ketone bodies ◑

At high concentrations of acetyl-CoA in the liver mitochondria, two molecules condense to form **acetoacetyl CoA** [1]. The transfer of another acetyl group [2] gives rise to 3-hydroxy-3-methylglutaryl-CoA (**HMG CoA**), which after release of acetyl CoA [3] yields free **acetoacetate** (*Lynen cycle*). Acetoacetate can be converted to **3-hydroxybutyrate** by reduction [4], or can pass into **acetone** by nonenzymatic decarboxylation [5]. These three compounds are together referred to as *"ketone bodies,"* although in fact 3-hydroxybutyrate is not actually a ketone. As reaction [3] releases an H^+ ion, metabolic acidosis can occur as a result of increased ketone body synthesis (see p. 288).

The ketone bodies are released by the liver into the blood, in which they are easily soluble. Blood levels of ketone bodies therefore rise during periods of hunger. Together with free fatty acids, 3-hydroxybutyrate and acetoacetate are then the most important energy suppliers in many tissues (including heart muscle). Acetone cannot be metabolized and is exhaled via the lungs or excreted with urine.

To channel ketone bodies into the energy metabolism, acetoacetate is converted with the help of succinyl CoA into succinic acid and acetoacetyl CoA, which is broken down by β-oxidation into acetyl CoA (not shown; see p. 180).

If the production of ketone bodies exceeds the demand for them outside the liver, there is an increase in the concentration of ketone bodies in the plasma (*ketonemia*) and they are also eventually excreted in the urine (*ketonuria*). Both phenomena are observed after prolonged starvation and in inadequately treated *diabetes mellitus.* Severe ketonuria with ketoacidosis can cause electrolyte shifts and loss of consciousness, and is therefore life-threatening (*ketoacidotic coma*).

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A. Lipid metabolism

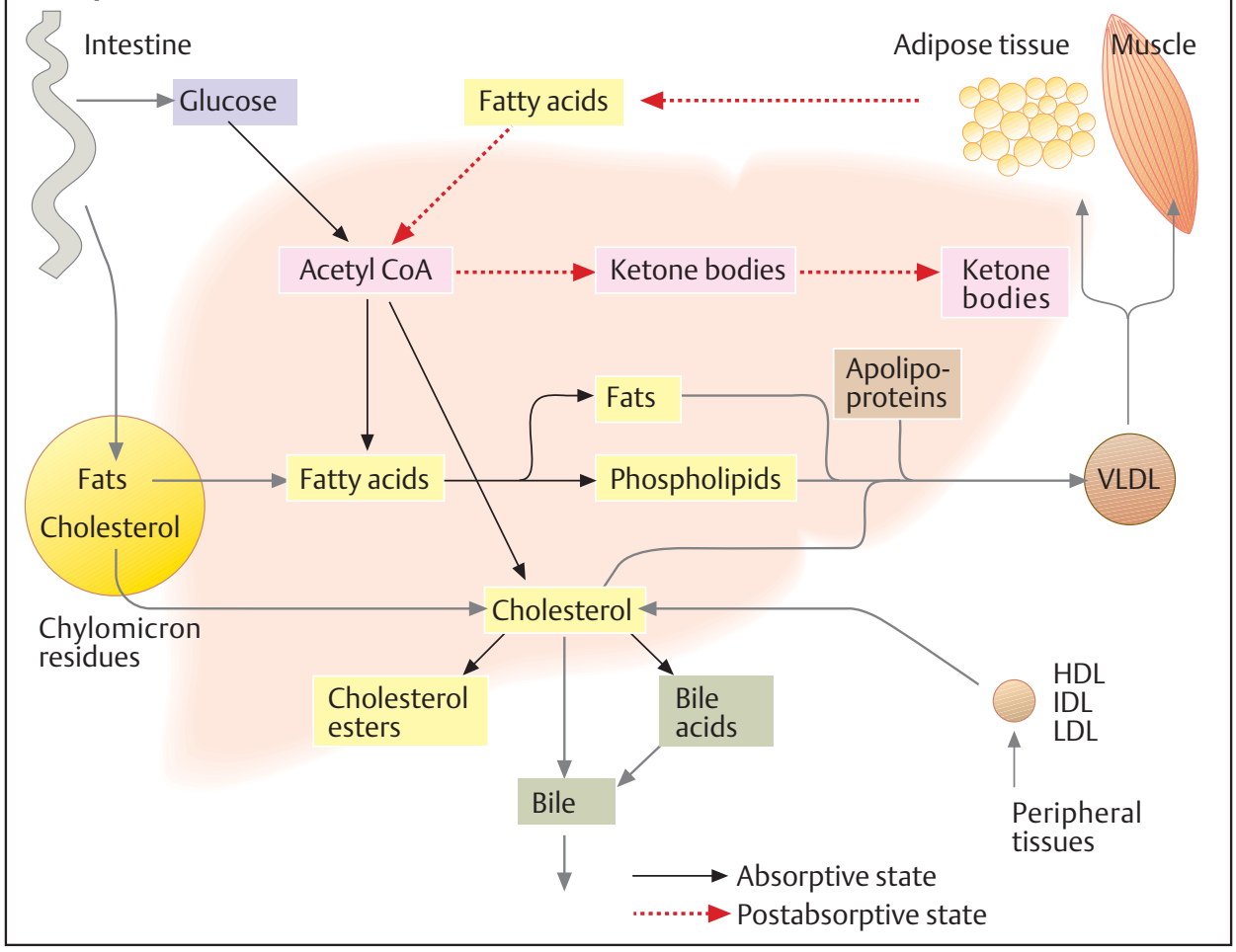

A. Biosynthesis of ketone bodies

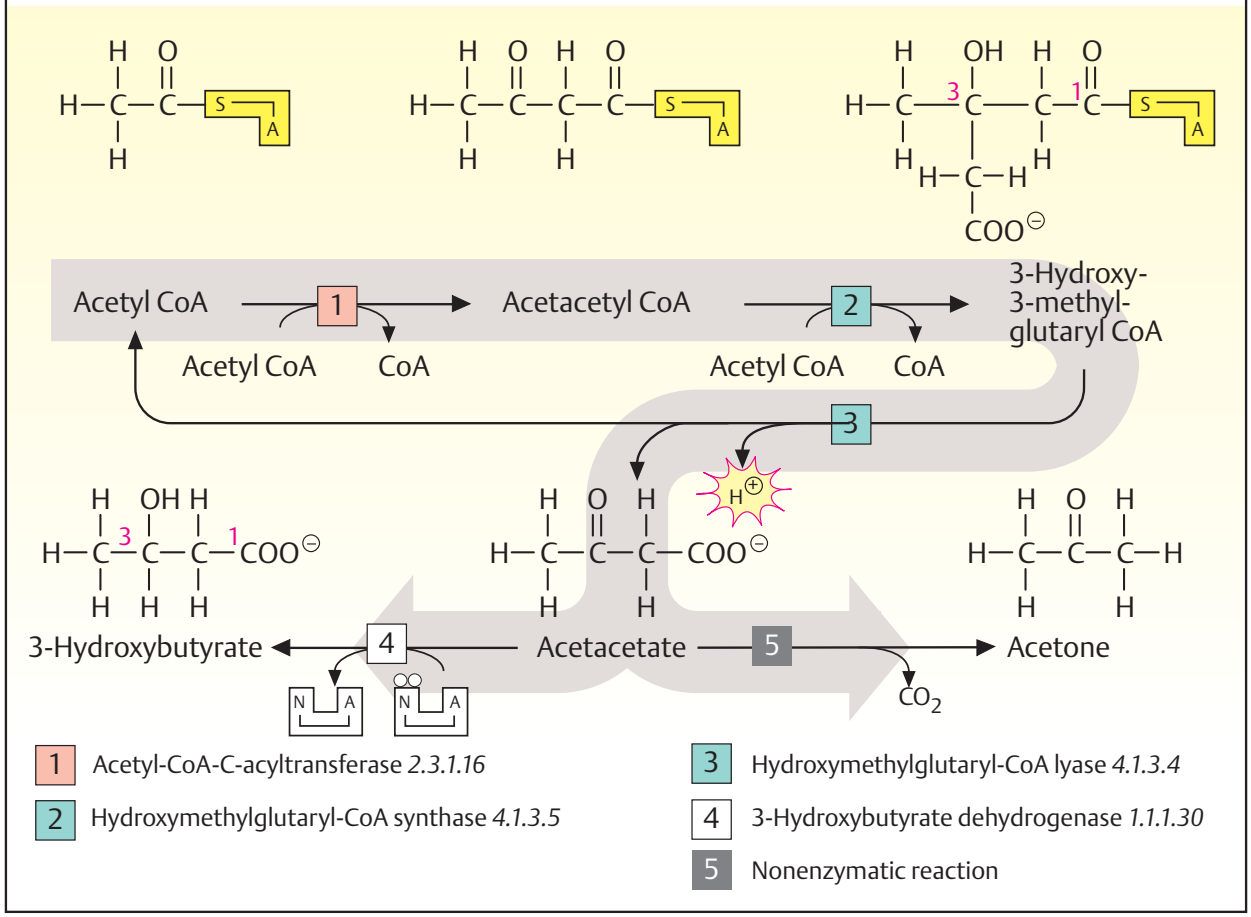

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Bile acids

Bile is an important product released by the hepatocytes. It promotes the digestion of fats from food by *emulsifying* them in the small intestine (see p. 2770). The emulsifying components of bile, apart from phospholipids, mainly consist of **bile acids** and **bile salts** (see below). The bile also contains free cholesterol, which is excreted in this way (see p. 312).

A. Bile acids and bile salts ◑

Bile acids are steroids consisting of 24 C atoms carrying one carboxylate group and several hydroxyl groups. They are formed from cholesterol in the liver via an extensive reaction pathway (top). Cytochrome P450 enzymes in the sER of hepatocytes are involved in many of the steps (seep. 318). Initially, the cholesterol double bond is removed. Monooxygenases then introduce one or two additional OH groups into the sterane framework. Finally, the side chain is shortened by three C atoms, and the terminal C atom is oxidized to a carboxylate group.

It is important that the arrangement of the A and B rings is altered from *trans* to *cis* during bile acid synthesis (see p. 54). The result of this is that all of the hydrophilic groups in the bile acids lie on one side of the molecule. Cholesterol, which is weakly amphipathic (top), has a small polar "head" and an extended apolar "tail." By contrast, the much more strongly amphipathic bile acid molecules (bottom) resemble disks with polar top sides and apolar bottom sides. At physiological pH values, the carboxyl groups are almost completely dissociated and therefore negatively charged.

Cholic acid and *chenodeoxycholic acid,* known as the **primary bile acids**, are quantitatively the most important metabolites of cholesterol. After being biosynthesized, they are mostly activated with coenzyme A and then conjugated with *glycine* or the non-proteinogenic amino acid *taurine* (see p. 62). The acid amides formed in this way are known as **conjugated bile acids** or **bile salts**. They are even more amphipathic than the primary products.

Deoxycholic acid and *lithocholic acid* are only formed in the intestine by enzymatic cleavage of the OH group at C-7 (see **B**). They are therefore referred to as **secondary bile acids**.

B. Metabolism of bile salts ◑

Bile salts are exclusively synthesized in the liver (see **A**). The slowest step in their biosynthesis is hydroxylation at position 7 by a *7-α-hydroxylase.* Cholic acid and other bile acids inhibit this reaction (*end-product inhibition*). In this way, the bile acids present in the liver regulate the rate of cholesterol utilization.

Before leaving the liver, a large proportion of the bile acids are activated with CoA and then conjugated with the amino acids *glycine* or *taurine* (**2**; cf. **A**). In this way, cholic acid gives rise to *glycocholic acid* and *taurocholic acid.* The *liver bile* secreted by the liver becomes denser in the gallbladder as a result of the removal of water (*bladder bile*; **3**).

Intestinal bacteria produce enzymes that can chemically alter the bile salts (**4**). The acid amide bond in the bile salts is cleaved, and dehydroxylation at C-7 yields the corresponding secondary bile acids from the primary bile acids (**5**). Most of the intestinal bile acids are resorbed again in the ileum (**6**) and returned to the liver via the portal vein (*enterohepatic circulation*). In the liver, the secondary bile acids give rise to primary bile acids again, from which bile salts are again produced. Of the 15–30 g bile salts that are released with the bile per day, only around 0.5 g therefore appears in the feces. This approximately corresponds to the amount of daily de novo synthesis of cholesterol.

Further information

The cholesterol excreted with the bile is poorly water-soluble. Together with phospholipids and bile acids, it forms micelles (see p. 270), which keep it in solution. If the proportions of phospholipids, bile acids and cholesterol shift, *gallstones* can arise. These mainly consist of precipitated cholesterol (cholesterol stones), but can also contain Ca^{2+} salts of bile acids and bile pigments (pigment stones).

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A. Bile acids and bile salts

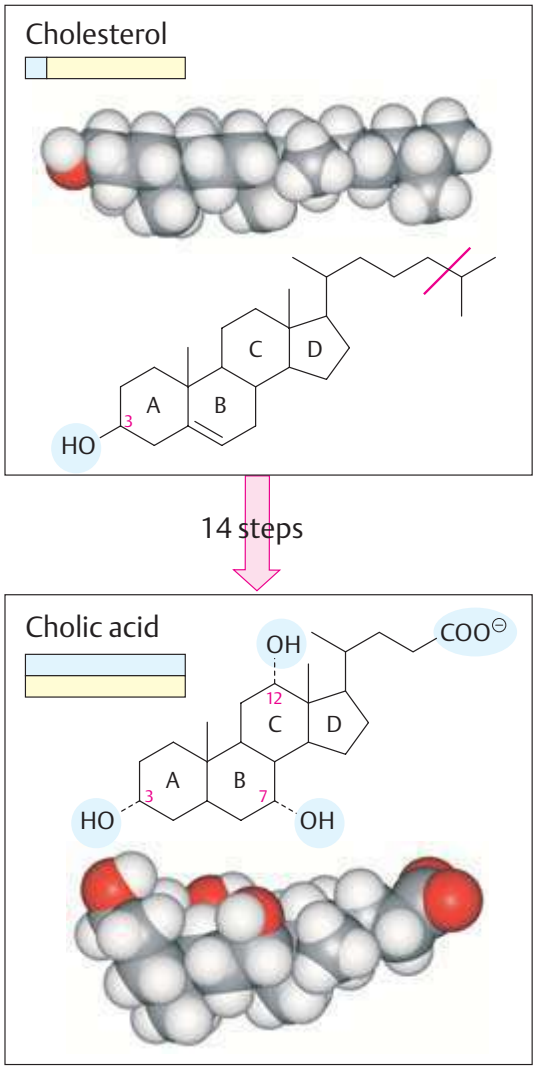

Bile acids	HO– in position		
Primary bile acids			
— Cholic acid	C-3	C-7	C-12
— Chenodeoxycholic acid	C-3	C-7	-
Secondary bile acids			
— Deoxycholic acid	C-3	-	C-12
— Lithocholic acid	C-3	-	-

Bile salts

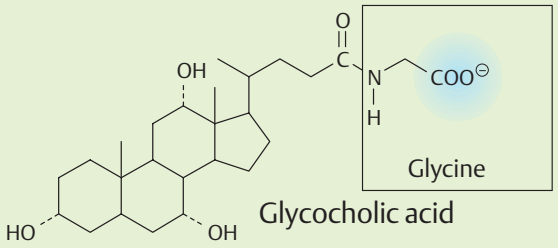

Glycocholic acid

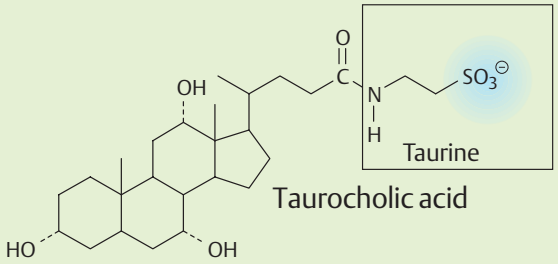

Taurocholic acid

Bile salts = conjugated bile acids

B. Metabolism of bile salts

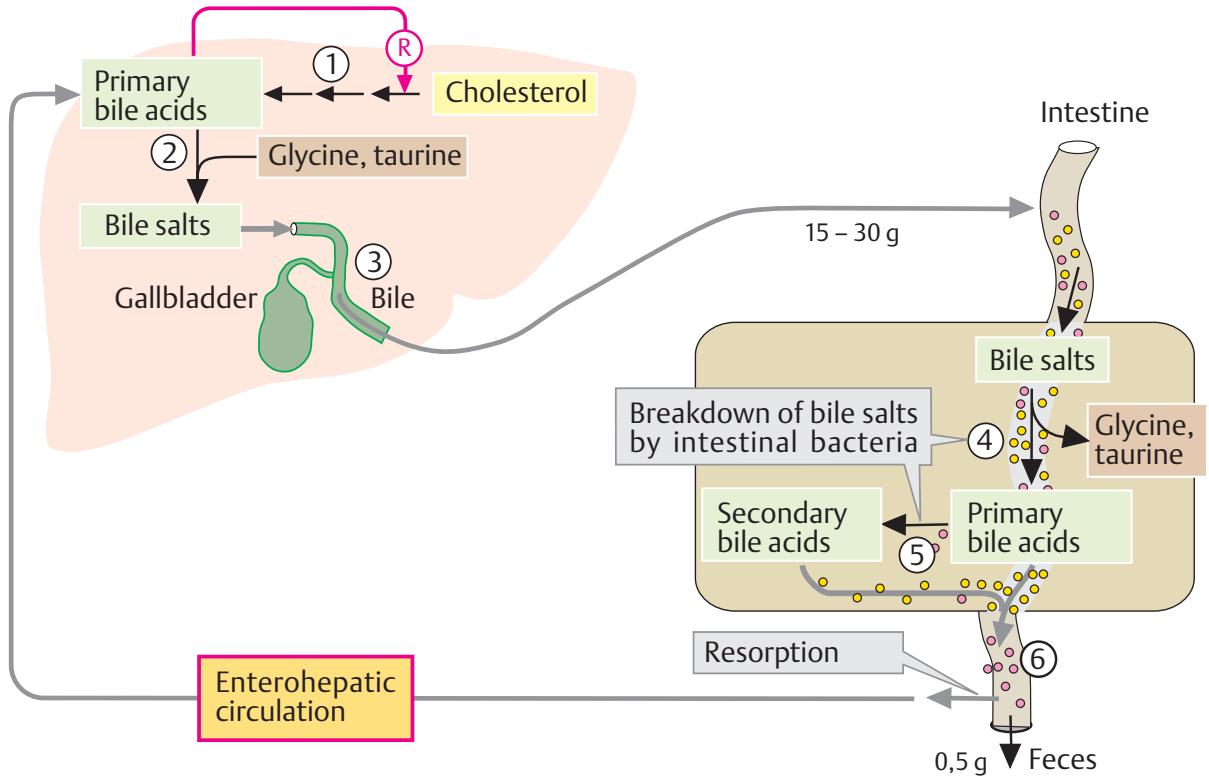

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Biotransformations

The body is constantly taking up **foreign substances** (= *xenobiotics*) from food or through contact with the environment, via the skin and lungs. These substances can be natural in origin, or may have been synthetically produced by humans. Many of these substances are toxic, particularly at high concentrations. However, the body has effective mechanisms for inactivating and then excreting foreign substances through *biotransformations.* The mechanisms of biotransformation are similar to those with which **endogenous substances** such as bile pigments and steroid hormones are enzymatically converted. Biotransformations mainly take place in the *liver.*

A. Biotransformations ◑

Phase I reactions (interconversion reactions). Type I reactions introduce functional groups into inert, apolar molecules or alter functional groups that are already present. In many cases, this is what first makes it possible for foreign substances to conjugate with polar molecules via phase II reactions (see below). Phase I reactions usually reduce the *biological activity* or *toxicity* of a substance ("detoxification"). However, some substances only become biologically active as a result of the interconversion reaction (see, for example, benzo[*a*]pyrene, p. 256) or become more toxic after interconversion than the initial substance ("toxification").

Important phase I biotransformation reactions include:

- **Hydrolytic cleavages** of ether, ester, and peptide bonds. Example (**1**) shows hydrolysis of the painkiller *acetylsalicylic acid.*
- **Oxidations.** Hydroxylations, epoxide formation, sulfoxide formation, dealkylation, deamination. For example, benzene is oxidized into phenol, and toluene (methylbenzene) is oxidized into benzoic acid.
- **Reductions.** Reduction of carbonyl, azo-, or nitro- compounds, dehalogenation.
- **Methylations.** Example (**2**) illustrates the inactivation of the catecholamine *norepinephrine* by methylation of a phenolic OH group (see p. 334).
- **Desulfurations.** The reactions take place in the hepatocytes on the smooth endoplasmic reticulum.

  Most oxidation reactions are catalyzed by **cytochrome P450 systems** (see p. 318). These monooxygenases are induced by their substrates and show wide specificity. The substrate-specific enzymes of the steroid metabolism (see p. 376) are exceptions to this.

Phase II reactions (conjugate formation). Type II reactions couple their substrates (bilirubin, steroid hormones, drugs, and products of phase I reactions) via ester or amide bonds to highly polar negatively charged molecules. The enzymes involved are transferases, and their products are known as **conjugates.**

The most common type of conjugate formation is coupling with *glucuronate* (GlcUA) as an *O*-or *N*-glucuronide. The coenzyme for the reaction is uridine diphosphate glucuronate, the *"active glucuronate"* (see p. 110). Coupling with the polar glucuronate makes an apolar (hydrophobic) molecule more strongly polar, and it becomes suf ciently water-soluble and capable of being excreted. Example (**3**) shows the glucuronidation of *tetrahydrocortisol,* a metabolite of the glucocorticoid cortisol (see p. 374).

The biosynthesis of sulfate esters with the help of *phosphoadenosine phosphosulfate* (PAPS), the *"active sulfate",* (see p. 110) and amide formation with *glycine* and *glutamine* also play a role in conjugation. For example, benzoic acid is conjugated with glycine to form the more soluble and less toxic *hippuric acid* (*N*-benzoylglycine; see p. 324).

In contrast with unconjugated compounds, the conjugates are much more water-soluble and capable of being excreted. The conjugates are eliminated from the liver either by the *biliary* route—i. e., by receptor-mediated excretion into the bile—or by the *renal* route, via the blood and kidneys by filtration.

Further information

To detoxify **heavy metals**, the liver contains *metallothioneins,* a group of cysteine-rich proteins with a high af nity for divalent metal ions such as Cd^{2+}, Cu^{2+}, Hg^{2+}, and Zn^{2+}. These metal ions also induce the formation of metallothioneins via a special metal-regulating element (MRE) in the gene's promoter (see p. 244).

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A. Biotransformations

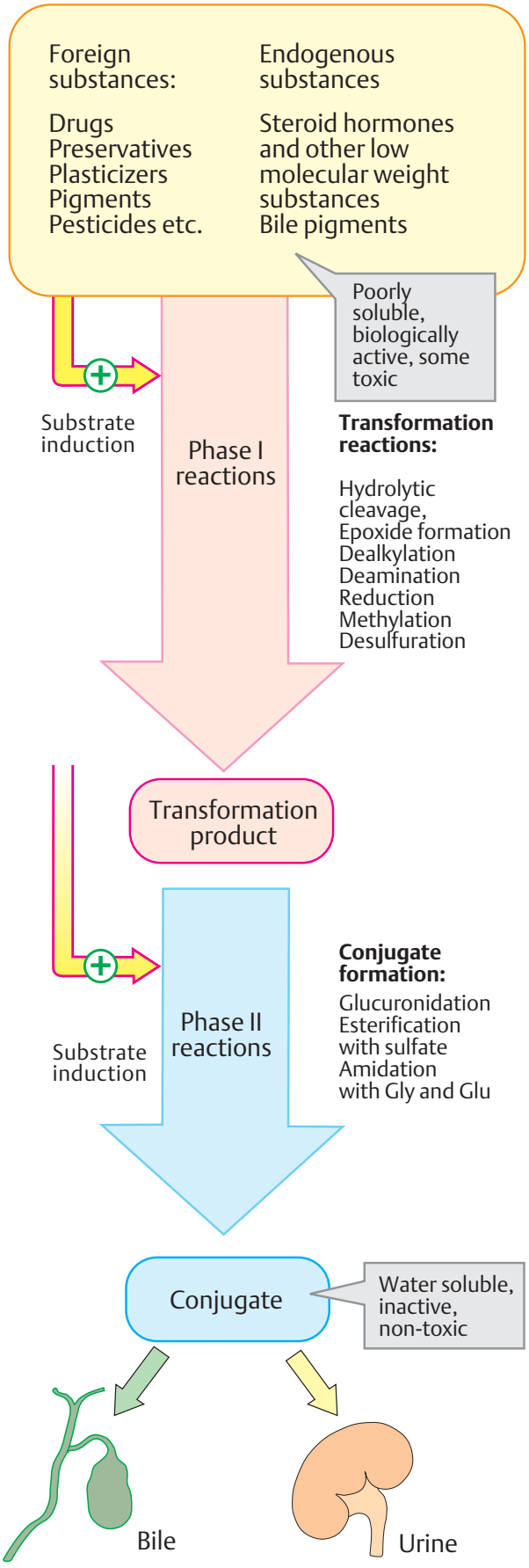

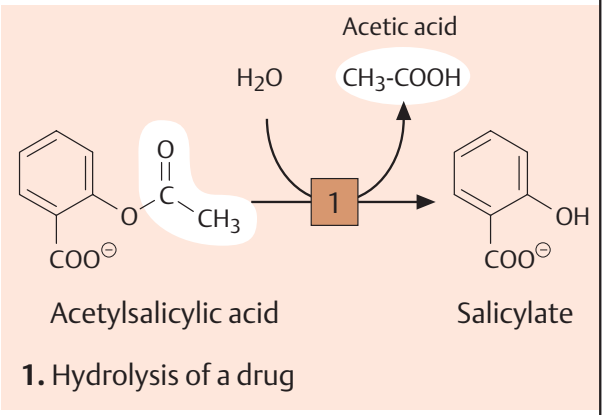

1. Hydrolysis of a drug

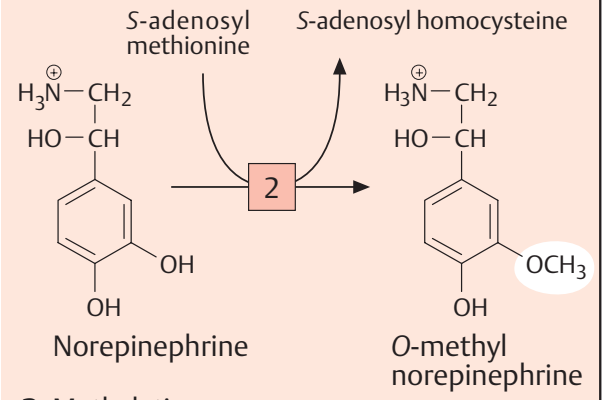

2. Methylation of a hormone/neurotransmitter

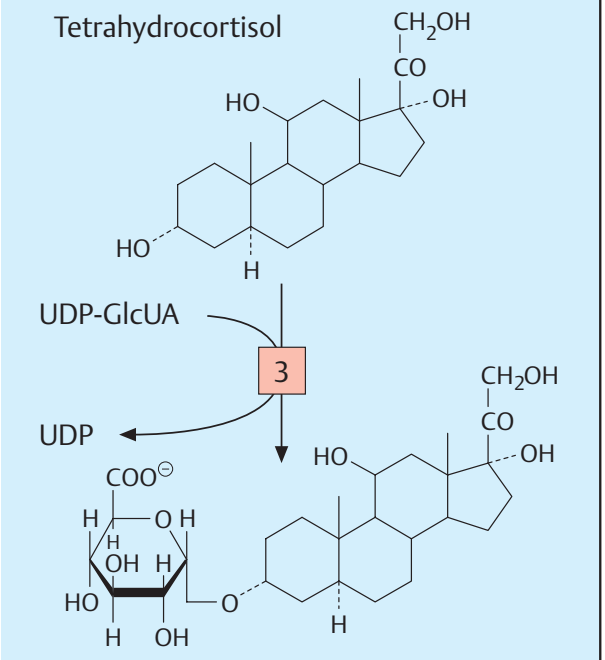

3. Glucuronidation of a hormone

1 Arylesterase *3.1.1.2*
2 Catechol *O*-methyl-transferase *2.1.1.6*
3 Glucuronosyltransferase *2.4.1.17*

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Cytochrome P450 systems

During the first phase of biotransformation in the liver, compounds that are weakly chemically reactive are enzymatically hydroxylated (see p. 316). This makes it possible for them to be conjugated with polar substances. The hydroxylating enzymes are generally *monooxygenases* that contain a **heme** as the redox-active coenzyme (see p. 106). In the reduced form, the heme can bind carbon monoxide (CO), and it then shows characteristic light absorption at 450 nm. This was what led to this enzyme group being termed **cytochrome P450** (Cyt P450).

Cyt P450 systems are also involved in many other metabolic processes—e. g., the biosynthesis of steroid hormones (see p. 172), bile acids (see p. 314), and eicosanoids (see p. 390), as well as the formation of unsaturated fatty acids (see p. 409). The liver's reddish-brown color is mainly due to the large amounts of P450 enzymes it contains.

A. Cytochrome P450-dependent mono oxygenases: reactions ◑

Cyt P450-dependent monooxygenases catalyze reductive cleavage of molecular oxygen (O_2). One of the two oxygen atoms is transferred to the substrate, while the other is released as a water molecule. The necessary reducing equivalents are transferred to the actual monooxygenase by an FAD-containing auxiliary enzyme from the coenzyme $NADPH+H^+$.

Cyt P450 enzymes occur in numerous forms in the liver, steroid-producing glands, and other organs. The substrate specificity of liver enzymes is low. Apolar compounds containing aliphatic or aromatic rings are particularly easily converted. These include endogenous substances such as steroid hormones, as well as medical drugs, which are inactivated by phase I reactions. This is why Cyt P450 enzymes are of particular interest in pharmacology. The degradation of ethanol in the liver is also partly catalyzed by Cyt P450 enzymes (the "microsomal ethanol-oxidizing system"; see p. 304). As alcohol and drugs are broken down by the same enzyme system, the effects of alcoholic drinks and medical drugs can sometimes be mutually enhancing—even sometimes to the extent of becoming life-threatening.

Only a few examples of the numerous Cyt P450-dependent reactions are shown here. *Hydroxylation* of aromatic rings (**a**) plays a central part in the metabolism of medicines and steroids. Aliphatic methyl groups can also be oxidized to hydroxyl groups (**b**). *Epoxidation* of aromatics (**c**) by Cyt P450 yields products that are highly reactive and often toxic. For example, the mutagenic effect of benzo[*a*]pyrene (see p. 244) is based on this type of interconversion in the liver. In Cyt P450 dependent *dealkylations* (**d**), alkyl substituents of *O, N,* or *S* atoms are released as aldehydes.

B. Reaction mechanism ○

The course of Cyt P450 catalysis is in principle well understood. The most important function of the *heme group* consists of converting molecular oxygen into an especially reactive atomic form, which is responsible for all of the reactions described above.

[1] In the resting state, the heme iron is trivalent. Initially, the substrate binds near the heme group.

[2] Transfer of an electron from $FADH_2$ reduces the iron to the divalent form that is able to bind an O_2 molecule (2).

[3] Transfer of a second electron and a change in the valence of the iron reduce the bound O_2 to the peroxide.

[4] A hydroxyl ion is now cleaved from this intermediate. Uptake of a proton gives rise to H_2O and the reactive form of oxygen mentioned above. In this ferryl radical, the iron is formally tetravalent.

[5] The activated oxygen atom inserts itself into a C–H bond in the substrate, thereby forming an OH group.

[6] Dissociation of the product returns the enzyme to its initial state.

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A. Cytochrome P450-dependent monooxygenases: reactions

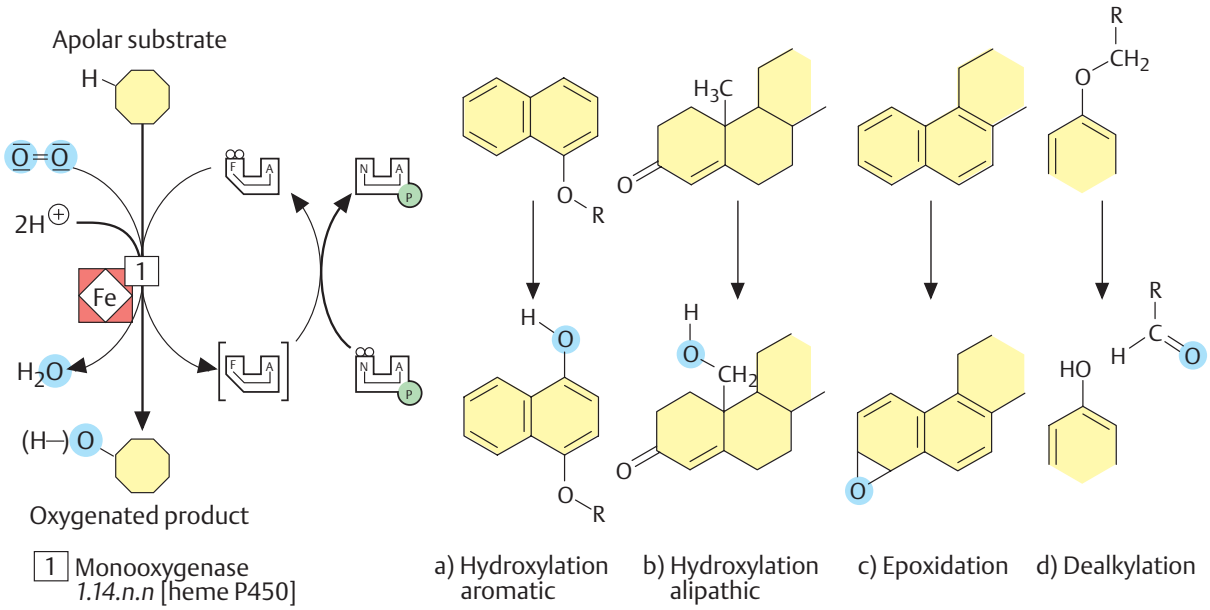

B. Reaction mechanism

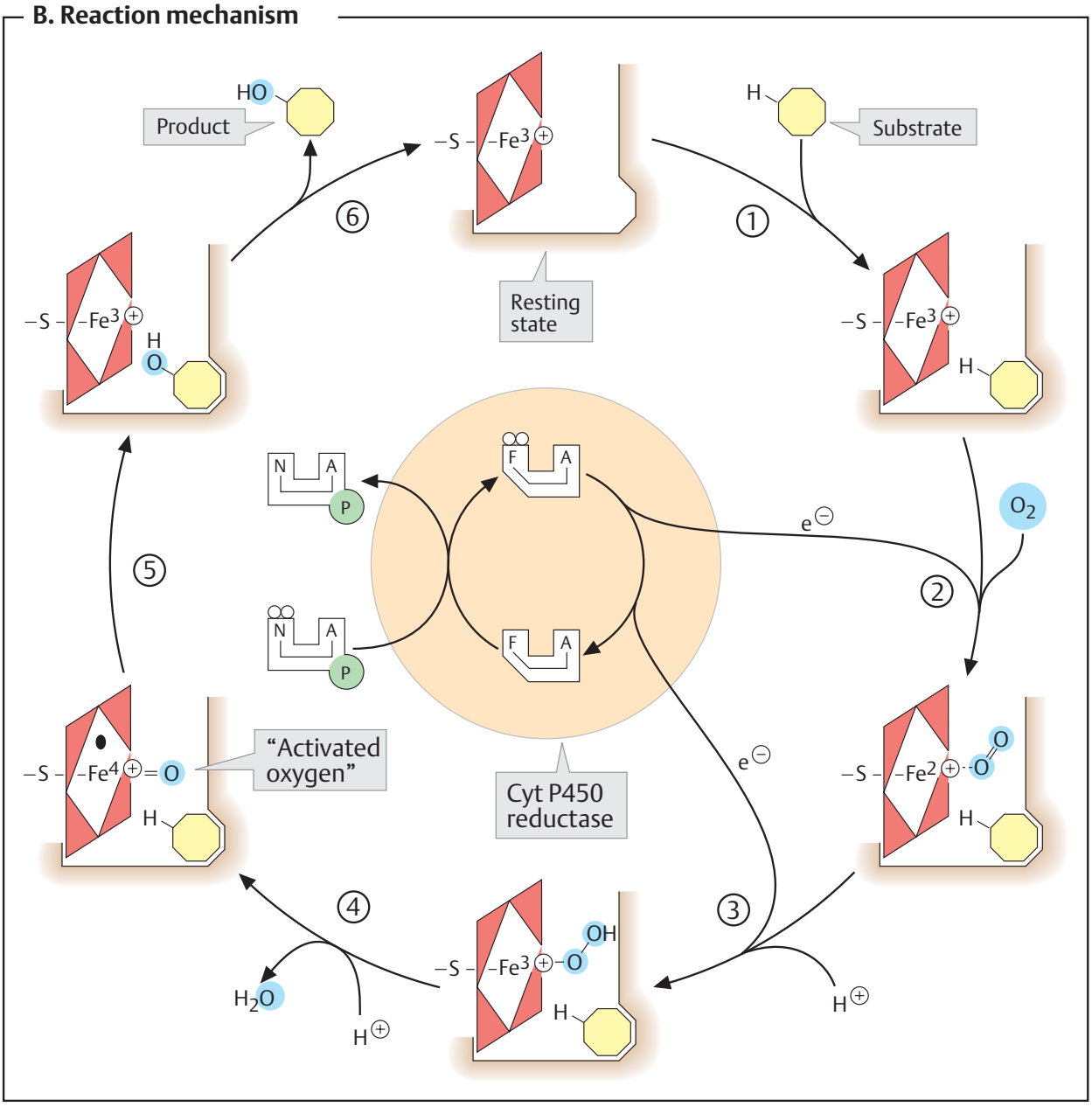

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Ethanol metabolism

A. Blood ethanol level ◑

Ethanol (EtOH, "alcohol") naturally occurs in fruit in small quantities. Alcoholic drinks contain much higher concentrations. Their alcohol content is usually given as percent by volume. To estimate alcohol uptake and the blood alcohol level, it is useful to convert the amount to grams of ethanol (density 0.79 kg L^{-1}). For example, a bottle of beer (0.5 L at 4% v/v alcohol) contains 20 mL = 16 g of ethanol, while a bottle of wine (0.7 L at 12% v/v alcohol) contains 84 mL = 66 g ethanol.

Ethanol is membrane-permeable and is quickly resorbed. The maximum blood level is already reached within 60–90 min after drinking. The *resorption rate* depends on various conditions, however. An empty stomach, a warm drink (e.g., mulled wine), and the presence of sugar and carbonic acid (e.g., in champagne) promote ethanol resorption, whereas a heavy meal reduces it. Ethanol is rapidly distributed throughout the body. A large amount is taken up by the muscles and brain, but comparatively little by adipose tissue and bones. Roughly 70% of the body is accessible to alcohol. Complete resorption of the ethanol contained in one bottle of beer (16 g) by a person weighing 70 kg (distribution in 70 kg 70/100 = 49 kg) leads to a blood alcohol level of 0.33 per thousand (7.2 mM). The lethal concentration of alcohol is approximately 3.5 per thousand (76 mM).

B. Ethanol metabolism ◑

The major site of ethanol degradation is the liver, although the stomach is also able to metabolize ethanol. Most **ethanol** is initially oxidized by *alcohol dehydrogenase* to form **ethanal** (acetaldehyde). A further oxidization, catalyzed by *aldehyde dehydrogenase,* leads to acetate. Acetate is then converted with the help of *acetate-CoA ligase* to form **acetyl CoA**, using ATP and providing a link to the intermediary metabolism. In addition to cytoplasmic alcohol dehydrogenase, *catalase* and inducible *microsomal alcohol oxidase* ("MEOS"; see p. 318) also contribute to a lesser extent to ethanol degradation. Many of the enzymes mentioned above are induced by ethanol.

The rate of ethanol degradation in the liver is limited by alcohol dehydrogenase activity. The amount of NAD^+ available is the limiting factor. As the maximum degradation rate is already reached at low concentrations of ethanol, the ethanol level therefore declines at a constant rate (zero-order kinetics). The *calorific value* of ethanol is 29.4 kJ g^{-1}. Alcoholic drinks—particularly in alcoholics—can therefore represent a substantial proportion of dietary energy intake.

C. Liver damage due to alcohol ◑

Alcohol is a socially accepted drug of abuse in Western countries. Due to the high potential for addiction to develop, however, it is actually a "hard" drug and has a much larger number of victims than the opiate drugs, for example. In the brain, ethanol is deposited in membranes due to its amphipathic properties, and it influences receptors for neurotransmitters (see p. 352). The effect of GABA is enhanced, while that of glutamate declines.

High ethanol consumption over many years leads to liver damage. For a healthy man, the limit is about 60 g per day, and for a woman about 50 g. However, these values are strongly dependent on body weight, health status, and other factors.

Ethanol-related high levels of $NADH+H^+$ and acetyl-CoA in the liver lead to increased synthesis of neutral fats and cholesterol. However, since the export of these in the form of VLDLs (see p. 278) is reduced due to alcohol, storage of lipids occurs (**fatty liver**). This increase in the fat content of the liver (from less than 5% to more than 50% of the dry weight) is initially reversible. However, in chronic alcoholism the hepatocytes are increasingly replaced by connective tissue. When **liver cirrhosis** occurs, the damage to the liver finally reaches an irreversible stage, characterized by progressive loss of liver functions.

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A. Blood ethanol level

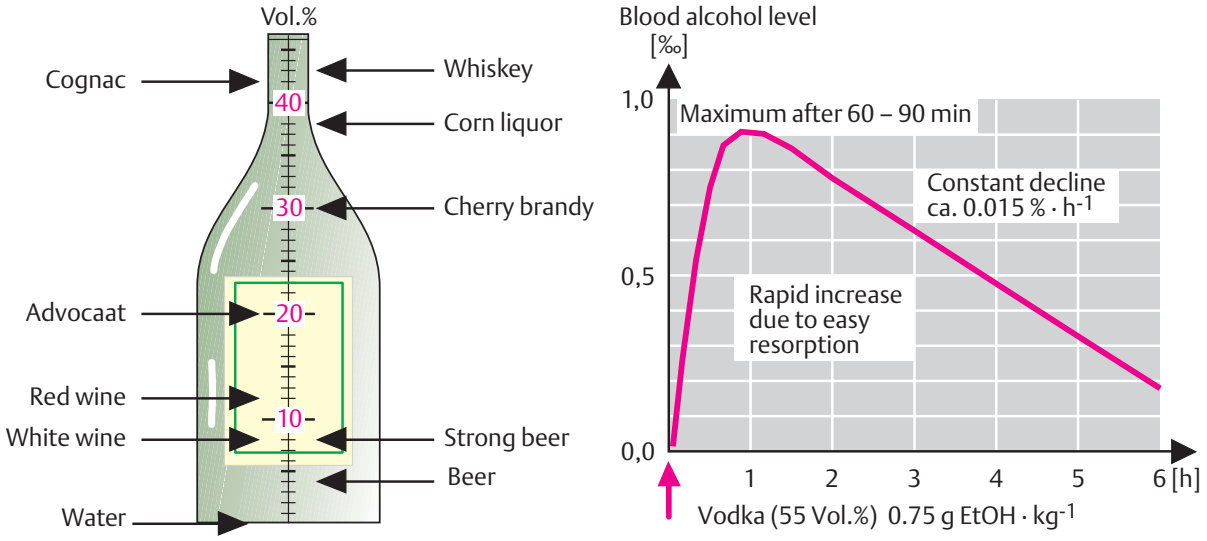

B. Ethanol metabolism

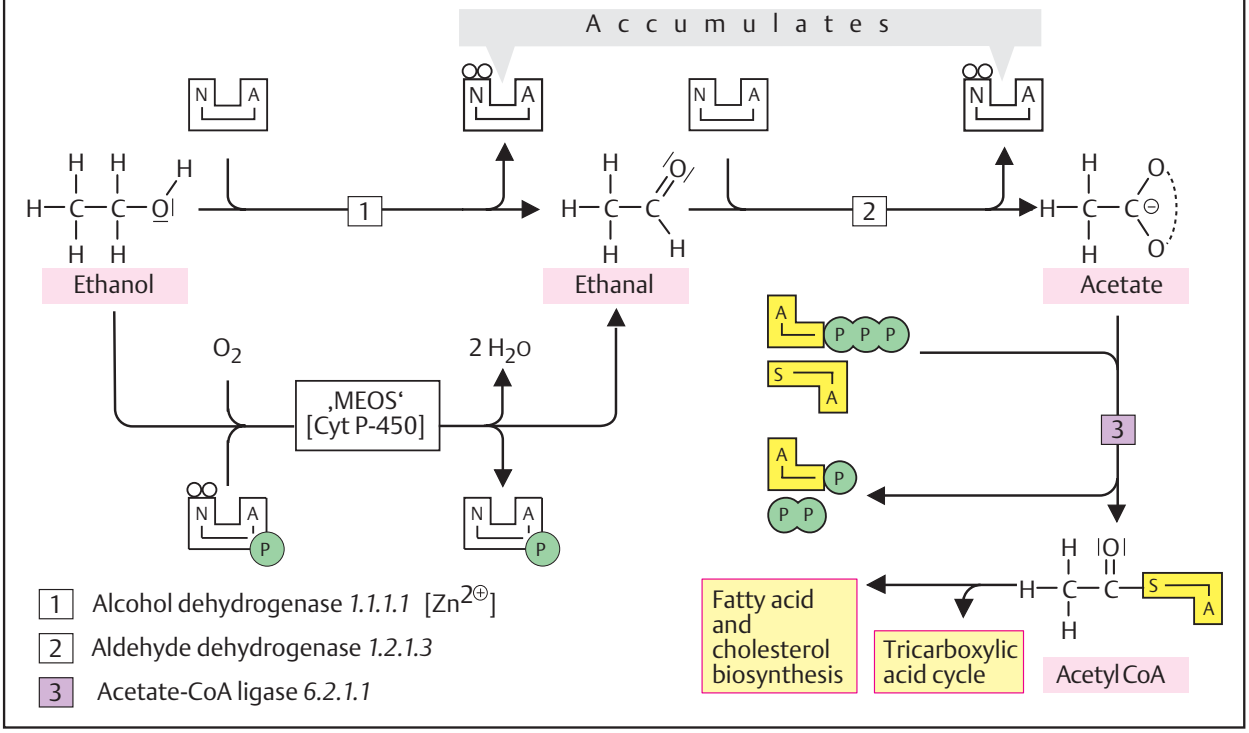

C. Liver damage due to alcohol

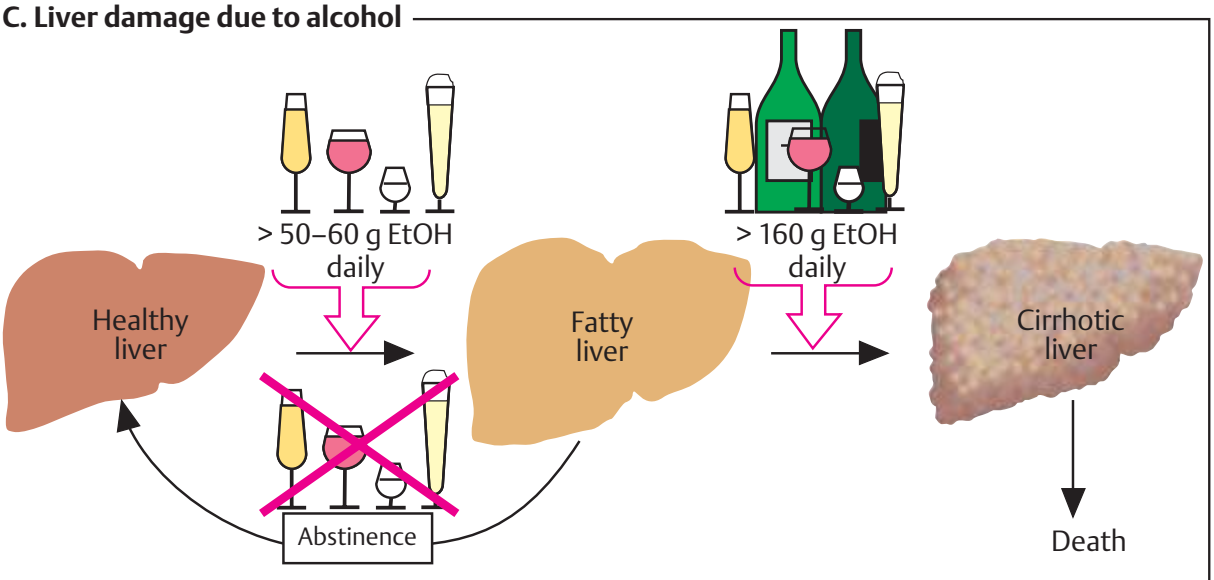

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Kidney: functions

A. Functions of the kidneys ●

The kidneys' main function is **excretion** of water and water-soluble substances (**1**). This is closely associated with their role in regulating the body's electrolyte and acid–base balance (**homeostasis, 2**; see pp. 326 and 328). Both excretion and homeostasis are subject to hormonal control. The kidneys are also involved in synthesizing several **hormones** (**3**; see p. 315). Finally, the kidneys also play a role in the **intermediary metabolism** (**4**), particularly in amino acid degradation and gluconeogenesis (see p. 154).

The kidneys are extremely well-perfused organs, with about 1500 L of blood flowing through them every day. Approximately 180 L of primary urine is filtered out of this. Removal of water leads to extreme concentration of the primary urine (to approximately one-hundredth of the initial volume). As a result, only a volume of 0.5–2.0 L of **final urine** is excreted per day.

B. Urine formation ◑

The functional unit of the kidney is the **nephron**. It is made up of the Malpighian bodies or renal corpuscles (consisting of Bowman's capsules and the glomerulus), the proximal tubule, Henle's loop, and the distal tubule, which passes into a collecting duct. The human kidney contains around one million nephrons. The nephrons form urine in the following three phases.

Ultrafiltration. Ultrafiltration of the blood plasma in the glomerulus gives rise to *primary urine,* which is *isotonic* with plasma. The pores in the glomerular basal membrane, which are made up of type IV collagen (see p. 344), have an effective mean diameter of 2.9 nm. This allows all plasma components with a molecular mass of up to about 15 kDa to pass through unhindered. At increasing masses, molecules are progressively held back; at masses greater than 65 kDa, they are completely unable to enter the primary urine. This applies to almost all plasma proteins—which in addition, being anions, are repelled by the negative charge in the basal membrane.

Resorption. All low-molecular weight plasma components enter the primary urine via glomerular filtration. Most of these are transported back into the blood by resorption, to prevent losses of valuable metabolites and electrolytes. In the proximal tubule, organic metabolites (e.g., glucose and other sugars, amino acids, lactate, and ketone bodies) are recovered by secondary active transport (see p. 220). There are several group-specific transport systems for resorbing amino acids, with which hereditary diseases can be associated (e.g., *cystinuria, glycinuria,* and *Hartnup's disease*). HCO_3^-, Na^+, phosphate, and sulfate are also resorbed by ATP-dependent (active) mechanisms in the proximal tubule. The later sections of the nephron mainly serve for additional water recovery and regulated resorption of Na^+ and Cl^- (see pp. 326, 328). These processes are controlled by hormones (aldosterone, vasopressin).

Secretion. Some excretable substances are released into the urine by *active transport* in the renal tubules. These substances include H^+ and K^+ ions, urea, and creatinine, as well as drugs such as penicillin.

Clearance. Renal clearance is used as a quantitative measure of renal function. It is defined as the plasma volume cleared of a given substance per unit of time. *Inulin,* a fructose polysaccharide with a mass of ca. 6 kDa (see p. 40) that is neither actively excreted nor resorbed but is freely filtered, has a clearance of 120 mL min^{-1} in healthy individuals.

Further information

Concentrating urine and transporting it through membranes are processes that require large amounts of energy. The kidneys therefore have very high energy demands. In the proximal tubule, the ATP needed is obtained from oxidative metabolism of *fatty acids, ketone bodies,* and several *amino acids.* To a lesser extent, lactate, glycerol, and citric acid are also used. In the distal tubule and Henle's loop, *glucose* is the main substrate for the energy metabolism. The endothelial cells in the proximal tubule are also capable of *gluconeogenesis.* The substrates for this are mainly the carbohydrate skeletons of amino acids. Their amino groups are used as ammonia for buffering urine (see p. 311). Enzymes for peptide degradation and the amino acid metabolism occur in the kidneys at high levels of activity (e.g., amino acid oxidases, amine oxidases, glutaminase).

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A. Functions of the kidneys

1. Excretion

Water
Salts
Metabolic wastes
Foreign substances

2. Homeostasis

Acid-base balance
Electrolyte balance

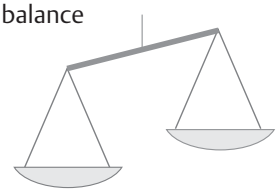

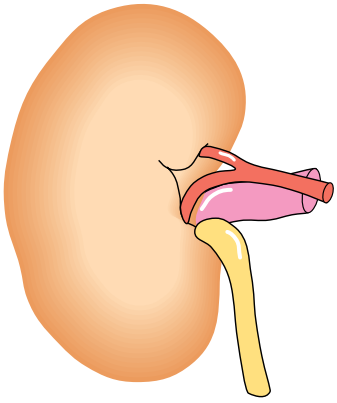

3. Hormone synthesis

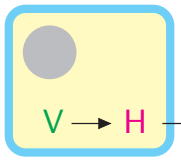

→ Erythropoietin
Calcitriol

4. Metabolism

Glucose → Blood

Amino acids → Gluconeo-genesis

NH_3 → Urine

B. Urine formation

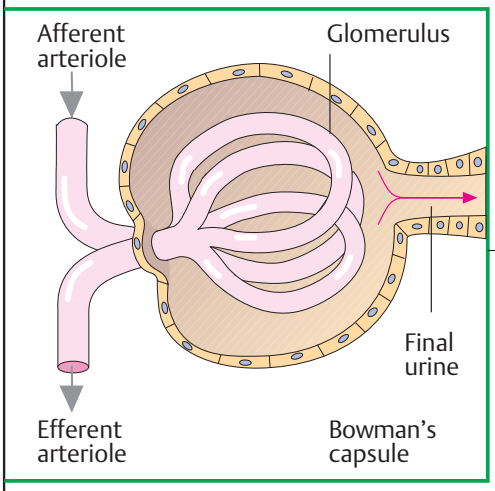

Renal corpuscle

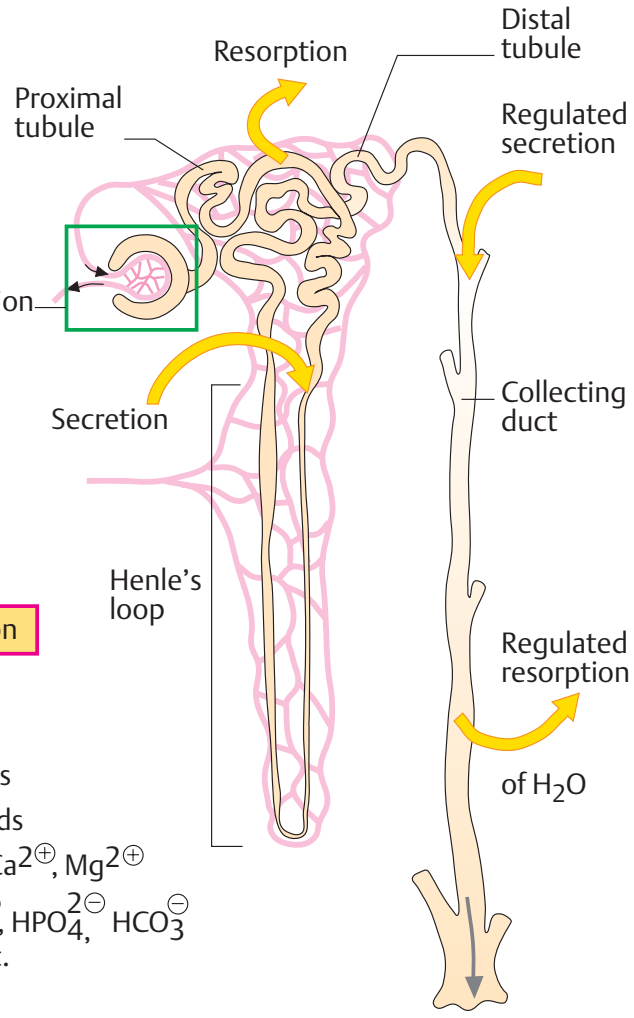

Ultrafiltration	Secretion	Resorption
All solute plasma components smaller than 3 nm = 15 kDa	$H^{\oplus}$	Glucose
	$K^{\oplus}$	Lactate
	Drugs	2-Oxoacids
	Uric acid	Amino acids
	Creatinine	$Na^{\oplus}$, $K^{\oplus}$, $Ca^{2\oplus}$, $Mg^{2\oplus}$
		$Cl^{\ominus}$, $SO_4^{2\ominus}$, $HPO_4^{2\ominus}$, $HCO_3^{\ominus}$
		Water, etc.

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Urine

A. Urine ◑

Water and water-soluble compounds are excreted with the urine. The volume and composition of urine are subject to wide variation and depend on food intake, body weight, age, sex, and living conditions such as temperature, humidity, physical activity, and health status. As there is a marked circadian rhythm in urine excretion, the amount of urine and its composition are usually given relative to a 24-hour period.

A human adult produces 0.5–2.0 L urine per day, around 95% of which consists of water. The urine usually has a slightly acidic pH value (around 5.8). However, the pH value of urine is strongly affected by metabolic status. After ingestion of large amounts of plant food, it can increase to over 7.

B. Organic components ◑

Nitrogen-containing compounds are among the most important organic components of urine. **Urea,** which is mainly synthesized in the liver (urea cycle; see p. 182), is the form in which nitrogen atoms from amino acids are excreted. Breakdown of pyrimidine bases also produces a certain amount of urea (see p. 190). When the nitrogen balance is constant, as much nitrogen is excreted as is taken up (see p. 174), and the amount of urea in the urine therefore reflects protein degradation: 70 g protein in food yields approximately 30 g urea in the urine.

Uric acid is the end product of the purine metabolism. When uric acid excretion via the kidneys is disturbed, gout can develop (see p. 190). **Creatinine** is derived from the muscle metabolism, where it arises spontaneously and irreversibly by cyclization of creatine and creatine phosphate (see p. 336). Since the amount of creatinine an individual excretes per day is constant (it is directly proportional to muscle mass), creatinine as an endogenous substance can be used to measure the glomerular filtration rate. The amount of **amino acids** excreted in free form is strongly dependent on the diet and on the ef ciency of liver function. Amino acid derivatives are also found in the urine (e. g., **hippurate**, a detoxification product of benzoic acid). Modified amino acids, which occur in special proteins such as *hydroxyproline* in collagen and *3-methylhistidine* in actin and myosin, can be used as indicators of the degradation of these proteins.

Other components of the urine are conjugates with sulfuric acid, glucuronic acid, glycine, and other polar compounds that are synthesized in the liver by biotransformation (see p. 316). In addition, metabolites of many hormones (catecholamines, steroids, serotonin) also appear in the urine and can provide information about hormone production. The proteohormone *chorionic gonadotropin* (hCG, mass ca. 36 kDa), which is formed at the onset of pregnancy, appears in the urine due to its relatively small size. Evidence of hCG in the urine provides the basis for an immunological *pregnancy test.*

The yellow color of urine is due to *urochromes,* which are related to the bile pigments produced by hemoglobin degradation (see p. 194). If urine is left to stand long enough, oxidation of the urochromes may lead to a darkening in color.

C. Inorganic components ◑

The main inorganic components of the urine are the *cations* Na^+, K^+, Ca^{2+}, Mg^{2+}, and NH_4^+ and the *anions* Cl^-, SO_4^{2-}, and HPO_4^{2-}, as well as traces of other ions. In total, Na^+ and Cl^- represent about two-thirds of all the electrolytes in the final urine. Calcium and magnesium occur in the feces in even larger quantities. The amounts of the various inorganic components of the urine also depend on the composition of the diet. For example, in acidosis there can be a marked increase in the excretion of ammonia (see p. 326). Excretion of Na^+, K^+, Ca^{2+}, and phosphate via the kidneys is subject to hormonal regulation (see p. 330).

Further information

Shifts in the concentrations of the *physiological components* of the urine and the appearance of *pathological urine components* can be used to diagnose diseases. Important examples are glucose and ketone bodies, which are excreted to a greater extent in *diabetes mellitus* (see p. 160).

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A. Urine

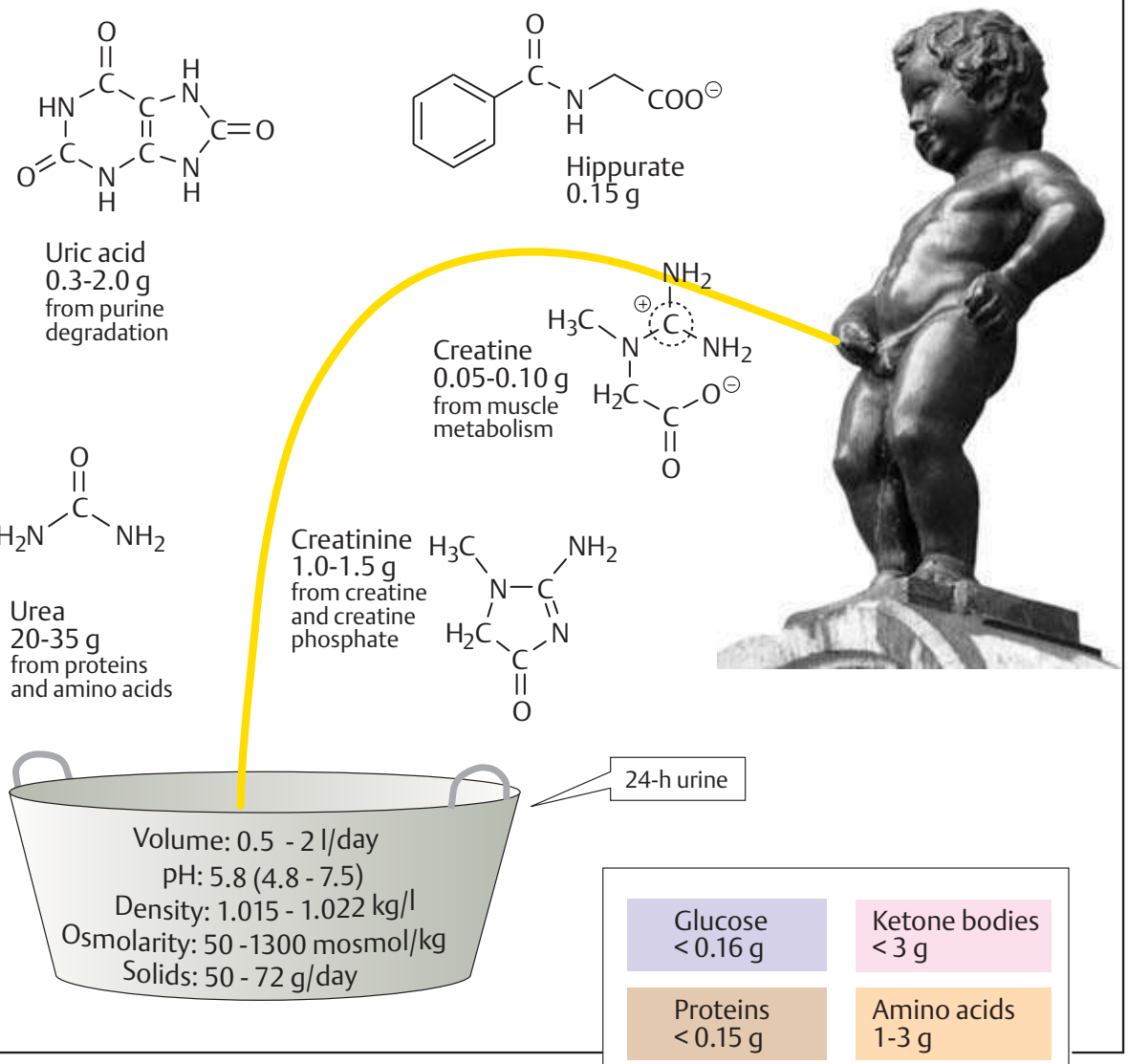

B. Organic constituents

Glucose < 0.16 g	Ketone bodies < 3 g
Proteins < 0.15 g	Amino acids 1-3 g

C. Inorganic constituents

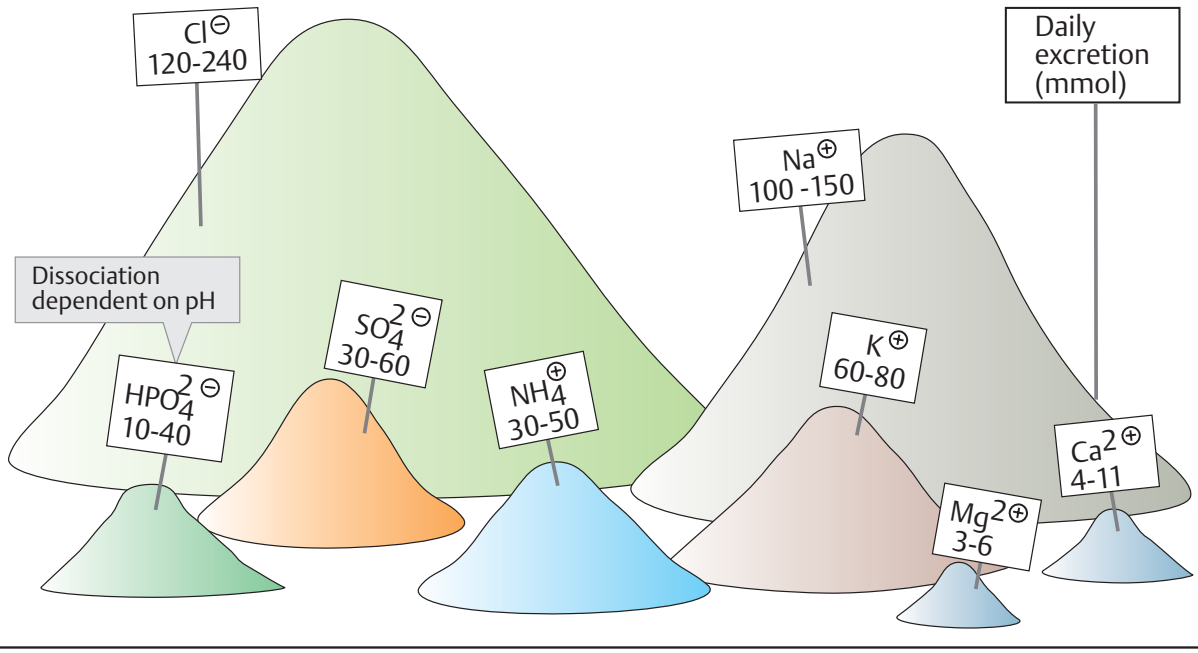

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Functions in the acid–base balance

Along with the lungs, the kidneys are particularly involved in keeping the pH value of the extracellular fluid constant (see p. 288). The contribution made by the kidneys particularly involves resorbing HCO_3^- and actively excreting protons.

A. Proton excretion ◑

The renal tubule cells are capable of secreting protons (H^+) from the blood into the urine against a concentration gradient, despite the fact that the H^+ concentration in the urine is up to a thousand times higher than in the blood. To achieve this, carbon dioxide (CO_2) is taken up from the blood and—together with water (H_2O) and with the help of *carbonate dehydratase* (carbonic anhydrase, [1])—converted into hydrogen carbonate ("bicarbonate," HCO_3^-) and one H^+. Formally, this yields carbonic acid H_2CO_3 as an intermediate, but it is not released during the reaction.

The hydrogen carbonate formed in carbonic anhydrase returns to the plasma, where it contributes to the blood's base reserve. The proton is exported into the urine by *secondary active transport* in antiport for Na^+ (bottom right). The driving force for **proton excretion**, as in other secondary active processes, is the Na^+ gradient established by the ATPase involved in the *Na^+/K^+* exchange ("Na^+/K^+ ATPase", see p. 220). This integral membrane protein on the basal side (towards the blood) of tubule cells keeps the Na^+ concentration in the tubule cell low, thereby maintaining Na^+ inflow. In addition to this secondary active H^+ transport mechanism, there is a V-type H^+-transporting ATPase in the distal tubule and collecting duct (see p. 220).

An important function of the secreted H^+ ions is to promote **HCO_3^- resorption** (top right). Hydrogen carbonate, the most important buffering base in the blood, passes into the primary urine quantitatively, like all ions. In the primary urine, HCO_3^- reacts with H^+ ions to form water and CO_2, which returns by free diffusion to the tubule cells and from there into the blood. In this way, the kidneys also influence the CO_2/HCO_3^- buffering balance in the plasma.

B. Ammonia excretion ◑

Approximately 60 mmol of protons are excreted with the urine every day. Buffering systems in the urine catch a large proportion of the H^+ ions, so that the urine only becomes weakly acidic (down to about pH 4.8).

An important buffer in the urine is the *hydrogen phosphate/dihydrogen phosphate system* ($HPO_4^{2-}/H_2PO_4^-$). In addition, *ammonia* also makes a vital contribution to buffering the secreted protons.

Since plasma concentrations of *free* ammonia are low, the kidneys release NH_3 from **glutamine** and other amino acids. At 0.5–0.7 mM, glutamine is the most important amino acid in the plasma and is the preferred form for ammonia transport in the blood. The kidneys take up glutamine, and with the help of *glutaminase* [4], initially release NH_3 from the amide bond hydrolytically. From the **glutamate** formed, a second molecule of NH_3 can be obtained by oxidative deamination with the help of *glutamate dehydrogenase* [5] (see p. 178). The resulting **2-oxoglutarate** is further metabolized in the tricarboxylic acid cycle. Several other amino acids—*alanine* in particular, as well as *serine, glycine,* and *aspartate*—can also serve as suppliers of ammonia.

Ammonia can diffuse freely into the urine through the tubule membrane, while the **ammonium ions** that are formed in the urine are charged and can no longer return to the cell. Acidic urine therefore promotes ammonia excretion, which is normally 30–50 mmol per day. In metabolic **acidosis** (e.g., during fasting or in *diabetes mellitus*), after a certain time increased *induction of glutaminase* occurs in the kidneys, resulting in increased NH_3 excretion. This in turn promotes H^+ release and thus counteracts the acidosis. By contrast, when the plasma pH value shifts towards alkaline values (*alkalosis*), renal excretion of ammonia is reduced.

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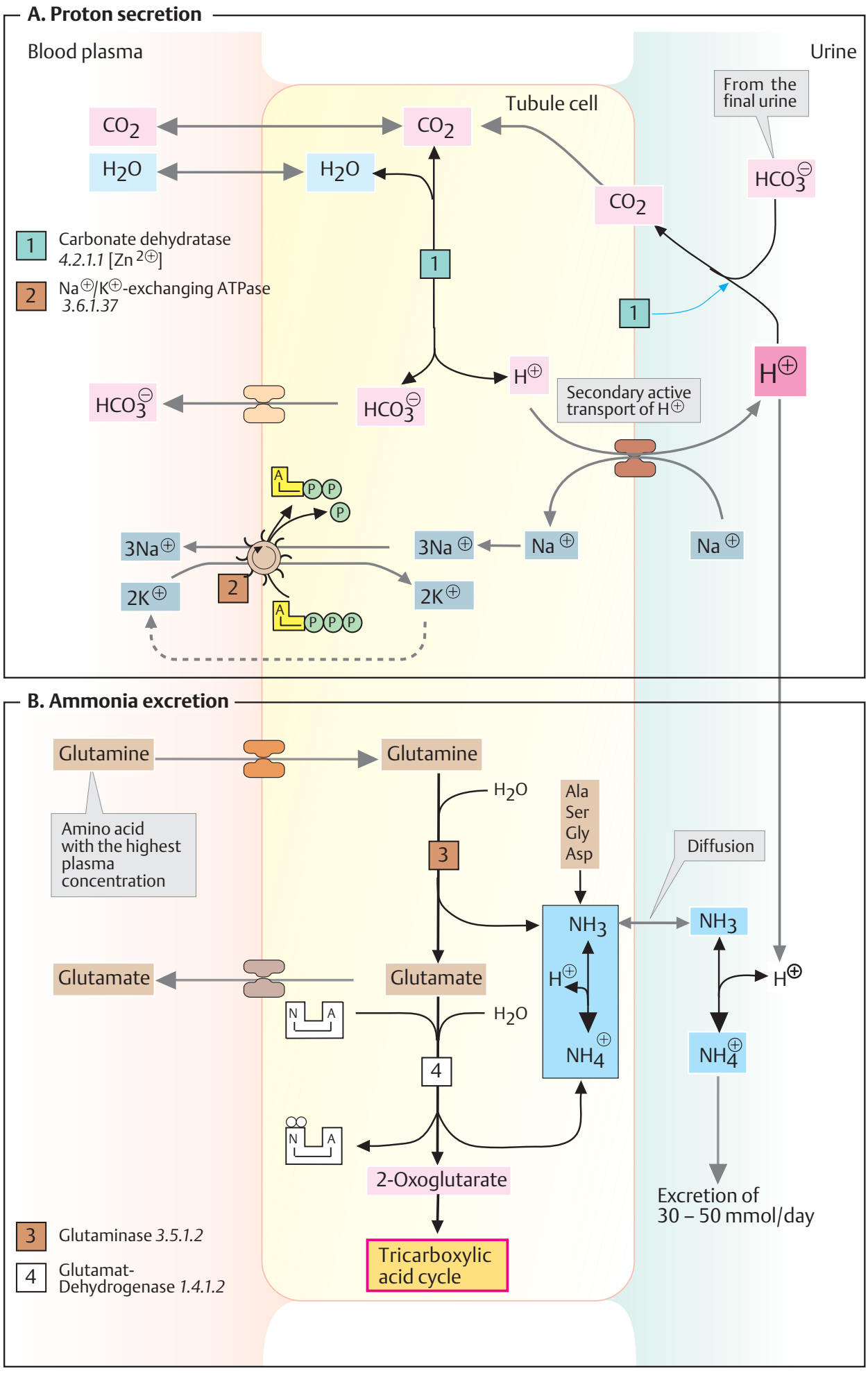

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Electrolyte and water recycling

A. Electrolyte and water recycling ◑

Electrolytes and other plasma components with low molecular weights enter the *primary urine* by ultrafiltration (right). Most of these substances are recovered by energy-dependent resorption (see p. 322). The extent of the resorption determines the amount that ultimately reaches the final urine and is excreted. The illustration does not take into account the *zoning* of transport processes in the kidney (physiology textbooks may be referred to for further details).

Calcium and phosphate ions. Calcium (Ca^{2+}) and phosphate ions are almost completely resorbed from the primary urine by active transport (i.e., in an ATP-dependent fashion). The proportion of Ca^{2+} resorbed is over 99%, while for phosphate the figure is 80–90%. The extent to which these two electrolytes are resorbed is regulated by the three hormones parathyrin, calcitonin, and calcitriol.

The peptide hormone *parathyrin* (PTH), which is produced by the parathyroid gland, stimulates Ca^{2+} resorption in the kidneys and at the same time inhibits the resorption of phosphate. In conjunction with the effects of this hormone in the bones and intestines (see p. 344), this leads to an *increase in the plasma level of* Ca^{2+} and a reduction in the level of phosphate ions.

Calcitonin, a peptide produced in the C cells of the thyroid gland, inhibits the resorption of both calcium and phosphate ions. The result is an overall *reduction in the plasma level* of both ions. Calcitonin is thus a parathyrin antagonist relative to Ca^{2+}.

The steroid hormone *calcitriol,* which is formed in the kidneys (see p. 304), stimulates the resorption of both calcium and phosphate ions and thus increases the plasma level of both ions.

Sodium ions. Controlled resorption of Na^+ from the primary urine is one of the most important functions of the kidney. Na^+ resorption is highly effective, with more than 97% being resorbed. Several mechanisms are involved: some of the Na^+ is taken up passively in the proximal tubule through the junctions between the cells (paracellularly). In addition, there is secondary active transport together with glucose and amino acids (see p. 322). These two pathways are responsible for 60–70% of total Na^+ resorption. In the ascending part of Henle's loop, there is another transporter (shown at the bottom right), which functions electroneutrally and takes up one Na^+ ion and one K^+ ion together with two Cl^- ions. This symport is also dependent on the activity of Na^+/K^+ ATPase [2], which pumps the Na^+ resorbed from the primary urine back into the plasma in exchange for K^+.

The steroid hormone *aldosterone* (see p. 55) increases Na^+ reuptake, particularly in the distal tubule, while *atrial natriuretic peptide* (ANP) originating from the cardiac atrium reduces it. Among other effects, aldosterone induces Na^+/K^+ ATPase and various Na^+ transporters on the luminal side of the cells.

Water. Water resorption in the proximal tubule is a *passive process* in which water follows the osmotically active particles, particularly the Na^+ ions. Fine regulation of water excretion (**diuresis**) takes place in the collecting ducts, where the peptide hormone *vasopressin* (antidiuretic hormone, ADH) operates. This promotes recovery of water by stimulating the transfer of aquaporins (see p. 220) into the plasma membrane of the tubule cells via V_2 receptors. A lack of ADH leads to the disease picture of *diabetes insipidus,* in which up to 30 L of final urine is produced per day.

B. Gluconeogenesis ◑

Apart from the liver, the kidneys are the only organs capable of producing glucose by neosynthesis *(gluconeogenesis;* see p. 154). The main substrate for gluconeogenesis in the cells of the proximal tubule is **glutamine**. In addition, other amino acids and also **lactate**, **glycerol**, and **fructose** can be used as precursors. As in the liver, the key enzymes for gluconeogenesis are induced by *cortisol* (see p. 374). Since the kidneys also have a high level of glucose consumption, they only release very little glucose into the blood.

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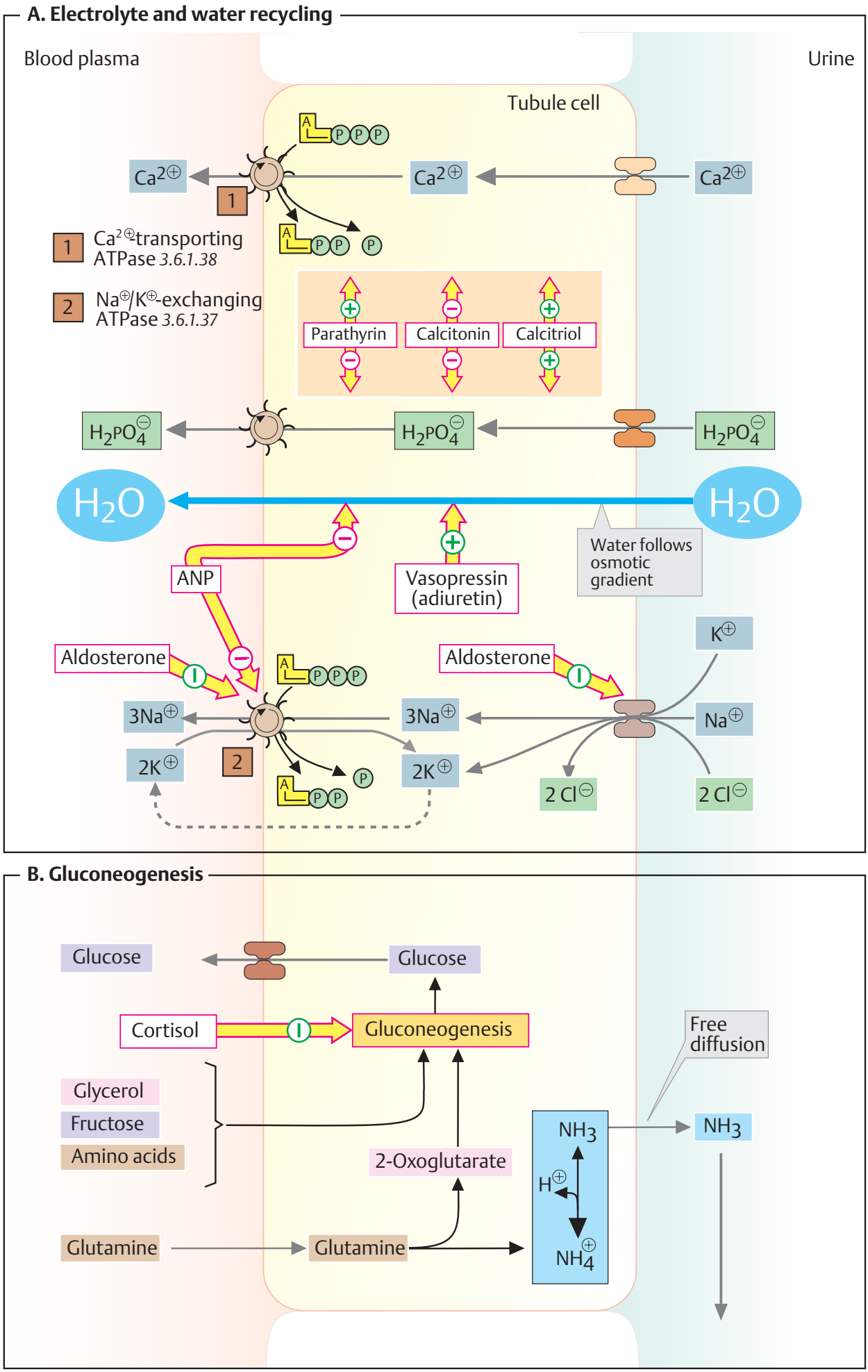

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Renal hormones

A. Renal hormones ◑

In addition to their involvement in excretion and metabolism, the kidneys also have endocrine functions. They produce the hormones **erythropoietin** and **calcitriol** and play a decisive part in producing the hormone **angiotensin II** by releasing the enzyme *renin.* Renal prostaglandins (see p. 390) have a local effect on Na^+ resorption.

Calcitriol (vitamin D hormone, 1α,25-dihydroxycholecalciferol) is a hormone closely related to the steroids that is involved in Ca^{2+} homeostasis (see p. 342). In the kidney, it is formed from calcidiol by hydroxylation at C-1. The activity of *calcidiol-1-monooxygenase* [1] is enhanced by the hormone *parathyrin* (PTH).

Erythropoietin is a peptide hormone that is formed predominantly by the kidneys, but also by the liver. Together with other factors known as *"colony-stimulating factors"* (CSF; see p. 392), it regulates the differentiation of stem cells in the bone marrow.

Erythropoietin release is stimulated by hypoxia (low pO_2). Within hours, the hormone ensures that erythrocyte precursor cells in the bone marrow are converted to erythrocytes, so that their numbers in the blood increase. Renal damage leads to reduced erythropoietin release, which in turn results in *anemia.* Forms of anemia with renal causes can now be successfully treated using erythropoietin produced by genetic engineering techniques. The hormone is also administered to dialysis patients. Among athletes and sports professionals, there have been repeated cases of erythropoietin being misused for doping purposes.

B. Renin–angiotensin system ◑

The peptide hormone angiotensin II is not synthesized in a hormonal gland, but in the blood. The kidneys take part in this process by releasing the enzyme renin.

Renin [2] is an aspartate proteinase (see p. 176). It is formed by the kidneys as a precursor (prorenin), which is proteolytically activated into renin and released into the blood. In the blood plasma, renin acts on **angiotensinogen,** a plasma glycoprotein in the α_2-globulin group (see p. 276), which like almost all plasma proteins is synthesized in the liver. The decapeptide cleaved off by renin is called **angiotensin I.** Further cleavage by *peptidyl dipeptidase A* (*angiotensin-converting enzyme,* ACE), a membrane enzyme located on the vascular endothelium in the lungs and other tissues, gives rise to the octapeptide **angiotensin II** [3], which acts as a hormone and neurotransmitter. The lifespan of angiotensin II in the plasma is only a few minutes, as it is rapidly broken down by other peptidases (angiotensinases [4]), which occur in many different tissues.

The plasma level of angiotensin II is mainly determined by the rate at which renin is released by the kidneys. Renin is synthesized by juxtaglomerular cells, which release it when sodium levels decline or there is a fall in blood pressure.

Effects of angiotensin II. Angiotensin II has effects on the kidneys, brain stem, pituitary gland, adrenal cortex, blood vessel walls, and heart via membrane-located receptors. It increases blood pressure by triggering *vasoconstriction* (narrowing of the blood vessels). In the kidneys, it promotes the *retention of* Na^+ and water and reduces potassium secretion. In the brain stem and at nerve endings in the sympathetic nervous system, the effects of angiotensin II lead to increased tonicity (neurotransmitter effect). In addition, it triggers the *sensation of thirst.* In the pituitary gland, angiotensin II stimulates *vasopressin release* (antidiuretic hormone) and corticotropin (ACTH) release. In the adrenal cortex, it increases the *biosynthesis and release of aldosterone,* which promotes sodium and water retention in the kidneys. All of the effects of angiotensin II lead directly or indirectly to *increased blood pressure,* as well as increased *sodium and water retention.* This important hormonal system for blood pressure regulation can be pharmacologically influenced by *inhibitors* at various points:

- Using angiotensinogen analogs that inhibit renin.
- Using angiotensin I analogs that competitively inhibit the enzyme ACE [3].
- Using hormone antagonists that block the binding of angiotensin II to its receptors.

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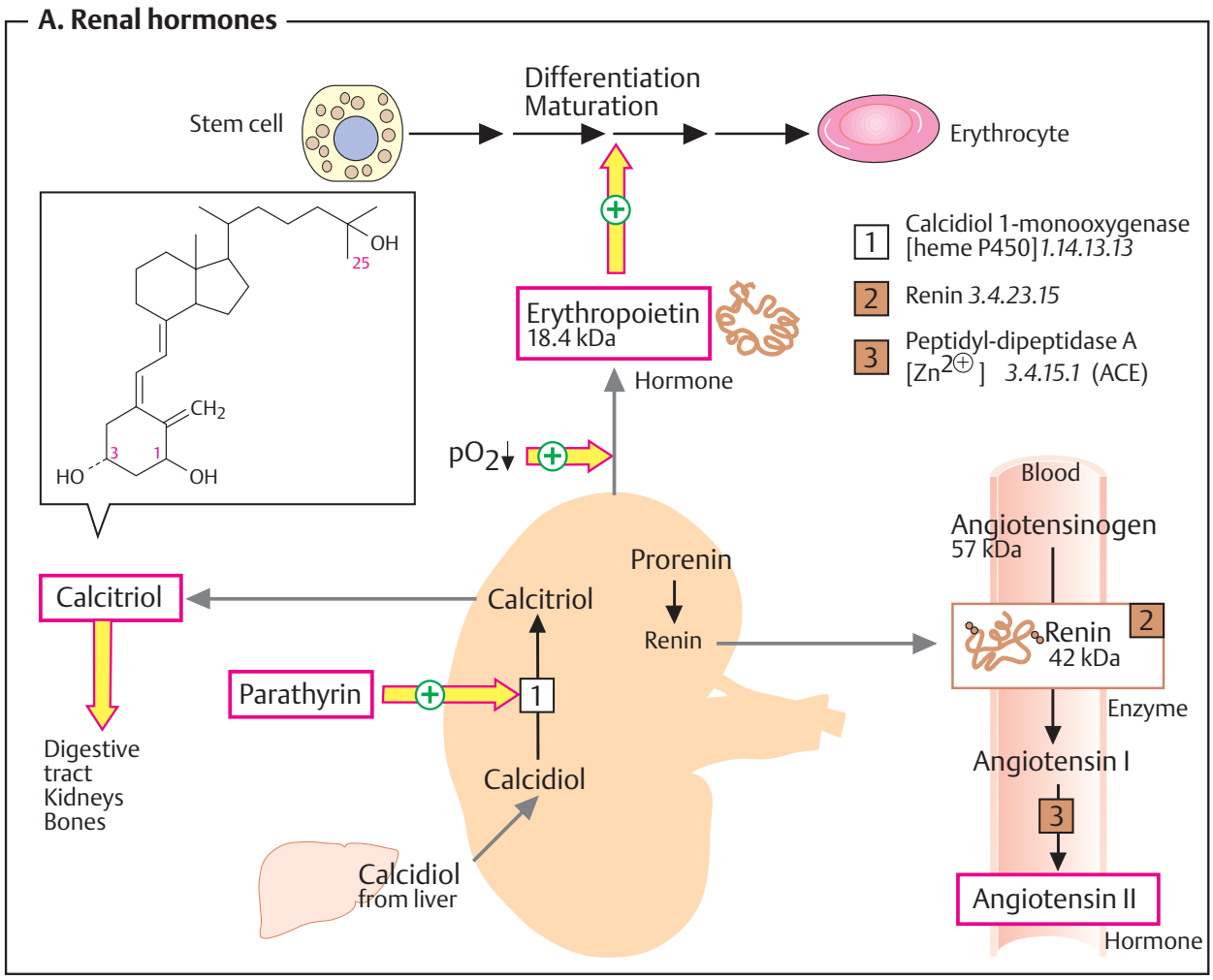

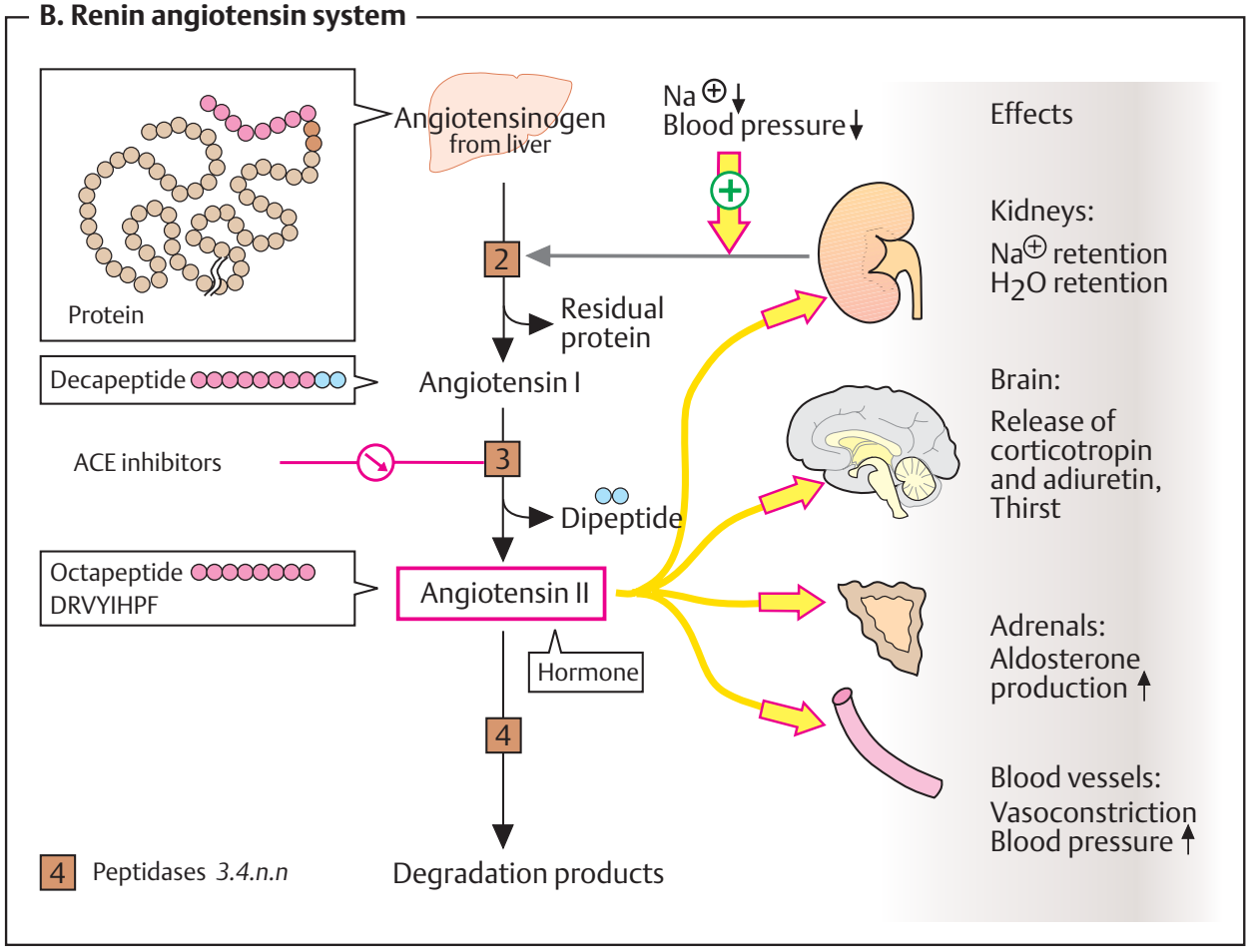

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Muscle contraction

The musculature is what makes movements possible. In addition to the **skeletal muscles**, which can be contracted voluntarily, there are also the autonomically activated **heart muscle** and **smooth muscle**, which is also involuntary. In all types of muscle, contraction is based on an interplay between the proteins actin and myosin.

A. Organization of skeletal muscle ◑

Striated muscle consists of parallel bundles of **muscle fibers.** Each fiber is a single large multinucleate cell. The cytoplasm in these cells contains **myofibrils** 2–3 μm thick that can extend over the full length of the muscle fiber.

The *striation* of the muscle fibers is characteristic of skeletal muscle. It results from the regular arrangement of molecules of differing density. The repeating contractile units, the **sarcomeres**, are bounded by Z lines from which thin filaments of **F-actin** (see p. 204) extend on each side. In the A bands, there are also thick parallel filaments of **myosin**. The H bands in the middle of the A bands only contain myosin, while only actin is found on each size of the Z lines.

Myosin is quantitatively the most important protein in the myofibrils, representing 65% of the total. It is shaped like a golf club (bottom right). The molecule is a hexamer consisting of two identical *heavy chains* (2 × 223 kDa) and four *light chains* (each about 20 kDa). Each of the two heavy chains has a globular "head" at its amino end, which extends into a "tail" about 150 nm long in which the two chains are intertwined to form a superhelix. The small subunits are attached in the head area. Myosin is present as a bundle of several hundred stacked molecules in the form of a *"thick myosin filament."* The head portion of the molecule acts as an *ATPase,* the activity of which is modulated by the small subunits.

Actin (42 kDa) is the most important component of the *"thin filaments."* It represents ca. 20–25% of the muscle proteins. **F-actin** is also an important component of the cytoskeleton (see p. 204). This filamentous polymer is held in equilibrium with its monomer, **G-actin.** The other protein components of muscle include tropomyosin and troponin. **Tropomyosin** (64 kDa) attaches to F-actin as a rod-like dimer and connects approximately seven actin units with each other. The heterotrimer **troponin** (78 kDa) is bound to one end of tropomyosin.

In addition to the above proteins, a number of other proteins are also typical of muscle—including *titin* (the largest known protein), *α-* and *β-actinin, desmin,* and *vimentin.*

B. Mechanism of muscle contraction ◑

The *sliding filament model* describes the mechanism involved in muscle contraction. In this model, sarcomeres become shorter when the thin and thick filaments slide alongside each other and telescope together, with ATP being consumed. During contraction, the following reaction cycle is repeated several times:

[**1**] In the initial state, the myosin heads are attached to actin. When ATP is bound, the heads detach themselves from the actin (the "plasticizing" effect of ATP).

[**2**] The myosin head hydrolyzes the bound ATP to ADP and P_i, but initially withholds the two reaction products. ATP cleavage leads to allosteric tension in the myosin head.

[**3**] The myosin head now forms a new bond with a neighboring actin molecule.

[**4**] The actin causes the release of the P_i, and shortly afterwards release of the ADP as well. This converts the allosteric tension in the myosin head into a conformational change that acts like a rowing stroke.

The cycle can be repeated for as long as ATP is available, so that the thick filaments are constantly moving along the thin filaments in the direction of the Z disk. Each rowing stroke of the 500 or so myosin heads in a thick filament produces a contraction of about 10 nm. During strong contraction, the process is repeated about five times per second. This leads to the whole complex of thin filaments moving together; the H band becomes shorter and the Z lines slide closer together.

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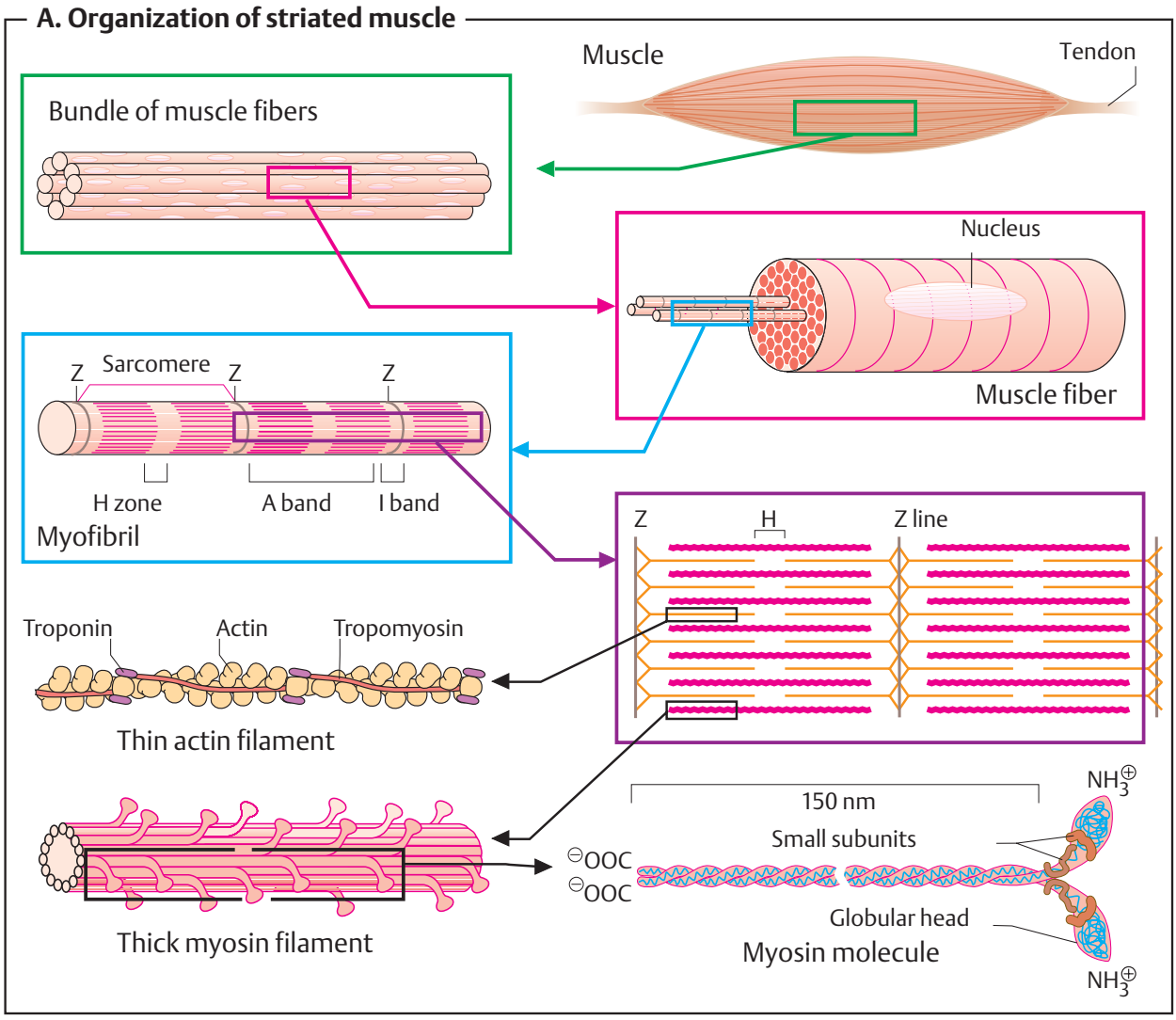

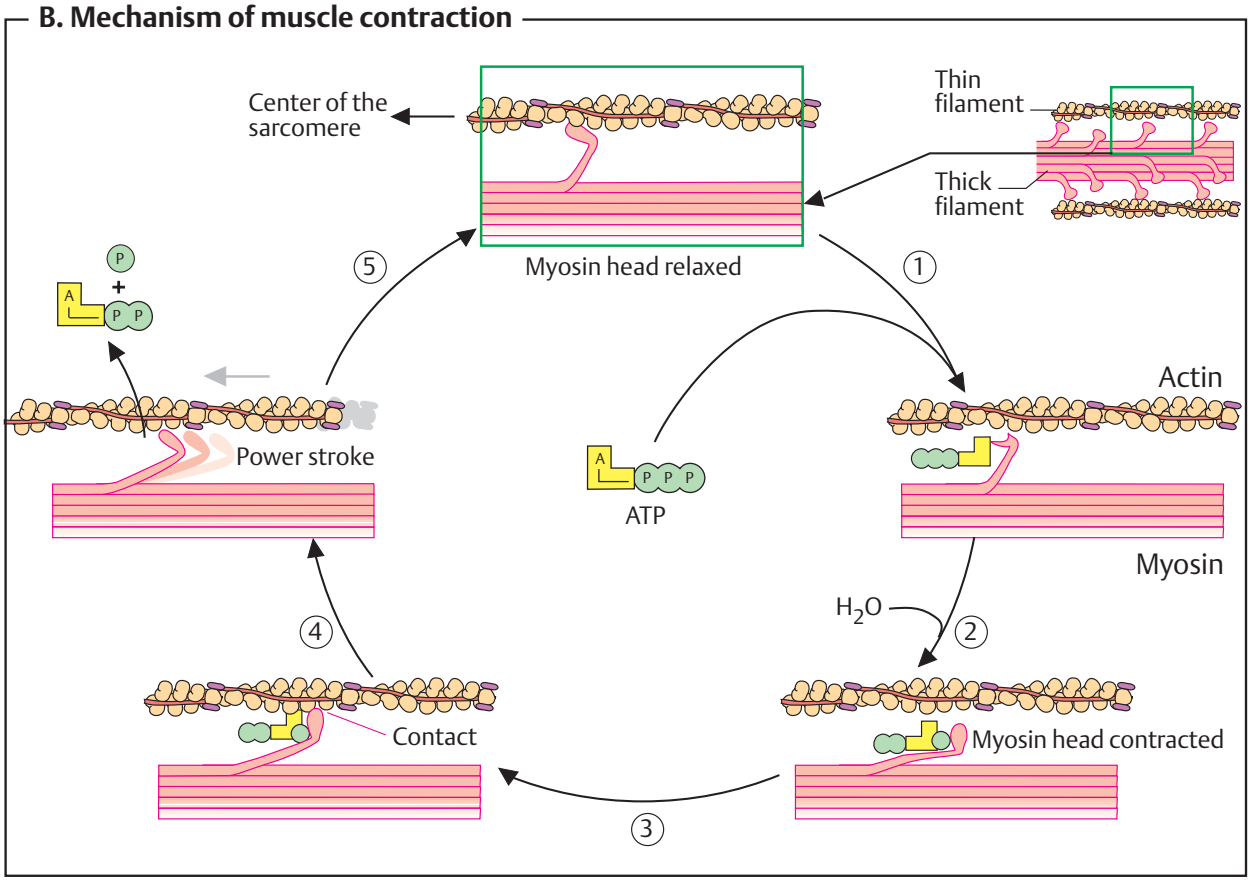

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Control of muscle contraction

A. Neuromuscular junction ◑

Muscle contraction is triggered by *motor neurons* that release the neurotransmitter *acetylcholine* (see p. 352). The transmitter diffuses through the narrow synaptic cleft and binds to nicotinic *acetylcholine receptors* on the plasma membrane of the muscle cell (the *sarcolemma*), thereby opening the ion channels integrated into the receptors (see p. 222). This leads to an inflow of Na^+, which triggers an *action potential* (see p. 350) in the sarcolemma. The action potential propagates from the end plate in all directions and constantly stimulates the muscle fiber. With a delay of a few milliseconds, the contractile mechanism responds to this by contracting the muscle fiber.

B. Sarcoplasmic reticulum (SR) ◑

The action potential (**A**) produced at the neuromuscular junction is transferred in the muscle cell into a transient increase in the Ca^{2+} concentration in the cytoplasm of the muscle fiber (the *sarcoplasm*).

In the resting state, the Ca^{2+} level in the sarcoplasm is very low (less than 10^{-7} M). By contrast, the **sarcoplasmic reticulum** (SR), which corresponds to the ER, contains Ca^{2+} ions at a concentration of about 10^{-3} M. The SR is a branched organelle that surrounds the myofibrils like a net stocking inside the muscle fibers (illustrated at the top using the example of a heart muscle cell). The high Ca^{2+} level in the SR is maintained by Ca^{2+}-transporting ATPases (see p. 220). In addition, the SR also contains *calsequestrin,* a protein (55 kDa) that is able to bind numerous Ca^{2+} -ions via acidic amino acid residues.

The transfer of the action potential to the SR is made possible by **transverse tubules** (T tubules), which are open to the extracellular space and establish a close connection with the SR. There is a structure involved in the contact between the T tubule and the SR that was formerly known as the "SR foot" (it involves parts of the *ryanodine receptor;* see p. 386).

At the point of contact with the SR, the action potential triggers the opening of the *Ca^{2+} channels* on the surface of the sarcolemma. Calcium ions then leave the SR and enter the sarcoplasm, where they lead to a rapid increase in Ca^{2+} concentrations. This in turn causes the myofibrils to contract (**C**).

C. Regulation by calcium ions ◑

In relaxed skeletal muscle, the complex consisting of **troponin** and **tropomyosin** blocks the access of the myosin heads to actin (see p. 332). Troponin consists of three different subunits (**T**, **C**, and **I**). The rapid increase in cytoplasmic Ca^{2+} concentrations caused by opening of the calcium channels in the SR leads to binding of Ca^{2+} to the C subunit of troponin, which closely resembles calmodulin (see p. 386). This produces a conformational change in troponin that causes the whole troponin–tropomyosin complex to slip slightly and expose a binding site for myosin (red). This initiates the contraction cycle. After contraction, the sarcoplasmic Ca^{2+} concentration is quickly reduced again by active transport back into the SR. This results in troponin losing the bound Ca^{2+} ions and returning to the initial state, in which the binding site for myosin on actin is blocked. It is not yet clear whether the mechanism described above is the only one that triggers binding of myosin to actin.

When **triggering of contraction** in striated muscle occurs, the following sequence of processes thus takes place:

1. The sarcolemma is depolarized.
2. The action potential is signaled to Ca^{2+} channels in the SR.
3. The Ca^{2+} channels open and the Ca^{2+} level in the sarcoplasm increases.
4. Ca^{2+} binds to troponin C and triggers a conformational change.
5. Troponin causes tropomyosin to slip, and the myosin heads bind to actin.
6. The actin–myosin cycle takes place and the muscle fibers contract.

Conversely, at the **end of contraction**, the following processes take place:

1. The Ca^{2+} level in the sarcoplasm declines due to transport of Ca^{2+} back into the SR.
2. Troponin C loses Ca^{2+} and tropomyosin returns to its original position on the actin molecule.
3. The actin–myosin cycle stops and the muscle relaxes.

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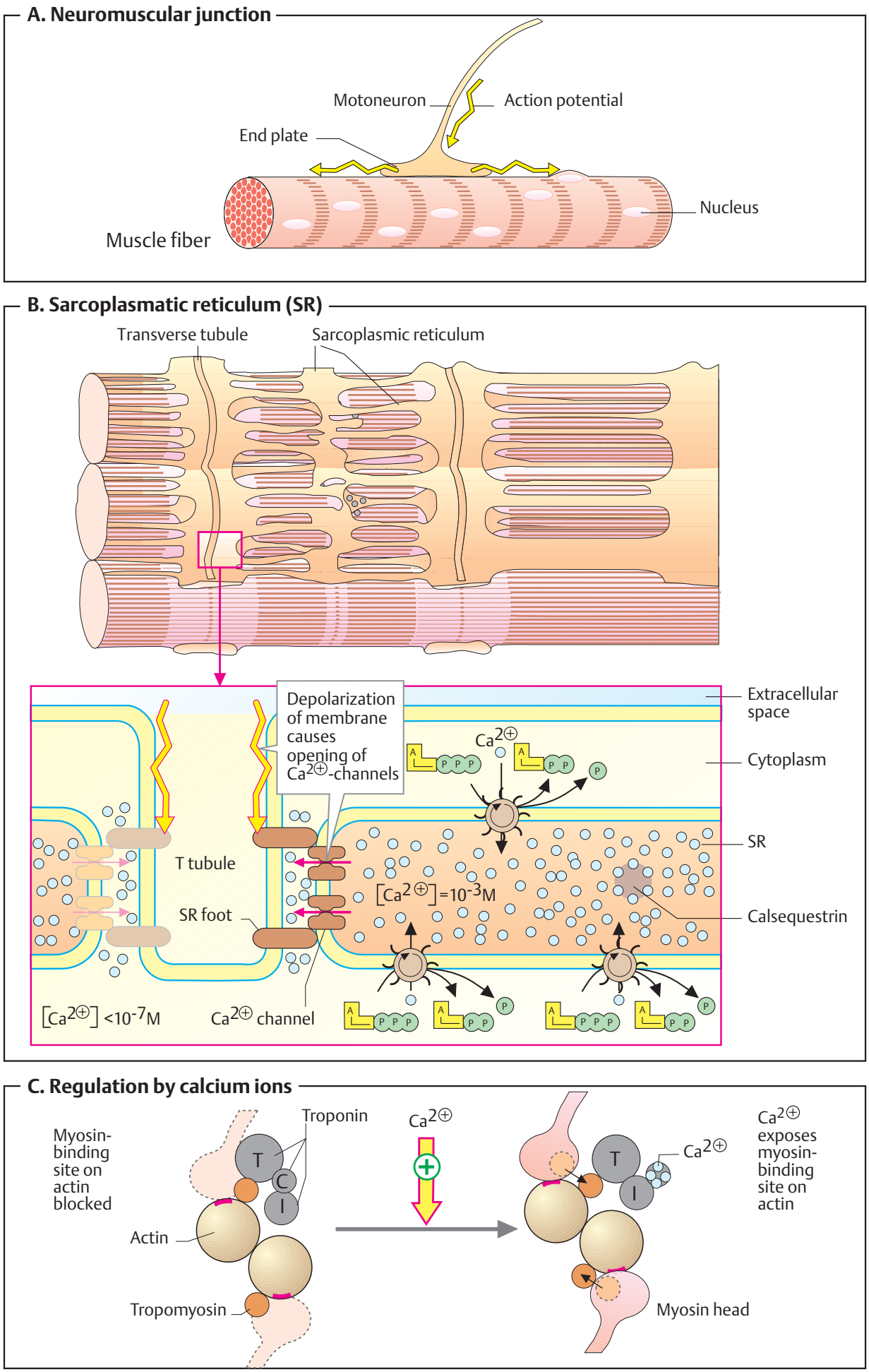

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Muscle metabolism I

Muscle contraction is associated with a high level of ATP consumption (see p. 332). Without constant resynthesis, the amount of ATP available in the resting state would be used up in less than 1 s of contraction.

A. Energy metabolism in the white and red muscle fibers ◑

Muscles contain two types of fibers, the proportions of which vary from one type of muscle to another. **Red fibers** (type I fibers) are suitable for prolonged effort. Their metabolism is mainly aerobic and therefore depends on an adequate supply of O_2. **White fibers** (type II fibers) are better suited for fast, strong contractions. These fibers are able to form suf cient ATP even when there is little O_2 available. With appropriate training, athletes and sports participants are able to change the proportions of the two fiber types in the musculature and thereby prepare themselves for the physiological demands of their disciplines in a targeted fashion. The expression of functional muscle proteins can also change during the course of training.

Red fibers provide for their ATP requirements mainly (but not exclusively) from **fatty acids**, which are broken down via β-oxidation, the tricarboxylic acid cycle, and the respiratory chain (right part of the illustration). The red color in these fibers is due to the monomeric heme protein **myoglobin**, which they use as an O_2 reserve. Myoglobin has a much higher af nity for O_2 than hemoglobin and therefore only releases its O_2 when there is a severe drop in O_2 partial pressure (cf. p. 282).

At a high level of muscular effort—e. g., during weightlifting or in very fast contractions such as those carried out by the eye muscles—the O_2 supply from the blood quickly becomes inadequate to maintain the aerobic metabolism. White fibers (left part of the illustration) therefore mainly obtain ATP from **anaerobic glycolysis**. They have supplies of **glycogen** from which they can quickly release glucose-1-phosphate when needed (see p. 156). By isomerization, this gives rise to glucose-6-phosphate, the substrate for glycolysis. The $NADH+H^+$ formed during glycolysis has to be reoxidized into NAD^+ in order to maintain glucose degradation and thus ATP formation. If there is a lack of O_2, this is achieved by the formation of **lactate**, which is released into the blood and is resynthesized into glucose in the liver (Cori cycle; see p. 338).

Muscle-specific auxiliary reactions for ATP synthesis exist in order to provide additional ATP in case of emergency. **Creatine phosphate** (see **B**) acts as a buffer for the ATP level. Another ATP-supplying reaction is catalyzed by *adenylate kinase* [1] (see also p. 72). This disproportionates two molecules of ADP into ATP and AMP. The AMP is deaminated into IMP in a subsequent reaction [2] in order to shift the balance of the reversible reaction [1] in the direction of ATP formation.

B. Creatine metabolism ◑

Creatine (*N*-methylguanidoacetic acid) and its phosphorylated form **creatine phosphate** (a guanidophosphate) serve as an ATP buffer in muscle metabolism. In creatine phosphate, the phosphate residue is at a similarly high chemical potential as in ATP and is therefore easily transferred to ADP. Conversely, when there is an excess of ATP, creatine phosphate can arise from ATP and creatine. Both processes are catalyzed by *creatine kinase* [5].

In resting muscle, creatine phosphate forms due to the high level of ATP. If there is a risk of a severe drop in the ATP level during contraction, the level can be maintained for a short time by synthesis of ATP from creatine phosphate and ADP. In a nonenzymatic reaction [6], small amounts of creatine and creatine phosphate cyclize constantly to form **creatinine**, which can no longer be phosphorylated and is therefore excreted with the urine (see p. 324).

Creatine does not derive from the muscles themselves, but is synthesized in two steps in the kidneys and liver (left part of the illustration). Initially, the guanidino group of arginine is transferred to glycine in the kidneys, yielding **guanidino acetate** [3]. In the liver, *N*-methylation of guanidino acetate leads to the formation of creatine from this [4]. The coenzyme in this reaction is *S-adenosyl methionine* (SAM; see p. 110).

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A. Energy metabolism in the white and red muscle fibers

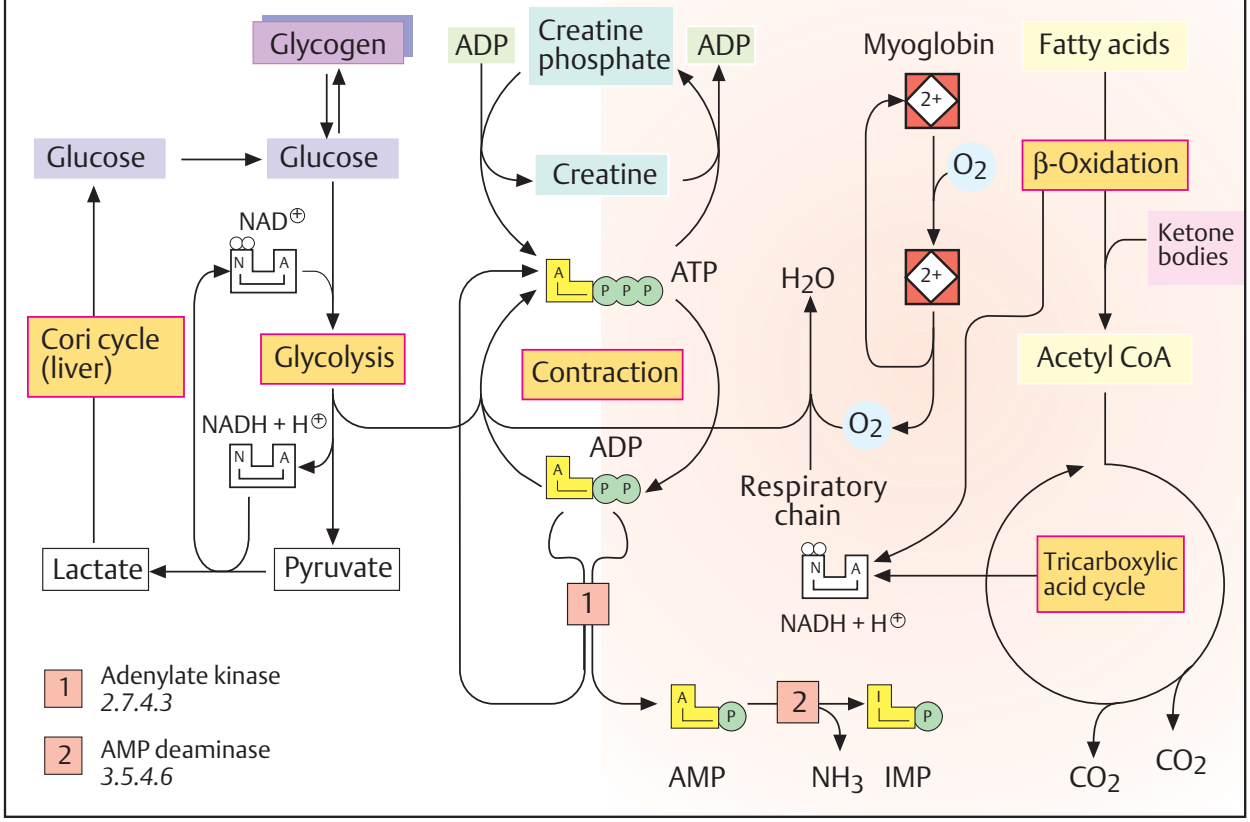

B. Creatine metabolism

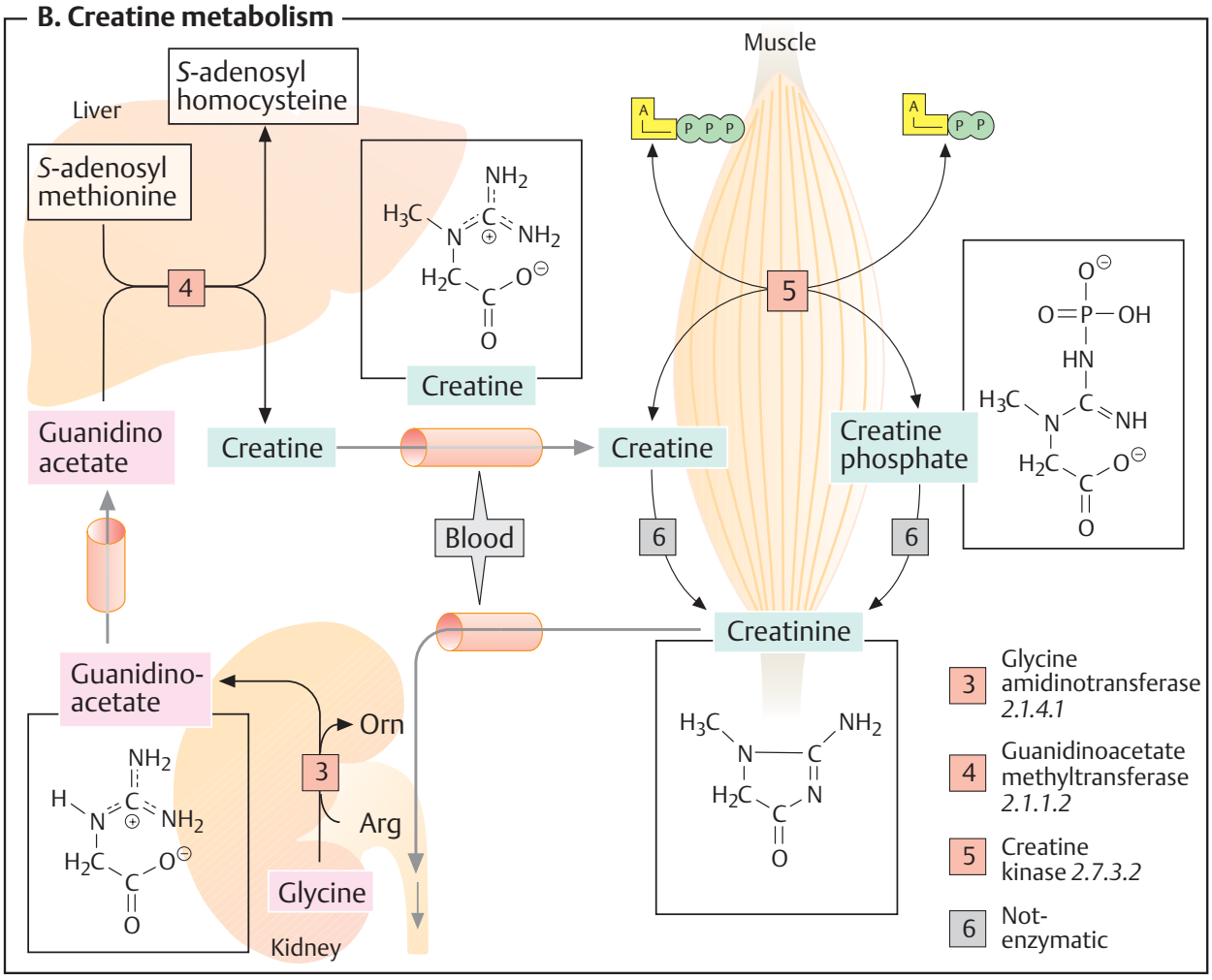

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Muscle metabolism II

A. Cori and alanine cycle ◑

White muscle fibers (see p. 336) mainly obtain ATP from **anaerobic glycolysis**—i. e., they convert glucose into lactate. The **lactate** arising in muscle and, in smaller quantities, its precursor **pyruvate** are released into the blood and transported to the liver, where lactate and pyruvate are resynthesized into glucose again via *gluconeogenesis,* with ATP being consumed in the process (see p. 154). The glucose newly formed by the liver returns via the blood to the muscles, where it can be used as an energy source again. This circulation system is called the **Cori cycle**, after the researchers who first discovered it. There is also a very similar cycle for erythrocytes, which do not have mitochondria and therefore produce ATP by anaerobic glycolysis (see p. 284).

The muscles themselves are not capable of gluconeogenesis. Nor would this be useful, as gluconeogenesis requires much more ATP than is supplied by glycolysis. As O_2 deficiencies do not arise in the liver even during intensive muscle work, there is always suf - cient energy there available for gluconeogenesis.

There is also a corresponding circulation system for the amino acid alanine. The **alanine cycle** in the liver not only provides alanine as a precursor for gluconeogenesis, but also transports to the liver the amino nitrogen arising in muscles during protein degradation. In the liver, it is incorporated into urea for excretion.

Most of the amino acids that arise in muscle during proteolysis are converted into glutamate and 2-oxo acids by *transamination* (not shown; cf. p. 180). Again by transamination, glutamate and pyruvate give rise to alanine, which after glutamine is the second important form of transport for amino nitrogen in the blood. In the liver, alanine and 2-oxoglutarate are resynthesized into pyruvate and glutamate (see p. 178). Glutamate supplies the urea cycle (see p. 182), while pyruvate is available for gluconeogenesis.

B. Protein and amino acid metabolism ◑

The skeletal muscle is the most important site for degradation of the *branched-chain amino acids* (Val, Leu, Ile; see p. 414), but other amino acids are also broken down in the muscles. **Alanine** and **glutamine** are resynthesized from the components and released into the blood. They transport the nitrogen that arises during amino acid breakdown to the liver (*alanine cycle;* see above) and to the kidneys (see p. 328).

During periods of hunger, **muscle proteins** serve as an energy reserve for the body. They are broken down into amino acids, which are transported to the liver. In the liver, the carbon skeletons of the amino acids are converted into intermediates in the tricarboxylic acid cycle or into acetoacetyl-CoA (see p. 175). These amphibolic metabolites are then available to the energy metabolism and for gluconeogenesis. After prolonged starvation, the brain switches to using ketone bodies in order to save muscle protein (see p. 356).

The synthesis and degradation of muscle proteins are regulated by hormones. **Cortisol** leads to muscle degradation, while **testosterone** stimulates protein formation. Synthetic **anabolics** with a testosterone-like effect have repeatedly been used for doping purposes or for intensive muscle-building.

Further information

Smooth muscle differs from skeletal muscle in various ways. Smooth muscles—which are found, for example, in blood vessel walls and in the walls of the intestines—do not contain any muscle fibers. In smooth-muscle cells, which are usually spindle-shaped, the contractile proteins are arranged in a less regular pattern than in striated muscle. Contraction in this type of muscle is usually not stimulated by nerve impulses, but occurs in a largely spontaneous way. Ca^{2+} (in the form of Ca^{2+}-calmodulin; see p. 386) also activates contraction in smooth muscle; in this case, however, it does not affect troponin, but activates a protein kinase that phosphorylates the light chains in myosin and thereby increases myosin's ATPase activity. Hormones such as epinephrine and angiotensin II (see p. 330) are able to influence vascular tonicity in this way, for example.

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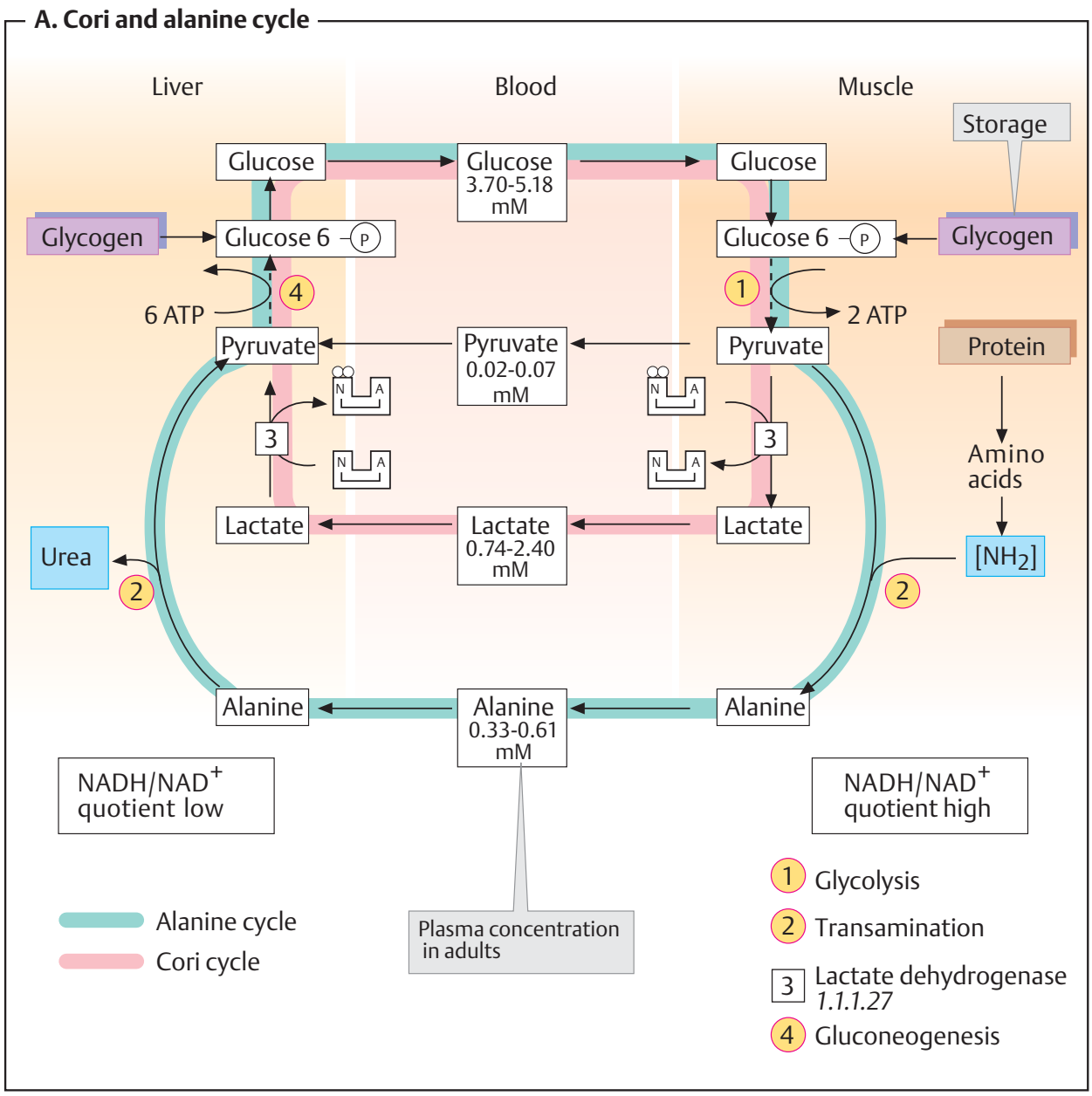

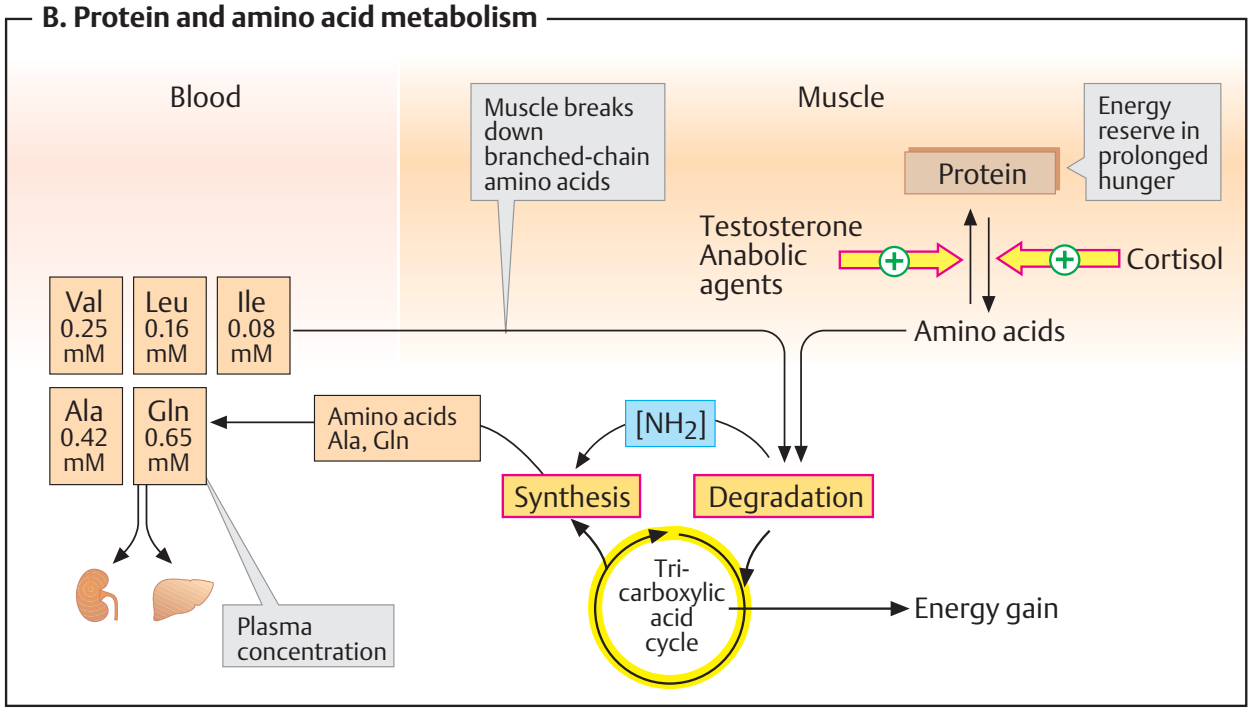

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Bone and teeth

The family of connective-tissue cells includes *fibroblasts, chondrocytes* (cartilage cells), and *osteoblasts* (bone-forming cells). They are specialized to secrete extracellular proteins, particularly collagens, and mineral substances, which they use to build up the *extracellular matrix* (see p. 346). By contrast, *osteoclasts* dissolve bone matter again by secreting H^+ and collagenases (see p. 342).

A. Bone ◑

Bone is an extremely dense, specialized form of connective tissue. In addition to its supportive function, it serves to store calcium and phosphate ions. In addition, blood cells are formed in the bone marrow. The most important mineral component of bone is **apatite**, a form of crystalline *calcium phosphate.*

Apatites are complexes of cationic Ca^{2+} matched by HPO_4^{2-}, CO_3^{2-}, OH^-, or F^- as anions. Depending on the counter-ion, apatite can occur in the forms *carbonate apatite* $Ca_{10}(PO_4)_6CO_3$, as *hydroxyapatite* $Ca_{10}(PO_4)_6(OH)_2$, or *fluoroapatite* $Ca_{10}(PO_4)_6F_2$. In addition, alkaline earth carbonates also occur in bone. In adults, more than 1 kg calcium is stored in bone.

Osteoblast and *osteoclast* activity is constantly incorporating Ca^{2+} into bone and removing it again. There are various hormones that regulate these processes: *calcitonin* increases deposition of Ca^{2+} in the bone matrix, while *parathyroid hormone* (PTH) promotes the mobilization of Ca^{2+}, and *calcitriol* improves mineralization (for details, see p. 342).

The most important *organic components* of bone are **collagens** (mainly type I; see p. 344) and **proteoglycans** (see p. 346). These form the extracellular matrix into which the apatite crystals are deposited (*biomineralization*). Various proteins are involved in this not yet fully understood process of bone formation, including collagens and phosphatases. *Alkaline phosphatase* is found in osteoblasts and *acid phosphatase* in osteoclasts. Both of these enzymes serve as *marker enzymes* for bone cells.

B. Teeth ◑

The illustration shows a longitudinal section through an incisor, one of the 32 permanent teeth in humans. The majority of the tooth consists of **dentine**. The crown of the tooth extends beyond the gums, and it is covered in **enamel**. By contrast, the root of the tooth is coated in dental **cement**.

Cement, dentin, and enamel are bone-like substances. The high proportion of inorganic matter they contain (about 97% in the dental enamel) gives them their characteristic hardness. The organic components of cement, dentin, and enamel mainly consist of *collagens* and *proteoglycans;* their most important mineral component is *apatite,* as in bone (see above).

A widespread form of dental disease, **caries**, is caused by acids that dissolve the mineral part of the teeth by neutralizing the negatively charged counter-ions in apatite (see **A**). Acids occur in food, or are produced by microorganisms that live on the surfaces of the teeth (e. g., *Streptococcus mutans*).

The main product of anaerobic degradation of sugars by these organisms is lactic acid. Other products of bacterial carbohydrate metabolism include extracellular dextrans (see p. 40)—insoluble polymers of glucose that help bacteria to protect themselves from their environment. Bacteria and dextrans are components of *dental plaque,* which forms on inadequately cleaned teeth. When Ca^{2+} salts and other minerals are deposited in plaque as well, *tartar* is formed.

The most important form of protection against caries involves avoiding sweet substances (foods containing saccharose, glucose, and fructose). Small children in particular should not have very sweet drinks freely available to them. Regular removal of plaque by cleaning the teeth and hardening of the dental enamel by fluoridization are also important. Fluoride has a protective effect because fluoroapatite (see **A**) is particularly resistant to acids.

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A. Bone

Functions:
Mechanical support
Storage for $Ca^{2\oplus}$ and phosphate
Synthesis of blood cells
Maturation of B cells

Composition:
Inorganic
Apatite
Carbonate
Water
Organic
Type I collagen
Proteoglycans
Phosphatases

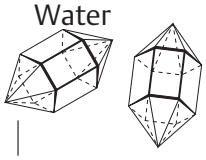

Hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$

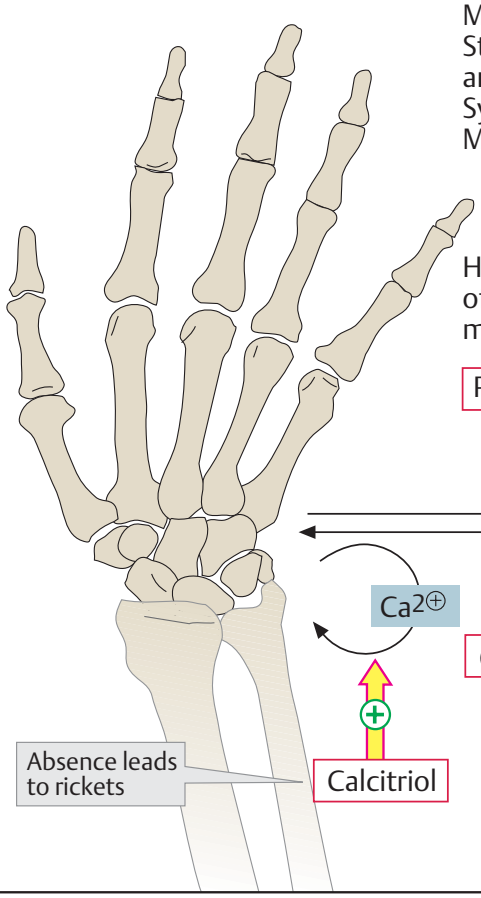

Hormones of the calcium metabolism

Parathyroid hormone (+)
$Ca^{2\oplus}$ in plasma
$Ca^{2\oplus}$
Calcitonin (+)
Calcitriol (+)
Absence leads to rickets

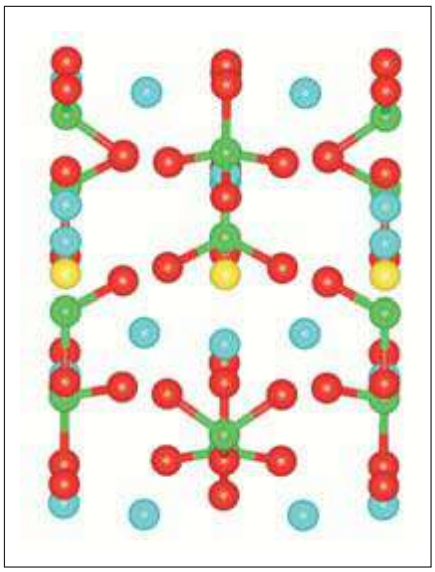

O
Ca
P
$OH^{\ominus}$

B. Teeth

Hardest substance in the body

Dental enamel	97%
Dentin	70%
Cement	65%
Jawbone	45%

Crown
Neck
Root
Dental plaque
Inorganic components

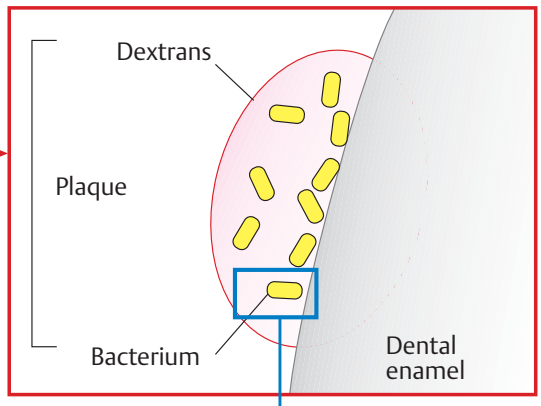

Protect bacteria
Sugar
Saccharose
Glucose
Fructose
Attack apatite
Dental enamel
Dextrans
Anaerobic metabolism
Acids
Lactic acid
Propionic acid
Acetic acid
Butyric acid
Bacterium E.g., *Streptococcus mutans*
Calcium salts
De-mineral-ization

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Calcium metabolism

A. Functions of calcium ●

The human body contains 1–1.5 kg Ca^{2+}, most of which (about 98%) is located in the mineral substance of bone (see p. 362).

In addition to its role as a **bone component**, calcium functions as a **signaling substance**. Ca^{2+} ions act as *second messengers* in signal transduction pathways (see p. 386), they trigger *exocytosis* (see p. 228) and *muscle contraction* (see p. 334), and they are indispensable as cofactors in *blood coagulation* (see p. 290). Many *enzymes* also require Ca^{2+} for their activity. The intracellular and extracellular concentrations of Ca^{2+} are strictly regulated in order to make these functions possible (see **B**, **C**, and p. 388).

Proteins bind Ca^{2+} via oxygen ligands, particularly carboxylate groups and carbonyl groups of peptide bonds. This also applies to the structure illustrated here, in which a Ca^{2+} ion is coordinated by the oxygen atoms of carboxylate and acid amide groups.

B. Bone remodeling ◑

Deposition of Ca^{2+} in bone (*mineralization*) and Ca^{2+} mobilization from bone are regulated by at least 15 hormones and hormone-like signaling substances. These mainly influence the maturation and activity of bone cells.

Osteoblasts (top) deposit collagen, as well as Ca^{2+} and phosphate, and thereby create new bone matter, while **osteoclasts** (bottom) secrete H^+ ions and collagenases that locally dissolve bone (*bone remodeling*). Osteoblasts and osteoclasts mutually activate each other by releasing **cytokines** (see p. 392) and **growth factors**. This helps keep bone formation and bone breakdown in balance.

The Ca^{2+}-selective hormones calcitriol, parathyroid hormone, and calcitonin influence this interaction in the bone cells. **Parathyroid hormone** promotes Ca^{2+} release by promoting the release of cytokines by osteoblasts. In turn, the cytokines stimulate the development of mature osteoclasts from precursor cells (bottom). **Calcitonin** inhibits this process. At the same time, it promotes the development of osteoblasts (top). *Osteoporosis,* which mainly occurs in women following the menopause, is based (at least in part) on a reduction in **estrogen** levels. Estrogens normally inhibit the stimulation of osteoclast differentiation by osteoblasts. If the effects of estrogen decline, the osteoclasts predominate and excess bone removal occurs.

The effects of the steroid hormone **calcitriol** (see p. 330) in bone are complex. On the one hand, it promotes bone formation by stimulating osteoblast differentiation (top). This is particularly important in small children, in whom calcitriol deficiency can lead to mineralization disturbances (*rickets;* see p. 364). On the other hand, calcitriol increases blood Ca^{2+} levels through increased Ca^{2+} mobilization from bone. An overdose of vitamin D (cholecalciferol), the precursor of calcitriol, can therefore have unfavorable effects on the skeleton similar to those of vitamin deficiency (*hypervitaminosis;* see p. 364).

C. Calcium homeostasis ◑

Ca^{2+} metabolism is balanced in healthy adults. Approximately 1 g Ca^{2+} is taken up per day, about 300 mg of which is resorbed. The same amount is also excreted again. The amounts of Ca^{2+} released from bone and deposited in it per day are much smaller. Milk and milk products, especially cheese, are particularly rich in calcium.

Calcitriol and parathyroid hormone, on the one hand, and calcitonin on the other, ensure a more or less constant level of Ca^{2+} in the blood plasma and in the extracellular space (80–110 mg 2.0–2.6 mM). The peptide **parathyroid hormone** (PTH; 84 AA) and the steroid **calcitriol** (see p. 374) promote direct or indirect processes that raise the Ca^{2+} level in blood. Calcitriol increases Ca^{2+} resorption in the intestines and kidneys by inducing transporters. Parathyroid hormone supports these processes by stimulating calcitriol biosynthesis in the kidneys (see p. 330). In addition, it directly promotes resorption of Ca^{2+} in the kidneys (see p. 328) and Ca^{2+} release from bone (see **B**). The PTH antagonist **calcitonin** (32 AA) counteracts these processes.

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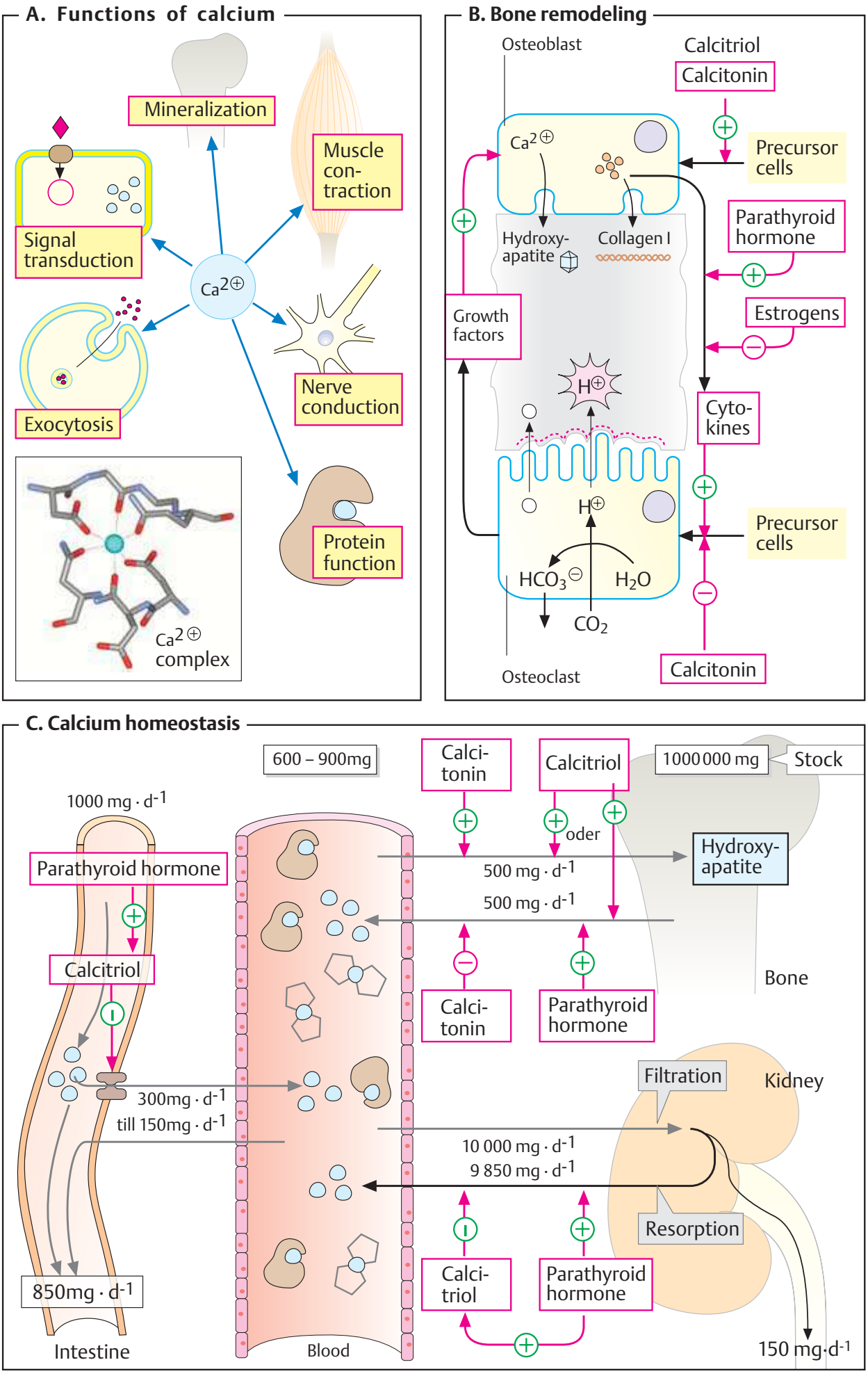

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Collagens

Collagens are quantitatively the most abundant of animal proteins, representing 25% of the total. They form insoluble tensile fibers that occur as structural elements of the extracellular matrix and connective tissue throughout the body. Their name (which literally means "glue-producers") is derived from the gelatins that appear as a decomposition product when collagen is boiled.

A. Structure of collagens ◑

Nineteen different collagens are now known, and they are distinguished using roman numerals. They mostly consist of a dextrorotatory **triple helix** made up of three polypeptides (α-chains) (see p. 70).

The triplet **Gly-X-Y** is constantly repeated in the sequence of the triple-helical regions—i. e., every third amino acid in such sequences is a *glycine*. *Proline* (Pro) is frequently found in positions X or Y; the Y position is often occupied by *4-hydroxyproline* (4Hyp), although *3-hydroxyproline* (3Hyp) and *5-hydroxylysine* (5Hyl) also occur. These hydroxylated amino acids are characteristic components of collagen. They are only produced after protein biosynthesis by **hydroxylation** of the amino acids in the peptide chain (see p. 62).

The formation of Hyp and Hyl residues in procollagen is catalyzed by iron-containing *oxygenases* ("proline and lysine hydroxylase," *EC 1.14.11.1/2*). *Ascorbate* is required to maintain their function. Most of the symptoms of the vitamin C deficiency disease *scurvy* (see p. 368) are explained by disturbed collagen biosynthesis.

The hydroxyproline residues stabilize the triple helix by forming hydrogen bonds between the α-chains, while the hydroxyl groups of hydroxylysine are partly **glycosylated** with a disaccharide (–Glc–Gal).

The various types of collagen consist of different combinations of α-chains (α1 to α3 and other subtypes). Types I, II, and III represent 90% of collagens. The **type I** collagen shown here has the structure $[\alpha1(I)]_2\alpha2(1)$.

Numerous **tropocollagen** molecules (mass 285 kDa, length 400 nm) aggregate extracellularly into a defined arrangement, forming cylindrical **fibrils** (20–500 nm in diameter). Under the electron microscope, these fibrils are seen to have a characteristic banding pattern of elements that are repeated every 64–67 nm.

Tropocollagen molecules are firmly linked together, particularly at their ends, by covalent networks of altered lysine side chains. The number of these links increases with age. **Type IV** collagens form networks with a defined mesh size. The size-selective filtering effect of the basal membranes in the renal glomeruli is based on this type of structure (see p. 322).

B. Biosynthesis ◑

The precursor molecule of collagen (*preprocollagen*), formed in the rER, is subject to extensive **post-translational modifications** (see p. 232) in the ER and Golgi apparatus.

Cleavage of the signal peptide gives rise to **procollagen**, which still carries large *propeptides* at each end [1]. During this phase, most proline residues and some lysine residues of procollagen are hydroxylated [2]. The procollagen is then glycosylated at hydroxylysine residues [3]. Intramolecular and intermolecular disulfide bonds form in the propeptides [4], allowing correct positioning of the peptide strands to form a triple helix [5]. It is only after these steps have been completed that procollagen is secreted into the extracellular space by exocytosis. This is where the *N*- and *C*-terminal propeptides are removed proteolytically [6], allowing the staggered aggregation of the **tropocollagen** molecules to form fibrils [7]. Finally, several ε-amino groups in lysine residues are oxidatively converted into aldehyde groups [8]. Covalent links between the molecules then form as a result of condensation [9]. In this way, the fibrils reach their final structure, which is characterized by its high *tensile strength* and *proteinase resistance.*

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A. Structure of collagens

Special amino acids:
4-Hydroxyproline (4Hyp)
3-Hydroxyproline (3Hyp)
5-Hydroxylysine (5Hyl)

– Gly – X – Y – Gly – X – Y – Gly – X – Y –

Basic unit

Primary structure

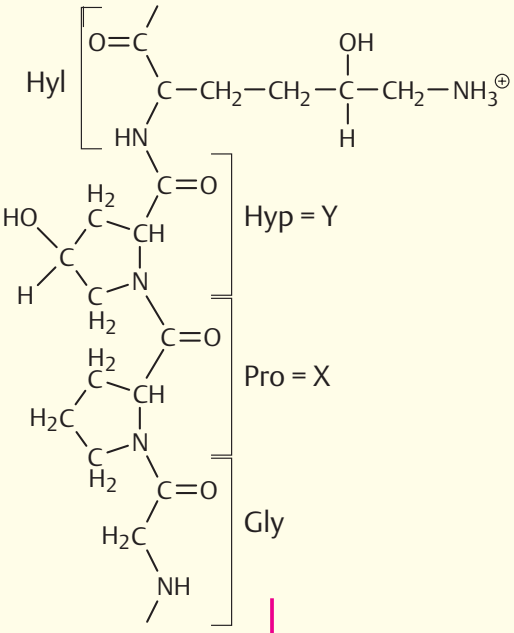

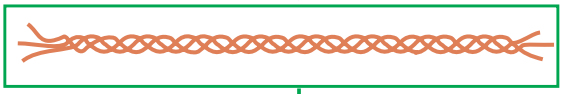

Type I tropocollagen ~285 kDa

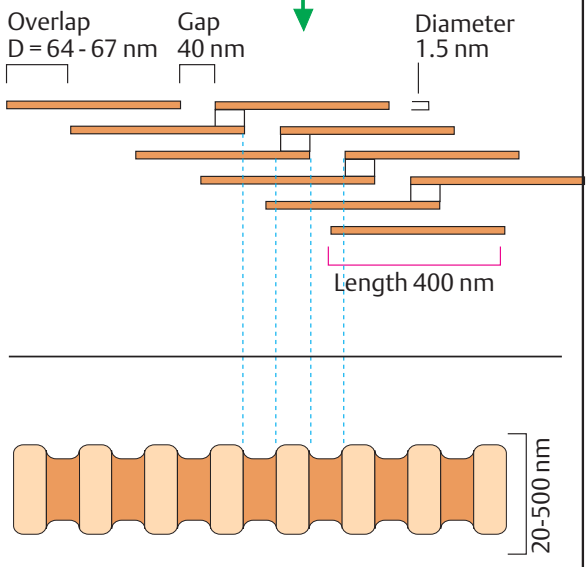

Collagen fibril (section)

B. Biosynthesis

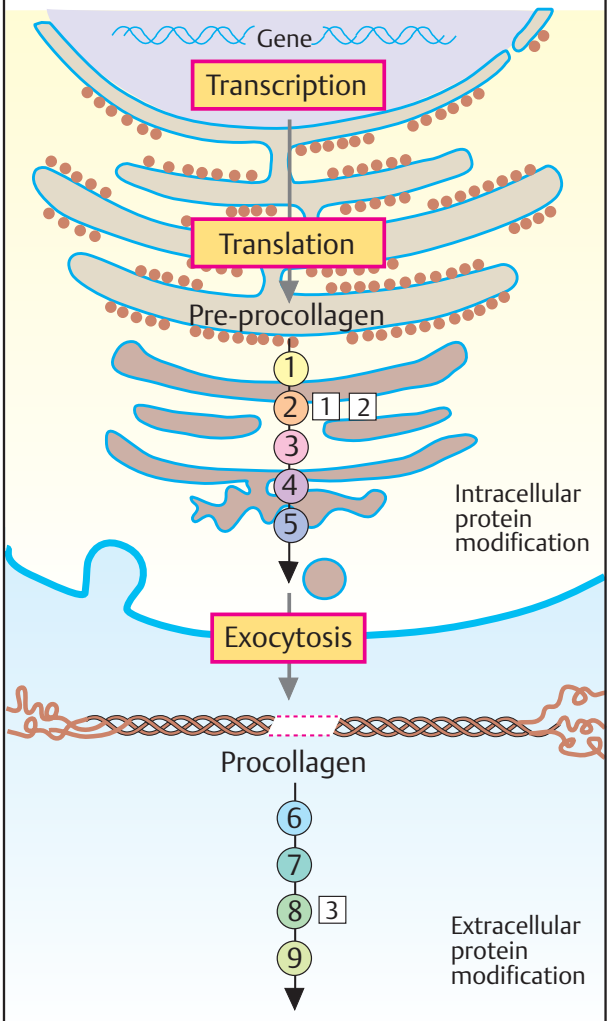

Collagen fibril

1. Removal of the prepeptide
2. Hydroxylation of Pro and Lys residues
3. Glycosylation of 5Hyl and Asn
4. Oxidation of Cys in propeptides
5. Assemblage to form triple helix
6. Removal of the propeptide
7. Staggered deposition to form fibrils
8. Oxidation of Lys and 5Hyl to aldehydes
9. Cross-linking to form supramolecules

[1] Procollagen-proline 4-dioxygenase *1.14.11.2* [ascorbate, Fe]
[2] Procollagen-lysine 5-dioxygenase *1.14.11.4* [ascorbate, Fe]
[3] Protein-lysine 6-oxidase *1.4.3.13* [Cu]

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Extracellular matrix

A. Extracellular matrix ◑

The space between the cells (the interstitium) is occupied by a substance with a complex composition known as the **extracellular matrix** (ECM). In many types of tissue—e.g., muscle and liver—the ECM is only a narrow border between the cells, while in others it forms a larger space. In *connective tissue, cartilage,* and *bone,* the ECM is particularly strongly marked and is actually the functional part of the tissue (see p. 340). The illustration shows the three main constituents of the extracellular matrix in a highly schematic way: collagen fibers, network-forming adhesive proteins, and space-filling proteoglycans.

The ECM has a very wide variety of functions: it establishes mechanical connections between cells; it creates structures with special mechanical properties (as in bone, cartilage, tendons, and joints); it creates filters (e.g., in the basal membrane in the renal corpuscles; see p. 322); it separates cells and tissues from each other (e.g., to allow the joints to move freely); and it provides pathways to guide migratory cells (important for embryonic development). The chemical composition of the ECM is just as diverse as its functions.

Collagens (see p. 344), of which there are at least 19 different varieties, form fibers, fibrils, networks, and ligaments. Their characteristic properties are *tensile strength* and *flexibility*. **Elastin** is a fiber protein with a high degree of elasticity.

Adhesive proteins provide the connections between the various components of the extracellular matrix. Important representatives include **laminin** and **fibronectin** (see **B**). These multifunctional proteins simultaneously bind to several other types of matrix component. Cells attach to the cell surface receptors in the ECM with the help of the adhesive proteins.

Due to their polarity and negative charge, **proteoglycans** (see **C**) bind water molecules and cations. As a homogeneous "cement," they fill the gaps between the ECM fibers.

B. Fibronectins ○

Fibronectins are typical representatives of adhesive proteins. They are filamentous dimers consisting of two related peptide chains (each with a mass of 250 kDa) linked to each other by disulfide bonds. The fibronectin molecules are divided into different *domains,* which bind to cell-surface receptors, collagens, fibrin, and various proteoglycans. This is what gives fibronectins their *"molecular glue"* characteristics.

The domain structure in fibronectins is made up of a few types of *peptide module* that are repeated numerous times. Each of the more than 50 modules is coded for by one exon in the fibronectin gene. *Alternative splicing* (see p. 246) of the hnRNA transcript of the fibronectin gene leads to fibronectins with different compositions. The module that causes adhesion to cells contains the characteristic amino acid sequence –Arg–Gly–Asp–Ser–. It is these residues that enable fibronectin to bind to cell-surface receptors, known as **integrins**.

C. Proteoglycans ◑

Proteoglycans are giant molecule complexes consisting of carbohydrates (95%) and proteins (5%), with masses of up to 2 10^6 Da. Their bottlebrush-shaped structure is produced by an axis consisting of **hyaluronate**. This thread-like polysaccharide (see p. 44) has **proteins** attached to it, from which in turn long polysaccharide chains emerge. Like the central hyaluronate, these terminal polysaccharides belong to the glycosaminoglycan group (see p. 44).

The **glycosaminoglycans** are made up of repeating disaccharide units, each of which consists of one *uronic acid* (glucuronic acid or iduronic acid) and one *amino sugar* (*N*-acetylglucosamine or *N*-acetylgalactosamine) (see p. 38). Many of the amino sugars are also esterified with sulfuric acid (sulfated), further increasing their polarity. The proteoglycans bind large amounts of water and fill the gaps between the fibrillar components of the ECM in the form of a hydrated gel. This inhibits the spread of pathogens in the ECM, for example.

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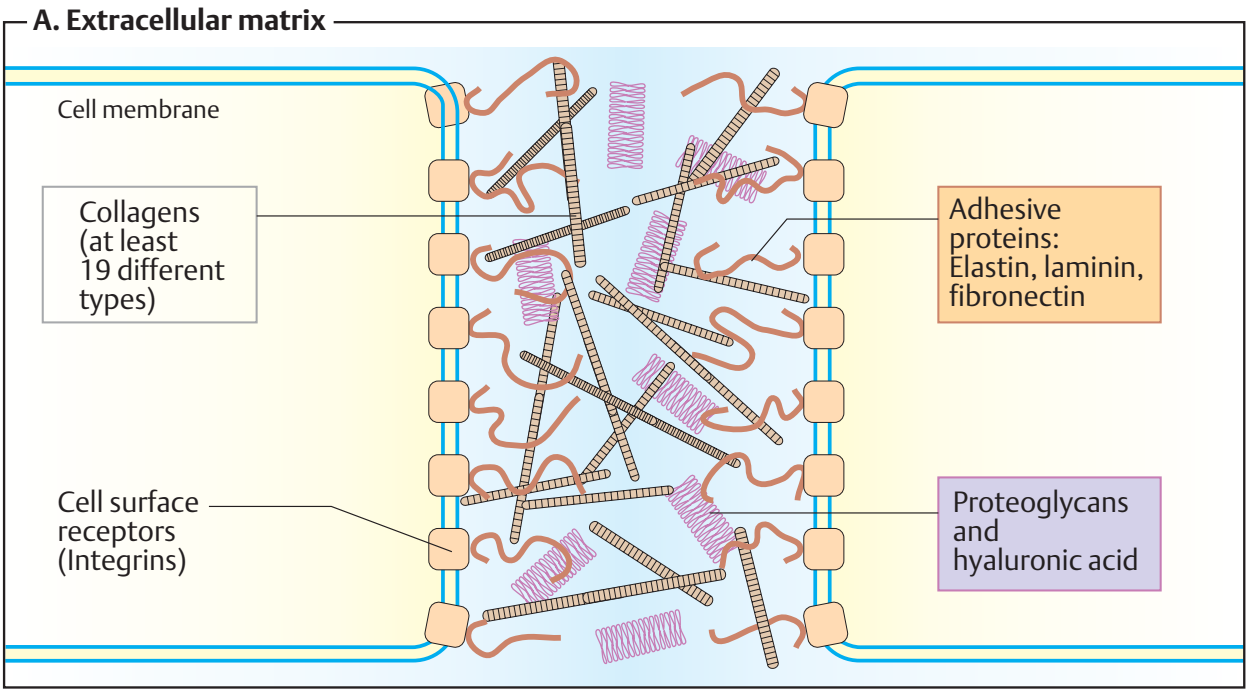

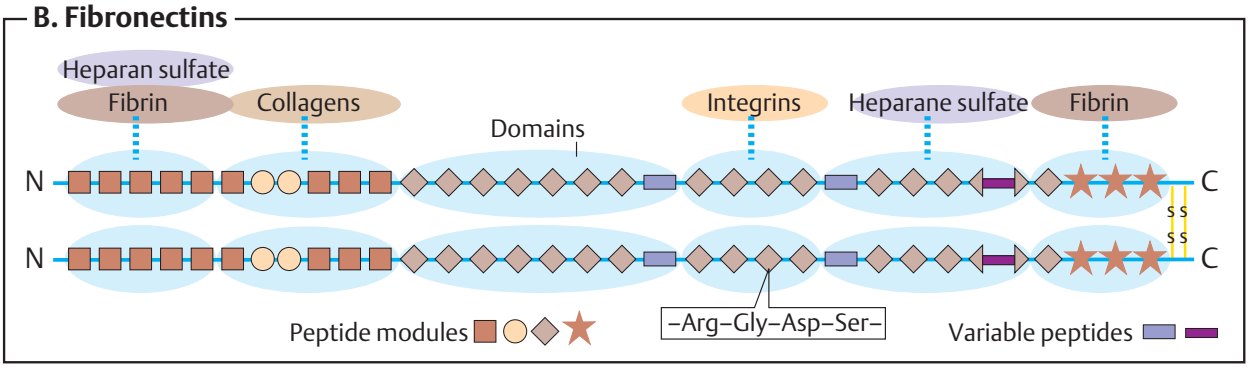

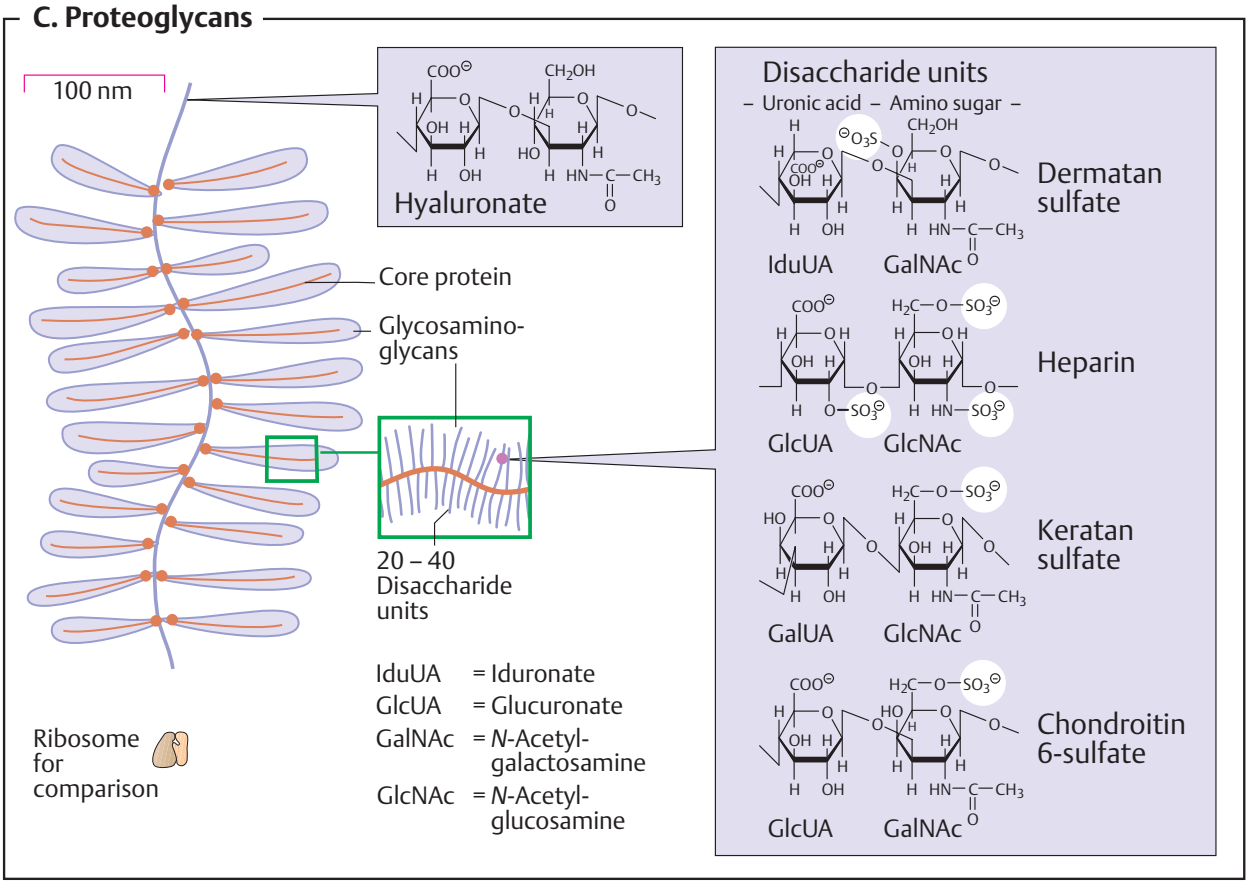

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Signal transmission in the CNS

A. Structure of nerve cells ●

Nerve cells (neurons) are easily excitable cells that produce electrical signals and can react to such signals as well. Their structure is markedly different from that of other types of cell. Numerous branching processes project from their **cell body** (soma). Neurons are able to receive signals via **dendrites** and to pass them on via **axons**. The axons, which can be up to 1 m long, are usually surrounded by *Schwann cells,* which cover them with a lipid-rich myelin sheath to improve their electrical insulation.

The transfer of stimuli occurs at the **synapses,** which link the individual neurons to each other as well as linking neurons functionally to muscle fibers. *Neurotransmitters* (see p. 352) are stored in the axonal nerve endings. These signaling substances are released in response to electrical signals in order to excite neighboring neurons (or muscle cells). It is estimated that each neuron in the brain is in contact via synapses with approximately 10 000 other neurons.

There is a noticeably high proportion of lipids in the composition of nerve cells, representing about 50% of their dry weight. In particular, there is a very wide variety of phospholipids, glycolipids, and sphingolipids (see p. 216).

B. Neurotransmitters and neurohormones ◑

Neurosecretions are classed into two groups: **neurotransmitters** are released into the *synaptic cleft* in order to influence neighboring cells (**C**). They have a short range and a short lifespan. By contrast, **neurohormones** are released into the blood, allowing them to cover larger distances. However, the distinction between the two groups is a fluid one; some neurotransmitters simultaneously function as neurohormones.

C. Synaptic signal transmission ◑

All chemical synapses function according to a similar principle. In the area of the synapse, the surface of the signaling cell (*presynaptic membrane*) is separated from the surface of the receiving cell (*postsynaptic membrane*) only by a narrow *synaptic cleft*. When an **action potential** (see p. 350) reaches the presynaptic membrane, *voltage-gated Ca^{2+} channels* integrated into the membrane open and trigger **exocytosis** of the neurotransmitter stored in the presynaptic cell (for details, see p. 228).

Each neuron usually releases *only one type* of **neurotransmitter**. Neurons that release dopamine are referred to as "dopaminergic," for example, while those that release acetylcholine are "cholinergic," etc. The transmitters that are released diffuse through the synaptic cleft and bind on the other side to **receptors** on the postsynaptic membrane. These receptors are integral membrane proteins that have binding sites for neurotransmitters on their exterior (see p. 224).

The receptors for neurotransmitters are divided into two large groups according to the effect produced by binding of the transmitter (for details, see p. 354).

Ionotropic receptors (bottom left) are *ligand-gated ion channels.* When they open as a result of the transmitter's influence, ions flow in due to the membrane potential (see p. 126). If the inflowing ions are cations (Na^+, K^+, Ca^{2+}), **depolarization** of the membrane occurs and an action potential is triggered on the surface of the postsynaptic cell. This is the way in which stimulatory transmitters work (e.g., acetylcholine and glutamate). By contrast, if anions flow in (mainly Cl^-), the result is **hyperpolarization** of the postsynaptic membrane, which makes the production of a postsynaptic action potential more dif cult. The action of inhibitory transmitters such as glycine and GABA is based on this effect.

A completely different type of effect is observed in **metabotropic receptors** (bottom right). After binding of the transmitter, these interact on the inside of the postsynaptic membrane with *G proteins* (see p. 384), which in turn activate or inhibit the synthesis of **second messengers**. Finally, second messengers activate or inhibit **protein kinases**, which phosphorylate cellular proteins and thereby alter the behavior of the postsynaptic cells (*signal transduction;* see p. 386).

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A. Structure of nerve cells

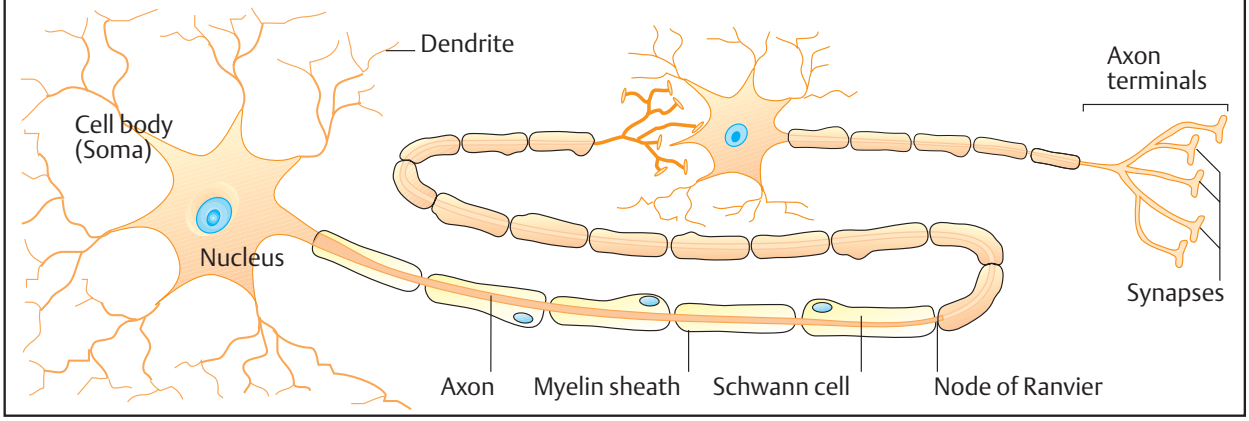

A. Neurotransmitters and neurohormones

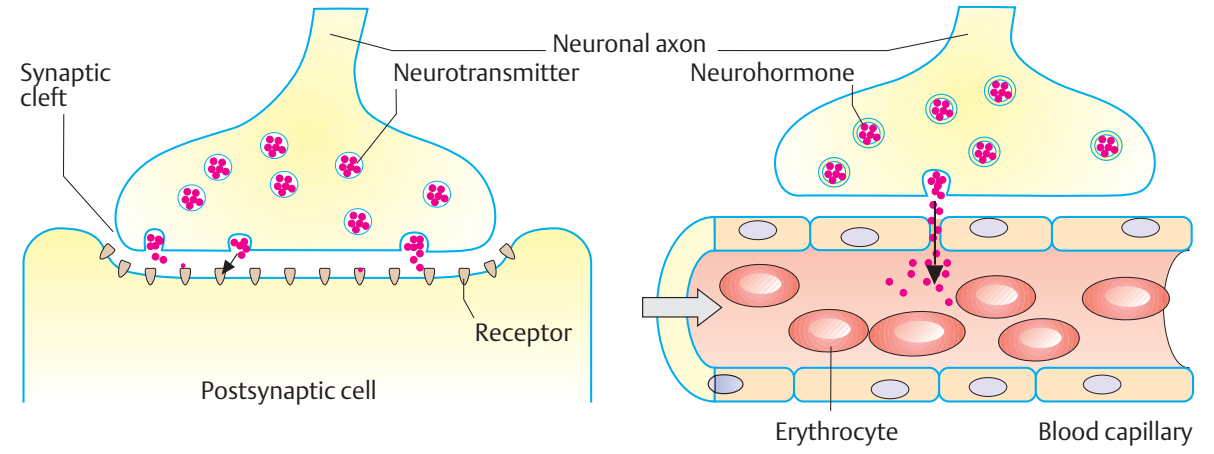

C. Synaptic signal transmission

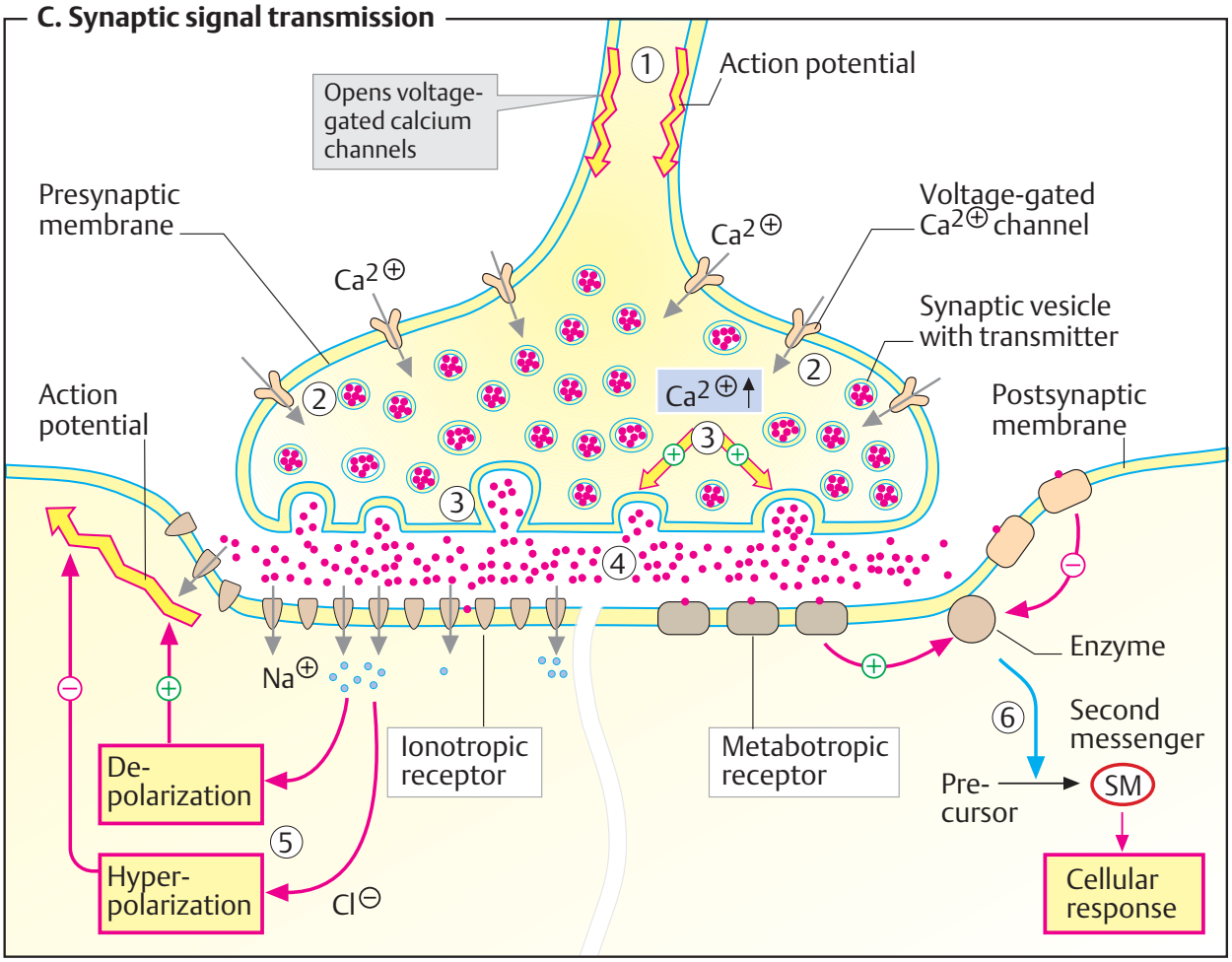

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Resting potential and action potential

A. Resting potential ◑

A characteristic property of living cells is the uneven distribution of positively and negatively charged ions on the inside and outside of the plasma membrane. This gives rise to a **membrane potential** (see p. 126)—i. e., there is electrical voltage between the two sides of the membrane, which can only balance out when *ion channels* allow the unevenly distributed ions to move.

At rest, the membrane potential in most cells is –60 to –90 mV. It mainly arises from the activity of *Na^+/K^+ transporting ATPase* ("Na^+/K^+ ATPase"), which occurs on practically all animal cells. Using up ATP, this P-type enzyme (see p. 220) "pumps" three Na^+ ions out of the cell in exchange for two K^+ ions. Some of the K^+ ions, following the concentration gradient, leave the cell again through *potassium channels*. As the protein anions that predominate inside the cell cannot follow them, and inflow of Cl^- ions from the outside is not possible, the result is an excess of positive charges outside the cell, while anions predominate inside it.

An **equilibrium potential** exists for each of the ions involved. This is the value of the membrane potential at which there is no net inflow or outflow of the ions concerned. For K^+ ions, the resting potential lies in the range of the membrane potential, while for Na^+ ions it is much higher at +70 mV. At the first opportunity, Na^+ ions will therefore spontaneously flow into the cell. The occurrence of action potentials is based on this (see **B**).

Nerve cell membranes contain **ion channels** for Na^+, K^+, Cl^-, and Ca^{2+}. These channels are usually closed and open only briefly to let ions pass through. They can be divided into channels that are regulated by membrane potentials ("*voltage-gated*"—e. g., fast Na^+ channels; see p. 222) and those regulated by ligands ("*ligand-gated*"—e. g., nicotinic acetylcholine receptors; see p. 222).

B. Action potential ◑

Action potentials are special signals that are used to transmit information in the nervous system. They are triggered by chemical stimuli (or more rarely electrical stimuli). Binding of a neurotransmitter to an ionotropic receptor results in a brief local increase in the membrane potential from –60 mV to about +30 mV. Although the membrane potential quickly returns to the initial value within a few milliseconds (ms) at its site of origin, the depolarization is propagated because neighboring membrane areas are activated during this time period.

[1] The process starts with the opening of voltage-gated Na^+ channels (see p. 222). Due to their high equilibrium potential (see **A**), Na^+ ions flow into the cell and reverse the local membrane potential (**depolarization**).

[2] The Na^+ channels immediately close again, so that the inflow of positive charges is only very brief.

[3] Due to the increase in the membrane potential, voltage-dependent K^+ channels open and K^+ ions flow out. In addition, Na^+/K^+ ATPase (see **A**) pumps the Na+ ions that have entered back out again. This leads to **repolarization** of the membrane.

[4] The two processes briefly lead to the charge even falling below the resting potential (**hyperpolarization**). The K^+ channels also close after a few milliseconds. The nerve cell is then ready for re-stimulation.

Generally, it is always only a very small part of the membrane that is depolarized during an action potential. The process can therefore be repeated again after a short refractory period, when the nerve cell is stimulated again. Conduction of the action potential on the surface of the nerve cell is based on the fact that the local increase in the membrane potential causes neighboring voltage-gated ion channels to open, so that the membrane stimulation spreads over the whole cell in the form of a *depolarization wave*.

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A. Resting potential

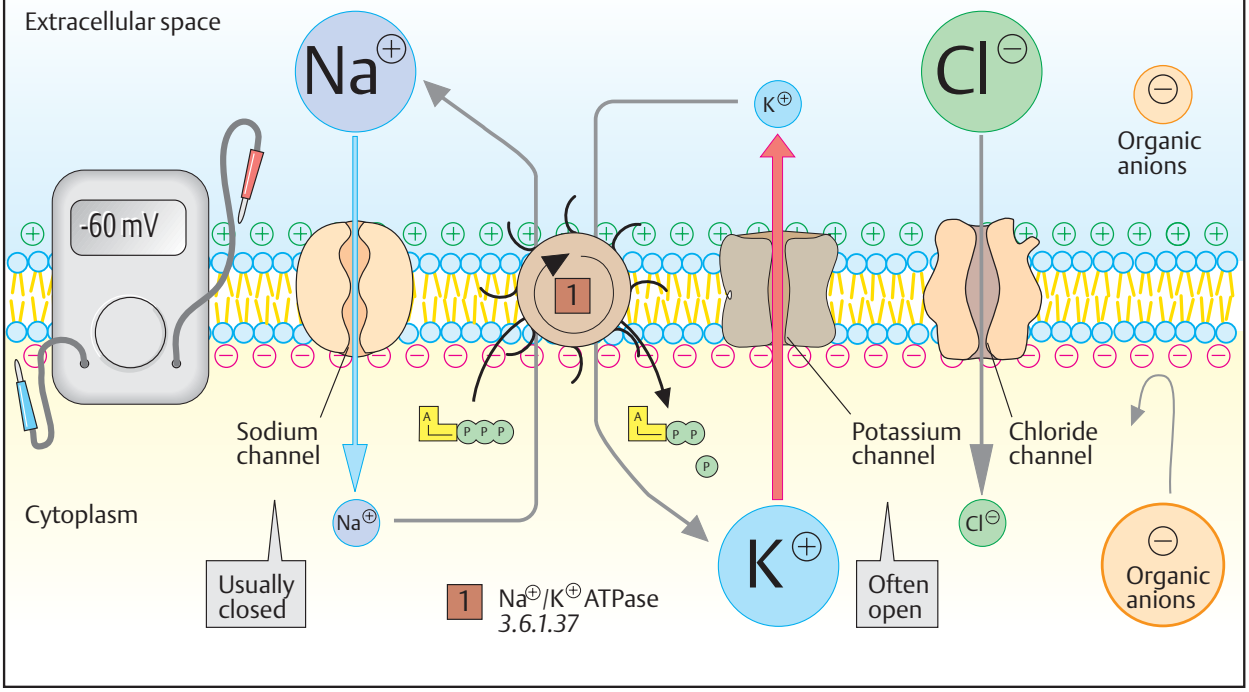

B. Action potential

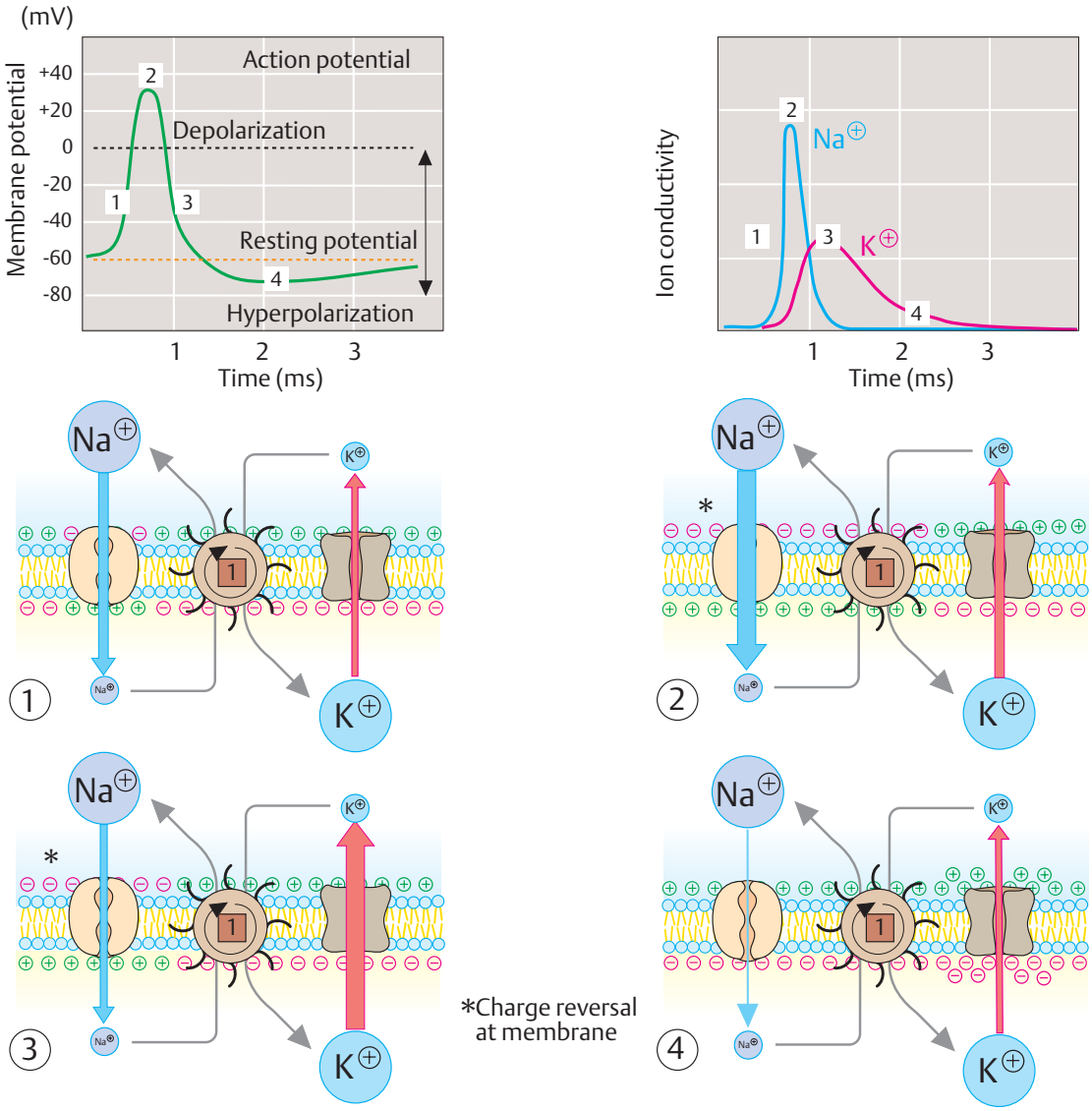

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Neurotransmitters

Neurotransmitters in the strict sense are substances that are produced by neurons, stored in the synapses, and released into the synaptic cleft in response to a stimulus. At the postsynaptic membrane, they bind to special receptors and affect their activity.

A. Important neurotransmitters ◑

Neurotransmitters can be classified into several groups according to their chemical structure. The table lists the most important representatives of this family, which has more than 100 members.

Acetylcholine, the acetic acid ester of the cationic alcohol choline (see p. 50) acts at neuromuscular junctions, where it triggers muscle contraction (see p. 334), and in certain parts of the brain and in the autonomous nervous system.

Several proteinogenic **amino acids** (see p. 60) have neurotransmitter effects. A particularly important one is *glutamate,* which acts as a stimulatory transmitter in the CNS. More than half of the synapses in the brain are glutaminergic. The metabolism of glutamate and that of the amine GABA synthesized from it (see below) are discussed in more detail on p. 356. *Glycine* is an inhibitory neurotransmitter with effects in the spinal cord and in parts of the brain.

Biogenic amines arise from amino acids by decarboxylation (see p. 62). This group includes *4-aminobutyrate* (γ-aminobutyric acid, GABA), which is formed from glutamate and is the most important inhibitory transmitter in the CNS. The *catecholamines* norepinephrine and epinephrine (see **B**), *serotonin,* which is derived from tryptophan, and *histamine* also belong to the biogenic amine group. All of them additionally act as hormones or mediators (see p. 380).

Peptides make up the largest group among the neurosecretions. Many peptide hormones—e. g., thyroliberin (TRH) and angiotensin II—simultaneously act as transmitters. Most neuropeptides are small (3–15 AA). At their N-terminus, many of them have a glutamate residue that has been cyclized to form *pyroglutamate* (5-oxoproline, <G), while the C-terminus is often an acid amide ($-NH_2$). This provides better protection against breakdown by peptidases.

Endorphins, dynorphins, and *enkephalins* are a particularly interesting group of neuropeptides. They act as "endogenous opiates" by producing analgetic, sedative, and euphoriant effects in extreme situations. Drugs such as morphine and heroin activate the receptors for these peptides (see p. 354).

Purine derivatives with neurotransmitter function are all derived from adenine-containing nucleotides or nucleosides. ATP is released along with acetylcholine and other transmitters, and among other functions it regulates the emission of transmitters from its synapse of origin. The stimulatory effect of *caffeine* is mainly based on the fact that it binds to adenosine receptors.

B. Biosynthesis of catecholamines ◑

The catecholamines are *biogenic amines* that have a catechol group. Their biosynthesis in the adrenal cortex and CNS starts from **tyrosine**.

[1] Hydroxylation of the aromatic ring initially produces **dopa** (3,4-dihydroxyphenylalanine). This reaction uses the unusual coenzyme *tetrahydrobiopterin* (THB). Dopa (cf. p. 6) is also used in the treatment of Parkinson's disease.

[2] Decarboxylation of dopa yields **dopamine**, an important transmitter in the CNS. In dopaminergic neurons, catecholamine synthesis stops at this point.

[3] The adrenal gland and adrenergic neurons continue the synthesis by hydroxylating dopamine into **norepinephrine** (noradrenaline). *Ascorbic acid* (vitamin C; see p. 368) acts as a hydrogen-transferring coenzyme here.

[4] Finally, *N*-methylation of norepinephrine yields **epinephrine** (adrenaline). The coenzyme for this reaction is *S*-adenosylmethionine (SAM; see p. 110).

The physiological effects of the catecholamines are mediated by a large number of different receptors that are of particular interest in pharmacology. Norepinephrine acts in the autonomic nervous system and certain areas of the brain. Epinephrine is also used as a transmitter by some neurons.

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A. Important neurotransmitters

Acetylcholine

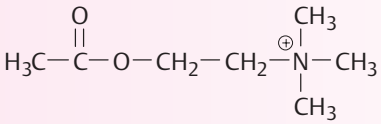

Amino acids: Glutamate, Glycine, Dopa

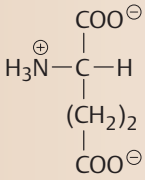

Glutamate

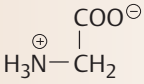

Glycine

Biogenic amines: γ-Aminobutyrate (GABA), Dopa, Dopamine, Norepinephrine, Epinephrine, Serotonine, Histamine

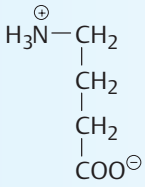

GABA

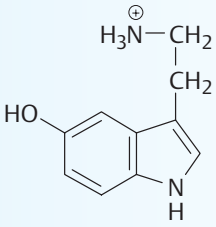

Serotonin

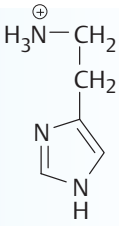

Histamine

Peptides:

β-Endorphin	YGGFMTSEKSQTPLVTLFKNAITKNAYKKGE
Met- and Leu-enkephalin	YGGFM und YGGFL
Thyroliberin (TRH)	<GHP-NH_2
Gonadoliberin (GnRH)	<GHWSYGLRPG-NH_2
Substance P	RPKPQQFFGLM
Somatostatin	AGCKNFFWKTFTSC
Angiotensin II	DRVYIHPF
Cholecystokinin (CCK-4)	WMDF-NH_2
and many others	

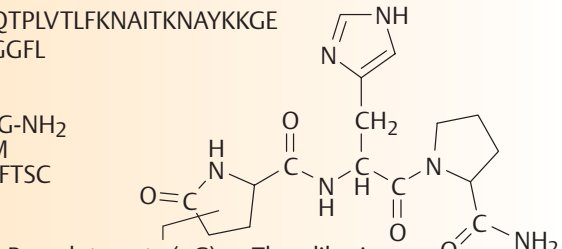

Pyroglutamate (<G) Thyroliberin

Purine derivatives: ATP, ADP, AMP, Adenosine

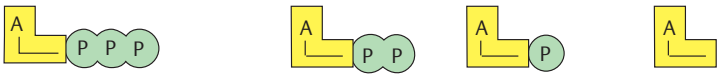

B. Biosynthesis of the catecholamines

1 Tyrosine 3-monooxygenase [$Fe^{2\oplus}$,THB] *1.14.16.2*

2 Aromatic-L-amino-acid decarboxylase (Dopa decarboxylase) [PLP] *4.1.1.28*

3 Dopamine β-monooxygenase[Cu] *1.14.17.1*

4 Phenylethanolamine *N*-methyltransferase *2.1.1.28*

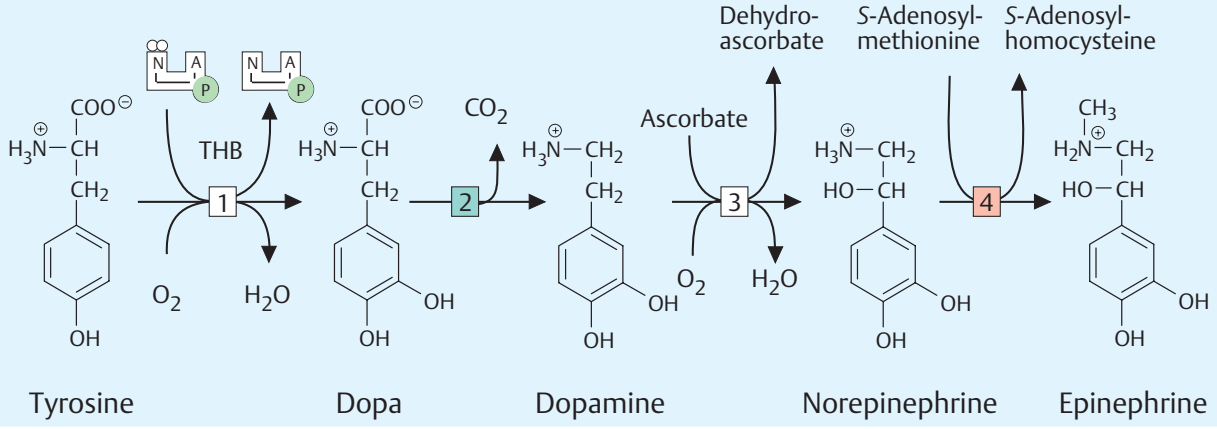

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Receptors for neurotransmitters

Like all signaling substances, neurotransmitters (see p. 352) act via receptor proteins. The receptors for neurotransmitters are integrated into the membrane of the postsynaptic cell, where they trigger ion inflow or signal transduction processes (see p. 348).

A. Receptors for neurotransmitters ◑

A considerable number of receptors for neurotransmitters are already known and new ones are continuing to be discovered. The table only lists the most important examples. They are classified into two large groups according to their mode of action.

Ionotropic receptors are *ligand-gated ion channels* (left half of the table). The receptors for stimulatory transmitters (indicated in the table by a ⊕) mediate the inflow of cations (mainly Na^+). When these open after binding of the transmitter, local *depolarization* of the postsynaptic membrane occurs. By contrast, inhibitory neurotransmitters (GABA and glycine) allow Cl^- to flow in. This increases the membrane's negative resting potential and hinders the action of stimulatory transmitters (*hyperpolarization,* Θ).

Metabotropic receptors (right half of the table) are coupled to G proteins (see p. 386), through which they influence the *synthesis of second messengers.* Receptors that work with type G_s proteins (see p. 386) increase the cAMP level in the postsynaptic cell ([cAMP] ↑), while those that activate G_i proteins reduce it ([cAMP] ↓). Via type G_q proteins, other receptors increase the intracellular Ca^{2+} concentration ($[Ca^{2+}]$ ↑).

There are several **receptor subtypes** for most neurotransmitters. These are distinguished numerically (e.g., D_1 to D_5) or are named after their agonists—i.e., after molecules experimentally found to activate the receptor. For example, one specific subtype of glutamate receptors reacts to NMDA (*N*-methyl-D-aspartate), while another subtype reacts to the compound AMPA, etc.

B. Acetylcholine receptors ◑

Acetylcholine (ACh) was the neurotransmitter first discovered, at the beginning of the last century. It binds to two types of receptor.

The **nicotinic ACh receptor** responds to the alkaloid *nicotine* contained in tobacco (many of the physiological effects of nicotine are based on this). The nicotinic receptor is ionotropic. Its properties are discussed in greater detail on p. 222.

The **muscarinic ACh receptors** (of which there are at least five subtypes) are metabotropic. Their name is derived from the alkaloid *muscarine,* which is found in the fly agaric mushroom (*Amanita muscaria*), for example. Like ACh, muscarine is bound at the receptor, but in contrast to ACh (see **C**), it is not broken down and therefore causes permanent stimulation of muscle.

The muscarinic ACh receptors influence the cAMP level in the postsynaptic cells (M_1, M_3 and M_5 increase it, while subtypes M_2 and M_4 reduce it).

C. Metabolism of acetylcholine ◑

Acetylcholine is synthesized from acetyl-CoA and choline in the cytoplasm of the presynaptic axon [1] and is stored in **synaptic vesicles**, each of which contains around 1000–10 000 ACh molecules. After it is released by exocytosis (see p. 228), the transmitter travels by diffusion to the receptors on the postsynaptic membrane. Catalyzed by *acetylcholinesterase,* hydrolysis of ACh to acetate and choline immediately starts in the synaptic cleft [2], and within a few milliseconds, the ACh released has been eliminated again. The cleavage products **choline** and **acetate** are taken up again by the presynaptic neuron and reused for acetylcholine synthesis [3].

Substances that block the serine residue in the active center of acetylcholinesterase [2]—e.g., the neurotoxin E605 and other *organophosphates*—prevent ACh degradation and thus cause prolonged stimulation of the postsynaptic cell. This impairs nerve conduction and muscle contraction. *Curare,* a paralyzing arrow-poison used by South American Indians, competitively inhibits binding of ACh to its receptor.

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A. Receptors for neurotransmitters

Ionotropic				Metabotropic		
Receptor	**Transmitter**	**Ion(s)**	**Effect**	**Receptor**	**Transmitter**	**Effect**
Acetyl-choline (nicotinic)	Acetyl-choline	$Na^{\oplus}$	$\oplus$	Acetylcholine (muscarinic) M1, M3, M5, M2, M4	Acetylcholine	$[Ca^{2\oplus}]\uparrow$ $[cAMP]\downarrow$
5HT3	Serotonin	$Na^{\oplus}$	$\oplus$	$5HT_1$ $5HT_2$ $5HT_4$	Serotonin „ „	$[Ca^{2\oplus}]\uparrow$ $[cAMP]\uparrow$ $[cAMP]\downarrow$
GABAa	GABA	$Cl^{\ominus}$	$\ominus$	α_1 α_2 $\beta_1, \beta_2, \beta_3$	Norepinephrine „ „	$[Ca^{2\oplus}]\uparrow$ $[cAMP]\uparrow$ $[cAMP]\downarrow$
Glycine	Glycine	$Cl^{\ominus}$	$\ominus$			
AMPA NMDA Kainate	Glutamate Glutamate Glutamate	$Na^{\oplus}$ $K^{\oplus}$ $Na^{\oplus}$ $K^{\oplus}$ $Ca^{2\oplus}$ $Na^{\oplus}$ $K^{\oplus}$	$\oplus$ $\oplus$ $\oplus$	D_1, D_5 D_2, D_3, D_4	Dopamine „	$[cAMP]\uparrow$ $[cAMP]\downarrow$
				δ,κ,μ	Opioids	$[cAMP]\downarrow$

B. Acetylcholine receptors

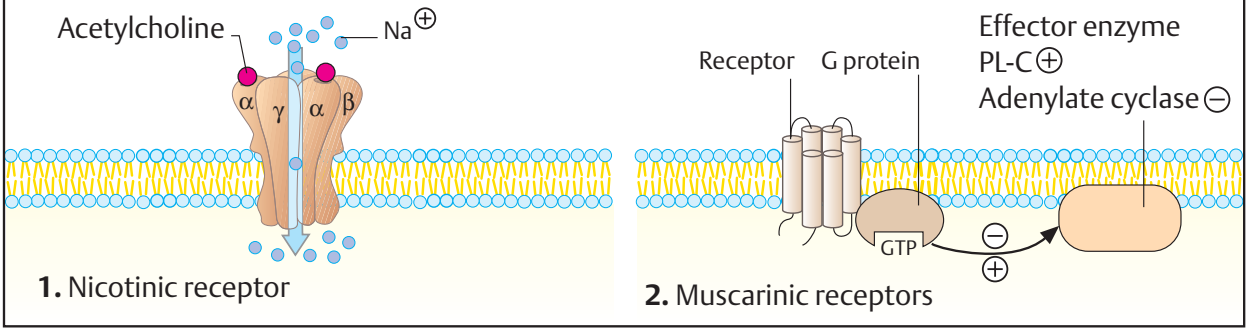

C. Metabolism of acetylcholine

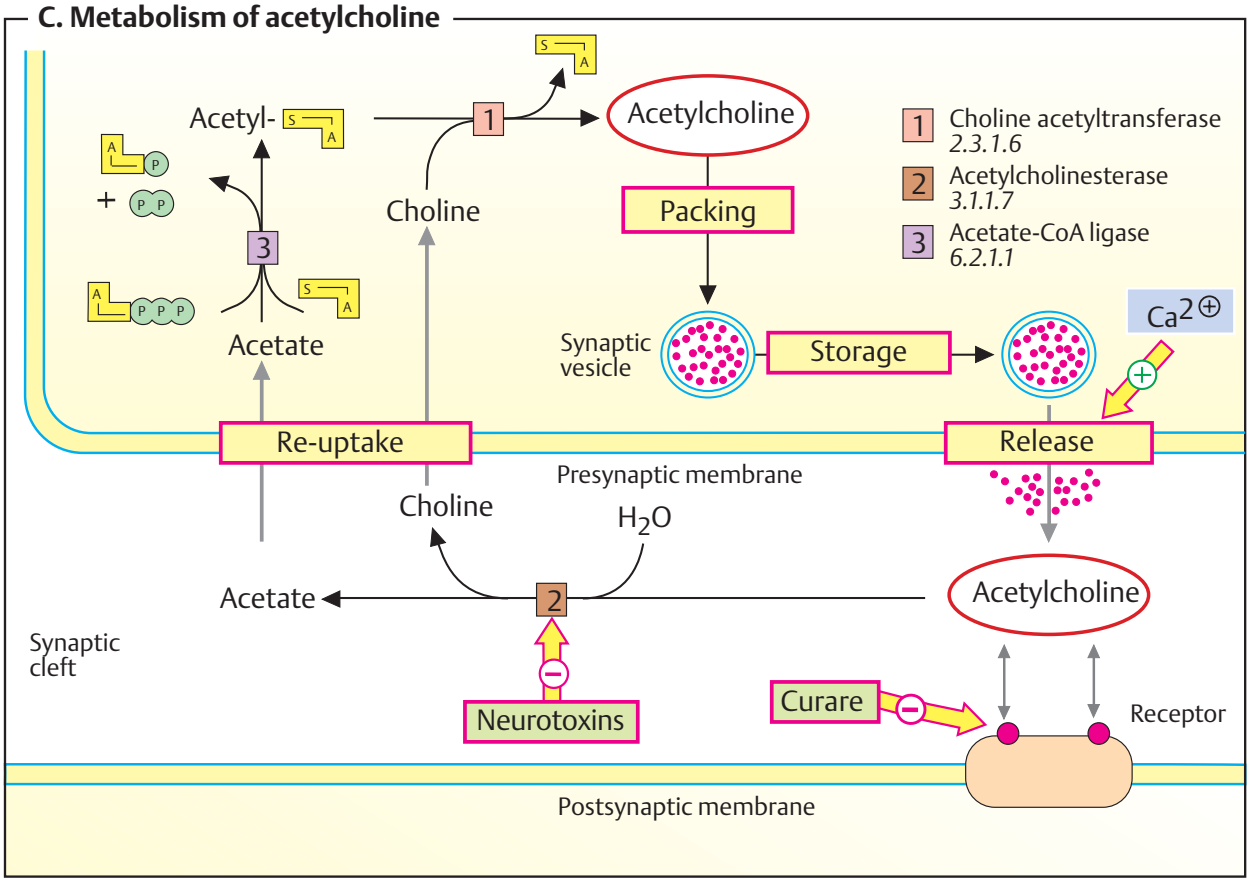

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Metabolism

The brain and other areas of the central nervous system (CNS) have high ATP requirements. Although the brain only represents about 2% of the body's mass, it consumes around 20% of the metabolized oxygen and ca. 60% of the glucose. The neurons' high energy requirements are mainly due to ATP-dependent ion pumps (particularly Na^+/K^+ ATPase) and other active transport processes that are needed for nerve conduction (see p. 350).

A. Energy metabolism of the brain ●

Glucose is normally the only metabolite from which the brain is able to obtain adequate amounts of ATP through aerobic glycolysis and subsequent terminal oxidation to CO_2 and H_2O. Lipids are unable to pass the **blood–brain barrier**, and amino acids are also only available in the brain in limited quantities (see **B**). As neurons only have minor glycogen reserves, they are dependent on a constant supply of glucose from the blood. A severe drop in the blood glucose level—as can occur after insulin overdosage in diabetics, for example—rapidly leads to a drop in the ATP level in the brain. This results in loss of consciousness and neurological deficits that can lead to death. Oxygen deficiency (hypoxia) also fint affects the brain. The effects of a brief period of hypoxia are still reversible, but as time progresses irreversible damage increasingly occurs and finally complete loss of function ("brain death").

During periods of starvation, the brain after a certain time acquires the ability to use **ketone bodies** (see p. 312) in addition to glucose to form ATP. In the first weeks of a starvation period, there is a strong increase in the activities of the enzymes required for this in the brain. The degradation of ketone bodies in the CNS saves glucose and thereby reduces the breakdown of muscle protein that maintains gluconeogenesis in the liver during starvation. After a few weeks, the extent of muscle breakdown therefore declines to one-third of the initial value.

B. Glutamate, glutamine, and GABA ◑

The proteinogenic amino acid **glutamate** (Glu) and the biogenic amine **4-aminobutyrate** derived from it are among the most important neurotransmitters in the brain (see p. 352). They are both synthesized in the brain itself. In addition to the neurons, which use Glu or GABA as transmitters, *neuroglia* are also involved in the metabolism of these substances.

Since glutamate and GABA as transmitters must not appear in the extracellular space in an unregulated way, the cells of the neuroglia (center) supply "glutaminergic" and "GABAergic" neurons with the precursor **glutamine** (Gln), which they produce from glutamate with the help of *glutamine synthetase* [1].

GABA neurons (left) and glutamate neurons (right) initially hydrolyze glutamine with the help of *glutaminase* [1] to form glutamate again. The glutamate neurons store this in vesicles and release it when stimulated. The GABA neurons continue the degradation process by using *glutamate decarboxylase* [3] to convert glutamate into the transmitter GABA.

Both types of neuron take up their transmitter again. Some of it also returns to the neuroglia, where glutamate is amidated back into glutamine.

Glutamate can also be produced again from GABA. The reaction sequence needed for this, known as the **GABA shunt**, is characteristic of the CNS. A *transaminase* [4] first converts GABA and 2-oxoglutarate into glutamate and succinate semialdehyde ($-OOC-CH_2-CH_2-CHO$). In an NAD^+-dependent reaction, the aldehyde is oxidized to succinic acid [5], from which 2-oxoglutarate can be regenerated again via tricarboxylic acid cycle reactions.

The function of glutamate as a stimulatory transmitter in the brain is the cause of what is known as the "Chinese restaurant syndrome." In sensitive individuals, the monosodium glutamate used as a flavor enhancer in Chinese cooking can raise the glutamate level in the brain to such an extent that transient mild neurological disturbances can occur (dizziness, etc.).

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A. Energy metabolism of the brain

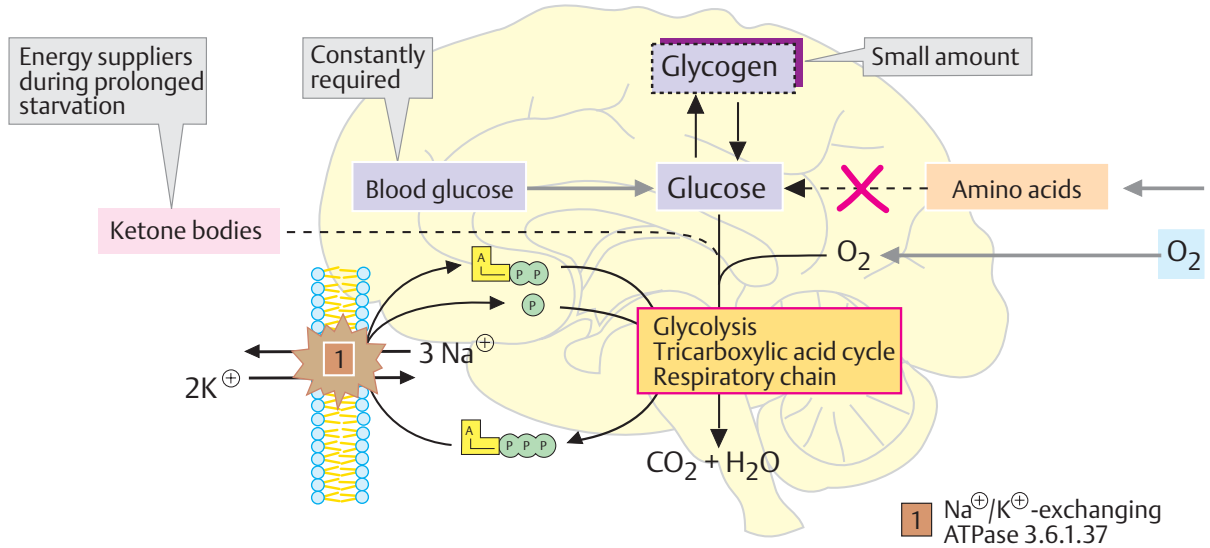

B. Glutamate, glutamine, and GABA

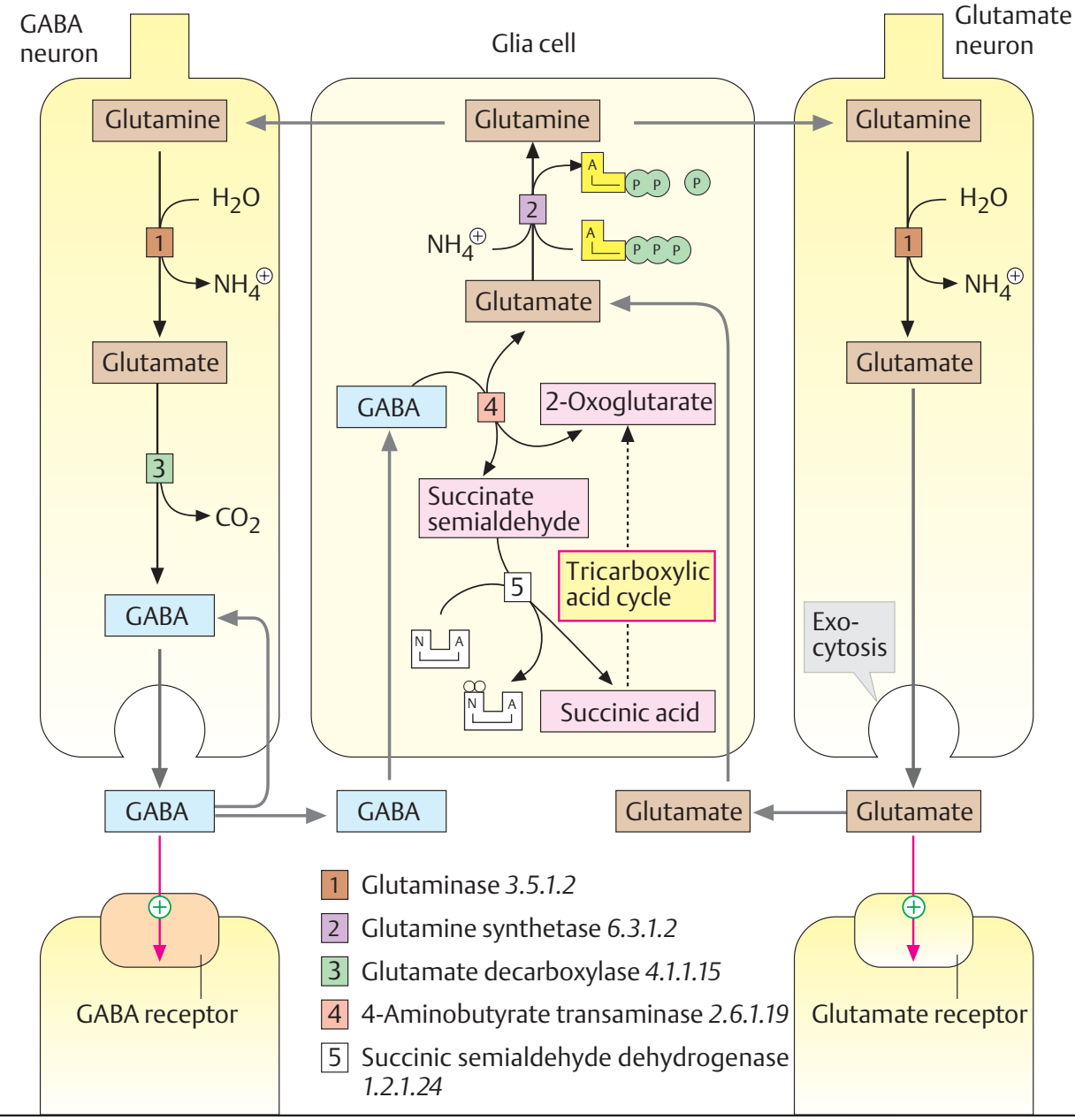

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Sight

Two types of photoreceptor cell are found in the human retina—*rods* and *cones.* Rods are sensitive to low levels of light, while the cones are responsible for color vision at higher light intensities.

Signaling substances and many proteins are involved in visual processes. Initially, a **light-induced** *cis–trans* **isomerization** of the pigment retinal triggers a conformational change in the membrane protein *rhodopsin.* Via the G protein *transducin,* which is associated with rhodopsin, an enzyme is activated that breaks down the second messenger *cGMP.* Finally, the cGMP deficiency leads to *hyperpolarization* of the light-sensitive cell, which is registered by subsequent neurons as *reduced neurotransmitter release.*

A. Photoreceptor ◑

The cell illustrated opposite, a **rod**, has a structure divided by membrane discs into which the 7-helix receptor **rhodopsin** is integrated (see p. 224). In contrast to other receptors in the 7-helix class (see p. 384), rhodopsin is a light-sensitive *chromoprotein.* Its protein part, **opsin**, contains the aldehyde **retinal** (see p. 364)—an isoprenoid which is bound to the ε-amino group of a lysine residue as an *aldimine*.

The light absorption of rhodopsin is in the visible range, with a maximum at about 500 nm. The absorption properties of the visual pigment are thus optimally adjusted to the spectral distribution of sunlight.

Absorption of a photon triggers isomerization from the 11-*cis* form of retinal to all-*trans*-retinal (top right). Within milliseconds, this *photochemical process* leads to an allosteric conformational change in rhodopsin. The active conformation (**rhodopsin***) binds and activates the G protein **transducin**. The *signal cascade* (**B**) that now follows causes the rod cells to release less neurotransmitter (glutamate) at their synapses. The adjoining bipolar neurons register this change and transmit it to the brain as a signal for light.

There are several different rhodopsins in the **cones**. All of them contain retinal molecules as light-sensitive components, the absorption properties of which are modulated by the different proportions of opsin they contain in such a way that colors can also be perceived.

B. Signal cascade ◑

Dark (bottom left). Rod cells that are not exposed to light contain relatively high concentrations (70 μM) of the cyclic nucleotide **cGMP** (3′,5′-cycloGMP; cf. cAMP, p. 386), which is synthesized by a *guanylate cyclase* ([2], see p. 388). The cGMP binds to an ion channel in the rod membrane (bottom left) and thus keeps it open. The inflow of cations (Na^+, Ca^{2+}) depolarizes the membrane and leads to release of the neurotransmitter glutamate at the synapse (see p. 356).

Light (bottom right). When the G protein transducin binds to light-activated rhodopsin* (see **A**, on the structure of the complex; see p. 224), it leads to the GDP that is bound to the transducin being exchanged for GTP. In transducin* that has been activated in this way, the GTP-containing α-subunit breaks off from the rest of the molecule and in turn activates a membrane *cGMP phosphodiesterase* [1]. This hydrolyzes cGMP to GMP and thus reduces the level of free cGMP within milliseconds. As a consequence, the cGMP bound at the ion channel dissociates off and the channel closes. As cations are constantly being pumped out of the cell, the membrane potential falls and **hyperpolarization** of the cell occurs, which interrupts glutamate release.

Regeneration. After exposure to light, several processes restore the initial conditions:

1. The α-subunit of transducin* inactivates itself by GTP hydrolysis and thus terminates the activation of cGMP esterase.
2. The reduced Ca^{2+} concentration causes activation of guanylate cyclase, which increases the cGMP level until the cation channels reopen.
3. An isomerase [3] transfers all-*trans* -retinal to the 11-*cis* -form, in which it is available for the next cycle. A dehydrogenase [4] can also allow retinal to be supplied from vitamin A (retinol).

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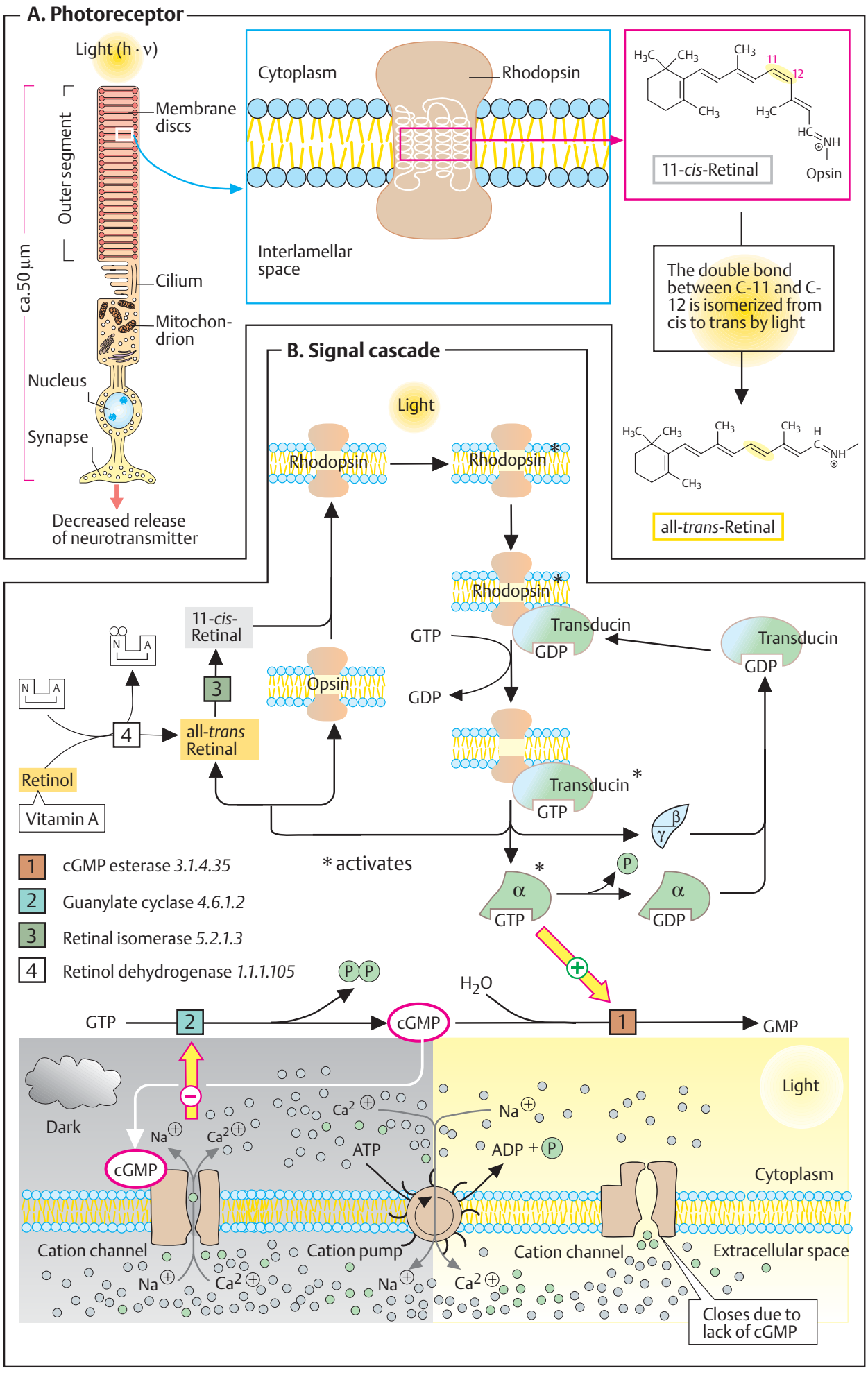

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Organic substances

A balanced human diet needs to contain a large number of different components. These include *proteins, carbohydrates, fats, minerals* (including water), and *vitamins.* These substances can occur in widely varying amounts and proportions, depending on the type of diet. As several components of the diet are *essential for life,* they have to be regularly ingested with food. Recommended daily minimums for nutrients have been published by the World Health Organization (WHO) and a number of national expert committees.

A. Energy requirement ●

The amount of energy required by a human is expressed in kJ d^{-1} (kilojoule per day). An older unit is the kilocalorie (kcal; 1 kcal = 4.187 kJ). The figures given are recommended values for adults with a normal body weight. However, actual requirements are based on age, sex, body weight, and in particular on physical activity. In those involved in competitive sports, for example, requirements can increase from 12 000 to 17 000 kJ d^{-1}.

It is recommended that about half of the energy intake should be in the form of carbohydrates, a third at most in the form of fat, and the rest as protein. The fact that *alcoholic beverages* can make a major contribution to daily energy intake is often overlooked. Ethanol has a caloric value of about 30 kJ g^{-1} (see p. 320).

B. Nutrients ●

Proteins provide the body with amino acids, which are used for endogenous protein biosynthesis. Excess amino acids are broken down to provide energy (see p. 174). Most amino acids are *glucogenic*—i. e., they can be converted into glucose (see p. 180).

Proteins are essential components of the diet, as they provide **essential amino acids** that the human body is not capable of producing on its own (see the table). Some amino acids, including cysteine and histidine, are not absolutely essential, but promote growth in children. Some amino acids are able to substitute for each other in the diet. For example, humans can form tyrosine, which is actually essential, by hydroxylation from phenylalanine, and cysteine from methionine.

The *minimum daily requirement* of protein is 37 g for men and 29 g for women, but the recommended amounts are about twice these values. Requirements in pregnant and breastfeeding women are even higher. Not only the quantity, but also the quality of protein is important. Proteins that lack several essential amino acids or only contain small quantities of them are considered to be of low value, and larger quantities of them are therefore needed. For example, pulses only contain small amounts of methionine, while wheat and corn proteins are poor in lysine. In contrast to vegetable proteins, most animal proteins are high-value (with exceptions such as collagen and gelatin).

Carbohydrates serve as a general and easily available energy source. In the diet, they are present as *monosaccharides* in honey and fruit, or as *disaccharides* in milk and in all foods sweetened with sugar (sucrose). Metabolically usable *polysaccharides* are found in vegetable products (starch) and animal products (glycogen). Carbohydrates represent a substantial proportion of the body's energy supply, but they are not essential.

Fats are primarily important energy suppliers in the diet. Per gram, they provide more than twice as much energy as proteins and carbohydrates. Fats are essential as suppliers of *fat-soluble vitamins* (see p. 364) and as sources of *polyunsaturated fatty acids,* which are needed to biosynthesize eicosanoids (see pp. 48, 390).

Mineral substances and trace elements, a very heterogeneous group of essential nutrients, are discussed in more detail on p. 362. They are usually divided into macrominerals and microminerals.

Vitamins are also indispensable components of the diet. The animal body requires them in very small quantities in order to synthesize coenzymes and signaling substances (see pp. 364–369).

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A. Energy requirement

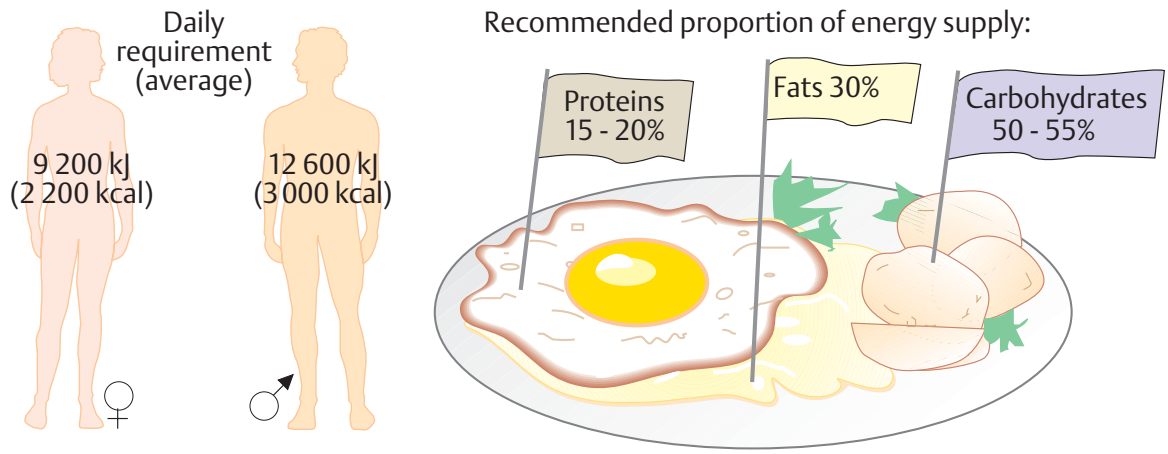

B. Nutrients

	Quantity in body (kg)	Energy content kJ · g^{-1} (kcal · g^{-1})	Daily requirement (g) a	b	c	General function in metabolism	Essential constituents
Proteins	10	17 (4.1)	♂ 37 ♀ 29	55 45	92 75	Supplier of amino acids Energy source Daily requirement in mg per kg body weight	Essential amino acids:: Val (14) Leu (16) Ile (12) Lys (12) Phe (16) Trp (3) Met (10) Thr (8) Cys and His stimulate growth
Carbohydrates	1	17 (4.1)	0	390	240-310	General source of energy (glucose) Energy reserve (glycogen) Roughage (cellulose) Supporting substances (bones, cartilage, mucus)	Non-essential nutritional constituent
Fats	10-15	39 (9.3)	10	80	130	General energy source Most important energy reserve Solvent for vitamins Supplier of essential fatty acids	Poly-unsaturated fatty acids: Linoleic acid Linolenic acid Arachidonic acid (together 10 g/day)
Water	35-40	0	2 400	–	–	Solvent Cellular building block Dielectric Reaction partner Temperature regulator	
Minerals	3	0				Building blocks Electrolytes Cofactors of enzymes	Macrominerals Microminerals (trace elements)
Vitamins	–	–				Often precursors of coenzymes	Lipid-soluble vitamins Water-soluble vitamins

a: Minimum daily requirement b: Recommended daily intake c: Actual daily intake in industrialized nations

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Minerals and trace elements

A. Minerals ◑

Water is the most important essential inorganic nutrient in the diet. In adults, the body has a daily requirement of 2–3 L of water, which is supplied from drinks, water contained in solid foods, and from the *oxidation water* produced in the respiratory chain (see p. 140). The special role of water for living processes is discussed in more detail elsewhere (see p. 26).

The elements essential for life can be divided into **macroelements** (daily requirement > 100 mg) and **microelements** (daily requirement < 100 mg). The macroelements include the **electrolytes** sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg), and the nonmetals chlorine (Cl), phosphorus (P), sulfur (S), and iodine (I).

The essential microelements are only required in trace amounts (see also p. 2). This group includes iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), cobalt (Co), chromium (Cr), selenium (Se), and molybdenum (Mo). Fluorine (F) is not essential for life, but does promote healthy bones and teeth. It is still a matter of controversy whether vanadium, nickel, tin, boron, and silicon also belong to the essential trace elements.

The second column in the table lists the average **amounts** of mineral substances in the body of an adult weighing 65 kg. The **daily requirements** listed in the fourth column also apply to an adult, and are *average values.* Children, pregnant and breast-feeding women, and those who are ill generally have higher mineral requirements relative to body weight than men.

As the human body is able to store many minerals, deviations from the daily ration are balanced out over a given period of time. Minerals stored in the body include water, which is distributed throughout the whole body; calcium, stored in the form of apatite in the bones (see p. 340); iodine, stored as thyroglobulin in the thyroid; and iron, stored in the form of ferritin and hemosiderin in the bone marrow, spleen, and liver (see p. 286). The storage site for many trace elements is the liver. In many cases, the metabolism of minerals is regulated by *hormones*—for example, the uptake and excretion of H_2O, Na^+, Ca^{2+}, and phosphate (see p. 328), and storage of Fe^{2+} and I^-.

Resorption of the required mineral substances from food usually depends on the body's requirements, and in several cases also on the composition of the diet. One example of dietary influence is calcium (see p. 342). Its resorption as Ca^{2+} is promoted by lactate and citrate, but phosphate, oxalic acid, and phytol inhibit calcium uptake from food due to complex formation and the production of insoluble salts.

Mineral deficiencies are not uncommon and can have quite a variety of causes—e. g., an unbalanced diet, resorption disturbances, and diseases. *Calcium deficiency* can lead to rickets, osteoporosis, and other disturbances. *Chloride deficiency* is observed as a result of severe Cl^- losses due to vomiting. Due to the low content of iodine in food in many regions of central Europe, *iodine deficiency* is widespread there and can lead to goiter. *Magnesium deficiency* can be caused by digestive disorders or an unbalanced diet—e. g., in alcoholism. Trace element deficiencies often result in a disturbed blood picture—i. e., forms of anemia.

The last column in the table lists some of the functions of minerals. It should be noted that almost all of the **macroelements** in the body function either as *nutrients* or *electrolytes.* Iodine (as a result of its incorporation into iodothyronines) and calcium act as *signaling substances.* Most **trace elements** are *cofactors for proteins,* especially for enzymes. Particularly important in quantitative terms are the *iron proteins* hemoglobin, myoglobin, and the cytochromes (see p. 286), as well as more than 300 different *zinc proteins.*

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A. Minerals

Mineral	Content * (g)	Major source	Daily requirement (g)	Functions/Occurrence
Water	35 000-40 000	Drinks Water in solid foods From metabolism 300g	1200 900	Solvent, cellular building block, dielectric, coolant, medium for transport, reaction partner
Macroelements (daily requirement >100 mg)				
Na	100	Table salt	1.1-3.3	Osmoregulation, membrane potential, mineral metabolism
K	150	Vegetables, fruit, cereals	1.9-5.6	Membrane potential, mineral metabolism
Ca	1 300	Milk, milk products	0.8	Bone formation, blood clotting, signal molecule
Mg	20	Green vegetables	0.35	Bone formation, cofactor for enzymes
Cl	100	Table salt	1.7-5.1	Mineral metabolism
P	650	Meat, milk, cereals, vegetables	0.8	Bone formation, energy metabolism, nucleic acid metabolism
S	200	*S*-containing amino acids (Cys and Met)	0.2	Lipid and carbohydrate metabolism, conjugate formation
Microelements (trace elements)			(mg	
Fe	4-5	Meat, liver, eggs, vegetables, potatoes, cereals	10	Hemoglobin, myoglobin, cytochromes, Fe/S clusters
Zn	2-3	Meat, liver, cereals	15	Zinc enzymes
Mn	0.02	Found in many foodstuffs	2-5	Enzymes
Cu	0.1-0.2	Meat, vegetables, fruit, fish	2-3	Oxidases
Co	<0.01	Meat	Traces	Vitamin B_{12}
Cr	<0.01		0.05-0.2	Not clear
Mo	0.02	Cereals, nuts, legumes	0.15-0.5	Redox enzymes
Se		Vegetables, meat	0.05-0.2	Selenium enzymes
I	0.03	Seafood, iodized salt, drinking water	0.15	Thyroxin
Requirement not known				Metals Non-metals
F		Drinking water (fluoridated), tea, milk	0.0015-0.004	Bones, dental enamel

* Content in the body of a 65 kg adult

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Lipid-soluble vitamins

Vitamins are essential organic compounds that the animal organism is not capable of forming itself, although it requires them in small amounts for metabolism. Most vitamins are **precursors of coenzymes**; in some cases, they are also precursors of **hormones** or act as **antioxidants**. Vitamin requirements vary from species to species and are influenced by age, sex, and physiological conditions such as pregnancy, breast-feeding, physical exercise, and nutrition.

A. Vitamin supply ●

A healthy diet usually covers average daily vitamin requirements. By contrast, malnutrition, malnourishment (e.g., an unbalanced diet in older people, malnourishment in alcoholics, ready meals), or resorption disturbances lead to an inadequate supply of vitamins from which **hypovitaminosis,** or in extreme cases avitaminosis, can result. Medical treatments that kill the intestinal flora—e.g., antibiotics—can also lead to vitamin deficiencies (K, B_{12}, H) due to the absence of bacterial vitamin synthesis.

Since only a few vitamins can be stored (A, D, E, B_{12}), a lack of vitamins quickly leads to **deficiency diseases.** These often affect the skin, blood cells, and nervous system. The causes of vitamin deficiencies can be treated by improving nutrition and by administering vitamins in tablet form. An overdose of vitamins only leads to **hypervitaminoses**, with toxic symptoms, in the case of vitamins A and D. Normally, excess vitamins are rapidly excreted with the urine.

B. Lipid-soluble vitamins ◑

Vitamins are classified as either lipid-soluble or water-soluble. The lipid-soluble vitamins include vitamins A, D, E, and K, all of which belong to the isoprenoids (see p. 52).

Vitamin A (retinol) is the parent substance of the *retinoids,* which include *retinal* and *retinoic acid.* The retinoids also can be synthesized by cleavage from the provitamin β-carotene. Retinoids are found in meat-containing diets, whereas β-carotene occurs in fruits and vegetables (particularly carrots). **Retinal** is involved in visual processes as the pigment of the chromoprotein *rhodopsin* (see p. 358). **Retinoic acid**, like the steroid hormones, influences the transcription of genes in the cell nucleus. It acts as a differentiation factor in growth and development processes. Vitamin A deficiency can result in *night blindness, visual impairment,* and *growth disturbances.*

Vitamin D (calciol, cholecalciferol) is the precursor of the hormone *calcitriol* (1α,25-dihydroxycholecalciferol; see p. 320). Together with two other hormones (parathyrin and calcitonin), calcitriol regulates the calcium metabolism (see p. 342). Calciol can be synthesized in the skin from 7-dehydrocholesterol, an endogenous steroid, by a photochemical reaction. Vitamin D deficiencies only occur when the skin receives insuf cient exposure to ultraviolet light and vitamin D is lacking in the diet. Deficiency is observed in the form of *rickets* in children and *osteomalacia* in adults. In both cases, bone mineralization is disturbed.

Vitamin E (tocopherol) and related compounds only occur in plants (e.g., wheat germ). They contain what is known as a *chroman ring.* In the lipid phase, vitamin E is mainly located in biological membranes, where as an *antioxidant* it protects unsaturated lipids against ROS (see p. 284) and other radicals.

Vitamin K (phylloquinone) and similar substances with modified side chains are involved in carboxylating glutamate residues of coagulation factors in the liver (see p. 290). The form that acts as a cofactor for carboxylase is derived from the vitamin by enzymatic reduction. Vitamin K antagonists (e.g., coumarin derivatives) inhibit this reduction and consequently carboxylation as well. This fact is used to inhibit blood coagulation in *prophylactic treatment against thrombosis*. Vitamin K deficiency occurs only rarely, as the vitamin is formed by bacteria of the intestinal flora.

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A. Vitamin supply

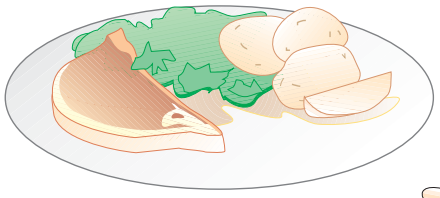

Healthy nutrition

Vitamin requirement satisfied

Vitamin poisoning

Vitamin A and D

Poor nutrition
Malnutrition
Antibiotics
Disturbed resorption

Vitamin intake

Hypervitaminosis

Excess vitamins

Overdose

Diseases

Hypovitaminosis

Urine

B. Lipid-soluble vitamins

* Adult daily requirement

Provitamin	Functional form	Important for
β-Carotene	Retinal	Sight
Retinol	Retinol	Sugar transport
	Retinoic acid	Development Differentiation
Cholesterol	Calcitriol	Calcium metabolism
Tocopherols	Tocopherols	Anti-oxidant
Phylloquinones	Phyllohydroquinones	Blood clotting (carboxylation of plasma proteins)

A

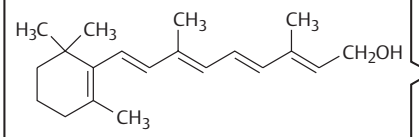

β-Carotene

Vegetables
Fruit

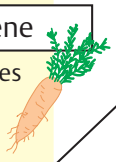

Retinal

Visual pigments

Retinol

1

Milk
Liver
Egg yolk

Retinol

Coenzyme

Retinoic acid

Signal molecule

D

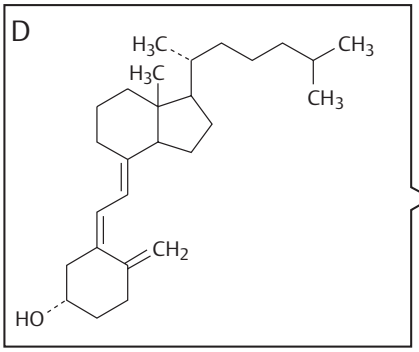

Cholesterol

uv

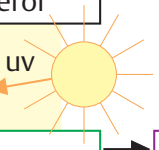

Calciol

0.01

Cod liver oil
Milk
Egg yolk

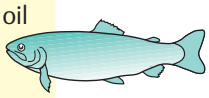

Calcitriol

Hormone

E

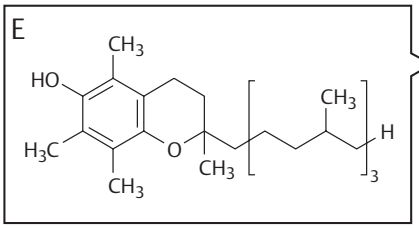

Tocopherols

10

Cereals
Liver
Eggs
Seed oil

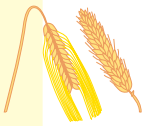

Tocopherols

Reducing agent

K

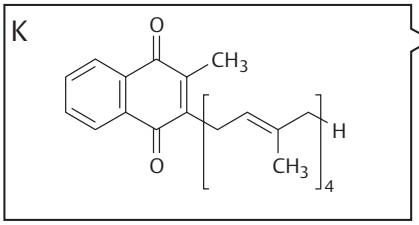

Phylloquinones

0.08

Intestinal bacteria
Vegetables
Liver

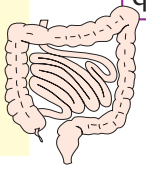

Phyllohydroquinones

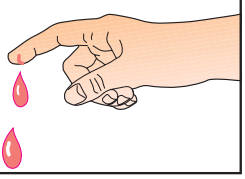

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Water-soluble vitamins I

The B group of vitamins covers water-soluble vitamins, all of which serve as precursors for coenzymes. Their numbering sequence is not continuous, as many substances that were originally regarded as vitamins were not later confirmed as having vitamin characteristics.

A. Water-soluble vitamins I ◑

Vitamin B_1 (thiamine) contains two heterocyclic rings—a *pyrimidine ring* (a six-membered aromatic ring with two Ns) and a *thiazole ring* (a five-membered aromatic ring with N and S), which are joined by a methylene group. The active form of vitamin B_1 is **thiamine diphosphate** (TPP), which contributes as a coenzyme to the transfer of hydroxyalkyl residues (active aldehyde groups). The most important reactions of this type are oxidative decarboxylation of 2-oxoacids (see p. 134) and the transketolase reaction in the pentose phosphate pathway (see p. 152). Thiamine was the first vitamin to be discovered, around 100 years ago. Vitamin B_1 deficiency leads to *beriberi,* a disease with symptoms that include neurological disturbances, cardiac insuf ciency, and muscular atrophy.

Vitamin B_2 is a complex of several vitamins: riboflavin, folate, nicotinate, and pantothenic acid.

Riboflavin (from the Latin *flavus,* yellow) serves in the metabolism as a component of the redox coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD; see p. 104). As prosthetic groups, **FMN** and **FAD** are cofactors for various oxidoreductases (see p. 32). No specific disease due to a deficiency of this vitamin is known.

Folate, the anion of folic acid, is made up of three different components—a *pteridine derivative, 4-aminobenzoate,* and one or more *glutamate* residues. After reduction to tetrahydrofolate (**THF**), folate serves as a coenzyme in the C_1 metabolism (see p. 418). Folate deficiency is relatively common, and leads to disturbances in nucleotide biosynthesis and thus cell proliferation. As the precursors for blood cells divide particularly rapidly, disturbances of the blood picture can occur, with increased amounts of abnormal precursors for megalocytes (*megaloblastic anemia*). Later, general damage ensues as phospholipid synthesis and the amino acid metabolism are affected.

In contrast to animals, microorganisms are able to synthesize folate from their own components. The growth of microorganisms can therefore be inhibited by *sulfonamides,* which competitively inhibit the incorporation of 4-aminobenzoate into folate (see p. 254). Since folate is not synthesized in the animal organism, sulfonamides have no effect on animal metabolism.

Nicotinate and **nicotinamide,** together referred to as "niacin," are required for biosynthesis of the coenzymes nicotinamide adenine dinucleotide (**NAD^+**) and nicotinamide adenine dinucleotide phosphate (**$NADP^+$**). These both serve in energy and nutrient metabolism as carriers of *hydride ions* (see pp. 32, 104). The animal organism is able to convert *tryptophan* into nicotinate, but only with a poor yield. Vitamin deficiency therefore only occurs when nicotinate, nicotinamide, and tryptophan are all simultaneously are lacking in the diet. It manifests in the form of skin damage (*pellagra*), digestive disturbances, and depression.

Pantothenic acid is an acid amide consisting of β-alanine and 2,4-dihydroxy-3,3′-dimethylbutyrate (pantoic acid). It is a precursor of *coenzyme A,* which is required for activation of acyl residues in the lipid metabolism (see pp. 12, 106). *Acyl carrier protein* (ACP; see p. 168) also contains pantothenic acid as part of its prosthetic group. Due to the widespread availability of pantothenic acid in food (Greek *pantothen* = "from everywhere"), deficiency diseases are rare.

Further information

The requirement for vitamins in humans and other animals is the result of mutations in the enzymes involved in biosynthetic coenzymes. As intermediates of coenzyme biosynthesis are available in suf cient amounts in the diet of heterotrophic animals (see p. 112), the lack of endogenous synthesis did not have unfavorable effects for them. Microorganisms and plants whose nutrition is mainly autotrophic have to produce all of these compounds themselves in order to survive.

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A. Water-soluble vitamins I

* Adult daily requirement

Vitamin	Active form: coenzyme	Function in metabolism
B_1 Thiamine	TPP Thiamine diphosphate	Transfer of hydroxy-alkyl residues
B_2 Riboflavin	FMN, FAD	Hydrogen transfer
Folate	THF Tetrahydro-folate	C_1-metabolism
Nicotinate Nicotinamide	NADP, NAD	Hydride transfer
Pantothenate	CoA	Activation of carboxy-lic acids

Thiamine

1.5 mg *

Grain
Yeast products
Pork

Riboflavin

1.8 mg*

Milk
Eggs

Folate

0.2 mg*

Fresh green vegetables
Liver

Nicotinate Nicotinamide

20 mg*

(or 1.2 g tryptophan)

Meat, yeast products
Fruit and vegetables

Pantothenate

7 mg*

Widely distributed

4-Aminobenzoate residue

Pteridine derivative

Glu

Nicotinate

Nicotinamide

Pantoinate

β-Alanine

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Water-soluble vitamins II

A. Water-soluble vitamins II ◑

Vitamin B_6 consists of three substituted pyridines—**pyridoxal**, **pyridoxol**, and **pyridoxamine.** The illustration shows the structure of pyridoxal, which carries an aldehyde group (–CHO) at C-4. Pyridoxol is the corresponding alcohol ($–CH_2OH$), and pyridoxamine the amine ($–CH_2NH_2$).

The active form of vitamin B_6, **pyridoxal phosphate,** is the most important coenzyme in the amino acid metabolism (see p. 106). Almost all conversion reactions involving amino acids require pyridoxal phosphate, including transaminations, decarboxylations, dehydrogenations, etc. *Glycogen phosphorylase,* the enzyme for glycogen degradation, also contains pyridoxal phosphate as a cofactor. Vitamin B_6 deficiency is rare.

Vitamin B_{12} (cobalamine) is one of the most complex low-molecular-weight substances occurring in nature. The core of the molecule consists of a tetrapyrrol system (*corrin*), with cobalt as the central atom (see p. 108). The vitamin is exclusively synthesized by microorganisms. It is abundant in liver, meat, eggs, and milk, but not in plant products. As the intestinal flora synthesize vitamin $B_{12,}$ strict vegetarians usually also have an adequate supply of the vitamin.

Cobalamine can only be resorbed in the small intestine when the gastric mucosa secretes what is known as *intrinsic factor*—a glycoprotein that binds cobalamine (the *extrinsic factor*) and thereby protects it from degradation. In the blood, the vitamin is bound to a special protein known as *transcobalamin.* The liver is able to store vitamin B_{12} in amounts suf cient to last for several months. Vitamin B_{12} deficiency is usually due to an absence of intrinsic factor and the resulting resorption disturbance. This leads to a disturbance in blood formation known as *pernicious anemia.*

In animal metabolism, derivatives of cobalamine are mainly involved in rearrangement reactions. For example, they act as coenzymes in the conversion of methylmalonyl-CoA to succinyl-CoA (see p. 166), and in the formation of methionine from homocysteine (see p. 418). In prokaryotes, cobalamine derivatives also play a part in the reduction of ribonucleotides.

Vitamin C is L-**ascorbic acid** (chemically: 2-oxogulonolactone). The two hydroxyl groups have acidic properties. By releasing a proton, ascorbic acid therefore turns into its anion, **ascorbate**. Humans, apes, and guinea pigs require vitamin C because they lack the enzyme L-*gulonolactone oxidase (1.1.3.8),* which catalyzes the final step in the conversion of glucose into ascorbate.

Vitamin C is particularly abundant in fresh fruit and vegetables. Many soft drinks and foodstuffs also have synthetic ascorbic acid added to them as an antioxidant and flavor enhancer. Boiling slowly destroys vitamin C. In the body, ascorbic acid serves as a reducing agent in variations reactions (usually hydroxylations). Among the processes involved are *collagen synthesis, tyrosine degradation, catecholamine synthesis,* and *bile acid biosynthesis.* The daily requirement for ascorbic acid is about 60 mg, a comparatively large amount for a vitamin. Even higher doses of the vitamin have a protective effect against infections. However, the biochemical basis for this effect has not yet been explained. Vitamin C deficiency only occurs rarely nowadays; it becomes evident after a few months in the form of *scurvy,* with connective-tissue damage, bleeding, and tooth loss.

Vitamin H (**biotin)** is present in liver, egg yolk, and other foods; it is also synthesized by the intestinal flora. In the body, biotin is covalently attached via a lysine side chain to enzymes that catalyze carboxylation reactions. Biotin-dependent carboxylases include *pyruvate carboxylase* (see p. 154) and *acetyl-CoA carboxylase* (see p. 162). CO_2 binds, using up ATP, to one of the two N atoms of biotin, from which it is transferred to the acceptor (see p. 108).

Biotin binds with high af nity ($K_d = 10^{-15}$ M) and specificity to *avidin*, a protein found in egg white. Since boiling denatures avidin, biotin deficiency only occurs when egg whites are eaten raw.

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A. Water-soluble vitamins II

* Adult daily requirement

Vitamin	Active form: coenzyme	Function in metabolism
B_6	Pyridoxal Pyridoxol Pyridoxamine	PLP Pyridoxal phosphate	Activation of amino acids
B_{12}	Cobalamine	5-Deoxy-adenosyl cobalamine	Isomerization e.g.
C	Ascorbic acid	Ascorbate	Stabilization of enzyme systems, coenzyme, antioxidant
H	Biotin	B Biotin	Transfer of carboxyl groups

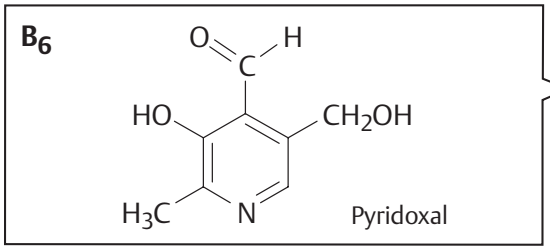

2 mg*
Meat
Vegetables
Grain products

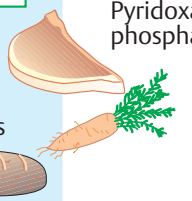

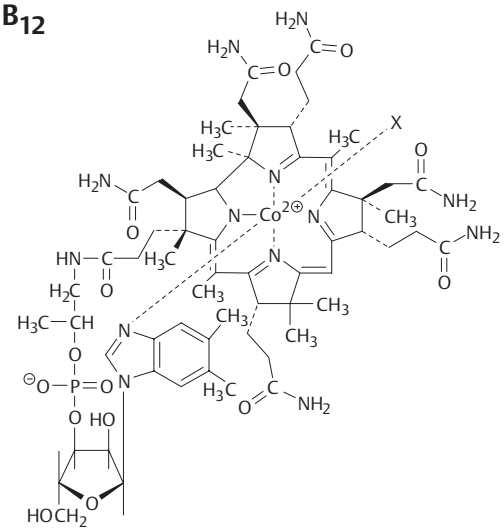

0.002 mg*
Meat
Liver
Milk
Eggs

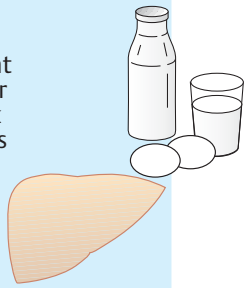

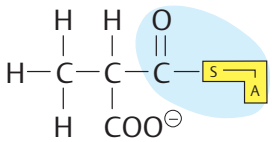

Methylmalonyl CoA

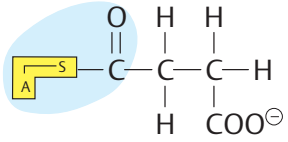

Succinyl CoA

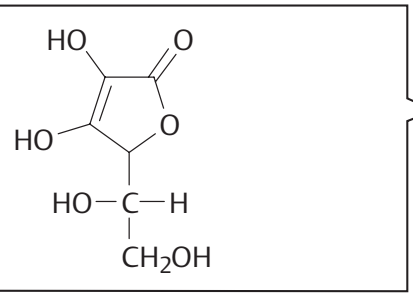

60 mg*
Fruit
Vegetables

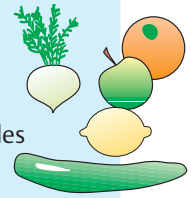

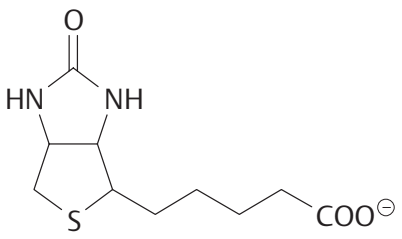

0.1 mg*
Yeast products
Legumes
Nuts

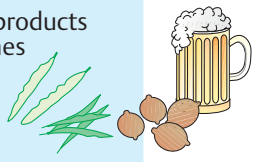

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Basics

Hormones are *chemical signaling substances.* They are synthesized in specialized cells that are often associated to form *endocrine glands.* Hormones are released into the *blood* and transported with the blood to their *effector organs.* In the organs, the hormones carry out physiological and biochemical regulatory functions. In contrast to endocrine hormones, **tissue hormones** are only active in the immediate vicinity of the cells that secrete them.

The distinctions between hormones and other signaling substances (mediators, neurotransmitters, and growth factors) are fluid. **Mediators** is the term used for signaling substances that do not derive from special hormone-forming cells, but are form by many cell types. They have hormone-like effects in their immediate surroundings. *Histamine* (see p. 352) and *prostaglandins* (see p. 390) are important examples of these substances. **Neurohormones** and **neurotransmitters** are signaling substances that are produced and released by nerve cells (see p. 348). **Growth factors** and **cytokines** mainly promote cell proliferation and cell differentiation (see p. 392).

A. Hormones: overview ●

The animal organism contains more than 100 hormones and hormone-like substances, which can be classified either according to their structure or according to their function. In chemical terms, most hormones are *amino acid derivatives, peptides* or *proteins,* or *steroids.* Hormones regulate the following processes:

- **Growth and differentiation of cells, tissues, and organs**
  These processes include cell proliferation, embryonic development, and sexual differentiation—i. e., processes that require a prolonged time period and involve proteins de novo synthesis. For this reason, mainly steroid hormones which function via transcription regulation are active in this field (see p. 244).
- **Metabolic pathways**
  Metabolic regulation requires rapidly acting mechanisms. Many of the hormones involved therefore regulate *interconversion* of enzymes (see p. 120). The main processes subject to hormonal regulation are the uptake and degradation of storage substances (glycogen, fat), metabolic pathways for biosynthesis and degradation of central metabolites (glucose, fatty acids, etc.), and the supply of metabolic energy.
- **Digestive processes**
  Digestive processes are usually regulated by locally acting peptides (paracrine; see p. 372), but mediators, biogenic amines, and neuropeptides are also involved (see p. 270).
- **Maintenance of ion concentrations (homeostasis)**
  Concentrations of Na^+, K^+, and Cl^- in body fluids, and the physiological variables dependent on these (e. g. blood pressure), are subject to strict regulation. The principal site of action of the hormones involved is the kidneys, where hormones increase or reduce the resorption of ions and recovery of water (see pp. 326–331). The concentrations of Ca^{2+} and phosphate, which form the mineral substance of bone and teeth, are also precisely regulated.

Many hormones influence the above processes only indirectly by regulating the synthesis and release of other hormones (*hormonal hierarchy;* see p. 372).

B. Hormonal regulation system ●

Each hormone is the center of a hormonal regulation system. Specialized glandular cells synthesize the hormone from precursors, store it in many cases, and release it into the bloodstream when needed (**biosynthesis**). For **transport**, the poorly water-soluble lipophilic hormones are bound to plasma proteins known as hormone carriers. To stop the effects of the hormone again, it is inactivated by enzymatic reactions, most of which take place in the liver (**metabolism**). Finally, the hormone and its metabolites are expelled via the excretory system, usually in the kidney (**excretion**). All of these processes affect the concentration of the hormone and thus contribute to regulation of the hormonal signal.

In the effector organs, target cells receive the hormone's message. These cells have hormone receptors for the purpose, which bind the hormone. Binding of a hormone passes information to the cell and triggers a response (**effect**).

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A. Hormones: overview

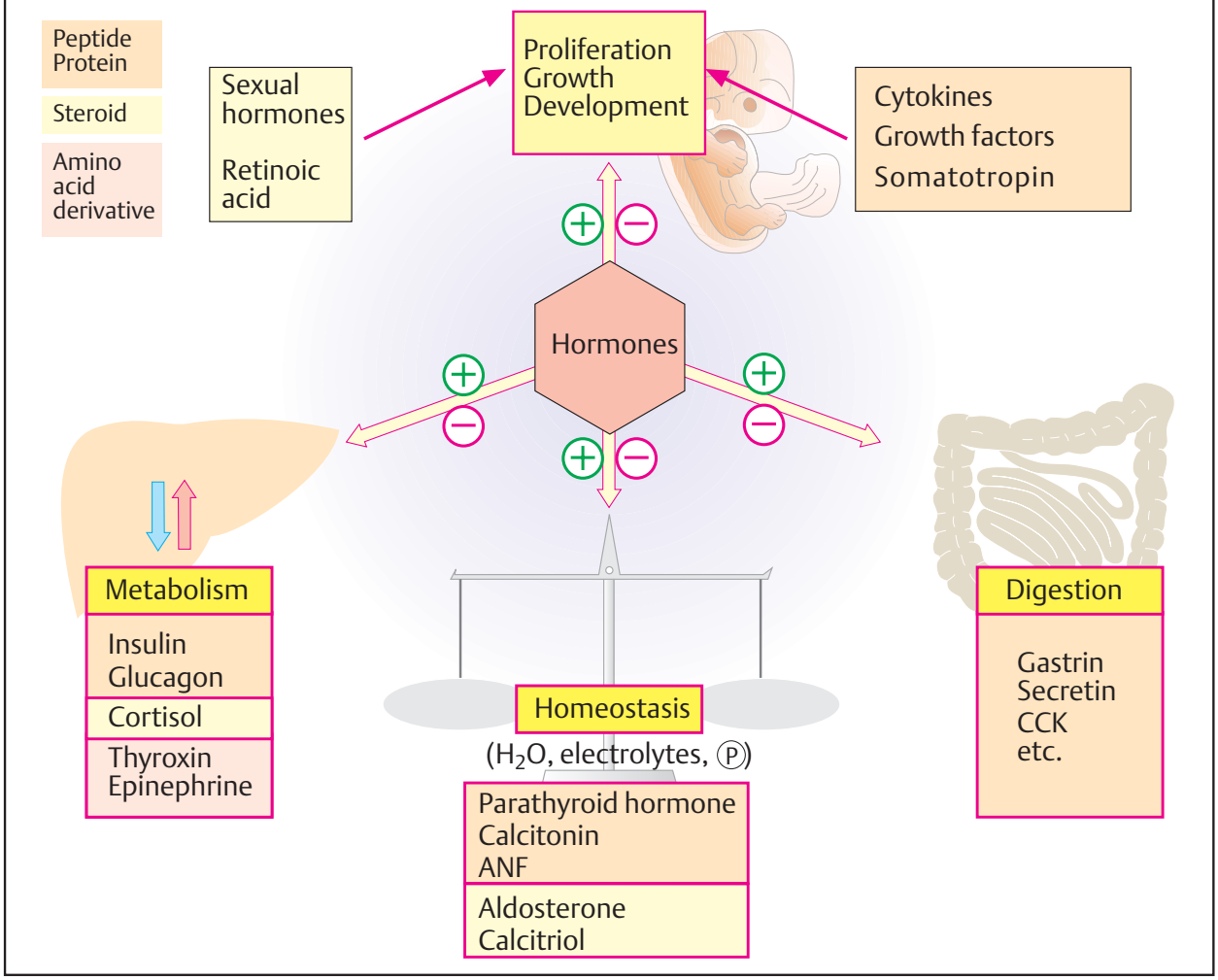

A. Hormonal regulation system

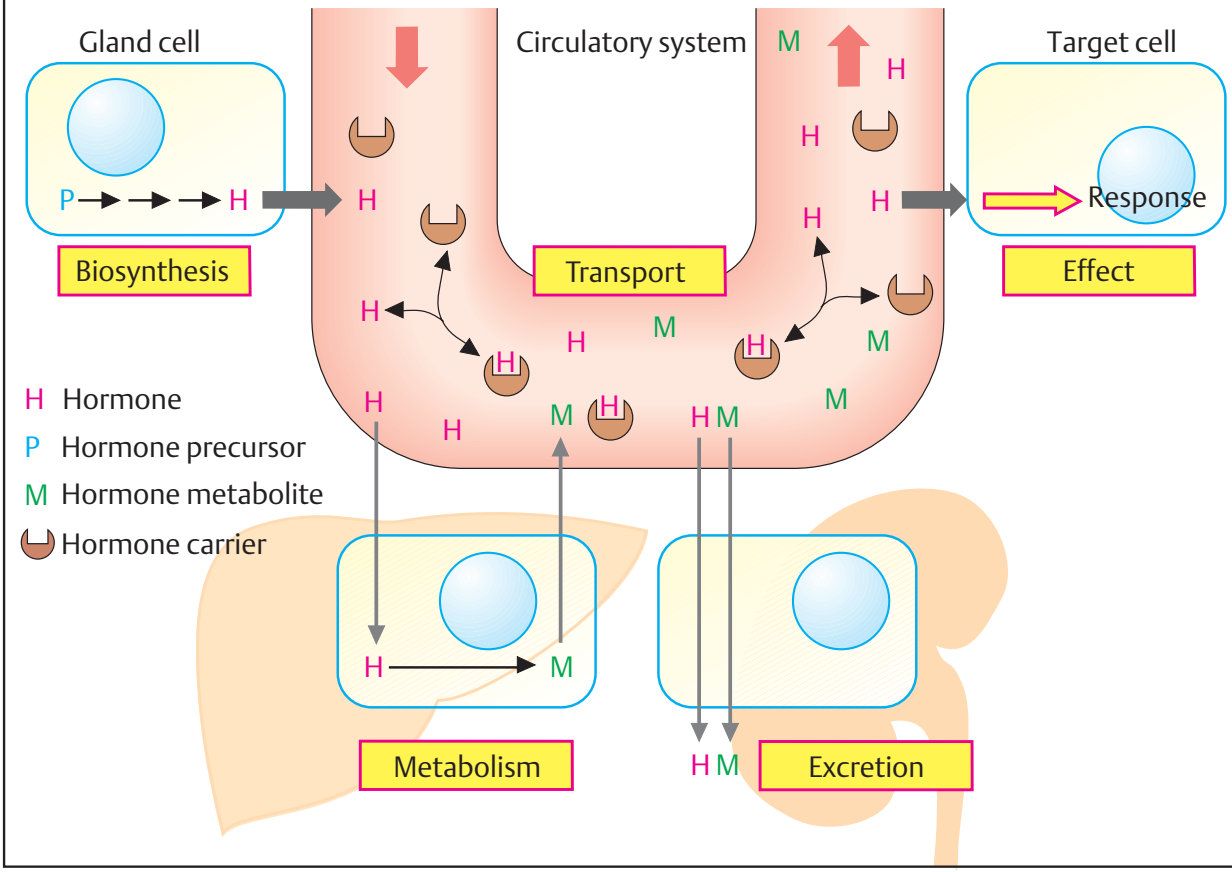

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Plasma levels and hormone hierarchy

A. Endocrine, paracrine, and autocrine hormone effects ◑

Hormones transfer signals by migrating from their site of synthesis to their site of action. They are usually transported in the blood. In this case, they are said to have an **endocrine effect** (**1**; example: *insulin*). By contrast, *tissue hormones,* the target cells for which are in the immediate vicinity of the glandular cells that produce them, are said to have a **paracrine effect** (**2**; example: *gastrointestinal tract hormones*). When signal substances also pass effects back to the cells that synthesize them, they are said to have an **autocrine effect** (**3**; example: *prostaglandins*). Autocrine effects are often found in tumor cells (see p. 400), which stimulate their own proliferation in this way.

Insulin, which is formed in the B cells of the pancreas, has both endocrine and paracrine effects. As a hormone with endocrine effects, it regulates glucose and fat metabolism. Via a paracrine mechanism, it inhibits the synthesis and release of *glucagon* from the neighboring A cells.

B. Dynamics of the plasma level ◑

Hormones circulate as signaling substances in the blood at very low concentrations (10^{-12} to between 10^{-7} mol L^{-1}). These values change periodically in rhythms that depend on the time of day, month, or year, or on physiological cycles.

The first example shows the **circadian** rhythm of the cortisol level. As an activator of gluconeogenesis (see p. 158), cortisol is mainly released in the early morning, when the liver's glycogen stores are declining. During the day, the plasma cortisol level declines.

Many hormones are released into the blood in a spasmodic and irregular manner. In this case, their concentrations change in an **episodic** or **pulsatile** fashion. This applies, for instance, to luteinizing hormone (LH, lutropin).

Concentrations of other hormones are **event-regulated**. For example, the body responds to increased blood sugar levels after meals by releasing *insulin.* Regulation of hormone synthesis, release, and degradation allows the blood concentrations of hormones to be precisely adjusted. This is based either on simple feedback control or on hierarchically structured regulatory systems.

C. Closed-loop feedback control ◑

The biosynthesis and release of *insulin* by the pancreatic B cells (see p. 160) is stimulated by high blood glucose levels (> 5 mM). The insulin released then stimulates increased uptake and utilization of glucose by the cells of the muscle and adipose tissues. As a result, the blood glucose level falls back to its normal value, and further release of insulin stops.

D. Hormone hierarchy ◑

Hormone systems are often linked to each another, giving rise in some cases to a hierarchy of higher-order and lower-order hormones. A particularly important example is the *pituitary–hypothalamic axis,* which is controlled by the central nervous system (CNS).

Nerve cells in the hypothalamus react to stimulatory or inhibitory signals from the CNS by releasing activating or inhibiting factors, which are known as **liberins** (*"releasing hormones"*) and **statins** (*"inhibiting hormones"*). These neurohormones reach the adenohypophysis by short routes through the bloodstream. In the adenohypophysis, they stimulate (liberins) or inhibit (statins) the biosynthesis and release of tropines. **Tropines** (*glandotropic hormones*) in turn stimulate peripheral glands to synthesize glandular hormones. Finally, the **glandular hormone** acts on its target cells in the organism. In addition, it passes effects back to the higher-order hormone systems. This (usually negative) feedback influences the concentrations of the higher-order hormones, creating a feedback loop.

Many steroid hormones are regulated by this type of axis—e.g., thyroxin, cortisol, estradiol, progesterone, and testosterone. In the case of the glucocorticoids, the hypothalamus releases corticotropin-releasing hormone (CRH or corticoliberin, a peptide consisting of 41 amino acids), which in turn releases corticotropin (ACTH, 39 AAs) in the pituitary gland. Corticotropin stimulates synthesis and release of the glandular steroid hormone cortisol in the adrenal cortex.

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A. Endocrine, paracrine and autocrine hormone effects

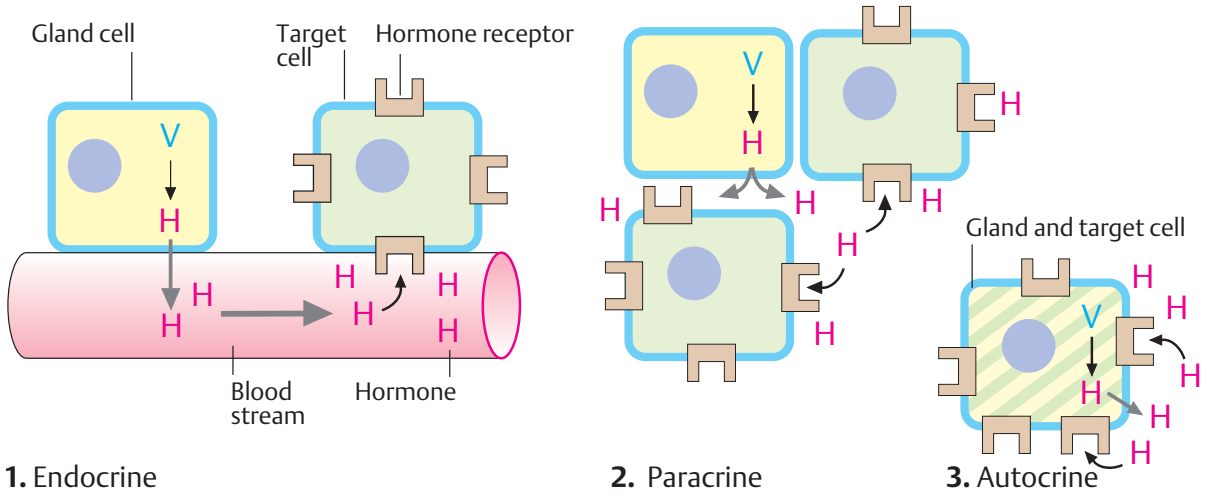

B. Plasma level dynamics

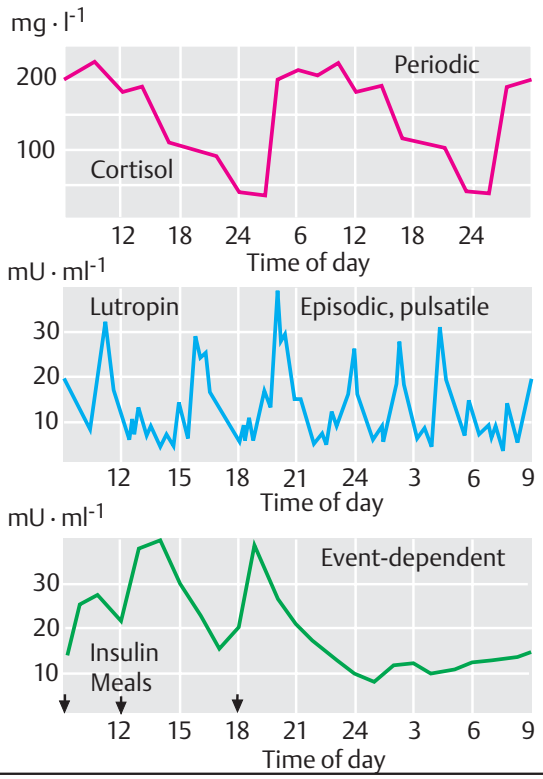

C. Regulatory circuit

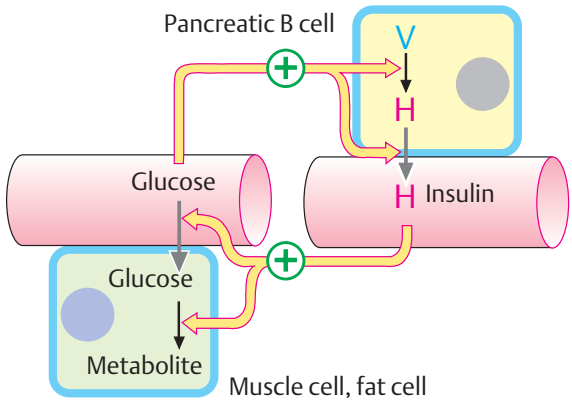

D. Hormone hierarchy

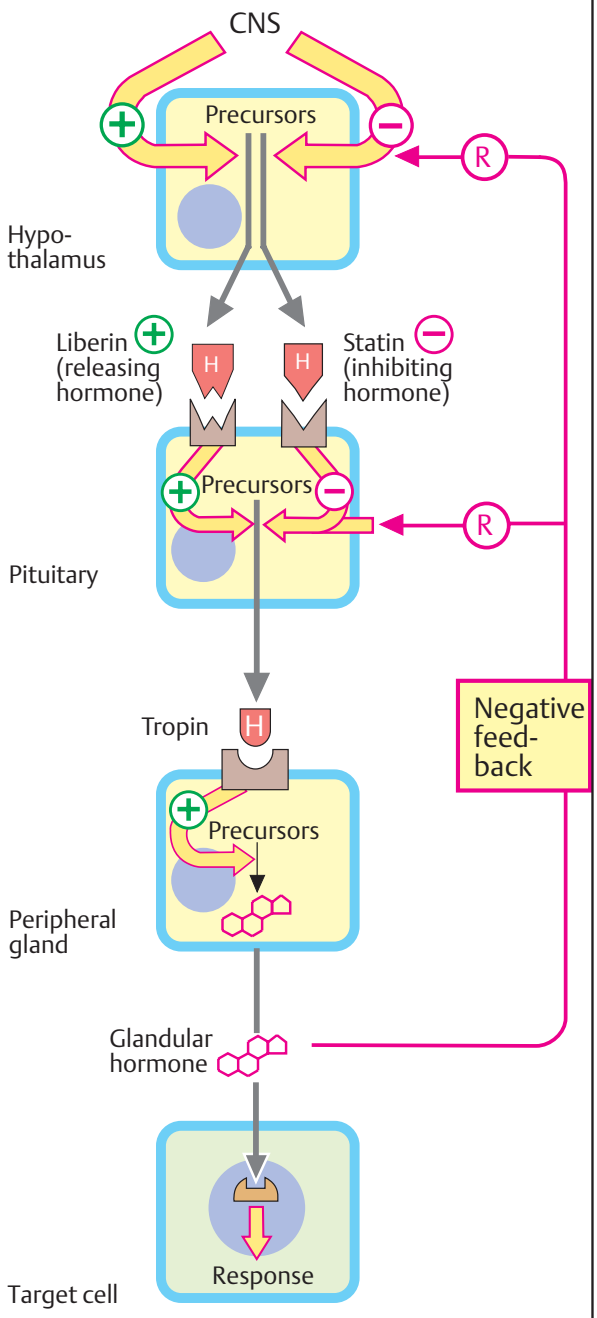

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Lipophilic hormones

Classifying hormones into hydrophilic and lipophilic molecules indicates the chemical properties of the two groups of hormones and also reflects differences in their mode of action (see p. 120).

A. Lipophilic hormones ◑

Lipophilic hormones, which include *steroid hormones, iodothyronines,* and *retinoic acid,* are relatively small molecules (300–800 Da) that are poorly soluble in aqueous media. With the exception of the iodothyronines, they are not stored by hormone-forming cells, but are released immediately after being synthesized. During transport in the blood, they are bound to specific carriers. Via intracellular receptors, they mainly act on transcription (see p. 358). Other effects of steroid hormones—e. g., on the immune system—are not based on transcriptional control. Their details have not yet been explained.

Steroid hormones

The most important steroid hormones in vertebrates are listed on p. 57. *Calcitriol* (vitamin D hormone) is also included in this group, although it has a modified steroid structure. The most important steroid hormone in invertebrates is *ecdysone*.

Progesterone is a female sexual steroid belonging to the progestin *(gestagen)* family. It is synthesized in the corpus luteum of the ovaries. The blood level of progesterone varies with the menstrual cycle. The hormone prepares the uterus for a possible pregnancy. Following fertilization, the placenta also starts to synthesize progesterone in order to maintain the pregnant state. The development of the mammary glands is also stimulated by progesterone.

Estradiol is the most important of the *estrogens.* Like progesterone, it is synthesized by the ovaries and, during pregnancy, by the placenta as well. Estradiol controls the menstrual cycle. It promotes proliferation of the uterine mucosa, and is also responsible for the development of the female secondary sexual characteristics (breast, fat distribution, etc.).

Testosterone is the most important of the male sexual steroids (*androgens*). It is synthesized in the Leydig intersitial cells of the testes, and controls the development and functioning of the male gonads. It also determines secondary sexual characteristics in men (muscles, hair, etc.).

Cortisol, the most important *glucocorticoid,* is synthesized by the adrenal cortex. It is involved in regulating protein and carbohydrate metabolism by promoting protein degradation and the conversion of amino acids into glucose. As a result, the blood glucose level rises (see p. 152). Synthetic glucocorticoids (e. g., dexamethasone) are used in drugs due to their anti-inflammatory and immunosuppressant effects.

Aldosterone, a *mineralocorticoid,* is also synthesized in the adrenal gland. In the kidneys, it promotes Na^+ resorption by inducing Na^+/K^+ ATPase and Na^+ channels (see p. 328). At the same time, it leads to increased K^+ excretion. In this way, aldosterone indirectly increases blood pressure.

Calcitriol is a derivative of vitamin D (see p. 364). On exposure to ultraviolet light, a precursor of the hormone can also arise in the skin. Calcitriol itself is synthesized in the kidneys (see p. 330). Calcitriol promotes the resorption of calcium in the intestine and increases the Ca^{2+} level in the blood.

Iodothyronines

The thyroid hormone **thyroxine** (tetraiodothyronine, T_4) and its active form **triiodothyronine** (T_3) are derived from the amino acid *tyrosine*. The iodine atoms at positions 3 and 5 of the two phenol rings are characteristic of them. Post-translational synthesis of thyroxine takes place in the thyroid gland from tyrosine residues of the protein *thyroglobulin,* from which it is proteolytically cleaved before being released. Iodothyronines are the only organic molecules in the animal organism that contain iodine. They increase the basal metabolic rate, partly by regulating mitochondrial ATP synthesis. In addition, they promote embryonic development.

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A. Lipophilic hormones

Hormone	Site of formation	Sites of action	Actions
Progesterone	Ovaries	Uterus: Prepares uterus for pregnancy; Promotes implantation of fertilized egg	Maintenance of pregnancy ↑ Development of mammary glands ↑
Estradiol	Ovaries	Uterus and other organs: Stimulates proliferation of endometrium	Menstrual cycle Bone development ↑ Development of secondary female sex characteristics e.g., fat distribution, breasts, body hair ↑
Testosterone	Testes	Causes: Sexual differentiation to male phenotype; Formation of ejaculate; Spermatogenesis	Development of secondary male sex characteristics e.g., skeleton, muscles, body hair ↑ Protein synthesis ↑
Cortisol	Adrenal glands (cortex)	Proteins ⇄ Amino acids → Glucose	Proteolysis ↑ Protein synthesis ↓ Gluconeogenese ↑ Blut-Glucose ↑ Activity of the immune system ↓
Aldosterone	Adrenal glands (cortex)	Kidneys: $3Na^{\oplus}$, $2K^{\oplus}$; ATP → ADP+P_i	$Na^{\oplus}$ retention ↑ $K^{\oplus}$ excretion ↑ Blood pressure ↑
Calcitriol	Kidneys	Gut; Bones ⇄ $Ca^{2\oplus}$	$Ca^{2\oplus}$- and phosphate resorption ↑ $Ca^{2\oplus}$ metabolism of bones ↑
Thyroxine	Thyroid gland	Embryo; Intermediary metabolism: O_2, H_2O, S, CO_2, ADP+P_i, ATP, Heat	Fetal development, growth, and maturation ↑ Basal metabolic rate ↑ Heat generation ↑ O_2 consumption ↑

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Metabolism of steroid hormones

A. Biosynthesis of steroid hormones ○

All steroid hormones are synthesized from **cholesterol.** The gonane core of cholesterol consists of 19 carbon atoms in four rings (A–D). The D ring carries a side chain of eight C atoms (see p. 54).

The cholesterol required for biosynthesis of the steroid hormones is obtained from various sources. It is either taken up as a constituent of LDL lipoproteins (see p. 278) into the hormone-synthesizing glandular cells, or synthesized by glandular cells themselves from acetyl-CoA (see p. 172). Excess cholesterol is stored in the form of fatty acid esters in lipid droplets. Hydrolysis allows rapid mobilization of the cholesterol from this reserve again.

Biosynthetic pathways. Only an overview of the synthesis pathways that lead to the individual hormones is shown here. Further details are given on p. 410.

Among the reactions involved, hydroxylations (H) are particularly numerous. These are catalyzed by specific *monooxygenases* ("hydroxylases") of the cytochrome P450 family (see p. 318). In addition, there are NADPH-dependent and $NADP^+$-dependent *hydrogenations* (Y) and *dehydrogenations* (D), as well as *cleavage* and *isomerization reactions* (S, I). The estrogens have a special place among the steroid hormones, as they are the only ones that contain an aromatic A ring. When this is formed, catalyzed by *aromatase,* the angular methyl group (C-19) is lost.

Pregnenolone is an important intermediate in the biosynthesis of most steroid hormones. It is identical to cholesterol with the exception of a shortened and oxidized side chain. Pregnenolone is produced in three steps by hydroxylation and cleavage in the side chain. Subsequent dehydrogenation of the hydroxyl group at C-3 (b) and shifting of the double bond from C-5 to C-4 results in the gestagen **progesterone**.

With the exception of calcitriol, all steroid hormones are derived from progesterone. Hydroxylations of progesterone at C atoms 17, 21, and 11 lead to the glucocorticoid **cortisol**. Hydroxylation at C-17 is omitted during synthesis of the mineralocorticoid **aldosterone.** Instead, the angular methyl group (C-18) is oxidized to the aldehyde group. During synthesis of the androgen **testosterone** from progesterone, the side chain is completely removed. Aromatization of the A ring, as mentioned above, finally leads to **estradiol**.

On the way to **calcitriol** (vitamin D hormone; see p. 342), another double bond in the B ring of cholesterol is first introduced. Under the influence of UV light on the skin, the B ring is then photochemically cleaved, and the secosteroid *cholecalciferol* arises (vitamin D_3; see p. 364). Two Cyt P450-dependent hydroxylations in the liver and kidneys produce the active vitamin D hormone (see p. 330).

B. Inactivation of steroid hormones ○

The steroid hormones are mainly inactivated in the liver, where they are either reduced or further hydroxylated and then conjugated with *glucuronic acid* or *sulfate* for excretion (see p. 316). The *reduction reactions* attack oxo groups and the double bond in ring A. A combination of several inactivation reactions gives rise to many different steroid metabolites that have lost most of their hormonal activity. Finally, they are excreted with the *urine* and also partly via the *bile*. Evidence of steroids and steroid metabolites in the urine is used to investigate the hormone metabolism.

Further information

Congenital defects in the biosynthesis of steroid hormones can lead to severe developmental disturbances. In the *adrenogenital syndrome* (AGS), which is relatively common, there is usually a defect in *21-hydroxylase,* which is needed for synthesis of cortisol and aldosterone from progesterone. Reduced synthesis of this hormone leads to increased formation of testosterone, resulting in masculinization of female fetuses. With early diagnosis, this condition can be avoided by providing the mother with hormone treatment before birth.

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A. Biosynthesis of steroid hormones

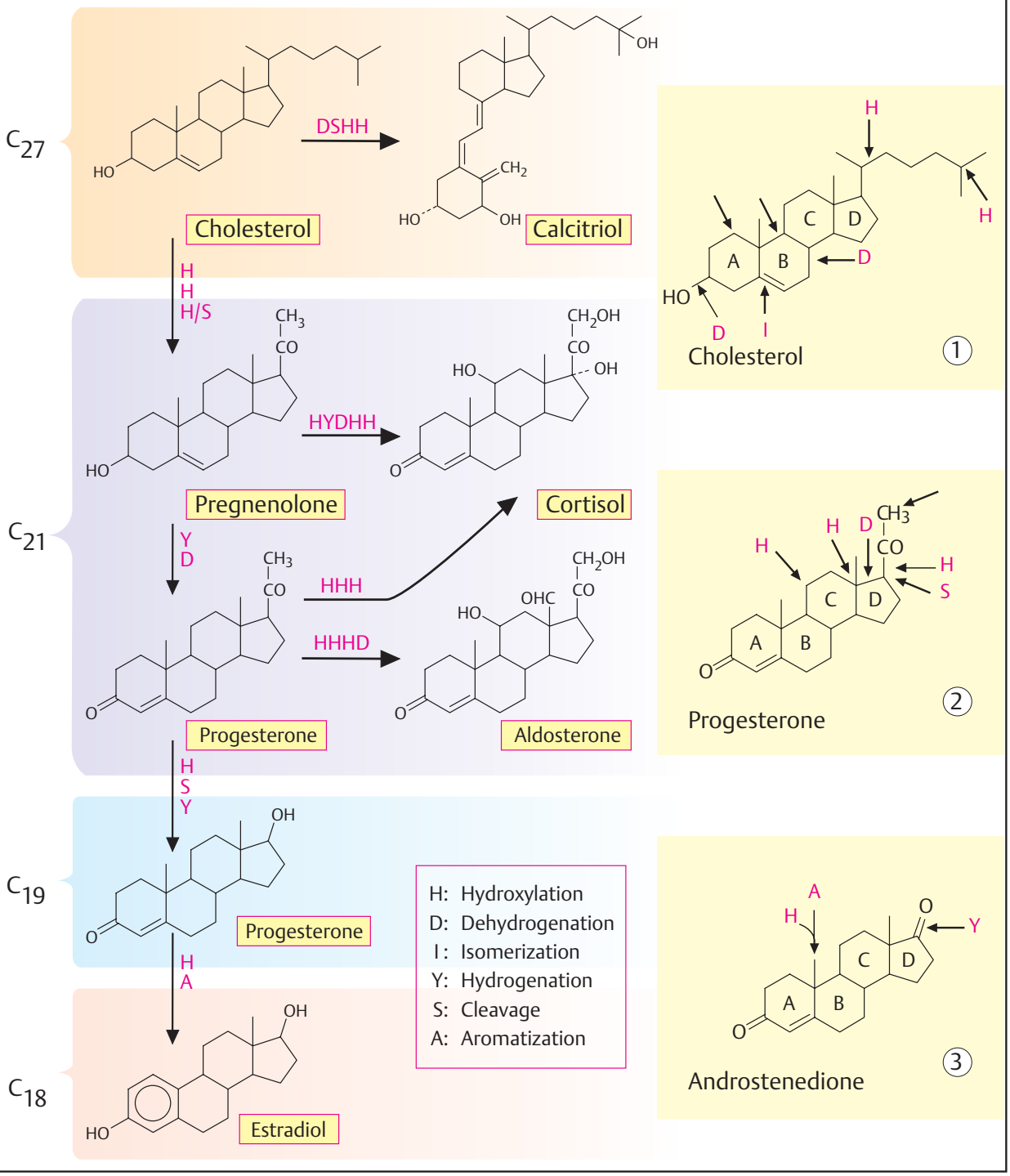

B. Inactivation of steroid hormones

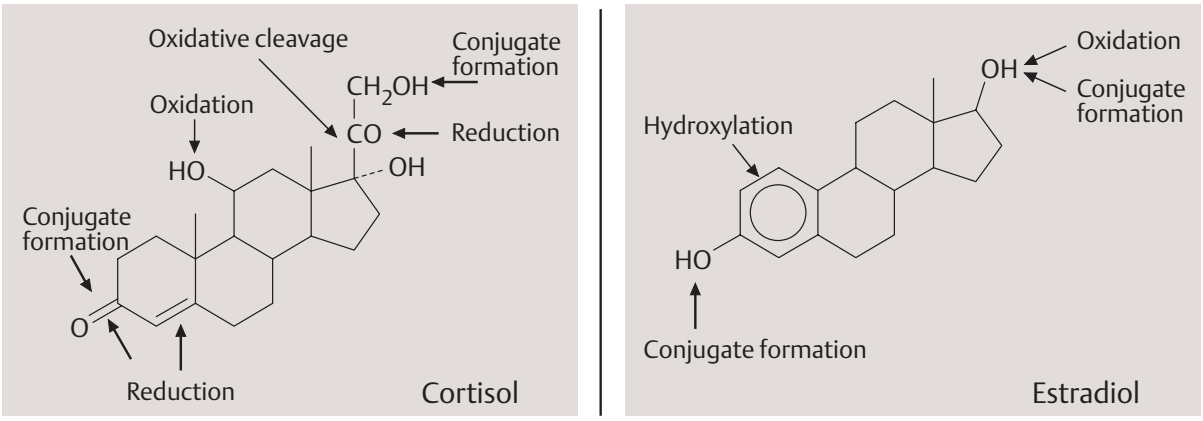

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Mechanism of action

A. Mechanism of action of lipophilic hormones ◑

Lipophilic signaling substances include the *steroid hormones, calcitriol,* the *iodothyronines* (T_3 and T_4), and *retinoic acid.* These hormones mainly act in the *nucleus* of the target cells, where they regulate gene transcription in collaboration with their receptors and with the support of additional proteins (known as coactivators and mediators; see p. 244). There are several effects of steroid hormones that are not mediated by transcription control. These alternative pathways for steroid effects have not yet been fully explained.

In the blood, there are a number of transport proteins for lipophilic hormones (see p. 276). Only the free hormone is able to penetrate the membrane and enter the cell. The hormone encounters its receptor in the nucleus (and sometimes also in the cytoplasm).

The **receptors** for lipophilic hormones are rare proteins. They occur in small numbers (10^3–10^4 molecules per cell) and show marked *specificity* and high *affinity* for the hormone (K_d = 10^{-8}–10^{-10} M). After binding to the hormone, the steroid receptors are able to bind as homodimers or heterodimers to *control elements* in the promoters of specific genes, from where they can influence the transcription of the affected genes—i. e., they act as *transcription factors.*

The illustration shows the particularly well-investigated mechanism of action for **cortisol**, which is unusual to the extent that the hormone–receptor complex already arises in the cytoplasm. The free receptor is present in the cytoplasm as a monomer in complex with the chaperone **hsp90** (see p. 232). Binding of cortisol to the complex leads to an *allosteric conformational change* in the receptor, which is then released from the hsp90 and becomes capable of DNA binding as a result of *dimerization.*

In the nucleus, the hormone–receptor complex binds to nucleotide sequences known as **hormone response elements** (HREs). These are short palindromic DNA segments that usually promote transcription as enhancer elements (see p. 244). The illustration shows the HRE for glucocorticoids (GRE; "n" stands for any nucleotide). Each hormone receptor only recognizes its "own" HRE and therefore only influences the transcription of genes containing that HRE. Recognition between the receptor and HRE is based on interaction between the amino acid residues in the DNA-binding domain (**B**) and the relevant bases in the HRE (emphasized in color in the structure illustrated).

As discussed on p. 244, the hormone receptor does not interact directly with the RNA polymerase, but rather—along with other transcription factors—with a coactivator/mediator complex that processes all of the signals and passes them on to the polymerase. In this way, hormonal effects lead within a period of minutes to hours to altered levels of mRNAs for key proteins in cellular processes ("cellular response").

B. Steroid receptors ○

The receptors for lipophilic signaling substances all belong to one *protein superfamily.* They are constructed in a modular fashion from **domains** with various lengths and functions. Starting from the N terminal, these are: the *regulatory domain,* the *DNA-binding domain,* a *nuclear localization sequence* (see p. 228), and the *hormone-binding domain* (see p. 73D).

The homology among receptors is particularly great in the area of the DNA-binding domain. The proteins have cysteine-rich sequences here that coordinatively bind zinc ions (**A**, Cys shown in yellow, Zn^{2+} in light blue). These centers, known as "zinc fingers" or "**zinc clusters**," stabilize the domains and support their dimerization, but do not take part in DNA binding directly. As in other transcription factors (see p. 118), "recognition helices" are responsible for that.

In addition to the receptors mentioned in **A**, the family of steroid receptors also includes the product of the oncogene *erb*-A (see p. 398), the receptor for the environmental toxin *dioxin,* and other proteins for which a distinct hormone ligand has not been identified (known as "orphan receptors"). Several steroid receptors—e. g., the retinoic acid receptor—form functional heterodimers with orphan receptors.

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A. Mechanism of action of lipophilic hormones

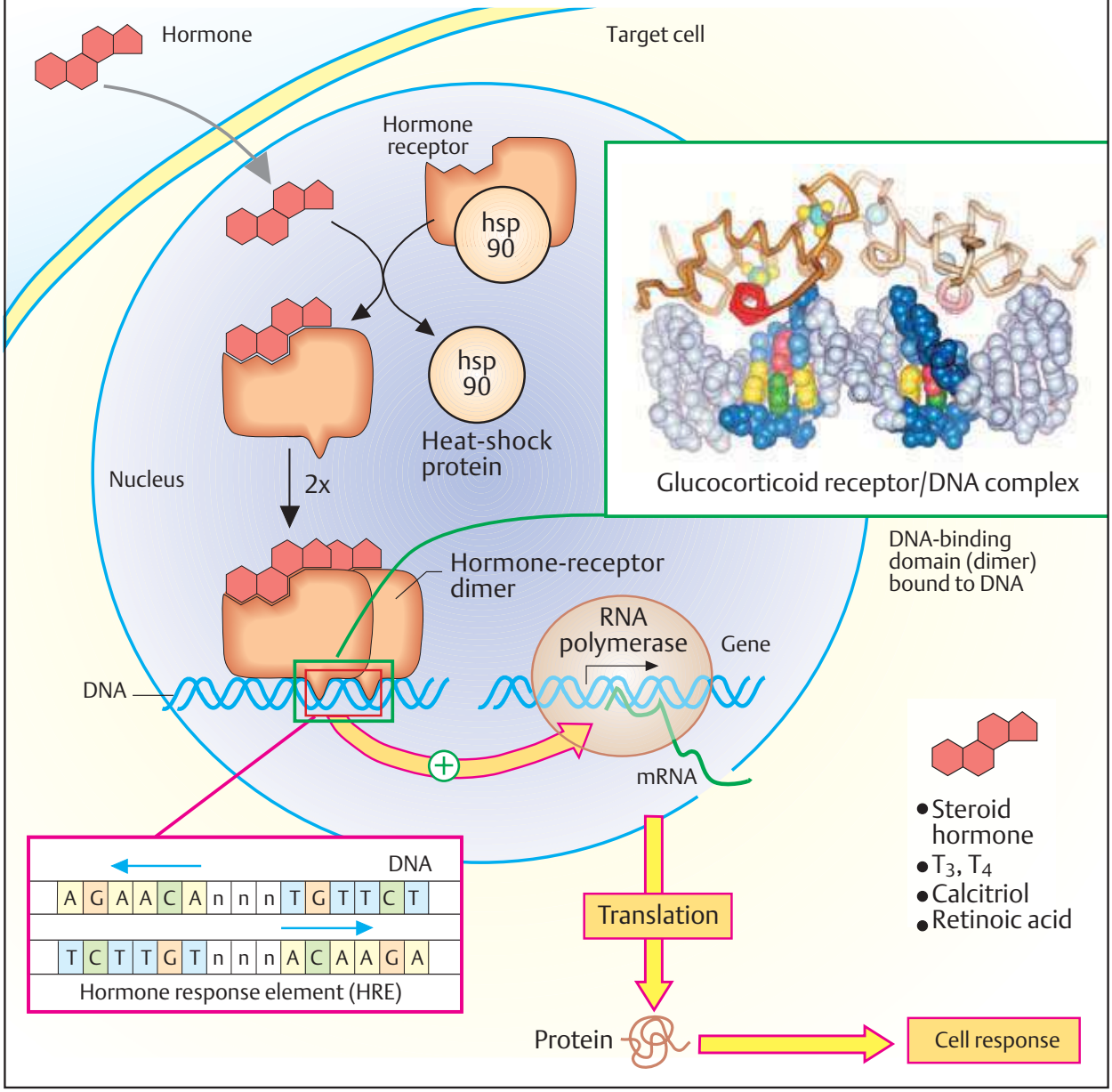

B. Receptors of lipophilic hormones

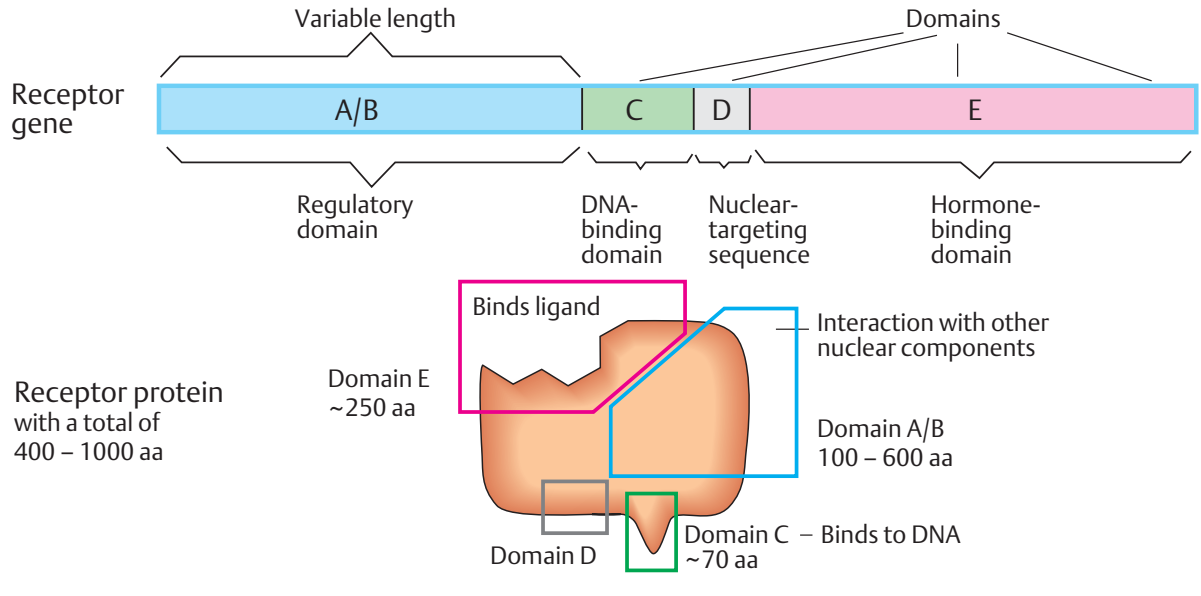

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Hydrophilic hormones

The hydrophilic hormones are derived from amino acids, or are peptides and proteins composed of amino acids. Hormones with endocrine effects are synthesized in glandular cells and stored there in vesicles until they are released. As they are easily soluble, they do not need carrier proteins for transport in the blood. They bind on the plasma membrane of the target cells to receptors that pass the hormonal signal on (signal transduction; see p. 384). Several hormones in this group have paracrine effects—i.e., they only act in the immediate vicinity of their site of synthesis (see p. 372).

A. Signaling substances derived from amino acids ◑

Histamine, serotonin, melatonin, and the catecholamines dopa, dopamine, norepinephrine, and epinephrine are known as *"biogenic amines."* They are produced from amino acids by decarboxylation and usually act not only as hormones, but also as neurotransmitters.

Histamine, an important *mediator* (local signaling substance) and *neurotransmitter,* is mainly stored in tissue mast cells and basophilic granulocytes in the blood. It is involved in inflammatory and allergic reactions. "Histamine liberators" such as tissue hormones, type E immunoglobulins (see p. 300), and drugs can release it. Histamine acts via various types of receptor. Binding to H_1 receptors promotes contraction of smooth muscle in the bronchia, and dilates the capillary vessels and increases their permeability. Via H_2 receptors, histamine slows down the heart rate and promotes the formation of HCl in the gastric mucosa. In the brain, histamine acts as a neurotransmitter.

Epinephrine is a hormone synthesized in the adrenal glands from tyrosine (see p. 352). Its release is subject to neuronal control. This "emergency hormone" mainly acts on the blood vessels, heart, and metabolism. It constricts the blood vessels and thereby increases blood pressure (via α_1 and α_2 receptors); it increases cardiac function (via β_2 receptors); it promotes the degradation of glycogen into glucose in the liver and muscles (via β_2 receptors); and it dilates the bronchia (also via β_2 receptors).

B. Examples of peptide hormones and proteohormones ◑

Numerically the largest group of signaling substances, these arise by protein biosynthesis (see p. 382). The smallest peptide hormone, thyroliberin (362 Da), is a tripeptide. Proteohormones can reach masses of more than 20 kDa—e.g., thyrotropin (28 kDa). Similarities in the primary structures of many peptide hormones and proteohormones show that they are related to one another. They probably arose from common predecessors in the course of evolution.

Thyroliberin (thyrotropin-releasing hormone, TRH) is one of the neurohormones of the hypothalamus (see p. 330). It stimulates pituitary gland cells to secrete thyrotropin (TSH). TRH consists of three amino acids, which are modified in characteristic ways (see p. 353).

Thyrotropin (thyroid-stimulating hormone, TSH) and the related hormones *lutropin* (luteinizing hormone, LH) and *follitropin* (follicle-stimulating hormone, FSH) originate in the adenohypophysis. They are all dimeric glycoproteins with masses of around 28 kDa. Thyrotropin stimulates the synthesis and secretion of thyroxin by the thyroid gland.

Insulin (for the structure, see p. 70) is produced and released by the B cells of the pancreas and is released when the glucose level rises. Insulin reduces the blood sugar level by promoting processes that consume glucose—e.g., glycolysis, glycogen synthesis, and conversion of glucose into fatty acids. By contrast, it inhibits gluconeogenesis and glycogen degradation. The transmission of the insulin signal in the target cells is discussed in greater detail on p. 388.

Glucagon, a peptide of 29 amino acids, is a product of the A cells of the pancreas. It is the antagonist of insulin and, like insulin, mainly influences carbohydrate and lipid metabolism. Its effects are each opposite to those of insulin. Glucagon mainly acts via the second messenger cAMP (see p. 384).

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A. Signaling substances derived from amino acids

Hormone	Sites of formation	Sites of action	Actions
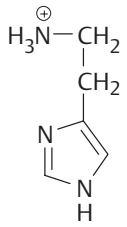 Histamine	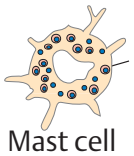 Mast cell; Basophilic granulocyte	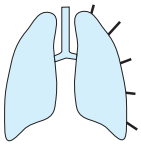 Lungs; Stomach	Width of bronchi ↓ Capillaries: width ↑ permeability ↑ Gastric acid secretion by parietal cells ↑
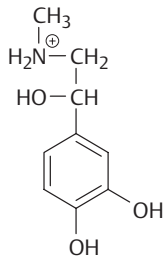 Epinephrine	Adrenal glands (medulla)	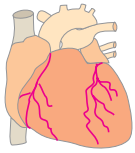 Heart; 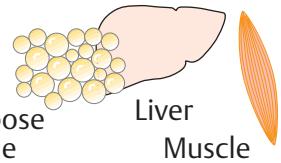 Adipose tissue, Liver, Muscle	Cardiac output ↑ Width of blood vessels ↓ Blood pressure ↑ Metabolism: Glycogenolysis ↑ Blood glucose ↑ Lipolysis ↑

B. Examples of peptide hormones and proteohormones

Thyroliberin (TRH) 3 AA
Thyrotropin (TSH) α chain 92 AA β chain 112 AA

Hypothalamus; Pituitary
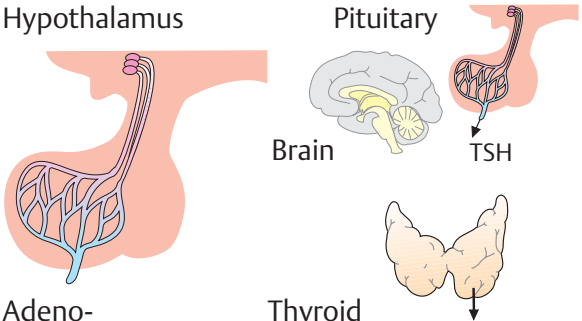

Thyrotropin secretion ↑
Neurotransmitter action
Synthesis and secretion of thyroxine ↑

Insulin A chain 21 AA B chain 30 AA

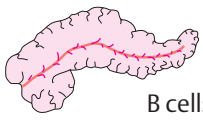

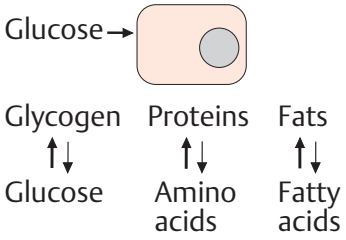

Glucose uptake by cells ↑ Blood glucose ↓
Storage compounds: formation ↑ degradation ↓

Glucagon 29 AA

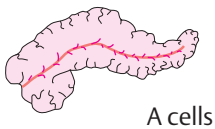

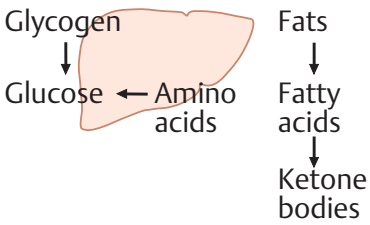

Glycogenolysis ↑
Gluconeogenesis ↑
Blood glucose ↑
Ketone body formation ↑

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Metabolism of peptide hormones

Hydrophilic hormones and other water-soluble signaling substances have a variety of biosynthetic pathways. Amino acid derivatives arise in special *metabolic pathways* (see p. 352) or through *post-translational modification* (see p. 374). Proteohormones, like all proteins, result from *translation* in the ribosome (see p. 250). Small peptide hormones and neuropeptides, most of which only consist of 3–30 amino acids, are released from precursor proteins by *proteolytic degradation*.

A. Biosynthesis ○

The illustration shows the synthesis and processing of the precursor protein **proopiomelanocortin** (POMC) as an example of the biosynthesis of small peptides with signaling functions. POMC arises in cells of the adenohypophysis, and after processing in the rER and Golgi apparatus, it supplies the opiate-like peptides *met-enkephalin* and *β-endorphin* (implying "opio-"; see p. 352), three *melanocyte-stimulating hormones* (α-, β- and γ-MSH, implying "melano-"), and the glandotropic hormone *corticotropin* (ACTH, implying "-cortin"). Additional products of POMC degradation include two *lipotropins* with catabolic effects in the adipose tissue (β- and γ-LPH).

Some of the peptides mentioned are overlapping in the POMC sequence. For example, additional cleavage of ACTH gives rise to α-MSH and corticotropin-like intermediary peptide (CLIP). Proteolytic degradation of β-LPH provides γ-LPH and β-endorphin. The latter can be further broken down to yield met-enkephalin, while γ-LPH can still give rise to β-MSH (not shown). Due to the numerous derivative products with biological activity that it has, POMC is also known as a **polyprotein**. Which end product is formed and in what amounts depends on the activity of the proteinases in the ER that catalyze the individual cleavages.

The principles underlying protein synthesis and protein maturation (see pp. 230–233) can be summed up once again using the example of POMC:

[1] As a result of *transcription* of the POMC gene and *maturation of the hnRNA,* a mature **mRNA** consisting of some 1100 nucleotides arises, which is modified at both ends (see p. 246). This mRNA codes for prepro-POMC—i.e., a POMC protein that still has a signal peptide for the ER at the N terminus (see p. 230).

[2] **Prepro-POMC** arises through *translation* in the rough endoplasmic reticulum (rER). The growing peptide chain is introduced into the ER with the help of a signal peptide.

[3] Cleavage of the signal peptide and other modifications in the ER (formation of disulfide bonds, glycosylation, phosphorylation) give rise to the mature prohormone ("**pro-POMC**").

[4] The **neuropeptides** and **hormones** mentioned are now formed by *limited proteolysis* and stored in vesicles. Release from these vesicles takes place by exocytosis when needed.

The biosynthesis of peptide hormones and proteohormones, as well as their secretion, is controlled by higher-order regulatory systems (see p. 372). Calcium ions are among the substances involved in this regulation as *second messengers;* an increase in calcium ions stimulates synthesis and secretion.

B. Degradation and inactivation ◑

Degradation of peptide hormones often starts in the blood plasma or on the vascular walls; it is particularly intensive in the kidneys.

Several peptides that contain disulfide bonds (e.g., insulin) can be inactivated by reductive *cleavage of the disulfide bonds* (**1**). Peptides and proteins are also cleaved by *peptidases,* starting from one end of the peptide by *exopeptidases* (**2**), or in the middle of it by proteinases (endopeptidases, **3**). *Proteolysis* gives rise to a variety of hormone fragments, several of which are still biologically active. Some peptide hormones and proteohormones are removed from the blood by binding to their receptors with subsequent *endocytosis* of the hormone–receptor complex (**4**). They are then broken down in the lysosomes. All of the degradation reactions lead to amino acids, which become available to the metabolism again.

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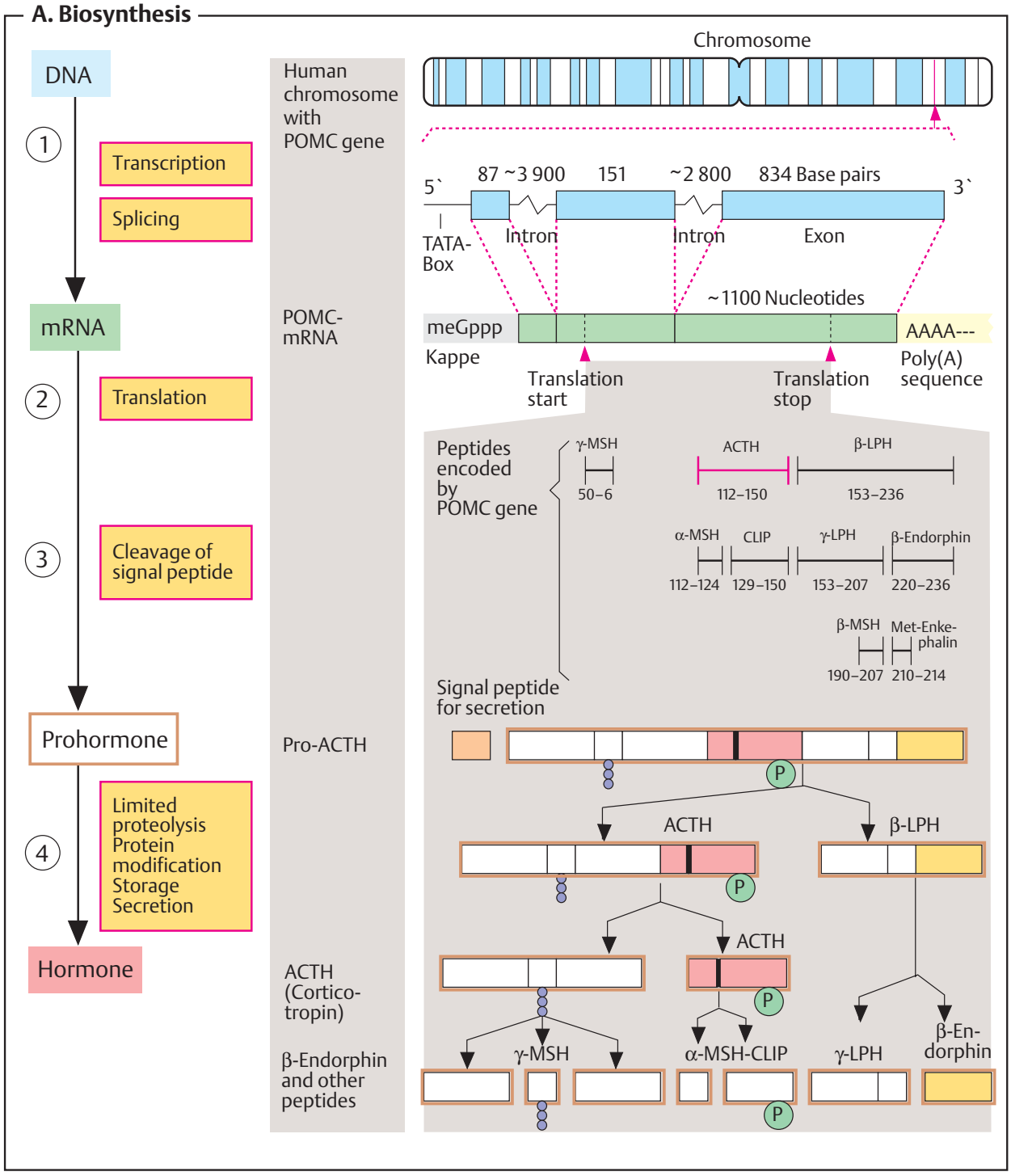

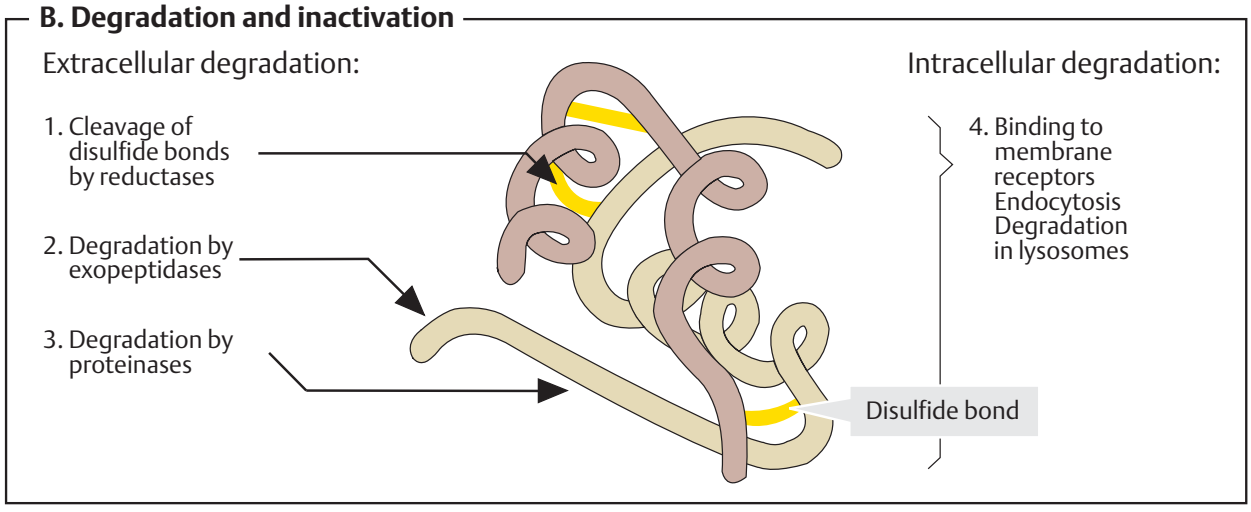

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Mechanisms of action

The messages transmitted by hydrophilic signaling substances (see p. 380) are sent to the interior of the cell by *membrane receptors.* These bind the hormone on the outside of the cell and trigger a new second signal on the inside by altering their conformation. In the interior of the cell, this secondary signal influences the activity of enzymes or ion channels. Via further steps, *switching of the metabolism,* changes in the *cytoskeleton,* and activation or inhibition of *transcription factors* can occur *("signal transduction")* can occur.

A. Mechanisms of action ◑

Receptors are classified into three different types according to their structure (see also p. 224):

1. 1-Helix receptors (left) are proteins that span the membrane with only one α-helix. On their inner (cytoplasmic) side, they have domains with *allosterically activatable enzyme activity.* In most cases, these are *tyrosine kinases.*

Insulins (see p. 388), *growth factors,* and *cytokines* (see p. 392), for example, act via 1-helix receptors. Binding of the signaling substance leads to activation of internal kinase activity (in some cases, dimerization of the receptor is needed for this). The activated kinase phosphorylates itself using ATP (*autophosphorylation*), and also phosphorylates tyrosine residues of other proteins (known as *receptor substrates*). Adaptor proteins that recognize the phosphotyrosine residues bind to the phosphorylated proteins (see pp. 388, 392). They pass the signal on to other protein kinases.

2. Ion channels (center). These receptors contain *ligand-gated ion channels.* Binding of the signaling substance opens the channels for ions such as Na^+, K^+, Ca^{2+}, and Cl^-. This mechanism is mainly used by *neurotransmitters* such as *acetylcholine* (nicotinic receptor; see p. 224) and *GABA* (A receptor; see p. 354).

3. 7-Helix receptors (serpentine receptors, right) represent a large group of membrane proteins that transfer the hormone or transmitter signal, with the help of *G proteins* (see below), to *effector proteins* that alter the concentrations of *ions* and *second messengers* (see **B**).

B. Signal transduction by G proteins ◑

G proteins transfer signals from 7-helix receptors to effector proteins (see above). G protein are *heterotrimers* consisting of three different types of subunit (α, β, and γ; see p. 224). The α-subunit can bind GDP or GTP (hence the name "G protein") and has *GTPase activity.* Receptor-coupled G proteins are related to other GTP-binding proteins such as *Ras* (see pp. 388, 398) and *EF-Tu* (see p. 252).

G proteins are divided into several types, depending on their effects. *Stimulatory G proteins* ($\mathbf{G_s}$) are widespread. They activate adenylate cyclases (see below) or influence ion channels. *Inhibitory G proteins* ($\mathbf{G_i}$) *inhibit* adenylate cyclase. G proteins in the G_q *family* activate another effector enzyme—phospholipase c (see p. 386).

Binding of the signaling substance to a 7-helix receptor alters the receptor conformation in such a way that the corresponding G protein can attach on the inside of the cell. This causes the α-subunit of the G protein to exchange bound GDP for GTP (**1**). The G protein then separates from the receptor and dissociates into an α-subunit and a βγ-unit. Both of these components bind to other membrane proteins and alter their activity; *ion channels* are opened or closed, and *enzymes* are activated or inactivated.

In the case of the β_2-catecholamine receptor (illustrated here), the α-subunit of the G_s protein, by binding to adenylate cyclase, leads to the synthesis of the **second messenger** cAMP. cAMP activates protein kinase A, which in turn activates or inhibits other proteins (**2**; see p. 120).

The βγ-unit of the G protein stimulates a kinase (βARK, not shown), which phosphorylates the receptor. This reduces its af nity for the hormone and leads to binding of the blocking protein *arrestin.* The internal GTPase activity of the α-subunit hydrolyzes the bound GTP to GDP within a period of seconds to minutes, and thereby terminates the action of the G protein on the adenylate cyclase (**3**).

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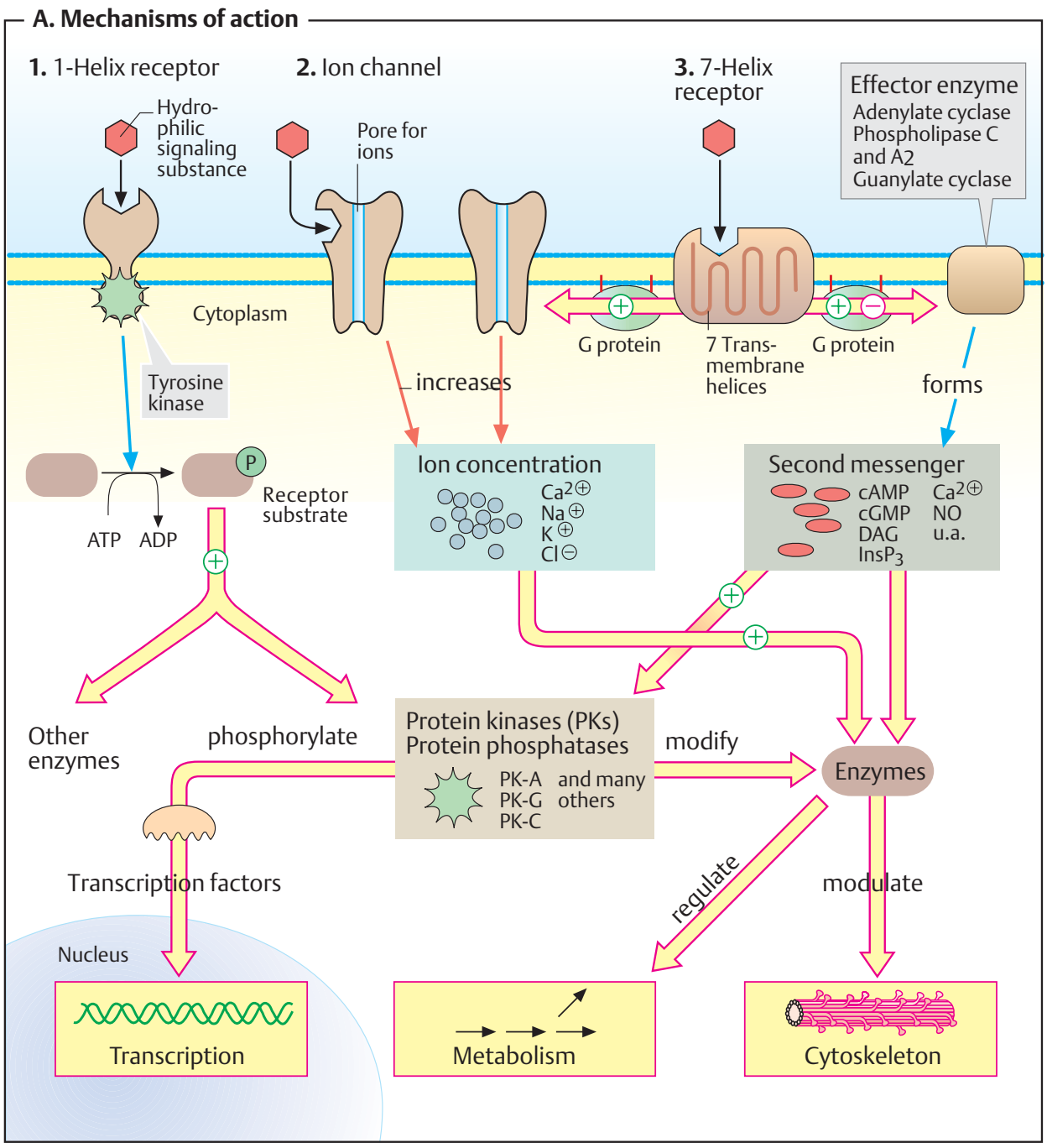

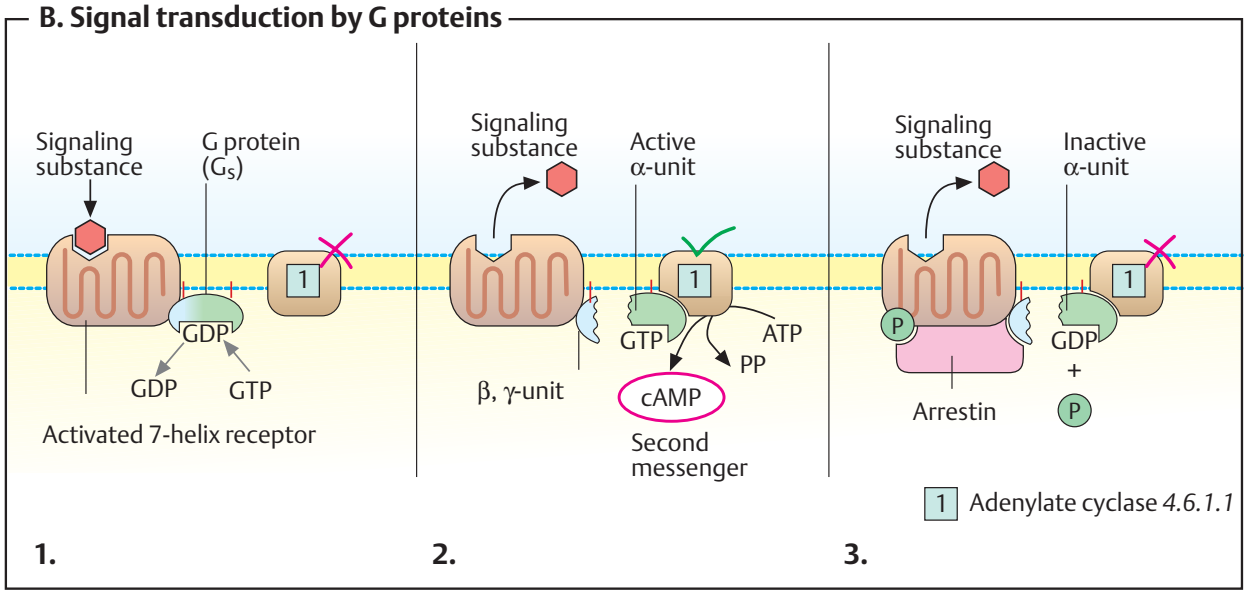

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Second messengers

Second messengers are *intracellular* chemical signals, the concentration of which is regulated by hormones, neurotransmitters, and other extracellular signals (see p. 384). They arise from easily available substrates and only have a short half-life. The most important second messengers are cAMP, cGMP, Ca^{2+}, inositol triphosphate ($InsP_3$), diacylglycerol (DAG), and nitrogen monoxide (NO).

A. Cyclic AMP ◑

Metabolism. The nucleotide **cAMP** (adenosine 3′,5′-cyclic monophosphate) is synthesized by membrane-bound *adenylate cyclases* [1] on the inside of the plasma membrane. The adenylate cyclases are a family of enzymes that cyclize ATP to cAMP by cleaving diphosphate (PP_i). The degradation of cAMP to AMP is catalyzed by *phosphodiesterases* [2], which are inhibited by *methylxanthines* such as caffeine, for example. By contrast, *insulin* activates the esterase and thereby reduces the cAMP level (see p. 388).

Adenylate cyclase activity is regulated by *G proteins* (G_s and G_i), which in turn are controlled by extracellular signals via *7-helix receptors* (see p. 384). Ca^{2+}-calmodulin (see below) also activates specific adenylate cyclases.

Action. cAMP is an allosteric effector of *protein kinase A* (PK-A, [3]). In the inactive state, PK-A is a heterotetramer (C_2R_2), the catalytic subunits of which (C) are blocked by regulatory units (R; autoinhibition). When cAMP binds to the regulatory units, the C units separate from the R units and become enzymatically active. Active PK-A phosphorylates serine and threonine residues of more than 100 different proteins, enzymes, and transcription factors. In addition to cAMP, **cGMP** also acts as a second messenger. It is involved in sight (see p. 358) and in the signal transduction of NO (see p. 388).

B. Inositol 1,4,5-trisphosphate and diacylglycerol ◑

Type G_q G proteins activate *phospholipase C* [4]. This enzyme creates two second messengers from the double-phosphorylated membrane phospholipid *phosphatidylinositol bisphosphate* ($PInsP_2$), i.e., inositol 1,4,5-trisphosphate (**InsP3**), which is soluble, and diacylglycerol (**DAG**). $InsP_3$ migrates to the endoplasmic reticulum (ER), where it opens Ca^{2+} channels that allow Ca^{2+} to flow into the cytoplasm (see **C**). By contrast, DAG, which is lipophilic, remains in the membrane, where it activates type C *protein kinases*, which phosphorylate proteins in the presence of Ca^{2+} ions and thereby pass the signal on.

C. Calcium ions ◑

Calcium level. Ca^{2+} (see p. 342) is a signaling substance. The concentration of Ca^{2+} ions in the cytoplasm is normally very low (10–100 nM), as it is kept down by ATP-driven Ca^{2+} pumps and Na^+/Ca^{2+} exchangers. In addition, many proteins in the cytoplasm and organelles bind calcium and thus act as Ca^{2+} buffers.

Specific signals (e.g., an action potential or second messenger such as $InsP_3$ or cAMP) can trigger a sudden increase in the cytoplasmic Ca^{2+} level to 500–1000 nM by opening Ca^{2+} channels in the plasma membrane or in the membranes of the *endoplasmic* or *sarcoplasmic reticulum*. *Ryanodine,* a plant substance, acts in this way on a specific channel in the ER. In the cytoplasm, the Ca^{2+} level always only rises very briefly (Ca^{2+} "spikes"), as prolonged high concentrations in the cytoplasm have cytotoxic effects.

Calcium effects. The biochemical effects of Ca^{2+} in the cytoplasm are mediated by special Ca^{2+}-binding proteins (*"calcium sensors"*). These include the *annexins, calmodulin,* and *troponin C* in muscle (see p. 334). **Calmodulin** is a relatively small protein (17 kDa) that occurs in all animal cells. Binding of four Ca^{2+} ions (light blue) converts it into a *regulatory element.* Via a dramatic conformational change (cf. 2a and 2b), Ca^{2+}-calmodulin enters into interaction with other proteins and modulates their properties. Using this mechanism, Ca^{2+} ions regulate the activity of enzymes, ion pumps, and components of the cytoskeleton.

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A. Cyclic AMP

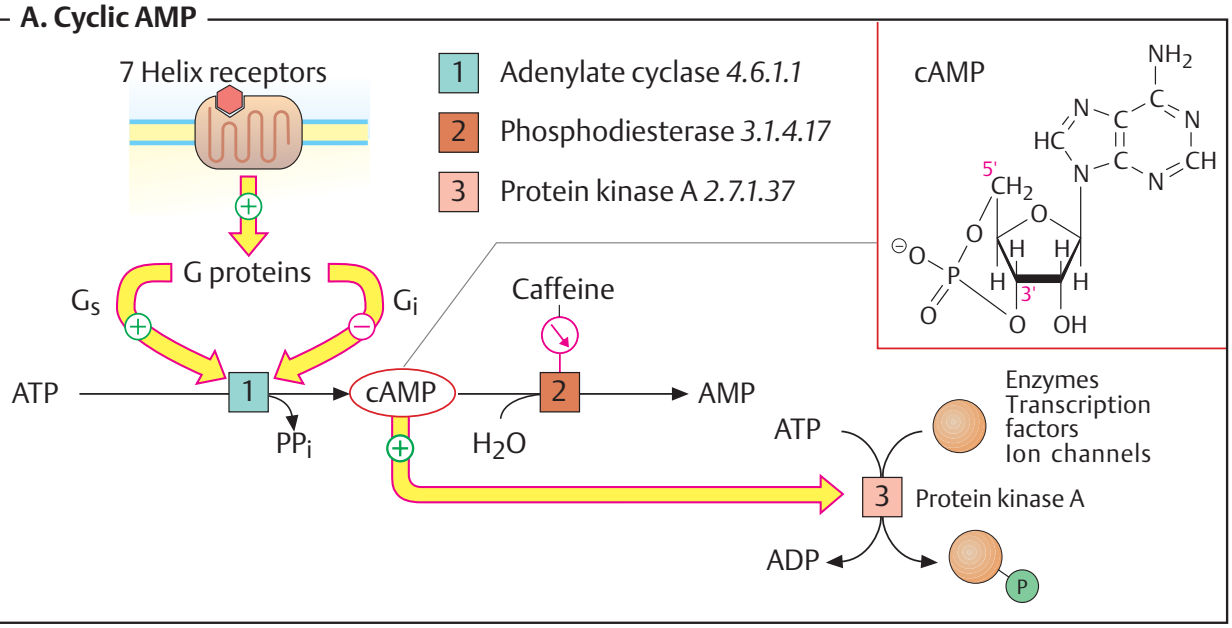

B. Inositol 1,4,5-trisphosphate and diacylglycerol

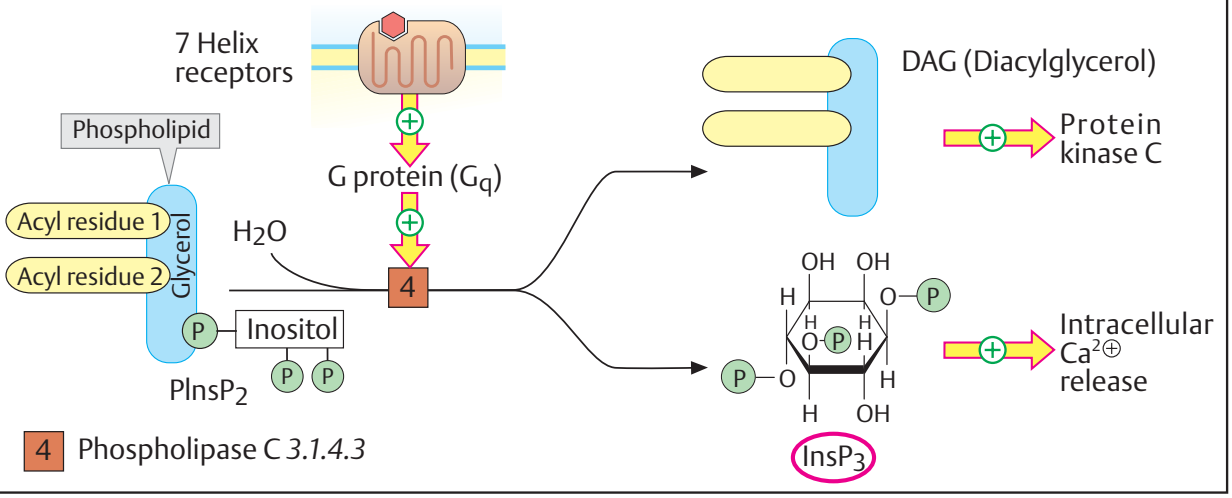

C. Calcium ions

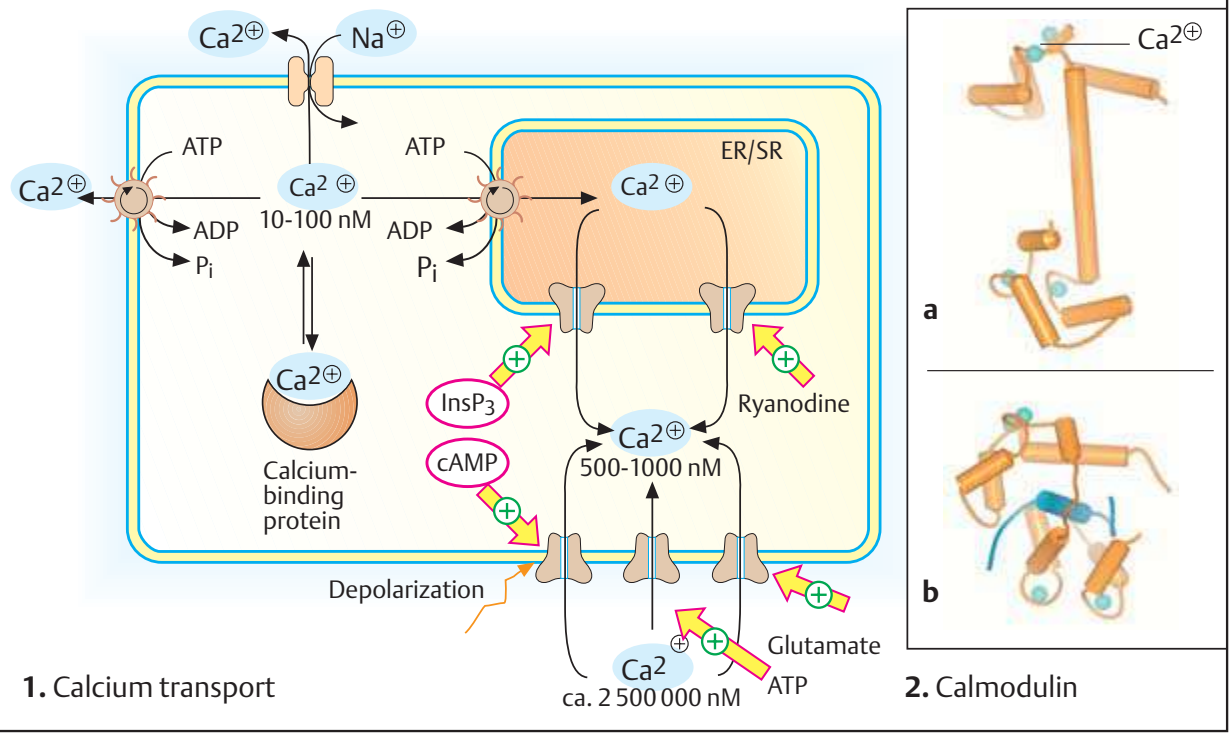

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Signal cascades

The signal transduction pathways that mediate the effects of the metabolic hormone **insulin** are of particular medical interest (see **A**). The mediator **nitrogen monoxide** (NO) is also clinically important, as it regulates vascular caliber and thus the body's perfusion with blood (see **B**).

A. Insulin: signal transduction ○

The diverse effects of insulin (see p. 160) are mediated by protein kinases that mutually activate each other in the form of enzyme cascades. At the end of this chain there are kinases that influence gene transcription in the nucleus by phosphorylating target proteins, or promote the uptake of glucose and its conversion into glycogen. The signal transduction pathways involved have not yet been fully explained. They are presented here in a simplified form.

The **insulin receptor** (top) is a dimer with subunits that have activatable tyrosine kinase domains in the interior of the cell (see p. 224). Binding of the hormone increases the tyrosine kinase activity of the receptor, which then phosphorylates itself and other proteins (**receptor substrates**) at various tyrosine residues. **Adaptor proteins**, which conduct the signal further, bind to the phosphotyrosine residues.

The effects of insulin on transcription are shown on the left of the illustration. Adaptor proteins **Grb-2** and **SOS** ("son of sevenless") bind to the phosphorylated **IRS** (insulin-receptor substrate) and activate the G protein **Ras** (named after its gene, the oncogene *ras*; see p. 398). Ras activates the protein kinase **Raf** (another oncogene product). Raf sets in motion a phosphorylation cascade that leads via the kinases **MEK** and **ERK** (also known as MAPK, "mitogen-activated protein kinase") to the phosphorylation of transcription factors in the nucleus.

Some of the effects of insulin on the **carbohydrate metabolism** (right part of the illustration) are possible without protein synthesis. In addition to Grb-2, another dimeric adaptor protein can also bind to phosphorylated IRS. This adaptor protein thereby acquires *phosphatidylinositol-3-kinase* activity (**PI_3K**) and, in the membrane, phosphorylates phospholipids from the phosphatidylinositol group (see p. 50) at position 3. Protein kinase **PDK-1** binds to these reaction products, becoming activated itself and in turn activating protein kinase B (**PK-B**).

This has several effects. In a manner not yet fully understood, PK-B leads to the fusion with the plasma membrane of vesicles that contain the glucose transporter Glut-4. This results in inclusion of Glut-4 in the membrane and thus to increased glucose uptake into the muscles and adipose tissue (see p. 160). In addition, PK-B inhibits glycogen synthase kinase 3 (**GSK-3**) by phosphorylation. As GSK-3 in turn inhibits glycogen synthase by phosphorylation (see p. 120), its inhibition by PK-B leads to *increased* glycogen synthesis. Protein phosphatase-1 (**PP-1**) converts glycogen synthase into its active form by dephosphorylation (see p. 120). PP-1 is also activated by insulin.

B. Nitrogen monoxide (NO) as a mediator ○

Nitrogen monoxide (NO) is a short-lived radical that functions as a locally acting mediator (see p. 370).

In a complex reaction, NO arises from arginine in the endothelial cells of the blood vessels [1]. The trigger for this is Ca^{2+}-calmodulin (see p. 386), which forms when there is an increase in the cytoplasmic Ca^{2+} level.

NO diffuses from the endothelium into the underlying vascular muscle cells, where it leads, as a result of activation of *guanylate cyclase* [2], to the formation of the second messenger **cGMP** (see pp. 358, 384). Finally, by activating a special protein kinase (**PK-G**), cGMP triggers relaxation of the smooth muscle and thus dilation of the vessels. The effects of atrionatriuretic peptide (**ANP**; see p. 328) in reducing blood pressure are also mediated by cGMP-induced vasodilation. In this case, cGMP is formed by the guanylate cyclase activity of the ANP receptor.

Further information

The drug *nitroglycerin* (glyceryl trinitrate), which is used in the treatment of *angina pectoris,* releases NO in the bloodstream and thereby leads to better perfusion of cardiac muscle.

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A. Insulin: signal transduction

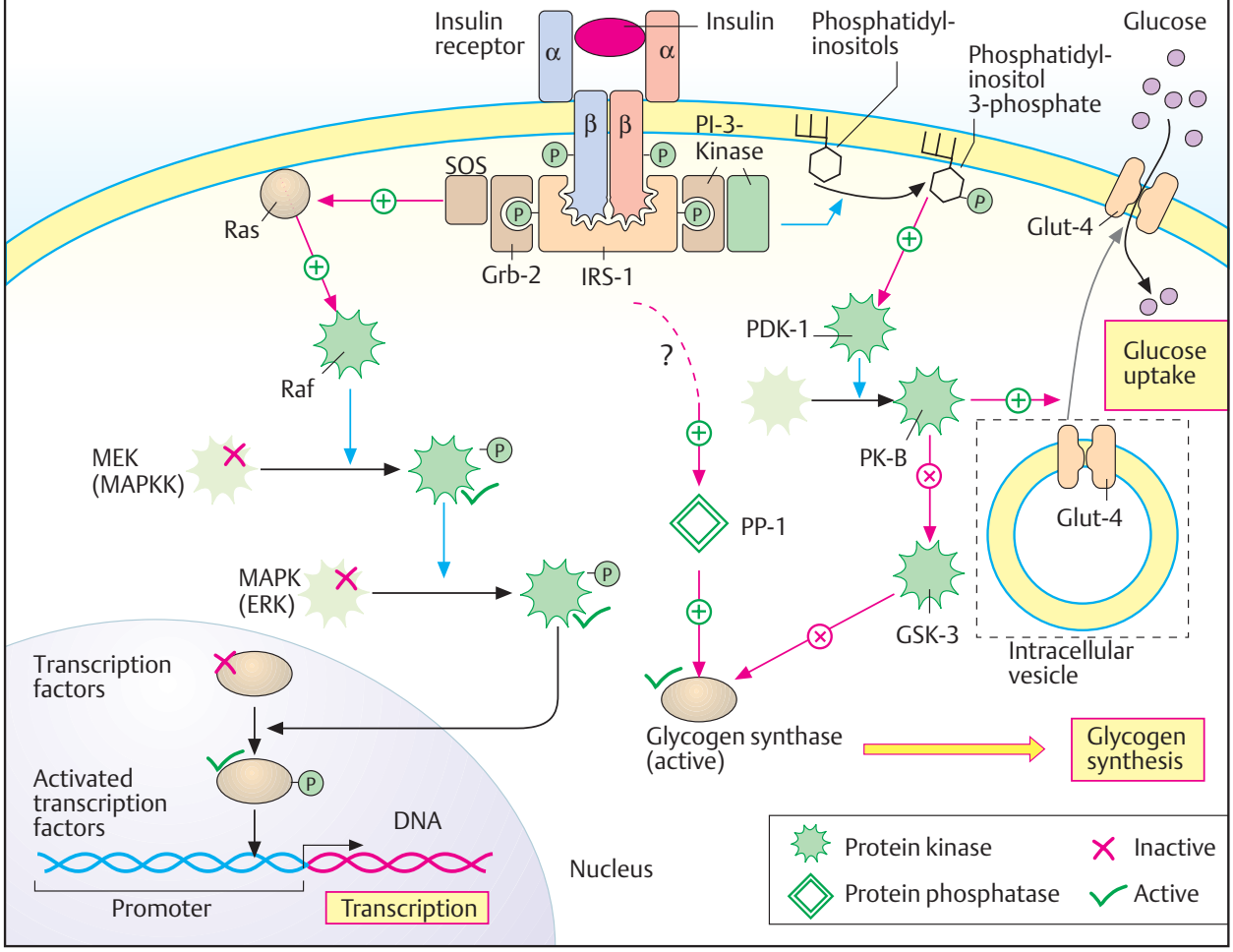

B. Nitrogen monoxide (NO) as a mediator

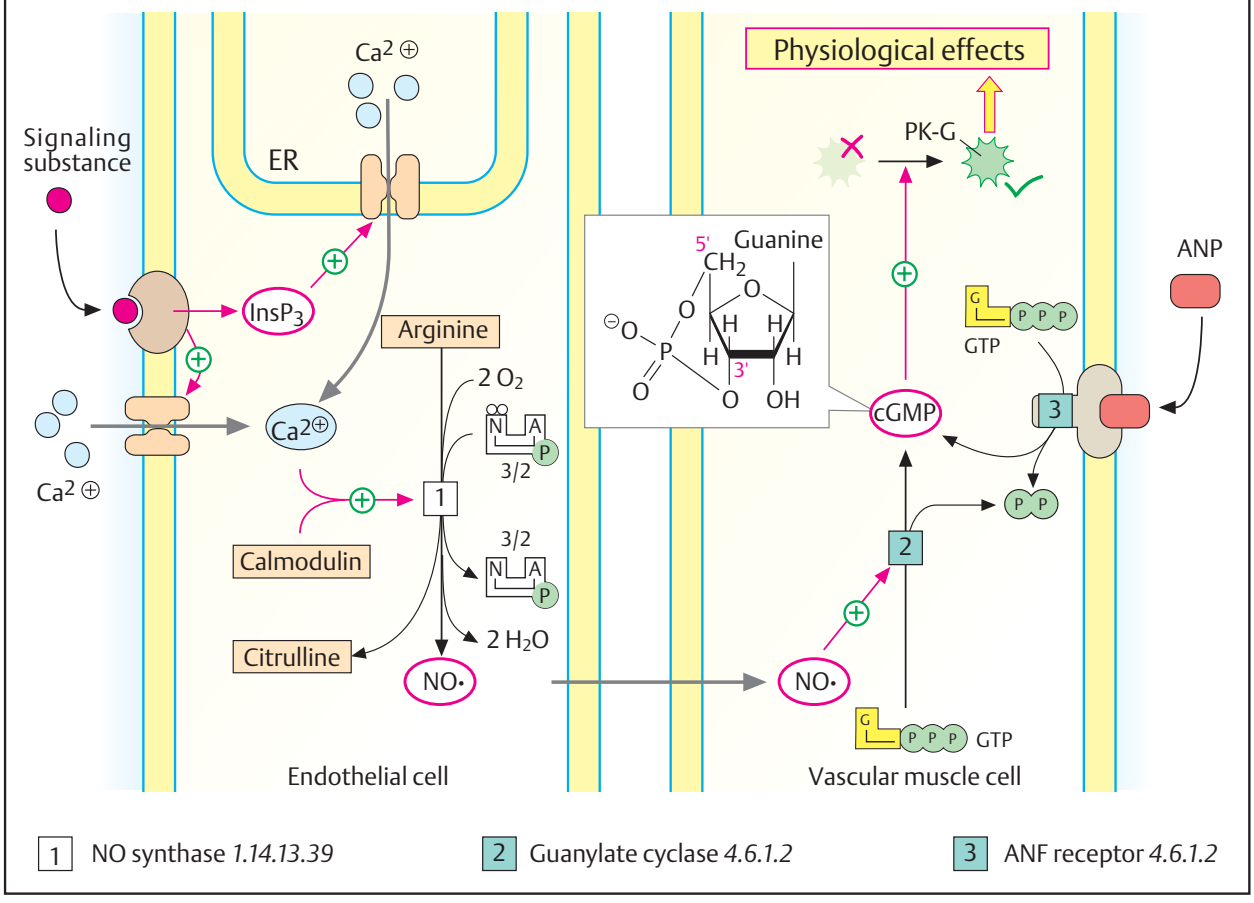

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Eicosanoids

The eicosanoids are a group of signaling substances that arise from the C-20 fatty acid *arachidonic acid* and therefore usually contain 20 C atoms (Greek *eicosa* = 20). As mediators, they influence a large number of physiological processes (see below). Eicosanoid metabolism is therefore an important drug target. As short-lived substances, eicosanoids only act in the vicinity of their site of synthesis (paracrine effect; see p. 372).

A. Eicosanoids ○

Biosynthesis. Almost all of the body's cells form eicosanoids. Membrane phospholipids that contain the polyunsaturated fatty acid **arachidonic acid** (20:4; see p. 48) provide the starting material.

Initially, *phospholipase* A_2 [1] releases the arachidonate moiety from these phospholipids. The activity of phospholipase A_2 is strictly regulated. It is activated by hormones and other signals via *G proteins.* The arachidonate released is a signaling substance itself. However, its metabolites are even more important.

Two different pathways lead from arachidonate to **prostaglandins**, **prostacyclins**, and **thromboxanes**, on the one hand, or **leukotrienes** on the other. The key enzyme for the first pathway is *prostaglandin synthase* [2]. Using up O_2, it catalyzes in a two-step reaction the cyclization of arachidonate to prostaglandin H_2, the parent substance for the prostaglandins, prostacyclins, and thromboxanes. Acetylsalicylic acid (aspirin) irreversibly acetylates a serine residue near the active center of prostaglandin synthase, so that access for substrates is blocked (see below).

As a result of the action of *lipoxygenases* [3], hydroxyfatty acids and hydroperoxyfatty acids are formed from arachidonate, from which elimination of water and various conversion reactions give rise to the leukotrienes. The formulae only show one representative from each of the various groups of eicosanoids.

Effects. Eicosanoids act via membrane receptors in the immediate vicinity of their site of synthesis, both on the synthesizing cell itself (*autocrine* action) and on neighboring cells (*paracrine* action). Many of their effects are mediated by the second messengers cAMP and cGMP.

The eicosanoids have a very wide range of physiological effects. As they can stimulate or inhibit smooth-muscle contraction, depending on the substance concerned, they affect blood pressure, respiration, and intestinal and uterine activity, among other properties. In the stomach, prostaglandins inhibit HCl secretion via G_i proteins (see p. 270). At the same time, they promote mucus secretion, which protects the gastric mucosa against the acid. In addition, prostaglandins are involved in bone metabolism and in the activity of the sympathetic nervous system. In the immune system, prostaglandins are important in the inflammatory reaction. Among other things, they attract leukocytes to the site of infection. Eicosanoids are also decisively involved in the development of pain and fever. The thromboxanes promote thrombocyte aggregation and other processes involved in hemostasis (see p. 290).

Metabolism. Eicosanoids are inactivated within a period of seconds to minutes. This takes place by enzymatic reduction of double bonds and dehydrogenation of hydroxyl groups. As a result of this rapid degradation, their range is very limited.

Further information

Acetylsalicylic acid and related non-steroidal anti-inflammatory drugs (NSAIDs) selectively inhibit the *cyclooxygenase activity* of prostaglandin synthase [2] and consequently the synthesis of most eicosanoids. This explains their analgesic, antipyretic, and antirheumatic effects. Frequent side effects of NSAIDs also result from inhibition of eicosanoid synthesis. For example, they impair hemostasis because the synthesis of thromboxanes by thrombocytes is inhibited. In the stomach, NSAIDs increase HCl secretion and at the same time inhibit the formation of protective mucus. Long-term NSAID use can therefore damage the gastric mucosa.

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A. Eicosanoids

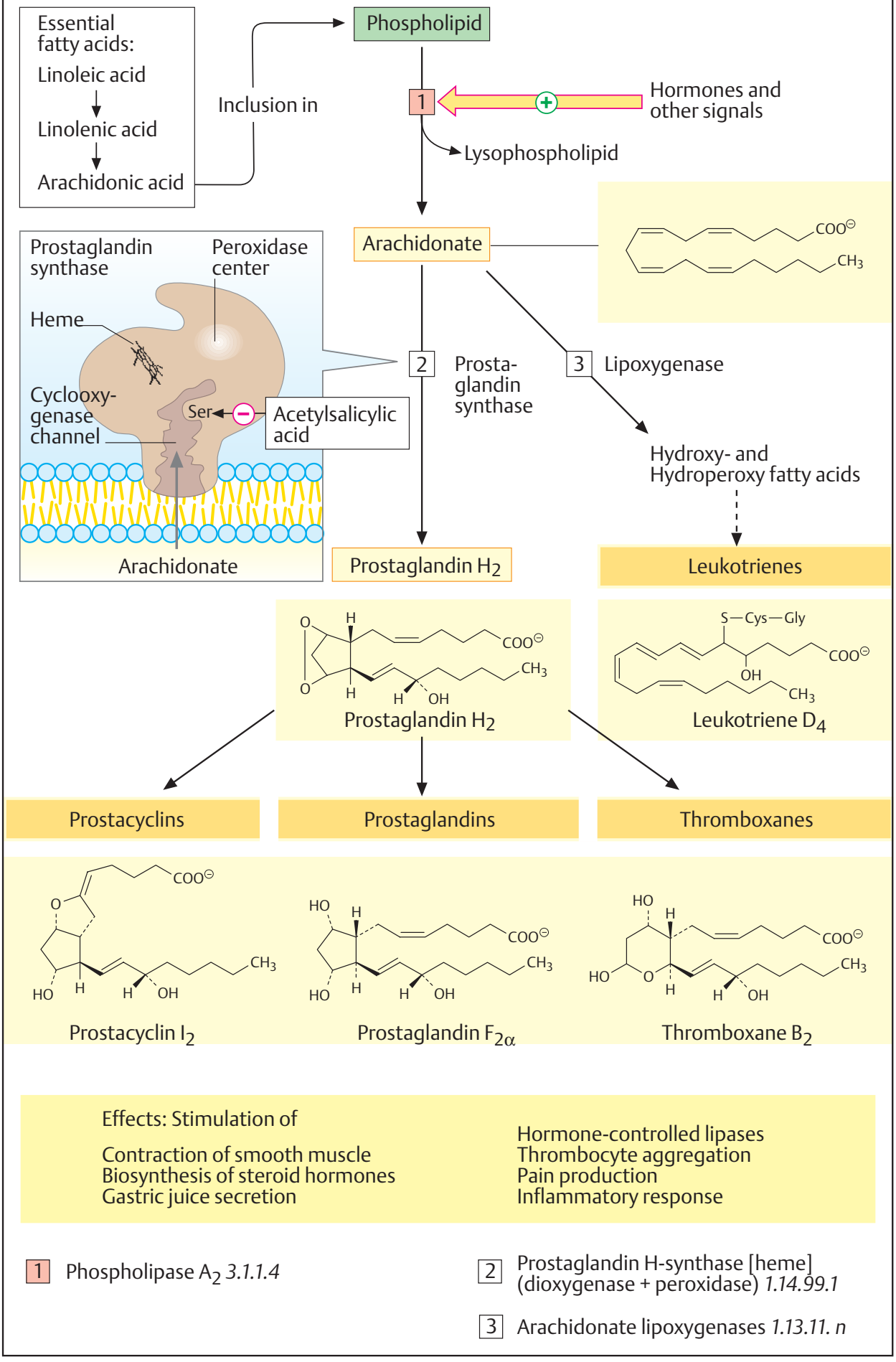

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Cytokines

A. Cytokines ◑

Cytokines are hormone-like *peptides* and *proteins* with signaling functions, which are synthesized and released by cells of the immune system and other cell types. Their numerous biological functions operate in three areas: they regulate the *development and homeostasis of the immune system;* they control the *hematopoietic system;* and they are involved in *non-specific defense,* influencing inflammatory processes, blood coagulation, and blood pressure. In general, cytokines regulate the growth, differentiation, and survival of cells. They are also involved in regulating apoptosis (see p. 396).

There is an extremely large number of cytokines; only the most important representatives are listed opposite. The cytokines include *interleukins* (IL), *lymphokines, monokines, chemokines, interferons* (IFN), and *colony-stimulating factors* (CSF). Via interleukins, immune cells stimulate the proliferation and activity of other immune cells (see p. 294). Interferons are used medically in the treatment of viral infections and other diseases.

Although cytokines rarely show structural homologies with each other, their effects are often very similar. The cytokines differ from *hormones* (see p. 370) only in certain respects: they are released by many different cells, rather than being secreted by defined glands, and they regulate a wider variety of target cells than the hormones.

B. Signal transduction in the cytokines ○

As peptides or proteins, the cytokines are **hydrophilic signaling substances** that act by binding to *receptors* on the cell surface (see p. 380). Binding of a cytokine to its receptor (**1**) leads via several intermediate steps (**2** –**5**) to the activation of transcription of specific genes (**6**).

In contrast to the receptors for insulin and growth factors (see p. 388), the **cytokine receptors** (with a few exceptions) have *no* tyrosine kinase activity. After binding of cytokine (**1**), they associate with one another to form homodimers, join together with other signal transduction proteins (STPs) to form dimers, or promote dimerization of other STPs (2). Class I cytokine receptors interact with three different STPs (gp130, β_c, and γ_c). The STPs themselves do not bind cytokines, but conduct the signal to tyrosine kinases (**3**). The fact that different cytokines can activate the same STP via their receptors explains the overlapping biological activity of some cytokines.

As an example of the signal transduction pathway in cytokines, the illustration shows the way in which the **IL-6 receptor**, after binding its ligand **IL-6** (**1**), induces the dimerization of the STP **gp130** (**2**). The dimeric gp130 binds cytoplasmic *tyrosine kinases* from the Jak family ("**Janus kinases**," with two kinase centers) and activates them (**3**). The Janus kinases phosphorylate cytokine receptors, STPs, and various cytoplasmic proteins that conduct the signal further. In addition, they phosphorylate transcription factors known as **STATs** ("**s**ignal **t**ransducers and **a**ctivators of **t**ranscription"). STATs are among the proteins that have an *SH2 domain* and are able to bind phosphotyrosine residues (see p. 388). They therefore bind to cytokine receptors that have been phosphorylated by Janus kinases. When STATs are then also phosphorylated themselves (**4**), they are converted into their active form and become dimers (**5**). After transfer to the nucleus, they bind—along with auxiliary proteins as transcription factors—to the promoters of inducible genes and in this way regulate their transcription (**6**).

The activity of the cytokine receptors is terminated by *protein phosphatases,* which hydrolytically cleave the phosphotyrosine residues. Several cytokine receptors are able to lose their ligand-binding extracellular domain by proteolysis (not shown). The extracellular domain then appears in the blood, where it competes for cytokines. This reduces the effective cytokine concentration.

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A. Cytokines

IL-1	Interleukin 1	G-CSF	Granulocyte colony-stimulating factor
IL-2	Interleukin 2	GM-CSF	Granulocyte/macrophage colony-stimulating factor
IL-3	Interleukin 3		
IL-4	Interleukin 4	MIF	Macrophage migration inhibitory factor
IL-5	Interleukin 5	M-CSF	Monocyte colony-stimulating factor
IL-6	Interleukin 6	TNFα	Tumor necrosis factor- α
IFN-α	Interferon α	TNFβ	Tumor necrosis factor- β
IFN-β	Interferon β		
IFN-γ	Interferon γ	and others	

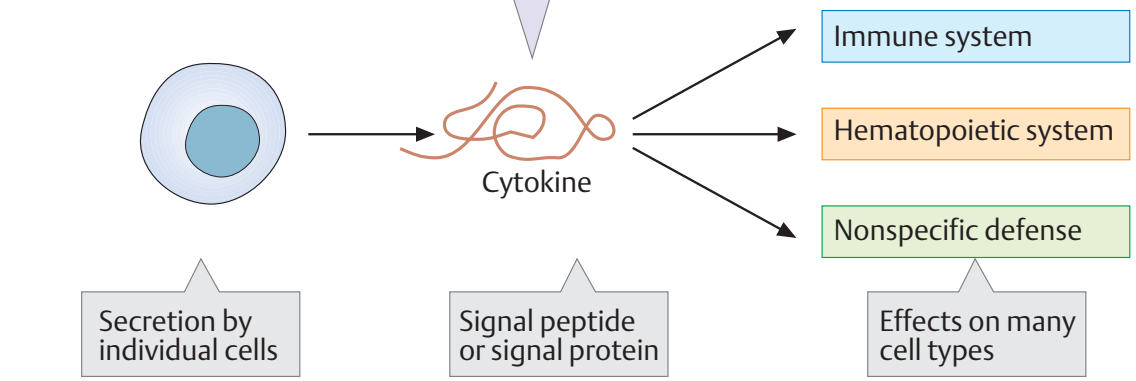

B. Signal transduction in the cytokines

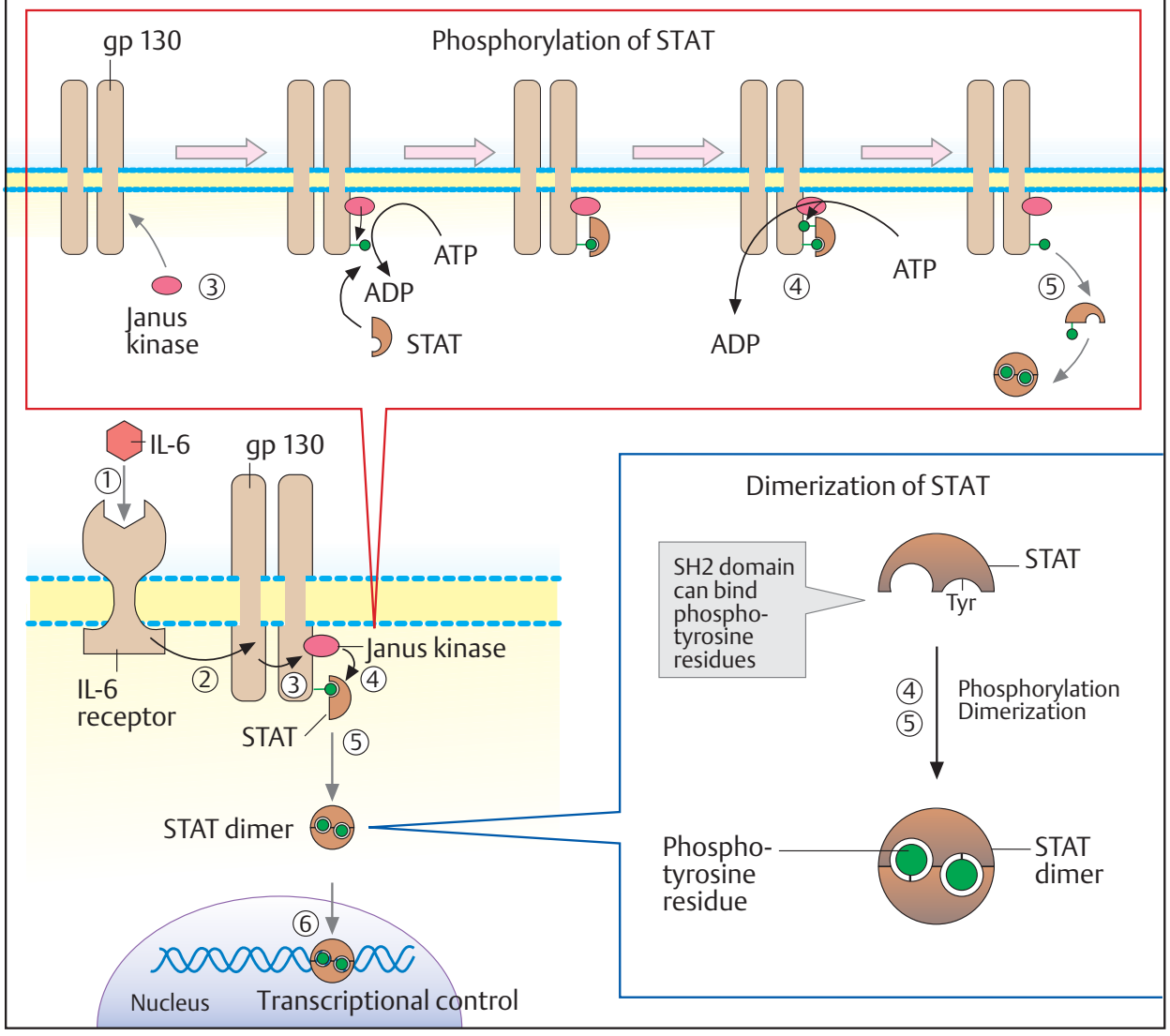

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Cell cycle

A. Cell cycle ◑

Proliferating cells undergo a cycle of division (the cell cycle), which lasts approximately 24 hours in mammalian cells in cell culture. The cycle is divided into four different phases (G_1, S, G_2, and M—in that sequence).

Fully differentiated animal cells only divide rarely. These cells are in the so-called **G_0 phase**, in which they can remain permanently. Some G_0 cells return to the **G_1 phase** again under the influence of mitogenic signals (growth factors, cytokines, tumor viruses, etc.), and after crossing a *control point* (G_1 to S), enter a new cycle. DNA is replicated (see p. 240) during the **S phase**, and new chromatin is formed. Particularly remarkable in morphological terms is the actual mitosis (**M phase**), in which the chromosomes separate and two daughter cells are formed. The M and S phases are separated by two segments known as the **G_1** and **G_2** phases (the G stands for "gap"). In the G_1 phase, the duration of which can vary, the cell grows by de novo synthesis of cell components. Together, the G_1, G_0, S, and G_2 phases are referred to as the **interphase**, which alternates in the cell cycle with the short M phase.

B. Control of the cell cycle ○

The progression of the cell cycle is regulated by **interconversion processes**. In each phase, special *Ser/Thr-specific protein kinases* are formed, which are known as cyclin-dependent kinases (**CDKs**). This term is used because they have to bind an activator protein (**cyclin**) in order to become active. At each control point in the cycle, specific CDKs associate with equally phase-specific cyclins. If there are no problems (e. g., DNA damage), the CDK–cyclin complex is activated by phosphorylation and/or dephosphorylation. The activated complex in turn phosphorylates **transcription factors**, which finally lead to the formation of the proteins that are required in the cell cycle phase concerned (enzymes, cytoskeleton components, other CDKs, and cyclins). The activity of the CDK–cyclin complex is then terminated again by proteolytic **cyclin degradation**.

The above outline of cell cycle progression can be examined here in more detail using the G_2–M transition as an example.

Entry of animal cells into mitosis is based on the "mitosis-promoting factor" (**MPF**). MPF consists of **CDK1** (cdc2) and **cyclin B**. The intracellular concentration of cyclin B increases constantly until mitosis starts, and then declines again rapidly (top left). MPF is initially inactive, because CDK1 is phosphorylated and cyclin B is dephosphorylated (top center). The M phase is triggered when a *protein phosphatase* [1] dephosphorylates the CDK while cyclin B is phosphorylated by a *kinase* [2]. In its active form, MPF phosphorylates various proteins that have functions in mitosis—e. g., *histone H1* (see p. 238), components of the cytoskeleton such as the *laminins* in the nuclear membrane, *transcription factors, mitotic spindle* proteins, and various *enzymes.*

When mitosis has been completed, cyclin B is marked with **ubiquitin** and broken down proteolytically by *proteasomes* (see p. 176). Protein phosphatases then regain control and dephosphorylate the proteins involved in mitosis. This returns the cell to the interphase.

Further information

The G_1–S transition (not shown) is particularly important for initiating the cell cycle. It is triggered by the CDK4–cyclin D complex, which by phosphorylating the protein **pRb** releases the transcription factor E2F previously bound to pRb. This activates the transcription of genes needed for DNA replication.

If the DNA is damaged by mutagens or ionizing radiation, the protein **p53** initially delays entry into the S phase. If the DNA repair system (see p. 256) does not succeed in removing the DNA damage, p53 forces the cell into apoptosis (see p. 396). The genes coding for pRb and p53 belong to the **tumor-suppressor genes** (see p. 398). In many tumors (see p. 400), these genes are in fact damaged by mutation.

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A. Cell cycle

M phase

Mitosis
Chromosome separation
Cell division

G_2 phase

Preparation for mitosis

S phase

DNA replication
Histone synthesis
Centrosome formed
Chromosome duplication

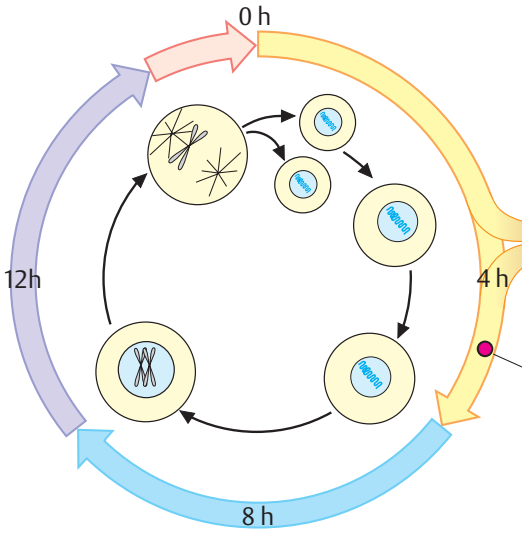

G_1 phase

RNA and protein synthesis
Cell growth

G_0 phase

No cell division

Restriction point

B. Control of the cell cycle

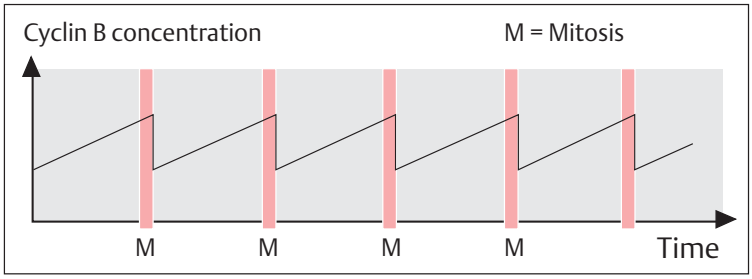

Reactions early in mitosis
Reactions late in mitosis

Cyclin-dependent protein kinases
CDK 1 – 6

Cyclin
Cyclins A – E

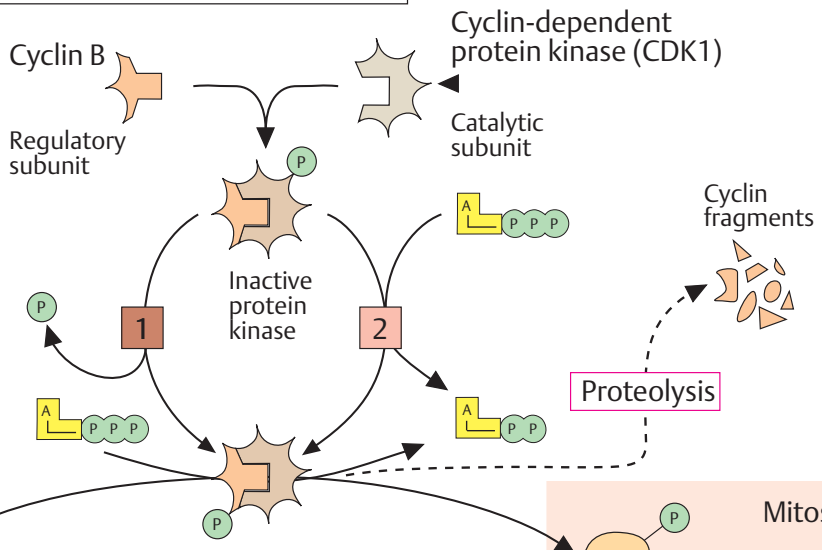

Interphase

Protein

Histone H1
Laminin
Protein kinases
Transcription factors

Other proteins

Mitosis

Spindle formation
Chromosome condensation
Disappearance of nuclear membrane
Transcription stop
Cyclin degradation

1 Phosphoprotein phosphatase

2 Protein kinase

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Apoptosis

A. Cell proliferation and apoptosis ◑

The number of cells in any tissue is mainly regulated by two processes—cell **proliferation** and *physiological cell death*, **apoptosis**. Both of these processes are regulated by stimulatory and inhibitory factors that act in solute form (growth factors and cytokines) or are presented in bound form on the surface of neighboring cells (see below).

Apoptosis is genetically programmed cell death, which leads to "tidy" breakdown and disposal of cells. Morphologically, apoptosis is characterized by changes in the cell membrane (with the formation of small blebs known as "apoptotic bodies"), shrinking of the nucleus, chromatin condensation, and fragmentation of DNA. *Macrophages* and other phagocytic cells recognize apoptotic cells and remove them by phagocytosis without inflammatory phenomena developing.

Cell necrosis (not shown) should be distinguished from apoptosis. In cell necrosis, cell death is usually due to physical or chemical damage. Necrosis leads to swelling and bursting of the damaged cells and often triggers an inflammatory response.

The growth of tissue (or, more precisely, the number of cells) is actually regulated by apoptosis. In addition, apoptosis allows the elimination of unwanted or superfluous cells—e. g., during embryonic development or in the immune system. The contraction of the uterus after birth is also based on apoptosis. Diseased cells are also eliminated by apoptosis—e. g., tumor cells, virus-infected cells, and cells with irreparably damaged DNA. An everyday example of this is the peeling of the skin after sunburn.

B. Regulation of apoptosis ○

Apoptosis can be triggered by a number of different signals that use various transmission pathways. Other signaling pathways prevent apoptosis.

At the center of the apoptotic process lies a group of specialized *cysteine-containing aspartate proteinases* (see p. 176), known as **caspases**. These mutually activate one another, creating an *enzyme cascade* resembling the cascade involved in blood coagulation (see p. 290). Other enzymes in this group, known as **effector caspases**, cleave cell components after being activated—e. g., laminin in the nuclear membrane and snRP proteins (see p. 246)—or activate special DNases which then fragment the nuclear DNA.

An important trigger for apoptosis is known as the **Fas system**. This is used by cytotoxic T cells, for example, which eliminate infected cells in this way (top left). Most of the body's cells have *Fas receptors* (CD 95) on their plasma membrane. If a T cell is activated by contact with an MHC presenting a viral peptide (see p. 296), binding of its *Fas ligands* occurs on the target cell's Fas receptors. Via the mediator protein FADD ("Fas-associated death domain"), this activates *caspase-8* inside the cell, setting in motion the apoptotic process.

Another trigger is provided by **tumor necrosis factor-α** (TNF-α), which acts via a similar protein (TRADD) and supports the endogenous defense system against tumors by inducing apoptosis.

Caspase-8 activates the effector caspases either directly, or indirectly by promoting the **cytochrome c** (see p. 140) from mitochondria. Once in the cytoplasm, cytochrome c binds to and activates the protein Apaf-1 (not shown) and thus triggers the caspase cascade. Apoptotic signals can also come from the cell nucleus. If irreparable DNA damage is present, the **p53 protein** (see p. 394)—the product of a *tumor suppressor gene*—promotes apoptosis and thus helps eliminate the defective cell.

There are also inhibitory factors that oppose the signals that activate apoptosis. These include **bcl-2** and related proteins. The genomes of several viruses include genes for this type of protein. The genes are expressed by the host cell and (to the benefit of the virus) prevent the host cell from being prematurely eliminated by apoptosis.

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A. Cell proliferation and apoptosis

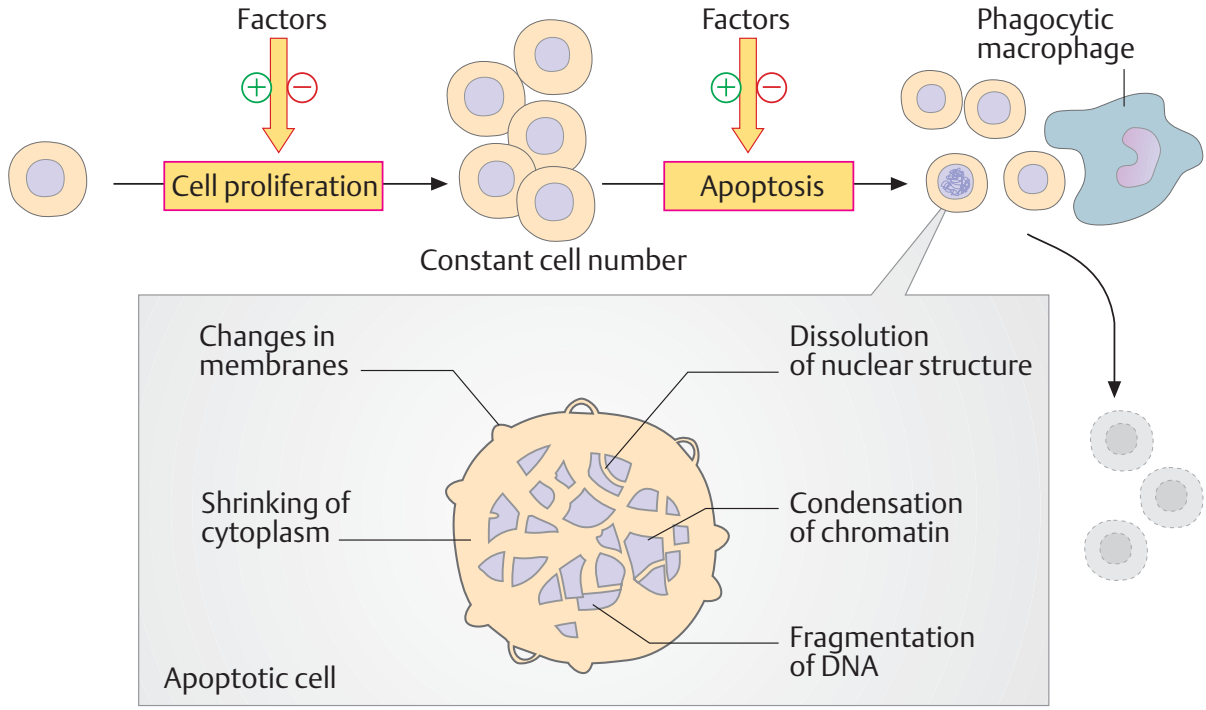

B. Regulation of apoptosis

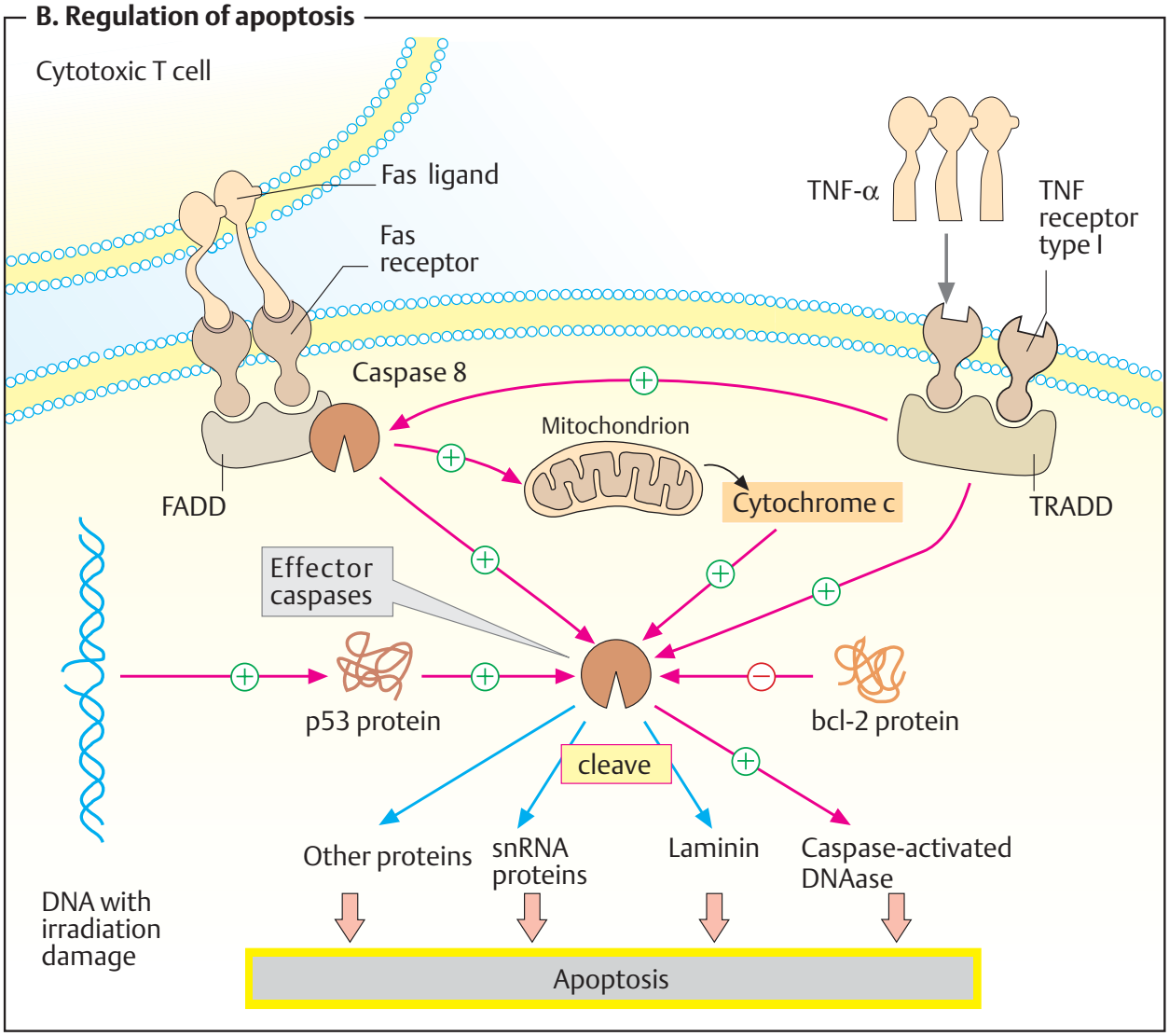

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Oncogenes

Oncogenes are cellular genes that can trigger uncontrolled cell proliferation if their sequence is altered or their expression is incorrectly regulated. They were first discovered as *viral (v-) oncogenes* in retroviruses that cause tumors (tumor viruses). Viruses of this type (see p. 404) sometimes incorporate genes from the host cell into their own genome. If these genes are reincorporated into the host DNA again during later infection, tumors can then be caused in rare cases. Although virus-related tumors are rare, research into them has made a decisive contribution to our understanding of oncogenes and their functioning.

A. Proto-oncogenes: biological role ◑

The cellular form of oncogenes (known as c-oncogenes or **proto-oncogenes**) code for proteins involved in controlling growth and differentiation processes. They only become oncogenes if their sequence has been altered by *mutations* (see p. 256), *deletions,* and other processes, or when excessive amounts of the gene products have been produced as a result of *overexpression.*

Overexpression can occur when **amplification** leads to numerous functional copies of the respective gene, or when the gene falls under the influence of a highly active promoter (see p. 244). If the control of oncogene expression by **tumor suppressor genes** (see p. 394) is also disturbed, **transformation** and unregulated proliferation of the cells can occur. A single activated oncogene does not usually lead to a loss of growth control. It only occurs when over the course of time mutations and regulation defects accumulate in one and the same cell. If the immune system does not succeed in eliminating the transformed cell, it can over the course of months or years grow into a macroscopically visible **tumor**.

B. Oncogene products: biochemical functions ◑

A feature common to all oncogenes is the fact that they code for proteins involved in *signal transduction processes.* The genes are designated using three-letter abbreviations that usually indicate the origin of the viral gene and are printed in italics (e.g., *myc* for myelocytomatosis, a viral disease in birds). Oncogene products can be classified into the following groups according to their functions.

1. **Ligands** such as *growth factors* and *cytokines,* which promote cell proliferation.
2. **Membrane receptors** of the 1-helix type with tyrosine kinase activity, which can bind growth factors and hormones (see p. 394).
3. **GTP-binding proteins.** This group includes the G proteins in the strict sense and related proteins such as Ras (see p. 388), the product of the oncogene c-*ras.*
4. **Receptors for lipophilic hormones** mediate the effects of steroid hormones and related signaling substances. They regulate the transcription of specific genes (see p. 378). The products of several oncogenes (e.g., *erbA*) belong to this superfamily of *ligand-controlled transcription factors.*
5. **Nuclear tumor suppressors** inhibit return to the cell cycle in fully differentiated cells. The genes that code for these proteins are referred to as *anti-oncogenes* due to this function. On the role of p53 and pRb, see p. 394.
6. **DNA-binding proteins.** A whole series of oncogenes code for *transcription factors.* Particularly important for cell proliferation are *myc,* as well as *fos* and *jun.* The protein products of the latter two genes form the transcription factor AP-1 as a heterodimer (see p. 244).
7. **Protein kinases** play a central role in intracellular signal transduction. By phosphorylating proteins, they bring about alterations in biological activity that can only be reversed again by the effects of *protein phosphatases.* The interplay between protein phosphorylation by protein kinases and dephosphorylation by protein phosphatases (*interconversion*) serves to regulate the cell cycle (see p. 394) and other important processes. The protein kinase Raf is also involved in the signal transduction of insulin (see p. 388).

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A. Proto-oncogenes: biological role

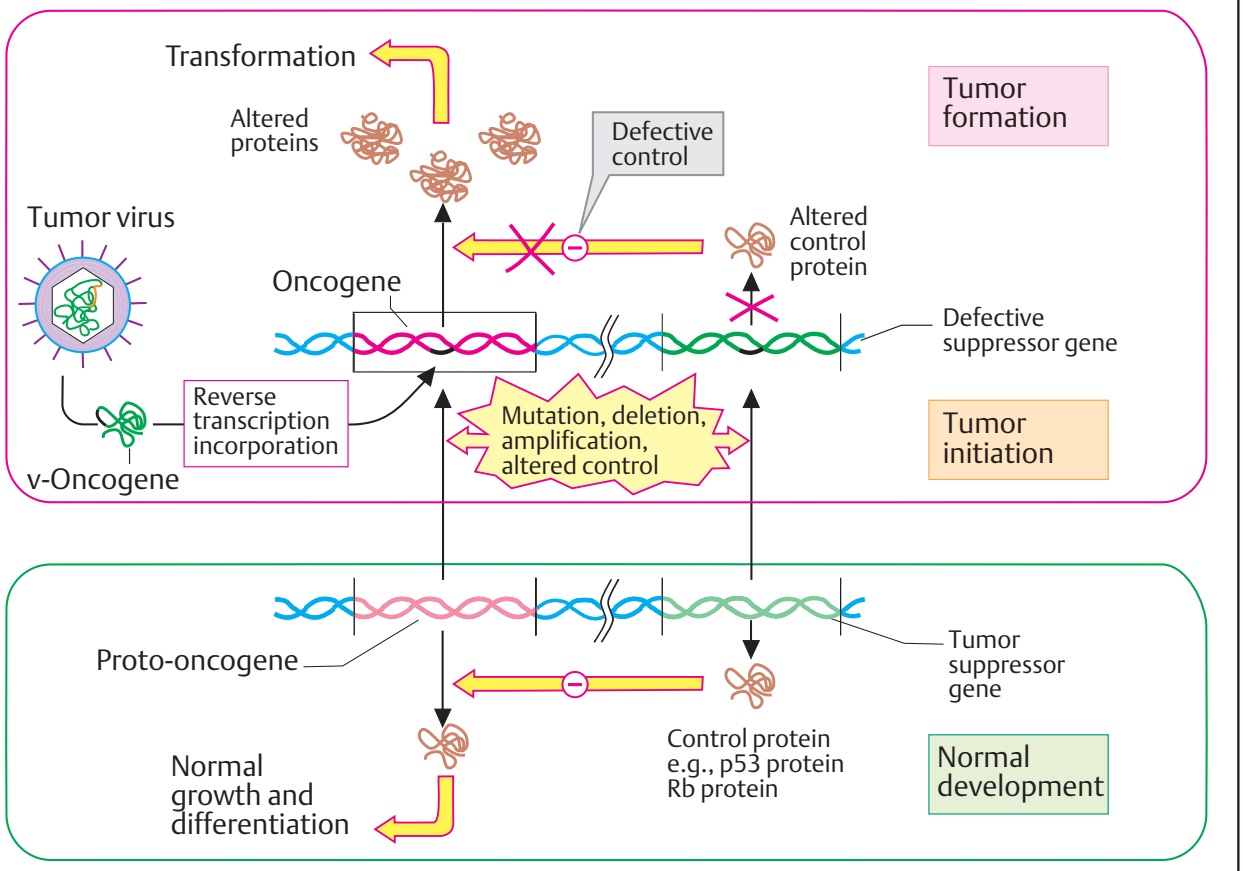

B. Oncogene products: biochemical functions

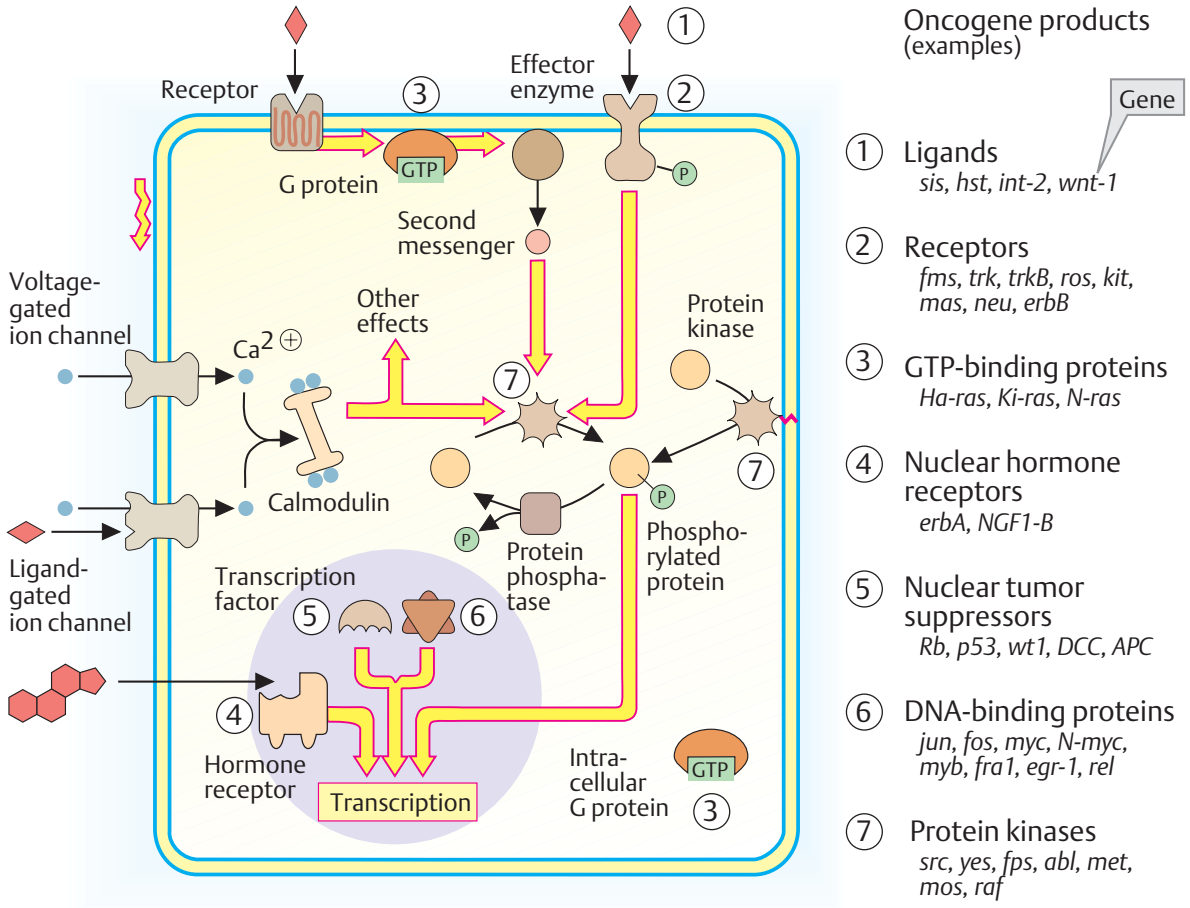

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Tumors

A. Division behavior of cells ◑

The body's cells are normally subject to strict "social" control. They only divide until they come into contact with neighboring cells; cell division then ceases due to *contact inhibition.* Exceptions to this rule include embryonic cells, cells of the intestinal epithelium (where the cells are constantly being replaced), cells in the bone marrow (where formation of blood cells takes place), and **tumor cells.** *Uncontrolled cell proliferation* is an important indicator of the presence of a tumor. While normal cells in cell culture only divide 20–60 times, tumor cells are potentially immortal and are not subject to contact inhibition.

In medicine, a distinction is made between *benign* and *malignant tumors.* Benign tumors consist of slowly growing, largely differentiated cells. By contrast, malignant tumors show rapid, invasive growth and tend to form *metastases* (dissemination of daughter lesions). The approximately 100 different types of tumor that exist are responsible for more than 20% of deaths in Europe and North America.

B. Transformation ◑

The transition of a normal cell into a tumor cell is referred to as **transformation.**

Normal cells have all the characteristics of fully differentiated cells specialized for a particular function. Their division is inhibited and they are usually in the G_0 phase of the cell cycle (see p. 394). Their external shape is variable and is determined by a strongly structured cytoskeleton.

In contrast, *tumor cells* divide without inhibition and are often de-differentiated—i. e., they have acquired some of the properties of embryonic cells. The surface of these cells is altered, and this is particularly evident in a disturbance of contact inhibition by neighboring cells. The cytoskeleton of tumor cells is also restructured and often reduced, giving them a rounded shape. The nuclei of tumor cells can be atypical in terms of shape, number, and size.

Tumor markers are clinically important for detecting certain tumors. These are proteins that are formed with increasing frequency by tumor cells (group 1) or are induced by them in other cells (group 2). Group 1 tumor markers include *tumor-associated antigens,* secreted hormones, and enzymes. The table lists a few examples.

The transition from a normal to a transformed state is a process involving several steps.

1. Tumor initiation. Almost every tumor begins with damage to the DNA of an individual cell. The genetic defect is almost always caused by environmental factors. These can include tumor-inducing chemicals (*carcinogens*—e. g., components of tar from tobacco), physical processes (e. g., UV light, X-ray radiation; see p. 256), or in rare cases tumor viruses (see p. 398). Most of the approximately 10^{14} cells in the human body probably suffer this type of DNA damage during the average lifespan, but it is usually repaired again (see p. 256). It is mainly defects in **proto-oncogenes** (see p. 398) that are relevant to tumor initiation; these are the decisive cause of *transformation.* Loss of an **anti-oncogene** (a tumor-suppressor gene) can also contribute to tumor initiation.

2. Tumor promotion is preferential proliferation of a cell damaged by transformation. It is a very slow process that can take many years. Certain substances are able to strongly accelerate it—e. g., *phorbol esters.* These occur in plants (e. g., *Euphorbia* species) and act as activators of protein kinase C (see p. 386).

3. Tumor progression finally leads to a macroscopically visible tumor as a result of growth. When solid tumors of this type exceed a certain size, they form their own vascular network that supplies them with blood (angiogenesis). *Collagenases* (matrix metalloproteinases, MMPs) play a special role in the metastatic process, by loosening surrounding connective tissue and thereby allowing tumor cells to disseminate and enter the bloodstream. New approaches to combating tumors have been aimed at influencing tumor angiogenesis and metastatic processes.

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A. Division behavior of cells

Growth inhibition due to contacts with adjacent cells

Uncontrolled cell proliferation

Nutrient medium

Normal cells

Tumor cells

B. Transformation

Normal cell

Indicators:
Differentiated
Non-dividing
Defined form

Tumor initiators

Viruses

Carcinogenic chemicals

Physical processes

UV

1 **Tumor initiation:** Genetic damage

Tumor promoters

e.g. Esters of phorbol

Hormones

Phorbol

2 **Tumor progression:** Preferential propagation

Tumor cell

Indicators:
De-differentiated
Uncontrolled cell division
Altered cell surface
Altered cytoskeleton and nucleus

Tumor markers (examples)

Tumor-associated antigens

CEA	Carcinoembryonic antigen
AFP	α1-Fetoprotein
Hormones	Calcitonin ACTH
Enzymes	Acid phosphatase

3 **Tumor progression:** Acquisition of malignancy

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Cytostatic drugs

Tumors (see p. 400) arise from degenerated (transformed) cells that grow in an uncontrolled way as a result of genetic defects. Most transformed cells are recognized by the immune system and eliminated (see p. 294). If endogenous defense is not sufficiently effective, rapid tumor growth can occur. Attempts are then made to inhibit growth by physical or chemical treatment.

A frequently used procedure is targeted irradiation with γ-rays, which block cell reproduction due their mutagenic effect (see p. 256). Another approach is to inhibit cell growth by chemotherapy. The growth-inhibiting substances used are known as **cytostatic drugs**. Unfortunately, neither radiotherapy nor chemotherapy act selectively—i. e., they damage normal cells as well, and are therefore often associated with severe side effects.

Most cytostatic agents directly or indirectly inhibit DNA replication in the S phase of the cell cycle (see p. 394). The first group (**A**) lead to chemical changes in cellular DNA that impede transcription and replication. A second group of cytostatic agents (**B**) inhibit the synthesis of DNA precursors.

A. Alkylating agents, anthracyclines ○

Alkylating agents are compounds capable of reacting covalently with DNA bases. If a compound of this type contains *two* reactive groups, intramolecular or intermolecular *crosslinking* of the DNA double helix and "bending" of the double strand occurs. Examples of this type shown here are **cyclophosphamide** and the inorganic complex **cisplatin**. Anthracyclines such as **doxorubicin** (adriamycin) insert themselves non-covalently between the bases and thus lead to local alterations in the DNA structure (see p. 254 B).

B. Antimetabolites ○

Antimetabolites are enzyme inhibitors (see p. 96) that selectively block metabolic pathways. The majority of clinically important cytostatic drugs act on *nucleotide biosynthesis*. Many of these are modified nucleobases or nucleotides that *competitively* inhibit their target enzymes (see p. 96). Many are also incorporated into the DNA, thereby preventing replication.

The cytostatic drugs administered (indicated by a syringe in the illustration) are often not active themselves but are only converted into the actual active agent in the metabolism. This also applies to the adenine analogue **6-mercaptopurine**, which is initially converted to the mononucleotide tIMP (thioinosine monophosphate). Via several intermediate steps, tIMP gives rise to tdGTP, which is incorporated into the DNA and leads to crosslinks and other anomalies in it. The second effective metabolite of 6-mercaptopurine is *S*-methylated tIMP, an inhibitor of *amidophosphoribosyl transferase* (see p. 188).

Hydroxyurea selectively inhibits *ribonucleotide reductase* (see p. 190). As a radical scavenger, it removes the tyrosine radicals that are indispensable for the functioning of the reductase.

Two other important cytostatic agents target the synthesis of DNA-typical thymine, which takes place at the level of the deoxymononucleotide (see p. 190). The deoxymononucleotide formed by **5-fluorouracil** or the corresponding nucleoside inhibits *thymidylate synthase*. This inhibition is based on the fact that the fluorine atom in the pyrimidine ring cannot be substituted by a methyl group. In addition, the fluorine analogue is also incorporated into the DNA.

Dihydrofolate reductase acts as an auxiliary enzyme for thymidylate synthase. It is involved in the regeneration of the coenzyme N^5,N^{10}-methylene-THF, initially reducing DHF to THF with NADPH as the reductant (see p. 418). The folic acid analogue **methotrexate**, a frequently used cytostatic agent, is an extremely effective competitive inhibitor of dihydrofolate reductase. It leads to the depletion of N^5,N^{10}-methylene-THF in the cells and thus to cessation of DNA synthesis.

Further information

To reduce the side effects of cytostatic agents, new approaches are currently being developed on the basis of **gene therapy** (see p. 264). Attempts are being made, for example, to administer drugs in the form of precursors (known as prodrugs), which only become active in the tumor itself ("tumor targeting").

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A. Alkylating agents, anthracyclines

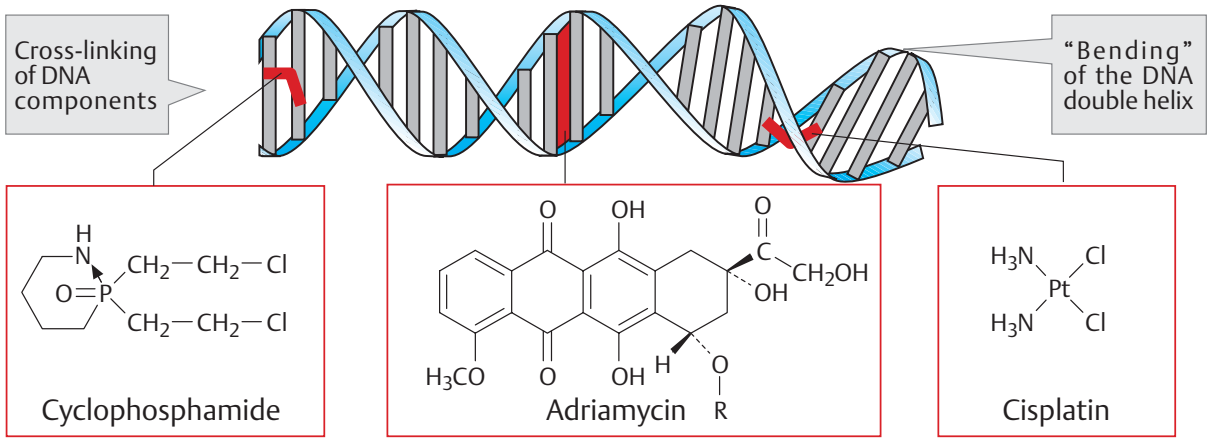

B. Antimetabolites

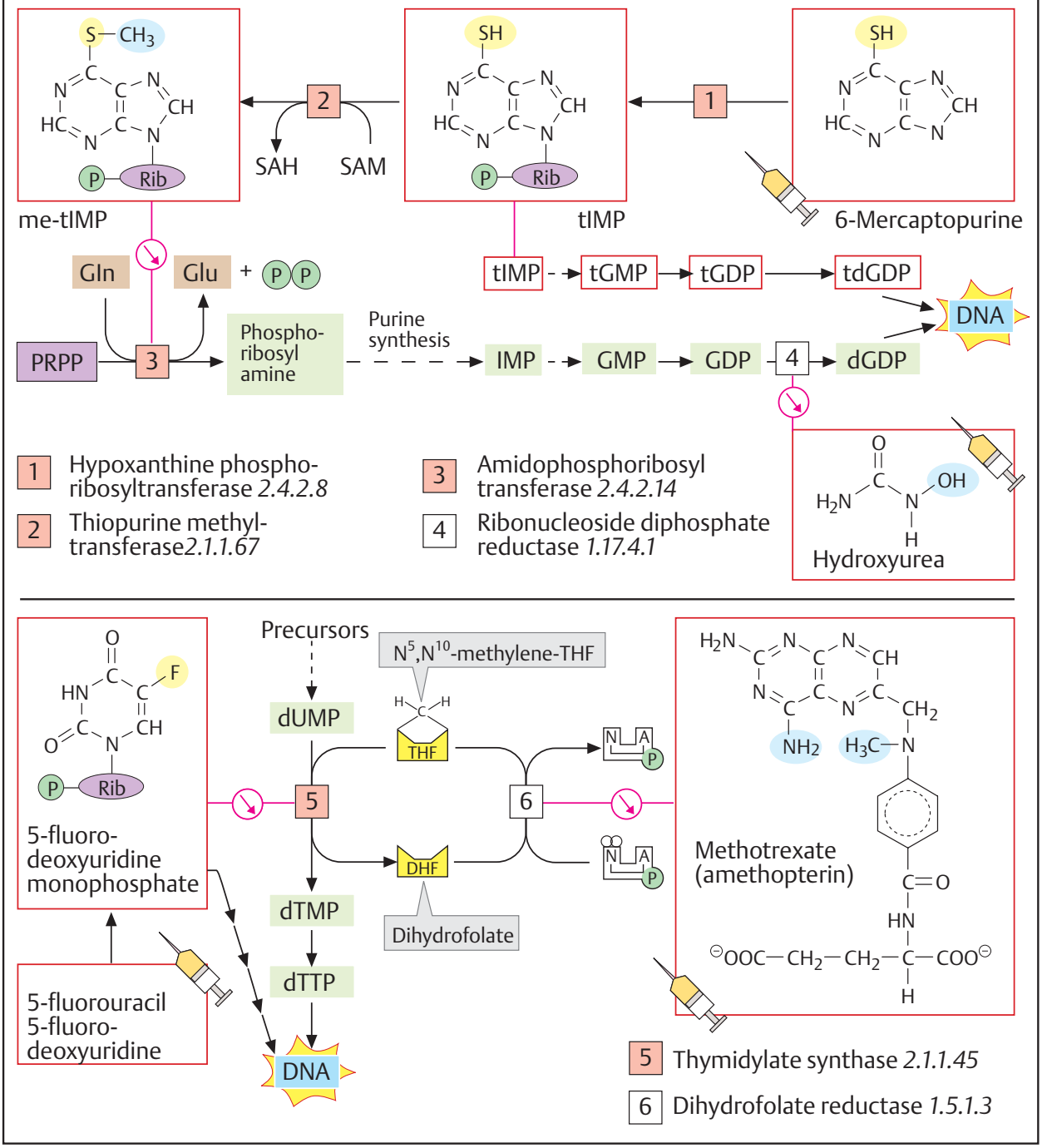

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Viruses

Viruses are *parasitic nucleoprotein complexes.* They often consist of only a single nucleic acid molecule (DNA or RNA, never both) and a protein coat. Viruses have *no metabolism of their own,* and can therefore only replicate themselves with the help of host cells. They are therefore not regarded as independent organisms. Viruses that damage the host cell when they replicate are *pathogens.* Diseases caused by viruses include AIDS, rabies, poliomyelitis, measles, German measles, smallpox, influenza, and the common cold.

A. Viruses: examples ◑

Only a few examples from the large number of known viruses are illustrated here. They are all shown on the same scale.

Viruses that only replicate in bacteria are known as **bacteriophages** (or "phages" for short). An example of a phage with a simple structure is **M13.** It consists of a single-stranded DNA molecule (ssDNA) of about 7000 bp with a coat made up of 2700 helically arranged protein subunits. The coat of a virus is referred to as a *capsid,* and the complete structure as a *nucleocapsid.* In genetic engineering, M13 is important as a *vector* for foreign DNA (see p. 258).

The phage **T4** (bottom left), one of the largest viruses known, has a much more complex structure with around 170 000 base pairs (bp) of double-stranded DNA (dsDNA) contained within its "head."

The **tobacco mosaic virus** (center right), a plant pathogen, has a structure similar to that of M13, but contains ssRNA instead of DNA. The **poliovirus**, which causes poliomyelitis, is also an RNA virus. In the **influenza virus**, the pathogen that causes viral flu, the nucleocapsid is additionally surrounded by a *coat* derived from the plasma membrane of the host cell (**C**). The coat carries viral proteins that are involved in the infection process.

B. Capsid of the rhinovirus ○

Rhinoviruses cause the common cold. In these viruses, the capsid is shaped like an *icosahedron*—i. e., an object made up of 20 equilateral triangles. Its surface is formed from three different proteins, which associate with one another to form pentamers and hexamers. In all, 60 protein molecules are involved in the structure of the capsid.

C. Life cycle of HIV ◑

The *human immunodeficiency virus (HIV)* causes the immunodeficiency disease known as **AIDS** (*acquired immune deficiency syndrome*). The structure of this virus is similar to that of the influenza virus (**A**).

The HIV genome consists of two molecules of ssRNA (each 9.2 kb). It is enclosed by a double-layered capsid and a protein-containing coating membrane. HIV mainly infects T helper cells (see p. 294) and can thereby lead to failure of the immune system in the longer term.

During infection (**1**), the virus's coating membrane fuses with the target cell's plasma membrane, and the core of the nucleocapsid enters the cytoplasm (**2**). In the cytoplasm, the viral RNA is initially transcribed into an RNA/DNA hybrid (**3**) and then into dsDNA (**4**). Both of these reactions are catalyzed by *reverse transcriptase,* an enzyme deriving from the virus. The dsDNA formed is integrated into the host cell genome (**5**), where it can remain in an inactive state for a long time.

When viral replication occurs, the DNA segment corresponding to the viral genome is first transcribed by host cell enzymes (**6**). This gives rise not only to viral ssRNA, but also to transcription of mRNAs for precursors of the viral proteins (**7**). These precursors are integrated into the plasma membrane (**8**, **9**) before undergoing proteolytic modification (**10**). The cycle is completed by the release of new virus particles (**11**).

The group of RNA viruses to which HIV belongs are called **retroviruses**, because DNA is produced from RNA in their replication cycle—the reverse of the usual direction of transcription (DNA → RNA).

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A. Viruses: examples

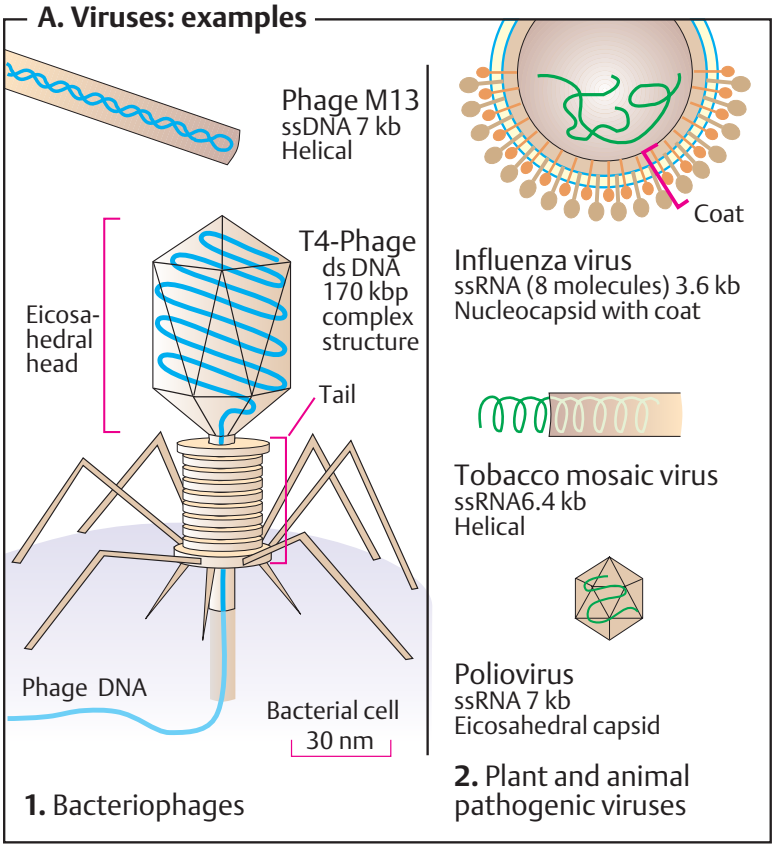

1. Bacteriophages

2. Plant and animal pathogenic viruses

B. Capsid of the rhinovirus

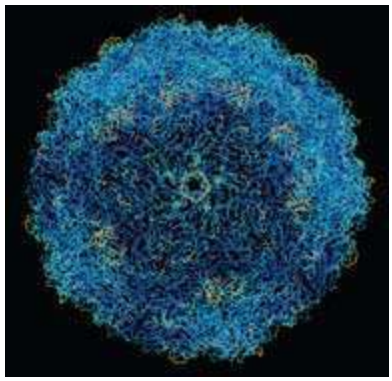

1. Structure

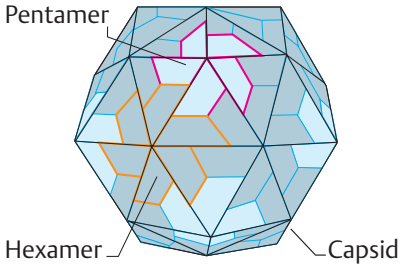

2. Diagram

C. Life cycle of the human immunodeficiency virus (HIV)

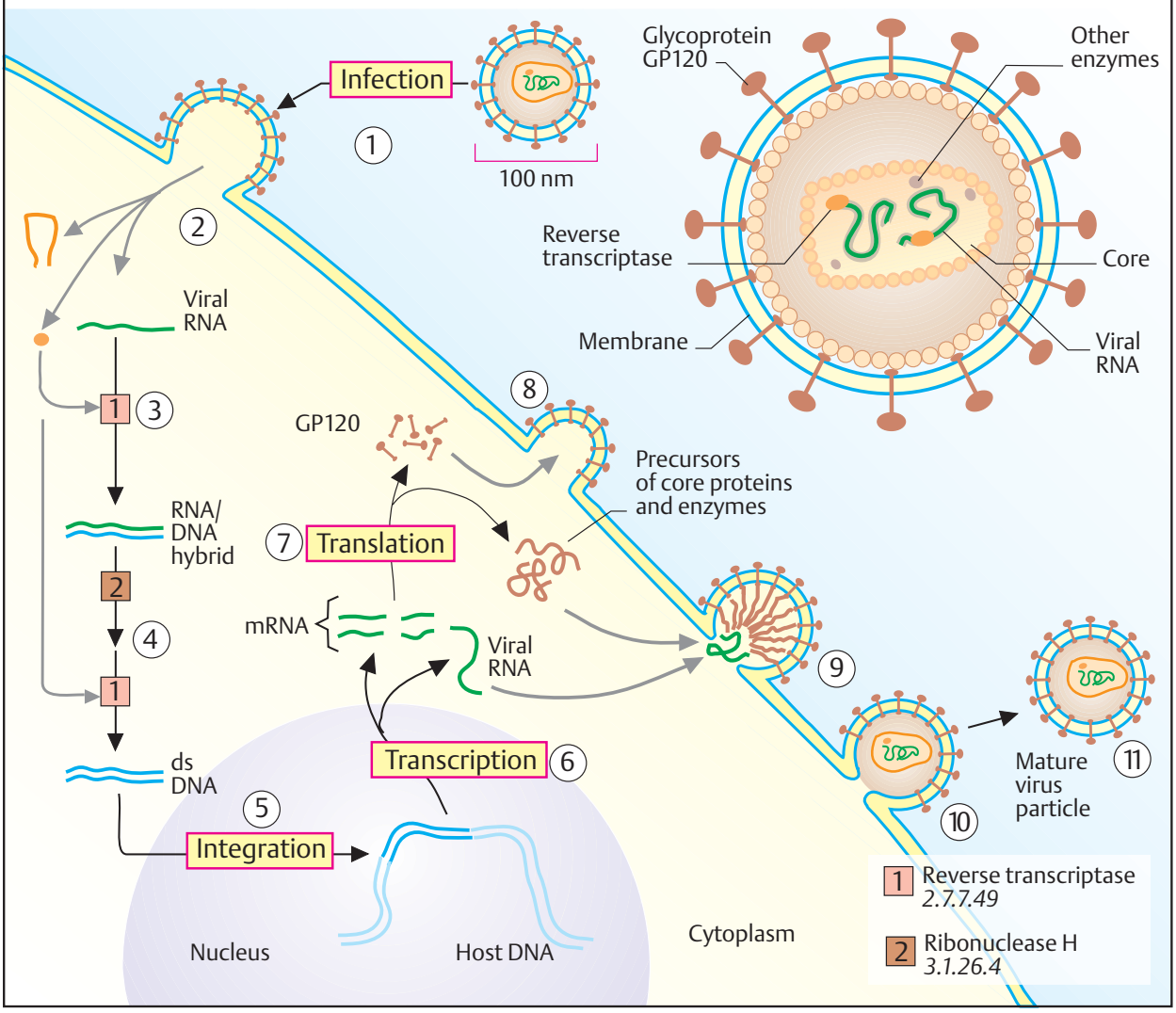

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Metabolic charts

Explanations

The following 13 plates (pp. 407–419) provide a concise schematic overview of the most important metabolic pathways. Explanatory text is deliberately omitted from them.

These "charts":

- Contain details of metabolic pathways that are only shown in outline in the main text for reasons of space. This applies in particular to the synthesis and degradation of the amino acids and nucleotides, and for some aspects of carbohydrate and lipid metabolism.
- Offer a quick overview of a specific pathway, the metabolites that arise in it, and the enzymes involved.
- Can be used for reference purposes and for revising material previously learned.

The most important **intermediates** are shown with numbers in the charts. The corresponding compounds can be identified using the table on the same page.

In addition, at each step the four-figure EC number (see p. 88) for the **enzyme** responsible for a reaction is given in *italics*. The enzyme name and its systematic classification in the system used by the *Enzyme Catalogue* are available in the following **annotated enzyme list** (pp. 420–430), in which all of the enzymes mentioned in this book are listed according to their EC number. The book's index is helpful when looking for a specific enzyme in the text.

In reactions that involve **coenzymes**, the coenzyme names are also given (sometimes in simplified form). Particularly important starting, intermediate, or end products are given with the full name, or as formulae.

Example

On p. 407, the initial step of the dark reactions in plant photosynthesis (in the Calvin cycle) is shown at the top left.

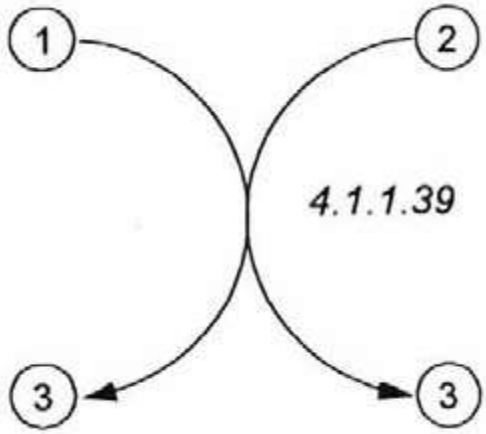

In this reaction, one molecule of ribulose-1,5-bisphosphate (metabolite 1) and one molecule of CO_2 (metabolite 2) give rise to two molecules of 3-phosphoglycerate (metabolite 3). The enzyme responsible has the EC number *4.1.1.39*. The annotated enzyme list shows that this refers to *ribulose bisphosphate carboxylase* ("rubisco" for short). Rubisco belongs to enzyme class 4 (the lyases) and, within that group, to subclass 4.1 (the carboxy-lyases). It contains copper as a cofactor ([Cu]).

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A. Calvin cycle (plant chloroplasts)

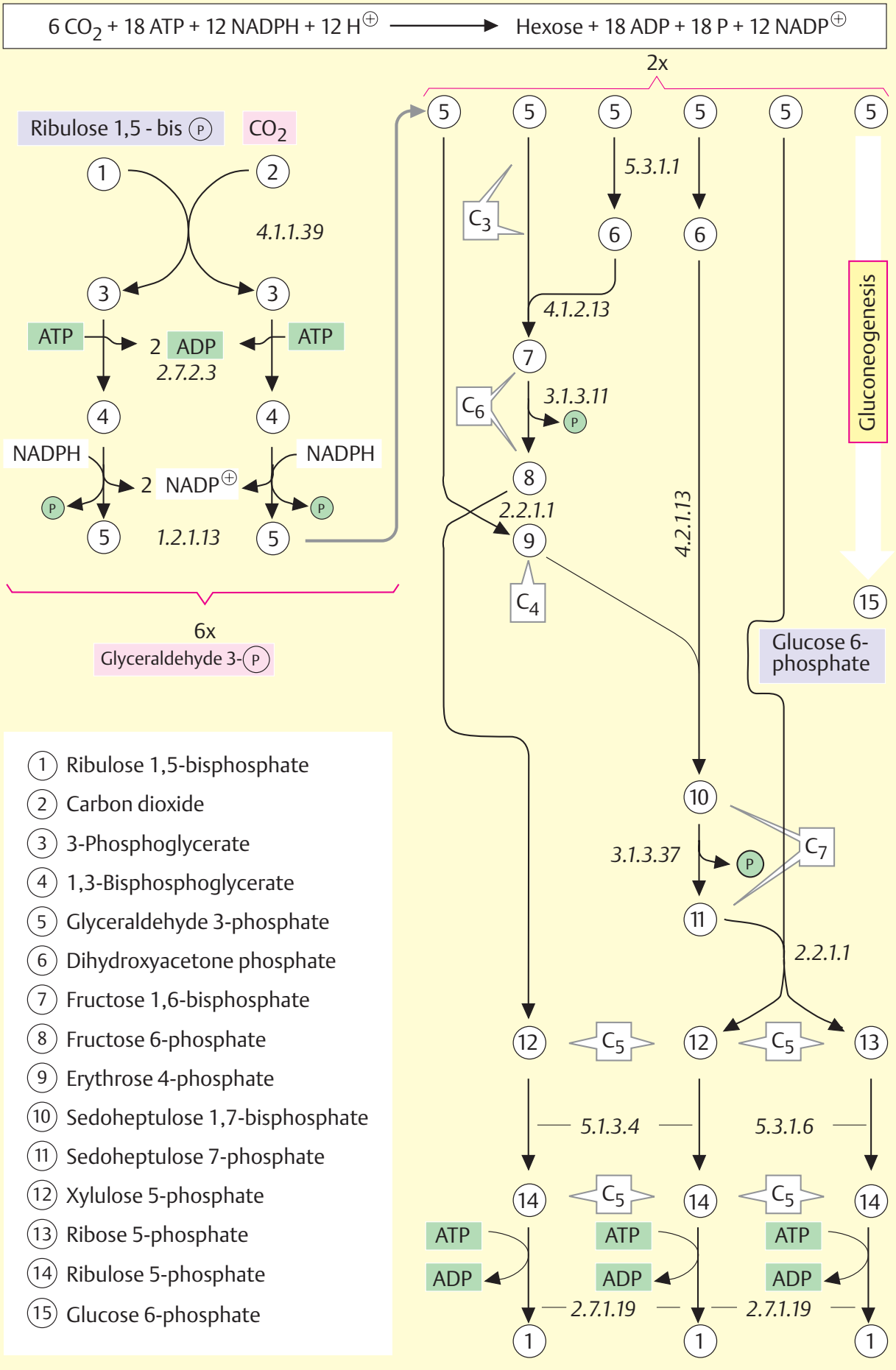

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A. Carbohydrate metabolism

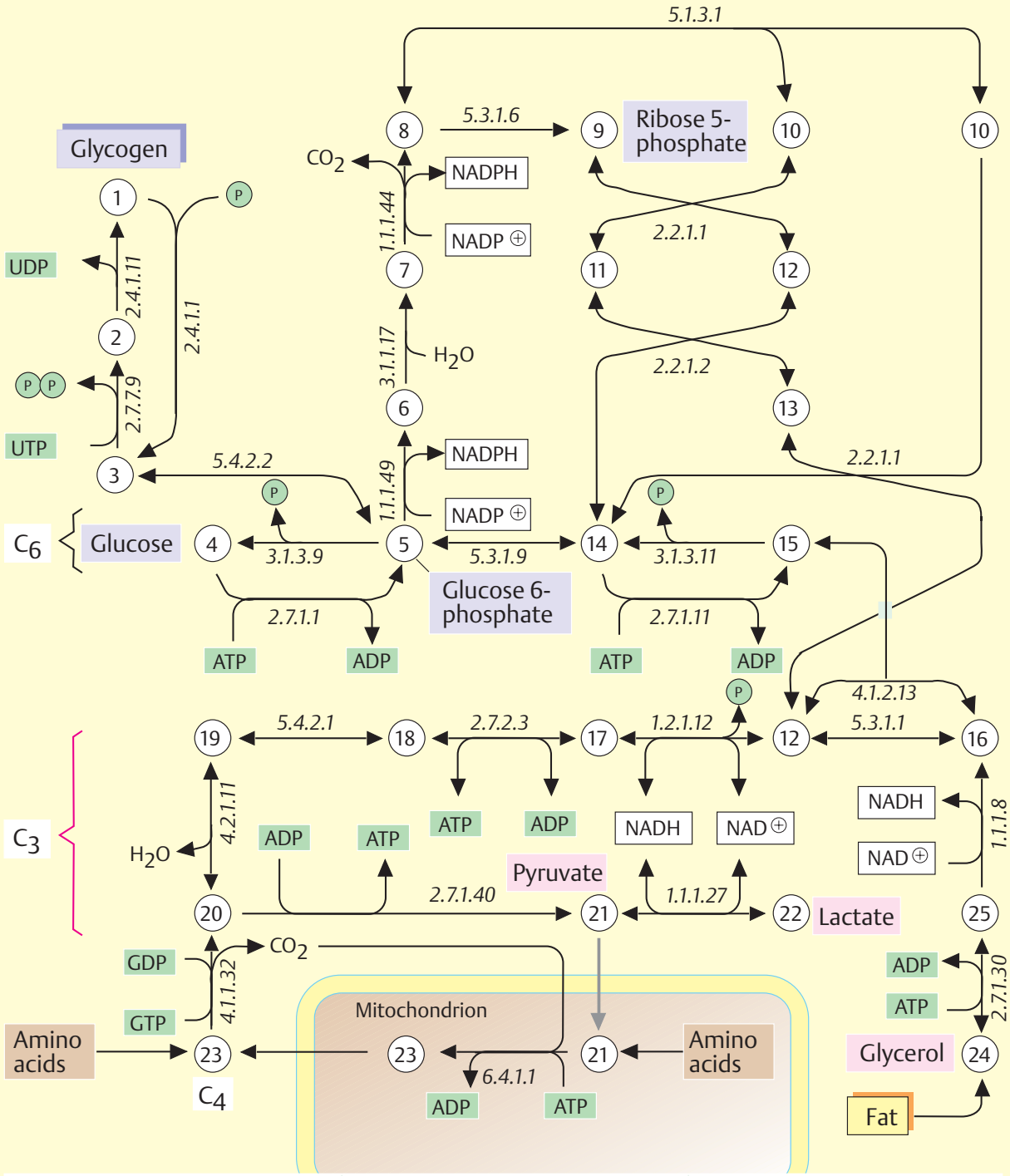

1	Glycogen	9	Ribose 5-phosphate	17	1,3-Bisphosphoglycerate
2	UDP-Glucose	10	Xylulose 5-phosphate	18	3-Phosphoglycerate
3	Glucose 1-phosphate	11	Sedoheptulose 7-phosphate	19	2-Phosphoglycerate
4	Glucose	12	Glyceraldehyde 3-phosphate	20	Phosphoenolpyruvate
5	Glucose 6-phosphate	13	Erythrose 4-phosphate	21	Pyruvate
6	Gluconolactone 6-Ⓟ	14	Fructose 6-phosphate	22	Lactate
7	Gluconate 6-phosphate	15	Fructose 1,6-bisphosphate	23	Oxaloacetate
8	Ribulose 5-phosphate	16	Glycerone-3-phosphate	24	Glycerol
				25	Glycerol 3-phosphate

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A. Biosynthesis of fats and membrane lipids

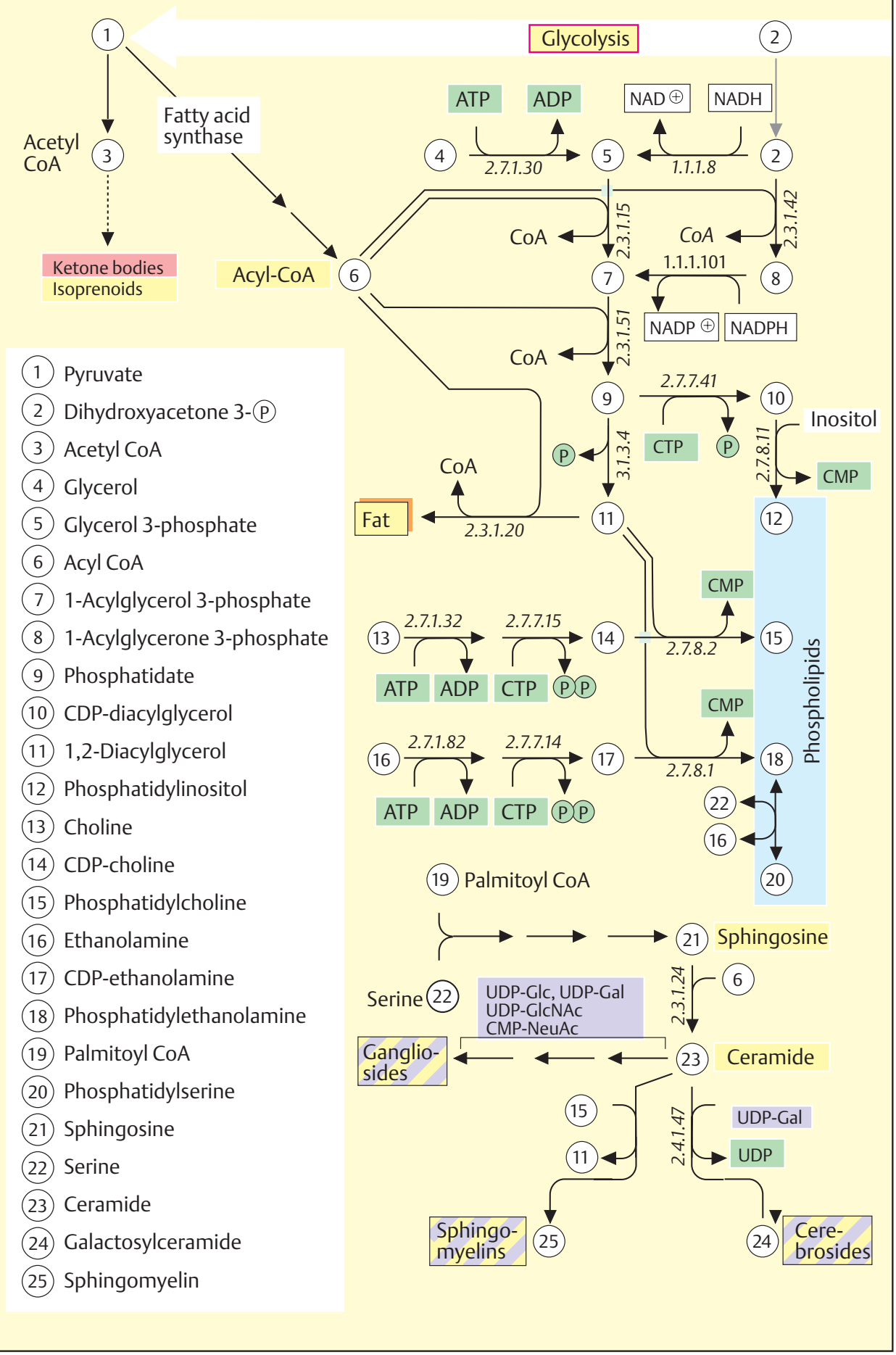

1 Pyruvate
2 Dihydroxyacetone 3-Ⓟ
3 Acetyl CoA
4 Glycerol
5 Glycerol 3-phosphate
6 Acyl CoA
7 1-Acylglycerol 3-phosphate
8 1-Acylglycerone 3-phosphate
9 Phosphatidate
10 CDP-diacylglycerol
11 1,2-Diacylglycerol
12 Phosphatidylinositol
13 Choline
14 CDP-choline
15 Phosphatidylcholine
16 Ethanolamine
17 CDP-ethanolamine
18 Phosphatidylethanolamine
19 Palmitoyl CoA
20 Phosphatidylserine
21 Sphingosine
22 Serine
23 Ceramide
24 Galactosylceramide
25 Sphingomyelin

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A. Synthesis of ketone bodies and steroids

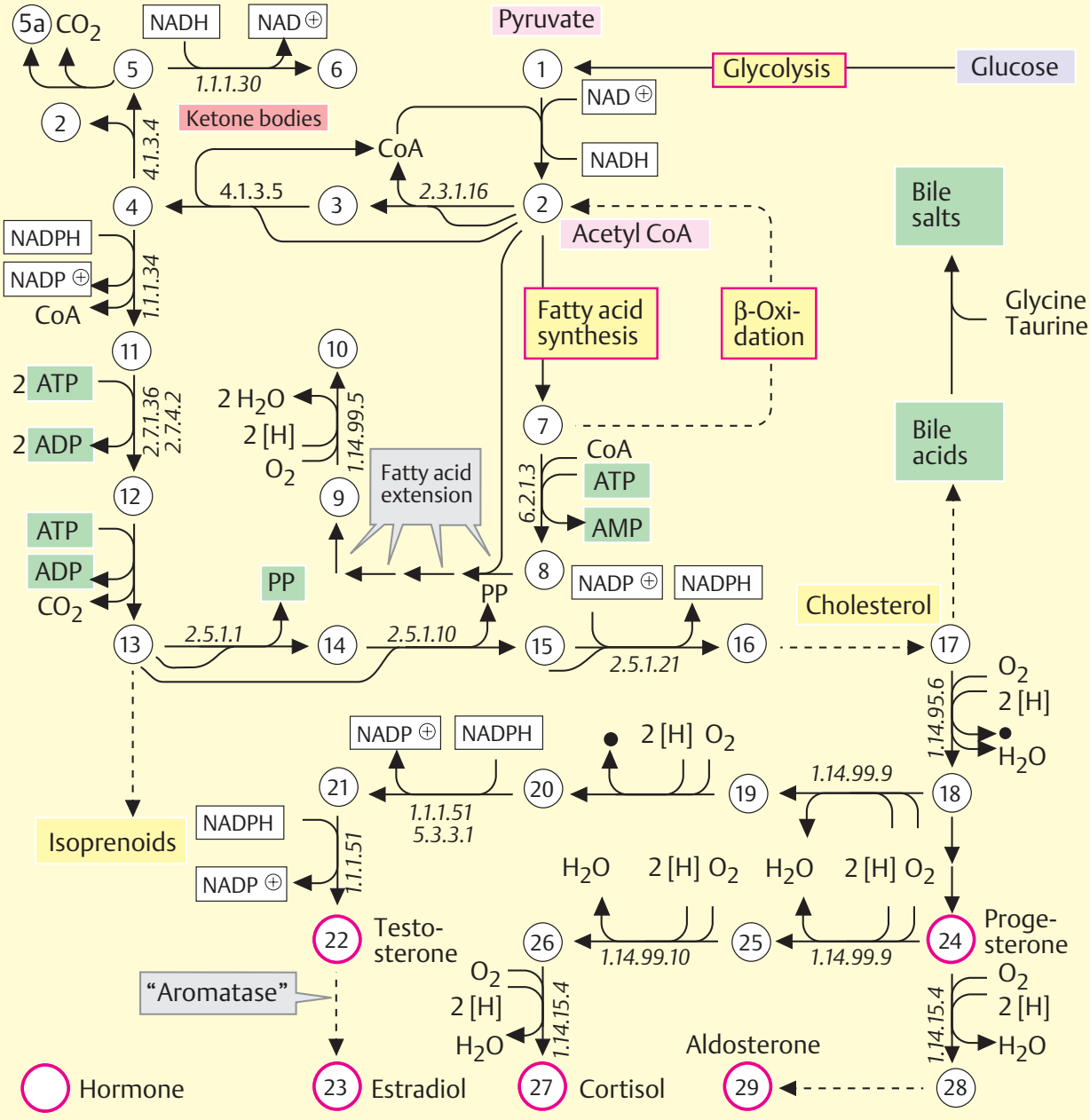

1 Pyruvate	10 Oleyl CoA	20 Dehydroepiandrosterone
2 Acetyl CoA	11 Mevalonate	21 Androstene-3,17-dione
3 Acetoacetyl CoA	12 Mevalonate 5-diphosphate	22 Testosterone
4 3-Hydroxy-3-methyl-glutaryl CoA	13 Isopentenyl diphosphate	23 Estradiol
5 Acetoacetate	14 Geranyl diphosphate	24 Progesterone
5a Acetone	15 Farnesyl diphosphate	25 17-OH-Progesterone
6 3-Hydroxybutyrate	16 Squalene	26 11-Deoxycortisol
7 Palmitate	17 Cholesterol	27 Cortisol
8 Palmitoyl CoA	18 Pregnenolone	28 11-Deoxycorticosterone
9 Stearoyl CoA	19 17-OH-Pregnenolone	29 Aldosterone

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A. Degradation of fats and phospholipids

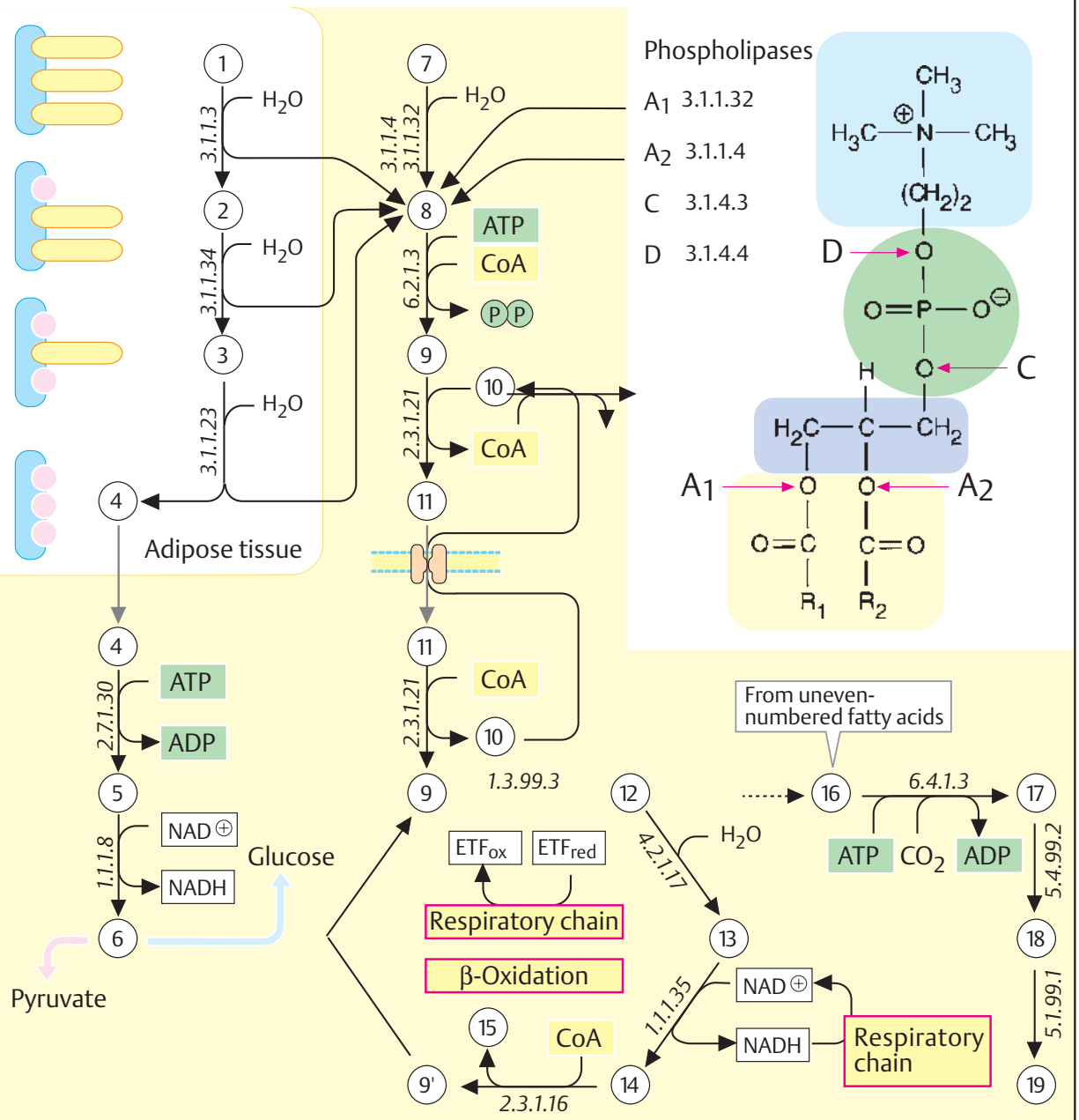

1 Triacylglycerol	8 Free fatty acid	14 3-Oxoacyl CoA
2 Diacylglycerol	9 Acyl CoA	15 Acetyl CoA
3 Monoacylglycerol	9' Shortened acyl CoA	16 Propionyl CoA
4 Glycerol	10 Carnitine	17 (S)-Methylmalonyl CoA
5 Glycerol 3-phosphate	11 Acyl carnitine	18 (R)-Methylmalonyl CoA
6 Glycerone 3-phosphate	12 2,3-Dehydroacyl CoA	19 Succinyl CoA
7 Phospholipid	13 3-Hydroxyacyl CoA	

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A. Biosynthesis of the essential amino acids

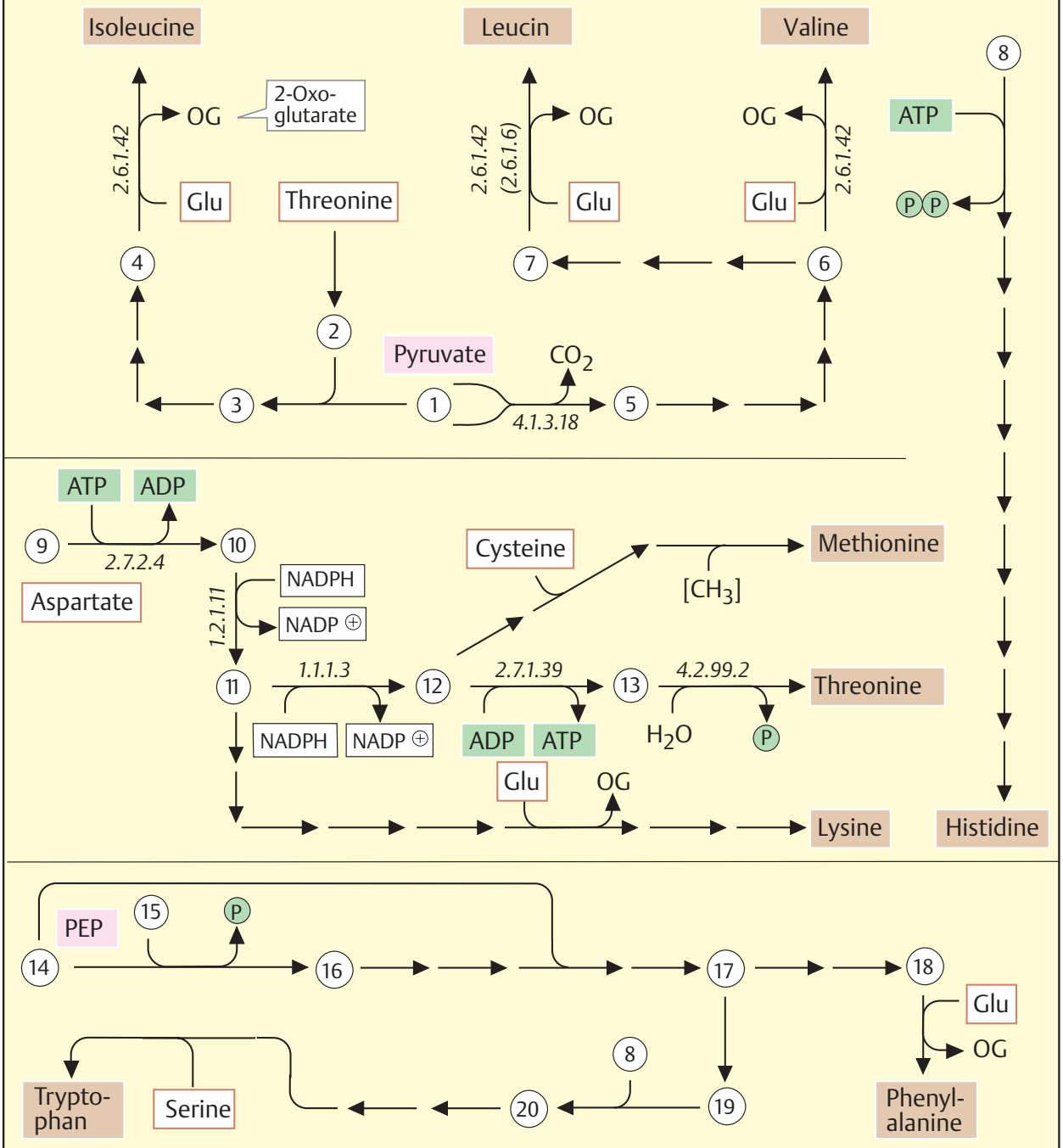

1. Pyruvate
2. 2-Oxobutyrate
3. 2-Aceto-2-hydroxybutyrate
4. 2-Oxo-4-methylvalerate
5. 2-Acetolactate
6. 2-Oxoisovalerate
7. 2-Oxoisocaproate
8. Phosphoribosyl diphosphate
9. Aspartate
10. Aspartyl 4-phosphate
11. Aspartate 4-semialdehyde
12. Homoserine
13. Phosphohomoserine
14. Phosphoenolpyruvate
15. Erythrose 4-phosphate
16. 2-Oxo-3-deoxy-arabinoheptulosonate 7-phosphate
17. Chorismate
18. Phenylpyruvate
19. Anthranilate
20. *N*-(Phosphoribosyl)-anthranilate

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A. Biosynthesis of the non-essential amino acids

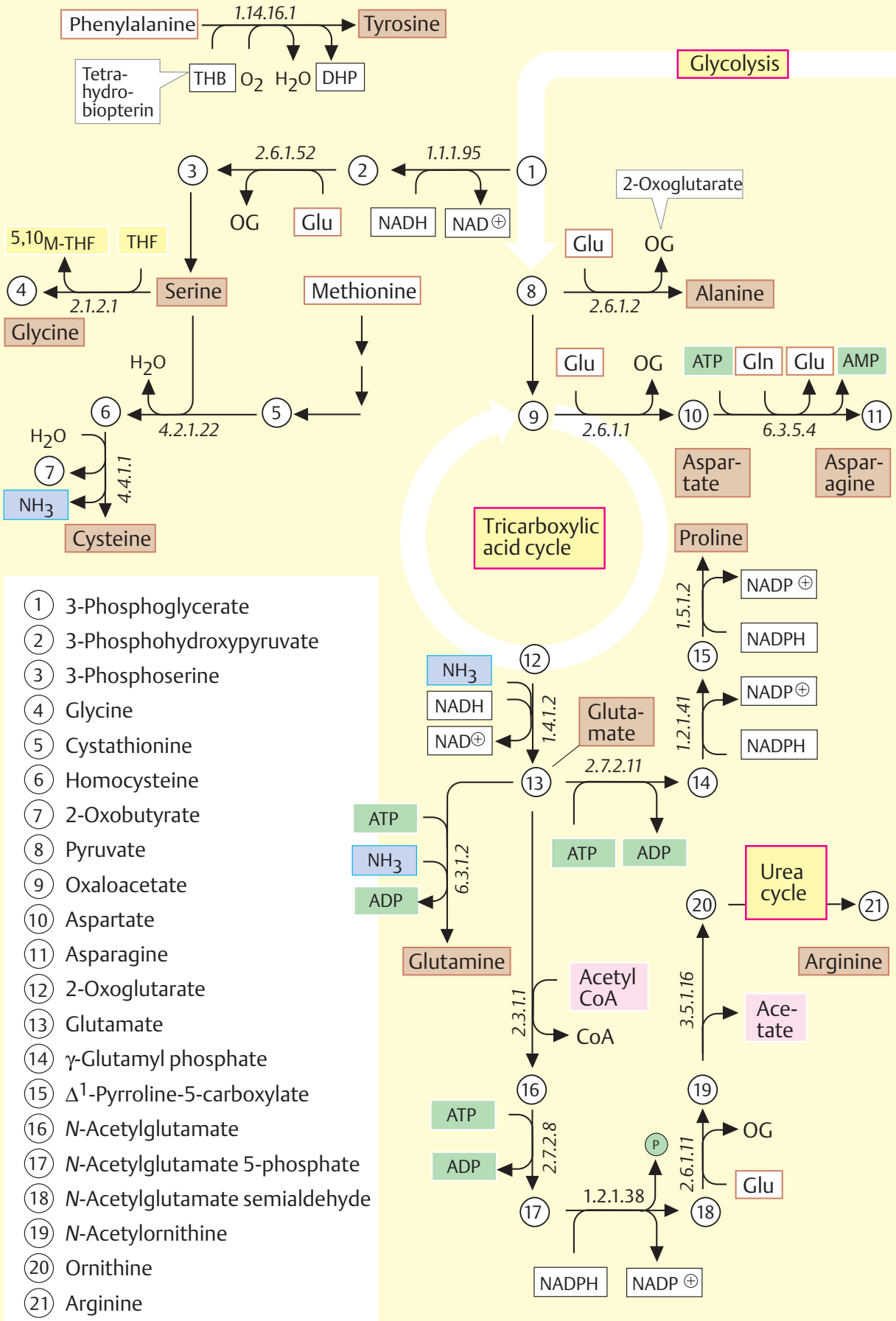

1. 3-Phosphoglycerate
2. 3-Phosphohydroxypyruvate
3. 3-Phosphoserine
4. Glycine
5. Cystathionine
6. Homocysteine
7. 2-Oxobutyrate
8. Pyruvate
9. Oxaloacetate
10. Aspartate
11. Asparagine
12. 2-Oxoglutarate
13. Glutamate
14. γ-Glutamyl phosphate
15. Δ^1-Pyrroline-5-carboxylate
16. *N*-Acetylglutamate
17. *N*-Acetylglutamate 5-phosphate
18. *N*-Acetylglutamate semialdehyde
19. *N*-Acetylornithine
20. Ornithine
21. Arginine

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A. Amino acid degradation I

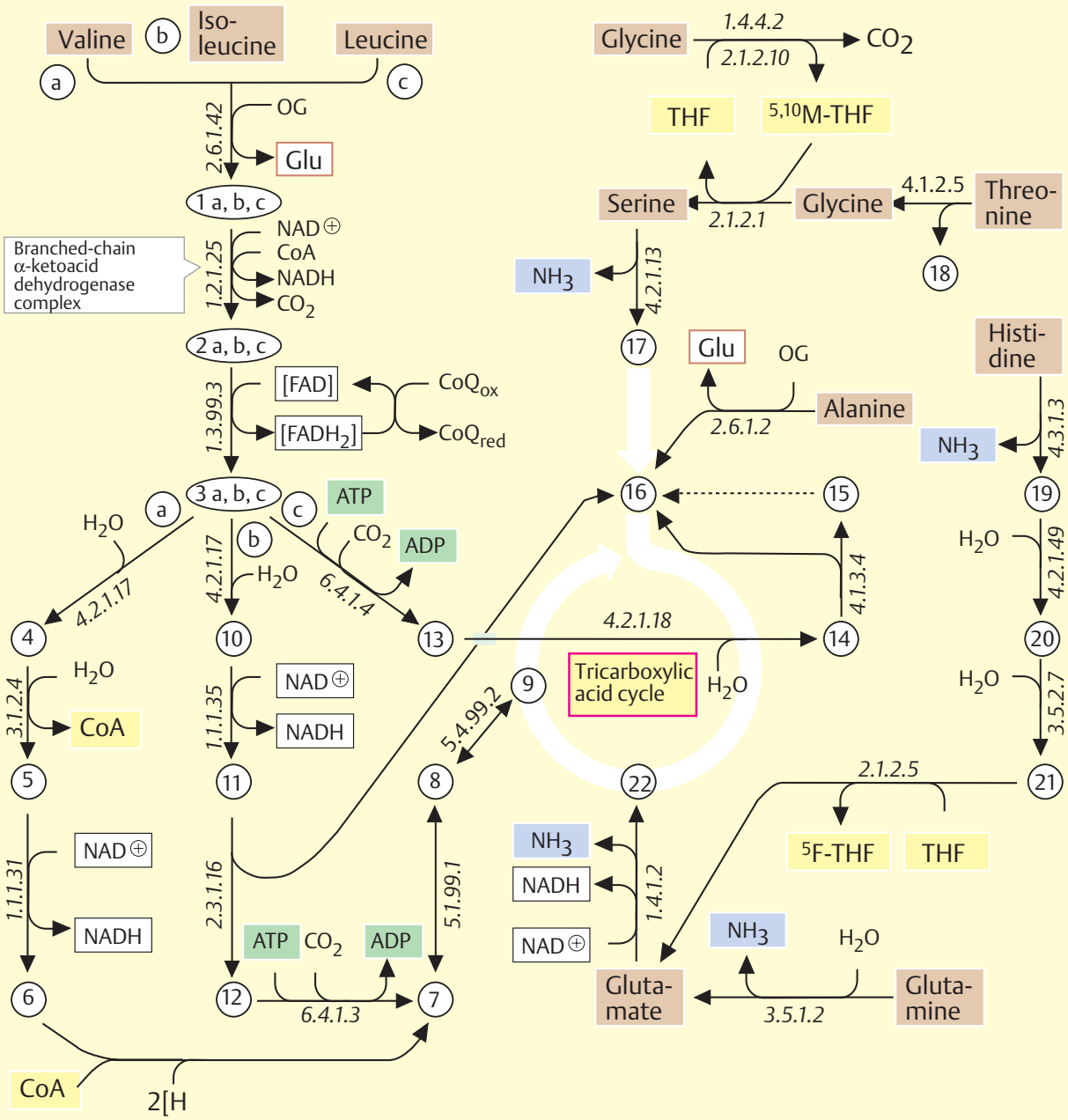

1a	2-Oxoisovalerate	5	3-Hydroxyisobutyrate	15	Acetoacetate
1b	2-Oxo-3-methylvalerate	6	Methylmalonyl-semialdehyde	16	Acetyl CoA
1c	2-Oxoisocapronate	7	(S)-Methylmalonyl CoA	17	Pyruvate
2a	Isobutyryl CoA	8	(R)-Methylmalonyl CoA	18	Acetaldehyde
2b	2-Methylbutyryl CoA	9	Succinyl CoA	19	Urocanate
2c	Isovaleryl CoA	10	2-Methyl-3-hydroxybutyryl CoA	20	Imidazolone-5-propionate
3a	Methylacrylyl CoA	11	2-Methylacetoacetyl CoA	21	*N*-Formimino-glutamate
3b	Tiglyl CoA	12	Propionyl CoA	22	2-Oxoglutarate
3c	3-Methylcrotonyl CoA	13	3-Methylglutaconyl CoA		
4	3-Hydroxyisobutyryl CoA	14	3-Hydroxy-3-methylglutaryl CoA		

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A. Amino acid degradation II

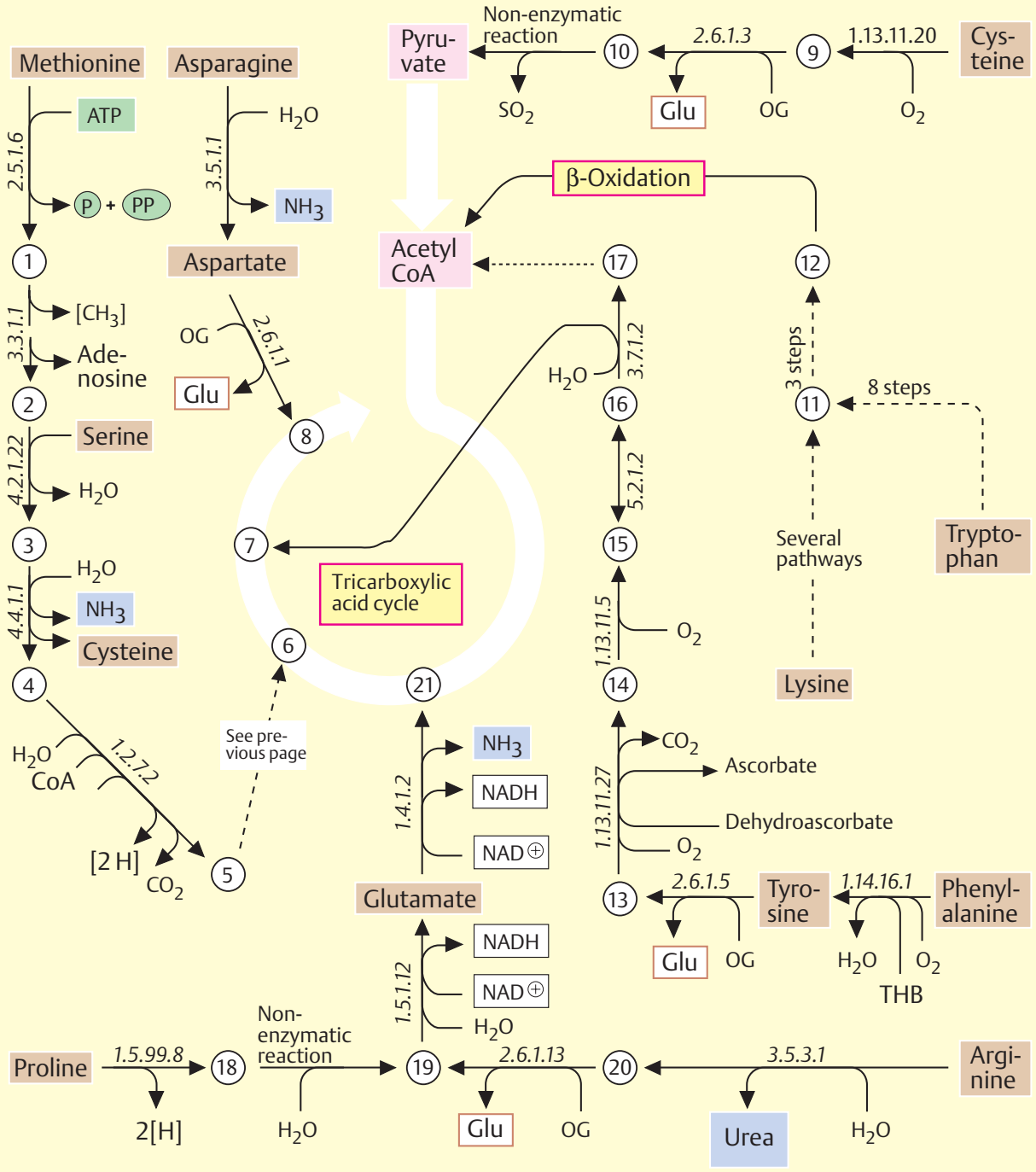

1. *S*-Adenosylmethionine
2. Homocysteine
3. Cystathionine
4. 2-Oxobutyrate
5. Propionyl CoA
6. Succinyl CoA
7. Fumarate
8. Oxaloacetate
9. Cysteine sulfinate
10. 3-Sulfinylpyruvate
11. 2-Oxoadipate
12. Crotonyl CoA
13. 4-Hydroxyphenylpyruvate
14. Homogentisate
15. 4-Maleylacetoacetate
16. Fumarylacetoacetate
17. Acetoacetate
18. Glutamate 4-semialdehyde
19. Δ^1-Pyrroline-5-carboxylate
20. Ornithine
21. 2-Oxoglutarate

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A. Ammonia metabolism

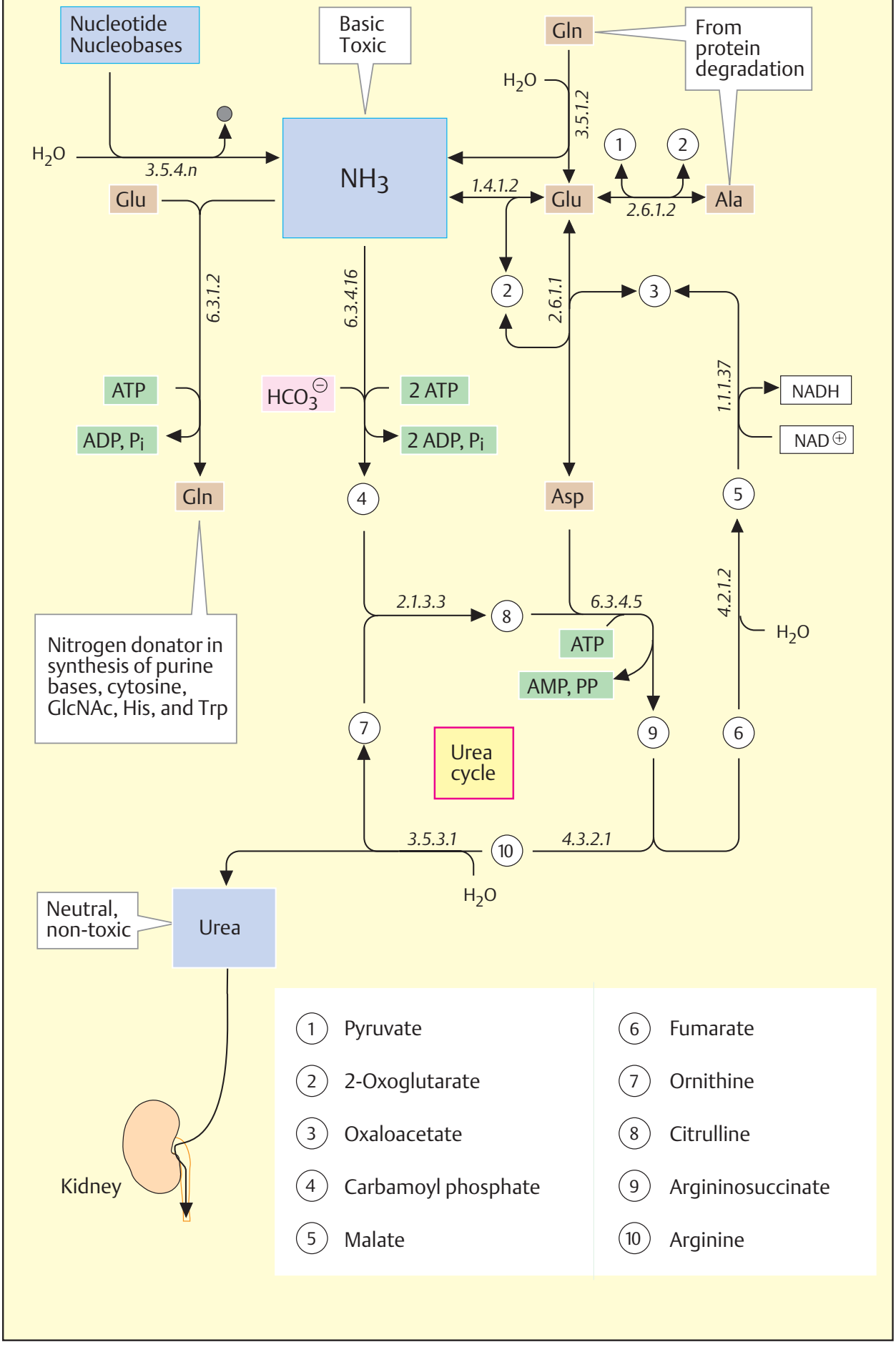

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A. Biosynthesis of purine nucleotides

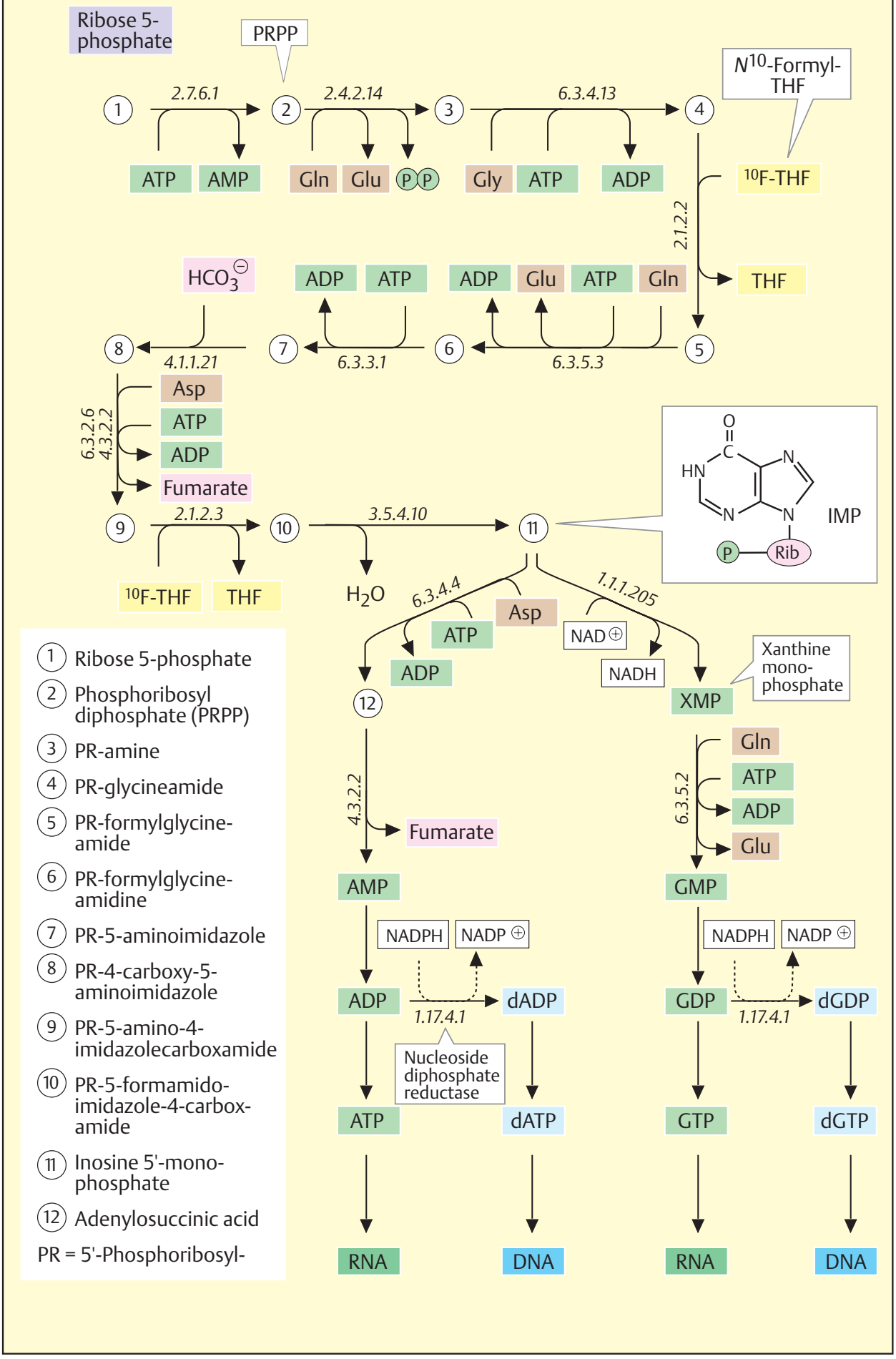

1. Ribose 5-phosphate
2. Phosphoribosyl diphosphate (PRPP)
3. PR-amine
4. PR-glycineamide
5. PR-formylglycine-amide
6. PR-formylglycine-amidine
7. PR-5-aminoimidazole
8. PR-4-carboxy-5-aminoimidazole
9. PR-5-amino-4-imidazolecarboxamide
10. PR-5-formamido-imidazole-4-carbox-amide
11. Inosine 5'-mono-phosphate
12. Adenylosuccinic acid

PR = 5'-Phosphoribosyl-

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A. Biosynthesis of the pyrimidine nucleotides and C_1 metabolism

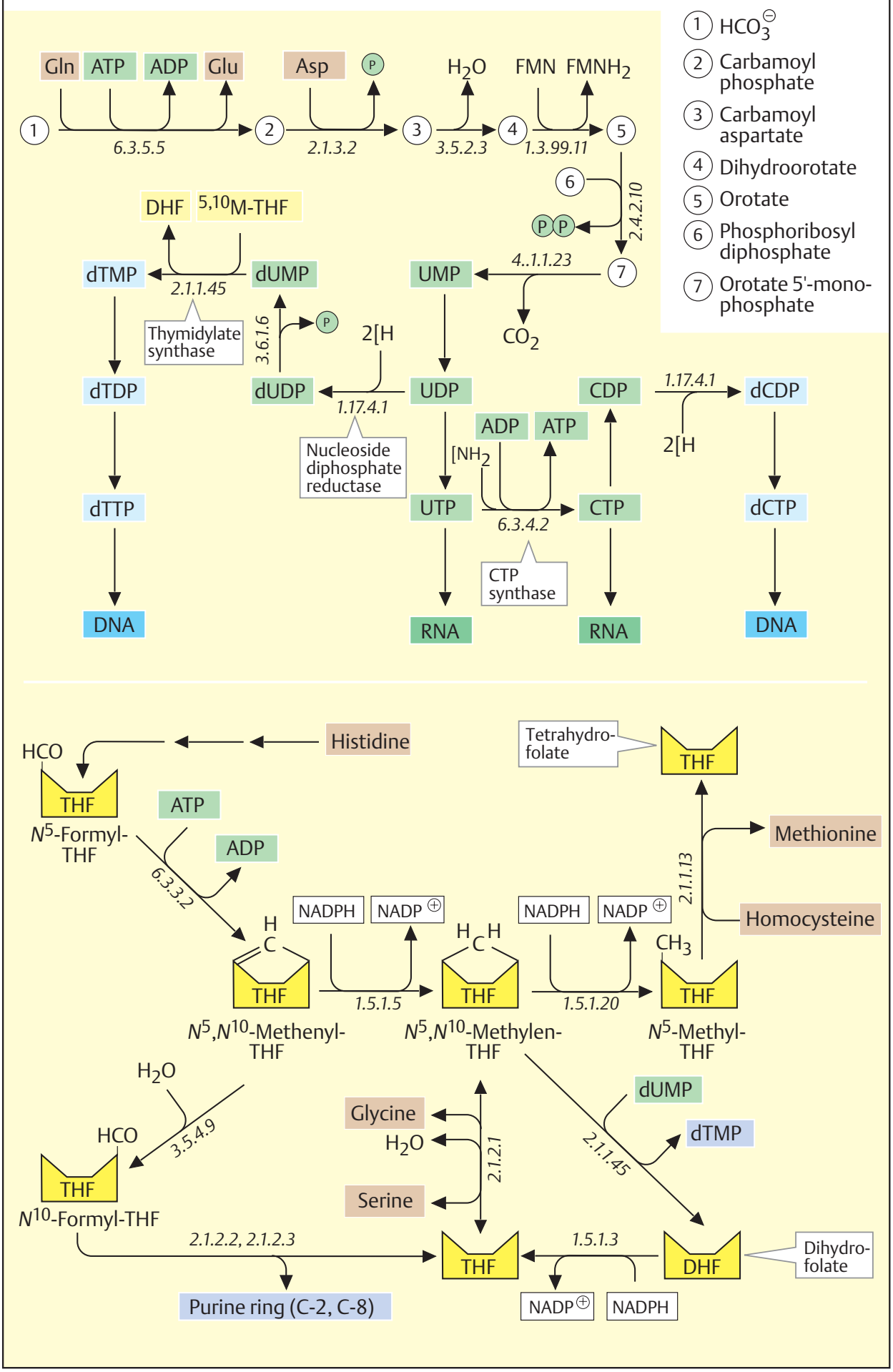

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A. Nucleotide degradation

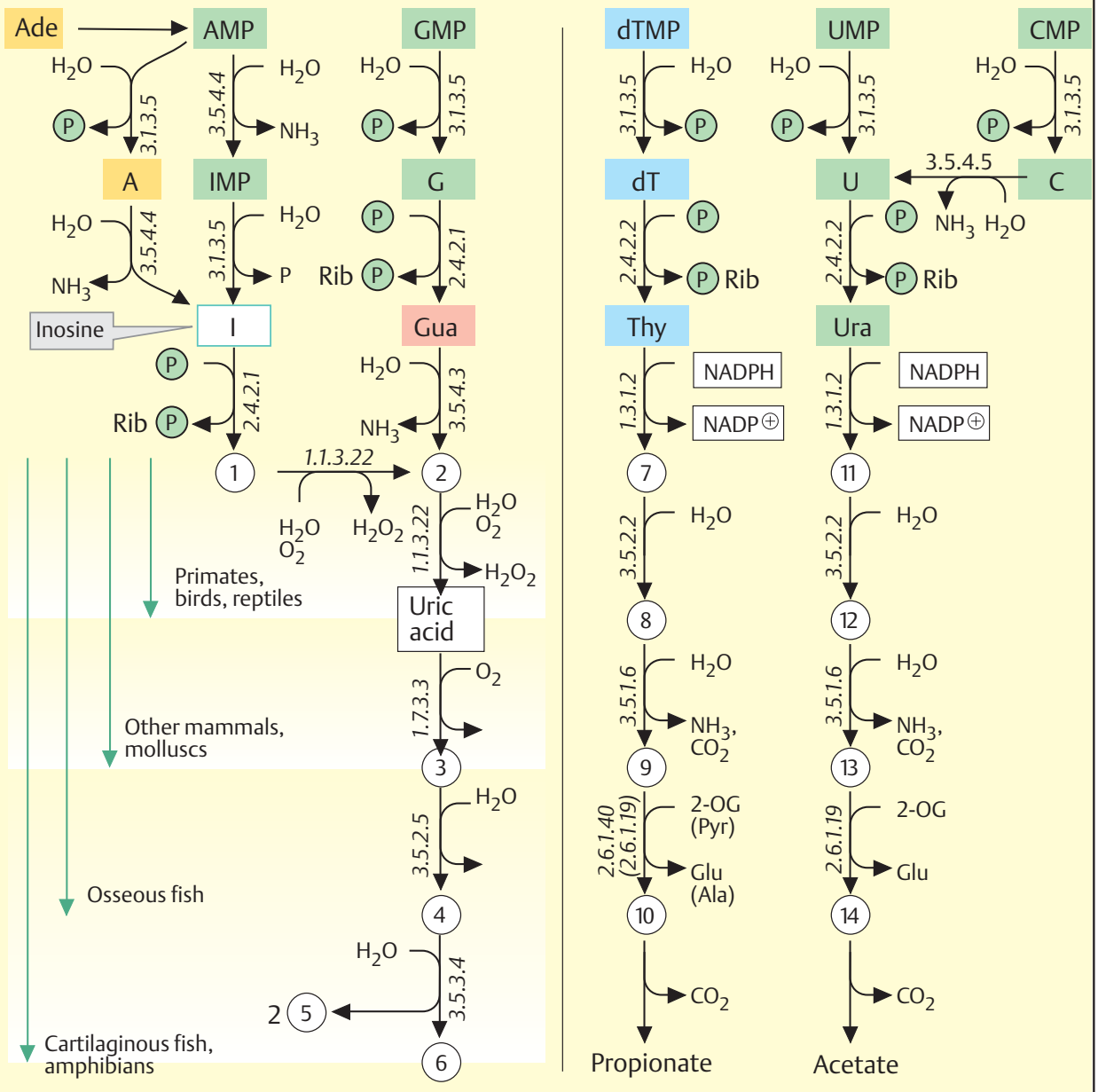

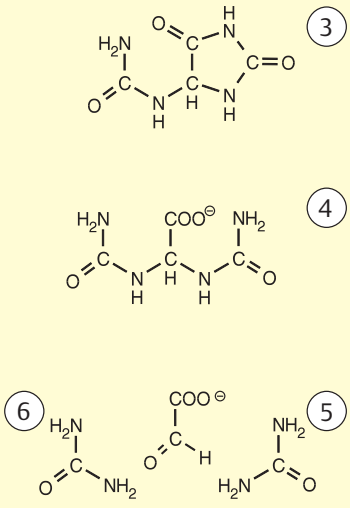

1	Hypoxanthine (Hyp)
2	Xanthine (Xan)
3	Allantoin
4	Allantoic acid
5	Glyoxylate
6	Urea
7	Dihydrothymine
8	Carbamoyl-β-amino-isobutyrate
9	β-Aminoisobutyrate
10	2-Methyl-3-oxopropionate
11	Dihydrouracil
12	Carbamoyl-β-alanine
13	β-alanine
14	3-oxopropionate

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Annotated enzyme list

Only the enzymes mentioned in this atlas are listed here, from among the more than 2000 enzymes known. The enzyme names are based on the IUBMB's of cial *Enzyme nomenclature 1992*. The additions shown in round brackets belong to the enzyme name, while prosthetic groups and other cofactors are enclosed in square brackets. Common names of enzyme groups are given in italics, and trivial names are shown in quotation marks.

Class 1: Oxidoreductases (catalyze reduction-oxidation reactions)

Subclass 1.n: What is the electron *donor?*
Sub-subclass 1.n.n: What is the electron *acceptor*?

1.1 A –CH–OH group is the donor

1.1.1 NAD(P)$^+$ is the acceptor (*dehydrogenases, reductases*)
1.1.1.1 Alcohol dehydrogenase [Zn^{2+}]
1.1.1.3 Homoserine dehydrogenase
1.1.1.8 Glycerol 3-phosphate dehydrogenase (NAD^+)
1.1.1.21 Aldehyde reductase
1.1.1.27 Lactate dehydrogenase
1.1.1.30 3-Hydroxybutyrate dehydrogenase
1.1.1.31 3-Hydroxyisobutyrate dehydrogenase
1.1.1.34 Hydroxymethylglutaryl-CoA reductase (NADPH)
1.1.1.35 3-Hydroxyacyl-CoA dehydrogenase
1.1.1.37 Malate dehydrogenase
1.1.1.40 Malate dehydrogenase (oxaloacetate-decarboxylating, $NADP^+$)—"malic enzyme"
1.1.1.41 Isocitrate dehydrogenase (NAD^+)
1.1.1.42 Isocitrate dehydrogenase ($NADP^+$)
1.1.1.44 Phosphogluconate dehydrogenase (decarboxylating)
1.1.1.49 Glucose 6-phosphate 1-dehydrogenase
1.1.1.51 3(or 17)β-Hydroxysteroid dehydrogenase
1.1.1.95 Phosphoglycerate dehydrogenase
1.1.1.100 3-Oxoacyl-[ACP] reductase
1.1.1.101 Acylglycerone phosphate reductase
1.1.1.105 Retinol dehydrogenase
1.1.1.145 3β-Hydroxy-Δ^5-steroid dehydrogenase
1.1.1.205 IMP dehydrogenase

1.1.3 Molecular oxygen is the acceptor (*oxidases*)
1.1.3.4 Glucose oxidase [FAD]
1.1.3.8 L-Gulonolactone oxidase
1.1.3.22 Xanthine oxidase [Fe, Mo, FAD]
1.1.99.5 Glycerol-3-phosphate dehydrogenase (FAD)

1.2 An aldehyde or keto group is the donor

1.2.1 NAD(P)$^+$ is the acceptor *(dehydrogenases)*
1.2.1.3 Aldehyde dehydrogenase (NAD^+)
1.2.1.11 Aspartate semialdehyde dehydrogenase
1.2.1.12 Glyceraldehyde 3-phosphate dehydrogenase
1.2.1.13 Glyceraldehyde 3-phosphate dehydrogenase ($NADP^+$) (phosphorylating)
1.2.1.24 Succinate semialdehyde dehydrogenase
1.2.1.25 2-Oxoisovalerate dehydrogenase (acylating)
1.2.1.38 *N*-Acetyl-γ-glutamylphosphate reductase
1.2.1.41 Glutamylphosphate reductase

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1.2.4 A disulfide is the acceptor
1.2.4.1 Pyruvate dehydrogenase (lipoamide) [TPP]
1.2.4.2 Oxoglutarate dehydrogenase (lipoamide) [TPP]

1.2.7 An Fe/S protein is the acceptor
1.2.7.2 2-Oxobutyrate synthase

1.3 A –CH–CH– group is the donor
1.3.1.10 Enoyl-[ACP] reductase (NADPH)
1.3.1.24 Biliverdin reductase
1.3.1.34 2,4-Dienoyl-CoA reductase
1.3.5.1 Succinate dehydrogenase (ubiquinone) [FAD, Fe_2S_2, Fe_4S_4], "complex II"
1.3.99.3 Acyl-CoA dehydrogenase [FAD]
1.3.99.11 Dihydroorotate dehydrogenase [FMN]

1.4 A –CH–NH2 group is the donor
1.4.1.2 Glutamate dehydrogenase
1.4.3.4 Amine oxidase [FAD], "monoamine oxidase (MAO)"
1.4.3.13 Protein lysine 6-oxidase [Cu]
1.4.4.2 Glycine dehydrogenase (decarboxylating) [PLP]

1.5 A –CH–NH group is the donor
1.5.1.2 Pyrroline-5-carboxylate reductase
1.5.1.3 Dihydrofolate reductase
1.5.1.5 Methylenetetrahydrofolate dehydrogenase ($NADP^+$)
1.5.1.12 1-Pyrroline-5-carboxylate dehydrogenase
1.5.1.20 Methylenetetrahydrofolate reductase (NADPH) [FAD]
1.5.5.1 Electron-transferring flavoprotein (ETF) dehydrogenase [Fe_4S_4]
1.5.99.8 Proline dehydrogenase [FAD]

1.6 NAD(P)H is the donor
16.4.2 Glutathione reductase (NADPH) [FAD]
1.6.4.5 Thioredoxin reductase (NADPH) [FAD]
1.6.5.3 NADH dehydrogenase (ubiquinone) [FAD, Fe_2S_2, Fe_4S_4]—"complex I"

1.8 A sulfur group is the donor
1.8.1.4 Dihydrolipoamide dehydrogenase [FAD]

1.9 A heme group is the donor
1.9.3.1 Cytochrome *c* oxidase [heme, Cu, Zn] – "cytochrome oxidase," "complex IV"

1.10 A diphenol is the donor
1.10.2.2 Ubiquinol cytochrome *c* reductase [heme, Fe_2S_2]—"complex III"

1.11 A peroxide is the acceptor (*peroxidases*)
1.11.1.6 Catalase [heme]
1.11.1.7 Peroxidase [heme]
1.11.1.9 Glutathione peroxidase [Se]
1.11.1.12 Lipid hydroperoxide glutathione peroxidase [Se]

1.13 Molecular oxygen is incorporated into the electron donor (*oxygenases*)

1.13.11 One donor, both O atoms are incorporated (*dioxygenases*)
1.13.11.5 Homogentisate 1,2-dioxygenase [Fe]
1.13.11.20 Cysteine dioxygenase [Fe]
1.13.11.27 4-Hydroxyphenylpyruvate dioxygenase [ascorbate]
1.13.11.n Arachidonate lipoxygenases

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1.14 Two donors, one O atom is incorporated into both (*monooxygenases, hydroxylases*)
1.14.11.2 Procollagen proline 4-dioxygenase [Fe, ascorbate]—"proline hydroxylase"
1.14.11.4 Procollagen lysine 5-dioxygenase [Fe, ascorbate]—"lysine hydroxylase"
1.14.13.13 Calcidiol 1-monooxygenase [heme]
1.14.15.4 Steroid 11β-monooxygenase [heme]
1.14.15.6 Cholesterol monooxygenase (side-chain-cleaving) [heme]
1.14.16.1 Phenylalanine 4-monooxygenase [Fe, tetrahydrobiopterin]
1.14.16.2 Tyrosine 3-monooxygenase [Fe, tetrahydrobiopterin]
1.14.17.1 Dopamine β-monooxygenase [Cu]
1.14.99.1 Prostaglandin H-synthase [heme]
1.14.99.3 Heme oxygenase (decyclizing) [heme]
1.14.99.5 Stearoyl-CoA desaturase [heme]
1.14.99.9 Steroid 17α-monooxygenase [heme]
1.14.99.10 Steroid 21-monooxygenase [heme]

1.15 A superoxide radical is the acceptor
1.15.1.1 Superoxide dismutase

1.17 A $-CH_2$ group is the donor
1.17.4.1 Ribonucleoside diphosphate reductase [Fe]—"ribonucleotide reductase"

1.18 Reduced ferredoxin is the donor
1.18.1.2 Ferredoxin-$NADP^+$ reductase [FAD]
1.18.6.1 Nitrogenase [Fe, Mo, Fe_4S_4]

Class 2: Transferases (catalyze the transfer of groups from one molecule to another)

Subclass 2.n: *Which group* is transferred?

2.1 A C_1 group is transferred

2.1.1 A methyl group
2.1.1.2 Guanidinoacetate *N*-methyltransferase
2.1.1.6 Catechol *O*-methyltransferase
2.1.1.13 5-Methyltetrahydrofolate-homocysteine *S*-methyltransferase
2.1.1.28 Phenylethanolamine *N*-methyltransferase
2.1.1.45 Thymidylate synthase
2.1.1.67 Thiopurine methyltransferase

2.1.2 A formyl group
2.1.2.1 Glycine hydroxymethyltransferase [PLP]
2.1.2.2 Phosphoribosylglycinamide formyltransferase
2.1.2.3 Phosphoribosylaminoimidazolecarboxamide formyltransferase
2.1.2.5 Glutamate formiminotransferase [PLP]
2.1.2.10 Aminomethyltransferase

2.1.3 A carbamoyl group
2.1.3.2 Aspartate carbamoyltransferase [Zn^{2+}]

2.1.3.3 Ornithine carbamoyltransferase

2.1.4 An amidino group
2.1.4.1 Glycine amidinotransferase

2.2 An aldehyde or ketone residue is transferred
2.2.1.1 Transketolase [TPP]
2.2.1.2 Transaldolase

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2.3 An acyl group is transferred

2.3.1 With acyl-CoA as donor
2.3.1.1 Amino acid *N*-acetyltransferase
2.3.1.6 Choline *O*-acetyltransferase
2.3.1.12 Dihydrolipoamide acetyltransferase [lipoamide]
2.3.1.15 Glycerol 3-phosphate *O*-acyltransferase
2.3.1.16 Acetyl-CoA acyltransferase
2.3.1.20 Diacylglycerol *O*-acyltransferase
2.3.1.21 Carnitine *O*-palmitoyltransferase
2.3.1.22 Acylglycerol *O*-palmitoyltransferase
2.3.1.24 Sphingosine *N*-acyltransferase
2.3.1.37 5-Aminolevulinate synthase [PLP]
2.3.1.38 [ACP] *S*-acetyltransferase
2.3.1.39 [ACP] *S*-malonyltransferase
2.3.1.41 3-Oxoacyl-[ACP] synthase
2.3.1.42 Glycerone phosphate *O*-acyltransferase
2.3.1.43 Phosphatidylcholine-sterol acyltransferase—"lecithin-cholesterol acyltransferase (LCAT)"
2.3.1.51 Acylgylcerol-3-phosphate *O*-acyltransferase
2.3.1.61 Dihydrolipoamide succinyltransferase
2.3.1.85 Fatty-acid synthase

2.3.2 An aminoacyl group is transferred
2.3.2.2 γ-glutamyltransferase
2.3.2.12 Peptidyltransferase (*a ribozyme*)
2.3.2.13 Protein-glutamine γ-glutamyltransferase [Ca]—"fibrin-stabilizing factor"

2.4 A glycosyl group is transferred

2.4.1 A hexose residue
2.4.1.1 Phosphorylase [PLP]—"glycogen (starch) phosphorylase"
2.4.1.11 Glycogen (starch) synthase
2.4.1.17 Glucuronosyltransferase
2.4.1.18 1,4-α-Glucan branching enzyme
2.4.1.25 4-α-Glucanotransferase
2.4.1.47 *N*-Acylsphingosine galactosyltransferase
2.4.1.119 Protein glycotransferase

2.4.2 A pentose residue
2.4.2.7 Adenine phosphoribosyltransferase
2.4.2.8 Hypoxanthine phosphoribosyltransferase
2.4.2.10 Orotate phosphoribosyltransferase
2.4.2.14 Amidophosphoribosyl transferase

2.5 An alkyl or aryl group is transferred
2.5.1.1 Dimethylallyltransferase
2.5.1.6 Methionine adenosyltransferase
2.5.1.10 Geranyltransferase
2.5.1.21 Farnesyl diphosphate farnesyltransferase

2.6 A nitrogen-containing group is transferred

2.6.1 An amino group (*transaminases*)
2.6.1.1 Aspartate transaminase [PLP]—"GOT"
2.6.1.2 Alanine transaminase [PLP]—"GPT"

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2.6.1.3 Cysteine transaminase [PLP]
2.6.1.5 Tyrosine transaminase [PLP]
2.6.1.6 Leucine transaminase (PLP]
2.6.1.11 Acetylornithine transaminase [PLP]
2.6.1.13 Ornithine transaminase [PLP]
2.6.1.19 4-Aminobutyrate transaminase [PLP]
2.6.1.42 Branched-chain amino acid transaminase [PLP]
2.6.1.52 Phosphoserine transaminase [PLP]

2.7 A phosphorus-containing group is transferred (*kinases*)

2.7.1 With –CH–OH as acceptor
2.7.1.1 Hexokinase
2.7.1.3 Ketohexokinase
2.7.1.6 Galactokinase
2.7.1.11 6-Phosphofructokinase
2.7.1.19 Phosphoribulokinase
2.7.1.28 Triokinase (triosekinase)
2.7.1.30 Glycerol kinase
2.7.1.32 Choline kinase
2.7.1.36 Mevalonate kinase
2.7.1.37 Protein kinase
2.7.1.38 Phosphorylase kinase
2.7.1.39 Homoserine kinase
2.7.1.40 Pyruvate kinase
2.7.1.67 1-Phosphatidylinositol-4-kinase
2.7.1.68 1-Phosphatidylinositol 4-phosphate kinase
2.7.1.82 Ethanolamine kinase
2.7.1.99 [Pyruvate dehydrogenase] kinase
2.7.1.105 6-Phosphofructo-2-kinase
2.7.1.112 Protein tyrosine kinase

2.7.2 With –CO–OH as acceptor
2.7.2.3 Phosphoglycerate kinase
2.7.2.4 Aspartate kinase
2.7.2.8 Acetylglutamate kinase
2.7.2.11 Glutamate 5-kinase

2.7.3 With a nitrogen-containing group as acceptor
2.7.3.2 Creatine kinase

2.7.4 With a phosphate group as acceptor
2.7.4.2 Phosphomevalonate kinase
2.7.4.3 Adenylate kinase
2.7.4.4 Nucleoside phosphate kinase
2.7.4.6 Nucleoside diphosphate kinase

2.7.6 A diphosphate residue is transferred
2.7.6.1 Ribose phosphate pyrophosphokinase

2.7.7 A nucleotide is transferred
2.7.7.6 DNA-directed RNA polymerase—"RNA polymerase"
2.7.7.7 DNA-directed DNA polymerase—"DNA polymerase"
2.7.7.9 UTP-glucose-l-phosphate uridyltransferase
2.7.7.12 Hexose-1-phosphate uridyltransferase
2.7.7.14 Ethanolamine phosphate cytidyltransferase

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2.7.7.15 Choline phosphate cytidyltransferase
2.7.7.41 Phosphatidate cytidyltransferase
2.7.7.49 RNA-directed DNA polymerase—"reverse transcriptase"

2.7.8 Another substituted phosphate is transferred
2.7.8.1 Ethanolaminephosphotransferase
2.7.8.2 Diacylglycerol cholinephosphotransferase
2.7.8.11 CDPdiacylglycerol-inositol 3-phosphatidyltransferase
2.7.8.16 1-Alkyl-2-acetylglycerol cholinephosphotransferase
2.7.8.17 *N*-Acetylglucosaminephosphotransferase

Class 3: Hydrolases (catalyze bond cleavage by hydrolysis)

Subclass 3.n: *What kind of bond* is hydrolyzed?

3.1 An ester bond is hydrolyzed (*esterases*)

3.1.1 In carboxylic acid esters
3.1.1.2 Arylesterase
3.1.1.3 Triacylglycerol lipase
3.1.1.4 Phospholipase A_2
3.1.1.7 Acetylcholinesterase
3.1.1.13 Cholesterol esterase
3.1.1.17 Gluconolactonase
3.1.1.32 Phospholipase A_1
3.1.1.34 Lipoprotein lipase, diacylglycerol lipase

3.1.2 In thioesters 3.1.2.4
3-Hydroxyisobutyryl-CoA hydrolase
3.1.2.14 Acyl-[ACP] hydrolase

3.1.3 In phosphoric acid monoesters (*phosphatases*)
3.1.3.1 Alkaline phosphatase [Zn^{2+}]
3.1.3.2 Acid phosphatase
3.1.3.4 Phosphatidate phosphatase
3.1.3.9 Glucose 6-phosphatase
3.1.3.11 Fructose bisphosphatase
3.1.3.13 Bisphosphoglycerate phosphatase
3.1.3.16 Phosphoprotein phosphatase
3.1.3.37 Sedoheptulose bisphosphatase
3.1.3.43 [Pyruvate dehydrogenase] phosphatase
3.1.3.46 Fructose-2,6-bisphosphate 2-phosphatase
3.1.3.n Polynucleotidases

3.1.4 In phosphoric acid diesters (*phosphodiesterases*)
3.1.4.1 Phosphodiesterase
3.1.4.3 Phospholipase C
3.1.4.4 Phospholipase D
3.1.4.17 3′,5′-cNMP phosphodiesterase
3.1.4.35 3′,5′-cGMP phosphodiesterase
3.1.4.45 *N*-Acetylglucosaminyl phosphodiesterase

3.1.21 In DNA
3.1.21.1 Deoxyribonuclease I
3.1.21.4 Site-specific deoxyribonuclease (type II)—"restriction endonuclease"

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3.10.26–7 **In RNA**
3.1.26.4 Ribonuclease H
3.1.27.5 Pancreatic ribonuclease

3.2 **A glycosidic bond is hydrolyzed** (*glycosidases*)

3.2.1 **In *O*-glycosides**
3.2.1.1 α-Amylase
3.2.1.10 Oligo-1,6-glucosidase
3.2.1.17 Lysozyme
3.2.1.18 Neuraminidase
3.2.1.20 α-Glucosidase
3.2.1.23 β-Galactosidase
3.2.1.24 α -Mannosidase
3.2.1.26 β-Fructofuranosidase—"saccharase," "invertase"
3.2.1.28 α,α-Trehalase
3.2.1.33 Amylo-1,6-glucosidase
3.2.1.48 Sucrose α-glucosidase
3.2.1.52 β-*N*-Acetylhexosaminidase
3.2.2.n Nucleosidases

3.3 **An ether bond is hydrolyzed**
3.3.1.1 Adenosylhomocysteinase

3.4 **A peptide bond is hydrolyzed** (*peptidases*)

3.4.11 **Aminopeptidases** (*N*-terminal exopeptidases)
3.4.11.n Various aminopeptidases [Zn^{2+}]

3.4.13 **Dipeptidases** (act on dipeptides only)
3.4.13.n Various dipeptidases [Zn^{2+}]

3.4.15 **Peptidyl dipeptidases** (*C*-terminal exopeptidases, releasing dipeptides)
3.4.15.1 Peptidyl-dipeptidase A [Zn^{2+}]—"angiotensin-converting enzyme (ACE)"

3.4.17 **Carboxypeptidases** (*C*-terminal exopeptidases)
3.4.17.1 Carboxypeptidase A [Zn^{2+}]
3.4.17.2 Carboxypeptidase B [Zn^{2+}]
3.4.17.8 Muramoylpentapeptide carboxypeptidase

3.4.21 **Serine proteinases** (endopeptidases)
3.4.21.1 Chymotrypsin
3.4.21.4 Trypsin
3.4.21.5 Thrombin
3.4.21.6 Coagulation factor Xa—"Stuart–Prower factor"
3.4.21.7 Plasmin
3.4.21.9 Enteropeptidase—"enterokinase"
3.4.21.21 Coagulation factor VIIa—"proconvertin"
3.4.21.22 Coagulation factor IXa—"Christmas factor"
3.4.21.27 Coagulation factor XIa—"plasma thromboplastin antecedent"
3.4.21.34 Plasma kallikrein
3.4.21.35 Tissue kallikrein
3.4.21.36 Elastase
3.4.21.38 Coagulation factor XIIa—"Hageman factor"
3.4.21.43 C3/C5 convertase (complement—classical pathway)
3.4.21.47 C3/C5 convertase (complement—alternative pathway)

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3.4.21.68 Plasminogen activator (tissue)—"tissue plasminogen activator (t-PA)"
3.4.21.73 Plasminogen activator (urine)—"urokinase"

3.4.22 Cysteine proteinases (*endopeptidases*)
3.4.22.2 Papain

3.4.23 Aspartate proteinases (*endopeptidases*)
3.4.23.1 Pepsin A
3.4.23.2 Pepsin B
3.4.23.3 Gastricsin (pepsin C)
3.4.23.4 Chymosin
3.4.23.15 Renin

3.4.24 Metalloproteinases (*endopeptidases*)
3.4.24.7 Collagenase

3.4.99 Other peptidases
3.4.99.36 Signal peptidase

3.5 Another amide bond is hydrolyzed (*amidases*)
3.5.1.1 Asparaginase
3.5.1.2 Glutaminase
3.5.1.16 Acetylornithine deacetylase [Zn^{2+}]
3.5.2.3 Dihydroorotase
3.5.2.7 Imidazolonepropionase
3.5.3.1 Arginase
3.5.4.6 AMP deaminase
3.5.4.9 Methylenetetrahydrofolate cyclohydrolase
3.5.4.10 IMP cyclohydrolase

3.6 An anhydride bond is hydrolyzed
3.6.1.6 Nucleoside diphosphatase
3.6.1.32 Myosin ATPase
3.6.1.34 H^+-transporting ATP synthase—"ATP synthase," "complex V"
3.6.1.35 H^+-transporting ATPase
3.6.1.36 H^+/K^+-exchanging ATPase
3.6.1.37 Na^+/K^+-exchanging ATPase—"Na^+/K^+-ATPase"
3.6.1.38 Ca^{2+}-transporting ATPase

3.7 A C–C bond is hydrolyzed
3.7.1.2 Fumarylacetoacetase

Class 4: Lyases (cleave or form bonds without oxidative or hydrolytic steps)

Subclass 4.n: *What kind of bond* is formed or cleaved?

4.1 A C–C bond is formed or cleaved

4.1.1 Carboxy-lyases (*carboxylases, decarboxylases*)
4.1.1.1 Pyruvate decarboxylase [TPP]
4.1.1.15 Glutamate decarboxylase [PLP]
4.1.1.21 Phosphoribosylaminoimidazole carboxylase
4.1.1.23 Orotidine-5′-phosphate decarboxylase
4.1.1.28 Aromatic L-amino acid decarboxylase [PLP]
4.1.1.32 Phosphoenolpyruvate carboxykinase (GTP)
4.1.1.39 Ribulose bisphosphate carboxylase [Cu]—"rubisco"

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4.1.2 Acting on aldehydes or ketones
4.1.2.5 Threonine aldolase [PLP]
4.1.2.13 Fructose bisphosphate aldolase—"aldolase"
4.1.3.4 Hydroxymethylglutaryl-CoA lyase
4.1.3.5 Hydroxymethylglutaryl-CoA synthase
4.1.3.7 Citrate synthase
4.1.3.8 ATP-citrate lyase
4.1.3.18 Acetolactate synthase [TPP, flavin]

4.1.99 Other C–C lyases
4.1.99.3 Deoxyribodipyrimidine photolyase [FAD]—"photolyase"

4.2 A C–O bond is formed or cleaved

4.2.1 Hydrolyases (*hydratases, dehydratases*)
4.2.1.1 Carbonate dehydratase [Zn^{2+}]—"carbonic anhydrase"
4.2.1.2 Fumarate hydratase—"fumarase"
4.2.1.3 Aconitate hydratase [Fe_4S_4]—"aconitase"
4.2.1.11 Phosphopyruvate hydratase—"enolase"
4.2.1.13 Serine dehydratase
4.2.1.17 Enoyl-CoA hydratase
4.2.1.18 Methylglutaconyl-CoA hydratase
4.2.1.22 Cystathionine β-synthase [PLP]
4.2.1.24 Porphobilinogen synthase
4.2.1.49 Urocanate hydratase
4.2.1.61 3-Hydroxypalmitoyl-[ACP] dehydratase
4.2.1.75 Uroporphyrinogen III synthase

4.2.99 Other C–O lyases
4.2.99.2 Threonine synthase [PLP]

4.3 A C–N bond is formed or cleaved

4.3.1 Ammonia lyases 4.3.1.3
Histidine ammonia lyase
4.3.1.8 Hydroxymethylbilane synthase

4.3.2 Amidine lyases 4.3.2.1
Argininosuccinate lyase
4.3.2.2 Adenylosuccinate lyase

4.4 A C–S bond is formed or cleaved
4.4.1.1 Cystathionine γ-lyase [PLP]

4.6 A P–O bond is formed or cleaved
4.6.1.1 Adenylate cyclase
4.6.1.2 Guanylate cyclase

Class 5: Isomerases (catalyze changes within one molecule)

Subclass 5.n: *What kind of isomerization* is taking place?

5.1 A racemization or epimerization (*epimerases*)
5.1.3.1 Ribulose phosphate 3-epimerase
5.1.3.2 UDPglucose 4-epimerase
5.1.3.4 L-Ribulose phosphate 4-epimerase
5.1.99.1 Methylmalonyl-CoA epimerase

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5.2 A *cis–trans* isomerization
5.2.1.2 Maleylacetoacetate isomerase
5.2.1.3 Retinal isomerase
5.2.1.8 Peptidyl proline *cis–trans*-isomerase

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5.3.1.1 Triose phosphate isomerase
5.3.1.6 Ribose 5-phosphate isomerase
5.3.1.9 Glucose 6-phosphate isomerase
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5.99 Another kind of isomerization
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5.99.1.3 DNA topoisomerase (ATP-hydrolyzing, type II)—"DNA gyrase"

Class 6: Ligases (join two molecules with hydrolysis of an "energy-rich" bond)

Subclass 6.n: *What kind of bond* is formed?

6.1 A C–O bond is formed
6.1.1.n (Amino acid)-tRNA ligases (*aminoacyl-tRNA synthetases*)

6.2 A C–S bond is formed
6.2.1.1 Acetate-CoA ligase
6.2.1.3 Long-chain fatty-acid-CoA ligase
6.2.1.4 Succinate-CoA ligase (GDP-forming)—"thiokinase"

6.3 A C–N bond is formed
6.3.1.2 Glutamate-NH_3 ligase—"glutamine synthetase"
6.3.2.6 Phosphoribosylaminoimidazolesuccinocarboxamide synthase *(sorry!)*
6.3.3.1 Phosphoribosylformylglycinamidine cycloligase
6.3.3.2 5-Formyltetrahydrofolate cycloligase
6.3.4.2 CTP synthase
6.3.4.4 Adenylosuccinate synthase
6.3.4.5 Argininosuccinate synthase
6.3.4.13 Phosphoribosylamine glycine ligase
6.3.4.16 Carbamoylphosphate synthase (NH_3)
6.3.5.2 GMP synthase (glutamine-hydrolyzing)
6.3.5.3 Phosphoribosylformylglycinamidine synthase
6.3.5.4 Asparagine synthase (glutamine-hydrolyzing)
6.3.5.5 Carbamoylphosphate synthase (glutamine-hydrolyzing)

6.4 A C–C bond is formed
6.4.1.1 Pyruvate carboxylase [biotin]
6.4.1.2 Acetyl-CoA carboxylase [biotin]
6.4.1.3 Propionyl-CoA carboxylase [biotin]
6.4.1.4 Methylcrotonyl-CoA carboxylase [biotin]

6.5 A P–O bond is formed
6.5.1.1 DNA ligase (ATP)

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Abbreviations

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AA	Amino acid
ACE	Angiotensin-converting enzyme (peptidyl-dipeptidase A)
ACP	Acyl carrier protein
ACTH	Adrenocorticotropic hormone (corticotropin)
ADH	Antidiuretic hormone (adiuretin, vasopressin)
ADP	Adenosine 5′-diphosphate
AIDS	Acquired immunodeficiency syndrome
ALA	5-Aminolevulinic acid
AMP	Adenosine 5′-monophosphate
ANF	Atrial natriuretic factor
ANP	Atrial natriuretic peptide (= ANF)
ATP	Adenosine 5′-triphosphate
AVP	Arginine vasopressin
b	Base
bp	Base pair
BPG	2,3-Bisphosphoglycerate
cAMP	3′,5′-Cyclic AMP
CAP	Catabolite activator protein
CDK	Cyclin-dependent protein kinase (in cell cycle)
cDNA	Complementary DNA
CDP	Cytidine 5′-diphosphate
cGMP	3′,5′-Cyclic GMP
CIA	Chemoluminescence immunoassay
CMP	Cytidine 5′-monophosphate
CoA	Coenzyme A
CoQ	Coenzyme Q (ubiquinone)
CSF	colony-stimulating factor
CTP	Cytidine 5′-triphosphate
d	Deoxy-
Da	Dalton (atomic mass unit)
DAG	Diacylglycerol
dd	Dideoxy-
DH	Dehydrogenase
DNA	Deoxyribonucleic acid
dsDNA	Double-stranded DNA
EA	Ethanolamine
EIA	Enzyme-linked immunoassay
ER	Endoplasmic reticulum
FAD	Flavin adenine dinucleotide
Fd	Ferredoxin
FFA	Free fatty acid
fMet	*N*-formylmethionine
FMN	Flavin mononucleotide
Fp	Flavoprotein (containing FMN or FAD)
GABA	γ-Aminobutyric acid
GDP	Guanosine 5′-diphosphate
Glut	Glucose transporter
GMP	Guanosine 5′-monophosphate
GSH	Reduced glutathione
GSSG	Oxidized glutathione
GTP	Guanosine 5′-triphosphate
h	hour
HAT medium	Medium containing hypoxanthine, aminopterin, and thymidine
Hb	Hemoglobin
HDL	High-density lipoprotein
HIV	Human immunodeficiency virus
HLA	Human leukocyte-associated antigen
HMG-CoA	3-Hydroxy-3-methylglutaryl-CoA
HMP	Hexose monophosphate pathway
hnRNA	Heterogeneous nuclear ribonucleic acid
HPLC	High-performance liquid chromatography
hsp	Heat-shock protein
IDL	Intermediate-density lipoprotein
IF	Intermediary filament
IFN	Interferon
Ig	Immunoglobulin
IL	Interleukin
$InsP_3$	Inositol 1,4,5-trisphosphate
IPTG	Isopropylthiogalactoside
IRS	Insulin-receptor substrate
kDa	Kilodalton (10^3 atomic mass units)
K_m	Michaelis constant

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LDH	Lactate dehydrogenase
LDL	Low-density lipoprotein
M	Molarity (mol L^{-1})
Mab	Monoclonal antibody
MAP kinase	Mitogen-activated protein kinase
MHC	Major histocompatability complex
MPF	Maturation-promoting factor
mRNA	Messenger ribonucleic acid
N	Nucleotide with any base
NAD^+	Oxidized nicotinamide adenine dinucleotide
NADH	Reduced nicotinamide adenine dinucleotide
$NADP^+$	Oxidized nicotinamide adenine dinucleotide phosphate
NADPH	Reduced nicotinamide adenine dinucleotide phosphate
NeuAc	*N*-acetylneuraminic acid
nm	Nanometer (10^{-9} m)
ODH	2-Oxoglutarate dehydrogenase
PAGE	Polyacrylamide gel electrophoresis
Pan	Pantetheine
PAPS	Phosphoadenosine phosphosulfate
PCR	Polymerase chain reaction
PDH	Pyruvate dehydrogenase
PEG	Polyethylene glycol
PEP	Phosphoenolpyruvate
pH	pH value
P_i	Inorganic phosphate
PK	Protein kinase
PLP	Pyridoxal phosphate
PP	Protein phosphatase
PPP	Pentose phosphate pathway
PQ	Plastoquinone
PRPP	5-Phosphoribosyl 1-diphosphate
PS	Photosystem
PTH	Parathyroid hormone
Q	Oxidized coenzyme Q (ubiquinone)
QH_2	Reduced coenzyme Q (ubiquinol)
R	Gas constant
rER	Rough endoplasmic reticulum
RES	Reticuloendothelial system
RFLP	Restriction fragment length polymorphism
RIA	Radioimmunoassay
RNA	Ribonucleic acid
ROS	Reactive oxygen species
RP	Reversed phase (of silica gel)
rRNA	Ribosomal ribonucleic acid
S	Svedberg (unit of sedimentation coef cient)
SAH	*S*-adenosyl L-homocysteine
SAM	*S*-adenosyl L-methionine
SDS	Sodium dodecylsulfate
sER	Smooth endoplasmic reticulum
sn	Stereospecific numbering
snRNA	Small nuclear ribonucleic acid
SR	Sarcoplasmic reticulum
ssDNA	Single-stranded DNA
TBG	Thyroxine-binding globulin
THB	Tetrahydrobiopterin
THF	Tetrahydrofolate
TLC	Thin-layer chromatography
TPP	Thiamine diphosphate
TRH	Thyrotropin-releasing hormone (thyroliberin)
Tris	Tris(hydroxymethyl)aminomethane
tRNA	Transfer ribonucleic acid
TSH	Thyroid-stimulating hormone (thyrotropin)
UDP	Uridine 5′-diphosphate
UMP	Uridine 5′-monophosphate
UTP	Uridine 5′-triphosphate
UV	Ultraviolet radiation
V_{max}, V	Maximal velocity (of an enzyme)
VLDL	Very-low-density lipoprotein

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Quantities and units

1. SI base units

Quantity	SI unit	Symbol	Remarks
Length	Meter	m	1 yard (yd) = 0.9144 m 1 inch (in) = 0.0254 m 1 Å = 10^{-10} m = 0.1 nm
Mass	Kilogram	kg	1 pound (lb) = 0.4536 kg
Time	Second	s	
Current strength	Ampere	A	
Temperature	Kelvin	K	°C (degree Celsius) = K – 273.2 Fahrenheit: °C = 5/9 (°F – 32)
Light	Candela	Cd	
Amount of substance	Mol	mol	

2 Derived units

Quantity	Unit	Symbol	Derivation	Remarks
Frequency	Hertz	Hz	s^{-1}	
Volume	Liter	L	10^{-3} m^3	1 U.S. gallon (gal) = 3.785 L
Force	Newton	N	kg m s^{-2}	
Pressure	Pascal	Pa	N m^{-2}	1 bar = 10^5 Pa 1 mmHg = 133.3 Pa
Energy, work, heat	Joule	J	N m	1 calorie (cal) = 4.1868 J
Power	Watt	W	J s^{-1}	
Electrical charge	Coulomb	C	A s	
Voltage	Volt	V	W A^{-1}	
Concentration	Molarity	M	mol L^{-1}	
Molecular mass	Dalton	Da	1.6605 10^{-24} g	
Molar mass	–	–	g	
Molecular weight	–	M_r	–	Nondimensional
Reaction rate		v	mol s^{-1}	
Catalytic activity	Katal	kat	mol s^{-1}	1 unit (U) = 1.67 10^{-8} kat
Specific activity	–	–	kat (kg enzyme)$^{-1}$	Usually: U (mg enzyme)$^{-1}$
Sedimentation coef cient	Svedberg	S	10^{-13} s	
Radioactivity	Becquerel	Bq	Decays s^{-1}	1 curie (Ci) = 3.7 10^{10} Bq

3 Multiples and fractions

Factor	Prefix	Sym-bol	Example
10^9	Giga	G	GHz = 10^9 hertz
10^6	Mega	M	MPa = 10^6 pascal
10^3	Kilo	k	kJ = 10^3 joule
10^{-3}	Milli	m	mM = 10–3 mol L^{-1}
10^{-6}	Micro	µ	µV = 10^{-6} volt
10^{-9}	Nano	n	nkat = 10^{-9} katal
10^{-12}	Pico	p	pm = 10^{-12} meter

4 Important constants

General gas constant, R	R = 8.314 J mol^{-1} K^{-1}
Loschmidt (Avogadro) number, N (number of particles per mol)	N = 6.0225 10^{23}
Faraday constant F	F = 96480 C mol^{-1}

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LANGE

MICHAEL J. PARMELY

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USMLE

ROAD MAP

IMMUNOLOGY

- HIGH-YIELD FACTS
- ILLUSTRATIONS
- CLINICAL PROBLEMS
- CLINICAL CORRELATIONS

The Best Route to Step 1 Success

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CHAPTER 1
INNATE IMMUNITY

I. Immunity is distinguished by the following features.

A. The immune system, which protects the body against microbial invaders and environmental agents, takes two forms.

1. Innate immunity is available at birth and protects the newborn from pathogenic microbes.

2. Adaptive or acquired immunity arises in the host as a consequence of exposure to a microbe or foreign substance.

B. The life-style of the microbe determines the nature of the protective immune response.

1. Extracellular microbes can be neutralized by antibodies and other soluble immune mediators.

2. Elimination of **intracellular pathogens** requires their recognition by immune cells that can destroy pathogen-infected host cells.

C. Both forms of immunity require a specific recognition of the pathogen or environmental agent and an ability to distinguish it from "self."

D. Innate immunity is a phylogenetically ancient defense mechanism designed for rapidly recognizing, lysing, or phagocytozing pathogenic microbes and signaling their presence to the host.

1. The innate immune system recognizes **microbial patterns** that are widely distributed across genera, rather than the discrete antigenic determinants that characterize a particular species of microbe (Chapter 2).

2. Innate immunity does not require prior exposure to the offending agent and is not altered by a previous encounter with it.

3. Innate immunity is expressed within minutes to hours, representing the first response of the host to microbial pathogens.

E. The **effector mechanisms** used by the innate immune system to eliminate foreign invaders (eg, phagocytosis) are often the same as those used for immune elimination during an adaptive immune response (Chapter 2).

F. Many of the responses we consider to be part of the innate immune system also play a central role in **inflammatory responses** to tissue injury (Table 1–1).

II. First lines of defense limit microbial survival.

A. Physical and chemical barriers provide some of the first lines of innate defense by preventing microbial attachment, entry, or local tissue survival in a nonspecific manner.

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Table 1–1. Components shared by the innate immune and inflammatory systems.

Component	Innate Immune Effects	Inflammatory Effects
Phagocytic leukocytes	Intracellular killing of microbes	Elimination of damaged host cells
Complement system	Chemoattraction of leukocytes Lysis, opsonophagocytosis and clearance of microbes	Chemoattraction of leukocytes Increased vascular permeability
Fibrinolysis system	Complement activation Leukocyte chemotaxis	Increased vascular permeability Leukocyte chemotaxis
Vascular endothelium	Delivery of immune mediators to sites of infection	Delivery of inflammatory mediators to sites of damaged tissues
Cytokines	Danger signaling Phagocyte activation Respiratory burst Fever	Leukocyte adhesion, chemotaxis, and uptake of cellular debris Phagocyte activation Fever Tissue healing
Neutrophil granules	Antimicrobial cationic peptides	Extracellular matrix degradation

1. The **epithelium** of the skin and mucous membranes provides a physical barrier.
2. The **mucocilliary movement** of the lung epithelium and the **peristalsis** of the gastrointestinal tract move microbes and other foreign agents across mucosal surfaces and out of the body.
3. The **low pH** and high fatty acid content of the skin inhibit microbial growth.
4. The low pH of the stomach damages essential structures of microbes and limits their survival.
5. **Mucins** associated with mucosal epithelia prevent microbial penetration and bind soluble immune factors (eg, antibody molecules).
6. A variety of **iron-binding proteins** (eg, lactoferrin) compete with microbes for extracellular iron.
   a. Lactoferrin competes for iron in the extracellular space.
   b. The ***Nramp1*** gene product enables host cells to acquire the Fe^{2+} ions necessary to generate reactive oxygen species.
   c. ***Nramp2*** aids cells in depleting Fe^{2+} from the phagosome, thus inhibiting microbial survival.

B. The **normal flora** found at epithelial surfaces provides a **biological barrier** to pathogenic microbes that attempt to survive at that site.
1. Normal microbial flora competes with pathogens for nutrients and environmental niches, especially at external body surfaces, such as the skin, intestines, and lungs.
2. Normal flora can induce innate immune responses in the epithelium that limit the survival of pathogenic microorganisms.

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III. Pathogens that breach the primary barriers initiate an innate immune response.

A. Pathogen-associated molecular patterns (PAMP) are recognized by innate immune cells and soluble mediators.

1. PAMP are often highly charged surface structures or unique spatial arrangements of chemical groups (eg, sugar moieties) that are not seen on host tissues.

2. PAMP are phylogenetically conserved structures that are essential for the survival of microorganisms.

3. Host cell receptors capable of recognizing PAMP are encoded within the germline and are phylogenetically conserved.

a. Relatively few host cell surface receptors are required to recognize a wide range of pathogens.

b. The **Toll-like receptor** (TLR) family is an important example of phylogenetically conserved PAMP-specific host molecules (Table 1–2).

4. A number of soluble host proteins also recognize PAMP.

a. Mannose-binding protein (MBP) (also called **mannose-binding lectin**) binds to mannose residues of a particular spacing that is seen on microbial, but not mammalian, cells.

(1) MBP serves as an opsonin promoting phagocytosis.

(2) MBP promotes lysis and phagocytosis of microbes by activating complement (Chapter 8).

b. Lysozyme degrades the peptidoglycan layer of bacterial cell walls.

Table 1–2. The Toll-like receptor (TLR) family.

TLR	Microbial Ligands
TLR1	Bacterial lipopeptides
TLR2	Bacterial peptidoglycan, lipoteichoic acid, lipoarabinomannan, glycolipids, porins
TLR3	Viral double-stranded RNA
TLR4	Bacterial lipopolysaccharide, viral proteins
TLR5	Bacterial flagellin
TLR6	Bacterial lipopeptides; fungal cell wall
TLR7	Viral single-stranded RNA
TLR8	Viral single-stranded RNA
TLR9	Bacterial CpG-containing DNA

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B. The recognition of PAMP activates leukocyte functions.

1. Phagocytic **leukocytes** (blood neutrophils and tissue macrophages) can recognize microbes directly through their **mannose receptors, scavenger receptors, Toll-like receptors**, or **chemotactic receptors**.

a. The recognition of microbial **chemotactic factors** directs leukocytes to the site of infection.

(1) Chemotactic factors can be either microbial or host in origin (Table 1–3).

(2) Chemotactic factors are recognized by seven transmembrane G protein-coupled **receptors**.

b. **Opsonic receptors** on leukocytes recognize host components that have bound to the surface of microbes.

c. Attachment of a microbe to the surface of a phagocyte is followed by its **uptake** by membrane invagination (Figure 1–1).

(1) The microbe is ingested into a **phagosome**.

(2) The **phagosome** fuses with an organelle called the **lysosome** to form a **phagolysosome**.

d. Intracellular killing of the microbe occurs within the phagolysosome.

(1) Lysosomal **hydrolytic enzymes** (acidic proteases, lipases, and nucleases) degrade microbial structures.

(2) Leukocyte cytoplasmic granules containing cationic antimicrobial peptides (**defensins** and **cathelicidins**) fuse with the phagolysosome.

(a) These peptides act as disinfectants by disrupting the membrane functions of microorganisms.

(b) Defensins recognize the highly charged phospholipids on the outer membranes of microbes.

(c) Antimicrobial peptides of very similar structure have been found both in the vernix caseosa covering the skin of newborn humans and the skin secretions of frogs.

Table 1–3. Chemotactic factors that attract innate immune cells.

Cell Type	Chemotactic Factors
Neutrophil	Bacterial lipoteichoic acid Bacterial formyl-methionyl peptides Complement peptide C5a Fibrinogen-derived peptides Leukotriene B_4 Mast cell-derived chemotactic peptide NCF-A Cytokines: interleukin-8
Macrophage	Cytokines: transforming growth factor-β, monocyte chemotactic protein-1
Lymphocyte	Cytokines: macrophage inflammatory protein-1

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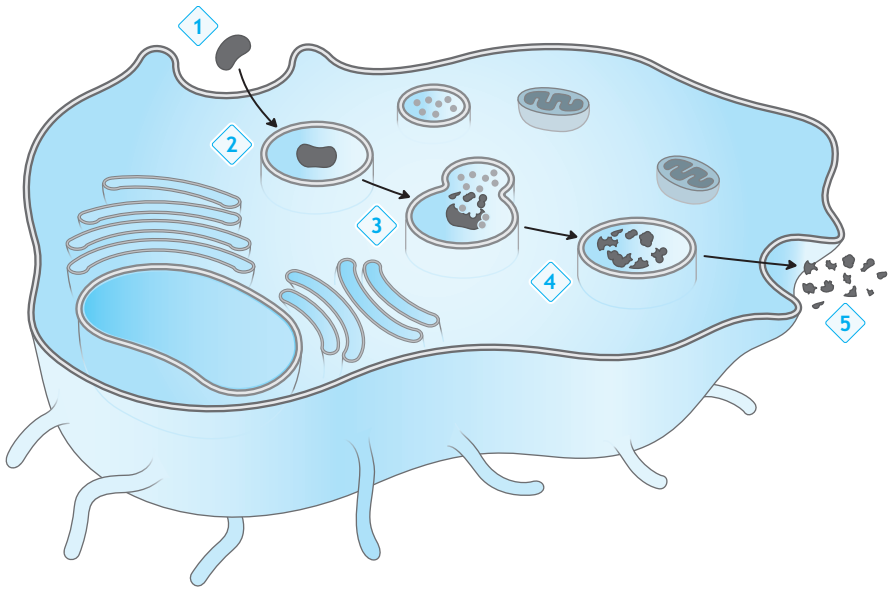

Figure 1–1. Opsonophagocytosis and intracellular killing of a pathogen by a phagocytic cell. 1, Attachment; 2, ingestion (phagosome); 3, phagolysosome; 4, killing, digestion; 5, release.

(3) In the presence of adequate oxygen, microbe recognition at the phagocytic cell surface can initiate a **respiratory burst**, the one electron reduction of molecular oxygen (Figure 1–2).

- ***(a)*** **Reactive oxygen intermediates** (oxidants and radicals) produced during this process irreversibly damage essential microbial structures.
- ***(b)*** The reaction begins with the **respiratory burst oxidase**, a multicomponent membrane-associated enzyme.
- ***(c)*** This oxidase catalyzes the reduction of oxygen (O_2) to the radical **superoxide** ($O_2^{\bullet}$).
- ***(d)*** The dismutation of superoxide to form **hydrogen peroxide** (H_2O_2) is catalyzed by the enzyme **superoxide dismutase** (SOD).
- ***(e)*** In the presence of a halide (eg, chloride ion), neutrophil-specific **myeloperoxidase** catalyzes the production of hypohalite (eg, **hypochlorite** or bleach) and organic chloramines.
- ***(f)*** In the presence of ferric ion, the highly reactive **hydroxyl radical** ($OH^{\bullet}$) is formed from superoxide and hydrogen peroxide.

CHRONIC GRANULOMATOUS DISEASE (CGD) IS A MUTATION OF THE RESPIRATORY BURST OXIDASE

CLINICAL CORRELATION

- *Mutations in the subunits of the **respiratory burst oxidase** (also called NADPH oxidase) can lead to a decreased production of the superoxide radical by phagocytes.*

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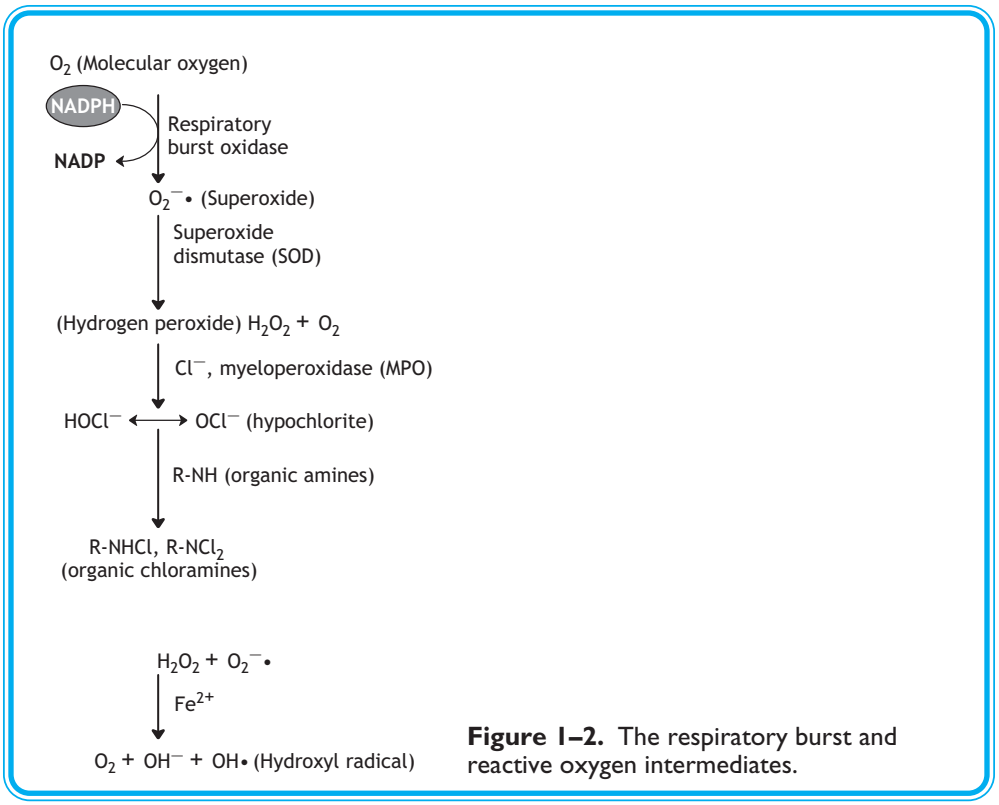

Figure 1–2. The respiratory burst and reactive oxygen intermediates.

- *Leukocytes of CGD patients fail to produce many of the oxidants that mediate killing of microorganisms within the phagolysosome.*
- *CGD patients are at risk for acquiring **opportunistic infections** with microbes that would otherwise show low virulence in normal individuals.*
- *Because the phagocytosis of microbes is normal in these patients, some pathogens that are not killed replicate within the phagolysosome.*
- *The host attempts to wall off leukocytes containing viable microbes by forming a structure called a **granuloma** in the lungs and liver.*

(4) Oxygen-independent intracellular killing is essential when tissue oxygen is limited, as in deep tissue abscesses.

(5) Some phagocytic cells (eg, tissue macrophages) produce the radical **nitric oxide ($NO^{\bullet}$)**, which can damage microbial structures.

(a) $NO^{\bullet}$ is formed from L-arginine and oxygen through a reaction catalyzed by **nitric oxide synthase (NOS)**:

$$\text{L-arginine-NH}_2 + \text{NADPH} + \text{O}_2 \rightarrow NO^{\bullet} + \text{L-citruline} + \text{NADP}$$

(b) In macrophages and hepatocytes, the **inducible form of NOS (iNOS)** catalyzes high level, sustained production of $NO^{\bullet}$ that functions as an antimicrobial agent.

(c) Only a few microbes (eg, *Mycobacteria* and *Listeria* species) are highly susceptible to $NO^{\bullet}$.

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(d) When $NO^{\bullet}$ and $O_2^{\bullet}$ combine, they form **peroxynitrite** ($ONOO^-$), an especially potent oxidant.

2. **Epithelial cells also produce the defensins.**
   a. Defensins limit microbial survival at the mucosal surface of the lung, intestine, and genitourinary tract.
   b. Defensins are chemotactic for dendritic cells, monocytes, and T lymphocytes that mediate mucosal defense.
3. **Intraepithelial T lymphocytes** are found in the skin, lung, and small intestine.
   a. These cells bear germline gene-encoded antigen receptors (Chapter 6) that recognize conserved microbial glycolipids.
   b. Intraepithelial T cells mediate host protection by the secretion of cytokines that can activate phagocytic cells.
4. **Natural killer (NK) cells** recognize host cells that are infected with intracellular pathogens, such as viruses.
   a. NK cells bear two types of receptors, one for activating the cell and another for inhibiting its activation.
      (1) NK cell **activating receptors** are specific for host and microbial ligands.
      (2) NK cell **inhibitory receptors** are specific for **major histocompatibility complex (MHC)** molecules that are widely distributed on host tissues (Chapter 7).
      (3) When the inhibitory receptor binds host MHC molecules, activation of the NK cell is blocked.
      (4) When the expression of MHC molecules is decreased on host tissues, NK cells become activated through their activating receptors.
      (5) The expression of MHC is often decreased on virus-infected cells.
   b. Upon activation, NK cells can eliminate microbial pathogens by secreting cytokines, which activate macrophages.
   c. NK cells can also lyse infected host cells.
   d. NK cells also synthesize **interferons** (Chapter 12) that block the replication of viruses within infected cells.
5. **Natural killer T (NKT) cells** bear many of the surface receptors present on NK cells as well as an unconventional form of the **T cell antigen receptor** (Chapter 6).
   a. Most NKT cells are specific for microbial glycolipids.
   b. NKT cells can produce cytokines capable of activating macrophages.
   c. NKT cells can express cytotoxic activity, although the role of this function in host defense is still unclear.

C. The recognition of microbial pathogens signals "danger" to the host.
1. **TLRs** (Table 1–2) initiate danger signaling when they bind microbial PAMP.
   a. Intracellular signal transduction initiated by TLR leads to the activation of transcription factors.
   b. For example, **TLR4** mediates the recognition of bacterial **lipopolysaccharides (LPS)**, which are common components of the outer membrane of gram-negative bacteria (Figure 1–3)
   c. TLR4 signaling results in the activation of the **nuclear factor-κB (NFκB)** and **AP-1** transcription factors.
   d. Among the genes regulated by NFκB and AP-1 are those encoding proinflammatory cytokines and their receptors, cell adhesion molecules, immunoglobulins, and antigen receptors.

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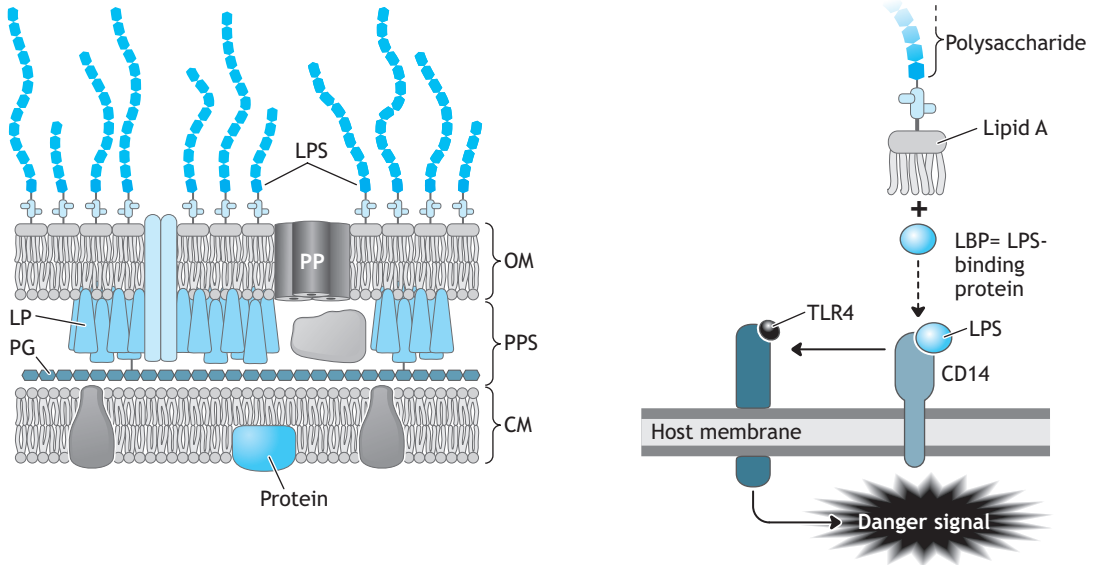

Figure 1–3. Cellular responses to bacterial lipopolysaccharide (LPS) are mediated by toll-like receptor 4 (TLR4). CM, cytoplasmic membrane; LP, lipoprotein; LPS, lipopolysaccharide; OM, outer membrane; PG, peptidoglycan; PP, porin protein; PPS, periplasmic space.

EXCESSIVE DANGER SIGNALING AND SEPSIS

CLINICAL CORRELATION

- ***Sepsis*** *is a systemic host response to disseminated infection characterized by fever, tachycardia, tachypnea, hemodynamic dysfunction, coagulopathy, and multiorgan damage.*
- *These processes result from microvascular changes, diminished tissue perfusion, and inadequate tissue oxygenation.*
- *Sepsis represents excessive danger signaling on the part of the host; soluble and cellular mediators of innate immunity are produced in excess.*
- *The cytokines interleukin (IL)-1, interferon (IFN)-γ, and tumor necrosis factor (TNF)-α are important early mediators of sepsis.*
- *Clinical trials using reagents (eg, antibodies) designed to neutralize any one of these mediators have been disappointing, probably owing to mediator redundancy.*

2. Cytokine genes are induced by danger signaling and are essential for appropriate innate immune responses to infection.

a. Cytokines are peptide hormone-like mediators of immunity and inflammation (Chapter 12).

b. Cytokines are produced by a variety of immune cells and induce gene expression, cell growth, and differentiation.

c. Cytokines act through specific **cytokine receptors**, many of which activate gene transcription.

d. Among the important effects of cytokines are fever, hematopoiesis, chemotaxis, increased cell adhesion, changes in blood vessel function, antibody production, and apoptosis (Table 1–4).

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Table 1–4. Cytokines that act as danger signals.[a]

Cytokine	Functions Related to Danger Signaling
TNF-α	Fever, leukocyte adhesion to endothelium, acute phase protein synthesis, respiratory burst, cachexia, cardiac suppression, disseminated intravascular coagulation and shock
IL-1, IL-6	Fever, leukocyte adhesion to endothelium, acute phase protein synthesis, B lymphocyte coactivation
Chemokines	Lymphocyte and leukocyte migration to sites of infection
IL-4	Lymphocyte coactivation and antibody production
IL-12	Lymphocyte coactivation and cell-mediated immunity
IFN-α, IFN-β	Antiviral state, coactivation of macrophages and NK cells, increased MHC expression
IFN-γ	Coactivation of macrophages, increased MHC expression

[a]TNF, tumor necrosis factor; IL, interleukin; IFN, interferon; NK, natural killer; MHC, major histocompatibility complex.

e. The **interferons (IFN)** are a family of cytokines first noted for their antiviral activity.
(1) IFN-α and IFN-β block virus replication within cells.
(2) IFN-γ is a potent activator of macrophages for the killing of intracellular bacteria and fungi.

DEFECTIVE IFN-γ RECEPTOR FUNCTION LEADS TO OPPORTUNISTIC INFECTIONS

- *The killing of intracellular microbial pathogens by macrophages requires that the cells be activated by microbial or host signals, including cytokines.*
- *IFN-γ is a potent macrophage activating cytokine that acts on cells through its receptor.*
- *Point mutations in the human IFN-γ receptor 1 gene impair signaling and macrophage activation for the killing of intracellular pathogens.*
- *Life-threatening infections with Mycobacterium and Salmonella species are common and can become widely disseminated throughout the body.*
- *Because the receptors for IFN-α and IFN-β are distinct from those that bind IFN-γ, the affected individuals do not suffer from increased viral infections.*

3. PAMP can activate the **complement** system of serum proteins.
a. Several complement components can recognize highly charged microbial structures, such as bacterial LPS and surface mannose residues.

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   b. Peptides produced during complement activation mediate host defense and inflammatory functions, such as the chemotaxis of neutrophils, opsonization, and the lysis of microbial membranes.
   c. The activation of mast cell degranulation by complement peptides, called **anaphylatoxins**, leads to the release of an additional wave of inflammatory mediators that are stored in mast cell cytoplasmic granules (Chapter 13).

4. The synthesis of **acute phase proteins** is a response to danger signaling.
   a. Many acute phase proteins are produced in the liver in response to the cytokines IL-1, IL-6, and TNF-α.
   b. **C-reactive protein (CRP)** binds to bacterial surface phospholipids, activates complement, and serves as an opsonin.
   c. Increased **fibrinogen** in plasma increases the **erythrocyte sedimentation rate (ESR)**, a clinical laboratory test indicative of acute inflammation.

5. The **coagulation** and **fibrinolysis** systems are activated during acute infections and inflammation.
   a. Coagulation serves to localize infection by retaining microbes within a fibrin clot.
   b. Peptides derived from fibrinogen during fibrinolysis are chemotactic for neutrophils.
   c. **Plasmin** generated during fibrinolysis can activate the complement system.

DYSREGULATION OF THE COMPLEMENT SYSTEM RESULTS IN ACUTE INFLAMMATION

- *Unabated activation of the complement system is potentially harmful to the host due to the production of inflammatory mediators.*
- *An important regulator of the classic pathway of complement activation is the protease inhibitor **C1 inhibitor (C1 Inh)**.*
- *Patients with **hereditary angioedema (HAE)** have significantly decreased levels of plasma C1 Inh.*
- *Episodic activation of complement in HAE patients results in the production of complement peptides that increase vascular permeability.*
- *The resulting subcutaneous and submucosal edema can lead to airway obstruction, asphyxiation, and severe abdominal pain.*

IV. Danger signals can promote the activation of antigen-specific T and B lymphocytes of the adaptive immune system.

A. The nature of danger signaling depends on the type of microbe.
   1. Intracellular pathogens often induce innate signals (eg, IL-12) that promote the development of cellular immunity.
   2. Extracellular pathogens often favor induction of antibody responses to microbial antigens (Chapter 2).

B. Danger signals activate T and B lymphocytes through their cell surface **coreceptors**.
   1. The complement peptide C3d generated during an innate immune response is the ligand for the **B cell coreceptor CR2**.
   2. C3d costimulates B cells that have bound antigen through their antigen receptors (Chapter 8).

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C. Cytokines produced by innate immune cells are important regulators of lymphocyte activation during adaptive immune responses.
1. IFN-α and IFN-β enhance T lymphocyte responses to microbial antigens by controlling the expression of MHC molecules (Chapter 7).
2. IL-4 and IL-5 promote the production of certain classes of antibodies by B lymphocytes.
3. IL-12 promotes differentiation of T lymphocytes.

D. Adjuvants are substances that promote adaptive immune responses.
1. Most adjuvants act by inducing danger signaling.
2. Adjuvants can increase the expression of lymphocyte coreceptors.
3. Adjuvants can induce the expression of ligands for lymphocyte coreceptors.
4. Adjuvants can induce cytokine production or increased cytokine receptor expression.

CLINICAL PROBLEMS

Ms. Jones is a retired secretary who has been admitted to the hospital for treatment of an apparent urinary tract infection. She is administered a third-generation cephalosporin antibiotic at approximately 1:00 PM, at which time she has a fever of 101°F, blood pressure of 110/60, and a pulse of 115. The patient tolerates the antibiotic well during the first hour, but when the nurse returns to her room at 3:00 PM, Ms. Jones' vital signs have deteriorated. Her blood pressure has decreased to 80/50, her pulse is now 128, and she no longer responds when called by name. Her physician concludes that Ms. Jones is septic.

1. Which of the following treatments should be administered immediately?

A. Increase the dose of antibiotic to control the infection.

B. Administer a vasodilator, such as verapamil.

C. Discontinue the antibiotic and administer intravenous fluids.

D. Administer TNF-α to control the infection.

E. Administer complement components to control the systemic inflammatory response.

Johnny is a 1-month-old healthy child who has not, as yet, received any childhood immunizations. He presents with his first episode of otitis media (middle ear infection) that is successfully treated with a 3-week course of antibiotics.

2. Which one of the following immune components contributed the most to his clearing the infectious agent during the first few days of his infection?

A. Antigen receptors on his B lymphocytes

B. Toll-like receptors on his neutrophils

C. Cytokines that promoted antibody formation

D. T cell responses to bacterial antigens

E. Memory B cells

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Recently a patient was identified who had a defect in IL-1 receptor-associated kinase (IRAK)-dependent cellular signaling associated with her TLR4 receptor.

3. Which one of the following groups of pathogens would be expected to cause recurrent infections in this individual?

A. Retroviruses, such as HIV-1

B. Fungi that cause vaginal yeast infections

C. Gram-negative bacteria

D. Gastrointestinal viruses

E. Insect-borne parasites

Anaerobic bacteria are often cultured from infected deep tissue abscesses.

4. If you were a neutrophil recruited to an anaerobic site to kill such a bacterium, which of the following substances would you most likely use?

A. IL-12

B. Nitric oxide

C. Interferon-α

D. Respiratory burst oxidase

E. Cathelicidin

You are part of a research team that is attempting to design a better vaccine for the prevention of tuberculosis, which is caused by the intracellular bacterial pathogen *Mycobacterium tuberculosis*. One of your colleagues suggests that you include an adjuvant in the vaccine formulation.

5. Based on your knowledge of protective immunity to this pathogen, which one of the following would be a reasonable choice of an adjuvant component?

A. A cytokine that promotes an IFN-γ response to mycobacterial antigens

B. The complement peptide C3d, which will ensure adequate antibody production.

C. Interleukin-10

D. Bacterial lipopolysaccharide

E. Lactoferrin

ANSWERS

1. The answer is C. Sepsis is a systemic inflammatory response to infection that results from exposure of the host to diverse microbial components expressing PAMP. With antibiotic treatment, large quantities of bacteria die and release these proinflammatory components, including bacterial LPS. The most important initial step is to discontinue antibiotic treatment until the septic episode has passed. Fluids are given to correct hypotension, and severe cases may need to be treated with pressors (eg, dopamine) to

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maintain blood pressure. The patient's symptoms (hypotension, tachycardia, and hypoxia) are indicative of extreme vasodilation, the loss of fluid to the extravascular tissues, and inadequate tissue oxygenation. TNF-α is thought to be a major central mediator of systemic septic shock. The activation of complement would be expected to aggravate the systemic inflammatory response by further inducing vascular changes, hypotension, and hypoxia.

2. The correct answer is B. In a child of this age who has not previously been exposed to this bacterial pathogen or immunized against its antigens host defense is primarily mediated by the innate immune system. Neutrophils play a central role in clearing bacteria and recognize molecular patterns on these pathogens via their TLR. By contrast, T and B lymphocytes mediate adaptive immunity (eg, antibody formation), which requires several days to develop in an immunologically naive individual.

3. The correct answer is C. TLR4 is the signaling receptor for bacterial LPS, a component of the outer membrane of gram-negative bacteria. Patients with impaired TLR4 signaling are at risk for recurrent, life-threatening infections with gram-negative bacteria. TLR4 is not known to mediate protective responses to viruses, fungi, or parasites.

4. The correct answer is E. In the absence of molecular oxygen, neither reactive oxygen species (eg, superoxide) nor NO can be produced in sufficient quantities to kill bacteria. Under these conditions, the neutrophil must rely on oxygen-independent killing mechanisms, such as the action of its antimicrobial granule peptides.

5. The correct answer is A. Any cytokine that would promote the development of antigen-specific, IFN-γ-producing lymphocytes would probably have a favorable effect. Patients who cannot produce IFN-γ are at risk for developing mycobacterial infections. Interleukin-12 is a good example of an IFN-γ-inducing cytokine. Because this pathogen resides within tissue macrophages in chronically infected individuals, macrophage activation for intracellular killing is an essential protective response to infection.

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CHAPTER 2
ADAPTIVE IMMUNITY

I. Adaptive immunity is distinguished by the following features.

A. Unlike innate immunity, **adaptive immunity** is an *acquired* response to antigen that is initiated by the recognition of discrete *antigenic determinants* on foreign invaders (Table 2–1).

B. The host is changed by its exposure to antigen; the individual becomes **"immunized"** against a particular antigen.

1. The **primary response** to an antigen takes several days and requires antigen recognition, the activation and proliferation of T and B lymphocytes, and the differentiation of these cells into populations of **effector lymphocytes**.

2. Sets of antigen-specific **memory T and B cells** are also generated that mediate **secondary responses** to the antigen at a later time.

3. The long-term maintenance of memory and the return of lymphocytes to a nonactivated state are carefully controlled.

C. T and B lymphocytes are the primary mediators of adaptive immunity and recognize antigenic determinants by their cell surface **antigen receptors**.

1. Receptors with specificity for **autoantigens** are expressed during the development of the adaptive immune system.

a. Most lymphocytes with autoreactive receptors are deleted.

b. Some autoreactive lymphocytes survive, but their activation is carefully controlled in the periphery.

2. Whereas B cell receptors predominantly recognize soluble native antigens, T cell receptors recognize foreign antigens only on the surfaces of other host cells.

D. Many of the effector cells and molecules that mediate antigen clearance in adaptive immunity are the same as those that mediate protective innate immune responses.

II. Primary and secondary adaptive immune responses differ.

A. Evidence of a **primary immune response** to an antigen appears only after an initial **lag phase** (Figure 2–1).

B. Antibody produced following **active immunization** is **specific** for the immunizing antigen.

C. The host has enormous **diversity** in its capacity to respond to different antigens.

1. Estimates of the number of different antigen receptors potentially expressed by B or T cells range from 10^8 to 10^9.

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Table 2–1. Comparison of the properties of innate andadaptive immunity.

Property	Innate Immunity	Adaptive Immunity
Time	Immediate	Delayed
Recognition	Conserved, widely distributed microbial components	Discrete, diverse antigenic determinants Antigen presentation
Cells	Many cells: phagocytes, some lymphocytes, epithelial cells	Lymphocytes
Response	Uptake and clearance, danger signaling	Clearance, lysis, memory

2. A diverse **immune repertoire** exists at birth in human beings and undergoes further changes based on the immunological experiences of the individual.

D. Immunity mediated by lymphocytes or the antibodies they produce can be transferred from an immune host to a naive recipient.

1. The transfer of antibodies is called **passive immunization**.

2. The transfer of immune cells is called **adaptive immunization**.

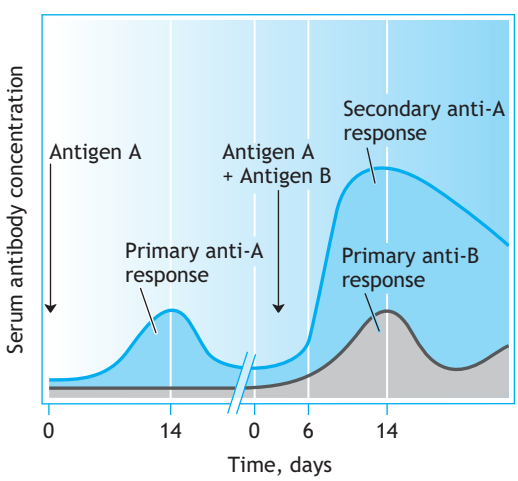

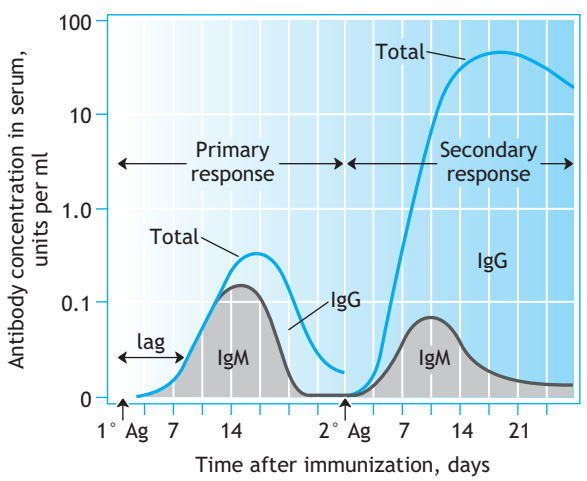

Figure 2–1. Time course of a typical primary and secondary antibody response. Ig, immunoglobulin.

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NEWBORNS ACQUIRE MATERNAL IMMUNITY BY PASSIVE IMMUNIZATION

- *Newborns are passively immunized when their mothers transfer protective antibodies to them either across the placenta or through the colostrum and milk.*
- *The relative importance of these two routes in various mammalian species is determined by the structure of their placentas.*
- *Human beings have two cell layers separating fetal and maternal blood and actively transport maternal antibodies across the placenta.*
- *The class of antibody that is transported is immunoglobulin G (IgG) (Chapter 3) and it provides systemic antibody protection to the newborn.*
- *Colostral antibodies in humans are predominantly immunoglobulin A (IgA) and they protect the newborn intestinal tract from infectious pathogens.*
- *By contrast, the fetal calf receives no immunoglobulin from its mother during gestation, and is highly dependent upon suckling colostrum containing IgG antibodies during its first few days of life.*

E. **Secondary responses** to an antigen in immune animals differ from primary adaptive immune responses (Figure 2–1).

1. The lag period is shorter for the secondary response.

2. The overall amount of antibody produced is greater in the secondary response.

3. The class of antibody differs in the two responses.

a. Primary antibody responses are mostly **immunoglobulin M (IgM)**.

b. Secondary antibody responses consist primarily of non-IgM classes, especially **IgG**.

c. The change that occurs in the class of antibody produced is called **isotype switching** and results in new functions being associated with the same antibody specificity (Chapter 3).

d. The longer duration of the secondary response reflects the large number of memory B cells that are activated and the longer half-life of IgG in circulation compared to IgM.

III. Cells of the adaptive immune system are found in discrete lymphoid tissues and organs.

A. **Primary lymphoid organs** are organs in which the antigen-independent development of lymphocytes occurs.

1. The **bone marrow** is a major site of hematopoiesis and lymphopoiesis in both young and adult animals.

2. Under the influence of the bone marrow stromal cells and growth factors, the various blood lineages develop.

HEMATOPOIETIC GROWTH FACTORS CAN CORRECT IMMUNE DEFICIENCIES

- ***Cyclic neutropenia*** *is a 3-week oscillating deficiency in the production of blood neutrophils that can leave patients at risk for infections (Table 2–2).*
- *The inherited form of the disease results from point mutations in the neutrophil elastase gene, suggesting that this protease participates in myelopoiesis.*
- *Treatment with* ***colony-stimulating factor for granulocytes (CSF-G)*** *replenishes neutrophil numbers in the blood during the neutropenic phase.*
- *By contrast,* ***severe congenital neutropenia****, which is due to a mutation in the gene for the receptor for CSF-G, is not responsive to CSF-G therapy.*

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Table 2–2. Congenital leukocyte and lymphocyte deficiencies affecting immunity.

Cell Type	Subsets	Normal Cell Numbers (10^3 per μL) in the Blood of Adults	Congenital Deficiencies Affecting the Number of Cells in the Periphery
Leukocytes	Total	4–11	
	Neutrophils	2–7	Neonatal and cyclic neutropenia
	Monocytes	0.2–1.2	
Lymphocytes	Total	1.0–4.8	Severe combined immune deficiency
	B cells	0.1–0.7	X-linked agammaglobulinemia
	T cells	0.5–3.6	DiGeorge syndrome
	$CD4^+$ T cells	0.2–1.8	MHC class II deficiency
	$CD8^+$ T cells	0.1–0.9	MHC class I deficiency

- *Colony-stimulating factors for other hematopoietic progenitor cells, including erythropoietin and interleukin-3, have become standard treatments for many selective hematopoietic deficiencies.*

3. Lymphocytes are also derived from a common self-renewing **hematopoietic stem cell** that gives rise to all blood cell lineages.

a. In the appropriate inductive microenvironment, the pluripotent stem cell differentiates into a **lymphoid progenitor cell (LPC)**.

b. The LPC can become a **progenitor T (pro-T) cell** or a **progenitor B (pro-B) cell**.

c. In human beings, B lymphopoiesis occurs primarily in the bone marrow (Chapter 9), but T lymphocyte development moves to the thymus at the pro-T cell stage (Chapter 10).

d. An important process that accompanies T and B cell differentiation in the bone marrow and thymus is the expression of surface antigen receptors.

DIGEORGE SYNDROME PATIENTS LACK A THYMUS

- *DiGeorge syndrome is a congenital condition arising from defective embryogenesis of the third and fourth pharyngeal pouches.*
- *Patients with DiGeorge syndrome show abnormalities in the structure of their major blood vessels, heart, and parathyroids and evidence thymic hypoplasia.*
- *Immunological abnormalities include severe lymphopenia (Table 2–2) at birth and early onset infections by opportunistic viruses and fungi.*
- *Antibody levels are normal at birth due to the transplacental passage of antibodies from the mother in utero.*
- *The immune deficiencies of these children can be cured by thymic transplantation from a suitable donor.*

B. **Secondary lymphoid organs** are sites at which the host mounts adaptive immune responses to foreign invaders.

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1. Secondary lymphoid organs and tissues include the spleen, lymph nodes, Peyer's patches, and widely distributed lymphoid follicles.
2. The **lymph node** is an encapsulated organ that receives antigens from subcutaneous and submucosal tissues via its **afferent lymphatics** (Figure 2–2).
   - **a.** B cells are concentrated in discrete **primary and secondary follicles** within the cortex of lymph nodes, where they undergo antigen-driven differentiation.
   - **b.** Memory B cells develop within the **germinal centers** of the cortex.
   - **c.** T cells are located primarily in the **diffuse cortex** (or **paracortex**), where they associate with dendritic cells.
   - **d.** Cells enter the lymph nodes in large numbers by crossing the high endothelial layer of **postcapillary venules** located in the diffuse cortex.
   - **e.** Terminally differentiated B cells, called **plasma cells**, are found in the **medullary cords**, where they produce large amounts of antibody during their limited life-span.
   - **f.** Secreted antibodies exit the lymph nodes via the **efferent lymphatics** and eventually enter the blood stream.
3. The **spleen** receives antigens through the blood circulation and contains areas functionally equivalent to those of the lymph nodes (Table 2–3).
4. Other important peripheral lymphoid tissues include the **Peyer's patches** and submucosa of the small intestine, which are sites in which mucosal antibody responses are induced (Chapter 9).

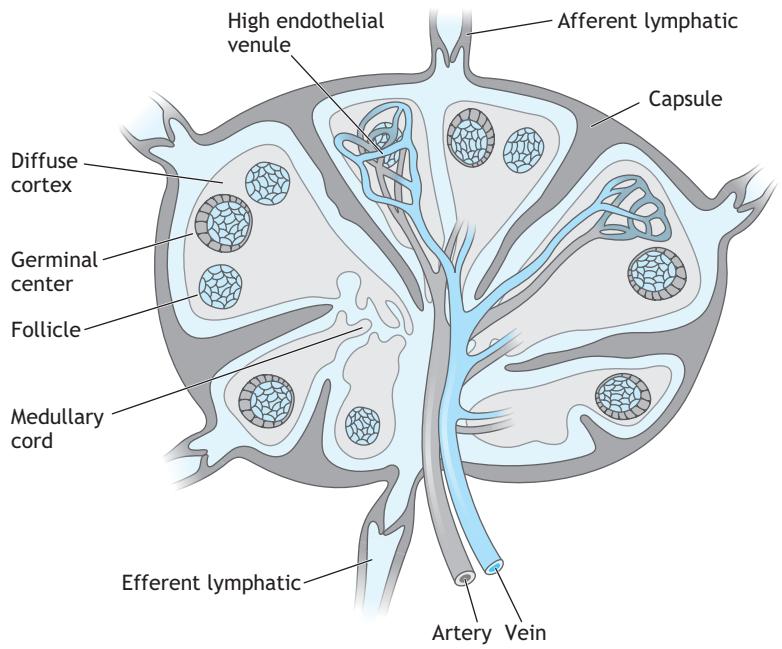

Figure 2–2. Schematic structure of a lymph node.

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Table 2–3. Comparison of analogous structures in the lymph nodes and spleen.

Lymph Node	Spleen	Function
Follicles	Follicles	B cell activation and differentiation
Diffuse cortex	Periarteriolar lymphoid sheath	T cell activation and differentiation
Medullary cords	Red pulp cords	Antibody production by plasma cells
High endothelium of postcapillary venules	Marginal sinuses	Site of entry of lymphocytes from the recirulating lymphocyte pool
Afferent lymphatics	Marginal sinuses	Site of entry of antigens
Efferent lymphatics	Marginal sinuses	Point of exit of effector lymphocytes to join the recirculating pool

C. A **recirculating lymphocyte pool** of long-lived small lymphocytes continually travels between the various lymphoid tissues by a route that includes the blood and lymph (Figure 2–3).

1. Recirculating lymphocytes enter the lymph nodes from the blood by crossing the **high endothelial venules** in the diffuse cortex.

2. The cells exit the lymph nodes via the **efferent lymphatics** and migrate via the **common thoracic duct** to the blood stream.

3. Lymphocytes can exit the blood circulation by crossing the endothelium at many locations.

IV. The clonal selection theory of adaptive immunity proposes that an antigen selects and activates the appropriate clone of lymphocytes from a preformed diverse pool.

A. The theory predicts the following:

1. Each lymphocyte is precommitted to a particular antigen prior to encountering that antigen (Figure 2–4).

2. Lymphocytes recognize their antigens with cell surface antigen receptors.

3. The receptor on a given lymphocyte is specific for only one antigen.

4. Antigen binding to the receptor induces the expansion of a **clone** of cells, all with identical receptor specificity.

5. The antigen receptor on a given lymphocyte is uniform and identical to the antibody molecules secreted by the cell.

B. The theory has proven correct for both B and T lymphocytes with the following exceptions:

1. The B cell antigen receptor is actually a modified form of an antibody molecule (Chapter 4).

2. The T cell antigen receptor is not an antibody molecule (Chapter 6).

3. T cells do not secrete large amounts of their receptor molecules.

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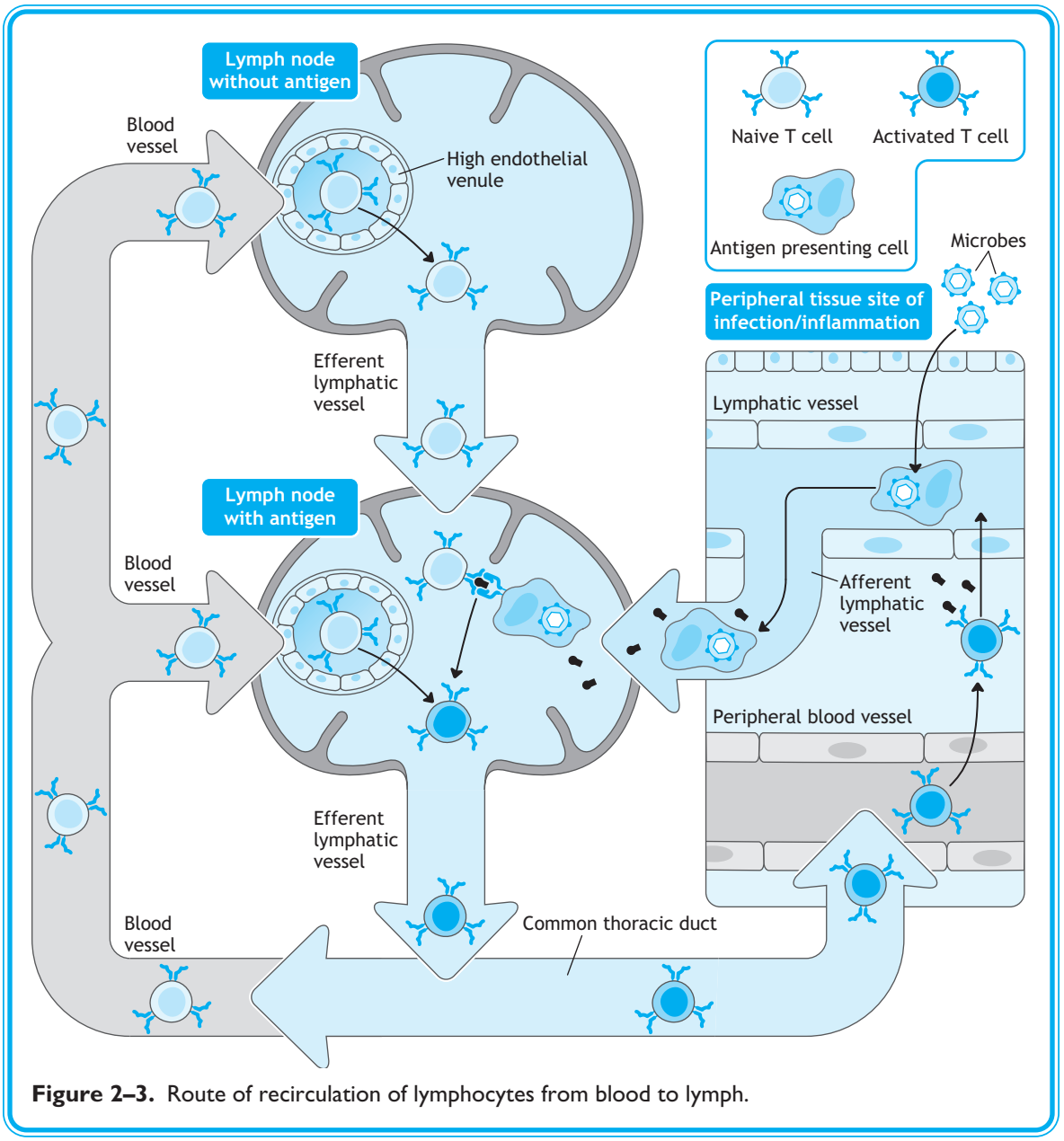

Figure 2–3. Route of recirculation of lymphocytes from blood to lymph.

C. The production of a pool of **memory lymphocytes** ensures that a higher concentration of specific antibody is produced in a more rapid fashion during a secondary response.

D. Because lymphocytes with receptors specific for autoantigens (**"forbidden clones"**) are mostly deleted or inactivated during their differentiation, **autoimmunity** is rare.

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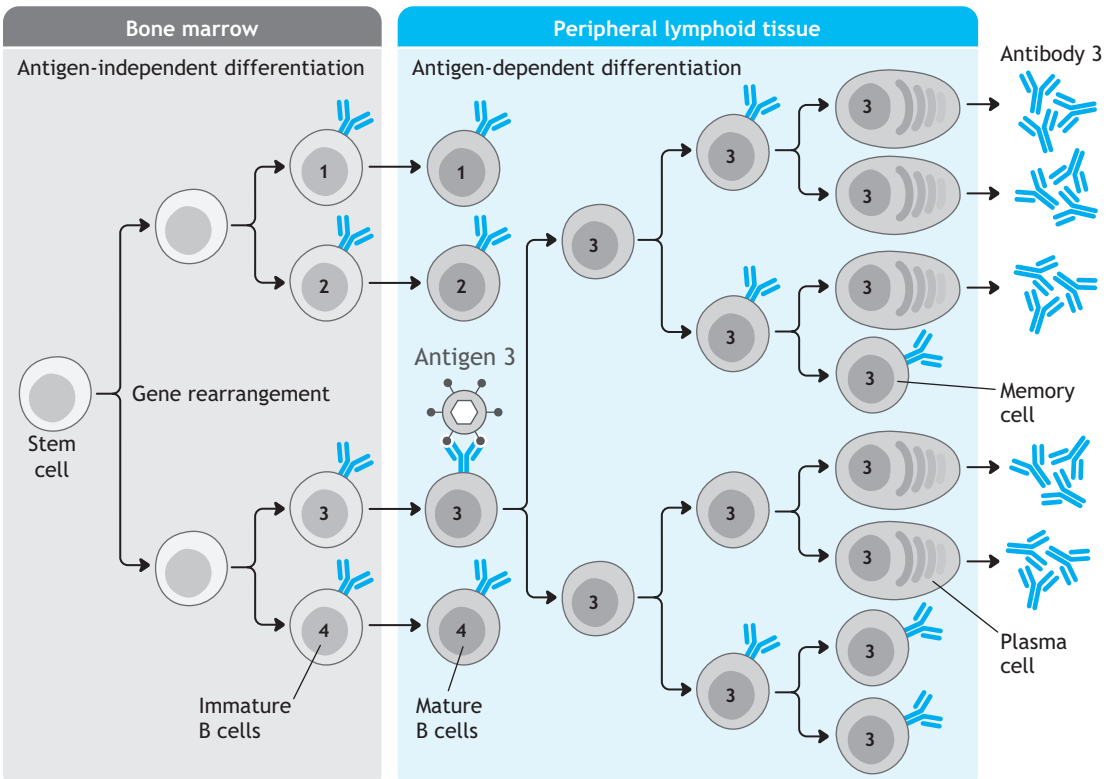

Figure 2–4. Clonal selection theory of adaptive immunity.

PERNICIOUS ANEMIA

CLINICAL CORRELATION

- ***Pernicious anemia (PA)*** *is an organ-specific autoimmune disease characterized by a decreased absorption of dietary vitamin* B_{12}.
- *Vitamin* B_{12} *is normally absorbed in the ileum as a complex with* ***intrinsic factor****, a protein synthesized by gastric parietal cells.*
- *Failure to absorb vitamin* B_{12} *in PA results from an autoimmune attack on gastric parietal cells and the clearance of intrinsic factor by autoantibodies.*
- *The resulting vitamin* B_{12} *deficiency results in impaired erythropoiesis (megaloblastic anemia).*

V. Lymphocytes express antigen receptors.

A. The **antigen receptor complexes** of T and B lymphocytes are similar in structure and function (Figure 2–5).

1. The B cell receptor (BCR) for antigen consists of a membrane form of antibody and the accessory peptides **Ig**α and **Ig**β.

a. The BCR recognizes discrete antigenic determinants (epitopes) on soluble antigens.

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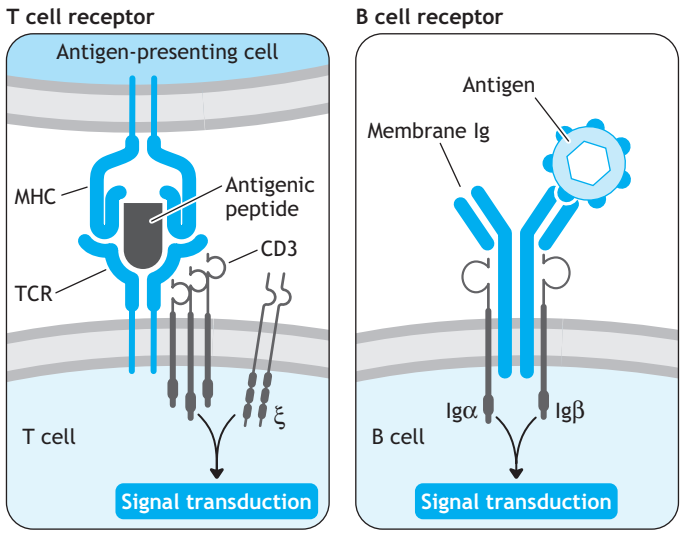

Figure 2–5. Antigen receptors on B and T lymphocytes. MHC, major histocompatibility complex; TCR, T cell receptor; Ig, immunoglobulin.

B. Igα and Igβ mediate antigen-induced transmembrane signaling in B cells.

1. The **T cell receptor (TCR)** complex consists of antibody-like peptides and signaling peptides.

a. Unlike the BCR, the TCR can recognize only foreign antigens that are displayed on the surfaces of other cells.

(1) T cells recognize surface-bound small peptides that are derived by proteolysis from native protein antigens.

(2) The TCR recognizes determinants of the foreign peptide plus host cell surface molecules called **major histocompatibility complex (MHC) molecules**.

(3) The cells on which these processed foreign peptides are displayed are collectively referred to as **antigen-presenting cells (APC)**.

b. The MHC regulates antigen recognition by T cells.

(1) Only peptides that can bind to the host's MHC molecules are recognized by T cells.

(2) Two classes of MHC molecules control T cell antigen recognition in this fashion (Figure 2–6).

(a) **MHC class I** is expressed on nearly all nucleated cells.

(b) **MHC class II** is expressed on dendritic cells, macrophages, and B cells.

(3) MHC restriction ensures that T cells will be activated by antigen only in proximity to other host cells.

(a) **T helper (Th) cells** recognize antigen presented by MHC class II-expressing **dendritic cells (DC)**, B cells, and macrophages.

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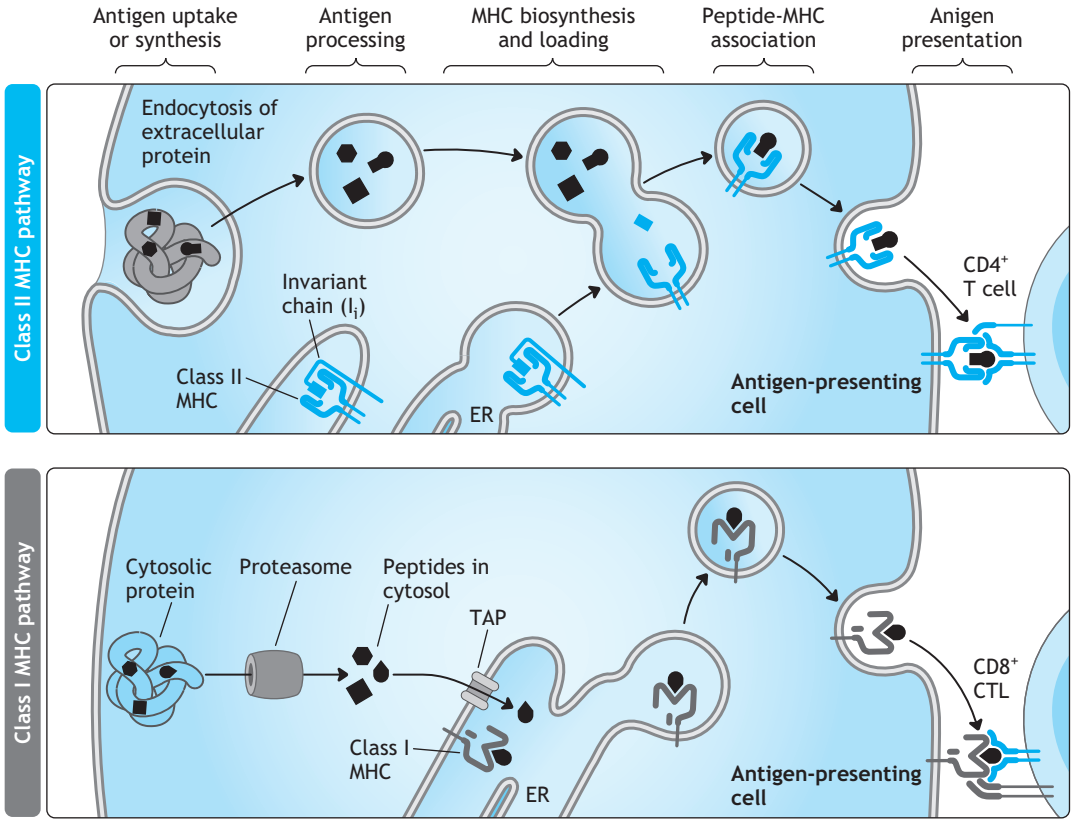

Figure 2–6. Schematic of antigen presentation. MHC, major histocompatibility complex; ER, endoplasmic reticulum; CTL, cytotoxic T lymphocyte; TAP, transporter of antigenic peptide.

(b) **Cytotoxic T (Tc) cells** recognize antigen-expressing (eg, viral antigens), MHC class I-expressing host cells.

c. The signaling peptides of the TCR are collectively referred to as **CD3**.

d. The TCR complex is first expressed during T cell development in the thymus (Chapter 10).

T CELL DEFICIENCIES DUE TO ABNORMAL CD3 EXPRESSION

CLINICAL CORRELATION

- *Mutations in two different CD3 peptides (CD3γ and CD3ε) have been described that decrease TCR expression.*
- *These patients show few peripheral T cells, susceptibility to viral and fungal infections, and autoimmunity.*
- *In addition to treatment for infections, these patients are candidates for hematopoietic stem cell transplantation, which can correct the defects.*
- *This and other congenital immune deficiencies are described in detail at the Online Mendelian Inheritance in Man web site maintained by the National Library of Medicine (www.ncbi.nlm.nih.gov/omim).*

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C. Antigen presentation requires the processing and MHC-dependent display of antigenic determinants (Figure 2–6).

1. Any nucleated cell can potentially present peptide antigens through MHC class I.
   a. T cells that recognize peptides + MHC class I bear a distinguishing cell surface coreceptor called **CD8**.
   b. Most $CD8^+$ T cells are cytotoxic.
2. DC, B cells, monocytes, and macrophages express MHC class II and can present antigenic peptides via class II molecules.
   a. T cells that recognize peptides + MHC class II bear a distinguishing cell surface coreceptor called **CD4**.
   b. Most $CD4^+$ T cells secrete cytokines that regulate the activation of other immune cells.

VI. Lymphocytes bear a number of additional cell surface molecules that control their activation, migration, or effector functions.

Table 2–4. Properties of CD markers.[a]

CD Category	Examples	Expression	Major Functions
Antigen presentation	CD1	Dendritic cells	Presents glycolipid antigens
Adhesion molecules	CD18	Leukocytes	Adhesion to endothelium
Coreceptors	CD4	T cells	Coactivates with TCR-CD3
Cytokine receptors	CD25	B cells	Binding of IL-2
Ig-binding receptors	CD32	Macrophages	Binding IgG–antigen complexes
Signal transduction	CD3	T cells	Mediates signaling of TCR
Homing receptors	CD62L	B and T cells	Homing to lymph nodes
Death-inducing receptors	CD120	Many cells	TNF-α-induced apoptosis
Enzymes	CD45	T cells	Phosphatase; regulates TCR signaling
Complement receptors	CD55	Many cells	Regulates complement activation
Blood group markers	CD240D	Erythrocytes	Major Rh antigen

[a]For a more complete list of CD markers, see Appendix I. TCR, T cell receptor; IL-2, interleukin 2; IgG, immunoglobulin G; TNF, tumor necrosis factor.

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A. **Coreceptors** on lymphocytes promote signaling through the TCR and BCR.
   1. Coreceptors lower the threshold for lymphocyte activation through their antigen receptors.
   2. Coreceptors can act by modulating intracellular signaling pathways or increasing the expression of other receptors.

B. T and B cells express a range of **cytokine receptors** that provides additional signals for cell activation.

C. Receptors that bind **IgG molecules** present in antigen–antibody complexes (**Fc receptors**) typically inhibit B cell activation.

D. **Cell adhesion molecules** mediate lymphocyte migration between and within tissues and increase the binding between lymphocyte subsets.

E. One method for cataloging cell surface molecules is the **cluster of differentiation (CD)** scheme that assigns a CD number to each unique cell surface molecule (Table 2–4, Appendix I, and www.hlda8.org/).

PHENOTYPING OF LYMPHOCYTE SUBSETS

- *Human lymphocyte subsets are routinely enumerated in the clinical laboratory by a technique known as **flow cytometry** (Chapter 5).*
- *Monoclonal antibodies to the **CD markers** of interest (Table 2–4) are labeled with a fluorochrome and used to stain cells.*
- *The flow cytometer detects labeled antibody binding to the cell and thereby enumerates surface CD molecules on blood cells or cells prepared from solid tissues (eg, tumors).*
- *Abnormal lymphocyte numbers are associated with congenital or acquired immune deficiencies, infections, and neoplastic conditions.*
- *Leukemias and lymphomas can be typed and staged by defining the CD markers they express.*

CLINICAL PROBLEMS

A 2-month-old male child presents with thrush (a yeast infection in the oral cavity), diarrhea, and failure to thrive. His complete blood count reveals a severe lymphopenia. Flow cytometry demonstrates a very low number of $CD3^+$ lymphocytes in his blood, but normal numbers of membrane IgM^+ lymphocytes when compared to age-matched controls.

1. Which one of the following represents the most likely underlying disease in this child?

A. X-linked agammaglobulinemia (XLA)

B. DiGeorge syndrome

C. Neonatal neutropenia

D. Myeloperoxidase deficiency

E. Aplastic anemia

A patient has a history of recurrent pneumonias that reappear within a week following completion of antibiotic therapy. She is found to have a deficiency in the expression of CD18.

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2. Which of the following two clinical abnormalities would you most expect to find in such a patient? More than one answer may be correct.

A. Lymphopenia
B. Leukocytosis
C. Recurrent viral infections
D. Recurrent bacterial infections
E. Abnormal BCR cell signaling
F. Agammaglobulinemia
G. Reduced T lymphocyte receptor expression

3. Which of the following is a "pattern recognition receptor"?

A. BCR
B. Interleukin-1 receptor
C. Fc receptor
D. CD4
E. Mannose receptor

A patient presents with a lymphocytosis and enlarged lymph nodes, and a biopsy of the bone marrow is performed. Ninety percent of the patient's bone marrow cells stain with a fluorescent antibody specific for CD3.

4. Which of the following is a reasonable differential diagnosis?

A. AIDS
B. DiGeorge syndrome
C. T cell leukemia
D. Cytomegalovirus infection
E. This is a normal laboratory finding.

Patients with deficiencies in antibody production can often present with the same types of infections as are seen in patients with phagocytic cell deficiencies.

5. Which of the following statements **best explains** this observation?

A. Autoantibodies can remove phagocytic cells from the blood circulation.
B. Plasma cells are the direct progenitors of certain phagocytic cells.
C. Macrophages can differentiate into antibody-producing plasma cells.
D. Antibodies are important opsonins that promote microbe recognition by phagocytes.
E. Antibodies are essential for the continued production of phagocytic cells by the bone marrow.

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ANSWERS

1. The correct answer is B. The finding of low lymphocyte counts in the blood (lymphopenia) affecting only T cells suggests a deficiency in cell-mediated immunity secondary to decreased T cell numbers, such as in thymic dysplasia (DiGeorge syndrome). This would be expected to lead to opportunistic infections by intracellular pathogens, such as the yeast *Candida albicans*.
2. The correct answers are B and D. The CD18 gene encodes for an adhesion molecule, and patients with decreased CD18 expression show poor leukocyte adhesion to the vascular endothelium. The increase in leukocyte production seen during infections results in an increased number of leukocytes in the blood (leukocytosis). The resulting decreased leukocyte migration to infection sites impairs clearance of extracellular bacterial pathogens.
3. The correct answer is E. The mannose receptor recognizes the spatial arrangement of mannose residues that is found only on microbial surfaces.
4. The correct answer is C. Finding large numbers of $CD3^+$ cells in the bone marrow is most likely indicative of neoplastic T cells (leukemia), because CD3 is normally expressed only after the pro-T cell migrates to the thymus.
5. The answer is D. Antibodies of certain classes can bind to microbial surface antigens and mark them for uptake by phagocytic cells. This is because phagocytes bear opsonic receptors that bind antibody-coated particles and signal an increased rate of uptake. Thus, patients who lack certain antibodies will show diminished phagocytic cell function due to impaired opsonophagocytosis.

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CHAPTER 3
ANTIGENS AND ANTIBODIES

I. Antigens

A. An **antigen** is a substance that can elicit an adaptive immune response.

B. Most natural and medically important antigens are macromolecules or substances that can bind covalently to them.

C. Naturally occurring antigens include proteins, polysaccharides, lipids, and nucleic acids.

D. The region of an antigen that is recognized by the immune system is called an **antigenic determinant** or **epitope**.

E. Antigens generally have two properties.

1. **Immunogenicity** is the capacity to induce an immune response.
   - **a.** Immunogenicity is determined by the molecular mass, molecular complexity (number of potential determinants), and conformation of an antigen.
   - **b.** A high degree of phylogenetic disparity between an antigen and the host generally promotes immunogenicity.
2. **Antigenicity** is the ability to bind specifically to antibody molecules or antigen receptors on lymphocytes.
3. A **hapten** is a molecule that is antigenic, but not immunogenic.
   - **a.** A hapten generally has a molecular mass of less than 10,000 Da.
   - **b.** A hapten can become immunogenic if it is covalently attached (conjugated) to a **carrier molecule**.
   - **c.** Some haptens can cause **allergic dermatitis** if they bind to proteins in the skin.
   - **d.** Conjugating microbial epitopes (haptens) to carrier proteins is an effective approach to producing highly immunogenic vaccines.

PENICILLIN IS A HAPTEN THAT CAN INDUCE IMMUNE-MEDIATED TISSUE DAMAGE

CLINICAL CORRELATION

- *Penicillin G is a small drug (MW 356) that can bind to a variety of host proteins, including those on the surface of human erythrocytes.*
- *Antipenicillin antibodies can be produced that cause **autoimmune hemolytic anemia**.*
- *The **Coombs test** is used to determine if an anemia has an immune basis by determining whether immunoglobulin G (IgG) antibodies are present on the patient's erythrocytes.*
- *The treatment of Coombs-positive anemias includes discontinuing the drug (hapten) and transfusing normal ABO-matched erythrocytes.*

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F. Antigenic determinants that bind to antibodies and B cell antigen receptors are often different from those that bind to T cell antigen receptors (Table 3–1).

1. Determinants recognized by antibodies or B cells are typically found on the exposed **hydrophilic** surface of an antigen molecule.

2. Antigens that bind to the T cell antigen receptor typically do not possess their native conformation.

a. Most antigens that stimulate T cells are proteins.

b. For a protein to be recognized by a T cell it must be degraded into peptides and presented by an antigen-presenting cell (APC).

c. T cell determinants are not limited to surface exposed regions of proteins and can be derived from internal hydrophobic protein domains.

II. Antibodies

A. All antibodies are **immunoglobulins (Igs)**.

B. Igs are a homologous family of proteins with considerable structural heterogeneity.

C. Most Igs migrate in the "gamma" region upon **serum protein electrophoresis** and are therefore called **γ-globulins** (Figure 3–1).

INTRAVENOUS IMMUNOGLOBULIN (IVIG)

- *Immunoglobulins (γ-globulins) are routinely given to patients for the prevention or treatment of various diseases.*
- *IVIGs are often used to treat congenital antibody deficiencies and must be given repeatedly.*
- *Because IVIG is greater than 95% IgG, its primary immune benefit in immunodeficient patients is to provide protection against extracellular microbial pathogens or their toxic products.*
- *Some infectious diseases in normal individuals, such as rabies and hepatitis, can be effectively prevented with γ-globulins prepared from specific immune donors that are administered shortly after a suspected infection.*

D. The structure of antibodies was first determined by studying Igs purified from the sera of patients with **multiple myeloma**.

Table 3–1. Comparison of the antigenic determinants recognized by B and T lymphocytes.

Property	B cells	T cells
Conformation dependent	+	–
Hydrophillic/hydrophobic	Hydrophillic	Hydrophillic and hydrophobic
Location of determinants	Surface	Surface and internal
MHC dependent	–	+
Examples	Native proteins and carbohydrates	Peptides

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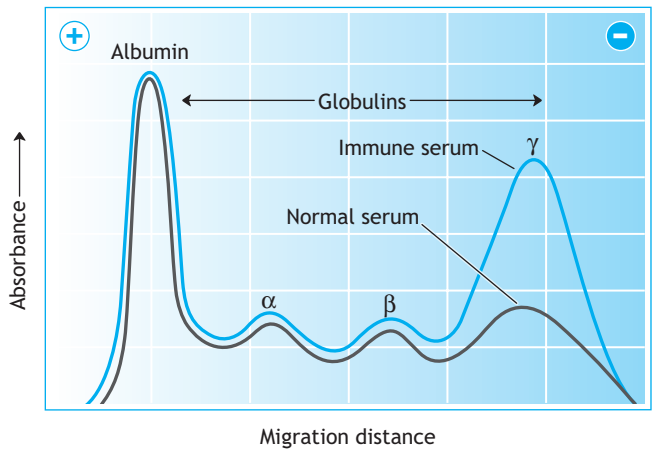

Figure 3–1. Serum protein electrophoresis.

1. Multiple myeloma is a malignancy of a clone of Ig-producing plasma cells.
2. Myeloma Igs (also called **M proteins**) are monoclonal and structurally homogeneous.
3. All M proteins belong to one of five structurally distinct Ig **classes** or **isotypes**.
4. The most frequently encountered isotype among myeloma proteins is IgG.
   - **a.** IgG molecules have the molecular formula H_2L_2 and show **bilateral symmetry** (Figure 3–2).
     - ***(1)*** Each IgG molecule contains two identical **heavy (H) chains**.
     - ***(2)*** The H chains of IgG molecules are designated γ chains and have a molecular mass of approximately 50,000 Da.
     - ***(3)*** H chains are linked to one another by *inter*-chain disulfide bonds.
     - ***(4)*** Each IgG molecule contains two identical **light (L) chains**, each with a molecular mass of approximately 25,000 Da.
     - ***(5)*** L chains are covalently linked to H chains by *inter*-chain disulfide bonds.
   - **b.** *Intra*-chain disulfide bonds in both H and L chains maintain protein folds that define **Ig domains** of approximately 110 amino acids in length (Figure 3–2).
   - **c.** There are two such domains in L chains and four in γ H chains.
5. There are a total of five **classes or isotypes** of human Ig, designated IgG, IgM, IgA, IgE, and IgD (Table 3–2).
   - **a.** Each Ig has the core molecular H_2L_2 structure and contains H chains unique to that isotype.
   - **b.** IgG, IgM, IgA, IgE, and IgD have γ, μ, α, ε, and δ, H chains, respectively.
     - ***(1)*** γ, α, and δ chains have molecular masses of 50,000–60,000 Da.
     - ***(2)*** μ and ε chains, which have an additional Ig domain, have molecular masses of 65,000–70,000 Da (Table 3–2).

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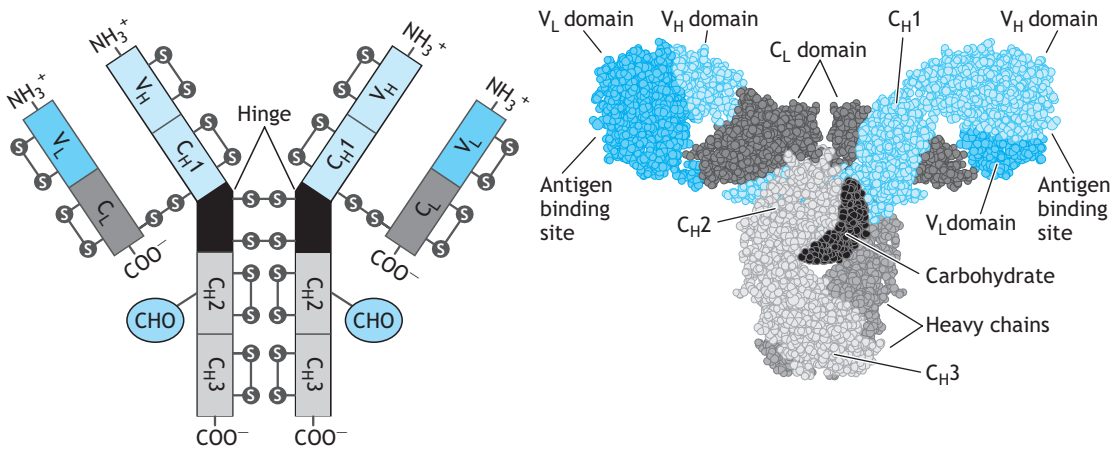

Figure 3–2. Structure of an immunoglobulin (Ig) G molecule.

c. The IgG class is further subdivided into the IgG_1, IgG_2, IgG_3, and IgG_4 subclasses.

d. The IgA class is further subdivided into the IgA_1 and IgA_2 subclasses.

6. All Igs can occur in two forms, secreted and membrane bound.

7. There are two human L chain **types**, termed κ and λ.

a. In any one immunoglobulin molecule, both L chains are either κ or λ.

b. The overall κ:λ ratio for the Igs found in human serum is approximately 60:40.

8. Oligosaccharides are covalently attached to the carboxyl-terminal half of H chains, especially within μ and ε chains.

MULTIPLE MYELOMA

- *Patients with multiple myeloma can have extremely high levels of Igs in their plasma that are often first detected by serum protein electrophoresis (Figure 3–1).*
- *Because their cancers are monoclonal and have a homogeneous charge, the abnormal M protein appears on electrophoresis as a "spike."*
- *Each M protein has a single H chain class and a single L chain type.*
- *Many patients with myeloma also have high concentrations of Ig L chains in their urine, which are produced in excess by their myeloma cells.*
- *In a given patient, these **Bence–Jones proteins** are monoclonal, dimeric, and either κ or λ, but not both.*
- *Finding a significant departure from the normal 60:40 κ:λ ratio in serum or urinary L chains is diagnostic of a **monoclonal gammopathy**, such as myeloma.*

E. IgM and IgA molecules can exist as multimers (Figure 3–3).

1. Serum IgM is a pentamer of the core H_2L_2 structure that is joined together by intersubunit disulfide bonds and stabilized by a 15-kDa **joiner (J) chain**.

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Table 3–2. Properties of human immunoglobulin isotypes.

Property	IgG	IgM	IgA	IgE	IgD
Subclasses	IgG_{1-4}	None	IgA_{1-2}	None	None
Heavy chain	γ	μ	α	ε	δ
C_H domains	3	4	3	4	3
L chain	κ or λ	κ or λ	κ or λ	κ or λ	κ or λ
Molecular mass[a] (secreted form)	150,000	900,000	150,000 570,000[b]	190,000	170,000
Serum concentration (mg/dL)	1350	150	300	0.05	3
Serum half-life (days)	23	5	6	2	3
Activates complement (classical pathway)	+	++	–	–	–
Placental transport	+	–	–	–	–
Mucosal epithelial transport	–	+	++	–	–
Mast cell degranulation	–	–	–	+	–
Binding to phagocyte Fc receptors	+	–[c]	–	–	–
Binding to Fc receptors on natural killer cells	+	–	–	–	–
Antigen receptor of naive B cells	–	+	–	–	+

[a]Refers to the predominant forms in serum and external secretions, not the form found on B cell surfaces.
[b]Secretory IgA found in external secretions is a dimer with an associated J chain and secretory component.
[c]Recent evidence suggests Fc_μ receptors on neutrophils may mediate host defense against spirochetes.

2. Serum IgA is primarily a monomer, but secretory IgA that is found in external secretions (eg, saliva and colostrum) is dimeric and contains a J chain polypeptide.

a. Dimeric IgA is synthesized in the intestinal submucosa and efficiently translocated across the mucosal epithelium.

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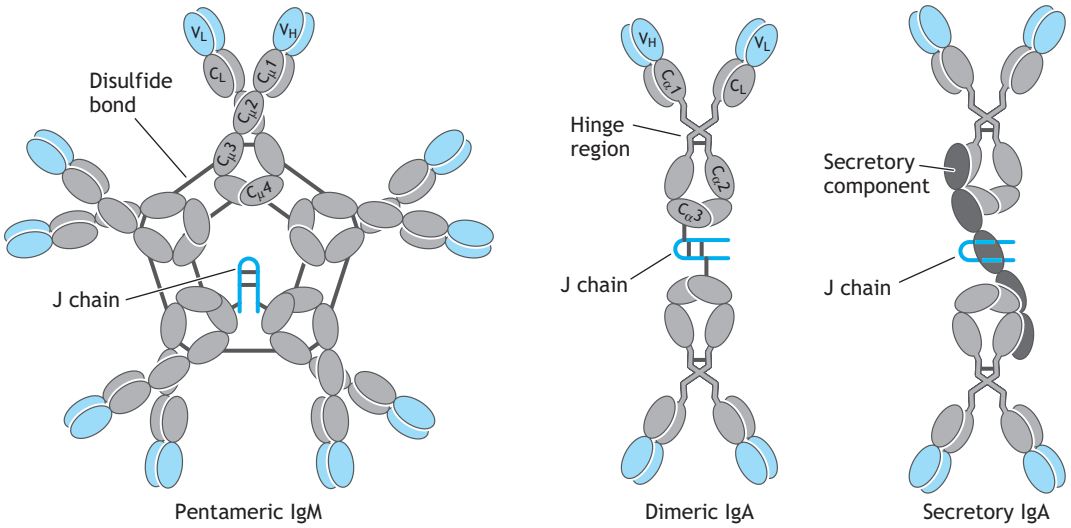

Figure 3–3. Polymeric immunoglobulins (Ig).

b. During the process of translocation, epithelial cells add a 70-kDa peptide, called a **secretory component (SC)**, to the IgA molecule (Figure 3–3).
(1) SC protects secretory IgA from proteolytic digestion.
(2) SC promotes the binding of secretory IgA to the mucous layer of the epithelium.

F. Amino acid sequencing of myeloma H and L chains shows that they have constant (C) and variable (V) regions.

1. The amino-terminal half of an L chain is designated the **variable light (V_L) domain.**

a. Amino acid sequence diversity in V_L domains is greatest within the three **hypervariable regions**, HV1, HV2, and HV3.

b. HV regions are also called **complementarity determining regions (CDR)**, because they comprise the walls of the antigen-binding cleft.

2. The carboxyl-terminal half of an L chain is relatively constant and is designated as the **constant light (C_L)** domain (C_κ or C_λ).

3. As with V_L domains, the amino-terminal **V_H** domains of H chains are highly variable when several H chains are compared.

a. V_H domains contain three hypervariable regions.

b. V_H domains that have different amino acid sequences generally have different specificities.

4. The antigen-binding activity of an Ig depends on both its V_H and V_L domains.

5. The three carboxyl-terminal **C_H** domains of IgG H chains are designated **C_H1**, **C_H2**, and **C_H3**.

G. Structure and function in Igs are related.

1. The distribution of Ig function within Ig domains was first revealed by studying proteolytic fragments of the molecules.

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2. Enzymatic digestion of rabbit IgG antibodies with the protease **papain** yields three fragments.
   a. Two are identical **antigen-binding fragments (Fab)** consisting of the V_H + C_H1 domains.
   b. Each Fab can bind one molecule of antigen.
   c. One **Fc fragment** is also generated and consists of the carboxyl-terminal half of the two disulfide-linked H chains (ie, the C_H2 + C_H3 domains in IgG).
   d. The Fc region mediates the opsonic activity of IgG antibodies by binding them to **Fc receptors** on phagocytic cells.
3. The **effector functions** of antibodies depend on the structures of their C_H domains.
   a. Many functions of antibodies are not expressed until they have bound their antigens, which induces conformational changes in the C_H domains.
   b. Transplacental transport, transepithelial transport, and mast cell binding of Igs do not require prior binding of the Ig to its antigen.
   c. A **hinge region** in many C_H domains is responsible for the flexibility in antibody conformation necessary for cooperative antigen binding.
4. The principal functions of IgG antibodies are to serve as opsonins, activate the complement system, provide fetal protection following transplacental transport, and inhibit B cell activation (Table 3–2).
5. The principal functions of IgM antibodies are to serve as antigen receptors on naive B cells, activate the complement system, clear circulating antigen, and provide host defense at mucosal surfaces.
6. The principal function of IgA antibodies is to provide antibody defense at mucosal surfaces.
7. The principal function of IgE antibodies is to mediate allergic reactions by promoting mast cell degranulation.
8. The principal function of IgD antibodies is to serve as an antigen receptor on naive B cells.

ISOTYPE SWITCHING AND CONJUGATE VACCINES

- *Antibody production undergoes **isotype switching** late in the primary adaptive immune response (Chapter 2).*
- *This associates new antibody functions with the same antibody specificity, a principle illustrated by the Haemophilus influenzae type b (Hib) conjugate vaccine.*
- *Hib is one of the leading causes of bacterial nasopharyngeal infections in children and can progress to pneumonia and life-treatening meningitis.*
- *Immune elimination of H influenzae requires antibodies to the polysaccharide capsule of this organism.*
- *H influenzae capsular polysaccharide vaccines have not proven effective at eliciting opsonic IgG antibodies in children.*
- *By contrast, the conjugate vaccine consisting of Hib capsular polysaccharides covalently linked to a foreign carrier protein (eg, the tetanus toxoid vaccine protein) is quite effective at inducing protective IgG antibodies in children.*
- *A description of the Hib conjugate vaccine and other recommended pediatric vaccines can be found at www.cdc.gov/nip/recs/child-schedule.pdf.*

H. **Natural antibodies** appear early in life.
   1. Most natural antibodies belong to the **IgM class** of Igs.

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2. Many natural antibodies are produced in response to carbohydrate antigens present on microbial flora.
3. Some natural antibodies also cross-react with carbohydrate structures on host cells.
   a. The **isohemagglutinins**, natural antibodies to the **ABO blood group antigens**, can mediate the destruction of transfused mismatched blood.
   b. Isohemagglutinins recognize the terminal sugar groups of the ABO polysaccharide antigens expressed by erythrocytes and endothelial cells (Figure 3–4).
      (1) Three blood group antigens are defined by this sytem: A, B, and H.
      (2) Because the ABO genes are expressed in a codominant fashion, the potential ABO types are A, B, AB, and O.
      (3) Individuals produce isohemagglutinins specific for the ABO antigens that they lack (Table 3–3).
      (4) With regard to blood transfusions, the **universal donor** is type O, because this individual lacks antigens that would be recognized by ABO-incompatible recipients.
      (5) The **universal recipient** is type AB, because this individual lacks antibodies that would destroy ABO-incompatible donor erythrocytes.
   c. Natural antibodies can also mediate the rejection of **xenotransplants**, organs exchanged between species (Chapter 17).

III. Additional Ig heterogeneity

A. Slight sequence variations can exist between immunoglobulin molecules of the same isotype (eg, IgG_1) from different individuals.
1. These inherited genetic markers reside within the C_H or C_L domains of human Igs and are called **allotypes**.
2. Antiallotype antibodies are sometimes produced following pregnancy, blood transfusions, or γ-globulin therapy.

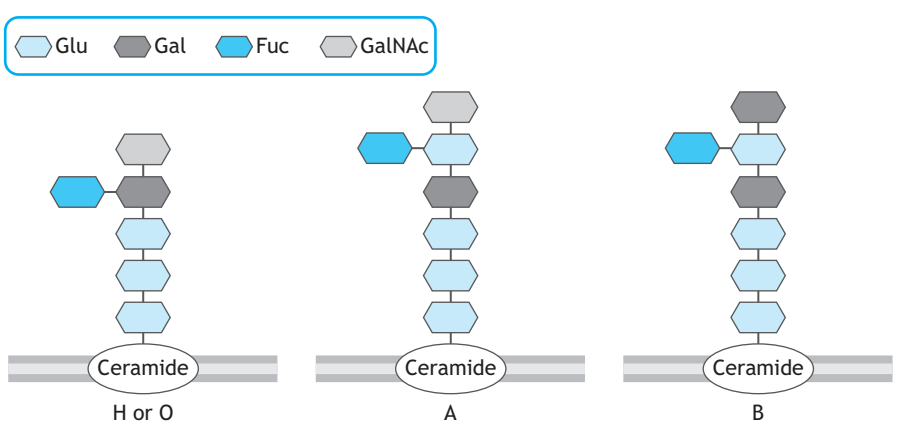

Figure 3–4. Structures of the ABO blood group antigens.

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Table 3–3. Antigens and antibodies of the ABO blood group system.

Blood Group Type	Genotypes	Antigens	Isohemagglutinins
A	AA, AO	A	Anti-B
B	BB, BO	B	Anti-A
AB	AB	A and B	None
O	OO	H	Anti-A and anti-B

B. Igs of the same isotype can also be distinguished from one another by their V regions.

1. An antibody of a given specificity has unique V_L + V_H domains, the combination of which specifies its **idiotype**.

2. An antibody molecule and the B cell receptor of the clone of B cells that produced it have the same idiotype (Chapter 2).

3. Antiidiotype antibodies can block the binding of antigen to its antibody.

IV. Monoclonal Igs

A. Monoclonal antibodies are only rarely produced in response to active immunization with natural antigens.

B. In abnormal conditions called **monoclonal gammopathies** a single clone of B cells or plasma cells produces a monoclonal Ig.

1. Malignant monoclonal gammopathies include **multiple myeloma, non-Hodgkin's lymphoma**, and **Waldenström's macroglobulinemia**.

2. Benign monoclonal gammopathies include **light chain disease** and **monoclonal gammopathy of undetermined significance (MGUS)**, a condition that is common in the elderly.

3. Bence–Jones proteins are monoclonal Ig L chains that are found in the urine.

a. The exclusion properties of the renal glomeruli permit passage of L chains, but not H chains.

b. These Bence–Jones proteins can accumulate in renal tubular epithelial cells, where they can cause necrosis.

ABNORMAL IG SYNTHESIS AND CRYOPATHIES

- *The excess production of Ig L chains can result in a number of systemic effects, including **cryoglobulinemia**, the microprecipitation of circulating proteins in the cold.*
- *Complications of cryoglobulinemia involving Ig proteins include cyanosis of the digits, hemorrhage, thrombosis, and gangrene.*
- *In B cell malignancies, cryoglobulins are monoclonal and can include intact M components or free L chains.*
- *In addition to treatment of the primary disease (eg, myeloma), plasma exchange and **cryophoresis** (reinfusion of autologous plasma following removal of the cryoglobulins) have met with some success.*

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C. **Hybridoma antibody technology** allows production of a monoclonal antibody with a desired specificity.
   1. Hybridomas are produced by fusing a nonsecreting myeloma cell with B cells from an animal that has been immunized with an antigen of interest.
   2. Monoclonal antibody-producing hybridomas with the desired specificity are then identified, selected, and expanded in cell culture.
   3. Hybridoma antibodies show less cross-reactivity than conventional antisera and are preferred for diagnostic tests (Chapter 5).

NOVEL ANTIBODY-MEDIATED THERAPIES

- ***Immunotoxins*** *are conjugates composed of lethal plant or microbial toxins covalently linked to antibodies that target the conjugate to specific cells or tissues (eg, leukemia cells).*
- ***Bispecific antibodies*** *are genetically engineered to contain Fab regions specific for two different antigens (eg, CD3 on T cells and a tumor target antigen).*
- ***Humanized mouse hybridoma antibodies*** *are genetically engineered to contain mouse Ig hypervariable regions embedded in a human IgG antibody framework.*
- *This minimizes the likelihood that the host will mount an immune response to the foreign mouse hybridoma antibody sequences.*
- ***Fusion proteins*** *produced by covalently linking cytokine receptor domains to Ig molecules have extended half-lives in circulation and have proven effective for the treatment of cytokine-mediated inflammatory diseases.*

CLINICAL PROBLEMS

You are considering treatment options for a 1-year-old child with a congenital immune deficiency. He has very low serum IgG levels and recurrent bacterial infections, and he lacks B cells in his peripheral lymph nodes. You decide to treat with IVIGs, which you realize may be required throughout his life.

1. How often will you have to administer IVIG to maintain a consistent level of protective immunity in this child?

A. Twice per week

B. Once per week

C. Once every 3 weeks

D. Once every 6 months

E. Yearly

A child is immunized by the intramuscular route at 2, 4, and 6 months of age with tetanus toxoid, a protein antigen. One week following each immunization her serum is collected and analyzed for antitoxoid antibodies.

2. Which of the following properties would characterize the serum collected after the third immunization compared to that collected after the first immunization?

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A. Increased specificity for tetanus toxoid
B. Increased ability of the serum to promote the uptake of the toxoid by phagocytic cells
C. Increased complement activation by antigen–antibody complexes formed with the serum
D. Increased reactivity with autoantigens of the host
E. Decreased binding of the toxoid

An 80-year-old man presents with slight pain on urination, and his physician orders a test for protein in his urine. An elevated urinary protein level prompts the physician to request a urine protein electrophoresis, which shows a protein spike.

3. Which of the following additional findings would be most consistent with a diagnosis of a benign monoclonal gammopathy?

A. A high concentration of serum IgG and elevated β and γ region proteins on protein electrophoresis
B. Elevated concentrations of κ and λ L chains in his serum
C. A high κ:λ ratio (100:1) among his urinary L chains
D. An elevated erythrocyte sedimentation rate
E. Recurrent bacterial infections

Johnny is a 3-month-old infant in need of a blood transfusion. The blood bank has determined that Johnny's parents are both blood group type AB.

4. Which of the following findings would indicate that Johnny has an ABO type different from that of his parents?

A. His serum reacts with type O erythrocytes.
B. His cells react with anti-A.
C. His cells react with both anti-A and anti-B.
D. His serum reacts with his father's cells.
E. His cells react with his mother's serum.

A researcher has produced an idiotype-specific antibody by immunizing a rabbit with an M protein purified from the serum of a myeloma patient. This antibody does not react with any other M protein tested.

5. With which of the following structures would this antibody react?

A. Fab fragment
B. J chain
C. C_H1 domain
D. Fc fragment
E. Fc receptor binding site

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ANSWERS

1. The correct answer is C. IVIG is a γ-globulin preparation derived from pooled immune donor plasma and contains primarily IgG, which is what this patient lacks. The half-life of human IgG in the circulation is 23 days (approximately 3 weeks).
2. The correct answer is B. One of the principal reasons for repeated immunizations is to induce Ig class switching (eg, a change from predominantly IgM to predominantly IgG production). This has the effect of introducing new functions associated with the additional isotypes. For example, IgG (but not IgM) is a potent opsonin due to the presence of Fc receptors on phagocytic cells that recognize γ heavy chains.
3. The correct answer is C. To diagnose a monoclonal gammopathy the clinical laboratory must demonstrate a predominance of one L chain (κ or λ) over the other, which would alter the normal 60:40 ratio. Monoclonal gammopathies appear on electrophoresis as a "spike," whereas polyclonal gammopathies appear as an elevated amount of protein across a wide electrophoretic range (ie, the entire γ region). Monoclonal gammopathy of undetermined significance is a common finding in patients in this particular age group.
4. The correct answer is D. Johnny could theoretically be either A, B, or AB. If his serum reacts with his father's cells, he must have either anti-A or anti-B in his serum. Either finding would indicate he has a blood type that is different from his parents, because AB individuals have no antibodies to ABO antigens.
5. The correct answer is A. If this antibody is indeed specific for only this patient's M protein, it must be recognizing the V region of the Ig. The only structure listed that contains V region domains is the Fab fragment.

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CHAPTER 4
IMMUNOGLOBULIN GENE EXPRESSION

I. A fundamental problem posed by the unusual structure of immunoglobulin (Ig) molecules is solved by a novel genetic mechanism.

A. Igs are unusual in that millions of different V region sequences exist among the pool of Ig polypeptide chains.

B. These diverse V regions are found within polypeptides that show limited diversity in their C region sequences.

C. The germ line genome of a species is not large enough to encode all of the potential Ig V region sequences.

D. To form the pool of Ig V region sequences a limited number of inherited **Ig gene segments** undergoes genetic recombination and random reassortment.

1. The genetic capacity to generate the diverse family of Ig proteins exists within the germ line of every cell.

2. Rearrangements of Ig DNA by somatic recombination occurs only in B cells and is a random pretranscriptional process.

3. Diversity is generated prior to exposure to foreign antigen.

4. Each member of the species has a similar **potential repertoire** of Igs.

II. Ig genes are initially organized in a germ line configuration.

A. There are three **gene families** (also referred to as **loci**) that encode Ig polypeptides, the κ, λ, and H chain gene families.

1. There are only 10–100 **gene segments** at each locus.

2. Both the κ and λ chain loci contain **constant (C), variable (V),** and **joiner (J) gene segments** (Figure 4–1).

3. The H chain locus has a similar arrangement with a 5′ cluster of V_H gene segments, several J_H segments, a group of **diversity (D_H)** segments (not seen in the L chain loci), and nine C_H segments.

a. The C_H gene segments correspond to the nine classes and subclasses of human H chains.

b. Each of the C_H segments consists of a cluster of three or four exons encoding the different C_H domains of secreted Ig H chains (Figure 3–2).

c. One or two short exons follow these C_H exon clusters that code the transmembrane and cytoplasmic regions of membrane H chains.

4. Latent promoters are found upstream of each $V_κ$, $V_λ$, and V_H segment.

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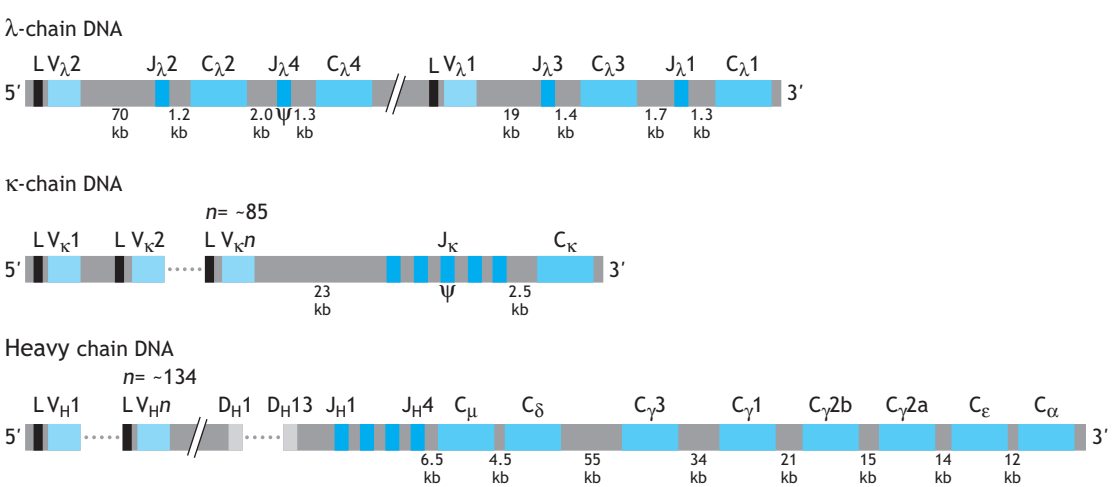

Figure 4–1. Germ line configuration of the three Ig gene families.

Ig LOCUS DELETIONS

CLINICAL CORRELATION

- *Deletion mutations affecting large regions of the human Ig loci are known to exist.*
- *Among a consanguineous population of Tunisians, several individuals with homozygous deletions in the H chain locus have been identified.*
- *One haplotype has a multigene deletion of the entire $C_\gamma 1$-to-C_ε segment (Figure 4–1).*
- *An affected individual showed normal numbers of B cells in his peripheral lymphoid tissues, but his serum contained no detectable IgG_1, IgG_2, IgG_4, or IgA_1.*
- *In some instances of Ig locus deletions one Ig class can apparently compensate for the absence of another, thus preventing any increased susceptibility to infection.*

III. The recombination of Ig gene segments precedes the expression of a complete Ig gene.

A. Somatic recombination rearranges the order of the various segments within the L chain loci to create a functional Ig gene.

B. Recombination generates diversity within the V regions of L chain polypeptides.

1. For example, recombination at the κ locus brings one V_κ segment, one J_κ segment, and one C_κ segment into proximity with one another (Figure 4–2).

2. Recombination involves the cleavage of double-stranded DNA and its religation.

3. A **V(D)J recombinase** catalyzes cleavage and is expressed only in lymphocytes.

a. V(D)J recombinase consists of two components encoded by **recombination activating gene 1 (*Rag1*)** and **recombination activating gene 2 (*Rag2*)**.

b. Mutations within *Rag1* or *Rag2* prevent the rearrangement of the Ig and T cell receptor (TCR) loci.

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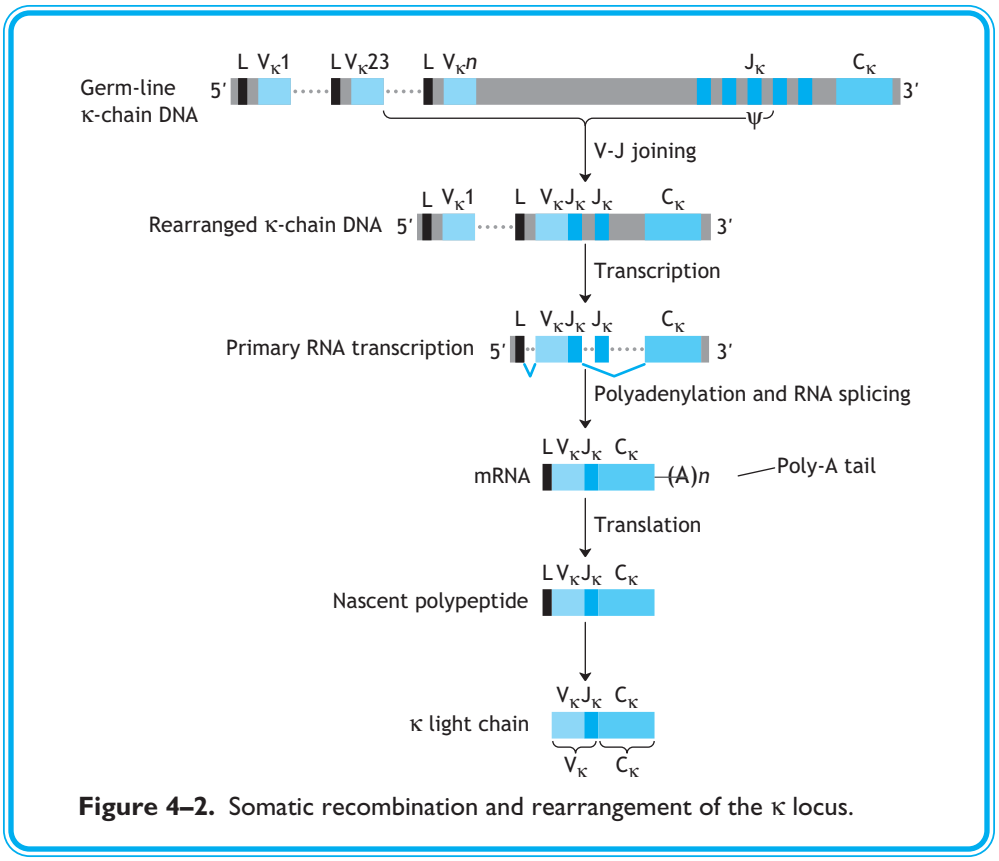

Figure 4–2. Somatic recombination and rearrangement of the κ locus.

RAG DEFICIENCY

CLINICAL CORRELATION

- *Mutations in the Rag1 or Rag2 genes dramatically alter lymphocyte differentiation and cause **severe combined immune deficiency (SCID)**.*
- *SCID is characterized by $T^-B^-NK^+$ lymphopenia, because neither immature B cells nor thymocytes survive differentiation if they cannot successfully express their antigen receptor genes.*
- *SCID is a pediatric emergency due to the rapid onset of fatal opportunistic infections by intracellular pathogens (primarily viral and fungal) early in postnatal life.*
- *Hematopoietic stem cell transplantation in the early neonatal period is a highly successful treatment for SCID.*

4. Sequences within the noncoding introns, called **recombination signal sequences**, determine which gene segments can be juxtaposed by recombination.
5. Additional enzymes catalyze the repair of these double-stranded DNA breaks.
6. The joining of a V segment to a J segment (**V–J joining**) results in the looping out and loss of intervening V and J segments.
7. Any J segments not joined to the V segment as well as intervening introns are excised at the RNA processing stage.
8. The same processes occur at the λ locus.

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C. Recombination at the κ and λ loci occurs primarily in the bone marrow independent of any exposure to foreign antigen.

D. Once rearranged, the κ locus can be transcribed into a primary RNA transcript (Figure 4–2).

1. Rearrangement permits the expression of the κ locus by positioning promoters and enhancers close to one another and the transcriptional start site.

2. Transcription ends at a stop codon that follows the rearranged C_κ segment.

3. Intervening RNA and nonjoined J_κ segments are removed by processing the primary RNA transcript.

4. A messenger RNA (mRNA) is produced by splicing and is then polyadenylated and translated into a κ chain polypeptide.

E. The same process permits the expression of a rearranged λ locus.

CHROMOSOMAL TRANSLOCATIONS TO IG LOCI

- *Many malignant lymphoid cells, including Burkitt s lymphoma and multiple myeloma, show chromosomal translocations that involve the Ig loci.*
- *The high level of genetic recombination that occurs at Ig loci during lymphocyte development makes them particularly susceptible to these genetic abnormalities.*
- *Particularly frequent are translocations that include oncogenes, such as c-myc.*
- *Translocating genes for growth factors, various growth factor receptors, antiapoptosis genes (eg, bcl-2), and transcription factors to the transcriptionally active Ig loci can promote uncontrolled cell proliferation.*

F. The process of gene rearrangement at the H chain locus is slightly different (Figure 4–3).

1. The first rearrangement involves the joining of a D segment with a J segment (**D–J joining**).

2. Following D–J joining, the V region is joined to the D–J segment by a second recombination.

3. Intervening D, J, and V regions are deleted during these recombinations.

4. H locus rearrangement occurs only in pre-B cells (Chapter 9).

5. Transcription yields a primary RNA transcript consisting of joined $V_HD_HJ_HC_\mu C_\delta$ segments.

a. Transcription is initiated by promoters upstream of the joined V_H segment.

b. The first downstream stop codon for transcription is found downstream of the C_δ segment.

(1) There is no stop codon following the C_μ segment.

(2) Primary transcripts from the rearranged H locus have the capacity to encode complete μ and δ polypeptide chains.

(3) The same $V_HD_HJ_H$-encoding region is shared by the μ and δ mRNA (see below).

6. A primary RNA transcript is synthesized, processed, polyadenylated, and translated into an Ig H chain.

7. Assembly of H and L polypeptide chains occurs in the rough endoplasmic reticulum.

8. Glycosylation and packaging for secretion occur within the Golgi.

G. The random process of recombination that occurs within each B cell adds to the diversity of the entire B cell pool.

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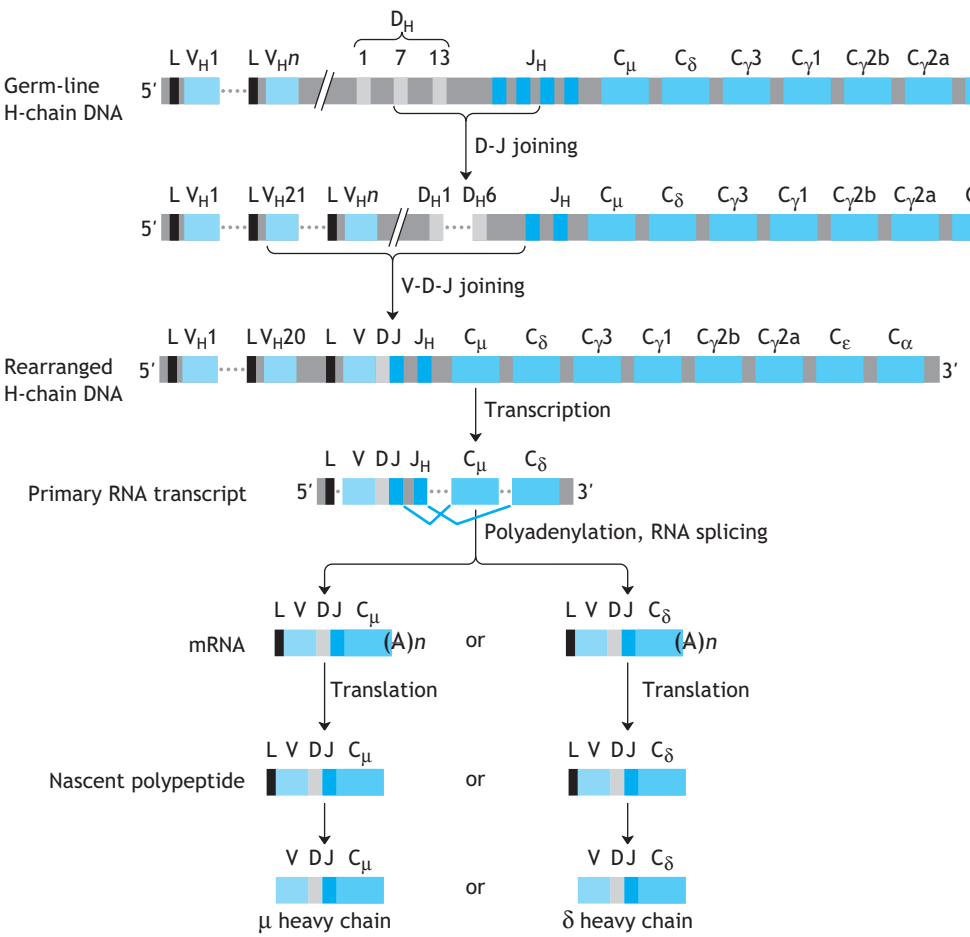

Figure 4–3. Ig H locus rearrangements.

H. A relatively small pool consisting of several hundred V, D, and J segments recombines to generate a very large potential pool (> 10^{10}) of V region-encoding genes (Table 4–1).

I. **Allelic exclusion** ensures that a single B cell expresses no more than one BCR.

1. Diploid species have an opportunity to express both alleles at a given locus.

2. Successful rearrangements at one allele signal inhibition of rearrangements at the homologous allele.

a. If rearrangement at the first H-chain locus is nonproductive, rearrangement is attempted at the second H locus.

b. If the first allele rearranges successfully, rearrangement at the second allele is inhibited.

c. If both alleles fail to productively rearrange, the cell may undergo apoptosis.

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Table 4–1. Various mechanisms contribute to the diversity in Ig molecules.

Mechanism	κ	λ	H
A pool of V, D, and J segments	40 V segments 5 J segments	30 V segments 4 J segments	50 V segments 27 D segments 6 J segments
Combinations of VDJ joining	$40 \times 5 = 200$	$30 \times 4 = 120$	$51 \times 27 \times 6 = 8262$
Imprecise joining	Significant amplification	Significant amplification	Significant amplification
Nucleotide addition or deletion	Significant amplification	Significant amplification	Significant amplification
Combinations of H + L polypeptides[a]	(200	+ 120)	$\times 8262 = 2.64 \times 10^6$
BCR editing[b]	+	+	+
Somatic hypermutation[b]	+	+	+

[a]This estimate of the potential Ig repertoire does not include the amplification derived from imprecise joining and nucleotide additions or deletions.
[b]The effects of these processes are difficult to estimate, can depend upon exposure to antigen, and affect both L and H chain gene expression (Chapter 9). BCR, B cell receptor.

d. Successful rearrangement of either κ allele inhibits rearrangements at both of the λ loci.
e. Failing to rearrange both κ alleles signals rearrangement at the λ locus.

IV. Antibody diversity has a genetic basis.

A. The **immune repertoire** of an individual is the sum of his or her Ig and TCR V regions.

B. Several mechanisms contribute to the generation of the **potential Ig repertoire** (Table 4–1).

1. Hundreds of V, D, and J segments are present in the germ line that can combine to code for Ig V regions.
2. Combinatorial association of these segments in a random fashion adds diversity.
3. Imprecise joining (joining flexibility) can generate several sequence variations spanning the recombined region.
4. Nucleotide addition or deletion can occur at joining sites during recombination.

a. Nucleotides are added by the enzyme **terminal deoxynucleotidyltransferase (TdT)** to generate **junctional diversity**.

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b. Because the HV3 region of Ig polypeptides is encoded by the sites of V(D)J joining, junctional diversity is greatest within this hypervariable region (Figure 4–3).

5. Combinatorial pairing of H and L polypeptide chains further expands the potential repertoire of Ig molecules.

6. Somatic hypermutation of V region sequences and **BCR editing** (Chapter 9) add to the diversity of mature B cell specificities.

C. The **utilized repertoire** of an individual can be different from the potential repertoire of the species.

1. Many recombinations are nonproductive and signal either cell death or a second recombination event.

2. Some V regions show specificity for self antigens resulting in the deletion of the clone expressing those antigen receptors.

3. Some H and L polypeptide chains do not pair to form functional antigen receptors.

4. At any one time the host may not possess sufficient numbers of B cells to accommodate expression of all potential BCR of the species.

5. Any expansion in a clone of effector or memory B cells can reduce the size of the available repertoire by limiting the space for newly emerging naive B cells with novel specificities.

6. The generation of memory B cells can increase the repertoire by signaling somatic hypermutation of V regions (Chapter 9).

V. A single B cell can express BCRs of different Ig classes.

A. A mature naive B cell in the periphery expresses both μ- and δ-containing membrane BCRs.

1. The primary RNA transcribed from a rearranged H locus gene contains exons for both μ and δ constant regions (Figure 4–4).

a. Differential processing of the RNA produces mRNAs that code for either μ or δ H chains.

b. The VDJ sequences of the two mRNA species are the same.

2. These two BCRs differ from one another only in their C_H domains.

a. The V regions and L chains of the two BCRs are identical.

b. The idiotypes and specificities of the two BCRs are identical.

3. At different stages in the differentiation of B cells (Chapter 9), RNA processing and translation determine whether membrane IgM, membrane IgD, or both are expressed by the cell.

BICLONAL MYELOMA

- *Very rarely patients with multiple myeloma will synthesize two different M components in their plasma.*
- *These monoclonal Igs belong to different Ig classes (eg, IgM and IgG) but typically have identical V region sequences.*
- *Antiidiotype antibodies specific for the combining site of one M protein react with the combining site of the second M protein.*
- *The disease process of myeloma is thought to begin at the pre-B or immature B cell stage, at which time V(D)J sequences are being established by recombination.*
- *Commitment to the H chain class occurs later, during which these rare multiple isotypic neoplasias arise.*

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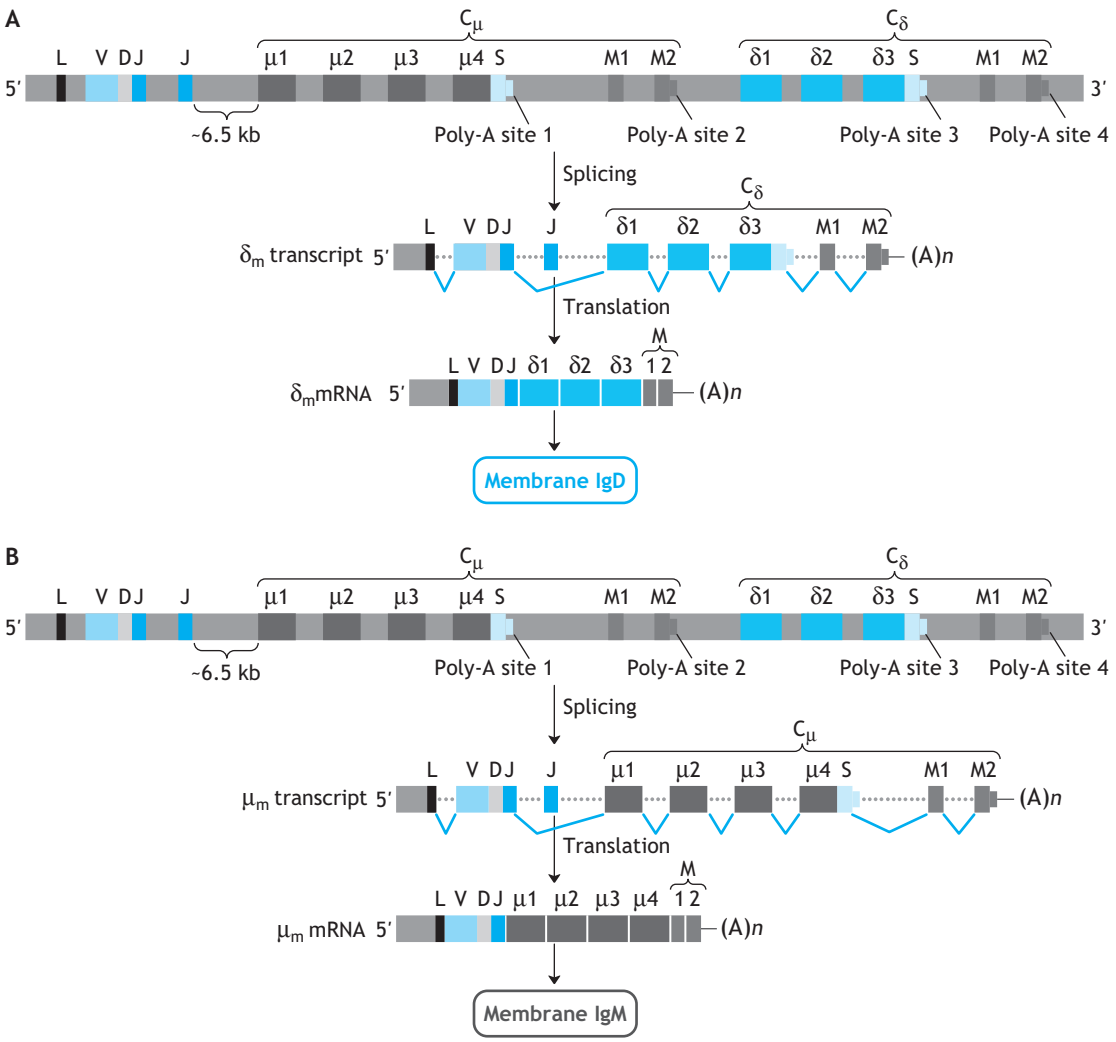

Figure 4–4. B cell receptors (BCRs) containing μ and/or δ heavy chains.

B. Normal B cells maintain their specificity as they undergo Ig class switching following antigen stimulation.

1. **Class (or isotype) switching** refers to a change from the expression of IgM and IgD to the expression of one of the other isotypes (ie, IgG).
   - **a.** Class switching involves a change in the C_H region of the heavy polypeptide chain of the Ig molecule.
   - **b.** During class switching, the L chain remains the same.
   - **c.** The V_H and V_L regions of the Ig, which determine specificity, remain the same during class switching.

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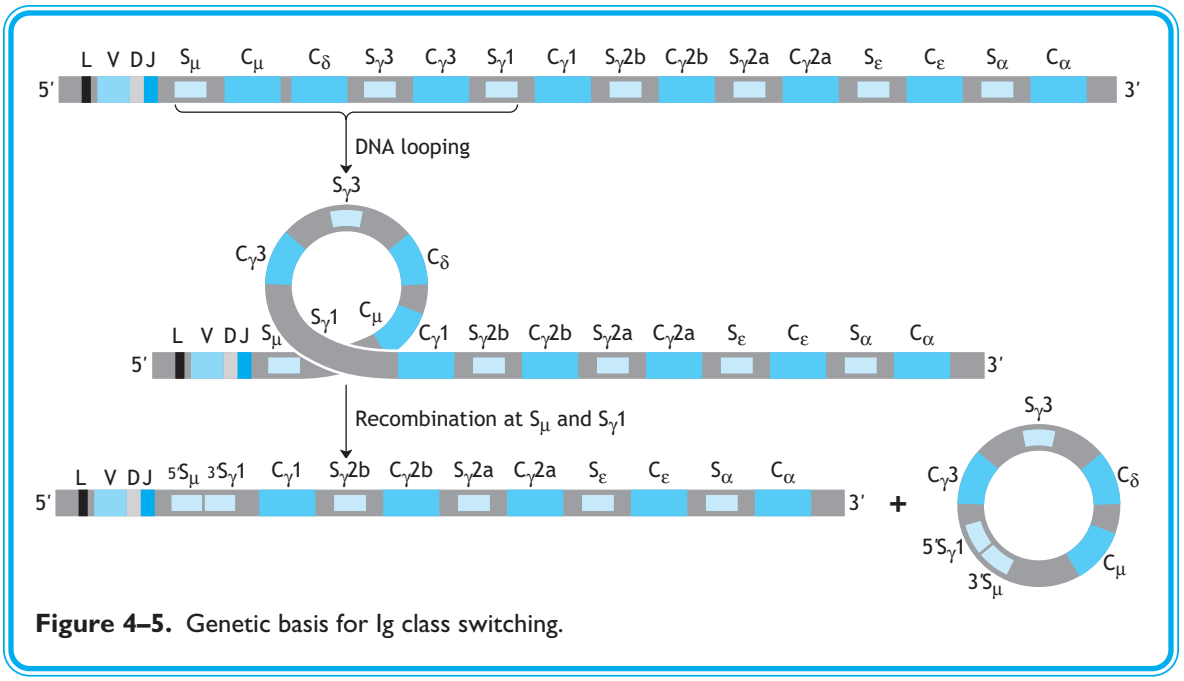

Figure 4–5. Genetic basis for Ig class switching.

2. At the DNA level, Ig class switching involves a change in the order of the C_H segments (Figure 4–5).
- **a.** DNA between the rearranged VDJ segment and the new C_H segment is looped out by recombination.
- **b.** Class switching is irreversible, because the intervening DNA is excised and discarded.
- **c.** Isotype switching always involves a new *downstream* (3′) C_H gene segment.
- **d.** A switch from IgM and IgD to IgG expression, for example, can be followed by a second switch to another isotype (eg, IgE).

C. Membrane Ig H chains differ from the secreted form of the same polypeptide only in the presence of membrane-spanning domains at their carboxy-termini (Figure 4–4).
1. A single primary RNA transcript is differentially processed to yield two different mRNAs that encode for either membrane or secreted heavy chains.
2. All of the Ig isotypes have membrane and secreted forms.
3. The membrane antigen receptor (BCR) and secreted antibody molecules of a clone of B cells have the same idiotype and specificity.

VI. Defining the genetic basis for Ig diversity and expression explains much of the unique behavior of B cells (Table 4–2).

A. B cells express antigen receptors that are membrane-bound forms of secreted antibody molecules.

B. Allelic exclusion ensures that the BCR expressed by a B cell is monospecific.

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Table 4–2. Molecular correlates of the clonal selection theory.

Prediction	Molecular Explanation
Lymphocytes are precommitted in their antigen specificity.	Gene rearrangement occurs in each lymphocyte during its differentiation in the bone marrow and thymus.
A single cell expresses receptors with a uniform antigen specificity.	Rearrangements that lead to BCR[a] or TCR[a] expression are followed by the inhibition of further Ig or TCR locus rearrangements (allelic exclusion).
All antigen receptors on a cell are uniform and identical.	Each antigen receptor variant on a cell uses the same rearranged V region segments.
Daughter cells retain the antigen specificity of the parental cell.	Once expressed, V region genes are relatively stable in lymphocytes.
The antigen receptor of a cell has a specificity identical to the antibody the cell produces.	The same V regions are used to encode for membrane and secreted Ig molecules.

[a]BCR, B cell receptor; TCR, T cell receptor.

C. The antigenic specificity of a B cell is maintained throughout its life span despite clonal expansion, memory cell production, antibody secretion, and isotype switching.

D. T cells utilize many of the same mechanisms to express an even more diverse set of antigen receptors.

CLINICAL PROBLEMS

Mary is a 3-year-old patient who presents with a fever, labored breathing, and shortness of breath. Her history includes recurrent bacterial infections (sinusitis and otitis media) since 1 year of age. She has been prescribed oral antibiotics as often as six times per year. After each course of treatment, the infections subside, but a recurrence of symptoms often follows within several weeks. Laboratory tests indicate a mild neutropenia, but no other hematological abnormalities. Her serum IgG and IgA levels are far below those of age-matched controls, whereas her serum IgM levels are significantly elevated. When immunized with tetanus toxoid, a vaccine she has received before, she makes no detectable IgG antibody response.

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1. Which of the following is the most likely cellular or molecular defect in this patient?

A. Failure of her B cells to undergo Ig class switching

B. A block in all B cell differentiation

C. Rag1 deficiency

D. Toll-like receptor deficiency

E. DiGeorge syndrome

A 2-year-old patient presents with a history of infections that suggests an immune defect, and the clinical laboratory reports serum IgG levels one-third that of age-matched controls. The child is ABO blood type A.

2. Which of the following findings would be more consistent with a diagnosis of H locus deletion affecting only C_γ segments than a complete absence of B cells?

A. Decreased IgM levels in her serum

B. The absence of follicles in her splenic white pulp

C. The absence of Ig in her saliva

D. The presence of B cells in the follicles of her lymph nodes

E. The lack of isohemagglutinins in her serum

You have isolated a population of plasma cells from a patient who was recently immunized with a protein vaccine. Her cells secrete IgG in vitro, but lack any membrane IgG.

3. Which of the following accounts for this finding?

A. DNA rearrangement following antigen stimulation deletes BCR-encoding gene segments.

B. The Ig H chain locus does not code for a membrane form of γ chains.

C. Differential RNA processing favors the synthesis of a secreted form of γ heavy chains.

D. Plasma cells that secrete IgG express IgA on their surface.

E. Only surface L chains are expressed by B cells.

You have a patient with an $IgG_1\kappa$ myeloma. Analysis of DNA from the myeloma cells indicates that the H and κ alleles that he inherited from his father (paternal) have been rearranged.

4. Which of the following loci could still be in the germ line configuration in these cells?

A. Maternal κ allele

B. Maternal λ allele

C. Paternal λ allele

D. Maternal H allele

E. All of the above loci could be in the germ line configuration.

You have a patient with multiple myeloma and examine a preparation of cellular mRNA from the myeloma cells by Northern blotting. The probe you use detects a $V_HD_HJ_H$ sequence that is unique to this particular myeloma cell. The results of this experiment indi-

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cate that the myeloma cells have four mRNA species of different sizes, each containing the target sequence.

5. Which one of the following lists of Ig polypeptides is probably encoded by these four mRNAs?
   A. μ, δ, γ, and α H chains
   B. κ, λ, μ, and δ chains
   C. Membrane μ, membrane δ, secreted μ, and secreted δ H chains
   D. Secreted μ, δ, κ, and λ chains
   E. Secreted μ, δ, α, and ε H chains

ANSWERS

1. The correct answer is A. Mary produces IgM, which rules out an absence of B cells or a Rag deficiency. The latter would cause a complete absence of both T and B cells, which would have resulted in the onset of viral and fungal infections shortly after birth. Mary's history of infections, serum IgG and IgA levels, and diminished antibody response suggest that she lacks the ability to class switch from IgM production to the more "mature" isotypes (IgG and IgA).
2. The correct answer is D. With γ chain gene deletions, mature B cells are still produced and can be found in the periphery. They simply fail to synthesize IgG antibodies after antigen stimulation. With a complete absence of B cells, follicles in the lymph nodes and spleen fail to develop.
3. The correct answer is C. Whereas mature B lymphocytes express membrane BCR molecules, plasma cells do not normally express membrane Ig. This decision in the B cell lineage to express membrane Ig, secreted Ig, or both is made at the level of RNA processing.
4. The correct answer is E. The H locus rearranges first, followed by either the κ or λ locus. If successful rearrangements had first been undertaken at the paternal H and κ alleles, then the maternal H and κ alleles would remain in the germ line arrangement. Because the κ locus was successfully rearranged in this cell, both λ alleles could have been suppressed and could have remained in the germ line configuration.
5. The correct answer is C. Because the probe detects only mRNAs with VDJ sequences of H chains, light chain mRNA should not be detected. Messenger RNA for μ and δ chains could be expressed by one myeloma cell by differential splicing, and these mRNA would differ only in their C_H regions. μ and δ H chains have different molecular masses, and their membrane forms, which are expressed by a portion of the myeloma cells, are longer than their secreted forms.

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CHAPTER 5
ANTIGEN RECOGNITION BY ANTIBODY

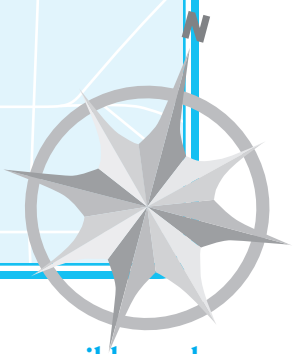

I. Interactions between antibodies and antigens are specific, reversible, and reach a state of equilibrium defined by the following equation:

$$Ab + Ag \leftrightarrows AbAg$$

A. The molecular forces that contribute to the strength of antibody–antigen (Ab–Ag) binding include ionic bonding, hydrophobic interactions, hydrogen bonding, and van der Waals interactions.

1. Affinity is a measure of the strength of binding between an antibody and a monovalent antigen.

a. Antibody affinities are reflected in **dissociation constants** (K_d) and typically range from 10^{-6} to 10^{-11} M.

b. The average affinity of an antiserum generally increases with repeated immunizations, a phenomenon referred to as **affinity maturation** (Chapter 9).

c. As a general rule, immunoglobulin (Ig) G antibodies have higher affinities than IgM antibodies.

2. Antibody avidity refers to the aggregate strength of Ab–Ag binding when multiple antibody-combining sites of an antibody molecule interact with more than one determinant of a multivalent antigen.

a. High avidity reactions are common with natural antigens that contain multiple copies of the same antigenic determinant (eg, polysaccharides).

b. Because of their pentameric structure, IgM antibodies generally have a higher avidity than IgG antibodies.

B. The **specificity** of Ab–Ag reactions is similar to the specificity that enzymes show for their substrates.

1. Antibodies can distinguish between sterioisomeric forms of chemical groups.

2. Cross-reactivity is the tendency of an antibody to react with more than one antigen.

a. Cross-reactive antigens (eg, bovine and equine serum albumin) share the same or similar antigenic determinants.

b. In general, **polyclonal antisera** are more cross-reactive than **monoclonal antibodies**.

c. B cell and T cell receptors (BCR and TCR) can also show cross-reactivity (Chapter 6).

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CROSS-REACTIVITY AND CROSS-PROTECTION

- *Immunity induced by vaccination, infection, or environmental exposure to antigens can lead to either beneficial or deleterious immunological cross-reactions (Table 5–1).*
- *Edward Jenner developed an effective means of eliciting cross-protective immunity to the variola (smallpox) virus by immunizing individuals with vaccinia virus, which causes cowpox.*
- *The nonpathogenic mycobacterium bacille Calmette-Guérin (BCG) induces in vaccinees cross-protective immunity against the causative agent of tuberculosis, Mycobacterium tuberculosis.*
- *Allergic responses to cross-reactive determinants on birch pollen can lead to food allergies to apples, plums, and hazelnuts.*

C. When antibodies bind to their respective antigens, neither is covalently modified, although both can undergo important conformational changes.

1. Some cell surface **Fcγ receptors** bind IgG Fc regions only after they have bound antigen.

a. These Fcγ receptors are generally of low affinity (K_d = 10^{-6}–10^{-7} M) and mediate opsonization by phagocytic cells.

b. High affinity Fcγ and Fcε receptors (K_d = 10^{-8}–10^{-10} M) can bind monomeric IgG and IgE, respectively, in the absence of antigen.

c. High-affinity Fc receptors mediate placental transfer of monomeric IgG.

2. The activation of **complement** by IgG and IgM antibodies requires antigen binding that reveals cryptic complement-binding sites within the C_H2 domains (Chapter 8).

3. Membrane Igs that serve as antigen receptors on B cells undergo conformational changes when their antigens are bound.

a. This permits protein–protein interactions between the C-terminal domains of membrane H chains and two other members of the receptor complex, Igα and Igβ.

b. BCR–Igα–Igβ interactions initiate transmembrane signaling in B cells (Chapter 9).

Table 5–1. Clinically important immunological crossreactions.

Antibody Specificity	Cross-reactive Antigens	Effect
Microbial carbohydrates	ABO erythrocyte antigens	Mediate transfusion reactions
Steptococcal M protein	Cardiac antigens	Rheumatic fever
Beef heart cardiolipin	Human cardiolipin	False positive tests for syphilis
House dust mite allergens	Shrimp	Food allergies
Timothy grass allergens	June grass allergens	Seasonal allergies
Methyldopa	Rh antigens	Autoimmune hemolytic anemia

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D. A complex formed between an antibody and its antigen is often referred to as an **immune complex**.
   1. Both circulating and tissue-bound immune complexes have proinflammatory effects (Chapter 13).
   2. Circulating soluble immune complexes typically form in antigen excess and deposit in the skin, blood vessel walls, joint spaces, and basement membranes of renal glomeruli.
   3. A number of important laboratory tests can detect immune complexes in body fluids or tissues and aid in diagnosing **immune complex diseases** (Chapters 13 and 16).

II. The measurement of Ab–Ag reactions is the basis for many clinical diagnostic tests in immunology and microbiology (Table 5–2).

A. **Serology** refers to techniques that measure the reactivity of serum antibodies with their antigens.

Table 5–2. Selected applications of immunoassays in the clinical laboratory.[a]

Measurement	Assay	Specific Examples
Ig concentration	Nephelometry	Serum IgG, IgM, IgA, and IgE
Monoclonal gammopathy	Immunoelectrophoresis Immunofixation	M component
Complement		
Individual components	ELISA	C1, C2, C3, C4
Total hemolytic activity	Complement fixation test	CH_{50}
Antibodies to infectious agents		
HIV	ELISA, Western blot	Anti-gp24, gp41, gp120, gp160
Streptococcus	Agglutination	Anticapsular polysaccharide
Treponema pallidum	Agglutination	VDRL test for syphilis
Autoimmunity		
Anti-Ig antibody	Passive hemagglutination	Rheumatoid factor
Antinuclear antibodies	Immunofluorescence	ANA, anti-dsDNA
Cell surface markers		
Normal lymphocytes	Flow cytometry	CD4, CD8, CD19
Tumor cells	Flow cytometry	CD10 on leukemia cells

[a]Ig, immunoglobulin; ELISA, enzyme-linked immunosorbent assay; HIV, human immunodeficiency virus; VDRL, Venereal Disease Research Laboratory; ANA, antinuclear antibody; dsDNA, double-stranded DNA.

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B. The relative concentration of an antibody is often expressed as a **titer**, which is the reciprocal of the greatest dilution of the antiserum that shows a reaction with its antigen.

C. Particulate antigens agglutinate when combined with their antibodies.

1. Hemagglutination occurs when antibodies to erythrocyte surface antigens cause aggregation of cells bearing the respective antigen.

a. In **blood typing**, agglutinating antibodies of known specificities (eg, anti-RhD) are used to determine the antigenic phenotypes of prospective donors and recipients.

b. In the **major cross-match**, cells from the donor are mixed with serum from the recipient as a means of detecting preformed recipient antidonor antibodies.

2. The **Coombs test** (Chapter 16), a specialized hemagglutination test, detects antibodies on erythrocytes or platelets.

a. In the Coombs test, the patient's cells are mixed with the **"Coombs reagent,"** which is an antihuman IgG.

b. IgG antibody-coated erythrocytes or platelets agglutinate in the presence of the Coombs reagent.

c. Agglutination can indicate the presence of antibodies against haptens (eg, drugs) bound to the cell surface or antibodies specific for endogenous erythrocyte antigens (eg, anti-RhD).

RH DISEASE OF THE NEWBORN

- *Rh incompatibility between Rh-negative mothers and their Rh-positive children can lead to the production of antibodies by the mother that cause hemolytic anemia in the fetus.*
- *First pregnancies are generally not affected, because the initial maternal IgM antibodies do not cross the placenta.*
- *Subsequent pregnancies are at risk due to isotype switching to IgG in the mother.*
- *A definitive diagnosis of Rh disease in an affected newborn can be made, in part, with the Coombs test, which detects IgG on the surface of the neonate's erythrocytes.*

3. The species or strain of a bacterium can be determined by serological agglutination tests.

a. Serological typing provides a more rapid identification of a bacterial species or group (eg, group A *Streptococcus* or *Salmonella* serogroups) than does culturing the specimen.

b. Agglutination assays can also reveal serotypes associated with specific diseases (eg, *Escherichia coli* serotype O157:H7 and hemorrhagic colitis).

D. Soluble antigens present at high concentrations form visible precipitates when combined with their antibodies.

1. Immunoprecipitation techniques are relatively insensitive and require microgram per milliliter to milligram per milliliter concentrations of antigen.

2. Large insoluble Ab–Ag precipitates can be detected by light scatter using an instrument known as a **nephelometer**.

3. The amount of immune precipitate that forms is a function of the Ab:Ag ratio (Figure 5–1).

a. At an optimum ratio, called **equivalence**, the maximum amount of precipitate is observed and neither free Ab nor free Ag is found in solution.

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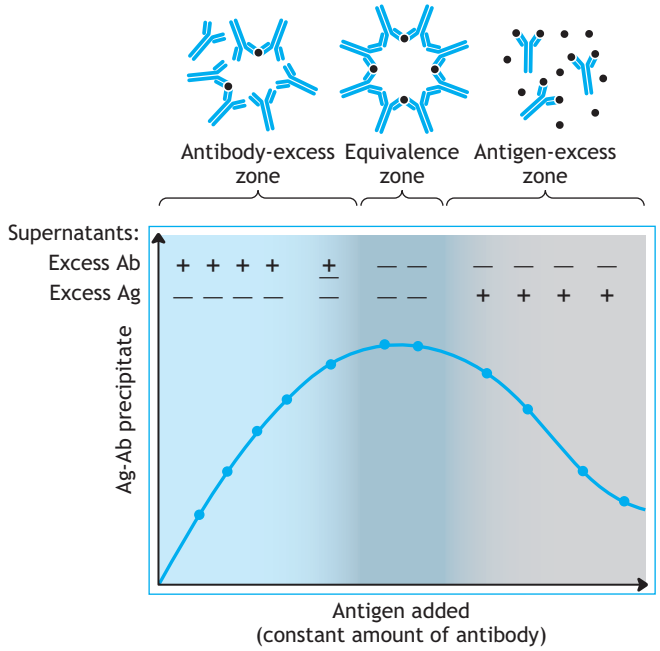

Figure 5–1. The precipitin curve. Ag, antigen; Ab, antibody.

b. In the range of **Ag excess**, small soluble Ab_1Ag_2 complexes are formed.

c. Large complexes are typically cleared by phagocytic cells, whereas smaller soluble complexes can cause **immune complex disease**.

4. Precipitated Ab–Ag complexes can also be visualized in agar gels.

a. In **agar gel immunodiffusion**, solutions of Ab and Ag diffuse toward one another resulting in the formation of a visible precipitate at the diffusion interface (Figure 5–2).

(1) A pattern of **identity** indicates that two antigens are identical with respect to the determinant(s) recognized by the antiserum.

(2) A pattern of **partial identity** occurs when two antigens share some, but not all, of their antigenic determinants.

(3) A pattern of **nonidentity** forms when two antigens have unique determinants not found in the other.

b. **Immunofixation**, which combines the technique of electrophoresis with immunoprecipitation, is used to analyze antigens in complex biological samples, such as serum (Figure 5–3).

(1) Test samples are first electrophoresed in an agar gel.

(2) The electrophoresed proteins are then detected with specific antibodies that precipitate the antigen.

(3) These insoluble immune precipitates are stained with a protein stain.

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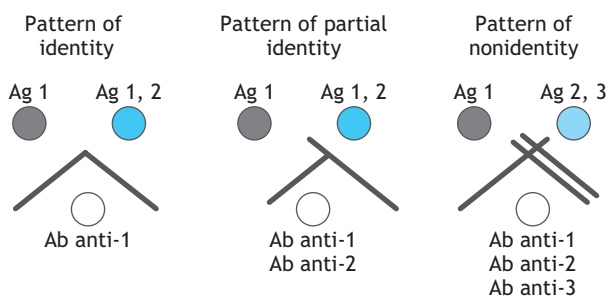

Figure 5–2. Agar gel immunodiffusion. Ag, antigen; Ab, antibody.

POLYCLONAL AND MONOCLONAL GAMMOPATHIES

- ***Hypergammaglobulinemia*** *can occur following repeated immunization, infection, or abnormal B cell differentiation, including neoplasia.*
- *A* ***polyclonal gammopathy*** *generally signals infection, whereas a* ***monoclonal gammopathy*** *indicates a benign or malignant condition affecting a single clone of B cells.*
- *Benign* ***monoclonal gammopathy of undetermined significance (MGUS)*** *is common in the elderly, occurring at a frequency of approximately 3% in persons over 70 years of age.*
- *Because many monoclonal conditions are malignant, it is important to determine whether a hypergammaglobulinemia is monoclonal.*
- *Immunofixation is used to ascertain whether the elevated γ-globulins have a single H chain class and L chain type, which means they are likely monoclonal.*

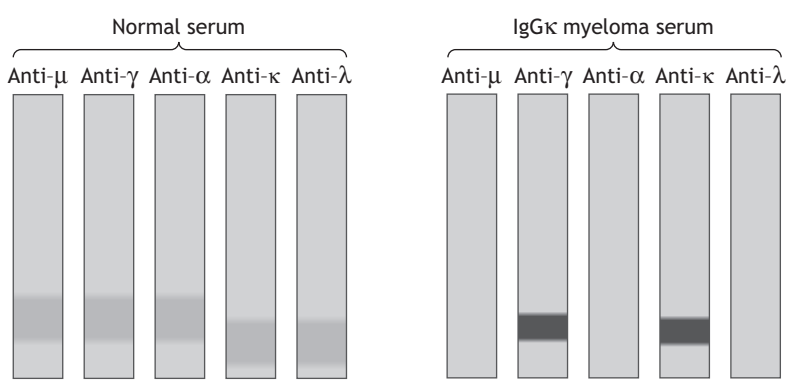

Figure 5–3. Detection of a monoclonal gammopathy by immunofixation.

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E. Sensitive immunoassays are required to detect antigens that exist at low concentrations (picogram per milliliter to nanogram per milliliter) in clinical samples.

1. Radioimmunoassays use radiolabeled antigens or antibodies.

a. The competitive radioimmunoassay measures the ability of a test sample (eg, patient serum) to compete with a radiolabeled antigen for binding to an immobilized antibody.

b. Immunoassays of this type require that dilutions of purified antigen be included as standards.

c. The **radioallergosorbant test** is a radioimmunoassay that measures the concentration of serum IgE antibody to a known allergen (Chapter 13).

2. Enzyme-linked immunosorbent assays (EIA or ELISA) use enzyme-conjugated antibodies (E-Ab) to detect antigens.

a. The E-Ab–Ag complexes are detected by their ability to convert a chromogenic substrate into a colored product.

b. Like radioimmunoassay (RIA), the ELISA can be used to measure antigen or antibody concentrations and shows sensitivity for antigens in solution in the picogram per milliliter range.

c. Many **home pregnancy tests** use ELISA technology to detect human chorionic gonadotropin in the urine.

3. Immunoblotting (Western blotting) uses either radiolabeled or enzyme-conjugated antibodies to detect antigens within a complex sample, such as serum or a tissue extract.

a. The sample is first electrophoresed in a polyacrylamide gel under conditions that separate antigens according to their molecular weights.

b. Separated proteins are then transferred from the gel to a membrane.

c. The membrane is treated with an E-Ab.

d. E-Ab–Ag complexes are detected by incubating the membrane with a chromogenic substrate, which forms an insoluble colored precipitate on the complex.

e. Western blots are often used to confirm initial screening tests, such as an ELISA.

F. Immunofluorescence assays use fluorescenated antibodies to detect tissue- or cell-bound antigens.

1. Because of their specificity, the most popular antibodies for this purpose are monoclonal antibodies.

2. The availability of multiple fluorochromes (dyes) enables polychromatic analysis of more than one antigen at a time.

3. Specialized equipment (eg, a fluorescence or confocal microscope or flow cytometer) is required to detect the fluorescence emitted from the stained sample.

4. Tissue immunofluorescence is routinely used to enumerate certain markers in tissue sections (eg, tumors).

5. Flow cytometry is a specialized application of immunofluorescence in which individual cells in suspension are analyzed for the expression of a given marker(s)(Figure 5–4).

a. The cell suspension (eg, blood) is first treated with the fluorescenated antibody to label the cell subset of interest.

b. The labeled cell suspension is then sprayed across the path of a laser to excite the fluorochrome.

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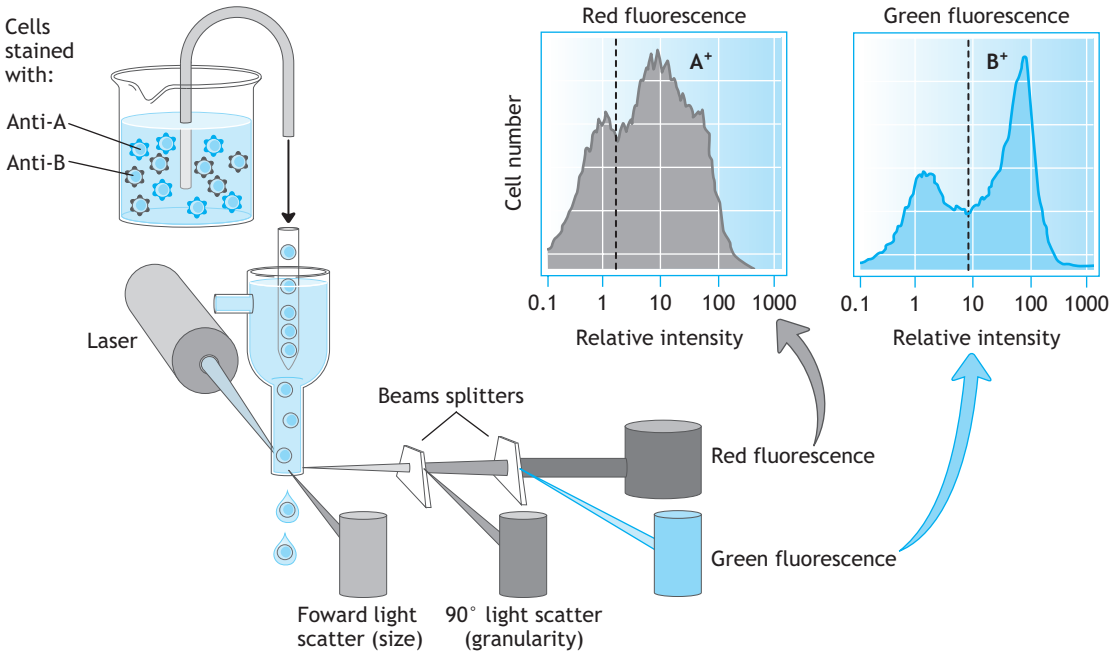

Figure 5–4. Schematic of a flow cytometer.

c. Individual cells are scored for their intensity of fluorescence emission.
d. Flow cytometry is the preferred technique for enumerating CD markers on human cells (Appendix I).
e. **Polychromatic flow cytometry** simultaneously detects multiple markers on a single cell (Figure 5–5).
f. Individual cells expressing these markers can be physically purified by a modification of flow cytometry called **fluorescence-activated cell sorting (FACS)**.

PHENOTYPING LYMPHOMAS AND LEUKEMIAS BY FLOW CYTOMETRY

CLINICAL CORRELATION

- *An important application of flow cytometry is the phenotyping of hematological malignancies using monoclonal antibodies to various CD markers.*
- *This approach can establish the number of different cell populations present in a sample, their lineage, and their stage of differentiation.*
- *For example, a typical B cell chronic lymphocytic leukemia (B cell-CLL) expresses membrane Ig, CD5, CD19, CD20, and CD22.*
- *By comparison, a plasmacytoma typically does not express membrane Ig, CD19, CD20, or CD22, but contains intracytoplasmic Ig.*

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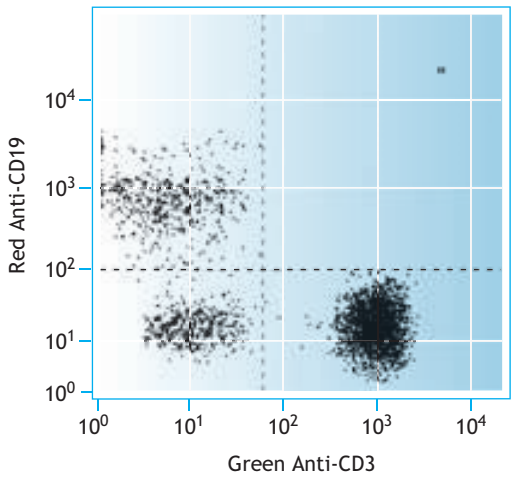

Figure 5–5. Multicolor flow cytometry analysis of human blood lymphocytes.

CLINICAL PROBLEMS

A 1-year-old child with a history of chronic sinusitis, otitis media, and pneumonia is suspected of having a primary immune deficiency. He has benefited from antibiotics and intravenous immunoglobulins and shows a very low concentration of serum IgG and no IgM. Analysis of the patient's lymph node cells by flow cytometry shows normal numbers of $CD3^+$ lymphocytes, but an absence of cells expressing membrane IgM.

1. Which of the following diagnoses is most consistent with the data presented for this patient?

A. Severe combined immune deficiency (SCID)

B. X-linked agammaglobulinemia (XLA)

C. Selective IgG deficiency

D. Light chain disease

E. B cell chronic lymphocytic leukemia

You decide to determine whether the patient in question 1 can mount a secondary antibody response to tetanus toxoid. Ten days after immunizing with the toxoid, you measure the titer of serum antibodies to the foreign protein.

2. Which of the following laboratory tests would be most appropriate for measuring this response?

A. Flow cytometry

B. ELISA

C. Immunofluorescence

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D. Immunoblotting (Western blotting)

E. Immunodiffusion in gels

You have a patient with recurrent infections and decide to examine a biopsy of her lymph node for potential structural abnormalities. Immunohistological staining reveals very few cells in the diffuse cortex that stain with a peroxidase-conjugated antibody to CD3 followed by a chromogenic peroxidase substrate. Unstained cells are present in the superficial cortex of the lymph node.

3. Which of the following diseases is consistent with this finding?

A. Toll-like receptor deficiency

B. Severe combined immunodeficiency (SCID)

C. Chronic granulomatous disease

D. DiGeorge syndrome

E. Multiple myeloma

A 32-year-old patient presents with lymphopenia, but no other hematological abnormalities. He has mucocutaneous candidiasis, a yeast infection of the mucous membranes, and is seronegative for HIV-1 by ELISA.

4. Which of the following flow cytometry findings with blood lymphocytes [peripheral blood mononuclear cells (PMBCs)] would nonetheless still support a diagnosis of HIV infection in this patient?

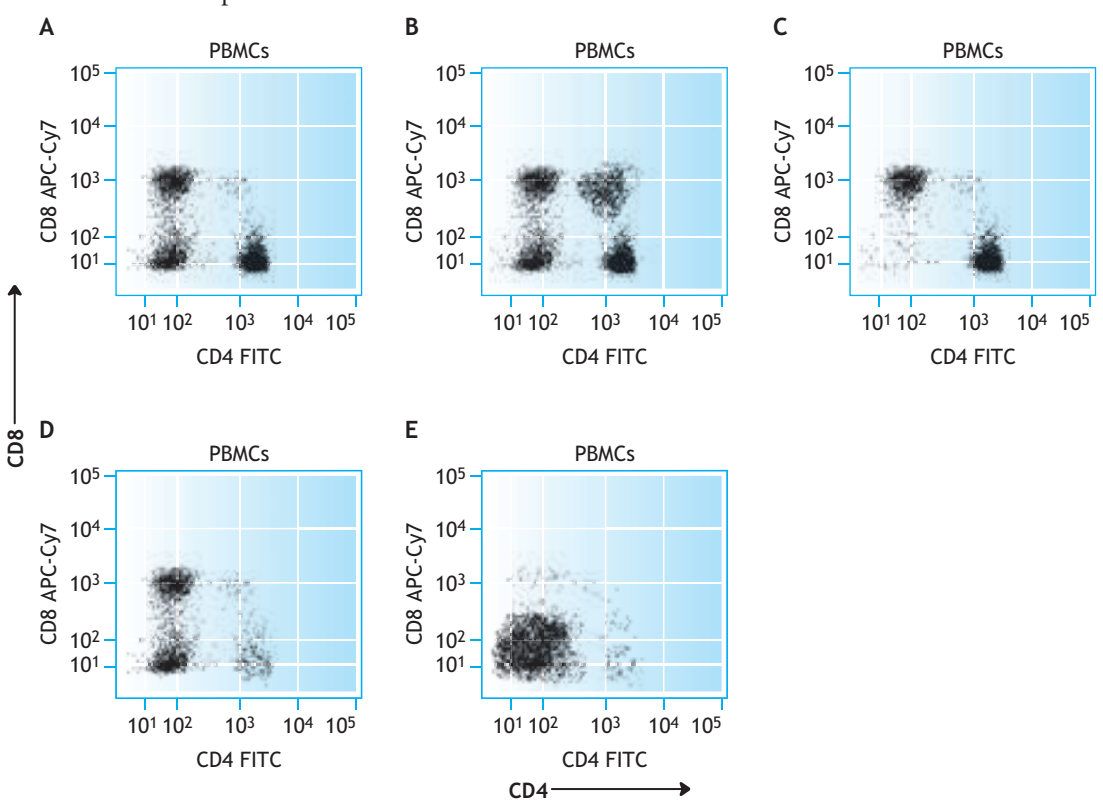

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A. Panel A
B. Panel B
C. Panel C
D. Panel D
E. Panel E

A patient with multiple myeloma shows proteinuria, and you wish to characterize the urinary protein. Using immunodiffusion, you react a rabbit antiserum specific for human IgG with the patient's serum and her urine.

5. Which of the patterns shown below would suggest that the urinary protein is an Ig L chain?

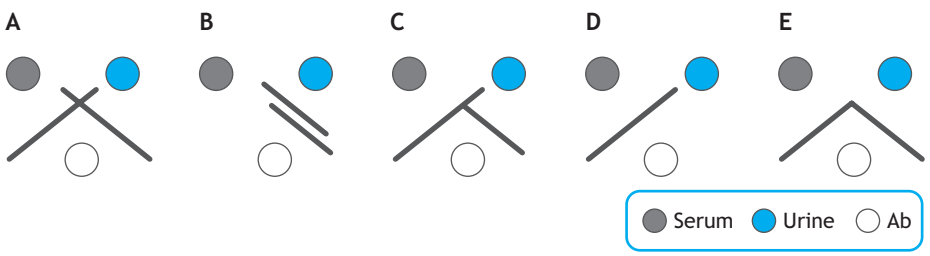

A. Pattern A
B. Pattern B
C. Pattern C
D. Pattern D
E. Pattern E

ANSWERS

1. The correct answer is B. The history and flow cytometry data are consistent with an antibody deficiency that results from the absence of peripheral B cells. Although SCID would also show aberrant B cell differentiation, T cells would be absent in this disease as well.

2. The correct answer is B. Among the choices, only ELISA is a quantitative assay. Immunoblotting is not quantitative, and immunodiffusion requires high concentrations of antibody and antigen to visualize immune precipitates.

3. The correct answer is D. DiGeorge syndrome (thymic dysplasia) results in a selective deficiency of T cells and an acellular appearance in T cell-dependent areas of the lymph nodes.

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4. The correct answer is D. There is a selective depletion of $CD4^+$ T cells in patients with HIV infections. For a comparison with the normal pattern, see panel A. The pattern in panel B is not typical for blood because it contains double-positive cells, which are normally seen only in the thymus.

5. The correct answer is C. The excess urinary proteins in myeloma are generally Ig L chains (Bence–Jones proteins), which would show a cross-reaction with the patient's serum monoclonal Ig (M component). Because the serum Ig would contain antigenic determinants on their H chains not found on the urinary L chains, a pattern of partial identity would appear.

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CHAPTER 6
T CELL RECOGNITION OF AND RESPONSE TO ANTIGEN

I. The T cell receptor (TCR) for antigen is a complex consisting of an antigen-specific heterodimer (TCR) and four additional peptides of the CD3 family (Figure 2–5).

A. TCR structure is similar to that of the B cell receptor (BCR) (Table 6–1).

1. The α, β, γ, and δ polypeptides are transmembrane proteins with short cytoplasmic domains.

2. TCR peptides have amino acid sequence homology with Ig peptides and belong to the **immunoglobulin gene superfamily**.

3. Each TCR peptide has a V domain and a C domain (eg, $V_\alpha C_\alpha$ in α chains), which are stabilized by intrachain disulfide bonds.

4. The two V domains (eg, $V_\alpha + V_\beta$) form a monovalent ligand-binding site much like an Ig Fab fragment.

5. The membrane-distal face of the TCRαβ and TCRγδ receptors that contact their ligands has a flat conformation, rather than the cleft seen in immunoglobulins (Igs) (Figure 6–1).

6. Of peripheral T cells 95% bear TCRs composed of αβ heterodimers; the remaining T cells bear TCRs composed of γδ heterodimers.

7. **CD3 γ, δ, ε, and ζ** polypeptide chains are transmembrane signaling components of the receptor complex.

8. The TCR is never expressed without CD3 peptides; the complete CD3 complex is never expressed on the cell surface without a TCR heterodimer.

CD3 DEFICIENCY

- *Rare immune deficiencies affecting the expression of the TCR result from natural mutations in the CD3 γ and ε chains.*
- *These patients present with severe lymphopenia at birth due to an inability of their thymocytes to signal through an early form of the TCR called the **pre-TCR**, which requires CD3 for its expression.*
- *Without a functional pre-TCR, immature thymocytes do not develop properly and cellular immunity is impaired (Chapter 10).*
- *Opportunistic viral and fungal infections occur early in life and require aggressive treatment.*

B. The expression of TCR genes requires their rearrangement by recombination during cell differentiation in the thymus (Figure 6–2).

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Table 6–1. Distinguishing features of the BCR and TCR.[a]

Feature	BCR	TCR
Antigen-specific component	Membrane Ig	αβ or γδ heterodimer
Receptor valence	Bivalent	Monovalent
Signaling peptides	Igα, Igβ	CD3 γ, δ, ε, ζ
Ligand	Native epitopes of proteins, carbohydrates, lipids, nucleic acids	Processed peptides plus MHC or glycolipids plus CD1
Isotype switching	Yes	No

[a]BCR, B cell receptor; TCR, T cell receptor; Ig, immunoglobulin; MHC, major histocompatibility complex.

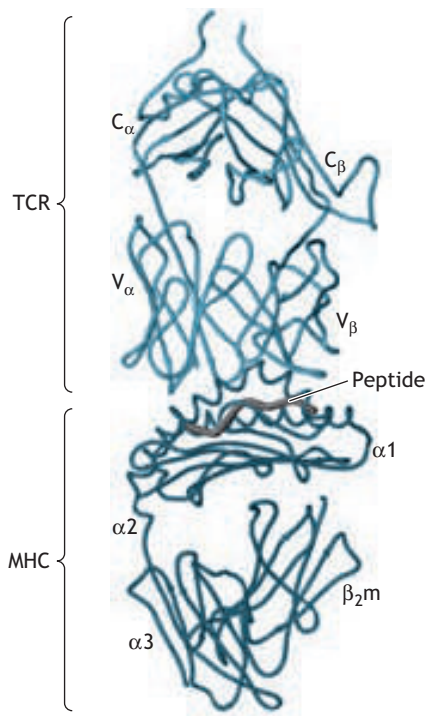

Figure 6–1. Model of a typical T cell receptor (TCR) showing the structure of the ligand-binding surface. MHC, major histocompatibility complex. (Adapted, with permission, from Garcia KC: An αβT cell receptor structure at 2.5 A and its Orientation in the TCR-MHC complex. Science 1996;274:209.)

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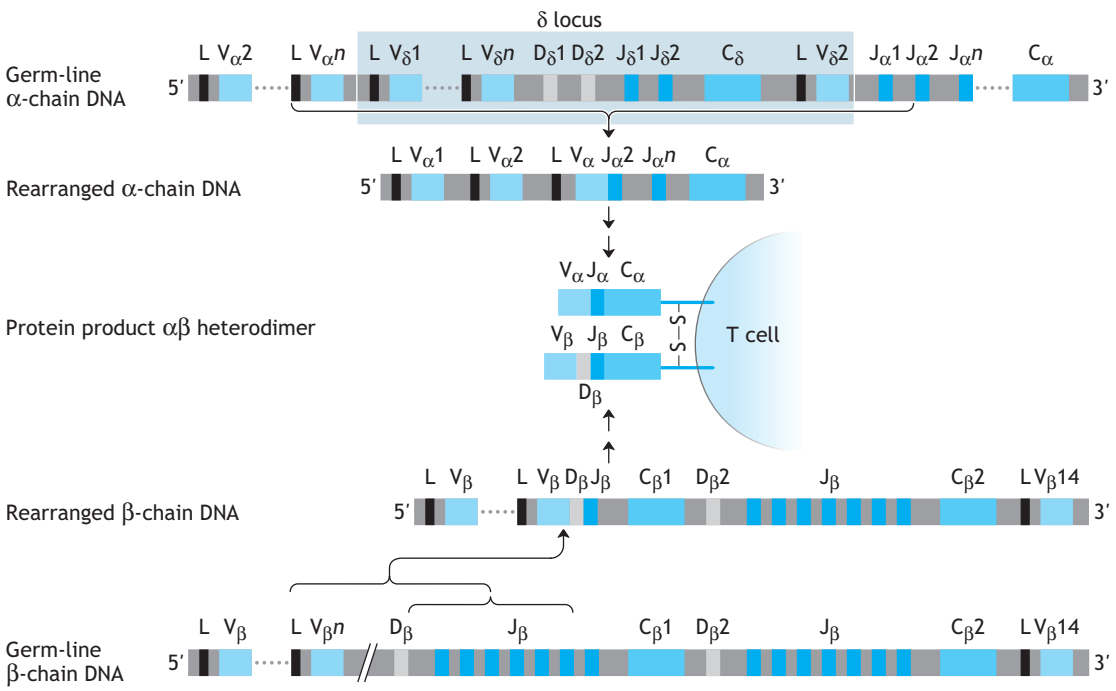

Figure 6–2. Germ line and rearranged α and β T cell receptor (TCR) gene loci.

1. The TCR genes are found at three genetic loci, α/δ, β, and γ.
2. Variable (V), joining (J), and constant (C) gene segments are found at each locus (Table 6–2).
3. Diversity (D) segments are present within the β and δ loci.

C. The diversity of the TCR repertoire arises from genetic mechanisms that are similar to those used to create a diverse set of Ig molecules.

Table 6–2. TCR locus gene segments.[a]

Segment	TCRα	TCRβ	TCRγ	TCRδ
V	50	57	14	3
D	0	2	0	3
J	70	13	5	3
C	1	2	2	1

[a]TCR, T cell receptor.

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1. There are several hundred V, D, and J segments that recombine randomly to create a pool of rearranged TCR V genes.
2. Imprecise joining and nucleotide addition add diversity.
3. Combinatorial association between the α and β or the γ and δ chains further expands the repertoire.
4. TCR editing occurs infrequently, and there is no somatic hypermutation of TCR V region sequences as there is for BCR V region genes.

TCR REARRANGEMENTS IN CANCER

- *The molecular diagnosis of human T cell leukemias and lymphomas is greatly aided by showing that they are monoclonal and express a TCR with a uniform V_α or V_β region.*
- *This can be accomplished by molecular techniques, such as the polymerase chain reaction (PCR), that demonstrate the proliferating cells have rearranged a uniform TCR V_α or V_β segment.*
- *This type of molecular approach aids in early diagnosis and monitoring the status of the neoplastic clone during therapy.*

D. The natural ligand for the TCR is a foreign peptide plus a host MHC molecule.
1. The TCR recognizes peptides derived from foreign protein antigens that are bound to a major histocompatibility complex (MHC) molecule and presented by an antigen-presenting cell (APC).
2. The complementarity determining regions (CDRs) of the TCR make contact with amino acid residues of both the peptide and the MHC molecule (Figure 6–1).

E. **Superantigens** produced by microbes can bind the TCR and the MHC outside the peptide-binding site.
1. *Staphylococcus* and *Streptococcus* species produce exotoxins that act as superantigens.
2. Microbial superantigens cross-link TCR V_β regions to MHC class II molecules.
3. Binding of superantigens to the TCR induces polyclonal activation of T cells.

TOXIC SHOCK SYNDROME

- ***Toxic shock syndrome (TSS)*** *is a systemic disease associated with vaginal or surgical wound infections with the gram-positive bacterium Staphylococcus aureus.*
- *S aureus produces a superantigen, called* ***toxic shock syndrome toxin (TSST)****, which activates $CD4^+$ T cells to produce massive quantities of inflammatory cytokines.*
- *The systemic nature of the inflammatory response manifests as fever, coagulopathies, extreme hypotension, skin rash and exfoliation, and diarrhea.*

F. **Natural killer T (NKT) cells** express an unusual form of the TCR.
1. **Invariant NKT cells (iNKT cells)** express a uniform α chain composed of a single V_α region called $V_\alpha 24$.
2. The β chain of the iNKT cell TCR is created by recombination using only a subset of the V_β gene segments.
3. The known ligands of the iNKT cell TCR are glycolipids that are presented by CD1 molecules, not MHC molecules (Chapter 7).
4. iNKT cells produce cytokines and become cytotoxic when activated through their TCR.

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II. Optimum T cell activation by antigen requires TCR stimulation and signals derived from the APC.

A. Compared to antibodies, TCRs bind their ligands with relatively low affinity (K_d 10^4–10^5 M).

B. The binding between a T cell and its APC is strengthened by the T cell **adhesion molecules** LFA-1 and CD2 (Table 6–3).

C. **Coreceptors** on T cells augment the intracellular signal transduction pathways that are initiated by the TCR–CD3 complex.

1. Many coreceptors promote TCR signaling by phosphorylating **immunotyrosine activation motifs (ITAMs)** of CD3.
2. T cells that express TCR specific for peptide-MHC *class II* complexes use **CD4** as a signaling coreceptor.
3. T cells that express TCR specific for peptide-MHC *class I* complexes use **CD8** as a coreceptor.
4. **CD28** provides important coactivation signaling for T cells.
5. **CD154** is a ligand for the CD40 coreceptor found on B cells.

D. **Cytokines** provide a second source of costimulatory signals (Chapter 12).

HYPER IGM SYNDROME

- *Children with X-linked **hyper IgM syndrome** show elevated levels of serum IgM, but extremely low concentrations of IgG, IgA, and IgE.*
- *Their activated T cells lack **CD154**, which results in impaired Th cell function and B cell signaling.*
- *Impaired Ig class switching in B cells results in elevated IgM antibody levels.*
- *With the failure to produce opsonizing IgG antibodies, infections with pyogenic (pus-forming) bacteria are common in these patients.*

Table 6–3. Adhesion molecules and coreceptors on T cells.[a]

T Cell Coreceptor	Ligand on APC	Cells That Express the Receptor Ligand
LFA-1	ICAM-1	Endothelial cells, many others
CD2	CD58	Many cells
CD4	MHC class II	Dendritic cells, B cells, macrophages
CD8	MHC class I	Nearly all nucleated cells
CD28	B7	Dendritic cells, activated B cells, macrophages
CD154	CD40	Dendritic cells, B cells, macrophages, others

[a]APC, antigen-presenting cell; LFA-1, lymphocyte function-associated antigen 1; ICAM, intercellular adhesion molecule; MHC, major histocompatibility complex.

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III. Signaling through the TCR leads to gene transcription.

A. The binding of the TCR to it ligand recruits the CD3 peptides to the αβ chains via charge interactions in their transmembrane domains.

B. **ITAMs** in the cytoplasmic tails of CD3 peptides are sites for the assembly of signaling intermediates, including the kinase **ζ-associated protein-70 kDa (ZAP-70)** (Figure 6–3).

1. ZAP-70 becomes phosphorylated and, in turn, phosphorylates **phospholipase Cγ (PLCγ)**.

a. PLCγ hydrolyzes the membrane phospholipid phosphatidylinositol 4,5-biphosphate (PIP_2) producing **diacylglyceride (DAG)** and **inositol 1,4,5-triphosphate (IP_3)**.

(1) DAG activates **protein kinase C (PKC)**, which activates the **nuclear factor-κB (NFκB)** transcription factor pathway (Figure 6–4).

(2) IP_3 mobilizes intracellular Ca^{2+}, which activates **calmodulin**.

(3) Ca^{2+}/calmodulin-dependent enzymes, including the phosphatase **calcineurin**, are activated.

(4) Calcineurin mediates *de*phosphorylation of the latent transcription factor **nuclear factor of activated T cells (NFAT)**.

2. ZAP-70 also phosphorylates adapter proteins that lead to the activation of the G protein-mediated Ras/Rac pathways.

a. **Mitogen-activated protein (MAP) kinases** are then activated.

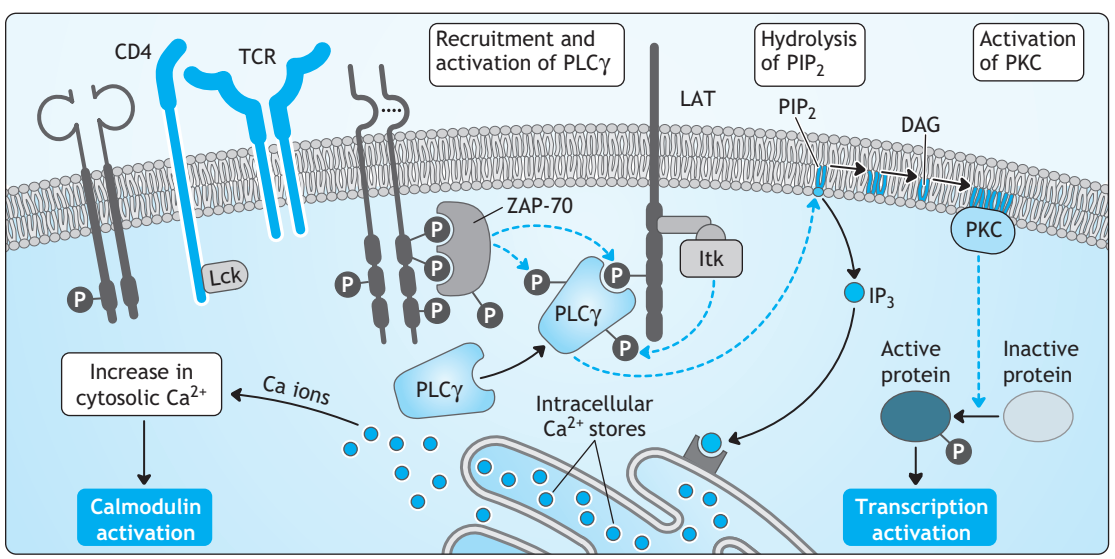

Figure 6–3. Intracellular signaling events accompanying T cell activation. PLC, phospholipase C; PIP_2, phosphatidylinositol 4,5-biphosphate; PKC, protein kinase C; ZAP-70, ζ-associated protein-70 kDa; LAT, linker for activation of T cells; DAG, diacylglyceride; IP_3, inositol 1,4,5-triphosphate.

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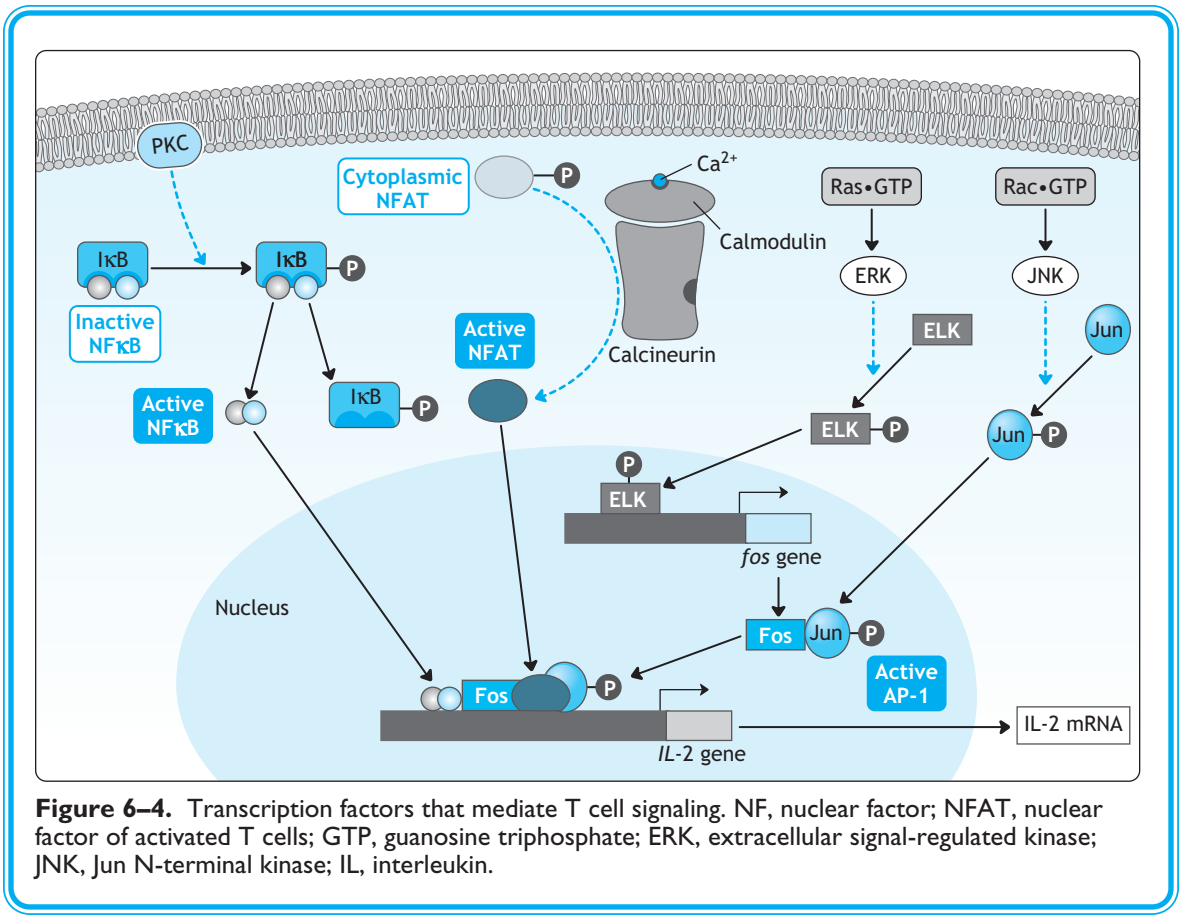

Figure 6–4. Transcription factors that mediate T cell signaling. NF, nuclear factor; NFAT, nuclear factor of activated T cells; GTP, guanosine triphosphate; ERK, extracellular signal-regulated kinase; JNK, Jun N-terminal kinase; IL, interleukin.

b. The MAP kinases phosphorylate and activate the **AP-1** family of transcription factors (Figure 6–4).

C. The transcription factors NFκB, NFAT, and AP-1 act coordinately to initiate the transcription of important T cell genes.

1. NFAT regulates the transcription of the interleukin (IL)-2, IL-4, interferon (IFN)-γ, and tumor necrosis factor (TNF)-α genes.

2. NFκB transcription factors induce the expression of the IL-2, IFN-γ, and TNF-α genes.

3. AP-1 activates transcription of the IL-2 and many other cytokine genes.

CYCLOSPORINE AND TRANSPLANTATION

- *Cyclosporine and the related drug FK-506 (Tracolimus) have proven effective in managing allograft rejection episodes that are mediated by activated T cells.*
- *Both drugs inhibit the cellular phosphatase calcineurin and thereby diminish NFAT activation and cytokine gene expression.*
- *The use of these powerful immunosuppressive drugs has allowed clinical transplantation to be performed successfully even when some genetic disparity exists between donor and host (Chapter 17).*

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D. Coreceptors augment signaling initiated by the TCR (Figure 6–3).
1. CD4 and CD8 binding to MHC molecules recruits the kinase **Lck** to the TCR complex.
2. Lck then phosphorylates the CD3ζ ITAM residues, which promotes ZAP-70 recruitment to the complex.
3. CD28 coreceptor binding to its ligand, B7 on dendritic cells, recruits PLCγ to the cell membrane.
4. TCR ligation in the absence of coreceptor signaling can lead to **anergy** (unresponsiveness) in T cells.
a. Clonal anergy is important in maintaining unresponsiveness to certain self antigens (Chapter 16).
b. Conversely, the loss of clonal anergy among T cells that bear receptors for autoantigens can result in autoimmunity.

IV. The functions of antigen-activated T cells emerge after several cycles of cell division and differentiation.

A. Most activated $CD4^+$ T cells express helper activity by secreting cytokines that act on other immune system cells.
1. The $CD4^+$ T helper population can be further subdivided into the Th1 and Th2 cell subsets based upon the cytokines they secrete (Table 6–4 and Figure 6–5).

Table 6–4. Th1 and Th2 $CD4^+$ T cell subsets.[a]

Cytokine	Th1 Cells	Th2 Cells	Principal Functions
IL-2	++	–	Lymphocyte proliferation
IFN-γ	++	–	Macrophage activation Inhibition of IL-4 effects
LT (TNF-β)	++	–	Cytotoxicity
GM-CSF	++	+	Monocyte and dendritic cell differentiation
IL-4	–	++	B cell activation; Ig class switching; mast cell growth; inhibition of Th1 pathway
IL-5	–	++	B cell activation; Ig class switching; eosinophil growth and differentiation
IL-10	–	++	Inhibition of macrophage and lymphocyte activation
IL-13	–	++	Induction of mucus secretion; inhibition of IFN-γ action

[a]IL, interleukin; IFN, interferon; LT, lymphotoxin; TNF, tumor necrosis factor; GM-CSF, granulocyte macrophage colony-stimulating factor; Ig, immunoglobulin.

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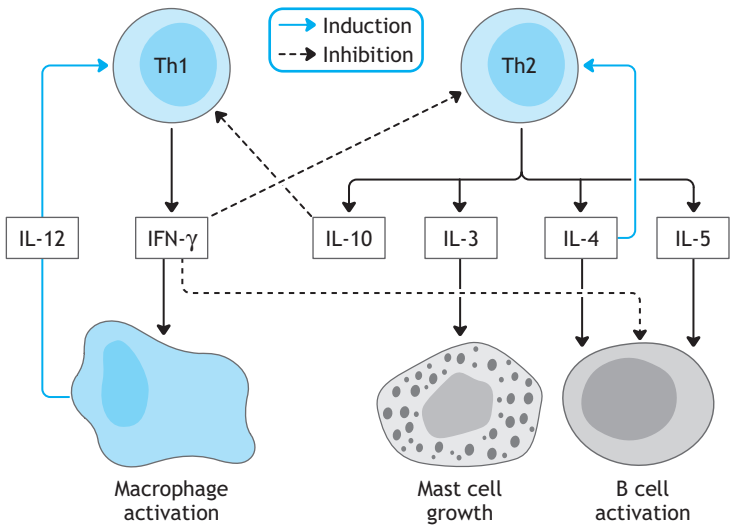

Figure 6–5. Cross-regulation of the Th1 and Th2 cell subsets. IL, interleukin.

a. The **Th1 cell** subset produces cytokines primarily associated with **cell-mediated immunity** (ie, cytotoxic T cell growth and macrophage activation).
b. The **Th2 cell** subset produces cytokines primarily associated with **humoral immunity** (ie, B cell activation, proliferation, differentiation, and Ig class switching).

2. Some of the cytokines produced by the two Th cell subsets promote the development of their respective subset.
   a. IL-4 is an important inducer of the Th2 response.
   b. IFN-γ favors the development of a Th1 response.
3. Each subset produces at least one cytokine that inhibits the functions of the other subset pathway (Figure 6–5).
   a. IL-10 and IL-4 produced by Th2 cells inhibit IL-12 production by APCs.
   b. IL-4 antagonizes the macrophage-activating effects of IFN-γ.
   c. IFN-γ produced by Th1 cells inhibits the proliferation of the Th2 cell subset.
   d. IFN-γ antagonizes the B cell-activating effects of IL-4.
4. Dedicated transcription factors mediate the genetic control of Th1/Th2 development.
   a. **T-bet** is activated by IFN-γ and promotes Th1 cell development.
   b. **GATA-3** favors the development of a Th2 cell response.

B. Several populations of T cells express cytotoxic activity against foreign target cells (Table 6–5).

1. Conventional $CD8^+$ **cytotoxic T lymphocytes (CTL)** kill targets expressing foreign peptides and MHC class I molecules.
2. Some $CD4^+$ T cells are cytotoxic for targets expressing foreign peptides and MHC class II molecules.

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Table 6–5. Cytotoxic lymphocytes.[a]

Property	CTL	NKT Cell	NK Cell
Receptors	TCRαβ; TCRγδ	Invariant TCRαβ	a
Receptor ligands	Peptides + MHC class I	Lipids and glycolipids + CD1	a
Surface markers	CD8 > CD4	CD8, CD4, and NK cell markers	NK cell markers (eg, CD161)
Functions	Cytotoxicity and cytokine production	Cytotoxicity and cytokine production	Cytotoxicity and cytokine production
Pathogens recognized	Viruses and intracellular bacteria	Unknown	Viruses

[a]For a description of the diverse NK cell receptors and their ligands, see Chapter 10. CTL, cytotoxic T cells; NKT, natural killer T; NK, natural killer; TCR, T cell receptor.

3. iNKT cells are cytotoxic against cells expressing glycolipid antigens presented by CD1 molecules.
4. All of these cytotoxic T cells require direct contact with their target cells and induce death by apoptosis (Figure 6–6).
   - **a.** CTL reorient their killing components toward the cellular pole in contact with their target cell.
   - **b.** Membrane-bound cytosolic **granules** of the cytotoxic cell then fuse with the cell membrane.
     - ***(1)*** **Perforin** is a granule protein that polymerizes in the target cell membrane and facilitates the delivery of granzymes.
     - ***(2)*** **Granzymes** are serine proteases that cleave caspases and initiate apoptosis in the target cell.
   - **c.** **Fas ligand**, which is expressed on activated T cells and NKT cells, can induce apoptosis.
     - ***(1)*** Fas ligand binds to a widely distributed receptor called **Fas**.
     - ***(2)*** Fas contains death domains that recruit and activate the cytosolic caspases within the target cell.
   - **d.** Cytotoxic cells secrete TNF-α and **lymphotoxin (LT)**, which bind to **TNF receptors**.
     - ***(1)*** TNF receptors contain death domains that recruit adaptor proteins and activate caspases.
     - ***(2)*** TNF receptors can also activate transcription factors that regulate gene expression (Chapter 12).
5. After delivering a lethal hit, the cytotoxic cell dissociates from its target cell and repeats the process with another target cell.

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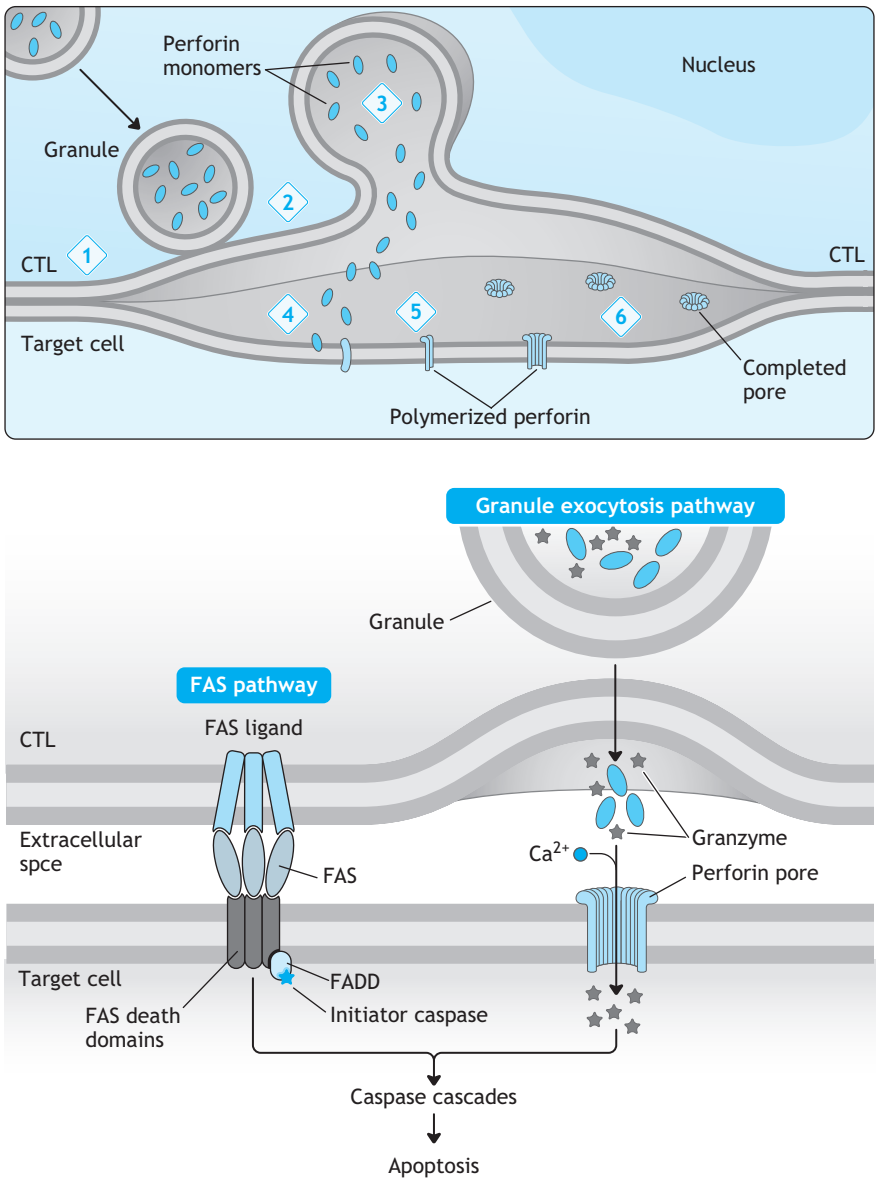

Figure 6–6. Conjugate formation and cell-mediated lysis by a cytotoxic T cell (CTL). (1) CTL-target cell contact, (2) granule fusion, (3) degranulation, (4) perforin insertion into target cell membrane, (5) polymerization of perforin, (6) pore formation

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CLINICAL PROBLEMS

Infection of cells with certain herpes viruses leads to a decrease in the expression of class I MHC molecules by the infected cells.

1. For which of the following cytotoxic cells would this *decrease* its ability to recognize the virus-infected cell?

A. $CD4^+$ T cell

B. $CD8^+$ T cell

C. NK cell

D. NKT cell

E. NK and NKT cell

A patient in renal failure received a kidney transplant from an unrelated donor. The patient was treated immediately with cyclosporine. Three weeks posttransplant, he developed an infection with cytomegalovirus that was attributed to his immunosuppressive therapy.

2. A decrease in which of the following responses would best explain this type of opportunistic infection?

A. Transcriptional activation in B cells

B. Ca^{2+} mobilization in macrophages

C. Cytokine gene expression in T cells

D. Neutrophil chemotaxis

E. Signaling through the BCR

Ronald is a 2-year-old boy who presents with a 1-year history of recurrent sinus infections caused by gram-positive bacteria, including Group A streptococci. He has not had infections with viruses or fungi. He was successfully treated with antibiotics in the past, but his infections often returned after treatment ended. Laboratory tests indicate an elevated titer of anti-A and anti-B isohemagglutinins, but an IgG level that is less than 5% of the normal level for his age.

3. Which of the following mechanisms or diseases would be most consistent with this clinical picture?

A. Bruton's X-linked agammaglobulinemia

B. A deficiency of ZAP-70

C. DiGeorge syndrome

D. A lack of CD154 expression

E. HIV-1 infection

Mary is an 11-year-old child with asthma. Allergy skin testing has revealed allergic reactions to 10 different household and outdoor allergens.

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4. If you were to design an experimental therapy directed at reducing cytokine production in this disease, which of the following cytokines would be the best target of this therapy?
   A. IL-1
   B. IL-2
   C. IL-4
   D. IL-8
   E. IL-12

A patient with recurrent viral infections has normal numbers of blood lymphocytes, but the cells do not express granzymes when activated in vitro.

5. A mutation in the gene encoding which of the following signaling intermediates would produce this phenotype?
   A. Lck
   B. Fas
   C. MyD88
   D. ZAP-70
   E. Btk

ANSWERS

1. The correct answer is B. Among the choices, only $CD8^+$ T cells require MHC class I molecules for their recognition of viral peptide antigens. The expression of this protein can be inhibited by viruses that interfere with the synthesis of β_2-microglobulin, which is shared by MHC class I and CD1 molecules (Chapter 7).
2. The correct answer is C. Cyclosporine inhibits the phosphatase calcineurin, which is important in activating the transcription factor NFAT. NFAT regulates a number of cytokine genes in T cells, including those that coinduce virus-specific $CD8^+$ cytotoxic T cells to differentiate (eg, IL-2).
3. The correct answer is D. Elevated IgM antibody together with very low or absent IgG is an indication that the patient's B cells do not switch Ig class efficiently. This is typical of hyper IgM syndrome type 1, the congenital absence of CD154. The patient does not lack B cells, but fails to receive the proper signal from Th cells.
4. The correct answer is C. IL-4 plays a central role in the development of allergy by promoting Ig class switching to IgE and inducing more Th2 helper cells that produce IL-4. Mast cells are the source of inflammatory mediators in asthma, and their growth is also promoted by IL-4 (Chapter 13).
5. The correct answer is D. ZAP-70 deficiency causes a decreased signaling in both $CD4^+$ and $CD8^+$ T cells. Granzyme expression is a marker for activated cytotoxic lymphocytes.

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CHAPTER 7
MAJOR HISTOCOMPATIBILITY COMPLEX

I. The principal function of the major histocompatibility complex (MHC) of genes is to regulate antigen recognition by T cells.

A. In the thymus, MHC molecules determine the content of the T cell receptor (TCR) repertoire.

1. Clones of thymocytes expressing TCRs that recognize foreign peptide antigens presented by the host's own MHC molecules are retained (Chapter 10).

2. Clones of thymocytes with TCRs that recognize peptide antigens presented by nonhost MHC molecules are deleted.

3. Mature thymocytes leave the thymus bearing TCRs capable of recognizing foreign peptides + self MHC in the periphery.

B. In the postthymic environment, the MHC controls antigen recognition by mature T cells.

1. The TCR recognizes antigenic peptides in the periphery only when they are complexed with a self MHC molecule.

a. Antigen recognition by T cells is "MHC restricted."

b. The TCR has a dual specificity for "altered self" (ie, self MHC + a foreign peptide).

2. MHC genes are **immune response genes** that determine the magnitude of T cell activation by foreign protein antigens.

C. MHC genes control the activation of natural killer (NK) cells by two mechanisms (Chapter 10).

1. MHC gene products present peptides to NK cell **activating receptors**.

2. MHC glycoproteins are also recognized by **inhibitory receptors** that suppress NK cell activation.

D. The MHC serves as the most important genetic barrier to organ transplantation between two unrelated individuals of a species.

1. In organ transplantation, the MHC molecules on a donor's tissues can be viewed by the recipient's T cells as foreign.

a. In this context MHC molecules are **alloantigens**, antigens expressed by some, but not all, members of a species.

b. MHC alloantigens stimulate vigorous T cell responses leading to graft rejection (Chapter 17).

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II. MHC genes encode two classes of polypeptides that control antigen recognition by T cells.

A. MHC class I gene products present foreign peptides to $CD8^+$ T cells.

1. Antigen recognition by $CD8^+$ T cells is restricted by MHC class I molecules.

2. Only peptides bound to MHC class I molecules activate $CD8^+$ T cells.

3. The three MHC class I genetic loci in human beings are called *human leukocyte antigen-A (HLA-A), HLA-B,* and *HLA-C.*

4. Each HLA class I gene encodes an ~45-kDa α polypeptide chain.

a. Class I α chains are always expressed on the cell surface noncovalently associated with a 12-kDa invariant chain called **β_2**-microglobulin (Figure 7–1).

b. Class I α chains are integral membrane proteins with three external domains.

(1) Amino acids within the membrane-distal α1 and α2 domains are highly variable.

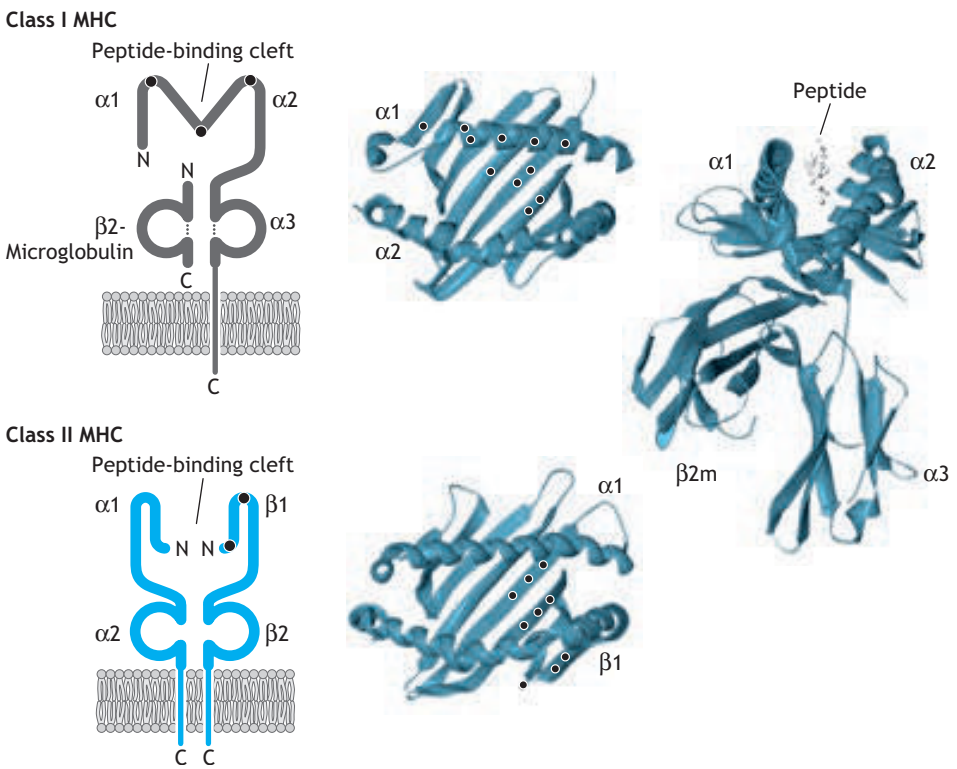

Figure 7–1. Structure of major histocompatibility complex (MHC) molecules. β2m, β_2-microglobulin. (Top: Adapted, with permission, from Bjorkman PJ: Structure of the human class I histocompatibility antigen, HLA-A2. Nature 1987;329:506.) (Bottom: Adapted, with permission, from Brown JH: Three-dimensional structure of the human class II histocompatibility antigen HLA-DR1. Nature 1993;364:33.)

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(2) The α1 and α2 domains determine the peptide-binding specificity and alloantigenicity of class I.
(3) The membrane proximal α3 domain and β_2-microglobulin stabilize the overall structure.

5. MHC class I molecules possess a single **peptide-binding groove** within the α1 and α2 domains (Figure 7–1).
a. Contact residues within the groove determine specificity.
b. The typical peptide that binds to a class I molecule is 9–11 amino acids in length.
c. MHC class I-binding peptides contain terminal hydrophobic residues that anchor them into the groove.
d. Each MHC class I molecule shows **"promiscuous binding"** in that it can bind several different peptides.

B. The principal function of **MHC class II molecules** in the periphery is to present peptide antigens to $CD4^+$ T cells.
1. Antigen recognition by $CD4^+$ T cells is MHC class II restricted.
2. Only foreign peptides bound to MHC class II molecules can activate $CD4^+$ T cells.
3. The MHC class II genes in human beings are found in three genetic regions called ***HLA-DP, HLA-DQ,*** and ***HLA-DR***.
4. Each class II genetic region contains one or more α and β genes.
a. The class II α and β loci encode for 33- and 28-kDa polypeptide chains, respectively.
b. The class II molecules form αβ heterodimeric cell surface glycoproteins (Figure 7–1).
c. Each chain has a membrane-distal domain (ie, α1 or β1) that is highly variable.
d. The α1 and β1 domains of class II molecules contain the peptide-binding groove.
e. These regions of sequence variability also prescribe the alloantigenic nature of class II molecules.
5. The peptide-binding groove of a typical class II molecule is similar in structure to that of a class I molecule.
a. Contact residues in the binding groove determine binding specificity.
b. MHC class II molecules typically bind 12–15 amino acid peptides that can extend beyond the limits of the groove.
c. Like class I, class II molecules show binding promiscuity.

C. Class I and class II MHC genes belong to the Ig supergene family.

D. MHC class III genes do not control T cell activation directly.
1. Class III genes include those for the complement proteins C2, C4, and Factor B (Chapter 8).
2. The gene for tumor necrosis factor (TNF)-α is also found in the class III MHC family.

ALTERED MHC-BINDING PEPTIDE LIGANDS

- *The nature of a T cell response to a peptide antigen can be altered by changing only a few of the contact residues of the peptide that interact with the TCR.*

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- *These **altered peptide ligands** include "superagonistic" peptides that can enhance T cell activation, which would be useful in designing antitumor immunotherapy.*
- *Similarly, altered peptide ligands can theoretically be designed that would inhibit unwanted T cell activation, such as that seen in autoimmune diseases.*

III. MHC molecules show extensive functional diversity due to polygeny and genetic polymorphism.

A. **Polygeny** refers to the existence of multiple genetic loci that have similar functions.

1. Three MHC class I gene loci, *HLA-A, HLA-B,* and *HLA-C,* control antigen presentation to $CD8^+$ T cells.

2. Many MHC class II genetic loci control antigen presentation to $CD4^+$ T cells (eg, *DPα1, DPα2, DPβ1,* and *DPβ2*).

3. The existence of multiple MHC gene products increases the number of foreign peptides that can be presented to T cells.

B. **Polymorphism** within the MHC refers to the existence of multiple **alleles** of a gene within a population (Table 7–1).

1. Each class I allele encodes an α chain.

2. Each class II allele encodes either an α or a β chain.

3. A diploid individual can express at most two allelic products at each MHC locus (ie, in the heterozygote).

4. The β_2-microglobulin gene is *not* polymorphic.

5. Polymorphism has a greater effect on HLA diversity within the species than within an individual (Table 7–2).

a. Thus, in the human population there is the capacity to present an enormous number of antigenic peptides.

b. Each individual of that population has a much narrower potential repertoire of MHC-encoded molecules.

C. HLA diversity is sufficient for recognizing most protein antigens.

1. Each allelic product (eg, HLA-A1) can bind multiple peptides.

2. Each cell expresses multiple allelic forms (Figure 7–2).

Table 7–1. Examples of polymorphism at the HLA loci.

MHC Class	HLA Locus	Number of Alleles
I	*HLA-A*	250
I	*HLA-B*	490
I	*HLA-C*	119
II	*HLA-DPA1*	20
II	*HLA-DPB1*	99
II	*HLA-DQA1*	22
II	*HLA-DQB1*	53
II	*HLA-DRB1*	315
II	*HLA-DRB3*	38

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Table 7–2. The basis for diversity among immunoglobulins and MHC molecules.

Feature	Immunoglobulin Genes	MHC Genes
Repertoire of an individual	~10^4 genes; ~10^9 Igs	6 class I alleles 6 class II alleles
Repertoire of the species	~10^4 genes; ~10^9 Igs	> 400 class I alleles > 500 class II alleles
Diversity mechanisms	Large pools of germ-line V, D, J segments Combinatorial joining of V, D, J segments Imprecision in joining sites Nucleotide additions at joining sites Somatic hypermutation Combinatorial association of H and L polypeptides	Heterozygosity Codominant expression Polygeny Polymorphism

3. Mounting a successful response to a limited number of antigenic epitope–MHC complexes is apparently adequate to protect the host.

IV. MHC genes are inherited as a closely linked group of loci and are codominantly expressed (Figure 7–3).

A. HLA class I loci are clustered at the 3′ end of the complex on chromosome 6.

1. Each class I locus encodes an α chain, which is paired with β_2-microglobulin prior to surface expression (Figure 7–4).

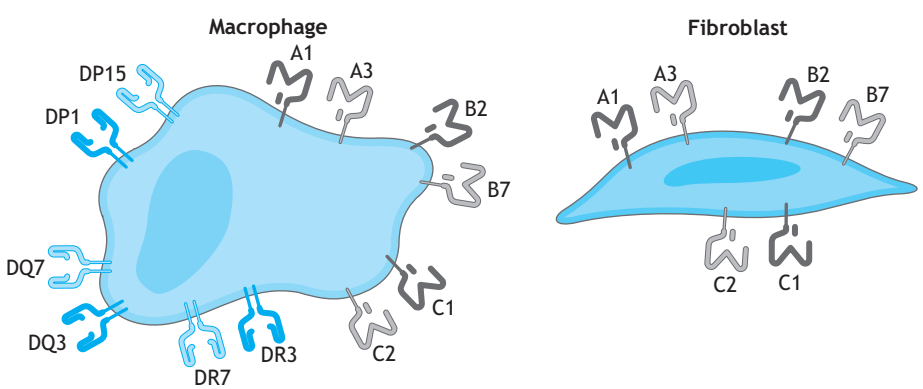

Figure 7–2. Patterns of expression of *HLA* class I and class II genes.

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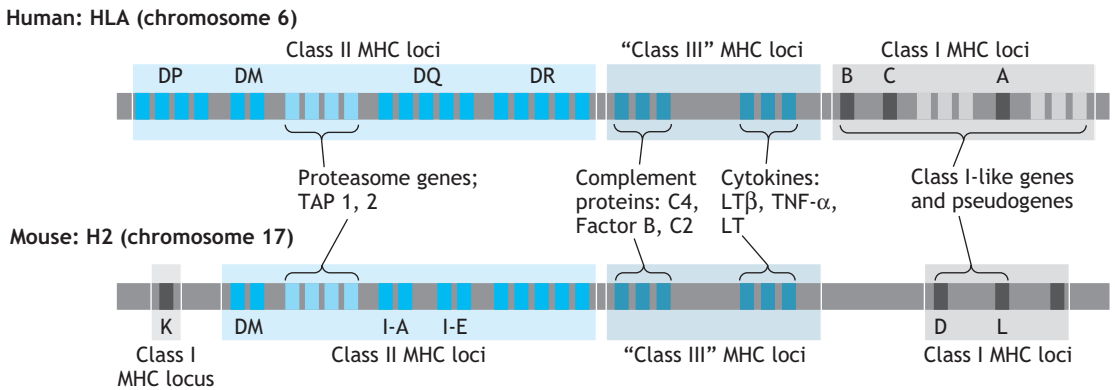

Figure 7–3. Genetic map of the *HLA* complex. MHC, major histocompatibility complex; TAP, transporter in antigen processing; LT, lymphotoxin; TNF, tumor necrosis factor.

B. The class II loci are clustered at the 5′ end of the complex and code for either an α or a β chain.
- **1.** Different α and β gene products from a given region (eg, DP) can pair with one another to form heterodimeric products.
- **2.** Additional loci between the DP and DQ regions encode proteins that function in antigen presentation (see below).

C. The closely linked genes of the MHC are inherited in a Mendelian fashion.
- **1.** The constellation of linked MHC genes on a given chromosome is called a **haplotype** (Table 7–3).
- **2.** Haplotype inheritance ensures that certain predictions can be made about HLA relationships within families (Figure 7–5).
  - **a.** Assuming no genetic recombination has occurred, parents are always **haploidentical** with their children.
  - **b.** Each child has a 75% chance of haploidentity with a sibling.
  - **c.** Each child has a 25% chance of complete **HLA identity** with a sibling.

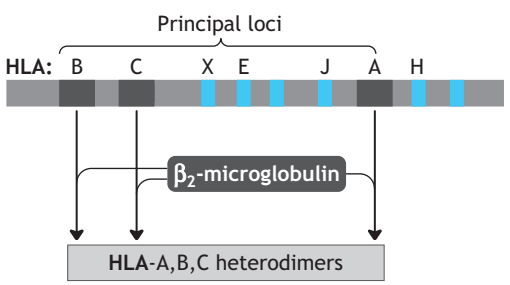

Figure 7–4. HLA class I heterodimers.

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Table 7–3. Nomenclature of the HLA genetic system.

Term	Definition	Example
Region	A region within the HLA complex containing related genes	HLA-DR
Locus	An open reading frame that encodes for an HLA peptide	HLA-DRB1 (encodes a β chain of HLA-DR)
Allele	One of the alternative sequences at a locus	HLA-DRB1*0101
Antigen	A cell surface heterodimeric protein	HLA-DR1
Haplotype	The constellation of linked genes across the entire HLA complex on one chromosome	HLA-A1, B2, C5, DP2, DQ1, DR4

D. Individuals inherit parental MHC genes in their germ line DNA.
- **1.** The specificity of an individual's T cells is an inherited trait.
- **2.** The MHC loci do *not* rearrange prior to expression (Table 7–2).

E. MHC loci are expressed in a **codominant** fashion (Figure 7–2).
- **1.** All six allelic products of the HLA class I loci are expressed in the heterozygote.
  - **a.** Each MHC class I heterodimer is expressed on all nucleated cells, except cells of the trophoblast.
  - **b.** Any nucleated cell that expresses MHC class I molecules can present peptide antigens to $CD8^+$ T cells.
  - **c.** Each MHC class II heterodimer is expressed on all dendritic cells, B cells, and macrophages.
  - **d.** Any such cell can present peptide antigens to $CD4^+$ T cells.

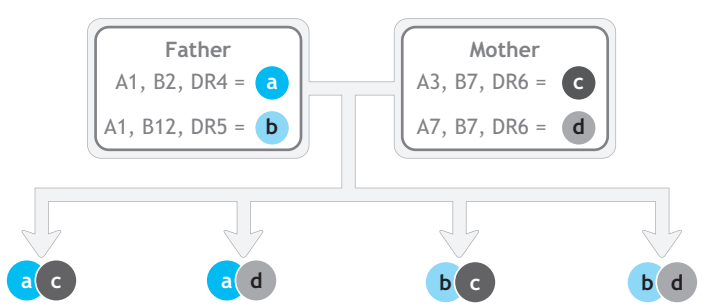

Figure 7–5. Inheritance of *HLA* genes within a family.

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F. The expression of MHC class II genes is coordinately controlled by tissue-specific transcription factors, including the **class II transactivator (CIITA)**.

1. Constitutive expression of MHC class II is seen in B cells, monocytes, macrophages, and dendritic cells ("professional antigen-presenting cells").

2. Several other cell types (eg, epithelial cells) can be induced to express class II molecules by inflammatory signals.

COORDINATED EXPRESSION OF MHC CLASS II

- *An autosomal recessive condition expressed in infants called **bare lymphocyte syndrome (BLS) type 2** is characterized by lymphopenia, diarrhea, and a variety of opportunistic infections.*
- *These patients have significantly decreased numbers of blood $CD4^+$ T cells, and show decreased cellularity in their peripheral lymphoid tissues.*
- *HLA-DP, DQ, and DR molecules are essentially absent from their tissues.*
- *In many BLS type II patients, the expression of CIITA is defective.*

V. Two distinct pathways of antigen presentation ensure that foreign peptide antigens are presented by the proper MHC molecule to the appropriate T cell subset (Table 7–4 and Figure 7–6).

A. Intracellular microbes (eg, viruses and intracellular bacteria) express protein antigens that are presented on class I molecules to $CD8^+$ T cells.

1. Antigen presentation involves the degradation of these foreign proteins following their synthesis within the **cytosol**.

2. The resulting peptides are directed to newly synthesized class I molecules in the endoplasmic reticulum.

Table 7–4. Pathways of antigen processing and presentation.[a]

Pathway	Source of Antigen	Essential Cellular Components	Typical Antigens Processed
Class I	Endogenous	MHC class I α chains β_2-Microglobulin Ubiquitin Proteasome TAP-1,2 Chaperones (calnexin, tapasin, calreticulin)	Viral capsule proteins and nucleoproteins Proteins derived from intracellular bacteria
Class II	Exogenous	MHC class II α and β chains Ii chain CLIP HLA-DM	Proteins derived from extracellular pathogens Traditional protein vaccines

[a]TAP, transporter associated with antigen processing; CLIP, class II-associated invariant chain peptide.

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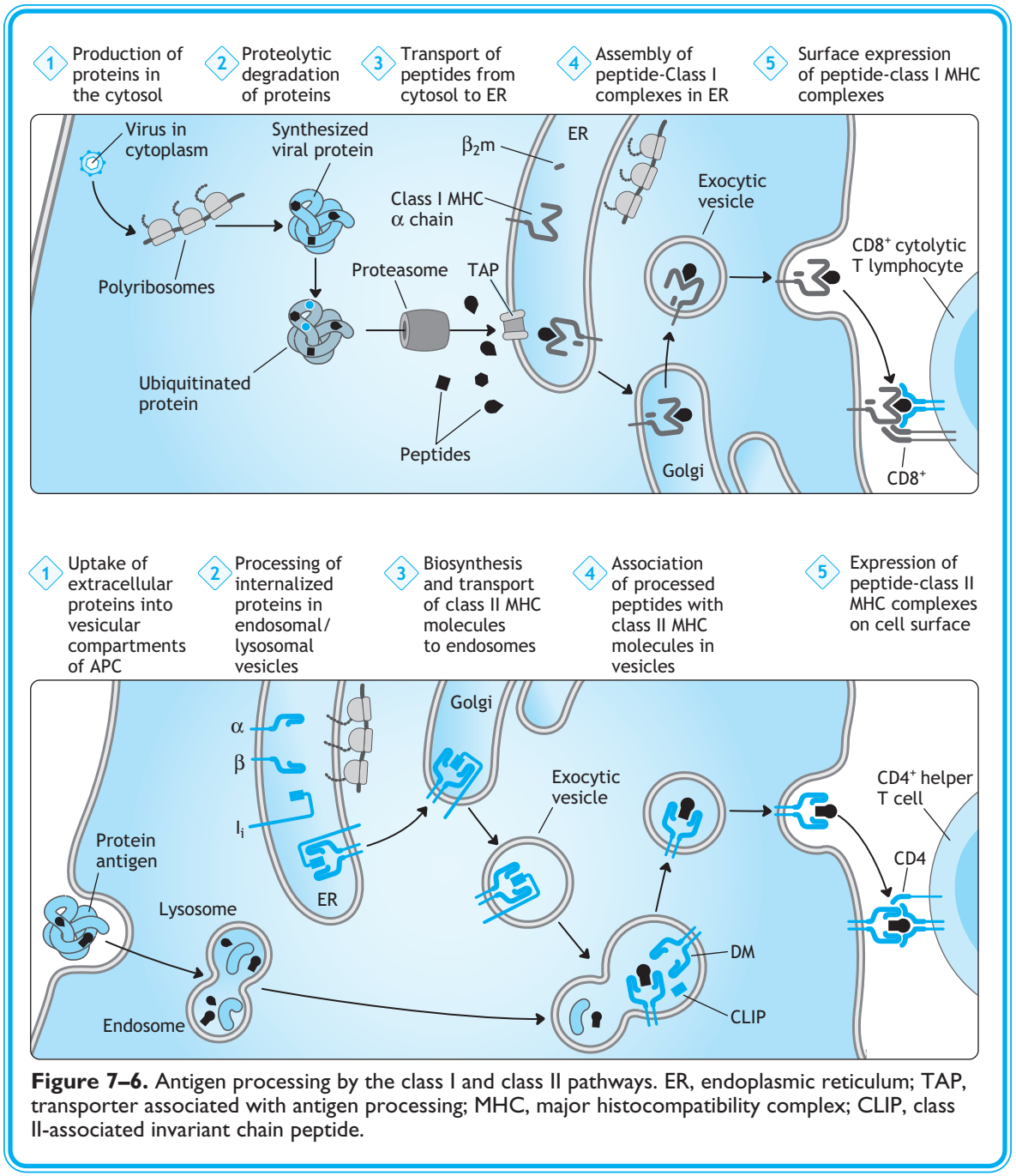

Figure 7–6. Antigen processing by the class I and class II pathways. ER, endoplasmic reticulum; TAP, transporter associated with antigen processing; MHC, major histocompatibility complex; CLIP, class II-associated invariant chain peptide.

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3. These **endogenous protein antigens** are expressed on MHC class I and recognized by $CD8^+$ T cells.

B. **Extracellular microbes** activate $CD4^+$ T cells by expressing antigenic peptides that are presented on MHC class II molecules.

1. The uptake of these exogenous antigens can be accomplished by **phagocytosis, endocytosis,** or **receptor-mediated endocytosis**.
2. Antigen processing and presentation require an intracellular pathway that degrades proteins within an **endosome**.
3. The resulting peptides are directed to an **exocytic vesicle** containing newly synthesized class II molecules.
4. These exogenous protein epitopes are then presented by the **class II molecules** to $CD4^+$ T cells.

C. Components of the **class I (endogenous or cytosolic) antigen presentation pathway** are dedicated to proteolysis, peptide sizing, peptide transport, and protein targeting.

1. The foreign protein antigen is first covalently attached to the small peptide **ubiquitin** via the ε-amino group of lysine residues of the antigen molecule (Figure 7–6).
2. Ubiquitination targets the protein for degradation by the multicatalytic **proteasome**.
   a. The proteasome subunits LMP-2 and LMP-7, in part, determine substrate cleavage specificity.
   b. LMP-2 and LMP-7 are encoded by genes in the MHC (Figure 7–3).
   c. Peptides that leave the cylindrical proteasome vary in size and charge.
3. Peptides that will fit the binding groove of MHC class I molecules are transported from the cytosol to the endoplasmic reticulum.
   a. The **transporter associated with antigen processing (TAP)** complex mediates peptide transport across the ER membrane.
   b. TAP selects peptides of the appropriate length (9–11 amino acids) with hydrophobic ends.
   c. The genes encoding the TAP complex, ***TAP-1*** and ***TAP-2***, reside in the MHC (Figure 7–3).
4. Newly synthesized MHC class I α chains are present in the ER membrane associated with β_2-microglobulin and the **chaperone proteins calnexin, tapasin,** and **calreticulum**.
   a. Chaperones direct the trafficking of MHC class I molecules to the TAP complex.
   b. Dissociation of the chaperones enables the loading of peptides into the MHC class I molecules.
5. The MHC class I–peptide complex is then directed to the membrane for expression.
   a. The absence of β_2-microglobulin precludes surface expression of MHC class I molecules.
   b. The absence of a peptide in the binding groove of MHC class I prevents its surface expression.
   c. Pathogenic intracellular microbes often block the class I pathway by inhibiting β_2-microglobulin synthesis or TAP function.

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6. In the absence of *foreign* antigenic peptides, MHC class I molecules are always loaded with *self* peptides.

BARE LYMPHOCYTE SYNDROME TYPE 1

- *Mutations in either the TAP1 or TAP2 gene prevent the transport of cytosolic peptides into the ER and result in incomplete peptide loading.*
- *Patients with these mutations do not express HLA-A, B, and C molecules on their nucleated cells, because class I molecules cannot be expressed unless they are loaded with peptide.*
- *These patients also fail to develop $CD8^+$ T cells due to a defect in positive selection in the thymus (Chapter 10).*
- *The resulting immunodeficiency is not as severe as severe combined immunodeficiency (SCID), but can lead to opportunistic viral infections.*
- *Patients with BLS type 1 generally show normal numbers of circulating lymphocytes due to the normal development of the $CD4^+$ T cell subset.*

D. Peptides presented by MHC class II molecules are generally derived from extracellular proteins that are taken up by antigen-presenting cells.

1. Following uptake into an endocytic or phagocytic vesicle, the organelle becomes increasingly acidic with time.

2. Hydrolytic enzymes of the endolysosomes and phagolysosomes mediate proteolysis of the antigen.

3. These vesicles then fuse with exocytic vesicles containing newly synthesized MHC class II molecules.

a. Newly synthesized class II molecules are associated with a chaperone membrane protein called the **invariant chain (Ii)** .

b. Ii ensures proper folding and protects the binding groove of the class II heterodimer.

4. When the vesicles fuse, the Ii chain is degraded into a small peptide, called a **class II-associated invariant chain peptide (CLIP)**.

5. **HLA-DM** catalyzes the removal of CLIP and the binding of appropriately sized antigenic peptides.

6. The loaded MHC class II molecule is then directed to the cell surface.

VI. There are notable associations between specific HLA phenotypes and the susceptibility for certain diseases (Table 7–5).

A. The relative risk of **hereditary hemochromatosis** is higher in individuals with the HLA-A3 + B14 haplotype than in the general population.

1. Persons with this haplotype have an elevated incidence of mutations in a nonclassical MHC class I molecule called **HLA-H** (also known as HFE).

2. HLA-H appears to regulate the function of the transferrin receptor, thereby affecting the absorption of dietary iron in the stomach and small intestine.

3. Thus, certain mutations in HLA-H result in a chronic systemic exposure to excess iron resulting in hereditary hemochomatosis.

B. HLA associations are particularly common among autoimmune diseases.

1. **HLA-B27** expression is associated with an increased relative risk of **spondylarthropathies**.

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Table 7–5. Disease associations with HLA phenotypes.

Disease	HLA Antigen or Haplotype	Relative Risk
Hereditary hemochromatosis	HLA-A3 + HLA-B14	90
Ankylosing spondylitis	HLA-B27	90
Reiter's syndrome	HLA-B27	37
Gluten enteropathy	HLA-DR3	12
Rheumatoid arthritis	HLA-DR4	14

a. Spondylarthropathies are characterized by inflammation of the joints and characteristic extraarticular tissues.
b. Individuals expressing HLA-B27 have an increased relative risk of developing the autoimmune conditions ankylosing spondylitis and Reiter's syndrome (Table 7–5).
c. **Relative risk** is the prevalence of the disease in those carrying the HLA marker compared to the prevalence of the disease among the general population.
d. A number of microbial antigens cross-react with HLA-B27–peptide complexes, suggesting an infectious etiology for these autoimmune diseases.

CLINICAL PROBLEMS

The HLA genetic system was used in a civil case to resolve a paternity suit. The case involved a woman who sued an acquaintance for child support for her newborn twins. The court ordered tissue typing (serological identification of the HLA markers; Chapter 17) of the mother, the two children, and the defendant. Partial results of the typing are shown below.

Individual	HLA-A Markers	HLA-B Markers
Mother	1,2	8,12
Son	1,3	8,7
Daughter	2,5	12,9
Defendant	3,3	7,28

1. Assuming there has been no recombination within the HLA complex, which haplotype did the son inherit from his mother?

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A. HLA-A1 + HLA-A2
B. HLA-A1 + HLA-B7
C. HLA-A1 + HLA-B8
D. HLA-A3 + HLA-B7
E. HLA-B8 + HLA-B7

2. Assuming no recombination within the HLA complex, which haplotype did the daughter inherit from her mother?

A. HLA-2 + HLA-B12
B. HLA-2 + HLA-A5
C. HLA-B12 + HLA-B9
D. HLA-A2 + HLA-B9
E. HLA-A5 + HLA-B12

3. Which of the following is a paternal haplotype that could have been inherited by one of the children from the defendant?

A. HLA-A3 + HLA-B7
B. HLA-A1 + HLA-B8
C. HLA-A2 + HLA-B9
D. HLA-A5 + HLA-B9
E. HLA-A1 + HLA-B7

4. Based on these data alone, which of the following could be true?

A. The son cannot be related to the defendant.
B. The daughter cannot be related to the defendant.
C. Neither child is related to the defendant.
D. Both children could be related to the defendant.
E. The two children have different fathers.

Below is a pedigree showing the HLA phenotypes of the Smith family. This is the second marriage for both the father and the mother.

5. Which of the five children shown here is most likely the child of a previous marriage involving the mother?

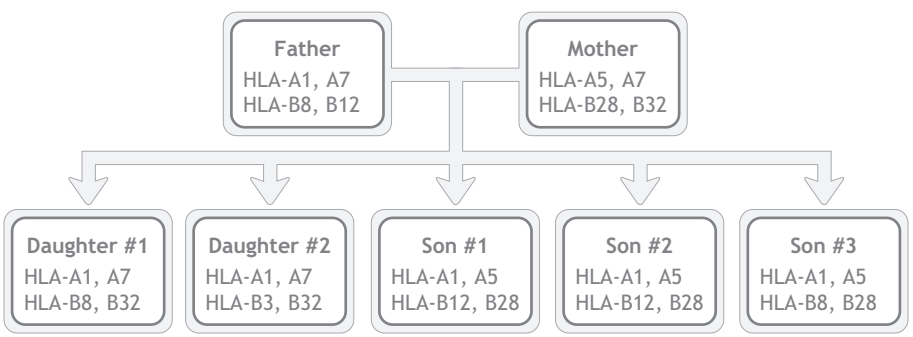

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James is a 13-year-old child in need of a kidney transplant. He is the third of 14 children all with the same parents.

6. What are the chances that one of his siblings will be fully HLA compatible with James?

A. There is almost no chance this will occur.

B. 1 chance in 13

C. 1 chance in 4

D. 1 chance in 2

E. All of his siblings would be HLA compatible.

ANSWERS

1. The correct answer is C. A haplotype is a group of linked genes (eg, HLA-A1 + HLA-B8) on one chromosome. In this case, the maternal haplotype can be derived by noting that these are the only HLA antigens shared between the mother and the son.

2. The correct answer is A. As with the son, these are the only HLA antigens shared with the mother. Thus, the son and daughter define the two maternal haplotypes, HLA-A1 + B8 and HLA-A2 + B12.

3. The correct answer is A. If A1, B8, A2, and B12 are of maternal origin, then the remaining HLA antigens were derived from the father. What is surprising in this case is that only the HLA-A3 + HLA-B7 haplotype is represented in the defendant's type.

4. The correct answers are B and E. Based on HLA typing it is safe to conclude that the daughter is *not* related to the defendant. Because these children are fraternal twins, it can only be concluded that the two children had different fathers. This is a case of apparent superfecundity, which occurs when two ova are produced during one ovulation cycle and become fertilized by sperm from two different fathers.

5. The correct answer is daughter #2. Analysis of the pedigree indicates that the haplotypes of the father are A1 + B8 and A7 + B12. The mother's haplotypes are A7 + B32 and A5 + B28. Daughter #2 bears the maternal haplotype A7 + B32, but the paternal haplotype does not correspond to those of the father. Therefore, the child must be from a previous marriage.

6. The correct answer is C. Based on Medelian inheritance in a codominant system, there is a 25% chance of full haplotype identity between siblings, assuming no recombinations or mutations.

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CHAPTER 8
COMPLEMENT

I. Complement is a primitive immune effector and amplification system consisting of more than two dozen serum proteins.

A. Complement components are designated by a **"C"** followed by a number (eg, C1) or the word **"Factor"** followed by an upper case letter (eg, Factor B).

B. The **biological functions** of complement include cell membrane lysis, opsonization, activation of inflammatory responses, clearance of immune complexes, and B cell activation.

1. Many of the biological activities are mediated by cell surface **complement receptors**.

2. The complement system can be activated during either innate or adaptive immune responses.

C. Complement system proteins become enzymatically or biologically active when they are cleaved, form multimers, or bind to other biomolecules.

II. The complement system can be activated by three different pathways (Table 8–1).

A. In each pathway, complement is activated by the recognition of molecular patterns, on either antibody molecules or microbial components.

B. All three activation pathways share a set of **core elements** that includes C3, C5, and the so-called **terminal components** C6–C9 (Figure 8–1).

1. Initiation of each of the pathways requires recruitment or assembly of a serine protease.

2. The critical second step is the cleavage of C3 by **C3 convertase** to form the peptide fragments C3a + C3b.

3. Then C5 is cleaved by a **C5 convertase**.

4. Amplification at each step results from the cleavage of multiple substrate molecules by these two convertases.

C. The three pathways can be distinguished by their processes of initiation, their unique components, their unique functions, and the manner by which they are regulated (Table 8–1).

D. The **classical pathway of complement activation** is initiated by antigen–antibody complexes.

1. Only immunoglobulin (Ig) M and IgG antibodies participate in classical pathway activation.

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Table 8–1. Three pathways of complement activation.[a]

Property	Classical Pathway	Lectin Pathway	Alternative Pathway
Initiating factors	IgG- or IgM-containing immune complexes	Microbial mannose residues	Highly charged surfaces
Unique components	C1, C2, C4	MBL, MASP	Factor B, Factor D, Factor P, Factor H
C3 convertase	C4b2a	C4b2a	C3bBb
C5 convertase	C4b2a3b	C4b2a3b	C3bBb3b
Unique functions	Adaptive immunity	Innate immunity	Innate immunity; positive feedback amplification; C3 tickover function
Unique regulators	C1 Inh		Factor H

[a]Ig, immunoglobulin; MBL, mannose-binding lectin; MASP, MBL-associated serine protease; C1 Inh, C1 inhibitor.

2. Activation begins with the binding of the **C1q** peptide to the C_H domains of μ and γ heavy chains (Figure 8–2).
   - **a.** C1q is a hexamer that cross-links two adjacent binding sites located on the C_H domains of μ or γ Ig heavy chains.
   - **b.** IgM antibodies are more efficient than IgG antibodies in binding C1q, because the pentameric nature of IgM ensures that two C_H domains will be in close proximity to one another.

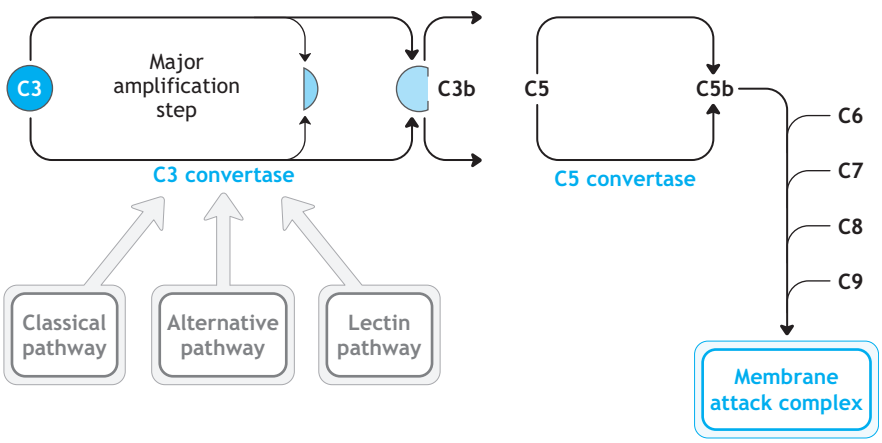

Figure 8–1. The core elements shared by the three pathways of complement activation.

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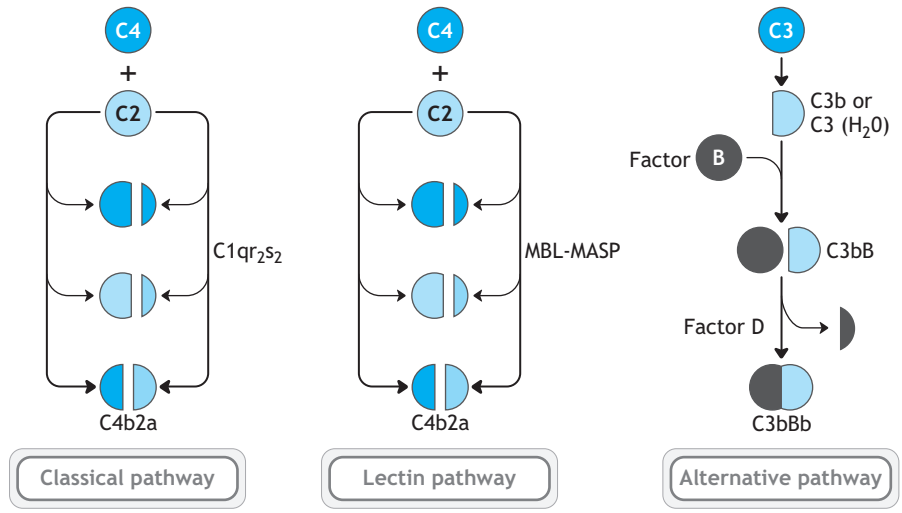

Figure 8–2. The initiation steps in the three pathways of complement activation. MBL–MASP, mannose-binding lectin–MBL-associated serine protease.

3. Once bound, C1q recruits two copies each of **C1r** and **C1s** to form an active enzyme.
4. The **$C1qr_2s_2$** complex can cleave C4 to yield peptides C4a and C4b.[1]
5. $C1qr_2s_2$ then cleaves C2 to yield the C2a + C2b peptides.
   a. C2a binds to C4b to produce C4b2a, the **classical C3 convertase**.
   b. This enzyme complex can cleave C3 to yield C3a + C3b.
6. Multiple copies of peptides are produced at each cleavage step.

HEREDITARY ANGIOEDEMA

- ***Hereditary angioedema*** *is a autosomal dominant trait characterized by acute, nonpainful, nonpruritic, and nonerythematous swelling of the skin and mucous membranes.*
- *Edema of the bowel wall can be painful, and laryngeal swelling is potentially life-threatening due to asphyxiation.*
- *The genetic defect is a decrease or absence of the complement regulatory protein,* ***C1 Inhibitor (C1 Inh)****, that regulates $C1qr_2s_2$, Hageman factor, kallikrein, and plasmin.*
- *Unabated complement activation through the classical pathway appears to contribute to the acute angioedema, although the precise biochemical mediator has not been defined.*

E. The **lectin pathway of complement activation** shares properties and components with the classical pathway (Figure 8–2).

[1]A common convention in the complement field is the use of an overbar to designate enzymatically active complement components or complexes (eg, $C1\overline{qr_2s_2}$ or $\overline{C4b2a}$). For simplicity, this convention has been omitted here.

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1. Activation is initiated by the binding of **mannose-binding lectin (MBL)** to microbial carbohydrate residues.
   a. MBL is another name for **mannose-binding protein** (Chapter 1).
   b. MBL recruits and binds **MBL-associated serine protease (MASP)**, an enzyme with substrate specificity similar to that of $C1qr_2s_2$.
2. MASP cleaves C4 and C2 to form the **lectin pathway C3 convertase**, C4b2a.

F. The **alternative pathway of complement activation** is initiated by at least three different mechanisms (Figure 8–2).
1. Highly charged microbial surface patterns, including polysaccharides, can bind C3.
2. In fluid phase, C3 can spontaneously hydrolyze with water to form an intermediate designated $C3(H_2O)$.
3. The C3b peptide, derived from the classical or lectin pathways, can activate the alternative pathway directly.
4. Bound C3, $C3(H_2O)$, or C3b then binds **Factor B**.
5. Bound B is then cleaved by the constitutively active enzyme **Factor D** to produce Ba + Bb.
6. C3Bb, $C3(H_2O)Bb$, and C3bBb are the **alternative pathway C3 convertases**.
   a. Whereas $C3(H_2O)Bb$ is unstable, the other two complexes are relatively stable.
   b. C3bBb can be further stabilized by binding **Factor P**.
7. The ability of the alternative pathway C3 convertases to generate more C3b constitutes a **feedback amplification loop** (Figure 8–3).

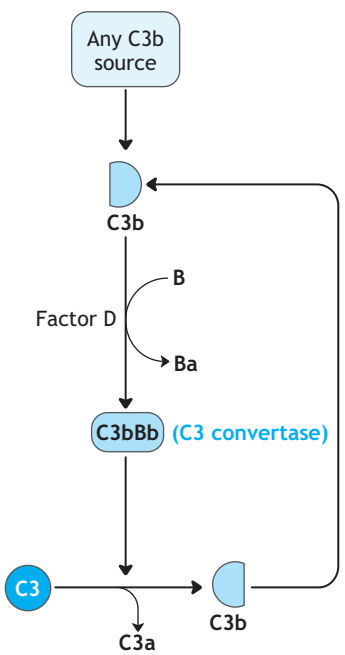

Figure 8–3. The positive feedback amplification loop of the alternative pathway.

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8. Another unique feature of the alternative pathway is called **C3 tickover**.
- **a.** C3 constantly interacts with H_2O in fluid phase to form $C3(H_2O)$, an initiator of alternative pathway activation.
- **b.** However, the $C3(H_2O)$ intermediate is very unstable.

G. The peptides C3b and C4b can establish stable sites for further complement activation by covalently binding to appropriate surfaces.
1. C3b and C4b contain internal **thioester bonds** that can be rearranged to form ester or amide linkages with biomolecules.
2. These sites also provide covalently attached ligands for complement receptors.

III. The terminal steps in complement activation are shared by the three pathways.

A. C3 convertases are converted to **C5 convertases** by the binding of C3b (Table 8–1).

B. The C5 convertases cleave C5 generating C5a + C5b.
1. C5a is a biologically active peptide that mediates chemotaxis and mast cell activation (see below).
2. C5b is the first component of the **membrane attack complex (MAC)** (Figure 8–4).
- **a.** The assembly of the MAC does not require proteolysis.
- **b.** The assembled C5b678 complex can intercalate into the lipid membranes of both microbial and host cells.
- **c.** The C5b678 complex recruits multiple copies of C9 to form a stable membrane pore.
- **d.** Membrane disruption and rapid cell lysis result.

IV. The activation of complement is controlled at several levels (Table 8–2).

A. Some regulatory elements **inhibit** the formation of or **dissociate** active enzyme complexes.
1. Many such inhibitors (eg, C1 Inh and **C4b-BP**) block early pathway initiation.
2. Other inhibitors prevent the inadvertent lysis of host cells.
3. Components, such as **HRF, CD59**, or **decay accelerating factor (DAF)**, are species specific and block complement activation on host, but not microbial, membranes.

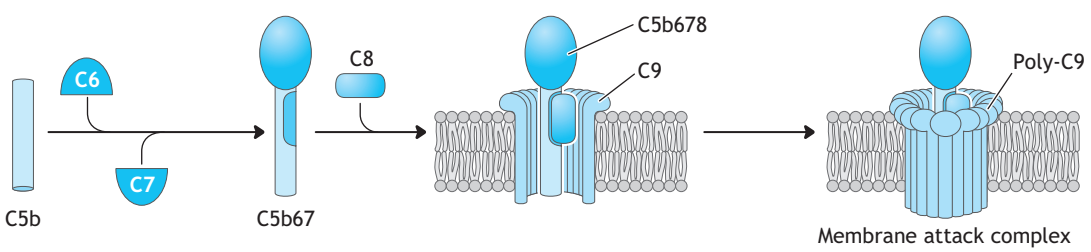

Figure 8–4. Terminal steps in complement activation.

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Table 8–2. Regulation of the complement system.

Regulator	Pathway Affected	Mechanism of Action
C1 inhibitor (C1 Inh)	Classical	A serine protease inhibitor that dissociates $C1r_2s_2$ from C1q
C4b-binding protein (C4bBP)	Classical	Prevents formation of the classical and lectin pathway C3 convertase by blocking binding of C4b to C2a
CR1	All	Prevents formation of C3 convertases by blocking the binding of C3b to Factor B or the binding of C4b to C2a
Factor P	Alternative	Stabilizes C3bBb
Factor H	Alternative	Blocks formation of C3bBb by binding to C3b
Decay accelerating factor (DAF)	All	Accelerates the decay of the C3 convertases C4b2a and C3bBb
Factor I	All	Cleaves C3b and C4b to produce iC3b and iC4b, respectively
Anaphylatoxin inhibitor (AI)	All	Cleaves and inactivates the anaphylatoxins C3a, C4a, and C5a
S protein	All	Prevents membrane insertion of the C5b67 complex
Hemologous restriction factor (HRF)	All	Prevents binding of poly-C9 to the C5b678 complex

B. Several regulatory factors **inactivate** biologically active complement peptides by proteolysis.

1. **Anaphylatoxin inhibitor (AI)** cleaves the terminal arginine residues of peptides C3a, C4a, and C5a, rendering them inactive.
2. **Factor I** cleaves C3b and C4b, destroying their ability to form C3 convertases.

C. Some factors (eg, S protein) prevent membrane attack by **blocking the assembly** of a mature MAC.

TRANSGENIC PIGS, MEMBRANE ATTACK, AND XENOTRANSPLANTATION

CLINICAL CORRELATION

- *The worldwide shortage of organs suitable for clinical transplantation has stimulated research on the transplantation of organs between species (**xenotransplantation**).*

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- *The early rejection of xenografts, including pig grafts in human beings, appears to be mediated by natural human antibodies and complement.*
- *The membranes of pig cells appear to be particularly susceptible to membrane attack, because their complement regulatory proteins do not inhibit human complement components (eg, C3 convertases and MAC).*
- *A novel approach to this dilemma has been to create transgenic pigs expressing human complement regulatory proteins (eg, DAF).*
- *If successful, these animals could be developed as a source of organs for clinical transplantation.*

V. The biological activities of the complement system depend on the action of its peptides and assembled complexes (Table 8–3).

A. Membrane damage is caused by the assembly of the **MAC** in a lipid bilayer.

1. This is an important mechanism of host cell lysis in transfusion reactions, transplantation rejection, and autoimmunity.

2. The MAC can lyse the exposed outer membranes of Gram-negative bacteria.

3. Membrane damage caused by MAC is similar to that caused by perforin produced by cytotoxic T cells (Chapter 6).

a. Poly-C9 and poly-perforin produce membrane pores.

b. Perforin and C9 show considerable amino acid sequence homology.

FACTOR I DEFICIENCY

- *Because Factor I destroys C3 convertases by cleaving C3b and C4b, it regulates complement activation at a key amplification step.*
- *The importance of **Factor I** in this regard is illustrated by individuals with hereditary Factor I deficiency.*

Table 8–3. Summary of important complement components and complexes.[a]

	Classical Pathway	Lectin Pathway	Alternative Pathway
Enzymatic components	$C1qr_2s_2$ C4b2a C4b2a3b	MBL-MASP C4b2a C4b2a3b	Factor D C3bBb C3bBb3b
Biologically active peptides or complexes	C3b C4b C3d C3a C4a C5a $C5b\text{-}9_n$	C3b C4b C3d C3a C4a C5a $C5b\text{-}9_n$	C3b C4b C3d C3a C4a C5a $C5b\text{-}9_n$
Important regulatory components	C1 Inh C4b-BP Factor I	C4b-BP Factor I	Factor P Factor I Factor H

[a]MBL-MASP, mannose-binding lectin-MBL-associated serine proteases; C1 Inh, C1 inhibitor; C4b-BP, C4b binding protein.

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- *These patients suffer from recurrent pyogenic infections, including meningococcal meningitis.*
- *The treatment of these patients with recombinant Factor I provides some relief during acute infections, but its long-term clinical effectiveness is unknown.*

B. Many complement peptides exert their biological effects through cell surface **complement receptors (CR)** (Table 8–4).

1. Complement receptor 1 (CR1) mediates the clearance of circulating immune complexes that bear C3b or C4b.

a. Erythrocytes bear the highest densities of CR1 and mediate the greatest share of immune complex clearance.

b. The complexes are delivered to the liver, where they are taken up by Kupffer cells.

2. CR2 mediates B cell coactivation when C3d-coated antigens cross-link CR2 and BCR (Figure 8–5).

3. The **opsonic** activity of C3b, iC3b, C4b, and iC4b is due to the binding of particles coated with these peptides to **CR1, CR3,** and **CR4**.

4. The **C3a/4a receptor (CR3a/4aR)** mediates mast cell degranulation (Chapter 13).

5. C5aR is a G protein-coupled seven transmembrane chemotactic receptor that mediates the chemoattraction of neutrophils.

C. Microbes have developed elaborate mechanisms of immune evasion by targeting the complement system and diminishing its biological activities.

1. Herpes simplex virus produces a glycoprotein (C) that promotes C3 decay.

Table 8–4. Complement receptors.

Complement Receptor	Ligands	Cell Expressing the Receptor	Principal Biological Activities
CR1	C3b, iC3b C4b, iC4b	Erythrocytes, phagocytic cells	Clearance of immune complexes
CR2	C3d	B cells	B cell coactivation
CR3	C3b, iC3b C4b, iC4b	Phagocytic cells	Immune complex binding, opsonophagocytosis, cell adhesion
CR4	C3b, iC3b C4b, iC4b	Phagocytic cells	Immune complex binding, opsonophagocytosis, cell adhesion
C3a/C4a R	C3a, C4a	Mast cells	Degranulation leading to inflammatory mediator release
C5aR	C5a	Neutrophils Mast cells	Chemotaxis Degranulation and mediator release

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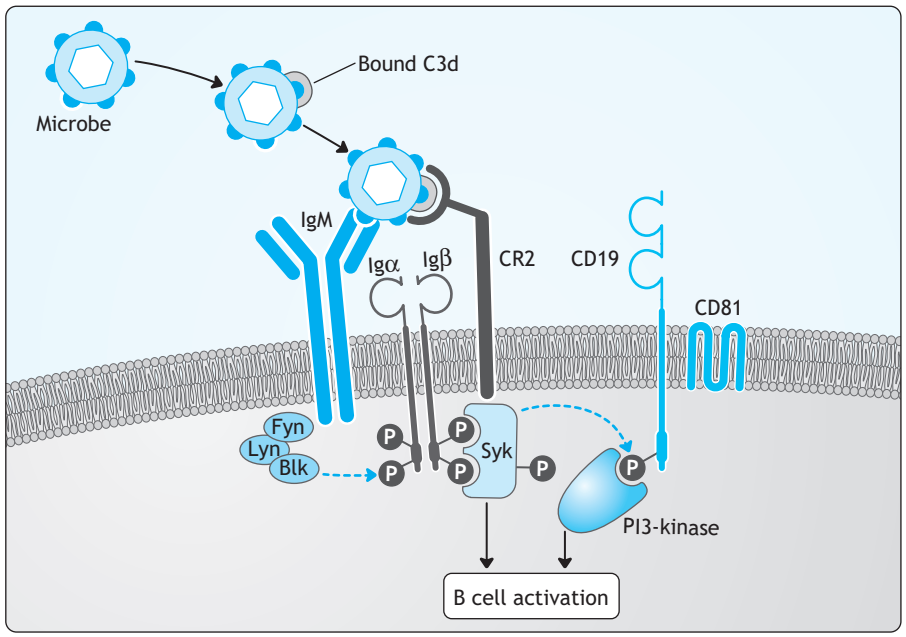

Figure 8–5. Signaling through the B cell coreceptor by binding C3d. Ig, immunoglobulin; PI3-kinase, phosphatidylinositol-3-kinase.

2. The long, branching polysaccharide chains of bacterial surface lipopolysaccharides are thought to direct complement activation away from the outer lipid membrane (Figure 1–3).

3. *Pseudomonas aeruginosa* produces a protease that cleaves C3b.

VI. Complement plays a central role in the pathogenesis of human disease.

A. Serum complement levels can be markedly decreased in **immune complex diseases**.

1. The circulating levels of C1, C2, C3, and C4 decline when immune complexes containing IgM or IgG antibodies activate the classical pathway.

a. Total complement activity is measured in **complement hemolytic 50% (CH_{50})** units.

b. Standard CH_{50} assays measure the activity of the classical pathway.

2. Regularly measuring total serum complement can be an effective means of monitoring the therapy of immune complex diseases.

B. C3b often deposits within tissues and induces inflammation (Chapter 13).

C. **Primary deficiencies of complement** components cause inflammatory and infectious diseases.

1. Inherited deficiencies (generally autosomal recessive) of most of the individual complement components have been described.

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2. Deficiencies of the early classical and alternative pathways (eg, C1, C2, C4, and Factor B) are most often associated with an increased risk of bacterial infections.
3. The absence of C9 has only a minimum effect on infection rates.
4. Patients with congenital deficiencies of C5, C6, C7, or C8 have an increased risk of disseminated *Neisseria* infections (eg, meningitis).
5. These observations would suggest that complement-dependent lysis of bacteria is *less* important to the host than is its role in the chemotaxis and opsonophagocytosis by neutrophils.

D. Paroxysmal nocturnal hemoglobinuria (PNH) is a condition characterized by episodes of intravascular hemolysis and hemoglobinuria.
1. Patients' erythrocytes are particularly sensitive to complement-mediated lysis.
2. PNH patients lack the GPI-linked membrane proteins DAF and CD59.
   a. Membrane C3 convertases are not well controlled, resulting in the deposition of C3b (Table 8–2).
   b. Assembly of the MAC is also not regulated at the cell membrane.

E. Leukocyte adhesion defect type 1 (LAD-1) is a deficiency in the expression of complement receptors CR3 and CR4.
1. LAD-1 involves a mutation in the β_2 integrin CD18 (Table 8–5).
2. **CD18** normally forms heterodimers with **CD11a, CD11b,** or **CD11c**.
   a. The CD11a–CD18 dimer is the adhesion molecule **LFA-1**, which facilitates neutrophil binding to endothelial cells and leukocyte emigration from the blood.
   b. The CD11b–CD18 and CD11c–CD18 dimers are **CR3** and **CR4**, respectively, which are adhesion and opsonic receptors on phagocytic cells.
3. LAD-1 patients suffer from recurrent pyogenic infections.

COMPLEMENT DEFICIENCIES AND AUTOIMMUNITY

- *Patients with deficiencies of the early classical pathway components (eg, C2 and C4) have an increased incidence of autoimmune disorders, especially lupus-like nephritis.*
- *This may reflect their inability to clear immune complexes that contain C3b generated by the classical pathway.*
- *Conversely, patients with immune complex-mediated autoimmunity often show depressed levels of C1, C2, C3, and C4 during acute attacks.*
- *$C1qr_2s_2$, C4b, C2a, and C3b are removed from the circulation when immune complexes are cleared by CR1-expressing erythrocytes.*

Table 8–5. Leukocyte adhesion defect type 1.[a]

CD18 Heterodimeric Partner	Receptor Formed	Receptor Ligands
CD11a	LFA-1	ICAM-1
CD11b	CR3	iC3b, iC4b
CD11c	CR4	iC3b, iC4b

[a]LFA-1, lymphocyte function-associated antigen-1; ICAM-1, intercellular adhesion molecule 1.

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CLINICAL PROBLEMS

A patient presents with recurrent joint pain and renal insufficiency, which is associated with immune complex deposition in these organs. It is determined that the patient does not clear IgG-containing immune complexes from the circulation at a normal rate.

1. A defect in which of the following complement receptors would most contribute to this latter finding?

A. CR1
B. CR2
C. CR3
D. CR4
E. CR5

Mary is a 2-year-old child with a history of recurrent upper respiratory tract infections. She has normal serum Ig levels for her age, and her complete blood count (CBC) and tests for neutrophil functions are normal. The total complement activity of her serum is normal in terms of supporting the lysis of antibody-coated erythrocytes. However, her serum complement is not activated by bacterial lipopolysaccharide (LPS).

2. Which of the following primary deficiencies of the complement system would be most consistent with these findings?

A. C2 deficiency
B. Factor D deficiency
C. MBL deficiency
D. C1 Inh deficiency
E. DAF deficiency

A 4-year-old child is referred to you with a diagnosis of leukocyte adhesion defect. She has a history of recurrent bacterial infections, including pneumonias and skin abscesses. Radiology demonstrates granuloma-like lesions in her lung and liver. However, the data in the table below suggest this condition has not been properly diagnosed.

3. Which element of the table is **inconsistent** with a diagnosis of LAD?

CD Marker	Patient (%)	Normal Range (%)
CD2	76	75–93
CD3	75	60–85
CD4	52	30–65
CD8	26	20–52
CD11a	65	62–85
CD18	73	70–86
CD19	12	7–17
CD45	52	44–62

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A. CD2
B. CD3
C. CD19
D. CD11a
E. CD45

A pediatric patient presents with recurrent staphylococcal infections (pneumonias, sinusitis, and otitis media). Because many of her immune parameters are normal, you hypothesize that she has a defect in her complement system.

4. For which of the following complement components or receptors would a deficiency produce this pattern of recurrent infections?

A. C2
B. C6
C. C8
D. CR1
E. CD59

A patient with the immune complex autoimmune disease systemic lupus erythematosus (SLE) is experiencing significant symptoms, including a worsening of her skin rash and evidence of impaired renal function.

5. If you were to test her serum complement levels during this acute phase of disease, which of the following would be most consistent with a worsening clinical course?

A. A decline in C9 levels
B. A decline in C3 and C4 levels
C. An increase in Factor P levels
D. An increase in C1 Inh levels
E. A decline in C7 levels

ANSWERS

1. The correct answer is A. Complement receptor CR1 is responsible for clearing immune complexes from the circulation by binding to C3b or iC3b. While CR3 and CR3 show the same ligand specificity, the substantially larger number of CR1 receptors expressed by numerous erythrocytes in the blood make this receptor the primary vehicle of immune complex clearance.

2. The correct answer is B. Of the choices, only Factor D is unique to the alternative pathway of complement, which is activated by bacterial LPS. A deficiency of Factor D prevents cleavage of Factor B, which is essential for producing the alternative pathway C3 convertase.

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3. The correct answer is D. This patient appears to express normal levels of all of the CD markers shown here. This would *not* be expected of a patient with LAD type 1. Such patients lack CD18, which impairs the expression of CD11a, CD11b, and CD11c.

4. The correct answer is A. Of the components listed, only deficiencies in C2, C6, and C8 result in an increased susceptibility to bacterial infections. With C6 and C8, the pathogens are members of the *Neisseria* genus and certain other gram-negative bacteria. Defects in early classical components, such as C2, result in recurrent pyogenic infections by gram-positive bacteria, such as staphylococci.

5. The correct answer is B. Lupus is an autoimmune disease in which complement is activated by IgG autoantibodies via the classical pathway. This can lead to an acute depletion in the early classical components, such as C1, C2, C3, and C4. The concentrations of the terminal components are affected much less.

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CHAPTER 9
B CELL DIFFERENTIATION AND FUNCTION

I. The development of a diverse, self-tolerant population of antigen-specific B cells is central to creating an adaptive immune system.

A. The initial events of **lymphopoiesis** occur in the fetal liver and bone marrow and do not require exposure to foreign antigens.

1. **Hematopoietic stem cells (HSC)**, which express **CD34**, are **pluripotent** and can become any of the blood cell lineages (eg, erythroid, lymphoid, myeloid).

2. Lineage commitment is determined by the **hematopoietic inductive microenvironment**, which includes stromal cell ligands and growth factors (Chapter 12).

3. **Interleukin-7 (IL-7)** is an important growth factor for B and T lymphocyte development.

4. Lymphocyte lineage commitment is indicated by the formation of the **lymphoid progenitor cell.**

5. Commitment to the B lymphocyte lineage occurs at the **progenitor B (pro-B) cell** stage (Table 9–1).

a. Most pro-B cells express **CD19** as do all subsequent cells of the B cell lineage.

b. **Recombination activating genes 1 and 2 (Rag1, Rag2)** and **terminal deoxynucleotidyltransferase (TdT)** are expressed in preparation for immunoglobulin (Ig) locus rearrangements.

c. The Ig H chain locus is rearranged by VDJ recombination, but H chain polypeptides are not expressed.

6. The pro-B cell differentiates into a **precursor-B (pre-B) cell**, which expresses a pre-B cell receptor (BCR).

a. The **pre-BCR** consists of a membrane μ chain, an invariant **surrogate L chain,** and Igα and Igβ polypeptides.

b. Signaling through the pre-BCR induces allelic exclusion at the Ig H locus and rearrangement of the κ locus.

7. The pre-B cell differentiates into an **immature B cell** expressing an authentic BCR.

a. The BCR complex consists of membrane μ chains, κ or λ light chains, and the Igα and Igβ polypeptides.

b. Immature B cells exit the bone marrow and complete their differentiation into mature B cells in the periphery.

c. Most immature B cells die in the periphery unless they encounter antigen.

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Table 9–1. Stages of antigen-independent B cell differentiation.[a]

	HSC	Pro-B	Pre-B	Immature B	Mature B
Igα, Igβ	–	+	+	+	+
Rag1, 2	–	+	+	+	–
TdT	–	+	+	–	–
Surrogate L chain	–	+	+	–	–
Membrane μ chain	–	–	+	+	+
Membrane δ chain				–	+
Membrane κ or λ chain	–	–	–	+	+
Btk kinase	–	+	+	+	+
Positive selection	-	–	+	+	–
Negative selection	–	–	–	+	–

[a]HSC, hematopoietic stem cells; Ig, immunoglobulin; Rag1, Rag2, recombination activating genes 1 and 2; Tdt, terminal deoxynucleotidyltransferase; Btk, Bruton's tyrosine kinase.

8. **Mature B cells** express two forms of the BCR, membrane IgM and membrane IgD (Chapter 4).
   a. **B-1 B cells** are among the first peripheral B cells and are found predominantly in the peritoneal and pleural cavities.
   b. B-1 B cells produce natural antibodies thought to be induced by microbial flora.
   c. B-1 B cells have a limited BCR repertoire.
      (1) Most B-1 B cells produce low-affinity IgM antibodies specific for **polysaccharide antigens**.
      (2) The BCRs of B-1 B cells contain relatively conserved V regions.

B. **Selection** occurs at several differentiation checkpoints and determines the peripheral B cell repertoire.
   1. **Positive selection** rescues bone marrow B cells from apoptosis ("death by neglect") (Table 9–2).
      a. Positive selection occurs at the pre-B and immature B cell stages.
      b. Selection requires signaling through the pre-BCR or BCR.
      c. The pre-BCR signals differentiation to the immature B cell stage and the BCR promotes differentiation into mature B cells.
      d. Positive selection through the BCR probably involves low affinity binding to self-ligands.

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Table 9–2. Positive and negative selection of developing B cells.[a]

	Positive Selection	Negative Selection
Stage of B cell development	Pre-B cell Immature B cell	Immature B cell
Receptors	Pre-BCR BCR	BCR
Ligands	Unknown	Self antigens
Events triggered by selection	Allelic exclusion of H locus Proliferation of pre-B cells κ locus rearrangement	Apoptosis BCR editing Secondary κ locus rearrangement
Outcome	Advancement to immature B cell stage Monoclonal expression of μ chain BCR expression	Elimination of autoreactive B cell clones Replacement of autoreactive BCRs

[a]BCR, B cell receptor.

X-LINKED AGAMMAGLOBULINEMIA

- ***X-linked agammaglobulinemia (XLA)*** *is a congenital immune deficiency characterized by the lack of peripheral B cells.*
- ***Agammaglobulinemia*** *becomes apparent only after maternal IgG disappears during the first year of life.*
- *XLA patients have a mutation in the gene coding for* ***Bruton's tyrosine kinase (Btk)****.*
- *Btk is first required for signaling by the pre-BCR at the pre-B cell stage and mediates positive selection.*
- *A similar phenotype exists in patients with H locus deletions that prevent functional μ chain synthesis and pre-BCR expression.*

2. Negative selection mediates removal of autoreactive B cell clones.
- **a.** Negative selection establishes **self-tolerance**.
- **b.** Negative selection occurs at the immature B cell stage and is mediated by high-affinity BCR binding of self antigens.
- **c.** Negative selection can signal either apoptosis or anergy within B cells.
- **d.** Negative selection can stimulate **BCR editing**.
  (1) The cell undergoes a second light chain locus rearrangement.

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(2) The second rearrangement replaces the L chain of the self-reactive BCR.
(3) The B cell undergoes another round of selection based on its new BCR.

II. In the periphery, antigen induces further differentiation of mature B cells into antibody-producing plasma cells and memory cells.

A. Antigen enters the spleen, lymph nodes, and submucosal lymphoid follicles via the blood, the lymph, or by transport across the mucosal epithelium, respectively.

B. A single antigen-reactive B cell can give rise to thousands of daughter cells through 10—12 cell doublings.

C. Activated B cells differentiate into sessile **plasma cells** that live for only a few days.
1. Differential RNA processing ensures that plasma cells synthesize secreted, rather than membrane, Igs (Chapter 4).
2. The progeny of a single B cell can synthesize up to 10^{12} antibody molecules.

D. Antigen-specific, long-lived **memory B cells** also arise during B cell clonal expansion in lymph node **germinal centers.**
1. Follicular dendritic cells promote memory B cell development by retaining antigens over long periods of time.
2. Germinal center development is T cell dependent.
3. Memory B cells undergo Ig isotype switching.
4. Memory B cells mediate **secondary responses** characterized by the following:
a. A requirement for less antigen to induce the response.
b. A shorter lag period before antibody is detected.
c. Higher average affinity of the antibodies produced.
d. The presence of additional Ig isotypes.

E. Affinity maturation accompanies memory B cell development.
1. Affinity maturation is an increase in the average affinity of an antibody response over time.
2. Affinity maturation is T cell dependent.
3. Affinity maturation requires **somatic hypermutation** of Ig V region genes.
a. Proliferating B cell clones bear mutations in the complementarity determining regions of their BCRs.
b. The average affinities of the antibodies these cells produce increase by 10- to 100-fold.
c. Cells that express mutated, high-affinity BCRs are **positively selected** by antigen for additional cycles of proliferation.

III. Antigen-induced activation of B cells is mediated through the BCR, coreceptors, and cytokine receptors (Figure 9–1).

A. The BCRs on mature naive B cells are membrane IgM and IgD.

B. Memory B cells utilize membrane IgG, IgA, or IgE as their BCRs.

C. Each of these BCRs signals through Igα and Igβ and intermediates that are similar to those used by the T cell receptor (TCR) (Chapter 6) (Table 9–3).

D. Signaling is initiated by clustering of the BCR complex.
1. Polyvalent antigens with repeating identical determinants can activate B cells without coreceptor signals.
2. Most native protein antigens contain univalent epitopes that do not mediate BCR cross-linking.

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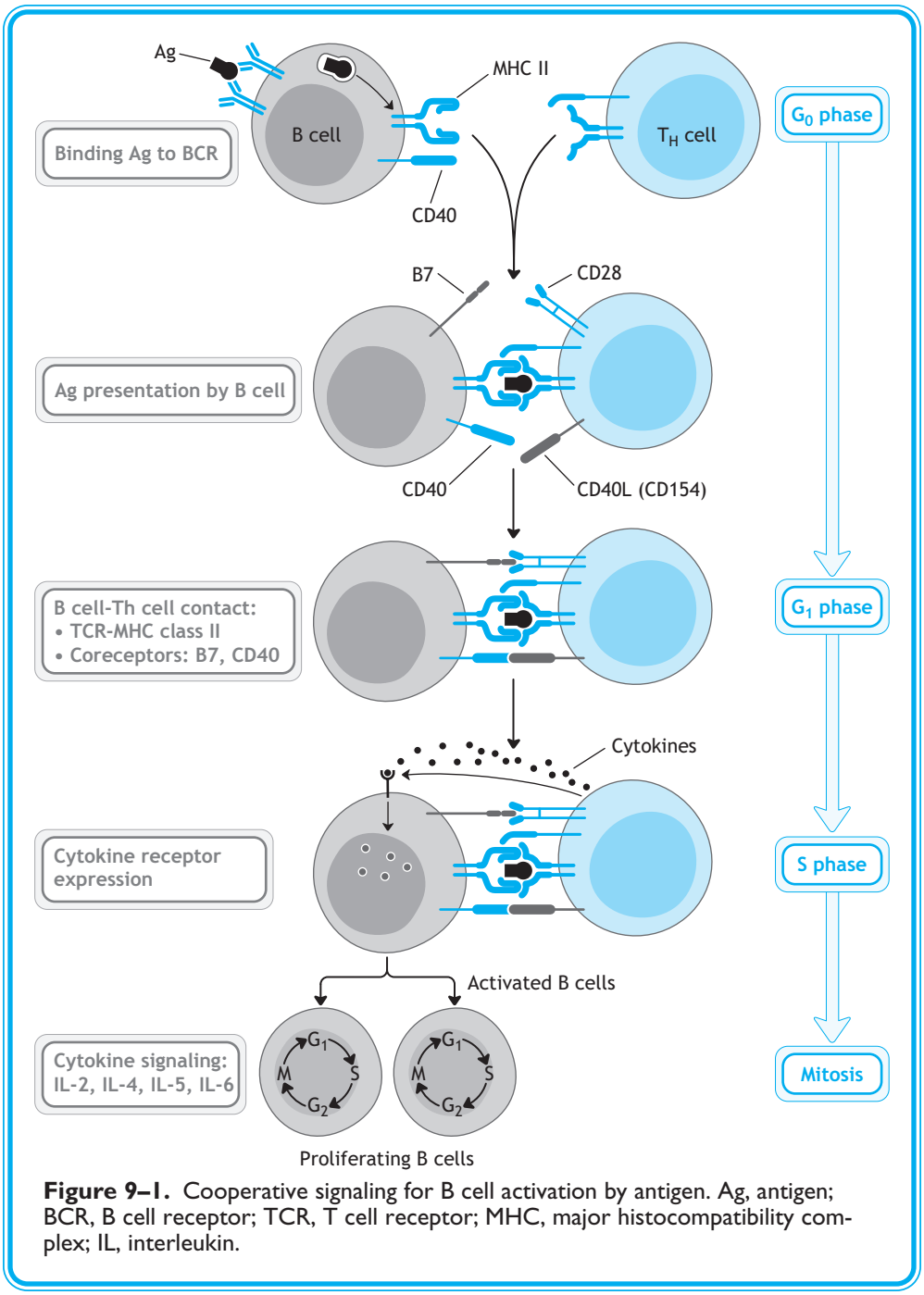

Figure 9–1. Cooperative signaling for B cell activation by antigen. Ag, antigen; BCR, B cell receptor; TCR, T cell receptor; MHC, major histocompatibility complex; IL, interleukin.

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Table 9–3. Analogous components of the TCR and BCR signaling pathways.[a]

Signaling Event or Intermediate	TCR Associated	BCR Associated	Effects
Clustering of receptors in the membrane	TCRαβ or TCRγδ with CD3 peptides	BCR with Igα and Igβ	Concentrate subsequent signaling mediators
Phosphorylation of ITAMs	Phosphorylation of CD3 ITAMs by Lck	Phosphorylation of Igα and Igβ ITAMs by Src kinases	Binding sites for downstream adaptor proteins and kinases
Effector kinase recruitment and activation	ZAP-70	Syk	Phosphorylates downstream adapters and kinases
Phospholipase activation	PLCγ	PLCγ	PIP_2 hydrolysis
IP_3 and DAG	Ca^{2+} mobilization PKC activation	Ca^{2+} mobilization PKC activation	Calcineurin activation
Calcineurin activation	NFAT dephosphorylation	NFAT dephosphorylation	Transcriptional activation through NFAT
PKC activation of IκB kinase	IκB phosphorylation	IκB phosphorylation	Transcriptional activation through NFκB
Rac, Ras activation of MAP kinases	Fos/Jun phosphorylation	Fos/Jun phosphorylation	Transcriptional activation through NFκB

[a]TCR, T cell receptor; BCR, B cell receptor; Ig, immunoglobulin; ITAM, immunotyrosine activation motif; ZAP-70, ζ-associated protein-70 kDa; PLC, phospholipase C; PIP_2, phosphatidylinositol 4,5-biphosphate; IP_3, inositol triphosphate; DAG, diacylglycerol; PKC, protein kinase C; MAP, mitogen-activated protein.

3. Igα and Igβ transmit BCR signals across the cell membrane.
   a. The cytoplasmic domains of Igα and Igβ contain **immunotyrosine activation motifs (ITAM)**(Figure 9–2).
   b. **Src family kinases** phosphorylate ITAM tyrosine residues.
4. The tyrosine kinase **Syk** is recruited to the phosphorylated ITAMs, becomes phosphorylated, and phosphorylates downstream adapter proteins (eg, BLNK) and latent kinases.
   a. Btk kinase is recruited to BLNK and activates **phospholipase Cγ (PLCγ)**.
      (1) PLCγ hydrolyzes the membrane phospholipid phosphatidylinositol 4,5-biphosphate (PIP_2) to form inositol triphosphate (IP_3) and diacylglycerol (DAG).
      (2) IP_3 mobilizes intracellular Ca^{2+} and activates **calcineurin**.
      (3) Calcineurin activates the transcription factor **NFAT** by dephosphorylation.

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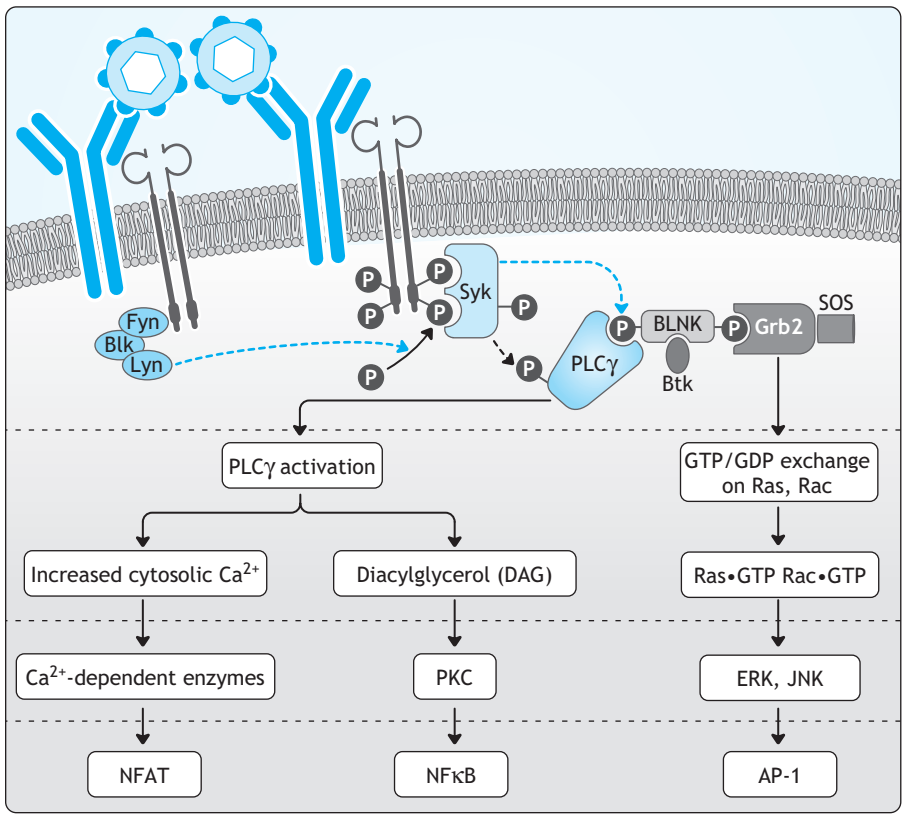

Figure 9–2. B cell receptor (BCR) signaling. PLC, phospholipase C; GTP, guanosine triphosphate; GDP, guanosine diphosphate; PKC, protein kinase C.

(4) **Protein kinase C** is activated by DAG, which indirectly induces the degradation of **IκB**, the inhibitor of **NFκB**.
(5) The transcription factor NFκB is activated.

b. The guanosine triphosphate/guanosine diphosphate (GTP/GDP) exchange proteins **Rac** and **Ras** are activated.
(1) Rac and Ras activate mitogen-activated protein (MAP) family kinases.
(2) The MAP kinases activate the **AP-1** family of transcription factors (eg, Fos and Jun) by phosphorylation.

5. NFAT, NFκB, and AP-1 translocate to the nucleus and initiate gene transcription by binding to their respective enhancers.

6. The transcription of Ig, coreceptor, and cytokine receptor genes is initiated or increased.

E. Coreceptors enhance signals delivered through the BCR (Table 9–4).

1. Contact with T helper cells is required for coreceptor signaling.

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Table 9–4. Important receptors and coreceptors on B cells.[a]

Receptor or Coreceptor	Ligand	Biological Response
Pre-BCR	Unknown	Positive selection of pre-B cells
BCR	Self antigens	Positive and negative selection of immature B cells
	Foreign antigens	Activation of peripheral mature B cells
CR2	C3d	Coactivation of mature B cells Enhancement of BCR signaling
CD40	CD154 (CD40L)	Coactivation of mature B cells Enhancement of BCR signaling
IL-2R	IL-2	Growth of activated B cells
IL-4R	IL-4	Switching to IgE
IL-5R	IL-5	Switching to IgA
IL-6R	IL-6	Differentiation of cycling B cells Increased Ig synthesis
CCR7	CCL7	Chemotaxis of germinal center B cells

[a]BCR, B cell receptor; IL, interleukin; Ig, immunoglobulin.

   a. The chemokine **CCL7** mediates chemoattraction of B cells to the outer edge of germinal centers where they bind Th cells.
   b. Contact-dependent signaling is promoted by **major histocompatibility complex (MHC) class II,** on B cells, which is bound by the TCR.
   c. T cell contact-dependent signaling promotes B cell **proliferation**, increases **MHC class II** expression, induces **coreceptor**, **cytokine receptor**, and **chemokine receptor** expression, promotes **affinity maturation**, and induces **Ig class switching**.

2. **CD154** (CD40 ligand or CD40L) on $CD4^+$ Th cells coactivates B cells by binding to CD40.
   a. **CD40** signals B cells to switch Ig class by H chain gene locus rearrangement.
   b. Mutations in the CD154 gene can block T cell-induced Ig class switching in B cells (**hyper-IgM syndrome type 1**).
3. Complement activation during innate and adaptive immune responses can generate the **B cell coreceptor** ligand **C3d** (Figure 8–5).
   a. C3d can covalently bind to antigens.
   b. C3d–antigen complexes cross-link the BCR with **CR2**, which is composed of the CD19 and CD21 peptides.

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c. Src kinases associated with CR2 promote BCR signaling through phosphorylation.

SWITCH RECOMBINASE DEFICIENCY

- *Ig class switching involves a DNA recombination event mediated by the recombinase **activation-induced cytidine deaminase (AID)**.*
- *Mutations in the AID gene have been described and result in impaired antigen-induced isotype switching, somatic hypermutation in B cells, and affinity maturation of the antibody response.*
- *The resulting phenotype, designated **hyper-IgM syndrome type 2**, resembles the X-linked CD154 deficiency known as **hyper-IgM syndrome type 1**.*

F. Cytokines produced by T helper cells promote B cell activation.
1. Interleukin (IL)-2, IL-4, and IL-5 promote B cell proliferation.
2. IL-6 enhances the differentiation of activated B cells into antibody-producing plasma cells.
3. IL-2, IL-4, and IL-6 promote antibody synthesis by activated B cells and plasma cells.
4. Several cytokines promote Ig class switching.
a. **Switch cytokines** promote specific **switch recombinase** interactions with specific switch sites within the Ig H gene locus (Chapter 4).
b. IL-4 and IL-13 promote switching to IgE.
c. Interferon (IFN)-γ promotes switching to IgG_1 and IgG_3.
d. IL-5 and transforming growth factor-β (TGF-β) induce switching to IgA.

ANTICYTOKINE THERAPIES FOR CONTROLLING B CELL ACTIVATION

- *Monoclonal antibodies capable of neutralizing cytokines or blocking their receptors have potential for the treatment of allergic or neoplastic diseases involving B cells.*
- *For example, atopic allergies could theoretically be treated by blocking B cell switching to IgE synthesis with anti-IL-4 or anti-IL-13.*
- *Another application undergoing clinical trials is the use of anti-IL-6 or anti-IL-6 receptor antibodies to inhibit the growth and Ig production of myeloma cells.*

IV. Foreign polysaccharides, glycolipids, and nucleic acids induce antibody production without the need for T cell help.

A. These **T-independent (TI) antigens** contain repeating epitopes that cross-link multiple BCRs on a single B cell.

B. Some TI antigens (eg, bacterial LPS) also coactivate B cells through Toll-like receptors (Chapter 1).

C. Some TI antigens [eg, lipopolysaccharide (LPS)] can activate complement and coactivate B cells through CR2.

D. Because TI antigens are not presented by antigen-presenting cells (APCs), they do not activate $CD4^+$ Th cells.

E. The responses to TI antigens differ from responses to foreign proteins.
1. There is little **Ig class switching** in TI antibody responses; IgM and IgG_2 antibodies predominate.
2. A limited repertoire of antibody-mediated **effector functions** results.

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3. **Memory B cell** populations are not formed and **affinity maturation** through somatic hypermutation does not occur.
4. **High-titered antibody** responses are not seen on secondary challenge.

SELECTIVE IGG$_2$ DEFICIENCY

CLINICAL CORRELATION

- *IgG$_2$ is a common subclass of antibody produced in response to T-independent antigens in humans.*
- *Antibody responses to protein antigens are predominantly of the IgG$_1$ subclass.*
- *Children with selective IgG$_2$ subclass deficiency have difficulty clearing bacteria that express polysaccharide capsules (eg, Streptococcus pneumoniae and Haemophilus influenzae).*
- *The increased survival of encapsulated bacteria in IgG$_2$-deficient patients suggests that other (sub)classes of Igs do not provide sufficient host defense against these organisms.*

V. Antibody responses at mucosal surfaces are mediated by a specialized set of B cells that synthesizes IgA antibodies.

A. Most of the IgA in the body is synthesized in the small intestine.

B. IgA-secreting plasma cells are most abundant within the lamina propria of the submucosum and produce 2 g of Ig per day.

C. The secretory form of IgA is the central mediator of mucosal humoral immunity.
1. **Secretory IgA** is dimeric and contains J chain and **secretory component (SC)**(Chapter 3).
   a. The α, κ, λ, and J chains of dimeric IgA are produced by mucosal B cells.
   b. Secretory component is synthesized by the intestinal **epithelial cell**.
2. Secretory component mediates transepithelial transport of IgA.
   a. On the basolateral surface of epithelial cells, a precursor of SC called **poly-Ig receptor** is expressed (Figure 9–3).
   b. The poly-Ig receptor binds the polymeric Igs (IgA and IgM).
   c. The loaded receptor is internalized into endosomes, which are translocated to the apical cell surface.

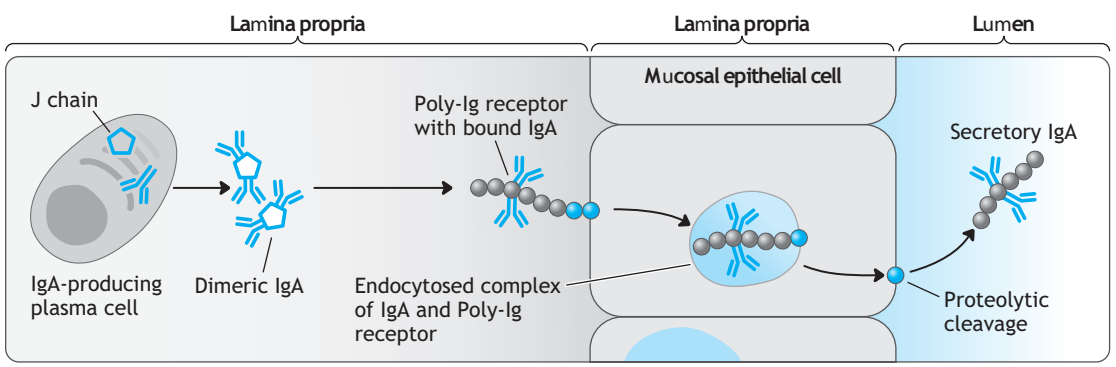

Figure 9–3. Transport of dimeric immunoglobulin A (IgA) by poly-Ig receptor.

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d. Proteolytic cleavage of the poly-Ig receptor releases secretory component with its polymeric Ig attached.

D. At the mucosal surface, secretory IgA neutralizes toxins and allergens and prevents microbial entry.

SELECTIVE IGA DEFICIENCY

CLINICAL CORRELATION

- *Selective IgA antibody deficiency is the most common antibody deficiency in humans with frequencies as high as 1:333 reported in some populations.*
- *This deficiency is characterized by recurrent bacterial and viral infections originating at mucosal surfaces (respiratory, gastrointestinal, and genitourinary tract infections).*
- *Increased incidences of food allergies, autoimmunity, and certain types of cancers have also been reported in these patients.*
- *However, half of all persons with this deficiency are asymptomatic.*

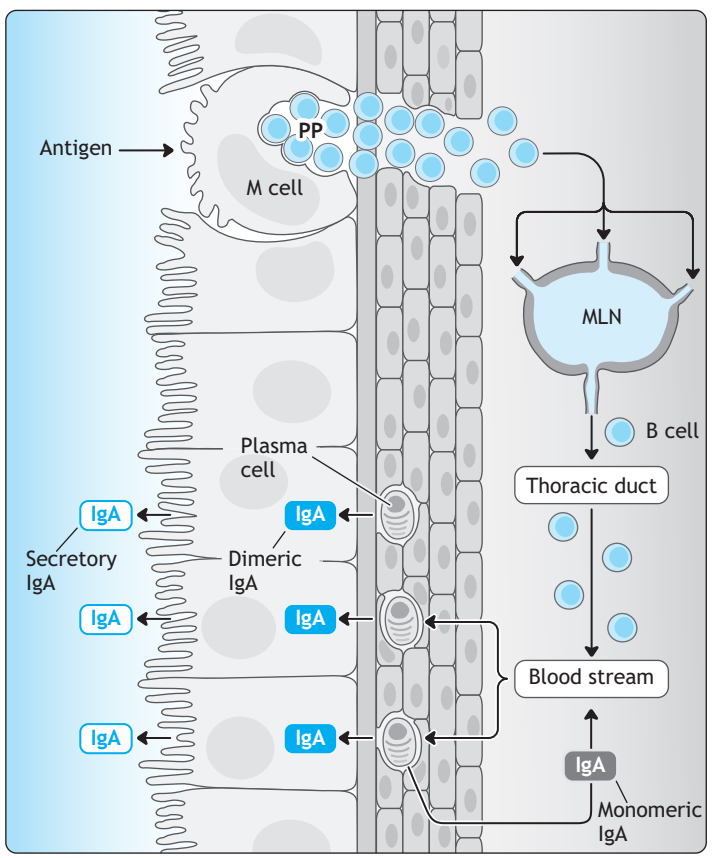

Figure 9–4. Induction of a mucosal immunoglobulin A (IgA) antibody response. M, microfold; PP, Peyer's patch; MLN, mesenteric lymph node.

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- *The absence of increased rates of infection in the unaffected subset of IgA-deficient individuals probably reflects the translocation of secretory IgM by the poly-Ig receptor.*

E. Mucosal IgA antibody responses are initially induced within submucosal Peyer's patches of the small intestine (Figure 9–4).

1. The epithelium overlying the patch is composed of specialized nonvillous epithelial cells, called **M cells**, which efficiently transport antigens to lymphoid cells within the patch.

2. Peyer's patch Th cells produce IL-5 and TGF-β, two IgA switch cytokines.

3. B cells activated in the Peyer's patches migrate via draining lymph nodes into the lymph and blood.

4. Circulating IgA-expressing B cells then seed the intestine and other **mucosal-associated lymphoid tissues (MALT)**.

5. By this process, the recognition of enteric antigens leads to the production and transport of secretory IgA at multiple mucosal tissue sites.

MUCOSAL AND PARENTERAL VACCINES

- *In the 1950s two competing vaccines were produced against the polio virus.*
- *The parenteral (Salk) vaccine was injected by the intramuscular route and induced IgG antibody production.*
- *These antibodies prevented disease by neutralizing virus particles in transit from the gastrointestinal tract to the nervous tissues.*
- *The Sabin vaccine was an inactivated virus, and oral immunization resulted in secretory IgA responses in the gut-associated lymphoid tissues.*
- *Secretory IgA antibodies prevented viral attachment and entry into intestinal epithelial cells.*
- *Current recommendations are for children to receive the parenteral vaccine at 2, 4, and 6 months of age (www.cdc.gov/nip/recs/child-schedule.PDF).*

CLINICAL PROBLEMS

A patient is shown to have a mutation in his *Btk* tyrosine kinase gene.

1. Which of the following stages of lymphocyte differentiation is blocked in this patient?

A. Differentiation of mature B cells into plasma cells

B. Generation of memory B cells

C. Differentiation of pre-B cells into immature B cells

D. Negative selection of mature B cells

E. Activation of mature B cells

A patient presents with recurrent bacterial infections and is found to have low serum levels of IgA and IgG_1, but elevated concentrations of serum IgM. Flow cytometry of his lymph node cells reveals an absence of CD154.

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2. In which of the following areas of the lymph node would this cell surface marker normally be found?

A. Medullary cords
B. Diffuse cortex
C. Germinal centers
D. High endothelial cells of the venules
E. Subcapsular sinuses

Lymphocytes from an immunodeficient patient are found to lack mRNA for AID.

3. Which of the following lymphocyte subsets would be expected to be absent in this patient?

A. Lymph node B cells expressing membrane IgG
B. $CD4^+$ T lymphocytes in the blood
C. Natural killer (NK) cells in the spleen
D. All lymphocytes in peripheral lymphoid tissues
E. $CD19^+$ B cells in the bone marrow

You have a patient with recurrent infections, but normal T cell function.

4. Which of the following laboratory tests would help you determine if this immune deficiency is due to an *absence* of B cells?

A. Radioimmunoassay
B. Flow cytometry
C. Enzyme-linked immunosorbent assay (ELISA)
D. Immunofixation
E. Coombs test

A lymph node biopsy stained with hematoxylin and eosin shows numerous germinal centers in the superficial cortex.

5. Which of the following best describes the source of this biopsy tissue?

A. A patient who lacks CD154
B. A patient who lacks Rag1
C. A patient who has been immunized repeatedly with a protein vaccine
D. A patient who has been immunized repeatedly with streptococcal polysaccharides
E. A newborn

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ANSWERS

1. The correct answer is C. Whereas the Btk kinase is used for both BCR and pre-BCR signaling, an absence of Btk is manifest first in pre-B cells. The mutation causes defective positive selection of pre-B cells and apoptotic death. There are no peripheral immature or mature B cells in Btk-deficient individuals, a condition known as XLA.
2. The correct answer is B. CD154 would normally be found on Th cells in the diffuse or deep cortex. Its absence is indicative of hyper-IgM syndrome type 1.
3. The correct answer is A. The switch recombinase AID is normally expressed in B cells that are undergoing Ig isotype switching.
4. The correct answer is B. Only flow cytometry would be able to demonstrate the absence of B cells. The other techniques would not distinguish between an absence of B cells and the inability of those cells to secrete antibody.
5. The correct answer is C. Germinal center development is antigen, Th cell, and CD40 dependent. The antigen must be a T-dependent antigen, such as a protein. Polysaccharide antigens do not induce germinal center formation, and newborns have generally not encountered protein antigens in utero that elicit this type of response.

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CHAPTER 10
T CELL DIFFERENTIATION AND FUNCTION

I. The development of T lymphocytes is similar to that of B cells, although unique events occur in the inductive environment of the thymus.

A. Thymic maturation does not require exposure to foreign antigen.

B. Like B cells, T cells are derived from pluripotent **hematopoietic stem cells** in the fetal liver and bone marrow, which differentiate into common **lymphoid progenitor cells** and **progenitor T (pro-T) cells** (Table 10–1).

C. The pro-T cell begins its migration from the bone marrow to the thymus during the first trimester of human pregnancy.

D. In the thymus the cells are called **thymocytes** and undergo considerable cell division and apoptotic death.

1. Differentiation is induced by **stromal cells** and **growth factors**.

a. Epithelial cells, macrophages, and dendritic cells provide both contact-dependent and secreted signals.

b. **Interleukin (IL)-7** is a key growth-promoting factor for thymocytes.

c. Major histocompatibility complex (MHC) molecules promote thymocyte growth and apoptosis.

2. Thymocytes are subjected to both positive and negative selection based on the specificity of their T cell receptors (TCRs).

E. The production of mature T cells occurs throughout life, but the thymus becomes less important as it atrophies with age.

THE BUBBLE BOY

CLINICAL CORRELATION

- *In the 1976 movie "Boy in a Bubble," a child with a severe immunodeficiency avoided life-threatening infections by living in a pathogen-free plastic tent.*
- *A number of molecular defects can cause this condition, known as **severe combined immune deficiency**.*
- *These include mutations in the genes for the Rag recombinases, adenosine deaminase, and the γ chain of the IL-2 receptor (Chapter 16).*
- *The microbial pathogens that establish early opportunistic infections in these children include intracellular fungi, viruses, and bacteria.*
- *While B cell differentiation can also be directly or indirectly affected (depending on the mutation), maternal IgG provides immune protection early in life.*
- *Hematopoietic stem cell transplantation provides the only practical cure.*

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Table 10–1. Stages of T cell differentiation.[a]

	HSC	Pro-T	Pre-T	Double Positive	Single Positive	Naive Mature T Cell
Rag	–	+	–	+	–	–
TdT	–	+	–	–	–	–
TCR DNA	Germline	Germline	Rearranged β chain	Rearranged β and α chain	Rearranged β and α chain	Rearranged β and α chain
TCR	None	None	Pre-TCR	TCR	TCR	TCR
CD3	–	–	+	+	+	+
Surface markers	–	–	–	$CD4^+8^+$	$CD4^+$ or $CD8^+$	$CD4^+$ or $CD8^+$
Anatomic site	Bone marrow	Thymus	Thymus	Thymus	Thymus	Periphery
Response to TCR ligation	None	None	Positive selection	Positive and negative selection	Negative selection	Activation

[a]Tdt, terminal deoxynucleotidyltransferase.

II. Thymocyte differentiation is accompanied by the generation of the TCR repertoire and the establishment of functional cell subsets.

A. Four important events in the development of the T cell lineage occur.

1. TCRαβ and TCRγδ genes are rearranged by recombination (Chapter 6) and are expressed.

2. The MHC restriction specificity of the T cell lineage is established.

3. Thymocytes with autoreactive TCRs are eliminated.

4. Two major functional T cell subsets ($CD4^+$ and $CD8^+$) are generated.

B. Clonal proliferation, apoptotic death, and differential gene expression accompany thymocyte differentiation.

1. **Pro-T** cells migrate to the superficial cortex and become part of the pool of **double-negative ($CD4^-CD8^-$)** thymocytes (Table 10–1 and Table 10–2).

a. Pro-T cells begin to express recombination activating genes 1 and 2 (Rag1, Rag2) and terminal deoxynucleotidyltransferase (TdT) in preparation for TCRβ locus rearrangements.

b. In most pro-T cells, the β locus undergoes D–J rearrangement.

c. Approximately 5% of the descendants of these cells will express γδ TCRs and the remainder will become $TCR\alpha\beta^+$.

2. Pro-T cells then differentiate into **pre-T cells**, in which $V–DJ_\beta$ joining occurs and a β chain polypeptide is expressed.

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Table 10–2. The major subsets of the TCRαβ lineage of thymocytes.[a]

Thymocyte Subset	Surface Phenotype	Major Events or Properties
Double negative		
Pro-T cell	$CD4^-CD8^-TCR^-$	$TdT^+Rag1,2^+$; D-J_β rearrangement
Pre-T cell	$CD4^-CD8^-TCR^-CD3^+$pre-TCR^+	$Rag1,2^+$; V-DJ_β rearrangement
Double positive	$CD4^+CD8^+CD3^+TCR\alpha\beta^+$	V-J_α rearrangement Positive and negative selection
Single positive		
$CD4^+$	$CD4^+CD8^-CD3^+TCR\alpha\beta^+$	Negative selection
$CD8^+$	$CD4^-CD8^+CD3^+TCR\alpha\beta^+$	Negative selection

[a]TCR, T cell receptor.

   a. A **pre-TCR** is expressed that contains a β chain plus a **pre-Tα chain** and CD3 peptides.
   b. Activation of pre-T cells through the pre-TCR stimulates cell proliferation, β locus allelic exclusion, α locus rearrangement, and the expression of CD4 and CD8.

3. **Double positive** thymocytes express TCRαβ with CD3 peptides.
   a. Rag1,2 are expressed for a second time to facilitate rearrangement of the α locus.
   b. TCRαβ binding to MHC molecules signals further maturation.
      (1) Rag1,2 genes become silent.
      (2) Positive and negative selection occurs as the cells transition to a single positive ($CD4^+8^-$ or $CD4^-8^+$) state.
4. **Single positive** cells emerge from the thymus and undergo further maturation in the peripheral lymphoid tissues.
5. The maturation of thymocytes can be monitored by polychromatic flow cytometry (Figure 10–1).
   a. Using antibodies to CD4 and CD8, each with a different fluorochrome, four cell subsets can be identified.
      (1) Double negative ($CD4^-CD8^-$) cells are the pro-T and pre-T cells.
      (2) Double positive ($CD4^+CD8^+$) cells express TCRαβ or TCRγδ and are positively and negatively selected based on their TCR specificities.
      (3) Single positive ($CD4^+CD8^-$ or $CD4^-CD8^+$) cells are fairly mature and ready to exit the thymus.
   b. A similar analysis of peripheral T cells would identify only the two single-positive subsets.

SIGNIFICANCE OF ORAL THRUSH IN INFANTS

CLINICAL CORRELATION

- *A cardinal clinical sign of defective cellular immunity in a neonate is the appearance of mucocutaneous candidiasis or **thrush**.*

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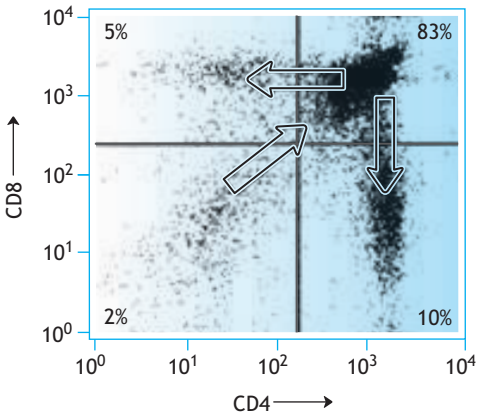

Figure 10–1. Identification of the major subsets of thymocytes by flow cytometry. (Courtesy of Thomas Yankee, University of Kansas Medical Center)

- *Oral thrush is uncommon in immunocompetent individuals.*
- *This painful condition is caused by a superficial infection by the opportunistic yeast* Candida albicans, *which is normal flora in the oral cavity.*
- *The most frequent immune deficiency causing neonatal thrush is AIDS.*
- *However, any cellular immune deficiency, including severe combined immunodeficiency (SCID), selective T cell deficiencies (eg, DiGeorge syndrome, CD3 mutations), and MHC deficiencies, can increase the risk of thrush.*

III. Host MHC molecules determine the specificities of the TCRs that survive thymic selection.

A. The **potential repertoire** of TCRαβ and TCRγδ receptors is determined by the quasirandom recombination events within the DNA that codes for TCR V regions (Chapter 6).

B. The **utilized repertoire** of TCRs results from the selection of receptors with the ability to recognize foreign peptides presented by the MHC of the host.

C. The affinity with which thymocyte TCRs bind MHC molecules in the thymus determines whether positive or negative selection will occur.

1. In the absence of binding, thymocytes undergo death by neglect.
2. Low-affinity TCR–MHC interactions trigger positive selection.
3. High-affinity TCR binding to MHC signals negative selection.

D. Positive selection promotes the development of thymocytes with TCRs specific for foreign peptides plus the host's own MHC molecules.

1. Cells bearing TCRs specific for non-self MHC (ie, that of another individual) die by neglect.
2. Positive selection occurs at the double-positive thymocyte stage and induces differentiation to the single-positive phenotype.
a. Double-positive thymocytes with TCRs that bind to self MHC *class I* molecules are induced to become $CD4^{-}CD8^{+}$.

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b. Double positive thymocytes with TCRs that bind to MHC *class II* molecules become $CD4^+CD8^-$ single positive.
c. Clones that express TCRs specific for nonhost MHC class I or II are not positively selected and die by default.
d. The majority of developing thymocytes are *not* positively selected and undergo apoptosis.

MHC DEFICIENCIES PREVENT POSITIVE SELECTION

- *Two important groups of immune deficiency diseases result from inefficient positive selection of thymocytes.*
- ***Bare lymphocyte syndrome (BLS)** type 1 and type 2 (Chapter 7) are congenital deficiencies in which MHC class I and class II molecules, respectively, are not expressed.*
- *The absence of MHC molecules precludes positive selection of double positive thymocytes and the corresponding T cell subset fails to develop.*
- *For example, BLS type 2 patients are lymphopenic, because $CD4^+$ T cells, which normally constitute the majority of T cells in the blood, do not develop.*
- *The differential diagnosis of BLS type 2 requires exclusion of HIV-1 infection, which is a much more common cause of decreased CD4:CD8 ratios (Chapter 15).*

E. **Negative selection** eliminates potentially harmful thymocyte clones that bear high affinity receptors for self peptides plus self MHC molecules.
1. Negative selection establishes **central tolerance** to self antigens (Chapter 16).
2. Negative selection occurs at the double positive-to-single positive transition.
3. Both MHC class I and class II can signal negative selection.
4. Coreceptor signaling through CD4 and CD8 promotes negative selection.
5. The death signal during negative selection is delivered through **Fas–Fas ligand** interactions between thymocytes and stromal cells of the thymus.

F. Four potential outcomes result from the binding of peptide–MHC complexes by TCRs.
1. Thymocyte clones are induced to proliferate and differentiate (positive selection).
2. Thymocyte clones undergo apoptosis (negative selection).
3. Peripheral T cells proliferate and differentiate in response to foreign antigens.
4. Peripheral T cells can become anergic (**peripheral tolerance**) if coreceptor signaling is lacking (Chapter 16).

DEFECTIVE THYMIC APOPTOSIS

- *Apoptotic death regulates thymocyte selection and T cell activation in the periphery.*
- ***Autoimmune lymphoproliferative syndrome (ALPS)** (also known as Canale–Smith syndrome) is a defect in the apoptosis of activated T cells.*
- *In most patients a mutation exists in the gene coding for **Fas** (CD95).*
- *Patients present with greatly enlarged lymph nodes, splenamegaly, and autoimmunity (eg, Coombs-positive hemolytic anemias).*
- *Affected individuals also show lymphocytosis and an elevated number of double negative ($TCR\alpha\beta^+CD4^-CD8^-$) T cells in the blood.*
- *Similar phenotypes occur with patients bearing mutations in Fas ligand or certain caspase genes.*

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IV. Cell surface adhesion molecules, coreceptors, and cytokine receptors regulate T cell activation in the periphery.

A. **Cell adhesion molecules** promote T cell homing to specific tissues by binding to ligands on vascular endothelial cells and matrix proteins.

1. T cells express **integrins**, such as **lymphocyte function-associated antigen-1 (LFA-1)**, that mediate lymphocyte homing to sites of infection and inflammation.
2. Specialized integrins direct T cells to mucosal lymphoid tissues.
3. Integrins increase the avidity of binding between T cells and their antigen-presenting cells.
4. Integrins promote binding between cytotoxic T cells and their target cells.

B. **Coreceptors** are induced and recruited to the **immunological synapse** that forms between a T cell and its antigen-presenting cell.

1. The cell surface expression of coreceptors and their ligands is often regulated to avoid the unwanted activation of resting T cells.
2. Receptor clustering brings coreceptors in proximity to TCRs.
3. Receptor clustering promotes synergy between intracellular signaling pathways.
4. **CD4** and **CD8** are coreceptors that bind to nonpolymorphic residues of MHC class II and class I molecules, respectively.
   - **a.** The T cell-specific kinase **Lck** is associated with CD4 and CD8 in the membrane.
   - **b.** Lck phosphorylates immunotyrosine activation motif (ITAM) residues on CD3 peptides.
   - **c.** Thymocytes lacking Lck are not positively selected at the double-positive stage.
5. **CD28** and **cytotoxic T lymphocyte-associated protein 4 (CTLA-4)** (CD152) on T cells modify TCR signaling.
   - **a.** The **costimulatory ligands** for these coreceptors are members of the B7 family and are expressed on antigen-presenting cells.
   - **b.** Ligation of CD28 on naive T cells by B7 induces phosphatidylinositol-3-kinase activation.
   - **c.** Stimulation of T cells through CD28 activates NFκB.
   - **d.** CTLA-4 is expressed on activated T cells and mediates negative signaling when B7 is bound.
6. **CD154** is a coreceptor for $CD4^+$ Th cells.

C. **Cytokine receptors** augment or inhibit T cell responses to antigen.

1. The expression of cytokine receptors is often induced by antigen and coreceptor stimulation.
2. **IL-2** is a growth factor for activated $CD4^+$ and $CD8^+$ T cells.
3. **IL-4** promotes the differentiation of the Th2 subset from naive, antigen-stimulated $CD4^+$ T cells.
4. **Interferon (IFN)-γ** promotes the differentiation of the Th1 subset of T cells.
5. **IL-10** and **transforming growth factor (TGF-β)** inhibit the activation of Th1 cells.
6. **IFN-γ** inhibits the activation of Th2 cells.

D. Different types of costimulatory and cytokine signals are derived from different types of antigen-presenting cells (Table 10–3).

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Table 10–3. Differences between APCs related to T cell activation.[a]

Property	Dendritic Cell	B Cell	Macrophage
Antigen uptake	Active endocytosis	BCR-mediated endocytosis	Endocytosis and phagocytosis
MHC class II expression	Constitutive	Constitutive	Inducible
Costimulatory ligand expression	Constitutive B7	Inducible B7	Inducible B7
T cells activated	Naive, effector and memory	Effector and memory	Effector and memory

[a]APC, antigen-presenting cells; BCR, B cell receptor.

1. **Dendritic cells** are particularly effective at activating naive $CD4^+$ T cells, because they express B7 and MHC class II constitutively.
2. **B cells** have the advantage of being able to capture limited quantities of antigen through their BCR, which aids in activating memory T cells with high-affinity TCRs.
3. **Macrophages** can phagocytize particulate antigens and present their epitopes to T cells.

V. The activation of mature T cells by antigen in the periphery leads to clonal expansion and differentiation into effector and memory cell subsets.

A. The frequency of T cells specific for a given antigen changes during an immune response.
1. Clonal frequencies among resting naive T cells is approximately 10^{-6}.
2. The frequency of antigen-specific T cells increases to 10^{-2} at the peak of the expansion phase.
3. Memory cells for a given antigen exist at a frequency of 10^{-4}.

B. $CD4^+$ helper T cells (Th cells) can be subdivided into two subsets (Figure 6–5).
1. **Th1 cells** mediate cellular immunity to intracellular microbial pathogens by the secretion of cytokines [eg, IL-2, IFN-γ, and tumor necrosis factor (TNF)-α] that promote T cell growth and activate macrophages and neutrophils.
2. **Th2 cells** promote humoral immunity to extracellular microbial pathogens by producing cytokines (IL-4, IL-5, and IL-13) that activate B cells.

C. **Memory T cells** divide at a low rate and recirculate for decades.
1. The chemokine receptor CCR7 and certain adhesion molecules facilitate memory T cell migration into lymph nodes.
2. The antigen-presenting cell (APC) signals required to activate a memory T cell with antigen are different than those required by naive T cells (Table 10–2).
3. Memory T cells become a greater proportion of the T cell pool with age.

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D. Regulatory T (Treg) cells inhibit immune responses (Chapter 11).
1. Treg cells are most often $CD4^+$ and express **CD25**, the α chain of the high-affinity IL-2 receptor.
2. Treg cells produce the inhibitory cytokines **IL-10** and **TGF-β**.
3. Treg cells contribute to the maintenance of self tolerance (Chapter 16).

E. Several subsets of T cells and related lymphocytes are **cytotoxic** (Table 10–4).
1. **Cytotoxic T lymphocytes (CTL)** are induced by antigen, terminally differentiated and short lived.
   a. Most CTL are $CD8^+$ and MHC class I restricted.
   b. Cytotoxic $CD4^+$ cells exist, but are MHC class II restricted.
   c. Both TCRαβ and TCRγδ T cells can be cytotoxic.
   d. Cytotoxicity is mediated by the granzyme–perforin pathway, the Fas–Fas ligand pathway, and the TNF receptor pathway (Chapter 6).
2. The **γδ T cell** subset shows specificity for pathogens associated with epithelial surfaces.
   a. γδ T cells are **intraepithelial lymphocytes** that accumulate in the skin, small intestine, lung, and genitourinary tract.
   b. Most $TCR\gamma\delta^+$ cells do not express CD4 or CD8.
   c. TCRγδ is specific for nonpeptides, including glycolipids that represent pathogen-associated molecular patterns.
   d. TCRγδ is not MHC restricted.

Table 10–4. A comparison of conventional T cells, γδ T cells, NKT cells, and NK cells.[a]

Property	Conventional T Cell	γδ T Cell	NKT Cell	NK Cell
Tissue location	Spleen, lymph nodes, lymphoid follicles	Intraepithelial	Thymus, liver, spleen	Liver > spleen
Receptor type	TCRαβ + CD3	TCRγδ + CD3	Invariant TCRαβ + CD3	Activating FcγR NKG2D Inhibitory KIR Lectins
Receptor specificity	Peptide + MHC class I or class II	Microbial glycolipids	Microbial glycolipids Stress-induced host ligands There are two receptor types and two receptor specificities: activating and inhibitory	Activating IgG antibody Stress-induced host ligands Inhibitory HLA-A,B,C

[a]NKT, natural killer T; TCR, T cell receptor; MHC, major histocompatibility complex; KIR, killer inhibitory receptor; IgG, immunoglobulin G.

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e. Signaling through **TCRγδ** is similar to that of TCRαβ.
f. γδ T cells can be cytotoxic or cytokine producing.

3. **Natural killer T (NKT) cells** express both TCRs and NK cell markers.
   a. The invariant TCRαβ of NKT cells is restricted by CD1 and specific for microbial glycolipids.
   b. NKT cells respond rapidly to antigen and produce IL-4 and IFN-γ.

F. Although not thymus derived, **NK cells** share a number of properties with T cells and NKT cells.

1. NK cells recognize host cells infected with intracellular microbial pathogens using unique receptors.
   a. NK cell **inhibitory receptors** recognize MHC class I molecules and deliver signals that are dominant over NK cell-**activating receptor** signals.
   b. NK cell-**activating receptors** recognize host cell ligands that are present on infected or stressed cells.
   c. When host cells fail to express MHC class I (as during virus infections), the inhibitory signal is lost and the NK cell becomes activated.
   d. Activating receptors signal through their ITAMs and inhibitory receptors utilize **immunotyrosine *inhibitory*** motifs (ITIMs) to transmit intracellular signals.
   e. The functions of NK cells are promoted by cytokines.
2. NK cells mediate innate immunity by producing cytokines (eg, IFN-γ) and killing infected target cells without the need for clonal expansion.
3. Important coactivating signals for NK cells include IL-12 and IFN-α/β.

CHEDIAK–HIGASHI SYNDROME

- *Chediak–Higashi Syndrome (CHS) is a rare autosomal recessive condition characterized by recurrent infections and poor NK cell activity.*
- *The genetic defect resides in the gene for **lysosomal trafficking regulator (LYST)** and causes a fusion of cytoplasmic granules in NK cells, neutrophils, monocytes, and other granule-containing cells.*
- *CHS NK cells bind normally to their target cells, but killing is absent.*
- *The immune deficiencies of CHS patients are probably more related to defective neutrophil function than impaired NK cell activity.*

CLINICAL PROBLEMS

You have a patient with enlarged lymph nodes, splenamegaly, and anemia. During an immunological work-up you find that the patient has a slight lymphocytosis. You perform multicolor flow cytometry after staining the patient's blood lymphocytes with antibodies to CD3, CD4, and CD8. Shown below are $CD3^+$ blood lymphocytes stained for CD4 (x-axis) and CD8 (y-axis) expression.

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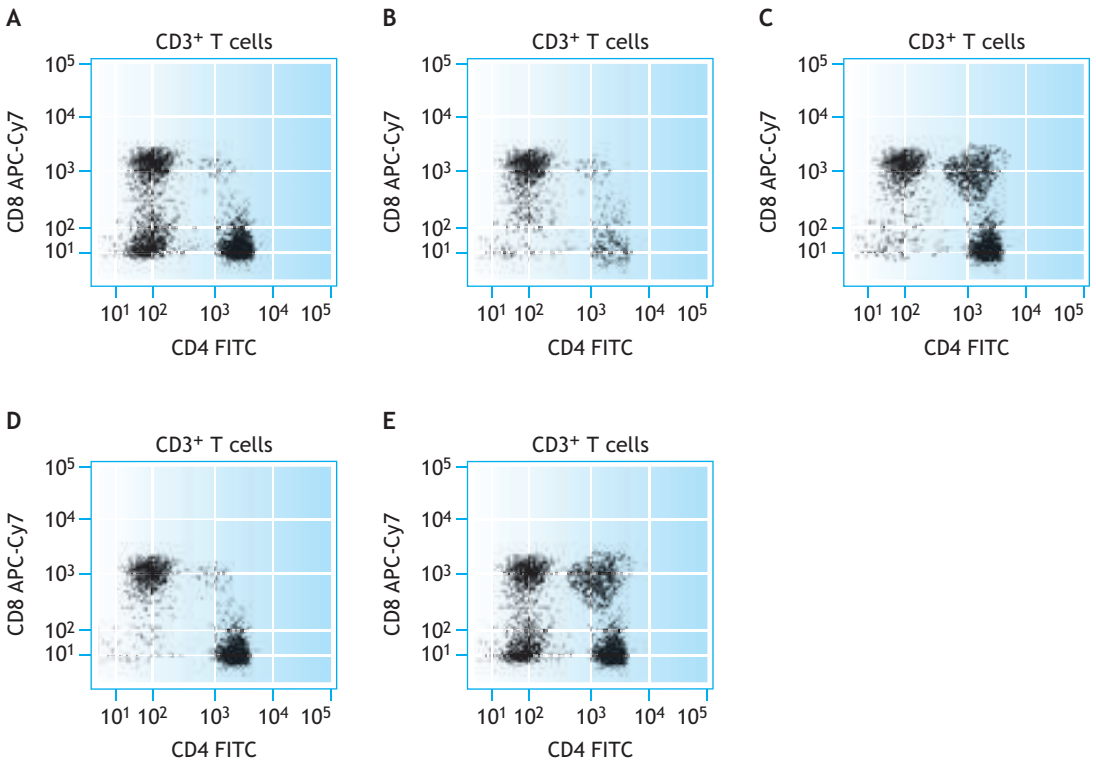

1. Which of the patterns shown above would suggest an apoptosis defect is responsible for this patient's disease?

A. A
B. B
C. C
D. D
E. E

A patient with BLS type 1 presents with a herpes virus infection. His blood lymphocytes are found to kill autologous virus-infected target cells rapidly in vitro.

2. Which of the following cell types is probably mediating this killing?

A. $CD8^+$ T cells
B. γδ T cells
C. Macrophages
D. NK cells
E. B cells

You are a member of a cardiac transplantation team in a medical school and meet with second-year medical students to explain the surgical procedure and posttransplantation therapy. One of the drugs you review is cyclosporine.

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3. Which of the following would be a reasonable summary of its immunosuppressive effect?

A. The drug kills dividing T and B cells in metaphase.

B. The drug inhibits antigen processing by dendritic cells.

C. The drug inhibits IL-2 gene transcription in T cells.

D. The drug blocks NK cell recognition of foreign HLA antigens.

E. The drug inhibits HLA class I expression by cardiac muscle cells.

Mutations in either Rag1 or Rag2 cause severe immunodeficiencies in human beings.

4. Which of the following cell types would show normal numbers in a patient with a Rag1 deficiency?

A. $CD3^+$ cells with a CD4 coreceptor

B. $CD19^+$ cells

C. Single positive thymocytes

D. Lymphocytes with a coreceptor specific for C3d

E. Cells with an inhibitory receptor specific for MHC class I

Johnny is an 8-month-old child with recurrent viral and fungal infections. His blood lymphocytes can bind IL-2, and his macrophages can bind IFN-γ in vitro. It has been determined that his parents are both heterozygous for a mutation in the ZAP-70 gene known to disrupt the activity of this kinase.

5. Assuming Johnny has inherited this mutation from both parents, which of his cells should be *normal*?

A. Monocytes and macrophages

B. TCRαβ T lymphocytes

C. TCRγδ T lymphocytes

D. NK cells

E. NKT cells

ANSWERS

1. The correct answer is A. This pattern is abnormal in the sense that the blood contains large numbers of double negative T lymphocytes ($CD3^+CD4^-CD8^-$). Normally, double negative $CD3^+$ cells are found only in the thymus (panel E). This finding suggests altered thymic selection and peripheral homeostasis of T cell subsets secondary to defective apoptosis induced by the Fas–Fas ligand system (ie, autoimmune lymphoproliferative syndrome). The normal pattern for blood $CD3^+$ cells is shown in panel D.

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2. The correct answer is D. NK cells recognize virus-infected and neoplastic cells that lack MHC class I, which is characteristic of cells from patients with BLS type 1.

3. The correct answer is C. Cyclosporine inhibits the Ca^{2+}/calmodulin-dependent phosphatase calcineurin, which leads to decreased TCR-initiated dephosphorylation of the latent transcription factor NFAT. With diminished NFAT activation, IL-2 and IL-4 gene transcription is decreased, which has a general immunosuppressive effect on activated T cells.

4. The correct answer is E. $T^-B^-NK^+$ SCID is caused by Rag recombinase deficiency. The patients have normal numbers of NK cells, which bear inhibitory receptors for MHC class I molecules.

5. The correct answer is A. All of the lymphocyte subsets listed use ZAP-70 as a signaling intermediate for receptor-induced cell activation.

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CHAPTER 11
REGULATION OF IMMUNE RESPONSES

I. The immune response is regulated at the level of antigen recognition by mechanisms designed to distinguish self from nonself.

A. The innate immune system recognizes **pathogen-associated molecular patterns** that are not seen on host tissues.

B. The adaptive immune system recognizes nonself **epitopes** using T and B cell receptor repertoires that have been selected for their specificity during lymphocyte differentiation.

C. Both systems are imperfect, and immune responses to self components can arise even in healthy individuals (Chapter 16).

1. Toll-like receptors recognize self components derived from damaged tissues (eg, heat shock proteins).

2. Antibody production against self antigens occurs frequently without any adverse effect.

II. Antigen-presenting cells (APCs) control the induction of adaptive immune responses.

A. The constellation of major histocompatibility complex (MHC) molecules expressed by an APC determines the peptides it can present.

B. **Coreceptor signals** derived from APCs influence the type of immune response induced.

1. Whereas mature dendritic cells (DC) activate $CD4^+$ Th cells, immature DC activate $CD4^+$ Treg cells.

2. CD28 binding of B7 molecules induces Th cell activation, whereas cytotoxic T lymphocyte-associated protein 4 (CTLA-4) binding of B7 molecules inhibits Th cell activation.

C. **Cytokines** influence APC functions and lymphocyte activation.

1. Interferon (IFN)-γ and tumor necrosis factor (TNF)-α increase MHC class II expression and APC function.

2. Macrophage- and DC-derived interleukin (IL)-12 promotes Th1 cell activation.

3. IL-4 produced by T cells and mast cells promotes Th2 cell differentiation.

III. When an immune response does occur, its duration is limited, and the immune system returns to a basal homeostatic state.

A. As antigen is cleared from the body, lymphocyte activation subsides.

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B. Antigen-activated lymphocytes undergo **activation-induced cell death**.

1. Activated T lymphocytes express both **Fas** and **Fas ligand**, which signals apoptotic death.

a. The cytoplamic domains of Fas contain death domains that bind adapter proteins, recruit and activate caspases, and trigger apoptosis.

b. Fas deficiency in humans causes **autoimmune lymphoproliferative syndrome (ALPS)** (Chapter 10), the failure of activated T cells to undergo apoptosis.

2. Oxidant production by activated cells initiates cell death through the endogenous apoptosis pathway.

C. Effector lymphocytes, neutrophils, and macrophages are relatively **short lived**.

D. Memory B and T cells show only **low levels of proliferation**.

E. **Antibodies** regulate immune responses to their antigens.

1. Maternal antibodies that cross the placenta can interfere with the immunization of the newborn in the first few months of life.

2. Complement-activating antibodies enhance B cell activation through the **CR2 coreceptor** (Chapter 9).

3. Immune complexes containing immunoglobulin G (IgG) can also inhibit B cell activation (Figure 11–1).

a. IgG antibody–antigen complexes can simultaneously bind to the **Fcγ receptor IIB (FcγRIIB)** and BCR.

b. BCR cross-linking to FcγRIIB blocks B cell receptor (BCR) signaling.

(1) The cytoplasmic tail of FcγRIIB contains **immunotyrosine inhibitory motifs (ITIMs)**, which recruit **Src homology 2 domain-containing inositol polyphosphate 5-phosphatase (SHIP)**.

(2) SHIP disrupts phospholipase Cγ (PLCγ) and Bruton's tyrosine kinase (Btk) activation.

RHOGAM THERAPY

- ***Hemolytic disease of the newborn (erythroblastosis fetalis)*** *is caused when an Rh-negative mother produces IgG antibodies to the Rh antigens of her fetus.*
- *Fetal anemia and jaundice occur when these antibodies cross the placenta.*
- *To prevent this condition, Rh-negative mothers are given* ***Rhogam*** *(Rh-specific γ-globulin) during and immediately after pregnancy.*
- *Rhogam prevents immunization of the mother by clearing fetal erythrocytes from her blood circulation.*
- *Rhogam also cross-links the BCR and FcγRIIB on maternal B cells and inhibits maternal B cell activation.*

4. IgG immune complex binding to macrophage **FcγRI** (CD64) also induces the release of **IL-10, transforming growth factor (TGF)-β**, and **prostaglandin E_2 (PGE_2),** all of which inhibit lymphocyte activation.

5. Antibodies produced against the idiotypic determinants of a BCR can inhibit B cell activation.

a. Autoantibodies against idiotypes are produced regularly during adaptive immune responses.

b. Antiidiotype antibodies can block B cell activation by cross-linking the BCR to FcγRIIB.

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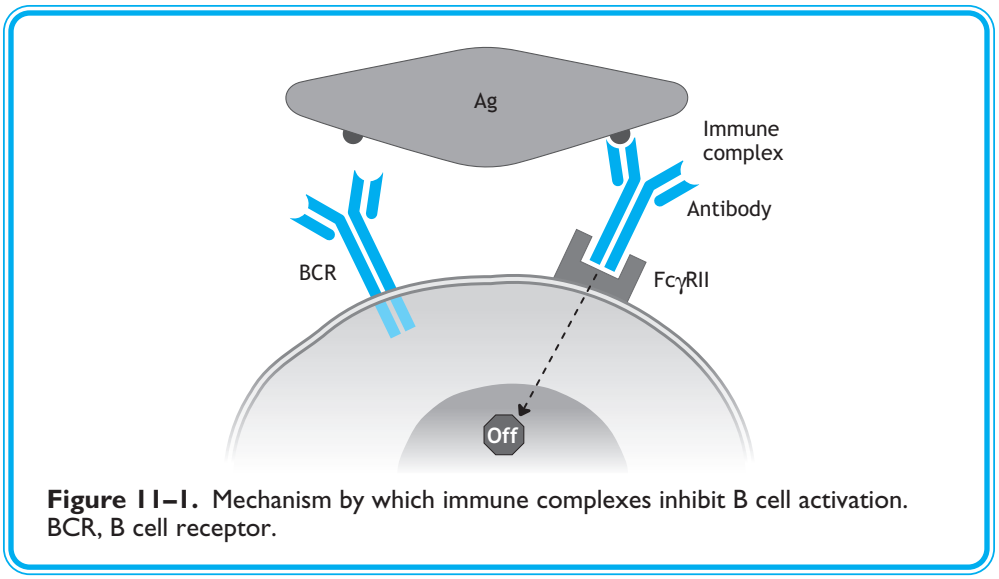

Figure 11–1. Mechanism by which immune complexes inhibit B cell activation. BCR, B cell receptor.

6. When high circulating antibody concentrations are achieved, the rate of Ig catabolism also increases.

INTRAVENOUS IMMUNOGLOBULIN (IVIG) THERAPY IN MULTIPLE MYELOMA

- *Multiple myeloma is characterized by pancytopenia due to the depression of hematopoiesis by the malignant cells within the bone marrow.*
- *This causes a functional **hypogammaglobulinemia** (ie, decreased production of useful antibodies) and increases the risk of infections.*
- *Prophylactic treatment with IVIG has not always proven useful for correcting this defect.*
- *The extremely high circulating levels of the M component cause an elevated clearance rate for all Ig, which limits the lifespan of exogenous IVIG.*

IV. $CD4^+CD25^+$ regulatory T cells (Treg cells) mediate immune homeostasis.

A. Treg cells suppress immune responses by several mechanisms.

1. They consume IL-2 and deprive other lymphocytes of its growth-promoting activity.

2. Treg cells inhibit activated T cells by cell–cell contact and the secretion of the inhibitory cytokines **IL-10** and **TGF-β**.

3. Treg cells are induced late in immune responses and act by suppressing T cell effector functions.

B. Treg cells prevent immune-mediated diseases.

1. Treg cells limit host tissue damage that might otherwise occur during exuberant immune responses to microbes.

2. Treg cells assist in the maintenance of self tolerance and prevent autoimmunity.

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THE IMMUNOLOGICAL ENIGMA OF PREGNANCY

- *In human pregnancies, the fetus is generally considered a **semiallograft** (ie, half of its tissue antigens are genetically foreign to the mother) (Chapter 17).*
- *It is not clear why such a foreign tissue graft is not rejected by the mother, but several mechanisms appear to contribute to fetal survival.*
- *Trophoblastic cells that form the fetal interface with the maternal circulation are devoid of most HLA antigens and certain costimulatory molecules, such as B7.*
- *Inhibitory factors, including IL-10, B7 isoforms, death receptor ligands, and PGE_2, are expressed at high levels at sites of implantation.*
- *Some fetal cells do cross the placenta and are tolerated by the mother's immune system for years after pregnancy, suggesting a central immune anergy.*

V. Polymorphisms exist in genes that regulate immune functions.

A. Dozens of genes that control immune cell differentiation and activation have been described, some of which will be discussed in Chapter 16.
  1. The majority of heritable defects in adaptive immunity have been genetically mapped, and the gene products have been identified.
  2. Much less is known about human genetic polymorphisms or mutations linked to defects in innate immunity.

B. Functionally significant mutations and polymorphisms in genes affecting complement components, components of antigen presentation pathways, cytokines, cytokine receptors, and Ig switch recombinases have been described.

VI. Dysregulation of the immune system can cause immunological diseases.

A. **Autoimmunity** occurs when self-tolerance is lost (Chapter 16).
  1. T cells specific for autoantigens can be activated when coreceptor ligands (eg, B7) are abnormally expressed.
  2. B cells that produce high affinity autoantibodies can be activated by costimulatory signals derived from infection.
  3. Defects in apoptosis (eg, Fas mutations) can result in a failure to delete autoreactive T cells.

B. Adaptive immune responses to microbial antigens can **cross-react** with self tissue antigens and cause immune-mediated tissue damage.

RHEUMATIC FEVER

- *Rheumatic fever in school age children is a complication secondary to pharyngitis caused by the bacterium* Streptococcus pyogenes.
- *Damage to the heart and joints appears 2–4 weeks after the pharyngitis.*
- *Antibodies produced against the streptococcal M protein **cross-react** with cardiac autoantigens.*
- *Autoantibodies to myosin, keratin, and laminin play a key role in cardiac valve damage.*

C. **Atopic allergies** result when excessive immune responses are made to relatively innocuous environmental antigens (Chapter 13).
  1. Immune dysregulation causes **Th2 polarization.**
  2. IgE antibody production favors acute inflammatory responses.

D. **Immune responses to microbes** can exceed what is necessary to clear the pathogen.

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1. **Inflammatory bowel disease** results from immune responses to microbial flora that initiate chronic inflammation.
2. **Infectious mononucleosis** is caused by an excessive $CD8^+$ T cell response to Epstein–Barr virus antigens that damages host tissues.

SEPSIS REVISITED

CLINICAL CORRELATION

- ***Sepsis*** *is a systemic inflammatory response to infection and one of the leading causes of death among hospitalized patients.*
- *The disease also illustrates what happens when immune mechanisms designed to protect the host are excessively activated (Figure 11–2).*
- *A complex pathogenesis results from the activation of multiple host defense systems by pathogenic and opportunistic microbes.*
- *Bacterial components, including lipopolysaccharide (LPS), can activate the complement, coagulation, and fibrinolysis systems.*
- *Macrophage activation for the production of proinflammatory cytokines (eg, TNF-α) and arachidonic acid metabolites results from Toll-like receptor stimulation.*
- *Endothelial and smooth muscle cells are activated, resulting in coagulopathies, severe hypotension, impaired organ perfusion, and hypoxic tissue damage.*

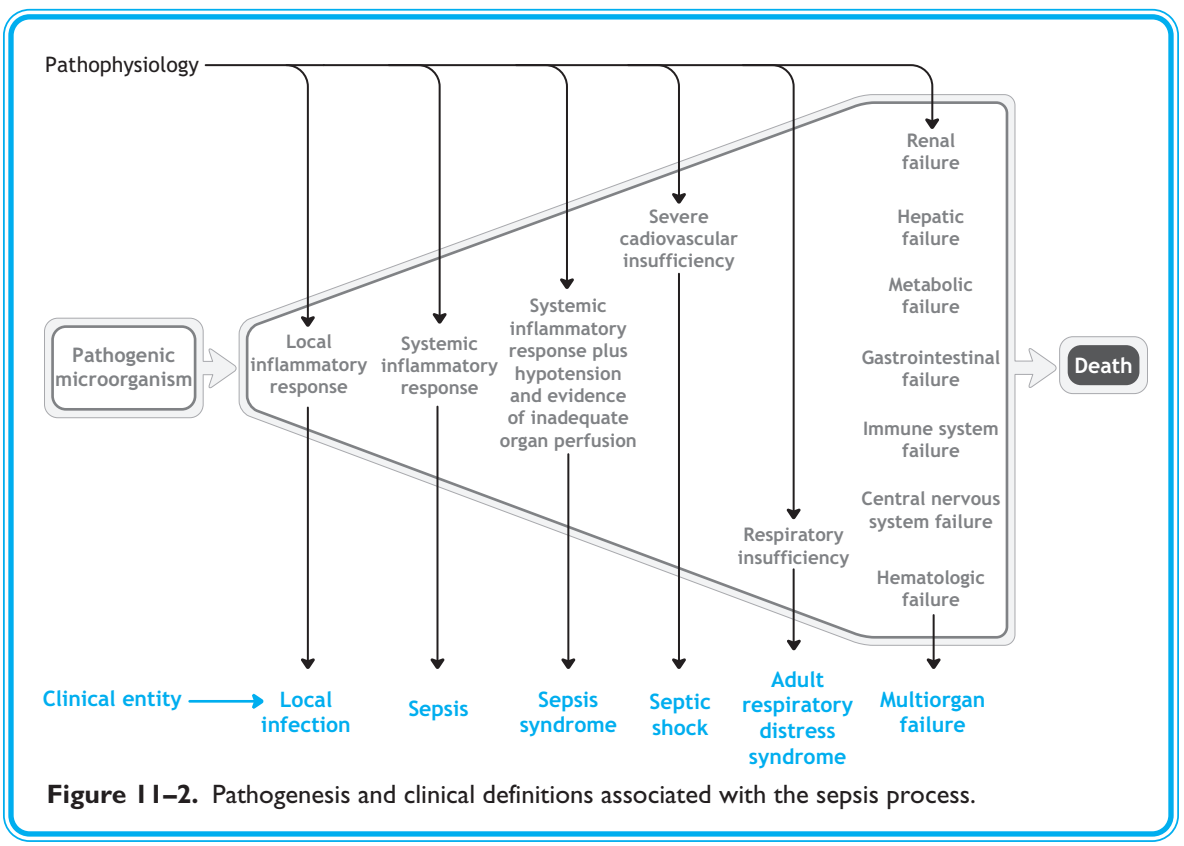

Figure 11–2. Pathogenesis and clinical definitions associated with the sepsis process.

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CLINICAL PROBLEMS

Clinical vaccine trials using a nine-amino acid peptide immunogen from an HIV-1 glycoprotein have been performed. The vaccine is effective at inducing high-affinity IgG virus-neutralizing antibodies in only a subset of healthy adult vaccinees.

1. Which of the following immune properties probably characterizes the responsive individuals?

A. They share HLA class II genes.

B. They lack Treg cells.

C. They are high producers of IL-10.

D. They lack IL-2 receptors.

E. They are all over 70 years of age.

A patient with lupus presents with impaired renal function, and a biopsy shows IgG and C3b deposits in the renal glomerulus. The patient's serum contains antibodies to her DNA and erythrocytes. Her total IgG is significantly elevated (1900 mg/dL).

2. Which of the following best explains the hypergammaglobulinemia seen in this patient?

A. Reduced clearance of IgG by the damaged kidney

B. Destruction of Treg cells by anti-DNA antibodies

C. Polyclonal B cell activation by numerous self antigens

D. An opportunistic virus infection

E. Depletion of serum complement

Mary is a 2-year-old child with an unremarkable medical history, but presents today with enlarged cervical lymph nodes. Her complete blood count shows lymphocytosis (10,500/μL) and her serum contains elevated concentrations of IgG and IgM. Flow cytometry indicates that her $CD3^+$ lymphocytes are 25% $CD4^+$ and 20% $CD8^+$. She has no history of recurrent infections and no evidence of a current infection or cancer.

3. Which of the following is the most likely basis for Mary's immune abnormalities?

A. HIV-1 infection

B. IgA deficiency

C. Thymic hypoplasia (DiGeorge syndrome)

D. An apoptosis defect (Fas deficiency)

E. A monoclonal gammopathy

A 2-month-old healthy child is immunized with a new bacterial protein vaccine as part of a clinical trial. His preimmunization titer of IgG antibody to the vaccine protein is 1:16, and the titer is unchanged 2 weeks postimmunization.

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4. Which of the following is a likely explanation for this observation?
   A. The child has had an infection with the bacterium during gestation.
   B. Maternal antibody to the bacterial protein blocked active immunization of the child.
   C. The child has severe combined immune deficiency.
   D. The child has a Th cell defect that prevents Ig class switching.
   E. Children cannot make antibodies at this age.

ANSWERS

1. The correct answer is A. The high responding vacinees probably share HLA antigens that can present the peptide vaccine. Because this is an exogenous antigen, class II molecules would be involved. Presumably, the HLA class II molecules of the nonresponders failed to bind and present the peptide.

2. The correct answer is C. Elevated IgG levels in this patient are probably due to polyclonal B cell activation by autoantigens. Most patients of this type produce autoantibodies to a wide range of self antigens, suggesting that they have defects in general immune regulation mechanisms.

3. The correct answer is D. Mary has an unusual pattern of T cell markers. Only 45% of her T cells express either CD4 or CD8; the remaining T cells are apparently double negative. This is a classic sign of ALPS (Chapter 10). The condition arises from a defect in apoptosis among T cells resulting from a Fas mutation. Her elevated immunoglobulins probably represent autoantibodies against a range of self antigens, because self-reactive T cells are not controlled by Fas-mediated apoptosis.

4. The correct answer is B. The IgG antibodies present prior to immunization were probably maternally derived, because children of this age do not synthesize much IgG. The fact that the titer did not increase following immunization seems to indicate that the maternal antibodies interfered with B cell activation. This would occur if the vaccine and preformed maternal antibodies formed immunosuppressive immune complexes and cross-linked the BCR and FcγRIIB.

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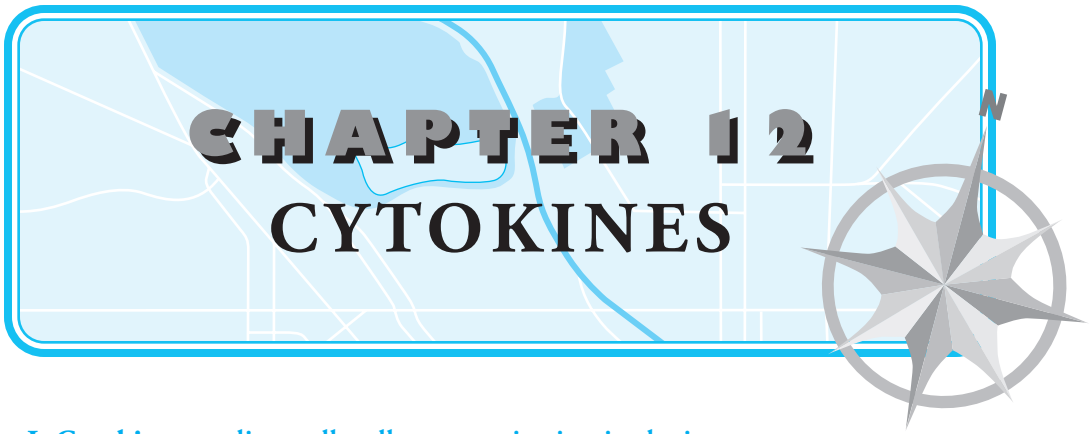

CHAPTER 12
CYTOKINES

I. Cytokines mediate cell–cell communication in the immune system.

A. Cytokines are 8- to 25-kDa polypeptides that include **interleukins (IL), chemokines, growth factors (GF), interferons (IFN)**, and **colony-stimulating factors (CSF)** (Appendix II).

B. Most cytokines are designed for rapid, short-term effects.
1. They are often secreted immediately after their synthesis.
2. Their short half-lives in circulation reflect the action of inactivators and binding proteins.

C. Cytokines typically act over short distances.
1. Many cytokines (eg, IL-2) have **autocrine** effects; they act on the cells that produce them.
2. Other cytokines have localized **paracrine** effects; one cell produces a cytokine that acts on a nearby cell.
3. Cell–cell contact promotes the action of cytokines.
4. A few cytokines show **endocrine** effects; they act at a distance after secretion into the blood stream.
a. Tumor necrosis factor (TNF)-α produced by tissue macrophages during bacterial infections can have systemic inflammatory effects.
b. IL-1β produced during inflammation or infections causes fever by its endocrine effects on the hypothalamus.

D. Cytokines activate cells through specific high-affinity receptors.
1. Dissociation constants for cytokine receptors are in the picomolar range.
2. Receptors for cytokines that mediate acute inflammatory or innate immune responses are typically constitutively expressed.
3. Receptors for lymphocyte-activating cytokines are often induced.
4. The same receptor for a given cytokine may have significantly different effects when expressed on different cell types.

E. The most common cellular response to a cytokine is the rapid initiation of gene transcription.

F. Cytokines have **redundant** biological effects (Table 12–1).
1. This ensures that a deficiency of one cytokine does not eliminate an essential biological function.
2. Cytokine redundancy frustrates anticytokine therapies.

G. Most cytokines are **pleiotropic**; they exhibit several functions.

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Table 12–1. Redundancies between TNF-α and IL-1β.[a]

Response	TNF-α	IL-1β
Fever induction	+	+
Acute phase protein induction through IL-6	+	+
Induction of vascular adhesion molecule expression	+	+
Induction of IL-8	+	+
Activation of NFκB	+	+
Joint inflammation in rheumatoid arthritis	+	+
Systemic inflammatory response syndrome (SIRS)	+	+
Cachexia	+	–
Induction of apoptosis	+	–

[a]TNF, tumor necrosis factor; IL, interleukin.

H. When combined, cytokines can have **synergistic** effects.
1. One cytokine may induce the expression of receptors for the second cytokine.
2. Distinct cytokine receptor signaling pathways can converge at the same cellular response (eg, NFκB activation).

I. Cytokines can **amplify** a biological response by inducing additional cytokine synthesis (Figure 12–1).

J. Certain cytokines **antagonize** the effects of other cytokines.
1. IFN-γ inhibits the effects of IL-4 on B cells.
2. IL-10 and transforming growth factor (TGF)-β antagonize the effects of IFN-γ on macrophages.

K. There are dedicated **inhibitors** of cytokines.
1. **IL-1 receptor antagonist (IL-1ra)** is produced by the same cells that secrete IL-1 and binds to the same receptor.
2. The amino-terminus of TGF-β maintains the secreted cytokine in a latent form until it is removed by proteolysis.

TUBERCULOSIS IN RHEUMATOID ARTHRITIS

- ***Rheumatoid arthritis (RA)*** *is an autoimmune disease characterized by inflammation of the joints and a progressive loss of joint function.*
- *New therapies for RA include the use of anticytokine reagents to block the action of TNF-α or IL-1β.*
- *For example, Etanercept is a recombinant protein consisting of a portion of a TNF receptor (p75) fused to the Fc portion of human immunoglobulin (Ig) G to prolong its circulating half-life.*

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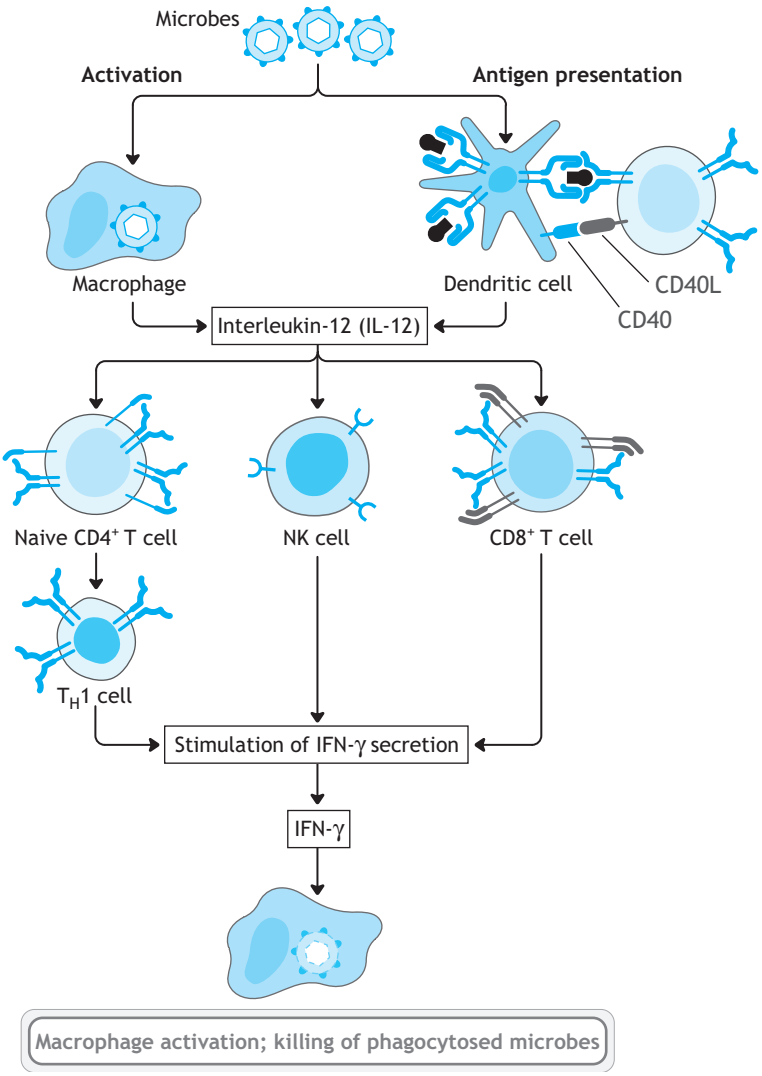

Figure 12–1. A cytokine cascade. NK, natural killer; IFN, interferon.

- *Combining an anti-TNF-α and an anti-IL-1β drug in these patients increases the risk of pulmonary tuberculosis.*
- *This finding emphasizes the importance of using anticytokines under conditions that inhibit inflammation without impairing innate host defenses.*

II. Macrophages, natural killer (NK) cells, and NKT cells are important sources of **proinflammatory cytokines** that also mediate **innate immunity** (Table 12–2).

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Table 12–2. Cytokines that mediate innate immunity and acute inflammation.[a]

Biological Function	Important Cytokines	Specific Examples
Leukocyte adhesion	TNF-α	Induces ICAM-1 expression on endothelium
Chemotaxis	TGF-β IL-8	Recruits blood monocytes Recruits blood neutrophils
Induction of other inflammatory mediators	IFN-γ	Promotes macrophage activation for IL-1 and TNF-α production
Fever induction	IL-1β	Activates cells of the hypothalamus
Acute phase protein synthesis	IL-6, IL-1, TNF-α	Activates hepatocytes and Kupffer cells to produce fibrinogen and complement components
Oxidant production	TNF-α IFN-γ	Activates neutrophils for superoxide production Activates macrophages for NO production
Inhibition of immunity	IL-10, TGF-β	Inhibits TNF-α synthesis by IFN-γ-activated macrophages
Apoptosis	TNF-α LT, IL-2	Apoptosis of tumor cells Activation induced cell death in T cells

[a]TNF, tumor necrosis factor; ICAM, intercellular adhesion molecule; TGF, transforming growth factor; IL, interleukin; IFN, interferon; LT, leukotriene.

A. These cells bear receptors that recognize both conserved microbial structures and endogenous ligands derived from damaged host cells.
  1. Macrophages express Toll-like receptors (TLRs) (Table 1–2).
  2. NK cells and NKT cells recognize exogenous and endogenous ligands from infected, stressed, or injured host cells (Table 10–4).

B. The cytokines produced by these cells signal **danger** to phagocytes and endothelial cells.
  1. TNF-α has the following functions.
    a. It stimulates the expression of **adhesion molecules** and **integrins** on endothelial cells and leukocytes, respectively.
    b. It primes **neutrophils** and **macrophages** for respiratory bursts and NO production.
    c. It induces the synthesis of **acute phase proteins**.
    d. It induces **apoptosis** through its death domain-containing receptor.

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2. **IL-1β** has the following functions.
   a. It is redundant with TNF-α (Table 12–1).
   b. It synergizes the effects of TNF-α.
   c. It induces **fever** by stimulating the hypothalmus.
3. **IL-12** has the following functions.
   a. It coactivates NK cells and T cells.
   b. It coinduces **IFN-γ production** and cytotoxicity by NK cells and NKT cells.
   c. It induces the differentiation of $CD4^+$ Th1 cells.
4. **IFN-γ** (type II interferon) has the following functions.
   a. It **activates macrophages**.
   b. It induces the production of other **proinflammatory cytokines**, including TNF-α, IL-1β, IL-6, and the chemokine CCL4.
   c. It promotes **major histocompatibility complex (MHC) class II** gene expression.
   d. It promotes the differentiation of $CD4^+$ Th1 cells.
5. **Type I interferons (IFN-α/β)** have the following functions.
   a. They **block virus replication** by autocrine signaling.
   b. They increase **MHC class I expression**.
   c. At low levels they **coactivate macrophages**.
   d. At high concentrations they inhibit macrophage and lymphocyte activation.
6. **Chemokines** have the following characteristics.
   a. Chemokines are chemotactic cytokines that are produced rapidly in response to the danger signals associated with infection and inflammation.
   b. They **attract cells** to sites of infection or inflammation.

C. The proinflammatory effects of these cytokines are balanced by **antiinflammatory cytokines (eg, IL-10), cytokine-binding proteins**, and **receptor antagonists** (see above).

D. The amount of a cytokine that is secreted determines its overall effects.
1. In **low to moderate levels** of production, proinflammatory cytokines initiate important innate mechanisms of host defense.
2. When produced at **high concentrations**, proinflammatory cytokines cause the **systemic inflammatory response syndrome (SIRS)**.
   a. **Sepsis** is a form of SIRS initiated by infection (Chapter 11).
   b. SIRS can be induced by any stimulus that activates large numbers of inflammatory cells and mediators.

SYSTEMIC INFLAMMATORY RESPONSE SYNDROME (SIRS)

- *SIRS is defined as a constellation of clinical signs and symptoms, including **hyperthermia** (> 38°C) or **hypothermia** (< 36°C), **tachycardia** (> 90 bpm), **tachypnea** (> 20 breaths/min), and/or **altered white blood cell (WBC) counts** (> 12,000/μL or < 4,000/μL).*
- ***Septicemia** (microbes in the blood stream) and microbial **toxemia** (toxins in the blood stream) are among the leading causes, in which case the syndrome is called **sepsis** or **septic shock**.*
- *Regardless of the initiating event, proinflammatory cytokines play a central role.*
- *Multiorgan dysfunction, including acute respiratory distress syndrome, is a common sequela.*
- *Mortality rates when multiorgan failure is present approach 90%.*

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E. Cytokines of innate immunity are secreted in a temporal sequence.
1. TNF-α is produced early and promotes leukocyte localization at sites of infection.
2. Chemokines are produced early as a means of recruiting leukocytes to affected tissue sites.
3. Cytokines that activate phagocytes (eg, IFN-γ) are produced somewhat later.

III. Cytokines of adaptive immunity provide coactivating signals for lymphocytes and regulate antigen-presenting cells.

A. Cytokines that induce **humoral immunity** are concerned with B cell recruitment, activation, growth, and differentiation.
1. **IL-2** from $CD4^+$ Th1 cells induces B cell proliferation and increases Ig and J chain synthesis.
2. **IL-4** from **$CD4^+$ Th2 cells** promotes **Ig class switching** to IgE, induces the differentiation of naive $CD4^+$ T cells into **Th2 cells**, and **antagonizes** IFN-γ-driven Ig class switching to IgG_3.
3. **IL-5** and **TGF-β** promote the synthesis of IgA by B cells.
4. The chemokine **CCL7** directs antigen-stimulated B cells to T-dependent areas of the lymph nodes.
5. The coactivating effects of IL-4 on B cells are balanced by the inhibitory effects of IFN-γ.

B. Cytokines that promote **cellular immunity** induce the activation, growth, and/or differentiation of T cells, NK cells, NKT cells, and macrophages.
1. **IL-2** has the following characteristics.
   - **a.** It is an autocrine **growth factor** for many $CD4^+$ and $CD8^+$ T cells.
   - **b.** It enhances the cytotoxic activity of NK cells and conventional $CD8^+$ T cells.
   - **c.** It costimulates T cells for the production of IL-4, IL-5, and IFN-γ.
   - **d.** It promotes the development of **Treg cells**.
   - **e.** It induces autocrine **activation-induced cell death** in T cells (Chapter 11).
2. **IFN-γ** has the following characteristics.
   - **a.** It is primarily produced by $CD4^+$ Th1 cells and $CD8^+$ T cells during adaptive immune responses.
   - **b.** It activates macrophage **intracellular killing** of microbes.
   - **c.** It increases both class I and class II **antigen presentation** pathways by increasing MHC, transporter associated with antigen processing (TAP) protein, the proteasome subunits, and HLA-DM expression (Chapter 7).
   - **d.** It promotes Th1 polarization by naive $CD4^+$ T cells.
   - **e.** It inhibits Th2-associated humoral immunity.

DEFICIENCY IN IFN-γ SIGNALING

- *Genetic deficiencies have been described for either chain of the heterodimeric IFN-γ receptor.*
- *Patients with these defects are susceptible to infections by viruses and* Mycobacterium *and* Salmonella *species, two intracellular bacterial pathogens.*
- *The same phenotype is associated with defects in the expression of either IL-12 or the IL-12 receptor, illustrating the importance of IL-12 as an inducer of IFN-γ.*

3. **Lymphotoxin (LT** or **TNF-β)** has the following characteristics.
   - **a.** It is produced by activated T cells.

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b. It has many of the same proinflammatory and apoptosis-inducing effects as TNF-α.

4. TGF-β is chemotactic for blood monocytes.

IV. Cytokines, referred to as colony-stimulating factors (CSFs) or poietins, coordinate the diverse process of hematopoiesis (Figure 12–2).

A. **Stem cell factor (SCF)** and **IL-3** have broad growth-promoting effects on multiple blood cell lineages.

B. **Lymphopoiesis** is regulated by **IL-7** (T and B cells), **IL-2** (T cells), and **IL-15** (NK cells).

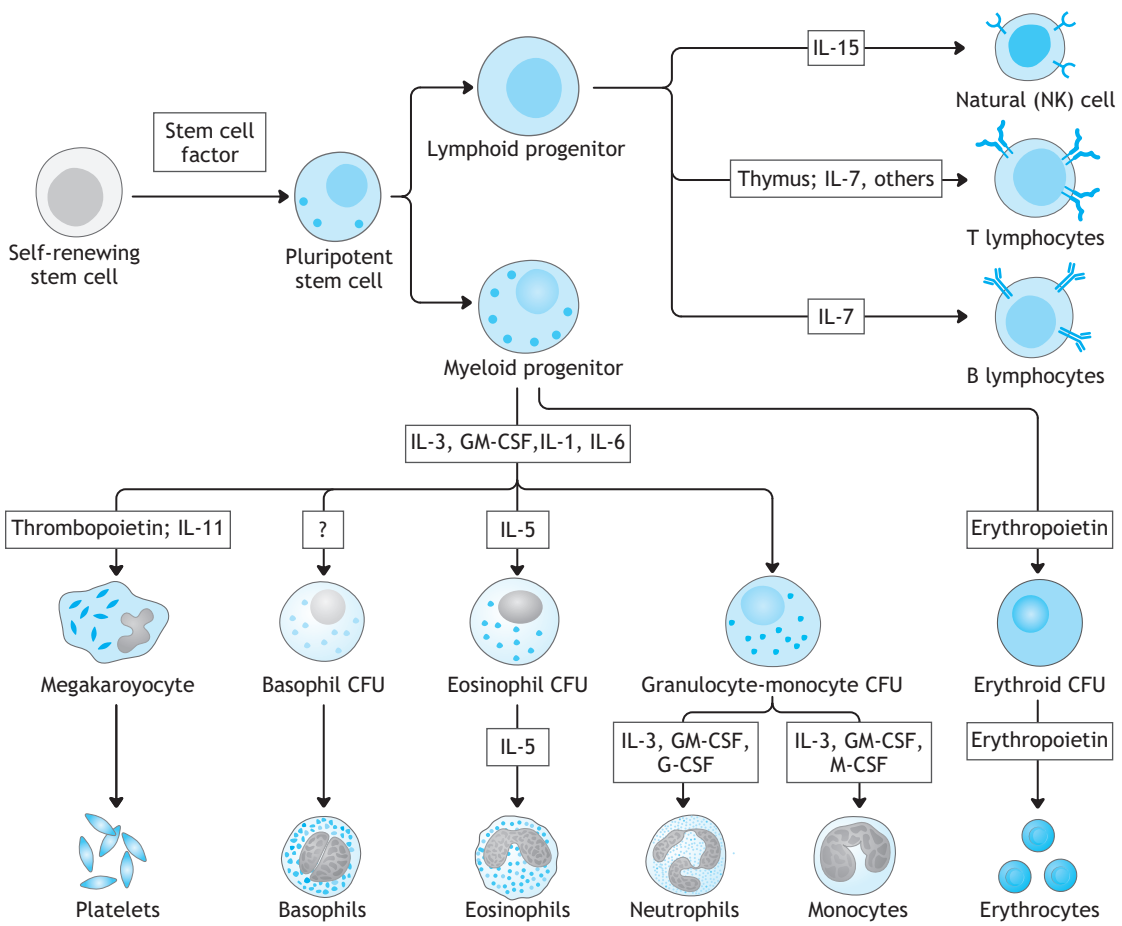

Figure 12–2. Cytokines that regulate hematopoiesis. IL, interleukin; GM-CSF, granulocyte/macrophage colony-stimulating factor; CFU, colony-forming unit.

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C. Myelopoiesis is controlled by **erythropoietin (EPO)**(erythrocytes), **thrombopoietin** (platelets), **IL-5** (eosinophils), **granulocyte/macrophage (GM)-CSF** and **G-CSF** (neutrophils), and GM-CSF and **M-CSF** (monocytes).

D. Recombinant CSFs are now used routinely to correct certain defects in hematopoiesis.

ANEMIA AND ERYTHROPOIETIN

- ***Anemia*** *is a reduction in red cell mass and has a number of causes, including depressed erythropoiesis.*
- *Chronic diseases, such as renal failure, malignancy, autoimmune diseases, and certain infections, are often accompanied by decreased EPO production.*
- *For the treatment of anemia associated with end-stage renal disease, EPO has replaced blood transfusions as a therapy.*
- *Repeated transfusions of whole blood to prospective renal transplant recipients often immunizes them against the HLA antigens of the blood donors.*
- *This can result in antibody-mediated hyperacute rejection of a subsequent transplant (Chapter 17).*

V. Chemokines, a diverse family of chemotactic cytokines, regulate normal cell traffic, tissue architecture, and inflammatory cell recruitment.

A. Chemokines establish a chemical concentration gradient that is sensed by the cell.

B. They induce the expression of leukocyte integrins that mediate leukocyte binding to and migration between vascular endothelial cells.

C. Chemokines induce cytoskeletal changes that mediate cell migration.

D. The two largest chemokine families are designated **CCL#** or **CXCL#** (distinguished by the arrangement of their cysteine residues)(Table 12–3).

1. CCL chemokines attract monocytes, lymphocytes, and eosinophils.
2. Most CXCL chemokines attract neutrophils, although some act on lymphocytes.

Table 12–3. Examples of CC and CXC chemokines and their receptors.[a]

Chemokine (Ligand)	Also Known as	Receptors	Cells Attracted
CCL4	MIP-1β	CCR5	T cells, NK cells, DC, and monocytes
CCL11	Eotaxin	CCR3	Eosinophils, basophils, Th2 cells
CXCL2	ENA-78	CXCR2	Neutrophils
CXCL8	IL-8	CXCR1, CXCR2	Neutrophils
CXCL10	IP-10	CXCR3	T cells

[a]MIP, macrophage inflammatory protein; NK, natural killer; DC, dendritic cells; ENA-78, epithelial neutrophil-activating protein 78; IL, interleukin; IP-10, interferon-γ-inducible protein 10.

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E. Chemokine production is induced by a variety of immune and inflammatory stimuli, including TNF-α, IL-1β, IFN-γ, and IL-4.

F. Cellular responses to chemokines are mediated by seven-transmembrane, G protein-coupled cell surface receptors designated CCR# or CXCR#.

G. Some chemokine receptors serve as coreceptors for virus entry.

1. HIV-1 uses both CCR5 and CXCR4 as coreceptors with CD4.

2. The tissue distribution of these chemokine receptors specifies the tissue tropism of a particular HIV-1 clone.

VI. Cytokines activate cells by binding to high-affinity receptors (Table 12–4)

A. Cytokine receptors induce gene expression by activating latent cytosolic transcription factors.

B. The **type I (hematopoietic) receptors** activate the **Janus kinase (Jak)** signaling pathway.

1. Jak is a family of receptor-associated tyrosine kinases that is activated upon receptor clustering.

2. Jak phosphorylation of cytokine receptors recruits **signal transducers and activators of transcription (STAT)** peptides.

3. Jak phosphorylates STAT peptides and the peptides dimerize.

4. Dimerization of STAT results in nuclear localization, DNA binding, and transcriptional activation.

Table 12–4. Cytokine receptor families.[a]

Receptor Family	Ligands	Signaling Mechanism
Type I (hematopoietic)	IL-2, 3, 4, 5, 6, 7, 12, 13, 15, G-CSF, GM-CSF	Jak activation of latent, preformed STAT transcription factors
Type II (interferon-like)	IFN-α/β, IFN-γ, IL-10	Jak activation of latent, preformed STAT transcription factors
TNF	TNF, LT, CD40L, FasL	Binding of adapter proteins and activation of NFκB and AP-1 Binding of adapter proteins and activation of caspases
Ig superfamily	IL-1, M-CSF, SCF	Binding of adapter proteins and activation of latent NFκB
Seven-transmembrane G protein coupled	Chemokines	GTP exchange Activation of PLC and PI3K

[a]IL, interleukin; Jak, Janus kinase; STAT, signal transducers and activators of transcription; GM-CSF, granulocyte/macrophage colony-stimulating factor; IFN, interferon; TNF, tumor necrosis factor; LT, leukotriene; SCF, stem cell factor; PLC, phospholipase C; PI3K, phosphatidylinositol-3′-kinase.

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5. The receptors for **IL-2, 3, 4, 6, 7, 12, and 13, G-CSF, and GM-CSF** utilize the Jak/STAT pathway for signaling.

C. **Type II interferon-like receptors** for IFN-α/β, IFN-γ, and IL-10 also signal through Jak/STAT.

D. The **TNF receptor** family utilizes adapter proteins to activate diverse signaling pathways.
1. When adapter proteins with **death domains** are recruited, caspase activation signals apoptosis.
2. When adapters without death domains are recruited, **kinase activation** results in the activation of NFκB.

E. The **Ig superfamily** of receptors, such as the IL-1 receptor, activates NFκB using specialized adapter proteins (eg, MyD88) (Figure 1–3).

F. G protein-coupled **chemokine receptors** signal through phospholipase C (PLC), phosphatidylinositol-3′-kinase (PI3K), and guanosine triphosphate (GTP) exchange proteins.

G. Different forms of the IL-2 receptor show different affinities for IL-2.
1. Resting T cells, B cells, and NK cells express the β and γc chains of IL-2R, which shows a moderate affinity for IL-2 (10^{-9} M).
2. Activated T cells express an additional α chain in their IL-2R, which increases receptor affinity to 10^{-11} M.

COMMON γ CHAIN (γC) DEFICIENCY

- *Whereas cytokine deficiencies are extremely rare, an X-linked recessive cytokine receptor defect is the most common cause of **severe combined immune deficiency**.*
- *Mutations in the common γ chain (γc) impair the development of T cells and NK cells, because the receptors for IL-2, IL-4, IL-7, and IL-15 share the γc subunit.*
- *The resulting $T^-B^+NK^-$ phenotype places these infants at risk for infections with intracellular pathogens.*

CLINICAL PROBLEMS

A 5-month-old male patient presents with enlarged lymph nodes, and a biopsy shows acid-fast bacteria, a feature of infections with mycobacteria. The patient shows a normal complete blood count (CBC) and differential, normal T and B cell subsets by flow cytometry, and normal serum Ig levels when referenced to age-matched controls.

1. For which of the following cytokines would a mutation in its receptor explain this clinical picture?

A. IL-1

B. IL-2R

C. TNF-α

D. IFN-γ

E. IL-10

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2. Which of the following additional cytokine deficiencies would produce a similar phenotype?

A. IL-12 deficiency
B. IL-7 deficiency
C. IL-15 deficiency
D. SCF deficiency
E. IL-4 deficiency

A patient who received a cardiac transplant from an unrelated donor is given the drug cyclosporine to control rejection of his allograft.

3. Which of the following receptors signals through an intermediate that is sensitive to the drug cyclosporine?

A. IL-1 receptor
B. IL-2 receptor
C. T cell receptor (TCR)
D. TLR4
E. CXCR4

The blood lymphocytes of a 6-month-old child with recurrent, complicated viral and fungal infections do not respond normally to IL-2 and IL-4 in vitro. The patient currently has thrush and a cytomegalovirus (CMV) infection. The patient has a single gene mutation that explains all of these findings.

4. Which of the following immune functions might you expect to be **normal** in this child?

A. Neutrophil ingestion of bacteria
B. NK cell killing of virus-infected cells
C. T cell activation by antigen + antigen-presenting cells (APCs)
D. Ig class switching by B cells cultured with the patient's T cells
E. Killing of CMV-infected cells by $CD8^+$ cells

A menstruating teenager presents to the emergency room in shock and is diagnosed as suffering from toxic shock syndrome secondary to a vaginal infection with the bacterium *Staphylococcus aureus*.

5. Which of the following cytokines is both key to host defense against this organism and a central mediator of toxic shock pathogenesis?

A. IL-10
B. TNF-α
C. IL-3
D. TGF-β
E. IL-5

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ANSWERS

1. The correct answer is D. Mutations in the IFN-γR result in susceptibility to intracellular pathogens (bacterial and fungal) early in life. This probably results from the failure to activate infected macrophages, a cell type commonly infected by these pathogens.
2. The correct answer is A. Because of its role as a coinducer of IFN-γ, IL-12 is also essential for the induction of cellular immunity to intracellular bacterial pathogens, such as the mycobacteria. Defects in the IL-12R produce a similar clinical picture.
3. The correct answer is C. None of the cytokine receptors signals through a cyclosporine-sensitive pathway, although the production of IL-2 and IL-4 by activated T cells is inhibited by the drug. Cyclosporine inhibits calcineurin and the activation of nuclear factor of activated T cells (NFAT), which induces transcription of genes in T and B cells.
4. The correct answer is A. The only known gene defect that could interfere with responses to both IL-2 and IL-4 is a mutation in the γc chain of the IL-2R and IL-4R. This defect also blocks IL-15R signaling, which would result in an absence of NK cells. The overall phenotype in the periphery would be $T^{-}B^{+}NK^{-}$.
5. The correct answer is B. TNF-α is a key mediator of both toxic (Chapter 6) and septic shock (Chapters 1 and 12). Toxic shock is initiated when superantigens produced by certain microbes, including the gram-positive *Staphylococcus*, activate Th cells and macrophages by cross-linking TCRs to MHC class II molecules. Massive cytokine production results when both cell types are activated.

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CHAPTER 13
IMMUNE TISSUE INJURY

I. Robust immune responses, even to relatively nonthreatening antigens, can cause host tissue damage.

A. An **allergy** (or **hypersensitivity**) is an adaptive immune response to an environmental antigen that damages tissues and causes organ dysfunction.
1. Allergy is mediated by specific antibodies and/or effector T cells.
2. The signs and symptoms of allergy include watery eyes, runny nose, sneezing, coughing, wheezing, and pruritic (itchy) hives.
3. An **allergen** is an antigen that can produce these signs and symptoms (Table 13–1).
4. Typical allergens include pollens, animal dander, insect venoms, and foods.

B. **Atopic allergies** are familial, rapid, and strong reactions mediated by immunoglobulin (Ig) E.
1. **Atopy** is a heritable predisposition to produce IgE antibodies and other allergic mediators in response to environmental antigens.
2. Atopic conditions are more common in developed countries with high levels of air pollutants and closed living spaces.
3. Common manifestations of atopic allergies are **allergic rhinitis, allergic asthma, atopic dermatitis,** and **allergic anaphylaxis**.

C. **Anaphylaxis** is a systemic form of allergy involving the cardiovascular, respiratory, cutaneous, and gastrointestinal systems.
1. **Anaphylactic shock** includes hypotension, tissue hypoxia, and the loss of consciousness.
2. **Anaphylactoid shock** is similar in its presentation, but is not mediated by IgE.
   a. IgG antibodies mediate systemic anaphylactoid reactions.
   b. Complement-mediated mast cell activation produces anaphylaxis-like symptoms.

D. Allergies can develop to inhaled, ingested, or injected antigens or antigens encountered by contact with the skin (Table 13–1).
1. Tree and grass pollens induce seasonal **rhinitis** and **conjunctivitis**.
2. Peanuts, shellfish, eggs, and dairy products often cause **food allergies**.
3. Insect and snake venoms and injected drugs (eg, penicillin) can cause **allergic anaphylaxis**.
4. Plant resins (eg, poison ivy pentadecacatechol), industrial chemicals, and metals can cause **allergic contact dermatitis**.

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Table 13–1. Common allergies and allergens.

Clinical Manifestations	Typical Sources of Allergens
Atopic allergic rhinitis and allergic asthma	Tree and grass pollens, mold spores, mites in house dust, pet dander
Allergic gastroenteritis	Food products (milk, eggs, shellfish)
Occupational allergies	Pharmaceuticals, organic and inorganic compounds, enzymes, microbial agents, dyes, plant products, shellfish, animal products
Urticaria and anaphylaxis	Foods (shellfish, nuts, seeds), drugs (polypeptide hormones, enzymes, haptenic drugs, opiates), insect venoms
Contact dermatitis	Nickel and other metals, formaldehyde, epoxy resins, neomycin cream, benzocaine, plant resins
Drug allergies	β-Lactam antibiotics, NSAIDs[a]

[a]NSAIDs, nonsteroidal antiinflammatory drugs.

E. Gell and Coombs first described the four major mechanisms of immune tissue injury that underlie human hypersensitivities (Table 13–2).
1. The mechanisms differ in terms of the nature of the antigen, the immune components involved in their pathogenesis, and the nature and onset of clinical symptoms.
2. Antigenic specificity is mediated by antibodies and/or T cells.
3. Tissue damage results from the activation of complement, mast cells, neutrophils, macrophages, or lymphocytes.
4. Immune tissue injury mediated by the **innate immune system** is not included in the Gell and Coombs classification scheme.

F. Immune tissue injury mediated by adaptive immunity requires two phases.
1. **Sensitization** occurs on first exposure to the allergen (Figure 13–1).
   a. Antibody production and/or the proliferation of T cells occur during the sensitization phase.
   b. Antibody can either bind to cellular Fc receptors or remain in the circulation, depending on Ig class.
   c. Tissue damage is not generally seen during the sensitization phase.
2. During the **elicitation phase**, antibodies or immune T cells recognize the allergen and trigger effector mechanisms.
   a. For example, large numbers of memory $CD4^+$ Th1 cells are activated to produce cytokines.
   b. Allergen–antibody complexes activate complement to produce inflammatory peptides.

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Table 13–2. The Gell and Coombs classification of immune tissue injury mediated by adaptive immunity.[a]

Type	Time from Exposure to Response	Form of the Antigen	Antibodies	Cellular Immune Mediators	Soluble Immune Mediators	Clinical Examples
I	Minutes	Protein or hapten-protein	IgE	Mast cells, basophils, eosinophils	Histamine, proteases, eicosinoids, cytokines, chemokines	Atopic allergies Allergic asthma
II	Hours to days	Cell or tissue bound	IgG or IgM	Neutrophils	C3b, C3a, C4a, C5a	Transfusion reactions
III	Hours to days	Soluble	IgG or IgM	Neutrophils	C3b, C3a, C4a, C5a	Lupus nephritis
IV	Days	MHC-bound peptide	None	APCs, T cells, NK cells, macrophages	IL-2, IFN-γ, chemokines	Allergic contact dermatitis

[a]Ig, immunoglobulin; MHC, major histocompatibility complex; APC, antigen-presenting cells; NK, natural killer; IL, interleukin; IFN, interferon.

c. Mast cells with IgE antibodies bound to their surface Fc receptors degranulate when allergen is encountered.

G. Innate immunity also causes localized tissue damage, but does not require a prior exposure to the foreign agent (ie, a sensitization phase).

1. The tissue damage seen in **septic arthritis** is caused by the activation of neutrophils recruited to an infected joint.

2. Innate immune tissue injury can be elicited by relatively nontoxic microbial products, such as bacterial DNA or cell wall lipopolysaccharide (LPS).

a. **Sepsis** is an acute systemic inflammatory response to infection mediated by **danger signals** and the excessive production of inflammatory mediators.

b. Responses to components of nonpathogenic microbial flora can induce organ-specific inflammatory tissue damage.

(1) **Crohn's disease** is thought to be initiated by innate immune responses to intestinal microbial flora.

(2) **Ulcerative colitis** appears to involve a similar imbalance of the mucosal immune system.

CROHN'S DISEASE

- *Crohn's disease (CD) is a chronic transmural inflammation of the large and small bowel that begins with the loss of epithelial barrier function in the intestine.*
- *Some CD patients have mutations in the Nod2 antimicrobial protein, which diminishes their ability to clear bacteria that breach the epithelium.*

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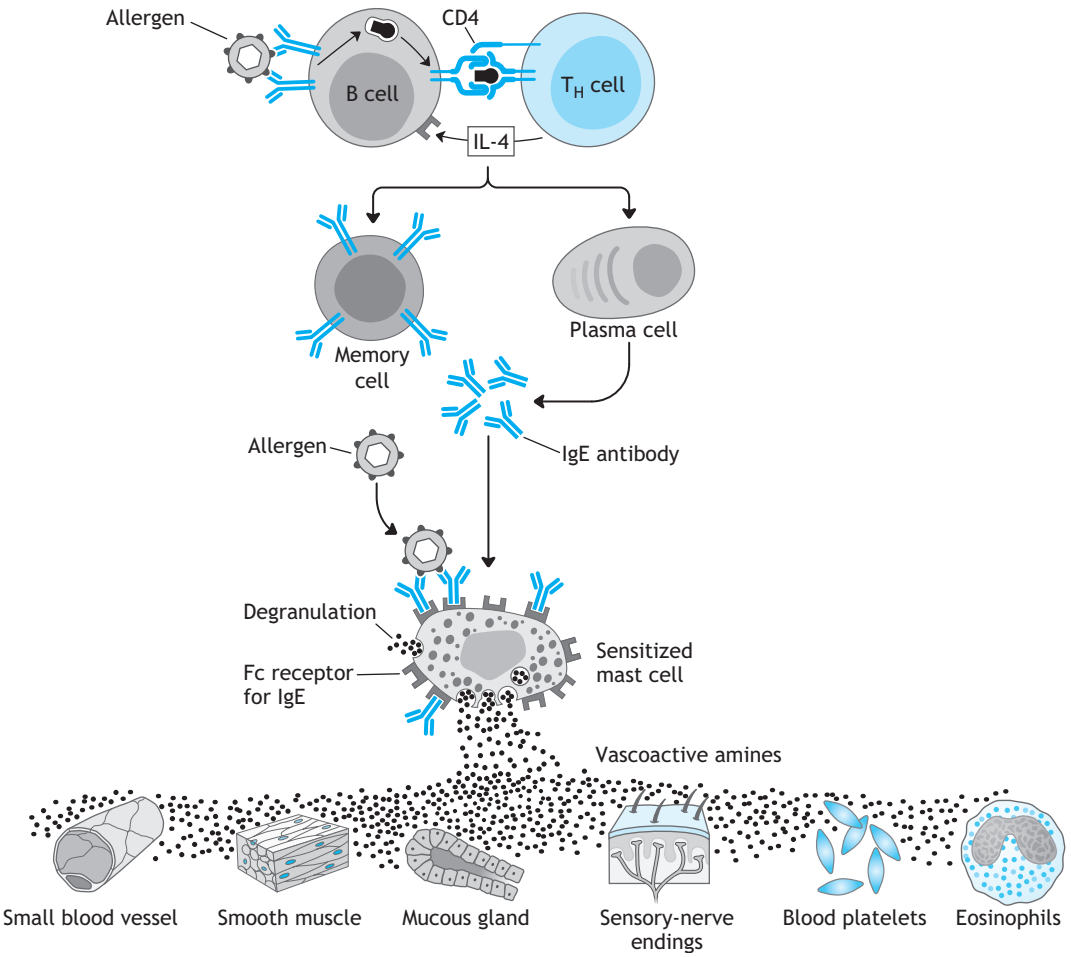

Figure 13–1. The sensitization and elicitation phase of immediate type immune tissue injury. IL-4, interleukin 4; IgE, immunoglobulin E.

- *Aberrant innate immune responses develop in the gastrointestinal tract to the intestinal flora.*
- *Activated macrophages and Th1 cells produce excessive interleukin (IL)-12, interferon (IFN)-γ, and tumor necrosis factor (TNF)-α.*
- *Sustained macrophage and neutrophil activation contributes to chronic inflammation.*
- *Blocking the action of TNF-α with monoclonal antibodies to the cytokine has proven effective in the treatment of CD.*

II. Type I (immediate-type) immune tissue injury (Table 13–2) is a rapid response to environmental antigens mediated by IgE antibodies and vasoactive inflammatory mediators released by mast cells.

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A. The antigens that elicit these responses are **proteins** or **haptens** (eg, drugs) that can bind to proteins.
  1. The allergens are presented by major histocompatibility complex (MHC) class II molecules and activate **$CD4^+$** Th2 cells.
  2. Th2 cells produce IL-4 and IL-13, which induce class switching to IgE.

B. The propensity to make high-titer IgE antibodies to environmental allergens is, in part, genetically determined.
  1. Multiple genes control susceptibility to allergy and asthma.
  2. Among the traits that appear to be genetically controlled are total IgE levels, Th2 polarization, and mast cell and eosinophil growth.

C. Allergen-specific IgE antibodies bind to **Fcε receptor I (FcεRI)** on tissue **mast cells**.
  1. FcεRI is a very high-affinity receptor (K_d = 10 pM).
  2. The activation of mast cells through FcεRI requires receptor cross-linking by multideterminant antigens.
  3. Because the antibodies displayed on mast cells are specific for many different epitopes, polyvalent protein antigens can cross-link surface FcεRI molecules.

D. The tissue distribution and density of mast cells as well as the surface density of FcεRI determine the distribution of tissue injury.
  1. The route of immunization (eg, respiratory versus gastrointestinal) determines the local distribution of antibody specificities on tissue mast cells.
  2. Mucosal and connective tissue mast cells produce distinct patterns of inflammatory mediators.

HYPER-IgE SYNDROME

- ***Hyper-IgE syndrome*** *or* ***Job's syndrome*** *is an immune deficiency characterized by recurrent and severe staphylococcal skin abscesses and pneumonia.*
- *Th1:Th2 imbalance results in a decreased production of IFN-γ, a cytokine that normally inhibits Th2 responses, such as switching to IgE production.*
- *These patients can also show pruritic dermatitis, but increased allergy is not common, despite exceedingly high serum IgE levels (> 2000 IU/mL).*

E. Signaling through FcεRI results in three mechanisms of inflammatory mediator release (Figure 13–2).
  1. Preformed mediators stored in cytoplasmic granules are released when mast cells **degranulate**.
    a. Allergen binding triggers FcεRI clustering.
    b. Phospholipase Cγ (PLCγ) is recruited to the immunotyrosine activation motifs (ITAMs) of the FcεRI and is activated.
    c. Protein kinase C (PKC) is then activated by diacylglycerol and phosphorylates myosin light chains.
    d. Cytoskeleton changes are induced that promote granule exocytosis and the release of granule constituents.
      (1) The preformed vasoactive amine **histamine** (Table 13–3) is released.
      (2) **Heparin**, the proteases **chymase** and **tryptase**, and **chemotactic peptides** that recruit neutrophils and eosinophils are also released from granules.
    e. Degranulation can be inhibited by maintaining elevated levels of **intracellular cyclic AMP (cAMP)**.

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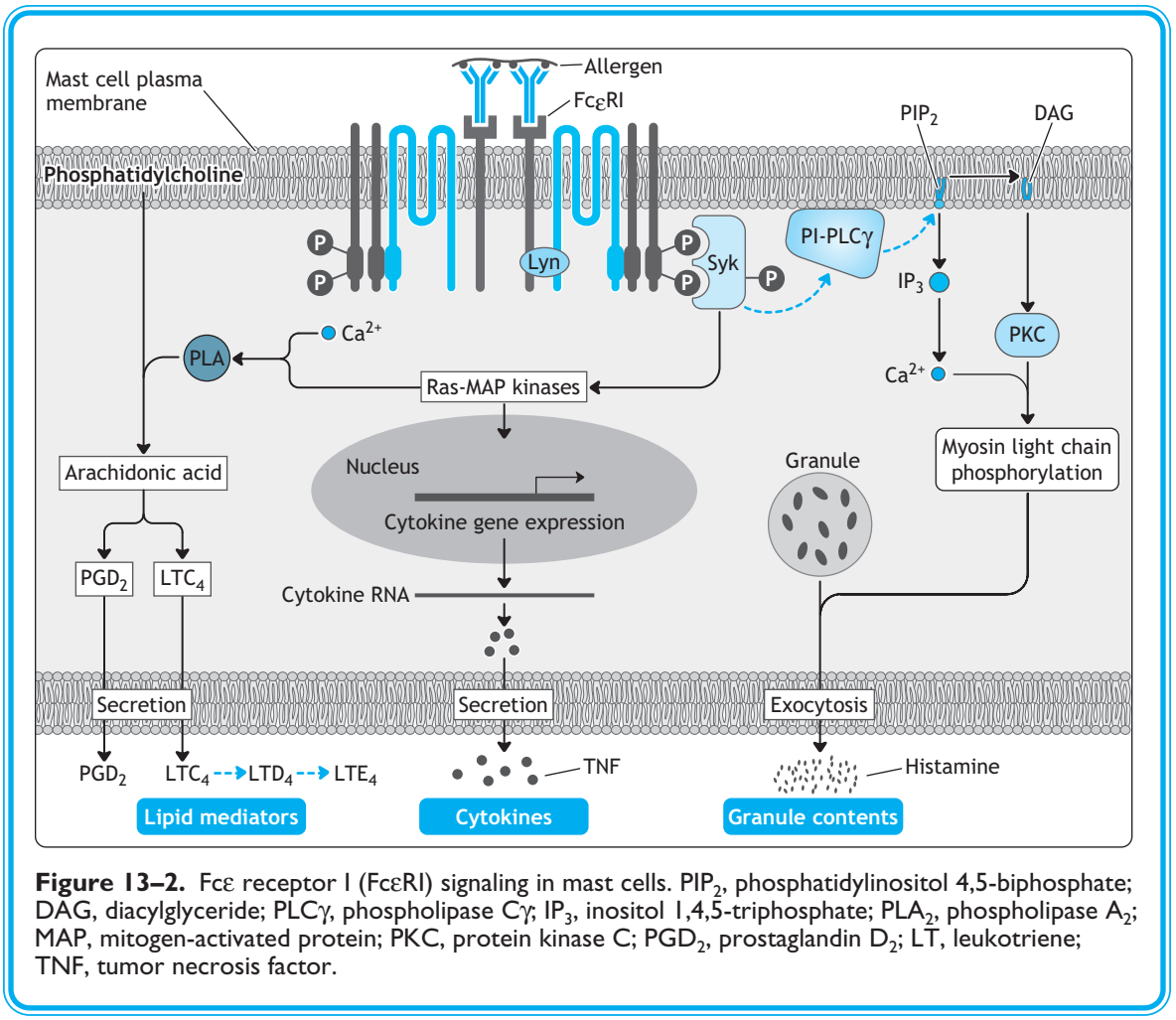

Figure 13–2. Fcε receptor I (FcεRI) signaling in mast cells. PIP_2, phosphatidylinositol 4,5-biphosphate; DAG, diacylglyceride; PLCγ, phospholipase Cγ; IP_3, inositol 1,4,5-triphosphate; PLA_2, phospholipase A_2; MAP, mitogen-activated protein; PKC, protein kinase C; PGD_2, prostaglandin D_2; LT, leukotriene; TNF, tumor necrosis factor.

2. FcεRI cross-linking also activates **phospholipase A_2** (PLA_2).
   a. PLA_2 cleaves phosphatidylcholine to form **arachidonic acid**.
   b. Arachidonic acid is metabolized by the **cyclooxygenase** and **lipoxygenase** pathways to form **prostaglandins (PGs)** and **leukotrienes (LTs)**, respectively.
3. The de novo expression of **cytokine genes** is induced by the activation of transcription factors.
   a. **Nuclear factor of activated T cells (NFAT), nuclear factor-κB (NFκB),** and **AP-1** are activated in mast cells.
   b. The genes for **IL-3, IL-4, IL-5, IL-6, IL-13,** and **TNF-α** are transcribed.

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Table 13–3. Inflammatory mediators derived from activated mast cells.[a]

Preformed or Newly Synthesized	Mediators	Proinflammatory Effects	Mast Cell Signaling Intermediates
Preformed mediators	Histamine Heparin Tryptase Chymase E-CFA N-CFA	Itchy sensation, vasodilation, increased vascular permeability, bronchoconstriction, mucus secretion, leukocyte chemotaxis, gut peristalsis	PLCγ, Ca^{2+} mobilization, PKC activation, myosin phosphorylation, granule exocytosis
Newly synthesized mediators	PAF, prostaglandins (PGD_2), leukotrienes (LTC_4) IL-3, IL-4, IL-5, IL-6, TNF-α, eotaxin	Vasodilation, increased vascular permeability, bronchoconstriction, eosinophil chemotaxis, mucus secretion, platelet aggregation, ICAM-1 expression, mast cell growth, Th2 cell differentiation	PLA_2 activation, arachidonic acid, COX-2 NFκB, NFAT, and AP-1 activation

[a]E-CFA, eosinophil chemotactic factor of anaphylaxis; N-CFA, neutrophil chemotactic factor of anaphylaxis; PLCγ, phospholipase Cγ; PKC, protein kinase C; PAF, platelet-activating factor; IL, interleukin; TNF, tumor necrosis factor; ICAM, intercellular adhesion molecule; PLA_2, phospholipase A_2; COX, cyclooxygenase; NFκB, nuclear factor κB; NFAT, nuclear factor of activated T cells.

IgE-INDEPENDENT MAST CELL ACTIVATION

- *Several agents can activate mast cells without binding as allergens to cell surface IgE.*
- *Certain **drugs** (morphine, codeine, calcium ionophores, vancomycin, radiocontrast agents) can activate mast cells directly and induce anaphylaxis.*
- *The **anaphylatoxins** C3a, C4a, and C5a trigger mast cell degranulation.*
- *The **neuropeptides** substance P and somatostatin mediate cholinergic triggering of asthma by activating mast cells.*
- *Lectins, such as those found in some foods, can bind carbohydrate residues on IgE and induce adverse reactions to foods.*

F. The signs and symptoms of allergy reflect the action of mast cell mediators on target tissues (Table 13–3).

1. Most of the inflammatory effects of **histamine** in allergy are mediated through binding of histamine to H_1 **histamine receptors**.

a. H_1 receptors are G protein coupled and activate adenylate cyclase.

b. Adenylate cyclase activation leads to a *transient* increase in intracellular cAMP concentrations.

2. The effects of histamine depend on the cell type affected.

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   a. Histamine relaxes smooth muscle cells in peripheral blood vessels causing **vasodilation**.
   b. Histamine induces **bronchospasms** in the lungs and **peristalsis** in the intestines by stimulating smooth muscle contraction.
   c. Histamine causes contraction of vascular endothelial cells resulting in **increased vascular permeability** and edema.

3. **Tryptase** and **chymase** are serine proteases stored in granules.
   a. The circulating levels of tryptase are a clinical measure of recent mast cell degranulation.
   b. Tryptase induces **mucus secretion** in the lungs.
   c. Tryptase can activate certain matrix metalloproteases.
   d. Tryptase cleaves plasminogen to form plasmin, which cleaves C3.
4. Mast cell granules contain two chemotactic peptides.
   a. **Eosinophil chemotactic factor of anaphylaxis (E-CFA)** attracts eosinophils to the lung in asthma and to the intestine in certain parasitic infections.
   b. **Neutrophil chemotactic factor of anaphylaxis (N-CFA)** recruits neutrophils that contribute to tissue damage.
5. Proteoglycans, including **heparin** and **chondroitin sulfate**, are granule constituents to which other mast cell mediators are bound.

SYSTEMIC ALLERGIC ANAPHYLAXIS

- *The allergens that typically induce systemic anaphylaxis include drugs, insect venoms, and certain foods.*
- *Key target organs include the cardiovascular, pulmonary, gastrointestinal, and cutaneous systems.*
- *Typical signs and symptoms of anaphylatic shock include generalized pruritis, apprehension, hypotension, abdominal cramping, tachycardia, tachypnea, and hives.*
- *Timely injection of epinephrine is life saving.*
- *Drugs that inhibit the late phase of anaphylaxis are essential to avoid a secondary shock response several hours later.*

6. Three groups of **lipid mediators** contribute to allergic responses.
   a. **Platelet activating factor (PAF)** is derived from the PLA_2-mediated hydrolysis of membrane phospholipids.
      (1) PAF is produced by mast cells, basophils, and endothelial cells.
      (2) PAF induces **vasodilation, bronchoconstriction,** and increased **vascular permeability**.
   b. **PGs** are derived from the metabolism of arachidonic acid via the **cyclooxygenase (COX) pathway**.
      (1) **COX-2** is the principal mast cell cyclooxygenase.
      (2) **PGD_2** is the principal prostaglandin produced.
      (3) PGD_2 causes **vasodilation** and **bronchoconstriction**.
   c. **LTs** are derived from arachidonic acid by the **lipoxygenase pathway**.
      (1) **LTC_4**, **LTD_4**, and **LTE_4** are the principal leukotriene mediators of allergy.
      (2) LTC_4 is produced by mucosal mast cells, but not connective tissue mast cells (eg, in the skin).
      (3) LTC_4 is a major cause of **bronchoconstriction**.

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7. **Cytokines** are expressed by mast cells following transcription.
   - **a.** **IL-3** and **IL-4** promote the growth of mast cells.
   - **b.** **IL-4** and **IL-13** induce B cell class switching to IgE.
   - **c.** **IL-5** is a chemotactic factor for eosinophils.
   - **d.** **IL-4** promotes eosinophil growth.
   - **e.** **TNF-α** facilitates leukocyte chemotaxis by inducing vascular intercellular adhesion molecule (ICAM)-1 and leukocyte integrin expression.
   - **f.** Cytokines mediate many of the **late-phase** allergic responses.

ALLERGIC ASTHMA

- *The allergic form of asthma is caused by IgE-mediated immunity to inhaled allergens.*
- *Th2 polarization probably begins early in life.*
- *Asthmatic "attacks" can be triggered by either intrinsic signals (eg, cold outside air or exercise) or extrinsic signals (ie, allergens).*
- *Chronic mast cell activation leads to persistent mediator release, bronchoconstriction (chest tightness), mucus secretion, and eosinophil recruitment and activation.*
- *Eosinophils damage the mucosal epithelium, cause perivascular edema, and initiate lung tissue remodeling.*
- *Mucus plugging of the bronchi results in the hyperinflation of the lungs, an inability to expire air, and expiratory wheezing.*
- *Early intervention is designed to diagnose and treat the underlying allergic conditions.*
- *As the disease progresses, more aggressive treatment to control chronic inflammation (eg, corticosteroids) must be considered.*

G. The proper diagnosis of atopic allergies requires a careful patient history and allergy skin testing.

1. The diagnostic gold standard for allergy is the **skin test**.
   - **a.** Allergen injected into the skin induces histamine release, localized edema **(wheal)**, and a zone of erythema (**flare**) within 20 minutes.
   - **b.** Negative and positive controls (eg, saline and histamine, respectively) are essential to validate the test.
2. The **radioallergosorbant test (RAST)** is useful for measuring the circulating levels of IgE antibodies to known allergens (Chapter 5).

HAY FEVER

- ***Allergic rhinitis*** *or* ***hay fever*** *can be a perennial or seasonal condition.*
- *For example, in the Midwest, ragweed pollenosis shows a well-delineated season with symptoms appearing first in mid-August and lasting through the first frost.*
- *Rhinitis presents as sneezing, nasal congestion, and watery, itchy eyes.*
- *Typical allergens include pollens, fungal spores, animal dander, and house mites.*
- *The accurate identification of the allergen requires a careful patient history combined with skin testing using standardized allergens.*

H. Prophylaxis and treatment of allergic conditions take many forms.

1. The first approach to prophylaxis is to avoid the allergen.
2. **Immunotherapy** is an effort to divert the immune system away from IgE-mediated triggering of mast cells.

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a. The patient receives repeated intradermal injections of the allergen over several months.
b. Some patients produce IgG and IgA antibodies that compete with allergenic IgE.
c. The IgE antibody levels in some patients decrease by unknown mechanisms.
d. A Th2 to Th1 shift in immunity to the allergen may occur.

3. Antibodies to the Fc portion of IgE (omalizumab) are beneficial for treating severe allergic asthma (Table 13–4).
   a. The antibodies decrease circulating levels of IgE.
   b. They decrease the density of FcεRI on tissue mast cells.
4. **Desensitization** is a therapy designed to establish a temporary block of allergen-induced mast cell mediator release.
   a. Desensitization is most often used when no alternative therapy exists for a patient with a drug allergy.
   b. The patient is given the allergenic drug in incrementally increasing doses beginning with a subclinical dose.
   c. Desensitization probably results from the gradual, controlled release of mast cell mediators.
   d. The desensitized state persists only while the drug is given.

Table 13–4. Pharmacological treatment of allergy.[a]

Group	Examples	Mechanisms of Action	Clinical Uses
Anti-IgE	Omalizumab	Decreasing circulating IgE	Asthma
Antihistamines	Diphenhydramine, fexofenadine	H_1 receptor antagonists	Allergic rhinitis, urticaria, anaphylaxis
β_2-Agonists	Epinephrine, albuterol	β_2-Adrenergic agonist	Anaphylaxis, asthma, urticaria
NSAIDs	Indomethacin	Blocks PG synthesis	Urticaria
Corticosteroids	Beclomethasone, methylprednisolone	Blocks PLA_2 and cytokine expression	Allergic rhinitis, asthma, anaphylaxis
Mast cell stabilizers	Cromolyn sodium	Prevents granule fusion	Allergic rhinitis Asthma
Methylxanthines	Theophylline	Inhibits phosphodiesterase	Asthma
Leukotriene receptor antagonists	Zafirlukast	Blocks LT action	Asthma

[a]IgE, immunoglobulin E; NSAIDs, nonsteroidal antiinflammatory drugs; PG, prostaglandin; PLA_2, phospholipase A_2; LT, leukotriene.

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5. Inhibiting mast cell degranulation is effective against allergy.
- **a.** **Cromolyn sodium** inhibits Ca^{2+} influx, an important step in FcεRI signaling.
- **b.** **Theophylline** maintains high intracellular cAMP levels in mast cells.
- **c.** **Nonsteroidal antiinflammatory drugs (NSAIDs)** (eg, indomethasone) inhibit arachidonic acid metabolism.
- **d.** **Hydrocortisone** acts at multiple steps in mast cells.
  - ***(1)*** It inhibits histamine synthesis from histidine.
  - ***(2)*** It inhibits the activation of PLA_2.
  - ***(3)*** The drug blocks NFκB activation by increasing the expression of its inhibitor IκB.

FOOD ALLERGIES

- *Food intolerance can be IgE dependent or IgE independent.*
- *Most adults show the IgE-dependent form, whereas significant numbers of infants or children have food intolerance that is not IgE mediated.*
- *Common allergens include proteins of peanuts, soybeans, shellfish, milk, and eggs.*
- *Oropharyngeal symptoms (pruritis and urticaria in the mouth) appear first followed by nausea, cramping, vomiting, flatulence, and diarrhea.*
- *Urticarial rashes and even anaphylaxis can result from allergic reactions to foods.*
- *IgA deficiency increases the childhood risk of developing IgE-mediated food allergies.*

6. Some drugs block the effects of allergic mediators.
- **a.** The β-adrenergic receptor agonist **epinephrine** blocks histamine action.
- **b.** Epinephrine is life saving in acute allergic anaphylaxis.
- **c.** The β_2-receptor agonist **albuterol** is an effective bronchodilator used for the treatment of allergic asthma.
- **d.** Antihistamines include the H_1 receptor antagonists (eg, **diphenhydramine** and **chlorpheniramine**).
- **e.** Leukotriene receptor antagonists are used to treat asthma.
- **f.** **Hydrocortisone** and other corticosteroids also block inflammatory gene expression in target cells.

III. Type II (cytotoxic) immune tissue injury results from the recognition of cell- or tissue-bound antigens by IgG and IgM antibodies (Table 13–2).

A. Tissue damage generally requires hours or days to become evident.

B. **IgM** and **IgG antibodies** activate **complement** through the classical pathway.
1. Tissue damage can result from the formation of the **membrane attack complex** C5b-9.
2. C5a is **chemotactic** for neutrophils.
3. C3a, C4a, and C5a are **anaphylatoxins** that directly activate mast cells.
4. Phagocytic cells can cause tissue damage when they attach to IgG- or iC3b-coated tissues and cells.

C. Anemia is a common effect of cytotoxic immune tissue injury directed toward erythrocyte antigens.
1. **Transfusion reactions** result when mismatched blood is transfused to a patient with a preformed antibody.

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2. **Rh disease** of the newborn is due to maternal IgG antibodies that cross the placenta and bind to fetal Rh antigens.
3. A number of **autoimmune diseases** (eg, Coombs-positive hemolytic anemias and thrombocytopenias) are mediated by host antibodies reacting with autoantigens (Chapter 16).

D. Damage to solid tissues and extracellular matrix is also mediated by cytotoxic immune tissue injury.
1. **Hyperacute graft rejection** is mediated by anti-HLA antibodies.
2. Autoantibodies in **Goodpasture syndrome** react with type IV collagen of the glomerular basement membrane.

E. The **diagnosis** of type II immune tissue injury is often based on detecting an abnormal distribution of IgG.
1. The Coombs test detects Ig on erythrocytes.
2. Immunofluorescence can detect IgG deposition within tissues.

IV. Type III (immune complex) tissue injury results when soluble antigen–antibody complexes form in the blood and deposit in tissues.

A. Immune complex deposition in the kidneys causes **nephritis**.

B. Immune complexes in the joints result in **arthralgia** and **arthritis**.

C. Immune complexes in the skin cause a range of lesions, including **rashes**.

D. Immune complex deposition in blood vessel walls causes **vasculitis, purpura,** and **edema**.

E. IgG-containing immune complexes activate complement in tissues.
1. C5a attracts neutrophils to sites of immune complex deposition.
2. iC3b serves as an adhesion ligand promoting neutrophil binding.
3. The membrane attack complex damages cells.
4. Immune complex formation often causes a transient decrease in the serum levels C1, C2, C3, and C4.

F. **Diagnosis** involves the detection of antibodies in the serum or affected tissues.

SERUM SICKNESS

- ***Serum sickness*** *was first described in the preantibiotic era as a reaction to horse antitoxins given repeatedly for the treatment of toxin-mediated infectious diseases.*
- *The condition can arise after antibody production to either protein [eg, intravenous immunoglobulins (IVIG), foreign monoclonal antibodies, vaccines] or nonprotein (eg, penicillin or sulfonamides) antigens.*
- *Serum sickness typically becomes evident 1–3 days after exposure to the antigen.*
- *Signs and symptoms include fever, rash, hypotension, anaphylactoid purpura, lymphadenopathy, myalgia, arthralgia, and nephritis.*
- *The treatment of* ***anaphylactoid syndrome*** *is the same as that for anaphylaxis, ie, discontinuance of the antigen and administration of epinephrine, antihistamines, and corticosteroids.*

V. Type IV (delayed-type) immune tissue injury is a manifestation of cell-mediated immunity to haptens or protein antigens.

A. The immunologically specific component of **delayed-type hypersensitivity (DTH)** is the Th1 cell, rather than antibody.

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1. Allergens must be proteins or chemically reactive groups capable of binding covalently to proteins.
2. Important cytokines include **IL-1, TNF-α, IL-2, IL-12, IFN-γ**, and the **CCL** group of chemokines (Chapter 12).

B. Host tissue damage is mediated by cytotoxic T lymphocytes, natural killer (NK) cells, macrophages, and a range of soluble inflammatory mediators.
1. Macrophages and Th1 cells produce the proinflammatory cytokines IL-1, IL-2, IFN-γ, and TNF-α.
2. Macrophages produce eicosinoids (LTs and PGs), hydrolytic enzymes, and reactive oxygen species.

C. The important clinical manifestations of type IV hypersensitivity show delayed onset (2–3 days) and include **contact dermatitis**.
1. Plant resins (eg, poison ivy pentadecacatechol), metals (eg, nickel) and chemicals (eg, cosmetics) cause a variety of rashes.
2. Industrial exposure to certain drugs, including antibiotics, can cause type IV hypersensitivities.

D. Delayed-type hypersensitivity (DTH) skin lesions are initially characterized by their **indurated** (firm) nature, rather than the edematous (fluid-filled) lesions of atopic allergy.

E. The diagnosis of allergic contact dermatitis is aided by the **patch test**.
1. Solutions of test allergens are placed on absorbent skin patches.
2. The extent of induration and erythema beneath each patch is determined 48–72 hours later.

CLINICAL PROBLEMS

A 44-year-old school teacher who paints houses in the summer presents in early June with erythematous, indurated, and blistering lesions limited to his hands and forearms. The lesions typically appear each summer within several days of beginning to use painting products, including solvents and epoxy resins. He indicates that he does not wear protective gloves when working with these chemicals. The lesions disappear several weeks after he returns to his teaching position in the fall.

1. Which of the following represents a likely step in the pathogenesis of this disease?

A. Activation of C1

B. Chemotaxis of neutrophils

C. Induction of IgE antibodies

D. Antigen presentation by the MHC class II pathway

E. Immune complex deposition

2. Which of the following test results would best fit the clinical findings in this case?

A. A positive skin test after 20 minutes with a dilute solution of epoxy resin

B. A positive skin patch test with a dilute solution of epoxy resin

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C. Decreased serum levels of C1, C2, C3, and C4

D. A decreased CD4:CD8 ratio

E. Elevated serum tryptase

Jim received penicillin for pneumonia several years ago and presented last week with what appeared to be an allergic reaction to the drug when it was taken for a sinus infection. The next day after beginning oral penicillin, Jim's eyelids became puffy and his abdomen was covered with itchy, nearly confluent hives. After the administration of diphenhydramine and hydrocortisone his condition improved. Laboratory tests performed on his acute serum showed an elevated level of tryptase and decreased C1 and C3. A skin test with penicillin was negative.

3. Which of the elements of this case suggests this reaction was caused by circulating IgG antibody–drug complexes, rather than IgE antibody to penicillin?

A. His plasma tryptase level was elevated.

B. His symptoms were corrected by administering antihistamines.

C. His C1 and C3 levels were decreased.

D. His skin lesions were pruritic (itchy).

E. He showed evidence of altered vascular permeability.

Jesse is a 10-year-old child who complains of chest tightness and wheezing after gym class and upon exposure to cold outside air. He experiences sneezing, nasal itching, and nasal congestion indoors and following contact with his friend's dog. His allergist has determined by skin testing that he is allergic to oak pollen, Bermuda grass, house dust, and dog dander. His pulmonary function tests indicate a forced expiratory volume in 1 second (FEV_1) < 60% of the expected value for his age and a peak flow rate of 180 L/min (normal > 350 L/min).

4. Which of the following drugs would be most beneficial in alleviating Jesse's pulmonary symptoms?

A. Albuterol

B. Anti-TNF-α monoclonal antibody

C. IVIG

D. Cyclosporin

E. Recombinant IL-4

Anna is a 7-year-old child who presents with itchy, erythematous, indurated lesions on her forearms and legs 3 days after a camping trip with her classmates. Her mother treats Anna with antihistamines, which reduces the itching sensation, but does not correct the skin lesions.

5. What additional therapy would probably benefit this child?

A. Albuterol by inhaler

B. Topical corticosteroids

C. Epinephrine

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D. Anti-IgE
E. Cromolyn sodium

ANSWERS

1. The correct answer is D. The patient's history suggests this is an occupational exposure to a contact allergen in solvents. The indurated nature of the lesions suggests mononuclear cell infiltration into the skin, and the time necessary for their development (several days) is consistent with allergic contact dermatitis.
2. The correct answer is B. The standard diagnostic test for allergic contact dermatitis is the patch test. Dilute solutions of well-standardized test allergens are available that can be placed on the skin. It is essential that the test samples be dilute enough to not cause primary irritant reactions on the skin.
3. The correct answer is C. This clinical picture would normally be attributed to a type I hypersensitivity reaction mediated by IgE antibodies. However, two aspects of his reaction suggest this is not the pathogenic mechanism. First, he did not test positive to the allergen in an immediate-type skin test. Second, his complement levels were decreased, suggesting the activation and depletion of complement by circulating antigen–antibody complexes. It should also be noted that his symptoms did not appear immediately.
4. The correct answer is A. Albuterol is a β_2-receptor agonist and is used as a bronchodilator in asthma. It acts by antagonizing histamine-induced signaling in the lung. Jesse's pulmonary dysfunction results from his lungs being hyperinflated. In addition, his breathing is impaired by bronchoconstriction and mucus plugging.
5. The correct answer is B. The time to onset of symptoms and the indurated nature of the lesions suggest this is a case of poison ivy rash. Corticosteroids are administered topically to inhibit macrophage and lymphocyte activation in the skin, which are two features of delayed-type contact dermatitis.

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CHAPTER 14
PROTECTIVE IMMUNITY AND VACCINES

I. Only a subset of the immune responses we make to microbes is protective.

A. **Neutralizing antibodies** are very effective at controlling infectious agents and limiting the effects of their toxins.

1. Antibodies can prevent viral entry into and uncoating within host cells.

2. Neutralizing antibodies against microbial exotoxins (eg, tetanus toxin) block toxin binding to host cells.

3. **Seroconversion** refers to the appearance of antibodies to a microbial pathogen in a patient.

a. Seroconversion can aid in the diagnosis of a specific infectious disease.

b. Alternatively, seropositivity may simply indicate a prior encounter with the organism (or a cross-reacting species), rather than an ongoing or recent infection.

B. The **clearance** of extracellular microbes is primarily mediated by opsonophagocytosis.

1. Opsonins include antibodies, complement peptides, and soluble pattern recognition molecules (Chapter 1).

2. Opsonic receptors also initiate microbial killing mechanisms.

C. **Killing** of microbes can occur either outside or inside immune cells.

1. Extracellular pathogens that are small enough to be phagocytized (eg, bacteria) are killed within phagocytic cells.

2. Large extracelluar pathogens (eg, filamentous fungi) are killed when phagocytes adhere to the surface of the microbe.

D. The **resolution** of an infection requires the complete eradication of the infectious agent.

1. Patients with underlying cellular immune defects often do not resolve infections well.

2. Infections often reappear in these patients after antimicrobial therapy is discontinued.

3. Unresolved infections can also persist in normal individuals if the microbe (eg, *Mycobacterium tuberculosis*) establishes a **latent infection**.

E. Innate and adaptive immunity provide distinct forms of protection.

1. **Innate immunity** to microbes is essential early in an infection and lowers the early microbial burden in the host.

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2. Innate immunity is more important in immunologically naive hosts (eg, neonates) who lack **adaptive immunity** to the pathogen.
3. Adaptive immunity arises late in primary infections and often mediates resolution of infections.
4. Adaptive immunity can mediate lifelong specific protection against a particular pathogen.
5. Adaptive immunity is the objective of our current **vaccines**.

WORLDWIDE INFECTION RATES

- *Each year infectious diseases account for one-third of all deaths worldwide.*
- *Infectious diseases that are prevalent in developing countries are often not common in the United States.*
- *For example, tens of millions of individuals worldwide have schistosomiasis, leishmaniasis, and tuberculosis.*
- *Malaria, tuberculosis, and AIDS each causes several million deaths each year.*
- *Because of the complexity of these organisms and the relatively low level of research on these pathogens, effective vaccines have been slow to emerge.*

II. The specific protective immune response to a microbial pathogen depends on the life-style of the microorganism (Tables 14–1 and 14–2).

A. Protection against **extracellular pathogens** (eg, most bacteria) requires killing of the microbe within an intracellular organelle by phagocytic cells.

B. Large **extracellular pathogens** (eg, filamentous fungi) are killed when phagocytes direct these antimicrobial responses to the extracellular environment.

C. Protective responses to **obligate intracellular microbes** limit microbial replication or kill the infected cell as a means of destroying the microbe.

D. While in the extracellular phase of their life cycle, **obligate and facultative intracellular microbes** can be neutralized and cleared from the host by antibodies and complement.

III. At least eight distinct immune mechanisms are known to provide protection against microbial pathogens.

A. **Membrane lysis** is most effective against microbes with outer membranes (eg, gram-negative bacteria) or lipid envelopes (eg, enveloped viruses).
   1. Among the gram-negative bacteria, *Neisseria* species are among the most susceptible to complement-mediated membrane attack.
   2. **Antimicrobial peptides** appear to act by damaging the outer membranes of bacteria.

B. **Opsonophagocytosis** is primarily directed at extracellular bacteria, fungi, and parasites.
   1. Most opsonic receptors signal phagocytes for increased antimicrobial activity.
   2. **Pyogenic bacteria** are particularly susceptible to opsonophagocytic clearance and killing.

C. **Microbial killing** by neutrophils is essential for elimination of extracellular microbes.

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Table 14–1. Protective immune responses to infectious agents.[a]

Protective Mechanisms	Immune Components	Groups of Pathogens	Specific Pathogens
Membrane attack	Defensins, cathelicidins Complement	Gram-negative bacteria	*Pseudomonas aeruginosa* *Neisseria* species
Opsonophagocytosis	Neutrophils, macrophages Opsonic receptors (CR3, FcR) and ligands (iC3b, IgG)	Extracellular pyogenic bacteria and yeasts	*Staphylococcus, Streptococcus, Pseudomonas* species
Intracellular killing	Phagolysosomes; reactive oxygen	Extracellular bacteria and yeasts	Many catalase-negative bacteria and fungi
Toxin neutralization	IgM, IgG, IgA antibodies Immune complex clearance	Exotoxin-producing microbes	*Clostridium tetani, Staphylococcus aureus, Escherichia coli*
Virus neutralization	IgM, IgG, IgA antibodies Phagocytic cells, mucus	Respiratory and gastrointestinal viruses	Rhinoviruses, adenoviruses, rotaviruses
Extracellular killing	Neutrophils, macrophages	Filamentous fungi, parasites	*Histoplasma capsulatum, Candida albicans*
Macrophage-mediated intracellular killing	Th1 cells, NK cells, IFN-γ, nitric oxide	Obligate or facultative intracellular pathogens	*Mycobacterium tuberculosis, Listeria monocytogenes, Candida albicans, Histoplasma capsulatum*
Cytotoxic T cell killing	$CD8^+$ T cells, MHC class I, $CD4^+$ Th cells, and IL-2	Viruses and many intracellular bacteria and fungi	Herpes simplex virus, *Listeria monocytogenes*
Eosinophil-mediated cytotoxicity	Eosinophils, IgE antibodies, FcεR	Intestinal parasites (helminths)	*Taenia saginata*
Inhibition of intracellular replication	Type I interferons	Most viruses	Herpesviruses
NK cell-mediated cytotoxicity	NK cells, MHC class I	Many viruses	Herpesviruses

[a]Ig, immunoglobulin; NK, natural killer; IFN, interferon; MHC, major histocompatibility complex.

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Table 14–2. Important protective immune components organized by microbe class.[a]

Immune Component	Extracellular Bacteria	Intracellular Bacteria	Viruses	Fungi	Parasites
Antibody	++	Minimal	++	–	++
Complement	++	Minimal	+ (enveloped)	–	–
Neutrophils	++	– or +	–	+	– (eosinophils)
Th2 cells	++	–	++	–	–
Th1 cells	–	++	++	++	++
Macrophages	+	++	+	++	++
Cytotoxic T cells	–	+	++	–	–
NK cells	++ (cytokines)	+ (cytokines)	+ (lysis)	Unknown	Unknown

[a]NK, natural killer.

1. **Reactive oxygen species** (eg, hydrogen peroxide) mediate killing of many aerobic microbes.
2. A more limited range of microbes (eg, *Lysteria, Mycobacterium* species) is killed by **reactive nitrogen species** (eg, nitric oxide).
3. For the killing of anaerobic microbes, oxidants are less important than antimicrobial peptides and lysosomal hydrolases.

D. Intracellular microbes (eg, *Mycobacterium, Legionella, Listeria, Salmonella,* and *Francisella* species) that replicate within mononuclear phagocytes are particularly susceptible to **Th1-type cellular immunity**.

1. Macrophage activation by Th1 cytokines is a key step.
2. A combination of reactive oxygen and nitrogen metabolites and oxygen-independent mediators mediates killing.

E. **Toxin neutralization** is important in decreasing the severity of infectious diseases mediated by endo- and exotoxins.

F. **Virus neutralization** is particularly important in blocking virus attachment to mucosal surfaces and in clearing viruses from the blood stream.

1. Secretory immunoglobulin (Ig) A antibodies protect against inhaled and ingested viruses.
2. IgG antibodies reduce viremia and block virus spread.
3. Antibodies are particularly important for viruses (eg, rabies, polio) that require hematogenous dissemination.

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G. **Cytotoxic T cells (CTL)** provide protection against intracellular pathogens whose antigens are presented by major histocompatibility complex (MHC) class I molecules.
1. Most virus-infected cells are susceptible to CTL attack.
2. Microbes that block the class I pathway of antigen presentation (eg, herpesviruses) can evade CTL-mediated clearance.
3. Intracellular bacteria that escape the phagosome (eg, *Listeria, Francisella*) are also subject to detection by CTL.

H. **Natural killer (NK) cells** also protect against pathogen-infected host cells.
1. NK cells can recognize and kill infected host cells in which the microbe has inhibited **MHC class I** expression.
2. NK cells produce **type I interferons** (IFN-α, β) early in infection.
   a. IFN-α, β establishes an antiviral state within infected cells.
   b. IFN-α, β induces RNase L and protein kinase R, which degrade viral mRNA and block translation, respectively.

I. **Eosinophils** use **IgE antibodies** to attack extracellular parasites (eg, intestinal worms) by antibody-dependent cellular cytotoxicity (ADCC).

III. The nature of opportunistic infections in immunocompromised patients can reveal important protective immune responses (Table 14–3).

A. Infections with intracellular pathogens are common in patients lacking **Th1 cell, CTL, NK cell,** or **macrophage** functions.

B. Microbes that replicate within the cytosol (eg, viruses) are particularly problematic for patients with **CTL** or **MHC class I** defects.

Table 14–3. Common infections in the immunocompromised patient.[a]

	T Cells	B Cells	Phagocytic Cells	Complement
Bacteria	*Mycobacterium, Listeria*	*Stahpylococcus, Streptococcus, Haemophilus*	*Staphylococcus, Streptococcus, Haemophilus*	*Staphylococcus, Streptococcus, Neisseria*
Fungi	*Candida, Histoplasma, Pneumocystis*		*Aspergillus, Candida*	
Viruses	CMV, HSV, VZV, EBV, JC	Enteroviruses, influenza, RSV		
Principal mechanisms	Macrophage, NK cell, and CTL activation	Virus neutralization, opsonophagocytosis	Phagocytosis, intracellular killing	Membrane attack, chemotaxis and opsonophagocytosis

[a]CMV, cytomegalovirus; HSV, herpes simplex virus; VZV, varicella-zoster virus; EBV, Epstein–Barr virus; RSV, respiratory syncytial virus; NK, natural killer; CTL, cytotoxic T cell.

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C. Opportunistic infections with extracellular bacteria (eg, *Staphylococcus aureus*) and some cytolytic viruses (eg, influenza viruses) are common in **antibody-deficiency** states.

D. Extracellular bacteria and fungi commonly infect patients with **neutrophil** defects, including deficiencies in oxidant production or granule expression.

E. Patients with **complement** deficiencies cannot lyse gram-negative bacteria and enveloped viruses or clear extracellular microbes.

IV. Microbial immune evasion mechanisms have evolved to circumvent the most important protective responses by the host.

A. **Antigenic variation** allows bacteria, viruses, and parasites to avoid immune recognition.

1. Point mutations in antigenic proteins **(antigenic drift)** occur in influenza and human immunodeficiency virus (HIV)-1 by error-prone nucleic acid replication.

2. Other organisms, including *Neisseria gonorrhea* and *Trypanosoma cruzii*, scramble the genes that encode their major surface antigens.

3. More substantial changes in antigens **(antigenic shift)** occur by genetic recombination between related viruses.

B. Adopting an **intracellular life cycle** is a microbial response to immune elimination mediated by antibody and complement.

1. The host response to this microbial strategy has been to evolve CTL and NK cells capable of recognizing a microbe-infected cell.

2. Antigen presentation can be viewed as a host adaptation to intracellular microbial parasitism.

C. **Disguising microbial antigens** prevents immune recognition and attack.

1. Schistosomes coat themselves with host MHC molecules.

2. *Plasmodium* species (etiological agents of malaria) infect erythrocytes that do not express MHC molecules.

3. Many bacteria (eg, *Streptococcus pneumoniae* and *Haemophilus influenzae*) express thick polysaccharide capsules that disguise their more antigenic cell wall components.

4. The long polysaccharide chains of bacterial lipopolysaccharide (LPS) molecules direct complement activation away from the bacterial outer membrane.

ANTIGENIC SHIFT IN THE INFLUENZA A VIRUS

- *The influenza A virus is responsible for periodic worldwide pandemics.*
- *Protective immunity to this virus depends on the production of neutralizing antibodies to two surface glycoproteins, neuraminidase (N) and hemagglutinin (H).*
- ***Antigenic drift** is the gradual change in the N and H serotypes by mutation.*
- *Regular monitoring of the N and H gene sequences determines the serotype of the predominant influenza virus each flu season, and an appropriate vaccine is produced.*
- *Occasionally, a major **antigenic shift** occurs due to reassortment of genomes between different influenza virus strains, including those of animals.*
- *The 1957 "Asian flu" pandemic resulted from the sudden emergence of new H and N serotypes by genetic reassortment between antigenically distinct influenza viruses.*

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D. Suppression of the immune response is another common approach to evasion.

1. HIV-1 infects and depletes $CD4^+$ T cells.
2. Herpesviruses, HIV-1, and adenoviruses inhibit MHC expression or transporter associated with antigen processing (TAP) function and thereby depress CTL activation.
3. Many viruses produce proteins that mimic inhibitory cytokines or bind to activating cytokines (eg, Epstein–Barr virus and poxviruses, respectively).
4. Protein A produced by staphylococci binds IgG Fc regions.
5. *Streptococcus pyogenes* produces a C5a peptidase.
6. *N gonorrhea* produces a protease that degrades secretory IgA.
7. *Legionella* and *Listeria* species avoid intracellular killing by blocking phagosome–lysosome fusion or escaping from the phagosome, respectively.

V. Effective vaccines augment protective host responses to infection.

A. Vaccines do not typically prevent infections, although they reduce the severity of infectious diseases.

B. Most existing vaccines are **preemptive**; they must be given prior to infection (Table 14–4).

Table 14–4. Recommended immunizations for children.[a]

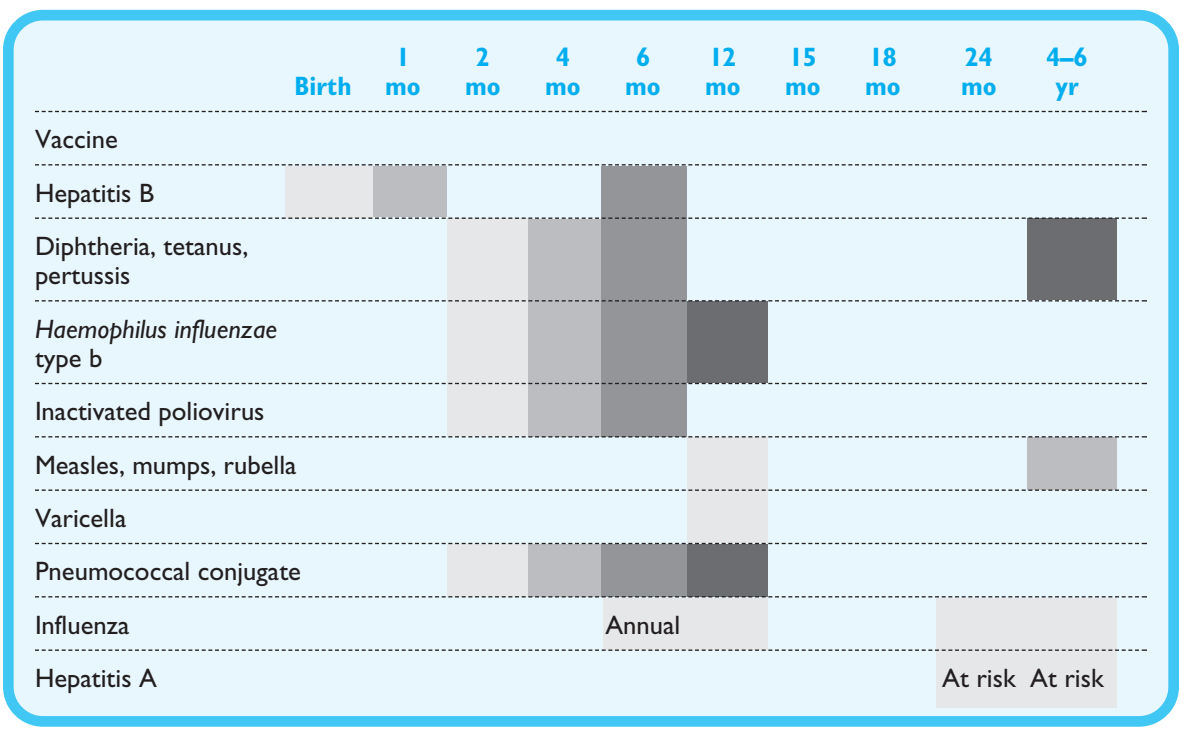

[a]Adapted from www.cdc.gov/nip/recs/child-schedule.htm#printable. The different shades denote the different number of immunizations (eg, children should receive three immunizations with the hepatitis B vaccine).

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1. Only a few vaccines (eg, rabies, hepatitis) are **therapeutic vaccines** that can be used to treat an infected patient.
2. Rabies is a slowly progressing infection that does not outpace the immune response.

C. All existing vaccines are directed at **epitopes**, not microbial patterns, and induce adaptive immunity.

D. We have very few vaccines against complex microbes (eg, parasites).

E. Most of our best vaccines induce neutralizing antibodies.

F. Routine **pediatric vaccines** (Table 14–4) are designed to prevent life-threatening infectious diseases of childhood.

1. These diseases typically outpace the ability of the neonate to mount an adequate protective immune response.
2. Immunization is also valuable when the dose of a microbial toxin (eg, tetanus toxin) sufficient to cause disease is far less than the immunizing dose.
3. Some vaccines (eg, *H influenzae* type b conjugate vaccine) are designed to elicit opsonic IgG antibodies that would not normally be made during an infection in children.

G. Practical issues dictate the design and use of vaccines.

1. Live attenuated vaccines can cause disease in an immunodeficient individual and should be avoided.
2. Repeated immunizations are required to attain high-titered, long-lasting protective immunity or to compensate for antigenic shift.
3. Multiple immunizations are necessary to induce Ig isotype switching (eg, IgG antibody formation).

COMMON COLDS IN CHILDREN

- *Children normally contract five or six colds (upper respiratory tract infections) each year.*
- *This frequency is increased by exposure to day care centers and cigarette smoke, allergies and asthma, cystic fibrosis, congenital immune defects, and ciliary dyskinesia.*
- *Several hundred different viruses can cause the common cold, including the rhinoviruses, influenza viruses, adenoviruses, and respiratory syncytial virus.*
- *The development of a vaccine for this disease has been hampered by the wide variety of antigenically distinct agents responsible for these infections.*

4. The design of a vaccine should theoretically reflect the principal protective response desired in the host (Table 14–5).
   - **a.** Immunization against intracellular pathogens requires a live vaccine that duplicates the intracellular infection.
   - **b.** **Live attenuated vaccines** are useful when inducing a CTL response.
   - **c.** **Polyvalent vaccines** (eg, *Neisseria* species) are useful when multiple serotypes of a pathogen cause disease.
   - **d.** **Subunit vaccines** (eg, hepatitis B) are effective when inducing immunity to surface antigens or toxins.
   - **e.** **Conjugate vaccines** (eg, *H influenzae* type b) promote the production of IgG antibodies to T-independent epitopes.
   - **f.** **Mucosal immunization** (eg, influenza nasal vaccine) can protect against respiratory or gastrointestinal pathogens.

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Table 14–5. Types of vaccines.

Type of Vaccine	Examples
Live attenuated	Oral polio, varicella; mumps, measles, rubella, bacillus Calmette–Gúerin (BCG)
Killed or inactivated	Inactivated polio
Subunit	Diphtheria toxoid, tetanus toxoid
Recombinant subunit	Hepatitis B
Conjugate	*Haemophilus influenzae* type b, *Streptococcus pneumoniae*
Polyvalent	*S pneumoniae*

NOVEL VACCINE STRATEGIES

- *Molecular biological techniques provide the means for isolating genes from microbial pathogens and expressing them in relatively safe viral vectors.*
- *This permits the construction of **polyvalent vaccines** carrying genes for a large number of microbial antigens.*
- ***Adjuvant** activity can be included by also expressing genes for human cytokines (eg, switch cytokines or Th1 cell-inducing cytokines) and costimulatory molecules.*
- ***DNA vaccines** are another approach that could be used to induce T cell-mediated immunity by directing microbial protein expression associated with host MHC.*

CLINICAL PROBLEMS

A 15-month-old child is seen by his pediatrician for a cough, congestion, and fever of 39°C. He has a rapid pulse, appears ill, and is unresponsive. His white blood cell count is elevated. His mother seems unsure of his immunization history, but recalls only two visits to the county health clinic for immunizations. The pediatrician prescribes the antibiotic ampicillin, and the child's condition improves substantially over the next few days.

1. A routine pediatric vaccine for which of the following pathogens might have prevented this condition?

A. Rabies

B. Poliovirus

C. *Legionella pneumophila*

D. *Haemophilus influenzae* type b

E. Hepatitis B

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Harry is aware that he has a congenital deficiency of the C6 complement peptide.

2. For which of the following infectious agents is Harry particularly susceptible?

A. *Streptococcus pneumoniae*
B. *Neisseria meningitidis*
C. *Clostridium tetani*
D. *Mycobacterium tuberculosis*
E. *Clostridium difficile*

Donald has a defect in his IFN-γ receptor resulting from an inherited mutation in one of the receptor-encoding genes.

3. Which of the following pathogens would most likely cause recurrent infections in this child?

A. *Pseudomonas aeruginosa*
B. *Streptococcus pyogenes*
C. *Staphylococcus aureus*
D. *Legionella pneumophila*
E. *Neisseria meningitidis*

A 1-day-old child born of an uncomplicated full-term pregnancy presents with jaundice. The mother is Rh^+, and the newborn is not anemic. Suspecting a congenital virus infection, viral serology on a sample of the child's serum is ordered. High-titered IgG antibodies to cytomegalovirus are found.

4. What can be concluded from these clinical and laboratory findings?

A. The patient has a congenital cytomegalovirus (CMV) infection.
B. The infant suffers from Rh disease of the newborn.
C. The child should be immunized immediately to limit CMV infection.
D. The infant should be given broad-spectrum antibiotics.
E. The positive CMV serology reflects the immune status of the mother.

Milind is a 56-year-old immigrant from India who is brought to the emergency room with a cough that produces blood-containing sputum. He has a positive skin test with tuberculin purified protein derivative (PPD), and his chest x-ray shows lesions typical of mycobacterial pneumonia. He indicates that he was immunized with bacillus Calmette–Gúerin (BCG) as a child.

5. What is the nature of this vaccine?

A. Subunit vaccine
B. Conjugate vaccine
C. Live attenuated vaccine
D. Recombinant vaccine
E. Polyvalent vaccine

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ANSWERS

1. The correct answer is D. *H influenzae* is a gram-negative bacterium that can cause mild nasopharyngeal infections. In young children, these conditions can progress to meningitis, and vaccination has proven effective at reducing morbidity and mortality. Multiple immunizations in children are recommended by 15 months of age (Table 14–4).
2. The correct answer is B. *Neisseria* species are among the most susceptible to complement-mediated lysis by the C5b-9 membrane attack complex due to the structure of their outer membranes. The other organisms listed do not have classic outer membranes.
3. The correct answer is D. Only *Legionella pneumophila* is an intracellular pathogen. Defective IFN-γ signaling would impair Th1 cellular immunity, especially the activation of macrophages. This bacterium establishes an intracellular infection within resting macrophages and is killed when macrophages become activated.
4. The correct answer is E. High-titered antibodies to CMV in a newborn's serum most likely reflect IgG that has crossed the placenta from the mother. Vaccinating the child at this point would not limit the infection, and there currently is no CMV vaccine.
5. The correct answer is C. The BCG strain is a live bovine mycobacterium that induces cross-protective immunity to other *Mycobacterium* species in humans. Its effectiveness derives from its ability to establish life-long Th1-type cellular immunity against mycobacterial antigens, but protection is variable among vaccines.

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CHAPTER 15
IMMUNE DEFICIENCY STATES

I. Primary immune deficiency diseases in human beings are generally rare, inherited conditions affecting a defined immune component (Figure 15–1 and Table 15–1).

A. The term **congenital** is also used to describe these diseases, because they are inherited and become apparent early in life.

B. Recurrent infections are the most common clinical presentation.

1. The nature of the infections in an immunocompromised patient can provide important clues for establishing a diagnosis.

a. These infections are often with **opportunistic pathogens**, which do not pose problems for healthy individuals.
(1) Opportunistic agents generally show low virulence.
(2) Many opportunistic microbes are normal flora.

b. The infections may resist aggressive antimicrobial therapy or may not **resolve** (Chapter 14) after the completion of the therapy.

c. The infection may **progress more rapidly** than it would in an immunocompetent individual of the same age.

d. The course of the infections may be unusual in **severity** or **organ involvement**.

e. The infections may occur much **earlier in life** (eg, during the first week) than would be seen in a normal child.

f. The infections may show **delayed onset** in infancy (eg, after 6 months of life), reflecting the normal decline of maternal antibody acquired during pregnancy.

g. Similar infections may have occurred **within a family**, especially among male infants.

h. The infections may follow shortly **after immunization** with a live vaccine.

2. In adults, recurrent infections more often indicate an **acquired** or **secondary immune deficiency**.

a. A history of **high risk behavior for human immunodeficiency virus (HIV)-1 infection** (intravenous drug abuse, unprotected sex with an infected partner) supports a diagnosis of an acquired immune deficiency.

b. Chemotherapy for cancer or **occupational exposure** to ionizing radiation increases the risk of immunodeficiency.

c. Patients who are receiving **immunosuppressive therapy** for autoimmune disease or following transplantation are at risk for recurrent infections.

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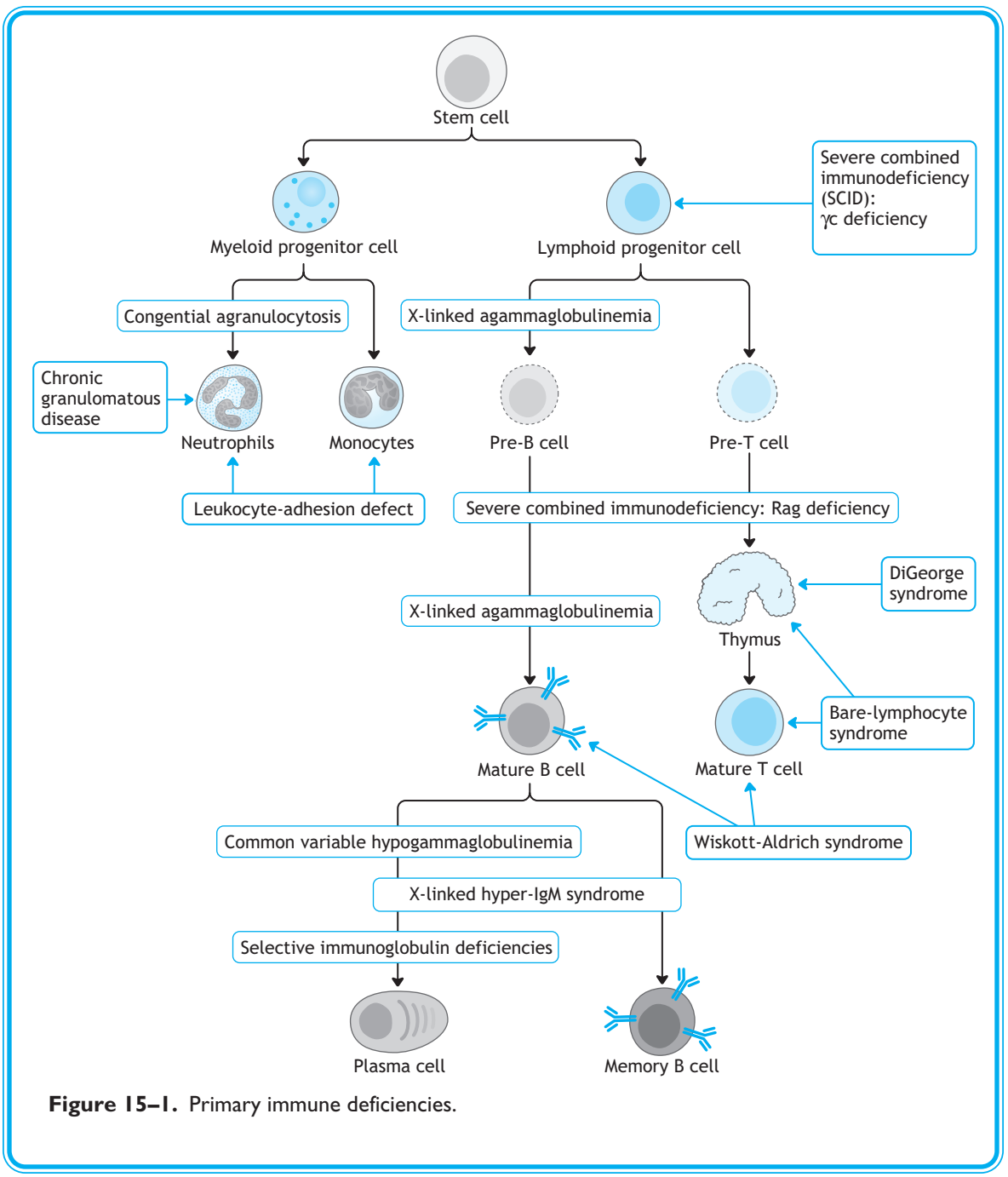

Figure 15–1. Primary immune deficiencies.

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Table 15–1. Examples of selective primary T and B cell deficiencies.[a]

Category of Deficiency	Examples	Molecular or Cellular Defect	Clinical Presentation	Therapies
Antibody or humoral immunity	XID	Btk kinase mutation	Infections with extracellular bacteria commencing at 6–9 months of age	Antibiotics, IVIG
	Selective IgA deficiency	Varied	Sinopulmonary infections and diarrhea; increased incidence of atopic allergies	Antibiotics
	Hyper-IgM syndrome	CD154 or AID mutations	Elevated IgM; little or no IgG or IgA; absence of Ig class switching; bacterial infections	Antibiotics, IVIG
T cell or cellular immunity	DiGeorge syndrome	Thymic epithelium	Parathyroid deficiency; heart defects; early onset of fungal and viral infections; lymphopenia	Antimicrobial agents; thymic transplant
	BLS-II	Transcription of HLA class II genes	Absence of HLA-D expression; opportunistic viral and fungal infections; $CD4^+$ T cell lymphopenia	Antimicrobial agents; stem cell transplant
	Deficiency of TCR signaling	ZAP-70 mutation	Recurrent viral and fungal infections; depressed cellular immunity	Antimicrobial agents; stem cell transplant

[a]XID, X-linked immunodeficiency; Btk, Bruton's tyrosine kinase; Ig, immunoglobulin; IVIG, intravenous immunoglobulin; AID, activation-induced cytidine deaminase; BLS-II, bare lymphocyte syndrome type II; TCR, T cell receptor; ZAP-70, ζ-associated protein-70.

3. Conversely, the successful resolution of an infection aids in establishing a differential diagnosis of immune deficiency diseases.
   a. Children who resolve a viral infection (eg, chickenpox) in a normal manner are not likely to be deficient in T cells.
   b. Patients who do not have a history of recurrent bacterial infections probably have normal neutrophil function.

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4. The nature of the infectious agent can suggest the type of selective immune deficiency.
   a. Patients with primary antibody, phagocytic cell, or complement deficiencies present with recurrent infections involving **extracellular bacteria** and certain **fungi**.
   b. Patients with primary T cell or combined [T cell plus antibody and/or natural killer (NK) cell] immune deficiencies present with recurrent infections involving **viruses, intracellular bacteria, fungi,** and certain **parasites**.

C. A differential diagnosis is essential for determining appropriate therapy.
1. Antibody, phagocytic cell, and complement deficiencies present with similar types of infections, but require distinct therapies.
2. Similarly, deficiencies in recombination activating gene 1 (Rag1), transporter associated with antigen processing (TAP)-1, and thymus development present with similar opportunistic virus infections.

II. Antibody deficiencies are the most common immune deficiency state in infants and children, accounting for nearly half of all conditions (Table 15–2).

A. The prevalence of these diseases ranges from a few reported cases to 1 case per 350 individuals.

B. Antibody deficiencies range from generalized **agammaglobulinemia** to selective immunoglobulin (Ig) (sub)class deficiencies (eg, IgG_2 deficiency).

C. Some patients with normal serum levels of Igs fail to make antibodies to important microbial antigens.

D. The most frequent antibody deficiencies represent a failure to synthesize or secrete Ig, rather than an absence of B cells.
1. **Selective IgA deficiency** is the most common primary immune deficiency with a frequency of 1 in 350.
   a. In some patients, IgA is synthesized but not secreted.

Table 15–2. Distinguishing features of primary antibody deficiencies.[a]

Disease	Distinguishing Features
Selective IgA deficiency	Most common primary immune deficiency; many affected individuals are asymptomatic; IVIG contraindicated
Selective IgG_2 deficiency	Impaired antibody responses to bacterial polysaccharide antigens; recurrent infections with encapsulated bacteria
Transient hypogammaglobulinemia of infancy	Delayed onset of IgM and IgG production; IVIG contraindicated; recurrent sinopulmonary infections
XLA	Absence of peripheral $CD19^+$ B cells; delayed onset to 6 months of age; X-linked; pyogenic bacterial infections

[a]Ig, immunoglobulin; IVIG, intravenous immunoglobulin; XLA, X-linked agammaglobulinemia.

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b. Nearly half of IgA-deficient patients are asymptomatic due to the translocation of IgM across the mucosal epithelium.

2. Selective IgG_2 deficiency is a common form of IgG deficiency.
- **a.** These patients do not respond to polysaccharide vaccines.
- **b.** Infections with encapsulated bacteria are common.

3. Transient hypogammaglobulinemia of infancy is a condition that can lead to infections toward the end of the first year of life.
- **a.** These infants have normal numbers of mature B cells.
- **b.** They show delayed IgG secretion that becomes apparent as maternal IgG levels subside (ie, at 6–8 months of age).
- **c.** Otitis media, pneumonia, and diarrhea are common.

E. B cells are absent in only a few antibody deficiency diseases.

1. X-linked agammaglobulinemia (XLA) is a mutation in the gene for Bruton's tyrosine kinase (**Btk**).
- **a.** B cell development is blocked at the pre-B cell stage.
- **b.** XLA patients have a peripheral phenotype of $T^+B^-NK^+$.
- **c.** Normal levels of serum IgG are present at birth and wane over time.
- **d.** XLA patients suffer from recurrent infections with pyogenic (pus-forming) extracellular bacteria.

2. A similar phenotype is seen in patients with **Ig H chain locus deletions** that prevent the expression of a functional μ chain.

3. Igα deficiency blocks B cell development at the pre-B stage.

4. κ-chain deficiency blocks the differentiation of κ-bearing B cells.

F. Most antibody deficiencies can be diagnosed using simple laboratory tests.

1. Except for certain rare conditions (eg, XLA), the measurement of B cell numbers is not essential to establishing a diagnosis.

2. Ig concentrations can be measured by nephelometry (Chapter 5).

3. Isohemagglutinin titers reflect the ability to produce antibody.

4. Responses to the tetanus toxoid and pneumococcal polysaccharide vaccines provide information on memory and naive B cell function.

5. A differential diagnosis requires the elimination of phagocytic cell and complement deficiencies.

G. The treatment of B cell deficiencies addresses both infections and the underlying hypogammaglobulinemia.

1. Antibiotics are given to treat bacterial infections.

2. Intravenous immunoglobulins (IVIG) restore antibody levels.
- **a.** Because the half-life of IgG is approximately 3 weeks, IVIG must be given frequently.
- **b.** IVIG is prepared from the pooled sera of immune donors.
- **c.** IVIG therapy is not recommended for children with transient hypogammaglobulinemia of infancy or patients with selective IgA deficiency.

3. Because IVIG is relatively safe and effective, stem cell transplantation is rarely performed to correct B cell deficiencies.

IVIG AND SELECTIVE IGA DEFICIENCY

- *Selective IgA deficiency is an important exception to the general use of IVIG to treat antibody deficiencies.*
- *The use of IVIG in these patients carries a risk of anaphylactic or anaphylactoid shock.*

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- *This is thought to result from the tendency of these patients to produce IgE and IgG antibodies to IgA that is present in the IVIG preparations.*
- *Such antibodies mediate type I and type III hypersensitivity responses to IVIG.*

III. Patients with primary T cell ($T^-B^+NK^+$) and combined ($T^-B^-NK^+$, $T^-B^+NK^-$, or $T^-B^-NK^-$) immune deficiencies acquire infections in their first few weeks of life.

A. These infections are **pediatric emergencies**.

1. The infectious agents include **viruses, fungi,** and other **intracellular pathogens**.

2. Many of the organisms that infect T cell-deficient patients (eg, *Cryptosporidium, Pneumocystis, Leishmania* species) show low virulence and only rarely cause disease in the general population.

3. The infections in T cell-deficient patients are often disseminated and rapidly progressing.

GRAFT-VERSUS-HOST DISEASE (GVHD) IN PREGNANCY

- ***GVHD** is typically seen only in stem cell transplantation (Chapter 17).*
- *T cells of the donor recognize and attack the recipient's tissues.*
- *Because pregnancy provides an opportunity for maternal T cells to recognize fetal HLA antigens inherited from the father, GVHD can also occur in this setting.*
- *Because the fetal immune system is sufficiently mature to destroy maternal T cells that cross the placenta, the disease is rarely seen in normal pregnancies.*
- *However, when fetuses have congenital T cell deficiencies, GVHD can occur.*
- *GVHD also occurs when fresh whole blood is transfused to a T cell-deficient child.*

B. Selective T cell deficiencies are due to blocks in thymocyte differentiation and/or receptor-initiated cell signaling (Table 15–3).

1. DiGeorge syndrome is a rare thymic hypoplasia due to dysmorphogenesis of the third and fourth pharyngeal pouches.

a. Embryonic abnormalities are also seen in the heart, major vessels, parathyroid, and facial structures.

b. Antibody deficiency results from the absence of Th cells.

c. T cell lymphopenia and opportunisitic viral and fungal (eg, *Pneumocystis*) infections result.

2. Defects in **T cell receptor (TCR)-initiated signaling** (Chapter 6) cause deficiencies in cell-mediated immunity.

a. Loss-of-function mutations exist in **CD3ζ, Lck,** and **ζ-associated protein-70 (ZAP-70)**.

b. Defective positive selection in the thymus causes peripheral lymphopenia with a **$T^-B^+NK^+$** phenotype.

3. Bare lymphocyte syndrome type I (BLS-I) is a selective deficiency of $CD8^+$ T cells.

a. This condition is caused by mutations in the **TAP** proteins.

b. Major histocompatibility complex (MHC) class I expression and positive selection in the thymus are impaired.

c. The peripheral lymphocyte phenotype is **$CD4^+CD8^-B^+NK^+$.**

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Table 15–3. Distinguishing features of primary T cell deficiencies.[a]

Disease	Distinguishing Features
DiGeorge syndrome	Lymphopenia with hypoparathyroidism, cardiac and facial defects; corrected by thymic transplant
ZAP-70 or CD3ζ deficiency	Absence of both $CD4^+$ and $CD8^+$ T cell function with normal numbers of B cells and NK cells
BLS type I	Absence of HLA class I expression and decreased numbers of $CD8^+$ T cells
BLS type II	Absence of HLA class II expression and decreased numbers of $CD4^+$ T cells
Th1 deficiency	Decreased IL-12 and IFN-γ signaling; mycobacterial pneumonia
Hyper-IgM syndrome type I	Absence of CD154; elevated IgM antibody responses; decreased IgG and IgA
AID deficiency	Elevated IgM antibody responses; normal expression of CD154 and CD40

[a]ZAP-70, ζ-associated protein-70; NK, natural killer; BLS, bare lymphocyte syndrome; IL, interleukin; IFN, interferon; Ig, immunoglobulin; AID, activation-induced cytidine deaminase.

4. **Bare lymphocyte syndrome type II (BLS-II)** results in a **$CD4^-CD8^+B^+NK^+$** phenotype.
   a. These patients have mutations in transcription factors, such as **CIITA**, that coordinately regulate MHC class II gene expression.
   b. Positive selection of $CD4^+$ thymocytes is impaired.
   c. The activation of peripheral $CD4^+$ T cells is blocked.
5. A family of related **Th 1 cell deficiencies** is caused by deficient cytokine signaling.
   a. **Interleukin (IL)-12** and **IL-12 receptor** defects block Th1 cell differentiation and activation.
   b. **Interferon (IFN)-γ receptor deficiency** blocks macrophage activation.
   c. Recurrent infections with intracellular bacteria (eg, *Mycobacterium* and *Salmonella* species) result.
6. The absence of the coreceptor CD40 or its ligand, CD154, causes **hyper-IgM syndrome type 1**.
   a. This leads to a deficiency of the Th2 signals necessary for Ig class switching in B cells (Chapter 6).
   b. Patients have elevated levels of IgM antibodies, but no IgG, IgA, or IgE.
7. **Hyper-IgM syndrome type 2** results from a mutation in the gene for **activation-induced cytidine deaminase (AID)** (Chapter 9).

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a. T helper cell signaling for Ig class switching is absent.
b. Somatic hypermutation and affinity maturation in B cells are also impaired.

C. **Severe combined immune deficiency (SCID)** is caused by a number of different genetic mutations (Table 15–4).

1. The X-linked recessive form of SCID is most prevalent.
   a. It is caused by an absence of the **common γ chain (γc)** of the receptors for IL-2, IL-4, IL-7, IL-9, and IL-15.
   b. Abnormal development of T cells and NK cells results in a **$T^-B^+NK^-$** phenotype.
2. The same phenotype (**$T^-B^+NK^-$**) is seen in deficiencies of **Janus kinase 3 (Jak3)**, which mediates signaling from these receptors.
3. Mutations in the gene coding for the enzyme **adenosine deaminase (ADA)** cause SCID.
   a. ADA catalyzes the breakdown of intracellular adenosine and deoxyadenosine.
   b. Excess adenosine inhibits methyltransferase reactions in T cells, B cells, and NK cells resulting in a **$T^-B^-NK^-$** phenotype.
4. Mutations in the **Rag1** and **recombination activating gene 2 (Rag2)** genes block T and B cell development by preventing TCR and B cell receptor (BCR) gene rearrangements.
   a. Lymphocyte differentiation is blocked at the pre-T and pre-B cell stages.
   b. The lymphocyte phenotype in this condition is **$T^-B^-NK^+$.**
5. **Wiscott–Aldrich syndrome (WAS)** is a condition characterized by thrombocytopenia and immune deficiency.
6. **Perforin and granzyme deficiencies** manifest as decreased T cell and NK cell cytotoxic activity.

Table 15–4. Distinguishing features of primary SCID.[a]

Gene Mutation	Overall Cellular Phenotype	Distinguishing Features
γc	$T^-B^+NK^-$	Most frequent cause; impaired signaling through multiple cytokine receptors; normal B cell numbers
Jak3	$T^-B^+NK^-$	Rare, but otherwise indistinguishable from γc deficiency
ADA	$T^-B^-NK^-$	Decline in the numbers of all lymphocyte subsets over time
Rag1, Rag2	$T^-B^-NK^+$	Absence of peripheral T and B cells from birth; normal NK cells

[a]Jak3, Janus kinase 3; ADA, adenosine deaminase; Rag1, Rag2, recombination activating genes 1 and 2; NK, natural killer.

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D. The **diagnosis** of T cell and combined immune deficiencies depends on recognizing the typical infections that characterize these conditions and measuring lymphocyte numbers and functions.
1. Infections begin in the first few months of life.
2. Lymphopenia is common.
3. Measuring anti-HIV antibodies or viral load is essential when a T cell deficiency is suspected.
4. Measuring CD3, CD4, CD8, CD19, and CD154 expression by flow cytometry can help detect lymphocyte subset deficiencies.
5. T cell proliferation in response to polyclonal activators (the plant mitogen phytohemagglutinin) can be measured in vitro.
6. Delayed-type hypersensitivity (DTH) skin tests (eg, intradermal or patch testing) are used to evaluate $CD4^+$ Th1 cell responses to common microbes.

E. **Therapy** includes antiviral and antifungal agents and hematopoietic stem cell replacement.
1. **Thymus transplantation** is effective in treating DiGeorge syndrome.
2. **Stem cell transplantation** (Chapter 17) is effective for SCID and selective T cell deficiency patients.
3. **Gene therapy** is being tested for some of these immune deficiencies (eg, ADA deficiency).
4. Other therapies are **contraindicated**.
   a. T cell-deficient patients should not be immunized with **live viral vaccines**.
   b. All blood products (whole blood, platelets, and plasma) should be irradiated prior to transfusion.

GENE THERAPY FOR IMMUNE DEFICIENCIES

- *The identification of specific genetic mutations that cause immunodeficiency diseases provides the opportunity to correct these conditions by gene therapy.*
- *The most promising approach appears to be "repairing" the defective gene within the patient's own hematopoietic stem cells by retroviral transfer followed by reinfusion.*
- *ADA deficiency was the first human disease treated by gene therapy in the 1990s.*
- *Other immune deficiencies that have been considered include γc deficiency, leukocyte adhesion defect (LAD; CD18 deficiency), and chronic granulomatous disease (respiratory burst deficiency).*

IV. Primary phagocytic cell deficiencies result from decreased cell number, abnormal cell adhesion and migration, defective intracellular granules, or impaired intracellular killing mechanisms (Table 15–5).

A. **Cyclic neutropenia** is caused by a mutation in the **neutrophil elastase** gene.
1. Neutropenia (< 200 cells/μL) occurs periodically.
2. Treatment with recombinant **colony-stimulating factor-granulocyte (CSF-G)** has proven effective.

B. **LAD** is characterized by poor leukocyte adhesion to the vascular endothelium, delayed wound healing, and defective complement-dependent opsonophagocytosis.
1. **LAD type 1** is a mutation in the gene for **CD18**, a β2 integrin family member (Chapter 8).
   a. Patients show chronic leukocytosis involving neutrophils and fail to phagocytize iC3b-coated particles.

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Table 15–5. Distinguishing features of phagocytic cell deficiencies.[a]

Disease	Distinguishing Features
Cyclic neutropenia	Oscillating neutropenia; responsiveness to CSF-G
LAD type 1	Chronic leukocytosis; absence of CD18-containing receptors; limited neutrophil extravasation and pus formation; impaired iC3b-mediated phagocytosis
LAD type 2	Leukocytosis; infections; normal CD18
LAD type 3	Decreased selectin expression
LAD type 4	Impaired CD18 initiated signaling
Chediak–Higashi syndrome	Formation of giant fused granules in neutrophils and NK cells
CGD	Absence of superoxide production; infections with catalase-positive microbes; granulomas
Job's syndrome	Decreased IFN-γ synthesis; IgE levels, skin abscesses without erythema or tenderness
Th1 pathway defects	Impaired macrophage activation

[a]CSF-G, colony-stimulating factor-granulocyte; IFN, interferon; LAD, leukocyte adhesion defect; NK, natural killer; CGD, chronic granulomatous disease.

b. Diagnosis is aided by demonstrating the absence of CD11 or CD18 on blood leukocytes.

2. **LAD type 2** is a defect in fucose metabolism that impairs selectin function.
3. **LAD type 3** is a defect in selectin expression.
4. **LAD type 4** is caused by a mutation in the rac signaling molecule activated by CD18.

C. **Chediak–Higashi syndrome (CHS)** results from the excessive fusion of granules in a number of granulated cells, including leukocytes.

1. The defect is caused by a mutation in a regulator of lysosomal trafficking.
2. CHS cells show poor chemotaxis and impaired NK cell function.

D. **Neutrophil-specific granule deficiencies**, including the absence of α and β defensins, result in impaired intracellular killing of microbes.

IMMUNE DEFICIENCY IN JOB'S SYNDROME

- ***Job's syndrome*** *(hyper-IgE syndrome; Chapter 13) is characterized by highly elevated levels of serum IgE, eczema, and sinopulmonary and skin infections.*
- *Given the elevated IgE levels, atopic dermatitis is a common misdiagnosis.*
- *Infections can cause deep skin and lung abscesses.*

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- *An unusual characteristic of the skin lesions is the absence of erythema, tenderness, and warmth, similar to the appearance of the skin boils of the biblical character Job.*
- *A marked decrease of IFN-γ production by these patients may explain both the elevated IgE levels and the impaired phagocyte responses to infection.*

E. **Chronic granulomatous disease (CGD)** is a heterogeneous condition caused by a defective respiratory burst oxidase.
1. Mutations in any of four subunit genes have been reported.
2. Diagnosis is based on the nitroblue tetrazolium (NBT) dye reduction test for oxidant production.
3. CGD is characterized by bacterial and fungal infections, especially *Staphylococcus* and *Aspergillus* species.
4. **Granulomas** form in the lungs, liver, and spleen when microbes that cannot be killed are "walled off."
5. Prophylactic antibiotics, recombinant IFN-γ, and granulocyte transfusions are beneficial.
6. Stem cell transplantation is potentially curative.

F. **Myeloperoxidase (MPO) deficiency** causes a block in the production of hypohalous acids.

G. Aggressive **treatment** with antibiotics is necessary to control infections in phagocytic cell deficiencies.
1. Some conditions benefit from prophylactic antimicrobial agents.
2. Recombinant cytokines are of value in treating cyclic neutropenia and CGD.
3. Leukocyte transfusions during acute infections are beneficial.
4. Stem cell transplantation is potentially curative in CGD, Chediak–Higashi syndrome, and LAD.

ANTIBIOTICS AND PHAGOCYTE DEFICIENCIES

- *Neutrophil deficiencies tend to manifest as gingivitis and periodontal diseases, cutaneous infections and abscesses, pneumonias, and/or granulomas caused by multiple infectious agents.*
- *While IFN-γ deficiency affects macrophage function and results in infections primarily with intracellular bacterial pathogens, diverse types of pathogens cause infections in Chediak–Higashi syndrome or cyclic neutropenia.*
- *Prophylactic antimicrobial therapy is less effective when infections are caused by diverse microbial species.*

V. Inherited deficiencies in the complement system cause both infectious and noninfectious diseases (Table 15–6).

A. Rare deficiencies in all of the individual components have been described.
1. A deficiency of **mannose-binding protein (MBP)** is the most common single component defect.
2. **C2 deficiency** is the most common deficiency affecting the classical pathway.

B. Deficiencies in the classical, lectin, or alternative pathways can increase the susceptibility to bacterial and some viral infections.
1. Early pathway deficiencies result in recurrent pyogenic infections.
2. Defects in the terminal components C5–C8 lead to disseminated *Neisseria* infections.

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Table 15–6. Primary deficiencies in the complement system.

Type of Deficiency	Components Involved	Clinical Characteristics
Classical pathway	C1q,r,s, C4, C2	Lupus nephritis Bacterial, viral, and fungal infections
Alternative pathway	P, B, D	*Neisseria* infections Pyogenic infections
Lectin pathway	MBL	Diverse infections
Common components	C3	Pyogenic infections
Terminal components	C5–C8	Disseminated *Neisseria* infections
Inhibitors	C1 Inh, H, I, C4b-BP	Angioedema, nephritis, infections
Cell surface inhibitors	DAF, CD59	Paroxysmal nocturnal hemoglobinuria
Receptors	CR3, CR4	Leukocyte adhesion, pyogenic infections, delayed wound healing

C. Defects in the expression of the **complement regulatory components** cause both infectious and noninfectious diseases.

1. **Factor I deficiency** increases the risk of pyogenic infections, including meningococcal meningitis.
   - **a.** Unrestrained complement activation leads to C3 consumption (Chapter 8).
   - **b.** Exogenous Factor I provides relief in acute disease.
2. **Factor H deficiency** also results in increased complement activation, C3 depletion, and an increased risk of infection.
3. **C1 inhibitor (C1 Inh) deficiency (hereditary angioedema)** and **C4b-BP deficiency** are characterized by episodic cutaneous and submucosal edema.
   - **a.** Both conditions result in unabated activation of the classical complement pathway.
   - **b.** A C2-derived peptide is thought to cause increased vascular permeability and localized edema in hereditary angioedema.
   - **c.** C1 Inh also regulates the production of bradykinin, which can have a similar effect on endothelial permeability.
4. **Paroxysmal nocturnal hemoglobinuria (PNH)** is due to a failure of cells to express glycosylphosphatidylinositol (GPI)-linked membrane proteins, including CD59 and CD55 (decay accelerating factor).
   - **a.** CD59 blocks insertion of C8 and C9 into the membrane.
   - **b.** CD55 inhibits C3 and C5 convertases on the cell surface.
   - **c.** Erythrocytes of PNH patients are highly susceptible to complement-mediated lysis.

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D. Complement deficiencies and **autoimmunity** are often associated with one another.
1. Patients with defects in the early classical pathway components often develop a lupus-like nephritis.
2. Circulating immune complexes in autoimmunity deplete the early classical components.
3. Autoantibodies to complement components (eg, anti-C1q) are sometimes produced by patients with systemic lupus erythematosus (SLE) (Chapter 16).
4. Patients with SLE, Sjögren's syndrome, and autoimmune hemolytic anemias often show decreased expression of **complement receptor 1 (CR1)** on their erythrocytes.

E. The treatment of complement deficiencies focuses primarily on controlling infections and correcting acute symptoms.
1. Aggressive antibiotic therapy is the first objective for infections.
2. Plasma infusion or injection of individual components (eg, recombinant C1 Inh) has some clinical value for acute disease.
3. The various treatments for autoimmunity associated with complement deficiencies are discussed in Chapter 17.

VI. Inherited innate immune defects can cause inflammatory or infectious diseases.

A. An increased susceptibility to infections results from mutations in **interleukin-1 receptor-associated kinase (IRAK)** of the Toll-like receptors.

B. Mutations in **mannose-binding lectin** increase the risk of infection, especially in the presence of other chronic diseases (eg, cystic fibrosis).

C. Deficiencies in the antimicrobial **Nod proteins** (Chapter 1) are thought to contribute to the induction of inflammatory bowel disease.

VII. Acquired or secondary immune deficiency states typically show adult onset.

A. Acquired immune deficiencies can also result from **infections**.
1. **Acquired immune deficiency syndrome (AIDS)** is the most prevalent immune deficiency in the United States.
   a. $CD4^+$ T cells are depleted by the lymphotrophic virus **human immunodeficiency virus-1 (HIV-1)**.
   b. Th1 cell functions are particularly affected.
   c. Opportunistic infections with intracellular pathogens (Table 15–7) are the primary causes of morbidity and mortality.
2. Transient neutropenia in children is seen in some viral (eg, measles) and bacterial (eg, tuberculosis) infections.
3. A number of microbial pathogens (eg, herpesviruses) have developed immune evasion mechanisms that cause selective immunosuppression of the host (Chapter 14).

B. Immune deficiency can arise secondary to **therapy**.
1. **Splenectomy** impairs the ability to produce antibodies.
   a. Splenectomized patients are at increased risk for sepsis.
   b. Splenectomy decreases IgG antibody responses to polysaccharide vaccines.
2. **Immunosuppressive drugs** increase the risk of infections.

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Table 15–7. Opportunistic pathogens causing infections in AIDS.

Bacteria	Fungi	Viruses	Parasites
Mycobacteria	*Pneumocystis*	Herpes simplex	*Toxoplasma*
Salmonella	*Cryptococcus*	Cytomegalovirus	*Cryptosporidium*
	Candida	Varicella-Zoster	*Leishmania*

a. Many **chemotherapeutic agents** used to treat malignancies are immunosuppressive.
b. Drugs that block allograft rejection (Chapter 17) also inhibit immune responses to microbial pathogens.
c. **Corticosteroids** increase the risk of infection when used at high doses or over long periods of time.
d. **Disease-modifying antirheumatic drugs (DMARDS)** used for treating chronic autoimmune diseases carry a similar risk of increasing infection rates.
e. The use of certain **anticytokine reagents** can inhibit protective immunity to specific pathogens [eg, antitumor necrosis factor (TNF)-α antibodies and tuberculosis].

C. **Cancer** is a common cause of secondary immune deficiencies.
1. Malignancies that grow within the bone suppress hematopoiesis, including lymphopoiesis and granulopoiesis.
2. Lymphoid malignancies (eg, lymphomas) inhibit normal lymphocyte functions in the peripheral lymphoid tissues.
3. Cancer cells often produce excessive quantities of cytokines and growth factors that cause immune imbalance.

D. **Protein-losing enteropathies, extensive burns**, and **nephrotic syndrome** result in protein loss, hypogammaglobulinemia, and hypocomplementemia.

E. **Common variable immune deficiency** is a heterogeneous syndrome that shows early or adult onset.
1. B cell numbers are normal, but plasma cells are infrequent and antibody production is impaired.
2. T cell numbers and subsets are also typically normal, but cellular immunity can be decreased.
3. Bacterial agents constitute the greatest threats of infection, which resemble those seen in XLA.

CLINICAL PROBLEMS

A 4-year-old child is referred with the diagnosis of type 1 LAD. She has a history of recurrent bacterial infections, including pneumonias and skin abscesses. Radiography demonstrates granuloma-like lesions in her lungs and liver. However, the data in the following table suggest this condition has not been properly diagnosed.

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1. Which of the elements in the table is **inconsistent** with a diagnosis of type 1 LAD?

CD Marker	Patient (%)	Normal Range (%)
CD2	76	75–92
CD3	75	60–85
CD4	52	30–65
CD8	26	20–52
CD11a	65	65–85
CD18	73	70–86
CD19	12	7–17
CD45	52	44–62

A. The CD2 value
B. The CD19 value
C. The CD11a value
D. The CD45 value
E. The CD3 value

A 3-month-old child presents with a history of persistent diarrhea and oral thrush beginning at age 3 weeks and has developed signs and symptoms consistent with *Pneumocystis carinii* pneumonia. Both he and his parents are HIV negative based on serological and polymerase chain reaction (PCR) testing. Complete blood counts demonstrate profound lymphopenia.

2. Which of the following blood cell types should show normal numbers if this condition was caused by a Rag deficiency?

A. $CD3^+$ cells with a CD4 coreceptor
B. $CD19^+$ cells
C. Single-positive thymocytes
D. Memory B cells
E. NK cells

An 8-month-old male child has an apparent antibody deficiency. The diagnosis has been narrowed to two possibilities.

3. Measuring which of the following immune parameters would distinguish hyper-IgM syndrome (type 1) from X-linked agammaglobulinemia?

A. IgG levels in the serum
B. $CD19^+$ cells in the blood
C. IL-2 production by the patient's lymphocytes in vitro

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D. NK cell-mediated cytotoxicity in vitro

E. IgA levels in the saliva

A pediatric patient has a history of recurrent infections, and it is hypothesized that she has a defect in the neutrophil-mediated killing of phagocytized bacteria.

4. Which of the following laboratory assays would most directly test this hypothesis?

A. Complement fixation test

B. Quantitative test for serum Igs

C. NBT dye reduction test

D. Flow cytometry for CD18 expression

E. Complete blood count and differential

An adolescent with a history of childhood upper respiratory tract infections and diarrhea continues to have recurring sinusitis, which is attributed to *Pseudomonas aeruginosa*, a gram-negative bacterium. Laboratory tests over the past 5 years have repeatedly indicated that he has normal T cell numbers (based on CD3, CD4, and CD8), normal serum complement levels and activity, and normal serum IgM and IgG levels for his age. Isohemagglutinin titers are normal. Neutrophil numbers and function (chemotaxis, opsonophagocytosis, and respiratory burst) are all normal. His IgG antibody response to tetanus toxoid challenge is also within the normal range. He shows 4+ reactions in delayed hypersensitivity skin tests against several common fungal antigens.

5. What therapy is appropriate for this patient?

A. Antibiotics only

B. Antibiotics and IVIG

C. Antibiotics, IVIG, and stem cell transplantation

D. Stem cell transplantation

E. Antibiotics and IFN-γ

Johnny is an 8-month-old child with recurrent fungal and viral infections. His blood lymphocyte numbers are normal and they bind IL-2 in vitro. It has been determined that his parents are both heterozygous for a mutation in their ZAP-70 genes that can explain Johnny's disease.

6. In addition to antimicrobial agents to treat his infections, what therapy should be considered for Johnny?

A. Thymus transplant

B. IVIG and all of the pediatric vaccines

C. Recombinant IL-2

D. Stem cell transplantation

E. Besides antimicrobial agents, there is no effective therapy for this patient.

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ANSWERS

1. The correct answer is C. The diagnosis of LAD type 1 requires demonstrating that the patient lacks CD18 or any of the α chains that pair with the CD18 β chain (ie, CD11a, CD11b, or CD11c). This patient has normal levels of CD11a, which means she does not have LAD type 1.
2. The correct answer is E. Rag-deficient SCID patients show a $T^{-}B^{-}NK^{+}$ overall lymphocyte phenotype.
3. The correct answer is B. In hyper-IgM syndrome, normal numbers of B cells are present in the periphery. However, they do not receive the normal signaling from Th cells due to a defect in the coreceptor ligand CD154. In XLA the absence of the Btk kinase blocks B cell differentiation at the pre-B cell stage, and the patients have no peripheral $CD19^{+}$ B cells.
4. The correct answer is C. The NBT dye reduction test measures cellular production of oxidants, which are important in the oxygen-dependent killing of microbes by neutrophils (Chapter 1). The other tests could confirm phagocyte dysfunction as well, but would not directly relate to intracellular killing function.
5. The correct answer is A. This patient lacks any clear evidence of an immune deficiency that would explain his recurrent bacterial infections. There is no rationale for stem cell transplantation, and there is no antibody defect that would suggest giving IVIG. Only conventional antibiotic therapy is indicated for the treatment of the infection.
6. The correct answer is D. ZAP-70 deficiency affects TCR-initiated signaling in his T cells. Replacing the defective T cells with normal T cell precursors would theoretically be of value here.

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CHAPTER 16
AUTOTOLERANCE AND AUTOIMMUNITY

I. Tolerance is an acquired condition of specific unresponsiveness to an antigen.

A. **Autotolerance** (unresponsiveness to self antigens) is established within B and T lymphocytes as they encounter self antigens during development.

1. Self tolerance is antigen specific and can be induced either in a primary lymphoid organ or in the periphery.

2. Autotolerance continues to be established throughout life, even after the thymus atrophies.

B. Three mechanisms contribute to the induction of tolerance.

1. **Clonal deletion** results in the apoptosis of specific B and T cell clones.

a. Clonal deletion generally occurs among immature B and T cells through a process called **negative selection** (Chapters 9 and 10).

b. Deletion requires antigen recognition by immature lymphocytes through their B cell receptor (BCR) or T cell receptor (TCR).

2. **Clonal anergy** is a form of unresponsiveness in lymphocytes caused by antigen recognition in the absence of essential stimulatory coreceptor signals.

a. Antigen presentation by antigen-presenting cells (APCs) that lack the B7 ligand for the CD28 coreceptor induces **T cell anergy**.

b. Antigen presentation by cells that engage the inhibitory cytotoxic T lymphocyte-associated protein 4 (CTLA-4) coreceptor can also induce T cell anergy.

3. Tolerance, including autotolerance, can also be mediated by active suppressor cells in the periphery.

a. **Regulatory T cells** (Treg cells) mediate unresponsiveness to specific antigens.

b. Treg cells are induced in both the thymus and the periphery by autoantigens.

c. Suppression is generally mediated by the production of inhibitory cytokines, such as interleukin (IL)-10 and transforming growth factor (TGF)-β.

C. Autotolerance is established at two levels.

1. **Central tolerance** to self antigens is established during the differentiation of B and T cells in the bone marrow and thymus, respectively.

a. Central tolerance results in the deletion of autoreactive clones (negative selection).

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b. Self-specific B cells can be rescued from clonal deletion by undergoing secondary immunoglobulin (Ig) locus rearrangements (BCR editing.)

2. Peripheral tolerance involves all three mechanisms of tolerance induction—deletion, anergy, and suppression.

a. The induction of autotolerance in the periphery continues throughout life.

b. Because quiescent autoreactive B and T cell clones reside in normal individuals, autoimmunity is common.

TRANSPLANTATION TOLERANCE

- *It is not uncommon for transplant recipients to become tolerant to their foreign organ grafts over time, despite significant genetic disparities with the organ donor.*
- *Pretransplantation lymphoablation appears to favor the induction of tolerance, as does the establishment of donor–recipient chimerism when donor bone marrow cells are provided.*
- *The continual exposure of the recipient to the HLA antigens of the donor may also induce active suppressor cells, including Treg cells.*
- *Blocking CD28/B7 and CD40/CD154 costimulatory signaling may be another mechanism for inducing specific unresponsiveness to allografts.*
- *The ultimate goal of inducing transplantation tolerance is to reduce the dependence on powerful immunosuppressive therapies in the posttransplant period.*

II. Autoimmunity results from the loss of self tolerance.

A. The **molecular mimicry theory of autoimmunity** proposes that autoimmunity occurs when microbial antigens cross-react with self antigens.

1. Antibodies to the M protein of *Streptococcus pyogenes* that are induced during infection can react with cardiac autoantigens of the sarcolemma and heart valves and cause **rheumatic fever**.

2. Antibodies to *Treponema pallidum* induced during syphilis can cross-react with human fibronectin and collagen.

3. Antibodies to the insulin receptor are induced during papilloma virus infections.

B. The **costimulatory theory of autoimmunity** proposes that silent autospecific lymphocytes are activated when tissues inappropriately express stimulatory coreceptor ligands.

1. Major histocompatibility complex (MHC) class II molecules are expressed by pancreatic β cells in type 1 diabetes mellitus.

2. Microglial cells of patients with multiple sclerosis express B7.

C. Autoimmunity is induced when cryptic or **sequestered autoantigens** that are normally not seen by the immune system are released to the periphery.

1. Autoimmune uveitis is thought to develop when ocular antigens released from a damaged eye induce immune damage to the contralateral eye.

2. Autoantigens of spermatogonia can be recognized as nonself if they are later released from the testes by vasectomy.

D. Modified self antigens can induce autoimmune responses.

1. Autoimmune hemolytic anemias result when drugs bind to erythrocyte surface proteins.

2. Autoantibodies to the Fc domains of IgG molecules (**rheumatoid factors**) are often produced in **rheumatoid arthritis**.

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VASECTOMY AND AUTOIMMUNE ORCHITIS

CLINICAL CORRELATION

- *Vasectomy is the most common means by which men elect permanent sterilization for the purpose of contraception.*
- *Vasectomy does not halt spermatogenesis, and sperm can become accessible to the immune system following the procedure.*
- *Sperm-agglutinating antibodies develop in over 50% of vasectomized males.*
- *Epididymitis and orchitis mediated by autoantibodies occur at a rate of 5–6%.*

III. Autoimmunity often exists without overt autoimmune disease.

A. The elderly commonly produce low-affinity autoantibodies that do not cause disease.

B. **Witebsky's postulates** establish a set of criteria for designating a disease as autoimmune in nature.

1. Autoantibodies or autoreactive T cells must be demonstrated in the patient.
2. The autoantigen(s) must be identified.
3. Immunizing a laboratory animal with the autoantigen must induce a comparable autoimmune response and autoimmune disease.
4. The disease manifestations must be transferable to a naive recipient with autoantibody or autospecific T cells.

C. Several human diseases appear to satisfy Witebsky's postulates.

1. Myelin-specific T cells of the type found in **multiple sclerosis** can transfer disease to laboratory rats and mice.
2. The lesions found in **myasthenia gravis** can be duplicated in animals by the transfer of patient serum.
3. Harrington's experiments with **idiopathic thrombocytopenia purpura** clearly identify this condition as an autoimmune disease.

WILLIAM HARRINGTON AND IDIOPATHIC THROMBOCYTOPENIA PURPURA

CLINICAL CORRELATION

- *In 1951, a young hematologist named William Harrington was caring for a group of patients with bleeding disorders and low platelet counts.*
- *Dr. Harrington proposed that their thrombocytopenia was immune based.*
- *After injecting himself with the plasma of one of his patients, he developed severe, but transient thrombocytopenia.*
- *Because his megakaryocytes were spared destruction, he eventually recovered.*
- *This experiment firmly established that autoantibodies can cause human disease.*

D. The diagnosis of autoimmune diseases is aided by laboratory tests.

1. Some tests detect **tissue-bound autoantibodies**.
a. Antibodies to glomerular basement membrane antigens in **Goodpasture's disease** show a characteristic linear distribution in the kidney by immunofluorescence.
b. By contrast, the "lumpy-bumpy" appearance of IgG in the glomerulus is typical of immune complex autoimmune diseases (eg, **systemic lupus erythematosus or SLE**).
2. Many laboratory tests are designed to detect **circulating autoantibodies**.
a. **Antinuclear antibodies (ANA)** are detected by immunofluorescence.

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(1) The autoantigens include DNA, histones, and nucleolar proteins.
(2) These antibodies are seen in SLE, Sjögren's syndrome, and scleroderma.

b. **Antineutrophil cytoplasmic antigen (ANCA)** is characteristic of certain forms of autoimmune nephritis and vasculitis (eg, Wegener's granulomatosis).

c. **Rheumatoid factor (RF)** is common to rheumatoid arthritis and a number of other autoimmune diseases.
(1) RF is an autoantibody to the Fc region of IgG.
(2) RF is mostly IgM anti-IgG, but IgG and IgA autoantibodies have also been described.

d. The **Coombs test** detects IgG antibodies on erythrocytes and platelets.
(1) These antibodies can be specific for endogenous or exogenous (ie, haptenic) cell surface antigens.
(2) "Coombs-positive" is synonymous with immune-based when used to describe an anemia.

3. Tests that measure the serum concentrations of **complement** can be used to follow the status of autoimmune diseases.

a. Complement activity is often depressed during acute exacerbations of immune complex autoimmune diseases.

b. Measuring complement levels can be useful for monitoring the success of therapy.

IV. The spectrum of autoimmune diseases ranges from those that are organ specific to those that are essentially systemic in nature.

A. In **organ-specific autoimmune diseases** symptoms reflect the distribution of the target autoantigen(s).

1. Hashimoto's thyroiditis, pernicious anemia, and Addison's disease are examples of organ-specific autoimmune diseases.

2. The organ-specific disease manifestations of these conditions (eg, thyroid dysfunction) are important clues to their diagnosis.

B. **Systemic autoimmune diseases** (ie, the **rheumatological disorders**) typically involve the skin, kidneys, muscles, joints, and blood vessels.

1. Tissue damage is widely distributed.

2. Symptoms can reflect the deposition of soluble immune complexes, which is an important step in disease pathogenesis.

AUTOIMMUNE POLYENDOCRINE SYNDROME

- *Autoimmune polyendocrine syndrome (APS) type 1 is a rare condition caused by a mutation in the gene for the transcription factor autoimmune regulator (AIRE).*
- *Patients present with chronic mucocutaneous candidiasis, hypoparathyroidism, and/or adrenal insufficiency.*
- *AIRE is expressed in thymic epithelial cells and may control induction of self tolerance.*
- *Twenty percent of affected individuals develop type 1 diabetes mellitus.*

C. Tissue damage and symptoms in autoimmune diseases can change with time, because autoantibody responses become increasingly polyspecific.

1. The initial autoantibody is specific for a dominant self epitope.

2. Autoimmunity broadens with time by **epitope spreading** (Figure 16–1).

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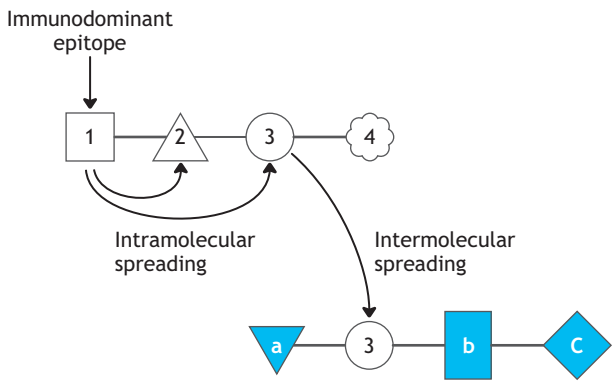

Figure 16–1. Epitope spreading in autoimmunity.

a. B cells specific for the initial epitope elicit new responses by presenting additional epitopes on the same antigen (**intramolecular spreading**).
b. B cells specific for the epitopes of the first autoantigen can cross-react with a second autoantigen (**intermolecular spreading**).

V. One of four pathogenic mechanisms underlies the development of most autoimmune diseases (Table 16–1).

A. **Antireceptor autoantibodies** can cause autoimmune disease.
1. **Myasthenia gravis** is a neurological condition presenting as muscle weakness and fatigue.
a. Manifestations include diplopia, dysphonia, and difficulty swallowing, breathing, and walking.
b. Antagonistic antibodies to the **acetylcholine receptor** block neurotransmission at motor end plates.
2. **Grave's disease** is mediated by agonistic antibodies to the thyroid-stimulating hormone (TSH) receptor.
a. Anti-TSH receptor antibodies are diagnostic.
b. Hyperthyroidism and thyroid hyperplasia are common.
c. Females are affected seven times more often than males.
d. Many patients require thyroid ablation by radiotherapy or surgery.

B. **Cytotoxic immune tissue injury** is the basis for many forms of organ-specific autoimmune disease.
1. **Coombs-positive hemolytic anemias** and thrombocytopenias result from the immune lysis and/or clearance of blood cells.
a. Complement plays a central role in cell destruction.
b. "**Cold reactive antibodies**" are IgM and show high avidity.
(1) They are more commonly found after certain infections (eg, mycoplasma).
(2) They typically induce intravascular hemolysis.
c. "**Warm reactive antibodies**" are IgG and have a lower avidity.

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Table 16–1. Major pathogenic mechanisms underlying autoimmune diseases.

Mechanism of Disease	Examples	Initial Target Autoantigen	Distinguishing Clinical Features
Antireceptor autoantibody	Myasthenia gravis	Acetylcholine receptor	Muscle fatiguability
	Grave's disease	Thyroid-stimulating hormone receptor	Hyperthyroidism; goiter
	Pernicious anemia	Intrinsic factor	Vitamin B_{12} deficiency
	Addison's disease	Adrenal cell antigens	Adrenal insufficiency
Cytotoxic immune injury	Coombs-positive hemolytic anemia	Endogenous erythrocyte antigens or haptens	Intravascular hemolysis, clearance, and anemia
	Crohn's disease	Unknown	Transmural colitis and ileitis, ulceration
	Goodpasture's disease	Basement membrane collagen	Nephritis, pneumonitis
	Pemphigus vulgaris	Desmosome antigens in the skin	Blistering skin lesions, immunoglobulin G staining on epidermal cells
	Rheumatic fever	Cardiac muscle antigens	Heart valve damage
	Sjögren's syndrome	Nucleoproteins Ro and La	Dry eyes and mouth
	Thrombocytopenia purpura	Platelet integrins	Hemorrhagic purpura
Immune complex tissue injury	Drug-induced serum sickness	Drug hapten	Vasculitis, hemorrhage, arthralgia, nephritis
	Rheumatoid arthritis	Unknown	Synovitis, arthritis, cartilage and bone loss
	Systemic lupus erythematosus	Nucleic acids, nucleoproteins	Malar skin rash, arthralgia, anemia, arthritis, nephritis
Cellular immune tissue injury	Diabetes mellitus (type 1)	β cell antigens	Hyperglycemia; pancreatic β cell loss
	Hashimoto's thyroiditis	Thyroglobulin; thyroid peroxidase	Hypothyroidism
	Multiple sclerosis	Myelin proteins	Progressing sensory deficits, fatigue, weakness

(1) These antibodies cause Fc receptor-mediated clearance of erythrocytes.
(2) They are often induced by drugs that bind to cell surface proteins.

2. The **direct Coombs test** detects IgG antibodies on a patient's erythrocytes.
3. The **indirect Coombs test** detects circulating IgG autoantibodies that can react with endogenous erythrocyte antigens (eg, Rh).

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4. **Drug-induced autoimmune hemolytic anemias** are caused by several mechanisms.
   a. Penicillin induces **direct Coombs-positive** anemias.
      (1) The drug binds directly to the erythrocyte surface and induces an antidrug antibody.
      (2) These conditions improve when the drug is discontinued.
   b. Methyldopa induces anemias that are **direct and indirect Coombs positive**.
      (1) This drug induces an antidrug antibody that cross-reacts with an Rh antigen.
      (2) Treatment may require immunosuppression and/or plasmapheresis to remove the autoantibodies.
   c. Other drugs can induce autoantibodies that form immune complexes with the drug.
      (1) The immune complexes can bind to the erythrocyte surface through CR1 (Chapter 8).
      (2) Such conditions are direct and indirect Coombs positive.
      (3) Treatment may require immunosuppression and/or plasmapheresis to remove the immune complexes.
5. **Goodpasture's disease** is mediated by IgG antibodies to basement membrane antigens, which together with neutrophils cause nephritis and pneumonitis.
   a. Autoantibodies in this disease are directed at epitopes of type IV collagen that are found in basement membranes.
   b. Treatment involves antiinflammatory and immunosuppressive drugs and plasmapheresis.
   c. End-stage renal disease may require kidney transplantation.

INFECTIONS AND AUTOIMMUNITY

- *An increased incidence of infection is not always seen in autoimmune diseases.*
- *However, when autoimmunity adversely affects the integrity of an epithelial barrier (eg, Crohn's disease or Sjögren's syndrome) opportunistic infections can occur.*
- *Complement consumption in immune complex autoimmune diseases can also impair host responses to infectious agents.*
- *Immunosuppressive therapies for autoimmunity increase the risks of infection.*
- *Paradoxically, with a decrease in the overall infection rate in developed countries, an increase in the incidence of allergy and autoimmune disease has occurred.*
- *This may reflect the failure of a microbe-poor environment to induce adequate inhibitory immune responses (eg, Treg cells) that prevent allergy and autoimmunity.*

C. **Immune complex-mediated diseases** share certain clinical features.
1. **Drug-induced serum sickness** results when antibodies to drugs (eg, penicillin) form soluble immune complexes with their antigens.
   a. These complexes deposit in the skin, blood vessel walls, joints, and kidneys, activate complement, and recruit inflammatory cells.
   b. Vasculitis, hemorrhage, arthralgia, skin rashes, and nephritis are among the principal clinical findings.
2. **SLE** is one of the most common autoimmune disease in women 20–40 years of age, especially African-Americans (Table 16–2).

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Table 16–2. Epidemiology of autoimmune diseases.

Disease	HLA Associations	Female to Male Ratios	Approximate Incidence (per 100,000)
Myasthenia gravis	A1, B8, DR4		3
Grave's disease		7	100–300
Addison's disease	DR3, DR4		4
Sjögren's syndrome	B8, DRw52, DR3	9	<600
Crohn's disease	DR1 with DQw5		200
Pemphigus	DR4, DRw6		3
SLE[a]	DR2, DR3	5	50
Diabetes mellitus (type 1)	DR4 or DR1 with DQ1	<1	250
Rheumatoid arthritis	DR4, DR1	3	1000–3000
Hashimoto's thyroiditis	DR3, DR4, DR5	10	500

[a]SLE, systemic lupus erythematosus.

a. The condition is characterized by fever, arthralgia, nonerosive arthritis, myalgia, photosensitivity, skin rashes, anemia, and glomerulonephritis.

b. The autoantibodies produced in patients with SLE become increasingly polyspecific with epitope spreading.

(1) Antibodies to **double-stranded DNA** are diagnostic.

(2) Additional autoantibodies are produced against nuclear antigens (histones, ribonuclear proteins) and erythrocyte surface antigens.

c. Immunofluorescence staining for immune complexes or C3b in the kidney shows a "lumpy-bumpy" pattern.

d. Therapy for this condition is directed at reducing pain, inflammation, and autoantibody production (Table 16–3).

3. Rheumatoid arthritis is the most common autoimmune disease in the United States today.

a. Patients usually first present with morning stiffness and joint pain.

b. Synovitis results from the infiltration of lymphocytes and macrophages and synovial growth in the form of a **pannus**.

c. Th1 cells infiltrate the joint and contribute to macrophage and osteoclast activation.

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Table 16–3. Therapies used to treat autoimmune diseases.[a]

Treatment	Intent	Diseases
Plasmapheresis	Reduce circulating autoantibodies and immune complexes	Grave's disease, hemolytic anemias, SLE
NSAIDs	Reduce pain and inflammation	Rheumatic diseases in general
Corticosteroids	Antiinflammatory effects	RA, SLE
Cytotoxic drugs (azathioprine)	Inhibit lymphocyte activation and proliferation	SLE
Anticytokine reagents	Block proinflammatory cytokine effects	Crohn's disease (TNF-α), RA, (IL-1β or TNF-α)
Corrective surgery	Removal or replacement of damaged tissues	Crohn's disease, Hashimoto's thyroiditis, RA
Transfusion and transplantation	Organ or tissue replacement	Hemolytic anemias, type I diabetes mellitus

[a]SLE, systemic lupus erythematosus; NSAIDs, nonsteroidal antiinflammatory drugs; RA, rheumatoid arthritis; TNF, tumor necrosis factor; IL, interleukin.

d. Macrophages activate matrix metalloproteases and osteoclasts, which leads to cartilage and bone erosion.
e. Immune complexes, including rheumatoid factor, are present in the joint spaces.
f. Therapy includes immunosuppression, synovectomy, and joint replacement (Table 16–3).

D. Cell-mediated autoimmune diseases do not require autoantibodies.

1. Multiple sclerosis is a neurodegenerative condition resulting from central nervous system (CNS) demyelination by activated macrophages.
a. Inflammation is initiated by $CD4^+$ T cells specific for myelin autoantigens (myelin basic protein, myelin oligodendrocyte glycoprotein).
b. Th1 cytokines recruit and activate T cells and macrophages.
c. MHC class II and the B7 coreceptor ligand are induced on astrocytes and microglia.

2. Type 1 (immune-mediated) diabetes mellitus involves the destruction of pancreatic islet β cells and hyperglycemia.
a. Target autoantigens include the insulin receptor, β cell granule proteins, and insulin.
b. Increased HLA-DR expression on β cells is common.

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c. $CD4^+$ Th1 cells, $CD8^+$ T cells, and macrophages infiltrate the islets and induce β cell apoptosis.
d. Insulin replacement by injection, pancreas transplantation, or islet cell transplantation is the preferred therapy.

3. **Sjögren's syndrome** is a disease involving T cell-mediated damage to lacrimal and salivary glands that leads to dry eyes and dry mouth (sicca symptoms).

CLINICAL PROBLEMS

A patient recently diagnosed with SLE is experiencing significant symptoms of 3 weeks duration that include edema and skin rash. Her serum blood urea nitrogen (BUN) and creatinine levels are increased, and a biopsy of her kidney shows IgG and C3b at the glomerular basement membrane. Her serum complement levels are monitored over time.

1. Which of the following findings would be most consistent with a worsening clinical course?
   A. A decline in C9 levels
   B. A decline in C3 and C4 levels
   C. An increase in Factor P levels
   D. An increase in C1 inhibitor (C1 Inh) levels
   E. A decline in C7 levels

2. Of the following laboratory test findings, which would have been most useful in making the initial diagnosis of this disease?
   A. A positive ANA
   B. A positive cross-match
   C. Bence–Jones urinary proteins
   D. A positive mixed lymphocyte reaction
   E. Antibodies to myelin basic protein

Helen's physician has prescribed methyldopa for the treatment of her hypertension. She visits the outpatient medicine clinic several months later complaining of fatigue and has a noticeable pale color in the palms of her hands. Her hemoglobin is 9.5 g/dL (normal range = 13–15 g/dL).

3. What laboratory test should be ordered to determine if her anemia is due to an antibody?
   A. HLA typing
   B. Antithyroglobulin
   C. Coombs test
   D. ANA
   E. Major cross-match

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Bill is a 30-year-old man who presents with lower right quadrant abdominal pain, a 10-pound weight loss over the past month, fever, and nonbloody diarrhea. Barium enema contrast imaging indicates mucosal swelling of the wall of the ileum and ascending colon. A biopsy of the colon shows the presence of transmural granulomatous inflammation. Laboratory tests indicate mild anemia, leukocytosis, and decreased total serum protein and albumin, which suggest anorexia.

4. Which of the following therapies would be expected to be most beneficial in treating this condition?

A. Plasmapheresis

B. Anti-tumor necrosis factor (TNF)-α

C. Recombinant C1 Inh

D. Appendectomy

E. Antifungal agents

A 72-year-old man complains of bilateral swelling and pain in the joints of his hands and feet. Several of his proximal phalangeal joints are noticeably deformed. A radiograph of the right hand shows a narrowing of the joint spaces in three digits.

5. Which of the following additional findings would support a diagnosis of rheumatoid arthritis?

A. A decreased erythrocyte sedimentation rate

B. Serum antibodies to double-stranded DNA

C. Antibodies to IgG in the serum

D. A positive response to antibiotics

E. Autoantibody to the TSH receptor

ANSWERS

1. The correct answer is B. Acute episodes in lupus are accompanied by complement depletion by activation of the classical pathway. This leads to a decline in the serum levels of C1, C2, C3, and C4.

2. The correct answer is A. Over 95% of lupus patients have antinuclear antibodies. The other choices do not fit a diagnostic approach to autoimmunity, except choice E. Antibodies to myelin are typical of multiple sclerosis, but not SLE.

3. The correct answer is C. The most appropriate test for establishing an immune basis for an anemia is the Coombs test, which detects IgG antibodies on erythrocytes. This patient's fatigue is most likely related to her low erythrocyte mass.

4. The correct answer is B. This case fits the classic signs and symptoms of Crohn's disease and the imaging and laboratory data support this diagnosis. Chronic inflammation is maintained by the activation of a Th1 type of cytokine production, including IL-12,

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interferon (IFN)-γ, and TNF-α. Anti-TNF-α has proven effective in treating Crohn's disease in many patients.

5. The correct answer is C. Although not diagnostic of this condition, the presence of rheumatoid factor certainly distinguishes rheumatoid arthritis from several other forms of arthritis. Lupus patients can develop arthritis, but the condition of not erosive in nature. *Increased* sedimentation rates are common in acute disease.

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CHAPTER 17
TRANSPLANTATION

I. The principles of transplantation predict the survival of transplanted tissues.

A. Tissue or organs transplanted within an individual are accepted.
- **1.** Such grafts are called **autografts**.
- **2.** Examples of autografts include skin transplants to treat local burns and cosmetic hair follicle transplantation to treat hair loss.

B. Grafts exchanged between genetically identical individuals are accepted.
- **1.** These grafts are called **isografts**.
- **2.** The donor and recipient are **isogeneic** or **syngeneic** to one another.

C. Grafts between genetically dissimilar individuals are rejected.
- **1.** The donor and recipient are **allogeneic** to one another.
- **2.** The grafts are referred to as **allografts**.

D. Grafts exchanged between species are normally rejected.
- **1.** The donor and recipient are **xenogeneic**.
- **2.** The grafts are called **xenografts**.

E. Foreign **histocompatibility antigens** initiate graft rejection.
- **1. Major histocompatibility complex (MHC) alloantigens** (ie, human HLA) are the strongest stimuli for inducing allograft rejection.
- **2. Minor histocompatibility antigens** and **tissue-specific antigens** can mediate graft rejection.
  - **a.** Vascular endothelial cells express ABO antigens that can stimulate hyperacute rejection.
  - **b.** Endothelium-specific antigens can trigger graft rejection.
- **3. MHC alloantigens** are recognized directly by large numbers of cross-reacting $CD4^+$ and $CD8^+$ T cells (Figure 17–1).
  - **a.** Most T cell receptors (TCRs) cross-react with allogeneic forms of MHC.
  - **b.** Up to 15% of all peripheral T cells can be activated by a single MHC alloantigen.
- **4.** Multiple MHC incompatibilities lead to more vigorous graft rejection than does a disparity at a single locus (Figure 17–2).
- **5.** Disparities at MHC class I + MHC class II loci induce greater responses than does either a class I or a class II difference alone.
- **6.** Prior immunization can increase the pace of allograft rejection.

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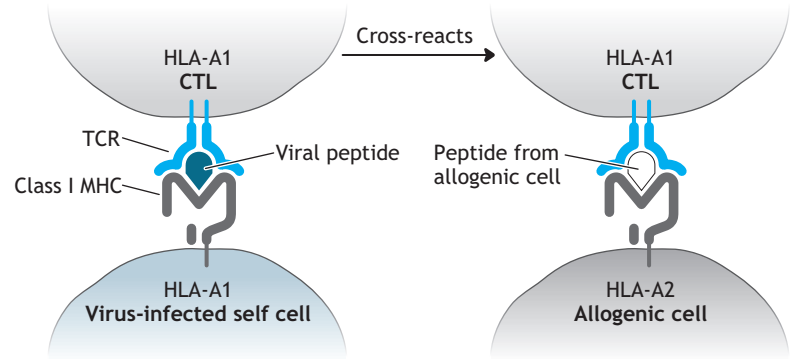

Figure 17–1. Recognition of an allogeneic major histocompatibility complex (MHC) molecule by T cells. CTL, cytotoxic T lymphocyte; TCR, T cell receptor.

a. **"First set" rejection** occurs within days because the number of T cells activated by a foreign graft is large.

b. Repeated exposure to the same MHC alloantigens (eg, through blood transfusions) can cause even more rapid rejection **("second set" rejection)**.

F. The fate of allografts varies somewhat depending on the nature of the tissue or organ transplanted (Table 17–1).

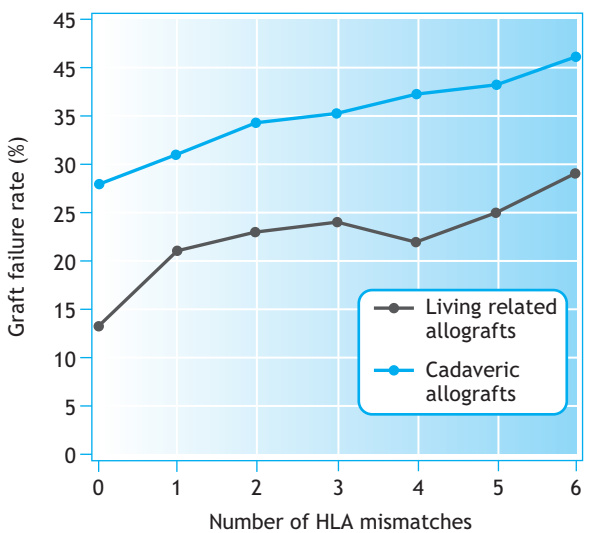

Figure 17–2. Influence of HLA on 5-year allograft failure rates.

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Table 17–1. Special considerations related to particular forms of transplantation.

Organ or Tissue Transplanted	Considerations
Kidney	95% overall success rate after 1 year when living related kidneys are used; diabetes is the most frequent cause of end-stage renal failure
Heart	Reserved for imminently life-threatening cardiac disease; often combined with lung transplantation; relaxed criteria for donor selection due to organ shortage and effectiveness of cyclosporin
Lung	Low success rate compared to other solid organs
Blood	Transfusions are typically tolerated despite HLA disparity; preformed anti-HLA antibodies can cause transfusion reactions
Liver	Less requirement for HLA typing; evidence that tolerance to allogeneic transplants develops with time; contraindicated in certain malignancies, viral hepatitis, and human immunodeficiency virus (HIV) infection
Pancreas	Prevention of secondary effects of diabetes; whole organ, segmental, or isolated islet cell transplantation possible
Hematopoietic stem cells	Concern for graft-versus-host disease and infections; graft-versus-tumor effect beneficial
Cornea	Benefits from the privileged status of the anterior chamber

CORNEAL TRANSPLANTS

- *Approximately 40,000 corneal transplants are performed in the United States each year.*
- *The donors are not routinely matched with recipients for HLA, and recipients do not receive systemic immunosuppression following transplantation.*
- *The immunologically privileged status of the anterior chamber of the eye results in a low level of graft rejection (~10%).*
- *Immune privilege is maintained by a lack of lymphatic drainage and the expression of* ***Fas ligand*** *(Chapter 6) on corneal endothelial and epithelial cells.*
- *Invading activated T cells expressing Fas are killed by binding to ocular Fas ligand.*
- *When they occur, rejection episodes can be treated with topical corticosteroids.*

II. Allograft rejection involves a diverse set of immune mediators (Figure 17–3).

A. **$CD4^+$** Th1 cells activate various effector cells by secreting cytokines.

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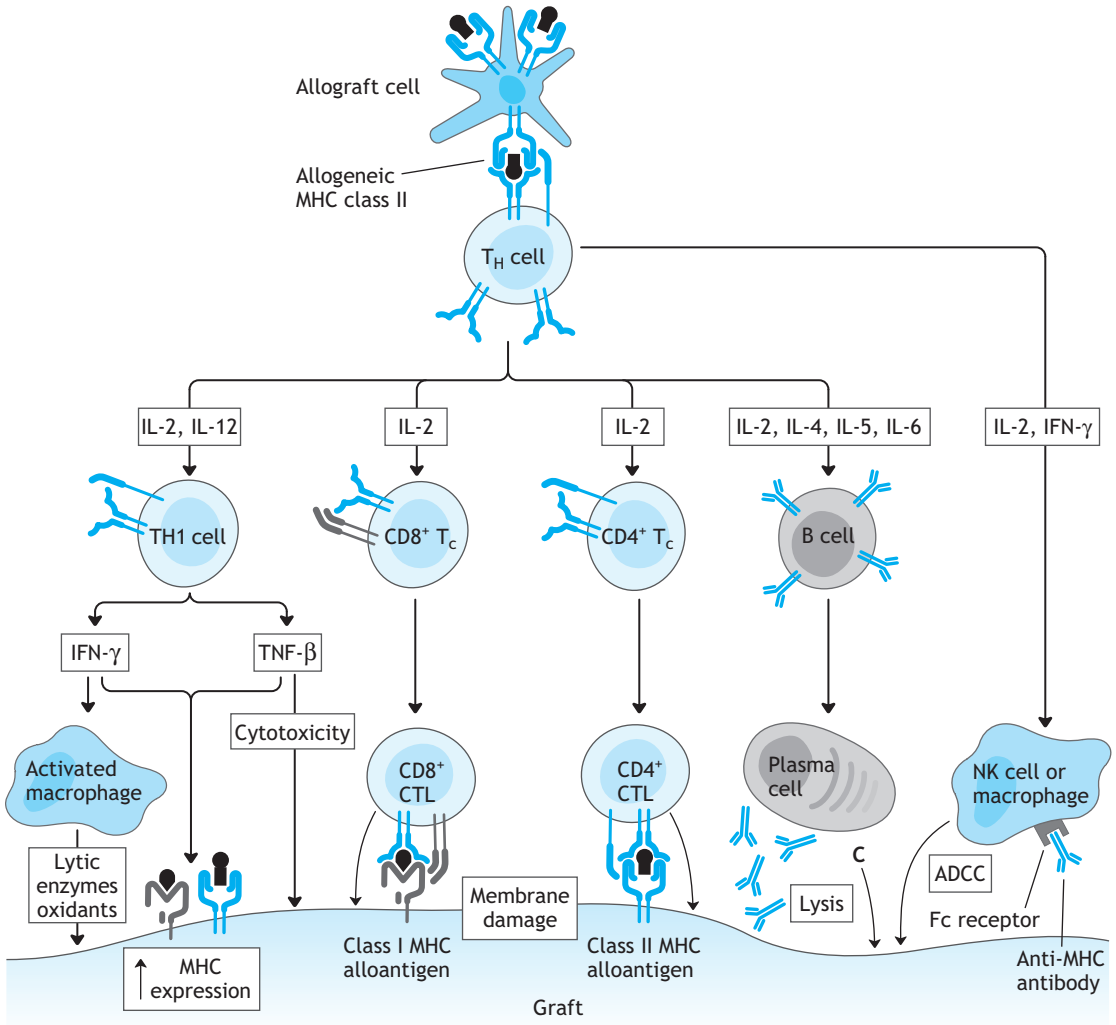

Figure 17–3. Mediators of allograft rejection. MHC, major histocompatibility complex; T_H, T helper; IL, interleukin; T_C, cytotoxic T cell; IFN, interferon; TNF, tumor necrosis factor; NK, natural killer; ADCC, antibody-dependent cell-mediated cytotoxicity.

1. Th1 cells recognize **allogeneic HLA-DP, DQ, and DR** molecules.
2. The Th1 cell subset produces interleukin (IL)-2, interferon (IFN)-γ, and tumor necrosis factor (TNF)-α, which activate cytotoxic T cells, natural killer (NK) cells, and macrophages.

B. **$CD4^+$ Th2 cells** are activated by allogeneic MHC class II molecules.

1. The Th2 cytokines IL-4 and IL-5 induce growth, class switching, and antibody production by B cells.

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2. **Antibodies** specific for allogeneic donor MHC molecules can mediate **hyperacute rejection** (see below).
3. Immunoglobulin (Ig) G alloantibodies can promote **antibody-dependent cellular cytotoxicity (ADCC)** by NK cells and macrophages.

C. **Cytokines** that mediate allograft rejection are also produced by NK cells (IFN-γ), $CD8^+$ T cells (IFN-γ), and macrophages (TNF-α).

D. **$CD8^+$ cytotoxic T cells** recognize allogeneic MHC class I molecules.
1. Killing is mediated by the perforin–granzyme, Fas–Fas ligand, and TNF receptor pathways (Chapter 10).
2. Rejection is due to apoptotic cell death in the transplanted tissues.

E. **Macrophages** kill donor cells with oxidants, hydrolytic enzymes, and TNF-α.

F. **NK cells** kill by recognizing the absence of self MHC class I molecules.

III. Three mechanisms of allograft rejection exist.

A. **Hyperacute allograft rejection** occurs within minutes to hours and is mediated by preformed antibodies in the recipient.
1. The principal target antigens include allogeneic HLA and ABO, both of which are expressed on the donor's vascular endothelial cells.
2. Anti-HLA antibodies are produced in response to pregnancy, blood transfusions, or prior transplants.
3. These IgM and IgG antibodies activate complement through the classical pathway.
   a. C5a attracts neutrophils to the allograft.
   b. iC3b promotes neutrophil attachment and activation.
   c. C3a, C4a, and C5a activate mast cells, which increases the inflammatory response within the graft.
4. Activated neutrophils, monocytes, and NK cells damage the endothelium.
5. Activation and damage to the vascular endothelium cause important hemodynamic changes in the allograft.
   a. Tissue factor is expressed by endothelial cells and initiates thrombosis.
   b. Endothelial cell damage promotes platelet activation, thrombosis, infarction, edema, and hemorrhage.

B. **Acute allograft rejection** occurs over weeks to months and is mediated by $CD4^+$ Th1 cells, $CD8^+$ cytotoxic T cells, NK cells, and macrophages that infiltrate the graft.

C. **Chronic allograft rejection** occurs over months to years.
1. **Fibrosis, infarction, and ischemia** are common features.
2. Chronic rejection is difficult to control by immunosuppression.

IV. Graft rejection can be predicted or prevented by matching the donor and recipient histocompatibility antigens (Table 17–2).

A. **Tissue typing** determines the tissue antigens expressed by prospective donors and recipients and any preformed immunity to those antigens.
1. **ABO matching** is essential for preventing endothelial damage by isohemagglutinins.
2. Preformed antibodies to ABO are detected with the **major cross-match** (incubating donor cells in recipient serum).

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Table 17–2. Prospective HLA typing for the transplantation of solid organ allografts.

	Mediator of Rejection		
	$CD4^+$ Th Cells	$CD8^+$ Cytotoxic T Cells	Antibodies
HLA antigens recognized	HLA-DP, DQ, DR	HLA-A, B, C	ABO; HLA-A, B, C, DP, DQ, DR
Important typing procedures	Type and match HLA-DP, DQ, DR Perform mixed lymphocyte reaction (MLR)	Type and match HLA-A, B, C	Major cross-match to detect anti-ABO and anti-HLA

TRANSPLANTATION ACROSS ABO INCOMPATIBILITIES

- *Conventional wisdom advises against transplanting organs when an ABO incompatibility exists between the donor and recipient.*
- *This restriction has limited the number of cardiac transplants, especially those involving infants with congenital heart defects.*
- *Recently, it was discovered that ABO incompatibility need not prevent the transplantation of HLA-matched hearts into very young children.*
- *The isohemagglutinins that mediate hyperacute rejection develop slowly over time in the neonate.*
- *The antigenic stimulus for inducing isohemagglutinins appears to be the cross-reacting polysaccharides of microbial flora.*
- *The delayed appearance of these natural antibodies reflects a gradual acquisition of commensal organisms during the initial months of postnatal life.*

3. **HLA typing** is performed by molecular techniques [eg, polymerase chain reaction (PCR)].
   - **a.** The best donor–recipient pair is selected based on similarities between their HLA genotypes.
   - **b.** HLA typing and matching can minimize acute rejection.
   - **c.** Extensive matching of HLA types is not as important in liver transplants as in kidney transplants (Table 17–1).
   - **d.** The shortage of heart allografts and the effectiveness of cyclosporine in cardiac transplantation obviate the need for extensive HLA typing.
   - **e.** HLA typing is important for identifying haplotype segregation within a family (Figure 7–7).
   - **f.** Transplantation using organs from deceased donors may not afford an opportunity for detailed tissue typing.
   - **g.** High-resolution typing of HLA-D region antigens is important in stem cell transplantation to avoid graft-versus-host disease (GVHD).
4. Preformed anti-HLA antibodies are detected with a **major cross-match**.

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a. Such antibodies can be formed against either class I or class II alloantigens.
b. The major cross-match can prevent hyperacute rejection.

5. The **mixed lymphocyte reaction (MLR)** detects T cell-mediated reactivity between donor and recipient (Figure 17–4).
a. The assay measures the recognition of allogeneic MHC by coculturing the lymphocytes from two individuals.
b. The MLR also predicts the potential for **GVHD** following stem cell transplantation.

TRANSPLANTATION WAITING LISTS

- *Recent national data (www.ustransplant.org) indicate that over 80,000 patients in the United States are waiting for organ transplants, a number that has doubled in less than 10 years.*
- *Nearly 60,000 patients await kidney transplantation, while only 15,000 renal transplants are performed each year.*
- *Two-thirds of prospective kidney transplant recipients spend over a year on the waiting list.*
- *The median time until transplantation is over 3 years.*

V. Xenotransplantation has the potential to address the shortage of available donor organs and tissues.

A. The species providing a xenotransplant to a human patient is determined by organ physiology as well as social and ethical concerns.
1. Kidneys from minipigs are suitable for transplantation into humans, based on anatomical and physiological considerations.
2. Pigs are also suitable for genetic manipulation (see the Clinical Correlation on transgenic pigs in Chapter 8).

B. Xenotransplantation carries the risk of transmitting **zoonotic infections**.
1. Retroviruses similar to human immunodeficiency virus type 1 (HIV-1) are a particular concern.

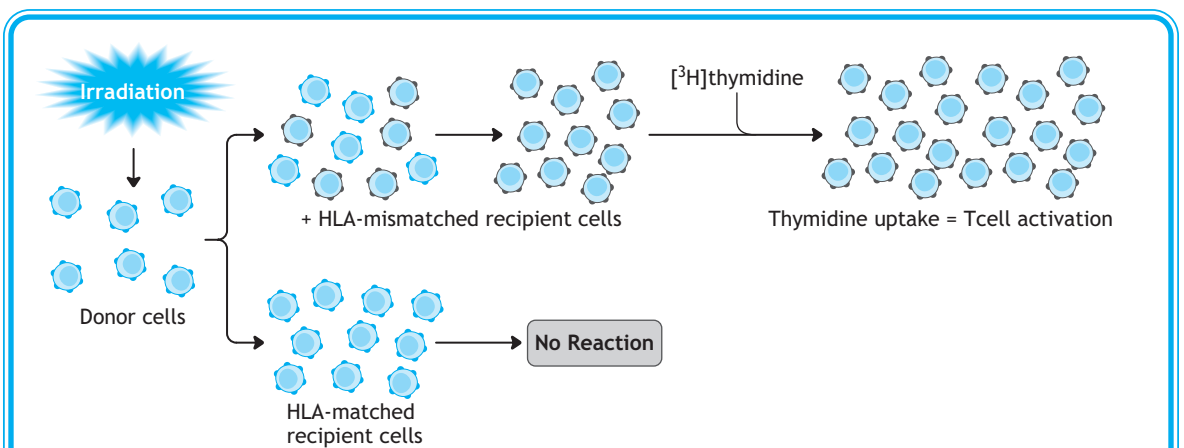

Figure 17–4. Mixed lymphocyte reaction. *Blood mononuclear cells.

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2. Immunosuppressed transplant recipients are at increased risk for such infections.

C. The primary immunological barrier to xenotransplantation appears to be **hyperacute rejection**.
1. Natural IgM antibodies against widely distributed ABO-like carbohydrate xenoantigens are present in nearly all species.
2. These antibodies activate complement and initiate neutrophil-mediated damage to vascular endothelial cells.
3. Because the membrane complement regulatory proteins [eg, decay-accelerating factor (DAF)] of the pig do not inhibit the human C3 convertases, uncontrolled complement-mediated damage also occurs.

D. T cells that recognize the MHC molecules of the xenogeneic species are also activated and mediate strong rejection responses.

VI. Hematopoietic stem cell (HSC) transplantation provides a therapy for hematopoietic disorders, immune deficiencies, and cancer (Table 17–3).

A. HSCs bear the **CD34** marker and can be purified from bone marrow cells.
1. HSCs can also be purified from peripheral blood after mobilization in the donor by injection of **colony-stimulating factor-granulocyte (CSF-G)**.
2. For the treatment of malignant conditions, autologous HSCs can be collected during remission and transplanted at a later time.

B. Several potential outcomes of stem cell transplantation must be balanced.
1. **Rejection** of an HSC transplant can be minimized by tissue typing.
2. **GVHD** represents a significant risk in HSC transplantation beginning at the first month posttransplantation.
   a. Acute GVHD presents as a sunburn-like rash, hepatosplenomegaly, jaundice, elevated billirubin, and diarrhea.
   b. GVHD occurs when the recipient expresses HLA antigens not present on the donor.

Table 17–3. Diseases treated by hematopoietic stem cell transplantation.

Defects in Hematopoiesis	Immune Deficiencies	Malignancies
Sickle cell disease	Severe combined immune deficiency	Acute myeloid leukemia
Thalassemia	Wiscott–Aldrich syndrome	Acute lymphoblastic leukemia
Aplastic anemia	Leukocyte adhesion defect	Chronic myelogenous leukemia
Pure red cell aplasia	Chediak–Higashi syndrome Hyper-IgM syndrome	Multiple myeloma

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c. GVHD requires donor T cells capable of responding to allogeneic HLA of the recipient.
d. GVHD is most evident when the recipient is immunosuppressed or genetically incapable of rejecting donor T cells.
e. GVHD can be anticipated by tissue typing in the direction of donor anti-host.

3. Despite the negative effects of GVHD, donor T cells can also have a beneficial **graft-versus-tumor effect** in malignant diseases.
4. The use of preconditioning regimens (eg, chemotherapy prior to transplantation) and powerful immunosuppressive drugs increases the risks of **opportunistic infections**.
   a. Depending on the degree of myeloablation, early infections can be severe and can be caused by viruses, fungi, and bacteria.
   b. Common pathogens include cytomegalovirus, herpes simplex virus, *Candida albicans,* and *Aspergillus* species.
   c. Neutrophil functions are generally restored first.
   d. Prophylactic therapies include antimicrobial agents, laminar flow rooms, intravenous immunoglobulin (IVIG), and pediatric vaccines after lymphocyte reconstitution.

VII. Posttransplantation immunosuppressive therapy primarily targets lymphocyte activation, growth, and differentiation and inhibits inflammation (Table 17–4).

Table 17–4. Immunosuppressive drugs used in transplantation.[a]

Agents	Targets	Clinical Use
Irradiation	Many cells	Conditioning for stem cell transplantation
Methotrexate, azathioprine	Many cells	Organ transplantation, autoimmunity
Mycofenolate mofetil	Lymphocytes	Organ transplantation
Cyclosporine A (CsA), tacrolimus (FK506), sirolimus (rapamycin)	Lymphocytes	Organ transplantation
Corticosteroids	Many cells	Inflammatory diseases, organ transplantation
OKT3	T cells	Organ transplantation
ALG, ATG, daclizumab	Lymphocytes	Organ transplantation

[a]ALG, antilymphocytic globulin; ATG, antithymocyte globulin.

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A. **Cyclosporine** and related drugs block calcineurin-dependent activation of nuclear factor of activated T cells (NFAT) in T cells and inhibit cytokine (eg, IL-2) production (Chapter 6).

B. Azathioprine and methotrexate are cytotoxic to lymphocytes.
1. **Azathioprine** inhibits DNA synthesis.
2. **Methotrexate** is a folate antagonist.
3. The drugs are also used to treat autoimmune diseases (Chapter 16).

C. Antibodies against lymphocytes or their receptors block signaling and cause lymphocyte death.
1. **OKT3** is an antibody to CD3 used in pancreas transplantation.
2. **Antilymphocyte globulin** and **antithymocyte globulin** deplete T cells.
3. **Daclizumab** is an antibody against the IL-2 receptor (CD25), which inhibits lymphocyte proliferation.

D. **Corticosteroids** inhibit inflammation (eg, neutrophil and macrophage activation) associated with graft destruction.

E. **Mycophenolate mofetil** inhibits purine metabolism and blocks lymphocyte proliferation.

F. All of these drugs are essentially nonspecific in the sense that they inhibit protective immune responses while suppressing graft rejection.

CLINICAL PROBLEMS

Mary is a 52-year-old woman with end-stage renal disease secondary to diabetes. She received an allogeneic renal transplant 2 months ago and has progressed to a maintenance dose of immunosuppressive therapy. However, within the last week she has been experiencing a progressive decline in renal function [decreased urine output, elevated blood urea nitrogen (BUN) and creatine] and currently has a temperature of 39°C. Her kidney is now tender, painful, and swollen. A renal biopsy shows a dense interstitial mononuclear infiltration.

1. Which of the following is most likely responsible for the change in her clinical course over the past week?

A. An opportunistic viral infection

B. Renal toxicity due to her immunosuppressive drugs

C. Graft-versus-host disease

D. Acute allograft rejection

E. Diabetic nephropathy

Two months after having received an allogeneic stem cell transplant for the treatment of acute lymphoblastic leukemia, a patient presented with diarrhea and a blistering, erythematous appearance to the skin of his anterior neck and back. Serum chemistry revealed elevated liver enzymes and billirubin, and the liver and spleen appeared enlarged on physical examination.

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2. Which of the following diseases or pathogenic mechanisms is most likely causing this clinical picture?

A. Rejection of the transplant
B. Autoantibody production against the patient's lymphocytes
C. Deposition of immune complexes in the skin and liver
D. A reaction to his immunosuppressive drugs
E. Graft-versus-host disease

As a treatment for end-stage renal disease, xenotransplantation involves unique clinical challenges not seen in allotransplantation.

3. Which of the following mechanisms is more common in the rejection of renal *xeno*grafts than renal allografts?

A. Production of IgE antibodies
B. Activation of HLA class I-restricted $CD4^+$ T cells
C. Binding of anti-HLA antibodies to donor tissues
D. Activation of complement by natural antibodies
E. Attraction of eosinophils into the graft

The HLA phenotypes of a family, including a patient who requires a kidney transplant, are listed below.

Family Member	HLA-A Alleles	HLA-B Alleles	HLA-DR Alleles
Mother	1,7	8,12	4,5
Father	5,7	28,32	4,6
Daughter #1	1,7	8,32	5,6
Daughter #2	1,7	8,28	4,4
Son #1	1,5	12,28	4,5
Son #2	1,7	12,32	5,6
Patient	**1,5**	**8,28**	**4,4**

4. All other considerations being equal, which of the family members is best suited as the transplant donor?

A. Daughter #1
B. Daughter #2
C. Mother
D. Son #1
E. Son #2

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5. Which of the donors above would be most appropriate to donate *stem cells* to the patient if that were the indicated therapy?
   A. Daughter #1
   B. Daughter #2
   C. Mother
   D. Son #1
   E. Son #2

ANSWERS

1. The correct answer is D. This is a typical description of acute renal allograft rejection. The histopathology confirms rejection, but does not fit a virus infection or diabetic nephropathy (hyaline thickening of the glomerular capillaries).
2. The correct answer is E. GVHD is common in allogeneic stem cell transplantation and involves the liver, spleen, gastrointestinal tract, and skin.
3. The correct answer is D. Although allografts can also undergo hyperacute rejection initiated by isohemagglutinins, this rarely occurs due to the now routine use of the major cross-match. Hyperacute rejection is currently the major initial barrier to successful xenografting.
4. The correct answer is B. Daughter #2 has only a single disparity at one MHC class I locus. Particularly important in selecting a donor–recipient pair is avoiding disparities at both class I and class II loci.
5. The correct answer is B. The most important consideration in selecting a stem cell donor is avoiding GVHD, which is primarily induced by donor cells that recognize HLA-D region alloantigens of the recipient. The second consideration in selecting a donor for stem cell transplantation is the survival of the graft, which is dictated by the same rules that govern solid organ transplantation.

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Appendix I. CD markers and their functions.[a]

CD Marker	Principal Functions
CD1	Presentation of glycolipids to NKT cells
CD3	Signaling chains of the TCR
CD4	Coreceptor for MHC class II-restricted T cells
CD8	Coreceptor for MHC class I-restricted T cells
CD11	α chain of the β_2 integrin family
CD14	Nonsignaling component of the LPS receptor
CD18	β chain of the β_2 integrin family
CD19	Signal transducer on B cells
CD20	Chain of the CR2 coreceptor
CD21	Chain of the CR2 coreceptor
CD25	α chain of the IL-2 receptor
CD28	Coreceptor on T cells that binds B7
CD34	Marker on hematopoietic stem cells
CD40	Coreceptor on B cells
CD45	Tyrosine phosphatase of T and B cells
CD55	Membrane decay accelerating factor
CD59	Membrane regulator of MAC assembly
CD80	B7-1 coreceptor on APCs
CD154	Ligand on T cells for CD40

[a]NKT, natural killer T; TCR, T cell receptor; MHC, major histocompatibility complex; LPS, lipopolysaccharide; IL, interleukin; MAC, membrane attack complex; APC, antigen-presenting cell.

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Appendix II. Cytokines.[a]

Cytokine	Principal Functions
IL-1 α, β	Similar to TNF-α; fever, leukocyte adhesion, lymphocyte costimulation
IL-2	T, B, and NK cell proliferation
IL-3	Proliferation of progenitor cells; growth factor for mast cells
IL-4	Differentiation of Th2 cells and B cells; Ig class switching to IgE.
IL-5	Differentiation of B cells and eosinophils; Ig class switching to IgA
IL-6	Hematopoiesis, acute phase response
IL-7	Progenitor B and T cell growth
IL-8	Chemotaxis of neutrophils
IL-10	Inhibits the Th1 pathway
IL-12	Coactivator of the Th1 pathway; induces IFN-γ production
IL-13	Ig class switching to IgE
IL-15	NK cell growth
IL-18	Coactivator for IFN-γ production
TGF-β	Antiinflammatory; promotes wound healing; chemotaxis; Ig class switching to IgA
TNF-α	Proinflammatory; neutrophil and endothelial cell activation; proapoptotic
IFN-α,β	Inhibits viral replication; primes macrophages
IFN-γ	Macrophage activation; inhibition of Th2 pathway
CSF-M	Growth and differentiation of monocyte/macrophage lineage
CSF-G	Growth and differentiation of granulocytes
CSF-GM	Growth and differentiation of myeloid lineage cells

[a]IL, interleukin; TNF, tumor necrosis factor; NK, natural killer; Ig, immunoglobulin; IFN, interferon; TGF, transforming growth factor; CSF, colony-stimulating factor; M, macrophage; G, granulocyte. See also Table 12-3 for a list of important chemokines.

Abiogenesis

Abiogenesis, or informally the **origin of life**,[3][4][5][note 1] is the natural process by which life arises from non-living matter, such as simple organic compounds.[6][4][7][8] While the details of this process are still unknown, the prevailing scientific hypothesis is that the transition from non-living to living entities was not a single event, but a gradual process of increasing complexity that involved molecular self-replication, self-assembly, autocatalysis, and the emergence of cell membranes.[9][10][11] Although the occurrence of abiogenesis is uncontroversial among scientists, there is no single, generally accepted model for the origin of life, and this article presents several principles and hypotheses for *how* abiogenesis could have occurred.

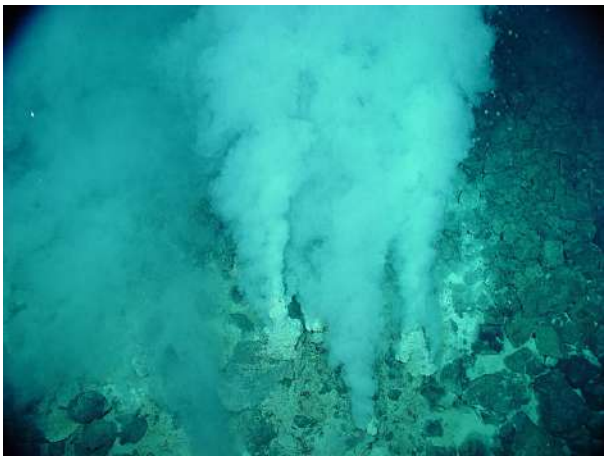

The earliest known life-forms on Earth are putative fossilized microorganisms, found in hydrothermal vent precipitates, that may have lived as early as 4.28 billion years ago, relatively soon after the oceans formed 4.41 billion years ago, and not long after the formation of the Earth 4.54 billion years ago.[1][2]

Researchers study abiogenesis through a combination of molecular biology, paleontology, astrobiology, oceanography, biophysics, geochemistry and biochemistry, and aim to determine how pre-life chemical reactions gave rise to life.[12] The study of abiogenesis can be geophysical, chemical, or biological,[13] with more recent approaches attempting a synthesis of all three,[14] as life arose under conditions that are strikingly different from those on Earth today. Life functions through the specialized chemistry of carbon and water and builds largely upon four key families of chemicals: lipids (fatty cell walls), carbohydrates (sugars, cellulose), amino acids (protein metabolism), and nucleic acids (self-replicating DNA and RNA). Any successful theory of abiogenesis must explain the origins and interactions of these classes of molecules.[15] Many approaches to abiogenesis investigate how self-replicating molecules, or their components, came into existence. Researchers generally think that current life on Earth descends from an RNA world,[16] although RNA-based life may not have been the first life to have existed.[17][18]

The classic 1952 Miller–Urey experiment and similar research demonstrated that most amino acids, the chemical constituents of the proteins used in all living organisms, can be synthesized from inorganic compounds under conditions intended to replicate those of the early Earth. Scientists have proposed various external sources of energy that may have triggered these reactions, including lightning and radiation. Other approaches ("metabolism-first" hypotheses) focus on understanding how catalysis in chemical systems on the early Earth might have provided the precursor molecules necessary for self-replication.[19] Complex organic molecules occur in the Solar System and in interstellar space, and these molecules may have provided starting material for the development of life on Earth.[20][21][22][23]

The biochemistry of life may have begun shortly after the Big Bang, 13.8 billion years ago, during a habitable epoch when the age of the universe was only 10 to 17 million years.[24][25] The panspermia hypothesis suggests that microscopic life was distributed to the early Earth by space dust,[26] meteoroids,[27] asteroids and other small Solar System bodies and that life may exist throughout the universe.[28] The panspermia hypothesis proposes that life originated outside the Earth, but does not definitively explain its origin.

Nonetheless, Earth remains the only place in the universe known to harbour life,[29][30] and fossil evidence from the Earth informs most studies of abiogenesis. The age of the Earth is about 4.54 billion years;[31][32][33] the earliest undisputed evidence of life on Earth dates from at least 3.5 billion years ago,[34][35][36] and possibly as early as the Eoarchean Era (between 3.6 and 4.0 billion years ago), after geological crust started to solidify following the molten Hadean Eon. In May 2017 scientists found possible evidence of early life on land in 3.48-billion-year-old geyserite and other related mineral deposits (often found around hot springs and geysers) uncovered in the Pilbara Craton of Western Australia.[37][38][39][40] However, a number of discoveries suggest that life may have appeared on Earth even earlier. As of 2017, microfossils, or fossilised microorganisms, within hydrothermal-vent precipitates dated from 3.77 to 4.28 billion years old found in Quebec, Canadian rocks may harbor the oldest record of life on Earth, suggesting life started soon after ocean formation 4.4 billion years ago.[1][2][41][42][43] According to biologist Stephen Blair Hedges, "If life arose relatively quickly on Earth ... then it could be common in the universe."[44][45][46]

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Early geophysical conditions on Earth

The Hadean Earth is thought to have had a secondary atmosphere, formed through degassing of the rocks that accumulated from planetesimal impactors. At first, it was thought that the Earth's atmosphere consisted of hydrogen compounds—methane, ammonia and water vapour—and that life began under such reducing conditions, which are conducive to the formation of organic molecules. According to later models, suggested by study of ancient minerals, the atmosphere in the late Hadean period consisted largely of water vapour, nitrogen and carbon dioxide, with smaller amounts of carbon monoxide, hydrogen, and sulfur compounds.[47] During its formation, the Earth lost a significant part of its initial mass, with a nucleus of the heavier rocky elements of the protoplanetary disk remaining.[48] As a consequence, Earth lacked the gravity to hold any molecular hydrogen in its atmosphere, and rapidly lost it during the Hadean period, along with the bulk of the original inert gases. The solution of carbon dioxide in water is thought to have made the seas slightly acidic, giving it a pH of about 5.5. The atmosphere at the time has been characterized as a "gigantic, productive outdoor chemical laboratory."[49] It may have been similar to the mixture of gases released today by volcanoes, which still support some abiotic chemistry.[49]

Oceans may have appeared first in the Hadean Eon, as soon as two hundred million years (200 Ma) after the Earth was formed, in a hot 100 °C (212 °F) reducing environment, and the pH of about 5.8 rose rapidly towards neutral.[50] This has been supported by the dating of 4.404 Ga-old zircon crystals from metamorphosed quartzite of Mount Narryer in the

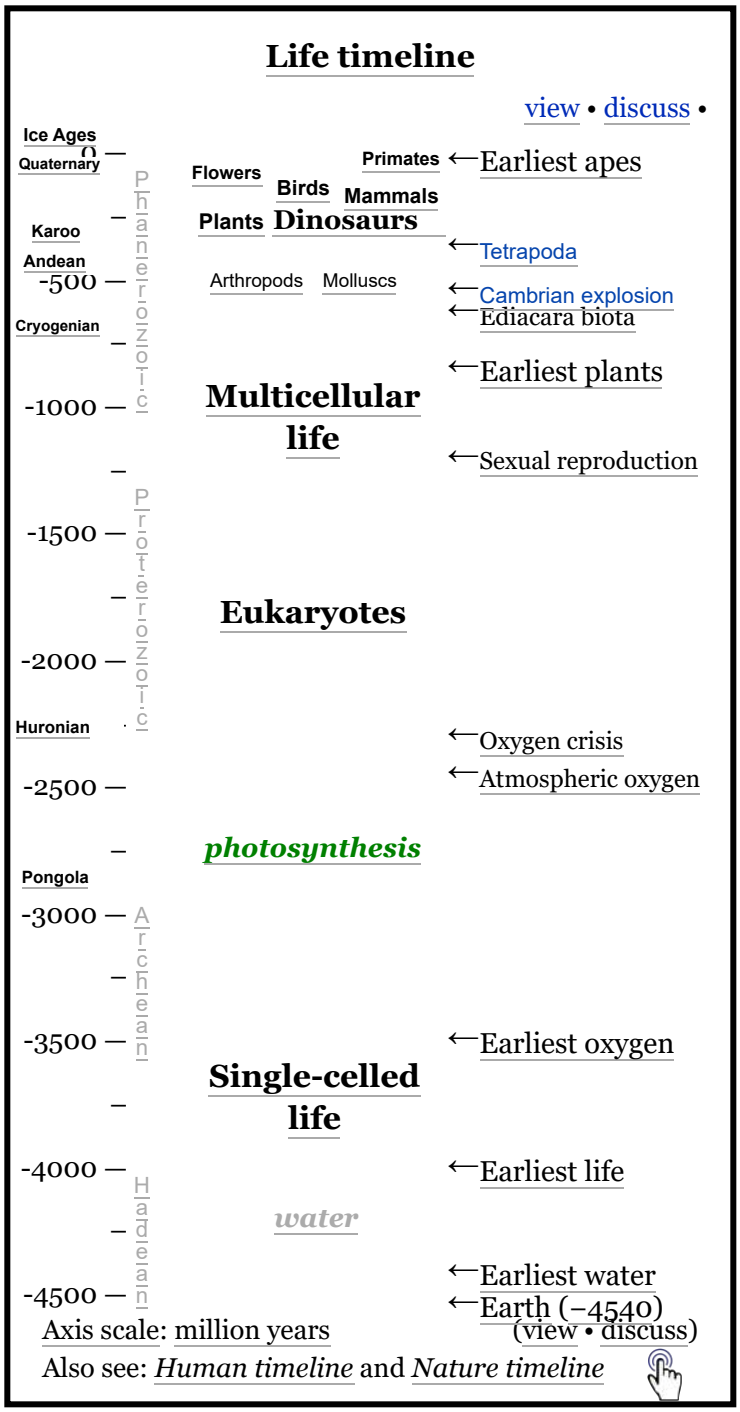

Western Australia Jack Hills of the Pilbara, which are
evidence that oceans and continental crust existed within 150 Ma of Earth's formation.[51] Despite the likely increased volcanism and existence of many smaller tectonic "platelets," it has been suggested that between 4.4 and 4.3 Ga (billion year), the Earth was a water world, with little if any continental crust, an extremely turbulent atmosphere and a hydrosphere subject to intense ultraviolet (UV) light, from a T Tauri stage Sun, cosmic radiation and continued bolide impacts.[52]

The Hadean environment would have been highly hazardous to modern life. Frequent collisions with large objects, up to 500 kilometres (310 mi) in diameter, would have been sufficient to sterilize the planet and vaporize the ocean within a few months of impact, with hot steam mixed with rock vapour becoming high altitude clouds that would completely cover the planet. After a few months, the height of these clouds would have begun to decrease but the cloud base would still have been elevated for about the next thousand years. After that, it would have begun to rain at low altitude. For another two thousand years, rains would slowly have drawn down the height of the clouds, returning the oceans to their original depth only 3,000 years after the impact event.[53]

Earliest biological evidence for life

The most commonly accepted location of the root of the tree of life is between a monophyletic domain Bacteria and a clade formed by Archaea and Eukaryota of what is referred to as the "traditional tree of life" based on several molecular studies starting with C. Woese.[54] A very small minority of studies have concluded differently, namely that the root is in the Domain Bacteria, either in the phylum Firmicutes[55] or that the phylum Chloroflexi is basal to a clade with Archaea+Eukaryotes and the rest of Bacteria as proposed by Thomas Cavalier-Smith.[56] More recently Peter Ward has established an alternative view which is rooted in abiotic RNA synthesis which becomes enclosed within a capsule and then creates RNA ribozyme replicates. It is proposed that this then bifurcates between Dominion Ribosa (RNA life), and after the loss of ribozymes RNA viruses as Domain Viorea, and Dominion Terroa, which after creating a large cell within a lipid wall, creating DNA the 20 based amino acids and the triplet code, is established as the last universal common ancestor or LUCA, of earlier phylogenic trees.[57]

Precambrian stromatolites in the Siyeh Formation, Glacier National Park. In 2002, a paper in the scientific journal *Nature* suggested that these 3.5 Ga (billion years) old geological formations contain fossilized cyanobacteria microbes. This suggests they are evidence of one of the earliest life forms on Earth.

The earliest life on Earth existed more than 3.5 billion years ago,[34][35][36] during the Eoarchean Era when sufficient crust had solidified following the molten Hadean Eon. The earliest physical evidence so far found consists of microfossils in the Nuvvuagittuq Greenstone Belt of Northern Quebec, in "banded iron formation" rocks at least 3.77 billion and possibly 4.28 billion years old.[1][58] This finding suggested that there was almost instant development of life after oceans were formed. The structure of the microbes was noted to be similar to bacteria found near hydrothermal vents in the modern era, and provided support for the hypothesis that abiogenesis began near hydrothermal vents.[42][1]

Also noteworthy is biogenic graphite in 3.7 billion-year-old metasedimentary rocks from southwestern Greenland[59] and microbial mat fossils found in 3.48 billion-year-old sandstone from Western Australia.[60][61] Evidence of early life in rocks from Akilia Island, near the Isua supracrustal belt in southwestern Greenland, dating to 3.7 billion years ago have shown biogenic carbon isotopes.[62][63] In other parts of the Isua supracrustal belt, graphite inclusions trapped within garnet crystals are connected to the other elements of life: oxygen, nitrogen, and possibly phosphorus in the form of phosphate, providing

further evidence for life 3.7 billion years ago.[64] At Strelley Pool, in the Pilbara region of Western Australia, compelling evidence of early life was found in pyrite-bearing sandstone in a fossilized beach, that showed rounded tubular cells that oxidized sulfur by photosynthesis in the absence of oxygen.[65][66][67] Further research on zircons from Western Australia in 2015 suggested that life likely existed on Earth at least 4.1 billion years ago.[44][68][69]

Traditionally it was thought that during the period between 4.28[1][2] and 3.8 Ga, changes in the orbits of the giant planets may have caused a heavy bombardment by asteroids and comets[70] that pockmarked the Moon and the other inner planets (Mercury, Mars, and presumably Earth and Venus). This would likely have repeatedly sterilized the planet, had life appeared before that time.[49] Geologically, the Hadean Earth would have been far more active than at any other time in its history. Studies of meteorites suggests that radioactive isotopes such as aluminium-26 with a half-life of 7.17×10^5 (717 thousand) years, and potassium-40 with a half-life of 1.250×10^9 (1.25 billion) years, isotopes mainly produced in supernovae, were much more common.[71] Internal heating as a result of gravitational sorting between the core and the mantle would have caused a great deal of mantle convection, with the probable result of many more smaller and more active tectonic plates than now exist.

The time periods between such devastating environmental events give time windows for the possible origin of life in the early environments. If the deep marine hydrothermal setting was the site for the origin of life, then abiogenesis could have happened as early as 4.0 to 4.2 Ga. If the site was at the surface of the Earth, abiogenesis could only have occurred between 3.7 and 4.0 Ga.[72]

In 2016, a set of 355 genes likely present in the Last Universal Common Ancestor (LUCA) of all organisms living on Earth was identified.[73] A total of 6.1 million prokaryotic protein coding genes from various phylogenic trees were sequenced, identifying 355 protein clusters from amongst 286,514 protein clusters that were probably common to LUCA. The results "depict LUCA as anaerobic, CO_2-fixing, H_2-dependent with a Wood–Ljungdahl pathway, N_2-fixing and thermophilic. LUCA's biochemistry was replete with FeS clusters and radical reaction mechanisms. Its cofactors reveal dependence upon transition metals, flavins, S-adenosyl methionine, coenzyme A, ferredoxin, molybdopterin, corrins and selenium. Its genetic code required nucleoside modifications and S-adenosylmethionine-dependent methylations." The results depict methanogenic clostridia as a basal clade in the 355 phylogenies examined, and suggest that LUCA inhabited an anaerobic hydrothermal vent setting in a geochemically active environment rich in H_2, CO_2 and iron.[74] M.D. Brazier has shown that early micro-fossils came from a hot world of gases such as methane, ammonia, carbon dioxide and hydrogen sulphide, which are toxic to much current life.[75] Another analysis of the conventional threefold tree of life shows thermophilic and hyperthermophilic bacteria and archaea are closest to the root, suggesting that life may have evolved in a hot environment.[76]

Conceptual history

Spontaneous generation

Belief in spontaneous generation of certain forms of life from non-living matter goes back to Aristotle and ancient Greek philosophy and continued to have support in Western scholarship until the 19th century.[77] This belief was paired with a belief in heterogenesis, i.e., that one form of life derived from a different form (e.g., bees from flowers).[78] Classical notions of spontaneous generation held that certain complex, living organisms are generated by decaying organic substances. According to Aristotle, it was a readily observable truth that aphids arise from the dew that falls on plants, flies from putrid matter, mice from dirty hay, crocodiles from rotting logs at the bottom of bodies of water, and so on.[79] In the 17th century, people began to question such assumptions. In 1646, Sir Thomas Browne published his *Pseudodoxia Epidemica* (subtitled *Enquiries into Very many Received Tenets, and commonly Presumed Truths*), which was an attack on false beliefs and "vulgar errors." His contemporary, Alexander Ross, erroneously refuted him, stating: "To question this

[spontaneous generation], is to question Reason, Sense, and Experience: If he doubts of this, let him go to *Ægypt*, and there he will finde the fields swarming with mice begot of the mud of *Nylus*, to the great calamity of the Inhabitants."[80][81]

In 1665, Robert Hooke published the first drawings of a microorganism. Hooke was followed in 1676 by Antonie van Leeuwenhoek, who drew and described microorganisms that are now thought to have been protozoa and bacteria.[82] Many felt the existence of microorganisms was evidence in support of spontaneous generation, since microorganisms seemed too simplistic for sexual reproduction, and asexual reproduction through cell division had not yet been observed. Van Leeuwenhoek took issue with the ideas common at the time that fleas and lice could spontaneously result from putrefaction, and that frogs could likewise arise from slime. Using a broad range of experiments ranging from sealed and open meat incubation and the close study of insect reproduction he became, by the 1680s, convinced that spontaneous generation was incorrect.[83]

The first experimental evidence against spontaneous generation came in 1668 when Francesco Redi showed that no maggots appeared in meat when flies were prevented from laying eggs. It was gradually shown that, at least in the case of all the higher and readily visible organisms, the previous sentiment regarding spontaneous generation was false. The alternative seemed to be biogenesis: that every living thing came from a pre-existing living thing (*omne vivum ex ovo*, Latin for "every living thing from an egg").

In 1768, Lazzaro Spallanzani demonstrated that microbes were present in the air, and could be killed by boiling. In 1861, Louis Pasteur performed a series of experiments that demonstrated that organisms such as bacteria and fungi do not spontaneously appear in sterile, nutrient-rich media, but could only appear by invasion from without.

The belief that self-ordering by spontaneous generation was impossible begged for an alternative. By the middle of the 19th century, the theory of biogenesis had accumulated so much evidential support, due to the work of Pasteur and others, that the alternative theory of spontaneous generation had been effectively disproven. John Desmond Bernal, a pioneer in X-ray crystallography, suggested that earlier theories such as spontaneous generation were based upon an explanation that life was continuously created as a result of chance events.[84]

Etymology

The term *biogenesis* is usually credited to either Henry Charlton Bastian or to Thomas Henry Huxley.[85] Bastian used the term around 1869 in an unpublished exchange with John Tyndall to mean "life-origination or commencement". In 1870, Huxley, as new president of the British Association for the Advancement of Science, delivered an address entitled *Biogenesis and Abiogenesis*.[86] In it he introduced the term *biogenesis* (with an opposite meaning to Bastian's) as well as *abiogenesis*:

> And thus the hypothesis that living matter always arises by the agency of pre-existing living matter, took definite shape; and had, henceforward, a right to be considered and a claim to be refuted, in each particular case, before the production of living matter in any other way could be admitted by careful reasoners. It will be necessary for me to refer to this hypothesis so frequently, that, to save circumlocution, I shall call it the hypothesis of *Biogenesis*; and I shall term the contrary doctrine–that living matter may be produced by not living matter–the hypothesis of *Abiogenesis*.[86]

Subsequently, in the preface to Bastian's 1871 book, *The Modes of Origin of Lowest Organisms*,[87] Bastian referred to the possible confusion with Huxley's usage and explicitly renounced his own meaning:

> A word of explanation seems necessary with regard to the introduction of the new term *Archebiosis*. I had originally, in unpublished writings, adopted the word *Biogenesis* to express

> the same meaning—viz., life-origination or commencement. But in the mean time the word *Biogenesis* has been made use of, quite independently, by a distinguished biologist [Huxley], who wished to make it bear a totally different meaning. He also introduced the word *Abiogenesis*. I have been informed, however, on the best authority, that neither of these words can—with any regard to the language from which they are derived—be supposed to bear the meanings which have of late been publicly assigned to them. Wishing to avoid all needless confusion, I therefore renounced the use of the word *Biogenesis*, and being, for the reason just given, unable to adopt the other term, I was compelled to introduce a new word, in order to designate the process by which living matter is supposed to come into being, independently of pre-existing living matter.[88]

Louis Pasteur and Charles Darwin

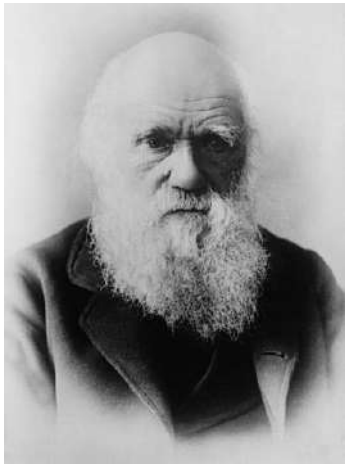
Charles Darwin in 1879

Louis Pasteur remarked, about a finding of his in 1864 which he considered definitive, "Never will the doctrine of spontaneous generation recover from the mortal blow struck by this simple experiment."[89][90] One alternative was that life's origins on Earth had come from somewhere else in the universe. Periodically resurrected (see Panspermia, above) Bernal said that this approach "is equivalent in the last resort to asserting the operation of metaphysical, spiritual entities... it turns on the argument of creation by design by a creator or demiurge."[91] Such a theory, Bernal said, was unscientific. A theory popular around the same time was that life was the result of an inner "life force", which in the late 19th century was championed by Henri Bergson.

The idea of evolution by natural selection proposed by Charles Darwin put an end to these metaphysical theologies. In a letter to Joseph Dalton Hooker on 1 February 1871,[92] Darwin discussed the suggestion that the original spark of life may have begun in a "warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, &c., present, that a proteine compound was chemically formed ready to undergo still more complex changes." He went on to explain that "at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed." He had written to Hooker in 1863 stating that, "It is mere rubbish, thinking at present of the origin of life; one might as well think of the origin of matter." In *On the Origin of Species*, he had referred to life having been "created", by which he "really meant 'appeared' by some wholly unknown process", but had soon regretted using the Old Testament term "creation".[93]

"Primordial soup" hypothesis

No new notable research or hypothesis on the subject appeared until 1924, when Alexander Oparin reasoned that atmospheric oxygen prevents the synthesis of certain organic compounds that are necessary building blocks for the evolution of life. In his book *The Origin of Life*,[94][95] Oparin proposed that the "spontaneous generation of life" that had been attacked by Louis Pasteur did in fact occur once, but was now impossible because the conditions found on the early Earth had changed, and preexisting organisms would immediately consume any spontaneously generated organism. Oparin argued that a "primeval soup" of organic molecules could be created in an oxygenless atmosphere through the action of sunlight. These would combine in ever more complex ways until they formed coacervate droplets. These droplets would "grow" by fusion with other droplets, and "reproduce" through fission into daughter droplets, and so have a primitive metabolism in which factors that promote "cell integrity" survive, and those that do not become extinct. Many modern theories of the origin of life still take Oparin's ideas as a starting point.

Robert Shapiro has summarized the "primordial soup" theory of Oparin and J. B. S. Haldane in its "mature form" as follows:[96]

1. The early Earth had a chemically reducing atmosphere.
2. This atmosphere, exposed to energy in various forms, produced simple organic compounds ("monomers").
3. These compounds accumulated in a "soup" that may have concentrated at various locations (shorelines, oceanic vents etc.).
4. By further transformation, more complex organic polymers – and ultimately life – developed in the soup.

Alexander Oparin (right) in his laboratory, 1938

About this time, Haldane suggested that the Earth's prebiotic oceans (quite different from their modern counterparts) would have formed a "hot dilute soup" in which organic compounds could have formed. Bernal called this idea *biopoiesis* or *biopoesis*, the process of living matter evolving from self-replicating but non-living molecules,[84][97] and proposed that biopoiesis passes through a number of intermediate stages.

One of the most important pieces of experimental support for the "soup" theory came in 1952. Stanley L. Miller and Harold C. Urey performed an experiment that demonstrated how organic molecules could have spontaneously formed from inorganic precursors under conditions like those posited by the Oparin-Haldane hypothesis. The now-famous Miller–Urey experiment used a highly reducing mixture of gases – methane, ammonia, and hydrogen, as well as water vapour – to form simple organic monomers such as amino acids.[98] The mixture of gases was cycled through an apparatus that delivered electrical sparks to the mixture. After one week, it was found that about 10% to 15% of the carbon in the system was then in the form of a racemic mixture of organic compounds, including amino acids, which are the building blocks of proteins. This provided direct experimental support for the second point of the "soup" theory, and it is around the remaining two points of the theory that much of the debate now centres.

Bernal showed that based upon this and subsequent work there is no difficulty in principle in forming most of the molecules we recognize as the necessary molecules for life from their inorganic precursors. The underlying hypothesis held by Oparin, Haldane, Bernal, Miller and Urey, for instance, was that multiple conditions on the primeval Earth favoured chemical reactions that synthesized the same set of complex organic compounds from such simple precursors. A 2011 reanalysis of the saved vials containing the original extracts that resulted from the Miller and Urey experiments, using current and more advanced analytical equipment and technology, has uncovered more biochemicals than originally discovered in the 1950s. One of the more important findings was 23 amino acids, far more than the five originally found.[99] However, Bernal said that "it is not enough to explain the formation of such molecules, what is necessary, is a physical-chemical explanation of the origins of these molecules that suggests the presence of suitable sources and sinks for free energy."[100]

More recent studies, in October 2017, support the notion that life may have begun right after the Earth was formed as RNA molecules emerging from "warm little ponds".[46]

Proteinoid microspheres

In trying to uncover the intermediate stages of abiogenesis mentioned by Bernal, Sidney W. Fox in the 1950s and 1960s studied the spontaneous formation of peptide structures (small chains of amino acids) under conditions that might plausibly have existed early in Earth's history. In one of his experiments, he allowed amino acids to dry out as if puddled in a warm, dry spot in prebiotic conditions. He found that, as they dried, the amino acids formed long, often cross-linked, thread-like, submicroscopic polypeptide molecules now named "proteinoid microspheres".[101]

In another experiment to set suitable conditions for life to form, Fox collected volcanic material from a cinder cone in Hawaii. He discovered that the temperature was over 100 °C (212 °F) just 4 inches (100 mm) beneath the surface of the cinder cone, and suggested that this might have been the environment in which life was created—molecules could have formed and then been washed through the loose volcanic ash into the sea. He placed lumps of lava over amino acids derived from methane, ammonia and water, sterilized all materials, and baked the lava over the amino acids for a few hours in a glass oven. A brown, sticky substance formed over the surface, and when the lava was drenched in sterilized water, a thick, brown liquid leached out. The amino acids had combined to form proteinoids, and the proteinoids had combined to form small globules that Fox called "microspheres". His proteinoids were not cells, although they formed clumps and chains reminiscent of cyanobacteria, but they contained no functional nucleic acids or any encoded information. Based upon such experiments, Colin S. Pittendrigh stated in December 1967 that "laboratories will be creating a living cell within ten years," a remark that reflected the typical contemporary naivety about the complexity of cell structures.[102]

Current models

There is no single, generally accepted model for the origin of life. Scientists have proposed several plausible hypotheses, which share some common elements. While differing in the details, these hypotheses are based on the framework laid out by Alexander Oparin (in 1924) and by J. B. S. Haldane (in 1925), who postulated the molecular or chemical evolution theory of life.[103] According to them, the first molecules constituting the earliest cells "were synthesized under natural conditions by a slow process of molecular evolution, and these molecules then organized into the first molecular system with properties with biological order".[103] Oparin and Haldane suggested that the atmosphere of the early Earth may have been chemically reducing in nature, composed primarily of methane (CH_4), ammonia (NH_3), water (H_2O), hydrogen sulfide (H_2S), carbon dioxide (CO_2) or carbon monoxide (CO), and phosphate (PO_4^{3-}), with molecular oxygen (O_2) and ozone (O_3) either rare or absent. According to later models, the atmosphere in the late Hadean period consisted largely of nitrogen (N_2) and carbon dioxide, with smaller amounts of carbon monoxide, hydrogen (H_2), and sulfur compounds;[104] while it did lack molecular oxygen and ozone,[105] it was not as chemically reducing as Oparin and Haldane supposed. In the atmosphere proposed by Oparin and Haldane, electrical activity can produce certain small molecules (monomers) of life, such as amino acids. The Miller–Urey experiment reported in 1953 demonstrated this.

Bernal coined the term *biopoiesis* in 1949 to refer to the origin of life.[106] In 1967, he suggested that it occurred in three "stages":

1. the origin of biological monomers
2. the origin of biological polymers
3. the evolution from molecules to cells

Bernal suggested that evolution commenced between stages 1 and 2. Bernal regarded the third stage – discovering methods by which biological reactions were incorporated behind a cell's boundary – as the most difficult. Modern work on the way that cell membranes self-assemble, and the work on micropores in various substrates may be a halfway house towards the development of independent free-living cells.[107][108][109]

The chemical processes that took place on the early Earth are called *chemical evolution*. Since the end of the nineteenth century, 'evolutive abiogenesis' means increasing complexity and evolution of matter from inert to living state.[110] Both Manfred Eigen and Sol Spiegelman demonstrated that evolution, including replication, variation, and natural selection, can occur in populations of molecules as well as in organisms.[49] Spiegelman took advantage of natural selection to synthesize the Spiegelman Monster, which had a genome with just 218 nucleotide bases, having deconstructively evolved from a 4500-base bacterial RNA. Eigen built on Spiegelman's work and produced a similar system further degraded to just 48 or 54 nucleotides – the minimum required for the binding of the replication enzyme.[111]

Following on from chemical evolution came the initiation of biological evolution, which led to the first cells.[49] No one has yet synthesized a "protocell" using simple components with the necessary properties of life (the so-called "bottom-up-approach"). Without such a proof-of-principle, explanations have tended to focus on chemosynthesis.[112] However, some researchers work in this field, notably Steen Rasmussen and Jack W. Szostak. Others have argued that a "top-down approach" is more feasible. One such approach, successfully attempted by Craig Venter and others at J. Craig Venter Institute, involves engineering existing prokaryotic cells with progressively fewer genes, attempting to discern at which point the most minimal requirements for life are reached.[113][114][115]

The NASA strategy on abiogenesis states that it is necessary to identify interactions, intermediary structures and functions, energy sources, and environmental factors that contributed to the diversity, selection, and replication of evolvable macromolecular systems.[116] Emphasis must continue to map the chemical landscape of potential primordial informational polymers. The advent of polymers that could replicate, store genetic information, and exhibit properties subject to selection likely was a critical step in the emergence of prebiotic chemical evolution.[116]

In October 2018, researchers at McMaster University announced the development of a new technology, called a *Planet Simulator*, to help study the origin of life on planet Earth and beyond.[117][118][119][120] It consists of a sophisticated climate chamber to study how the building blocks of life were assembled and how these prebiotic molecules transitioned into self-replicating RNA molecules.[117]

Chemical origin of organic molecules

The elements, except for hydrogen and helium, ultimately derive from stellar nucleosynthesis. On 12 October 2016, astronomers reported that the very basic chemical ingredients of life — the carbon-hydrogen molecule (CH, or methylidyne radical), the carbon-hydrogen positive ion (CH+) and the carbon ion (C+) — are largely the result of ultraviolet light from stars, rather than other forms of radiation from supernovae and young stars, as thought earlier.[121] Complex molecules, including organic molecules, form naturally both in space and on planets.[20] There are two possible sources of organic molecules on the early Earth:

1. Terrestrial origins – organic molecule synthesis driven by impact shocks or by other energy sources (such as UV light, redox coupling, or electrical discharges; e.g., Miller's experiments)
2. Extraterrestrial origins – formation of organic molecules in interstellar dust clouds, which rain down on planets.[122][123] (See pseudo-panspermia)

Based on recent computer model studies, the complex organic molecules necessary for life may have formed in the protoplanetary disk of dust grains surrounding the Sun before the formation of the Earth.[124][125] According to the computer studies, this same process may also occur around other stars that acquire planets. (Also see Extraterrestrial organic molecules).

Estimates of the production of organics from these sources suggest that the Late Heavy Bombardment before 3.5 Ga within the early atmosphere made available quantities of organics comparable to those produced by terrestrial sources.[126][127]

It has been estimated that the Late Heavy Bombardment may also have effectively sterilized the Earth's surface to a depth of tens of metres. If life evolved deeper than this, it would have also been shielded from the early high levels of ultraviolet radiation from the T Tauri stage of the Sun's evolution. Simulations of geothermically heated oceanic crust yield far more organics than those found in the Miller-Urey experiments (see below). In the deep hydrothermal vents, Everett Shock has found "there is an enormous thermodynamic drive to form organic compounds, as seawater and hydrothermal fluids, which are far from equilibrium, mix and move towards a more stable state."[128] Shock has found that the available energy

is maximized at around 100 – 150 degrees Celsius, precisely the temperatures at which the hyperthermophilic bacteria and thermoacidophilic archaea have been found, at the base of the phylogenetic tree of life closest to the Last Universal Common Ancestor (LUCA).[129]

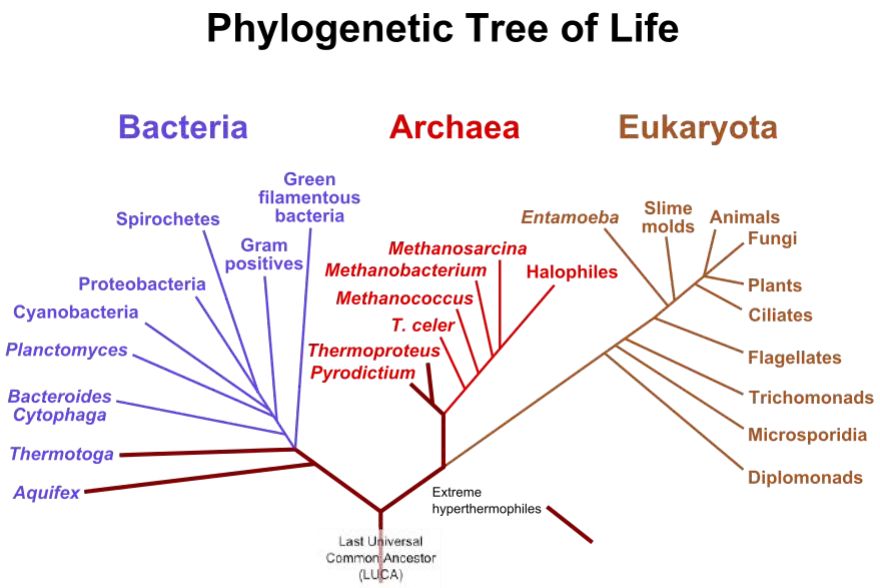

A cladogram demonstrating extreme hyperthermophiles at the base of the phylogenetic tree of life.

The accumulation and concentration of organic molecules on a planetary surface is also considered an essential early step for the origin of life.[116] Identifying and understanding the mechanisms that led to the production of prebiotic molecules in various environments is critical for establishing the inventory of ingredients from which life originated on Earth, assuming that the abiotic production of molecules ultimately influenced the selection of molecules from which life emerged.[116]

Chemical synthesis

While features of self-organization and self-replication are often considered the hallmark of living systems, there are many instances of abiotic molecules exhibiting such characteristics under proper conditions. Stan Palasek suggested based on a theoretical model that self-assembly of ribonucleic acid (RNA) molecules can occur spontaneously due to physical factors in hydrothermal vents.[130] Virus self-assembly within host cells has implications for the study of the origin of life,[131] as it lends further credence to the hypothesis that life could have started as self-assembling organic molecules.[132][133]

Multiple sources of energy were available for chemical reactions on the early Earth. For example, heat (such as from geothermal processes) is a standard energy source for chemistry. Other examples include sunlight and electrical discharges (lightning), among others.[49] Computer simulations also suggest that cavitation in primordial water reservoirs such as breaking sea waves, streams and oceans can potentially lead to the synthesis of biogenic compounds.[134] Unfavourable reactions can also be driven by highly favourable ones, as in the case of iron-sulfur chemistry. For example, this was probably important for carbon fixation (the conversion of carbon from its inorganic form to an organic one).[note 2] Carbon fixation via iron-sulfur chemistry is highly favourable, and occurs at neutral pH and 100 °C (212 °F). Iron-sulfur surfaces, which are abundant near hydrothermal vents, are also capable of producing small amounts of amino acids and other biological metabolites.[49]

As early as the 1860s, experiments have demonstrated that biologically relevant molecules can be produced from interaction of simple carbon sources with abundant inorganic catalysts. In particular, experiments by Butlerov (the formose reaction) showed that tetroses, pentoses, and hexoses are produced when formaldehyde is heated under basic conditions with divalent metal ions like calcium. The reaction was scrutinized and subsequently proposed to be autocatalytic by Breslow in 1959. Similar experiments (see below) demonstrate that nucleobases like guanine and adenine could be synthesized from simple carbon and nitrogen sources like hydrogen cyanide and ammonia.

Formamide produces all four ribonucleotides and other biological molecules when warmed in the presence of various terrestrial minerals. Formamide is ubiquitous in the Universe, produced by the reaction of water and hydrogen cyanide (HCN). It has several advantages as a biotic precursor, including the ability to easily become concentrated through the evaporation of water.[135][136] Although HCN is poisonous, it only affects aerobic organisms (eukaryotes and aerobic bacteria), which did not yet exist. It can play roles in other chemical processes as well, such as the synthesis of the amino acid glycine.[49]

In 1961, it was shown that the nucleic acid purine base adenine can be formed by heating aqueous ammonium cyanide solutions.[137] Other pathways for synthesizing bases from inorganic materials were also reported.[138] Leslie E. Orgel and colleagues have shown that freezing temperatures are advantageous for the synthesis of purines, due to the concentrating effect for key precursors such as hydrogen cyanide.[139] Research by Stanley L. Miller and colleagues suggested that while adenine and guanine require freezing conditions for synthesis, cytosine and uracil may require boiling temperatures.[140] Research by the Miller group notes the formation of seven different amino acids and 11 types of nucleobases in ice when ammonia and cyanide were left in a freezer from 1972 to 1997.[141][142] Other work demonstrated the formation of s-triazines (alternative nucleobases), pyrimidines (including cytosine and uracil), and adenine from urea solutions subjected to freeze-thaw cycles under a reductive atmosphere (with spark discharges as an energy source).[143] The explanation given for the unusual speed of these reactions at such a low temperature is eutectic freezing. As an ice crystal forms, it stays pure: only molecules of water join the growing crystal, while impurities like salt or cyanide are excluded. These impurities become crowded in microscopic pockets of liquid within the ice, and this crowding causes the molecules to collide more often. Mechanistic exploration using quantum chemical methods provide a more detailed understanding of some of the chemical processes involved in chemical evolution, and a partial answer to the fundamental question of molecular biogenesis.[144]

At the time of the Miller–Urey experiment, scientific consensus was that the early Earth had a reducing atmosphere with compounds relatively rich in hydrogen and poor in oxygen (e.g., CH_4 and NH_3 as opposed to CO_2 and nitrogen dioxide (NO_2)). However, current scientific consensus describes the primitive atmosphere as either weakly reducing or neutral[145][146] (see also Oxygen Catastrophe). Such an atmosphere would diminish both the amount and variety of amino acids that could be produced, although studies that include iron and carbonate minerals (thought present in early oceans) in the experimental conditions have again produced a diverse array of amino acids.[145] Other scientific research has focused on two other potential reducing environments: outer space and deep-sea thermal vents.[147][148][149]

The spontaneous formation of complex polymers from abiotically generated monomers under the conditions posited by the "soup" theory is not at all a straightforward process. Besides the necessary basic organic monomers, compounds that would have prohibited the formation of polymers were also formed in high concentration during the Miller–Urey and Joan Oró experiments.[150] The Miller–Urey experiment, for example, produces many substances that would react with the amino acids or terminate their coupling into peptide chains.[151]

A research project completed in March 2015 by John D. Sutherland and others found that a network of reactions beginning with hydrogen cyanide and hydrogen sulfide, in streams of water irradiated by UV light, could produce the chemical components of proteins and lipids, as well as those of RNA,[152][153] while not producing a wide range of other compounds.[154] The researchers used the term "cyanosulfidic" to describe this network of reactions.[153]

Autocatalysis

Autocatalysts are substances that catalyze the production of themselves and therefore are "molecular replicators." The simplest self-replicating chemical systems are autocatalytic, and typically contain three components: a product molecule and two precursor molecules. The product molecule joins together the precursor molecules, which in turn produce more product molecules from more precursor molecules. The product molecule catalyzes the reaction by providing a

complementary template that binds to the precursors, thus bringing them together. Such systems have been demonstrated both in biological macromolecules and in small organic molecules.[155][156] Systems that do not proceed by template mechanisms, such as the self-reproduction of micelles and vesicles, have also been observed.[156]

It has been proposed that life initially arose as autocatalytic chemical networks.[157] British ethologist Richard Dawkins wrote about autocatalysis as a potential explanation for the origin of life in his 2004 book *The Ancestor's Tale*.[158] In his book, Dawkins cites experiments performed by Julius Rebek Jr. and his colleagues in which they combined amino adenosine and pentafluorophenyl esters with the autocatalyst amino adenosine triacid ester (AATE). One product was a variant of AATE, which catalyzed the synthesis of themselves. This experiment demonstrated the possibility that autocatalysts could exhibit competition within a population of entities with heredity, which could be interpreted as a rudimentary form of natural selection.[159][160]

In the early 1970s, Manfred Eigen and Peter Schuster examined the transient stages between the molecular chaos and a self-replicating hypercycle in a prebiotic soup.[161] In a hypercycle, the information storing system (possibly RNA) produces an enzyme, which catalyzes the formation of another information system, in sequence until the product of the last aids in the formation of the first information system. Mathematically treated, hypercycles could create quasispecies, which through natural selection entered into a form of Darwinian evolution. A boost to hypercycle theory was the discovery of ribozymes capable of catalyzing their own chemical reactions. The hypercycle theory requires the existence of complex biochemicals, such as nucleotides, which do not form under the conditions proposed by the Miller–Urey experiment.

Geoffrey W. Hoffmann has shown that an early error-prone translation machinery can be stable against an error catastrophe of the type that had been envisaged as problematical for the origin of life, and was known as "Orgel's paradox".[162][163][164]

Hoffmann has furthermore argued that a complex nucleation event as the origin of life involving both polypeptides and nucleic acid is compatible with the time and space available in the primitive oceans of Earth[165] Hoffmann suggests that volcanic ash may provide the many random shapes needed in the postulated complex nucleation event. This aspect of the theory can be tested experimentally.

Homochirality

Homochirality refers to a geometric uniformity of some materials composed of chiral units. Chiral refers to nonsuperimposable 3D forms that are mirror images of one another, as are left and right hands. Living organisms use molecules that have the same chirality ("handedness"): with almost no exceptions,[166] amino acids are left-handed while nucleotides and sugars are right-handed. Chiral molecules can be synthesized, but in the absence of a chiral source or a chiral catalyst, they are formed in a 50/50 mixture of both enantiomers (called a racemic mixture). Known mechanisms for the production of non-racemic mixtures from racemic starting materials include: asymmetric physical laws, such as the electroweak interaction; asymmetric environments, such as those caused by circularly polarized light, quartz crystals, or the Earth's rotation, statistical fluctuations during racemic synthesis,[167] and spontaneous symmetry breaking.[168][169][170]

Once established, chirality would be selected for.[171] A small bias (enantiomeric excess) in the population can be amplified into a large one by asymmetric autocatalysis, such as in the Soai reaction.[172] In asymmetric autocatalysis, the catalyst is a chiral molecule, which means that a chiral molecule is catalyzing its own production. An initial enantiomeric excess, such as can be produced by polarized light, then allows the more abundant enantiomer to outcompete the other.[173]

Clark has suggested that homochirality may have started in outer space, as the studies of the amino acids on the Murchison meteorite showed that L-alanine is more than twice as frequent as its D form, and L-glutamic acid was more than three times prevalent than its D counterpart. Various chiral crystal surfaces can also act as sites for possible concentration and assembly of chiral monomer units into macromolecules.[174][175] Compounds found on meteorites suggest that the chirality of life derives from abiogenic synthesis, since amino acids from meteorites show a left-handed bias, whereas sugars show a predominantly right-handed bias, the same as found in living organisms.[176]

Self-enclosement, reproduction, duplication and the RNA world

Protocells

A protocell is a self-organized, self-ordered, spherical collection of lipids proposed as a stepping-stone to the origin of life.[177] A central question in evolution is how simple protocells first arose and differed in reproductive contribution to the following generation driving the evolution of life. Although a functional protocell has not yet been achieved in a laboratory setting, there are scientists who think the goal is well within reach.[178][179][180]

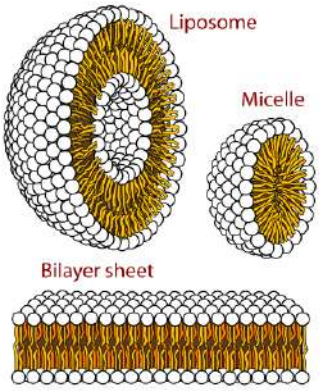

The three main structures phospholipids form spontaneously in solution: the liposome (a closed bilayer), the micelle and the bilayer.

Self-assembled vesicles are essential components of primitive cells.[177] The second law of thermodynamics requires that the universe move in a direction in which entropy increases, yet life is distinguished by its great degree of organization. Therefore, a boundary is needed to separate life processes from non-living matter.[181] Researchers Irene A. Chen and Jack W. Szostak amongst others, suggest that simple physicochemical properties of elementary protocells can give rise to essential cellular behaviours, including primitive forms of differential reproduction competition and energy storage. Such cooperative interactions between the membrane and its encapsulated contents could greatly simplify the transition from simple replicating molecules to true cells.[179] Furthermore, competition for membrane molecules would favour stabilized membranes, suggesting a selective advantage for the evolution of cross-linked fatty acids and even the phospholipids of today.[179] Such micro-encapsulation would allow for metabolism within the membrane, the exchange of small molecules but the prevention of passage of large substances across it.[182] The main advantages of encapsulation include the increased solubility of the contained cargo within the capsule and the storage of energy in the form of a electrochemical gradient.

A 2012 study led by Armen Y. Mulkidjanian of Germany's University of Osnabrück, suggests that inland pools of condensed and cooled geothermal vapour have the ideal characteristics for the origin of life.[183] Scientists confirmed in 2002 that by adding a montmorillonite clay to a solution of fatty acid micelles (lipid spheres), the clay sped up the rate of vesicles formation 100-fold.[180]

Another protocell model is the Jeewanu. First synthesized in 1963 from simple minerals and basic organics while exposed to sunlight, it is still reported to have some metabolic capabilities, the presence of semipermeable membrane, amino acids, phospholipids, carbohydrates and RNA-like molecules.[184][185] However, the nature and properties of the Jeewanu remains to be clarified.

Electrostatic interactions induced by short, positively charged, hydrophobic peptides containing 7 amino acids in length or fewer, can attach RNA to a vesicle membrane, the basic cell membrane.[186]

RNA world

The RNA world hypothesis describes an early Earth with self-replicating and catalytic RNA but no DNA or proteins.[188] It is widely accepted that current life on Earth descends from an RNA world,[16][189] although RNA-based life may not have been the first life to exist.[17][18] This conclusion is drawn from many independent lines of evidence, such as the observations that RNA is central to the translation process and that small RNAs can catalyze all of the chemical groups and information transfers required for life.[18][190] The structure of the ribosome has been called the "smoking gun," as it showed that the ribosome is a ribozyme, with a central core of RNA and no amino acid side chains within 18 angstroms of the active site where peptide bond formation is catalyzed.[17] The concept of the RNA world was first proposed in 1962 by Alexander Rich,[191] and the term was coined by Walter Gilbert in 1986.[18][192]

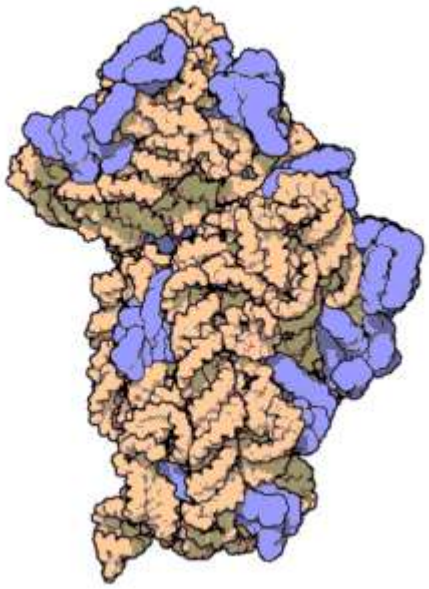

Molecular structure of the ribosome 30S subunit from *Thermus thermophilus*.[187] Proteins are shown in blue and the single RNA chain in orange.

Possible precursors for the evolution of protein synthesis include a mechanism to synthesize short peptide cofactors or form a mechanism for the duplication of RNA. It is likely that the ancestral ribosome was composed entirely of RNA, although some roles have since been taken over by proteins. Major remaining questions on this topic include identifying the selective force for the evolution of the ribosome and determining how the genetic code arose.[193]

Eugene Koonin said, "Despite considerable experimental and theoretical effort, no compelling scenarios currently exist for the origin of replication and translation, the key processes that together comprise the core of biological systems and the apparent pre-requisite of biological evolution. The RNA World concept might offer the best chance for the resolution of this conundrum but so far cannot adequately account for the emergence of an efficient RNA replicase or the translation system. The MWO ["many worlds in one"] version of the cosmological model of eternal inflation could suggest a way out of this conundrum because, in an infinite multiverse with a finite number of distinct macroscopic histories (each repeated an infinite number of times), emergence of even highly complex systems by chance is not just possible but inevitable."[194]

Viral origins

Recent evidence for a "virus first" hypothesis, which may support theories of the RNA world, has been suggested.[195] [196] One of the difficulties for the study of the origins of viruses is their high rate of mutation; this is particularly the case in RNA retroviruses like HIV.[197] A 2015 study compared protein fold structures across different branches of the tree of life, where researchers can reconstruct the evolutionary histories of the folds and of the organisms whose genomes code for those folds. They argue that protein folds are better markers of ancient events as their three-dimensional structures can be maintained even as the sequences that code for those begin to change.[195] Thus, the viral protein repertoire retain traces of ancient evolutionary history that can be recovered using advanced bioinformatics approaches. Those researchers think that "the prolonged pressure of genome and particle size reduction eventually reduced virocells into modern viruses (identified by the complete loss of cellular makeup), meanwhile other coexisting cellular lineages diversified into modern cells.[198] The data suggest that viruses originated from ancient cells that co-existed with the ancestors of modern cells.

These ancient cells likely contained segmented RNA genomes.[195][199] Although the virus-first hypothesis is highly controversial today, some astrobiologists have suggested looking for viruses on other celestial bodies such as Mars if they do emerge before cells.[200]

RNA synthesis and replication

A number of hypotheses of formation of RNA have been put forward. As of 1994, there were difficulties in the explanation of the abiotic synthesis of the nucleotides cytosine and uracil.[201] Subsequent research has shown possible routes of synthesis; for example, formamide produces all four ribonucleotides and other biological molecules when warmed in the presence of various terrestrial minerals.[135][136] Early cell membranes could have formed spontaneously from proteinoids, which are protein-like molecules produced when amino acid solutions are heated while in the correct concentration of aqueous solution. These are seen to form micro-spheres which are observed to behave similarly to membrane-enclosed compartments. Other possible means of producing more complicated organic molecules include chemical reactions that take place on clay substrates or on the surface of the mineral pyrite.

Factors supporting an important role for RNA in early life include its ability to act both to store information and to catalyze chemical reactions (as a ribozyme); its many important roles as an intermediate in the expression of and maintenance of the genetic information (in the form of DNA) in modern organisms; and the ease of chemical synthesis of at least the components of the RNA molecule under the conditions that approximated the early Earth. Relatively short RNA molecules have been synthesized, capable of replication.[202] Such replicase RNA, which functions as both code and catalyst provides its own template upon which copying can occur. Jack W. Szostak has shown that certain catalytic RNAs can join smaller RNA sequences together, creating the potential for self-replication. If these conditions were present, Darwinian natural selection would favour the proliferation of such autocatalytic sets, to which further functionalities could be added.[203] Such autocatalytic systems of RNA capable of self-sustained replication have been identified.[204] The RNA replication systems, which include two ribozymes that catalyze each other's synthesis, showed a doubling time of the product of about one hour, and were subject to natural selection under the conditions that existed in the experiment.[205] In evolutionary competition experiments, this led to the emergence of new systems which replicated more efficiently.[17] This was the first demonstration of evolutionary adaptation occurring in a molecular genetic system.[205]

Depending on the definition, life started when RNA chains began to self-replicate, initiating the three mechanisms of Darwinian selection: heritability, variation of type, and differential reproductive output. The fitness of an RNA replicator (its per capita rate of increase) would likely be a function of its intrinsic adaptive capacities, determined by its nucleotide sequence, and the availability of resources.[206][207] The three primary adaptive capacities may have been: (1) replication with moderate fidelity, giving rise to both heritability while allowing variation of type, (2) resistance to decay, and (3) acquisition of process resources.[206][207] These capacities would have functioned by means of the folded configurations of the RNA replicators resulting from their nucleotide sequences.

Carl Zimmer has speculated that the chemical conditions, including the presence of boron, molybdenum and oxygen needed for the initial production of RNA, may have been better on early Mars than on early Earth.[208][209][210] If so, life-suitable molecules originating on Mars may have later migrated to Earth via meteor ejections.

Pre-RNA world

It is possible that a different type of nucleic acid, such as PNA, TNA or GNA, was the first to emerge as a self-reproducing molecule, only later replaced by RNA.[211][212] Larralde *et al.*, say that "the generally accepted prebiotic synthesis of ribose, the formose reaction, yields numerous sugars without any selectivity."[213] and they conclude that their "results suggest

that the backbone of the first genetic material could not have contained ribose or other sugars because of their instability." The ester linkage of ribose and phosphoric acid in RNA is known to be prone to hydrolysis.[214]

Pyrimidine ribonucleosides and their respective nucleotides have been prebiotically synthesized by a sequence of reactions which by-pass the free sugars, and are assembled in a stepwise fashion by using nitrogenous or oxygenous chemistries. Sutherland has demonstrated high yielding routes to cytidine and uridine ribonucleotides built from small 2 and 3 carbon fragments such as glycolaldehyde, glyceraldehyde or glyceraldehyde-3-phosphate, cyanamide and cyanoacetylene. One of the steps in this sequence allows the isolation of enantiopure ribose aminooxazoline if the enantiomeric excess of glyceraldehyde is 60% or greater.[215] This can be viewed as a prebiotic purification step, where the said compound spontaneously crystallized out from a mixture of the other pentose aminooxazolines. Ribose aminooxazoline can then react with cyanoacetylene in a mild and highly efficient manner to give the alpha cytidine ribonucleotide. Photoanomerization with UV light allows for inversion about the 1' anomeric centre to give the correct beta stereochemistry.[216] In 2009 they showed that the same simple building blocks allow access, via phosphate controlled nucleobase elaboration, to 2',3'-cyclic pyrimidine nucleotides directly, which are known to be able to polymerize into RNA. This paper also highlights the possibility for the photo-sanitization of the pyrimidine-2',3'-cyclic phosphates.[217]

Origin of biological metabolism

Metabolism-like reactions could have occurred naturally in early oceans, before the first organisms evolved.[19][218] Metabolism may predate the origin of life, which may have evolved from the chemical conditions in the earliest oceans. Reconstructions in laboratories show that some of these reactions can produce RNA, and some others resemble two essential reaction cascades of metabolism: glycolysis and the pentose phosphate pathway, that provide essential precursors for nucleic acids, amino acids and lipids.[218] A study at the University of Düsseldorf created phylogenic trees based upon 6 million genes from bacteria and archaea, and identified 355 protein families that were probably present in the LUCA. They were based upon an anaerobic metabolism fixing carbon dioxide and nitrogen. It suggests that the LUCA evolved in an environment rich in hydrogen, carbon dioxide and iron.[219] Following are some observed discoveries and related hypotheses.

Iron–sulfur world

In the 1980s, Günter Wächtershäuser, encouraged and supported by Karl R. Popper,[220][221][222] postulated his iron–sulfur world, a theory of the evolution of pre-biotic chemical pathways as the starting point in the evolution of life. It systematically traces today's biochemistry to primordial reactions which provide alternative pathways to the synthesis of organic building blocks from simple gaseous compounds.

In contrast to the classical Miller experiments, which depend on external sources of energy (simulated lightning, ultraviolet irradiation), "Wächtershäuser systems" come with a built-in source of energy: sulfides of iron (iron pyrite) and other minerals. The energy released from redox reactions of these metal sulfides is available for the synthesis of organic molecules, and such systems may have evolved into autocatalytic sets constituting self-replicating, metabolically active entities predating the life forms known today.[19][218] Experiments with such sulfides in an aqueous environment at 100 °C produced a relatively small yield of dipeptides (0.4% to 12.4%) and a smaller yield of tripeptides (0.10%) although under the same conditions, dipeptides were quickly broken down.[223]

Several models reject the self-replication of a "naked-gene", postulating instead the emergence of a primitive metabolism providing a safe environment for the later emergence of RNA replication. The centrality of the Krebs cycle (citric acid cycle) to energy production in aerobic organisms, and in drawing in carbon dioxide and hydrogen ions in biosynthesis of complex organic chemicals, suggests that it was one of the first parts of the metabolism to evolve.[224] Concordantly, geochemist Michael Russell has proposed that "the purpose of life is to hydrogenate carbon dioxide" (as part of a

"metabolism-first," rather than a "genetics-first," scenario).[225][226] Physicist Jeremy England of MIT has proposed that life was inevitable from general thermodynamic considerations: "... when a group of atoms is driven by an external source of energy (like the sun or chemical fuel) and surrounded by a heat bath (like the ocean or atmosphere), it will often gradually restructure itself in order to dissipate increasingly more energy. This could mean that under certain conditions, matter inexorably acquires the key physical attribute associated with life."[227][228]

One of the earliest incarnations of this idea was put forward in 1924 with Oparin's notion of primitive self-replicating vesicles which predated the discovery of the structure of DNA. Variants in the 1980s and 1990s include Wächtershäuser's iron–sulfur world theory and models introduced by Christian de Duve based on the chemistry of thioesters. More abstract and theoretical arguments for the plausibility of the emergence of metabolism without the presence of genes include a mathematical model introduced by Freeman Dyson in the early 1980s and Stuart Kauffman's notion of collectively autocatalytic sets, discussed later that decade.

Orgel summarized his analysis by stating, "There is at present no reason to expect that multistep cycles such as the reductive citric acid cycle will self-organize on the surface of FeS/FeS_2 or some other mineral."[229] It is possible that another type of metabolic pathway was used at the beginning of life. For example, instead of the reductive citric acid cycle, the "open" acetyl-CoA pathway (another one of the five recognized ways of carbon dioxide fixation in nature today) would be compatible with the idea of self-organization on a metal sulfide surface. The key enzyme of this pathway, carbon monoxide dehydrogenase/acetyl-CoA synthase, harbours mixed nickel-iron-sulfur clusters in its reaction centres and catalyzes the formation of acetyl-CoA (similar to acetyl-thiol) in a single step. There are increasing concerns, however, that prebiotic thiolated and thioester compounds are thermodynamically and kinetically unfavourable to accumulate in presumed prebiotic conditions (i.e. hydrothermal vents).[230] It has also been proposed that cysteine and homocysteine may have reacted with nitriles resulting from the Stecker reaction, readily forming catalytic thiol-reach poplypeptides.[231]

Zn-world hypothesis

The Zn-world (zinc world) theory of Armen Y. Mulkidjanian[232] is an extension of Wächtershäuser's pyrite hypothesis. Wächtershäuser based his theory of the initial chemical processes leading to informational molecules (RNA, peptides) on a regular mesh of electric charges at the surface of pyrite that may have facilitated the primeval polymerization by attracting reactants and arranging them appropriately relative to each other.[233] The Zn-world theory specifies and differentiates further.[232][234] Hydrothermal fluids rich in H_2S interacting with cold primordial ocean (or Darwin's "warm little pond") water leads to the precipitation of metal sulfide particles. Oceanic vent systems and other hydrothermal systems have a zonal structure reflected in ancient volcanogenic massive sulfide deposits (VMS) of hydrothermal origin. They reach many kilometres in diameter and date back to the Archean Eon. Most abundant are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and sphalerite (ZnS), with additions of galena (PbS) and alabandite (MnS). ZnS and MnS have a unique ability to store radiation energy, e.g. from UV light. During the relevant time window of the origins of replicating molecules, the primordial atmospheric pressure was high enough (>100 bar, about 100 atmospheres) to precipitate near the Earth's surface, and UV irradiation was 10 to 100 times more intense than now; hence the unique photosynthetic properties mediated by ZnS provided just the right energy conditions to energize the synthesis of informational and metabolic molecules and the selection of photostable nucleobases.

The Zn-world theory has been further filled out with experimental and theoretical evidence for the ionic constitution of the interior of the first proto-cells before archaea, bacteria and proto-eukaryotes evolved. Archibald Macallum noted the resemblance of body fluids such as blood and lymph to seawater;[235] however, the inorganic composition of all cells differ from that of modern seawater, which led Mulkidjanian and colleagues to reconstruct the "hatcheries" of the first cells combining geochemical analysis with phylogenomic scrutiny of the inorganic ion requirements of universal components of modern cells. The authors conclude that ubiquitous, and by inference primordial, proteins and functional systems show

affinity to and functional requirement for K^+, Zn^{2+}, Mn^{2+}, and phosphate. Geochemical reconstruction shows that the ionic composition conducive to the origin of cells could not have existed in what we today call marine settings but is compatible with emissions of vapour-dominated zones of what we today call inland geothermal systems. Under the oxygen depleted, CO_2-dominated primordial atmosphere, the chemistry of water condensates and exhalations near geothermal fields would resemble the internal milieu of modern cells. Therefore, the precellular stages of evolution may have taken place in shallow "Darwin ponds" lined with porous silicate minerals mixed with metal sulfides and enriched in K^+, Zn^{2+}, and phosphorus compounds.[236][237]

Deep sea vent hypothesis

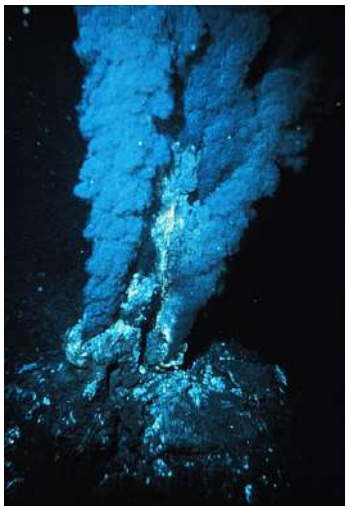
Deep-sea hydrothermal vent or black smoker

The deep sea vent, or alkaline hydrothermal vent, theory posits that life may have begun at submarine hydrothermal vents,[238][239] William Martin and Michael Russell have suggested "that life evolved in structured iron monosulphide precipitates in a seepage site hydrothermal mound at a redox, pH, and temperature gradient between sulphide-rich hydrothermal fluid and iron(II)-containing waters of the Hadean ocean floor. The naturally arising, three-dimensional compartmentation observed within fossilized seepage-site metal sulphide precipitates indicates that these inorganic compartments were the precursors of cell walls and membranes found in free-living prokaryotes. The known capability of FeS and NiS to catalyze the synthesis of the acetyl-methylsulphide from carbon monoxide and methylsulphide, constituents of hydrothermal fluid, indicates that pre-biotic syntheses occurred at the inner surfaces of these metal-sulphide-walled compartments,..."[240] These form where hydrogen-rich fluids emerge from below the sea floor, as a result of serpentinization of ultra-mafic olivine with seawater and a pH interface with carbon dioxide-rich ocean water. The vents form a sustained chemical energy source derived from redox reactions, in which electron donors (molecular hydrogen) react with electron acceptors (carbon dioxide); see Iron–sulfur world theory. These are highly exothermic reactions.[238][note 3]

Michael Russell demonstrated that alkaline vents created an abiogenic proton motive force (PMF) chemiosmotic gradient,[240] in which conditions are ideal for an abiogenic hatchery for life. Their microscopic compartments "provide a natural means of concentrating organic molecules," composed of iron-sulfur minerals such as mackinawite, endowed these mineral cells with the catalytic properties envisaged by Wächtershäuser.[224] This movement of ions across the membrane depends on a combination of two factors:

1. Diffusion force caused by concentration gradient—all particles including ions tend to diffuse from higher concentration to lower.
2. Electrostatic force caused by electrical potential gradient—cations like protons H^+ tend to diffuse down the electrical potential, anions in the opposite direction.

These two gradients taken together can be expressed as an electrochemical gradient, providing energy for abiogenic synthesis. The proton motive force can be described as the measure of the potential energy stored as a combination of proton and voltage gradients across a membrane (differences in proton concentration and electrical potential).

Jack W. Szostak suggested that geothermal activity provides greater opportunities for the origination of life in open lakes where there is a buildup of minerals. In 2010, based on spectral analysis of sea and hot mineral water, Ignat Ignatov and Oleg Mosin demonstrated that life may have predominantly originated in hot mineral water. The hot mineral water that contains bicarbonate and calcium ions has the most optimal range.[241] This case is similar to the origin of life in hydrothermal vents, but with bicarbonate and calcium ions in hot water. This water has a pH of 9–11 and is possible to have the reactions in seawater. According to Melvin Calvin, certain reactions of condensation-dehydration of amino acids

and nucleotides in individual blocks of peptides and nucleic acids can take place in the primary hydrosphere with pH 9-11 at a later evolutionary stage.[242] Some of these compounds like hydrocyanic acid (HCN) have been proven in the experiments of Miller. This is the environment in which the stromatolites have been created. David Ward of Montana State University described the formation of stromatolites in hot mineral water at the Yellowstone National Park. Stromatolites survive in hot mineral water and in proximity to areas with volcanic activity.[243] Processes have evolved in the sea near geysers of hot mineral water. In 2011, Tadashi Sugawara from the University of Tokyo created a protocell in hot water.[244]

Experimental research and computer modelling suggest that the surfaces of mineral particles inside hydrothermal vents have catalytic properties similar to those of enzymes and are able to create simple organic molecules, such as methanol (CH_3OH) and formic, acetic and pyruvic acid out of the dissolved CO_2 in the water.[245][246]

The research reported above by William F. Martin in July 2016 supports the thesis that life arose at hydrothermal vents,[247][248] that spontaneous chemistry in the Earth's crust driven by rock–water interactions at disequilibrium thermodynamically underpinned life's origin[249][250] and that the founding lineages of the archaea and bacteria were H2-dependent autotrophs that used CO2 as their terminal acceptor in energy metabolism.[251] Martin suggests, based upon this evidence that LUCA "may have depended heavily on the geothermal energy of the vent to survive".[252]

Thermosynthesis

Today's bioenergetic process of fermentation is carried out by either the aforementioned citric acid cycle or the Acetyl-CoA pathway, both of which have been connected to the primordial Iron–sulfur world. In a different approach, the thermosynthesis hypothesis considers the bioenergetic process of chemiosmosis, which plays an essential role in cellular respiration and photosynthesis, more basal than fermentation: the ATP synthase enzyme, which sustains chemiosmosis, is proposed as the currently extant enzyme most closely related to the first metabolic process.[253][254]

First, life needed an energy source to bring about the condensation reaction that yielded the peptide bonds of proteins and the phosphodiester bonds of RNA. In a generalization and thermal variation of the binding change mechanism of today's ATP synthase, the "first protein" would have bound substrates (peptides, phosphate, nucleosides, RNA 'monomers') and condensed them to a reaction product that remained bound until after a temperature change it was released by thermal unfolding.

The energy source under the thermosynthesis hypothesis was thermal cycling, the result of suspension of protocells in a convection current, as is plausible in a volcanic hot spring; the convection accounts for the self-organization and dissipative structure required in any origin of life model. The still ubiquitous role of thermal cycling in germination and cell division is considered a relic of primordial thermosynthesis.

By phosphorylating cell membrane lipids, this "first protein" gave a selective advantage to the lipid protocell that contained the protein. This protein also synthesized a library of many proteins, of which only a minute fraction had thermosynthesis capabilities. As proposed by Dyson,[13] it propagated functionally: it made daughters with similar capabilities, but it did not copy itself. Functioning daughters consisted of different amino acid sequences.

Whereas the Iron–sulfur world identifies a circular pathway as the most simple, the thermosynthesis hypothesis does not even invoke a pathway: ATP synthase's binding change mechanism resembles a physical adsorption process that yields free energy,[255] rather than a regular enzyme's mechanism, which decreases the free energy. It has been claimed that the emergence of cyclic systems of protein catalysts is implausible.[256]

Other models

Clay hypothesis

Montmorillonite, an abundant clay, is a catalyst for the polymerization of RNA and for the formation of membranes from lipids.[257] A model for the origin of life using clay was forwarded by Alexander Graham Cairns-Smith in 1985 and explored as a plausible mechanism by several scientists.[258] The clay hypothesis postulates that complex organic molecules arose gradually on pre-existing, non-organic replication surfaces of silicate crystals in solution.

At the Rensselaer Polytechnic Institute, James P. Ferris' studies have also confirmed that clay minerals of montmorillonite catalyze the formation of RNA in aqueous solution, by joining nucleotides to form longer chains.[259]

In 2007, Bart Kahr from the University of Washington and colleagues reported their experiments that tested the idea that crystals can act as a source of transferable information, using crystals of potassium hydrogen phthalate. "Mother" crystals with imperfections were cleaved and used as seeds to grow "daughter" crystals from solution. They then examined the distribution of imperfections in the new crystals and found that the imperfections in the mother crystals were reproduced in the daughters, but the daughter crystals also had many additional imperfections. For gene-like behaviour to be observed, the quantity of inheritance of these imperfections should have exceeded that of the mutations in the successive generations, but it did not. Thus Kahr concluded that the crystals "were not faithful enough to store and transfer information from one generation to the next."[260]

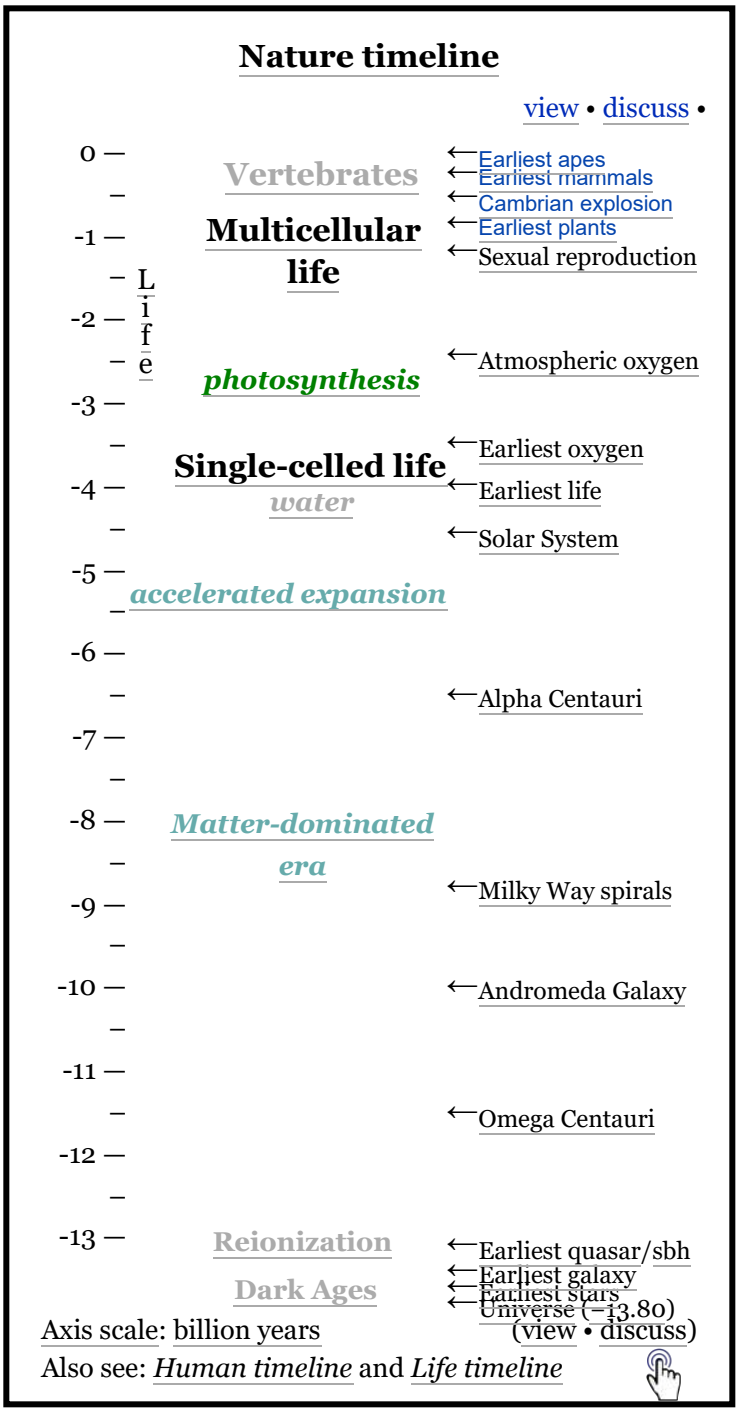

Gold's "deep-hot biosphere" model

In the 1970s, Thomas Gold proposed the theory that life first developed not on the surface of the Earth, but several kilometres below the surface. It is claimed that discovery of microbial life below the surface of another body in our Solar System would lend significant credence to this theory. Thomas Gold also asserted that a trickle of food from a deep, unreachable, source is needed for survival because life arising in a puddle of organic material is likely to consume all of its food and become extinct. Gold's theory is that the flow of such food is due to out-gassing of primordial methane from the Earth's mantle; more conventional explanations of the food supply of deep microbes (away from sedimentary carbon compounds) is that the organisms subsist on hydrogen released by an interaction between water and (reduced) iron compounds in rocks.

Panspermia

Panspermia is the hypothesis that life exists throughout the universe, distributed by meteoroids, asteroids, comets,[261] planetoids,[262] and, also, by spacecraft in the form of unintended contamination by microorganisms.[263][264]

The panspermia hypothesis does not attempt to explain how life first originated, but merely shifts it to another planet or a comet. The advantage of an extraterrestrial origin of primitive life is that life is not required to have formed on each planet it occurs on, but rather in a single location, and then spread about the galaxy to other star systems via cometary and/or meteorite impact.[265] Evidence to support the hypothesis is scant, but it finds support in studies of Martian meteorites found in Antarctica and in studies of extremophile microbes' survival in outer space tests.[266][267][268][269] (See also: List of microorganisms tested in outer space.)

Extraterrestrial organic molecules

An organic compound is any member of a large class of gaseous, liquid, or solid chemicals whose molecules contain carbon. Carbon is the fourth most abundant element in the Universe by mass after hydrogen, helium, and oxygen.[270] Carbon is abundant in the Sun, stars, comets, and in the atmospheres of most planets.[271] Organic compounds are relatively common in space, formed by "factories of complex molecular synthesis" which occur in molecular clouds and circumstellar envelopes, and chemically evolve after reactions are initiated mostly by ionizing radiation.[20][272][273][274] Based on computer model studies, the complex organic molecules necessary for life may have formed on dust grains in the protoplanetary disk surrounding the Sun before the formation of the Earth.[124] According to the computer studies, this same process may also occur around other stars that acquire planets.[124]

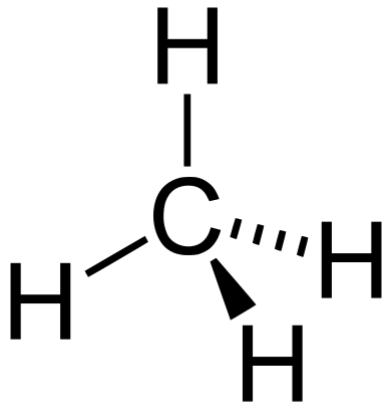

Methane is one of the simplest organic compounds

Observations suggest that the majority of organic compounds introduced on Earth by interstellar dust particles are considered principal agents in the formation of complex molecules, thanks to their peculiar surface-catalytic activities.[275][276] Studies reported in 2008, based on $^{12}C/^{13}C$ isotopic ratios of organic compounds found in the Murchison meteorite, suggested that the RNA component uracil and related molecules, including xanthine, were formed extraterrestrially.[277][278] On 8 August 2011, a report based on NASA studies of meteorites found on Earth was published suggesting DNA components (adenine, guanine and related organic molecules) were made in outer space.[275][279][280] Scientists also found that the cosmic dust permeating the universe contains complex organics ("amorphous organic solids with a mixed aromatic–aliphatic structure") that could be created naturally, and rapidly, by stars.[281][282][283] Sun Kwok of The University of Hong Kong suggested that these compounds may have been related to the development of life on Earth said that "If this is the case, life on Earth may have had an easier time getting started as these organics can serve as basic ingredients for life."[281]

Glycolaldehyde, the first example of an interstellar sugar molecule, was detected in the star-forming region near the centre of our galaxy. It was discovered in 2000 by Jes Jørgensen and Jan M. Hollis.[284] In 2012, Jørgensen's team reported the detection of glycolaldehyde in a distant star system. The molecule was found around the protostellar binary IRAS 16293-2422 400 light years from Earth.[285][286][287] Glycolaldehyde is needed to form RNA, which is similar in function to DNA. These findings suggest that complex organic molecules may form in stellar systems prior to the formation of planets, eventually arriving on young planets early in their formation.[288] Because sugars are associated with both metabolism and the genetic code, two of the most basic aspects of life, it is thought the discovery of extraterrestrial sugar increases the likelihood that life may exist elsewhere in our galaxy.[284]

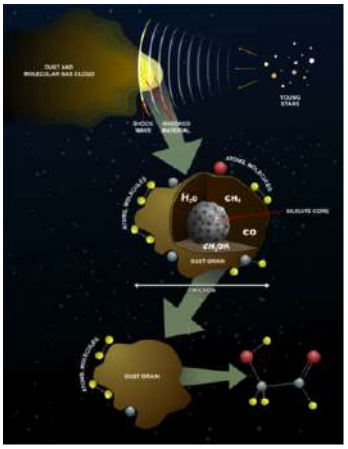

Formation of glycolaldehyde in stardust

NASA announced in 2009 that scientists had identified another fundamental chemical building block of life in a comet for the first time, glycine, an amino acid, which was detected in material ejected from comet Wild 2 in 2004 and grabbed by NASA's *Stardust* probe. Glycine has been detected in meteorites before. Carl Pilcher, who leads the NASA Astrobiology Institute commented that "The discovery of glycine in a comet supports the idea that the fundamental building blocks of life are prevalent in space, and strengthens the argument that life in the universe may be common rather than rare."[289] Comets are encrusted with outer layers of dark material, thought to be a tar-like substance composed of complex organic material formed from simple carbon compounds after reactions initiated mostly by ionizing radiation. It is possible that a rain of material from comets could have brought significant quantities of such complex organic molecules to Earth.[290][291][292] Amino acids which were formed extraterrestrially may also have arrived on Earth via comets.[49] It is estimated that during the Late Heavy Bombardment, meteorites may have delivered up to five million tons of organic prebiotic elements to Earth per year.[49]

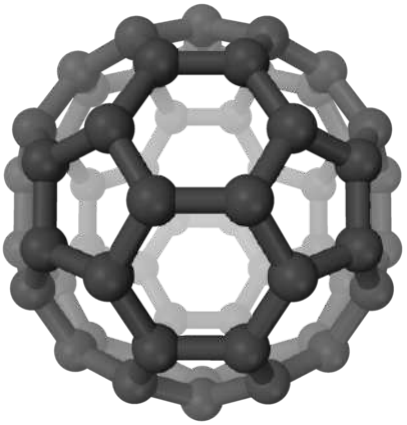

The C_{60} buckyball is a complex molecule that has been detected in nebulae.

Polycyclic aromatic hydrocarbons (PAH) are the most common and abundant of the known polyatomic molecules in the observable universe, and are considered a likely constituent of the primordial sea.[293][294][295] In 2010, PAHs, along with fullerenes (or "buckyballs"), have been detected in nebulae.[296][297] In March 2015, NASA scientists reported that, for the first time, complex DNA and RNA organic compounds of life, including uracil, cytosine and thymine, have been formed in the laboratory under outer space conditions, using starting chemicals, such as pyrimidine, found in meteorites. Pyrimidine, like PAHs, the most carbon-rich chemical found in the Universe, may have been formed in red giant stars or in interstellar dust and gas clouds.[298] A group of Czech scientists reported that all four RNA-bases may be synthesized from formamide in the course of high-energy density events like extraterrestrial impacts.[299]

Lipid world

The lipid world theory postulates that the first self-replicating object was lipid-like.[300][301] It is known that phospholipids form lipid bilayers in water while under agitation—the same structure as in cell membranes. These molecules were not present on early Earth, but other amphiphilic long-chain molecules also form membranes. Furthermore, these bodies may expand (by insertion of additional lipids), and under excessive expansion may undergo spontaneous splitting which preserves the same size and composition of lipids in the two progenies. The main idea in this theory is that the molecular composition of the lipid bodies is the preliminary way for information storage, and evolution led to the appearance of polymer entities such as RNA or DNA that may store information favourably. Studies on vesicles from potentially prebiotic amphiphiles have so far been limited to systems containing one or two types of amphiphiles. This in contrast to the output of simulated prebiotic chemical reactions, which typically produce very heterogeneous mixtures of compounds.[177] Within the hypothesis of a lipid bilayer membrane composed of a mixture of various distinct amphiphilic compounds there is the opportunity of a huge number of theoretically possible combinations in the arrangements of these amphiphiles in the membrane. Among all these potential combinations, a specific local arrangement of the membrane would have favoured the constitution of a hypercycle,[302][303] actually a positive feedback composed of two mutual catalysts represented by a

membrane site and a specific compound trapped in the vesicle. Such site/compound pairs are transmissible to the daughter vesicles leading to the emergence of distinct lineages of vesicles which would have allowed Darwinian natural selection.[304]

Polyphosphates

A problem in most scenarios of abiogenesis is that the thermodynamic equilibrium of amino acid versus peptides is in the direction of separate amino acids. What has been missing is some force that drives polymerization. The resolution of this problem may well be in the properties of polyphosphates.[305][306] Polyphosphates are formed by polymerization of ordinary monophosphate ions PO_4^{-3}. Several mechanisms of organic molecule synthesis have been investigated. Polyphosphates cause polymerization of amino acids into peptides. They are also logical precursors in the synthesis of such key biochemical compounds as adenosine triphosphate (ATP). A key issue seems to be that calcium reacts with soluble phosphate to form insoluble calcium phosphate (apatite), so some plausible mechanism must be found to keep calcium ions from causing precipitation of phosphate. There has been much work on this topic over the years, but an interesting new idea is that meteorites may have introduced reactive phosphorus species on the early Earth.[307]

PAH world hypothesis

Polycyclic aromatic hydrocarbons (PAH) are known to be abundant in the universe,[293][294][295] including in the interstellar medium, in comets, and in meteorites, and are some of the most complex molecules so far found in space.[271]

The Cat's Paw Nebula lies inside the Milky Way Galaxy and is located in the constellation Scorpius.
Green areas show regions where radiation from hot stars collided with large molecules and small dust grains called "polycyclic aromatic hydrocarbons" (PAHs), causing them to fluoresce. (Spitzer space telescope, 2018)

Other sources of complex molecules have been postulated, including extraterrestrial stellar or interstellar origin. For example, from spectral analyses, organic molecules are known to be present in comets and meteorites. In 2004, a team detected traces of PAHs in a nebula.[308] In 2010, another team also detected PAHs, along with fullerenes, in nebulae.[296] The use of PAHs has also been proposed as a precursor to the RNA world in the PAH world hypothesis. The Spitzer Space Telescope has detected a star, HH 46-IR, which is forming by a process similar to that by which the Sun formed. In the disk of material surrounding the star, there is a very large range of molecules, including cyanide compounds, hydrocarbons, and carbon monoxide. In September 2012, NASA scientists reported that PAHs, subjected to interstellar medium conditions, are transformed, through hydrogenation, oxygenation and hydroxylation, to more complex organics—"a step along the path toward amino acids and nucleotides, the raw materials of proteins and DNA, respectively."[309][310] Further, as a result of these transformations, the PAHs lose their spectroscopic signature which could be one of the reasons "for the lack of PAH detection in interstellar ice grains, particularly the outer regions of cold, dense clouds or the upper molecular layers of protoplanetary disks."[309][310]

NASA maintains a database for tracking PAHs in the universe.[271][311] More than 20% of the carbon in the universe may be associated with PAHs,[271][271] possible starting materials for the formation of life. PAHs seem to have been formed shortly after the Big Bang, are widespread throughout the universe,[293][294][295] and are associated with new stars and exoplanets.[271]

Radioactive beach hypothesis

Zachary Adam claims that tidal processes that occurred during a time when the Moon was much closer may have concentrated grains of uranium and other radioactive elements at the high-water mark on primordial beaches, where they may have been responsible for generating life's building blocks.[312] According to computer models,[313] a deposit of such radioactive materials could show the same self-sustaining nuclear reaction as that found in the Oklo uranium ore seam in Gabon. Such radioactive beach sand might have provided sufficient energy to generate organic molecules, such as amino acids and sugars from acetonitrile in water. Radioactive monazite material also has released soluble phosphate into the regions between sand-grains, making it biologically "accessible." Thus amino acids, sugars, and soluble phosphates might have been produced simultaneously, according to Adam. Radioactive actinides, left behind in some concentration by the reaction, might have formed part of organometallic complexes. These complexes could have been important early catalysts to living processes.

John Parnell has suggested that such a process could provide part of the "crucible of life" in the early stages of any early wet rocky planet, so long as the planet is large enough to have generated a system of plate tectonics which brings radioactive minerals to the surface. As the early Earth is thought to have had many smaller plates, it might have provided a suitable environment for such processes.[314]

Thermodynamic dissipation

The 19th-century Austrian physicist Ludwig Boltzmann first recognized that the struggle for existence of living organisms was neither over raw material nor energy, but instead had to do with entropy production derived from the conversion of the solar spectrum into heat by these systems.[315] Boltzmann thus realized that living systems, like all irreversible processes, were dependent on the dissipation of a generalized chemical potential for their existence. In his book "What is Life", the 20th-century Austrian physicist Erwin Schrödinger[316] emphasized the importance of Boltzmann's deep insight into the irreversible thermodynamic nature of living systems, suggesting that this was the physics and chemistry behind the origin and evolution of life. However, irreversible processes, and much less living systems, could not be conveniently analyzed under this perspective until Lars Onsager,[317] and later Ilya Prigogine,[318] developed an elegant mathematical formalism for treating the "self-organization" of material under a generalized chemical potential. This formalism became known as Classical Irreversible Thermodynamics and Prigogine was awarded the Nobel Prize in Chemistry in 1977 "for his contributions to non-equilibrium thermodynamics, particularly the theory of dissipative structures". The analysis of Prigogine showed that if a system were left to evolve under an imposed external potential, material could spontaneously organize (lower its entropy) forming what he called "dissipative structures" which would increase the dissipation of the externally imposed potential (augment the global entropy production). Non-equilibrium thermodynamics has since been successfully applied to the analysis of living systems, from the biochemical production of ATP [319] to optimizing bacterial metabolic pathways [320] to complete ecosystems.[321][322][323]

In his "Thermodynamic Dissipation Theory of the Origin and Evolution of Life",[324][325][326][327] Karo Michaelian has taken the insight of Boltzmann and the work of Prigogine to its ultimate consequences regarding the origin of life. This theory postulates that the hallmark of the origin and evolution of life is the microscopic dissipative structuring of organic pigments and their proliferation over the entire Earth surface.[327] Present day life augments the entropy production of Earth in its solar environment by dissipating ultraviolet and visible photons into heat through organic pigments in water. This heat then catalyzes a host of secondary dissipative processes such as the water cycle, ocean and wind currents, hurricanes, etc.[325][328] Michaelian argues that if the thermodynamic function of life today is to produce entropy through photon dissipation in organic pigments, then this probably was its function at its very beginnings. It turns out that both RNA and DNA when in water solution are very strong absorbers and extremely rapid dissipaters of ultraviolet light within the 230–290 nm wavelength (UV-C) region, which is a part of the Sun's spectrum that could have penetrated the prebiotic atmosphere.[329] In fact, not only RNA and DNA, but many fundamental molecules of life (those common to all three

domains of life) are also pigments that absorb in the UV-C, and many of these also have a chemical affinity to RNA and DNA.[330][331] Nucleic acids may thus have acted as acceptor molecules to the UV-C photon excited antenna pigment donor molecules by providing an ultrafast channel for dissipation. Michaelian has shown using the formalism of non-linear irreversible thermodynamics that there would have existed during the Archean a thermodynamic imperative to the abiogenic UV-C photochemical synthesis and proliferation of these pigments over the entire Earth surface if they acted as catalysts to augment the dissipation of the solar photons.[332] By the end of the Archean, with life-induced ozone dissipating UV-C light in the Earth's upper atmosphere, it would have become ever more improbable for a completely new life to emerge that didn't rely on the complex metabolic pathways already existing since now the free energy in the photons arriving at Earth's surface would have been insufficient for direct breaking and remaking of covalent bonds. It has been suggested, however, that such changes in the surface flux of ultraviolet radiation due to geophysical events affecting the atmosphere could have been what promoted the development of complexity in life based on existing metabolic pathways, for example during the Cambrian explosion [333]

Many salient characteristics of the fundamental molecules of life (those found in all three domains) all point directly to the involvement of UV-C light in the dissipative structuring of incipient life.[326] Some of the most difficult problems concerning the origin of life, such as enzyme-less replication of RNA and DNA, homochirality of the fundamental molecules, and the origin of information encoding in RNA and DNA, also find an explanation within the same dissipative thermodynamic framework by considering the probable existence of a relation between primordial replication and UV-C photon dissipation. Michaelian suggests that it is erroneous to expect to describe the emergence, proliferation, or even evolution, of life without overwhelming reference to entropy production through the dissipation of a generalized chemical potential, in particular, the prevailing solar photon flux.

Multiple genesis

Different forms of life with variable origin processes may have appeared quasi-simultaneously in the early history of Earth.[334] The other forms may be extinct (having left distinctive fossils through their different biochemistry—e.g., hypothetical types of biochemistry). It has been proposed that:

> The first organisms were self-replicating iron-rich clays which fixed carbon dioxide into oxalic and other dicarboxylic acids. This system of replicating clays and their metabolic phenotype then evolved into the sulfide rich region of the hotspring acquiring the ability to fix nitrogen. Finally phosphate was incorporated into the evolving system which allowed the synthesis of nucleotides and phospholipids. If biosynthesis recapitulates biopoiesis, then the synthesis of amino acids preceded the synthesis of the purine and pyrimidine bases. Furthermore the polymerization of the amino acid thioesters into polypeptides preceded the directed polymerization of amino acid esters by polynucleotides.[335]

Fluctuating hydrothermal pools on volcanic islands or proto-continents

Armid Mulkidjanian and co-authors think that the marine environments did not provide the ionic balance and composition universally found in cells, as well as of ions required by essential proteins and ribozymes found in virtually all living organisms, especially with respect to K^+/Na^+ ratio, Mn^{2+}, Zn^{2+} and phosphate concentrations. The only known environments that mimic the needed conditions on Earth are found in terrestrial hydrothermal pools fed by steam vents.[238] Additionally, mineral deposits in these environments under an anoxic atmosphere would have suitable pH (as opposed to current pools in an oxygenated atmosphere), contain precipitates of sulfide minerals that block harmful UV radiation, have wetting/drying cycles that concentrate substrate solutions to concentrations amenable to spontaneous formation of polymers of nucleic acids, polyesters[336] and depsipeptides,[337] both by chemical reactions in the

hydrothermal environment, as well as by exposure to UV light during transport from vents to adjacent pools. Their hypothesized pre-biotic environments are similar to the deep-oceanic vent environments most commonly hypothesized, but add additional components that help explain peculiarities found in reconstructions of the Last Universal Common Ancestor (LUCA) of all living organisms.[338]

Bruce Damer and David Deamer have come to the conclusion that cell membranes cannot be formed in salty seawater, and must therefore have originated in freshwater. Before the continents formed, the only dry land on Earth would be volcanic islands, where rainwater would form ponds where lipids could form the first stages towards cell membranes. These predecessors of true cells are assumed to have behaved more like a superorganism rather than individual structures, where the porous membranes would house molecules which would leak out and enter other protocells. Only when true cells had evolved would they gradually adapt to saltier environments and enter the ocean.[339]

Colín-García *et al.* (2016) discuss the advantages and disadvantages of hydrothermal vents as primitive environments.[238] They mention the exergonic reactions in such systems could have been a source of free energy that promoted chemical reactions, additional to their high mineralogical diversity which implies the induction of important chemical gradients, thus favoring the interaction between electron donors and acceptors. Colín-García *et al.* (2016) also summarize a set of experiments proposed to test the role of hydrothermal vents in prebiotic synthesis.[238]

Information theory

A theory that speaks to the origin of life on Earth and other rocky planets posits life as an information system in which information content grows because of selection. Life must start with minimum possible information, or minimum possible departure from thermodynamic equilibrium, and it requires thermodynamically free energy accessible by means of its information content. The most benign circumstances, minimum entropy variations with abundant free energy, suggest the pore space in the first few kilometres of the surface. Free energy is derived from the condensed products of the chemical reactions taking place in the cooling nebula.[340]

See also

- Anthropic principle
- Artificial cell
- Artificial life
- Astrochemistry
- Biological immortality
- Carbon Mineral Challenge
- Common descent
- Entropy and life
- Formamide-based prebiotic chemistry
- GADV protein world
- Mediocrity principle
- Mycoplasma laboratorium
- Nexus for Exoplanet System Science
- Noogenesis
- Planetary habitability
- Rare Earth hypothesis
- Shadow biosphere
- Tholin

Notes

1. Also occasionally called biopoiesis.
2. The reactions are:

   $FeS + H_2S \rightarrow FeS_2 + 2H^+ + 2e^-$
   $FeS + H_2S + CO_2 \rightarrow FeS_2 + HCOOH$

3. The reactions are:
   Reaction 1: Fayalite + water → magnetite + aqueous silica + hydrogen

OPINION

A new perspective on radiation resistance based on *Deinococcus radiodurans*

Michael J. Daly

Abstract | In classical models of radiation toxicity, DNA is the molecule that is most affected by ionizing radiation (IR). However, recent data show that the amount of protein damage caused during irradiation of bacteria is better related to survival than to DNA damage. In this Opinion article, a new model is presented in which proteins are the most important target in the hierarchy of macromolecules affected by IR. A first line of defence against IR in extremely radiation-resistant bacteria might be the accumulation of manganese complexes, which can prevent the production of iron-dependent reactive oxygen species. This would allow an irradiated cell to protect sufficient enzymatic activity needed to repair DNA and survive.

One early goal of radiobiology was to explain why most organisms are so sensitive to X-rays and γ-rays. A whole-body exposure of just 10 Gy (gray; absorbed radiation dose) is lethal to most vertebrate animals, including humans[1], and most bacteria[1] cannot survive 200 Gy. Invertebrate animals are more resistant if the adult form has no somatic cell division (for example, fruit flies, which are largely post-mitotic)[2], and can survive 500 Gy. The freshwater invertebrate animal *Philodina roseola*[3], the water bear *Milnesium tardigradum*[4] and the roundworm *Caenorhabditis elegans*[5] can tolerate 3,000–5000 Gy, but are rendered sterile. As a haploid, the basidiomycete fungus *Ustilago maydis* carries a single set of chromosomes per cell in the G2 phase (after its chromosomes have been duplicated but before cell division) and can withstand ~3,600 Gy[6]. The archaeal species *Pyrococcus furiosus*[7] and *Halobacterium* sp. NRC-1 (REF. 8) can resist ~3,000 and ~5,000 Gy, respectively, whereas some bacteria from the *Deinococcus–Thermus* group can survive doses of more than 12,000 Gy[9]. Perhaps if we knew why some cells are so resistant to radiation, we could find ways to protect people from atomic radiation.

In the 1950s, DNA, lipids and proteins were proposed to be the main targets of ionizing radiation (IR) in cells. By the mid 1960s, 'death by DNA damage' became the predominant paradigm of radiation toxicity[10]. In the decades that followed, radiation biologists attempted to explain the extreme IR resistance of radioresistant organisms that can withstand extraordinary genome fragmentation and DNA base damage. This damage is caused by reactive oxygen species (ROS), the chemical agents that are principally responsible for cellular radiation damage[11] (BOX 1).

Because the fate of an irradiated cell ultimately depends on whether its genome is preserved, most studies have focused on how DNA that is damaged during irradiation is repaired[11–14]. DNA double-strand breaks (DSBs) are presumed to be the most lethal damage, although they are significantly less frequent than single-strand breaks (SSBs) and DNA base damages. IR damage that affects only one strand (for example, SSBs or damage to DNA bases) can be repaired using the undamaged complementary strand as a template, but DSBs provide little guidance for mending without mutagenesis, as neither of the two strands is intact. Non-mutagenic repair of DSBs is dependent on the presence of at least two sets of chromosomes per cell[12–15], although genome multiplicity by itself is insufficient for radioresistance. For example, *Escherichia coli* contains 4–8 haploid genomes per cell during exponential growth but cannot survive 200 Gy, which causes approximately 4 DSBs per haploid genome[14]. Because the linear density of genomic DSBs inflicted per Gy per Mbp (0.004–0.01) is similar for diverse organisms[3,9,12,16–18], during irradiation, cells with small genomes suffer fewer DSBs than cells with large genomes. For example, an acute dose of 1,000 Gy that inflicts ~30 DSBs in a 3 Mbp chromosome would be expected to inflict ~150 DSBs in a 15 Mbp chromosome. Therefore, cell survival would be predicted to decline as genome size increases, but significantly improve as ploidy increases to more than two. A similar result emerged for radiation-induced DNA base damage: the differences in base lesion yields for resistant and sensitive bacteria exposed to ultraviolet C (UVC) radiation (265 nm) or γ-rays were not nearly sufficient to account for the differences in bacterial survival[19,20].

UVC causes substantial direct damage to both DNA and proteins *in vivo*[19]. For proteins, UVC disrupts certain types of disulphide bonds and causes protein aggregation[21]. Antioxidants can increase the survival of cells exposed to UVC[21]. Thus, although cellular macromolecules are clearly not protected from direct damage caused by either UVC[19] or IR[9,16], any antioxidants in the cells would also be expected to help avert ROS-mediated toxicity that is secondary to the radiation itself; for example, caused by damaged proteins involved in energy metabolism[22]. Irradiated *Deinococcus radiodurans* is predicted to rid itself of damaged proteins using an expanded family of subtilisin-like proteases[23] that are expected to be highly expressed.

Radiation-resistant organisms suffer from similar levels of genomic damage following irradiation as sensitive organisms, but they can survive the formation of hundreds of IR-induced DSBs per genome[3,9,12,14,16–18]. The first reports of homologous recombination in an extremely IR-resistant organism

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14. ABSTRACT

In classical models of radiation toxicity, DNA is the molecule that is most affected by ionizing radiation (IR). However, recent data show that the amount of protein damage caused during irradiation of bacteria is better related to survival than to DNA damage. In this Opinion article, a new model is presented in which proteins are the most important target in the hierarchy of macromolecules affected by IR. A first line of defence against IR in extremely radiation-resistant bacteria might be the accumulation of manganese complexes, which can prevent the production of iron-dependent reactive oxygen species. This would allow an irradiated cell to protect sufficient enzymatic activity needed to repair DNA and survive.

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Box 1 | **Primary reactive oxygen species generated and their cellular targets**

H_2O is the most abundant chemical found in living cells. The primary source of reactive oxygen species (ROS) generated in irradiated cells is the radiolysis of H_2O, which generates $HO^•$, H^+ and e^-_{aq} (REFS 11,69) (see the figure, Equation 1). $HO^•$ radicals react with each other to generate H_2O_2 (REFS 11,69) (see the figure, Equation 2), which can diffuse throughout the cell[11,34]. Dissolved O_2, either derived from the atmosphere or generated endogenously, reacts with e^-_{aq} to form $O_2^{•-}$ (REFS 11,34,69) (see the figure, Equation 3), which can reform H_2O_2 in the presence of H^+ (REF. 69) (see the figure, Equations 4 and 5). Whereas H_2O_2 and $O_2^{•-}$ are relatively inert, $HO^•$ are extremely oxidizing, indiscriminately reacting with organic molecules and oxidizing DNA, RNA, lipids and proteins[11,34]. However, the short lifetime of the $HO^•$ precludes damage to molecules beyond a few Angstroms from where $HO^•$ is formed. For DNA, as the dose of ionizing radiation (IR) increases, the linear density of base damages and single strand breaks (SSBs) increases on both strands, which gives rise to double-strand breaks (DSBs). In addition to the widespread 'indirect damage' caused in cells by IR-induced ROS, IR also can inflict 'direct damage' when macromolecules absorb X-ray and γ-ray photons[11]. A dose of IR typically causes 40 times more SSBs than DSBs[9,11]. A secondary source of $HO^•$ in cells during irradiation is the Fenton reaction, which is one of the most powerful oxidizing reactions known and involves the catalytic decomposition of H_2O_2 by ferrous ions ($H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^- + HO^•$)[61] (FIG. 3); the analogous reaction with Mn(II) does not occur[51]. In contrast to $HO^•$, the reactivity of $O_2^{•-}$ is high only for selected targets: small inorganic prosthetic Fe–S groups of some proteins[57,61]. The damaging potential of $O_2^{•-}$ is greater than that of H_2O_2 for Fe–S groups because $O_2^{•-}$ is negatively charged.

Sources of ionizing radiation

- Radionuclides (for example, ^{235}U (γ and α)[E], ^{137}Cs (γ and β^-)[E] and ^{60}Co (γ and β^-)[E])
- Cosmos (for example, stars and γ-ray bursts)
- Medical procedures (for example, computerized axial tomography (CAT) scans and radiotherapies)

γ-rays and X-rays

Representative primary radiolytic reactions and rate constants (theoretical)

Reaction	Rate constant (moles per second)
1) $H_2O \rightarrow HO^•$ (hydroxyl radical) + H^+ (proton) + e^-_{aq} (hydrated electron)	5.9×10^{-8}
2) $2\ HO^• \rightarrow H_2O_2$ (hydrogen peroxide)	6.0×10^9
3) $O_2 + e^-_{aq} \rightarrow O_2^{•-}$ (superoxide)	2.0×10^{10}
4) $H^+ + O_2^{•-} \rightarrow HO_2^•$ (hydroperoxyl radical)	2.0×10^{10}
5) $HO_2^• + H^• \rightarrow H_2O_2$	2.0×10^{10}
6) $e^-_{aq} + H_2O_2 \rightarrow HO^• + OH^-$ (hydroxide ion)	1.1×10^{10}
7) $HO^• + HO_2^• \rightarrow H_2O + O_2$	6×10^9
8) $H_2O_2 + HO^• \rightarrow H_2O + O_2^{•-} + H^+$	2.7×10^7
9) $H^+ + OH^- \rightarrow H_2O$	1.44×10^{11}

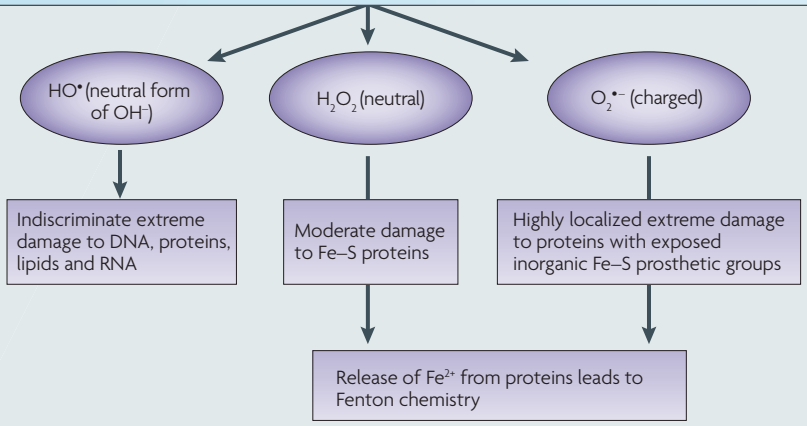

were for *U. maydis*, which carries two sets of chromosomes per cell and can survive ~6,000 Gy as a diploid[6,13]. The only other extremely IR-resistant organism in which the physical products of homologous recombination during genome reassembly have been mapped following irradiation is the bacterium *D. radiodurans* (BOX 2), which as a polyploid (4–10 haploid genome copies per cell) can survive ~17,000 Gy[12,15,24] (FIG. 1a). *U. maydis* and *D. radiodurans* rely on efficient systems for genome reassembly and require the induction of DNA-repair genes[13,25]. Homologous recombination processes in these organisms depend on proteins that actively promote pairing of DNA, which results in efficient exchange of genetic information between homologous DNA regions[12–15]. Over the past two decades, several hypotheses to explain the efficiency of homologous recombination in *D. radiodurans* have been proposed, building on the idea that *D. radiodurans* maintains a novel chromosome alignment that keeps homologous regions together and facilitates access of broken ends to homologous templates[14,26,27]. However, a series of molecular studies on irradiated *D. radiodurans* cells showed that high levels of recombination between homologous DSB fragments originated from widely separated genomic locations[12,15,24,26], and cryoelectron microscopy of vitreous sections of *D. radiodurans* showed that DNA fragments in the cells were mobile[28]. Thus, IR-induced DSB fragments in *D. radiodurans* are not immobilized and the structural form of its nucleoids does not seem to have a key role in radioresistance[22]. Indeed, sensitivity to DSB damage can increase when the mobility of broken DNA ends is restricted[29].

Early on, it became evident that the enzymes which mediate DNA repair in *D. radiodurans* were probably not unique[30,31]. For example, a highly IR-sensitive mutant of *D. radiodurans* that contains a mutated DNA polymerase I gene (*polA*) was fully restored by expression of the corresponding gene from the IR-sensitive *E. coli*[30].

The nature of extreme IR resistance in *Deinococcus* spp. thus remains unclear and is made even more curious by their impressive ability to resist desiccation[14,16,32] and UV radiation[30,31]. Hypotheses that explain why repair proteins (either native or introduced by genetic engineering from IR-sensitive bacteria) in *D. radiodurans* cells function better after irradiation than repair proteins in other organisms generally fall into two categories. First, a subset of uncharacterized genes encode proteins that somehow facilitate the homologous recombination systems

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of *D. radiodurans*[14,23,33], or second, the accumulation of near-millimolar concentrations of Mn^{2+} in cells somehow prevents protein oxidation during irradiation, with the result that sufficient repair enzymes survive radiation damage and allow subsequent DNA repair[16,22,26,34].

This Opinion article considers how, after exposure to huge doses of γ-rays, or to months of desiccation and exposure to UV sunlight in a desert, some bacteria retain sufficient protein activity to reconstitute their DNA. I propose that the accumulation of Mn^{2+} complexes in resistant organisms decreases the cellular concentration of ROS formed during irradiation. This in turn prevents IR-induced protein oxidation, which leaves sufficient recombination activity in place to repair the DSBs in the genome and enable survival.

The *Deinococcus* paradox

D. radiodurans was the first extremely IR-resistant organism to be sequenced[35]. Surprisingly, DNA-repair proteins in *D. radiodurans* seemed to be unremarkable, as the *D. radiodurans* genome encoded approximately the same number and types of DNA-repair proteins as IR-sensitive bacteria[23,26]. Similarly, the sequencing of genomes of the IR-resistant organisms *Bacillus pumilus*[36], *U. maydis*[6], *P. roseola*[3], *P. furiosus*[37] and *Halobacterium* sp. NRC-1 (REF. 38) did not provide clear insights into IR resistance mechanisms. Although the global transcriptional response to IR in *D. radiodurans* involved the upregulation of many novel genes, hundreds of characterized genes that were unrelated to DNA repair were also induced[25,39]. At least 12 novel *D. radiodurans* genes with discernible functional relevance to the preservation of genome integrity were knocked out, and the resulting mutants were characterized for IR resistance. Remarkably, there was no drastic change in the level of IR resistance of most of the mutants, indicating that few of the putative resistance genes, at least individually, make a substantial contribution to the recovery of irradiated *D. radiodurans*[26]. For example, DdrA is a protein that binds to and protects the 3′ ends of DNA from nuclease degradation *in vitro*, but 50% of *D. radiodurans ddrA*$^-$ mutant cells survived 10,000 Gy in an undefined rich medium[40]. Furthermore, a whole-genome analysis of gene gain and gene loss between *Deinococcus geothermalis* (BOX 2) and *D. radiodurans*, which are equally resistant to radiation[26], failed to produce a coherent picture of the systems that were thought to be important for survival. Instead, the number of novel genes that were thought to be implicated in recovery from IR in these *Deinococcus* species was substantially reduced[26].

Challenging radiation dogma

Because individual proteins are typically present at much higher levels than their corresponding genes, IR damage to one protein is not a lethal event, unlike an unrepaired DSB. As a dose of IR that causes indiscriminate cellular DNA damage should damage a similar portion of proteins in the same cell[11], the tacit assumption has been that IR-induced cell death is mainly mediated by DNA damage. However, recent investigations contradict this radiation dogma[34].

Whereas a specific dose of IR causes similar numbers of DSBs in sensitive and resistant bacteria[9,16,17], sensitive bacteria are more susceptible to oxidative protein damage than resistant bacteria[34] (FIG. 2). Based on this finding, I propose that the ability of IR-resistant organisms to minimize protein damage from IR allows them to retain sufficient DNA-repair functions to restore the chromosomal damage. I further argue that extremely IR-sensitive bacteria, such as *Shewanella oneidensis*, which are killed by IR doses (40 Gy) that cause less than 1 DSB per genome, do not survive mainly owing to protein damage[22,34,41]. Only for the few organisms that are extremely resistant to IR owing to their ability to protect proteins

Box 2 | **Where *Deinococcus* bacteria roam**

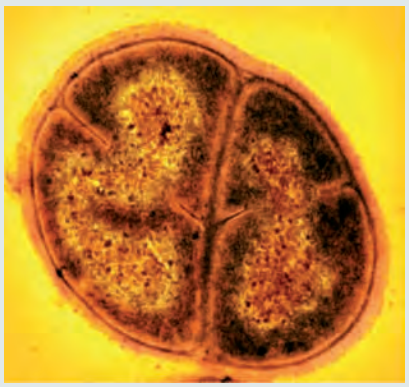

Representatives of the extremely radiation-resistant family Deinococcaceae can typically survive acute exposures to ionizing radiation (≥12,000 Gy (gray; absorbed radiation dose)), ultraviolet (≥1,000 J per m^2), and desiccation (years)[14,23,26,32,70], and can grow under harsh conditions of chronic irradiation (50 Gy per hour)[16]. Only approximately 30 distinct species have been described, despite their apparent ancient derivation[71]. The first member to be isolated was *Deinococcus radiodurans* (see the figure), originally named *Micrococcus radiodurans*[72]. This bacterium belongs to the *Deinococcus–Thermus* group, which is putatively related to cyanobacteria and is deeply branched in bacterial phylogenetic trees[23]. To date, the natural distribution of the deinococci has still not been explored systematically. Members have been isolated worldwide but have diverse and patchy distributions[23].

A wide range of natural and man-made environments on the Earth are characterized by their physical extremes of temperature, pressure and radiation. These harsh environments are different from the preferred environments of life typically encountered by humans, but can be colonized by *Deinococcus*. Some species live in highly radioactive soils at nuclear waste sites[73] and alpine environments[74], some have settled on sandstone, marble and ice in Antarctica[75], and others are ubiquitous microbial inhabitants of deserts[32]. High temperatures and pressures also do not seem to be an obstacle to their survival. *Deinococcus geothermalis* was originally isolated from a hot spring in Italy[76], and *D. geothermalis* DNA has been extracted from deep-ocean subsurface environments (68–118 meters below the sea floor)[77].

The astonishing survival of *Deinococcus* bacteria following irradiation has given rise to some whimsical descriptions of their derivation, including that they had an extraterrestrial origin[78]. Whole-genome comparisons of *D. geothermalis* with *D. radiodurans* and two *Thermus* species, however, have firmly established that the evolutionary steps which led to the *Deinococcus–Thermus* group occurred in their terrestrial ancestors[26]. *D. geothermalis* requires little more than some carbohydrates and oxygen to grow[79]. By contrast, *D. radiodurans* is metabolically less proficient. *D. radiodurans* requires a rich source of amino acids and vitamin B3 analogues in addition to sugars and oxygen for growth[79], representing biosynthetic deficiencies predicted by its genome sequence[23,35]. It is remarkable, therefore, that *D. radiodurans* has been isolated from nutrient-poor radioactive environmental waste sites and from deserts[32,73]. Indeed, numerous other *Deinococcus* species isolated from an elephant, a llama, a duck and a fish have similar growth requirements[23]. The picture that has emerged for the life cycle of most *Deinococcus* species is one that comprises a cell-replication phase that requires nutrient-rich conditions, such as in the gut of an animal[23], followed by release, drying and dispersal. Dried deinococci can endure for years, and if blown by winds through the atmosphere would be expected to survive and land worldwide — some becoming encased in ice, some becoming entombed in dried desert soils and some even ending up in the stomachs of humans[80].

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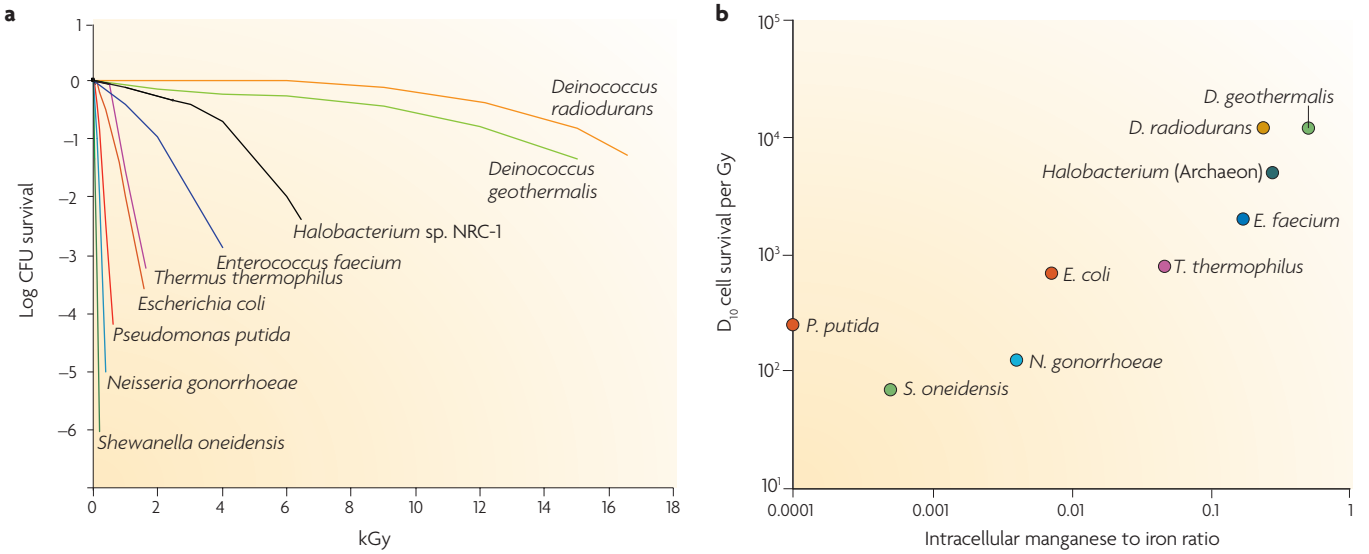

Figure 1 | **Relationship between survival following exposure to ionizing radiation and intracellular manganese and iron contents. a** | Ionizing radiation (IR) survival curves for whole-genome sequenced strains that encode a similar repertoire of DNA-repair proteins[8,16,38]. Standard growth, irradiation (^{60}Co at 0 °C) and recovery conditions were used[16]. **b** | Intracellular manganese to iron concentration ratios. For cells cultured under standard growth conditions, total manganese and iron contents were determined by inductively coupled plasma mass spectrometry[16]. D_{10} represents the IR dose that reduces the number of viable cells by 90%. Other manganese to iron ratios and D_{10} survival values reported recently for novel IR-resistant desert bacteria[32] include *Deinococcus radiodurans* 7b-1 (D_{10} = 13 kGy; manganese:iron = 0.14), *Deinococcus* sp. 1A1 (D_{10} = 17 kGy; manganese:iron = 0.15), *Deinococcus* sp. 5A5 (D_{10} = 15 kGy; manganese:iron = 0.38), *Deinococcus* sp. 1A6 (D_{10} = 7 kGy; manganese:iron = 0.15), *Deinococcus* sp. 3B1 (D_{10} = 10.5 kGy; manganese:iron = 0.12), alphaproteobacterium 4A4 (D_{10} = 1.5 kGy; manganese:iron = 0.07) and alphaproteobacterium 4A6 (D_{10} = 1.5 kGy; manganese:iron = 0.15). We did not investigate the distribution of manganese or iron in the desert strains, nor did we evaluate the extent of cell grouping before irradiation, which can significantly increase D_{10} survival values based on colony forming unit (CFU) assays[16,22]. Part **b** is modified, with permission, from REF. 81 © (2006) Elsevier Science.

from the indirect effects of IR (BOX 1) is survival ultimately determined by the level of DNA damage[12]. In the early 1970s, Holliday's work on IR-induced homologous recombination strongly supported the notion that the most radiosensitive targets in extremely IR-resistant *U. maydis* cells were single genes[13], an inference that has been applied by others to IR toxicity in general.

Resistance to DNA-damaging agents

In addition to IR and UV, *D. radiodurans* is profoundly resistant to the lethal and mutagenic effects of many redox-active (ROS-mediated) xenobiotics, such as mitomycin C[42], an antibiotic produced by *Streptomyces* that is known for its ability to cross-link DNA. Whereas *E. coli* is readily mutated by mitomycin C, *D. radiodurans* cells that survive mitomycin C treatment show approximately the same low level of mutagenesis that occurs during one normal round of replication[31,42]. Thus, *E. coli* has an error-prone DNA-repair pathway but *D. radiodurans* apparently does not[31]. Under our model, I attribute error-prone DNA repair to ROS-damaged enzymes, which passively promote mutations by repair malfunction[34]. By contrast, *D. radiodurans* and *E. coli* are equally sensitive to the mutagenic effects of *N*-methyl-*N*′-nitro-*N*-nitrosoguanidine, a direct mutagen[31,42] that was used to construct most *D. radiodurans* mutants prior to 1990 (REF. 31). Because DNA-repair-defective *D. radiodurans* mutants (such as *recA* and *polA* mutants) are approximately as sensitive to IR, UV and indirect (ROS-mediated) mutagens as repair-defective *E. coli*[9,30,31,43], accurate repair of DNA in *D. radiodurans* might require little more than protection against protein oxidation and genome multiplicity. I attribute protein protection in *D. radiodurans* to the presence of high levels of manganese complexes[16,34]. In radiation-resistant fungi and cyanobacteria, it is possible that resistance is conferred by different sorts of antioxidants, perhaps based on melanin[44] and trehalose[45], respectively.

Manganese within resistant bacteria

As no clear explanation has been inferred from the genome sequences of IR-resistant organisms for their survival capabilities, there have been no reliable physiological predictors of the ability of a cell to tolerate IR. In 1976, Bruce and colleagues reported that *D. radiodurans* accumulates substantially more manganese than the IR-sensitive bacterium *Micrococcus luteus*[46]. Furthermore, the IR-resistant bacterium *Lactobacillus plantarum*[16,47], which lacks the enzyme superoxide dismutase, and *Synechocystis* sp. PCC 68034 (REF. 48) accumulated exceptionally high levels of manganese[49,50]. The growth of IR-resistant bacteria was reported to be relatively independent of iron compared with IR-sensitive bacteria[16]. This set of reports led my research team to examine the relationship between manganese and iron accumulation and bacterial radioresistance[16]. FIGURE 1b shows the correlation between IR resistance and the ratio of intracellular manganese to iron concentrations for eight bacteria and one archaeon. For example, *D. radiodurans* (manganese:iron = 0.24) accumulates 157 times more manganese and 3.3 times less iron than the IR-sensitive *S. oneidensis* (manganese:iron = 0.0005)[16]. Bacteria with high manganese to iron ratios are extremely resistant to IR-induced protein oxidation, whereas bacteria with low manganese to iron ratios are hypersensitive to protein oxidation[16,32,34] (FIG. 2). Measurement of the accumulation of protein carbonyl groups[34] revealed that Mn^{2+} accumulation in bacteria specifically prevented protein oxidation, but did not affect DSB levels[16]. This led to the hypothesis that manganese-accumulating bacteria have an enhanced capacity to

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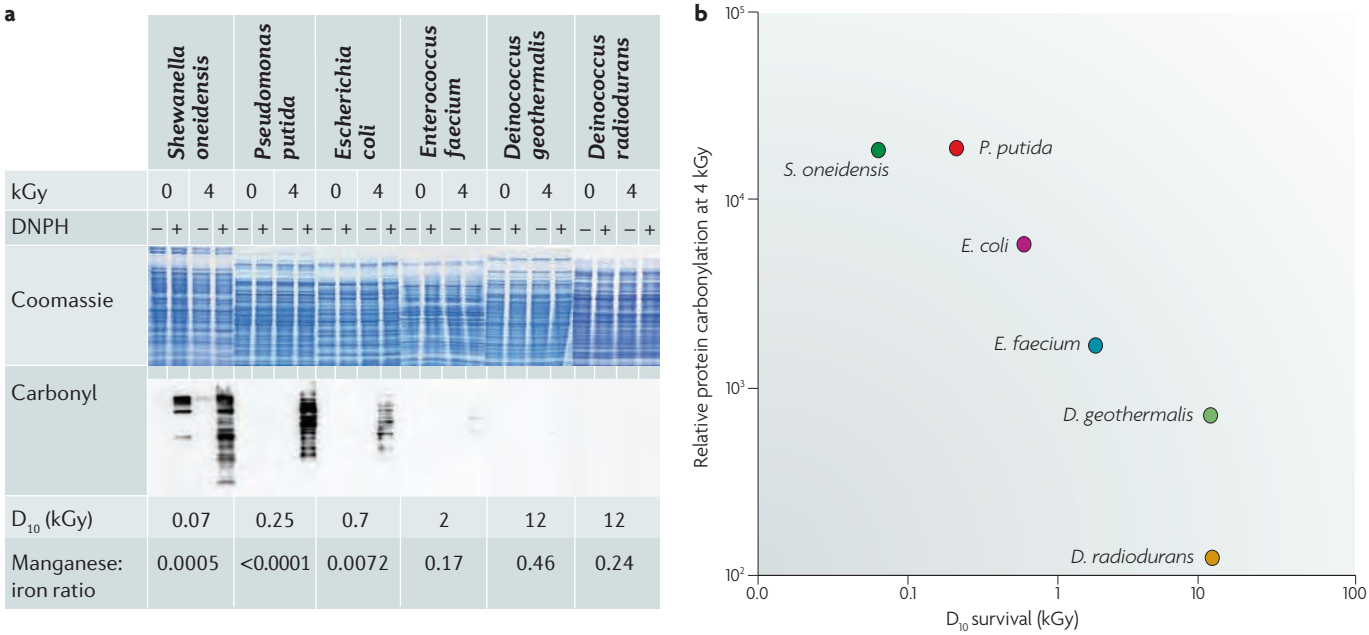

Figure 2 | ***In vivo* ionizing radiation-induced oxidative protein damage.** **a** | Western blot immunoassay of protein-bound carbonyl groups in cell extracts prepared from bacteria irradiated to 4 kGy (^{60}Co at 0 °C; 20 μg of a protein sample (soluble fraction) was loaded per lane). Coomassie represents a coomassie-stained polyacrylamide denaturing gel, whereas carbonyl represents the corresponding western blot, which reveals the presence (black) or absence of protein oxidation (no signal). Carbonyl groups (aldehydes and ketones) are widely used as markers of irreversible protein damage, which cannot be repaired and represents a small fraction of the total oxidative protein damage[34]. **b** | Relationship between bacterial survival (D_{10}; the ionizing radiation dose that reduces the number of viable cells by 90%) and relative protein carbonylation following exposure of the strains to 4 kGy. Carbonylation in relative units was quantified: the intensity profile of a particular lane (part **a**; carbonyl) was generated from previously published digitized membrane images[34]. DNPH, 2,4-dinitrophenylhydrazine. Part **a** is modified from REF. 34.

prevent the formation of iron-dependent ROS (through the Fenton reaction)[16,22,34] (FIG. 3). As the ability of manganese to protect the cell becomes depleted, DNA-repair systems and other essential cellular enzymes are expected to become increasingly subjected to damage[22,34]. This model explains the ability of orthologues from radiosensitive bacteria to complement *D. radiodurans* DNA-repair mutants, in which manganese complexes in *D. radiodurans* shield proteins irrespective of their origin[34]. It also explains the long 'shoulders' of IR-response curves for extremely resistant organisms (FIG. 1a), which are ultimately overwhelmed and killed owing to the hundreds of recalcitrant DSBs per cell[3,12] rather than protein damage[34].

Biological evidence

Direct evidence for a biological role of manganese accumulation in IR resistance comes from studies of *D. radiodurans*, which actively transports manganese into the cell[16]. Mn^{2+} sensing occurs widely in bacteria and influences both Mn^{2+} homeostasis and genes involved in the oxidative stress response[51]. *D. radiodurans* possesses two of the three types of known Mn^{2+} transporters: one from the Nramp (natural resistance-associated macrophage) family and one from the ATP-dependent ABC-type transporter family[16]. The third type of manganese transporter, the unique P-type ATPase with a high specificity for Mn^{2+}, has been detected in *L. plantarum*, but has not been found in *D. radiodurans*. Manganese transport in *D. radiodurans* is predicted to be regulated by a transcriptional regulator of the MntR–DtxR (manganese transport regulator–diphtheria toxin repressor) family by a metal-binding motif that is more closely related to the Mn^{2+}-binding configuration than the Fe^{2+} form[16,51]. Repression of manganese transport in *D. radiodurans* is predicted to be controlled by TroR[16].

When *D. radiodurans* was grown in conditions that limit manganese accumulation, the manganese to iron ratio of the cells decreased from 0.24 to 0.04, and the cells became highly sensitive to IR and highly susceptible to IR-induced protein oxidation, but there were no other obvious effects on other traits[16,34]. Furthermore, when *D. radiodurans* cells with normal manganese levels were irradiated under conditions that were known to perturb manganese-dependent ROS scavenging *in vitro*, such as high pH, the cells lost their ability to prevent IR-induced protein oxidation and became sensitive to IR[34]. Increasing evidence indicates that accumulated manganese ions can act as chemical antioxidant protectants by decreasing the levels of ROS to prevent oxidative stress. This mode of ROS control is not specific for radiation-resistant organisms, but is applicable to diverse settings. Addition of manganese can rescue yeast and bacterial mutants that are deficient in ROS-scavenging enzymes[51–53], and manganese supplementation can restore the lifespan of short-lived *C. elegans* mutants[54]. Mitochondria accumulate high Mn^{2+} concentrations[55], and the level of carbonylated proteins, which is recognized as a marker of oxidative stress, is reduced in animal cells[56] treated with Mn^{2+}.

Manganese and iron in IR resistance

The effects of radiation in cells are mediated primarily through ROS. Dissolved oxygen, either derived from the atmosphere, generated endogenously from IR-induced H_2O_2 by redox-cycling of iron, manganese and/or other biologically relevant transition metals, or produced enzymatically (for example, by the intracellular decomposition of H_2O_2 by catalase), reacts rapidly with electrons released during water radiolysis[11] to form superoxide ($O_2^{\bullet-}$) (BOX 1; FIG. 3). Because $O_2^{\bullet-}$ does not easily cross membranes, it can

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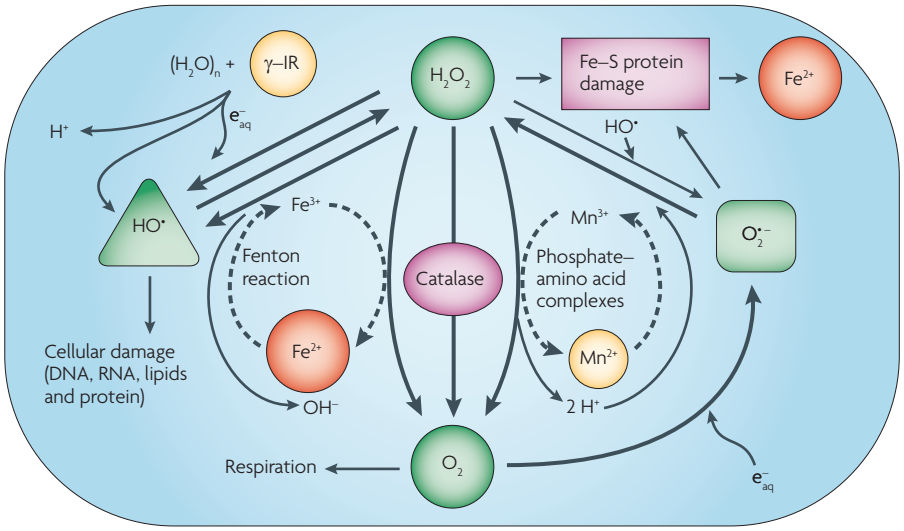

Figure 3 | **Model of ionizing radiation-driven manganese and iron redox cycling.** Under ionizing radiation (IR), Fe^{2+} and Fe^{3+} redox cycling is predicted to generate HO• and $O_2^{\bullet-}$, whereas Mn^{2+} and Mn^{3+} redox cycling is predicted to favour $O_2^{\bullet-}$ scavenging without HO• production. Catalase is a common enzyme that catalyses the decomposition of H_2O_2 to O_2 and H_2O. Thus, under anaerobic or aerobic irradiation conditions, in a cascade of events, $O_2^{\bullet-}$ would damage and inactivate enzymes with exposed Fe–S clusters[57,61], thereby triggering the release of Fe^{2+}, and 'free' Fe^{2+} would promote IR-driven Fe^{2+} and Fe^{3+} redox cycling. Fe–S clusters participate in a range of biochemical processes, including electron transfer, substrate binding and activation, redox catalysis, DNA replication and repair, regulation of gene expression, and tRNA modification. Thus, Mn^{2+} and Mn^{3+} redox cycling is predicted to prevent the proliferation of iron-dependent reactive oxygen species and protect diverse cellular functions[22,34]. Radiolysis of water exposed to ionizing radiation[11,69] (BOX 1), $H_2O + \gamma\text{-IR} \rightarrow HO^\bullet + H^+ + e^-_{aq}$; primary radiolytic reaction yielding H_2O_2 (REF. 11), $2\ HO^\bullet \rightarrow H_2O_2$; IR-induced superoxide[11], $O_2 + e^-_{aq} \rightarrow O_2^{\bullet-}$; Fenton reaction[61], $H_2O_2 + Fe^{2+} \rightarrow HO^\bullet + OH^- + Fe^{3+}$; Haber–Weiss reaction[11], $Fe^{3+} + HO_2^\bullet \rightarrow Fe^{2+} + O_2 + H^+$ and $2\ Fe^{3+} + H_2O_2 \rightarrow 2\ Fe^{2+} + O_2 + 2\ H^+$; manganese oxidation[34,49,51,58], $Mn^{2+} + O_2^{\bullet-} + 2\ H^+ \rightarrow H_2O_2 + Mn^{3+}$; manganese reduction[34,49,51], $2\ Mn^{3+} + H_2O_2 \rightarrow 2\ Mn^{2+} + O_2 + 2\ H^+$. Figure modified from REF. 34.

transiently build up in cells under aerobic or anaerobic irradiation conditions[34]. Although $O_2^{\bullet-}$ does not react with DNA or most proteins, it can damage and inactivate enzymes with exposed 2Fe–2S or 4Fe–4S clusters, which contain Fe^{2+} and can therefore trigger the release of ferrous ions (Fe^{2+})[57]. In turn, when Fe^{2+} ions are made accessible to H_2O_2 they can catalyse Fenton reactions[57] (FIG. 3). Thus, $O_2^{\bullet-}$ is not readily consumed by other cellular targets and the damaging potential of $O_2^{\bullet-}$ lingers for Fe–S clusters. I have proposed that Mn^{2+} ions that accumulate in resistant bacteria form complexes that shield Fe–S cluster-containing proteins from $O_2^{\bullet-}$-related ROS generated during irradiation (FIG. 3). By preventing the release of Fe^{2+} from Fe–S-cluster containing proteins, the global collateral damaging effects of Fenton chemistry during irradiation would be minimized, allowing enzyme systems involved in recovery to survive and function efficiently[22,34].

Because Mn^{2+} has a higher reduction potential than Fe^{2+} (REF. 51), Mn^{2+} is less likely than Fe^{2+} to donate an electron to reduce another molecule. Fe^{2+} thus catalyses the Fenton reaction, whereas the analogous reaction between Mn^{2+} and H_2O_2 does not occur[51]. All of the proposed benefits of manganese accumulation compared with iron accumulation in irradiated cells are related to the limitation of Fenton chemistry (FIG. 3). Like iron, manganese can cycle between the divalent and trivalent oxidation states[34,51]. In contrast to Fe^{2+} and Fe^{3+} redox cycling, Mn^{2+} and Mn^{3+} redox cycling during IR is predicted to favour $O_2^{\bullet-}$ scavenging without hydroxyl radical (HO•) production[34] (FIG. 3). Because the intrinsic reduction potentials of Mn^{2+} and Fe^{2+} are similar to those of many common biological compounds, each metal can be recruited, by carefully choosing the liganding environment, to perform biologically useful redox catalysis[51]. For example, as Mn^{2+} increases to millimolar concentrations, complex formation with ligands such as phosphate promotes catalytic $O_2^{\bullet-}$ scavenging during IR[34,58]. Indeed, Mn^{2+} efficiently scavenges for ROS at near-millimolar concentrations *in vitro*. Fridovich and Archibald demonstrated that Mn^{2+} scavenges $O_2^{\bullet-}$ in phosphate buffer[49], and Stadtman and colleagues detected Mn^{2+}-dependent disproportionation of H_2O_2 in bicarbonate buffer that contained amino acids[59], which endowed the mixtures with peroxidatic and catalatic activities[51]. Because Mn^{2+} is innocuous under conditions (notably aerobic environments) where Fe^{2+} tends to promote ROS, cells can tolerate high cytoplasmic concentrations of Mn^{2+} with virtually no negative redox consequences[51], unlike other biologically relevant redox-active metals. The IR-resistant bacteria *L. plantarum*, *Synechocystis* sp. PCC 6803 and *D. radiodurans* have intracellular Mn^{2+} concentrations that range from 1 to 30 mM[16,50,51,60]. Electronic paramagnetic resonance spectroscopy[16,46] and X-ray-absorption near-edge structure spectroscopy[34] revealed that manganese exists predominantly as divalent ions in *D. radiodurans*. An ample supply of Mn^{2+} would also ensure that the demands for this cation by manganese-dependent ROS-scavenging enzymes are met[61], and in cells in which iron is limited or sequestered, accumulated Mn^{2+} ions might functionally replace Fe^{2+} as mononuclear cofactors in enzymes, thereby protecting the active sites[61]. Thus, the accumulation of intracellular Mn^{2+} and its cofactors (for example, phosphate) might constitute chemical antioxidant protectants.

Location, location, location

The manganese-based protection hypothesis (FIG. 3) requires a global distribution of this metal within cells. X-ray fluorescence microspectroscopy showed that manganese is dispersed throughout *D. radiodurans* cells, but surprisingly, iron, as well as copper, which also catalyses the conversion of H_2O_2 to HO• *in vitro*, is sequestered between dividing cells (FIG. 4). By contrast, in *S. oneidensis* cells iron is dispersed throughout the cell[62]. Because of the sequestration of iron, the manganese to iron ratio in the cytosol of *D. radiodurans* is probably even higher than 0.24.

Banding patterns for oxidized proteins in carbonyl assays for sensitive bacteria exposed to IR[34] (FIG. 2a) revealed that some proteins are highly oxidized, whereas other proteins in the same cells are undamaged. By contrast, all proteins in *D. radiodurans* cells are resistant to IR-induced oxidation. However, proteins purified from *D. radiodurans* are not resistant to oxidation when irradiated *in vitro*[34]. As H_2O_2 generated during irradiation diffuses throughout a cell, any Fe^{2+} encountered (bound or unbound) would produce a torrent of ROS that would react with their immediate neighbours until either the H_2O_2 was exhausted or the iron was removed[57,61]. Owing to the short lifetime of HO• (BOX 1), HO• cannot damage

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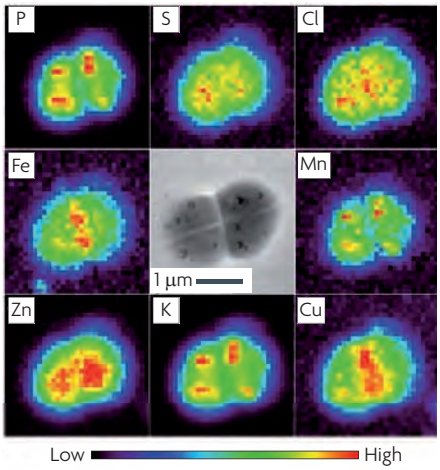

Figure 4 | **X-ray fluorescence maps of the qualitative distribution and concentration gradients of various metals and non-metals in *Deinococcus radiodurans*.** The tetracoccus was harvested from a mid-logarithmic culture in undefined rich medium, imaged and quantified as described previously[26,34]. The central panel is a transmission electron micrograph (TEM) of the tetracoccus after X-ray fluorescence (XRF) imaging. The panels that surround the TEM are the element distribution images of indicated metals and non-metals, which qualitatively depict high and low X-ray fluorescent intensities as indicated by the colour key (bottom): red represents the highest element concentration and black represents the lowest element concentration. A mathematical model of the original morphology of the cells was constructed in approximate likeness to the tetracoccus to determine the distribution of the elements[34]. XRF analysis measurements were made using the hard X-ray microprobe beamline 2ID-D at the Advanced Photon Source, Argonne National Laboratory, Chicago, USA, under previously described conditions[34,62]. Figure modified from REF. 34.

molecules beyond a few Angstroms from the ferrous ion where they are generated. One predicted repercussion is that proteins with predominantly negatively charged surfaces would become the focal points of Fenton chemistry during irradiation because they attract Fe^{2+}. This indicates that iron-dependent IR damage in sensitive cells is highly localized at the molecular level. By contrast, $HO^{\bullet}$ generated directly by the radiolysis of water would cause global, indiscriminate cellular damage (FIG. 3). The proposed perspective on IR toxicity has converged with a theory of eukaryotic ageing that postulates a causal relationship between oxidative protein damage and the decline of physiological functions and metabolic processes: carbonylation of specific proteins increases almost exponentially as animals age[63]. This model could also help us to understand the toxicity of redox-active heavy metals (for example, Cr^{6+} and Hg^{2+}) and hypochlorous acid (bleach), both of which would also be expected to knock down the activity of proteins they encounter in a selective manner[64].

This leaves the question of why chromosomal and plasmid DNA in extremely resistant bacteria are not similarly protected but instead are damaged with a similar dose dependence as DNA in sensitive bacteria[9]. Only 3% of a typical bacterial nucleoid by mass is DNA; the multitude of small proteins in the nucleoid that are involved in chromosomal condensation provide substantial shielding from $HO^{\bullet}$ generated by radiolysis. In the presence of cations (for example, Ca^{2+} and K^{+}), the genome is compacted by 1,000-fold by reducing the electrostatic repulsion between the negative charges of DNA[65,66]. When packaged in IR-resistant or IR-sensitive bacteria, DNA is more than 20 times as resistant to IR damage as when the same DNA is purified and irradiated in water[9]. Thus, DNA that is highly condensed in different organisms might be similarly susceptible to IR-induced DNA damage because of a combination of excluded water volume effects and the abundance of proteins[65,66]. In this context, DNA would remain prone to the direct damaging effects of IR, but might be out of reach of most of the indirect damage caused by $HO^{\bullet}$ generated by radiolysis (BOX 1). Provided that any iron atoms associated with DNA-binding proteins were tightly coordinated, and any Fe^{2+} or Fe^{3+} released within nucleoids was quickly removed and caged inside proteins, such as DPS (DNA protection during starvation)[67], DNA in bacterial nucleoids would be generally less prone to Fenton chemistry than regions of a cell where proteins with exposed Fe–S groups predominate.

Summary

Based on the radiochemistry of Mn^{2+} *in vivo* and *in vitro*[34,58], I propose that a combination of Mn^{2+} with ligands, such as phosphate[49,58], and perhaps other small molecules, spontaneously form intracellular complexes that act as potent catalytic scavengers[34,49,51,58,59] of $O_2^{\bullet-}$ and related ROS (FIG. 3). Mn^{2+} complexes are therefore expected to provide immediate cytosolic protection from IR-induced ROS. By shielding proteins with exposed Fe–S groups in particular, Mn^{2+} complexes would prevent the proliferation of iron-dependent ROS during irradiation in a way that is not highly dependent on the induction of enzymes, stage of growth or temperature over a range at which cells are metabolically active. It must be emphasized, however, that the fate of an irradiated cell in this 'death by protein damage' model rests not only on the level of protein oxidation, but also on the number of genome copies per cell and genome size. Cells that are proficient at homologous recombination but lack systems that can rejoin random DSB ends[15] (for example, non-homologous end joining) would not benefit from high levels of protein protection during irradiation if their genome copy number was less than two, as one DSB would be lethal. For polyploid cells, however, the presence of chemical antioxidant protectants of DNA-repair proteins would be expected to substantially increase the number of DSBs an organism could survive following irradiation.

A recent report shows that the dose-response relationship for desiccation killing in bacteria isolated from desert environments parallels the levels of protein damage and manganese to iron ratios[32]. Therefore, desiccation resistance also seems to depend on the abundance of cellular manganese complexes that protect proteins. The relative contribution to survival of accumulated Mn^{2+} ions compared with ROS-scavenging processes that have been classically attributed to enzymes has been explored for IR. Based on experimental analyses in *D. radiodurans*, Mn^{2+} accumulation trumps enzymatic ROS defence systems by far[16]; the genes that encode the constitutively and highly expressed ROS-scavenging enzymes *sodA* and *katA* can be disrupted in *D. radiodurans* with little effect on IR resistance, but the Mn^{2+} transporter gene (*nramp*) is essential[26]. The possibility that proteins with exposed Fe–S clusters are the most vulnerable macromolecules in irradiated cells (FIG. 3) warrants careful further investigation because of the practical implications. If the predictive power of IR-induced protein damage on bacterial survival extends to human cells exposed to low doses of IR, various analytical techniques could be applied to biodosimetry, which could be used to identify and quantify proteins that are covalently modified by ROS.

The ability of a complex eukaryotic genome to undergo extensive repair and rebuilding from the most extreme genomic insults is underscored by a recent report that diploid yeast cells can survive 250 IR-induced DSBs per cell[18]. This has led to the idea that higher eukaryotes could be made more resistant to IR. In 1968, Serianni and Bruce reported radioprotection of

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E. coli (strain *B/r*) by a radioresistant factor extracted from *D. radiodurans*, but the nature of the protective agents and their cellular targets were not identified[68]. Based on insights presented in this Opinion article, delivery of *D. radiodurans* Mn^{2+} complexes into cells would be expected to protect proteins from oxidative damage and thereby increase survival. Several prominent questions now remain: can the putative antioxidant Mn^{2+} complexes of *D. radiodurans* be purified and identified and can they be used to prevent radiation injury and other forms of oxidative stress in human cells?

Michael J. Daly is at the Uniformed Services University of the Health Sciences, Bethesda, Maryland 20814, USA.
e-mail: mdaly@usuhs.edu or mdaly@usuhs.mil

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DATABASES
Entrez Genome Project: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=genomeprj
Bacillus pumilus | *Caenorhabditis elegans* | *Deinococcus geothermalis* | *Deinococcus radiodurans* | *Escherichia coli* | *Halobacterium* sp. NRC-1 | *Lactobacillus plantarum* | *Micrococcus luteus* | *Pyrococcus furiosus* | *Shewanella oneidensis* | *Synechocystis* sp. PCC 68034 | *Ustilago maydis*

FURTHER INFORMATION
Michael J. Daly's homepage: http://www.usuhs.mil/pat/deinococcus/index_20.htm

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OPINION

Antimicrobial peptides: linking partition, activity and high membrane-bound concentrations

Manuel N. Melo, Rafael Ferre and Miguel A. R. B. Castanho

Abstract | An increasing amount of information on the action of antimicrobial peptides (AMPs) at the molecular level has not yet been translated into a comprehensive understanding of effects in bacteria. Although some biophysical attributes of AMPs have been correlated with macroscopic features, the physiological relevance of other properties has not yet been addressed. Pertinent and surprising conclusions have therefore been left unstated. Strong membrane-binding and micromolar therapeutic concentrations of AMPs indicate that membrane-bound concentrations may be reached that are higher than intuitively expected, triggering disruptive effects on bacteria.

Antimicrobial peptides (AMPs) represent a wide range of short, cationic, gene-encoded peptide antibiotics that can be found in virtually every organism[1]. Different AMPs display different properties, and many peptides in this class are being intensively researched not only as antibiotics, but also as antivirals[2,3], templates for cell-penetrating peptides[4], immunomodulators[5] and antitumoural drugs[6].

Despite sharing a few common features (for example, cationicity, amphipathicity and short size), AMP sequences vary greatly, and at least four structural groups (α-helical, β-sheet, extended and looped) have been proposed to accommodate the diversity of the observed AMP conformations[7,8]. Likewise, several modes of action as antibiotics have been proposed, and there is debate about whether the primary target of many of these peptides is the cell membrane or whether the primary target is cytoplasmic invasion and disruption of core metabolic functions[9].

Several bilayer interaction and disruption models have been proposed for those AMPs that depend on membrane interference for their antimicrobial activity[10–12] (FIG. 1). However, it is now becoming obvious that such models might be too rigid to account fully for the many interactions that these small molecules can establish in a complex environment, such as the cell membrane. The limitations of the previously proposed models have been exposed in molecular dynamics simulations of AMPs interacting with phospholipid bilayers. Observations from these studies included multiple coexistent structures (frequently unrelated to clean α-helices or β-sheets), nonspecific peptide–peptide interactions and membrane perturbation dictated by stochastic events[13–15] (FIG. 1). The advantage of this indefinite behaviour is that bacteria seem to find it hard to circumvent AMP action, which is certainly a reason behind the multistep mutations usually required for resistance to evolve[16].

Independently of the chosen membrane perturbation model, an implicit concentration threshold is always required for disruption (FIG. 1). This is supported by several observations, in model systems, of phenomena related to such threshold crossings[13,17–19]. Nevertheless, AMP concentrations that are close to full membrane coverage, which are often considered unphysiological conditions, are a frequent requisite for such observations (TABLE 1).

In this Opinion, we survey reports of threshold events of AMPs and propose a correlation between these events and properties such as bactericidal concentration and membrane binding. We use this relationship to support our view, which reconciles existing interaction models with

> "Independently of the chosen membrane perturbation model, an implicit concentration threshold is always required for disruption."

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Fine Structure of the *Deinococcus radiodurans* Nucleoid Revealed by Cryoelectron Microscopy of Vitreous Sections

Mikhail Eltsov* and Jacques Dubochet

Laboratoire d'Analyse Ultrastructurale, Bâtiment de Biologie, Université de Lausanne, CH-1015 Lausanne, Switzerland

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Transmission electron microscopy revealed that the nucleoid of the extremely radioresistant bacteria *Deinococcus radiodurans* may adopt an unusual ring shape. This led to the hypothesis that the tight toroidal package of the *D. radiodurans* genome might contribute to radioresistance by preventing diffusion of ends of double-stranded DNA breaks. The molecular arrangement of DNA in the nucleoid, which must be determined to test this hypothesis, is not discernible by conventional methods of electron microscopy. We have applied cryoelectron microscopy of vitreous sections and found that the DNA arrangement in *D. radiodurans* differs from toroidal spooling. Diffuse coralline nucleoids of exponentially growing *D. radiodurans* do not reveal any particular molecular order. Electron-dense granules are generally observed in the centers of nucleoids. In stationary-phase cells, the nucleoid segregates from cytoplasm and DNA filaments show locally parallel arrangements, with increasing aspects of cholesteric liquid crystalline phase upon prolonged starvation. The relevance of the observed nucleoid organization to the radiation resistance of *D. radiodurans* is discussed.

Deinococcus radiodurans is a gram-positive, nonsporulating bacterium which usually grows in tetrad form. This organism is interesting because of its extreme resistance to DNA damage induced by ionizing radiation (4). It exhibits detectable survival after irradiation of 15,000 Gy (4) and grows continuously at 60 Gy/h (25). The unusual radiation resistance of *D. radiodurans* results from its ability to repair the genome, containing more than a hundred double-stranded DNA breaks, without mutations and loss of genome integrity (4, 32). The double-stranded DNA break repair in *D. radiodurans* is *recA*-dependent (10), but an explanation for its remarkable efficiency is yet to be found.

Initial analysis of *D. radiodurans* by transmission electron microscopy was performed in the 1970s (39, 40). Analysis focused mainly on the structure of the cell wall, in which a periodic S layer was described and characterized in detail (5, 38, 40). Methods available at that time did not reveal an unusual structure which could contribute to the radioresistance of *D. radiodurans*.

Interest in the organization of *D. radiodurans* has reawakened with recent advances in transmission electron microscopy techniques. Levin-Zaidman et al. (29). applied rapid freezing and freeze-substitution for their study of *D. radiodurans* nucleoids. They found that its nucleoid adopts an unusual ring shape. It is known that in vitro DNA tends to form toroidal aggregates in the presence of condensing agents (21). In these toroids, DNA molecules are condensed in a closely packed hexagonal arrangement (20). Levin-Zaidman at al. assumed that the ring-shaped nucleoid of *D. radiodurans* has basically the same structure. The hypothesis has been made that the toroidal shape facilitates repair of the fragmented genome because its densely packed structure prevents double-stranded DNA break ends from diffusing (13, 29).

The molecular arrangement of the DNA in the *D. radiodurans* nucleoid must be determined in order to test this hypothesis. Conventional methods of electron microscopy do not reveal the arrangement of DNA in bacteria, even when rapid freezing and freeze-substitution study are used because the bacterial chromatin aggregates during dehydration in the organic solvents, which are necessary in such preparations (23). Obtaining the fine structure of bacterial chromatin requires that fully hydrated specimens be observed.

Cryoelectron microscopy of vitreous sections (CEMOVIS) enables transmission electron microscopy observation of fully hydrated biological material. This method relies on vitrification of biological samples by rapid cooling, similar to the technique used in freeze-substitution. Then, instead of replacing the solidified water with an organic solvent and embedding the specimen in resin, native, unstained vitreous samples are cut at −140°C into thin sections which are observed in a cryoelectron microscope at even lower temperatures (2). CEMOVIS has been successfully applied to different biological samples, including bacteria. A number of new structural details not preserved by other methods of electron microscopy have been visualized in the cell envelope and extracellular matrixes of bacteria (3, 30, 31).

Single isolated DNA molecules can be visualized in a thin layer of vitreous water (12), but tracing DNA inside the crowded environment of a living cell remains a challenging task even if the structure is perfectly preserved by vitrification. Only when the DNA filaments are ordered and favorably oriented it is possible to determine their arrangement. CEMOVIS resolved the local DNA package in human and horse spermatozoa (36). It therefore seems probable that, if there is an ordered DNA package in *D. radiodurans*, it should be revealed in vitreous sections.

In this study we used CEMOVIS to examine the structure

* Corresponding author. Mailing address: Laboratoire d'Analyse Ultrastructurale, Bâtiment de Biologie, Université de Lausanne, CH-1015 Lausanne, Switzerland. Phone: 41 21 6924289. Fax: 41 21 6924285. E-mail: Mikhail.Eltsov@unil.ch.

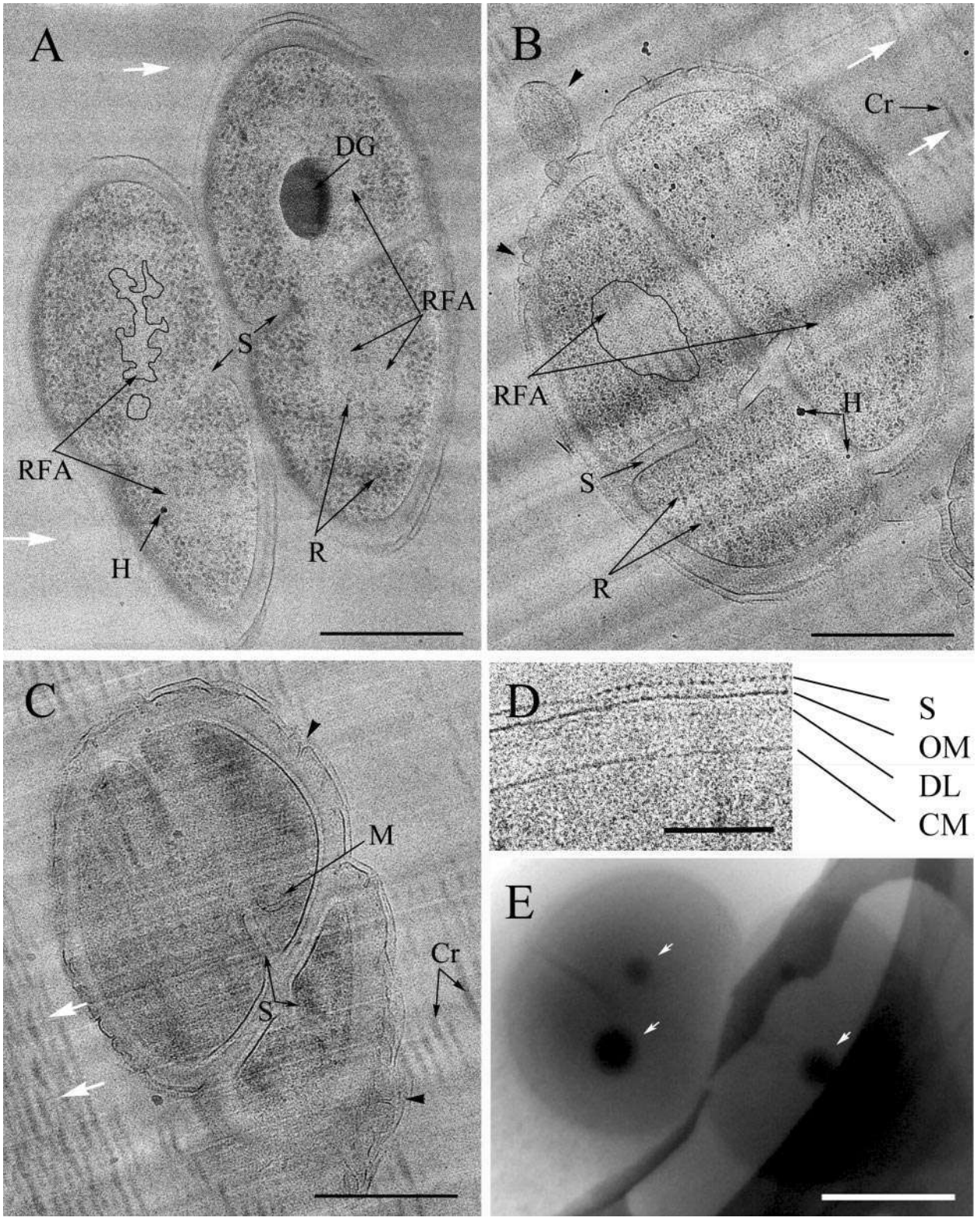

FIG. 1. (A, B, C) Vitreous sections of typical *D*. radiodurans tetrads from exponentially growing (A), stationary-phase (B), and long-stationary-phase (C) cultures were imaged with high defocus (5 to 10 μm) to obtain strong contrast favorable for general morphology mapping. Knife marks (white arrows) and crevasses (Cr) are cutting artifacts. H, surface contamination with hexagonal ice. The cytoplasm of some adjacent cells in the tetrad is interconnected through incomplete septa (S). A large electron-dense granule (DG) is visible inside the exponentially growing cell. The small granules are ribosomes (R). In the central part of the exponentially growing and stationary-phase cells, ribosome-free areas (RFA) are seen and are outlined in one cell of the tetrad. Note the dispersed coralline shape of the ribosome-free areas in exponentially growing cells (A) and the compact roundish shape in stationary-phase cells (B). Some membranous structures (M) are the only distinguishable structures in the highly dense

of nucleoids in exponentially growing and stationary-phase *D. radiodurans*. We found that nucleoids of exponentially growing bacteria have diffuse coralline shapes and do not show a visible molecular order. Electron-dense granules are generally observed in the center of nucleoids. In stationary-phase cells, the nucleoid segregates from the cytoplasm and DNA filaments show locally parallel arrangements, with increasing aspects of cholesteric liquid crystalline phase upon prolonged starvation. The possible relevance of the observed nucleoid organization to the radiation resistance of *D. radiodurans* and to the hypothesis of Levin-Zaidman et al. will be discussed.

MATERIALS AND METHODS

D. radiodurans strain SARK was grown in TGY broth (0.8% Bacto tryptone, 0.1% glucose, 0.4% yeast extract) at 30°C with vigorous shaking. Exponentially growing bacteria were collected after 10 to 12 h of growth at an optical density at 600 nm of 0.4 to 0.6. Stationary-phase and long-stationary-phase bacteria were collected after 4 days and 12 days of incubation, respectively. Bacteria were harvested by centrifugation with a Sorvall RS28S centrifuge for 5 min at 3,000 rpm. A soft pellet of bacteria was suspended with the same volume of 30% dextran (42 kDa, Sigma-Aldrich, St. Louis, MO), mixed by pipetting, and high-pressure frozen within 5 min in a Leica EMPACT (Leica, Vienna, Austria) apparatus. Thin frozen hydrated sections were obtained with a diamond cryoknife (Diatome, Biel, Switzerland) in a Leica FCS Ultracut S cryomicrotome with a nominal cutting feed of 50 nm at −140°C as described previously (3). For plunge freezing, 5 μl of bacterial suspension was placed on a holey carbon grid and frozen by plunging into liquid ethane, as described (1).

Grids containing thin frozen-hydrated sections or vitrified thin layers were mounted in a Gatan 626 cryospecimen holder (Gatan, Warrendale, PA) and observed below −180°C in Philips CM12 and CM100 cryoelectron microscopes (FEI, Eindhoven, The Netherlands) operating at an acceleration voltage of 80 kV. Electron micrographs were recorded on Kodak SO-136 electron image films or a 1K Multiscan charge-coupled device camera (Gatan, Warrendale, PA) or 2K TemCam charge-coupled device camera (TVIPS GmbH, Gauting, Germany). Negatives were digitalized using an Imacon Flextight Precision III scanner (Imacon, Redmond, WA). The contrast of micrographs was adjusted with Adobe Photoshop. No other image correction was performed. Fourier transforms of images were made with the Image J program (National Institutes of Health [http://rsb.info.nih.gov/ij/]).

RESULTS

General morphology of *D. radiodurans*. The cell morphology of *D. radiodurans* was checked immediately before vitrification by phase-contrast light microscopy. In all cultures *D. radiodurans* cells were observed mainly in tetrads, but diplococci were also seen occasionally.

D. radiodurans was well visible in vitreous sections. Figure 1 shows typical tetrads from exponentially growing (A), stationary-phase (B), and long-stationary-phase (C) cultures. The cytoplasm of the adjacent cells in the tetrad was either separated or interconnected through incomplete septa. Cutting artifacts such as compression, knife marks (white arrows), and crevasses are seen in the sections. Compression appears as a shortening of cell dimensions along the direction of cutting, resulting in the elliptical shape of the bacteria. The cutting direction is revealed by series of knife marks (Fig. 1A, B, and C, white arrows), which are irregularities in the thickness of sections originating from unevenness of the cutting edge of the knife. Crevasses are fissures perpendicular to the cutting direction. These cutting-induced artifacts are still frequent in vitreous sections (3) and must be considered during the interpretation of images.

A cell envelope is clearly visible around *D. radiodurans* cells. In regions of favorable orientation three sharp, high-contrast layers and one diffuse dense layer are visible in the cell envelope (Fig. 1A, B, and C). Such organization of the cell envelope is observed in all types of cultures. Figure 1D shows a magnified fragment of the cell envelope. The innermost sharp layer is the cytoplasmic membrane, while the intermediate one is the outer membrane. The outermost layer is the S-layer in which a periodic organization is seen on cross-sections and a hexagonal order on tangential sections (not shown). The diffuse dense layer is seen in the periplasmic space. It is most pronounced in long-stationary-phase cells. The outer membrane and the S-layer surround the entire tetrad and do not enter the septa. Irregularities in the structure of the outer part of the cell envelope, appearing as bubbles and wrinkles of the outer membrane and S-layer, are often observed in vitreous sections (Fig. 1C, black arrowheads).

Internal organization of cells differs in exponentially growing, stationary-phase, and long-stationary-phase cells. Multiple small granules and one or several large electron-dense granules are visible inside exponentially growing cells (Fig. 1A). The small granules are identified as ribosomes from their characteristic size and appearance. Ribosomes are distributed unevenly within the cell volume. The highest concentration of ribosomes is seen at the cell periphery. In the central part of the cell, individual ribosomes or small groups of ribosomes are spaced by ribosome-free areas. In a majority of exponentially growing cells these ribosome-free areas have a dispersed coralline shape (Fig. 1A, outlined).

Electron-dense granules are located in the central part of exponentially growing cells. Electron-dense granules have an elliptical shape in vitreous sections (Fig. 1A, dg). The large diameter of electron-dense granules rarely exceeds 400 nm. The small diameter of the ellipse is oriented along the cutting direction. This suggests that electron-dense granules are spherical bodies deformed into an elliptical shape by cutting-induced compression. In order to check whether electron-dense granules are an artifact of incubation with the cryoprotector, we performed plunge-freezing of whole-mount bacteria directly in culture medium. The thickness of the bacteria frozen in vitreous thin layers is too large for high-resolution imaging with a normal-voltage microscope, but due to their high electron density, electron-dense granules are nevertheless well visible (Fig. 1E, white arrows). This proves that electron-dense granules are a natural component of exponentially growing cells.

content of long-stationary-phase cells (C) in these imaging conditions. Irregularities in the structure of the outer part of the cell envelope (black arrowheads) are often observed in vitreous sections. (D) Magnified fragment of the cell envelope. The cytoplasmic membrane (CM), the diffuse dense layer (DL), the outer membrane (OM), and the outermost periodic S-layer (S) of the cell wall are distinguishable in vitreous sections. (E) Whole-mount exponentially growing tetrad plunge-frozen in culture medium. Note electron-dense granules (white arrows). Scale bars: A, B, and C, 500 nm; D, 100 nm; E, 1 μm.

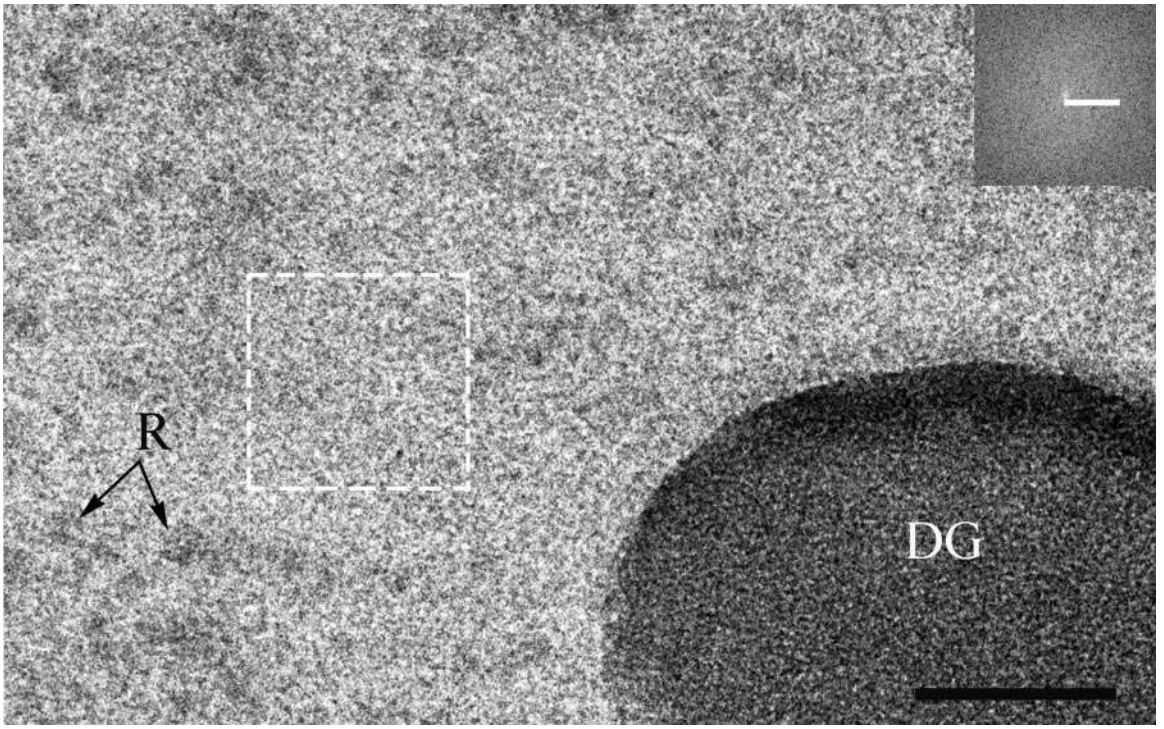

FIG. 2. High-resolution view of the central part of an exponentially growing cell (defocus, 1.8 μm). Electron-dense granule (DG), ribosomes (R), and other granules are visible. The space between the granules is disordered. Inset: Fourier transform of the outlined region. Scale bars: image, 100 nm; Fourier transform, $(5\ nm)^{-1}$.

Vitreous biological material is prone to beam damage. Irradiation with the electron beam changes the structure of the biological material. The ultimate state of damage is apparent as bubbling. We found that electron-dense granules begin to bubble simultaneously or soon after cell membranes, whereas ribosome-free areas are the most bubbling-resistant regions of cells.

In typical stationary-phase cells (Fig. 1B) electron-dense granules are not observed and ribosomes are excluded from the central part of the cells, forming large unified ribosome-free areas. These ribosome-free areas have a roundish shape and homogenous contents. Ribosome-free areas in adjacent stationary-phase cells can be interconnected (Fig. 1B).

On a few occasions, in both exponentially growing and stationary-phase cells, we found ring-shaped ribosome-free areas with an island of ribosome-rich cytoplasm in the center.

The content of a typical long-stationary-phase cell (Fig. 1C) has a high electron density, which makes it difficult to identify the internal components. Ribosomes and electron-dense granules are not distinguishable in long-stationary-phase cells. Occasionally some membranous structures are seen inside long-stationary-phase cells.

Interestingly, the bacterial populations in stationary-phase and long-stationary-phase cultures are not completely uniform. About 1% of the cells in a stationary-phase culture and few cells in a long-stationary-phase culture present aspects typical of exponentially growing cells; diffuse ribosome-free areas and electron-dense granules.

Fine structure of the nucleoid seen on vitreous sections. It is known from studies of freeze-substituted bacteria stained with osmium amine (19) that the bacterial nucleoid is located in ribosome-free areas. Hence, the ribosome-free regions visible in vitreous sections of exponentially growing and stationary-phase cells of *D. radiodurans* can be identified with the nucleoid.

Contrary to what happens in stained embedded specimens, the average density of the various regions of *D. radiodurans* is about the same everywhere, except in the dense granules. Imaging conditions favoring phase contrast over large areas must be used in order to obtain a significant contrast between the nucleoid and the rest of the bacteria.

Such conditions, implying high defocus (5 to 10 μm), have been used for recording Fig. 1 A to C. They are, however, not adequate for high-resolution observations. In order to reveal the molecular arrangement of the DNA in the nucleoid, a defocus compatible with the expected distances of few nanometers has been used (<3 μm).

Exponentially growing cells. Figure 2 shows a high-resolution view of the central region of an exponentially growing cell. Electron-dense granules are recognized because of the high contrast. As well as electron-dense granules, ribosomes and other granules, which can be transcription or replication complexes, are visible. The space between granules is disordered, and Fourier transform of the image does not reveal any predominant distance (Fig. 2, inset). Together these results suggest a dispersed, actively transcribed nucleoid without ordered compaction.

Stationary-phase cells. At high resolution, compact, roughly circular ribosome-free areas of stationary-phase cells do not appear to be homogenous any more, and specific textures

become apparent in them (Fig. 3A). The "dotted" pattern (Fig. 3B) consists of highly contrasting dots and lines which are clustered and, in several cases, form regularly spaced arrays (Fig. 3B, underlined with white). The "stripy" pattern is formed from longer and partially parallel lines (Fig. 3C) with lower contrast than the dots in the dotted pattern. Figures 3D and 3E show an intermediate case between dotted and stripy patterns which simultaneously contains dots and short and longer lines.

The high contrast of the dots suggests an accumulation of density along most of the section with a thickness averaging 70 nm. The diameter of the dots is in the range of 2 to 2.5 nm. Taken together, these aspects are characteristic of a DNA fragment seen along the viewing direction (6, 27). The dotted pattern can only be seen as a bundle of locally parallel DNA filaments whose direction is perpendicular to the section plan. The stripy patterns confirm the local parallel orientation of the DNA. They appear when the bundle is tilted with respect to the viewing direction. The Fourier transform reveals no reinforced dimensions in the ribosome-rich area (cytoplasm, Fig. 3A, left inset), whereas distances corresponding to 4 to 6 nm are reinforced in the ribosome-free regions. This characteristic order is best seen in the dotted regions (maximum at ca. 4.8 nm; Fig. 3A, right inset) and in the stripy areas.

The regions with local order do not entirely occupy ribosome-free areas. The clusters of dots and lines are spaced by regions without definable structure (Fig. 3B, C, and D, asterisks). The aspects of the local order are less pronounced in some nucleoids (Fig. 3E).

Long-stationary-phase cells. The crowded interior of long-stationary-phase cells does not allow us to distinguish the ribosome-containing area from the ribosome-free area at low magnification. Nevertheless, the specific organization of the central region of the cell revealed at higher resolution is similar to the dotted-stripy pattern observed in stationary phase (Fig. 4). The lines are frequently organized in arches characteristic of a cholesteric arrangement (8). This suggests that the DNA in the nucleoids of long-stationary-phase cells has a higher degree of order than in stationary-phase cells. The Fourier transform shows that the average interfilament distance corresponds to 4 nm (Fig. 4, inset), which is slightly shorter than in stationary-phase cells.

DISCUSSION

CEMOVIS revealed aspects of *D. radiodurans* structure which are not resolved by conventional electron microscopy embedding and sectioning techniques. For example, the periodic structure and hexagonal order of the S-layer of the cell envelope are directly seen in vitreous sections, whereas they were previously observed only on biochemically isolated S-layers or on freeze-etched cells (5, 37, 38).

Another characteristic aspect of native *D. radiodurans* structure is the dense spherical granules (electron-dense granules). Recent structural studies did not report electron-dense granules (9, 29), although early freeze-etching studies described spherical structures reminiscent of electron-dense granules in their size and location (37). Thornley et al. also observed dense granules in resin sections on a few occasions, but their content was often lost during cutting (39). It seems, therefore, that electron-dense granules do exist in *D. radiodurans* but they are optimally preserved only in frozen-hydrated material.

Electron-dense granules are located in the central part of exponentially growing bacteria in the nucleoid region. This addresses a question about the possible chromatin nature of electron-dense granule. However, their high sensitivity to beam-induced bubbling suggests that they do not have a high nucleic acid concentration, since aromatic-rich materials are radiation resistant (11). Due to structural similarity, Thornley et al. (39) associated electron-dense granules with polyphosphate granules observed in other species of bacteria. Phosphate, in combination with proteins, would account for the high density and radiation sensitivity of the granules. The precise composition of electron-dense granules, however, remains to be identified.

CEMOVIS successfully revealed aspects of the molecular arrangement of DNA within *D. radiodurans* nucleoids. The diffuse coralline nucleoids of exponentially growing cells do not show any particular order. We attribute this to the high transcriptional and replication activity required for active growth. A local order first appears in stationary-phase cells in the form of bundles of locally parallel DNA filaments with an average interfilament distance of 4.8 nm. Upon prolonged starvation the aspect of cholesteric liquid crystalline order is observed and the average interfilament distance shortens to 4.0 nm. The gradual increase in the local order together with reduction of the interfilament distance suggests a liquid crystalline organization of the *D. radiodurans* nucleoid.

It is known that liquid crystalline phases of DNA spontaneously assemble in vitro with increasing DNA concentration (26). In bacteria, the increased DNA concentration leading to liquid crystallization may result from accumulation of high-copy plasmids (34), but this is not the case for stationary-phase cells of *D. radiodurans*, in which DNA content per cell is lower than in exponentially growing cells (18). Since at stationary phase the nucleoid segregates to a compact round domain excluding ribosomes, the crowding of DNA can be originated by its redistribution into the confined part of the cell volume. This effect can be related to the fact that cholesteric liquid crystalline nucleoids were found in starving *Escherichia coli* lacking Dps, an abundant starvation-induced unspecific DNA binding protein (16). In contrast, wild-type *E. coli* and strains overexpressing Dps show nucleoid compaction by formation of DNA-Dps cocrystals with a specific structural appearance different from that observed in *D. radiodurans* (15, 16). It can therefore be concluded that the segregation and compaction of the *D. radiodurans* nucleoid can be driven by a decrease of protein-DNA binding in the stationary phase. In addition, an unusually high concentration of Mn^{2+} ions found in *D. radiodurans* (9, 28) can facilitate liquid crystalline compaction by compensating for repulsive forces between DNA molecules.

A minority of cells in stationary-phase cultures of *D. radiodurans* have the typical morphology of exponentially growing cells. We attribute this morphological polymorphism to the presence of mutants gaining a growth advantage during the extended stationary phase (14).

Nucleoid shapes that can be interpreted as rings have been found in only a few cases. This observation argues against the results of other researchers showing an abundance of ring-like nucleoids, which were considered DNA toroids (29). We sus-

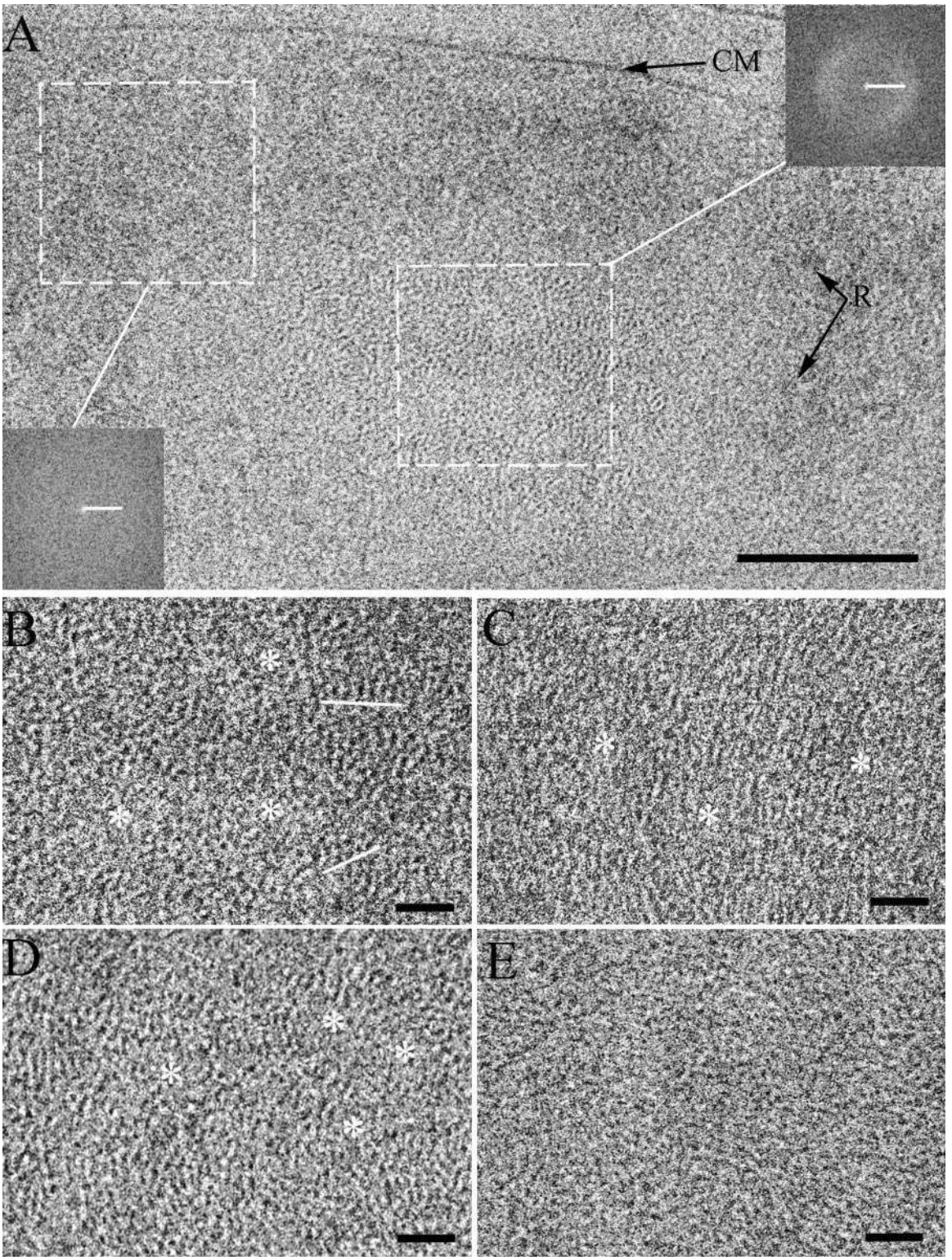

FIG. 3. Fine structure of the nucleoid in stationary-phase cells. A, High-resolution view of stationary-phase cell (defocus, 2 μm). At this defocus the contrast of ribosomes (R) is faded, but fine structural details are visible in the nucleoid. Insets show Fourier transforms of the corresponding marked regions of the cell. CM, cytoplasmic membrane. B, C, D, and E, Different structural textures of the nucleoid. B, Dotted pattern. Regularly spaced arrays of dots are underlined in white. C, Stripy pattern. D and E, Intermediate case between dotted and stripy patterns which simultaneously contains dots and short and longer lines. The clusters of dots and lines are spaced by the regions without definable structure (asterisks). The aspects of the local order are less pronounced in some nucleoids (E). Scale bars: A, 100 nm; B, C, D, and E, 20 nm; Fourier transforms, $(5\ \text{nm})^{-1}$.

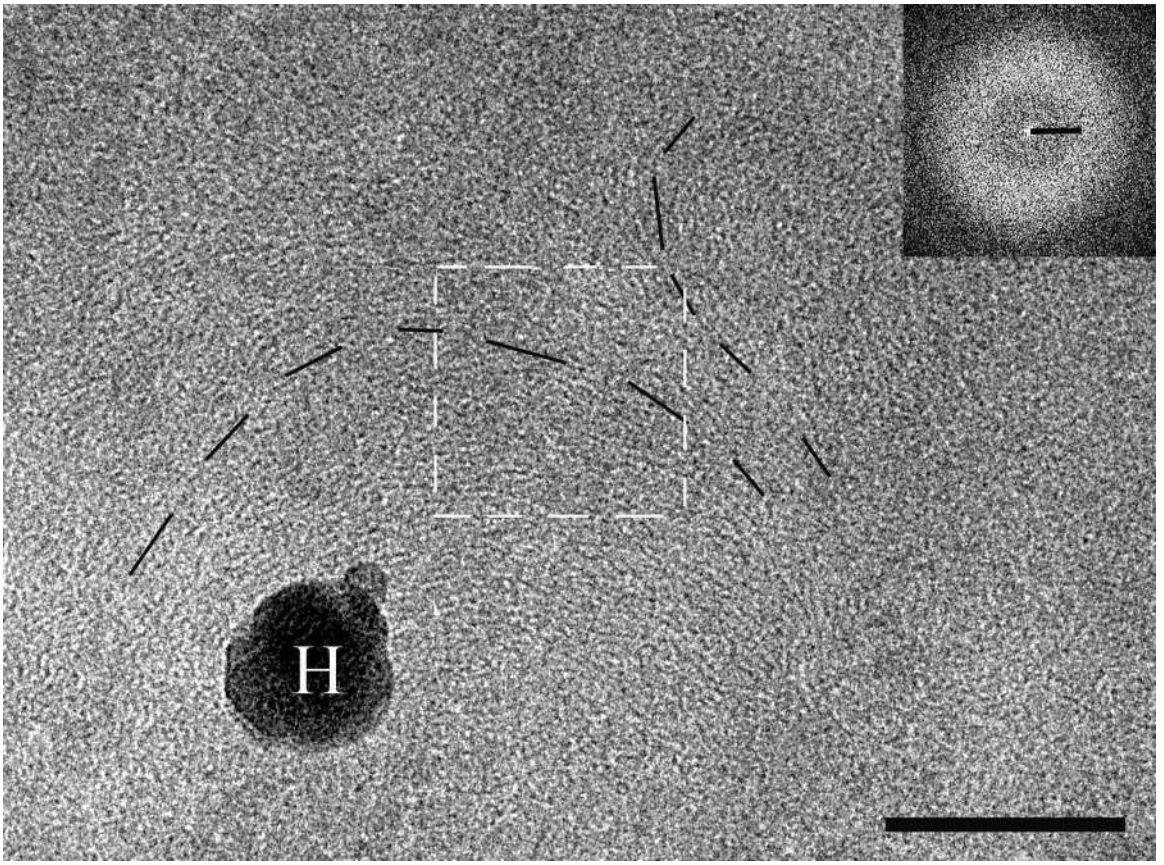

FIG. 4. Nucleoid of long-stationary-phase cells shows the aspect of cholesteric arrangement: arches (dashed lines) formed by dots and lines (defocus, 1.6 μm). H, surface contamination with hexagonal ice. Inset: Fourier transform of the marked region. Scale bars: image, 100 nm; Fourier transform, $(5\ \text{nm})^{-1}$.

pect that conventional studies have misinterpreted the dispersed nucleoids as DNA toroids when the central electron-dense granule is lost during sample preparation and the resolution is insufficient to define the molecular arrangement. Our high-resolution analysis reveals that the DNA arrangement in nucleoids of *D. radiodurans* differs from toroidal DNA spooling both in actively growing and in stationary-phase cultures.

Diffuse coralline nucleoids without a specific molecular order observed in exponentially growing *D. radiodurans* are similar to those of nonradioresistant bacteria (7, 19, 30). Nevertheless, exponentially growing cells of *D. radiodurans* are known to tolerate 5,000 Gy (33). Stationary-phase cultures have a radioresistance approximately three times higher, but this increase already occurs at the beginning of the stationary-phase (24) and is therefore independent of the ordered genome compaction which appears with the aging of the culture. This suggests that the arrangement of the nucleoid does not play a key role in the radioresistance of *D. radiodurans*. Even if it does, the mechanism must differ from the one proposed by Levin-Zaidman et al. (29), in which the dense toroidal package prevents separation of double-stranded DNA break ends, thus favoring efficient repair.

We have found that the dense toroidal package probably does not exist in *D. radiodurans*. Furthermore, we observed that the ordered condensation of DNA, leading to cholesteric organization, always remains changing and dynamic. It might well be that the diffusibility of DNA fragments is reduced in liquid crystals but that is the nature of this type of order; they still remain mobile. This is confirmed by experiments in λ phage DNA cyclization in the presence of polyamines, which show that DNA ends remains mobile in most condensed liquid crystalline phases (22). The hypothesis that the liquid crystalline order of DNA is not directly related to radioresistance is also supported by the fact that dinoflagellata, whose genome is normally in the form of cholesteric liquid crystal (35), are not unusually radioresistant.

The fact that the segregation of the nucleoid from the ribosome-rich cytoplasm is already complete at the early phase of DNA ordering suggests that nucleoid separation is the basic structural change accompanying the transition to the stationary phase. Therefore it could be relevant to the increase in radioresistance at the beginning of stationary phase. This idea is supported by fact that the nucleoids of radiation-sensitive bacteria remain coralline and dispersed at stationary phase (17, 41), whereas the nucleoids of radioresistant bacterial species are more localized (41). We speculate that the segregation of nucleoids reduces the damage caused by free radicals generated in the cytoplasm by radiation (17).

The molecular arrangement of DNA revealed in the nucle-

oid of *D. radiodurans* cannot directly serve as a structural support for DNA repair. We believe that the unusual efficiency of the latter in *D. radiodurans* is more likely to have a physiological than a structural basis. Nevertheless, nucleoid segregation at the stationary phase can be protective and requires further study.

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DEINOCOCCUS RADIODURANS — THE CONSUMMATE SURVIVOR

Michael M. Cox and John R. Battista‡*

Abstract | Relatively little is known about the biochemical basis of the capacity of *Deinococcus radiodurans* to endure the genetic insult that results from exposure to ionizing radiation and can include hundreds of DNA double-strand breaks. However, recent reports indicate that this species compensates for extensive DNA damage through adaptations that allow cells to avoid the potentially detrimental effects of DNA strand breaks. It seems that *D. radiodurans* uses mechanisms that limit DNA degradation and that restrict the diffusion of DNA fragments that are produced following irradiation, to preserve genetic integrity. These mechanisms also increase the efficiency of the DNA-repair proteins.

IONIZING RADIATION
Any electromagnetic or particulate radiation powerful enough to strip electrons from atoms to produce ions.

**Department of Biochemistry, University of Wisconsin–Madison, Wisconsin 53706-1544, USA.*
‡Department of Biological Sciences, Louisiana State University and A&M College, Baton Rouge, Louisiana 70803, USA.
Correspondence to J.R.B.
e-mail: jbattis@lsu.edu
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In 1956, Anderson *et al.*[1] isolated a novel vegetative bacterium from canned ground meat that had been γ-irradiated at 4,000 Gray (Gy), a dose that is approximately 250 times higher than that typically used to kill *Escherichia coli*. The authors named this species *Micrococcus radiodurans* because of its superficial morphological similarity to members of the genus *Micrococcus*. However, research on *M. radiodurans* over the next 30 years resulted in reclassification of this species and its closest relatives into a distinct phylum within the domain Bacteria[2–7]. The genus name — *Deinococcus* — was based on the Greek adjective 'deinos', which means strange or unusual[8]; an apt description for an organism with an ability to survive genetic damage that sets it apart from much of the life on Earth.

Treatment of *Deinococcus radiodurans* with high levels of IONIZING RADIATION can produce hundreds of genomic double-strand breaks (TABLE 1), but the genome is reassembled accurately before initiation of the next cycle of cell division. The extraordinary capacity of *Deinococcus* spp. to reconstitute their genomes has inspired a small but growing community of researchers who are interested in the relevant mechanisms that are used to achieve this. In recent years, investigation of the biology and biochemistry of *Deinococcus* spp. has accelerated, catalysed by the availability of genome information and the development of genetic tools. Evidence has accumulated for both passive and enzymatic contributions to genome restitution (FIG. 1), which provides a framework for our discussion in this review.

Ionizing-radiation resistance

Of all the phenotypes associated with prokaryotes, resistance to ionizing radiation is one of the most difficult to rationalize in terms of natural selection. As there are no naturally occurring environments known that result in exposures exceeding 400 mGy per year[9], it is unlikely that species evolved mechanisms to protect themselves against the effects of high-dose ionizing radiation *per se*. Instead, it seems that the damage introduced by γ-irradiation shares features with the damage that results from other stresses to which bacteria have adapted. For example, desiccation introduces many DNA double-strand breaks into the genomes of *D. radiodurans*[10] and members of the cyanobacterial genus *Chroococcidiopsis*[11]. Both organisms are tolerant to desiccation and are resistant to the potentially lethal effects of ionizing radiation, which might indicate that the radioresistance of these species is a fortuitous consequence of their ability to tolerate desiccation-induced strand breaks.

TABLE 2 lists members of six bacterial phyla that are resistant to ionizing radiation. The Deinococcaceae are the best-known family on this list, and have been

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Table 1 | **Double-strand breaks formed in *E. coli* and *D. radiodurans***

Species*	Genomes per cell	DNA double-strand breaks‡ at D_{37}	Average distance between lesions
Escherichia coli K12	4–5	8–9	530,000 bp
Deinococcus radiodurans R1	8–10	275	10,000 bp

*In each study, actively growing aerobic cultures were irradiated and the number of double-strand breaks determined using neutral sucrose-gradient centrifugation. ‡For *D. radiodurans* this is lesions per unit length of chromosome I (2.64 Mb). Chromosome I is used because it is the largest target within the cell. Calculations are based on a measured rate of 1 DNA double-strand break per 10 Gray per 5×10^9 Da of double-stranded DNA. D_{37}, the dose at which 37% of the cells survive.

studied for five decades. Little has been learnt about the other bacterial species listed, other than their capacity to tolerate ionizing radiation. Draft genome sequences of *Rubrobacter xylanophilus* and *Kineococcus radiotolerans* have been released in the past year, but detailed analyses of these sequences have not yet been reported.

There is no clear pattern of evolution among ionizing-radiation-resistant species (FIG. 2). The scattered appearance of ionizing-radiation resistance among distinct prokaryotic lineages indicates two possibilities. First, radioresistance could be a vestige of DNA-repair mechanisms that were present in ancestral species and have been retained in those organisms that continue to require this phenotype. This explanation assumes that the ancestor's ability to cope with DNA damage has been lost by most descendents, and predicts that the molecular mechanisms of radioresistance should be similar among ionizing-radiation-resistant species. Second, given the infrequent occurrence of ionizing-radiation resistance, it is possible that this phenotype has arisen in unrelated species through horizontal gene transfer, or possibly convergent evolution. Much as birds and bats evolved wings despite distinct evolutionary origins, it is possible that these diverse prokaryotic cells adapted differently to a similar selective pressure and that there might be multiple mechanisms of radioresistance. This latter possibility seems more probable, as fewer independent evolutionary events (the loss of resistance from each species being considered a separate event) would be required to generate the handful of known radioresistant species.

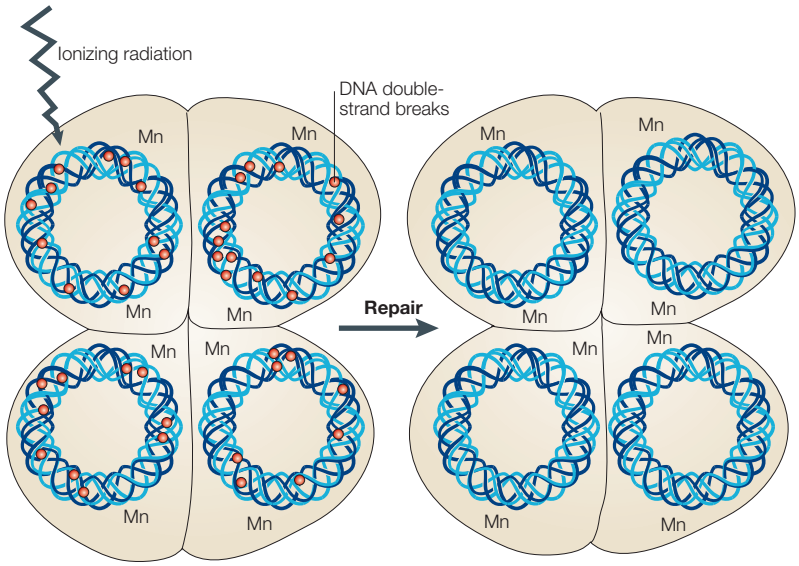

Figure 1 | **Potential contributions to the recovery from radiation damage in *Deinococcus radiodurans*.** The schematic depicts a *D. radiodurans* tetracoccus. The nucleoid in each compartment is highly condensed and maintains its overall architecture after irradiation. High levels of Mn(II) might contribute to the recovery from DNA damage. A wide range of enzymes probably also contribute to genome reconstitution.

Radiation resistance is not restricted to the domain Bacteria. Several HYPERTHERMOPHILIC archaea (members of the Euryarchaeota and Crenarchaeota) show extreme ionizing-radiation resistance[12–15], in some cases (for example, *Thermococcus gammatolerans*) comparable to that of *Deinococcus radiodurans*[14].

The Deinococcaceae

The Deinococcaceae family comprises 11 validly described species — *D. radiodurans*, *Deinococcus proteolyticus*, *Deinococcus radiopugnans*, *Deinococcus grandis*, *Deinococcus radiophilus*, *Deinococcus geothermalis*, *Deinococcus murrayi*, *Deinococcus indicus*, *Deinococcus frigens*, *Deinococcus saxicola* and *Deinococcus marmoris* — all grouped in a single genus, *Deinococcus*[16–18]. Deinococci do not form spores and are non-motile. Most species grow best in rich media at temperatures between 30 and 37°C, with a doubling time between 1.5 and 3 hours. However, *D. geothermalis* and *D. murrayi* are true thermophiles, with optimal growth temperatures of 45–55°C. With the exception of *D. grandis*, which is rod-shaped, all *Deinococcus* species are spherical cells that exist singly or as pairs and tetrads in liquid culture.

To date, *D. radiodurans* has received more attention than the other deinococci. The genome of *D. radiodurans* strain R1 (ATCC BAA-816) has been sequenced[19,20] and can be accessed at the TIGR Comprehensive Microbial Resource database (see Online links box). The *D. radiodurans* chromosome is 3.28 Mb, with a GC content of 66.6%. There are nine types of short nucleotide repeats, ranging in size from 60 to 215 bp, found at 295 sites that are randomly scattered in the genome. The genome is segmented and consists of a 2.64-Mb chromosome (chromosome I), a 0.41-Mb chromosome (chromosome II), a 0.18-Mb megaplasmid and a 0.045-Mb plasmid[21]. *D. radiodurans* has between 4 and 10 genome copies per cell, depending on the stage of the bacterial growth phase[22,23].

The γ-irradiation survival curves of actively growing cultures of *D. radiodurans* R1 have a shoulder of resistance up to 5,000 Gy[24], and until this dose is achieved there is no measurable loss of viability in the irradiated culture. Under these conditions, the D_{37} dose (BOX 1) for *D. radiodurans* R1 is approximately 6,500 Gy. Assuming that there are eight genome copies per cell in these cultures, a 5,000-Gy dose will introduce approximately 1,600 double-strand breaks per cell. As this dose is sublethal, it can be inferred that potentially catastrophic deletions and genome rearrangements occur at low frequencies. Although there is no formal proof, it seems that the process of double-strand-break repair in *D. radiodurans* is error-free.

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Table 2 | **Species of ionizing-radiation-resistant bacteria**

Species	Representative D_{10} value*	Phylum	Refs
Methylobacterium radiotolerans	1,000 Gray	α-Proteobacteria	80,81
Kocuria rosea	2,000 Gray	Actinobacteria	4,8
Acinetobacter radioresistens	2,000 Gray	γ-Proteobacteria	82
Kineococcus radiotolerans	2,000 Gray	Actinobacteria	83
Hymenobacter actinosclerus	3,500 Gray	Flexibacter–Cytophaga–Bacteroides	84
Chroococcidiopsis spp.	4,000 Gray	Cyanobacteria	11
Rubrobacter xylanophilus	5,500 Gray	Actinobacteria	85
Deinococcus radiodurans R1	10,000 Gray	Deinococcus–Thermus	86
Rubrobacter radiotolerans	11,000 Gray	Actinobacteria	85

*The D_{10} defines the dose that is needed to eradicate 90% of the irradiated population. The D_{10} values for a given species vary substantially depending on growth conditions. The values provided are for actively growing oxygenated cultures.

TABLE 1 compares the number of double-strand DNA breaks that occur in the large chromosome of *D. radiodurans* R1 (REF. 25) and the *E. coli* K12 (REF. 26) genome at the D_{37} radiation dose. The difference is striking: compared with *E. coli* K12, *D. radiodurans* tolerates approximately 30-fold more DNA double-strand breaks before succumbing to the damage. Clearly, *D. radiodurans* R1 cells have mechanisms to avoid the lethal effects of double-strand breaks that are absent in *E. coli*.

Whatever the mechanisms that *D. radiodurans* uses, they do not prevent DNA damage. Recent evidence from two groups of researchers has shown that measurable double-strand breaks form at the same rate in *E. coli* and *D. radiodurans* if cultures are irradiated under identical conditions[27,28], which makes the existence of a mechanism that blocks the formation of strand breaks in the *D. radiodurans* genome unlikely. In contrast to most other cells, *D. radiodurans* has the ability to efficiently and accurately repair that damage.

The observation that *D. radiodurans* cannot passively prevent DNA damage does not rule out the possibility that other passive mechanisms contribute to the capacity of the cell to tolerate DNA damage. Experimental evidence indicates that the recovery of *D. radiodurans* from substantial DNA damage relies on both passive features of deinococcal physiology and a robust complement of repair enzymes. There are several mechanisms that have the potential to contribute to ionizing-radiation resistance. For example, there is a clear requirement for RecA-dependent homologous recombination — this process has been examined and reviewed extensively[29–36].

In this review, we do not attempt to attribute the contribution to recovery from DNA damage that is made by each different mechanism, and the reader should bear in mind that new recovery mechanisms might still await discovery.

Passive contributions to radioresistance

Genome copy number. Cells with increased numbers of genome copies have enhanced resistance to ionizing radiation[26,37]. The extra genetic material is thought to protect the cell in two ways. First, when multiple genomes are present, there are additional copies of crucial loci that improve the chance of the cell surviving irradiation. The probability of inactivating a specific gene in an organism is given by $P=1-(1-1/M)^L$ (where M is the total number of genes present, and L is the number of inactivating lesions per genome). For a specific dose of radiation, the probability of inactivating all the copies of a specific gene is equivalent to P^N, where N is the number of gene copies present (assuming that

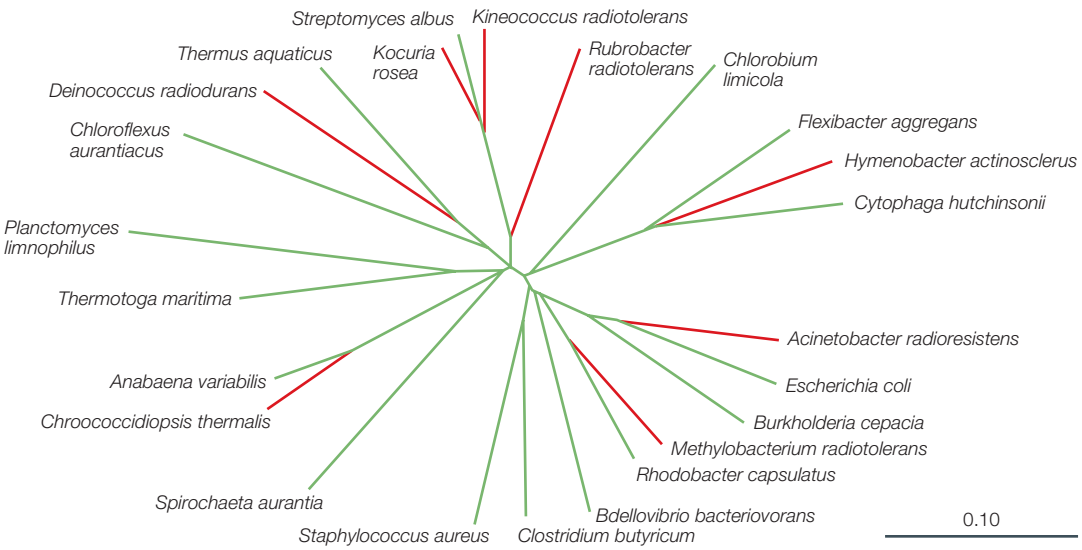

Figure 2 | **A 16S-rRNA-gene-sequence-based phylogeny of the main lineages of the domain Bacteria.** The branches in red are those in which ionizing-radiation-resistant taxa have been described. The scale bar represents 10 inferred nucleotide substitutions per 100 nucleotides.

HYPERTHERMOPHILIC
Organisms that have an optimal growth temperature above 80°C.

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Box 1 | **High-energy radiation and its effect on DNA**

Ionizing radiation is radiation with sufficient energy to ionize molecules. There are two types of ionizing radiation, both produced by the decay of radioactive elements: electromagnetic (X- and γ-radiation that form part of the electromagnetic spectrum that includes visible light and radio waves) and particulate (α- and β-particles). Different types of ionizing radiation deposit energy in matter at different rates. α- and β-particles produce ionization by collisions, depositing their energy within a short range after entering matter. γ-rays are photons that generate ions by several types of energy-absorption events (most commonly by the Compton effect, an increase in the wavelength of electromagnetic radiation when it collides with electrons in matter, see the figure) and can penetrate deeply into a cell or tissue. Ion production is accompanied by the release of energetic electrons (see the figure), and multiple ions and electrons can be generated in one event. The figure shows the tracks of three different types of ionizing radiation. Small dots indicate energy deposition events. The inset depicts the ejection of an electron from an atom to generate an ion, mediated by an encounter with a γ-ray photon. The γ-ray transfers part of its energy to a valance electron, which is thereby ejected from the nucleus to create an ion. The scattered γ-ray can undergo additional Compton effects within the matter.

Ions react with other molecules to produce free radicals on a nanosecond timescale. In water, the products include highly reactive hydroxyl radicals. Typically, each energy deposition event can generate 2–5 radical pairs within a radius of a few nm.

The energy deposited (the dose absorbed by the cell, tissue or other matter) is measured in rads or in Gray (SI measurement; 100 rad = 1 Gray). The radioresistance of microorganisms is compared by measurement of the D_{37} dose (the dose at which 37% of the cells survive). At the D_{37} dose, each cell on average has experienced a lethal event (those that survive are balanced by other cells with two or more lethal events).

The ions and free radicals produced as radiation passes through matter react rapidly and modify molecules. Of all the effects, genome damage probably has the greatest impact on cell viability. The reasons for this are threefold. First, genomic DNA occupies the largest fraction of the cell volume, and will therefore be 'hit' most often. Second, the genome is present in lower copy numbers than other molecules — there is little redundancy. Third, and most importantly, the genome regulates all cellular functions, so loss of any portion is catastrophic for a single-celled organism.

Ionizing radiation generates multiple types of DNA damage. As much of the damage results from the action of hydroxyl radicals, the spectrum of damage is similar to that produced by oxidative damage associated with endogenous aerobic metabolism. In DNA, the nucleobase is most often modified, and many dozens of different structural modifications to the bases have been characterized. However, 10–20% of the time the sugar-phosphate moiety is affected, which can lead to a single-strand break. The 5′ and 3′ ends at these breaks are usually phosphorylated, indicating that one or more nucleotides have been excised at the break site. The 3′ ends sometimes include a glycolate moiety derived from fragmentation of the deoxyribose.

Most of the lesions are accurately repaired by robust DNA-repair systems present in all cells, but double-strand breaks are the most difficult to repair, and therefore the most lethal. They can arise when single-strand breaks occur by chance in close proximity on opposite strands, when a cluster of hydroxyl radicals introduce strand breaks in both strands at one location, or when the cell attempts to enzymatically excise damaged bases present in close proximity on both strands. Double-strand breaks can result in significant loss of genetic information and, if not repaired, will prevent replication of the prokaryotic genome. How an organism deals with double-strand breaks lies at the heart of that organism's capacity to survive radiation exposure.

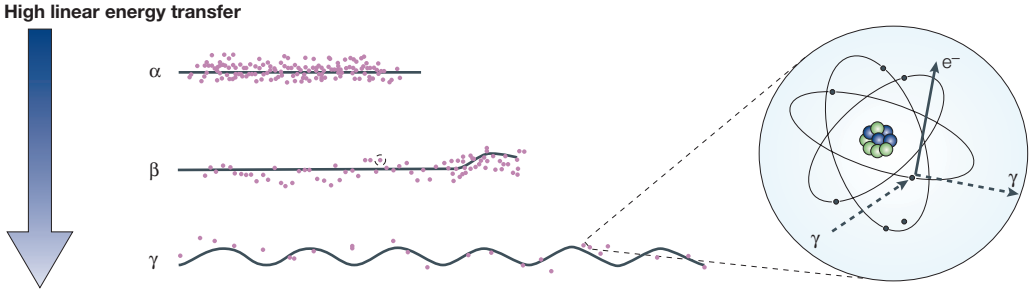

there is one copy of each gene on each genome copy, N is equal to the number of genome copies). If 100 inactivating lesions are randomly introduced into a single copy of the *D. radiodurans* genome (2,897 genes), the probability of inactivating any specific gene on that genome copy is 3.4%. The probability of inactivating all the copies of the same gene is reduced to 0.12% when two genomes are present, and to 0.004% when there are three genomes.

Redundant genetic information also functions as a reserve that can be used to repair DNA segments that are damaged (or degraded) beyond repair. In *E. coli* K12, repair of DNA double-strand breaks only occurs during the exponential growth phase in rich media, when cells contain multiple chromosomes[26], and diploid and tetraploid yeast are more resistant to ionizing radiation than isogenic haploid strains[37]. It has been hypothesized that genetic redundancy contributes

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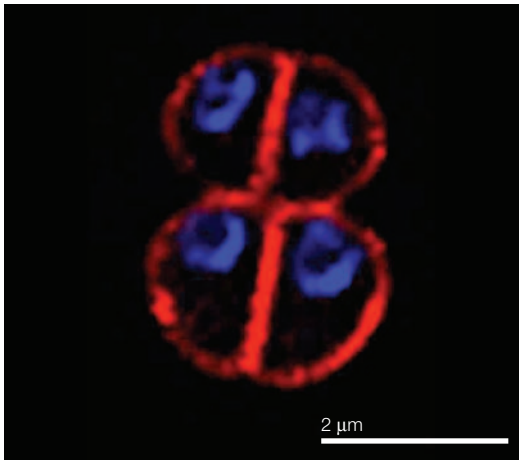

Figure 3 | **A tetrad of *Deinococcus radiodurans*.** An epifluorescence image of stationary-phase *D. radiodurans* R1. DNA is stained with DAPI and appears blue in the figure; the membrane is stained with the dye FM4-64 and appears red.

to the radioresistance of *Deinococcus* spp., although this idea has not been tested. The number of genome copies in *D. radiodurans* has never been reported to be less than four, and cells have the same survival rate whether they contain four or ten genome copies[23]. The contribution of genome redundancy to radioresistance in *D. radiodurans* (relative to other mechanisms) is unclear. Many bacteria contain more than one genome copy, particularly during exponential growth. For example, *E. coli* contains between five and 18 genome equivalents during exponential-phase growth[38], and *Azotobacter vinelandii* can accumulate more than 100 genome copies[39]. Neither species is radioresistant, so genetic redundancy alone does not account for radioresistance. Nevertheless, repair of DNA double-strand breaks by recombination requires the presence of more than one genome[26,37], so it seems probable that genome redundancy is necessary for genome repair.

Nucleoid organization. The nucleoids of stationary-phase *D. radiodurans* cells (FIG. 3) are arranged as a tightly structured ring[40] that remains unaltered by high-dose irradiation[41]. Minsky and colleagues[40] have suggested that this structure passively contributes to *D. radiodurans* radioresistance by preventing the fragments that are formed by double-strand breaks from diffusing apart during repair, which maintains the linear continuity of the genome even when it is fragmented. Although intellectually appealing, this hypothesis is controversial and has been criticized because the prevalence of ring-like nucleoids under different growth conditions does not always correlate with ionizing-radiation resistance[27,41]. A recent examination of the nucleoids of members of the radioresistant genera *Deinococcus* and *Rubrobacter* revealed a high degree of genome condensation — regardless of nucleoid shape — relative to the more radiosensitive species *E. coli* and *Thermus aquaticus*[41], which could indicate that species with a condensed genome might be better protected from ionizing radiation.

Manganese content. Daly and colleagues examined the effects of the high concentrations of Mn(II) that can accumulate in *D. radiodurans*[27] on the capacity of these cells to survive irradiation. When *D. radiodurans* cultures are starved of Mn(II), their resistance to ionizing radiation decreases[27]. The numbers of DNA double-strand breaks formed are the same for a specific dose of ionizing radiation both in the presence or absence of Mn(II), so Mn(II) does not prevent DNA damage[27]. Instead, cellular damage that results from exposure to high radiation doses is better tolerated if Mn(II) is present.

Most DNA damage that occurs after exposure to ionizing radiation results from the generation of reactive oxygen species (ROS) and the hydrolytic cleavage of water. Intracellular Mn(II) can be protective by scavenging ROS. For example, *Lactobacillus plantarum* lacks the protective enzyme superoxide dismutase, and instead substitutes with intracellular Mn(II) concentrations of 20–25 mM[42,43]. As the levels of double-strand breaks in *D. radiodurans* seem to be unaffected by Mn(II), any scavenging of ROS must protect macromolecules other than DNA. Daly *et al.*[27,44] have proposed that Mn(II) accumulation prevents superoxide and related ROS that are produced during irradiation from damaging proteins. If this is the case, bacteria that do not accumulate sufficient Mn(II) might succumb to ionizing-radiation-induced protein damage before DNA is significantly damaged[44].

Alternatively, the increased Mn(II) concentration could contribute to the condensation of the *D. radiodurans* genome[40,45]. DNA can be condensed *in vitro* by adding multivalent cations to an aqueous solution of DNA — the cations neutralize the repulsion of phosphate groups in the DNA backbone[46]. In this way, the proposals of Daly[27,44] and Minsky[40,45] could be related and have similar positive consequences in the context of genome reconstitution.

Regulation of cellular responses to extensive radiation damage. When *D. radiodurans* is exposed to ionizing radiation, a well characterized sequence of physiological events take place, including rapid cessation of DNA replication. At sublethal doses, the duration of the replication delay always exceeds the time that is required to repair the DNA damage that caused inhibition of replication[47–49]. The capacity to inhibit DNA replication is not unlike the DNA-damage checkpoints of eukaryotes — mechanisms that sense DNA damage and initiate a delay in the cell cycle until the damage is repaired[50]. However, the existence of a DNA-damage checkpoint operating in *D. radiodurans* has not been formally established.

Potential enzymatic contributions to repair

Ultimately, DNA strand breaks must be enzymatically repaired, and *Deinococcus* spp. can use novel repair processes. In 1996, Daly and Minton provided evidence for a genome-repair process that involved a temporal progression through at least two distinct stages[31]. Substantial chromosome repair occurs during the first

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Table 3 | **Selected *Deinococcus radiodurans* proteins with putative functions in DNA repair**

Protein	Region of homology	% identity	% similarity	Comments
Ligase (DnlJ)	11–669/671 *Escherichia coli*, 29–681/708 *D. radiodurans*	42	57	-
PolA	5–924/928 *E. coli*, 43–952/965 *D. radiodurans*	35	49	-
PriA	202–729/731 *E. coli*, 404–922/924 *D. radiodurans*	26	42	-
RecA	4–324/353 *E. coli*, 16–336/362 *D. radiodurans*	57	72	-
RecD	30–598/609 *E. coli*, 218–705/716 *D. radiodurans*	27	40	N-terminal extension in *D. radiodurans*
RecF	3–330/358 *E. coli*, 6–326/360 *D. radiodurans*	28	43	-
RecG	6–693/694 *E. coli*, 107–777/785 *D. radiodurans*	39	53	N-terminal extension in *D. radiodurans*
RecJ	68–570/579 *E. coli*, 3–461/685 *D. radiodurans*	34	51	C-terminal extension in *D. radiodurans*
RecN	2–553/553 *E. coli*, 34–564/564 *D. radiodurans*	31	49	-
RecO	7-157/242 *E. coli*, 10-159/224 *D. radiodurans*	*18*	*34*	Low homology; required PSI-BLAST
RecQ	9–600/608 *E. coli*, 8–605/824 *D. radiodurans*; 557–605/608 *E. coli*, 680–728/824 *D. radiodurans;* 549–606/608 *E. coli*, 768–825/824 *D. radiodurans*	46, 36, 33	63, 64, 59	HRDC domain repeated three times in *D. radiodurans*
RecR	1–199/202 *E. coli*, 1–196/220 *D. radiodurans*	42	55	C-terminal extension in *D. radiodurans*
RuvA	1–199/203 *E. coli*, 1–197/201 *D. radiodurans*	33	49	-
RuvB	13–332/337 *E. coli*, 2–321/333 *D. radiodurans*	56	75	A second orthologue with weaker similarity is present
RuvC	4–168/174 *E. coli*, 3–166/179 *D. radiodurans*	33	51	-
SbcC	27–1032/1049 *E. coli*, 22–896/909 *D. radiodurans*	21	35	-
SbcD	1–293/400 *E. coli*, 24–319/417 *D. radiodurans*	28	46	C-terminal changes

For each protein, the region of homology is indicated as residue numbers, followed by the total number of residues in the protein. The gene for the single-stranded-DNA-binding protein (SSB) is described in the text. No homology found for DnaC, DnaT, PriB, PriC, RecB, RecC, RecE, RecT or SbcB.

1.5 hours after *D. radiodurans* is treated with a high dose of ionizing radiation, through RecA-independent repair processes. Almost one-third of the double-strand breaks were repaired in this phase. RecA-dependent recombinational DNA repair becomes important several hours after irradiation, and predominates in the later stages of genome reconstitution[31]. Proteins that are known to be potentially important in genome-repair processes are listed in TABLE 3.

A search for novel genes that are induced in response to ionizing radiation and desiccation, using genome-based microarrays, provided new evidence for both RecA-independent and RecA-dependent pathways of double-strand-break repair[51]. In exponentially growing cells, 72 genes are induced three-fold or more after γ-irradiation. Seventy-three loci were induced during recovery from extended desiccation, and 33 of these genes were also induced following irradiation. The five genes most highly induced in response to both stresses were identical and encode proteins of unknown function. Inactivation of these loci — *ddrA*, *ddrB*, *ddrC*, *ddrD* and *pprA* — produces phenotypes that are relevant for genome repair. Genetic analyses defined three EPISTASIS GROUPS that affect ionizing-radiation resistance, and established that two of the loci (*ddrA* and *ddrB*) contribute to radioresistance through different RecA-independent processes. The *pprA* and *recA* loci form a third epistasis group, indicating that the *pprA* gene product interacts with RecA. Identification of these novel loci indicates that there are new mechanisms with an important role in genome repair of *D. radiodurans* post-irradiation.

EPISTASIS GROUP
This occurs when two or more genes control a phenotype. The combined effect of mutations in these genes on a phenotype deviates from the sum of their individual effects.

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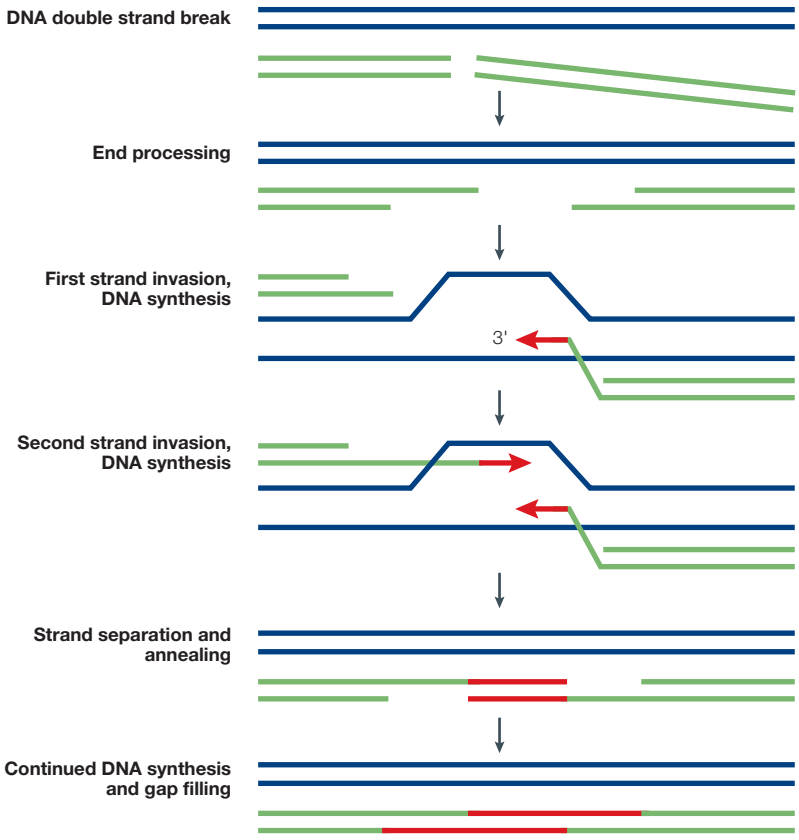

Figure 4 | **Synthesis-dependent strand annealing.** A mechanism of error-free double-strand-break repair that is initiated by creating 3′ overhangs from the ends of the broken DNA duplex (green in the figure). One of these 3′ ends invades a homologous region on an undamaged sister duplex (blue in the figure), priming DNA synthesis and creating a D-loop that acts as a template or DNA synthesis primed by the other 3′ end. If displaced, the newly synthesized DNA can anneal, closing the double-strand break. Newly synthesized DNA is coloured red.

NON-HOMOLOGOUS END JOINING
One of several pathways that can be used to repair chromosomal double-strand DNA breaks. The process is non-homologous because adjacent broken strands are fused by direct end-to-end contact without regard to sequence homology. Therefore, non-homologous end joining is error-prone because it results in joining of the breaks without a template.

DNA end protection. The *ddrA* locus was the first of the five new genes to be characterized[52]. Deletion of *ddrA* function results in a modest increase in radiation sensitivity in cells grown in rich media. However, when cells are irradiated and then starved, deletion of *ddrA* results in a 100-fold loss of viability over 5 days compared with wild-type cells. The loss in viability of the *ddrA* mutant is accompanied by a dramatic decrease in genomic DNA content by nucleolytic degradation. The DdrA protein binds to the 3′ ends of single-stranded DNA *in vitro* and protects them from nucleolytic degradation[52].

DdrA seems to function as a DNA-end-protection system. As double-strand breaks occur, DdrA (and perhaps other proteins) binds to the exposed DNA ends and prevents nuclease digestion of the chromosomal DNA. This strategy is particularly useful in the genome repair that occurs after desiccation. DNA repair uses a lot of metabolic energy, but cells recovering after desiccation in an environment that lacks nutrients would not have the opportunity to repair DNA damage. As DNA strand breaks occur, nuclease action could degrade genomic DNA. By protecting the broken DNA ends, cells could preserve genomic DNA until conditions become suitable for cell growth and DNA repair.

Bioinformatics initially failed to identify any DdrA homologues, but further bioinformatics investigation revealed that DdrA was distantly related to the eukaryotic Rad52 protein and to the prokaryotic Redβ, Erf and RecT proteins[52,53], so additional functions for DdrA have not been ruled out.

RecA-independent double-strand-break repair. Both NON-HOMOLOGOUS END JOINING (NHEJ) and single-strand annealing (SSA) pathways have been hypothesized to function in *D. radiodurans*. Minsky and colleagues[40,45] suggested that NHEJ would be a useful process for the repair of double-strand breaks in the context of a condensed chromosome, in which ends might not be free to diffuse away from each other. An NHEJ system has been identified in *Bacillus subtilis*[54] and is probably present in other bacteria. Two other laboratories also recently suggested that NHEJ occurs in *D. radiodurans*[55,56]. PprA and PolX are two proteins with predicted activities that are consistent with the existence of NHEJ[55,56]. However, classical NHEJ systems are generally error-prone[57] and seem unsuited to the accurate genome repair that is observed in *Deinococcus* spp. Patterns of recombination between plasmids and the re-circularization of integrated plasmids in irradiated *Deinococcus* cells are not consistent with NHEJ[31].

Plasmid repair and re-circularization of genome-integrated plasmids during the RecA-independent phase of DNA double-strand-break repair in *D. radiodurans* is dependent on homology, indicating that SSA might have a role[31]. Recent research has suggested a compelling model for genome restitution in this species, in which the related but more efficient process called synthesis-dependent single-strand annealing (SDSA) plays a necessary part (M. Radman, personal communication). It provides evidence that *D. radiodurans* R1 uses SDSA as a first step in genome re-assembly. During SDSA, the 3′ end of a strand derived from a DNA double-strand break invades the homologous region of a sister duplex (FIG. 4). The invading 3′ end is used to prime DNA synthesis, unwinding the sister duplex and enlarging the D-loop. The displaced strand in the undamaged complex anneals to the remaining free 3′ end created by the double-strand break. As each 3′ end primes complementary DNA synthesis, the resulting newly synthesized strands can anneal, sealing the breach in the damaged duplex in an error-free manner. This work shows that all RecA-independent genome assembly requires extensive *polA*-dependent DNA synthesis, and that the pattern of nucleotide incorporation, as measured by density labelling post-irradiation, indicates a distributive mode of replication that is consistent with SDSA. The amount of newly synthesized DNA recorded during this phase of post-irradiation recovery indicates that the tails are longer than expected based on precedent in other species that exhibit SDSA. The authors suggest that the long tails assure precise annealing, ensuring an error-free recovery.

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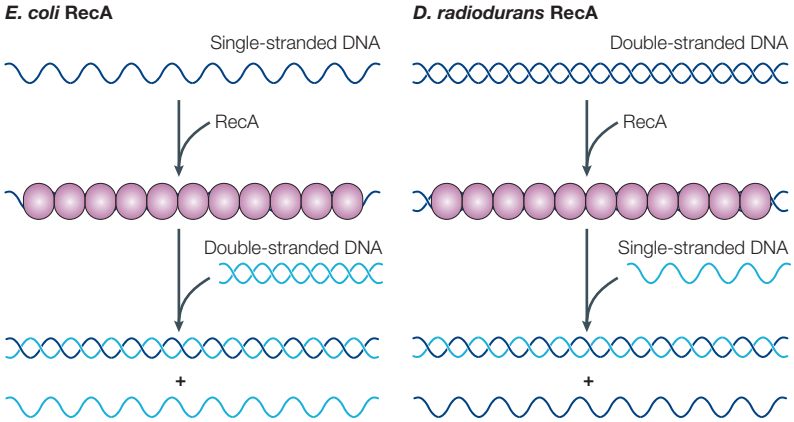

Figure 5 | **Inverse DNA-strand exchange promoted by the *Deinococcus radiodurans* RecA protein.** Instead of forming a filament on single-stranded DNA and then reacting with a homologous duplex, strand exchange is initiated by a filament formed on duplex DNA.

At least one additional RecA-independent pathway mediated by the DdrB protein is present in *D. radiodurans*[51]. Although DdrB has not yet been characterized *in vitro*, deletion of *ddrA* and *ddrB* produces a mutant that is significantly more sensitive to ionizing radiation than either *ddrA* or *ddrB* mutants, indicating that DdrA and DdrB have complementary activities.

Recombinational DNA repair. Any ends that lack overlapping sequence or other means to guide accurate repair require recombinational repair using redundant genome information. Studies of the roles of the classical proteins involved in bacterial recombinational DNA repair in *D. radiodurans* have been initiated (TABLE 3), including studies of recombinase A (RecA), single-strand-binding protein (SSB), recombinase D (RecD), DNA polymerase I, recombinase R (RecR) and recombinase O (RecO).

The *D. radiodurans* RecA protein (361 amino acids, M_r 38,013) is 57% identical (72% similar) to the *E. coli* RecA protein (352 amino acids, M_r 37,842). *In vitro*, the protein promotes all of the key recombinogenic activities of RecA-class recombinases. It forms filaments on DNA, hydrolyses ATP and dATP in a DNA-dependent fashion and promotes DNA-strand exchange[58]. However, the *D. radiodurans* RecA protein has one distinct function. The DNA strand-exchange reactions of the *E. coli* RecA protein, and all other homologues examined to date, are ordered so that the single-stranded DNA is generally bound first, before the double-stranded DNA is bound. This order of DNA binding makes sense from a biological standpoint, as the RecA protein must be targeted to single-strand gaps at stalled replication forks and other damaged DNA sites. By contrast, the *D. radiodurans* RecA protein promotes an obligate inverse DNA-strand-exchange reaction[59], binding the duplex DNA first and the homologous single-stranded DNA substrate second (FIG. 5). It is probable that this reaction pathway reflects the function of *D. radiodurans* RecA in double-strand-break repair, although its significance is not yet clear.

Based on the properties of an E142K mutant of *D. radiodurans* RecA (also known as RecA424), Satoh *et al.*[60] suggested that the effect of *D. radiodurans* RecA on double-strand-break repair primarily reflected a regulatory rather than a recombination function. The mutant protein does not complement the null phenotype of a *recA* knockout in *E. coli*, but does have residual regulatory functions associated with RecA. Strains harbouring the E142K mutation seem to retain resistance to γ-irradiation. However, the E142K mutation does retain significant DNA-strand-exchange activity in some assays, and more work is needed to define the function of RecA in *D. radiodurans*. Assuming that *D. radiodurans* must locate and splice together overlapping segments of its chromosomes to reconstruct a functional genome, a DNA-pairing activity such as that provided by RecA would be at the centre of such a process.

The *ssb* gene in *D. radiodurans* was originally annotated as a tripartite gene, with two frameshifts required to form a functional open reading frame (ORF) for translation[20,61–63]. However, this locus seems to be specific to the *D. radiodurans* R1 strain that was sequenced (ATCC BAA-816), as it differs substantially from that of the *D. radiodurans* R1 type strain (ATCC 13939). In the type strain, the *ssb* locus is a single continuous ORF that encodes the largest bacterial SSB polypeptide identified to date. It has two oligonucleotide/oligosaccharide-binding (OB) folds rather than the one present in most bacterial SSB proteins, and it functions as a dimer rather than a tetramer[64]. The gene is highly homologous to *ssb* genes found in *Thermus* species, to which *D. radiodurans* is closely related. The *D. radiodurans* SSB protein is efficient at stimulating the DNA-strand exchange that is promoted by RecA proteins from both *E. coli* and *D. radiodurans*, being more active than the *E. coli* SSB in both cases. The atomic structure of *D. radiodurans* SSB has been solved[65]. This protein could be important in chromosome repair. The concentration of the *D. radiodurans* SSB is an order of magnitude higher than the normal *in vivo* levels of the SSB protein in *E. coli*.

Less is known about other classical repair proteins in *D. radiodurans*. In the absence of a *recB* or *recC* gene, the *recD* gene product has been characterized. The *D. radiodurans* RecD protein has a 5′ to 3′ helicase activity, in common with the RecD subunit of the *E. coli* RecBCD enzyme[66]. It can unwind short (20 bp) duplexes if a 5′ single-strand tail is adjacent. The atomic structure of the *D. radiodurans* RecO protein has been solved[67], but nothing is known about its function. Similarly, the structure of the *Deinococcus* RecR protein has been determined[68].

Narumi and colleagues have shown that purified PprA protein can bind to duplex DNA with strand breaks *in vitro*, protect the strands from nuclease digestion and facilitate the ligation of duplex DNA fragments[56]. They speculate that PprA is part of a deinococcal NHEJ system, although this role seems inconsistent with the absence of mutations observed after irradiation in this species. As with most *D. radiodurans* proteins, PprA characterization is at an early stage.

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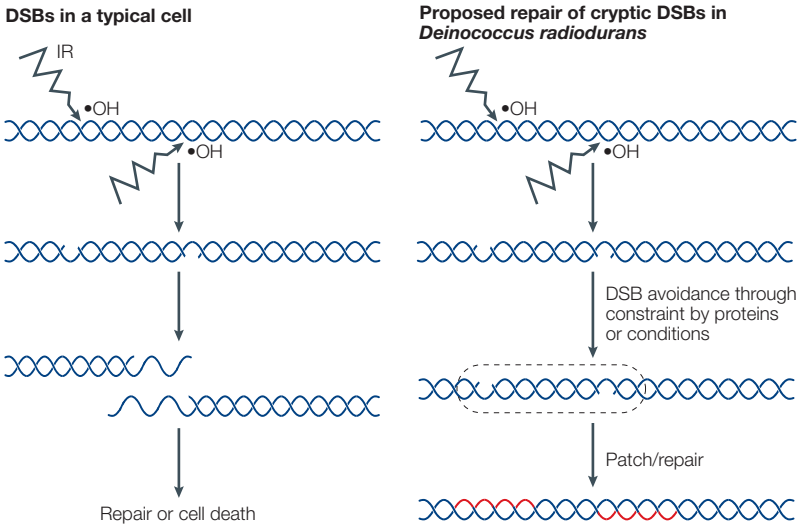

Figure 6 | **A proposed mechanism that might contribute to the tolerance of radiation damage in *Deinococcus radiodurans*.** Potential double-strand breaks (DSBs) are constrained, held together by proteins and/or their local environment, so that many breaks scored as DSBs in *in vitro* assays are cryptic in the cell. IR, ionizing radiation; •OH, hydroxyl radical.

A new proposal for radiation tolerance

To the list above, we add one more mechanism, which is a new proposal (FIG. 6). It is particularly difficult to explain the accurate repair of the hundreds of scattered repeat elements in the *D. radiodurans* genome[20,63,69] after the introduction of hundreds of double-strand breaks. How does *D. radiodurans* avoid the potentially disruptive recombination events that could occur between these repeated elements to maintain the continuity of its genome? We speculate that *D. radiodurans* uses a strategy that potentially combines elements of many of the systems described in this review to avoid this problem — including the condensed nucleoid structure first highlighted by Minsky[40,45] and the high concentrations of Mn(II) ions discussed by Daly[27,44] — thereby improving the cell's capacity to tolerate ionizing radiation.

Many DNA double-strand breaks arise from the juxtaposition of two single-strand breaks that form as a function of the distance in base pairs between these breaks (BOX 1). In general, the further apart the single-strand breaks, the less likely it is that the DNA ends will separate to form a double-strand break. We suggest that a significant contribution to the observed tolerance of ionizing radiation in *D. radiodurans* could arise if many of the measured double-strand breaks that occur are cryptic *in vivo*. In other words, some fraction of the measured double-strand breaks could actually be held together so that the separation of the DNA ends never really occurs in the cell. This proposal assumes that the organism has a mechanism to stabilize opposed breaks, constraining the intervening base pairs so that actual separation of the two DNA ends does not occur. This idea is distinct from proposals[40,45] in which the ends separate and are repaired by NHEJ. The cryptic breaks we propose would be scored as double-strand breaks during the processing and analysis of genomic DNA because the conditions necessary to stabilize the paired single-strand breaks are lost when the cell is disrupted. However, in *situ* the DNA strands are not separated. Unlike classical NHEJ, repair of these cryptic breaks would be effectively templated, as genomic continuity would never be lost.

This proposal envisions a specialized system operating in the condensed chromosome that prevents the formation of double-strand breaks at those sites where some base pairing is present. Opposed single-strand breaks would be repaired using a set of enzymes that could deal with the close proximity of the breaks in opposing strands without affecting this base pairing. By this mechanism, the linear continuity of the genome sequence, including regions rich in short nucleotide repeats, would be preserved at many potential sites of double-strand breaks in a manner that is error-free. Experimentally, this process would be indistinguishable from a non-mutagenic type of NHEJ. If such a system exists, the repair would be accurate and RecA-independent, passively reducing the cell's dependence on recombinational DNA repair and the accompanying homology search at any break site that is stabilized in this manner.

Examples from the literature indicate that the cell might use two alternative, but not mutually exclusive, mechanisms to stabilize base pairing between opposed single-strand breaks. First, *D. radiodurans* might encode proteins that hold the DNA together. Second, the intracellular ionic composition could be sufficient to physically limit dissociation of DNA base pairs. If proteins are responsible, we assume that they will be functionally analogous to the structural-maintenance-of-chromosomes (SMC) proteins that are present in many eukaryotic and prokaryotic species[70–72]. In eukaryotes, these proteins are referred to as cohesins and condensins, and the significance of their role in genome stabilization and DNA repair is becoming apparent[73]. The stability of annealed complementary DNA is dependent on the ionic strength of the medium in which the DNA is dissolved, and increased intracellular Mn(II) concentrations[27] might help to hold DNA that contains several single-strand breaks together. Freifelder and Trumbo[74] have shown that high-ionic-strength media stabilize opposed breaks separated by as little as two base pairs

A system for the repair of cryptic double-strand breaks might exist in many organisms. Conceptually, the damage that is caused by high-dose ionizing radiation is similar to the damage that would occur if a type II restriction enzyme was expressed *in vivo*. A large number of opposed single-strand breaks would be formed and would produce double-strand breaks unless stabilized. In yeast, the prolonged expression of *Eco*RI produces thousands of breaks but results in a surprisingly modest (2–3 fold) loss of viability[75–77]. Similarly, prolonged artificial expression of the yeast mating-type-specific HO endonuclease results in only a 35% loss of viability[78] in strains that have four HO-sensitive chromosomal loci. Survival

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in these strains does not depend on homologous-recombination systems. Lethal fragmentation of chromosomes only occurs in cells that have defective NHEJ or checkpoint-control systems. Even *E. coli* cells are surprisingly resistant to *Eco*RI-mediated chromosomal cleavage as long as the appropriate DNA ligases are not inactivated[79]. Once the cryptic breaks are repaired, breaks where the ends have separated could be repaired by additional processes such as SSA and recombinational DNA repair.

Conclusion

The extraordinary phenotypes of *D. radiodurans* have encouraged a host of rather fanciful descriptions of the origin of this organism. Stories of the arrival of this species on earth on a comet, or arising through mutations owing to mankind's attempts to harness nuclear power, are readily available on the internet (See Online links box). These ideas are likely to flourish until this remarkable organism is better understood. *D. radiodurans* has a readily documented evolutionary origin within the domain Bacteria. It is clearly related to the rest of life on this planet, carrying out all of the fundamental processes that have been characterized in prokaryotes.

Our interpretation of the literature published to date on the Deinococcaceae suggests no extraordinary survival strategies, or at least no single 'magic bullet' that provides a complete explanation for the phenomenon. Instead, enhanced radioresistance seems to be the consequence of an evolutionary process that has coordinated various passive and active mechanisms, enabling survival from stresses such as desiccation. The almost ubiquitous classical DNA-repair pathways, perhaps with some specialized properties, seem to be augmented by novel features of deinococcal nucleoid structure and metabolism. It is currently difficult to predict which mechanism(s) will be most important in radioresistance, or even whether all of the contributing mechanisms have been discovered. Each of the many enhancements could individually have a modest effect, but collectively they mediate radioresistance. These changes need not be unique to *D. radiodurans*, but might be present in other organisms.

Therefore, the capacity of the deinococci to deal with stresses that cause massive genetic damage might not be as strange or as unusual as it once seemed. The combination of repair strategies is sophisticated and effective, but the individual strategies delineated so far are based on mechanisms present in many other organisms.

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Competing interests statement

The authors declare no competing financial interests

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DATABASES

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Quantum Time Crystals

Frank Wilczek

Center for Theoretical Physics Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

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Some subtleties and apparent difficulties associated with the notion of spontaneous breaking of time-translation symmetry in quantum mechanics are identified and resolved. A model exhibiting that phenomenon is displayed. The possibility and significance of breaking of imaginary time-translation symmetry is discussed.

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Symmetry and its spontaneous breaking is a central theme in modern physics. Perhaps no symmetry is more fundamental than time-translation symmetry, since time-translation symmetry underlies both the reproducibility of experience and, within the standard dynamical frameworks, the conservation of energy. So it is natural to consider the question, whether time-translation symmetry might be spontaneously broken in a closed quantum-mechanical system. That is the question we will consider, and answer affirmatively, here.

Here we are considering the possibility of time crystals, analogous to ordinary crystals in space. They represent spontaneous emergence of a clock within a time-invariant dynamical system. Classical time crystals are considered in a companion Letter [1]; here the primary emphasis is on quantum theory.

Several considerations might seem to make the possibility of quantum time crystals implausible. The Heisenberg equation of motion for an operator with no intrinsic time dependence reads

$$\langle\Psi|\dot{\mathcal{O}}|\Psi\rangle = i\langle\Psi|[H, \mathcal{O}]|\Psi\rangle \underrightarrow{\Psi=\Psi_E} 0, \tag{1}$$

where the last step applies to any eigenstate Ψ_E of H. This seems to preclude the possibility of an order parameter that could indicate the spontaneous breaking of infinitesimal time-translation symmetry. Also, the very concept of ''ground state'' implies the state of lowest energy, but in any state of definite energy (it seems) the Hamiltonian must act trivially. Finally, a system with spontaneous breaking of time-translation symmetry in its ground state must have some sort of motion in its ground state, and is therefore perilously close to fitting the definition of a perpetual motion machine.

Ring particle model.—And yet there is a familiar physical phenomenon that almost does the job. A superconductor, in the right circumstances, can support a stable current-carrying ground state. Specifically, this occurs if we have a superconducting ring threaded by a flux that is a fraction of the flux quantum. If the current is constant then nothing changes in time, so time-translation symmetry is not broken, but clearly there is a sense in which something is moving.

We can display the essence of this situation in a simple model, that displays its formal structure clearly. Consider a particle with charge q and unit mass, confined to a ring of unit radius that is threaded by flux $2\pi\alpha/q$. The Lagrangian, canonical (angular) momentum, and Hamiltonian for this system are, respectively,

$$L = \tfrac{1}{2}\dot{\phi}^2 + \alpha\dot{\phi}, \qquad \pi_\phi = \dot{\phi} + \alpha, \qquad H = \tfrac{1}{2}(\pi_\phi - \alpha)^2. \tag{2}$$

π_ϕ, through its role as generator of (angular) translations, and in view of the Heisenberg commutation relations, is realized as $-i\frac{\partial}{\partial\phi}$. Its eigenvalues are integers l, associated with the states $|l\rangle = e^{il\phi}$. For these states we have

$$\langle l|\dot{\phi}|l\rangle = l - \alpha, \qquad \langle l|H|l\rangle = \tfrac{1}{2}(l - \alpha)^2. \tag{3}$$

The lowest energy state will occur for the integer l_0 that makes $l - \alpha$ smallest. If α is not an integer, we will have

$$\langle l_0|\dot{\phi}|l_0\rangle = l_0 - \alpha \neq 0. \tag{4}$$

The case when α is half an odd integer requires special consideration. In that case we will have two distinct states $|\alpha \pm \tfrac{1}{2}\rangle$ with the minimum energy. We can clarify the meaning of that degeneracy by combining two simple observations. First, that the combined operation G_k of multiplying wave functions by $e^{ik\phi}$ and changing $\alpha \to \alpha + k$, for integer k, in the Lagrangian leaves the dynamics invariant. Indeed, if we interpret α in L as embodying a constant gauge potential, G_k is a topologically nontrivial gauge transformation on the ring, corresponding to the multiply valued gauge function $A \to A + \nabla\Lambda$, $\Lambda = k\phi/q$. Note that the total flux is *not* invariant under this topologically nontrivial gauge transformation, which cannot be extended smoothly off the ring, so L is modified. Second, that the operation of time-reversal T, implemented by complex conjugation of wave functions, takes $|l\rangle \to |-l\rangle$ and leaves the dynamics invariant if simultaneously $\alpha \to -\alpha$. Putting these observations together, we see that the combined operation

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$$\tilde{T} = G_{2\alpha} T \tag{5}$$

leaves the Lagrangian invariant; it is a symmetry of the dynamics and maps $|l\rangle \rightarrow |2\alpha - l\rangle$. $\tilde{T}$ interchanges $|l \pm \alpha\rangle \rightarrow |l \mp \alpha\rangle$. Thus the degeneracy between those states is a consequence of a modified time-reversal symmetry. We can choose combinations $|\alpha + \frac{1}{2}\rangle \pm |\alpha - \frac{1}{2}\rangle$ that simultaneously diagonalize H and $\tilde{T}$; for these combinations the expectation value of $\dot{\phi}$ vanishes.

Returning to the generic case: For α that are not half-integral time-reversal symmetry is not merely modified, but simply broken, and there is no degeneracy. How do we reconcile $\langle l_0|\dot{\phi}|l_0\rangle \neq 0$ with Eq. (1)? The point is that $\dot{\phi}$, despite appearances, is neither the time-derivative of a legitimate operator nor the commutator of the Hamiltonian with one, since ϕ, acting on wave functions in Hilbert space, is multivalued. By way of contrast, operators corresponding to single-valued functions of ϕ, spanned by trigonometric functions $\mathcal{O}_k = e^{ik\phi}$, do satisfy Eq. (1) for the eigenstates $|\Psi\rangle = |l\rangle$.

Wave functions of the quantized ring particle model correspond to the (classical) wave functions that appear in the Landau-Ginzburg theory of superconductivity. Those wave functions, in turn, heuristically describe the wave function for macroscopic occupation of the single-particle quantum state appropriate to a Cooper pair, regarded as a particle. Under this correspondence, the nonvanishing expectation value of $\dot{\phi}$ for the ground state of the ring particle subject to fractional flux maps onto the persistent current in a superconducting ring.

Symmetry breaking and observability.—The choice of a ground state that violates time-translation symmetry τ must be based on some criterion other than energy minimization. But what might seem to be a special difficulty with breaking τ, because of its connection to the Hamiltonian, actually arises in only a slightly different form for all cases of spontaneous symmetry breaking. Consider, for example, the breaking of number (or dually, phase) symmetry. We characterize such breaking through a complex order parameter, Φ, that acquires a nonzero expectation value, which we can take to be real:

$$\langle 0|\Phi|0\rangle = v \neq 0. \tag{6}$$

We also have states $|\sigma\rangle$ related to $|0\rangle$ by the symmetry operation. These are all energetically degenerate and mutually orthogonal in the appropriate "infinite volume" limit (see immediately below), and satisfy

$$\langle \sigma|\Phi|\sigma\rangle = v e^{i\sigma}. \tag{7}$$

The superposition

$$|\Omega\rangle \propto \int_0^{2\pi} d\sigma |\sigma\rangle \tag{8}$$

is energetically degenerate with all the $|\sigma\rangle$, and it is symmetric, with

$$\langle \Omega|\Phi|\Omega\rangle = 0. \tag{9}$$

[Normalization of $|\Omega\rangle$ depends on how the limit is taken. If we arrange $\langle \sigma|\sigma'\rangle \rightarrow \delta(\sigma - \sigma')$, then the proportionality constant is $(2\pi)^{-1}$.]

Why then do we prefer one of the states $|\sigma\rangle$ as a description of the physical situation? The reason is closely related to the emergent orthogonality of the different $|\sigma\rangle$ states, as we now recall. We envisage that our system extends over a large number N of identical subsystems having correlated values of the long-range order parameter σ, but otherwise essentially uncorrelated. Then we can express the total wave function in the form

$$\Psi_\sigma(x_1, \ldots, x_N) \approx \prod_{j=1}^{N} \psi_\sigma(x_j). \tag{10}$$

For different values σ, σ' we have therefore

$$\langle \Psi_{\sigma'}|\Psi_\sigma\rangle \approx \prod_{j=1}^{N} \langle \psi_{\sigma'}(x_j)|\psi_\sigma(x_j)\rangle = (f_{\sigma'\sigma})^N \rightarrow 0 \tag{11}$$

for $\sigma' \neq \sigma$ and large N, since $|f_{\sigma'\sigma}| < 1$. Similarly, for any finite set of local observables (that is, observables whose arguments include only upon a finite subset of the x_j), we have

$$\langle \Psi_{\sigma'}|\mathcal{O}_1(x_a)\mathcal{O}_2(x_b)\ldots|\Psi_\sigma\rangle \propto (f_{\sigma'\sigma})^{N-\text{finite}} \rightarrow 0 \tag{12}$$

for $\sigma' \neq \sigma$. Since the off-diagonal matrix elements vanish, any world of local observations (including "observations" by the environment) can be described using a single $|\sigma\rangle$ state. Averaging over them, to produce $|\Omega\rangle$, is a purely formal operation. Measurement of a nonsinglet observable will project onto a $|\sigma\rangle$ state.

This analysis, which elaborates [2], brings out several relevant points. The physical criterion that identifies useful "ground states" is not simply energy, but also robust observability—that is, relevance to the description of observations in a world of mutually communicating observers. Mathematically, that requirement is reflected in the orthogonality of the Hilbert spaces built upon $|\sigma\rangle$ states by the action of physical observables. The large N limit is crucial for spontaneous symmetry breaking. It is only in that infinite degree of freedom, or (as it is usually called) infinite volume, limit, that the $|\sigma\rangle$ states and their Fourier transforms $|j\rangle \propto \int d\sigma e^{ij\sigma}|\sigma\rangle$, with definite charge j, become degenerate, and the former are preferred. Important for present purposes: The preceding discussion applies, with only symbolic changes, when we consider possible breaking of time-translation τ in place of phase symmetry.

Soliton model.—After these preparations, it is not difficult to construct an appropriate model. We consider a large number of ring-particles with an attractive interaction. Heuristically, we can expect that they will want to form a lump and, in view of Eq. (4), that they will want to move. So we can expect that the physical ground state features a moving lump, which manifestly breaks τ.

To make contact with the argument of the previous section, we need an appropriate notion of locality. We assume that the particles have an additional integer label, besides the common angle ϕ, and that the local physical observables are of finite range in that additional label. One can imagine an array of separate rings, displaced along an axis, so that the coordinates of particle j are $(\phi, x = ja)$. Note that with this interpretation, the basic interaction is infinitely long ranged, and would have to be specially engineered. I will revisit this issue below, after describing the construction.

An appropriate Hamiltonian is

$$H = \sum_{j=1}^{N} \frac{1}{2}(\pi_j - \alpha)^2 - \frac{\lambda}{N-1} \sum_{j \neq k,1}^{N} \delta(\phi_j - \phi_k)$$
$$\equiv \sum_{j=1}^{N} \frac{1}{2}(\pi_j - \alpha)^2 + V(\phi_1, \ldots, \phi_N), \tag{13}$$

with the understanding that H acts on periodic functions, so the δ interaction is well defined. (Here the discrete index appears as a subscript.)

We work in the mean field approximation, taking a product ansatz

$$\Psi(\phi_1, \ldots, \phi_n) = \prod_{j=1}^{N} \psi(\phi_j), \tag{14}$$

and solving an approximate one-body equation for ψ. To get such an equation, we define an effective potential

$$V_{\text{eff.}}(\phi_1, \ldots, \phi_N) = \sum_{j=1}^{N},$$
$$W(\phi_j)W(\phi_j) = \int \prod_{k \neq j} d\phi_k \psi^*(\phi_k) V \psi(\phi_k), \tag{15}$$

so that

$$\langle \Psi | V_{\text{eff.}} | \Psi \rangle = \langle \Psi | V | \Psi \rangle. \tag{16}$$

Then the effective Schrödinger equation for Ψ,

$$i \frac{\partial \Psi}{\partial t} = \left(\sum_{j=1}^{N} \frac{1}{2}(\pi_j - \alpha)^2 + V_{\text{eff.}} \right) \Psi, \tag{17}$$

reduces to the one-body nonlinear Schrödinger equation

$$i \frac{\partial \psi}{\partial t} = \frac{1}{2}(\pi_\phi - \alpha)^2 \psi - \lambda |\psi|^2 \psi \tag{18}$$

for ψ.

Consider first the case $\alpha = 0$. Eq. (18) can be solved for a stationary state in terms of the Jacobi dn elliptic function, with

$$\psi(\phi, t) = e^{-i\mathcal{E}t} \psi_0(\phi + \beta), \qquad \psi_0(\phi) = r \,\mathrm{dn}(r\sqrt{\lambda}\phi, k^2),$$
$$\mathcal{E} = -r^2 \lambda \left(1 - \frac{k^2}{2}\right), \tag{19}$$

with β a disposable parameter. To fix the parameters k, r we must impose 2π periodicity in ϕ and normalize ψ_0. Those conditions become

$$E(k^2) = \frac{\sqrt{\lambda}}{2r}, \qquad K(k^2) = \pi r \sqrt{\lambda} \tag{20}$$

in terms of the complete elliptic integrals $E(k^2)$, $K(k^2)$. We can solve $E(k^2)K(k^2) = \frac{\pi\lambda}{2}$ for k^2, given λ. The minimum value of the left-hand side occurs at $k = 0$ and corresponds to $\lambda = \frac{\pi}{2}$. Here $\mathrm{dn}(u, 0)$ reduces to a constant, and $\mathcal{E} = -1/4$. As λ increases beyond that value k rapidly approaches 1, as does $E(k^2)$. $\mathrm{dn}(u, k^2) \to \mathrm{sech} u$ and $\mathcal{E} \to -\lambda^2/8$ in that limit. Of course the constant solution with $\mathcal{E} = -\lambda/2\pi$ exists for any value of λ, but when λ exceeds the critical value the inhomogeneous solution is more favorable energetically. These results have simple qualitative interpretations. The hyperbolic secant is the famous soliton of the nonlinear Schrödinger equation on a line. If that soliton is not too big it can be deformed, without prohibitive energy cost, to fit on a unit circle. The parameter β reflects spontaneous breaking of (ordinary) translation symmetry. Here that breaking is occurring through a kind of phase separation.

Our Hamiltonian is closely related, formally, to the Lieb-Liniger model [3], but because we consider ultraweak ($\sim 1/N$) attraction instead of repulsion, the ground state physics is very different. In general low-dimensional models of spontaneous symmetry breaking are subject to derangement by fluctuations [4]. Since our extremely inhomogeneous approximate ground state does not support low-energy, long-wavelength modes (apart from overall translation, but note that the mass of the lump is growing with N), it has no serious infrared sensitivity. It would be interesting to the model with attractive couplings more deeply, and at finite coupling. In any case, it is not difficult to realize the same ideas in higher-dimensional models, such as the Wigner crystal briefly mentioned below (and now analyzed in depth as a proposed experiment [5]). In finite systems the correlation time will be finite, of course, but in interesting cases it becomes very long. Its growth with system size might, by analogy with more familiar cases [6], be algebraic rather than exponential for some low-dimensional systems.

Now since nonzero α can be interpreted as magnetic flux through the ring, we might anticipate, from Faraday's law, that as we turn it on, starting from $\alpha = 0$, our lump of charge will feel a simple torque. (Note that since Faraday's law is a formal consequence of the mathematics of gauge potentials, its use does not require additional hypotheses.) We can also apply "gauge transformations", as in the discussion around Eq. (5). These observations are reflected mathematically in the following construction: For any l, we solve

$$i \frac{\partial \psi_l}{\partial t} = \frac{1}{2}(-i\partial_\phi - \alpha)^2 \psi_l - \lambda |\psi_l|^2 \psi_l, \tag{21}$$

with

$$\psi_l(\phi, t) = e^{-il\phi}\tilde{\psi}(\phi + (l+\alpha)t, t) i\frac{\partial\tilde{\psi}}{\partial t}$$
$$= \frac{1}{2}(-i\partial_\phi)^2\tilde{\psi} - \lambda|\tilde{\psi}|^2\tilde{\psi} + \frac{(l+\alpha)^2}{2}\tilde{\psi}. \quad (22)$$

As in the noninteracting ring particle model, the lowest energy is obtained by minimizing $l_0 + \alpha$, for integral l_0. This will supply appropriate $\tilde{\psi}$. If α is not an integer $\psi_{l_0}(\phi, t)$ will be a moving lump, and time-translation symmetry will have been spontaneously broken. If α is half an odd integer, then its $\tilde{T}$ symmetry is spontaneously broken too.

This example exhibits several characteristic features of natural τ breaking [1]. The lump moves along a constant energy trajectory. The parameter β, which parameterizes an orbit of (ordinary) translation symmetry, changes at a constant rate; both τ and translation symmetry are broken, but a combination remains intact.

Now let us return to address the conceptual issues alluded to earlier, around locality. Our model Hamiltonian was nonlocal, but we required observables to be local. That schizophrenic distinction can be appropriate, since the Hamiltonian might be—and, for our rather artificial dynamics, would have to be—carefully engineered, as opposed to being constructed from easily implemented, natural observables and interactions, which are local. However it is not unlikely that the assumption of all-to-all coupling, adopted for mathematical convenience, could be relaxed, in particular, by locating the rings at the nodes of a multidimensional lattice and limiting the couplings to a finite range.

Were we literally considering charged particles confined to a common ring, and treating the electromagnetic field dynamically, our moving lump of charge would radiate. The electromagnetic field provides modes that couple to all the particles, and in effect provide observers who manifestly violate the framework of Eq. (12). That permits, and enforces, relaxation to a $|k\rangle$ state. Simple variations can ameliorate this issue, e.g., use of multipoles in place of single charges, embedding the system in a cavity, or simply arranging that the motion is slow. A more radical variation, that also addresses the unrealistic assumption of attraction among the charges, while still obtaining spatial nonuniformity, would be to consider charged particles on a ring that form—through repulsion—a Wigner lattice.

Imaginary-time crystals.—In the standard treatment of finite temperature quantum systems using path integral techniques, one considers configurations whose arguments involve imaginary values of the time, and imposes imaginary-time periodicity in the inverse temperature $\beta = 1/T$. In this setup the whole action is converted, in effect, into a potential energy: time derivatives map onto gradients in imaginary time, which is treated on the same footing as the spatial variables.

At the level of the action, there is symmetry under translations in imaginary time (iTime). But since iTime appears, in this formulation, on the same footing as the spatial variables, it is natural to consider the possibility that for appropriate systems the dominant configurations in the path integral are iTime crystals. Let the iTime crystal have preferred period λ. When β is an integer multiple of λ the crystal will fit without distortion, but otherwise it must be squeezed or stretched, or incorporate defects. Periodic behavior of thermodynamics quantities in $1/T$, with period λ, arise, and provide an experimental diagnostic. Integration over the collective coordinate for the broken symmetry contributes to the entropy, even at zero temperature. Inspired by the spatial crystal—iTime crystal analogy, one might also consider the possibility of iTime glasses (iGlasses), which would likewise have residual entropy, but no simple order, or iQuasicrystals.

Comments.—(i). It is interesting to speculate that a (considerably) more elaborate quantum-mechanical system, whose states could be interpreted as collections of qubits, might be engineered to traverse, in its ground configuration, a programmed landscape of structured states in Hilbert space over time.

(ii). Fields or particles in the presence of a time crystal background will be subject to energy-changing processes, analogous to crystalline Umklapp processes. In either case the apparent nonconservation is in reality a transfer to the background. (In our earlier model, $O(1/N)$ corrections to the background motion arise.)

(iii). Many questions that arise in connection with any spontaneous ordering, including the nature of transitions into or out of the order at finite temperature, critical dimensionality, defects and solitons, and low-energy phenomenology, likewise pose themselves for time crystallization. There are also interesting issues around the classification of space-time periodic orderings (roughly speaking, four dimensional crystals [7]).

(iv). The ac Josephson effect is a semimacroscopic oscillatory phenomenon related in spirit to time crystallization. It requires, however, a voltage difference that must be sustained externally, so it is not a ground state effect.

(v). Quantum time crystals based on the classical time crystals of [1], which use singular Hamiltonians, can be constructed by combining the ideas of this Letter with those of [8,9]. The appearance of swallowtail band structures in [10], and emergence of complicated frequency dependence in modeling finite response times [1], as in [11], suggest possible areas of application.

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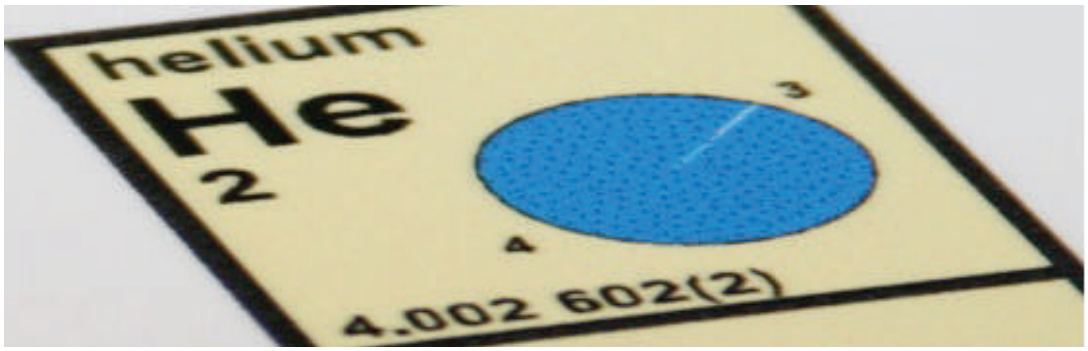

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Physical and chemical properties	
Chemical purity	≥99.9995% Total impurities as specified below ≤5ppm
Isotopic enrichment ^{3}He atomic fraction (%)	≥99.9 Atom%
Molecular weight	3.016g/mol
Gas density @ 21.1°C (70°F) ("NTP"):	0.0078 Lb/ft$_3$ (0.125 Kg/m3) (0.125 G/ltr)
@ 0°C ("STP"):	0.0084 Lb/ft$_3$ (0.135 Kg/m3) (0.135 G/ltr)
Boiling point @ 1 atm	-269.96°C
Freezing/Melting point @ 1 atm:	None
Solubility in water vol/vol at 20°c (68°F) and 1 atm:	8.61 M$_3$/1 kg water
Gas Density	0.125g/L
Critical pressure:	-2.7 Psia (0.186 Bar)
Coefficient water/Oil distribution:	Not applicable
Odor threshold:	Helium-3 is odorless
Appearance, odor and state:	Colorless, odorless gas

Chemical Purity	
COMPONENT	SPECIFICATIONS (MOLE/MOLE)
Oxygen (ppm)	≤ 1
Nitrogen (ppm)	≤ 1
Carbon Dioxide (ppm)	≤0.5
Carbon Monoxide (ppm)	≤1
Argon (ppm)	≤0.5
Water (ppm)	≤0.1
Activity (uCi/cc)	≤1.3 x 10-7

Cylinder Specifications

Size	Water Volume	Maximum Gas Contained
Lecture Bottle (Linde 2)	0.42L	50L
6 (Linde 6)	1.45L	200L
5 (Linde 10)	3L	400L
4 (Linde 30)	8L	1100L

U.S. Shipping information

U.S. Dot proper shipping name	Helium, compressed
Hazard class number and description:	2.2 (Non-flammable gas)
UN identification number:	UN 1046
U.S. DOT shipping label(s) required:	Non-flammable gas
CAS number	7440-59-7

Linde Electronics and Specialty Gases
One Greenwich Street, Suite 100, Stewartsville, NJ 08886
Phone +1.908.329-9700 or +1.800.932-0624, Fax +1.908.329-9740, www.lindeus.com

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Helium-3

Helium-3 (^{3}He, see also helion) is a light, non-radioactive isotope of helium with two protons and one neutron (common helium having two protons and two neutrons). Its hypothetical existence was first proposed in 1934 by the Australian nuclear physicist Mark Oliphant while he was working at the University of Cambridge Cavendish Laboratory. Oliphant had performed experiments in which fast deuterons collided with deuteron targets (incidentally, the first demonstration of nuclear fusion).[1] Helium-3 was thought to be a radioactive isotope until it was also found in samples of natural helium, which is mostly helium-4, taken both from the terrestrial atmosphere and from natural gas wells.[2] Other than protium (ordinary hydrogen), helium-3 is the only stable isotope of any element with more protons than neutrons.

Helium-3 occurs as a primordial nuclide, escaping from the Earth's crust into the atmosphere and into outer space over millions of years. Helium-3 is also thought to be a natural nucleogenic and cosmogenic nuclide, one produced when lithium is bombarded by natural neutrons, which can be released by spontaneous fission and by nuclear reactions with cosmic rays. Some of the helium-3 found in the terrestrial atmosphere is also a relic of atmospheric and underwater nuclear weapons testing.

Much speculation has been made over the possibility of helium-3 as a future energy source. Unlike most other nuclear fusion reactions, the fusion of helium-3 atoms releases large amounts of energy without causing the surrounding material to become radioactive. However, the temperatures required to achieve helium-3 fusion reactions are much higher than in traditional fusion reactions,[3] and the process may unavoidably create other reactions that themselves would cause the surrounding material to become radioactive.[4]

The abundance of helium-3 is thought to be greater on the Moon than on Earth, having been embedded in the upper layer of regolith by the solar wind over billions of years,[5] though still lower in abundance than in the solar system's gas giants.[6][7]

Helium-3, ^{3}He

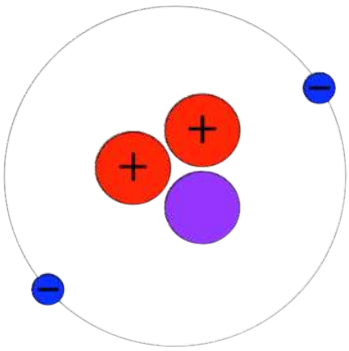

General	
Name, symbol	Helium-3, He-3, ^{3}He
Neutrons	1
Protons	2
Nuclide data	
Natural abundance	0.000137% (% He on Earth)
Half-life	stable
Parent isotopes	^{3}H (beta decay of tritium)
Isotope mass	3.0160293 u
Spin	½
Complete table of nuclides	

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Physical properties

Because of its low atomic mass of 3.02 atomic mass units, helium-3 has some physical properties different from those of helium-4, with a mass of 4.00 atomic mass units. Because of the weak, induced dipole–dipole interaction between the helium atoms, their microscopic physical properties are mainly determined by their zero-point energy. Also, the microscopic properties of helium-3 cause it to have a higher zero-point energy than helium-4. This implies that helium-3 can overcome dipole–dipole interactions with less thermal energy than helium-4 can.

The quantum mechanical effects on helium-3 and helium-4 are significantly different because with two protons, two neutrons, and two electrons, helium-4 has an overall spin of zero, making it a boson, but with one fewer neutron, helium-3 has an overall spin of one half, making it a fermion.

Helium-3 boils at 3.19 K compared with helium-4 at 4.23 K, and its critical point is also lower at 3.35 K, compared with helium-4 at 5.2 K. Helium-3 has less than half the density of Helium-4 when it is at its boiling point: 59 gram per liter compared to the 125 gram per liter of helium-4—at a pressure of one atmosphere. Its latent heat of vaporization is also considerably lower at 0.026 kilojoules per mole compared with the 0.0829 kilojoules per mole of helium-4.[8][9]

Fusion reactions

^{3}He can be produced by the low temperature fusion of $^2\mathrm{H} \overset{\text{(D-p)}}{+} {}^1\mathrm{p} \rightarrow {}^3\mathrm{He} + \gamma + 4.98$ MeV. If the fusion temperature is below that for the helium nuclei to fuse, the reaction produces a high energy alpha particle which quickly acquires an electron producing a stable light helium ion which can be utilized directly as a source of electricity without producing dangerous neutrons.

^{3}He can be used in fusion reactions by either of the reactions $^2\mathrm{H} + {}^3\mathrm{He} \rightarrow {}^4\mathrm{He} + {}^1\mathrm{p} + 18.3$ MeV, or $^3\mathrm{He} + {}^3\mathrm{He} \rightarrow {}^4\mathrm{He} + 2\,{}^1\mathrm{p} + 12.86$ MeV.

The conventional deuterium + tritium ("D-T") fusion process produces energetic neutrons which render reactor components radioactive with activation products. The appeal of helium-3 fusion stems from the aneutronic nature of its reaction products. Helium-3 itself is non-radioactive. The lone high-energy by-product, the proton, can be contained using electric and magnetic fields. The momentum energy of

Comparison of neutronicity of reactions[10][11][12][13][14]

Reactants		Products	*Q*	n/MeV
First-generation fusion fuels				
$^2\mathrm{D} + {}^2\mathrm{D}$	→	$^3\mathrm{He} + {}^1_0\mathrm{n}$	3.268 MeV	0.306
$^2\mathrm{D} + {}^2\mathrm{D}$	→	$^3\mathrm{T} + {}^1_1\mathrm{p}$	4.032 MeV	0
$^2\mathrm{D} + {}^3\mathrm{T}$	→	$^4\mathrm{He} + {}^1_0\mathrm{n}$	17.571 MeV	0.057
Second-generation fusion fuel				
$^2\mathrm{D} + {}^3\mathrm{He}$	→	$^4\mathrm{He} + {}^1_1\mathrm{p}$	18.354 MeV	0

this proton (created in the fusion process) will interact with the containing electromagnetic field, resulting in direct net electricity generation.[15]

Because of the higher Coulomb barrier, the temperatures required for ^{2}H + ^{3}He fusion are much higher than those of conventional D-T fusion. Moreover, since both reactants need to be mixed together to fuse, reactions between nuclei of the same reactant will occur, and the D-D reaction (^{2}H + ^{2}H) does produce a neutron. Reaction rates vary with temperature, but the D-^{3}He reaction rate is never greater than 3.56 times the D-D reaction rate (see graph). Therefore, fusion using D-^{3}He fuel at the right temperature and a D-lean fuel mixture, can produce a much lower neutron flux than D-T fusion, but is not clean, negating some of its main attraction.

Third-generation fusion fuels				
$^{3}He + {}^{3}He$	→	$^{4}He + 2\,^{1}_{1}p$	12.86 MeV	0
$^{11}B + {}^{1}_{1}p$	→	$3\,^{4}He$	8.68 MeV	0
Net result of D burning (sum of first 4 rows)				
6 D	→	$2(^{4}He + n + p)$	43.225 MeV	0.046
Current nuclear fuel				
$^{235}U + n$	→	2 FP+ 2.5n	~200 MeV	0.001

The second possibility, fusing ^{3}He with itself (^{3}He + ^{3}He), requires even higher temperatures (since now both reactants have a +2 charge), and thus is even more difficult than the D-^{3}He reaction. However, it does offer a possible reaction that produces no neutrons; the charged protons produced can be contained using electric and magnetic fields, which in turn results in direct electricity generation. ^{3}He + ^{3}He fusion is feasible as demonstrated in the laboratory and has immense advantages, but commercial viability is many years in the future.[16]

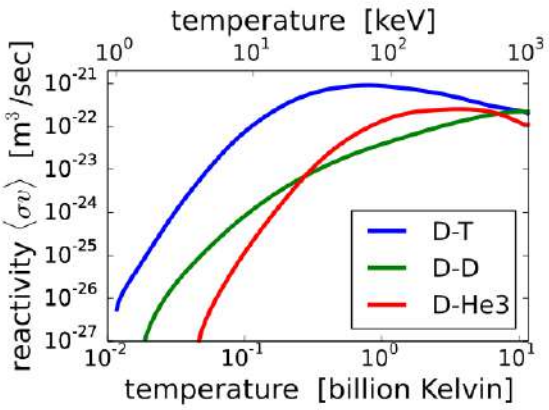

The fusion reaction rate increases rapidly with temperature until it maximizes and then gradually drops off. The DT rate peaks at a lower temperature (about 70 keV, or 800 million kelvins) and at a higher value than other reactions commonly considered for fusion energy.

The amounts of helium-3 needed as a replacement for conventional fuels are substantial by comparison to amounts currently available. The total amount of energy produced in the ^{2}D + ^{3}He reaction is 18.4 MeV, which corresponds to some 493 megawatt-hours (4.93×10^{8} W·h) per three grams (one mole) of ^{3}He If the total amount of energy could be converted to electrical power with 100% efficiency (a physical impossibility), it would correspond to about 30 minutes of output of a gigawatt electrical plant per mole of ^{3}He. Thus, a year's production (at 6 grams for each operation hour) would require 52.5 kilograms of helium-3. The amount of fuel needed for large-scale applications can also be put in terms of total consumption: electricity consumption by 107 million U.S. households in 2001[17] totaled 1,140 billion kW·h (1.14×10^{15} W·h). Again assuming 100% conversion efficiency, 6.7 tonnes per year of helium-3 would be required for that segment of the energy demand of the United States, 15 to 20 tonnes per year given a more realistic end-to-end conversion efficiency.

Neutron detection

Helium-3 is a most important isotope in instrumentation for neutron detection. It has a high absorption cross section for thermal neutron beams and is used as a converter gas in neutron detectors. The neutron is converted through the nuclear reaction

$$n + {}^{3}He \rightarrow {}^{3}H + {}^{1}H + 0.764\ MeV$$

into charged particles tritium ions (T, ^3H) and Hydrogen ions, or protons (p, ^1H) which then are detected by creating a charge cloud in the stopping gas of a proportional counter or a Geiger-Müller tube.[18]

Furthermore, the absorption process is strongly spin-dependent, which allows a spin-polarized helium-3 volume to transmit neutrons with one spin component while absorbing the other. This effect is employed in neutron polarization analysis, a technique which probes for magnetic properties of matter.[19][20][21][22]

The United States Department of Homeland Security had hoped to deploy detectors to spot smuggled plutonium in shipping containers by their neutron emissions, but the worldwide shortage of helium-3 following the drawdown in nuclear weapons production since the Cold War has to some extent prevented this.[23] As of 2012, DHS determined the commercial supply of boron-10 would support converting its neutron detection infrastructure to that technology.[24]

Cryogenics

A helium-3 refrigerator uses helium-3 to achieve temperatures of 0.2 to 0.3 kelvin. A dilution refrigerator uses a mixture of helium-3 and helium-4 to reach cryogenic temperatures as low as a few thousandths of a kelvin.[25]

An important property of helium-3, which distinguishes it from the more common helium-4, is that its nucleus is a fermion since it contains an odd number of spin ½ particles. Helium-4 nuclei are bosons, containing an even number of spin ½ particles. This is a direct result of the addition rules for quantized angular momentum. At low temperatures (about 2.17 K), helium-4 undergoes a phase transition: A fraction of it enters a superfluid phase that can be roughly understood as a type of Bose–Einstein condensate. Such a mechanism is not available for helium-3 atoms, which are fermions. However, it was widely speculated that helium-3 could also become a superfluid at much lower temperatures, if the atoms formed into *pairs* analogous to Cooper pairs in the BCS theory of superconductivity. Each Cooper pair, having integer spin, can be thought of as a boson. During the 1970s, David Lee, Douglas Osheroff and Robert Coleman Richardson discovered two phase transitions along the melting curve, which were soon realized to be the two superfluid phases of helium-3.[26][27] The transition to a superfluid occurs at 2.491 millikelvins on the melting curve. They were awarded the 1996 Nobel Prize in Physics for their discovery. Tony Leggett won the 2003 Nobel Prize in Physics for his work on refining understanding of the superfluid phase of helium-3.[28]

In a zero magnetic field, there are two distinct superfluid phases of ^3He, the A-phase and the B-phase. The B-phase is the low-temperature, low-pressure phase which has an isotropic energy gap. The A-phase is the higher temperature, higher pressure phase that is further stabilized by a magnetic field and has two point nodes in its gap. The presence of two phases is a clear indication that ^3He is an unconventional superfluid (superconductor), since the presence of two phases requires an additional symmetry, other than gauge symmetry, to be broken. In fact, it is a *p*-wave superfluid, with spin one, $\mathbf{S}=1$, and angular momentum one, $\mathbf{L}=1$. The ground state corresponds to total angular momentum zero, $\mathbf{J}=\mathbf{S}+\mathbf{L}=0$ (vector addition). Excited states are possible with non-zero total angular momentum, $\mathbf{J}>0$, which are excited pair collective modes. Because of the extreme purity of superfluid ^3He (since all materials except ^4He have solidified and sunk to the bottom of the liquid ^3He and any ^4He has phase separated entirely, this is the most pure condensed matter state), these collective modes have been studied with much greater precision than in any other unconventional pairing system.

Medical lung imaging

Helium-3 nuclei have an intrinsic nuclear spin of ½, and a relatively high magnetogyric ratio. Helium-3 can be hyperpolarized using non-equilibrium means such as spin-exchange optical pumping.[29] During this process, circularly polarized infrared laser light, tuned to the appropriate wavelength, is used to excite electrons in an alkali metal, such as caesium or rubidium inside a sealed glass vessel. The angular momentum is transferred from the alkali metal electrons to the noble gas nuclei through collisions. In essence, this process effectively aligns the nuclear spins with the magnetic field

in order to enhance the NMR signal. The hyperpolarized gas may then be stored at pressures of 10 atm, for up to 100 hours. Following inhalation, gas mixtures containing the hyperpolarized helium-3 gas can be imaged with an MRI scanner to produce anatomical and functional images of lung ventilation. This technique is also able to produce images of the airway tree, locate unventilated defects, measure the alveolar oxygen partial pressure, and measure the ventilation/perfusion ratio. This technique may be critical for the diagnosis and treatment management of chronic respiratory diseases such as chronic obstructive pulmonary disease (COPD), emphysema, cystic fibrosis, and asthma.[30]

Industrial production

Production, sales and distribution of helium-3 in the United States are managed by the US Department of Energy (DOE) Isotope Program.[31] Virtually all helium-3 used in industry today is produced from the radioactive decay of tritium. Tritium is a radioactive isotope of hydrogen and is typically produced by bombarding lithium-6 with neutrons in a nuclear reactor. The lithium nucleus absorbs a neutron and splits into helium-4 and tritium. Tritium decays into helium-3 with a half-life of 12.3 years, so helium-3 can be produced by simply storing the tritium until it undergoes radioactive decay.

Tritium is a critical component of nuclear weapons and historically it was produced and stockpiled primarily for this application. The decay of tritium into helium-3 reduces the explosive power of the fusion warhead, so periodically the accumulated helium-3 must be removed from warhead reservoirs and tritium in storage. Helium-3 removed during this process is marketed for other applications.

For decades this has been, and remains, the principal source of the world's helium-3.[32] However, since the signing of the START I Treaty in 1991 the number of nuclear warheads that are kept ready for use has decreased[33][34] This has reduced the quantity of helium-3 available from this source. Helium-3 stockpiles have been further diminished by increased demand,[35] primarily for use in neutron radiation detectors and medical diagnostic procedures. US industrial demand for helium-3 reached a peak of 70,000 liters (approximately 8 kg) per year in 2008. Price at auction, historically about $100/liter, reached as high as $2000/liter[36] Since then, demand for helium-3 has declined to about 6000 liters per year due to the high cost and efforts by the DOE to recycle it and find substitutes.

The DOE recognized the developing shortage of both tritium and helium-3. and began producing tritium by lithium irradiation at the Tennessee Valley Authority's Watts Bar Nuclear Generating Station in 2010.[35] In this process tritium-producing burnable absorber rods (TPBARs) containing lithium in a ceramic form are inserted into the reactor in place of the normal boron control rods[37] Periodically the TPBARs are replaced and the tritium extracted.

Currently only one reactor is used for tritium production but the process could, if necessary, be vastly scaled up to meet any conceivable demand simply by utilizing more of the nation's power reactors. Substantial quantities of tritium and helium-3 could also be extracted from the heavy water moderator in CANDU nuclear reactors.[35][38]

Natural abundance

Solar nebula (primordial) abundance

One early estimate of the primordial ratio of ^{3}He to ^{4}He in the solar nebula has been the measurement of their ratio in the atmosphere of Jupiter, measured by the mass spectrometer of the Galileo atmospheric entry probe. This ratio is about 1:10,000,[39] or 100 parts of ^{3}He per million parts of ^{4}He. This is roughly the same ratio of the isotopes as in lunar regolith, which contains 28 ppm helium-4 and 2.8 ppb helium-3 (which is at the lower end of actual sample measurements, which vary from about 1.4 to 15 ppb). However, terrestrial ratios of the isotopes are lower by a factor of 100, mainly due to enrichment of helium-4 stocks in the mantle by billions of years of alpha decay from uranium and thorium.

Terrestrial abundance

^{3}He is a primordial substance in the Earth's mantle, considered to have become entrapped within the Earth during planetary formation. The ratio of ^{3}He to ^{4}He within the Earth's crust and mantle is less than that for assumptions of solar disk composition as obtained from meteorite and lunar samples, with terrestrial materials generally containing lower ^{3}He/^{4}He ratios due to ingrowth of ^{4}He from radioactive decay.

^{3}He has a cosmological ratio of 300 atoms per million atoms of ^{4}He (at. ppm),[40] leading to the assumption that the original ratio of these primordial gases in the mantle was around 200-300 ppm when Earth was formed. A lot of ^{4}He was generated by alpha-particle decay of uranium and thorium, and now the mantle has only around 7% primordial helium,[40] lowering the total ^{3}He/^{4}He ratio to around 20 ppm. Ratios of ^{3}He/^{4}He in excess of atmospheric are indicative of a contribution of ^{3}He from the mantle. Crustal sources are dominated by the ^{4}He which is produced by the decay of radioactive elements in the crust and mantle.

The ratio of helium-3 to helium-4 in natural Earth-bound sources varies greatly.[41][42] Samples of the lithium ore spodumene from Edison Mine, South Dakota were found to contain 12 parts of helium-3 to a million parts of helium-4. Samples from other mines showed 2 parts per million.[41]

Helium is also present as up to 7% of some natural gas sources,[43] and large sources have over 0.5% (above 0.2% makes it viable to extract).[44] The fraction of ^{3}He in helium separated from natural gas in the U.S. was found to range from 70 to 242 parts per billion.[35][45] Hence the US 2002 stockpile of 1 billion normal m^3[44] would have contained about 12 to 43 kilograms of helium-3. According to one expert, about 26 m^3 or almost 5 kg of ^{3}He is available annually for separation from the US natural gas stream. If the process of separating out the ^{3}He could employ as feedstock the liquefied helium typically used to transport and store bulk quantities, estimates for the incremental energy cost range from US$34 to $300 per liter NTP, excluding the cost of infrastructure and equipment.[35] Algeria's annual gas production is assumed to contain 100 million normal cubic metres[44] and this would contain between 7 and 24 m^3 of helium-3 (about 1 to 4 kilograms) assuming a similar ^{3}He fraction.

^{3}He is also present in the Earth's atmosphere. The natural abundance of ^{3}He in naturally occurring helium gas is 1.38×10^{-6} (1.38 parts per million). The partial pressure of helium in the Earth's atmosphere is about 0.52 Pa, and thus helium accounts for 5.2 parts per million of the total pressure (101325 Pa) in the Earth's atmosphere, and ^{3}He thus accounts for 7.2 parts per trillion of the atmosphere. Since the atmosphere of the Earth has a mass of about 5.14×10^{15} tonnes,[46] the mass of ^{3}He in the Earth's atmosphere is the product of these numbers, or about 37,000 tonnes of ^{3}He.

^{3}He is produced on Earth from three sources: lithium spallation, cosmic rays, and beta decay of tritium (^{3}H). The contribution from cosmic rays is negligible within all except the oldest regolith materials, and lithium spallation reactions are a lesser contributor than the production of ^{4}He by alpha particle emissions.

The total amount of helium-3 in the mantle may be in the range of 0.1–1 million tonnes. However, most of the mantle is not directly accessible. Some helium-3 leaks up through deep-sourced hotspot volcanoes such as those of the Hawaiian Islands, but only 300 grams per year is emitted to the atmosphere. Mid-ocean ridges emit another 3 kilogram per year. Around subduction zones, various sources produce helium-3 in natural gas deposits which possibly contain a thousand tonnes of helium-3 (although there may be 25 thousand tonnes if all ancient subduction zones have such deposits). Wittenberg estimated that United States crustal natural gas sources may have only half a tonne total.[47] Wittenberg cited Anderson's estimate of another 1200 metric tonnes in interplanetary dust particles on the ocean floors.[48] In the 1994 study, extracting helium-3 from these sources consumes more energy than fusion would release.[49]

Extraction from extraterrestrial sources

Materials on the Moon's surface contain helium-3 at concentrations between 1.4 and 15 ppb in sunlit areas,[50][51] and may contain concentrations as much as 50 ppb in permanently shadowed regions.[7] A number of people, starting with Gerald Kulcinski in 1986,[52] have proposed to explore the moon, mine lunar regolith and use the helium-3 for fusion. Because of the low concentrations of helium-3, any mining equipment would need to process extremely large amounts of regolith (over 150 million tonnes of regolith to obtain one gram of helium 3),[53] and some proposals have suggested that helium-3 extraction be piggybacked onto a larger mining and development operation.

The primary objective of Indian Space Research Organisation's first lunar probe called Chandrayaan-I, launched on October 22, 2008, was reported in some sources to be mapping the Moon's surface for helium-3-containing minerals.[54] However, no such objective is mentioned in the project's official list of goals, although many of its scientific payloads have noted helium-3-related applications.[55][56]

Cosmochemist and geochemist Ouyang Ziyuan from the Chinese Academy of Sciences who is now in charge of the Chinese Lunar Exploration Program has already stated on many occasions that one of the main goals of the program would be the mining of helium-3, from which operation "each year, three space shuttle missions could bring enough fuel for all human beings across the world."[57] In January 2006, the Russian space company RKK Energiya announced that it considers lunar helium-3 a potential economic resource to be mined by 2020,[58] if funding can be found.[59][60]

Mining gas giants for helium-3 has also been proposed.[61] The British Interplanetary Society's hypothetical Project Daedalus interstellar probe design was fueled by helium-3 mines in the atmosphere of Jupiter, for example. Jupiter's high gravity makes this a less energetically favorable operation than extracting helium-3 from the other gas giants of the solar system, however.

Not all authors feel the extraterrestrial extraction of helium-3 is feasible. Dwayne Day, writing in The Space Review, identifies some major obstacles to helium-3 extraction from extraterrestrial sources for use in fusion, and questions the feasibility of extraterrestrial extraction when compared to production on Earth.[62]

Power generation

A second-generation approach to controlled fusion power involves combining helium-3 ($^3_2$He) and deuterium ($^2_1$H). This reaction produces a helium-4 ion ($^4_2$He) (like an alpha particle, but of different origin) and a high-energy proton (positively charged hydrogen ion) ($^1_1$p). The most important potential advantage of this fusion reaction for power production as well as other applications lies in its compatibility with the use of electrostatic fields to control fuel ions and the fusion protons. High speed protons, as positively charged particles, can have their kinetic energy converted directly into electricity, through use of solid-state conversion materials as well as other techniques. Potential conversion efficiencies of 70% may be possible, as there is no need to convert proton energy to heat in order to drive a turbine-powered electrical generator.

There have been many claims about the capabilities of helium-3 power plants. According to proponents, fusion power plants operating on deuterium and helium-3 would offer lower capital and operating costs than their competitors due to less technical complexity, higher conversion efficiency, smaller size, the absence of radioactive fuel, no air or water pollution, and only low-level radioactive waste disposal requirements. Recent estimates suggest that about $6 billion in investment capital will be required to develop and construct the first helium-3 fusion power plant. Financial breakeven at today's wholesale electricity prices (5 US cents per kilowatt-hour) would occur after five 1-gigawatt plants were on line, replacing old conventional plants or meeting new demand.[63]

The reality is not so clear-cut. The most advanced fusion programs in the world are inertial confinement fusion (such as National Ignition Facility) and magnetic confinement fusion (such as ITER and Wendelstein 7-X). In the case of the former, there is no solid roadmap to power generation. In the case of the latter, commercial power generation is not

expected until around 2050.[64] In both cases, the type of fusion discussed is the simplest: D-T fusion. The reason for this is the very low Coulomb barrier for this reaction; for D+^{3}He, the barrier is much higher, and it is even higher for ^{3}He–^{3}He. The immense cost of reactors like ITER and National Ignition Facility are largely due to their immense size, yet to scale up to higher plasma temperatures would require reactors far larger still. The 14.7 MeV proton and 3.6 MeV alpha particle from D–^{3}He fusion, plus the higher conversion efficiency, means that more electricity is obtained per kilogram than with D-T fusion (17.6 MeV), but not that much more. As a further downside, the rates of reaction for helium-3 fusion reactions are not particularly high, requiring a reactor that is larger still or more reactors to produce the same amount of electricity.

To attempt to work around this problem of massively large power plants that may not even be economical with D-T fusion, let alone the far more challenging D–^{3}He fusion, a number of other reactors have been proposed – the Fusor, Polywell, Focus fusion, and many more, though many of these concepts have fundamental problems with achieving a net energy gain, and generally attempt to achieve fusion in thermal disequilibrium, something that could potentially prove impossible,[65] and consequently, these long-shot programs tend to have trouble garnering funding despite their low budgets. Unlike the "big", "hot" fusion systems, however, if such systems were to work, they could scale to the higher barrier "aneutronic" fuels, and therefore their proponents tend to promote p-B fusion, which requires no exotic fuels like helium-3.

References in science fiction

Several science fiction works have featured helium-3 extraction on the moon, including the films *Moon* (2009) and *Iron Sky* (2012), the manga and corresponding anime Planetes, the video game *Anno 2205* (2015) and the novel *Luna: New Moon* (2015). The novel *Morning Star* (Pierce Brown, 2016) features helium-3 mining on Phobos (a moon of Mars), while his novel *Red Rising* (2014) features helium-3 extraction from Mars itself. The titular mech of Godzilla vs. Mechagodzilla II is powered by heavy hydrogen and helium-3 in pellet form.

See also

- Colonization of the Moon

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RESEARCH, SCIENCE & ENVIRONMENT, TECHNOLOGY & ENGINEERING

Scientists unveil new form of matter: time crystals

By **Robert Sanders**, Media relations | JANUARY 26, 2017

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To most people, crystals mean diamond bling, semiprecious gems or perhaps the jagged amethyst or quartz crystals beloved by collectors.

To Norman Yao, these inert crystals are the tip of the iceberg.

If crystals have an atomic structure that repeats in space, like the carbon lattice of a diamond, why can't crystals also have a structure that repeats in time? That is, a time crystal?

In a paper published online last week in the journal *Physical Review Letters*, the UC Berkeley assistant professor of physics describes exactly how to make and measure the properties of such a crystal, and even predicts what the various phases surrounding the time crystal should be — akin to the liquid and gas phases of ice.

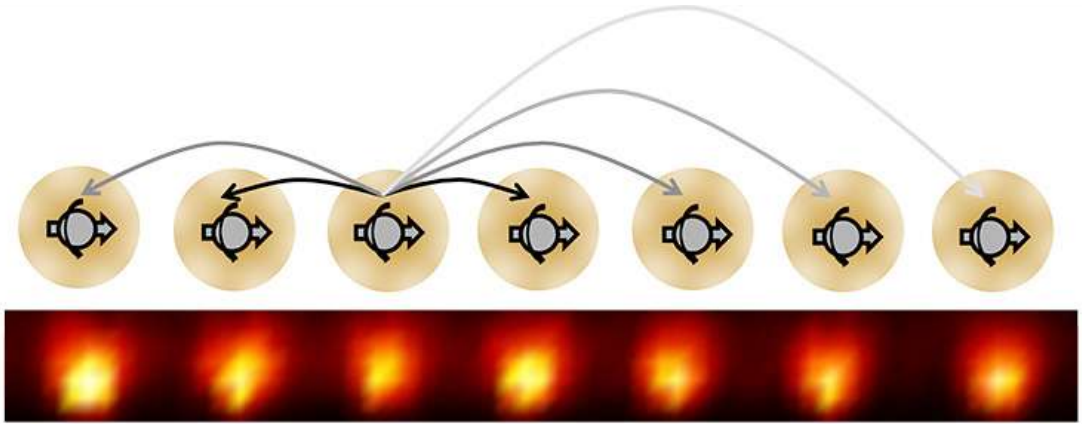

A one-dimensional chain of ytterbium ions was turned into a time crystal by physicists at the University of Maryland, based on a blueprint provided by UC Berkeley's Norman Yao. Each ion behaves like an electron spin and exhibits long-range interactions indicated as arrows. (Image courtesy of Chris Monroe)

This is not mere speculation. Two groups followed Yao's blueprint and have already created the first-ever time crystals. The groups at the University of Maryland and Harvard University reported their successes, using two totally different setups, in papers posted online last year, and have submitted the results for publication. Yao is a co-author on both papers.

Time crystals repeat in time because they are kicked periodically, sort of like tapping Jell-O repeatedly to get it to jiggle, Yao said. The big breakthrough, he argues, is less that these particular crystals repeat in time than that they are the first of a large class of new materials that are intrinsically out of equilibrium, unable to settle down to the motionless equilibrium of, for example, a diamond or ruby.

"This is a new phase of matter, period, but it is also really cool because it is one of the first examples of non-equilibrium matter," Yao said. "For the last half-century, we have been exploring equilibrium matter, like metals and insulators. We are just now starting to explore a whole new landscape of non-equilibrium matter."

While Yao is hard put to imagine a use for a time crystal, other proposed phases of non-equilibrium matter theoretically hold promise as nearly perfect memories and may be useful in quantum computers.

An ytterbium chain

The time crystal created by Chris Monroe and his colleagues at the University of Maryland employs a conga line of 10 ytterbium ions whose electron spins interact, similar to the qubit systems being tested as quantum computers. To keep the ions out of equilibrium, the researchers alternately hit them with one laser to create an effective magnetic field and a second laser to partially flip the spins of the atoms, repeating the sequence many times. Because the spins interacted, the atoms settled into a stable, repetitive pattern of spin flipping that defines a crystal.

Time crystals were first proposed in 2012 by Nobel laureate Frank Wilczek, and last year theoretical physicists at Princeton University and UC Santa Barbara's **Station Q** independently proved that such a crystal could be made. According to Yao, the UC Berkeley group was "the bridge between the theoretical idea and the experimental implementation."

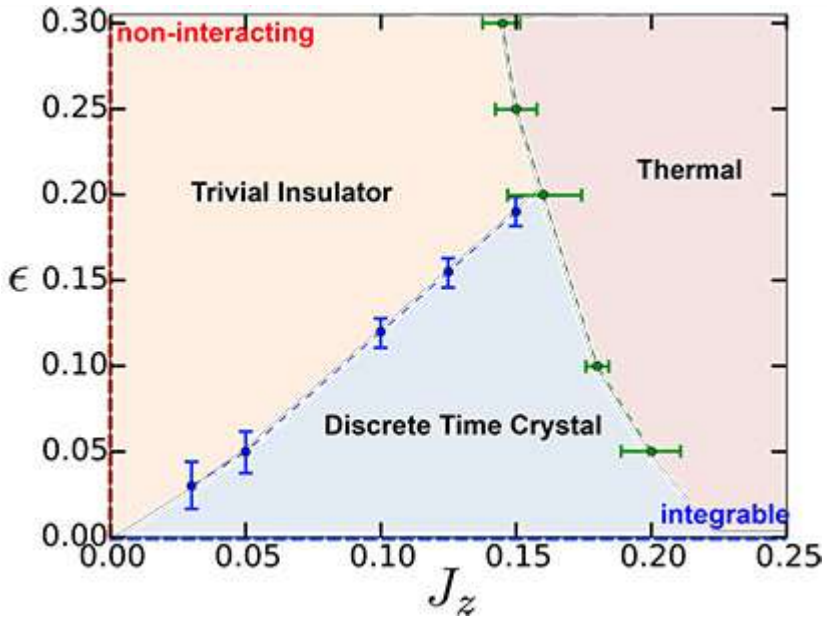

This phase diagram shows how changing the experimental parameters can 'melt' a time crystal into a normal insulator or heat up a time crystal to a high temperature thermal state. Norman Yao graphic.

From the perspective of quantum mechanics, electrons can form crystals that do not match the underlying spatial translation symmetry of the orderly, three-dimensional array of atoms, Yao said. This breaks the symmetry of the material and leads to unique and stable properties we define as a crystal.

A time crystal breaks time symmetry. In this particular case, the magnetic field and laser periodically driving the ytterbium atoms produce a repetition in the system at twice the period of the drivers, something that would not occur in a normal system.

"Wouldn't it be super weird if you jiggled the Jell-O and found that somehow it responded at a different period?" Yao said. "But that is the essence of the time crystal. You have some periodic driver that has a period 'T', but the system somehow synchronizes so that you observe the system oscillating with a period that is larger than 'T'."

Yao worked closely with Monroe as his Maryland team made the new material, helping them focus on the important properties to measure to confirm that the material was in fact a stable or rigid time crystal. Yao also described how the time crystal would change phase, like an ice cube melting, under different magnetic fields and laser pulsing.

The Harvard team, led by Mikhail Lukin, set up its time crystal using densely packed nitrogen vacancy centers in diamonds.

FORENSIC CHEMISTRY HANDBOOK

Edited by

LAWRENCE F. KOBILINSKY

WILEY

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PREFACE

In February 2009 a report entitled *Strengthening Forensic Science in the United States: A Path Forward* was issued by the National Research Council (NRC) of the National Academy of Sciences. The committee members who wrote the report included scientists, judges, lawyers, statisticians, and forensic scientists. The authors of the report recognized that there is an ongoing need to assure that evidence analysis is held to the highest standards and that what is reported in writing and in testimony must be reliable and credible. Forensic science is a large umbrella science consisting of many subdisciplines, including serology, forensic DNA analysis, toxicology, document examination, hair and fiber analysis, arson investigation, firearms and toolmarks, explosives analysis, blood spatter pattern analysis, digital evidence, impression evidence, forensic pathology, forensic anthropology, forensic odontology, and others. Crime scene personnel are trained to identify and collect biological and physical evidence for subsequent laboratory analysis. This evidence can shed light on events leading up to and during the commission of a crime. Often, evidence collected at a crime scene can be associated with either a victim or a suspect. Criminals can often be linked to the crime scene and/or to the victim. At the same time, those falsely accused can be excluded or exonerated based on reliable analysis of physical evidence. Following scientific analysis, the criminalist writes a report and will testify in a court of law. The testimony of an expert witness must be unbiased, accurate, and based on a sound scientific foundation. The admissibility of novel scientific evidence must be determined prior to expert testimony. The use of a novel scientific method to analyze evidence and the subsequent testimony that describes the results of such testing can be challenged for a variety of reasons.

The *Strengthening Forensic Science* (SFS) report recognized that not all forensic disciplines were at the same level with respect to standards and reliability. This problem is based in part on insufficient funding for forensic research and lack of oversight by any national organization. Although ASCLD-LAB accredits forensic laboratories, American Board of Criminalistics (ABC) certifies forensic analysts, and the National Institute of Justice provides funding for some forensic research projects, techniques and principles used in many forensic disciplines are not at the same level of reliability as that achieved by DNA scientists. The science of using DNA for human identification dates back to the work of Alec Jeffries, who applied restriction fragment length polymorphism analysis for this purpose in the mid-1980s. This major breakthrough was complemented by a second breakthrough technique, polymerase chain reaction, developed by Kary Mullis. He used this in vitro method to amplify a relatively small number of template nucleic acid

molecules (derived from biological evidence) into billions of copies for subsequent identification of the DNA donor. These procedures are considered highly reliable and are admissible in all courts in the United States.

The SFS report spells out 13 recommendations that if accomplished would certainly expand funded research and establish the reliability of non-DNA forensic evidence analysis.

- Congress should establish a new National Institute of Forensic Science (NIFS), which would involve itself with research and education, the forensic science disciplines, physical and life sciences, measurements and standards, and testing and evaluation.
- NIFS should establish standard terminology and standards to be used in reporting and testifying about the results of forensic testing.
- NIFS should competitively fund research in forensic science to address the accuracy, reliability, and validity of the subdisciplines.
- NIFS, through congressional funding, should provide funding to remove public forensic labs from the administrative control of law enforcement agencies or prosecutors' offices.
- NIFS should encourage research on observer bias and sources of human error in forensic examinations.
- Congress should fund (through NIFS) the development of tools to advance measurement, validation, reliability, information sharing, and proficiency testing in forensic science and to establish protocols for forensic examinations, methods, and practices.
- Laboratory accreditation and analyst certification should be mandatory.
- Forensic laboratories should establish routine quality control and quality assurance programs to ensure the accuracy of forensic analyses.
- NIFS should establish a national code of ethics for all forensic disciplines.
- Congress should provide funding to NIFS to work with appropriate organizations and educational institutions to improve and develop graduate education programs and to provide scholarships and fellowships with emphasis on developing research methods and methodologies applicable to forensic science practice.
- NIFS should support replacing coroner systems with medical examiner systems to improve medicolegal death investigation.
- Congress should provide funds for NIFS to launch a new effort to achieve nationwide fingerprint data interoperability.
- Congress should provide funding for NIFS to help forensic scientists manage and analyze evidence from events that affect homeland security.

The full SFS report, which describes all of the above, is available through the National Academies Press, 500 Fifth Street N.W., Washington, DC 20001.

Some of the issues faced by forensic experts who write official reports and present courtroom testimony about their analysis are (1) whether or not the

techniques of the discipline are founded on a sound scientific foundation, so that the experimental findings are accurate and reliable; (2) whether or not there is any significant possibility of human error or analyst bias that could potentially taint the results; and (3) whether or not rigorous standards have been established for interpreting the results.

The authors of the SFS report believe that with the exception of DNA, no subdiscipline of forensic science is sufficiently reliable that a unique identification can be made of physical evidence: for example, "This bullet was fired from this gun and from no other gun in the world"; or "This fingerprint was left by this person and by no other person"; or "This tire track impression was made by this tire and by no other tire". What is the statistical basis for such a statement? What is the measurement error rate? What is the human error rate? How should conclusions be expressed in a report or in testimony?

With all of this in mind, I invite you to read through the various chapters in this book and keep in mind that the subject matter is about science and technology and not about art. Keep in mind how the expert comes to a conclusion and how that conclusion is reported. What is the statistical basis for the expert's report and testimony? Can the expert testify to a high degree of scientific certainty that the questioned and known specimens have a common origin? I leave that to the reader to decide.

This handbook begins with a review of forensic environmental chemistry which involves the use of trace chemical techniques for investigating environmental spills in an effort to determine if there is any civil or criminal liability. The field can be broken down into two broad areas based on the techniques used to determine liability: chemical fingerprinting and spatial association. In chemical fingerprinting, complex mixtures of chemicals or chemical isotopes are used to associate a spill or environmental release with a specific source. In spatial association, a geographical information system and geochemical techniques are used to attribute the location of a contaminant with a possible source in physical space.

Chapter 2 addresses the principles and issues that exist in the forensic analysis of explosives. It lays out the foundation for proper handling of evidence, which is critical to identifying and convicting the criminal. Evidence at the scene of an explosion, especially a large explosion, offers some unique challenges. Basic principles of evidence collection, handling, storing, and identifying various explosives are discussed herein.

Chapter 3 is a review of arson and fire debris analysis. The isolation and identification of ignitable liquid residues (ILRs) from fire debris is a critically important aspect of arson investigation. This chapter covers common techniques for the isolation and identification of ILRs. Analytical procedures have become more sensitive, and results of testing play a very important role during litigation in a criminal or civil court. Quality control is an important component in fire debris analysis. Reports of findings should be written in a scientific manner describing the fire under investigation, evidence handling, a description of the evidence and where it was collected, the isolation procedure and what testing was done and with what

kind of equipment, observations made, and conclusions, with a discussion of the meaning of the results.

Chapter 4 reviews the forensic examination of soils. Soils and sediment are excellent sources of trace evidence in both criminal and civil cases because there are an almost unlimited number of identifiable soil types based on the content of rocks, minerals, glasses, and human-made particles and chemicals. Forensic examination commonly identifies the original geographic location of soils associated with a crime, thus assisting an investigation. Studies of soil and related material samples associated with a suspect and crime scene can produce evidence that the samples had or did not have a common source, thus indicating whether or not a suspect was ever at a particular location. Gathering intelligence for criminal and civil investigations, as well as gem and art fraud studies, often use the methods of forensic geology

Chapter 5 deals with the analysis of paint evidence. Paint and coatings often appear in criminal, civil, and art-authenticity investigations. This chapter reviews the current methodologies and approaches used by forensic paint examiners to analyze this type of physical evidence as well as the problems that they may encounter. Fragments of multilayered in-service paint are one of the most complex types of materials encountered in the forensic science laboratory. They consist of both organic and inorganic components heterogeneously distributed in very small samples, often on the order of only 1 square millimeter. These characteristics dictate the requirements of the analytical chemistry approaches to be used, and they can present a formidable challenge to the forensic analyst responsible for classification of the materials and an evaluation of their evidential significance. Several case examples are presented to illustrate these concepts.

Chapter 6 describes analytical techniques used for the forensic examination of writing and printing inks. The analysis and identification of writing and printing inks and toners are generally very important in document examination, especially when used in conjunction with a reference library. Inks can be differentiated based on the chemistry of colorants, solvents, resins, and additives. Instrumental analysis, including GC–MS, HPLC, and FT–IR and Raman spectroscopy, can often be used following visual examination, microscopic observation, and thin-layer chromatography. Analysis of toners can be performed with XRF, SEM–EDS, or pyrolysis GC. Although chemical analysis of materials used to create documents can provide vast amounts of relevant information and strongly support associations between questioned and known materials, in nearly all cases, the data obtained will not support a conclusion that identifies a particular writing instrument of printing device.

Chapter 7 describes the role of vibrational spectroscopy in forensic chemistry. Spectroscopy is the study of the interaction of electromagnetic radiation with matter to determine the molecular structure of a solid sample or one dissolved in a specific solvent. This interaction depends on the intrinsic properties of the sample material and can be classified by the energy of the probing electromagnetic radiation. Energy can be in the form of ultraviolet, visible, or infrared light, as well as other forms of energy. Infrared spectroscopy is a good technique to use to identify such fibers as acrylics, nylons, or polyesters or paints or alkyds, acrylics,

or nitrocellulose. The size of the sample may require the use of microscopic infrared spectroscopy, and the nature of the sample may indicate the use of external reflection spectroscopy or attenuated total reflectance spectroscopy. These techniques are reviewed as well as related methods of sample identification.

Chapter 8 discusses the important science of forensic serology, an important area of modern forensic science. The primary activity of the forensic serologist is the identification of bodily fluids, as these fluid stains are commonly associated with violent criminal cases. Proving the presence of blood, semen, saliva, and so on, can often confirm alleged violent acts.

Chapter 9 reviews the field of forensic DNA analysis. It describes how DNA became a valuable forensic tool in identifying the source of physical evidence left at a crime scene. The use of restriction fragment length polymorphism analysis in the mid-1980s was replaced by the use of the polymerase chain reaction (PCR) method, which is more sensitive, requiring far less high-molecular-weight DNA, uses less hazardous materials, and is faster and more economical. PCR-STR-based genetic profile typing methods have improved in sensitivity over the past 20 years and have become a basic tool in the crime lab. Where nuclear DNA is insufficient to generate a full genetic profile, mitochondrial DNA can sometimes be used to provide identifying information. Also described are low-copy-number procedures and the typing of single-nucleotide polymorphisms within the human genome.

Chapter 10 reviews current and future uses of DNA microarrays in forensic science. DNA microarrays have revolutionized basic research in molecular and cellular biology, biochemistry, and genetics. Through hybridization of labeled probes, this high-throughput technology allows the screening of tens or even hundreds of thousands of data points in a single run. The technology is most advanced with nucleic acids, but protein and antibody microarrays are coming of age as well. Because of the unique ability to screen for large numbers of molecules, such as DNA sequences, simultaneously, the potential utility to forensic investigations is tremendous. Indeed, progress has been made demonstrating that microarrays are powerful tools for use in the forensic laboratory. As the technology matures and associated costs come down, the day that microarray analysis becomes a routine part of the forensic toolkit draws nearer.

Chapter 11 reviews the problem of date-rape drugs such as MDMA, flunitrazepam, and ketamine, with an emphasis on GHB. Recreational, predatory, and lethal doses, metabolism, and diagnostic metabolites are described. Similarities to and differences from the effects and metabolism of ethanol are also discussed. The advantages of field tests to detect date-rape drugs, and limitations of antibodies and advantages of enzymes for field testing, are discussed. The development of a rapid enzymatic test for the detection of GHB is described.

Chapter 12 covers forensic and clinical issues in alcohol analysis. Ethanol, a clear volatile liquid that is soluble in water and has a characteristic taste and odor, is a central nervous system (CNS) depressant and causes most of its effects on the body by depressing brain function. CNS depression is correlated directly with the concentration of alcohol in the blood (BAC). The Estimation of a person's blood alcohol concentration is based on important parameters such as body weight,

ethanol concentration of the beverage consumed and number of beverages consumed, and length of time and pattern of the drinking. Because men and women have different body water amounts (men average 68% and women 55%), there are differences between the ethanol concentration achieved in men and women of similar weight for the same amount of alcohol. Various methods are described that can help to determine BAC in the field as well as in the laboratory.

Chapter 13 discusses fundamental issues of postmortem toxicology. The basic principles of forensic postmortem toxicology are presented. This chapter covers the acquisition and usefulness of different specimens, current analytical techniques, and the interpretation of findings. Special problems associated with the interpretation of drug levels include the conditions of the specimens and the effects of postmortem redistribution, postmortem drug changes, pharmacogenomics, drug interactions, and embalming fluid.

Chapter 14 reviews a field of growing importance in forensic science, entomotoxicology: drugs, toxins, and insects. Forensic entomology is gaining widespread acceptance within the forensic sciences as one method of estimating a portion of the postmortem interval by utilizing the time of insect colonization of a body, also known as the period of insect activity. Additionally, insect evidence can be utilized as alternative toxicology samples in cases where no other viable specimens exist. This subfield, known as entomotoxicology, can provide useful qualitative information to investigators as to the presence of drugs in the tissues at the time of larval feeding. The presence of drugs can alter the developmental period of the insects and should always be taken into consideration by the forensic entomologist. The relationship between toxicology and forensic entomology is also examined.

LAWRENCE KOBILINSKY

CONTRIBUTORS

Jason H. Byrd, University of Florida, College of Medicine, Gainesville, Florida

Anthony Carpi, Environmental Toxicology, John Jay College of Criminal Justice, The City University of New York, New York

Donald B. Hoffman, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Lawrence Kobilinsky, Chairman, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Ali Koçak, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Sarah L. Lancaster, Forensic Explosives Laboratory, Defence Science and Technology Laboratory, Fort Halstead, Sevenoaks, Kent, UK

Gerald M. LaPorte, National Institute of Justice, Office of Investigative and Forensic Sciences, Washington, DC

John J. Lentini, Scientific Fire Analysis, LLC, Big Pine Key, Florida

Nathan H. Lents, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Richard Li, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Henrietta Margolis Nunno, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Maurice Marshall, (Formerly) Forensic Explosives Laboratory, Defence Science and Technology Laboratory, Fort Halstead, Sevenoaks, Kent, UK

Raymond C. Murray, University of Montana, Missoula, Montana

Jimmie C. Oxley, University of Rhode Island, Chemistry Department, DHS Center of Excellence for Explosives Detection, Mitigation, and Response, Kingston, Rhode Island

Stanley M. Parsons, Department of Chemistry and Biochemistry, Program in Biomolecular Science and Engineering, Neuroscience Research Institute, University of California, Santa Barbara, California

Michelle R. Peace, Department of Forensic Science. Virginia Commonwealth University, Richmond, Virginia

Scott G. Ryland, Florida Department of Law Enforcement, Orlando, Florida

Andrew J. Schweighardt, John Jay College of Criminal Justice, The City University of New York, New York

Joseph C. Stephens, United States Secret Service, Forensic Services Division, Questioned Document Branch, Instrumental Analysis Section, Washington, DC

Richard Stripp, Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Edward M. Suzuki, Washington State Crime Laboratory, Washington State Patrol, Seattle, Washington

Beth E. Zedeck, Pediatric Nurse Practitioner, New York

Morris S. Zedeck, (Retired) Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

CHAPTER 1

Forensic Environmental Chemistry

ANTHONY CARPI and ANDREW J. SCHWEIGHARDT

John Jay College of Criminal Justice, The City University of New York, New York

Summary Forensic environmental chemistry involves the use of trace chemical techniques for investigating environmental spills in an effort to determine civil or criminal liability. The field can be broken down into two broad areas based on the techniques used to determine liability: chemical fingerprinting and spatial association. In chemical fingerprinting, complex mixtures of chemicals or chemical isotopes are used to associate a spill or environmental release with a source. In spatial association, geographical information systems and geochemical techniques are used to attribute the location of a contaminant with a possible source in physical space.

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1.1 INTRODUCTION

As technology for trace chemical analysis has expanded in recent decades, so has its application to criminal and civil casework. This has transformed traditional forensic investigations and has expanded their applicability to less traditional areas, such as those involving environmental crimes. Prior to 1950, environmental law in the United States was based on tort and property law and was applied to a very limited number of incidents. Driven by growing environmental awareness in the 1950s and 1960s, the U.S. Congress passed the first Clean Air Act in 1963. This was followed by a slow but steady string of further developments, including the founding of the Environmental Protection Agency (EPA) in 1970 and the passage of the Clean Water Act in 1972, the Endangered Species Act in 1973, and the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) in 1980. International law began to address environmental issues with the signing of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975 and other international treaties. These early milestones have been bolstered by recent amendments, new agencies, and renewed funding, all of which make up a series of laws and regulations that define criminal practices and govern civil liability cases involving the environment. Increased legislation and improved enforcement have led to a significant decrease in easily identifiable environmental disasters, such as when the Cuyahoga River in Cleveland, Ohio burst into flames in 1969 as a result of industrial discharge. As these visible issues have diminished, environmental scientists have found themselves faced with questions that are more difficult to identify and are more intractable in nature. This has led, in turn, to advances in the investigative techniques used to investigate environmental crimes.

It is impossible to pinpoint the exact birth date of forensic environmental science. However, one source attributes the origin of the term *environmental forensics* to the scientific contractor Battelle in the late 1990s (Haddad, 2004). One of the company's specialties is forensic environmental chemistry, and the company provides services in hydrocarbon fingerprinting, contamination identification, and product identification. Regardless of when the field was named, most sources would agree that the field began gathering momentum about 30 years ago. Since that time, various subdivisions have emerged. Some of these divisions have their roots in diverse areas such as geology, toxicology, biology, physics, and chemistry. As such, the term *environmental forensics* might be considered a misnomer for two reasons. The first is the tendency of the word *forensics* to be semantically confusing, because it has no real meaning when used in this context. The second is the loss of the word *science*, for this serves as a necessary reminder of the field's vast and diverse capabilities, spanning across not just one but many sciences.

The term *environmental forensics* is often misapplied to what should rightfully be called *forensic environmental chemistry*. For example, environmental forensics has been defined as "the systematic investigation of a contaminated site or an event that has impacted the environment," a definition that is clearly biased toward the chemistry perspective (Stout et al., 1998). The broad capabilities of the field are unnecessarily simplified to the question: Who caused the contamination, and when

did it occur? (Ram et al., 1999). Surely this is not the only question that environmental forensics is capable of answering. Nevertheless, this mindset has persisted because it is acknowledged and reaffirmed repeatedly. Many of the shortfalls of the earlier definitions of environmental forensics have been identified and amended in subsequent definitions. Many of these revisions offer a more generic, all-inclusive definition. One source defines forensic environmental science simply as "litigation science" (Murphy, 2000); another as "environmental 'detective work' . . . operating at the interface junction points of several main sciences including chemistry and biochemistry, biology, geology and hydrogeology, physics, statistics, and modeling" (Petrisor, 2005). Vives-Rego (2004) defines it not just as the environmental application of chemistry, biology, and geology, but as "science and the art of deduction." Finally, Carpi and Mital (2000) define it as "the scientific investigation of a criminal or civil offense against the environment." These updated definitions more accurately reflect the capabilities of forensic environmental science beyond the chemistry realm. In particular, the definition provided by Carpi and Mital (2000) specifically includes the use of DNA to solve crimes perpetrated against wildlife and plant life. In this chapter we focus on the specific subarea of forensic environmental chemistry and leave to another source the broader description of the methods and techniques that apply to environmental forensics.

However one chooses to define this growing field, one thing is certain: Forensic environmental science is filling the significant niche left void by forensic science and environmental science. Due in large part to its close association with the core sciences, forensic environmental science has experienced significant growth since its inception, especially in recent years. Aside from technological achievements in the past 30 years, several important advances have helped propel forensic environmental science from a burgeoning offshoot of forensic science to a scientific discipline in its own right. One such advancement was the founding of the journal *Environmental Forensics* in 2000 (Taylor & Francis, London). Although research pertaining to forensic environmental science occurred before the journal existed, the journal can be credited with offering a place for environmental research that falls under the forensic science umbrella. Thus, *Environmental Forensics* provides a forum to facilitate the exchange of information, ideas, and investigations unique to forensic environmental science (Wenning and Simmons, 2000).

Forensic environmental science has become such a diverse field that it is difficult to find a single work that adequately covers all its subdisciplines. The literature on the subject that enjoys the most success does so because it focuses on a specific area of forensic environmental science. As such, in this chapter we focus on forensic environmental chemistry. Our aim is to elaborate on several key areas of forensic environmental chemistry, perhaps where other resources have been unable to or have failed to do so. In particular, we focus on chemical fingerprinting and its subsidiaries, such as hydrocarbon fingerprinting, isotope fingerprinting, and complex mixture fingerprinting. Chemical fingerprinting attempts to individualize a chemical and trace it back to its origin. This technique has become increasingly important not only to identify that a chemical spill has indeed occurred, but also to identify the party responsible. We also focus on spatial analysis for the purpose

of source attribution. Several cases are discussed that are illustrative of the capabilities of spatial analysis and chemical fingerprinting as they pertain to forensic environmental chemistry.

1.2 CHEMICAL FINGERPRINTING

Chemical fingerprinting is a subsidiary of forensic environmental chemistry that examines the constituents of a mixture for the purpose of creating a unique chemical signature that can be used to attribute the chemicals to their source. At one time it was sufficient to arrive at a generic classification and quantitation of the chemical mixture so that appropriate remediation measures could be designed and implemented. However, modern analytical techniques that are focused on individualizing and associating a mixture with a source have become increasingly popular, both for liability reasons and because of the recognition and attempt to apportion liability when multiple and/or temporally distant parties may be responsible for chemical contamination. The main objectives of chemical fingerprinting are to characterize, quantitate, and individualize a chemical mixture (Alimi et al., 2003). In this section we provide the reader with a review of some of the constituents of a mixture that are useful for assembling a chemical fingerprint as well as the techniques used to screen for these constituents. The efficacy of these analytes and of detection techniques are evaluated by illustrating their application in several cases.

1.2.1 Hydrocarbon Mixtures

The majority of chemical spills involve hydrocarbon mixtures; as a result, many techniques are tailored for these mixtures (Sauer and Uhler, 1994). Early techniques were used simply to quantify the total petroleum hydrocarbon concentration, but modern techniques must be capable of quantification as well as identification and individualization (Zemo et al., 1995). The latter two are especially important for litigation purposes. However, identification and individualization may also provide for the design of a more effective remediation plan that accounts for dispersal, weathering, and degradation of the chemical mixture (Zemo et al., 1995).

Petroleum hydrocarbon mixtures may be broadly classified into three general groups. *Petrogenic hydrocarbons* are present in crude oil or its refined products. *Pyrogenic hydrocarbons* are the combusted remnants of petrogenic hydrocarbons and other by-products. *Biogenic hydrocarbons* are those that arise from more recent natural processes: for example, swamp gas or the volatile hydrocarbon mixtures released by decaying plant or animal tissue exposed to anaerobic conditions. Within each of these three broad groups, hydrocarbons are generally separated into three types: saturated aliphatics (alkanes), unsaturated aliphatics (alkenes, etc.), and aromatic hydrocarbons. Aromatic hydrocarbons include both light petroleum products [e.g., benzene, toluene, ethylbenzene, and xylenes (BTEX)] and heavier products such as polycyclic aromatic hydrocarbons.

Analytical techniques such as gas chromatography are usually adequate for differentiating among petrogenic, pyrogenic, and biogenic hydrocarbon mixtures

because of the unique ratios of alkanes, alkenes, and aromatic structures that can be expected in these mixtures. Furthermore, gas chromatography can be used to differentiate different grades of petrogenic hydrocarbons because crude mixtures have a variety of hydrocarbon components (i.e., unresolved complex mixtures), which often present themselves as a "hump" on a chromatogram, whereas more refined mixtures have less variety in their components. Retention time for various petrogenic compounds is affected by the structure of these compounds: for example, gasoline elutes first (C_4 to C_{12}), along with Stoddard solvents (C_7 to C_{12}), which are followed by middle distillate fuels (C_{10} to C_{24}), and crude mixtures (up to C_{40}) (Zemo et al., 1995). Crude oil mixtures contain a diverse array of hydrocarbons and, on average, are comprised of 15 to 60% paraffins and isoparaffins, 30 to 60% naphthenes, and 3 to 30% aromatics, with the remainder of the mixture being composed of asphaltenes and various trace compounds (Bruce and Schmidt, 1994). Pyrogenic hydrocarbon mixtures can be recognized on the chromatogram because large molecules undergo combustion first, leaving behind a disproportion of smaller molecules. However, pyrogenic compounds are more difficult to attribute to a source because the chemical signature is further removed from the original petrogenic source (Bruce and Schmidt, 1994). Steranes and hopanes are often used as target analytes when the focus of a study is biogenic hydrocarbons, because these analytes are more resistant to many more forms of weathering than are other biogenic components (Alimi et al., 2003).

Although it is worthwhile to classify a mixture as petrogenic, pyrogenic, or biogenic in origin, this is commonly not enough. To arrive at a unique chemical signature, the analysis must extend beyond identifying the class characteristics of a mixture. Modern methods often involve the examination of ancillary components of a mixture, such as dyes, additives, stable isotopes, radioactive isotopes, biomarkers, polycyclic aromatic hydrocarbons (PAHs). PAH homologs, and metabolized PAHs. It is customary to screen for many of these analytes with the intent of providing the most comprehensive chemical signature possible. Before selecting a suite of analytes, it is wise first to consider if these analytes may already have been present at a location (due to a prior contamination or natural processes) and if these analytes are highly susceptible to degradation. Indeed, the characteristics of a good chemical marker are that it is resistant to degradation and that it can uniquely identify the hydrocarbons released from other sources (Sauer and Uhler, 1994).

The first step in confirming hydrocarbon contamination is accomplished by screening for saturated hydrocarbon molecules such as pristane and phytane. These are isoparaffins that are resistant to degradation and are highly indicative of hydrocarbon contamination (Sauer and Uhler, 1994). Pristane and phytane usually represent themselves to the right of C_{17} and C_{18} peaks on a chromatogram. Fresh hydrocarbon mixtures have prominent C_{17} and C_{18} peaks in relation to pristane and phytane peaks, whereas the converse is true for degraded mixtures (Bruce and Schmidt, 1994; Morrison, 2000b). Due to the proportionality between the ratios of these compounds and the extent of degradation, the ratios of pristane and phytane to the C_{17} and C_{18} peaks are often used to estimate the degree of weathering.

1.2.2 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are hydrocarbon compounds with two to six rings. Homologs of the PAH compounds may be similar to the parent compound except that they are substituted for by one or more alkyl groups. The ratio of two PAHs to two other PAHs is sometimes expressed in double-ratio plots, in which certain regions of the plot are diagnostic for one source or another. It is also becoming increasingly common to screen for metabolized PAHs (as well as BTEX compounds), whose structures differ predictably from the original PAH. PAHs are often very useful in studies involving weathered mixtures, because the complex structure of PAHs makes them more resistant to degradation. The rate of degradation is proportional to the complexity of the ring structure, with the compounds having the fewest number of rings degrading first (Alimi et al., 2003). Some target parent PAH compounds and their alkyl homologs are shown in Table 1.1.

One of the most prominent applications of PAH analysis has been the study of the *Exxon Valdez* oil spill. The spill occurred when the tanker hull was punctured as it ran aground on March 24, 1989, releasing some 10.8 million gallons of oil into Prince William Sound, Alaska. The oil released was dispersed by water currents and a windstorm that followed the spill a few days later, and concern

TABLE 1.1 Target Parent PAH Compounds and Their Alkyl Homologs

Naphthalenes	Chrysenes
C_0-naphthalene (N)	C_0-chrysene (C)
C_1-naphthalenes (N1)	C_1-chrysenes (C1)
C_2-naphthalenes (N2)	C_2-chrysenes (C2)
C_3-naphthalenes (N3)	C_3-chrysenes (C3)
C_4-naphthalenes (N4)	C_4-chrysenes (C4)
Phenanthrenes	EPA priority pollutant
C_0-phenanthrene (P)	Biphenyl (Bph)
C_1-phenanthrenes (P1)	Acenaphthylene (Acl)
C_2-phenanthrenes (P2)	Acenaphthiene (Ace)
C_3-phenanthrenes (P3)	Anthracene (An)
C_4-phenanthrenes (P4)	Fluoranthene (Fl)
Dibenzothiophenes	Pyrene (Py)
C_0-dibenzothiophene (D)	Benzo[*a*]anthracene (BaA)
C_1-dibenzothiophenes (D1)	Benzo[*b*]fluoranthene (BbF)
C_2-dibenzothiophenes (D2)	Benzo[*k*]fluoranthene (BkF)
C_3-dibenzothiophenes (D3)	Benzo[*e*]pyrene (BeP)
Fluorenes	Benzo[*a*]pyrene (BaP)
C_0-fluorene (F)	Perylene (Pe)
C_1-fluorenes (F1)	Indeno[1,2,3-*cd*]pyrene (IP)
C_2-fluorenes (F2)	Dibenz[*a*,*h*]anthracene (DA)
C_3-fluorenes (F3)	Benzo[*ghi*]perylene (BP)

Source: Alimi et al. (2003).

was raised over the dispersal of the oil into adjacent bodies of water (Galt et al., 1991). Many of these concerns were seemingly corroborated by the detection of oil in neighboring bays. However, it was speculated that some of the oil detected in these neighboring waters may have been from biogenic sources, petrogenic sources from previous spills, or pyrogenic sources from hydrocarbons that had previously undergone combustion. A massive effort was mounted to identify the extent to which Exxon was responsible for oil detected in these adjacent waters.

The study immediately focused on components of oil that were the most resistant to degradation, such as PAHs and biomarkers. A substantial part of the investigation focused on evaluating the effects of weathering on the *Exxon Valdez* cargo if it was to be accurately differentiated from other sources (Figure 1.1). As expected, lighter components of the oil matrix were preferentially lost to weathering. With the effects of weathering understood, the investigation then turned to PAH analysis. Two PAHs that were focused on for distinguishing different crude mixtures were phenanthrenes and dibenzothiophenes; chrysenes were used to differentiate crude from refined mixtures because chrysenes are removed during the refining process (Boehm et al., 1997). The ratios of the PAH compounds to one another were particularly useful

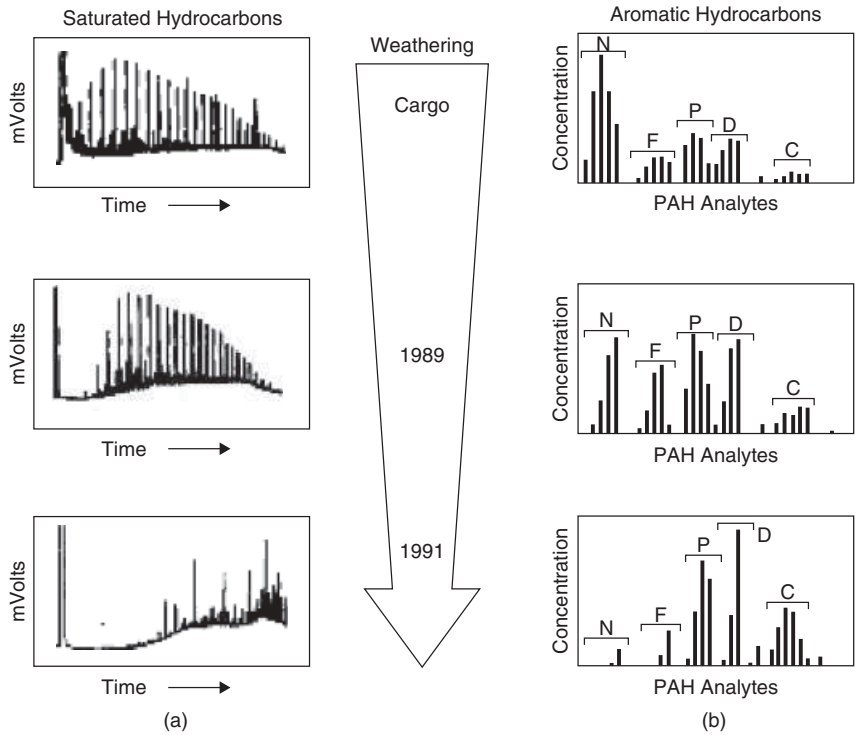

Figure 1.1 Effects of weathering on (a) saturated hydrocarbons and (b) aromatic hydrocarbons from the *Exxon Valdez* spill. N, naphthalenes; F, fluorenes; P, phenanthrenes; D, dibenzothiophenes; C, chrysenes (Boehm et al., 1997).

because the concentrations of the PAHs will change with weathering; however, the ratio of one PAH to another generally remains constant (Boehm et al., 1997). In this case, researchers created a double-ratio plot comparing dibenzothiophenes to phenanthrenes in order to distinguish PAHs of the *Exxon Valdez* spill from PAHs of other sources (Figure 1.2). As seen in the figure, the double-ratio plot showed distinct clustering of oil samples from different sources, allowing a differentiation to be made. When the PAHs in neighboring bays were analyzed, some were attributed to the *Exxon Valdez* spill, but many were found to have originated from other sources, both natural and anthropogenic (Boehm et al., 1998).

PAHs have also been used to study contamination at former manufactured gas plant (MGP) facilities. Prior to the use of natural gas, MGPs made coal gas to use as fuel. Former MGP sites are evaluated for contamination by screening for PAHs that would have been introduced to the environment as coal tar, which is a by-product of the coal gas manufacturing process. This can sometimes be a difficult task because the sites often contain PAHs that may be unrelated to the MGP, having been introduced via other natural and anthropogenic avenues. The investigations are further complicated because similar PAH signatures are obtained for MGP coal tar residues and background residues. Although the composition of the PAHs contained in MGPs and background sources may be similar, the PAH ratios and patterns (i.e., petrogenic or pyrogenic) can be used to differentiate PAHs from different sources. One study examined the ratios and patterns of PAHs for the purpose of distinguishing MGP PAHs from background PAHs in soil samples collected in and around a stream near an MGP (Costa et al., 2004).

PAHs may be present either as unsubstituted parent compounds or as a substituted alkyl homolog (see Table 1.1 for examples). Petrogenic patterns of PAHs are recognized because they contain a bell-shaped distribution of the parent PAH and its homologs where concentration of the single- or double-substituted homologs

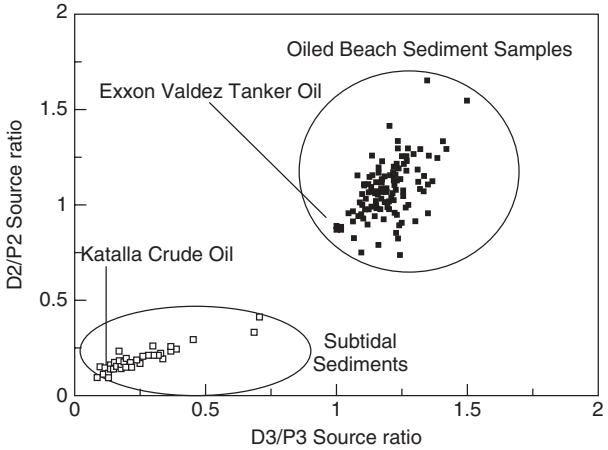

Figure 1.2 Double-ratio plot showing how the ratio of PAHs (dibenzothiophenes to phenanthrenes) can be diagnostic for one source or another (Boehm et al., 1997).

are highest, and concentrations decrease as one moves in either direction toward the unsubstituted parent or toward the complex, multisubstituted homolog (see Figure 1.4 for an example). Pyrogenic patterns of PAHs are recognized because they contain a distribution in which the parent PAH is more abundant, due to preferential combustion of the substituted homologs. Researchers observed a pyrogenic pattern in PAH residues derived from the MGP site in question (Figure 1.3), but samples collected from an adjacent stream indicated a mix of petrogenic and pyrogenic PAHs (Figure 1.4).

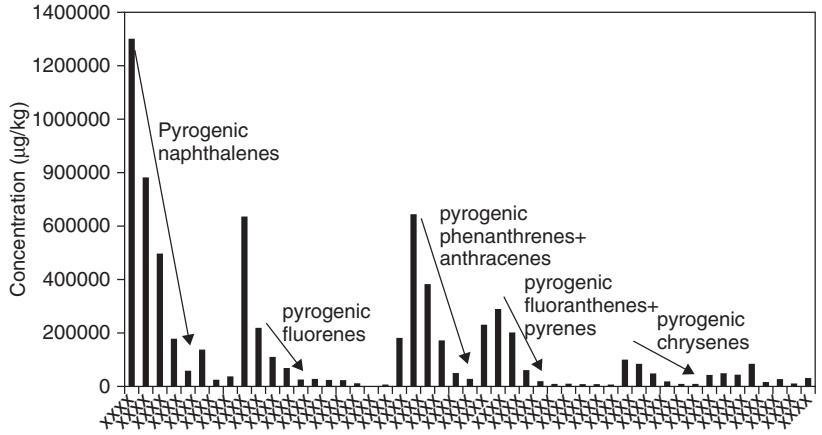

Figure 1.3 PAH composition of residues derived from an MGP site. Decreasing concentrations of substituted homologs of the parent compounds indicate the pyrogenic origin of the sample (Costa et al., 2004).

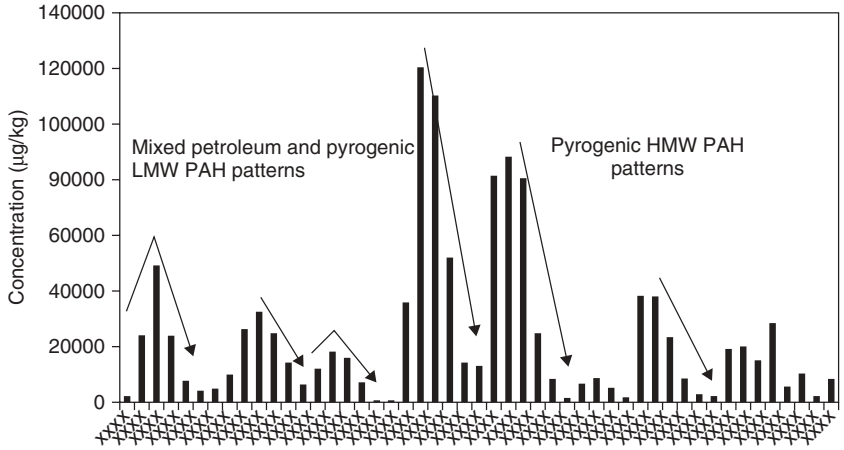

Figure 1.4 PAH composition of residues derived from a streambed. Mixed patterns indicate the presence of a mixture of pyrogenic and petrogenic hydrocarbons (Costa et al., 2004).

The researchers then turned to high-molecular-weight PAH ratios to determine if the pyrogenic pattern observed in the stream was from weathered MGP residues or from recent background contamination. Several PAHs were chosen to create double-ratio plots in which certain sections of the plot were diagnostic for either the MGP, background sources, or a mix of the two. A comparison of samples from the streambed surface (Figure 1.5) and samples from the streambed subsurface (Figure 1.6) indicated that most of the surface (i.e., newer) PAHs were derived

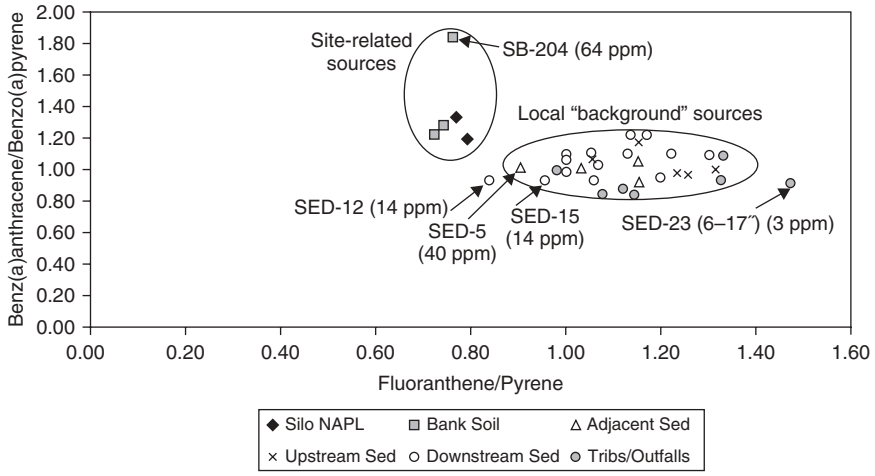

Figure 1.5 Double-ratio plot used to distinguish site-related, background, and mixed PAH signatures in streambed surface samples (Costa et al., 2004).

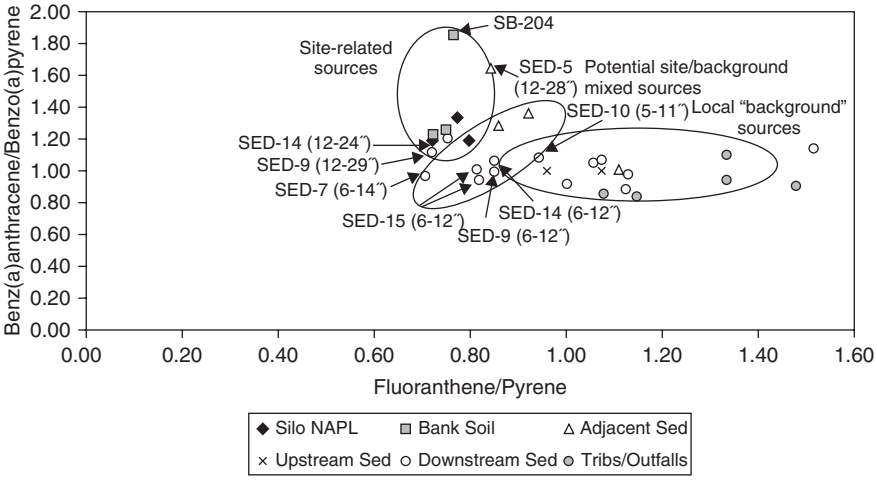

Figure 1.6 Double-ratio plot used to distinguish site-related, background, and mixed PAH signatures in streambed subsurface samples (Costa et al., 2004).

from background sources, whereas most of the subsurface (i.e., older) PAHs were derived from the MGP site. Results of studies such as this can help to draw attention to other potential sources of contamination in order achieve the most efficacious remediation effort.

1.2.3 Biomarkers

Biomarkers such as steranes and hopanes are hydrocarbon remnants of deceased organisms that are useful in chemical fingerprinting because they are extremely resistant to weathering (Alimi et al., 2003). Thus, biomarkers can often be useful to individualize a hydrocarbon mixture when saturated hydrocarbons and PAHs have already been degraded (Sauer and Uhler, 1994). A comprehensive list of biomarkers that are useful in hydrocarbon mixture studies is provided by Alimi et al. (2003).

1.2.4 Additives

Inorganic compounds are often added to hydrocarbon mixtures to serve as anti-knock agents, octane boosters, corrosion inhibitors, and anti-icers (Kaplan, 2003). Additives are not present in crude mixtures, of course, so their presence is indicative of a refined mixture (Bruce and Schmidt, 1994). Because refining practices and additives change over time, and since these changes have been well documented, the presence of particular additives in a hydrocarbon mixture can be highly indicative of a certain time frame during which a sample was produced. For example, lead was first added to gasoline in 1923, and its concentration in gasoline decreased steadily until it was phased out in U.S. automobile fuels in 1995 (Kaplan, 2003). Other gasoline additives that have predictably appeared and disappeared throughout history are methylcyclopentadienyl manganese tricarbonyl (MMT) and methyl *tert*-butyl ether (MTBE). The chronology of some popular additives has been thoroughly documented in several sources (Morrison, 2000a,b; Kaplan, 2003). Some additives, such as lead, have been used over large time frames, but the concentration of lead in gasoline has varied predictably over the years. Although this can be used to arrive at a reasonable estimate of time of manufacture of the hydrocarbon mixture in question, it is not an infallible method because additive concentrations are often reported based on a pooled standard, which ignores batch-to-batch variation (Morrison, 2000a).

The use of additives for dating a release can be complicated by the fact that additives may be discontinued in certain countries or for certain applications, but may still be used in others. Additives that are supposedly absent in a mixture may also be present in very dilute amounts. The utility of additives in dating manufacture or release dates is greater than their capacity to individualize a mixture. This is because many companies often purchase additives from the same manufacturer. These additives are then added unaltered into various hydrocarbon mixtures, so many different mixtures may have the same additives present (Morrison, 2000a). Further complications when screening for old additives may be encountered because

these compounds often contain oxygen, which contributes to their rapid weathering over time (Morrison, 2000b).

1.2.5 Isotopes

When complex hydrocarbon mixtures cannot be identified by analysis of stable components, the mixtures can be identified by analysis of stable isotopes within the mixture. Stable isotopes are often analyzed with respect to one another. In other words, the ratio of one stable isotope to another stable isotope within the same mixture can often be unique, thereby allowing for the creation of an isotope signature. In contrast to stable isotopes, unstable isotopes decay predictably such that the degree of decay can be correlated with the age of the mixture. Analysis of unstable isotope decay is often referred to as a *long-term method* because it is capable of estimating release dates thousands of years prior. Unstable isotopes are also useful because their decay is independent of environmental factors such as weathering (Kaplan, 2003).

Isotopes can be useful in chemical fingerprinting in two ways. The ratio of two isotopes can be compared as a means of individualization because no two mixtures will have exactly the same ratio of two isotopes. Carbon and lead isotope ratios are commonly used for source identification. Radioactive isotopes are also useful for dating a release because these isotopes have known rates of decay that are independent of environmental conditions.

Carbon isotopes were used in one study to determine the origin of soil gas methane near the site of a prior gasoline spill (Lundegard et al., 2000). The investigation was triggered by the detection of high methane levels near a service station where approximately 80,000 gallons of gasoline had been spilled 20 years earlier. Initially, it was speculated that the methane was due to the bacterial degradation of the gasoline, but the investigators were considering other possibilities. Suspicion was raised because high levels of methane were detected outside the original gasoline plume, and in some cases the levels detected outside the plume were higher than those within the plume (Figure 1.7).

The initial hypothesis of methane generation by bacterial degradation of the gasoline was also challenged because this is not a common degradation pathway. For gasoline to be fermented to methane, it would first have to be converted to the necessary precursor compounds for methanogenesis by fermentation (Lundegard et al., 2000). Although the generation of methane via this pathway is possible, the investigators were considering more plausible origins of the methane that, coincidentally, were unrelated to the gasoline spill. One of the potential origins considered was the biodegradation of organic matter.

The methanogenesis of petrogenic compounds can be distinguished from that of organic compounds from biogenic origins through the use of ^{13}C, which is a stable carbon isotope. Differentiating the methanogenesis of petrogenic and organic compounds is accomplished based on the idea that older, petrogenic compounds have lower quantities of ^{13}C isotopes than does newer organic matter. The process of methanogenesis significantly reduces the amount of ^{13}C present in the original

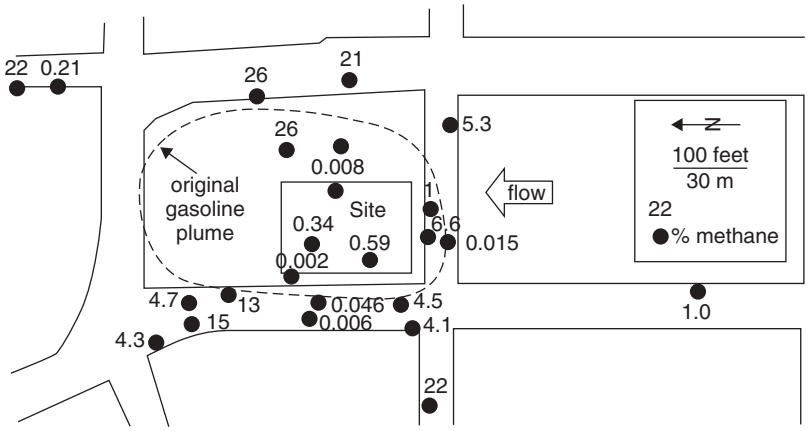

Figure 1.7 Service station map showing methane concentrations within and surrounding the original plume (Lundegard et al., 2000).

organic matter, but the ^{13}C in the nascent methane remains stable regardless of environmental conditions (Lundegard et al., 2000). The study indicated that wood fill from beneath the service station site and gasoline from within the original plume had indistinguishable ^{13}C quantities.

Another way of differentiating methane from petrogenic and biogenic sources is through the use of ^{14}C, which is a naturally occurring radioactive isotope of carbon taken up by all living organisms. The age of the source from which the methane was formed can be predicted because ^{14}C has a half-life of about 5700 years, and therefore it will still be detectable in methane formed from biogenic organic matter less than 50,000 years old. The hypothesis that methane originated from the degradation of biogenic organic matter was corroborated by the ^{14}C analysis, which indicated that the highest ^{14}C levels were detected outside the original plume (Figure 1.8). The level of ^{14}C in petrogenic hydrocarbons is zero, so the researchers concluded that the methanogenesis must be of biogenic origins. This hypothesis was further supported because a review of the site history indicated that the area consisted of organic fill, including wood and sawdust.

1.2.6 Tracers

When none of the analytes discussed previously are amenable to the case at hand, techniques that rely on tracers can sometimes be used for forensic tracking of environmental chemicals. A tracer can be any molecule that is diagnostic of one source but not others. Sometimes, multiple tracers are used to augment the significance of the results. One study used organic tracers to determine the origin of gas- and particle-phase air pollutants in two California cities (Schauer and Cass, 2000). The objective of the study was to determine the primary source(s) of air pollutants in Fresno and Bakersfield, California. The results and chemical composition of samples collected at the two locations were compared to those collected at a remote

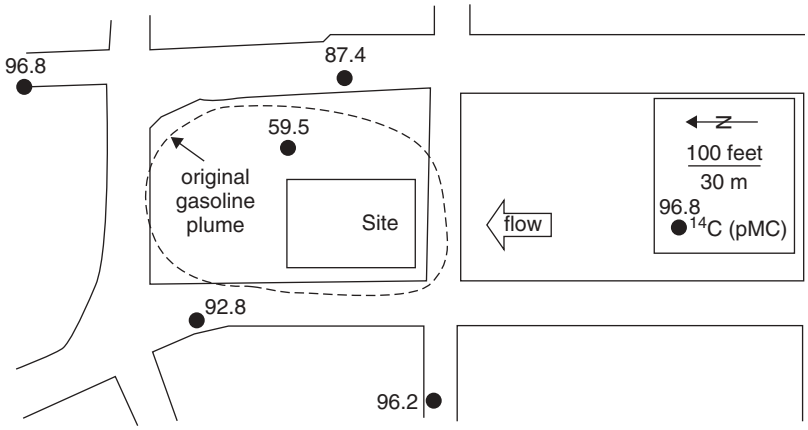

Figure 1.8 ^{14}C levels detected within and surrounding the original plume of a gasoline spill exhibiting high methane concentrations. High ^{14}C concentrations indicated methanogenesis of biogenic hydrocarbons and countraindicated gasoline as the source of origin (Lundegard et al., 2000).

site located at the Kern Wildlife Refuge and distant from anthropogenic sources of air pollutants. Previous tests for air pollutants have used generic compounds to draw connections between air pollutants and their sources (Harley et al., 1992). However, some of the analytes used in these other studies are not exclusive to a particular source. The researchers in the California study aimed to develop a more accurate method for tracing the origin of the air pollutants. Atmospheric samples in the two cities were collected, as well as single-source control samples that consisted of combustion emissions from gasoline-powered motor vehicles, diesel engines, hardwood combustion, softwood combustion, and meat-cooking operations. Tracers that were unique to sources and those that were common between multiple sources were chosen both to fingerprint and then apportion emissions in particulate samples with mixed origins. Further criteria used to choose tracers were (1) that they were not selectively removed from the environment, and (2) that they were not formed by atmospheric reactions to any significant extent. The researchers used direct measurements of these tracer compounds to draw conclusions about the source of particulate pollutants in the areas indicated.

Specific tracers were used to apportion the results obtained from specific sources. For example, the compound levoglucosan was found to be specific to wood combustion, so the concentration of levoglucosan in proportion to other constituents in a mixed sample could be used to apportion the contribution of wood combustion to particulate loading in an area (see Figure 1.9). Based on the concentrations of the other tracers in the samples, the relative contributions of each source (e.g., automobiles, wood combustion) were apportioned (Figure 1.10). Low levels of pollutants derived from anthropogenic sources at the remote site were noteworthy. The researchers concluded that local anthropogenic emissions (particularly automobile exhaust) were responsible for the majority of air pollutants in the two urban

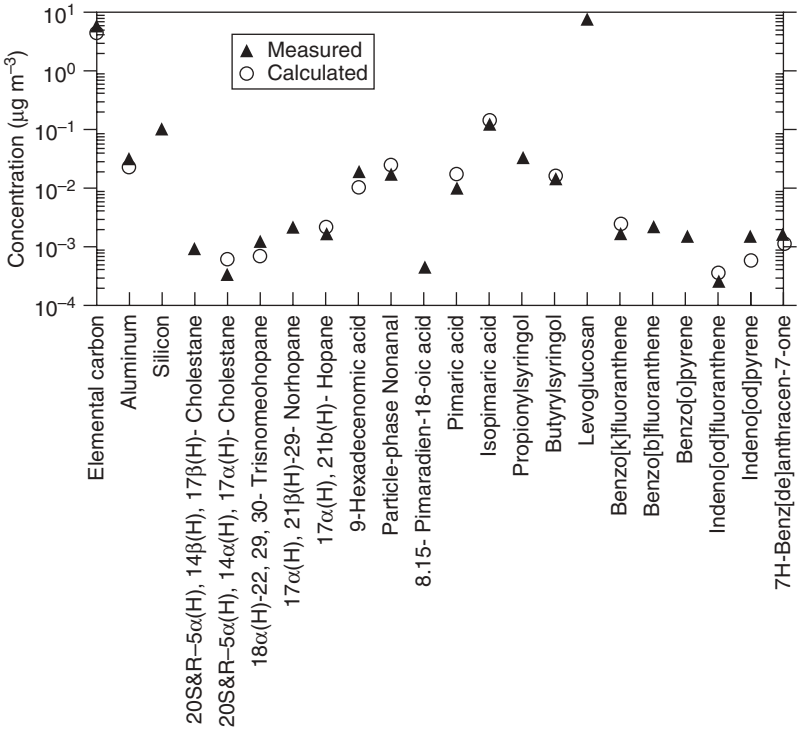

Figure 1.9 Ambient concentrations of various air pollution tracer compounds in samples (Schauer and Cass, 2000).

environments, whereas naturally occurring dusts were primary contributors at the remote site.

Inorganic compounds can also be used for forensic chemistry purposes. One study used metal tracers to identify dust that resulted from the collapse of the World Trade Center (WTC) buildings (Scott et al., 2007). The analysis of particulate matter arising from this catastrophic event has been an area of great interest because there are significant health implications associated with inhalation of the dust. Substantial amounts of the dust were transferred from the collapse to nearby buildings, so the objective of the research was to develop a method based on metal tracer detection to determine which buildings were most affected, and for those that were severely affected, to determine if appropriate remediation efforts had been undertaken.

Techniques employed included screening for human-made vitreous fibers, as well as trace metals, including As, Cd, Cr, Cu, Pb, Mn, Ni, V, and Zn. Trace metal detection was found to be more applicable to the identification of WTC dust because the atmosphere and buildings around the WTC were probed routinely for these metals after the collapse (Scott et al., 2007). Although these metals can originate from other sources as well, the researchers expected trace metals to be detected in quantities and ratios that were unique to WTC dust.

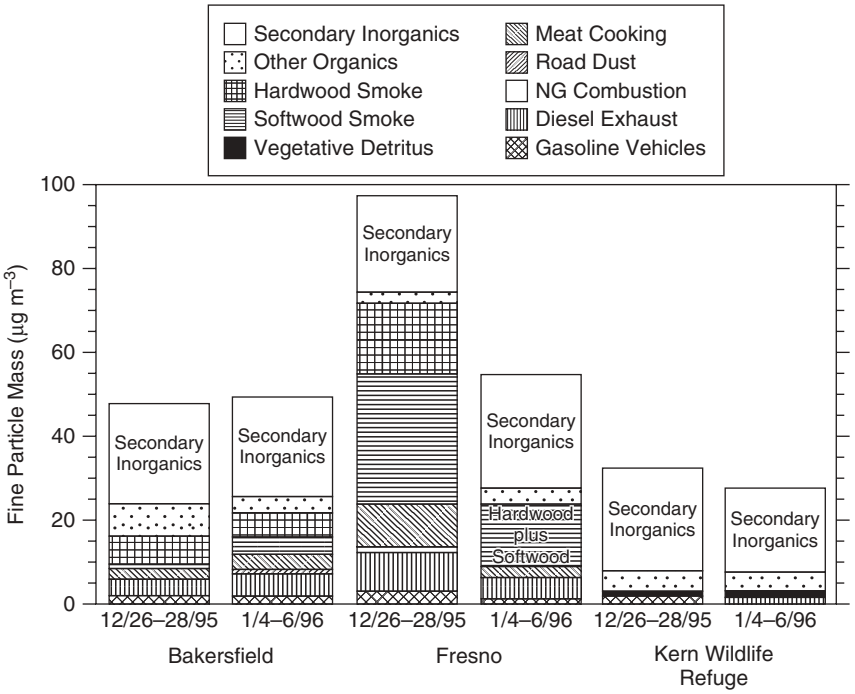

Figure 1.10 Source apportionment to particulate air pollution in two urban areas and one remote site in California (Schauer and Cass, 2000).

Concentrations of the nine metals in WTC dust as reported by four studies were compared to concentrations in background dust collected from Arizona. A discriminant analysis model was used to classify each sample as having originated from WTC or background dust based on the relative concentrations of the nine metals (Figure 1.11). The analysis indicated that WTC dust had elevated levels of Cr and Mn and low levels of As, Cd, and Cu compared to background dust. The researchers were able to demonstrate that trace metals could be used to distinguish pure WTC dust from background dust with 94% accuracy; however, mixed dust samples had lower levels of accuracy (Scott et al., 2007).

1.2.7 Methods of Detection

One of the most widely used techniques in chemical fingerprinting for hydrocarbons is gas chromatography. This is based on the concept that each compound has a unique structure and will therefore be retained differentially in the gas chromatograph before being eluted. As long as other parameters (e.g., temperature, column length, column packing) are held constant, any differences in retention time can be attributed to the structure of the compound (Bruce and Schmidt, 1994). Mixtures contain many different compounds, so a gas chromatogram represents a chemical fingerprint of all the chemical constituents in a mixture. Gas chromatography

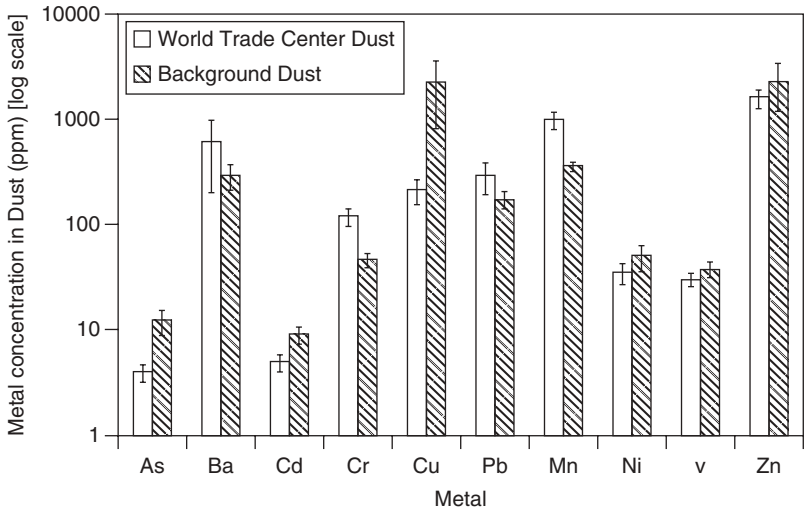

Figure 1.11 Comparison of trace metal fingerprints in dust from the WTC (white bars) and from background (striped) (Scott et al., 2007).

is often combined with other techniques to achieve a more detailed analysis. For example, a gas chromatograph is commonly used as a preliminary separation technique that is followed by detection using mass spectroscopy. Some researchers even use two-dimensional gas chromatography (GC × GC) to achieve superior resolution (Gaines et al., 1999). A good review of the literature focusing on these techniques is provided by Suggs et al. (2002). The potential weaknesses and vulnerabilities of these techniques are discussed by Morrison (2000b).

Although many of the aforementioned techniques are highly effective, they often have a deleterious impact on the sample. That is, substantial portions of the sample are often destroyed in the course of the analysis. Sample destruction may not be a major concern in other disciplines, but evidence is sometimes limited in forensic investigations, and what little sample may be available often attains the status of a precious and rare commodity. Another example of when the destruction of a sample is avoided is when the sample itself is, quite literally, a rare commodity, such as an archaeological treasure or artifact. For samples of limited quantity or prized value, less invasive methods of analysis are often sought.

One study that warranted the use of a minimally invasive technique involved the analysis of ancient tools made of obsidian (Tykot, 2002). The purpose of the analysis was to evaluate the Mediterranean sources and trade routes of obsidian tools without damaging them. To bolster the results and to compensate for the potential weaknesses of certain techniques, this study relied on a series of methods, including scanning electron microscopy (SEM), x-ray fluorescence (XRF), neutron activation analysis (NAA), and inductively coupled plasma mass spectroscopy (ICP-MS). The elemental compositions indicated by the four techniques were used to construct possible sources and distributions of obsidian. The results helped lend

credence to the theory of a vast distribution network for the tools rather than the lone source theory that was once promulgated.

1.2.8 Weathering

When screening for various analytes, one variable that must be kept in mind is weathering. This is the process by which the chemical signature of a mixture is altered due to evaporation, dispersal, biodegradation, or oxidation of certain components of the mixture. Short-chain hydrocarbons are most vulnerable to weathering mainly because their simple structure makes them susceptible to degradation, particularly to biodegradation (Alimi et al., 2003). Compounds with more complex structures are generally more resistant to weathering. Weathering generally occurs at predictable rates such that the age of the mixture can be estimated accurately based on the relative amount of weathering of short-chain hydrocarbons to larger, more resistant molecules. However, weathering can vary because of site-specific differences in environmental conditions (Morrison, 2000b). The compounds that exhibit the greatest longevity are generally the most useful for estimating the degree of weathering and therefore the age of a particular compound. Isotopes, BTEX compounds, PAHs, and biomarkers have all been used with varying degrees of success for determining the extent of weathering of hydrocarbon samples.

Certain studies have focused on families of constituents of oil that are resistant to degradation, specifically paraffins, isoparaffins, aromatics, naphthenes, and olefins, all of which generally range from three to 13 carbons (Kaplan et al., 1997). These compounds, commonly referred to as PIANO compounds, are useful because their ratios vary among different hydrocarbon mixtures. For example, fuels of different grades and octane levels are composed of unique ratios of PIANO compounds. PIANO analysis is particularly useful to spatial analysis because the concentration of the various PIANO constituents and additives has changed over time, due to evolving oil refining practices, varying octane levels, and increasingly stringent legal regulations (Davis et al., 2005).

1.3 SPATIAL ASSOCIATION OF ENVIRONMENTAL INCIDENTS

Spatial analysis is used to associate a pollutant release or plume with a source by tracing back its geographic point of origin to a particular place in space or time. This approach is often thought of as one of the more esoteric areas of forensic environmental chemistry; however, this reputation is, for the most part, undeserved because spatial analysis is inherently simple and straightforward. Spatial analysis applies all of the usual tools of forensic environmental chemistry to a spatial problem. For example, spatial analysis relies on many of the analyses with which we are familiar, such as those that screen for various hydrocarbons, fuel additives, isotopes, and biomarkers. However, spatial analysis attempts to determine more than the source and content of a particular contamination. Spatial analysis goes further by elucidating not only the “what” and “who” of a chemical contamination incident, but also the “where” and “for how long.”

Spatial analysis of chemical transport involves integrating the results of chemical analyses with spatial and sometimes historical information about a site. For example, Carpi et al. (1994) examined the spatial distribution of airborne mercury pollution around a municipal solid-waste incinerator. The study used transplanted and prepared samples of sphagnum moss as biological monitors of air pollutants. Clean moss samples were distributed to 16 sites within a 5-km (3.1-mi) radius of the waste incinerator, plus one remote site about 20 km (12.4 mi) away. Samples of the moss at each of these stations were collected in duplicate every 2 weeks for about three months. The samples were analyzed by cold vapor atomic absorption spectroscopy for mercury contamination in two ways: Each sample was split and half was analyzed as received and the other half was first oven-dried at 105°C for 24 h before analysis.

Higher concentrations of mercury were correlated with sites closest to the incinerator, which then led the researchers to use meteorological data from the nearest weather service station [38 km (23.6 mi) away] to determine if mercury near the incinerator could indeed be traced back to the incinerator. It was determined that plants from sites with the highest levels of mercury were downwind of the incinerator. A locally weighted spatial statistics technique called *kriging* was used to develop regression surfaces for the pollutants over the area and these regression surfaces showed that proximity to the incinerator accounted for a high degree of the variability in mercury concentrations with location (Opsomer et al., 1995). The study benefited by incorporating topographical data to support the conclusions.

Interestingly, the mercury concentration in moss from the remote site was approximately equivalent to the mercury detected in some of the samples within the 5-km radius of the incinerator. However, comparison of the undried to dried moss samples demonstrated that the volatility of mercury at the remote site, and thus chemical species of mercury accumulating in samples at the remote site, was significantly different than it was near the incinerator. Samples collected near the incinerator demonstrated relatively low volatility, and indeed incinerators are known to emit high levels of $HgCl_2$, which has a low volatility (Carpi, 1997). In contrast, mercury at the remote site demonstrated high volatility, indicating that the form of mercury in the samples was primarily volatile elemental mercury. The authors conducted a site history at the remote site that revealed that whereas the site was distant from any anthropogenic source of mercury, it was close to a recently flooded reservoir system, and flooding of land is known to release naturally occurring elemental mercury from soil.

Spatial analysis can sometimes be complicated if samples have been collected sporadically or randomly, or if the data are otherwise incomplete. Such was the case in a study that investigated unusually high radiocesium (^{137}Cs) levels in a river basin near the Chernobyl nuclear power plant (Burrough et al., 1999). An explosion occurred at the power plant in April 1986 and released radioactive materials to large areas surrounding the plant. After the explosion, ^{137}Cs levels in the contaminated areas generally decreased due to radioactive decay and various environmental factors that resulted in dispersal and dilution. However, some locations near a river basin exhibited high or increasing levels of ^{137}Cs after the explosion.

The research attempted to find a correlation between hydrological events (e.g., flooding) and spatial and temporal variations in ^{137}Cs contamination by using a method of statistical analysis involving *geographical information systems* (GISs) (Burrough, 2001).

GIS was used to construct various maps showing soil types, land cover, and proximity of the flooded areas to main rivers. Using the maps to inspect the spatial distribution of ^{137}Cs over the contaminated area was complicated because samples were collected only in 1988, 1993, and 1994. The sparsely collected samples necessitated data interpolation, in which new data points were created to augment existing data points. However, interpolation of GIS data can sometimes be unrealistic unless the propagation of errors is understood through the use of geostatistics. Ultimately, the use of a GIS and geostatistics in this study helped to establish that there was a relationship between flood events in the river basin and high concentrations of ^{137}Cs.

GISs have been used for many years, but it has only recently been suggested that a GIS be combined with geostatistics, for the precise reasons illustrated in the case above. The GIS technique was developed to automate the mapmaking process by aiding in storage, retrieval, analysis, and display of spatial data (Burrough, 2001). The flaw in the GIS method is that it analyzes the attributes of an object or surface but does not consider spatial variation. Geostatistics has been proposed as the perfect complement to GISs because geostatistics is more realistic, in that it considers chance, uncertainty, and incompleteness in a data set (Burrough, 2001). Unfortunately, the fundamental differences between the two fields, combined with the fact that GISs were not designed with geostatistics in mind, have often caused some recalcitrance when the combination of GISs and geostatistics is suggested (Wise et al., 2001). The benefits of using both methods have only begun to be appreciated, mostly because the advantages can no longer be ignored. Geostatistics stands to profit from the union primarily because a visual interpretation of the data is made available. GISs will benefit because they often rely on data sets that are incomplete and uncertain, and geostatistics offers a method for interpolating such data and understanding the error (Burrough, 2001).

Spatial analysis is a blend of many techniques that are not necessarily exclusive to spatial analysis. At times, its boundaries may even seem amorphous. Spatial analysis may be regarded as superior to other disciplines that share these techniques because only spatial analysis attempts to discern both the spatial and temporal extent of a contamination. Other disciplines merely apply these techniques to determine the identity of the contaminant. Spatial analysis is likely to be relied on increasingly in the future as a supplement to more conventional techniques when there is a need to identify the source and dispersal pattern of widespread contamination.

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CHAPTER 2

Principles and Issues in Forensic Analysis of Explosives

JIMMIE C. OXLEY

University of Rhode Island, Chemistry Department, DHS Center of Excellence for Explosives Detection, Mitigation, and Response, Kingston, Rhode Island

MAURICE MARSHALL

(Formerly) Forensic Explosives Laboratory, Defence Science and Technology Laboratory, Fort Halstead, Sevenoaks, Kent, UK

SARAH L. LANCASTER

Forensic Explosives Laboratory, Defence Science and Technology Laboratory, Fort Halstead, Sevenoaks, Kent, UK

Summary Proper handling of evidence is critical to identifying and convicting a criminal. Evidence at the scene of an explosion, especially a large explosion, offers some unique challenges. Basic principles of evidence collection, handling, storing, and identifying are discussed herein.

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2.1 INTRODUCTION

Many types of laboratories engage in chemical analysis. In forensic science laboratories, a wide variety of chemical, biological, and physical analyses are undertaken. The principal difference between forensic analysis and more general analysis is the degree of certainty required of the results. The technical issues depend on the nature of the sample: in particular, on whether bulk samples or invisible traces are being sought. Bulk samples are considered to be anything that is visible to the naked eye and can range from micrograms to several kilograms of material.

The most obvious difference between analyses of bulk versus trace samples is the relationship between the sample and the environment. Sometimes the desired analyte may be in the environment, and sometimes a species in the environment (e.g., water, oxygen, iron particles) may degrade the sample or affect the results. The analyte in the environment is not generally an issue in bulk samples. In trace samples, the amount of contamination may be large enough to distort results. Thus, if the sample contains a tiny amount of the analyte sought and the environment contains a large concentration of that species, extreme precautions will need to be taken to protect the sample and exclude contact with the environment. Conversely, if the sample contains a large concentration of the analyte and the environment a tiny amount, the issue is trivial. An understanding of the composition of the background environment is therefore highly desirable, but not always possible. This needs to be considered when reporting results.

A robust and well-designed trace analysis protocol is likely to involve (1) physical separation between the analyst and the sample; (2) the use of disposable items for handling, packaging, and containment; (3) appropriate blank and control samples; and (4) environmental monitoring. The precise detail of the measures will depend on the environmental challenge to the integrity of the analysis, and it is often possible to strengthen one protective technique to counter the weakness or absence of another.

Although explosives are, of course, simply chemicals or chemical mixtures, in some respects their analysis is easier because many explosives (e.g., the organic explosives) are rarely found in the general public environment. In response to the Provisional Irish Republican Army (PIRA) bombing campaign on the mainland (1970s to 1990s), the United Kingdom (UK) led the way in protocols pertaining to explosive evidence. Over the course of a decade four studies were produced documenting explosives in the environment: two on background levels of military explosives and two on levels of inorganic ions (Crowson et al., 1996; Walker et al., 2001; Cullum et al., 2004; Sykes and Salt, 2004). Of 670 samples collected on the British mainland, only eight showed traces of organic explosives. A recent repeat of this study in the United States showed that only three out of 333 samples had traces of high explosives (Laboda et al., 2008). Both the UK and U.S. studies showed nitrates at the microgram level in 20 to 30% of the samples.

Much attention has quite correctly been paid to issues of cross-contamination in the analysis of explosive traces because of the generally very serious nature of the criminal offences involved. However, in reality, all forensic trace analyses need to

be protected against the risk of compromise by ill-founded suspicions of all types of cross-contamination. There should, of course, be no such suspicion that is well founded! Trace analysis procedures need to be designed, tested, and validated to ensure that positive evidence is produced showing the integrity of the results. This applies whether the sample is a few nanograms of explosive or a few nanograms of DNA.

This is a field where contamination of evidence can easily occur due to the wide range of vapor pressures exhibited by explosive formulations. Did the Madrid bombing use Goma 2 ECO or Titadyn? The answer is critical because it would point to one or another terrorist group. Dinitrotoluene (DNT) and nitroglycerin were found as part of the evidence. Was it in the explosives used to make the terrorist devices, or was it a result of cross-contamination during storage since DNT is highly volatile?

2.2 SAMPLE COLLECTION

Unfortunately, forensic chemists do not always have control over the vital aspect of collection and packaging of the materials they must examine. There is a world of difference between the effort and preplanning required for dealing with a large bombing attack and that required for the investigation of a bombing of a mailbox or single residence. Most forensic scientists will only deal with the latter. Nonetheless, preplanning will be worthwhile. Clean containers and packaging materials should be procured and stockpiled ready for use. Examples of such items are disposable scoops, scrapers, dustpans, and brushes, as well as metal cans and nylon bags of various sizes. Similarly, collection devices such as brushes, scoops, scrapers, and vacuum pumps and filters should be obtained. Minivacuums can be constructed from disposable plastic tubing, syringe filters, and plastic syringes.

Preferably all items used for collection should be subjected to quality assurance tests before use. The easiest way to ensure the cleanliness of tools used for collection of trace explosive evidence is to use disposable items from a known supplier which have just come from the box. If possible, a statistical sample of each item should be prescreened before operational employment. However, if a prescreen is not possible, a more rigorous regime of analysis of blank and control samples can be substituted. It is to be understood that this may entail the risk of loss of evidence if a control is analyzed as being positive. It should also be noted that suitable control samples should still be obtained, even with the use of prescreened materials.

Swabbing to collect trace explosive evidence is a common practice. Swabs may be pre-prepared using solvent-washed cotton balls that are either dry or have been wetted with a solvent (Jenkins and Yallop, 1970). Although ideally the swabs should be premade and preanalyzed, necessity may drive the investigator to use improvised swabs (e.g., alcohol-wetted hand-wipes, facial tissues, paper towels). Although swabbing is a superficially simple technique, in fact a plethora of interacting variables and issues need to be considered. A key issue is to identify the

type of explosive being sought: for example, inorganic or organic? Another issue is practicality and generality. Although it is arguably possible to design swabbing protocols that are optimized for the collection of particular explosives, our experience is that it is better to design for the widest possible application. Bomb scenes are generally places of chaos where decision making is handicapped by lack of information, and it is operationally much better to avoid the need to make choices by providing sample collection kits of general application.

In the UK in the early 1970s, dry swabs, water-wetted swabs, and solvent-wetted swabs were all used for collecting different types of residue. Subsequently, it was realized that the choice of dry or water- or solvent-wetted swabs was usually little better than guesswork prior to laboratory analysis. Furthermore, the choice of solvent or water was less significant than it first appeared. Although the solubility of diverse inorganic and organic explosive species varies dramatically in water and organic solvents, the small amounts present in trace samples means that the actual concentration that has to be dissolved in the swabbing solvent is rather low. Moreover, too strong a solvent will not necessarily recover more explosive residue; rather, it will merely pick up more unwanted background material, thereby complicating the subsequent preanalytical cleanup and concentration in the laboratory. Another very important consideration in the choice of a swabbing solvent is toxicity. These various issues led the UK to adopt a 50 : 50 ethanol–water mixture in their swab kits. This was found to provide recovery of a broad spectrum of both inorganic and organic explosive traces and to be compatible with subsequent laboratory protocols (Douse, 1985; Warren et al., 1999).

Very large samples do not lend themselves to solvent washing. Large containers for solvent extraction may be available, but plastics may allow interferents to elute. Generally, borosilicate glass rather than plastic containers are preferred, but extraction of ions from soda glass can also be a problem. Since large containers are generally not available, large samples should be swabbed. The swabs found in premise kits could be used. (Premise kits are useful if prepared ahead of time. They contain clean, validated swabs; disposable gloves; tweezers; and a solvent such as ethanol–water 50 : 50. A control in a premise kit would be a solvent-wetted but unused swab. Like hand kits, premise kits are heat sealed under positive pressure.)

Driven by the pressures of dealing with the long-term PIRA campaign, the UK has pioneered the use of premade, screened kits for both hand testing and premise screening. In addition, in a pilot program hair kits have been prepared specifically for explosives, and some laboratories include materials for hair sampling in kits used for the recovery of gunshot residue.

Every effort should be made to ensure that the investigator does not contaminate the scene. This includes using fresh, disposable tweezers to handle and manipulate swabbing materials and donning disposable outerwear before entering the scene. Ideally, different investigators should obtain samples from the crime scene and a suspect's premise to eliminate the possibility of cross contamination (of explosives traces and other types of evidence, such as DNA or fiber). If this is not possible and the same investigators are screening the scene and the suspect's premises, they need to take steps to ensure that (1) they do not inadvertently transfer contamination

between scenes, and (2) they provide objective documented evidence to prove the efficacy of their measures to prevent cross-contamination. Such measures might include, for example, use of disposable overalls, gloves, hats, hoods or hairnets, and bootees or overshoes; handwashing, hairwashing, or whole-body showers, and possibly the taking of personal control swabs or personal checking with airport-style explosive screening instruments. In addition, attention needs to be paid to the cleaning or overwrapping of personal items such as spectacles, hair bands, wristwatches, and jewelry. These are excellent potential sources of trace evidence from suspects and present a risk of cross contamination for the scene examiner and the laboratory scientist. The simplest approach is, of course, the best; do not wear such items to a scene.

Searching a scene for bulk and trace evidence involves somewhat different approaches. The investigator generally is called upon by law enforcement to identify bulk explosives based on visual identification. This is likely to come about because police have entered a suspect's premises and found something that seems suspicious, have intercepted an attempted bombing and disrupted the device, or have discovered a device that fails to function or functions inefficiently, such as a poorly constructed pipe bomb. Trace explosive evidence is not evident; that is, it is invisible to the investigator or the collector of evidence. Both the collector and the investigator must rely on good training, sense, and good luck. It is vital that collection material and people be shown to be free of contamination prior to entering a scene.

At the scene of an explosion, the investigator will start by attempting to identify the seat of the explosion. Generally, this will be indicated by the presence of a crater. A crater is not always formed, such as in the case of a low level of explosives; if a disperse-phase (gas-phase) explosion has occurred; or if a high-explosive condensed-phase explosion has occurred either in midair or on a frangible surface that has been destroyed in the process. The location of the explosion seat may also be identified by tracking back from the patterns of physical damage at the scene, such as the marks made by objects that have been moved, or from patterns of fragment penetration in nearby items.

Once the explosion seat has been located, the investigator can begin to look for likely places to find explosive residue. The best candidates will be substrates that were close to the explosion when it happened. The obvious first step is to take samples from the crater left by the explosion. However, most of the residue is expected to be found "near," not "in," the crater where it has been thrown, spalled from the exploding charge, or where it has condensed out of the fireball onto relatively colder surfaces. Nearby metallic items such as door frames and furniture, window frames, and light fittings are such surfaces and should be examined. In general, if a surface shows evidence of explosive damage or disruption [i.e., microcratering, pitting, or sooting (either visible to the naked eye or through a low-power lens)], it may be a good source of explosive residue. In the search for explosives at a bomb scene, impermeable surfaces offer the best chance of finding explosive residue for the majority of explosives. However, for very volatile explosives, such as triacetone triperoxide (TATP), the issue is the rapid loss of the explosive from surfaces due to

evaporation or sublimation. In these circumstances, an absorbent, porous substrate (e.g., carpet or wood) is likely to retain the volatile explosive much longer than is a hard surface such as metal. In any case, sealed packaging is critical for retaining this evidence. As discussed below, for most explosives evidence nylon bags are preferable. Because one does not know a priori which type of explosive has been used, the on-scene investigator must take samples that cover either possibility.

In the case of a car bombing, such as a booby trap attack intended to kill the occupants, the preferred option would be to package the vehicle and take it to the forensic laboratory. Whether the vehicle is examined at the scene or in the lab, the first step is to identify the seat of the explosion and then take samples from both the nonporous surfaces, such as plastic and metal, and the porous surfaces, such as carpet and upholstery. If a vehicle, a car or truck, was used to contain the bomb, explosive residue will probably be found on those scattered vehicle parts that were in close proximity or contact with the explosive before detonation; thus, depending on the initial location of the bomb, residues are likely on parts from the trunk or passenger compartment, whereas they are generally not to be found on the engine block.

When searching for evidence that explosives may have been stored or hidden in a location or a suspect's premises, the investigator will look for explosive traces in likely storage places. Apart from cupboards and shelving, other locations, such as hidden spaces behind removable paneling in bathrooms, should also be sampled. In some instances, dusty surfaces may reveal the outline of containers that have been removed. If it is suspected that a premises has been used for explosives manufacture or processing, it will also be worthwhile to remove the pipes and waste traps from sinks and washbasins to see if any explosive residue has collected there.

If manufacture or chemical synthesis is suspected, clearly any obvious items of laboratory equipment will be seized for examination. However, amateur experimenters and makers of improvised explosives are also quite likely to press ordinary domestic equipment into service: for example, kitchen mixing bowls, cooking spatulas, measuring cylinders or jugs, food processors and stirrers, and scales or balances. All of these should be examined for explosive residue. In the absence of any obvious laboratory work area at a suspect's premises, it is often worthwhile to swab the kitchen work surfaces for traces of explosives residue, paying particular attention to cracks or crevices where residues might have been missed by any cleaning efforts. Discovery of clandestine laboratories presents a number of difficult issues for an investigator. First and foremost is the likelihood that unknown hazardous materials are present, often in unlabeled containers. Second is the very real risk of booby traps and antihandling devices. The investigator will wish at an early stage to assess whether a clandestine laboratory is likely to be drug or explosives related. The presence of technical literature dealing with one or the other subject can help. In addition, the chemical synthesis of most illicit drugs is chemically more complex than that of the common organic explosives. Hence, as an initial guide, an elaborate laboratory with complex equipment is more likely to be drug than explosive related. It should be noted that there have been examples of drug laboratories being booby trapped with explosive devices precisely to guard

against the arrival of law enforcement. For example, packets wrapped to appear as illegal drugs were in reality Armstrong's mixture, an extremely sensitive formulation used in toy caps and party poppers. Moreover, the first encounter with TATP in a criminal context in the United States was in booby traps in a drug laboratory (Christian, 2005).

Frequently, the investigator needs to collect evidence from a suspect's person. Typically, the options are hands, hair, clothing, jewelry, and glasses. The law enforcement investigator and forensic examiner will be familiar with the use of pre-prepared kits for examining hands for gunshot residue. The principle can be extended to explosive residues, but the design details must be modified. Hair is washed much less frequently than hands; furthermore, it has been shown that explosive handlers can be allowed to wash their hair and in some instances still exhibit detectible levels of contamination. Examination of hair for trace explosives can be performed simply by combing the hair with a comb on which clean gauze has been threaded. After multiple passes through hair, the gauze can be disengaged from the comb and extracted with solvent for chemical analysis (Sanders et al., 2002; Oxley et al., 2005,2007a,b). Chemical digestion of hair is performed when looking for evidence of drug use, but such procedures have not yet been investigated for explosives.

Clothing evidence has been pivotal in a number of high-profile cases. The Oklahoma City bomber, Timothy McVeigh, had traces of pentaerythritol tetranitrate (PETN) on his clothing; and Ressam Amad, the would-be millennium bomber, had acid burns and other traces of explosives on his trousers. In high-profile cases it is usual not only to confiscate and examine the clothing worn when the suspect was apprehended, but also the entire contents of his wardrobe as well as bags, backpacks, and holdalls, which may have been used to transport devices. It is commonplace when a person is handling items for him to wipe his hands on the seat of his trousers. Other common hand movements that potentially transfer residue from hands to clothing are adjusting the knees of one's trousers when sitting down or putting hands in one's pockets. All these spots are good places to look for explosives traces.

As mentioned previously, jewelry, rings, bracelets, watch straps, hair bands, and glasses are likely to be worn for long periods of time with no rigorous attempts at cleaning. These readily become contaminated with any explosive handled by a suspect and are likely to retain traces in crevices over long periods of time. This is a positive feature in terms of finding evidence of malfeasance and a negative feature in preventing the investigator from contaminating the evidence. Generally, these items are seized and solvent washed, preferably with the aid of an ultrasonic bath, although items such as leather watch straps can be wiped with a solvent-wetted swab rather than being solvent washed.

2.3 PACKAGING

Without the proper packaging, all the effort made in the collection of evidence is for naught. Selection of container material should be done well in advance of

need and should consider the size of the object to be collected and the degree of isolation required between the sample and the environment. For example, does the sample need to be protected against sorption of external vapors? Or is it a potential source of vapors that might be lost as evidence or contaminate other samples? Some samples, of course, should not be sealed in nonpermeable bags; these included dried or wet blood, which may be subject to attack by bioorganisms, as well as items likely to undergo chemical decomposition and generate gaseous decomposition products.

Small samples are usually sealed in nylon bags with the neck twisted and taped, doubled over twice, and taped again. Of the plastics commonly available, nylon is the most impervious to vapors; commercial evidence bags are usually polyethylene. Large samples, such as cars, light fixtures, or window and door frames, which may have trace residue and might show evidence of explosive cratering, should be sealed in polymer sheeting (tarpaulins) and taped together with adhesive tape. Medium-sized samples that will not be analyzed for trace explosives can be packed in plastic tubs or crates with lids, evidence seals, and labels.

It is likely that the collection of evidence at the scene will result in contamination of the outside of the collection container. For this reason, after the initial bagging at the scene, a second bagging should occur well away from the scene at an established workstation. Some laboratories actually perform a third bagging upon receipt at reception to contain any external contamination picked up in transit (or at the scene) and to prevent any contamination from the nontrace areas of the laboratory itself. An on-site workstation outside the target premises can be produced simply by laying out clean disposable paper at a convenient spot protected from the elements [e.g., the back of a police van (assuming it is known and can be shown not to have contained explosives or firearms)]. If it is known that evidence of trace explosives is to be sought and operational constraints allow time for preplanning, it may be worthwhile considering hiring clean vehicles and prescreening them to ensure the absence of explosive contamination before the operation.

Opening the evidence at the forensic laboratory requires as much thought as does packaging it. If the sample has been triple-wrapped, its wrappings need to be removed sequentially as it moves to progressively cleaner areas. The multiple layers of packaging are pealed off sequentially with gloved hands in a manner that ensures no transfer of contamination from the outside world into the trace area. This means that fresh gloves are used at each step. The innermost layer of packaging is not opened until the item is in a location guaranteed to be free from contamination.

2.4 SORTING

The Forensic Explosive Laboratory in the UK, which has had a great deal of experience processing debris from large bombing events, has found it useful to use large, lidded plastic bins for large pieces of evidence. At the height of the PIRA bombing campaign, stashes of these bins were maintained at various locations

in England. With huge volumes of debris it was found much easier to locate the anomalies if the debris were sorted into bits of similar size. Therefore, in the field or directly on returning to the analytical facility, they presorted what was considered the most promising debris. The goal of such sorting was to find pieces derived from the bomb or its container.

2.5 DOCUMENTATION

A great deal of material is required to fully document a crime scene: for example, photographs and drawings as well as notes and logbooks. Every item of evidence that is collected needs to be uniquely labeled and controlled. Each person involved in evidence collection and labeling must have a notebook to keep track of the exhibit references he or she has generated. For forensic purposes the collection and packaging procedure needs to ensure evidential continuity and integrity, with a properly documented chain of custody. This is usually accomplished by attaching a signature seal and receipt that is countersigned as the item passes from hand to hand. As one might expect, modern electronic solutions have been tested in some jurisdictions with the aim of supplanting the traditional paper-and-ink systems. Although barcode labels and electronic scanners are widely used in retailing, this technique is more easily implemented in the laboratory than in the field.

Adequate documentation is essential to the satisfactory progress of a case. Conversely, it is all too easy to generate superfluous paperwork, with accompanying nugatory effort. In the late 1980s it was normal in the UK to divide a bomb scene into numerous zones, often on a grid pattern, and expend much effort recording the fact that a particular item was found in a specific zone. Eventually, the pressure of work generated by a massive terrorist bombing campaign forced an evaluation of such practices. It was realized that it was rarely, if ever, possible to draw any useful evidential conclusion from such detailed information about the location of bomb debris. The key piece of information for a court was that a specific item had been found at the bomb scene. Consequently, the practice of zoning at bomb scenes was curtailed dramatically. Typically, a scene might use the area around the crater and other natural boundaries for zoning, or if the scene was a building, perhaps divided according to rooms and whether the evidence was recovered from inside or outside the building.

2.6 ENVIRONMENTAL CONTROL AND MONITORING

As stated in Section 2.1, the precautions necessary to protect sample integrity depend on the challenges presented by the environment. For example, does the environment contain significant amounts of the target analyte so that contamination of the sample becomes a real rather than a theoretical risk? This issue is particularly relevant when handling trace rather than bulk evidence. To protect the integrity of the sample, a rigorous protocol is needed to ensure laboratory cleanliness, complemented by a measuring regime to demonstrate that the requisite standards of

cleanliness have actually been achieved and maintained. The process begins with the initial design of the laboratory. The laboratory layout should impose barriers between the unknown outside environment and the controlled trace environment. Physical features include airlocks, filtered air with positive pressure, and a separate antechamber through which personnel must enter or exit, in the process changing into clean, disposable overgarments, removing watches, jewelry, and eyeglasses.

The antechamber. In the antechamber, personnel will wash hands and other exposed skin and don hair covers, disposable overalls, shoe covers, and gloves. They should also ensure cleanliness by a quick screen using explosive detection instrumentation [e.g. ion mobility spectrometry (IMS)]. Pens, papers, watches or other jewelry, and eyeglasses should be left here. Duplicates should be waiting on the other side of the airlock in the trace examination room. Administrative controls include access control to ensure that only appropriately trained or supervised personal can enter the trace laboratory. In fact, since every entry and egress represents a theoretical contamination risk, the number of people entering the analysis area should be minimized. A log of visits should be maintained. It is from this antechamber that the forensic chemist and the sample, still wrapped in its innermost layer of packaging, enter the trace laboratory.

The trace laboratory. A regular cleaning schedule is necessary. The primary defense is a filtered air system, whose performance is monitored both by differential pressure gauges and atmospheric particulate monitors. Floors should be washed at least once a week with strong alkaline detergent. One approach to ensuring cleanliness is to predefine a number of squares (e.g., 50 cm $\times$ 50 cm) on the floor which are regularly swabbed for contamination (e.g., weekly). The tops and insides of cupboards and drawers and air intakes need a less frequent scheduled cleaning and screening. The goal is to see that every surface is cleaned and tested for contamination at a known interval. It is important that the forensic chemist hypothesizes where contamination might accumulate. Analytical instruments may be elevated on small blocks to facilitate cleaning under each instrument. It is useful if instruments and materials can be dedicated to a particular stage in the analysis. As far as possible, disposable tools should be used. For example, the trace laboratory should have its own paper and pens, which are used only once. Wrenches, screwdrivers, and beakers should be cleaned by heating in an oven ($\sim 250^{\circ}$C) and either storing the materials in the oven or removing then and wrapping them individually in nylon bags until use.

At the beginning of the work cycle, the analytical bench should be cleaned: for example, with alkaline detergent solution and ethanol, and wiped down with paper towels. A fresh disposable benchtop surface, such as butcher paper, aluminum foil, or Benchkote, should be used for each sample. The forensic chemist should change gloves frequently, at least between samples. To provide evidence that no contamination is present, the forensic chemist should take control swabs of the work surface, the front of her suit and gloved hands, and the disposable benchtop surface. These are considered control samples; they are necessary to show that contamination has not occurred (Hiley, 1998; Crowson et al., 2001; Beardah et al., 2007).

2.7 STORAGE

Like most evidence, aging can result in loss or contamination of explosives evidence. A rapid turnaround time is important. In the UK during the PIRA terrorist campaign, the Forensic Explosives Laboratory, responsible for analysis of trace and other evidence, pledged a 6 hour turnaround time for a single hand-test kit and two weeks for a preliminary report, regardless of the type of case.

Storage conditions are also critical; for example, the first bombings using TATP were in Israel. Even in cases where intelligence pointed to the use of TATP, forensic examiners found no residue. Subsequent studies showed that TATP is so highly volatile that evidence should be thoroughly sealed and, ideally, examined immediately, to maximize the chances of recovery and detection. Sealing and storing at subambient temperatures are not always necessary but can hardly hurt explosive evidence. (*Note:* Samples with moist blood or other biological media present may be subject to bacterial growth if sealed without the additional precaution of subambient temperature. However, consideration should then be given to the effect of thawing on the other materials.)

2.8 ANALYSIS

Bulk analysis may be of visible particles of an explosive and/or its combustion products, but it may be of bomb components, such as timers, fuses, wiring, or tape. The analysis is usually performed to identify the material and to make comparisons, for example, between a material recovered from a crime scene and one recovered from a suspect's premises. At best, it is only possible to say that two materials are different or to list those aspects in which they are similar. However, to make such a statement, it is necessary to have a well-founded understanding of the likely variations in a material and the practical significance of such variations. This highlights the value of reference collections and surveys of items and materials likely to be encountered in case work (e.g., carpets, car paints, accelerants, and explosives). Comprehensive databases or reference collections are useful for all sorts of bomb-making gear (e.g., pipes, timers, tapes, and batteries).

In some cases the explosive material used in the bomb can be seen. Inefficient devices such as those using smokeless powder or black powder often leave visible residue. High explosives usually leave residue, too, but since it is not visible to the human eye, it may not make the multiple down-selects to end up in the final analytical protocol. In efficient bombs, the residual explosive has probably been thrown out from the surface of the bomb—spalled off the surface (Kelleher, 2002). Thus, looking just outside the crater may be more productive than looking at evidence inside the crater.

Visible explosive particles should first be examined intact (i.e., with nondestructive techniques, as clues are available at this point). Although prilled ammonium nitrate is made at several hundred locations around the world, there are wide variations in prill shape (to be determined visually) and prill coating (to be determined

analytically). With the proper reference collection, such variations may make it possible to trace the material back to its original manufacturer.

For bomb scene materials with no visible residue, prescreening for trace explosives may be possible using an explosive detector. In practice, this approach is less labor-saving than it first appears and, more important, runs the risk of inadvertent contamination of valuable trace evidence or the inadvertent exclusion of evidence with traces of material not detected by the specific detector. Otherwise, the more accurate but laborious approach is a multistep extraction of the debris to separate organic from polar species. One approach is to extract the debris with the aid of an ultrasonic bath using a solvent for both polar and nonpolar species. If one uses a strong solvent, such as acetone or acetonitrile, all of the explosive residue will dissolve, but so will many unwanted species, which serve to obscure the analysis and clog the system. The Forensic Explosives Laboratory in the UK has settled on a technique using a relatively weak solvent system.

The debris is extracted with ethanol–water (50 : 50) and run through a glass pipette containing a few grams of a solid adsorbent such as Chromosorb 104. The packing retains the common organic explosives (e.g., TNT, PETN) and allows the polar species to elute. This polar fraction is analyzed by ion chromatography looking for species such as nitrates (ammonium or uronium) or chlorates. The Chromosorb column is then eluted with ethyl acetate to extract the organic species. These are analyzed by gas chromatograph (GC) or liquid chromatography (LC), depending on the anticipated volatility of organic explosives suspected (see Figure 2.1). For example, the thermal stability of hexamethylene triperoxide diamine (HMTD) is so poor that LC is the preferred technique; otherwise, samples break down in the inlet port of the GC. Obviously, the GC or LC can be attached to a variety of detectors. For GC, an electron capture detector (ECD) is the most sensitive detector, and a thermal energy analyzer (TEA), which analyzes for nitro groups, is the most specific. If LC is used, a mass selective detector (MSD) is usually employed. This has the added feature of providing orthogonal confirmation: not only retention time but also fragmentation patterns. While the field of mass spectroscopy (MS) is developing rapidly, for the common benchtop GC–electron ionization–MS, most explosives rarely exhibit a parent peak (P). Identification is based on fragmentation patterns, where P–OH is often observed. Yinon has discussed this extensively (Yinon and Zitrin, 1981, 1993; Yinon, 2007). An MS database of explosives is available online at http://expdb.chm.uri.edu, but it is essential that forensic scientists also create their own libraries using their own experimental conditions, as mass spectral fragmentation patterns are highly dependent on the exact conditions under which they are obtained.

Orthogonal techniques are defined as two techniques for which sample identification is based on completely different principles (e.g., infrared spectroscopy and mass spectroscopy). In practice, finding two absolutely orthogonal techniques is rarely achievable; rather, in practice, significantly different techniques are used (e.g., using two different GC columns which yield significantly different retention times). The more orthogonal the techniques, the higher the level of confidence in the assignment of identity.

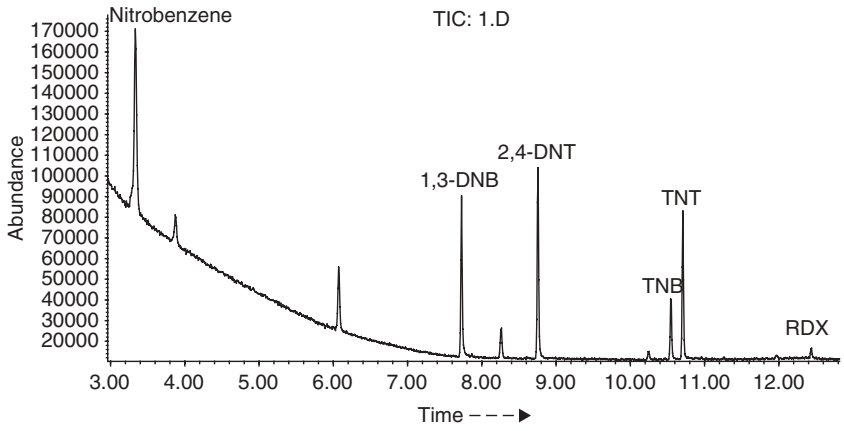

Restek 8330 Calibration Mix #1

Shipped as 1000 ppm in ACN of:

HMX	RDX	1,3-DNB	TNB
NB	TNT	2,4-DNT	

Diluted to 20 ppm in ACN

GC/MS Conditions
HP-5MS: 0.25mm x 30m x 0.25μm
Inlet: 20.94 psi, 225°C, Constant Flow
Splitless 15 sec., purge flow 20 mL/min,
Flow Rate: 2 mL/min Average velocity: 53 cm/sec
Oven Program: Initial 100°C x 2 min.,
Ramp 10°C/min. to 250°C, Hold 250°C 8 min.
Transfer Line: 270°C

Figure 2.1 Chromatogram of explosive calibration standard.

In developing the analytical protocols discussed above, it is important to use standard solutions with known concentrations of explosives. Mixed standards are useful. Not only do they demonstrate the system suitability and performance across the entire range of explosive species being sought, but the mixed standard can never be confused as the real result. For high precision in retention results, a retention time marker [e.g., musk tibetine or fluoronitrotoluene (for GC)] should be added to both sample and standard solutions.

Although forensic samples are rarely quantified, if accurate quantification is desired, explosive recoveries should be determined. A good approach is to use the method of standard additions. This involves dividing the sample into two parts, spiking one part of the sample with a reasonable amount of explosive, typically between one-third and two-thirds of the amount estimated to be present in the sample, then performing the standard workup on the original and spiked samples and determining what percentage of the spike was recovered.

Isotope ratio mass spectroscopy (IRMs) applied to forensic evidence is a vibrant research area at the time of this writing. Much work is needed to establish reproducibility of results and degree of variability among "identical" samples. In principle it is easy to say that if two samples differ in some significant respect, they are in fact different. However, the converse is not true. One can never state with absolute forensic certainty that two items are identical. All one can do is to list all those features in which the two samples match. In practice there comes a point at which a reasonable person will conclude that a match has been established beyond

a reasonable doubt. Thus, it may be possible, in a few years, that with the aid of foreseeable improvements in isotope ratio mass spectrometry, one could testify that a sample of explosive recovered from a pipe bomb at a scene matches a sample of explosive recovered from a mixing bowl at a suspect's premises and that it is highly probable that the samples came from the same original batch of explosive. This issue of the definition of a match is a more general one for forensic science, and would benefit from wider consideration, and preferably agreement within the judicial system. The obvious parallel is the long-established UK criterion that for two fingerprints to match, at least 16 points of agreement must be identified. Other jurisdictions accept a lower figure; for example, in the United States, 12 points are considered sufficient. For this to become possible, large reference collections and databases will become essential, and possibly the very expensive IRMS instrument will become so widely purchased that the price will become affordable to every forensic lab (much as has happened with GC–MS). Rapid improvements in electronic instrumentation suggest that the limitation in precision currently encountered in this technique may be attributed to the chemical methods used in the sample preparation.

2.9 RECORDS

While keeping good records of work is always useful, it is absolutely essential in a forensic laboratory. The written record becomes a legal document. Whether the employee leaves the laboratory or is not called to testify for five years, every step of the procedure and every aspect of the results, including negative results, are extremely important to document. Given the fugacity of electronic records, it is wise to archive all materials in the form of printed paper. Such paper records should, of course, be signed and dated by the scientist producing them. Records should include the printouts from various instruments: chromatograms with standards, mass spectral fragmentation patterns, infrared spectra.

ISO 9001 requires that all quality-related records be retained for a minimum of seven years. Although this would apply to forensic evidence, some jurisdictions require much longer document retention (e.g., 20 years in the UK for explosive offenses).

2.10 QUALITY ASSURANCE

For forensic work only techniques and methods of proven validity should be used. These methods should be documented in the form of standard methods or standard operating procedures (SOPs) to which the laboratory staff can refer readily. Similarly, only persons of proven competence should be allowed to report forensic results, and these people should be subjected to periodic proficiency tests. Requirements for personnel training and method validation are found, for example, in ASCLD (American Society of Crime Laboratory Directors) protocols and ISO 17025 (for laboratory work) and ISO 17020 (for scenes).

To create a new laboratory protocol, the developer should undertake any necessary research and precision and validation studies, producing both a draft method and a report documenting his or her findings. Once the method is accepted, the originator would be expected to become the first trainer in this protocol; it would be sensible to bear the latter requirement in mind when selecting a scientist to undertake the method research and development. Elements that should be part of the new method are a clear statement of precision based on a statistical study of replicate analyses; procedures for calibration, preparation of standards, traceability and uncertainty of measurements; and guidance as to the interpretation of results for forensic purposes.

2.11 SAFETY AND OTHER ISSUES

For a newly set up explosive laboratory, a number of issues will arise. These include acquisition of pure explosive standards, explosive storage, licensing and regulatory compliance, and disposal of hazardous materials.

Generally, licensing and approved storage are required before any explosive can be acquired or stored. Once storage is available, it will be necessary to find an entity that can provide pure explosive standards. Most commercial explosives have been formulated with plasticizers, stabilizers, phlegmatizers, and so on. In consequence, commercial explosives will contain significantly less than 100% of the desired explosive. It may be necessary to synthesize the desired explosive or recrystallize a commercial explosive. The physical properties of this explosive must be characterized and recorded. Differential scanning calorimetry (DSC) allows the determination of material purity, provided that the materials have observable melting points (see Figure 2.2). It should be noted that the purified explosive, freed from the additives present in commercial products, may be significantly more hazardous.

Waste from the explosive laboratory will represent various types of hazards: explosive; flammable; toxic; biological; sharps. Proper arrangements need to be made for disposal for each of these waste streams. In general this will require the services of specialist contractors. Explosive laboratories attached to explosive firing ranges may be able to send their explosive waste for disposal. In large facilities, this is typically achieved by incineration. However, for small amounts of explosive and in most laboratories, the best option is chemical destruction. Suitable methods may be found in the literature.

One point that has yet to be mentioned is the fact that many explosives are toxic. This should be obvious from a historic point of view since nitrate esters are used to treat angina, and cyclonite (RDX) was patented for use as a rat poison.

CONCLUSION

Forensic analysis differs from routine chemical analysis in the critical nature of the results and the fact that the results and documentation of it may come under severe

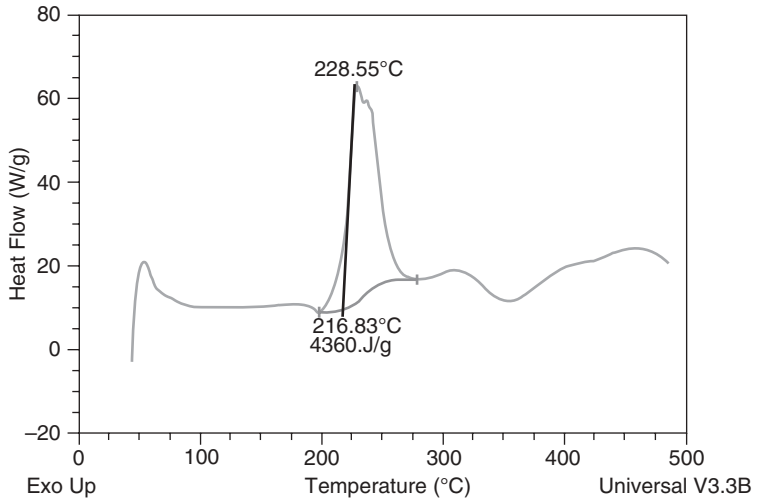

Figure 2.2 Differential scanning calorimetric scan of unknown black solid (suspected of being an explosive). *(See insert for color representation.)*

scrutiny. For trace analysis, every pathway for contamination must be anticipated and mitigated. The differences in analyte concentration between sample and environment must be characterized and proper barriers put in place. There are only two standards in forensic analysis: perfect and useless.

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CHAPTER 3

Analysis of Fire Debris†

JOHN J. LENTINI

Scientific Fire Analysis, LLC, Big Pine Key, Florida

Summary The isolation and identification of ignitable liquid residues (ILRs) from fire debris are critically important aspects of arson investigation. In this chapter we describe common techniques for the isolation and identification of ILRs. Analytical procedures have become more sensitive, and results of testing play a very important role during litigation in a criminal or civil court. Quality control is an important component in fire debris analysis. Reports of findings should be written in a scientific manner, describing the fire under investigation, evidence handling, a description of the evidence and where it was collected, the isolation procedure and what testing was done with what kind of equipment, observations made, and conclusions, with a discussion of the meaning of the results.

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†This chapter is essentially an updated version of the chapter entitled "Analysis of Ignitable Liquid Residues" that appears in the author's textbook, *Scientific Protocols for Fire Investigation* (CRC Press, 2006), and is used here with permission.

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3.1 INTRODUCTION

The laboratory analysis of fire debris is one of the most important hypothesis tests that can be performed in an investigation, especially when the investigator forms a hypothesis that the fire was set using ignitable liquids. It has been widely acknowledged that making a determination that ignitable liquids were used in a fully involved compartment is not valid based on visual observation alone (NFPA 921, 2011). A laboratory analysis is necessary. Even when the compartment is not fully involved, and there is an exceptional burn pattern similar to the one shown in Figure 3.1, the investigator still needs to determine the identity of the ignitable liquid.

In the past, the laboratory analysis was referred to as "the icing on the cake," because by the time samples were collected, the fire investigator had already decided what caused the fire, and the stated purpose of the laboratory analysis was merely to help determine the identity of the flammable or combustible liquid used to start the fire. Investigators were accustomed to receiving negative reports from their laboratory, even when they "knew" that a fire had been intentionally set with ignitable liquids.

In those days, the term *ignitable liquid* had not yet been coined. *Flammable or combustible liquids* were generally referred to as *accelerants*, even by people in the laboratory who had no idea how such liquids may have been used. Many of the findings were, in fact, false negatives, because laboratory methods were not sensitive enough to detect ignitable liquid residues at low levels. The sensitivity has improved dramatically since this author began distilling fire debris in 1974, so much so that it is now possible to detect the petroleum products that are a natural part of the background. Many fire investigators, however, still distrust negative reports from laboratories, based on this earlier experience.

The development of analytical procedures has paralleled the development of standards for fire debris analysis. The first vague outline of a standard was not published until 1982 (AA Notes, 1982), and prior to that, analysts would report that a sample contained "an oily liquid" that exhibited "sufficient similarities" to a known sample of gasoline or kerosene or diesel fuel. What was sufficient, however, was not clearly defined until there were standards.

Figure 3.1 "Obvious pour pattern." The only surface that was burned in this mobile home was the floor. There were no furnishings in the house. The carpet was tested and found to be positive for the presence of a medium petroleum distillate such as mineral spirits or charcoal lighter fluid. This is a unique case where visual observation alone can lead to valid conclusions about what caused the pattern. *(See insert for color representation.)*

3.2 EVOLUTION OF SEPARATION TECHNIQUES

Paul Kirk reported in 1969 that the normal manner of isolating a liquid accelerant from other materials is "to distill the liquid from a solid residue in a current of steam." Kirk reported that the distillate would then be subjected to fractional distillation, flash point, refractive index, or density determination, but that a better procedure was to employ a gas–liquid chromatograph. Kirk stated, "From all of these laboratory procedures, the most important single piece of information that is made available is that a foreign flammable liquid was present at the fire scene. This alone is strong evidence for arson, at least after the possibility of accidental placing of the liquid is eliminated" (Kirk, 1969). The operative word here is *foreign*.

Figure 3.2 shows a steam distillation apparatus for the isolation of ignitable liquid residue from fire debris. In this classical separation technique, the debris is

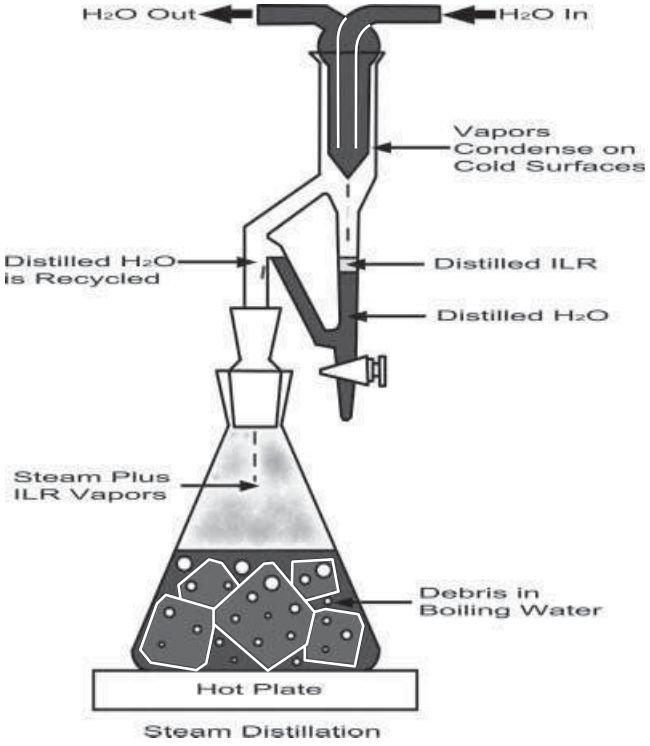

Figure 3.2 Steam distillation apparatus. The sample is boiled. Vapors condense on a "cold finger" and fall into the trap, which allows the water to recycle while the immiscible oil layer builds up on top of the water column.

covered with water and boiled, and the steam and other vapors are condensed in a trap that recycles the water and allows any nonmiscible oily liquids to float on top. There is actually a visible layer of liquid isolated from the sample. More often than not, this layer consisted of a drop or two, or simply a rainbow film on top of the column of water. This could be extracted with a solvent and analyzed, but even so, steam distillation was not a very sensitive technique. If the sample did not exhibit a detectable petroleum odor, steam distillation was almost always ineffective at isolating any ignitable liquid. Despite its lack of sensitivity, steam distillation did have the advantage, given a sufficiently concentrated sample, to produce a visible layer of liquid that could be shown to a jury.

In 1969, Kirk suggested that the debris could be heated in a closed container and the internal gaseous phase could be sampled and analyzed by gas chromatography, but indicated that he was unaware of its use in routine analyses (Kirk, 1969). By the mid-1970s, this technique, known as *heated headspace* (Figure 3.3), was used routinely but had sensitivity limitations similar to those of steam distillation and, because of the low volatility of higher-molecular-weight compounds, was ineffective at isolating the heavier components of common combustible liquids

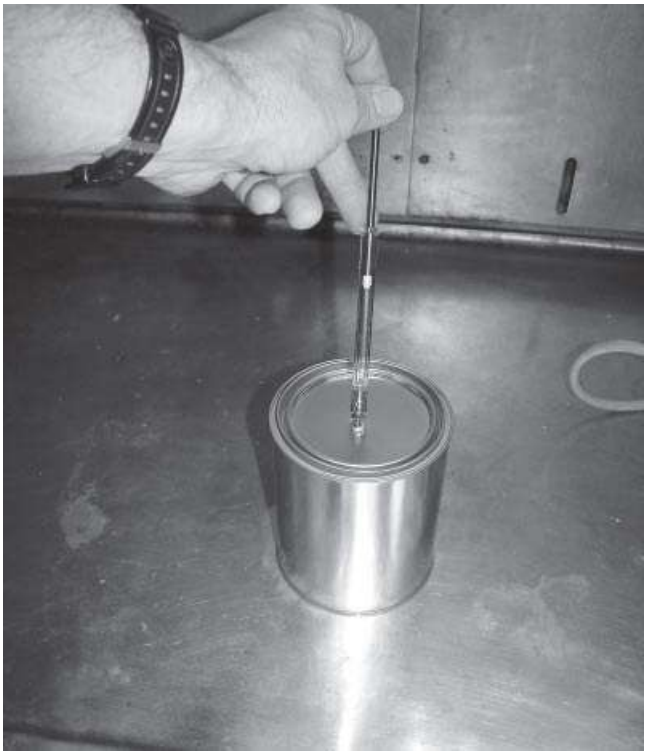

Figure 3.3 Using a gastight syringe to withdraw a sample of headspace from a fire debris sample. The headspace sample, about 500 μL, is injected directly into the GC–MS injection port.

such as diesel fuel. Heated headspace (Kirk called it a "shortcut") is still used as a screening tool in some laboratories today.

The first quantum jump in sensitivity took place in 1979, when two chemists from the Bureau of Alcohol and Firearms Philadelphia laboratory reported in the *Arson Analysis Newsletter* on the separation process known as *dynamic headspace concentration*. They used a dry nitrogen purge and a vacuum pump to draw ignitable liquid vapors from a heated sample through a Pasteur pipette filled with activated coconut charcoal (Chrostowski and Holmes, 1979). The vapors were rinsed off the charcoal using carbon disulfide and analyzed by gas chromatography. Over the next decade, the apparatus for conducting this type of analysis resulted in the publication of many articles describing newer and more wonderful apparatuses. Dynamic headspace concentration is still a recognized analytical technique, but because it is both destructive and complicated, it is not used by many laboratories.

In 1982, Juhala made the case for using *passive headspace concentration* on fire debris, wherein an adsorbent package is placed in the sample container and heated up. He used charcoal-coated copper wires and Plexiglas beads, and reported

an increase in sensitivity of two orders of magnitude over distillation and heated headspace analysis (Juhala, 1982). Many laboratories had just completed setting up their dynamic systems; however, adoption of passive headspace concentration took some time, but gradually its advantages made it the dominant method of separation. Dietz reported on an improved package for the adsorbent called C-bags (Dietz, 1993), but these quickly gave way to activated carbon strips (ACSs), which required much less preparation. In 1993, Waters and Palmer reported on the essentially nondestructive nature of ACS analysis, performing up to five consecutive analyses on the same sample with little discernible change and no change in the ultimate classification of the residue (Waters and Palmer, 1991). This separation technique is the method of choice in most laboratories today. Figure 3.4 is a conceptual drawing of the procedure for passive headspace concentration, and Figure 3.5 is a photograph of a typical adsorption device, which consists of a 10 mm $\times$ 10 mm square of finely divided activated charcoal impregnated on a polytetrafluoroethylene (PTFE) strip. The technique was actually adapted from the industrial hygiene industry. Charcoal disk badges are worn by employees to determine their exposure to hazardous chemicals. The charcoal adsorbs a wide variety of organic compounds.

Solid-phase microextraction (SPME) represents yet another kind of passive headspace concentration technique. The SPME fiber is a more active adsorber of most ignitable liquid residues than is an activated carbon strip. Exposing an ACS to the headspace of a sample at elevated temperatures for 16 h allows for the isolation of less than 0.1 μL of ignitable liquid residue if there is no competition from

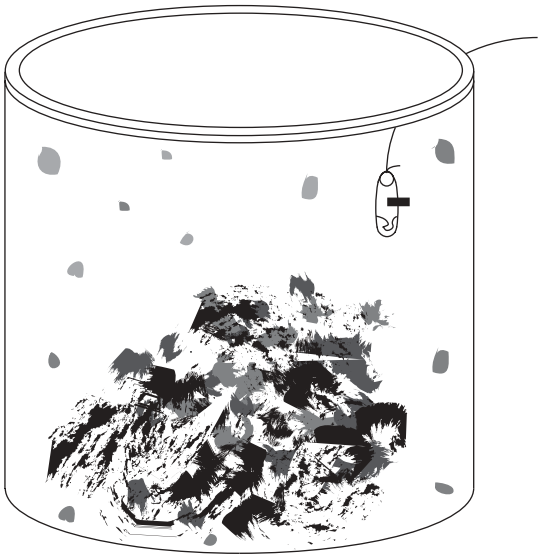

Figure 3.4 Schematic drawing of passive headspace concentration using an activated carbon strip. Vapors are produced by heating the container with debris to 80°C. The ACS adsorbs the vapors for 16 h, then is rinsed with diethyl ether spiked with 100 ppm, and the resulting solution is analyzed by GC–MS.

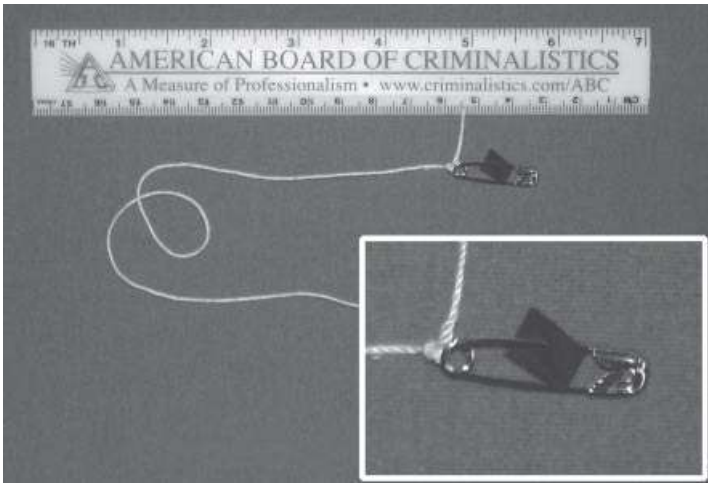

Figure 3.5 Close-up view of an activated carbon strip.

the substrate. A SPME fiber can accomplish the same task in 20 min or less. The advantages and disadvantages of the various separation techniques are discussed later in the chapter.

3.3 EVOLUTION OF ANALYTICAL TECHNIQUES

As the ability of the separation step to isolate smaller quantities of ignitable liquid residue improved, the sensitivity of the analytical instruments improved as well. In the 1950s and 1960s, extracts were analyzed by infrared (IR) or ultraviolet (UV) spectroscopy (Midkiff, 1982), but because most extracts were mixtures, these techniques were neither very sensitive nor very specific. The IR spectrum of gasoline looks very much like the IR spectrum of kerosene. Gas chromatography (GC) using pattern recognition techniques became the analytical method of choice beginning in the late 1960s. GC is actually a separation technique rather than an identification technique, but unlike separating the ignitable liquid residue from the sample matrix, GC works by separating similar compounds in an extract from each other.

In the 1970s, GC columns, the engine that makes the technique work, were glass or metal tubes, $\frac{1}{4}$ in. in diameter by 6 to 10 ft long. Chemists typically purchased empty columns and packed the columns themselves, using a coated powdery substance (stationary phase). It was known that $\frac{1}{8}$-in. columns provided better resolution than $\frac{1}{4}$-in. columns, but these had to be made from metal, and the chemist could not see inside the tube to check for gaps. These columns were usually purchased already packed. As the column manufacturers experimented with narrower and narrower columns, they went back to drawn-glass tubes coated on the inside with the oily stationary phase. There were problems with these early capillary columns, not the least of which was the forensic science community's

resistance to change. As the bugs were worked out, capillary columns became the standard choice, but as late as 1990, packed columns were contemplated in ASTM E1387, *Standard Test Method for Flammable or Combustible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography*. In the 1995 edition the standard "recommended," but did not require, capillary columns. The 2001 edition requires "A capillary, bonded phase, methylsilicone or phenylmethylsilicone column or equivalent. Any column length or temperature program conditions may be used provided that each component of the test mixture is adequately separated" (ASTM E1387-01, 2001). Today, very few laboratories use packed columns.

Gas chromatography detectors originally measured the change in thermal conductivity (TC) of the effluent from the column. Flame ionization detection (FID) improved the sensitivity by a couple of orders of magnitude over TC detectors. In a flame ionization detector, there is a hydrogen flame burning between two charged plates. As indicated by the flow of current between the two plates, the electrical conductivity changes when a hydrocarbon compound comes through the hydrogen flame and is burned.

Some laboratories were using gas chromatography–mass spectrometry as early as 1976 (GC–MS) (Stone, 1976). At that time, mass spectrometers were expensive, not terribly reliable, and required a computer (this was before the days of the personal computer, when computers took up half of the room), and GC–MS was the exception rather than the rule. With the earlier instruments, the operator watched a stripchart recorder and pushed a button to collect a mass spectrum when a peak indicated that a compound was coming off. This was a very labor-intensive process. There were people who argued that chemists had an obligation to use the best technology available, and the advantages of GC–MS over GC–FID required that MS be used. One of the leading proponents of GC–MS was Jack Nowicki, who also noted that GC–MS would make the previous accelerant classification system obsolete (Nowicki, 1990). He was eventually proved correct. Most laboratories stayed with the FID methods because of the difficulties with implementing GC–MS and because they felt comfortable with their ability to read patterns using FID alone. By the early 1980s, mass spectrometry was still expensive, but its use had become more widespread in fire debris analysis, particularly in the better-funded laboratories. Public laboratories acquired GC–MS instruments for use in drug identification, and this was another reason that they became available for fire debris analysis. The instrumentation of the 1980s was more automated and could collect a mass spectrum several times per second, even if no peak was eluting. This resulted in a much more efficient process, but the data files were very large. Today's GC–MS, collecting data every tenth of a second, uses sophisticated software to keep the file size to around a megabyte, an amazing feat considering that 18,000 spectra may be collected during a single run.

In 1982, Martin Smith published an article about a technique he had developed, called *mass chromatography*, which utilized a computer to separate the mass spectral signals according to the functional groups of the compounds that produced them. This technique allowed chemists to view many simple and easy-to-recognize patterns as opposed to looking at one large complicated pattern (Smith, 1982).

Today this powerful analytical tool is known as *extracted ion profiling* or *extracted ion chromatography* and forms the basis of most identifications.

The development of the personal computer made it possible for average laboratories to control a mass spectrometer, and the instrument manufacturers responded to the demand by producing benchtop models with increasing sensitivity and extraordinary robustness. The *quadrupole mass filter*, which is at the heart of the most popular mass selective detectors, has no moving parts. Only those parts of the instrument required to maintain a vacuum are subject to mechanical problems.

3.4 EVOLUTION OF STANDARD METHODS

As fire debris analysis technology improved, so did the approach of the forensic science community to the problems encountered by analysts. *Arson Analysis Newsletter* continued publication through 1984, and much valuable information was exchanged. Through this informal journal, forensic scientists analyzing fire debris had a means of communicating with each other that was unavailable to scientists in many other disciplines. In 1982, based on work conducted at the Center for Fire Research at the National Bureau of Standards (NBS) (now the NIST) and the ATF National Laboratory, an *accelerant classification system* was published (AA Notes, 1982). Not only was there a description of five classes recognized as "usually identifiable by GC–FID patterning alone when recovered from fire debris," but the authors (who were not named in the publication but are believed to include Philip Wineman and Mary Lou Fultz) also published minimum requirements for class identification. This was the first time that anyone explained what "sufficient similarities" should mean and was a watershed moment in the history of fire debris analysis. Although the original publication of the classification system stated that the final report was not yet available and that the results of the evaluation would be printed in a future issue of the *Arson Analysis Newsletter*, that never happened. The classification system was used informally for the next six years.

The International Association of Arson Investigators (IAAI) has had, almost since its beginning, a standing committee of forensic scientists and engineers that it called upon to advise fire investigators about laboratory analysis issues. In 1987, IAAI President John Primrose approached the Forensic Science Committee and requested that it produce a position paper on what should appear in a laboratory report. It quickly became apparent to members of the committee that in order to prescribe the contents of a report, it would first be necessary to set down an acceptable method of analysis. Four sample preparation techniques (steam distillation, headspace analysis, solvent extraction, and dynamic headspace–purge and trap) were the separation techniques described. Gas chromatography with flame ionization detection, photo ionization, or mass spectral detection was required. Although the publication was called a "guideline," it contained the following sentence: "Unless a petroleum distillate has been identified by the pattern recognition techniques described below, it has not been sufficiently identified" (IAAI Forensic Science Committee, 1988). The guidelines then reproduced the NBS–ATF classification and identification scheme and described how some materials would not fall

within the guidelines. Isoparaffinic hydrocarbons were cited as one example of an ignitable liquid not described in the guidelines. At that time, the only place that a fire debris chemist would be likely to encounter isoparaffinic hydrocarbons was in Gulflite charcoal starter fluid. With the introduction of the IAAI guidelines, fire debris chemists became accustomed to the idea that they needed to follow standard methods. In the private sector, laboratories advertised to the membership of the IAAI, their main source of clients, that they followed the guidelines. Laboratories that did not follow the guidelines lost business.

In 1990, ASTM Committee E30 on Forensic Sciences took the IAAI guidelines and formulated them into six different standards for the preparation, cleanup, and analysis of fire debris extracts. ASTM E1387, the *Standard Test Method for Flammable or Combustible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography*, was published originally in 1990. In 1995, the cumbersome phrase "flammable or combustible liquid" was changed to "ignitable liquid." In 1993, Committee E30 enlisted the aid of Martin Smith, Jack Nowicki, and several other prominent chemists to draft a *Guide for Fire Debris Analysis by Gas Chromatography–Mass Spectrometry*. The guide was revised in 1997, and in 2001 it was "promoted" to a standard test method.

The ignitable liquid classification scheme from 1982 was updated in an attempt to keep up with the ever-changing output of the petrochemical industry. New products were constantly being brought on line, including "environmentally friendly" alternatives to solvents such as mineral spirits and fuels such as charcoal lighter fluid. When ASTM E1387 was first published, a "Class 0" was added to the original classification scheme to account for the liquids that did not fit into one of the five original classes. Further classification within Class 0 was, however, possible, so Classes 0.1 through 0.5 appeared in ASTM E1387-95. By the time the next revision was due, Class 0.6 had been created for de-aromatized distillates, but the committee realized it was time for a change, as the miscellaneous classes now outnumbered the original classes. In 2000, the system was completely redesigned, resulting in nine differently named but no longer numbered classes, with subdivisions of light (C_4–C_9), medium (C_8–C_{13}), and heavy (C_8–C_{20+}) in eight of those nine classes (ASTM E1618-10, 2010).

In 2009, after much discussion, Committee E30 on Forensic Sciences made the decision that analysis of ILRs by GC alone no longer represented the "best practice." ASTM E1387 was allowed to expire and become a "historical" standard. Most fire debris analysts had long ago made the transition to GS-MS. As of this writing, gas chromatography-mass spectrometry is the only generally accepted method for analyzing ignitable liquid residues.

The last 30 years have seen dramatic improvements in separation technology, in analytical technology, and in the scientific community's approach to fire debris analysis. In 1999, the U.S. Department of Justice Office of Law Enforcement Standards produced a report entitled *Forensic Sciences: Review of Status and Needs*, compiled by more than 40 eminent forensic scientists. In reviewing the state of the art, fire debris analysis was described as "a sub discipline of trace analysis that is in good standing because there is sufficient published work on the analysis and

interpretation of the material involved. Standard guides for the examination and interpretation of chemical residues in fire debris have been published through the consensus process of ASTM Committee E30 on Forensic Science. These standardization documents are often quoted in the scientific literature, helping to meet the requirements of the legal community" (U.S. Department of Justice, 1999). Most of the other forensic disciplines discussed in this review were reported as still needing standardization and/or validation of standard methods. Fire debris analysts can point to a history of standardization that existed even before the *Daubert* court made it a necessity.

3.5 ISOLATING THE RESIDUE

3.5.1 Initial Sample Evaluation

Once the receipt of a sample has been documented, and the chain of custody protected (as described in ASTM E1492-05, 2005) the first critical step in the analysis of fire debris is the selection of a separation technique. Choosing an inappropriate technique could result in a false negative, a misidentification, or the destruction of evidence. The first step in this selection process (and the first step in any chemical analysis process) is to *look at the sample*. One purpose of looking at the sample is to ensure that it is what it purports to be. Sample characteristics will determine the most appropriate method for isolating any ignitable liquid residues (ILRs) that may be present. Once the visual examination has taken place, the next step is a "nasal appraisal." Occupational safety experts will no doubt frown on this recommendation, but it can be done carefully. There is no need to put one's nose in the can, even though the analyst can be reasonably certain that the fire investigator who collected the sample has already done exactly that. Unless the sample is a liquid sample for comparison purposes, it can be safely appraised by removing the lid, and waving the hand gently over the top of the sample to see if it exhibits any obvious odors. If there is an odor present, it becomes possible to do a rapid and accurate analysis by removing a small piece of the sample and extracting it with solvent. If the odor is very strong, it is advisable to remove a small piece of the sample and place it into a separate container for analysis.

3.5.2 ILR Isolation Method Selection

Solvent extraction according to ASTM E1386 is an appropriate method for rinsing out empty containers, for extracting small aliquots of samples with a high concentration of ILR, and for isolating residues from very small samples. Not every investigator who comes to the laboratory will have the experience and knowledge to know how to find the best samples, and it is not unusual for an inexperienced investigator to bring in a sample in a film canister.

The vast majority of samples, however, are likely to be samples of burned building materials, floor coverings, and furnishings that do not exhibit a strong odor and are best analyzed by passive headspace concentration, as described in ASTM E1412 (ASTM E1412-07, 2007). This technique is essentially nondestructive. If the

analyst decides to use another technique later, running passive headspace concentration will not interfere with that.

Other methods of isolation have been studied thoroughly over the last 30 years, and although they have some utility, none match the advantages of passive headspace concentration using an activated carbon strip. Headspace sampling, described in ASTM E1388, which involves warming the container and sampling the vapors in the headspace directly and then injecting those vapors into the gas chromatograph, is a good screening technique, but it does not result in the production of an archiveable extract, nor does it detect compounds much heavier than C_{15} (ASTM E1388-05, 2005). Dynamic headspace concentration, described in ASTM E1413, was useful in demonstrating the effectiveness of adsorption or elution as a valid approach to ILR isolation, but it is destructive, requires far more attention than passive headspace concentration, and the apparatus can be cumbersome and finicky. It is no more sensitive than passive headspace concentration, and it is possible for *breakthrough*, loss of analyte out the effluent end of the tube, to occur (ASTM E1413-07, 2007). The only advantage that it offers is speed. If the results can be reported in 24 h, there is no advantage at all. Most laboratories (unfortunately) take several days or weeks to report on a fire debris analysis, due to sample backlogs. Solid-phase microextraction is another alternative, but like dynamic headspace concentration, it is very labor intensive and, like headspace sampling, does not have the potential to produce an archiveable sample that can be analyzed again (ASTM E2154-01, 2008) Using passive headspace concentration results in a solution that can be injected many times, and when the carbon strip is left in the solution, it will gradually readsorb ignitable liquid residues as the eluting solvent evaporates. (Juhala reported the readsorption by small portions of the activated charcoal that fell off his Plexiglas beads in 1982.) The solution can be reconstituted years later if a second look at the sample is desired. Because of the transient nature of many fire debris sample containers, the archived activated carbon strip is often the best evidence after a few years have passed.

The only equipment required for passive headspace concentration is a convection oven, vials, ACS strips, and a solvent dispenser. Caseload will determine the required oven size. In our laboratory, the convection oven can hold up to ten 1-gallon cans and more than twenty 1-quart cans.

Every laboratory should optimize the parameters in its ACS procedure to make sure that they are getting the best results possible. “Good” results from ACS are those where the chromatogram of the concentrated headspace vapors of a standard closely matches the chromatogram of that same standard in the eluting solvent.

A 10 mm $\times$ 10 mm carbon strip is the minimum size recommended. This 100-mm^2 strip can easily accommodate the headspace vapors from 10 μL of any ignitable liquid placed on a Kimwipe in a 1-quart can. It is possible to overload carbon strips, and this results in the preferential adsorption of heavier hydrocarbons over light hydrocarbons and of aromatics over aliphatics, but this effect is generally not large enough to affect the identification. Usually, samples that are capable of overloading the carbon strip will exhibit a strong odor, and the analyst can take an aliquot of the sample or reduce the analysis time.

Figure 3.6 One-quart can equipped with a pressure relief device, a short strip of cellophane tape over a small hole pierced in the lid.

For samples with a high water content, there exists a danger that the vapor pressure in the sample container will cause the lid to pop off. This has the potential to contaminate the sample oven. A pressure relief device is easy to construct for such samples. Puncture a small hole in the lid, and cover with cellophane tape. Figure 3.6 shows a can so equipped.

The adsorption time of a typical ACS procedure is 16 h. The analyst is encouraged to experiment with different adsorption times and temperatures, with the goal of finding a balance between the maximum recovery and the minimum time necessary. Sixteen hours is convenient because the samples can be put in the oven at 4:00 P.M. and taken out at 8:00 A.M. the next day. One of the major advantages of ACS is that it requires very little attention from the analyst. Once the strip is in the can and the can is in the oven, nothing is going to happen until it is time to take the strip out of the can, put it in the vial, and add the eluting solvent. At this point in the analysis, however, the analyst must be extremely attentive to the procedure. Once the carbon strips are taken out of the sample container, they have an identical appearance. It is at the point of placing the strips into their vials that an unrecoverable error can occur—a strip can be misidentified. The analyst should not allow himself or herself to be distracted by phone calls or other people in the lab. The operative word here is *focus*.

Many laboratories use a pre-concentration step, wherein they add approximately 500 μL of solvent to the strip in a vial; then after the strip has had a chance to

equilibrate, it is removed and the solvent is evaporated down to 100 μL or so. This will result in a fivefold increase in concentration, but that increase can usually be achieved electronically with very little loss of signal or increase in noise. The first analysis, in this analyst's view, does not require the pre-concentration step. That can be accomplished at a later time, if necessary, but pre-concentration runs the risk of skewing the results if not done very carefully. The only safe way to evaporate the solvent is to blow a stream of dry nitrogen over it. Heating the solvent is a bad idea, because lower-molecular-weight compounds are likely to be lost.

3.5.3 Solvent Selection

The solvent used for the elution is another critical choice, not so much in terms of the quality of results but in terms of the analyst's quality of life. The most popular eluting solvent is carbon disulfide, a highly toxic, carcinogenic, teratogenic, smelly, nasty liquid that will ignite upon exposure to boiling water. It does work very well to elute aromatics and aliphatics approximately equally from ACSs, but so does diethyl ether. Studies indicate that carbon disulfide is superior to diethyl ether, or to pentane, the other solvent recommended by ASTM Committee E30 (Newman and Dolan, 2001), but if standards are prepared using diethyl ether, the slight change in the chromatographic profile does not affect the identification. Armstrong and Lentini (1997) found only marginal differences between diethyl ether and carbon disulfide when applied to carbon strips exposed to 10-μL samples of ignitable liquid residues. Comparing the relative health risks makes diethyl ether an obvious choice for this analysis.

Carbon disulfide was originally selected as a fire debris solvent because of its high desorption efficiency and its relatively quiet signal when passing through a flame ionization detector. When using a mass spectral detector, the advantage of its low signal disappears because the detector is turned off while the solvent is passing through.

Some concerns have been expressed about the capability of diethyl ether to form explosive peroxides, but that will not occur if the ether is kept in a refrigerator and used on a regular basis. Explosions of cans of ether have only been reported when those cans have been allowed to sit for years, unused, in the back of an unrefrigerated stockroom. Carbon disulfide, diethyl ether, and pentane are all highly flammable; however, with respect to fire, carbon disulfide poses the greatest risk, as it has the lowest ignition temperature and the broadest flammable limits (NFPA 325, 1994). Finally, carbon disulfide costs almost 10 times what the other solvents cost. A comparison of the properties of the three solvents recommended by ASTM E1412 is shown in Table 3.1.

3.5.4 Internal Standards

There are two places in the analysis of fire debris where the use of internal standards is appropriate. Addition of an internal standard to the sample itself allows the analyst to develop at least a qualitative feel for the "tenacity" of the sample and for

TABLE 3.1 Elution Solvent Comparison[a]

	Carbon Disulfide	Diethyl Ether	Pentane
Flash point	−30°C (−22°F)	−45°C (−49°F)	−40°C (−40°F)
Lower elution limit (LEL) (vol% in air)	1.0	1.9	1.5
Upper elution limit (UEL) (vol% in air)	50.0	48.0	7.8
Specific gravity	1.3	0.7	0.9
Boiling point	40°C (115°F)	35°C (95°F)	36°C (97°F)
Autoignition temp.	90°C (194°F)	180°C (356°F)	260°C (500°F)
Exposure limit, TWA[b]	4 ppm	400 ppm	600 ppm
Exposure limit, STEL[c]	12 ppm	500 ppm	750 ppm
Carcinogenic	yes	no	no
Teratogenic	yes	no	no
IDLH	500 ppm	19,000 ppm (LEL)	15,000 ppm (LEL)
FID signal	small	large	very large
Cost per liter[d]	$399.7.70	$44.25	$38.10

[a] Refer to your laboratory's hazard communication literature or MSDS for more complete information.
[b] Time-weighted average for an 8-h exposure.
[c] Short-term exposure limit (up to 15 min).
[d] Source: J.T. Baker, online catalogue, Aug. 18, 2007. All prices are for case quantities of Ultra Resi–analyzed grade.

the effectiveness of the isolation procedure. In our laboratory, this is accomplished by the addition of 0.5 μL of 3-phenyltoluene (actually, 20 μL of a 2.5% solution of 3-phenyltoluene in ether). In the eluting solvent, we use a second internal standard consisting of 0.1% (100 ppm) perchloroethylene. If the 3-phenyltoluene does not appear in the chromatogram, this means that we have an exceedingly tenacious sample (some samples come equipped with their own active sites, which can compete very effectively with the ACS for analyte molecules) and suggests that the tenacity of the sample might be the reason that the chromatogram appears so flat. If the perchloroethylene peak does not appear, or is significantly reduced in height, something has gone wrong with the injection.

Comparison of the signal from the sample to the perchloroethylene signal allows for a semiquantitative determination of the amount of ILR present. For 10-μL standards of known ignitable liquids isolated according to ASTM E1412, the two internal standard peaks are roughly on the same order of magnitude as the sample peaks. Essential blanks include the 3-phenyltoluene applied to filter paper and the blank strip eluted with the spiked solvent. Some analysts may perceive the danger of being accused of "contaminating" a sample, but this is easily overcome by having a proper blank in the file. The advantages of using internal standards far outweigh this disadvantage.

3.5.5 Advantages and Disadvantages of Isolation Methods

Two drawbacks have been cited for use of the ACS method, the time required to perform the adsorption, and the relative lack of sensitivity compared to SPME. If laboratories were in the habit of providing same-day service, the first argument might have merit. Turnaround times generally range from two days to two months. In that context, a 16-h versus a 15-min analysis time is meaningless. With respect to sensitivity, the ACS method is capable of routinely detecting 0.1 μL of ignitable liquid from a nontenacious background, which should be low enough. Our goal is to help the fire investigator understand whether a foreign ignitable liquid was present at the fire scene. We now have the ability to detect the solvent in polyurethane finish five years or more after it has been applied to a hardwood floor. We have no need to be more sensitive than that. A technique that is capable of adsorbing significant quantities of ignitable liquid residue in 15 min is also capable of becoming contaminated much more easily than a carbon strip that might take 16 h to come to equilibrium with a dilute sample.

The use of a "screening" technique for fire debris samples is an issue that each laboratory should address. There is usually not a need to screen samples, since an ACS separation is likely to be more sensitive. A sample that tests negative on a quick headspace analysis (per ASTM E1388) needs to be tested further anyway. If a request is made to look for light oxygenates (alcohols, acetone) or to get a ballpark estimate of analyte concentration (other than through a "nasal appraisal"), running a headspace can be useful. Screening techniques also allow for a swift, if less than definitive, result. For routine analyses, however, passive headspace concentration, conducted according to ASTM E1412, should be the norm. Solvent extraction, as described in ASTM E1386, is appropriate for sampling aliquots of very strong samples or for extracting very small samples or empty containers (ASTM E1386-10, 2010).

Steam distillation may be selected in the odd case where it is desired to produce a neat liquid extract of the fire debris. The benefit of this is that a vial of the liquid can be brought into a courtroom, shown to a jury, lit on fire on a Q-tip, and passed around. Because steam distillation is appropriate only on very concentrated samples, however, it is preferable to make sure that the sample is preserved, and the sample itself can be passed around for the jury to smell. For the most part, steam distillation is a technique whose time has come and gone. The last reapproval of an ASTM steam distillation standard took place in 2001, and the Committee on Forensic Sciences in 2006 took the decision to allow the standard to expire. A comparison of the advantages and disadvantages of the various isolation techniques is shown in Table 3.2.

3.6 ANALYZING THE ISOLATED ILR

Despite the improvements in separation and detection technology, the overall approach to identification of ignitable liquid residues is the same as it was in the early 1970s. A chromatogram from the sample is compared with chromatograms

TABLE 3.2 Comparison of ILR Isolation Techniques

Method	Advantages	Disadvantages
E1385, steam distillation	Produces a visible liquid, simple to explain	Labor intensive, destructive, not sensitive, requires expensive glassware
E1386, solvent extraction	Useful for small samples and empty containers, does not cause significant fractionation, useful for distinguishing heavy petroleum distillates from each other	Labor intensive, expensive, co-extracts nonvolatile substances, increased risk of fire, solvent exposure, destructive
E1388, headspace sampling	Rapid, more sensitive to lower alcohols, nondestructive	No archiveable sample, not sensitive to heavier compounds, poor reproducibility
E1412, passive headspace	Requires little analyst attention, sensitive, nondestructive, produces archiveable sample, inexpensive	Requires overnight sampling time
E1413, dynamic headspace using activated charcoal	Rapid, sensitive, produces archiveable sample, inexpensive	Labor intensive, subject to breakthrough, destructive
E1413, dynamic headspace using Tenax	Rapid, sensitive	Labor intensive, requires thermal desorption, no archiveable sample, destructive
E2154, solid-phase microextraction	Rapid, highly sensitive, useful for field sampling with portable GC–MS	Labor intensive, expensive, requires special injection port, reuse of fibers, no archiveable sample

from known standards, and the analyst determines whether there are "sufficient similarities" to make an identification. What has changed is the quantity of information available because of the increased resolution provided by capillary columns and the ability to obtain a mass spectrum up to 10 times per second, as well as reaching a consensus on the meaning of "sufficient." So, although there is more information to compare, the technique is still one of pattern recognition and pattern matching.

An argument can be made that when one looks at a mass spectrum, one is looking at structural details rather than simply matching patterns, but the patterns still have to match. The same argument has been made about structural elucidation in the use of FTIR for drug identification. Although it would be nice to think that analysts routinely consider molecular structure, the day-to-day operation is one of pattern matching.

There exists a specific skill set that is required to compare chromatographic patterns. This skill set must be learned carefully and used routinely if it is to

remain sharp. Pattern recognition is one "scientific" skill that has historically been problematic. Although fire debris analysts use the same equipment as drug analysts, the drug analyst typically looks for a single peak with a particular retention time. The fire debris analyst must compare an entire pattern of peaks produced by a sample to the pattern of peaks produced by a standard. This exercise includes a comparison of inter- and intragroup peak heights and can be quite complex. Although it is true that many drug analysts also conduct ignitable liquid residue analyses, a different set of skills is involved.

Fire debris analysis also involves a set of skills different from those employed by environmental scientists, who are typically trying to quantify the components of an oil spill or contaminants at a Superfund site. Environmental methods typically assume the presence of gasoline or other petroleum products, then look for benzene, toluene, ethylbenzene, and xylene (BTEX) to quantify the amount present. Unless they are trying to identify the source of the spill, environmental analysts are usually not employing the same skill set used by fire debris analysts.

If one thinks about the nature of many petroleum products and the processes that are going on when those products are isolated from debris samples, one can begin to understand why chromatographic patterns look the way they do. Many petroleum products are straight-run distillates, particularly the medium and heavy petroleum distillates. The overall pattern of these products is a Gaussian (bell-shaped) distribution of peaks, dominated by the normal alkanes. The patterns produced by kerosene and diesel fuel have been likened to a stegosaurus, because the chromatograms bear a passing resemblance to the dinosaur's dorsal fin. (Actually, a spinosaurus' sail back fin more closely resembles the pattern, but stegosaurus is the term of art.). A medium petroleum distillate produces the same pattern, shrunken and coming off early.

A fractionation process similar to distillation occurs in the isolation of an ignitable liquid residue from a sample. This is caused by the very low vapor pressure of ILR components above C_{18} and by the selective adsorption of the heavier hydrocarbons on complex substrates. Hydrocarbons up to C_{23} can be captured from diesel fuel placed on a noncompeting substrate such as filter paper. That same fuel placed on charred wood, however, may exhibit a pattern that ends at C_{18}. If compounds do not get into the air in the headspace, they will not be adsorbed onto the carbon strip. The tenacity of the sample needs to be considered, particularly when trying to distinguish between kerosene and diesel fuel.

This author learned pattern recognition the old-fashioned way: running dozens, then hundreds of standards, and learning what the patterns looked like. Today's analysts are fortunate in that the ASTM standards give examples of many of the patterns that an analyst is likely to see in positive samples, and there exists a detailed compilation of literally hundreds of patterns available in a standard text (Newman et al., 1998). Both the ASTM standards and the *GC–MS Guide to Ignitable Liquids* provide sufficient information to allow the analyst to set up an instrument to provide patterns that look very much like the ones in the texts. Although these texts are an important resource, it is imperative that every fire debris analysis laboratory have its own library of ignitable liquid residues. This provides for patterns with exactly the

TABLE 3.3 Ions Used for Extracted Ion Chromatography

Ion	Compounds	Ion	Compounds
57	Alkanes	119	C_4 alkylbenzenes
83	Cycloalkanes	131	Methyl, dimethylindans
91	Toluene, xylenes	142	Methylnaphthalenes
105	C_3 alkylbenzenes	156	Dimethylnaphthalenes
117	Indan, methylindans		

same retention times and mass spectra with exactly the same fragmentation patterns. The in-house library is also a quality assurance tool, which lets the analyst know when there has been some drift in the instrument, when a sensitivity loss has taken place, and when it is time to run a new set of standards. Whatever approach is taken, it will take time to develop the ability to recognize ILR patterns.

The mass spectrometer provides the ability to simplify what can be very complex and confusing patterns. This is a result of the ability of the data analysis software to separate out only those peaks having particular ions present in the pattern. For example, if one wants to look at the alkanes, one only needs to obtain an extracted ion chromatogram for m/z (mass/charge ratio) 57, hereafter referred to as ion 57, and most of the balance of the components will disappear. It is thus possible to break down a total ion chromatogram (TIC) into its component parts—see Table 3.3.

Although there are more patterns to learn, they are simpler patterns and easier to remember. This approach to data analysis, known as *mass chromatography*, was first proposed by Smith in 1982. There are basically two ways to approach mass chromatography: the single-ion approach and the multiple-ion approach. Dolan (2004) has proposed referring to the single-ion chromatograms as *extracted ion chromatograms* (EICs) and multiple-ion chromatograms as *extracted ion profiles* (EIPs).

When working with software that scales the extracted ion chromatogram or profile to the tallest peak, some caution is advised when using multiple ions. To the extent that the second, third, and fourth ions contribute to a pattern, they tend to make it more complicated, thus defeating some of the purpose of extracting the ions in the first place. To the extent that these additional ions do not change the pattern, they may convince the analyst that he or she is seeing more than is actually present. Finally, to the extent that these additional ions are present at substantially lower concentrations, they would be better observed on their own rather than in the profile. Figure 3.7 is a comparison of ion 57 from a kerosene standard versus a profile based on ions 57, 71, 85, and 99. The profile is slightly more complicated, but since ion 57 is the base peak for almost every component in the chromatogram, the ion 57 profile is the tallest.

Another example is shown in Figure 3.8, which presents ions 128, 142, and 156, the naphthalenes, from a gasoline sample. In the top chart, the ions are combined into a profile, which although it gives the analyst an idea about the relative abundance of the three ions, shows very little detail for the dimethylnaphthalenes represented by ion 156. When the extracted ions are presented separately, the analyst still gets the quantitative data by reading the abundance numbers next to the

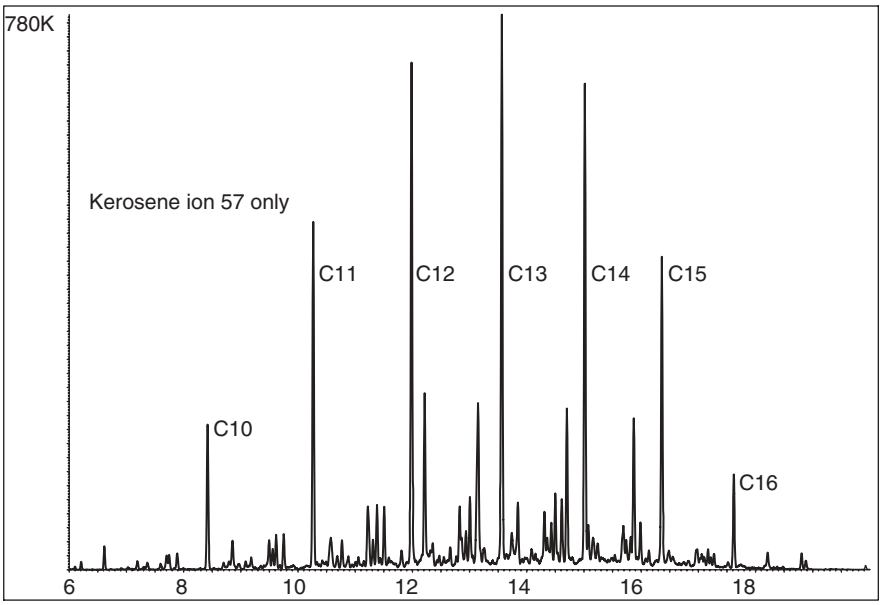

(a)

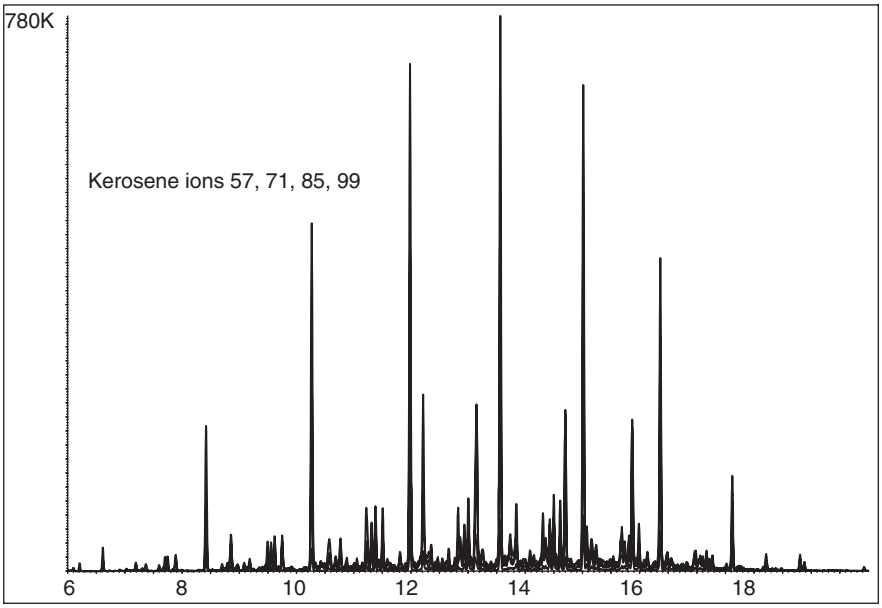

(b)

Figure 3.7 Ion profiling versus ion chromatography. Comparison of (a) the ion 57 chromatogram with (b) the ion profile combining ions 57, 71, 85, and 99 from a kerosene standard. The four ions in the profile are plotted in the merged format. Plotted individually, they are all very similar, with ion 57 presenting the tallest peaks.

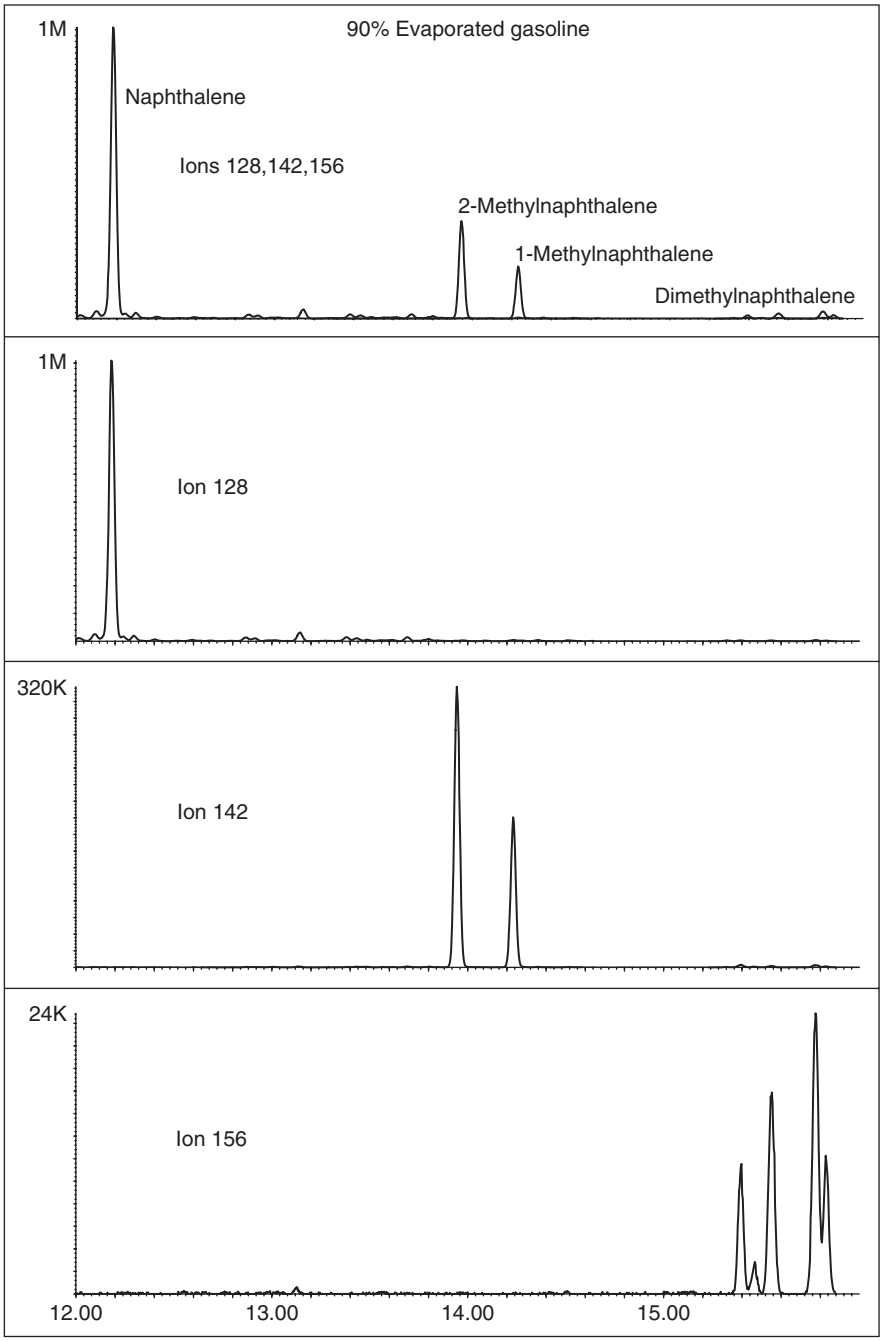

Figure 3.8 Ion chromatography versus ion profiling. Comparison of the ion profile of the naphthalenes from a gasoline standard (top chart). Compare with the detail provided by presenting the three ions (128, 142, and 156) separately.

Y-axis, but also gets to see the fine details in the shape of the peaks at the right side of the chart.

A similar example is shown in Figure 3.9(a). These charts show ions 91, 105, and 119 from a 75% evaporated gasoline standard. The effect is even more pronounced at 90% evaporation, shown in Figure 3.9(b), when the ion 91 peaks are smaller. Whether an analyst chooses extracted ion chromatography or extracted ion profiling is largely a matter of taste. It is easier for this author to use the simpler patterns

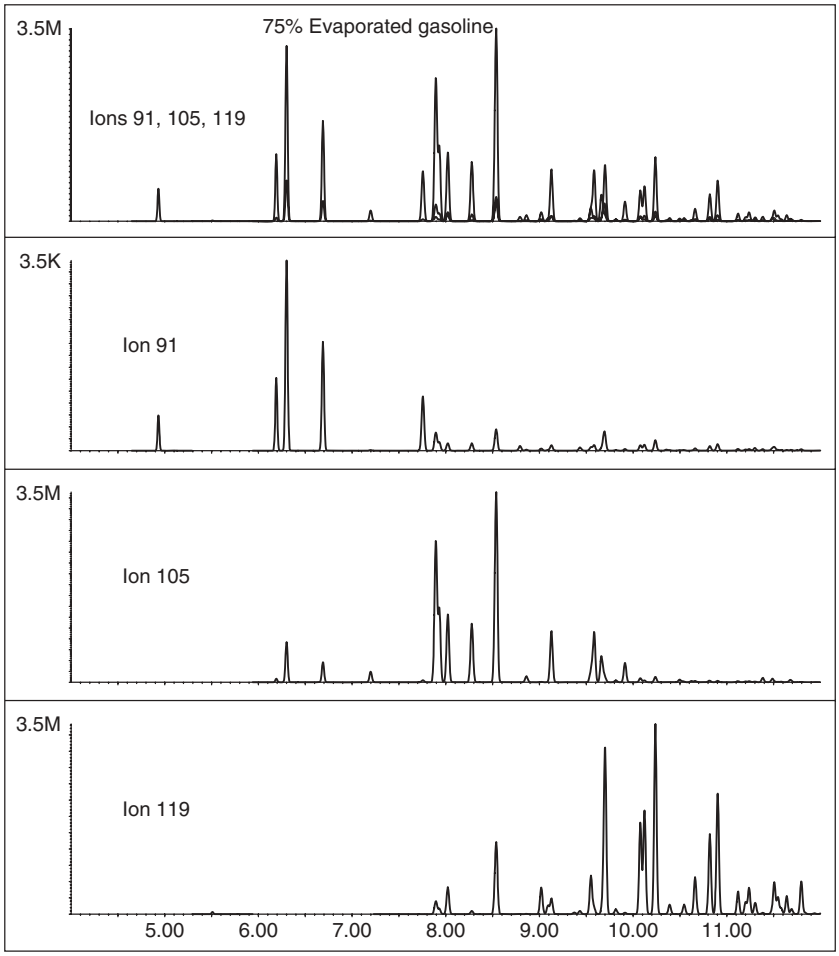

(a)

Figure 3.9 Ion profiling versus ion chromatography. (a) Comparison of ion profiles from 75%-evaporated gasoline. The top chart shows a combination of ions 91, 105, and 119. The next three charts show those ion chromatograms plotted independently. (b) Comparison of ion profiles from 90%-evaporated gasoline. The top chart shows a combination of ions 91, 105, and 119. The next three charts show those ion chromatograms plotted independently. Note the improvement in the level of detail presented for the xylenes.

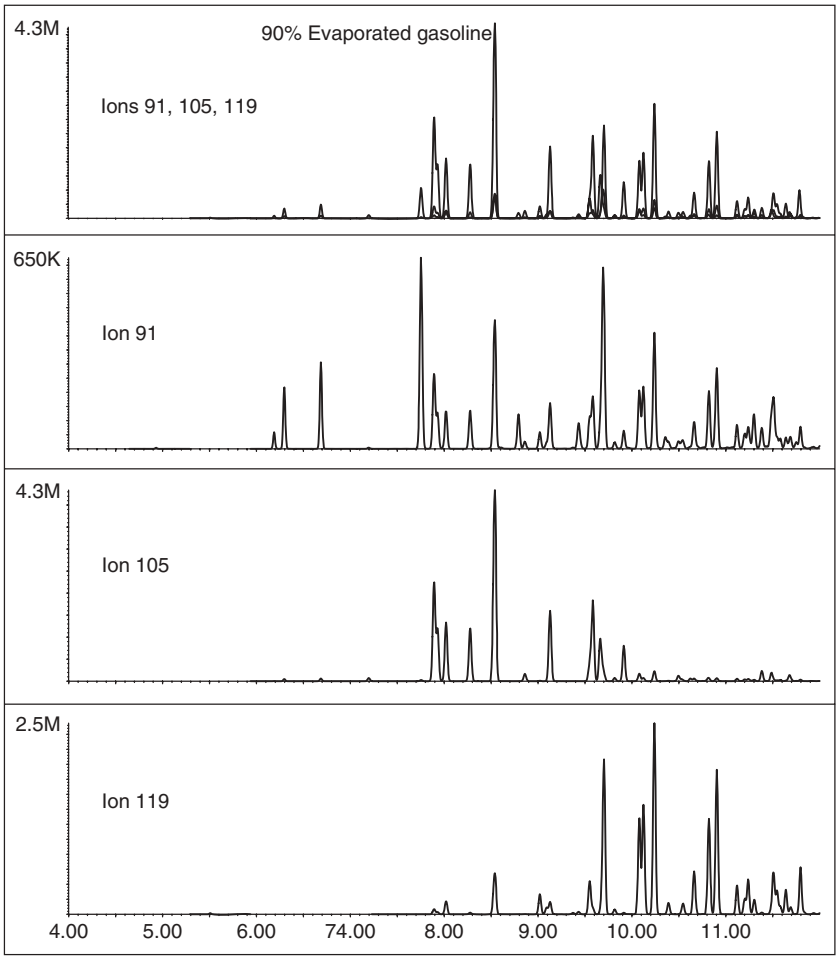

(b)

Figure 3.9 (*Continued*)

and avoid the eyestrain required to see the smaller peaks in the profiles. The typical set of six ion chromatograms used in our laboratory to document the presence of gasoline is shown in Figure 3.10, and the set of three ion chromatograms used for distillates is shown in Figure 3.11. Details of each are discussed below.

3.6.1 Criteria for Identification

Most of the chromatograms that an analyst uses to make a positive identification of an ignitable liquid residue will match (exhibit "sufficient similarities" to the standard) at the level of the TIC. Samples with low concentrations of ILR, high backgrounds, or both, can sometimes yield a positive identification for ILR if the

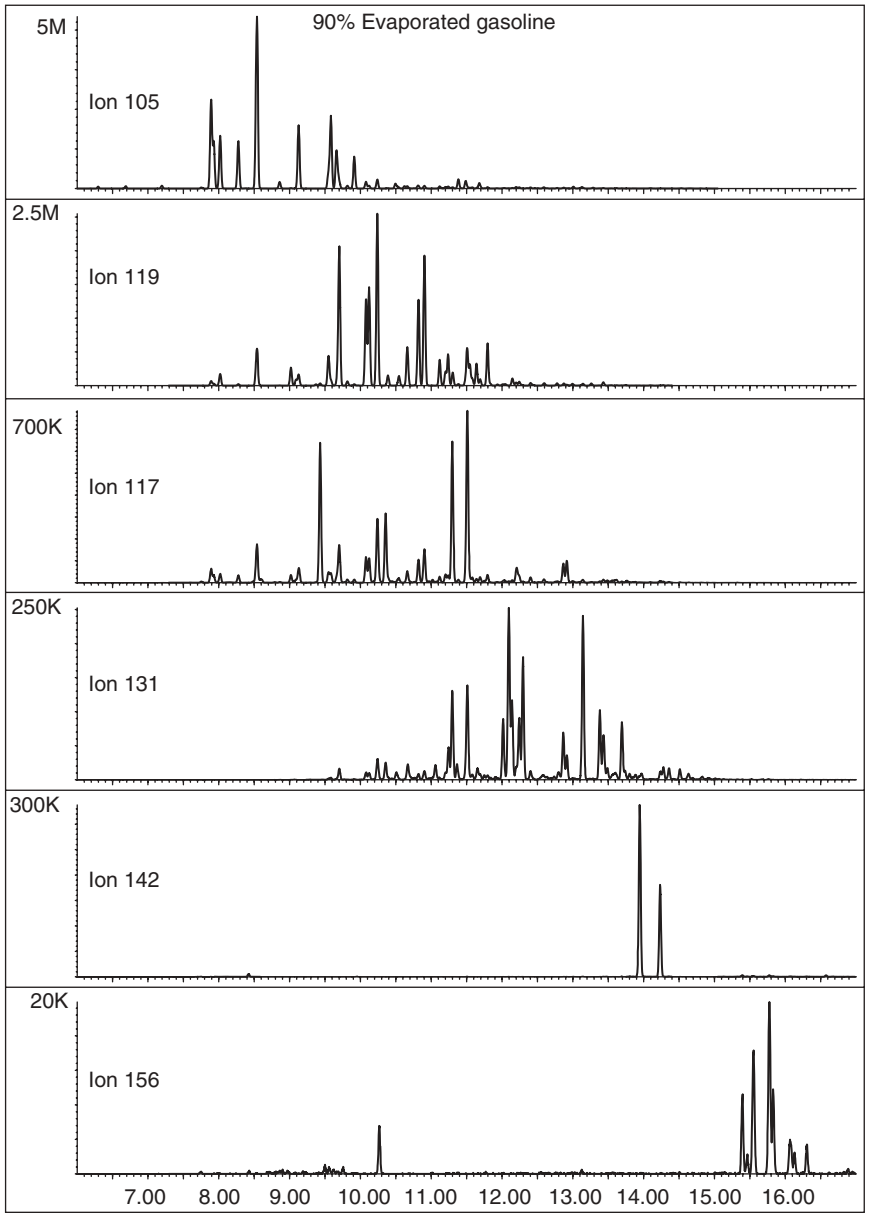

Figure 3.10 Typical set of six ion chromatograms used in our laboratory to document the presence of gasoline. Ions we use are 105 for C_3 alkylbenzenes, 119 for C_4 alkylbenzenes, 117 for indan and methyl indans, 131 for dimethyl indans, 142 for 2- and 1-methylnaphthalene, and 156 for dimethylnaphthalenes.

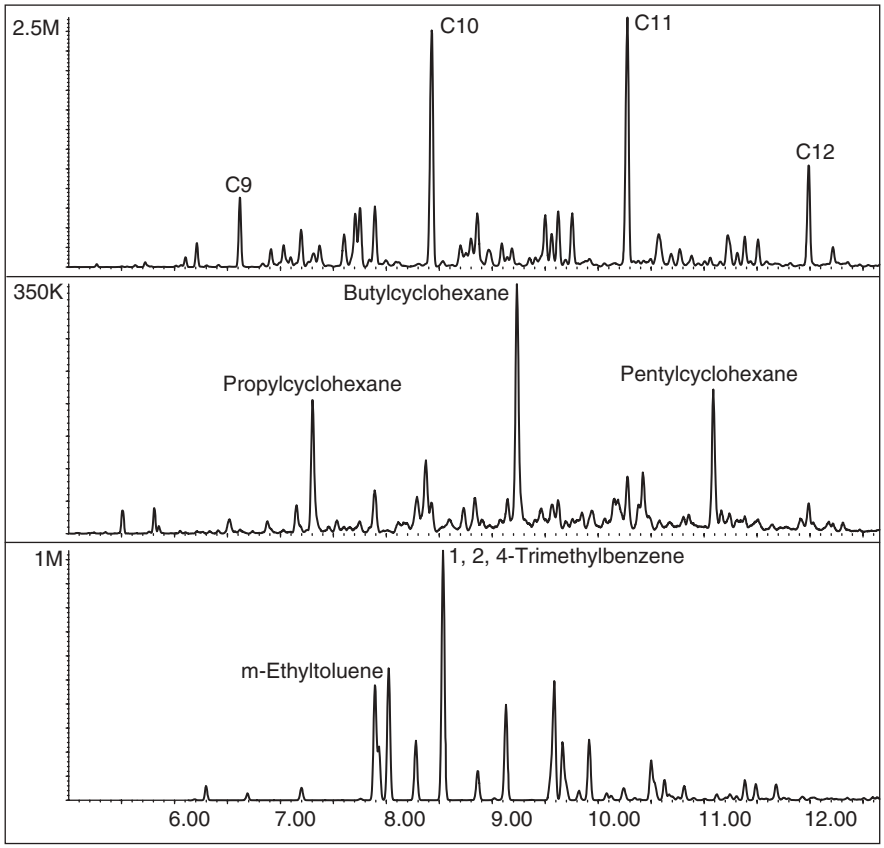

Figure 3.11 Typical set of three ion chromatograms used in our laboratory to document the presence of distillates. These are the ion 57, 83, and 105 chromatograms from Smokey Bear charcoal lighter, a medium petroleum distillate.

analyst is very careful. Usually, but not always, if the TIC from the sample does not match the TIC from the standard, the sample is likely to be negative (determined to contain no detectible ignitable liquid residue). Examples of cases where this is not true are presented following this general discussion of criteria for identification of an ILR in routine cases.

ASTM E1618 identifies eight classes of ignitable liquids identifiable by GC–MS:

1. Gasoline
2. Petroleum distillates
3. Isoparaffinic products
4. Aromatic products, including dearomatized distillates
5. Naphthenic–paraffinic products

6. *N*-Alkane products
7. Oxygenated solvents
8. Miscellaneous

With the exception of gasoline and oxygenated solvents, each of the classes above can be placed into one of three ranges: light (C_4–C_9), medium (C_8–C_{13}), and heavy (C_8–C_{20+}). This standard presents criteria for identifying the various kinds of compounds (alkanes, cycloalkanes, aromatics, and condensed ring aromatics) found in each one of the nine classes. The alkanes include both straight-chain and branched hydrocarbons, and can be extracted using ion 57. The cycloalkanes are mostly substituted cyclohexanes, which can be seen by extracting ion 83. Cycloalkanes also have a strong ion at 55, and as the length of the substituted alkane increases, ion 57 begins to dominate the mass spectra. *Aromatics* means alkyl-substituted benzenes with a single ring. These can be extracted using ions 91, 105, and 119. Ion 91 will show toluene and xylenes, ion 105 will show xylenes and C_3 alkylbenzenes, and ion 119 will show C_4 alkylbenzenes. There will be some overlap in the extracted ion chromatograms, as shown in Figure 3.9. *Condensed ring aromatics* refers to indans and naphthalenes. Indans have a five-membered ring attached to a benzene ring, and may be substituted. The naphthalenes that we usually see are naphthalene itself, 2- and 1-methyl naphthalene (written in that order because that is the order of elution from a nonpolar column), and the dimethyl naphthalenes. Naphthalene presents a single peak when ion 128 is extracted. There are two peaks for the methyl naphthalenes seen when ion 142 is extracted, and there are eight peaks in the dimethyl naphthalene chromatogram seen when ion 156 is extracted. The indans can be visualized by extracting ions 117 and 131.

Identification of Gasoline The composition of petroleum products as found in fire debris is influenced by three factors: crude oil parentage, the effects of petroleum refining processes, and the effects of weathering. Gasoline is the way it is largely because of the second of these influences, petroleum refining. Although all crude stocks contain aromatics, aliphatic hydrocarbons comprise the bulk of most crude oils. Because the aliphatics cause knocking in gasoline engines, the value of the crude stock is enhanced by *cracking*, making small molecules out of larger ones, and by *reformation* through a process of dehydrogenation. Toluene and xylenes are the most abundant compounds produced in these processes. Gasoline does contain numerous light aliphatics (as light as butane) present when gasoline is first pumped, but by the time it has been through a fire, most of the lighter ($<C_7$) aliphatics have evaporated. Consequently, toluene is usually one of the first tall peaks seen in a sample of gasoline, and once the gasoline has weathered to 50% or more, the toluene peak is much shorter than the C_3 alkyl benzene or xylene peaks. Gasoline changes considerably as it evaporates, which is what makes it one of the more difficult classes to identify. When a Gaussian distribution of normal alkanes changes because of evaporation, it is still a Gaussian distribution of normal alkanes, just a heavier one. Most of the samples of gasoline that this author has

seen in samples of fire debris have been more than 75% evaporated. (Estimating the degree of evaporation is discussed later.)

Gasoline is, in this author's experience, the most frequently misidentified ignitable liquid residue. That is because many of the compounds present in gasoline as it comes from the pump are also produced when polymers, such as poly(vinyl chloride) (PVC) and polystyrene, degrade as a result of exposure to heat. The key to avoiding misidentifications is making sure that the ratios between groups of compounds and *within* groups of compounds are consistent with the standard. Toluene is a very common pyrolysis product. Note that the polymer need not be an aromatic one to produce aromatic pyrolysis products. In fact, the pyrolysis products of PVC, because of the way it responds to heat, consist almost entirely of aromatics (Stauffer, 2003). It is an unusual fire debris sample that does not contain toluene at some level. Since it is one of the first gasoline compounds to evaporate, one does not expect to see a tall toluene peak in the absence of equally tall xylene peaks in a sample that is positive for gasoline. Figure 3.12 shows the chromatogram of a 10-μL standard of gasoline adsorbed using an activated charcoal strip and eluted with diethyl ether spiked with 100-ppm perchloroethylene. The toluene and xylene peaks are almost equally tall. If a fire debris sample contains toluene from gasoline, it will be accompanied by xylenes

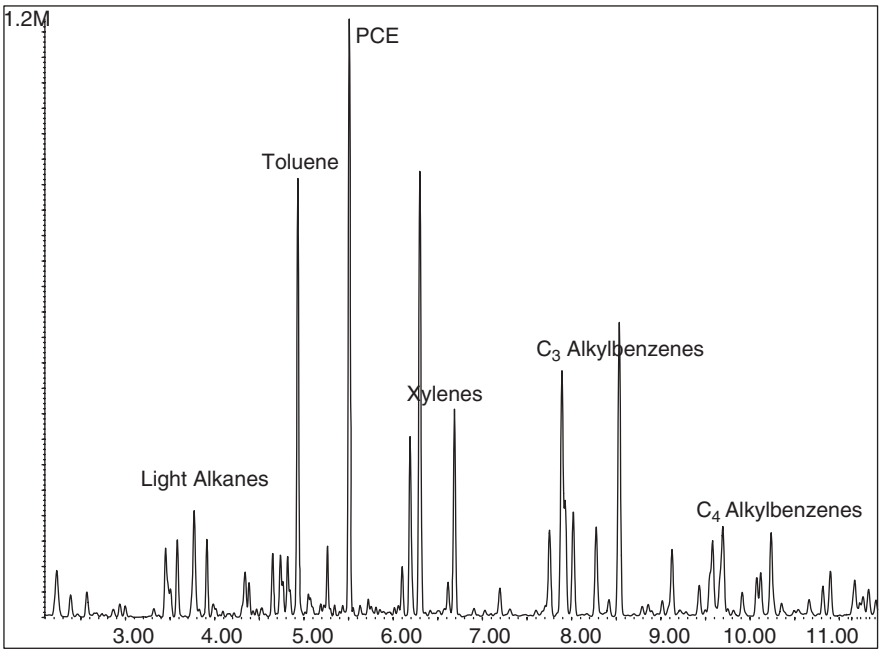

Figure 3.12 Total ion chromatogram of fresh gasoline; 10 μL was spotted on a piece of filter paper and the headspace was concentrated using ASTM E1412. The eluting solvent was diethyl ether spiked with 100 ppm of perchloroethylene, shown here eluting between toluene and the xylenes.

and the higher peak groupings of gasoline. Toluene that is not so accompanied comes from something other than gasoline.

Xylenes are also produced by the decomposition of plastics, but unlike toluene, the xylenes can be examined for correct intergroup ratios. Figure 3.13 shows ion 91, the base ion for xylenes, from gasoline in three different stages of evaporation, kerosene, and a medium petroleum distillate. The relative ratios for the three peaks are almost indistinguishable. Note that the ethylbenzene peak in the 50% evaporated gasoline is slightly lower. This trend continues as the degree of evaporation increases, but generally, one will find that if the xylenes in a sample are from an ignitable liquid, they will exhibit this characteristic ratio. Note that there are three isomers of xylene, *ortho*-, *meta*-, and *para*-, but that the three peaks seen in the chromatograms actually represent four compounds, because *meta*- and *para*-xylene cannot be resolved except in the longest columns (ethyl benzene followed by the three xylenes). If xylenes are found in ratios other than the one shown in Figure 3.13, particularly if ethyl benzene is the tallest peak in the group, one can safely conclude that neither gasoline nor any other petroleum product was the sole source of the xylene. If styrene is present at a higher concentration than the ethylbenzene, one is certainly looking at polymer decomposition products.

The next group to consider is the C_3 alkyl benzenes. This is by far the most important of the patterns in any sample of gasoline. Like the xylenes, it is also found in all petroleum products from which the aromatics have not been removed, and unless evaporation has decreased the concentration of the lighter compounds, the peak ratios will always be the same. This is the group identified in the 1982 guidelines (and in every standard since) as "the *m*-ethyltoluene pseudocumene five-peak group." This group appears in many samples that contain no gasoline, and it is the failure to exhibit the proper ratio of peaks that is sometimes the analyst's only clue that he or she is looking at data that can easily be misinterpreted. The group of peaks must be present to identify gasoline, but sometimes it is overemphasized, and sometimes it is "seen" where it really is not present. Figure 3.14 shows one such sample, where there was a misidentification of gasoline. The figure shows the suspect sample at the top, as well as four standards that exhibit the proper ratios of components in the C_3 alkyl benzene group. As with the xylenes, *meta*- and *para*-ethyl toluene cannot be resolved, although the resolution is somewhat better here than in the xylenes—we see a shoulder. In nearly all cases where the C_3 alkyl benzene group is, in fact, present as a component of a petroleum product, the pseudocumene peak will be the tallest. Because most of the residues encountered in gasoline will be highly evaporated, the pseudocumene peak will be the tallest peak on the chart—both the TIC and the EIC. Note that in the questioned sample at the top of Figure 3.14(a), it is the second peak that is the tallest, not the pseudocumene peak. The first peak has the same retention time as *m*- and *p*-ethyltoluene, but the shape is wrong, and the mass spectrum indicates that the peak actually represents benzaldehyde. The mass spectrometer unequivocally identified the second peak in the questioned sample as 1,3,5-trimethylbenzene, but the third peak, which may have represented *o*-ethyltoluene, also contained a significant 118 ion, indicating the

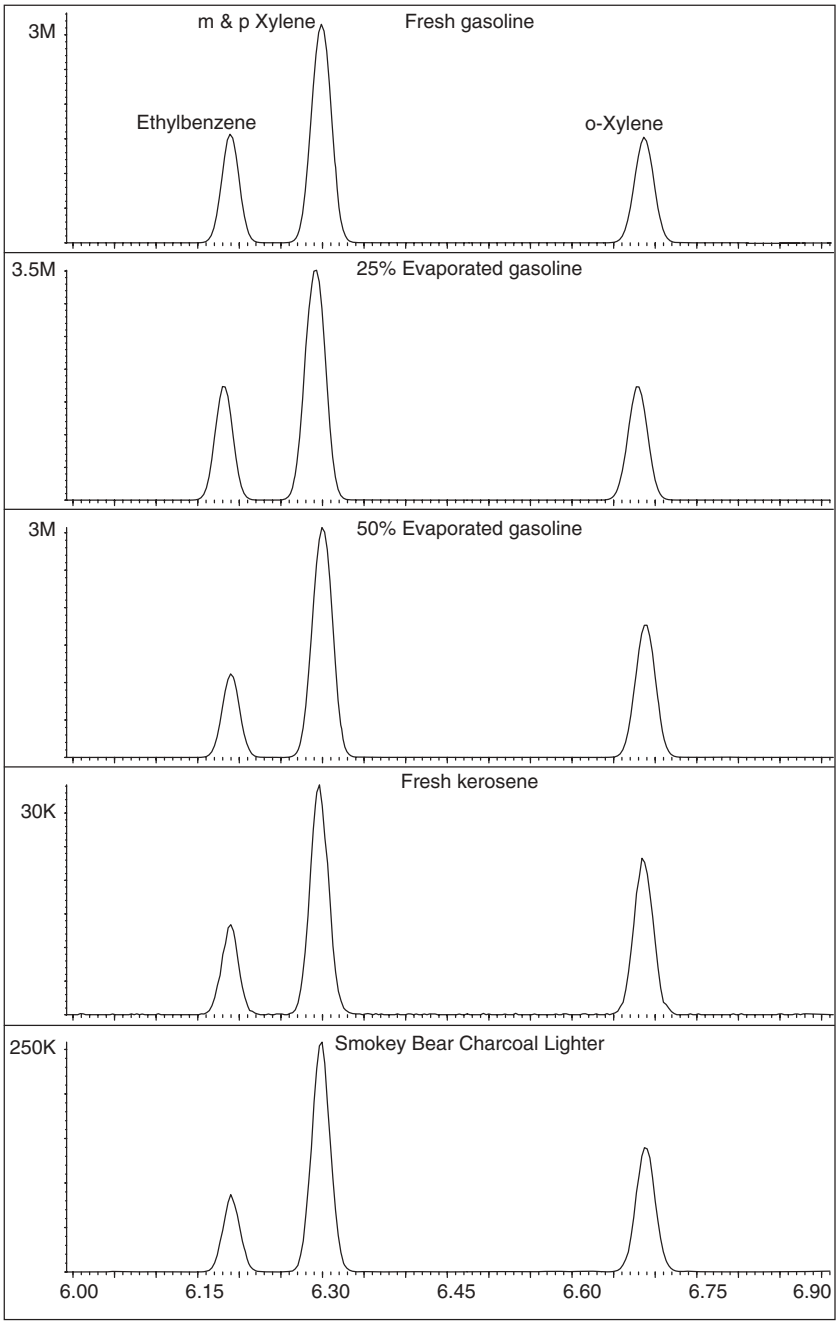

Figure 3.13 Ion chromatogram for ion 91 from gasoline in three different stages of evaporation, kerosene, and a medium petroleum distillate. Note that the relative ratios for the three peaks in the xylene group are almost indistinguishable. Evaporation causes the ethylbenzene peak in the 50%-evaporated gasoline to be slightly shorter.

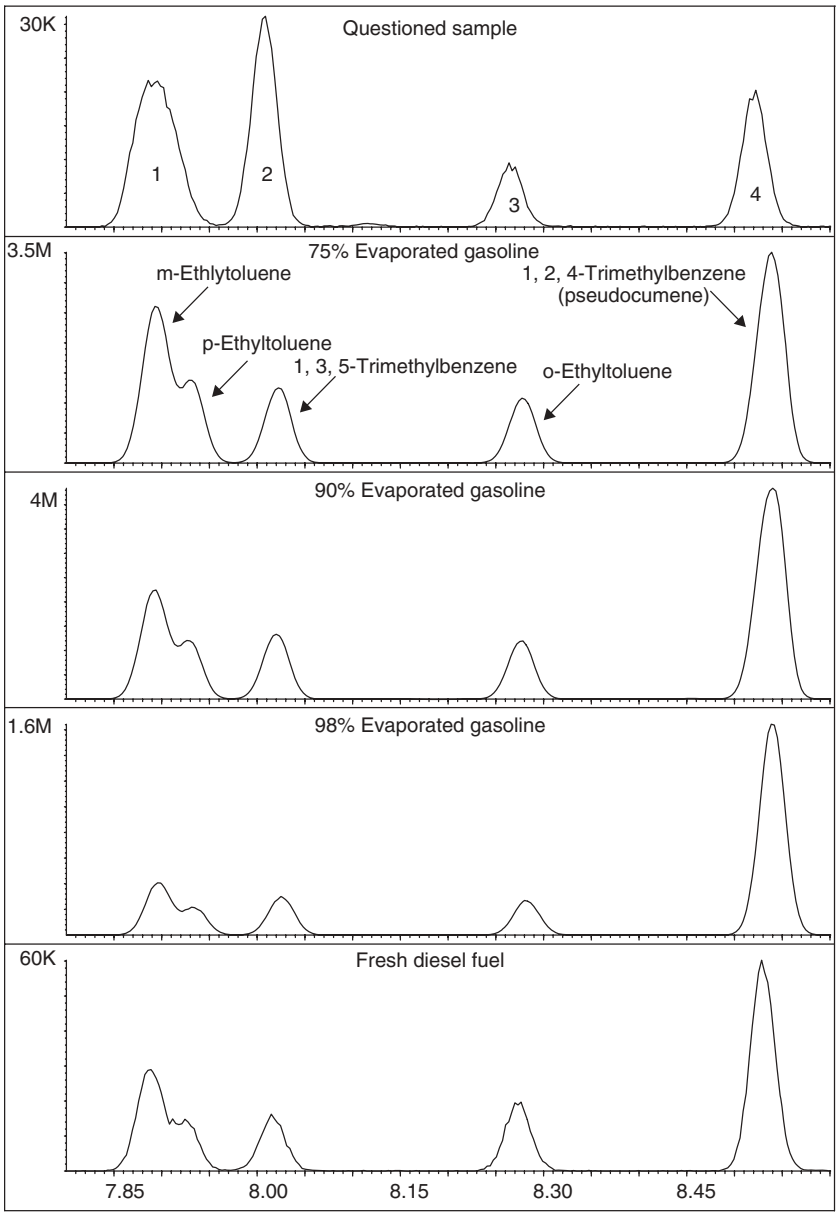

(a)

Figure 3.14 Study of the C_3 alkylbenzene group. (a) The top chromatogram shows an unknown sample. This is followed by gasoline in three stages of evaporation, and fresh diesel fuel. The TIC of the unknown did not look like gasoline, but based on this EIP and a few other ion chromatography comparisons, an analyst called the sample positive for gasoline.

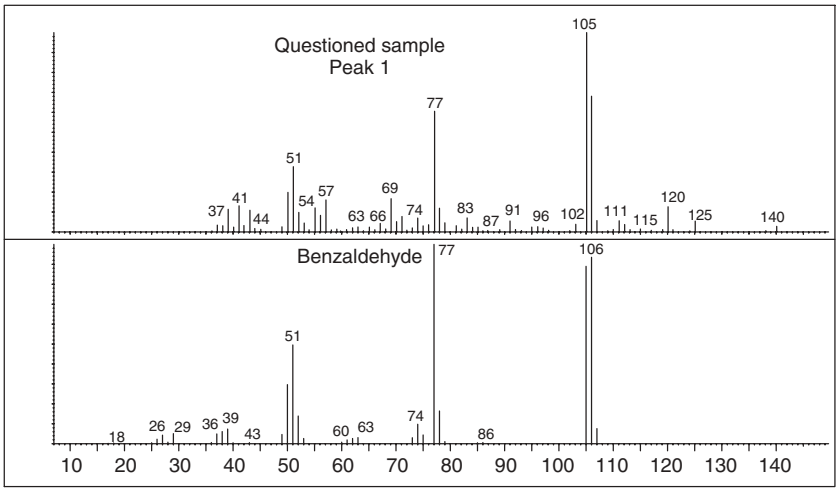

(b)

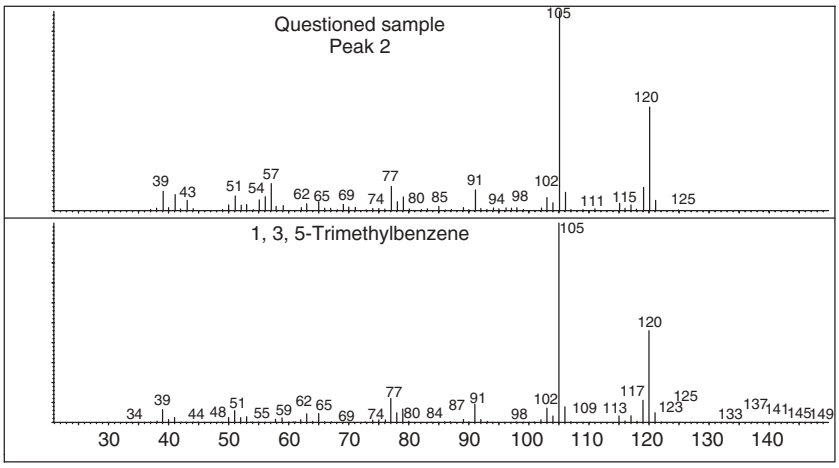

(c)

Figure 3.14 (*Continued*) The mass spectra shown in parts (b) to (e) show that two of the peaks, 1 and 3, were not gasoline components (b). Mass spectrum and library match of the first peak in the top chart shown in part (a). This peak actually represents benzaldehyde, not *m*-ethyltoluene. (c) Mass spectrum of the second fully resolved peak in the top chart shown in part (a). As with gasoline, this peak is identified as 1,3,5-trimethylbenzene (d). Mass spectrum of the third major peak in the chart shown at the top of part (a). This mass spectrum changed across the peak but clearly contained α-methylstyrene. 1-Decene, a common decomposition product, was also suggested by the spectrum. There may be some *o*-ethyltoluene coeluting as well, but that cannot be demonstrated (e). Comparison of the mass spectrum fourth peak in the chart shown in part (a) with 1,2,4-trimethyl benzene (pseudocumene). This is a reasonably straightforward match.

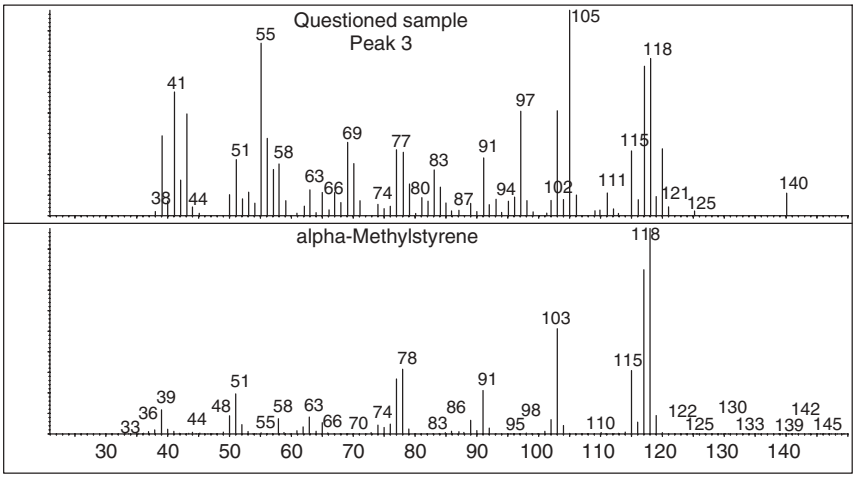

(d)

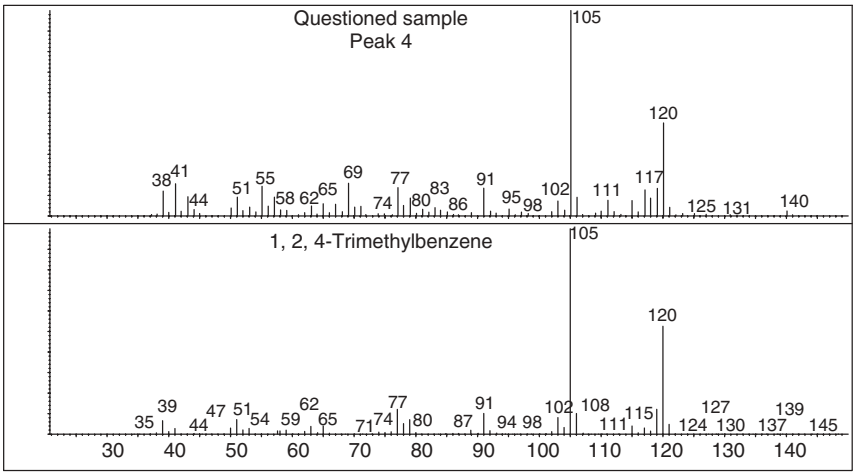

(e)

Figure 3.14 (*Continued*)

presence of ∝-methylstyrene, a common pyrolysis product. Phenol, which exhibits a base peak at 94, is also a confounding compound that elutes in the range of the five-peak group. *Simply matching the components when the ratios are not right can lead to misidentifications*. The odds against three background components coeluting in exactly the right concentrations to skew the peaks in this group are pretty high. Three other samples from the same fire scene were similarly misidentified, and exhibited similar peak ratios and mass spectral characteristics. As with almost all

misidentifications, there was not a good pattern match with the TIC. Extracted ion chromatography or extracted ion profiling can be very useful; however, the analyst should remember that it is a spectral as well as a chromatographic technique. The individual mass spectra should be examined, especially when the peak ratios are "off."

A word about the use of the mass spectrometer beyond generating mass chromatograms is in order. Most analysts will use the mass selective detector or mass spectrometer as a tool for generating extracted ion chromatograms and extracted ion profiles. Obviously, if one is looking at very simple mixtures or single components, the mass spectrum is necessary in order to make an identification. A sometimes-overlooked function of the mass spectrometer is the evaluation of extracted ion chromatograms and profiles. As we saw in Figure 3.14(a), an extracted ion chromatogram with the intragroup ratios just slightly "off" has the potential to be misleading. Figure 3.14(b) to (e) show the mass spectra of each of those five peaks, as well as the library's best match. The first peak, which is coincident with *m*-ethyl toluene, has a large peak at m/z 77, but no such ion is present in the spectrum of *m*-ethyl toluene. There may be some *m*-ethyl toluene hidden under this peak, but there is definitely some benzaldehyde as well.

One way to determine whether there are coeluting compounds under a chromatographic peak is to examine the mass spectra at different points across the peak. If the peak represents a pure compound, the mass spectrum will change little, if at all. In Figure 3.14(c), the second peak in the five-peak group is a nearly-perfect match for 1,3,5-trimethylbenzene, which is the third peak in the five-peak group required to identify gasoline. The third peak, whose mass spectrum is shown in Figure 3.14(d), clearly contains more than one substance, but the strong peak at 118, as well as the retention time, indicates that α-methylstyrene is coeluting. Like the second peak, the fourth peak is a pure compound and a nearly perfect match for pseudocumene. (The mass spectra of all of the aromatics in this group are quite similar. In fact, using a library search usually results in a list of match candidates that includes all four members of the group.) Because the peak ratios are off, and especially because two of the four peaks in the ion 105 chromatogram represent compounds not found in gasoline, it must be concluded that the first identification was in error.

Background subtraction is a tool found in most data analysis software and can frequently resolve questions as to whether a particular compound is really there. A detailed evaluation of the quality of the spectra underlying a mass chromatogram, whether it is a single-ion extraction or a multiple-ion profile, should be carried out periodically just to keep the analyst in practice, but it should be carried out routinely on any sample where either the peak ratios or retention times are "just a little off." Note in Figure 3.14(a) that when a sample is sufficiently evaporated, the peaks at the left side of the chart begin to diminish. This result is expected. The initial guidelines for identifying gasoline stated that the *m*-ethyl toluene/pseudocumene

five-peak group was still present in gasolines that had lost 90% of their fresh weight. In fact, this group does not disappear until the gasoline is more than 98% evaporated. If this group cannot be positively identified, an analyst is on very thin ice indeed when identifying a sample as containing gasoline. In such a case, there must be a peak-for-peak match of all of the higher peak groupings. As with many of the other components of gasoline, this five-peak group is present in almost all petroleum products from which the aromatics have not been removed. The bottom chart in Figure 3.14(a) is from unevaporated diesel fuel.

The C_4 alkyl benzenes are best viewed by extracting ion 119. Because there are more ways to build a C_4 alkyl benzene than a C_3, this is a more complex pattern, but it is present in almost all petroleum products. Figure 3.15 shows the patterns found in highly evaporated gasoline, as well as in kerosene and diesel fuel, which are produced by the presence of the C_4 alkyl benzenes. Note that in kerosene and diesel fuel, this pattern is more complex than in gasoline.

The next group of compounds that must be present in order to make a solid identification of gasoline is the indans. These can be extracted using ions 117 and 131. The doublet at 11.3 and 11.5 min in the ion 117 chart is, in this analyst's experience, always present. It has traditionally not been an absolute requirement of the ASTM standards, but it probably should be. The standard states, "Indan (dihydroindene) and methylindans are usually present." The first tall peak in the 117 chart is indan, appearing at 9.4 min. Figure 3.16 shows the peak groupings characteristic of gasoline for the indans, methylindans, and dimethyl indans. Like the C_3 alkyl benzenes, the indans and alkyl-substituted indans can be found in roughly the same proportions in gasoline that is 98% evaporated. Other petroleum products, particularly the distillates, contain indans and methylindans, but their mass chromatographic patterns are more complex than the ones for gasoline.

The next group of compounds that should be present in a sample identified as containing gasoline is the methyl- and dimethylnaphthalenes. Naphthalene is also present, but naphthalene is so common that its presence in a sample is meaningless. 2-Methylnaphthalene elutes before 1-methylnaphthalene and is almost always more abundant than the 1-methylnaphthalene. In any case where this ratio is reversed, the extract should be considered suspect. The boiling point of the methylnaphthalenes is high enough that the ratio, unlike xylenes or C_3 alkyl benzenes, is unlikely to be affected by evaporation. All petroleum products are likely to contain both the naphthalenes and the dimethylnaphthalenes, and the ratios should be highly comparable to each other.

There are some aromatic products in the marketplace that meet almost all of the ASTM criteria for the identification of gasoline. Such products are used as solvents for stains, insecticides, adhesives, and industrial and commercial products. The way to differentiate these aromatic products from gasoline is to look for the presence of alkanes. All gasolines contain high percentages of alkanes when fresh, but even highly evaporated gasolines will contain some branched alkanes. Straight-chain hydrocarbons are an unusual finding in gasoline, because they are undesirable components that cause knocking when burned in gasoline engines. [Knocking is

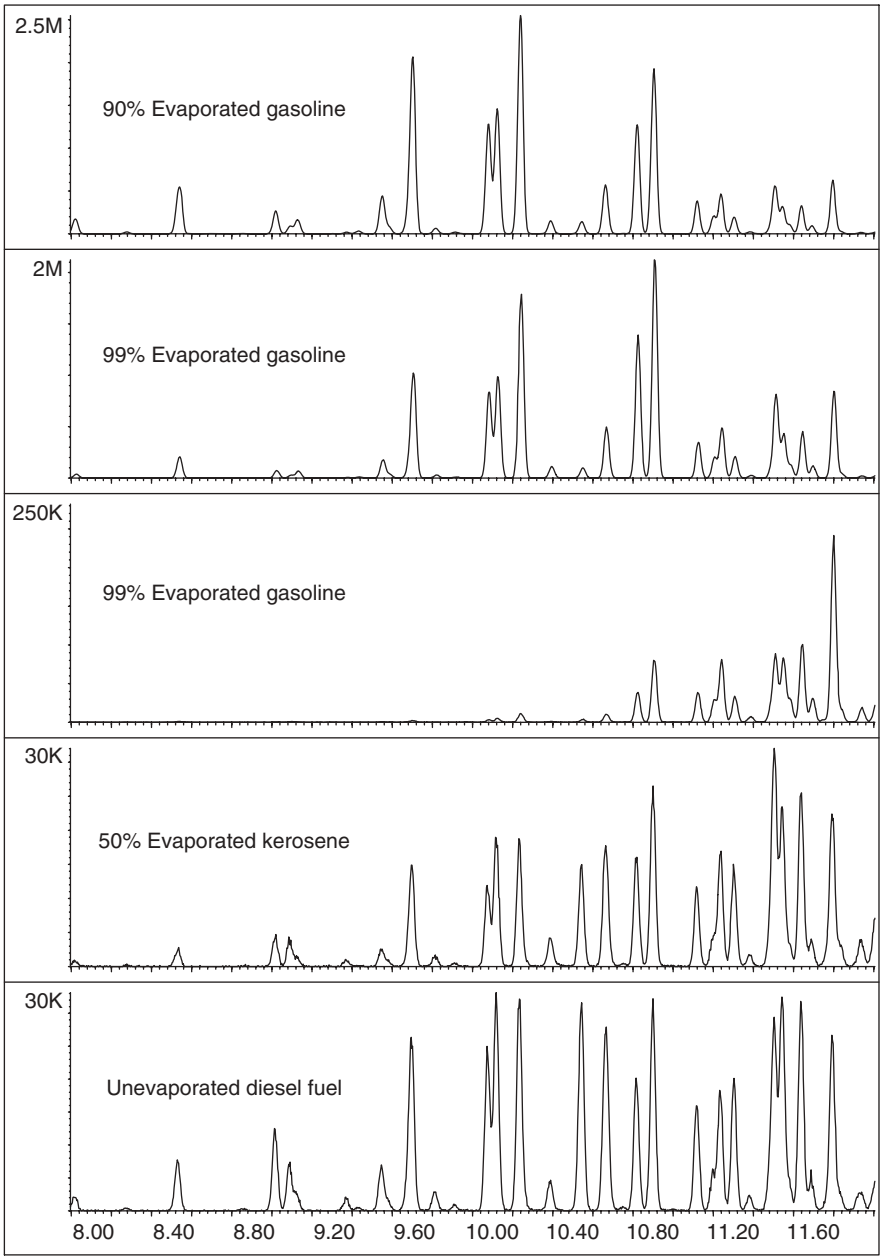

Figure 3.15 C_4 alkylbenzenes represented by ion 119 in gasoline in three different stages of evaporation, 50%-evaporated kerosene, and unevaporated diesel fuel. All samples were prepared by spotting 10 μL on a piece of filter paper, and processed using ACS adsorption–elution.

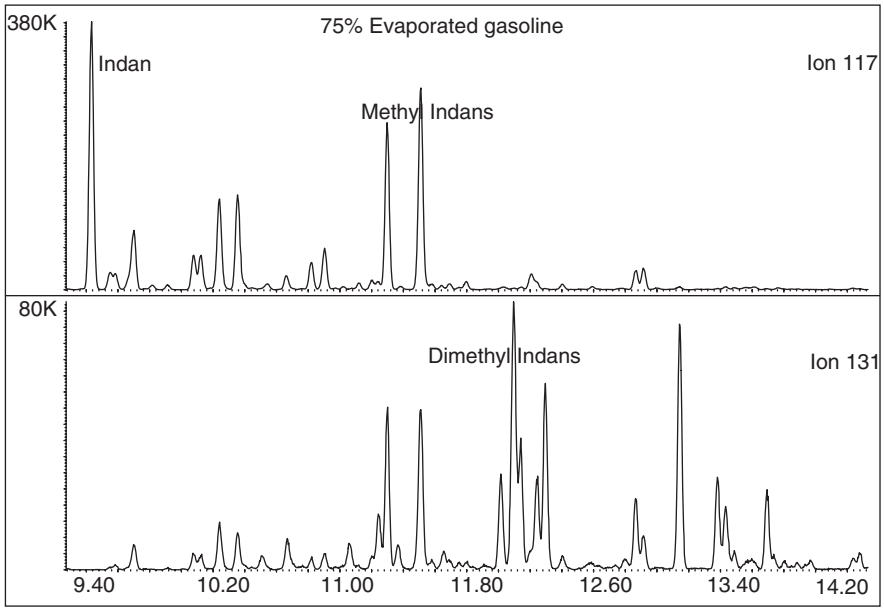

Figure 3.16 Ion chromatograms for indan, the methylindans, and dimethylindans found in 75%-evaporated gasoline.

the premature detonation of a fuel and occurs more readily with straight-chain hydrocarbons than with branched-chain hydrocarbons or aromatics. Resistance to knock is known as the *octane rating*. Octane rating is based on a scale of 0 to 100, where 0 is the resistance to knock of 100% *n*-heptane and 100 is the resistance to knock of 100% iso-octane (2,2,4-trimethylpentane). *N*-Octane actually has an octane rating below zero.]

Identification of Distillates Most distillates likely to be encountered in fire debris are straight-run distillates from crude oil. They have not been subjected to cracking or reforming, so they lack the high aromatic content found in gasoline, but aromatics are still present. The distillates are characterized by an abundance of normal alkanes, along with branched alkanes and cycloalkanes.

Distillates are usually easy to recognize, except for light petroleum distillates, which might be missed unless the analyst checks for them in every sample before calling it negative for ILR. Because of their high volatility, they tend to be present at low concentrations in fire debris samples and are typically found on the left side of the chart, where they may be mistaken for decomposition products. This is a particular hazard when the higher-boiling components are decomposition products. Light petroleum distillates (LPDs) do not generally exhibit the Gaussian distribution seen in medium and heavy petroleum distillates (MPDs and HPDs). When the peaks that elute prior to 8 min are examined, and the analyst sees a mixture of cycloalkanes, branched alkanes, and perhaps some normal alkanes in the C_7

through C_9 range, an LPD should be suspected. The analyst should have in the library as many LPDs as possible, because unlike the heavier distillates, the patterns tend to vary from one to the other,. Figure 3.17(a) shows three different brands of cigarette lighter fluid, each exhibiting a different pattern of peaks. The recommended extracted ion profiles for LPDs are 57, 55, 83, and 91, which can be seen in Figure 3.17(b). This particular LPD is unusual in that it contains xylenes but no toluene is present. Because of their high volatility, LPDs are not persistent in the environment and are not usually expected to be found as background material. There are some cleaning agents and automotive products that contain LPDs, but if the sample was collected from somewhere other than the garage, the workshop, or under the kitchen sink, a finding of LPD generally indicates the presence of a foreign ignitable liquid.

This is not the case with medium or heavy petroleum distillates, which are far more common in our environment (Lentini et al., 2000). A typical medium petroleum distillate, Sparky charcoal lighter fluid, is shown in Figure 3.18(a). The ions necessary to make a valid identification of a medium petroleum distillate are 57 and 83, shown in Figure 3.18(b). The analyst should also check for ion 105 or 91, to be certain that the aromatics have not been removed, in which case the ILR can be identified as a dearomatized distillate. One does not notice much difference between the TIC and the ion 57 EIC, because distillates are dominated by the normal and branched alkanes. The alkylcyclohexanes, which elute about midway between the normal alkanes, present an overall appearance similar to that of the alkane chromatogram. If the normal alkanes are not present, or if they are present

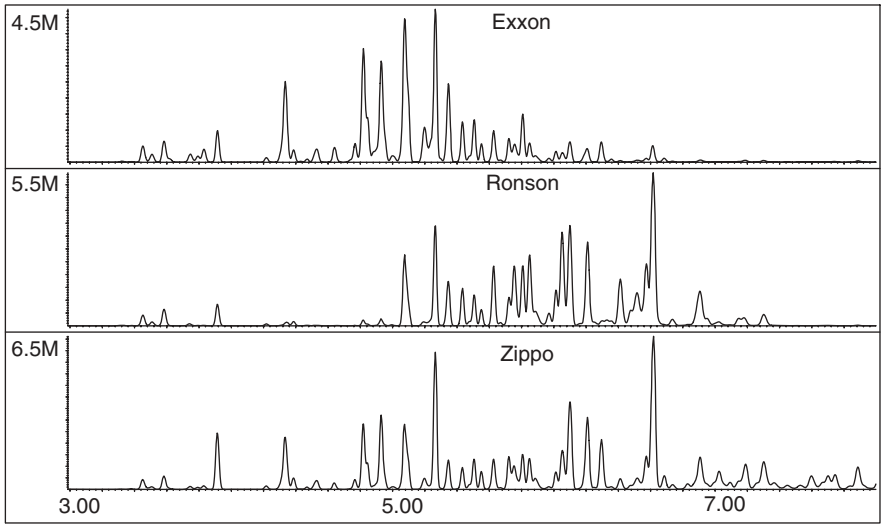

(a)

Figure 3.17 (a) Total ion chromatograms of three different brands of cigarette lighter fluid. (b) Ion chromatograms of ions 57, 55, 83, and 91 from a standard of Ronson lighter fluid.

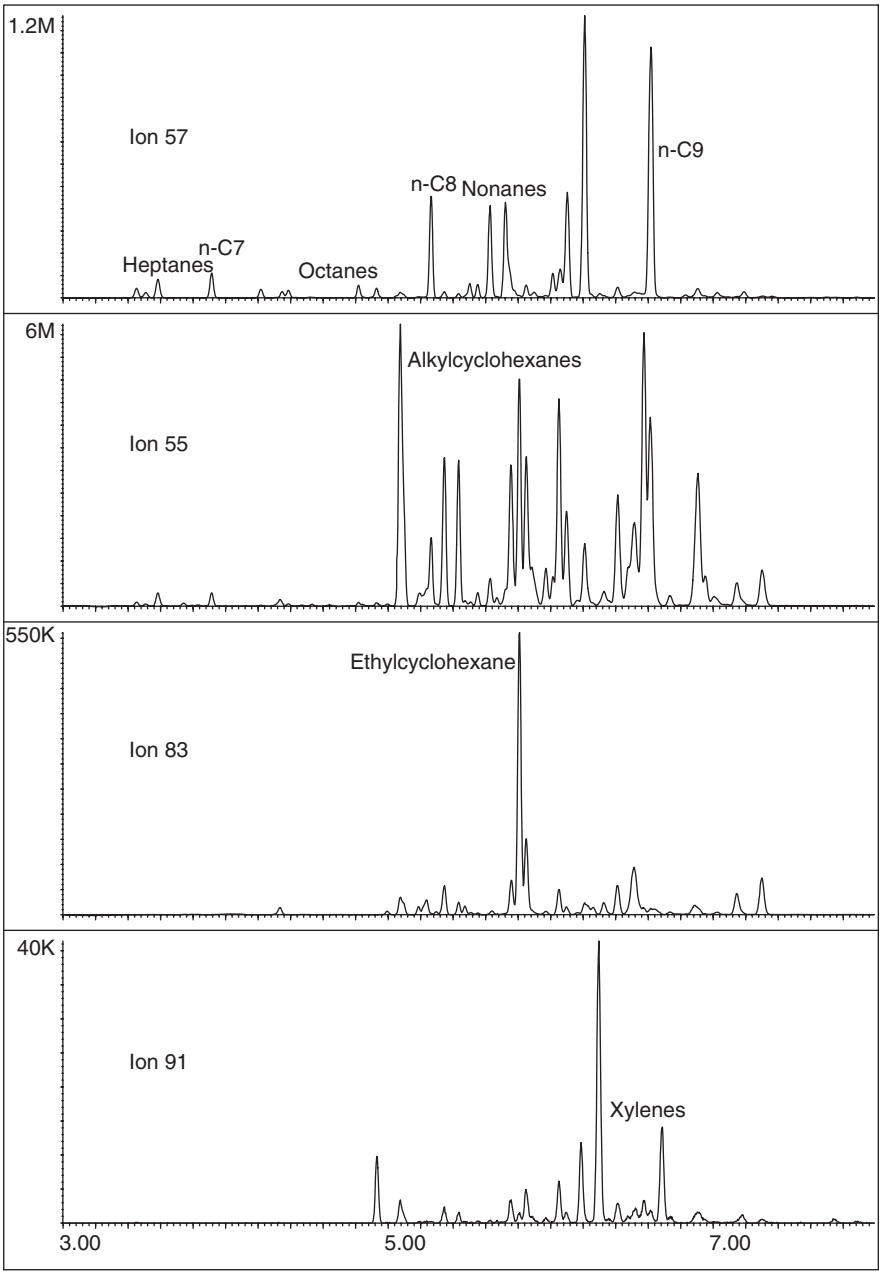

(b)

Figure 3.17 (*Continued*)

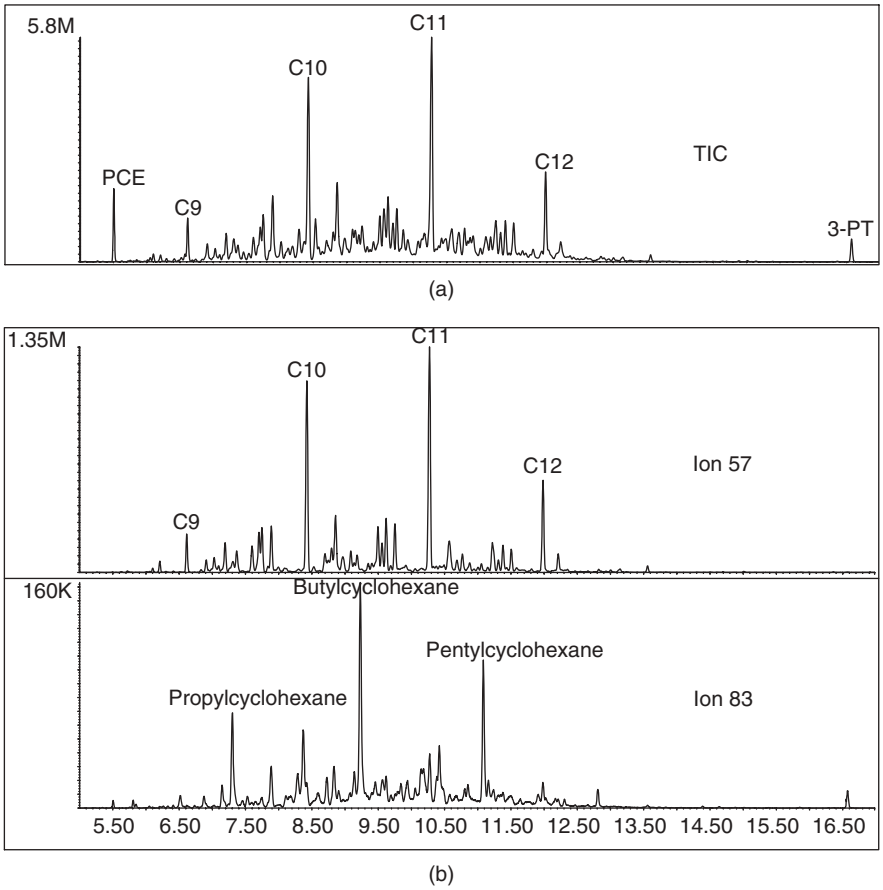

Figure 3.18 Total ion chromatogram of (a) a typical medium petroleum distillate, Sparky charcoal lighter fluid, and (b) extracted ion profiles for ions 57 and 83.

at approximately the same concentration as the branched alkanes, an isoparaffinic product should be suspected. When the cycloalkanes are present at an abundance greater than about 20% of the abundance of the alkanes, a naphthenic–paraffinic source is indicated. In most distillates, the cycloalkanes will be present at about 5 to 10% of the concentration of the normal and branched alkanes. Medium petroleum distillates cover a wide range of products and may be used as fuels, such as lamp oil or charcoal starter, or as solvents, such as mineral spirits or insecticide carriers. This wide range of products and formulations requires that the library of reference materials include numerous MPDs.

Heavy petroleum distillates (HPD) include kerosene and diesel fuel. Except for HPDs that are formulated for specific applications, such as jet fuel, the carbon number range of heavy petroleum distillates can vary. Thus, unless one has a sample of the unevaporated liquid, it is difficult to determine the degree of evaporation

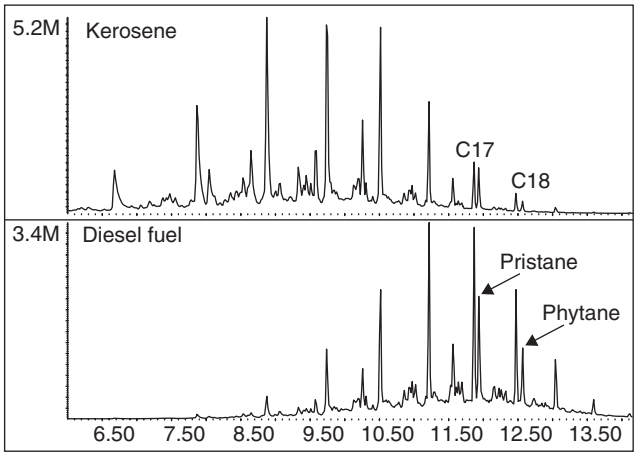

Figure 3.19 Total ion chromatograms showing a comparison of kerosene and diesel fuel.

of the residue isolated from a sample. In northern parts of the country, diesel fuel sold in the winter may actually be kerosene.

Figure 3.19 shows a comparison of kerosene and diesel fuel. These distillates come with internal carbon number markers, in the form of pristane and phytane. Pristane is 2,6,10,14-tetramethyl pentadecane ($C_{19}H_{40}$) and it elutes immediately after normal heptadecane. Phytane is 2,6,10,14-tetramethyl hexadecane ($C_{20}H_{42}$) and it elutes immediately after normal octadecane. (Although pristane and phytane elute immediately after two normal hydrocarbons, they come from different sources. The n-alkanes started out as fatty acids, but pristane and phytane started out as parts of the chlorophyll molecule.) Thus, one can identify the two doublets on the high side of the bell-shaped curve and can count carbons up and down from there. In Figure 3.19 these doublets occur at 12 and 12.5 min. Kerosene, which is a known standard that has been evaporated to 50% of its original volume, covers the range C_{11} to C_{19}, while the diesel fuel range is C_{12} to C_{21}. If the kerosene is evaporated further, it will look more like the diesel fuel. Had the diesel fuel been evaporated less, it would look more like the kerosene.

As with the medium petroleum distillates, interpretation of a finding of heavy petroleum distillates should be approached with caution. There are numerous household products that contain HPDs, including many of the same kinds of products in which MPDs are found. The safer charcoal lighters are made from kerosene rather than mineral spirits. They are safer because of their higher flash point. Figure 3.20 shows a total ion chromatogram of lemon oil furniture polish. This polish has a carbon number range from C_{12} to C_{22}, with C_{17} being the tallest peak on the chart. The limonene peak at the left side of the chart could easily be attributed to a pine substrate. Pinenes and limonene are very common in samples containing structural (coniferous) wood. If found in a fire debris sample, this particular furniture polish could easily be misreported as diesel fuel.

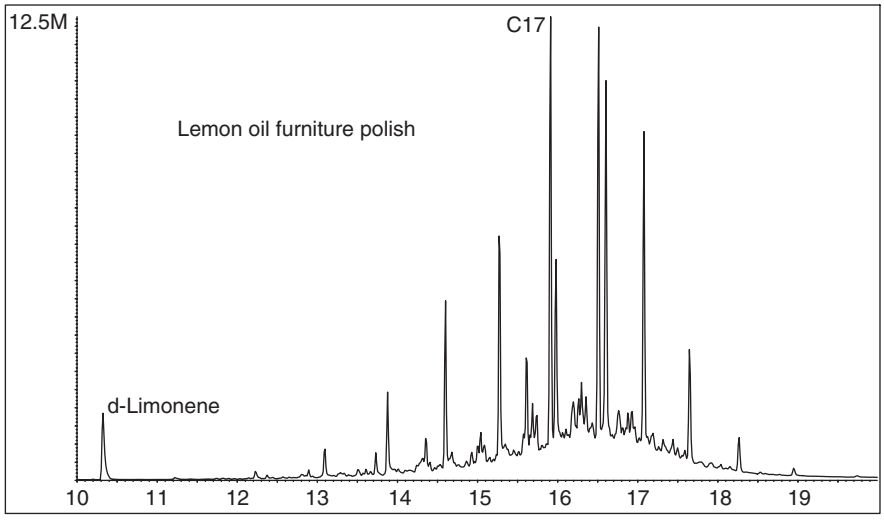

Figure 3.20 Total ion chromatogram of lemon oil furniture polish. This sample could easily be reported out as diesel fuel.

It is not necessary for a liquid to be present in order for a distillate to be detected. Figure 3.21(a) shows the total ion chromatogram of a piece of pine wood that was stained with Minwax finish 10 months before it was subjected to headspace concentration. The naturally occurring terpenes, α- and β-pinene and *d*-limonene, are the dominant peaks on the chart, but the mineral spirits solvent is still clearly visible. When ions 57 and 83 are extracted, the terpenes disappear, to yield the charts shown in Figure 3.21(b). These results show the critical necessity of asking for comparison samples, particularly when samples of flooring are submitted for analysis. The flooring does not need to be recently painted to exhibit the distillate solvent used to apply the floor coating. This author has reported finding distillates 24 months after application (Lentini, 2001) and has detected distillates in samples of finished flooring and furniture up to 10 years old. There is no reason to believe that these solvents do not persist indefinitely, trapped in either the wood matrix or in the polymer coating matrix.

In addition to true distillates, there are some distillate-like residues produced as the result of decomposition of other products. Asphalt is what is left at the bottom of the distillation pot after all of the volatiles have been distilled from crude oil. It contains hydrocarbons ranging from C_{30} to C_{60}. When these long-chain hydrocarbons undergo pyrolysis, they do so in much the same way as that of the long-chain hydrocarbons in polyethylene, via random scission. This results in the production of normal alkanes in the range C_9 to C_{18} (Lentini, 1998). When these pyrolysis products are present in fire debris and subjected to headspace concentration, they produce a chromatogram that can be and has been mistaken for the chromatogram of a heavy petroleum distillate. Such a chromatogram is shown in Figure 3.22(a). In 1982 it was reported that roof shingles could produce "accelerant-like residues,"

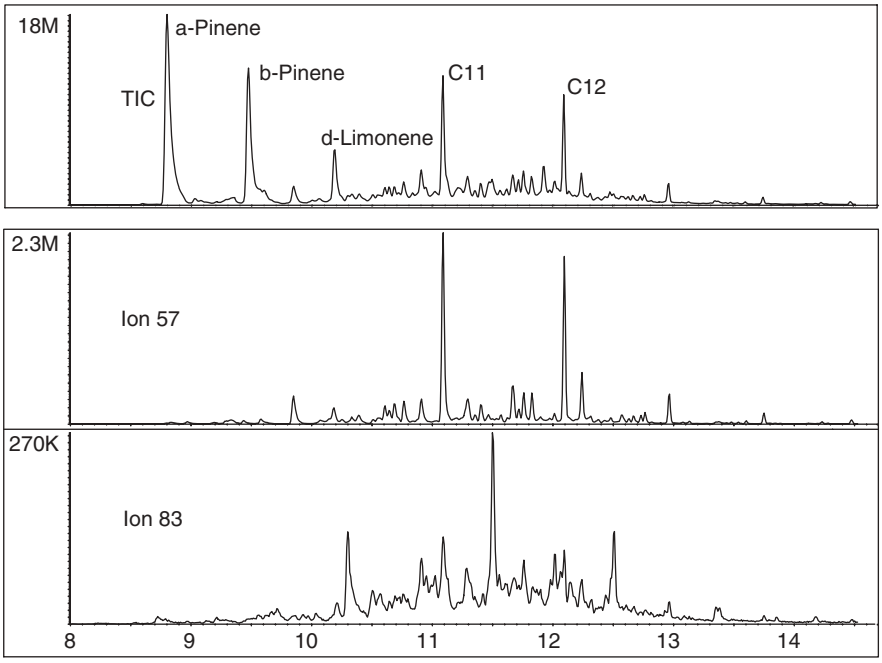

Figure 3.21 Total ion chromatogram of (a) a piece of pine wood stained with Minwax Finish 10 months prior to its analysis, and (b) extracted ion profiles for ions 57 and 83.

and at that time, there existed no reliable methods for distinguishing HPDs from asphalt shingle residues (Lentini and Waters, 1982). The increased use of capillary columns allowed for the occasional visualization of a "double-peak kerosene," sometimes called "pseudokerosene," but even with capillary columns, it was not uncommon for asphalt residue to be misidentified as a liquid petroleum distillate. This author learned how to make the differentiation in 1995 in connection with the investigation of an insurance claim that had been erroneously denied because of a finding of HPDs where none should have been present. Figure 3.22(b) shows how the distinction is made. One compares ion 57 with ion 55. If a second peak appears in front of the *n*-alkane peak, or if a small peak grows larger, we can conclude (particularly after we collect the mass spectrum) that the second peak is the 1-olefin. A sample such as this must be classified as asphalt smoke condensate or asphalt decomposition residue.

The amount by which the olefin peak "grows" will vary depending on the sample. When one looks at kerosene and diesel fuel, the only difference in appearance between the ion 55 chart and the ion 57 chart is that the abundance of ion 55 is lower. The relative abundances of the individual peaks with respect to each other do not change.

Another way to distinguish asphalt decomposition products from HPDs is to look for the cycloalkanes. They are not present in asphalt decomposition products. A Gaussian pattern will be observed when ion 83 is extracted, but this is due

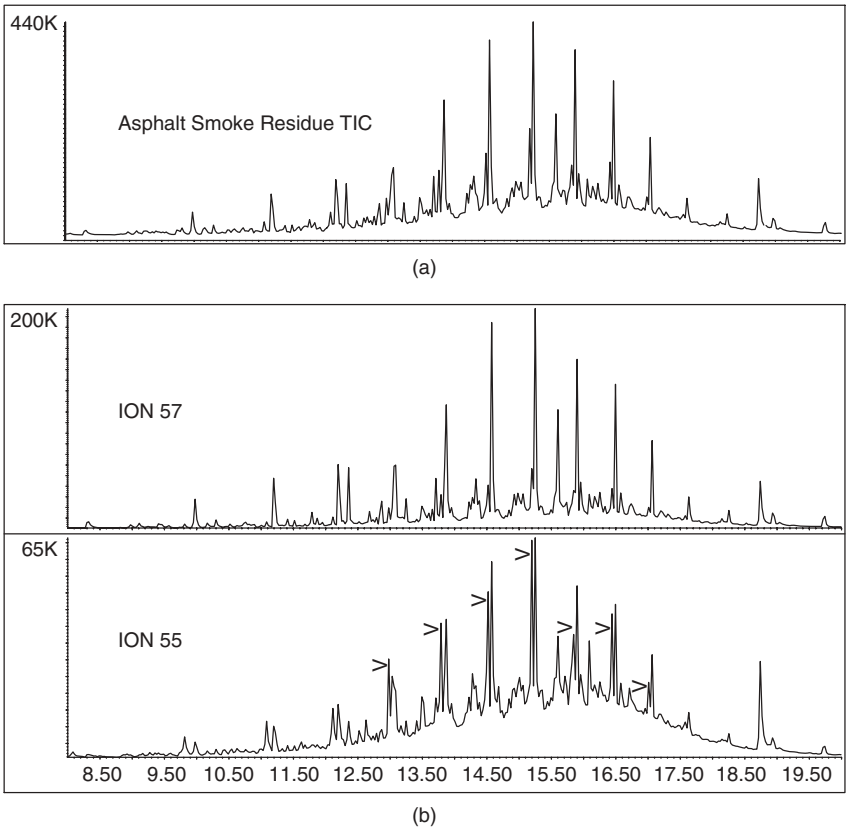

Figure 3.22 Total ion chromatogram of (a) asphalt smoke residue of the type that can be mistaken for a petroleum distillate, and (b) extracted ion profiles for ions 57 and 55. The growth of the peak in front of the normal alkane when comparing 55 to 57 demonstrates the presence of alkenes, which allows the identification of the residue as a decomposition product rather than a foreign petroleum distillate.

entirely to the presence of the olefins. The ion 83 and ion 55 ion chromatograms show the same peaks. Asphalt smoke condensates also contain little if any pristane and phytane.

Polyethylene is another substance that produces a distillate-like appearance in the chart, but if the capillary column has any resolution at all, it will be obvious that one is looking at polyethylene residue rather than at a distillate. Figure 3.23(a) shows the total ion chromatogram of polyethylene smoke condensate. All of the peaks are doublets and most are actually triplets, owing to the presence of the 1,($n - 1$)-diene in the mixture. When one looks at ion 57 and compares it with ion 55, as shown in Figure 3.23(b), the growth in the olefin peak is obvious relative to the alkane peak. The diene peak also grows, because the dienes contain more ion 55 than ion 57. Lubricating oils are subject to the same decomposition processes as asphalt and polyethylene, and the smoke condensates of lubricating oils appear similar.

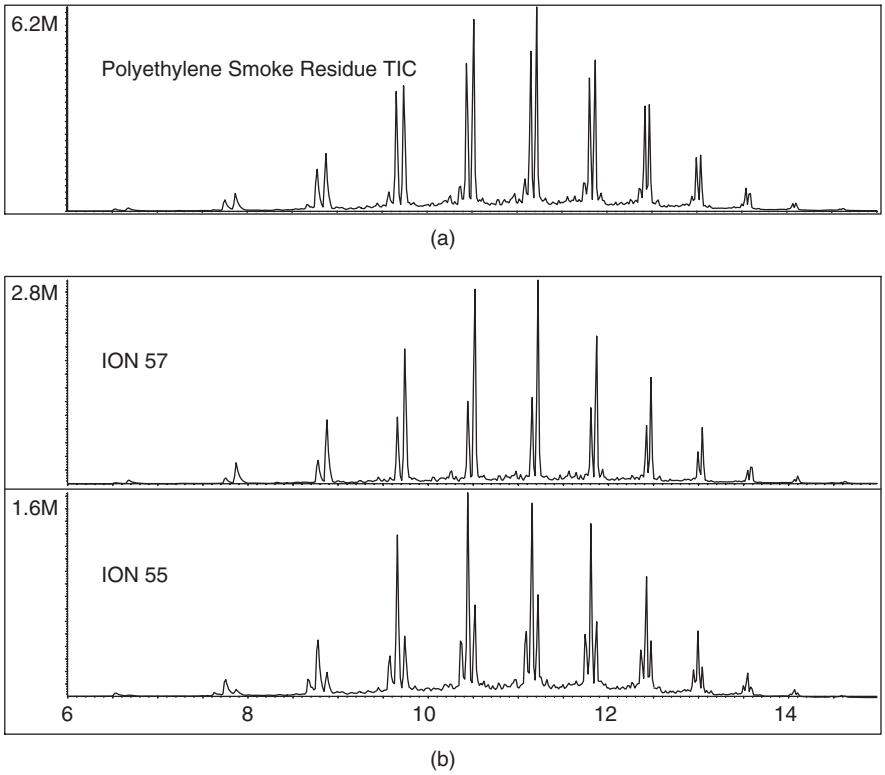

Figure 3.23 Total ion chromatogram of (a) polyethylene smoke condensate. The first peak in each doublet is the alkene; the second is the alkane. Pristane, phytane cycloalkanes, and aromatics are all absent. (b) Ion 57 EIC, and (c) ion 55 EIC. In the ion 55 chromatogram, a third peak, representing the n, $(n-1)$-diene, appears.

A careful examination of the chromatographic and mass spectral data will prevent the analyst from misidentifying decomposition products as distillates, but automation of pattern recognition is coming and presents some dangers if not handled properly. As with all computer "answers," one should always do a "reality check." The same pattern recognition software that allows a mass spectrum from an unknown compound to be matched against the spectra of 100,000 compounds can be applied to chromatograms. The chromatogram is converted using Microsoft Excel into a bar graph that has the same general appearance as a mass spectrum. This graph can then be compared against a library of known ignitable liquids that have been transformed similarly. As with the mass spectral libraries, "extra" peaks do not necessarily keep the database from recognizing a "match." The polyethylene smoke condensate chart shown in Figure 3.23(a), matched up against a database that contains only ignitable liquids, will yield a match of exceptionally high quality for diesel fuel. This is why it is necessary to populate ignitable liquid libraries used for this purpose with known background chromatograms. The chart would make

an even better match for polyethylene smoke condensate, but only if it is available in the database.

Identifying Other Classes of Products The remaining classes of ignitable liquid residues can frequently be identified by what is and is not present. A dearomatized distillate, for example, will have a signal from the aromatics that is less than 1% of the signal from the aliphatics. Otherwise, it will look the same with respect to both the alkanes and the cycloalkanes. Because of environmental regulations governing the aromatic content of distillates, there has been, since 1973, an ASTM standard for this determination. ASTM D3257-07 is entitled *Standard Test Methods for Aromatics in Mineral Spirits by Gas Chromatography* (ASTM D3257-07, 2007) and uses a specified test blend for calibration. If the calculation of aromatic content is an issue, a forensic scientist might avoid a *Daubert* challenge by using this established method rather than by devising a new one.

The normal alkane products are very easy to recognize, as long as one makes sure that one is looking at a homologous series of normal alkanes as opposed to a homologous series of aldehydes or some other group of homologues that are pyrolysis or decomposition products. Groups of compounds that differ from each other only in that they have one additional CH_2 group look pretty much the same as a series of normal alkanes, and require some caution. Figure 3.24 shows a series of normal alkane products marketed by Exxon, as well as a sample of Lamplight Farms ultrapure lamp oil, which also consists of normal alkanes. One common source of normal alkanes is carbonless forms (NCR paper). The bottom chromatogram in Figure 3.24 shows the chromatogram of concentrated headspace vapors from a 2-in. $\times$ 2-in. square of a carbonless form. These forms contain microspheres filled with normal alkane solvent that, when broken, causes color to develop in the ink. There are only a few microliters per square foot, but this concentration is easily detectable. Figure 3.25 is a scanning electron micrograph, showing the bottom side of a carbonless form. It should be noted that the alkanes found in carbonless forms are usually accompanied by a pair of substituted biphenyls. Normal alkane products are also found in some brands of linoleum floor covering. Any time that a sample is collected from a floor likely to have linoleum in its structure (kitchen, bathroom, laundry room), a finding of normal alkanes is probably not meaningful. A comparison sample is an absolute necessity in such cases.

Isoparaffinic hydrocarbons are made by removing the normal hydrocarbons with a molecular sieve. These liquids are becoming more common as petrochemical manufacturers move to more environmentally friendly and odor-free replacements for the straight-run distillates, such as mineral spirits. Similar to the isoparaffinic hydrocarbons are the naphthenic–paraffinic products, which are characterized by an abundance of cycloalkanes. Whereas one might expect to find cycloalkanes present at less than 5% in the isoparaffinic hydrocarbons, they may be present at up to 30% in naphthenic–paraffinic products. The distinction requires looking at the ion profiles for the cycloalkanes versus the alkanes, as well as looking at the abundance numbers on the left side of the chart. Figure 3.26 shows a comparison

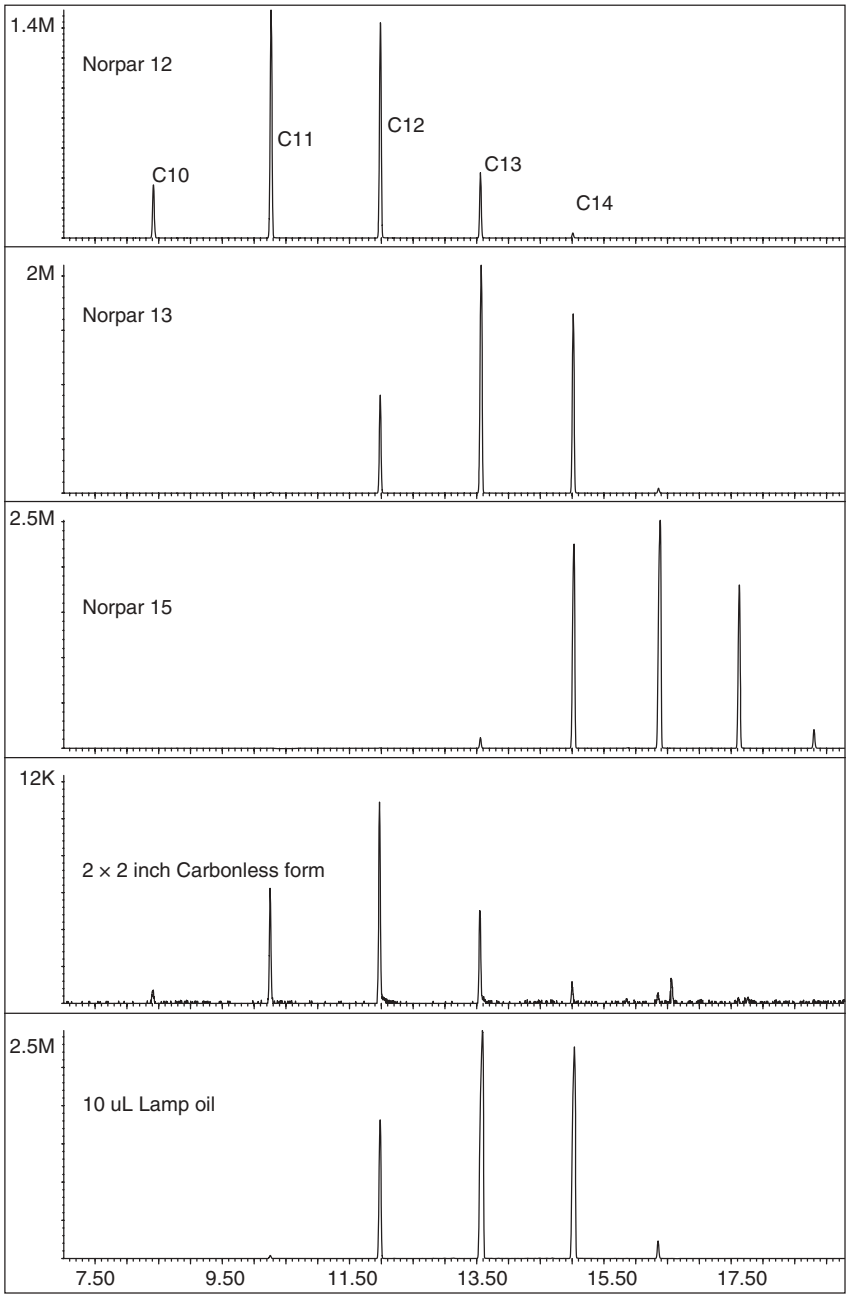

Figure 3.24 Ion 57 chromatogram of three Exxon Isopar products, compared with an ACS extract from a carbonless form, and the ACS extract of a 10-μL sample of Lamplight Farms ultrapure lamp and candle oil.

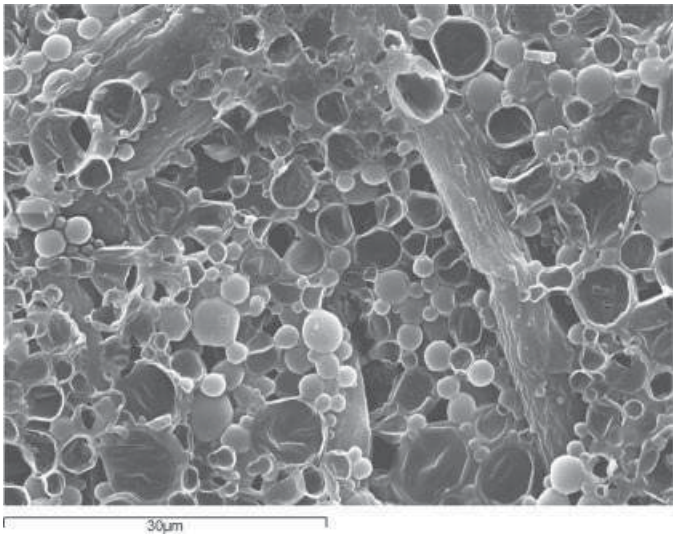

Figure 3.25 Scanning electron micrograph of the underside of a carbonless form. The microspheres range in size from 2 to 20 µm and are filled with normal alkanes.

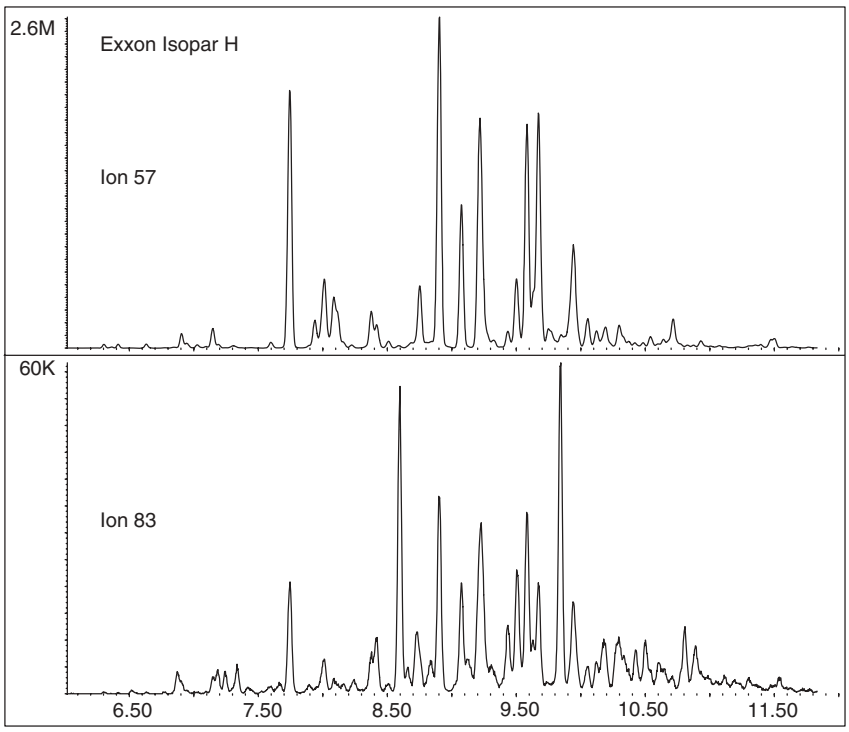

Figure 3.26 Comparison of the alkane (ion 57) and cycloalkane (ion 83) chromatograms from Exxon Isopar H. The cycloalkane peaks are only about 2% of the height of the branched alkane peaks.

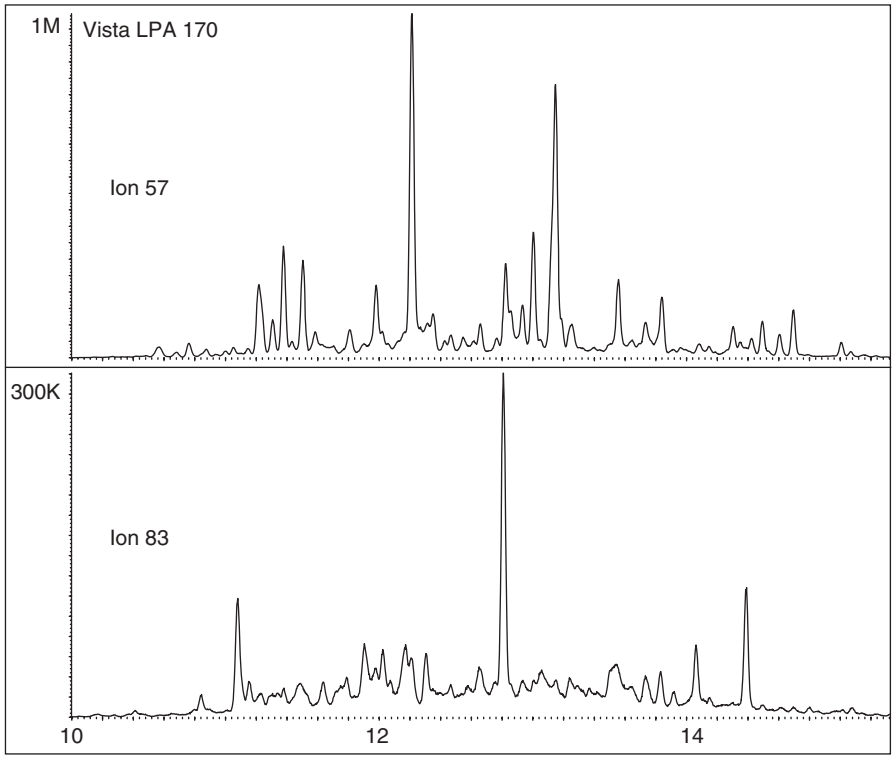

Figure 3.27 Comparison of the alkane (ion 57) and cycloalkane (ion 83) chromatograms from Vista LPA 170, a naphthenic–paraffinic product. The height of the cycloakane peaks is about 30% of the height of the branched alkane peaks.

of the ion 57 and ion 83 chromatograms from Isopar H, a common solvent used in cosmetics and other household products. Compare this to Figure 3.27, which compares those same ion chromatograms from a naphthenic–paraffinic solvent, Vista LPA 170. Instead of having an ion 83 chromatogram that is 2% the height of the ion 57 chromatogram, the ion 83 is more than 30% of the height of the ion 57 chromatogram in the naphthenic–paraffinic solvent. Also, note that the tall peaks in the ion 57 chromatogram from the naphthenic–paraffinic product are not normal alkanes, but are branched alkanes.

Another way to make the distinction between the isoparaffinic products and the naphthenic–paraffinic products is to take an average mass spectrum. Representative isoparaffinic products are shown in Figure 3.28. A average mass spectrum of any of these looks very much like the mass spectrum of a single alkane. Ion 57 is the base peak, and the other fragments are spread out in a Gaussian distribution with a spacing of 14 mass units between them. A typical isoparaffin average mass spectrum, that of Isopar L, taken over a 3-min portion of the chromatogram, is shown in Figure 3.29.

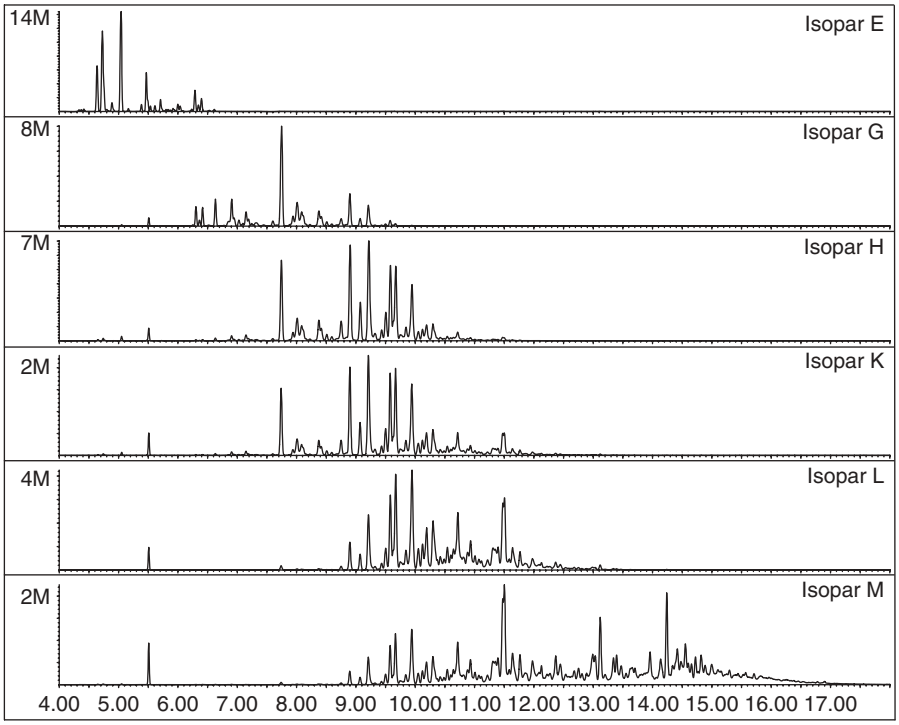

Figure 3.28 Total ion chromatograms of six isoparaffinic hydrocarbon products, Exxon Isopars E, G, H, K, L, and M.

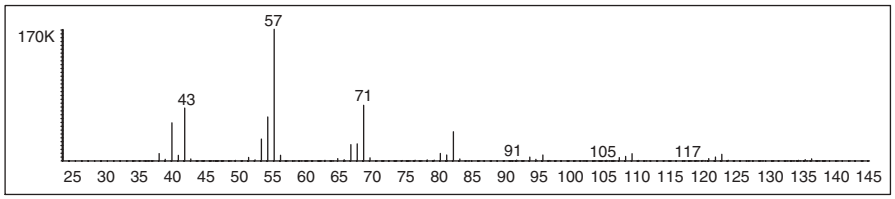

Figure 3.29 Average mass spectrum taken from Isopar L, over the range of 9 to 12 min. This spectrum has an appearance very similar to that of a branched alkane.

The same exercise can be performed on the naphthenic–paraffinic products, several of which are shown in Figure 3.30. The average mass spectrum of a typical naphthenic–paraffinic product, shown in Figure 3.31, looks quite different from that of the isoparaffinic product. While it still exhibits a base peak of 57, there will be a greater abundance of ions 55, 69, and 83 than in the isoparaffinic product.

The identification of other ignitable liquid residues requires an individual examination of the peaks in the chromatogram. It is possible to find just about any single compound in just about any sample. Findings of alcohols, turpentines,

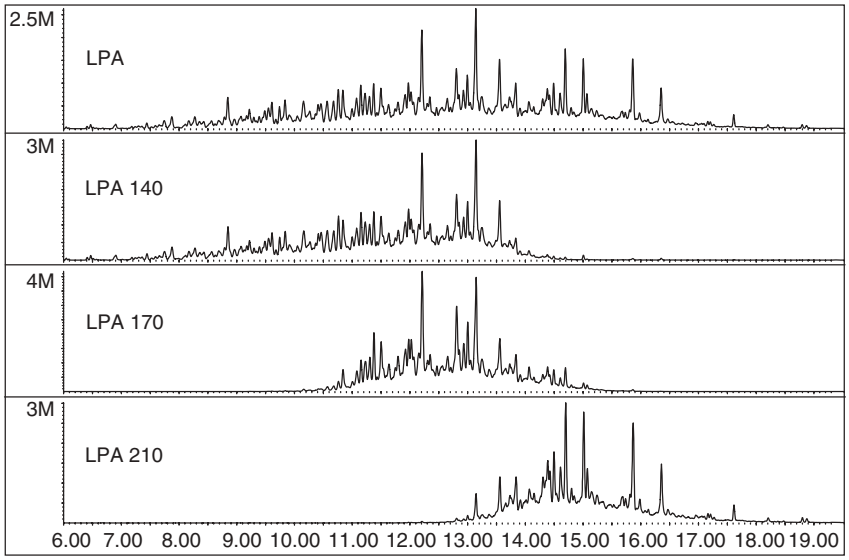

Figure 3.30 Total ion chromatograms of four naphthenic–paraffinic products: Vista LPA, LPA 140, LPA 170, and LPA 210. The numbers in the product names correspond approximately to flash points.

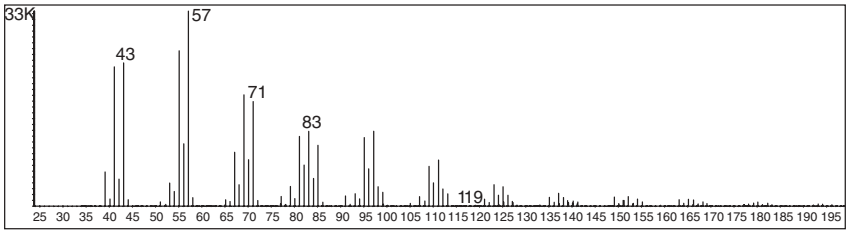

Figure 3.31 Average mass spectrum of Vista LPA taken from 8 to 17 min..

aromatic solvents, and other "flammable" liquids need to be undertaken with great caution. ASTM E1618 recommends not making an identification of these single compounds unless they are present in such concentrations that the signal is *at least two orders of magnitude greater than the background*. Just about every fire debris sample will contain methanol. Just about every fire debris sample will contain toluene. Unless these substances are present at concentrations sufficiently high for the analyst to feel comfortable saying they are not native to the background, they should not be reported.

3.6.2 Improving Sensitivity

The techniques used routinely to isolate and analyze ignitable liquid residues are quite sensitive. In samples with nontenacious substrates, it is possible to detect as

little as one-tenth of 1 μL of ignitable liquid residue such as gasoline in 1 kg or more of debris. The task gets a little more difficult when there are active surfaces in the fire debris, such as charcoal, but an activated carbon strip is more tenacious than most debris that one is likely to encounter.

Before attempting to improve the sensitivity of the detection method, it is useful to have some idea about how much sensitivity one already has. This is best accomplished by preparing serial dilutions of an ignitable liquid with an internal standard, and comparing the signals to those generated by extracts from known amounts of ignitable liquid run through the laboratory's adsorption or elution process. In our laboratory we typically use 10-μL standards. The liquid is applied to a piece of filter paper in a 1-quart can, and the filter paper is subjected to ACS headspace concentration, just like any debris sample. When exposed to 10 μL of 75% evaporated gasoline, a 10 mm × 10 mm carbon strip eluted with 500 μL of diethyl ether spiked with 100 ppm of perchloroethylene yields a concentration of approximately 1000 ppm. This is easily detectable. (This translates to a recovery rate of about 5%; 500 μL at 1000 ppm equals 0.5 μL recovered out of 10 μL placed in the sample can.) One microliter in the sample can yields a concentration of approximately 100 ppm in the eluate: again, very easily detectable. At 0.1 μL (10 ppm in the eluate), the signal is noisy and it becomes difficult to extract acceptable ion chromatograms except for ion 105, showing the C_3 alkyl benzenes. To obtain better ion chromatograms, a number of different strategies can be followed. The lower limit of detection is formally defined as that concentration of analyte that will give a signal that is twice the background level; for this analyst, the detection limit is that concentration of analyte that produces a signal large enough to feel comfortable about a determination. One can lower the detection limit either by increasing the signal or by decreasing the background noise. Increasing the signal can be accomplished in a number of ways. One obvious way is to increase the concentration of the analyte. In the case of fire debris eluates from C-strips, this is accomplished by evaporating off some of the solvent. This strategy is not without its costs. It is time consuming and must be done very carefully if one is to avoid losing the analyte along with the solvent. No heat should be used in this process. At some point, the volume of the solution becomes too small to be handled by an autosampler, and this requires manual injection. Although it can be done, easier ways exist to increase the signal. Another obvious strategy is simply to increase the size of the injection. Normally, we inject 1 μL. When we are looking at samples of low concentration, we inject 2 μL.

One way to increase the signal dramatically is to run the gas chromatograph in the *splitless mode*. (Running splitless is one reason that SPME techniques are so sensitive.) Most laboratories use a split ratio of 20 : 1 to 50 : 1. This dilution of the sample improves resolution. Turning off the split will increase the amount of analyte presented to the detector, and the signal will increase by up to a factor of 10. The only cost is likely to be a small decrease in resolution.

Another way to increase the signal from the ions of interest in order to produce better ion chromatograms is to increase the dwell time, the time that the detector spends looking at a particular ion. This is accomplished by using the selected ion

monitoring (SIM) mode on a quadrupole instrument. In the full-scan mode, we typically look from 33 to 300 amu, resulting in a dwell time of less than 1 ms per ion. If we ask the instrument to look only at the ions in which we are interested, we can increase the dwell time dramatically. The detector response will increase in proportion to the square root of the dwell time (i.e., if one increases the dwell time by a factor of 4, the signal strength will increase by a factor of 2. Our instrument performs 5.24 scans/s in the full-scan mode, resulting in a dwell time of 0.7 ms. In the SIM mode, there is only about one scan per second, resulting in somewhat rougher peaks, but with a dwell time of 50 ms (an increase of about 70-fold), the signal will increase by about a factor of 8. It is not the increasing signal that is the most attractive feature of SIM, however. It is the reduction in noise. "Changing channels" 267 times per scan (1400 times per second) generates an abundance of noise in the instrument. This is known as *housekeeping noise*. If one looks only at the 23 ions listed in Table 3.4, the noise is reduced by a factor of 60 or more.

Figure 3.32 shows a comparison of the noise generated in the full-scan mode versus the noise generated in the SIM mode. It is easy to see that even with a much smaller signal, the peaks of interest will be plainly visible.

The price to be paid for this increase in sensitivity is a decrease in specificity. (There is no such thing as a free lunch.) The mass spectra produced in the SIM mode do not contain enough ions for a library to match. The analyst can, however, make certain that the ion of interest is the base peak for a particular compound, and make sure that a "qualifier ion" is present. The abbreviated spectrum from a SIM peak can be compared with the SIM spectrum from a known compound, but that is as far as it can go. For this reason, the analyst should apply more rigid criteria when trying to determine whether a SIM pattern exhibits "sufficient similarities" to a standard pattern.

Figure 3.33 shows a comparison of a 10-ppm standard of 75% evaporated gasoline run in the full-scan mode, in the full-scan splitless mode, and in the SIM mode. Looking at just the total ion chromatograms, one might conclude that the SIM mode does not add value compared to the splitless mode, but when one generates the

TABLE 3.4 Ions Used for SIM

Ion	Compounds	Ion	Compounds
31	Methanol	117	Indan, methylindans
43	Alkanes	118	Methylstyrene
45	Ethanol	119	C_4 alkylbenzenes
55	Alkenes, cycloalkanes	120	C_3 alkylbenzenes
57	Alkanes	128	Naphthalene
69	Alkenes	131	Methyl, dimethylindans
71	Alkanes	133	C_5 alkylbenzenes
83	Cycloalkanes, alkenes	134	C_4 alkylbenzenes
85	Alkanes	142	Methylnaphthalenes
91	C_1, C_2 alkylbenzenes	156	Dimethylnaphthalenes
104	Styrene	168	3-phenyltoluene
105	C_3 alkylbenzenes		

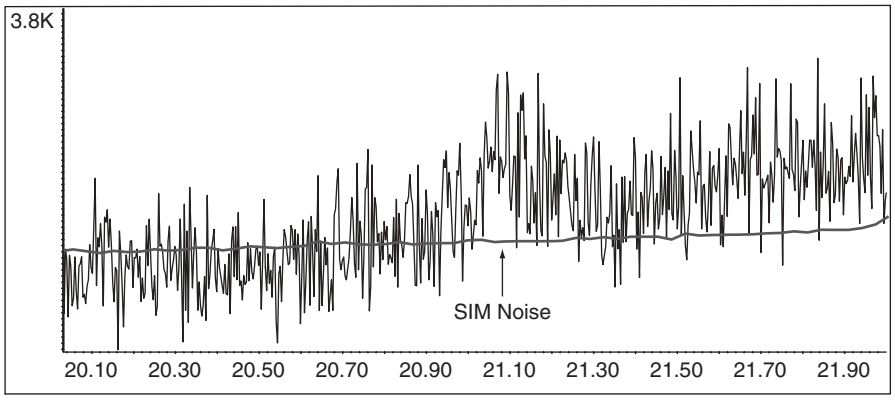

Figure 3.32 Comparison of the baseline noise generated by a full scan with that generated in the SIM mode. *(See insert for color representation.)*

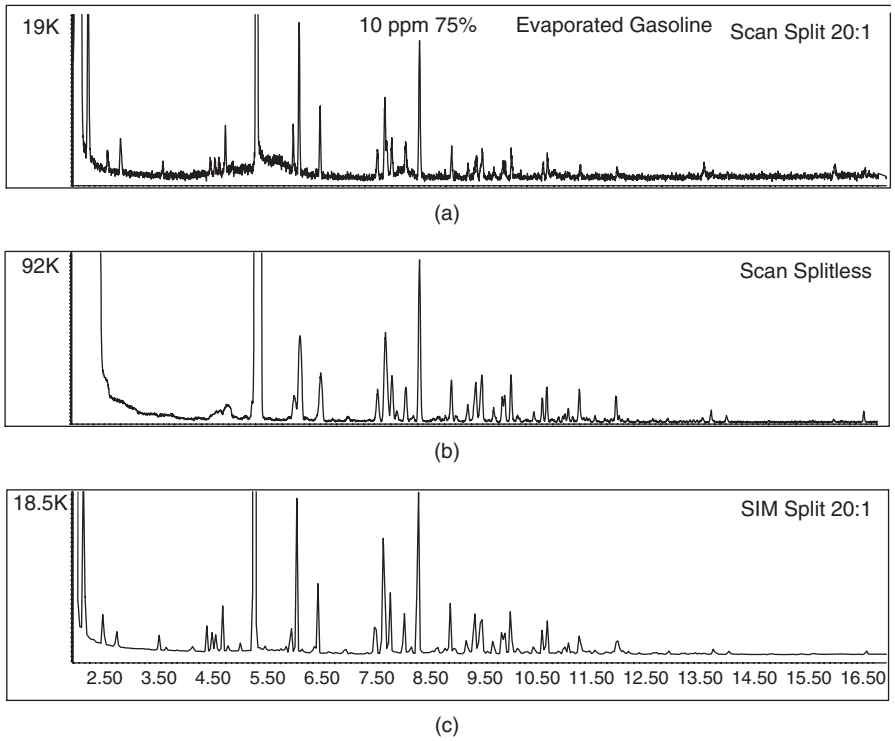

Figure 3.33 10-ppm solution of 75%-evaporated gasoline. (a) Run in the full-scan mode with a 20 : 1 split ratio. In each of these three charts the off-scale peak at 5.5 min is the perchloroethylene internal standard. (b) Run in the full-scan mode with a splitless injection. The abundance is increased by about a factor of 5 over the split injection. (c) Run in the SIM mode with a 20 : 1 split ratio. The abundance is not increased compared to the scan mode, but the noise is reduced significantly.

six extracted ion profiles for gasoline, the SIM chromatograms clearly outshine those produced in the full-scan mode, even with no split. This is demonstrated in Figure 3.34.

This process of increasing sensitivity can be taken even one step further, by using a splitless injection and selected ion monitoring, although in doing so, we are approaching territory where findings of lower and lower amounts may not be meaningful. Figure 3.35 shows the six gasoline ions from a solution of 0.1-ppm standard of 75% evaporated gasoline. This is roughly equivalent to a sample containing 0.001 μL of gasoline (1 nL!). Even at a concentration in the eluate of 0.01 ppm (10 ppb), the baseline does not go completely flat in the SIM splitless mode.

By simply using the tools available, we can see that the sensitivity of the analysis can be increased by four orders of magnitude. It does not seem to this analyst that lowering the detection limit further than this would be worthwhile. Table 3.5 shows

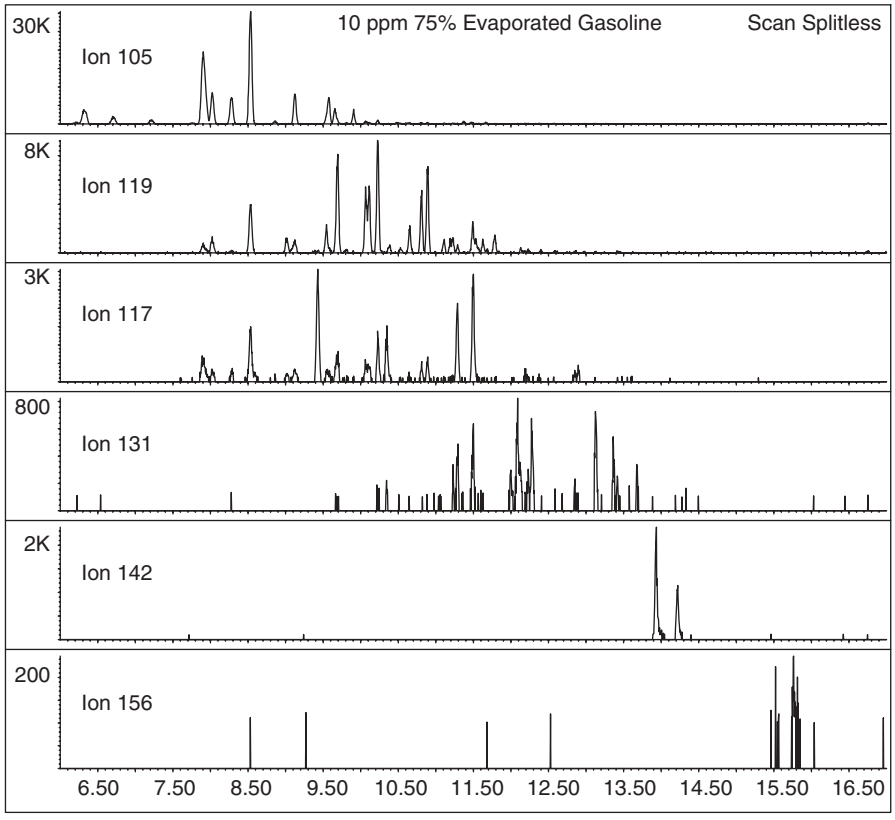

(a)

Figure 3.34 Six ion chromatograms produced by a 10-ppm solution of 75% evaporated gasoline run in the full-scan mode, with splitless injection; (b) run in the SIM mode, with a 20 : 1 split ratio..

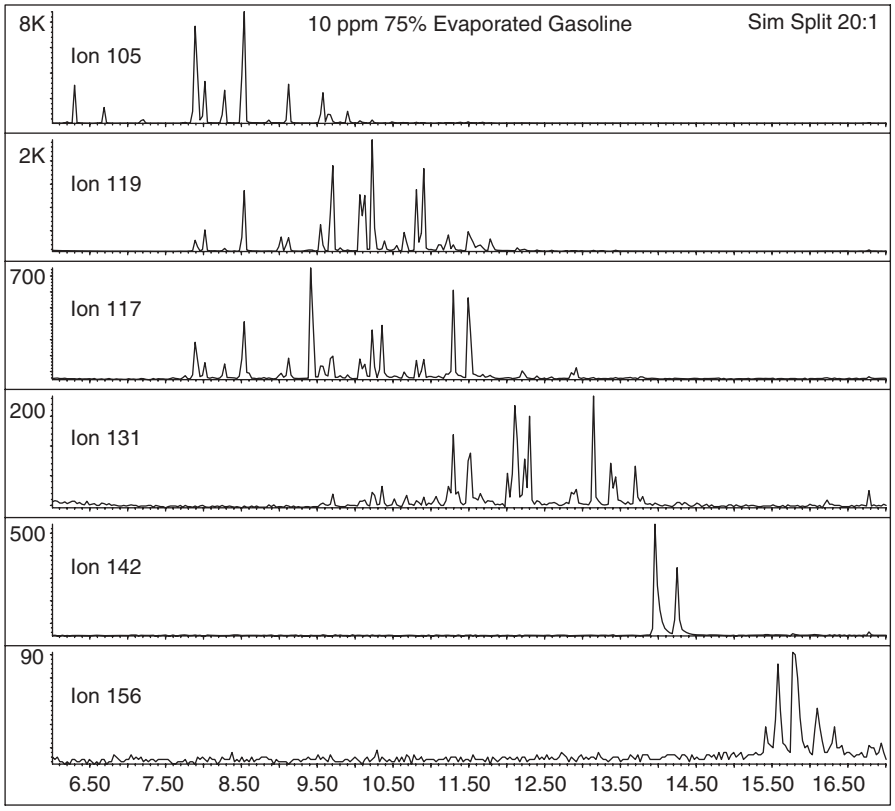

(b)

Figure 3.34 (*Continued*)

a rough order-of-magnitude calculation of the detection limits available using the techniques described above.

3.6.3 Estimating the Degree of Evaporation

Estimating the degree of evaporation is a task that an analyst is occasionally asked to perform. Usually, evaporation is not an issue, and frequently, even if it is an issue, estimating how much of the original volume of a sample may have evaporated is difficult. Comparing degrees of evaporation may be helpful in source or common source determinations, as will be discussed later.

Unless we know what the ignitable liquid was to start with, it is next to impossible to determine how much it has evaporated. This is particularly true for distillates, which may range from C_7 through C_{12} in one batch and C_9 through C_{13} in the next batch of the same product. Similarly, kerosene and diesel fuel formulations change with latitudes and seasons. So, unless there is a container that is suspected of being

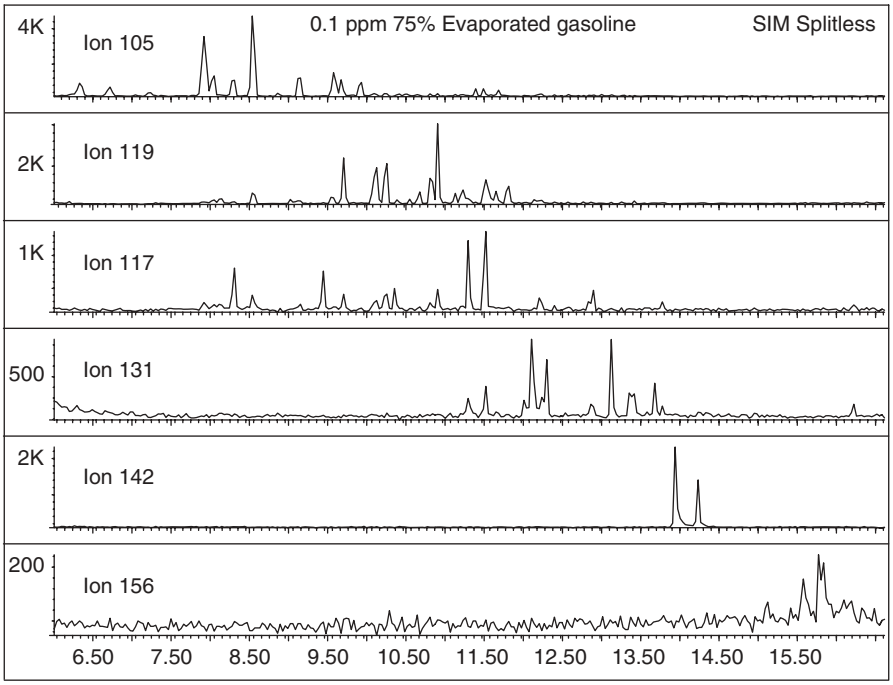

Figure 3.35 Six gasoline ions produced by a 2-μL splitless injection of a solution of 0.1 ppm 75%-evaporated gasoline.

TABLE 3.5 Detection Limits for Four Instrumental Configurations

Method	LLD (Solution)[a]	LLD (Sample)[b]
Full scan, split 20 : 1, 1-μL injection	100 (ppm)	1.0(μL)
Full scan, splitless, 1-μL injection	10	0.1
SIM, split 20 : 1, 2-μL injection	1	0.01
SIM, splitless, 2-μL injection	0.1	0.001

[a] Concentration at which this analyst feels comfortable calling a sample positive.
[b] Assumes little or no competition from the sample, and a 5% recovery rate.

the source of the residue, this is a task that simply cannot be accomplished, with the possible exception of gasoline.

Fresh from the pump, gasolines look pretty much alike, particularly with respect to major components, and they change in a reasonably predictable fashion as a result of exposure to fire. The issue of evaporation frequently arises in the context of trying to decide whether gasoline was present in a sample before the fire or introduced during or after the fire. It sometimes happens that firefighters bring gasoline-powered equipment to fire scenes, and it is sometimes necessary to eliminate such equipment as the source of residue found in a debris sample. A number of different techniques can be brought to bear on this question. The simplest way to

make the estimation is to compare the total ion chromatograms. In fresh gasoline, toluene will be the tallest peak, and there will be numerous light (C_5 to C_8) alkane peaks to the left of the toluene peak. By the time that gasoline is 25% evaporated, many of these light alkane peaks have disappeared. Also, in a 25%-evaporated gasoline sample, the tallest peak is the *m*- and *p*-xylene peak.

The analyst's library of gasolines should include gasoline in many stages of evaporation, as well as fresh gasoline. In our laboratory, we keep gasoline standards on file at 0-, 25-, 50-, 75-, 90-, 98- and 99%-evaporated. Performing a rough estimation of the degree of evaporation happens every time we identify gasoline, simply because it is necessary to put a hard copy of at least one standard in the file (ASTM E1618), and it is desirable for the reference chromatogram to match the sample chromatogram as closely as possible.

By the time gasoline is 50% evaporated, the toluene peak is significantly shorter than the *m*- and *p*-xylene peak, and in fact, is shorter than the ethylbenzene peak. The pseudocumene peak, meanwhile, has grown so that it is almost as tall as the *m*- and *p*-xylene peak. At 75% evaporation, the pseudocumene peak is the tallest peak in the chart, and the toluene peak has almost disappeared. At 90% evaporation, the toluene peak is gone and the xylenes are far shorter than the C_3 alkylbenzenes. The C_4 alkylbenzenes, meanwhile, have grown as tall as most of the C_3 alkylbenzenes, but pseudocumene is still the tallest peak in the chart. By the time the sample is 90% evaporated, the C_4 alkylbenzenes are taller than the C_3 alkylbenzenes.

A more quantitative technique for estimating evaporation involves use of the mass spectrometer. Collecting the average mass spectrum from C_6 to C_{13} (about 3 to 13 min in our laboratory) yields an average that changes predictably from one stage of evaporation to the next. In fresh gasoline, ions 91 and 105 are the tallest, followed by 119, 43, 57, and 71. The 43 fragment is produced by the light branched alkanes to the left of toluene. At 25% evaporation, 91 and 105 still dominate the mass spectrum, but the 57 ion is now taller than the 43. At 50% evaporation, ion 91 is no longer equal to 105, and 119 and 120 exceed the height of ion 57.

At 90% evaporation, the 119 ion is almost equal in size to the 105 ion, and ion 134 is beginning to catch up with ion 91. At 98% evaporation, ion 119 is the tallest, followed by 105, 134, and 91. Figure 3.36 shows these six average mass spectra. Keep in mind that the substrate can contribute to the spectra, thus making this approach more difficult in some cases.

Any attempt to estimate evaporation should be done by comparing "apples to apples." Although it is hoped that the analyst has optimized the isolation process so that an eluate from an ACS looks like the liquid in solution that has not gone through the ACS process, standards should be eluates rather than solutions prepared simply by diluting the liquids. Further, samples and standards should have approximately equal concentrations. More concentrated samples tend to appear more evaporated, due to the effects of displacement (Newman et al., 1996).

There are certain substrates that hold certain compounds preferentially, and substrate effects need to be considered before reporting a sample as having a problematic evaporation level. Concrete, for example, tends to retain lighter hydrocarbons, making residues appear less evaporated than the fire scene conditions

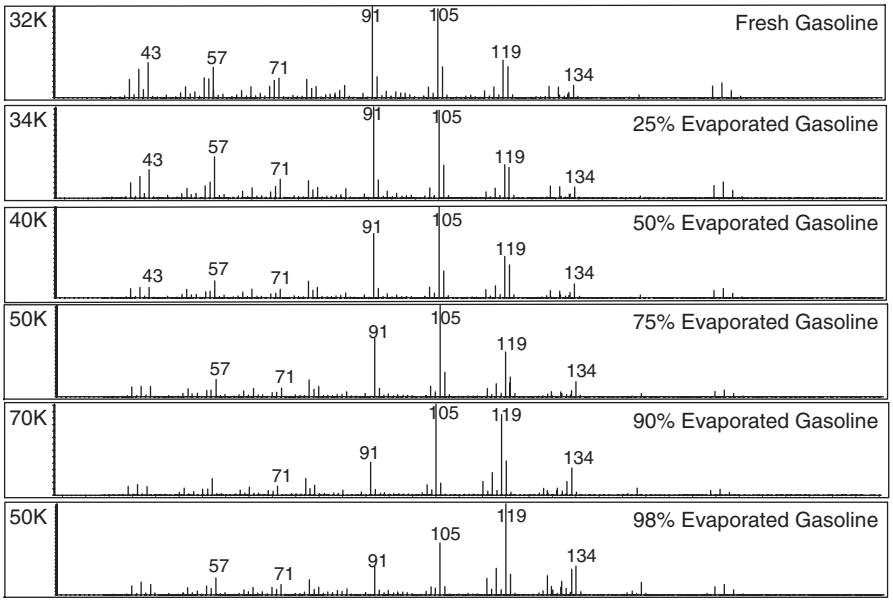

Figure 3.36 Average mass spectra from 3 to 13 min of fresh gasoline, followed by the same spectrum taken for gasoline evaporated 25, 50 75, 90, and 98%.

would indicate. One of the more important reasons for estimating the degree of evaporation is to allow for an "apples to apples" comparison when attempting to match a questioned sample to a known source.

3.6.4 Identity of Source

The ability to match a weathered ignitable liquid residue with a proposed source of unburned ignitable liquid has eluded fire debris analysts until just recently. The environmental forensics community has developed some tools to identify the sources of petroleum spills, but they have the advantage of having huge quantities of material available for characterization. Petroleum hydrocarbons contain trace quantities of biomarkers, substances that have changed little since they were first synthesized inside a living organism. The relative amounts of these biomarkers frequently allows for the identification of the source of a major spill. Polycyclic aliphatic and aromatic hydrocarbons are also useful in "fingerprinting" hydrocarbons. Examination of additives, such as oxygenates, or in the case of old gasolines, the alkyl lead compounds, can also provide clues as to the identity of the source of a spill.

There are three levels of "control" on the composition of petroleum. The primary control is the genesis of the petroleum: its "genetic" features, including its geographic location, the original source of the fuel (terrestrial or marine), and the conditions in the rock where the oil resided for millions of years.

The second level of control affecting the hydrocarbon fingerprint is processes imposed on the hydrocarbon by the refiner. Activities such as distillation, hydrocarbon cracking, isomerization, alkylation, and blending change the composition of the fuel. The tertiary controls are those that occur after the petroleum product leaves the refiner. The most important tertiary control of interest to fire debris analysts is, of course, weathering, or evaporation. Mixing in the service station tank is also critical. Because the tanks are seldom empty, each time a new delivery is made, the fuel service station tank assumes a new temporary identity. For a more extended discussion on chemical fingerprinting in the environmental forensic science arena, see *Introduction to Environmental Forensics* (Murphy and Morrison, 2002).

Some of the early work to identify the source of ignitable liquid residues from fire debris was done by Dale Mann (1987a,b). Using a 60-m column, Mann learned that it was possible to make comparisons on samples of fresh gasoline and to correctly identify the source by examining the relative ratios of the light hydrocarbons, ranging from *n*-pentane to *n*-octane. It is, unfortunately, exactly these hydrocarbons that are lost before a gasoline is even 25% evaporated. Mann's second paper describes the limitations of making comparisons between ignitable liquid residues and fresh samples, due to the contamination of residues with pyrolysis products, changes introduced by the isolation method, and the loss of volatiles resulting from weathering. Comparison of residues with fresh sources was, therefore, not studied frequently after Mann's extensive work. More recently, however, Dolan and Ritacco reported that they had devised a way to measure the relative abundances of 20 peak pairs in gasolines and were able to identify the source of 30 samples that were evaporated to 25% and 50%. This process uses the relative abundances of branched alkanes that occur generally in the center of the gasoline chromatogram. Because the peaks are sequential, eluting only a few seconds apart, the relative ratios are not affected significantly by evaporation. The peaks examined are all minor components. The major components of gasoline are similar enough to each other that they are not useful in discriminating between sources (Dolan and Ritacco, 2002).

Following up on this work, Wintz and Rankin applied principal components analysis only to learn that while the ratios within the pairs show little if any change between unevaporated and 50%-evaporated gasoline, only a few of those pairs were actually useful in distinguishing between one gasoline source and another, and some of those pairs occurred in the light petroleum distillate range, and so are unlikely to be found in gasolines evaporated to more than 50% (Wintz and Rankin, 2004).

Further work by Barnes and Dolan identified six ratios of sequentially eluting minor components in 50% evaporated gasoline and four ratios in 75% evaporated gasoline. Using these ratios, they were able to discriminate successfully among 16 gasoline samples evaporated 50% and 10 gasoline samples evaporated 75%. They used a blind study to confirm the ability of the technique to identify the source of three gasolines correctly matched against a library of 10 candidate sources. The technique uses a 60-m column, and is automated using a target compound program. The program takes the abundance of the base peak from the mass spectrum of each compound of interest and divides the base peak abundance of the later eluting

compound by the base peak abundance of the earlier eluting compound. As well as this technique appears to work, the authors state that it is most useful for *eliminating* a source, and caution that the analyst's statement of conclusions reflect that a common origin is indicated but is not a certainty. (Barnes et al., 2004).

A somewhat simpler approach, using an analysis of naphthalene, methyl, and dimethylnaphthalenes has been reported by Sandercock and Du Pasquier in a three-part series published in 2003 and 2004 (Sandercock and Du Pasquier, 2003, 2004a,b). The column used was an everyday 30-m HP-5 column of the type used for routine fire debris analysis. A SIM method was used, and in order to have all of the peaks capable of being integrated at the same approximate level of precision, the signal for naphthalene and the methylnaphthalenes was selectively reduced by monitoring ions 127 and 129 rather than 128 for naphthalene, and 141 and 143 rather than 142 for methylnaphthalene. The base peak of 156 was used for the dimethylnaphthalenes. Sandercock and Du Pasquier started their research by pretreating the gasoline with an alumina column to separate out both polynuclear aromatic hydrocarbons and the polar alkylphenols, but learned that the alkylphenols did not provide much help in discriminating among different samples. The PAH ratios do not change significantly upon evaporation and seem to be a characteristic imparted by the refinery.

One way to compare any type of ILR to a suspected source, or to see if two ILRs within the same class came from the same source is to compare the average molecular weights. When exposed to a fire, ignitable liquid evaporates, and its average molecular weight necessarily increases. No predictable experience will cause the average molecular weight of the fire-exposed liquid to decrease. If the suspected source of an ignitable liquid, which was not exposed to the fire, exhibits a higher average molecular weight than the residue extracted from samples collected at the scene, the suspected source can be conclusively eliminated.

In doing comparisons of gasolines or any ignitable liquid, the best approach takes the proposed source liquid, evaporates some of it so that it matches the residue in terms of carbon number range, and then subjects it to the same separation procedure that was applied to the questioned sample. Once this has been accomplished, a detailed examination of the finer points in the chromatogram can be carried out.

A really good match between chromatograms not only matches the peaks but also matches the valleys. Examining multiple extracted ion chromatograms for both quality and quantity is a necessary step when doing comparisons. This practice has been codified with respect to the analysis of distillates heavier than kerosene in ASTM D5739-06, *Standard Practice for Oil Spill Source Identification by Gas Chromatography and Positive Ion Electron Impact Low Resolution Mass Spectrometry* (ASTM D5739-06, 2006). The approach in this method compares 24 extracted ion chromatograms of polynuclear aromatics and certain biomarkers. Although this method is not applicable to kerosene and lighter mixtures such as gasoline, the general approach seems workable. Given the state of the art, it is probably a good thing that comparisons are not frequently requested.

3.7 REPORTING PROCEDURES

The analyst's report can be one of the most important documents generated during the investigation of a fire. The report should therefore be written carefully enough so that readers are not misled. The objective of fire debris analysis is to determine whether any foreign ignitable liquid residue is present in a sample.

The report from a forensic science laboratory is supposed to be a scientific report. As such, it should include an introduction, a section detailing the test methods and results, and a discussion and conclusion section, if necessary. The laboratory report should also state what was done with the evidence. There is an unfortunate tendency in some agencies to provide checklists and merely state "positive for gasoline" or "negative for accelerants" rather than preparing a real laboratory report. Reading such a report, a reviewer cannot tell whether the analyst used a GC–MS or a Ouija board!

Given that it is now possible to store templates with all possible results in them, the excuse that it is "too time-consuming" to prepare an understandable narrative report is unacceptable. Although laboratory reports are intended to assist investigators, they should also be understandable to people asked to review the work. At a minimum, a report should include the following:

- Identification of the fire in question.
- A description of the how the sample was delivered to the laboratory, when, and by whom.
- A description of the samples, including container size, substrate material, and a reported location from where the sample was collected.
- A description of the isolation procedure used to separate the ILR from the sample substrate.
- A description of the analytical technique applied to the sample extract.
- The results of the analysis of the data.
- A discussion of the meaning of the results if there is any chance of misinterpretation or misuse.

In the discussion section, the analyst can provide examples of potential sources for whatever ignitable liquid residues may have been identified. This is also an appropriate place to put in a disclaimer about the possibility that the ILR may not be foreign to the background.

- A conclusion or bottom line understandable even to an attorney is a helpful thing.
- A sentence stating what has happened to the sample.

If a substance is found that is natural or incidental to the background, it is the analyst's job to say so. ASTM E1618 allows for the inclusion of disclaimers on both positive and negative reports. With respect to negative reports, a disclaimer to

the effect that negative results do not preclude the possibility that ignitable liquids were present at the fire scene is suggested as an aid to help readers avoid misunderstanding the report. Similarly, in the case of a positive report, the standard states: "It may be appropriate to add a disclaimer to the effect that the identification of an ignitable liquid residue in a fire scene does not necessarily lead to the conclusion that a fire was incendiary in nature. Further investigation may reveal a legitimate reason for the presence of ignitable liquid residues." Certainly, a finding of gasoline in the living room is noteworthy. It is not so noteworthy to find gasoline in the basement near the chain saw. On occasion, it seems that the fire debris analyst is too eager to "help" with an arson investigation. Reporting a sample as being "positive" when all the analyst has identified is background compounds is neither helpful nor morally defensible. Karen and Paul Stanley of Akron, Ohio, were falsely accused of setting a fire that killed their infant son. The fire debris samples were submitted to a laboratory that reported finding turpentine in a sample consisting of charred Douglas fir. The laboratory analyst had absolutely no business reporting turpentine, or at the very least, should have reported the finding of turpentine with a huge disclaimer stating that the turpentine was indistinguishable from naturally occurring turpentine found in coniferous woods. The case was dismissed after the prosecutor understood the significance (or lack thereof) of the chemist's findings (Trexler, 2002).

A similar case of an analyst being too "helpful" occurred in a homicide case in Georgia, where the laboratory analyst reported finding "toluene, a flammable liquid" on a suspect's "clothing." Actually, the "clothing" included a pair of tennis shoes, and the examination of a new pair of tennis shoes directly from the shoestore revealed the presence of a high concentration of toluene. A closer examination of the first analysis revealed that in addition to toluene, diethylene glycol and butylated hydroxytoluene (BHT) were also present in the suspect's shoes and the exemplar shoes in identical relative proportions. Less than a year earlier, there had been a presentation on the analysis of suspects' shoes in arson cases at an AAFS seminar (Cherry, 1996). Perhaps if the analyst had attended that presentation (or read the proceedings), the toluene would have been reported properly as being native to the sample background, or more appropriately, not reported at all. Typical positive and negative reports from our laboratory are shown as Figure 3.37.

3.8 RECORD KEEPING

Each case file that includes a positive identification of an ignitable liquid residue should contain not only the sample charts but also a standard to which that sample can be compared. This means that both the sample and the standard should be printed with the same time scale, so that the data can easily be reviewed. Even if there is no criminal prosecution, the analyst should be aware that many fire cases involve civil litigation, so the case file should be kept for a reasonable period of time.

Electronic data files should also be protected and stored. There are only a few versions of GC–MS software in widespread use, so it is possible for one analyst

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CHEMICAL ANALYSIS REPORT

File No. Lab File # **Date** **Page** 1 **of** 1

Fire Investigator
Agency
Address
City, State ZIP

Subject

Incident # (Claim # 78910)
Your File # 23456.
Victim (Insured): Name.
Date Of Loss: July 28, 2004.
Analysis of Fire Evidence.

Background

On August 3, 2004, John Lentini of ATS received from client via UPS the following:

Item 1. A one-quart can containing debris identified as removed from the north end of the laundry room.

Item 2. A one-quart can containing debris identified as removed from the center of the laundry room.

ATS was requested to analyze the samples for ignitable liquid residues.

Test Methods and Results

The samples were separated according to ASTM Practices E1412-07 and E1386-05, and analyzed according to ASTM Standard Method E1618-10.

Gas chromatographic/mass spectrometric (GC/MS) analysis of concentrated headspace vapors from Item 1 reveals the presence of components having retention times and mass spectra characteristic of components of known weathered gasoline.

GC/MS analysis of a solvent extract from Item 2 reveals the presence of components having retention times and mass spectra characteristic of components of known weathered gasoline.

Conclusion

Gasoline was present in both samples.

Sample Disposition

Samples have been returned to client via UPS.

Prepared by John J. Lentini, F-ABC

Reviewed by P. E. Rogers, Senior Chemist

Figure 3.37 (a) Typical positive report from our laboratory; (b) typical negative report from our laboratory.

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CHEMICAL ANALYSIS REPORT

File No. Lab File # **Date** **Page** 1 **of** 1

Fire Investigator
Agency
Address
City, State ZIP

Subject

Incident # (Claim # 78910)
Your File # 23456.
Victim (Insured): Name.
Date Of Loss: July 21, 2004.
Analysis of Fire Evidence.

Background

On August 4, 2004, John Lentini of ATS received from client via UPS the following:

Item 1. A one-quart can containing burned carpet and pad identified as removed from the north end of the south bedroom.

Item 2. A one-quart can containing debris identified as removed from the center of the living room.

ATS was requested to analyze the samples for ignitable liquid residues.

Test Methods and Results

The samples were separated according to ASTM Practices E1412-07 and E1386-05, and analyzed according to ASTM Standard Method E1618-10.

Gas chromatographic/mass spectrometric (GC/MS) analysis of concentrated headspace vapors from Items 1 and 2 fails to reveal the presence of any ignitable liquid residues.

These results do not eliminate the possibility that ignitable liquids were present at the fire scene.

Sample Disposition

Samples have been returned to client via UPS.

Prepared by_____ John J. Lentini, F-ABC

Reviewed by_____ P. E. Rogers, Senior Chemist

Figure 3.37 (*Continued*)

to review another's raw data. Such reviews should be facilitated by preservation of the data. Instrumental data such as tune reports or spectrum scans should be kept, if only to keep track of the performance of the instrument. Certainly, if a case file has matching standards and samples, there is no need to review the tune report for that particular week. No matter what happened, the instrument tune parameters would not cause a false positive. Blanks, on the other hand, should be stored somewhere, particularly for those cases where the detection limit of the procedure is being reduced.

3.9 QUALITY ASSURANCE

The factors affecting the overall quality of a laboratory's work product are numerous. For this reason, accreditation programs have been set up so that an outside agency can verify that a laboratory is performing appropriately. Each laboratory should have a detailed written procedure for the examination of fire debris. As part of the quality assurance program, fire debris analysts should participate in proficiency testing at least once a year. This can be internal or external, but certainly, external proficiency testing carries more credibility. Proficiency tests are available from a number of commercial suppliers, but it is not necessary to actually purchase proficiency tests. Groups of analysts can form round-robin groups and take turns preparing samples for each other. Because it is not necessary to demonstrate one's ability to place a strip in a can, samples can be prepared by exposing 10 strips to the same sample, then just mailing the strips. By doing regular proficiency tests or round robins, analysts can monitor their own performance, and laboratory directors can be assured that their analysts are performing adequately.

Individual professional development and continuing education is an important component of any quality assurance program. Analysts should take the time to keep up with the literature and should attend professional meetings when possible. Although the science of fire debris analysis is reasonably settled, this is an interesting field with a large cadre of professionals who perform and publish research on a continuing basis. Keeping up with this research is a professional responsibility.

The ultimate sign that an analyst is keeping up with the profession is the decision to become certified. The American Board of Criminalistics offers a certification in fire debris analysis. Certification can be maintained only by continuing education and annual participation in external proficiency testing. Becoming certified is a way for an analyst to demonstrate that he or she cares about professional development. Supporting individual certification is a way that a laboratory director can assure his or her employees that the agency also cares.

CONCLUSION

The isolation and identification of ignitable liquid residues from fire debris samples is an important part of the fire investigation process. The fire debris analyst

should be familiar with the common techniques of fire investigation and understand the language used by investigators. The analyst must also understand the stakes involved. If an ignitable liquid residue is identified, a hypothesis that a fire was incendiary may be supported, and a long litigation process may ensue in either civil or criminal court. The laboratory results are often the deciding factor in a prosecutor's decision to indict or an insurance company's decision to resist a claim.

The technology for fire debris analysis has improved dramatically over the last 20 years, to the point where our methods are now as sensitive as they need to be, and possibly more sensitive than they need to be. The analytical procedure requires focus and creativity, but also adherence to the generally accepted criteria for making an identification. The analysis should be conducted and reported in such a way that it is capable of being reviewed by another analyst. There is no reason that a reviewing analyst should reach a different conclusion, and such reviews should not only be expected but be welcomed. Science is based on "multiple witnessing." Fire debris analysts need to be acutely aware of the stakes involved in what they are doing and of the need to communicate effectively about the meaning of their findings.

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CHAPTER 4

Forensic Examination of Soils

RAYMOND C. MURRAY

University of Montana, Missoula, Montana

Summary Soils and sediment constitute excellent trace evidence in both criminal and civil cases because there are an almost unlimited number of identifiable soil types based on the content of rocks, minerals, glasses, human-made particles, and chemicals. Forensic examination commonly identifies the original geographic location of soils associated with a crime, thus assisting an investigation. Studies of soil and related material samples associated with a suspect and crime scene can produce evidence that the samples had or did not have a common source, thus indicating whether or not the suspect was ever at a particular place. Gathering intelligence and mine, gem, and art fraud studies often use the methods of forensic geology.

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4.1 INTRODUCTION

As with so many other types of physical evidence, forensic geology began with the writings of Sir Arthur Conan Doyle, who wrote the Sherlock Holmes series between 1887 and 1927. He was a physician who apparently had two motives: writing salable literature and using his scientific expertise to encourage the use of science as evidence.

In 1893, Hans Gross, an Austrian forensic scientist, wrote a handbook for examining magistrates (Gross, 1893) in which he suggested that "perhaps the dirt on someone's shoes could tell more about where a person had last been than toilsome inquiries." It was only a matter of time before these ideas from an author of fiction and a criminalists' handbook would appear in a courtroom.

In 1908, a German chemist, Georg Popp, undertook the study of soil evidence in the homicide case of Margarethe Filbert. In this case Popp was able to demonstrate that soil samples from two locations associated with the crime had characteristics similar to the sample collected from the suspect's shoes. In addition, using soil from the suspect's shoes he was able to show a sequence of events in soil accumulation that was consistent with the theory of the crime, and he found no soil evidence that supported the suspect's alibi (Thorwald, 1967).

A century later, the use of geologic materials in criminal and civil cases is commonplace (Pye and Croft, 2004). Public and private laboratories around the world have trace evidence examiners qualified to examine soil, glass, and related material (Murray, 2011; Pye, 2007; Ruffell and McKinley, 2008).

Forensic geology studies vary in scope. A common type of investigation involves identifying a material that is key to a case: for example, examining pigments in a painted picture or material in a sculpture when authenticity or value is at issue. Identification is also important in questions of mining, mineral, or gem fraud to determine if the material is what its sellers claim it to be. Identification of fire-resistant safe insulation on a person or individual's property may provide probable cause for further investigation.

Beyond identification, forensic geologists can also look at the source of particular material. Here the examiner needs a broad knowledge of the geology and the best geologic and soil maps to answer questions. For example, if the soil on a body does not match the location where the body is found, from where was the body moved? Similarly, examiners can compare two samples, one associated with the suspect and the other collected from the crime scene, to see if they had a common source. For example, does the soil on the suspect's shoe have characteristics similar to those of the soil type collected at the crime scene?

Another new developing area of forensic geology is its use in intelligence work. For example, a person may claim never to have been to a particular location, but is then found with rocks from that spot, thus linking the person to the location. Remember the outcrop you saw behind Osama bin Laden on your television screen after 9/11? What was the location? A geologist who has done field work in the area would be able to locate that outcrop, and that actually happened: A geologist, John Shroder, was able to identify the region where bin Laden had been sighted in

Afghanistan in 2001. As with all class evidence, geologic evidence rarely provides a unique solution for which the geologic mind cannot imagine another possibility (Murray, 2005). But there are some exceptions, as illustrated in the following two cases.

4.2 MURDER AND THE POND

The murder of John Bruce Dodson produced one of the most interesting cases in the entire history of forensic geology. Here, the geologic evidence is unequivocal, in that it tied the suspect directly to the crime and eliminated the suspect's alibi. Most important, the investigator of the crime recognized the potential importance of the geologic evidence and arranged for an examination of that evidence. The testimony of the forensic geologist was critical to the prosecution of the case. The case began on October 15, 1995, when John Dodson was found dead while on a hunting trip with his wife of three months, Janice. The scene was high in the Uncompahgre Mountains of western Colorado.

At first glance it appeared to be a hunting accident. However, the autopsy revealed two bullet wounds to the body and one bullet hole through John's orange vest. The investigation showed that the Dodsons were camped near other hunters, one of whom was a Texas law enforcement officer. He responded to Janice's frantic call that her husband had been shot. She was standing about 200 yards from the camp in a grassy field along a fence line. The officer determined that John was dead and started the process of getting help. Prior to calling for help, Janice had returned to her camp and removed her hunting coveralls, which were covered with mud from the knees down. She later told investigators that she had stepped into a mud bog along the fence near the camp. Investigators found a. 308-caliber shell case approximately 60 yards from the body. In addition, they found a. 308-caliber bullet in the ground on the other side of the fence, which created a direct line from the location of the case to the body to the bullet.

Janice's ex-husband, J. C. Lee, was camped three-fourths of a mile from the Dodsons. Janice knew that the site was his favorite camp location. He naturally came under suspicion. However, Lee was hunting far away from camp with his boss at the time of the shooting. Most important, Lee reported to investigators that while he was out hunting, someone had stolen his. 308 rifle and a box of. 308 cartridges from his tent. Winter comes early at 9000 ft in the Umcompahgre, and little more could be done at the scene. However, investigators Bill Booth, Dave Martinez and Wayne Bryant returned during the summers of 1996, 1997, and 1998 and searched for the rifle and other evidence. They tried to search every place a weapon could have been hidden. They combed the entire area, including ponds, with metal detectors in the hope of finding the rifle; it has never been found. During the final search of the pond near Janice's ex-husband's camp, Al Bieber of NecroSearch International commented that the mud in and around a cattle pond near Lee's camp was bentonite, a clay that someone brought to the pond to stop the water from seeping out of the bottom. That evening, Booth and Martinez were camped near the crime scene. They were discussing the evidence in the

Figure 4.1 Pond lined with bentonite clay where Janice Dodson got clay on her shoes and pants when she went to steal the rifle that she used to kill her husband, John. *(See insert for color representation.)*

case when investigator Booth said, "The mud." He was referring to the dried mud that was found on Janice Dodson's clothing. If Janice had obtained the rifle from Lee's camp, she would probably have stepped or fallen into the bentonite clay that drained across the road from the cattle pond (see Figure 4.1). Remembering Janice's statement that she was returning to camp on the morning of the crime and stepped into a mud bog near her camp, Booth and Martinez decided they needed to obtain dried mud samples from the bog near the Dodsons' camp, the area around a pond nearby the camp, and the human-made pond and runoff near Lee's camp.

Booth and Martinez packaged the dried mud from each location and sent the samples along with the dried mud that had been recovered from Janice's overalls to the laboratory section of the Colorado Bureau of Investigation in Denver, where it was examined by Jacqueline Battles, a forensic scientist and lab agent. She concluded and later testified to the fact that the dried mud found on Janice Dodson's clothing was consistent with the dried mud recovered from the pond near Lee's camp. The dried mud that had been recovered from Janice's overalls was found not to be consistent with the mud bog or the pond near her camp. This was a breaking point in the case that allowed Booth and Martinez to put Janice Dodson in her ex-husband's camp around the time that his rifle had been stolen. There are no other bentonite-lined ponds in the area and no bentonite deposits.

Booth and Martinez went to Texas and served an arrest warrant on Janice. She was extradited to Colorado, tried in court, and convicted in the murder of John Bruce Dodson. The jury understood the results that followed Booth's insightful "the mud" exclamation. Janice is now serving a life sentence without the possibility of parole in Colorado's state prison for women. An appreciation of the value of soil evidence and the collection of that evidence was critical in this case.

4.3 OIL SLICKS AND SANDS

A case that illustrates many of the issues comparing soil and related material occurred in Canada a few years ago. The body of 8-year-old Gupta Rajesh was found alongside a road outside Scarboro, Ontario. The back of his shirt had a smear of oily material, and the preliminary conclusion was that he was the victim of a hit-and-run accident, with the oily material coming from the undercarriage of a vehicle. But examination of the oily material and the particles suspended in it by forensic geologist William Graves of the Centre of Forensic Sciences in Toronto told a different story.

Investigators had collected samples of oily material on the floor of an indoor concrete parking garage where a suspect, Sarbjit Minhas, parked her Honda automobile. Analysis of the samples showed that the sand and other particles within the oil from the victim's clothes and the parking garage were similar. Analysis of the oil from the victim's shirt and garage floor showed them to be both similar and different from oil collected on the floor of 10 other garages in the area.

Particles in samples from the victim's clothes and the suspect's parking place provided considerable information. The sand from both samples was sieved and subsamples produced of the various size grades for the two samples. When compared after the oil had been removed, the color of each pair of subsamples was identical.

Additionally, the heavy minerals in both samples were similar, and three distinct types of glass were found in the two samples: amber glass, tempered glass, and lightbulb glass. Each of the different glasses was identical in refractive index value (the amount that a ray of light bends when passing through the glass into another medium). Small particles of yellow paint with attached glass beads were found in both samples. This type of paint is often found on center stripes of highways and reflects light.

Graves concluded that there was a high probability that the body of Gupta Rajesh had been in contact with the concrete floor of the garage at the place where the suspect parked her car. Interestingly, the same oil and particles were found in the suspect's Honda. Whether the oil and particles on the victim came from inside the vehicle or the floor of the garage, the presence and distinctiveness of the samples still strongly associated those two areas with the victim. Minhas was tried in the Superior Court of the Province of Ontario in November 1983 and convicted, with help from testimony by Graves.

This case illustrates an important concept in the presentation of soil evidence and perhaps all physical evidence, except DNA. We have become awed and impressed by the high probabilities that result from DNA evidence. Some people expect that other types of evidence should have similar statistical information. But in the Minhas case, we see a conclusion based on at least 10 different materials and observations. Because we do not know the probability of a tempered glass fragment, a particular group of heavy minerals, or sand of the same color being on a particular parking place in a concrete garage in Scarboro, Ontario—and in all likelihood we will never know—a frequency statistic cannot be generated. A useful database of

sands, particles, glass, oils, and heavy minerals would be too difficult to generate. Additionally, it may not apply to any one specific case because of the variability of mineral particles—the very distinctiveness that makes geologic materials such good evidence. Thus, we rely on the skilled and honest examiner to reach a conclusion expressed in words rather than in numbers to inform the jury or judge so that they can reach a verdict. In this way the expert is a teacher, instructing the judge, attorneys, and jury in the basic concepts and premises that allow them to do the work they do. The triers of fact must be schooled in the methods of production of the evidence (how light bulb glass is made, for example), the procedures used to analyze it, and what makes the evidence significant. That understanding will lead the courts to an appreciation of unquantifiable evidence and give the jury a basis for weighing its significance (Houck, 1999).

4.4 MEDICAL LINK

A recent case does not fit the pattern of most soil evidence but clearly illustrates the contribution being made by forensic geologists. Washington State Patrol forensic geologist Bill Schneck became involved in the investigation into the serious illness of a small child caused by arsenic poisoning. The suspected person was absolved when an examination of the child's house revealed a number of mineral specimens left in the house and the yard by a former occupant who was a mineral collector. Many of those specimens were arsenopyrite, an iron arsenic sulfide. The child had been eating and chewing on the material. This case is a good reminder that lead is not the only material that can cause health problems in children.

4.5 EXAMINATION METHODS

The value of any type of physical evidence depends in large part on how many different types that can be characterized exist on this Earth and how they are distributed. The value of soil evidence rests on the fact that there are an almost unlimited number of rock types, mineral types, fossils, and artificial rock material, including glass and brick and concrete. In addition, it is not uncommon for soil material to have incorporated human-made particles such as plastics, metals, and chemicals such as fertilizer and pesticides.

Various instruments, methods, and procedures are used to study minerals, rocks, soils, and related materials for forensic purposes. These methods are used to collect data from the various questioned and known samples, which are then used to make a judgment as to comparison or lack of comparison. The evidential value of some of these methods is greater than others. However, they are all standard methods long accepted for use in the identification of material. Because of the extreme diversity of soils and related material, the examiner may decide that in a particular case some other method will provide information that will assist in reaching a conclusion. Because soils often have added particles, such as fibers, hair, and/or paint chips,

these can be collected for examination by experts in those forensic science fields (Junger, 1996). One of the reasons that microscopic examination is so important is that it is only way that particles of other forms of evidence can be found and unusual mineral particles discovered. We must remember that examination is focused on determining whether two samples have the same properties and thus have the possibility of having a common source. That determination is greatly strengthened when rare and unusual minerals and particles are found. The experienced forensic geologist can express an opinion based on experience and education (Stam, 2002). The strength of that opinion is often based on knowledge of the rarity of particular minerals, rocks, particles, and related properties.

4.5.1 Color

Color is one of the most important identifying characteristics of minerals and soils (Dudley, 1975; Sugita and Marumo, 1996; Guedes et al., 2009). Minerals form a mosaic of grays, yellows, browns, reds, blacks, and even greens and brilliant purples. Virtually all possible colors of the visible light spectrum are represented. With most geologic materials and soils, the native minerals contribute directly to the soil color. This is particularly true with stream deposits, windblown silts, and other recent formations that have been in place a comparatively short period of time. If sands along a river channel are examined, the color of each sand grain can generally be recognized individually; however, after a deposit has weathered for a long period of time, there is a degree of leaching, accumulation, and/or movement of substances within the soil. Soil particles become stained, coated, and impregnated with mineral and organic substances, giving the soil an appearance different from its original one. The mineral grains, especially the larger ones, are generally coated. In most situations the coatings on the soil particles consist of iron, aluminum, organic matter, clay, and other substances. The coloring of the coatings alone can give some indication as to the history of the sample.

The “redness” of a soil depends not only on the amount of iron present but also on its state of oxidation, with a highly oxidized condition tending to have a more reddish color. The iron on the coatings of the particles probably is in the form of hematite, limonite, goethite, lepidocrocite, and other iron-rich mineral forms. Black mineral colors in the soil are generally related to manganese or various iron and manganese combinations. Green colors are generally due to concentrations of specific minerals rather than of the mineral coatings. For example, some copper minerals, chlorite, and glauconite are usually green. Deep blue to purple coloration in the soil is generally due to the mineral vivianite, an iron phosphate.

Apart from the mineral colors in the soil are those that result from organic matter. The organic litter on the soil surface is generally black. Humus percolates through the mineral horizons, giving various dark colors. In some instances the iron and humic acids combine to form a dark reddish brown to nearly black color. To have some uniformity in descriptions of the color of geologic materials and soils, certain standards have been established. The color standards most frequently used in the United States are those of the Munsell Color Company. The color

standards are established on three factors: hue, value, and chroma. *Hue* is the dominant spectral color, *value* is the lightness color, and *chroma* is the relative purity of the spectral color. Soil and rock colors are generally recorded as, for example, 7.5YR5/2 (brown). The 7.5YR refers to the hue, 5 the value, and 2 the chroma. This standardization of colors offers some degree of uniformity, but moisture content will also affect the color of the soil, as will light intensity and wavelength. Soil color is different in natural light than in fluorescent and different still in incandescent light. If a soil is air dry, it may be recorded as yellow, but if moist the recording may be yellowish brown. Moisture added to a dry soil will usually result in a more brilliant appearance. It is therefore important to record not only the color of the soil but also an estimate of the "wetness factor" at the time of the recording.

In the 1970s, investigators at the UK Home Office Forensic Science Service studied the use of color as an examination method and made many contributions to establishing the study of color as an important first step. Soil, being a mixture of materials of various sizes and compositions, contains individual minerals of different colors. If soil is fractionated into various sizes—coarse sand, medium sand, fine sand, silt, and clay—there is a tendency for the finer-sized particles to exhibit more red or reddish-brown colors as opposed to grays and yellows in the coarser fractions. In considering coarser sand particles, the matrix will commonly have a speckled appearance, with the quartz and feldspar particles being gray or yellowish; but the heavy minerals such as ilmenite and magnetite will generally be black. Sand particles from soils of recent origin, such as recent glacial or stream deposits, usually retain their original mineral appearance and we can usually detect a mosaic of colors. But sand fractions from the old landscapes commonly have coatings of clay, and the sand grains may be iron stained, which results in a more uniform color of the entire matrix. Soil grains veneered with organic matter give the particles a dark gray appearance. It is important first to record the color of the untreated soil sample and then to remove the organics so that the true color and appearance of the sand grains can be studied.

In studying soil samples for forensic purposes, the sample is normally dried at approximately 100°C and viewed with natural light, preferably coming from a northerly direction. A north-facing window is a good location for such observations. Such studies should be made on samples that have the same general size distribution of particles. The color of samples prepared from the individual sieved-out particle-size ranges gives important additional data. Two or more samples, collected for study, can be compared directly by the observer (see Figure 4.2). It is then possible to use a color chart with the samples to determine the Munsell color numbers for precise description of the color.

Instrumental determination of color provides more quantitative information and can now be done with a precision which exceeds that the human eye. Pye Associates of Great Britain have found that rapid, reliable, and highly reproducible results are achieved using the Minolta CM-2002 photospectrometer. This instrument covers the visible wavelength range 400 to 700 nm, providing a number of light source types and observer angles, and producing a range of color indices, including Munsell hue,

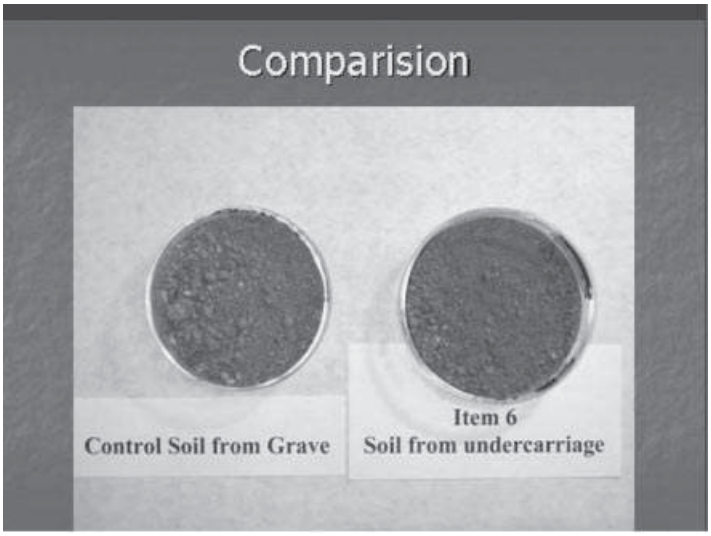

Figure 4.2 Two soil samples available for examination for color comparison. *(See insert for color representation.)*

value, and chroma; L*a*b* indices; and reflectance data and curves. Calibration of the instrument is carried out for every analysis to black, white, and CERAM II color standard materials.

4.5.2 Particle-Size Distribution

The determination of the distribution of particle sizes in a sample can often provide significant evidence. This determination is often produced for a variety of reasons: (1) to produce samples for comparison studies that are similar, in which case the control sample may contain some larger or smaller particles that are not present in the sample being questioned or an associated sample, and they must be removed; (2) the samples may be broken down into subsamples in which all the particles are in the same size range for mineral or color studies; or (3) a determination of the distribution of particle sizes may be produced as a method of comparison. A diagram showing the distribution of grain sizes can be used as a presentation and in many cases may be of evidential value (see Figure 4.3). For example, when abrasive particles have been introduced into machinery for the purpose of sabotage, the size distribution of the particles may be diagnostic of the material, assuming that changes in particle size have not taken place in the machinery.

The basic methods used for the separation of sizes are (1) passing the sample through a nest of wire sieves, with the size of the openings decreasing from top to bottom; (2) determining the rate of settling of the grains in a fluid, which is a measure of the size of the particles; and (3) instruments that measure the size of particles in a microscopic view and record the number of particles of each size. The distribution of particle sizes is then plotted on a diagram.

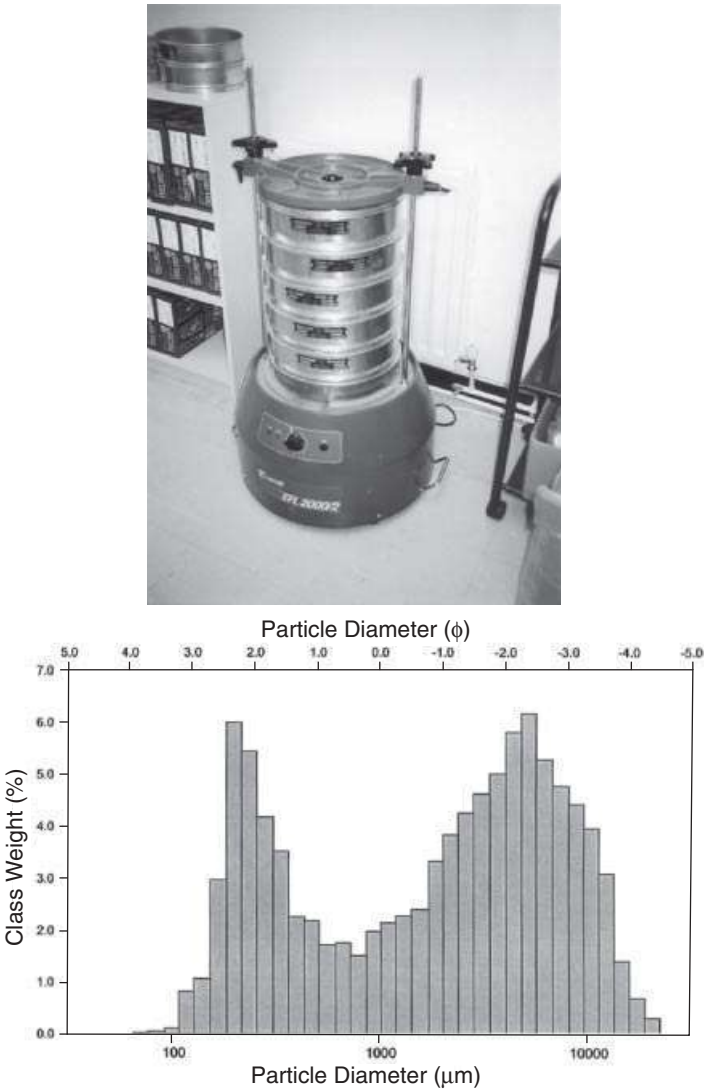

Figure 4.3 Nest of sieves used to separate particles into different size grades and a diagram showing the size distribution of particles. *(See insert for color representation.)*

Before making a mechanical analysis to determine the size distribution of particles, it is necessary to disperse the soil. Individual soil particles tend to stick together in the form of aggregates. Cementing agents of the aggregates must be removed; otherwise, a cluster of silt and clay particles would have the physical dimensions of sand or gravel. Cementing agents consist of organic matter, accumulated carbonates, and iron oxide coatings, and in some situations there is a mutual attraction of particles by physicochemical forces.

If carbonates have cemented the particles together, it is desirable to pretreat the sample with dilute hydrochloric acid to remove the carbonates. The sample is then treated with hydrogen peroxide to remove the organic cementing agents. All samples must be treated in the same way, and it must be determined before treatment that important information will not be lost, such as dissolving carbonate cement from grains that should be treated as single grains. It is almost always desirable to determine the size distribution of soil by sieving in a liquid, usually water. Dry sieving of the entire sample is generally unsatisfactory because the small particles tend to cluster together, and clay tends to adhere to larger particles. Sometimes a dispersing agent is added to the water.

A number of methods can then be used to determine the size distribution of the finer particles in a dispersed suspension. The hydrometer method is a rapid method for determining the percentage of sand, silt, and clay in a sample. It is based on the principle of a decreasing density of the suspension as the solid particles settle out. This method, although rapid and accurate, is unsatisfactory if we want to make a subsequent examination of the various size ranges, because there is actually no physical separation of the various-sized particles.

One of the most accurate and satisfactory procedures for fractionating soil samples is by the pipette method. This consists of pretreating the sample as is done in the hydrometer method, dispersing the soil in water, and calculating the time required for various-sized particles to settle out from the suspension. The principle is based on the fact that the rate of settling depends on the size of the mineral matter, with larger particles settling at a more rapid rate. The procedure is based on Stokes' law: $V = (2/9)gr^2(d - d')/n$, where V is the velocity of fall in centimeters per second g the acceleration due to gravity, r the radius of the particle in centimeters, d the density of the particle in grams per cubic centimeter, d' is the density of the fluid in grams per cubic centimeter, and n the viscosity of the fluid in poise. Although this method is generally considered the most satisfactory in regard to accuracy, it is not infallible. Several assumptions are made: that all particles have the same shape and that all the soil particles have the same density, neither of which is usually the case. Nevertheless, the pipette method is generally considered to be the best available mechanical method.

In making a mineral analysis of a sample, one fact becomes apparent: the sample contains different groups of minerals within various size ranges. Sands are made up of a set of minerals that are usually completely different from those within the clay size range. Therefore, in comparative analysis it is important to make comparisons within the same size ranges. It can be quite deceptive to compare the minerals found in one size range in one sample with a different size range in another sample.

When a transfer is made from a soil it is unlikely that the transferred sample is truly representative of the distribution of sizes that existed at that place. For this reason two samples that are to be compared using grain size distribution may not show exactly the same distribution of grain sizes. The method can be useful in coming to a conclusion of comparison or lack of comparison but is seldom definitive in itself.

Figure 4.4 Forensic scientist using a binocular microscope to identify particles in a soil sample.

4.5.3 Stereo Binocular Microscope

The stereo binocular microscope can be a most useful tool to the forensic geologist (see Figure 4.4). After an analysis of color has been made, the information that can be obtained by examination of soil samples with this instrument makes it the logical first step in the direct examination of particles.

Light microscopes are generally of two types, transmitted light and reflected light. In transmitted light microscopes, the light source is placed beneath the specimen, which must be transparent. Biological microscopes that are used in studying tissue are of this type. Reflected light microscopes have a light source above the object, and the surface features of the particle are viewed. Such a microscope is essentially a stationary, higher-power magnifying glass. Most of these microscopes have two sets of lenses, and thus the object is viewed in three dimensions, that is, in stereo. The magnification of a microscope is determined by multiplying the magnification of the ocular lens, commonly 10×, by the magnification of the objective lens, which differs from microscope to microscope but seldom exceeds 10×. This gives a maximum magnification of approximately 100×. The objectives may be individual lenses of fixed magnification, or in some microscopes a zoom objective is used. Such lenses can change magnification continuously from less than 1× to about 5×. Most viewing with stereo binocular microscopes is done at magnifications between 10× and 40×. Some of these microscopes are seated on a base that contains a second light source so that objects can be viewed in both transmitted and reflected light. When the transmitted light is polarized, the microscope may be used for both stereo reflected light viewing and low-power transmitted polarizing light studies.

Objects as small as approximately 10 μm in diameter can be viewed with a stereo binocular microscope. The upper limit is determined by how large a sample can fit under the instrument so that the surface of pebbles and cobbles can easily be viewed. The sample is normally placed on a tray having a dull black finish for ease of viewing light-colored minerals or a white finish for viewing dark-colored minerals. Various inserts are available for these microscopes that permit measurement of the size of objects or provide grids that aid in counting the various particles. The sample tray may have an etched grid that serves a similar purpose. Trays are available with various gummed surfaces that hold the grains in place for ease of counting.

In examining a soil sample or similar material, the scientist will commonly first examine the entire sample as it is received and observe the types of grains and particles. Recording a general impression of the material is normally done at this time. It is not uncommon to observe in soil samples nonmineral materials such as fibers, metals, paint, glass, and plastics. These objects can have important evidential value. In some situations they can be the most important parts of the sample. Materials such as metals, hair, fibers, paint, and plastic are removed for further examination by specialists. Plant particles can be of great value. The total amount of plant material is in general relatively useless for forensic purposes. However, identification of the individual grasses, seeds, leaves, and the like can be most useful.

Preliminary examination of the entire sample with the binocular microscope is normally very difficult. The mixture of particles of all sizes commonly obscures the grains and makes identification difficult. The presence of organic material contributes to this problem. The sample must be cleaned for the study of minerals and rock. Sieving of the samples removes the larger particles and most of the larger organic fragments. If the sample is washed carefully in water, the lighter organic particles will generally float and can be removed and saved for study. Treatment with hydrogen peroxide will remove the fine organic matter and clean the sample. The use of ultrasonic cleaners is dangerous in many cases. Many times the scientist has taken a sample that contained chips of red shale before ultrasonic cleaning and found that the sample contained thousands of silt-sized quartz grains and clay minerals after cleaning and that the shale chips had been broken up into its components. If the rocks and minerals are of a type that would not be disaggregated by ultrasonic cleaning, the method can be most useful.

With a clean sample, the experienced scientist can identify the rocks and minerals at sight or by using simple tests. In addition, it is possible to observe the texture and coatings on the surface of the grains. Properties of grains such as shape, rounding, weathering, inclusions, color, and polish can be observed and recorded. The counting of different types of grains is especially important. When we record our information in numbers, it is normally more useful than qualitative impressions. However, the samples may be so different on first examination that further work is not useful because a determination of comparison could never be made. The number or percentage of different types of grains is an extremely important tool in determining comparison or lack of comparison. In counting grains of different

types, it is important that the sample counted be representative of the whole sample, that the identification be consistent and accurate, and that the same grain not be counted twice because the sample moved. The latter problem can usually be avoided by placing the sample on a gummed surface or by removing the grains as they are counted and placing each grain, as it is removed, in a container or gummed individual tray. Most important is the judgment and caution used by the scientist, whatever method is used.

4.5.4 Petrographic Microscope

A petrographic microscope differs in detail from an ordinary compound microscope (see Figure 4.5). However, its primary function is the same: to produce an enlarged image of an object placed on the stage. The magnification is produced by a combination of two sets of lenses, the objective and the ocular. The function of the objective lens, at the lower end of the microscope tube, is to produce an image that is sharp and clear. The ocular lens merely enlarges this image. For mineralogical work, three objectives—low, medium, and high power—are normally used. The magnification produced by objectives is usually 2× (low), 10× (medium), and 50× (high). Oculars have different magnifications, usually 5×, 7×, 10×, 15×, and 20×. The total magnification of the image is determined by multiplying the magnification of the objective by that of the ocular as follows: 50× times 10× = 500× (see Figure 4.2).

Oculars normally contain a crosshair that is useful for locating grains under high power when changing objectives. A condensing lens system is normally provided under the stage for use with high magnification and for assisting the viewing of the various optical effects produced by minerals. Petrographic microscopes have a rotating stage and a polarizing filter under the stage that transmits light usually

Figure 4.5 Forensic scientist using a petrographic microscope to identify particles.

vibrating in a N-S (front-to-back) direction. Above the stage a second, removable polarizing filter is placed in the tube of the microscope. It transmits light usually in an E-W (left-to-right) direction. When the upper filter is inserted, light is blocked out from passing through the microscope. In this case the filters, which are called *polars*, are said to be crossed. Only when an *anisotropic* material, that is, a material that is not isotropic (meaning that it forms in the isometric crystal system or is amorphous), is placed on the microscope stage under crossed polars can it be seen. The effect of the anisotropic mineral is to rotate the N-S vibrating light from the lower polarizing filter, thus permitting some of it to pass the upper E-W polarizing filter. When the stage is rotated, there will be four positions when the vibration directions in an anisotropic crystal will line up with the N-S and E-W direction. At these positions the crystal is said to be at extinction and will appear black and thus not be seen.

In identifying mineral grains under the petrographic microscope, it is common to use the immersion method. Mineral grains are placed on a microscope slide in a liquid of known refractive index. These liquids are available commercially. The range 1.46 to 1.62, with a difference of 0.02 between adjacent liquids, serves most purposes. When the grain is viewed, a narrow line of light is commonly seen surrounding the grain. If the distance between the objective and the sample is increased slightly, usually by raising the tube of the microscope, the line of light, called a *Becke line*, will move in the direction of the higher refractive index. If the mineral has a higher refractive index, the Becke line will move into the grain. If the liquid of known refractive index is higher, the Becke line will move away from the grain into the liquid.

By trial and error with different liquids, a match is found. At this point the grain will be almost invisible in the liquid. In most cases the refractive index of the grain is found to fall between the refractive indexes of two liquids, and the value can be estimated by an experienced observer.

The petrographic microscope is an important tool in many aspects of forensic work and is the best method for a study of the optical properties of rocks and minerals. A study of individual mineral grains or thin sections of rocks and related material is easily accomplished by anyone trained in the use of the instrument. A thin section is a thin slice of rock mounted on a glass slide. The slice is normally 30 μm in thickness and may be prepared from a solid rock or loose material impregnated with plastic. The rock is cut with a diamond saw and the surface polished. This polished surface is cemented to a glass microscope slide with an adhesive of known refractive index such as epoxy or Canada balsam. A saw cut is then made parallel to the glass, leaving a wafer of rock cemented on the slide. Grinding of the wafer proceeds until it is thinned to approximately 30 μm. A thin class cover is then glued onto the polished rock surface to protect the rock and improve viewing with the microscope. Most rocks are transparent at this thickness and can be viewed in transmitted light (see Figure 4.6). Loose mineral grains of the same general size, also commonly mounted in epoxy or Canada balsam on a microscope slide, are covered with a thin platelet of glass (cover glass) and studied. This is the method used when the heavy minerals, that is, those minerals with high

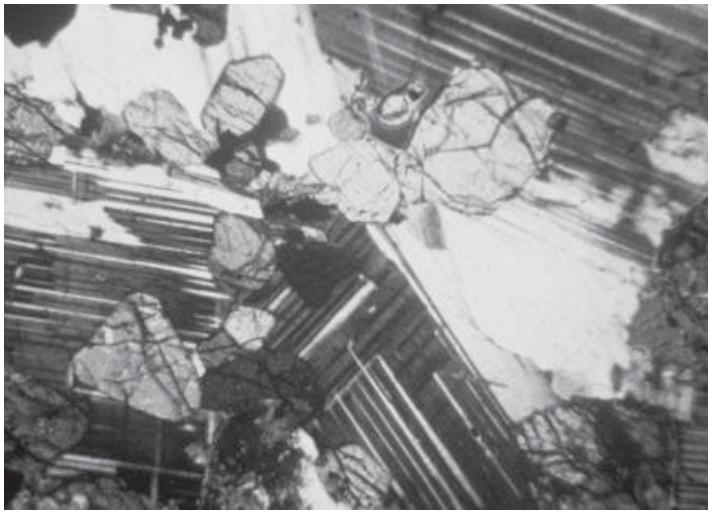

Figure 4.6 Photomicrograph of a rock thin section as viewed through a petrographic microscope, Note the different minerals with different sizes and shapes. *(See insert for color representation.)*

specific gravity (such as rutile, garnet, zircon, and tourmaline), are separated from the more common lighter minerals (such as quartz and feldspar) by settling in a heavy liquid such as sodium polytungstate or one of the other tungsten-based heavy liquids and studied.

4.5.5 Refractive Index

The index of refraction of a transparent material is the ratio of the velocity of light in a vacuum, normally considered to be 1, to the velocity of light in the material being analyzed. Thus, a refractive index of 2.4553 means that light travels 2.4553 times as fast in a vacuum than in the transparent material. The measurement of refractive index, which is one of the most important methods for the comparison of glass, may be made using the Becke line method discussed for minerals. Most forensic laboratories today use the semiautomated refractive index instrument GRIM 11 for glass identification (see Figure 4.7).

4.5.6 Cathodoluminescence

The instrument used for cathodoluminescence is a luminoscope that is attached as a stage on a microscope or a scanning electron microscope. The specimen—for example, mineral grains or a thin section—is bombarded with a beam of electrons generated by the instrument. When the electrons strike the surface of the specimen, an optical luminescence is produced, which is seen as a display of colors. The colors and their intensity depend in large part on very small changes in the concentration of

Figure 4.7 Forensic geologist using GRIM 11 instrumentation to determine the refractive index of a glass.

trace impurities, the minerals present, and where the trace impurities are located in the structure of the minerals. Thus, the method has wide application in determining or observing a variety of differences in mineral grains that otherwise appear similar.

4.5.7 Scanning Electron Microscope

The scanning electron microscope (SEM) has a wide range of magnifications, generally from 25× to over 650,000× and can record something as small as 1.5 nm. Needless to say, most of the work of the forensic geologist falls well within these limits. This instrument became commercially available in the mid-1960s and has been introduced rapidly in forensic work, especially in the study of gunshot residues and various other very small particles. It has the advantage that the surface of a sample may be viewed directly. However, an ultrathin coating of carbon or gold plated on the specimen improves the quality of the picture. The depth of field is very large, and most SEM pictures have an excellent three-dimensional appearance. In using the instrument it is possible to change magnification easily and thus study the appearance of the surface from very low to very high magnification. Differences in very small fossils that were not previously known can now be seen during routine examination. Surface features of individual grains of minerals such as quartz can be seen and shown to have many different types of scratches, pitting, and mineral growth. Some of these features may be useful in telling us the past history of the individual grain. It is not uncommon to observe other minerals, such as clay flakes, filling the scratches and thus adding another characteristic that can be useful in comparing the minerals.

When using these powerful instruments in forensic work, it is well to keep in mind that no two objects are ever exactly the same. No two sand grains are ever

exactly alike when studied under the high magnifications of an electron microscope. This is true even if they have been side by side for the past million years. Observations made with these instruments can be very useful for establishing similarity or dissimilarity between samples. However, the very power of the instruments permits the possibility of their abuse in the hands of the unscrupulous. If we were to do a complete chemical analysis of a total person by the most modern methods in the morning and repeat the analysis on the same person in the afternoon, we would find chemical differences. However, this would not demonstrate that we had analyzed two different people. Similarly, the demonstration of small differences in soil does not prove in itself that they do not compare. It is equally true that showing a common similarity among soil samples, such as their both containing quartz, the most common mineral in soil and sediment, is poor evidence on which to base a comparison. The professional judgment of the scientist thus becomes increasingly important when these powerful instruments are used.

Scanning electron microscopes have the ability to determine the elemental composition of the particles being examined. This is possible because x-rays are produced when the electron beam of the microscope strikes a target. The scanning electron microscope can be coupled to an x-ray analyzer. The emitted x-rays are sorted by their energy or wavelength values, which are related to specific elements, and the analyzer produces information that identifies the elements present in the material being viewed. The amount of each element present is determined by the intensity of the emitted x-rays. Thus, the examiner can determine the chemical composition of the individual particle or particles being viewed.

4.5.8 X-Ray Diffraction

X-ray diffraction is one of the most important and reliable methods of identifying the composition of geologic, soil, and other crystalline substances (see Figure 4.8). The method is based on the arrangement of atoms, ions, and molecules within the specimen. The sample is analyzed by passing x-rays through a crystal and measuring the angle of the diffracted x-rays. Each crystalline material has its own distinctive x-ray pattern. The x-ray diffraction pattern of a sample is controlled by the internal structure of the specimen. The diffraction pattern can be collected on film, on an image plate, or by using an electronic detector. The interpretation of x-ray patterns under normal situations is a comparatively simple matter. Two factors are of prime importance in the interpretation: the d-spacing from d in Bragg's law, which is expressed in angstroms (Å; 1×10^{-8} centimeter or 0.0039 millionths of an inch), and the intensity.

There are at least two avenues for interpreting x-ray diffraction data: The first involves measuring the d values and intensities and comparing this information with published lists of data on minerals. The second involves comparing the x-ray pattern directly with the pattern produced by a known mineral. If a comparison between samples is to be made, there are situations in which the x-ray diffractograms themselves may be compared without actual identification of the substance. This is obviously less useful as evidence than actual identification.

Figure 4.8 Forensic geologist using an x-ray diffractometer to identify minerals.

Among the strong points favoring the use of x-ray diffraction patterns is that they record the crystal structure. If two substances, diamond and graphite, were analyzed chemically, they would be identical because both are composed of pure carbon, but x-ray diffractograms of the two minerals would be quite different. Many samples are mixtures of two or more substances. If substances are analyzed chemically, some difficulties may be encountered because the actual chemical form of the substances at times cannot be established. As an example, we can use a mixture of two salts, sodium chloride and potassium nitrate. If the composition of the sample were determined by the usual chemical methods, it would reveal sodium, potassium, chloride, and nitrate; but what were the original compounds? Were they sodium chloride and potassium nitrate, sodium nitrate and potassium chloride, or a mixture of four salts? An x-ray diffractogram of such a salt mixture would tell us specifically the form of the salt.

X-ray diffraction is used as the principal tool in the modern identification of clay minerals. The chemical composition of clays generally tells us very little as to the nature of clay substances, but the possibilities of identification of clays by x-ray diffraction are almost unlimited. Clays, as well as other crystalline substances, can be x-rayed, and if identification is desired, the composition of the sample can be ascertained by measuring the diffraction patterns from a standard reference book or from reference cards.

4.6 CHEMICAL METHODS

There are a large number of instruments and methods that measure the chemical composition of organic and inorganic materials. There are times where these methods can be very useful and provide valuable information. For example, the

chemical composition of glass is often a valuable addition to the optical and physical properties. Identification of organic compounds in a soil such a fertilizer adds an entirely new dimension to the list of properties used in determining comparison.

Methods for determining the amounts and types of elements in a sample may rely on the fact that as one of its properties, an element selectively emits or adsorbs light. This is the basis for emission spectroscopy and atomic adsorption spectrophotometry. Neutron activation analyses is a nondestructive method that produces a detection sensitivity of one-billionth of a gram. This method requires a nuclear reactor to bombard the sample with neutrons. The resulting gamma-ray radioactivity is measured to identify the elements present and their amounts. Needless to say, this method is expensive to operate and maintain and leaves the samples radioactive. Organic compounds contain carbon, and their identification requires different methods. There are several techniques for separating out the various compounds in a mixture. Generally, these methods depend on the relative amounts of the gas phase of a compound and the liquid phase under fixed conditions. That amount is a characteristic property of each compound. Because those compounds that have a higher tendency to go to the gas phase will move faster away in a given time, the distance they move in that time identifies and separates the compounds. These methods are generally called chromatography. Identification is also done using spectrophotometers, which measure the light-adsorbing properties of a compound. Mass spectrometers have the ability to uniquely identify compounds if analyzed under proper laboratory procedures. This instrument bombards the sample with high-energy electrons, causing the molecules to lose electrons and become positively charged. This is an unstable state and the molecules immediately break up into fragments. The instrument then passes the fragments through an electric or magnetic field where they are separated according to their masses. This permits the specific identification of the compounds because the distribution of masses is a unique property.

4.6.1 FTIR and Raman Spectroscopy

Fourier transform infrared spectroscocopy (FTIR) and Raman spectroscopy are nondestructive analytical tools that are commonly applied to the identification of minerals and material of organic origin. They are often combined with a microscope, thus facilitating the identification of a very small object or part of a sample. The nondestructive aspect is important because most owners do not appreciate removing part of their art object or gems for analyses. In addition, in criminal cases the sample may be very small and removal of material for analysis might leave little remaining for additional study or verification. In applying these methods, a source generates light across the spectrum of interest. The sample absorbs light according to its chemical properties. A detector collects the radiation that passes through the sample. Computer software analyzes the data collected and the results are compared with known spectra of inorganic and inorganic materials.

4.7 LOOKING AHEAD

The last several years have witnessed a tremendous increase in both the quantity and quality of forensic examination of soil and related material. There are now three comprehensive books on the subject, and the reader is encouraged to use them as source material (Murray, 2011; Pye, 2007; Ruffell and McKinley, 2008). The future will depend on how well we address a series of issues that include the following:

1. New methods are being developed that take advantage of the discriminating power inherent in earth materials. The opportunities appear to lie primarily in quantitative mineral identification. For this reason, the development of quantitative x-ray diffraction techniques that will provide quantitative data on the mineral composition of a sample would seem to be an important direction for research.
2. Considerable effort must be devoted to defining appropriate sampling methods and the training of those who collect samples. Communicating to law enforcement personnel the potential evidential value of soil and related material is particularly important, because unless the evidence is collected there will never be an opportunity for forensic examination.
3. There is a tremendous need for studies that attempt to demonstrate the diversity of soils. Such studies provide the opportunity for establishing worthwhile information on the distribution of the various soil types. The information should be data based and widely distributed.
4. There must be a continuing effort at all levels to improve the qualifications of examiners in forensic geology.
5. A problem has developed that result from the availability of new instruments that provide increasingly detailed measurements or observations, such as the scanning electron microscope. These instruments are capable of discriminating between individual grains. When you discriminate between individual grains, you lose the ability to say that the sample being examined was once part of, and thus had a common source with, another sample. When this is done, the entire concept of comparison is eliminated and the evidential value is lost. The forensic geologist must choose methods that provide the maximum discriminating power between samples without falsely excluding samples that are in fact associated.

The real future of the science lies with education: the education of the investigator and evidence collector that earth materials can make a major contribution to justice if they are both collected and studied properly. The real challenge of yesterday, today, and tomorrow is the production of the best evidence by the most skillful and objective people to serve the cause of justice. Our system of justice is still run by people, people who are human and in many cases people who are trained advocates. Those who the courts honor by allowing them to express an opinion, the expert scientific witnesses, must rise to the highest standard. If they don't, the advocates may find ways to remove the privilege and return to a legal world populated only by human witnesses reciting their stories from memory.

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CHAPTER 5

Analysis of Paint Evidence

SCOTT G. RYLAND

Florida Department of Law Enforcement, Orlando, Florida

EDWARD M. SUZUKI

Washington State Crime Laboratory, Washington State Patrol, Seattle, Washington

Summary Paint and coatings often appear in criminal, civil, and art authenticity investigations. In this chapter we review the current methodologies and approaches used by forensic paint examiners to analyze this type of physical evidence as well as the problems that they may encounter. Fragments of multilayered in-service paint are one of the most complex types of materials encountered in the forensic science laboratory. They consist of both organic and inorganic components heterogeneously distributed in very small samples, often on the order of only 1 mm^2 in size. Each layer is an entity onto itself and its autonomy must be maintained throughout the analysis. These characteristics dictate the requirements of the analytical chemistry approaches to be used, and they can present a formidable challenge to the forensic analyst responsible for the classification of the materials and an evaluation of their evidential significance. Several case examples are presented to illustrate these concepts.

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5.1 INTRODUCTION

The body of Wendy Coffield, 16, was discovered in the Green River, south of Seattle, on July 15, 1982. In the months to follow, the bodies of several more young women were found in or near the Green River. By the early 1990s, the total number of victims believed to be associated with this unsolved case had reached 60 or more, and investigators were faced with the very real possibility that the most prolific serial killer in U.S. history would never be apprehended. In 2001, based on recently developed DNA technology, semen samples collected from three of the victims were found to be those of Gary L. Ridgway, a paint detailer at a local truck manufacturing plant. Ridgway pleaded not guilty when charged with homicide, claiming that he only had sex with the victims. Although usable DNA evidence was not recovered from any of the other bodies, hundreds of very small colored spherical particles were found on the clothing of four of them as well as on the clothing of two of the victims associated with Ridgway's DNA (Palenik, 2007). Similar particles were found on Ridgway's work clothing and in his home and work environments. These particles were identified as dried droplets produced from the plume of spray paint, and the paint was found to have an acrylic urethane composition. In the early 1980s, this formulation was not used at all on North American original automotive finishes and it would also have been quite unusual for architectural coatings, with the possible exception of certain varnishes, but these would not have been pigmented as were the samples found on the bodies. The paint was identified as Imron, a DuPont high-end specialty product not sold to the general public; more specifically, it was found to be Imron that had been manufactured before 1984. This product had been used at the truck plant where Ridgway was employed, and the paint evidence was the basis for charging him with four additional counts of homicide. In 2003, Gary L. Ridgway pleaded guilty to 48 counts of homicide, prompted by his desire to avoid the death penalty and his fear of a conviction in the face of more physical evidence linking him to the victims. Ridgway's attorney was quoted in the press as stating that the paint evidence was crucial in his client's decision to change his plea.

This example illustrates the value of paint as physical evidence and as an investigative tool, and although the majority of cases involving paint may not be in the national limelight, this important category of trace evidence provides crucial links in criminal investigations and prosecutions on a daily basis. Typically, forensic paint examiners are asked to perform a comparison of two or more samples to determine if they could share a common origin. The samples may result from transfer of paint from one item to another, as may occur when a vehicle strikes another vehicle, a building or road structure (such as a guardrail), or an individual. If the object that is struck also has a painted surface, a double transfer may result, with each item now having paint from the other. Other circumstances may also facilitate a transfer, as when a crowbar is used to pry open a window, safe, or some other item with a painted surface; a bullet or other projectile strikes a painted surface; a person or object comes into contact with wet paint; or when paint particles are transferred from the clothing of one person to another due to contact. The latter two transfer scenarios are believed to have occurred in the Green River cases.

In other instances, an unknown paint chip is recovered from the scene of a hit-and-run accident or from clothing of a victim struck by a vehicle, and the forensic paint examiner is asked to try to identify the type of vehicle involved. On a few occasions, the paint examiner may be asked to determine if a material *is* paint, and if so, the type of the paint and its possible relevance to the circumstances of the investigation.

In the Green River cases, elements of all three types of examinations (comparison, vehicle identification, and determination if paint) were involved. After the unknown colored particles were removed from the victims' clothing, the trace analyst first had to determine what they were. Finding them to be dried droplets of spray paint, the analyst next had to determine their chemical composition and whether the specimens were similar to those associated with the suspect. Based on chemical composition, an original automotive finish—which usually serves as the basis for identifying the type of vehicle involved in a hit-and-run incident—appeared very unlikely. The nature of the paint, dried droplets of spray paint, also suggested that an original automotive finish was probably not involved, as the nearest automotive assembly plant was thousands of miles away. Nonetheless, an identification of the paint was sought to assess the significance of the match that was found between the specimens from the suspect and the victims. In this case, this resulted in the determination not only of the specific brand of paint that was involved, but also of a time frame for when it was manufactured.

One other type of examination that the forensic paint examiner may be asked to perform concerns whether a painting or some other artifact is a forgery. Although authenticity in such cases cannot be established by paint composition alone, in certain instances, forgeries can. If a painting or other artifact that was supposed to have been made on a certain date or during a certain time period contains pigments or other paint components that were first available only after this date or period, the painting or artifact could not have been produced when purported (assuming that no modern restorations were performed).

How the forensic paint examiner goes about accomplishing these varied tasks is described in this chapter. We begin with an overview of paint chemistry and color science, briefly describe the types of coatings encountered, and discuss some issues and concerns specific to paint evidence of which analysts must be cognizant. The various analytical methods that are used to examine paint evidence and the types of information that these methods provide are then described. Since correct interpretation of analytical data is the cornerstone of formulating appropriate conclusions, we discuss analytical methods in some depth. Because data collected for two or more samples are frequently compared, differences that may occur and *their significance* are central issues in forensic science. Aspects of a particular analysis that can significantly affect data—such as sample preparation, instrument parameters used, nature of the samples, and possible alterations of samples caused by the analysis process—are therefore emphasized. We conclude by presenting three more case examples to illustrate the concepts discussed and to demonstrate further the wide variety of analyses that an examination of paint evidence may entail.

5.2 PAINT CHEMISTRY AND COLOR SCIENCE

Paint is a film or coating that serves both decorative and protective functions. In the coatings industry, *paint* usually refers to a pigmented coating, but in this chapter it is synonymous with the term *coating*. Dried paint consists of three components: a binder, pigments, and additives. The *binder* comprises the matrix that holds the paint together, within which are suspended very small particles of pigments and additives. The binder consists of an organic polymer that not only forms a strong film but also adheres to the substrate to which it is applied. A *pigment* is a finely powdered compound or mixture that imparts color, opacity, or other essential properties (such as luster or texture) to the paint. An *additive* is a substance added to a paint (usually in a small quantity) to improve its properties; it includes components such as corrosion inhibitors, catalysts, ultraviolet absorbers, and *plasticizers*. Plasticizers are moderate-weight organic compounds (often esters) or polymers that serve to fill the spaces between adjacent polymer chains, making the product more flexible and less brittle.

5.2.1 Binders

The polymers that are used for paint binders include acrylics, alkyds, polyesters, urethanes, epoxies, vinyls, cellulosics, and silicones (Morgans, 1990; Ryland, 1995; Thornton, 2002). Binder polymers may consist of single repeating units (homopolymers); two or more units, usually in a random order (copolymers); different homopolymer or copolymer units joined together (block copolymers); or homopolymers, copolymers, or block copolymers associated in the same binder matrix but without covalent bonds between them. Depending on the binder,

the polymer chains may be linear, branched, cross-linked, or a combination of these, and many of the polymers cited may constitute the main backbone chain, a side chain, or a cross-linking chain (Oil and Colour Chemists' Association, 1983). Binders are typically manufactured by a chemical company, such as Rohm & Haas or Union Carbide, and then sold to a paint manufacturer, such as Sherwin-Williams or Inmont, for incorporation into the paint batch. There are exceptions to this trend with large companies such as DuPont, which has facilities to manufacture the binders as well as divisions devoted solely to paint manufacture.

Several different processes are used to create binders from polymers or monomers. One straightforward method involves a preformed polymer, usually linear, which is dissolved in an appropriate solvent. A film of the paint is formed by simple solvent evaporation and this type of paint is referred to as a *lacquer*. The adjacent polymer chains of the binder are held together by relatively weak forces (van der Waals and polar forces), so such paints can be redissolved in appropriate solvents.

One lacquer that many readers may be familiar with is nitrocellulose, since it is the main binder of most fingernail polishes. Nitrocellulose is a linear polymer that is produced by forming nitric acid esters with roughly two-thirds of the free hydroxyl groups of cotton (cellulose). It is soluble in acetone, ethyl acetate, and other organic solvents but forms a rather brittle film by itself, so a plasticizer is also used in the formulation. An additional polymer, such as tosylamide–formaldehyde, may be included to improve adhesion to the fingernail surface (Drahl, 2008). As a lacquer, fingernail polish is readily removed using acetone or other solvents. A nitrocellulose lacquer was used for the first production-line automobiles, manufactured in the 1920s (Fettis, 1995).

A second method of forming binders also involves a mostly preformed polymer, but in this case, small *micelles* of the polymer are suspended in the paint solvent (similar to fat globules dispersed in milk) rather than forming a true solution. These colloidal systems are known as *emulsion* or *dispersion finishes*, although when water is used as the medium and architectural coatings are involved, they are more commonly referred to as *latex paints*. Upon evaporation of the solvent, the micelles coalesce to form a film and further polymerization occurs. Depending on the specific polymer used, the film formed from this process may be an *enamel* (a finish that is not soluble in most solvents) or a lacquer. Solubility usually reflects polymer structure, with lacquers normally comprised of linear chains whereas enamels exhibit considerable cross-linking. Other methods of forming binder polymers are also used.

One of the most common automotive paint binders is the acrylic melamine enamel, which has served as a staple for North American automobile finish layers during the past 40 years or so (Rodgers et al., 1976a; Ryland, 1995; Suzuki, 1996a; Ryland et al., 2001). The polymer chain of this binder is comprised of a sequence of acrylic copolymers, and methylated, butylated, or isobutylated melamine–formaldehyde is used to cross-link the acrylic backbone (Nylen and

Sunderland, 1965; McBane, 1987; Fettis, 1995). This composition is shown schematically in Figure 5.1; eight different acrylic copolymers are depicted to illustrate the variety that may be used, although in practice, no more than five are normally found in a single formulation (Nylen and Sunderland, 1965). The various copolymers are chosen to impart specific properties, such as hardness, flexibility, durability, adhesion, gloss, and water and chemical resistance. Although not an acrylic, styrene is also frequently incorporated into the backbone. In addition to specific copolymer composition, the properties of this binder are determined by the extent of cross-linking. Original automotive paints are baked to cure the finish, that is, to promote the cross-linking process, and also to increase gloss.

5.2.2 Pigments

Pigments are distinguished from dyes in that they are insoluble in most solvents, and in particular they are insoluble in the solvent used for the paint itself. Dyes, in contrast, are soluble, and they are not used in most paints, as they are less durable than pigments and also because they are usually too transparent; it would be difficult and probably cost prohibitive to try to incorporate enough dye into a paint to make it opaque. Dyes also suffer from one other serious drawback regarding tint control. The optical properties of a color-imparting agent (such as hue and *tinctorial strength*) depend on particle size, particle-size distributions, and crystal structure (Braun, 1993). Many common paint pigments exhibit *polymorphism*; that is, they can occur in more than one crystal structure, and in some cases, two different crystal structures of the same pigment will exhibit quite different hues. Particle size, particle-size distributions, and specific crystal structures cannot be controlled when a dye recrystallizes from solution; hence, a color-imparting agent that is insoluble in the paint must be used.

Even with the use of pigments, paint formulators must be aware of the effects of polymorphism. Copper Phthalocyanine Blue (Figure 5.2) is a very common organic pigment used in automotive and other paints and it can occur in any of four different crystal forms (Lewis, 1995). The polymorph of this pigment that is used in most paints is treated to prevent its slow conversion to another crystal form that has a green rather than a blue hue, as most consumers do not appreciate their blue vehicle turning green with age.

The most common pigment used in paint is titanium dioxide. This compound occurs in three polymorphic forms, rutile, anatase, and brookite, but only the first two are used in paints. Rutile is, by far, the more common of the two, both because of its slightly greater index of refraction and, especially, its greater durability to light exposure and heat. Rutile serves to make a paint opaque, that is, to make it white (or a lighter color—adding a large amount of rutile to a red paint, for example, makes it pink). A binder that is cured to form a dried film is normally transparent, but the presence of numerous small particles of rutile causes light incident on this medium to scatter in all directions. Rutile is effective at scattering light because its index of refraction ($\sim$2.7) is quite high compared to that of paint binders ($\sim$1.5).

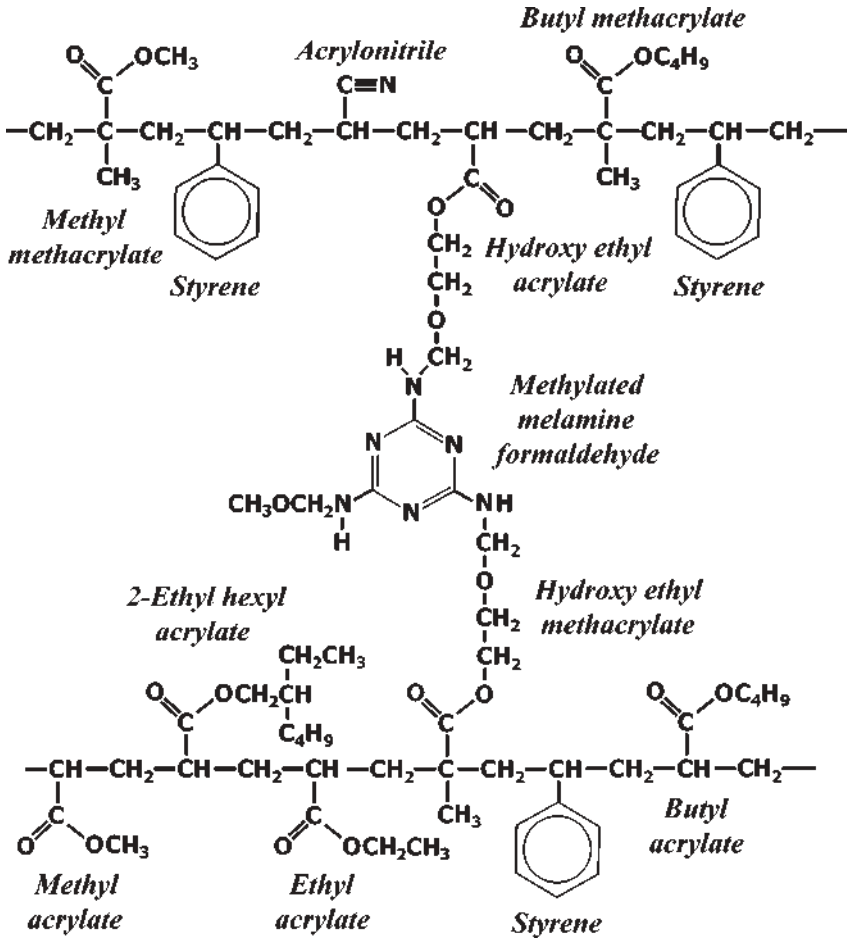

Figure 5.1 Composition of an acrylic melamine enamel binder commonly used in automotive finish layers.

Particles of a substance that have the same index of refraction as the paint binder will not produce any optical effects, but they do serve to add bulk to a paint. Pigments that have indices of refraction that are close to that of the binder are thus referred to as *extender pigments*. They are sometimes used to modify the optical, physical, or chemical characteristics of paint, such as gloss, surface texture, viscosity, strength, chemical resistance (weatherability), or abrasion resistance. Some of the more common extender pigments used in paints include talc, kaolin (clay), calcite (calcium carbonate), quartz (silicon dioxide), mica, and barytes (barium sulfate), all of which have indices of refraction near 1.6.

The vast majority of pigments used in paint produce color by selective absorption of certain wavelengths of visible light. Most inorganic pigments are comprised of transition metal complexes or salts, and their visible absorption properties arise

from electronic transitions of valence electrons in d orbitals (Judd and Wyszecki, 1975). Electronic transitions between d orbitals of isolated atoms are not allowed by *selection rules*, but they may become "weakly allowed" when these orbitals form ligand bonds.

Organic pigments are flat planar systems with extensive conjugation (Figure 5.2) and light absorption involves π-electron transitions. These are allowed transitions, and organic pigments are strong absorbers of visible light. Organic pigments therefore have higher tinctorial strengths than inorganic pigments. In regard to other pigment properties, organic pigments tend to produce brighter and more vivid colors, have smaller particle sizes, are less opaque, are less durable to long-term light exposure, and are more expensive than inorganic pigments (Oil and Colour Chemists' Association, 1983).

In attempting to mimic the iridescence of pearls, butterfly wings, and some other visually striking objects in nature, chemists have devised several specialized pigments for use in cosmetics, paints, and other products. Most such *effect pigments* produce colors by means of light interference (Droll, 1999). A common example of this is the change in color of an oil slick when viewed from different angles. The oil slick consists of a very thin layer of hydrocarbons on water, and interference between light waves reflected from the top of this film and from the oil–water interface produces different colors, depending on the angle at which the film is viewed, the thickness of the film, and its index of refraction. This results from constructive and destructive interference between the two reflected rays. Pearlescent and certain colored and color-shifting pigments are based on this principle, and they consist of refractive laminated flakes that are oriented mostly horizontally in the paint. Color-shifting pigments based on very small

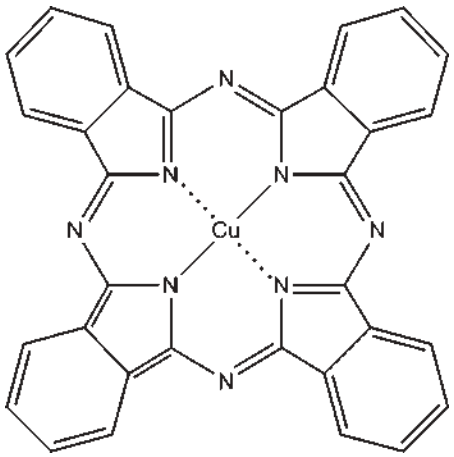

Figure 5.2 Structure of Copper Phthalocyanine Blue (Pigment Blue 15), a very common organic pigment used in automotive and other paints. Note that this structure is only one of several canonical structures and that the four isoindole ring systems are equivalent.

striated plates acting as miniature diffraction gratings have also been introduced recently.

The types of pigments and pigment combinations that are used in a particular paint depend very heavily on the applications of the paint and the visual effects that are desired. All white and light-colored exterior paints normally contain large amounts of rutile, while varnishes, automotive clearcoats, and other transparent finishes contain little or no pigmentation. Metallic paints must have a semitransparent finish so that the metal flakes, which are usually composed of aluminum metal, can be observed. Organic pigments are usually more prevalent in such paints, as they are more transparent than inorganic pigments, owing to their smaller particle sizes and lower indices of refraction. Extender pigments are normally used to control luster in paints, and architectural finishes with low lusters contain large amounts of such pigments. More details regarding paint composition, manufacture, and use are described by Nylen and Sunderland (1965), Oil and Colour Chemists' Association (1983, 1984), Morgans (1990), Lambourne and Strivens (1999), and Bentley (2001).

5.3 TYPES OF PAINT

There is no such thing as a universal finish, as even when discounting consumer tastes regarding color and type of finish, there is no single binder or binder and pigment combination that will meet all of the varied demands of every paint application. Certainly, this is a beneficial situation for the forensic scientist since, as we saw, the composition of a paint can tell us a lot about its uses, and it is this very wide diversity that makes paint so valuable as evidence.

Paint composition is ultimately a compromise between various conflicting performance characteristics, economic issues, and environmental and safety concerns. It is not possible, for example, for a paint to have an extremely hard finish and to be quite flexible at the same time. An epoxy with a bisphenol A component is often used for automotive undercoats and many indoor applications because of its excellent adhesion and other desirable properties, but it is not durable enough with respect to light exposure to be used in automotive finish layers. Acrylics and alkyds have been used extensively for automotive finish layers, providing a hard durable finish on rigid metal and plastic substrates, but they are not used (by themselves) on flexible plastic automobile bumper covers because they are too brittle and would crack readily when subjected to the minor collisions that the bumper itself is designed to withstand.

5.3.1 Automotive Finish Systems

The demands of an automotive finish are among the most stringent of any type produced in the coatings industry. Appearance is paramount for a consumer product, where utility often takes a back seat to status, and visually, automotive finishes are the most diverse in the industry (Panush, 1975; Ehlich, 1988). Such paints span the entire spectrum of colors from black to white (both of which are also

popular choices), with virtually everything in between, and more than half of the original finishes contain some sort of "effect" pigment flake (metallic, pearlescent, interference, or diffraction). About the only color that is not used in an original automotive finish is nonmetallic pink ("shocking pink"), but even that hue may be found in some fleet or special-order original finishes. Flat and satin finishes are rare and the overwhelming majority of automotive finishes have high gloss. Durability (color and gloss retention) is a very important consideration, and vehicle paints also have very demanding mechanical requirements, such as chip, corrosion, and chemical resistance. They are carefully applied as highly engineered layer systems, with each layer serving a specific purpose. Binder formulations are highly complex and a broad variety of polymer types are employed.

5.3.2 Architectural Coatings (Structural Paints or House Paints)

Architectural paints are the second most common type of paint encountered in the forensic science laboratory. Unlike automotive paints, they are seldom designed to be applied as layer systems; consequently, layer colors and sequences will vary with the whim of the customer. They are designed either for interior or exterior application, and a good portion of their design is targeted at ease of use. This affects choices as to the binders and pigments to be used, the additives to control viscosity and, consequently, film buildup; and the additives to control stability during storage after use. There are two general chemical classifications for the binders; water-based (latexes) and oil-based. The latexes permit easy cleanup with soap and water, a big selling point for the home user. The oil-based systems require mineral spirits or turpentine for cleanup. Only three major binders are used, although there are many variations within each major class. The latex binders include the poly(vinyl acetate)–acrylic (PVA–acrylic) and acrylic resins, while the oil-based binders are almost solely alkyd resins. There are some poly(vinyl acetate)–polyethylene binders on the latex market, but they command a very small share of the sales (less than 2%), as do some newer latex paints with low concentrations of alkyd resin incorporated. Unlike the case of automotive finishes, appearance other than color is not paramount. This results in a highly competitive market with many more manufacturers than exist for automotive paints. Almost an infinite number of colors are available, but many fall into the off-white or pastel classes, employing very low concentrations of coloring pigments. The paints are pigmented at the retail store and offered in a series of gloss levels, including flat, satin, eggshell, semigloss, and high gloss. The pigment is added to a tint base, which is a 1- or 5-gallon can of white paint of the chosen binder type and gloss type. Even the high-gloss paints do not approach the gloss levels of automotive finish coats. It is extremely unusual for these paints to include effect pigments.

It is difficult to specifically place certain finishes in this general class of coatings; however, some applications deserve mention. Wood coatings, such as colorless varnishes, are of note, with most binders being alkyds or urethanes and some having acrylic copolymers incorporated as well.

5.3.3 Other Coatings

The third most common type of paint encountered in the forensic science laboratory falls into the class of maintenance paints. These finishes are designed primarily for their protective properties and functional characteristics, with color and gloss quality being of secondary importance. They are quite diverse and may be found as coatings on tools, appliances, lawn and garden tools, circuit boxes, safes, ATM devices, valves, bridges, traffic signs, and so on. Considering the applications, it does not take too much imagination to deduce why they are encountered as evidence. The binders and pigments used cover a broad range, with original finishes demanding durability similar to that of automotive coatings. They may be high gloss and may also have effect pigment in them, but rarely interference decorative flake.

Trade-sale spray paints, the type found on the shelves of your local hardware or home improvement store, are yet another general class of end-use product encountered in the forensic science laboratory. Binders typically include alkyds, acrylics, nitrocelluloses, urethanes, and epoxies. Some silicone binders may be found as well. The finishes may have effect pigments incorporated in them; however, application methods are obviously not nearly as controlled as in the automotive industry.

5.4 PAINT EVIDENCE INTERPRETATION CONSIDERATIONS

Although one often thinks of paint as a "wet" medium that is applied and allowed to dry, the forensic paint examiner deals predominately with cured in-service paint films. There may, however, be occasions where a can of paint or spray paint is submitted as evidence and the paint examiner is asked to determine if the contents of the can could have been the source of a paint film. In these instances, the paint examiner will prepare a film of dried paint for comparison.

In a comparison case, two samples are typically received for analysis, referred to as *known* and *questioned* specimens. The former denotes the reference sample, which usually has a known origin (e.g., a vehicle suspected of being involved in a hit-and-run incident), and this is to be compared to sample recovered from a scene (a paint chip from a hit-and-run location) or a suspect, or some other source that may provide a link between events and individuals.

Although it may seem like a straightforward process to compare two paint samples, the forensic paint examiner deals with real-world specimens that are often far from ideal for analysis. Because of the nature of the events that usually produce paint evidence, the questioned specimens are often quite small, such as those recovered in the Ridgway case. The paint may have been in service for many years, subjected to weathering, marring, contamination, repaints, and so on. These processes result in what is decidedly a double-edged sword as far as interpretation of evidence is concerned. They can make obtaining and interpreting data a very demanding task; at the same time, however, some of the unique characteristics that they might confer to a paint can be quite significant if similar features are found on both known and questioned samples.

There are many factors that the forensic paint examiner must consider when interpreting data for paint comparisons. Many of these arise from the inhomogeneities in paint, not only at the microscopic level but at the macroscopic level as well. Many readers have probably seen the effects of weathering on an interior house paint arising from differences in exposure to light: the paint behind a picture on the wall may have a different hue compared to the same paint that has been exposed to sunlight. Bleaching and other effects may be even more pronounced for automotive paints, where, for example, the roof has received considerably more exposure to sunlight and other environmental conditions than has the vertical side of a fender. The original paint systems on many automobiles are likely to be varied to begin with, considering that some have two tone colors, and as noted, paint systems used on metal substrates may differ from those used on plastic bumpers and other plastic parts. Another possible source of inhomogeneity of an original automotive finish commonly arises from factory touch-ups. These occur when a portion of the vehicle is damaged during the assembly process and must be repaired and refinished before leaving the plant. A nonfactory repaint will usually result in even more heterogeneity when only a portion of the vehicle is refinished, as typically occurs. Refinished areas may also differ due to removal of one or more previous layers as a result of sanding. Paint systems therefore cannot automatically be excluded as having a common origin, even if the number of layers does not match. For cases involving paint from a spray can, differences in paint composition can also occur, depending on whether the can has been shaken or not prior to use (Zeichner et al., 1992). Assessing heterogeneity in samples—and its significance—is a major portion of the forensic paint examiner's task.

These considerations emphasize the importance of having appropriate reference samples when comparisons are made, and the various circumstances of which the forensic paint analyst must be cognizant when interpreting paint evidence. Unfortunately, appropriate reference samples are not always available, and the condition of the questioned samples can be an analytical chemist's nightmare. Sample size, sample heterogeneity, layer smearing, or contamination by the substrate onto which the specimen was transferred epitomize some of the difficulties that may confront the paint examiner. Such realities, as well as the lack of comprehensive databases for all types of paints, underscore the reasons why the conclusions that the forensic paint examiner can draw run the gamut from unequivocal to simply unattainable.

5.5 ANALYTICAL METHODS

As discussed, dried paint is a complex matrix comprised of a variety of mostly nonvolatile and inert inorganic and organic ingredients spanning a very wide range of concentrations, and most paints that forensic analysts examine are insoluble enamels. It is thus not surprising that paint examiners typically use a battery of different methods to obtain as much information as practical to characterize, differentiate, identify, and compare such evidence. Methods that provide maximum discrimination between paints are sought and it is desirable that the suite of methods chosen

provides complementary information. At the same time, the forensic paint examiner finds it helpful to have some overlap in this information, because by themselves, the methods may provide only limited data for identifying certain components or else provide general class characteristics rather than unequivocal data to identify each component conclusively. Methods that are nondestructive are preferred, both to preserve the evidence and to allow further testing using other techniques. If destructive methods are used, they are normally performed after the nondestructive methods. The choice of methods that are used may also be dictated by the type of paint that is encountered, as well as its size and nature (e.g., the analysis of a paint smear versus the analysis of paint from the entire door of a vehicle).

5.5.1 Microscopic Examinations

As mentioned previously, paint evidence can be found as smears on clothing, smears on objects, minute fragments fused to the surface of an object, or fragments contained in the surface debris recovered from an object. As with any trace evidence, microscopy is necessary in finding and examining the specimen. If you cannot find the material, you obviously cannot analyze it. Furthermore, if you cannot accurately characterize its form and structure, no matter what sophisticated analytical techniques you may have at your disposal, the analysis will ultimately not generate complete and accurate results. The initial instrument of choice for searches and preliminary characterization of recovered specimens is the stereomicroscope. This technique provides a three-dimensional view, with magnifications on the order of 5 to 60 times the object's actual size. It has a broad field of view, permitting relatively large areas to be searched microscopically. Furthermore, it offers long working distances providing ample room to manipulate the specimen for observation and sample preparation for subsequent examination techniques.

Unlike other common types of materials encountered as trace evidence, such as fibers, glass, plastics, adhesives, rubbers, foams, metals, and most composites, paint evidence often has a laminate structure comprised of multiple complex layers. Stereomicroscopy provides the initial view of this layer structure. Layer colors, order, textures, and relative thicknesses are often the initial clue as to the general source of origin of the specimen. Did it originate from a motor vehicle or from an architectural application? Is it more likely a maintenance coating, such as might be found on tools, commercial door frames, or electrical junction boxes? This initial information is important for several reasons. First, it lets the examiner know what to expect from the sample. Thorough background knowledge of all types of coatings is essential. If you are going to perform a forensic comparison of any material, first know your product. In the case of paint, it is important to know how it is manufactured, how it is applied to the substrate, of what is it composed, and what types of common manufacturing irregularities may be encountered. All become important in knowing what to look for and in recognizing what is unusual.

Second, it permits the examiner to deduce from where the sample may have originated. This is commonly an integral question in the investigation, whether it be a hit-and-run investigation or a homicide investigation involving forced entry to

a structure. For example, there is usually little benefit in analyzing an architectural paint in detail when it comes from the debris recovered from the surface of a hit-and-run victim. Finally, it permits the examiner to know which pool of background knowledge to access when evaluating the evidential significance of a sample. Just as one does not want to testify that the layer structure of an architectural paint discovered in a homicide investigation is unusual based on their background knowledge of automotive paint layer structures, one equally does not want to attempt to determine the year/make/model vehicle origin of an architectural paint sample discovered in debris recovered from the garments of a hit-and-run victim. All these points may seem unwittingly basic, but striving to accomplish them is anything but.

To appreciate the microscopical methods used in forensic paint examinations, it is probably necessary first to discuss some of the attributes of the various end-use categories described previously (e.g., automotive, architectural, maintenance, and trade-sale spray paints). Due to the specialized nature of the forensic examination of cultural artifacts, this topic is not addressed, although many of the techniques to be discussed are employed in that endeavor as well.

Automotive Paints Automotive paints consist of finish coats applied over primer coats and generally fall into two distinct categories, original finishes and refinishes. Original finishes consist of the multiple paint layers applied at the factory at the time of manufacture. Refinishes commonly refer to either single or multiple layers applied after the vehicle leaves the factory (i.e., aftermarket applications). Refinishes applied at the factory, however, present a third category. Although these systems employ a reapplication of paint layers, the material used commonly has the same composition as that used in the original application. As might be expected, it is valuable to be able to recognize these three categories when assessing the evidential significance of a transfer, and various types of microscopy play an integral part in making those decisions.

Finish coats impart the visual appearance to the paint system and are the uppermost layers of the coating. They are found as either monocoats, clearcoat/basecoats, or tricoats. Monocoats consist of opaque layers designed to have high gloss and color. Both the clearcoat/basecoat and tricoat systems have a transparent layer on top that is typically colorless but may be lightly tinted. This is followed by a single colored and opaque basecoat layer in the former system or a transparent or translucent colored layer followed by the opaque basecoat layer in the latter system. Any one of these finish coat layers other than the clearcoat may have decorative flake dispersed throughout. The decorative flake is commonly either some form of aluminum flake, pearlescent flake, or interference flake. Stoecklein (2002) describes the latter in detail.

Below the finish coats are primers, designed to be an interface between the finish coats and the substrate material. They serve several functions, including adhesion, ease of sanding for leveling out imperfections, and corrosion resistance. There may be anywhere from one to four or five of these layers present; however, the most common layer structures employ only one or two. The primers may usually be distinguished from the finish coats, as they are opaque and include much higher

concentrations of extender pigment. This in turn gives them a lower gloss and more particulate appearance. Color-coordinated primers are designed to have a similar color to the basecoat above them and often have slightly lower concentrations of extender pigment present. Figure 5.3 depicts the most common original finish layer systems. The primer-surfacer is a primer that is often present between the base primer and the finish coats. The term *surfacer* is added to the name in order to describe its primary function, a layer that is easily sanded to produce an acceptably smooth surface on which to apply the finish coats. Traditionally, it appeared in a rather limited color palette, consisting of various shades and tints of gray, black, or red-browns. Since the mid-1990s, some vehicle manufacturers began using colors coordinated to the general color of the monocoat or basecoat. Further descriptions of these systems may be found in Fettis (1995), Ryland (1995), Thornton (2002), and Streitberger and Dossel (2008). Anticorrosion treatment of the steel used in automotive panels leaves a characteristic pattern on the bottom of original primers commonly referred to as "orange peel," similar in appearance to that shown in Figure 5.4. Weathering of the surface of the top layer can result in oxidation of the resin and pigment and sometimes cracking of the surface. Improper refinish techniques may result in dirt or foreign material trapped between layers and visible at the interface between the layers. Occasionally, poor painting procedures result in foreign overspray paint droplets deposited on the surface of a topcoat.

Architectural (Structural) Paints Forensic laboratories may also have a substantial caseload, dealing with architectural paints ranging from cases involving

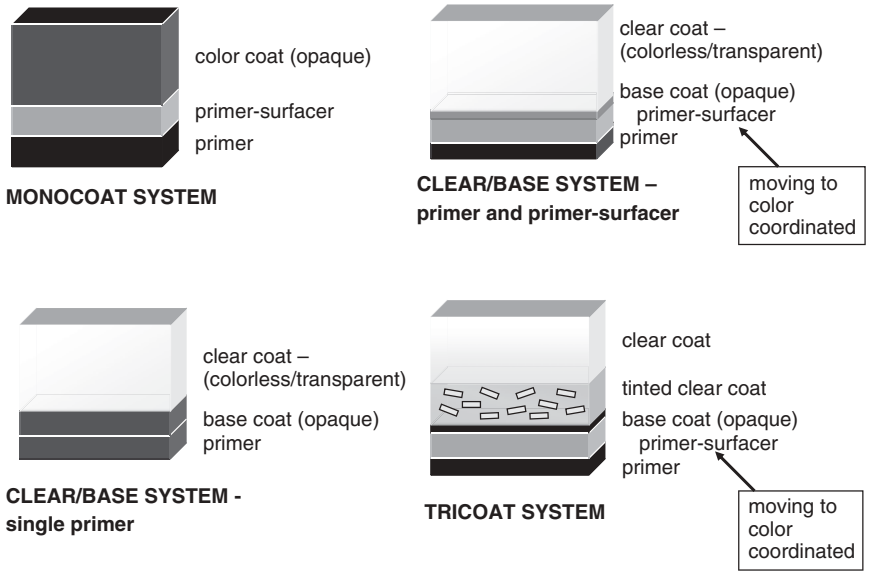

Figure 5.3 Diagrammatic representation of common original automotive finish layer structures. *(See insert for color representation.)*

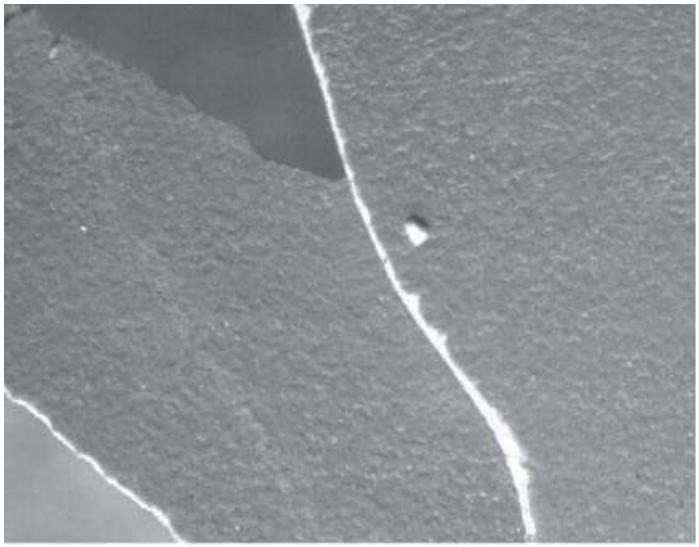

Figure 5.4 Stereomicroscopic view of the underside of the original base primer from an automotive application revealing the characteristic "orange peel" appearance. Magnification of 20×. *(See insert for color representation.)*

forced entry to those dealing with debris recovered from either a suspect's or a victim's garments. There is seldom a predesigned system of layers in these samples—the layer colors, textures, and chemistry changing with the whim of the consumer. The variety of finishes encountered can range from flat wall paints to colorless glossy varnishes on wood. The flat wall paints contain very high concentrations of extender pigments. Even semigloss to high-gloss wall paints are characterized by the presence of some extender pigment, with the grain size being much larger than that encountered in vehicle primers. The surfaces are typically somewhat rough, even though they may have a relatively high gloss, and the pigment dispersion is heterogeneous compared to automotive finishes. One can often see clumps of undispersed coloring pigment throughout the paint layer. Latex paints have a softer texture than automotive paints and when treated with a bit of chloroform form a gummy residue during solvent evaporation, quite unlike automotive paints treated in the same manner. It is unusual to encounter decorative flake, except for the occasional use of retail spray paints for finishing architectural accessories. In those cases, the decorative flake is usually quite dense in distribution compared to that found in most automotive applications. On occasion, a portion of the substrate material will cling to the bottom layer of the paint fragment. Discovery of wood or wallboard obviously indicates that the application was not automotive. Consecutive applications of light pastel or off-white colors that are similar to one another in color and texture are sometimes encountered and present difficulty discerning between layer interfaces. Microscopy is the basic tool for recognizing these characteristics.

Maintenance and Trade-Sale Spray Paints Maintenance and trade-sale spray paints have microscopic characteristics that lie somewhere between architectural finishes and automotive finishes. In the case of tools or commercial metal door frames, they are often coated with both a primer and a finish coat. The finish coats may be high gloss, resembling automotive monocoats. Their surfaces typically will have rough pitted spots over larger areas, but these may not be noticeable in small samples. The chemistry used in the paints is similar to that employed in the automotive industry and hence the textures are quite similar. Often, the layers are quite a bit thinner than automotive paint layers and may be brittle, giving rise to a suspicion that the origin is both nonautomotive and nonarchitectural. In the case of trade-sale spray paints, they are usually encountered as thin layers applied to the surface of existing finish systems and frequently display significant heterogeneity in pigment dispersion. This layer structure suggests nonautomotive applications.

5.5.2 Physical Nature of the Transfer

In addition to the various morphological characteristics attributable to different end-use types of paint, the physical nature of paint transfers encountered in forensic investigations plays a significant role in the choice of examination techniques. In a majority of automotive paint cases, the samples are quite small and multilayered, as depicted in Figures 5.5 and 5.6. Both the microscopical and analytical techniques chosen for comparisons must be compatible with this sample size and morphology, keeping in mind that each layer contains a wealth of morphological and both organic and inorganic chemical information. Some evidence will have numerous layers, suggesting the possibility of encountering another source with a corresponding

Figure 5.5 Paint fragment placed on the date of a penny for sample size perspective. *(See insert for color representation.)*

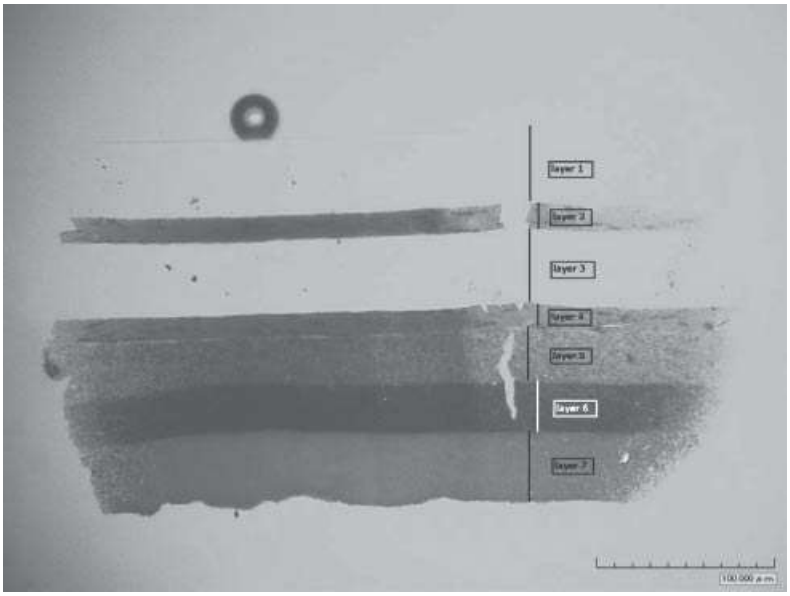

Figure 5.6 Cross section of a seven-layer automotive paint sample mounted on a microscope slide with a 1.56 refractive index mounting media and coverslip and viewed with transmitted brightfield light on a polarized light microscope. Layers 1 and 3 are clearcoats, layers 2 and 4 are basecoats with a decorative flake in them, and layer 5 is a color-coordinated primer followed by two additional primers (layers 6 and 7). *(See insert for color representation.)*

layer structure is extremely remote (Tippett et al., 1968; Gothard, 1976; Ryland and Kopec, 1979; Gothard and Maynard, 1996; Willis et al., 2001; Edmondstone et al., 2004; Wright et al., 2011). In such instances, further chemical analyses may not be deemed necessary (ASTM, 2007). In the case of larger paint fragments, be they automotive or not, the examiner must guard against damaging the edges and surfaces of the evidence since the potential for comparison of the fractured edge contours and the paint chip surface configurations with an appropriate known source hold the possibility of a physical correspondence that is definitive, unlike any compositional comparison. If such a correspondence is found, the analyst will conclude that the paint fragment whose origin is in question originated from and was at one time a part of the paint on the known exhibit.

Paint transfers also occur in the form of smears onto substrates. One such example is a multiple-layer architectural paint smeared onto a tool used to gain entry to premises. Mixing of the smeared layers and contamination of the transfer by the material on the tool's surface become serious analytical issues. Microscopy offers the initial means to evaluate and mitigate the impact of these problems on subsequent analytical techniques. Another such example is an automotive paint smeared onto the clothing of a hit-and-run victim. In such instances, it is often difficult to discern by stereomicroscopic examination alone whether the thin transfer

is paint or plastic from a vehicle part. Other microscopic techniques and perhaps analytical techniques are usually necessary to draw a conclusion. Application of those techniques is often thwarted by contamination of the paint smear by the underlying synthetic fabric. Polyester and acrylic fibers have chemical characteristics similar to those of many paint binders, and the abrasion transfer process often generates heat that melts, mixes, and fuses the substrate fiber polymers into the paint transfer.

As described earlier, paint transfers may also occur with uncured paint. If the transferred paint dries following the transfer, microscopy is the only way to ascertain that it was wet when deposited. That little bit of additional information can be extremely valuable in an investigation, as evidenced in the Green River cases. Occasionally, tiny droplets of spray paint will float through the air at an automotive refinish facility and land on the painted surface of a nearby vehicle. This is obviously not good quality control and represents an unusual situation, not to mention that the color and chemistry of the contaminating paint is somewhat random. Recognizing these tiny cured droplets on the surface of both questioned and known paint chips represents a very unusual characteristic that adds immensely to the associative evidence afforded by the corresponding paint fragments alone. The transfer may also occur from a person rubbing against a freshly painted object. A transfer such as this seldom finds its way into the forensic laboratory, but it may. Recognizing this type of transfer is often of value when searching for automotive paint transfers on the clothing of a hit-and-run victim. If a paint smear is found that was transferred in a wet condition, it is probably not from the striking vehicle and routinely turns out to be an architectural paint. As another example, one of the authors (SGR) examined a case where the suspect of a sexual assault rolled over the victim's palette of paints she was using while painting at a secluded area on the beach. The significance of the numerous corresponding colors and chemistries of paints discovered on the suspect's clothing was reinforced further by the fact that the paints were transferred in an uncured condition. All of these transfers demonstrate very smooth surfaces and rounded edges at the perimeters of the deposits upon stereomicroscopic examination. The rounded edges are a result of flow during the curing process and are not present in abraded transfers of cured paint. Even when glossy automotive paint partially melts onto the fabric of a hit-and-run victim's garments as a result of heat generated from friction, the surface of the paint is not smooth nor are the corners at the perimeters rounded from flow.

5.5.3 Microscopy

With an understanding of the sample attributes present in a forensic paint examination, let us now focus in a bit more detail on the types of microscopy and sample preparation available to permit evaluation of those attributes. Stereomicroscopy affords views of the bulk sample on all sides, including the intact bulk layer structure. The small surface area of thin layers, the rough surface of neighboring layers, and the interplay of neighboring layer colors make it difficult to view all layers definitively. Smoothing the surface of the cross-sectional view will help

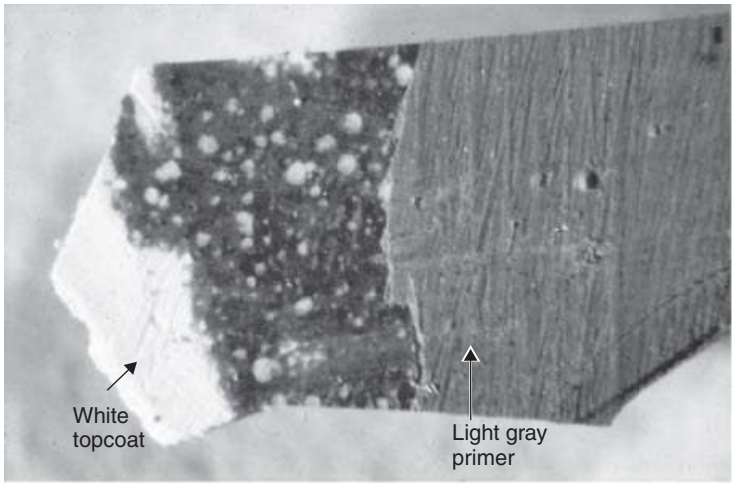

Figure 5.7 Peeling of successive layers to expose larger surface areas permits visualization of unusual characteristics, such as this thin mottled primer–surfacer between the white finish coat and the light gray primer. Stereomicroscopic view at 10× magnification. *(See insert for color representation.)*

somewhat, whether done manually with a sharp blade or polished using abrasives. This does not solve the problem of color rendition of small surface areas or the interplay of neighboring layer colors. Typically, the sample is carved manually from either the top or bottom layer to expose larger areas of each layer, including those on the interior of the sample. Portions of these carvings may be saved for subsequent testing. The carving and subsequent increased layer-area exposure permit stereomicroscopic evaluation of colors, textures, pigment heterogeneity, decorative flake size, shape and color in reflected light, and layer interface materials and their distribution (such as the mottled primer-surfacer between the topcoat and base primer shown in Figure 5.7). However, very thin layers may be missed by this method, especially if they are colorless and transparent. It is also difficult to see the transition from a basecoat to a color-coordinated primer (especially black on black or white on white) or the transition from one layer to another in a multilayered white architectural paint fragment.

To solve this problem, it is advisable to prepare thin cross sections like that in Figure 5.6. This can sometimes be done manually or by embedding a specimen in a plastic medium and then cutting very thin cross sections with a microtome. The sample can be observed on the stereomicroscope, but it is often advisable to view it at greater magnification on a transmitted light compound microscope. This can be accomplished on a simple compound microscope, on a polarized light microscope, or in the case of comparisons on a properly color-balanced compound comparison microscope. The cross sections are placed on a microscope slide and covered with a drop of mounting medium having a refractive index substantially different from the 1.50 to 1.52 of most paint resins. This permits the boundaries of colorless

clearcoat layers to be observed distinctly. A coverslip is then placed on top, and the preparation is ready for viewing. It permits critical evaluation of layer structure, layer inclusions, and pigment color and distribution throughout the thickness of the layers. It can often allow classification of an automotive paint layer as a finish coat or a primer, primers having a much more particulate appearance, and is invaluable in discovering tricoat layer structures. In the case of some multiple-layer low-gloss white architectural paints, even this method does not reveal layer interfaces clearly. In that case, it is often of value to observe the cross section using a reflected light fluorescence microscope with a variety of excitation wavelengths, as reported by Allen (1994). This technique may also be of value in distinguishing similarly colored automotive paint primers, as described by Stoecklein (1994).

Aluminum decorative flakes and some interference decorative flakes cannot be distinguished when paints containing them are viewed with reflected light using a stereomicroscope. Transmitted light brightfield microscopy, however, can be used to differentiate the two types by observing thin peels cut from the finish coats that have been placed on a microscope slide with mounting medium and a coverslip. As reported by Stoecklein (2002), many types of interference flakes are based on mica substrates, which are transparent in transmitted light, unlike the opaque aluminum metallic flake (see Figure 5.8). Furthermore, the interference flakes that are opaque typically have sharp-lined geometric shapes, unlike the opaque aluminum flake profiles, which resemble a flake of cornflakes cereal or a sand dollar.

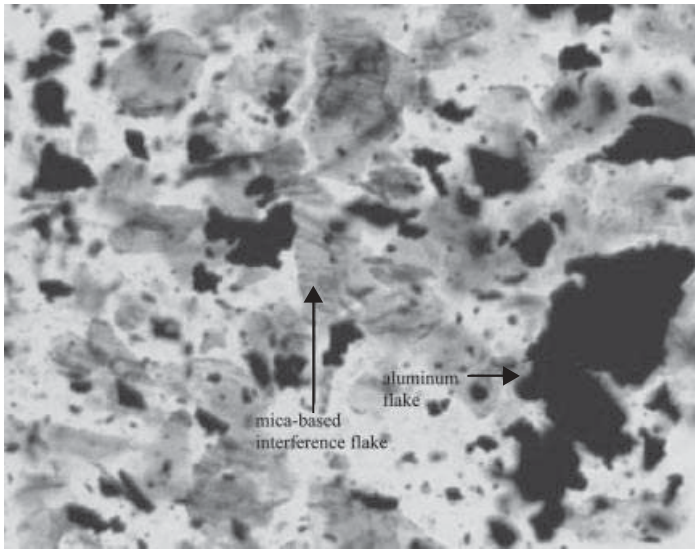

Figure 5.8 Transmitted light microscopic view of a thin peel of an automotive finish coat having two types of decorative flake: mica-based interference flake and aluminum flake. The hand-cut peel is mounted in Norland Type 64 optical adhesive on a microscope slide with coverslip and viewed at 250× magnification on a polarized light microscope with the polars uncrossed. *(See insert for color representation.)*

Observation of thin sections of paint on a polarized light microscope employing crossed polars can also aid in recognizing or even identifying anisotropic extender pigments. If noted in an automotive paint layer, it is a strong indication that the layer is a primer, not a finish coat. If observed in a thin peel of an architectural or spray paint, the grain size may be large enough to permit identifications using basic optical characteristics, as demonstrated by Kilbourn and Marx (1994).

The value of using various microscopic techniques in analyzing paint samples has been demonstrated over the years by a number of authors. McCrone (1979) describes the use of polarized light microscopy in characterizing particulate matter encountered in the forensic science laboratory, while Hammer (1982) describes the use of transmitted light microscopy for automotive paints. Stoecklein (1994) discusses the value of various microscopic techniques for examining automotive paints, and the ASTM *Standard Guide for Forensic Paint Analysis and Comparison* (ASTM, 2007) further details the basic use of microscopy in forensic paint examinations in general.

5.5.4 Microspectrophotometry

Although not all coatings are colored, paint is generally considered to be a pigmented liquid or liquefiable composition which is converted to a solid film after application as a thin layer. Coloring pigments may be either inorganic or organic, and both impart color to the film. Color by its basic definition involves the absorption and reflection of visible light. Beyond observation with the human eye, what more intuitive way is there for the chemist to measure and compare this characteristic than with visible light absorption spectrophotometry?

The comparison of color is one of the first steps taken in a forensic paint comparison. The human eye is a very discriminating sensor, being able to distinguish anywhere from over 100,000 to several million colors (Hunter, 1975; Boynton, 1979); hence, its value as a discriminating tool for paint evidence cannot be overemphasized. However, it is possible to formulate paints that appear the same color to the human eye, yet are comprised of different pigment combinations. Analytical instruments that permit the chemist and industrial technologist to discriminate such colors have been available for six decades. The ultraviolet–visible (UV–Vis) absorption spectrophotometer is known to every undergraduate chemistry and biology major. It is sensitive to the different degrees to which various wavelengths of visible and UV light are absorbed by a material, most typically a solution of the material contained in a UV-transparent cuvette. If two solutions are the same color but contain different chromophores, they will typically produce differing visible absorption spectra. And, of course, the solutions may have no color at all, yet contain organic molecules that have differing aromatic structures and thereby produce differing UV spectra. The chromophores in the organic pigments used in paints are typically rich in aromatic and conjugated ring systems and as such often produce characteristic UV absorption spectra.

UV–Vis spectrophotometry therefore seems to be a natural choice to include in an analytical scheme to compare paint samples. However, the task is not as

simple as it may seem. As mentioned previously, the sample is typically dissolved in a solvent to decrease its absorption to a level within the dynamic range of the spectrometer's detector when performing UV–Vis absorption spectrophotometry. Many paint binders, the resins that bind the pigments together and adhere to the substrate, are insoluble in most common organic and aqueous solvents that do not affect the chromophore chemically. In those instances the only way to achieve the aforementioned goal is to make the solid sample very thin, which is often done by slicing or crushing the specimen. However, we also know that it is important to control the pathlength of the samples being compared, because Beer's law states that the absorbance is proportional to the pathlength. This is no easy task when slicing or crushing two samples. Hence, the *Standard Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis* (Scientific Working Group for Materials Analysis, 2007) recommends that for detailed comparisons of thin sections of paint the specimens be prepared by cutting the two simultaneously using microtomy. This procedure involves embedding the two samples in a liquid resin, curing the resin, and then mounting the block in a microtome and cutting at controlled thicknesses to produce the same pathlength for both sections. This solves the first problem of dealing with solid specimens; however, most forensic samples present the examiner with a second issue. The samples are quite small and often multilayered. How is one to introduce this sample to a UV–Vis spectrophotometer?

Microspectrophotometers (MSPs) allow for objective measurement of the color of small or microscopic samples and are more precise and quantitative than the more subjective results of visual microscopical color comparisons. As the name suggests, they are UV–Vis spectrophotometers incorporated into microscopes (see Figure 5.9). The design of such instruments is difficult, for typical microscope

Figure 5.9 CRAIC model QDI 1000 ultraviolet–visible microspectrophotometer with Cassegrainian optics and a semiconductor array detector.

objectives are made of glass, which does not transmit UV light. Additionally, the amount of light transmitted through the small apertures required to define the area of interest in microscopic samples is quite limited and the sensitivity of the photometric detectors must be high while at the same time controlling deterioration of the signal-to-noise ratio. The first problem has been solved either by using non-UV-absorbing glass to make the microscope objectives (which is very expensive) or by using Cassegrainian objectives, which are constructed of mirrors and never pass the beam of light through any glass. The latter suffer from inferior image quality and control of the light path. The second problem has been solved by using very sophisticated focusing optics and highly stabilized photomultiplier tubes or by using fast-response semiconductor array detectors, which permit co-addition and averaging of the signals collected. In either design, the specimen is mounted in a non-UV-light-absorbing mounting medium (typically, glycerin), placed on a quartz microscope slide with a quartz coverslip, and then placed on the MSP's stage. The area of interest is physically defined by adjustable or fixed apertures viewed in the same field of view as the specimen and then background and sample measurements are made. The instrument software ratios the two, and plots of the resulting absorption or percent transmittance spectrum are obtained.

As might be expected, analysis of solid samples is not as straightforward as solution absorption spectrophotometry. There are microscopical concerns, such as light path focusing, sample focusing, and diffraction at specimen edges; spectrometer concerns, such as appropriate calibration standards for wavelength and photometric accuracy; and specimen concerns, such as microheterogeneity and sampling area. Eyring (2002), Stoecklein (2001), and the *Standard Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis* (Scientific Working Group for Materials Analysis, 2007) discuss all these concerns in detail. Given the concern for controlling path length and the effect that it has on the interpretation of results, perhaps a brief discussion of sample microtomy might be in order.

Microtomy is a technique employed to prepare thin sections of controlled thickness using a microtome, a mechanical instrument designed especially for this purpose. The discipline finds its primary roots in the histology laboratory; however, its application also finds its way into the field of materials science. For the purpose of paint fragment sectioning, a basic instrument will suffice. Most laboratory or medical supply vendors will carry the array of available equipment, ranging from basic manual models using steel knives to motorized automatic models using cryostatic freezing to attain submicrometer sections. A used rotary microtome with a sharp steel blade will perform adequately, although the use of glass knives will produce sections that do not have striae (from knife blade sharpening) and are much less prone to curling while being cut. The use of glass knives will require a knife maker, special microtomy glass, and a glass knife microtomy stage. A typical rotary microtome with a glass knife can be seen in Figure 5.10 and with a steel knife in Figure 5.11.

The choice of embedding medium is just as important as the choice of microtome. The sample(s) will be placed in this liquid resin and then the resin will be cured to form a rigid block that is placed into the microtome sample jig for

Figure 5.10 Microm manual rotary microtome with glass knife stage and universal sample holder.

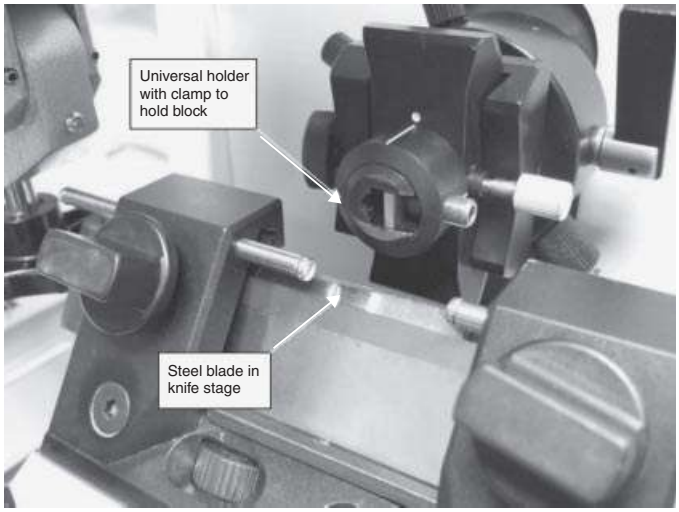

Figure 5.11 Microm rotary microtome with a steel knife stage and the sample block held in a universal specimen holder.

sectioning. It is recommended that the embedding medium be approximately the same hardness as the specimen to be sectioned for optimum results. If it is too soft, the specimen will be dislodged from the embedding medium when encountering resistance with the blade. If it is too hard the blade will quickly be dulled and produce poor-quality sections. Both Stoecklein (2001) and Derrick (1995) provide

guidance on these topics. For those familiar with this technique, one of the authors of this chapter SGR finds that a UV-curing optical adhesive (UV-74 Lens Bond, Summers Optical Co., Fort Washington, PA) works quite nicely, permitting the examiner to place some embedding medium resin in the well of the mold and to cure it for approximately 6 s with a high-intensity UV light to form a thin skin on which to place the first paint fragment. This permits critical positioning of the paint chip so that it will be parallel to the remaining chips placed in the block. After positioning the first chip, some additional embedding resin is added and then flash-cured for about 6 s to form another partially cured surface. The next paint chip is then positioned and more resin added. This process is continued until the block has been completed. After adding the final aliquot of resin, the mold is cured under high-intensity UV light for approximately 6 to 10 min. It is then removed from the mold and all sides are exposed to the UV light to remove the tack from the optical adhesive. The block is then ready to be cut at this time or within a day or two, as depicted in Figure 5.12. Typically, excess resin is trimmed away manually to expose the specimens near the surface. The block is then secured in the microtome jig and trimmed even further using the steel blade until a position very close to the specimens is reached. The microtome knife stage is then switched to the glass knife stage, where the final sections are produced. Three-micrometer sections are cut for brightfield microscopy and UV–Vis microspectrophotometry, while 5-μm sections may be cut for Fourier transfer–infrared (FT–IR) microspectroscopy. Either the remaining block with the exposed paint chip surfaces or a very thick section (20 μm) may be used for subsequent scanning electron microscopy in conjunction with energy-dispersive x-ray spectrometry (SEM–EDS) analyses.

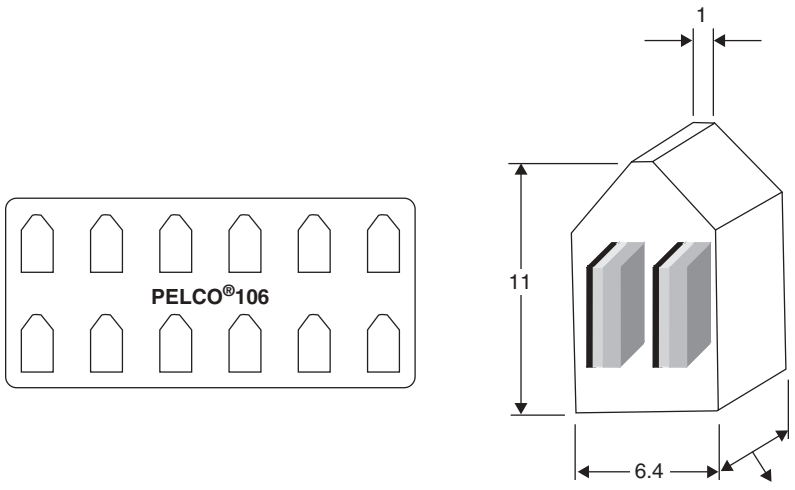

Figure 5.12 Representation of two automotive paint fragments embedded in the same microtome sectioning block (right) and of the top view of the silicone mold used to form the block (left). Dimensions are in mm. *(See insert for color representation.)*

Although this sample preparation approach may seem very appealing given the minimal sample manipulation of the native paint fragment, the production of controlled-thickness paint sections, and the control of surface topography and orientation (critical factors in SEM–EDS analyses), there are drawbacks to the preparation of samples by microtomy alone. First, very small areas of the sample are exposed in cross section. This forces the analyst to deal with microheterogeneity problems, since large analytical areas cannot be used to average heterogeneity. Cured paint is simply not homogeneous on the microscopic scale. Second, difficulties in control of the analytical area may be encountered when using an infrared microscope, due to diffraction produced with the small imaging apertures required, and in SEM–EDS analyses due to excited volumes crossing over into neighboring layers. These concerns are discussed by Ryland (1995), Henson and Jergovich (2001), Bartick (2010), and in the *Standard Guide for Using Scanning Electron Microscopy/X-Ray Spectrometry in Forensic Paint Examination* (Scientific Working Group for Materials Analysis, 2002).

As with most spectrophotometric methods of analysis of solid specimens, visible-light microspectrophotometry can be performed in the reflectance mode as well as in the transmission mode. This approach offers the lure of apparent minimal sample preparation but has notable disadvantages compared to transmission analyses. The signal-to-noise ratio is typically lower in reflectance measurements, and there are sample geometry, spectral distortion, and reproducibility concerns. The sample surface must be sufficiently smooth so as to have ridges and valleys measuring less than the size of the particles contained therein. If not, light is scattered randomly and signal targeting and signal-to-noise quality are lost. To achieve this goal, the sample must be polished on a microscopic level using a series of abrasives typically performed on embedded samples, much as would be encountered in the preparation of samples for microtomy. In addition, it is critical that the specimen(s) surfaces be oriented parallel to the reflectance objective of the microspectrophotometer, as failure to do so results in variation in spectral features. For certain monocoats containing high concentrations of strongly absorbing pigments (such as Copper Phthalocyanine Blue), specular reflection distortion of the measurement can occur (Suzuki, 2010). This process produces *more* reflection for strongly absorbing wavelengths and results in a *bronzing effect* (this phenomenon can also occur for some dark blue inks, which appear to have a metallic bronze sheen when viewed at certain angles). For metallic paints, the incident beam can undergo either direct reflection from a metal flake or diffuse reflectance from the paint matrix, and differences in the ratios of these two processes also affect spectral reproducibility. Hence, it is much more difficult to achieve precision with reflectance techniques than with transmission techniques. Discussion of this shortfall can be found in Eyring (2002), Stoecklein (2001), and in the *Standard Guide for Microspectrophotometry and Color Measurement in Forensic Paint Analysis* (Scientific Working Group for Materials Analysis, 2007).

Despite the intuitive application of microspectrophotometry to forensic paint comparisons, the technique is not widely used. Reports from paint proficiency tests offered by Collaborative Testing Services (2007) over a three-year span indicate

only 7 to 15% of the participating laboratories used microspectrophotometry in the examinations. These rates are similar for both architectural and automotive paint samples. The limited application is understandable for either white or pastel flat architectural paints, for they have little color present and are loaded with extender pigments. However, this does not explain the limited use for automotive exemplars. Perhaps this can be traced to the fact that little work has been published to demonstrate the improved discrimination of this method over the classical microscopical and instrumental techniques. This is not surprising given the complexity of automotive paint formulations and layer systems. If different paint manufacturers used different pigments to achieve the same color, it is quite likely that other chemical differences would be present in the formulations as well (Contos and Ryland, 2001). That is not to say that very careful analyses may not have the ability to distinguish between batches, where slight color adjustments have been made to achieve an acceptable final color and appearance, as presented by Stoecklein and Palenik (1998). Similar analyses may even be able to discriminate between the quantity of UV absorbers remaining in the clearcoats of two cars painted with the same paint-layer system but subjected to varying degrees of exposure to the sun (Stoecklein and Fujiwara, 1999). In the case of automotive paints, Kopchick and Bommarito (2006) demonstrated that apparently achromatic finish coats can be discriminated by visible microspectrophotometry, although the study did not evaluate which of those finishes were also distinguishable by other routine analytical examinations. This rationale for automotive finish coats should not be carried over into the realm of other end-use paints, such as household spray paints, where the variation in binders and layer structures is much more limited.

As the number of available organic pigments expands and the diversity in binder formulations appears to be diminishing due to company mergers, international markets, and environmental concerns, it is argued that pigment identification may take on a new role in forensic paint examinations. This may be in the arena of comparisons or even in the task of provenance determinations. Certainly, with some care in sample preparation and access to high-magnification objectives, microspectrophotometry has the ability to focus on individual pigment grains in situ and effect identifications based on collections of known pigment spectra. The future will tell what benefits and acceptance this approach holds.

5.5.5 Infrared Spectroscopy

This technique involves measuring the absorptions of a sample in the infrared region, which consists of electromagnetic radiation with frequencies lower than that detected by the human eye. The frequencies in this region are denoted by the wavenumber, which is the reciprocal of the wavelength given in centimeters (cm^{-1}); the region of primary interest is between 4000 and 200 cm^{-1}.

The infrared absorption process results in an increase in the quantized vibrational energies of the molecules of the sample. Some of the energies are localized in vibrational modes involving specific chemical bonds of the compound, and these

absorptions often occur over a narrow and characteristic range in the infrared region. Other vibrational modes may involve the entire molecule or large portions of the molecule, and their absorptions occur over a wide range of frequencies and tend to be characteristic of the molecule as a whole. For organic compounds, the former class of absorptions allows an analyst to determine the presence of functional groups, whereas the latter allows the differentiation—and hence the identification—of even closely related compounds. Organic chemists thus use this technique for both diagnostic and identification purposes.

For inorganic compounds containing predominantly covalent bonds (such as silica and other framework silicates), a somewhat similar situation occurs, although these infrared absorptions tend to occur at lower frequencies than for organic compounds with absorption breadths that are often broader. For salts involving cations or anions with covalent bonds (such as NH_4^+ or CO_3^{-2}), characteristic absorptions of these ions also occur, although they tend to be less distinct than those of organic compounds since they are often broader and far fewer in number. The only compounds that do not absorb in the region examined by infrared spectroscopy are homonuclear diatomic molecules (most of which are gases such as N_2 and O_2), and simple inorganic salts that do not contain covalent bonds (such as KBr and CsI, which are used as windows for infrared spectroscopy).

All of the components of paint thus produce infrared absorptions, and infrared spectroscopy is one of the main tools used by both the coatings chemist and the forensic analyst to determine the overall composition of paint. For most paints, the binders that are used can be identified by these means, as well as the pigments that are present in high concentrations. The notable exception to this occurs for some architectural coatings with low lusters, as these typically contain large quantities of inorganic extender pigments, the strong broad absorptions of which typically obscure most binder absorptions.

Paint Analysis Methods The two main sampling accessories that are used with FT–IR spectrometers to obtain paint spectra are the diamond anvil cell (DAC) and the infrared microscope. Less often, attenuated total reflectance (ATR) may also be used. Both high- and low-pressure DACs are used for the analysis of paint evidence, although the latter has become the main device used in the United States, due to its thinner windows, ability to be used on an infrared microscope, and lower cost. Paint samples are pressed between the two 1-mm-thick diamond windows (known as *anvils*) of the DAC, or they may be pressed onto a single window. Although the DAC requires much larger samples than can be analyzed with the infrared microscope, one of the main advantages of this accessory is that when used on an extended-range FT–IR spectrometer, the lower frequency (far-infrared) absorptions of the sample can be observed.

An infrared microscope accessory allows the paint examiner to choose a small rectangular area of the sample to be analyzed by the spectrometer while viewing the paint specimen optically. Areas as small as 20 by 20 μm can be analyzed, and multilayered paint specimens can be cross-sectioned, then each layer analyzed

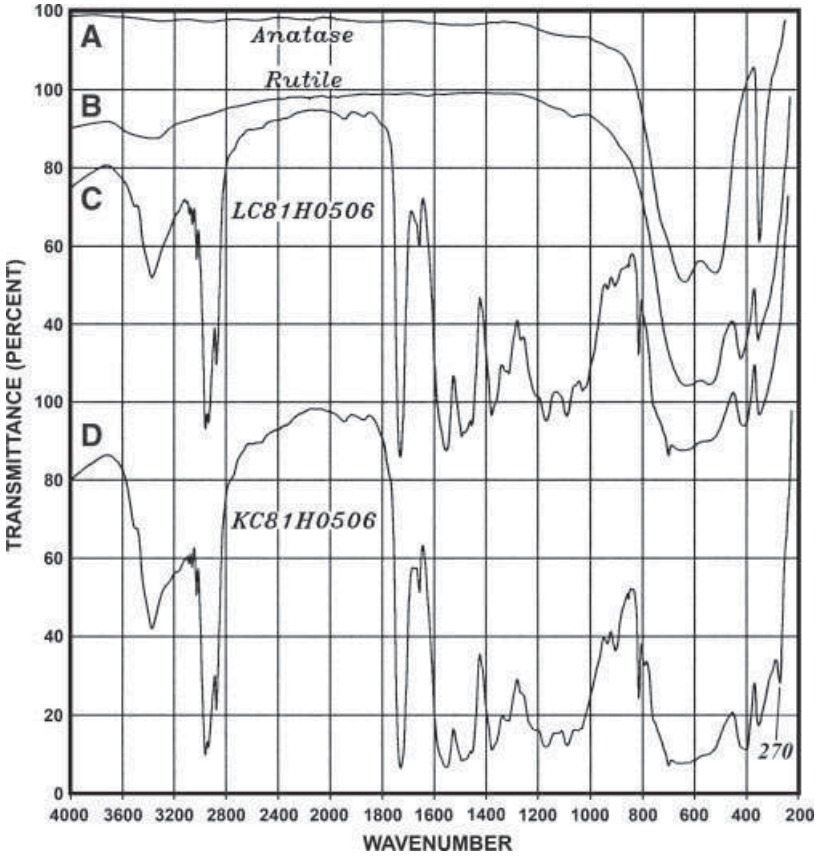

Figure 5.13 Infrared spectra of rutile, anatase, and two yellow nonmetallic automotive monocoats from the *Reference Collection of Automotive Paints*. The monocoats are identified by their *Reference Collection* codes: (A) rutile; (B) anatase; (C) LC81H0506; (D) KC81H0506. Both monocoats have acrylic melamine enamel binders with styrene and contain rutile, Nickel Titanate, and an organic pigment. KC81H0506 also contains hydrous ferric oxide. [From Suzuki (1996b); copyright © ASTM International; reprinted with permission.]

sequentially. The main advantages of the infrared microscope are thus its size and sequential analysis capabilities. Care must be exercised when performing a sequential analysis to set the edge of the aperture as far from the adjacent layer or layers as possible. This minimizes the amount of stray light from an adjacent layer or layers (caused by diffraction) that might contribute to the spectrum of the layer of interest. This is not an easy task in the case of thin layers.

One drawback of the infrared microscope arises from the sensitive detectors that must be used with this accessory, as they have limited spectral ranges. Their low-frequency cutoff points vary between 700 and 450 cm^{-1} and there is an inverse relationship between sensitivity and range; the wider the range, the less sensitive

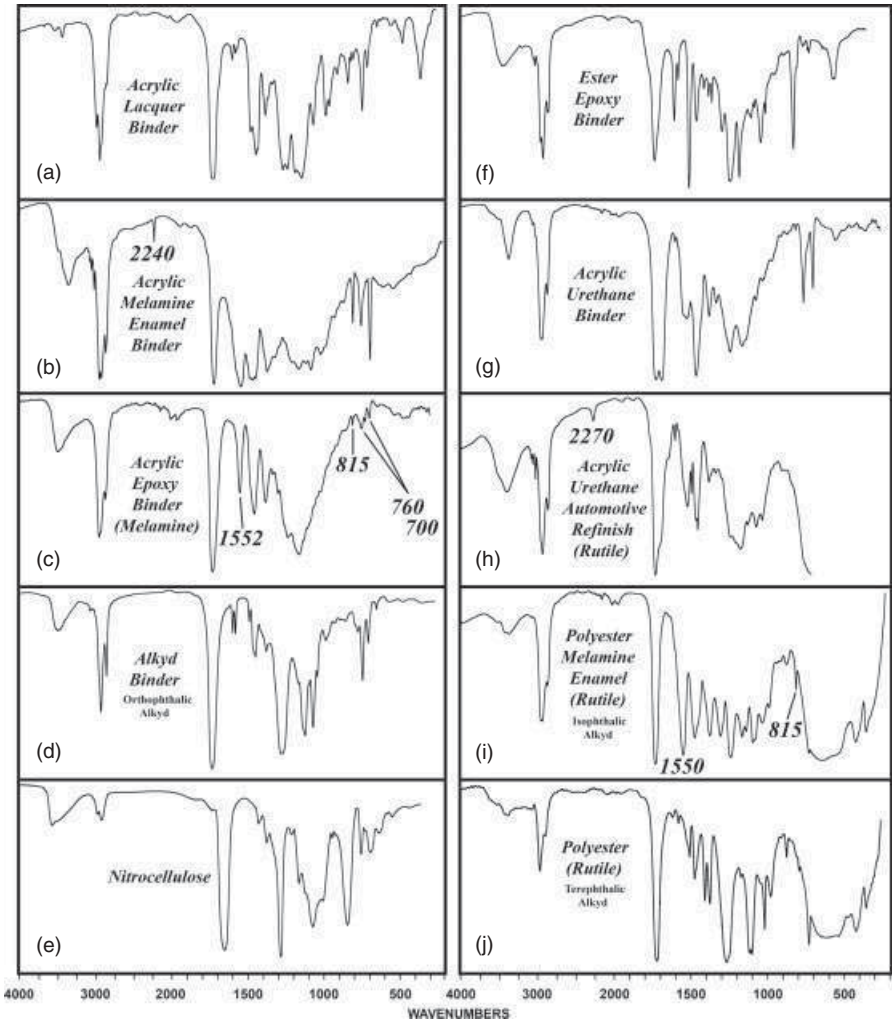

Figure 5.14 Infrared spectra of 10 different paint binders or paints that consist primarily of binders; three of the paints also contain significant amounts of rutile. (A) Acrylic lacquer. (B) Acrylic melamine enamel that contains styrene and an acrylonitrile copolymer. (C) Acrylic epoxy clearcoat (an acrylic melamine enamel with a small amount of styrene; the minor aliphatic epoxy component does not produce a characteristic infrared absorption). (D) Alkyd (orthophthalic alkyd). (E) Nitrocellulose. (F) Epoxy (aromatic) with an ester modifier. (G) Acrylic urethane with a small amount of melamine. (H) An acrylic urethane used in automotive refinishes that contains rutile; the weak absorption at 2270 cm^{-1} is due to unreacted isocyanate starting material. (I) Polyester melamine enamel (isophthalic alkyd) that contains rutile. (J) Polyester (terephthalic alkyd) that contains rutile.

the detector. Many infrared microscopes are thus equipped with the most sensitive detector, even with its narrower range. This does not adversely affect the identification of most paint binders, but it does limit the identification of those inorganic pigments that have most or all of their absorptions below 700 cm^{-1}. Differentiation of the two polymorphs of titanium dioxide used in paints (rutile and anatase), for example, requires the observation of low-frequency absorptions between 500 and 300 cm^{-1} (see Figure 5.13A and 5.13B). The infrared microscope spectrum of a white automotive monocoat that contains rutile is depicted in Figure 5.14H, and only the shoulder of its absorption is observed (the detector used for this analysis has a cutoff point at 680 cm^{-1}). Spectra of two other paints that were collected using a DAC on an extended-range instrument are shown in Figure 5.14I,J, and as can be seen, both contain rutile and not anatase. Another very common inorganic pigment used in paints is ferric oxide (Fe_2O_3, rust-colored). The three absorptions of this pigment occur below 700 cm^{-1} (Figure 5.15A) and they may be observed in the spectrum of a maroon nonmetallic automotive monocoat that contains this pigment (Figure 5.15B). The number of Fe_2O_3 absorptions that are observed using an infrared microscope will depend on the specific range of the detector, but none will be observed using the most sensitive detector.

ATR is a reflectance method that is utilized in either a single-pass accessory or as an objective of an infrared microscope. Paint samples are simply pressed against an ATR element, which is a refractive infrared-transparent material such as zinc selenide or diamond. ATR has a very shallow penetration depth that is proportional to wavelength, so ATR spectra have stronger relative intensities for the lower-frequency absorptions than those of transmission spectra. ATR spectra of paints containing inorganic constituents may also exhibit considerable distortions of the absorptions of these constituents. This occurs because ATR penetration depths also depend on indices of refraction of the sample, and inorganic compounds typically exhibit large changes in their indices of refraction across an absorption band.

Because of the very shallow ATR penetration depths, thin slices of paint do not have to be prepared and paint specimens can be analyzed intact, allowing spectra of the outer layers of a multilayered paint chip to be readily obtained. An ATR objective of an infrared microscope also provides the best means to analyze paint smears that are too thin to be physically removed from the substrate. Such smears can be analyzed in situ, although the spectra obtained by this method should always be compared to those of the substrate since, even with a shallow penetration depth, absorptions of the substrate may be observed in the resulting spectra. If this occurs, it is possible that only the lower-frequency absorptions of the substrate will be observed since these frequencies are more likely to reach the substrate. An ATR spectrum of a thin smear of an automotive clearcoat layer onto a light-colored paint, for example, may well exhibit a "tail" of a rutile absorption (as seen in Figure 5.14h). Although the clearcoat does not contain rutile, the substrate paint does, so the differential nature of the analysis process must always be considered when interpreting such spectra. This point was emphasized in a case involving several smears of automotive paint, which were analyzed using ATR (Giang et al., 2002).

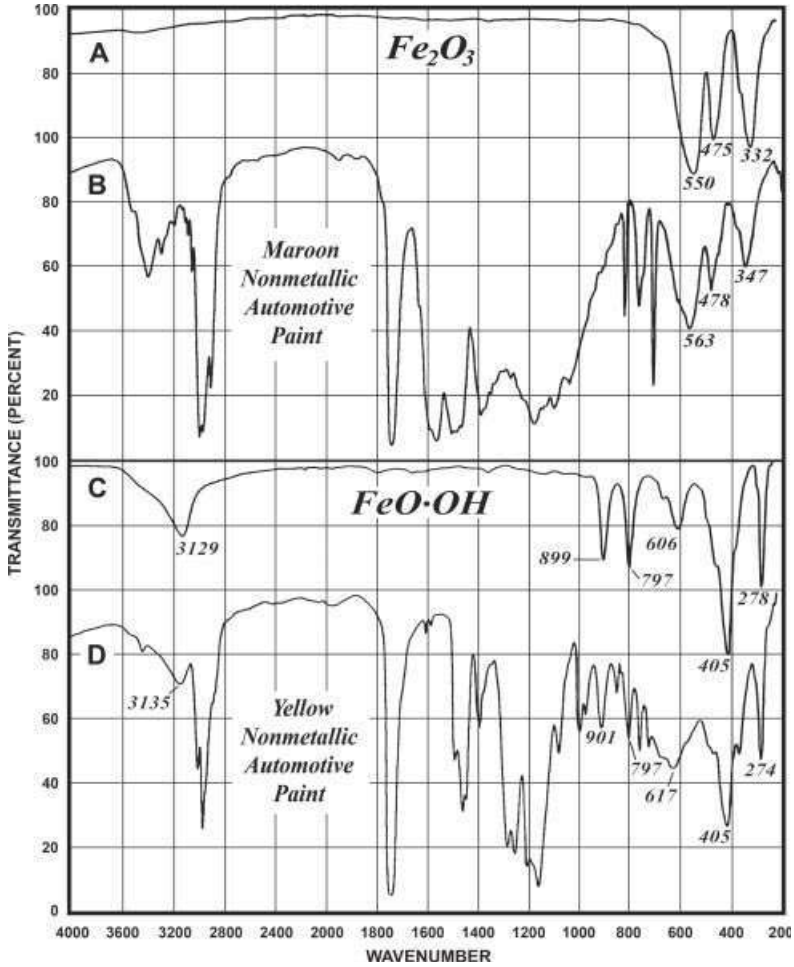

Figure 5.15 Infrared spectra of two iron oxide pigments and two automotive monocoats from the *Reference Collection of Automotive Paints* that contain these pigments. (A) Ferric oxide, Fe_2O_3. (B) Maroon nonmetallic acrylic melamine enamel with styrene that contains ferric oxide. (C) Hydrous ferric oxide, FeO•OH. (D) Yellow nonmetallic acrylic lacquer that contains hydrous ferric oxide. [From Suzuki (1996b); copyright © ASTM International; reprinted with permission.]

More details regarding the ATR analysis process are described by Mirabella (1993), while the differences between ATR and transmission paint data are noted by Ryland et al. (2001) and discussed in general by Suzuki (2010). Bartick et al. (1994) describe some forensic applications using an ATR objective of an infrared microscope. Paint analyses using the DAC (Schiering, 1988; Suzuki, 2010) and the infrared microscope (Allen, 1992; Ryland, 1995; Bartick, 2010) are also described in more detail elsewhere.

Binder Analyses One of the most common binders that the forensic paint examiner is likely to encounter is the acrylic melamine enamel (Figure 5.1) since, as noted, it is often used in automotive finish layers (basecoats and clearcoats). The absorptions of this binder are thus discussed in some detail to illustrate the types of information that forensic paint examiners can deduce from infrared spectra, as well as the limitations of this technique.

The spectrum of a typical acrylic melamine enamel binder is shown in Figure 5.16, and the characteristic absorptions that paint analysts use to identify components of this binder are indicated. The main absorptions of the acrylic component are the ester carbonyl stretching absorption at 1730 cm^{-1} and the series of C—O stretching absorptions between 1300 and 900 cm^{-1}. The latter are somewhat more characteristic of acrylics than the ester carbonyl absorption, since spectra of almost all paint binders contain an ester absorption (produced either by the binder or binder-related components). Melamine produces a broad absorption near 1550 cm^{-1} and a sharper, weaker absorption at 815 cm^{-1} due to vibrations of the triazine ring (Figure 5.1), and these two absorptions are observed in spectra of other binders containing melamine (such as the polyester melamine enamel of Figure 5.14I). Styrene, present in most acrylic melamine enamels, may produce three sets of absorptions (Figure 5.16): (1) weak or very weak ═C—H stretching absorptions above 3000 cm^{-1}; (2) two very weak overtone-combination bands between 2000 and 1800 cm^{-1} which appear as "blips"; and (3) weak to medium ═C—H out-of-plane bending vibrations at 760 and 700 cm^{-1} (Figure 5.16).

Some of the variations that are observed between spectra of acrylic melamine enamels arise from differences in the relative amounts of melamine or styrene present, as well as differences in the acrylic copolymers that are used. One means

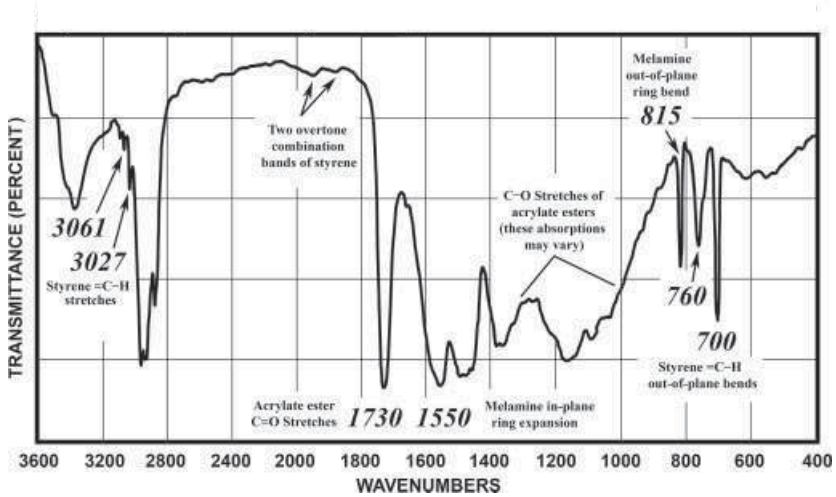

Figure 5.16 Infrared spectrum of a typical acrylic melamine enamel binder with styrene.

to gauge the relative amount of melamine present is to compare the intensity of the carbonyl stretching absorption at 1730 cm^{-1} (which reflects the presence of all of the acrylic copolymers that comprise the backbone) to that of the adjacent melamine 1550 cm^{-1} absorption. Care must be exercised when judging relative infrared intensities, as a nonlinear logarithmic scale is involved in the percent transmittance presentation. Variations may be introduced when working with samples of differing thicknesses or nonpristine samples of limited sizes. Nonetheless, noticeable differences in this ratio may occur, as seen by comparing the spectra of the two automotive monocoats depicted in Figures 5.17A, and 5.17B; a more dramatic difference is seen by comparing Figure 5.14B and 5.14C. Although the binder of Figure 5.14C is referred to as an acrylic epoxy by PPG, the manufacturer of this paint, the aliphatic epoxy component does not produce significant infrared absorptions for characterization, and in terms of its composition, the spectrum is indicative of an acrylic melamine enamel with a relatively small amount of melamine (and a small amount of styrene).

Styrene is found in the vast majority of acrylic melamine enamels used for automotive finishes, and its levels may also vary. The 760/700 cm^{-1} styrene pair may appear to be quite weak when there is a large amount of rutile present, as seen in Figure 5.13C,D. This is a consequence of the logarithmic nature of the percent transmittance scale, which produces a compression of absorption intensities when baselines are low. The other absorptions of styrene (═C—H stretches above 3000 cm^{-1} and the two overtone-combination band "blips" between 2000 and 1800 cm^{-1}), however, are easily seen in Figure 5.13C,D. The three sets of styrene absorptions can be seen in spectra of the acrylic melamine enamels depicted in Figures 5.14B, 5.15B, 5.17B and 5.18C. They may not all be observed, however, when small amounts of styrene are present (Figures 5.14C, 5.17A, and 5.18B) or when large amounts of rutile or other pigments are present (Figure 5.19A, 5.19F). Styrene is used in other binders, and this same set of absorptions may be observed in their spectra; styrene ═C—H stretches and the two "blips" are seen, for example, in the spectrum of the acrylic urethane automotive refinish of Figure 5.14H.

Several different acrylic copolymers are used to create the backbone of an acrylic melamine enamel (Figure 5.1), and in some cases this produces differences in their infrared spectra (Rodgers et al., 1976a). The differences occur mainly in the C—O stretching region between 1300 and 900 cm^{-1} (Figure 5.16), as can be seen by comparing these absorptions in Figure 5.17A and 5.17B and Figure 5.18B and 5.18C. These differences are empirical, that is, they do not permit one to identify which set of copolymers is present. However, acrylonitrile, which contains the —C≡N group (see Figure 5.1), produces a sharp nitrile stretching peak at 2240 cm^{-1}, which does allow one to identify the presence of this copolymer (Suzuki, 1996a). Although weak, this absorption is readily identified (see Figure 5.14B) because it occurs in a region usually devoid of other significant features.

Another common acrylic binder that was used for many General Motors vehicles from the 1960s to the early 1990s is acrylic lacquer (Ryland, 1995). Although it, too, contains a mixture of acrylic copolymers, the main copolymer is poly(methyl methacrylate) (Plexiglas) and the infrared spectrum of this binder

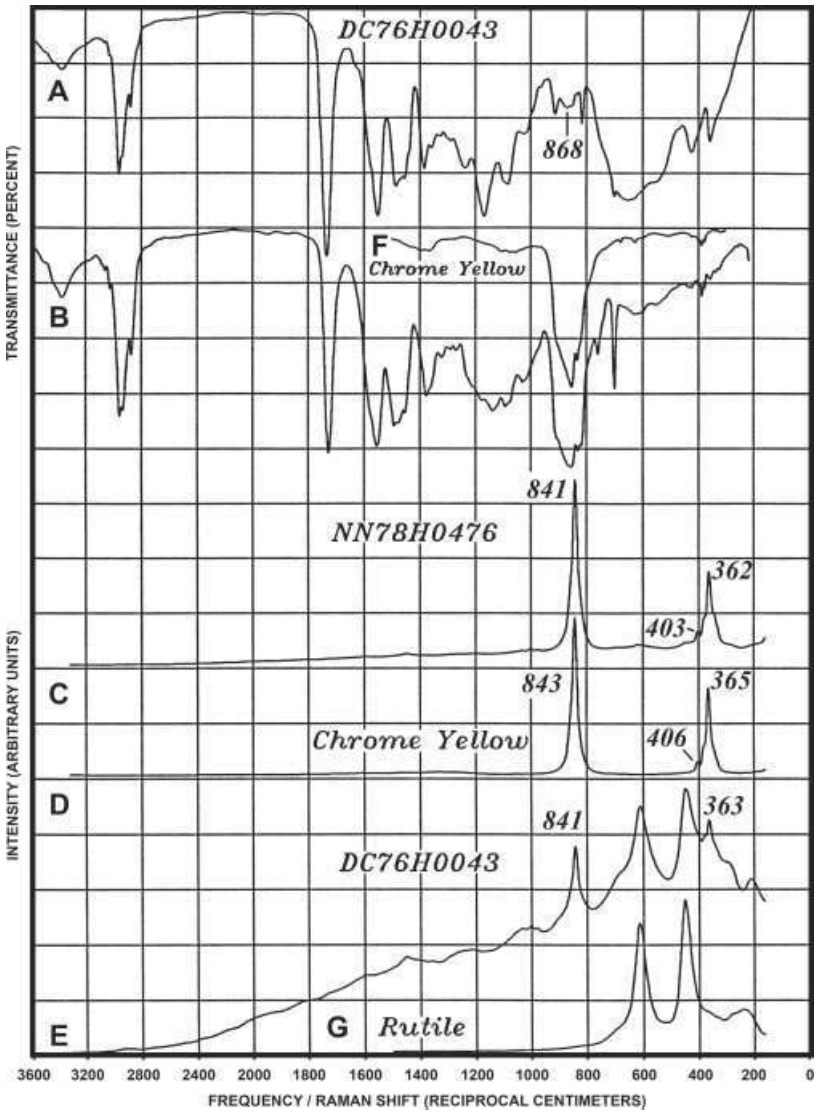

Figure 5.17 (A) Infrared spectrum of a yellow nonmetallic acrylic melamine enamel automotive monocoat with styrene, DC76H0043, which contains a large amount of rutile and a small amount of Chrome Yellow (the Chrome Yellow absorption is marked with its frequency). (B) Infrared spectrum of a yellow nonmetallic acrylic melamine enamel automotive monocoat with styrene, NN78H0476, which contains a large amount of Chrome Yellow. (C) Raman spectrum of NN78H0476. (D) Raman spectrum of Chrome Yellow. (E) Raman spectrum of DC76H0043. (F) Infrared spectrum of Chrome Yellow. G. Raman spectrum of rutile. [From Suzuki and Carrabba (2001); copyright © ASTM International; reprinted with permission.]

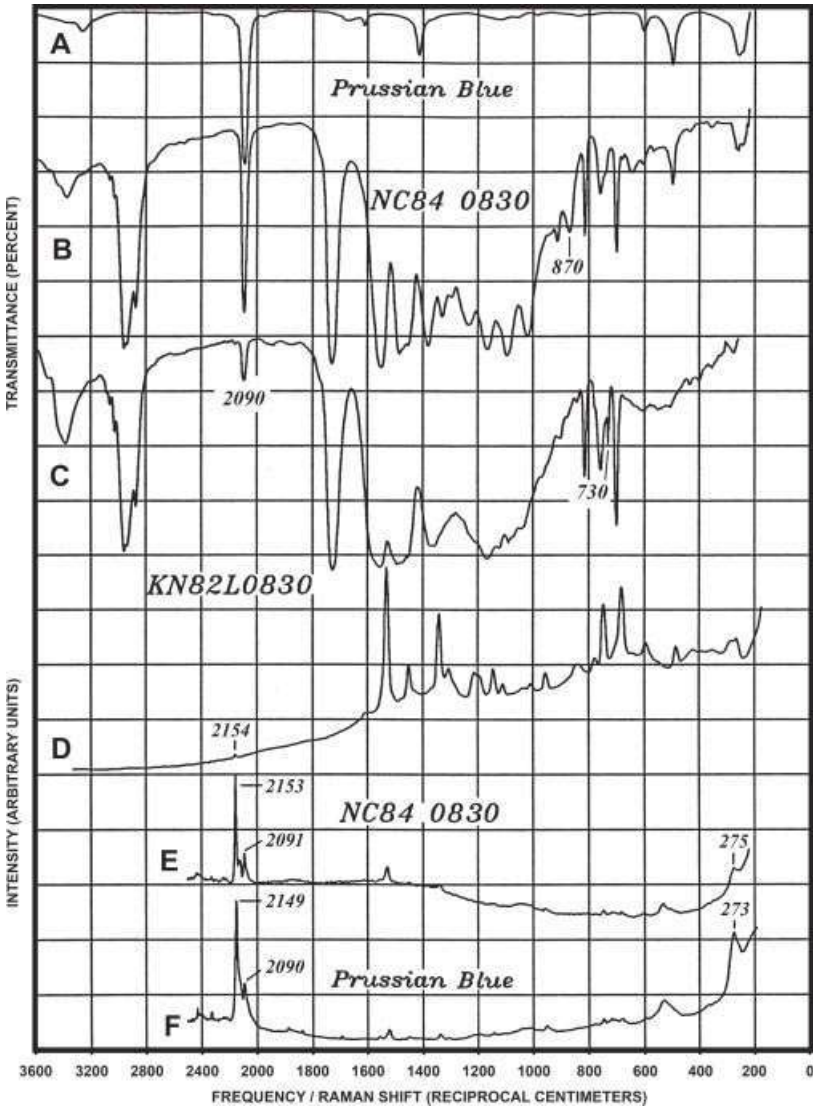

Figure 5.18 (A) Infrared spectrum of Prussian Blue. (B) Infrared spectrum of a dark blue nonmetallic acrylic melamine enamel automotive monocoat with styrene, NC84 0830, which contains a large amount of Prussian Blue. (C) Infrared spectrum of a dark blue nonmetallic acrylic melamine enamel automotive monocoat, KN82L0830, which contains a small amount of Prussian Blue; this paint has the same color as NC84 0830. (D) Raman spectrum of KN82L0830. (E) Raman spectrum of NC84 0830. (F) Raman spectrum of Prussian Blue. [From Suzuki and Carrabba (2001); copyright © ASTM International; reprinted with permission.]

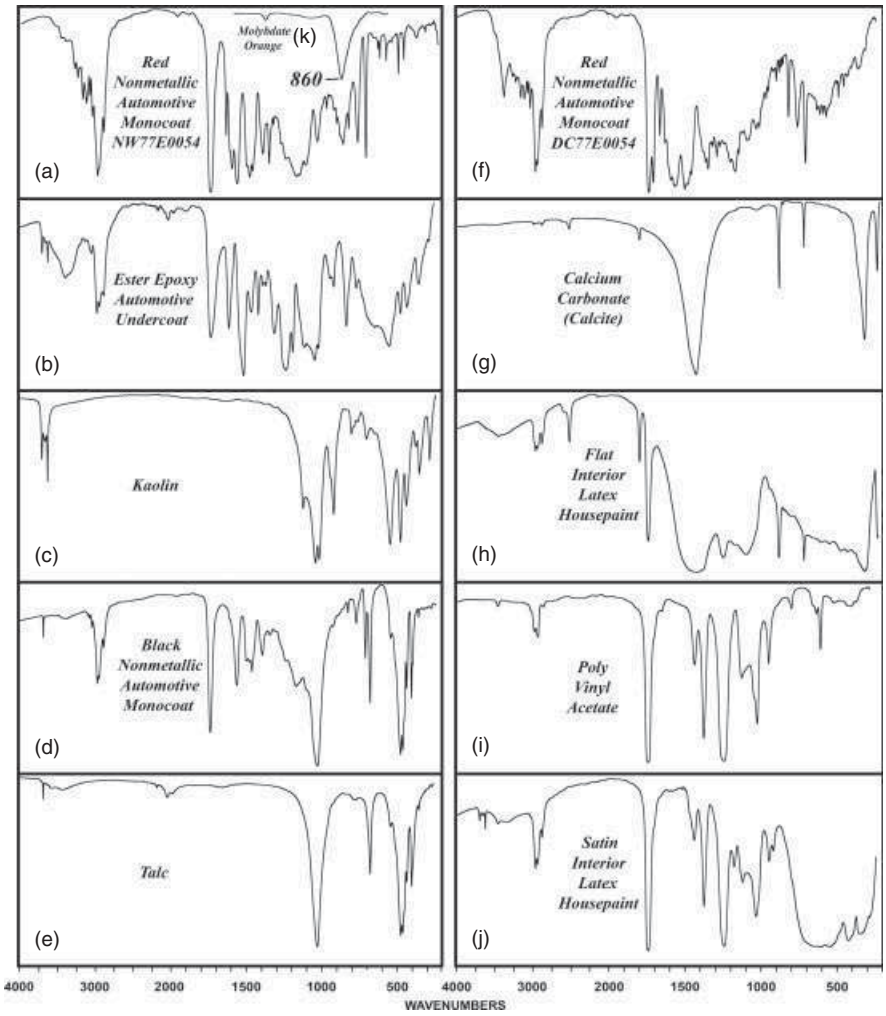

Figure 5.19 Infrared spectra of paints and pigments. (A) Red nonmetallic acrylic melamine enamel monocoat with styrene that contains Molybdate Orange and Quinacridone Red Y. (B) Automotive undercoat with an ester epoxy binder that contains rutile and kaolin. (C) Kaolin. (D) Nonmetallic black automotive monocoat with styrene that contains talc. (E) Talc. (F) Red nonmetallic acrylic melamine enamel monocoat with styrene that contains rutile, ferric oxide, Quinacridone Red Y, and Benzimidazolone Orange. (G) Calcium carbonate (Calcite). (H) Flat interior latex house paint that contains calcite, a silicate, and titanium dioxide or some other oxide. (I) Poly(vinyl acetate). (J) Satin interior latex paint that contains rutile and a small amount of kaolin. (K) Molybdate Orange.

(Figure 5.14A) bears a gross similarity to that of this plastic. Binders referred to simply as "acrylics" are also used in automotive and other paints and have spectra similar to that of Figure 5.14C (the "acrylic epoxy"), except that melamine may not be present, or there may be more styrene (Rodgers et al., 1976a).

The spectra of some other paint binders are depicted in Figure 5.14D to J and Figure 5.19I to illustrate the diversity of their absorption patterns. These are spectra of the binders themselves or of paints that contain little or no observable pigment absorptions (except for the paints of Figure 5.14H to J, which contain large amounts of rutile). Figure 5.14D,I,J are spectra of an alkyd (orthophthalic alkyd) binder, an automotive undercoat with a polyester (isophthalic alkyd) melamine binder and rutile, and a beige paint from a three-ring binder hole punch consisting of a polyester (terephthalic alkyd) binder and rutile. The compositions of the three binders differ primarily in the substitution pattern of two ester groups on an aromatic ring, which are *ortho, meta*, and *para*, respectively, and they produce distinct absorption patterns. All three binders are polyesters, but for historical and chemical reasons, different nomenclatures have been used to describe them, and the term *polyester* has been used for two distinct compositions.

The nominal polymers of three other paint binders—nitrocellulose, epoxy, and urethane—do not by themselves contain an ester carbonyl group, but when used in paints, they almost always have a modifier (copolymer, block copolymer, cross-linking chain, side chain, or plasticizer) that does. The spectrum of nitrocellulose is depicted in Figure 5.14E. As noted, a film of this polymer by itself is quite brittle and it is always used with a block copolymer such as an alkyd or a plasticizer; the absorptions of nitrocellulose, however, are often the strongest in spectra of such binders. The epoxy binders used in paints are aromatic epoxies based on bisphenol A and are actually polyethers; they always contain a modifier such as an acrylic, alkyd, or polyester, so an ester carbonyl absorption is observed in their spectra (Figure 5.14F).

Urethanes are carbamates with the $R_1O—(C{=}O)—NHR_2$ functional group, which has a C═O stretching absorption that occurs below 1700 cm^{-1}. This characteristic absorption of urethanes is usually manifested as either a doublet with the ester carbonyl absorption (Figure 5.14G) or as a shoulder to the ester peak (Figure 5.14H), and is accompanied by the urethane C—N stretch absorption at 1520 to 1530 cm^{-1}. The spectra of a few urethanes may also have a weak to medium absorption in the region 2270 to 2260 cm^{-1} (Figure 5.14H) produced by an isocyanate (R—N═C═O) functional group (Suzuki, 1976a). An isocyanate compound is used as the starting material for most urethanes, and its presence in the paint represents unreacted precursor. Like the nitrile group of acrylonitrile (Figure 5.14B), this absorption is usually readily identified because so few compounds absorb in this region. (The very weak triplet of absorptions near 2200 cm^{-1} in Figure 5.14C,G,I, are artifacts; the paints were sandwiched between both DAC anvils, and this may result in what appear to be weak absorptions caused by differences in reflection from the diamond faces.) The acrylic urethane of Figure 5.14G also appears to contain a small amount of melamine, evidenced by the shoulder band near 1550 cm^{-1} and the very weak sharp peak at 815 cm^{-1}. Figure 5.19I

is the spectrum of poly(vinyl acetate) (PVA); a PVA–acrylic binder is the most common used in latex house paints, and the spectrum of this binder is primarily that of PVA since the acrylic component is minor and its absorptions generally overlap those of PVA.

The identification of paint binders based on their infrared absorptions is treated in more detail by Ryland (1995), who also presents an automotive paint binder classification flowchart for their identification based on certain key absorptions. Flowcharts are intended primarily for use with paints lacking significant pigment absorptions or for use by analysts who already possess some pattern recognition skills for absorptions of common binders and pigments. Some caution should thus be exercised in their use and it should be remembered that as new products evolve, their spectral characteristics may not be reflected in existing flowcharts. Nonetheless, they may be a useful aid when used with the proper precautions, and an updated chart used for the identification of automotive paint binders is presented in Figure 5.20.

Several new binders were introduced for automotive paints during the period from roughly the mid-1980s to the mid-1990s. A collaborative study using infrared spectroscopy was therefore conducted to determine the discriminating characteristics of this technique for black nonmetallic basecoat/clearcoat finishes used in the 1990s (Ryland et al., 2001). Such finishes lack most of the microscopic discriminating features described previously, and carbon black, which does not produce

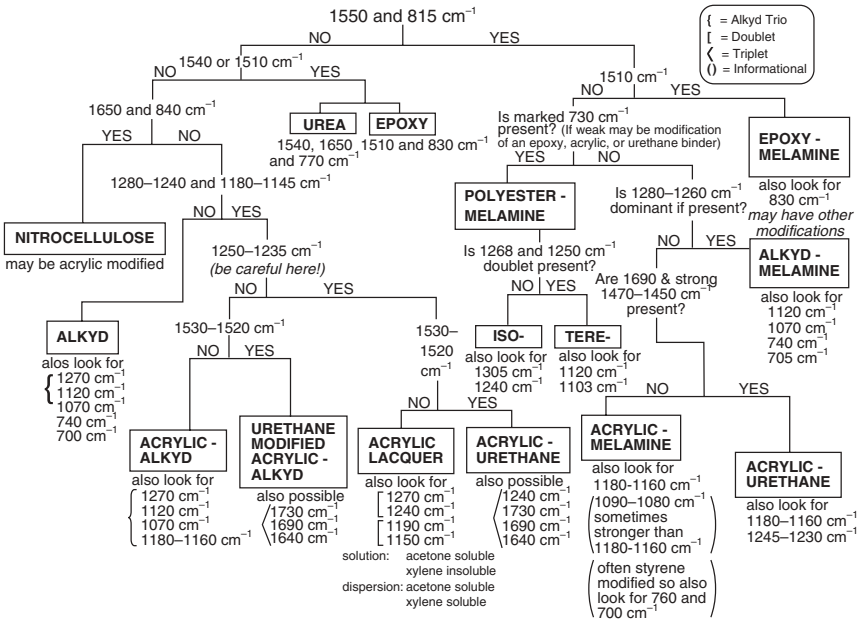

Figure 5.20 Automotive paint binder classification flowchart based on infrared absorptions. Updated from an earlier version published in Ryland (1995).

discrete infrared absorptions, is typically the only pigment used. Binder composition thus assumes a much greater role as a means to distinguish such finishes, and this collaborative study confirmed the suitability of using infrared spectroscopy for this purpose and demonstrated the reproducibility of infrared spectra acquired by numerous laboratories using different instrumentation.

Inorganic Pigment Analyses Because colored inorganic pigments are generally weak absorbers of visible light and strong absorbers of infrared radiation, high concentrations are used in some paints, and their absorptions may be prominent in the spectra of these paints. In addition to ferric oxide (Figure 5.15A,B), there are two other common iron-containing inorganic pigments, hydrous ferric oxide and Prussian Blue. The spectrum of hydrous ferric oxide ($FeO \cdot OH$), a yellow pigment, is shown in Figure 5.15C. Absorptions of this pigment may be seen in the spectrum (Figure 5.15D) of a yellow nonmetallic automotive paint with an acrylic lacquer binder (compare to Figure 5.14A).

Prussian Blue, which has a dark blue hue (Navy Blue), is comprised of iron and other salts of the $[Fe(CN)_6]^{4-}$ anion; its spectrum is depicted in Figure 5.18A (Suzuki, 1996a). The strongest absorption of this pigment is the cyano ($C{\equiv}N^-$) stretching peak at 2090 cm^{-1}, which like the acrylonitrile (Figure 5.14B) and isocyanate (Figure 5.14H) peaks, occurs in a region where it can readily be observed. It is easily seen in the spectra of two blue nonmetallic automotive monocoats (Figure 5.18B,C) that contain this pigment; both paints have acrylic melamine enamel binders with styrene.

The lead chromates are another important family of colored inorganic pigments, comprised of Chrome Yellow, Molybdate Orange, and silica-encapsulated versions of the two (Suzuki, 1996b). The spectrum of Chrome Yellow, a bright yellow–orange inorganic pigment that consists of lead chromate with a lesser amount of lead sulfate ($PbCrO_4 \cdot x PbSO_4$), is shown in Figure 5.17F. The absorptions of this pigment can be seen in the spectrum (Figure 5.17B) of a bright yellow–orange nonmetallic automotive monocoat, which has an acrylic melamine enamel binder with styrene. Molybdate Orange is comprised of lead chromate, lead molybdate, and lead sulfate ($PbCrO_4 \cdot x PbMoO_4 \cdot y PbSO_4$) and its spectrum consists of one main absorption near 860 cm^{-1} (Figure 5.19K), in the same region as the Chrome Yellow absorption (Figure 5.17F). When present in high concentrations, the minor differences in the absorptions of Chrome Yellow and Molybdate Orange may be observed in some paint spectra, although this is usually not the case when low concentrations are used. Figure 5.19A is the spectrum of a red nonmetallic automotive topcoat with an acrylic melamine enamel binder and styrene that contains Molybdate Orange together with an organic pigment.

Three of the most common inorganic extender pigments used in paints are kaolin (Figure 5.19C), talc (Figure 5.19E), and calcium carbonate (Figure 5.19G). Kaolin and talc are silicates that contain hydroxyl groups involving little or no hydrogen bonding, hence the frequencies of the O—H stretches are relatively high (above 3650 cm^{-1}) and the bands are quite sharp. Although weak, these peaks are

thus conspicuous and are often easy to detect in paint spectra. The spectrum of an automotive undercoat with an epoxy binder is depicted in Figure 5.19B, and absorptions of both rutile (Figure 5.13B) and kaolin can be seen. The spectrum of the satin latex paint depicted in Figure 5.19J also contains weak kaolin absorptions, along with strong absorptions of rutile. All of the absorptions of talc (Figure 5.19E) are observed in the spectrum of the black nonmetallic acrylic melamine enamel automotive monocoat with styrene shown in Figure 5.19D. This paint is quite unusual in that it has a flat finish, whereas almost all automotive finishes have a high gloss. The presence of such a large amount of talc is, in fact, the reason for this lack of luster, as this extender pigment is serving as a flatting agent.

Calcium carbonate has two common polymorphic forms, calcite and aragonite, both of which may be used in paints. The spectra of the two can be distinguished (Infrared Spectroscopy Committee of the Chicago Society for Coatings Technology, 1980), and the spectrum of calcite, the more common of the two, is shown in Figure 5.19G. This spectrum lacks the sharp O—H "handles" seen in the spectra of kaolin or talc, but it does have two very weak peaks at 2515 and 1797 cm^{-1}. When calcite is used in high concentrations in paint, the two are often conspicuous in spectra because the former is too low in frequency for a C—H stretch and the latter is quite high for a carbonyl stretching absorption. The two can be seen in the spectrum of a flat interior latex house paint (Figure 5.19H), which contains a very large amount of calcite, a silicate (probably silica), and titanium dioxide or some other oxide. As noted, paints having low lusters typically contain large amounts of inorganic pigments, and their broad and strong absorptions often obscure binder features in paint spectra. Only two of the PVA absorptions below 2000 cm^{-1} (Figure 5.19I) are observed in Figure 5.19H. In contrast, most of the PVA absorptions are observed in the spectrum of an interior latex house paint that has a satin finish (Figure 5.19J). Although characterization of the binder is hampered for such low-luster paints, the prominent absorptions of the extender pigments are an important means to differentiate such paints, since the concentrations and combinations of these pigments vary considerably.

Organic Pigment Analyses Organic pigments can be identified by their absorptions in certain paint infrared spectra, although these features are typically weaker than those of inorganic pigments. Organic pigment peaks are narrower than most binder or inorganic pigment absorptions, and they occur over a wider spectral range than inorganic pigments. They are mostly observed in spectra of some paints that have bright vivid colors (characteristic of many automotive finishes), however, and are rarely seen in spectra of paints with pastel or pale shades and blue hues (Suzuki, 2010).

Figure 5.19A,F show spectra of two bright red automotive monocoats that contain absorptions of both organic and inorganic pigments (Suzuki and Marshall, 1998); both paints have acrylic melamine enamel binders with styrene, and the organic pigment absorptions are the sharp features not observed in the spectrum of this binder (Figure 5.16). Analysts who are not familiar with binder absorptions,

however, would probably find it very difficult to distinguish binder features from those of either inorganic pigments or organic pigments. The spectrum of Figure 5.19F, in fact, contains significant absorptions of two inorganic pigments and two organic pigments. Familiarity with binder absorption patterns is thus the most important skill for paint analysts to acquire, followed by familiarity with common inorganic pigment absorptions. Organic pigments, in contrast, are best identified by comparisons to literature reference spectra rather than by trying to memorize their absorptions.

Some of the organic pigments or classes of organic pigments that have been identified in automotive finishes using infrared spectroscopy include benzimidazolones (Suzuki and Marshall, 1997), quinacridones (Suzuki and Marshall, 1998), DPP Red BO and Thioindigo Bordeaux (Suzuki, 1999a), Isoindolinone 3R, Isoindoline Yellow, and Anthrapyrimidine Yellow (Suzuki, 1999b), and perylenes (Massonnet and Stoecklein, 1999a). Other spectra of organic pigments may be found in the various editions of *An Infrared Spectroscopy Atlas for the Coatings Industry* (Infrared Spectroscopy Committee of the Chicago Society for Coatings Technology, 1980; Infrared Spectroscopy Atlas Working Committee, 1991). These volumes are also the most comprehensive compilations of spectra of other paint ingredients, including binders, inorganic pigments, and additives.

Color is the most distinguishing feature of certain types of paints, particularly automotive finishes (Ryland and Kopec, 1979). It is thus desirable that the analytical methods that are used in addition to microscopy and microspectrophotometry provide as much discrimination as possible between paints having very similar colors. For paints of the same color where different binders are used, there will clearly be differences in their infrared spectra. Similar pigment formulations are often used to produce the same color; however, this is not always the case, even when similar binders are used. Different pigments or pigment combinations may be used to produce the same color, as illustrated by the spectra of Figures 5.13C,D,B,C, and Figures 5.19A,F. These are spectra of pairs of original automotive monocoats from two different suppliers used for a specific color on a particular vehicle model. As discussed previously, the monocoats of Figure 5.18B,C both contain Prussian Blue, but with significantly different concentrations. Figure 5.19A, 5.19F show spectra of two automotive monocoats with bright orange–red nonmetallic hues (referred to in the industry as "Fire Engine Red"). The first paint (Figure 5.19A) contains Molybdate Orange and Quinacridone Red Y; the second (Figure 5.19F) contains rutile, ferric oxide, Quinacridone Red Y, and Benzimidazolone Orange. The main difference between the spectra of Figure 5.13C and 5.13D is a peak of hydrous ferric oxide (Figure 5.15C) in the latter spectrum (the other peaks of this pigment are mostly obscured).

Rodgers et al. performed most of the early work on the forensic identification of automotive paint constituents using infrared spectroscopy, and their series of papers serves as an excellent introduction to this subject (Rodgers et al., 1976a–c). A statistical method has been applied to evaluate the significance of minor differences in the infrared spectra of some automotive topcoats to determine their

value as evidence (Zieba and Pomianowski, 1981). The infrared spectra of various automotive refinish paints were examined and considerable variations in their compositions were noted, as well as differences in the types of refinish binders compared to those of original finishes (Percy and Audette, 1980). A collaborative study involving the infrared analysis of automotive undercoats has demonstrated that even when two or more pigments are present, it is usually possible to identify the pigments and the major binder components based on their absorptions (Norman et al., 1983). Buzzini et al. (2005) used infrared spectroscopy to analyze paint on 207 crowbars that had been seized as evidence. The purpose of this study was to determine the types and frequencies of such paints. Simulations involving crowbars and painted wood surfaces were also conducted, and it was found that paint transfers, including surface to tool and tool to surface, were common.

The infrared analysis of paint evidence has been described in review treatments by Ryland (1995) and Beveridge et al. (2001). The analysis of paint using FT–IR spectroscopy has also been reviewed from the perspective of the coatings chemist (Hartshorn, 1992). General guidelines for forensic paint analyses are outlined in the *Standard Guide for Using Infrared Spectroscopy in Forensic Paint Examinations* (Scientific Working Group for Materials Analysis, 2009).

Vehicle Identification The identification of an unknown paint recovered from the scene of a hit-and-run incident requires a suitable reference collection or database. Until 1990, paint examiners in the United States relied on the *Reference Collection of Automotive Paints* (Collaborative Testing Services, 1989), a comprehensive collection of original finishes used on American automobiles manufactured between 1974 and 1989. Many of the automotive paints discussed in this chapter are from this collection, and they are referred to by their *Reference Collection of Automotive Paints* identification codes. The codes provide information about the paint manufacturer, binder composition, and the year that formulation was first used. The *Reference Collection of Automotive Paint Technical Data* booklet (Collaborative Testing Services, 1989) provides a list of the vehicle models for which each such paint may have been used.

As an example, the two dark blue nonmetallic monocoats with spectra shown in Figure 5.18B (NC84 0830) and 5.18C (KN82L0830) have the same color, which is indicated by the "0830" numerals. Older paints have a letter color code and the "L" of KN82L0830 signifies that this paint was classified as blue. The "N" of NC84 0830 indicates that the paint was manufactured by BASF Inmont, while the "C" denotes an acrylic enamel binder; this paint was first manufactured in 1984 based on the "84." KN82L0830 was manufactured by Glasurit America, has a nonaqueous dispersion enamel binder, and was first produced in 1982. This paint was used on some 1982 Jeeps and on American Concords, Eagles, and Spirits. NC84 0830 was used on some 1984 Jeep Cherokees and on American Alliances, Eagle 30s, Eagle SX4s, and Encores.

Although a useful aid for identifying domestic vehicles, the *Reference Collection of Automotive Paints* had two major limitations. It did not include the complete finish system, including primers and other undercoats, nor did it include paint

from imported vehicles. In addition, after 1989 the only comprehensive original automotive paint finish coat collection in the United States was maintained by the FBI Laboratory. In 1994, a committee of international forensic paint examiners, then known as TWGPAINT (now part of SWGMAT, the Scientific Working Group for Materials Analysis), addressed this issue. TWGPAINT obtained funding to expand an existing database maintained by the Royal Canadian Mounted Police (RCMP) Laboratories, known as the Paint Data Query (PDQ) system.

The goal of the PDQ system is to compile data for the complete original finish systems of all vehicles in North America, domestic and import, with infrared data collected for each individual layer of the finish system. The system includes both text and spectral search capabilities, and users input data about binders and pigments, as well as color information, from an unknown original automotive finish. When all of these factors are included in the search, it has generally been found that the list of possible vehicles is quite short. Often, the list consists only of vehicles manufactured during a short time period at one specific assembly plant. More information regarding the PDQ system is discussed elsewhere (Buckle et al., 1997; Beveridge et al., 2001; Ryland et al., 2006).

5.5.6 Raman Spectroscopy

Like infrared spectroscopy, Raman spectroscopy involves vibrational transitions of the molecules of a sample. Raman spectra are generated by an entirely different mechanism, however, involving *inelastic scattering* of a monochromatic laser source. The laser may have any frequency in the near-ultraviolet, visible, or near-infrared region, and the interaction of this radiation with the molecules of the sample can be viewed as an oscillating electric field driving a dipole (the molecules). This generally results in *elastic scattering* (*Rayleigh scattering*), where the scattered radiation has the same frequency. Inelastic scattering (Raman scattering) occurs when some of the energy is transferred to vibrational modes of the molecules of the sample. As a result, the scattered radiation has less energy, and this difference is equal to the energy of the vibrational transition that occurs. A Raman spectrum is a plot of the intensity of the scattered radiation versus its frequency, with the abscissa depicting the *Raman shift*, the difference in frequency (in wavenumbers) between the laser line and the scattered radiation.

The Raman effect is quite weak, and the vast majority of the scattered light (by a factor or 10^5 or so) occurs as Rayleigh scattering. Florescence is a much more efficient process than Raman scattering, and if it occurs (caused either by the analyte itself or by impurities), it may overwhelm the much weaker Raman peaks. In addition to fluorescence, the other main difficulty that may occur when attempting to obtain a Raman spectrum of paint arises from the absorption of the laser light by the sample. This can cause localized heating and possibly destruction of the sample, so that low laser power levels and defocused beams are normally used.

Dispersive charge-coupled device (CCD) array and Fourier transform (FT) Raman spectrometers are the two main types of Raman instruments commercially available. The former uses gratings to separate different wavelengths

of Raman-scattered light, which is then dispersed onto a CCD detector array. Dispersive CCD spectrometers use near-ultraviolet or visible lasers. FT–Raman spectrometers employ an FT–IR interferometer in lieu of a dispersing device, a near-infrared laser, and a separate near-infrared detector. Because Raman scattering is proportional to the fourth power of the frequency of the scattered radiation, Raman spectral peaks are stronger when they occur in the visible region compared to the near-infrared region. CCD detector arrays are also more sensitive than near-infrared detectors, so dispersive CCD instruments are inherently more sensitive devices than are FT–Raman spectrometers. Since fluorescence is the main problem encountered with Raman spectroscopy, however, FT–Raman systems may be more applicable for some samples. Both types of instruments may be fitted with a microscope attachment that allows selection of the area to be examined while viewing the sample optically, analogous to an infrared microscope.

Essentially no sample preparation is required with Raman spectroscopy when examining many paints, other than ensuring that the surface is clean. The specimen is simply positioned at the focal point of the instrument collection optics. Using a Raman microscope, sequential analyses of individual layers of cross-sectioned multilayered paint can be conducted. Unlike infrared microscopy, thin sections do not have to be prepared, and spectral contributions from adjacent layers are much less of a concern. For the most part, the technique is nondestructive, although it is possible to create small craters in the paint when laser power levels are too high. Because clearcoat layers are mostly transparent to the incident laser, Raman spectra of basecoats can often be obtained without removing the clearcoat.

A Raman spectrum is generally quite distinct from an infrared spectrum of the same compound. For a few very symmetric compounds, in fact, the transitions that are observed in a Raman spectrum cannot be observed using infrared spectroscopy, and vice versa. Although this is usually not the case, the two techniques are still very complementary, particularly when they are applied to a complex matrix such as a paint that contains inorganic and organic components spanning a wide range of concentrations. Symmetric vibrational modes may produce no infrared absorptions or only weak ones, whereas they often give strong Raman scattering peaks. As noted for pigments, inorganic compounds may produce broad infrared absorptions, but their Raman scattering peaks are usually narrow. Many inorganic pigments are much stronger Raman scatterers than binders. In certain instances, pigments (usually organic) that can absorb the laser light produce significantly enhanced Raman scattering, known as the *resonance Raman effect* (Johnson and Peticolas, 1976), and even when present in very low concentrations, Raman peaks of such pigments may be observed. Raman spectra of paints are thus typically much simpler than corresponding infrared spectra, as they are usually dominated by pigment features.

Some of the differences that are observed between infrared and Raman spectra of paints can be seen by comparing Figures 5.17A, and 5.17E, 5.17B and 5.17C, 5.18B and 5.18E, and 5.18C and 5.18D. These are infrared and Raman spectra, respectively, of four automotive monocoats, and the Raman

spectra were acquired using a dispersive CCD system (Suzuki and Carrabba, 2001). As discussed previously, Figure 5.17B is the infrared spectrum of a yellow acrylic melamine enamel with styrene that contains Chrome Yellow. The Raman spectrum of this paint (Figure 5.17C), however, is predominantly that of Chrome Yellow (Figure 5.17D), and binder peaks are almost totally absent. Figure 5.17A is the infrared spectrum of another yellow acrylic melamine enamel with styrene that contains a large amount of rutile. A small amount of Chrome Yellow is also present, but the weak infrared absorption at 868 cm^{-1} cannot be definitely attributed to this pigment since it may also be due to either Molybdate Orange (Figure 5.19K) or a binder feature (Figure 5.18B). The Raman spectrum of this paint, however, indicates clearly that Chrome Yellow is present along with rutile (Figure 5.17G), as the Raman spectrum of Molybdate Orange has a doublet with equal intensities near 362 cm^{-1} (Suzuki and Carrabba, 2001) rather than a singlet. The sloping baseline of Figure 5.17E is caused by fluorescence.

Copper Phthalocyanine Blue is by far the most common blue pigment used in automotive paint as well as many other paints. Copper Phthalocyanine Blue has a very high tinctorial strength (unlike Prussian Blue), so the concentrations of this pigment used in paint are quite low. Consequently, infrared absorptions of Copper Phthalocyanine Blue are rarely observed in paint spectra. As discussed previously, Figure 5.18B,C show infrared spectra of two dark blue nonmetallic automotive monocoats with the same color, but they have noticeably different intensities for the Prussian Blue cyano absorption. The difference in concentration of Prussian Blue is actually greater than might be inferred from the two spectra, as a logarithmic scale is involved and weak peaks appear stronger than in a linear scale. How can two paints have the same color if there is much more pigment present in one of them? A good guess would be that there is another blue pigment in the paint of Figure 5.18C. In fact, the pigment is Copper Phthalocyanine Blue, but the only manifestation of its presence in the infrared spectrum of Figure 5.18C is a weak sharp absorption at 730 cm^{-1} (sandwiched between the two styrene absorptions at 760 and 700 cm^{-1}). The Raman spectrum of this paint (Figure 5.18D), however, is predominantly that of Copper Phthalocyanine Blue, which produces resonance-enhanced peaks (Palys et al., 1995). Prussian Blue, in contrast, is not a particularly strong Raman scatterer. Its peaks (Figure 5.18F) are seen in the Raman spectrum of the paint with the larger quantity of Prussian Blue (Figure 5.18E), but are barely perceptible in the Raman spectrum with the lesser amount (Figure 5.18D).

Massonnet and Stoecklein (1999b) collected FT–Raman spectra of some yellow, orange, and red organic pigments used in automotive finishes along with spectra of some red paints that contain some of these pigments. De Gelder et al. (2005) also examined automotive paints using FT–Raman spectroscopy and concluded that the Raman peaks of organic pigments in basecoats provide the best discrimination. Raman peaks of rutile, calcite, and barium sulfate in spectra of undercoats were also found useful for characterization. Unlike infrared spectroscopy, however, Raman spectroscopy is not useful for detecting a wide variety of inorganic pigments. In their study of pigments in automotive paint, Suzuki and Carrabba (2001) found that

silicates (talc, kaolin, quartz, and others) do not produce significant Raman peaks, even when present in high concentrations.

In three studies, Bell et al. examined the discriminating capabilities of Raman spectroscopy for house paints using a dispersive CCD spectrometer. In the first study (Bell et al., 2005a), the spectra of 51 lilac-colored house paints were collected and compared. The three components producing the strongest Raman peaks of these paints were rutile, Copper Phthalocyanine Blue, and a bluish-violet dioxazine pigment, Pigment Violet 23. In their two other studies, a combination of infrared and Raman spectroscopy was used to study the discrimination between binders used in house paints (Bell et al., 2005b) and between white house paints (Bell et al., 2005c). These studies reiterated the complementary nature of the two techniques.

Kendix et al. (2004) examined some historical (nineteenth century) house paints using a Raman microscope. Some of the inorganic pigments that they identified include calcium carbonate, barium sulfate, lead carbonate, rutile, and anatase. The rutile-to-anatase ratio varied considerably in these older paints, and differences in this ratio were readily detected because the two pigments produce discrete narrow Raman peaks; in contrast, such differences are difficult to observe using infrared spectroscopy—compare Figure 5.13A and 5.13B. Buzzini and Massonnet (2004) analyzed 40 green spray paints using a combination of infrared and dispersive CCD Raman spectroscopy and found that this combination allowed discrimination of most of the 40, although when used alone, infrared spectroscopy provided a higher discrimination power than did Raman spectroscopy. Resonance Raman peaks of two green phthalocyanine pigments, Pigment Green 7 and Pigment Green 36, were identified in some spectra. Buzzini et al. (2006) discussed six case examples involving automotive, household, and spray paints in which the combination of infrared and dispersive CCD Raman spectroscopy also proved useful.

5.5.7 Pyrolysis Gas Chromatography and Pyrolysis Gas Chromatography–Mass Spectrometry

Pyrolysis gas chromatography (PyGC) and pyrolysis gas chromatography in conjunction with mass spectrometry (PyGC–MS) are additional techniques used to examine and compare the organic portion of a cured coating: the binder and additives. In *analytical pyrolysis*, the sample is subjected to a sufficiently high temperature under controlled conditions in an oxygen-free environment so that its constituent molecules break down into smaller fragments. Those molecular fragments (pyrolyzates) are then swept into an analytical instrument, most commonly a gas chromatograph, where they are separated chromatographically and detected by either a flame ionization detector (FID) or a mass selective detector (MSD) upon eluting from the chromatography column. The FID offers a relatively inexpensive, sensitive, and broadly applicable means for the detection of analytes eluting from the column. The data obtained from such a detector can provide a pattern of pyrolyzates that can be used either to identify the class of polymer that is present or to perform a detailed comparison of resin compositions. If a MSD is used in

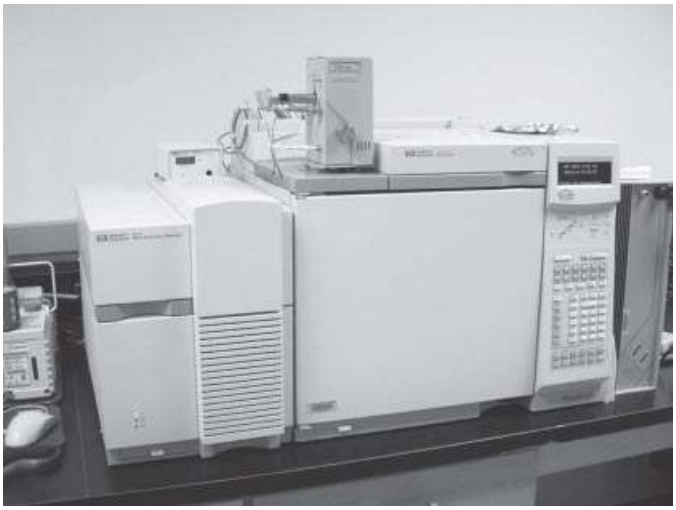

Figure 5.21 Typical pyrolysis gas chromatograph–mass spectrometer (PyGC–MS) equipped with an inductively heated pyrolysis probe, pyrolysis interface, and single capillary column having a mass selective detector (MSD).

place of a FID, much more information can be obtained from the sample. In addition to the pattern information obtained with the FID, the data acquired from a MSD can be used for the potential identification of select compounds of interest. This often aids in identifying the class of polymer that is present. Of course, this additional information comes at a price, as the MSD is considerably more expensive than the FID. A typical PyGC–MS system is shown in Figure 5.21, and an inductively heated pyrolysis probe that inserts into the pyrolysis interface on the gas chromatograph in Figure 5.22.

Why pyrolyze the sample in the first place? Paint binders consist of high-molecular-weight polymers that are simply too large to volatize and introduce into a gas chromatograph. Even if the resin is soluble in a volatile organic solvent such as acetone or chloroform, the polymer chains are still of extremely high molecular weight and cannot be volatized when injected into the standard injection port of a gas chromatograph. By thermally fragmenting the polymers, pyrolyzates are produced that are amenable to volatization and chromatographic separation in a vaporous state. The technique requires little sample (on the order of 10 to 20 μg) and can be performed on most solid polymeric specimens. One may ask why gel permeation chromatography or high-pressure liquid chromatography could not be used, to avoid fragmentation of the polymers. These techniques may be suitable in polymer laboratories but are less so when dealing with real-world forensic samples. First, they require the sample to be in solution, a feat unachievable for a majority of cured, cross-linked paint resins. Second, these techniques typically require a substantial quantity of polymer, which is not available from each layer of most multilayered forensic paint specimens. Finally, these techniques do not

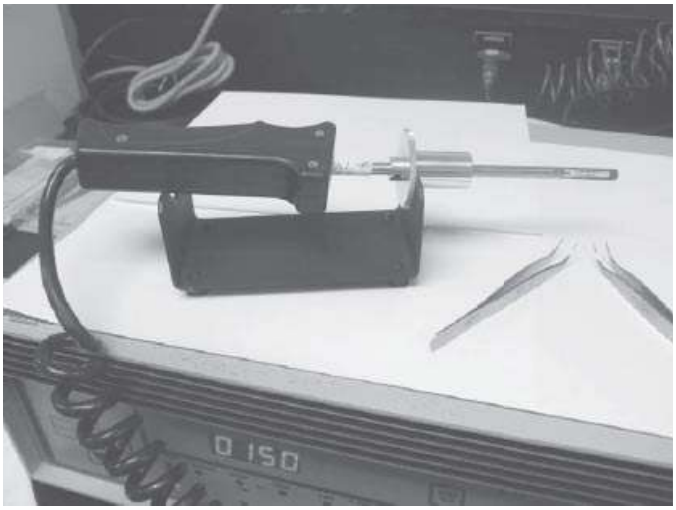

Figure 5.22 Chemical Data Systems inductively heated pyrolysis probe which inserts into the pyrolysis interface mounted on the gas chromatograph injection port.

provide chromatographic characteristics that are specific to the component polymeric species and hence do not maximize discrimination.

Perhaps the more pressing question is why use PyGC or PyGC–MS at all? As we have seen earlier, infrared spectroscopy is a versatile nondestructive technique available to most laboratories which provides spectral data that permit both discrimination and classification of most binders. Furthermore, often it simultaneously provides spectral data characterizing the major inorganic constituents in a paint. Demonstrating its discriminating capabilities, Contos and Ryland (2001) reported 97.5% of the 80 possible pairs of similarly colored *Reference Collection of Automotive Paints* (Collaborative Testing Services, 1989) finish coats having no decorative flake were discriminated by infrared spectroscopy. Edmondstone et al. (2004) reported on a discrimination study of 260 randomly acquired automotive paints, yielding 32,670 possible pairs for comparison. Samples were initially discriminated by microscopical comparison of their finish coat colors, which differentiated all but 28 of the 32,670 possible pairs. Following attenuated total reflectance (ATR) FT–IR microspectroscopic analyses of these 28 indistinguishable pairs' clearcoats, only two pair could not be distinguished. Subsequent transmission FT–IR microspectroscopy of the two pairs' primers served to discriminate another one of the pairs. Obviously, the technique is capable of substantial discrimination.

Infrared spectroscopy does have limitations in the analysis of coating samples. The first is in the discrimination of binders consisting of a mixture of similarly structured polymers. This occurs in the acrylics and alkyds used in automotive paints, in the acrylics used in architectural latex paints, and in the alkyds used in architectural oil-based paints and household spray paints. When performing infrared spectroscopy on a paint resin, the spectrum is comprised of the resulting absorptions of each component in the polymeric mixture, overlaid upon one

another. Detection of characteristics arising from minor components in the mixture is difficult to achieve when the spectra of the individual polymers are all similar to one another. PyGC, on the other hand, employs a chromatographic separation of the pyrolyzates generated from the mixture, permitting detection of characteristics produced from even small amounts of organic components. One such example can be seen in Figures 5.23 and 5.24. The transmission infrared spectra of two different acrylic–melamine enamel automotive finish coats are displayed in Figure 5.23.

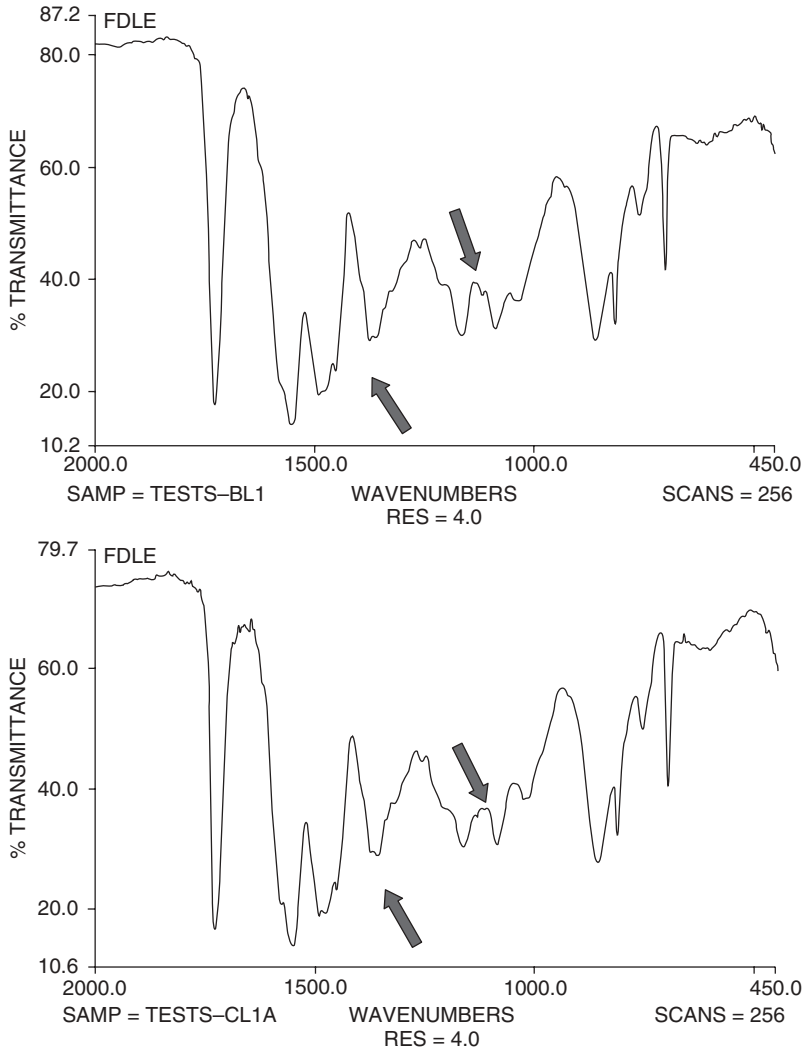

Figure 5.23 Transmission infrared spectra of two different acrylic–melamine enamel automotive finish coats that have the same color. The arrows point out reproducible spectral differences.

They are quite similar, with small differences noted by the arrows. The pyrograms of the same two are displayed in Figure 5.24, presenting no difficulty in differentiating the two. Another example is given in Figures 5.25 and 5.26, these also being two automotive acrylic–melamine enamel finish coats produced by the same paint manufacturer in the same year in the same color. Again, the pyrograms demonstrate little difficulty in differentiating the two. As mentioned previously, the same type of situation can occur in the alkyd enamels, where the same diacid and polyol are used as precursors, but the drying oils are different. Burke et al. (1985), Fukuda (1985), Cassista and Sandercock (1994), and Ryland (1995) all have noted the capacity of PyGC to detect binder variations that go unnoticed, or are at least questionable, when samples are analyzed by infrared spectroscopy alone.

The second major limitation of infrared spectroscopy is a consequence of one of the aforementioned benefits of the technique. In paints that are heavily loaded with extender or coloring pigment, the absorptions resulting from the binder are masked by those that are detected simultaneously from the pigment (Figure 5.19H). Thus, little is present to discriminate between differing binders when performing comparisons. These include some automotive primers, flat architectural paints, flat household spray paints, and some low-gloss maintenance finishes. On the other hand, PyGC in effect performs an automatic extraction prior to analysis. Upon pyrolysis

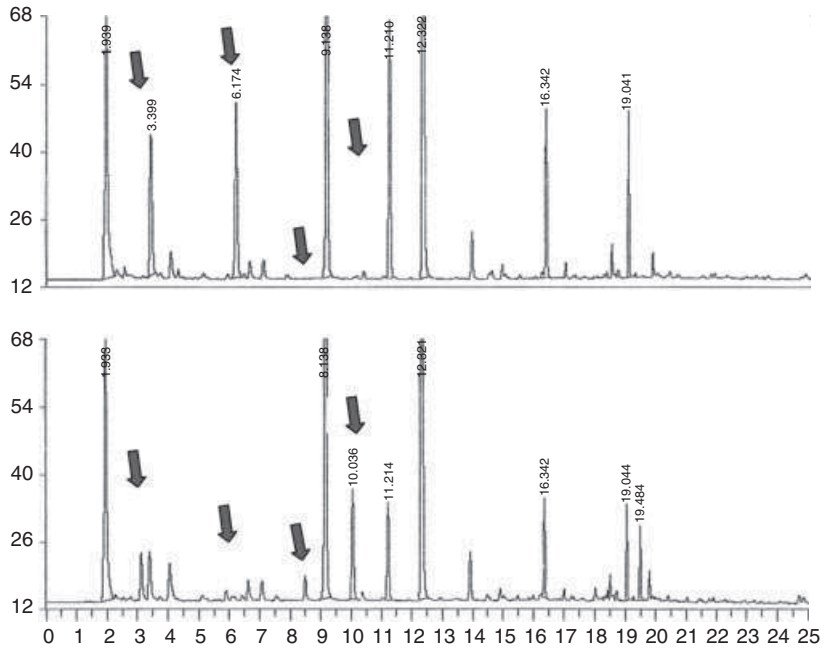

Figure 5.24 Pyrograms of the same two finishes whose infrared spectra are depicted in Figure 5.23. Arrows indicate obvious reproducible differences between the two. The X axis is labeled in minutes and the Y axis is relative intensity.

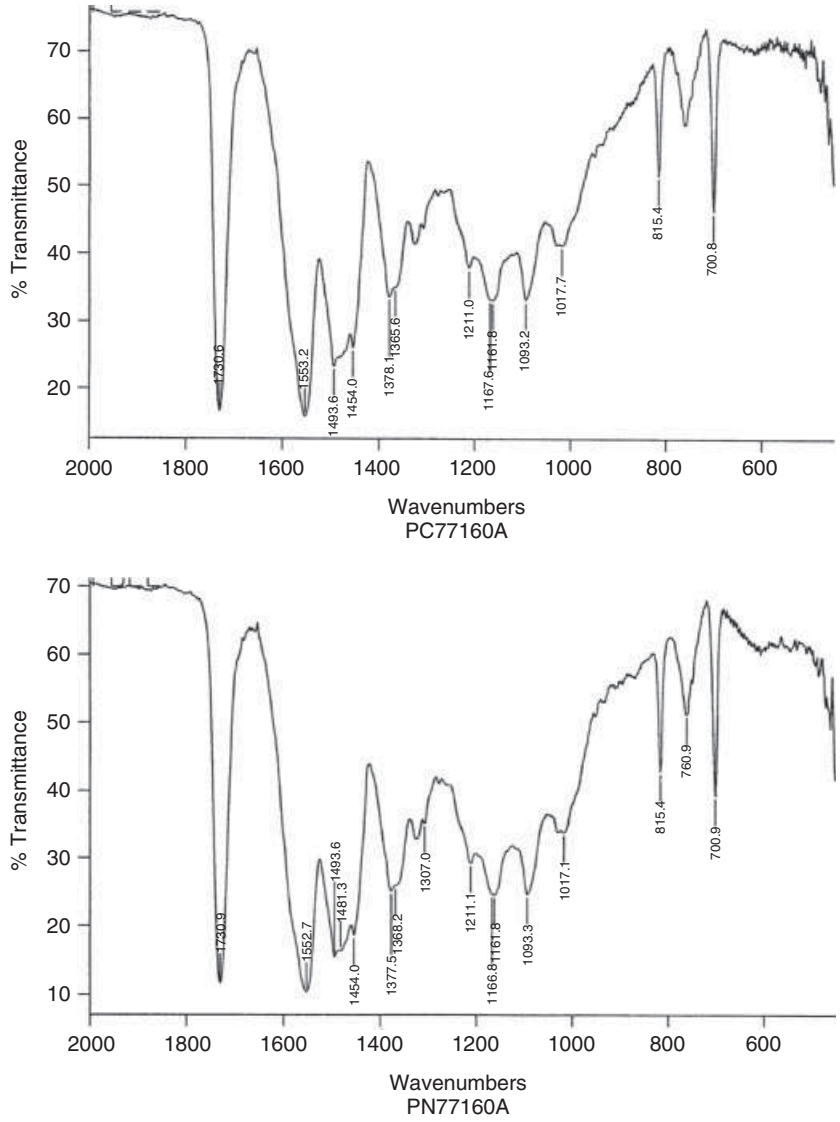

Figure 5.25 Transmission infrared spectra of two different acrylic–melamine enamel automotive finishes having the same color. Both were manufactured by PPG for use on the same year vehicle line; however, one is a low-solvent-emission formulation while the other is not.

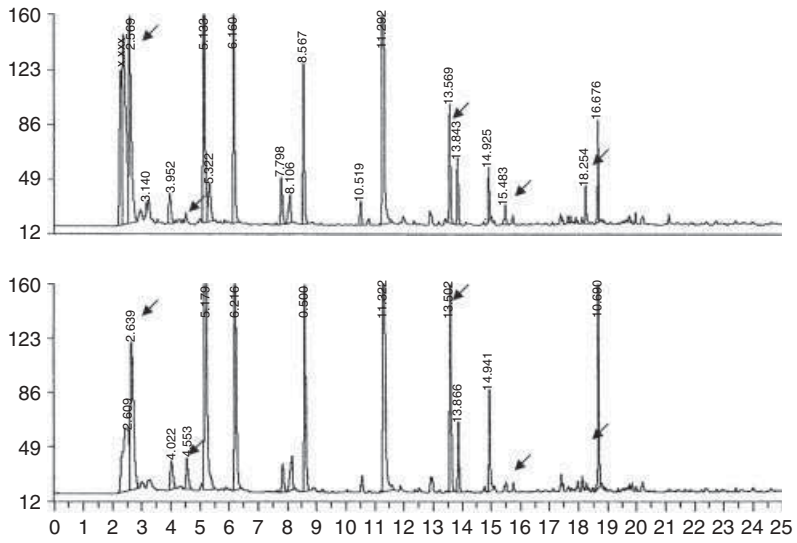

Figure 5.26 Pyrograms of the same two finishes whose infrared spectra are depicted in Figure 5.25. Arrows indicate some of the reproducible differences between the two finishes. The X axis is labeled in minutes and the Y axis is relative intensity.

at an appropriate temperature, the organic portion of the paint is volatilized, fragmented, and passed onto the gas chromatograph while the inorganic portion of the paint remains behind, effectively eliminating any inorganic interference.

It becomes apparent that unlike many other types of trace evidence, paint presents some complex analytical chemistry challenges that demand the use of several analytical techniques to properly characterize its composition. PyGC offers distinct advantages over infrared spectroscopy, but is not without its limitations as well. It requires approximately 10 to 20 μg of sample, on the order of 10 times more than is required for an infrared microscope. In the case of smeared architectural exemplars or very tiny multilayered automotive paint fragments, which are increasingly becoming the norm, PyGC is simply not an option. Furthermore, it is destructive and the organic portion of the sample cannot be reclaimed for further analytical examinations. The inorganic portion of the sample can be reclaimed; however, it has suffered potential deterioration due to exposure to high temperatures. It is much more time consuming than infrared spectroscopy, as the typical run takes approximately 30 to 45 min plus an additional 15 min or more to clear out the column between analyses. It has rather poor long-term reproducibility, making it a poor choice for databasing. However, the discrimination benefits are compelling given certain types of specimens, particularly when used in a comparative mode.

A variety of pyrolysis accessories are available on the market, including inductively heated filament, Curie point, and furnace. Their design, benefits, and shortfalls are discussed by Wampler (2006). In the inductively heated filament type, the sample is placed either on a platinum ribbon probe or in a quartz tube contained within a platinum filament coil probe and inserted into a heated interface

attached to the injection port of the gas chromatograph. Heat is supplied by electrical resistance in the platinum element with both the rate of heating and the final temperature being controlled by the electrical power supplied by the control module. Sophisticated electrical circuitry is used to control the rate of heating reproducibly, and the final temperature is calibrated for each pyrolysis probe. Upon completion of analysis, the sample is heated to a very high temperature to clean the platinum ribbon or the quartz tube. An overwhelming majority of instruments used in forensic laboratories in the United States are of the inductively heated filament type, such as that depicted in Figure 5.22. In the Curie point type, the sample is either wedged into a crimped metal alloy wire or placed inside a neatly folded metallic foil pack. The metal carrier along with the sample is then placed into the pyrolysis probe, which houses a radio-frequency (RF) coil. When power is supplied to the RF coil, the metallic carrier quickly heats to its Curie point temperature, that temperature being determined by the metal alloy being used in the carrier. A number of alloys are available, providing an array of fixed final temperatures. Upon completion of analysis, the Curie point wire is either cleaned of any residual inorganic material or the Curie point foil is simple removed and discarded. In the furnace type, the sample is placed in a carrier which drops into an inductively heated furnace held at an adjustable final pyrolysis temperature. Following analysis, the residual sample containing any inorganic residue is removed with the carrier.

No matter what the design, the basic principles of effective, reproducible pyrolysis are the same. The specimen must be small enough to be pyrolyzed completely, yet large enough to provide sufficient pyrolyzates to be detected by the analytical instrument following pyrolysis. Precision will suffer if the samples are not pyrolyzed completely, since differing quantities of pyrolyzates will be produced from run to run. The specimen must be heated to the final pyrolysis temperature both quickly and at a reproducible rate. An overwhelming amount of the fragmentation occurs in the first few milliseconds of the run, and the temperatures experienced by the samples must be reproducible at this point as well as at the final temperature, or the pyrolyzates will differ. The final temperature will determine the amount of energy available for cleaving the bonds and obviously must be reproducible as well. It is typically minimized so that higher-molecular-weight pyrolyzates are produced, being more characteristic of their polymeric source, while being kept high enough to assure complete pyrolysis. The latter can be checked quickly by initiating another run following the sample run and its "bakeout" to see if any additional material is eluted. If pyrolysis was complete, no material should be eluted. Most paint resins are pyrolyzed in the range 650 to 750°C. In addition, small thin specimens are more desirable than large thick specimens. The outer surface of the specimen is exposed to the pyrolysis heat first and this is where the initial pyrolyzates are formed. If the specimen is thick, the inner portion will remain cooler and the newly formed species will have a tendency to condense on these surfaces and form secondary pyrolysis species, which tend to be much less reproducible than the initial pyrolyzate species. It is best that the energy sweep rapidly through sample to prevent the formation of temperature gradients. Finally, the placement of the samples must be reproducible such that they are exposed to

the same thermal environment every time. This is quite critical in the inductively heated filament pyrolysis probes.

These concepts should be kept in mind when preparing paint samples for PyGC analysis. Samples should be single-layer peels if possible, not thick, intact layered fragments. Replicate analyses are essential if one is to establish precision and then use that range of variation to judge if one material produces a pyrolysis pattern similar to that of another. Precision will change from one type of resin to another. For example, pyrograms of acrylic resins are much more reproducible than those of alkyds. Samples should also be of approximately the same mass. This can usually be deduced from size as long as the morphology of the specimens is similar.

The data produced are in the form of the familiar chromatogram, with eluted material producing peaks displayed on an x-axis of time. The y-axis is proportional to the quantity of material eluted, although this is reflected more accurately in individual peak areas. The chromatograms are typically quite complex, as can be seen in the Figure 5.27 flame ionization–detected pyrogram of an automotive acrylic–melamine binder. The *thermal fragmentation* of one polymeric species will produce numerous characteristic pyrolyzate fragments, not just one peak. The concept is akin to electron impact mass spectrometry, where a beam of electrons breaks the molecule apart into fragments which are then recorded by the mass spectrometer's analyzer. This fragmentation pattern is quite characteristic of the parent molecule and is often thought of as being a definitive identification of the material. In PyGC the polymer is fragmented by thermal energy and the resulting fragments (*pyrolyzates*) are quite characteristic of the parent polymer. It is not simply gas chromatography with a liquid injection of a solution of intact molecules; it is a fragmentation process that imparts uniqueness to the pattern. This pattern (the pyrogram) can be used for comparison (i.e., to ascertain if one paint is like the other); or it can be used for classification (i.e., to ascertain what kind of material it is). To achieve the latter, the analyst must have pyrograms collected from the full array of materials of interest since the classification is based on pattern similarity to a known material, not primary molecular information. This shortfall of PyGC is often overcome by incorporating a mass spectrometer as the detector. Primary molecular information can then be acquired for the pyrolyzates, which leads to pyrolyzate identification and subsequently, to polymer classification. This is not to say that PyGC–MS is more discriminating than PyGC when comparing two resins, merely that it will produce additional information that often permits classification (identification) of the polymer. Remember, pyrolysis of one polymeric species does not just produce one fragment. It produces many fragments, as demonstrated in the pyrogram of pure polystyrene in Figure 5.28. One would be hard pressed to find another material that produces the same thermal fragmentation pattern.

In using PyGC–MS to classify polymers, it is important to keep in mind that the monomer used to construct the polymer is not necessarily what is detected following pyrolysis. Some copolymers, such as the acrylates, fragment primarily back to their monomeric form. An example can be seen in the Figure 5.29 pyrogram of an acrylic–melamine enamel automotive finish (Figure 5.1). The various acrylates and styrene used to construct the binder are readily apparent. On the other hand,

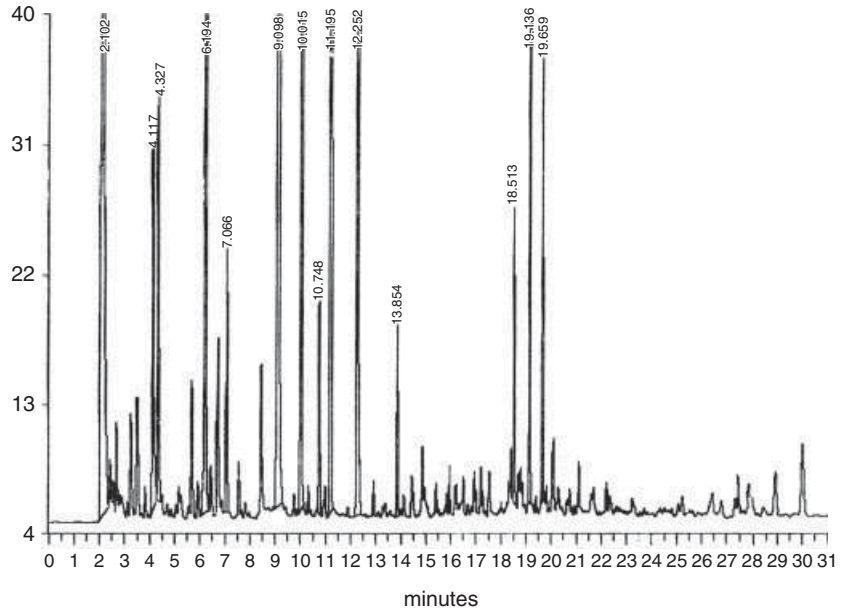

Figure 5.27 Pyrogram of an automotive acrylic–melamine enamel analyzed on a pyrolysis gas chromatograph equipped with an inductively heated pyrolysis probe, a 25-m medium-bore free fatty acid phase (FFAP) fused-silica capillary column and a flame ionization detector.

there is no indication of the presence of melamine other than the presence of *n*-butanol, a cleavage fragment from the butylated melamine cross-linker. Another example can be found in the pyrolysis of poly(vinylacetate). Vinyl acetate is not the major pyrolyzate detected, but instead it is acetic acid. One can deduce why that pyrolysis fragment is produced in the degradation of poly(vinylacetate), but the classification is not straightforward. In other instances, the deduction is not nearly as easily understood. Pyrolysis of an isophthalate-based polyester resin yields benzene, toluene, and benzoic acid as primary pyrolyzates, with no intact indication of the *meta*-substituted aromatic monomer. This point has been demonstrated by numerous authors, such as Challinor (2001, 2006) and Learner (2004).

In an effort to solve this problem to some degree, Challinor (1995) reviewed previous work he published using *tetra*-methylammonium hydroxide (TMAH) in a methanol solution to stabilize pyrolysis frgments as soon as they form (Challinor, 1989, 1991a,b). A small quantity of the solution is placed on the sample prior to introducing it into the pyrolysis chamber, and upon pyrolysis the reagent forms the stabilized methyl esters of the fragile pyrolysis fragments most characteristic of the mother polymer's precursors. For example, this approach permits recognition of the intact methyl esters of the diacids and polyols used to form polyester and alkyd resins as well as the fatty acids comprising the various drying oils used to cross-link alkyd resins. This information is difficult to come by using infrared

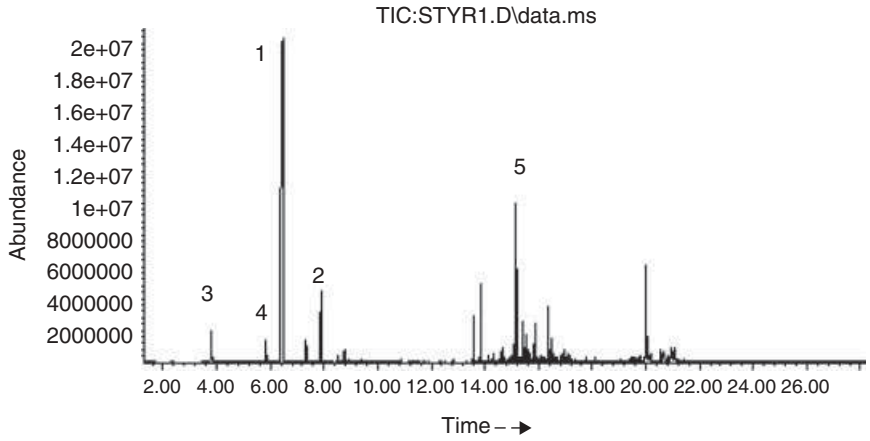

Figure 5.28 Pyrogram of pure polystyrene pyrolyzed at 750°C in an inductively heated pyrolysis probe and chromatographed on a PyGC–MS system using a 30-m narrow-bore 5% phenyl methyl siloxane fused-silica capillary column. The pyrogram consists of many other pyrolyzates in addition to the styrene peak (1), including methyl styrene (2), toluene (3) and ethyl benzene (4). Some of the longer retention time pyrolyzates are dimmers and trimers of these pyrolyzates (5).

spectroscopy alone, especially in the case of polyester resins employing a mixture of ortho-, iso-, and tere- substituted phthalates or alkyd resins formed from similar diacids and polyols but different drying oils.

5.5.8 Elemental Analysis Methods

The two yellow nonmetallic automotive monocoats with spectra depicted in Figure 5.13C and D appear to contain rutile, but both actually contain a mixture of rutile and Nickel Titanate, a yellow inorganic pigment closely related to rutile (Suzuki and McDermot, 2006). Nickel Titanate and other titanate pigments are formed by partial replacement of titanium in the rutile crystal lattice by two other transition metals (Hackman, 1988). For Nickel Titanate (which has the formula $20TiO_2 \cdot Sb_2O_5 \cdot NiO$), antimony and nickel are used. The elements present in some other titanate pigments are apparent from their names: Chromium Antimony Titanate, Nickel Niobium Titanate, Chromium Niobium Titanate, and Manganese Antimony Titanate. The titanates and rutile all have similar infrared spectra, so titanate absorptions in paint spectra can easily be mistaken for those of rutile. Elemental analysis, used in conjunction with infrared spectroscopy, is therefore required to detect and differentiate members of this pigment family.

Based on the infrared data of Figure 5.19H, calcium from the calcium carbonate and silicon from the silicate should be present. If silicates other than silica are present, other silicate elements might be observed, such as aluminum from kaolin, magnesium from talc, or aluminum and potassium from mica. Titanium

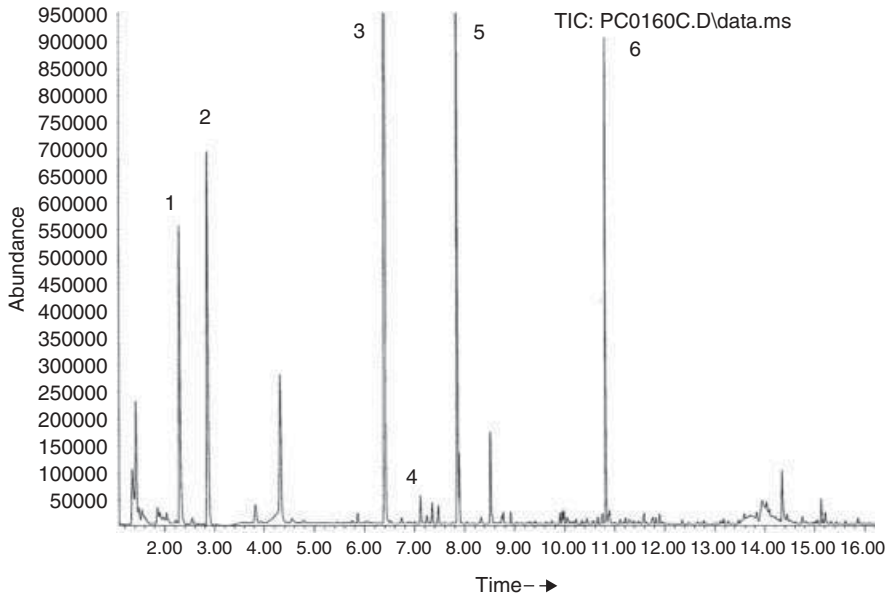

Figure 5.29 PyGC–MS program of an acrylic–melamine enamel automotive finish. The major pyrolyzate peaks are (1) *n*-butanol, (2) methyl methacrylate, (3) styrene, (4) 2-hydroxyethyl acrylate, (5) *n*-butyl methacrylate, and (6) 2-ethylhexyl acrylate.

dioxide (Figure 5.13A,B) appears to be present in this paint, but the additional low-frequency absorptions of calcium carbonate and the silicate render interpretation of this region ambiguous at best. Other oxides, such as zinc oxide and antimony oxide, might be used in house paint, and they also produce broad absorptions in this region.

As noted previously, the detectors used on infrared microscopes have cutoff energies that deny the analyst important information about inorganic pigments (both coloring and extender) in the region below 700 cm^{-1}. Elemental analysis aids in counteracting this limitation by providing comparative data related to the elements comprising these extender pigments. For example, if a paint contains a mixture of kaolin, hydrous silica, and mica, detection of the silica and mica will be difficult, if not impossible, using an infrared microscope. However, elemental analysis will not only reveal differences in the quantities of kaolin and silica present based on the relative intensities of the silicon and aluminum signals, but will also reveal characteristics of the mica based on the potassium signal.

Elemental analyses therefore serve to confirm, augment, and clarify the data obtained by infrared spectroscopy and other methods. Further information about the paint may be provided by the detection of elements not revealed by other methods. When such elements are found, however, the lack of definitive corresponding molecular structural information necessarily limits the degree to which they can be attributed to specific compounds. Since paint data are typically used in a

comparative mode, this limitation is not usually a serious issue. At the same time, the presence of some elements can be revealing when trying to determine the type of coating involved, as some elements are found only in certain types. Information about the possible sources of various elements can also aid in interpretation when differences between known and questioned samples occur, as may arise from contaminants or from actual differences. Some knowledge of the possible origins of paint elements is therefore essential, as this can have a bearing on the nature and strengths of the conclusions that can be drawn. In the following discussion, only elements with atomic numbers of 9 (fluorine) or higher are considered since lower atomic number elements are of more limited value for forensic paint examinations.

Detectable elements in paint may arise from binders, although they are much more prevalent in pigments and additives. Except for acrylic silanes and silicones, which contain silicon, other common binders do not contain detectable elements that are an integral component of the polymer structure (although such elements might be present in a binder formulation as a catalyst or other additive). In contrast, virtually all inorganic pigments (both coloring and extender) and many organic pigments contain elements that can be detected. Tabulations of these materials can be found in sources such as Morgans (1990) and Thornton (2002). Some of the elements that are observed for a particular pigment, however, are actually from compounds closely associated with their formulation and not from the pigment itself. Two of the most common paint pigments, rutile and Copper Phthalocyanine Blue, illustrate this point.

The surface of a rutile (TiO_2) particle is capped with hydroxyl groups. In the presence of water and oxygen and with exposure to ultraviolet light, the hydroxyl groups catalyze the production of free radicals, which can lead to degradation of the binder (Morgans, 1990). Individual particles of rutile intended for outdoor use (including all automotive paints) are therefore coated (encapsulated). The most common encapsulating agent is silica (SiO_2), but alumina (Al_2O_3) or zirconia (ZrO_2) may also be used. In addition, rutile is usually treated with alumina to prevent flocculation (the formation of pigment agglomerates or clusters). Therefore, silicon and aluminum will usually be observed along with titanium when analyzing outdoor paints containing rutile. Rutile that is encapsulated with zirconia may also contain tin oxide (Tyler, 2000), and titanium, zirconium, and tin were found in a zirconia-encapsulated rutile product that was analyzed by XRF (Suzuki and McDermot, 2006). Some formulations of lead chromate pigments are also silica-encapsulated to minimize reactions of the chromate anion, an oxidizing agent.

As noted, Copper Phthalocyanine Blue can exist in four different crystal forms, and the most common formulation (known as Pigment Blue 15 : 2) is stabilized to prevent both polymorphic conversion and flocculation. The exact nature of the stabilization process is proprietary, but it usually includes incorporation of chlorinated and sulfonated forms of this pigment (Lewis, 1995). Consequently, in addition to copper, chlorine and sulfur are usually found in paints containing Copper Phthalocyanine Blue. The green phthalocyanine pigments, Pigment Green 7 and Pigment Green 36, have the same structures as Copper Phthalocyanine Blue (Figure 5.2)

except that the aromatic rings are highly chlorinated, or highly chlorinated and brominated. These pigments are normally not treated, so paints containing Pigment Green 7 or Pigment Green 36 will contain copper and chlorine, or copper, chlorine, and bromine, respectively.

Encapsulation coatings, antiflocculating agents, and stabilizers are often bound intimately to the pigment particles. Some pigments, however, might also contain small quantities of a diluting agent. These may be added to adjust the tinctorial strength, which is done to ensure that the hue of a particular pigment lot falls within a specified tolerance range. Barium sulfate is commonly used for this, and since it is also a common extender pigment and antisettling additive, its levels in paint can span a very wide concentration range.

Metallic and pearlescent pigments, which are common in automotive finishes, always contain one or more detectable elements. The most common metallic pigment consists of aluminum flakes. Aluminum flakes used in aqueous dispersion basecoats are treated with phosphate surfactants (Bentley, 2001), so phosphorus may be detected in addition to aluminum. Gold-bronze metallic pigments have a composition ranging from pure copper to pure zinc or various alloys (brass) of the two, and these produce various hues (Thornton, 2002). Stainless steel metallic pigments contain chromium, nickel, molybdenum, and manganese, in addition to iron. Zinc metallic pigments may contain traces of iron, lead, and cadmium, and nickel metal pigments may contain traces of iron and sulfur.

Mica-based pearlescent pigments may include laminates of rutile, ferric oxide, chromium oxide, or zirconia, so in addition to silicon and other elements of mica, titanium, iron, zirconium, or a combination may be observed. Some pearlescent pigments are based on bismuth oxychloride, so bismuth and chlorine may be observed in addition to elements of the laminates. The elements of mica (muscovite, the most common form) include potassium, aluminum, and silicon, but micas often include several other minerals, and elements of these might also be present. Chromatic shift interference pigments consist of a core low-refracting dielectric material with a thin coating of a semitransparent highly reflecting layer. The core may transmit light or it may be reflective. Core materials include silicon dioxide, aluminum oxide, magnesium fluoride, and aluminum, while outer coatings include aluminum, chromium, or even molybdenum sulfide, thus expanding the list of detectable elements even further.

Driers are used to catalyze reactions involved in cross-linking between double bonds of a substance, such as unsaturated fatty acids. Elements of driers may thus be found in paints with binders such as alkyds, which use the fatty acids found in drying oils. Driers are probably the source of the greatest variety of elements in paint, and some of the elements that have been used or are currently used include (in order of increasing atomic number) potassium, calcium, vanadium, chromium, manganese, iron, cobalt, zinc, zirconium, cadmium, tin, barium, lanthanum, cerium, and lead. Other transition metals probably have also been used. Unfortunately, their concentrations are quite low, typically 0.1% by weight or less. Some of the elements cited do not function as driers by themselves but do so only when used with others, as discussed by Morgans (1990) and Thornton (2002).

Contaminants that might be introduced during the paint manufacturing process are another possible source of elements. Pigment dispersion techniques rely on various grinding media, which have included steel or porcelain balls, glass or zirconia beads, sand, and other objects (Bentley, 2001). Such media require periodic replacement due to wear, and their fragments are introduced into the paint. Although this might be expected to result in a very minor component, highly variable levels of zirconium were found in a number of automotive paints of various colors using XRF analysis (Suzuki and Marshall, 1998). Various sources of this element were thus considered. Most of the paints with zirconium contained little or no rutile, and tin was not found, so a zirconia-encapsulated rutile product was ruled out. Driers were another possible source of zirconium, but for an automotive paint, they would probably be found in an alkyd; all of the paints involved had either acrylic melamine enamel or acrylic lacquer binders. In addition, if zirconium were used as a drier, it would usually occur with cobalt (Morgans, 1990), but cobalt was not detected. Wear from zirconia dispersion beads thus became the prime suspect, and the paint manufacturers who were contacted concurred that this was the most likely source.

Preservatives, particularly fungicides used in exterior architectural coatings, are another source of elements. Some of the elements that have been used, or are currently used, in fungicides and other preservatives include chlorine, copper, chromium, zinc, iodine, mercury, and other heavy metals, although the recent trend has been to avoid heavy metals due to health concerns.

Silicates (talc, kaolin, quartz, diatomaceous silica, synthetic silica, mica, bentonite, asbestine, wollastonite, montmorillonite, etc.) are very common extender pigments. As noted, extender pigments are frequently used in low-luster finishes and automotive undercoats since in addition to lowering the cost of the paint by adding bulk, they serve as flatting or delustering agents. Synthetic silica and treated montmorillonite are used as thickening agents for paints with low viscosities, such as automotive clearcoats, where they help to keep the wet paint of a thick layer on a vertical surface from dripping; talc is used as an antisettling agent to help keep other pigments suspended in the liquid medium; mica is used in pearlescent paints; silica is used to encapsulate certain pigments; silicates are minor components of some inorganic pigments, such as ochres (which are mainly ferric oxide or hydrous ferric oxide); and so on.

Not surprisingly, silicon is a common element in paint. In some cases, the presence of other elements associated with the source of the silicon might serve to clarify its origin. Magnesium, for example, is present in talc [$Mg_3Si_4O_{10}(OH)_2$], and aluminum in kaolin [$Al_2Si_2O_5(OH)_4$]. For some minerals, including talc, cation substitution is a common occurrence. Magnesium (Mg^{2+}) and iron (Fe^{2+}) can occur interchangeably in these minerals since they have the same charge and the same size. Talc may thus contain iron even though its nominal formula may not indicate this. Since the function of extender pigments is not usually affected adversely by minor impurities, there are probably many other impurities in them as well, although they may be present in levels below the detection limits of the method used for analysis.

Silicon in paint can thus originate from any number of components, including binders (silanes), extender pigments, mica-containing pearlescent pigments, impurities in other pigments, encapsulating agents, products of dispersion bead wear, and additives serving a wide variety of functions. This element can therefore occur in virtually any type of coating, including every layer of an automotive finish. It is also a very common element in soil, so the condition of the sample(s) must be evaluated carefully to decide if it may be present as a result of contamination from material that is *external* to the paint.

Although detectable elements are less common for organic pigments, they do occur. Twenty-nine pigments were examined in four studies of organic pigments used in automotive paint (Suzuki and Marshall, 1997, 1998; Suzuki, 1996a,b). Ten contain chlorine, one chlorine and sulfur, one chlorine and nickel, one sulfur, one nickel, one copper, and one fluorine. Chlorine is therefore relatively common (12 of 29) in organic pigments. This element, which is usually present as a substituent on an aromatic ring, is serving at least two functions (Lewis, 1995). It imparts insolubility to a pigment and is used to modify the color of a base structure by changing its chromophore (as evidenced by the effects of chlorine and bromine substitution on the phthalocyanine ring).

Extensive lists of pigments are presented in compilations by Crown (1968) and Eastaugh et al. (2004), and the detectable elements of pigments can be obtained from their chemical formulas. It should be noted, however, that components that might be associated with some of their formulations are not included, and these may contain additional elements. Nolan and Keeley (1979) also compiled classes of paint elemental constituents based on their frequency encountered in SEM–EDS analysis of random samples.

Scanning Electron Microscopy/Energy-Dispersive X-Ray Spectrometry

SEM–EDS is the main method used in U.S. forensic science laboratories for elemental analysis of paint evidence (Henson and Jergovich, 2001; Ryland et al., 2006). This instrument can be used both as an imaging device with very high magnifications (greater than 100,000× in some cases) and as a means to obtain elemental profiles for selected areas of a sample. Elemental data for individual layers of multilayered paint specimens can be collected sequentially and the high magnifications of the microscope permit the analysis of very small samples. The range of elements that can be detected simultaneously with an EDS analysis is extremely wide and, with an appropriate detector window, all elements of atomic number six (carbon) or higher can be identified. The detector has a broad dynamic range and the technique may be nondestructive to the specimen. It is, however, limited to a minimum detection level of approximately 0.1% by weight for median atomic weight elements.

The terminology *energy-dispersive* x-ray spectrometry is intended to distinguish it from a related technique, wavelength-dispersive x-ray spectrometry (WDS). These two methods employ different mechanisms to measure x-ray energies. Both may be mounted on a scanning electron microscope. In a WDS instrument, x-rays are separated by wavelength using a crystal, which serves as a diffraction

grating. Multielemental analysis is much slower than with EDS and higher beam currents are required to produce enough x-rays to be detected; however, sensitivity is increased tenfold and the improved resolution provides a solution to the peak overlap problems experienced in the EDS analysis of some elements. In an EDS system, a solid-state silicon–lithium (SiLi) detector not only counts the number of x-ray photons that arrive at the detector, but also measures their energies. An x-ray photon in the SiLi detector loses its energy in a series of steps, after which a number of electrons are promoted from the valence band to the conduction band. This number is proportional to the original energy of the photon and is measured electronically. The total number of photon counts for a given characteristic energy is proportional to the quantity of the element present in the sample.

For an SEM–EDS analysis, samples that are nonconductive, such as paint, must be coated with a film of a conducting material, usually carbon. This prevents the material from developing a negative charge during analysis, which would cause it to repel further electrons. Most instruments are operated in a high vacuum, as atmospheric gases not only impede the electron beam, but also absorb the lower-energy x-rays. Variable-pressure SEMs are available at a nominal increase in cost and make it unnecessary to coat a specimen. By leaking just a small amount of air or selected gas into the specimen chamber, the charge on the uncoated sample is dissipated. This does, however, result in a slightly diminished signal from the sample and a slight loss in control of the analytical area due to spread of the electron beam diameter.

The operation of an SEM–EDS instrument is not unlike that of a cathode ray tube (CRT) monitor. An electron beam, directed and focused by electric and magnetic fields, traces a raster pattern on the selected rectangular area of interest of the sample. An image is formed by measuring the intensity of electrons ejected by the sample as the beam traverses the selected area. Analogous to an optical image, lighter areas of the image correspond to a higher flux of electrons. Two detectors located at different positions relative to the sample are used to collect *secondary electrons* and *backscattered electrons*. Secondary electrons result from ionization of atoms of the sample near the surface and have relatively low energies. Backscattered electrons, in contrast, have nearly the same energy as that of the incident beam. Backscattering results when an incident electron passes very close to an atomic nucleus, and the strong electric field of the nucleus swings the much lighter electron around, sending it in the opposite direction. Backscattering increases with atomic number, so an SEM image based on backscattered electrons provides a compositional map, with lighter areas representing domains comprised of heavier atoms. Imaging of paint specimens in this mode provides a considerable advantage over other elemental analysis techniques since it provides a rapid visual assessment of heterogeneity (Figure 5.30) and aids in selecting appropriate analytical sizes and locations.

The energy of the electrons striking the sample is set by the analyst, and this is an important parameter for x-ray analysis because it determines the energy range of the x-rays that can be produced. An electron that is accelerated through a voltage

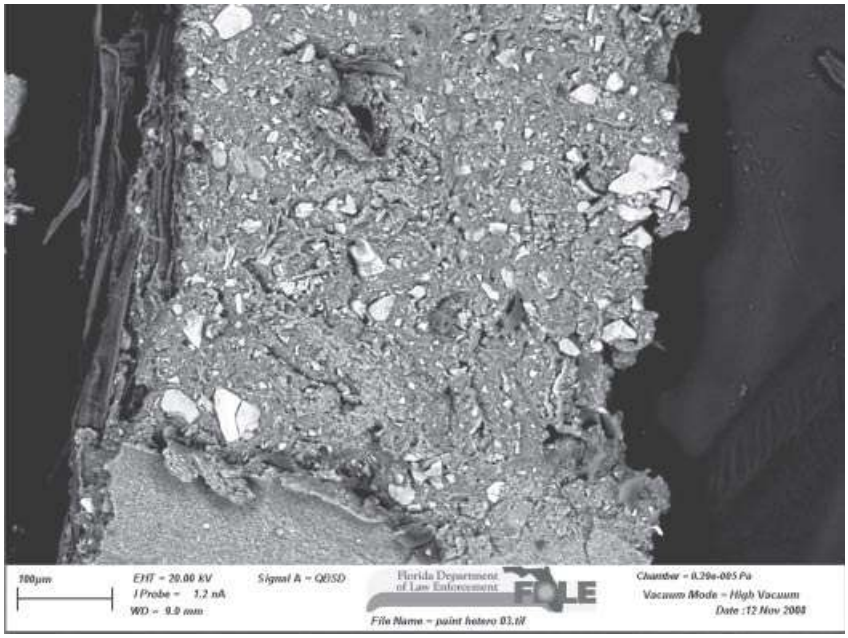

Figure 5.30 SEM backscatter image of an architectural paint layer exposed by peeling back the layer above. Note the visual rendering of the large extender pigment grain heterogeneity.

potential of 20,000 V (20 kV) acquires an energy of 20,000 electron volts (20 keV). The range of possible voltages for an SEM–EDS is typically between 1 and 40 kV, although voltages higher than 25 kV are generally not used with paint because of the excessive heat that may be generated and the increased depth of the beam's penetration. X-ray energies are also measured in electron volts, and the range of an SEM–EDS x-ray detector is typically from 0.1 to 40 keV. The flux of x-rays reaching the detector is controlled by the electron beam current.

When the electron beam strikes the sample, x-rays are generated by two different mechanisms. The first involves a process known as *bremsstrahlung*, a German word meaning "braking radiation." When a charged particle accelerates (meaning that it increases or decreases its velocity or is deflected from a straight path), it can produce radiation. In the case of the electron beam of an SEM–EDS instrument, electrons are decelerated and their paths deflected as they interact with the sample. The bremsstrahlung x-rays that result from this have a continuum of energies, ranging from zero to that of the incident electron, and this is manifested as a broad background (having a roughly skewed semicircular shape) in all EDS spectra. Bremsstrahlung backgrounds can be seen in the EDS spectra of Figures 5.31A,B, 5.32C, and 5.33. In general, a matrix having a low average atomic number composition, such as an automotive finish coat, will have a much higher bremsstrahlung

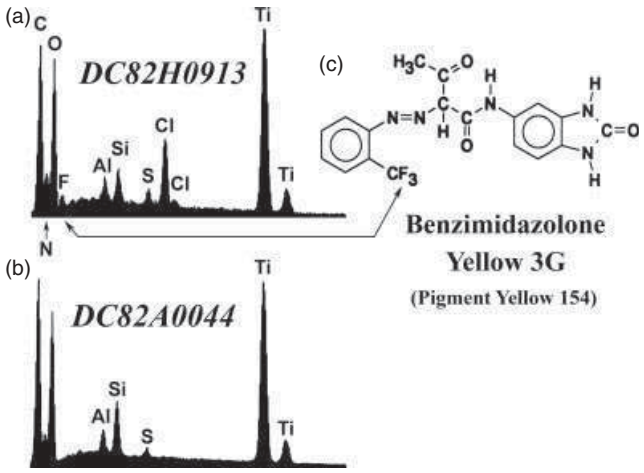

Figure 5.31 (A) SEM–EDS spectrum of a yellow nonmetallic automotive monocoat, DC82H0913, which contains rutile and Benzimidazolone Yellow 3G. (B) SEM–EDS spectrum of a white automotive monocoat, DC82A0044, which contains rutile. An electron beam voltage of 20 kV was used for both SEM–EDS analyses. (C) Structure of Benzimidazolone Yellow 3G. [From Suzuki and Marshall (1997); copyright © ASTM International; reprinted with permission.]

background than that having a relatively higher average atomic number composition, such as an automotive primer or architectural paint. This decreases the elemental minimum detection levels in the former.

The second type of x-rays produced is referred to as *characteristic x-rays*. This process begins with ionization of the atoms of the sample, and the electrons of the incident beam must have sufficient energies to remove electrons from one of the first three shells of an atom. Atomic shells are designated as K, L, or M, corresponding to electrons in orbitals of the first three principal quantum numbers. The K shell is comprised of 1s electrons, the L shell of 2s and 2p electrons, and the M shell of 3s, 3p, and 3d electrons. Following removal of an electron from one of these shells, a "hole" is created in the atom and an electron from a higher-energy shell decays to fill the vacancy and bring the atom to a lower-energy state. In so doing, it emits an x-ray having an energy equal to the energy difference between the two shells. The 2s and 2p electrons have different energies, as do the 3s, 3p, and 3d electrons. Consequently, the L to K shell decays represented by $2s \rightarrow 1s$ and $2p \rightarrow 1s$ have different energies, as do the various transitions from the M to the L shell. There is therefore more than one x-ray energy produced when an electron is removed from a particular shell. The x-rays emitted by electrons decaying to fill the K shell are referred to as the K series, with analogous definitions for the L and M series.

X-rays produced by individual transitions of a series may have very similar energies that cannot be resolved by the SiLi detector, In the case of heavier elements, separate peaks occur for the K series and for the L series. The lower-energy peak

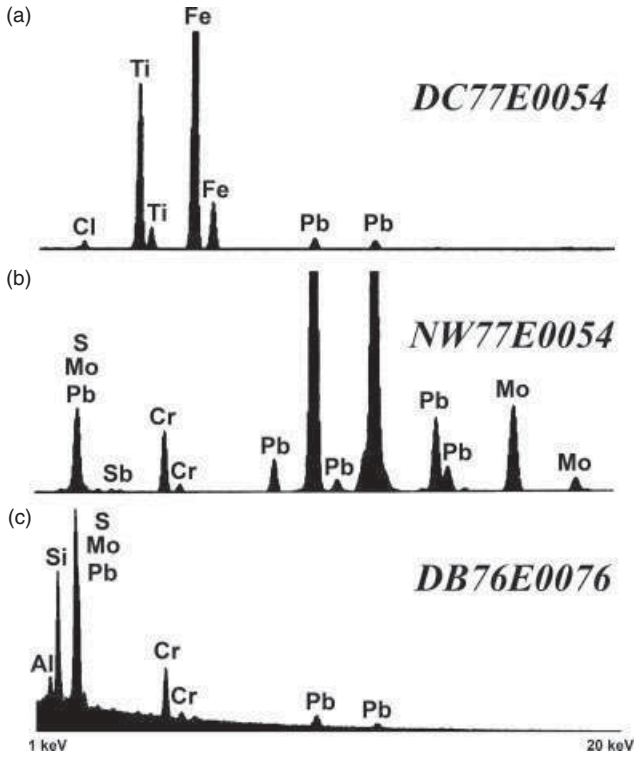

Figure 5.32 XRF and SEM–EDS spectra of three red nonmetallic automotive monocoats depicted between 1 and 20 keV. The two XRF spectra were obtained using a tin secondary target. (A) XRF spectrum of DC77E0054; the infrared spectrum of this paint is shown in Figure 19f. (B) XRF spectrum of NW77E0054; the infrared spectrum of this paint is shown in Figure 19A. (C) SEM–EDS spectrum of DB76E0076, acquired using an electron beam voltage of 22 kV. (From Suzuki and Marshall, 1998; copyright © ASTM International; reprinted with permission.)

of the K series (known as K_α) typically has an intensity roughly six times that of the second peak (known as K_β), whereas the two peaks of the L series have more nearly equal intensities. All of the peaks observed in Figure 5.31A are from the K series, and the two L-series peaks of lead can be seen in Figure 5.32C (compare to the same peaks of lead obtained by XRF in Figure 5.32A and 5.32B). M series transitions cannot be resolved and only one peak is observed. Experienced paint examiners can usually distinguish between peaks of the three series, but instrument software may also be used to aid in this task, as they include markers that indicate the positions and relative intensities of K, L, and M peaks for each element.

As the atomic number increases, the inner-shell electrons become more tightly bound to the nucleus, lowering their energies, and the energy differences between adjacent shells increase. There is thus a regular increase in the energies of each series as the atomic number increases (*Mosley's law*); the differences in energies

between peaks of adjacent elements also increases with atomic number. Consequently, there is no element for which *K*, *L*, and *M* peaks can all be observed in the range 0.1 to 40 keV, although for some elements, two series are observed. As noted, electron energies much above 25 keV may damage the paint specimens or penetrate too deeply into its surface, so only about half of the detectable range is used in any case. Even with this more limited range, detection of a single element present in sufficient concentration is not a problem, and this is also often true when several elements are present. However, due to overlap of *K*, *L*, and *M* peaks in the low-energy region, certain combinations of elements may be difficult to determine.

This is illustrated by the EDS spectrum (Figure 5.32C) of a red nonmetallic automotive monocoat that contains Molybdate Orange ($PbCrO_4 \cdot x PbMoO_4 \cdot y PbSO_4$), for which peaks of lead, chromium, molybdenum, and sulfur are expected. *L*-series peaks of lead and *K*-series peaks of chromium are observed, but the *K*-series peaks of molybdenum are not (compare to Figure 5.32B, which is the XRF spectrum of another paint that contains Molybdate Orange). *L*-series peaks of molybdenum do occur in the range of the instrument, but in this case they are buried in the strongest peak of Figure 5.32C. This peak represents an overlap of the *M* peak of lead, the *L* peaks of molybdenum, and the *K* peaks of sulfur, so the presence of molybdenum and sulfur cannot be definitely established in this case. This confluence of *K*, *L*, and *M* peaks of three elements of a single pigment is *extremely* unusual (if not unique), but it does illustrate the interpretation difficulties that overlapping peaks can present.

Secondary electrons arise from atoms very near the surface of the sample, and backscattered electrons originate from somewhat greater depths. SEM images thus reveal predominately surface characteristics. The electron beam, however, penetrates beyond these relatively shallow depths. As it interacts with the sample, it begins to lose its directionality and individual electron paths become more random. Consequently, the morphology of the volume from which x-rays originate is not a well-defined narrow cylinder, but rather, has a hemispherical or a teardrop shape, depending on beam energy, sample composition, and x-ray energies.

The interactions of the electrons with the sample also affect their energies. An electron beam energy of 22 keV was used to acquire the EDS spectrum of Figure 5.32C, and this energy is sufficient to ionize a *K*-shell electron of molybdenum, but no *K*-series peaks of this element are observed. The sample contains much more lead than molybdenum, and lead requires even less energy to ionize its *L*-shell electrons, yet the lead *L*-series peaks are quite weak. The intensities of the lead *L*-series peaks and the molybdenum *K*-series peaks can be increased slightly by employing a higher beam excitation potential, ideally 2.5 times the minimum required to ionize the electrons in those shells. However, as mentioned earlier, there are drawbacks to doing this.

The preferential excitement of the lower-atomic-number elements of a sample is a characteristic feature of an SEM–EDS analysis. It results from the numerous interactions that the electron beam experiences as it travels through the sample, constantly losing energy. Consequently, most of these electrons can only excite elements of lower atomic numbers. Low-atomic-number elements are thus readily

observed in SEM–EDS spectra, as may be seen for the *K*-series peaks of carbon, nitrogen, oxygen, and fluorine of Figure 5.31A (which is the spectrum of a yellow nonmetallic automotive monocoat). Some of the carbon is from the thin coating used to make the sample conductive, while the fluorine is from a yellow organic pigment, Benzimidazolone Yellow 3G (Figure 5.31C).

Figure 5.31B is the SEM–EDS spectrum of a white nonmetallic automotive monocoat that contains a large quantity of rutile, and in addition to the titanium peak of rutile, the silicon and aluminum from the encapsulation coating and the antiflocculating agent, respectively, are also observed. Similar ratios of these three elements are observed for the spectrum of the yellow monocoat (Figure 5.31A), which also contains a large amount of rutile. It is also instructive to note that the aluminum and silicon are not originating from a clay extender pigment that also might be suspected as a source from the SEM–EDS spectrum alone.

Because of the differences in the sample domains that are responsible for image formation and generation of x-rays, SEM–EDS analysts should always remember the caveat, "What you see is not always what you get." It is especially important to remember when analyzing individual layers of an intact multilayered paint.

Four different methods have been used to obtain SEM–EDS data for individual layers of multilayered paint samples, each with its merits, limitations, and degree of skill (and patience) required to obtain optimal results. In the first, each paint layer is excised and analyzed separately. This requires a fair amount of sample preparation, but it is the only method for which analysts can be assured that elements of adjacent layers are not being observed. A second procedure involves what is referred to as the stair-step method since after preparation of a specimen, it has a steplike appearance when viewed from the side. This method also requires a considerable amount of sample preparation, as beginning with what will be the bottom layer, a rectangular portion consisting of all of the overlaying layers is removed, exposing a portion of the bottom layer. An adjacent rectangle is then removed, exposing a portion of the next-to-bottom layer, and so on. The sample is positioned in the SEM–EDS instrument, so that all of the exposed layers are perpendicular to the beam. Analysis of very thin layers may yield x-rays from a underlying layers, and it may help to reduce electron beam energies to determine if this is the case.

The last two methods involve cutting a cross section through the layers and situating this cut surface perpendicular to the SEM–EDS beam. This can be done without any further sample preparation, or the sample can be embedded in a medium that hardens and the surface of the cross section polished. Care must be taken in either case to ensure that the surface is situated horizontally and that the cut was made perpendicular to the layers, so that electrons traveling straight down do not encounter another layer. Embedding and polishing require considerable sample preparation, but this process also yields the most reproducible results regarding relative ratios of EDS x-ray peaks. Embedding, however, makes removal of the sample difficult, if not impossible, should there be a need for further analysis. For either type of cross-sectional analysis, a major concern is the possibility that the EDS analysis volume may extend into an adjacent layer or into two adjacent layers. To minimize this possibility, long narrow rastering areas with edges as far from

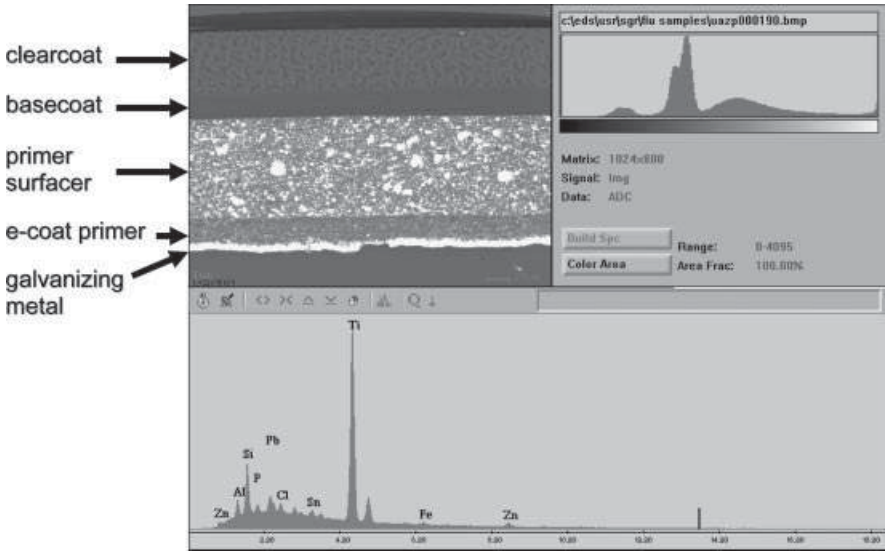

Figure 5.33 SEM–EDS analysis of the base primer in an automotive paint cross section block cut by microtomy. The red box superimposed on the e-coat primer defines the visual boundaries of the analytical area. *(See insert for color representation.)*

the adjacent layers as practical are used, as depicted in Figure 5.33. Regardless of which of the four methods is used, it is important that both questioned and known samples be subjected to the same procedures.

As mentioned, the analytical area is typically chosen by scanning the electron beam over a large defined area to average out the effects of heterogeneity, a constant concern in paint samples. The relative success of this endeavor is assessed by comparing spectra collected from one area of a layer to another of the same layer. If the analytical area is large enough to average out the lack of precision introduced by heterogeneity, the spectra will appear like one another. The SEM offers another mode of sample collection called the *spot mode*. This approach is quite valuable in analyzing particulate material in the matrix, such as metallic flake and interference pigment flake (the rich elemental and morphological information contained in these pigments was described previously). The beam is targeted on the particle of interest and is held stationary, as seen in Figure 5.34. The excitation voltage is typically reduced in an attempt to keep the excited volume within the boundaries of the target particle, keeping in mind the necessity to maintain enough energy to effectively excite the elements of interest. In addition to analyzing effect pigment flake in paints, the same method may be used to enhance the inferred identification of other pigments in the paint. If a large area is scanned and barium, sulfur, magnesium, aluminum, and silicon are detected, this merely informs the analyst that these elements are present in the layer in their respective relative ratios. Should spot mode be used in addition to this technique, it can be demonstrated that the barium and sulfur are associated with one particulate population, magnesium and silicon

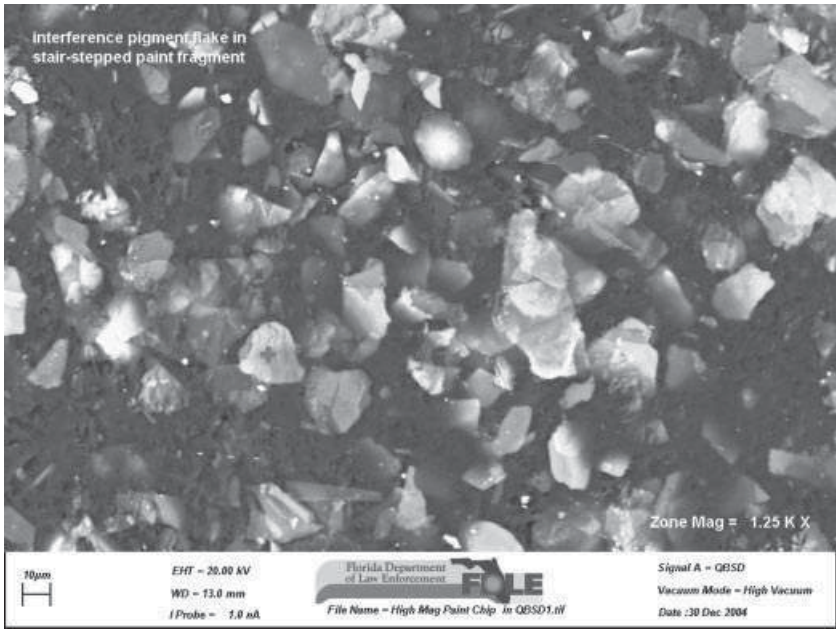

Figure 5.34 SEM–EDS spot analysis of interference pigment flake in situ. The flake is visualized by viewing the exposed layer in the backscatter mode. The red + indicates the beam target spot. *(See insert for color representation.)*

are associated with another, and aluminum and silicon are associated with a third. This significantly strengthens the deduction that the paint layer contains barium sulfate, talc, and clay extender pigments. Although these are typically recognized in infrared spectra collected down to at least 450 cm^{-1}, it may not be apparent in situations where there is a significant quantity of titanium dioxide present, and one of the extenders is present in a low concentration relative to the others.

More information about SEM–EDS instrumentation is given by Goldstein et al. (1992), while the preparation of paint samples for SEM–EDS analysis is discussed in more detail by Ryland et al. (2006). An introduction to paint analysis using an SEM–EDS analysis is given by Wilson and Judd (1973), and Henson and Jergovich (2001) provide an extensive review of this topic. General guidelines for such analyses are outlined in the *Standard Guide for Using Scanning Electron Microscopy/X-Ray Spectrometry in Forensic Paint Examination* (Scientific Working Group for Materials Analysis, 2002).

X-Ray Fluorescence Spectrometry XRF spectrometry is the second most frequently used method in the United States for the elemental analysis of paint evidence (Henson and Jergovich, 2001; Ryland et al., 2006). *Fluorescence* refers to a process whereby atoms or molecules absorb electromagnetic radiation, then reemit radiation with lower energies. In XRF spectrometry, as opposed to SEM–EDS, x-rays are used to ionize atoms instead of electrons. It should be noted, however,

that the emission process is the same for both techniques. XRF spectra might therefore be expected to mirror EDS spectra, but this is generally far from the case. As we saw, the forte of an EDS analysis is the detection of lighter elements. XRF spectrometry, in contrast, is better suited for the identification of heavier elements, so the two are complementary. There is no need to coat samples for an XRF analysis, and if only the heavier elements are sought, sample chambers do not have to be evacuated. XRF instruments with the lowest detection limits (tens of parts per million or lower in some cases) require considerably larger samples than are required for an SEM–EDS analysis, while micro-XRF systems, which have higher detection limits, allow smaller samples. There are concerns regarding the increased beam penetration experienced when using x-rays as opposed to electrons; consequently, the current approach for individual layer analysis favors preparation of individual layer peels. When comparing spectra of layers excised from small multilayered samples, one must also be concerned with the inherent imprecision introduced by critical depth effects experienced in samples of different thicknesses (Howden et al., 1977).

As with an EDS analysis, the energies of the x-rays used for excitation must be sufficient to ionize K, L, or M electrons. With x-rays, however, the most efficient means to do this is with an x-ray energy that is slightly greater than the minimum required (known as an *absorption edge*), and as x-ray energies increase beyond this value, the excitation efficiencies decrease.

X-rays for XRF excitation are generated in an x-ray tube. The tube consists of a metal anode or target, typically rhodium, housed in a vacuum. A voltage between 1 and 50 or 60 kV is used to accelerate a beam of electrons toward the target. Analogous to what occurs in an SEM–EDS instrument, bremsstrahlung and characteristic x-rays of rhodium are produced. Depending on the voltage used, Rhodium L peaks, or K and L peaks, are generated. All XRF instruments may use x-rays from the tube for excitation. Since the distribution of x-ray energies from the tube includes the broad bremsstrahlung continuum, this serves to excite a wide range of elements.

For some instruments, an alternative mode of excitation is possible using *secondary targets*, which consist of several elements spanning a range of atomic numbers. X-rays from the tube are directed toward a selected secondary target, causing it to emit K-series peaks. These x-rays are then used to excite the sample, and since K_α is more intense than K_β, this amounts to using mostly monochromatic radiation for excitation. Since this is the most effective means to excite a particular element or small group of elements with similar atomic numbers, this mode provides the lowest detection limits, particularly for heavier elements. To achieve this for a wide range of elements, however, analyses using several different secondary targets are required. The intensities of x-rays produced by secondary targets are limited, so relatively large samples and long collection times are normally required for paint samples. Secondary targets are not available on micro-XRF spectrometers, which use collimators or focus optics to produce beam diameters between 300 and 10 μm. Micro-XRF instruments with selectable filters that improve the detection limits for selected elemental ranges are now available. Appropriate thin elemental

(metal) films are positioned selectively in front of the x-ray tube to reduce the bremsstrahlung continuum and/or characteristic tube x-ray lines striking the sample. This in turn reduces the x-ray scatter background or eliminates the scattered x-ray tube lines emanating from the specimen and still leaves enough higher continuum x-rays to excite the elements of interest. Like secondary target instruments, however, much longer data collection times are required.

The complementary nature of an EDS and XRF analysis can be seen by comparing Figure 5.32B,C, which are spectra of two red automotive monocoats (NW77E0054 and DB76E0076) that contain Molybdate Orange. For the XRF analysis (Figure 5.32B) a tin secondary target ($K_\alpha = 25.2$ keV) was used, while an electron beam energy of 22 keV was used to obtain the EDS spectrum (Figure 5.32C). DB76E0076, which was analyzed by EDS, contains more Molybdate Orange than NW77E0054, judging from relative infrared absorption intensities. Note that even with an XRF analysis (Figure 5.32B), the presence of the sulfur of Molybdate Orange cannot be determined because of the overlap discussed earlier. In these situations additional techniques may be employed, such as wavelength-dispersive x-ray spectrometry (WDS).

The XRF spectrum of a second automotive paint (DC77E0054) that has the same color as NW77E0054 is shown in Figure 5.32A. The infrared spectra of these two paints (Figure 5.19A,F) were discussed previously and it is informative to see how the infrared and elemental analysis data correlate. NW77E0054 (Figures 5.19A and 5.32B) contains Molybdate Orange and Quinacridone Red Y. Quinacridone Red Y does not contain any detectable elements, but peaks of all of the elements of Molybdate Orange, except for sulfur, are observed in the XRF spectrum of NW77E0054. DC77E0054 contains rutile, ferric oxide, Quinacridone Red Y, and Benzimidazolone Orange, and its XRF spectrum (Figure 5.32A) has peaks of titanium (rutile), iron (ferric oxide), and chlorine (Benzimidazolone Orange). A small quantity of lead is also observed, and analyses using other secondary targets and longer collection times detected very small amounts of molybdenum and chromium. The presence of a small quantity of Molybdate Orange is thus indicated, although its absorptions (Figure 5.19K) are not observed in the infrared spectrum of this paint (Figure 5.19F).

The XRF spectra have reiterated the value of elemental analysis when used in conjunction with infrared spectroscopy and other methods, and the additional information about the paint that may be obtained. They were obtained, however, with secondary targets using large pristine samples, and the data were collected overnight. Micro-XRF systems are currently better suited for most case samples, since much smaller specimens can be analyzed with sensitivities intermediate between those of an EDS and a secondary target XRF analysis. These sensitivities are still sufficient to detect low concentrations of tinting pigments or even drier metals having concentrations on the order of 0.005% by weight. Other innovations have continued to allow smaller samples to be subjected to XRF analyses. A micro-XRF attachment for an SEM–EDS instrument, for example, has recently been introduced. It consists of an x-ray tube using poly capillary focus optics to form an excitation beam diameter of 40 μm. Fluorescent x-rays are detected using

the SiLi detector of the SEM–EDS system. There are, however, concerns for background scatter levels on samples mounted on carbon substrates and for isolation of layers given the increased penetration of x-rays versus electrons from the SEM.

Fiber optic x-ray guide tubes are also used on a new micro-XRF spectrometer that produces spot sizes as small as 10 μm. Kanngiesser et al. (2005) demonstrated the feasibility of analyzing individual layers of a multilayered paint sample using a micro-XRF instrument with a 10-μm spot size, but this required use of synchrotron radiation. This new system focuses x-rays from a conventional x-ray tube without the need for a synchrotron.

Jenkins (1999) provides more information about XRF spectrometry theory and instrumentation. Howden et al. (1977) examined the discrimination of white, red, and green single-layer household paints using XRF spectrometry. All of the red and green paints could be distinguished by this means and the white paints were divided into nine groups. Haag (1977) used XRF spectrometry to study elemental profiles of automotive paint chips. Zieba-Palus and Borusiewicz (2006) examined several multilayered paint samples using a combination of infrared and Raman microscopy and micro-XRF spectrometry. The discrimination of black (Govaert et al., 2001) and red (Govaert and Bernard, 2004) spray paints was examined using a combination of optical microscopy, infrared spectroscopy, and XRF spectrometry.

Other Elemental Analysis Methods Several other elemental analysis techniques have been used for the analysis of paint. Emission spectrography was one of the first such methods used in forensic science, but it has been supplanted by inductively coupled plasma emission spectroscopy (ICP-ES) and its even more sensitive offspring, inductively coupled plasma mass spectrometry (ICP-MS). ICP methods, however, require samples that are soluble—not an easy task for most coatings, which are enamels that contain pigments designed to be insoluble. Neutron activation analysis (NAA), which is gamma-ray emission spectrometry of nuclei in excited states, is probably the most esoteric of the methods that have been applied to paint. NAA requires a neutron source such as a nuclear reactor, and although not destructive, it produces, at least temporarily, a radioactive sample. Like an SEM, an electron microprobe analysis uses an electron beam to produce characteristic x-rays, but this method has few, if any, advantages over SEM–EDS analysis. A proton beam is used in a related technique known as proton-induced x-ray emission or particle-induced x-ray emission (PIXE). This method has lower detection limits for many elements compared to an SEM–EDS analysis, but like an electron microprobe instrument, it lacks the imaging capabilities of an SEM–EDS system. Thornton (2002) provides a more detailed review of these methods as applied to paint.

Two relatively new techniques show some potential as future tools for the examination of paint evidence, as both allow trace levels of a wide variety of elements to be detected. Major issues regarding reproducibility occur with both techniques, however, and they are currently used primarily for qualitative analyses.

Total-reflection x-ray fluorescence spectrometry (TXRF) is a variation of a conventional XRF analysis where a grazing incident angle ($<0.1^\circ$) of an x-ray beam

is used for excitation (Klockenkamper et al., 1992). A standing wave is produced, and this results in significantly enhanced (parts per billion) sensitivities. TXRF has been used for several elemental analyses of artists' paints and other pigmented historical or archeological objects (Klockenkamper et al., 2000).

Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) is an alternative method for detecting trace elements in materials that cannot easily be subjected to a conventional ICP-MS analysis. A pulse from a laser is used to vaporize a sample and create an aerosol, which is swept into the plasma torch of the ICP-MS instrument. The high temperatures of the plasma (>6000°C) produce mostly monoatomic ions, so that the mass spectrometer yields elemental analysis data. Hobbs and Almirall (2003) examined the feasibility of using this method for the analysis of automotive paint. Typically, a suite of suspected elements must be selected prior to analysis. While a number of elements were identified at trace levels, their relative ratios varied considerably between results obtained from successive pulses. More stability was found in primer layers; however, the diameter of the ablation crater had to be increased to approximately 200 μm to improve precision. There is a "charred" discolored zone that extends approximately 300 μm beyond this crater, and precision of analysis within this zone has currently not been assessed. This has a practical impact on sampling, as replicate analyses would require a sample much larger than 1 mm^2. Assuming that the precision concerns can be overcome, there is some potential for batch discrimination of automotive primers resulting from the variation of trace elements contained as contaminants in different lots of the minerals used as extender pigments. The same holds true for architectural paint tint bases, although full-thickness 1-mm^2 samples are seldom encountered in casework.

Deconinck et al. (2006) also examined automotive paint using LA-ICP-MS, although their work focused on demonstrating inaccuracies suffered by quadrapole-based ICP-MS instruments, due to spectral interferences during trace element depth profiling of multilayered paint samples. They concluded that a high-resolution sector field–based mass spectrometer would be required to avoid such problems. Like the earlier study by Hobbs and Almirall, this technique was found useful for qualitative analyses, but it did not resolve issues of reproducibility and quantitative analyses on small samples. Although it was stated that four-layered car paints of the same color produced by different manufacturers could be discriminated from one another using the technique proposed, improved discrimination over current methodology was not documented.

5.5.9 Other Methods

X-Ray Diffraction Like emission spectrography, XRD was one of the first methods used for the analysis of inorganic components in paint evidence. The term *x-ray diffraction* actually refers to two related methods. In one, usually referred to as *x-ray crystallography*, a single crystal is analyzed using an incident monochromatic x-ray beam, and the three-dimensional pattern of spots that results from reflection from various crystal planes is analyzed. The planes are formed by the particular arrangement that individual atoms or ions assume in the crystal, and they

are not only peculiar to each compound but also differ for each crystal structure of a polymorphic substance. X-ray crystallography is used predominantly for molecular structural determinations, although it has also been used for analytical chemistry.

The technique that is used for the analysis of paint is *powder XRD*, which is applicable to materials that consist of, or contain, crystalline substances where the orientations of individual crystals of the sample are random. To further ensure that the orientations are completely isotropic, the sample is rotated during analysis. Instead of a pattern of spots, x-rays are reflected from the sample in cones with apices at the sample. The cones are characterized by their angles relative to the direction of the incident beam and their intensities. A graph of an XRF powder diffraction pattern, known as a *diffractogram*, is produced with the abscissa representing the angle of reflection (actually 2θ, or twice this angle), and the ordinate depicting the intensities of the reflected x-rays. In principle, all of the major crystalline components of paint can be identified by powder XRD. Some paint binders may exhibit localized regions of crystallinity, but because they lack large-scale regularities in their structures, binders cannot be identified by these means. Reflections from crystal planes arise from x-ray scattering from individual atoms or ions; such scattering is caused by the electrons of the sample, so the intensity of x-ray scattering increases with atomic number. Organic pigments are therefore weak scatterers of x-rays, so powder XRD analyses are limited primarily to inorganic pigments.

Because of its limited scope and past requirements for relatively large samples and long analysis times, powder XRD has not been widely used for forensic paint examinations. Newer instruments, however, are capable of analyzing paint samples as small as 20 μm in reasonable periods of time with essentially no sample preparation. Unlike an elemental analysis, powder XRD provides molecular structural information, and for some paints, it provides more definitive data than either infrared or Raman spectroscopy. Silicates, for example, cannot be identified by Raman spectroscopy, and when large quantities of extender pigments are present in paint (as typically occurs for low-luster house paints; see Figure 5.19H), their strong broad infrared absorptions usually overlap, hampering identification of individual pigments. Powder XRD diffractogram peaks, in contrast, are quite narrow and because there are no contributions from binders or most organic pigments, relatively simple patterns occur for paint. This is illustrated by Figure 5.35A, which is the diffractogram of a paint that contains significant quantities of four common extender pigments (Snider, 1992). Diffractograms of two of these, kaolin and quartz, are shown in Figure 5.35B and 5.35D, respectively, along with that of hydrous ferric oxide (Figure 5.35C). Different polymorphs of a given compound are readily distinguished by powder XRD, so mixtures of such polymorphs can also be identified easily.

Laser Desorption Mass Spectrometry LDMS is a relatively new technique that, unlike its cousin LA-ICP-MS, provides molecular structural information. Both techniques use a pulse from a laser to volatilize and ionize samples, but in LA-ICP-MS, all molecular species are destroyed in the plasma. In LDMS, much less

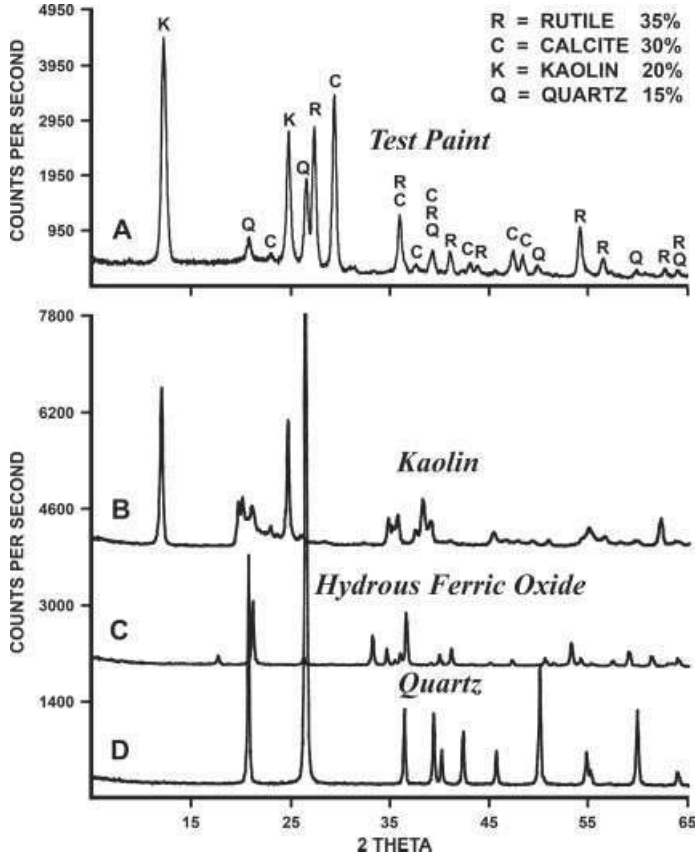

Figure 5.35 Powder XRD diffractograms of a test paint and three common inorganic paint pigments: (A) test paint that contains rutile (35%), calcite (30%), kaolin (20%), and quartz (15%); (B) kaolin; (C) hydrous ferric oxide; (D) quartz. [From Snider (1992); copyright © ASTM International; reprinted with permission.]

vigorous conditions are used to vaporize and ionize paint constituents, which are then introduced directly into a mass spectrometer. No sample preparation is required other than separating individual layers of a multilayered paint if they are to be subjected to analysis.

Stachura et al. (2007) demonstrated the feasibility of using LDMS to identify some organic and inorganic pigments in automotive paints. Positive and negative ions were examined, and both mass spectra were found to be useful since they provided different types of information. Molecular ions of Copper Phthocyanine Blue with expected isotopic ratios were identified in mass spectra obtained for a blue automotive paint. Lesser amounts of molecular ions of the mono- and dichloro-substituted compounds were also observed, from the stabilizers discussed previously. Of all the methods that have been described, this is the only one that has elucidated the nature of these stabilizers.

5.6 EXAMPLES

5.6.1 Example 1

The body of Veronica Hill was found several feet off the side of a little-traveled dirt road in Daytona Beach, Florida. Her clothed body was wrapped in a peach-colored sheet, a floral print white sheet, and an old blanket. The cause of death was determined to be blunt trauma to the head. There was no evidence of sexual assault. Subsequent investigation disclosed that she frequently had sex with men in exchange for money, and several of her recent acquaintances were identified by the clientele in establishments she frequented. Time lines pointed to one primary suspect, David Cartwright. He appeared quite cooperative upon questioning and agreed that the police could search his apartment and garage after obtaining the appropriate paperwork. He acknowledged being with Ms. Hill in the past, but claimed that he was not with her on the night of her death.

Mr. Cartwright's apartment appeared to be in order, with no signs of struggle or evidence of Ms. Hills' suspected presence. Even had such evidence been discovered, it would have been of little value, as Mr. Cartwright already said he had known her and she had previously been to his apartment. In searching the garage, a strong scent of chlorine bleach was noted along with signs of a recent acid wash of the concrete floor. A search for blood resulted in failure. Examination of his 1984 Toyota pickup truck revealed that it was customized both inside and out. It had a relatively new coat of deep purple paint with a distinctive sparkling effect. The interior had the headliner and seats covered with purple imitation fur and there was evidence that the bed area of the truck had at one time also had a similar treatment. The rear of the cab had previously been removed and a truck bed cover was welded to the cab, modifying the pickup truck into somewhat of a sport utility vehicle. The purple faux fur fabric lining was torn from the bed of the truck as well as from the sides of the compartment. The roof's interior still had the fabric present as a custom headliner. Mr. Cartwright explained that he was in the process of refurbishing the interior, and a search failed to reveal the presence of blood stains. Mr. Cartwright shared photos of the interior of the custom vehicle prior to his removal of the appointments and acquaintances related that the work must have been done recently, as the interior was intact just the prior week. He was an avid do-it-yourself customizer as evidenced by the paint and refinish supplies in his garage.

Witness statements and cell phone logs continued to point to Mr. Cartwright and Ms. Hill being together the night of her demise. He held to his claim of not being with her but had no alibi, since he was home alone that night. No murder weapon had been discovered and there was no DNA evidence. Examination of the sheets and blanket in which Ms. Hill's body was wrapped revealed an odd pattern of apparent oversprayed black paint on one of the sheets and the blanket. There were straight lines with no paint on one side and thin overspray on the other. One even had a curve at the top of it, as if something was placed on the fabric and spray-painted. There were two other round spray areas on the blanket, as if a can of spray paint was being tested or the nozzle cleared. These areas were cut out and

the adhering surface debris from the remainder of the fabrics was collected and searched stereomicroscopically. This search disclosed the presence of numerous purple synthetic fibers, some appearing to be long and furlike in shape. Comparison of these fibers to various standards taken from the headliner, side compartment liners, and seat covers of Mr. Cartwright's customized truck revealed several corresponding types. There were three different types that were alike generically (acrylic, modacrylic, and polyester) in addition to their microscopical morphology and color. Morphology was compared by polarized light microscopy, fluorescence comparison microscopy, and brightfield comparison microscopy. Color was compared by comparison brightfield microscopy and microspectrophotometry. Of course, one could argue that Ms. Hill had probably been in Mr. Cartwright's truck and could have had some of the fibers on her clothing from previous contact. However, the number of fibers found was striking; and they were found not only on the victim's clothing but on the outer blanket and sheets as well. Also, there was the paint overspray.

Stereomicroscopical examination of the overspray areas on the outer blanket and the floral sheet used to wrap the body revealed tiny droplets of cured paint fused to the fibers comprising the fabrics. The surfaces of the droplets were smooth and tapered down to the shaft of the fibers, indicating that the paint had been applied wet and then cured on the fabric as opposed to being abraded onto the fabric's surface. Examination by polarized light microscopy (PLM) and FT–IR microspectroscopy revealed that the droplets consisted of a black urethane-modified alkyd enamel paint with interference decorative flake present, providing a purple tint. This paint was encased with a clear, colorless coating that was also a urethane-modified alkyd enamel, similar to the underlying black layer in binder chemical characteristics. The binder chemistry and compatible layer system of the two paints suggested a vehicle refinish paint. Refinish paints are particularly valuable evidence, due to the number of manufacturers and the variety of binder types marketed by each manufacturer. Considering the combination of these two factors, there are over 30 differentiable binder formulations for each color offered.

No potential sources of this paint were discovered in Mr. Cartwright's garage; however, there were numerous overspray areas on the concrete walls and cabinetry. One such area consisted of a black urethane-modified alkyd enamel paint containing interference decorative flake, providing a purple tint. It was the same color as the paint on the blanket around the victim's body. Examination of paint samples collected from his 1984 Toyota truck disclosed that the uppermost finish coat consisted of a clear colorless urethane-modified alkyd enamel with either metallic decorative flake or both metallic and pearlescent flake distributed sparsely throughout. This was followed by a black urethane-modified alkyd enamel containing interference decorative flake providing a purple tint. Numerous refinish layers were present below these topcoats, varying in layer structure from one panel of the vehicle to another. Comparison of the top two paints with the paint overspray found on the blanket and the garage wall revealed that they are like one another with respect to their colors, binder characteristics, and pigment characteristics, including the elemental characteristics of the interference decorative flake present in the black basecoat. Stereomicroscopy, comparison brightfield microscopy, comparison

polarized light microscopy, infrared spectroscopy, and scanning electron microscopy in conjunction with energy-dispersive x-ray spectroscopy were all used in the comparisons. PyGC was not used, due to the limited quantity of paint present in the overspray transfers.

As with many cases involving trace circumstantial evidence, the two layers of paint overspray discovered on the blanket and sheet wrapped around Ms. Hill's body corresponding to the paint on Mr. Cartwright's vehicle and garage wall was certainly not definitive proof of the association in and of itself. Paint is a mass- and batch-produced material and typically escapes the realm of source individualization. But on the other hand, considering that the paint on the body's wrappings was applied as a wet spray of a compatible two-layer vehicle refinish paint system which coincided with the outermost finish on Mr. Cartwright's vehicle along with the presence of the numerous unusual fibers of varying types found on the body's wrappings that also coincided to the upholstery in Mr. Cartwright's vehicle makes for very compelling evidence of an association.

5.6.2 Example 2

By far the most common type of paint examination encountered in public forensic science laboratories involves vehicle paint transferred in hit-and-run cases. There are two types of investigations. In the first, a victim's clothing and/or possessions are examined for the presence of automotive paint in order to determine the year, make, and model of the striking vehicle. This investigative lead information is provided to authorities to aid in the search for a suspect vehicle. In the second, paint exemplars taken from a suspect vehicle (knowns) are compared to paint transfers found on the victim to determine whether or not the suspect vehicle could have been the source of the paint transferred. Occasionally, the investigations become very challenging, such as in a 2002 "cold case" from a city on the east coast of Florida, where the suspect vehicle of a hit-and-run fatality was a white 1977 GMC van that had been discovered in a salvage yard eight months after the incident occurred.

The suspect had sold the van for parts shortly after the accident, and many accessories were missing (see Figure 5.36). It had been stripped of all interior parts, front-end exterior lamps, lenses, and side rear-view mirrors. All windows had been broken and removed. No fabric marks were found on the vehicle. There was some body damage to the front passenger side of the vehicle, especially the right-front fender and hood; however, other panels on the vehicle were also damaged. The exterior passenger side of the vehicle had been spray painted white by hand, as evidenced by the thin coating where the paint had run down the surface of the door and quarter panel.

The accident scene had pieces of broken amber plastic side marker lens, pieces of broken side-view mirror glass, pieces of broken headlight glass, and a right exterior rear-view mirror assembly strewn about. The victim was injured primarily by blunt trauma to the rear of the head, apparently from being struck by the mirror assembly. Search of the victim's clothing revealed the presence of white paint

Figure 5.36 The suspect 1977 GMC van recovered from a salvage yard. *(See insert for color representation.)*

deposits fused to the back of the victim's jeans. Numerous borosilicate headlight glass fragments and nontempered window glass fragments were found in the surface debris recovered from the clothing, along with several fragments of multilayered paint fragments having a white topcoat.

Examination of the suspect vehicle revealed rust-encrusted mounting points for an exterior right rear-view mirror, which corresponded in general configuration to the mirror mount found at the scene. However, no detailed characteristics remained at the mounting sites due to the corrosion present. This was associative evidence, but far from definitive. The pieces of amber plastic side maker lens were similar to the red lenses remaining on the rear of the vehicle. Both they and the exterior side-view mirror assembly were consistent with the types used on mid- to late-1970 to early-1980 General Motors (GM) vans and panel trucks. No headlight, mirror, or window glass remained in the vehicle for use as standards to compare to the glass fragments recovered from the victim's garments. Following comparisons by stereomicroscopy, polarized light microscopy, FT–IR microspectroscopy of all layers, PyGC of the finish coats, and SEM–EDS of all layers, it was found that the paint chips fused to the rear of the victim's jeans had two-layer structures corresponding to the finishes on the right front fender and hood of the suspect vehicle. One panel has a three-layer original finish paint system underneath a poorly applied refinish paint (see Figure 5.37), while the other has a two-layer refinish paint system (see Figure 5.38). The two types of corresponding paint, along with the parts found at the scene, provide strong evidence of an association between the victim and the suspect 1977 GMC van.

The forensic examiner's task often does not end with the completion of examinations in the laboratory and authoring a report of the findings. He or she may be called to court to give testimony not only of what was found but also of its

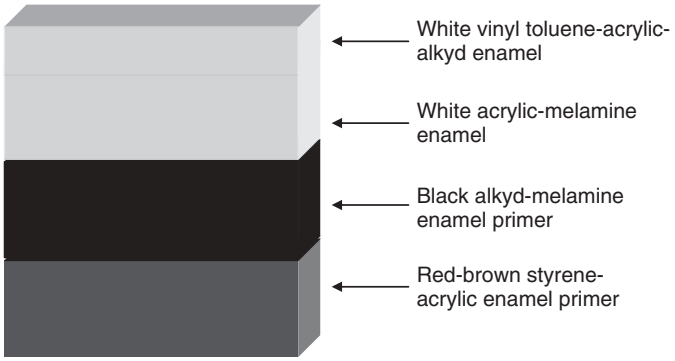

Figure 5.37 Layer structure of the paint from the passenger side door and quarter panel of the 1977 GMC van. *(See insert for color representation.)*

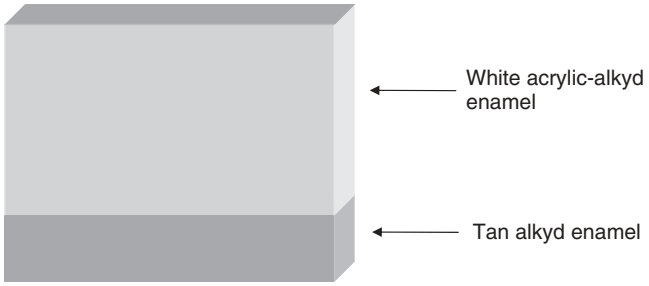

Figure 5.38 Layer structure of the paint from the right side of the hood of the 1977 GMC van. *(See insert for color representation.)*

significance. Although the work on this case could have stopped at this point, a search of the Paint Data Query (PDQ) International Original Automotive Paint database was undertaken to further evaluate how many other vehicles may have had the same original finish as that on the 1977 GMC van produced in GM's Lordstown, Ohio plant. The original finish paint layer structure consists of a white acrylic–melamine enamel topcoat over a black alkyd–melamine enamel primer-surfacer over a reddish-brown styrene–acrylic enamel primer. There is a thin white vinyl toluene–acrylic–alkyd enamel layer on the surface of the original topcoat. This surface paint binder is typical of a household spray paint. The characteristics of the remaining three original automotive finish layers were entered into the PDQ database and searched. Although there was no record of a finish system exactly like that on the Lordstown, Ohio–manufactured 1977 GMC van in this case, all queries did lead to General Motors products manufactured between 1977 and 1980. A further search of these "hits" removed the possibility of the finish coat being an acrylic lacquer, thus restricting the possibilities to GM trucks and vans, with the exception of several types of cars being manufactured in California. Insistence on

the color and chemistry of the base electro-coat primer in the PDQ search, even without the black primer-surfacer, points to 1977 to 1980 GM trucks or vans.

To what end did this additional work bring the examiner? Testimony would surely stress that two types of paint were found on the victim that correspond to the coatings on the front passenger side of the suspect vehicle. One is a refinish and the other is an original finish with a repaint on its surface (determined by their layer structures and chemistry). Furthermore, the binder chemistry of the latter refinish is consistent with a household spray paint. When asked the question, "But how many other vehicles could have an original paint like this common white finish on them?" the examiner can now respond, "In the case of the three-layer original finishes found in the questioned and known samples in this case, a search of an automotive paint database containing over 14,000 original-finish layer systems used over the past 30 years resulted in similar paint layer systems being found only on vehicles produced by General Motors from 1977 to 1980, primarily vans and trucks."

5.6.3 Example 3

Human use of pigments for paintings, decorations, and other ritual purposes has a very long history. The earliest known cave paintings, for example, are well over 30,000 years old. The pigments used for these were predominantly inorganic compounds (especially ferric oxide and hydrous ferric oxide), although a few naturally occurring organic compounds, such as chlorophyll from plants, were also used. The vast majority of synthetic pigments were not available until the early twentieth century, and this is certainly the case for synthetic paint binders. When dealing with art and other painted or pigmented objects, the presence of synthetic pigments and binders is therefore one of the most definitive markers used by art conservation and provenance chemists to indicate either a modern restoration or a forgery. Introduction dates for earlier paint components, however, can also serve to limit the time periods when they could have been used. Although some inorganic pigments have been used for tens of thousands of years, their modern formulations have characteristic signatures that serve to distinguish them from their ground mineral counterparts. Modern pigments, for example, have definite particle size and particle-size distributions, morphologies, specific crystal structures in the case of polymorphic substances, additives, and so on.

The Shroud of Turin There has probably never been an object analyzed by a forensic science laboratory that has generated more controversy than the Shroud of Turin. The shroud is a linen cloth that appears to bear the image of a man. It is believed by some to be the cloth that was placed on Jesus Christ prior to his burial, with the image formed by blood, secretions, or other means. The shroud is kept at the Cathedral of Saint John the Baptist in Turin, Italy.

In 1977, a team of scientists was selected to study the shroud, with this investigation given the designation Shroud of Turin Research Project (STURP). One of the STURP team members was Walter McCrone (1916–2002), a leading microscopist and founder of the McCrone Research Institute and McCrone Associates in Chicago. McCrone's main tool for this investigation was polarized

light microscopy, although he confirmed his findings using a variety of other analytical methods. In 1979, based on his analyses, McCrone concluded that there is no blood on the shroud and that the image is produced by a paint consisting of a collagen tempera binder pigmented with red ochre (mainly ferric oxide) and vermilion (mercuric sulfide) (McCrone and Skirius, 1980; McCrone, 1980, 1981). This was a common paint composition during the fourteenth century and McCrone stated that "the Shroud is a beautiful painting by an inspired medieval artist."

McCrone was the only STURP team member to reach this conclusion, and when other members learned that he disagreed with them, his samples were confiscated and he was removed from the team. When his conclusions became public, he received hate mail and death threats. In 1989, three independent radiocarbon studies of the shroud were conducted at the University of Arizona, Oxford University, and the Swiss Federal Institute of Technology. The data from all three laboratories were consistent and indicated that the shroud originated from the time period 1260 to 1390 (Damon et al., 1989), confirming McCrone's earlier claim. More details of this case are described in *Judgement Day for the Shroud of Turin* (McCrone, 1999b). In 2000, the American Chemical Society acknowledged McCrone for his contributions to chemical microscopy—specifically citing his studies on the shroud—by honoring him with the American Chemical Society Award in Analytical Chemistry.

The Vinland Map The Vinland map is purported to be a fifteenth-century document that was discovered in 1957. Its authenticity gained some credibility from the fact that at one time it was probably bound together with another ancient document of undisputed authenticity. The map depicts most of the world, including Europe and Asia, Africa, Greenland, and a large island west of Greenland labeled "Vinland" (North America). The map was donated to Yale University, but before accepting it, the university had it examined by two museum curators and a librarian, who pronounced it authentic. Unfortunately, this was done in secret and other specialists were not consulted.

In the scientific community, the Vinland map has probably generated more controversy than the Shroud of Turin, owing to both its content and its chemical composition. The map depicts Greenland as an island with a shape that is quite accurate, considering that in the fifteenth century it was thought to be a peninsula, and there were no recorded passages of ships around the island until the twentieth century. Some of the Latin names cited on the map were not believed to have been used until hundreds of years later.

One of the main factors that has continued to fuel the Vinland map controversy is the radiocarbon dating analysis, which indicates the map parchment to be from the 1423 to 1445 time period, consistent with its purported date of origin. The map, however, has a coating of an unidentified substance from the 1950s. The British Museum examined the map in 1967 and found that it appeared to have been drawn with two superimposed lines consisting of black and yellow inks, and was unlike any that had been examined previously.

In 1972, Yale University sent the map to McCrone Associates for chemical analysis of the ink. Walter McCrone found that the map was produced with a yellow

line overlaid with a black line in the middle (McCrone, 1976). McCrone indicated that this was done with considerable skill, but he did find segments where the yellow and black lines were not parallel. The use of two lines was apparently done to simulate the natural weathering of medieval black iron-containing inks, which would develop such an appearance as the ink migrated slowly along the parchment fibers. Using polarized light microscopy, SEM–EDS, transmission electron microscopy (TEM), XRD, and other methods, McCrone identified anatase in the yellow ink, with the anatase having morphologies, particle sizes, and particle-size distributions consistent with those of modern formulations. Anatase was first used as an ink pigment in the 1920s and may have a yellow hue from iron impurities. McCrone thus concluded that the Vinland map could not have been produced when purported.

Proponents of the authenticity of the Vinland map have argued that since anatase is present in trace quantities in some of the components of inks used in the medieval period, McCrone's findings do not support a forgery. However, there have been no investigations into the microscopic characteristics of anatase found in such documents to show that these impurities cannot be distinguished from modern formulations, which was the key to McCrone's findings. In 1991, McCrone performed a second examination of the map ink. Using an infrared microscope, he identified the ink binder as gelatin, probably made from animal skin (McCrone, 1999a). Although this does not rule out a medieval origin, McCrone confirmed that significant quantities of anatase are present. This had become an issue since his first study, as an examination of the ink using PIXE suggested that the titanium levels were too low to be from anatase in the ink (Cahill et al., 1987). However, a 2002 study using a Raman microscope confirmed that a significant amount of anatase is present in the yellow ink, and found that most of the black ink consists of carbon (Brown and Clark, 2002). Such inks would not be expected to produce yellowing with age, which is characteristic of iron-containing inks.

Judging from the titles of two letters to *Analytical Chemistry* and a recent review article—*Evidence That the Vinland Map Is Medieval* (Olin, 2003), *The Vinland Map Ink Is NOT Medieval* (Towe, 2004), and *Analysing the Vinland Map: A Critical Review of a Critical Review* (Towe et al., 2008)—the heated controversy over the authenticity of this document will probably not end any time soon. McCrones's detailed examinations of the anatase particles of the yellow ink, however, provide convincing evidence for a modern pigment rather than a natural contaminant in a medieval pigment.

A Trove of Previously Undiscovered Paintings by Jackson Pollock?

In 2002, Alex Matter reported his discovery of more than 20 previously unknown paintings that he attributed to the American abstract expressionist artist Jackson Pollock (1912–1956). He found them in a storage locker belonging to his deceased father, who had been a friend of Pollock's. Based on the style of the paintings and an inscription on the paper wrapper in which the paintings were said to have been discovered, at least one leading expert on Pollock's work concluded that the

collection was genuine. This expert felt that "there are too many things about them that are pure Jackson" (Kennedy, 2005). In preparation for an exhibition that featured the paintings, the owners sent them to the Harvard University Art Museum Laboratory, the Museum of Fine Arts (Boston) Laboratory, and to Orion Analytical LLC in Massachusetts for paint analysis. Scientists at these laboratories also examined previous known paintings by Jackson Pollock as a comparison (Martin, 2008).

The following are some of the paint components that were identified in most of the paintings that were analyzed: (1) an acrylic binder with styrene, (2) Benzimidazolone Yellow 4G (Pigment Yellow 151), (3) Benzimidazolone Orange (Pigment Orange 62), (4) rutile-coated mica pearlescent pigments, (5) iron oxide–coated mica pearlescent pigments, and (6) DPP Red BO (Pigment Red 254). These components were identified by infrared spectroscopy, with additional methods, including microscopy and elemental analysis, used to identify the pearlescent pigments. Benzimidazolone Yellow 4G, Benzimidazolone Orange, and DPP Red BO were first identified in automotive paints. Because they were fairly new, their introduction dates and their first known use for American vehicles were also reported to aid forensic paint examiners interpret data from unknown paint chips recovered from hit-and-run scenes. The art provenance chemists performing the Pollock studies relied on these automotive paint studies, as well as others (Martin, 2008).

None of the six paint components cited was found in previous known works by Pollock. More revealing, however, are the commercial introduction dates for the six: (1) 1961, (2) 1969, (3) 1971, (4) 1978, (5) 1979, and (6) 1983 (Martin, 2008). All six were therefore introduced *after* Pollock's death in 1956, and all three laboratories concluded that the paintings containing these compounds could not have been produced by Pollock.

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The co-author (EMS) is eternally grateful for the involvement of the principal author, who was extremely reluctant to get involved in yet another writing project. He only consented after considerable arm-twisting and cajoling, as—being a very tactful person—he was concerned about offending those who in the past have sought his considerable knowledge, skills, and writing ability, but whom he was unable to accommodate.

CHAPTER 6

Analysis Techniques Used for the Forensic Examination of Writing and Printing Inks†

GERALD M. LaPORTE

National Institute of Justice, Office of Investigative and Forensic Sciences, Washington, DC

JOSEPH C. STEPHENS

United States Secret Service, Forensic Services Division, Questioned Document Branch, Instrumental Analysis Section, Washington, DC

Summary The analysis and identification of writing and printing inks and toners is generally very important in document examination, especially when used in conjunction with a reference library. Inks can be differentiated based on the chemistry of colorants, solvents, resins, and additives. Instrumental analysis, including GC–MS, HPLC, and FT–IR and Raman spectroscopy, can often be used following visual examination, microscopic observation, and thin-layer chromatography. Analysis of toners can be performed with XRF, SEM–EDS, or pyrolysis GC. Although chemical analysis of materials used to create documents can provide vast amounts of relevant information and strongly support associations between questioned and known materials, in nearly all cases the data obtained will not support a conclusion that identifies a particular writing instrument or printing device.

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†All references pertaining to manufacturers and their products do not imply endorsement by the United States government, or the authors.

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6.1 INTRODUCTION

Crimes that involve questioned documents can include matters of national security (National Commission on Terrorist Attacks Upon the United States, 2004), homicides, and various types of document fraud. In all cases it is imperative for investigators and forensic scientists to recognize the realm of examinations that can be conducted on documents and the potential information that may be gleaned from their findings. A questioned document (QD) is defined by Lindblom (2006) as ". . . any material containing marks, symbols, or signs that convey meaning or message." Documents can present themselves in numerous formats, including letters, envelopes, packages, calendars, diaries, currencies, identification cards, financial documents, contracts, wills, and business records. Forensic document examiners (FDEs) can also evaluate a variety of evidence that does not fall into the traditional category of a document, but requires similar expertise, such as written entries found on the body of a victim, or a threat written or painted on a wall.

General acceptance of handwriting analysis to identify a suspected author dates back several decades. While handwriting evaluations are a valuable QD examination, there is a gamut of nonhandwriting examinations that require chemical analyses. Given the variation of materials encountered on a questioned document and the diversity of analytical techniques available, the purpose of this chapter is to provide an overview of the chemical procedures that may be used for document examination. The authors have chosen to highlight some common procedures that may be employed to gather information from documents submitted for forensic analysis. The appropriate scientific procedure is heavily dependent on the composition of the material being analyzed. Often, documents are created using a combination of inks and paper. Correction fluid, adhesives, stains, and various other materials may be encountered on a document as well.

6.2 INK

Ink is one of the most common materials used in the production of a document. Although there are various types of writing and printing inks, chemical and

instrumental techniques remain similar when attempting to characterize their basic components. Typically, the goal of such examinations is to determine the source of the manufacturer, compare questioned and known items, and ascertain when the document was produced and/or decipher alterations, erasures, and obliterations.

6.2.1 Ink Composition

All inks, in their basic form, are composed mainly of a colorant(s) suspended in a vehicle (solvents and resins). There are also other organic and inorganic ingredients that may be present in inks, which can include antioxidants, preservatives, wetting agents, lubricants, and trace elements, but these typically form a small fraction of the overall formulation. Nevertheless, their importance should not be discounted because it is possible that a combination of these components allows otherwise similar inks to be discriminated. Before delving into the various analytical approaches for the examination and characterization of inks, it is necessary to gain an understanding of the major components.

Colorants Colorants are a crucial part of all inks because without them, inks would not be discernible under visible light (approximately 380 to 780 nm). The molecular composition of the colorants will dictate how certain wavelengths of visible light are absorbed and reflected, thereby influencing their color. Depending on the vehicle and its interaction with the colorant, two types of colorants can be used: dyes and/or pigments. Dyes are generally considered to be compounds with highly conjugated resonance structures. Their molecular weights can vary from the low hundreds to the high thousands. Dyes can be classified according to their chemical structure or how they are applied to material. It is beyond our scope in this chapter to adequately review the various types of dyes. The most comprehensive volume regarding dye information is *The Colour Index*, published by the Society of Dyers and Colourists and the American Association of Textile Chemists and Colorists (1971). Dyes may be listed by their International Union of Pure and Applied Chemistry (IUPAC) name, Chemical Abstracts Services (CAS) number, or the Colour Index (C.I.) name. *The Colour Index* divides dyes into a series of large groups: acid dyes, azoic dyes (monoazo-, diazo-, triazo-), basic dyes, developers dyes, direct dyes, disperse dyes, fluorescent brighteners, food dyes, ingrain dyes, leather dyes, mordant dyes, natural dyes, oxidation bases, phthalocyanine dyes, reactive dyes, reducing agents, solvent dyes, sulfur dyes, and vat dyes. These colorants are used in many industries to yield colors on an array of substrates; however, solvent dyes and pigments are the most commonly used colorants in writing instruments. Acid dyes and reactive dyes are also used, but less frequently. The molecular structures of a common phthalocyanine dye and a monoazo reactive dye are shown in Figure 6.1.

The major distinguishing feature between dyes and pigments is that the latter consists of fine particles of insoluble material that are suspended in the vehicle. Pigments are generally considered more stable and long-lasting than dyes because pigments are less prone to photodecomposition (lightfast) and are insoluble in

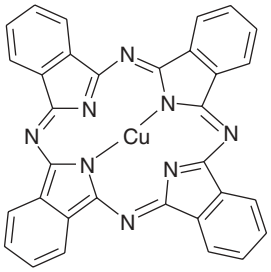

Copper Phthalocyanine

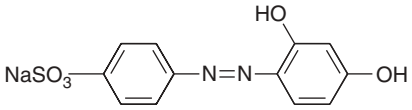

C.I. Acid Orange 6 (mono)-azo dye

Figure 6.1 Molecular structures of copper phthalocyanine and a monoazo reactive dye that can be found in writing and printing inks.

water (waterfast). Their color can be derived from a metal-centered complex and is generally less vibrant than dyestuffs. Additionally, pigments are more opaque than dyes, so the colorant is more efficient at masking any underlying material. There are five major categories of pigments: organic pigments, toners, lakes, extended pigments, and inorganic pigments. Toners, lakes, and extended pigments are all precipitated from an aqueous solution in conjunction with some catalyst(s).

Solvents The fluid portion of ink that suspends and delivers the colorant to the substrate is known as the *vehicle*. Vehicles are necessary to carry the color from the cartridge to the paper. Once on the paper, the solvent undergoes a series of changes over a fixed period of time, causing the colorant to dry onto the paper. Changes that occur to the solvent–ink mixture over time can include polymerization, evaporation, oxidation, or photodecomposition. These modifications to the original chemical composition of the ink have been the focus of methodologies that are employed when attempting to date a document. A more extensive discussion of ink aging will be covered in the ink analysis section of this chapter.

Although much of the specific information on each company's ink formulations is proprietary, there are some standard chemicals that are used as vehicles. Glycols, alcohols, and water are the most commonly found solvents in use for pens today (Brunelle and Crawford, 2003). 2-Phenoxyethanol (2-PE), ethanol, 1-phenoxypropan-2-ol, benzyl alcohol, and many more solvents can also be used as vehicles. The choice of which solvent or solvents to use often relies on properties related to the writing instrument. The writing instrument type (e.g., fountain pen, ballpoint, felt-tip marker), composition of the ink cartridge, region of sale (e.g., dry, humid), and type of colorants and resins are all considerations when attempting to determine the type of solvent(s) to be used. The desired properties for a single formulation are often achieved through a combination of several vehicles. Other considerations, such as the solubility of the colorants in the vehicles, are also critical, since vehicles are the primary means of delivering the colorant to the substrate.

Resins and Additives Resins, which can be natural or synthetic, are incorporated into inks to provide them with a desired viscosity and a means to bond

the ink and the substrate as the ink dries. Normally, the resinous material is dissolved into the vehicle to create a solution in which colorants can be added. Phthalates, ketone resins, styrene-type resins, phenol-type resins, rosin-type resins, and poly(vinylpyrrolidones) are just a few plasticizers that find use in ink formulations as binding resins (U.S. patent 7,462,229). Along with the resins, additives such as biocides, surfactants, lubricants, corrosion inhibitors, preservatives, buffers, and diluting agents are included in ink formulations to enhance properties of the ink (Brunelle and Crawford, 2003). Bügler et al. (2005) used thermal desorption and gas chromatography–mass spectrometry (GS–MS) to characterize ballpoint pen inks. Table 6.1 is a summary of the resins and solvents found in a population of 25 inks.

TABLE 6.1 Summary of Resins and Solvents Found in 25 Different Ballpoint Inks Analyzed Using Thermal Desorption and Gas Chromatography–Mass Spectrometry

Manufacturer	Year of Introduction	Color	Resin Class[a]	Solvents[b]
1	1997	Black	AF	PE, PDE, *N*-methylpyrrolidone
2	2000	Blue	AF	PE, PDE
1	2000	Black	AF	PE
3	2000	Blue	AF	PE, PDE
	2000	Black	CF	PE, PDE
4	2000	Black	AF	PE, PDE
5	2001	Blue	CF	PE, dipropylene glycol
	1999	Black	AF	PE, PDE, ethyl diethylene glycol
6	2002	Black	Alkyd	PE
7	2002	Black	Alkyd	PE, PDE, propylene glycol
8	2003	Blue	AF	PE, PDE, diisopropylene glycol
	2003	Black	AF	PE, PDE, ethyl diglycol
9	2003	Blue	CF, Alkyd	PE, PDE, hexylene glycol
	2003	Black	AF	PE, PDE, hexylene glycol
10	2003	Blue	Alkyd	PE, butylene glycol
11	2003	Blue	Alkyd	PE, PDE, benzyl alcohol
12	2003	Blue	AF	PE, PDE, butylene glycol
	2003	Black	AF, Alkyd	PE, PDE, butylene glycol
13	2004	Blue	AF	PE, benzyl alcohol
	2004	Black	Unknown	PE, benzyl alcohol
14	2005	Blue	Alkyd	PE, benzyl alcohol
	2005	Black	Alkyd	PE, benzyl alcohol
15	2005	Blue	CF, Alkyd	PE, PDE
	2005	Black	CF, Alkyd	PE, PDE
	2005	Blue	CF	PE, PDE, trioctylphthalate

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[a] AF, acetophenone–formaldehyde resin; CF, cyclohexanone–formaldehyde resin.

[b] PE, 2-phenoxyethanol; PDE, 2-(2-ethoxy) ethoxybenzene.

TABLE 6.2(a) Ink Formulation Containing Glycol

U.S. patent: 4,077,807	Formula
Ethylene glycol monophenyl ether	20.0
1,3-Butylene glycol	20.0
Fatty acid (oleic acid type)	12.0
Solvent Blue 5 dye (such as Victoria Pure 6 Blue BO base)	5.0
Solvent Violet 8 dye (such as Methyl 4 Violet base)	5.0
Resin, ketone condensation type	35.0
Resin, poly(vinylpyrrolidone) type	3.0
Corrosion inhibitor	1.0
Antioxidant	2.0
Parts by weight	103.0

TABLE 6.2(b) Series of Ink Formulas Containing Benzyl Alcohol, Antioxidants, and Corrosion Inhibitors

	Formula			
U.S. patent: 4,077,807	A	B	C	D
Benzyl alcohol	22.0	22.0	22.0	22.0
Ethylene glycol phenyl ether	22.0	22.0	22.0	22.0
Oleic acid	12.0	12.0	12.0	12.0
1,2-Propylene glycol	4.7	4.7	4.7	4.7
Blau Base KG (Solvent Blue 64, BASF)	15.9	15.9	15.9	15.9
Victoria Blue base F4R (Solvent Blue 2, BASF)	7.5	7.5	7.5	7.5
Hexane triol phthalate resin	15.9	15.9	15.9	15.9
2,2-Methylene bis(4-methyl-6-tertiary-)butylphenol (antioxidant)	0.0	2.0	0.0	2.0
Benzotriazole (corrosion inhibitor)	0.0	0.0	0.1	0.1
Parts by weight	100.0	102.0	100.1	102.1

Additional information on specific ink formulations can often be found in patents. Tables 6.2 and 6.3 depict the chemical profiles of several inks obtained from U.S. patents 4,077,807 and 4,097,290.

6.3 INK ANALYSIS

The information obtained from forensic ink examinations can be a critical component of a case, but the analysis process can be extraordinarily complex. We have chosen to generically describe modern techniques that pertain to more commonly encountered inks such as writing instruments and office machine printers (i.e., photocopiers, laser printers, and inkjet printers). Ink analysis revolves around classifying and identifying the various components of ink: colorants, vehicles, and additives. It is very rare to identify a questioned ink as coming from a specific pen or printer, so in most cases, conclusions are reached about the formulation of the ink. Being a mixture, an analytical profile for the ink formulation can be developed using an assortment of instrumental techniques on the various components.

TABLE 6.3 Ink Formulations for the Gillette Company

U.S. Patent 4,097,290	839-41A Black	814-96A Black	814-92C Red	839-41 Green	839-26C Blue
Natural rubber	22.5%	26%	29%	22.5%	22.5%
Aliphatic diluent No. 6	23.5%	—	—	23.5%	23.5%
Aliphatic solvent 360-66	—	17%			
VM&P naphtha	—	14%	19%		
Terphenyl (HB40)	30%	26%			
DOP	—	—	—	33.5%	27%
Mineral oil	—	—	27%		
Pigment	20%	17%	15%	16.5%	23%
Stearic and lauric acid	4%	—	—	4%	4%
	Carbon black (0.08 μm)	Graphite (2–5 μm)	Organic Red (0.015 μm) suspended in mineral oil (35% pigment dry basis)	Phthalocyanine Green (0.015 μm)	Phthalocyanine Blue (0.015 μm) Victoria Blue 10.5% (0.025 μm)

Numerous formulations of writing inks are available to the general public, thereby greatly decreasing the frequency of occurrence of any particular ink formulation. Personal preferences (e.g., fountain, ballpoint, roller, and gel pens), changes in technological features, cost considerations, and the availability of raw materials are some examples of why so many writing inks exist. Furthermore, most ink companies spend substantial resources on research and development. As a result, many of these formulations are considered proprietary and kept secret. It is also important to recognize the significance when two inks are determined to be chemically indistinguishable or "match" each other. As outlined in Section 9.3 in the ASTM's *Standard Guide for Test Methods for Forensic Writing Ink Comparison* (ASTM E1422-05, 2005):

> When the comparison of two or more ink samples by optical or chemical analyses, or both reveals no significant, reproducible, inexplicable differences and there is significant agreement in all observable aspects of the results, it may be concluded that the ink samples match at the level of analysis and that the results indicate that the ink samples are of the same formula or two similar formulas with the same non-volatile components.

Determining the significance of a match can be further interpolated when the analyst has a reference collection for comparison as outlined in the ASTM's *Standard Guide for Writing Ink Identification* (ASTM E1789-11). The U.S. Secret Service (USSS) and the Internal Revenue Service (IRS) jointly maintain the largest known forensic collection of writing inks in the world. The collection includes more than 10500 samples of ink that date back to the 1920s and has been obtained from various manufacturers throughout the world. Pen and ink manufacturers are contacted on an annual basis and requested to submit any new formulations of inks, along with appropriate information, so that the new standards can be chemically tested and added to the reference collection. In addition, writing pens are obtained on the open market and compared with the library of standards to identify additional inks that may not have been formally submitted by a manufacturer. Maintenance of the library is a formidable task that obviously requires significant resources and is not often practical for most forensic laboratories. Consequently, the USSS generally considers offering forensic assistance (made on a case-by-case request) to law enforcement agencies requesting the analyses of writing inks. The Bavarian State Bureau of Investigation in Munich, Germany also maintains a reference collection of over 6000 writing inks (personal communication, Dec. 4, 2009).

Requests for ink analysis typically comprise three types. The first may involve comparing two or more inks to determine if the formulations match each other. This may help to ascertain if any of the written entries were added or altered. The second is to attempt to identify the writing ink on a questioned document and provide investigative information regarding the possible source of the ink. The third and most challenging request is to establish when the written entries were created to help determine if they are authentic with respect to the purported date of preparation of a document(s). This type of request, usually referred to as *ink dating*, is addressed in further detail in a separate discussion. The first two tasks

can be achieved by comparing the questioned ink(s) with an adequate collection of standards, as described previously.

Prior to conducting chemical analysis, it is important to determine how the entries on a document were produced (e.g., writing instrument, inkjet printer, toner-based office machine). Without this knowledge it will be difficult to select an appropriate analytical scheme. Moreover, there are physical and optical characteristics of inks that, when in combination with the chemical properties, allow one to form an analytical profile of the ink. It is important to recognize that it is the combination of physical, optical, and chemical results that will allow one to make more accurate and objective conclusions.

6.3.1 Physical Examinations

Physical examinations include the determination of the color and type of ink. Determining the type of ink (e.g., ballpoint, felt tip, fountain pen) often requires training and experience in the evaluation of morphological characteristics using a stereomicroscope (approximately 5× to 50×). It is important to establish the type of writing instrument used to make a questioned entry, as this dictates the extraction solvent necessary for a chemical ink examination. There are various types of writing instruments and writing inks, but generally, inks are separated into three categories: nonaqueous or glycol-based (ballpoint), fluid (porous, felt or fiber tips, gel, and roller pens), and fountain pens. Definitive microscopic differentiation of these three categories of inks is possible in most cases due to their unique morphological characteristics on a substrate. Although there are a variety of writing instruments that utilize fluid inks (e.g., gel pens, roller pens, felt-tip markers), their physical properties are not always definitively discernible. In addition to class characteristics, individual characteristics may be identified, thereby making the microscopic examination a necessary part of the procedure. As an example, Figure 6.2 illustrates a damaged ballpoint casing and the microscopic scratching that appears on

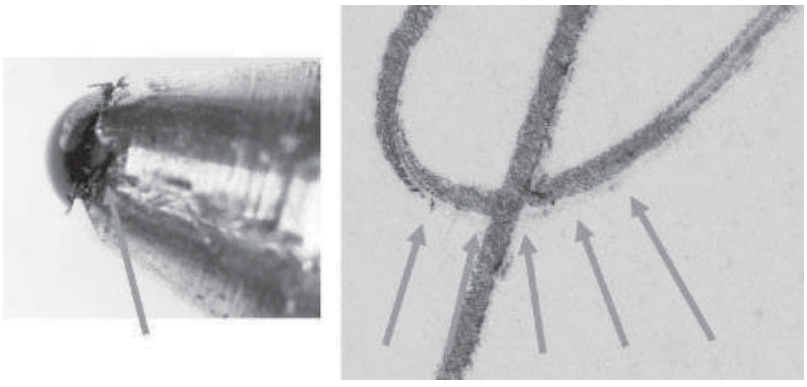

(a) (b)

Figure 6.2 (a) Damaged ballpoint pen casing. (b) Visual defects generated by damaged writing instrument. *(See insert for color representation.)*

the paper. Such damage to the writing tip may be used to help associate a suspect writing instrument with the questioned document.

Morphological Characteristics in the Written Line When examining a written line, the first step is to make a distinction between absorbent and nonabsorbent (or semiabsorbent) ink. Inks that are water based will absorb into the paper fibers, providing nearly uniform coverage of the substrate over the width of the stroke. Semiabsorbent inks such as ballpoint inks generally do not penetrate the fibers as much but merely rest on top of the paper fibers.

Hesitations, or pauses in the flow of writing, are also indicative of a particular type of writing mechanism. While related to vehicle composition, the absorbing inks tend to saturate and bleed into surrounding paper fibers when the pen is left in contact with the paper for a period of time. To a lesser extent, gel pens exhibit some bleeding, while ballpoint pens yield no bleed when left in contact with a piece of paper for an extended period of time. Figure 6.3 shows ballpoint ink, which exhibits no bleed, and a gel ink with minimal bleed. Both the felt-tipped and roller ball inks bleed significantly on paper.

Strokes of each type of writing instrument are shown in Figure 6.4. Both ballpoint ink, and to a lesser extent gel inks, fail to provide complete coverage of the paper fibers because they are semi- or nonabsorbent. Roller ball inks and felt-tipped (porous) inks are absorbent and therefore fully penetrate most porous substrates, creating uniform coverage.

Additional characteristics observed in the written line can further distinguish writing instruments. For example, fountain pens are often noted for their shading and, when the ink is in short supply, for the appearance of two lines. When there is insufficient ink, the two separate nibs will appear on the substrate as two parallel lines. This phenomenon can also be observed if significant pressure is applied to the fountain pen nib.

Ballpoint inks tend to have a sheen and provide incomplete inking across the paper fibers. Gooping, the release of a large volume of ink in a small area, is unique to ballpoint inks. Striations are voids in the inking that are a result of the ball not rolling through the ink supply prior to being rolled over the paper. Striations that

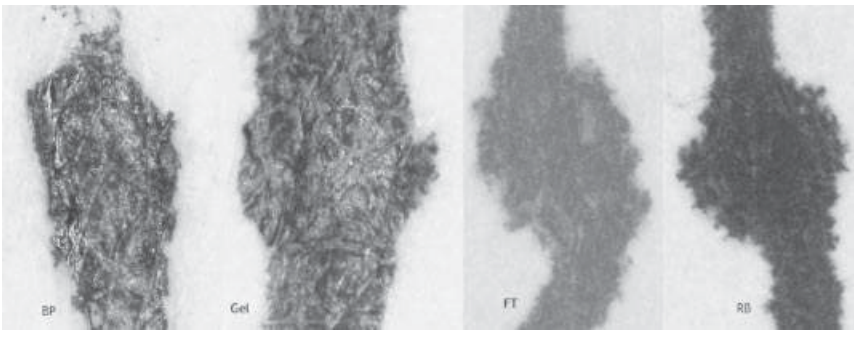

Figure 6.3 Characteristics of the written line from various writing instruments. *(See insert for color representation.)*

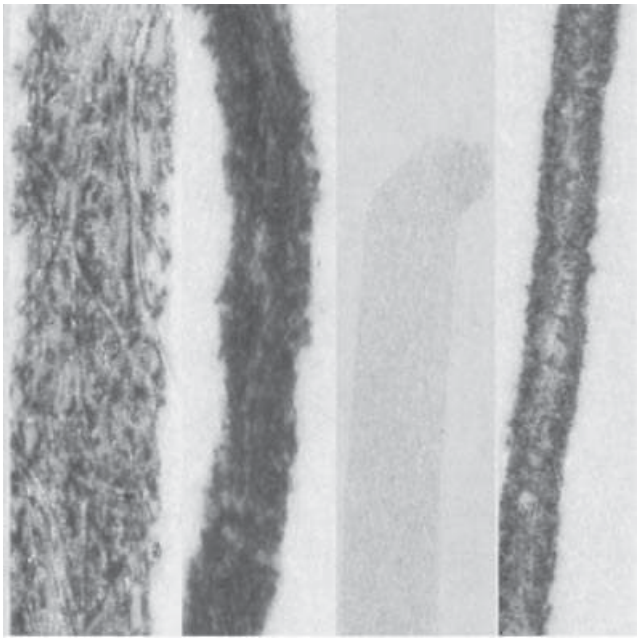

Figure 6.4 Written lines from various writing instruments. *(See insert for color representation.)*

result from the ball are seen only in ballpoint inks because they do not absorb like other ball mechanism inks (gel, roller ball). The ballpoint mechanism typically leaves a writing groove in the substrate.

Non-ballpoint (porous-tipped) inks are noted for their complete coverage across the width of the inked line. No grooves in the substrate are found and the ink tends to bleed if there is hesitation. There are instances where a felt-tipped pen may become degraded and stray fibers on the tip will leave stray markings off the main inked line.

Gel pens, which utilize a ballpoint mechanism, tend to have heavy saturation at the edge of the written line and less saturation in the center. Since little pressure is needed to apply ink to the substrate, the writing groove present is typically not as deep as one would expect to find from a ballpoint pen. Neither gooping nor striations are visualized.

Writing instruments can often leave information that is pertinent to a handwriting examination. Determining the direction of stroke is a valuable forensic examination. The ink saturation on gel pens, porous-tipped pens, steel pens, and fountain pens makes determination of the direction of stroke challenging. Fountain and steel pens may, in some instances, indicate a direction of stroke, as writers tend to apply more pressure on the downstroke (Hilton, 1982). As pressure is applied to the nib-tipped pens, the nibs separate and the one visible line may become two. The striations in

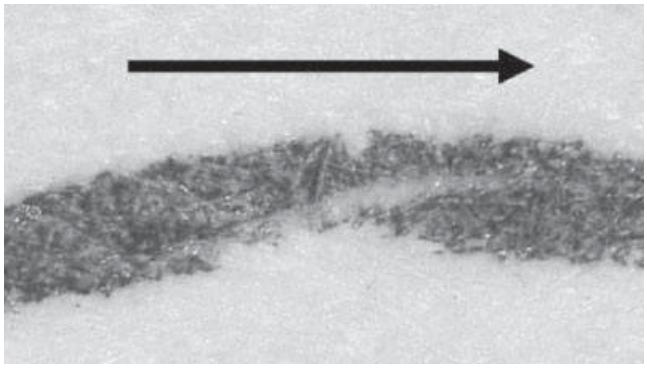

Figure 6.5 Ballpoint pen striations. *(See insert for color representation.)*

ballpoint pens are the best indicator for the direction of stroke. When a ballpoint pen is rotated around the curve of a letter, it often leaves striations on the paper where the inking is incomplete. The striation works its way from the inside of the curve outward. In effect, the thinnest part of the "top" of the curve is always pointing in the direction of the stroke. Figure 6.5 illustrates the direction of stroke of a ballpoint pen. Table 6.4 lists the various physical characteristics that can be used to identify the type of writing instrument.

6.3.2 Optical Examinations

An optical examination, also referred to as a filtered light examination (FLE) or video spectral analysis (VSA), can provide valuable insight regarding the overall composition of an ink. The presence of colorants and other materials will directly affect the manner in which an ink absorbs, reflects, and transmits electromagnetic radiation. Ultraviolet (UV) and infrared (IR) radiation are forms of energy that can be used to examine inks on a document. Near-infrared reflectance (IRR) and infrared luminescence (IRL) properties can help significantly when evaluating properties of an ink. Instruments designed specifically for the purpose of a filtered light examination are best suited for document analysis. Foster & Freeman, Projectina, and other manufacturers provide equipment suited for such analyses.

TABLE 6.4 Summary of the Various Characteristics Typically Found in Writing Inks

	Gooping?	Complete Inking?	Writing Groove?	Ink Bleed?
Fountain pen	—	Some	Yes	Yes
Ballpoint pen	Yes	—	Yes	—
Porous pen	—	Yes	—	Yes
Roller ball pen	—	Yes	Yes	Yes
Gel pen	—	Some	Yes	Some

Drexler and Smith (2002) have described a self-made apparatus that can be manufactured using off-the-shelf equipment, and Richards (1977) provides a basic model for the application of infrared and ultraviolet techniques. Modern commercial equipment typically incorporates the use of a charge-coupled device (CCD), providing users with the opportunity to examine and save images electronically. When illuminating a sample, there are two ways in which the sample can give off energy. The first involves the energy from the illuminant being reflected to the detector. The second way to detect energy from a sample is through luminescence. Luminescence is the absorption of energy at one wavelength and the reradiation of energy at another, typically longer, wavelength. The greatest advantage in examining the luminescence of a sample is the ability to filter out the incident energy on the sample. By filtering out the illuminant, the detector displays only energy that has been reradiated at a longer wavelength. When ink examinations are conducted, both IRL and IRR properties of the ink are recorded. While IRR and IRL properties are often used to determine the regions of interest on a document, they are rarely used to eliminate inks under comparison. Inks that exhibit varying IRR and IRL properties generally contain dyes in the formulation. Typically, dyes do not absorb IR radiation, whereas pigments do. Therefore, pigments will appear black at long wavelengths, whereas dyes often seem to disappear (transmit) in the IR region. When dyes become transparent in the IR region, the underlying substrate often reflects the incident energy, making it seem as though the ink has disappeared. It is important to note that a FLE can be completed before or after chemical analysis is conducted on the ink components. Since ink is a complex combination of chemicals, competing colorants can often reabsorb IRL from other colorants. Some components exhibiting IRL may be visible only after they are separated using chemical analysis, as other components can mask the luminescence. Figure 6.6 demonstrates two inks used for a check alteration with different IRL properties.

An evaluation using optical methods should always be considered, especially when the request is to compare two or more entries, or when evaluating multiple entries on a page. Often, VSA will be used to evaluate if the writing ink on a page is homogeneous. Determining homogeneity may be necessary if further chemical

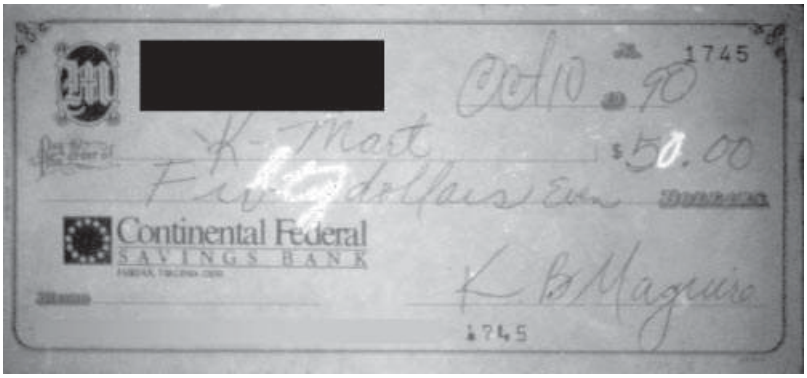

Figure 6.6 Altered check created using two inks with different IRL properties.

testing is warranted. It is not practical to sample and chemically analyze all entries in most cases, so VSA is used as a screening tool. Additionally, it may be possible to detect if there have been any changes to the document or written entries, such as addition of solvents or materials, alterations, insertions, obliterations, and deletions using a FLE. It is critical to emphasize that if two inks cannot be differentiated via their IRR, IRL, and UV properties, this is not conclusive evidence that they are a match as described in the ASTM's *Standard Guide for Test Methods for Forensic Writing Ink Comparison* (ASTM E1422-05, 2005). It is not uncommon that different inks will exhibit similar or even identical optical properties. Furthermore, when performing such examinations, caution must be taken in rendering conclusions if the evaluations are made on different substrates. The substrate can have an overwhelming effect by masking or absorbing the energy that is reradiated from the ink.

6.3.3 Chemical Examinations

Determining the chemical components present in a writing ink is a critical piece for developing an overall profile. The first stage of analysis typically involves extraction of the ink into the appropriate solution. Often, inks with different extractabilities will have different components. Extracting the same inks that have undergone different aging processes, were stored in different environmental conditions, or were found on different substrates may yield different extractabilities. It is important for an analyst to evaluate ink extractability in order to verify that the ink colorants are being extracted appropriately. Occasionally, some non-ballpoint inks may not extract in an aqueous solvent mixture. These are usually pigment-based fluid inks.

Typically, ballpoint inks are extracted with organic solvents such as pyridine, methanol, or acetonitrile. Fluid inks can be extracted with a mixture of ethanol and water (1 : 1), but this is not always the ideal extracting solvent since some fluid inks are non-aqueous-based (e.g., permanent markers). Recently unpublished research suggests that a tetrahydrofuran (THF) and water mixture (4 : 1) may be suitable for both ballpoint and fluid inks. In some instances, inks may have to be extracted in other solvents, depending on the formulation. While it is necessary to maintain a single solvent or solvent system across a reference collection for searching purposes, there are numerous solvents that can be utilized when conducting an intraplate comparison. Figure 6.7 shows the variations in dyes that are extracted based on the assortment of extraction solvents that were used.

Thin-Layer Chromatography Thin-layer chromatography (TLC) is one of the most widely used and generally accepted scientific methodologies employed to compare and help characterize ink formulations. TLC is an effective and efficient method for separating and identifying colorants. For example, two or more questioned inks can be compared to determine if they are the same, or questioned inks can be associated to a known standard. However, it must be emphasized that TLC is only one portion of an analytical scheme, and the "profile" of an ink is achieved only by using the results from a series of physical, optical, and chemical

Sample	Extraction solvent
1	Methanol
2	Acetone
3	Tetrahydrofuran
4	Ethanol
5	Ethyl acetate
6	Chloroform
7	tert-Butylmethyl ether
8	Methanol, water (8:2)
9	Methanol, water (1:1)
10	Methanol, acetone (1:1)
11	Ethanol, water (6:4)
12	Ethanol, water (1:1)
13	Ethanol, water (8:2)
14	Dimethylformamide, water (1:1)

Figure 6.7 Different banding patterns based on changes to extraction solvent. *(See insert for color representation.)*

examinations. In 1999, Roux et al. conducted studies on black and blue ballpoint inks using a FLE, TLC, and reflectance visible microspectrophotometry (MSP). The authors concluded that "the power of the individual techniques to discriminate inks between and within brands, models and batches varied, the most informative techniques being TLC > FLE > MSP." They showed that filtered light examinations of blue inks ($n = 49$) and black inks ($n = 42$) resulted in a discriminating power (DP) of 0.83 and 0.96, respectively. After conducting TLC and in conjunction with FLE, the DP was 0.98 for blue and 0.99 for black, where

$$\text{DP} = \frac{\text{number of discriminated pairs}}{\text{number of possible pairs}}$$

TLC for writing inks has been discussed extensively by Brunelle and Crawford (2003), Witte (1963), Brunelle and Pro (1972), Brunelle and Reed (1984), Kelly and Cantu (1975), and Aginsky (1993a). TLC analysis begins by removing an ink sample from a document and subsequently extracting the ink in an appropriate solvent. The extract is then applied to a silica-coated TLC plate (glass or plastic backing) and placed in a solvent-equilibrated glass chamber containing a solvent or mixture of solvents. A mixture of solvents, often referred to as a solvent system, is often employeed to gain timely separation of ink components across the retardation factor range. The sample components then migrate up the plate via capillary action. Typically, the colorants (e.g., dye components) that are present in the ink sample will separate into colored bands or spots.

Other Instrumentation There are numerous research papers regarding the use of instrumental methodologies for the analysis of ink that have been published. The use of gas chromatography–mass spectrometry (GC–MS) and high-performance liquid chromatography (HPLC) for the characterization and/or dating of inks has been discussed by Tebbett et al. (1992), Aginsky (1994, 1996), Andrasko (2001a), Gaudreau and Brazeau (2002), Hofer (2004), LaPorte et al. (2004), Wilson et al. (2004), and Bügler et al. (2005). In addition, spectroscopic techniques such as Fourier transform–infrared (FT–IR) and Raman spectroscopy have been studied for the characterization of inks by Humecki (1985), Merrill and Bartick (1992), and Andermann and Neri (1998). All of these instrumental methods may help

further delineate an ink formulation into its individual components, but it is not always necessary. One must take into consideration the environmental changes that can significantly affect the noncolorant components over a period of time immediately following their application to the paper. In cases where a standard reference collection is available, an ink may be determined to match a standard from a database to the exclusion of all others, and further discrimination may not be warranted.

It is critical to understand some fundamental concepts regarding the analysis of inks submitted for forensic examination. First, many inks are composed of volatile and semivolatile components that will evaporate as an ink ages. Therefore, some components that are present in a fresh sample of ink may not be detectable in an aged sample using GC–MS. Although obtaining a supplemental volatile profile may increase the degree of discrimination, limitations may include solvent loss over time or other external factors, such as exposure to high temperatures, light, and/or humidity. Therefore, caution is warranted when making interpretations of qualitative, and especially quantitative, data from instrumental techniques. In addition, there are some commonly utilized dyes that can photodecompose. Triarylmethanes (e.g., methyl violet) are one such group of dyes. They undergo a photochemical reaction that can be "influenced by the concentration of the reactants, the reaction medium, the temperature, the wavelength and intensity of the light" (Weyermann, 2005). Second, when inks are applied to a substrate such as paper, there can be numerous interfering components in the paper that can affect data interpretation. Modern papers can contain optical brighteners, resins, and fillers that can inhibit the analysis of inks. Many inks absorb into the substrate, making FT–IR a difficult methodology, due to the significant contribution of some paper components to IR spectra. Even with spectral subtraction of a paper blank, there may still be an overwhelming effect from some paper ingredients. However, these matrix challenges do not preclude use of the aforementioned technologies. Rather, the implication is that the examiner must consider these variables and the type of request when choosing the appropriate instrumental technique.

In summary, developing a single standardized analytical approach to ink analysis can be challenging, but physical, optical, and TLC examinations should be routine. GC–MS, HPLC, and FT–IR should be considered, but will be dependent on the type of ink, the necessity for further discrimination, and other practical considerations, such as the age of the document.

6.3.4 Ink Dating

Cantu (1995, 1996) has outlined analytical approaches for determining the age of an ink on a questioned document through both static and dynamic methods. The static approach to ink dating generally applies to methods that are based on comparisons with a standard reference collection of inks to determine the first date of production. Numerous ink formulations have been introduced commercially in the past several decades. With the appropriate information and documentation acquired from an ink manufacturer, a database can be used to render more reliable conclusions.

The dynamic approach includes methods that incorporate procedures for the purpose of measuring the physical and/or chemical properties of an ink that change with time. The changes that occur over a given period of time can generally be referred to as *aging characteristics*. Different approaches to measuring the age of an ink once it has been placed on a document have been discussed in the literature by Gaudreau and Brazeau (2002), Hofer (2004), Humecki (1985), Cantu (1987), Brunelle (1992, 1995), Aginsky (1993a, 1998), Andermann and Neri (1998), Brazeau et al. (2000), and Andrasko (2001b, 2003).

When an ink is applied to a substrate and begins "drying," it undergoes numerous changes due to solvent evaporation, oxidation, polymerization, and/or photodecomposition. These processes can change the chemical composition of the ink on the substrate. Given the diversity of inks, substrates, and environmental exposure factors, the complexity of determining what process or processes directly affect the rate at which the ink dries is extremely difficult. The real challenge lies in finding a suitable analytical procedure to isolate the appropriate component for analysis. Brunelle and Crawford (2003) provide a comprehensive review of various methodologies that have been attempted; however, to date, no single ink-dating procedure that has been found to be reliable for all types of inks.

The use of GC–MS for volatile analysis of ballpoint inks in an attempt to determine the age of inks on paper has been studied and reviewed in the literature for more than a decade. Much of the research on volatiles has focused on the analysis of 2-phenoxyethanol (2-PE; also referred to as ethylene glycol monophenyl ether, 1-hydroxy-2-phenoxyethane, β-hydroxyethylphenyl ether, Dowanol EP, and Phenyl Cellosolve). 2-PE is a volatile organic compound commonly used as a principal vehicle in the majority of ballpoint writing inks. Furthermore, it is used in many ink formulations because it is stable in the presence of acids and alkalis. It is nonhygrosopic, nonhazardous, economical, and especially good at dissolving resins and nigrosine (a common solvent black dye used in writing ink formulations). In 1985, Stewart conducted a preliminary study on ballpoint ink aging and the relationship to volatile organic compounds. Beshanishvily et al. (1990) were the first to discuss the identification of 2-PE as it relates to the aging of inks. Since then, Aginsky (1993b) reported that "... significant aging [takes] place over a period of about three months. After this period until the age of fifteen years the extent of the extraction of the volatile component (phenoxyethanol) from the ink entries has been kept at a level of about 20%." Aginsky also describes the ink drying process and surmises that volatile components stop evaporating from a dried sample of ink unless they are freed by heating or a solvent extraction. In 2008, Bügler et al. published a procedure for assessing the age of some ballpoint pen inks using GC–MS coupled with thermal desorption to evaluate the quantity of 2-PE.

Ideally, *ink tags* would be the most reliable method for the dating of inks. Tags can be added to formulations in the form of fluorescent compounds or rare earth elements, and were incorporated into some formulations beginning about 1970 until 1994. Factors have precluded some ink manufacturers from participating in such a program, including, but not limited to, insufficient resources, low priority, and/or disagreement about the type of tag utilized. This is not to say that a widespread

tagging agenda is unachievable. On the contrary, efforts continue to convince ink companies to add tags to their formulations. As recently as November 2002, a major ink manufacturer began adding tags to its ink in collaboration with the U.S. Secret Service.

6.4 OFFICE MACHINE SYSTEMS

For the purpose of this discussion, we have chosen to limit the discussion of office machine systems to those that utilize inkjet or toner technology because they are the most commonly encountered printing and copying devices accessible to the general public. Although documents produced via typewriting and dot matrix are not as ubiquitous as some of the other office machine systems mentioned, this does not preclude their importance in some investigations. Occasionally, physical print defects from typewriters, dot matrix, and thermal printers may arise in the printed material and should be examined carefully. Individual and class characteristics from these machines can be important identifying features.

6.4.1 Inkjet Ink

Formulating an inkjet ink to create a high-quality image is an obviously complex task. Inkjet inks for small office/home office (SOHO) machines can have very complex formulations to create acceptable images. In fundamental terms, a well-designed inkjet ink should be able to withstand high heat, dry quickly so as not to smear, have nearly photographic quality, and be light- and water-fast. Since inkjet-printed documents comprise a significant portion of all documents created in the SOHO market and ink formulations are complex, manufacturers utilize a great deal of their resources on the research and development of inks.

Inkjet ink poses several differences as compared to writing inks. Writing ink colorants are mixed together in a single ink formulation to provide a single colored line. Color inkjet, however, is a combination of multiple single-color ink formulations, and each ink formulation can contain one or more colorants. Currently, many SOHO inkjet office machine systems comprise four color printers, incorporating cyan, magenta, yellow, and black (CMYK) into a single print head. The colors can come from either a three-reservoir tricolor cartridge or three single-reservoir cartridges. Typically, the black ink formulation is independent of the colors. Small droplets of ink are jetted onto the substrate to produce a broad range of colors. Figure 6.8 shows microscopic images of inkjet printing on plastic.

Inkjet ink manufacturers typically use acid, direct, and reactive dyes in their formulations. Acid dyes (e.g., azo, anthraquinone, triphenylmethane, azine, and xanthene) are water-soluble anionic dyes that have a wide gamut of hues. Direct dyes (e.g., phthalocyanines) have a variety of bright hues, some of which are fluorescent, as well as possessing relatively good light and water fastness properties. Within the past decade, reactive dyes have been added to some formulations because they contain desired chromophores. This class of dyes link very strongly with

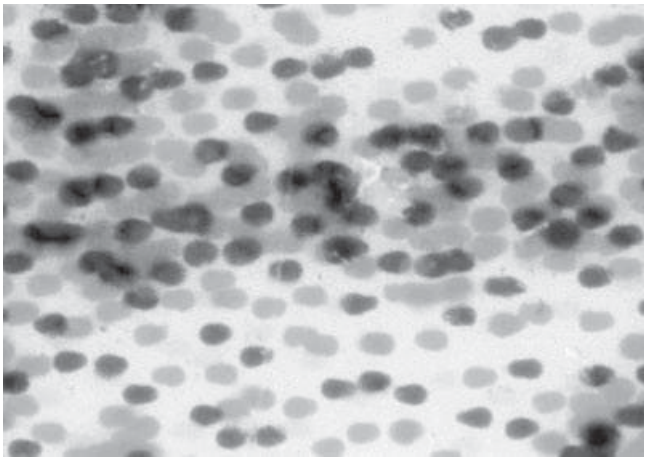

Figure 6.8 Inkjet droplets on a plastic substrate. *(See insert for color representation.)*

cellulosic fibers when heated and they are found in some magentas. Understandably, manufacturers keep their formulations proprietary, which can result in more diverse formulations and thus in greater potential for forensic discrimination. Table 6.5 is a list of various ingredients that are generally used in inkjet ink formulations.

6.4.2 Inkjet Ink Analysis

Many of the same forensic examinations that can be conducted on writing inks may also be completed for inkjet inks. Inkjet inks are typically treated as non-ballpoint pen inks, as they often share similar ink solvents and characteristics. Pagano et al. (2000) presented methodologies for the analysis of jet inks and the different chromatographic systems utilized. Furthermore, LaPorte and Ramotoski (2003) discuss how color inks vary from one manufacturer to the next, making it possible to compare with known standards. LaPorte (2004) also discusses a multifaceted approach to the examination of inkjet printed documents that encompasses physical, optical, and chemical examinations. The U.S. Secret Service maintains the largest known forensic collection of inkjet standards in the world. This collection is composed of print and inkjet ink samples for hundreds of printers and cartridges.

Physical examinations are performed on a printed document to determine the printing process employed. Using at least 10× magnification, inkjet printing appears as a series of irregularly spaced colored dots with some peripheral bleeding. As with writing inks, a FLE is often conducted on inkjet inks. As part of the optical examination, properties of IRR and IRL are noted. Some inkjet inks are formulated using dye-based colorants while others utilize pigments, either in combination or as a replacement to dyes. The selection of colorant (pigment or dye) affects the IRR and IRL properties that are exhibited by the ink. The FDE should exercise caution when evaluating fluorescence and/or absorbance characteristics since inkjet inks may be quenched or enhanced on different types of paper. Optical examinations

TABLE 6.5 Some Common Ingredients That May Be Found in an Inkjet Formulation, Their Purpose, and Approximate Percentage of the Total Weight

Inkjet Ingredient	Purpose	Composition (wt%)
Colorant	Provides the desired color and aesthetic properties	2–8
Solvent	Vehicle that dissolves or suspends the colorant (e.g., water, alcohol)	35–80
Humectant	Inhibits evaporation (e.g., diethylene glycol)	10–30
Surfactant	Lowers the surface tension of the ink to promote wetting (e.g., Surfynol 465)	0.1–2.0
Penetrant	Allows ink to penetrate fibers and promote ambient drying (e.g., pentane-1,5-diol)	1–5
Viscosity modifier	Added to increase viscosity and can be a humectant (e.g., long-chain glycols)	1–3
Dye solubilizer	Helps maintain dye solubility in the solvent because of evaporation in the nozzle (e.g., *n*-methylpyrrolidone)	2–5
Dispersant	Maintains pigment suspensions [e.g., Derussol carbon black (Degussa)]	3–8
Fixative	Helps maintain image permanence and smear resistance (e.g., water-soluble latex)	1–3
pH buffer	Maintains overall pH to promote colorant stability in the vehicle [e.g., Trizma base (Aldrich Chemical)]	0.1–1.0
Chelation agent	Used to complex metal ions (e.g., ethylenediaminetetraacetic acid)	0.1–0.5
Biocide	Kills bacterial growth in aqueous inks [e.g., Dowicil (Dow Chemical)]	0.1–0.3
UV blocker	Increase lightfastness [e.g., Tinuvin 171 (Ciba-Geigy)]	1–5

can sometimes demonstrate that two or more different inkjet formulations were used to prepare a document(s), but this does not necessarily mean that multiple printers were utilized. It is possible for a single printer to use more that one type of inkjet cartridge or for a cartridge to be refilled with a different ink. Some companies, other than the original manufacturer of an office machine, produce compatible cartridges and ink for aftermarket use that are chemically different from those of the original equipment manufacturer (OEM).

Forensic analysis of inkjet inks centers around TLC. In addition to the physical and optical examinations, chemical analysis is an efficient analytical method for classifying inkjet inks. It is important to note that inkjet individualization based on colorant combinations is extremely difficult, due to the interchangeability of inkjet cartridges. Manufacturers often utilize the same dye combinations through several designs of ink cartridges. Given the complexity of the ink, gross changes in formulation are rare. Investigative research on inkjet inks has shown that plastic-backed

TLC plates seem to be as, if not more, efficient at separating the colorants over a fixed distance. Therefore, most TLC comparisons of inkjet inks are completed on plastic-backed TLC plates. It is critical that TLC plates be visualized with an UV source, minimally short wave (254 nm) and long wave (366 nm), since some inkjet inks incorporate proprietary rhodamine dyes.

TLC is only one of several chemical techniques used for examining inkjet inks. However, there has been limited research focusing on other methods of instrumental analyses. Mazella (1999) used diode array MSP to measure the cyan and magenta components in the range 380 to 760 nm on 70 different brands and models of inkjet printers. Doherty (1998) performed a battery of chemical tests, including tests for waterfastness, solubility, and TLC, on documents produced with various inkjet printers. To date, this has been the most comprehensive study on the examination and classification of office machine systems that utilize inkjet technology.

6.4.3 Toner Printing

Laser printers and photocopiers commonly utilize a resinous, powderlike material referred to as *toner*, which is fused to the paper using heat and/or pressure. Toners consist primarily of organic resins, polymers, and colorants such as carbon black, nigrosines, phthalocyanines, azo-pigments, and quinacrodone (Pagano, 2000). Although manufacturers have a selection of resins to choose from, styrene acrylate copolymer and polyester resins are frequently used. Liquid toners, which are often formulated with a hydrocarbon carrier solvent to deliver extremely fine particles to the substrate surface before the liquid evaporates, can also be utilized. Particle-size ranges are approximately 1 to 3 μm for liquid toner and from 6 to 18 μm for dry toner. The size of the toner particle obviously affects the maximum print resolution.

Laser printers and photocopiers function similarly, such that each contains a rotating drum with a photoconductive coating. The surface of the drum is illuminated by a light source controlled by a series of signals based on the image, causing the exposed areas to be charged. As the drum rotates, oppositely charged toner is deposited, thus adhering to the illuminated areas that have been charged with a positive potential. When the paper passes through the machine, an electrical current imparts a static electrical charge onto the paper. The paper then passes through a series of rollers and comes in contact with the rolling drum, causing the toner to be transferred to the paper, resulting in the creation of text or image(s). Since the nonimage areas of the drum are not charged, they do not attract oppositely charged toner and result in white areas on the paper. Afterward, heat and/or pressure is applied to fuse the toner permanently. For a multicolored process, the same steps are repeated for each color component (i.e., cyan, magenta, and yellow).

Two different types of toner are currently produced: conventional toner and chemically prepared toners (CPTs) (Figure 6.9). Conventional toners are created by mixing the colorant(s) into a large batch of polymer. The fine toner powder is then broken away from the large homogeneous mass. CPTs, on the other hand, are grown chemically from small particles. CPTs have gained favor in recent years

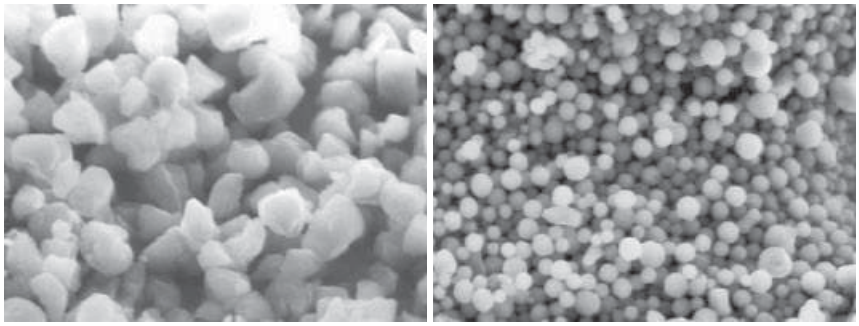

(a) (b)

Figure 6.9 (a) Conventional toner. (b) Chemically prepared toner. *(See insert for color representation.)*

due to their more uniform particle-size distributions and shapes. The CPT process allows smaller toner particles to be generated, affording CPTs higher resolutions than conventional toners.

Black toners can be differentiated further based on whether they are mono or dual component. Monocomponent toners incorporate the colorant and the resin into the same large particle. To do so, Fe_xO_y is often used, giving the monocomponent toner a magnetic property. Dual-component toners are typically composed of smaller toner particles and larger developer particles. Although some dual-component particles have magnetic properties, they are not as strong as monocomponent toners. Since dual-component toners have smaller toner particle sizes, they provide better resolution.

6.4.4 Toner Analysis

The analytical scheme for analyzing toners will depend on whether an extensive library is available or if the request is simply to compare a questioned document with other documents or a known printing device. At this time, we are not aware of an extensive collection of black toners that are used for law enforcement purposes, but this does not preclude the possibility that a laboratory has its own internal collection. Various instrumental approaches can be used to analyze toners, and potentially to create a collection of standards, such as pyrolysis GC–MS (Munson, 1989), FT–IR (Andrasko, 1994), x-ray fluorescence (XRF), and SEM–energy-dispersive spectroscopy (SEM–EDS). TLC can also be used to analyze toners and may prove beneficial when conducting comparisons between multiple documents or suspect office machines. Toners can be extracted with chloroform to characterize extractable colorants from the CMY and black components. Given that a number of black toners are carbon black, the forensic value of TLC analysis of black toner can be minimal; however, there are other dyes used in combination with carbon black that may be visualized on a TLC plate. It is highly recommended to visualize developed TLC plates using an UV source. Most important, the results can be used to corroborate other tests and findings.

TLC can be followed with additional methods, but it is critical to understand that the analytical procedures described are not sufficient to individualize a specific printer or copier. It is possible that a manufacturer, or even model, may be distinguished; however, the results are only good enough for discrimination at the class level. XRF analysis can be useful in providing the elemental composition of the toner. The presence and percentage concentration of iron is often a distinguishing factor.

Determining that a toner is iron based (monocomponent) can also be of forensic value, and an excellent area of further research is investigating if quantitative elemental analysis (e.g., Fe) can be used to discriminate toners from different manufacturers or models from the same manufacturer. Scanning electron microscopy (SEM) is also a useful analytical technique, as it provides the high magnification necessary for examining fusing characteristics. Additionally, the method of production used in making the toner can be surmised based on quality images of particle morphology. Given that CPT toners have seen significant use only in the past decade or so, determining that a toner is a CPT is an excellent method for roughly dating a document.

Brandi et al. (1997) offer an extensive discussion and study of toner analysis using diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS), SEM–EDS, and pyrolysis gas chromatography (PyGC). They concluded that DRIFTS was highly discriminating, sensitive, and reproducible after 55 different toners were classified into 15 distinct classes. SEM–EDX was also used to analyze the inorganic contents of 50 toners, subsequently placed into 22 separate classes. The best approach was the combination of the aforementioned techniques, resulting in the characterization of 30 distinct groups of toners. Finally, the authors concluded that "PyGC, with the equipment available, did not appear to provide any greater differentiating power than infrared spectroscopy, gave poor reproducibility, and was a time consuming technique." However, they do acknowledge that a better pyrolysis technique and the use of a mass spectrometer would result in a more discriminating method.

CONCLUSION

The chemical analysis of questioned documments has been relied upon in forensic laboratories for over 50 years. TLC has proven to be a reliable method for the discrimination and identification of some writing and printing inks, especially when used in conjunction with a reference collection. GC–MS is an excellent supplemental procedure and may provide additional information about other components, but the interpretation of the chromatographic and spectral data must be approached with great caution. Inks undergo a drying process that can take place over several months or, possibly, years. Moreover, inks have variable compositions, making the drying processes of different inks nonuniform. This property, in combination with the unknown ink–paper interactions when combined with different substrates and not knowing the storage conditions of a questioned document, result in significant

challenges when attempting to characterize and date inks using GC–MS. HPLC and FT–IR can provide additional molecular information, but there has been limited research in the areas of dating inks and characterizing non-ballpoint and printing inks via these methods. Office machines that utilize inkjet and toner technology are ubiquitous and commonly the focus of investigations involving a multitude of crimes. The approach to chemical analyzing inkjets and toners is similar to procedures used for writing inks such that physical, microscopic, and TLC examinations should be a minimum. The gamut of instrumental approaches that follow can vary depending on previous results and the extent of discrimination needed to formulate a reliable conclusion, but it must be recognized that in nearly all cases, the data obtained will not support a conclusion that identifies a particular writing instrument or printing device. Although the information that can be attained from printing and writing inks is based on reliable and generally acceptable analytical methods, it is critical that any person conducting the tests described in this chapter have sufficient training in the physical and microscopic examination of documents. The results from the physical exams help determine how to proceed with chemical methods of analysis, but more important, the combination of all results is necessary to draw relevant and useful conclusions.

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CHAPTER 7

The Role of Vibrational Spectroscopy in Forensic Chemistry

ALI KOÇAK

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Summary Spectroscopy is the study of the interaction of electromagnetic radiation with matter to determine the molecular structure of a solid sample or one dissolved in a specific solvent. This interaction depends on the intrinsic properties of the sample material and can be classified by the energy of the probing electromagnetic radiation. Energy can be in the form of ultraviolet, visible, or infrared light, as well as other forms of energy. One can detect transmitted, absorbed, and/or reflected light. Due to the wide scope of samples typically found in a forensic investigation, a variety of spectroscopic techniques may be needed. Infrared spectroscopy is a good technique to use to identify fibers such as acrylics, nylons, or polyesters, or paints or alkyds, acrylics, or nitrocellulose. The size of the sample may require the use of microscopic infrared spectroscopy, and the nature of the sample may indicate the use of external reflection spectroscopy or attenuated total reflectance spectroscopy. In the chapter we review these techniques as well as related methods of sample identification.

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7.1 INTRODUCTION TO VIBRATIONAL SPECTROSCOPY

Molecular spectroscopy is the study of interaction of electromagnetic radiation with matter to elucidate information on molecular structure and dynamics, the environment of the sample molecules and their state of association, interactions with solvents, and many other topics (Graybeal, 1988; Colthup et al., 1990; Schrader, 1995). This interaction depends on the intrinsic properties of the material, classified by the frequency range (energy) of the probing electromagnetic radiation, such as ultraviolet–visible (UV–Vis), infrared (Kocak et al., 2006).

The intrinsic properties of a material that govern its interaction with electromagnetic radiation are described by its complex refractive index (Kocak et al., 2006). Usually represented as having a real part, the *refractive index*, and an imaginary part, the *absorption index*. The complex refractive index of a material is a function that describes the response of the material to the electromagnetic radiation applied. The refractive and absorption indices are both functions of the frequency of the electromagnetic radiation applied (Kocak et al., 2006). Different spectroscopic probes are used to observe and measure the interactions between material and the radiation applied. These measured observables (e.g., transmittance, reflectance, emittance), which are in principle expressible in terms of the intrinsic properties of the material, the molecular composition of the substance, and the wavelength of the illuminating radiation, will determine the type and nature of the spectroscopic technique selected. Due to the wide scope of samples under investigation, a variety of spectroscopic techniques are needed. Selection of the appropriate technique will minimize the time needed for analysis and investigation (Diem, 1993; Schrader, 1995; Mirabella, 1998).

Molecules consist of atoms that have a certain mass, which are connected by elastic covalent bonds. As a result, they can perform periodic motions and continual vibrations relative to each other. The energies associated with these vibrations are quantized; within a molecule, only specific vibrational energy levels are allowed (Colthup et al., 1990; Levine, 1991). For a molecule to absorb radiation, the frequency of the illuminating electromagnetic radiation must match the natural frequency of a bond vibration (Colthup et al., 1990). This phenomenon is similar to the example of a child on a swing: energy is transferred to the swing only if the frequency and the phase of the energy delivered match the frequency of swing movement.

This field of spectroscopy in which the vibration of molecules is involved is called *vibrational spectroscopy* (Colthup et al., 1990; Diem, 1993; Schrader, 1995). Vibrational spectroscopy involves different methods, the most important of which in observing the vibration of molecules are infrared and Raman spectroscopy. Depending on the nature of the vibration, which is determined by the symmetry of the molecule (Cotton, 1990); vibrations may be active or forbidden in the infrared or Raman spectrum (Cotton, 1990; Levine, 1991; Diem, 1993).

The infrared and Raman spectra of two molecules are different depending on whether these molecules have, for whatever reason, different constitutions, isotopic distributions, configurations or conformations, or environments (Diem, 1993; Schrader, 1995). Vibrational spectroscopy detects the characteristic vibrational frequencies of molecules, which provide detailed information about chemical bonding and hence the molecular structure. Consequently, its most common application is in the analysis and identification of small particles. As such, the technique lends itself easily to the study of forensic materials such as controlled drug substances, automotive paint chips, inks, fragments of polymers, textile fibers, papers, inorganic compounds, adhesives, and explosives. In this chapter we describe different sampling techniques and methods involved in both infrared and Raman spectroscopy, along with their forensic applications.

7.2 INFRARED SPECTROSCOPY

Infrared spectroscopy is in principle based on arrangements similar to those of any other spectroscopy: a radiation source, such as globar or another infrared-emitting source, is directed at a sample (Kocak, 1998; Griffiths and de Haseth, 2007). This infrared radiation, which is in the mid-infrared-region range (approximately (400 to 4000 cm^{-1}), interacts with a molecule and its chemical bonds (see Figure 7.1). Most organic functional groups have vibrational and rotational frequencies in the mid infrared region. After interaction with the sample, the infrared radiation is collected by an infrared-sensitive detector, such as a deuterated triglycine sulfate (DTGS) or mercury cadmium telluride (MCT) detector (Kocak, 1998; Griffiths and de Haseth, 2007) and in infrared imaging, a focal-plane array (FPA) detector (Lewis and Levin, 1995).

In classical dispersive infrared instrumentation, a Czerny Turner monochrometer (Ingle and Crouch, 1988; Strobel and Heineman, 1989; Skoog et al., 2007) is used to disperse the infrared light into a single wavelength to plot the spectrum of intensity versus wavelength or wavenumber (Ingle and Crouch, 1988). In modern Fourier transform instrumentation, a Michelson interferometer is used. Based on the development of interferometry, Michelson developed the interferometer in 1880 to study the speed of light (Kocak, 1992; Griffiths and de Haseth, 2007). Using the Michelson interferometer, an interferogram is created by the interference of two or more radiation beams (Ingle and Crouch, 1988; Kocak, 1998; Griffiths and de Haseth, 2007). As a result, all frequencies are detected at once in the time or distance domain. The two domains of time or distance and frequency

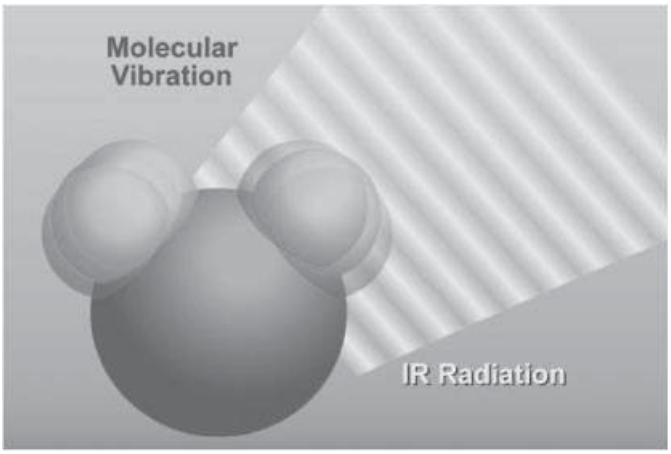

Figure 7.1 Basic principles of IR spectroscopy. *(See insert for color representation.)*

contain the same essential information, and they are interconvertable by fast Fourier transformation (Kocak, 1998; Griffiths and de Haseth, 2007). The spectrum is then plotted as intensity versus wavelength or wavenumber.

Infrared spectroscopy is an important technique for the identification of a class of compound groups or an individual compound present within a specimen. For example, it can be used to identify fibers as acrylics, nylons, or polyesters, or paints as alkyds, acrylics, nitrocellulose, and so on (Kirkbride, 2000). It has a great advantage over other techniques in its ability to obtain structural information that might be difficult to elicit using other techniques. Spectral data representing absorption at specified wavelengths of infrared light characterize chemical and structural groups within the sample, thus providing a molecular "fingerprint" and a tool for sensitive and fast sample composition determination. This allows the technique to be used in the characterization of stereoisomers. For example, it can be a very efficient technique to discriminate between positional isomers of aromatic substances such as various isomers of dimethoxyamphetamine or trimethyl benzene, as well as between other stereoisomers: for example, the isomeric group cocaine, or the group butyl nitrate, isobutyl nitrate, or isoheroin and heroin (Kirkbride, 2000). In drug determination, infrared spectroscopy can be an important tool to distinguish between a free organic and a salt because they have different spectral properties. The N—H stretch in an amine salt is found between 2500 and 3000 cm^{-1}, whereas the N—H stretch in its free base is above 3000 cm^{-1}. Therefore, the spectral properties for drug free bases and their salts are very different within the frequency range of N—H stretch (Kirkbride, 2000; Alzate et al., 2006).

The limit of detection for this technique is usually in the microgram range; this limit may be lowered by using microscope infrared techniques (see below). The technique is relatively rapid and requires minimal sample preparation, which makes it economical and time efficient.

7.3 INFRARED SAMPLING TECHNIQUES

7.3.1 Transmission Spectroscopy

The term *transmission spectroscopy* is used to denote the qualitative and quantitative measurement of the transmittance or absorbance of a material as a function of the wavelength or wavenumber (Ingle and Cronch, 1988; Mirabella, 1998; Griffiths and de Haseth, 2007). The technique involves passing a parallel beam of infrared light through a sample placed in the light beam of the spectrometer, and the *transmittance* of the radiation is measured (see Figure 7.2). This relationship between the incident electromagnetic beam and the pathlength and the concentration of absorbing media is described by Lambert–Beer's law (Swinehart, 1962):

$$A = -\log \frac{I}{I_0} = abc$$

where A is the absorbance, I the intensity of the light, a the absorptivity or extinction coefficient, b the length of the beam in the absorbing medium, and c the concentration of the absorbing species. The resulting spectrum depends on the pathlength or sample thickness, the absorption coefficient of the sample, the reflectivity of the sample, the angle of incidence, the polarization of the incident radiation, and, for particulate matter, on particle size and orientation.

Transmission spectroscopy was the only method in general use until the early 1960s. Thus, large libraries of transmission spectra are readily available. These are frequently used for comparison of spectra obtained by other techniques, even though the frequency response differs between techniques, depending on factors described below. This technique can be used for solid, liquid, and gas sampling. However, to produce useful spectra, in many cases the analyst must engage in a careful and sometimes lengthy sample preparation. The choice of the sample compartment, or cell, is ofen critical. This can cause variations in peak shapes and intensities; for example, a small bubble in a liquid cell will distort intensity ratios (Harrick Scientific Corp., 1987; Mirabella, 1998).

7.3.2 External Reflection Spectroscopy

External reflection spectroscopy is the application of infrared spectroscopy on the characterization of the light reflected from a smooth surface, such as metals, semiconductors, and liquids (Harrick Scientific Corp., 1987; Mirabella, 1998; Humecki,

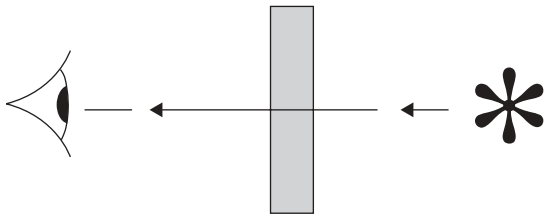

Figure 7.2 Transmitted light as a function of the material and wavelength.

1995). This technique can analyze two classes of samples. The first consists of a highly reflecting substrate (usually, a metal) upon which a material has been deposited (films, contaminants, etc.). The sample beam is reflected from the metal and interacts with film. Since the metal is largely noninteracting, the result is actually an absorption spectrum of the film. This application is sometimes referred to as *reflection–absorption* or *double transmission* (Schrader, 1995; Mirabella, 1998; Griffiths and de Haseth, 2007). A second type of external reflection study is referred to as *specular reflection*, which is the front-surface reflection from the exterior surface of a material. In specular reflection the angle of reflection equals the angle of incidence. These angles are measured from the normal to the reflecting surface. In practice, most external reflection experiments involve a combination of reflection–absorption and specular reflection components from the sample. Since spectral features will differ in the two, it is important to consider these possibilities when interpreting external reflection spectra.

External reflection spectra depend on polarization, angle of incidence, and the substrate's optical properties (see Figure 7.3) (Kortüm, 1969; Harrick Scientific Corp., 1987). The sensitivity of reflected light increases with p-polarized incident light; the phase shift of the reflected light varies with angle of incidence, and hence at large angles of incidence with p-polarized light an optimum sensitivity is obtained. For s-polarized light, the electric field at all angles of incidence has very small values at the interface, resulting in less sensitivity (Harrick Scientific Corp., 1987).

To convert reflectance spectra into absorption-like proportional spectra a Kramers–Kronig transformation (Kocak et al., 2006) should be employed, which is easy to accomplish nowadays, owing to readily available software and computerized spectrometers. Because reflection methods require little or no sample preparation, they are used as frequently as traditional methods. It is a nondestructive method for the measurement of surfaces and coatings without sample preparation. In forensic science it is useful to analyze and distinguish illicit drugs such as cocaine. Koulis et al. (2001) collected and compared the external reflection spectra of cocaine salt and cocaine base.

7.3.3 Attenuated Total Reflectance

The use of internal reflection in infrared (IR) spectroscopy was first suggested by Fahrenfort and Harrick independently in 1959 (Harrick, 1987; Mirabella, 1998). In

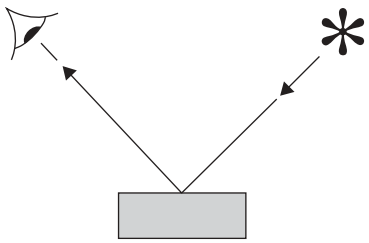

Figure 7.3 External reflection.

the internal reflection mode, an infrared transmissive material with a higher index of refraction than the sample is brought into contact with the sample. The higher-refractive-index material is defined as the internal reflection element (IRE). Typical IREs are ZnSe (refractive index: 2.4), Ge (refractive index: 4.0) and diamond (refractive index: 2.4). In most forensic applications, diamond internal reflection elements are used since they are more durable.

The radiation from the spectrometer's source is directed onto the interface between the sample and the IRE at an incident angle such that the radiation is totally internally reflected (see Figure 7.4). This process causes what is referred to as an *evanescent wave* to be produced a few micrometers beyond the surface of the IRE (Harrick, 1987; Schrader, 1995; Griffiths and de Haseth, 2007). The evanescent wave is absorbed and attenuated by the sample at the characteristic wavelength corresponding to an IR absorption band, producing an attenuated total reflectance (ATR) spectrum. Because the magnitude (the depth of penetration) of the evanescent wave is small, only a few micrometers, ATR is a surface analytical technique and particularly useful for strongly absorbing or thick samples. Several factors can affect the depth of penetration, such as the refractive index of the sample and the crystal, the angle at which the radiation is brought into the crystal, and the wavelength of the radiation (Harrick, 1987; Harrick Scientific Corp., 1987; Griffiths and de Haseth, 2007). Data obtained from ATR measurements are different from the data obtained in transmission measurements. Therefore, they should be compared only for general qualitative purposes. It is worth noting however, that these differences between the two techniques are caused by optical differences rather than compositional ones.

In contrast to external reflection spectroscopy, which requires smooth surface properties, ATR spectroscopy can be used for any surface brought into intimate contact with the internal reflection element. The technique has found a large scope of applications for the analysis of a variety of sample types in a wide spectral range.

For forensic applications, ATR can be utilized in the analysis of pressure-sensitive adhesive tapes (Merrill, 2000). Duct tapes are used in binding victims of violent crimes, and other tapes can be used in packing drugs and illegal materials. Using ATR spectroscopy the major chemical components of these can be determined and leads to the characterization of tapes submitted as evidence to determine if two samples are similar or distinguishable. The brand and the origin

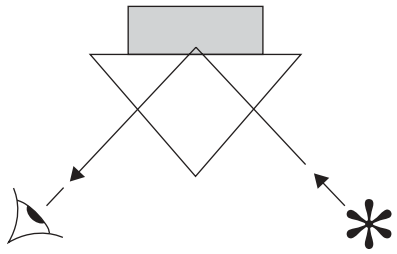

Figure 7.4 Attenuated total reflectance.

of these tapes can also sometimes be determined. It is worthy to note that ATR is a nondestructive technique. However, it may be semidestructive in some cases because the pressure applied to establish a good contact between the sample and the crystal may crush the sample.

7.3.4 Diffuse Reflectance Spectroscopy

Diffuse reflectance is the radiation that penetrates a specimen to a shallow depth and reemerges after scattering off within the sample. It is based not only on reflection and refraction but also on diffraction. These emerging photons from the sample will be collected and analyzed using an infrared detector (see Figure 7.5). Since scattering of the radiation within the sample is an essential phenomenon of the diffuse reflectance technique, it is suitable for inhomogeneous samples that exist as powders or can be converted to powder form. This technique permits the sampling of a solid that has been properly reduced in size, either neat or mixed ($\sim$10%) with nonabsorbing powder such as KBr or KCl. The process requires grinding and diluting the sample with KBr or KCl to ensure deeper penetration of the incident light into the sample (Harrick Scientific Corp., 1987; Schrader, 1995; Mirabella, 1998).

The diffuse reflectance technique offers the advantage of having a wide solid sampling range; this in particular is useful when a very wide range of solid samples need to be analyzed, as in forensic laboratories. Suzuki and Gresham (Suzuki et al., 1986b) demonstrated a broad study for the use of the diffuse reflectance technique in forensic analysis. They analyzed the antidepressant drug Alprazolam and obtained the spectral results at two extreme concentrations with a lower limit of 20 μg. In general, the diffuse reflectance technique offers several advantages, among them minimal sample preparation, a high degree of sensitivity (less than 100 ng in some cases), and its suitability for very weakly absorbing samples.

Kubelka and Munk (Suzuki et al., 1986a) were first to describe the effect on paint layers of the pigment particles or other scattering inclusions. This model leads to the well-known Kubilka–Munk equation, which is used for the conversion of the measured reflectance spectrum to an absorption-like proportional representation. Almost all modern Fourier transfer (FT)–IR instrument software packages now contain this conversion program.

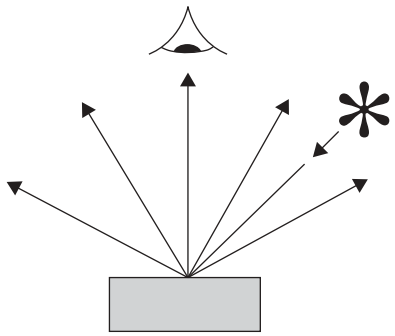

Figure 7.5 Diffuse reflectance.

7.3.5 Infrared Microspectroscopy

The conventional light microscope is an important analytical instrument that is used frequently by forensic scientists, and they are familiar with the technique. It is used in the examination of criminal evidence, including illicit drug crystals, paints, hair and textile fibers, bullets, and documents. These microscopic images are powerful data for the legal evidence, and people without technical backgrounds may have some understanding of the interpretation of the data.

The difficulty that may occur is in distinguishing data obtained from a visual microscope: when, for example, two colored fibers may appear similar under microscopic analysis but are actually stained with two different dyes; or two textile fibers may appear similar under visual microscopical analysis but differ in their molecular composition. A cross section of a polymer may show a uniform microstructure but may have gone through photooxidative degradation.

Combining a conventional light microscope with infrared spectroscopy techniques enables an analyst to obtain an infrared spectrum, or "molecular fingerprint," of a sample and overcome the difficulties of discriminating the molecular differences mentioned above (Katon and Sommer, 1992; Griffiths and de Haseth, 2007). Using infrared microspectroscopy, it is easily possible to obtain high-quality infrared spectra for chemical composition of an unknown substance as small as about micrometers in area. This enables the analyst to obtain the spectral mapping of the specimen and identify the area within. Spectral mapping involves collecting spectra within a region of a sample while maintaining the spatial resolution inherent in infrared microscopy. Spectra collected at a series of positions can be located spatially within the sample. By mapping these data with respect to a particular band of infrared light, the spatial distribution of the specific chemical components in the sample can be obtained.

Application of IR spectral mapping can readily define the presence and distribution of components of a nonhomogeneous specimen (e.g., drug distribution in human hair). This area of research has been the subject of considerable work, and many interesting results have been obtained (Kalasinsky, 1993). Microscopic probing of small areas within longitudinally microtomed hair sections provides a profile of deposition of a drug along a growth line, and thus individual hairs may reveal the hydrophobic or hydrophilic characteristics of a substance.

Infrared microspectroscopy can record specular, diffuse, internal, or ATR spectra in addition to conventional transmission techniques. It is only the sample itself that determines the choice of the type of analysis technique. Infrared microscopy can be employed in the analysis of small samples of paint, as from motor vehicle accidents; in the case of hit-and-run offenses, for example, one may find small paint chips on the clothes of the victim. A paint chip is embedded and a thin section is produced on a microtome and analyzed. This paint chip analysis can lead to identifying the car type, model, and production year by searching the car paint chip library. Other forensic examples could be single textile fibers as evidence of contact and concentrated extracts of low-dosage drugs (Krishnan and Hill, 1990).

7.4 RAMAN SPECTROSCOPY

Like infrared spectroscopy, Raman spectroscopy probes the vibrational states of complex molecules. However, in Raman spectroscopy the excitation mechanism is different from that of infrared spectroscopy. Raman is concerned with the scattering of radiation by the sample rather than absorption of radiation (Herzberg, 1945; Gerrard, 1994; Schrader, 1995). In a Raman spectrometer the sample is irradiated with an intense source of a monochromatic (laser beam) light with much more energy than that required to cause a transition between vibrational energy states. Since the energy of the illuminating radiation does not correspond to a molecular energy level, no absorption transition will occur. This type of interaction between the illuminating light and the molecule, where no absorption takes place, is called *scattering* (see Figure 7.6). This type of scattered light, which produces photons with the same energy, or color, as exciting radiation is called *Rayleigh scattering* (Gerrard, 1994; Schrader, 1995).

In Rayleigh scattering there will be an elastic collision between the incident photon and the molecule. Since as a result of this type of collision the rotational and vibrational energy of the molecule is unchanged, the energy and therefore the frequency of the scattered photon is the same as that of the incident photon. This appears as the strongest component of the scattered radiation. In 1928, C. V. Raman described another type of scattering, now known as the *Raman effect*. Raman scattering, however, occurs when the molecule does not return to the same energy level from which it originated but ends up in the excited state. As a result, the scattered photon no longer has the same energy or frequency as that of the exciting photon. The Raman effect can be described as an inelastic collision between the incident photon and the molecule where, as a result of the collision, the vibrational and rotational energy of the molecule is changed by an amount ΔE, where ΔE is the difference between incident and scattered radiation. This change will cause a small

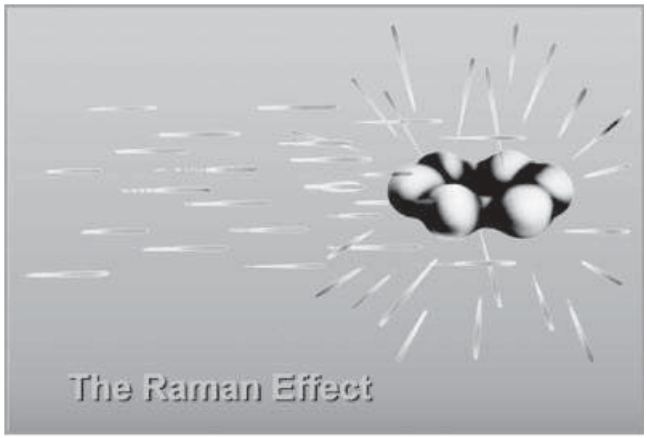

Figure 7.6 The Raman effect: Illuminating light is not absorbed but is scatterred. *(See insert for color representation.)*

fraction of the scattered radiation to exhibit shifted frequencies that correspond to the sample's vibrational transitions. Lines shifted to energies lower than the source are produced by ground-state molecules, while lines at higher frequency are due to molecules in excited vibrational states. These lines, the result of inelastic collision of the light with the sample, are called *Stokes* and *anti-Stokes bands*, respectively. Since molecules of the sample are in the ground state, at room temperature less energy from the source radiation is more favorable than energy gain, and the Stokes band is more intense (see Figure 7.7) (Herzberg, 1945; Diem, 1993; Gerrard, 1994; Schrader, 1995).

The strength of the Raman signal is weak and is inversely proportional to the fourth power of the wavelength of the incident radiation. Therefore, in Raman it is desirable to utilize radiation of relatively short wavelength in the visible region. This may induce fluorescence in the specimen. Fluorescence is likely to block the weak Raman signal and is highly undesirable. A red He–Ne laser (at 632 nm), near-infrared (NIR) diode laser (at about 785 nm), and an Nd:YAG laser (at 1064 nm) can be employed to somewhat reduce this problem and to inhibit fluorescence effect (Turrell and Corset, 1996).

Although both Raman and IR spectroscopy methods probe vibrational states of a specimen, they are both used for qualitative analysis and for molecular structure elucidations, the mechanism of origin of the two techniques is completely different and the two do not produce identical spectra. Infrared absorption can be detected

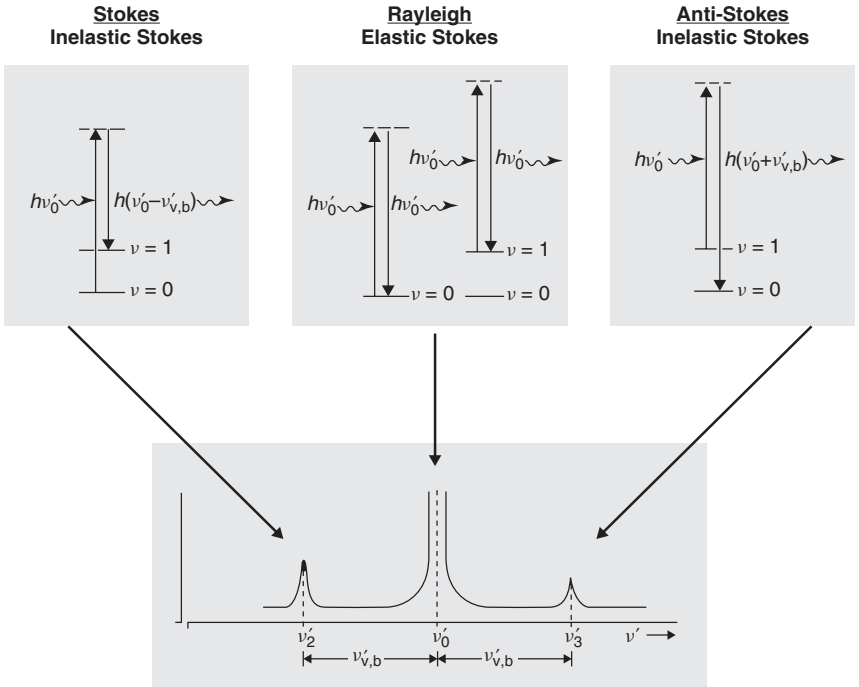

Figure 7.7 The Raman principle. *(See insert for color representation.)*

if the dipole moment in a molecule is changed during the normal vibration. The intensity of an infrared absorption band depends on the change in the dipole moment during this vibration (Colthup et al., 1990).

A Raman active vibration, on the other hand, can be detected if the polarizibility in a molecule is changed during the normal vibration (Colthup et al., 1990; Schrader, 1995). The polarizibility is a measure of how readily the electrons within the molecule are displaced by the electric field of the incident light. The intensity of a Raman band depends on the change of polarizibility during the vibration (Colthup et al., 1990; Schrader, 1995). Therefore, infrared spectroscopy is a very useful probe for those molecules that contain functional groups such as C—O, C—N, N—H, and O—H. Infrared spectroscopy provides little information on nonpolar bonds such as C—C, C═C, and N—N. Raman spectroscopy, on the other hand, can provide useful information in relation to polarizibility of the bond. Nonpolar bonds, particularly double and triple bonds, yield strong Raman bands. Therefore, Raman is considered to be more useful in fiber identification and comparison, as most fibers are composed of long chains of C—C bonds or aromatic rings. Also, Raman techniques are useful for many dyes and pigments, such as aromatic rings or azo linkage.

Raman spectroscopy has several advantages in the analysis, which can be difficult with IR spectroscopy, particularly when dealing with samples of forensic evidence where the chance of losing or destroying the sample is critical. This is particularly important when analyzing fiber samples mounted on a glass slide for visual microscope analysis. Light microscopy analysis requires embedding the sample on a glass slide. Because glass absorbs strongly in the infrared, the fiber needs to be removed from the slide and cleaned prior to IR analysis. This may involve a high risk of losing a evidentiary sample. In Raman spectroscopy, however, one can analyze the sample directly without removing it from the slide (Bartick, 2002).

Raman spectroscopy has long been utilized in forensic research laboratories. However, recent advanced developments in instrumentation have brought about its use in forensic laboratories. The instrumentation has advanced significantly over the last 10 years compared to what it was 20 to 30 years ago. The spectrum can be acquired more rapidly and the technique has become more sensitive and easier to use. During the last few years, Raman spectroscopic imaging has become one of the most popular topics of spectroscopy.

7.5 RAMAN SPECTROSCOPIC TECHNIQUES

7.5.1 Surface-Enhanced Raman Spectroscopy

Surface-enhanced Raman spectroscopy (SERS) is a Raman spectroscopic technique that provides greatly enhanced Raman signal (typically, 10^3- to 10^6-fold) from Raman-active analyte molecules that have been adsorbed onto colloidal metallic surfaces (e.g., on colloidal Ag prepared with citrate), in the particle-size range 25 to 500 nm (Diem, 1993; Schrader, 1995; Campion and Kambhampati, 1998). The importance of SERS is its surface selectivity and high sensitivity. Conventional

Raman spectroscopy is insensitive for surface studies because the photons of the incident laser light simply propagate through the bulk, and the signal from the bulk overwhelms any Raman signal from the analytes at the surface. SERS selectivity at the surface overcomes this problem.

Surface-enhanced Raman scattering arises from two mechanisms: electromagnetic and chemical enhancement. Usually, the electromagnetic effect is dominant, the chemical effect contributing enhancement only in the range of an order or two of magnitude, but this depends on the surface features of SERS-activated substrate (Campion and Kambhampati, 1998). Electromagnetic enhancement is dependent on the presence of the metal surface's roughness features, while chemical enhancement involves changes to the adsorbate electronic states due to chemisorption of the analyte. The magnitude of the electromagnetic enhancement also depends on the intrinsic characteristics of the metal: Ag, Cu, Au, Pt, and so on. The magnitude of electromagnetic enhancement may vary for each of them. The potential used (i.e., the voltage) will also have an effect on both the electromagnetic and chemical mechanisms of enhancement.

7.5.2 Resonance Raman Scattering

Resonance Raman enhancement occurs if the energy of the photon of the exciting laser beam is close to the energy of an electronic transition of the sample. Intensity enhancement can occur by a factor of 10^2 to 10^6 compared with normal Raman scattering (Diem, 1993). Resonance Raman is used in forensic chemistry to achieve detection limits of 10^{-6} to 10^{-8} M.

7.5.3 Coherent anti-Stokes Raman Spectroscopy

In coherent anti-Stokes Raman spectroscopy (CARS), the sample is illuminated by two lasers, one of them with a fixed wavelength, usually referred to as the *pump laser*, and a second tunable laser beam, referred to as the *Stokes frequency*. The pump beam excites the molecule to the first virtual Raman level. The second laser, a tunable probe beam, stimulates the Stokes transition. The pump then again excites the molecule to a higher virtual level, but starting from the higher vibrational state. Finally, the molecule decays back to the ground state, emitting an anti-Stokes photon (Diem, 1993). CARS produces the same Raman signals as those of conventional Raman spectroscopy, but at levels four to five orders of magnitude greater.

7.5.4 Confocal Raman Spectroscopy

Confocal Raman extracts information about the interior of a sample, pinpointing the exact location of an element embedded inside a sample (Everall, 2004a, 2004b). Laser radiation is focused on a spot with the help of a microscope objective. Advantages of confocal Raman are (1) that it extracts information from a small point within the interior of a large sample, (2) that there is better axial and lateral

resolution than with a conventional microscope, (3) that stray light is rejected, which avoids interference and eliminates fake peaks, and (4) superior rejection of fluorescence.

7.6 APPLICATIONS OF VIBRATIONAL SPECTROSCOPY IN FORENSIC ANALYSIS

Vibrational spectroscopy has long played a significant role in both research and applications of forensic science. Indeed, the technique has become one of the important tools in many fields of forensic science. A wide range of applications to physical evidence involved in crime investigations have been developed, including examining everything from drugs and paints, fibers, explosives, polymers, and inks to documents. Vibrational spectra has also been an effective tool for analyzing samples collected from crime scenes, such as blood, fabrics, and soil particles.

De Gelbder et al. (2005) utilized the Raman spectroscopy technique for the analysis of automotive paints to determine the origin of the paint and hence the type of automobile. Determining the origin of the paint is important forensic evidence in many car accidents, particularly in hit-and-run cases.

Several researchers have used vibrational spectroscopic techniques to analyze other types of paints, including white household paints (Bell et al., 2005), which are considered important forensic evidence. However, unlike automotive paints, which can be distinguished by color or type, many household paints cannot be distinguished based on color because they are white. Therefore, the composition of the paint needs to be discriminated, and Raman spectroscopy is a useful tool for this purpose. Bell et al. (2005) have demonstrated that Raman spectroscopy has a considerable potential for the analysis of white paints.

Vibrational spectroscopy is an effective tool for an analysis of evidence samples for the presence of explosive materials, and many vibrational spectroscopy techniques have been used for this purpose (Bartick, 2002). Bartick and Mount (2001) demonstrated the use of Raman and infrared spectroscopy in the analysis of suspect explosive components submitted as case evidence (Bartick and Mount, 2001). Samples of evidence were taken from the home of a suspect who was under suspicion for producing bombs. The evidence included all the components needed to prepare an extremely unstable explosive material, hexamethylenetriperoxideamine (HMTD). One of the major components found was a bottle labeled Welloxide, a liquid stabilizer developer. Welloxide is a hair-coloring developer that contains hydrogen peroxide. Hydrogen peroxide is one of the components used to produce HMTD. Batrick at el. analyzed Welloxide using IR and Raman spectroscopic methods to determine if there was sufficient H_2O_2 to produce HMTD. As a result, they concluded that there was sufficient H_2O_2 in the suspect's possession to produce a bomb. Raman spectroscopy, however, was their method of choice, which showed the distinct presence of hydrogen peroxide's O—O stretching peak at 876 cm^{-1}document. The infrared spectrum, on the other hand, was not observable until the water spectrum was subtracted, and the peak of interest was still weak.

Characterization of drug-packing plastic bags is important forensic evidence in the courtroom to trace the origin of a package. Causin et al. (2006) have utilized the ATR infrared spectroscopic technique to differentiate and discriminate apparently similar plastic shopping bags that were used to pack individual doses. Their study showed that using ATR spectroscopy in combination with other techniques is a useful technique to discriminate mass-produced plastic bags and to trace the source of illicit drug doses with significant results.

ATR is also an important technique in the analysis of pressure-sensitive tapes. Merrill (2000) utilized the ATR technique with single-reflection diamond IRE to analyze four different types of pressure-sensitive adhesive tapes, including duct tapes, electric tape, packing tape, and office tape.

Maynard et al. (2001) used the diffuse reflectance IR spectroscopy technique to study personal lubricants found in sexual assault cases. Using extracts from the lubricant specimen, they were able to define classes and subclasses of these lubricants. The samples used were categorized in groups of three bases: siloxane-, poly(ethylene glycol)-, and glycerin-based lubricants. The infrared results indicated that the base component of each lubricant does not change over the course of three months, and it is possible to identify lubricant traces at least three months after preparing a sample for analysis.

Kimberley et al. (2004) demonstrated the possible use of Raman microspectroscopy to determine the presence of drugs on U.S. dollar bills, which requires minimum sample handling and preserves the sample for further analysis. They were able to measure Raman spectra and identify individual crystals on the currency in a heterogeneous mixture of three compounds: benzocaine, isoxsuprine, and norephedrine.

Documents involving fraud and threatening letters produced on printers and copy machines have been an important concern for forensic investigators. Tracing the model and the origin of the printer or the copy machine is an important hint for crime scene investigators. Merrill et al. (2003) were able to track the origin of a packaged bomb with an address label mailed to a victim's address. Investigators suspected that the bomb was mailed by an employee at a company that had 400 copiers of 61 different models. They requested 61 documents copied from the available 61 models, and they prepared the sample by heating the back of the paper onto aluminum foil attached to a glass microscope slide. Spectra were obtained using microscopic reflection–absorption IR spectroscopy, where the IR beam reflected from the aluminum foil to the detector. Analyzing the documents and comparing the spectra to the ink obtained from the address label allowed the investigators to trace the model of the copier and the suspect.

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CHAPTER 8

Forensic Serology

RICHARD LI

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Summary Forensic serology is an important component of modern forensic science. The primary activity of forensic serologists is the identification of bodily fluids. Bodily fluid stains are commonly associated with violent criminal cases. Proving the presence of bodily fluids can confirm alleged violent acts for an investigation.

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8.1 INTRODUCTION

Forensic serology is an important component of modern forensic science. The primary activity of forensic serologists is the identification of bodily fluids. It focuses on identifying the presence of blood, semen, saliva, or other bodily fluids in a questioned sample (DeForest et al., 1983; Gaensslen, 1983; Lee et al., 2001; Shaler, 2002; Greenfield and Sloan, 2005; Jones, 2005; Kobilinsky et al., 2005; Saferstein, 2007; Li, 2008). Bodily fluid stains are commonly associated with violent criminal cases. For example, the identification of blood evidence is often necessary for cases involving homicide, aggravated assault, sexual assault, and burglary. Proving the presence of blood can confirm alleged violent acts for an investigation. The identification of semen and saliva is especially important for the investigation of sexual assault cases. For example, the presence of a suspect's semen stains on a victim's clothing can confirm an alleged sexual activity, and the presence of a suspect's saliva stains on a victim's sex organ can confirm alleged oral copulation. In this chapter we focus on the identification of blood, semen, and saliva evidence.

In certain specific circumstances, the identification of other bodily fluids, although less frequently encountered than blood, semen, and saliva evidence, can have probative value for criminal investigations. The identification of urine can be important for an investigation of alleged assault with urination. The identification of vaginal secretions, menstrual blood, and fecal materials can be important for the investigation of sexual assault cases. For example, the identification of vaginal secretions may be important for the investigation of an alleged vaginal rape with a foreign object. Determining whether bloodstains are attributed to vaginal trauma or menstrual bleeding may be necessary in cases of alleged rape. The identification of fecal samples can be important for cases involving anal rape.

Forensic serology can be considered the process of examining and identifying biological evidence, which occurs prior to the individualization of the biological evidence. *Individualization* of biological evidence is used to determine whether or not a bodily fluid sample has come from a particular person. Today, individualization can be achieved by using forensic DNA analysis. However, the identification of bodily fluid cannot be omitted or replaced by forensic DNA analysis. For example, if a stain from a victim's clothing was processed with forensic DNA analysis for a sexual assault case and the DNA profile of the stain was found to match an alleged suspect, then based on the DNA profiling results alone, one may conclude that the suspect's DNA was found on the victim's clothing, thus, establishing a link between the suspect and the victim. However, if forensic serology testing identified the biological stain as a semen stain, one can conclude that semen was found on the clothing taken from the victim and that the suspect is the source of DNA from the semen stain. Thus, it appears that a sexual act may have occurred.

The identification of bodily fluid can be carried out using presumptive and confirmatory assays to test that the sample is the bodily fluid in question. The advantages of *presumptive assays* are that these assays are sensitive, rapid, and simple. A positive reaction of a presumptive assay indicates the possibility of the presence of the bodily fluid in question. However, presumptive assays are not very

specific. Therefore, they should not be considered to be conclusive to the presence of a type of bodily fluid. In contrast, a negative assay suggests that the questioned bodily fluid is absent. Thus, they can be used as a screening method and narrow down biological stains prior to other types of analyses, such as forensic DNA testing. Moreover, these assays can be used as a search method to locate biological stains at the crime scene. Additional assays, such as confirmatory assays, should be conducted afterward if necessary. *Confirmatory assays* are more specific for the bodily fluid in question. These assays are employed to identify bodily fluids with higher certainty than presumptive assays. However, confirmatory assays are more time consuming than presumptive assays.

8.2 IDENTIFICATION OF BLOOD

The identification of blood can be performed using presumptive and confirmative assays (Figure 8.1). The most commonly utilized presumptive assays among forensic laboratories are *oxidation–reduction reaction* assays. The presence of blood can then be confirmed further using confirmatory assays. The most commonly utilized confirmatory assays are *microcrystal assays*.

Currently, since time and budget constraints often exist, confirmatory assays for blood identification are infrequently performed. A reddish-brown stain identified through visual examination is usually tested by using presumptive assays. If the presumptive assay of the alleged blood stain is positive, the stain is then analyzed further by forensic DNA analysis. This approach can only derive a conclusion that the results *indicate* the presence of blood. Therefore, if sufficient amounts of biological materials are available, confirmatory assays should be performed if possible. Thus, if the confirmatory assay is positive, one can conclude that *blood was identified* from the evidence. Additional tests to determine if blood evidence originated from a human or animal source can be performed as necessary and are discussed in Section 8.3.

The blood volume of a normal human is approximately 8% of the body weight. The fluid portion of the blood is called *plasma*. The cellular portion of the blood,

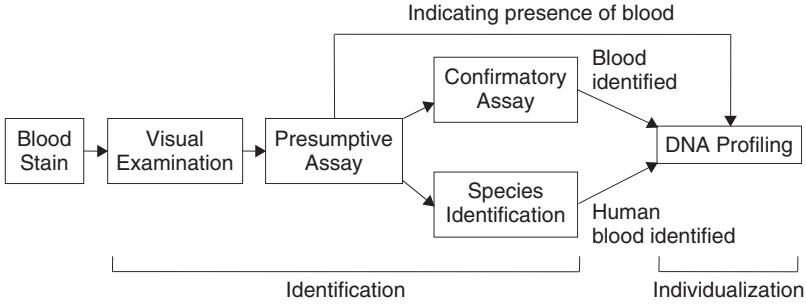

Figure 8.1 Example of the protocol for processing blood samples.

which is suspended in the plasma, consists of *erythrocytes* (also called *red blood cells*), *leucocytes* (also called *white blood cells*), and *thrombocytes* (also called *platelets*). Most presumptive and confirmatory assays of blood identification are based on the detection of hemoglobin. *Hemoglobin* is the protein responsible for the transportation of oxygen and is located in the erythrocytes. The majority of adult human hemoglobin consists of four subunits, two α and two β subunits (designated as $\alpha_2\beta_2$). Each hemoglobin subunit contains a *heme* molecule (also called *ferroprotoporphyrin*). The heme molecule consists of a protoporphyrin IX and a *ferrous* (Fe^{2+}) iron atom (Figure 8.2).

8.2.1 Oxidation–Reduction Reactions

This type of presumptive assay for blood identification is based on the biochemical properties of the heme molecule, which can catalyze an oxidation–reduction reaction. In an oxidation–reduction reaction, changes occur in the oxidation state of chemicals. For example, during the reaction, an oxidant becomes reduced and a reductant becomes oxidized. In the presumptive assays for blood identification, oxidation often coincides with the loss of hydrogen, and reduction often coincides with the gain of hydrogen. An example of an oxidation–reduction reaction for blood identification is shown in Figure 8.3(a).

In an oxidation–reduction reaction for blood identification assays, the most commonly used *reductants* are phenolphthalein, leucomalachite green, tetramethylbenzidine, and luminol (Lee, 1982; Gaensslen, 1983; Sutton, 1999; Greenfield and Sloan, 2005; Laux, 2005; Marie, 2008). Additionally, hydrogen peroxide is usually employed as an *oxidant*. In the presence of heme, a colorless reductant is oxidized, forming a product with color or chemiluminescence. Thus, a positive reaction indicates the possible presence of blood.

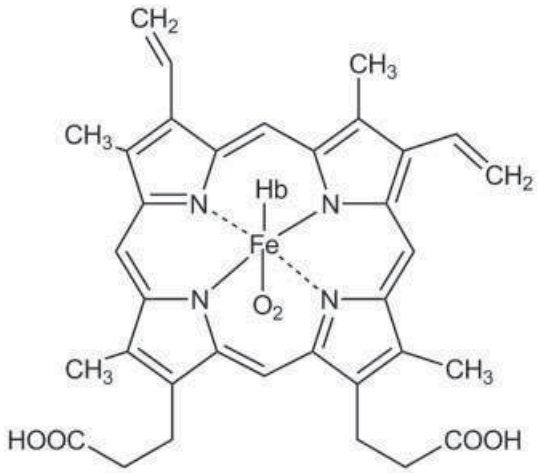

Figure 8.2 Chemical structure of heme. A heme molecule, also called *ferroprotoporphyrin*, consists of a protoporphyrin IX and a ferrous (Fe^{2+}) iron atom.

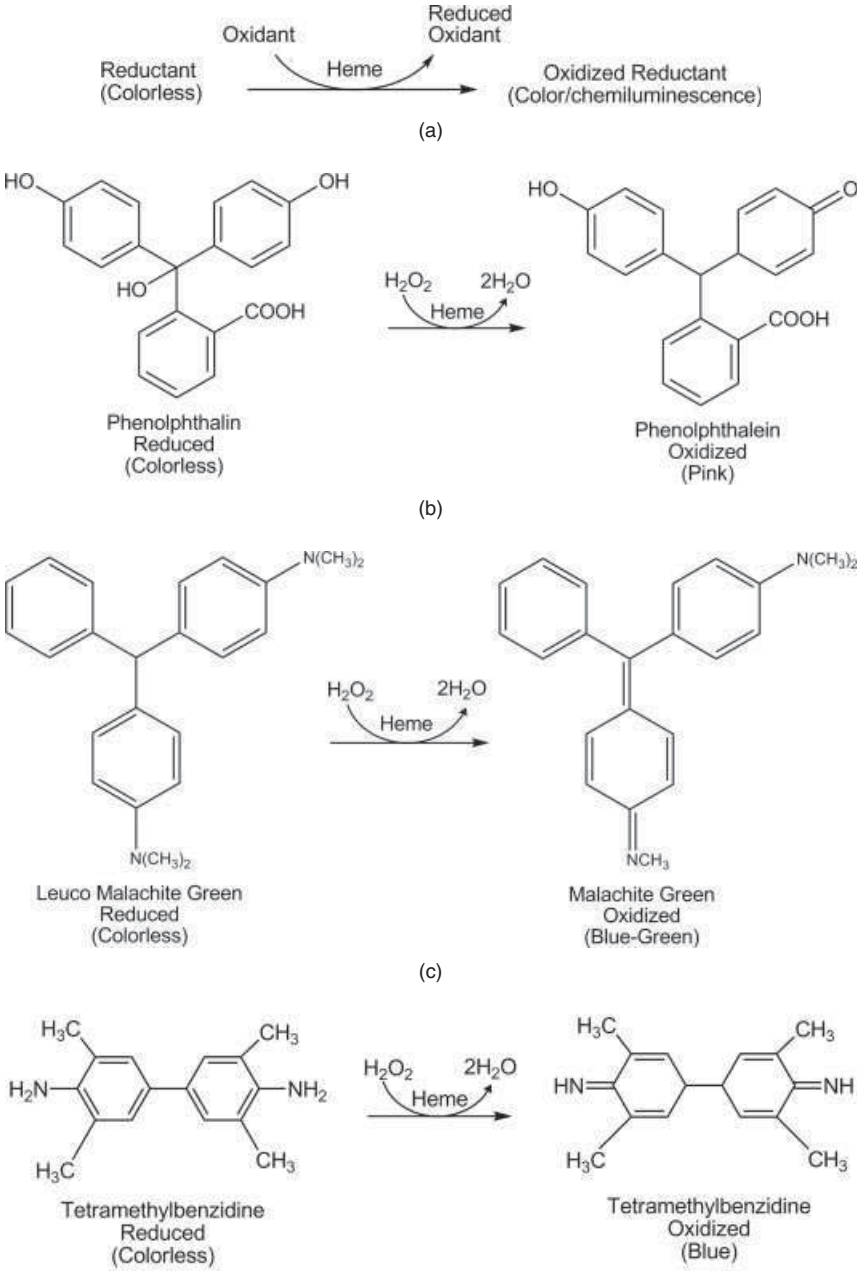

Figure 8.3 Oxidation–reduction reaction and presumptive assays for blood identification: (a) oxidation–reduction reaction as a basis for presumptive assays for blood identification; chemical reactions of (b) Kastle–Meyer assay, (c) leucomalachite green assay, (d) tetramethylbenzidine assay, and (e) luminol assay.

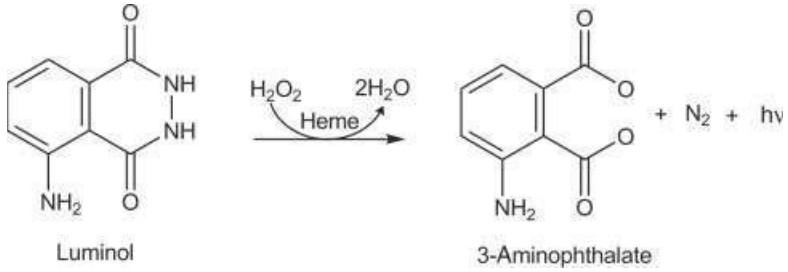

(e)

Figure 8.3 (*Continued*)

For example, the *Kastle–Meyer assay* utilizes colorless phenolphthalin as a reductant. In an oxidation–reduction reaction catalyzed by heme, phenolphthalin can be oxidized to phenolphthalein. Phenolphthalein shows a pink color in alkaline conditions [Figure 8.3(b)]. The *Leucomalachite green assay* utilizes the leuco base form of malachite green, which is colorless. It can be oxidized in the presence of heme to produce malachite green, which shows a green color [Figure 8.3(c)]. The reaction is carried out under acid conditions. In the *tetramethylbenzidine assay*, the oxidation of tetramethylbenzidine can be catalyzed by heme to produce a green color under acidic conditions [Figure 8.3(d)]. The Hemastix assay (Miles Laboratories) is a portable tetramethylbenzidine assay kit that can be used in laboratories and at crime scenes. In a *luminol assay*, oxidation of luminol (3-aminophthalhydrazide), catalyzed by heme, emits a chemiluminescent light [Figure 8.3(e)]. Thus, the assay can be performed in the dark. Luminol reagents can be sprayed at crime scenes to search for alleged bloodstains. A positive reaction not only locates the blood but also detects the patterns, such as footprints, fingerprints, and splatter patterns. This method can help to pinpoint the location of even small traces of blood. Additionally, it is useful for crime scenes that have been cleaned up and where the blood evidence has been tampered with, leaving no visible stains.

The assays discussed above are very sensitive and able to detect blood samples with up to a 10^{-5}-fold dilution. However, they are not blood specific and possibly lead to false-positive results. For example, a false-positive reaction can be caused by the presence of chemicals that are strong oxidants (such as certain metal salts), even in the absence of heme. Plant peroxidases can also catalyze the oxidation reaction in the absence of heme. Thus, peroxidase-containing plants (such as horseradish) can cause a false-positive result. The presumptive assays can be carried out using the swabbing method. A small amount of the questioned stain is transferred onto a moistened cotton swab. Additionally, a substance control (swabbing a nonstained area adjacent to the stained area) can be prepared. The test is conducted in two steps. First, a drop of the testing reagent (reductant) is added onto the swab with the blood sample. If color develops, it is an indication of a false-positive reaction. If no color develops, the assay can be continued by adding a drop of oxidant reagent (e.g., 3% hydrogen peroxide) onto the swab. The presence of blood results

in an immediate development of color, while the absence of blood results in no development of color.

8.2.2 Microcrystal Assays

In microcrystal assays, blood crusts from a bloodstain are treated chemically to convert native heme to heme derivatives. These heme derivatives can form crystals with distinctive morphologies. The crystal morphology of heme derivatives can be examined by using microscopic observation. As a result, the presence of the crystals of heme derivatives confirms the presence of blood. One disadvantage of microcrystal assays is that these assays are less sensitive than the presumptive assays for blood identification. The most commonly utilized microcrystal assays are Takayama and Teichmann crystal assays (Lee, 1982; Gaensslen, 1983). Under normal physiological conditions, the ferrous ion of the heme can form six bonds: four bonds with the nitrogen of protoporphyrin IX, one bond with oxygen, and one bond with a hemoglobin subunit. In the *Takayama crystal assay*, blood crusts are treated in an alkaline condition with pyridine and a reducing sugar, such as glucose, that is capable of reducing other chemicals. Following the treatment, pink-colored pyridine ferroprotophorphyrin crystals form and can be observed under a microscope [Figure 8.4(a)]. In the *Teichmann crystal assay*, blood crusts are treated with glacial acetic acid and salts with heating. Brown-colored prismatic crystals of ferriporphyrin chloride form. Ferriporphyrin chloride is a heme derivative in which the iron is in the ferric (Fe^{3+}) state [Figure 8.4(b)].

8.2.3 Other Assays for Blood Identification

Other confirmatory assays for detecting the presence of hemoglobin are available to confirm the presence of blood. For example, human hemoglobin can be detected by using immunological methods with antihuman hemoglobin antibodies. This type of assays is discussed in Section 8.3. Additionally, hemoglobin can be identified using chromatographic and electrophoretic methods based on the mobility characteristics of hemoglobin, and spectrophotometric methods based on the characteristic light spectrum absorbed by hemoglobin.

Recently, RNA-based assays have been developed and can potentially be utilized for the identification of blood (Juusola and Ballantyne, 2003; Nussbaumer et al., 2006). These assays can detect specific types of *messenger RNA* (mRNA) that are only present in erythrocytes. Messenger RNA is transcribed from a gene and is then translated to produce a protein. The erythrocyte-specific genes utilized for blood identification are *HBA1, PBGD*, and *SPTB* (Table 8.1). *HBA1* encodes for the human hemoglobin α1 subunit, which is abundant in erythrocytes. *PBGD* encodes for porphobilinogen deaminase, an erythrocyte-specific isoenzyme of the heme biosynthesis pathway. *SPTB* encodes β-spectrin, which is a subunit of the major protein of the erythrocyte membrane skeleton. These assays are carried out using the *reverse transcription polymerase chain reaction* (RT-PCR) technique to detect erythrocyte-specific mRNA for blood identification. The RT-PCR usually

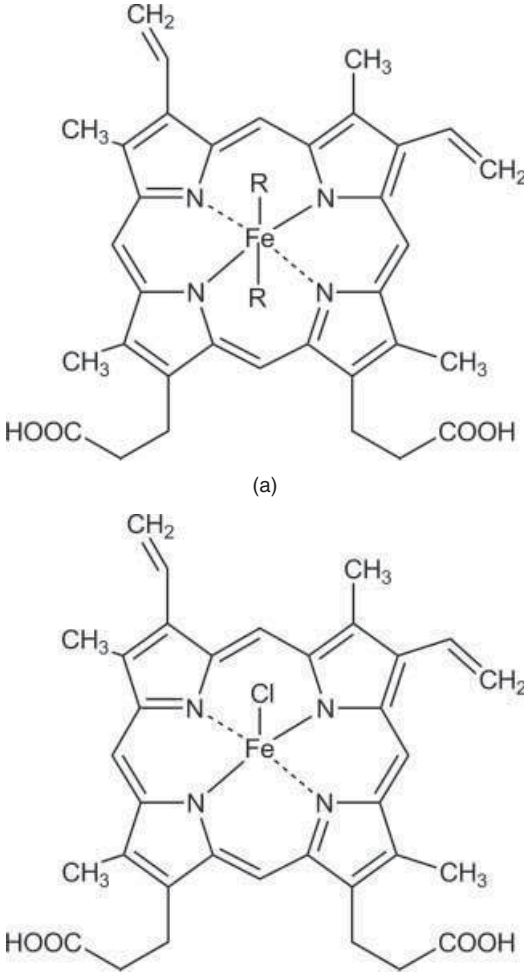

Figure 8.4 Chemical structures of heme derivatives: (a) pyridine ferroprotoporphyrin (R = pyridine) and (b) ferriprotoporphyrin chloride.

consists of two steps (Figure 8.5). In the first step, an mRNA strand is used as a template for the synthesis, carried out by reverse transcriptase, of a DNA strand of complementary sequence, which is referred to as *complementary DNA* (cDNA). In the second step, the resulting cDNA is amplified and the amplified products can then be detected. The advantages of RNA-based assays are that this technique is sensitive and can be used to detect very small quantities of mRNA. Additionally, this technique is specific and can detect erythrocyte-specific mRNA. Moreover, the technique is adaptable to automation. The disadvantage of this technique is that the mRNA present in the sample can be degraded by endogenous ribonucleases.

TABLE 8.1 Use of RNA-Based Assays for Bodily Fluid Identification[a]

Bodily Fluid	Gene Symbol	Gene Product	Description
Blood	*HBA1*	Hemoglobin α1	Hemoglobinα1 subunit abundant in erythrocytes; transports oxygen
	PBGD	Porphobilinogen deaminase	Erythrocyte-specific isoenzyme of the heme biosynthesis pathway
	SPTB	β-Spectrin	Subunit of the major protein of the erythrocyte membrane skeleton
Semen	*KLK3*	Kallikrein 3	Also called prostate-specific antigen (PSA)
	PRM1	Protamine 1	DNA-binding proteins involved in condensation of chromatin of spermatozoa
	PRM2	Protamine 2	DNA-binding proteins involved in condensation of chromatin of spermatozoa
Saliva	*HTN3*	Histatin 3	Histidine-rich protein involved in the nonimmune host defense in the oral cavity
	STATH	Statherin	Inhibitor of the precipitation of calcium phosphate salts in the oral cavity

Source: Adapted from Li (2008).
[a]Tissue-specific genes for identification of bodily fluid are shown.

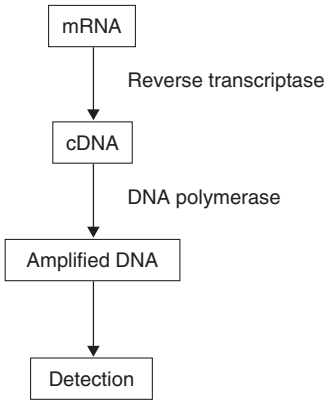

Figure 8.5 RT-PCR technique for bodily fluid identification. The synthesis of cDNA from mRNA can be carried out using reverse transcriptase, and the resulting cDNA is amplified using DNA polymerase.

However, the degree of mRNA degradation, measured by the RT-PCR technique, can potentially be used for determining the age of a bloodstain (Anderson et al., 2005). It is known that mRNA in a blood stain degrades over time after the blood stain is deposited. Thus, the age of a blood stain deposited at a crime scene can be estimated by measuring the detection level of mRNA. This estimation can provide investigative leads, such as when the crime occurred and the length of the postmortem interval.

8.3 SPECIES IDENTIFICATION

Once a stain is identified as blood, the determination of the origin of a blood stain is critical in forensic casework. The blood sample is tested to determine if it is of human or nonhuman origin. Thus, species identification assays can be useful as a screening method to exclude or eliminate nonhuman stains that are not related to the investigation. Thus, if the blood stain is nonhuman, it is not necessary to analyze the stain further. However, if the case involves animals, it may be necessary to identify the species of the blood sample. Currently, species identification is performed infrequently in forensic laboratories. A blood stain is usually processed for DNA profiling analysis. The DNA isolated is quantified using techniques that detect only higher-primate DNA. Thus, the detection of the DNA can indicate that the donor of a blood stain is of human origin, based on the assumption that the crimes involving primate blood are extremely rare in the United States.

The majority of assays for species identification use antibody-based techniques. *Antibodies* are capable of binding to *antigens* (substances that trigger the generation of antibodies). For example, antihuman antibodies are antibodies bound to human antigens and can be used to determine if the sample is a human blood sample. To produce antihuman antibodies, human antigens are usually introduced into a host animal. The host animal generates specific antibodies against the human antigens. The blood is then removed from the host animal to prepare antibodies. The resulting antibody is a *polyclonal* antihuman antibody containing a mixture of antibodies against various human antigens. Additionally, purified human proteins can be used to generate *monoclonal* antibodies. Monoclonal antibodies are specific, homogeneous, and react with a single determinant site of the antigen. The antihuman antibodies utilized should not cross-react with commonly encountered animals but usually have cross-reactivity with higher primates. However, this is not a great concern, due to the fact that crimes involving primates are very rare. An antibody against animal antigens can also be produced using a similar method for determining the animal species in question.

One commonly employed assay is the immunochromatographic assay (Table 8.2). Additional assays that can be utilized are the Ouchterlony assay and the crossed-over immunoelectrophoresis assay, which relies on the binding of an antigen to an antibody causing the formation of a visible precipitate.

8.3.1 Immunochromatographic Assays

A schematic immunochromatographic membrane device is shown in Figure 8.6. The mechanism of the immunochromatographic assays is illustrated in Figure 8.7. The samples can be prepared by cutting out a portion of a stain or scraping off stains from a surface. The sample is then extracted with a small volume of buffer. The extracted sample is loaded into the sample well of the immunochromatographic device. The loaded sample diffuses across the nitrocellulose membrane. The presence of antigens in the sample results in a colored line at the test zone. The immunochromatographic device also utilizes a control zone to ensure that the

TABLE 8.2 Commonly Used Immunochromatographic Assays for Forensic Application

Forensic Application	Assay	Antigen
Blood identification, species identification	ABAcard HemaTrace (Abacus Diagnostics)	Hemoglobin
	RSID-Blood (Independent Forensics)	Glycophorin A
Semen identification	ABAcard p30 (Abacus Diagnostics)	Prostate-specific antigen
	RSID-Semen (Independent Forensics)	Semenogelin
Saliva identification	RSID-Saliva (Independent Forensics)	Human salivary α-amylase

Source: Adapted from Li (2008).

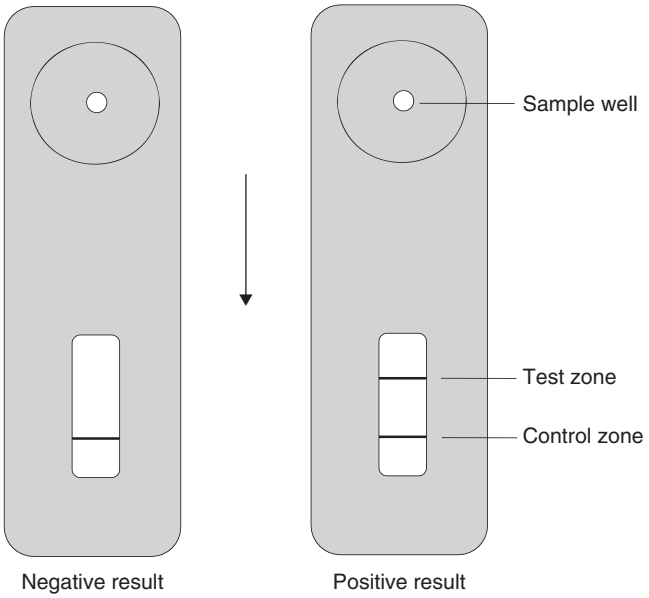

Figure 8.6 Immunochromatographic device. Examples of negative and positive results are shown.

sample has diffused properly along the test strip. Thus, the presence of antigens results in a line at the control zone as well. The assay is considered valid only if the line in the control zone is observed. In contrast, the absence of antigens results in a line in the control zone only. However, a false-negative result may occur in a sample consisting of a very high concentration of antigens. This false-negative result is known as the *high-dose hook effect*. Nevertheless, immunochromatographic assays are rapid, specific, and sensitive and can be used in both laboratory and field tests for species identification.

Most of these assays are based on the detection of human erythrocyte proteins (Lee, 1982; Gaensslen, 1983; Greenfield and Sloan, 2005). For example, purified

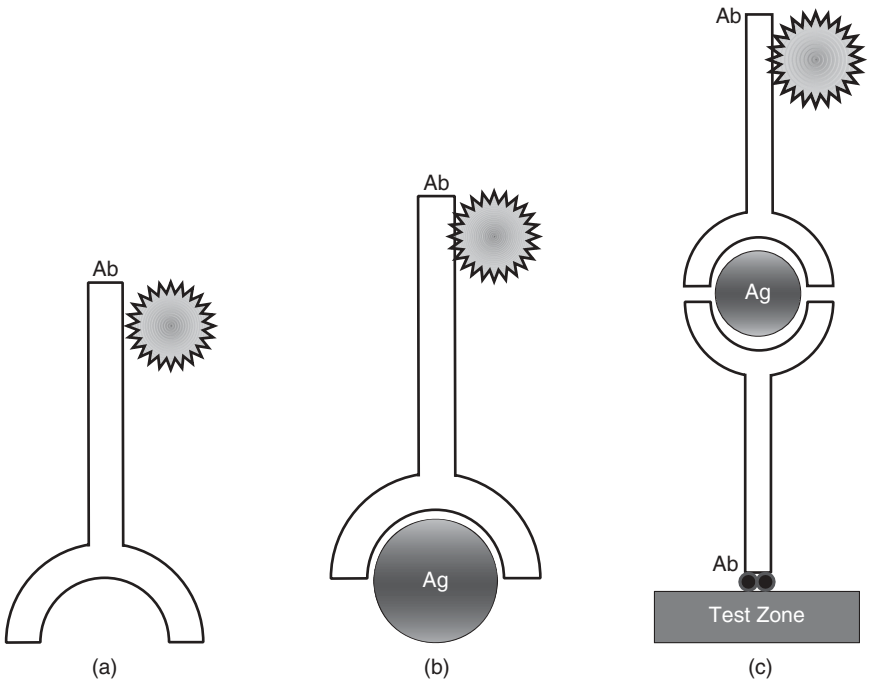

Figure 8.7 Immunochromatographic assay. (a) Dye-labeled antibody (Ab) is placed in the sample well. (b) Sample containing antigen (Ag) is loaded into the sample well and binds to the labeled antibody. This antigen–antibody complex diffuses along the immunochromatographic membrane device. (c) The antigen–antibody complex is captured by an immobilized antibody at the test zone, which forms a colored line for observation.

human hemoglobin can be used to generate antihuman hemoglobin antibodies that detect human hemoglobin. Commercially produced immunochromatographic kits are available, such as the ABAcard HemaTrace kit (Abacus Diagnostics, California). The range of normal blood hemoglobin concentration is 121 to 165 mg/mL. The ABAcard HemaTrace kit can detect very low levels of hemoglobin (as low as 0.07 μg/mL), and specificity studies have shown that the kit is specific for higher primates, including humans. Another immunochromatographic assay utilizes antibodies, recognizing human *glycophorin A* (GPA). Glycophorin A is a human erythrocyte membrane antigen. The RSID-Blood kit (Independent Forensics, Hillside, IL), a commercially produced glycophorin A immunochromatographic kit, is available. The sensitivity of the RSID-Blood kit can be as low as 100 nL of human blood. Species specificity studies have shown that there is no cross reactivity with various animal species, including nonhuman primates.

8.3.2 Ouchterlony Assay

This assay can be performed in an agarose gel supported by a glass slide or polyester film (Lee, 1982; Greenfield and Sloan, 2005). Wells are created by punching holes

in the gel layer at desired locations. For example, a pattern with six wells surrounding a center well may be used. An antibody (such as the antihuman antibody) is loaded into the central well with the stain extracts and controls are loaded into the surrounding wells. The diffusion of the antigen and the antibody from the wells is allowed to occur during incubation. In a positive reaction, a line of precipitate forms between each antigen well and the antibody well (Figure 8.8). The gel can then be stained with a dye to enhance the visibility of the line of precipitate. This assay can also analyze more than one antigen in the same assay to determine if the samples in question are from the same or different species of origin.

8.3.3 Crossed-Over Immunoelectrophoresis

Crossed-over immunoelectrophoresis is also known as counterimmunoelectrophoresis (Lee, 1982; Greenfield and Sloan, 2005). In this method, an agarose gel is prepared which contains sample wells opposing each other (Figure 8.9). The antibody and questioned samples are loaded into the wells by pairs. The antihuman antibody is loaded into the wells proximal to the anode, and questioned samples are loaded into the wells proximal to the cathode. The gel electrophoresis is then carried out. During the electrophoresis, the antigen present in a question sample, carrying a negative charge, migrates toward the anode. In contrast, the antibody migrates toward the cathode as a result of flow of fluid. In a positive reaction, a precipitate line forms between the opposing antigen and antibody wells.

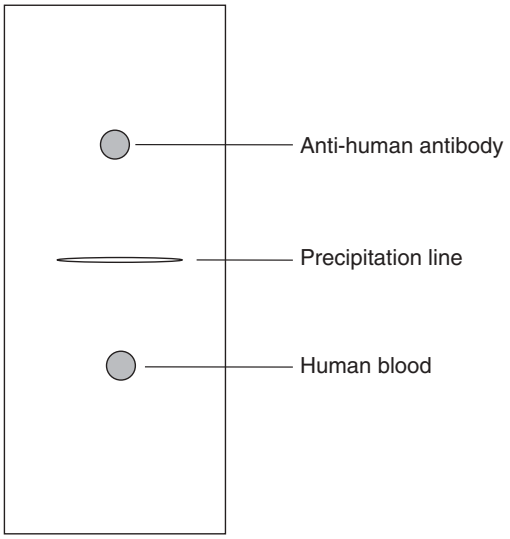

Figure 8.8 Result of an Ouchterlony assay. A precipitate line is observed between a human blood sample and an antihuman antibody.

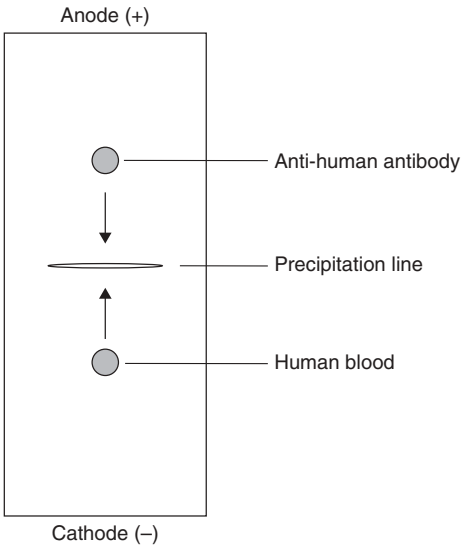

Figure 8.9 Result of a crossover electrophoresis. A precipitate line is observed between a human blood sample and an antihuman antibody.

8.4 IDENTIFICATION OF SEMEN

Normal semen contains seminal fluid and sperm cells (also called *spermatozoa)*. The seminal fluid is a mixture of secretions from male accessory glands largely from the seminal vesicles and prostate. Spermatozoa count ranges from 10^7 to 10^8 (spermatozoa/mL of semen) among healthy males. Abnormality in spermatozoa count can be observed among males. For example, *oligospermia* refers to the condition of a male with an abnormally low spermatozoa count. *Aspermia* refers to the condition of a male with no spermatozoa. However, the secretion of the seminal fluid is not affected among these males. A *vasectomy* is a surgical procedure that blocks spermatozoa from reaching the distal portions of the male reproductive tract. A vasectomized male can still produce seminal fluid.

To search for seminal stains on evidence, visual examination of evidence can be facilitated by utilizing alternate light sources. The presence of semen can then be indicated by presumptive assays that detect enzymes present in seminal fluid. The presence of semen can be confirmed by performing confirmatory assays. The most commonly used confirmatory assays are microscopic examination of spermatozoa and immunochromatographic assays that utilize antibody-detecting antigens present in seminal fluid. Recently, RNA-based assays have been developed and are potentially useful for semen identification.

8.4.1 Visual Examination

The visual examination of semen stains can be facilitated by using alternate light sources (Jones, 2005). Semen stains fluoresce when irradiated with alternate light

sources. For example, excitation wavelengths from 450 to 495 nm can be used. Fluorescence emitted from a seminal stain can be visualized with colored goggles. Thus, a fluoresced stain indicates the presence of semen and can be tested further using acid phosphatase assays.

8.4.2 Acid Phosphatase Assays

Semen contains high concentrations of *acid phosphatase*, which is secreted primarily from the prostate gland. Thus, acid phosphatase is a useful marker for the identification of semen (Gaensslen, 1983; Greenfield and Sloan, 2005; Jones, 2005). The most commonly used acid phosphatase assays in forensic laboratories are *colorimetric* and *fluororimetric* assays. These assays are based on the principle that acid phosphatase can catalyze a hydrolysis reaction to remove a phosphate group from a substrate.

The acid phosphatase is water soluble and can be transferred from a stain by rubbing the questioned stain area with a moistened cotton swab. The swab can then be used for acid phosphatase assays. The most commonly used colorimetric assay for forensic applications is the use of α-*naphthyl phosphate* as the substrate [Figure 8.10(a)]. The substrate reagent is added to the swab prepared as described above. In the presence of acid phosphatase, the hydrolysis of α-naphthyl phosphate

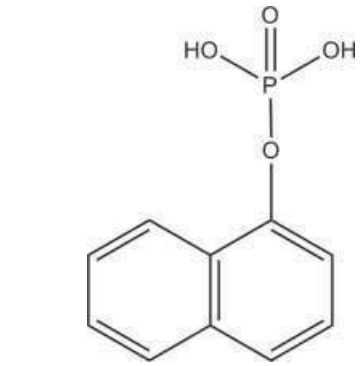

(a)

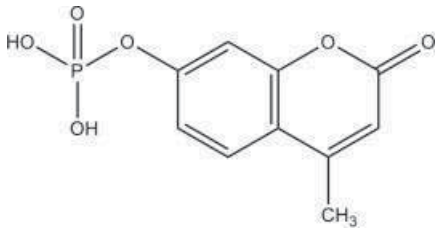

(b)

Figure 8.10 Chemical structures of acid phosphatase substrates: (a) α-naphthyl phosphate and (b) 4-methylumbelliferone phosphate.

occurs. By subsequently adding brentamine Fast Blue B solution, a purple precipitate forms at the sites of acid phosphatase activity. The immediate color change to purple indicates the presence of semen.

The fluororimetric assay of acid phosphatase detection is highly sensitive and is generally used for mapping semen stains located on evidence. A piece of moistened filter paper is used to transfer the acid phosphatase from the evidence. The moistened filter paper is overlaid in close contact with the evidence, such as a garment. The filter paper is then lifted from the evidence. Background fluorescence on the filter paper is examined in a dark room with long-wave ultraviolet (UV) light. Any background fluorescence should be marked. The filter paper can then be sprayed with the *4-methylumbelliferone phosphate* reagent [Figure 8.10(b)]. In the presence of acid phosphatase, the hydrolysis of the phosphate residue on 4-methylumbelliferone phosphate occurs, which immediately generates fluorescence under UV light. Semen stains can be visualized as fluorescent areas on the filter paper.

The presumptive assays described above cannot distinguish completely between prostatic acid phosphatase and non-prostatic acid phosphatase *isoenzymes* (multiple forms of acid phosphatase). For example, interference due to contamination with acid phosphatase present in vaginal secretions can occur in specimens collected from victims. Thus, the presence of semen should be confirmed by the performance of confirmatory assays.

8.4.3 Microscopic Examination of Spermatozoa

To prove the presence of semen, light microscopic identification of spermatozoa can be carried out (Jones, 2005). The morphology of human spermatozoa can be characterized as the head, the middle piece, and the tail structures (Figure 8.11). The head contains a nucleus and an acrosomal cap (a membranous compartment at the tip of the head). The head is attached to the midpiece, where the mitochondria are located. The midpiece is attached to the tail, which is a flagellum responsible for the motility of a spermatozoon.

To prepare a sample for microscopic examination, it is necessary to transfer spermatozoa from a questioned stain to a microscope slide. A small portion of a stain is cut and extracted with water followed by gentle vortexing. This suspension containing spermatozoa is then placed onto a slide and is air-dried with low heat. To facilitate the microscopic observation of spermatozoa, a histological staining method, using the *Christmas tree stain*, is utilized to stain the spermatozoa held on the slide. This staining technique utilizes a combination of two dyes. Nuclear fast red is a red dye that stains the nucleus and acrosomal cap of the spermatozoa. Picroindigocarmine is a green dye that stains the neck and tail portions of the sperm. As a result, the nucleus and acrosomal cap are red, while the sperm tails and midpiece are green. In addition to spermatozoa, a victim's epithelial cells can often be observed if the sample is collected from the victim. The epithelial cells are stained blue-green with red nuclei. Today, the spermatozoa from such a slide can be separated from the victim's epithelial cells by utilizing the *laser capture*

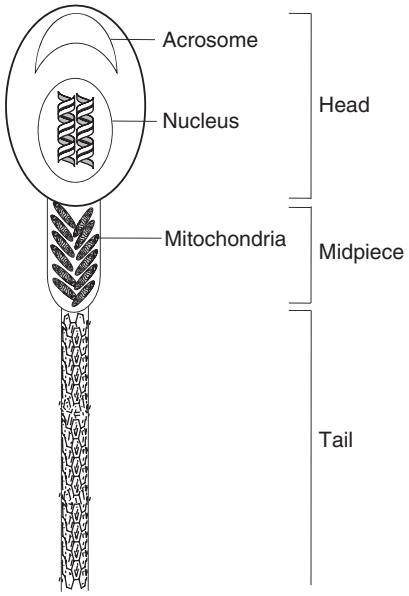

Figure 8.11 Structure of a spermatozoon.

microdissection technique. After the spermatozoa are located on the slide, the head portion of the spermatozoa can be captured. The DNA of the spermatozoa can then be isolated for forensic DNA analysis.

8.4.4 Immunochromatographic Assays

These assays (Jones, 2005) utilize antibodies specific for proteins present in semen such as the *prostate-specific antigen* (PSA) and *seminal vesicle–specific antigens*. PSA (also known as P30 and Kallikrein 3) is a serine protease with a molecular weight of 30 kDa. PSA is produced in the prostate gland and secreted into the seminal fluid. Low levels of PSA can also be found in blood, fecal material, milk, sweat, and urine. Therefore, it can be a concern when a questioned sample is contaminated with those biological materials. Commercially produced immunochromatographic kits are available, such as the ABAcard p30 (Abacus Diagnostics, California). In this device, antihuman PSA antibodies are utilized. The assay is carried out by loading an extracted sample into the sample well. The presence of human PSA results in a pink line at both the test zone and the control zone, while the absence of human PSA results in a pink line in the control zone only. However, the high-dose hook effect, which may cause false-negative results, as described previously, occurs when high quantities of seminal fluid are tested.

Seminal vesicle–specific antigens (also known as *semenogelins*) are the major seminal vesicle–secreted proteins in semen and form a coagulum upon ejaculation. In humans, semenogelin I (SgI) and semenogelin II (SgII) are two major forms

of semenogelins. They are present primarily in tissues of the male reproduction system and secreted into seminal fluid. The seminal semenogelin concentration is much higher than seminal PSA concentration. Therefore, the semenogelin test can achieve higher sensitivity than the PSA test. Additionally, semenogelin I and II are present in low amounts in several other tissue types, such as skeletal muscle, kidney, colon, and trachea tissues. However, this is not a great concern since these tissue samples are usually not analyzed for semen detection.

Commercially produced immunochromatographic kits are available, such as the RSID-Semen kit (Independent Forensics, Hillside, IL), in which antisemenogelin antibodies are utilized. The assay is carried out by loading an extracted sample into the sample well. The presence of semenogelins results in a pink line at both the test zone and control zone, while the absence of semenogelins results in a pink line in the control zone only. The RSID-Semen kit can detect seminal fluid with 5×10^4-fold dilution. However, the high-dose hook effect occurs when high amounts of seminal fluid are tested.

8.4.5 RNA-Based Assays

Recently, RNA-based assays have been developed for the identification of semen (Juusola and Ballantyne, 2003; Nussbaumer et al., 2006). These assays can detect specific mRNA that is present exclusively in the spermatozoa and the male accessory glands. For example, the tissue- or cell-specific genes utilized for seminal fluid identification are *KLK3, PRM1* , and *PRM2* . *KLK3* encodes for human PSA. *PRM1* and *PRM2* encode for protamine 1 and protamine 2, respectively. Protamines are DNA-binding proteins involved in the condensation of chromatin in spermatozoa.

8.5 IDENTIFICATION OF SALIVA

The human salivary glands produce 1.0 to 1.5 L of saliva a day. Saliva is a fluid composed mostly of water, but also contains small amounts of electrolytes, proteins, and enzymes. Salivary amylase is one of the enzymes that can be found in saliva. The biochemical function of the amylase is to cleave polysaccharides, such as starch, which is a major component of one's diet. Thus, the identification of the amylase indicates the presence of saliva. Two major amylase isoenzymes (multiple forms of amylase) can be found in humans: human *salivary* α*-amylase* (HSA) and human *pancreatic* α*-amylase* (HPA). HSA is produced in the salivary glands and HPA is produced in the pancreas. In addition to saliva, a low level of amylase activity is found in other bodily fluids, such as blood, milk, perspiration, semen, tears, and vaginal secretions.

Visual examinations using alternate light sources can facilitate the search for saliva stains (Jones, 2005). The identification of saliva is carried out by detecting amylase in a questioned sample (Gaensslen, 1983; Greenfield and Sloan, 2005; Jones, 2005). These assays can be divided into presumptive and confirmatory assays. Presumptive assays measure the enzymatic activity of amylase. These assays

are not HSA specific and cannot distinguish HSA and its isoenzymes. They are not conclusive as to the specific presence of saliva in a sample. False positives can occur due to contamination by HPA and amylases from plant and bacterial sources. The confirmatory assays, including direct detection of HSA proteins, are more specific than the presumptive assays. Additionally, RNA-based assays (Juusola and Ballantyne, 2003) can potentially be useful as a confirmatory assay for saliva identification.

8.5.1 Visual and Microscopic Examination

The search for saliva stains can be facilitated by using alternate light sources. Saliva stains fluoresce when irradiated with alternate light sources. For example, a 470-nm excitation wavelength can be used. Fluorescence emitted from a saliva stain can be visualized with colored goggles. However, the intensity of fluorescence emitted from saliva stains is less than that of seminal stains. Furthermore, a microscopic examination can be carried out to identify buccal epithelial cells from the stain. The presence of buccal epithelial cells indicates a saliva stain.

8.5.2 Identification of Amylase

Starch–Iodine Assay This assay is based on the principle that iodine (I_2) reacts with starch and develops a dark blue color. In the presence of amylase, starch is cleaved to monosaccharides or disaccharides. The monosaccharides or disaccharides do not react with iodine to develop color. The assay can be carried out in a starch-containing agarose gel with sample wells. The questioned sample is then loaded into the sample well. The gel is incubated and then stained with an iodine solution. The starch-containing gel is stained blue. If amylase is present in the sample, it diffuses out from the sample well and cleaves starch in the gel as it diffuses. A clear area around the sample well indicates amylase activity. The size of the clear area is proportional to the amount of amylase present in the sample. Therefore, the amount of amylase present in a questioned sample can be estimated by comparing it to a standard curve (Figure 8.12).

Phadebas Assay Phadebas (Pharmacia) reagent is an insoluble blue dye–labeled amylase substrate commonly used in forensic laboratories. In the presence of amylase, the dye motif of substrates can be cleaved. The cleaved dye motif is soluble in water and develops a blue color. The amylase reaction can be terminated at an alkaline pH by adding a sodium hydroxide solution. The degree of coloration can be measured (as optical density) at 620 nm using a spectrophotometer and is proportional to the amount of amylase. Then the number of amylase units present in a sample can be determined by comparing the degree of coloration to a standard curve.

Amylase tests can also be used to locate possible saliva stains on evidence through the process of amylase mapping. To perform this process, a piece of filter paper containing Phadebas reagent is placed over the evidence to be tested. The

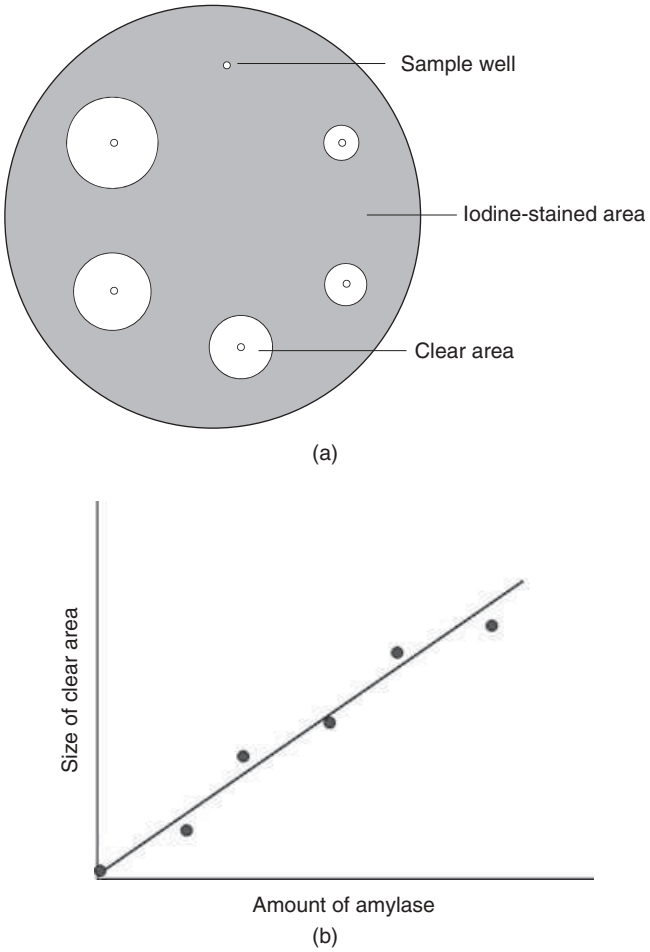

Figure 8.12 Starch–iodine assay for identification of amylase. (a) A series of known concentrations of amylase standards are applied. (b) The size of the clear area resulting from amylase activity is plotted and a liner standard curve (in log scale) can be constructed. The standard curve can be used to determine the amount of amylase present in a questioned sample.

paper is dampened slightly by spraying it with distilled water. The amylase is water soluble and can be transferred from evidence to the moistened filter paper. The amylase transferred to the filter paper reacts with the Phadebas reagent and develops a blue color which corresponds to the site of the saliva stain.

Immunochromatographic Assays Commercially produced immunochromatographic kits are available, such as the RSID-Saliva kit (Independent Forensics). With this device, anti-HSA antibodies are utilized. The assay is carried out by loading an extracted sample into the sample well. The presence of HSA

results in a pink line at both the test zone and the control zone, while the absence of HSA results in a pink line in the control zone only. The sensitivity of the RSID-Saliva kit can be as low as 1 μL of saliva.

8.5.3 RNA-Based Assays

Recently, RNA-based assays have been developed for the identification of saliva. These assays can detect specific mRNA that is present exclusively in cells of the oral cavity. Specifically, the tissue- or cell-specific genes utilized for saliva identification are *HTN3* and *STATH*. *HTN3* encodes histatin 3, which is a protein involved in the nonimmune host defense in the oral cavity. *STATH* encodes statherin, which is a salivary protein inhibiting the potentially harmful precipitation of calcium phosphate salts in the salivary glands and the oral cavity.

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CHAPTER 9

Forensic DNA Analysis

HENRIETTA MARGOLIS NUNNO

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Summary In this chapter we describe how DNA became a valuable forensic tool in identifying the source of physical evidence left at a crime scene. The use of restriction fragment length polymorphism analysis in the mid-1980s was replaced by polymerase chain reaction (PCR) methods, which were more sensitive, requiring far less high-molecular-weight DNA; used less hazardous materials; and were more rapid and more economical. PCR-short tandem repeat–based genetic profile typing methods have improved in sensitivity over the past 20 years and have become a basic tool in the crime lab. Where nuclear DNA is insufficient to generate a full genetic profile, mitochondrial DNA can be used to provide identifying information. The chapter also covers low-copy-number procedures and the typing of single-nucleotide polymorphisms within the human genome.

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9.1 INTRODUCTION

9.1.1 Background on DNA Typing

The structure of DNA was first elucidated by Watson and Crick in 1953. It was shown to take the form of a double helix made by two parallel strands, each of which is composed of four different nucleotides (Figure 9.1) linked together in a specific sequence (Watson and Crick, 1953). While the sequence of the DNA nucleotides is virtually identical in every cell in a person's body, different people differ in portions of their DNA sequences, and each sequence difference is known as a *polymorphism*. In addition, certain sequences of nucleotides are repeated numerous times, frequently one after another, and because people may differ in the number of times that each of these tandem sequence repeats is repeated, there are even more polymorphisms between individuals. It is the examination of such a DNA sequence or repeat number (length) polymorphism that is the basis of DNA identification.

DNA profiling or *typing* (originally called *DNA fingerprinting*) was first used for forensic purposes in the 1980s. The methodology, first described by Alec Jeffreys, used the differences in length of DNA regions created by variations in numbers of repeated sequences to distinguish between individuals (Jeffreys et al., 1985). The repeated regions of DNA that Jeffreys examined are called *variable number tandem repeats* (VNTRs) and the DNA profiling technique that he developed is called

Figure 9.1 DNA structure. The two parallel strands of DNA take the form of a double helix, with each strand composed of four different nucleotides. A is adenine, T is thymine, G is guanine, and C is cytosine.

restriction fragment length polymorphism (RFLP). RFLP uses restriction enzymes, which cut the DNA at specific sequences of bases called *restriction endonuclease recognition sites*, to chop up large pieces of double-stranded DNA in a specific manner. RFLP identifies people by the pattern their DNA segments make when they are separated by size and then hybridized with complementary DNA probes. Because different people may differ in the particular endonuclease recognition sites that are present in their DNA and may also differ in the number of repeats that are present between their recognition sites, the length and therefore the pattern of the various DNA fragments produced by the restriction enzyme digestion will differ from person to person when separated by size.

After the polymerase chain reaction (PCR) was developed in the mid-1980s (Saiki et al., 1985; Mullis, 1990), DNA typing methods began incorporating PCR technology and RFLP was phased out for forensic DNA identification. Because PCR-based methods increase the copy number of DNA fragments to the millions or billions, they greatly reduce the amount of crime scene DNA necessary for DNA identification. In addition, because PCR-based methods are used to amplify relatively small DNA fragments, there is no need for the undegraded DNA required for RFLP. Although the first PCR-based tests used for human identification did not have a high power of discrimination, over the years DNA typing technology has

evolved into the current PCR-based methods, which examine short tandem repeat (STR) loci and have powers of discrimination of one in more than a trillion.

9.1.2 DNA Structure

In the Watson and Crick model of DNA structure, each of the two parallel strands forming the double helix is made of linked nucleotides. Each nucleotide contains a phosphate group, a five-carbon sugar (deoxyribose), and one of four nitrogen-containing bases: adenine, thymine, guanine, or cytosine, referred to as A,T, G, and C, respectively. A and G are double-ringed purines and T and C are single-ringed pyrimidines (Figure 9.2). The nucleotides in DNA are linked by bonds (phosphodiester) between the 3′-hydroxyl and 5′-hydroxyl groups of the deoxyribose sugars and the phosphate groups, forming a sugar phosphate backbone on the outside of the double helix [Figure 9.3(a)]. The bases project into the inside and each strand is connected to what is called its *complementary strand* by hydrogen bonding between specific bases. In this complementary base pairing, adenine always pairs with thymine (by forming two hydrogen bonds) and guanine always pairs with cytosine (by forming three hydrogen bonds) (Figure 9.3). There are about 10 nucleotide pairs for each turn of the helix. Polynucleotides are read from the 5′ end to the 3′ end; since the two polynucleotide chains of the helix run in opposite 5′-to-3′ directions, they are said to be *antiparallel* [Figure 9.3(b)].

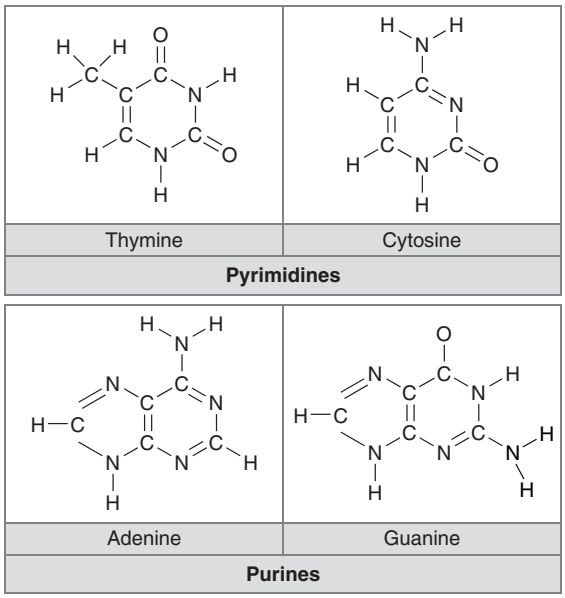

Figure 9.2 Pyrimidines and purines in DNA. The single-ring pyrimidines, thymine (T) and cytosine (C), are shown in the upper panel, and the double-ring purines, adenine (A) and guanine (G), are shown in the lower panel.

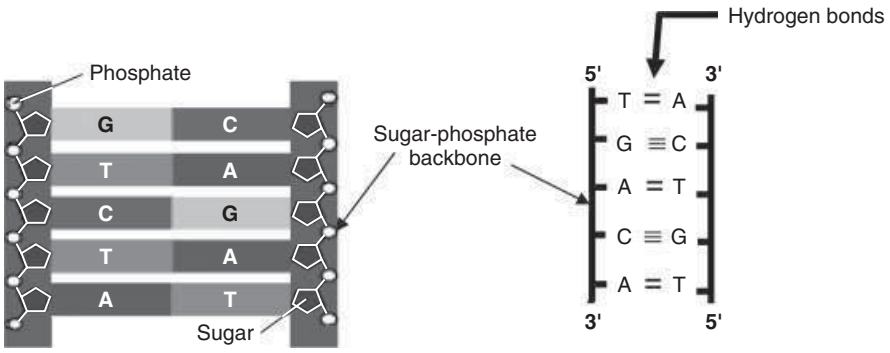

Figure 9.3 Complementary base pairing in DNA structure. (a) A sugar phosphate backbone is on the outside and the four different bases are on the inside of the DNA molecule (left panel). (b) There is base pairing by hydrogen bonding between complementary bases A and T (with two hydrogen bonds) and G and C (with three hydrogen bonds) and both strands run from 5′ to 3′ in opposite directions.

9.1.3 Nuclear and Mitochondrial DNA Organization

Within most human cells DNA is present in both the nucleus and the cytoplasm; cytoplasmic DNA is found in energy-producing organelles called *mitochondria*. Although the DNA found in these two different locations has the same basic double-stranded structure, many differences exist as well.

Nuclear DNA molecules form linear chromosomes and mitochondrial DNA (mtDNA) molecules form circular chromosomes. Whereas nuclear chromosomes are present as pairs (homologs), with one chromosome of each pair received from each parent, mtDNA is inherited uniparentally only through the maternal line. While the nucleus of a typical human cell contains 46 chromosomes made up of 22 pairs of nonsex chromosomes (autosomes) and two sex chromosomes, the total number of mitochondria in a cell varies greatly with the type of cell and its stage of development. Although a set of 23 nuclear chromosomes contains about 3.1 billion nucleotides, the total number of nucleotides in a single mitochondrial chromosome is only 16,569.

Both nuclear and mitochondrial chromosomes contain coding sequences (nucleotides that make up the genes) and noncoding nucleotide sequences whose function is largely unknown. But while the coding and noncoding sequences are distributed intermittently along the length of each nuclear chromosome, in the mitochondrial genome the coding and noncoding areas are separate from each other. The noncoding portion of mtDNA is known as the *control region* (also known as the *D-loop* or *displacement loop*) and it contains about 1100 base pairs (bp), which encompass the two polymorphic hypervariable regions (HV1 and HV2) that are generally used for forensic mtDNA sequencing analysis (Figure 9.4). HV1 occupies positions 16,024 to 16,365, and HV2 occupies positions 73 to 340 in the control region of the mitochondrial chromosome.

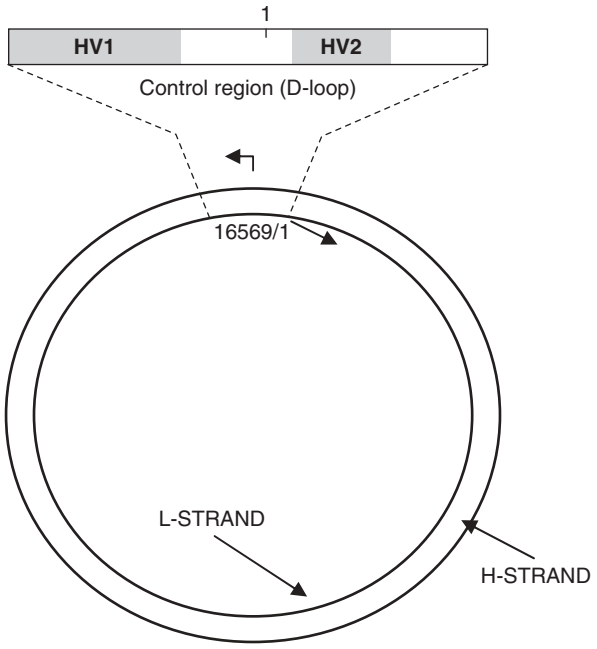

Figure 9.4 Mitochondrial DNA: a schematic representation of the 16,569 bp of the circular mitochondrial DNA genome. Both heavy (H-, outer circle) and light (L-, inner circle) strands are indicated, as are the positions of HV1 (composed of bp 16,024 to 16,365) and HV2 (composed of bp 73 to 340), which are the regions used in forensic mtDNA sequencing.

In addition to differences in organization and number, there are differences in the way that nuclear and mitochondrial DNA molecules are transferred from one generation to the next. Nuclear chromosomes, which are inherited from both parents, undergo genetic recombination, whereas mitochondrial chromosomes, which are inherited from only one parent, do not.

9.2 METHODOLOGY

9.2.1 Sample Collection and DNA Extraction

The isolation of genomic DNA from crime scene evidence samples is complicated by variations in both the quality and quantity of the material that is to be examined. Samples used for DNA analysis may be taken from varied materials, such as fabric, contact swabs, or cigarette butts, and the DNA in these samples may originate from various sources (e.g., blood, saliva, semen, skin). To serve as evidence in court, the biological material must be collected carefully and a chain of custody must be established. In addition, reference DNA samples are necessary to provide material for comparison to crime scene evidence; these can come from convicted offenders,

suspects, and/or people who may have left their DNA at the scene merely because they happened to be in the area (elimination specimens).

As methodologies improve, crime scene evidence samples containing less and less DNA (such as those from single fingerprints) are being analyzed. When samples contain very little DNA, purification methods must yield the maximum amount of DNA in the smallest volume possible. Samples containing very small amounts of DNA (usually $<$100 pg) fall into a category known as low-copy-number DNA (Gill et al., 2000).

The first step in DNA analysis, DNA extraction, involves isolation of the DNA and its separation from other cell components. (Where applicable, cells may first be separated from their substrate swab or fabric by agitation in a minimal amount of liquid.) There are various possible DNA extraction methods, and when dealing with crime scene samples, the type of evidence and the amount of DNA it contains will help determine the extraction method used. Common forensic DNA extraction methods include the use of Chelex beads, solid-phase commercial kits, or organic extraction. [Various methods for manual sample preparation and extraction are described in detail by Butler (2005, Chap. 3).] Whatever extraction method is used, care must be taken to avoid contamination between the samples as well as contamination by extraneous DNA.

For many years most crime labs used the Chelex method for DNA extraction. Chelex is an ion-exchange resin that protects DNA by binding to magnesium ions, thereby inhibiting the function of the magnesium, which requires enzymes that destroy DNA. Cells are first broken open and their DNA released by boiling the cellular material in the presence of Chelex beads. After the centrifugation step that follows, the Chelex and all cellular components except the DNA form a tight pellet at the bottom of the tube. The supernatant liquid containing the extracted DNA is then transferred to a new tube and usually stored frozen at -20°C or -80°C until it is used for analysis.

There is currently a backlog of samples from convicted offenders that must be analyzed and entered into the national database. To ease this backlog and to analyze reference and elimination samples, many laboratories now use commercial kits and/or robotic instruments to prepare these samples, which have abundant DNA and are of a similar type. In addition, new methods and equipment that greatly improve DNA recovery are now available for sample collection, extraction, and quantification, including individualized collection and extraction kits and robotic extraction methodologies (see Brettell et al., 2005, 2007, 2009).

9.2.2 DNA Quantification

Because methods for DNA analysis usually require that the DNA be within a specific concentration range, the amount of human DNA present in an extracted sample must be measured before analysis. In most of the methods used for determining DNA concentration, results for extracted DNA are compared to those for calibrated standards that contain known quantities of DNA. Recent DNA quantification methods have moved from slot blot, to real-time (rt) or quantitative (q)

PCR-based methodology; rtPCR-based methods are more exact than blot-based procedures and can quantify samples with much lower DNA concentrations. Because rtPCR measures the change in fluorescence due to the increase in amplified product that occurs during the initial PCR cycles, it not only quantifies the DNA but indicates how much amplifiable DNA is present in the sample (Butler, 2005, Chap. 4). Kits such as the Quantifiler Human DNA Quantification kit from Applied Biosystems, Inc. are now being used to determine the amount of human DNA present in a sample by rtPCR. In addition, a Quantifiler Duo Quantification kit (Applied Biosystems), which simultaneously quantifies total human and human male DNA, has recently been validated (Barbisin et al. 2009).

9.2.3 Polymerase Chain Reaction

PCR is a process that amplifies DNA and makes millions to billions of copies of a specific DNA sequence through the use of primers. Primers are short segments of DNA (usually 18 to 30 nucleotides in length) that specify which region of the DNA will be copied. For each sequence amplified, two different primers (a forward and a reverse) are used; each primer attaches to a complementary region on one of the two separated DNA strands and designates the beginning or end of the DNA segment to be copied (Figure 9.5). By constructing primers with the appropriate nucleotide sequences, any specific segment of DNA may be amplified. In addition to the primer and the template DNA that is to be copied, a sample undergoing PCR must contain a special type of DNA polymerase which has its optimum function at high temperatures (e.g., *Taq* polymerase, which comes from bacteria native to hot springs), the four building blocks of DNA in a deoxynucleotide triphosphate (dNTP) form (i.e., dATP, dTTP, dGTP, and dCTP), a buffer solution, and salts (e.g., $MgCl_2$) necessary for the DNA polymerase to function.

The PCR process is similar to cellular DNA replication, but with PCR it is temperature changes that accomplish amplification of the DNA. A PCR cycle (see Figure 9.5) consists of three steps. Each cycle starts with a denaturation step where the double-stranded DNA sequence to be copied is separated into two strands by heating to a temperature of about 94°C. The temperature is lowered to about 60°C in the next step, annealing, and the two primers bind by complementary base pairing to each of the single-stranded segments of the target DNA. In the last step, extension, the temperature is raised to about 72°C and the DNA polymerase replicates the DNA by adding the appropriate nucleotide bases (dNTPs) through complementary base pairing. By doubling the amount of DNA with each cycle, the total amount increases exponentially as PCR progresses. The three-step PCR cycle is usually repeated 28 to 30 times for standard forensic DNA analysis.

9.2.4 Short Tandem Repeats

Currently, forensic DNA identification is usually done by PCR-based analysis of short tandem repeat (STR) loci. With PCR of STRs, only small quantities of biological material are necessary and the small PCR product size (about 100 to 500 bp) allows even partially degraded DNA to give full DNA profiles.

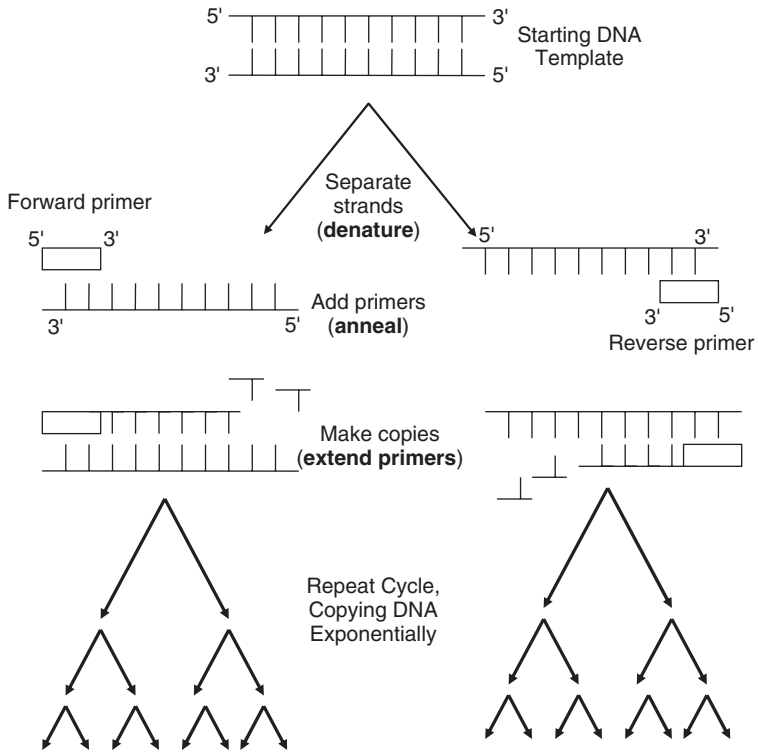

Figure 9.5 DNA amplification by polymerase chain reaction (PCR). A PCR cycle consists of the three steps depicted above, which involve changes in the temperature of the sample. In the first step, denaturation, the two DNA template strands are separated by heat. In the next step, annealing, the sample is cooled to a temperature appropriate for the two primers (forward and reverse) to bind. In the last step, extension, the temperature of the sample is raised to the optimal temperature for the DNA polymerase to extend the primers and produce a copy of each DNA template strand. In each cycle, the number of DNA molecules (containing the sequence between the two PCR primers) doubles and the number of copies increases geometrically. [From Butler (2005), copyright ©2005 Elsevier Academic Press, Fig. 4.2.]

STRs (also known as *microsatellite DNA*) are loci that contain units of short sequences of DNA (two to seven, usually four nucleotides long) that are tandemly repeated (Figure 9.6) anywhere from about a half dozen to several dozen times (see Butler, 2005, Chap. 5). There is a great deal of variation in the human population in the number of times the units of four bases are repeated in an STR, and this length variability is used to distinguish between DNA profiles. Polymorphic STR sequences, which vary throughout the population in the number of repeat units displayed, can be found in all parts of the genome, including introns, exons, and flanking portions of coding areas of the DNA as well as in extragenic areas (Economou et al., 1990; Edwards et al., 1991; Beckman and Weber, 1992). There

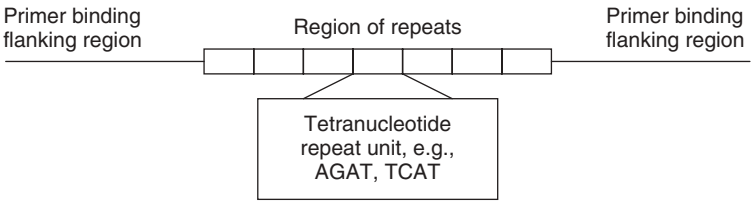

Figure 9.6 Schematic representation of a short tandem repeat (STR) locus. Most STR loci used for forensic DNA analysis contain units of four bases (tetranucleotides) which are repeated one after another. The repeat portion of the locus is surrounded by flanking regions that contain the DNA segments to which the primers bind. One of the primers (usually the forward one) is labeled with a fluorescent dye of a particular color so that the alleles of the STR being amplified can be identified when its size overlaps with that of a different STR.

are probably more than 1 million STRs in the human genome, and among the more than 20,000 tetranucleotide STR loci that have been characterized (Butler, 2006), a set of 13 core loci have been selected for use in forensic DNA profiling in the United States. These 13 STRs are required for a full DNA profile to be uploaded into the FBI's Combined DNA Index System (CODIS) database. The existence of these core loci allows equivalent genetic information to be shared by national, and in many cases international, databases. The 13 core STR loci are used for various forms of human identity testing, including DNA databasing, forensic casework, missing persons/mass disaster victim identification, or parentage testing.

For each of the 13 core STR loci, a person inherits one maternal allele and one paternal allele. Because these loci are either located on different chromosomes or far enough apart on the same chromosome, the 13 core STR loci assort independently of each other during cell division. This allows their population frequencies to be multiplied by each other to obtain a high power of discrimination.

In addition to their presence on autosomal chromosomes, STRs are also found on the sex chromosomes. Y-chromosome STRs, which are present only in males, have been studied for many years as aids in forensic DNA analysis, and commercial kits are now available for their detection. Since Y chromosomes are inherited uniparentally and only one Y chromosome is present in a male individual, Y-STRs do not have the power of discrimination of core autosomal STRs. However, Y-STRs are frequently used to gain additional information when full autosomal STR profiles are lacking and to help distinguish DNA profiles in samples containing both male and female DNA and/or mixtures of DNA from more than one male. STRs can also be found on X chromosomes and, although not used for forensic DNA typing, many of these have been identified and characterized (Gomes et al., 2009; also see Brettell et al., 2005, 2007, 2009).

9.2.5 PCR of STRs

The primers used for PCR-based STR analysis are complementary to the regions that lay outside (flank) the area of the tandem repeats (Figure 9.6), and one of the

two PCR primers is labeled with a fluorescent dye. PCR amplification is usually performed on multiple STR loci simultaneously (i.e., by multiplexing). Different fluorescent dyes are used to label the loci that overlap in size so that these STRs can also be distinguished by color. Simultaneous amplification of many loci enables a high power of discrimination to be attained in a single test without the use of too much DNA (e.g., only 1 ng or less of starting material is necessary). Commercial kits containing fluorescent-labeled primers are available for both autosomal STR and Y-STR analysis.

Numerous multiplex STR test kits are available for DNA typing. Newer multiplex kits increase the number of genetic loci that may be amplified and analyzed simultaneously. To analyze all 13 CODIS loci plus the sex-typing locus, amelogenin, many laboratories use a combination of two commercial kits, either the AmpF*l*STR Cofiler and AmpF*l*STR Profiler Plus, or the GenePrint PowerPlex 1.1 and GenePrint PowerPlex 2.1. Some labs use a newer multiplex kit (i.e., the AmpF*l*STR Identifiler or the PowerPlex 16 System), which can amplify the 13 core STR loci plus amelogenin and two extra STR loci in a single reaction. AmpF*l*STR kits are manufactured by Applied Biosystems Inc. (ABI) and PowerPlex kits by Promega Corp. Four different fluorescent dyes are used in the ABI Profiler and Cofiler kits and in all the Promega kits, while the ABI Identifiler kit uses five dyes.

Commercial kits for STR analysis come with solutions of labeled primers whose relative concentrations are appropriate for multiplexing and a "master mix" in which buffers, dNTPs, and necessary salts are already included. The ease and consistency achieved by these kits in generating STR profiles on the same set of core STR loci make national sharing of criminal DNA profiles possible. In addition, STR kits supply fragment sizing standards as well as allelic ladders containing common STR alleles that have been previously sequenced and characterized for the number of repeat units. The sizing standards are used to determine PCR product size, while the allelic ladders calibrate fragment size in relation to STR repeat number for genotyping purposes.

9.2.6 Separation and Sizing of STR Alleles

Electrophoresis exposes DNA to an electrical field that is used to separate DNA fragments. Because of its negative charge in solution, DNA always moves from a negative to a positive electrode when current is applied. Two types of electrophoresis, slab gel and capillary electrophoresis (CE), have been used for forensic DNA analysis. In slab gel electrophoresis, the separation method that was used for RFLP analysis and for early STR analysis, the DNA samples are placed in separate lanes (depressions) on a gel covered with a buffer solution. When current is applied, shorter DNA pieces move faster than longer pieces and the DNA fragments in each lane are separated by size. Bands of DNA are formed by fragments of the same size migrating together. Sample bands are compared to those of DNA fragment sizing standards (and/or a ladder of common STR alleles) and the length of the DNA in each band is estimated by matching the distance it traveled to a ladder standard that traveled a similar distance. The DNA bands formed in RFLP were

detected by hybridization to labeled probes, while STR gel detection first involved silver staining of bands. More recent methodologies for STR analysis by either gel electrophoresis or CE use detection of PCR primers labeled with different color fluorescent dyes.

In forensic DNA labs today, CE is the method generally used for STR profiling. The separation, detection, and analysis of STR fragments of different sizes is accomplished using CE instruments such as the single-capillary ABI 310 or the 16-capillary ABI 3100 Genetic Analyzers made by Applied Biosystems Inc. (Butler et al., 2004); laboratories with very high throughput may use the ABI 3700 Genetic Analyzer, which has 96 capillaries that operate simultaneously.

CE is fairly similar to gel electrophoresis, except that the separation of fragments takes place in a long narrow glass tube or capillary that is filled with a polymer solution. Samples containing PCR amplified, fluorescently labeled STRs are first added to the capillary and when the current is applied the smaller fragments move faster in the polymer than the larger ones. As they pass through the capillary, the STR fragments are exposed to a laser beam that causes the fluorescent dyes in their primers to emit light of specific wavelengths. Sizing standard fragments labeled with a different dye color are also added to each sample tube. This allows a comparison of test sample fragment movement (measured as migration time) with

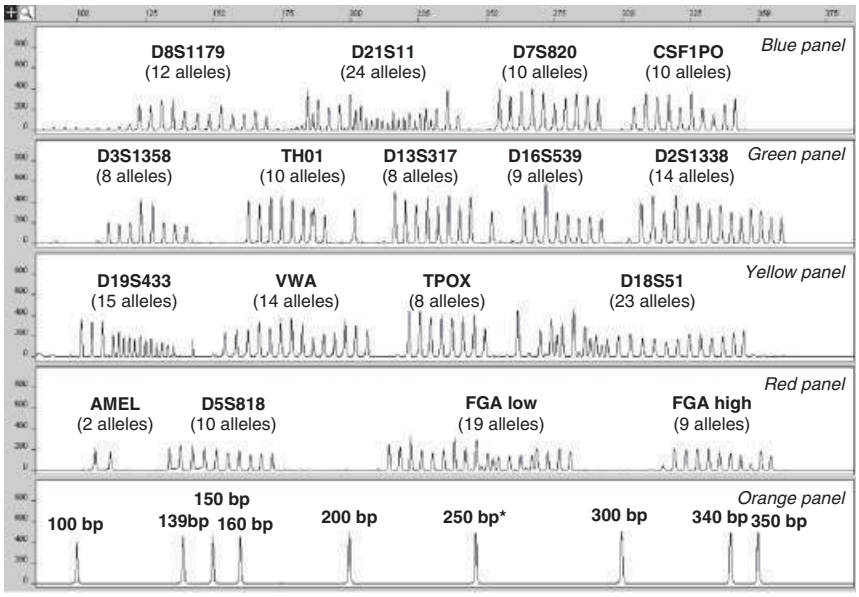

Figure 9.7 Allelic ladders for the AmpF*l*STR Identifiler kit (Applied Biosystems). This allelic ladder, which includes a total of 205 alleles, is used for genotyping a multiplex PCR reaction involving 15 STRs and the sex-typing test for amelogenin (AMEL). The kit uses five dyes, the colors of which are shown in the upper right portion of each panel. The upper four panels show possible alleles for each locus, and the bottom panel shows the peaks produced by the internal DNA sizing standard that is used with this kit. [From Butler (2005), copyright ©2005 Elsevier Academic Press, Fig. 5.6.]

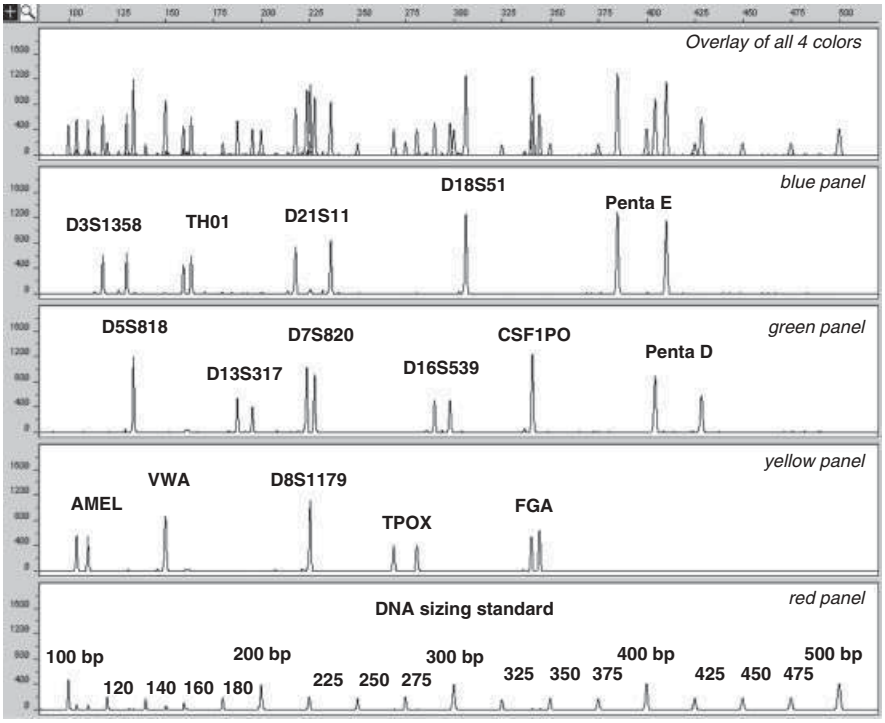

Figure 9.8 Electropherogram showing results for a 1-ng genomic DNA sample produced using the PowerPlex 16 (Promega) kit. This multiplex kit uses four dyes, the colors of which are shown in the upper right portion of each panel, for the labeling of 15 STRs and the amelogenin (AMEL) sex-typing locus. The top panel is an overlay of all four lower panels, including the red lower panel for the internal DNA sizing standard. [From Butler (2005), copyright ©2005 Elsevier Academic Press, Fig. 5.5.]

that of the sizing fragments. A fluorescently labeled allelic ladder sample made up of most of the known alleles for a particular locus is present in the same run and serves as the standard for naming the genotype of the alleles. The allelic ladder for the widely used AmpF*l*STR Identifiler kit (Applied Biosystems) is shown in Figure 9.7. It contains 205 of the alleles present in the 16 loci that are amplified together. These loci represent 15 STRs plus an amelogenin sex-typing assay.

CE data are presented in the form of an electropherogram (e.g., Figure 9.8) which shows a series of peaks, each of which represents the relative fluorescence of an amplified fragment (allele) plotted as relative fluorescence units (rfu) versus migration time (which is related to size). [Figure 9.8 is an electropheragram of results obtained using the PowerPlex 16 System (Promega), which also amplifies the 13 core loci, two extra STRs, and amelogenin in a single reaction.] In addition, CE instrument software calculates the size and genotype of the various alleles in the electropherograms. A peak is identified as a particular allele based on its fluorescent color emission and its length in base pairs, which should match that

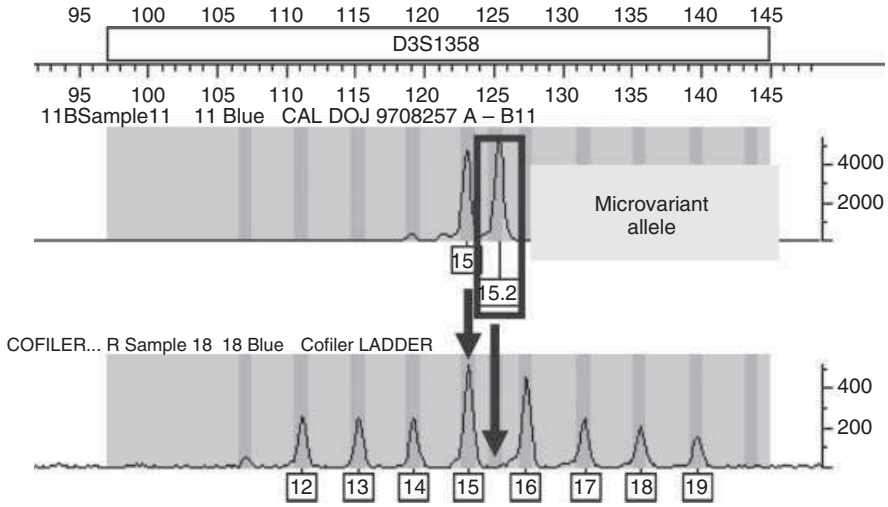

Figure 9.9 Detection of a microvariant allele for D3S1358. When genotyping STRs, alleles are named by a comparison of sample peaks to those of allelic ladders. The sample in the top panel is compared to the allelic ladder for the D3S1358 locus shown in the bottom panel. (Peaks are labeled with the allele number by use of an internal sizing standard.) The allele labeled 15.2 in the top panel does not match any of the ladder alleles. It is a microvariant whose size is two bases larger than allele 15 in the ladder. (www.cstl.nist.gov/STRbase)

of a fragment in the allelic ladder. Alleles that do not match ladder standards are known as *off-ladder* or *microvariant alleles*; these are usually far less common than those in the allelic ladder and therefore may be more statistically significant for human identification. Standard STR allele genotypes are named for the number of repeats they contain. Microvariant alleles contain an incomplete repeat (fewer than four bases) in addition to complete repeats and therefore fall between two allelic ladder standards; they are named by giving the number of full repeats followed by a decimal and then the number of bases in the incomplete repeat (see Figure 9.9).

Like any other experimental, scientific procedure, DNA analysis, requires the inclusion of controls. Negative controls are samples that do not contain any DNA but are subjected to all the same procedures as the samples being analyzed. (Negative controls monitor contamination starting from amplification, whereas reagent blanks, which are frequently used in mitochondrial DNA analysis, are negative controls that monitor contamination starting from extraction.) When no contamination is present, these controls will be negative for DNA. Substrate controls may be run if applicable, and these are specimens taken from an area adjacent to the area (stain) of interest to ensure that the DNA found in the sample did not come from its underlying fabric. Unlike negative controls, a substrate control may contain DNA which may or may not be relevant to the case. To indicate that the test is being done correctly, a known positive control must be included with every analysis and must produce the expected alleles. If negative controls are shown to contain DNA,

or if a positive control does not produce the alleles expected, the test is considered inconclusive and the analysis of all samples must be repeated.

DNA fragments of different sizes, whether they come from a heterozygous STR locus or from different STR loci, have different migration times and are therefore distinguishable by CE. For identification purposes, discrimination power increases as more STR loci are studied, and as stated above, at least 13 STRs are required for a DNA profile to be uploaded into the CODIS offenders database. By amplifying multiple STR loci in the same PCR reaction and running them together in the same capillary, evidence is conserved and time and effort expended for DNA analysis are decreased. Many of the alleles of the 13 core STR loci overlap in size, and because of this, primers for each of these overlapping loci must be labeled with different fluorescent dyes so that they may be distinguished from one another.

9.2.7 Combined DNA Index System (CODIS) Database

The 13 core loci that are currently the basis of the U.S. CODIS database were selected in November 1997. The national CODIS database or national DNA index system (NDIS) contains profiles that have been uploaded from various state DNA testing laboratories through their respective systems. A laboratory that wishes to enter data into the CODIS database must meet certain standards to ensure the reliability of its test results.

The national database includes the following 13 core STR loci: D3S1358, D16S539, THO1, TPOX, CSF1PO, D7S820, VWA, FGA, D8S1179, D21S11, D18S51, D5S818, and D13S317. All 13 of these loci are highly polymorphic, and 11 of them are located on different chromosomes. Although CSF1PO and D5S818 are on the same chromosome, they are far enough from each other to assort independently during cell division. None of the core loci are located in coding regions, so they have no functional significance.

Several databases make up CODIS, including a convicted offender database, an evidentiary database, and other specialized databases. DNA obtained from crime scene evidence is included in the evidentiary database. Offenses that require submission of a DNA specimen to the convicted offender database vary from state to state, and the data uploaded to CODIS must meet certain standards. State and local data that differ from those meeting CODIS standards can be used on a local level only. Although most states originally included only those offenders who had been convicted, and usually only those convicted of violent felonies, some states either now include or will soon include profiles of all persons arrested for any serious criminal activity.

Most European countries (including the United Kingdom) uses 10 core STR loci in their DNA databases, and these include eight of the CODIS loci: VWA, FGA, THO1, D8S1179, D21S11, D18S51, D3S1358, and D16S539 (Butler, 2006). The two remaining European core STR loci (D2S1338 and D19S433) can be amplified with the AmpF*l*STR Identifiler kit, which amplifies a total of 15 STR loci in one reaction (Collins et al., 2004).

9.2.8 Frequency and Probability

STR analysis may demonstrate that the genetic profile from the crime scene sample differs from that of the suspect and thus excludes or eliminates the suspect as a potential donor of the evidence. However, if the genetic profiles of the suspect and the crime scene sample are the same, the suspect is included. Thus, DNA evidence can either link a suspect to a crime scene or prove that a person accused incorrectly is innocent of a crime. As of August 2009, 273 prisoners have been exonerated from crimes they did not commit through the use of DNA evidence.

If there is a DNA match, the meaning of that match must be determined. The probability of finding an identical genetic profile in a particular population depends on the frequency of the profile in that population. Because the United States is populated by people from all over the world, it is sometimes difficult to establish the population or populations of origin for a person. The FBI lists the following five large ethnic groups in their CODIS database: (1) African-American, (2) Asian-American, (3) European-American, (4) Southeastern-Hispanic, and (5) Southwestern-Hispanic.

Many data are available giving the frequencies of the core STR alleles in various populations groups, and Table 9.1 shows the frequencies of the most common alleles of some CODIS STR loci in a Caucasian (European-American) population using data from a study conducted by Butler et al. (2003a).

To calculate the probable or expected frequency of a heterozygote in a population, one would multiply the individual allele frequencies by each other and then multiply that product by 2. Since there are two different ways that a heterozygote can be formed (i.e., either one of the two alleles could have come from either the sperm or the egg), the product of the allele frequencies must be doubled. Homozygote probability is calculated differently since only one set

TABLE 9.1 STR Allele Frequencies, U.S. Population Data[a]

Locus	Allele	Caucasian ($n = 302$)	African-American ($n = 258$)	Hispanic ($n = 140$)
CSF1PO	10	0.21689	0.25681	0.23214
	11	0.30132	0.24903	0.29286
	12	**0.36093**	**0.29767**	**0.35714**
TPOX	8	**0.53477**	**0.37209**	**0.47143**
	9	0.11921	0.17829	0.10357
	11	0.24338	0.21899	0.27500
FGA	21	0.18543	0.11628	**0.16786**
	22	**0.21854**	**0.19574**	0.15000
	23	0.13411	0.17054	0.13571
VWA	16	0.20033	**0.24806**	**0.26429**
	17	**0.28146**	0.24225	0.21786

Source: Data from Butler et al. (2003a).

[a]Frequencies for some of the most frequent alleles are given for four CODIS loci. Alleles with highest frequencies are indicated in bold.

of circumstances (i.e., where both the sperm and the egg carry the same allele) leads to homozygote formation. Thus, the frequency of the homozygous allele is multiplied by itself or squared. As an example, in the Caucasian population in Table 9.1, the probability of a person being a 12,11 heterozygote for the CSF1PO locus would be $0.36093 \times 0.30132 \times 2$ (or 0.10876), while the probability that they are an 8,8 homozygote for the TPOX locus would be 0.53477×0.53477 (or 0.28598).

To determine the probability of a "random match" for a genetic profile which contains, for example, two of the 13 STRs, the frequency calculated for each of the two genotypes is multiplied by the other because the two loci are inherited independently. Because the chance of multiple genotypes occurring together in the same person is the product of their individual probabilities, calculations of this type follow what is known as the *product rule*. Thus, the frequency of a person possessing the genotype for CSF1P0 and TPOX described in the paragraph above would be 0.10876×0.28598, or 0.03110. As a genotype for an additional STR is added to a profile, its frequency is multiplied by the product of the frequencies of the other STRs examined.

For the European-American population, the probability of a random match for the genotype that includes all of the most frequent alleles of the 13 CODIS STRs greatly exceeds the entire population on Earth. Thus, one can say with virtual certainty that this genetic profile would be unique on this planet. In addition, all other profiles for the 13 core STRs in the various population groups provide virtual certainty that a particular genetic profile is unique. (There are various web sites that will calculate the random match probability for any core STR profile; see Butler, 2006.)

9.3 PROBLEMS ENCOUNTERED IN STR ANALYSIS

9.3.1 Low-Copy-Number DNA

Blood or semen stains recovered from violent crime scenes usually contain more than enough DNA to perform traditional STR analysis. To obtain amplification of all of the STR alleles present, most commercial STR kits require that starting samples contain from 0.5 ng (500 pg) to 2 ng of DNA. If full profiles could be obtained for samples with much less DNA, a greater range of evidence samples could be analyzed and many more nonviolent crime investigations might be solved by DNA profiling. More and more crime labs are now performing DNA analysis on crime scene samples such as contact swabs and fingerprints which contain very little DNA.

DNA that is present in a very small amount (i.e., less than 100 pg) is known as *low-copy-number* (LCN) *DNA* (Gill et al., 2000; Gill, 2001). Since there are about 6 pg of DNA in a typical human diploid cell, a LCN sample would contain fewer than 17 cells. To analyze samples containing LCN amounts of DNA, the sensitivity of the assay must be increased. This is usually done by increasing to about 34 cycles the number of PCR cycles from the 28 or 30 that are suggested for

most commercial STR kits. Since increased sensitivity also increases the potential for analyzing contaminating DNA, extra care should be taken with LCN DNA analysis.

There are also numerous artifacts that frequently arise with LCN DNA analysis that may interfere with interpretation of the DNA profile (Gill et al., 2000). Because such a small quantity of DNA is present in a LCN sample, less than a full complement of the genome may be available for amplification in each PCR reaction; since it is only the loci that are amplified in the first rounds of PCR that will probably show up in the final DNA profile, repeated amplifications of the same LCN sample may give different results. This phenomenon, known as *stochastic variation*, occurs frequently with LCN DNA analysis. Sometimes only one of the two alleles of a heterozygous STR locus will be amplified, and the locus will mistakenly appear in the profile as homozygous (allele dropout). Other times, an entire STR locus may fail to amplify (locus dropout), or extra alleles may appear (allele drop-in). Because of the stochastic variation of these amplification artifacts, PCR of LCN DNA samples is usually done three times, and the only alleles that are reported are those that are present in at least two of the three profiles produced from the same sample (Gill et al., 2000).

Additional complications occur with LCN DNA because the smaller amount of input DNA and the increased sensitivity of the PCR amplification make contamination artifacts such as allele drop-in much more likely. Thus, ultraclean laboratories and DNA-free reagents must be used for LCN DNA analysis. In addition, with LCN DNA it is possible that all the DNA in the original sample was not connected to the crime under investigation; the DNA may have come into the evidence sample by secondary transfer: that is, from people with whom the offender had contact before touching the evidence, or from other people who may have touched the item before the evidence was collected. Thus, LCN DNA analysis results must be interpreted with extreme caution.

Many crime labs in the United States are now analyzing material with LCN amounts of DNA for leads in burglary cases. In England, where LCN DNA analysis was pioneered, forensically relevant DNA profiles have been generated successfully from items such as discarded tools, matchsticks, and weapon handles. Increased use of LCN DNA analysis by crime labs has led to the development of various testing and interpretation protocols (e.g., Caragine et al., 2009; Gill et al., 2009), and there is still controversy surrounding the use of LCN DNA typing techniques (Buckleton, 2009).

9.3.2 Degraded DNA and Reduced-Size (Mini) STR Primer Sets

DNA degradation refers to the breakdown of relatively large fragments of DNA into smaller fragments, and there are various processes (e.g., physical, oxidative, or biological) that may contribute to this degradation. As fragments get smaller in size, the target DNA sequences that are used for the PCR amplification reaction are also broken down and the larger alleles of a locus may decrease in peak height in the electropherogram. If the larger allele for a heterozygous STR is missing,

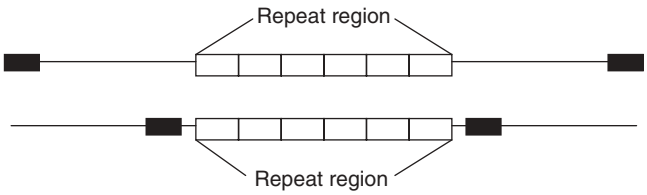

Figure 9.10 Schematic of mini-STR primer positions. Mini STRs are created when primer binding sites (black rectangles) are moved closer to the repeat region in order to shorten the length of the amplified product. The upper portion of the figure shows possible primer positions for a hypothetical traditional STR, while the lower portion shows possible primer positions for a miniSTR with the same number of repeats.

the locus would appear erroneously to be homozygous, and with larger STRs, the entire locus could be missing from the profile. In order to have complete PCR amplification, the full target sequence must be present in the regions where the primers anneal as well as in the portion of DNA between the primer binding sites (Hoss et al., 1996).

Frequently, when the DNA in a forensic sample is present in fragmented form, a full DNA profile cannot be obtained using standard methodology. This problem has been addressed by the development of reduced-size STR primer sets known as *miniplexes*, in which the primer sequences have been moved as close as possible to the repeat region (Figure 9.10) so that smaller STR fragments can be formed (Wiegand and Kleiber, 2001; Butler et al., 2003b). Reduced-size primer sets were first developed for the analysis of STRs by matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF) mass spectrometry, a technique that required shorter DNA fragments for accurate sizing without ladder standards (Butler et al., 1998). Primers for reduced-size STRs also held promise as being better for analyzing degraded DNA and they were used, along with other methods of DNA analysis, to aid in the identification of victims of the World Trade Center disaster. Recent studies comparing mini-STRs with standard STRs and single-nucleotide polymorphism (SNP) assays (see below) found that miniSTRs were usually most effective for the analysis of degraded DNA (Dixon et al., 2006).

Mini-STRs are becoming an important tool for the analysis of degraded DNA in forensic casework samples. Mini primer sets which produce PCR products ranging in size from 50 to 150 bp have been developed for 26 non-CODIS STR markers (Coble and Butler, 2005; Opel et al., 2007; Hill et al., 2008), and a commercial kit for mini-STR amplification of CODIS loci, the AmpFlSTR MiniFiler PCR Amplification kit, is now available from ABI. This kit contains reagents for the mini-STR amplification of the eight largest CODIS loci, which would be the first to drop out in a degraded DNA sample. The MiniFiler kit has recently been validated according to FBI/National Standards and SWGDAM guidelines (SWGDAM, 2000) and was shown to have significant performance improvements over standard STR kits in models of DNA degradation and PCR inhibition (Mulero et al., 2008).

9.3.3 PCR Inhibition

Sometimes substances that interfere with the PCR reaction are present in a forensic sample and coextract with the DNA; the presence of these inhibitors may prevent amplification of some loci or even all the loci. PCR inhibitors may interfere with either the DNA itself or with the polymerase enzyme. Such inhibitors may be present in crime scene DNA samples that were deposited on wood, soil, fabrics, and so on. In addition, hemoglobin in blood, melanin in hair, and certain textile dyes in fabrics, such as that from blue jeans, are inhibitors that coextract with DNA and are frequently present in forensic casework samples (see Besseti, 2007).

The following methods are among those that can be used to decrease PCR inhibition: the DNA sample, and therefore the template, may be diluted so that the inhibitors are also diluted; extra DNA polymerase may be added to overcome inhibition, or bovine serum albumen or betaine may be added to minimize or prevent PCR inhibition; a filtration step may be performed prior to PCR to separate the extracted DNA from the inhibitor [see Raadstom et al. (2004) for a review].

Larger STR loci are more sensitive than smaller loci to PCR inhibition. Because of this, resulting profiles from samples containing inhibitors frequently resemble those of degraded DNA, where larger loci are likely to drop out before smaller ones do. Mini-STR primers, which produce smaller amplified fragments and work well with degraded DNA, may therefore be useful for obtaining full-STR profiles when PCR inhibitors are present.

9.3.4 Interpretation of Mixtures of DNA

If an evidence sample contains a mixture of DNA from more than one person, the profile observed may be confusing and complicated. Mixtures may contain DNA from multiple victims, multiple assailants, victim(s) and assailant(s), or from a single person plus contaminating DNA. If more than two peaks are found for a particular STR locus, the sample is probably a mixture. However, there are cases where three alleles for a single locus (triallelic pattern) may actually be present in a single individual (Butler, 2006), and there are also biological and technological artifacts (described below) that can produce extra peaks. Thus, one must first examine the overall genetic profile in order to determine whether a mixture is present.

Even a two-peak locus that appears to be heterozygous could, in fact, be a mixture from (1) two contributors each of whom is homozygous for a different allele, (2) two contributors both of whom are heterozygous for the same alleles at this locus, or (3) a combination of one contributor who is homozygous and a second who is heterozygous for that locus. If equal amounts of DNA from each person are present, then in the third case one of the two alleles will produce a peak that is three times higher than the other. If the mixture comes from two homozygotes, relative peak heights for the two alleles will depend on how much DNA from each person was present in the mixture.

Since results obtained when DNA mixture components are combined in different ratios are confusing and contain variable peak heights that require further interpretation, it has been suggested that manual interpretation of mixtures not be attempted unless the mixture is the only evidence sample available (Butler 2005, Chap. 7). To aid in mixture interpretation, computer programs are now available to help determine mixture components and ratio; ABI is currently developing GeneMapper ID-X Software Mixture Analysis Tool software for this purpose.

9.3.5 Null Alleles and Allele Dropout

Even with a 1-ng sample of undegraded DNA, there are times when one allele from a person with a heterozygous genotype is not amplified during PCR and the person appears erroneously to be homozygous for that locus. Allele dropout such as this usually occurs because of mutations (sequence polymorphisms) in the flanking region of an STR locus; a mutation in the primer-binding site may prevent one of the primers from annealing, or a mutation close to the primer binding site may block the extension of new DNA during amplification. The presence of alleles with such mutations, known as *null alleles*, can cause errors in the interpretation of STR profiles. However, because the flanking sequence around the tandem repeats is fairly stable and usually not prone to sequence polymorphism, null alleles are rather rare. If a null allele is present and different primers are used for different amplifications, it is possible to obtain a heterozygous genotype with one primer set and an apparent homozygote with another. Since different multiplex kits generally use different primers for the same locus, mutations in or near one of the primer binding sites could produce apparently different genotypes with the different kits. Primer concordance studies have been conducted to examine this phenomenon and, in a comparison of the PowerPlex 16 kit to the Profiler Plus and COfiler kits, allele dropout due to a primer mismatch was found in 22 of 2000 samples in seven of the 13 core STR loci (Budowle and Sprecher, 2001). In addition, because the new MiniFiler STR kit uses new primers with different primer binding sites, it was recently tested for the concordance of its results with those for primers from conventional STR kits (Hill et al., 2007).

Since two identical samples amplified using the same kits will always produce the same genotype results, all samples from the same case should, wherever possible, be tested with the same multiplex primers. However, because DNA database samples (e.g., those of convicted offenders) may have been obtained using a different kit containing primers which differ from those used on the evidence sample, in such a case a database search for an exact match would overlook the true perpetrator if a null allele were present for a primer in one kit but not in the other. To overcome this problem, it has been suggested that fewer stringent match criteria be used in database searches, such as a match of 25 rather than 26 of 26 alleles (Butler, 2005, Chap. 6). In addition, if a primer binds to a region where a polymorphism that produces a null allele is known to occur in some people, the null allele problem may be solved by including "degenerate primers." These are multiple primers for the same locus, each of which will bind to one of the sequence

polymorphisms that may be present for that primer binding site. The AmpFlSTR kits contain degenerate primers for the D16S539 locus, which was found to have sequence polymorphism for its primer binding site; degenerate primers for VWA and D8S1179 are also present in some commercial kits (see Butler, 2005, Chap. 6).

9.3.6 Factors Causing Extra Peaks in Results Observed

Electropherograms should always be examined manually to determine that all peaks called are real and not due to artifacts produced during fragment amplification, separation, or detection. Stutter and incomplete adenine addition are two biological artifacts that can cause extra peaks to appear on an electropherograms while pull-up (bleed-through), dye bobs, and spikes are among the technological artifacts that can produce extra peaks (see Figure 9.11 and below).

9.3.7 Stutter Product Peaks

Additional small peaks, several bases shorter than each STR allele peak, are usually present on STR electropherograms. Called *stutter product peaks*, these are formed during PCR when the STR loci are copied by the DNA polymerase. Stutter peaks have been shown to contain one repeat unit less than the true allele peak (Walsh et al., 1996) and they occur because of slipped-strand mispairing during primer extension, which causes either the primer or the template strand to slip, so that one repeat forms a loop that is not base-paired (Hauge and Litt, 1993). (Stutter peaks that are one repeat unit larger than the true allele can occur but are rarely seen.) Stutter peaks can affect DNA profile interpretation, and when mixtures of DNA

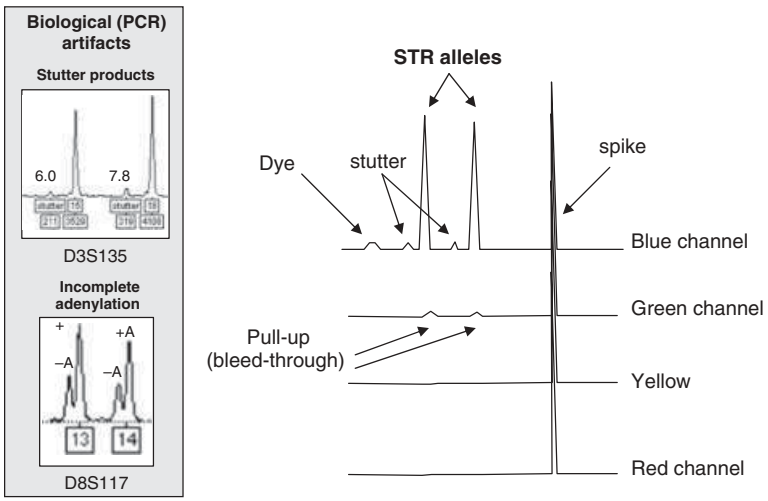

Figure 9.11 Various biology- (left panel) and technology-related artifact peaks that can be observed with STR typing. [From Butler (2005) copyright ©2005 Elsevier Academic Press, Fig. 15.4.]

from two or more sources are present, it can be difficult to determine whether a small peak is a real allele from a minor contributor or a stutter product peak.

Although stutter peak height is proportionally different for each of the different STRs, it is almost always less than 15% of that of the actual allele. Stutter height usually ranges from about 2 to 14% of the adjacent true peak, and the genotyping software does not call peaks in this peak height range.

9.3.8 Nontemplate Addition (Incomplete Adenylation)

The *Taq* polymerase used in PCR frequently adds an extra adenine (A) nucleotide to the 3′ end of a PCR product as it is copying the template strand. This nontemplate addition can lead to the formation of a PCR product that is one base longer than the template DNA. Thus, a peak for an STR may contain two fragments differing in size by only a single adenine base, and this can lead to the formation of electropherograms containing split peaks, broad peaks, or peaks with shoulders. Since sharper peaks increase the accuracy of allele calls by genotyping software, it is preferential to have all peaks either +A or −A rather than a mixture of both. The production of PCR products that all contain an additional adenine can be accomplished by adding an incubation step at 60 or 72°C after the PCR cycles are completed (Kimpton et al., 1993). A final extension step is therefore included in most PCR protocols so that there is enough time for the DNA polymerase to fully adenylate all PCR products. To ensure that accurate calls are made, allelic ladder fragments are also adenylated completely.

9.3.9 Technological Artifacts

Pull-up, also known as *bleed-through* or *matrix failure*, may appear on an electropherogram as a low peak in the same position as a very high allelic peak of a different color. Pull-up is caused by spectral overlap and occurs if the linear range of detection is exceeded due to sample overloading; a peak of a different color pulls up or bleeds through in the same position.

Spikes are sharp peaks that appear as vertical lines. They may be caused by air bubbles in the capillary or by voltage spikes and are easy to distinguish from true peaks since they occur at the same position in all colors.

Dye blobs form peaks that are broader and lower than allele peaks. They are caused by fluorescent dyes coming off their primers and moving through the capillary independently. Dye blobs will possess the spectrum of one of the primer labeling dyes.

9.3.10 Single-Nucleotide Polymorphism Analysis of Autosomal DNA SNPs

A single-nucleotide polymorphism (SNP) is a single base difference between individuals at a particular point in the genome. The human genome contains millions of SNPs (Stoneking 2001), and many have been used for years as markers to track

genetic diseases. In addition, SNPs are frequently used together with STR analysis for DNA identification, especially with degraded DNA samples where a complete STR profile cannot be obtained. Both SNP and mini-STR analysis (along with mitochondrial DNA sequencing) were among the methods used in the identification of victims of the World Trade Center disaster (Biesecker et al. 2005).

Whereas STR analysis involves differences in the numbers of multiples of four base repeats, a SNP involves only one differing nucleotide; thus, PCR products from SNPs can be much smaller than those of STRs, making them appropriate for analyzing degraded DNA. However, SNPs are not as informative as STRs since usually only two different nucleotides will be present for a particular SNP, whereas with STRs more than five variations in the number of repeated tetranucleotides can be found at most loci. Thus, to achieve the same random match probability provided by the 13 CODIS STRs, many more SNP markers would have to be analyzed. It has been estimated that 50 to 100 SNPs would probably have to be analyzed to have the same discrimination power as 10 to 16 STRs (Chakraborty et al., 1999; Gill, 2001; Gill et al., 2004).

Because SNPs have lower mutation rates than those of STRs, they are more likely to become fixed in a population and therefore may be potentially useful in predicting phenotypes such as the ethnic origin of an offender. Most of the work on such phenotypic SNPs has, thus far, been related to pigmentation, and certain SNPs have been found to be linked to red hair and fair skin (see Budowle and van Daal, 2008).

9.3.11 Methods Used for SNP Analysis

SNPs are frequently analyzed by *minisequencing*, sometimes called *SNaPshot*, a variation of the typical DNA sequencing method of Sanger et al. (1977) that is described in more detail below for mitochondrial DNA (mtDNA) analysis. In minisequencing the SNP and the DNA region immediately surrounding it are amplified, and this PCR product is then used in a PCR reaction where only one new nucleotide, the one that defines the SNP, is added after the primer binds. In this second PCR, a special type of nucleotide [a dideoxynucleotide triphospate (ddNTP)] is used to stop amplification immediately, and each of the four different ddNTPs is labeled with a different fluorescent dye so that the nucleotide present in the SNP can be identified. In addition, SNP analysis can be performed as a multiplex so that many SNPs can be identified simultaneously. This is done by adding a varying number of extra nucleotides to the 5′ end of the primer (usually, poly T) so that each primer, and therefore each PCR product, differs from the others by several nucleotides, and fragments can then be separated by size (Tully et al., 1996; Vallone et al., 2004).

Other assays used to detect SNPs are variations of techniques used in DNA microarrays (described below in more detail for mtDNA). These arrays consist of many single-stranded DNA probes (fragments representing possible SNPs) attached to a matrix or membrane in a known position in a tightly spaced grid (microarray) or in a linear fashion (linear arrays). The regions of interest are labeled during

amplification of the DNA sample (many SNPs can be amplified at once), and the labeled PCR product is then hybridized to the array. Only DNA that is complementary to the various probes will bind to the array and after developing the label, be detectable after washing. By examining which positions on the array are labeled, the sequences (or SNPs) present in the original DNA sample can be determined.

9.3.12 Mitochondrial DNA Analysis

DNA evidence samples may be too limited in amount or too degraded for conventional nuclear DNA analysis or even mini-STR analysis. MtDNA analysis is frequently used to determine the origin of this type of sample. Before miniplex STR primers were developed, mtDNA analysis was the only way to generate any identity information from degraded DNA samples, and it is still used for analysis when there is not enough nuclear DNA or when the nuclear DNA is so degraded that mini-STR analysis is impossible.

Because mitochondrial DNA is inherited from only one parent and therefore does not undergo genetic recombination, mtDNA analysis provides much less genetic identity information than does analysis of nuclear DNA. However, because so many more copies of mtDNA are present in a cell, its analysis can frequently provide information when nuclear DNA cannot. While each cell contains only two copies of each nuclear DNA chromosome (one maternal and one paternal), mtDNA is present in hundreds to thousands of copies per cell. The average cell contains about four or five (with a range of 1 to 15) copies of mtDNA in each mitochondrion, with an estimated average of 500 mtDNA molecules per cell (Satoh and Kuroiwa, 1991).

In addition to the higher number of copies present, other factors contribute to the survival of mtDNA under conditions where nuclear DNA may be highly degraded. The circular nature of the mitochondrial chromosome protects the DNA from enzyme degradation, as does its encapsulation in a double-walled structure within the cell (Butler 2005, Chap. 10). These factors have enabled the success of mtDNA analysis in determining the origin of bones, teeth, and ancient remains.

MtDNA is inherited maternally; thus, all children inherit their mtDNA sequence from their mother and the mtDNA of a male is not passed along. Women have the same mtDNA profile as their siblings, male and female, their children, their grandchildren, and all their maternal relatives. Because the mitochondrial genome does not undergo the type of recombination events that occur in nuclear DNA, unless a mutation occurs, mtDNA is transmitted unchanged in sequence from generation to generation.

Mitochondrial chromosomes are closed circles of double-stranded DNA that contain 16,569 base pairs (bp) numbered in a clockwise direction (Figure 9.4). There is an asymmetric distribution of guanines, the heaviest of the four DNA nucleotides, on the two complementary strands of mtDNA. The strand with the most guanines is known as the heavy (H-) strand and the other as the light (L-) strand. The 16,569 bp of the mitochondrial genome include 37 genes that code for products used in mitochondrial structure and function (exons). There are no introns and very few nucleotides between the coding regions.

The mitochondrial genome also contains a noncoding control region that is 1122 bp in length and contains the origin of replication for one of the two mtDNA strands. The replication of mtDNA begins in the H-strand of the control region. There are two segments of the control region DNA that are highly polymorphic, and these are called *hypervariable* (HV1 and HV2) *regions* (see Figure 4). HV1 is 342 bp long and HV2 is 268 bp long. For forensic mtDNA analysis, all 610 of the HV region bases are sequenced. Unrelated individuals have been shown to vary about 1 to 2% in their hypervariable control region DNA, meaning that 7 to 10 nucleotides of these 610 bases are different (Budowle et al., 1999).

9.4 METHODOLOGY FOR mtDNA ANALYSIS

9.4.1 Preparation of Samples

Because it is present in higher copy number and because its analysis requires more PCR cycles, mtDNA is more sensitive to contamination than nuclear DNA. Thus, care should be taken to avoid contamination by other mtDNA, and the extraction of mtDNA should be performed in a very clean laboratory environment. In addition, the analysis of reference samples should be done after all evidence samples have been processed completely. Reagent blanks and negative controls should also be run to monitor levels of exogenous DNA that may be present in reagents and/or the laboratory environment.

There is usually very little DNA present in the materials that require mtDNA analysis in forensic cases (e.g., hair, teeth, and bones). In the past, mtDNA was frequently quantified indirectly by assuming a fixed ratio between nuclear and mtDNA and taking a fraction of the nuclear DNA; however, there are now methods for the direct measurement of mtDNA using rtPCR (e.g., Meissner et al., 2000; Andreasson et al., 2002). In addition, because the type of sample used for mtDNA analysis frequently contains PCR inhibitors that can be coextracted with the DNA, purification of mtDNA is usually more extensive than that needed for nuclear DNA.

9.4.2 MtDNA Sequencing Methods

The FBI began to examine mtDNA sequences for identification purposes in June of 1996. For forensic analysis, dideoxynucleotide (ddNTP) sequencing (Sanger et al., 1977) is the method generally used to determine the order of the nucleotides in HV1 and HV2, the hypervariable areas of the control region. However, because of the extensive amount of time and labor required for sequencing, more rapid screening methods (described below) are frequently used first, to exclude samples that do not match.

MtDNA sequencing uses the same CE instruments that are used for STR analysis; however somewhat different PCR and CE analysis strategies are used. First, the DNA of each hypervariable region is amplified, usually using 34 to 38 cycles, many more than the 28 to 30 cycles commonly used for nuclear DNA amplification. (Since PCR inhibitors such as melanin can be present in hair samples for

mtDNA analysis, extra *Taq* polymerase is sometimes added to overcome this inhibition.) The PCR product for each region is then individually amplified in another PCR reaction. In this PCR, self-terminating nucleotides that stop DNA replication (ddNTPs) are present in addition to the usual dNTP building blocks (Sanger et al., 1977). In the methods currently used with CE sequencing (see Figure 9.12), the four ddNTPs are each labeled with a different color fluorescent dye. When a ddNTP is added to a segment of DNA instead of a dNTP, the extension of the DNA stops immediately and no new nucleotides are added. Because both dNTPs and ddNTPs are present in the PCR reaction, different amplification products are terminated at different points on the DNA template, thereby forming a mixture that contains a series of DNA fragments, each differing by one base pair in length. CE is then used to separate the PCR fragments by length, and because each fragment contains the label of the last base added (in the form of a fluorescent ddNTP), the sequence of bases is obtained for the entire DNA region examined.

9.4.3 Reference Sequences

Following sequencing, the mtDNA sequence of each questioned (evidence) and known (e.g., suspect) sample is compared to a reference sequence and the differences found at specific sites are noted. Human mtDNA was first sequenced in 1981

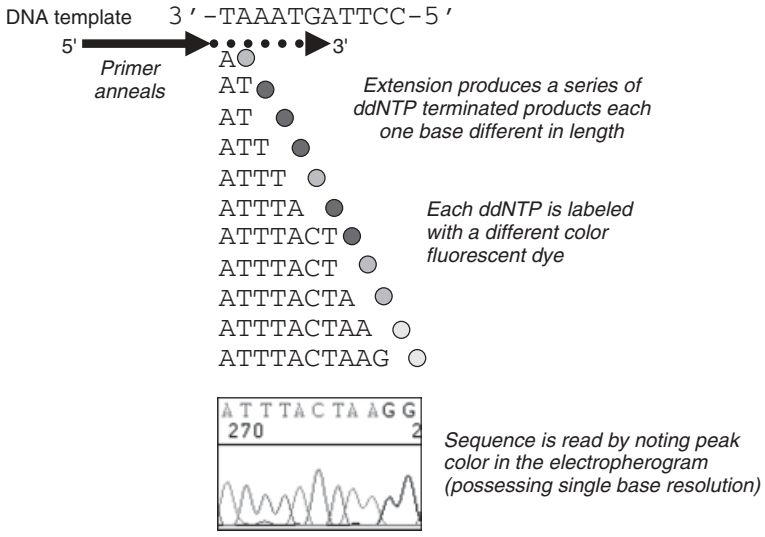

Figure 9.12 DNA sequencing using fluorescent dideoxynucleotide triphosphates (ddNTPs). A primer that anneals next to the specific DNA region to be sequenced is extended by DNA polymerase. Since each sample contains a mixture of dNTPs and ddNTPs for each of the possible nucleotides, some of the extension products continue to be extended, while others are stopped by incorporation of a ddNTP. Each ddNTP is labeled with a different dye, and this allows each extension product to be distinguished by color. The separation of extension products by size allows the DNA sequence to be deduced. [From Butler (2005), copyright ©2005 Elsevier Academic Press, Fig. 10.5.]

(Anderson et al., 1981), and this sequence, known as the Anderson or Cambridge Reference Sequence (CRS), has been used as the reference sequence for forensic mtDNA analysis. Sequencing results are reported in terms of variation from the control region on the L-strand of the CRS. Only the bases that deviate from the reference sequence are reported, and all others are assumed to be the same. For example, a sample differing from the CRS because it has a G instead of an A at position 1620 in the HV1 region would be listed as 1620 G in the sequence report. In the absence of mutation, mtDNA coming from the same person or from a person with the same maternal lineage is expected to have the same DNA sequence and therefore the same differences from the reference sequence. Software packages such as Sequencher (Gene Codes Corp., Michigan) are available to align and compare sequences to the reference sequence and to each other.

The same material that was used to generate the CRS was sequenced again in 1999. Although 11 differences in nucleotides were reported, none of these differences were in the control region (Andrews et al., 1999). Thus, for the HV1 and HV2 regions that are used for forensic mtDNA analysis and reporting, the revised CRS (rCRS) does not differ from the CRS. One difference that was found upon resequencing was the loss of a cytosine at position 3106, making the rCRS standard now used one base shorter than the CRS (16,568 vs.1659 bp). To keep base numbers consistent with those reported previously, a deletion is reported for the rCRS at position 3107. Thus, all numbering is the same as in the original sequence, and each base is assigned a number from 1 to 16,569.

9.4.4 Screening Assays for mtDNA

The regions of the mtDNA genome that are sequenced are those that show the most variability between individuals: the hypervariable control regions, HV1 and HV2. Rapid screening techniques for mtDNA have been developed to determine quickly which samples can be excluded and therefore do not have to be sequenced. Although the variations in mtDNA are scattered throughout HV1 and HV2, there are certain hypervariable sites and regions (hotspots) where most of the variation occurs (Stoneking, 2000), and rapid screening methods concentrate primarily on these hotspots. Mitochondrial SNPs have been examined in these areas (Kline et al., 2005) and minisequencing methods (Tully et al., 1996) similar to that described above for nuclear chromosomal SNPs (e.g., SNaPshot technology) is sometimes used for this purpose (Quintans et al., 2004). In addition, many popular screening methods make use of sequence-specific oligonucleotide (SSO) probes (Stoneking et al., 1991), and these have been used in reverse dot blot and linear array assays (Comas et al., 1999; Gabriel et al., 2003). Rather than sequencing the entire hypervariable regions, SSO probes examine the most polymorphic sites in HV1 and HV2 through hybridization of PCR products to oligonucleotide probes designed to base-pair with the different sequence variants.

Roche Applied Sciences has developed the Linear Array Mitochondrial DNA HVI/HVII Region-Sequence Typing kit. This assay uses SSO probes to distinguish 19 polymorphic sites in 10 different locations within the control region, and it

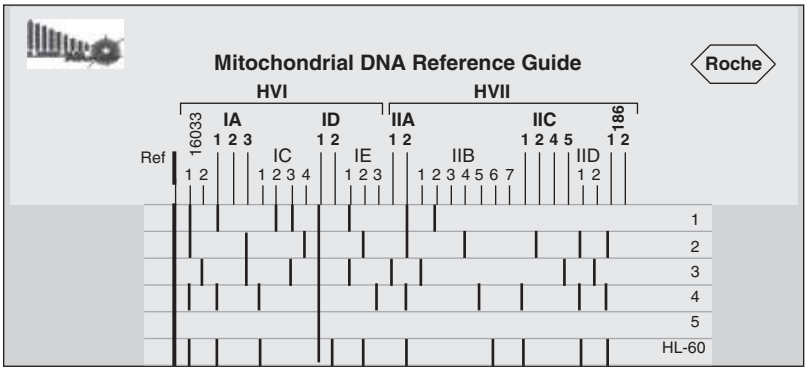

Figure 9.13 Roche linear array mitochondrial DNA HVI/HVII region-sequence typing kit panel results. Samples 1 to 4 are quality control DNA samples; sample 5 is a negative control; sample HL-60 is positive control DNA [HL-60 (NIST) SRM 2392.1]. (Reprinted with permission from Roche Applied Science.)

can do so in only 6 to 8 hours. The primer mix that comes with the kit contains four biotin-labeled primers that amplify the HV1 and HV2 regions simultaneously. Typing of the DNA is accomplished by hybridizing the labeled PCR products to panels containing 33 DNA probes which are striped in 31 lines, and then performing a reaction that produces a color product where fragments containing the biotin-labeled primers have hybridized (see Figure 9.13). In all regions examined, probe 1 is always the Anderson sequence (CRS). This kit has been used successfully for the examination of forensic mtDNA samples (Divne et al., 2005).

9.4.5 Interpretation of mtDNA Sequencing Results

There are FBI guidelines for interpreting mitochondrial sequence comparisons. Known and questioned samples are compared to the rCRS and a comparison of the two samples can result in an exclusion, a failure to exclude, or an inconclusive finding. Following are the guidelines recommended by the Scientific Working Group on DNA Analysis Methods for analyzing mitochondrial sequence data (SWGDAM, 2003).

Exclusion:

> If there are two or more differences in the base sequence of the known and the questioned sequences, one can conclude that there is no common origin between the two specimens and there is an *exclusion*.

Failure to exclude:

a. If there is no difference in sequence between the questioned and the known samples, one *cannot exclude a common origin*.
b. If there is heteroplasmy (described below) at the same site for both the known and questioned samples and there are identical bases at every other position, one *cannot exclude a common origin*.

c. If there is heteroplasmy (described below) at one position in one sample but not in the other, and every base at the other positions is identical, one *cannot exclude a common origin*.
d. If there is an ambiguous base (usually denoted as "N") at a specific position in either or both samples and identical bases at every other position, one *cannot exclude a common origin* for the two samples.

Inconclusive:

If there is only one base difference between the known and the questioned sequence, this result is *inconclusive*.

9.4.6 Statistics: The Meaning of a Match for mtDNA

When mtDNA analysis shows a "failure to exclude," a statistical calculation is required to find the meaning of a match. Unlike the 13 core nuclear STR loci whose individual frequencies can be multiplied because they assort independent of each other during cell division, all sites of the mitochondrial genome, and therefore all mtDNA polymorphisms, are linked on the single mitochondrial chromosome. The method currently used to describe the frequency of mtDNA sequences is the counting method; for example, if after the examination of 4000 samples a particular sequence appears for the first time, the frequency of this genetic profile is said to be 1 in 4001. If the sequence had been found once before, the frequency would be indicated as 2 in 4001. Although statistics such as these may not accurately reflect the actual frequency of any sequence because the population studied may be relatively small in size, the counting method is still the primary method used in forensic cases. Another way to express the frequency of mtDNA sequences is by providing 95% confidence limits and providing the upper and lower limits (the highest and lowest frequency estimates) to indicate the range of possible values for the actual frequency of the profile in the relevant population.

A major problem with mtDNA typing occurs because many sequences fall into categories called "most common types." These are particular sequences for HV1 and HV2 that are present in a disproportionately large portion of the population studied. As an example, an analysis of data for more than 1600 persons found that although the sequences for more than 50% of them were unique for the database, the most common type, which has the same sequence as the rCRS, was present 7.1% of the time. In addition, more than 20% of this Caucasian data set was made up of only 18 mtDNA types (Coble et al., 2004). There are numerous databases containing collections of mitochondrial sequence information (Butler, 2005, Chap. 10; Parson and Dür, 2007), and the FBI has compiled published mtDNA sequence data into the mtDNA population database (CODIS).

9.4.7 Heteroplasmy

Heteroplasmy is defined as the presence in a single person of more than one mitochondrial DNA type at a particular base position in the mtDNA sequence. Heteroplasmy can occur in sequence and/or length. Sequence heteroplasmy is detected

when two nucleotides appear at a single site as overlapping peaks in a sequencing electropherogram. Length heteroplasmy occurs most often in the hypervariable regions in areas where there are long stretches of cytosines (C-stretches), that is, in positions 16,184 to 16,193 in HV1 and in positions 303 to 310 in HV2, and there are differing numbers of C's within the same sample.

Heteroplasmy can occur in the known and/or the questioned sample. If heteroplasmy at a specific position is found in both samples, this might help indicate an inclusion because heteroplasmy at a specific position can be an important identifying characteristic.

Heteroplasmy has been shown to differ from tissue to tissue in the same person (e.g., hair and blood may show different levels and types of heteroplasmy) (Salas et al., 2001). There may also be heteroplasmy differences in mtDNA populations between a person's other cells, and also differences within a single cell or within one mitochondrion (Butler, 2005, Chap. 6). All persons are thought to be heteroplasmic at some level, even if it is below the level of detection (Comas et al., 1995; Tully et al., 2000). High rates of heteroplasmy are not surprising since the mutation rate in mtDNA is much higher than the rate in nuclear genes; some regions of the mitochondrial genome have been shown to evolve at 6 to 17 times the rate of single-copy nuclear genes (Tully, 1999). In addition, although there is only one copy of a nuclear gene present within a human egg, that egg may contain 100,000 copies of the mitochondrial genome (Chen et al., 1995). Thus, multiple mutations and a good deal of heteroplasmy, some of which may be undetectable, could be present in a person.

9.4.8 The Future of DNA Analysis

As of June 2010, the National DNA Index (NDIS) portion of the FBI CODIS database contained almost 8.5 million profiles from convicted offenders and more than 324,318 forensic (evidentiary) profiles (see http://www.fbi.gov/hq/lab/codis/clickmap.htm for updates). Since STR analyses form the bulk of the profiles already present in CODIS as well as in other DNA databases throughout the world, changing to another type of DNA profiling would probably make current data unusable without reanalysis. Thus, STR typing is expected to continue as the preferred DNA profiling method for many years to come (Gill et al., 2004; Butler et al., 2007). However, since profiles from reduced-size core STRs are fully compatible with existing database information and because mini-STRs can broaden the range of degraded samples that can be analyzed, mini-STR analysis may eventually replace STR typing analysis with currently used primers (Gill et al., 2004). In addition, DNA markers such as SNPs will probably continue to be used along with STRs in order to obtain additional information about particular samples. In addition to the possibility of providing phenotype information (Budowle and van Daal 2008), SNPs are helpful in mtDNA testing and Y-SNPs can serve as lineage markers for Y-chromosome analysis (Butler et al., 2007).

Forensic DNA analysis is a rapidly progressing field, and new instruments are constantly being developed. Most of the advances currently being made in DNA

analysis instrumentation are related to increasing the number of samples that can be processed at once (throughput), decreasing processing time and/or decreasing the size of the instruments that are used. To help speed up the analysis of reference samples, robotic instruments that automate DNA extraction and processing are being developed, and many are already in use in high-throughput laboratories. In addition, there is always a need for new user-friendly data analysis software and "expert" software to lessen the manual input required for accurate data interpretation.

The miniaturization of instruments used for forensic DNA analysis is a popular area of current research. Miniature thermal cyclers and small microchip capillary electrophoresis devices are being developed that greatly shorten analysis time and reduce the consumption of sample and of expensive reagents (Yeung et al., 2006; Greenspoon et al., 2007; Liu et al., 2007). A microfabricated capillary array electrophoresis device was recently tested and found to be appropriate for separating STRs (Greenspoon et al., 2008). The ultimate aim of equipment miniaturization is to produce instruments capable of integrating sample preparation, PCR, and DNA analysis which are also small enough and portable enough to be used at the scene of a crime or mass disaster. A prototype of such an instrument was recently developed and tested at a mock crime scene (Liu et al., 2008).

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CHAPTER 10

Current and Future Uses of DNA Microarrays in Forensic Science

NATHAN H. LENTS

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Summary DNA microarrays have revolutionized basic research in molecular and cellular biology, biochemistry, and genetics. Through hybridization of labeled probes, this high-throughput technology allows the screening of tens or even hundreds of thousands of data points in a single run. The technology is most advanced with nucleic acids, but protein and antibody microarrays are coming of age as well. Because of the unique ability to screen for large numbers of molecules, such as DNA sequences, at once, the potential utility to forensic investigations is tremendous. Indeed, progress has been made demonstrating that microarrays are powerful tools of use to the forensic laboratory. As the technology matures and associated costs come down, the day that microarray analysis becomes a routine part of the forensic toolkit draws nearer.

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10.1 INTRODUCTION

Perhaps once each decade, a technique or technology emerges that revolutionizes scientific research in a way that makes scientists wonder what we ever did without it. In the area of molecular biology, restriction enzymes and molecular cloning, and the polymerase chain reaction, come to mind as examples. More recently, the development of DNA microarray technology is just such an event, allowing molecular research to advance with a rapidity and precision unimaginable just a few years ago (Schena et al., 1995; Shoemaker et al., 2001). Indeed, like polymerase chain reaction (PCR) before it, microarrays have quickly become a seemingly irreplaceable implement in the arsenal of nearly all areas of molecular and genetic research. And as research continues, microarrays are now poised to have a similar impact on molecular forensic investigations.

10.2 WHAT IS A DNA MICROARRAY?

Simply put, DNA microarrays are small pieces of glass, usually the size of a standard microscope slide, onto which tiny spots of DNA have been "printed." The DNA spots on a given microarray, or *chip*, could number in the hundreds, thousands, or even *hundreds of thousands*, allowing a user to probe a given sample quantitatively for the presence of countless specific DNA sequences simultaneously (Schena et al., 1998). In basic research, myriad uses of the DNA microarray platform have evolved, and microarrays printed with other macromolecules, proteins and antibodies especially, have been developed as well (but are not discussed here) (Schena et al., 1998; Hoheisel, 2006; Hughes et al. 2006; Wu and Dewey, 2006; Hall et al., 2007; Werner, 2007; Klenkar and Liedberg, 2008). The information gained in a single cDNA microarray, for example, is equivalent to that of many thousands of gene-specific Northern blots or reverse transcription (RT)-PCR analyses (Allison et al., 2006; Ness, 2006). Thus, by the sheer volume of data obtained in a single run, it is no surprise that microarray technology has had such a revolutionary effect on basic research (Shoemaker et al., 2001). Table 10.1 lists the five major types of DNA microarray and their most common applications.

The use of microarrays in forensics is largely still at the developmental stage, but as research into this area continues, new and powerful possibilities are rapidly

TABLE 10.1 Common Types of DNA Microarrays

Type of Microarray	Printed Spots	Specific Use
cDNA microarray	18 to 30-mers, complementary to coding open reading frames	(a) Analysis of mRNA/miRNA transcription (expression profiling) (b) mRNA splicing analysis
Promoter microarray	PCR products or oligos from known gene promoters	Transcription factor location analysis
Entire chromosome tiling	Varies widely; high resolution: 15–25 bp spanning every ~35 bp of genomic sequence	(a) Transcription factor location analysis (b) Analysis of transcription
Comparative genomic hybridization	60-mers from throughout the genome (coding and noncoding)	Detection of gene deletion or amplification (e.g., during cancer)
SNP microarrays	25-mers	Detection of SNP alleles

emerging. In this chapter we first summarize the basics of microarray technology and the well-established uses in basic research. Then we detail some of the forensic applications of microarrays that are currently under development. Along the way we provide insight into future possibilities for the use of microarrays in forensic science.

10.2.1 cDNA Microarray

The most expansive use of DNA microarrays in scientific laboratories around the world is in the technique of *expression profiling* (Mandruzzato, 2007). Microarrays for this purpose are spotted with DNA molecules, usually 30 to 50-mers, representing complementary DNA sequences from within the coding regions of known or predicted genes (Kreil et al., 2006; Larsson et al. 2006). This platform has been developed so extensively that current high-end cDNA chips bear millions of spots, or *probes*, representing every currently known and predicted coding region in the human genome with multiple spots each. Entire or nearly entire genome coverage has also been achieved for mouse, rat, chicken, sheep, dog, cat, cow, macaque, *Xenopus* (frog), zebrafish, *Drosophila melanogaster, Caenorhabditis elegans*, maize, wheat, rice, barley, grape, cotton, tomato, soybean, sugarcane, *Arabidopsis thaliana*, plasmodium, several species of yeast, *Escherichia coli, Staphylococcus aureus*, and many other microorganisms, plants, animals, and fungi (Affymetrix web site).

cDNA microarrays allow researchers to take a "snapshot" of the gene expression profile, at the level of messenger RNA (mRNA), of a given cell population, as shown in Figure 10.1. Obviously, the utility of this approach is best found in the comparison of two populations: for example, cancer cells vs. tissue-matched normal cells, pre- and postviral infection, or pre- and postexposure to a drug or poison. In this way, the alterations of gene expression that occur as a result of such

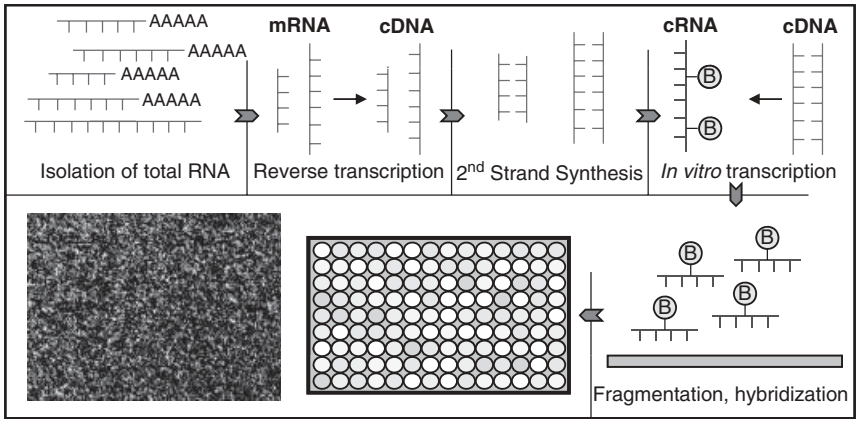

Figure 10.1 Expression profiling by cDNA microarray. Total RNA is isolated from living cells, followed by conversion of mRNA into single-stranded cDNA by reverse transcription using poly(dT) primers. Next, the cDNA is made double-stranded to serve as a template for in vitro transcription using biotinylated NTPs. The cRNA is then fragmented and hybridized onto the microarray platform. cRNA is visualized using a fluorophore-confugated streptavidin moiety and the microarrays are scanned at high resolution to allow quantitation of the fluorescent signal.

treatment conditions can be observed. Following repeated experiments in various settings, contexts, and conditions, a profile of gene expression events emerges. Furthermore, genes for micro-RNAs as well as many known and predicted mRNA splice variants can be discriminated using this same type of chip, and the complexity of the expression profiling data gleaned from microarrays is steadily increasing (Cuperlovic-Culf et al., 2006; Hughes et al., 2006; Kreil et al., 2006; Valencia-Sanchez et al., 2006). It might even be said that our ability to acquire vast amounts of exceedingly complex data is far outpacing our ability to interpret the data.

10.2.2 Other Types of DNA Arrays

Expression profiling is but one application of DNA microarray technology, concerned exclusively with coding regions of the genome. Promoter microarrays are another, displaying DNA sequences representative of gene promoter regions, that is, transcription start sights and proximal sequences of 1 to 10 kb (Ren and Dynlacht, 2004; Blais et al., 2005). Obviously, these types of arrays are not useful for expression studies but, rather, to probe exactly which genes a given transcription factor is physically associated with, at a certain point in time, through a technique called *ChIP-on-chip* or *location analysis* (Buck and Lieb, 2004; Blais et al., 2005; Lee et al., 2006). Other microarrays harbor sequences spanning an entire human chromosome, usually called *tiled arrays* due to the printing pattern of short sequence intervals, or *tiles* (Ishkanian et al., 2004; Graf et al., 2007). These arrays have several uses, including the comprehensive mapping of RNA transcripts and splice

variants and chromosome-wide (and eventually true genome-wide) location analysis for transcription factors (Ji and Wang, 2005; Carninci, 2006; Huber et al., 2006). One dramatic example, research using these entire-chromosome arrays, has unexpectedly demonstrated that much more of the "noncoding" regions of the human genome are transcribed than thought previously (Bertone et al., 2004; Johnson et al., 2005). The last major type of DNA array is the comparative genomic hybridization (CGH) array (du Manoir et al., 1993; Kallioniemi et al., 1993). These types of arrays contain DNA sequences, both coding and noncoding, from throughout the genome and are used to detect changes in DNA copy number (gene deletion or gene amplification) that are frequently seen in human cancer and certain genetic diseases (Houldsworth and Chaganti, 1994; Yang et al., 2006; Stjernqvist et al., 2007).

These gene expression arrays, promoter arrays, tiling arrays, and CGH arrays are the most dominantly used microarray platforms in basic molecular research, including toxicogenomics (discussed below) (Ness, 2006). But for most forensic applications, the scrutiny at hand is of small discrete *differences* in closely related DNA sequences that differentiate one individual from another or one strain of bacteria from a close relative. Neither cDNA nor tiling arrays are appropriate for, or capable of, analyzing these subtle DNA differences. Thus, several varieties of microarrays for exactly this purpose have been developed, such as single-nucleotide polymorphism (SNP) arrays and resequencing arrays, which are discussed below. Because they are simply glass slides with spots of DNA, microarrays are easily customized to the application at hand, and countless clever variations have been documented (Mendoza et al., 1999; Lorenz et al., 2003; Dondeti et al., 2004; Thomson et al., 2004; Newton et al., 2005; McGrath et al., 2007). As development costs continually decrease, some laboratories even routinely print their own custom microarrays specific for their area of research and the experimental questions of interest (Ren et al., 2002; Cam et al., 2004; Balciunaite et al., 2005; Blais and Dynlacht, 2005a,b; Acosta-Alvear et al., 2007).

10.2.3 The Birth of "-Omics"

The complete sequencing of the human genome (and that of many other species) has affected nearly every field of biological research (Lander et al., 2001; Venter et al., 2001). Microarray technology is one of the major applications in which these enormous volumes of sequence data are put to direct use (Schena et al., 1998; Shoemaker et al., 2001; Hoheisel, 2006). Indeed, this sequence information, hand-in-hand with the required bioinformatics, was a necessary prerequisite for the development of microarray technology (Schena et al., 1995, 1998; Heller et al., 1997). With this new ability to perform such global genome-wide studies, entirely new scientific disciplines have materialized, and indeed, a new vocabulary has emerged. This is most recognizable by the addition of the suffix "-ome" or "-omics" onto various terms which implies that a global "in total" approach is being applied: for example, genome/genomics, proteome/proteomics, transcriptome, kinome, lipidome, metallome, spliceome, phosphoylome, and glycome (Palsson, 2002; Bishop, 2003, Chaussabel, 2004; Figeys, 2004). Obviously, these new

"disciplines" are simply technological approaches to research within existing scientific fields, which are represented by their respective prefixes: for example, metabolomics and toxicogenomics (Aardema and MacGregor, 2002; Dettmer and Hammock, 2004). A new era of molecular research is clearly upon us, the -omics era, and microarrays are at the forefront of this information wave (Chauard et al., 2002; Abu-Issa and Kirby, 2004; Kiechle et al., 2004). In the next few pages we detail how current and future research will bring the -omics wave into the realm of forensic science through the use of DNA microarrays.

10.3 DNA MICROARRAYS IN TOXICOGENOMICS

No area of research has experienced a more profound impact due to advances in microarray technology than the field of genomics (Schena et al., 1998; Bueno-Filho et al., 2006). Stated simply, genomics is the study of the structure and function of DNA and DNA sequences on the genome scale. The field of genomics and, similarly, microarray technology, is intimately connected to the success of the mass sequencing of the human genome (and that of other species) (Schena et al., 1998; Belacel et al., 2006; Lerman et al., 2007). Toxicogenomics is a subdiscipline of genomics that is concerned with deciphering the impact of exogenous molecules such as drugs, poisons, and xenobiotic compounds on gene expression (Lovett, 2000; Aardema and MacGregor, 2002; Gershon, 2002; Hamadeh et al., 2002; Gatzidou et al., 2007). As this name implies, this field was the result of a merger between traditional toxicology research and functional genomics: microarrays are the platform that made this merger possible (Neumann and Galvez, 2002; Pennie, 2002; Ulrich and Friend, 2002; Irwin et al., 2004).

Mechanistic toxicology is the attempt to decipher why and how a drug or poison does what it does. In this way, toxicology is closely related to pharmacology in the search for a "mechanism of action." Predictive toxicology attempts to use this physiological information to make predictions about the toxicity of a related or novel molecule. Toxico*genomics* has greatly accelerated both approaches and deepened our understanding of the biological perturbations caused by chemical compounds (Cunningham, 2006; Fielden and Kolaja, 2006). Drugs and poisons are now grouped in increasingly narrow categories based on common induction of discrete cellular gene expression changes (Oberemm et al., 2005). By aligning physiological response to chemical structures, reliable predictions can be made regarding the toxic effects of a previously untested compound (Raghavan et al., 2005; Fielden and Kolaja, 2006; Martin et al., 2006).

Forensic toxicology is often concerned with the converse situation: the identification of a poisoning agent (which itself may be difficult or impossible to detect), based on the biological effects of that agent. This is often a tenuous process, but a more complete picture of toxin-induced gene expression responses, achieved by microarrays, gives forensic researchers much more to work with in the hunt for specific telltale biomarkers (Lettieri, 2006). Indeed, significant progress has been made in the elucidation of a toxicological "fingerprint" for several drugs and

toxins, including arsenic, chromium, nickel, cadmium, methapyriline, clofibrate, hexachlorobenzene, doxorubicin, 5-fluorouracil, and acetaminophen [reviewed by Lettieri (2006)]. The dominant type of microarray technology employed in toxicogenomics is the cDNA microarray for expression profiling (Figure 10.1), although other types of microarrays, such as splicing arrays and CGH arrays, have revealed important pharmacological effects as well (Lee et al., 2005).

10.3.1 Sharing Information

For the voluminous amounts of data gleaned from toxicogenomic studies to be truly useful to the community at large, there must be in place a rigorous common method of analyzing and sharing data. There are several national and international efforts to do just that. The first critical milestone in the creation of public databases for genomic data was the establishment of the MIAME (minimum information about a microarray experiment) guidelines, developed by the European Bioinformatics Institute (EBI) (Brazma et al., 2001). These guidelines provide a common language through which researchers around the world can understand each other's experimental data. Following these guidelines, several publicly accessible repositories for microarray data have been created, the largest being the Gene Expression Omnibus (GEO) (Edgar et al., 2002; Barrett and Edgar, 2006). Within the field of toxicology, the National Center for Toxicology (NCT) within the National Institute of Environmental Health Science (NIEHS) is developing the Chemical Effects in Biological Systems (CEBS) knowledge base (Waters et al., 2003). CEBS, and its counterpart at the EBI, tox-MIAMExpress, aim to compile and integrate vast amounts of genomic data and thus build a complete picture of the complex biological response to toxicological agents and provide that information to the public (Brazma et al., 2003, 2006).

10.3.2 Forensic Application

Our ability to apply what is learned in experimental toxicogenomics to forensic toxicology rests not only on our understanding of the biological response to a given chemical agent, but also on our ability to detect that response in biological tissues, which often present themselves as evidence in very trace amounts or in degraded condition (Nygaard and Hovig, 2006). This presents a serious problem for gene expression analysis, as mRNA is arguably the most labile biological macromolecule of all. But this challenge is certainly not insurmountable and does not apply whatsoever to freshly harvested samples, as is also often possible in forensic practice. But even when access to fresh tissue sample is not possible, conceivable breakthroughs in microarray technology could one day allow recreation of gene expression information. For example, research into chemical modifications of DNA histones has revealed that gene expression is heavily influenced by chromatin architecture, and the precise structure–function relationships of the "histone code" are being teased out methodically (Jenuwein et al., 2001; Turner, 2002).

It seems increasingly likely that scientists will one day be able to infer with relative certainty the level of active transcription of a given gene simply by examining

the chromatin structure of the gene promoter (Gilmore and Washburn, 2007). This is relevant to forensic investigations because chromatin is formed by DNA–protein interactions and is far more stable than mRNA. Further, genome-wide scanning of chromatin structure by microarray is already possible through the technology of modified histone-specific ChIP-on-chip (or location analysis) (Roh et al., 2004; Huebert et al., 2006). Regardless of the approach taken to scrutinize gene expression, the unparalleled multiplex capacity of microarrays will be absolutely essential for detecting these residual biological "fingerprints" of drug exposure in a tissue because it will probably involve the altered expression of hundreds of genes. Examining a small number of genes would be far too ambiguous for forensic casework. Without microarrays, the immense labor of examining the expression of hundreds of genes manually makes it difficult to envision the reasonable forensic utility of establishing gene expression signatures in response to drug or toxin exposure.

10.4 DETECTION OF MICROORGANISMS USING MICROARRAYS

DNA microarrays are powerful tools for the rapid detection and identification of microorganisms, and there are countless scenarios in which the identification of a potentially infectious agent is of paramount importance. Indeed, the improved detection of biothreats tropic to humans, livestock, or agricultural plants is a major focus of research efforts at the Centers for Disease Control, the Food and Drug Administration, the National Institutes of Health, the Department of Health and Human Services, and countless nongovernmental research centers. Beyond malicious and bioterrorism-related scenarios, rapid pathogen identification has enormous lifesaving potential in the area of infectious disease diagnostics. Furthermore, and particularly relevant to the current text, precise recognition of microorganisms can be crucial to the investigation of criminal activity. Examples include the detection of microorganisms in deliberate or accidental biopoisoning, and the analysis of bacterial flora to scrutinize or match samples of soil, water, and biological specimens or fluids.

Microarrays are particularly well suited for these purposes for at least three reasons. First, the ability to multiplex with microarrays (i.e., screen for multiple targets simultaneously) far exceeds that of any other method. Second, because there is no need for time-consuming bioassays or decision-tree iterative protocols, microarrays are usually far faster than most currently dominant strategies. Finally, and most powerfully, microarray platforms can be designed intelligently such that little or no prior knowledge of the nature of the microorganism being detected is necessary. All of these advantages have already been demonstrated, as we discuss below. Although microarray technology is not yet commonplace in the forensic analysis of microorganisms, the rapid development and declining costs of the technology will probably lead to increased utilization.

10.4.1 Historical Perspective

Since the invention of the microscope, classifying the various types of microscopic life has challenged and fascinated microbiologists. But the association of various

bacteria and fungi with illness brought these classification and identification efforts into the realm of public health. (Because they are even smaller than the maximum resolving power of light microscopes, viruses were not discovered until centuries later.) The Gram stain, which distinguishes bacteria into two classes based on cell wall characteristics, was among the first biochemical techniques in the classification of bacteria and is still in use today. Microscopic size and physical appearance (circular, rod, or corkscrew shape); colony size, shape, and color; growth rate; nutritional requirements; toxicity to laboratory animals; and even traits such as odor once helped scientists tell one species of bacteria from another. Needless to say, all of these methods are laborious and none distinguishes closely related strains or species.

More recently, serological methods have largely supplanted these descriptive techniques. Briefly, *serotyping* is the classification of bacteria based on the presence of certain "markers," usually receptor proteins, that can be detected easily using antibody-based procedures such as ELISA (enzyme-linked immunosorbant assay) (Yolken, 1978). For some pathogenic bacteria, detection assays are designed toward the very receptor that comprises the pathogenic component (Ashkenazi and Cleary, 1989; Munoz et al., 1990; Hearty et al., 2006). This important feature affords these assays a reasonable chance of success in detecting most virulent strains (of that particular species), even, potentially, novel ones. For this reason, along with the rapidity, ease, and negligible expense, serotyping is likely to remain a dominant means of identifying and classifying bacteria (Cebula et al., 2005a).

10.4.2 DNA Fingerprinting

In an effort to distinguish closely related strains of microorganisms, microbiologists and forensic specialists are working to establish a working library of strain-specific genetic fingerprints or *signatures* (Pannucci et al., 2004). These are akin to the DNA fingerprinting that is conducted for identity confirmation of humans using short tandem repeat (STR) or SNP analysis. Knowing the unique genetic features harbored by various strains of pathogenic and benign bacteria, viruses, and fungi will allow investigators to quickly screen biological samples for the presence of these known agents and discriminate between harmless flora and their close virulent relatives.

Several approaches have been taken in an effort to establish DNA fingerprints for individual bacterial strains. RFLP (restriction fragment length polymorphism) analysis of bacterial rRNA genes is one example but fails to distinguish closely related strains or even species (Brindley et al., 1991; Pebay et al., 1992; Alonso et al., 1993; Sriprakash and Gardiner, 1997). RFLP analysis of the entire bacterial chromosome, followed by PFGE (pulse-field gel electrophoresis) is a more dominant technique in bacterial DNA fingerprinting (Linhardt et al., 1992; Gundisch et al., 1993). However, the very large DNA fragments generated by this technique (2 to 5 Mbp) cannot be resolved with great precision. Thus, strain-specific mutations and even larger genomic rearrangements (due to recombination events) could result in no detectable difference in the RFLP fingerprint. In that case, two significantly divergent strains could be indistinguishable by RFLP. Conversely,

an otherwise insignificant or even silent mutation that happens to reside within a restriction site could result in a markedly different RFLP fingerprint with little or no phenotypic difference. This slight genetic difference hardly gives rise to a distinct bacterial strain. The point made by both cases is that RFLP analysis simply compares relative sizes of random chunks of the genome. Thus, while perfectly appropriate for identification of humans, RFLP analysis is somewhat clumsy for the identification of rapidly evolving and mutating microorganisms. DNA sequence–based methods would be inherently more discriminating and yield far more information about discrete genetic differences between closely related microbiota.

More recently, amplification-based approaches have emerged that track amplification fragment length polymorphisms (AFLPs) (Janssen et al., 1996; Lin et al., 1996). While some employ random priming and others target specific genomic regions, the readout is again a "fingerprint" of random fragment sizes (Vaneechoutte, 1996). These techniques have proven to be sufficiently discriminating to differentiate closely related strains of bacteria and races of fungi (Keim et al., 1997; Kis-Papo et al., 2003; Hynes et al., 2006). But once again, because the objects of these analyses are (1) chunks of DNA (bands on a gel), not sequences, and (2) totally unrelated to any phenotypic difference, such as pathogenicity, these techniques offer very little genetic insight into the nature of the microorganism of interest. In this new era of high-throughput entire-genome sequencing, sequence-independent techniques for genetic characterization of organisms seem blunt indeed.

10.4.3 DNA Fingerprinting by Microarrays

Microarray technology has now been employed in an effort to establish genetic fingerprints for microorganisms (Willse et al., 2005; Doran et al., 2007). One such example involves the amplification of established repetitive extragenic palindromic (REP) sequences, followed by hybridization onto a small microarray harboring about 200 random nonamers (Willse et al., 2004). This approach was successful in clearly distinguishing 25 closely related strains of *Salmonella enterica* (Willse et al., 2004). A microarray-based genetic fingerprinting system offers distinct advantages over electromobility-based systems. First, the increased complexity of the fingerprint allows much greater precision and statistical confidence, important features for any forensic technology that must withstand scrutiny in a court of law. Second, microarrays afford the potential to screen for hundreds of strains of hundreds of species simultaneously. Third, fingerprints from previously unobserved isolates could be compared to those of known strains and some knowledge of genetic heritage could be inferred. Indeed, bioinformatic methods of designing robust and precise DNA fingerprinting arrays for pathogen detection are maturing (Satya et al., 2008). However, similar to other fingerprinting methods, while microarray fingerprints of repetitive sequences could provide clues into the nature of known or novel microbes, important phenotypic characteristics, such as virulence, could not be predicted with confidence.

10.4.4 DNA Sequence-Based Detection

Single-nucleotide polymorphisms (SNPs) represent the smallest and most discrete genetic difference between two living organisms. These single-base-pair differences can result in a slightly different protein product (a nonsynonymous SNP) or not (a synonymous SNP), based on the degeneracy of the genetic code. Regardless, the comparison of SNPs between closely related strains of bacteria, viruses, or fungi allows a much more thorough appreciation of genetic differences and facilitates the recapitulation of evolutionary lineage (Bochner, 2003). The importance of this cannot be overstated. Consider the hypothetical example of the emergence of a novel strain of *Salmonella enterica* in a poultry packing plant; considering its unique RFLP or AFLP pattern would provide little information other than that this strain is *not* one that has been observed previously. In contrast, a SNP analysis would reveal which known strains of *Salmonella* are the closest genetic relatives to this new strain, and thus a quick and reasonably accurate prediction could be made as to whether or not this new strain is a health hazard. (Prediction of virulence is discussed further in the next section.)

The painstaking process of using SNPs derived from sequencing data to classify strains of bacteria into groups based on hereditary relationships involves statistical analyses, cladisitics, and computer-assisted hierarchical clustering [see Cebula et al. (2005a,b) for two excellent reviews]. Nevertheless, to date, SNP analyses have been used to resolve and identify strains of *Bacillus anthracis, Mycobacterium tuberculosis, Helicobacter pylori, Escherichia coli, Shigella dysenteriae*, and *Salmonella enterica* (Levy et al., 2004; Pearson et al., 2004; Cebula et al., 2005b; Filliol et al., 2006; Van Ert et al., 2007). The most famous example is that of the SNP analysis used to confirm that the multiple *B. anthracis* samples of the fall 2001 anthrax terrorist attack were of the same genetic strain (Hoffmaster et al., 2002).

10.4.5 Where DNA Microarrays Come In

Microarrays afford the possibility of rapid and thorough SNP analyses without having to perform actual sequencing reactions. One such technique, known as *resequencing*, first involves the amplification (and fluorescent labeling) of several specific regions of interest (i.e., those with well-established strain-specific SNPs) from a sample containing an unknown bacterial strain (Hacia, 1999). Target amplicon size is kept relatively small, about 200 bp, and amplicons are denatured and fragmented prior to hybridization. The probe spots on the microarray are small oligonucleotides around 25 bp in length containing a variable SNP at the central position. Each SNP of interest comprises eight spots on the chip: all four possible variations of the SNP, in both DNA strand orientations. Thus, for each biological sample, the two brightest spots will correspond to the SNP version harbored by that particular bacterium, virus, and so on. Of course, the beauty of the microarray is that an essentially unlimited number of SNPs could be analyzed in a single scan (Zwick et al., 2005; Malanoski et al., 2006; Wang et al., 2006). Further, selections of SNPs from many hundreds or even thousands of bacterial species could be printed on a single array. Thus, one could easily envision a single microarray that

provides coverage for all known enteric bacteria, for example. It is worth noting that because the resequencing technique involves an amplification step with a fairly small amplicon, only minute amounts of starting material are required.

An approach similar to resequencing, called *minisequencing*, represents another microarray-based method of SNP analysis (Huber et al., 2001; Lindroos et al., 2002). However, the small amplicons containing the SNPs of interest are not fluorescently labeled. Further, the 25-bp probes on the microarray do not harbor the SNP itself. Rather, they are the 25 bp of sequence immediately 5′ of the SNP base. Either prior to hybridization (in-solution minisequencing), or following hybridization (in situ minisequencing), of the targets to the probes, DNA polymerization reactions are performed to extend the probes, but only chain-terminating di-deoxynucleotides (fluorescently labeled) are provided. Thus, the DNA polymerase can only add one base to the probes before chain termination, but this $n + 1$ position will correspond to the SNP base with a coded fluorescent label for each of the four possible bases, as revealed by confocal fluorescent scanning of the chip (see Figure 10.2). The minisequencing approach has two advantages over resequencing. First, it only requires two spots for each SNP rather than eight. (Again, both DNA strands are analyzed as an internal duplicate sample.) Second and more important, the data scan of different color fluorescent spots is unambiguous and far more straightforward to analyze and interpret than the single-color scanning of resequencing. However, the additional chemistry and manipulation of the polymerization step adds cost, labor, and experimental variability, important considerations in the search for a highly automated high-throughput platform for forensic application.

10.4.6 Looking Forward: Genetic Virulence Signatures

Bioinformatics researchers are currently mining the ever-increasing volumes of complete genome sequences from various strains of bacteria in search of "virulence signatures" (Pannucci et al., 2004). The rationale for this search is twofold. First, if a given DNA motif could be established as "necessary" for virulence (and thus present in all pathogenic strains, absent in all innocuous strains), this would represent a potentially momentous breakthrough for the basic scientists investigating mechanisms of microbial pathogenesis. Second, and more germane to the forensics realm, knowing the "virulence signature" of pathogenic strains of *E. coli*, for example, would give investigators a robust tool in detecting the appearance of those pathogens, even, at least in theory, those that have not yet been discovered or are the product of malevolent bioengineering.

It goes without saying that the "training set" of sequence data regarding these virulence signatures would need to be monitored and updated continually as more strains, of both the pathogenic and benign variety, emerge. Experimental validation of the pathogenic mechanisms of virulence-associated DNA sequences should be sought in as timely a manner as possible because of the potential to "overfit" the sequence data, honing in on sequences that are merely correlative and thus not in any way connected with pathogenesis. Examples of "red herring" sequences could

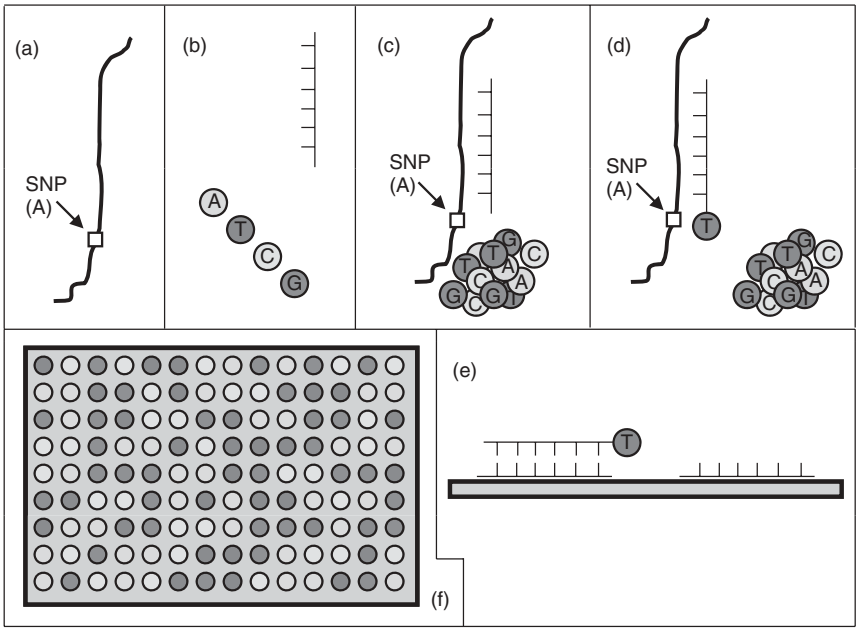

Figure 10.2 SNP analysis by in-solution minisequencing using a four-color microarray. (A) First, the genomic regions containing the target SNPs are amplified by small-amplicon PCR. (B) Then minisequencing reactions are carried out in solution using only dideoxynucleotides (fluorescently labeled). (C) The sequencing primers hybridize with the 3′ end oriented one base upstream of the SNPs. (D) The sequencing primers are extended by one labeled base, complementary to each SNP. (E) The mixture is denatured and hybridized to a microarray printed with DNA sequences containing the SNPs. (F) The microarray containing thousands of SNPs is scanned and each spot is called based on fluorescence.

lead to potentially disastrous false-negative readouts during the screening of an unknown. This potential pitfall can only be overcome by experimental rigor and the diligent reporting and sharing of sequence data.

Although traditional sequencing efforts and "shotgun sequencing" had previously been at the forefront of the search for bacterial and viral genetic fingerprints and virulence signatures, the emergence of relatively low-cost whole-genome sequencing is poised to accelerate this research dramatically (Lorenz, 2002; Read et al., 2003; Pannucci, et al., 2004; Dorrell et al., 2005; Afset et al., 2006; Burrack and Higgins, 2007). Comparative genomics and bioinformatics, followed by experimental validation, will probably illuminate the key genomic elements that confer the pathogenic phenotype(s) for each organism. Indeed, in a spectacularly successful example, a detailed virulence signature for *Staphylococcus aureus* has been established, corresponding to genetic elements in 84 different genes, including those for antibioitic resistance (Spence et al., 2008). Such information is immediately applicable toward building a robust and extremely sensitive microarray that could be used to detect the presence of a virulent form of *S. aureus* with relative certainty.

Once established and validated, virulence signatures for multiple pathogens (each in tens or hundreds of naturally occurring degenerate permutations) can be spotted onto DNA microarrays. Because the spot density capability of DNA chips is so high and increasing (currently >1,000,000 unique probes per chip is possible), it is conceivable that a single chip could harbor the virulence signatures of thousands of different pathogens, allowing broad but precise screening of biological samples in a single pass.

Although the use of microarrays in the forensic identification of microorganisms is still in its infancy, the enormous advantages justify further development of this technology. As costs continue to decline and access increases, it is not inconceivable that microarrays will, one day soon, become indispensables tools for the rapid and reliable identification of microbial strains.

10.5 PROBING HUMAN GENOMES BY DNA MICROARRAYS

The identification of human beings by "DNA fingerprint" has, in a relatively short time, revolutionized forensic science and criminal proceedings (Higuchi et al., 1988; Kobilinsky and Levine, 1988; Lee et al., 1994). This revolution cannot possibly be overstated. However, recent advances in molecular biology and genomics have made possible even further development of forensic DNA technology. Despite this, the extent of DNA technology in most forensic laboratories is currently limited to "DNA fingerprinting" for matching an unknown biological sample to that of a known person. In that regard, DNA microarrays offer several advantages over traditional STR analysis, including adding significant automation, quantitative analysis, and statistical power, as well as further extending the technique to even smaller and more degraded DNA samples than is currently possible. In addition, looking beyond, DNA microarrays may one day allow forensic investigators to transform an unknown and therefore unhelpful DNA sample into a crucial clue for investigating crime.

10.5.1 STR Analysis

Short tandem repeat (STR) analysis is the current technique of choice for identifying unique individual markers of a given DNA sample, and in most cases provides such immense discriminating power that the U.S. and British judicial systems fully accept STR results into a court of law, provided that the technical execution is within established protocols. This technique exploits the polymorphic nature of some repetitive sequences within the human genome, called *microsatellite DNA*. These regions consist of a simple DNA sequence, 3 to 7 bp in length, that is repeated anywhere from 3 to 15 times. [There exists examples of both shorter and longer repeats (satellite or minisatellite DNA) and regions where many hundreds or thousands of repeats exist in tandem, but these are not typically part of forensic STR analysis.] Biallelic in nature (one each on the paternal and maternal chromosome), these microsatellites, or STRs, are highly polymorphic and stably inherited. That

is, a given person will have two alleles for a given STR (e.g., 12 and 8 repeats on each of a pair of homologous chromosomes, one inherited from her biological mother, the other from her father), and one will be passed on to each of her children at random. Thus, two nonrelated individuals will have a very low probability of having the same two alleles for this given STR. Even siblings have only a 25% chance of inheriting the same two numbers of repeats for each and every STR. When examining multiple STRs, the likelihood that two different individuals will harbor the same alleles drops dramatically with each additional STR included in the analysis. Accordingly, the standard U.S. Department of Justice's CODIS protocol calls for an examination of 13 established STR loci, which places the statistical odds of two nonidentical individuals having the same two alleles for all 13 loci at less than 2×10^{-15}, a number whose reciprocal is more than 10,000 times more than the number of human persons who have ever walked the Earth (Lee et al., 1994; McEwen, 1995; Budowle et al., 1999; Ruitberg et al., 2001). (Government officials are currently deliberating an increase in the number of CODIS STR loci to 20.)

Clearly, the discovery, development, and careful propagation of STR analysis represented an unparalleled triumph in the application of molecular biology to criminal justice, and it may be tempting to think that current abilities of DNA analysis already meet or exceed their usefulness, with no further improvement necessary. However, a critical examination of current techniques in STR analysis reveals several compelling reasons to pursue further development in this area. First, the approach of STR analysis itself could benefit with increased automation, multiplexing, and high-throughput capabilities, as current protocols call for extensive sample handling and manipulation and significant technician labor. In addition to the costs of time and labor, these manipulations bring opportunities for experimental error which could potentially jeopardize the trustworthiness of a given DNA match. Although the PCR amplifications can now be multiplexed routinely and efficiently (reducing labor and handling), traditional STR analysis still requires forensic researchers to electro-resolve the PCR products and make judgments regarding relative mobility rates of these DNA fragments, as compared to known DNA standards. The result is a DNA "fingerprint" that is somewhat qualitative, rather than strictly quantitative, as is most desirable when objectivity is of such supreme importance.

Without altering the basic premise, small DNA microarrays can be used in the execution of traditional STR analysis. A major challenge in any microarray-based, and thus hybridization-based, approach to forensic STR analysis is the detection of subtle differences in sequence repeat number. For example, while discriminating between 3 and 15 repeats would be relatively straightforward, it is exceedingly difficult to discriminate between 9 and 10 repeats using differential hybridization onto a standard microarray with the necessary degree confidence. Accordingly, researchers have devised two creative solutions to this obstacle. First, electronically active microarrays can be utilized to establish and fine-tune an extremely high stringency hybridization environment (Radtkey et al., 2000). In this way, even the subtlest differences in hybridization energies can be exaggerated and the results are clear spot calls on the microarray, indicating the exact repeat number for each

STR with precision. For this reason, the technology of electronic microarrays has found its way into several microarray platforms (including forensic SNP analysis, discussed below) and development continues (Heller, 2002).

More recently, a second approach to array-based STR analysis has been reported that involves the use of standard glass microarrays and a sequence of enzymatic steps (Kemp et al., 2005). In this somewhat complicated method, called variable-length probe array (VLPA), the microarray spots harbor single-stranded probes containing STRs of various lengths (repeat numbers) bound to the microarray surface at their 5′ end. Following amplification and 5′ fluorescent labeling of STR regions in the target DNA sample, the labeled amplicons are hybridized to the microarray. Obviously, the targets will hybridize to probes with both more and fewer numbers of STR repeats than those of the target itself. To ensure proper alignment at each STR set, complementary *clamp sequences* are included at the 5′ end of the probe DNAs and the 3′ end of the target sequences. Thus, at probe spots containing *fewer* repeats than the hybridized target sequence, the 5′ end of the target DNA (which contains the label) will overhang. At probe spots containing *more* repeats than the target DNA, the spotted 3′ end of the probe DNA will overhang the target DNA. Next, the slides are treated with S1 endonuclease, which digests single-stranded DNA. Thus, all overhangs are removed and, importantly, the fluorescent label will be released from any target DNA that is bound to a probe spot containing an STR sequence that is shorter (fewer repeats) than the target DNA. Conversely, the fluorescent label will remain on all target DNAs that are bound at spots containing probes of equal or greater length, despite the digestion of the 3′ end of probe DNAs that are longer than the target DNA. For example, if a target DNA sample contains 11 repeats of a given STR, fluorescent signals of approximately equal intensities would be detected at probe spots harboring 11, 12, 13, 14,... repeats, but no signal whatsoever would be detected at probe spots harboring 10, 9, 8, 7,... repeats. Although it is not yet clear how this system can delineate heterozygous alleles, a major advantage of this approach is that the spot calls are unambiguous (signal or no signal) and thus easy to automate in a high-throughput manner. Creative use of the clamp sequence could also allow a great deal of multiplexing of many samples simultaneously.

A third microarray-based approach toward STR analysis that has been reported involves the use of the branch migration capabilities of double-stranded DNA. This assay begins similarly to VLPA with hybridization of labeled target DNA to probes of varying length using a clamp sequence to ensure alignment. Next, a succession of two competing probes in opposite orientations initiate branch migration to displace probe–target interactions that are not perfect matches for the number of tandem repeats. Thus, array scanning will elicit signal from only one spot per STR allele, and heterozygosity can be detected and delineated using an algorithm specially designed for this system (Pourmand et al., 2007). In summary, several options for array-based STR analysis have been developed, each with distinct advantages and caveats. The major advantage of any microarray-based platform is the enormous potential for rapid high-throughput screening of thousands of samples

simultaneously. And as microarray costs continue to decline, the feasibility of their routine use in forensic applications increases.

10.5.2 SNP Analysis

Although the power of STRs in forensic investigations is truly remarkable, there are limitations to STR analysis that warrant continued research in alternative technologies. Specifically, because each STR locus is first amplified in a PCR reaction, there is a lower limit for required template, beneath which amplification is too inefficient and unreliable for forensic purposes. This minimum sample size is indeed minute, allowing complete DNA profiles to be collected from scant physical evidence such as one intact hair follicle. However, biological material that serves as a template in a PCR reaction is consumed in the process, and when the amount of sample is limiting, as is often true in forensic investigations, there is little or no margin for error. Currently, the lower limit of input DNA to achieve a reliable CODIS (FBI's Combined DNA Index System) DNA profile is between 100 and 200 pg of pristine human genomic DNA (Lorente et al., 1997; Krenke et al., 2002; Leclair et al., 2003). With 6 pg of DNA in each human nucleus, this means that in the best of circumstances and with flawless technique, a biological sample must contain at least 15 to 30 intact cells with undamaged DNA. Although this is certainly an impressive level of detection, the collection of trace forensic evidence often falls below this standard in quantity or quality of DNA. Following the death of a human cell, DNA begins the steady process of decay, and trace DNA specimens from hair or dead skin cells collected at a crime scene are often not of adequate quality for any type of STR analysis.

Single-nucleotide polymorphism (SNP) analysis provides an alternative to STR analysis with much lower requirements of quantity and quality of input DNA, thus allowing further reduction of the threshold requirements of biological material from which a quality DNA profile can be extracted (Walsh, 2004; Nygaard and Havig, 2006). This increased sensitivity arises due to the amplification of significantly smaller amplicons. Unavoidably, forensic STR analysis involves the amplification of repeat sequences as large as 400 bp, and there is a direct relationship between the size of an amplicon and the amount of intact template DNA required for efficient amplification. Because SNPs are a single base in length, amplicons can be designed that are less than 50 bp in length. Thus, SNP analysis is far more robust than STR analysis with trace and/or degraded DNA samples. However, because there are only four possible alleles for each SNP (A, T, C, or G), rather than 7 to 22 possible alleles for each CODIS STR, a far greater panel of SNPs must be examined in order to achieve discriminating power similar to that of forensic STR analysis. For the level of certainty required of a criminal prosecution, at least 50 SNPs would be needed for a positive identification, and a panel of about 100 SNPs would probably be appropriate for a universal forensic protocol. It is this large number of individual loci that need to be examined that has probably discouraged more widespread application of SNP analysis in forensic DNA matching. However, microarrays circumvent this challenge completely, and hundreds or even thousands

of SNPs could be analyzed simultaneously with relative ease. Further, clamping sequences or a similar mechanism could facilitate complete SNP screening for multiple (even hundreds) of different biological samples on a single chip.

Human SNP analysis by microarray is already a well-established technology, although application is limited primarily to basic research and clinical diagnosis of genetic diseases. Further, the current dbSNP database at the National Institutes of Health contains millions of documented SNPs in the human population (NCBI web site, http://www.ncbi.nlm.nih.gov/projects/SNP/). Thus, it will not require great strides to bring the technology of SNP microarrays to the forensic realm. Indeed, electronically active arrays have already proven their utility in forensic applications (Borsting et al., 2004, 2005; Huang et al., 2004; Tsang et al., 2004). Exactly which cadre of SNPs will perform best for forensic purposes remains to be seen, but among the most important considerations are high variability of alleles in the human population and ease of amplification in a large multiplex PCR. The latter factor is determined by the genomic "neighborhood" of each SNP and must be tested empirically. A microarray-based strategy for detecting SNPs involves either resequencing or minisequencing (see Section 10.4.4 and Figure 10.2). Although to date, current reports of forensic SNP analysis by microarray have utilized in-solution minisequencing prior to hybridization, resequencing microarrays could prove just as powerful and would involve less labor and manipulation (Allen and Divne 2005; Divne and Allen, 2005).

10.5.3 Exploring an Unknown Genome?

Consider the example, as happens often, when a DNA sample collected from a crime scene does not match with a known DNA profile in any database or from a possible suspect. Currently, the unknown DNA sample would then be considered a "dead end," useful only for screening additional suspect(s), if they are somehow identified by further criminal investigation. However, the DNA sample itself is an entire genome, containing much more information than the simple DNA fingerprints that are used to match samples. Within the DNA sequence of a genome is all the genetic information necessary to build that person, and *only* that person. Thus, a DNA sample with no known matches could be far from a dead-end. It could potentially tell us much about the perpetrator him- or herself, including such genetic traits as eye color, hair color, race and ethnic origin, approximate height/weight/build, and genetic diseases or predispositions. When investigating a crime, such information could be extremely valuable for narrowing down overwhelmingly large pools of suspects into just a few people or one person. Focusing on a smaller suspect pool would greatly reduce the disturbance of innocent people, as well increase the likelihood that detectives could discover additional evidence implicating the guilty party. Further, if a suspect pool was narrowed to a sufficiently small number of people, a court of law could then compel the collection of DNA samples to facilitate a comprehensive match.

Forensic research into the precise genetic basis for physical traits such as race/ethnic origin and eye color is already proceeding rapidly (Frudakis et al.,

2003; Rowold and Herrera, 2003; Sturm and Frudakis, 2004; Amorim and Pereira, 2005; Ray et al., 2005; Sobrino and Carracedo, 2005; Wetton et al., 2005; Lao et al., 2006; Kayser et al., 2008). However, information of this type will be most valuable to forensic science when many traits are analyzed at once; for example, "the DNA sample left at the crime scene was from a woman of mixed Central European and East Asian descent, with green eyes, blonde natural hair color, medium build, projected height between 5′6″ and 5′9″ and strong predisposition for asthma." Even accepting the caveat that many of these characteristics will fluctuate and are influenced by environment in combination with genetics, it is easy to imagine the power of such information when investigating a crime. However, this area of forensic research is still in its infancy, awaiting rigorous research, and must be accompanied by careful consideration of the social and ethical concerns that are raised by such an approach. Notwithstanding, there exists no technological or scientific barrier to the development of this approach.

CONCLUSION

The genomics revolution, led by microarray technology, has already informed various subdisciplines in forensic science, most notably toxicogenomics and SNP analysis, and further microarray-catalyzed innovation is surely afoot. One of the hallmark features of the genomics era is the staggering scale and speed with which research and technology development is now progressing. Thus, the wait might not be as long as one would think. It can now be said that the revolutionary potential of microarray technology rivals that of PCR. However, the potential application to forensics is much broader than just DNA fingerprinting and human ID. It will be interesting to observe how quickly potential becomes reality and innovative research becomes the gold standard. A currently limiting factor, both in terms of research and in application, is the seemingly exorbitant cost of microarray printing, fluidics, and high-resolution scanners. However, these costs are steadily decreasing and the ability to strip and reuse microarrays would dramatically slash research costs (although it would not be appropriate for casework). Further, the need to purchase and maintain such microarray instrumentation, including array printers, fluidics stations, and even scanners, is being alleviated by a more "full service" approach, for both in-stock and custom arrays, from the major microarray companies. As declining costs bring microarray technology within reach for more research laboratories, increased numbers of thorough forensic validation studies can be performed and published. Hopefully, this will persuade forensic practitioners that the technology is not just powerful but *reliable* as a bona fide tool for forensic casework.

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CHAPTER 11

Date-Rape Drugs with Emphasis on GHB

STANLEY M. PARSONS

Department of Chemistry and Biochemistry, Program in Biomolecular Science and Engineering, Neuroscience Research Institute, University of California, Santa Barbara, California

Summary The date-rape drugs γ-hydroxybutyrate (GHB), 3,4-methylenedioxy-methamphetamine, flunitrazepam, and ketamine are discussed with an emphasis on GHB. Recreational, predatory, and lethal doses, why polydosing is dangerous, metabolism including membrane transport, and diagnostic metabolites are covered. Similarities to and differences from the effects and metabolism of ethanol are also discussed. The advantages of field tests to detect date-rape drugs, and limitations of antibodies and advantages of enzymes for field tests, are described. Development of a rapid enzymatic test for GHB is described.

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11.1 INTRODUCTION

Prominent examples of *date-rape drugs* are the natural compound γ-hydroxybutanoic acid (GHB) and the synthetic compounds 3,4-methylenedioxymethamphetamine (MDMA), 5-(2-fluorophenyl)-1,3-dihydro-1-methyl-7-nitro-2H-1,4-benzodiazepin-2-one (flunitrazepam), and 2-(2-chlorophenyl)-2-(methylamino)cyclohexanone (ketamine) (Figure 11.1; Scott-Ham and Burton, 2005; Saint-Martin et al., 2006; Abanades et al., 2007a; Juhascik et al., 2007). These compounds are grouped in ignominy because they can be administered surreptitiously in the relatively small amounts required to make a person compliant with sexual assault. Ethanol has similar effects, but generally it is not called a date-rape drug because it is legal and knowingly consumed. The term *agent* as used here refers to ethanol and date-rape drugs, whereas the term *drug* is restricted to date-rape drugs.

In this chapter we discuss primarily date-rape drugs.[1] We also touch on ethanol just enough to point out some similarities, differences, and interactions between ethanol and date-rape drugs. As GHB is a research topic of special interest to the author, it is emphasized throughout. Much important progress has been made recently in understanding the physiology, biochemistry, cell biology, and molecular biology relevant to these agents. Important progress has also been made in developing better methods to detect dosing. The goals of this chapter are to unify the biological and chemical perspectives of date-rape drugs and to improve our ability to detect dosing. The wide range of subjects covered has required the use of footnotes to explain specialized terminology. References are numerous, but to keep the number of them reasonable, they are not comprehensive (apologies to authors not cited). A number of recent excellent reviews of individual date-rape drugs and forensic methods to detect them may be consulted for more citations: Maitre et al., 2000; Palmer, 2004; Wong et al., 2004a,b; Britt and McCance-Katz, 2005; Gonzalez and Nutt, 2005; Drasbek et al., 2006; Pardi and Black, 2006; Snead and Gibson, 2006; Wedin et al., 2006; Wolff and Winstock, 2006; Colado et al., 2007; Kintz, 2007; Seamans, 2008; Sinner and Graf, 2008.

11.2 MOLECULAR MECHANISMS OF ACTION

11.2.1 Receptors and Transporters

To cause cognitive and behavioral effects, psychotropic agents must interact with neuroreceptors or neurotransporters in the central nervous system. This

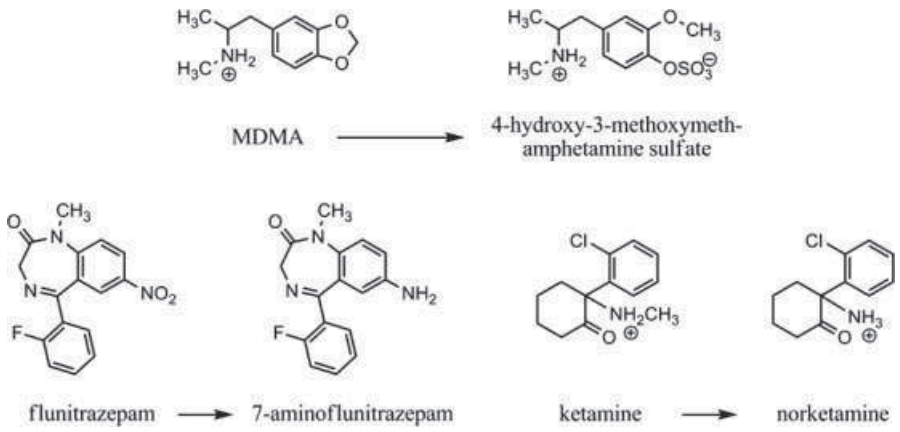

Figure 11.1 Structures of some synthetic date-rape drugs and their major metabolites found in human urine.

requirement means that the agents must pass through the blood–brain barrier to come into contact with neurons. A neuroreceptor generally spans the cytoplasmic membrane of a neuron, and the active site faces the extracellular space so that it can bind to a neurotransmitter coming from there. A neurotransporter can span either the cytoplasmic membrane or the membrane of a synaptic vesicle[2] inside a neuron.

The blood–brain barrier is breached by nonspecific diffusion for ethanol, flunitrazepam, and ketamine (Adachi et al., 2005; Cuadrado et al., 2007). It is breached by specific transport for MDMA, metabolites of MDMA, and GHB (Drewes et al., 2001; Bhattacharya and Boje, 2004; Escobedo et al., 2005). Thus, access by the latter compounds to brain potentially is saturable and inhibitable. More will be said later about transport versus nonspecific diffusion of GHB and related molecules. Some date-rape agents have actions in the periphery, but such actions won't be discussed much, except for metabolism.

Once they have reached neurons in the brain, the agents have many effects. Recent research indicates that ethanol acts primarily by means of a limited number of molecular mechanisms (Vengeliene et al., 2008). Prominent among them is a three-way, synergistic interaction of ethanol, neurosteroids[3], and the inhibitory neurotransmitter γ-aminobutanoic acid (GABA) on separate sites in the ionotropic $GABA_A$ receptor. Together these agents promote opening of the chloride channel in the receptor at concentrations of GABA lower than otherwise required (Herd et al., 2007; Mody et al., 2007; Mody, 2008).[4] Open chloride channels make most neurons resistant to electrical stimulation. This three-way synergy is especially effective at a subtype of the $GABA_A$ receptor located *outside* of synapses, where extracellular GABA concentrations are low but do not fluctuate much. As $GABA_A$ receptors are distributed throughout the brain, the result of ethanol consumption is widespread tonic (i.e., persistent) neural depression.

GHB is present naturally in brain at concentrations that depend on the region (Doherty et al., 1978; Vayer et al., 1988). Values range up to about 10 μM, averaged across tissue compartments. At the >100-fold-higher concentrations reached in sexual assault and self-abuse situations, GHB is a partial agonist for $GABA_B$, the metabotropic receptor (Gobaille et al., 1999; Lingenhoehl et al., 1999; Wong et al., 2004a,b).[5] Activation of $GABA_B$ receptor inhibits the release of neurotransmitters from nerve terminals by several intracellular second-messenger mechanisms (Ulrich and Bettler, 2007). GHB does not produce the full range of its behavioral effects in mice that have one of the two subunit types in $GABA_B$ receptors deleted from the genome (Bettler and Braeuner-Osborne, 2004; Gassmann and Bettler, 2007). The observation confirms involvement of $GABA_B$ receptors in GHB effects in vivo.

GHB increases neurosteroid levels three- to fivefold when it activates $GABA_B$ receptors (Barbaccia et al., 2002; Biggio et al., 2007). Increased neurosteroid levels in turn potentiate opening of chloride channels in $GABA_A$ receptors. Thus, high doses of GHB directly or indirectly activate both major classes of GABA receptor. These actions produce molecular, cellular, and behavioral responses partially overlapping those produced by ethanol and GABAergic drugs[6] such as flunitrazepam, another date-rape drug discussed in this chapter (see below; Baker et al., 2008; Helms et al., 2008; Carter et al., 2009).

Activation of GABA receptors by GHB is entangled with the possibility that a small fraction of ingested GHB or GHB prodrug is converted to GABA itself by reversal of the biosynthetic pathway from GABA to GHB (Figure 11.2; Sections 11.5.2 and 11.5.3) (Collier and De Feudis, 1970; Vayer et al., 1985a; Hechler et al., 1997; Gobaille et al., 1999). Such reversal is thermodynamically feasible. GABA derived from GHB potentially could act on all GABA receptors, including recently discovered $GABA_A$-ρ (also known as $GABA_C$; Schmidt, 2008). However, reversal is controversial (Mohler et al., 1976; Snead et al., 1989; Crunelli et al., 2006; Ren and Mody, 2006). It might not occur when membrane barriers are intact, and the issue is unresolved. Action of GHB on recently identified GHB receptors is described in Section 11.2.2.

Other date-rape drugs have different molecular mechanisms of action. Flunitrazepam binds to an allosteric site in both synaptic and nonsynaptic $GABA_A$ receptors, where it potentiates GABA action to depress the central nervous system (Brenneisen and Raymond, 2001). MDMA (and/or an MDMA metabolite) interacts with several types of transporter to cause release of the neurotransmitter 5-hydroxytryptamine (also known as serotonin) and the neurotransmitter-hormone oxytocin.[7] In addition, extensive use of MDMA can cause permanent neuronal damage, probably by promoting the formation of reactive oxygen species such as hydrogen peroxide and hydroxyl radical (de la Torre et al., 2004)! Ketamine is an antagonist at the NMDA type of receptor for the excitatory neurotransmitter glutamate (Raeder, 2003).[8]

11.2.2 Real GHB Receptors

The mechanisms described above do not involve a receptor selective for GHB. Two forms of the human GHB receptor (GHBh1 and C12K32) have been cloned,

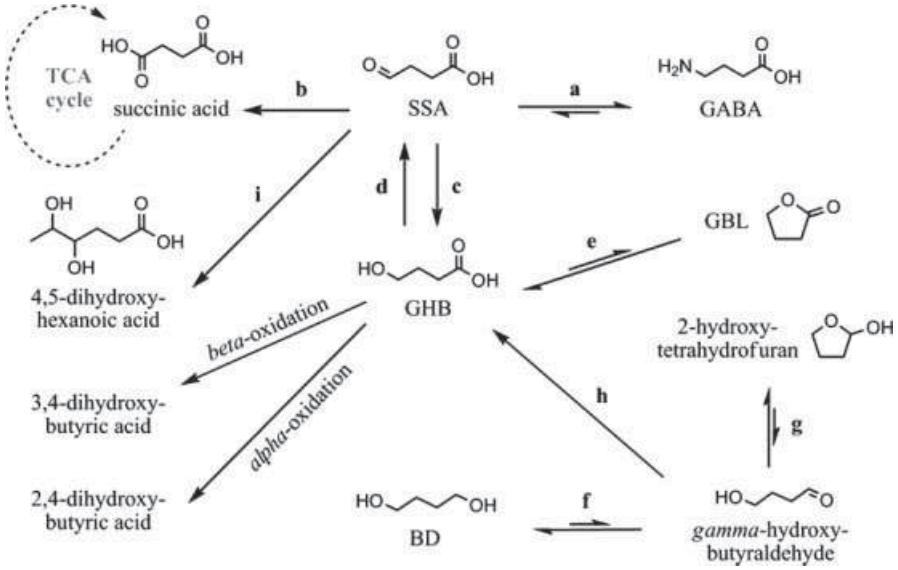

Figure 11.2 Known metabolism of GHB and its prodrugs. Chemical structures are shown above or next to the names or abbreviations. Reversible steps between metabolites are shown with paired half-head arrows and irreversible steps with a single arrow. An arrow longer than a paired arrow indicates the favored direction. Enzymes catalyzing the reactions alphabetically labeled are listed in Table 11.2. Reaction a: GABA transaminase makes SSA in mitochondrial matrix. Reaction b: ALDH5A1 in mitochondrial matrix oxidizes SSA to succinic acid that enters the tricarboxylic acid cycle. Reaction c: AKR1A1 and AKR7A2 reduce SSA in cytoplasm. This step requires transport of SSA from mitochondrial matrix (Figure 11.3). Reaction d: ADHFe1 oxidizes GHB in mitochondrial matrix after transport of GHB into matrix. The reaction probably is irreversible because reaction b is very fast. Untested is the possibility that irreversible ω-oxidation of GHB by cytochrome P450 and catalase also occurs (Section 11.15). Reaction e: γ-Lactonase 1 in blood and liver hydrolyzes GBL. Reaction f: One or more unidentified ADHs oxidize BD in the periphery. A different, irreversible oxidative mechanism that might involve cytochrome P450 and catalase occurs in brain (Section 11.15). Reaction g: Cyclization is spontaneous. Reaction h: Unidentified ALDH in the periphery. A different oxidative mechanism also might exist by analogy to the metabolism of ethanol (Section 11.15). Reaction i: An intermediate in the pyruvate decarboxylase reaction in mitochondria probably forms 5-keto-4-hydroxyhexanoic acid that then is reduced. α- and β-oxidation of GHB also occur, possibly in mitochondria, peroxisomes, and smooth endoplasmic reticulum (Section 11.15).

expressed, and characterized preliminarily (Kemmel et al., 2006; Andriamampandry et al., 2007). Both forms bind to physiologically relevant, sub-μM concentrations of GHB to regulate intracellular second messengers. The receptors also bind to the specific antagonist NCS-382, but not to GABA. GHBh1 expressed in a heterologous host quickly desensitizes after exposure to a saturating concentration of

GHB, whereas C12K32 does not.[9] A putative GHB receptor, which is of uncertain significance because it has aberrant pharmacological properties, has also been cloned from rat (Andriamampandry et al., 2003).

The cloning of the human receptors, combined with prior discoveries of neurotransmitter-like properties of GHB, such as its storage by synaptic vesicles, establishes GHB as a classical neurotransmitter (Kemmel et al., 1998; Muller et al., 2002). The full significance of neuro-signaling by endogenous GHB is not known (Ticku and Mehta, 2008). The terms *de novo* and *endogenous* are used here as synonyms. They mean not arising from ingested GHB or GHB prodrug. Whether GHB receptors in vivo desensitize during dosing with exogenous GHB, and what the physiological consequences of such desensitization would be, are not known. Characterization of these properties is just beginning (Coune et al., 2010).

11.3 SOCIETAL CONTEXT OF DATE-RAPE AGENTS

11.3.1 Acute Effects of Date-Rape Agents on Cognition and Behavior

Ethanol reduces social inhibition, increases suggestibility, and at large doses induces sedation and amnesia (Vengeliene et al., 2008). GHB increases libido and suggestibility, causes euphoria, relaxation, and reduction of social inhibitions, and at large doses induces sedation and amnesia (Drasbek et al., 2006; Kueh et al., 2008). Flunitrazepam induces hypnosis, sedation, anxiolysis, and at large doses, amnesia (Lane et al., 2008). MDMA causes mild euphoria and stimulates feelings of love, empathy, and connection to other people (Colado et al., 2007). Ketamine produces analgesia, anesthesia, and hallucinations (Rowland, 2005). Despite differences in the molecular mechanisms of action and required doses (Sections 11.2.1, 11.2.2, and 11.3.3), the agents are similar to each other in producing mental states that make victims compliant with sexual assault (Elliott, 2008; Lawyer et al., 2010).

11.3.2 Medicinal Uses of Date-Rape Drugs

Date-rape drugs have been used to treat clinical indications. For example, GHB is used for sleep disorders and alcohol-withdrawal syndrome (Agabio and Gessa, 2002; Johnston et al., 2003; Pardi and Black, 2006; Robinson and Keating, 2007; Castelli, 2008; Caputo et al., 2009). GHB might also be useful in cancer treatment and protection from or functional recovery after focal cerebral ischemia (Sadasivan et al., 2006; Emi et al., 2007; Gao et al., 2008). Flunitrazepam has been used for insomnia and anxiety (Matsuo and Morita, 2007), and ketamine has been used for pain (Okon, 2007; Morton, 2008). MDMA is being tested for treatment of posttraumatic stress disorder (Parrott, 2007; Vastag, 2010). Accordingly, the compounds are manufactured by reputable pharmaceutical companies and are

available through prescription. Unfortunately, they also are available from illicit sources.

11.3.3 Self-Abuse

Date-rape agents frequently are ingested voluntarily without medical supervision (http://www.drugabuse.gov/Infofacts/clubdrugs.html). Some people engage in this behavior because they perceive the cognition- and behavior-altering properties of the agents to be compatible with recreation (Camacho et al., 2005; Griffiths and Johnson, 2005; Abanades et al., 2007a; Kim et al., 2007b; Horowitz et al., 2008; Lee and Levounis, 2008). Common oral doses for recreational use by people who have not developed tolerance are given in Table 11.1. Effective doses differ over a 50,000-fold range for the various agents!

In addition to having cognitive and behavioral effects, GHB stimulates release of human growth hormone (Volpi et al., 2000; Gonzalez and Nutt, 2005). Some bodybuilders consume it in huge amounts (18 to 250 g/day divided into multiple doses) in an effort to increase muscle mass. The practice results in tolerance and addiction, and severe withdrawal symptoms occur when addicted individuals attempt to discontinue use (Bennett et al., 2007; LeTourneau et al., 2008; Wojtowicz et al., 2008). In rats, the addiction decreases membrane fluidity and increases GABA reuptake from extracellular space in brain (Bhattacharya et al., 2006). GHB greatly alters the levels of some brain proteins (van Nieuwenhuijzen et al., 2010). It increases the acetylation of histone H3, thereby causing epigenetic modification of gene expression (Klein et al., 2009). The latter observations demonstrate physiological adaptation consistent with addiction.

TABLE 11.1 Effective Oral Doses for Human Beings[a]

Compound	LD_{50} (mg/kg)	Recreation (mg/kg)	$\frac{LD_{50}}{\text{Recreation}}$
Ethanol	5000[b]	500[c]	10
GHB	400	50	8
GBL/BD[d]	200	25	8
MDMA	30	2	16
Flunitrazepam	0.4	0.01	30[e]
Ketamine	40	1	>38

Source: Data from Miller (1979), Wang and Bai (1998), Gable (2004), Carai et al. (2006), and http://toxnet.nlm.nih.gov/. Effective doses for rodents are higher.

[a] The numbers apply to normal, healthy, and otherwise undrugged human adults of either gender who have not developed tolerance.

[b] This amount corresponds to about 0.6% ethanol in physiological fluids.

[c] This amount corresponds to consumption of about one-half bottle of wine.

[d] GBL and 1,4-butane diol (BD) are quickly converted to GHB in the body (Sections 11.13.1 and 11.13.2). Effective doses are lower than for GHB because the compounds are absorbed faster (Table 11.5). Safety factors are similar, however.

[e] Rounding errors create the apparent discrepancy relative to the ratio computed from numbers on the left.

11.3.4 Date Rape, Death, and Regulation

In chemical assault for the purpose of date rape, the perpetrator attempts to deliver a high recreational dose that incapacitates the victim. However, date-rape agents can be lethal. The estimated oral LD_{50} values for human beings who have not developed tolerance are given in Table 11.1. The ratio of the LD_{50} to the recreational dose (i.e., the safety factor) is also given for each agent. Some agents have small safety factors, particularly ethanol, GHB, and its prodrugs γ-butyrolactone (GBL) and 1,4-butanediol (BD) (Sections 11.13.1 and 11.13.2). Because different agents have mostly different molecular targets that can interact with each other physiologically, these agents have the potential to synergize and push the central nervous system into an extremely depressed state. Deaths occur at doses of combined agents that are difficult to predict and often much lower than those required for single agents (Jonasson et al., 2000; Lalonde and Wallage, 2004; Mazarr-Proo and Kerrigan, 2005; Jones et al., 2007; Verschraagen et al., 2007; Hovda et al., 2008; Knudsen et al., 2008; Akins et al., 2009). To impede drug-assisted date-rape and possible death, most national governments restrict access to date-rape drugs. Proscription has created a need for reliable analytical procedures to detect the compounds and their metabolites.

11.4 METABOLISM FUNDAMENTALS

11.4.1 Complexity in Unraveling Metabolism of GHB-Related Compounds

Because it is a neurotransmitter, GHB is degraded (catabolized) and biosynthesized (anabolized) at more-or-less constant low rates in mammals. Conceptually, such turnover can be divided into two phases, one starting with and one ending with GHB. In contrast, when GHB is ingested, catabolism starts with a very high concentration and proceeds at a high rate. The cascade of steps that ensues can be conceptualized as parallel to that followed in the catabolism of endogenous GHB. However, is it precisely the same or partially different when much higher concentrations are involved? When prodrug GBL or BD is ingested, rapid metabolic activation generates a higher concentration of GHB. Activation can be conceptualized as being parallel to the de novo biosynthesis of GHB, except that the steps are different. Overall, a full understanding of the actions of GHB and GHB-related compounds in vivo requires descriptions of at least four distinguishable phases of metabolism. The intellectual and experimental overlay of these phases onto each other creates much more complexity than exists for other date-rape drugs, each of which undergoes only one catabolic phase.

To provide the reader with the concepts needed to resolve uncertainties encountered in GHB metabolism, the rest of Section 11.4 covers some relevant fundamentals. In addition to its utility in defining metabolic pathways with certainty, information at the substantial level of detail presented in this chapter is important because it will probably reveal new ways to detect dosing and to mitigate the

adverse effects of an overdose. Indeed, the potential payoff motivates the comprehensive approach taken.

11.4.2 Isozymes in GHB-Related Metabolism

Before the tools of recombinant DNA, cell biology, and genomic sequences were available, research on GHB metabolism was extraordinarily difficult. In part, this occurred because of the existence of *isozymes*, which catalyze the same type of reaction on the same type of chemical functional group in different substrates. For example, isozymic alcohol dehydrogenases catalyze the oxidation of alcohols (GHB is an alcohol) to carbonyl compounds. Isozymes are encoded by different genes.[10] Moreover, enzymes catalyze reversible reactions in both directions. In the case of biosynthesis and catabolism of GHB, it can be unclear in which direction a reversible reaction proceeds in vivo.

Isozymes often resemble each other in molecular weight, net charge, and other physicochemical properties due to evolutionary kinship. Isolation of an enzymatic activity from a natural source such as brain, kidney, or liver can produce a mixture of isozymes. Mixtures are especially likely when isozymes form heterooligomers with each other. Unfortunately, some in vitro data are compromised by lack of convincing isozymic identity and/or homogeneity. Many of the isozymes discussed in the chapter now have been expressed in and isolated from a heterologous host such as the bacterium *Escherichia coli*, which is methodology that produces a single isozyme. Where the issue is critical, we cite only references not suffering from isozyme ambiguity.

Genomic and mRNA sequences reveal that more forms of many enzymes exist than formerly realized, including the enzymes that catalyze reduction and oxidation (redox) reactions in GHB-related pathways. There are nine functional human genes for NAD^+-dependent alcohol dehydrogenases (ADHs), 14 for NADPH-dependent aldo-keto reductases (AKRs), and 23 for $NAD(P)^+$-dependent aldehyde dehydrogenases (ALDHs) (http://www.ihop-net.org/; http://www.med.upenn.edu/akr; Hyndman et al., 2003; Hoffmann and Valencia, 2004; Vasiliou and Nebert, 2005; Jin and Penning, 2007). ADHs generally bind NAD^+ in preference to $NADP^+$, and thus they catalyze oxidation of alcohols using primarily NAD^+ rather than $NADP^+$ in vivo. AKRs generally bind NADPH in preference to NADH, and thus they catalyze reduction of aldehydes and ketones primarily using NADPH rather than NADH in vivo. In contrast, many aldehyde dehydrogenases catalyze oxidation of aldehydes to carboxylic acids using either NAD^+ or $NADP^+$.[11]

11.4.3 Subcellular Compartmentalization of Enzymes, Transporters, and Substrates

An isozyme can be located in the same or different cellular and subcellular compartments as another isozyme of the same superfamily. It can have multiple natural substrates, some better than others. Also, a metabolite of interest might be a good substrate for several isozymes when characterized in vitro. When complexity in

substrate–isozyme relationships exists in vitro, one cannot choose on the basis of substrate selectivity alone which isozyme functions in a particular pathway in vivo.[12] Rather, the choice can require knowledge of organ, cellular, and subcellular locations for both substrates and isozymes. Also, the levels of expression and cofactors, and the values for Michaelis–Menten parameters, can be important.[13]

If a pathway flows through a noncytosolic compartment such as the mitochondrion, a candidate isozyme and its substrate must be in that compartment. Delivery of a protein to the compartment requires an appropriate intracellular trafficking signal. If the signal is coded in the amino acid sequence, which it usually is, it is coded in the mRNA sequence also. Delivery of the substrate is spontaneous if it is hydrophobic enough to pass through membranes rapidly by nonspecific diffusion. However, if a substrate is highly polar or ionic (e.g., GHB; Section 11.14), delivery requires an appropriate transporter in the compartmental membrane. Isoporters also exist.[14]

11.4.4 Dynamics and Equilibria for Enzymes and Transporters

A transporter and an enzyme are similar to each other in that both are catalysts and both exhibit Michaelis–Menten constants for reaction in the forward and reverse directions. However, they can respond to substrate analogs very differently. For an enzyme, a binding analog of a substrate is always an inhibitor with respect to the substrate, as it blocks binding by substrate. For a transporter, membrane sidedness opens an additional possibility (Figure 11.3). Suppose that the rate at which the empty binding site for substrate reorients across the membrane is slower than the rate for the filled binding site. Such behavior is common. The steady-state rate for transport is limited by the rate of the slowest step, so it is limited in this case by reorientation of the empty binding site to begin a new transport cycle. Binding of an analog to the empty binding site facing the *trans* side of the membrane can speed the steady-state rate for transport of substrate by creating fast exchange between the substrate and the analog. Alternatively, if an analog binds but is not a substrate, it will slow the rate of substrate transport.

A proposed reaction in a metabolic pathway, whether catalyzed by an enzyme or a transporter, cannot have a very unfavorable equilibrium constant in order to function. The constant is important in part because of the Haldane relationship, which for a saturable, single-substrate single-product reaction is $K_{eq} = V_{maxforward}K_{Mproduct}/V_{maxreverse}K_{Msubstrate}$ (Cleland, 1982). The symbols have the conventional meanings defined in Michaelis–Menten kinetics. The Haldane relationship is valid even for crude preparations of enzyme or transporter. When $K_{eq} < 1, V_{maxforward}$ or $K_{Mproduct}$ (or both terms) is small relative to the corresponding term in the denominator. When $V_{maxforward}$ is small, the reaction is intrinsically slow. When $K_{Mproduct}$ is small (which means tight binding), product inhibition can prevent the enzyme or transporter from combining with more substrate. In either case, the reaction proceeds slowly, or not at all, in the direction written. This conclusion is important when analyzing incompletely characterized enzymes and transporters, as the K_{eq} value often can be estimated even when Michaelis–Menten values are unknown.

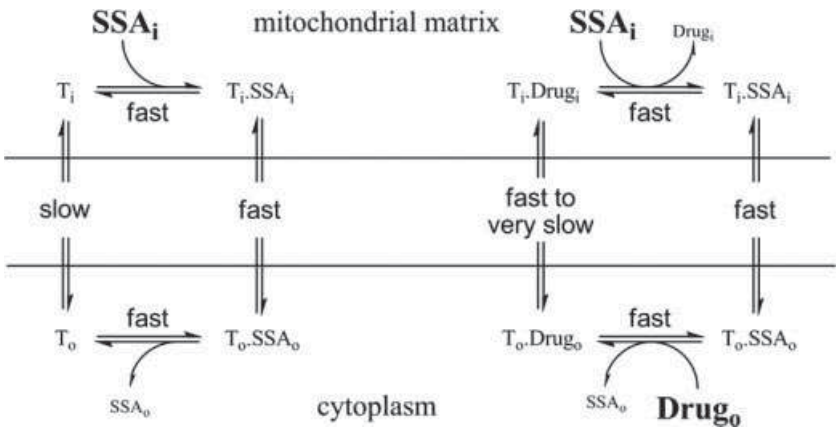

Figure 11.3 *Trans*-stimulation and inhibition of succinic semialdehyde efflux from mitochondria. The transporter for mitochondrial efflux of SSA is unknown, but it might be a member of the MCT family, which as a group has low substrate selectivity (Section 11.6.1). A hypothetical transport cycle starts with an empty binding site for substrate facing mitochondrial matrix (T_i in the cycle on the left) or a drug-loaded binding site facing mitochondrial matrix ($T_i \cdot Drug_i$ in cycle on right). The cycle on the left is rate limited by slow reorientation of an empty transporter to generate T_i. The cycle on the right runs faster than the cycle on the left if a drug molecule in cytoplasm ($Drug_o$) binds to T_o, and reorientation of the $T_o \cdot Drug_o$ complex and exchange to $T_i \cdot SSA_i$ are fast. The cycle would not run at all if a drug molecule binds and stops reorientation of the transporter. Both transport cycles are driven clockwise by net flow of substrates thermodynamically downhill.

11.4.5 Thermodynamics-Based Analysis of Metabolic Flux

But what minimal value for K_{eq} makes a reaction favorable enough for metabolism? Thermodynamics-based analysis of metabolic networks incorporating mass and flux balances provides insights (Beard and Qian, 2005; Henry et al., 2007). The concentrations of substrates and products common to many steps in metabolism, such as $[H^+]$, $[NAD^+]$, $[NADP^+]$, [NADH], and [NADPH], are set by the network as a whole. Homeostasis often maintains them constant even in the face of large metabolic stress. If this condition applies, relevant concentrations can be substituted into the overall expression for K_{eq}. Substitution produces a modified K_{eq} value equal to the concentration of reaction-specific product divided by the concentration of reaction-specific substrate that would be present at equilibrium. If the modified K_{eq} is > 1, robust flux in the forward direction occurs because the reaction seeks equilibrium for which [product]/[reactant] > 1. If the modified K_{eq} value is < 1, flux in the reverse direction would occur *if* there is a source of reactant (which is the product of forward-direction flux) from the network. The principles apply whether reactions in vivo reach equilibrium or are in steady state.

A cell can often overcome a single modified $K_{eq} < 1$ in a multistep pathway in order to produce flux in the forward direction. It does so by adjusting the

steady-state concentrations of the reaction-specific substrate and product to make the free-energy change at that step negative (think LeChâtelier's principle). However, when modified $K_{eq} \ll 1$, mass and flux constraints in the network preclude adjustments sufficient to obtain forward-direction flux (Feist et al., 2007). In this chapter, modified $K_{eq} \leq 10^{-4}$ is assumed to be too unfavorable to support normal in vivo metabolism in the direction written. This value is a low threshold requirement, as it is smaller than the modified K_{eq} values for all dehydrogenase and reductase reactions of the tricarboxylic acid (TCA) cycle and glycolysis. In a similar but inverse manner, modified $K_{eq} \geq 10^{4}$ will be taken as irreversible in vivo.

11.4.6 Metabolism of Endogenous GHB versus Ingested GHB and Prodrugs

Metabolism of endogenous GHB occurs within a metabolic network, and it is subject to the modified K_{eq} threshold and mass and flux balances outlined in Section 4.5. In contrast, because concentrations of ingested GHB (and its prodrugs) are not limited by anabolism, the catabolism of ingested GHB is not subject to the network restrictions. A large in vivo concentration of exogenous GHB might overcome high K_M and subthreshold values for modified K_{eq} at steps that endogenous GHB cannot overcome. Thus, catabolism of ingested GHB and prodrugs might follow multiple pathways (Sections 11.7.3 and 11.15), whereas catabolism of endogenous, low-concentration GHB probably follows mostly a single high-affinity pathway.

11.4.7 Directionality of in Vivo and in Vitro Enzymatic Activity

Reversible reactions producing no significant flux in the forward direction in vivo often can be made to run in that direction in vitro. This phenomenon occurs because constraints on $[H^+]$, [oxidant], [reductant], and pathway-specific [reactant] and [product] are much less restrictive in vitro than they are in vivo. Typically, the initial velocity for an enzymatic reaction is characterized in nearly saturating concentrations of substrates, the absence of products, and optimal nonphysiological pH. Demonstration of an enzymatic reaction under such conditions does not mean that the reaction functions in vivo. On the other hand, barring an unknown activation requirement, an enzyme that does not catalyze a reaction of interest under otherwise optimized conditions in vitro is unlikely to function in vivo.

11.4.8 Transporters and Enzymes Mediating GHB-Related Metabolism

Transporters carrying GHB across plasma membranes of human beings for absorption by the body and metabolism by organs are listed in Table 11.2. Enzymes mediating GHB-related metabolism in human beings are listed in Table 11.3. Some of the listings are certain and some are speculative, as explained in the text. The table includes accession numbers for annotated amino acid sequences at the National Center for Biotechnology Information (NCBI). It also includes

TABLE 11.2 Some Monocarboxylate Transporters for GHB in Cytoplasmic Membranes[a]

Abbreviation	Synonym	NCBI Accession
MCT1[b]	SLC16A1	NP_003042
MCT2[b]	SLC16A7	O60669
MCT4[b]	SLC16A4	NP_004687
SMCT1[c]	SLC5A8[d]	NP_666018
SMCT2[c]	SLC5A12	Q1EHB4

[a] All of these transporters have low substrate affinity and selectivity.
[b] H^+-dependent monocarboxylate transporters 1, 2, and 4.
[c] Sodium-coupled monocarboxylate transporters 1 and 2.
[d] Also known as the sodium iodide–related cotransporter.

identification numbers for three-dimensional atomic-resolution structures in the Protein Data Bank (PDB) when they are known (http://www.ncbi.nlm.nih.gov/; http://www.rcsb.org/pdb/home/home.do). Inspection of Tables 11.2 and 11.3 confirms that impressive progress in knowledge of the molecular and cellular biology of GHB-related pathways has been made, but much more remains to be done. The structures of known and probable chemical intermediates in the pathways are shown in Figure 11.2.

11.5 BIOSYNTHESIS OF ENDOGENOUS GHB

11.5.1 First Step for GHB Biosynthesis in the Known Pathway

A well-documented de novo pathway for the biosynthesis of GHB in brain originates primarily with glutamate. The pathway is shown in Figure 11.2. Glutamate decarboxylases 1 and 2 yield GABA in mitochondrial matrix. The enzymes are isozymes of each other, and the relative frequency of occurrence of cDNA clones reveals that the mRNAs are highly to well expressed in all human tissues (http://www.ncbi.nlm.nih.gov/IEB/Research/Acembly/). Minor amounts of GABA also arise by deamination of the polyamines spermine, ornithine, and putresine (Tillakaratne et al., 1995).

11.5.2 Second Step for GHB Biosynthesis in the Known Pathway

GABA transaminase reacts GABA with 2-oxoglutarate to produce succinic semialdehyde (SSA) plus glutamate in mitochondrial matrix (Figure 11.2). The reaction transfers the pro-(*S*)-hydrogen from GABA (Santaniello et al., 1978). Only one gene exists for human GABA transaminase. The mature polypeptide is 472 amino acids long, M_r 53.3 kDa, and a soluble homodimer (Schousboe et al., 1980; Kugler, 1993; Rao and Murthy, 1993). The relative frequency of cDNA clones has revealed that the mRNA is expressed at high to moderate levels in essentially all human tissues (http://www.ncbi.nlm.nih.gov/IEB/Research/Acembly/).[15] GABA

TABLE 11.3 Enzymes Mediating GHB-Related Metabolism[a]

Common Name	Isozyme	Probable Compartment[b]	Substrate	Product	K_M (mM)	NCBI Accession	Isoform[c]	PDB
GABA transaminase	Only one	Mitochondria	GABA	Succinic semialdehyde (SSA)	0.4	P80404	—	1OHW[d]
Low K_M SSA reductase[e]	AKR7A2	Cytoplasm[f]	SSA	GHB	0.020	O43488	AAH07352, AAH10852	2BP1
Aldehyde reductase	AKR1A1	Cytoplasm	SSA	GHB	0.231	P14550	—	2ALR
2-Oxoglutarate-dependent GHB transhydrogenase[g]	ADHFe1	Mitochondria	GHB	SSA	0.07	NP_653251		
SSA dehydrogenase	ALDH5A1	Mitochondria	SSA	Succinate	0.006	P51649	NP_733936, NP_001071	2 W8N, 2 W8O[h]
α-Oxidation (cytochrome P450)	–	Endoplasmic reticulum/ peroxisomes	GHB	2,4-Dihydroxy-butanoate	1.4 ?	–	–	–
β-Oxidation	Enzymes of fatty acid oxidation	Endoplasmic reticulum/ peroxisomes	GHB	3,4-Dihydroxy-butanoate	–	–	–	–
ω-Oxidation (cytochrome P450)	–	Endoplasmic reticulum	GHB	SSA	1.4 ?	–	–	–
ω-Oxidation (catalase)	Only one	Peroxisomes	GHB	SSA	–	P04040	—	1DGB
γ-Lactonase[i]	1	Blood and liver	γ-Butyrolactone (GBL)	GHB	10	NP_000437	P27169	1V04[j]
β-Oxidation (cytochrome P450)	–	Endoplasmic reticulum	GBL	3-Hydroxy-GBL	–	–	–	–

(*continued*)

TABLE 11.3 (*Continued*)

Common Name	Isozyme	Probable Compartment[b]	Substrate	Product	K_M (mM)	NCBI Accession	Isoform[c]	PDB
γ-oxidation (cytochrome P450)	–	Endoplasmic reticulum	GBL	4-Hydroxy-GBL → SSA	–	–	–	–
Unidentified NAD^+-dependent ADH	–	–	BD	γ-Hydroxy-butyraldehyde[k]	–	–	–	1HSZ, 1U3V, 1U3U[l]
Cytochrome P450	2E1	Endoplasmic reticulum	BD	γ-Hydroxy-butyraldehyde[k]	–	–	–	–
Unidentified ALDH	–	–	γ-Hydroxy-butyraldehyde[m]	GHB	–	–	–	–
NAD^+-dependent GHB dehydrogenase	Only one	Bacterial cytoplasm	GHB	SSA	2	AAT18823		

[a] The enzymes correlate with some of the pathways in Figure 11.2.
[b] In human beings, except for bacterial NAD^+-dependent GHB dehydrogenase.
[c] NCBI accession for mRNA sequences of alternatively spliced variants. Other polymorphisms are not considered.
[d] Pig enzyme.
[e] Also known as aflatoxin B1 aldehyde reductase.
[f] A few reports support mitochondrial and Golgi localization.
[g] Also known as hydroxyacid-oxoacid transhydrogenase (HOT) and ADH8. However, the term ADH8 is also used for retinol dehydrogenase. ADHFe1 uses added 2-oxoglutarate instead of added NAD^+ as the oxidant. No operative NAD^+-dependent GHB dehydrogenase has been identified in human beings.
[h] Oxidized and reduced forms.
[i] The enzyme is also known as paraoxonase.
[j] Chimeric human, rabbit, mouse, and rat γ-lactonase enzyme (NCBI accession AAR95986).
[k] Presumed but based on indirect evidence.
[l] These are structures of ADH1B, which is only very weakly implicated.
[m] Assumed reactant on basis of indirect evidence.

and 2-oxoglutarate (a TCA cycle intermediate) are present in essentially all organs (Tanaka, 1985; Zambonin et al., 1991; Abe et al., 1998). Thus, SSA is probably produced in all organs, although this speculation has not been tested. Because SSA is the immediate precursor to GHB (below), it would be of interest to determine SSA levels in all organs of the mammalian body now that a quantitative analytical method has been developed (Struys et al., 2005a).

The overall equilibrium constant from GABA to SSA is 0.04 (Van Bemmelen et al., 1985). As [2-oxoglutarate]/[glutamate] in mitochondrial matrix is ~15, the modified K_{eq} value is ~0.6 (Wiesner et al., 1988). Although modified $K_{eq} < 1$, the reaction can readily be made to run robustly in the forward direction by lowering the SSA concentration. Lowering indeed occurs by irreversible and rapid conversion of SSA to succinate by SSA dehydrogenase (isozyme ALDH5A1, Section 11.12).

Other than from catabolism of ingested GHB or GHB prodrug, the only significant source of SSA known in mammals is GABA by means of the transaminase reaction. A very minor source is catabolism of vitamin B_6 (http://www.genome.ad.jp/kegg/pathway.html). Another theoretically possible source is 2-oxoglutarate, which in turn is derived from many metabolites. The enzyme 2-oxoglutarate decarboxylase is part of the 2-oxoglutarate dehydrogenase complex in the TCA cycle. It makes SSA bind covalently to thiamine pyrophosphate, which then transfers the SSA to dihydrolipoyl acyltransferase, also in the dehydrogenase complex. The transfer reaction is a form of substrate channeling in which a newly made product molecule is passed directly into the active site of another enzyme without dissociation of free product into solution. There has been no report of the SSA intermediate escaping from the 2-oxoglutarate dehydrogenase complex, although the possibility appears not to have been tested at the level of accuracy required to detect the small amount of free SSA used for the production of endogenous GHB (Section 11.5.3). Human beings and other mammals contain a gene and mRNA coding for 2-oxoglutarate decarboxylase-like hypothetical mitochondrial protein (i.e., OGDHL) of uncertain function that could possibly release SSA (Bunik and Degtyarev, 2008). Formation of free SSA by 2-oxoglutarate decarboxylase not part of a 2-oxoglutarate dehydrogenase complex is a robust reaction in some microbial species.

11.5.3 Third Step for GHB Biosynthesis in the Known Pathway

In brain, a very small fraction (~0.1%) of the SSA made from GABA is reduced to GHB (Gold and Roth, 1977; Rumigny et al., 1981). The remaining 99.9% is oxidized to succinate (Section 11.12). The only enzymes known to be capable of reducing aldehydes to alcohols in mammals are AKRs acting in their forward (reductive) direction and ADHs acting in their reverse (reductive) direction (http://www.genome.ad.jp/kegg/pathway.html). Among human AKRs tested, only AKR1A1 and AKR7A2 reduce SSA at a significant rate in vitro (Cash et al., 1979). Among tested mammalian ADHs, only ADHFe1 reduces SSA at a significant rate in vitro (Section 11.7.2). Reduction of SSA by an enzyme that

prefers NADH over NADPH has not been demonstrated to exist in mammals. Nevertheless, it can be inferred potentially to exist from a single observation of apparent NAD^+-dependent oxidation of GHB by a mammalian extract (Lyon et al., 2007). For reasons discussed in Sections 11.7.2, 11.7.3, and 11.10, however, only AKR1A1 and AKR7A2 currently are realistic candidates for GHB biosynthesis.

The AKR1A1 polypeptide is 325 amino acids long, M_r 36.6 kDa, and a soluble monomer. The atomic-resolution structure has been determined (El-Kabbani et al., 1994). The AKR7A2 polypeptide is 359 amino acids long, M_r39.6 kDa, and a soluble dimer of 79 kDa. It also is known as aflatoxin B1 aldehyde reductase (AFAR; Ireland et al., 1998; Schaller et al., 1999).[16] The atomic-resolution structures of AKR7A2 and the mouse ortholog (Akr7a5) have been determined (Debreczeni et al., 2005; Zhu et al., 2006). AKR1A1 has a k_{cat} value for SSA fivefold higher than that of AKR7A2, but AKR7A2 has a K_M value for SSA 11-fold lower (20 μM) than that of AKR1A1 (230 μM) (O'Connor et al., 1999).[17] Thus, the catalytic efficacies (k_{cat}/K_M) are very similar to each other. However, AKR7A2 is twofold faster at low concentrations of SSA, and AKR1A1 is fivefold faster at high concentrations. The analysis does not take into account different levels of expression of the enzymes in vivo.

Which of the isozymes is likely to dominate GHB biosynthesis? To begin the analysis, consider the distribution of endogenous GHB. It is found in brain, heart, kidney, liver, lung, skeletal muscle, and brown fat of human beings and rodents (Nelson et al., 1981; Maitre, 1997; Moriya and Hashimoto, 2005; Richard et al., 2005; Zacharis et al., 2008). GHB is not restricted to the nervous system, but its nonnervous role is not understood. In brain, GHB is located primarily in cytosol and synaptic vesicles, as indicated by subcellular fractionation of homogenates (Snead, 1987; Muller et al., 2002). Brown fat contains an especially high concentration (37 nmol/g), which suggests the possibility that GHB is catabolized slowly in this tissue. A question regarding detection of dosing presents itself. Does the brown fat of dosed human adults take up ingested GHB (or converted prodrug) and retain it longer than other tissues do? If so, is biopsy of brown fat an acceptable forensics technique for living human beings (van Marken Lichtenbelt et al., 2009)?

Only trace levels of endogenous GHB occur in blood and cerebrospinal fluid. The very low levels mean that transfer of GHB from organs that make it to organs that do not is unlikely. Such transfer would require high-affinity ($K_M \leq 1$ μM) uptake of GHB with high selectivity to prevent competitive inhibition of uptake by other common monocarboxylic acids present in blood and cerebrospinal fluid. However, a transporter having these properties has not been described (Section 11.6.1). Tissues that contain endogenous GHB thus make it. They must contain both the biosynthetic enzymes and the initial, pathway-specific substrate, which in the only well-documented de novo pathway to GHB is SSA generated from mitochondrial GABA. However, if another significant pathway to GHB exists in human beings, it is possible that an intermediate of that pathway could be passed from one organ to another through blood or cerebrospinal fluid (below).

Immunostaining for human AKR1A1 and AKR7A2 proteins and their rodent orthologs indicates that AKR7A2 and its orthologs are present in essentially

all tissues but that AKR1A1 and its orthologs are not (Ireland et al., 1998; O'Connor et al., 1999; Kelly et al., 2000; Grant et al., 2001; Hedberg et al., 2001; Picklo et al., 2001a,b; Hinshelwood et al., 2002, 2003; Fung et al., 2004; Cui et al., 2009).[18] Assays for mRNA and relative frequencies for cDNA clones coding for AKR1A1 and AKR7A2 reveal that both mRNAs are present at very high to significant levels in essentially all human tissues (http://genome.ucsc.edu/; http://bioinfo2.weizmann.ac.il/cgi-bin/genenote/home_page.pl; http://www.ncbi.nlm.nih.gov/IEB/Research/Acembly/).[19] Why do the cellular distribution maps for mRNA and protein corresponding to AKR1A1 disagree? It is possible that immunostaining of AKR1A1 in some tissues does not occur because the major epitopes are masked (Shi et al., 1995).[20] On the other hand, comparisons between the transcriptome and the proteome of human beings often exhibit poor correlations. The disjunction suggests that control mechanisms responding to different physiological imperatives operate at the transcriptional and proteomic levels of expression (Rogers et al., 2008). More research would be required to determine whether substantially more AKR7A2 than AKR1A1 truly is present in vivo. This situation presumably would mean AKR7A2 rather than AKR1A1 dominates GHB biosynthesis, as in fact has been concluded by some researchers (Rumigny et al., 1981). The results reported in Section 11.5.4 support this possibility. They also indicate, however, that it probably does not matter which of these AKRs dominates in different cell types.

11.5.4 Which Step in GHB Biosynthesis is Rate Limiting?

In cultured human SH-SY5Y neuroblastoma cells, suppression of AKR7A2 expression with siRNA causes about a 90% decrease in AKR7A2 protein and SSA reductase activity, but only a 35% decrease in the amount of GHB (Lyon et al., 2007).[21] The compound zopolrestat, a selective inhibitor of AKR1A1 activity, blocks only about one-half of the 10% residual SSA reductase activity in an extract from suppressed cells, even when the SSA concentration is saturating for AKR1A1. Apparently, SH-SY5Y cells express only a small amount of AKR1A1 ($\leq$5% of the total SSA reductase activity), although they make substantial amounts of GHB whether or not AKR7A2 is fully expressed.[22] The results are consistent with rate-limiting AKR7A2 activity in normal GHB biosynthesis and induction of an unknown AKR1A1-independent pathway when AKR7A2 is suppressed.

However, there is a simpler hypothesis. The results are *also* consistent with neither AKR7A2 nor AKR1A1 activity being rate limiting to GHB biosynthesis. Instead, the rate-limiting step could be presentation of SSA for reduction. In this scenario, about 10% residual SSA reductase activity in SH-SY5Y cells could be sufficient to support 65% of the normal rate of GHB biosynthesis.

To assess the feasibility of this model, subcellular compartmentalization of SSA reduction must be analyzed. AKR7A2 and AKR1A1, and their rodent orthologs, have been shown to be in cytosol or adsorbed to cytosolic surfaces of nuclear, Golgi, and mitochondrial membranes (Claros and Vincens, 1996; Andriamampandry et al.,

1998; Witzmann et al., 1998; O'Connor et al., 1999; Picklo et al., 2001a; Kelly et al., 2002, 2004; Keenan et al., 2006; Lyon et al., 2007).[23,24] Moreover, reduction by NADPH is nearly 1000-fold more favorable in cytosol than in mitochondrial matrix (Section 11.10). Both factors argue that SSA is reduced in cytosol. This conclusion requires that SSA made in mitochondria be exported to cytosol before it is reduced to GHB.

Presentation of SSA to AKR1A1 and AKR7A2 could be a complex process. It might require three steps, and none of them has been well characterized.

1. Assuming that the GABA transaminase reaction is the only significant source of SSA (Section 11.5.2), a possible rate-limiting step is escape of newly made SSA from substrate channeling in a complex formed between GABA transaminase and ALDH5A1, as discussed in Section 11.12. Such potential channeling should not be confused with the known channeling that occurs in the glutamate dehydrogenase complex (Section 11.5.2).
2. A definitely required and possibly rate-limiting step is transport of SSA out of mitochondrial matrix. The transport might be performed by the same transporter that takes exogenous GHB into mitochondria for catabolism (Section 11.7.1). Alternatively, it might be performed by an unknown transporter.
3. Another possible rate-limiting step is dehydration of SSA hydrate. The fraction of SSA that hydrates spontaneously to form *gem*-diol during steady-state metabolism in vivo is not known. It could be as much as one-half (Section 11.8). Hydrated and nonhydrated forms of SSA probably are transported out of mitochondrial matrix at different rates, and such discrimination could influence the fraction of the SSA in cytoplasm that is unhydrated and available for reduction.

Overall, because the hypothesis is parsimonious, it seems likely that the rate-limiting step in biosynthesis of endogenous GHB is presentation of reducible SSA to AKR1A1 and AKR7A2 in cytoplasm. However, the slow molecular process within the presentation requirement is unidentified.

11.5.5 Are There Other Biosynthetic Pathways to Endogenous GHB?

Some experimental observations have been interpreted to support the existence of a GABA-independent pathway to endogenous GHB:

1. Substantial amounts of endogenous GHB are found in organs containing $\leq 1\%$ as much GABA as brain has (Drummond and Phillips, 1974; Nelson et al., 1981). The implication is that such organs do not contain enough GABA to explain their GHB contents.
2. Anticonvulsants and inhibitors of glutamate decarboxylase and GABA transaminase affect levels of GABA and GHB in rat brain paradoxically (Snead et al., 1982).
3. Exogenous BD is converted quickly to GHB (Section 11.13.2) by a pathway that does not involve GABA (Snead et al., 1989). Free and chemically bound

forms of BD have been reported to be present in undosed human beings and rats at about one-tenth the amount of GHB, as required if BD were part of a biosynthetic pathway to GHB (Barker et al., 1985; Poldrugo et al., 1985).

4. NAD^+-dependent ADH activity that is able to oxidize exogenous BD increases in SH-SY5Y cells treated with siRNA suppressing AKR7A2, as if ADH activity were up-regulated by a feedback mechanism sensing levels of GHB or AKR7A2 (above).

Although many of them have nagged the field for years, the observations and their interpretations are ambiguous or uncertain. Observation 1 is not compelling because GHB biosynthesis in the "reference" organ brain is very curious. Only 1 part in 1000 of GABA-derived SSA is transported to cytosol to become GHB (Sections 11.5.3 and 11.12). Low levels of GABA characteristic of peripheral organs could support the formation of relatively large amounts of GHB if (1) the presentation of reducible SSA to AKR1A1 and AKR7A2 in cytoplasm is rate limiting, and (2) a larger fraction of mitochondrial SSA is presented for reduction in those organs than in brain. Even a 100-fold increase would decrease mitochondrial flux of SSA to succinate only 10%!

The results of an experiment monitoring metabolism of [2,3,3,4,4−$^2H_5$]glutamic acid to SSA and GHB are informative (Niwa et al., 1983). A high concentration of unlabeled GHB and about one-third additional [$^2H_4$]GHB are present in spent culture medium after incubation of primary kidney cells in a minimum essential medium containing 2 mM DL-[$^2H_5$]glutamic acid. GHB is barely detectable after similar incubation of primary liver cells. Instead, high concentrations of SSA are found. The observation is consistent with the approximately 17-fold greater amount of GHB in intact kidney (22 to 28 nmol/g) compared to intact liver (1.4 to 1.6 nmol/g), even though these organs contain similar amounts of GABA (21 and 15 nmol/g, respectively) (Drummond and Phillips, 1974; Nelson et al., 1981). As there are many metabolic sources of glutamic acid, the presence of excess deuterium atoms in about one-fourth of the GHB indicates that most GHB secreted by kidney cells comes from glutamic acid. Different partitioning ratios at metabolic branch points in the conversion of glutamate to GHB probably account for different GHB/GABA ratios in different organs.

The experiment also observed small amounts of 4-hydroxy-2-butenoic acid in both spent media. The compound does not arise from GHB or glutamic acid, as it did not contain excess deuterium. Brain and kidney contain the compound at levels one-sixth to one-half of the amounts of GHB (Niwa et al., 1982; Vayer et al., 1985b). Possibly, 4-hydroxy-2-butenoic acid can be reduced in vivo to GHB, but the conversion has not been demonstrated. This possibility should be tested.

Observation 2 used drugs and inhibitors thought at the time to act primarily on ion channels and enzymes. However, the analysis did not consider the role of the mitochondrial exporter for SSA. Aminooxyacetic acid, valproic acid, and 3-mercaptopropionic acid are three of the compounds utilized in the study, and they are monocarboxylic acids. As discussed in Section 11.4.3 and

illustrated in Figure 11.3, depending on how they interact with the unknown exporter for SSA, monocarboxylic acids could either stimulate or inhibit the rate of SSA export and thus GHB biosynthesis. Unfortunately, there is no information available on this issue for the compounds used. All of the "inhibitors" utilized are now known to be much less selective than once thought (Meldrum and Rogawski, 2007), and their effects on the known pathway for GHB biosynthesis cannot be predicted.

Regarding observation 3, recent mass spectrometric analyses have not found BD in human beings, rats, or mice (Sakurada et al., 2002; Richard et al., 2005; http://www.metabolibrary.ca/). Extracts of plants contain minor amounts of long-chain diesters of BD, so trace BD in mammals might arise from diet, which could change through time (Bergelson, 1969). However, a trace dietary source is unlikely to support a robust alternative pathway to GHB, and such a source certainly cannot do so in cultured SH-SY5Y cells. A report that GBL is present in the brains of undosed rats at about one-tenth the amount of GHB (Snead et al., 1989) also has not been confirmed by more recent literature.

Finally, observation 4 is not compelling either, as no demonstration has been reported that the ADH activity induced in SH-SY5Y cells is selective for BD. Overall, available data do not make a persuasive case that a second pathway for biosynthesis of endogenous GHB exists in human beings.

11.6 ABSORPTION AND DISTRIBUTION OF INGESTED GHB

11.6.1 Gastrointestinal Tract

The first signs of intoxication by GHB can appear in as little as 10 min, which suggests that the stomach absorbs some GHB (Tanaka et al., 2003). Strong behavioral disturbances and peak concentrations of GHB in blood occur between 0.5 and 2 h, which is $\geq$ the time required for gastric emptying (Poggioli et al., 1999; Carter et al., 2006b; Abanades et al., 2007b; Goodwin et al., 2009). Thus, the small intestine absorbs most of each ingested dose of GHB.

Intestinal absorption probably is mediated by H^+-dependent monocarboxylate transporters (MCTs) and sodium-coupled monocarboxylate transporters (SMCTs) located in apical and basolateral membranes of epithelial cells in the stomach and small intestine (Table 11.2; Goddard, 1998; Iwanaga et al., 2006; Ganapathy et al., 2008). SMCTs and MCTs transport a wide range of metabolites involved in energy metabolism. Substrates include lactic acid, pyruvic acid, β-D-hydroxybutanoic acid, acetoacetic acid, and butanoic acid. The transporters are found throughout the human body, including in the blood–brain barrier and nerve terminals (Benavides et al., 1982; Halestrap and Price, 1999; Tunnicliff, 2002; Enerson and Drewes, 2003; Nishimura and Naito, 2005; Pierre and Pellerin, 2005; Simpson et al., 2007; Wang and Morris, 2007; Morris and Felmlee, 2008; Cui and Morris, 2009). SMCTs and MCTs exhibit moderate to low affinity and low selectivity for substrates. The K_M values for GHB are 30 to 700 μM for different SMCTs and 1 to 10 mM for different MCTs.

11.6.2 Blood

Liver, kidney, lung, heart, brain, brown fat, white fat, skeletal muscle, and pancreas catabolize exogenous GHB (Kleinzeller, 1944; Roth and Giarman, 1966; Khizhnyak, 1976; Lettieri and Fung, 1976; Shumate and Snead, 1979; Struys et al., 2006b; Lenz et al., 2008). Because they express different amounts and mixes of SMCTs and MCTs, different organs probably dominate uptake (and catabolism) of different doses of GHB. However, when fatal dosing occurs with GBL, the postmortem amounts of GHB per gram of tissue are within a factor of 2 of each other for all organs (Lenz et al., 2008).

11.7 INITIAL CATABOLISM OF GHB

11.7.1 Transport into Mitochondria

After GHB is taken into cells, where is it catabolized? Mitochondria isolated from rat liver and kidney convert GHB to SSA, and the rate increases when the mitochondria are disrupted (Gibson and Nyhan, 1989). The observations suggest that (1) metabolizing enzyme(s) is(are) in mitochondrial matrix, and (2) *transport* of GHB into mitochondrial matrix *is capacity limited*. The latter term is synonymous with the existence of rate limitation at high doses of GHB. Mitochondrial uptake probably is mediated by an isoform of the MCT family (Gladden, 2007; Yoshida et al., 2007; Hashimoto and Brooks, 2008; Hashimoto et al., 2008). Comprehensive characterization of the roles that intracellular transporters have in GHB catabolism would be welcomed.

11.7.2 Iron-Dependent Alcohol Dehydrogenase ADHFe1

An atypical alcohol dehydrogenase called ADHFe1 initiates one pathway for mitochondrial catabolism of GHB (Kaufman et al., 1988).[25] Antibody against recombinantly tagged ADHFe1 heterologously expressed in a mammalian cell line stains mitochondria intensely (Kim et al., 2007a).[26] mRNA for ADHFe1 is expressed at very high or significant levels in essentially all human and mouse tissues and in SH-SY5Y cells (Deng et al., 2002; Kardon et al., 2006; Kim et al., 2007a; Lyon et al., 2009; http://www.genecards.org/cgi-bin/carddisp.pl?gene=ADHFE1&search=adhfe1; http://www.ncbi.nlm.nih.gov/IEB/Research/Acembly/). Four alternatively spliced mRNAs encoding different putative isoforms of the enzyme (M_r = 50.3, 45.1, 32.5, and 27.4 kDa) have been detected (Deng et al., 2002; http://www.uniprot.org/uniprot/Q8IWW8#Q8IWW8-2). Two of the isoforms encode an N-terminal targeting sequence for import by mitochondria, and two do not, suggesting that some ADHFe1 is in matrix and some in cytosol. The two-compartment hypothesis has not been tested carefully, however, and it could have important consequences for the location of GHB catabolism. Because the dehydrogenase activity characterized requires unique oxidants (not a nicotinamide, *o*-quinone, or flavin cofactor; see below), it can be detected unambiguously. It

has been found in homogenates of liver, kidney, heart, brain, skeletal muscle, and lung of rats.

The active site of ADHFe1 probably contains tightly bound iron in the +2 oxidation state [i.e., Fe(II) or Fe^{2+}] (Gibson and Nyhan, 1989; Kaufman and Nelson, 1991; Struys et al., 2004; 2006a; Kardon et al. 2006). However, this statement is an inference based on sequence homology with iron-dependent alcohol dehydrogenases isolated from microorganisms. No chemical analysis of mammalian ADHFe1 for metal ions has been reported, as the enzyme has not been purified to homogeneity. The enzyme prefers to use 2-oxoglutarate as the oxidant, from which stoichiometric D-2-hydroxyglutarate [also known as (*R*)-2-hydroxyglutarate] results. The activity does not require added nicotinamide cofactor. Nevertheless, the sequence contains the NAD(P)-binding motif G-X-G-X-X-G, where G is glycine and X is any amino acid (Wierenga et al., 1985). Presumably, a nicotinamide cofactor is very tightly bound, but again this statement is an inference. Such a cofactor would have to cycle between its oxidized and reduced states as the enzyme binds to and reacts with GHB or 2-oxoglutarate in alternating fashion (Figure 11.4). This kinetic mechanism couples the thermodynamics of GHB oxidation to free [2-oxoglutarate]/[D-2-hydroxyglutarate] and not free $[NAD(P)^+]/[NAD(P)H]$.[27]

ADHFe1 has interesting substrate selectivity, as GHB, D-2-hydroxyglutarate, L-3-hydroxybutanoic acid, and L-lactic acid are substrates for the oxidative reaction. SSA, 2-oxoglutaric acid, 2-oxoadipic acid, oxaloacetic acid, pyruvic acid, and 2-oxobutanoic acid are substrates for the reductive reaction. The substrates are listed here in order of decreasing preference (Kaufman et al., 1988; Struys et al., 2005b). Although the reaction couple between GHB and SSA presumably proceeds best in vitro, it produces no net chemical change. The next best reaction couple is GHB/2-oxoglutarate, which is why we assume here that ADHFe1 in vivo uses 2-oxoglutarate preferentially to oxidize GHB. The reverse reaction between the SSA/D-2-hydroxyglutarate couple can be made to proceed in vitro. However, it is very unlikely to occur in vivo, as the modified equilibrium constant probably is $\ll 1$ (Section 11.10) and the concentration of SSA is low (Section 11.12).

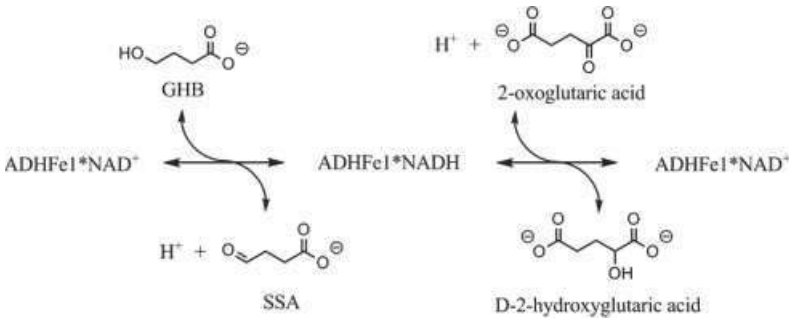

Figure 11.4 ADHFe1-catalyzed reaction. The asterisks indicate very tight complexes that do not release NAD^+ or NADH. Substrate-binding steps are implicit. GHB and 2-oxoglutarate are preferred substrates, but they are not the only substrates.

The known substrates differ in the length of the carbon chain, the terminal or internal position of the redox site, and the number of carboxylate groups. The great diversity in structures suggests that unidentified substrates exist. However, 2-hydroxyisovalerate, 3-hydroxyisovalerate, malate, 3-hydroxyglutarate, L-2-hydroxyglutarate, lactate, glycolate, and 2-hydroxybutanoic acid are not substrates. K_M values for 2-oxoglutaric acid differ up to 70-fold when the enzyme is prepared from liver, fibroblasts, or kidney (Struys et al., 2005b). A smaller variation occurs for SSA (Kaufman et al., 1988). This observation, combined with the existence of alternatively spliced mRNAs (above), raises the possibility that different organs predominantly express isoforms of ADHFe1 that have different substrate selectivities (and possibly cofactor requirement).

11.7.3 Poorly Characterized Catabolism of GHB

Additional pathways for catabolism of GHB *do* exist, but they are poorly characterized. When the GHB load in rodents and human beings is large, some of it is converted to 2,4-dihydroxybutanoic acid (also known as 3-deoxytetronic acid) and 3,4-dihydroxybutanoic acid (also known as 2-deoxytetronic acid) by α- and β-hydroxylations, respectively (Figure 11.2; Walkenstein et al., 1964; Lee, 1977; Jakobs et al., 1981; Niwa et al., 1982; Vayer et al., 1985b; Brown et al., 1987; Vamecq and Poupaert, 1990; Gibson et al., 1998; Shinka et al., 2002, 2003). These metabolites are also derived from sugars and fatty acids, so they are not distinctive for dosing by GHB (http://www.metabolibrary.ca/). Enzymes and subcellular compartments that might mediate α- and β-hydroxylations of GHB are discussed in Section 11.15.

An NAD^+-dependent GHB dehydrogenase activity has been reported in a crude preparation of mitochondria from human SH-SY5Y cells (Lyon et al., 2007). Unfortunately, the activity was not otherwise characterized. Could it be due to an alternatively spliced ADHFe1 that requires NAD^+?

"$NADP^+$-dependent dehydrogenase" was suggested to catalyze oxidation of GHB using tightly coupled reduction of D-glucuronate (Kaufman et al., 1979; Kaufman and Nelson, 1991). The name is confusing, as it names an oxidizing agent rarely used by the ADH superfamily in vivo (Section 11.10). The reaction proposed is similar in concept to obligatorily coupled oxidation of GHB and reduction of 2-oxoglutarate catalyzed by ADHFe1. In vitro, D-glucuronate does stimulate oxidation of GHB under certain conditions. However, the effect apparently is an artifact of optimized conditions that efficiently capture binary $NADP^+$ enzyme or NADPH·enzyme complexes with GHB or D-glucuronate, respectively. Under in vivo–like conditions for substrate concentrations and pH, bound NADPH has time to dissociate and join the pool of free NADPH. Such dissociation couples GHB oxidation to free [$NADP^+$]/[NADPH] and not free [D-glucuronate]/[L-gulonate]. Ironically, $NADP^+$-dependent dehydrogenase is biosynthetic AKR1A1 discussed in Section 11.5.3. Moreover, the suggested coupling between the oxidation of GHB and the reduction of D-glucuronate has been tested comprehensively in rats and found wanting (Bhattacharya and Boje, 2007). Because critical information was not available when it was proposed, the hypothesis should be gently retired.

11.8 CHEMISTRY OF GHB AND RELATED METABOLITES NOT REQUIRING ENZYMES

A surprisingly large number of spontaneous reactions affects the stability, enzymatic kinetics, equilibrium constants, or subcellular compartmentalization of GHB-related compounds and reactions. GHB cyclizes to GBL with elimination of water, and GBL hydrolyzes to GHB over a period of several days at pH 2 to form an equilibrium mixture consisting of about one-third GHB and two-thirds GBL (Ciolino et al., 2001; Perez-Prior et al., 2005). At pH 7.4, the reactions require months to form an equilibrium mixture containing 1.5% GBL (Fishbein and Bessman, 1966). They are too slow to be of physiological significance, but they can become important during long-term storage of urine and blood for forensic analysis.

At 37°C and neutral pH, SSA covalently hydrates in about 1 min to form an equilibrium mixture consisting of approximately equal amounts of the free aldehyde and *gem*-diol (Le Henaff, 1967; Pocker and Dickerson, 1969). Dehydration occurs at a similar rate. Enzymes catalyzing reduction or oxidation of SSA act only on the free aldehyde (Miller and Pitts, 1967; O'Connor et al., 1999). Thus, dehydration can be the rate-limiting step for reduction or oxidation of SSA (Deetz et al., 1984; Marchitti et al., 2008). Hydrated SSA is likely to form in vivo primarily when newly synthesized SSA must be transported to a different compartment before the next covalent change to SSA occurs. This circumstance probably arises during biosynthesis of endogenous GHB (Section 11.5.4).

In tris(hydroxymethyl)aminomethane (Tris) buffer, SSA rapidly forms the imine (also known as the Schiff base) (Hauptmann and Gabler, 1968; Ogilvie and Whitaker, 1976). In organic solvent and thus possibly in fat droplets of adipocytes, SSA rapidly cyclizes to form an equilibrium mixture consisting of about one-third 4-hydroxybutyrolactone and two-thirds open-chain SSA (Jaeger et al., 2008). The cyclization does not occur in water at pH 7. A cyclic trimer of SSA called 1,3,5-trioxane–2,4,6-tripropanoic acid forms in organic solvent but not in dilute aqueous solution (Carriere, 1921). If 4-hydroxy-GBL is formed by cytochrome P450–mediated hydroxylation of GBL, it will undergo spontaneous ring opening to SSA. The presumed γ-hydroxybutyraldehyde intermediate of BD catabolism cyclizes in water to form the hemiacetal (Section 11.13.2).

11.9 EXPERIMENTAL EQUILIBRIUM CONSTANTS FOR REDOX REACTIONS OF GHB

The reactions considered in this section reversibly interconvert GHB and SSA. Irreversible oxidations (e.g., to form 2,4-dihydroxybutanoic acid, 3,4-dihydroxybutanoic acid, or succinic acid; see Section 11.15) are not considered. A reversible reaction exhibits an equilibrium constant that is independent of the enzyme used to establish the equilibrium or even whether an appropriate enzyme exists. The experimental constant (K_{eq}) obtained from literature sources has been adjusted in this section to pH 7.0 to yield K'_{eq}.[28] Experimental constants were obtained at 25°C and not 37°C, but the temperature effect is small.

A K_{eq} value for the reaction catalyzed by bacterial NAD^+-dependent GHB dehydrogenase in the direction toward SSA has been determined (Nirenberg and Jakoby, 1960). Unfortunately, Tris buffer was used, and spontaneous formation of the imine made oxidation of GHB much more favorable than it would be in vivo. Nevertheless, there is a way to estimate a relevant value. As the structures of the alcohol functional groups in GHB and other simple primary alcohols (except methanol) are essentially the same as each other, the K_{eq} values for oxidation to aldehydes by NAD^+ must be essentially the same. They are available for ethanol, 3-hydroxypropionate, and 1-butanol in phosphate or pyrophosphate buffer (Goldberg et al., 1993). Adjusted to pH 7.0, the values are 9.97×10^{-5}, 9×10^{-5}, and 9.1×10^{-5}, respectively, which as expected are essentially the same. Accordingly, the average value (9.5×10^{-5}) is assumed for K'_{eq} in the NAD^+-dependent oxidation of GHB. Formation of aldehyde hydrate is ignored, as the reaction occurs to the same extent for all of these aldehydes and is physiological. Also, the reciprocal of K'_{eq} for the NAD^+-dependent oxidation of GHB gives K'_{eq} for the NADH-dependent reduction of SSA to GHB, or 1.1×10^4.

Because the reduction potentials for $NADP^+$ and NAD^+ are essentially the same, the K'_{eq} values for the NADP-dependent reactions are essentially the same as for the NAD-dependent reactions, namely 9.5×10^{-5} for $NADP^+$-dependent oxidation of GHB and 1.1×10^4 for NADPH-dependent reduction of SSA to GHB at pH 7.0.[29]

K_{eq} for the reaction between GHB and 2-oxoglutarate catalyzed by ADHFe1 has not been determined. However, the sum of the NAD^+-dependent GHB dehydrogenase-catalyzed and NAD^+-dependent D-2-hydroxyglutarate dehydrogenase-catalyzed reactions in opposite directions is the ADHFe1-catalyzed reaction. K'_{eq} for the half-reaction to form D-2-hydroxyglutarate in phosphate buffer is 6.8×10^4 (Buckel and Miller, 1987). K'_{eq} for the reaction catalyzed by ADHFe1 is the product of the constants for the half-reactions, or $(9.5 \times 10^{-5})(6.8 \times 10^4) = 6.5$. The prime in K'_{eq} is not strictly needed because the equilibrium is independent of pH. For simplicity of nomenclature it will be retained.

K'_{eq} for this reaction can also be calculated using published Michaelis–Menten parameters and the Haldane relationship for a two-substrate, two-product enzyme ($K'_{eq} = V_{maxforward} K_{Mproduct1} K_{Mproduct2} / V_{maxreverse} K_{Msubstrate1} K_{Msubstrate2}$). For ADHFe1 from human liver, the estimate is 7.5, and for ADHFe1 from rat kidney, it is 12 (Kaufman et al., 1988; Struys et al., 2005b). All three of the values calculated are reassuringly similar. The average of 8.7 is taken here for K'_{eq} in the ADHFe1 reaction.

11.10 ESTIMATED EQUILIBRIUM CONSTANTS FOR REDOX REACTIONS OF GHB IN VIVO

This section incorporates into K'_{eq} expressions the pH and [oxidant]/[reductant] values found in vivo. The resulting numbers are modified equilibrium constants

that predict $[SSA]_{eq}/[GHB]_{eq}$ values for cytosolic and mitochondrial compartments. They differ $>10^{10}$-fold, depending on the direction of reaction, type of oxidant or reductant, and the subcellular compartment. The values are instructive in determining which class of redox enzyme in which compartment can function at a particular metabolic step. Modified equilibrium constants do not inform among isozymes utilizing the same [oxidant] and [reductant] reaction couple, however.

In mitochondrial matrix, pH = 7.7, free $[NAD^+]/[NADH] \approx 7.7$ (coincidentally the same number as the pH), and free $[NADP^+]/[NADPH] \approx 12$.[30] In cytosol, the values are pH = 7.4, free $[NAD^+]/[NADH] \approx 1164$, and free $[NADP^+]/[NADPH] \approx 0.014$ (Veech et al., 1969; Zhang et al., 2002; Balut et al., 2008). Free $[NAD^+]/[NADH]$ and free $[NADP^+]/[NADPH]$ exclude enzyme-bound forms, which substantially exceed the free forms and distort many published ratios. The uncertainty in the ratios is about twofold, which in the current discussion is small (Lin and Guarente, 2003). Moreover, dosing of rats with GHB does not affect cytosolic $[NAD^+]/[NADH]$ or $[NADP^+]/[NADPH]$, although minor alkalosis occurs (MacMillan, 1979). Thus, metabolic homeostasis is nearly maintained. Although extensive analyses of NAD and NADP levels in different organs are not available, mitochondrial redox states in normal brain, heart, kidney, liver, and testis are similar to each other (Mayevsky and Chance, 2007). Published values for pH, free $[NAD^+]/[NADH]$, and free $[NADP^+]/[NADPH]$ in cytosol and mitochondrial matrix should be applicable to all major organs. Adjustment of K'_{eq} values to incorporate pH, free $[NAD^+]/[NADH]$, and free $[NADP^+]/[NADPH]$ yields K_{red}^{mito}, K_{red}^{cyto}, K_{ox}^{mito}, and K_{ox}^{cyto}[31] values in the reducing or oxidizing direction in mitochondrial matrix or cytosol (each as indicated) (Table 11.4). No reversible GHB metabolism is known to occur in other subcellular compartments.

Reactions catalyzed by NAD^+-dependent ADHs are addressed first. For oxidation of GHB, $K_{ox}^{mito} \approx 3.7 \times 10^{-3}$ and $K_{ox}^{cyto} \approx 2.8 \times 10^{-1}$. The reaction is unfavorable in both compartments, but not so unfavorable that similar reactions do not occur. For example, NAD^+ oxidizes malate to oxaloacetate in the mitochondrial matrix ($K_{ox}^{mito} \approx 4 \times 10^{-4}$, or about 10-fold smaller than estimated here for GHB) and NAD^+ oxidizes ethanol to acetaldehyde in cytosol ($K_{ox}^{cyto} \approx 2.8 \times 10^{-1}$, or equal to that estimated here for GHB). It is clear that NAD^+ *could* oxidize GHB in both cytosol and mitochondrial matrix. Whether it *does* depends on additional factors discussed in Sections 11.11 and 11.15.

The reciprocals of the constants for oxidation of GHB by NAD^+ give the constants for reduction of SSA by NADH. They are $K_{red}^{mito} \approx 2.7 \times 10^2$ and $K_{red}^{cyto} \approx 3.6 \times 10^0 = 3.6$. The reaction is favorable in both compartments. However, of six human ADH isozymes that have been tested in vitro under conditions even more favorable to reduction than exist in vivo, none catalyzes the reduction of SSA (Deetz et al., 1984). Why? Apparently, none of the isozymes forms a productive complex with SSA. Also, no other well-documented mammalian NADH-dependent ADH reduces SSA. Not only must the modified equilibrium constant be acceptable

TABLE 11.4 Modified Equilibrium Constants for Reactions Interconverting GHB and Succinic Semialdehyde[a]

Reduction Reaction	Enzyme[b]	K_{red}^{mito}	K_{red}^{cyto}
SSA + NADH + H^+ ↔ GHB + NAD^+	NAD^+-dependent GHB dehydrogenase (reverse)	2.7×10^2	3.6×10^0
SSA + NADPH + H^+ ↔ GHB + $NADP^+$	SSA reductase	1.8×10^2	1.5×10^5
Oxidation Reaction	**Enzyme**	K_{ox}^{mito}	K_{ox}^{cyto}
GHB + NAD^+ ↔ SSA + NADH + H^+	NAD^+-dependent GHB dehydrogenase	3.7×10^{-3}	2.8×10^{-1}
GHB + $NADP^+$ ↔ SSA + NADPH + H^+	$NADP^+$-dependent GHB dehydrogenase or SSA reductase (reverse)	5.7×10^{-3}	6.7×10^{-6}
GHB + 2-oxoglutarate ↔ SSA+ D-2-hydroxyglutarate	2-Oxoglutarate-dependent GHB transhydrogenase	> 8.7[c]	-

[a] All equilibrium constants are unitless. The experimentally determined, pH-independent, overall equilibrium constant at 25°C from the literature was adjusted to pH 7.0 (footnote 28). Then the constants were adjusted to mitochondrial and cytoplasmic conditions to give K_{red}^{mito}, K_{red}^{cyto}, K_{ox}^{mito}, and K_{ox}^{cyto} in the reducing and oxidizing directions, respectively, by the reductant and oxidant couple indicated (footnote 31). The values apply to most or all organs. Values less than 10^{-4} probably cannot support metabolism in the direction written, and values greater than 10^4 probably produce irreversible reaction (Section 11.4.5).

[b] The enzyme names are phenomenological descriptions and not assigned isozyme names.

[c] This value is a lower boundary based on [2-oxoglutarate]/[D-2-hydroxyglutarate] > 1. The actual value probably is ≥ 870 (Section 11.10).

in vivo, but an isozyme that binds SSA productively must exist for the reaction to occur.

Reactions catalyzed by AKRs are addressed next. For reduction of SSA and other simple aldehydes by NADPH, $K_{red}^{mito} \approx 1.8 \times 10^2$ and $K_{red}^{cyto} \approx 1.5 \times 10^5$. The reaction is strongly favorable in both compartments. Cytosolic reduction probably is irreversible, as K_{red}^{cyto} is well above the threshold of 10^4 for irreversibility (Section 11.4.5)! But is a human AKR known that catalyzes this reaction? Yes, AKR1A1 and AKR7A2 do so (Section 11.5.3).

The reciprocals of K_{red}^{mito} and K_{red}^{cyto} for AKRs give the constants for oxidation of GHB and other simple alcohols by $NADP^+$. They are $K_{ox}^{mito} \approx 5.7 \times 10^{-3}$ and $K_{ox}^{cyto} \approx 6.7 \times 10^{-6}$. The reaction is unfavorable in both compartments. Nevertheless, as K_{ox}^{mito} is ≈ 10-fold more favorable than for oxidation of malate (although by NAD^+), oxidation of GHB by $NADP^+$ in mitochondrial matrix probably *could* occur. Whether it *does* occur depends on additional factors discussed in Section 11.11. In contrast, $NADP^+$-dependent oxidation of GHB in cytosol is nearly 1000-fold less favorable than in mitochondrial matrix and well below the 10^{-4} threshold for function (Section 11.4.5). Cytosolic $NADP^+$-dependent GHB dehydrogenase has very little chance of functioning in vivo.

The oxidation of GHB by 2-oxoglutarate catalyzed by ADHFe1 in mitochondrial matrix is addressed next. Free [2-oxoglutarate]/[D-2-hydroxyglutarate] controls K_{ox}^{mito}. The ratio is not known. Nevertheless, a useful boundary on its value can be set. FAD-dependent (*not* NAD^+-dependent) D-2-hydroxyglutarate dehydrogenase is present in human and rat mitochondrial inner membrane facing the matrix (Rzem et al., 2004). Mutations in the gene lead to a human disorder called D-2-hydroxyglutaric aciduria, which presents with up to 30-fold increase in the concentration of D-2-hydroxyglutarate in urine (Struys, 2006; Wickenhagen et al., 2009). The phenotype tells us that FAD-dependent D-2-hydroxyglutarate dehydrogenase controls free [2-oxoglutarate]/[D-2-hydroxyglutarate]. Moreover, the ratio in normal people is > 1, as otherwise a reservoir of 2-oxoglutarate sufficient to produce the observed large increase in [D-2-hydroxyglutarate] when the dehydrogenase is blocked would not exist. The physiological observations are consistent with biochemical determinations that oxidations by FAD-dependent ADHs are $\geq$ 100-fold more favorable than oxidations by NAD^+-dependent ADHs (Goldberg and Alberty, 2008). Because [2-oxoglutarate]/[D-2-hydroxyglutarate] surely is > 1, K_{ox}^{mito} for ADHFe1 surely is > 8.7, and it probably is ≥ 870 (Table 11.4). Thus, the reaction of GHB with 2-oxoglutarate catalyzed by ADHFe1 probably is very favorable in vivo. However, it is reversible in vitro (Section 11.7.2).

If isoforms of ADHFe1 exist that prefer an oxidant other than 2-oxoglutarate or are present in cytoplasm, perhaps as a result of alternative splicing of the mRNA (Section 11.7.2), the calculation just presented could change. Reduction of SSA catalyzed by ADHFe1 in vivo has not been proposed, and as already indicated, it is very unlikely to occur due to a low SSA concentration. It will not be addressed.

11.11 DIFFERENT PERSPECTIVES ON TURNOVER OF ENDOGENOUS GHB ARE CONSISTENT

Cytosolic reduction of SSA to GHB catalyzed by NADPH-dependent AKRs, and oxidation of GHB to SSA in mitochondrial matrix catalyzed by ADHFe1, are strongly favored among reactions interconverting SSA and GHB. This conclusion is consistent with most of what is known about substrate selectivity by AKR and ADH isozymes, subcellular distributions of isozymes, and the presence of MCTs in mitochondrial inner membrane. If one hypothesizes that transport of SSA out of mitochondrial matrix is rate limiting for biosynthesis of endogenous GHB, and transport of GHB into mitochondrial matrix is rate limiting for degradation of exogenous but not endogenous GHB, a generally consistent picture emerges. Endogenous GHB is made by excess AKR1A1 and AKR7A2 activity in cytosol. Because its concentration is low, cycling endogenous GHB probably is degraded almost entirely by ADHFe1. In contrast, exogenous GHB probably saturates mitochondrial uptake and/or ADHFe1 activity. Under these conditions, other pathways for catabolism of GHB set in, as evidenced by the formation of products other than SSA. Several possible alternative catabolic pathways are discussed in Section 11.15.

11.12 DISPOSITION OF SUCCINIC SEMIALDEHYDE

Most SSA is irreversibly and rapidly oxidized to succinate by SSA dehydrogenase in mitochondrial matrix (Ryzlak and Pietruszko, 1988).[32] GABA aminotransferase, which in the absence of ingested GHB or GHB prodrug makes most and perhaps all SSA, might form a complex with SSA dehydrogenase (Hearl and Churchich, 1984). Such a complex could allow most newly made SSA to be transferred directly into the active site of SSA dehydrogenase without dissociation into free solution. In this event, escape from channeling would be required for export of GABA-derived SSA from mitochondria (Section 11.5.2). The idea is untested, but such an escape could be the rate-limiting step in GHB biosynthesis and a regulatory control point. More should be learned about the reported complex between GABA aminotransferase and SSA dehydrogenase.

Even though the selectivity of ALDH isozymes for SSA has not been studied systematically, ALDH5A1 can be assigned to SSA dehydrogenase activity in vivo (Marchitti et al., 2008). The primary reason is that rare genetic defects map to the ALDH5A1 gene in human beings, cause GHB aciduria, and block SSA dehydrogenase activity (Knerr et al., 2007; Malaspina et al., 2009). The enzyme has been expressed in *E. coli*, purified to homogeneity, and characterized as a soluble homotetramer of 58 kDa monomers 544 residues long (Kang et al., 2005). It strongly prefers NAD^+ over $NADP^+$, and the K_M value for SSA is ~6 μM. The protein and mRNA are present in essentially all organs at levels that correlate approximately with those for GABA transaminase, which is consistent with the possible existence of substrate channeling between GABA transaminase and ALDH5A1 (Miller and Pitts, 1967; Chambliss et al., 1995a,b; Tillakaratne et al., 1995; http://www.ncbi.nlm.nih.gov/IEB/Research/Acembly/). Two isoforms of ALDH5A1 presumably exist, although they have not been observed directly, as alternative splicing in the coding region of the mRNA occurs (Blasi et al., 2002). Both isoforms are predicted to contain N-terminal mitochondrial targeting sequences (Claros and Vincens, 1996). Succinate resulting from ALDH5A1 activity enters the tricarboxylic acid cycle for final disposition, which includes conversion to α-amino acids and CO_2 (Figure 11.2).

Mice carrying deletion of the orthologous gene (Aldh5a1) have been created as a model for human GHB aciduria (Hogema et al., 2001; Pearl et al., 2009). The block causes levels of GHB and GABA in urine and organ extracts to increase as much as about 20- and threefold, respectively (Gibson et al., 2002; Gupta et al., 2004; Chowdhury et al., 2007). The different percent increases support the notion that different GHB/GABA ratios can arise from causes not related to the existence of a GABA-independent pathway to endogenous GHB (Section 11.5.5). Metabolic profiles of people and mice lacking ALDH5A1 activity are similar to those of genetically normal people who ingest large amounts of GHB (Brown et al., 1987; Gibson et al., 1997; Shinka et al., 2002, 2003; Struys et al., 2006a,b; Sauer et al., 2007).

Human beings and mice lacking SSA dehydrogenase activity produce a small amount of 4,5-dihydroxyhexanoic acid and its γ-lactone [both compounds occur as

(4*R*, 5*R*) and (4*S*, 5*R*) stereoisomers] (Brown et al., 1987; Gibson et al., 2002). The reaction probably occurs by condensation of SSA with the nucleophilic thiamine-bound acetyl intermediate created by pyruvate decarboxylase in the pyruvate dehydrogenase complex (Shaw and Westerfeld, 1968; Brown et al., 1987). Resulting 5-oxo-4-hydroxyhexanoic acid [in a mixture of (4*R*) and (4*S*)] could then be reduced by an AKR at the 5-oxo center. Spontaneous cyclization would produce the γ-lactone. The condensates are not found in baboons acutely dosed with GHB, however, which suggests that they might not be satisfactory markers for acute dosing of people (Struys et al., 2006b). Moreover, the γ-lactone, which is also known as solerole, is found in many foods and beverages, further indicating that these compounds are not satisfactory markers for GHB dosing (Krajewski et al., 1995; Aubert et al., 2003; Rocha et al., 2005).

The atomic-resolution structure of human ALDH5A1 has been obtained (Kim et al., 2009). The enzyme is controlled by redox modulation. It is active when two cysteine residues in the active site are reduced and is inactive when the cysteines are oxidized to the disulfide. Reactive oxygen species such as H_2O_2 cause formation of the disulfide. This phenomenon links GHB catabolism to other oxidative physiology (Mamelak, 2007). $GABA_A$ and NMDA receptors are regulated by redox modulation as well, thereby creating the potential for high-order physiological synergism from abuse of GHB, flunitrazepam, ketamine, and ethanol (Pan et al., 2000; Ikonomidou et al., 2000)! Indeed, GHB recently was shown to increase oxidative stress in vivo by decreasing defenses to oxidative insults (Sgaravatti et al., 2007, 2009).

11.13 CONVERSION OF PRODRUGS TO GHB AND RELATED METABOLITES

11.13.1 γ-Butyrolactone

Exogenous GBL is rapidly converted to GHB in human beings, baboons, cats, and rodents (Roth and Giarman, 1966; Richard et al., 2005; Lenz et al., 2008, Goodwin et al., 2009). It is thus a prodrug that is hydrolyzed by γ-lactonase present primarily in blood and liver (Figure 11.2; Ingels et al., 2000; Teiber et al., 2003; Draganov et al., 2005). There are three γ-lactonase isozymes in human beings, but GBL is hydrolyzed overwhelmingly by γ-lactonase 1 in vitro (Billecke et al., 2000). The enzyme is very nonselective and targets many xenobiotic compounds, as it hydrolyzes phosphotriesters, aryl carboxylate esters, carbonates, and lactones. There is very little γ-lactonase activity in hen, rat, and rabbit brains (Monroy-Noyola et al., 2007). The low activity in brain, combined with the good ability of low-polarity GBL to permeate membranes nonspecifically (Section 11.14) and pass into the periphery (Sgaragli and Zilletti, 1970; Abraham et al., 1995), probably explains why GBL injected into a cerebral ventricle has no behavioral effect in cat, rabbit, and rat (Gessa et al., 1967; Carter et al., 2006a).

GBL is predicted by a computer-based, expert toxicological system to undergo hydroxylations by cytochrome P450 to give 3-hydroxy-GBL and 4-hydroxy-GBL (Rosenkranz, 2001). Although not tested, both of these compounds probably

would be hydrolyzed by a γ-lactonase. Also, 4-hydroxy-GBL will undergo spontaneous ring opening to SSA. Hydrolysis of 3-hydroxy-GBL produces 3,4-dihydroxybutanoic acid, which is made as well by β-oxidation of GHB and metabolism of carbohydrates and fatty acids. It would be of interest to determine whether 3,4-dihydroxybutanoic acid arising from GBL and exogenous GHB differs in chirality from 3,4-dihydroxybutanoic acid arising from carbohydrates and fatty acids (Sakata, 1990).

11.13.2 1,4-Butanediol

Similar to GBL, exogenous BD is rapidly converted to GHB in human beings, rodents, and baboons. It thus is a prodrug (Figure 11.2; Maxwell and Roth, 1972; Vree et al., 1978; Poldrugo and Snead, 1984; Snead et al., 1989; Ingels et al., 2000; Richard et al., 2005; Irwin, 2006; Kapadia et al., 2007; Goodwin et al., 2009). Metabolism of BD in the periphery is inhibited by pyrazole and 4-methylpyrazole, which are inhibitors of many Zn^{2+}-dependent ADHs (Bessman and McCabe, 1972; Quang et al., 2004; Carai et al., 2006). Partially purified ADHs, probably containing mixtures of isozymes obtained from human and horse livers, oxidize BD in vitro (Pietruszko et al., 1978). In contrast, metabolism of BD injected into a cerebral ventricle of rat is not inhibited by pyrazole (Poldrugo and Snead, 1986; Snead et al., 1989). Ethanol competitively inhibits BD metabolism in both the periphery and brain. The findings suggest that BD is metabolized by (1) ADH in the periphery, similarly to ethanol, and (2) a non-ADH pathway in brain that ethanol also follows (Gerak et al., 2004; Nishimura and Naito, 2005). As 4-methylpyrazole blocks the behavioral effects of peripherally administered BD in mice, most BD metabolism occurs in the periphery (Carai et al., 2002; Quang et al., 2002). The metabolic competition between BD and ethanol has been simulated numerically, and metabolism of BD has been shown to be capacity limited (Fung et al., 2008). A weak correlation between slower metabolism of BD in human beings and a common allele of ADH1B has been reported (Thai et al., 2007).[33] Nevertheless, no compelling evidence supports assignment of BD dehydrogenase to a particular ADH isozyme. A moderate rate of conversion of BD to GHB in brain, combined with the good ability of low-polarity BD to permeate membranes nonspecifically (Section 11.14) and pass into the periphery (Abraham et al., 1995), probably explains why BD injected into a cerebral ventricle has no behavioral effect in rat (Carter et al., 2006a).

The first step in conversion of BD to GHB, no matter what the enzymatic mechanism, presumably produces γ-hydroxybutyraldehyde. About 86% of this compound spontaneously cyclizes in aqueous solution to the hemiacetal called 2-hydroxytetrahydrofuran (Hurd and Saunders, 1952). However, neither the open-chain nor the hemiacetal form has been identified in human beings or rodents. A search for these compounds, or a distinctive condensate of them (as occurs for SSA, Section 11.12), could be rewarding. Such a metabolite might be more metabolically stable than are BD and GHB and serve as an indicator of dosing after BD has disappeared from blood and urine. The open-chain form of γ-hydroxybutyraldehyde

is probably oxidized to GHB by an ALDH, as the ALDH inhibitor disulfiram partially blocks the behavioral effects of BD in mice (Carai et al., 2002). The cyclized hemiacetal form could be oxidized to GBL, but whether this occurs in vivo (e.g., catalyzed by a cytochrome P450 or catalase; see Section 15) is not known.

11.14 SUBCELLULAR COMPARTMENTALIZATION OF GHB-RELATED COMPOUNDS

The logarithm to the base 10 of the distribution coefficient D ($\log D$) measures partitioning of a compound between octanol and water at a given pH and 25°C. At a pH of about 7, the GHB-related compounds GABA, SSA, GHB, 2,4-dihydroxybutanoic acid, 3,4-dihydroxybutanoic acid, and 4,5-dihydroxyhexanoic acid each carry one or two electrical charges, and they have $-\log D$ values of ≥ 2.65 (Table 11.5). In vivo these compounds are subject to compartmentalization controlled by membrane transporters. This restriction in turn means that only certain isozymes can access the compounds.

In contrast, ingested GHB is exposed to intragastric pH between 1 and 4, depending on the person, time of day, and presence or absence of food in the stomach (van Herwaarden et al., 1999). Because its pK_a value is 4.72, GHB is predominantly protonated and uncharged while it is in the stomach (Tao et al., 2008). Protonated GHB has a $-\log D = 0.70$, which is 200-fold less polar than unprotonated GHB is (Table 11.5). This value approaches that for ethanol ($-\log D = 0.19$), which the stomach absorbs nonspecifically (Levitt et al., 1997). Thus, the stomach probably absorbs some ingested GHB nonspecifically. Ingested GHB is not exposed to the acid in the stomach long enough to cyclize to GBL (Sections 11.6.1 and 11.8).

TABLE 11.5 Octanol–Water Partition Coefficients

GHB Related	$-\log D^a$	Prodrug Related	$-\log D^a$
GABA	3.14	GBL	0.76
SSA	2.65	BD	1.02
GHB	3.01, 0.70*	4-Hydroxybutyraldehyde	0.57
2,4-Dihydroxybutanoate	4.18	2-Hydroxytetrahydrofuran[b]	0.93
3,4-Dihydroxybutanoate	4.79		
4,5-Dihydroxyhexanoate	3.63		

[a] -Log D values are for pH 7 and 25°C, except for the GHB value marked with *, which applies to pH 1–3 (GHB is mostly protonated and uncharged in this pH range in the stomach). The acids are named to indicate they are charged. Estimates were done by SciFinder Scholar with Advanced Chemistry Development (ACD/Labs) Software V8.14 for Solaris. Larger positive values mean less solubility in octanol, which correlates approximately with less nonspecific permeation through membranes. Compare these values with the values for ethanol (0.19) and acetaldehyde (0.16), which quickly and nonspecifically permeate biological membranes by partitioning into and across the lipid bilayer.
[b] Cyclized 4-hydroxybutyraldehyde in the hemiacetal form.

GBL, BD, and the probable BD metabolites 4-hydroxybutyraldehyde and 2-hydroxytetrahydrofuran are uncharged and have small $-\log D$ values at all physiological values of pH (Table 11.5). These molecules probably permeate membranes nonspecifically (Roth and Giarman, 1966; Lenz et al., 2008). BD has been shown to permeate barrier epithelia resistant to polar but uncharged molecules (Wright and Pietras, 1974). Thus, ingested GBL and BD are absorbed rapidly and efficiently by the stomach (Arena and Fung, 1980; Perez-Prior et al., 2005; Thai et al., 2007; Fung et al., 2008; Hicks and Varner, 2008; Goodwin et al., 2009). Poor compartmentalization is especially relevant to BD, which consequently has access to many, perhaps all, isozymes that could act on it during its presumed two-step conversion to GHB (Section 11.13.2).

11.15 COMPARATIVE CATABOLISM OF ETHANOL, 1,4-BUTANEDIOL, FATTY ACIDS, AND GHB

Most ethanol consumed by human beings is catabolized in the stomach and liver, which use primarily NAD^+-dependent cytosolic ADH1B and ADH1C for the initial step to acetaldehyde (Lee et al., 2006). However, these organs also use hydrogen peroxide (H_2O_2)-dependent catalase located in peroxisomal matrix and NADPH- and oxygen (O_2)-dependent cytochrome P450 2E1 located on the cytosolic face of smooth endoplasmic reticulum for the initial step to acetaldehyde. Some ethanol is catabolized by the brain, which uses primarily catalase and cytochrome P450 2E1 (Zimatkin et al., 2006; Hipolito et al., 2007). In the catalase reaction, H_2O_2 is reduced to two water molecules as the alcohol group is oxidized to the aldehyde group. In the cytochrome P450 reaction, one of the O atoms from O_2 attacks C1 of ethanol to form hydrated acetaldehyde, and the other O atom is reduced to H_2O by NADPH. These reactions are irreversible. Human beings have one gene for catalase but ≥ 58 genes for cytochrome P450s. Overall, human beings use *three* types of enzymatic reactions to oxidize ethanol to acetaldehyde. The prominence of each type depends on the organ, and due to different K_M values, probably the dose of ethanol. Does similar parallelism occur in the catabolism of BD and GHB?

Observations presented in Section 11.13.2 strongly suggest that metabolism of BD in the periphery and brain proceeds along the same pathways that ethanol uses. Consistent with this hypothesis, BD is oxidized in vitro to formaldehyde and uncharacterized products by cytochrome P450 in rat liver microsomes (Clejan and Cederbaum, 1992).[34] The BD isomer 2,3-butandiol is oxidized in vitro to 3-hydroxy-2-butanone by catalase (Magner and Klibanov, 1995). Unidentified isozymes of NAD^+-dependent ADH also act on BD in vitro (Section 11.13.2). Thus, all three types of enzymes acting on ethanol in human beings also act on BD or BD isomer in vitro.

Similar studies should be carried out on GHB, which can be conceptualized as either a primary alcohol such as ethanol or a small fatty acid. As a primary alcohol, catalase and cytochrome P450 could convert GHB to SSA. As a fatty acid, catalase and cytochrome P450 could convert GHB to 2,4-dihydroxybutanoic acid by α-hydroxylation (Poulos et al., 1993; Alderson

et al., 2004; http://pfam.sanger.ac.uk/family?acc=PF00067). Also as a fatty acid, mitochondria and peroxisomes could convert GHB to 3,4-dihydroxybutanoic acid by β-hydroxylation (Visser et al., 2007). In addition, a cytochrome P450 might convert GHB to SSA by ω-oxidation (Orrenius, 1969). As discussed in Section 11.7.3, large amounts of 2,4-dihydroxybutanoic acid and 3,4-dihydroxybutanoic acid, respectively, are formed after dosing by GHB. No in vitro test of whether catalase or cytochrome P450 acts on GHB has been reported. However, GHB competitively inhibits demethylation of *N*-nitrosodimethylamine by rat cytochrome P450 2E1 with an IC_{50} value of 1.4 mM, which implies that it probably is bound to the active site (Wang et al., 1995). The IC_{50} value is similar to the concentrations of GHB reached during dosing.

Overall, there are ample hints that exogenous BD and GHB follow multiple catabolic pathways in human beings. It would be of great interest to characterize them systematically in vitro and in vivo. GBL probably will follow GHB pathways, as it is rapidly hydrolyzed in vivo (Section 11.13.1).

11.16 CATABOLISM OF MDMA, FLUNITRAZEPAM, AND KETAMINE

Because MDMA, flunitrazepam, and ketamine are not natural compounds, there are no biosynthetic pathways for them. The constraints of a metabolic network do not apply (Section 11.4.5). Even the Haldane relationship does not apply, as most of the steps are irreversible and do not have a K_{eq}. For MDMA the major end metabolite is 4-hydroxy-3-methoxymethamphetamine sulfate ester, for flunitrazepam it is 7-aminoflunitrazepam, and for ketamine it is norketamine (Figure 11.1) (Feng et al., 2007).

11.17 DETECTION OF DATE-RAPE DRUGS

11.17.1 Compounds Diagnostic for Dosing by Synthetic Date-Rape Drugs

Because MDMA, flunitrazepam, and ketamine, and their metabolites are not part of natural metabolism, the presence of any one of them in a physiological sample is per se evidence for ingestion of the drug. However, as flunitrazepam and ketamine are used occasionally in medicine, evidence of dosing is not necessarily evidence of drug-assisted sexual assault or self-abuse. The context must be considered in reaching a conclusion.

11.17.2 Compounds Diagnostic for Dosing by GHB

D-2-hydroxyglutaric acid, 4,5-dihydroxyhexanoic acid, and SSA have strong, direct metabolic links to GHB (Figure 11.2; Sections 11.7.2 and 11.12). Nevertheless, none of these metabolites currently is a good marker of dosing, as the endogenous levels in undosed human beings are only partially characterized. Variance in

endogenous levels of 2,4-dihydroxybutanoic acid and 3,4-dihydroxybutanoic acid, and of their breakdown products (formic acid, 3-hydroxypropanoic acid, glycolic acid, and acetic acid), is very large because of person-to-person differences in metabolism and diet. Elevated levels provide little evidence for dosing by GHB (Chalmers et al., 1976). GBL and BD are excreted at detectable levels only if they per se have been ingested and not after GHB has been ingested (McCusker et al., 1999; Blanchet et al., 2002; Lora-Tamayo et al., 2003; Wood et al., 2004; Shima et al., 2005).[35]

The amount of GHB present in blood and urine taken from undosed normal people has been comprehensively characterized, and it is always less than 5 and 10 μg/mL, respectively (Elliott, 2003; LeBeau et al., 2006). Persons suffering from uncontrolled diabetes excrete large amounts of the GHB isomers α- and β-hydroxybutanoic acid, but they excrete no excess GHB (Shima et al., 2005). Persons suffering from SSA dehydrogenase deficiency excrete large amounts of the GHB, but the frequency of this disorder is so low that it can be ignored in testing of the public for dosing (Koelker et al., 2008). Even though 96 to 99% of ingested GHB or prodrug typically undergoes catabolism, the current best physiological marker for dosing by these substances is a value of GHB above 5 or 10 μg/mL in serum or urine, respectively (Villain et al., 2003; Yeatman and Reid, 2003; Crookes et al., 2004; Kasprzak et al., 2006; LeBeau et al., 2006). As discussed above for other date-rape drugs, evidence of dosing is not necessarily evidence for drug-assisted sexual assault or self-abuse, as GHB is occasionally used in medicine. The context must be considered.

11.17.3 Gold-Standard Testing

Most regional forensic laboratories and many large clinical laboratories conduct *gold-standard tests* for date-rape drugs and their metabolites. Such tests include, but are not limited to, such techniques as spiking of a urine sample with deuterated drug or metabolite, extraction into organic solvent, chemical derivatization to improve physical properties, high-performance liquid or gas chromatography to reduce background signals, and mass spectrometry to quantitate isotope dilution (Kastrissios et al., 2005; Rendle, 2005; de Oliveira et al., 2007; Kraemer and Paul, 2007; Langman, 2007; Maurer, 2007; Musshoff and Madea, 2007a,b; Pizzolato et al., 2007; Pragst, 2007; Samyn et al., 2007; Smith et al., 2007; Snow, 2007; Tagliaro et al., 2007; de Paoli and Bell, 2008; Gong et al., 2008). Such sophisticated methods can provide superior sensitivity as well as quantitative and unambiguous results that constitute evidence of dosing suitable to systems of justice. However, the certitude that these methods provide is gained at high cost. Expensive instrumentation, highly trained persons to maintain the instruments and perform the tests, relatively slow turnaround, and substantial operating costs are characteristic. For these reasons, gold-standard testing must be strongly justified by circumstances. It is usually not used for routine screening and not available outside high-end laboratories.

11.17.4 Many Applications for Reliable Field Tests

Rapid, reliable, inexpensive, and semiquantitative testing by responsible principals could clarify many situations in which illicit drugs are suspected. Such test results assist in making rapid decisions and taking immediate appropriate action. The principals include staff persons working in hospitals and medical clinics, narcotics enforcement, prisons, and probation departments. The public also has an interest in reliable and easy detection of illicit drugs in bars, schools, and households. These and similar circumstances are termed "field" situations in this chapter to distinguish them from laboratory situations.

An international panel has recommended that at least two uncorrelated test methods be used to document presence of an illicit drug when the evidence is to be presented to a judicial system. The result of a validated field test can qualify for one of the methods if it is supported by the result from a gold standard, category A test (Santos, 2007). An opportunity for synergism exists here, as gold-standard testing can be made to be faster, more efficient, and less expensive by targeting the illicit drug putatively identified in a field test (Cone and Huestis, 2007; Peters, 2007).

11.17.5 Hospital Emergency Department Example

Because their molecular mechanisms of action are generally different, each agent causes some distinctive symptoms after an overdose. However, when agents are co-ingested, as often occurs, mixed symptoms are produced (Ricaurte and McCann, 2005; Wu et al., 2006; Van Sassenbroeck et al., 2007; Munir et al., 2008). A medical doctor can find it difficult to reach a correct diagnosis based on symptoms and oral history alone when dealing with possible polydosing (Bjornaas et al., 2006; Liechti et al., 2006; Devlin and Henry, 2008).

A hypothetical scenario that illustrates the need for both field and gold-standard testing is the following. A disheveled and comatose woman is brought into a hospital emergency department by a friend who does not know what happened. Staff members are aware that recent cases of sexual assault in the city involved date-rape drugs, and they want to test immediately for candidate drugs and ethanol. Rapid discovery of specific agents has many benefits. A correct diagnosis would be more likely, and appropriate treatment could be selected quickly. Expensive and unnecessary tests for head trauma, metabolic disorders, central nervous system infection, and increased intracranial pressure might be avoided. Also, physiological samples could be collected and preserved for gold-standard testing if warranted: for example, when sexual assault was suspected (Zvosec et al., 2007). Field and gold-standard testing are not competitive; they are complementary.

Rapid tests for ethanol are available, of course. Field tests based on antibody recognition of MDMA, ketamine, flunitrazepam, and other date-rape drugs are also available. They require 10 to 20 min to complete (Kunsman et al., 1996; Salamone and Tsai, 2002; Negrusz et al., 2005), and many suppliers are available (http://www.varianinc.com/cgi-bin/nav?products/dat/index&cid=KJOQJOKKFJ; http://www.biocompare.com/jump/2831/Immunoassays.html). Antibody test kits typically are

cross-reactive for the major metabolites of a drug. The ketamine kit, for example, picks up both ketamine and norketamine. Cross-reactivity for the metabolites extends the window of time available for detection of dosing, as metabolites can linger in persons longer than the original drug does.

Unfortunately, no reliable field test for GHB is currently available. Purported tests exist, but they are very insensitive, based on unreliable or poorly selective chemistry, or require unrealistically ideal conditions. They should not be used by a responsible principal (Meyers and Almirall, 2004; Grossman et al., 2005; Beynon et al., 2006; Child and Child, 2007; Quest and Horsley, 2007). A sensitive and reliable field test for GHB is described in Section 11.20.3.

11.17.6 Preparation of a Sample for Delayed Analysis

If a physiological fluid is to be tested for a date-rape drug, it should be obtained as soon as possible after a suspected incident, as any drug will be subject to metabolism and excretion (Kastrissios et al., 2005; Drummer, 2007). However, for many reasons that include short-term amnesia caused by the drug, victims often do not report suspected assault until one or more days after an incident. A victim usually will have ingested only a single dose of the drug. The combination of a single dose and significant delay before the report greatly increases the sensitivity required to detect dosing. If testing is to be done days to months after sampling, such as often occurs for gold-standard analysis, the sample must be stored properly to avoid degradation, sequestration, or artifactual generation of analyte (El Mahjoub and Staub, 2000; Clauwaert et al., 2001; Hijazi et al., 2001; Elliott et al., 2004; Holmgren et al., 2004; Berankova et al., 2006; LeBeau et al., 2007; Saude and Sykes, 2007). When a physiological fluid is prepared properly and stored no more than several days in a refrigerator, large errors generally do not occur. However, "proper" depends on both the matrix and analyte. Also, enzymatic treatment to release covalently conjugated analyte can be important for some types of analytes in order to increase sensitivity. The ability of staff members to properly prepare a physiological fluid for gold-standard analysis would benefit from the knowledge gained in a positive field test.

11.17.7 Time Window Available to Detect Dosing

The window of time available to detect dosing depends on the drug. After single effective doses, MDMA, flunitrazepam, and ketamine are routinely detectable in urine for 1.5 to 4 days. Extremely sensitive gold-standard detection methods can extend the time window significantly. Also, metabolites often are detectable for even longer (Verstraete, 2004; Adamowicz and Kala, 2005).

In contrast, single doses of GHB are detectable above the threshold values of 5 and 10 μg/mL in serum or urine, respectively, for as little as 3 h and as long as 12 h in different persons (Section 11.17.2; Palatini et al., 1993; Kavanagh et al., 2001; Borgen et al., 2003; Brenneisen et al., 2004; Haller et al., 2006; Bodson et al., 2008). The time window is quite variable in part because large doses can be detected for

disproportionately longer time periods, as absorption, metabolism, and elimination of GHB are limited by physiological capacity (Palatini et al., 1993; Scharf et al., 1998; Bhattacharya and Boje, 2007; Odujebe et al., 2007; Jones et al., 2009). Also, metabolism rates are affected by diet and ethanol (Poldrugo et al., 1989; Kaufman and Nelson, 1991; Karch et al., 2001; Borgen et al., 2003; Haller et al., 2006; Thai et al., 2007; Wang et al., 2008). Time courses have been simulated numerically (Bhattacharya and Boje, 2006). In summary, physiological fluids must be sampled in $\leq$ 12 h of possible consumption in order to detect GHB above threshold. Merely increasing the sensitivity of testing does not solve the problem of a limited time window for GHB.

11.17.8 Extending the Time Window

Several relatively new gold-standard technologies extend the time available to detect dosing. One technology utilizes hair, which incorporates a circulating drug when the strands are being formed. In this technique, full-length hairs are obtained from a person, cleaned, and cut into 3-mm segments 4 to 5 weeks after putative dosing. The segments are dissolved, and the solubilized hair is analyzed by tandem mass spectrometry. If the person was dosed, the protocol produces a peak in drug concentration for the hair segment formed when the dosing occurred, and baseline values for hair segments that flank the segment that was formed during dosing. A single GHB dosing of a human being has been detected in this manner (Kintz, 2007).

Another applicable technology is *gene expression profiling* by DNA microarray analysis. Blood mRNAs for the proteins epiregulin (member of the epidermal growth factor family) and PEA-15 (phosphoprotein enriched in astrocytes of 15 kDa) were significantly elevated 48 h after mice were given a single large dose of GHB (Larson et al., 2007). Also, the Fos transcription factor is greatly elevated in rat brain after a high dose of GHB, although samples of brain normally would not be tested in living human beings (van Nieuwenhuijzen et al. 2009). Because Fos is widely distributed, Fos mRNA in the periphery is also probably elevated, although this hypothesis has not been tested. The effects of MDMA and ketamine on mRNA levels in rodent brain have been studied by gene expression profiling (Thiriet et al., 2002; Funada et al., 2005; Lowe et al., 2007). The method has great promise for forensic science. However, there remain the hurdles of (1) identifying suitable sources of mRNA, (2) identifying at least one mRNA that is diagnostic for a target drug, (3) establishing baseline values for mRNAs in the person tested, and (4) reducing statistical variation enough to make results accurate.

Gene expression profiling illustrates one reason why detailed knowledge of metabolic pathways might be valuable to forensic science. The RNAs coding for or regulating the expression of isoceptors, isozymes, and isoporters linked to a target drug are the most likely to respond to dosing. For example, mRNAs for MCTs (Section 6.1) and Fos in white blood cells are available from fresh blood, and one of them might be responsive to dosing by GHB.

11.18 SPECIAL CIRCUMSTANCES OF GHB

11.18.1 Industrial Connection

GHB differs from other date-rape drugs in one more important respect. Because of their rapid and efficient conversion to GHB in the body, GBL and BD have psychotropic effects very similar to those of GHB. Yet because GBL and BD are used by industry for multiple legitimate purposes, they are inexpensive, widely available, and weakly controlled. Chemical mixtures containing $\leq 70\%$ GBL recently were exempted (http://openregs.com/regulations/view/103806/exempt_chemical_mixtures_containing_gamma-butyrolactone). As a result, GBL and BD increasingly are being adopted as alternatives to GHB in drug-assisted sexual assault and self-abuse (Kapadia et al., 2007; Thai et al., 2007; Wood et al., 2008). The rapid test for GHB described below will not detect GBL or BD. However, it will flag their ingestion by detecting excess GHB in serum or urine.

11.18.2 Enzymes Acting on GHB in Bacteria, Yeast, and Plants

Many physiologically stressed bacteria and yeast biosynthesize polymers containing GHB. The polymers are a carbon- and energy-storage material (Moore et al., 2005; Song et al., 2005, Bach et al., 2009).[36] Polymerization requires activation of the GHB carboxyl group, which can be done by butyrate kinase, 4-hydroxybutyrate-CoA transferase, or 4-hydroxybutyryl-CoA synthetase (AMP forming) (Cary et al., 1988; Valentin et al., 2000; Huber et al., 2008). When environmental conditions become favorable to growth, microorganisms hydrolyze stored polymer to mobilize the carbon. Some species of bacteria also consume tetrahydrofuran, which is an environmental pollutant and a common solvent, by oxidizing it to GBL and then hydrolyzing the GBL to GHB (Kohlweyer et al., 2000). In all characterized cases, GHB is brought into central metabolism by an Fe(II)-containing ADH that uses dissociable NAD^+ as the hydride acceptor. These enzymes have sequences similar to human ADHFe1 (Section 11.7.2). Also, some plants use GHB as a redox ballast to survive periods of anoxia, and they make it with SSA reductase (Breitkreuz et al., 2003; Hoover et al., 2007). Only one isozyme is known for each of these enzymes.

11.18.3 Possible Accidental Intoxication by GHB in the Future

The possibility of accidental intoxication by GHB is increasing from an ironic source. Researchers have engineered microorganisms and plants to make large amounts of polymers containing GHB and/or BD monomers. Such polymers can resemble polyethylene and polypropylene in their rheological properties and are termed *bioplastics* (Van der Walle et al., 2001). Bionolle and Ecoflex are commercial examples (Gross and Kalra, 2002).[37]

Although currently minor, the fraction of plastics containing GHB and/or BD monomers could increase dramatically. The possibility arises because "synbio" organisms can make them from renewable low-value inputs such as corn stover and

sewage sludge (Zhang and Wang, 1994; Tsunemasa, 1998; Poirier, 2001; Rabetafika et al., 2006). Bioplastics require less input of energy and valuable feedstocks than petroleum-based plastics do (Kurdikar et al., 2000; Efe et al., 2008). Moreover, bioplastics are hydrophilic polyesters that are biodegradable by esterases found in soil-dwelling microorganisms. Some bioplastics are even compostable, meaning that they are degraded completely in only a few months (Tokiwa and Pranamuda, 2001; Deguchi et al., 2002; Abou-Zeid et al., 2004). Composting reduces the volume of waste that must be accommodated by landfills, which are increasingly scarce (Davis and Song, 2006). The combined virtues of renewability and biodegradability might encourage much greater use of bioplastics containing GHB and/or BD in the future (Dornburg et al., 2004; Okino, 2005a,b; Kale et al., 2007; http://www.bioplastics24.com/).

If disposal facilities were to contain large amounts of bioplastics, leachate from them will contain monomers, including GHB and BD. The concentrations in primary leachate will probably be low and nontoxic, assuming that both the bioplastics and drainage meet professional specifications (http://www.astm.org/Standard/index.shtml). However, concentrations could increase to intoxicating levels if leachate were allowed to form puddles that evaporate, as GHB and BD are not very volatile and are chemically stable. Bacteria in the puddles might not efficiently scavenge GHB and BD, due to lack of micronutrients or preferential use of better carbon sources, such as glucose derived from plasticized starch also present in the disposal facility (Greer, 2006). This scenario is most likely to occur around residential compost piles. Dosing of neighborhood wildlife and omnivorous children by decomposing bioplastics might become a significant problem, thanks to green products. Regular environmental monitoring for GHB and BD could become a necessity.

11.19 CONSIDERATIONS DURING DEVELOPMENT OF FIELD TESTS

11.19.1 Shortcomings of Antibody-Based Screens for Simple Analytes

Many field tests for date-rape drugs are based on binding of free drug and its metabolites to an antibody preparation (Singh et al., 2006). Although the method works well for complex synthetic molecules having multiple points of contact between the analyte and the antibody combining site, it often does not work for simple analytes.[38] The reasons are easy to identify. To make a small molecule immunogenic, it must be covalently "conjugated" to a large carrier such as a protein. Conjugation in this case causes a big perturbation in analyte structure. Thus, antibodies often bind to the conjugated analyte better than to the free analyte (Benacerraf and Paul, 1970). Moreover, most antibodies used in forensic science are polyclonal, which means that preparation begins with the blood obtained from an immunized animal. Many different amino acid sequences and three-dimensional structures are present in the antibody combining sites. Polyclonal heterogeneity has adverse consequences on analyte selectivity, as discussed below.

Another type of antibody is monoclonal, which means that the preparation is obtained from an amplified clonal line of an antibody-producing cell. One amino acid sequence and one three-dimensional structure are present in all of the antibodies made by the clonal line. A different clonal line generated against the same analyte will in general secrete an antibody having a different amino acid sequence exhibiting a different three-dimensional structure in the antibody combining site. Thus, cocaine has been found by x-ray crystallography to bind in different conformations and orientations to different monoclonal antibodies (Pozharski et al., 2005). The result implies that an analyte binds to individual members of a polyclonal preparation in many different ways.

It follows that within the diversity of complexes that form with an analyte, a preparation of polyclonal antibodies can also bind many analogs of the analyte. From highest to lowest affinity, the potential complexes will include conjugated analyte, structural relatives of conjugated analyte, free analyte, and metabolites and other analogs of free analyte. Indeed, the ability of a polyclonal preparation to recognize a drug *and* its metabolites depends on antibody heterogeneity. Moreover, if a polyclonal preparation is purified with an immunoaffinity step, which will of necessity use conjugated analyte, the final preparation is biased even more away from binding free analyte and toward binding conjugated analyte (Choi et al., 1999). It is not surprising that complex mixtures of antibody combining sites exposed to complex mixtures of small molecules, *none* of which were the actual immunogen, often produce the worst possible outcome for a small-molecule screen: namely, a high rate of false positives and negatives.

11.19.2 Advantages of Enzyme-Based Screens for Simple Natural Analytes

Enzymes can provide a solution to the shortcomings of antibodies in the detection of simple analytes. First, there is no need to conjugate the analyte covalently. Thus, misdirection toward analyte conjugates and their analogs does not happen. Second, an enzyme has a single amino acid sequence and three-dimensional structure, thereby eliminating binding-site heterogeneity that decreases substrate selectivity. Third, most enzymes have evolved to discriminate against metabolites similar in structure to the substrate desired. Such discrimination is important to minimize crosstalk between pathways (Hartl et al., 1985; Hartl, 1989; Galperin et al., 1998).[39] In contrast, immunization has no mechanism to discriminate against metabolites resembling the conjugated analyte. Fourth, substrate bound in an enzymatic active site must form the near attack conformation (NAC) before it can react (Bruice, 2002). The NAC is accessed by librational dynamics, which are optimized by evolution. The NAC theory is complementary to the better known theory that an enzyme binds to the transition state for a reaction tighter than to the ground state. In both theories, protein dynamics contribute to selectivity in catalysis. In contrast, protein dynamics play no consequential role in an ordinary antibody–analyte complex. In summary, enzymes possess numerous mechanisms for molecular

discrimination that antibodies in general and polyclonal antibodies in particular do not have.

Enzyme-based screens also have a time advantage that can be important in field applications. Positive results start to become known within seconds of mixing reagents and a test sample when a high concentration of analyte is present. In contrast, antibody-based screens require some sort of previsualization processing such as lateral flow chromatography or blocking of nonspecific protein adsorption to suppress background before the results can be read. An immunochemical method such as enzyme-linked immunosorbant assay (ELISA), which uses an enzyme to amplify the signal arising from analyte, does not negate the requirement for previsualization processing. In addition, enzymes often have a cost advantage. The complementary DNA sequence for an enzyme is cloned into an expression vector only one time, and the vector is used to transform bacteria only one time. Transformed bacteria can be propagated indefinitely and used to produce the enzyme in a genetically "tagged" form established by the vector. The tag is a polypeptide or protein chosen to allow facile purification of the resulting "fusion protein" by affinity chromatography at moderate cost. In contrast, polyclonal antibodies usually are obtained from immunized animals in a relatively time-consuming and expensive process. Monoclonal antibodies are even more expensive to produce.

The preceding observations suggest rules of thumb for choosing between an antibody and an enzyme for the development of a field test. An enzyme should be considered for a small natural metabolite, as a cognate enzyme *must* exist and an antibody has a high probability of failure. GHB is an example of this type of analyte. To avoid false positives the enzyme must be highly selective for analyte in the samples to be tested. Because of low selectivity, an enzyme that acts on xenobiotics usually would not be appropriate. Also, some readily implemented method must exist to visualize test results outside a laboratory.

An antibody should be considered for a structurally complex or large analyte, as the problem of immunological perturbation by conjugation is lessened. If the analyte is manufactured by synthetic organic chemistry, an enzyme selective for it will not exist in nature. MDMA, flunitrazepam, and ketamine are examples of this type of analyte. Also, even if the analyte is natural, the cloning, expression, and isolation of a cognate enzyme might not be practical, or the enzymatic reaction might not be easy to visualize in the field. An antibody might then be the best recourse. Cocaine is an example of this type of analyte. The pathway for its biosynthesis is not known with certainty, and thus an enzyme possibly having good selectivity for cocaine cannot be identified with certainty. Human carboxylesterase 1 and cytochrome P450 act on cocaine, but they are low-selectivity enzymes targeting many xenobiotic compounds (Ladona et al., 2000; Humphrey and O'Hagan, 2001; Bencharit et al., 2003).

Of course, no rule of thumb is infallible. Some analytes are large natural products, and new tools such as diabodies, aptamers, and directed evolution are being developed continually in the search for new types of biosensors (Fickert et al., 2006; Poyot et al., 2007).

11.20 DEVELOPMENT OF AN ENZYMATIC TEST FOR GHB

11.20.1 Sensitivity Required for the Hospital Emergency Department

Patients presenting to a hospital emergency department because of possible drug overdose are in crisis (Chin et al., 1998). Only moderate sensitivity is required to detect a drug if it is a major cause of the distress, as the amount in the patient's system *at that moment* must be large. In the case of GHB, levels of 30 to 600 μg GHB/mL of serum and 400 to 6000 μg GHB/mL of urine have been found by gold-standard analyses of samples that have been prepared and stored correctly (Louagie et al., 1997; Sporer et al., 2003; Couper et al., 2004; Elliott, 2004; Van Sassenbroeck et al., 2007). These levels are well within the capabilities of typical enzyme-based tests. *In the potentially life-and-death context of a hospital emergency department, a rapid test with good sensitivity is better than a slow test with superior sensitivity*.

11.20.2 Choice of Enzyme

As footnoted above, attempts to develop a field test based on antibody recognition of GHB have failed. An enzyme-based test is an attractive alternative. Three enzymes that act on GHB have been characterized well enough to consider. They are vertebrate NADPH-dependent SSA reductase (AKR1A1 or AKR7A2), vertebrate 2-oxoglutarate–dependent ADHFe1, and bacterial Fe(II)-containing NAD^+-dependent GHB dehydrogenase (Sections 11.5.3, 11.7.2, and 11.18.2). To use a reductase, the reaction would have to be run in the reverse direction using $NADP^+$ as oxidant.

What considerations can help us decide which of these enzymes might be suitable? The oxidation catalyzed by ADHFe1 is thermodynamically favorable, but ADHFe1 has only moderate selectivity for GHB among common metabolites. It would be susceptible to false-positive results when testing physiological fluids and other complex matrices. This possibility is decisively unfavorable, leaving vertebrate SSA reductase and bacterial ADH to consider. The overall equilibrium constants are the same, providing no thermodynamic basis to choose between them (Section 11.9). A search of online databases containing DNA and protein sequences reveals many putative SSA reductases and GHB dehydrogenases, as deduced by sequence homology (http://www.ncbi.nlm.nih.gov/; http://www.uniprot.org/). However, sequence homology is much better at predicting the chemistry carried out than the preferred substrate (Hulo et al., 2006). Unless substrate selectivity has been studied by direct biochemical methods, one cannot be sure which substrate is preferred.

A search of online databases for enzymatic substrates, followed by thorough reading of the primary literature, reveals that only a few SSA reductases and GHB dehydrogenases have been characterized biochemically. Examples of these databases are BRENDA (http://www.brenda-enzymes.info/) and KEGG (http://www.genome.ad.jp/kegg/pathway.html). Abstracts of primary literature are freely accessible in PubMed (http://www.ncbi.nlm.nih.gov/) or by subscription to SciFinder Scholar (http://www.cas.org/products/sfacad/index.html). Most SSA reductases have high affinity for SSA and low affinity for GHB, which

promotes fast and complete reduction of moderate concentrations of SSA but slow and incomplete oxidation of moderate concentrations of GHB, a decidedly unfavorable property (Keenan et al., 2006). This characteristic narrows the choice of enzyme to bacterial GHB dehydrogenase. Moreover, because a single isozyme is likely, and cloning and expression are usually easier, a bacterial enzyme is preferred to an enzyme from a eukaryotic organism such as an animal, plant, or yeast. The air-stable Fe(II)-containing NAD^+-dependent GHB dehydrogenase from the bacterium *Ralstonia eutropha* meets all criteria (Valentin et al., 1995). The properties of this family of enzymes have been summarized (http://pfam.sanger.ac.uk/family?acc=PF00465). GHB dehydrogenase from the bacterium *Clostridium kluyveri* has also been characterized biochemically. However, it is unacceptable because it is rapidly inactivated by oxygen, which would be a major liability in a field test (Wolff and Kenealy, 1995).

The GHB dehydrogenase reaction is not visible to the unaided eye. This circumstance means that a secondary reaction must be coupled to the reaction to visualize the results of the test. Fortunately, the electron pair stored in NADH can be used by a well-known "turnkey" reaction that reduces a large number of colorless prodyes to intensely colored products (Berridge et al., 2005). All required reagents are commercially available. Such a coupled secondary reaction also helps solve another problem. Oxidation of GHB with NAD^+ is significantly unfavorable at neutral pH (Section 9). Unless something is done to compensate, only a fraction of the GHB in a test sample will react, and it will do so slowly because of the asymptotic approach to equilibrium. Both properties are decidedly undesirable. However, the turnkey reactions are so favorable that the resulting two-step reaction is favorable overall.

11.20.3 Reliable Field Test for GHB

To develop the test, the gene for GHB dehydrogenase in *R. eutropha* was copied from total genomic DNA using appropriate primers and polymerase chain reaction. The resulting DNA was purified, end-trimmed with restriction enzymes, and fused to the gene for the affinity-tag glutathione *S*-transferase, which is under the control of a lactose promoter in the commercial expression vector pGEX-2T. *E. coli* was transformed with the recombinant vector to produce and isolate large quantities of fusion protein that links glutathione *S*-transferase to GHB dehydrogenase. About 150 mg of purified fusion protein typically is obtained from 1 L of bacterial culture in a fast procedure utilizing an affinity matrix containing covalently bound glutathione (Bravo et al., 2004).

A solution assay at pH 8.5 in 2-amino-2-methyl-1,3-propanediol buffer was devised for quantitative research using a laboratory spectrometer. The higher pH value decreases the concentration of product H^+ and makes the reaction more favorable (Fig. 5). The buffer is Tris-like, resulting in formation of the imine of SSA as it is formed. Formation of imine (Section 11.8) pulls GHB oxidation thermodynamically and prevents product inhibition due to SSA buildup. The NADH produced by the GHB dehydrogenase reaction is used to reduce (with the

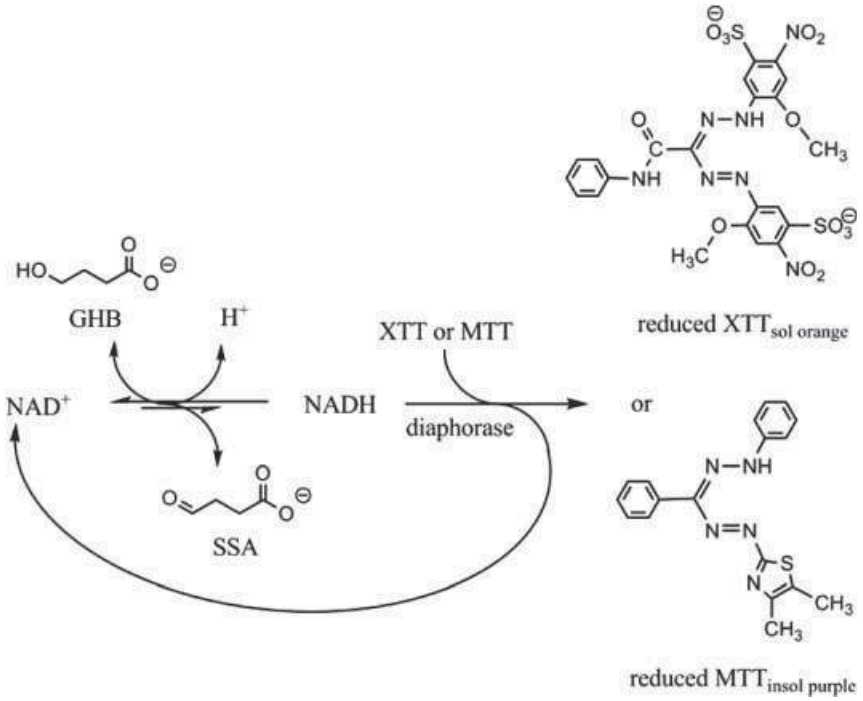

Figure 11.5 Coupled assay for GHB. NAD^+ and GHB dehydrogenase from *Ralstonia eutropha* oxidize GHB to SSA in the first step. Because it is otherwise unfavorable, the reaction is run under pulling conditions. A Tris-like buffer (2-amino-2-methyl-1,3-propanediol) that also forms the imine of SSA is utilized at pH 8.5. In addition, diaphorase uses NADH made in the first step to reduce nearly colorless XTT to a soluble orange dye for a laboratory assay using a spectrometer or MTT to an insoluble purple dye deposited on a dipstick for a field assay. Different prodyes that yield different colors and solubility are available.

aid of the electron transfer enzyme diaphorase) a prodye called XTT [sodium 3,3-[(phenylamino)carbonyl]-3,4-tetrazolium-bis(4-methoxy-6-nitro)benzenesulfonic acid hydrate] to form a soluble orange dye (λ_{max} 450 nm) and regenerate NAD^+ (Figure 11.5). This reaction also pulls GHB oxidation thermodynamically and removes product inhibition due to NADH buildup. Thus, the assay implements five strategies to make it favorable, faster, and visible.

Michaelis–Menten parameters were determined in 1 mM NAD^+. The K_M value for GHB is 2.19 ± 0.13 mM and the V_{max} value is 0.049 ± 0.001 absorbance/min per microgram of fusion protein. The lowest concentration of GHB reported in the urine of emergency department patients ($\sim$400 μg/mL) corresponds to about 4 mM. The K_M value is well matched to this concentration, thus providing a rapid and sensitive detection of GHB.

Ethanol is a weakly binding alternative substrate of the enzyme, having an estimated K_M value of 413 ± 14 mM, or 200 times higher than for GHB. The affinity

is low enough that ethanol concentrations realistically found in physiological fluids do not produce false-positive results. Recent research has shown that other simple alcohols, such as methanol, 1-propanol, 2-propanol, 1-butanol, and 1-pentanol, are significantly worse substrates than ethanol is (Vinckier et al., 2011).

Multiple studies agree that GHB arising from ingested GHB or GHB prodrug is concentrated about 10-fold in urine relative to blood (Liu et al., 2006). Thus, urine rather than serum is preferred for dose testing. If allowed to react for about 2 h in 1 mL of coupled assay buffer, all of the GHB in a small sample of spiked normal human urine (10 μL) is reacted. The amount of orange color produced is linearly dependent on the amount of GHB. No substances in urine contribute significantly to color development, even after 2 h of reaction. This variation of the test, called an *endpoint assay*, has a limit of detection of 37 μg GHB/mL urine (total A_{450} to background $A_{450} = 2$ to 1). The same procedure using urine containing 0.47% (w/v) ethanol gives the same results, confirming that a realistic concentration of ethanol in urine does not interfere with the endpoint assay.

The solution assay uses a spectrophotometer and is not as fast or convenient as a dipstick assay that can be used in the field. To develop a prototype for a dipstick, formation of an insoluble purple dye by reduction of the soluble prodye MTT (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide) was used (Figure 11.5). Small samples (10 μL) of water, normal human urine, or normal human urine containing 0.63% (w/v) ethanol and having different concentrations of spiked GHB were spotted onto paper, after which assay reagent (10 μL) was spotted. The test is developed for no longer than 2 min to avoid false-positive results. No significant color develops in the absence of GHB, and strong purple color develops within a few seconds for samples containing concentrations of GHB typically present in urine during an overdose. Color development is fast because both the test sample and reagents are diluted very little. The three tested matrices gave the same results, demonstrating that neither urine nor a physiologically high concentration of ethanol interfere (Figure 11.6). The precision around the cutoff was also assessed. Of 20 samples for each condition, none were positive in the absence of GHB, 25% were positive (and 75% were negative) at 20 μg GHB/mL, 75% were positive at 50 μg GHB/mL, and all were positive at 100 μg GHB/mL and more. Thus, a concentration of GHB four times lower than the lowest concentration found in the urine of patients suffering from GHB overdose is detected every time. A dipstick test strip not requiring spotting of reagents before use is under development for long shelf life and use in hospital emergency departments (Harper et al., 2008).

CONCLUSION

Impressive progress in understanding the fundamental molecular and cellular biology of date-rape drugs has been made in recent years. Nevertheless, many important questions remain. The roles of RNA and regulation of enzymatic activity and gene expression have been studied only a little. For example, does protein phosphorylation regulate the metabolism of date-rape drugs? Use of cultured human cells

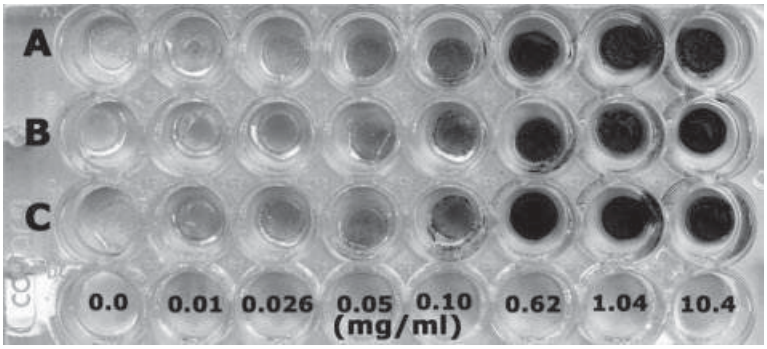

Figure 11.6 Prototype of a dipstick assay for GHB. Ten-microliter samples containing the concentrations of GHB indicated were spotted onto white-paper circles lying in wells of a microtiter plate. Ten microliters of assay reagent containing buffer, GHB dehydrogenase, NAD^+, diaphorase, and MTT prodye was spotted onto a circle of filter paper in each well, and color was allowed to develop for 2 min at 23° C. Row A, GHB in water; row B, GHB in normal human urine; row C, GHB in normal human urine containing 0.63% (w/v) ethanol. [From Bravo et al. (2004); used with permission.] *(See insert for color representation.)*

and genetically modified mice should be especially effective tools to answer these questions. In the case of GHB and its prodrugs, the cellular, subcellular, and enzymatic mechanisms for catabolism are not fully understood. Even when a particular isozyme or isoporter has been implicated in GHB catabolism (e.g., mitochondrial ADHFe1), we do not know whether it dominates other isozymes or isoporters under all relevant conditions in all relevant cell types, and whether it is rate limiting to the pathway. Neuronal signaling by GHB under normal and overdose conditions is not understood. Thus, potential consequences of GHB overdose that manifest in subtle, delayed, or synergistic damage have not been identified.

Impressive progress in the forensic science of date-rape drugs has also been made in recent years. Especially sensitive analytical methods have been developed. A surrogate for drugs and their metabolites in the form of perturbed mRNA levels has been discovered. The window of time available to detect dosing has been greatly extended. In the case of GHB, new metabolites have been found that are potentially diagnostic, and more probably remain to be found. An enzyme-based test for GHB has been developed that fills a gap in field tests for date-rape drugs. Moreover, the demand for forensic expertise in date-rape drugs will probably increase in the future due to (1) the possible need for comparison of two uncorrelated test methods in judicial proceedings, (2) development of new tests based on increased knowledge of biology, and (3) greater need for environmental testing. It is a rewarding and exciting time to be working in forensic science!

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NOTES

1. GHB also is known as Xyrem and "grievous bodily harm"; MDMA as ecstasy; flunitrazepam as Rohypnol and roofies; and ketamine as Ketanest and special K.
2. Synaptic vesicles are small and spherical or ellipsoidal and reside inside nerve terminals. They store concentrated neurotransmitter for evoked release as a quantum.
3. The central and peripheral nervous systems can synthesize neurosteroids at higher levels in females than in males. This difference might help explain why women often are more susceptible to ethanol at equivalent body burdens. An example of a neurosteroid is allopregnanolone.
4. Subtypes of $GABA_A$ receptor located inside synapses are not as responsive to ethanol as the subtype located outside synapses, which contains the δ-subunit.
5. The $GABA_B$ receptor modulates intracellular second messengers. An agonist activates a receptor. In this case, a high concentration of GHB activates the $GABA_B$ receptor similarly to a low concentration of GABA.
6. GABAergic means GABA-like or GABA-potentiating.
7. All neurotransmitters are agonists, even if transported instead of secreted out of a neuron.
8. An antagonist does not activate a receptor when it binds, but it inhibits binding of agonist, thus preventing activation by agonist.
9. Desensitization means that the receptor becomes unresponsive to agonist, even though no antagonist is present. Many different molecular and cellular mechanisms can mediate desensitization by receptors.
10. Isozymes (also known as *paralogs*) usually, but not always, have partially conserved sequences. The following examples illustrate nomenclature for the dehydrogenases and reductases discussed here. AKR1A1 is listing 1 (the last "1") in family 1 (the first "1", having $\geq$ 40% sequence identity among members) and subfamily A ($\geq$60% sequence identity among members) of the AKR superfamily. This enzyme is also commonly called aldehyde reductase, as it reduces a wide range of aldehydes. Similar nomenclature is used for ADHs and ALDHs by replacing "AKR" with "ADH" or "ALDH," as appropriate. AKR1A1 has no necessary relationship to ADH1A1. An isozyme could have several isoforms that arise from alternative splicing of the pre-mRNA.
11. This occurs because oxidation of an aldehyde to a carboxylate is irreversible. The reduction potential of an NAD^+/NADH or $NADP^+$/NADPH couple is not very important in an irreversible oxidation. A few mammalian alcohol dehydrogenases use non-nicotinamide redox cofactors such as flavins.
12. For example, SSA is a good substrate for AKR1A1 *and* AKR7A2 (Section 11.5.3). AKR1A1 also prefers the natural substrates 4-hydroxynonenal, methylglyoxal, 16-oxoestrone, D-glyceraldehyde, and D-glucuronic acid. AKR7A2 also prefers the natural substrates aflatoxin B1 aldehyde and 16-oxoestrone.

13. When two enzymes act on the same substrate, one of them can dominate at a low concentration of substrate and the other one at a high concentration if the Michaelis–Menten parameters for the two enzymes (and potentially also for an intervening transporter) have appropriate relationships. This possibility is relevant for GHB and its metabolites, as concentrations in vivo change > 100-fold between normal and dosed conditions.
14. Similar to isozymes, isoporters are transporters coded by different genes, and they often exhibit conservation of sequence and transport mechanism. Different isoporters usually have different preferred substrates.
15. However, mRNA levels often do not correlate quantitatively with protein levels, due in part to regulation of translation and differences in protein stability.
16. Amazingly, both SSA and aflatoxin B1 are preferred substrates for AKR7A2/AFAR1, even though the structures of SSA and aflatoxin B1 differ greatly. The observation warns us that in the absence of experimental evidence, one cannot eliminate the possibility that an isozyme having a preferred substrate very different in structure from SSA nevertheless also prefers SSA.
17. AKR7A2 sometimes is called the low-K_M SSA reductase.
18. An ortholog is the same enzyme in a different species. It will have a somewhat different sequence, due to species divergence, but its functional properties are usually very similar.
19. DNA microarray analysis determines the amount of specific mRNAs in total mRNA isolated from a tissue. Single-stranded synthetic DNA is anchored to thousands of microscopic spots in an indexed two-dimensional pattern on the surface of a "chip." The DNA on each spot is complementary to a different mRNA. A preparation of total mRNA (or its DNA complement) is hybridized to the chip-bound DNA, after which each spot optically reveals the amount of hybridization.
20. Epitope masking can occur when tissue fixatives react with and destroy an epitope or when the epitope is dependent on native conformation destroyed by denaturing electrophoresis, as occurs in Western blots.
21. Small interfering RNA (siRNA) blocks effective expression of a specific gene by inducing cellular degradation of the mRNA transcribed from that gene.
22. A low level of AKR1A1 in SH-SY5Y cells is not necessarily indicative of the amounts in vivo, as transformed cells are disregulated.
23. Golgi is a subcellular organelle that among other tasks forms synaptic vesicles that secrete neurotransmitters from nerve terminals.
24. Isoforms can have different amino acid sequences even though they arise from the same gene. This often occurs by alternative splicing of the mRNA. The total number of isoforms for ADHs, AKRs, and ALDHs thus exceeds the 46 genes for these enzymes by an unknown margin.
25. ADHFe1 is also known as HOT (hydroxyacid-oxoacid transhydrogenase) and ADH8. However, the latter designation has been used by some authors for retinol dehydrogenase, which is a completely different enzyme from ADHFe1.
26. Genetic tagging attaches a peptide to a protein to make a fusion protein that is to be expressed heterologously. In this case, an epitope tag recognized by a commercially available antibody was attached to ADHFe1.
27. Square brackets around a chemical name indicate the activity of the chemical species, which we approximate as molar concentration.

28. The ratio of the multiplicative concentrations of all chemical products divided by the multiplicative concentrations of all chemical reactants present at equilibrium is equal to K_{eq}. Thus, for ADH-catalyzed oxidation of an alcohol, $K_{eq} = [\text{aldehyde}]_{eq}[\text{NADH}]_{eq}[\text{H}^+]_{eq}/([\text{alcohol}]_{eq}[\text{NAD}^+]_{eq})$, which has net units of molar. The apparent value of K_{eq} for the reaction at pH 7.0 is given by $K'_{eq} = K_{eq}/[10^{-7.0}\text{M}]$, which is unitless. Similar equations apply to other reactions considered in this chapter.
29. A reported equilibrium constant of $K'_{eq} = 5.8$ for reduction of SSA must be in error (Hearl and Churchich, 1985).
30. At the pH and $[\text{NAD}^+]/[\text{NADH}]$ prevailing in mitochondria, $[\text{aldehyde}]_{eq}/[\text{alcohol}]_{eq} = K_{ox}^{mito} = K'_{eq}([10^{-7.0}\text{M}]/[10^{-7.7}\text{M}])([\text{NAD}^+]_{mito}/[\text{NADH}]_{mito}) = (9.5 \times 10^{-5})(10^{0.7})(7.7) = 3.7 \times 10^{-3}$. The free-energy change for the reaction is given by $\Delta G_{ox}^{mito} = -2.3RT \log K_{ox}^{mito}$, where the symbols have their usual meanings. Analogous expressions apply to NADP^+-dependent reactions, reverse reactions, and cytoplasm.
31. K_{ox}^{cyto}, equilibrium constant for oxidation of GHB modified for the pH and ratio of oxidant to reductant prevailing in cytosol; K_{red}^{cyto}, equilibrium constant for reduction of SSA modified for the pH and ratio of reductant to oxidant prevailing in cytosol; K_{ox}^{mito}, equilibrium constant for oxidation of GHB modified for the pH and ratio of oxidant to reductant prevailing in mitochondrial matrix; K_{red}^{mito}, equilibrium constant for reduction of SSA modified for the pH and ratio of reductant to oxidant prevailing in mitochondrial matrix.
32. Oxidation of an aldehyde to a carboxylic acid is irreversible in part because three driving forces are present that are not present in the oxidation of alcohols: neutralization of the carboxylic acid proton, electronic delocalization of the negatively charged carboxylate, and strong hydration of the carboxylate.
33. An allele is a mutant (or wild-type) form of a gene.
34. Microsomes are vesicles created from shearing of endoplasmic reticulum by homogenization of an organ such as liver, which is rich in endoplasmic reticulum. They are rich in P450 isozymes.
35. From this point onward in the chapter, any time that consequences of dosing by GHB are discussed, it should be assumed that similar, and perhaps even more extreme, consequences attach to dosing by GBL or BD.
36. Such species include *Ralstonia eutropha, Azotobacter vinelandii, Escherichia coli, Clostridium kluyveri*, and *Pseudomonas putida*. Poly(GHB) is also known as poly(γ-butyrolactone).
37. The trademark Bionolle is registered to Showa Highpolymer Co., Ltd. The chemical name is poly(butylene succinate). Butylene refers to 1,4-butanediol diester. Ecoflex is registered to BASF Group. The chemical name is poly(butylene adipate).
38. Several companies have attempted to raise antibodies that are selective for GHB, which is a small molecule in the immunogenic context, but they failed (personal communications to SMP).
39. Enzymes that act on xenobiotics are exceptions.

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CHAPTER 12

Forensic and Clinical Issues in Alcohol Analysis

RICHARD STRIPP

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

Summary Ethanol is a clear volatile liquid that is soluble in water and has a characteristic taste. Ethanol is a central nervous system (CNS) depressant and causes most of its effects on the body by depressing brain function. CNS depression correlates directly to the concentration of alcohol in the blood. The estimation of blood alcohol concentration for a person is based on important parameters such as body weight, ethanol concentration of the beverage consumed and number of such beverages consumed, and length of time and pattern of the drinking. Because men and women have different body water amounts (men average 68% and women 55%), there are differences between the ethanol concentration achieved in men and women of similar weight for the same amount of alcohol. Various methods are described that can help to determine blood alcohol concentration in the field as well as in the laboratory.

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12.1 INTRODUCTION

Alcohol (Ethanol: CH_3CH_2OH) Disposition

Half-life: plasma half-life, dose dependent
Volume of distribution: about 0.6 L/kg
Distribution in blood: plasma/whole blood ratio = 1.2
Saliva: plasma/saliva ratio is about 0.93
Protein binding: in plasma, not significantly bound

Ethyl alcohol has been consumed by humans for millennia and is probably one of the oldest and most commonly consumed drugs in most societies. A very high percentage of the adult population regularly consumes some form of alcohol to varying degrees. Approximately 10% use alcohol to an extent that may result in the manifestation of adverse heath effects. People who regularly consume six or more drinks per day are known to have higher mortality rates, and alcohol contributes to deaths in a variety of ways, including violence, accidents, and other drug-related deaths. Acute ethanol intoxication and its effect is the single most commonly encountered subject in forensic toxicology today. The blood alcohol concentration is commonly determined in medicolegal and forensic cases, and it is the ethanol in blood that is correlated with impairment of human performance. Ethanol is a product of fermentation by the action that yeasts on sugars found in fruit and grains. The content of alcoholic beverages varies for different types of drinks (see Table 12.1).

Alcohols are a class of organic chemicals that are characterized by the presence of a hydroxyl group (OH) on the hydrocarbon chain of the molecule (Figure 12.1). They all share common properties and ethanol is one of many alcohols. Other commonly encountered alcohols are methanol and isopropanol. Ethanol is a clear volatile liquid that is soluble in water and has a characteristic taste. As a drug, ethanol falls into the category of a *central nervous system* (CNS) *depressant* (Garriott, 2003). This means that the predominant effects of alcohol are to depress brain function. CNS depression is directly correlated to the concentration of alcohol in the blood (BAC). In a progressive manner, as the BAC rises, so does the degree of CNS depression. The most common reported units for BAC (%) are expressed as grams of ethanol per 100 mL of blood. Therefore, a BAC of 0.05 g/dL is equivalent to 0.05%. The American Medical Association has defined the BAC where impairment begins to be 0.04%, but for some functions it may be much lower. In most states in the United States a person is legally intoxicated at a BAC of 0.08% and is considered to be impaired at 0.05%. The consequences of impairment are

TABLE 12.1 Alcohol Content of Various Beverages

Beverage	Alcohol Content (%)
Beers (lager)	3.2–4.0
Ales	4.5
Porter	6.0
Stout	6.0–8.0
Malt liquor	3.2–7.0
Sake	14.0–16.0
Table wines	7.1–14.0
Sparkling wines	8.0–14.0
Fortified wines	14.0–24.0
Brandies	40.0–43.0
Whiskies	40.0–75.0
Vodkas	40.0–50.0
Gin	40.0–48.5
Rum	40.0–95.0
Tequila	45.0–50.5

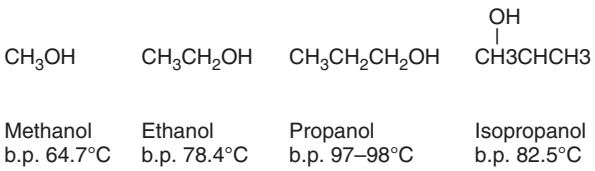

Figure 12.1 Structure of common alcohols.

the major reasons for the intense forensic interest in alcohol consumption. The individual assessment of impairment due to acute alcohol intoxication is of great medical–legal importance and is a complex matter that is influenced by many factors. There is significant variation between individual persons and their alcohol-related effects, but for the most part, predictable effects at various levels of BAC are encountered for a large percentage of the general population (Table 12.2).

It must be emphasized that a specific individual would show signs that can be markedly different for the ranges that are indicated. As already noted, many tolerant individuals may show little sign of physical impairment at the higher end of the table, although significant cognitive, judgmental, and psychological impairment may reasonably be presumed to be present.

12.2 BLOOD ALCOHOL CONCENTRATION

The estimation of blood alcohol concentration must be based on important parameters such as body weight, ETOH concentration of the beverage consumed

TABLE 12.2 Stages of Alcohol Intoxication

BAC (g/100 mL of blood or g/210 L of breath)	Stage	Clinical Symptoms
0.01–0.05	Subclinical	Behavior nearly normal by ordinary observation
0.03–0.12	Euphoria	Mild euphoria, sociability, talkativeness Increased self-confidence; decreased inhibitions Diminution of attention, judgment and control Beginning of sensory-motor impairment Loss of efficiency in finer performance tests
0.09–0.25	Excitement	Emotional instability; loss of critical judgment Impairment of perception, memory and comprehension Decreased sensatory response; increased reaction time Reduced visual acuity; peripheral vision and glare recovery Altered sensory-motor coordination; impaired balance Drowsiness
0.18–0.30	Confusion	Disorientation, mental confusion; dizziness Exaggerated emotional states Disturbances of vision and of perception of color, form, motion and dimensions Increased pain threshold Increased muscular loss in coordination; staggering gait; slurred speech Apathy, lethargy
0.25–0.40	Stupor	General inertia; approaching loss of motor functions Markedly decreased response to stimuli Marked muscular coordination impairment; inability to stand or walk Vomiting; incontinence Impaired consciousness; sleep or stupor
0.35–0.50	Coma	Complete unconsciousness Depressed or abolished reflexes Subnormal body temperature Incontinence Impairment of circulation and respiration Possible death
0.45+	Death	Death from respiratory arrest

(Table 12.3), number of alcoholic beverages consumed, and length and pattern of the drinking.

Other factors that will affect the rate of absorption from the gastrointestinal tract will further affect the final BAC curve (Morgan Jones and Vega, 1972; Karch, 1997; Drummer, 1999; Garriott, 2003). Approximation of the time frame of when the alcohol was consumed is usually of crucial importance (Morgan Jones and Vega, 1972; Karch, 1997). It is also essential to determine if the subject's BAC was on the ascending or descending limb of the BAC curve. The blood alcohol concentration reached after drinking depends not only on the volume of ethanol consumed but

TABLE 12.3 Estimated BAC by Number of Drinks in Relation to Body Weight[a]

Body Weight (lt)	Number of Drinks											
	1	2	3	4	5	6	7	8	9	10	11	12
100	.038	.075	.113	.150	.188	.225	.263	.300	.338	.375	.413	.450
110	.034	.066	.103	.137	.172	.207	.241	.275	.309	.344	.379	.412
120	.031	.063	.094	.125	.156	.188	.219	.250	.281	.313	.344	.375
130	.029	.058	.087	.116	.145	.174	.203	.232	.261	.290	.320	.348
140	.027	.054	.080	.107	.134	.161	.188	.214	.241	.268	.295	.321
150	.025	.050	.075	.100	.125	.151	.176	.201	.226	.251	.276	.301
160	.023	.047	.070	.094	.117	.141	.164	.188	.211	.234	.258	.281
170	.022	.045	.066	.088	.110	.132	.155	.178	.200	.221	.244	.265
180	.021	.042	.063	.083	.104	.125	.146	.167	.188	.208	.229	.250
190	.020	.040	.059	.079	.099	.119	.138	.158	.179	.198	.217	.237
200	.019	.038	.056	.075	.094	.113	.131	.150	.169	.188	.206	.225
210	.018	.036	.053	.071	.090	.107	.125	.143	.161	.179	.197	.215
220	.017	.034	.051	.068	.085	.102	.119	.136	.153	.170	.188	.205
230	.016	.032	.049	.065	.081	.098	.115	.130	.147	.163	.180	.196
240	.016	.031	.047	.063	.078	.094	.109	.125	.141	.156	.172	.188

[a]One standard drink equals: 12 oz regular beer, 5 oz table wine, 1 oz 80 proof liquor (National Highway Traffic Safety Administration (NHTSA)).

also on the speed and pattern of drinking and the rates of absorption, distribution, metabolism, and excretion (ADME) of ethanol, all of which in turn may be affected by a multitude of other factors (Drummer, 1999). Age, gender, race, body mass index, presence of other drugs, beverage type, food, genetics, and health status are a few examples of factors that can alter the ADME of ethanol and hence are important considerations when interpreting BAC levels in a person (Millar et al., 1992; Jones and Jonsson, 1994; Ammon et al., 1996; Karch, 1997; Drummer, 1999; Garriott, 2003). Once ethanol is absorbed it is distributed throughout the body via the blood to other tissues. Ethanol is distributed to the body water, and the greater the water contents of a tissue, the greater the ethanol concentration. The individual factors that determine BAC are body weight and adiposity, and distribution ratio (based on the total body water content) of ethanol. It follows that the concentration of alcohol within a person depends primarily on the amount of alcohol he or she drinks, the person's drinking pattern and total body water, and various other life and environmental issues.

Because men and women have different body water amounts (men average 68% and women 55%), there are differences between the ethanol concentration achieved in men and women of similar weight for the same amount of alcohol consumed. In other words, if a man and a woman of the same weight drink equivalent amounts of ethanol, the female will have a higher BAC on average. Similarly, if two men of different body weights drink the same amount of ethanol, the lighter man will have a higher BAC compared to the heavier man, and so on. In general, the less you weigh, the more you will be affected by a given amount of alcohol, all other factors assumed to be equal for this purpose.

The volume of distribution for ethanol was first expressed by Widmark using a formula that still bears his name (Garriott, 2003):

$$A = \frac{WRC}{0.8}$$

where A is the volume of pure ethanol consumed, W the body weight, R the distribution ratio, C the blood ethanol concentration, and 0.8 the specific gravity of ethanol.

There is a time lag from the period of intake of alcohol until the peak blood alcohol concentration is reached. This is regulated by the rate of alcohol absorption after oral intake. As described above, alcohol absorption is affected by numerous factors. Because of these factors, the time to reach peak blood alcohol concentrations varies greatly and can range between 15 min and 2 h. Hence, if alcohol absorption is not complete, peak alcohol levels will not yet be reached. The BAC is a balance between absorption and elimination of ethanol (Winek and Esposito, 1985).

There can be a threefold variation in ethanol elimination rates among individuals. Gender, age, body weight, and even the time of day can influence the rate of ethanol metabolism. To back-extrapolate from a blood alcohol concentration at one time to a value at an earlier time, one needs to know an accurate value for the ethanol elimination rate, which is difficult in view of the large interindividual variability in ethanol elimination kinetics. Also, to back-extrapolate, one uses linear kinetics, which may not be accurate, especially for the concentration range under consideration. The variability in individual rates of ethanol elimination, the difficulty in knowing exactly when absorption of ethanol was completed and how rates of ethanol elimination can change at different blood ethanol concentrations, cast some uncertainty on such retrograde calculations to an earlier blood ethanol concentration.

Since BAC is a function of the balance between how much is entering the blood versus how much is cleared or removed, the liver, via metabolism, plays a very important role. The liver removes most of the ethanol via oxidation, with lesser amounts excreted in the breath, urine, feces, and saliva or converted to ethyl glucuronide (Figure 12.2). The cytochrome P450 enzymes in liver microsomes catalyze the conversion of ethanol to acetaldehyde and water in the presence of molecular oxygen and NADPH (Figure 12.3). The toxic acetaldehyde product is quickly converted to acetic acid via acetaldehyde dehydrogenase, as shown in Fig. 2. The rate at which ethanol is cleared from the blood varies from one person to another. Heavy drinkers and alcoholics tend to eliminate alcohol much faster than does the inexperienced drinker. In most people the rate of clearance from blood ranges from 0.01 to 0.025% per hour, and is even higher in some very tolerant drinkers, with a mean of about 0.017%. This is very important for the forensic toxicologist.

Assume, for example, that an accident occurs at midnight and the alcohol content of a blood sample taken from the driver at a hospital at 2:00 A.M. (two hours later) was found to be 0.07%. Does this mean that the level was below 0.08% at the

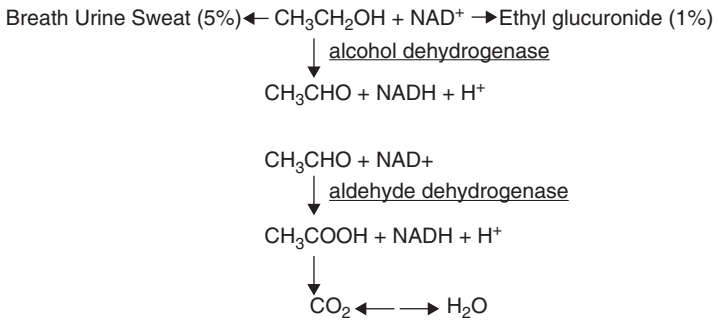

Figure 12.2 General scheme for ethanol oxidation. (a) <10% ethanol excreted in breath, sweat, and urine; (b) ~90% ethanol removed by oxidation; (c) most of this ethanol oxidation occurs in the liver; (d) ethanol cannot be stored in the liver; (e) no major feedback mechanisms to pace the rate of ethanol metabolism to the physiological conditions of the liver cell.

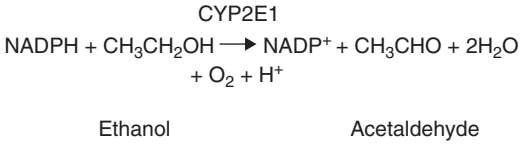

Figure 12.3 Microsomal (cytochrome P450) oxidation of ethanol in the liver.

time of the accident? Well . . . it depends. Let's assume that the person stopped drinking at a time prior to the accident, so that all the ethanol was absorbed from the person's gastrointestinal tract at midnight (time lag). We can extrapolate the BAC to the time of the accident as follows: Using the average rate of 0.017 g/dL per hour for two hours, the BAC two hours earlier (12:00 midnight) would yield a BAC of 0.104 g/dL, using the average "burn-off" rate of 0.017 g/dL per hour. Under these circumstances this person would be considered legally intoxicated at the time of the accident. On the other hand, if the person stopped drinking very shortly before the time of the accident, the BAC would still be rising at midnight and would continue to rise and peak sometime between midnight and 2:00 A.M. This clearly complicates the estimation of what the level would have been at midnight, and caution needs to be applied to such assessments. Therefore, a considerable range of BACs may be possible, depending on the drinking pattern, and this must be taken into consideration when interpreting the data.

12.3 ALCOHOL IMPAIRMENT AND DRIVING SKILLS

Driving or operating automobiles or any other vehicles while under the influence of alcohol is dangerous and perhaps the most commonly encountered forensic issues associated with this drug. Legislation around the country has enacted various rules

mandating fines and penalties for driving under the influence of alcohol. Alcohol is a central nervous system depressant. The precise mechanism by which alcohol affects cognition and psychomotor control is not known completely, but the fact that it does so is very well documented and is well understood by most members of the public. To appreciate the effects of alcohol on driving skill, the complexity of driving itself must be recognized. Driving is a multifaceted process that requires a combination of hand–eye coordination, psychomotor function, muscle control, and cognitive function. Furthermore, driving is a divided-attention task, and the driver does not have the comfort of focusing exclusively on any one of these components, but rather, must concentrate on all simultaneously (i.e., monitoring a number of sensory inputs and responding appropriately with all the changing circumstances). Alcohol use can affect the implementation of individual tasks, and its effects are therefore more pronounced on more complex tasks, of which driving is a perfect example.

Alcohol causes a slowing of nerve conduction, which results in slower reaction times, difficulty in processing information, and thus impaired performance in divided-attention tasks. People are clearly affected differently at different BAC values for various reasons discussed previously. Sometimes the effects of alcohol are not apparent without specialized testing and must be elicited by tasks that challenge those abilities (see field sobriety tests for impairment). A person can be affected by alcohol to the extent that it can impair driving skills before overt signs of intoxication (e.g., staggering and slurred speech) materialize. The BAC value at which driving ability is affected by alcohol use is a recurrent issue confronting forensic toxicologists, although most toxicologists agree that any person with a BAC above 0.1 g/dL would have impaired driving skills, and those above 0.2 g/dL would show signs of overt intoxication on close inspection, even by a nonexpert.

The pharmacology and toxicology of alcohol differ from person to person. Various behaviors and physiological functions affected by ethanol result in impairment of driving skills, including reaction time, tracking, vigilance or concentrated attention, divided attention, information processing, visual functioning, perception, and psychomotor functions. Detrimental effects on reaction time are known to occur at BAC values in excess of 0.07 g/dL. Bloods levels of ethanol ranging from 0.012 to 0.12 g/dL increase the reaction time more than threefold and BAC values over 0.12 g/dL impair reaction times even further. With more complicated tasks that require more than one attentive task occurring simultaneously (e.g., driving), increased reaction time is even more evident. This situation is known to occur with the impairing effects of ethanol on driving skills. Driving requires that a person control speed, track position, and maintain lane control, and monitor various outside signals visually and react to them, all of which are impaired by increasing BAC. Since alcohol is a central nervous system depressant, it affects a wide range of these functions. (Connors and Maisto, 1980; Linnoila et al., 1980; Moskowitz et al., 1985; Steele and Josephs, 1988; Maylor et al., 1989 Lipscomb and Nathan, 1980). Statistics consistently show that the crash risk is increased significantly when BAC values are above 0.04 g/dL. Several studies with automobile simulators have

shown that risk taking is affected at higher levels of alcohol, described as 0.106 g/dL (Mongrain, 1974).

The area most often showing the greatest impairment with alcohol consumption is divided-attention performance. Driving is a task that requires considerable divided attention, and decrements have been shown to occur with BAC as low as 0.02 g/dL and worsens with increasing BAC. The second-fastest rise in impairment occurs with tracking performance, which can occur at or below 0.05 g/dL. Driving is a time-sharing task that requires two activities: compensatory tracking and visual search. Divided-attention tasks are particularly sensitive to the effects of rising BAC, and such impairment may begin to occur at very low levels of BAC (<0.02 g/dL) for some people. There is sufficient evidence to suggest that BAC values of 0.05 g/dL and above are capable of producing impairment of the major components of driving skills, including reaction time, tracking, divided-attention performance, information processing, visual functions, and psychomotor impairment (Nito et al., 1964; Money et al., 1965; Aschan and Gergstedt, 1975; Baloh et al., 1979; Fagan et al., 1987). A major factor that determines the magnitude of such impairing effects in a person is tolerance (see the discussion below). Tolerance to some of the impairment parameters of ethanol can occur, but the extent to which it develops is very difficult to predict (Levine et al., 1975; Lipscomb et al., 1980; Wilson et al., 1984; Niaura et al., 1988). However, it is known that the impairing effects of alcohol on experienced versus naive drinkers is attenuated for some of these tasks in heavy drinkers. Even so, serious effects of alcohol on driving skills occur in all subjects at BAC levels of 0.10 g/dL or higher, and cognitive function will also be affected in these subjects.

12.4 FIELD SOBRIETY TESTS

Field sobriety tests, including the walk and turn, one-leg stand, and horizontal gaze nystagmus, are commonly used in field testing to detect impairment (Aschan, 1958). Fundamentally, these are only screening tests that presumptively detect impairment and must be followed by some other analytical measurement of blood alcohol content directly or via extrapolation. Horizontal gaze nystagmus is more reliable at predicting blood alcohol content than the walk and turn and the one-leg tests. Field sobriety testing is generally applicable to blood alcohol levels of 0.08 g/dL and above. At lower levels more studies are needed. Consequently, at levels lower than 0.08 g/dL, field sobriety tests will not be helpful. Furthermore, the field sobriety test must take into account factors such as prescription medications or altered health status, such as neurological or orthopedic problems.

Pharmacologically what happens when a person starts to drink alcohol? At first, as the BAC begins to rise, there is an apparent stimulatory effect. The person may become more talkative and they may seem more social and have increased self-confidence. This effect is not a stimulatory effect of ethanol but a depression of the inhibitory centers of the brain. As the BAC increases, impairment of judgment, decision making, perception, motor function, and reaction time occurs. The

impairment of motor function and muscular coordination starts to affect the ability to walk, speak, and maintain balance. Significant and progressive reduction in mental and physical abilities continues as the BAC rises and the person is visibly intoxicated. In relatively low-tolerant or inexperienced drinkers, a BAC value over 0.30% can result in loss of consciousness and possible death, and with concentrations rising over 0.40%, death becomes increasingly likely. Chronic heavy use leads to a high incidence of brain damage, liver disease, heart disease, stroke, metabolic disorders, and oral, lung, and liver cancers, and abuse during pregnancy increases the risk of fetal malformations and development of fetal alcohol syndrome.

Tolerance is the lessening of the effectiveness of a drug after a period of prolonged or heavy use (Levine et al., 1975; Lipscomb et al., 1980; Wilson et al., 1984; Niaura et al., 1988). Studies have shown that chronic alcohol users can have as much as twice the tolerance for alcohol as an average person. Tolerance develops from two separate mechanisms: dispositional (or metabolic) and functional. *Metabolic tolerance* occurs because the drug is metabolized or inactivated at a faster rate after prolonged use (Lipscomb and Nathan, 1980). Thus, a given dose produces a lower BAC value. *Functional tolerance* is an actual change in a person's sensitivity to the drug at an organ or biochemical system level. With functional tolerance, greater amounts of the drug are required to elicit similar effects with increasing use of the drug. It is important to note that even in heavy users of alcohol, impairment is clearly measurable at the BAC levels that are currently used for traffic law enforcement. Tolerance is not complete for all systems and may be marked in some but not others. However, it is significant to note that even though cognitive impairment is present, many highly tolerant persons are capable of engaging in physical activities and actions (including fighting) at levels that would result in unconsciousness or even death in nontolerant persons.

12.5 BLOOD ALCOHOL MEASUREMENTS

Early blood alcohol testing involved distillation methods based on alcohol from the blood, followed by oxidation and titration. One of the carryovers of these techniques is the use of whole blood as the sample of choice for legal blood alcohol determinations in body fluids. Although popular up until the 1970s, such methods have largely been replaced by enzymatic and gas chromatographic methods (Jones and Pounder, 1997).

12.5.1 Enzymatic Methods

Enzymatic methods are attractive because they can be automated readily and thus allow for high-throughput analysis. Typically, enzymatic ethanol determinations are often done as part of a test panel on plasma or serum for other clinical chemistry parameters. This is often done in a medical laboratory setting and is not considered "forensic" testing. The use of plasma is an important consideration, since the reports issued by hospital laboratories often do not specify the specimen type.

Plasma contains more water than whole blood, and correspondingly more alcohol per milliliter. The accepted practice for converting a plasma or serum alcohol into a whole blood alcohol is to divide by 1.18, although a range of 1.10 to 1.30 gives a 95% confidence interval for the corresponding whole BAC. The fact that there is a range associated with this conversion makes measurement directly in whole blood the method of choice.

Enzymatic methods rely on the enzyme-specific oxidation of ethanol to acetaldehyde with alcohol dehydrogenase. This oxidation requires reduction of the cofactor oxidized nicotinamide–adenine dinucleotide (NAD^+) to NADH, which is accompanied by a change in absorbance that can be monitored spectrophotometrically. Enzymatic methods can be susceptible to interference from other alcohols oxidized by the same enzyme, but the differential kinetics of these reactions lends some specificity to the method. When calibrated using the appropriate standards, conducted in duplicate, and analyzed alongside matrix-matched controls with acceptable results, enzymatic oxidation can be an acceptable forensic method of determining BAC. These precautions are rarely followed in a clinical setting, however, and the use of hospital alcohol results for forensic purposes should be interpreted with this limitation in mind.

12.5.2 Headspace Gas Chromatography

By far the most popular, precise, and accurate method of determining blood alcohol is by gas chromatography (GC). This technique has the advantages of being semiautomatable, extremely reproducible, and compatible with multiple sample types. Currently, both packed column and capillary column procedures are popular and acceptable for forensic blood alcohol analysis. GC assays provide the greatest amount of flexibility and specificity in analyzing for these volatile compounds. Direct injection of biological samples into GC columns has been used in the past as the method of sample introduction. This typically leads to column contamination and decreased performance.

The incorporation of headspace sampling into the method prevents the buildup of nonvolatile contamination at the head of the column and helps to maintain consistent performance and extend column lifetime. Analysis time and resolution are two critical factors when developing a GC assay for ethanol. Analysis time for each sample should be as short as possible, while maintaining baseline resolution for all analytes.

An aliquot of blood (200 μL) in sodium fluoride and potassium oxalate is removed in duplicate to test for ethanol and other volatiles of low relative molecular mass. This is performed by mixing the blood using an automated pipettor or diluter with 2 mL of a 3 M NaCl solution that contains 1.0 g/L of 1-propanol as the internal standard. The mixed sample is dispensed into a 10-mL septum-topped vial and sealed. The vials are loaded into an automated headspace autosampler attached to a GC equipped with flame ionization detection (FID) in duplicate. Each sample is run in combination with a set of contemporaneous calibrators (0.4, 0.8, 1.6, and 3.2 g/L), a blank following the highest standard, and an externally purchased

reference control after every tenth sample. The preservatives are important in this analysis. The sodium fluoride is an enzyme poison that will retard the formation or degradation of alcohol by bacteria. This is especially important in postmortem casework in which there is significant opportunity for bacterial contamination after death or at autopsy. It is less significant in blood drawn under sterile conditions from a living person. The potassium oxalate is an anticoagulant, which ensures that the blood remains homogeneous and does not separate into red cells and serum, since the water-enriched serum sample would contain more ethanol than would the whole blood. Since GC–mass spectrometry (GC–MS) is typically not used to test volatiles of low relative molecular mass, the use of complementary GC columns for duplicate testing is highly desirable, since (as in this case) the retention times obtained as a result of the different selectivity of the two columns provide an added dimension in the identification of a compound. Frequent calibration is desirable, but not essential. However, if a laboratory performs quantifications using a historical calibration curve, the reliability of the curve should be checked frequently with appropriate and comprehensive controls. Control samples obtained from and certified by an external vendor allow the laboratory to demonstrate the accuracy of its procedure by comparison with other laboratories.

When blood samples are analyzed for forensic purposes, civil or criminal, a standard procedure is to make duplicate determinations (Gullberg and Jones, 1994; Andreasson and Jones, 1996). The concentration of blood alcohol should be reported with the confidence limits such as 95% or 99% (Goldstein, 1983; Jones and Schubertz, 1989). Therefore, it is crucial that in hospital laboratories, the calibration of standards test by biological specimens along with the unknowns be done and kept on record for forensic evidence (Fraser, 1986). Cases have been thrown out of court due to the absence of the raw standardization data. Analyses done by a clinical toxicology laboratory and a certified forensic lab are dissimilar. Forensic laboratories perform analyses on samples of whole blood, whereas clinical laboratories usually measure plasma or serum ethanol concentration. The water content of plasma and serum is higher than that of whole blood and therefore requires an appropriate conversion (Winek and Carfagna, 1987; Frajola, 1993). Typically, the range is between 15 and 20% for plasma as compared to whole blood, and this conversion factor should be used in forensic work (Rainey, 1993). This difference may be significant in some cases, and should not be missed.

12.5.3 Breath Alcohol Testing

Driving under the influence (DUI or DWI) of alcohol and drugs is one of the most significant issues associated with abuse of these materials. Several testing strategies have been developed and introduced to assess the role of alcohol intoxication in impaired driving and to detect and prosecute offenders. Alcohol is still the drug that contributes most often to impaired driving. The smell of alcohol beverages on the breath has long been recognized as an indication that a person has consumed ethanol. Alcohol is eliminated unchanged in the breath and hence provides a means by which alcohol can be measured in the body. Breath alcohol instruments were

developed to provide a fast and easy way of monitoring BAC indirectly. Analysis of a person's expired air provides an indirect way of monitoring volatile substances in the pulmonary blood. Breath has become the biological specimen of choice for measuring alcohol concentration in association with the enforcement and prosecution of drivers suspected of being impaired. Some of the reasons for this preference include:

- Breath collection is generally considered to be noninvasive.
- Rapid and inexpensive analysis allows for timely results, often as a field test.
- Analysis is straightforward and requires minimal operator training.
- Analysis does not require sophistcated laboratory equipment to obtain results.

These factors have combined to establish breath alcohol analysis as the most common forensic analysis employed in drunk-driving enforcement and workplace alcohol testing. Typically applied as a field test by a trained user, the interpretation of results begins with a clear understanding of the purpose of such measurement. Two classes of instrument for breath alcohol analysis can be distinguished, based on whether the results are intended for qualitative screening or as evidentiary testing for prosecution purposes. For example, prearrest screening breath tests clearly have a different purpose from that of the subsequent evidential breath test, which may be used as binding evidence in court. The serious implications associated with a drunk-driving conviction necessitate, at a very minimum, a sound forensic breath test protocol, which includes:

1. Trained and qualified instrument operators
2. At least 15 min of pre-exhalation observation
3. Internal instrument standards to verify calibration
4. Collection of duplicate breath samples
5. Appropriate agreement (i.e., $\pm 10\%$ of the mean) between duplicates
6. External control standards
7. Blank tests performed between all measurments
8. Appropriate printout of all data
9. Error detection systems
10. Instruments evaluated periodically according to an established quality assurance procedure to ensure optimal analytical performance, including accuracy, precision, linearity, and critical-system evaluations (e.g., acetone detection, radio-frequency interference detection, mouth alcohol detection)

12.5.4 Breath Alcohol Instrumentation

Ethanol is detectable in the breath and hence provides a means by which evidentiary testing can be accomplished to provide direct onsite collection and analysis of blood alcohol concentration for forensic purposes, principally for traffic law enforcement. The important characteristic of ethanol that allows for its measurement in the field

is that ethanol is volatile. The theory that provides the foundation for such testing is based scientifically on the fact that the distribution of ethanol between the blood and the alveolar air obeys Henry's law. Therefore, at a given temperature, a direct relationship exists between the amount of alcohol (volatile substance) dissolved in blood (liquid) and the amount of alcohol in the vapor above the solution (alveolar air). At the temperature of expired air (34°C), the amount of ethanol in 2100 mL of alveolar air is assumed to be equivalent to the amount of ethanol in 1 mL of venous blood. Various instruments have been developed to take advantage of this ratio (2100 : 1). Various handheld devices are available for roadside testing and prearrest screening. For more controlled quantitative analysis of BrAC for evidential purposes, the instruments are much larger and more sophisticated, and include ways to check calibration, analyze alcohol free air, and produce hardcopies of the results. The best-known and most robust chemical handheld roadside breath alcohol screening tests generally utilize a fuel cell–based technology. These sensors oxidize ethanol to acetaldehyde and in the process produce free electrons, with the electric current generated directly proportional to the amount of alcohol present in the sample. Other alcohols present in the breath, such as methanol and isopropanol, also undergo chemical oxidation, although at different rates. Acetone (e.g., untreated diabetes) exhaled in the breath is not oxidized and will not cause a false positive. However, if acetone levels are exceedingly high, isopropanol can be formed in the body by reduction of acetone. Also for alcohol, enzymatic tests with a color endpoint have been developed for the field measurement of saliva alcohol. Such tests may have some potential value as screening tests in instances where the subject cannot provide breath, such as if injured and immobile.

In 1938, Rolla Harger developed the first commercially available forensic breath alcohol instrument intended for law enforcement applications, called the Drunk-o-meter. To use the Drunk-o-meter, the person being tested blew into a balloon and the air in the balloon was then released into a chemical solution containing potassium permanganate. If there was alcohol in the breath, the chemical solution changed color. The greater the color change, the more alcohol in the breath. The level of alcohol in a person's blood could then be estimated by a simple equation. This was a wet chemistry method based on optical measurement of the color change that occurred in potassium permanganate resulting from the oxidation of alcohol in the breath sample. This was largely replaced by the much more portable Breathalyzer developed in the 1950s. The Breathalyzer also utilized a colorimetric technique following the oxidation of alcohol in a potassium dichromate solution. As concerns began to develop that there was a lack of specificity and accuracy of wet chemical methods, instruments that employed the optical absorption of infrared energy according to Beer's law began to replace these methods for most forensic applications during the 1970s. Several variations of the infrared technology have been applied, including the use of multiple wavelengths to increase the specificity for ethanol. Most evidential breath-testing instruments used today identify and measure the concentration of alcohol by its absorption of infrared energy at wavelengths of 3.4 and/or 9.5 μm, which correspond, respectively, to the C—H and C—O vibration stretching in the ethanol molecules.

During the 1980s, fuel cell technology emerged as a useful analytical method in forensic breath alcohol measurement. Although fuel cells have been employed typically in screening devices, their technology has improved dramatically in recent years. Selectivity has been enhanced in one modern evidential instrument, the Alcotest 7110 (Draeger Instruments, Durango, CO), which now employs both infrared and fuel cell methodologies to quantify ethanol in breath and represents the first dual technology breath alcohol instrument. Employing two different and independent measuring systems, infrared spectroscopy and electrochemical cell technology, it provides the highest level of forensic and legal veracity. Such true dual-sensor instruments are now readily available on the market. By means of these instruments, both the electrochemical sensor and the infrared-optical sensor operating at 9.5-μm-wavelength quantify BrAC.

Modern breath alcohol instruments offer several advantages over their predecessors. The modern instruments are computerized, which greatly reduces the potential for operator error and ensures compliance with specific protocol requirements. In addition, automated instruments enable rapid analysis, error detection, ensured compliance with breath sampling parameters, automated purging of sample chamber and signal processing, regulation of test protocol and sequence, data collection and hardcopy printout of results. Measurement quality control is enhanced, therefore, by allowing only those test results that fully conform with predetermined standards to be printed out and to qualify as evidence in court. Contemporary instruments also allow features of "intelligent measurement" to be incorporated. These features permit the instrument to "make decisions" regarding test performance, run, or analytical properties. Data collection features also allow for the development of control charts and other methods to evaluate instrument and programmed performance over time. Various forms of data analysis can provide relevant information to the courts and enhance confidence in the results. Many features of the emergent analytical technology have been integrated advantageously into forensic breath test instruments.

12.5.5 Conversion from BrAC to BAC

The extrapolation from breath alcohol content to blood alcohol content level at the time of accident or arrest is one of the most important steps in the forensic process. While the conversion process takes into account simple mathematical conversion, it is imperative to understand that in most cases the extrapolation of the amount of blood alcohol concentration to a time other than the time when the specimen of body fluid or breath was taken from the subject is applicable only to the average person in a normal physical condition and may not be relevant otherwise. Current research has shown that there are multiple variables, such as blood breath ratio, absorption rates of alcohol, elimination rates of alcohol, and difference in total body water (Winek and Esposito, 1985; Karch, 1997). The analyst should be aware that the BAC/BrAC ratio of alcohol changes as a function of time after drinking, depending on whether the test was done on the absorptive or postabsorptive phase of the alcohol curve, which my have an important bearing on the interpretation of these results.

12.5.6 Urine and Saliva

Urine has been used in some jurisdictions as a specimen for forensic alcohol testing. It is amenable to analysis by both the enzymatic and chromatographic methods described above. Its major limitations are collection and interpretation. Urine collection, if observed, raises privacy issues, and if not observed, raises issues of chain of custody and the potential for adulteration, substitution or dilution. With respect to interpretation, urinary alcohol concentration is an indirect measure of BAC. Urine is formed in the kidneys as an ultrafiltrate of blood. As with plasma, therefore, a factor must be applied to account for the higher water content. Of more importance, however, is the fact that since urine is formed over time, the urine alcohol concentration is an average corresponding to the blood concentration over the time during which the urine was formed and collected in the bladder. Since this can cover an appreciable amount of time (up to several hours), even a urine sample corrected for water content may not reflect the true BAC at the time of urine collection. To correct for this, for forensic purposes urine is generally collected for analysis about an hour after an initial void. The subject is directed to empty his or her bladder, after which he or she is allowed a period of time (approximately an hour) during which new urine corresponding to their current BAC is formed and collected for testing. Such complications and the associated problems of interpretation mean that urine alcohol determination is not a preferred forensic approach, although it is acceptable in many jurisdictions. Problems with interpretation are generally legislated away with a statutory per se urine alcohol offence.

Saliva or oral fluid is a plasma ultrafiltrate produced through the parotid and other glands in the oral cavity. Drugs, including alcohol, that are present in the blood will also be found in the saliva (Jones, 1981, 1993). Care must be taken when examining oral fluid for alcohol because it can be subject to contamination from drugs and alcohol simply present in the oral cavity. The length of time of the contamination depends on the drug's lipophilicity and water solubility. Mouth alcohol is generally dissipated by absorption and exhalation within 15 min. This is why at least a 15- to 20-min observation and waiting period is stipulated prior to the subject being offered an evidential breath test, and a similar waiting period is essential for a test of salivary alcohol. A number of companies have marketed oral fluid alcohol test kits, which are based on the principle of enzymatic oxidation. These are to be used as screening devices because their quantitative accuracy is variable.

Generally, from an analytical standpoint there is a good correlation between circulating blood alcohol and oral fluid alcohol concentrations, and a properly collected and preserved oral fluid sample can be subjected to an analysis, usually by headspace GC, with good-quality results. Samples are usually collected in a tube with minimal headspace to prevent loss, together with appropriate preservative (enzyme inhibitor) to prevent postcollection alcohol production.

12.5.7 Ethyl Glucuronide

This is a compound formed from a minor metabolic pathway of ethanol (Yegles et al., 2004). Less than 1% of ingested ethanol is conjugated in the liver with

glucuronic acid to form a water-soluble compound that is present in blood and excreted in urine. It has also been detected in hair, and this is currently being used in some alcohol and drug monitoring plans clinically (Jurado et al., 2004; Skipper et al., 2004). Ethyl glucuronide is a stable compound and a specific indicator for ethanol ingestion and has been applied to some forensic applications; however, measurement of EG levels in both blood and urine do not bear a constant relationship to BAC (Schmitt et al., 1997; Bergstrom et al., 2003; Jurado et al., 2004; Skipper et al., 2004; Yegles et al., 2004). The demonstration of EG in a specimen only indicates recent (within the last 40 h or even longer) ingestion of ethanol, which limits its use. It is capable of determining whether or not the person had been drinking in the recent past. A serum ethyl glucuronide concentration of greater than 5 mg/L when the BAC is less than 0.10 g/dL has been suggested as representing alcohol misuse (Drummer, 1999).

12.5.8 Postmortem Determination of Alcohol

One of the primary roles of the forensic toxicologist is to determine the role of drugs and alcohol in establishing a cause of death (Pounder and Jones, 2006). Ethanol is a major analyte in postmortem forensic determinations (Turkel and Clifton, 1957; Zumwalt et al., 1982). Commonly, the forensic toxicologist must opine on the role that alcohol may have played in a forensic case in both criminal and civil cases. This includes traumatic injuries such as motor vehicle accidents, alcohol poisoning, criminal behavior and human performance toxicology, and occupational incidents, to name but a few. There are major issues associated with the interpretation of the analytical alcohol results on samples obtained at autopsy. These are mostly due to the lack of homogeneity of blood samples, postmortem alcohol production or loss, and disruption of the gastrointestinal tract following traumatic injury, resulting in the release of alcohol into the surrounding tissues. However, with proper care, ethanol analysis can be accomplished with high confidence on postmortem samples. Postmortem forensic analysis is discussed in detail in Chapter 13, so the topic is only summarized here.

Blood is the usual specimen provided for postmortem ethanol analysis. The site from which postmortem blood is collected is important (Plueckhahn, 1968; Prouty and Anderson, 1987). The preferred site is the femoral vein. Blood from the pericardial sac or chest cavity can have falsely elevated alcohol levels due to postmortem diffusion of alcohol from the stomach (Plueckhahn and Ballard, 1967; Pounder and Smith, 1995). As with antemortem blood, samples should be collected into containers with appropriate preservative (sodium fluoride) and anticoagulant (potassium oxalate), depending on how the analysis is to be performed. Because of ethanol's uniform distribution through the body, other fluids and tissues can be used for analysis as well. Vitreous fluid from within the eye consists of 99% water with small amounts of salts and mucoproteins. It is in an enclosed space and is not normally subject to contamination by microorganisms, and these specimens are easily collected at autopsy. Vitreous is important because due to its anatomical location, it is usually well preserved after death and is generally unaffected by postmortem changes. The high water content of vitreous means that measured

ethanol levels should be comparable to blood levels. The ratio of blood to vitreous concentration is between 0.57 and 0.96, with a value of 0.85 the most commonly used best estimate. Blood has a lower water content than vitreous, so the expectation is that the equilibrium blood vitreous alcohol ratio will be less than 1. In cases where the blood/vitreous ratio exceeds 1 it is likely that death occurred while the person was in the absorptive phase and before diffusion equilibrium had been obtained, and this observation may be of forensic significance (Sturner and Coumbis, 1966; Felby and Olson, 1969; Kraut, 1995; Yip, 1995).

Urine collected from the bladder like vitreous is resistant to postmortem contamination by microorganisms. Postmortem alcohol production in urine occurs only when the urine contains large amounts of glucose (diabetes) or there was a urinary tract infection during life (Drummer, 1999). Urine is easily sampled at autopsy provided that the bladder is intact. A urine alcohol measurement does not reflect the alcohol content of urine at any point in time (i.e., time of death). It may be a useful specimen to use to assess possible prior consumption of alcohol. Urine concentrations are generally similar to those of blood but may vary considerably and should not be used to predict BAC without incurring a large error. As long as this is recognized, urinary alcohol estimation can be a useful measurement.

12.5.9 Quality Assurance of Alcohol Testing

Monitoring of the day-to-day performance of the collection, storage, and analytical methodology is a vital component of a proper forensic alcohol analysis (Moffat et al., 2004). The laboratory must have the highest confidence that the quality of the data produced is of utmost precision and accuracy because the results are often used for criminal prosecution or civil litigation. Use of a range of replicate determinations is an important means of controlling the quality assurance of test results. All specimens are carefully inspected when they arrive and the condition is noted. When needed, preservatives and anticoagulant are used to inhibit enzyme activity to prevent post-collection microbiological production of alcohol and blood clotting in the samples, respectively. Proper labeling is essential, with all the required identifying information to be included in a suitable label. The collection container must be properly sealed to prevent unauthorized tampering or loss of sample during transport and storage. For specimens that are stored, appropriate refrigeration (-4°C) of the samples is needed to prevent loss of the volatile alcohol, and the rate of lost alcohol during this time needs to be established. Calibration and measurements of controls and standards must be completed and documented by the measuring laboratory, and copies of the analytical data, including chromatograms should be maintained in a secure storage facility so they are available for scrutiny or produced as evidence. The laboratory performing the alcohol analysis must be properly accredited and must participate in external proficiency testing to establish that all results produced are precise and accurate. Failure to do so greatly reduces the confidence in the data produced and may result in the data being inadmissible in court.

CHAPTER 13

Fundamental Issues of Postmortem Toxicology

DONALD B. HOFFMAN

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York

BETH E. ZEDECK

Pediatric Nurse Practitioner, New York

MORRIS S. ZEDECK

(Retired) Department of Sciences, John Jay College of Criminal Justice, New York

Summary The basic principles of forensic postmortem toxicology are presented. In this chapter we discuss the acquisition and usefulness of various specimens, current analytical techniques, and interpretation of findings. Special problems associated with the interpretation of drug levels include the conditions of the specimens and the effects of postmortem redistribution, postmortem drug changes, pharmacogenomics, drug interactions, and embalming fluid.

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13.1 INTRODUCTION

One aspect of forensic chemistry is forensic toxicology, the discipline that analyzes biological fluids and tissues for the presence of drugs and poisons, determines their concentration, and interprets the findings. The results may be helpful in determining whether one or more drugs played a role in a person's injury, illness, behavior, or death. Thus, forensic toxicology can be divided into clinical toxicology, human performance toxicology, employment drug testing, and postmortem toxicology. This fascinating and challenging profession draws on the disciplines of pharmacology and of biochemical, analytic, and organic chemistry. It is not our purpose here to present an inclusive detailed treatise on forensic toxicology, as excellent source materials of this nature are available. Methods for the extraction of drugs from various tissues and the analytical procedures used for the detection and measurement of drug concentration have been described in many textbooks and reference books (Chamberlain, 1995; Wong and Sunshine, 1997; Levine, 2006; Smith et al., 2007), as have the effects of drugs (Marquardt et al., 1999; Brunton, et al., 2005; Klaassen, 2008). The reader interested in pursuing these topics in more detail is encouraged to utilize these and all other relevant sources of information.

In this chapter we focus on a special area of forensic toxicology: postmortem toxicology. We wish to present to the forensic scientist an overview of the current key issues involved in the practice of postmortem toxicology. Several earlier articles discussing this particular area of forensic science are cited (Prouty and Anderson, 1990; Hilberg et al., 1999b; Drummer, 2004, 2007; Skopp, 2004; Dolinak, 2005; Levine, 2006; Rodda and Drummer, 2006; Spitz and Spitz, 2006; Watterson et al., 2006; Karch, 2007; Garriott, 2008).

Postmortem forensic toxicology is an essential and integral component of any comprehensive medicolegal investigation into the cause and contributing circumstances of death. As such, it is essential that it be carried out appropriately and efficiently in order to provide the necessary information. An inclusive toxicological investigation encompasses knowledge of case history, specimen selection, choice of extraction procedures, application of multiple analytic techniques, and interpretation of findings.

Postmortem toxicology involves the analysis of tissues and fluids taken from cadavers, either shortly after death or from decomposed or exhumed bodies, and also from formalin-fixed specimens. Each presents special situations that must be taken into consideration to ensure proper interpretation of the data. Drug samples, drug paraphernalia, and prescription items may also be found at the site of death and usually become part of the postmortem toxicological examination.

Postmortem tissues taken from a person who had been confined to a hospital for an extended period may have limited value because of drug clearance occurring over a period of time prior to death. However, the analysis of antemortem blood and urine, when available and especially if taken around the time of hospital admission, may become essential in postmortem protocols when there has been a prolonged period of survival, or when extensive administration of transfusions occurred prior to death.

Knowledge of the case history is very important. The circumstances surrounding the death or the indicated use of specific agents may require the use of non-routine procedures to check for the possible presence of certain classes of drugs or poisons that are not necessarily included in the routine protocols. Examples of such substances are digoxin and other cardiac glycosides, insulin, quaternary ammonium muscle relaxants, water-soluble or very highly polar compounds [e.g., γ-hydroxybutyrate (GHB)], and salts of heavy metals. Such substances have been encountered in homicidal or other criminal poisonings, and some following therapeutic treatments. There must be knowledge as to appropriate specimen selection and preservation. Certain specimens may be particularly appropriate for a particular drug or where the condition of the body is a factor. Issues such as postmortem redistribution of drug from its site at the time of death (discussed below) and postmortem drug stability or transformation play key roles both in the choice of specimen as well as in the subsequent interpretation of findings (Drummer, 2004; Skopp, 2004). Cases involving decomposed, dismembered, embalmed and exhumed bodies require special attention in order to maximize the utilization of such specimens as are available at autopsy.

Once an analyte has been detected in bodily fluids and tissues, questions arise. Is the concentration of analyte reflective of its concentration at the time of death, or is it higher or lower than at the time of death? Conditions that can alter drug concentration include changes resulting from human enzymes, bacterial enzymes, pH, temperature, and hydrolysis. Do the levels of drug found represent an overdose, intentional or otherwise, or a therapeutic level? Are tolerance and/or pharmacogenomics issues? Information as to the interval of time between death and the finding of the body, or information concerning therapeutic treatments of the person prior to death, is often not available. An additional factor to be considered when interpreting drug levels is the situation when a decedent had received significant amounts of replacement fluids prior to death. This is not, however, a simple "dilution" effect since the infusion of fluid results in efforts to reestablish new equilibrium between tissues and blood. Thus, the forensic toxicologist must consider a host of factors in reaching a decision as to the manner and cause of death. A primary objective of this chapter is to discuss those factors that can make it difficult to interpret

postmortem toxicological findings in deciding whether or not a drug played a role in causing a person's death.

13.2 TISSUE AND FLUID SPECIMENS

Postmortem specimens taken at autopsy may include blood, urine, bile, cerebrospinal fluid, vitreous humor, gastric contents, meconium, various organs, bone, teeth, hair, and nails. If an autopsy is not performed, the postmortem specimens collected usually include peripheral blood, urine, and vitreous humor.

13.2.1 Blood

It needs to be emphasized that postmortem blood, even if obtained quickly after death, has already been affected by processes that occur at the time of death, such as loss of cell membrane potential and the initiation of hemolysis. Other postmortem processes begin early on and generally increase with increasing postmortem interval. Hence, any sample of postmortem blood is not physiologically or toxicologically equivalent to a clinical sample. Proper selection of the sites for blood sampling is crucial because of the phenomenon of postmortem redistribution. This is defined as the postmortem movement of drug away from its location at the time of death to another site in the body. Several basic mechanisms are believed to be involved (Pélissier-Alicot et al., 2003).

One mechanism is diffusion of drug from inside cells into the surrounding blood. This starts with loss of integrity of the cell membrane, which occurs at the moment of death and generally results in unregulated flow of substances, both endogenous and exogenous, out of cells. Because of this mechanism, postmortem blood is not used for the determination of electrolytes and glucose.

A second mechanism is release of drug from certain tissue depots and the subsequent formation of drug concentration gradients directed toward blood in the heart chambers. Of particular importance is antemortem accumulation of drug in lung tissue, which can act as a depot for many drugs, especially those that are lipid soluble. The postmortem release of drugs from lung depots results in the movement of drug via the pulmonary veins into the heart chambers. Such postmortem diffusion generally occurs with those drugs that have high volumes of distribution ($\geq$3 L/kg) and attain high lung levels; however, there is no hard-and-fast rule for this (Hilberg et al., 1999a). The release of drug from tissue depots is believed to involve the disruption of nonspecific drug–macromolecular binding as a result of pH changes and denaturation. Those drugs that concentrate in heart tissue will be released directly into heart blood, and sampling from the chambers would give an incorrect concentration of drug in blood at the time of death. It is known, however, that highly lipophilic drugs may move from blood into adipose tissue.

A third mechanism is the diffusion of drug away from the gastrointestinal and hepatic systems, which ultimately enters heart blood. This mechanism is particularly relevant when death occurs in the nonequilibrium phase; that is, significant amounts

of drug are still present in the stomach, intestines, and in the portal vein–hepatic system. Thus, for example, ethanol from the gastrointestinal tract can redistribute to the pericardial and also to the pleural fluids (Plueckhahn, 1967). Thus, it is essential that when blood is taken for analysis, a sample be drawn from peripheral sites such as the femoral veins (or subclavian veins), as quantitation on femoral blood is considered to be the most reliable measure of the antemortem concentration just prior to death (Dalpe-Scott et al., 1995; Hilberg et al., 1999b). However, whenever possible, the results derived from femoral blood should be compared with results from other tissues and fluids.

The production of gases during decomposition and the resulting pressures can result in the mixing of blood from different sites (Prouty and Anderson, 1990). A sample of femoral blood may contain blood from the inferior vena cava, and cardiac blood may contain blood from the vena cava, subclavian, pulmonary, and aortic vessels. Other factors that make interpretation of postmortem blood data difficult include the degree of hemolysis, or any other changes in the blood matrix. Therefore, unlike clinical toxicology, where blood is separated into plasma or serum, whole blood is almost always analyzed in postmortem toxicology. Analysis of blood clots, especially after trauma such as head injury, may be useful for determining drug exposure prior to death, especially in cases of prolonged survival, during which time the circulating blood may have been cleared of drug. The concentration of drug in a blood clot may reflect the concentration in blood at the time of clotting, assuming that formation occurred at the time of injury. But care in quantitative interpretation is important since the consistency of the clot differs from that of circulating blood, because formation of the clot cannot always be assumed to be instantaneous (where there is a survival time before death) and because clots themselves may partially break down and release drug.

13.2.2 Urine

Unless death is so rapid as to preclude the drug from being excreted into the bladder, urine is useful for initial screening for the different classes of drugs and for their metabolites. Finding drugs in urine indicates prior usage but cannot itself be used to indicate any level of impairment or the concentration of drug in blood prior to death. Urine analysis presents fewer problems than blood analysis; for example, urine does not readily support bacterial growth.

13.2.3 Vitreous Humor and Cerebrospinal Fluid

Analysis of vitreous humor serves several useful roles. It must be emphasized, however, that vitreous humor is useful only when bodily decomposition has not set in. There is some evidence that determination of potassium levels in vitreous humor may be useful in some cases for approximating the postmortem interval (PMI). Potassium levels rise as the interval between death and collection of a sample increases; the correlation, however, is not always accurate (Stephens and Richards, 1987). More recent studies (Muñoz et al., 2001, 2002; Madea and Rödig, 2006) have

demonstrated that certain statistical treatments of the data observed provide a somewhat more accurate estimation of the PMI. Nonetheless, the relationship between the concentration of vitreous potassium and PMI remains a controversial issue.

Vitreous humor has been used to analyze for the presence of many drugs and alcohol (Hepler and Isenschmid, 1998; Jones, 1998). Vitreous humor contains very little protein compared to blood and tissues. Only free drug in blood enters the vitreous humor, and since most drugs exhibit at least some significant degree of binding to proteins and other macromolecules in blood, vitreous drug levels are lower than those in femoral blood. Vitreous humor is a protected site; usually, there is little bacterial contamination and therefore little fermentation. Thus, it may be useful for determining whether the presence of alcohol in tissues was due to consumption prior to death or formed as a result of postmortem fermentation. Vitreous humor is a good backup sample for blood ethanol. The levels of alcohol in vitreous humor pre- and post-embalming are in fairly good agreement (Scott et al., 1974; Coe, 1976). Since the pre- and post-embalming samples in these studies were taken within a relatively short interval of each other, one cannot draw conclusions about the effects of embalming fluid over long periods of time. However, caution must be exercised whenever inferring a blood alcohol level from vitreous humor. The vitreous/blood (femoral) ratio of alcohol can be a very useful indicator of whether death occurred in the absorptive or post-absorptive state. At equilibrium (post-absorptive state), the ratio of vitreous alcohol to blood alcohol averages about 1.10 to 1.20 (Garriott, 2008). But if death occurs during the absorptive state (rising blood alcohol level), this ratio will be lower, possibly even less than 1.00. Postmortem redistribution from ocular tissue into vitreous humor may also occur.

Vitreous humor can be very useful for the determination of such antemortem conditions as hypo- or hypernatremia, dehydration or uremic conditions, and hyperglycemia. Vitreous glucose is known to decline, often erratically, with increasing postmortem interval, thus making determination of hypoglycemia generally impractical, if not impossible. However, under certain very limited conditions, a precipitously low level found very shortly after death may be indicative of insulin overdose (Coe, 1972, 1974).

Many drugs are known to enter the cerebrospinal fluid (CSF). Absent blood, CSF has been found useful for the qualitative determination of drugs. Analysis of CSF may reveal recent use of heroin, as 6-monoacetylmorphine has a longer half-life in this specimen than that of other fluids (Jenkins and Lavins, 1998; Engelhart and Jenkins, 2007).

13.2.4 Gastric Contents

The entire gastric contents should be taken for analysis and the total weight should be recorded. Any undigested tablets or other medicinals should be analyzed separately. The total amount of drug present in gastric contents, including any undigested material, is of forensic importance because it may be useful in interpreting the manner of death (i.e., it may be indicative of suicidal overdose). Since gastric content is normally acidic, detecting trace amounts of basic drugs

in stomach contents may be due to back diffusion into the stomach as well as representing residual drug following ingestion.

13.2.5 Meconium

Exposure to maternal substance abuse during gestation is associated with many adverse social and significant perinatal complications, including a high incidence of stillbirths, premature rupture of the embryonic sac membranes, maternal hemorrhage, spontaneous abortion, fetal distress, and increased rate of mortality and morbidity (developmental and cognitive impairment) (Ostrea et al. 1989; Moriya et al., 1994; Moore and Negrusz, 1995; Ostrea, 2001). Previously, the history of in utero exposure to drugs was based on urinalysis and on maternal self-reporting, which may be unreliable, due to patient denial about addiction or fear of the consequences (Ostrea et al., 1989; Coles et al. 2005). In stillbirth infants and in infants that die after birth, meconium may be the specimen of choice for drugs of abuse testing because of the difficulty in obtaining urine specimens, and the use of organs may have limited value if the mother had stopped using drugs several days before delivery (Moriya et al., 1994).

Meconium, the first fecal matter of the neonate, which is normally expelled from the intestine during the first 24 to 48 h after birth, is a thick greenish-black material composed of epithelial cells, digestive tract secretions, and residue of swallowed amniotic fluid (Ostrea et al., 1992; Moore and Negrusz, 1995). Drugs accumulate in meconium either by direct deposition from bile or through swallowing of amniotic fluid (Ostrea et al., 1992; Moore and Negrusz, 1995; ElSohly et al., 1999b; Ortega García et al., 2006).

Meconium starts to accumulate in the intestines between weeks 12 and 16 of gestation and can provide a long history of in utero drug exposure as well as indicate during which period of gestation drug use took place (Callahan et al., 1992; Ostrea et al., 1994; Ortega García et al., 2006). Unlike urine, blood, and gastric contents, which allow the detection of drug exposure for 2 to 3 days, meconium extends this window to about 20 weeks (Ostrea et al., 1989; Abusada et al., 1993; Moore and Negrusz, 1995). Lewis et al. (1995) reported that meconium analysis detected threefold more cocaine-exposed babies than urinalysis did.

Meconium is readily available, and only a small sample is required for complete analysis, including confirmation analysis (Ortega García et al., 2006). Meconium testing does have some limitations. It is often an unfamiliar specimen in the clinical laboratory, being a sticky material that is more difficult to work with than urine and requires a thorough preliminary cleanup procedure prior to any analytical assay.

Solid-phase extraction (SPE) has been used to isolate drugs and metabolites from meconium, and both immunoassay and chromatographic techniques have been used for the screening of drugs in meconium. Preliminary screening results must be confirmed by gas chromatography–mass spectrometry (GC–MS). Coles et al. (2007) compared GC–MS with LC–MS–MS (liquid chromatography–tandem mass spectrometry) and found that LC–MS–MS has increased specificity and decreased interference rate, reporting fewer false-positive results. Marin et al.

(2008) developed a LC–MS–MS procedure that can detect and quantitate many benzodiazepines in meconium.

Various drugs and their metabolites that are found in neonatal or maternal urine have also been detected in meconium. Samples containing cocaine and/or cocaethylene also contained benzoylecgonine and *m*-hydroxybenzoylecgonine. The presence of cocaethylene in meconium suggests that both cocaine and alcohol were used during pregnancy (Callahan et al., 1992; Abusada et al., 1993; Steele et al., 1993; Moriya et al., 1994; ElSohly et al., 1999a). One study of postmortem analysis of three fetuses that had been exposed to cocaine showed the presence of cocaine in the meconium of a 17-week-old fetus, suggesting that fetal exposure can be determined early in gestation and in the very premature fetus. At this time, meconium contained a higher concentration of drugs than did neonatal urine (Ostrea et al., 1994).

Moore and Negrusz (1995) and Coles et al. (2005) found that some samples of meconium contained both 11-nor-Δ^9-tetrahydrocannabinol-9-carboxylic acid (THC-COOH) and 11-hydroxy-Δ^9-THC (11-OH-THC). Using trimethylsilyl derivatization and GC–MS, hydrocodone and hydromorphone were detected in meconium along with codeine and morphine (Moore et al., 1995). The level of codeine, hydrocodone, and hydromorphone increased dramatically following acid hydrolysis, while the morphine level also increased but not as significantly.

13.2.6 Brain

The brain is a good repository for lipophilic drugs such as anesthetics and hydrocarbons, whereas many polar compounds are not able to pass the blood–brain barrier in significant amounts. Clearly, psychotropic drugs enter the brain easily and their levels in brain are useful for determining the manner of death. Brain is also used as a backup specimen for blood alcohol. At equilibrium, the brain alcohol/blood alcohol ratio is about 0.85, but this number may be lower if death occurs during the period of a rising blood alcohol. Brain cocaine levels are useful for evaluating cocaine-related deaths (Bertol et al., 2008). From a few minutes to about 3 h after exposure, the brain/blood ratio for cocaine is approximately 4 to 10 (Spiehler and Reed, 1985). The ratio of brain to blood cocaine in cases of death within 3 to 6 h of exposure is approximately 0.4 to 0.8. These ratios may be different, however, in persons who had used cocaine chronically.

13.2.7 Liver and Bile

The liver concentrates most parent drugs and also metabolites, ethanol being the notable exception. There is an extensive body of data on the range of hepatic drug levels in therapeutic, toxic, and lethal cases. Bile is a good source for many drugs and their metabolites, in particular opioids and benzodiazepines, and because of its storage in the gallbladder, it may be the only specimen where residual drugs or metabolites may be detected when absent from other tissues. Bile may be useful in those cases where a prolonged interval elapsed between the last intake of

drug and death. However, bile may contain high concentration of drug in cases of acute overdose where death occurs while large amounts of drug are still in the gastrointestinal tract and in the portal system.

13.2.8 Lung, Spleen, Kidney, and Skin

The analysis of lung tissue is useful in cases involving volatile substances such as gases (other than carbon monoxide), anesthetics, and solvents. Because spleen concentrates red blood cells, it may be useful as a last resort specimen for determining cyanide- or carbon monoxide–bound hemoglobin. Since cyanide derived from antemortem toxic exposure may be lost rapidly with advanced decomposition, spleen may be the only organ where toxicologically significant levels of cyanide may still be found. Where a routine blood sample is not available or is not considered usable, spleen may be used cautiously to estimate antemortem exposure to carbon monoxide. Analysis of kidney tissue is useful for detecting heavy metals. Analysis of unburned skin may be useful for detecting use of accelerants in arson-related cases.

13.2.9 Muscle

Muscle tissue is not a routine specimen, but is particularly useful in cases of advanced decomposition because skeletal muscle, being more slowly affected by decomposition, may still be present when little or no other soft tissue is present. Great care must be exercised when interpreting the findings quantitatively. For skeletal muscle, there is little postmortem toxicology data from which one can draw conclusions relating drug level and cause of death. The studies that have been done on fresh skeletal muscle indicate that the data are best used qualitatively. Of interest is the fact that cocaine, which is unstable in blood, has been detected in numerous cases in decomposed but dry skeletal muscle.

13.2.10 Bone, Teeth, Nails, and Hair

It is known that many drugs and heavy metals become incorporated in bone, teeth, nails, and hair. These tissues will not necessarily, however, contain drugs or toxic substances if death occurred rapidly after intake or administration, but are good indicators of chronic dosing. They are usually not analyzed postmortem except for exhumed, badly decomposed, or skeletonized bodies. Teeth are useful for analysis in bodies that have been badly burned. There is an extensive body of data on the incorporation of drugs and heavy metals into hair, which is used primarily in clinical toxicology. Hair can be cut into segments and analyzed individually to determine a time pattern of drug usage. Since hair grows at a rate of approximately 1 cm per month, one can approximate when drug usage was discontinued. Hair may reflect a single acute dose, depending on the drug and dose involved, provided that sufficient time has elapsed to allow entry of drug into the hair. In this regard the analysis of

hair follicles may be particularly useful. Hair analysis requires careful and proper preliminary washing steps to remove as much as possible of any substances present as a result of external contamination.

13.2.11 Other Materials for Analysis

1. *Injection site*. If an injection site can be located, analysis may reveal useful qualitative and quantitative data. Since a drug may have come to what appears to be an injection site via the circulation, other skin samples should be taken for comparison.
2. *Insect larvae/maggots*. Larvae and maggots feed on decomposing tissue and will incorporate into their systems drugs that are in the tissues they consume. Collection of these insect specimens from decomposed or skeletonized bodies may provide much useful qualitative information.
3. *Nasal swabs*. Results from swabbing of the nasal cavities must be interpreted cautiously. Drugs are normally secreted into nasal mucosa. Finding small amounts of drug on a swab does not necessarily mean that the person snorted drugs prior to death. The amount of drug detected will help determine if snorting is a likely explanation.

13.3 SPECIMEN COLLECTION AND STORAGE

For all samples, proper collection of the sample in adequate amounts, and proper use of preservatives and storage containers (e.g., glass, plastic, nylon, foil) along with proper storage temperature are essential (Skopp, 2004). It is recommended that glass containers be used for liquids and glass or plastic containers for tissue and gastric contents. However, it must be noted that the use of certain types of plastic containers for storage can result in the loss of THC–COOH (Stout et al., 2000).

Blood should be collected in tubes containing at least 1 to 2% sodium fluoride as preservative and stored at 0 to 4°C. This will inhibit bacterial growth and enzyme activity, which can either produce alcohol or reduce the concentration of alcohol in alcohol-containing specimens. Without preservative, bacterial action at room temperature is likely, and alcohol production by bacteria can reach concentrations up to 0.10 to 0.15 g/dL. Sodium fluoride will also inhibit cholinesterase activity, which can metabolize cocaine and other ester-containing substances. Blood specimens held for long periods can be frozen. Tissues may be stored for short periods at 0 to 4°C. Most drugs are stable at this temperature range, but some drugs (e.g., cocaine) are labile. Tissues may also be frozen. However, the freezing and thawing of tissues before processing is not recommended, as this can rupture cells and cause a loss of drug-containing fluid. Where short- or long-term freezing is utilized, frozen tissues should be rapidly cut and weighed. Vitreous humor and urine can be stored at 0 to 4°C or frozen. Meconium stored at room temperature for 24 h shows a loss of drug, in particular cocaine and cannabinoids. Meconium can be stored at −15°C for nine months without loss of drug concentration (Ostrea,

2001). Samples to be analyzed for volatile substances other than alcohol must be stored frozen and, when appropriate, in hermetically sealed containers. If volatile substances are suspected in a death, the pathologist should submit duplicate samples so that analysis can be performed for nonvolatile drugs as well as for volatile compounds. It should be emphasized that blood and other fluids should be collected in such a manner as to minimize the headspace area in the collection vessel. All other biological-containing evidence should be sealed and stored frozen.

13.4 EXTRACTION PROCEDURES

Choice of the extraction procedures will determine the recovery of analytes from the tissue matrix, and improper selection may result in failure to recover adequately or even to detect one or more agents. The use of liquid–liquid extraction procedures requires careful selection of solvent and pH in relation to the analytes targeted. The polarity of the extracting solvent, or solvent mixture, should be similar to the polarity range of the target analytes. The pH used for the extraction of acidic and basic compounds should be 2 units below and above, respectively, the pK_a value of the analyte. Neutral drugs are not dependent on pH. However, when performing a general unknown analysis, the selection of solvent and pH should be done so as to obtain satisfactory recovery of a wide range of possible analytes, keeping in mind such factors as pH-related drug stability, drugs such as amphetamines that require very high basic pH, and the requirements of amphoteric compounds. The use of solid-phase extraction (SPE) generally requires protein-free extracts. SPE has a high versatility, owing to the broad range of columns available: polar, nonpolar, ion-exchange, and mixed-mode. Columns typically used for general unknown procedures consist of a combination of nonpolar and cation-exchange components. SPE can be very useful for the isolation of highly polar or water-soluble drugs and metabolites. It should also be noted that the condition or state of the biological matrix being extracted (i.e., “fresh”, decomposed, or embalmed) can affect the amount recovered (see below), and this needs to be taken into account when interpreting findings (Skopp, 2004). Experience has shown that many different types and classes of drugs and toxic metals can be recovered from exhumed bodies even after long periods of interment (Skopp, 2004). Great caution must be exercised, however, in the interpretation of all such findings.

13.5 ANALYTICAL TECHNIQUES

Knowledge of the basic theory, range of applicability to forensic samples, and the analytic limitations of all techniques currently utilized (i.e., immunoassay, chromatography, spectrometry, and spectroscopy) is essential. Immunoassays and chromatographic procedures are screening techniques, and all presumptive positives must be confirmed. The standard technique for confirmation is one or more of the modes of mass spectrometry, usually coupled with gas chromatography (GC) or liquid chromatography (LC).

It is beyond the scope of this chapter to discuss in detail the principles and applications of these analytic technologies. However, the following brief comments are relevant. There are ongoing advances in both GC and high-performance liquid chromatographic (HPLC) technology, resulting in the availability of more versatile and stable columns providing higher resolution and greater ranges of class retentivity.

The use of HPLC is gaining increasing popularity for several reasons. The development of mixed-mode or multimechanism columns for HPLC allows for the retention of drugs over a broad range of polarity. These columns incorporate both nonpolar and polar moieties. An analyst can choose from a multitude of normal, reversed-phase, and mixed-mode types of columns and, accordingly, tailor a separation. Compounds that do not chromatograph well on routinely used low- to intermediate-polarity GC columns because of high polarity or size or thermal instability will as a rule be effectively and conveniently separated by LC systems. In many cases this eliminates the need for derivatization required for GC. LC is essential for quaternary ammonium muscle relaxants such as tubocurarine and pancuronium. It has long been used for the acidic barbiturates (commonly analyzed along with neutral drugs as the acid/neutral fraction), and it has many advantages for the analysis of benzodiazepines (Levine, 2006; Marin et al., 2008). It is being applied increasingly to the routine analysis of basic drugs. Although still under development, the appearance of ultrafast or high speed HPLC does promise to increase the efficiency of obtaining effective and reliable separations with a very short run time. This involves the use of shorter columns, higher linear velocities, smaller porous particle size (ranging from less than 2 to 2.2 μm in size), and significantly higher operating pressures. It also generally requires cleaner sample extracts. LC is now commonly coupled to mass spectrometry by means of electrospray ionization or atmospheric pressure chemical ionization interfaces, and this is being used very effectively.

GC is, of course, still used very widely as a screening technique for basic drugs. Headspace GC is the standard method for routine analysis of the "volatile" fraction (i.e., ethanol, methanol, isopropanol, and acetone). A wide variety of columns of low, intermediate, and high polarity is available. As with LC, there is now available fast-track GC, which promises to bring effective separations in much shorter time. Fast GC typically involves the use of very rapid column heating systems, which provide much faster increases in temperature, higher carrier gas pressures, and very fast signal acquisition systems. Column length will vary, but 5-m columns are frequently used. Derivatization may be necessary for the following reasons: improvement of chromatographic characteristics, resolution of coeluting compounds, elimination of thermal instability, and in some cases, as with amphetamines, to produce a derivative with a much more characteristic mass spectral fragmentation pattern than is found with the underivatized compound. Where derivatization is necessary, this involves the replacement of "active" hydrogen with an alkyl, acyl (especially polyfluorinated acyls), or silyl group. A particular advantage to the use of polyfluorinated derivatives is that it allows for highly sensitive detection using an electron capture detector. One common application of this procedure is the gas chromatography–mass spectrometry analysis of cannabinoids.

There have been very significant developments in mass spectrometry technology which have dramatically increased its power and applicability for confirmation. The use of tandem MS, ramped fragmentation (smart fragmentation), simultaneous acquisition of both scan and select ion monitoring data, and the development of hybrid mass spectrometers have all expanded and improved the confirmatory process. Very fast mass scanning systems are available and required for use with fast chromatographic screening techniques. The use of current time-of-flight mass spectrometers can provide extremely accurate mass detection to differentiate compounds with similar masses.

Although generally no longer done routinely as part of a general unknown, the analysis of metals may be indicated based on the circumstances or suspicions associated with a particular case. Homicidal poisoning with certain metal salts (i.e., thallium or arsenic) is still encountered. The analysis of metals starts with digestion of the biological matrix. Wet ashing may involve refluxing the sample with a mixture of strong inorganic acids (i.e., a mixture of nitric, sulfuric, and perchloric acids), or for more volatile metals may involve just incubation with the acid solution. Dry ashing, which involves heating in a muffle furnace at elevated temperature to produce an ash residue, which is then treated with 5% nitric acid to dissolve the metals, cannot be used for mercury and other volatile metals and is used for selected metals only as appropriate. In general, mercury requires the use of cold vapor techniques. The state-of-the-art instrumental technique is inductively coupled plasma mass spectrometry, which provides very high sensitivity over the mass range of metals of forensic interest. However, graphite furnace atomic absorption spectroscopy (AAS) is still very widely used, and cold vapor AAS is the preferred technique for mercury.

The analysis of carboxyhemoglobin and the other hemoglobin species is today typically and conveniently achieved with the use of CO-oximeters, which involve automatic spectrophotometric determinations (Lee et al., 2002, 2003; Lewis et al., 2004). Thermocoagulated, putrified, and contaminated blood samples can pose potential problems. In such cases, sample pretreatment before oximetry has been found effective. Alternatively, the use of headspace GC on carbon monoxide released from the sample after treatment with liberating agents or the application of derivative spectroscopy to the sample itself can provide acceptable results (Perrigo and Joynt, 1989).

Cyanide may be determined conveniently by headspace GC using a nitrogen–phosphorus detector after liberation from the biological matrix under acidic conditions. Spectrophotometric and fluorometric procedures are also available (Felscher and Wulfmeyer, 1998; Gambaro et al., 2007).

It is essential that there be maintenance of all the accepted standards for quality assurance and quality control throughout the entire testing process from sample receipt and accession through all the analytic operations and continuing to sample storage, release, and disposal. This includes the generation and maintenance of all reports necessary to document every aspect of the processes. Proper maintenance logs must also be kept for all analytic instrumentation involved. If it should be necessary to convey test results verbally to an authorized party, then the results

and any specific information given should be recorded appropriately to avoid any future misunderstandings.

13.6 INTERPRETATION

The interpretation of postmortem findings is becoming increasingly complex. This is due to such factors as postmortem redistribution, significant differences in individual rates of metabolism arising from genetically based polymorphic variations in metabolic enzymes, the type and condition of the specimen, drug interactions arising from the concurrent use of multiple drugs, and a particular person's tolerance for a specific drug or class of drugs and cross tolerance.

13.6.1 Postmortem Redistribution

The mechanisms and consequences of postmortem redistribution were discussed earlier. The effects of postmortem redistribution increase with increasing postmortem interval, but the mechanism involving unregulated flow of drug out of cells becomes significant at the moment at which death occurs. In general, it has been observed that cardiac blood has a higher concentration of drug than that of peripheral blood, although the magnitude of the change depends on the physiochemical properties of the drug, its volume of distribution, whether death occurred under equilibrium or nonequilibrium conditions, the organ concentrations, and the length of the postmortem interval. Variations in the cardiac/peripheral ratio can be very significant, even for a given drug (Dalpe-Scott et al., 1995; Anderson and Muto, 2000). The general importance of always including a sample of peripheral blood has been noted. If peripheral blood is not available, the interpretation of findings based only on cardiac blood is frequently perilous, and, in such situations tissue concentrations, especially liver, are necessary to minimize the possibility of an erroneous conclusion. Postmortem redistribution may also occur between organs, as high levels of drug from liver, lung, stomach, and heart are released to neighboring sites (Moriya and Hashimoto, 1999). Where there has been traumatic injury to the organs (i.e., laceration or rupture of the stomach, intestines, liver, etc.), there is a high potential for contamination from drug that may be present in the affected organ and now spills out into adjacent areas. Sampling of multiple sites and testing of different specimens may be necessary to resolve such issues.

In cases involving alcohol when blood is not available postmortem, blood alcohol levels can be estimated from correlation data derived from studies comparing alcohol levels in blood with those in other postmortem tissues. The state of alcohol absorption (pre- or post-absorptive) can be determined by analyzing the stomach contents for alcohol, and the results are then helpful in deciding which tissue to use for the correlation (Backer et al., 1980).

Because of the complex processes involved in postmortem redistribution, calculation from a single postmortem blood sample of a dose of drug taken by the deceased prior to death is unwise, and it is especially dangerous when using a

single cardiac sample (Prouty and Anderson, 1990; Hilberg et al., 1999b). Back calculation of a dose from even a femoral blood concentration using a clinically derived plasma-based steady-state volume of distribution is strongly discouraged, as it can lead to an erroneous conclusion. The volume of distribution itself for a given drug can show wide interpersonal variation, and its use postmortem is contraindicated. Conversion of postmortem blood levels to time-of-death plasma or serum levels cannot be carried out accurately or reliably. Furthermore, in many cases (i.e., where an intentional or accidental overdose is involved), it cannot be assumed that a steady-state distribution existed at the time of death. The experienced toxicologist may, however, using data from different specimens, cautiously estimate what approximate minimum dose was taken or give a reasonable opinion as to whether "therapeutic" or overdose quantities were taken or administered.

13.6.2 Pharmacogenomics

The interpretation of postmortem drug levels as they relate to cause of death requires careful assessment of all the particulars of a case. Toxicologic analysis should consider genetic influences on the concentration of drug found. The field of pharmacogenomics attempts to explain a person's metabolic capabilities for drug metabolism in relation to the genotype. Poisoning, intentional or otherwise, may be the result of genetically influenced altered metabolism. A person's genetic makeup may also influence the transport of drugs across membranes and the interaction of drugs with receptors. All of these effects will play a role in attaining a concentration of drug in blood as well as the person's response to a given drug (Kupiec et al., 2006). The use of pharmacogenomics for understanding drug reactions and drug-related deaths has been termed *molecular autopsy* (Jannetto et al., 2002). A person's genetic makeup has already entered the clinical area and will be utilized increasingly in the future prior to prescribing medication to better maintain therapeutic levels.

There are many metabolic pathways for the metabolism of drugs and other xenobiotics. Basically, they are divided into phase I and phase II pathways. Phase I is responsible for oxidation, reduction, and hydrolysis reactions, preparing the metabolite for conjugation reactions by phase II enzymes. The final product is usually more water soluble than the parent drug and can easily be eliminated. Most phase I reactions are carried out by the cytochrome P450 (CYP450) monooxygenase enzyme system, located primarily in the liver but also less extensively in other tissues (Omiecinski et al. 1999). These heme-containing proteins are located in the smooth endoplasmic reticulum, and many of the isoenzymes exhibit genetic polymorphism. A list of the various isoenzymes and their substrates, along with inhibitors and inducers of the isoenzymes, is available (Flockhart, 2007). The CYP450 system may play a role in explaining drug-induced deaths by two different mechanisms.

First, based on a person's genomic makeup, one can be a "slow" or a "fast" metabolizer. Another classification of variants is ultrarapid, extensive, intermediate, or poor metabolizer. Those with the slow polymorphic form can accumulate high levels of drug that could result in death, even from therapeutic doses. About 25 to

30% of all xenobiotics are metabolized by one isoenzyme, CYP2D6 (debrisoquine hydroxylase); 5 to 10% of Caucasians have low levels of CYP2D6 or lack it completely, and doses of medications metabolized by this isoenzyme must be reduced (Kupiec et al., 2006; Roden et al., 2006). On the other hand, persons with multiple copies of the gene for CYP2D6 must be given higher doses to maintain therapeutic blood levels. The following examples will serve to illustrate the importance of such genetic variations.

Oxycodone, the opioid prescribed for relief of pain, is metabolized by CYP2D6. Three mutations of the polymorphic gene encoding for this isoenzyme have been identified and may play a role in oxycodone toxicity (Jannetto et al., 2002). Methadone, another opioid, is metabolized by CYP1A2, CYP3A4, and CYP2D6. Again, genetic variants of CYP2D6 showed a trend, although it is not statistically significant, toward poor metabolism of methadone, and higher levels were found in these people than in nonvariant controls (Wong et al., 2003). Fentanyl, another opioid used for relief of pain and as an anesthetic during surgery, is metabolized by CYP3A4 and CYP3A5. Variant alleles of the genes encoding these proteins are known and again may play a role in fentanyl toxicity (Jin et al., 2005). The response to the anticoagulant warfarin (coumadin) is dependent on cytochrome metabolism. Approximately 6% of the variation in response to warfarin is due to variation in the gene encoding CYP2C9, and 27% of the variation in response is due to variation in the gene VKORC1 encoding the warfarin target, vitamin K epoxide reductase (Berg, 2007). The metabolic rates of amphetamine and of methamphetamine are dependent on CYP2D6 activity, and genetic polymorphism for ring hydroxylation of amphetamine has been reported (Miranda-G et al., 2007).

Second, since different drugs can be metabolized by the same enzyme, taking two such drugs at the same time may lead to competition, with one drug being less metabolized than would occur had it been taken alone. This could result in an increase in drug concentration, leading to toxicity and even death. Such a result could also occur if one drug inhibits its own or another metabolic enzyme involved with other drugs. Such effects have been reported with the antidepressant selective serotonin reuptake inhibitors (SSRIs) that are both metabolized by CYP2D6 and inhibit CYP2D6 (Goeringer et al., 2000). The inhibitory effect of ethanol on the metabolism of certain other drugs, e.g. barbiturates when both are taken concurrently is well known. The inhibition of CYP3A4 by the antifungal agent ketoconazole results in terfenadine-induced cardiac toxicity. High concentrations of parent drug may therefore be due to a low rate of metabolism, to metabolic competition by other drugs, or to inhibition of the enzyme by one drug, allowing the second drug to increase in concentration. It must be remembered that frequently more than one CYP450 enzyme is involved in the metabolism of a given drug, and inhibition or induction of a nonprimary pathway may be significant.

13.6.3 Drug Interactions

Polydrug use can result in additive, synergistic, potentiating, inhibitory, or antagonistic interactions, and may involve inhibition or induction of metabolic enzymes by one agent affecting the clearance and effects of others. Some examples were

noted earlier. Other common examples are the frequently encountered difficulties in interpretation of methadone and other drug abuse–related deaths (Milroy and Forrest, 2000; Corkery et al., 2004; Jönsson et al., 2007). The widespread use of all types of over-the-counter herbal products, domestic and imported, is an additional, potential complicating factor. Many of these products are known to contain components that interact with prescribed medications or may contain unlisted drugs or toxic substances (Ang-Lee et al., 2001; Saper et al., 2004; Hu et al., 2005; Dasgupta and Bernard, 2006; Woo, 2008). For example, some imported products may contain toxic licit medications which are not listed on the label. Other products have been shown to contain toxic metals. Many of these components may not be routinely detectable in standard analytical protocols. It is hoped that the more stringent regulations issued by the U.S. Food and Drug Administration in June 2007 concerning the importation of these products will reduce this danger, but toxicological vigilance is crucial (U.S. Food and Drug Administration, 2007).

13.6.4 Drug Stability and Decomposed Tissue

The postmortem chemical stability (or the lack thereof) of a drug or toxin or of the metabolites is a function of the combined effects of the chemical's structure, the length of the postmortem interval, the conditions of temperature, bacteria, oxygen, water, pH, and so on, to which the body has been subjected, and the particular matrix containing the agent. The reader is referred to the references cited for a comprehensive discussion of all these issues as they pertain to many different drugs (Grellner and Glenewinkel, 1997; Drummer, 2004, 2007; Skopp, 2004).

The interpretation of toxicological findings in decomposed, exhumed, or embalmed (discussed below) bodies requires special vigilance. Decomposed bodies reflect the processes of autolysis and putrefaction. Autolysis, digestion by natural enzymes, occurs more readily in tissues with a high enzyme content, such as the pancreas and stomach. Tissues with a low content of digestive enzymes, such as heart and liver, are less readily autolyzed. Autolysis leads to liquefaction of the tissues, which can then mix with blood and result in erroneous conclusions. Putrefaction, destruction of tissue by bacteria, depends on the bacteria that are present, the temperature and oxygen content of the environment in which the body is located, and the substrates available for bacterial action. The intestine is particularly susceptible to putrefaction and bacterial fermentation, and is not normally used for postmortem analysis.

Ethanol can be produced because of fermentation in decomposing bodies, but can also decrease from initial antemortem levels due to chemical, microbial, and evaporative processes occurring with decomposition (Kugelberg and Jones, 2007). Postmortem changes are known to cause a rapid loss of the high levels of cyanide associated with fatal poisoning, but cyanide is also subject to varying postmortem production, particularly in deteriorating bodies (Skopp, 2004). Artifactual production of cyanide has also been found to occur in some blood samples from fire death cases, and extreme caution must be exercised in the interpretation of such levels. Cyanide can be a significant component of some toxic fire gases that cause

or contribute to death, but in such instances it must be reasonably shown that it derived from pyrolysis of nitrogenous material (e.g., nitrogen containing plastics) present in the fire environment.

Toxicologically significant concentrations of γ-hydroxybutyrate (GHB) may also be produced endogenously in postmortem fluids (Elliott, 2001, 2004; Moriya and Hashimoto, 2005; Beránková et al., 2006). GHB is a sedative-hypnotic agent not currently approved for routine use in the United States. It is, however, available from different sources, and is encountered both as a drug of abuse and as an agent in drug-facilitated sexual assault. Clearly, very serious misinterpretations can occur unless the potential ranges of postmortem production are taken into account.

The finding of a low or negative drug level in decomposed samples cannot be assumed to mean that no antemortem significance was involved. However, the presence in relatively intact or preserved exhumed specimens of significantly high levels of drug or toxin may be cautiously interpreted as being consistent with antemortem overdose, whatever was the circumstance of administration. In some cases where there are suspicions of the involvement of criminal poisoning, resulting in analysis of exhumed remains, the qualitative detection of a poison or of an agent not known to have been used by or prescribed to the deceased may be deemed sufficient to corroborate such allegations. This assumes, of course, that the idea may reasonably be eliminated that the source of any such agent was external contamination of exposed, buried remains or any of the other processes that may produce analytes, as discussed above. When dealing with buried but exposed remains or those in deteriorated coffins (often containing groundwater, soil, and other debris), appropriate controls from the areas in proximity to the remains should always be taken by the forensic investigator. An important example is when such remains are to be examined for metal content, where it is essential that control samples of soil and groundwater be tested.

13.6.5 Effects of Embalming Fluid

The effects of embalming fluid, which contains formaldehyde and small amounts of formic acid, on different classes and types of drugs is varied and complex (Rohrig, 1998; Cingolani et al., 2001–2005; Skopp, 2004). Many basic drugs (i.e., primary and secondary amines) are known to undergo varying degrees of methylation when the tissue containing them has been treated with formalin-containing solutions. Methylation will result in variable loss of the original compound as well as the appearance of a new methylated compound. In some cases the methylated compound may be the nonprescribed parent drug of the actual antemortem drug that has the demethylated structure. Primary amine drugs can be converted to secondary amines, and drugs containing a secondary amine can be methylated by formaldehyde to form *N*-methyl derivatives. This has been reported for the conversion of nortriptyline to amitriptyline, desipramine to imipramine, and fenfluramine to *N*-methylfenfluramine (Gannett et al., 2001). Sertraline was converted to *N*-methylsertraline (Suma and Sai Prakash, 2006). Methamphetamine converts

to *N*,*N*-dimethylamphetamine. It may also be noted here that the analysis of formalin-fixed tissue should always be accompanied by the appropriate use of formalin-spiked calibrators. Caution must be exercised in general when interpreting findings from any formalin-fixed tissue matrix as opposed to data derived from "fresh" tissue. These chemical conversions may make it difficult to determine the original concentration of the parent drug. Nonetheless, a wide variety of drugs and toxins have been detected in exhumed bodies, and this is often a crucial factor in the investigation. Exhumed bodies often present a combination of problems, due to decomposition and the effects of embalming fluid. Occasionally, the toxicologist must analyze stored formalin-fixed specimens. One must consider that drugs from the fixed tissue will diffuse into the formalin, thereby decreasing the tissue concentration of drug.

CONCLUSION

The concentration of drug found at the time of sampling from postmortem specimens is the result of many factors, some relating to the host, some to postmortem changes, and some to the physicochemical properties of the analyte, and may not represent the concentration of drug at the time of death. Thus, a negative finding does not always mean that drugs were not involved; and a finding of high levels of drug does not always mean that an overdose occurred. The decedent may have been tolerant of the drug in question and may have required or been using higher doses. Analysis and comparison of drug levels in both blood and tissue (e.g., liver or brain) may be necessary and should be done whenever possible for accurate interpretation of quantitative findings. Finding therapeutic levels of drug may be the result of drug loss due to the factors listed above. Where postmortem exposure to formalin-containing solutions has occurred, finding parent drug may be the result of metabolites having been converted back to the parent drug. Estimating the dose of drug consumed from postmortem data is often unreliable, as discussed above. Also, finding several drugs raises the issue of additive or synergistic effects or drug interactions in causing death. Clearly, the longer the delay between the time of death and the taking of samples, the less accurate may be the interpretation of the role the drugs played in causing the death.

In summary, the forensic toxicologist is presented with a broad spectrum of case findings, ranging from those that point readily toward a particular opinion concerning whether or not one or more substances had a role in the cause of death, to those where the complexity or circumstances do not allow for a definitive interpretation or conclusion. In the latter case, the toxicologist must always resist pressure from those seeking to obtain an opinion not supported by the facts. Where there is uncertainty in interpretation, it is the obligation of the toxicologist to make known to the inquiring party the scientific basis for the uncertainty and all possible conclusions. The toxicologist must never forget that the role of the forensic scientist is first to obtain the most reliable data possible and then, accurately and impartially, interpret and educate the participants in the medicolegal process.

CHAPTER 14

Entomotoxicology: Drugs, Toxins, and Insects

JASON H. BYRD

University of Florida, College of Medicine, Gainesville, Florida

MICHELLE R. PEACE

Department of Forensic Science, Virginia Commonwealth University, Richmond, Virginia

Summary Forensic entomology is gaining widespread acceptance within the forensic sciences as one method to estimate a portion of the postmortem interval by utilizing the time of insect colonization of the body, also known as the period of insect activity. Additionally, insect evidence can be utilized as alternative toxicology samples in cases where no other viable specimens exist. This subfield, known as entomotoxicology, can provide useful qualitative information to investigators as to the presence of drugs in the tissues at the time of larval feeding. The presence of drugs can also alter the developmental period of the insects and should always be taken into consideration by the forensic entomologist. In this chapter we examine the relationship between toxicology and forensic entomology.

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14.1 INTRODUCTION

The use of entomological evidence in a legal investigation can provide extraordinarily valuable information that may otherwise be overlooked. Most often, the utility of an insect in a forensic investigation is to assist investigators in establishing the postmortem interval. More specifically, the period of the postmortem interval is often termed the *period of insect activity* (PIA) or the *time of colonization* (TOC) and can be thought of as the minimum postmortem interval. It is often expressed as the minimum time period necessary to allow the insects collected to develop to the life stage in which they were discovered.

Several different approaches exist in making this determination; they range from insect succession to estimations based on larval length, larval weight, and the accumulated degree hour (or degree day) methodology. Each of these techniques has advantages and disadvantages. One of the most common issues in forensic entomology is that the investigator is not able to determine exactly what the climate conditions were at the death scene during the entire postmortem period. Since insect growth and development are heavily influenced by ambient temperatures, the difficulty in accounting for the conditions at the scene prior to the discovery introduces some uncertainty in application. Thus, the forensic entomologist must account for this variability when providing estimations of the time since colonization. If such variability is addressed properly, forensic entomology can be applied with an impressive degree of accuracy and precision.

Generally, this variability is accounted for by the extrapolation of meteorological recording station data from nearby locations. However, other factors can play a role in the influence and alteration of larval insect growth. One of these factors, often unaccounted for by the forensic entomologist, is the presence of various metabolites of illicit drugs and poisons within the insect that can alter its expected time of development. Such chemical compounds, if present in the host tissue and consumed by the larvae, may alter insect development by hours or days.

The term *Entomotoxicology* was first used in 1994 to describe the interface of entomology, forensic science, and toxicology, and we are only now beginning to understand how various drugs and toxins interact with a developing insect to alter the rate of development of various life stages. In its relatively short history, the discipline of entomotoxicology has been very broadly applied. The deposition of metals within the larvae has assisted in pinpointing human remains to a possible point of origin, or to corroborate or refute suspect and witness statements as to the activities of the victim prior to death. However, the most common utilization has been the detection of various chemical compounds from the larvae long after suitable soft tissues, blood, and urine from the body have decomposed or been consumed by the insects present (Nolte et al., 1992) (Table 14.1).

14.2 THE FLY AND FORENSIC SCIENCE

For many millennia, humans have been aware of, known, and understood the role of flies in the ecosystem. The first mention of the flies most commonly used in

TABLE 14.1 Drug Compounds Recovered from Calliphoridae and Sarcophagidae Larvae

Calliphoridae	Sarcophagidae
Alimenmazine	Amitrptyline
Amitrptyline	Barbiturates
Arsenic	Cocaine (benzoylecgonine)
Barbiturates	Heroin
Bromazepam	Malathion
Clomipramine	Methamphetamines
Cocaine (benzoylecgonine)	Mercury
Laudanum	phencyclidine
Levomepromazine	3,4-Methylenedioxymethamphetamine
Mercury	
Morphine	
Oxazepam	
Phenobarbital	
Triazolam	

present-day criminal investigations was in the fourteenth tablet of Harra-Hubulla, a list of wild animals from the time of Hammurabi 3600 years ago. The Egyptians also keenly understood the metamorphosis of flies, as indicated by the Papyrus Gizeh No. 18026:4:14 (Cairo, Egyptian Museum CG 58009), found in the mouth of a mummy, which bore the inscription: "The maggots will not turn into flies within you (Golénischeff 1927)."

The blowflies (Calliphoridae), flesh flies (Sarcophagidae), and house flies (Muscidae) are the most forensically important flies. These flies are most often the first insects to find and colonize remains. The blowfly can travel up to 20 km a day in search of an appropriate food source. A female can lay several batches of about 250 eggs each, depending on her size and health. Once a female has begun oviposition, other females will also lay in the same area, resulting in a mass of several thousand eggs. The eggs usually hatch within 24 hours and immature larvae penetrate the interior of the remains to avoid desiccation and predation. As the larvae feed and mature, they pass through three stadia: first, second, and third instars. In doing so, their feeding mass can reach temperatures of 50°C. Once the larvae stop feeding, they wander from the food source to find a suitable place to pupate, during which the soft-bodied larvae become shorter, wider, rigid, and dark. Once metamorphosis is complete, the adult flies will emerge from the casing, inflate their wings, and become sclerotized (Figure 14.1). (Kamal, 1958; Greenberg, 1991).

14.2.1 History of Forensic Entomology, Toxicology, and the Rise of Entomotoxicology

The *Washing Away of Wrongs*, a thirteenth-century Chinese manual on forensic and legal medicine, considered the oldest in existence from any civilization, detailed

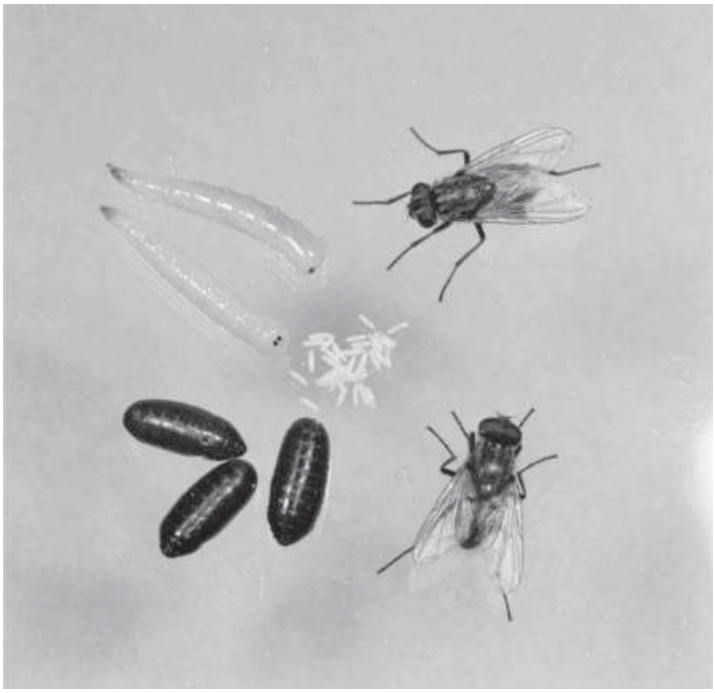

Figure 14.1 Life cycle of *Musca domestica*, showing complete metamorphosis. These life stages are typical of all Muscidae and Calliphoridae. (Photo courtesy of Clemson University; U.S. Department of Agriculture Cooperative Extension Slide Series.) *(See insert for color representation.)*

the death investigation of a man with a wound apparently inflicted by a sickle. The investigator gathered the local farmers with their sickles. In the hot afternoon sun, flies gathered on one sickle, indicating blood residue and incriminating the owner of that sickle. After interrogation and in light of the evidence, the owner of the sickle "knocked his head on the ground and confessed" to the murder (McKnight, 1981). In the late nineteenth century, scientists began to study and characterize the activities of arthropods and their application to death investigations. The first observation of insects on human remains in which the death was attributed to arsenic poisoning was in 1890. F. M. Webster noted that *Conicera* sp. were noted to have developed on remains buried for over two years. Analysis of the stomach contents proved that the poisoning was via arsenic. He noted that it was not surprising that these flies could develop on tissues laced with arsenic because "they are doubtless tenacious of life." Unfortunately, it is not apparent that he foresaw the forensic science application of their presence (Webster, 1890). In 1894, the French entomologist Mégnin pioneered the use of forensic entomology by painstakingly outlining and describing the eight successive waves of arthropod invasions on a corpse (Nuorteva, 1977; Keh, 1985; Smith, 1986). Those eight stages are still commonly recognized today.

Nonetheless, major issues still arose for forensic entomologists. Wide variability in geographical, topological, and environmental conditions led to even more widely variable insect species and behaviors for any given situation. These variable conditions made a well-characterized foundation of workable information difficult to attain. Differences between the entomologists' experimental conditions and actual forensic cases also compounded the problem of making useful correlations. Ultimately, a more thorough understanding of the basic principles as well as the limitations of using insects in forensic investigations was the result of the corroborative work of pathologists, biologists, detectives, and entomologists. These collaborative works had a significant impact in a variety of cases:

- Estimation of postmortem interval (PMI) by determining the life-cycle stage of the insects present on a body in conjunction with the stage of faunal procession (Bergeret, 1955; Nuorteva, 1977; Hall et al., 1986; Smith, 1986; Catts and Goff, 1992; Catts, 1992; Hall and Doisy, 1993).
- Estimation of PMI from the degree of insect colonization resulting from the degree of body exposure (totally exposed, partially covered, or completely buried) (Nuorteva, 1977; Smith, 1986).
- Acquittal of a person based on larval migration data (Nuorteva, 1977).
- Determination that a body had been moved from the original crime scene by identifying insects on that body not indigenous to the discovery area, thereby determining the area from which it was moved (Benecke, 1998).
- Linkage of suspects to the scene of a crime due to insect bites found on their bodies from insects specific to the vicinity where the body was discovered (Prichard et al., 1986).
- Determination of child abuse, neglect of the elderly, or disease or infection state from insect colonization prior to death (Goff, 1991; Benecke, 1998; Benecke and Lessig, 2001).
- Individualization of human DNA from insect gut contents (Lord et al., 1998).

Interestingly, Mathiew Orfila, a pathologist who is often credited as the father of modern toxicology, can potentially be credited with the first systematic observation of insect succession in a human cadaver (Greenberg, 1991). He documented 30 arthropods from a corpse and noted that live insects were recovered from bodies that were exhumed for several years. Bergeret (1955) is credited with the first case in which entomological evidence was utilized to create a time line. However, it turns out his assessment of the entomological evidence may have been incorrect; the period of insect activity could have been much shorter. Citations for the application of entomology to toxicological analysis did not begin to appear until the early 1970s. Nuorteva described a case in which the mercury concentration in larvae feeding on a corpse was used to determine if the deceased had lived in an area with high mercury pollution (Nuorteva, 1977). Subsequently, the deposition of copper, iron, and zinc and their effects on adult flies and larvae was demonstrated, and the bioaccumulation and effect of mercury on larvae was fully characterized (Sohal and Lamb, 1977; Nuorteva and Nuorteva, 1982).

The first examination of fly larvae from human remains for qualitative identification of drugs was proposed by Beyer et al. in 1980. In this case, Calliphoridae larvae were used to assist investigators in proving a suicide via an overdose of pentobarbital (Beyer et al., 1980). In this case fly larvae were used to determine the source of poisoning in a severely decomposed body that had no other source for a toxicological specimen (Beyer et al., 1980). Gunatilake and Goff (1989) utilized larvae collected from a body to aid in proving that a case involved poisoning by ingestion of malathion. This chemical was detected in the larvae as well as from body fat and gastric contents.

In 1990, Pascal Kintz published a landmark study from a 1987 case illustrating a "new" toxicological method of investigation which demonstrated the usefulness of entomological evidence. In this case example, larval concentrations of five drugs (triazolam, oxazepam, phenobarbital, alimenmazine, and clomipramine) were compared to concentrations in human heart, liver, lung, spleen, and kidney tissue as well as bile. In all cases, the drugs known to be in the human tissue were recovered form the larvae. One year later, in 1988, Kintz reported a case in which a severely decomposed corpse was found and insects were utilized as an alternative toxicological specimen because no other suitable tissue was available (Kintz et al., 1990).

Introna et al. (1990) collected livers from 40 decedents known to be positive for opiates (morphine) and colonized the tissues with eggs of *Calliphora vicina*. Upon analysis of the larvae and tissue via radioimmunoassay, the opiate concentration in the larvae correlated with that of the tissues on which they fed. Subsequently, investigations in entomology and toxicology illustrated the two important areas in forensic entomotoxicology: the effects of drugs on insect life cycles and the use of insects as an alternative toxicological sample (Goff et al., 1989, 1994).

The potential growth of entomotoxicology in casework can be moderately predicted based on the statistics that illustrate the increase in the abuse of illicit and prescription drugs in the past decade. The past decade has seen an increase in the abuse of illicit and prescription drugs. In a three-year time span alone (2000–2002), use of illicit drugs has increased from 6.3% to 8.3% in persons older than 12 years (NHS Survey, 2002). In 2000, 43% of emergency room visits were due to the misuse of prescription drugs (SAMHA, 2003). Not only have drug-related emergency room episodes and subsequent deaths increased (SAMHA 2003; DAWN, 2003), but a clear correlation exists among crime, violence, and drug usage. Of the approximate 14,000 homicides in the United States in 1998, 4.8% of them were murders committed during a narcotics felony (ONDCP, 2000). In the end, with this growth in potential must come research to support widespread acceptance and understanding of the expansive scope of applications and utility.

14.2.2 Drugs and the Fly Life Cycle

Sometimes, entomological evidence is used in death investigations as a tool to better understand the circumstances leading to death. Insects can be used to date a crime scene or estimate a PMI by applying the known developmental rates of insects and the successional patterns of different insect species on the remains (Smith, 1986;

Goff et al. 1988; Catts and Goff, 1992; Goff, 1993; Catts, 1992; Goff and Lord, 1994). As mentioned previously, the PMI estimation is an approximation of the time of colonization of the cadaver by insects. The succession of insects on carrion can be complicated by many geographical and environmental conditions, such as plant cover, water covering the body, inclement weather, and/or temperature (Nuorteva, 1977; Smith, 1986; Goff et al., 1988; Catts and Goff, 1992; Schoenly et al., 1992, 1996; Goff, 1993; Hall and Doisy, 1993; Catts, 1992; LaMotte and Wells, 2000). The time required for an insect to reach any developmental stage at certain environmental conditions has been well characterized, particularly for forensically important insects (Kamal, 1958; Greenberg, 1990a,b; Goff, 1991; Greenberg, 1991; Byrd and Butler, 1997, 1998; Anderson, 2000; Byrd and Allen, 2001). The time of colonization can be estimated using either of these techniques singularly or in combination. However, it is most common to use the stage of development in conjunction with meteorological data. This technique is most frequently referred to as the *accumulated degree method*. This method compares the temperature with the time of development and is often used to estimate the time of colonization and subsequent minimum postmortem interval.

Additionally, the stage of development or age can be determined by measuring the insect larvae's total length, crop length, or weight. Weight and crop length are the least useful estimates of age because broad variations result from the amount of food available, changes in the physiology of the developing larvae, and the lack of a well-defined informational database (Greenberg 1990a, 1991; Wells and LaMotte, 1995). The methods that utilize larval length and/or accumulated degree hours (which can incorporate larval length) are the most commonly used, particularly since an appreciable database has been developed (Greenberg, 1991; Goff, 1993; Byrd and Allen, 2001; Byrd and Castner, 2001).

Before Sohal and Nuorteva ushered in studies to investigate the effects of drugs on insects, Introna reported a solitary investigation in Japan in 1958 which found that flies were attracted to carrion differently depending on the poison ingested (Introna et al., 2001). Since then, Goff and Bourel have made strides in understanding the deposition and affects of drugs and toxins on forensically important insects. In 1989, Goff worked a case with Gunatilake in which a man expired from malathion intoxication. The man had been missing eight days, but the entomology-based PMI estimation was five days. Goff and Gunatilake concluded that the malathion had shortened the duration of the larval stage and that the pesticide retarded the succession of insects on the body (Gunatilake and Goff, 1989). Goff has also explored the effects of amitriptyline, cocaine, heroin, phencyclidine, methamphetamine, and 3,4-methylenedioxymethamphetamine (MDMA) on fly larvae. He found that amitriptyline had no effect on the rate of development of *Parasarcophaga ruficornis* larvae but prolonged the migratory stage. Amitriptyline also caused the body lengths and weights to be greater than those of the control larvae (Goff et al., 1993). Cocaine shortened total developmental times for *Boettcherisca peregrine* larvae and puparia. He found that heroin accelerated the growth rate of the *B. peregrine* larvae and that phencyclidine did not affect the rate of development for *P. ruficornis* larvae but shortened the migratory phase. Finally, Goff

concluded that methamphetamine and MDMA generally shortened the duration of the feeding larval stage for *P. ruficornis*, and methamphetamine caused the larvae to grow significantly smaller than the control (Goff et al., 1989, 1992, 1994, 1997). Interestingly, Bourel found that morphine, a drug structurally similar to heroin, slowed the developmental rate of larvae for *Lucilia sericata* (Bourel et al., 1999). Ultimately, these results indicated three potentially significant points: (1) that drugs can affect developmental rates, contrary to expectations; (2) that the same drugs may affect different fly species differently; and (3) that PMI estimations could potentially be miscalculated if drug effects are not taken into account.

14.2.3 Why Use Insects as a Toxicological Specimen?

Invariably, some death investigations involve human remains that are severely decomposed or need to be exhumed after embalming and burial. Typical postmortem specimens for a toxicological analysis include brain, liver, kidney, heart blood, peripheral blood, vitreous humor, bile, urine, and gastric contents (Poklis et al., 1998; Levine, 1999). The tissue alteration and breakdown that results during the process of decomposition can make some toxicological testing methods more challenging. In some cases, the tissue samples are rendered unsuitable for analysis, or they are simply no longer present in the body. The most common problem in warm and humid climates is that no soft tissue remains on which to perform a toxicological analysis (Levine et al., 2000). Additionally, when a body is embalmed, the tissues are fixed, and blood and urine are typically no longer available. Toxicological analyses on embalmed tissue can and will result in drug concentrations that are difficult to interpret (Hanzlick, 1994; Alunni-Perret et al., 2003). Therefore, in these extreme cases, alternative specimens often need to be examined.

Properly preserved or freshly collected larvae can be treated as any other tissue for toxicological analysis (Beyer et al., 1980; Poklis et al., 1998; Levine et al., 2000). Two important premises underscore the utility of entomotoxicology.

1. When larvae feed, they shred the food source with mouth hooks and deposit the meal into a crop, which generally "reflects the adaptive imperative to eat now and digest later" (Greenberg, 1991).
2. Any drug detected in larvae could only have come from the body on which it was feeding (Beyer et al., 1980).

Beyer's case was a landmark in forensic entomotoxicology as the first case that used larvae as the sole source for a toxicological analysis. Toxicological analyses were performed on larvae found on a skeletonized body after the badly decomposed soft tissue was deemed unsuitable for analyses. Phenobarbital was identified in the larvae using thin-layer chromatography and gas chromatography–mass spectrometry (Beyer et al., 1980). In 1987, Kintz also used larvae as a toxicological specimen in a case of completely putrified remains. Despite the severe decomposition, organs were identified and analyzed for drugs. The concentrations of drugs (triazolam, oxazepam, phenobarbital, alimemazine, and clomipramine) in the larvae were compared to the concentrations in the body's bile, heart, liver, lung, and

spleen. Kintz stated that they could not establish a correlation between the larval drug concentrations and organ concentrations. However, he concluded that "the application of the toxicological investigations in maggots will surely increase" and that the performance of these analyses on living material "is always more suitable" (Kintz et al., 1990). In 1989, larvae were used to detect the organophosphate suspected as the cause of death of a severely decomposed man (Gunatilake and Goff, 1989). In 1990, Introna reported results from the first systematic study in entomotoxicology in which he found a direct and significant correlation between the concentration of morphine in the food source and the larvae (Introna et al., 1990). In 1992, Nolte investigated a case in which he collected fly larvae and skeletal muscles from an almost completely skeletonized corpse for toxicological analysis. This was the first reported case in which cocaine and benzoylecgonine were recovered from fly larvae. Nolte concluded that the larvae were better specimens for toxicological analyses because the skeletal muscle contained tissue decomposition products which interfered with the analyses (Nolte et al., 1992). It is important to understand that the half-life of cocaine in human tissue is 0.7 to 1.5 h, depending on the route of administration (Baselt, 2004). Therefore, Nolte concluded that the detection of cocaine and its metabolites in larval tissue suggests the use of cocaine in the immediate hours before death. However, while finding that both the parent drug and its metabolite in the larvae could indicate drug usage immediately prior to death, other contributing factors, such as route of administration, dosage, and postmortem redistribution, will impinge on this conclusion, making it difficult or impossible to interpret the findings of drugs in larvae. During Goff's studies to better understand the effects of drugs on the insect life cycle, he found a direct correlation between the concentration of the drugs heroin, methamphetamine, and MDMA in the food source and the larvae. On the other hand, he observed no correlation between the two with phencyclidine (Goff et al., 1991, 1992, 1994, 1997).

Since the late 1990s, several attempts have been made to understand the implications of larval drug concentrations. Wilson and Sadler found that the larvae eliminated amitriptyline, nortriptyline, trimipramine, and trazodone and that the ratios of larvae to food source drug concentrations were widely variable (Wilson et al., 1993; Sadler et al., 1995, 1997a). Sadler also investigated barbiturates and other analgesics with variable results. He found that acetaminophen was eliminated from the larvae and that the ratios of larvae to food source drug concentrations were also widely variable for the barbiturates amphetamine and sodium salicylate. Ultimately, he concluded that his solid-phase drug extraction procedure was not rigorous enough (Sadler et al., 1997b). Most recently, Hédouin performed a whole animal study and found a correlation between mature larval morphine concentrations and the tissues (Hédouin et al., 1999, 2001).

A case in Maryland reported in 2000 underscores the growing importance of more thoroughly understanding the utility of fly larvae as an alternative toxicological specimen. In this case, larvae and the only soft tissue (a portion of calf muscle) from mostly skeletonized remains were analyzed for drugs. Secobarbital was found in the larvae but not in the skeletal muscle. If a large amount of drug

was ingested which led immediately to death, the drug had insufficient time to distribute to the calf muscle in any appreciable concentration. Second, the presence of decompositional fluids in the muscle potentially complicated the analysis. Had the larvae not been available for analysis, the prescription bottle found near the deceased would have only served as circumstantial evidence (Levine et al., 2000).

14.2.4 Drug Extraction Methods

If using entomological evidence as a toxicological specimen, larvae and pupae can be treated similarly to human specimens. Standard operating procedures for drug extractions from human tissue and fluid in a toxicology laboratory are a reasonable starting point for elucidating an optimum drug extraction procedure for what can be considered a fairly novel and certainly different biological matrix, insects. However, an extraction procedure for any given drug will probably have to be modified to compensate for the entomological matrix. For example, Sadler admits that he applied methods routinely used in his laboratory to extract barbiturates from urine to extract the same from larvae, but conceded that his inconclusive results were due to needing a more rigorous drug extraction technique.

When extracting drugs from larvae, the first consideration should be the large fat body of the larvae (Downer, 1981; Gullan and Cranston, 1994; Elzinga, 1999). Lipophilic drugs can potentially be sequestered in this fat body, requiring extraction solvents that are more lipophilic and back-extractions to adequately separate the matrix from the drug. Additionally, in order to actually extract the drugs from the larval matrix (the fat body, the hemocoel, and hemolymph), the pK_a of the drug must be considered carefully using the Henderson–Hasselbach equation for acidic drugs,

$$\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\mathrm{B}]}{[\mathrm{BH}^+]}$$

and for basic drugs (Levine, 1999),

$$\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\mathrm{A}^-]}{[\mathrm{HA}]}$$

Assuming that a drug will be mostly ionized in an aqueous-based biological fluid, the initial pH of the aqueous fluid should be adjusted so that the drug is no longer ionized. Once the drug is deionized, it can be sequestered into a hydrophobic solvent, thereby effectively extracting it from the biological matrix. Some cellular components in the matrix may also become sequestered in the hydrophobic extraction solvent (particularly the fat body), requiring a back extraction or a "cleanup" extraction. The cleanup extraction can be executed by changing the pH to drive the drug back into an aqueous layer, leaving hydrophobic cellular components behind in the solvent. Since the drugs need to be in an organic solvent for instrumental analysis, a final pH adjustment will deionize the drugs, allowing their final sequestering in a hydrophobic solvent.

14.2.5 Qualitative Versus Quantitative

Several studies have demonstrated the correlation between the dose and the concentration of drug within the larval body. However, researchers have differed greatly in their interpretation of the meaning of this correlation. In application, the quantitative evaluation of drug concentration in larvae in actual forensic casework is quite limited. One of the primary reasons for this limitation is because of the difficulty in determining exactly where the larvae have fed, since the absorption and distribution of a drug will vary among skeletal muscle and organ tissues. Thus, the location of larval feeding is of critical importance. However, due to the larval movement on the body while feeding, it is difficult (if not impossible) to determine on which tissues the larvae have fed. Although it is possible for an investigator to document the location of larvae as they are collected, it is not known which tissue or tissues were utilized as a food source prior to collection.

Although the rates of drug deposition in the larval body are not known for most species, most commonly, homogenates of the entire larval body are used. It is not known if the drugs and their metabolites are localized in the fat bodies, puparium, or chitinous exoskeleton of the adult (Nolte, 1992). However, much of the published research on entomotoxicology indicates that ingested chemicals can be recovered from the soft tissues of the larvae, pupae, and chitinous exterior of the pupal case. As a result, initial studies on the application of entomotoxicology to casework were promising. The window of opportunity for the detection of chemical compounds in human remains could be extended for days or even weeks by utilizing larvae and puparia. If the chitinous pupa stage had formed, chemicals ingested by the feeding larvae could be detected in the puparial casings years after the insect itself had completed development. In one particular death investigation case, the authors detected the metabolites of cocaine from the puparium two years after the death of the victim.

However, the quantitative use of insects as toxicological specimens in actual casework is problematic. Tracqui et al. (2004) analyzed 29 cases in which organic compounds were known to be present. These compounds were detected in both the human tissue and the insect body. However, no correlation between the drug concentration in the human versus larval samples were noted. Additionally, it was found that interlarvae and intersite variations in drug concentrations were not reproduced between samples. Therefore, arthropod larvae are, at best, most appropriate for qualitative analyses in a toxicological investigation and unreliable and unsuitable as a toxicological sample used to interpret the episode of intoxication prior to death based on a quantitative analysis.

The method of calculating the accumulated degree hours to estimate the time since colonization is as follows (Byrd and Castner, 2001):

1. Accumulated degree hours are calculated for the crime scene using temperature data gathered for a specified period of time prior to the collection of larval evidence.

$$\text{accumulated degree hours} = \text{ADH} = (T - B)(t)$$

where T is the mean temperature (°C)† B the minimum threshold development temperature and t the time in hours.

2. Larval evidence is measured (mm) and compared to species developmental charts (larval length vs. time, or instar molt vs. time) generated at specific temperatures to obtain the ADH required for that size.
3. The ADH required, which is given in the developmental chart, is compared to the ADH calculated at the scene to age the larvae and "date" the scene.

14.2.6 Changes in Insect Development: Toxins and Drugs

Nourteva and Nourteva (1982) were the first to demonstrate a negative effect on larvae from toxic compounds with the larval food source. However, Goff et al. (1989) was the first to show an altered developmental rate for larvae feeding on tissues containing illicit drugs. Goff's study was the first to show that cocaine, metabolized in tissue and ingested by larvae, would shorten the developmental time expected. Subsequent studies by Goff et al. (1993, 1994) have demonstrated significant differences in rates of development for *P. ruficornis* and *B. peregrina* (Diptera: Sarcophagidae). These developmental changes potentially can be of critical importance when estimating the time since colonization. Few studies have been conducted on this effect for the Calliphoridae, which are typically the predominate flies on human remains in the early postmortem period.

With this said, the alteration of insect development by drugs and toxins is problematic on several levels. Often, the forensic entomologist is not aware of the postmortem toxicology results and does not know to take drug-induced alterations into consideration when developing a window for time of colonization. Second, a thorough investigation of all major drugs has not been undertaken with every species of forensically important fly. Therefore, the entomologist has no foundation on which to make adjustments in the time of colonization range. Most important, while some studies have suggested that the developmental rate of some larvae is affected by some drugs, the interpretation of the data must be considered carefully. It is possible that alteration in the life cycle due to drugs or toxins on board is well within the standard error in life-cycle development of drug-free larvae.

14.2.7 The Future of Entomotoxicology

Considered generally, the published literature is only a preliminary treatise of the interface between entomology, toxicology, and medicolegal death investigation. More research is needed on drug accumulation and retention in insect physiology. However, it is clear that the use of entomotoxicology as a quantitative measure is not yet suitable for application in forensic casework. Such a circumstance is unfortunate because the technical application of the premise works well, as the amount

†Collected from a nearby weather station. If provided, hourly temperatures may be gathered to calculate ADH and provide a defined window for age assessment of the larvae.

of drug compound within the larval body can be determined with great accuracy and precision. Using larvae as a toxicological specimen is readily put into practice because the analysis takes no specialized equipment beyond what is necessary for a standard toxicology analysis for human or animal tissue. Therefore, most any postmortem forensic toxicology laboratory possesses the equipment necessary for the testing. From the technical viewpoint, entomotoxicology looks promising.

However, it is the biology and behavior of the insect itself that may limit its application in forensic investigations. Entomologists must first conduct fundamental research on larval feeding and aggregation behavior. Currently, entomologists do not fully understand larval movement and distribution within the maggot mass, which often forms during the actively feeding third instar. After simple visual observation of the larval feeding and aggregation behavior, it is obvious that the larvae are in constant motion. Individual larvae seem to spend time in the center as well as the periphery of the mass. However, the movement of a single larva within the mass has not been tracked with great accuracy, and no studies have been published on the positional effect on the intensity of larval feeding. With standard entomological procedures currently in practice, it is unknown on what tissues the collected larvae have fed.

The absorption, distribution, metabolism, and elimination of drugs are well documented for most drugs and provides for the understanding of postmortem tissue distributions. However, since larval feeding locations are unknown in applied casework, the resulting larval concentration proves meaningless under current collection and analytical protocols. Insect larvae do accumulate drugs and toxins within bodies as a result of their feeding. Therefore, the qualitative analysis of these compounds may provide valuable information to forensic investigators.

Forensic entomologists are able to provide vast amounts of information to other forensic investigators based on the comparatively limited nature of currently published data sets. Biological variation may lead to cautious, conservative, and "incomplete" answers to many commonly posed questions from investigators. A tremendous amount of research must be conducted to better understand the patterns and implications of natural variables, particularly as they affect forensic investigations in the entire scope of forensic entomology, but specifically with regard to toxicology. As the knowledge base expands and more becomes known about larval behavior, entomotoxicology may one day become a valuable quantitative tool.

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DIY – MAKE YOUR OWN ORGONITE

Making orgonite is easy!

This is the most important thing I have to tell you in this chapter.

A lot of people on the internet and elsewhere are spending a lot of time and money to make you believe it's otherwise.

Orgonite always works, even if you think you got it all wrong. Also the designs of the basic orgonite tools are very error tolerant. When you read about the mix having to be 50/50, that just means that you pour a bucket full of resin into a bucket full of aluminium filings. People have asked me the weirdest question about how to determine the exact volume of the filings since they come in this woolly state and….

It's much easier than that!

Making beautiful orgonite takes more practice and is not that easy, but as much as we all love to make things beautiful, a rough and dirty TB will neutralise a cell phone tower (death force transmitter) just as well as a high gloss one with neatly arranged gemstone inlays. At first you will need to source resin. Most of us work with simple polyester resin. This comes in different qualities. Preferable is the "clear casting" quality that is also used to embed butterflies and dried flowers into nice clear blocks, often used as key rings or for other decorative purposes. We buy this from industrial wholesalers who cater for the boat building and swimming pool manufacturers. If you have no idea where to get resin in your town, phone the guys who work with fibreglass and ask them where they buy their stuff. Polyester resin stinks a bit when it's curing because of the chemical reaction and release of solvents, so you should always work outside or in a very well ventilated room.

If you plan to do this regularly, get yourself a protective mask (against organic fumes like for spray painters) or build a fan into your room that guarantees at least a 40 x per hour air change.

The resin needs to be mixed with a catalyst that will bring about the chemical reaction that makes the resin cure into a crystalline clear substance. Please follow the instructions of the manufacturer regarding percentage of catalyst to be used etc.

Many people have tried other substances as a matrix to suspend the metal filings in, such as beeswax, sugar, tree resins and epoxy resins.

The epoxy and tree resins (when they are treated in a way that they can be cured to a non sticky crystalline matrix) seem to work ok, but we haven't tried it. We have learned to handle the polyester well and find it works so fantastic that we need not look for alternatives. Even sugar seems to work but is of course not exactly weatherproof for outside application.

Beeswax has been a great disappointment even though it's still periodically brought up by people

who don't like the notion of using a "chemical" material to restore the natural energy balance.

See it in a different way: Isn't it fun, that we can defeat the plans for global control by the self proclaimed elite, using exactly the addictive substances that are most pivotal in their global enslavement policies: Mineral oil (resin) and sugar.

Next you will need lots of aluminium shavings. (Some call them filings) You can get these at machine shops that work with aluminium a lot such as window manufacturers sign makers etc...

A lot of people who have read Wilhelm Reich's works are very prejudiced against aluminium because of some observations that Reich made in connection with his orgone accumulators. He spoke out strongly against aluminium use in accumulators, but nobody in our network has so far found any evidence that this would hold true for orgonite.

Don has also built many classical Reich-style accumulators with aluminium and also found no adverse effects. Could it be that another factor, as yet unknown, created the negative results, Reich was reporting?

Last but not least you will need crystals. Clear quartz crystals that is. But they can also be milky or otherwise of "inferior quality".

We have even used white and completely opaque quartz chips we found on a mountain near the track we were driving on, to add into some improvised TBs that we had to make when we ran out of ammo in Namibia in September 2004.
They worked well.

For TBs, any small crumbs of crystal breakage will suffice. For HHGs use single terminated crystals, that is crystals with one naturally formed tip.

For CBs one should preferably use double terminated crystals, which means they have a natural tip in both directions. Even when multiple small tips point all in one direction we still speak of single terminated.

The easiest to start with: making TBs

TBs or Tower Busters are the easiest to make. That's why I strongly recommend you start with them. You will get a feeling for working with resin that way which will come in handy when you start making the more sophisticated pieces. We make our TBs in standard muffin forms, but you can use anything that will hold approximately 100-150 ml (3-5 oz.) of resin and shavings. Plastic or paper cups are also popular.

If you want to re-use the mould, we strongly recommend that you wax it before pouring. We use "silicone release wax" which we get from the place that sells the resin and catalyst. Baking fat will work as well.

We use aluminium filings. (or sometimes they're also called shavings) Other metals work as well.

We get best results when the shavings are not to big or small and sufficiently loose so that the resin can run in between them.

Waxing the form

Shavings the way we like them

Apart from the shavings and resin, the mandatory ingredient is quartz.

You don't have to use A-grade tips. Any quartz breakage even of a milky or opaque quality will do. We have used white quartz pebbles collected from the road with great success on our Namibia Exhibition when we were out of TBs at some point.

We like to add some low grade amethyst because we get it cheaply and it makes them nicer. Also we like to add a few crumbs of black tourmaline. If available, powdered pyrite makes any orgonite much stronger in sheer power.

But again: simplicity is the rule. You do not need any crystals other than quartz in order to achieve stunning results.

Typical ingredients the way we make our TBs

The best resin for orgonite is polyester resin of the so called "clear casting" quality. It's the same that is used to cast Insects or leaves into decorative key ring pendants and the like. Make sure you get to the industrial suppliers.

Putting the crystals in

Otherwise you pay a fortune for small quantities.

If you don't know where to find those suppliers, talk to the guy who work with fibreglass. (Swimming pool and boat builders for example) The will know.

We start with a thin layer of filings and place the crystals on top of this little nest. That way they will end up being approximately at the centre of the finished TB.

Top layer

We top up to just under the rim. If you want to add some crushed pyrite or tourmaline, you can sprinkle it over the top layer in the end.

Now we can start the pouring procedure. We need the resin, and a suitable quantity of catalyst. The Resin suppliers normally sell special measuring bottles for the catalyst and we recommend that you get one if it's not supplied for free. We also recommend that you use industrial strength rubber gloves for the larger works while surgical latex gloves are good for finer work. If you plan to do this more often you should get yourself a mask with filter against organic solvent vapours. You don't really need that if you can work outside.

What you need for pouring

Wear a mask if you frequently do this inside. Make sure rooms are well ventilated.

Use bucket with measurements

Pour sufficient quantity of resin into a bucket with measurements.
For one standard muffin tray we use approximately 1.1-1.2 litres.

Measure needed quantity of catalyst

With most makes of resin the standard mix is 2% catalyst at 20°C. But beware: temperature and size of the piece you want to pour influence the need for catalyst. The hotter it gets or the bigger the piece, the least catalyst you need. Refer to resin manufacturers manual for exact quantities.

Pour catalyst into resin

Add pigments if you want colour

Stir thoroughly!

Pour into small jug with snout for easier pouring

And start pouring

Since the resin takes a while to sink in you will have to pour in several passes. It is always good to have a few more objects prepared by the side that can take any surplus resin in case you may have miscalculated the quantity.

You have (depending on the make of the resin and room temperature etc.) 15-25 minutes to do this. That is normally not a problem. If you feel that the resin is becoming like jelly before you are finished, quickly mix the remaining resin with metal filings to make at least some kind of usable orgonite. Keeping your bucket and jugs clean helps to avoid premature gelling.

Continue until muffin pan is filled to the rim

When the process is finished, you have to wait a while. The resin will nor start its chemical reaction during which it will get quite hot. If you have used the right amount of catalyst, the TBs should be easily removed after curing by just turning the pan upside down. A few gentle taps with a rubber hammer are sometimes needed.

If the mix has not cured properly (too cold or not enough catalyst) it can be put in direct sunlight to give it some after-curing.

The next step: making HHGs

For making HHGs you want a conical mould. We are using ordinary household funnels because the ones we get have a nice proportion with the base as well as the height being 100mm. But many other forms have been successfully tried: from conical paper party hats to cocktail glasses.

You have to close the nozzle in some elegant way. We used to do that with window putty which could be shaped any way we wanted but are now making a small cone of masking tape that we insert with the sticky side facing outward.

Apart from the filings you need 5 single terminated crystals of 30-40mm length. Additional healing stones are optional. We use crushed black tourmaline and a few of our low grade amethyst pebbles to beautify the energy emanating from the HHG.

Household funnels

Nozzle closed with masking tape

Our ingredients: 5 mandatory crystals, optional amethyst and tourmaline.

We start by putting a few filings into the top in order to make a nest for the top crystal. We want all crystals to be embedded in the orgonite. See the following picture sequence for the further procedure.

Make a nest for the top crystal

Place top crystal into nest with tip facing downward (up in finished HHG)

Add more filings and some of the optional additional stones if you wish

Add more stones as you build up in layers (optional)

Place the bottom crystals in a cross formation. Leave enough space for the crystals to be covered with a thin layer of filings

Cover crystals

Until they are invisible

Start pouring

Repeat several times until no more air bubbles come up and funnel is filled to the rim.

This is how the finished product comes out of the mould.

Now you only need to break the rough edge with a file now (or a sanding disk) and sand it until smooth. That's only if you want to make it into a nice piece of art of course. The full power is there without the cosmetics.

Of course any other conical mould will do the job. Cocktail glasses, party hats – anything will do.

There are other variations to the theme such as the ones that Done makes nowadays. They only have a crystal in the tip and a clockwise spiral (from the bottom up) is replacing the 4 bottom crystals.

Finally: Build your own CB

Again, this is only one way to make a functioning orgonite CB. Following these instructions will give you enough of a feel for the matter to deviate from the procedure wherever you feel it would lead to better results.
The standard pipe length according to the inventor of this device, is 6' or approximately 1800mm.

The recommended pipe diametre for a standard CB is 28mm which is almost but not entirely identical to the US 1-1/4"

The crystals may already be fitted inside the short pipe ends. We mostly insert them afterwards and fix them with a bit of resin.

In Don's original instruction they are wrapped into a short piece of garden hose and glued into the bottom end of the pipe.

That's what goes into the bucket

The short pipe ends should be closed with a stop fitting (standard from plumbing suppliers) or a copper plate soldered on. (See picture below) It is intended that the pipes form a resonant cavity, so the bottom should not be open. One could use thin foils to close it.

Short pipe ends with bottom plates and connectors soldered on

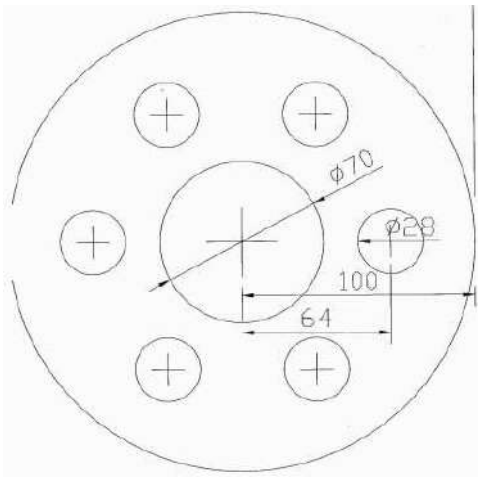

This is how we make our disks. All dimensions are in mm.

We use 3 of our standard spacer disks to connect the long pipe ends to a stable rig. We have found that better than inserting special spacers into the bucket as in Don's original instruction.

Wax bucket with silicone release agent.

Long pipe ends forming a stable rig

Stick short pipe ends onto the rig

Insert into bucket

You may have noticed that we have already prepared a bottom plate in a previous pouring session. We don't want the pipes to go through to the very bottom but rather want them embedded in orgonite. We make that plate approximately 20mm thick.

Place the rig upright

Apply some preliminary bracing

We always put it up next to a table. After applying some bracing, we start to make sure that it's really standing upright and the distance to the border of the bucket is equal on all sides. It helps when the floor is level of course. Otherwise you should use a piece of wood levelled with some wedges as floor. By looking at the pipes from various directions with one squinted eye, you can also ensure that they are parallel and not "drilled".

Laozu's vortex buster is something else. There you want the pipes "drilled" in a spiralling motion. So don't be afraid if you don't get them totally straight. Your CB will work nevertheless.

It is amazing how error tolerant these designs are. As long as you end up with 6 copper tubes with some sort of crystal in the closed bottom, sticking in a bucketful of

resin-metal mix in a halfway circular arrangement, you will have a powerful working cloud buster at hand.

Make sure the pipes are level

Now you can start filling up with filings

We fill up to about 2/3 of the intended height. This allows us to pour a substantial amount of resin in one go which will be pushed into the filings by it's own gravity. We put in some "misfired" TBs or other orgonite that hasn't passed the quality test. That way we can prevent cracks even when pouring in one go. Some people still advise to pour in layers. We don't really like it because it takes very long and resin always runs behind the finished parts, resulting in an uneven and messy surface.

Pouring

It is advisable to pour only from one side so that air can still escape on the other side. It helps to have a translucent bucket because then you can see how far the resin has penetrated.

Depending on the texture of your metal filings, you may also premix the orgonite and pour the mix of filings and liquid resin. That way you can prevent air bubbles much easier, but it is also more messy.

Resin almost down to the bottom

Once the resin has saturated all the filings, we fill up with filings to 1cm under desired height which is in the middle of the connectors. We do that quickly, so we can still use the same resin “wet in wet”.

Fill up and pour to centre of connectors

It is important to do that in one session with the same resin. Otherwise you’ll have to wait about 2 hours and get the problems described previously when pouring in layers.

This is how the raw CB base will look like

In most cases you will find that the surface of the raw base might need a final “glazing” coat for aesthetic purposes.

The easiest way to do that is by just taping a rim with masking tape. Small irregularities in the tape will be filed and sanded away afterward when you break the sharp edge.

Pouring a smooth top coating with tape

This is how our finished cloudbusters look like.

Yours may look slightly different.
It is very difficult to build a “bad” one. In Uganda we built one with the only copper tubing we could get and that was 22 mm on a roll. We had to straighten it by hand on a concrete floor, so it was never straight and we had no end caps, only chocolate paper to seal the pipes at the bottom..
We also had no pure quartz crystals but only amethyst with some quartz veins. Despite it’s irregular shape it’s influence was perceptible for hundreds of kilometres around it’s location in Kampala.

SP-Crystals and Mobius coils

Text based on Ryan McGinty’s Article on www.ethericwarriors.com with permission of the author.
Photos courtesy of Ryan Mc Ginty

The Items you will need:

1 cordless drill.1 spool of 30 gauge aluminium wire from Radioshack, comes in red, blue and white in 50ft. Do not get the magnet wire that is copper. The copper is very stiff while wrapping also the enamel insulator easily scrapes off causing minute shortages. 1 crystal.

First select a length of wire that will be appropriate for the size of crystal. Very small crystals will need only three feet of wire, larger ones with a diameter of 1 inch or larger will need 20-25 feet or more, the hole spool for giant crystals.

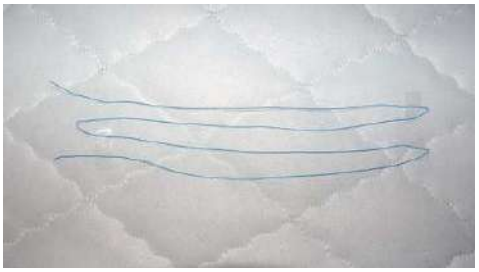

Fold the wire in half, then fold that in half again. Basically folding the wire into quarters.

Now take the end where both ends are bent, place them into the locking chuck of your cordless drill. The easiest way to keep them together evenly in the drill is by starting a small twist to hold them together.

Set the drill direction so that it will remove a screw. (Lefty loosie) With your other hand, hold onto the end with the two leads. Make sure you keep good tension while the drill is rotating. This will minimize irregularities. If the wire is longer than your arm span, have someone help hold it or clamp it to a sturdy stand.

You'll know the wire is correctly wound when the thread angles are at 45 degrees.

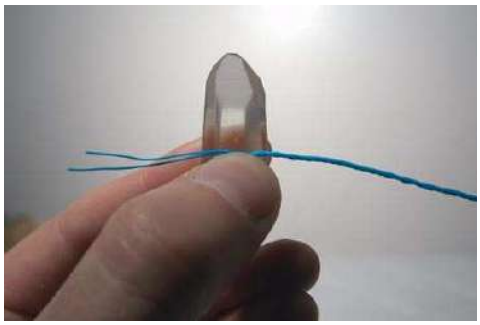

Hold your crystal and wire like so. You will be doing a counter clock wire wrap that works upward.

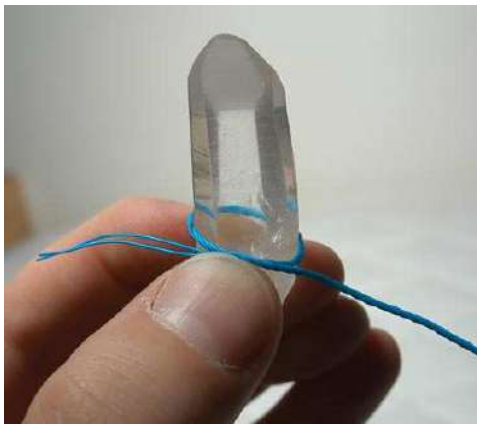

Here is how you start your first knot.

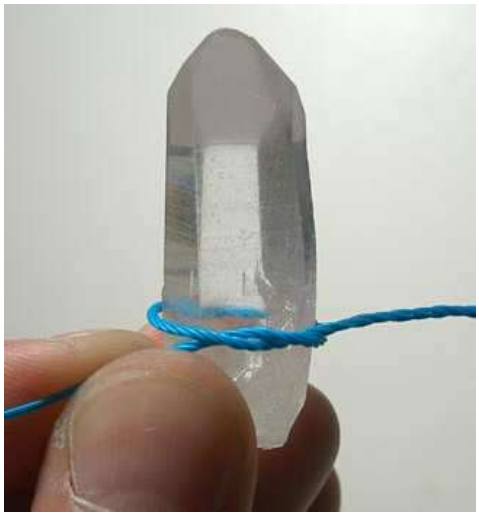

Notice that the knot goes over, down, up-around. It's basically a square knot. Keep this knot a little loose because you'll need the space for the remaining knots.

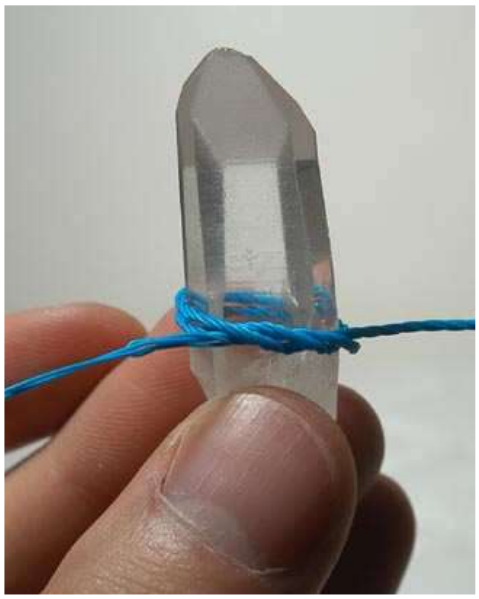

Now repeat the process. You'll notice the wire working upward. While the knot keeps getting larger. Start pulling the wire tight.

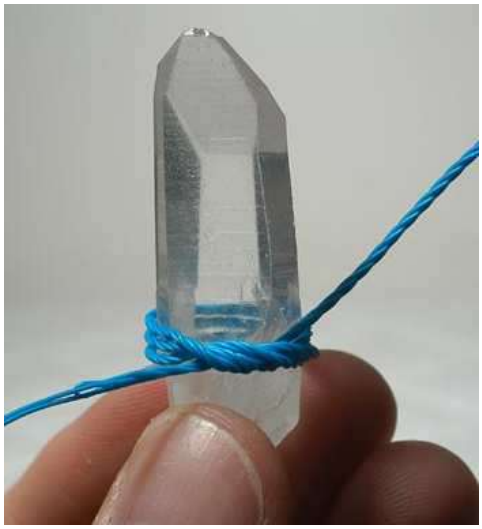

Here is how it looks going around a third time. Each time you start a new knot you start just before the last one. Remember to keep the wraps tight. This will ensure you don't have any wires overlapping on the back.

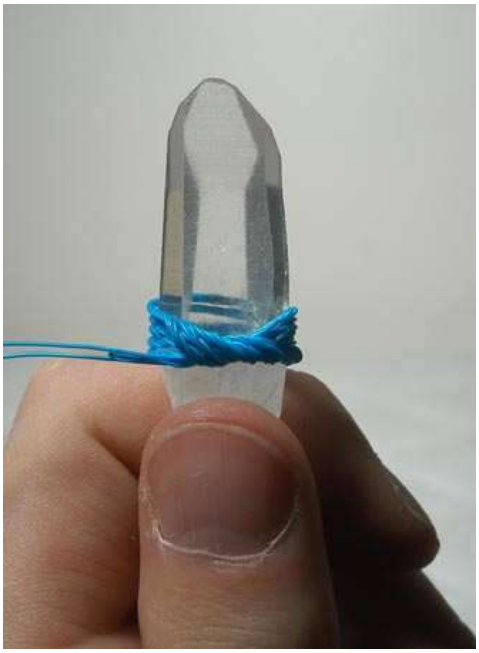

Here is the finished result. You'll notice that the knots start right after the last one begun. Use glue to hold wires in place, a hot glue gun or goop works great. Strip the ends and you got your self an SP! 8-) If you notice the knots getting too difficult to overlap then start another row the same way as the first. Pull the excess just a little above the first Mobius wrap, wrap the wire around CCW then do the knot and keep repeating as many times as needed. It's basically a simple pattern that keeps repeating.

IV. FURTHER READING

The following books and websites can help to understand the perspective from which this book is written and further the depth of your enquiry into some subjects marginally touched here. This does not mean that the author identifies with or endorses all particular views expressed in these sources.

Books

By Dr. Wilhelm Reich:
Character analysis
Mass psychology of fascism
The function of the orgasm
The discovery of the orgone
The cancer biopathy
Ether, god and devil
Cosmic superimposition
Contact with outer space

About Dr. Wilhelm Reich:
Wilhelm Reich – the evolution of his work - David A. Boadella
Der Traumvater - Peter Reich

Orgone and related:
The Life Etheric with Carol Croft – Don Croft
Die Wiederentdeckung des Lebendigen – Prof. Bernd Senf

Science and secret technology
The Tao of physics – Fritjof Capra
PSI – Ostrander, Schroeder
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The Orgone Revolution

During the last few years, a small but growing group of people worldwide has started a peaceful revolution: planet-wide environmental healing with orgone energy.
Based on easy-to-replicate inventions of US inventor and researcher Don Croft, a network of individuals has started to take active responsibility for their environment.
In *Operation Paradise* Georg Ritschl, a German architect who lives in South Africa, provides an introduction to the subject of orgone energy, including a history of the concept through time and its applications.
Showcasing his own experience based on work in more than 10 African countries, Ritschl demonstrates how orgone energy tools can neutralise the negative influence of electromagnetic pollution, weather manipulation based on HAARP-related technologies and the ubiquitous chemtrails, to create paradise when applied in sufficient quantities at critical places.
The book includes basic DIY instructions for 4 important orgone tools:

- **The Cloudbuster**
- **The Tower Buster**
- **The Holy Hand Grenade**
- **The SP-crystal**

This book is essential reading for anyone who is interested in holistic healing and the convergence of advanced science with the mystical world view.
It is also a book for all those who are worried about the tendencies of a small elite to create a worldwide Orwellian Superstate by means of secret manipulation of world events, centralisation, and secret chemical and electronic warfare against humankind.

It is time to reclaim planet earth for humanity. The compelling message of this book is:

Together we can create Paradise!

OPERATION PARADISE
b/w edition

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An Introduction to Orgonite™

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An overview of Orgone Matrix Material, it's manufacture and application.

Email – wizzer@littlemountainsmudge.com
Phone – 250-446-2032
Mail – PO Box 139, Westbridge BC V0H2B0
Url – www.littlemountainsmudge.com
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What is orgonite?

The word "Orgonite" refers to a new class of materials which are composed of a mixture of metallic particles suspended in an organic medium. The term "Orgonite" was coined by Karl Welz, the man who is generally credited with inventing it. Though initially intended by Welz to refer only to his commercial product, the name stuck- and has come into usage by most people familiar with the material. So... I suppose in the mind of Karl Welz and few other folks, orgonite means Welz's individual recipe, but to most others it has come to mean any material produced using the same basic conceptual approach. In any case, it refers to an orgone matrix material, as opposed to a layered orgone accumulator. To a degree, a piece of orgonite will act as an orgone accumulator in that it will tend to attract orgone from the area around it, but with an added dimension. The added dimension is that it will process the orgone energy as it interacts with it, whereas an orgone accumulator more simply condenses orgone energy.

There are many variations on the basic concept of suspending the metal within the organic element (as opposed to using thin layers of organic and metallic substances like in an orgone accumulator), and many other substances which can be added to the mixture to make it more potent, or to specialize it for different applications. Most of the people producing orgonite wind up developing their own exact recipes, I use several different recipes for slightly different applications. At the end of the day, the basic, fundamental ingredients of orgonite are metal particles and an organic medium to suspend them in, usually resin.

A wide range of metaphysical disciplines all work with the same energy, know it by various names ... (orgone, odic force, reiki energy, prana, chi, etheric energy, bio energy, bio magnetic energy, huna energy, animal magnetism, soft electrons, mass free electricity, radiesthetic color, astral energy, 4th dimensional energy, emotional body energy, life force energy, and no doubt a bunch of other names I have never even heard of) ... and so far orgone matrix material has proven itself a to be a readily adaptable and highly functional conceptual approach for work in these areas. Orgonite, (by any name) both releases orgone energy when stimulated by other forms of energy, and has the capacity to change orgone from one state to another. It is especially suited to taking the energy from an unhealthy state into a healthy, balanced state, and/or adding a selected property to the orgone energy which it processes. This makes it useful in a wide range of applications, from alternative health through to radionics and other traditional metaphysics.

Organic substances attract ORgone energy and soak it up like a sponge, while metallic substances tend to repel it. Basically, ORgonite pulls in the ORgone energy, and while the energy is inside the device, The metal particles and organic resin both push and pull on it in all directions at the same time. This puts the energy in a scrambled, chaotic state. When the energy comes back out of the device, it collapses back into an organized, defined state .As a side effect of being scrambled and put back together, it comes out clean! DOR is converted back into OR as it passes through the orgonite. (DOR=Deadly ORgone Radiation... Harmful ORgone. OR=ORgone Energy, the Healthy kind)

Orgone matrix material, or orgonite, has not only the property of changing OR (Orgone) from one form to another, but also the property of ‘generating’ OR when stimulated by other kinds of energy... like light, sound, physical motion, or electricity. When using a matrix of randomly arranged particles instead of orderly layers of the two substances (metal and organic) you get a different effect. Some benefits of using a matrix are:

A: Increased efficiency (higher proportionate orgone potential to mass) compared to a traditional ORAC.

B: Changes DOR (harmful ORgone) to OR (Healthy ORgone)... When orgone passes/percolates through the matrix, it is in effect reduced to its component polarities of + (positive/masculine/hot), 0 (zero point/omni potential/infinite), and - (negative/feminine/cool). It is then recombined, and re-emitted. The act of being broken down into its positive and negative charges and recombined basically flashes it across the 0 state and has the effect of restoring the orgone to a ‘base’ state, i.e.. it is no longer ‘healthy’ or ‘unhealthy’ orgone, it is no longer orgone of any specific ‘color’, rather it comes out of the matrix material as more or less undifferentiated orgone. That which makes the orgone ‘colored’ or differentiated is (oversimplified a tad) basically encoded in the proportions of +/-, (+/-)0, and in oscillation rate between + and -. When the orgone exits the matrix material, the conditions which 'force' it to exist in an undefined state no longer exist, and so it collapses back into a defined state, and is 'colored' to varying degree by the exact composition of the matrix material and any minerals/other substances included in the matrix.

C: Orgonite does not actually generate orgone, in the truest sense of the word, but I suppose that is a technicality. Orgonite, when excited with other forms of energy, both converts a portion of the energy used to excite it into orgone energy, and draws additional orgone energy from the Aether (the cosmic omni potential 'pool' of orgone energy that has yet to be 'put to work' in 3D terms), and puts it to work as orgone manifest in 3D terms. Thus for practical intents and purposes, orgonite 'generates' ORgone on demand when excited by scalar waves, magnetic fields, heat, sound, light, electrical energy, kinetic energy, etc.

HHGs and TBs

The type of orgone device which is commonly called a 'Holy hand grenade' is a medium-sized device which attracts harmful ORgone energy, converts it to healthy ORgone energy, and emits it again as a flow of healthy orgone energy. This is different from other orgone devices used up until this point, which had the ability to block or collect harmful energy, but not convert it to healthy energy. The device gets it's name from an old Monty Python movie ;)... When placed in an area, buried, or placed in a body of water, the ORgonite Holy hand grenade will act to continuously clean the ORgone energy within a surprisingly large radius (average 3/4 mile radius from the device). A TB (Towerbuster) does basically the same thing on a little bit smaller scale. The effective range of a towerbuster is generally somewhere around 1/4 mile.

A basic TB is a small (3 to 8 ounce volume), usually cylindrical or conical mass of orgonite with a quartz crystal embedded in it. Generally the xtal is on the verticals axis if the device is tall, and on the horizontal axis if it disk-shaped. A basic HHG is a little larger (usually 8 to 32 ounce volume), usually conical or pyramidal mass of orgonite with 5 double terminate quartz xtals embedded in it, one of them on the vertical axis and four of them on the horizontal axis. The vertical xtal is near the small end of the device, and the horizontal xtals are arranged radially, near the wide end of the device. Don Croft invented these two devices to counteract the adverse physical and mental health effects of HAARP, GWEN, ELF, SCALAR and HPRF transmission towers. In addition to serving well for this purpose, the HHG and TB devices are highly effective multipurpose energy cleaners. Think of them as air freshener for your aura.

To use one of these devices, simply place the device within an area and leave it alone. If possible, it increases the effectiveness to put them into a body of water or bury them in the earth. It is not necessary to bury them or put them in water, and most folks who use them have a few in their homes, to provide a constant cleaning action for the orgone envelope in their living space. With the HHGs, it helps a bit to align the device with the magnetic field of the earth, so that one of the xtals in the base of the unit points north. People who are familiar with natural energy vortices, Curry and Hartman lines, Ley lines, and so forth have been using these devices to restore many of the earth's energy centers to healthy state. This process is generally referred to as ‘gifting’ or ‘towerbusting’. As should be no surprise to anyone familiar with orgone (by any name) , many of us have noticed beneficial changes in the behavior of people within the effective range of such devices, whether they are aware of its presence or not. They are, in effect- getting the same sort of emotional healing and balancing (and in some cases the commensurate physical benefits) that one would expect from more traditional methods of life energy therapy. For several years I used xtals for basic pain relief and first aid in energy work on myself, and now I use something which is basically a fancy TB.

These devices can also be used as meditation aids, used by holding it between the hands while meditating, or by sitting near it while meditating. They can also be carried on the person in order to afford a constant cleaning action for your personal energy fields, and provide shielding against various forms of energy assault, ranging from psychic attack to EM pollution. And, while the devices can be used as intent amplifiers /radionics boosters, IMO there are more specialized orgonite devices which perform that task better. I have noticed that suspending water over the top of an HHG does charge it with orgone energy, and I regularly use this kind of charged water as a general tonic, I find that it has beneficial effects both physically and energetically (vitality, clarity of thought, emotional balance).

One thing which the HHGs and TBs seem to be good at is serving as a basic life energy therapy device, to speed healing and, in some cases, relieve pain. I of course am not a doctor, and am not giving you medical advice, and that applies to everything on this site, bla bla bla. There are several folks who find a TB or a slightly modified TB to be very useful (when held in the practitioner's hand or over the problematic body area on the person being treated) in Reiki, Reflexology, Massage Therapy, healing hands, and so on and so forth (these are all systems which effect healing by working with the human body's orgone energy).

Unlike orgone accumulators, These devices do not have to be carefully protected from EM pollution and DOR. They convert DOR to OR, so I think it is a good idea for most everyone to make at least one or two and put them in their homes, and enjoy the benefits of a healthy life energy environment where they live. As with some of the other similar devices which are already in use, these devices have applications in agriculture and alternative health, in addition to their primary function as an 'energy cleaner'- a device which processes life energy and removes harmful properties in so doing. Every day, we all take a bath in more energy pollution than most folks care to think about, ranging from huge uses of metaphysics with some very nasty intent behind it, to the modern phenomenon of technological assault on natural weather patterns (HAARP), The human mind and body (GWEN), and the harmful effects that various more mundane electrical systems have on life energy. These devices have been shown time and again to have a beneficial effect on the life energy of a given area, being adapted to many uses beyond the original purpose for them, and for which they are still heavily and successfully used, which is to restore natural weather patterns to the environment around us by mitigating or nullifying the effects of weather control technology.

I have seen no evidence that HHGs or TBs will become saturated with DOR from prolonged exposure, but I have seen that such devices have a processing capacity, and that capacity may be exceeded. I have been able to deal with that in most cases by simply using more devices. The capacity of the device is determined by the mass of the device, (larger mass of orgonite = more capacity) the way the internal components are assembled, and the composition of the orgonite itself. I have not found it necessary to move the HHGs and TBs around in order to keep them working, but I have noticed that doing so excites them and 'stirs things up' quite a bit. The exception to this is when you are using them to create a perimeter or clean field in or around your home or another area, in which case you ought to install them by placing them, rotating them clockwise until it 'feels right'... and then try to avoid moving them. Once moved, it takes some time for the fields to re-establish themselves. Where several devices are linked together to create a shield or ley line, moving one causes the whole thing to wobble. Stimulating one of them also stimulates the whole of the field in which the linked devices are included. If you have an SP, or a wand, or even a favorite xtal you use for a beamer you can go around the perimeter clockwise and touch each of the TBs with the tip of your device as you go around. This assists in linking the devices together.

The reason they work better when buried is that the orgonite works a bit more efficiently when in contact with the earth, since the orgone 'resistance' of air is slightly higher than the orgone 'resistance' of earth. Therefore, when the energy flows through the HHG or TB, it can flow a little more quickly if it is buried, because it has a huge potential (the earth or the body of water) to which it is grounded. Even if you do not bury them, just tossing TBs into a problem area works fine, burying them is a boost, and not absolutely necessary. Good thing, because there are many places where burying them is impractical. If possible, toss them where they will land in water (best) or on earth, as opposed to pavement. Drop one in your annoying neighbor's bushes hahaha ...

Orgone Accumulators, Orgone generators and Orgonite

The basic difference between orgone accumulators (ORACs) and orgonite is that orgonite processes orgone energy, whereas ORACs condense orgone energy. Some devices employ orgonites processing ability to 'generate' orgone from other forms of energy, and some devices employ orgonites processing ability to change orgone from one state to another. Examples of this latter use are changing orgone that is in an unhealthy state into a orgone that is in a healthy state, or converting orgone into the state which is most suitable for a given purpose at a given time (say, for therapy or radionics, etc.).

An orgone generator is a device that both collects orgone, and translates other forms of energy into orgone energy. It is possible, using orgonite, to convert heat, light, sound, scalar, kinetic, electrical and magnetic energies into orgone energy. Some people call orgone cleaners 'orgone generators', and in fact the man who invented orgonite has patented the term orgone generator, so indeed there are people who would define these terms differently than I do. However, I am trying to make the point that there are different functions involved, and as long as you are aware of them I suppose it does not matter what you call the, except for the sake of convenience in establishing a cohesive terminology with respect to orgonomy. Orgonomy, by the way, is a name for the study and application of orgone energy.

(Sigh), now... Orgonite does not actually generate orgone, in the truest sense of the word, but I suppose that is a technicality. Orgonite, when excited with other forms of energy, both converts a portion of the energy used to excite it into orgone energy, and draws additional orgone energy from the Aether (the cosmic omni potential 'pool' of orgone energy that has yet to be 'put to work' in 3D terms), and puts it to work as orgone manifest in 3D terms. Thus for practical intents and purposes, orgonite 'generates' ORgone on demand when excited by scalar waves, magnetic fields, heat, sound, light, electrical energy, kinetic energy, etc.

An orgone cleaner is a device that allows orgone to pass through it, and in the passing revitalizes the orgone energy. In addition to revitalizing the orgone, cleaner devices which employ orgonite or other similar conceptual approaches selectively remove and add qualities form the orgone. Again, there will be more articles at some point in the future which go into this matter further, but for now bear in mind that a cleaner is different from both a generator and an accumulator. HHGs, TBs, and Chembusters are examples of orgone cleaners. Also, it bears mentioning that orgonite-based orgone cleaners are not filters, though if overloaded of insufficiently grounded they will still function as filters. A filter picks the bad stuff out and collects it, and you have to periodically clean or replace the filter. Some folks have found that when their HHGs are not grounded well enough, the they have to periodically refresh them by sitting them on the earth or in running water for a few hours. But, if the HHG is in contact with earth or moving water, or connected electrically to the house electrical ground (I'll be producing a kit for this so you can modify your HHG easily at home... still in the testing phase, looks promising so far... and of course I'll post instruction so you can do it even if you do not want to buy it from me hahaha), then the HHG actually converts the bad stuff into good stuff, as opposed to just filtering it out. That is the chief benefit of orgonite-based orgone cleaners, and that is what they are designed to do, and that is what they do when they are constructed and installed properly.

An orgone accumulator is rather like a big capacitor. It is a device, usually in the form of a closed container, which collects the orgone energy from the surrounding area and stores it inside the container. Like a capacitor, an ORAC will collect as much orgone 'pressure' as it can hold, and then it will release some of the orgone so that more can come in. Therefore, it runs cyclically, if often the cycles may be days and months apart, instead of the fractions of a second which we call Hertz when considering the cycle duration of electrical capacitors. Unlike orgonite, an ORAC does not process the orgone, so it can collect a store of orgone on the inside of it which is either good for you or bad for you, depending on the condition of the orgone energy fields in which it is located. It will just collect whatever kind of orgone energy is around it. It is a good idea to have an HHG or TB inside your ORAC if you plan to build one, since most of our electrical grid produces a kind of orgone energy that is unhealthy, and ORACs operated within the EM fields produces by electrical appliances or high tension power lines tend to become saturated with this unhealthy orgone. Thanks to the higher levels of masonry for the decision that 60 Hz is the frequency of alternating current we use in North America. In terms of pulse rate, orgone is not in a healthy state when it pulses at 60 cycles per second (orgone energy will often pulse in sympathy to an electrical current which passes through it. 60 cycle electricity passes through the earth's orgone fields and puts them into a state which is more or less inimical to most living organisms). Of the places in your home to place an HHG, near your electrical mains (don't shock yourself and don't sue me. i mean to put it near the mains, not electrically connected to them) or fuse box is a likely candidate.

An ORAC is able to collect the energy because the sides of the container are composed of alternate layers of metallic and organic material. This arrangement of layers produces something like an orgone 'diode'. It is easier for the orgone to travel one direction through the lamination of metallic and organic layers, and much harder for it to travel in the other direction. So, like a diode, the layers move orgone in one direction. Build a box out of this material, and it will collect and condense orgone on the inside, since it can get into the box much more easily than it can get out. The ORAC was invented by Wilhelm Reich about 70 years ago.

Another thing to bear in mind is that TBs, HHGs, and chembusters will, to some degree, respond to the energy environment around them, becoming more active when there is a lot of DOR or unbalanced, harmful life energy around them, and less active (unless excited) when there is little problematic energy around them. They also respond to large potentials of healthy life energy when they are near them, and will often appear to sit inactive when the energy around them is relatively clean and undisturbed. If you are using an HHG to charge water, for example, it is a good idea to use sound or light to stimulate it, so that you can make sure it is active. Assuming you have the proportions of metal and resin correct, and the particle size of the metal is within working parameters, It is not possible for a TB or HHG to become saturated with DOR the same way as an ORAC because the orgonite has a quality of processing the orgone from one state to another, whereas an ORAC does not. I and several other use TBs to keep our ORACS clean, and (with a TB in it) I have been using a small cylindrical ORAC less than two miles from a large power line without any problems, this for years now (a/o mar 2004).

Chembusters and Cloudbusters

There is a lot of controversy on this subject now, and to be honest I consider it important to distinguish between a Croft-style Chembuster and a Reich-style Cloudbuster. After having had a chance to experiment with both devices, I find that they are indeed different in function. A Cloudbuster is a device invented by Wilhelm Reich about seventy years ago, and it uses orgone energy to influence weather patterns. It is basically an array of parallel pipes which are in turn connected by means of rubber or other organic hoses to either an ORAC or a body of moving water. It relies on the circulation of orgone energy within the water bodies of the earth to clean the orgone by virtue of the action of moving water over stone, this action takes place in riverbeds especially. A Chembuster (or Croft-style Cloudbuster) is a slightly different device, which is based on the Cloudbuster in that it uses a parallel array of pipes to channel orgone energy, in order to affect the weather patterns in the area around it. The main difference between a Cloudbuster and a Chembuster are that a Chembuster has a ballast of orgonite, while a Cloudbuster is grounded directly from the pipes to the earth, or water. And since orgonite processes orgone energy instead of simply collecting it or moving it around a Chembuster cleans the orgone as it passes through. A cloudbuster does not.

Although both Cloudbusters and Chembusters generally pull orgone in the form of DOR down from the atmosphere and channel it into the Earth, it is possible for both devices to work in the opposite direction and send orgone form the Earth into the atmosphere. In both cases, it is the changing orgone fields which affect weather patterns. I do not approve of novices using Reich-style Cloudbusters, but I do approve of just about anyone using Chembusters. This is because a Chembuster is a great deal more user-friendly than a Cloudbuster. A Cloudbuster, used carelessly, can cause tornadoes, imbalances in the earth's orgone fields, and torrential rains or severe droughts. It is nonetheless a very useful device, but one which requires knowledge both of meteorology and orgonomy in order to operate beneficially. The Chembuster, on the other hand, functions more like a 'safety release valve' between the earth and atmosphere, so that it becomes more active when there is a large unbalance in the ambient orgone fields and less active when the energy around it is in a balanced and healthy state.

I have some other articles coming which go into this matter further, but for now suffice it to say that you can cause problems with a Cloudbuster if you do not know what you are doing, but this is not true of a Chembuster, and that is because a Chembuster uses orgonite and quartz crystals to clean the orgone as it passes through, whereas a Cloudbuster does not. It is possible to further enhance the function of a Chembuster by grounding it to the earth. After experimenting with it for some time, I generally ground the orgonite base of my Chembuster instead of grounding the pipes, because if you ground the pipes, then the device will appear to work more rapidly, but what it is actually doing is dumping the excess
DOR into the ground rather than cleaning it. In my opinion, grounding the copper pipes directly is no better than a Reich style cloudbuster, because it is just dumping the DOR into the ground. If you are doing this, then you ought to add some HHGs and TBs or equivalent right near the ground wire where it enters the ground. Also, a wet ground is better than a dry ground. It is better to ground the Chembuster to moving water or wet earth than to dry earth. If you are grounding it to dry earth, you should use a long wire to maximize contact with the earth. You can either attach a length of copper wire to the orgonite, or just cut the bottom out of your bucket and let the orgonite touch the earth.

Orgonite Density

Not all orgonite is the same. The size of the particles used makes a lot of difference to the finished product. Below is a short description of some of the different grades of orgonite with which I have worked. Orgonite can be used for different devices, and the intended function of the device determines what kind of orgonite is best to use. Different materials offer differing amounts of resistance to the orgone as it flows through it, and the different grades of orgonite have sequentially higher 'orgone resistance' values.

LD - Low Density Orgonite

Low Density orgonite offers very little resistance to the orgone as it flows through the device. This means that the device is not very suited to cleaning the orgone, it will not convert DOR to OR with much efficiency. But, since it attracts the orgone and allows it to flow through it very easily, low density orgonite is useful for sending and receiving orgone energy, and for collecting and moving orgone energy from one place to another. One place I often use LD orgonite is to make a channel or layer of LD orgonite within an orgone device, which acts like a wire to conduct the orgone along a chosen path inside the device. LD orgonite also works well as an orgone 'antenna' to send and receive orgone energy within a network of devices. LD orgonite does not work well on its own for making TBs and HHGs, but a thin layer of LD or VLD (Very Low Density) orgonite at the base of an HHG or TB assists the device in grounding to the earth more efficiently. LD orgonite will release some orgone when excited, but not very much.

MD - Medium Density orgonite

MD orgonite offers enough orgone resistance to foster the cleaning action for which orgonite is well known, and works as a material from which to make TBs and HHGs. MD orgonite has a dense enough matrix to convert DOR to OR, but does not work very efficiently in an orgone-on-demand generator. It offers low enough orgone resistance to function well in a passive mode, and high enough orgone resistance to still afford the 'scrubbing' action which is desirable. MD orgonite will release some orgone energy when excited by external energy sources, but like LD orgonite, still not very much. The orgone resistance is low enough in MD orgonite that much of the energy used to excite it either passes through it or is attenuated. It is more suited to use in devices which are meant to operate in a passive mode. TBs, HHGs and Chembusters are generally meant to operate in a passive mode. While MD orgonite may not be the absolute best thing from which to make TBs and HHGs, it will work nonetheless.

MHD - Medium High Density orgonite

MHD orgonite is imo the most efficient type of orgonite from which to make TBs, HHGs, Chembusters and other devices which operate in a passive mode. MHD orgonite offers just low enough orgone resistance to operate in a passive mode, but offers high enough orgone resistance to maximize the 'scrubbing' action while still in a passive mode. MHD orgonite will convert DOR to OR efficiently without being excited by external energy sources (other than a potential of DOR to convert into OR). Because of its higher density, MHD orgonite will also release orgone when excited, and it will do so with more efficiency than MD orgonite. MHD orgonite works well to construct devices which are intended to operate in both passive and active modes. The spaces between the larger particles are filled with smaller particles. This is also the grade of orgonite that I make my HHGs and TBs from now. See the 3 small pics below? MHD orgonite can be gotten by either using smaller particles, as in the two cases on the left and center, or by adding superfine particles to the resin and then using larger metal particles which would ordinarily produce MD orgonite. Either way will produce MHD orgonite. I use about 2 teaspoons of mineral 'flour' to a liter of resin.

HD - High Density orgonite

HD orgonite offers a much higher orgone resistance than MD or MHD orgonite. The scrubbing action provided by HD orgonite is plentiful, provided it is excited in some way. TBs and HHGs made from HD orgonite need to be placed in an area with extreme inimical energy problems if they are to do much. They also benefit from being electrically grounded, though I suppose it is not absolutely necessary. TBs and HHGs made from HD orgonite can be a bit smaller than ones made from MHD orgonite, and still do the same job, provided they are excited in some way, either by external energy sources or by a LARGE potential of DOR to convert into OR. One place in which TBs and HHGs made from HD orgonite work well is on or near household electrical appliances. To make a long story short, HD orgonite processes orgone more efficiently than MHD orgonite, but you need to 'push on it' in order for the orgone to go through it very fast at all. There are few if any large particles, and that there is not very much space between them. HD orgonite does not work very well for devices which are meant to operate in a passive mode, but it does work well for devices which are meant to operate in an active, or 'powered' mode. HD orgonite works well to make orgone-on-demand generators which convert other forms of energy such as heat, light, sound, EM or scalar waves into orgone. HD orgonite works well to make intent amplifiers. HD orgonite can also be used inside an orgone device made from lower density orgonite to control the pattern of energy flow by offering more resistance at select places inside the device, acting like an 'orgone pressure valve' so that orgone will not pass through it until it has reached a sufficient intensity. HD orgonite is the highest density at which orgonite will work both in the passive and active modes, but is more suited to the active or 'powered' mode.

XHD - Extra High Density orgonite

XHD orgonite does not work very well in a passive mode, and does not appear to be doing much of anything until it is excited by some form of external energy. When excited by heat, light, physical motion, sound, EM fields, electrical current, scalar waves, etc., XHD orgonite is VERY efficient at producing orgone energy. XHD orgonite has uses in the internal composition of orgone devices built from lower densities of orgonite, just like HD orgonite, but is especially suited to making orgone-on-demand generators which are designed to operate in an active or 'powered' mode. Note the particle size, all of the have gone through a 1 mm sieve, the largest are about 1.5 x 1 mm, and the majority of the particles are in the form of a fine powder like flour. When making HD or XHD orgonite, you can add the organic part of the orgonite in the form of small particles, and just use enough resin to hold the mass together. While XHD orgonite works very well for making devices which operate in an active mode, it does not work very well at all for devices which operate in a passive mode, except as a small part of the finished device.

<u>Different materials for making orgonite</u>

While many people now use polyester resin and metal particles from a machine shop, there are many different materials from which orgonite can be made. In my experience, not all of these combinations produce a very durable substance, but in some cases produce more orgone than the basic polyester resin and metal filing mixture

Cheap orgonite from waste paint

An extremely cost-effective and colorful variety of orgonite with which I have been experimenting. The orgonite is not especially durable, and needs to be kept indoors or recast in plastic resin to seal it from the elements. It is made from old latex paint (often free at recycling depots) and commercially available waste paint hardener (about $3.00 CDN for enough to do 2/3 of a gallon). The waste paint hardener is in the form of a small packet of crystals which, when mixed into the paint, cause it to solidify. The metal has to be mixed into the paint prior to adding the hardener, since it turns stiff almost immediately. The mixture then takes several weeks to dry fully in a large casting like the 3.5" blue TB (with kyanite from revted ;) shown. This can be quickened by making the mixture and spreading it out into a thin sheet, allowing it to dry, and crumbling it into small pieces like the two shown on the right of the picture. The small pieces can then be combined in different colors and recast with just enough resin to hold them together. Doing it this way, you can reduce the cost of polyester resin by 50 to 70 percent, but it takes a lot longer.

Another orgonite recipe is made from polyester autobody filler, mixed with metal shavings and a little aluminum roof patch paint. You have to work quickly, and mix in the metal and paint before adding the catalyst to the autobody filler. While this kind of orgonite is not ideal for TBs and HHGs, it has the advantage of not leaking out of small holes in the molds, and therefore is useful for some hard-to-cast shapes, as it can be forced into the mold in small amounts with a spoon or spatula.

A few notes about using fine powders in orgonite

You don't need to have NASA grade powdered quartz or ultra fine metal particles. You can use them, but you can also make your own. I make most of my own. One source of copper powder that is easy to get is copper spray paint. Get the cheap kind that rubs off on your fingers after its dry. It is basically metal flakes, solvent, and a little oil. When the solvent evaporates, you are left with fine metal flakes and a little oil. Just spray it into the resin and mix thoroughly. Of course, you have to mix the fine powders into the resin before you pour. Also, if you are using any of the following powders (and probably a few I don't know about)...

copper

paramagnetic earth with high iron content

rust (iron oxide)

white polyester pigment (titanium oxide)

decomposed chalcopyrite (oxidized copper and iron and sulphur)

decomposed iron pyrite (oxidized iron and sulphur)

...then you have to add a bit more catalyst than you normally would, since the copper and paramagnetic earth (some kinds, anyway) slow down the curing (of POLYESTER resin) quite a lot.

There is no answer the question 'which is better, powder or shavings' because the two give different effects. That's kind of like asking whether apples or oranges are better. In short, for an orgone generator (which technically an HHG is NOT) powder is better. For an orgone FILTER/CLEANER (which is what an HHG is) powder can be used as an additive, and you will get a bit more out of it.

If you are trying to make HD orgonite at home, and have problems with the powder settling out, then you can do two things: 1... use less resin! 2... add the organic to the mix in a powdered form and then just use enough resin to stick it all together. To make the higher densities of orgonite, you have to actually mix the ingredients, you cannot just pour the resin over them. Mix all the dry stuff up in a vessel, and then add it to catalyzed resin. Use enough powder that you get a slurry, like oatmeal. Just use a little resin. However, for hhgs and tbs, unless you are gonna put them in a really bad spot or make sure to ground them by burying or tossing in water... you don't want it to be ALL powders. HD max, not XHD. Also, you can make the TBs a bit smaller if they are made from HD than the minimum size they would need to be if they were made from MD. A CB made with HD is a bit different because the pipes create a bit of flow, so there is something to push (or pull) the orgone through the orgonite. Depending on how you have it set up and configured, it may work really well, or not very well at all. Even so, it is possible to get the density too high and 'plug up' the device. I have had that happen before. If you can figure out a way to stimulate it enough, then it will work. One thing you can do is increase the diameter of the pipes a bit to compensate for the density of the ballast. The push or pull provided by the pipes of a CB can act as stimulation for the orgonite if it is of sufficient intensity.

There is one density rating that belongs to the orgonite. Then there is another density rating that belongs to the device as a whole. Ideally, the orgonite density of a TB should be as high as you can get it before it starts to 'plug up'. If you make it too dense, and expect it to work in a passive role, then you will get all discouraged perhaps and say 'it doesn't work'... but that will be because you are basically trying to use a pressure release valve set at 500 psi to relieve 20 psi of peak pressure, understand? Orgonite made with fine particles (high density) works just fine, as long as you use it right. ;)

Anyway, for a TB, the orgonite density should be as high as you can get it and still work, but the overall device density should be a bit lower, so that it will allow energy to flow through it relatively easily. A simple way to say this is the more orgone resistance the device has the better it cleans, but the less orgone resistance the device has, easier energy can flow through it. So you have to find the 'sweet spot' in that range. Imo, for things like TBs and HHGs (as opposed to radionics outputs, pulsers, powerwands, etc) that 'sweet spot' is what I call 'MHD' which stands for 'medium high density'. I also make HD (high density) towerbusters, and they work great... as long as they are deployed CORRECTLY which means being either:

A... right on top (metaphorically speaking) of the tower, or on top of your monitor, or TV, or something else which makes a lot of EM noise...

or B... well buried and spread out a bit in the pattern of gifting.

For HHGs and TBs, what most of us do is to use fine powders as an additive to larger metal particles. Doing this enables us to adjust the density of the orgonite to hit that 'sweet spot' and/or add other energy signatures to the output of the device. So, some people say 'powders are garbage, they don't work' because they try to make TBs with only powders, the density is too high, and (no surprise) it doesn't work. And others say 'well, Welz uses powders so they must be good'. Well... Welz doesn't make devices that have to function in a passive sense, or at least that's not what he's known for. He is not known for making HHGs and TBs. Welz makes devices that use EM (Electro-Magnetic) stimulation to translate EM into orgone, which he then integrates into a radionics machine's output stage. That's why he uses HD/XHD orgonite in his devices. And that's why in devices like my pulsers, ring generators, and so forth, I also use higher densities.

Ingredients for orgonite

Here are some of the ingredients I have worked with in orgonite, and a brief description of their properties according to my opinion and observations. All pronunciations of usefulness for a given purpose are my own views and based on my own perceptions. I am not giving you medical advice. I am not a medical doctor, but there's a good chance you may be ;) Experiment and form your own opinions. I will do my best to update this page from time to time. By no means are all possible ingredients listed here, nor are all the possible effects of the ingredients listed here. This list is my opinion, and is a work in progress. There are many different ingredients being used in orgonite. There are many different recipes of orgonite being used. Some perform better than others all around, and some perform better for a single purpose. In terms of energy work and metaphysics, whatever minerals are included in the orgonite will, to some degree, impart their energy qualities to the orgonite. The same holds true so far for the energy effects of hertzian frequencies, sounds, colors of light and energy impressions via reiki work or other traditional metaphysical discipline in application. The rate of success with this effect, the orgone signature programmed into the orgonite while it cures, seems to vary. In other words, say you have a little piece of turquoise that you like to use for body work. Or perhaps it is rose quartz. I dunno, it's up to you. Say this little piece of turquoise you have is 1 cc. 1 cubic centimeter. Say you cast it inside of 10 cc of orgonite. Well, now it's like you have between 1.5 and 7.5 cc of turquoise to work with. Suppose you are really finicky and you match the recipe of the orgonite to the turquoise, use minerals and metals that the turquoise likes in the orgonite, and maybe charge the orgonite with the energy signature of turquoise while it cures. Now, it's like you have 11 or 12 cc of turquoise to work with, all from that little 1 cc chunk of turquoise cast inside the orgonite. There are people in the world who know a lot more about the specific effects of various frequencies and minerals than I do, and in fact there is really a substantial body of information on the web dealing with the specific energy effects of minerals, colors, and frequencies. Point being, most or all of this knowledge is transferable to working with orgonite, and orgonite is complimentary to these already well established means of working with energy (sounds, colors, frequencies, minerals, etc.).

NOTE - Primary indicates that it can be the main ingredient of it's type, and secondary indicates that it can be used as an addition to the orgonite, but should not imo be used as the main ingredient of it's type.. For example, a TB would have to have at least 1 primary ingredient each (or equivalent not listed in the tables below) from the minerals, metals, and organics tables below. Coloration refers to the 'colors' of orgone that a given substance is harmonic to. I am using the same old 7 spectral colors system with which so many of us are familiar.

Minerals for orgonite:

Mineral	Coloration	Primary	Secondary	Effect
Quartz Crystal	All	✔	✔	Focuses and directs energy within the orgonite. Holds a program. The basic standby in TBs and HHGs, pulsers, succor punches, chembusters, radionics machines and other orgone devices. Is like the master crystal which will respond to some degree to virtually any orgone energy signature, regardless of color or frequency.
Quartz Powder	All		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite.
Selenite Crystal	White, Blue, Cream		✔	Provides some coloration. Useful for healing. Useful for cleansing and invigorating.. Holds a program. Similar effects to kyanite but a bit more gentle.
Selenite Powder	White, Blue, Cream		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Provides some coloration and is useful for healing and cleansing. Can be used to adjust the density of the orgonite.
Kyanite Crystal	Violet, Blue, Silver, White	✔	✔	Focuses and directs energy within the orgonite. A workable substitute for quartz in TBs and HHGs, with the condition that it significantly colors the output into the blue and violet range. Produces a surprisingly sharp energy considering it is mostly in the blue range. Useful for cleansing. Similar to selenite bit more sharp and stronger cleansing influence. Holds a program sometimes, but program parameters are limited to those harmonic to the coloration of the mineral.
Kyanite Powder	Violet, Blue, Silver, White		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite. Retains most of the properties of kyanite xtals.
Citrine Crystal	Gold, White, Yellow, Red	✔	✔	Focuses and directs energy within the orgonite. A workable substitute for quartz in TBs and HHGs, with the condition that it significantly colors the output into golds, yellow and some reds, depending on how darkly colored the specimen is. Holds a program sometimes, but program parameters are limited to those harmonic to the coloration of the mineral. Useful for cleansing and invigorating.

Minerals cont.

Citrine Powder	Gold, Yellow, Red		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite. Provides some coloration to the orgonite. Gives a nice warm feel to the energy.
Amethyst Crystal	Violet, Blue, White, Gold	✔	✔	Focuses and directs energy within the orgonite. A workable substitute for quartz in TBs and HHGs, with the condition that it significantly colors the output into the violet and gold range. Useful for healing, and for divining, and for cleansing. Holds a program sometimes, but program parameters are limited to those harmonic to the coloration of the mineral. Useful for divining. Useful also for self-searching.
Amethyst Powder	Violet, Blue, Gold		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite. Imparts some of the effects of amethyst xtals to the orgonite.
Rose Quartz Crystal	Pink, White, Red, Violet	✔	✔	Focuses and directs energy within the orgonite. A workable substitute for quartz in TBs and HHGs, with the condition that it significantly colors the output into the red range, but a light red, more like pink. Soothing and healing energy, surprisingly mellow considering it is mostly in the red range. Holds a program sometimes, but program parameters are limited to those harmonic to the coloration of the mineral. Invigorating.
Rose Quartz Powder	Pink, Red, Light Blue		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite. Gives a people-friendly, smooth feel to the energy. Invigorating.
Smoky Quartz	Gold, Brown, Green, White	✔	✔	Focuses and directs energy within the orgonite. A workable substitute for quartz in TBs and HHGs, with the condition that it significantly colors the output into the reds and browns and golds. Strongly masculine energy. Useful for diving and protecting.
Turquoise	Blue		✔	Soothing and healing, useful for pain reduction and physical healing. Strong feminine energy, good for healing and regrowth on many levels. Some shielding action but imo more useful for stimulating recovery from injuries physical or energetic. Strong synergy with blood coral and hematite. Increases orgonite's connection to water.
Hematite	Black, White		✔	Strong connection to the earth imparts a 'stability' to the energy from the orgonite. Increases orgonite's capacity to drain away harmful energy by increasing device's mean energy flow capacity. Use as a grounding stone in place of / in addition to electrically grounding the orgonite to earth. Strong synergy with many minerals, especially imo turquoise and blood coral. Somewhat invigorating.
Lapis Lazuli	Gold, Blue, Red, Violet		✔	Very high energy output from this stone for a variety of possible uses. Too much to go into here. Potent and worth reading upon elsewhere. Invigorating. Manifesting.
Garnet	Red		✔	Provides coloration into the red range. Synergy with amethyst.
Fluorite	Blue, Green, Violet		✔	Provides coloration into the green range, and sometimes into the blue or violet range. Rounds the feel of the energy. Assist orgonite with absorbing program while curing. Useful for healing. Does not hold and execute program terribly well, but stores an impression rather well. Useful as a means of transferring energy signatures from one device to another or storing them for future use. Increases orgonite's connection to water.

Minerals cont.

Mica	Green, White		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite. Sharpens the feel of the energy from the orgonite. Can be used as an organic. Provides coloration into the high green range. An energy "astringent".
Paramagnetic Earth Chunk	Varies, Generally includes Red and up the spectrum to a variable height.		✔	Strongly increases orgonite's mean output. Provides some grounding action similar to hematite, pyrite and chalcopyrite. Increases orgonite's responsiveness to electromagnetic stimulation. Sometimes invigorating, sometimes soothing. Depends on actual earth being used.
Azurite	Blue, White, Violet		✔	Provides strong coloration into the blue and violet ranges. Similar to kyanite in that it is a sharp blue, not a soft blue. Strong synergy with malachite.
Malachite	Green		✔	Provides coloration into the green range. Strong synergy with azurite. A relatively sharp kind of green energy, useful for cleansing and invigorating.
Agate	Yellow, Brown, Gold, White	✔	✔	Focuses and directs energy within the orgonite. substitute for Quartz in a pinch, but tends to flow more slowly than if quartz were used. Strong connection to earth and fire, useful for some protective/shielding influences.
Pearls	Gold, Silver, Cream		✔	Imparts a lovely smooth 'creamy' feel to the energy hahaha. Useful for cleansing and invigorating. Increases orgonite connection to water somewhat. Helps to bridge between fire and water.
Bloodstone	Red, Green		✔	Very masculine energy. Coloration into both green and red ranges. Useful for soul- search and overcoming obstacles. Tends to be invigorating, perhaps too much so for some.
Glass	All	✔	✔	Focuses and directs energy within the orgonite. A poor substitute for quartz xtal, but useful as a means of controlling energy flow within a device, especially if faceted. Tends to give the energy a bit of a rounding/mellowing effect, and gives some coloration of the orgone if it is colored glass.
Quartzite	White, All	✔	✔	Focuses and directs energy within the orgonite. A slightly Better substitute for quartz Than Cut Glass, But still not as good as quartz. Recommend using at least 3X the mass you would if you were using Quartz Xtal.
Quartzite Powder	White, All		✔	Enhances overall function of the orgonite. Increases the output and responsiveness of the orgonite. Can be used to adjust the density of the orgonite.
Blood Coral	Red		✔	Provides coloration into the red range. Strong synergy with turquoise and hematite. A gentle masculine to balance the strong feminine of turquoise. Increases orgonite connection to water somewhat.
Tourmaline Red	Red, Blue		✔	Provides coloration into the red range. Gentler than garnet.
Tourmaline Green	Green, Blue		✔	Provides coloration into the green range. Gentle and soothing energy.
Tiger Eye	Brown, Gold, Yellow, Red		✔	Increases orgonite's capacity to drain away harmful energy by increasing device's mean energy flow capacity. Use as a grounding stone in place of / in addition to electrically grounding the orgonite to earth. Useful for manifestation and repelling unwanted influences. Useful also for self-searching.
Pyrite Chunk	Dark Red, Gold, White, Black		✔	Increases orgonite's capacity to drain away harmful energy by increasing device's mean energy flow capacity. Use as a grounding stone in place of / in addition to electrically grounding the orgonite to earth.

Metals for orgonite:

Metal	Coloration	Primary	Secondary	Effect
Gold	Gold, White, All	✔	✔	High frequencies. Healing, and lifting of mind upwards. Head in the clouds. Useful for divining, soul-searching, overcoming obstacles, and of course purification. Increases orgonite's response to intent stimulation.
Copper	All, Blue, Red	✔	✔	Very wide response range of frequencies. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix. Gives a smooth feel to the energy. Strong synergy with steel or iron.
Brass	Gold, Silver, White, Blue	✔	✔	High and subtle effects. Quite potent, but may be difficult for some to feel. Good for clearing. Not so good for grounding. Increases orgonite's response to intent stimulation. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix.
Cobalt (in blue glass)	Blue, Silver, White		✔	Provides strong coloration into the blue range. Increases orgonite's connection to water. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix.
Bronze	Red, Gold, Blue, Red	✔	✔	Similar to brass but a bit lower on the scale. Increases orgonite's response to intent stimulation. A bit more grounding influence than brass.
Aluminum	All, White, Blue	✔	✔	Similar to copper but a second to copper in terms of the feel of the energy. A wide range of frequency response and coloration. Strong synergy with steel or iron.
Titanium	White, Silver, Gold		✔	Very high frequencies, and relatively sharp energy. Good for dissolving blockages / clearing / energy astringent. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix.
Steel	Blue, Red, Black	✔	✔	Provides stability to the energy signature of the orgonite. A relatively low response range. Provides some grounding influence. Increases orgonite's responsiveness to EM stimulation.
Iron	Red, Blue, Black	✔	✔	Provides stability to the energy signature of the orgonite. A very low response range. Provides more grounding influence than steel. grounding influence. Increases orgonite's responsiveness to EM stimulation.
Bismuth	Blue, Brown		✔	Strongly increases orgonite's response to magnetic stimulation. Some grounding influence. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix. Increases orgonite's responsiveness to intent stimulation.
Lead	Black, Silver		✔	Very low response range. Provides some stability to energy signature of orgonite. Some synergy with copper and gold.
Zinc	Silver, Blue		✔	Increases synergy between magnetic and non magnetic metals. Strong synergy with copper. Strong catalyst in energy terms, good for manifestation. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix.
Iron Pyrite	Dark Red, Gold, White, Black	✔	✔	Provides a grounding, stable note to the energy form the orgonite. Gentler and a bit rounder feel to the energy than steel or iron.
Chalcopyrite	Gold, Red, Blue, White	✔	✔	Provides some grounding and some uplifting action to the energy form the orgonite. Since it is a combination of iron and copper, it possesses the synergy between these two metals in its natural form. Gives a pleasant smooth and potent energy if used alone, mellows the output and increases the response range of the orgonite if used as an additive.

Metals cont.

Paramagnetic Earth Powder	Varies, Generally includes Red and up the spectrum to a variable height.		✔	Strongly increases both the orgonite's connection to the earth, and the orgonite's responsiveness to EM stimulation. Increases the orgonite's responsiveness to intent stimulation in some cases. May or may not carry it's own potent energy signature to impart to the orgonite. Varies greatly from place to place. Boosts flow of orgone through device by increasing dynamic action within orgonite matrix.

Organics for orgonite:

Organic	Primary	Secondary	Comments
Pitch	✔	✔	Wonderful smooth feeling energy. A bit nicer than polyester resin, but less durable. Better imo as a primary than a secondary. I make a fair amount of stuff out of pitch. Will melt in the sun so must be kept indoors or buried. Is ideal for water gifting. Does not dissolve in water. Absorbs a charge well during curing. Strong connection to earth and water.
Beeswax	✔	✔	A workable if not ideal organic primary. Energy output is less than pitch or polyester, and device must be contained somehow. Works better when cold.
Paraffin Wax		✔	Much less functional in orgonite as primary than natural wax. Dunno why.
Carnuba Wax		✔	A little mixed into the pitch gives it a bit 'brighter' feel.
Latex Paint with hardener added		✔	Gives a warm, comfortable, people-friendly feel to the energy when mixed with polyester based orgonite. Often provides coloration according to the color of the paint, but not always. Depends on the chemistry of the paint. With waste paint hardener added, it is a slightly better primary than wax, but not much. Excels as a secondary with polyester., Useful as a means of transferring energy signature form one botch of orgonite to another, for lightening the weight of the orgonite, or for adjusting the density of the orgonite. Absorbs a charge well during curing.
Flour		✔	Gives a warm, comfortable, people-friendly feel to the energy when mixed with polyester based orgonite. Can be used to adjust the density of the orgonite.
Acrylic Plastic	✔		A somewhat smoother feeling yet much more expensive alternative to polyester resin.
Polyester resin	✔		The basic standby against which I measure other organics. Provides some coloration according to the chemistry of the resin. Absorbs a charge well during curing.
Vegetative Matter		✔	Imparts to varying degrees the energy signature of the plants used to the orgonite. Useful for reproducing in orgonite the effects of various herbs. Recommend using well dried, evenly and finely shredded vegetative matter.
Hair		✔	Can be used to permanently link a body of orgonite to an individual. Caution advised. Useful for custom work or tailoring a device to a specific user.
Blood		✔	Can be used to permanently link a body of orgonite to an individual. Caution advised. Useful for custom work or tailoring a device to a specific user.
Dirt		✔	In small amounts can be used to adjust the density. Increases the orgonite's connection to earth.
Incense	✔	✔	Can be used to impart the energy signature of a given incense to the orgonite, if not always the smell.
Sugar	✔		Have not tried this myself yet, but some are reporting success with sugar (hard candy) as an alternative to polyester, similar to pitch.
Honey	✔	✔	Adds a soft, high frequency overtone to the orgonite.
Carbon		✔	Adds a strong grounding influence to the orgonite.

Recipes for orgonite:

Here are some different kinds of orgonite I have been playing with. All pronunciations of usefulness for a given purpose are my own views and based on my own perceptions. I am not giving you medical advice. I am not a medical doctor, but there's a good chance you may be ;) Experiment and form your own opinions. You are responsible for your own safety. *Note - "resin" in recipes refers to catalyzed resin, if applicable. In some recipes, extra catalyst is needed, and given as a percentage value above the regular mix ration. Eg. catalyst +10% means to use the normal amount of catalyst, plus an extra 10% on top of that. The normal resin / catalyst ration for your resin is generally marked on the side of the container you bought your resin in. Particle sizes are given as follows : fine = 0 - 1mm dia., small = 1 - 5 mm dia., large = 5 - 15 mm dia. Proportions of ingredients are approximate.*

Basic LD

Ingredient	Amount in parts	Process	Comments
Copper - Fine	.05 - .1	Mix the catalyst into resin. Add all other ingredients, stirring continually and pour into mold.	Useful for creating a path of lower resistance inside of a device, in order to control the flow of energy. On a more basic note, all HHGs and TBS benefit from a thin layer of something like this at their base. Also works nice as cosmetic second coat for orgonite pieces, and has a bit more output than if just resin were used for the second coat. Also some applications in linking modules for radionics devices.
Quartz Powder - Fine	.05 - .1		
Resin	1		
Catalyst	+50%		

Basic MHD

Ingredient	Amount in parts	Process	Comments
Aluminum - Large	1.5	Mix dry steel and aluminum together. Place mixture into molds. Add xtals / other internal components as applicable. Mix catalyst and resin. Add Quartz Powder to catalyzed resin and stir thoroughly. Pour resin Over metal particles and allow to seep down. Repeat layers as necessary.	A good all-purpose orgonite recipe. Other items can be added as desired.
Steel - Small	1		
Quartz Powder - Fine	.01 - .25		
Resin	To fill molds		

Basic HD

Ingredient	Amount in parts	Process	Comments
Steel - Small	1	Mix all dry ingredients together thoroughly. Add catalyzed resin a bit at a time until there is enough resin to just cover the surface of the particles. The mixture should have the consistency of thick oatmeal, and have just enough resin that all the particles are covered. Allow it to sit for a few minute. If there is more than 1/8" (2mm) of resin covering the surface of the particles, add more steel until the mixture is an even thick slurry like oatmeal. Pour into molds. Stir constantly, including while pouring.	A good basic recipe for use in either heavy-duty TBs and HHGs, or in actively stimulated orgone generators. Different primary and secondary ingredients can be used as desired. .
Secondary metal - Fine (copper or pyrite or bronze suggested)	.1 - .25		
Resin	.75 - 1.15		
Catalyst (if using copper or paramagnetic earth)	+50%		
Secondary Mineral - Fine	.1 - .25		
Secondary Organic - Small	.1 - .25		

Basic XHD

Ingredient	Amount in parts	Process	Comments
Primary Metal - Fine	1	The particles must be fine enough to suspend in the resin. One way to deal with it if this is not the case is to catalyze the resin, wait until it gels, and quickly mix in the other ingredients. Another is to use a thickening agent. In some cases, the thickening agent and the secondary organic can be the same. Premix all dry ingredients thoroughly, and the add the dry ingredients to the catalyzed resin, stirring continually. Add the dry ingredients a bit at a time. You should get a creamy thick liquid that pours slowly into the molds and still is liquid enough to smooth itself off at the surface. If the particles are settling out, there is too much resin. Usually, resin to dry ingredients should be about 1 to 1, sometimes a little more or less depending on the absorbency of the secondary organic.	A useful recipe for making orgone generators designed to be driven by outside power sources like zappers, magnetic pulsers, radionics machines and so forth. Also useful in making small orgonite devices to be carried in a pocket and handled a lot.
Secondary Metal - Fine	1		
Resin	3 - 4		
Secondary Organic - Fine	1.3		
Quartz Powder - Fine	.4		
Secondary Mineral - Fine	.3		
Catalyst if using copper	+ 30% - 50%		

Basic EHD

Ingredient	Amount in parts	Process	Comments
Primary Metal - Small	1	Mix the catalyst into the resin. Add the fine ingredients to the resin. If it is not thick enough at this point to suspend the primary metal particles, add a bit more flour until it is. Mix all the small ingredients into the resin, a bit at a time. It should come out looking like a thick slurry, with bits of metal visible in it. The metal should not all pile up on the bottom. Internal components of devices (like crystals) need to be supported in some way during curing since this orgonite will most likely not hold them in place during curing like MHD will.	It may take a bit of messing around to get this recipe working right, but it has (especially when made with wheat flour) a gentle, people friendly feel to it. This orgonite is good for many things, since it basically behaves like MHD. EHD stands for expanded high density. Good for devices which are meant to be used indoors in living space, and / or handled by people a lot. Useful for both passive and active roles.
Secondary Metal - Fine	.10		
Resin	.75 - 1		
Quartz Powder - Fine	.10		
Secondary Mineral - Small	.25 - .5		
Secondary Organic - Fine (wheat flour suggested)	.75 - 1		

Wood Sprite™

Ingredient	Amount in parts
Pitch Resin	2.5 - 3
Chalcopyrite or Pyrite - Small	.5
Aluminum - Large	1.5
Steel - Small	1
Paramagnetic Earth - Small or Large	.5
Dried Crumbled Sage or Chaparral - Small	.3 - .5
Citrine - Fine	.01

Process

Melt the pitch slowly over a heat source with no open flame. The fumes from melting pitch may be flammable. Don't burn yourself, wear gloves. Once the pitch is melted, Premix all the dry ingredients except for the citrine. Add the dry ingredients to the pitch and stir well. Then add the citrine. Spoon carefully into molds and allow to cool. You generally have a few minutes only before the mixture sets up once removed from the heat.

Charge with either sunlight or a charged water bath (or both) while cooling.

Comments

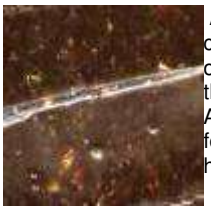

A lot of work, but well worth it. Strong connection to the earth, have gotten many obvious reactions from animals when gifting this kind of orgonite to natural energy centers. Also a nice kind to have indoors if protected form hot sun. Mixture will melt if exposed to high heat.

White Light

Ingredient	Amount in parts
Aluminum - Large	1
Titanium Oxide White Pigment	Enough to make resin opaque
Steel or Iron - Small	.25
Copper or Chalcopyrite - Small	.25
Resin	To fill molds
Catalyst	+50%

Process

Mix the catalyst Into the resin along with the pigment. The resin should come out bright white and opaque. Place the Large metal in the molds and sprinkle a little of the small metal over it. Place xtals if applicable and pour in enough resin to cover the metal.

Charge during curing with 741 Hz.

Comments

Produces a kind of MHD which is useful for repelling unwanted entities / energies. Also useful for clearing blockages. Energy tends to feel uplifting (as opposed to grounding) and somewhat astringent.

Chocolate Shine™

Ingredient	Amount in parts
Steel - Small or Large	1
Brass or Copper - Fine	.3
Paramagnetic earth - Fine	.3
Citrine Powder - Fine	.05
Quartz Powder - Fine	.1
Resin	1.25 - 1.3
Catalyst	+100%

Process

Mix all the fine ingredients together. Mix catalyst into resin and add fine ingredients. If the steel particles are large, then place them in the mold and pour the resin mixture over them stirring as you pour. If the steel particles are small, add them to the resin mixture and stir constantly as you pour the mixture into the molds.

Charge with 15Hz and / or Schumann frequencies while curing.

Comments

Cosmetically appealing and highly EM responsive HD or MHD orgonite. Good for TBS and HHGS as well as generators. Has a warm feel to the energy. Especially suited for work on Geopathic lines, ley lines, Curry / Hartman lines etc. Provided the paramagnetic earth of is sufficient quality, this general recipe has been proven to reduce EMF by conventional testing.

Ivory

Ingredient	Amount in parts
Copper - Fine	.05
Titanium Oxide Pigment	Enough to make resin opaque
Paramagnetic Earth - Fine	.05
Copper or Chalcopyrite - Small	1
Iron or Steel - Small	1
Selenite - Small	.3
Resin	2.5
Catalyst	+100%

Process

Mix all the dry ingredients together. Add the pigment to the resin along with the catalyst. Sift the dry ingredients into the resin, mixing continually, until you have an event consistency. You should have a slurry with the consistency of oatmeal.

Pour into molds and allow to set. This recipe will usually support the internal components at least somewhat, but is still thin enough to pour into complex shapes.

Charge with both high and low freqs while curing.

Comments

Produces HD orgonite that tends to exude a milky white color of orgone. Useful for applications in reiki healing hands radionic therapy body work etc. Useful for removing blockages and stimulating energy circulation. Orgonite tends to have affinity for human body and sunlight. Useful for active roles.

Water Baby™

Ingredient	Amount in parts
Blue latex paint with or without charged water added. Paint must be dried out and crumbled.	.3 - .6
Chalcopyrite or copper - Small or Large	1
Blue food dye.	10 drops per L of paint.
Kyanite Powder	.01
Turquoise - Large	At least 1 chunk per unit.
Resin	To fill molds

Process

The paint is a separate preparation that has to be done ahead of time. Mix 10 drops per liter blue food dye with paint. Then mix the kyanite powder into the paint. Then mix at least .01 part charged water to 1 part paint and dye mixture. Add hardener to paint and / or spread paint out on Wax paper to dry.

The paint has to be dry enough you can crumble it into pieces. It does not have to be fully dry as you will be encasing it in resin. Once the paint has dried enough, crumble it into pieces about 5-15mm dia. (1/4" to 1/2").

Mix the blue paint crumbs and the metal (copper) together. Add catalyst to resin and resin. Place metal mixture in molds and pour resin over the metal.

Use turquoise or blue glass as the secondary mineral.

Charge with the sound of running water while curing, and if possible with moonlight or other silvery blue light. In general, charge in with cool energy as opposed to hot energy.

Comments

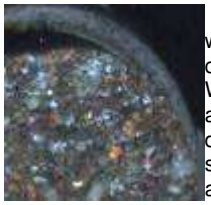

Produces MHD or HD with a strong affinity for water. Also can repeat the energy signature of charged water which was added to the paint. Waste paint hardener or other granular, absorbent material is useful to speed the drying out process. Generally the paint takes several weeks to fully dry, so I set a bunch on at time.

This kind of orgonite is pretty to look at if it comes out right, and it is well suited to water gifting. It also has the quality of not containing any ferromagnetic materials, which is useful for some applications. It is a bit less responsive to EM stimulation than other kinds of orgonite, but it works very well for charging water when placed in proximity to a glass vessel of water.

Orgonite and the curing process

In other articles, i have mentioned a few times that charging the orgonite while the resin is curing has a large effect. Here, i will go into that in a bit more detail. All information given here is based on my own experiments / perceptions, and/or things which other researchers / orgonite users / colleagues have confirmed. I am not a medical doctor, and you are responsible for your own discretion.

To start out with, not all organic components are not equally responsive to charging while the resin cures. Polyester resin, acrylic resin and pitch all demonstrate this property in significant degrees. The waxes seem a lot less responsive in this area, something which i attribute to the formation of crystalline structures within the resin while solidification takes place. Polyester resin, for example, is well know in conventional scientific circles to have significant electromagnetic attenuation properties. That means that it absorbs electromagnetic energy. Since energy is never created or destroyed and only changes form, the energy soaked up by the resin has to go somewhere, doesn't it?

After experimenting for a couple of years, i can comfortably say that the way orgonite is treated during construction creates **at least a 70% difference** in the finished product. In other words, by paying some attention to the thoughts, emotions, energies, ect to which the orgonite is exposed when you make it, you can generally get at least 70% more functionality than you would if you did not pay attention to these factors.

Now, i would like to point out that the beauty of orgonite is that you can get that 30% functionality, regardless of how you make it. It is not NECESSARY to charge the resin while it cures, it is an improvement. And in many cases, 30% functionality is more than enough to make a significant difference. But if the orgonite can be made yet more potent, why not do so? If you can optimize the orgonite to work with a specific ailment, or to do a chosen task, then it only seems prudent to do so.

There are, imo, 2 main ways in which the orgonite absorbs a charge / program while it is curing. One way is through the person making it, and the way that they influence the energy while handling the materials. Another way is to expose the orgonite to energies generated by various metaphysical tools while it cures. Obviously, both of these approaches encompass many different techniques. Both of these approaches can be used either alone, or in combination with each other. Myself, i generally use a combination of the two.

It is also possible for the orgonite to turn out with either a sympathetic or a counteractive effect. The frequencies used in the following description are just examples. So, if you expose orgonite to a hertzian frequency of say 15kHz, generated by a device of some kind, the orgonite will become more responsive to that 15kHz frequency. The fact that the orgonite is now more responsive to 15kHz can be applied in one of two primary ways, depending on what thoughts and intent you expose it to, or what other frequencies are present. If you expose the resin to 15kHz and leave it at that, the finished orgonite will tend to amplify the 15kHz frequency effects when stimulated by it. It will tend to produce that frequency effect as part of it's output, converting other energies it is stimulated with INTO the frequency effect of 15kHz. The same applies if you expose the resin to both a weak 10Hz signal and a strong 15kHz signal. It will tend to 'capture' the act of 10Hz being drowned out by 15kHz, and have that function programmed into it. Doing it that way, you are getting a sympathetic effect towards 15kHz.

But suppose you flip it around the other way. Suppose you expose the resin to a 15kHz signal, and at the same time give it a clear mental impression that you want to dampen out and get rid of 15kHz. If you do it that way, you will get a counteractive effect, in proportion to the clarity of the mental impression you give the resin. It will tend to respond well to 15kHz, but instead of amplifying 15kHz, it will dampen it out, and convert 15kHz into other energy 'colors' or frequencies. The same applies if you were to expose the orgonite to a strong 10Hz signal and a weak 15kHz signal. It would then capture the act of 15kHz being drowned out by 10Hz, and have that function as a 'program'.

In reality, the way that different frequencies interact with each other has arguably a bigger effect that the volume of each signal. There are frequencies that are harmonic to 15kHz, and they tend to boost it. There are frequencies that are discordant to 15kHz, and they tend to dampen it. So, both the relative strength of each signal and the effects of signals on each other produce an effect.

By default, orgonite seems to produce a sympathetic effect to that which excites it during curing. In other words, if you want to get a counteractive effect, you have to 'tell' it you want a counteractive effect. This, doubtless, is why some towerbusters have a greater effect than others. Many people are programming the orgonite with a counteractive effect to the tower's signals, whether or not they are consciously aware of it. Many other people are not, and so the orgonite is running at varying degrees of efficiency. Rather than criticizing, it is my hope that this will help people all around to improve their orgonite manufacture.

People who are already doing reiki, visualization, or other traditional metaphysical disciplines will find that whatever energy they put into the mixture will, to some degree at least, become a permanent part of the finished orgonite's energy signature. This applies, of course, whether or not a person is consciously using metaphysical discipline of some variety. Even if a person is not consciously directing energy into the orgonite while it cures, their thoughts and emotions, the state of their mind, the things they are thinking about while working with the materials... these all have some effect on the finished product. It appears to me (so far) that consciously directing your energy into the orgonite often produces a greater change in the finished product than not. The exception to this would be states of great emotional intensity. If you are in a state of emotional excitement, then a part of that emotional energy will be picked up and integrated into the orgonite.

So, if you are a person who uses prayers, affirmations, declarations, visualization, intent or the like, then you can program your orgonite with these techniques. One thing to bear in mind if using minerals other than quartz crystals is the kinds of jobs that various minerals are suited to doing. For example, if you are making orgonite and programming it to get rid of toxins in the body, then you could make that process either more efficient or less efficient, depending on what minerals you include. If you include minerals that have the effect of stimulating the body to release toxins, then the mineral and the program are harmonic. If you use a mineral that stimulates the body to absorb energy but program the orgonite with a purgative effect, then the result will generally be a bit less effective. In short, the orgone output spectrum of the finished orgonite is defined by a COMBINATION of the ingredients and the programming, so it pays to give a little thought to how you put those 2 factors together.

So what if you are making orgonite and you inadvertently put a bunch of nasty thoughts / emotions into it? Well, they WILL affect it somewhat, but not enough to reduce its effectiveness beyond the 30% line, in my experience. They will make it work less well, but not stop it from working entirely imo. One thing i have discovered is that say, for example, you think 'issue X is horrible'. well, you don't want the orgonite to enhance the horrible nature of issue X, obviously. But once you have thought that thought, it is difficult if not impossible to take it back. So give the orgonite a counteractive program with respect to issue X. Immediately think another thought, namely, that you wish to direct the healing / clearing properties of the orgonite toward issue X, and work on the problem. This produces orgonite that works specifically (counteractively) on issue X. Not a bad recovery from a little slip of the mind. Practitioners of radionics will likely be familiar with this concept, point being the concept is of course transferable to orgonite manufacture.

Another example. Some time ago i made some orgonite TBs which had a few flies fall into the resin while it was curing. I didn't think it that important, though maybe i felt a little sorry for the flies. The orgonite came out with a sympathetic effect towards houseflies. It was amazing to watch how they just couldn't leave it alone. They would be buzzing around the light bulb, and kept stopping and landing on the TBs, which i must admit i found rather annoying. But at the same time, others have reported success using TBs to get rid of problematic insect infestations, by including a sample of the insect in the orgonite. Whether they knew it or not, and i must assume they did, they included the intent that they wanted a counteractive effect. And they saw that the insect infestation was reduced. The difference between my TBs attracting the insects cast inside them, and their TBs repelling the insects cast inside them was simply the difference between a counteractive effect and a sympathetic effect. Again, those familiar with metaphysics will probably find this familiar territory.

Bearing that in mind, i am sure you will understand why programming the resin with the intent that you want to counteract the inimical health effects of the HAARP and GWEN towers is worthwhile. Also perhaps this sheds some light on why there exists such variance in the observable effects of TBs. Without the intent to get a counteractive effect (since if you live in area with towers the resin is exposed to the signal from the towers while it cures) you will get the cleansing effect in the 30% range. But if you add the simple thought that you want the orgonite to have a counteractive effect, you will get much more efficiency, up to several hundred percent improvement.

Rather than going into detail about how to do visualization or focus your intent, i will just say that your emotions are a big part of it. For example, if you are making orgonite to help your sore back, then you want to make sure that the orgonite is programmed by imagining a healthy back, free from pain. Or perhaps imagining a sore back turning into a comfortable, pain-free back. You do not want to program the orgonite with you wondering if it will work. That saps efficiency. So if you have doubts, well that just means you are human. We can not always instantly finish up with our doubts or uncertainty. But we can put them out of our minds for a few minutes. And in those few minutes when we have put our doubts out of our mind and have stopped thinking about them, that is the time to do your intent or programming or visualization. For posterity, the same thing applies with prayers, affirmations, declarations, etc., with or without orgonite.

Ideally, you want to charge the orgonite for the duration of time it takes to cure. This may or may not be possible. I have found so far that with the mental impressions, it is best to do it at least 3 times. Since polyester resin actually continues to cure for a long time after it has solidified, you generally have about a 3 day window of opportunity to charge the resin, though the initial period when it is solidifying appears to be the most critical. Once the plastic has cured, you cannot reprogram the resin, but you can reprogram the crystals embedded within it. You can also direct the energy that the orgonite is producing to a given task with your intent. Directing the output from the orgonite is different than charging the resin. Using your orgonite's energy output is giving the output a job to do. Charging the resin while it cures is defining what the output will be.

When using a machine to program the orgonite, depending on how strong the machine is, a ten to 15 minute period of exposure is often enough to produce an effect, but where possible i often give it up to 72 hours of exposure.

If you have a radionics machine, succor punch, pulser, wand, or some other kind of intent amplifier / orgone generator, you can use that to either charge the orgonite or enhance the mental impression (intent) that you give the orgonite. You can also set your favorite xtal (if you work with xtals) near it while it cures and use that to charge the resin. Varying methods of charging give varying degrees of success. Any kind of attention to the charging process will produce a more effect than none, i find.

One way you can charge the resin is to devise some means of connecting a quartz crystal wrapped with a mobius coil to the output of your pc sound card. I have a bit of info about one such device on the ring generator page (http://www.littlemountainsmudge.com/ringgenerator.htm). Even a smaller device such as a succor punch, connected to the output of a pc sound card, provides a very versatile apparatus for charging orgonite. If you are unable to set up something like that, then even using a tone generator and exposing the orgonite to the sound produced will charge the resin. I am amazed at orgonite's ability to accept a program and repeat it almost indefinitely.

Roberto Forcen, at his site Voicesync (http://www.voicesync.org/), has some very impressive sound analysis and sound generation software. One of his programs that i have worked with a fair amount is called mineral sounds. In his own words, it 'Generates resonant three octave compound tones from a list of more than 3000 minerals. Tones are generated using powder X-ray Diffraction parameters.' What i can say is that when i fist started playing with it, i was very impressed. When i run the sounds from this program through my big mobius-driven orgone generators, the energy produced is very similar in 'feel' and in 'color' to the energy from the minerals themselves. Aside from using it to program orgonite with the effects of a mineral i would like to have, but don't have on hand (not quite the same as having the actual mineral in the orgonite but close if you let it run several hours), i use it to compliment the ingredients of the orgonite. For example, if the orgonite contains steel, copper and quartz, i will open multiple copies of this program and charge the orgonite with the sounds of iron, copper, quartz, and gold. This gives the orgonite a lot more power when it is finished.

Sunlight is another wonderful thing to expose the resin to while it cures, and so is moonlight. These two methods of charging the orgonite are already in widespread use. Especially with exposing the resin to sunlight, you will often notice a difference in the visible color of the resin when it has cured, indication that you are in fact doing something and this is not all hocus pocus... ;)

Astrology also has a certain amount of influence on the orgonite, though not one with which i often work. Using a large orgone generator to charge it can drown out some of the astrological effects, it would appear. One batch i did during the harmonic concordance came out very nice, and it appears to have captured some of the intense catalytic energy of the harmonic concordance.

Another way you can do it is to pour the orgonite outdoors, preferably in contact with the earth, in a clean vortex or ley line. This way tends to both stimulate the vortex or ley line and program the orgonite with a permanent link to the area in which it was poured. Alternately, you can add some dirt or wood chips from the vortex to the orgonite and pour it elsewhere. I have used this technique to link together a few different medicine wheels in the area. Possibly, it could be used to create and/or divert energy lines in the earth's body, leading to or from the vortex.

While i was proofreading this article, i phoned my friend of several years Chris Gozdzik from diviningmind.com (http://www.diviningmind.com/), and asked him if he thought i had left out anything glaringly obvious. He reminded me about linking, which is another way that you can do several things with orgonite, including charging it while it cures. Basically, if you link the orgonite to the energy from an existing large source of energy, either by a sample of the source or clear visualization, then the orgonite will not only pick up the energy from the existing source as a program, but will also have a permanent link to the energy source. Thanks, Chris :)

And 2 final notes- If you are building a ring generator, power radionics machine, or other large power-driven orgone generator, first decide what frequencies you plan to use to drive it with. At least pick out a few of the ones you plan to use a lot. Then, charge the orgonite for the generator with the frequencies it will be running at. This increases power in the finished generator. Example, the pulsers run at 5075Hz and 32kHz, so whatever other programming i give them during curing, i give them a good zap of these two frequencies also.

Many of us have noted that orgonite, once cast, sometimes takes a certain amount of time 'start working'. Charging during curing dramatically reduces the amount of time that it takes a device to 'start working'.

Well, that about takes up the time i have today, but here are a few of my favorite hertzian frequencies for charging orgonite, and some the effects i have observed with them.

741Hz (sine wave) - This is one of the solfeggio tones, and is quite potent imo. When i first started using it i immediately felt a buildup of energy and subsequent release in the solar plexus and heart chakras. It may be a bit intense for some people at first, but they should rapidly acclimatize. It appears to have the effect it is reported to by others, that of assisting with finding the solution to a problem. I use it a fair amount these days, and thanks to whomever it was that posted about it on the yahoo cloudbusters (http://groups.yahoo.com/group/cloudbusters/) forum some time ago.

528Hz (sine wave) - This is another one of the solfeggio tones, and it has proven useful for me in manifestation.

5075Hz (square wave) - A frequency i chose myself for use in the driver circuits of the pulsers. It tends to have a grounding, stabilizing effect. I use it as a multipurpose frequency to drive generators, and to help me calm down when i get cranky ;)

32kHz (square wave) - Another frequency i chose for use in the pulsers, tends to have the opposite effect than 5075Hz, but meshes well with 5075Hz. I use it for removing blockages in body work, for shielding from energy attacks, and for an aid in the mental 'reach upwards' involved in meditation and remote viewing. When set to a frequency higher than 20 kHz, NCH toner produces a lower harmonic of target frequency. Since square waves especially produce many harmonics ranging up and down the scale, imo you are still getting this frequency (or one close to it) as a harmonic when you use a pc sound card connected to a coil and xtal.

15Hz (square wave) - The frequency many people use to drive their succor punches (http://www.educate-yourself.org/). It tends to have a solid, relatively stable effect. Of the low frequencies, it is one commonly used today. It is potent, though imo benefits from the company of a higher frequency. Useful for shielding from energy attacks. Also, if you have a 15Hz driven SP, then charging your orgonite with 15Hz will increase the responsiveness of your orgonite to your SP.

32Hz/31.7Hz (square or sine wave) - A frequency i first heard of from (i believe) Bruce Stenulson (http://www.stenulson.net/energy/doras.htm). It has proven very useful as an aid in programming quartz crystals. Because of it's tendency to carry programming information / intent from the user to a quartz crystal, it is useful imo for intent amplification, and as a general purpose frequency for driving mobius-powered orgone generators.

68.635kHz (square or sine wave) - This one of the Hodowanec frequencies. Now, since the upper end of the sound card is well below this frequency, i am not actually getting this frequency when i put it into the NCH toner (http://www.nch.com.au/tonegen/) program that i use as a signal generator. When set to a frequency higher than 20 kHz, NCH toner produces a lower harmonic of target frequency. Since square waves especially produce many harmonics ranging up and down the scale, imo you are still getting this frequency (or one close to it) as a harmonic. When run through the nch toner, and a mobius/quartz driven orgone generator, it produces an emission of orgone that is almost all in the violet range. Violet orgone is both soothing and cleansing, good for soul-searching as well as healing.

EHD Orgonite – Another step

As mentioned earlier, one can produce MHD or MD orgonite either by allowing the particle size to determine density (as in using larger, curly metal shavings, such as one would find in the average TB) or by adding the organic to the mixture in a particulate form. In fact, when making HD or higher densities, you basically have to add the organic in a particle form, along with the metal, since there is not enough space between the metal particles (when they are really small) to produce a ratio close to 50/50 between the metal and organic ingredients. Some time ago I began going a step further and using metal (fine and superfine particles) that would ordinarily produce HD and adding enough organic to bring the density of the orgone matrix material down to MHD or MD. The material produced this way has some very interesting differences from the standard TB / HHG mixture of curly shavings and polyester resin.

It appears that the matrix thus derived has a lot more capacity to store orgone than regular MHD. A given mass of EHD (Expanded High Density) orgone matrix material will have a slower rate at which the orgone flows through it than the same mass of regular MHD, and it will have a higher overall orgone field strength than the same mass of regular MHD, even though the density and the resistance afforded to the orgone as it flows through is about the same. I attribute the slower flow rate of EHD not to a difference in resistance from MHD, but to the fact that adding the organic element in both liquid and particle form increases the overall energy storage capacity of the matrix somehow. This effect is observed much more when superfine metal particles are used along with fine metal and organic particles, as opposed to using fine metal and organic particles alone.

After experimenting with several different organic particles, I have settled on flour as preferred material for the time being. One could use wheat flour, wood flour or other finely powdered absorbent organic substance. The particles should be absorbent enough that they combine with the polyester resin to produce a thick liquid the consistence of stiff pancake batter. The organic powder is mixed into the resin along with catalyst initially. The metal is added last, beginning with the superfine particles and finishing with the fine particles. For a readily available source of superfine metal particles, I suggest cheap metal spray paint. Just add extra catalyst and spray the paint directly on the surface of your resin in the mixing container. Another source of superfine metal particles are the bronzing powders and other metal powders sold by crafts stores for plating.

I have noticed that especially when the organic material is a fibrous material, the orgone matrix material both takes much longer to absorb a charge during curing, and absorbs much more of a charge than regular MHD. It absorbs a program, intent or energy signature with much higher fidelity than regular MHD. It also takes longer to accumulate enough energy to begin working. Regular MHD that I make is usually finished the curing process and has ‘come online’ by about 3 days after casting. EHD seems to take until about 5 to 7 days after casting to be finished the curing process and ‘powered up’.

EHD is also efficient for use in power driven orgone generating devices such as powerwands and ring generators and pulsers. It also affords the cleaning action of converting unhealthy orgone to healthy orgone, but the charging and curing process is much more determinative of the end result, in terms of cleaning capacity, than with MHD. In General, since it takes so long to store a charge and stores such a high potential of orgone, the energy it is subjected to while curing are much more an influence on the finished product than with regular MHD. I would not recommend making EHD orgonite without working in a clean energy environment. Provided you can supply a clean environment or preferably a clean and charged environment in bioenergy terms, EHD will produce TBS that have a higher output that regular TBs and are more ‘ergonomic’, they feel a bit more alive in the hand. If you make TBs from EHD but do not have a clean energy environment to cast them in, then you will get TBs that are not very efficient at doing anything until you pick them up and play with them, at which point you will still likely be able to feel a strong surge of energy when you hold them in your hand.

For personal orgone devices meant to be held in the hands or carried in a pocket, I now prefer EHD to the other recipes I formerly used.

EHD lends itself not so well to making conventional towerbusters which are designed to be high flow filter cleaners. It lends itself very well to making power driven generators or to making TBs and HHGs for indoor use and human contact. It is like taking a snapshot of an energy field (the field in which it cures), and then it will sit there and broadcast an image of that energy field, continuously and with respectable intensity. It will covert other forms of energy into the energy signature (that snapshot) that it has as it’s output. So, if you can handle the programming and charging end of it, it will turn out much more potent per cubic inch than regular MHD. Instead of producing devices which are simple filter/cleaner devices, making TBs with EHD produce SELECTIVE filter devices, in that they selectively convert orgone into the orgone signature they have as their output. That’s why the charging / curing process is so much more critical with EHD.

Though it produces an orgone energy field of higher intensity that MHD, EHD has an output that is much less chaotic than MHD, and the chaotic energy fields are much more contained within the physical matrix than with regular MHD. With regular MHD, the wave fronts of orgone energy collide within the device as they are reflected by curved surfaces which are relatively close together. The waves of orgone energy inside EHD orgone matrix material react less directly with each other, especially the waves reflected by the more widely spaced fine particles. It’s like instead of the waves smacking into each other up close, the matrix has to build enough pressure until the energy ARCS across between the more widely spaced fine particles. All the while, the superfine particles afford the waves the opportunity for up-close collisions but to a lesser degree, providing a stable basis for the matrix, if that makes any sense to you. For this reason, EHD made without superfine and fine particles will not work very well at all.

The mixture should be thick enough that the fine metal particles (say between .5 and 2 mm dia.) are fully suspended in the resin and do not settle out at all. The mixture should be just thin enough that it smoothes itself off at the surface when vibrated, but it should be thick enough that you have to vibrate it to get it to smooth over on the surface. You should be able to count 20 to 50 of the suspended fine metal particles in a square inch of surface area. There should be enough of the superfine metal particles that when wet, the mixture appears to be slight shiny and metallic. When the mixture cures, the surface will become dusty and opaque but a bit of sanding and a clear coat takes care of that. The mixture also takes longer to chemically cure than regular MHD, especially if copper or iron is the superfine metal. Extra time should be allowed for curing. EHD to be exposed to the elements should be protected with a clear coat of spray lacquer or poly resin.

So, in short, as long as it is programmed by a competent energy worker, it works really good for TBs and HHGs designed for human contact as opposed to agricultural and other nature gifting or tower busting. It also works pretty well for generators which will be excited in some active way while in use. And, it absorbs a charge of higher potential and with higher fidelity during the curing process.

Simple HHG instructions Item:	Quantity per HHG:
- Double terminate Quartz Crystal	- 5 (or 1 DT and 4 STs)
- Polyester Resin & enough Catalyst to cure it	- About 6 Ounces
- Metal particles	- About 5 Ounces of metal particles
- Suitable container to use for a mold	- 1 (min. 4" dia. plastic funnel)
- Small Jar or Can to sit the funnel in (hold it upright)	- 1

Note: While there are many other suitable vessels which could serve as mold for this device, I have used a plastic funnel for this example as it is readily available in most places and relatively durable. In any case, the same technique of construction applies regardless of the container used for a mold, which can be in the shape of a pyramid, cone, cylinder or hemisphere, so long as it has a volume at least great that of a as a cone 4" wide x 4" tall. Presently, pyramids and cones are the shape this device is most often built in.

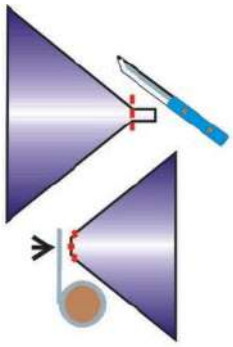

1. - Cut the tip off of the funnel and tape over the hole at the small end of the funnel with aluminum tape (preferable) or parcel tape. Electrical tape, duct tape & masking tape do not work as well for this as aluminum tape. In some way, plug the hole so that the resin does not leak out.

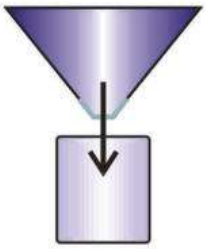

2. - Sit the funnel in the jar so that it is upright and more or less level.

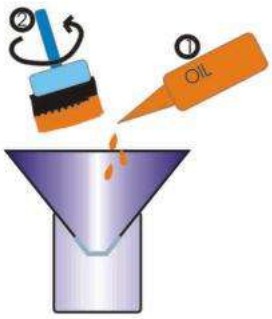

3. - Coat the inside of the funnel with a thin layer of vegetable oil, to keep the resin from sticking to the mold (funnel). Wipe away the excess oil with a brush or clean cloth.

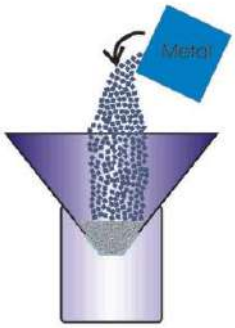

4. - Put about 1" of metal particles in the bottom of the mold.

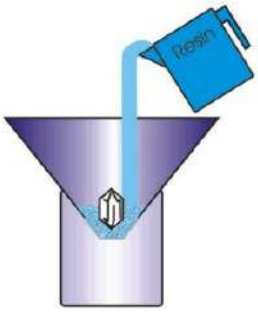

5. - Place one of the Quartz crystals in the tip of the mold, so that it is upright as shown. This one really should be a double terminate, but if you only have a single terminate, put it with the point towards the tip of the funnel. If it is a double terminate, the best tip of the crystal should be pointing towards the tip of the funnel, where you covered the hole with tape.

Mix enough resin and catalyst (be sure to mix well, min. 1 minute of mixing) to come up level with the surface of the metal filings. Pour the resin in and let it run down into the metal filings. Gently shake or tap the mold to release bubbles.

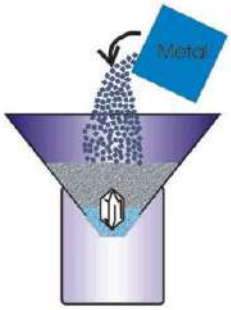

6. - Put in some more metal particles, enough to fill the mold about 1/2 to 2/3 full.

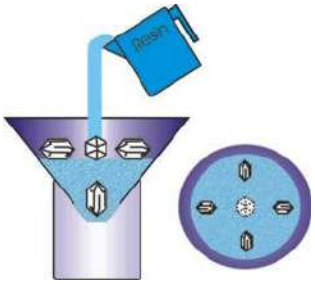

7. - Place the other 4 Quartz crystals on top of the metal filings as shown. They should be arranged like the spokes of a wheel. The better points of the crystals should be pointing towards the outside of the mold. If you have to, you can use single terminate crystals here, and put them with the points either facing in or out (facing out is preferable). Mix some more resin and catalyst, and pour in enough to come up level with the surface of the metal filings again. Gently tap or shake the mold to release bubbles, and let the resin run down into the metal filings.

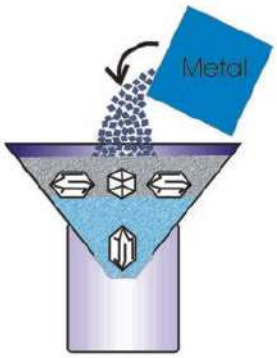

8. - Add some more metal filings, enough to almost (but not quite) fill the mold. Leave about 1/4 inch of empty space at the top of the mold as shown.

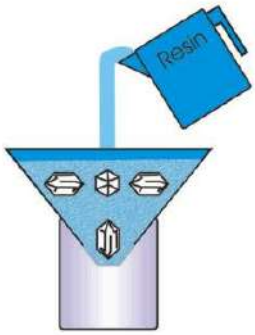

9. - Now, pour in enough resin to finish filling the mold. Let the resin run down into the metal filings, adding a little at a time. Use enough resin to completely cover the metal filings, so that there is a thin layer at the top of the mold which is only resin, no metal. The layer of resin only should be about 1/4" thick. Take a moment to adjust the molds so that they are more or less level at this point.

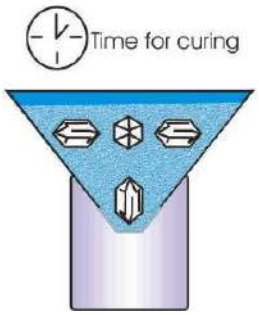

10. - Allow the resin to cure. Keep it warm if possible, cure in a well-ventilated area, and if possible, expose the resin to sunlight while it is curing. If you have a tone generator or other sonotherapy (healing using sound) device, then you can expose the resin to that as well while it cures.

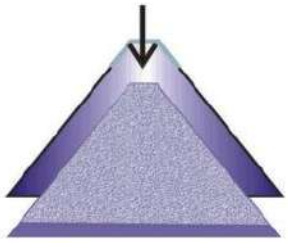

11. - Remove the molds from the jars, turn them upside down, and give them a smack to release the brand new HHG you just made. If the mold sticks, you can either use a thin bladed knife to push in between the mold and the resin, or you can try spraying penetrating oil around the edges where the mold meets the resin. Dropping it on the floor sometimes works, but sometimes it breaks the resin. There are many ways to modify an HHG for enhanced effects, but the basic model shown above will work just fine the way it is. This is one modification which is easy to perform when you are casting the Hhgs. Use an Amethyst point instead of a DT Quartz crystal for the vertical crystal... add a copper SBB coil to the base of the unit, just at the edge of the

metal filings as shown... add a small piece of hematite, pyrite, or a small permanent magnet to the SBB coil as shown (generally I put the N pole of the magnet facing toward the tip of the HHG)... and mix some crushed quartz, crushed Amethyst, or crushed Pyrite in with the metal particles before you cast it.

Simple TB Instructions Item:	Quantity per Tower Buster:
- Quartz Crystal	- 1
- Polyester Resin & enough Catalyst to cure it	- About 3 Ounces
- Metal particles	- About 3 Ounces of metal particles
- Suitable container to use for a mold	- 1 (min. volume about 4 ounces)

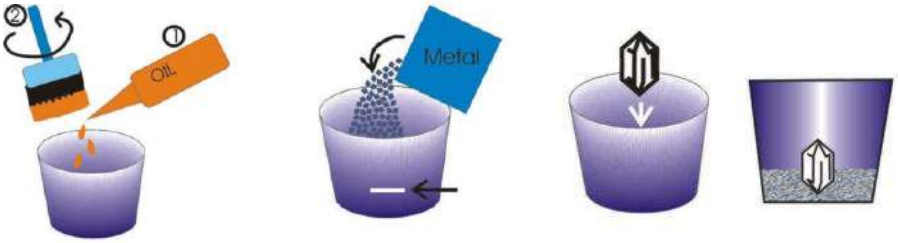

1 - Line the containers you will use for molds with a light coat of vegetable oil. This prevents the resin from sticking. Wipe the excess oil off with a brush or clean cloth. cover the surface of the mold evenly.

2 - Put about 1" of metal particles in the bottom of each mold.

3. - Place the quartz crystal in each mold, using the metal filings to hold it in position. put the crystal in the center of the mold, and if the crystal has a good point on it, most folks put the point towards what will be the top of the unit.

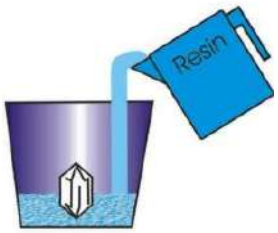

4. - Mix enough resin and catalyst to fill each mold level with the metal filings you have placed in the bottom. Pour enough resin into each mold to come up level with the top of the metal filings. Make sure to mix the resin and catalyst well (mix for about 1 full minute) before you pour it into the molds. Allow the resin to run down into the metal filings. Tap the mold lightly or stir carefully to remove bubbles.

5. - Add another inch or so of metal filings to each container, enough to cover the crystal.

6. - Mix and add enough resin to cover the metal filings you have placed in the molds. It will not harm the function of the device if some metal filings stick out the bottom, but it is a good idea to use enough resin to fully encase the metal filings. Allow the resin to run down into the metal filings. Tap the mold lightly or stir carefully to remove bubbles.

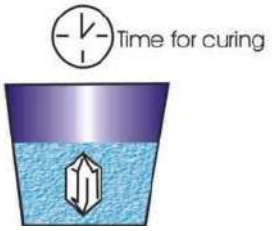

7. - Allow the resin to cure. Keep it warm if possible, cure in a well-ventilated area, and if possible, expose the resin to sunlight while it is curing. If you have a tone generator or other sonotherapy (healing using sound) device, then you can expose the resin to that as well while it cures.

8. - Turn the molds upside down, and give them a smack to release the brand new TB you just made. If the mold sticks, you can either use a thin bladed knife to push in between the mold and the resin, or you can just tear the paper away. Dropping it on the floor sometimes works, but sometimes it breaks the resin. It will not harm the function of the device to leave the paper mold on, but it may be more aesthetically appealing to remove it.

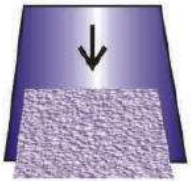

Mobius coils and quartz crystals

Many people have also lately begun using devices in conjunction with orgonite or not, which employ a mobius coil and quartz crystal. The coil can either have it's leads simply shorted together, or, more efficiently, be connected to a signal generator circuit or radionics machine. Doing this is like turbo charging your crystal.

One name this kind of device has become commonly known by as a succor punch, this is the name don Croft gave to it when he made it public domain. Since then, many variants of this device have been adapted for use in general metaphysics as an intent amplifier or powered wand. There are several different ways to make a mobius coil, the basic concept is that you want to have magnetic fields canceling each other out by intersecting at 90 degrees. This is accomplished by winding the coil in such a way that the wires cross each other at or close to 90 degrees. Then, when a current is put through the coil, either by induction of by direct stimulation with a signal generator (a common circuit used for these coils is the Beck or Clark or Croft style 'Zapper' devices invented for bioelectrification) the magnetic fields created by the wires cross at 90 degrees and cancel each other out. When the magnetic fields cancel each other out, they are converted into scalar energy. High voltages are not required in order to produce orgone emissions form the crystal, and could be dangerous. Low voltages are commonly used for this type of device.

The scalar energy then excites the crystal and the crystal produces much more orgone energy output that it would without the coil. The frequency used to stimulate such a device is often determinative of the exact effects, but any signal put through it will produce orgone energy output form the crystal as well as RF emissions. This basic device is at the core of a new generation of rife-style devices, since a pulsed orgone/scalar wave is more efficient at stimulating the human body that either radio waves or ultrasonics. Audio signal will also be translated into orgone/scalar waves when put through this type of coil, and people who use sound therapy will find that inserting this device into their apparatus markedly increases the effects. On the following pages, I have included the instructions for making the style of mobius coil that I use most.

With regard to using an audio signal instead of a simple hertzian frequency to drive this kind of coil, it appears that the underlying emotional current of the audio signal is translated into a pulser orgone / scalar emission. This is quite useful for things like sound therapy and manifestation. However, one should exercise care in the choice of audio signal used, I would stay with the classical music for example instead of heavy metal hahaha. In contrast to a TB or HHG, devices like this can do great good or great harm, depending especially on what kind of intent one is projecting into the device (which intent will be picked up and amplified by the crystal) and what frequencies are used to drive the device. Some frequencies that I know are safe to use are (in Hz) 15, 32, 741, 5075, 5100, 15000, 32000, and 68635. This device is at the core of the large orgone generators I use to charge and program orgonite while the resin is curing. There is a lot of information available on the web about the biological effects of different hertzian frequencies, especially with the Royal Raymond Rife crowd. A device like this will afford a low cost, low – tech, but highly functional output for a Rife style treatment system, without requiring the use of high voltage, plasma tubes, or expensive function generators, since it can be driven by the audio output of a home pc, substituting software for the function generator generally used to drive Rife machines.

As for the waveforms being used to drive the coils, bear in mind that using a frequency to drive a mobius coil has slightly different requirements than just using the properties of a sound. There is a reason that most Zapper circuits used to drive these coil employ a square wave.

When using a frequency for driving scalar producing coils, most of us have generally gotten our minds around the concept that we want to have magnetic fields canceling each other out, so they can be converted into scalar potentials and scalar waves. Well, another concept which applies is magnetic flux. The more rapid the magnetic flux, the more scalar energy you are going to coax out of your mobius coil. Magnetic flux is what you call it when you have a magnetic field that is changing.

Now in a waveform, when you look at that little wavy line, think of it as a line traced by something bobbing up and down, perhaps a pencil if you prefer. And the magnetic field is changing as the pencil goes up and down, understand? As the wave passes by you, the pencil traces it's path and bobs up and down in time with the highs and lows of the waves. How high the pencil goes up and how low the pencil goes down is called amplitude. How long the waves are is called frequency, as in 'how frequently does a wave pass by you' in a given time. The base unit of time used to measure this is the second, and a Hertz (Hz) means "waves per second".

so... a sine wave, which has a smooth and equal curve... work great for some applications where you are just using the sound. It also works to generate scalar waves in a mobius coil, but not as efficiently as a square or sawtooth wave. One difference is that a square wave produces more harmonics in the circuit than a sine wave does. In some cases a sine wave is therefore less efficient in terms of input power to output power, but it is more pure and produces a more ‘pure tone’ which is advantageous in some cases. The magnetic flux is not very abrupt with a sine wave.

For driving mobius coils, a square wave works best of the ones I have experimented with. See, in a square wave, the pencil does not go smoothly up and down (like it does in the sine wave)... it sits still for a little while, and then it jerks up, and then it sits still again for a while and then it jerks down.

And therefore the magnetic field changes very suddenly, that is to say the magnetic flux is much more abrupt in a square wave than in a sine wave. A sawtooth wave, or a triangle wave... is kind of in the middle. (between square waves and sine waves). A sawtooth wave is far better to use in a mobius coil than a sine wave, from my testing so far. The sine wave produces energy that is much more mellow. You have to crank the power up quite a bit to get similar effects to a square wave.

Triangle waves also will work, but a sawtooth wave seems to work a bit better than a triangle wave. Also, if possible, the leading edge of the sawtooth should not be too spiked. I suppose that phi in relation to the amplitude of the wave would be a good height for the spike at the leading edge of the sawtooth wave, but I cannot say for sure at this time. I do know that imo judging from the amount of energy they produce when put through the same device, square waves are best, followed by sawtooth, followed by triangles, followed by sine waves

Tachyon braking, as it applies to scalar wave generation, is basically a fancy way to say that when you are generating scalar waves in a coil, there is also something else happening. See, there is in the aether an infinite potential of scalar energy which already exists (as opposed to the scalar energy you are 'generating' by converting em fields into scalar energy). When you take magnetic energy and convert it to scalar energy, you also tap into that aether potential and draw on it a little, adding the scalar energy from the aether to the scalar energy you have just produced with your coil.

This in fact is the basic working principle of the majority of the 'free energy' devices out there. That is how you appear to, and in fact do... get more energy out that you put in, because you are tapping on the aether and drawing on it. The 'tachyons' (little bits of energy, or particles in a high energy state, depending on the way you want to look at them) are subject to a process called tachyon braking. They 'brake' (slow down) and change state into something else. From a metaphysics perspective, the energy reduces it's vibratory rate and therefore manifests as another, lower form of energy, which appears to pop out of nowhere. Rampa, Cayce, and a jillion others refer to this in metaphysics teaching, the slowing down of energy to produce effects..

So then if you are trying to get electricity out of it, you want the tachyons to pop out of nowhere as electrical potential. But, if you are only taking the process as far as generating scalar waves to excite quartz or orgonite, then the tachyon breaking just makes your mobius coil appear to be more powerful than it actually is hahaha because the scalar energy produced by tachyon breaking adds to the scalar energy produced by em fields canceling each other out in the coil.

The more abrupt the magnetic flux is, the more scalar energy you draw from the aether and add to the scalar energy you are generating with your coil.

First - Make yourself a "mobius Cable" to wind the coil from. While you can wind a mobius coil from single strands of wire, it certainly seems to be a lot more potent when you use a cable made in the manner described here to wind the coil from. Take a length of wire, and double it back on itself twice as shown to the right. Pull a little slack out at the ends of the wire, this will be the leads of the coil when it is finished. You should leave yourself at least 2" for leads, and it is a good idea to give yourself 6" or so, you can always trim the leads to the required length when the coil is finished. It is much easier to use a drill to twist the wires than doing it by hand. Run the drill in reverse and you will get a clockwise twist to the cable. I recommend that you wind the coil itself clockwise also.

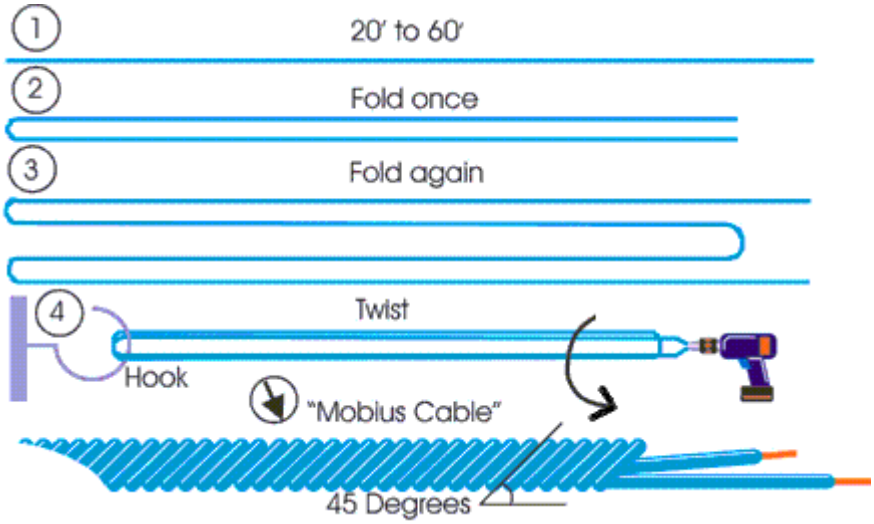

1. - Starting with the end of the cable which does not have the leads, make a circle in the clockwise direction about the size you want your finished coil to be. You can wind the coil around a core (xtal for your SP) or you can wind the coil by itself if you are using stiffer wire.

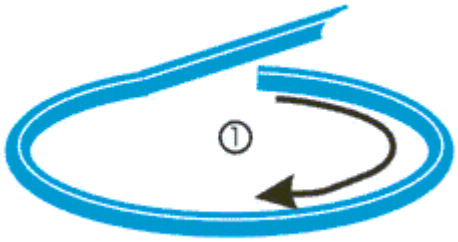

2. - When you complete the first wrap, feed the wire through the center of the circle so it wraps around itself in the clockwise direction as shown. Use a little glue (hot melt or silicone preferable) to hold the wire in place where it crosses over itself.

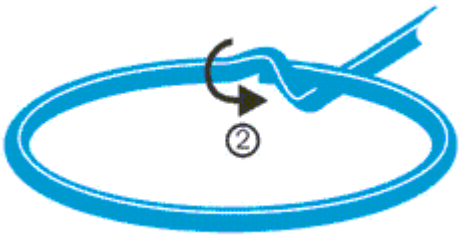

3. - Start winding the wire around the circle in the clockwise direction again.

4. - Go around the circle about one third of the way, and wrap the cable around itself again, just like in step 3.

Go around the circle another third of the way, and do the same thing again. You should have 3 wraps around the cable for each time you go around the circle.

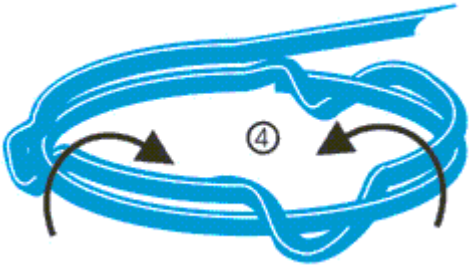

5. - Continue this way, repeating step 4, until you have used up all of the cable. As shown to the right, stay on the same side of the previous wrap with each new revolution.

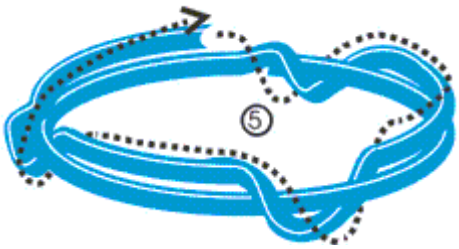

The 'knots' will run together.

When you are finished, use a little glue to hold the end of the cable in place.

The coil should look like this when you are finished.

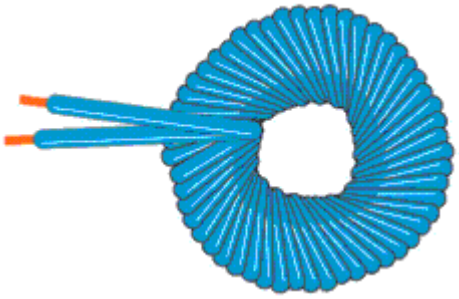

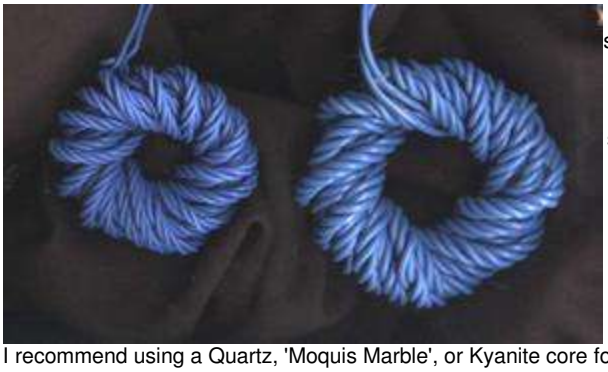

Hopefully, the pictures will be of more use to you than the words, as it is really quite simple to do, just a little cumbersome to try and explain in words. Basically, you just keep wrapping the cable around itself (clockwise) as you go around the circle. With a little practice, you will find that the windings form a pattern, and if you make a mistake it will be obvious as it does not fit the pattern. This coil tends to hold its shape better than the single knot style, and I generally just wind it by itself, not on a core. You should measure the diameter of the object you wish to place in the coil as a core when it is finished, and start with a circle a little larger than the diameter of the intended core.

I recommend using a Quartz, 'Moquis Marble', or Kyanite core for mobius coils, as the energy generated by a mobius coil (scalar waves) can be biologically disruptive when in its raw state. This information is primarily intended for those who wish to use mobius coils as a means of exciting Quartz crystals or ORgonite, and you are responsible for your own safety. By making this coil you agree not to hold me responsible for any damages your experiments may cause to persons or property. Mobius coils generate scalar waves. Scalar waves can interfere with and/or damage electronics when high voltage is put through them. For the purposes of ORgone research, low voltages are sufficient to drive mobius coils.

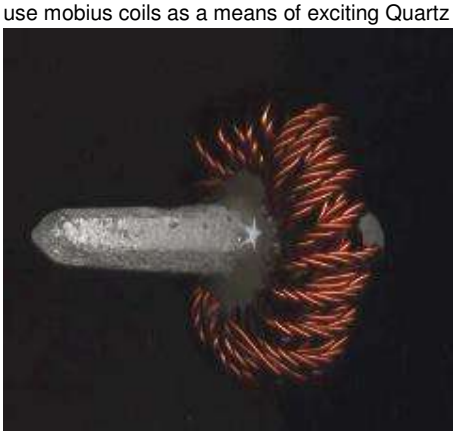

High performance – simple construction orgone generator – the Ring Generator

The design illustrated here is crude in execution and simple in construction. That's the point. My later versions of this device are more evolved than the one illustrated here, but I want to emphasize clearly that a device like this will work really well if you put it together right. This was my main generator for some time. I have posted the design here so that anyone who wants can have heavy-duty orgone generation capability without having to pay for a professionally built unit. It has been my experiences that the do it yourselfers will buy what they want to buy and build what they want to build anyways. A professionally built unit has many refinements over this crude design, but if you wanna do it yourself, here is a way to get a kick-ass if unrefined machine from stuff you probably already have... for about 50 bucks US, not counting the cost of the xtal. Interested?

This is a generator design I have been using for some time now. The design given here is highly adaptable, and can be modified to suit your needs. The pics here are from the first one that I built, and I used it for about 8 months for various things, with great success. The versions of this design I am using now are larger and more refined, but the pics shown here are the actual device which I used as my main generator for several months. In fact, the device is simple enough that it may be somewhat anticlimactic for you when you see how it's made.

The main things that I used this device, and continue to use devices based on this design... for, are as follows:

1- Heavy duty radionics applications, I.E. using the generator to send energy to persons or other entities through the Aether. Have done healing work, remote influence of persons and events, and in one case used this exact device to cut through the spells of a 'nameless' but well-known metaphysics practitioner like a hot knife through butter. Do not ask me for further details about who and when and why, because I will not provide them. It is immaterial. What matters is that the device works. I use the device for some of the radionics undertakings that require a lot of juice but not so much finesse. Finesse comes with refinement of the design and user skill.

2- Heavy duty orgone generation requirements, I.E. weather manipulation experiments, charging of water or other material, or psionics / intent amplification. You will have to figure out how to do that yourself, which if you are familiar with metaphysics should not be too difficult for you. The only input to it from you is by your intent, but you can reach out with your mind and direct the energy from this device same as with any other orgone generator. The frequency used to drive the device makes a lot of difference, and the use of select frequencies or audio signals to achieve desired results is a main aspect of using this device.

3- Charging and programming orgonite while the resin is curing, or cleaning, charging and programming quartz crystals. This use is the main reason why I am posting this design instead of limiting myself to offering much larger and more refined versions of it for sale. In due time I will come out with a production model of this device, but in the meantime it can radically improve the quality of orgonite made by the home orgone crafter. The production model of this device will contain much more orgonite that the one shown here. Pulsers can be used to charge resin while it cures as well. This device is a lot more powerful than a pulser, but less user friendly. Not everyone is going to be making enough orgonite to get their money's worth out of a unit like this when I decide to start selling the, but most people are definitely going to get their 50 bucks worth of use out of a homebuilt unit like this if they make much orgonite. Again, Pulsers, Powerwands and SPs are PORTABLE and therein lies one of their main beauties. This device is not portable, but rather requires both a stationary setup and the input of electrical power, and well as a home computer and an old stereo amplifier to drive it. This device offers more flexibility as well in that you can easily change out the core xtal for pretty much anything you want. Some materials may not be especially healthy for you when you expose them to scalar waves, and you are responsible for your own decision to make and use this device. Depending on how much voltage you put through it you may or may not harm electronics in the area. I have found that relatively low voltages on the RingGen suffice.

Some shots of a Ring Generator built by a man named David in New Jersey.

This is what you need to construct this device:

- 30 feet minimum of 18 to 15 gage copper wire.

- One large quartz crystal. There is a picture to the right of the xtal I used for the device shown. It does not have to be a nice DT like the one I used, but it should be about that size. In a pinch, you can also use several; smaller xtals together to get about the same amount of xtal mass. I got this xtal from ZSL, a generous gift on his part. He got it from the crystal man (in Canada). Another good place to get xtals is from revted (in America).

- 6 Plastic binder straps.

- Some aluminum tape.

- Enough stuff to make at least 1 liter of orgonite.

- The rings from 2 mason jar lids.

- A small shelving unit made from metal mesh of some kind. I used an old LP record rack, flipped upside down. You could make one from pieces of window screen stretched across a frame, or see what you can find in your garage or the second hand store. It should be a shelf that has the individual shelves made out of a metal GRID or SLATS, so that there is an open mesh, not solid pieces of metal. On the next one I make, I will probably use copper screens for the mesh. I have not tried using aluminum for the shelves, but I think steel or copper would be better for the shelves. Steel works well, I can attest to that.

- A large diameter hemispherical piece of metal to use as a reflector. I used the canister lid of an old steam cleaning rental unit I happened to have, you could use a large wok lid, or a large metal mixing bowl. It does not have to be a perfect parabolic curve, and aluminum will work for the reflector. Again, on the next one I make I will probably try to use copper. I imagine I will have to form a piece of copper sheet into a reflector. The reflector I am using right now is about 24" diameter, I would recommend it be at least 18" diameter. The metal should be bare on the inside of the reflector, it can be covered with paint or enamel on the outside.

- A long section of speaker wire (2 wires) to connect the device to your PC.

- A household stereo, boom box, or any other audio equipment that has an amplifier built into it, and also has a line in or auxiliary input jack so you can route the signal from your PC's sound card through it. I use an ancient 8-track player that has a 50 watt amplifier in it.

- Adapters to connect you PC sound output to the line in of the amplifier.

- Tone generator software for your PC. You can download it off the web, and there are some links provided on the links page of this site where you can find it. Roberto Forcen's stuff is amazing, as soon as I can afford it I will be sending him something for his efforts, in the meantime I can at least give him a plug, his site is called voicesync. He has wonderful donaware for sound generation and analysis. Also, NCH toner is a very adaptable and functional tone generator for your PC with a range from 1 to about 20,000 Hz with control over the waveform. You can also run multiple copies of the program and generate multiple tones at the same time.

Building it... Step 1 -

Build yourself a large mobius coil. Make it big enough you can fit a large xtal in the core, about 2.5" to 3" diameter. It does not have to be a fancy xtal. It can be single point. On the old device shown here I used a single knot mobius coil, but on my new one I am using the continuous knot style. Secure the coil with plastic binders to prevent it from losing it's shape. The coil shown here is from 15 gage magnet wire, and while I recommend using at least 18 gage, it does not have to be magnet wire. magnet wire just works a little better. It isn't necessary to use magnet wire.

Step 2 -

Using aluminum tape, connect 2 mason jar lid rings to the coil as shown. Work the tape firmly into place, and use at least one full wrap of tape all the way around,. This is not only for the effect of a metal shroud on the coil, it is to keep the orgonite from leaking into the coil. Do your best to line the rings up evenly with each other, so that the ring on one end is parallel to and plumb with the ring on the other end. Pull the leads from the coil out through the center, or if you want to be more precise you can form a little hole in the tape to pass the leads through, and fill the hole with glue so it doesn't leak.

Step 3 -

Find a suitable mold that is cylindrical, and deep enough to come up to the top of the coil assembly you have just built. It should be at least deep enough that you can cast orgonite up to the top of the coil assembly, and wide enough that there is at least one inch of orgonite all the way around the outside of the coil. On the generator I use now there is a lot more orgonite than on the old one shown here. The old one shown here worked well enough to impress me several times with its effectiveness. Coat the mold with release agent of some form, regular vegetable oil or WD40 will both work fine. If you are using orgonite made from polyester autobody filler, you do not have to seal the bottom of the coil assembly to the mold. If you are using orgonite made from resin, you will have to seal the bottom of the coil assembly to the mold so resin does not leak under the coil assembly into the cavity at the center. You want to cast a ring of orgonite with a hollow center where the coil is. A little hot melt glue works well for this (sealing it), since it will keep the resin from leaking into the hole, and is easily removable. It also sets fast, so you don't have to wait for it to dry like you would silicone or goop glue.

Step 4 -

Cast it with MHD, HD or XHD orgonite. Allow the orgonite to cure, and remove the coil cast in orgonite from the mold. You should now have a hollow cylinder of orgonite with a coil in the center of it. Place the cylinder with the coil in the center of the reflector as shown below. You can fasten it with a little glue if you want. Then place the reflector on the lowest shelf of the metal shelving unit as shown. The quartz xtal goes in the hole inside the coil, as I imagine ought to be obvious. You can also easily remove and change xtals this way. I have a large cluster of kyanite which I use inside the coil too, gives a great energy. Let your imagination be your guide. Experiment with using different minerals and other things inside the coil, but be aware that not everything you put in there will work as well as a quartz xtal. A safer way to experiment is to ADD things in there with the quartz xtal, and see what kind of orgone they produce before you try them alone. Now you're ready to hook it up. If you want to, you can line the metal shelf up with the compass directions (I.E. so that one side of it faces north) but this is not necessary, it just makes it work a bit more efficiently). The metal shelves and reflector should be insulated from each other electrically, or at least that is the way I find it works best so far. The metal rings on the ends of the cylinder do not have to be electrically insulated from the metal of the reflector.

Not only do the metal screens seem to act like an broadcast antenna / amplifier, they also work really slick for making orgonite. Later on, when making orgonite, fire up the generator and put your molds on them while the resin is curing. The metal in the shelves pulses in rhythm to the scalar energy coming off the coil, and although I guess I still haven't figured out exactly why, they emit a strong stream of orgone as well. Further refinements to the design would involve, among other things, the proportions of the metal shelves in relation to the rest of the assembly.

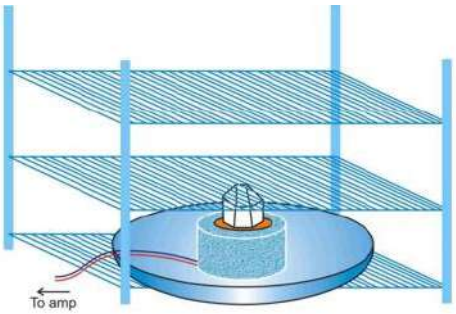

If you are going to use the device for radionics, then use the metal shelves as your witness well. You can also use the cavity inside the coil as witness well, but the energy sent to target that way may not be beneficial unless there is a quartz xtal in the coil along with it. If you just want to generate a big cloud of healthy orgone, then drop a large TB inside the coil and fire it up. If you have a wand or orgone beamer of some form, you can put that inside the coil and supercharge it.

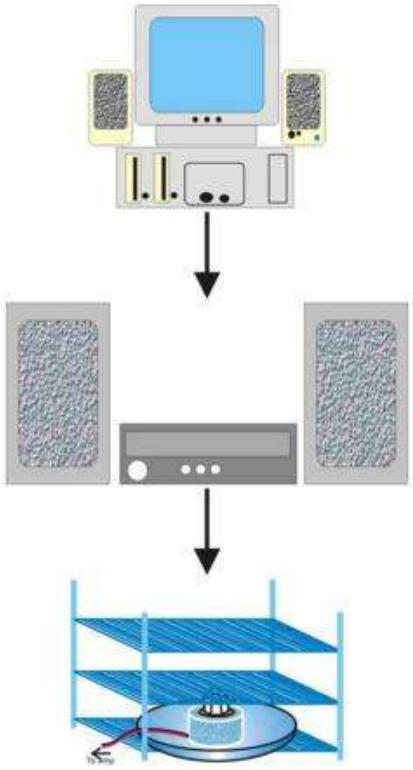

This is basically how you hook it up. You want to take the signal from your PC's sound card, route it through your amplifier, and then run it through the coil in the device. There are several ways you can do this, and no doubt those of you familiar with electronics will see that there are better ways than the method I have illustrated. I chose this method for this page because it is simple. Just use the adapter to connect the sound output from your PC to the line in or aux input of the amplifier. Then take one of the wire pairs leading to a speaker from the stereo, and cut ONE of the wires leading to the speaker. Leave the other wire intact. Preferably, use the positive wire. Then, connect the leads of the coil in the device to either end of the speaker wire which you have cut. This has the downside that you have to listen to the sounds being generated, but it PROTECTS YOUR AMPLIFIER from blowing. Mobius coils have very low resistance, and if you connect it directly to the amplifier output without having enough resistance you may damage your amp. The resistance in the method of connection shown is provided by the speaker. The current comes from the PC, is amplified by the amp, then goes through the coil. After it leaves the coil it goes through the speaker and back into the circuit.

Alternately, you could add a resistor to the mobius coil to give it enough resistance so that the amp would not perceive it as a short. In order to do this, you would need to find out what resistance your speakers are. Usually the speakers are marked (inside the speaker box on the back of the speaker magnet) with a little number beside an ohm symbol. This is the resistance. An ohm symbol looks like a little "O" with the bottom cut off and two little tails (Greek letter omega).

Again, alternately, you could connect the coil directly to your pc sound card by adding 8 ohm resistance to the mobius coil, as I gather 8 ohm is the standard resistance for small speakers like the ones used in PCs. In fact, I may be offering this (the ability to plug it directly into your PC sound output) as an option on the Pro Model Pulsers at some point in the future. For devices the size of the one shown on this page, I think it is better to have the extra power provided by the amp. If you use a device like this to charge your orgonite while it cures, you can increase the potency of your orgonite significantly. Some suggested frequencies: 15 Hz, 32 Hz, 5075 Hz. Obviously, one could build a more refined device based on this general concept, but hey, I can't give away all of my trade secrets ;). Besides, lots of folks won't mind that it looks hokey as long as it works

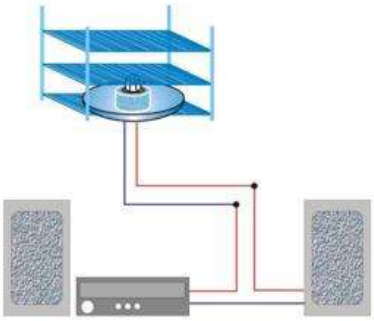

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Email – wizzer@littlemountainsmudge.com
Phone – 250-446-2032
Mail – PO Box 139, Westbridge BC V0H2B0
Url – www.littlemountainsmudge.com
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Cloudbusting

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Part I: Microbusting An offshoot of orgonomy, weather engineering offers both electrifying experiences and burdens of responsibility for the cloudbuster operator. Though theories as to how or why it works are abundant, research by such notables as Trevor James Constable, James DeMeo, Robert McCullough, and, of course, Wilhelm Reich) has unequivocably shown that methods employed in cloudbusting *do* influence weather patterns. Further investigations by backyard experimenters as myself only confirm this fact.

My own weather operations started in May of 1996 and ended in September of 1997, and although seventeen months may seem insignificant to the years of research conducted by others, the months were sufficient to allow an assemblage of theories and protocols for the production of desired atmospheric precipitation.

Traditional practices in cloudbusting centered around the concept of *orgone* energy, claimed by its discoverer, Wilhelm Reich, to be a negentropic life force affecting physical, biological, and psychological systems depending on its charge density, rate of flow, and excitability. The various forms of orgone, such as DOR (deadly orgone), and ORANUR (orgone excited by radioactive energy), all have specific effects upon these systems, which are described in the following chart:

	physical	biological	psychological	atmospheric
Orgone	Negative ionic, affinity for water, negentropic, blue glow, life-positive, alters alpha decay of radioactive material.	Abiogenesis of bions, tingling warmth on skin, enhances healthy growth of life, stimulates cilia movement.	Free flow of emotions, sense of well being, vitality, rapidly discharges during orgasm.	In dense concentrations accompanied by cumulous clouds and/or precipitation, in low densities by aridity, adds clarity to blueness of sky.
DOR	Positive ionic, signifies lack or stagnation of orgone, created by TV's, microwaves, and other	Destimulates cilia, slows intake of oxygen, dehydrates the body,	Creates fatigue, blocks emotional release, deppression.	Black clouds without rain, desert-like arid stagnation of climate, stagnant

	electromagnetic sources.	causes severe thirst.		weather patterns, haze
Oranur	Densely positive ionic, orgone dangerously excited by alpha radiation (as found in smoke detectors), decomposes minerals into brown melanor.	Along with symptoms of radiation sickness, clears life-forms within its field of effect.	In buildings, creates an atmosphere of aggression, hysteria, claustrophobia, and uneasiness.	Shred-like decomposition of cloud edges, cobalt-blue sky.

All three forms of orgone have specific atmospheric effects due to its intense affinity for water; strong concentrations of "good" orgone are accompanied by water, and low densities by arridity. A cloud, for example, is a pocket of dense orgone energy, but the surrounding blue sky contains a lower concentration. According to classic cloudbuster theory, in order for a cloud to "bust," its orgone content must be "drawn" away by some means.

It was by accident that such a means was found. Wilhelm Reich and his associates observed that pipes pointed at a lake before them influenced the shape of waves upon the water. Years later, Reich capitalized upon this effect by relieving what was then known as the DOR Emergency, during which the inhabitants of his laboratory in Rangeley, Maine, became victims to "DOR sickness." He sought ways to rid the area of this deadly orgone which had not only sickened his co-workers, but also caused the static accumulation of dark, drought-like clouds in the skies above. What soon evolved was a contraption composed of twelve copper pipes, each 1.5 - 2" diameter and 10' long, whose bottom ends were connected in parallel to BX electrical cables which were dropped in a well to siphon the DOR from the sky toward the water within the well. After ridding the region of DOR, the cloudbuster was found to be useful for either producing or preventing rain in the region. For several years, Reich offered his services in preventing forecasted rainstorms for special events such as parades and other special events, as well as breaking several droughts beflicting the region.

The theory behind cloudbusting involved a monumental principle: orgone flows from low potential to high. In practice, this meant that to draw orgone from a cloud into a collection of pipes, the orgone potential of the pipes had to be made higher than that of the cloud. This was the purpose of grounding the pipes in water, prefferably running water. Since much orgone was already present in the water contacting the pipes, much more so than within the cloud, when the pipes were aimed at the center of the cloud, the orgone by

means of the above principle naturally flowed from cloud to pipe and into the water to be flushed away.

Reich made an analogy between a lightning rods and cloudbusters: both discharge orgone from the sky (lightning was believed to be a super-dense bolt of electricity and orgone), except whereas a lightning rod does so in the fraction of a second, the cloudbuster extends its influence over tens of minutes -- an hour is the usual draw duration. Though lightning rods channel much greater magnitudes of energy than cloudbusters, it is not difficult to see why a cloudbuster produces a more apparent change in shape of a cloud than lightning rods do. It is not the *magnitude* of energy involved, but rather the *rate* of energy flow. With the cloudbuster's slower rate of orgone siphoning, the chaotically evolving cloud has a longer time to respond to the influence of a cloudbuster operator.

The rate of draw is dependent upon rate of water flow within the pipe, number of pipes, and the skill at which the cloudbuster is operated. The length-to-diameter ratio determines the range of influence of the cloudbuster; the larger the ratio, the longer the range. Requirements of fast-running water hint at the mechanism by which cloudbusters function. To fully understand how metal tubes pointed at the sky can change it, one must realize that orgone is both an *ionic* and *conscious* phenomena. The ionic interactions occuring within the cloud at a molecular level explain, for the most part, how and why cloudbusting is possible. As mentioned, orgone bears characteristics uncannily similar to electrical phenomena, specifically that of ionized air. Orgone and ionized air are compared as follows:

Orgone	Ions
Highly charged orgone accumulators placed in the dark are seen to emit a blue glow.	Objects ionized by high voltage electricity give off a blue corona.
A healthy dose of orgone "freshens" the air, creates an energized sense of well being.	Negative ion generators also freshen the air, stimulate cilia movement within air passages of subjects breathing negative ions -- leading to a better filtration of dirty air and increased oxygen utilization within the body.
DOR causes thirst, fatigue, irritability, and blank stares	Positive ions (lack of negative ions) decrease cilia movement, leading to throat irritations and thirst caused by lowered production of mucous and resulting increase of foreign particulates entering the lung, and oxygen utilization is lowered, also creating fatigue.

among its victims.	
Orgone is neutralized or absorbed by water.	Static electricity is also neutralized of absorbed by water.
Cloudbusters are like lightning rods, but draw orgone at a slower rate.	Lightning rods channel bolts of electricity, cloudbusters channel ions slowly.
Orgone can alter the decay rate of radioactive materials.	Ions are known to affect radioactive decay.

Quite clearly, orgone not only *resembles* electricity, but could actually *be* electricity with one exception: several behaviors of orgone cannot be fully explained by the physics of ionization alone, which leads to my hypothesis that the unnaccounted factor is of psychic origin, in other words, it is a *radionic/conscious* factor.

First, however, let's analyze the ionic aspects of orgone before we return to the radionic hypothesis in weather engineering. If we visualize the interaction between a cloudbuster and its target as being not one of orgone "drawn" into the pipe, but rather ions from the pipe being *released* into the atmosphere toward that target, then the generation of the ions and their resulting interaction with a cloud's water droplets can elegantly be explained.

One requirement when cloudbusting is fast running water, as mentioned above. The simplest of this type is a copper pipe with a spray nozzled hose inserted into its lower end, as shown in this diagram:

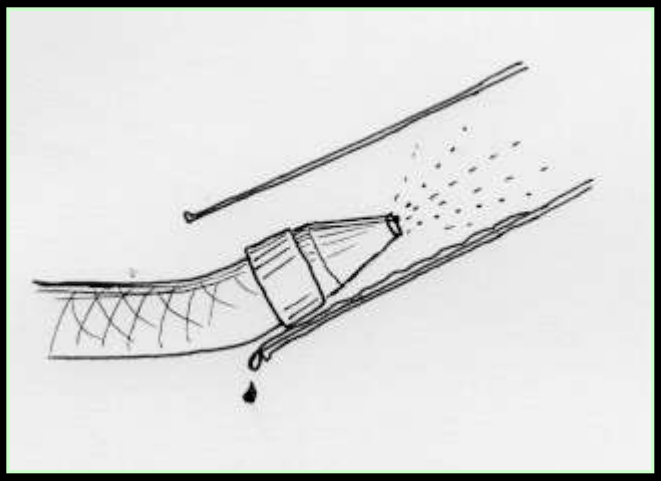

To allow full emersion of the pipe's end into water, a tub can be used:

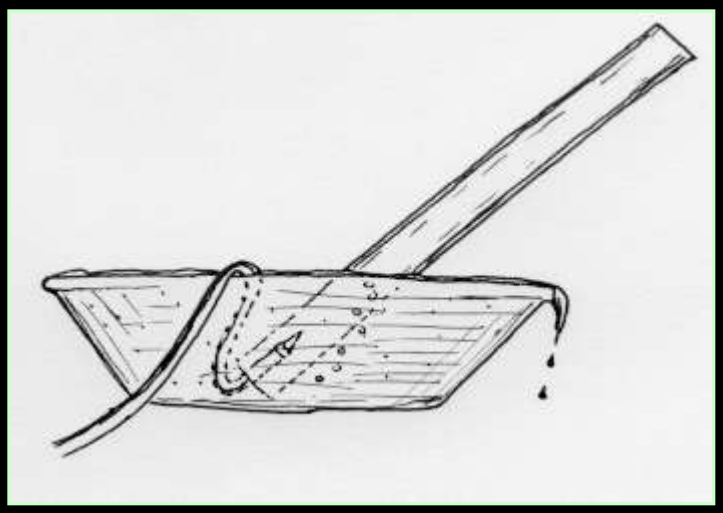

More advanced and efficient configurations involve atomizing the water into a fine mist before injecting them into the tube. A make-shift version of this type utilizes a motorized air humidifier commonly found at Wal-Mart for $15 during the winter season. A flexible, expandable hose is connected from the humidifier to the pipe:

At the molecular level, neutral streams of water are atomized by the nozzle or humidifier into small droplets light enough to be suspended in air. These droplets, by a well known phenomena, are ionized; when water is split into smaller globules, charge imbalances occur. Often, more negative ions are produced than positive ones as in a rainstorm, where raindrops splashing on the ground shoot off negatively charged droplets (in rare instances, such raindrops have been seen to discharge sparks of electricity upon contact with the ground). Within the cloudbuster's pipe, much of the positive ions are grounded, creating in effect a filter mechanism by which negatively ionized water droplets are produced and forced from the muzzle of a cloudbuster. This explains why fast-running water is a recommendation: the faster

the water, the larger the spray, and the more ionized droplets are created.

Ions leave the cloudbuster to dissipate into the atmosphere and interact with an aimed target, the cloud. Precision to which these ions are capable of being aimed shall be discussed below, for it is radionic fundamentals that explain the precision. Contrary to expectations the ions do not simply drift away like smoke from a pipe, but coherently reach their target in a conical, if not beam-like projection. Once the ions reach a water droplet in the cloud, the largely neutral droplet (which is really a collection of negative droplets around a positive condensation nucleus, the total charge being zero), is split into smaller negatively charged droplets now small enough to be classified as *water vapor*, which is invisible to the naked eye except for its filtering effect of the sun's rays causing our sky's blue hue. A cloud can therefore be made to "disappear" when its water droplets have been ionized by the cloudbuster's ions into invisible water vapor. Conversely, a section of blue sky, occupied mostly by uniformly charged positive water vapor ions, can be made to coalesce into visible water droplets through neutralization by the interaction with the cloudbuster's negative ions:

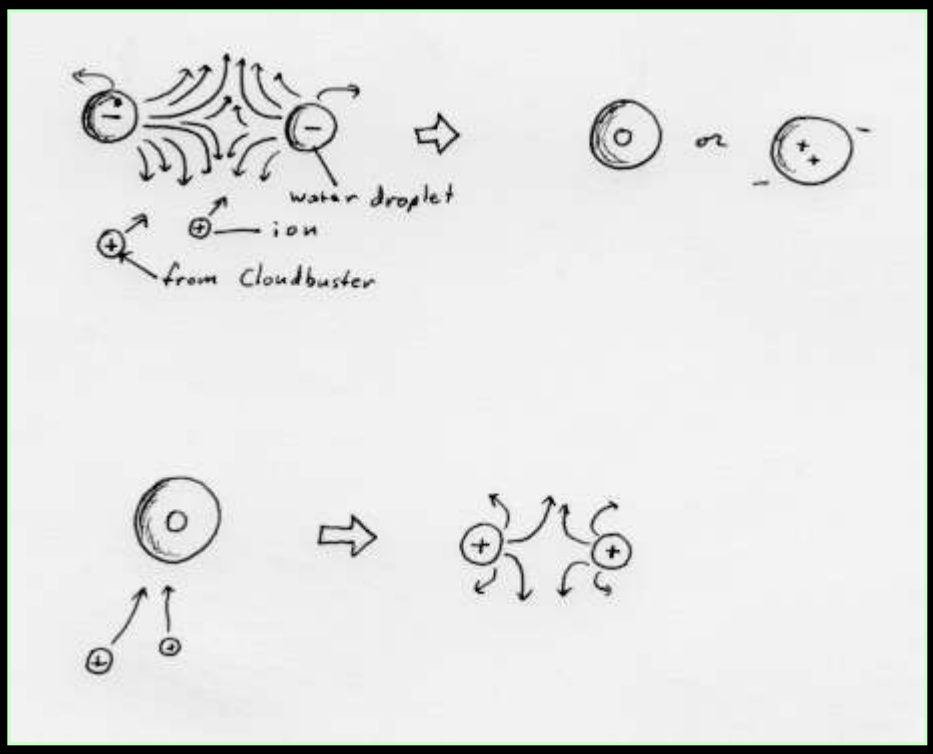

Because opposites attract and similars repel (Law of Attraction and Repulsion of Charges), large water droplets can either be made to split into two or more repelling water vapor molecules, or ionized water vapor molecules can be neutralized and caused to coalesce into a cloud.

Therefore, to destroy a cloud, the cloudbuster is aimed at the cloud, and the ions dissociate it:

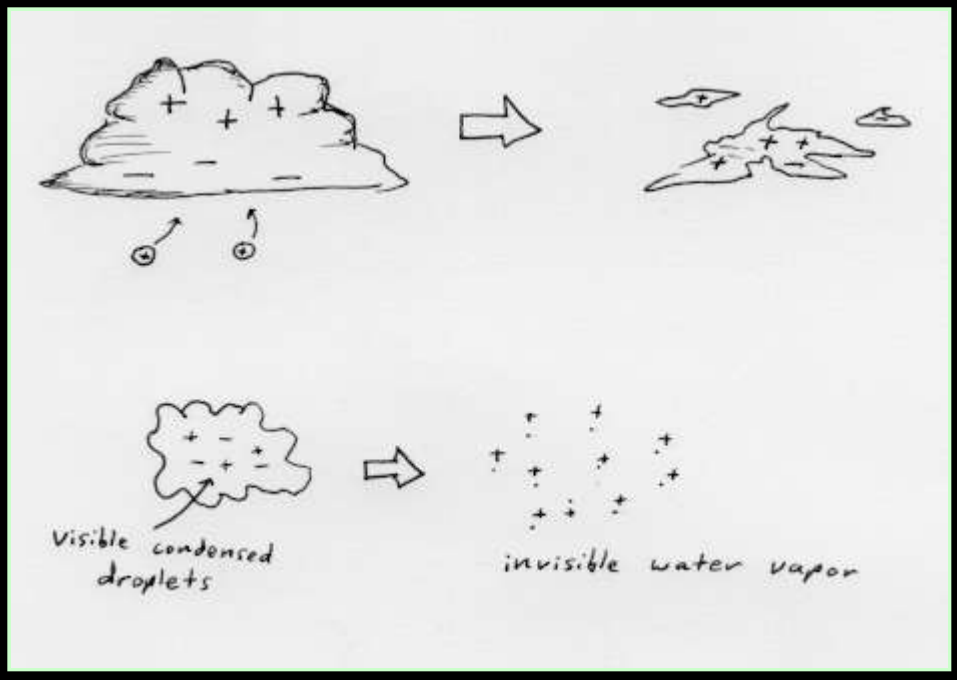

This is in complete agreement with classic cloudbusting protocol.

Now that ions are known to be partially responsible for weather modifying effects, one can see why waterless cloudbuster units are possible. Trevor James Constable, whose work is detailed in the book Loom of the Future (one I recommend you read for its philosophical insights and profuse number of photographs), mentions waterless units called "blue-bellies", which are in essence orgone accumulators wrapped around the lower half of PVC pipe and bound with duct tape. For those who do not know what an "orgone accumulator" is, visit the PORE webpage. Orgone accumulators are composed of layers of organic and inorganic material, most commonly cotton and steel wool in alternating layers. Such a configuration of materials is said to become charged with orgone, and radiate the orgone to objects near the accumulator. Any physics student can see that alternating layers of metal and insulator forms a capacitor. By virtue of its porous and fluffy texture, such accumulators gather electrical energy and emit a constant field of charged air ions. The source of this charge is gravity, known by Townsend Brown and George Hodowanec to produce self-charge on a capacitor. When an accumulator is wrapped around a pipe, plastic or metal as in the orgone "Volcano" model below,

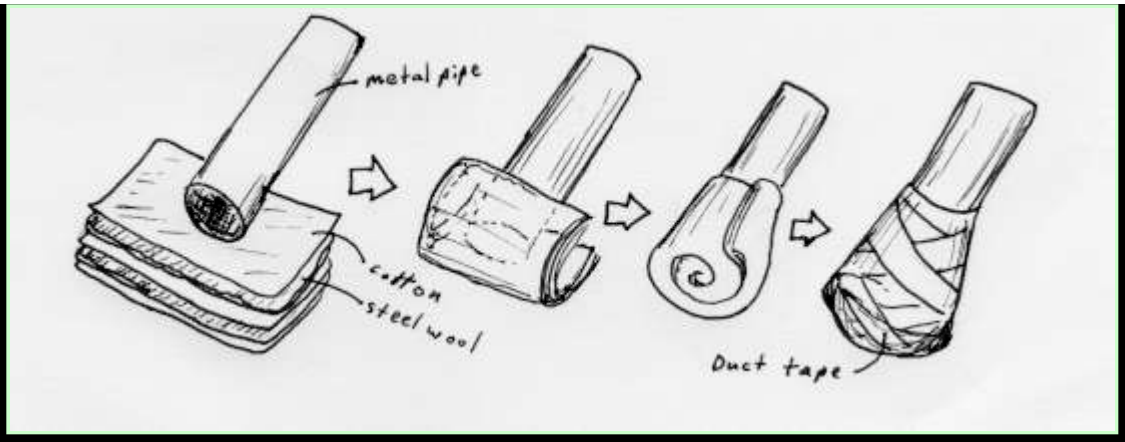

the pipe will emit ions just as a regular cloudbuster, except without the need for water.

This principle can thus be applied through a high voltage ion generator inserted into the end of a metal or plastic pipe and aimed at the sky. This method allows, in effect, a power-cloudbuster to be constructed which needs only to be pointed, set, plugged in, and monitored.

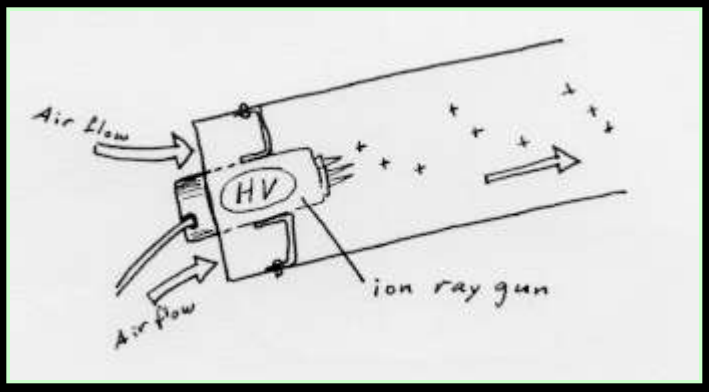

However, a question arises as to how so few ions can impact the development of thunderheads (cumulo-nimbus clouds hundreds of yards in height). The answer to this question is easily apparent and stems from the same reason why, under Chaos theory, the air currents generated by a butterfly flapping its wings could eventually lead to the formation of a hurricane. Cloud development, and weather, for that matter, is extremely chaotic and volatile to the smallest factors. A cloudbuster's ion can act as a a crucial trigger in causing millions of other water vapor molecules to coalesce in a chain reaction, much like cloud seeding utilizing dry ice dropped from airplanes into clouds also create a chain reaction.

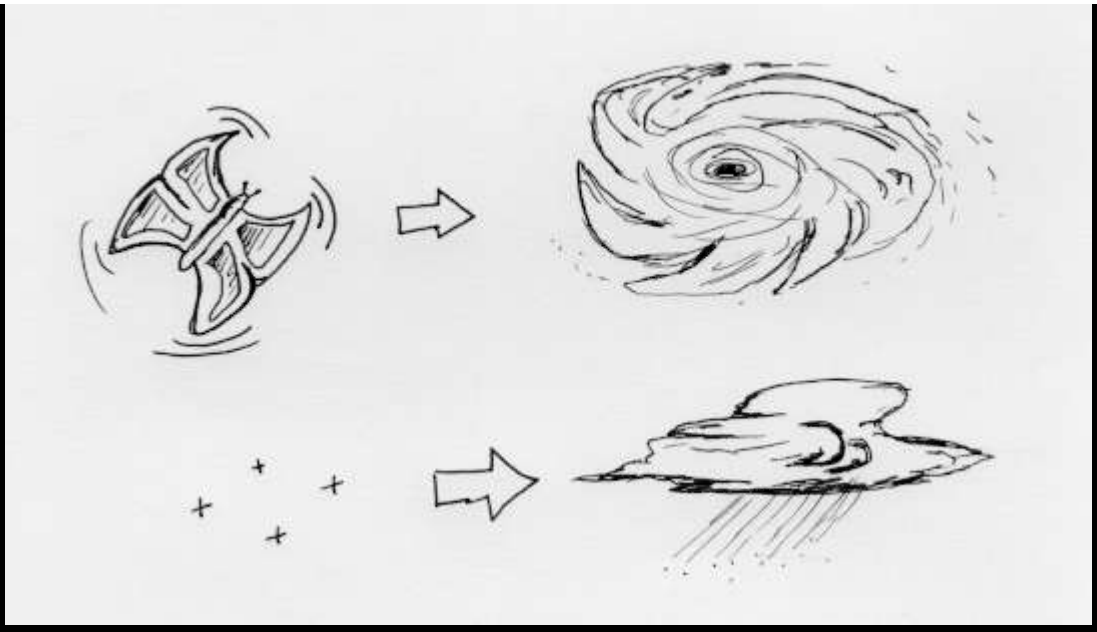

Unlike the butterfly effect, however, where the trigger's effect is chaotic, the effects of cloudbusting are controlled by radionic means through the mind of the cloudbuster operator. This is an example of consciousness affecting chaos. The more chaotic a system is, the more easily consciousness can both saturate and influence it. A cloud, or the weather itself, is quite chaotic. Just as a sculptor shapes a figure with his hands, so does a cloudbuster operator shape a cloud with his mind into a state more conducive to formation or dissipation, but not without the help of his tools, of course.

Cloudbusters are no different. Ions do, by evidence of their electrical properties, interact with water droplets in clouds, but it is the consciousness factor that tips the scale of the "butterfly effect" one way or the other, towards a thunderhead with a straight column, or a curved one, for example. Since the mind has a special connection to chaotic systems due to it being intelligent and resultingly unpredictable, the cloudbuster operator's mind can influence the otherwise unpredictable development of clouds *without* a cloudbuster, but unless he were extremely competent in parapsychological feats, his efforts would be in vain without the help of such a device. It is only through the interface of mind and machine that the average person can achieve the spectacular results of cloudbusting.

Orgone is thus a combination of mind and ion, whose effects range from wholly ionic (blue corona) to entirely psychological (emotional armoring).

Neither pure orgonomy nor pure present day science can comprehensively describe or explain the process of cloudbusting,

but a combination of orgonomy, radionics, and science can. Once again, it is consilience through which truth is revealed.

Part II: Macrobusting

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THE ORGONE ACCUMULATOR HANDBOOK

Construction Plans, Experimental Use and Protection Against Toxic Energy

by James DeMeo, Ph.D.
With a Foreword by Eva Reich, M.D.

The Orgone Accumulator Handbook

by James DeMeo, Ph.D., with a foreword by Eva Reich, M.D., and an appendix examining new experimental evidence demonstrating the effectiveness of the orgone energy accumulator.

Learn how to concentrate and work with orgone (life) energy using simple, readily-available materials. A limitless supply is freely available from the atmosphere. These experimental devices have been shown to stimulate plant growth and human physiology in controlled studies.

The orgone accumulator is based on discoveries by the late **Dr. Wilhelm Reich**, whose work remains vital and of wide interest, despite unprecedented hostility to his scientific research. In a court decision unique in American history, his books were ordered *burned* by the U.S. Federal government in 1957. Dr. Reich reported medical benefits for his patients who used the accumulators.

In this edition Dr. DeMeo updates information on the construction of orgone energy blankets, shooters, box-type accumulators, bion packs and "draw buckets" for atmospheric cleansing, with many instructional diagrams and photographs, as well as a complete bibliography and resource guide for research.

About the Author: James DeMeo has been researching the topic of the life energy, and specifically the works of Dr. Wilhelm Reich since 1970. He has authored or edited dozens of published articles, books and research compendiums (including *Saharasia, Heretic's Notebook, On Wilhelm Reich & Orgonomy*, and the German-language *Nach Reich*) which subjected Reich's ideas to rigorous testing. DeMeo formally studied Environmental Science and Geography at Florida International Univ., and the Univ. of Kansas, where he earned his Ph.D. He served on the Faculty of Geography at Illinois State Univ. and the Univ. of Miami, and founded the Orgone Biophysical Research Laboratory in 1978.

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* *Bibliography on Orgone Biophysics: 1934 to 1986*

THE ORGONE ACCUMULATOR HANDBOOK

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James DeMeo, Ph.D.

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Tel/Fax: 541-552-0118 Email: demeo@mind.net

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Cover: NASA photo of Apollo 12 astronaut walking on the surface of the moon (see Life Magazine, 12 Dec. 1969). His body orgone energy field is softly glowing a blue color in the lunar vacuum, possibly due to excitation by his high-frequency radio communications equipment. This blue coloration of the energy field in the photo, which has been seen in a few other lunar astronaut images, has been systematically ignored or explained away as an effect of "lunar dust" or "water vapor". In fact, it is a visible expression of the human orgone (life) energy field.

Acknowledgements

This book is the product of many years of study of the prior works of Wilhelm Reich, and other dedicated scientists, without whose research findings it would not have been possible. The reader will find their names and research papers listed in the reference section of this book. I have corresponded with, and learned from many of these researchers over the years. In particular, I thank Eva Reich and Jutta Espanca for their constructive criticisms of the first edition of this Handbook. Additionally, I thank my own mentors, Robert Morris, Robert Nunley, and Richard Blasband, from each of whom I learned different things about life energy. I thank Theirrie Cook and Don Bill, loyal friends who have helped with the progress of my research in many ways, and also Jim Martin for the initial ideas and encouragement to revise my original small Handbook into the present edition. Jim also prepared the typesetting and most of the graphics in this edition, providing many helpful points along the way. Thanks to Stephan Müschenich and Rainer Gebauer for the courage they showed in doing their double-blind, controlled study of the human physiological response to accumulator treatment, at the University of Marburg, and for the Appendix document. Thanks also to the various researchers and doctors in Germany, who today are openly working with the accumulator in a manner presently impossible in the USA. In particular, I thank Heiko Lassek, Dorothea Opferman-Fuckert and Manfred Fuckert from whom I learned about the possiblities and limitations of physical orgone therapy. Also thanks to Vince Wiberg, for the simple and inexpensive methods for detecting electromagnetic disturbances, presented here. And finally, thank you Wilhelm Reich, for the discovery of the orgone energy and the orgone accumulator.

"We consider the discovery of the orgone energy among the greatest events in human history."– from a letter to the American Medical Association, signed by 17 medical doctors in 1949.

"THE ORGONE ACCUMULATOR IS THE MOST IMPORTANT SINGLE DISCOVERY IN THE HISTORY OF MEDICINE, BAR NONE" – Theodore P. Wolfe, M.D., from *Emotional Plague Versus Orgone Biophysics*, 1948.

"It is justifiable that the discovery of orgone energy and its medical applications by means of the orgone accumulator, the orgone shooter, bionous earth, and orgone water have opened up an abundance of new and, it appears, amazingly good prospects." – Wilhelm Reich, M.D. from *The Cancer Biopathy (Discovery of the Orgone, Volume 2)*, 1948.

"What would you say of the leading philosophers here to whom I have offered a thousand times of my own accord to show my studies, but who with the lazy obstinacy of a serpent who has eaten his full have never consented to look at the planets, the moon, or telescope? To such people philosophy is a kind of book... where the truth is to be sought not in the Universe or in nature, but (I use their own words) by comparing texts." – Galileo Galilei, Italian astronomer of the 1600s who proved that the Earth moved in the heavens, shortly before being prosecuted and tortured by the Catholic Church.

"...the orgone energy does not exist."– Judge John D. Clifford, from a 1954 U.S. court ruling in which all of Dr. Reich's books and research journals were banned, and ordered burned in incinerators; Reich was sent to a Federal Penitentiary, where he died.

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1. Foreword

At last, thirty two years after the 1957 death of Wilhelm Reich, human beings can begin to study orgonomy like any other body of knowledge, helped by the *Orgone Accumulator Handbook*. This concise and informative book contains in a nutshell a condensed, clear account of the discovery, made usable by all who are interested in the cosmic life energy. Herein is printed: the scientific definition of the orgone energy; the history of how the steps of observation, experimentation, and theoretical insight led Reich to practical applications; the principles for construction and experimental uses of the orgone energy accumulator, with detailed suggestions for needed material, layering, and dimensions; and finally a very useful reference list. Professor J. DeMeo shows his thorough knowledge of the subject, which as yet is banned and omitted from the 20th Century academic curriculum, except for a few pioneering lecture courses (in New York and West Berlin).

Wilhelm Reich said that even though the life energy had been known for thousands of years, he managed to make it concretely usable, and that the era of its applications has just started. However, this *Handbook* is the first printed material in recent years on specifically how to concentrate the energy from the Earth's atmosphere. It is usable for a laboratory course on the subject of cosmic life energy. This material could be comprehended by intelligent high school or college students. It answers my almost fifty year old hope, for the inclusion of life energy facts in the body of knowledge that all educated people on Earth should learn in their schooling. Thank you James DeMeo.

Eva Reich, M.D.
West Berlin, March 1989

2. Author's Preface

When I was 12 years old, a favorite uncle of mine died a suffering death from lung cancer. The doctors had removed one of his lungs, and for a few months he lingered, being incapable of talking or moving very much, and in a great deal of pain. My aunts would not allow the children to see him in such sorry shape, except for one time, when he was dressed up for the entire family, which had gathered to quietly say good-bye. I was very sad when he died. When I was 15, my mother was diagnosed as having breast cancer. I was by her bed in the hospital when she recovered from surgery, and when she was told that her breast had been amputated in a radical mastectomy. I will never forget the look on her face. She survived the surgery, but the emotional resignation which she carried, and which preceded her cancer by several decades, was never diagnosed or discussed. Friends of our family had urged us to look into some alternative treatments for cancer, but everybody believed that the doctors in the hospital knew best. Listed as a "survivor" in the cancer statistics, my mother progressively declined after the surgery, and died about eight years later, having refused to undergo additional surgery.

My experience with relatives dying of cancer is not unusual, as degenerative disease is now at epidemic levels. The statistics today demonstrate that the "war on cancer" has been lost, and that in spite of all the radical surgeries, drugs and radiation treatments, patients today survive no longer or more frequently than they did in the 1950s. Indeed, degenerative disorders have today spread into youthful age groups and populations where they once were rare. Scientific evidence does not exist to support the assertion that surgery, radiation, and chemotherapy are effective forms of treatment for cancer, and traditional medicine today gives hardly more than lip service to preventative considerations. These troubling facts become all the more disturbing when one begins to study the various alternative, non-invasive

and non-toxic cancer therapies. Dismissed for decades as "quackery" by organized medicine, most of these therapies appear to be reasonably or even remarkably effective. Their advocates and practitioners have often taken great risks to bring what they believe are safe and effective treatments to sick people. The organized medical community, with financial links to the pharmaceutical industry, has not cared to seriously look into these techniques. Instead, the techniques have been unwarrantedly attacked, and pseudo investigations have been launched, with predictable outcomes: clinics have been shut by brute police force, through court orders; medical records and research protocols have been seized, and jail sentences have been handed out. Books have also been burned. In this context, a great fraud has been perpetrated upon the American people, and upon our courts and legal system, by the larger organized medical associations, and related government bureaucracies.

In this short *Handbook*, I cannot give a history of these antiscientific and unethical abuses, but a few articles and books on the question are listed in the reference section. Clearly, a major reason for the impotence of modern medicine in dealing with degenerative diseases lies in the fact that the organized medical community has used police-state tactics to suppress important new findings, and the unorthodox practitioner, irrespective of any scientific evidence that exists. In fact, the most well documented and effective unorthodox therapies have been the most hotly attacked. Many, many promising therapies have been suppressed over the years, through an emotional collusion, and some outright conspiracy for economic motives, between medical interests, drug companies, plague journalists, prejudiced academics, and puritanical government bureaucrats and judges. In this process, the truth has been trampled badly, and the methods of science, discarded.

The most clear and telling example of how these social forces combine to kill a new discovery, and its discoverer, is the case of Dr. Wilhelm Reich and his orgone energy accumulator. Reich had been one of Freud's younger co-workers, and was a prime mover in the early psychoanalytic move-

ment in Vienna and Berlin. However, his ideas were more revolutionary than those of the older psychoanalysts. He forcefully argued that human misery and mental illness were partly the result of social conditions, which could be changed to prevent neurosis. He urged reform in laws regarding the abusive treatment of children, and in the economic plight of women. He formed a viable social and political movement in pre-Hitler Germany, which urged reforms in laws restricting divorce and access to contraception, which were both then illegal. He championed the rights of young unmarried people to a healthy sexual life, and a loosening of the father's power and dominance over the family. He wrote extensively about these matters in the 1920s and 1930s, and exposed the roots of the Nazi movement in the obedience-demanding, patriarchal, sex-negative German family structure. For his writings on genitality, and his anti-fascist activities, Reich was eventually expelled from Freud's inner circle, and also from the International Psychoanalytic Association. German psychoanalysis was at that time leaning towards appeasement of the Nazis, and some analysts, such as Carl Jung, even became spokespersons or apologists for National Socialism. Reich was eventually placed on both Hitler's and Stalin's death lists in the 1930s, and had to flee to Scandinavia, and later from there to the United States. His writings were condemned to flames in both Germany and Russia.

By the time Reich arrived in the United States, in 1939, he had made a number of major scientific discoveries, and quickly attracted a group of young, enthusiastic scientists and doctors to assist with his work. The American period of his research, which lasted until his death in 1957, was particularly productive, in spite of the later court actions against him. It was during this period that Reich experimentally clarified, and made practical use of the biological and atmospheric life energy, which he called the orgone energy. The orgone energy, Reich observed, was a real, physical energy, which radiated from microbes, animals, humans, and from inorganic materials as well. It charged living creatures, yet also existed in the atmosphere in a free form. It

could be accumulated in special enclosures, where it could be observed, felt, and measured.

Reich's orgone energy experiments attracted the hostile criticisms of many in the medical community, and a smear campaign in the press triggered an investigation by the U.S. Food and Drug Administration (FDA). In its efforts to stop Reich's work, the FDA did not seek to responsibly or accurately reproduce his experimental findings. Instead, FDA bureaucrats relied upon gossip and rumor, ignored available published evidence, and secured the testimony of "expert" witnesses who had no real familiarity with or interest in the scientific facts involved. Many breaches of the scientific method, and of legal, moral, and scientific ethics occurred, as government officials, and a number of psychiatrists, analysts, and physicists, sought to put an end to his work.

We also know a lot more today about the inner workings of the FDA regarding the Reich case, given that several scholarly reviews of FDA files, using the *Freedom of Information Act*, have taken place. These are cited in the reference section. Reich originally offered to cooperate with the FDA investigators regarding the orgone energy. But they refused his offer, as they were hot to "get Reich" on whatever charges they could, and had been urged in this direction by various highly-placed individuals within the medical communities. The *Bulletin of the Menninger Clinic*, and the *Journal of the American Medical Association*, for example, participated in the spreading of false gossip and rumors regarding Reich's work. Reich was aware of these unethical actions, and a number of his co-workers had been professionally hurt by the lies, and by the actions of the FDA. At no time did any governmental or private scientific or medical organization attempt to seriously review or replicate his experiments.

These kinds of attacks made Reich understandably furious, such that when the FDA finally sought a Complaint for Injunction against his activities, he refused to appear in court, to act, as he put it, "as a 'defendant' in matters of basic natural scientific research". Instead, he wrote a compelling *Response* ("Motion to Dismiss") to the judge. Reich's refusal

to grant authority to the courts regarding the validity of his orgone research prompted a legal over-reaction, the likes of which we usually associate with despotic societies. In a judicial ruling that is, to the best of my knowledge, unique in American history, the FDA sought and obtained a Federal Court Decree of Injunction, which ruled that the orgone energy "does not exist". The court ordered a ban on the interstate shipment of books bearing the word "orgone". This included books into which the forbidden word appeared only in the preface, or introductory remarks. Additionally, all books and research journals discussing the orgone energy in detail were *ordered destroyed*, and devices using the energy, dismantled or destroyed. (Case #1056, March 19, 1954, US District Court, Portland, Maine, Judge John D. Clifford, Jr.)

"BANNED, until expunged of all references to the orgone energy:

The Discovery of the Orgone
Vol. I, The Function of the Orgasm
Vol. II, The Cancer Biopathy
The Sexual Revolution
Ether, God and Devil
Cosmic Superimposition
Listen, Little Man
The Mass Psychology of Fascism
Character Analysis
The Murder of Christ
People in Trouble

BANNED and ORDERED DESTROYED:

The Orgone Energy Accumulator, Its Scientific and Medical Use
The Oranur Experiment
The Orgone Energy Bulletin
The Orgone Energy Emergency Bulletin
International Journal of Sex-Economy and Orgone Research
Internationale Zeitschrift fur Orgonomie
Annals of the Orgone Institute"

And so, in the late 1950s and early 1960s, Reich's books and research journals, even those which were "only" banned, were periodically seized by FDA agents and Federal Marshals, and burnt in incinerators in Maine and New York. No scientific or professional organizations, journalists or writer's unions publicly objected to the book burnings, or acted to help Reich, whose laboratory headquarters was invaded by FDA agents, who destroyed instruments with axes. In addition to the above actions, the court ordered Reich to cease "disseminating information" on the orgone energy, effectively censoring his writing and speaking on the subject. Several years later, Reich was charged with Contempt of Court when his assistant committed a technical violation of the Injunction, at a time when Reich was more than a thousand miles away, engaged in field work in the deserts of Arizona. Though he appealed all the way to the Supreme Court, Reich lost the case, and was incarcerated in Lewisburg Federal Penitentiary, where he died in 1957. His death in prison occurred two weeks prior to his parole date, at a time when he was happily anticipating his freedom, and a life in Switzerland with his new wife.

Whatever we may think of Reich's response to the court challenge, the principles upon which he stood were very important, and date back at least to Galileo's trial by fire with the Catholic Church. The lesson from Galileo's time was that no Court, Tribunal, or religious or scientific organization on Earth has the capacity to say, on the basis of textual comparisons or divine revelation, just what is or is not Natural Law. The results of an experiment cannot be judged by those who have never reproduced it, and the unresearched opinions of scientists are no better than the unresearched opinions of anyone else, be they members of the American Medical Association, the National Academy of Sciences, or the same Country Club attended by the President. Galileo urged his critics to "look into the telescope", to verify his observations in a most direct and simple way. But they refused to do so on moral principle, and derisively mocked him. Reich's critics have taken the same approach, in their adamant refusal to reproduce his experiments, and in most cases, to even

review the published evidence. Today, over 30 years since Reich's death, his most vocal critics still take the same anti-scientific approach, and condemn what they have not personally read or investigated.

Based upon these historical facts, it is clear that **the FDA, and indeed, all courts, academic bodies, and governmental agencies of all kinds, have forever relinquished any right to say anything about what the average citizen may or may not do with respect to the orgone energy accumulator**. The discovery of the orgone is in much safer hands among the average citizen, than in the hands of the various politicians, academies of science, and medical organizations. This *Handbook* is therefore not primarily directed towards an academic or medical audience. Instead, the case of Dr. Wilhelm Reich and the orgone energy accumulator is taken directly to the general public. Like the sunlight, the air and water, the orgone energy is a part of nature, existing everywhere, and ought to be available to everyone, free of restrictive regulation and control. As an invention, the orgone accumulator is also now in the public domain, unpatentable, and cannot be dominated by any single individual or corporation. It is also still *perfectly legal* for citizens to build, own, and use orgone accumulators.

Of course, with this right comes a great deal of responsibility, as the proper use and maintenance of an accumulator makes both social and environmental demands upon its owner. The cosmic orgone energy ocean is, like our air, food, and water, fast becoming contaminated and poisoned, and swift action by concerned people is required if life on the planet is to continue. This *Handbook* will give a basic overview of the orgone energy, the accumulator, and the construction and safe use of orgone accumulating devices. For the more precise scientific details and data, the reader is encouraged to obtain and review the published materials listed in the Reference and Information sections.

Three years after Reich's death, the trustees of his estate arranged for republication of his works. Today, most of his books have been republished, or are available in libraries, and through other sources. A group of Reich's co-workers

also founded the American College of Orgonomy, and by 1967 had published the first issue of the *Journal of Orgonomy*. Since that time, interest in Reich's works has gradually increased, and many new studies verifying his findings on the orgone energy, and the accumulator, have taken place. College courses focusing upon Reich's life and works now exist, and he has been the subject of many reviews, biographies, and films. A younger generation of scientists and health practitioners is rediscovering Reich, and new journals devoted to orgone research or bioenergetic functions have appeared in the USA, Germany, France, Italy, England, Canada, and Japan. One major new study on the accumulator from Germany is summarized in the Appendix.

The effort to kill the discovery of the orgone has failed.

irritated protoplasm. It can be registered on specially adapted Geiger counters. The orgone also is the *medium* through which electromagnetic disturbances are transmitted, much in the manner of the older concept of *aether*, though it is not itself electromagnetic in nature.

Streamings of orgone energy within the Earth's atmosphere affect changes in air circulation patterns; atmospheric orgone functions underlie the buildup of storm potentials, and influence air temperature, pressure, and humidity. Cosmic orgone energy functions also appear to be at work in space, affecting gravitational and solar phenomena. Still, the mass-free orgone energy is not any one of these physicomechanical factors, or even the sum of them. The properties of the orgone energy derive more from life itself, much in the manner of the older concept of a *vital force*, or *élan vital*; unlike those older concepts, however, the orgone also has been found to exist in a mass-free form, in the atmosphere and in space. It is primary, primordial cosmic *life energy*, while all other forms of energy are secondary in nature.

In the living world, orgone energy functions underlie major life processes; pulsation, streaming, and charge of the biological orgone determines the movements, actions, and behavior of protoplasm and tissues, as well as the strength of "bioelectrical" phenomena. Emotion is the ebb and flow, the charge and discharge of the orgone within the membrane of an organism, just as weather is the ebb and flow, the charge and discharge of the orgone in the atmosphere. Both organism and weather respond to the prevailing character and state of the life energy. Orgone energy functions appear across the whole of creation, in microbes, animals, stormclouds, hurricanes, and galaxies. Orgone energy not only charges and animates the natural world; we are immersed in a sea of it, much as a fish is immersed in water. More, it is the medium which communicates emotion and perception, through which we are connected to the cosmos, and made kin to all that is living.

4. Wilhelm Reich's Discovery of the Orgone Energy, and Invention of the Orgone Accumulator

Reich's initial work on the question of a biological energy began in the 1920's, when he was a student of Sigmund Freud, the originator of psychoanalysis. Freud's early theories on human behavior discussed in metaphorical terms the energy of the drives, which he termed the *libido*. While Freud and most other analysts eventually ceased using this term, Reich found it to be a very useful concept, and he continued to seek evidence for this force, which governed human emotion, behavior, and sexuality.

Reich's extensive clinical work led to the observation of *vegetative streamings* or *currents* of emotional energy in the body, which occurred in healthy individuals during states of great relaxation, as following a strong release of emotion, or after a very gratifying genital orgasm. The free, uninhibited expression of emotion, and natural sexual excitation and gratification during orgasm were identified by Reich as expressions of unimpeded energetic movement in the body. When the individual experienced great pain, as from childhood traumas, when the emotions were rigidly suppressed and held back ("big boys don't cry", "nice girls don't get angry"), or when chronic sexual stasis and starvation was experienced, the entire nervous system and musculature participated in the process of emotional suppression, or warding off of feeling. This "holding back" of feeling was also accompanied by a greater or lesser anxious retreat from pleasurable, or even potentially pleasurable situations, which would otherwise stir up suppressed and unpleasant feelings. Reich observed that when this kind of response to feeling and pleasure became chronic, so too did the individ-

ual experience a chronic stiffening and desensitization of the body, along with a reduction in respiration and contactfulness.

This chronic neuromuscular *armoring*, as Reich called it, was not a natural condition, though it had a certain rational survival value for situations of pain and trauma. When the armoring became chronic, however, as a *way of life*, it would thwart the individual's natural biological functioning, and affect their behavior even in circumstances where pain or trauma was not likely. The armoring effectively perpetuated the individual's pleasure-avoiding behaviors and emotion-censoring attitudes. Deep seated fears, and pressures to conform to the prevalent armored form of social life, usually prevented the individual from moving towards emotional health, or taking effective steps to change their situation. The bulk of Reich's early writings focused upon these social, sexual, and emotional concerns.

Reich also argued that the heterosexual genital orgasm played a central regulatory role in the energy economy of the individual, as a means to periodically discharge accumulated bioenergetic tension. The more intense the orgastic discharge of accumulated bioenergy, the more gratified, relaxed and pleasurably expansive one felt afterward. When sexual urges and other emotions were chronically frustrated, dammed-up, and repressed, however, great internal tension could build up to a bursting point, where neurotic symptoms or sadistic urges would appear. Reich developed therapeutic techniques for releasing dammed-up emotional energy within his patients, techniques which led to the release of long-buried feelings, and to a greater capacity for pleasure in life, particularly genital pleasure. As his patients became more healthy sexually, and as they reported an increase in genital gratification, he observed that their neurotic symptoms disappeared, as the quantity of dammed-up emotion and sexual tension was reduced. Some of Reich's early contributions to psychoanalytic theory and technique were at first welcomed. But later on, as he increasingly focused upon the consequences of child abuse and sexual repression, the more conservative analysts rejected and attacked him.

Reich eventually left psychoanalysis altogether, and he articulated his work under the new term, *Sex-Economy*.

Reich's early observations regarding human behavior, emotions, the orgasm, and vegetative streaming sensations strongly suggested a real, tangible nature to the emotional energy. He later used sensitive millivoltmeters to confirm this point of view, and to quantify bioelectrical energy currents, and their emotional correlates. However, he was convinced that the very low levels of observed bioelectrical activity could not fully explain the powerful energy forces observed in human behavior. This was particularly so regarding chronic immobilizing psychic disturbances in catatonic and other completely withdrawn mental patients. When their emotions were finally broken lose, these patients would experience a tremendous outpouring of sadness or rage. Afterward, they would also experience a dramatic relaxation of musculature, a spontaneous deepening of respiration, and a return to more contactful lucidity. In these cases, the patient's emotional energy was held down and bound up, until finally set free in the clinical setting. These observations of energy bound, and energy released, were reinforced by parallel observations regarding the discharge function of the orgasm. Based upon these kinds of observations, the question of exactly how and from where the organism acquired its emotional energy, and its exact nature, became increasingly important.

It was at this point in his research that Reich was forced to flee Germany for Scandinavia, following Hitler's rise to power. In Norway, Reich sought to find a way to confirm his model of human functioning. Pleasure, he observed, was identified by an increasing bioelectrical charge at the skin surface, while anxiety was accompanied by a loss of this same peripheral bioelectrical charge. Persons with a deep respiration and a relaxed posture would, he observed, regularly give stronger readings at the millivoltmeter than contracted, anxious, highly armored persons, who had a life-history of trauma, abuse, repressed emotion, and ungratified sexuality. As a child grew to adulthood, and became habituated or conditioned towards pleasure-seeking, or pleas-

ure-avoiding (pain seeking) behaviors, so too would their skin charge, and other physiological measures, reflect a corresponding high or low energy charge. This movement of the organism, and their energy charge, in a direction "toward" or "away" from the world, he argued, was the result of one's life history. Life naturally moved towards pleasure, but retreated, and shrunk from pain. Chronic painful experience would eventually armor the organism, and make it difficult for them to reach out, towards the painful world. From this central set of observations, he postulated that a similar process could be duplicated and observed in lower organisms, such as the snail, earthworm, or even microscopic ameba.

Reich noted that the ameba had no "nervous system", or "brain", as with the higher animal, yet it expanded towards or contracted away from its environment in a manner similar to the higher animals. He believed that many of the functions attributed to the brain were really functions of whole-body processes, involving the participation of the autonomic nervous system, but primarily being the result of the energetic forces he had documented in a clinical and laboratory setting. These currents of biological energy, he argued, functioned the same in all living creatures, and he sought to test the idea by making millivoltmeter measurements of ameba during states of expansion and contraction. Reich went to the University of Oslo Microbiological Institute, and asked to obtain a culture of ameba. He was told that these kinds of simple organisms were never kept on hand in stored cultures, because they could be cultured directly from a moss or grass infusion. Reich was fully aware of the air germ theory, but was surprised to hear this, as the theory had not at that time been used to explain the genesis of more complex microbes, such as ameba and paramecium. These more complex microbes cannot be cultured directly from the air, for example.

Reich made the moss and grass infusions, but also made extended and careful microscopical observation of the process whereby the ameba developed. He did not see spores on the grass blades, swelling up to become new ameba. Instead,

he observed that the moss and grass itself would disintegrate and break down into small blue-green vesicles. The tiny vesicles would, over a period of several days, develop and clump together, after which a new membrane would form around the clump; the clump of vesicles would roll and pulsate inside the membrane for a period, and eventually the whole thing would move away on its own, having *turned into a new ameba*. Moreover, Reich observed that a number of materials, both organic and inorganic, would, when allowed to disintegrate and swell in a sterile nutrient solution, form the tiny blue-green vesicles. These observations were greeted by the university microbiologists with skepticism, and Reich developed a series of stringent control tests to answer their objections, and to more clearly demonstrate the observable process. These control procedures involved lengthy autoclaving of nutrient solutions, and heating over flame, to incandescence, of the materials placed in the sterile nutrient medium. His control procedures and observations on this question were repeated and confirmed by other scientists of the day, and were presented to the French Academy of Science in 1938. But this did little to satisfy his critics, who shamelessly refused to reproduce the experiments, while simultaneously attacking him in the Norwegian newspapers.

Reich used very high magnifications, around 3500 to 4500 power, but not the usual microbiological stains or procedures which kill the life in the specimen. These facts made Reich's preparations very different from those of the average microbiologist, who to this day still kill and stain their preparations with a religious fervor, and see little value to observing living microbes in the light microscope above 1000 power. Standard electron microscope images, for example, can not be made of living specimens.

Reich gave a new name to the unusual microscopic vesicle he had discovered: the *bion*. Bions of similar size, shape, and motility would appear in the light microscope when various materials were subject to a process of slow swelling and disintegration, or when substances were heated to incandescence, and then immersed into sterile nutrient solutions.

Boiling, autoclaving, or heating samples to glowing incandescence would not eliminate the bions from the cultures, but could actually liberate them in greater numbers. Reich also studied the process of disintegration and decay of foodstuffs in the microscope, and noted that similar bionous processes were at work. The bions exhibited a *bluish* coloration, and radiant energy effects were likewise observed. It was during these microscopic observations of the bions that Reich first discovered the orgone radiation, and later, the principle of the orgone energy accumulator.

Like his findings on human behavior, Reich's bion experiments are far too intricate and important to be fully reviewed here, but it can be noted that they have been widely replicated by various scientists around the world. Classical microbiology of today has made confirming discoveries of very similar small vesicles, though Reich's priority has yet to be acknowledged. His findings on the bions also resolved two parallel riddles, the origins of protozoa from disintegrated dead plant tissue in the natural environment, and the origins of protozoan *cancer cells* from the energetically (emotionally) deadened tissues of the human body. Reich observed similar processes at work in both dead grass and deadened animal tissue: disintegration into bions, followed by a spontaneous reorganization of bions into protozoan forms. In both cases, of soil or tissues, Reich argued that the process was initiated by a *loss of life energy charge* of the tissues, followed by putrefaction and disintegration.

One special bion preparation, made from pulverized beach sand heated to incandescence and immersed into a sterile nutrient broth, yielded a powerful radiant energy phenomena. Lab workers developed conjunctivitis if they observed the preparations too long, while a skin inflammation could be developed by placing the bion solution close to the skin for a period. Working for extended hours in the laboratory, Reich developed a dark tan through his clothing, in the middle of winter. The radiation imparted a magnetic charge to nearby iron or steel implements, and a static charge to nearby insulators, such as rubber gloves. Film stored in nearby metal laboratory cabinets spontaneously

fogged. He noted that whatever this bion radiation was, it was rapidly attracted to metals, but just as rapidly reflected away, or dissipated into the surrounding air. Organic materials, however, absorbed this radiation and held onto it. Attempts to identify the new radiation using traditional nuclear or electromagnetic radiation detectors failed.

Reich also noted that the air in rooms containing the special bion cultures would feel "heavy" or charged. When observed at night, in full darkness, the air would visibly scintillate and glow with a pulsing energy. He attempted to capture the energy radiating from his bion cultures inside a special cubical enclosure lined with sheet metal, which he felt would reflect and trap the radiations inside. As expected, the special metal-lined enclosure trapped and amplified the effects of the bion radiation. However, to his amazement, he found that the radiation was also present in the experimental enclosure *even when the bion cultures were removed*. In fact, there was nothing which could be done to make the observed radiation "go away". The special metal-lined enclosure appeared to pull the same form of radiation from the air which previously had been observed coming from the bion cultures.

Reich eventually became convinced that the special enclosures were capturing a free atmospheric form of the same energy that he also observed coming from living organisms. He called the newly discovered energy the *orgone*, and he developed ways to amplify the energy accumulating affects of the enclosure, mainly through multiple layering of the metallic and organic materials. No electricity, magnetism, electromagnetism, or nuclear radiations were employed in these accumulating structures, which were entirely passive in design. The special enclosures were thereafter called *orgone energy accumulators*.

The full sweep of Dr. Reich's clinical findings, his experiments with bioelectricality, the bions, on biogenesis and the origins of the cancer cell, and his discovery of the orgone energy and the orgone energy accumulator, cannot be given here, but a few points are summarized. The orgone accumulator was found to have specific life-positive effects upon

plants and animals exposed to the concentrated life force inside it. A host of quantifiable effects upon the physical properties of the air, or other materials charged up inside the accumulators, were also discovered and documented. Reich and his co-workers published a host of research articles on the orgone energy accumulator, its unusual physical properties, and its life-positive biomedical effects. These effects have been repeatedly confirmed, and a research tradition in orgone biophysics continues to this day. Briefly, we may identify some of the known properties of the orgone energy, and effects of the orgone energy accumulator.

Properties of the Orgone Energy:

A) Ubiquitous, fills all space.
B) Mass-free; cosmic, primordial in nature.
C) Penetrates all matter, but at different rates of speed.
D) Spontaneously pulsates, expands and contracts, and flows with a spinning wave characteristic.
E) Directly observable and measurable.
F) Negatively entropic.
G) Strong mutual affinity and attraction to/by water.
H) Accumulated naturally by living organisms through foods, water, breath, and through the skin.
I) Mutual excitation and attraction of separate orgone energy streams, or of separate systems charged with orgone.
J) Excitability via secondary energies (nuclear, electromagnetism, electrical sparking, friction).

Physical effects of a strong orgone charge:

K) Slightly higher air temperature as compared to surroundings.

L) Higher electrostatic potential, with a slower electroscopical discharge rate as compared to surroundings.

M) Higher humidity and lower water evaporation rates as compared to surroundings.

N) Squelching of ionization effects inside gas-filled ionization Geiger-Muller tubes.

O) Development of ionization effects inside non-ionizable vacuum tubes (0.5 micron pressure or lower).

P) Ability to impede and absorb electromagnetism.

Biological effects of a strong orgone charge:

Q) General vagotonic, expansive effect on entire system.

R) Sensations of tingling and warmth at skin surface.

S) Increased core and skin temperature, flushing.

T) Moderation of blood pressure and pulse rate.

U) Increased peristalsis, deeper respiration.

V) Increased germination, budding, flowering and fruiting of plants.

W) Increased rates of tissue growth, repair, and wound healing, as determined through animal studies and human clinical trials.

X) Increased field strength, charge, integrity of tissues and immunity.

Y) Greater energy level, activity, and liveliness.

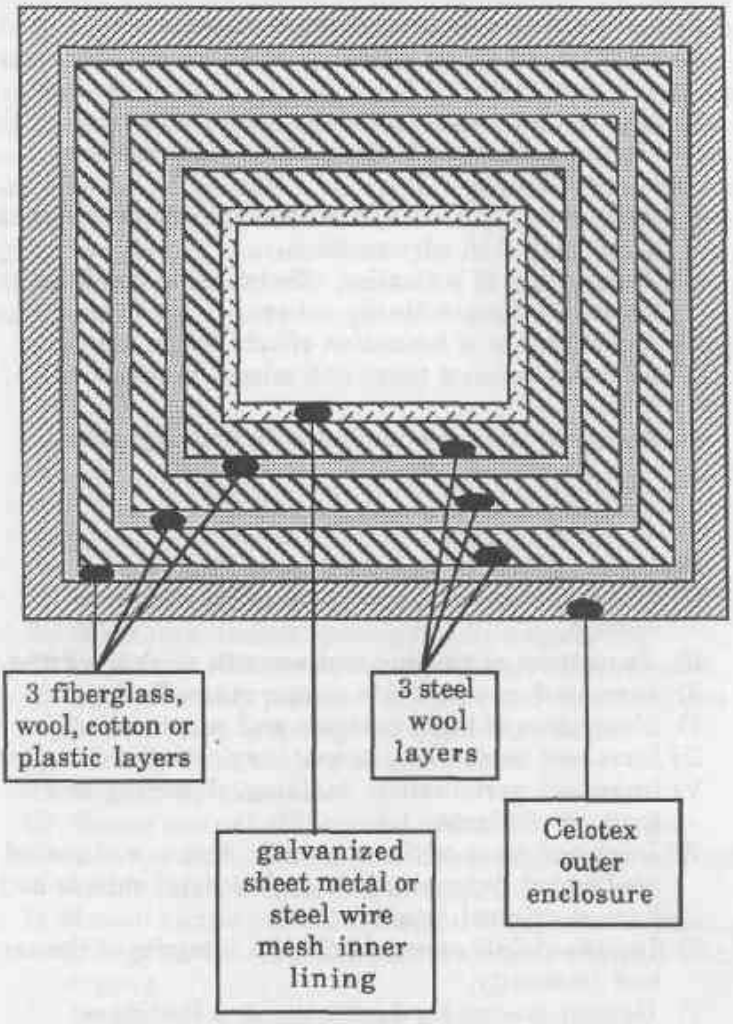

Simplified Diagram of the Orgone Energy Accumulator

A three-ply accumulator in the author's laboratory. A ten-ply charger, with attached funnel shooter, is at the lower left. This charger normally sits inside the larger accumulator, under a wooden bench inside the accumulator.

5. Objective Demonstration of the Orgone Energy

A number of techniques have been developed over the years to document, measure, and objectify the orgone energy. These techniques are briefly listed, but the interested reader is directed to the references for more specific details.

A) Bioelectric Fields: Reich identified various bioelectrical phenomenon which he felt demonstrated a more powerful energy current at work in the body. The small millivolt currents of "bioelectricality", he argued, were only a small portion of this stronger energy current in the body, which he identified as being both emotional and sexual in nature, and which was later objectively identified as the orgone energy.

B) Radiant Effects from Bion Cultures: Special bion cultures derived from beach sand emitted a powerful radiation which could be felt and seen in darkrooms. This radiation did not register on instruments for detecting nuclear or electromagnetic energies. Additionally, the radiation could fog film, impart a static charge to insulators, and a magnetic charge to steel laboratory implements.

C) Darkroom and Atmospheric Observations, the Orgonoscope: Reich also observed and categorized various observable phenomena which could be seen by the dark-adjusted eye in the open air of darkrooms. Scintillating fog-like forms, and dancing, luminescent pin-points of light were observed, and numerous techniques were developed which demonstrated their real, objective nature. One of these techniques involved the development of a new instrument, the *orgonoscope*, which used hollow tubes, lenses, and a fluorescent screen for magnifying the various subjective light phenomena. Large room-sized orgone accumulators were also constructed, and observations made in these amplified

and clarified many of the effects. A special corpuscular *orgone unit* was identified, whose lawful behavior changed according to cosmic and meteorological factors. These macroscopic particles were also observed in the daytime sky with the unaided eye, as a generally common phenomenon, visible to most people once they were pointed out. The Earth was observed to possess its own orgone energy envelope, or energy field, much as did individual living creatures.

D) X-Ray Photographs: Reich observed that the x-ray "ghost" phenomenon (spontaneous, unexplained fogging of x-ray films) could be explained as an effect of the orgone radiation, or life energy. He published several photos where the ghosts were purposefully created by excitation of orgone energy within the field of the x-ray machine.

E) Visible Light Photographs: Reich observed that his special radiating bion cultures would fog film stored in nearby metal cabinets. Culture dishes of radiating bions set directly upon the film would also render an image of the culture dish and its contents. More recently, Thelma Moss of UCLA has shown that life energy field photos can be made without electrical stimulation (as with Kirlian techniques), by energy field enhancement; living objects placed directly on a film for a few days within a darkened orgone accumulator will, under the proper conditions, render an image.

F) The Orgone Energy Field Meter: Reich developed this device to measure the strength of energy fields. Using a Tesla coil and special accumulator-like metal plates, the device could quantify the differences in energy level between people or objects.

G) The Orgone Energy Pulsation Demonstrator: Reich demonstrated that the energy field pulsations of a large metal sphere were capable of setting into motion a smaller metallic/organic pendulum suspended nearby.

H) The Accumulator Temperature Differential (To-T): An accumulator will spontaneously develop a slightly higher temperature than either its surroundings or a control enclosure, on those sunny and clear days when the orgone charge at the Earth's surface is strong. The effect vanishes during stormy, rainy weather, when the orgone charge at the

Earth's surface is weak (but strong in the Atmosphere). The results of this temperature experiment, which has been replicated many times, demonstrates that the orgone energy functions in opposition to the second law of thermodynamics.

I) The Accumulator Electrostatic Effects: An electroscope kept inside an orgone accumulator will dissipate its charge more slowly than an identical one kept in the open air, or inside of a control enclosure. A partly charged, or uncharged static electroscope which is kept inside an accumulator will sometimes spontaneously charge itself up. As with the temperature differential effect, the electrostatic effects vanished during rainy or overcast weather, when the orgone charge at the Earth's surface is weak.

J) The Accumulator Ionization Suppression/Amplification Effect: Geiger-Muller tubes and counters charged up inside a very strong accumulator for several weeks or months tend to go "dead" for a period, but may eventually yield an erratic count rate for background. Special vacuum tubes, which Reich had constructed and called vacor tubes (which mimic the design of the Geiger-Muller tube but are evacuated well below the level at which ionization could occur), will initially not yield any counts when hooked to a radiation detector. After charging up inside a very strong accumulator for weeks or months, however, these same vacor tubes will begin to yield very high counts per minute for background, even at very low exciting voltages. The results of this experiment run counter to the classical interpretation of the ionization effect inside the Geiger-Muller tube, and hence, to the classical particulate interpretation of radioactive decay.

K) The Accumulator Humidity/Water Evaporation Effect (EVo-EV): More recent studies have suggested that an accumulator tends to attract a slightly higher humidity into itself, and suppress the evaporation of water from an open vessel inside. As with other accumulator phenomena, this effect also diminishes or vanishes during rainy weather.

L) Atmospheric Energetic Pulsation, and the Reversed Orgonotic Potential: Based upon observations of the ther-

mal, electroscopical, and ionization characteristics of the orgone accumulator, Reich identified a patterned and lawful energetic cycle at work within the atmosphere and energy field of the Earth. These observations likewise led to the identification of a reversed potential at work in the orgone energy, running counter to thermodynamic principles, which explained why natural orgonotic systems (organisms, weather systems, planets) maintained a higher concentration of energy than their surrounding environments. The stronger of two orgonotic systems will drain energy from the weaker system, and increase its own potential or charge, until the weaker system is drained, or some maximum capacity level is achieved. Discharge may occur thereafter. Under sunny, clear weather, the orgone charge at the Earth's surface is quite strong, and in a state of expansion, preventing any significant growth of clouds. Where overcast or stormy conditions prevail, the orgone charge at the Earth's surface is weak, while the charge in the atmosphere is strong and in a state of general contraction. This loss of charge at the Earth's surface during rainy weather slows down the activity of living creatures, and the accumulator will not function well at those times.

M) The Millivoltmeter: Virtually all objects and organisms within a given environment, to include the air, water, and the Earth itself, have a charge that will increase and decrease in a cyclical or pulsatory manner, timed to cosmic and meteorological factors. In living creatures, high potentials produce more active physical and emotional periods, while low potentials signal less active periods. In Nature, high atmospheric potentials signal cloudy periods with stronger storms, while high Earth potentials signal cloud-free conditions. The tiny currents are excellent predictors of powerful biological or environmental processes, but are themselves too slight and weak to be the causative agent. Reich, and other researchers who have examined these small voltage potentials (such as H.S. Burr), viewed them as indicative of a more powerful, ubiquitous natural phenomena which energetically linked together the Sun, Moon, Earth, weather systems, and all living creatures.

N) Plant Growth Enhancement Studies: Seeds and plants correctly charged up inside an accumulator demonstrate higher growth rates and yields of fruit. This is one of the more telling, and widely replicated experiments with the orgone accumulator. In my own trials, I have seen a six-fold increase in the length of mung bean sprouts inside a strong accumulator, as compared to a control group of sprouts. Germination rates, growth rates, budding, flowering and fruiting can be increased by charging seeds or growing plants directly inside the accumulator. The seeds can be sprouted directly inside the accumulator, or charged up for a few hours, days, or weeks prior to planting. Growth enhancement effects may also occur when the water alone is charged, and then externally given to the plants.

O) Non-Human Animal Studies: Controlled studies on the effects of orgone radiation from an accumulator on cancer mice and wounded mice have been performed. These studies generally confirm Reich's earlier arguments that tissues with a stronger energetic charge will heal more quickly, and develop tumors more slowly, or not at all, as compared to energetically weakened tissues. These findings invalidate many aspects of the DNA theory of cellular differentiation, which appears to be more directly under the structuring influence of the organism's own life energy field.

P) Human Studies: Aside from those clinical trials performed by Reich and his co-workers in the 1940s and 1950s, very little work has been done in the USA regarding the bioeffects of the accumulator on humans. All research into these questions was halted by medical police actions in the 1950s. Recent studies from Germany, however, have confirmed such bioeffects. In general, a person sitting inside an accumulator will feel a variety of warm, glowing, or sometimes tingling sensations at the skin surface; their body core temperature will rise and skin flush, while blood pressure and pulse rate will trend towards moderate levels, being neither too high or low. When properly used, it has a distinct vagotonic, enlivening effect. The chapter on

"Physiological and Biomedical Effects", as well as the Appendix article, will provide details on these questions.

6. Discovery of an Unusual Energy by Other Scientists

Studies by various natural scientists have, over the years, demonstrated energetic principles at work in the natural world which are similar to the orgone energy. Early Chinese medicine acknowledged the existence of such a force, called *Chi*, and the traditional method of acupuncture is based upon the existence of such an energy principle within the human body. Acupuncture points do not correspond directly with nerve endings, and the most able acupuncturists do not rely upon the Western models of physiology to explain its effects. Given the absence of a vital energy principle, Western medicine cannot explain acupuncture, and has resisted its adoption in the United States. Acupuncture furthermore works on animals, invalidating invocation of the placebo effect; ancient texts from India have also referred to the life energy, called *Prana*, and provide maps of *Nila points* (similar to acupuncture points) on elephants. The texts from ancient China and India speak about an energy that is taken in through the breath, and flows through the body along the various meridians. Health is constituted by a free, unimpeded flow of this energy, while sickness occurs when the flow of vital energy is blocked. This is very similar to Reich's ideas on the orgone energy, though the Asian sources say little about the free expression of emotion; they also often advocated a conscious control of emotions and sexual feeling (*orgasm avoidance*). In contrast, Reich demonstrated that such chronic restraint or self-control was the reason why the life energy became blocked or dammed up in the first place.

In the Western tradition, the vitalists of the eighteenth and nineteenth centuries also discussed the existence of a biological energy or life force, which was called *animal magnetism*, the *odic force, psychic force, élan vital,* and so on.

Indeed, Mesmer spoke of animal magnetism as an atmospheric fluid which surrounded, charged, and animated living creatures, and could be projected across a distance by a therapist. Mesmer was a teacher of Charcot, who was, in turn, the teacher of Freud, who was one of Reich's early mentors. Reich also studied with other vitalists, such as Kammerer and Bergson, and the vitalist tradition has persisted as a quietly spoken minority viewpoint in biology. Besides Reich, the more recent advocates of a vital or dynamic energy principle in nature included the late Harold S. Burr of Yale University. Burr argued for the existence of a powerful *electrodynamic field* at work in nature, affecting both weather and living creatures. The biologist Rupert Sheldrake has similarly developed a theory on *morphogenetic fields* which also takes from this tradition. Like Burr's work, Sheldrake's theory provides a dynamic, energetic explanation for inheritance, making the biochemical DNA theory unnecessary. Most recently, editors for the academic publication *New Scientist* called Sheldrake's book the "best candidate for burning" they had seen in a while.

The surgeon Robert O. Becker developed these prior principles to a most amazing state of advancement. His early research led to the development of a class of devices for the electrical stimulation of bone healing and pain relief. His later work took these principles, and developed them to the point that he could artificially stimulate the *regenerative growth of amputated limbs of laboratory mice*, in a manner similar to the way in which a salamander or spider will regrow a lost limb. This kind of regrowth is by nature limited only to less complex creatures, and does not generally exist among mammals, such as mice, rabbits, and humans. Regrowth of an amputated limb had never been previously demonstrated in a mouse, or any mammal for that matter. Becker's work was a severe blow for both the biochemical DNA theory of cellular regulation, and the theory that the bioelectrical field of a creature was just a meaningless "by-product" of chemical metabolism, like the electric field surrounding a running automobile engine. His work proved that the energy field of the animal was a primary determi-

nant of growth and repair, as was the case with Reich's work. Becker was preparing to replicate the limb regrowth experiments on humans, when the biomedical community reacted with severe outrage against him, pulling dirty tricks of all sorts to have his research funding cancelled, and his laboratory shut down.

Another vitalist of our era is Bjorn Nordenstrom, director of the Karolinska Radiological Institute in Sweden. Nordenstrom, like Reich, made a study of the x-ray "ghost" phenomena, which is an unusual spontaneous fogging of x-ray films. It appears as a wispy, smoke-like or blob-like form on the x-ray images of patients, and sometimes can be seen on the monitors of airport baggage x-ray equipment. It cannot be predicted, and most radiologists consider it to be a nuisance. However, Nordenstrom studied it, and observed distinct patterns correlated to his patient's bioelectrical fields. Like Reich, he also discovered and measured currents of bioelectricality in the body. His meticulous research was summarized in a book titled *Biologically Closed Electric Circuits: Clinical, Experimental, and Theoretical Evidence for an Additional Circulatory System*. After being heavily advertised in medical journals in the USA, it sold less than 200 copies, evidencing a contempt among mainstream medical doctors for any new findings that would support the principle of a life energy, even one of a purely bioelectrical nature. Unable to find support for his work in the West, Nordenstrom recently went to China to pursue his clinical research.

Other biological scientists have inferred the existence of such a vital energy principle, on the basis of their experimental work. When they provide good confirming evidence, they are hotly attacked. The French scientist Louis Kervran, for example, spent years developing very elegant and simple experiments demonstrating that the basic elements of chemistry were being *transmuted* by living creatures. Chickens fed a diet free of calcium, for example, would not lay mushy or fragile eggs, unless dietary silica was restricted. With a restricted silica intake, however, they laid mushy and fragile eggs, and it did not matter how much calcium they ate. Likewise, laboratory mice would heal

broken bones very quickly when fed a diet high in organic silica, but not so fast when silica was minimized and only calcium was provided. These experiments strongly suggested that dietary silica was being transmuted into calcium in the bodies of animals. Kervran also experimentally demonstrated other likely transmutations, and other scientists in Europe and Japan confirmed his findings. He eventually came to the conclusion that there had to be some unknown form of powerful biological energy at work to drive the transmutations. But when he wrote to a prominent American scientist for assistance in obtaining equipment for an important experiment, he was impolitely told to go "read an introductory textbook on biology". In the United States, Kervran is better known among homeopathic doctors and organic farmers than by university professors. However, if Kervran is right–and the experimental evidence suggests that he is–then the textbooks of biochemistry will need to be rewritten. As Kervran pointed out, biology and biochemistry are two entirely different disciplines and should not be confused. Biology is concerned with observable fact, while biochemistry attempts to explain observed facts by a chemical theory which assumes elemental constancy. And it is with this basic assumption that part of the error lies.

Another French scientist, Jacques Benveniste, actually demonstrated such an energy principle at work in homeopathic dilutions. His experimental work was successfully replicated by independent laboratories in other countries, to satisfy his obstinate critics. But that was not good enough. For making this offending discovery, which lent some support to homeopathic physicians (who are often prosecuted and jailed in the United States), the science journal *Nature* dispatched a "hit squad" of fraud investigators, debunking magicians, and skeptical editors to his laboratory, under the guise of "evaluating" his laboratory procedures. The *Nature* science cops made a mess of Benveniste's lab, distracting laboratory workers, performing slight-of-hand tricks, and shouting, before finally being told to leave. *Nature* subsequently tried to smear Benveniste in their editorials, but did not factually refute his work through replication of experi-

ments. Such is the warp and weave of traditional academic science in the 1980s.

In the atmospheric sciences, the tradition of dynamic energy forces which affect entire regions was preserved for a period by older weather forecasters, who used streamline, rather than frontal theory to predict weather. Streamline analysis more coherently focused upon streaming movements of air, or jet streams as they are called today. For example, when you look at the dynamic images of clouds, as seen from a satellite in space, you do not see "fronts". But you do see *streaming movements of clouds*. Reich independently discovered the basic configurations of these streams, years before the first weather satellites were launched. Likewise, the older atmospheric scientists often argued for a great interconnectivity in the atmosphere. Charles G. Abbot, head of the Smithsonian Astrophysical Observatory in the 1950s, used related energetic concepts to predict the weather months into the future. But he was ignored and ridiculed for his findings, in spite of their uncanny accuracy. Irving Langmuir, one of the originators of cloudseeding techniques, once objectively demonstrated that cloudseeding in New Mexico would trigger rain storms all the way into Ohio, and he warned his fellow workers about this danger. The cloudseeders of today, funded by millions in Federal dollars, act as if Langmuir's work never took place, and refuse to replicated his simple experiment. They deny the existence of long distance effects from cloudseeding, knowing that if such effects became public knowledge, they would be forced to stop.

Among the physical scientists, the idea of an energy in space was embodied in the concept of an *aether,* which dates back hundreds of years. The theologian/physicist Isaac Newton forcefully argued that this aether *had to be static*, in order to prevent it from directly participating in the movement and ordering of the heavens. That role, Newton argued, belonged only to the anthropomorphic God (who at that time was demanding that unbelievers be ruthlessly tortured and burned at the stake). And, over the years, a dead, unmoving aether has never been detected. However, an *aether with more*

dynamic properties was objectively demonstrated by the physicist Dayton Miller. Miller also explained why prior attempts to measure the aether had failed. First, he observed that the aether is *entrained* at the Earth's surface, and moves faster at higher altitudes than lower altitudes. Prior attempts to measure its movement had taken place only at lower altitudes, or in heavy stone buildings or basement locations. Second, Miller's aether was *reflected by metals*, and prior attempts to measure it used instruments with the critical parts housed inside metal enclosures. Miller found that by doing the crucial aether-drift experiments on a mountain top, inside a flimsy building without metals or dense window materials, that it was readily detectable and measurable. He made over 200,000 separate measurements, over the course of 30 years of investigation. Contrast this to the famous Michelson-Morley experiment, which involved a grand total of six hours of actual measurement time, made over four days in 1887. The Michelson-Morley experiment is widely misquoted as having completely failed in the detection of the aether. It was a hinge-point in the sciences, after which the idea of the aether was given up entirely for the "empty space" theories of relativity and quantum dynamics.

Miller's extensive work on the aether question was never rebutted when he was alive, but his research was contemptuously compared with "searching for perpetual motion". After his death, the adherents of the empty space theory breathed a heavy sigh of relief. Today, every physics textbook starts out with the falsehood that "the aether was never measured or demonstrated". It should be pointed out that the theories of relativity and quantum dynamics, plus the expanding universe and "big bang" theories, are utterly shattered by the discovery of an energy in space, and many physicists, who cling to their theories religiously, simply refuse to look at this kind of evidence. Worse, the discipline of physics has become a military-oriented growth industry, with multi-billion dollar funding for the sustenance of nuclear power and bomb-making technology, for fusion plants, particle accelerators, and "star wars" experiments. This kind of research has not brought forth any real benefits or fruits for humankind, but

has become a self-perpetuating "research industry", a multi-billion dollar edifice which, like the medico-pharmaceutical industry, is threatened to the core by these discoveries of a primary, cosmic life energy. The physics community has unfortunately reacted to these new findings with the same arrogance and viciousness that characterizes the medical communities' reaction to the life energy. Einstein's followers, for example, have recently been accused, in print, of very nasty stab-in-the-back tactics of censorship and suppression. An entire new journal, *Scientific Ethics*, for a short period at least began to expose the whole stinking mess.

Of great interest for Reich's work is that Miller's dynamic aether was *more active at higher altitudes*, and *reflected by metals*. The capacity to be reflected by metals, with a more active state at higher altitudes, are basic properties of the orgone energy, as independently discovered by Reich. The orgone also satisfies many other of the basic properties and functions of an aether, being ubiquitous and mass-free, and by providing a medium for the transmission of electromagnetic excitation. However, the orgone also spontaneously pulses, superimposes, and directly participates in the creation of both matter and life. But even without using the taboo word "aether", or the more offending word "orgone", another group of physicists have detected or inferred the existence of dynamic energy currents at work in deep space. For example, the American astrophysicist Halton Arp made so many photographs of energy/matter bridges between deep-space objects, where those energy/matter bridges should not have been there, that he was actually banned from using the big American telescopes. His simple photos demolished the theories of empty space, the expanding universe, and the "big bang" with a single shutter click. So great was the hatred against his work that he ultimately had to go to Germany to continue with his research. Hannes Alfven, another famous physicist, also deeply offended his contemporaries by suggesting, like Reich, that space was filled with streaming currents of plasmatic energy. The space scientists to this day refuse to send satellite probes where he says they should,

as to do so might confirm that space is energetically rich. In fact, physics of today is in a state of turmoil, and is desperately trying to explain away the newer evidence for an energy in space, to preserve the big bang theory, relativity, quantum dynamics, and the billions of dollars of research money that supports the "empty space" religion, and its institutional priesthood.

Few of the above ideas, nor the findings on sunspot-weather correlations, are given much funding or investigation today. Science journals still routinely carry the false statement that "no mechanism" has been found for solar-terrestrial correlations, just as physics textbooks carry the falsehood that "the aether had never been detected". And it is true that these relationships cannot be true, nor do they make any sense, from the standpoint of the "empty space" theories of physics. They require a medium in the atmosphere and in space, through which excitations and influences can pass, independent from thermal or pressure phenomena, a force which propagates in the atmosphere faster than air currents, and which can likewise quickly propagate influences across the depths of space. Again, Reich's orgone energy fits such a description.

Other research has been done to show that living creatures, and the physical chemistry of water, are sensitive to weather or cosmic factors in a manner than cannot be explained according to simple mechanical phenomena, such as light, temperature, humidity, or pressure. Frank Brown, of Northwestern University, spent decades demonstrating that the biological clocks of various living creatures were sensitive to lunar cycles and other cosmic forces. Nobody could refute him when he was alive, but today, after his death, his findings are widely ignored. Likewise the works of the Italian chemist, Giorgio Piccardi, who demonstrated that the physical chemistry of water was changed by magnetism, sunspots, and other cosmic phenomena. His work helped to fuel an interest in the magnetic treatment of water in Europe, leading to new methods for reducing scale deposits in household plumbing, and in industrial boilers. Magnetism, correctly applied, can alter the solubility character-

istics of water, allowing dissolved substances to remain in solution at concentrations higher than normal for a given temperature. In the USA, these findings have been greeted with derision, as every physics textbook says magnetism has no effect upon water. Also, almost every chemical laboratory uses magnetic stirring devices to mix their chemical solutions, instead of the "old-fashioned" hand-operated glass stirring rods; these magnetic stirring devices would, if Piccardi is correct (and he is) alter the chemistry, precipitate quantity, and titration curves for every chemical reaction exposed to them. And so, the new findings are ignored in the USA, while abroad, new products based upon the discovery are entering the marketplace. Simple magnetic water treatment systems for the home are now common in Europe, replacing in many cases the ion-exchange water softeners, with their bags and bags of salt. In the USA, meanwhile, the water softener industry, in collusion with dogmatic academics and politicians, has managed to have laws passed in a few states to forbid the sale of magnetic water treatment devices.

Piccardi's work extends beyond the issue of simple magnetic treatment of water, however. At one point he attempted to isolate an unknown cosmic energy which was affecting his chemical experiments, in a manner similar to strong magnetism. In order to block out the unknown radiation, which was correlated to sunspots, he constructed an electromagnetic shield around his experiments, in the form of an Earth-grounded metal box enclosure. Then, in order to stabilize the temperature inside the metal box, he placed a layer of wool around the outside. To his amazement, the metal box did not extinguish the cosmic phenomena, but amplified it. He and his co-workers spent decades performing chemical experiments inside similar enclosures, which mirror the construction of Reich's orgone energy accumulator. This independent corroboration of the orgone accumulator principle by Piccardi was also confirmed, though in a less direct manner, by the biologist Brown. Brown observed that hermetically sealed *metal enclosures*, with a constant pressure, temperature, light and humidity inside, would not extin-

guish cosmic influences upon biological clocks, but would instead allow them to be more clearly observed, or even add an unusual dimension to their behavior. For example, inside the metal box, the metabolism of potatoes followed a cycle that correlated with lunar, solar, and galactic parameters. Potato metabolism additionally demonstrated a correlation to local weather; *not the weather today, but the weather two days into the future!* In the enclosure, the energized potato would respond to external energetic factors in the environment which were also determinants of future weather events.

The above are just a few of the kinds of evidence that exist for an energetic principle similar, or identical to the orgone energy. In many cases, these researchers had not known of Reich's work. In a few, they hated Reich's guts, and would hardly tolerate mention of his name by their students! And yet, the facts speak powerfully for a corroboration of Reich's orgone energy. It must be stated, however, that Reich's discovery on the orgone energy is far more inclusive, comprehensive, and tangible than any of the above concepts. In addition to having been quantified, photographed, and measured, the orgone can be seen, felt, and, as noted in this book, accumulated within special experimental enclosures.

An additional word must also be given regarding the response of the scientific and academic communities to these new discoveries. The reader will note that most, if not all, of the above researchers were hotly attacked, or isolated and ignored for their findings, irrespective of their credentials, reputations, or the amount of evidence they provided. This emotional reaction, of running away from or attacking disturbing new ideas, was explained by Reich as being the results of a specific emotional disorder, which he called the *emotional plague*. Virtually all scientists who have verified portions of this common natural energy principle have been assaulted by special *emotional plague characters*, who build their reputations not upon work or research, but upon political power, and the number of scalps they have taken. Gossip, slander, political tactics, the sneak attack, and even manip-

ulation of the courts and police are standard tactics of the plague. Their secret goal, like the Grand Inquisitors of the Church, is to kill disturbing new findings, and the men and women who make them. The history of science is filled with evidence for this kind of behavior. The reader is encouraged to read Reich's discussion on the emotional plague, in *Character Analysis (3rd Ed.)*, *People in Trouble*, and *The Murder of Christ*, as it still constitutes the major obstacle in the way of human social progress, and scientific research.

Part II: The Safe and Effective Use of Orgone Accumulating Devices

7. General Principles for Construction and Experimental Use of the Orgone Energy Accumulator

A) The interior surface of all accumulators must be composed of bare metal. Paints, varnishes or coatings on the metal will interfere with the accumulating effect, though zinc galvanizing does not.

B) The outer, exterior surface of all accumulators must be composed of an orgone-absorbing, generally organic, non-metallic substance.

C) Metals and non-metallic materials may be alternated in multiple layers within the walls of the accumulator for stronger energy accumulation. The more layers, the more powerful the accumulator, though one does not simply double the strength by doubling the layers. A three ply accumulator will have about 70% of the strength of a ten ply accumulator (one "ply" consists of a layer of metal plus a layer of non-metal). Accumulators of different sizes may also be nested one inside another, to develop an even stronger charge. Points A and B above must be strictly followed, however. In multiple ply accumulators, you can double-up the final outer organic, non-metal layer, and the innermost metal layer, for additional energy accumulating capacity.

D) A major common error made by some who reproduce Reich's orgone accumulator experiments is the use of inappropriate accumulator materials. For accumulators used on living systems, and particularly for human use, copper, aluminum, and other non-ferrous materials must be completely avoided as they yield *toxic effects*. Similarly, certain types of polyurethane foams, rigid or soft, do not have a good effect upon the living system when used in an accumulator. Any type of material impregnated with formaldehyde, or

made with other highly toxic glues or resins should not be used.

Good non-metals	*Poor or toxic non-metals*
wool, raw cotton	wood or plywood
acrylic, styrene plastic	urethane or polyurethane
celotex (soundboard)	pressboard (very hard)
cork sheeting	organic materials containing formaldehyde, asbestos, or other toxic chemicals
glasswool, fibreglass	
rock wool	
bees wax, candle wax	
soil, water	

Good metals	*Poor or toxic metals*
steel or iron, sheet, screen	aluminum, sheet or screen
galvanized steel	lead
steel wool	copper
stainless steel	
steel/tin can alloy	

E) Some individuals have experimented with accumulators composed of buried metal boxes, surrounded with rich dark soil, free of pesticides and herbicides. The larger of these kinds of accumulators give the appearance of a root cellar or "burial mound". Some authors familiar with ancient archaeological sites have even speculated that the life energy principles were known and used by ancient peoples. Certain ancient mounds and structures have a layered characteristic, using clay soils or stone of high iron content, covered over with other layers of organic-rich soils or peat.

F) An exceptionally powerful accumulator can be made by using bees wax or other dielectrical materials for the outer, non-metallic layers. These materials may be quite expensive for a larger accumulator, and are also fragile. If you use a fragile or crumbly material for the outer non-metal layer, you can coat the outer surface with clear shellac. This has been tried by many people, and does not appear to interfere with the accumulation or life enhancing quali-

ties of the energy. Never use shellac on the interior surfaces, however.

G) Experiments have demonstrated that the shape of the accumulator is a factor of lesser importance than its material composition. However, accumulators made in the shapes of cones, pyramids, or tetrahedrons have yielded occasional unexplainable life-negative effects. Unless one is testing for such effects, accumulators should be constructed in rectangular, cubical, or cylindrical shapes. These have given the best results, and are also easier to construct. One anecdote here: in 1980, the author was in Egypt, and went into the Great Pyramid of Cheops. While inside, I was struck down by a most intense choking, and could not get a breath. The feeling was relieved by emptying my canteen of water over my head and chest. Later, I heard reports of whole groups of tourists being similarly stricken, to the point that some people had fainted away, and had to be resuscitated outside. I cannot say if this is an effect of poor ventilation or not, but in my own case, I was the only one out of 8 people in a tour group to be badly affected. Given my observations of stunted and killed seedlings within conical and pyramidal accumulators, it seems possible to me that these effects are the result of a toxic accumulation or overcharge effect. More work needs to be done to clarify these factors related to shape, as well as accumulator use in energetically stagnated environments, such as deserts. See the chapter on "Warnings and Dangers" for more details.

H) Corners of accumulators do not have to be precisely constructed, nor do layers have to be air tight or precisely fitted, though one certainly wishes to have as neat and clean of construction as possible. In some cases, I have seen metal boxes loosely wrapped with layered steel wool and cotton, felt, or wool. Also, some have used tin cans, as used for food preservation, wrapped with plastic, and then placed inside another larger can which was, in turn, wrapped with more plastic. These tin-cans were nested inside each other to make reasonably effective four or five ply accumulators, for seed charging or other purposes. They do not look especially neat or "scientific", but they do function.

I) Accumulators should be kept where fresh air can circulate. The door or lid to the accumulator should also be kept partly open when not in use. Its interior may be kept fresh and sparkling by keeping an open basin of water sitting inside when not in use. Periodically wipe the interior and exterior clean with a damp cloth.

J) Larger accumulators used by humans or farm animals are best kept outdoors under a sheltered area, where rain will not fall on it. Good air circulation and sunlight will assist with the accumulation affect. The best location for accumulator research would be inside a large wooden barn in the countryside, away from all kinds of electrical transmission lines, electromagnetic devices, and nuclear facilities. This finding on the best environment for the life energy is in full agreement with more recent findings on *house ecology*, wherein a constructed habitat is critically reviewed for toxic effects upon its inhabitants. See the "Warnings and Dangers" chapter for more details.

K) The accumulator will not develop a strong charge during wet, rainy weather. On such days, the orgone charge at the Earth's surface is very low, most of it being taken up into the storm clouds overhead or at a distance. The strongest orgone charge is found in the accumulator on clear, sunny days, when the orgone charge at the Earth's surface is also quite strong.

L) Orgone accumulators used at higher altitudes tend to yield stronger charges than at lower altitudes; lower latitudes may yield stronger charges than higher latitudes; lower humidity atmospheres tend to yield stronger charges than higher humidity atmospheres. Periods with many sunspots and solar flares coincide with periods of stronger orgone charge, as compared to periods with few sunspots and flares. Alignments between the Earth, Sun and Moon, during full and new moon periods, appears to yield a stronger, more excited charge in the atmosphere, and within the accumulator.

M) If you run a controlled experiment with the accumulator, do not place any relevant instruments immediately adjacent to it. Remember that the accumulator has an energy field, and will partially influence nearby objects in a

manner similar to those kept inside it. The electrical or electromagnetic fields of various instruments might also disturb or otherwise affect an accumulator, making this caution doubly important for the research scientist.

N) Do not use any household electrical appliances connected to a wall plug inside or near to the accumulator. Neither should portable computers, TV sets, or other radiating devices be used. These will disturb the energy inside. The interior metal walls also conduct electricity, and there may be a danger of electrical shock. For human-sized accumulators, use a battery powered reading lamp if light is desired, or place a strong lamp just outside the door opening. Many people use such a light to read a book while sitting inside. Radio *receivers* do not appear to have a negative effect if used in the room, but the effects of "walkman" type headsets inside the accumulator are unknown.

O) For experimental accumulators, realize that any organic or moisture-bearing materials which are placed inside will absorb the orgone charge. Do not unnecessarily store or bring items inside an accumulator.

P) For human sized accumulators, one wishes the exterior walls to be no more than 2 to 4 inches from the skin surface. When sitting inside, it is best to partially or completely disrobe, as heavy clothing will interfere with absorption of the orgone radiation. A wooden chair or bench may be used as dry lumber is a relatively poor absorber of the orgone. Metal chairs are also OK, but may be uncomfortably cold to sit on.

Q) **NOTE: A too-frequent or too-long use of the accumulator may lead to symptoms of overcharge, such as pressure in the head, slight nausea, general ill-feelings or dizziness. In such a case, leave the accumulator immediately and rest in the fresh air for a moment. Such symptoms will go away in a few minutes. However, Reich warned persons with a history of overcharged biopathies to use the accumulator only with caution, and then only for shorter periods. These overcharged biopathies include: hypertension, decompensated heart diseases, brain tumors, arteriosclerosis, glaucoma, epilepsy, heavy obesity, apoplexia, skin inflammations, and**

conjunctivitis.

R) The question of "how much is enough" is related to one's own energy level, and is primarily a subjective determination, different for each individual. No one ever tells you how much water to drink to quench a thirst. You simply drink until you have the feeling of "having enough". The same is true regarding the use of the accumulator. When you have the feeling of "enough", then get out. With most people, this will be sometime after they have reached the point where their own energy field is gently *luminating*, or glowing with a warm excitement at their skin surface, and after sweating has commenced. If you are unsure about these kinds of feelings, be patient, as with some people, it may require many sessions before they can really feel the energetic effects. A good rule of thumb is to limit the sitting period to no longer than about 30 to 45 minutes. It may be used more than once a day, however. One should not attempt to "nap" inside for prolonged periods. Additional information on these bioeffects is given in the chapter on "Physiological and Biomedical Effects".

S) The qualitative state of the orgone, as well as its absolute charge, are constantly varying at any given location on the Earth's surface. Weather cycles cause the accumulator to vary its charge, and toxic environmental conditions (oranur and dor, see below) may periodically or chronically contaminate the accumulator, making its use potentially unsafe. Experimental use of the accumulator therefore demands that one learn about weather cycles and other environmental factors.

8. Warnings and Dangers: The Effects of Oranur and Dor

A common problem with use of the accumulator is the difficulty in finding an energetically clean environment in which to use it. The orgone energy in the atmosphere is very sensitive to certain kinds of disturbance and agitation. Much in the manner of living protoplasm, orgone energy can be *excited* or *irritated*, and certain environmental influences can drive it towards a toxic condition. If the energetic atmosphere in your home or neighborhood has been made toxic in this manner, use of an accumulator is disadvised, or advised only with great caution, as it will be very difficult to accumulate anything except a toxic charge.

For example, **orgone accumulators, particularly those intended for biological experiments or human use, should never be used in rooms with the following orgone-irritating devices:**

fluorescent lights
television sets
computer or microcomputer
other cathode ray tube devices
microwave ovens, or eddy-current stoves
electric blankets (even if only plugged in, and off)
diathermy, x-ray machines
sparking electric motors
induction devices or coils
other electromagnetic devices
ionization-type radioactive smoke detectors
clocks, wristwatches, or other devices containing radioactive, glow-in-the-dark materials (phospholuminescent materials, which work on the principle of absorbed visible light, are OK)
other radioactive materials, or strong chemical fumes

Orgone accumulators should not be used even in the same buildings where the more powerful of the above kinds of devices (such as x-ray machines) are used, or were recently used. Experiments by Reich, and more recently by others in large German hospitals, have demonstrated that x-ray equipment will destroy the life-enhancing effects of the orgone radiation. Additionally, there is a *persistence effect*, wherein toxic energetic conditions remain for a time after the irritating devices are shut down and removed from a room or building. **Orgone accumulators should likewise not be used in the immediate neighborhoods or vicinities where the following facilities are located:**

airport radar systems
cellular telephone or microwave relay towers
very high-tension power lines
AM, FM, or TV broadcast towers
nuclear power plants, storage facilities, or nuclear waste dumps
military installations with nuclear bomb storage
past or present nuclear bomb testing areas

Reich and others associated with him made warnings about these devices in the 1940s and 1950s, but only today do we see epidemiological studies corroborating their life-negative effects. Part of this problem has hinged upon the difficulty that, by simply demonstrating a correlation between two events, you do not prove causality. One has to show or demonstrate just what the mechanism is, and objectively demonstrate each step between the two correlated events, before cause and effect are proven. This is in most cases a very wise policy, but it is very unevenly applied in the world of the sciences. Orthodox theorems are rarely subjected to valid critical review based upon their failures to meet this strict criteria (eg, "bad genes", "viruses", etc.), while unorthodox theories are denied funding or simply thrown out or repressed for whatever weaknesses they may have. Industrial

polluters may also raise this issue to avoid taking responsibility for the environmental damage they have done.

Regarding energetic questions, according to the best calculations of the physical scientists, low-level radiation *ought not* to have a deleterious effect upon the living system. The energy present in the low-level radiation, *as detected with conventional radiation detection instruments*, is simply not sufficient to do significant damage. And yet, the damage occurs. I emphasize the concern about "conventional radiation detection instruments", because a major fallacy of physics is that if an instrument does not measure an environmental disturbance, then no disturbance has occurred. The error here lies in the false assumption that their energy detection instruments must be detecting 100% of any disturbance. This unprovable assumption is, of course, challenged by biological or epidemiological evidence which demonstrates that an effect does exist. There is furthermore a great distrust of the body in the modern sciences, in that average people who are made sick by our modern energy radiating devices often are not believed, or are viewed suspiciously.

It is precisely here that Reich's findings on the orgone energy provide a clarification, as the life energy (and disturbances within it) *cannot be detected with ordinary nuclear or electromagnetic sensing instruments*. One has to modify the instrument to pick it up, or use entirely different methods. The orgone is also an interconnecting energy continuum, which provides a connection between the offending facility or appliance (nuclear plant, microwave tower, fluorescent light, TV set) and the living creature that is affected. As the local orgone energy field of the Earth, or the energy field of a home is badly disturbed and agitated by these devices, so too does the orgone energy field of a person in that environment become disturbed.

Modern physics partly acknowledges these connections, in that all nuclear bombs, nuclear reactors, and related facilities are said to radiate unshieldable, undetectable, theoretical *neutrinos* in tremendous quantities. These neutrinos race out from the facilities, penetrating all forms of ra-

be done only on a very crisp, clear, and sparkling day, when the orgone charge at the Earth's surface, and in the accumulator, is quite strong and lively. Otherwise, charging may have to take place for slightly longer periods. Also note that seeds can be overcharged; attempts at charging seeds for 30 days or more often result in little difference between controls and charged seedlings, or even stunted growth.

E) Orgone Charging of Potted Plants: This can be done by charging up seeds prior to planting, as discussed above, or by charging up soil or water before using. One can also make a "wrap around" accumulator, using a metal can with the ends removed, and plastic and steel wool layers wrapped around the outside. Be sure that the final outside layer of plastic is fairly thick, and do not use aluminum materials. Leave the steel wool in a fluffy condition; don't compress it.

F) Home Seed Sprouting Experiments: The life-positive effects of the accumulator may also be observed in the way it enhances seed sprouting. Build an accumulator to house your seed sprouting apparatus. Store one sprout container in a darkened area away from the orgone accumulator, and another inside the darkened orgone accumulator. Make sure the temperature, ventilation, and light exposure of the two groups is identical and, once again, keep both groups away from oranur-producing devices. Measure the quantity of seeds going into each container, and make sure the quantity of water in each is about the same. Observe and record any subsequent differences in growth and taste. The accumulator group should have a greater growth and yield.

G) Laboratory Seed Sprouting Experiments: Obtain two small shallow glass dishes with a flat bottom, or two shallow glass laboratory culture dishes, about 4" diameter with a 1" lip. Into each dish place around 20 or 30 dry mung beans, to form a single layer of beans on the bottom of the dish. Add a measured quantity of water to each dish, which only halfway covers up the beans. The tops of the beans should remain exposed to the air, while the bottoms are wet. Place one dish of beans into a small but strong orgone accumulator, and the other dish into a control wood or cardboard enclosure of similar dimensions, but with no metals. Cover both the accumu-

lator and control enclosure with a layer of black plastic, to seal them against any intruding light. Place the enclosures in a well-ventilated area, of equal temperature, and out of the direct sunlight. The enclosures should be in nearly identical environments with respect to light and temperature, but not placed closer to each other than about a meter. Again, no oranur-producing devices should be nearby. Each day, open the enclosures up and add as much water as is needed to keep the bean dishes wet to approximately the same height as originally was necessary to cover the beans halfway. If one dish begins to grow more quickly it will require more water, and this should be provided on demand. After one of the dishes of sprouts has reached about 4" high, record your observations of germination rate, length or weight of sprouts, general appearance, and other characteristics. Contrast the two groups. The accumulator group should have a greater growth and germination rate.

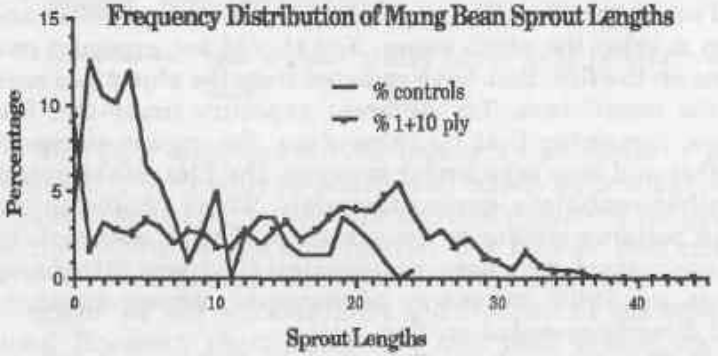

Contrast of mung bean sprout lengths between a group sprouted inside an orgone accumulator, and a group sprouted inside a control enclosure. (from DeMeo, J.: "Seed Sprouting Inside the Orgone Accumulator", *J. Orgonomy,* 12:253-258, 1978)

H) Passive Life Energy Photographs: Orgone energy field photographs can be made in a manner similar to that used to make *Kirlian* electrophotos, except that no electricity is needed. The techniques given here were developed by Thelma Moss, who pioneered the techniques of energy field electrophotography. From Dr. Moss' descriptions, you will need either a darkroom and photo lab, or access to a camera shop which can develop individual sheets of photo print paper. First, obtain some light-sensitive color or black and white print paper, making sure you do not open the package except in complete darkness. Obtain also a separate, empty, light-tight film box in which you can run your experiments. While in the dark, remove a piece of film paper and place it on the bottom of the empty film box. On top of the sheet of film, place a flower bud, leaf, piece of fruit, sprouting seedling, magnet, or other energized, living, or once-living object. Close the box and wrap it completely inside an orgone energy blanket, or place it inside a strong orgone accumulator. Make sure the film box is light-tight; cover it and the blanket with black plastic, or otherwise insure that no outside light will reach the film. Wait a day or two, or up to a week, and then develop the photo paper. You should see exposure patterns on the film that have radiated from the object you used in the experiment. Try different exposure times and film types; remember that on rainy days, the orgone charge is weaker and may take longer to expose the film. Make note of weather conditions during the trials. These photos should yield patterns similar to those seen on Kirlian electrophotographs, except that here, no electrical field was introduced. These are 100% *life energy photographs,* orgone-enhanced and directly recorded on film.

I) The Accumulator Temperature Differential Effect: Reich demonstrated that the warm glow felt inside the accumulator possessed an objective aspect which could be measured with a sensitive thermometer. An air-tight orgone accumulator will spontaneously warm up the air inside itself by a few tenths of a degree, up to several degrees. This temperature increase will make the accumulator interior slightly warmer than the surrounding air temperature, or

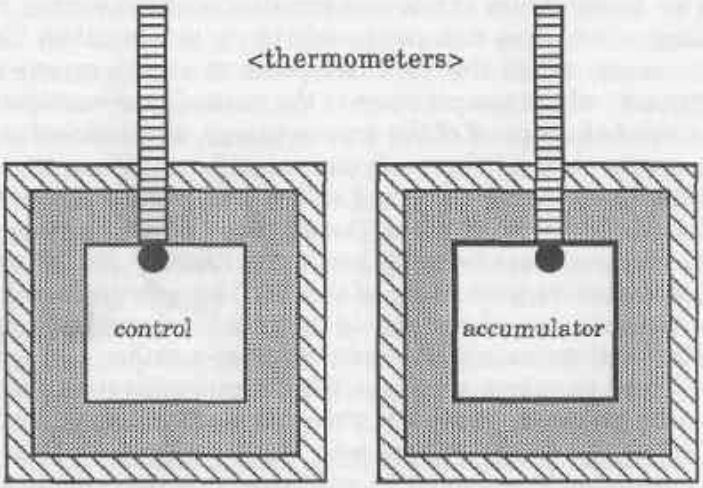

The To-T Experiment: The orgone accumulator (right) and control (left) must be matched as closely as possible with respect to size, ventilation, and thermal dynamics for quantitative orgone energy experiments. The interior and exterior of the control enclosure should be the same size and dimensions as the accumulator, with identical lid dimensions. However, sheet metal and steel wool should not be used in the control enclosure. While metals are used in construction of the accumulator, they are strictly excluded from construction of the control. In the control, additional plastic or fibreglass layering is used in the place of steel wool. The thermal resistance *and* heat capacity *must be as closely matched as possible. A similar set of environmental conditions must also be maintained for the two enclosures.*

the air temperature inside a thermally-balanced control enclosure which does not use metals in its construction. This experiment, called the To-T (temperature in the orgone accumulator minus temperature of the control) was considered by Reich to be a proof of the orgone energy, and a violation of the second law of thermodynamics. Albert Einstein once replicated the experiment and called it a "bomb in physics"; a fascinating booklet titled *The Einstein Affair* documents the correspondence between Reich and Einstein on the matter. A definitive evaluation of the To-T experiment requires the construction of thermally balanced accumulator and control enclosures, careful monitoring of weather and environmental temperatures, sensitive thermometers capable of recording down to tenths of a degree, and prolonged systematic measurements. Those who wish to reproduce this experiment should consult the published reports given in the reference section for details. It is an area ripe for innovative investigation, and I strongly encourage the experimentalist to carefully seek out this effect.

J) The Accumulator Electrostatic Effects: Obtain or build a simple aluminum or gold leaf static electroscope. If you do not know what this is, instructions can be found in a good library. Make sure that the electroscope is calibrated with degree markings, from 0 to 90, such that its degree of deflection can be accurately measured. By running a plastic rod or comb through your dry hair, you can gather a significant static electrical charge and transfer it to the electroscope. Using a stopwatch, or a watch with a second hand, determine how long it takes for the electroscope to slowly lose its charge into the air, through a predetermined deflection angle. For example, you want to know how long it will take for the electroscope to discharge from a 50 to a 30 degree angle. You therefore should charge the electroscope up to a deflection angle *greater* than 50 degrees, waiting until it discharges to the 50 degree mark. Once this happens, you can count the number of elapsed seconds that pass until it reaches 30 degrees. The time elapsed is the *electroscopical discharge rate*. On sunny days, the discharge rate will be quite slow, while on rainy days, the discharge rate will be very quick,

so quick that you might not even be able to measure it. If you time the electroscopical discharge rate inside an orgone accumulator, you will find that *it takes a longer time to discharge in the accumulator than in the open air*. The difference between the discharge rate inside the accumulator, and the discharge rate in the open air, is called the electroscopical discharge rate differential. This differential will be large on clear, sunny days, and minimal or zero on rainy overcast days. On rare occasions, an electroscope that is only weakly charged, or even completely discharged, may--if allowed to soak inside an orgone accumulator--spontaneously charge itself up to a higher level. All of these effects will vanish on rainy, overcast days. For more details, see the citations in the "Reference" section.

K) The Accumulator Evaporation Suppression Effect: This experiment requires a sensitive weighing scale that can measure to fractions of a gram. It also requires an accumulator and a thermally-balanced control enclosure of similar dimensions. For this control, do not use water-absorbent materials in the interior; instead, line the interior of the control with a non-metallic waterproofing material, such as plastic, enamel or varnish. Obtain and weigh two small, identically shaped and sized glass dishes of about 4" diameter and 1" high. Weight the dishes when empty, clean and dry. Next, add identical quantities of water to each vessel, filling them about halfway, and weigh again, calculating via subtraction the weight of water in each dish. Place one vessel of water inside the orgone accumulator, elevated on a small wood block, such that the bottom of the dish does not come into direct contact with the metal interior of the accumulator. The lid of the accumulator should be shut, but fixed open with a crack such that air may circulate. It should not be placed in a windy or sunlit area, however. Place the second vessel of water inside the control enclosure in a similar manner, on an identical wood block, and also prop its lid open. Place it in a location at least a meter away from the orgone accumulator, but with similar light, temperature, and wind characteristics. You may wish to drape a piece of black plastic over both the accumulator and control, in order to

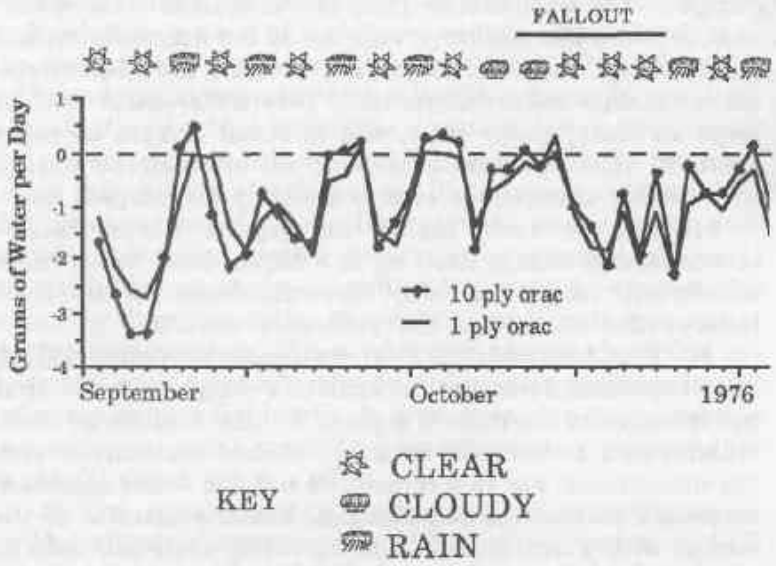

KEY
CLEAR
CLOUDY
RAIN

Water Evaporation Curve, EVo-EV: The curves identify the amount of water evaporated each day from a one cubic foot, ten ply orgone accumulator, and a similar one ply accumulator, minus the amount evaporated from a control enclosure. As the accumulator builds up its charge on clear, sunny days, it suppresses the evaporation of water inside itself. The control enclosure, however continues to evaporate moisture at a relatively high rate, up to several grams per day more than the accumulator. On wet, stormy days, the effect vanishes as orgone charge is lost at the Earth's surface, being taken up into the stormclouds. Disturbances in the regularity of the curve may also occur, such as (above) when radioactive fallout arrived at the laboratory site causing the accumulator to go temporarily "dead". (from DeMeo, J.: "Water Evaporation Inside the Orgone Accumulator", *J. Orgonomy*, 14:171-175, 1980)

control for slight differences in light. Wait exactly 24 hours and remove the dishes of water, being careful not to spill any. Carefully weigh the dishes and compute the evaporative loss for the 24 hour period. Make this measurement once per day, preferably in the late evening, such that you can determine the amount of water evaporated each day from each container. You should find that the control enclosure evaporates significantly more moisture on clear, sunny days, when the accumulator suppresses water evaporation. On rainy days, when the accumulator no longer builds up a charge, the evaporation in the accumulator and control will be nearly identical. Subtract the quantity of water evaporated in the orgone accumulator from the quantity evaporated in the control for each 24 hour period. This quantity, called EVo-EV, will reveal the changing quantity of orgone energy charge in the local atmosphere, and in the accumulator. The evaporative values on any one day are less interesting than the dynamic manner in which the evaporation differential increases and decreases, according to the orgone energy charge at the Earth's surface.

14. Questions and Answers

- Q: If the orgone energy really exists, why don't we hear about it from scientists working in the universities?

A: Scientists working in the universities and research institutions have engaged in verifying research on the bions, orgone accumulator, and cloudbuster, and on the bioelectrical aspects of life, which Reich also pioneered. For example, Dr. James DeMeo, author of this *Handbook*, did research on the weather-related aspects of Reich's discoveries while he was a graduate student and Instructor at the University of Kansas. He continued with that research while a member of the faculty at Illinois State University and the University of Miami. Müschenich and Gebauer, of the University of Marburg in West Germany, recently completed a double-blind, controlled study on the physiological effects of the orgone accumulator on humans. Other scholars with a research or historical interest in the works of Wilhelm Reich have held positions at Harvard University, Temple University, the State University of New York, York University, McGill University, and elsewhere. Other research scientists have repeatedly verified and confirmed Reich's findings. Workshops and courses devoted to his works are now held at a few colleges and universities in the USA. Nonetheless, the history of science repeatedly shows that large institutions do not easily accommodate innovative research which may force radical changes in the major theories of science.

- Q: Can an accumulator be used during wet or cloudy weather?

A: Use of an accumulator during wet weather conditions will not be harmful, but it will be less effective, as the charge is significantly lower or absent at those times. It is best to use it during clear and sunny weather, when the atmospheric orgone energy continuum is strong and expan-

sive, and the charge at the Earth's surface is greater.

- *Q: These accumulating devices are quite simple to construct. Aren't a lot of them accidentally constructed?*

A: A lot of "accumulators" are being constructed, without knowledge of the people involved. Every mobile home or house with a metal skin or side paneling will accumulate a charge, and a toxic one if aluminum is used. Oranur, and other toxic effects appear to readily occur in such houses, which are filled with all the modern orgone disturbing electromagnetic appliances, such as TV sets, microwave ovens, fluorescent lights, and so forth. Epidemiological studies that would address these general observations have never been performed.

- *Q: I have an old styrofoam beverage cooler. Can I line it with aluminum foil and make an accumulator?*

A: You can try this, but don't expect any firm results unless you comprehend and take into consideration virtually *all* of the procedures and warnings given in this *Handbook*. Styrofoam and aluminum are life-negative accumulating materials. If you run a biological experiment, you may wind up demonstrating only a life negative effect. For the scientist interested in orgone energy, these considerations are even more crucial and cannot be ignored.

- *Q: My accumulator gave very good charge the first months when it was in use, but now does not yield a good charge any more. Why is this?*

A: It is likely that the accumulator has been contaminated with dor. Some researchers have noted this effect, where the accumulator goes temporarily "dead", and hence keep their accumulators outdoors, sheltered from rain, but in the fresh air, with the lids or doors open so that air can circulate inside quite freely. You may be able to refresh a "dead" accumulator by wiping it inside and out with a damp cloth, every day for a week or so. Also, keep a bowl of water, or a draw bucket with draw tubes, inside it when it is not in use. Change the water in this bucket every day. Also, be certain

that the accumulator is not near any of the oranur-producing devices previously identified, and that your neighborhood is as oranur-free as possible. The accumulator can also be sun-charged, by allowing it to sit in the direct sunlight for a few days. These steps should eliminate any dorish tendencies, and "rekindle" the charge.

- *Q: I have heard that sitting inside an accumulator will make a person more sexually potent. Is this true?*

A: This is mostly a false rumor propagated by Reich's enemies, who wrote smear articles in the 1940s and 1950s that branded Reich a lunatic, the accumulator a "sex box", and put false words into his mouth about the ability of the accumulator to restore lost sexual potency. However, Reich never made such a claim; in fact, he continually stressed the emotional and psychological foundations of sexual dysfunction, which could not be touched by treatment in an accumulator.

- *Q: Is the orgone energy accumulator legal? Can I get in trouble with the law for building or using one?*

A: There is no law against orgone energy, or the orgone energy accumulator. You may build, own, and use the blanket or accumulator in your own home, or elsewhere, as you choose. It can also be legally used for the self-treatment of any health-related condition, just as you can make very beneficial soups, purchase vitamins, or take soaking baths, without asking a doctor or the police. Understand, however, that forces within the medical community, pharmaceutical industry, and government are hard at work to make it illegal for you to do these things. If you are concerned about protecting your health freedoms, you should join forces with those social organizations that are working to preserve or extend those freedoms. *The price of liberty is eternal vigilance!*

Part III: Construction Plans for Orgone Accumulating Devices

15. Construction of a 2-Ply Orgone Energy Blanket

The orgone energy blanket is the most simple to construct of all the orgone charging and accumulating devices. They can be made at any size, and can be easily transported. You can use small ones while resting, or place large ones under and over a person who is immobilized in a bed. Like a standard accumulator, orgone blankets are not meant to be used for any prolonged period, though one can rest or nap with one if there is a need. In my experience, people will, even when sleeping, push off an uncomfortable orgone blanket just as they would a regular blanket. The following steps tell how to make an orgone energy blanket with final dimensions of 2' by 2'.

A) Obtain enough 100% wool fabric, or acrylic felt, to make three 2' x 2' squares. Also obtain several packages of very fine ("000" or "0000") steel wool pads.

B) Lay a 2' x 2' piece of fabric on a flat surface. Cover the exposed top surface of this fabric with a layer of steel wool, from unwrapped steel wool pads. Spread the steel wool out, so that it is not too thick. You should be able to see parts of the underlying fabric here and there.

C) On top of the steel wool, lay another 2' x 2' piece of fabric.

D) Cover the exposed top surface of this second fabric piece with another layer of steel wool.

E) Finish with another 2' x 2' piece of fabric, placed on top of the last steel wool layer. You now should have

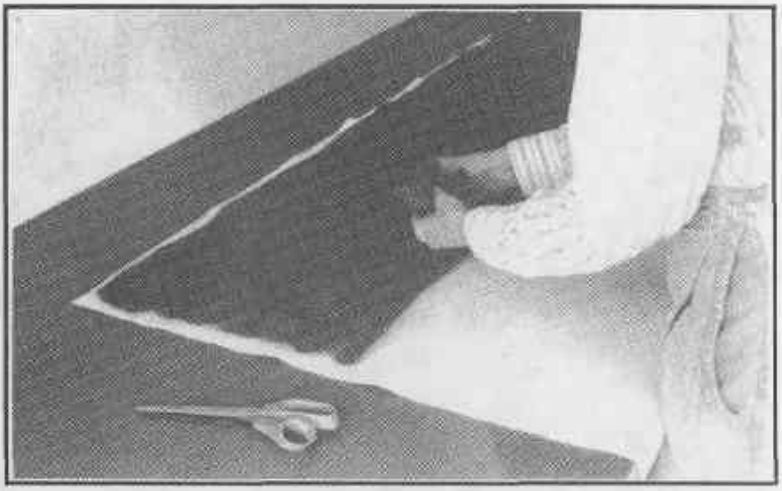

Spread steel wool loosely on section of cloth. Trim edges as shown.

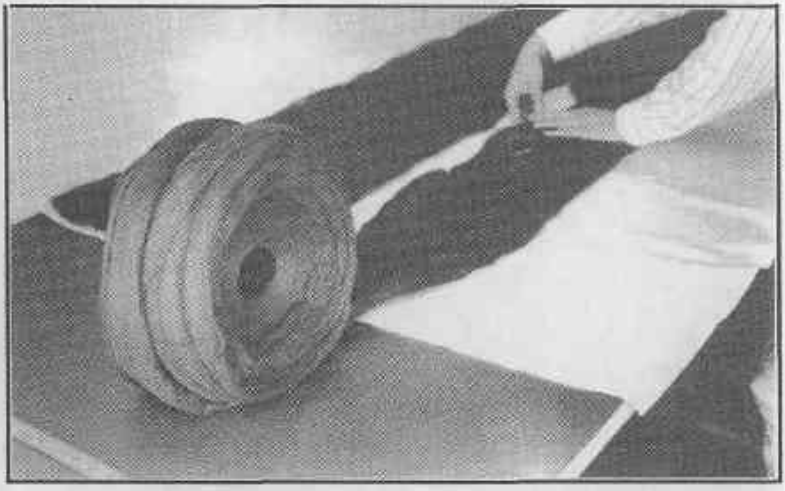

Rolls of steel wool can be purchased from manufacturers, or common steel wool pads, of "000" or "0000" grade, can be obtained at most hardware or paint stores.

Particle masks should be worn during construction to avoid breathing fine steel dust.

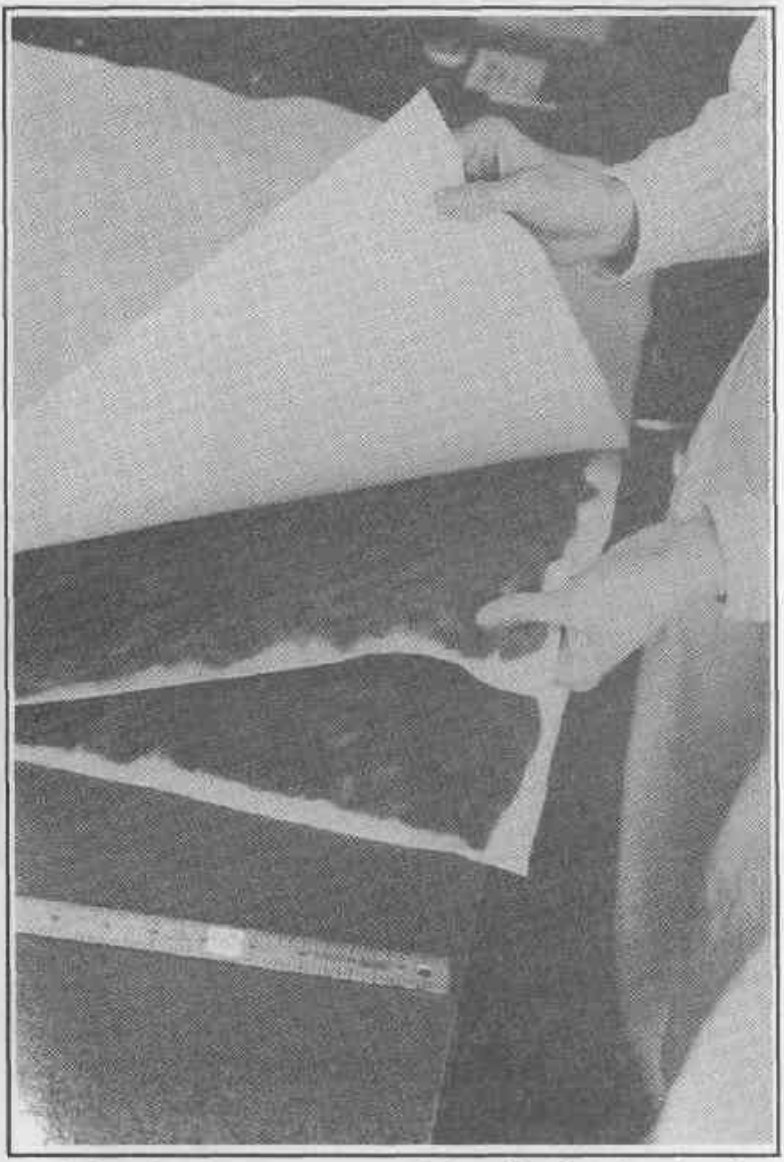

A functional orgone accumulating blanket showing the alternating layers of steel wool and cloth.

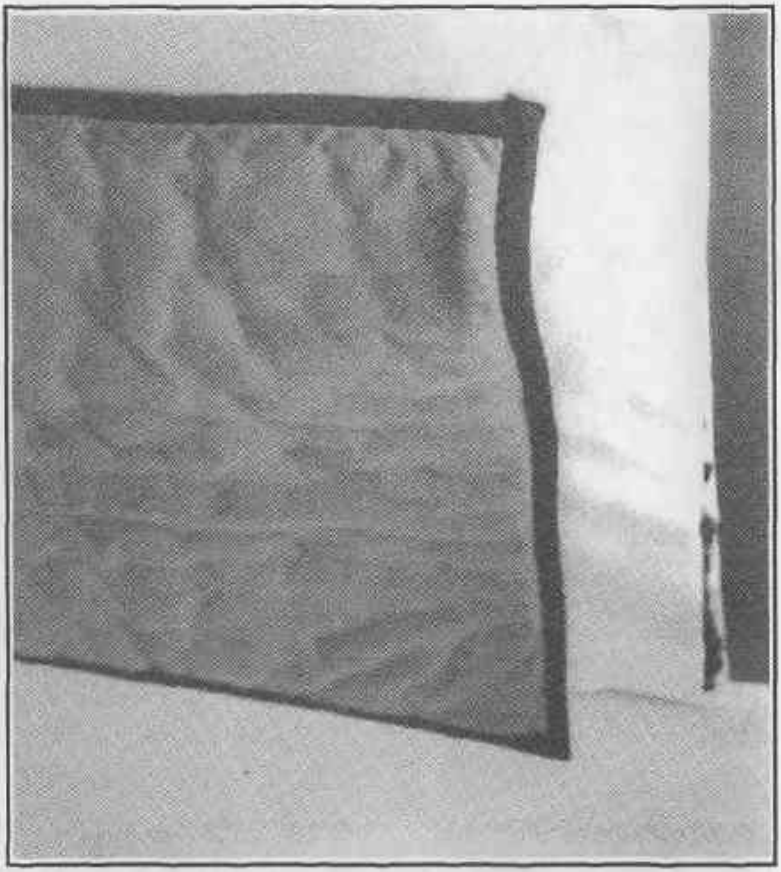

Finish off your blanket with a trim to keep everything together. Several quilt-stitches should be added to keep the insides from shifting around.

three pieces of fabric, with two layers of steel wool sandwiched in between.

F) Trim, stitch, and finish the borders, according to your own tastes and sewing skills.

G) Keep and use the blanket in an environment similar to that advised for a regular accumulator, away from any TV sets, microwave ovens, fluorescent lights, or other electromagnetic or radioactive gadgets. *Never use an orgone blanket with an electric blanket.* It can be stored on a hangar in the open air, or even inside a larger accumulator for greater charging.

H) Do not ever wash or dry clean your orgone blanket, as the steel wool will rust! Spot clean only with a *slightly* damp sponge.

I) Reich once made very heavy orgone blankets, composed of galvanized steel wire mesh, and alternating layers of wool and steel wool. While these work quite well, I find them to be uncomfortable and difficult to use. They do not appear to be any more effective than the simple design given here.

16. Construction of a 5-Ply Garden Seed Charger; The "Coffee Can" Accumulator

One can make a simple garden seed charger from a cleaned food container can or coffee can, using additional steel wool and fabric materials.

A) Empty a large coffee can or other steel or steel/tin food container (no aluminum!), clean it, remove all labels, and dry thoroughly. Make sure you save the cut-out metal lid, or make a replacement from another can, or from galvanized steel sheet metal. Use a can large enough to hold all the seeds you will be charging.

B) Obtain several yards of good 100% wool, or acrylic felt fabric. You will need enough fabric to go around the can about 5 times, plus enough for 5 round top pieces, and 5 similar bottom pieces.

C) Purchase several packages of very fine grade ("000" or "0000") steel wool. You will need enough unwrapped steel wool to cover an area equal to that of the fabric. Again, unwrap the steel wool pads as you need them, and spread it out.

D) Cut the fabric into a very long strip which is as wide as the can is tall. The length of this long strip should be about 6 times the circumference of the can. As you may not have a single strip of fabric this long. You can splice several pieces together.

E) Lay the long fabric strip out flat, and spread a thin layer of steel wool on top of it. Lay the empty can on

one end of the steel wool/fabric strip and roll the can up inside the strip. Stop when the strip has been wrapped around the can about five times or more. Add a final layer of fabric to the outside, and stitch or tape it in place so that it will not unravel.

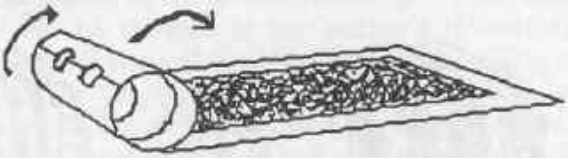

F) Measure the diameter across the top of the can, including the wrappings of fabric and steel wool. Cut out 10 circles of fabric material of this same diameter, 5 for the top, 5 for the bottom.

G) Sandwich steel wool between the fabric circles such that you have 4 layers of steel wool between 5 layers of fabric. Make two of these fabric/steel wool sandwiches, one of which will be used to cover the bottom of the can, and the other for the top.

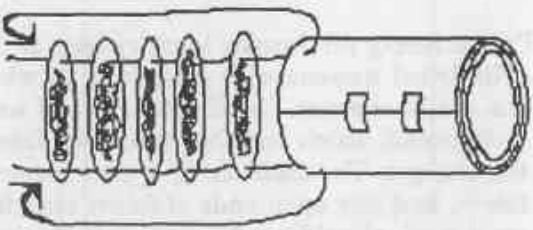

H) Take the metal disk cut from the top of the can and file smooth any jagged edges. Punch two small nail holes near the center, about 1/4" apart. Using a heavy upholstery or knitting needle, thread some heavy

twine, wire, or yarn through the center of one of the steel wool/fabric sandwiches, and bring the twine through the holes in the metal can lid. Secure the can lid to the center of the steel wool/fabric sandwich. The steel wool/fabric sandwich should be about 2" wider in diameter than the metal can lid.

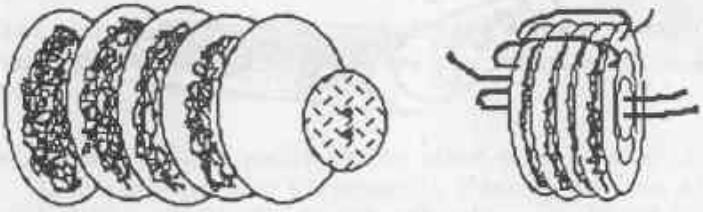

I) Using heavy thread, loosely stitch together the edges of the top steel wool/fabric sandwich (the one sewn to the metal can lid). Also loosely stitch the edges of the bottom steel wool/fabric sandwich together, and sew it to the bottom edge of the steel wool/fabric strip, wound around the can. Except for the top opening, the metal can should now be encased in the steel wool/fabric material.

J) Find a heavy pillowcase, laundry bag, or other larger cylindrical non-metallic container in which to keep the entire charger. Or, if you are good with a needle and thread, stitch together your own fabric cover for the charger. The main thing is that the outer layer of fabric, and any open ends of fabric showing pieces of steel wool, should not be subject to "knocking about" or moisture, such that it starts to fall apart or rust.

K) Review the section on seed charging, in the "Simple Experiments" chapter for instructions and additional ideas on the use of your charger. Or, as an alternative to constructing this accumulator, you could

store your seeds inside a large metal cookie tin which would then be wrapped up inside the multiple folds of a very large orgone blanket, or be stashed inside one of the other, larger accumulators. Just realize that the greater the number of plys, and the greater the absolute quantity of materials going into the construction of the accumulator "pile", the stronger will be the charge. At the author's laboratory, for instance, the small 5- ply coffee can charger is stored inside the 10-ply, one-cubic foot accumulator, which in turn is stored inside the 3-ply large accumulator. This is a total of 18 plys, and yields a charge which is readily sensible.

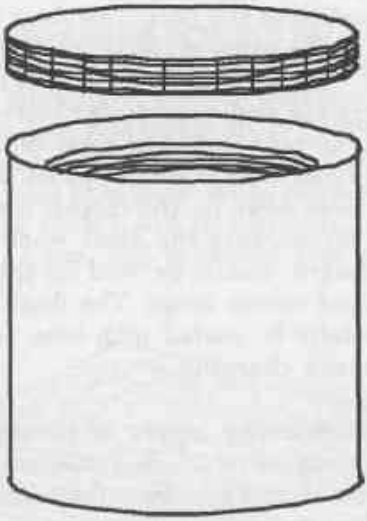

17. Construction of a 10-Ply Orgone Energy Accumulator

A very powerful, one-cubic foot, 10-ply accumulator can be made following the instructions below.

A) Cut six galvanized steel, 27 gauge sheet metal squares, measuring 1' x 1'. Use heavy tape, on the outer metal walls only, to construct a metal cube. Leave the top of the cube open, and do not tape it into place. The interior of the cube should remain bare metal, without any tape showing.

B) Use very fine ("000" or "0000") steel wool, and heavy clear plastic acrylic carpet protector material for construction of the plys. The clear plastic carpet protector is the same material used in model homes to protect carpets from wear, and is often sold on rolls in hardware and department stores. It is not cheap, but works very well. The clear plastic carpet runner should have rows of small tips on the side which normally faces down on the carpet; these tips work very nicely for holding the steel wool in place. Celotex (soundboard) should be used for the final outer layer, with wood corner strips. The final outer celotex may additionally be coated with bees wax and/or shellac to increase charging.

C) Ten alternating layers of plastic and steel wool roughly measure 2" in thickness. This being the case, you should construct the outer celotex casing in the shape of a cube, the interior dimensions of which will be 16" x 16" x 16". Cut six celotex panels with the following dimensions:

Celotex Panels:

top:	17" x 17"
bottom:	17" x 17"
2 sides:	17" x 16"
2 sides:	16" x 16"

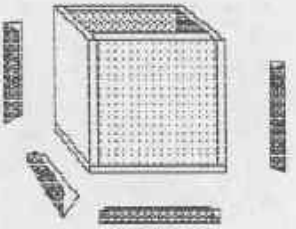

D) Use small nails and glue to fasten five of the six celotex panels together, to make a cube shape. Again, as with the metal box, do not attach the top. Add extra glue to the edges of the assembled celotex box, and allow it to dry before proceeding.

E) Using a mitre box, cut wood corner strips for the outside edges of the celotex box. Nail and glue these wood corner strips to the celotex box for added strength.

F) Cut 20 square pieces of plastic carpet runner, 16" x 16". Put ten of these squares aside for later use. Lay the other ten squares one at a time inside the bottom of the celotex box, tips facing up. In between each plastic square place a layer of steel wool, taken from unwrapped steel wool pads. When finished, the top of the last plastic square will face upward in the bottom of the celotex box, and it should also be covered with steel wool.

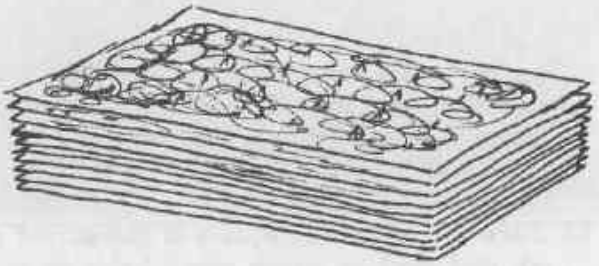

G) Place the galvanized steel sheet metal cube inside the celotex box, on top of the ten plys of plastic and steel wool. If you have constructed the celotex box correctly, the top of the metal cube should be about 2" below the top of the celotex box, and a space of about 2" should exist between the sides of the metal cube and the interior sides of the celotex box.

H) Cut 20 pieces of plastic, 12" x 16", and 20 more pieces, 12" x 12". These will be used to fill the side spaces between the metal cube and the celotex. Layer each plastic piece with steel wool, and stack into bunches of ten layers each. Do this on a flat surface before attempting to place them into a vertical position, in between the celotex and metal boxes.

I) Place the two stacks of 16" x 12" plastic/steel wool between the celotex and metal cube, on opposite sides of the metal cube. An outer layer of plastic should lay against the inner wall of the celotex box, while an inner layer of steel wool should rest against the outside of the metal box. The upper edge of the plastic should be nearly flush with the upper edge of the metal cube, both of which should remain about 2" below the upper edge of the celotex box.

J) Place the two stacks of 12" x 12" plastic/steel wool in the two remaining spaces between the celotex and metal cube, as given in the previous step.

K) Take the 10 remaining pieces of 16" x 16" plastic carpet runner and layer them with steel wool. Stack them up and set them aside. Unlike prior stacks, however, do not finish the final plastic layer with steel wool.

L) Take the remaining square of galvanized sheet metal, and drill or punch small holes in each corner, about 1/2" from each corner. The holes should be

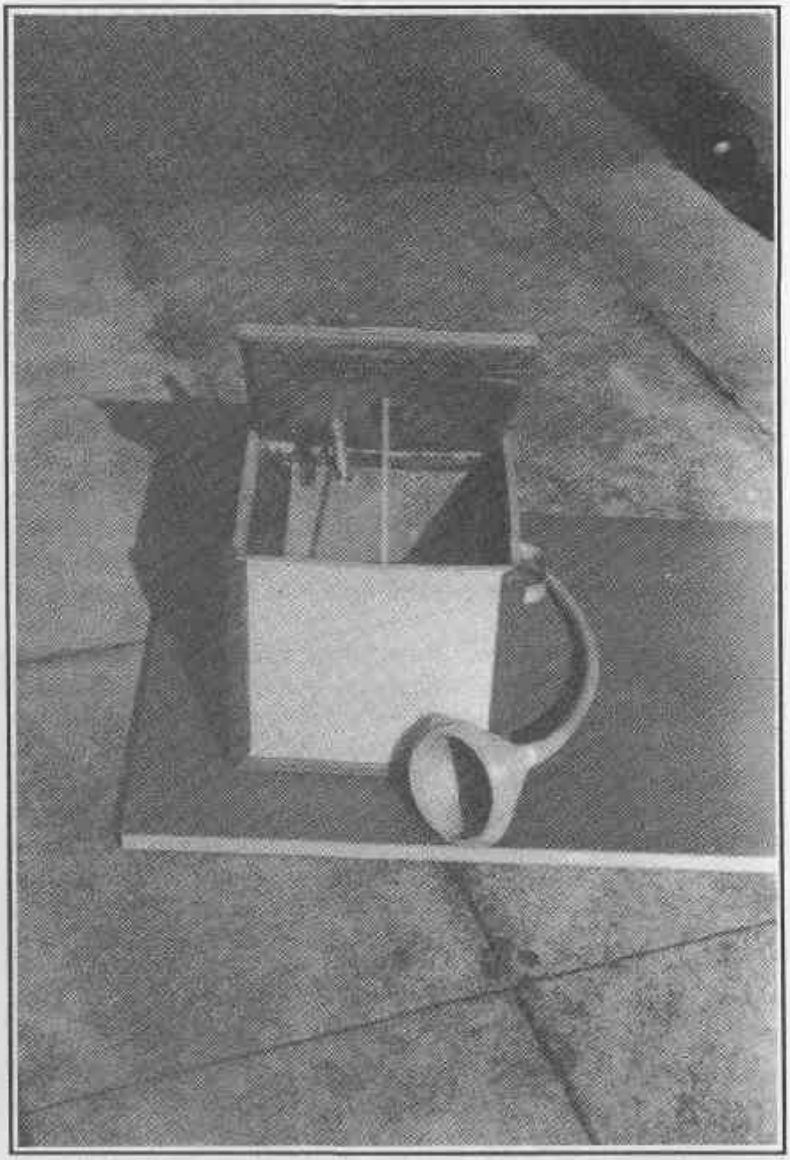

A one-cubic foot, 10-ply accumulator with attached funnel.

large enough to accommodate a long but narrow screw.

M) Find a rough wood or carpeted surface to work on. Lay the stack of plastic/steel wool squares on the last piece of celotex. Center it on the celotex; there should be about 1/2" of celotex appearing all around the stack. Now place the sheet metal square (with the holes) on top of the plastic/steel-wool/celotex stack, and center it also. There should be about 2" of plastic extending beyond the edge of the metal square on each side. Use some masking tape to temporarily hold the celotex/plastic/steel stack together.

N) Using an ice pick, carefully make four vertical holes through the plastic/steel wool stack, and through the celotex, using the corner holes in the sheet metal square as a guide. Do not use a drill, as the steel wool will spindle around the drill bit.

O) Using four skinny bolts, along with nuts and LARGE washers, secure the metal square and plastic/steel wool stack against the celotex square. Use a bolt no longer than necessary, such that the bolt ends will not protrude significantly. When completed, this whole lid assembly should fit snugly on top of the celotex box. The metal plate attached to the lid should closely, but not perfectly, align with the metal cube interior. With the lid in place, only bare metal should face to the interior of the accumulator.

P) For handles, first firmly glue a flat, wide and long wood strip to two outer sides of the celotex cube, near to the top. When completely dry, screw wood or metal handles to these wood strips. A handle should also be attached to the upper, outer side of the lid assembly, using a similar support mechanism. The celotex is simply too lightweight to accept screws or nails alone. You may likewise install a hinge between the

lid assembly and the box, or coaster wheels to the bottom, but these are not necessary.

Q) For additional charging strength, the outer celotex walls may be coated with melted bees wax or paraffin (not really necessary), but in any case should be given several coats of protective natural shellac.

R) For additional charging strength, store this cubical accumulator in the bottom part of a larger, human-sized accumulator, under the bench that you normally sit upon. Be sure to maintain a clean and uncontaminated environment for your accumulator, as per the points given in the previous chapters. Prop the lid open when not in use, and store in a clean, dry place, without electromagnetic or nuclear contamination.

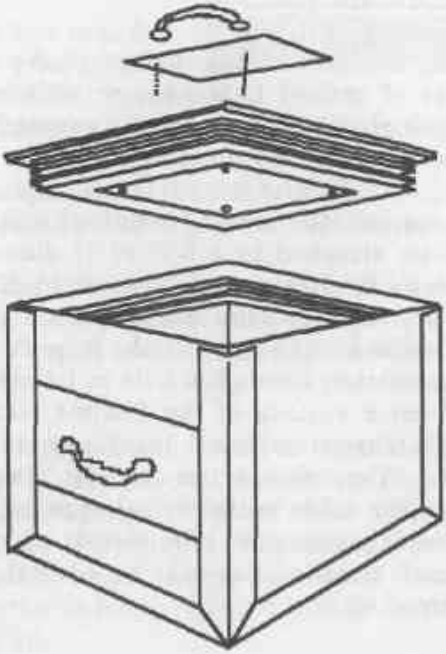

18. Construction of an Orgone Shooter Funnel

The shooter funnel is similar to other accumulating devices, but has an open face allowing for external irradiation of objects. It is often connected to a larger box accumulator, but this is not absolutely necessary.

A) Obtain a galvanized steel funnel with about 6" diameter at the large end, from a hardware, farm supply, or auto supply store. Auto supply stores sometimes sell these with a flexible metal hose already attached, for dispensing oil into a car engine, and this may help in the later attachment to a box accumulator.

B) Coat the outer metal surface of the funnel with a layer of melted bees-wax, or with strips of black plastic electrical tape, leaving exposed the bare metal surface of the funnel interior.

C) If desired, the small "draining" end of the funnel can be attached to a 3/4" or 1" diameter length of hollow, flexible metal "greenfield BX" cable (use galvanized steel, *not aluminum*). The other end of the cable is then run into the interior of a small box accumulator, through a hole in its side or lid. Wrap the outer surface of the flexible metal cable with black-plastic electrical insulation tape. (See page 121.) Your shooter funnel will then draw orgone down the cable to the funnel opening, increasing its radiating strength. Or, simply store the shooter funnel inside a box-type accumulator, to keep it charged up.

19. Construction of an Orgone Shooter Wand

The shooter wand is a very simple means for demonstrating the subjective sensations of the orgone radiation, and also for irradiation of orgone energy into body cavities. Simply store the completed shooter wand inside a well maintained accumulator, and remove it for use when necessary. Under relaxed conditions, most people can hold this wand in the hand, or place it on the solar plexus or upper lip, and readily feel the soft radiant glow of the orgone energy.

A) Obtain a pyrex test tube of about 3/4" to 1" diameter, and 6" to 9" long, from a laboratory or medical supply company.

B) Fill the test tube full of fine grade ("000" or "0000") steel wool. Compress to a reasonable firmness.

C) Seal the open end of the test tube with a rubber stopper, and tape it shut with plastic electrical tape.

D) Place the shooter wand inside a small orgone accumulator for a period of several days or weeks before using. Keep it stored inside the accumulator in between uses.

E) If you use the shooter wand to irradiate the throat or other body cavities, or if the pyrex glass otherwise becomes soiled, wipe the glass clean with isopropyl alcohol prior to putting it back inside the accumulator. The wand should always be alcohol cleaned and air dried prior to being replaced into the accumulator for charging.

20. Construction of a Large 3-Ply Orgone Energy Accumulator

This accumulator is large enough to sit in, and is composed of 6 large rectangular panels. Each panel is made from a wood frame, galvanized steel sheet metal (27 gauge), steel wool, fibreglass (*without* aluminum backing), and celotex (soundboard). One side of each wood frame is faced with galvanized steel, the other with celotex, and the three alternating layers of fibreglass and steel wool are sandwiched in between.

A) First compute the size of the panels for an accumulator that will fit your personal needs, adding the necessary dimensions for overlap between the various panels. The side panels and back panel should physically sit on the edges of the bottom panel. The back panel should snuggle between the two side panels. The top panel should overlap and rest upon both side panels and the back panel, covering them. The door panel should, like the back panel, snuggle between the side panels when it is shut. I believe this arrangement is the simplest possible, and most efficient to build. Dimensions are given below for accumulators to accommodate people of varying sitting heights, but of average weight. As the distance of the body surface from the metal walls increases, there will be a reduction in effectiveness of the accumulator. The dimensions of the accumulator should be carefully selected to meet your needs. An additional 1/2" clearance is provided in the width dimension (1/4" each side), such that the door will open and shut freely.

Panel Dimensions:	*Large Size*	*Medium Size*	*Small Size*
Top:	29.5" x 35"	26.5" x 32"	23.5" x 28"
Bottom:	29.5" x 35"	26.5" x 32"	23.5" x 28"
Left side:	35" x 58"	32" x 54"	28" x 50"
Right side:	35" x 58"	32" x 54"	28" x 50"
Back:	25" x 58"	22" x 54"	19" x 50"
Door:	25" x 52"	22" x 48"	19" x 44"
Interior Dimensions:			
Height:	58"	54"	50"
Width:	25"	22"	19"
Depth:	31"	28"	24"

You will need:
Height = height sitting erect in a chair + about 3"
Width = shoulder width + about 4" (2" each side)
Breadth = sitting, knee to back distance + about 3"

B) Make wood frames of 3/4" x 1-1/2" pine (called "one by two" in lumber yards), like picture frames, such that the outer edges conform to the computed dimensions for your accumulator panels. Nail and glue all joints.

C) Arrange the open wood frames together, as they will be when the accumulator is complete, to make sure that all dimensions have been properly calculated and cut. If there is an error in your calculations, now is the time to find out, before the more expensive celotex and galvanized sheet metal have been cut.

D) Cut the celotex panels to size, from 1/2" or 3/4" thick celotex sheet, to cover fully one side of each wood frame. Nail and glue the celotex panels to each wood frame. Use 1/4" plywood instead of celotex for the bottom panel (and only the bottom panel).

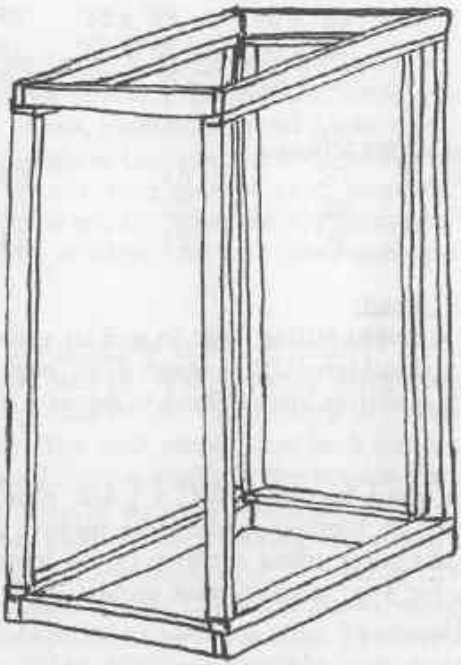

Assembled Wood Frames for Accumulator Panels

E) Cut batts of 1/4" thick fibreglass material to size and place a layer inside each of the open panel frames. Use gloves and a mask to protect yourself. Do not compress. Avoid lumps and holes. You can use wool, cotton, acrylic felt, or rock wool instead, if you wish, but for a large accumulator like this, the costs will be higher, and the accumulation will not be significantly stronger. These other materials may yield a different "feel" to the orgone charge, and if that is important to you, the cost may be justified.

F) Unroll very fine ("000" or "0000") steel wool pads and place a layer inside each of the open panel frames, on top of the fibreglass. Leave it fluffy, at around the same thickness as when unrolled, in as uniform a layer as possible. Some steel wool comes in large rolls which, if you can get it, will speed up construction for large accumulators.

G) Repeat steps E and F, placing a new layer of fibreglass on top of the previous steel wool layer, and another layer of steel wool on top of that.

H) Again repeat steps E and F, placing another new layer of fibreglass on top of the previous steel wool layer, and another layer of steel wool on top of that.

I) You should now have three alternating layers of fibreglass and steel wool contained in the open frame of each panel. The final layer facing you should be composed of steel wool. The panels should also be filling up, and may need to be slightly compressed before the final layer of galvanized steel sheet metal can be added. If you have used some other type of non-metallic material than fibreglass, and if the material lies loosely in the frame, you may have problems with slumping of the plys when the panels are finally sealed and placed in upright position. If this is the case, now is the time to do something to pre-

End Cross-Section of Side, Top, Back and Door Accumulator Panels

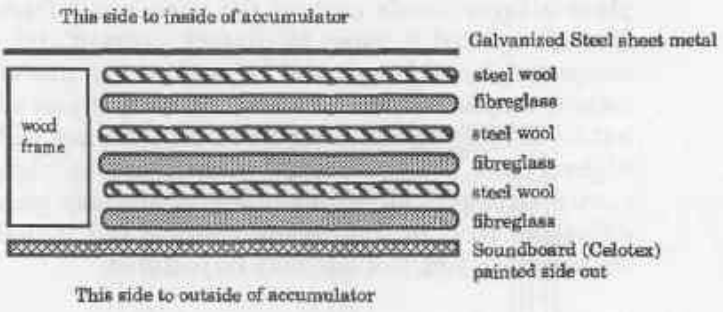

End Cross-Section of Bottom Accumulator Panel

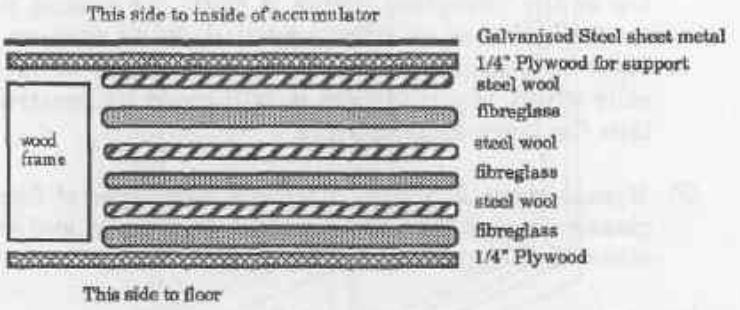

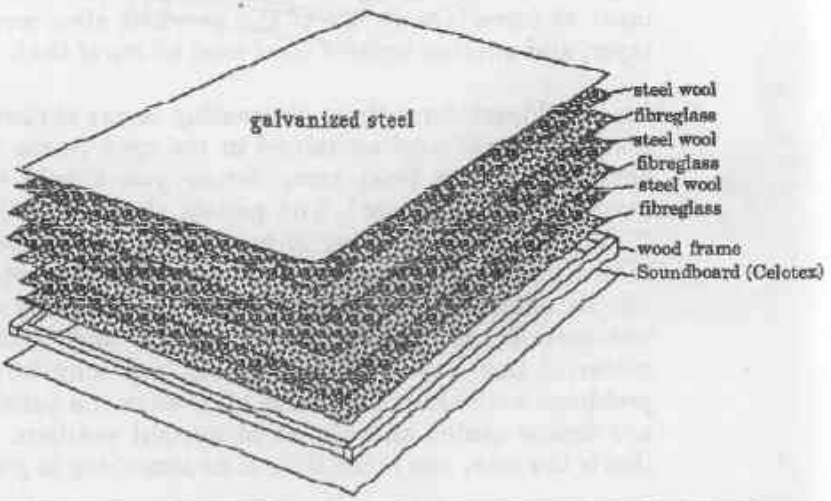

Front View, full-size 3-ply accumulator

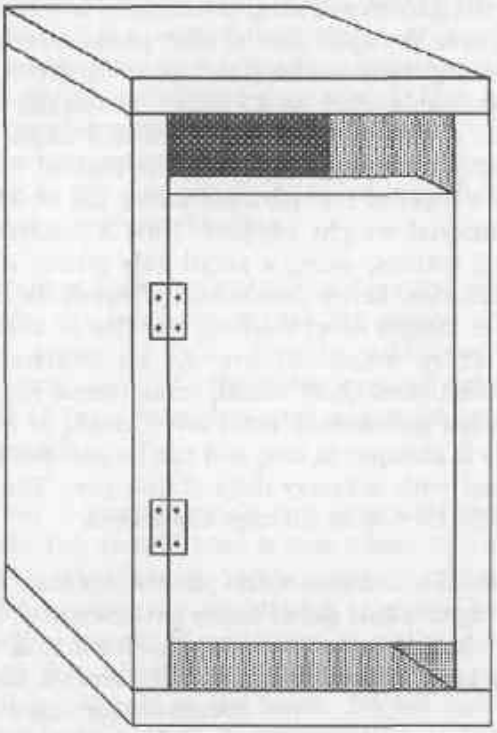

For Warmer, Tropical Climates: *Use door with 3" convection gaps at top and bottom, as per measurements on p.127. (Photo on p.23.) If needed, tack screen strips to door top and bottom, across gaps, to keep out insects.*

For Cooler or Cold Climates: *Use full height door with small window. (Photo on back cover.) Before cutting door materials, adjust door measurements (p.127) to only 1/4" less than full height of side panels. Before assembling door, cut matching 6" square openings in door sheet metal and celotex, centered at face height, then frame opening with 1x2" wood strips. Complete assembly as per instructions.*

Use hinges with removable hinge pins for easier assembly and take-down. Secure inside of door with hook and eye.

vent slumping.

J) Cut the galvanized steel sheet metal to size such that it fits over the open part of each panel, overlapping and covering the wood frames. Use the lightest sheet metal available, such as 27 gauge, which can be cut with hand shears for trimming, and still add to structural strength of the panels. For the bottom (floor) panel, add a layer of 1/4" plywood under the sheet metal, for additional weight support. Nail it securely onto the wood frames, using a small hole punch if necessary. Small steel tacks should easily penetrate through the sheet metal. After nailing, use file or shears to trim all sharp metal corners. As an alternative to galvanized steel sheet metal, some people have effectively used galvanized steel *wire mesh*, or *wire screen*. This is cheaper to use, and can be secured to the wood frame with a heavy duty staple gun. The steel wool should be visible through the screen.

K) Assemble and secure the panels together. Start by securing one side panel to the bottom panel, by using an "L" shaped metal brace at the front and rear of the side panel, near the bottom. Use screws, such that the accumulator can be taken apart later for easy moving. Secure the other side panel in a similar fashion, followed by the back panel. The back panel must be secured independently by small metal braces, placed between the wood frames of the bottom and back. Add the top panel, and secure it to the sides and back in a similar manner. The accumulator should now be quite sturdy, and is almost complete.

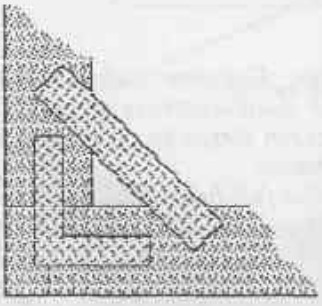

L) Carefully mark and drill holes for door hinges and

attach them to the door panel and side panel. Make sure you center the door in a way that leaves equal space at the top and bottom, either for convection gaps (for the vented door style), or as clearance to allow the door to freely swing open and shut (for the full-height windowed door style). Use hinges with removable pins so that you can easily take the door off when moving the accumulator. After fixing the door to the side panel, it should open fully and close snugly, without binding.

M) Attach a hook and eye to the door and side panel opposite the hinge, such that the person sitting inside can secure it shut. Finally, add several coats of natural shellac to the outer exposed celetox, to protect it from humidity and add to its accumulating strength.

N) Your accumulator is now complete, except for a seat. You should have a seat which will allow you to place other accumulator chargers underneath. For this purpose, you might wish to specially construct a wooden bench. Wood is a good material to use, as it does not absorb the orgone energy significantly, and is not cold to the touch. Do not use woods that have been soaked in preservative or formaldehyde, however. Metal chairs are OK, but will be quite cold to sit on unless covered with a light fabric.

O) You may also wish to construct a *chest board,* or *orgone pillow,* for use inside the accumulator. As you sit inside, notice that there is a great distance from your chest to the front metal wall. This large distance inhibits orgone irradiation to your chest. An additional, small accumulator panel, similar to those used for the wall panels, could be constructed for use inside the larger box, to bring the radiation closer to the chest. However, a simpler way is to use a bundle of cotton, wool, or acrylic felt, rolled

into a large pillow shape with equal layers of steel wool. The final outer layer should be composed of steel wool, and the entire bundle is then placed inside a thin cotton pillowcase. It should be large enough that it fits very snugly into the pillowcase. By holding this orgone pillow close to the chest, while you are in the accumulator, it will irradiate those frontal areas of your body that are not so well irradiated by the accumulator walls. Leave the orgone pillow inside the accumulator when not in use, to keep it charged up. You can also use this pillow outside of the accumulator, in a manner similar to the orgone blanket, with equally good results.

P) Do not connect electrical appliances to the accumulator. Follow the cautions given in the previous chapters. You can read a book while inside the accumulator, but should use either a strong *external* light source (to shine a beam of incandescent light into the accumulator), or you can use a battery-powered reading light inside. Again: *no fluorescent lights, television sets, heating blankets or pads, or other electrical or electromagnetic devices!!*

poor materials for orgone accumulator construction remain unchanged and time-tested.

Cautionary Note on New "Wireless" Electromagnetic Gadgets

On the subject of safe use of the accumulator (see Part II), we may add the following: Over the last decade, there has been an increased use of new "high tech" devices for telecommunications purposes which actively emit potentially toxic low-levels of electromagnetic radiation: cellular telephones and cell-phone relay systems (often located in populated areas) emit microwave radiations at potentially toxic levels, as well as new remote-control apparatus which employ *active far infrared (close to microwave) frequencies*, such as inventory scanners and various kinds of "wireless" technology. In all cases, orgone accumulators should not be located near to any of these devices, nor should any human being wish to live, work or sleep near them either! New electromagnetic devices should be viewed as contrary for safe use of orgone devices unless proven otherwise. On the other hand, various *passive* infra-red sensing devices (such as automated outdoor security lights) pose no problems.

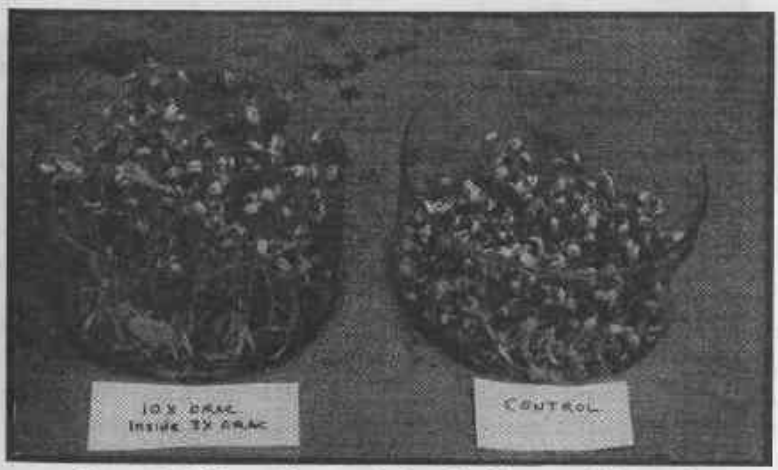

Sprouted Mung Beans: Left side, Orgone-Charged. Right side, Controls. *(Experimental protocol p.96-97)*

New Publications and Controlled Studies on the Human Bio-Effects of the Orgone Energy Accumulator

In recent years, mainstream publishers in Germany have expressed a growing interest in the works of Wilhelm Reich, and on the subject of his research findings (an interest not currently shared by any mainstream American publisher). Some examples of this interest are given below.

Appendix I of this *Handbook* (page 148-155) presents an extended abstract describing the first double-blind controlled study of human physiological response to the orgone accumulator, as undertaken by Stefan Müschenich and Rainer Gebauer. Their study was completed in 1986 at the University of Marburg in Germany. Dr. Müschenich subsequently wrote a major book on this same subject (in the German language):

Stefan Müschenich, *Der Gesundheitsbegriff im Werk des Arztes Wilhelm Reich (The Concept of Health in the Works of Dr. Wilhelm Reich)*, Doktorarbeit am Fachbereich Humanmedizin der Philipps-Universität Marburg, Verlag Görich & Weiershäuser, Marburg 1995, 425 pages. ISBN 3-922906-54-0.

In more recent years, another similar double-blind and controlled study was undertaken at the University of Vienna by Günter Hebenstreit, producing similar positive results. The Hebenstreit study, like that of Müschenich and Gebauer, used an orgone accumulator, a control dummy-box that looked like an accumulator, and a relaxation-chair in which test subjects were evaluated both before and after exposure to either the accumulator or control enclosure. It produced positive results, I am informed. Unfortunately, we do not have any printed protocols, but can give the exact citation for those who wish to obtain and read the original German-language publication:

Günter Hebenstreit, *Der Orgonakkumulator Nach Wilhelm Reich. Eine Experimentelle Untersuchung zur Spannungs-Ladungs-Formel*, Diplomarbeit zur Erlangung des Magistergrades der Philosophie an der Grung- und Integrativwissenschaftlichen Fakultät der Universität Wien, 1995.

Another German-language title of significance was published in 1998, containing the contributed research papers of

40 different scientific-professional authors on the subject of Wilhelm Reich's social and biophysical findings, to include many papers on the subject of bions, orgone energy, and the orgone energy accumulator:

James DeMeo & Bernd Senf, Editors, *Nach Reich: Neue Forschungen zur Orgonomie: Sexualökonomie, Die Entdeckung Der Orgonenergie (After Reich: New Research in Orgonomy: Sex-Economy, Discovery of the Orgone Energy)*, Zweitausendeins Verlag, Frankfurt, 1998. 898 pp. ISBN 3-86150-239-9.

An Orgone Energy Darkroom (room-sized accumulator) at the Orgone Biophysical Research Lab's high-altitude Greensprings Center near Ashland, Oregon. This structure is made in the form of a large accumulator, with a metal-lined interior and under-layering of fiberglass. Inside are several human-sized orgone accumulators and experimental chargers. The strength of the atmospheric orgone energy charge inside such an orgone room is dramatically increased. The orgone energy can be more easily felt and observed with the eye, and registers more clearly in experiments and with measuring apparatus.

About the
Orgone Biophysical Research Lab (OBRL) and Greensprings Center

The Orgone Biophysical Research Lab is a non-profit science research and educational foundation, established in 1978. Over the years, OBRL has supported various laboratory and field research projects, educational lectures and seminars in both the USA and overseas, focused upon the sex-economic and orgone biophysical discoveries of the late, great natural scientist, Wilhelm Reich. OBRL also publishes a journal, *Pulse of the Planet*, on an irregular basis. The founder and director of OBRL, James DeMeo, has been investigating and extending Dr. Reich's original findings in both the social and natural sciences since 1971. Early in 1995, the *Greensprings Center* was established in a vibrant forested region of rural Oregon, to provide a better foundation for continued public outreach and in-depth study of orgone energy functions in nature. The *Center* also has the West Coast's only *Orgone Energy Darkroom*, for experiments requiring a higher energy charge, and for direct visual observation of orgone energy functions. New books (described at right) are also occasionally published, and public educational programs, the *Greensprings Seminars*, are held each summer. Accomplished scholars in the field of orgonomy are invited each year to share their knowledge and experience with interested students and professionals from around the world. Yearly seminars include: *Bions, Biogenesis and the Reich Blood Test, The Orgone Energy Accumulator,* and *Guided Independent Study*. Contact OBRL for an informative brochure and publications catalog, and to get on the international mailing list for seminar announcements.

Orgone Biophysical Research Lab
Greensprings Center, PO Box 1148
Ashland, Oregon 97520 USA
Tel/Fax: 541-552-0118 Email: demeo@mind.net
OBRL's Global Internet Web Site:
http://www.orgonelab.org

Additional Publications Available

(Contact OBRL for ordering information)

Heretic's Notebook (Pulse of the Planet #5): Emotions, Protocells, Ether-Drift and Cosmic Life-Energy, with New Research Supporting Wilhelm Reich, Edited by James DeMeo

Contains 28 insightful essays and research articles by 17 different authors, on natural childbirth, sexuality, archaeology of early human violence, Reich's orgonomic functionalism, exposés on Reich's detractors, Giordano Bruno's work, bion-biogenesis research, Dayton Miller's ether-drift discoveries, emotional effects in REG (psychokinesis) experiments, new detector for orgone energy, dowsing research, cloudbusting desert-greening experiments in Africa, plant growth stimulation in the orgone accumulator, the orgone energy motor and "free energy", plus UFO research, book reviews, and much more, with color cover photos, text- photos and illustrations. 272 pages, Large format $24 Softcover

SAHARASIA: The 4000 BCE Origins of Child-Abuse, Sex-Repression, Warfare and Social Violence, In the Deserts of the Old World, by James DeMeo

Dr. DeMeo's *magnum opus* on the origins of human violence and biophysical armoring, the first geographical, cross-cultural study of human behavior around the world, using Wilhelm Reich's sex-economic discoveries as a basic starting point, presenting world

maps of different behaviors and social institutions. Source-regions (Arabia and Central Asia) for patriarchal authoritarian culture were identified, and migratory-diffusion patterns were traced, back in time, to pinpoint where and how the human tragedy began. Solves the riddle of the origins of human violence and armoring. A breakthrough in the scientific study of human sexuality, psychology and anthropology, and must-reading for every parent, student, professor and clinical worker in the field of human health and behavior. 454 pages, with over 100 maps, photos, and illustrations. Large format with vivid full-color cover, extensive bibliography and index. Softcover $34
Author-Signed Limited Hardbound First Edition $90

On Wilhelm Reich and Orgonomy (Pulse of the Planet #4)

Edited by James DeMeo

Contains Reich's milestone articles on psychic and somatic (mind-body) processes, and on the bioelectrical aspects of human emotion and sexuality, with articles by R.D. Laing on Reich, and a discussion on Reich's work in Denmark when he fled Nazi terror in Germany and was also expelled from the International Psychoanalytic Association. Other papers discuss: Reich's research on biogenesis and discovery of the microscopical *bion*; the discovery of orgone (life) energy, and the orgone energy accumulator. Also featured are articles about the Food & Drug Administration's attack upon Reich, and their present-day war against the natural health movement; the deadly effects from nuclear power plants, and an illuminating scientific challenge to the HIV theory of AIDS — plus other reports on current life energy research, weather anomalies from nuclear bomb tests, a cloudbusting desert-greening experiment in Israel, provocative book reviews, and more! 176 pp. Large format $20 Softcover.

PLANS

FOR
CONSTRUCTING

AN

ORGONE
ENERGY
ACCUMULATOR

Based on information originally distributed by the Wilhelm Reich Foundation

Notes Regarding the Use of the Orgone Accumulator

The Orgone Accumulator is built so as to collect the natural energy of the atmosphere (Orgone Energy) and to make this energy about five times more concentrated inside the accumulator than in the outside air. Since orgone is the same energy that is in the bodies of all living organisms, the accumulator has the effect of increasing the body energy of the user--increasing the natural charge of the user's tissue and blood--thus strengthening the user's resistance to disease.

Orgone is not electricity, and the orgone accumulator has no electrical connections. WARNING: DO NOT ALLOW EXPOSED ELECTRICAL WIRES TO COME IN CONTACT WITH THE ACCUMULATOR!

The accumulator should be used once or twice daily as follows: the user should sit inside the accumulator lightly clothed or without clothing until the user becomes quite warm, or for roughly 15 to 45 minutes. The effect of the orgone will be best if the user relaxes, breathing out deeply but not forcefully. Slight dizziness or heaviness in the head is a signal to come out. Fresh air will eliminate such effects immediately.

In humid weather, the normal time of use should be lengthened, as there is then less orgone in the atmosphere. Air the room in which the accumulator is kept every day, for the increased orgone concentration tends to make the air in the room heavy.

The funnel end from the shooter box-seat is used for local application of orgone. This unattached end should be held close to, but not quite touching, the region in question for between two and ten minutes, depending on the sensitivity of the region. If it is used on the eyes, they should be kept closed. A slight burning sensation in the region that is being treated is a signal that the body has had enough for the time being. In general, the tube should only be used until the area becomes warm. The shooter box-seat tube can be used several times a day.

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Questions Regarding the Use of the Orgone Accumulator

Q. Does it lessen the effect of the accumulator if any part of the body comes in direct contact with the metal walls?

A. It is better if no part of the body touches the metal walls. However this cannot always be avoided and it does not lessen the effect to any considerable degree.

Q. If two or three people use an accumulator rapidly in succession, is the orgone "used up"; does the last one to use it get energy?

A. The effect of the orgone accumulator consists of a mutual excitation of the orgone energy which is concentrated within the accumulator and the body-orgone energy of the user. It can be assumed that the successive use of the accumulator by several persons will not lessen the efficacy.

Q. Should you spend more or less time in the accumulator, depending on the humidity?

A. Since the orgone energy concentration in the atmosphere diminishes with high humidity, it is advisable to prolong the use of the accumulator on very humid days.

Q. Does the funnel for the pipe of the tube box have to be metal?

A. Yes, since plastic or other non-metallic material will tend to "hold" orgone energy, while the metal will give it off immediately.

Q. Can you use the tube box inside a larger accumulator for reasons of more intensity, or is it more advisable to use it outside?

A. The concentration of orgone energy in the tube box will be stronger if it is used within the larger accumulator.

Q. Is it all right to take objects into the accumulator while using it, such as books, magazines, notebook, pen, pillow?

A. There is no objection to taking reading or writing material into the accumulator or knitting or needlework, etc. We would advise against taking pillows into the accumulator because they will soak up orgone energy and thus divert it from the body.

Q. Is it all right to paint the accumulator to match walls?

A. As long as the paint does not contain lead or other metals, the accumulator can be painted in any color. It may also be covered with wallpaper.

Q. If one makes one's accumulator light-tight and then sits inside it, is it possible to see the orgone energy light phenomena that are described in The Cancer Biopathy?

A. No; bodily evaporation under these conditions creates too much humidity and the orgone phenomena cannot be seen when the humidity is high.

Q. What is the difference in strength between a one layer and three layer accumulator?

A. The one layer accumulator, has an orgone concentration, measured electroscopically, of about 3 times that of the surrounding atmosphere. The three layer accumulator, has an orgone concentration of about 4 to 5 times that of the surrounding atmosphere. However, the concentration of the orgone energy does not increase proportionally with the numbers of layers. Thus a tenfold accumulator will have a concentration of approximately 6 times that of the surroundings.

Q. My accumulator does not fit tightly together. Does this in any way lessen the effectiveness?

A. Occasionally when an accumulator is dismantled and put together again, the walls do not close tightly. These cracks, even if they are as large as one inch, do not in any way affect the strength of the accumulator. In fact, experimental accumulators have been built with openings at the top and bottom for circulation purposes.

Q. Can paper, felt or material other than fiberglass be used for the non-metallic layers of the accumulator?

A. Experiments have been made with other materials. However, all these materials are liable to absorb humidity, whereas the fiberglass will not absorb any humidity. Too strong an absorption of humidity would definitely lower the strength of the accumulator.

Q. If you go into the accumulator with a fever, is the fever increased?

A. In most cases, experience shows that the fever will be slightly increased while the person uses the accumulator, but that the temperature will drop below the previous level after the use of the accumulator.

Q. Is there any special time of day when the accumulator is more effective than at other times?

A. Electroscopic measurements show the greatest concentration of orgone energy between 12 noon and 2 p.m. However, these variations in a given day are so small that it will not make any significant difference at what time of the day the accumulator is used. It can easily be regulated by timing.

Construction of a Three-Fold Orgone Energy Accumulator

1. General information

a. The accumulator is made of six panels which are to be screwed together. All panels except the bottom are constructed in the same manner, and differ only in dimensions. Each panel consists of an inner surface of galvanized sheetmetal and an outer non-metallic surface of celotex which encloses a braced wood frame and alternate layers of fiberglass and steelwool.

b. The materials specified may, if necessary, be replaced by other materials: 1/4" plexiglass or 1/4" upsonite along with a 1/4" fiberglass layer may be used in place of the 1/2" celotex. If substitutions are made, some adjustments in dimensions of the frames may be necessary.

c. Consult the accompanying drawings and tables for dimensions, construction details, etc.

2. Construct the frames

a. Cut the 1 1/8" x 1 1/2" clear pine to the specified lengths (see fig. 1). Cut a 1/2" x 1/2" rabbet into one side of each piece (see fig. 2). The bottom panel frame requires two 1/4" x 1/2" rabbets (see fig. 3). Mitre the corners and join with carpenters' glue and 8-penny finish nails.

b. Brace each frame with two pieces of 1 1/8" x 1" clear pine (see fig. 4). Join with two 2 1/2" #8 drywall screws. The top and bottom frame do not need bracing.

3. Attach the outer surface

a. Cut the celotex to fit inside the rabbets of each frame except for the bottom frame. Fasten in place with 1" galvanized wire nails.

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1. For a five-fold accumulator, increase the dimensions of the frames to allow for four more 1/4" layers, two layers of fiberglass and two layers of steelwool.

2. The 1/2" celotex (which has one side coated with white primer paint) may be known as: white construction board, soundboard, etc. It is basically a composite of wood fibers. Flakeboard, chipboard, etc. are not the same product and are too dense. There is a styrofoam product with the trademark name Celotex; do not use this.

3. fiberglass building insulation

4. What is referred to as 5/4" stock by the building industry actually measures 1 1/8 inch.

b. Cut two pieces of 1/4" finish grade plywood to fit inside the rabbets of the bottom frame. Fasten one piece in place with 1" galvanized wire nails.

4. Place the steelwool and fiberglass in the panels

a. Place a layer of steelwool upon the celotex inside one of the frames. Steelwool pads (oo fine or finer) when unrolled are the correct thickness. Make the layer as uniform as possible; leave the steel wool fluffy.

b. Next place a layer of fiberglass about 1/4" thick upon the steelwool layer. Avoid lumps and holes. Do not compress the fiberglass. The standard 3 1/2" x 15" fiberglass insulation comes in a roll with either a paper or foil backing. Peel off the paper or foil. This type of fiberglass is difficult to peel evenly. Try to peel it carefully into roughly 1/4" thick pieces. Too much unevenness in the layering will cause the sides of the accumulator to bulge. (There is a fiberglass insulation that peels more uniformly but might be difficult to purchase. It is a Manville product called 1/2" duct liner. It comes in a roll 48" wide by 100 feet long and may be available at your local heating and airconditioning shop.)

c. In a similar manner place the remaining alternate layers of steelwool and fiberglass in position (see fig 2).

d. Place the steelwool and fiberglass layers in the other panels.

e. The bottom panel has a different number of layers. Start with a layer of fiberglass upon the 1/4" plywood inside the frame (see fig. 3).

5. Attach the inner surfaces

a. Cut the sheetmetal slightly smaller than the frames. You might need to have the 26 or 28 gage galvanized sheetmetal cut at a sheetmetal shop. It can be cut by hand, but the results may be too rough. File the edges smooth and round the corners. Cut a 9" x 12" hole for the window in one of the 53" x 24" sheets. Figure 4 will give the exact location.

b. Drill 1/8" holes at 1" intervals around the edge of the sheetmetal. They should be 1/4" from the edge.

c. Nail the pieces of sheetmetal to the frames with 3/4" galvanized wire nails. Nail the remaining piece of 1/4" plywood to the bottom frame before nailing the final piece of sheetmetal over it. (See fig. 3)

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5. Wear protective clothing and a dust mask when handling the steelwool and fiberglass.
6. Steelwool in long rolls can be purchased from an industrial supplier.

6. Attach supports to the bottom panel

a. Cut two pieces of 1 1/8" x 1 1/2" clear pine 25" long.

b. Screw them into the outer surface of the panel. (See fig 3.)

c. Nail two furniture slides to the undersurface of each support.

7. Assemble the accumulator

Accuracy is necessary in fastening the sides, top, bottom and door of the accumulator. You will want to be able to take apart and put back together your accumulator in the event that you need to transport it. It is very bulky when assembled.

a. Pre-drill holes for the 2 1/2" #10 flathead philips screws with a 3/16" drill bit. So that the screw heads will countersink, drill a 1/2" hole 1/4" deep. Figure 5 gives the locations of these holes.

b. Lay the two side panels upright on their long sides. Place the bottom panel upright against the bottom ends of the two side panels and screw together. Then place the top panel upright against the top ends of the two side panels and screw together. Place the back panel onto the side panels between the overlaps of the top and bottom panels and screw together (figure 5).

c. Turn the box over onto its back and place the door on the side panels. Make sure that the door is flush with the top of the box (this will leave a one-inch gap at the bottom to allow air circulation). Mount the hinges to the side panel and to the door (fig. 6). You can hang the door to open either left or right.

d. Now stand the accumulator up.

e. You will need a hook and eye to hold the door closed while you sit in the accumulator. Place it where most convenient.

8. Assemble the seat for the accumulator

You have two options. The simplest is to suspend a piece of 3/4" x 14" x 22" wood on two supports fastened to the lower support braces of the two side panels. The other option is to turn the seat into a combination shooter box and chest panel.

Construct the shooter box-seat

a. Construct two panels in a manner similar to the other panels as explained in sections 2 through 6. 1/4" finish grade plywood is needed for the top and front of the seat panels (fig. 7).

b. Prepare supports to hold the shooter box-seat panels. Cut four pieces of 1 1/8" x 1 1/2" pine 12 1/2" long. Fasten two 12 1/2" pieces to the lower supports in the side panels with 2" #8 drywall screws. Then fasten the other two pieces vertically between the horizontal support and the floor of the accumulator with 2" screws. Fasten one 14" x 21 3/4" panel to the horizontal cleat A with 2 1/2" drywall screws. The other 14" x 21 3/4" panel will rest against the vertical cleats B (fig. 8). Do not fasten this panel. Attach a cabinet pull (metal or ceramic) to the front of this panel so you can easily remove it to use as a chest panel (fig. 9).

9. Construct a shooter funnel for the box seat

a. Take a four-foot length of 3/8" steel Greenfield casing. (Greenfield casing can be purchased from an electrical supply store. If you can't find it, you can substitute #12 BX electrical cable, but remove the wiring from the flexible metal casing before using.)

b. Insert the spout of a 3" diameter galvanized sheetmetal funnel into one end of the flexible metal casing. Wrap carefully the outside of both the flexible casing and the funnel with plastic electricians tape, so that no metal is showing. Drill a 5/8" hole through the top back corner of the accumulator box seat's top panel. Push the flexible tubing into the space below.

10. Optional

In order to draw stagnant orgone energy from the accumulator and shooter box seat:

a. You will need approximately three 48" lengths of 3/8" Greenfield casing. Use more or less than three depending on individual circumstances.

b. Drill three 5/8" holes (in a vertical row) through the wood frame of one of the side panels. Make sure that one hole will lead into the shooter box seat. Insert the three casings into the three holes. Make sure that the casings don't protrude inside of the accumulator.

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7. Greenfield casing is a convenient hollow flexible metal tube. IT IS NOT an electrical connection and should NOT be used as one.

c. Place the loose ends of the three casings into a pail of clean water. You need to change the water every week.

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The principle of the accumulator box can be adapted to different shapes for specific needs. An orgone blanket, or a collar for the neck, or a large funnel for the breast can be made as long as the principle of alternating layers of non-metallic and metallic materials is maintained.

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8. The inner surface should be made of a flexible metal screen instead of galvanized sheetmetal. Screen made from galvanized steel or stainless steel is good. Screen made from copper, aluminum and other metals that are not body-own are NOT recommended.

MATERIALS LIST

ITEM	APPROXIMATE QUANTITY
1/2" celotex	four 4' x 8' sheets
galvanized sheetmetal (26 or 28 gage) " " " " " " " "	2 pieces 53" x 26 1/2" 2 pieces 53" x 24" 2 pieces 28" x 24"
fiberglass insulation	3 1/2" x 15"(1 roll or 40 linear feet)
steelwool (oo fine or finer)	200 pads or 10 lbs.
1/4" plywood (finish grade)	one 4' x 8' sheet
clear white pine: 1 1/8" x 1 1/2"	80 linear feet
" " " 1 1/8 x 1"	20 linear feet
2 1/2" #10 philips flathead wood screws	30 pcs.
2 1/2 #8 drywall screws	30 pcs.
2" #8 drywall screws	10 pcs.
3" non-mortise or surface mounted hinges	one pair
hook and eye	one 2"
nail-on furniture glides	4 pcs.
nails: 3/4" galvanized wire nails 1" galvanized wire nails 6-penny finish nails	3 oz. 3 oz. 2 lbs.
carpenters' glue	one small bottle
<u>For the shooter box seat panels:</u>	
galvanized sheet metal (26 or 28 gage)	2 pieces 13" x 20 3/4"
clear white pine: 1 1/8" x 1 1/2"	16 linear feet
3" diameter galvanized sheetmetal funnel	one
3/8" Greenfield flexible metal casing	16 feet
electricians' tape (plastic tape)	one roll

(FIG. 1) TABLE OF DIMENSIONS

PANEL	LENGTH	WIDTH
TOP	29"	25"
BOTTOM	29"	25"
SIDES (2)	54"	27 1/2"
BACK	54"	25"
DOOR	54"	25"
SEATS (2)	14"	21 3/4"

(FIG. 2) DETAIL OF LAYERING OF SIDES (2) TOP, BACK AND DOOR PANELS

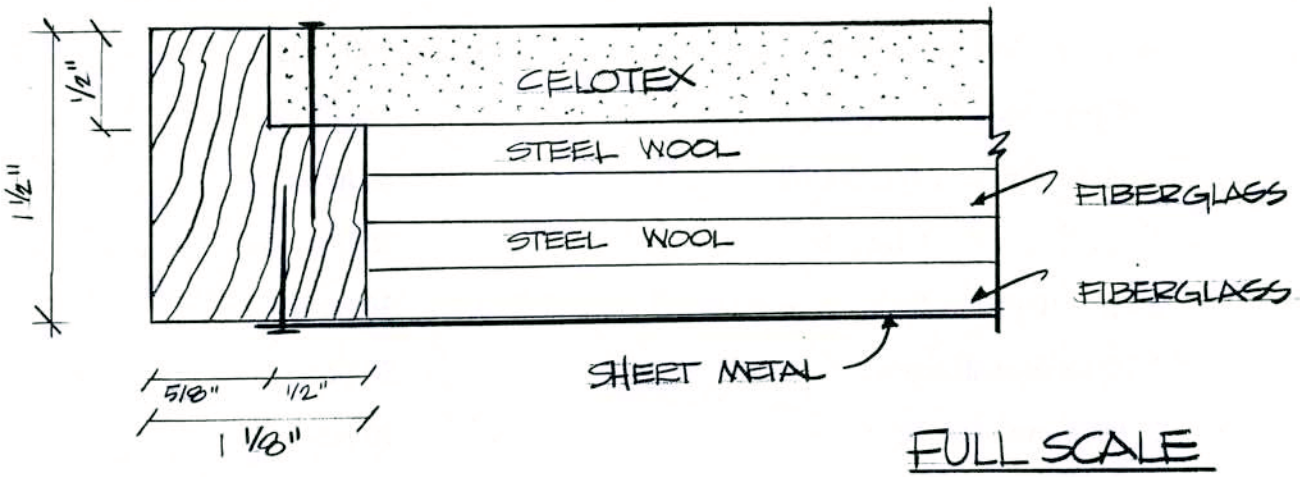

FULL SCALE

(FIG. 3) DETAIL OF LAYERING - BOTTOM PANEL

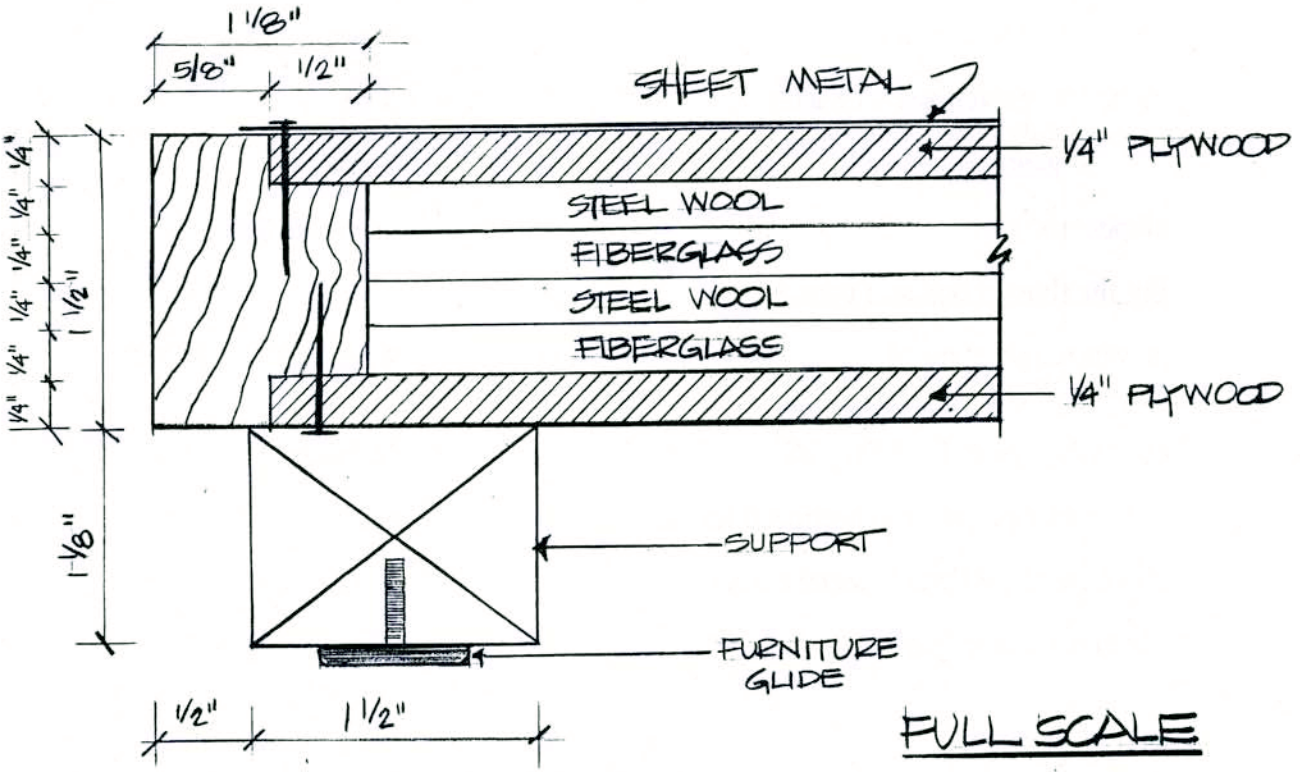

FULL SCALE

(FIG. 4) FRAMING DETAILS - SIDES (2), BACK, FRONT (DOOR), BOTTOM, TOP & SHOOTER BOX - SEAT (2)

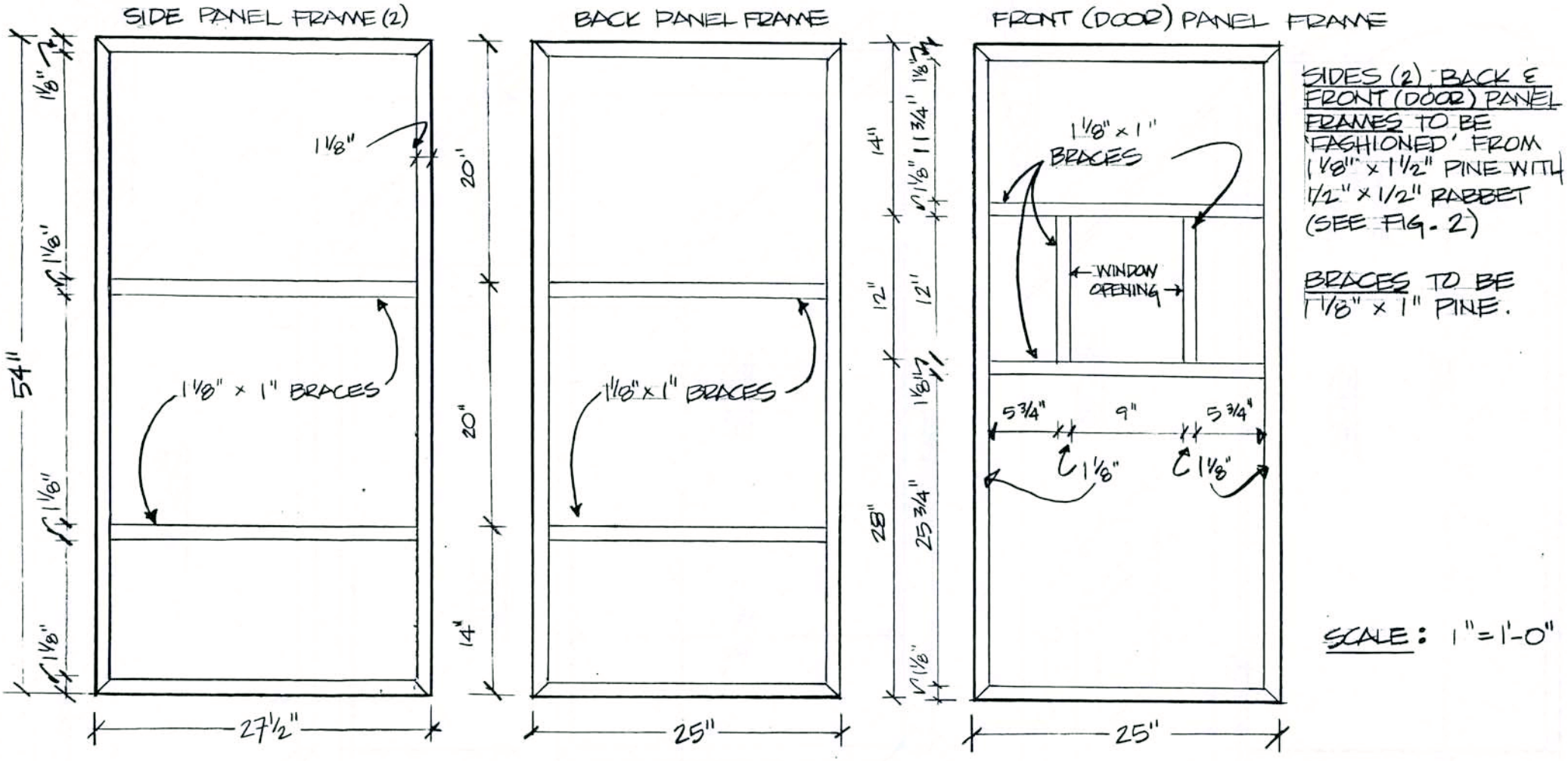

SIDES (2), BACK & FRONT (DOOR) PANEL FRAMES TO BE 'FASHIONED' FROM 1 1/8" x 1 1/2" PINE WITH 1/2" x 1/2" RABBET (SEE FIG. 2)

BRACES TO BE 1 1/8" x 1" PINE.

SCALE: 1" = 1'-0"

NOTE: TOP & BOTTOM FRAMES HAVE SAME WIDTH, LENGTH AND THICKNESS.

BOTTOM FRAME CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/4" x 1/2" RABBET ON TWO SIDES (SEE FIG. 3)

TOP FRAME CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/2" RABBET ON ONE SIDE. (SEE FIG. 2)

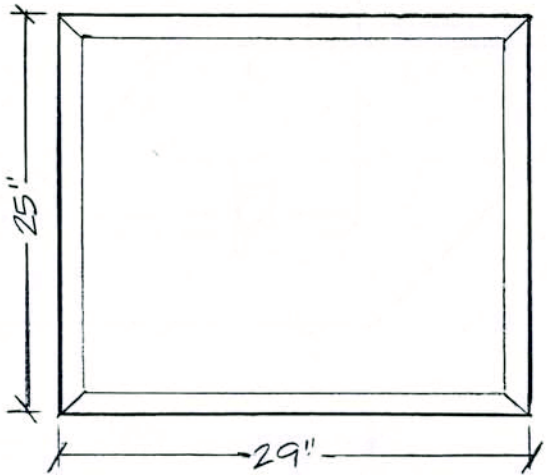

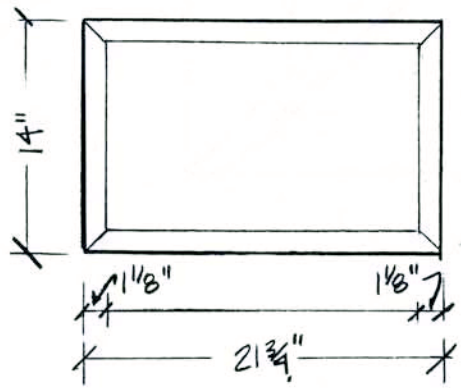

SHOOTER BOX SEAT (2)

FRAME TO BE CONSTRUCTED FROM 1 1/8" x 1 1/2" PINE WITH A 1/4" x 1/2" RABBET (SEE FIG. 7)

(FIG. 5)
ASSEMBLING THE PANELS

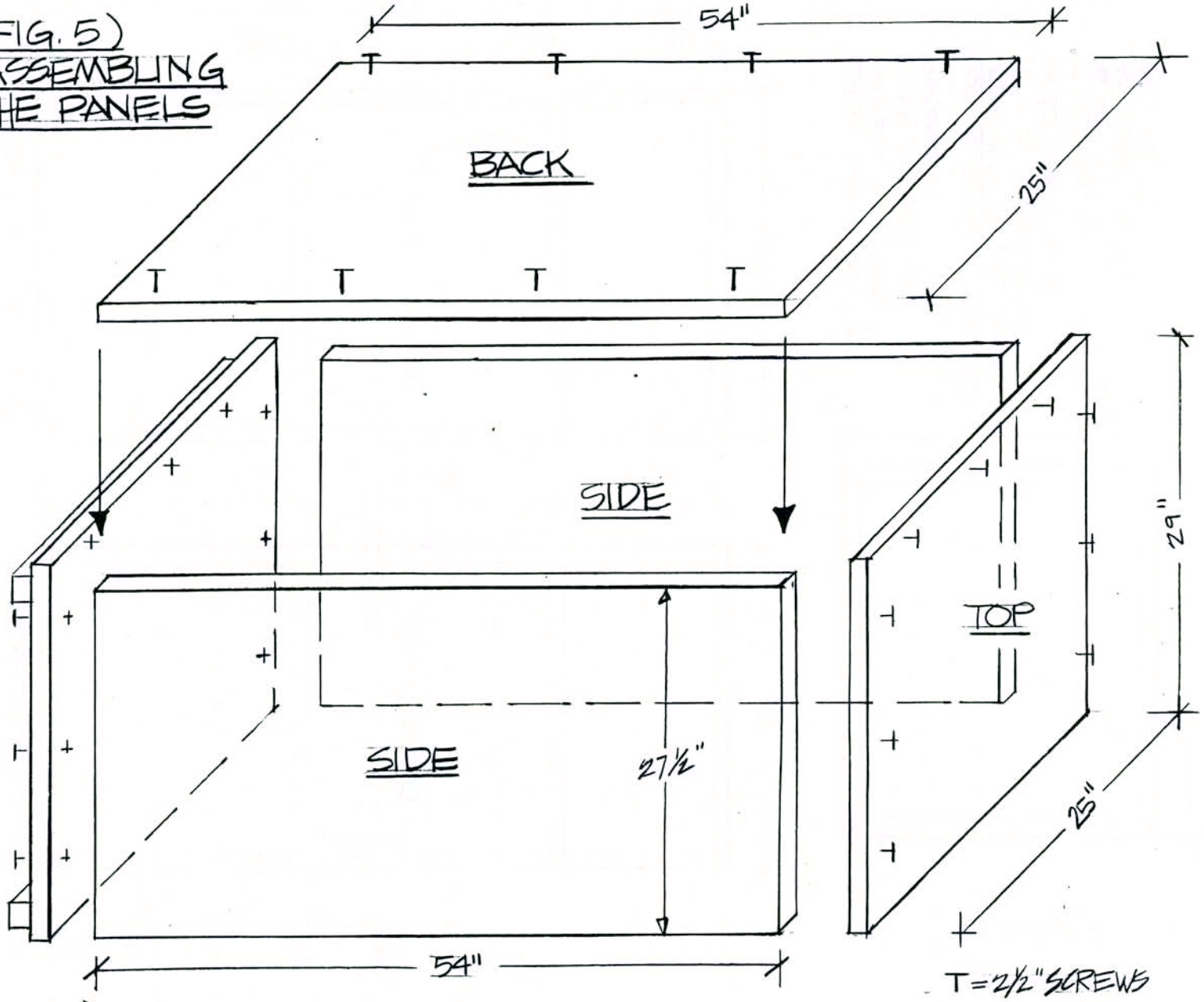

(FIG. 6)
ATTACH DOOR

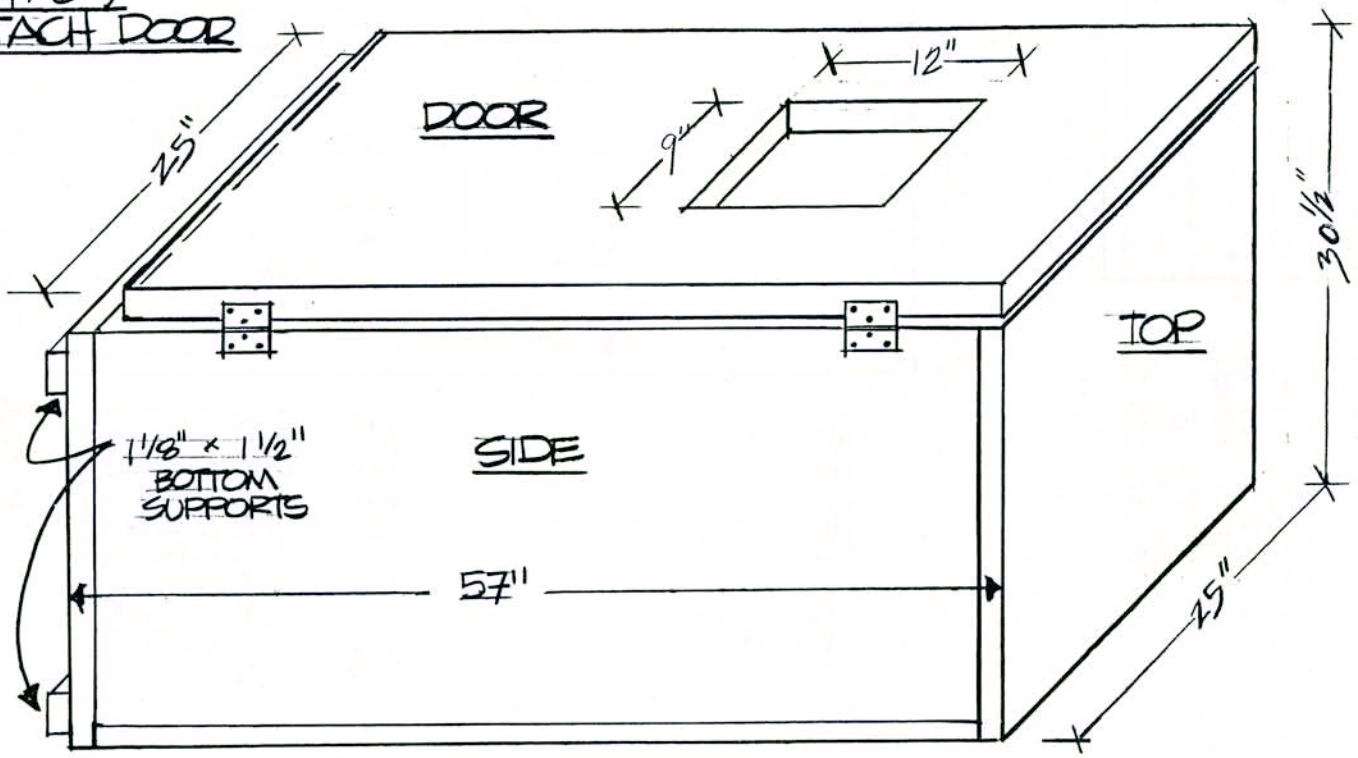

(FIG. 7) DETAIL FOR SHOOTER BOX - SEAT PANELS

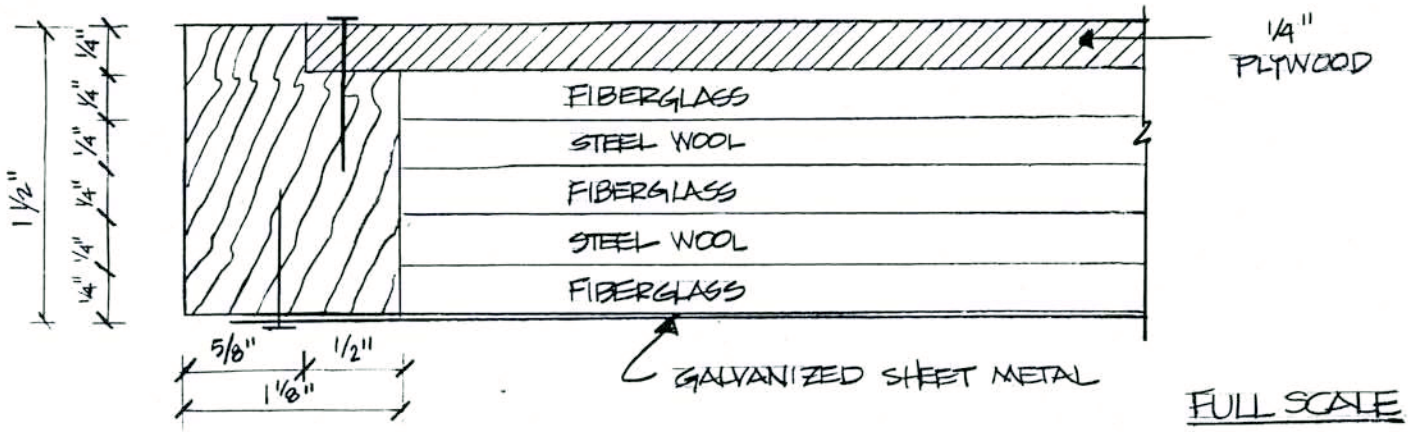

FULL SCALE

(FIG. 8) ASSEMBLING THE SHOOTER BOX - SEAT

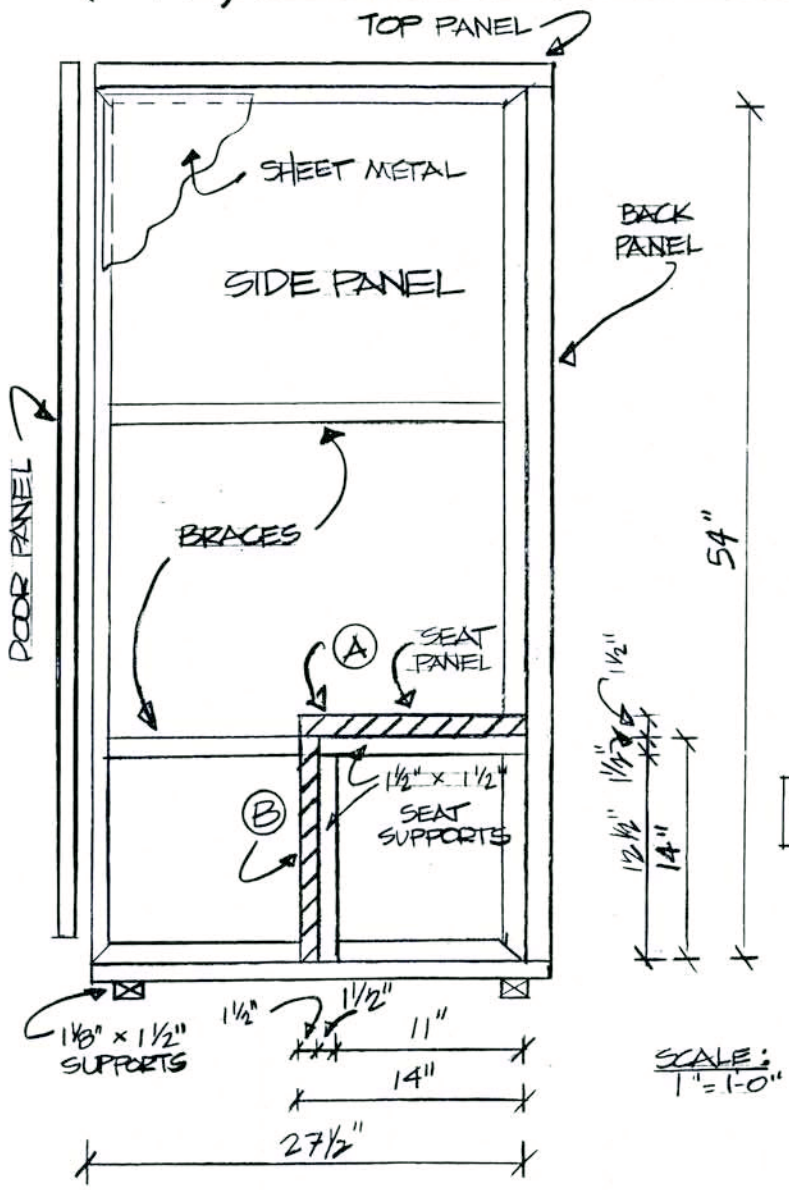

SCALE: 1" = 1'-0"

NOTE: ALLOW SPACE BETWEEN PANEL AND CHEST OF USER. SHEET METAL SIDE SHOULD FACE CHEST.

(FIG 9) HOW TO USE CHEST PANEL

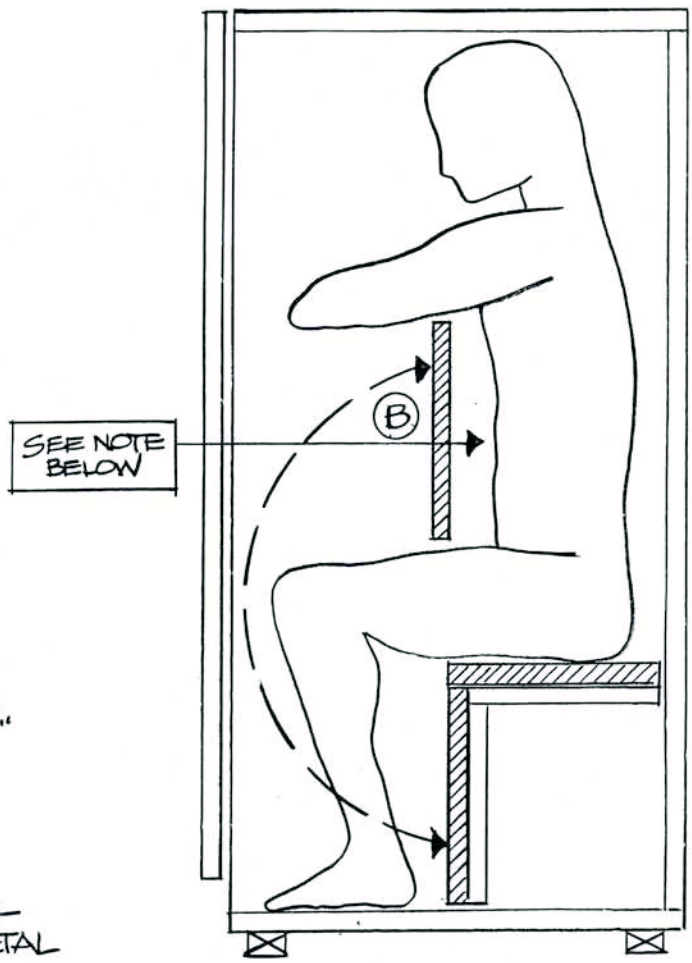

SCALE: 1" = 1'-0"